Proceedings; PR 2002-01

24th EWGLAM and 9th SRNWP meetings

7-10 October 2002
KNMI, De Bilt, The Netherlands

January 2003

Proceedings ; PR 2002-01

De Bilt, 2003

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PO Box 201
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UDC: 551.509.313
(063)

ISSN: 1570-9345

ISBN: 90-369-2228-3

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Contents

1. Introduction

1.1 Introduction

Introduction

The Royal Netherlands Meteorological Institute (KNMI) hosted the 2002 meetings of the European Working Group on Limited Area Modelling (EWGLAM) and of the Short Range Numerical Weather Prediction Network (SRNWP). There were 40 participants, representing 21 European countries and ECMWF.

The meetings followed the usual format: two days of EWGLAM presentations, followed by a day of SRNWP related matters. In the EWGLAM part, there were presentations from the participating consortia, poster presentations from the individual countries, and scientific presentations, many of which were related to the special topic of the 2003 meeting: "Clouds and Precipitation at High Resolution". In the SRWNP part, the SRNWP Lead Centres reported about last year's activities, and the annual SRNWP business meeting was held.

This Newsletter contains the programme of the meetings, a list of participants, extended abstracts of almost all presentations at the meetings, and a report of the final EWGLAM discussions. The EWGLAM section contains, in an Appendix, a table of limited area models currently operational in Europe. More information on the organisation of the meetings is in http://www.knmi.nl/hirlam/EWGLAM2002.

In reaction to the catastrophic flooding events in central Europe in August, the SRNWP meeting was followed by an ad hoc workshop on those events. Reports of that workshop are not included in this report of the EWGLAM and SRNWP meetings, because formally the workshop was not part of those meetings.

I thank all participants for their active participation, and for their contributions towards making the meetings interesting. I also greatly acknowledge the help of my colleagues at KNMI, in the organisation of the meetings, and in the production of this Newsletter.

De Bilt, January 2003

Gerard Cats

Cover:
Inspect http://www.knmi.nl/hirlam/EWGLAM2002/photos.html for a 'who is who'

1.2 List of Participants

List of participants

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1.3 Programme of the meetings

Programme of the 24th EWGLAM / 9th SRNWP meeting

De Bilt, 7 - 10 October 2002

Meeting room: Buys-Ballot zaal

Monday, 7 October: EWGLAM

Opening

09:00 *Fons Baede*

Group presentations (chair: Andras Horanyi)

09:15 ALADIN *(Dominique Giard)*

09:45 COSMO *(Günther Doms)*

10:15 *coffee*

10:45 ECMWF *(Anton Beljaars)*

11:15 HIRLAM *(Per Undén)*

11:45 UKMO *(Clive Wilson)*

12:15 *lunch*

13:15 LACE *(Radmila Brozkova)*

Introduction to national posters (chair: Jürgen Steppeler)

13:45

Austria	*(Thomas Haiden)*	France	
Belgium	*(Luc Gérard)*	Germany	*(Günther Doms)*
Bulgaria		Hungary	*(Andras Horanyi)*
Croatia	*(Stjepan Ivatek-Sahdan)*	Ireland	*(James Hamilton)*
Czech Republic		Italy	*(Massimo Bonavita)*
Denmark	*(Bent Sass)*	The Netherlands	*(Gerard Cats)*
Finland	*(Carl Fortelius)*	Norway	

14:45 *coffee*

15:30

Poland/IMGW	*(Katarzyna Starosta)*	Spain	*(Ernesto Rodriguez)*
Poland/IMWM		Sweden	*(Per Dahlgren)*
Portugal	*(Maria Monteiro)*	Switzerland	*(Guy De Morsier)*
Romania	*(Doina Banciu)*	United Kingdom	*(Clive Wilson)*
Slovakia	*(Jozef Vivoda)*	Yugoslavia	*(Sinisa Curic)*
Slovenia	*(Neva Pristov)*		

16:20 *posters*

Tuesday, 8 October: EWGLAM

Scientific presentations (data) (chair: Günther Doms)

09:00	*Steluța Alexandru*	3D-VAR data assimilation experiments for the double-nested limited area model ALADIN/Hungary
09:20	*François Bouyssel*	Evaluation of a variational assimilation cycle in ALADIN model on MAP IOP 14
09:40	*Hans Roozekrans*	Quantitative cloud observations by next generation meteorological satellites
10:00	*coffee*	
10:30	*Bogumil Jakubiak*	Assimilation of the rainrate from BALTRAD network using latent heat nudging technique
10:45	*Carl Fortelius*	Simulated radar measurements as a model validation tool
10:55	*excursion*	

Wednesday, 9 October: EWGLAM, SRNWP

Scientific presentations (model) (chair: Anton Beljaars)

09:30	*Pier Siebesma*	Cloud schemes in high resolution NWP
10:00	*Jürgen Steppeler*	Forecast of orographic precipitation with LM
10:30	*coffee*	
11:00	*Janneke Ottens*	Use of models in the weather room - products versus models
11:20	*Richard Forbes*	Modelling the high resolution structure of frontal rainbands
11:50	*Bent Sass*	Experience at DMI regarding precipitation forecasting at various resolutions
12:10	*Günther Doms*	The LM cloud ice scheme
12:30	*Henk Van Dorp*	To warn or not to warn, that's the question
12:50	*lunch*	

Final EWGLAM discussion (chair: Clive Wilson)

14:00

Report of the SRNWP Lead Centres (chair: Per Undén)

15:00	Nonhydrostatic Modelling	*(Jürgen Steppeler)*, DWD
15:15	*coffee*	
15:45	Numerical Technics	*(Dominique Giard)*, Météo-France
16:00	Variational Data Assimilation	*(Clive Wilson)*, MetOffice
16:15	Surface Processes	*(Ernesto Rodriguez)*, HIRLAM
16:30	Statistical and Dynamical Adaptation	*(Thomas Haiden)*, ZAMG

System Collaboration (chair: Ernesto Rodriguez)

16:45	Report on the Toulouse Workshop	*(Gerard Cats)*, HIRLAM
17:00	Discussion on Follow-up of the Workshop	

Thursday, 10 October: SRNWP

Report of the SRNWP Lead Centers (continued) (chair: Jean Quiby)

09:00 Verification Methods *(Ben Wichers Schreur)*, HIRLAM

SRNWP business meeting (chair: Jean Quiby)

09:15
- Composition of the Consortia: the latest change
- The Lead Centre Workshops for the next 12 months
- The scientific meetings of the Consortia for the next twelve months
- Follow-up of the SRNWP LAM-EPS Workshop 3-4 October 2002, Madrid: Should we have a LC for LAM-EPS?
- The EU Sixth Framework Programme (FP6).
  - We have submitted an Expression of Interest (EoI). Should we consider to submit a proposal for an "Integrated Project" or for a "Network of Excellence" when the calls for proposals will be issued?
- Place and date of the next SRNWP Annual Meetings: 2003 and 2004 (cf. EWGLAM final discussion)
- Other Matters

10:00 **Close**

2. Group reports

2.1 What's new? Group Report 2001-2002 (Dominique Giard)

ALADIN : What's new ? Group Report 2001-2002

A. LIFE OF THE PROJECT

The ALADIN project is addressing a new medium-term research plan, covering 2002-2004, while moving towards a new organization of research : more decentralization balanced by an enhanced coordination (both thematic and transversal) and a strict management of source code, to limit divergence between applications.
Three major training courses were or will be organized along 2002 :
- *"Numerical Methods and NWP Applications"* (ALATNET), 27-31 / 05 (*Si*)
- *"Physics"* (LACE), 16 / 09 - 04 / 10 (*Cz*)
- *"Code Maintenance"* (LACE), 25 - 29 / 11 (*Hu*)

The present status of the 15 operational suites is described in national presentations and in the latest ALADIN Newsletter, available on the web site :
http://www.cnrm.meteo.fr/aladin/

B. HIGH-RESOLUTION DYNAMICS

New NH prognostic variables

Linear stability analyses led to the following proposals for the replacement of the two additional non-hydrostatic prognostic variables :

pressure departure :

$$\mathrm{p}_0 = \frac{p-\pi}{\pi^*} \Rightarrow \mathrm{p} = \frac{p-\pi}{\pi} \text{ or } q = \ln(\frac{p}{\pi}) = \ln(1+\mathrm{p}) \Rightarrow q = \ln(\frac{p}{\pi})$$

pseudo-vertical divergence :

$$d_0 = -g\frac{\pi^*}{m^*RT^*}\frac{\partial w}{\partial \eta} \Rightarrow d_3 = -g\frac{p}{mRT}\frac{\partial w}{\partial \eta}\left(=\frac{\partial w}{\partial z}\right) \Rightarrow d_4 = d_3 + \frac{p}{mRT}\nabla_\eta \phi \cdot \frac{\partial V}{\partial \eta} = D_3 - \nabla_\eta \cdot V$$

$$(m = \partial\pi / \partial\eta)$$

Semi-implicit three-time-level semi-Lagrangian dynamics was proved to be unstable with the initial choice $(d_0\ \mathrm{p}_0)$ whenever the background flow differs from the semi-implicit values, denoted by a * in equations. Suppressing the reference to semi-implicit parameters in the definition of prognostic variables, i.e. using $(d_3\ q)$, significantly improves the situation, but is not enough in the presence of orography. The preliminary tests performed with $(d_4\ q)$ are quite convincing.

Predictor-corrector scheme

To ensure the stability of two-time-level semi-Lagrangian dynamics, a predictor-corrector approach, involving iterations of the semi-implicit scheme, is required. This was designed in cooperation with the IFS team, and is now available with the old and the first new sets of NH variables

Lower-boundary condition and vertical discretisation *(cf. LACE report)*

Smoothing of orography

A new and flexible method to smooth orography, damping the smallest scales, was proposed : adding a new spectral term to the cost-function used for the optimization of spectral orography.

High-resolution (quasi-)academic validation experiments

A large set of experimental frameworks was used to validate new developments and evaluate the skill of dynamics at high resolution.

2D academic cases

- nonlinear quasi-hydrostatic flow *(Héreil and Laprise, MWR, 1996)*
- various regimes with constant (U, h, a) for Agnesi mountain (from linear hydrostatic to nonlinear non-hydrostatic)
- potential flow
- steady trapped lee-waves with uniform wind-shear and Brunt-Vaisala frequency *(Keller, JAS, 1994)*

2D (quasi-)academic cases used for intercomparison

- nonlinear non-hydrostatic flow (breaking waves)
- non-steady trapped lee-waves : real profiles of wind and temperature, at 2 or 5 km *(Shutts and Broad, QJRMS, 1993)*

3D quasi-academic case **"ALPIA"** (following "SCANIA")

- uniform wind, constant Coriolis parameter, ICAO-like temperature profile
- 4 embedded domains over the French Alps :

Δx	10 km	5 km	2.5 km	1.25 km
vertical levels	30	42	60	85
Δt "safe" (NH)	200 s	60 s	25 s	10 s

- comparing options : Eulerian versus semi-Lagrangian (three-time-level), explicit versus semi-implicit, hydrostatic versus non-hydrostatic.
- searching the maximum "safe" time-step, with a still preliminary version, i.e. the intermediate choice for NH variables and no predictor-corrector scheme.

C. COUPLING PROBLEMS

Search for new time-interpolation methods

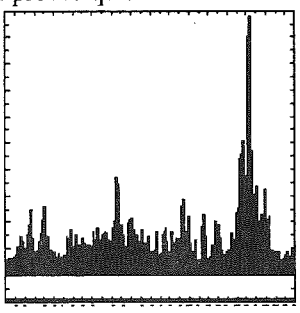
Further experiments were performed to evaluate the impact of the coupling frequency (6h, 3h, 1h), or the time-interpolation method (linear, quadratic, linear accelerated). Besides, new decompositions of fields were tested : phase / amplitude, growing / moving parts.

The most innovative approaches were not so successful in real case experiments, but may be used to design "warning indices". Such quantities, introduced at the level of the coupling model, could help controlling the coupling frequency in the case of linear time-interpolation. For instance, the

following index ("truncation error") was deduced from the linear-accelerated method :

$$e = \frac{1}{4}\left\| \left(\partial_t X(t_2) - \partial_t X(t_1)\right)(t_2 - t_1) \Big/ \left(X(t_2) + X(t_1)\right) \right\| = \left\| 1 - X\left(\frac{t_1 + t_2}{2}\right) \Big/ \left(\frac{X(t_1) + X(t_2)}{2}\right) \right\|$$

and proved quite efficient for ALADIN-Belgium and the 99 Christmas' storm :



date (December 1999)

"*e*", computed on msl-pressure over the whole coupling domain

minor ticks each 3 hours, forecast ranges : +6h, +9h, ..., +27h

Tendency-coupling for surface pressure

The coupling of tendencies, rather than fields, was proposed to handle the problem of large discrepancies in the orography between the coupling and the coupled models near the boundaries (still within Davies' relaxation scheme). It was first experimented with surface pressure, the most sensitive field. The new scheme is now running in 3D, but more targeted impact studies are required.

Spectral coupling

Spectral coupling was considered as an alternative / complementary method to Davies' one, allowing to extract more information from the coupling files. It is now coded in the 3D model, and the first experiments show a reasonable behaviour.

D. PHYSICAL PARAMETERIZATIONS

Trying to set up an efficient networking

That's not so easy ! However the several meetings organized along the first semester of 2002 allowed useful discussions and the emergence of new ideas (e.g. a renewal of convection schemes).

Solving problems in operations :

Most efforts, in physics, were dedicated to the cure of the many problems encountered in operations :

- towards a safer code (debugging, safety locks, reproducibility)
- strong oscillations : horizontally, on the vertical, in time ... *(cf. LACE report)*
- instable behaviours, such as spurious cyclogenesis (or even blow-up !) : This was addressed through changes in the convection schemes, retunings for PBL

parameterizations, etc. But more understanding is required to find the most appropriate solution. For instance, a problem of spurious cyclogenesis in the western Mediterranean sea may be cured either by changing the dependency on resolution within the present convection scheme or introducing a new "shear-linked" convection parameterization.

- underestimation of low-level cloudiness : This led to an investigation of the respective parts of shallow convection, vertical diffusion, ... and the proposal of a new parameterization, based on *Xu and Randall* and first tested in the EUROCS framework.

This list is far from exhaustive and the situation is evolving very quickly !

Restarting work on :

Going to more positive aspects, research restarted in the following domains :

- orographic forcing : That's just the beginning, goals look more clear.

- radiation : There is now a (small) dedicated ALADIN team ! The first steps were the introduction of a geographical and seasonal dependency for ozone profiles, and new tests using improved optical depths (especially near the surface), with unexpected good results.

- functional boxes for handling liquid water and ice : Work is at the stage of 3D experiments, and many of the problems encountered were shown to come from outside, i.e. from the fluxes provided by other physical parameterizations.

Validation and diagnostics

A "model to satellite" application was developed, with an expensive but complete version, using the Morcrette radiation code followed by a channel selection, and a cheap one, based on the RT-TOV7 code. It includes the decoding and filtering of GRIB data, to allow easier comparisons. "Cloudy" and "clear sky", "infrared" and "water vapour" pictures may be produced.
Besides the SCM version of ALADIN is more and more widely used and was interfaced with new field experiments.

E. DATA ASSIMILATION

Cycling

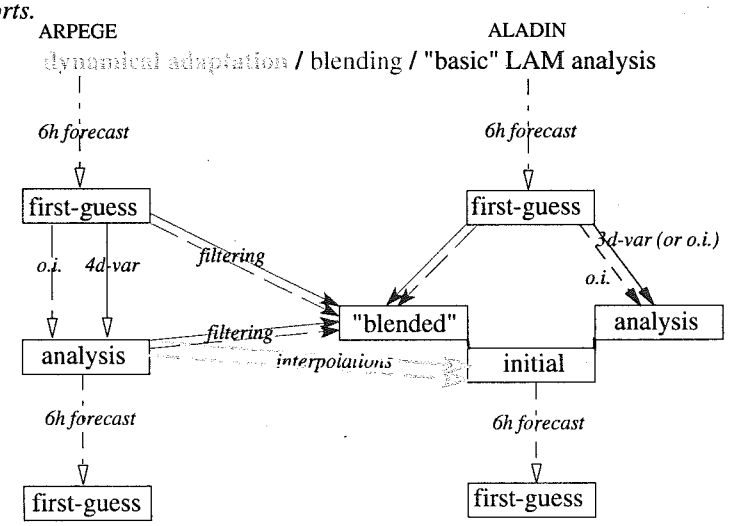
Many experiments aimed at testing and comparing various combinations of the following initialization methods :

- for upperair fields : dynamical adaptation, dfi-blending, O.I., 3d-var
- for soil and surface : dynamical adaptation, surface blending, O.I.

using various background error statistics and coupling methods, and different model configurations : ALADIN-Morocco, -LACE, -Hu, -France, -Belgium.

The figure below illustrates the basic configurations : pure data assimilation (operational in Morocco), blending (operational for LACE) and simple dynamical adaptation (used everywhere else). Other possible combinations were tested, e.g. between 3d-var and dfi-blending for upperair fields (blendvar and varblend) or between dfi-blending for upperair and O.I. for soil and surface

fields (canblend and blendcan). *More details are available in other ALADIN reports.*



Besides, the work on 3D-FGAT is progressing, 4D-screening is now ready.

3D-var : refinements for background error statistics

The requirements for LAM background error statistics were formalized and the presently used "NMC-lagged" method justified. Some refinements are on the way, trying to better represent geographical dependency.
Besides, other methods are tried, such as the use of "wavelet" functions or the "ensemble analyses" approach.

3d-var : intensive validation

A detailed case study was performed with ALADIN-France on "MAP IOP 14" (02-03/11/1999). *It is described in a dedicated presentation.*

Soil/surface assimilation

A new statistical model was designed for the O.I. analysis of 2m temperature and relative humidity. Statistics were first computed using the Lönnberg-Hollingsworth method, and considering geographical and seasonal variations. An improved formulation of the coefficient of correlation was proposed :

$$\rho_{T/H} = \exp(-r^2 / 2a^2_{T/H}) \quad \Rightarrow \quad \rho_{T/H} = \exp(-r / 2a_{T/H})$$

together with retunings of standard deviations and characteristic lengths.

A spatial smoothing of the soil-wetness-index (soil moisture) was introduced within diagnostic analyses first, within soil moisture assimilation afterwards. It enables to reduce horizontal heterogeneity and subsequent forecast errors.

A few combinations of the (O.I. based) assimilation of soil and surface fields with dfi-blending for upperair spectral fields were tested with ALADIN-LACE.

To end with, a prototype version of 2d-var assimilation for mean soil moisture is now ready. The underlying hypotheses : "linear variations" and "gridpoint

decoupling" were carefully checked, and a "double chess" approach chosen for the computation of the gain matrix. The next step is now the introduction of a spatial smoothing of soil moisture, as for O.I. .

Observations

The interfacing of the model with ODB is very slowly progressing, due to portability problems and the lack of documentation. Help from IFS is needed (and was asked, with a negative answer).

The first 3D-var experiments using raw radiances (ATOVS data) are running. The above-mentioned case study gave the opportunity to use pseudo-profiles of humidity, derived (a posteriori) from satellite data. Research on the use of IASI data over land is going on, background error matrix and emissivity maps are ready.

Simplified physics

Modifications in the simplified parameterization of large-scale precipitations were proposed (and successfully tested) in the framework of sensitivity studies using the adjoint model. This was done at a resolution of about 10 km.
Besides, the consistency between vertical diffusion schemes, in the full and simplified physics, was improved.

A posteriori validation and retuning of assimilation algorithms

More understanding of the method (validation, limitations, applications) was acquired along thess summer months. The main validation diagnostics are :

- "Talagrand index" :

  $E(J_{min} / P)$, with : $J_{min} = min\ (Jb+Jo)$, P= number of observational data

- "estimated global error variance rescaling", for background and observations :

  $Sb = Jb_{min} / Tr(KH)$ and $So = Jo_{min} / Tr\ (I_p\text{-}HK)$

  with H= observation operator, K= gain matrix

And the main remarks are the following. (1) These diagnostics provide a global information on the system. (2) There is a clear need to compare these "a posteriori" results with independent diagnostics (here output of a Lönnberg-Hollingsworth method, both for variances and correlation length-scales). (3) Since a posteriori validation contains all the scales, there is a fundamental difficulty in assessing the amount of scale-selective error variances. (4) The diagnostics exhibit clearly case-dependent behaviours, which indicates that the error statistics in the LAM are sensitive to weather systems. (5) Working with real data implies the design of tractable pragmatical applications, and a small departure from the theoretical framework.

Predictability

First explicit mention in the research plan !

2.2 The COSMO consortium in 2001-2002 (Günther Doms)

The COSMO Consortium in 2001-2002

GÜNTHER DOMS

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1. Organizational Structure of COSMO

The *Consortium for Small-Scale Modelling* (COSMO) aims at the improvement, maintenance and further development of a non-hydrostatic limited-area modelling system to be used both for operational and for research applications by the members of COSMO. The emphasis is on high-resolution numerical weather prediction by small-scale modelling. COSMO is initially based on the "Lokal-Modell" (LM) of DWD with its corresponding data assimilation system. At present, the following national, regional and military meteorological services are participating:

DWD	Deutscher Wetterdienst, Offenbach, Germany
HNMS	Hellenic National Meteorological Service, Athens, Greece
IMGW	Institute for Meteorology and Water Management, Warsaw, Poland
MeteoSwiss	Meteo-Schweiz, Zürich, Switzerland
UGM	Ufficio Generale per la Meteorologia, Roma, Italy
ARPA-SMR	Il Servizio Meteorologico Regionale di ARPA, Bologna, Italy
AWGeophys	Amt für Wehrgeophysik, Traben-Trarbach, Germany

All internal and external relationships of COSMO are defined in an Agreement between the national weather services, which was signed by DWD, HNMS, MeteoSwiss and UGM on 3 October 2001. The national weather service IMGW of Poland joined the consortium on 3 July 2002. There is no direct financial funding from or to either member. However, the partners have the responsibility to contribute to the model development by providing staff resources and by making use of national research cooperations. A minimum of 2 scientist working in COSMO research and development areas is required from each member. In general, the group is open for collaboration with other NWP groups, research institutes and universities as well as for new members.

The COSMO's organization consists of a steering committee (composed of representatives from each national weather service), a scientific project manager, work-package coordinators and scientists from the member institutes performing research and development activities in the COSMO working groups. At present, six working groups covering the following areas are active: Data assimilation, numerical aspects, physical aspects, interpretation and application, verification and case studies, reference version and implementation.

COSMOS activities are developed through extensive and continuous contacts among scientists, work-package coordinators, scientific project manager and steering committee members via electronic mail, special meetings and internal mini workshops. Once a year there is a General Meeting of the COSMO group in order to present results, deliverables and progress reports of the working groups and to elaborate a research plan with new projects for the next annual period. Following this meeting, a final work plan for each working group is set up. In 2002, the COSMO General Meeting was held on 25-27 September in Warsaw (Poland). More information about COSMO can be obtained from our web-site *www.cosmo-model.org*.

Table 1: The Lokal-Modell (LM)

Dynamics	
Basic equations:	nonhydrostatic, fully compressible, no scale approximations
Prognostic variables:	horizontal and vertical wind components, temperature, pressure perturbation, specific humidity, cloud water content. - optionally: cloud ice.
Diagnostic variables:	total air density, precipitation fluxes of rain and snow.
Coordinates:	rotated lat/lon coordinates horizontally and a generalized terrain-following height coordinate in the vertical.
Numerics	
Grid structure:	Arakawa C-grid, Lorenz vertical grid staggering.
Spatial discretization:	second order horizontal and vertical differencing.
Time integration:	Leapfrog HE-VI (horizontally explicit, vertically implicit) time-split integration scheme by default; includes extensions proposed by Skamarock and Klemp (1992). Additional options for: - a two-time level Runge-Kutta split explicit scheme (Wicker and Skamarock(1998), - a 3-d semi-implicit scheme (Thomas et al., 2000).
Numerical Smoothing:	4th order linear horizontal diffusion; - option for a monotonic version including an orographic limiter. Rayleigh-damping in upper layers.
Physics	
Clouds and precipitation:	bulk-parameterization including rain and snow; optional: cloud ice scheme.
Convection:	mass-flux convection scheme (Tiedtke, 1989) with moisture convergence closure; option for CAPE-type closure.
Vertical diffusion:	Level 2 diagnostic K-closure. Option for a Level 2.5 scheme with prognostic TKE.
Surface layer	parameterization scheme after Louis (1979); option for a new surface scheme including a laminar-turbulent roughness layer.
Radiation	δ-two stream radiation scheme after Ritter and Geleyn (1992) for short and longwave fluxes; full cloud-radiation feedback.
Soil processes	soil model with 2 soil moisture layers and Penman-Monteith transpiration; snow and interception storage included. optional: a new multi-layer soil model.
Initial and Boundary Conditions	
- initial and boundary data interpolated from GME or EM/DM as driving models.	
- one way nesting by Davies boundary relaxation scheme.	
- diabatic or adiabatic digital filtering initialization (DFI) scheme (Lynch et al., 1997).	
- Nudging analysis scheme.	
Topographical Data Sets	
- Mean orography derived from the GTOPO30 data set (30"x30") from USGS.	
- Prevailing soil type from the DSM data set (5'x5') of FAO.	
- Land fraction, vegetation cover, root depth and leaf area index from the CORINE data set.	
- Roughness length derived from the GTOPO30 and CORINE data sets.	
Code	
- Standard Fortran-90 constructs.	
- Parallelization by horizontal domain decomposition.	
- Use of the MPI library for message passing on distributed memory machines.	

Table 2: Data Assimilation for LM

Method	Nudging towards observations
Implementation	continuous cycle of 3-hour assimilation runs
Realization	identical analysis increments used during 6 advection time steps
Balance	1. hydrostatic temperature increments (up to 400 hPa) balancing 'near-surface' pressure analysis increments 2. geostrophic wind increments balancing 'near-surface' pressure analysis increments 3. upper-air pressure increments balancing total analysis increments hydrostatically
Nudging coefficient	$6 \cdot 10^{-4} s^{-1}$ for all analyzed variables
Analyzed variables	horizontal wind vector, potential temperature,relative humidity 'near-surface' pressure (i.e. at the lowest model level)
Spatial analysis	Data are analyzed vertically first, and then spread laterally along horizontal surfaces. vertical weighting: approximately Gaussian in log(p) horizontal weighting: isotropic as function of distance
Temporal weighting	1.0 at observation time, decreasing linearly to 0.0 at 3 hours (upper air) resp. 1.5 hours (surface-level data) before and 1.0 resp. 0.5 hours after observation time; linear temporal interpolation of frequent data.
Observations	SYNOP, SHIP, DRIBU: - station pressure, wind (stations below 100m), humidity TEMP, PILOT: - wind, temperature: all standard levels, significant levels up to 150 hPa - humidity: all levels up to 300 hPa - geopotential used for one 'near-surface' pressure increment AIRCRAFT: - all wind and temperature data
Quality control	Comparison with the model fields from assimilation run itself

2. Model System Overview

2.1 Lokal-Modell (LM)

The limited area model LM is designed as a flexible tool for numerical weather prediction on the meso-β and on the meso-γ scale as well as for various scientific applications down to grid spacings of about 100 m. Table 1 summarizes the key features of the LM.

2.2 Data Assimilation

The LM data assimilation system is based on the observational nudging technique. The scheme has been derived from an experimental nudging analysis scheme which has been developed for DM and the Swiss model version SM, and which compared favorably to the operational OI-analysis of the DM in various case studies. Table 2 summarizes the features of the LM nudging scheme.

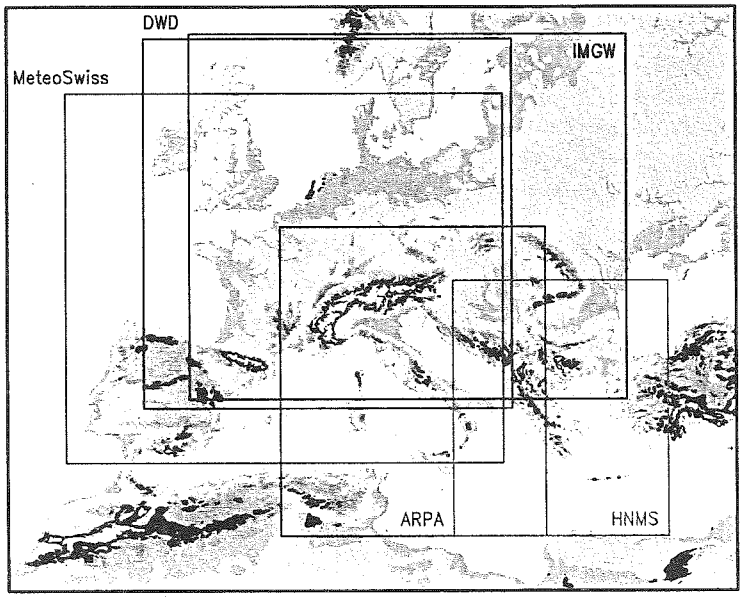

Figure 1: LM integration domains at DWD, MeteoSwiss, ARPA-SMR, HNMS and IMGW

As an external component of the LM-analysis, a new 1-d variational soil moisture analysis scheme scheme has also been developed (Hess, 2001). Two additional external analyses complete the LM data assimilation: a sea surface temperature (SST) analysis based on the correction method using SST data from ships and buoys and a snow depth analysis using SYNOP observations.

2.3 Pre- and Postprocessing

The LM can be one-way nested into the global models GME (Majewski, 2002) or IFS from ECMWF, or into itself. The lateral boundary conditions (and initial conditions, if no data assimilation suite is operated) are obtained by corresponding preprocessing programs GME2LM, IFS2LM or LM2LM. A number of postprocessing modules using LM output fields are available within COSMO. Examples are a wave prediction model, a trajectory model and a Lagrangian particle dispersion model.

3. Operational Application

The LM is operated in five centres of the COSMO members: ARPA-SMR, DWD, MeteoSwiss, HNMS and IMGW. Figure 1 shows the current integration domains of these LM-applications. All four centres use interpolated boundary conditions from forecasts of the global model GME of DWD. ARPA-SMR, HNMS and IMGW start the LM from interpolated GME analyses, followed by an initialization using the digital filtering scheme of Lynch et al. (1997). At DWD and MeteoSwiss, a comprehensive data assimilation system for LM has been installed. Besides the analysis by observational nudging, three external analyses are run: a SST analysis (00 UTC), a snow depth analysis (00, 06, 12 and 18 UTC) and a variational soil moisture analysis (12 UTC), which was brought into operations in March 2000. Figure 2 summarizes the present operational configurations of the LM at COSMO members.

Configurations	ARPA-SMR	DWD	HNMS	MeteoSwiss	IMGW
Domain Size	234 x 272	325 x 325	95 x 113	385 x 325	385x321, 193x161
Grid Spacing	0.0625°	0.0625°	0.1250°	0.0625°	0.0625°, 0.125°
Number of Layers	35	35	35	45	35
Time Step	40 sec	40 sec	80 sec	40 sec	40 sec, 80 sec
Forecast Range	48 hrs	48 hrs	48 hrs	48 hrs	36 hrs, 72 hrs
Model Runs	00, 12 UTC	00, 12, 18 UTC	00 UTC	00, 12 UTC	00, 12 UTC
Boundaries	GME	GME	GME	GME	GME
LBC Updates	1 hr	1 hr	1 hr	1 hr	1hr
Initial State	GME	Nudging	GME	Nudging	GME
Initialization	Digital Filtering	None	Digital Filtering	None	Digital Filtering
External Analyses	None	SST, S-Depth, Soil Moisture	None	SST, S-Depth	None
Hardware	IBM SP (Pwr3)	IBM SP (Pwr3)	CONVEX	NEC SX-5	SGI 3800
No. of Processors	32 / 64	160 / 1280	14 / 16	12 / 16	96 / 100

Figure 2: Operational configurations of the LM within COSMO

4. Progress Report and Research Activities

This section gives a brief overview of the main research activities of the COSMO working groups for the period Oct 2001 - Oct 2002. Further details on the results of various work packages will be available in COSMO Newsletter No. 3 (to appear in January 2003).

Working Group 1: Data Assimilation

- Work on the assimilation of aircraft data (AMDAR) within the nudging scheme has been completed, the data are now used operationally since May 2002 at DWD. Further activities considered the enhancement of the nudging of surface pressure and refinements of the use of screen-level data (wind and humidity).
- At MeteoSwiss, the nudging-based data assimilation cycle for the LM has been introduced operationally in November 2001.
- The development work to assimilate integrated water vapour, derived from GPS-data of about 80 stations in or near Germany, has been continued. In one of the case studies (3 May 2001), a heavy precipitation event in Germany was better simulated by using GPS and aircraft data. An erroneous reproduction of the diurnal cycle of integrated water vapour by the model, however, can sometimes result in problems with the assimilation of GPS data (Tomassini et al., 2002).
- A 27-day observation system experiment was conducted at MeteoSwiss for the EUCOS programme of EUMETNET (Bettems, 2002). A follow-up study considered the model sensitivity to Synop observations.
- Work on the 2-d latent heat nudging has been resumed and experiments on the assimilation of wind profiler data have been conducted.

Working Group 2: Numerical Aspects

- The development work on the LM z-coordinate version based on finite volumes using shaved cells has been continued. A 3-d testversion was realized and idealized cases using real topography (SCANDIA-test) were successfully integrated. Especially, an interface to the terrain-following physics package was developed.
- The current optional 2-time-level RK split-explicit integration scheme has been modified to include a consistent treatment of metric terms. The new scheme is in better accordance with analytic solutions. An evaluation for real data cases is in progress.
- A new non-local scale-dependent terrain-following vertical coordinate (Schär et al., 2002) has been implemented and is currently in evaluation (see also contribution by Guy de Morsier in this volume)
- Further work packages considered the use of ECMWF frames as lateral boundaries and a check of the water mass budget of the LM.

Working Group 3: Physical Aspects

- A new TKE-based turbulence scheme (level 2.5) and a new surface layer scheme have have been implemented. These schemes are applied operationally at DWD and much work was devoted to tuning and further development.
- A new multi-layer version of the soil model TERRA has been developed. The new version includes freezing and melting of soil layers and a revised formulation of the snow model. The new scheme is currently being evaluated and tuned, the operational use is scheduled for Spring 2003.
- The Kain-Fritsch convection scheme has been implemented for optional use and first tests revealed promising results. With respect to the operational Tiedtke mass-flux scheme, a number of sensitivity studies related to the convective drizzle problem have been conducted. Changes to the minimum mass-flux condition and to the formulation for the generation of precipitation within updraughts resulted in a significant reduction of convective drizzle.
- A new scheme for grid-scale precipitation including cloud ice as an explicit prognostic variable has been developed and implemented into both LM and GME. Final tests are currently under way. The operational application is planned for 2003.

Working Group 4: Interpretation and Applications

- Work on the COSMO limited-area ensemble prediction system (LEPS) has been continued. The goal of this activity is to run the LM with initial and boundary conditions given by the ECMWF ensemble (using the cluster technique) in order to catch probabilities of extreme events with higher spatial accuracy. Several MAP cases have been successfully run in hindcast mode. At present, a real-time test suite is implemented at ECMWF. The group decided to use a 10km resolution LM on a superdomain covering most of the domains of all participating members.

- A scheme for statistical postprocessing by spatial and temporal aggregations – resulting in smoothed fields with probabilities for extreme events – has been developed. At present, two different approaches using the neighborhood method and the wavelet method are compared and evaluated.
- Further activities considered the generation of new model-internal interpreted fields such as the snowfall-limit and convective wind gusts.

Working Group 5: Verification and Case Studies

- The operational verification of predicted surface weather parameters is done at each COSMO site for the corresponding LM application. The observational basis are SYNOP stations and regional high resolution networks. Also, a TEMP-verification is done at most of the COSMO centres. Verification results are distributed on a quarterly basis at our web-site. A summary of the annual scores for 2002 can be found in COSMO Newsletter No.3.
- An combined internal workshop of WG3 and WG5 was held in February 2002. The participants addressed items such as the selection of representative Synop stations, the statistical significance of various scores, the conditional verification of weather elements, the investigation of the realism of forecasts by alternative methods and variational techniques to estimate parameters in the physics schemes.
- Verification of precipitation using high resolution precipitation analyses from ARPA-SMR for the Emilia Romagna region. The analyses are available every hour and are obtained by using surface raingauges and calibrated radar data.
- Work on the pattern matching method to compare model predicted precipitation and radar precipitation fields has been continued.

Working Group 6: Reference Version and Implementation

- Work on the interpolation programs GME2LM, IFS2LM and LM2LM to provide initial and boundary conditions from driving models by one-way nesting has been carried on. It is planned to join these programs into a unified preprocessor program INT2LM.
- Installation, updating and running of the LM is a permanent task of the COSMO member sites. In 2002, a common update procedure has been defined.
- Work on the two-way interactive nesting version of LM has been continued.
- A new version of the model documentation including a description of the nudging analysis scheme and the new TKE-based turbulence scheme is planned to be available at the end of 2002.

5. Plans and Goals 2003

At the recent COSMO General Meeting, a detailed work plan for the next working period (Oct. 2002 - Oct. 2003) has been formulated. Some of the basic points are listed below.

Consolidation, Upgrade and Documentation of the LM
- increased quality of the quantitative precipitation forecasts
- tuning and optimization for both model and data assimilation components
- operational use of the new soil model and the cloud ice scheme
- assimilation of remote sensing data (radar, wind profiler, satellite)
- continue work on 2-way interactive self-nesting

Application and Interpretation
- evaluation of the COSMO LEPS system based on the ECMWF ensemble
- statistical interpretation of high resolution forecasts
- common postprocessing tools

'Paving the way' for NWP on the Meso-γ Scale
- continue the development work on the z-coordinate version of the model
- experimental work and test suites at very high resolution
- development and test of a 3-D TKE-based turbulence scheme
- 3-d transport of rain and snow in the cloud scheme
- development of a new scheme for shallow convection

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2.3 Recent developments at ECMWF (Anton Beljaars)

Recent developments at ECMWF

Anton Beljaars
(ECMWF)

1 General

Recent developments at ECMWF include:

- Revisions to the 4DVAR algorithm are motivated by the need for improved efficiency to offset the costs of higher resolution, better tangent linear physics and the increased number of satellite observations. Also the wish to assimilate radiances in cloudy and/or rainy areas will require more advanced physics in the data assimilation. The set of revisions that accommodates for these requirements consists of: quadratic inner iterations, conjugate gradient minimization, Hessian eigenvector pre-conditioning, a multi-incremental approach with resolutions T42/T95 and T159, interpolation of the trajectory from high resolution to low resolution and tangent linear physics during all iterations.

- Recent satellite operational milestones are: use of QuikScat data, modified thinning of ATOVS, new RT model which is better for water vapor channels, use of water vapor radiances from Meteosat, use of SBUV and GOME, passive monitoring of water vapor radiances of GOES-8/10, and passive monitoring of NOAA-17. Ongoing satellite work is focussing on: (i) data use from operational satellites, (ii) preparation for AIRS, ENVISAT, EOS and other research satellites, and (iii) assimilation of cloud or rain affected radiances.

- The numerics section has introduced finite elements in the vertical and is focussing now on conservation, vertical resolution around the tropopause, and the upper boundary condition. On the technical side, there is the migration to the IBM, optimization for the IBM and PrepIFS and PRISM related activities.

- A new short radiation scheme has been introduced with 6 spectral bands and revised absorption coefficients. The result is a better representation of solar absorption in the stratosphere and a slightly reduced downward solar radiation at the surface.

- Substantial changes to the cloud and convection schemes have been prepared and are currently under test. They consist of a complete rewrite of the cloud code with scientific changes to the ice settling, better numerics and many bug fixes. The convection scheme has new activation and cloud base cloud top algorithms.

New linear and adjoint code for radiation has been introduced but will only be activated after migration to the new IBM.

- The MAP period has been re-analyzed with a recent version of the 4DVAR system at T511 resolution, making use of the additional observations during the MAP project.

2 Assimilation and modelling of the hydrological cycle

A substantial effort is currently taking place at ECMWF to improve the moisture analysis. A status report entitled "Assimilation and Modelling of the Hydrological Cycle", by Holm et al. has been published as Research Technical Memo 383, and is available from ECMWF. The abstract of this memo is reproduced here.

Several new types of satellite instrument will provide a rich source of additional humidity information in the next few years. The assimilation of cloud and rain observations from existing types of instruments will also provide important new humidity information. In an effort to make the best possible use of these data a re-formulation of the 4D-Var humidity analysis has been developed. The new formulation will better account for the wide variations in humidity in the vertical and at small scales in the horizontal, thus improving the interpretation and the spatial interpolation of humidity information from space and ground based observing systems. The theoretical basis for the new formulation, its practical implementation within the ECMWF assimilation system, and several illustrations of its performance, are presented. The status of the preparations for cloud and rain assimilation is given, including the development of linearized moist physics, the development of fast radiative transfer codes and the recent experimental results using rainfall rates from space borne microwave radiometers.

Results of model validations (against *in-situ* data) of boundary-layer moisture are presented, indicating generally good agreement, often to within the absolute calibration accuracy of the measurements. We also present evidence of shortcomings in ECMWF's current humidity analysis, from the operational data assimilation and forecasting system, and from the 40-year reanalysis project (ERA-40). Examples are shown of biases in the data and in the model that lead to biased humidity analyses. Although these biases are relatively small, they contribute to an over-prediction of precipitation in short-range forecasts and a marked spin-down in tropical rainfall.

2.4 The HIRLAM-5 Project 2002. (Per Undén)

The HIRLAM-5 Project 2002.

Per Undén
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1 Introduction

The HIRLAM-5 Project is the LAM NWP research cooperation between the meteorological institutes in Denmark, Finland, Iceland, Ireland, Netherlands, Norway, Spain and Sweden as well as with Météo-France. The Hirlam Data assimilation and Forecast model is run operationally in 7 of the institutes in a many different configurations. Synoptic scale models with resolutions from 15-50 km are run with ECMWF boundary conditions, and within these models there are nested ones from 20 km down to 5 in some countries. The Project has continued development of its Variational Data Assimilation and use of non-conventional data and a number of modelling areas, particularly physical parameterisation have been worked on intensively. The Project is preparing to go into its 6th phase and with fairly similar objectives. The need for synoptic scale modelling persists, for e.g. Atlantic developments whilst gradually more emphasis will be put in the meso-scale non-hydrostatic very short range model. Use of non-conventional data and optimal use in 3D or 4D-VAR will be even more important.

2 Scientific Progress

2.1 Data Assimilation

The Hirlam institutes using 3D-VAR operationally show better general (upper air) forecast scores than the ones still using OI and this confirms the benefits documented for 3D-VAR. The Hirlam Variational DA system (HIRVDA) has been further updated and a number of corrections and new features have been added. The internal observation structure has been changed. The use of SHIP anemometer height is now included. First Guess at Appropriate Time (FGAT) has been introduced as an option and has been shown to give positive impact.

The use of background error (σ_b) values in HIRVDA software has been unified in the transforms of the background error constraint term, on one hand, and in the quality control, on the other hand. The so called "index-field" describing the spatial variations of the σ_b values owing to the climatological background errors and observation station density has been implemented. The 3D-VAR analysis then performs in the expected way. Further tuning and testing remains to be done. The computation of background

errors in observation space, necessary for non-conventional data has been implemented. Diagnostics and plotting software has been assembled and provided with the system.

A HIRLAM mini-Workshop on "Singular vectors and alternative methods used for estimation of forecast errors" was organised at SMHI 19-20 November 2001. The presentations and working groups recommendations have been published as a HIRLAM workshop report in March 2002. A full HIRLAM Workshop on Variational assimilation and remote sensing was then held i Helsinki 21-23 January 2002. Both were well attended and conclusions were drawn for guiding future developments.

The very simplified physics (Buizza) has been introduced in 4D-VAR and comparisons have been done between the different physics options. Results are good and the 4D-VAR convergences well. The minimisation can be done at a cost of about 6 times that of 3D-VAR and the forecast performance is so far similar to 3D-VAR, judging from the feasibility studies done so far.

The semi-Lagrangian version of the spectral model has been revived and its tangent linear and adjoints coded, in order to make 4D-VAR much more economical.

Software has been developed and introduced to compute eigenvectors of the Hessian of the cost function.

The new re-written surface analysis has been developed and implemented with ISBA. The soil moisture assimilation scheme has been tested with emphasis on usage of filters for T_{2m} errors and smoothing of soil water increments. Parameters controlling the limiting conditions for soil moisture analysis have been tuned (wind speed, cloudiness, local solar time...). The whole new package along with the new surface scheme has been tested in long assimilation experiments (INM and FMI).

The Quikscat scatterometer cost function from the KNMI SAF has been implemented in HIRVDA. De-aliasing code with the alternative DAR is being introduced as well, for comparison. KNMI has implemented a near-real time data stream of the data into operations, using the 2D-VAR retrieval.

The work on using ATOVS data has continued. Further work on bias correction and quality control and observation error statistics has been done. EUMETSAT is preparing a rapid delivery service of locally received data for real time data exchange over a large area. Further assimilation experiments have been run. A code for thinning of the ATOVS data has been implemented. Code for use of multiple satellites is ready and being tested. Preparations for the use of (A)TOVS radiances over ice has been done. An impact study has been performed for December 1999 when three deep depressions hit Western Europe. Over the month the impact was neutral, after correcting for a few problems. A definite positive impact was however noted particularly for the 2nd Christmas storm over France. The parallel run at DMI using their two receiving stations has now shown positive impact.

Work on humidities from GPS stations has mainly been organisational, securing funding and data exchange.

There has been further work on determining the error characteristics for Doppler wind data. The background errors in observation space are used for quality control. A radar simulation model has been implemented in Hirlam at FMI and used for validation of precipitation.

3

2.2 Forecast model

The CBR turbulence scheme has been revised and the KNMI length scale formulation introduced in the Reference system. This revision reduces the 10 wind bias significantly and also reduces the low cloud cover in winter somewhat. A further modification to make the scheme conservative by including density variation has been developed and shows small improvements. Unfortunately, the model still tends to show an increasing negative bias of MSL pressure. This bias was shown to be strongly correlated with too slow filling of the lows. Based on arguments of sub-grid scale variations of stability and non-linear effects when averaging and existence of non-resolved gravity waves, extra terms have been added for the stable regime. These terms have been shown to address much of the problem with only small effects on other forecast parameters.

The new surface scheme, ISBA, has now been tested and evaluated extensively and some remaining problems were corrected before implementation into the Reference system. Apart from many assimilations and very long runs evaluating ISBA alone, it has also been tried in combination with the other new developments. The CBR revision and ISBA were tested over 4 periods for the Reference system release. The strong positive impacts on 2m temperatures (and humidity) in the Nordic spring have been confirmed and there are positive or at least neutral impacts for all periods. Further diagnostics are being documented from the long runs of 5-6 months. Work on an alternative snow formulation has progressed further. It uses a separate snow fraction and an additional layer in the ground.

The work towards implementing the Kain-Fritsch convection plus Rasch-Kristjánsson condensation schemes has continued with and a subgroup has perfored coordinated testing. The results show some improvements of cloudiness and humidity but some deterioration of pressure and this is being investigated. Experience will show how much need there is for an optimised version. The Météo-France version may be an alternative, as the code is re-written in a more efficient way.

Further work on Reference condensation/convection STRACO scheme has been carried out to improve properties of the STRACO cloud scheme. The aim was to reduce the overprediction of small precipitation amounts and the parallel runs, that have been made so far, have been quite successful.

Tuning for the HIRLAM system and testing of the Météo-France mesoscale orography (MSO) parametrization scheme has continued. The scheme behaves in the expected way but gives so far overall neutral impact. Still, the drag processes are now treated separately by the turbulence scheme and the MSO scheme in a more correct way. It allows for adequate tuning in the future. It is being prepared for implementation and the climate system has been upgraded to allow for this. A Technical Report has been written.

The inclusion of the ECMWF physics has continued with data assimilation and forecast for a month's period and preliminary results show reduced forecast errors for pressure and 2m temperatures, compared with the pre-ISBA Hirlam surface scheme.

The increased noise in the vertical velocities with long semi-Lagrangian time steps and at 10 km resolution has being documented and investigated. An instability has been shown to occur due to orographic resonance in the temperature equation and this can be cured

by using a constant reference profile (Ritchie-Tanquay method). Another option for the semi-Lagrangian scheme reduces the noise further, to a level which is no different in the Eulerian scheme.

The natural next step on transparent Lateral Boundary Conditions (LBC) work was the setting up of the case of non-linear shallow water equations together with real data. A TR describing results has been published. Results are slightly better than the current Davies scheme when characteristic boundary conditions are applied.

The semi-implicit version of the non-hydrostatic Hirlam has been developed, tested and documented. It improves the economy of the model. Further assimilations have been run at various resolution and indicate stable and rather similar results compared with the hydrostatic version. The non-hydrostatic version has been set up in also in Sweden and Norway and has been run in a number of places now.

Investigations have been done on the effects of Digital Filter Initialisation (DFI), which in some aspects has a damping effect on physical (diabatic) processes. The incremental version does not suffer from this problem.

3 System developments

The Reference system has evolved with a new Reference release and many beta-releases.

A much more efficient I/O scheme for parallel execution was devised first at FMI/CSC and then a more advanced scheme by Jan Boerhout, when at SUN (as presented at the 2001 EWGLAM meeting). This has been developed further and generalised for the various systems (MPI and shared memory segments). It leads to a very significant improvement in performance and will be implemented soon.

The Delayed Mode Runs at ECMWF runs have continued but still remain to be brought under the control of mini-SMS.

The ECMWF Optional Project for Boundary Conditions with short cut-off forecast runs is used by the Hirlam members. The impact has been seen to be fairly small and the Project Leader has raised the question of verification of those forecasts with ECMWF. Such verifications are routinely available from the 00 UTC runs and show the expected results, not quite as good as the late cut-off 4D-VAR, but not so may hours behind. It will be discussed further(with ECMWF).

The latest Reference system releases (5.2) has been very extensively tested for four periods.

Further discussions, about how an overhauled Hirlam system should be, have taken place. A proposition paper about coding standards is available and the ideas for the European cooperation on a common NWP interface are in the announcement for the Météo-France Workshop in May. At this workshop agreements on provision of certain common tools and exchanges were made.

The planned activities of the verification system have now been implemented. These include the field verification, masking tools, new formats, and precipitation verification. A survey of user demands on verification has been done and compiled and developments following the main lines in the responses are taking place.

5

4 Meetings and Publications

- Hirlam singular vector mini-workshop, 19-20 November, SMHI, Norrköping.
- Variational Data Assimilation and remote sensing, 21-23 January 2002, FMI.
- Hirlam All Staff Meeting, 3-5 April 2002, DMI, Copenhagen.
- SRNWP Workshop on NWP system design, 13-15 May, Météo-France, Toulouse.

Reports from the meetings and also one Newsletter have been published:

HIRLAM Newsletter No. 39, October 2001.

SRNWP/HIRLAM workshop on surface processes, turbulence and mountain effects, January 2002.

HIRLAM mini-workshop in singular vectors and alternative methods used for estimation of forecast errors. February 2002.

HIRLAM Newsletter No. 40, February 2002.

HIRLAM workshop on variational data assimilation and remote sensing, March 2002.

The recent Technical Reports are available on the open HEX NET, http://www.knmi.nl/hirlam. During the period, the following ones have appeared:

50. Bent Hansen Sass. Modelling of the time evolution of low tropospheric clouds capped by a stable layer. Norrköping, October, 2001.

51. Günther Haase and Carl Fortelius. Simulation of radar reflectivities using Hirlam forecasts. Norrköping, October, 2001.

52. Magnus Lindskog, Heikki Järvinen and Daniel Michelson. Development of Doppler radar wind data assimilation for the HIRLAM 3D-Var. Norrköping, February, 2002.

53. Xiang-Yu Huang and Xiaohua Yang. A new implementation of digital filtering initialization schemes for HIRLAM. Norrköping, February, 2002.

54. Aidan McDonald. Testing transparent boundary conditions for the shallow water equations in a nested environment. Norrköping, March, 2002.

55. Rein Rõõm and Aarne Männik. Non-hydrostatic adiabatic kernel for HIRLAM. Part III. Semi-implicit Eulerian scheme. Norrköping, August, 2002.

2.5 RC LACE Status Report (Radmila Brozkova)

RC LACE Status Report

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Introduction

The year 2002 is the last year of the common operational application named ALADIN-LACE. Since 01/01/2003 it shall be replaced by the individual operational applications at every RC LACE Member. The focus of the RC LACE cooperation will be shifted to the research and development activities, as described in the Memorandum of Understanding which is under preparation. This Memorandum of Understanding should enter in force in January 2003 for a period of 3 years.

Changes in the operational suite of ALADIN-LACE in 2002

Within 2002 three operational changes took place:

- Increase of vertical resolution from 31 to 37 levels
  This modification followed the change of the vertical resolution in the coupling model ARPEGE, although with not exactly the same number and spacing of the levels. While in the troposphere the vertical levels spacing is almost the same, the high stratospheric levels were avoided in ALADIN-LACE. The reason is that in contrary to ARPEGE, the assimilation of raw radiances is not yet operational in ALADIN, and also that the description of these high levels in the model requires some precautions to avoid associated problems (mainly due to the presence of strong jet-streams, sudden temperature changes etc.). The change to 37 levels had only a weak impact on scores.
- Increase of the temporal resolution of Lateral Boundary Conditions (LBC)
  Since the previous change (increased resolution) required to use a shorter time-step (namely for keeping the stability of the vertical diffusion scheme), the computer cost of the model increased. It allowed to download LBC from ARPEGE with a higher frequency in order to re-balance the speed of computation and transfer of the necessary files. Hence the update frequency of LBC was increased from 6h to 3h. At the same time the quadratic time interpolation of LBC was kept since from the previous case study made on French 1999 storms it comes out that the combination of the 3h LBC frequency with the quadratic interpolation provides as good results as the 1h LBC update frequency. This result was confirmed also for a storm in February 2002 (Danish and German cost). Apart the better performance for the rapid cyclogenesis cases there is almost no impact on the classical scores.
- Physics package CYCORA-TER with some specific modifications
  This physics package known under the name of CYCORA-TER became operational in ARPEGE already in November 2001. ALADIN-LACE did not follow the change due to a negative impact on the screen level temperature scores in the continental winter type of weather. Many tests were made to understand the cause; finally the retuning of mixing length profiles provided more satisfactory results. Beside, in spring 2002 there were a few cases of too intense rain produced by the stratiform rain scheme. As a cure, shear-linked

convection scheme was introduced and tested. The results were mostly improving the precipitation patterns. Finally, a time-smoothing of the shallow convection scheme was introduced. All these changes were tested together in a parallel suite run for winter and summer periods. For both periods the score response was satisfactory.

It should be also mentioned that ALADIN-LACE precipitation forecast was excellent for the August 2002 flood event.

Common R & D on Data Assimilation

The research continued to concentrate on the algorithmic choices for an ALADIN 3DVAR scheme, namely regarding the approach of computing background model error statistics. As a reminder, these errors statistics are computed with help of the so-called NMC method and they are non-separable functions of the wave number (in a double Fourier space) and vertical level index (Berre, 2000). The central idea was how to analyse in ALADIN smaller scales than those analysed by ARPEGE without really modifying the basic result of ARPEGE 4DVAR assimilation. This lead to the development of the blending technique (Brožková et al., 2001) and so called lagged background error statistics (Široká et al., 2001) where the impact of ARPEGE errors is assumed to be eliminated by the constant coupling for forecasts providing the model errors. Thus three schemes were built: i) STANDARD with the classical errors statistics; ii) BLENDVAR where the guess is blended with ARPEGE analysis and then the lagged errors statistics are used to analyse smaller scales; iii) VARBLEND where the order of both operations is reversed with respect to BLENDVAR.

These schemes were compared to each other and also to the blending scheme alone (without the variational analysis step) as well as to the dynamical adaptation approach (when the initial state is simply interpolated from ARPEGE to the ALADIN grid). It should be added that when a 3DVAR or blending schemes were applied, the surface optimum interpolation was applied too for the soil scheme variables.

As a result of this comparison, we may conclude the following:

- the use of the straight (STANDARD) method seems inappropriate for a meso-scale LAM: it may bring in large and imbalanced increments (via the errors statistics) and these statistics do not provide a room for solving the problem of biperiodic projection of the analysis increments;
- Digital Filter Blending (DFB) keeps within the initial state a meso-scale guess from the previous forecast. Even if the meso-scale is not further improved by the use of observations, the beneficial impact on the forecast is visible up to the forecast ranges of 24 hours compared to the dynamical adaptation;
- 3DVAR still improves the blending step: BLENDVAR is better than DFB. For sure, there is a fit to the observations ensured at the initial time but the BLENDVAR solution converges to the DFB solution faster (within about 12 hours) than it is the case for DFB or the dynamical adaptation. The biperiodic projection of analysis increments is also present in BLENDVAR (the formulation of the lagged Jb term has the same geometrical problem) but it is much weaker thanks to smaller horizontal charateristic scales of the structure functions.
- For small domains (like LACE is) the role of lateral boundary conditions at the analysis time is crucial, that is how the boundary conditions are treated within the analysis in order to provide a consistent initial state. The DFB method is one possible

way to treat this problem by achieving both time and space consistency thanks to the application of digital filter.

Besides the upper air analysis algorithm, another piece of work was devoted to the assessment of the order in which the upper-air and surface analysis is treated. Within three options, as the best combination it was found to perform first the upper air analysis, which influences the guess of screen level parameters for the ensuing surface analysis.

Common R & D on Dynamics

Most of the research effort was concentrated on the non-hydrostatic version of ALADIN model. This effort is considerably supported by the EU research grant ALATNET (ALAdin Training NETwork) and it is conducted along two main streams: i) space disctretization issues and bottom boundary condition treatment; ii) stability and precision of the semi-implicit temporal scheme for the compressible model equations.

Regarding the first issue, there is a specific problem in ALADIN when the semi-Lagrangian advection is used for the vertical divergence type of prognostic variable. It is probably linked to the treatment of the bottom boundary condition for the vertical wind component. The problem is characterised by a "chimney pattern" above the mountain which is not present when the Eulerian advection is used. It can be illustrated on a simple case of the potential flow regime in a 2D case:

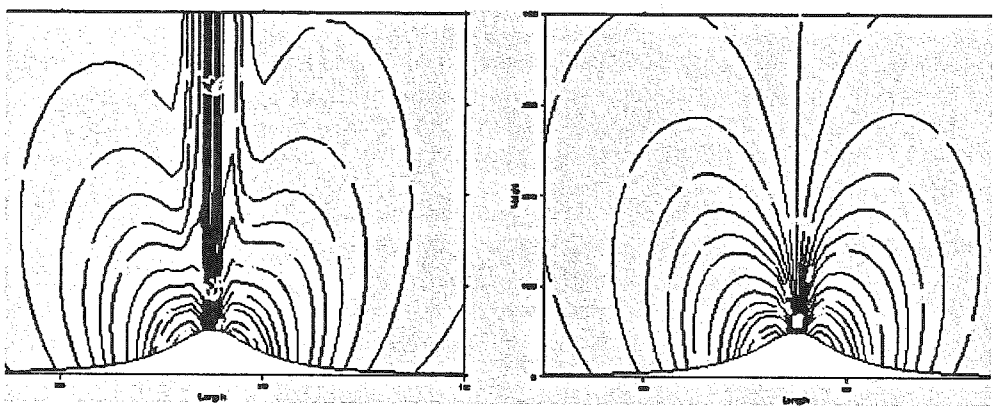

Figure 1: vertical velocity field in a vertical plane model for a potential flow regime; the semi-Lagrangian advection case is on the left picture, the Eulerian advection case is on the right.

It was found (C. Smith, personal communication) that when the advected variable is switched from the vertical divergence type to the vertical wind component w, the correct result (like on the right hand side of Figure 1) is recovered also for the semi-Lagrangian scheme. It should be noted that the change of the prognostic variable to w has several consequences: it considerably simplifies the source term of the vertical momentum equation but on the other hand due to the vertical staggering defined in ALADIN it imposes to perform the advection for the half-level quantity w with associated technical complications. In addition, the change of variable is not trivial for most of the vertical divergence type of variables. Hence, the w scheme provides a good reference but the reason of the chimneys in the vertical divergence

scheme ought to be better understood in order to combine the advantages of both type of formulations.

Regarding the stability of the temporal scheme, there were idealised tests done for recently proposed prognostic variables (for the vertical momentum equation). These variables have impact on the stability properties due to the changes in the linear residuals still explicitely treated in the semi-implicit scheme (there will be soon a comprehensive publication on the stability of the semi-implicit and centered iterated schemes by P. Bénard, P. Smolíková, J. Vivoda and J. Mašek). These tests were made with an increasing difficulty, starting from simple linear flows with a mild mountain and ending with a non-linear non-hydrostatic flow. There are large differences in the stability and unfortunately the quality of results depends also on set-up and tuning of the upper level sponge (J. Mašek, personal communication). The best performance was achieved for the prognostic variable based on w/z according to the linear stability analysis (the original variable is based on w/η). Although the semi-implicit temporal scheme does not provide a really stable solution for any of the prognostic variables, a good choice provides the best conditionner for getting a convergence and increased stability in case of the iterated schemes.

Further a semi-academic test ALPIA was made in order to examine the CFL and Lipschitz criteria in presence of steep mountains. The setup of the experiment was defined according to the SCANIA one (Bubnová, 2000) but using the southeastern Alpian orography (area of the French-Italian border). ALPIA was performed on four nested domains with increasing spatial resolution (10km/30levels, 5km/42levels, 2.5km/60levels, 1.25km/85levels). It was found that the semi-Lagrangian scheme keeps its economical advantage up to the resolution of 1.25km, when at least twice as long time step is applicable for three time level scheme. Hence the Lipschitz criterium is not the most limiting factor when going to fine scales.

Common R & D on physics

There were three small topics worked out on the ARPEGE/ALADIN physics:

- on gustinnes,
  where a scheme which may enhance the flux of heat, moisture and momentum over the sea surface was tested. The goal was that this enhancement is achieved in situations when the flow is rather weak and the vertical exchange is dominated by wind gusts caused by moist convection. First results of the proposed scheme are quite promising (M. Belluš, personal communication).
- on CYCORA TER
  where some modifications were introduced in order to mitigate negative results for winter continental weather as well as for some extreme forecast cases (like too intense cyclogenesis or too heavy precipitations). These modifications (mixing length tuning, shear-linked convection scheme, temporal smoothing of the shallow convection scheme) were introduced to the operational use.
- on diagnosis of the stiffness
  where it was tried to reveal time and space oscillations in the parameterisations. A throughout overview of all potential stiffness or non-linear instability problems in the physics is underway (and a first small "sleeping" bug was discovered within this work). The diagnostics gave also a basis for trying to time-smooth the shallow convection corrective term to Richardson criteria.

Special Events 2002

In LACE countries, the following actions took place:

- Hosting and organising the third ALATNET Seminar on Numerical Methods in Kranjska Gora by the Slovenian NMS (27/5 – 31/5/2002)
- Advanced training on the ARPEGE/ALADIN physics in Prague (16/09-04/10/2002)
- Training on the code maintenance issues in Budapest (25/11-29/11/2002)

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2.6 Unified Model Developments 2002 (Clive Wilson, Sean Milton, Bruce McPherson, Paul Burton)

Unified Model Developments 2002

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Paul Burton
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1 Operational Model changes 2001-2002

	Global Model changes 2001-2002	
G26	16 Oct 2001	3dvar upgrade: Increase Observation errors for AMVs Revise thinning of ATOVS to give preference to microwave-clear over IR-clear Use of fractional sea-ice in ATOVS processing
G27	7 August	New Dynamics and HadAM4 physics
G28	1 Oct	Introduce NOAA17
	Mesoscale Model changes 2002	
M24	7 August	New Dynamics introduced

The major change in model development was the operational implementation of the new dynamics on 7 August in both global and UK mesoscale models and the special crisis area models. For the global model there was also a major revsion in the physical parametrisation package. Most of the physics upgrades had already been included in the UK mesoscale model with the old dynamics, so rather smaller impact was expected in this version.The changes are as follows. There is a new radiation scheme ([Edwards and Slingo 1996]), based on the two-stream equations in both the long-wave and short-wave spectral regions. A new boundary layer scheme has also been introduced into the model ([Lock *et al* 2000]) and allows for non-local mixing in unstable regimes, and a cloud microphysical scheme with prognostic ice has been introduced ([Wilson and Ballard 1999]). The convection scheme is modified to take into account the changes in the boundary layer scheme and also to include a new scheme for shallow convection. The new model takes advantage of the more accurate GLOBE orography dataset and the gravity wave drag scheme has been reformulated and includes a flow blocking scheme.

New Dynamics	(Hadam4)Physics
Semi -Lagrangian advection (With monotone advection of potential temperature)	* Edwards-Slingo Radiation
Semi-implicit time integration	* Mixed phase precipitation Including iterative freezing level
Horizontal staggering - C grid	* New Boundary Layer + 38L
Vertical Staggering - Charney Philips	* MOSES II
Non-hydrostatic formulation	* Effective area cloud fraction Vertical gradient cloud fraction
	New physics compared to current operational
Lateral boundaries (8 points -5 outer global)	Orography -smoothed (Raymond e=1) Lateral boundaries 6 global, 10 point linear transition to mesoscale
	Convection CAPE closure, 30 min timescale Momentum transport
	New Gravity wave drag
	Visibility in snow correction
	*=already implemented in mesoscale model

A comprehensive set of trials have been carried out over the 4 seasons to compare the performance of the new model (NM) to that of the current operational global NWP model (OP). In general the NH RMS errors against observations in the NM have been reduced versus the OP model by up to 5%. (Figure 1). The SH hemisphere errors in Mar-Apr are somewhat worse than the old dynamics. This has since been alleviated by correctly using the background pressures interpolated to the observation time of ATOVS in the observation processing system for the 3dvar analysis. A full correction for proper time interpolation for all observation types will be implemented in December

Figure 2 shows the NH mean sea-level pressure and Tropical 250hPa vector wind errors as a times series through the implementation.There is clearly an improvement in pressure and a relative worsening in the winds since the introduction of the new dynamics. However the variance of tropical winds is maintained through the forecast better than the old dynamics did and tropical cyclone intensity is also better retained (eg Typhoon Phanfone Figure 3).

A real time parallel trial of the mesoscale model showed in general a small and neutral impact on forecasts. The screen temperature and humidity were

significantly improved with a lessening of the cold and overmoist biases. The underforecasting of the 10m wind strength over the UK is also reduced . Precipitation was worse however , with a larger bias and worse equitable threat score (ETS) especially the first few hours of the forecast (Figure 4). The nudging of satellite cloud data from the MOPS system has been found to be partly resposible for the degradation and a revised specification of background error covariance along with reduced nudging improves the precipitation forecasts (Figure 5). This change will be introduced operationally in December.

2 Plans

Immediate plans for 2003 include changing the stratospheric model to use the new dynamics and further model and data assimilation upgrades to the global and mesoscale models to improve on the intial implementation of new dynamics.

A new European area mesoscale model (Figure 6) will be introduced by the end of the year (in pre-operational mode) run between the global forecasts to day 2 and days 2-6 (Figure 7) The resolution will be 20km initially with a target of ~10km after relocation to Exeter and the acceptance of the new NEC SX6 supercomputer, which will have 30 nodes of 8 cpus each sharing 64Gbyte memory. This will give an enhancement of ~6 times the current T3Es. A single node version of the SX6 will be installed at Bracknell in November 2002 and will be increased to 4 nodes in Spring 2003 for porting of the operational models. Two resilient 15 node systems wil be installed in the new headquarters and operations centre in Exeter in summer 2003. In 2005 a further upgrade with a further 15 nodes of twice as powerful cpus will double the capability to ~ 12.5 times the current supercomputing power.

A 4dvar system has been successfully trialled at low resolution with encouraging results. A practicabel global synoptic scale system should be ready for pre-operational trials by end of 2003 on the NEC SX6. Physical processes should be included for an operational implementation in 2004. The increased power should also allow for better vertical resolution ~50 levels and a global resolution of ~40km. New schemes for both convection and prognostic cloud and cloud condensate are being developed.

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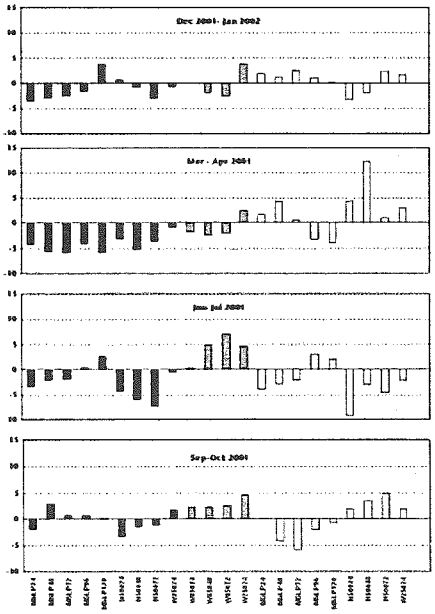

Figure 1: Bars show the %change in RMSE (NDHadAM4 - OP) for the components, which make up the NWP index. Verification is against observations. Black signifies Northern Hemisphere, grey the Tropics and clear is the Southern Hemisphere. A negative value implies NDHadAM4 is an improvement over OP.

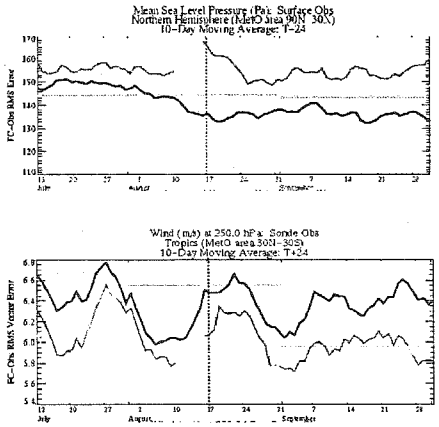

Figure 2: Rms errors of T+24 forecasts Mean sea-level pressure NH (top) and tropical vector winds at 250hPa (bottom) for MetO-black, ECMWF-light grey, NCEP-grey

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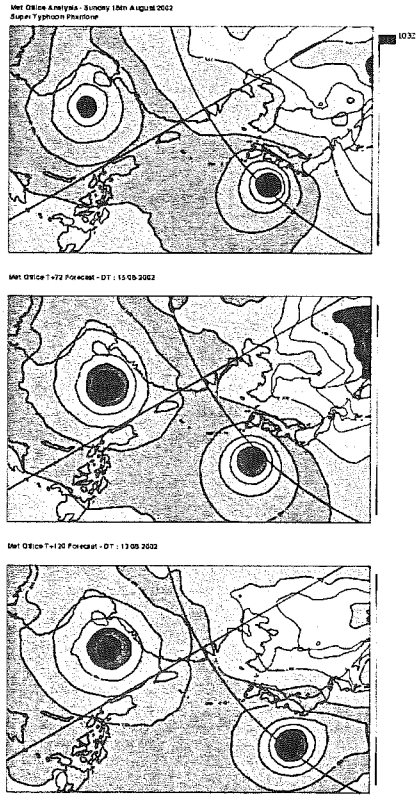

Figure 3: Analysis , T+72 and T+120 forecasts of TC phanfone, valid 12Z 18 August 2002

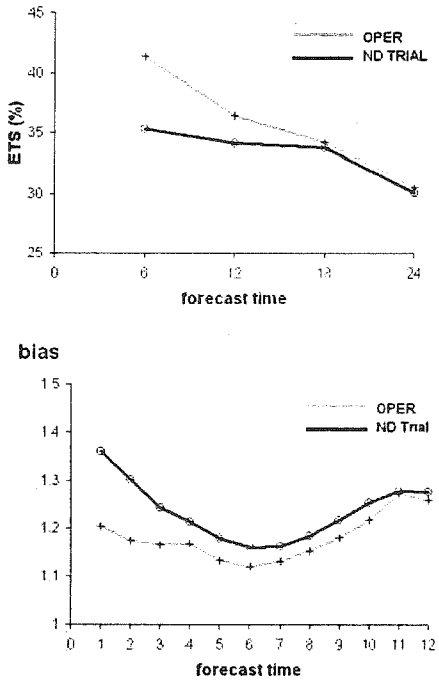

Figure 4: Equitable threat and bias scores from parallel suite (Dec01-Mar02) for New Dynamics (ND) and operational. Verification against Nimrod radar composites.

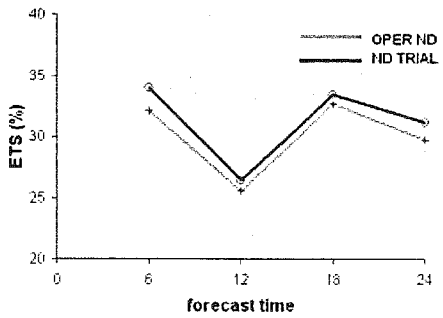

Figure 5: Equitable threat scores from 24 case studies for weaker nudging of cloud data and revised covariances. Verification against Nimrod radar composites.

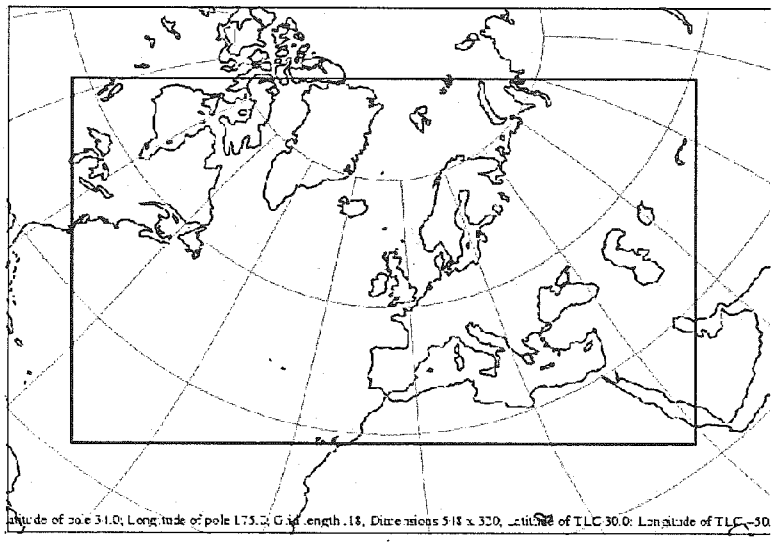

Figure 6: Proposed domain of European model

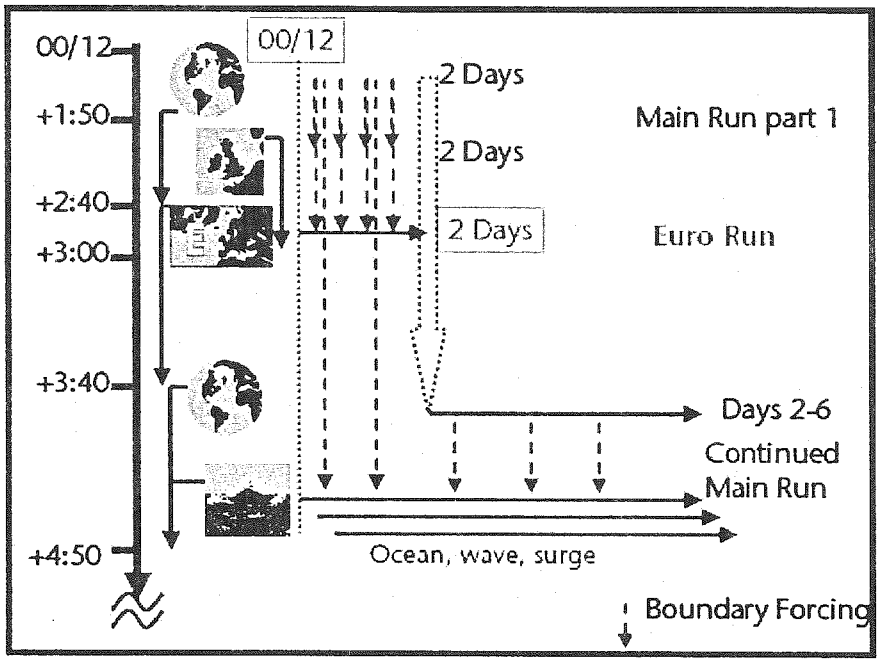

Figure 7: Proposed ne operational schedule

3. National reports

3.1 LAM activities in Austria (Thomas Haiden)

LAM ACTIVITIES IN AUSTRIA

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1. Operational changes

The Austrian version ALADIN-VIENNA of the spectral limited area model ALADIN is run on a Central European domain with 133x117 gridpoints, and a horizontal resolution of 9.6 km. The model is run in hydrostatic mode. The coupling model is ALADIN-LACE. In 2002, the main operational changes were an increase of the number of levels from 31 to 37 (following ALADIN-LACE), and a switch from AL11 to AL12 at the beginning of the year, and a further switch to AL15 in September. Among other things, the newer ALADIN versions contain successive modifications to the vertical diffusion, deep convection, and radiation schemes, the so-called CYCORA changes. Those changes were motivated to a large part by the necessity to improve the cyclogenetic activity without causing negative effects in the representation of the stable PBL, notably inversions.

The operational computing platform was changed from a single-processor DECalpha to an SGI Origin 3400 with 20 processors. This reduced the time needed for an 48-hr integration of the ALADIN-VIENNA domain from 2.5 h to ~10 min.

2. Research and applications

As part of COST Action 722, ZAMG is investigating the problem of low stratus forecasts in the ALADIN model. Using 1-d and 3-d simulations, it was found that the main reason for the systematic underestimation of low stratus in the model is the too smooth representation of the inversions capping the cloud layer. Specifically, the cold temperatures just below the inversion are not simulated and as a result the (diagnostic) cloud scheme underestimates cloud cover. It was also found that when the integration in the 1-d model is started with the observed sounding instead of the strongly smoothed analysis, the model is able to keep the sharpness of the inversion, even for +24 hrs. Some case studies were also performed with a modified stratiform cloudiness scheme, which showed a generally positive impact (Seidl and Kann, 2002).

Further tests of the Gerard prognostic convection scheme were performed during the summer of 2002. Comparison of predicted rainfall patterns with radar data over the Alps show that the more selective character of the prognostic scheme compared to the reference one brings the model results somewhat closer to observations in many cases (Greilberger, 2002).

Since 1999, ZAMG produces areal precipitation forecasts for hydrological purposes for a number of catchment-type areas in Austria and southern

Germany. The number of areas has been increased from 26 to 34 in 2002. Four different models are used: ECMWF, ALADIN-LACE, ALADIN-VIENNA, and a PPM using ECMWF input. In response to the Aug 2002 floods, an experimental precipitation warning system based on these forecasts is being tested. The performance of ALADIN during the August 2002 floods was quite satisfactory in the Austrian area, for both the 6-8 August event and the 12-14 August event. The intensity, region of heaviest rainfall, and approximate duration of the events was predicted well, up to the end of the forecast range (+48 hrs).

As part of the VTMX (Vertical Transport and Mixing) experiment, research on katabatic flows (Haiden and Whiteman, 2002; Zhong et al., 2002) and on the role of the nonhydrostatic pressure field in the slope wind layer was carried out (Haiden, 2003).

3. Verification

Starting in 2002, ZAMG issues bi-annual NWP verification reports which contain a comparative evaluation of standard scores of surface parameters from different models (ECMWF, ALADIN, PPM). Issue #2 also shows the heaviest precipitation events forecasted by ALADIN-VIENNA for individual catchments during the last 3 years in comparison with the heaviest observed events. This analysis confirms earlier results showing that the northern Alpine upslope precipitation belt is the area with the highest predictability of strong precipitation. Southern Alpine upslope areas within Austria are less skillfully predicted, apparently because of complications due to upstream mountain ranges in Italy and Slovenia. Heavy precipitation events in lowland areas are predicted least reliably, mostly because they usually have a stronger convective component.

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3.2 National status report of Aladin Research at IRM-KMI (Luc Gerard)

National status report of Aladin Research at IRM-KMI

Luc Gerard

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The Royal Meteorological institute of Belgium is presently running the Aladin Model twice a day, producing 48h forecast over a domain of 97x97 grid boxes of 7 km horizontally, and 41 hybrid vertical levels.
The version 12 of Aladin is still the operational one on our SGI Origin 3000, since the double chain with Aladin 15 produced some bad precipitation forecasts – probably linked to unsuitable tuning for the highest resolutions. The model takes its initial state and boundary conditions from Aladin France and Arpège.

Parallelly, Aladin 12 and 15 are run on Linux PCs, for research purposes.

In 2002, there were 7 persons (including 2 post-docs in the Alatnet network) doing research on the model, each having his/her own topic.
Main research fields are convection and cloud water, boundary layer (TKE), Physics-Dynamics interface, coupling, use of wavelets in variational assimilation, local implementation of optimal interpolation assimilation.

The poster presented some recent results:

- Wavelet representation of Background error covariance
- Developments around cloud water and prognostic convection
- Predicting peaks of pollution with Aladin

A4 copies of the poster are available on request.

3.3 NWP with ALADIN at Croatian Meteorological Service (Stjepan Ivatek-Sahdan et al.)

NWP with ALADIN at Croatian Meteorological Service, October 2002

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In the Croatian meteorological service ALADIN is operationally run twice a day, for 00 and 12 UTC. Coupling files are retrieved from Vienna to the *lahor* machine. The lancelot (ee927) and the integration (e001) are done on the new SGI machine *mrcina*. The post-processing is done in-line. The e001 runs on 10 processors while the ee927 runs on one. After the main forecast integration on the Croatian HRv8 domain with an 8 km resolution is finished, the surface wind field is dynamically adapted to orography on the 5 domains with 2 km resolution that cover the coastal part of Croatia: the Senj, Karlovac, Maslenica, Split and Dubrovnik domains. The ee927 and e001 for dynamical adaptation run sequentially for each output historical files, using one processor per domain. The historical output files from the main integration and the dynamical adaptations are retrieved from *mrcina* to one LINUX PC during integration. The production of grib files, the visualisation of numerous meteorological fields and the production of pseudo-TEMPs are made on this linux PC. The pseudo-TEMP messages are transferred on another LINUX PC where HRID meteorological diagrams are done for 54 points. The products are available on the Intranet & Internet.
The Croatian HRv8 domain consist of 144x120 grid-points (127x109) with an 8 km horizontal resolution and 37 vertical levels. The dynamical adaptation domains - Senj, Karlovac, Maslenica, Split and Dubrovnik, with a 2 km grid consist of 80x80 (72x72) grid-points, 15 levels.

Computer environment, integration and visualisation of the products

Main computer is SGI ORIGIN 3400 with 16 x 400 MHz IP35 Processors. Main memory size: 6144 Mbytes, OS IRIX 6.5.
For visualisation 2 HP KAYAK i686 computers are used with 2 x 667 MHz Processors. Main memory size: 2 x 128 Mbytes. OS Red Hat LINUX 6.2 Kernel 2.2.16.
Download of the LBC files for 00 UTC run starts at 3:25 UTC and usually finishes at 4:32 UTC, integration starts at 3:30 UTC and finishes at 4:38 UTC and the dynamical adaptation starts at 4:40 UTC finishes at 4:58 UTC. Visualisation for 00 UTC run starts at 3:50 and finishes at 5:10 UTC
Download of the LBC files for 12 UTC run starts at 15:48 UTC and usually finishes at 16:49 UTC, integration starts at 15:55 UTC and finishes at 16:55 UTC and the dynamical adaptation starts at 16:57UTC finishes at 17:18 UTC. Visualisation for 12 UTC run starts at 15:50 and finishes at 17:30 UTC

CAPE from Radio Sounding Data & ALADIN PSEUDOTEMPs

Comparisons of convective available potential energy (CAPE) calculated from radio sounding data from Zagreb-Maksimir with CAPE calculated from prognostic ALADIN/LACE pseudo-TEMPs were done for 00 & 12 UTC runs. When surface values of pressure, temperature and specific humidity of PSEUDOTEMPs were replaced with measured values for the same term a very good agreement between CAPE calculated from PSEUDOTEMPs and that from radio soundings is achieved. A very good forecast for CAPE were achieved, even for 48 hours in advance. More details kovacic@cirus.dhz.hr.

The surface wind field and dynamical adaptation of the wind field for the lower troposphere

The wind field in lower troposphere from the operational integration with 8 km horizontal resolution is dynamically adapted to sub-domain with a 2 km resolution. This procedure is very useful for the coastal parts of Croatia due to the complex local terrain. For the new highway, a special study was made. Few hours before 16th of December 2001 18 UTC a maximum wind speed for that month was measured (10-min mean 33.2 m/s, wind gust 65.5 m/s) on a Maslenica bridge (44.23°,15.52°).
Maximum forecasted wind speed for 16th of December 2001 18 UTC, in HRv8 domain with 8 km resolution was 21 m/s. In Maslenica domain with 2 km resolution 34 m/s was forecasted.

3.4 Operational DMI-HIRLAM system (Bent H. Sass)

Danish Meteorological Institute

Operational DMI-HIRLAM System

Fig. 1

The operational system consists of four nested models named "G", "N", "E" and "D". The model areas are shown in Fig.1. The system setup of the models with respect to resolution, time step, boundaries and data assimilation is illustrated in the table. The boundary files for model "G" are the latest available from ECMWF. The model "G" provides the lateral boundaries of models "N" and "E". Finally, model "E" supplies the boundaries for the very high resolution model "D" around Denmark.

Data-assimilation

i) Variational data-assimilation (3D-VAR) is implemented for models "G", "E" and "N".

ii) An analysis increment method is used for model "D" (see below).

iii) The initial states of the DMI forecasts are produced by analyses valid at 00 UTC, 06 UTC, 12 UTC and 18 UTC, respectively. The analysis states at 00 UTC and 12 UTC are potentially more accurate than the analyses at 06 UTC and 18 UTC. This is achieved by retrospective analysis cycles twice a day (see below). The first guess of the analyses at 00 UTC and 12 UTC is a 3 hour forecast while a 6 hour forecast is used as input to the analyses valid at 06 UTC and 18 UTC. Forecasts with the models "N" and "D" are run only twice a day from the 00 UTC and 12 UTC analyses.

iv) Retrospective analysis cycles.

Assimilation runs with a cycling of 3 hours are managed as a sequence of runs twice a day in delayed mode. The first series of runs starts around 11 UTC. Model "G" starts from the 00 UTC ECMWF analysis data prepared by an increment method where the available analysis for "G" is interpolated to a mesh with coarser resolution ECMWF data (a factor of 4 in resolution difference). The difference between this interpolated field and the new ECMWF analysis is an increment ('large scale increment') which is interpolated back to the HIRLAM field and added to get an updated HIRLAM analysis. Normal HIRLAM 3D-VAR cycles then follow immediately after (analyses valid at 03 UTC, 06 UTC, 09 UTC) to produce an 'up-to-date' state of the atmosphere. The second series of runs are made in the evening, using 12 UTC ECMWF analysis data in the processing. These cycles produce 3D-VAR analyses valid at 15 UTC, 18 UTC and 21 UTC, respectively.

The analyses and forecasts produced in the assimilation cycles of model "G" are used as boundaries for the corresponding 3 hourly cycles of the models "E" and "N". These are also run as sequences in the late morning and evening. The boundary age during data assimilation cycles for these models is either 0 hours, or -3 hours if an analysed boundary from the host model ("G") is available.

v) An analysis increment method as described above is implemented for model "D". In this case the first guess of model "D" is corrected using analyses from model "E". This method also applies to the 3 hourly cycles of model "D".

Physics

The parameterizations of radiation, condensation, convection, turbulence and surface processes are developed in collaboration with the international HIRLAM project (see DMI Tech. Rep. 02-05).

Coupling between dynamics and physics

Long physics time steps

Forcing of physics with time averaged dynamics tendencies determined from "leap-frog" substeps

Final iteration step included to recalculate surface fluxes and turbulence after a preliminary update of the new model state.

The operational DMI-HIRLAM Forecasting System (1 October 2002) is outlined below. A more detailed description is available in the DMI Technical Report 02-05 (available at www.dmi.dk).

Model Identification	G	N	E	D
grid points (mlon)	202	194	272	182
grid points (mlat)	190	210	282	170
number of vertical	31	31	31	31
horisontal resolution	0.45°	0.15°	0.15°	0.05°
resolution (assimilation)	0.45°	0.45°	0.45°	-
time step (dynamics)	240s	100s	100s	36s
time step (physics)	720s	600s	600s	216s
host model	ECMWF	G	G	E
boundary age (forecast)	6h	0h	0h	0h
boundary age	0h - 6h	-3h - 0h	-3h - 0h	-3h - 0h
boundary update cycle	3h	1h	1h	1h
data assimilation cycle	3h	3h	3h	3h
forecast length (long)	60h	36h	54h	36h
long forecasts per day	4	2	4	2

The table shows parameters related to model resolution, time stepping, boundary coupling and data-assimilation. Also length and frequency of forecast runs are provided.

Since September 2002 the operational DMI-HIRLAM system is run on a NEC-SX6 supercomputer which replaces the previous NEC-SX4 computer. The available computer power will increase by an order of magnitude in the coming years.

The lateral boundary conditions and observations are processed on two 4 processor ORIGIN 200 computers. The boundary conditions are received from ECMWF in the form of frames four times a day, valid for DMI-HIRLAM-G. The ORIGIN computers also contain an on-line database and take care of archiving on a mass storage device.

Severe Precipitation events

Several severe precipitation cases over Europe in 2002 have been studied with DMI-HIRLAM. A revised convection scheme (STRACO-021) has in general produced realistic results. The modifications comprise changes to the convective cloud model, the subgrid scale condensation and the microphysics (DMI Technical Rep. 02-10).

Two precipitation forecasts obtained with the new convection scheme are presented. The first case, the "Elben 2002" case covers the precipitation from 06 UTC -18 UTC on 12 August 2002. Figure 3 shows the observed 12 hour accumulations of precipitation in the area of interest. Large precipitation amounts of 50 -100 mm, locally more, occur in parts of the Eastern Germany, in the Check Republic and Austria. Figure 2 shows the results of a DMI-HIRLAM test run using a horizontal resolution of 0.10° and 31 vertical levels. The forecast range is +30 hours, showing accumulated precipitation from +18 hours to +30 hours. The peak value of 86 mm occurs at a location in Austria where a similar precipitation amount has been recorded. The model predicted area with 50 -75 mm also occurs in a region across the border between Germany and the Check Rep. where large accumulations are observed.

Finally, figure 4 shows a 24 hour forecast of precipitation for the Rhone valley in the south-eastern France at 06 UTC on 9 September 2002. The accumulation applies to the last 12 hours of the forecast. The model resolution is 0.15° with 31 levels in the vertical. On this day very large precipitation amounts were recorded in the Rhone valley. The locally observed maxima of accumulated precipitation amount to more than 400 mm in an area approximately between 44.0°N and 44.2°N and at 3.9°E - 4.3°E. The location of the forecasted extreme precipitation (almost 200 mm in 12 hours) is somewhat too far north. The earlier 36 hour forecast verifying at the same time shows similar precipitation amounts. The forecast 2002090818+12h gives a more correct position of the precipitation maximum further to the south. Note that the extreme precipitation amounts are forecasted in flat terrain and not on mountain slopes.

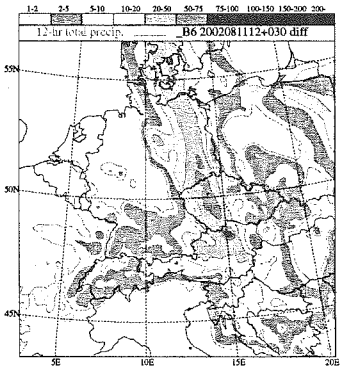

Fig. 2

Forecasted precipitation 18h - 30h on 12 August 2002 using a model resolution of 0.10°.

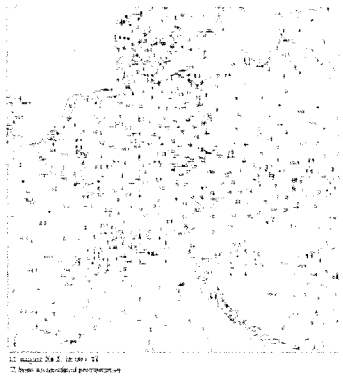

Fig. 3

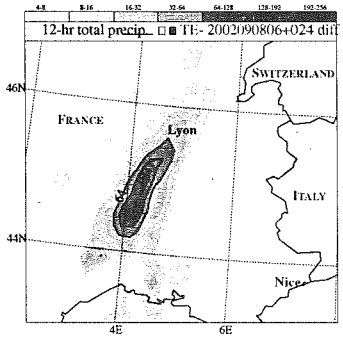

Fig. 4

Forecasted accumulated precipitation 12h - 24h with a DMI-HIRLAM test version (0.15°, 31 levels) using modified convection scheme.

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3.5 Operational NWP Activities at the Finnish Meteorological Institute in 2002 (Carl Fortelius and Kalle Eerola)

Operational NWP activities at the Finnish Meteorological Institute in 2002

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Finnish Meteorological Institute, carl.fortelius@fmi.fi

1 Introduction

The present operational NWP system at the Finnish Meteorological Institute (FMI) is based on the HIRLAM version 4.6.2 and has been implemented into operational use 15 November 1999. The technical environment and the differences from the reference HIRLAM 4.6.2 are described by Eerola (2000). The later status and modifications are described in the reports Eerola (2001) and Eerola (2002). The operational system has been kept fixed during the year 2002 and available resources have been directed towards implementing a substantially revised system in a new computing environment. Here we give a short technical and meteorological description of the current system and present a few features of special interest.

2 Technical environment

The co-operation between the Finnish Meteorological Institute (FMI) and the Center for Scientific Computing (CSC) has made it possible for FMI to run the operational HIRLAM system on the most powerful computers available in Finland.

The main computing facility for HIRLAM is still the T3E system, but an identical system has been implemented on the SGI Origin 2000 for backup purposes.Work is going on to replace T3E with a new IBM eServer cluster 1600 before the end of November 2002. The System Monitor Scheduler (SMS), developed at ECMWF, controls all the jobs and takes care of scheduling and dependencies between Hirlam jobs as well as all operational tasks at FMI.

On T3E the outer ATA suite (described below) is ready about 40 minutes after the cutoff time and the inner ENO suite is ready about 90 minutes after the cutoff time.

3 Meteorological setup

The meteorological setup contains two suites, ATA suite and ENO suite. Except area and resolution and related features the two suites are rather similar. The integration area of the Atlantic suite (ATA) contains Europe, North Atlantic and parts of North America

and the resolution is 0.4°. The European suite (ENO) is run on a smaller area containing mainly North Europe and the resolution is 0.2°. On both suites the number of vertical levels is 31. The horizontal areas of the two suites are shown Figure 1.

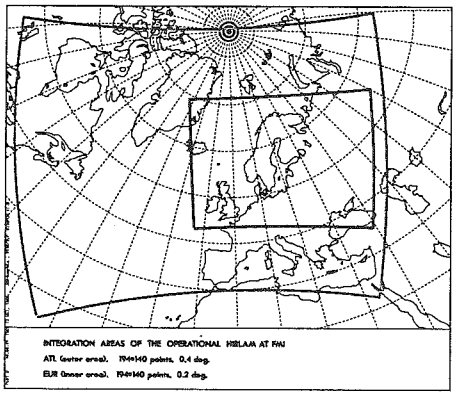

Figure 1: The integration areas of the operational HIRLAM at FMI.

Both suites, ATA and ENO, are run four times a day and the forecast length is 54 hours. This was the users' request to get an effective forecast length of two days in the end-products. The forecasts are available, both on model and pressure levels, at the frequency of one hour.

4 Special features of the FMI system

The HIRLAM-suites provide input for the advanced particle dispersion model SILAM, developed together with VTT Technical Research Centre of Finland (Valkama et al., 2000). It can be used to predict trajectories of harmful substances released into the atmosphere, and contains a module for computing dose rates of harmful radiation. SILAM can be activated to compute the dispersion of releases at any time anywhere within its domain, but the dispersion of particles released continuously at five locations corresponding to nuclear power plants in or near Finland are computed automatically every cycle.

There is a close cooperation between FMI and the Finnish Marine Research Institute (FIMR), extending to operational activities. A dynamically coupled wave-model (Järvenoja, 2002) has been developed together, and is now part of the ENO-suite. It provides forecasts of wave height and direction of propagation, and is operated mainly for the benefit of shipping and authorities. Parallel tests have shown the meteorological impact of the wave-model to be rather modest, effectively amounting to a reduction of near-surface wind speed in gales and storms.

Three times a week FMI receives from FIMR sea surface temperature and ice data covering the Baltic Sea. The data is provided in digital form and is used in the analysis of surface conditions.

Meteorological monitoring of the HIRLAM products is an important task. In order to detect possible problems, a set of diagnostic products are collected operationally on our internal WWW-pages. At the moment the monitoring window contains the following products:

- The observation coverage maps for every observation type.
- The departure of first guess from analysis for geopotential and wind components on the following pressure levels: 200 hPa, 500 hPa, 925 hPa and 1000 hPa.
- Maps of the following surface fields:
  1. sea surface temperature and the corresponding observations
  2. ice coverage of the sea and corresponding observations
  3. surface temperature
  4. surface moisture
  5. snow depth and the corresponding observations
- The EWGLAM Verification scores of the latest full month.

5 Plans for the future

The T3E system at CSC is beeing replaced by a new supercomputer strategy based on an IBM eServer cluster 1600. The current operational HIRLAM is ported to the new environment and will continue to be used until a new, substantially revised system is ready.

The next NWP-system will be based on HIRLAM version 5.2. Statistical interpolation will be abandoned in favour of a 3DVAR scheme in the analysis of upper-air fields, and the surface analysis will include screen-level temperature. The currently-used normal mode initialization will be replaced by a digital filter. Important new features of the forecast model will be semi-Lagrangean dynamics and the new ISBA surface scheme. The new model domain will cover the area of the present ATA-suite on 40 levels with a horizontal grid spacing of 0.3^o.

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3.6 Operational ALADIN models at Météo-France (Dominique Giard)

Operational ALADIN models at Météo-France

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A. PRESENT CONFIGURATION *(october 2002)*

ALADIN-France ("ALADIN-Métropole")

Running in dynamical adaptation mode :

- digital filter initialization + short-range forecast
- 4 runs a day, up to 48h, 42h, 36h, 30h at 00, 06, 12, 18 UTC respectively
- initial and boundary conditions from ARPEGE (- Métropole)
  tilted and stretched grid, average mesh-size over France : 20 km
- synchronous 3h-coupling
- post-processing every 3h
- providing coupling files for ALADIN - Belgium, every 3h

Geometry :

- mesh-size : 9.5 km
- spectral resolution : E149 × 149 (linear)
- gridpoints : 288 × 288 (including the extension zone, 11 gridpoints wide)
- vertical levels : 41
- corners : *SE* → [33.14°N; 11.84°W], *NE* → [56.96°N; 25.07°E]

(using 1 or 2 processors on Fujitsu VPP5000, CPU time /day : 6.2 h)

Pre-operational applications :

- parallel suites : 1 run per day (from 00 UTC, up to 48h)
- hourly diagnostic analyses for nowcasting (only every 3h in winter)
- *"soon" : blending suite, with a 6h cycling*

ALADIN-Réunion (new !)

Running in dynamical adaptation mode :

- digital filter initialization + forecast
- 1 run per day : from 00 UTC, up to 72h
- initial and boundary conditions from ARPEGE - Tropiques
  regular grid, mesh-size : 67 km
- synchronous 6h-coupling
- post-processing every 6h

Geometry :

- mesh-size : 33.4 km
- spectral resolution : E63 × 124 (linear)
- gridpoints : 128 × 150 (including the extension zone, 11 gridpoints wide)
- vertical levels : 41
- corners : *SE* → [1.12°S; 29.18°E], *NE* → [36.00°N; 100.41°E]

(using 1 processor on Fujitsu VPP5000, CPU time /day : 0.4 h)

B. MAIN CHANGES ALONG THE LAST YEAR

(mainly improvements in physics, increase in vertical and spectral resolutions, ... and debugging)

➢ **11 September 2001 :** ***"New cycles"*** (new libraries, changes in physics)

Cycles 24T1 (ARPEGE), 15 (ALADIN), etc

Avoiding snowfall on warm surfaces :

The distribution of convective/subgrid precipitations between rain and snow is now height-dependent, so as to avoid snowfall when the atmosphere is very warm and the soil simply between 0 °C and +3 °C.

+ changes in data assimilation for ARPEGE (4d-var + O.I.- surface)

➢ **12 November 2001 :** ***"CYCORA-ter"*** (changes in physics and post-processing)

Explicit dependency of deep convection on resolution while still taking into account large-scale precipitations (intermediate between the previous schemes)

No shallow convection allowed without potential moist instability

Improved description of mixing lengths and critical Richardson number

Correction of some inconsistencies in the vertical diffusion and "a few" other bugs in the physics

New post-processing :

-recomputation of diagnostic PBL fields on the target grid

-management of roughness lengths considering the land-sea mask

+ improved SST analysis in ARPEGE

☡ ***: bugs introduction !*** (in vertical diffusion)

➢ **6 December 2001 :** ***"Bug correction in ARPEGE"*** *(correction of a bug introduced on 11/09/2001 in 4d-var)*

➢ **17 January 2002 :** ***"Increase of resolutions"*** (new design of operational suites)

Improved stability and reproducibility of the physics

Retunings

imposed by the changes of resolution

Increase of vertical resolution :

-from 31 to 41 vertical levels

-(highest : from 5 hPa to 1 hPa, lowest : from 20 m to 17 m)

Increase of spectral resolution :

-the grid does not change

-the orography does not change

-the spectral resolution is increased by 50% for prognostic variables ("linear" truncation, also called "linear" grid)

+ *similar changes in ARPEGE and new 4d-var configuration*

☞ : ***bugs introduction !*** (in convection)

➢ **28 March 2002 :** ***"Bug corrections"*** (correction of the bugs introduced on 12/11/2001)

Corrections in the vertical diffusion and anti-fibrillation schemes

Retunings

➢ **14 May 2002 :** ***"Safer physics"*** (a few improvements in physics)

Stronger safety thresholds in the convection scheme

Improved anti-fibrillation scheme :

The vertical variations of the coefficient controlling the anti-fibrillation scheme are limited, with a maximum equal to the value at the lowest level, in order to avoid the previous (sometimes very strong) oscillations

➢ **Tested in ALADIN along summer 2002 :** ***"Convection"*** (improvements and bug corrections)

Correction of a bug introduced on 17/01/02

Better management of situations with dry air in the lowest levels

Time-smoothing of the shallow-convection scheme

Introduction of a "shear-linked" convection

Retunings

➢ **17 September 2002 :** ***"Hourly outputs"*** (up to 12h, for diagnostic analyses)

➢ **Under test :** ***"New observations"*** (*use of new observations in ARPEGE* and changes in post-processing)

3.7 Status Report of the Deutscher Wetterdienst DWD 2001-2002 (G. Doms)

Status Report of the Deutscher Wetterdienst DWD 2001 - 2002

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1. Operational Numerical Weather Prediction System GME and LM

Tab. 1 gives an overview of the operational numerical weather prediction system at the Deutscher Wetterdienst.

Table 1 The numerical weather prediction system at DWD

Model	Domain	D (km)	Layers	GP/layer	Flop/24 h (10^{12})	Initial date (UTC)	Forecast range (h)
GME	global	~ 60	31	~ 164000	7.2	00 12 18	174 174 48
LM	Germany/ surrounding	~ 7	35	~ 106000	25.0	00 12 18	48 48 48

The **Global Model (GME)** uses an icosahedral-hexagonal grid which allows a nearly uniform resolution with less than 20% variation of mesh size over the globe.
The key features of the GME include

- icosahedral-hexagonal grid (**Sadourny et al., 1968**), mesh size between 55 and 65 km, average mesh size ~ 60 km,
- Arakawa A grid, all variables are placed at triangle vertices,
- tangential plane with local spherical coordinate system at each node,
- hybrid vertical coordinate (**Simmons and Burridge, 1981**), 31 layers,
- second order accurate gradient and Laplace operators based on local coordinates and using the 6 (5) surrounding nodes,
- bilinear interpolation using the 3 surrounding nodes,
- biquadratic interpolation using the 12 surrounding nodes,
- prognostic variables: surface pressure, temperature, horizontal wind components, specific water vapour and cloud water contents,
- Eulerian, split semi-implicit (first 5 modes) treatment of surface pressure, temperature, horizontal wind components,
- semi-Lagrangian, positive-definite, monotone advection of water substances,
- three time level, Asselin filtering,
- physical package: adapted from the former operational regional model EM/DM plus the parameterization of sub-grid scale orographic drag by **Lott and Miller, 1997**,
- incremental Digital-Filtering-Initialization by **Lynch, 1997**,
- intermittent 4-d data assimilation based on OI scheme, 6-h cycle.

Detailed descriptions of GME are available in **Majewski (1998)** and **Majewski et al. (2002)**.

The current users of GME data are listed in Tab. 2.

The limited area **Lokal-Modell (LM)** is designed as a flexible tool for forecasts on the meso-ß and on the meso-γ scale as well as for various scientific applications down to grid spacings of about 100 m. For operational NWP, LM is nested within GME on a 325 x 325 grid with 35 layers. The mesh size is 7 km. The LM is based on the primitive hydro-thermodynamical equations describing compressible nonhydrostatic flow in a moist atmosphere without any scale approximations. The continuity equation

is replaced by an equation for the perturbation pressure (respective a height dependent base state) which becomes a prognostic variable besides the three velocity components, temperature, water vapour and cloud water. The set of model equations is formulated in rotated geographical coordinates and a generalized terrain-following vertical coordinate. Spatial discretization is by second order finite differences on a staggered Arakawa-C/Lorenz-grid. For the time integration, three different methods have been implemented:

- a Leapfrog scheme using the Klemp and Wilhelmson time splitting method including extensions proposed by **Skamarock and Klemp (1992)** to solve for the fast modes,
- a two-time level split-explicit scheme proposed by **Wicker and Skamarock (1998)**, and
- a fully 3D implicit scheme treating all pressure and divergence terms implicitly **(Thomas et al., 2000)**.

For more information about LM and its data assimilation system, see separate report on the COSMO-group in this volume.

2. High Performance Computer at DWD

The high performance computer system at DWD is an IBM RS/6000 SP (80 nodes with 16 processors each). The processors (PE: processing elements) are equipped with a 375 MHz CPU (Power3-II). Most of the nodes possess 8 GByte of shared memory, some possess 16 GByte. The peak performance of the total 80-node system (1280 PEs) will be around 2 Teraflop/s. The sustained performance for typical NWP codes on the full system is about 150 Gflops/s.

The operational NWP system, i.e. the

- global icosahedral-hexagonal grid point model GME and its data assimilation suite,
- nonhydrostatic local model LM and its data assimilation suite,
- global sea state model GSM,
- local sea state model LSM,
- Mediterranean sea state model MSM,
- trajectory model TM,
- Lagrangian particle dispersion model LPDM, and
- objective weather interpretation scheme for GME and LM,

is running on 28 nodes, for development 52 nodes are reserved. In the first quarter of 2003, all 80 nodes will be available for operational model runs.

3. International Usage of the HRM and Distributed Regional NWP

A portable version of the former hydrostatic regional model EM/DM of the DWD, called HRM (High resolution Regional Model) is being used by a number of National Meteorological Services (NMS), namely Brazil (NMS in Brasilia and Military Naval Service in Rio de Janeiro), Bulgaria, China (Regional Service of Guangzhou), Israel, Italy, Oman, Poland, Romania, Spain, Switzerland and Vietnam, for regional NWP. HRM is designed for shared memory computers, is written in Fortran90 and uses OpenMP for parallelization. Via the Internet, GME initial and lateral boundary data are sent to the users of the HRM. This enables distributed computation of regional NWP. The DWD starts sending the GME data 2h 55min past 00 and 12 UTC; only the sub-domain covering the region of interest is sent to the NMS in question. Depending on the speed of the Internet, the transmission of the 48-h (78-h) forecast data at 3-hourly intervals (i.e. 17 (27) GRIB1 code files each with a size between 0.3 to 3 MByte depending on the area of the regional domain) takes between 30 minutes to 2 (3) hours. Thus at the receiving NMS the HRM can run in parallel to the GME at DWD using the interpolated GME analysis as initial state and GME forecasts from the same initial analysis as lateral boundary conditions. This is a considerable step forward because up to now most regional NMS have to use 12h "old" lateral boundary data which degrade the regional forecast quality by more than 10%.

Table 2: Current Users of GME Data (September 2001)

Country	Service	Main Application
Brasilia	National Meteorological Service Navy Weather Service	**HRM** **HRM**
Bulgaria	National Meteorological Service	**HRM**
China	Regional Service of Guangzhou	**HRM**
Germany	National Meteorological Service	**LM**
Greece	National Meteorological Service	**LM**
Israel	National Meteorological Service	**HRM**
Italy	Regional Service SMR-ARPA	**LM**
Oman	National Meteorological Service	**HRM**
Poland	National Meteorological Service	**LM**
Romania	National Meteorological Service	**HRM**
Spain	National Meteorological Service	**HRM for LEPS**
Switzerland	National Meteorological Service	**LM**
United Kingdom	National Meteorological Service	**PEPS**
Yugoslavia	National Meteorological Service	**ETA**
Vietnam	National Meteorological Service	**HRM**

4. Planned future developments

The pre-operational trial of the new NWP system consisting of GME with a mesh size of 40 km and 40 layers and LM covering whole of Europe with a mesh size of 7 km and 40 layers will start in December 2002. The operational production of the new NWP system is scheduled for end of 2003.

After a planned upgrade of the IBM RS/6000 SP in 2003, research work will concentrate on a now-casting version of LM, called LMN, for Germany with a mesh size of 2.8 km and 50 layers. LMN will produce 18-h forecasts eight times a day (00, 03, ..., 18, 21 UTC) with a very short data cut-off. The main goal will be the explicit prediction of deep convection by LMN without the need to parameterize this complex process. This step will help to improve detailed local weather forecasts because for the first time an operational NWP model will handle explicitly convective processes and the interaction between the convective scale and larger scales. First case studies performed with LM at such high a resolution proved that the model is able to simulate properly the formation of convective cloud clusters and squall lines.

Of course, the development of this very high-resolution LM requires the solution of many scientific and technical problems in modelling, data assimilation (e.g. usage of radar data) and model interpretation. The COSMO group (Consortium for Small Scale Modelling) with the members Germany, Greece, Italy, Poland and Switzerland is concentrating all its efforts on this difficult task.

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3.8 Limited area modelling activities at the Hungarian Meteorological Service (2001/2002) (András Horányi)

LIMITED AREA MODELLING ACTIVITIES AT THE HUNGARIAN METEOROLOGICAL SERVICE (2001/2002)

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INTRODUCTION

The numerical weather prediction (NWP) group of the Hungarian Meteorological Service (HMS) belongs to the Department of Research and Development. Due to some reorganisation now the Satellite Research Laboratory is also part of the NWP team, so the enlargement of the team had been continued. The main topics of interest are as follows: limited area modelling, ALADIN (5 persons), nowcasting (5 persons), visualisation (3 persons), interpretation of medium-range and seasonal forecasts, ECMWF (2 persons) and automatic forecast generation (1 person). The main topics to be discussed in this report are the achievements related to the ALADIN model. A new homepage of the Department of Research and Development was created, where important information can be read about our activities (for instance also verification results). Please visit http://omsz.met.hu/english/kfo/neo_en.html for more details about numerical weather prediction.

ALADIN EXPLOITATION: ALADIN/LACE and ALADIN/HU

Two versions of the ALADIN model are available in Budapest: ALADIN/LACE regional model (nested in the French ARPEGE global model) version (see more details at the RC LACE international status report) exploited in Prague and ALADIN/HU local version (nested in the ALADIN/LACE model) running in Budapest. The main changes in the ALADIN operational suite were related to the migration of the model to our new computer (IBM Regatta p690 server, more details see below) and to the fact that the number of vertical model levels had been increased from 31 to 37 (for the other features see the Hungarian status report of 1999/2000). Several new configurations are tested with the help of our new computer and going to be introduced operationally in the near future. The SGI ORIGIN 2000 machine is now used entirely for nowcasting purposes (having already 16 500 MHz processors with further memory and disk increase). The ALADIN related research and development work is carried out in Toulouse, Prague and Budapest and detailed later in this report.

MAIN CHARACTERISTICS OF THE REGATTA P690 SERVER

Hereafter the main characteristics of our new IBM server is detailed:

- The machine is the small brother of the machine to be delivered at ECMWF,
- CPU: 32 processors (1,3 GHz),
- Peak performance: 5.2 Gflops/processor,
- 64 Gbyte internal memory,
- 364 Gbyte disk space,
- Loadleveler job scheduler is installed and used for the safe exploitation of the operational model.

RESEARCH AND DEVELOPMENT ACTIVITIES: 3D-VAR

The main research and development topic for the Hungarian Meteorological Service in the ALADIN project is the further development of the three-dimensional variational (3d-var) data assimilation scheme. The main contributions are related to the background error statistics, installation of observational data base (ODB), starting developments for the application of satellite data in the course of 3d-var, search for the best strategy for the cycling, initialisation, coupling of the scheme, assessment of the double nested versus simple nested strategy (see the report of Steluta Alexandru at the same volume).

The new observational data base (ODB) was installed in Toulouse and then at different ALADIN member states. We have actively participated in this action and the new data base system was installed and tested successfully in Budapest.

The discussions inside the ALADIN community had been continued regarding the computation of background error statistics for the ALADIN model. From our side the investigations had been continued for the potential use of constant coupling lagged background error statistics (a variant of the NMC method, when the two forecasts taking part in the computation of the difference fields have exactly the same lateral boundary conditions, thus substracting the large scale effects from the statistics). The main result of the last year that the lagged method can be used only with some limitations for the double-nested domain. The reason behind is that the resolution and domain size difference between the coupling and coupled model is small, which means too strong error variance reduction in the lagged scheme.

Regarding new data sources for 3d-var one of the major development was related to the possible local application of satellite (ATOVS) data in the 3d-var process. The positive impact of ATOVS data in the global model (ARPEGE) was proven, so the activities were related to the mostly technical (until now)

pre-processing and quality control of the data for the limited area. The AAPP software package is used for the pre-prcessing of the HRPT data.

RESEARCH AND DEVELOPMENT ACTIVITIES: LATERAL BOUNDARY CONDITIONS

Important topic of interest for our Service is the lateral boundary (coupling) problem. Our efforts were joined in the framework of the ALATNET project together with the Slovenian, Belgian and Romanian ALADIN team. The main direction of research is to find an alternative method to the Davies relaxation scheme and/or to improve the time interpolation between the available boundary information, especially, when fast propagating small scale weather phenomena are concerned. One candidate for complementing the Davies scheme in a spectral model is the spectral coupling, where the relevant scales are coupled in addition to the physical fields. This investigation is in its early stage, without new original results. As far as the time interpolation problem is concerned first the phase-amplitude decomposition was proposed (see last year's report), however the promising barotropic results were not reproduced in the 3D framework. This year Piet Termonia (from Belgium), while spending 2 months in Budapest gave new inertia to the investigations. His new approach is firstly to find an alternative description for the fast propagating waves based on the experiments for the 1999 Xmas storms, secondly generalise its results and thirdly to propose some a priori diagnostics tool, when one can decide what is the sufficient lateral boundary frequency, which is needed for the given meteorological situation. The cornerstone of the idea is the decomposition of the model state variables into moving and growing parts. Then this decomposition is transformed into spectral space (Fourier transformation) and then using the data of the Xmas storm a functional is derived and minimised in order to ensure the best fit to the real data. Using the traditional linear time interpolation the "dipole problem" appears, while it disappears using the proposed new formulation.

FUTURE PLANS

Very ambitious plans are considered for the future. The main planned changes in the operational ALADIN model version are due to the changes in the LACE project (the centralised model version will disappear). The new ALADIN/HU domain will cover entire Europe with a 6,5 km resolution and will be directly coupled by the ARPEGE global model (the lateral boundary frequency is anticipated for 3 hours). The introduction of the 3d-var data assimilation scheme for the determination of the initial conditions of the model is also in the plans and should be realised in the first half of 2003.

3.9 NWP at Met Éireann - Ireland - 2002 (Jim Hamilton)

NWP at Met Éireann – Ireland – 2002

Introduction

The Hirlam system is used at Met Éireann – the Irish Meteorological Service – to produce operational forecasts out to 48-hours. [Last year the system was ungraded from version 4.3.5 to version 5.0.1, the resolution was enhanced and 3DVAR was added]. The model is run four times per day using an IBM RS/6000 SP with 9 nodes each with 4 processores sharing 2 Gbytes of memory [i.e. a total of 36 CPUs and 18 Gbytes of memory].

Data Assimilation

Observations : SYNOP, SHIP, BUOY, AIREP, AMDAR, ACARS TEMP, TEMP-SHIP, PILOT, SATOB and SATEM observations are used. The data are packed into BUFR format both for storage and for input to Hirlam.

Analysis : Hirlam 3D-Var [3-dimensional variational assimilation]. The analysis runs on 31 hybrid [eta] levels. Upper-air observational data is accepted on all standard and significant levels (10 hPa to 1000 hPa) and interpolated to eta levels.

Assimilation Cycle : Three-hour cycle using the forecast from the previous cycle as a first-guess. [It is also possible to use an ECMWF forecast as a first-guess].

Analysed Variables : Wind components (u,v), geopotential and specific humidity.

Forecast Model

Forecast Model : Hirlam 5.0.1 reference system grid point model.

Horizontal grid : A rotated latitude-longitude grid is used with the South-Pole at (-30° longitude, -30° latitude). Fields are based on a 438x284 grid corresponding to a 0.15^o x 0.15^o horizontal Arakara C-grid.

Vertical Grid : Hybrid [eta] coordinate system with 31 levels.

Initialisation : Digital Filter.

Integration Scheme : We use a two time-level three-dimensional semi-Lagrangian semi-implicit scheme with a time-step of 300 seconds.

Filtering : Fourth order implicit horizontal diffusion.

Physics : CBR vertical diffusion scheme; Sundqvist condensation scheme with the 'STRACO' (Soft TRAnsition COndensation scheme) cloud scheme; Savijarvi radiation scheme.

Lateral Boundary Treatment : Davies-Kallberg relaxation scheme using a cosine dependent relaxation function over a boundary zone of 8-lines. The latest available ECMWF 'frame' files are used [based on 4 ECMWF runs per day at 00Z, 06Z, 12Z and 18Z, respectivly]. ECMWF data is received on a 0.3^o x 0.3^o rotated latitude-longitude grid on a selection of the 60 ECMWF eta levels. The data is interpolated both horizontally and vertically to the Hirlam 0.15^o x 0.15^o rotated latitude-longitude grid on 31 [Hirlam] eta levels. [The selected 0.3^o x 0.3^o grid corresponds to half the resolution of the 0.15^o x 0.15^o grid, the line speed is not sufficient to receive the data at full resolution].

ECMWF Rotated Frame Boundaries : As part of an optional project at ECMWF we receive boundary data data on a rotated latitude-longitude grid defined as a hollow frame. This is used to update the boundary files four times per day.

Data Monitoring

The analysis departures/flags are fed back to the original BUFR reports to create 'feed-back' files which are used to monitor the quality of the data on an ongoing basis and to identify problems [e.g. station elevation errors].

Verification

Verification against Fields : A small number of Hirlam parameters are verified against the corresponding Hirlam analysis fields. [This is to provide continuity with an earlier model which was used before Hirlam became operational].

Verification against Observations : The Hirlam verification system is used to verify forecasts against observations from EGWLAM stations within the area.

Operational Usage

General Forecasting : Hirlam forecasts are used for general forecasting in Met Éireann out to 48-hours. [ECMWF forecasts are used beyond that period]. Hirlam output can

be displayed using an interactive graphics sytem called **xcharts** (developed at Met Éireann).

WAM model : Forecast 10-metre winds from Hirlam are used to drive a WAM wave model.

Roadice Prediction System : Forecast surface parameters [temperature, wind, cloud-cover, humidity and rainfall] are used [after forecaster modification] as input to a roadice model.

SATREP : Hirlam output can be overlaid on satellite plots as part of the ZAMG SATREP analysis scheme.

Nested Hourly Analysis

A separate nested version of Hirlam is run every hour on a dual-processor 500Mhz PC running Linux. The purpose of the run is to provide an hourly analysis and also a short range [3-hour] local forecast.

Forecast Model : Hirlam 4.3 forecast model in conjunction with the Hirlam 4.8 analysis scheme.

Vertical grid : A set of 24 hybrid [eta] levels .

Horizontal grid : A rotated latitude-longitude grid is used with the South-Pole at (-9° longitude, -38° latitude). Fields are based on a 97x98 grid corresponding to 0.15^o x 0.15^o horizontal Arakara C-grid. It is planned to upgrade this system to a finer grid in the near future.

Research Activities

Better specification of boundary conditions for NWP models; 3DVAR; Operational Implementation of a Nested System.

3.10 Italian Meteorological Service Status Report (Massimo Bonavita and Lucio Torrisi)

Italian Meteorological Service Status Report

Massimo Bonavita and Lucio Torrisi
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Hydrostatic Modelling

The main focus of the activities over the past year has been the operational implementation of an intermittent 6-hourly data assimilation cycle for the HRM model over the EURO domain of integration. The main characteristics of the HRM hydrostatic model are summarized in tables 1.1 and 1.2 for the EURO integration domain and the nested MED integration domain.

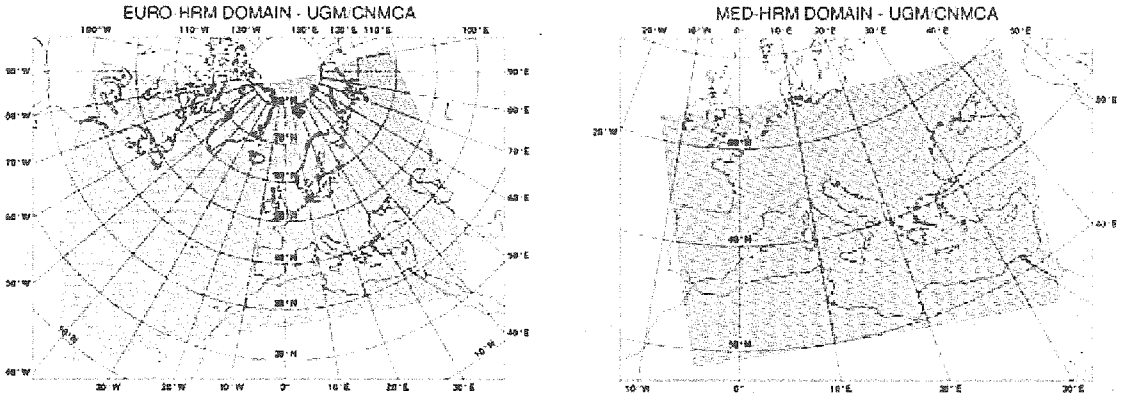

Fig.1 Integration domains for the HRM hydrostatic model

Domain size	181 x 121
Grid spacing	0.5 (56 km)
Number of layers	31
Time step and integration scheme	300 sec , split semi-implicit
Forecast range	72 hrs
Initial time of model run	00/12 UTC
Lateral boundary conditions	IFS
L.B.C. update frequency	3 hrs
Initial state	Statistical Analysis(Z,u,v,RH,Surf .Press.)
Initialization	N.M.I.
External analysis	None
Status	Operational
Hardware	Compaq DS20E
N° of processors used	2

Table 1 Characteristics of EURO-HRM operational implementation

Domain size	151 x 101
Grid spacing	0.25 (28 km)
Number of layers	31
Time step and integration scheme	150 sec , split semi-implicit
Forecast range	48 hrs
Initial time of model run	00/12 UTC
Lateral boundary conditions	IFS
L.B.C. update frequency	1 hrs
Initial state	EURO-HRM
Initialization	N.M.I.
External analysis	None
Status	Operational
Hardware	Compaq DS20E
N° of processors used	2

Table 2 Characteristics of MED-HRM operational implementation

The main features of the objective analysis scheme employed in the data assimilation cycle are:
1. Global solution of analysis equations by direct solver;
2. Analyzed variables: Z,u,v,RH;
3. Geostrophic, quasi non-divergent constraint;
4. Interpolation Statistics from statistical analysis of observation increments.

A flow diagram of the data assimilation cycle is given in Fig. 2.

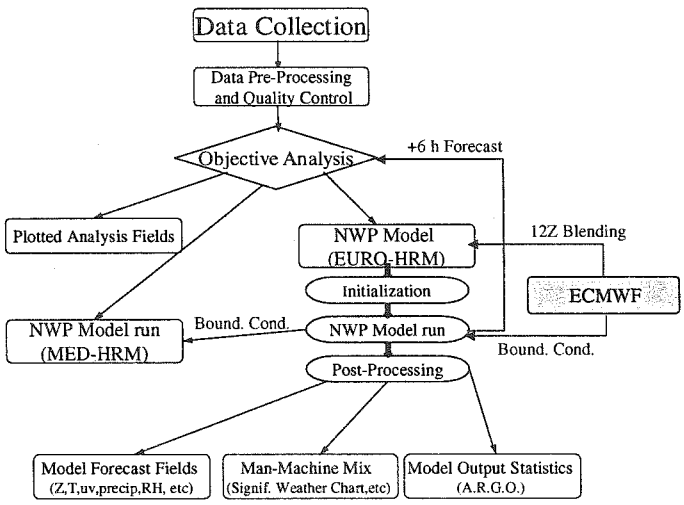

Fig. 2 Flow diagram of the data assimilation cycle

Non-Hydrostatic Modelling

The main features of the operational implementation of the Lokal Model over the Italian domain of integration (LAMI) are summarized in Table 3 and Fig. 3.

Domain size	234 x 272
Grid spacing	0.0625 (7 km)
Number of layers	35
Time step and integration scheme	40 sec . 3 timelevel split-explicit
Forecast range	48 hrs
Initial time of model run	00/12 UTC
Lateral boundary conditions	GME
L.B.C. update frequency	1 hrs
Initial state	GME
Initialization	None
External analysis	None
Special features	Use of filtered topography
Status	Operational
Hardware	IBM SP4 (Bologna)
N° of processors used	32

Table 3 Characteristics of LAMI operational implementation

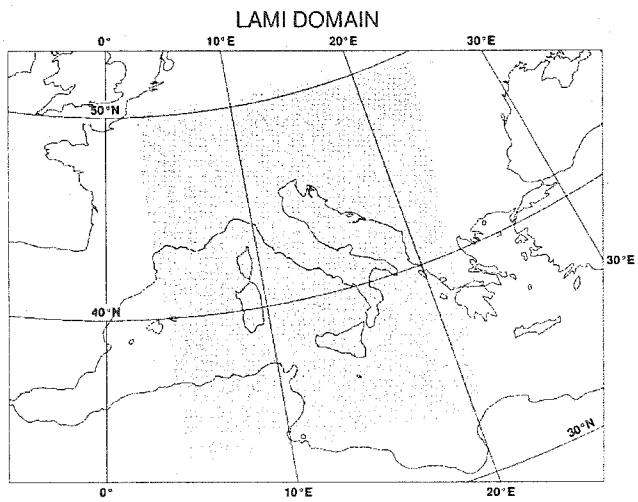

Fig.3 Integration domain for the LM non hydrostatic model.

3.11 NWP at KNMI - The Netherlands - 2002 (Toon Moene)

NWP at KNMI - The Netherlands - 2002

Toon Moene

Introduction

At KNMI the HIRLAM system is used; on the 5th of March 2002 KNMI switched from using version 4.3.4 on a 0.5°x0.5° grid (running on a 12 processor SGI Origin 2000) to using version 5.0.6 on a 0.2°x0.2° grid (running on a 36 processor Sun Fire 15000).

The vertical resolution is 31 layers.

Data Assimilation

The following observation types are used in the optimum interpolation data assimilation step:

SYNOP, SHIP, BUOY, AIREP, AMDAR, TEMP, PILOT and SATOB. These data are converted from their ASCII format as distributed over GTS to BUFR by a KNMI-specific application.

In the summer of 2002 we started the use of BUOY data derived from QuikScat scatterometer data, converted by a KNMI-developed algorithm.

The assimilation cycle has a three hour interval; the analysed variables are wind components (u and v), geopotential and specific humidity.

Forecast

The Forecast model is the 5.0.6 reference system grid point model, with some modifications of later versions to the STRACO scheme.

The horizontal grid has a resolution of 0.2°x0.2° in a rotated coordinate system that has the South Pole at 30° South, 15° West.
The extent of the grid is 406 points along the parallels in the rotated coordinate system and 324 points along the meridians.
The vertical coordinate system is based on the eta coordinate, with 31 levels.

The advection scheme used is the HIRLAM standard two time-level three-dimensional semi-Langrangian advection with a time step of 360 seconds. Filtering is done via a fourth order implicit horizontal diffusion scheme.

Initialisation is done by Digital Filtering using a Hamming filter.

The following physical parametrisations are used:

- CBR turbulent kinetic energy scheme.

- Sundqvist condensation scheme with the STRACO (Soft TRAnsition COndensation) scheme.
- Savijarvi radiation scheme.

Lateral boundaries are forced from 6 hour old ECMWF forecasts, interpolated to a 1.0°x1.0° grid in the same rotated coordinate system. The Davies-Kållberg relaxation scheme is used.

Verification

The standard HIRLAM verification system is run in delayed mode to provide KNMI with verification of the operational HIRLAM system.

Operational Usage

Usage of HIRLAM data is made both by the duty meteorologists, meteorological service providers (commercial entities) as well as various government agencies.

3.12 The implementation of DWD model at IMWM. (Katarzyna Starosta)

THE IMPLEMENTATION OF DWD MODEL AT IMWM.

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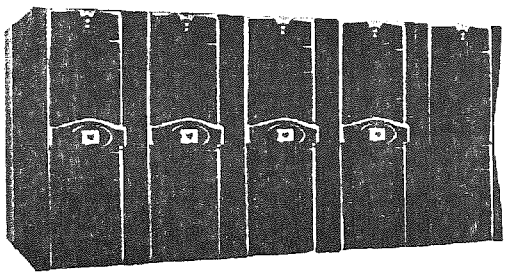
e-mail : Katarzyna.Starosta@imgw.pl

The DWD local model (LM) at IMWM is currently in the phase of 1 year long pre-operational trial. The operational use is planned to start by the end of the year 2002. The model is implemented on SGI ORIGIN 3800 supercomputer configured with 100 R14 RISC processors, 25 GB of memory and estimated performance of 83 GFLOPS. The model code is actually run on 96 processors with the remaining 4 assigned to communication tasks, twice a day at 00 and 12 GMT.

SGI Origin 3800 Origin Supercomputer with the following characteristics

100 x R14K/500MHz CPU
25 GB memory
300 GB of FibreChannel disk space (JBOD)



Location of Domain in rotated and in geographical coordinates.

Domain corners:	λ	ϕ	λ_g	ϕ_g
upper left	-10.0	3.5	-9.98	59.52
upper right	14.0	3.5	37.25	58.17
lower left	-10.0	-16.5	-2.57	40.07
lower right	14.0	-16.5	27.42	39.20

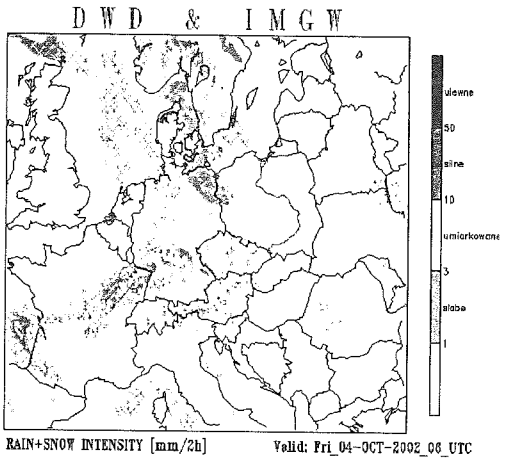
We use the interpolated boundary conditions from the forecast of the global model (GME) of DWD, which are received via the Internet. The forecast cycle takes two runs of the model. The first one uses the domain size of 193x161 gridpoints with grid spacing of 14-km and generates 78 hours forecast in 1.5 hours. The second run covers the domain of 385x321 gridpoints with 7-km grid spacing and produces 30 hours forecast in 3,5 hours.

Configuration at LM in Poland.

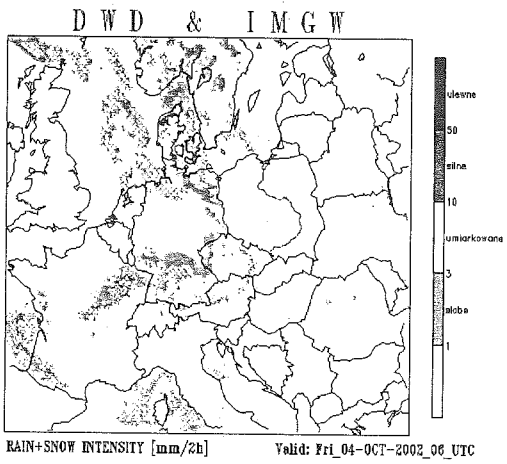
Domain size	193*161 (LM14), 385*321 (LM7)
Horizontal Grid Spacing	0.1250° (~ 14 km) 0.0625 (~ 7 km)
Number of Layers	35, base-state pressure based hybrid
Time Step and	80 sec, 3 time-level split explicit (LM14)
Integration Scheme	40 sec, 3 time-level split explicit (LM7)
Forecast Range	78 h (LM14), 30 h (LM7)
Initial Time of Model Runs	00 UTC, 12 UTC
Lateral Boundary Conditions	Interpolated from GME at 3-h intervals
Initial State	Nuding data assimilatin cycle, no initialization
External Analyses	See surface temperature (00 UTC)
	Snow depth (00,12 UTC)
	Variational soil moisture analysis (12 UTC)
Special Features	Default model version.
Model Version Running	lm.f90 2.12
Hardware	SGI 3800

30 hour precipitation forecast (start 3 October 00 UTC).

14 km grid spacing



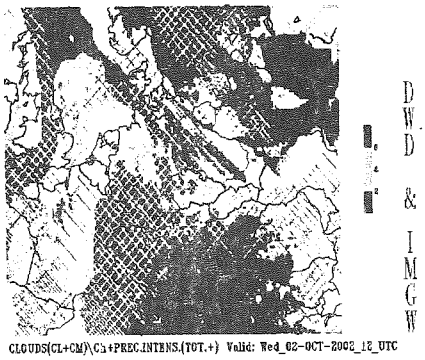
7 km grid spacing.

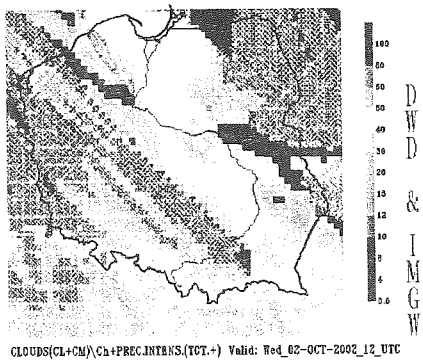


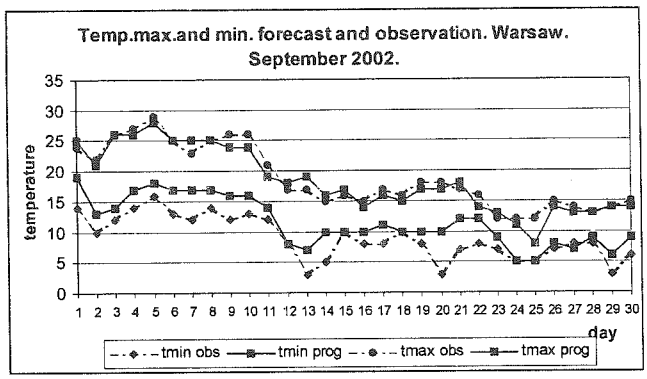
During the post-processing phase the VIS5d software package is used to visualise the selected prognostic fields, which are available to other applications via IMWM Intranet. At the time being the hydrological forecast uses the output of the model as an element of the input data set.

36 hour clouds forecast (start 1 October 00 GMT).

Europe **Poland**







On the 4th of July Poland has signed the COSMO (Consortium for Small-Scale Modelling) Agreement and the Center for Development of Numerical Weather Forecasts was established at IMGW with major tasks of LM development in the area of data assimilation, model code parallelization and applications.

References:
Consortium COSMO for Small-Scall Modelling. Newsletter. No.2. February 2002.

3.13 Limited Area Modelling Activities at Portuguese Meteorological Service (2001-2002) (Maria Monteiro)

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During the mentioned period the main effort has been put on the local maintenance of actual tools and no substantial changes occurred on the operational scheme of ALADIN/ Portugal. A continuous effort is happening on the implementation of an operational objective limited area analysis scheme using CANARI. Human resources have been dedicated to the development and verification activities. Concerning verification two studies were done, the AL12_bf cycle versus AL11T2 cycle and the annual objective verification of ALADIN/ Portugal. Other developments took place on the diagnostic tools, in particular some improvements on the stability indexes. An objective validation of those tools is now being undertaken. On the data assimilation field there was a first trial with CANARI (AL11) for training purposes. Support was given to ocean modelling activities.

Since 24 of April 2000, IM has a Limited Area Model (LAM) running in operational mode. This NWP model is a local installation of the ALADIN model, hereafter called ALADIN/ Portugal model. We refer the main changes:

Apr 2000	cycle AL09
Jun 2000	cycle AL11T2 (CYCORA included)
Jul 2001	cycle AL12_bf02 (CYCORA_bis included)

Maintenance of ALADIN/ Portugal WS actual operational version
Validation and operational installation of CANARY
Validation and operational implementation of diagnostic tools

Computer characteristics

DEC Alpha XP1000 (Compaq), 500MHz, 1 Gb memory
D. UNIX V4.0; DIGITAL F90 and 77 Compiler V5.1, native C Compiler

Model characteristics

Spectral hydrostatic model; hybrid vertical co-ordinates; DF initialisation; semi-implicit semi-Lagrangian two-time-level advection scheme; ISBA surface parametrisation scheme; initial and lateral boundary conditions from the latest ARPEGE forecast; 6 hour coupling frequency from ARPEGE.

Integration domain:

Size: 100x90 points
Number of vertical levels: 31
Horizontal resolution: 12,7 km
Time step: 600 s

Integration frequency: twice a day

Forecast range: 48 hours
Output frequency: 1 hour

Available configurations

001, e927, e923 and 701

Graphical software

The METVIEW/ MAGICS graphical software (ECMWF) is used to display ALADIN/ Portugal products under a development environment. Besides, a user-friendly visualisation tool for PC's was designed to display up to a maximum of three overlapped meteorological fields coming from the last two operational runs of the model.

(info: Margarida.Belo@meteo.pt & Manuel.Lopes@meteo.pt)

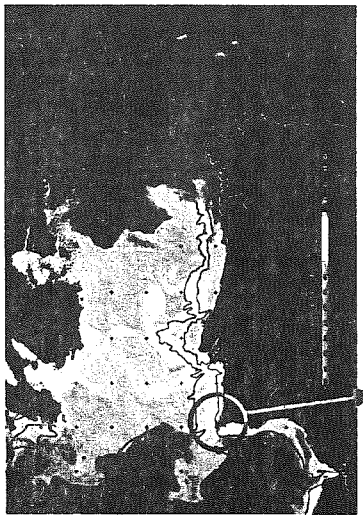
Further post-processing of direct model output has been developed to derive additional fields that can be useful, for instance, to diagnostic extreme weather events. These fields are being validated and tested with some extreme event cases, using ALADIN/ Portugal fields. In particular,

- Quasigeostrophic vertical forcing (Q vector divergence)
- Geostrophic frontogenetic function
- Stability indexes (energy index, convective instability index, Jefferson index, modified K index, severe weather threat index and modified total totals)
- Surface moisture convergence and moisture convergence in the layer 1000-850hPa
- Temperature advection and vorticity advection at 1000, 925, 850, 700 600, 500, 400 and 300hPa and differential temperature advection between those levels

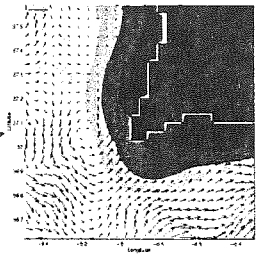
(info: Joao.Vitorino@hidrografico.pt)

The region offshore cape S. Vicente, in the SW tip of Portugal, is characterised by complex coastline and topography. Recently (April 2001), a navy exercise – Swordfish 2001 – was conducted by the Portuguese navy in this area. Forecasts of the oceanographic conditions were provided to the navy forces through a

combination of hydrographic observations (CTD) and modelling using an oceanographic model with data assimilation (HOPS). High resolution wind fields, provided by the ALADIN/ Portugal model were used to explore details of the upwelling dynamics around the Cape São Vicente region. The period under study was from the 18th to the 28th April 2001.



Sea surface temperature from the 14 April 2001 by a NOAA satellite (Satellite images were received by the NERC Dundee Satellite Receiving Station and processed by Peter Miller at the Plymouth Marine Laboratory Remote Sensing Group)

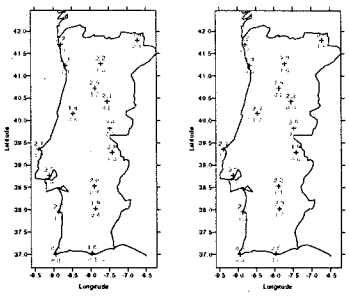


Near surface (20m depth) T and current fields obtained by 18 April 2001: small domain results

"...the results obtained for the surface layers of the ocean reflect the general upwelling conditions that characterised the month of April 2001."

(info: Margarida.Belo@meteo.pt)

Since August 1999 ALADIN/ Portugal forecasts are objectively verified on a regular basis. All the computations use the nearest grid point from the observation station point (SYNOP or TEMP observations). An annual report is usually published in English.



Spatial distribution of RMSE (blue) and ME (red) 2m temperature for 16 synoptic stations over Portugal at H+48 (12 UTC) for fall and winter (values in Celsius) from the period March 2001 to February 2002

"...there is a warm bias in the 48h forecast (valid at 12UTC) over all Portugal..."

3.14 Limited Area Modelling in Romania (D. Banciu et al.)

Limited Area Modelling in Romania

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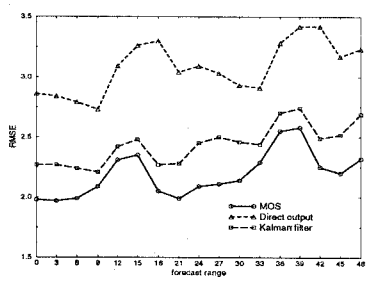
1 Numerical Weather Prediction System

During last year there were no important changes in the Romanian national numerical prediction system which is based on the Aladin model. The operational suite includes the post-processing for visualization, statistical adaptation (Kalman Filter and MOS) and the objective verification.

Since 2001 the statistical models are based on MOS technique using multiple linear regression (temperature, wind) and discriminant analysis (cloudiness and precipitation), leading to an improvement of the model scores (see figure) .

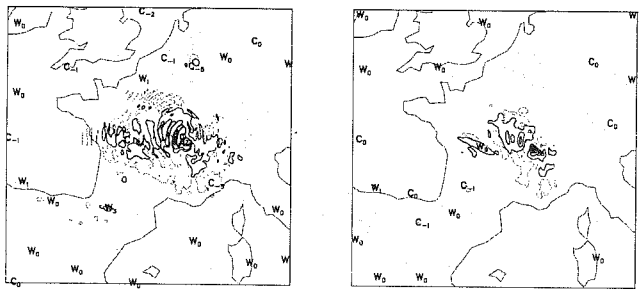


As a reserve, the workstation (updated) version of HRM developed by DWD is daily integrated at NIMH up to 78 hours (V. I. Pescaru).

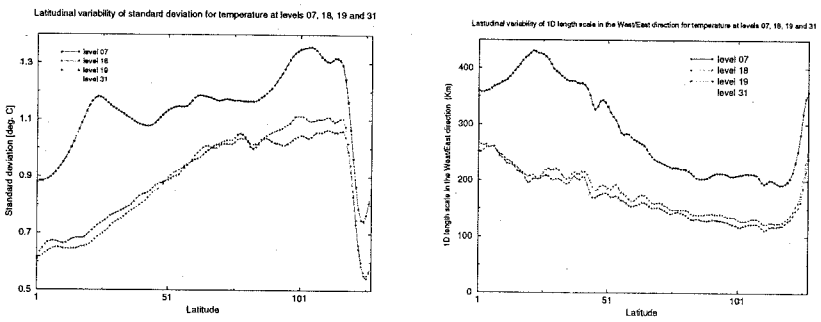
2 Research and development activities

The research and development activities were mainly related to the Aladin model and concerned the data assimilation and coupling problem at high resolutions.

Sensitivity study at high resolution using a limited-area model and its adjoint for the mesoscale range. This study gives a first experimental frame for the evolution and performance of an adjoint model for the mesoscale range. The results have shown that the adjoint of a high resolution model including a description of the moist processes such as large scale precipitation, became unstable (left side figure). After investigations the problem was cured by modifying the shape and shift of the regularization function (right side figure).



The spectral representation of the spatial variability of the bi-dimensional forecast error covariances for temperature. The used covariances have been derived using the NMC method from the ARPEGE coupling files for the ALADIN/Morocco domain over a 87 days winter period. Pseudo-single-observation experiments have been done, including calculation of the latitudinal and longitudinal variation of the correlation function for different levels of the model and different locations of the observation point. The latitudinal and longitudinal variation of standard deviation and length scale of the correlation function have been also investigated. Different evolutions for the latitudinal and longitudinal variability have been observed.



3.15 Limited Area Modelling Activities in Slovenia (Neva Pristov et al.)

Limited Area Modelling Activities in Slovenia

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November 2002

Environmental Agency of the Republic of Slovenia is a partner in the international projects ALADIN and RC LACE. Small NWP group is temporaily enlarged by two young researchers (PhD students in the scope of ALADIN training Network (ALATNET)): Klaus Stadlbacher (Austria, 4 months) and Raluca Radu (Romania, 8 months).

The main research and development topics are dealing with coupling problems, evaluation of the model skills in high resolution and in non-hydrostatic version. Besides looking after operational ALADIN model application some work was done in the field of objective verification.

Event

Third ALATNET Seminar on the Numerical Methods and NWP Applications took place in Kranjska gora, Slovenia, in May 2002. For one week 59 participants from 14 countries were attending the lectures: basis of numerical analysis, dynamical aspects, physical aspects, variational methods, numerical filters and stochastic aspects.

Operational ALADIN application

Operational suite of the local model version ALADIN/SI has not been changed since last year. It is running on cluster of workstations (5 Alpha processors) under Linux. Products are regularly available over 800 km by 800 km domain twice a day for next 48 hours. Besides products of local application also products of ALADIN/LACE, running in Prague, are available.

New computer system

Procurement for buying new computer system started in May 2002 and system was delivered and installed in October. It is a cluster based on Intel Xeon processors, has 14 dual processor boxes with 2.4 GHz processors (28 all together), 28 GB of memory and 0.5 TB of disk space. Processors are connected via gigabit fiber ethernet. It runs Linux OS (RedHat 7.3) + SCore global OS.

Local ALADIN application has to be redesigned till the end of the year, taking into account new computer power and ending of common computing ALADIN/LACE in center in Prague.

Spectral coupling

The failures of the forecast of LAM in some cases, as Christmas storm 1999, determined a deeper investigation of weakness of the present coupling scheme and its improvement. A spectral method for coupling is under development and will be used as an additional coupling step to the Davies-Kallberg relaxation. The main goal is to better capture incoming signals without losing the sponge effect of Davies scheme to damp out spurious wave reflections or wave re-entering. In spectral coupling the information contained in coupling files is interpolated in time in spectral space over limited area domain and combined with the spectral information of the coupled model, rather than just in the gridpoints values of coupling zone as in the classic one. By combining spectral and classic coupling it is expected to combine positive advantages of both: to catch the small scale features no matter where they are located inside the limited domain and to eliminate the spurious inward propagation in lateral boundaries.

Non-Hydrostatic modelling on High-resolution

Going to higher and higher resolution it seems obvious to change to non-hydrostatic dynamics. Nevertheless one question should be tried to answer: Which resolution already requires the use of hydrostatic dynamics? Comparative experiments have shown, that the introduction of the non-hydrostatism in the Aladin-model might just become relevant for resolutions around 5 kilometres. The positive influence of the non-hydrostatism is rather small compared to changes in the resolution of the coupling model and the use of NH or Hydrostatic dynamics, which either means a direct coupling of the prognostic non-hydrostatic variables or treating them in a diagnostic way for coupling purposes. Further and more general evaluation of the non-hydrostatic dynamics will be done. Another problem which occurs when going to high resolution concerns the treatment of orography. The description of orography as well as the connected parametrisations are undergoing intensive investigations. The orography problems are naturally independent of the used dynamics. Improved forecast fields (e.g. for precipitation) can be obtained by smoothing the orography, namely to use lower truncation numbers for spectral description of the orography compared to the other fields, which leads to more realistic precipitation fields in areas with high and steep mountains and diminishes the well known effect of precipitation peaks at the windward side of the mountain and the summit, respectively.

Improving ALADIN's 2m temperature forecast with machine learning

A method of using machine learning for improving ALADIN's 2m temperature forecasts has been tested. Regression tree learning is used to build a predictor from learning data.

The predicted variable is the 2m temperature at a given time and place. Our training set that is imported to the learning algorithm is based on data collected over two years (1999, 2000) and the data for 2001 is used as a test set. The initial attribute

set consists of ALADIN's predictions (ALADIN LACE pseudotemps for 5 different locations in Slovenia), for various meteorological variables at different places, height levels and time, and measured data (several synop station measurements in Slovenia and radiosounding measurements in Ljubljana, Udine and Zagreb). For purpose of machine learning data have to be reduced by carefully choosing the most informative attributes only. Several attribute selection algorithms are used, as well as expert opinion. So the initial set is reduced to typically between 5 to 20 attributes.

The results obtained with decision tree correction method and with further modified method with bagging are also compared to Kalman-filtered predictions (example in Table 1). The results show a statistically significant improvement of ALADIN's predictions. The improved predictions are of special interest in cases when ALADIN's error is large.

Table1: Comparison of accuracy of 2m temperature forecast for noon of the following day at Ljubljana airport (Brnik) - data from year 2001. (Abbreviations used: ME=mean error, MAE=mean absolute error, RMSE=root mean square error)

	ALADIN's forecast	Kalman correction	Decision tree correction	Decision tree correction with bagging
ME	1,566	0,121	0,240	0,226
MAE	2,199	1,988	1,767	1,718
RMSE	2,939	2,531	2,335	2,251

Verification of ALADIN/SI precipitation

Forecast of precipitation from ALADIN model are used by hydrologists for hydrological prediction of runoff. We were interested to what degree forecast precipitation amounts can be trusted, especially on high precipitation events. Precipitation measurements were interpolated using kriging method and compared with ALADIN/SI results for some typical precipitation events. It was noticed that there is constant overestimation of precipitation for some regions (mostly windward slopes) and underestimation for other regions (mostly lee slopes), while the total amounts of precipitation from the model in most cases agree with measurements within 30%. We concluded that regions with constant precipitation error are mostly due to the lack of liquid water parameterization scheme in a model.

ALADIN Verification project

In the ALADIN community a common project for objective verification at the synoptic scale was started this year where Slovenian group has the leading role. The aim is building of a coordinated centralized procedure which would produce time evolution and comparison of classical scores over various domains and for various model configurations. The application consists of: collecting forecast values from models and observations (for selected meteorological variables and stations), storing them to a relational database and a web interface to get on-line verification products of interest.

3.16 Progress Report for 2002, INM (Ernesto Rodríguez)

Progress Report for 2002

INM

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1.- Operational system in use at the end of 2002

• The operational system is still based on HIRLAM version 4.6.2 (see previous LAM Newsletters). Two suites are currently operational at INM: OPR (0.5 degrees, 31L) and HIR (0.2 degrees, 31L), (See figures for integration domains). Next enhancement in resolution will be conditioned by the arrival of the new mainframe (around June 2003). An independent 3-hourly assimilation with short cut-off time is also run to assist nowcasting activities.

• Apart from its use in the operational forecasting system, HIRLAM data are also used as input to different applications: a) trajectories and diffusion models to determine hazardous emissions; b) forecast automation: generation of written forecasts from direct NWP outputs and statistical adapted products based on Multimeteo software; c) sea state applications.

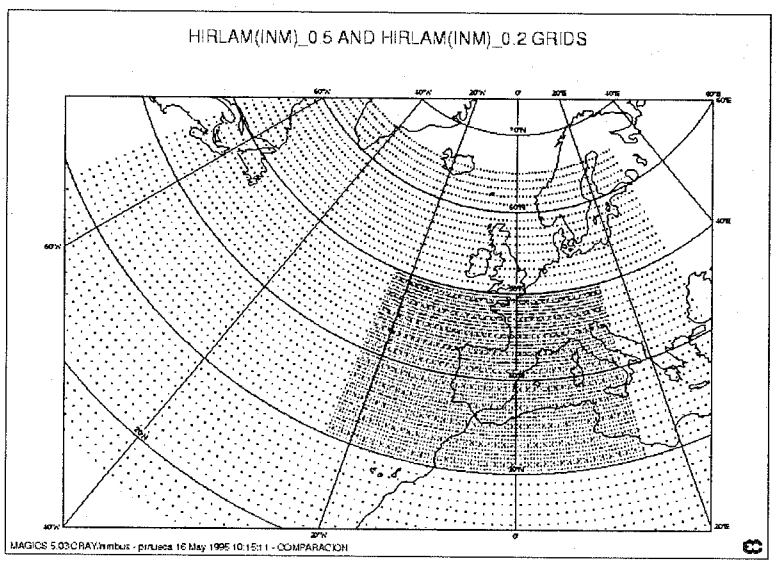

Fig. 1. Domain of the INM operational HIRLAM_0.5° and HIRLAM_0_2° models.

2.- Features of the new machine and of the foreseeable new suite

CRAY SV2 (40 vector processors) [June 2003] + CRAY SV2E (32 processors) [End of 2004]

The first implementation supplies sustained 140 Gflops using the IFS code, whereas the final one supplies 360 Gflops.

Tentatively and depending on the ongoing tests, the INM's assimilation and forecasting system will consist of a synoptic suite with European + North Atlantic domain (approx. 726 x 335 x 60, 0.15°) and a mesoscale suite with Iberian peninsula domain (0.05°). Latest version of HIRLAM available at the implementation time (3D-VAR assim., best physics options,...) will be used (5.3?).

3.- Verification and archive

The HIRLAM_INM verification bulletin can be consulted on-line: http://www.inm.es

A summary of the historic mean monthly scores comparing ECMWF (EC), HIRLAM 0.5° (OPR) and HIRLAM 0.2° (HIR) over an area covering the Iberian peninsula is shown in the figures. The operational archive for HIRLAM 0.5° (0.2°) dates back to March 1995 (October 1995).

4.- Research and development

Condensation processes. The Kain-Fritsch+Rash-Kristjansson scheme is still under testing tested both in long runs and case studies for its implementation on the reference system (García-Moya, Calvo). The Emanuel scheme is also being tested in 1D and 3D simulations. EUROCS EU Project (Calvo).

Surface issues (analysis + parameterization). After the implementation in the HIRLAM reference system of the new package most of the activity has been devoted to its evaluation in seasonal runs and against field experiments (EFEDA, RhoneAggr). Work on winter condition features: soil moisture freezing/melting, snow formulation, etc. ELDAS EU Project to develop and test a new algorithm for soil moisture assimilation (Navascués, Rodríguez).

Coupling physics-dynamics in the frame of the 2TLSLSI scheme. Noise removal in high resolution (Martínez)

Preparation for short range EPS, based on a multi-analysis, multi-model, multi-BCs ensemble (Santos, García-Moya).

5.- Future

• The arrival of the new computer CRAY SV2 and the tasks associated with the installation and testing of the new suite will condition the activity of the INM's group along the next year.
• Most of the research and development activity will be developed in the frame of the next HIRLAM6 project, particularly in the area of physics and surface assimilation.
• The starting point of our activity on short range EPS has been the INM/SRNWP workshop on SR EPS held on October 2002 at INM.

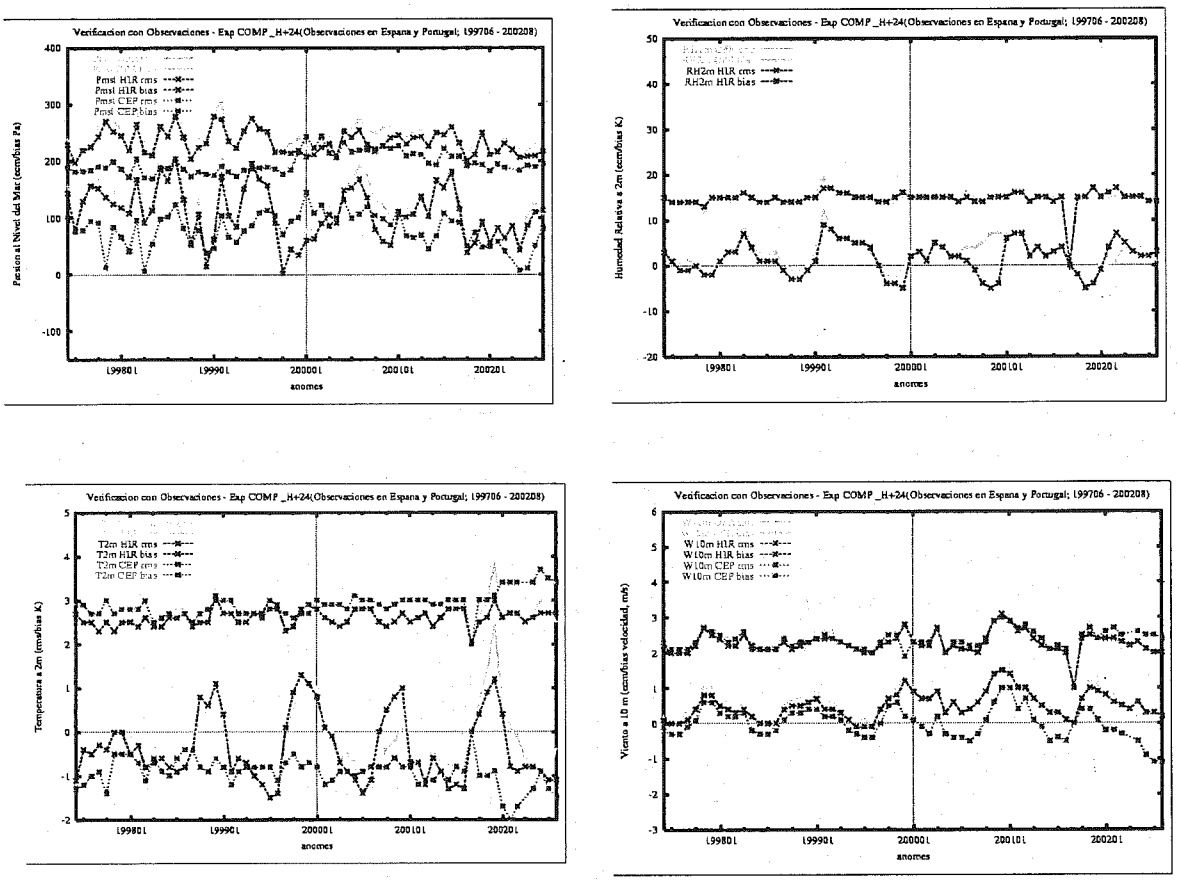

Fig. 2. Historic mean bias and rms error of msl pressure, 2m-relative humidity, 2m-temperature and 10m-wind over and area covering the Iberian peninsula for ECMWF, HIRLAM_0.5° and HIRLAM_0.2° models.

3.17 The Alpine Model (aLMo) in Switzerland (Guy de Morsier)

The Alpine Model (aLMo) in Switzerland

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Short poster description

aLMo is the Swiss implementation of the COSMO Local Model. This model is non-hydrostatic and fully compressible. The prognostic variables are the pressure, the three wind components, the temperature, the specific humidity and the liquid water content. The initial conditions are defined by newtonian relaxation (nudging) to the observations (including AIREP/AMDAR).

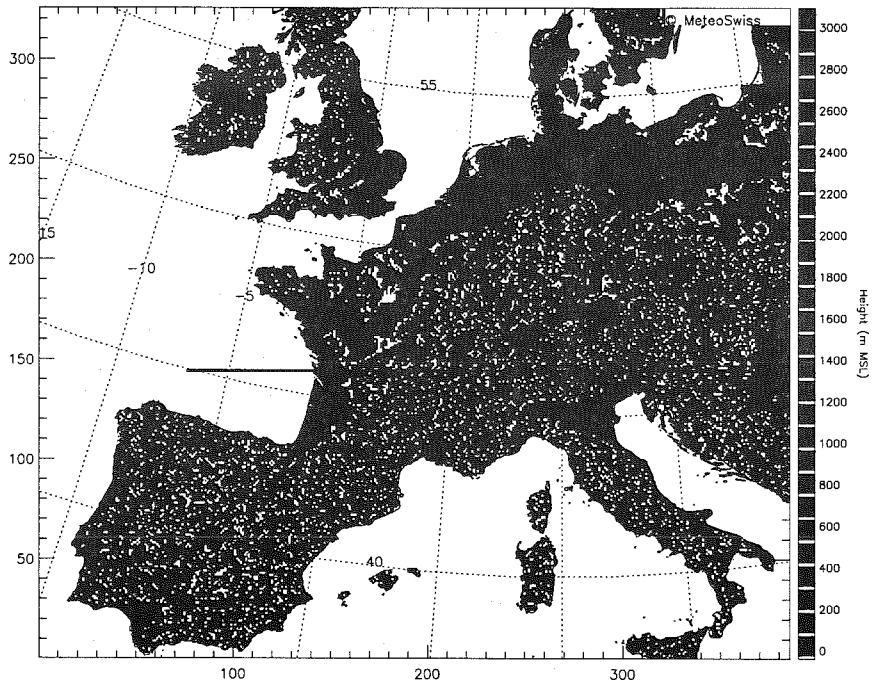

Figure 1: Operational domain and orography of aLMo with cross-section used in Fig. 2

The aLMo is operational since April 2001 and runs twice daily up to 48 hours with hourly boundary conditions from the DWD global model GME. The rotated latitude and longitude grid of 1/16°~ 7 km covers a domain of 385 grid points in the rotated West-East direction and 325 grid points in the rotated South-North direction. The aLMo uses 45 vertical hybrid levels (see Fig. 2, left) and the used orography is shown in Figure 1.

The start of an operational integration is dictated by the arrival of the boundary data. For one run this represents 61 MB which are directly transferred from the DWD to the Swiss Center for Scientific Computing (CSCS) of the Swiss Institute of Technology (ETH) in Manno in the southern italian part of Switzerland.

On the high performance vector processing machine, NEC SX-5, MeteoSwiss can use 12 processors in a dedicated mode. The operational forecast is produced with 25% of the peak performance (96 Gflops) in less than one hour and gives 8 GB of data which is then archived on the local StorageTek silos. About 1.2 GB of output (consumable products) is returned to the Central Office in Zurich where it is disseminated to all the other forecasting and operating sites (Geneva and Zurich airports, Locarno-Monti and Payerne) and to all the end-users.

Developments

Very soon a new smooth level vertical (SLEVE) coordinate will be implemented. This coordinate has a scale-dependent vertical decay of the underlying terrain features given by the operational orography.

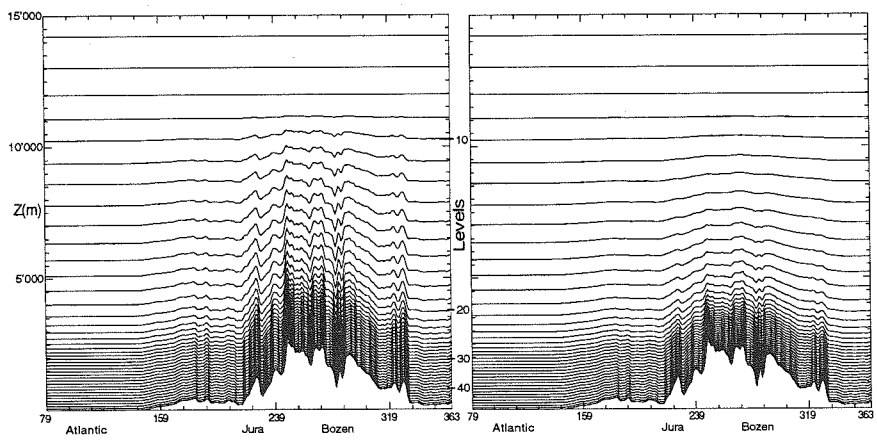

Figure 2: Vertical distribution of the bottom levels below 15 km height for a West-East cross-section at 46.5° N (thick line on Fig. 1). From the 45 operational hybrid levels (left) and with the new SLEVE coordinate (right) described in the text.

Small-scale topographic (h_1) variations decay much faster with height than their large-scale (h_2) counterparts. The decomposition expressed in horizontal longitude (λ) and latitude (φ) is: $h(\lambda,\varphi) = h_1(\lambda,\varphi) + h_2(\lambda,\varphi)$

The height-based non-normalized SLEVE coordinate μ represented in Figure 2 (right) has also 45 levels and the following inverse transformation:

$$z(\lambda, \varphi, \mu) = \mu + h_1(\lambda, \varphi)\frac{\sinh((\mu_T - \mu)/s_1)}{\sinh(\mu_T/s_1)} + h_2(\lambda, \varphi)\frac{\sinh((\mu_T - \mu)/s_2)}{\sinh(\mu_T/s_2)}$$

with: $\mu_T = 23'589\text{m}$, $s_1 = 10'000\text{m}$ and $s_2 = 2'000\text{m}$

The continuous data assimilation scheme by the means of nudging should in the near future comprise also information from wind profiler and radar data. An assimilation example using aLMo nudging with Global Positioning System (GPS) data in September 2001 is shown in Fig. 3.

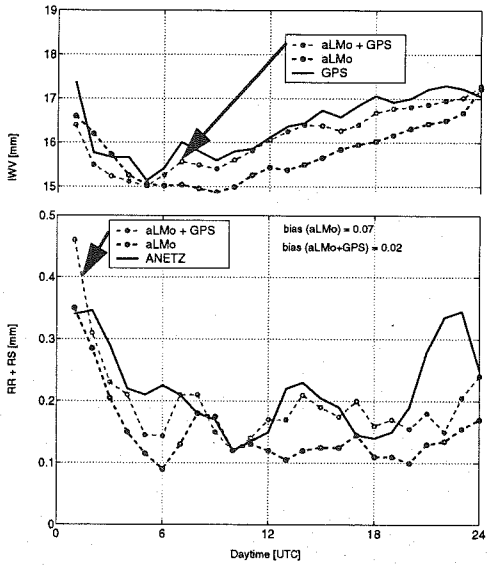

Figure 3: Assimilation experiment with Integrated Water Vapour (IWV) data from the Global Positioning System (GPS) for 14 days in September 2001 with aLMo.

Top: Daily cycle for 9 grid points below 800m above mean sea level (amsl) collocated with the GPS sites in Switzerland: GPS observations (solid black line), reference run (dashed black line) and GPS run (dashed grey line).

Bottom: Daily precipitation cycle for 29 grid points below 800m amsl collocated with automatic surface weather (ANETZ) stations: ANETZ observations (solid black line), reference run (dashed black line) and GPS run (dashed grey line).

The model is ready to use an extra prognostic equation for the specific cloud ice content (see contribution from G. Doms in this volume). As soon as the GME can provide us with these boundary fields a parallel suite will begin. A model version using a 2 time level scheme with prognostic precipitation, operations using boundary conditions from the IFS/ECMWF deterministic forecast model and the possibility of a 72h forecast for the 0 UTC run should also be tested.

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See also: www.meteoswiss.ch, www.cosmo-model.org and www.cscs.ch.

3.18 The Operational NWP System in FHMI of Yugoslavia (Sinisa Curic)

The operational NWP System in FHMI of Yugoslavia

The operational system for numerical weather prediction has been developed during the last twenty years. This system performs one of the most important functions of the national weather service – the collection of the observed data, numerical weather prediction, interpretation of the forecasting products and dissemination to the users.

The main components of the system are:

- Preprocessing of the NWP model (preparation of boundary conditions and input data for the model)
- Regional numerical model Eta
- Postprocessing (preparation of forecast products)

Preprocessing

The first part of the preprocessing of the Eta model is decoding of initial and lateral boundary conditions. Those conditions are Internet available large-scale GRIB products from National Center for Environmental Prediction (NCEP) Washington and from DWD Germany, AVN and GME global models with 6-hours time resolution.

Preprocesing contains source codes and programs for creating input files for the model. After interpolation of measured heights of terrain to E-grid points program (topo) makes topography on 32 eta levels.

After that, some climatological data, as SST (Sea Surface Temperature), vegetation and soil types and some other variables as soil temperature and soil wetness are calculated in every grid point.

Lateral and boundary conditions contain fields for geopotential, zonal and meridional wind components, and relative humidity for every 6 hours of 120-hours forecast. Preprocesing performs bilinear interpolation from lat-lon grid to model E-grid and interpolation from 10 standard pressure levels to 32 eta levels.

Regional Eta Model

Eta model is limited area grid point model , based on finite differences numerical methods. Horizontal coordinates is transformed lat-lon coordinate system on semi staggered E grid, vertical coordinate is Eta coordinate. Operational suite is, twice a day, 120-hours forecast for 00 and 12 UTC. Eta model runs on Beowulf cluster system with 9 nodes. Domain of integration is area of Europe. Timestep is 45sec, horizontal resolution in operational model is roughly 16 km, vertical resolution is 32 η levels.

Independent variables of the Eta model are: latitude, longitude, time and vertical coordinate η.

Dependent variables are: temperature, horizontal wind components, specific humidity, surface pressure, turbulent kinetic energy, surface potential

temperature, soil moisture and snow depth. Eta model also calculates diagnostic variables: precipitation, vertical velocity and turbulent exchange coefficients.

Postprocessing

Postprocessing includes conversion from the model levels to ten standard pressure levels, from 1000hPa to 100hPa and visualization and preparation of various specific products that may be required by users as well as Internet presentation of the weather forecast and verification of prognostic fields. The main products from the Eta model are prognostic charts of meteorological fields.
Numerical Weather prediction products: geopotential on ten standard level pressure, mean sea level pressure, temperature on ten standard level pressure, 2m temperature, wind components, precipitation (total and convective), specific humidity, short and long wave radiation, turbulent kinetic energy, turbulent exchange coefficients, surface potential temperature, soil moisture, snow depth, surface sensible heat flux, surface latent heat flux, convective cloud top and depth, total cloud cover.

Standard procedure in FHMIY are also:

- Meteograms show time variation of meteorological parameters, such as wind on standard pressure levels, temperature on 2m, relative humidity, precipitation, for one point in model domain
- Forecasting TEMPs that show vertical structure of the atmosphere for choosen point and forecast time
- Meteorological flight provision includes wind-temperature charts for two layers, from surface to 3000m and from 3000m to 9000m. These charts are very precise and they are graphical presentation of the model output. FHMIY prepares these charts on every three hours of forecast time, from 12 to 48 hours.
- Computation of head wind along the flight routes
  (Flight planning system of Yugoslav Airlines)
- Automatic weather forecast based on output of numerical model
- Backward and forward trajectories for major city in Europe
- Prognostic fields of turbulence, freezing, front-genetic parameter and prognostic heights of 0 and –10 isotherms

Main activity during last period

During this year main work within our department was paralleled source code of Eta model for cluster system, interpretation of model results with PPM, MOS and Neural networks, testing and operational use of coupled Eta and POM(ocean) model for medium range forecast and for climat simulation.

Future plans

Fundamental requirement of national center for weather forecasting is accurate products of numerical model in real-time. For this reason in future period we are planning to add more nodes in our cluster and increasing horizontal and vertical resolution of model.

Also we are testing non-hydrostatic meso models SAM (made by Phd. Zavisa Janjic) and workstation Eta model that is in operational use in NCEP and we are planning for operational use one of these models.

4. Scientific presentations

4.1 3D-VAR data assimilation experiments for the double-nested limited area model ALADIN/Hungary.

3D-VAR data assimilation experiments for the double-nested limited area model ALADIN/Hungary

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1 Introduction

The experiments with 3D-VAR data assimilation scheme were performed with the ALADIN/Hungary model, which is a *double-nested limited area model.* This means that the boundary conditions of the model are provided by another limited area model (ALADIN/LACE), which has a bigger domain, and a lower resolution. At his turn, ALADIN/LACE model is driven by a global model (ARPEGE).

The paper is organized as follows. A description of the experiments performed with 3D-VAR scheme and of the results is presented in section 2. Conclusions and discussion follow in section 3.

2 Experiments and results

The 3D-VAR data assimilation scheme for ALADIN/Hungary model consists in minimizing a cost-function. This function is given by a sum of two terms: the background term (J_b), measures the fit of the analysis to the background (usually, the 6h forecast from the previous integration of the model), the observation term (J_o) measures the fit of the analysis to observation. (Horányi, 2003).

For the observation term of the cost function (J_o) only SYNOP and TEMP observations were considered, and the standard NMC statistics for the background term (J_b). The NMC (National Meteorological Center) method estimates the background error statistics using a set of differences between forecasts valid at the same time, but at different ranges (usually 36h - 12h differences). (Parrish and Derber, 1992).

The ALADIN model is using the digital filter initialization (DFI) to provide a filtered state valid at the initial time, starting from the analysis.

It was was found that the classical DFI might destroy some useful signals of the 3D-VAR increments (Dziedzic, 2000). Therefore, it was proposed to test the incremental digital filter initialization (IDFI), when it is assumed that the first-guess is already balanced and the analysis increment (the difference between the analysis and the first-guess) should be filtered.

In the experiments with 3D-VAR scheme for the ALADIN/Hungary model, two lateral boundary treatments were applied in cycling and in production: time-consistency and space-consistency. The time-consistency means that the lateral boundary data are coming from the same run of the coupling model, thus the information is consistent in time (the initial file is 3D-VAR analysis, and the first two lateral boundary conditions (LBC) files are coming from ALADIN/LACE model).

The space-consistency means that the first two LBC files are not coming from the same integration of the model (the first LBC file is identical with the initial file, which is the 3D-VAR analysis). The information is consistent in space. (Široká, 2001).

As evaluation tools for all the experiments, simple statistical measures (RMSE, BIAS) and diagnostic measures (time-evolution of the fields, at different levels) were used. For a subjective evaluation, maps with the mean sea level pressure increments and with the representation of different fields were drawn.

The first set of experiments was performed for one week (25.02.2002 - 02.03.2002), using in cycling the first-guess (the 6h forecast from the previous integration), obtained with the ALADIN/LACE LBC files from the assimilation cycle, in time/space consistency, and in production the operational ALADIN/LACE LBC files were used for 24h forecast. Both in cycling and in production, digital filter initialization was applied.

Figure 1 shows that 3D-VAR analysis fits closer to the observations, for all the fields, which is expected. After 6h forecast 3D-VAR is losing from the initial improvement, but not for all levels. After 24h integration, the scores are the same (not shown). Time-consistency seems to give a better forecast so far. (Alexandru [1], 2002).

One explanation of this loss of improvement is that for the 3D-VAR forecast, the same TEMP observations are used, as the global model ARPEGE. So the new information is coming only from the SYNOP data, which is not very helpful, because 3D-VAR is acting for the upper-air fields. Also, the 6h forecast is compared with the data from 06 UTC, respectively 18 UTC. And for these moments of time, the number of observations is much smaller than at 00 UTC and 12 UTC.

In the second set of experiments, different initialization methods (DFI, IDFI, and no initialization) were tested, for the same period as the previous one. The time evolution of the mean sea level pressure was checked during the 6h integration in cycling, for six different points on the domain (three are over the mountains, one is in the middle of the domain, the others are

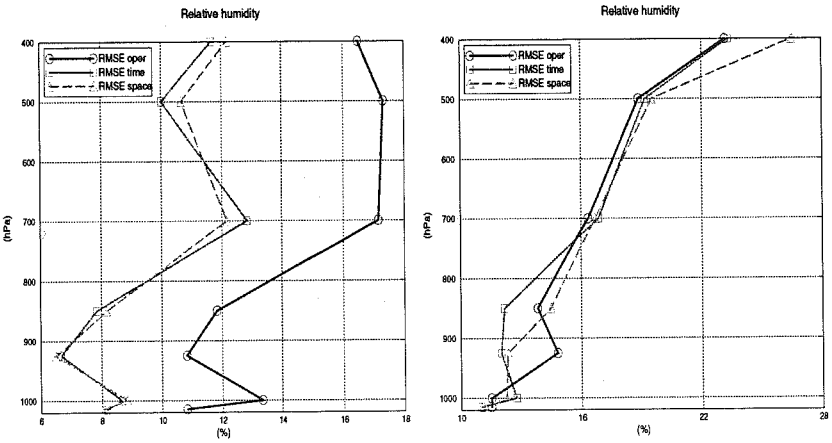

Figure 1: The vertical profile of RMSE of the operational analysis (*oper*), and using 3D-VAR scheme in time-consistency (*time*), and space-consistency (*space*), (left), and after 6h integration (right)

in the upper-right and bottom-left corners of the domain), for 02.03.2002 00 UTC (Figure 2). One can see large oscillations for some points (all three are over the mountains), when DFI was used. For other points the shapes are rather smooth, comparing with those with IDFI and no initialization, which look more irregular. These scores emphasize that for 3D-VAR experiments we have to use digital filter initialization in cycling.

The time evolution of the mean sea level pressure was checked during the 6h integration in production (not shown), for the operational forecast and using 3D-VAR scheme with different initialization methods in cycling and in production. It seems that the fields are in balance, when DFI was used in production (for the operational model, and also with 3D-VAR scheme). Without initialization, the noise appears especially for the first time-steps. This confirms that we need to apply digital filter initialization also in production.

The third set of experiments was made to see the implications of the double-nesting on the 3D-VAR results. It was realized for one month's period (25.02.2002 - 25.03.2002), using as LBC files the ALADIN/LACE and ARPEGE files (from the assimilation cycle), in space-consistency. In cycling, the 3D-VAR analysis, and ALADIN/LACE, respectively ARPEGE analysis were used as LBC files for the first-guess. Digital filter initialization was applied both in cycling and in production.

Figure 3 shows the verification of 6h forecast for relative humidity and zonal wind. The forecast using 3D-VAR scheme looks slightly better than in dynamical adaptation, for zonal wind, at almost all the upper-levels, and for relative humidity, especially near the surface. One can see that the choice of the LBC files in cycling (from the global model or from the limited

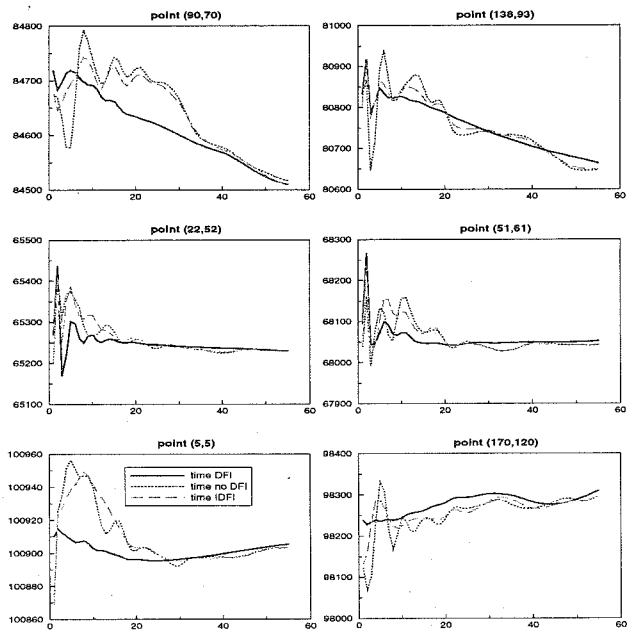

Figure 2: The time evolution of the mean sea level pressure in cycling

area model) is not so important. In the picture, the fields with the largest differences are presented. For other fields (temperature, geopotential, wind speed and direction), the scores are almost neutral. (Alexandru [2], 2002).

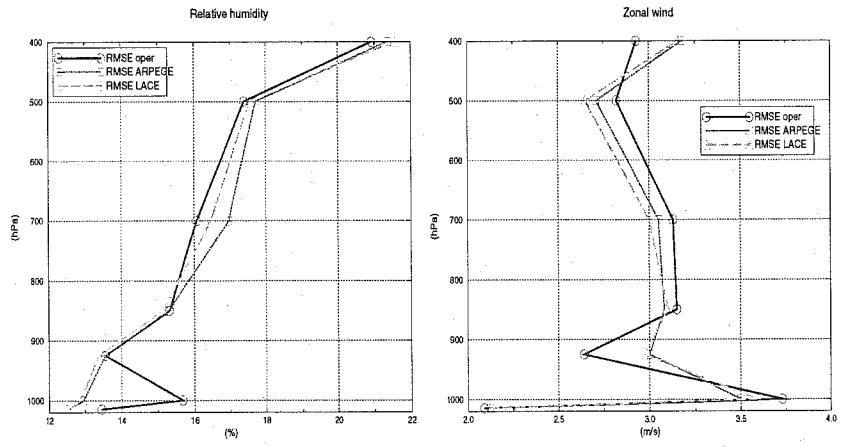

Figure 3: The vertical profile of RMSE for the operational forecast (*oper*), and using 3D-VAR scheme, with ALADIN/LACE (*LACE*) and ARPEGE LBC files (*ARPEGE*)

Other verification tools showed small differences when the two lateral

boundary treatments were used. Looking on the maps with the representation of some meteorological fields, the differences for the experiments with 3D-VAR scheme and different LBC files are not visible.

3 Conclusions

After all these experiments, we can conclude that the 3D-VAR analysis fits closer to the observations, as we expected. But after 6h, the forecast is losing from the initial improvement, for some levels. Probably because the new information for the assimilation cycle is provided only by the surface data. In the upper-air, the same data were used for the global model. Future experiments using other types of data (aircraft or satellite data) are expected to improve the 3D-VAR results.

Comparing the two lateral boundary treatments, one can say that, the time consistency seems to give a better forecast so far.

Digital filter initialization need to be applied in 3D-VAR cycling, and also in production, to filter the noise that appear.

From the last set of experiments, it can be seen that the choice of the lateral boundary coupling files in cycling (from the global model or limited area model) is not important.

These first experiments with 3D-VAR scheme for ALADIN/Hungary model were performed to select from many options that we have (different first-guesses, LBC files, initialization methods, lateral boundary treatments), the best ones, to be able to study 3D-VAR scheme more in detail. Future work will rely on the case studies, with some interesting meteorological situations.

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4.2 The LM Cloud Ice Scheme

The LM Cloud Ice Scheme

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1 Introduction and Background

Cloud processes take place on scales that are significantly smaller than those resolved by the grid boxes of a NWP-model. In large-scale models not only cumulus clouds but also precipitating stratiform frontal clouds are of subgrid nature and need to be represented by a suitable prognostic cloud fraction parameterization (e.g. Sundqvist, 1988; Smith, 1990; Tiedtke, 1993; Rasch and Kristjansson, 1998)). The formation of precipitation from subgrid stratiform clouds is further complicated by a necessary assumption on cloud overlap statistics (Jakob and Klein, 1999). This situation appears to be less complex in high-resolution mesoscale models with grid spacings of less than about 10 km. Frontal stratiform clouds are well resolved and bulk microphysical parameterizations similar to those used in cloud resolving models (e.g. Kessler, 1969; Lin et al., 1983, Rutledge and Hobbs, 1983) may be applied. In such grid-scale schemes, only the cloud condensate is predicted by budget equations and the cloud cover is set to 100% whenever condensate occurs.

Except cumulus convection, which is parameterized by dedicated schemes, all other non-resolved clouds in mesoscale models are of stratocumulus-type. A direct hydrological impact of these clouds may be neglected for NWP purposes, but not the interaction with radiation. In LM, we use a traditional scheme that diagnoses a cloud fraction and a corresponding liquid water content in terms of relative humidity, pressure and convective activity. Clearly, subgrid-scale cloudiness will become less important with increasing model resolution.

Ice-phase processes play a significant role in mid-latitude frontal cloud systems and their impact should be taken into account by parameterization schemes. Two mechanisms of precipitation enhancement are of particular importance: the Bergeron-Findeisen process and the Seeder-Feeder mechanism, which both are based on the presence of supercooled liquid water. Nucleation of ice in a water saturated environment will cause a rapid growth of the ice crystals by deposition (because of the ice supersaturation) and riming (because of the presence of supercooled cloud droplets). The ice particle growth is at the expense of liquid water, but if the cloud is kept at water saturation by thermodynamic forcings, high precipitation rates may result (Bergeron-Findeisen process). The Seeder-Feeder mechanism describes precipitation enhancement due to ice particles falling from a higher cloud into a lower cloud containing supercooled droplets. In this case, the droplets will also be converted into ice by deposition and riming, resulting in a more efficient removal of cloud water than by the collision-coalescence growth of water droplets.

Two gridscale cloud and precipitation schemes that include ice phase processes have been implemented in LM. They are described in the following sections and a shortcoming resulting from a simplified numerical treatment of precipitation fallout is also discussed. Both schemes neglect hail and graupel since these ice particle types are not relevant for precipitation formation in stratiform clouds at the current model resolution. The future application of LM on the mesoγ scale, however, will require a corresponding extension of the schemes.

2 The Operational Scheme

The default parameterization scheme for the formation of grid-scale clouds and precipitation is based on a Kessler-type bulk formulation and uses a specific grouping of various cloud and precipitation particles into broad categories of water substance. The particles in these categories interact by various microphysical processes which are parameterized in terms of the mixing ratios as the dependent model variables. Four categories of water substance are considered: water vapour, cloud water, rain and snow. Cloud water is treated a bulk phase with no appreciable terminal fall velocity relative to the airflow, whereas single-parameter exponential size-spectra and empirical size-dependent terminal fall velocities are assumed for raindrops and snow crystals.

To simplify the numerical solution of the budget equations for rain and snow, quasi-equilibrium in vertical columns is assumed by neglecting 3-d advective transport and by prescribing stationarity. The resulting balance between the divergence of the precipitation fluxes and the microphysical sources and sinks allows for a very efficient diagnostic calculation of P_r and P_s. While this assumption is well justified for large-scale models (Ghan and Easter, 1992), it is clearly not adequate for the meso-γ and smaller scales. Work on a prognostic treatment of the precipitation phases is in progress. With these key assumptions, the equations for the hydrological cycle read

$$\begin{aligned}
\frac{\partial T}{\partial t} &= A_T + \frac{L_V}{c_{pd}}(S_c - S_{ev}) + \frac{L_S}{c_{pd}} S_{dep} + \frac{L_F}{c_{pd}}(S_{nuc} + S_{rim} + S_{frz} - S_{melt}) \quad , \\
\frac{\partial q^v}{\partial t} &= A_{q^v} - S_c + S_{ev} - S_{dep} \, , \\
\frac{\partial q^c}{\partial t} &= A_{q^c} + S_c - S_{au} - S_{ac} - S_{nuc} - S_{rim} - S_{shed} \, , \\
-\frac{1}{\rho}\frac{\partial P_r}{\partial z} &= -S_{ev} + S_{au} + S_{ac} + S_{melt} - S_{frz} + S_{shed} \, , \\
-\frac{1}{\rho}\frac{\partial P_s}{\partial z} &= S_{nuc} + S_{rim} - S_{melt} + S_{frz} + S_{dep} \, .
\end{aligned} \tag{1}$$

The A_ψ-terms abbreviate advective and turbulent transport. L_V, L_S and L_F denote the latent heat of vapourization, sublimation and freezing, respectively. The other symbols have their usual meaning. The following microphysical mass-transfer rates S_x are considered by the scheme: condensation and evaporation of cloud water (S_c), autoconversion of cloud water to form rain (S_{au}), accretion of cloud water by rain (S_{ac}), formation of snow due to nucleation from cloud water (S_{nuc}), riming of snow (S_{rim}), shedding of rainwater from melting snow (S_{shed}), depositional growth of snow (S_{dep}), melting of snow to form rain (S_{melt}), heterogeneous freezing of rain to from snow (S_{frz}), and evaporation of rain in subcloud layers (S_{ev}).

Both the Bergeron-Findeisen process and the Seeder-Feeder mechanism are represented explicitly by this scheme. The calculation of cloud water condensation and evaporation is based on instantaneous adjustment to water saturation. From the latter assumption, however, a number of major drawbacks result:

(a) Clouds will always exist at water saturation independent of temperature. That is, only mixed phase clouds (cloud water, snow and rain) are simulated below freezing point.

(b) The cloud ice-phase is neglected by assuming a fast direct transformation from cloud water to snow. Thus, the glaciation of clouds cannot be simulated and cirrus will

be at a wrong thermodynamic state. Also, the precipitation enhancement from the Bergeron-Findeisen mechanism may be overestimated.

(c) High-level clouds usually exist at or close to ice saturation. Since the scheme requires water saturation for cloud formation, the initial conditions must be artificially adapted to avoid long spin-up periods: In the analysis scheme, the specific humidity obtained from measurements is increased by the ratio of the saturation vapour pressure over water and over ice for temperature below $0°C$. This affects the high-level humidity structure in an unphysical way.

3 Description of the LM Cloud-Ice Scheme

To overcome these problems, a new scheme including cloud ice has been developed. Many ice-phase schemes used in NWP-models solve only one prognostic equation for cloud condensate. Hence, the distinction of the water and the ice phase has to be determined diagnostically. This is done by (i) prescribing the liquid fraction in the total condensate as a function f_l of temperature and (ii) assuming that both ice and water are in thermodynamic equilibrium with respect to a hypothetical saturation vapour pressure given by $e_s = f_l\, e_s^w + (1 - f_l)\, e_s^i$, where e_s^w and e_v^i are the saturation vapour pressure over water and ice, respectively.

The function f_l for the liquid fraction is usually chosen to be 1 for $T > T_0 = 0°C$ and 0 for temperatures below a threshold T_{ice} with a linear or quadratic decrease with temperature in the range $T_{ice} < T < T_0$. Various values for T_{ice} are assumed in different schemes, ranging from -15 $°C$ to - 40 $°C$. Observational data for the liquid fraction show a large scatter in the temperature range - 15 to $0°C$ (Ryan, 1996), and a climatology shown by Feigelson (1978) suggests that there is also plenty of supercooled water in the range - 15 to - 30 $°C$.

Ice-schemes with a prescribed liquid fraction are widely in use but have a number of conceptional drawbacks. First, the assumption of thermodynamic equilibrium of both water and ice at temperatures below T_0 is not in accordance with thermodynamic principles. Second, for $T < T_{ice}$ a saturation adjustment is done for the calculation of condensate; since the number of cloud ice crystals is very small, such an instantaneous adjustment has no physical basis. Third, effects from the Bergeron-Findeisen process cannot be considered explicitly, since the ice-phase is in thermodynamic equilibrium. Fourth, the Seeder-Feeder mechanism is not represented: deep clouds are more likely to be glaciated than thin clouds at the same temperature (Ryan, 1996). Also, ice falling from above into subfreezing layers is forced to melt in order to maintain the prescribed liquid fraction. This is not very realistic.

Bearing in mind these difficulties, the new LM parameterization scheme was designed to take into account cloud ice by a separate prognostic budget equation. Cloud ice is assumed to be in the form of small hexagonal plates that are suspended in the air and have no appreciable fall velocity. As a novel feature of the scheme, we formulate the depositional growth of cloud ice as a non-equilibrium process and require, at all temperatures, saturation with respect to water for cloud liquid water to exist. Ice crystals which are nucleated in a water saturated environment will then grow very quickly by deposition at the expense of cloud droplets. Depending on local dynamic conditions, the cloud water will either evaporate completely, or will be resupplied by condensation. For strong dynamical forcings it is expected that water saturation will be maintained, resulting in a mixed phase cloud. In case of a comparatively weak forcing, the cloud will rapidly glaciate to become an ice cloud existing at or near ice saturation (i.e. at subsaturation with respect to water). Figure 1 gives an overview on the hydrological cycle and the microphysical processes considered by the scheme.

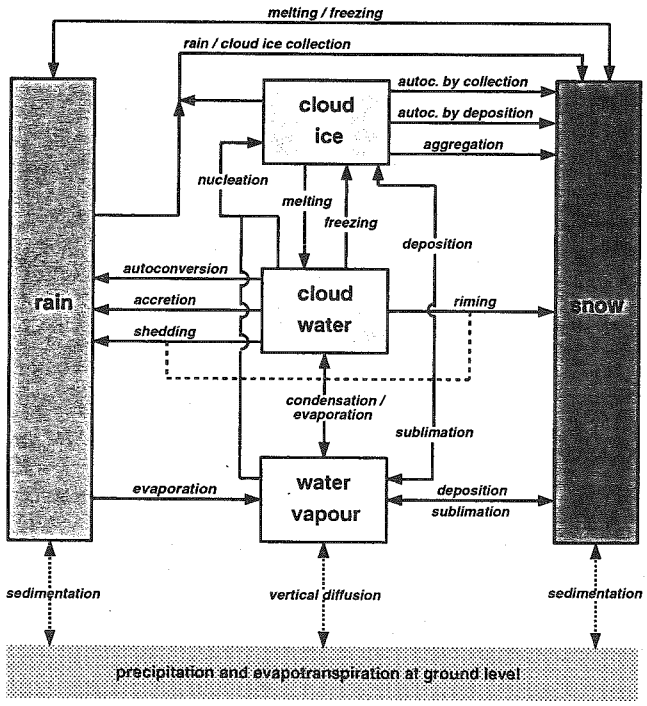

Figure 1: Hydrological cycle and microphysical processes in the LM cloud ice scheme

The explicit calculation of cloud ice depositional growth as a non-equilibrium process is based on the mass-growth equation of a single pristine crystal and requires some basic assumptions on the shape, size and number density of the ice crystals. Here, we assume a monodispers size distribution for cloud ice particles with the mean crystal mass

$$m_i = \rho q^i N_i^{-1}, \tag{2}$$

being diagnosed from the the predicted mixing ratio q^i and the number density N_i of cloud ice particles. The number density $N_i(T)$ of cloud-ice particles is prescribed as a function of ambient air temperature using the relation

$$N_i(T) = N_0^i \exp\{0.2\,(T_0 - T)\}, \qquad N_0^i = 1.0 \cdot 10^2 m^{-3}, \tag{3}$$

which is an empirical fit to data obtained by aircraft measurements in stratiform clouds (Hobbs and Rangno, 1985, and Meyers et al., 1992). For a given temperature, the experimental data may scatter by about two orders of magnitude. Nevertheless, we assume that (3) represents a meaningful average value for the cloud ice crystal concentration in cold stratiform clouds. Cloud ice crystals are assumed to be in the form of thin hexagonal plates with diameter D_i and thickness h_i, where the maximum linear dimension D_i is smaller than about 200 μm. This constant aspect ratio growth regime yields the following relation to calculate the size D_i of cloud ice particles from the diagnosed mean mass m_i,

$$D_i = (m_i)^{1/3}\,(a_m^i)^{-1/3}, \tag{4}$$

where $a_m^i = 130$ kgm^{-3}. A temperature dependency of the form factor a_m^i is neglected.

Using (2), (3) and (4) in the mass-growth equation for a single crystal, the total deposition rate of cloud ice, $S^i_{dep} = N_i \dot{m}_i / \rho$, may then be formulated by

$$S^i_{dep} = c_i N_i m_i^{1/3} (q^v - q^v_{si}) \tag{5}$$

in terms of ice supersaturation $q^v - q^v_{si}$ (or subsaturation for sublimation). The factor $c_i = 4 G_i d_v \sqrt[3]{a_m}$ varies slowly with temperature and pressure due to the Howell factor G_i and the water vapour diffusivity d_v. Here, c_i is approximated by the constant value of $1.5 \cdot 10^{-5}$.

Cloud ice is initially formed by heterogeneous nucleation or homogeneous freezing of supercooled droplets. The latter process is parameterized by instantaneous freezing of cloud water for temperatures below $-37°C$. To formulate heterogeneous nucleation, we simply assume that the number of ice forming nuclei activated within a time step Δt is given by Eq. (3) and that the temperature is below a nucleation threshold (set to $-7°C$). We will also neglect nucleation whenever ice is already present since this has been found to be of minor importance. Recent field experiments show that ice nucleation is not likely to occur in regions of the atmosphere which are subsaturated with respect to water, except for very low temperatures. In the present version of the scheme we thus require water saturation for the onset of cloud ice formation above a temperature threshold T_d (set to $-30°C$). For temperatures below T_d, deposition nucleation may occur for ice supersaturation. All other conversion rates are parameterized in a similar way as in the operational scheme. For 3-dimensional advection of cloud ice, the positive definite Lin and Rood (1996) algorithm is used.

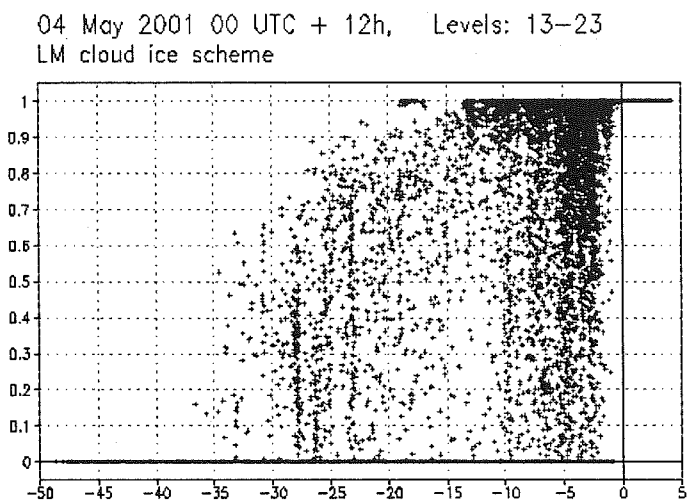

Figure 2: Variation with temperature of the liquid fraction for 4 May 2001 00 UTC + 12 h.

4 Preliminary Results

The LM cloud ice scheme has been tested for a number of case studies. Figure 2 shows the variation with temperature of the liquid fraction $f_l = q^c/(q^c + q^i)$ generated by the scheme. The values of f_l were obtained from a single time step after the model was run for 12 h starting from the 4 May 2001 00 UTC analysis. For temperatures warmer than about $-10°C$, there are cloudy grid-boxes which are composed of either liquid water or ice, and

there is a large number of boxes indicating a mixed phase state. Below $-10°C$, there is still a large number of mixed phase clouds with supercooled droplets, but the liquid fraction drops off with temperature. Below about $-35°C$ only ice clouds exist. There is a good qualitative agreement with the observations for stratiform clouds (Ryan, 1996), but the model indicates a larger number of mixed phase clouds for temperatures below about $-15°C$. A reason for this behaviour is that in Figure 2 not only stratiform clouds but all cloudy grid points are counted. For the convective 4 May 2001 case, a large number of gridpoints from anvils and embedded cold frontal convection contribute to the scatter plot. At such points, strong dynamical forcing can keep the air at water saturation allowing for mixed phase clouds at low temperatures. This example shows also that with the new scheme the liquid fraction adjusts reasonable in response to dynamical forcing and microphysical processes.

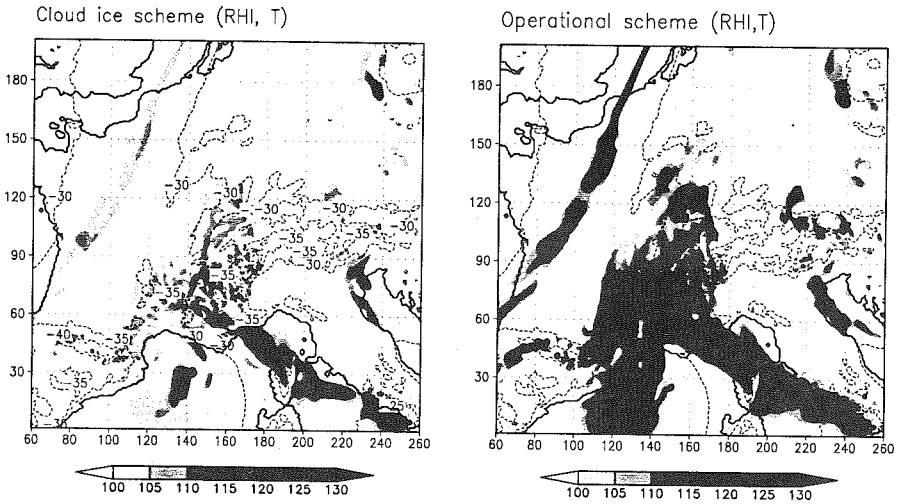

Figure 3: Relative humidity over ice (shaded, in %) and temperature ($°C$, isolines) for 4 May 2001 00 UTC + 12 h at model level 14. Left: cloud ice scheme. Right: operational scheme.

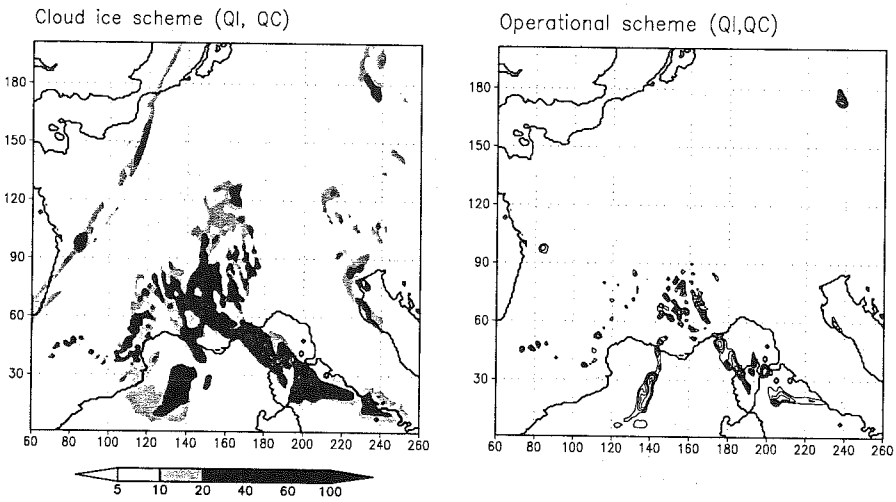

Figure 4: As in Fig. 3 but for specific cloud ice content (shaded, in mg/kg) and cloud water content (isolines at 10 mg/kg intervals).

There is also a large impact to the humidity structure of the upper atmosphere. To illustrate this, the relative humidity over ice obtained from runs with the cloud ice and the operational scheme is shown in Figure 3 for the same case and forecast time. Figure 4 displays the corresponding specific cloud ice and cloud water contents. The fields are plotted for a model subdomain at level 14, corresponding to a height of about 7000 m with temperatures ranging from -30 to $-40°C$. The operational run reveals high ice supersaturation of about 20 - 40 % in two regions: a band-like structure over western France which is associated with a cold front, and a more unstructured region in the warm sector ahead of the front. Here, widespread deep convection occurs which by vertical transport generates and maintains high humidity.

With the operational scheme, there is no ice but only cloud water by definition (Fig. 4, right). Since saturation with respect to water is required for grid-scale cloud formation, cloud water is found only at those gridpoints where dynamic forcing by convection drives the atmosphere to water saturation (at a temperature of $-35°C$, this will occur at about 35 % ice-supersaturation). However, these points are rather scattered whereas satellite images indicate a region of merged anvils above the northern Mediterranean Sea and southern France (not shown). This high level cloudiness is simulated much more realistic by the cloud ice scheme (Figures 3 and 4, left). Here, cloud ice is initially formed also at gridpoints which are at or near water saturation. Subsequently, however, it can be advected into regions which are ice-supersaturated but are below water saturation. In these regions, cloud ice will continue to grow by vapour deposition, thereby reducing the humidity to values more close to ice saturation (Fig. 3, left). Thus, a much larger region with grid-scale anvils – mostly composed of ice – is simulated than with the operational scheme. In the warm sector region, some mixed-phase clouds do also exist at gridpoints, where strong convective forcing maintains water saturation. Also, high-level ice clouds appear along cloud front.

Besides such single case tests, the new scheme was run in a parallel forecast suite with full data assimilation for two three-week periods in winter and spring 2002. The verification against radiosonde data showed a significant positive impact on temperature (reduction of a negative bias) and on relative humidity (reduction of a strong positive bias in the upper troposphere) when compared to the operational runs. The verification of parameters from surface observations revealed a neutral (precipitation) to slightly positive (2-m temperature) impact of the ice-scheme – except for high-level cloudiness which is increased to too high values. This deficiency is expected to be cured by future fine-tuning of the scheme.

5 Summary and Plans

A new microphysics parameterization scheme including cloud ice has been developed and successfully tested in LM. The main advantage of the scheme is a more physically based representation of ice and mixed-phase clouds, allowing for a direct simulation of cloud glaciation. The phase composition of high-level clouds appears to be well captured, which is important for a better cloud-radiation interaction. And in particular, the formation, growth and spreading of grid-scale anvil clouds can be simulated explicitly.

Following further testing it is planned to introduce the cloud ice scheme operationally in spring 2003. To provide consistent boundary conditions from the driving model, the scheme has also been implemented in our global model GME. A rerun of a one-year period during 2001/2002 revealed an overall benefcial impact of the cloud ice scheme, with a significant reduction of current imbalances in the average radiation an water budgets.

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4.3 To warn or not to warn...

To warn or not to warn...

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Introduction

The presentation consists of 3 parts:

1. the forecaster (past & present)
2. the model (deterministic or probabilistic?)
3. and I'll try to draw some conclusions

1. The forecaster

30 years ago I worked with pencil, paper, eraser and a lot of rubbish all over the place. So you can say: that was my meteorological cradle. In other words: I'm an old fashioned meteorologist! Those were the days when every 6 or 12 hours one map came up, and with one senior forecaster in charge this led to one deterministic handmade solution, so producing a forecast was well-ordered and clearly structured.
Nowadays on our working stations we have a bit more information available. And when you interpret each forecast as a deterministic one you'll get mixed up with some problems. So we have to change our perception, or to quote Anton Beljaars: "We have to learn to cope with uncertainty."

2. The model

To illustrate my point of view I have chosen a case from the 4th and the 5th of June last summer. It's a situation in which HiRLAM scored very good with its precipitation during the night, but made a bad performance in the wind forecast during the day, at least from a deterministic point of view.

3. Conclusions

Although the HiRLAM-model overestimated the deepness of the low and the track wasn't perfect, the signal of a small scale development was remarkably correct, better than all other models we have available on our workstation. Before there was anything visible in the observations the model gave an adequate signal,
so the forecaster was aware of a potential hazardous development !!
In the minds of quite a lot of my colleagues every HiRLAM-run produces one deterministic forecast, so from a deterministic point of view the performance of the model was bad, but as we all know every run is only one draw from the ensemble, one solution among thousands of other atmospheric possibilities. In other words: from a probabilistic point of view HiRLAM performed quite good.

In our forecasting room we'll have to work hard to change our minds from the deterministic orientation to the probabilistic one. Once we've done this, we can cash the benefits of the improved high resolution HiRLAM.
In my beckoning future the KNMI-forecaster is a meteorological professional who is able to combine his human pattern recognition capabilities with all the signals the model is offering him. That's one of the reasons that we're studying hard here in De Bilt with the so called SATREP-method. But that's another story.
To finish this short introduction in forecasters worries at KNMI a citation of Kahlil Gibran:

> If you wish to see the valleys,
> climb to the top of the mountain;
> if you wish to see the top of the mountain,
> lift yourself above the cloud;
> but if you try to understand the cloud,
> close your eyes and think.

4.4 Modelling the high resolution structure of frontal rainbands

MODELLING THE HIGH RESOLUTION STRUCTURE OF FRONTAL RAINBANDS

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1. Introduction

High resolution Numerical Weather Prediction (NWP) models driven by larger scale information are used to add finer scale structure to model forecasts. Added detail arises from (i) finer scale forcing from the surface boundary condition in the form of orography and surface characteristics, and (ii) internally generated structure due to non-linear effects in the model dynamics and parametrized physics which often takes the form of flow instabilities. Assessments of mesoscale models have been dominated by the first of these factors, and much skill has been demonstrated in predicting impacts from higher resolution surface forcing. Somewhat less attention has been paid to the inherent accuracy of internally generated structure.

The mesoscale structure of extra-tropical cyclones developing entirely over the sea is a good example of internally generated structure. The Fronts and Atlantic Storm Tracks Experiment (FASTEX) provided a number of high quality observational data sets concentrating on cyclone development over the northern Atlantic. Here, we focus on one Intensive Observation Period (IOP 16), during which a weak trough to the west of the Atlantic developed, over roughly a 12 hour period, into an intense secondary cyclone to the north west of Scotland. The mesoscale structure of the cyclone was well observed using airborne Doppler radar, dropsondes and *in-situ* aircraft measurements showing multiple bands of ascent within the frontal zone (Roberts and Forbes, 2002). The cyclone was associated with severe weather, in the form of strong winds, heavy rain and low cloud.

A number of forecasts using the Met Office NWP model are used to investigate the sensitivity to horizontal and vertical model resolution and whether the small scale frontal circulations resolved in the high resolution models act to modify the larger scales (Lean and Clark, 2003). One aspect of the physical parametrizations in the model that has been shown to affect the dynamics at the frontal scale is the evaporation of snow/ice particles beneath frontal cloud (Clough et al. 2000, Forbes and Clark 2003). Errors in the model parametrization of evaporation are identified by comparison with data from a vertically pointing cloud radar. Combined knowledge of the model error, parametrization uncertainty and model sensitivity is then used to improve the formulation of the NWP model.

2. Resolution dependence of extra-tropical cyclone modelling

A series of forecasts of the FASTEX IOP 16 cyclone are performed using the non-hydrostatic version of the Unified Model (Cullen et al. 1997) at various horizontal resolutions (60, 24, 12, 4 and 2 km gridlengths) and vertical resolutions (45, 90 and 135 levels with mid-tropospheric layer depths of approximately 300m, 150m and 100m respectively). As the horizontal resolution is increased, the fronts split into multiple bands in the across-front direction and into cells in the along-front direction. The impact of increasing vertical resolution is greatest for the 2km model, in which the cross frontal slantwise circulations split into a number of separate circulations in the 90 level and 135 level models. The splitting of the slantwise structures is realistic and in agreement with data from dropsondes. Conditional symmetric instability (CSI) could play a role in the formation of these multiple bands and the evaporative cooling of ice/snow is also shown to affect the characteristics of these circulations.

Power spectra of the vertical velocity fields show a turn up at the shortest wavelengths for all but the 2km and 60km runs. This implies that the models with 24, 12 and 4 km resolution have some aliasing at the gridscale, and comparison of spectra of a domain not including the fronts shows that this aliasing is taking place at the line convection on the fronts. The line convection in the 2km model is, at least partially, resolved. Dividing the vertical velocity power spectra by the power spectrum from the 2km model and re-normalising according to the gridlength shows there is a consistent filter function as scales reduce towards the gridlength. The implication is that the representation of any feature smaller than about 5 gridlengths is attenuated in the model, whatever the resolution.

To determine whether the lower resolution models are representing the larger scales accurately in the frontal region, the vertical velocity fields from the various resolution models are area averaged to a common 60km gridlength. Qualitatively, at 60km, the model fields look remarkably similar. Quantitatively, the average upward vertical velocity on 60km scales is approximately constant as the gridlength is changed. This implies that the detailed structure of the vertical velocity in the high resolution models does not have a significant impact on the larger scales of the frontal cyclone (at least on a timescale of a day), although it will have a significant impact on the accuracy of the local weather forecast. We can understand this in terms of potential vorticity (PV). On the larger scale, symmetric dipole/tripole anomalies associated with multiple frontal slantwise circulations (with condensation heating in the saturated ascent and evaporative cooling in the descent) cancel each other out (Fig. 1). The dipole/tripole component of a PV anomaly has only a weak influence on the far field and it is the monopole of PV that dominates the far-field (or large scale) response.

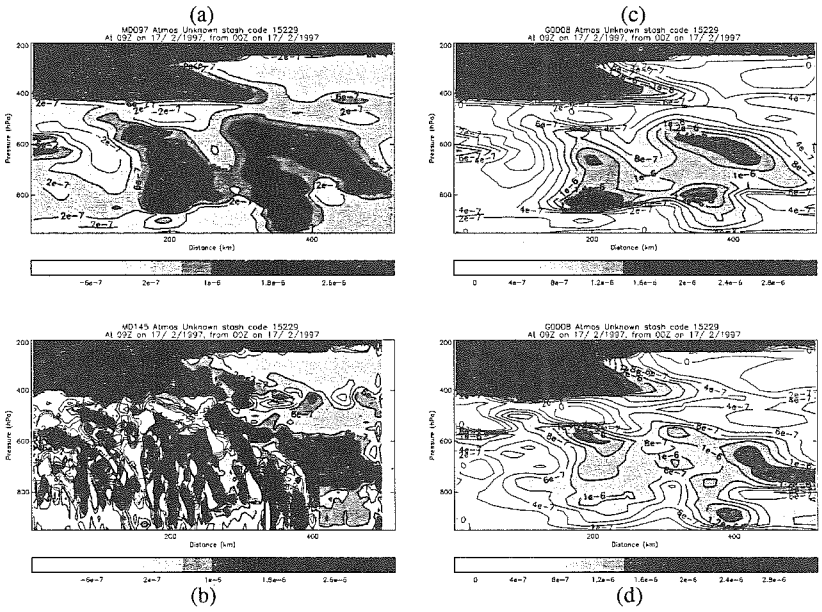

Figure 1 Cross-section of potential vorticity (K kg^{-1} m^2 s^{-1}) across the two main cold fronts in the FASTEX IOP 16 case study for (a) the 24 km 45 level model and (b) the 2 km, 90 level model. In the 2km model the fronts split into multiple slantwise circulations. (c) and (d) are the same as (a) and (b) respectively with data averaged to a 60 km gridlength in the horizontal.

3. The impact of ice evaporation on frontal dynamics

The parametrization of microphysical processes is a vital part NWP models, not only for the prediction of cloud and precipitation, but also for the impact on the dynamics through latent heating/cooling. One aspect that has had relatively little attention is the role of evaporative cooling in the development of mid-latitude fronts. Forbes and Clark (2003) describe the forecast sensitivity of mesoscale structure in a frontal zone to parameters in the ice microphysical parametrization scheme (Wilson and Ballard, 1999) in a 12km gridlength version of the Met Office Unified Model. A study of the rapidly developing cyclone observed during FASTEX IOP 16 showed there was a sensitivity of the downdraught beneath the frontal surface to changes in the formulation of the ice evaporation rate and ice terminal fall speed. The dynamical changes occurred because of the modified distribution and intensity of diabatic cooling due to evaporating ice. This lead to changes in forecasts of surface weather such as the spatial distribution of cloud and precipitation and low level wind. Greater cooling in a narrower depth beneath the frontal surface leads to enhanced descent that is essentially saturated due to the evaporation (Clough et al. 2000, Forbes 2002).

If the details of ice evaporation beneath stratiform frontal cloud are important for the accurate prediction of frontal structure then numerical models need to

produce an appropriate profile of ice evaporative cooling. The important parameters are the flux of ice into the evaporation zone and the depth scale of the evaporation. To identify deficiencies in the model representation of the ice evaporation zone, depth scales of ice evaporation are derived from a 1 year timeseries of data (May 1999 to April 2000) from a vertically pointing 94GHz cloud radar based at Chilbolton in the southern UK. Ice water content is first estimated from the radar reflectivity data (Liu and Illingworth, 2000) and averaged to the resolution of the model (12km). An algorithm is applied to the data to extract profiles considered to contain evaporating ice/snow beneath frontal cloud. The evaporation depth scale is then defined as the distance from the maximum ice water content in the profile to the point where the ice water content drops to 10% of the maximum. The same algorithm is applied to the equivalent timeseries over Chilbolton from the Met Office operational mesoscale model and statistics of the evaporation depth scales and ice water content are calculated for both the model and observational data.

The results from the radar observations (Fig. 2a) show that ice evaporation is rapid in the subsaturated zone beneath a frontal surface leading to significant cooling (~1K/hr) in a shallow layer generally less than 1km deep. A comparison between the model and observation statistics shows the model underestimates the amount of ice and overestimates the evaporative depth scales by a factor of 2 to 3 (Fig. 2b) which leads to a significant underestimate in the cooling and strength of frontal circulations. This is found to be due to a number of factors including poor vertical resolution, a parametrized ice evaporation rate that is too weak, and a parametrized ice terminal fall speed that is too high. The model evaporative depth scales can be significantly improved by varying microphysical parameters within their bounds of uncertainty (estimated to be a factor of two for the fall speed and evaporation rate). A further trial over many cases is required to determine whether the forecasts of cloud, precipitation and wind are improved over the longer term.

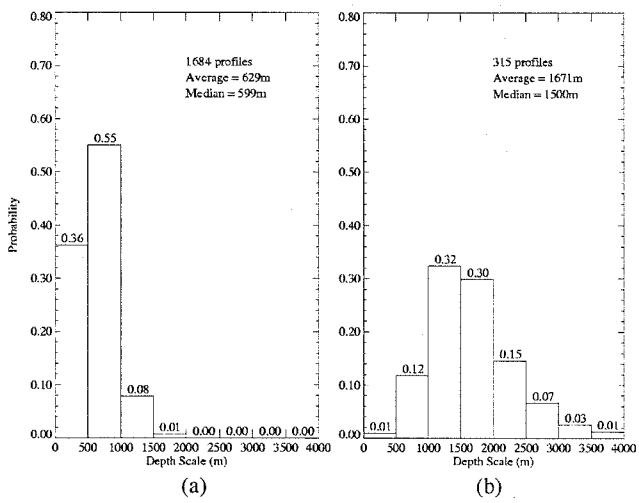

Figure 2
Probability distribution of frontal ice/snow evaporative depth scale for May 1999 to April 2000 over Chilbolton from (a) radar obs. averaged to 12km, and (b) the 12km mesoscale model

4. Summary

The high resolution simulations of the FASTEX IOP 16 frontal cyclone show the model is able to represent the observed splitting of fronts into multiple slantwise circulations. The process of ice/snow evaporative cooling does have a significant impact on these frontal circulations, keeps the downdraught close to saturation, and potentially affects both the frontogenesis process and the occurrence of CSI. It is therefore important for the model to have the correct representation of the evaporative cooling rate and vertical transport of ice for the correct profile of evaporative cooling. The impact of the multiple frontal circulations on the larger scale is relatively small, at least on the timescale of the order of a day. This is because small scale circulations in frontal zones have little net impact on the overall diabatic heating rate and on PV generation, i.e. slantwise overturning is not a strong net generator due to the evaporatively cooled descent being essentially saturated. This is probably why lower resolution models (10+ km) have so much success in representing frontal cyclones. As a final comment, it is important to note that these results apply to the development of high resolution structure in a frontal cyclone over the ocean. High resolution models do add benefit to the forecast of local significant weather, particularly in other meteorological regimes (e.g. convective), and over land, high resolution surface forcing can be a dominant factor.

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4.5 Simulated radar measurements in NWP model validation

Simulated radar measurements in NWP model validation

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December 2, 2002

1 Introduction

Producing accurate short-range forecasts of precipitation is a major challenge of high-resolution numerical weather prediction. Such forecasts rely on a realistic representation of convection and cloud-micro-physical processes in the NWP-model. Yet, the parameterization of convection at grid-lengths in the range of 3 to 20 km, as used in todays regional NWP-models, is an unsolved problem. The fundamental difficulty lies in the lack of a clear scale separation between resolved and unresolved phenomena. There is also a lack of observations whereby to verify predictions and validate models. Standard verification statistics from parallel experiments can tell which of two model-configurations performs best, but do not tell much about individual physical processes, or about individual events.

Case studies may provide additional insight, but suffer from problems of their own. Because of the extreme variability of precipitation in time and space, the network of rain-gauges is not very useful in case of individual events. Networks of weather radars are good at detecting the variability but precipitation amounts estimated from radars alone are not very accurate. The principal source of error is in the sampling geometry of the radar measurement. At ranges beyond 100 km, the radar samples volumes of air at altitudes of a few km, and there is no unique way to retrieve the correct values at the surface. Things can be improved by observing the vertical profile of the radar reflectivity at the radar site, or by using rain-gauges to derive a statistical correction factor for the radar-retrieval. But considerable uncertainty remains in individual cases.

However, for model validation purposes it is not necessary to convert the radar measurement to precipitation intensity at the surface. Instead, one can calculate the equivalent of a radar measurement corresponding to the model fields, and make a direct intercomparison. The application of this methodology to a case study using the HIRLAM NWP-system is described in the following.

The Radar simulation model (RSM) by Haase and Crewell (2000) is briefly described in Section 2. The case study is presented in Section 3, and results in in Section 4. Conclusions are drawn in Section 5.

2 The Radar Simulation Model

Application of the Radar Simulation Model (RSM) in the framework of the HIRLAM NWP-system is described in Haase and Fortelius (2001). Most meteorological radars transmit short pulses of electromagnetic radiation from a directional antenna, and register the power reflected from hydro-meteors and other objects. The amplitude of the returned signal is used to estimate the reflectance factor or reflectivity of the target volume. The reflectivity depends on the amount and phase of the hydro-meteors, and on the particle size distribution. Hence, radar measurements can be used to estimate e.g. the intensity of precipitation.

Simulation of radar measurements by the RSM proceeds in the following manner: First, the location and characteristics (frequency, scan pattern, etc.) of an arbitrary radar are specified. Next, fields of backscattering and extinction coefficients corresponding to the radar frequency are computed from predicted fields of hydro-meteors. RSM takes into account the phase of the hydro-meteors, and distinguishes between convective and stratiform precipitation by assuming different particle size distributions accordingly. From the computed cross-sections, measurements corresponding to the selected scan pattern can be computed, taking into account the propagation of the radar beam inside the model domain.

3 Experiments

The RSM was used to compare two different parameterizations of precipitation processes in HIRLAM. One scheme is an updated version of the Soft Transition Condensation (STRACO) by Sass (2001). STRACO uses a moisture convergence closure for convection. Startiform precipitation and micro physics are treated following Sundqvist et al. (1989). The other scheme (RKKF) treats convection according to Kain and Fritsch (1990), and uses a closure based on convectively available potential energy (CAPE). Stratiform precipitation is treated according to Rasch and Kristjansson (1998). The treatment of stratiform precipitation is very similar in the two schemes. The experiments are based on HIRLAM reference version 5.0.0 on 40 levels with a grid spacing of 0.05°, set up on the area shown in fig 1 (right hand side). Both experiments run their own data assimilation cycle, but use identical lateral boundary conditions from the operational archives of FMI, having a horizontal resolution of 0.2°.

4 Results

Results are presented for a case of northwesterly flow over Finland on May 25th, 2001, characterized by randomly organized convection of small scale as shown in fig. 1. During the day, the convective cells moved from northwest to southeast.

Two parallel experiments were initialized on 00 UTC of May 25th, 2001. Simulated radar data from the experiments were compared to measurements from three of the seven radars operated by FMI. The radars, shown in Fig. 1 are 5.6 GHz Doppler-radars from

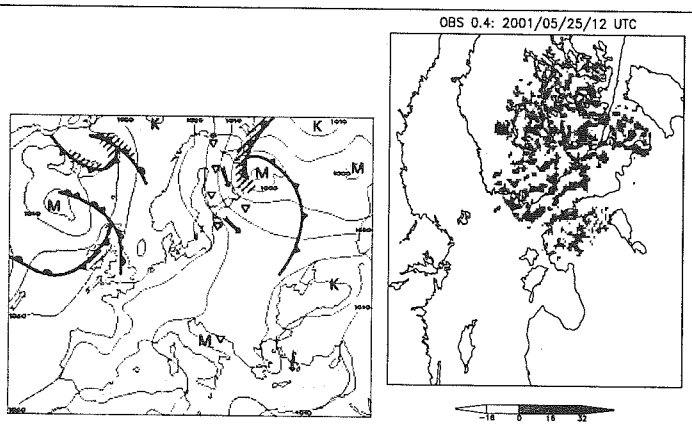

Figure 1: Left: Analyzed synoptic situation on 12 UTC May, 25th, 2001 Right: Integration are for HIRLAM, and composite image from the radars at Ikaalinen, Vantaa and Anjalankoski, shown as black circles in the figure. The elevation angle is 0.4 degrees and the unit is dBZ.

Gematronik. Every 15 minutes each radar scans a set of full circles at specified elevation angles. The horizontal resolution is 1.0° in azimuth and 500 m in range. The Doppler effect is used to identify and remove stationary echoes. To facilitate inter-comparison with the simulations, the radar reflectivity was transformed to the grid of the NWP-model by box-averaging.

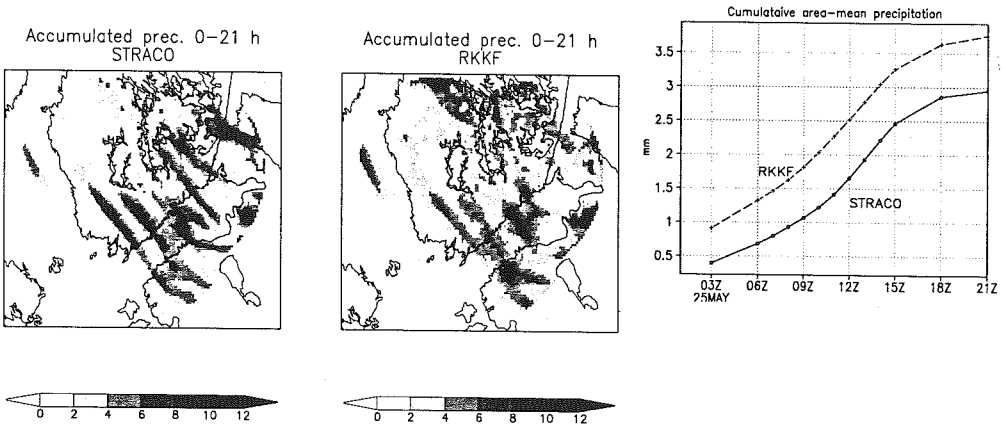

Figure 2: Accumulated rainfall in the study area (mm)

Figure 2 shows the accumulated rainfall in the study area during the first 21 hours of both experiments. Judged by these data, the two model configurations yield essentially equal results. Except for near the northern edge, very similar patterns are seen in both

maps, and the areally-averaged rainfall has nearly the same growth rate in both experiments. The offset seems to be established during the first hours of the integrations and remain nearly constant afterwards.

By contrast, the simulated instantaneous radar images from the two experiments show very different patterns (Fig. 3). The image of STRACO resembles somewhat the observations (Fig. 1)in the cellular structure, but the cells are much too large and much too strong. In marked contrast, RKKF shows a very uniform reflectivity.

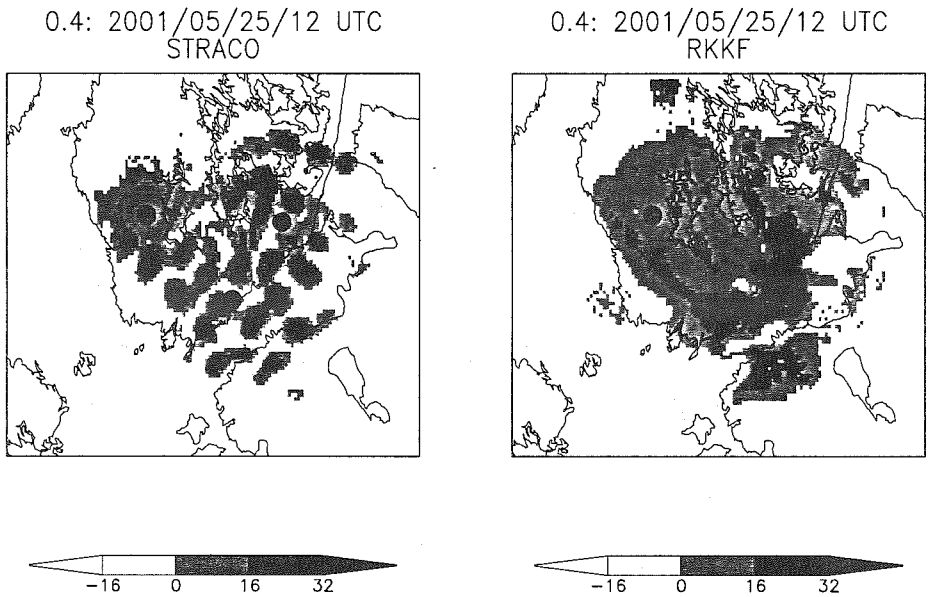

Figure 3: Simulated composite image from the radars at Ikaalinen, Vantaa and Anjalankoski, shown as black circles in the figure. The elevation angle is 0.4 degrees and the unit is dBZ.

Fig. 4 shows the frequency of different classes of reflectivity within the study area as functions of time. The relative frequencies of the four classes are correctly given by both experiments. However, STRACO is seen to overestimate the occurrence of strong echos, while RKKF overestimates the occurrence of weak echos and underestimates the occurrence of clear pixels. Both experiments are approximately four hours late in the timing of the medium-strong echos.

5 Conclusions

There is sufficient similarity between observed and simulated radar images for the RSM-technique to be a meaningful way of verifying vertically-distributed hydro-meteors from NWP-models. The method may thus be used as a powerful tool for a process-level evaluation of different model configurations.

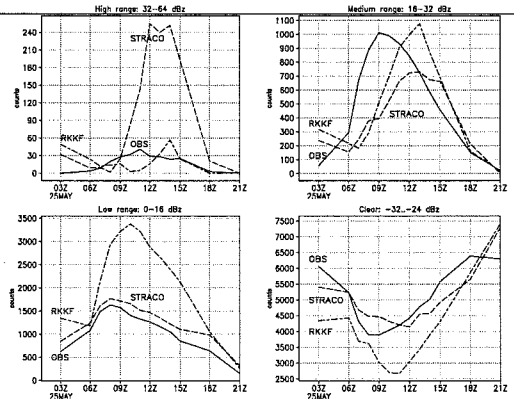

Figure 4: Simulated composite image from the radars at Ikaalinen, Vantaa and Anjalankoski. The elevation angle is 0.4 degrees.

Acknowledgements: The Radar Simulation Model is used with the kind permission of the German Weather Service. The HIRLAM-experiments were performed by Sami Niemelä at the University of Helsinki.

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4.6 Evaluation of an assimilation cycle in ALADIN on MAP IOP 14

Evaluation of an assimilation cycle in ALADIN on MAP IOP 14

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ALADIN is a limited area model (LAM) developed within international collaboration and coupled to the french global operational model ARPEGE. The ALADIN model used operationally at Météo-France (ALADIN-France) is run at 9.5 km resolution using an initial state corresponding currently to the interpolated ARPEGE analysis on which a digital filter initialization (DFI) is applied. Different strategies for ALADIN initialization have been tested on an intensive observation period (IOP 14) of the Mesoscale Alpine Programme experiment (MAP) which took place in the Alps during the autumn 1999. Between the 2nd and 4th of November 1999 a front crossed eastward Europe giving strong precipitations near Lyon, Barcelone, Gènes and in the south of the Alps. IOP 14 of MAP experiment is a well documented case (SYNOP observations, radar, satellite images, ...), which allows the evaluation of the assimilation techniques described below. The objective of the work is to introduce informations coming from new observations while keeping mesoscale features present in a previous ALADIN forecast.

The DFI-blending technique is a kind of mesoscale assimilation based on DFI, which does not directly use the observations. It combines large-scale features contained in ARPEGE analysis with small and meso-scale features provided by a short range ALADIN forecast. The latter are expected to be more realistic than those obtained by interpolation from the global model. ARPEGE analysis and ALADIN 6h forecast (guess) are first interpolated at low resolution. Then a DFI is applied on these two states before to be interpolated at ALADIN's resolution. The filtered analysis increment (difference between the filtered analysis and the filtered guess) is added to the 6h ALADIN forecast to produce the initial state of ALADIN model.

The experiments performed aim at testing the sensitivity of the forecast to the initial state for a given configuration. The evaluation is done on the 48h forecast starting on 2nd November 1999 at 12h UTC. The reference experiment corresponds to the operational configuration (dynamical adaptation). The blending technique is used with various tunings of the

digital filters and various lengths of cycling. The convective activity and the precipitation field are improved with blending initialization. Some rainfall patterns, not simulated by the control run, are well described in the experiments using blending technique like at west of Corsica over sea or in the coastal regions near Nice (Figure 1).

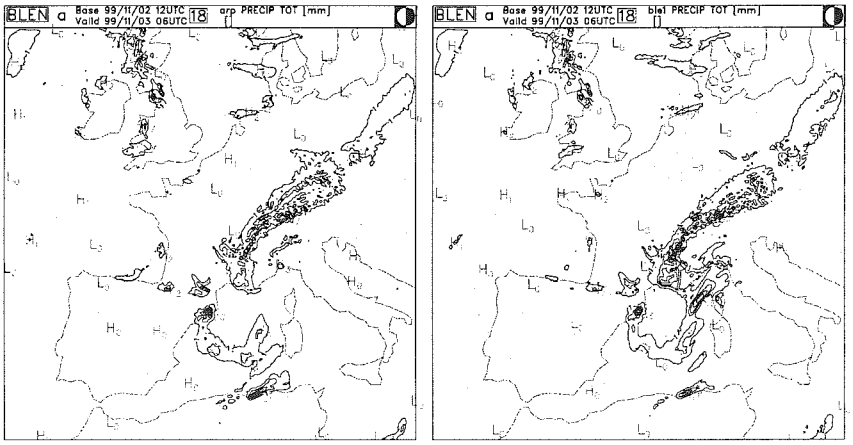

Figure 1: Precipitation cumulated between 00 and 06 UTC on 3rd November for two 18h forecasts corresponding to the control run (left) and a blending cycle (right).

A combination of blending and 3D variational analysis, named "blendvar" is used to introduce directly observations in the ALADIN model. The blended state is used as first guess in the variational analysis. The background error statistics have been obtained through an "NMC lagged" method. The benefits from the observations, shown by the analysis increments (Figure 2), are complementary to those of the blending. The system activity is better described, and the intensity of some patterns are more relevant. To highlight the importance of the blending step, two experiments only using 3D-VAR cycling were performed.

"New" data (i.e. data usually unused in variational analysis) are introduced through a 3D-VAR step. Humidity pseudo-profiles bring information about relative humidity in the troposphere and the initial state is better described. Such data can lead to an improvement of the simulation of precipitations for instance, even beyond 24h forecast.

The initialization step, performed before a 48 hour ALADIN forecast, is also studied. Its impact is compared with that of DFI-blending and that of 3D-VAR. Various kinds of initialization are evaluated and the following conclusions can be drawn : incremental DFI is to be used after a 3D-VAR step; non incremental DFI is to be applied to initialize an interpolated ARPEGE

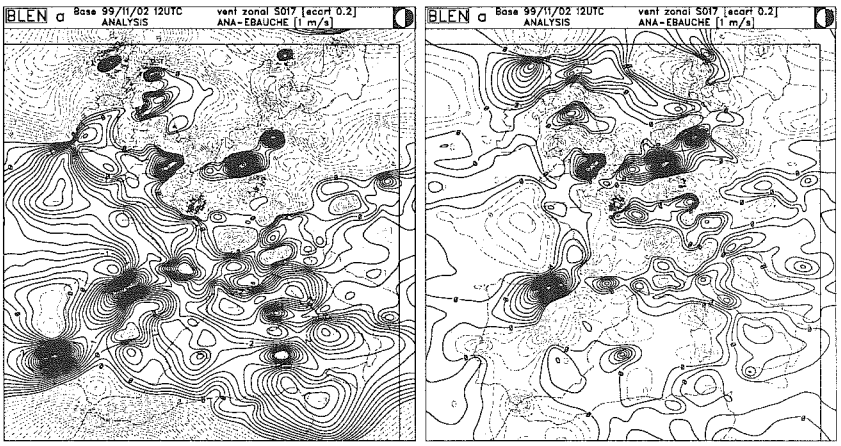

Figure 2: 3D-VAR analysis increments for zonal wind on model level 17 (mid-troposphere) when the first guess is an interpolated ARPEGE analysis (left) or a blended state (right).

analysis, and, less obviously, after a blending step.

The evaluation performed in this particular IOP 14 backgroud leads to very relevant and positive conclusions on blending and blendvar. Small and mesoscale features are taken into account in a good way, and the fields generated with blending have good realism.

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4.7 Assimilation of rainrates from BALTRAD network using latent heat nudging technique

Assimilation of rainrates from BALTRAD network using latent heat nudging technique

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Introduction

BALTEX Radar Data Center, BRDC, located in Sweden collects different radar products generated during BALTEX special observing periods. We used radar data stored during BRIDGE experiment. Data are available from November 1999 to February 2002. Four different types of products were generated: radar reflectivity factor (DBZ), composite image generated from radar reflectivity factor, accumulated precipitation analysis products based on DBZ products and synoptic observations (Michelson, 2001), and wind profiles from Doppler radars. In composite products the Lambert Azimutal Equal Area projection with the spherical earth model is used. In this article we concentrated on 3-hour accumulated precipitation data. Spatial resolution of 815x1195 points of data is 2x2 km. Composite picture includes from 23 to 27 radar sites, depending on the availability. At the ICM we run operationally Unified Model tailored to the Central Europe area from May 1997, and from that period we collect all analyses and forecasts produced by our UMPL system (Herman-Izycki et al. 2002).

Observation processing system

Unified Model assimilates different types of observations (Lorenc et al., 1991) with basic assumption that raw observational data passed quality control during a previous stage of data processing. For these purposes the Observation Processing System (OPS) was designed. The OPS extracts conventional and satellite data from UKMO operational database, checks the quality of data using UM model background fields and finally creates the input files for an assimilation within the Unified Model. Radar data, generally available locally, are treated in different way, as these and cloud data are produced by the nowcasting system NIMROD. We decided to use OPS for a creation of input files with radar precipitation data. Writing new computer code BaltProg we were able, using selected procedures from OPS system and including new procedures for reading the BALTRAD data structure, to produce input files with radar precipitation data in format required by the UM system. We did not implement the quality control procedures, as precipitation data from BRIDGE experiment were quality controlled during the process of blending radar precipitation rates with precipitation totals from rain gauges measurements.

Latent heat nudging in Unified Model

Vertically integrated latent heating rate due to condensation within a cloud is approximately proportional to the net rain rate. The assimilation algorithm is independent on the origin of the rain rat data. The basic structure of the scheme is to calculate latent heating profiles from the model physics step, and to derive increments within the Assimilation Correction (AC) scheme to the potential temperature. This is based on scaling of the profiles by the amount equal to the value of rain estimated from radar data analysis to the model first guess value (Macpherson, 2001). Field of analysed precipitation is created as the sum of total precipitation (rain and snow from large scale and convective processes) and precipitation increments estimated by AC scheme from radar precipitation data. The input to the increment analysis consists of 3-hour precipitation totals prepared at the resolution of 4 km and then averaged onto the model grid. As a background, 3-hour mesoscale model precipitation forecast is used. The analysis is performed by 2-dimensional recursive filter technique (Hayden and Purser, 1988). Total latent heating increments are combined from latent heating increments to potential temperature due to convection and latent heating increments to potential temperature due to dynamics. The important part of the scheme is the search for a suitable nearby latent heating profiles for use in the LHN scheme. Depending on results of the search the scaling is performed to profile at the point itself, to the nearby profile at nearby point, by prescribed profile or observation is ignored.

Preliminary results

Described scheme was tested of one selected day: 23 July 2000.

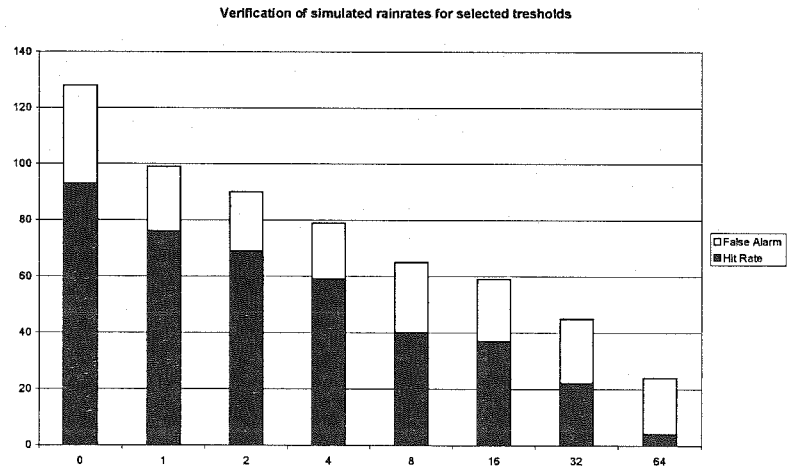
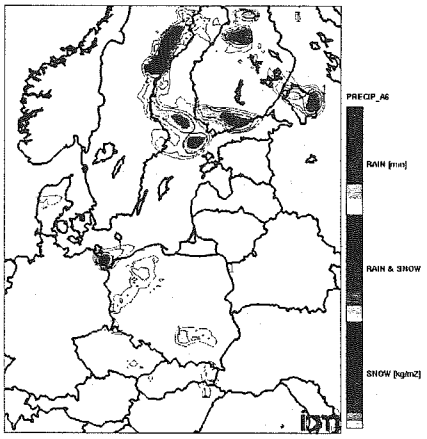
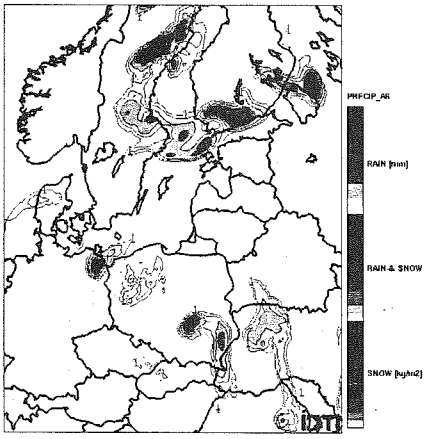


Fig. 1 Verification statistics for daily precipitation totals (control run)

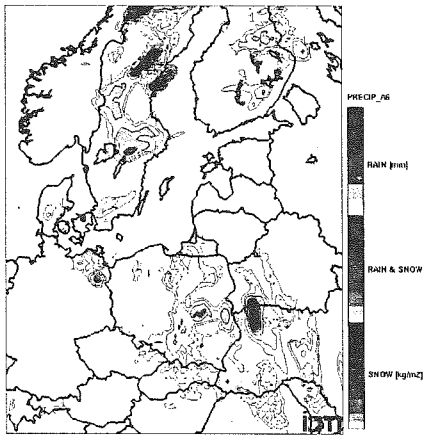
23 July 2000, 00:00 UTC



23 July 2000, 06:00 UTC



23 July 2000, 12:00 UTC



23 July 2000, 18:00 UTC

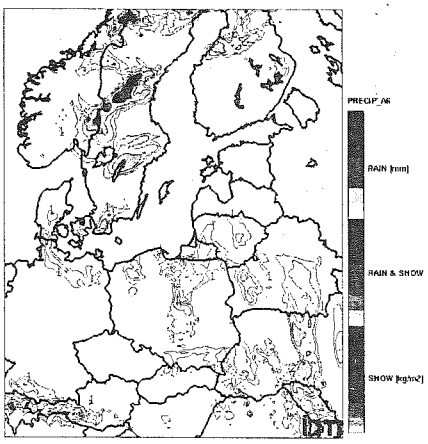
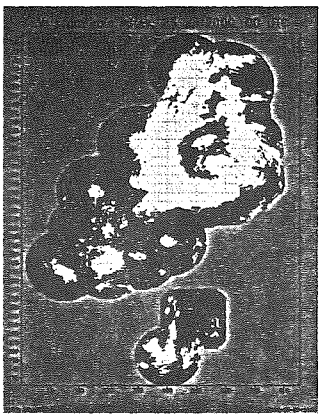
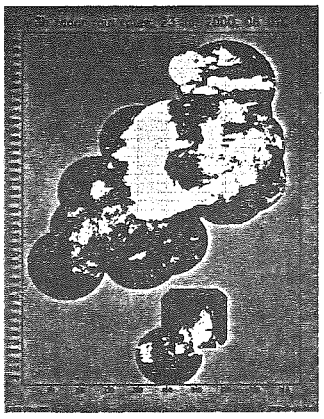


Fig. 2 Precipitation patterns from control model run (without assimilation of radar data)

23 July 2000, 00 UTC



23 July 2000, 06 UTC



23 July 2000, 12 UTC

23 July 2000, 18 UTC

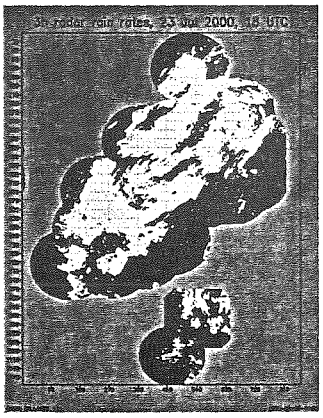


Fig. 3 3h precipitation totals from radar reflectivities

For verification purposes we implemented hit rate (HR) and false alarm rate (FAR) statistics computed from contigency table, which counts observed dry (less than a given treshold) and wet (great or equal than selected treshold) cases against forecasted dry and wet cases. Picture 1 presents both verification scores for number of selected tresholds. The model overestimates small precipitation rates and underestimates high precipitation rates. The hit rate is better than false alarm rate till the treshold of 16 mm/day. Picture 2 shows 6-hourly accumulated precipitation amount simulated by UMPL model. These images can be compared with 3-hourly accumulated precipitation amount estimated from radar reflectivity data presented on picture 3. After assimilation of rainfall rates by LHN technique similar verification scores were computed. Generally, behaviour of the model in assimilation run (scores not included) was similar to that in control run. Some moderate improvements were noticed. Hit alarm rate for small precipitation was 2% better, and for the treshold of 16 mm/day 6% better in the case of assimilated rainfall compared with control run.

Conclusions

To get these preliminary results quite heavy programming effort was involved. Practically to both systems used (OPS, UMPL) new procedures and many of changes to the code were introduced. Now we have tool to more detailed analysis of the impact of rainfall data assimilation on the quality of the model forecasts, and we planned to explore it more deeply. We acknowledge the UKMO for the possibility to use Unified Model and OPS source codes and the BALTEX Radar Data Center for the archive of the radar data.

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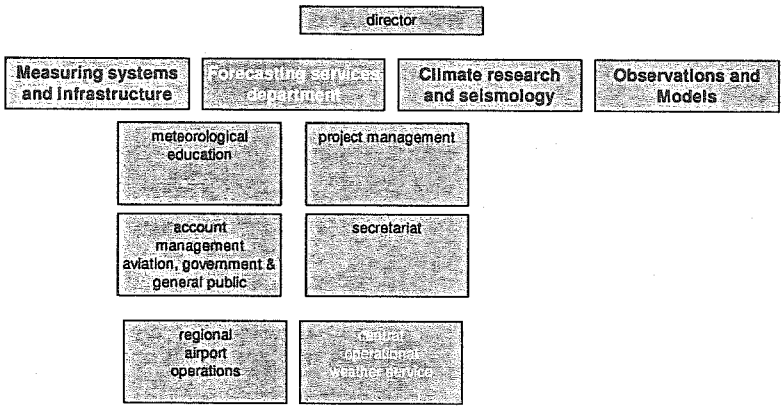
4.8 Use of models in the weather room

Use of models in the weather room
Models versus products

Janneke J. Ottens, head of forecasting, Royal Dutch Meteorological Institute (KNMI), the Netherlands

Abstract
KNMI-organisation
Developments and context
Forecasting services department
Examples of products
Forecasting and models
Probabilistic models versus deterministic products
Discussion

KNMI-organisation and the forecasting services department:



Developments and context:

Up to 1990:
- KNMI is governmental organisation on meteorology, climatology, oceanography and seismology
- part of ministry of transport, public works and watermanagement

After 1990:
- commercial activities are developing; mix between public tasks and commercial activities
- private company Meteoconsult comes into existence

Mid-nineties:
- governmental organisations have to minimise their commercial activities (committee Cohen): KNMI is first organisation to tackle this issue and this leads to splitting up into KNMI and HWS (Holland Weather Services)

April 1999
- HWS independent commercial firm; government customers still at KNMI

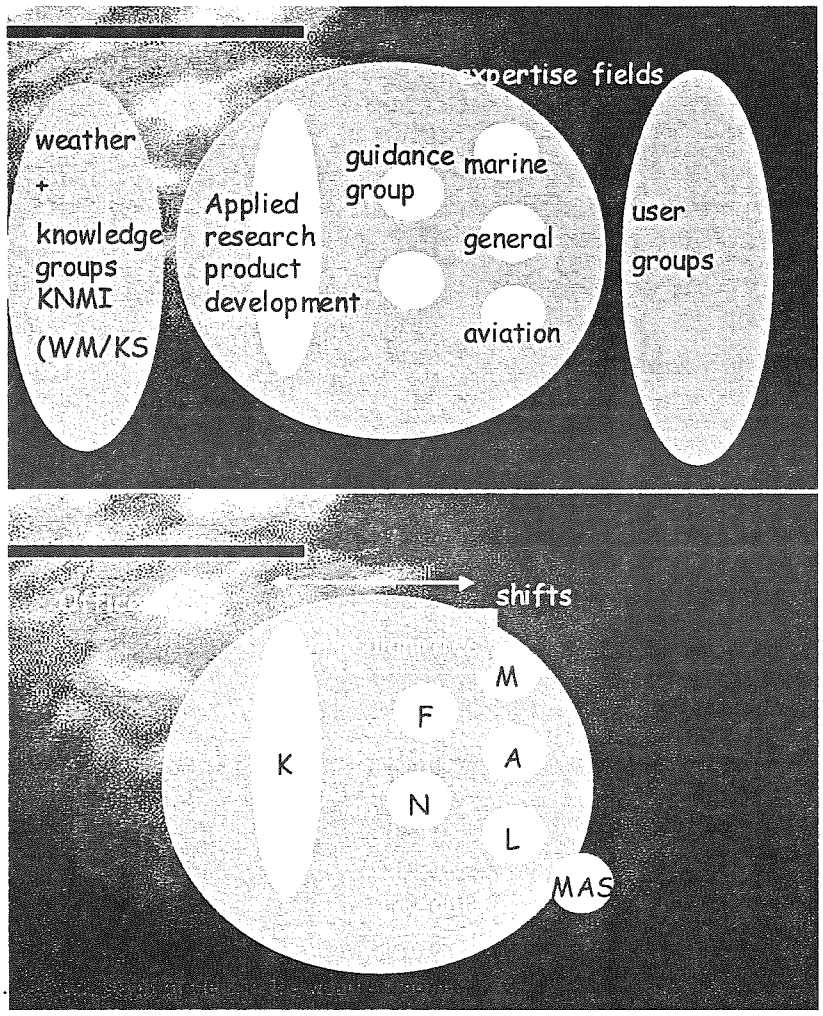
January 2000
- KNMI: knowledge based organisation; above parties: legal back-up laid down in a KNMI-law

KNMI still has to design its governmental role
KNMI: safety now- knowledge for future safety; therefore tasks are:
- general weather forecasting
- severe weather warnings
- improving meteorological methodologies

These tasks ask for a more knowledge oriented forecasting organisation. As a result the forecasting services department centralised its activities into the Bilt and started knowledge management, since research results from other divisions are not yet tailor-made and difficult to incorporate into operational forecasting. The centralised organisation also allowed for a further improvement of quality, the optimisation of business processes, the broadening of public support, the strengthening European co-operation on f.e. severe weather and growth from routine production to knowledge.

Forecasting services department

One central weather room results in more sharing of knowledge and experience and covers a broader field of expertise (marine, general and aviation meteorology). Because of optimisation of business processes more meteorologists can be active in research and case studies (active in knowledge building) through a temporal leave (weeks to month) from the operational shifts. The work in the so-called knowledge wheel is then supported by excellent project management. The knowledge wheel is not only important for the forecasting office, but also bridges the gap between the knowledge groups within the KNMI and operational forecasting demands.



Examples of products:

maritime:navtex

OTHER DISTRICTS NO WARNINGS SYNOPSIS AT 12.00 UTC

- HIGH 1033 OVER NORTHERN NORWAY IS STATIONARY. ASSOCIATED RIDGE OVER GERMAN BIGHT IS MOVING EAST. WEATHER FORECAST TILL WEDNESDAY 03.00 UTC THAMES EAST TO SOUTHEAST 4-5. GOOD. WAVEHEIGHT 1-1,5 HUMBER EAST TO SOUTHEAST 4-5. GOOD. WAVEHEIGHT AROUND 1,5 GERMAN BIGHT EAST 5-6. GOOD. WAVEHEIGHT AROUND 1,5 DOGGER SOUTHEAST 6-7 DECREASING 5-6. GOOD. WAVEHEIGHT 1,5-2 OUTLOOK TILL WEDNESDAY 15.00 UTC THAMES EAST TO SOUTHEAST 4-5 INCREASING 5-6. GOOD. WAVEHEIGHT 1-1,5 HUMBER EAST TO SOUTHEAST 4-5 INCREASING 5-6. GOOD. WAVEHEIGHT AROUND 1,5 GERMAN BIGHT DOGGER NO SIGNIFICANT CHANGE=

Products: 5 day forecast October 8 - 12

	we	th	fr	sa	su
Sun (%)	70	70	50	20	20
Precipitation (%)	10	10	20	50	60
Precipitation amount (mm)	0	0	0	3	3
Minimum temperature (ºC)	3	4	5	6	6
Maximum temperature (ºC)	12	12	11	10	11
Wind direction	E	E	E	E	E
Wind force (bft)	4	5	4	3	3

Probabilistic models versus deterministic products

At the moment our products are fairly deterministic in nature. However, the demands of our user groups will change through time and when decision support systems become part of their processes, probabilistic input will find its way.
Moreover, at the forecast office, we have to gain experience with the high resolution models in order to use theri benefits. Forecasters seem to trust the Hirlam 55 more because of its steady behaviour compared to the seemingly jumpy nature of the higher resolution Hirlam 22 and 11.

Discussion

Questions from the weather room or what are the user demands of the forecast office

- For operational use (read routine deterministic products)- H55? Or poor men ensemble LAM's NWC's??
- For applied research - H22 and H11?
- What to use for extreme weather and issuing warnings ??
- Will it be possible to run models on request?

- OSFM, Graphical interaction as input for new run of model?
- Zooming in on area of interest?
- Where stops modelling and starts statistical post processing?

To deal with these questions it is proposed to have more interaction between operational forecasters and researchers in model development. Also, more discussion between forecasters and model developers is needed in order to specify the information need in LAM's for operational forecasting.

4.9 Combining physical and statistical techniques for the downscaling of wind speed from a NWP model

Combining physical and statistical techniques for the downscaling of wind speed from a NWP model

Wim C. de Rooy and Kees Kok
Royal Netherlands Meteorological Institute, De Bilt, the Netherlands
Extended abstract of a paper submitted to Weather and Forecasting (October 2002), also available as KNMI reprint 2002-30

1 Introduction

Wind speed at 10m (u_{10m}) is an important output parameter of a Numerical Weather Prediction (NWP) model, e.g. when forecasting storms, calculating trajectories, or predicting the power output of wind farms. The interest is shifting towards higher resolution and more locally valid wind speed forecasts. A possible approach for the production of a local wind speed field is the downscaling of relatively course mesh model output using physical methods. In the last couple of years several of such methods have been developed (e.g. Achberger et. al., 2002, Landberg and Watson, 1994, Tijm, 2001). In this paper we too apply a physical approach but in addition we use statistical means to correct for large-scale model deficiencies.

Wind near the surface is strongly influenced by local terrain conditions, in particular its roughness. A NWP model with a limited horizontal resolution will never be able to take all the important local conditions into account, simply because it works with grid box mean conditions. Increasing the resolution or using a tile land surface scheme (e.g. Koster and Suarez, 1992), in which different surface covers can be defined within one grid box, can only reduce the mismatch between grid box mean and local conditions to a limited extent. The difference between the true grid box mean value and the local value will be referred to as the *Representation Mismatch* (from hereon RM). We handle this RM by a physically based (surface layer theory) estimator for the local 10m wind speed. However, after applying this physical downscaling there will still remain differences with respect to the observed wind speeds. These are not only due to the inevitable imperfectness of the downscaling technique used, but also due to underlying model deficiencies. Under the assumption that the RM is strongly reduced using the estimator, the remaining differences will be fairly homogeneous in space. This part of the error, referred to as the *NWP error*, can be reduced by statistical post-processing.

The NWP model used in this study is Hirlam version 2.7.3 (Källén, 1996). This Hirlam version has been replaced by a newer version a few years ago. We present arguments why most of our results and recommendations are valid for state of the art NWP models.

2 Results

Validation of the model against a three-year dataset suggests that the wind speed bias is primarily determined by a RM, associated with the difference between the locally valid roughness length (z_{0mloc}) and the model roughness length (z_{0mHL}), plus a *NWP error* probably originated for the larger part from a deficiency in the turbulence scheme. During stable conditions the turbulence scheme mixes momentum too much to avoid decoupling, leading to relatively high wind speeds, whereas during unstable conditions the mixing is too weak with relatively low wind speeds at 10m as a result. For locations where observations are available, *NWP errors* as well as the RM can be reduced with a simple statistical method and a physical

method seems redundant. As hypothesized by de Rooy and Kok (2002, from hereon RK02) the *NWP errors* are horizontally rather homogeneous, whereas the RM changes from location to location. This implies that, as far as the *NWP errors* are concerned, a regression determined for a certain location with observations, can also be useful for another location (e.g. without observations). However, this is not the case for the horizontally variable RM part. To handle this problem we introduce a method that compensates for the *NWP error* and the RM but is also applicable for locations without observations. Here a short outline will be given (for more details, see RK02). In the first step, local roughness length information is used to make the model wind speed more site-specific for a certain station. The resulting estimated u_{10m} without (or with less) RM is denoted as $\hat{u}_{10A}$ for station A. In this way we get pairs $(\hat{u}_{10A}(z_{0mA}),obs_A)$ of estimated and observed 10m wind speeds for different locations. Differences between both components of these pairs are supposed to be for a large part the result of *NWP errors*. Because *NWP errors* are fairly homogeneous, we can derive one single regression from a pool of pairs of different stations. After the regression on the pool, the regression coefficients can be used on a new location to compensate for the *NWP errors*. The RM on the new location is handled by substitution of the locally valid z_{0mloc} in the estimator. For arbitrary locations z_{0mloc} information can be derived from high-resolution land use or height maps (Verkaik and Smits 2001).

The above mentioned combined statistical/physical downscaling is validated for 12 UTC (6+6 forecasts) and 0 UTC (18+6 forecasts). The regressions on the estimated wind speed are derived from a pool of 5 land stations and subsequently applied on a sixth independent land station and time-independent data set.

For 0 UTC, improvements with the combined approach are small in comparison with standard Hirlam wind. This can be ascribed to the fact that Hirlam has two compensating errors for 0 UTC, namely:

- Deficiencies in the turbulence scheme (leading to too high wind speeds at 0 UTC), which is a *NWP error*.
- Generally Hirlam roughness lengths are larger than for the local situation (leading to too low wind speeds), which is a RM

For one station we still found a substantial improvement because here the RM dominates the *Total error*.

However substantial improvement is found for 12 UTC. The mean improvement in RMSE over the standard Hirlam output is about 20%. The improvements with the combined approach arise mainly from bias reduction and for a smaller part from a reduction in the SD (despite the generally higher wind speeds than standard Hirlam output due to the use of the regression and the estimators). For most stations the bias is practically eliminated with the regression.

3 An example of a downscaled wind speed field

Figure 1 shows a plot of a downscaled wind speed field, broadly following the combined statistical/physical approach. For simplicity reasons, several approximations are made (see RK02) and Fig. 1b should be considered as an illustration of a wind field constructed with the proposed method. We use information from a Hirlam +6h forecast valid for the 27th of October 1998, 12 UTC. Figure 1a shows the standard Hirlam wind output with a resolution of 55x55 km^2. To produce Figure 1b we use local roughness length information on a 1x1 km^2 grid derived from a land use map following Verkaik and Smits (2001). Outside the Netherlands no information about land use is available and local wind speeds should be ignored. As Fig. 1b reveals, the original grid boxes of Hirlam are still visible in the downscaled field. This effect will be reduced when a higher resolution model is used. One

can also use some kind of horizontal interpolation scheme before the combined method is applied. Here we just want to emphasize the effect of the downscaling. It can be seen that in coastal grid boxes over sea, the winds are well adapted to sea conditions. Over land there is a high degree of small-scale variability compared to standard model output. Downscaled wind speeds are much higher over the small lakes in the northern, centre and south-western part of The Netherlands. Differences of more than five $m \cdot s^{-1}$ occur. Local wind speeds are relatively low (blue) in urban areas and forests.

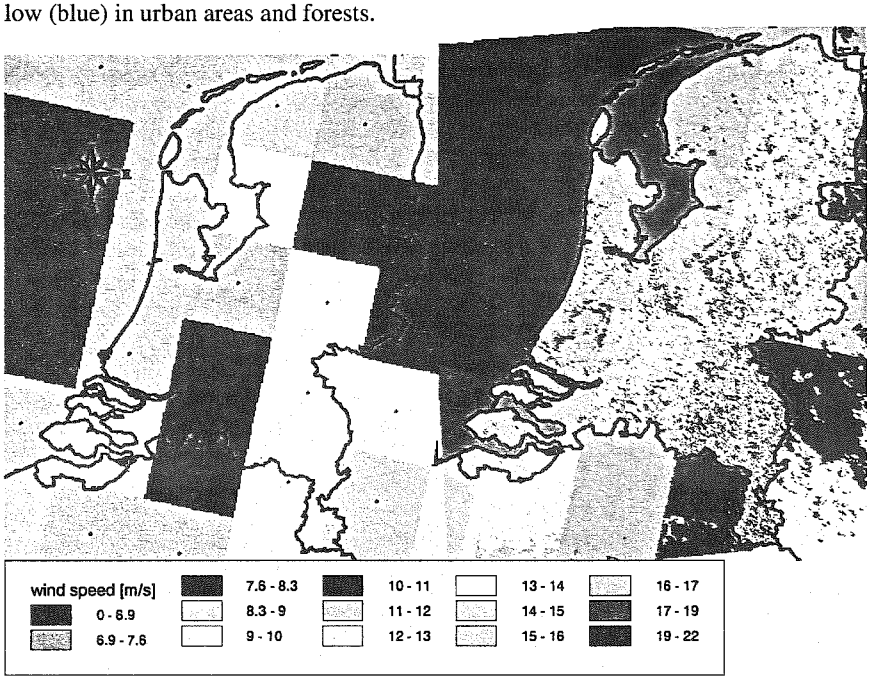


Figure 1a. (left panel) and 1b (right panel). Figure 1a shows the standard output of a Hirlam+6h forecast, valid for the 27th of October 1998, 12 UTC. Clearly visible are the 55x55km² blocks with the grid point in the middle. Figure 1b shows an example of a downscaled wind speed field (1x1km² resolution) according to the combined physical/statistical approach but with some simplifications (see text).

4 Discussion and conclusions

In downscaling wind speed usually only physical methods are applied. We began by taking a similar approach by investigating three different so-called estimators of local 10m winds, which are based on physical adaptation to local roughness length conditions. On top of that we also used statistical techniques to account for the larger scale model deficiencies. We have shown that the combination of the two techniques may result in a significant improvement in skill. This has been established by verifying a tentative system on independent locations and time period. A single predictor, namely the most promising estimator, was used in the statistical correction and this already resulted in an almost perfect reduction of the bias. Preliminary experiments have shown that further improvement can be established when additional large-scale predictors are used (e.g. wind direction or other predictors derived from the flow pattern). It is also possible to optimize the combined method for special conditions, e.g. high wind speed cases. Recommendations were given how to apply the downscaling in coastal zones.

In the proposed method, the regression is also effective at locations without observations. Important is the decomposition of the *Total error* (i.e. model output minus observation) in a *Representation Mismatch* (RM), which can fluctuate considerably on small

scales, and a larger scale *NWP error*. In verification studies and by operational forecasters the *Representation Mismatch* is often ignored and the model is blamed for the total error. By tuning the roughness length of the model in order to get the right 10m-wind speed for a specific station, a *NWP error* may unintentionally be introduced. The model should, however, simulate the mean conditions of the grid box.

The results in this paper confirm that statistical methods suffice when wind speed has to be forecast at locations where observations are available. Linear regression can tackle all kinds of model deficiencies (e.g. flow dependent) in combination with local peculiarities. However, for places outside observation sites the inclusion of physical downscaling seems necessary. We believe that downscaling wind speed should be a combination of physical and statistical techniques. Not only because in this way both the *Representation Mismatch* and the model errors can be handled, but also because this approach offers a lot of opportunities to optimize the system for a particular use or customer. For example, one can choose to use MOS techniques for the smallest possible errors for longer forecast times, or to use Perfect Prog techniques and regressions derived for high wind speeds only, to produce a storm warning system. The combined statistical/physical approach might also be valuable for other parameters. For example, for temperature similar experiments can be done, in which the upstream dryness of the soil (Brandsma et. al., 2002) can be seen as an equivalent of the roughness length for wind.

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4.10 Quantitative cloud observations by next generation meteorological satellites

Quantitative cloud observations by next generation meteorological satellites

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Introduction

Next generation Earth Observation (EO) satellites will be suitable to provide quantitative information on clouds. CLOUDMAP2 is a project that is funded by the European Commission under the 5th Framework programme for Energy, Environment and Sustainable Development. The project started in February 2001 and will end January 2004. The partnership in the CLOUDMAP2 project is a mixture of academic research groups and operational weather services. CLOUDMAP2 aims to produce and exploit value-added remote sensing data products on macroscopic (e.g. cloud-top height) and microscopic (e.g. cloud droplet radius) properties and water vapour distributions to characterise sub-grid scale processes within Numerical Weather Prediction Models (NWP) through validation and data assimilation. The CLOUDMAP results have high potential application to Global Climate Models. Current and near-future Earth Observation (EO) data, provided by ESA, EUMETSAT and NASA are employed to derive geophysical value-added data products for over a decade from the ATSR(2) sensor over Europe and the North Atlantic region as well as through the use of near real-time EO data for this region. Ground-based active microwave and passive thermal IR remote-sensing instruments are used to help validate EO-derived products as well as be merged to create new fused value-added products. Numerical simulation experiments based on state-of-the-art radiative transfer methods are used to quantify the effect of broken clouds on the Earth's radiation budget and lead to a better representation of clouds within GCMs.

Description of the work

The work proceeds in the following stages:
Data requirements are specified by the national meteorological agencies for use by data assimilation schemes for Numerical Weather Prediction (NWP) models.
Processing chains are developed for macroscopic (Cloud-top height/pressure, cloud amount, cloud type, cloud-top motion, cloud-top temperature) and microscopic (Cloud optical depth, cloud albedo, cloud droplet effective radius, cloud crystal size distribution, cloud droplet size distribution, water vapour total amount above clouds) data product retrievals for pre-existing, current and soon-to-be-launched EO sensors. A subset of these parameters are to be derived in near-real time.
A system for the routine near real-time production of macroscopic cloud parameters from active (radar+lidar) and thermal IR passive ground-based sensors (GBS) are developed as well as for accessing macroscopic and microscopic parameters derived at the US ARM sites
Cloud properties are derived for Europe, the North Atlantic and the US ARM sites including a climatological time series from ATSR(2) and from SEVIRI, MERIS, MODIS and MISR.
These cloud and water vapour properties are inter-compared as well as validated using ground-based sensor data. The result of this comparison are used to develop fused 3D cloud products.
Sub-gridscale issues in NWP and GCM climate models are studied using both the CLOUDMAP2 data-sets and numerical scene simulation experiments based on these products
The EO-derived data-sets are prepared for data assimilation experiments and the impact of using these EO data-sets on the NWP predictive skill are verified using inter-comparisons with EO & GBS.
The resultant data-sets will be made available at the end of the project to the scientific community through a web-page and possibly the publication of a CD-ROM or DVD
The resultant lessons learnt from the model verification and improvement will be made available to the wider scientific community through a series of demonstrations and workshops aimed at both EO, ground network and GCM climate modelling communities to try to maximise the impact of the CLOUDMAP2 project. These demonstrations and workshops are planned for the second half of 2003.

Milestones and expected results

Major milestones are (1) delivery of value-added EO data products from (a) current and (b) near-future sensors for the NWP/GCM communities, (2) validation of EO products using ground-based sensors (GBS); (3) production of fused EO-GBS data products; (4) development of data assimilation schemes for CLOUDMAP2 products; (5) evaluation of their potential impact on NWP and (6) development of RT scene simulation techniques for investigating the effects of clouds on the Earth's Radiation Budget Expected results are that (I) evidence that EO cloud and WV data is of sufficient accuracy to be useful to NWP/GCM communities; (II) EO data can be validated in the long-term using ground-based data, and (III) that performance of these NWP/GCM models can be improved.

Detailed information on CLOUDMAP2 and demo of products

The Web site of the CLOUDMAP2 project contains detailed background information and shows cloud products in near real-time (after observation):
http://www.cloudmap.org

4.11 Towards high resolution precipitation forecasts

Towards high resolution precipitation forecasts

by Bent H. Sass
Danish Meteorological Institute

1. The forecast problem

It is generally accepted that very accurate local shortrange forecasts of precipitation are extremely difficult to achieve. Precipitation forecasts are determined by the socalled 'moist physics' in combination with accurate modelling of the model dynamics and a well developed data-assimilation system. The moist physics may be defined to incorporate both turbulent and convective transports as well as the precipitation microphysics. The importance of incorporating observational data related to the moisture in the atmosphere is obvious, but it is perhaps less clear what will be the impact of different versions of model dynamics and moist physics. At DMI the sensitivity of precipitation prediction is being investigated with regard to different versions of advection and moist physics. The current developments and experimental results are summarized below:

2. Modelling of precipitation at a high resolution

As the horizontal model resolution is increased the possibilities of producing increased quality precipitation forecasts should in principle be better. However, objective verification at increasing model resolutions may easily show a degradation in model verification results when comparisons are made between observed and model predicted precipitation for specific measurement sites. This feature is often linked to the hard problem of predicting precipitation exactly at the right location and time.

However, the traditional precipitation schemes used at a high model resolution have also been developed for a more coarse mesh model. The assumptions made for convection and precipitation release made in the schemes become increasingly questionable when used at higher model resolution. For example, the real precipitation in the atmosphere is drifting with the wind, and it may often take 15-30 min. for precipitation to reach the ground. A natural way to proceed is then to use a fully 3-dimensional prognostic scheme for precipitation particles. This type of scheme requires a very high spatial resolution to resolve conective motions adequately and is computationally expensive. Recent developments intended to improve on the shortcomings for the precipitation scheme used operationally at DMI, are outlined below. A full account of the developments are given in a DMI Technical Report (Sass, 2002). Benefits of the modified scheme have been seen from objective and subjective verification during 2002 and are also described in a recent newsletter article (Sass and Yang, 2002).

The adapted strategy for the model developments is the following: Adapt the convection scheme for very high resolution in a 'physical way' such that the scheme gradually 'decouples' in the limit where precipitation can be described by resolved scale motions.

Furthermore, adapt the existing precipitation release formulas to simulate that a part

of growing precipitation particles will stay in the cloud when a significant upward motion exists, allowing precipitation particles to be carried horizontally before falling to the ground as precipitation. The most important developments may be summarized as follows:

A) Modified cloud ascent model:

A_1)
Perturbations δT of temperature and of specific humidity δq as a start condition (trigger) for convection depend on model resolution and decrease towards zero in the limit of an 'infinitesimal' grid size.

A_2)
Lateral entrainment of environmental (dry) air into the convective cloud ascent dilutes the cloud depending on environmental conditions, including wind shear.

Parameterized cloud dimension D is an order of magnitude smaller than the grid size (proportional). Assuming a quasi-constant turbulent entrainment mixing scale d_{mix} implies that the effective 'dilution' of cloud due to entrained environmental air increases, since d_{mix}/D increases as grid size decreases (the surface to volume ratio of convective cloud increases as grid size decreases).

B) Modified precipitation release parameterization.

The most fundamental parameters in the precipitation release parameterization of Sundqvist are the C_0, and the m_r (Sundqvist et al., 1989; Sundqvist, 1993).

$$G_p = C_0(\omega) \cdot m \cdot \left(1 - exp(-(\frac{m}{b \cdot m_r(\omega)})^2)\right) \tag{1}$$

The basic coefficients C_0 and m_r are already rather complex functions describing the effects of coalescence and Bergeron-Findeisen mechanism on precipitation release, but the basic coefficients can be made functions of the dynamical state, e.g., expressed as ω which may be thought of as vertical velocity.

Increase of m_r with a positive vertical velocity describes 'suspension' of precipitation particles while the cloud may be carried horizontally. Similarly $C_0(\omega)$, may be reduced under the same conditions. 1-dimensional experiments indicate that this type of modification may have potential if both coefficients are modified under strongly upward motions in the model.

3. Summary and discussion of recent results

From runs in the operational environment at DMI during 2002 it has been clearly seen that use of first order upstream scheme in 3 dimensions leads to strong damping and too much smoothing, consistent with theoretical arguments concerning simple upstream schemes. During the summer of 2002 this has lead to substantial shortcomings regarding precipitation forecasting in convective situations when compared to the corresponding results using a standard eulerian centered difference advection scheme. On the other

hand the damping effects has the ability to suppres small precipitation amounts which may be partly triggered from small scale features in the dynamics. These impacts on precipitation have been established from both objective and subjective precipitation verification at DMI.

It may be possible to 'tune' the model's cloud and precipitation scheme to compensate for damping model dynamics, but this is hardly desirable if the damping from the dynamics is excessive. Other model fields are indicative of too much smoothing by the dynamics, e.g., an 'thunder activity' index designed at DMI. While diagnosing convective instabilities quite well in the case of using a centered difference advection scheme the index computation fails to produce reasonable results when using the first order upstream scheme.

It is noted that there is no need for using horizontal diffusion in the model when running upstream advection. The smoothing of the scheme is taking care of horizontal diffusion. When using centered differences in the HIRLAM model a horizontal diffusion is needed. It is found that model instabilities in the Eulerian model are possible if explicit linear 4th order diffusion is applied together with physics computations every time step. More stable integrations are achieved if special time stepping schemes are implemented, e.g. the time stepping used operationally at DMI (Sass et al., 2002), implying time averaged dynamical tendencies as input to the physical parameterizations. Implicit horizontal diffusion provide stable integrations , but the diffusion coefficients need to be adequately low in order not to do harm to the model integration. Even though it is necessary with some horizontal diffusion the centered difference scheme retains the smaller scales in the model better than does the first order upstream advection scheme. It seems therefore desirable that an improved model dynamics should not only be numerically accurate and stable, but also not too damping.

Current work on moist physics, as mentioned above, indicates that various improvements are possible in high resolution models using grid sizes below 10 km without going to very detailed schemes which resolve convective phenomena explicitly. This statement, however, needs quantification from many more 3-dimensional runs and work on existing scheme(s) at the target resolution well below a grid size 10 km adequate for future short range weather prediction.

The modifications of the current precipitation scheme used at DMI has shown increased potential for the prediction of both small and large precipitation amounts. Various assumptions made in connection with the convection scheme, e.g. the modelling of the convective cloud ascent, is important for this result.

Objective verification based on monthly precipitation accumulations from Danish synoptic stations shows that increased model resolution, e.g. going from 0.45° to 0.15° produces increased spatial variation of the precipitation. The statistics for months with heavy convective precipitation episodes indicate that the spatial vatiation is not yet fully represented at a grid size of 5 km. However, for periods with more stratiform type of precipitation the variation in space seems to be already rather well captured at a horizontal resolution of 0.15 °. The very hard problem is still to predict precipitation with sufficient accuracy at the right location and time.

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4.12 Some aspects of statistical cloud Schemes in High-Resolution Numerical Weather Prediction Models

Some aspects of statistical cloud Schemes in High-Resolution Numerical Weather Prediction Models

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1 Introduction

Prediction of clouds and cloud related parameters like cloud cover, liquid water and ice is still one of the weakest points in atmospheric general circulation models (GCM's) (Gates, 1999). Yet, these parameters are extremely important because the have a large impact on radiation and turbulence. This applies specifically to boundary layer clouds such as stratocumulus (Sc) and cumulus (Cu). These clouds strongly influence the boundary layer structure and the surface weather through their interaction with the radiation and the turbulence. As such, reliable estimates of (at least) cloud fraction and liquid water are an essential prerequisite to take full advantage of sophisticated radiation and turbulence schemes that are currently developed for GCM's.

Several different approaches exist to parameterize cloud fraction a_c and liquid water q_l in GCM's. The traditional approach simply tries to diagnose $\overline{q}_l$ and a_c with empirical functions of large scale model variables such as relative humidity (Slingo, 1987). However, observations do not support such a one-to-one correspondence between these cloud variables and relative humidity (Albrecht, 1981). To improve on this deficiency, two types of approaches have been attempted:

- *Prognostic cloud schemes*: In this approach, extra prognostic model equations for q_l and (sometimes) a are introduced (Sundqvist, 1978; Roeckner, 1988; Tiedtke, 1993). These are merely budget equations that consist of a list of source and sink terms. This process oriented approach has the advantage that all processes that are believed to be relevant for cloud production and destruction can be incorporated in prognostic equations for q_l and a_c. However this approach has also severe drawbacks. Firstly, the used prognostic budget equations are rather arbitrary and ad hoc. and often dependent on parameters, such as detrainment, that are not well known and intrinsically impossible to measure experimentally. This makes it difficult to validate such schemes with experimental data or even with cloud resolving models such as Large Eddy Simulation (LES) models. Secondly and more specifically, the use of cloud liquid water q_l (and cloud cover a_c) requires a method to model vertical turbulent transport of such a variable. However, the modeling of turbulent transport of such variables that are not conserved for moist

adiabatic processes is problematic (Randall, 1987). For instance, simple down-gradient diffusion of q_l, presently applied in up to date climate models (Roeckner et al., 1996) leads to erroneous transport in the wrong direction (Lenderink et al., 1999).

- *Statistical cloud schemes*: This approach, pioneered by Sommeria and Deardorff (1977) and Mellor (1977) makes use of the fact that cloud cover and liquid water can be easily derived, presupposed the subgrid variability of moisture and temperature is known. This concept has been further developed by Bougeault (1981) by assuming specific analytical forms for the joint probability functions (pdf's) of total water q_t and liquid water potential temperature θ_l, which are the relevant thermodynamic moist conserved variables. One important conclusion from this study was that it is sufficient to have reliable estimates of only the variances of q_t and θ_l in order to to predict q_ℓ and a_{cl}.

One important additional argument in favour of a statistical cloud scheme is that it offers a avenue to take resolution dependance into account. One expects a decreasing subgrid variability with an increasing model resolution. Since a statistical cloud scheme is formulated in terms of subgrid variability, a resolution dependent parameterization is feasable, given the relation between the subgrid variability and the resolution. For prognostic cloud schemes it is not clear how to incorporate resolution dependency.

Not much is known on the relation between model resolution and the subgrid variability. The main purpose of this note is to measure this relation using Large Eddy Model (LES) results for trade wind cumulus.

2 Statistical cloud schemes

A statistical cloud scheme is most conveniently formulated in terms of the normalized saturation deficit (Sommeria and Deardorff, 1977)

$$t = \frac{\overline{s}}{\sigma_s} \quad \text{where} \quad s \equiv q_t - q_{sat}(p,T). \tag{1}$$

where overbars denote a grid average and σ_s denotes the standard deviation of the saturation deficit s. The advantage of this choice of variable is that the cloud cover and liquid water expressed as a one parameter problem

$$a_c = \int_0^{\infty} G(t)dt \qquad \overline{q_\ell}/\sigma_s = \int_0^{+\infty} tG(t)dt. \tag{2}$$

Clearly a form for the pdf $G(t)$ has to be postulated. It has been demonstrated that the exact form of the pdf is not crucial for as far a_c and q_l are concerned (Bougeault, 1981). We therefore assume a Gaussian pdf so that integration of (2) gives

$$a_c = 1/2\left(1 + erf(\bar{t}/\sqrt{2})\right) \qquad q_\ell/\sigma_s = a_c\bar{t} + \sqrt{\frac{1}{2\pi}}\exp\left(\bar{t}^2/2\right) \tag{3}$$

Equation (3) is the central result. It shows that the parameterization problem is reduced to obtain reliable estimates of σ_s. This can be provided by the vertical turbulent mixing

schemes so that the variance becomes a communicator between the cloud scheme and the mixing scheme Bechtold et al. (1995); Lenderink and Siebesma (2000).

An important property is that in the the limit of zero variance of s the solution (3) reduces to

$$\begin{cases} a_c = 0, \\ q_\ell = 0 \end{cases} if\ s < 0 \qquad \begin{cases} a_c = 1, \\ q_\ell = (\overline{q}_t - \overline{q}_{sat}) \end{cases} if\ s > 0 \tag{4}$$

which is of course the well known "all-or-nothing" limit. Especially for high resolurion NWP, it is of the utmost importance that cloud schemes do have the correct limiting behaviour. Large eddy simulation results support the Gaussian result (3) for boundary layer clouds Cuijpers and Bechtold (1995); Bechtold and Siebesma (1998). In the remainder of this note two points will be adressed

- The breakdown of σ_s into (co)variances of q_t and θ_ℓ.
- the possible resolution dependency of σ_s.

We will do this using LES results for a trade wind situation such as typically observed in the marine subtropics. In Figure 1 we show the mean profiles of q_t and θ_ℓ plus a typical 3d snapshot of the 3d cloud field. For a complete description and discussion of this case we refer to the literature (Siebesma and Cuijpers, 1995; Siebesma et al., 2002)

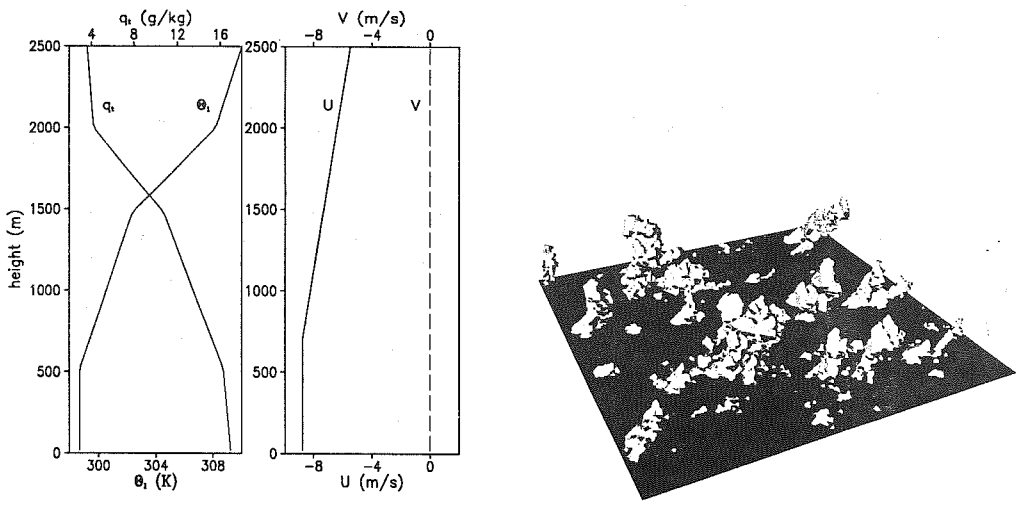

Figure 1: Initial profiles of the total-water specific humidity q_t, the liquid water potential temperature θ_ℓ and the horizontal wind components u and v. The shaded area denotes the conditionally unstable cloud layer. The right panel shpws a typical 3d snapshot of the cloud field produced by the LES model

3 Analysis of the variance of s

Since turbulence schemes usually give estimates of the variance of θ_ℓ and q_t it is useful to express σ_s in terms of (co)variances of q_t and θ_ℓ. Such an excercise gives

$$\sigma_s^2 = \overline{s'^2} = a^2\overline{q_t'^2} - 2ab\overline{q_t'\theta_\ell'} + b^2\overline{\theta_\ell'^2} \tag{5}$$

where

$$a = \left[1 + (L/c_p)\overline{q}_{sl,T}\right]^{-1} \qquad b = \pi\overline{q}_{sl,T} \tag{6}$$

and

$$\overline{q}_{sl} = (q_s(\overline{T}_l), \qquad \overline{q}_{sl,T} = \frac{\partial q_s(\overline{T}_l)}{\partial T}. \tag{7}$$

All notation is convential: π is Exner function, L is the latent heat, c_p is the specific heat capacity and T_l is the liquid water temperature.

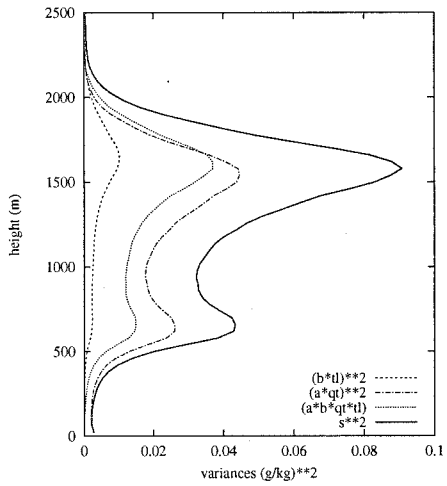

Figure 2: the variance of s and the decomposition into the (co)variances of q_t and θ_ℓ as given by (5)

An LES analysis for a run on a domain of 5 km for all terms in (5) can be found in Figure 2. A few conclusions can be drawn:

- All variances peak around cloud base and cloud top. This behaviour is typical for the cumulus topped boundary layer.
- The variance of q_t explains 50% of the variance of s. The other important contribution comes from the covariance, i.e. the second term of the the rhs of (5). Therefore reliable parameterizations of σ_q should be rescaled by a factor of 2 in order to obtain a reliable estimate for σ_s.

4 Resolution dependency of the variance of s

In order to investigate the resolution dependency of the variance we have generated a LES run on very large domain of $L = 25$ km using a grid size of $dx = 50m$. On this domain we calculate on horizontal slab variances of q_t within boxes of size l. The average variance on a scale l, i.e. $\langle \sigma_s(l) \rangle$, is calculated as the mean of all variances measured at that scale l. For $l = L$ this reduces to the slab average while for $l = dx = 50m$ the variance reduces to zero. Figure 3 shows the results for $\langle \sigma_s(l) \rangle$ at several heights in the cloud layer. The results suggests that for scales larger than 5 km the variances does not grow for trade wind cumulus. This results is in line with Landsat observations of cloud size distributions for trade wind cumuli. These observed cloud size distributions show a power law behaviour up to sizes of a few kilometer beyond which they fall off exponentially.

Further research for other cloud types is needed to explore possible scale dependencies of variances.

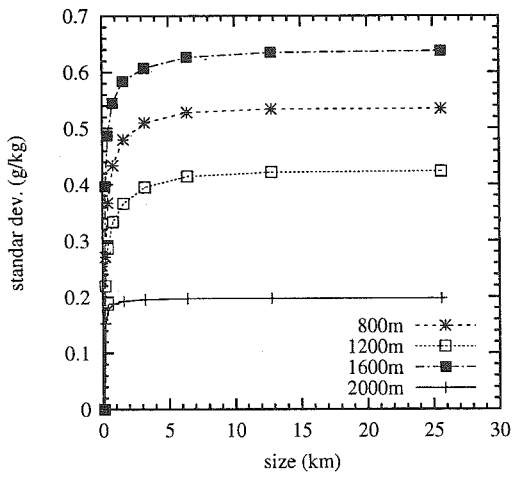

Figure 3: the standard deviation of the saturation deficit $\langle \sigma_s(l) \rangle$ as a function of the horizontal scale l for 4 different heights in the cloud layer

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4.13 Forecast of orographic precipitation with LM

Forecast of Orographic Precipitation with LM

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Introduction

A number of developments have been done in order to increase the quality of the prediction of precipitation with the model LM (Steppeler et al., 2003). Only a short summary will be given here for those developments which have been published recently. New developments concerning the z-coordinate will be described in more detail.

The prediction of precipitation depends critically on the pattern of vertical velocities and therefore in particular on a proper representation of the gravitational waves near mountains. This can be achieved only when the mountain is not represented by just one grid-point. It is necessary to represent the mountain by a sufficient number of points, in order that the circulation generated by the mountain is resolved. The resolution of a bell shaped mountain was systematically changed. It was found that about 4 grid-points on each side of the mountain are necessary, in order that the vertical winds and precipitation patterns are properly reproduced. For the operational version of the LM this was achieved by filtering the orogaphy. When doing this, the systematic error of the LM-precipitation forecasts was substantially reduced: Extreme and unrealistic precipitation forecasts at single gridpoints were reduced and the artificial lee effect was less strong. This latter consists of the LM producing too much precipitation on top of a mountain and too little in the lee. For a more detailed description of these results see Steppeler et al, 2003.

As the LM uses second order centred differences, the accuracy of the advection of fields such as moisture is not sufficiently accurate. Further inaccuracies are introduced by the three time level leapfrog scheme. A two time level scheme based on the second order Runge Kutta time integration scheme was introduced. It was tested in combination with a prognostic scheme for the precipitation. A more detailed description of this development is given by Gassmann et al 2003.

New developments of the z-coordinate scheme of LM

The z-coordinate LM uses model z-surfaces as model levels. As a consequence, these cut into the mountains. The principle of this scheme is described in Steppeler et al (2002). Here some recent developments and the current state of this project are reported.

The Z_LM is now available in a three dimensional version and has been tested using the 400 m mountain proposed by Gallus et al (2000). Other tests have been done

using high bell shaped mountains of about 2000 m height. The atmosphere at rest is represented exactly by the Z_LM.

Further tests have been done using the SCANIA test. This test consists of using the orography of Scandinavia together with an idealised flow field of 10 m/sec from the north west. In such tests the physical parameterizations are switched off. Integrations of four hrs have been done and the results were compared with the 30 min integrations reported by Cullen et al. (2000). The false lee effects reported with some models were not observed with the Z_LM.

The inclusion of the physical processes is done on a special grid, which is terrain following. Only the adiabatic part of the Z_LM is done on the Z-grid. Both grids describe the same atmospheric state and transformations are used to ensure this and to update the z-grid fields with the physics tendencies and vice verse. First test integrations have been done, using a mountain of 2300 m height and dry physics routines, that is radiation, surface processes and turbulence, as described by Steppeler et. al (2003). In Fig. 1 a 2hr calculation is given, using the atmosphere at rest as initial values. The radiation represents conditions at noon. Without radiation the atmosphere remains exactly at rest. With radiation a mountain wind appears. During night time the situation is reversed. The result is given in Fig. 2. A valley wind can be seen. The Z_LM can thus correctly represent the wind as it depends on the time of the day. As opposed to this, the LM with terrain following coordinates would create a circulation even without radiation in the model.

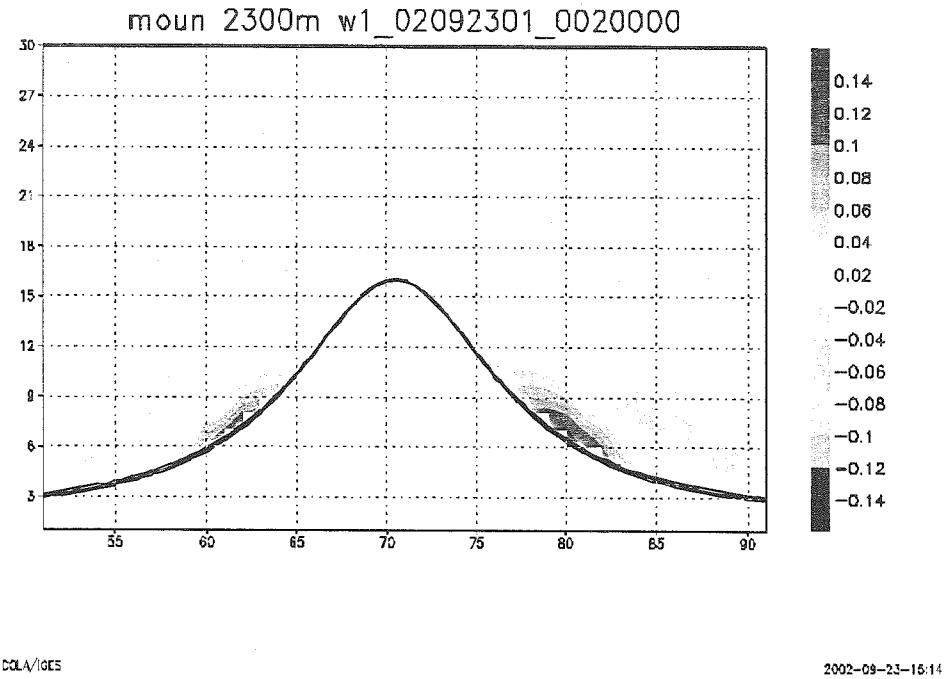

Fig. 1: Cross section of the vertical velocity field for a 2 hr forecast starting with the atmosphere at rest. The radiation corresponds to conditions at noon.

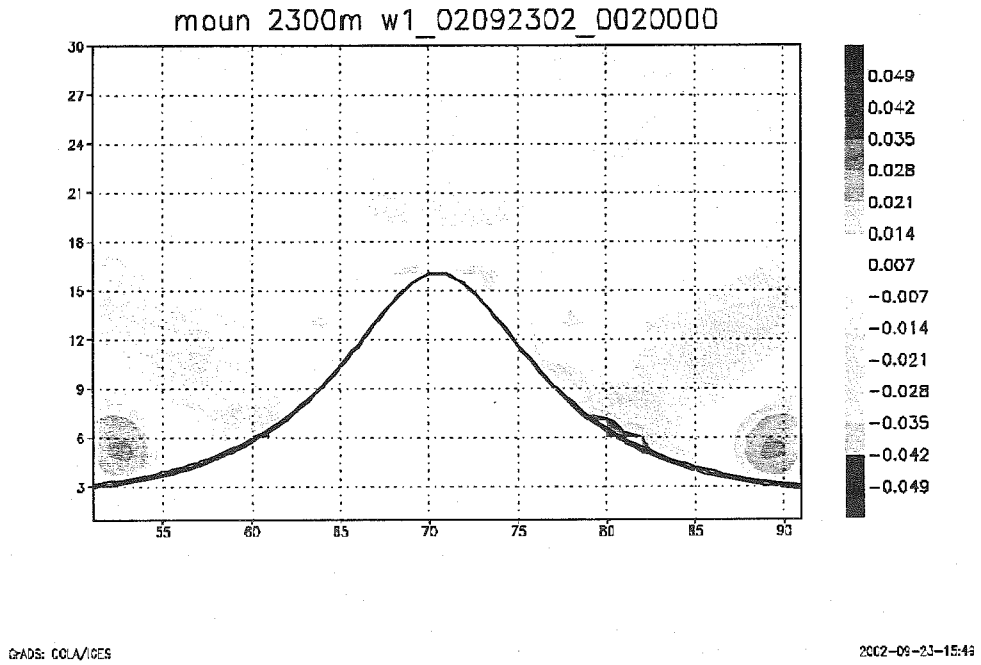

Fig. 2: As Fig. 1, for night time conditions

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4.14 Hirlam satellite images

Hirlam satellite images

Sander Tijm

1 Introduction

Determining the quality of a weather model analysis or short term forecast can be difficult and time consuming. Various model fields have to be compared to the observations (where present) while the judgement of the quality can only be made indirectly in data-sparse areas, on the basis of satellite images.

Clouds are the product of all processes in the atmosphere. Together with a thorough knowledge of conceptual models, satellite images can be translated to a 3-D state of the atmosphere. Also, with this knowledge, the evolution of the weather can be predicted a few hours in advance.

By producing satellite images from model parameters the comparison with of the model state with observations can be made over the entire model domain, even in data-sparse areas. The evolution of model satellite images also can give the forecaster a feeling for the developments in the model while model developers may get a better idea of model deficiencies.

This contribution explains the method that is used to produce artificial satellite images. The data comes from the 11 km version of Hirlam and may be used for SatRep and guidance purposes.

2 The method

The infrared satellite images as we see them are the intensity of the radiation from the surface and atmosphere at the top of the atmosphere, which is translated to the radiation temperature of a black body. This radiation comes from the surface when the sky is clear while the radiation comes from the clouds solely when they are optically thick enough. The translation of the infrared radiation to a temperature enables the meteorologists to determine the cloud top temperature from the infrared images. Together with temperature profiles from radiosondes or models this can be used to estimate the height of the cloud top of e.g. convective clouds. The principle of the cloud top temperature in infrared images now is used in the opposite way to make infrared images from model fields.

The Hirlam model also includes cloud water as prognostic variable. With this parameter we can calculate the cloud top temperature as follows. The start temperature is the temperature at the lowest model level. Then we go trough all levels from bottom to top. If there is no cloud water at the current model level, then the cloud top temperature remains the same. If there is cloud water present, the cloud top temperature is adjusted to the temperature of that level. In equation form it looks like:

$$T_{cld} = T_{cld,old}\left(1 - MIN\left\{1, \frac{Q_l \Delta P}{Q_{dp}}\right\}\right) + T_a\left(MIN\left\{1, \frac{Q_l \Delta P}{Q_{dp}}\right\}\right), \tag{1}$$

where T_{cld} is the cloud top temperature at the current model level, $T_{cld,old}$ is the cloud top temperature at the previous model level, Q_l is the cloud water content of the current model level, ΔP is the thickness of the model level in Pascal, Q_{dp} is the threshold value of the cloud water above which the new cloud top temperature will attain the current air temperature and T_a is the air temperature at the current model level.

Figure 2 gives a schematic representation of the procedure that is applied. The cloud top temperature starts with the air temperature at the lowest model level. This temperature does not change until the first cloud layer is reached. These clouds are more dense than the threshold value, so the cloud top temperature takes the value of air temperature at that level. Above the first cloud layer, there is a cloud free layer, causing the cloud top temperature to retain the old value. The clouds of the second layer are more transparent than the threshold value. Therefore the cloud top temperature is adjusted only to 75%

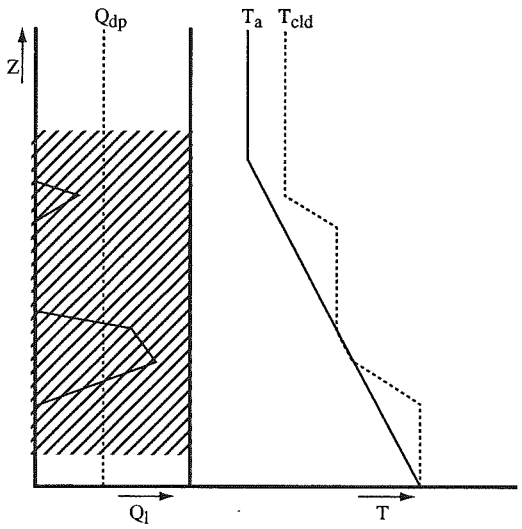

Figure 1: A schematic representation of the procedure that is applied to produce a cloud top temperature from model data.

of the difference between the current air temperature and the cloud top temperature. After this second cloud layer there is no more cloud water so the cloud top temperature does not change.

Applying the procedure and equation described above results in cloud top temperatures that resemble the cloud top temperatures in infrared images quite well. Shallow and optically thin clouds are only partly taken into account causing the end product to show gradation in the grey scales of the images.

The same procedure can be applied to water vapour. For these images the atmosphere between 600 and 200 hPa is sampled. You need another value of the threshold Q_{dp}. When this procedure is executed it results in images as in figure 2. This figure shows the situation of September 25, 2002, 12 UTC. A comparison with figure 2 shows that the main features are adequately resolved by the model. The main cloud areas over the Alps, Portugal, Southern Scandinavia and the United Kindom are present in the model. Also, in the water vapour images, the dark stripes over Central Europe and Scandinavia, the broad dark band over the Mediterranean Sea, Southern France and Northern Spain and the Bay of Biscay and the water vapour eyes just west of the Alps are well represented by the model.

There is, however, an important difference between the model images and the satellite images can be seen. North of Scotland, an eddy can be found in the infrared satellite image. This eddy is associated with a water vapour eye. This eye is not present in the model image. With a northwesterly steering flow over the North Sea, this disturbance travelled towards the Netherlands. The forecast of this model run therefore was not to be trusted at the time of passage of this disturbance, as could be stated in the model guidance on the basis of this comparison. This conclusion could be verified later when the forecast was compared to the analysis. The disturbance had evolved into a trough that was not forecasted by the model.

3 Conclusions

Images that have the same appearance as satellite images can be made on the basis of high resolution model data. These images can be a useful tool in the assessment of the quality of the model state, especially in data sparse areas. A loop of model images can help forecasters getting a feeling for the

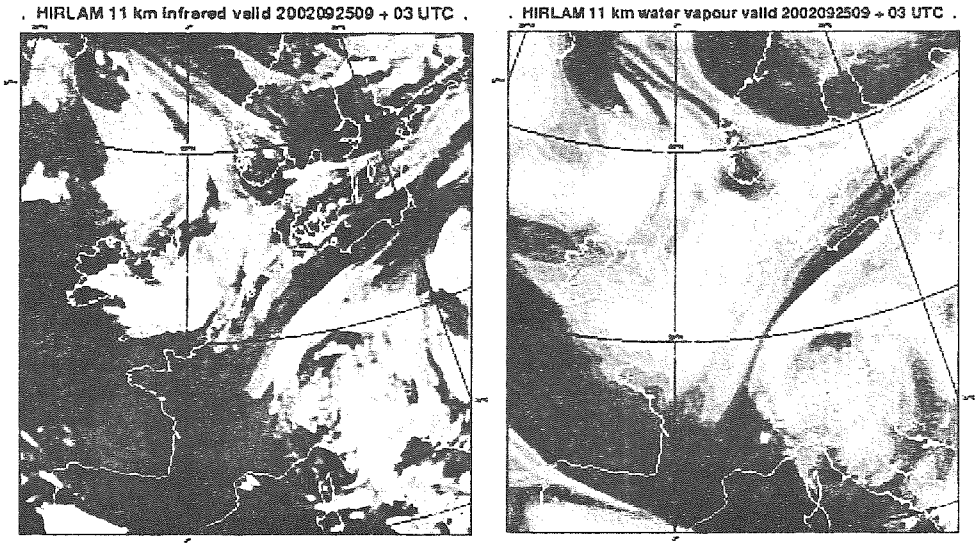

Figure 2: The model infrared and water vapour images based on Hirlam 11 km data. This is the +3 forecast valid on September 25, 2002, 12 UTC.

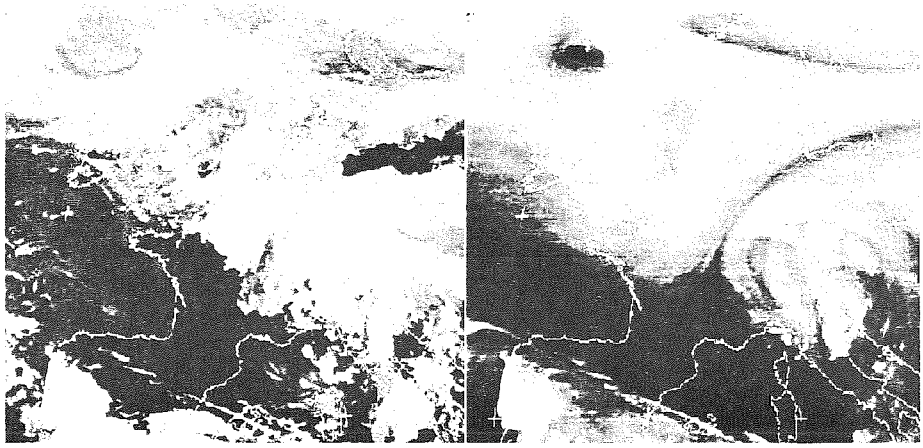

Figure 3: The infrared and water vapour satellite images based on September 25, 2002, 12 UTC.

developments in the model by checking them against satellite loops. Also, the model images may aid model developers to find model deficiencies like too many clouds, a wrong distribution of clouds or problems in the convection (onset too early or too late).

4.15 Evaluation of two convection schemes in the High Resolution Limited Area Model (HiRLAM)

Evaluation of two convection schemes in the High Resolution Limited Area Model (HiRLAM)

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[1] Wageningen University, The Netherlands
[2] Royal Dutch Meteorological Institute, The Netherlands

1. INTRODUCTION

In this study, we compare two different convection schemes in the High Resolution Limited Area Model at KNMI. The first convection scheme is the operational STRACO scheme, which is a Kuo-type of convection scheme, with moisture convergence as closure assumption. The second scheme, which might be implemented in the HiRLAM model in the future, is the Kain-Fritsch/Rasch-Kristjansson (KF-RK) scheme. This is a mass flux scheme with CAPE consumption as closure. Both schemes are tested at 22 km and 11 km resolution in HiRLAM version 5.1.4. In this extended abstract only the results of the 11 km runs are shown.
In this study, we are only interested in precipitation, which is a product of convection. To compare the precipitation amounts of the different runs, it is necessary to verify with some objective source. We have chosen to verify on the basis of cumulative 24hr radar precipitation observations, because they can be scaled to the right (model) resolution, which is necessary to make a fair comparison.
For verification, three methods have been used, e.g. correlation graphs, precipitation distributions and contingency tables. From the correlation graphs, we obtain a correlation coefficient, which is an objective verification score. We do not have such an objective score for the precipitation distribution. For the contingency tables, we use the Hanssen-Kuipers Score (HKS) to make an objective comparison between the different model runs.

2. CASE STUDY: 29 July 2000

On the 29th July 2000, weak onshore winds caused a cloud free coastal area in the Netherlands and Belgium. In the weak onshore winds the boundary layer over land grew as a function of the distance to the coast. 30 to 50 kilometers inland, the boundary layer became so deep that the atmosphere became unstable, causing thunderstorms to develop. In the weak advection the thunderstorms kept developing at the same line, causing some places to receive more than 50 mm of precipitation from subsequent thunderstorms.
This can be seen in figure 1, which shows the cumulative 24hr radar image over the Netherlands at 11 km resolution for the 29th July 2000. The model predictions for this 24hr period are shown in figure 2 (STRACO) and figure 3 (KF-RK). Although in figure 3, the intensity of the precipitation is too low, the position seems to be rather well predicted. This is in contradiction to figure 2, where we do see some high intensities, but these are not positioned near the coast. Furthermore, we see that with the STRACO scheme, the low precipitation amounts are overpredicted.

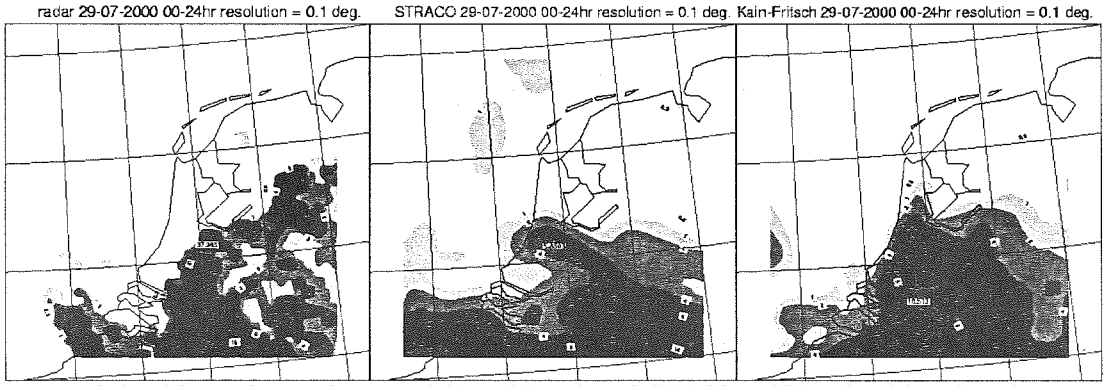

Figure 1, 2 and 3: cumulative radar image (left), model results with STRACO (middle) and model results with KF-RK (right) at 11 km resolution on 29 July 2000.

Correlation graph:

In figure 4, the correlation between the model and radar data is shown for the 29th July 2000 at 11 km resolution. In this figure we see that the linear regression line of the model run with the KF-RK scheme overlays the 1 to 1 line, while the linear regression line of the model run with the STRACO scheme lies below the 1 to 1 line. This means that the STRACO scheme overpredicts precipitation amounts. The correlation coefficient of the model run with the KF-RK scheme is higher than that for the STRACO scheme (0.68 vs. 0.52), so the structure of the model results with the KF-RK scheme correlates better with the structure of the radar observations.

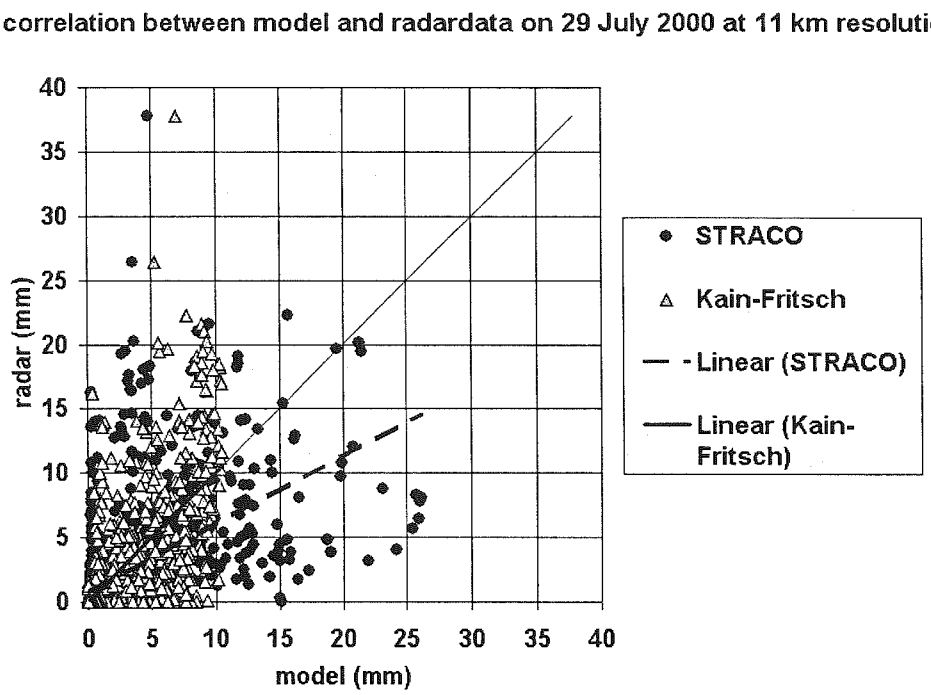

Figure 4: Correlation between model and radar data on 29 July 2000 at 11 km resolution.

Distribution of precipitation amounts:
In figure 5, the distribution of the precipitation amounts in the selected area (as displayed in figure 1, 2 and 3) is shown. On the y-axis, the fraction of all points that exceed a certain precipitation amount is plotted. On the x-axis, the precipitation amount that is exceeded is plotted. We can see that especially the model run with the STRACO schemes overpredicts the small precipitation amounts (< 1 mm), as could already be seen in figure 2. The overprediction of these small amounts is less in KF-RK. For the high precipitation amounts STRACO seems to do very well, but if we look at figure 2 again, we see that these high precipitation amounts are positioned incorrectly. Distributions of precipitation amounts therefore gives you insight in the correctness of the average precipitation amounts, but it gives no information about the correctness of the positioning of the precipitation sums.

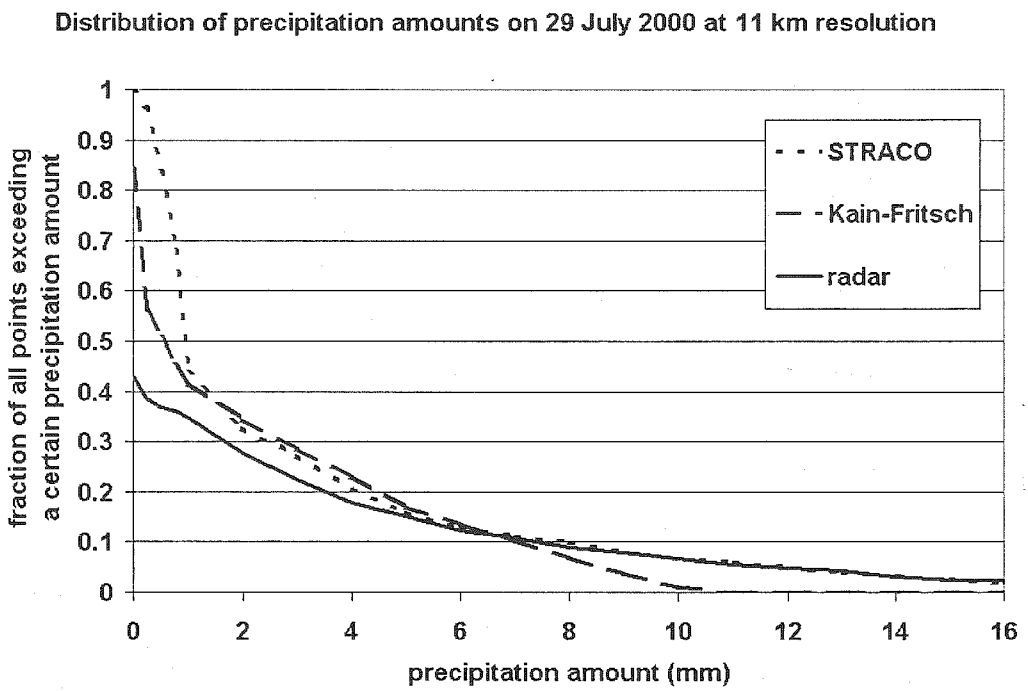

Figure 5: Distribution of precipitation amounts on 29 July 2000 at 11 km resolution.

Contingency table:
In figure 6, we see the Hanssen-Kuipers Scores (HKS) for several limits (x-axis) derived from contingency tables (not shown). The HKS are calculated for the model runs with STRACO and KF-RK on 29 July 2000 at 11 km resolution. The HKS for the model run with the KF-RK scheme is higher for almost all limits, except for the limit of 16 mm. Reason for this is that the model run with the KF-RK scheme does not calculate points with 16 mm or more precipitation, while the model run with the STRACO scheme does. However, especially for the high limits we should take into account that the number of cases affects the HKS. For the low limits (0.3 and 1 mm) the HKS is relatively low for the model run with STRACO scheme. This is because the model run with the STRACO scheme overpredicts the small precipitation amounts.

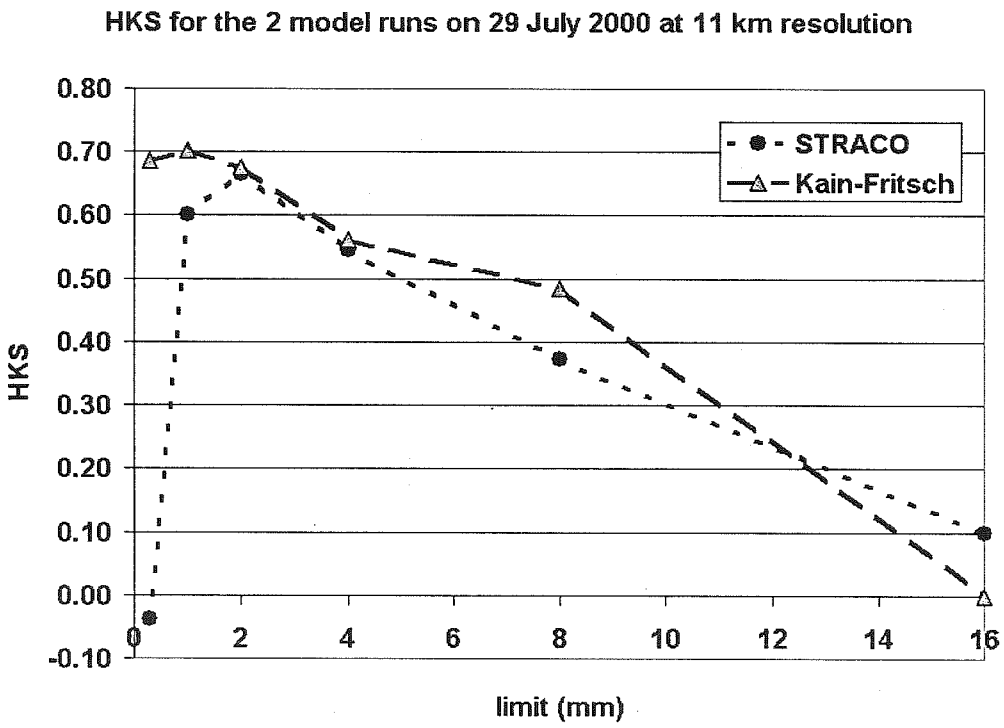

Figure 6: HKS for the 2 model runs on 29 July 2000 at 11 km resolution for 6 different limits.

3. CONCLUSIONS

In this case with weak large-scale forcing, there is little moisture convergence and thunderstorms can hardly develop with the STRACO scheme. The KF-RK scheme uses a more physically realistic approach and thunderstorms can easily develop in this situation. From the three verification methods can be concluded that the KF-RK scheme gives better results. From the distribution method, one would conclude that the STRACO scheme gives better results, especially in the high precipitation amount range. However, we have also seen that the area with high precipitation amounts in the model run with the STRACO scheme is not at the correct location. For a general conclusion about the performance of convection schemes, more than one verification method should be used.

5. Report of the EWGLAM final discussion

5.1 EWGLAM Final Discussion

EWGLAM Final Discussion _ Wednesday 9 October 2002

Clive Wilson, Met Office

Venue of 2003 and 2004 meetings

Maria Monteiro from the Portuguese Meteorological Institute confirmed the invitation to Lisbon for the 2003 meeting which was warmly accepted. The dates will be from Monday 6 October to Thursday 9 October.

Gerard Cats reported on behalf of Marit Jensen that the Norwegian Meteorological Institute (DNMI) had offered to host the 2004 meeting. This offer was also warmly welcomed by the participants.

Special Topic of 2003 meeting

After discussion it was agreed that the topic should be "Use of non conventional and new observing systems for short-range forecasts and validation" or "Use of new data for short-range NWP" as a short title.

Format of meeting

The format of the meeting had been changed as suggested at last year's discussion session. It had also been agreed that it should be reviewed this year how well this had worked . It was generally felt that the new shorter format of this year's meeting was better and that computer vendor's "sales" talks were not missed. The form of words on the invitation this year would be used again to discourage this type of talk whilst welcoming technical aspects and code optimization contributions. The invitation for data assimilation experts and representatives from special observation projects would also be retained in the context of the general theme of the meeting but without returning to the special sessions on these topics included in previous meeting formats. A presentation from local experts, such as the Land-SAF in Portugal, would also be very welcome. A talk by a local forecaster should also be encouraged to strengthen the links and promote discussion between modellers and forecasters.

2002 Abstracts & Newsletter

The deadline is 30 NOVEMBER 2002. Page limits are 3 pages for national reports and 5 pages for scientific and group reports. Please only use black and white for the abstract. The preferred format is pdf, without page numbers, and LATEX is also acceptable (see web site for details). Powerpoint presentation may also be sent for inclusion on the meeting web site with links to the SRNWP web site. All contributions should be sent to Gerard Cats at KNMI as soon as possible, preferably by ftp.

Send your abstract preferably by putting it on the ftp server:

ftp ftppro.knmi.nl
User: ewglam
Password: *as was sent around*
cd pub/2002/abstracts
binary
put abstract but use a unique name!
quit

2001 Abstracts

These would be put on the SRNWP web site when available.

The participants thought the meeting had been especially well organized and useful and warmly thanked KNMI and Gerard Cats for their efforts and hospitality.

6. Appendix

6.1 Operational NWP models in Europe (EUMETNET-SRNWP) as at November 2002

Country	Model	Mesh size (km)	# of gridpoints	# of levels	Computer
Denmark	HIRLAM	47	202 x 190	31	NEC SX 4
		17	194 x 210	31	
		17	272 x 282	31	
		6	182 x 170	31	
Finland	HIRLAM	44	194 x 140	31	Cray T3E
		22	194 x 140	31	SGI Origin
Ireland	HIRLAM	16	438 x 248	31	IBM SP
Netherlands	HIRLAM	22	406 x 324	31	SUN Fire
		11	306 x 290	40	
Norway	HIRLAM	56	188 x 152	31	SGI Origin
		11	224 x 324	31	
		5	150 x 152	31	
Spain	HIRLAM	56	194 x 100	31	Cray C94
		22	194 x 100	31	
Sweden	HIRLAM	44	202 x 178	31	SGI Origin
		22	162 x 142	31	
Austria	ALADIN	10	133 x 117	37	SGI Origin
Belgium	ALADIN	7	97 x 97	41	SGI Origin
Bulgaria	ALADIN	9	79 x 63	31	SUN
Croatia	ALADIN	8	127 x 109	37	SGI Origin
Czech Rep.	ALADIN	12	229 x 205	37	NEC SX4C/3A
France	ARPEGE	variable	*global*	41	Fujitsu VPP5000
	ALADIN	10	277 x 277		
Hungary	ALADIN	8	189 x 133	37	IBM p690
Poland	ALADIN	14	169 x 169	31	SGI Origin
Portugal	ALADIN	13	79 x 89	31	DEC Alpha
Romania	ALADIN	10	89 x 89	31	DEC Alpha
Slovakia	ALADIN	7	109 x 79	31	DEC Alpha
Slovenia	ALADIN	11	72 x 72	37	DEC Alpha
Bulgaria	HRM	28	49 x 37	20	SUN
Germany	GME	60	*global*	31	IBM SP
	LM	7	325 x 325	35	
Greece	LM	14	95 x 113	35	Convex SPP16
Italy-Bologna	LM	7	234 x 272	35	IBM SP
Italy-Rome	HRM	56	181 x 121	31	Compaq Alpha
		28	151 x 101	31	
Poland	LM	14	193 x 161	35	SGI Origin
		7	385 x 321	35	
Romania	HRM	28	41 x 37	20	Bull DPX
Switzerland	LM	7	385 x 325	45	NEC SX 5
Yugoslavia	ETA	16	245 x 305	32	Pentium III Cluster
United Kingdom	UM	60	*global*	30	Cray T3E
		12	146 x 182	38	
Poland	UM	17	144 x 116	31	Cray SV1

Operational NWP models in Europe (EUMETNET-SRNWP) as at November 2002 (compiled by D. Majewski, DWD, Germany)

7. SRNWP lead centre reports

7.1 SRNWP Assimilation Collaboration - Report 2002-09-25 (Andrew Lorenc)

SRNWP Assimilation Collaboration - Report 2002-09-25 - Andrew Lorenc

In March 2002 a proposal called EUCOS-THOR*pex* was submitted to the EU Framework Programme 5:

> We propose to test the hypothesis that the number and size of significant weather forecast errors could be reduced by extra observations over the oceanic storm-tracks, and other remote areas, and that cost-effective observing systems can be developed to provide them. To achieve this cost effectiveness, the extra observations will be targeted at key sensitive areas, determined each day from the forecast flow patterns. These are major goals of The Observing system Research and Predictability Experiment (THORpex). THORpex is a ten-year international research programme to accelerate improvements in short-range (up to 3 days) and medium-range (3 to 10 day) deterministic and probabilistic (ensemble) predictions and warnings of high-impact weather. We propose a small pilot experiment, in preparation for a later major THORpex field campaign. This project is planning to make significant innovations in the types of observations used, their management systems, and the science of targeting.

Partners were The EUMETNET Composite Observing System (EUCOS) programme, the Met Office, ECMWF, Météo-France, SMHI, DMI, LSE and University of Reading. Disappointingly, it was ruled as "Outside the scope of the Call" because "Short Range Weather Forecasting is not a thematic requirement of the GMES call".

In June 2002 a similar consortium put in an "Expression of Interest" into the EC Framework Programme 6, for an Integrated Project called *New European Weather Hazard Prediction Systems in the Changing Climate (Euro-THORpex)*:

> Euro-THORpex will bring together the international research community, National Meteorological Services, industry and others to develop a new integrated European weather hazard prediction system in the changing climate. To do this the programme will create a new multi-model ensemble weather prediction system. Key advances necessary for this system will be in predictability theory, data assimilation and understanding of dynamical processes and climate change; together with better use of observing systems. The new system will provide significantly improved short-range forecasts of high impact weather, building on recent breakthroughs in targeting observations and data assimilation, making it realisable now for the first time. These advances will allow European society to act more effectively to reduce the great losses incurred from severe meteorological phenomena (e.g. flooding and wind damage).

Discusions are underway on whether this EoI should be merged with related EoI (e.g. Euro-RISK and CLIMMET-RISK), before making a full proposal for a large integrated project. (I am aware that there are also proposed Networks of Excellence involving SRNWP - these are different.)

7.2 Report on the Lead centre of Nonhydrostatic Modelling (J.Steppeler)

Report on the Lead centre of Nonhydrostatic Modelling

J. Steppeler
DWD, Offenbach

A report on the lead centre activities of the last year will be given.

Forecast of Orographic Precipitation with LM

J. Steppeler
DWD, Offenbach

A number of developments in connection with the LM are described, which have an impact on the flow around mountains and the predicted precipitation. These are the z-coordinate, the orographic filtering, the introduction of a new two time level time integration using a third order spatial difference scheme and a prognostic precipitation scheme. Some idealised results will be shown. The effect of the developments mentioned will then be demonstrated in a case study.

7.3 SRNWP Lead Center for Numerical Techniques, provisional report for 2001-2002 (Dominique Giard)

SRNWP Lead Center for Numerical Technics provisional report for 2001-2002

A. Invitation to the next workshop

2002 SRNWP-NT mini-workshop : Toulouse, 12-13 December 2002

Scheduled list of participants :

SRNWP	Jean Quiby
COSMO	Jürgen Steppeler
HIRLAM	Eigil Kaas, Isabel Martinez, Ivar Lie
UKMO	Nigel Wood, Mohammed Zerroukat, Elisabetta Cordero
ALADIN	Jean-François Geleyn, Pierre Bénard, Radmila Brozkova (?), Gabor Radnoti (?), Petra Smolikova (?), Yong Wang (?)
ECMWF	Clive Temperton
INM-RAS	Mikhail Tolstykh, one other colleague (?)
RPN	(?)

Contact :
Pierre Bénard
(contact person for SRNWP-NT , *pierre.benard@meteo.fr*)

B. Some informal news from EWGLAM groups

ALADIN :
Still searching for new coupling methods
Trying to improve the smoothing of spectral orography
New NH dynamics nearly ready

COSMO :
Addressing the problem of very steep slopes
Investigating the accuracy of advection schemes
A new vertical coordinate (SLEVE) !
Design of a new dynamical core

HIRLAM :
Still searching for new coupling methods
Significant progress in NH dynamics

UKMO :
New dynamics operational
"New new dynamics" in pipeline

Else :
First intercomparisons of NH dynamics at Météo-France
(ALADIN, HIRLAM, Meso-NH, *external initiative)*

7.4 SRNWP Lead Centre for Statistical and Dynamical Adaptation (Thomas Haiden)

SRNWP Lead Centre for Statistical and Dynamical Adaptation

The next Workshop will be held 5-7 May 2003 in Vienna. In addition to statistical methods it invites presentations about physical and dynamical adaptation. An issue of particular interest is the prediction of extremes, and the problems associated with forecasts of rare events in general. The list of topics includes, but is not restricted to

- Classical statistical methods (e.g. MOS, PPM, Kalman filter)
- Nonlinear methods (e.g. neural networks, decision trees)
- Dynamical/physical adaptation (e.g. wind-field downscaling, orographic precipitation models, road temperature modelling)
- Use of EPS in adaptation
- Prediction of extremes

The deadline for submission of short abstracts is 28 Feb 2003. The homepage of the Workshop is http://www.zamg.ac.at/swsa2003/

7.5 Status report from the Lead Centre for surface processes and assimilation (E. Rodríguez-Camino and S. Gollvik)

Status report from the Lead Centre for surface processes and assimilation

E. Rodríguez-Camino (INM) S. Gollvik (SMHI)

1 3rd SRNWP Workshop on surface processes and assimilation

The third SRNWP Workshop on surface processes and assimilation of surface variables was held between 22nd and 24th October 2001 at the INM (Madrid). As in previous occasions it was convened as a part of a HIRLAM meeting devoted to different physical parameterizations. Presentations and conclusions from different working groups were compiled as a HIRLAM Workshop report (also available from the HIRLAM web site http://www.knmi.nl/ hirlam/project/Reports/HLworkshops/Surface2001/)

The short term recommendations of the Workshop are summarized in the following points:

- Improvement of snow formulation
- Minimum number of predictive equations to describe the snowpack evolution: snow temperature. snow height, liquid water content, snow albedo
- Improvement of the snow depth analysis
- Implementation of satellite based vegetation properties in climate files
- Review of definition and use of roughness length for heat and momentum

The medium term recommendations are:

- Increase the number of soil layers: 4-5
- Separate energy budget for the canopy
- Review roughness length averaging for momentum exchange
- Variational approach to soil moisture assimilation
- Use of SYNOP soil temperature for validation
- Use of satellite data for validation
- Improvement of run-off formulation

2 Activities at different centres

- Assimilation of surface/soil variables:
  - 3 different alternatives used for soil moisture assimilation: sequential (ECMWF, ALADIN, HIRLAM), off-line update (UKMO), variational (COSMO).
  - ELDAS EU-Project to develop soil moisture assimilation integrating ideas from different algorithms.
  - Activity on snow analysis both at HIRLAM (SC) and ALADIN (OI).
- Topographical and physiographical datasets. Most models have upgraded their generation of climate files using GTOPO30, CORINE datasets and satellite derived vegetation fields (*e.g.*, Champeaux *et al.*, Hagemann *et al.*, etc)
- Description of lakes is still very poor and a frequent source of errors in Nordic regions. The use of realistic climatological lake temperatures is an easy way to circumvect the lack of observations. Both HIRLAM and ALADIN are active in pursuing some simplified description of lakes within models.
- The tiling approach to describe surface heterogeneity has been adopted by several models (UKMO, HIRLAM, ECMWF). Although the improvement is hardly noticeable in terms of standard scores, it allows many posibilities when it comes to verify against observations.
- Activities within HIRLAM
  - Evaluation of the recently implemented new surface scheme based on tiles + ISBA by: i) seasonal integration; ii) EFEDA data; iii) Rhone Aggregation Exp; iv) Parallel 2 weeks runs; v) Relevancy of postprocessing and verification.
  - Improvement of the snow formulation: i) An extra thermal layer below surface layer; ii) one additional tile for bare land + low vegetation snow covered area; iii) one snow layer + water retained by the snow package + snow albedo ageing + constraints to latent heat flux (small Zo_{heat} for snow) + ...
  - Improvement of the run-off formulation by taking into account the heterogeneity of the land surface within the grid square.
  - Comparison of different formulations for freezing/thawing of soil water content.
- Recent comparison and evaluation exercises:
  - Rhone AGGregation experiment (http://www.cnrm.meteo.fr/mc2/projects/rhoneagg/)
  - SnowMIP (http://www.cnrm.meteo.fr/snowmip)
  - ELDAS (http://www.knmi.nl/samenw/eldas/)

3 Preferent fields of activity for the near future

- Runoff description is rather crude (field capacity?). Use of soil moisture subgrid variability, subgrid topography, subgrid precipitation, ...
- Horizontal complexity versus vertical complexity. The sole soil layer vertical framework does not match with real description of surface processes.
- Winter conditions are still a source of problems for surface schemes. A better snow description needed: a) ageing of albedo, density, emissivity, etc; b) snow albedo in forests and complex orography; c) effect of water retained by melting snow; d) freezing and melting of soil moisture, lakes; e) sea ice description.
- Substitution of land-use and look-up tables for vegetation parameters for directly measured (from satellite) vegetation parameters: veg, LAI, alb. The frequency of updating should also be reviewed (1 week?)

7.6 Report of the SRNWP Lead Centre for Mesoscale Verification (Ben Wichers Schreur)

Report of the SRNWP Lead Centre for Mesoscale Verification 2002

Ben Wichers Schreur, KNMI

14th January 2003

Abstract

This article is a report of the activities past, present and future of the SRNWP Lead Centre for Mesoscale Verification presented at the annual SRNWP meeting, edition 2002.

Past

The role of the SRNWP Lead Centre for Mesoscale Verification is to promote the exchange of advances in verification research and to stimulate cooperation in verification research within the SRNWP community. To that end a first mesoscale verification workshop was held in April 2001 at KNMI.

Results of the workshop were presented at the HIRLAM All Staff meeting in Reykjavik, at the WMO quantitative precipitation forecast workshop in Prague and at the EWGLAM/SRNWP conference 2001. Contributions to the workshop and summaries of the working group discussions were published as a HIRLAM Workshop Report in September 2002 (available through the HIRLAM project leader.)

As the demands on mesoscale short range numerical weather forecasts are changing with the new applications that increasing model resolutions enable, so do the demands on mesoscale verification change. Mesoscale verification is a new and largely uncharted field of research. Therefore much time at the workshop was spent in group discussions, charting avenues of future mesoscale verification R&D.

Presentations and discussions centered on the verification of precipitation, as the problems encountered in precipitation verification are exemplary of those of general mesoscale verification:

- the availability and uniformity of high resolution data sets for verification;
- the conversion of subjective forecast evalutions to objective scores;
- the development of new criteria for the evaluation of mesoscale forecasts;
- the probabilistic interpretation and verification of mesoscale forecasts.

Recommendations

The workshop participants made some practical recommendations. SMA was advised to continue its development of precipitation verification by pattern comparison. The SRNWP programme manager was given the task to promote the exchange of hourly synop data and the task to inform DWD that it is relieved of its commitment to facilitate a model intercomparison. The Lead Centre was asked to study the possibility of organizing a meaningful intercomparison of model results and to present ideas on such an intercomparison at the next SRNWP mesoscale verification workshop.

Present

For the Lead Centre the implications of the workshop are that it is to organize a second mesoscale verification workshop, that it has to prepare for a meaningful model intercomparison and that it has to explore additional means to promote cooperation in mesoscale verification R&D within the SRNWP community.

As a first step a questionnaire has been sent out to all workshop participants and SRNWP contacts asking for an evaluation of the first workshop and inputs for the second workshop. In addition SRNWP members are asked to specify essential Lead Centre activities.

Future

The Lead Centre has taken up the recommendations of the first workshop and will organize a second mesoscale verification workshop in 2003. The idea is to make this workshop more thematical, e.g. to focus on the value of quality. Suggestions by SRNWP members of relevant workshop themes are welcomed.

In preparation for a model intercomparison and as an additional means for the promotion of the exchange of verification knowledge, methods and data the Lead Centre will build an internet resource. This resource is thought to contain a library of mesoscale verification references (a summary of our collective knowledge so to speak), verification research reports published by SRNWP members, high resolution reference data sets (e.g. precipitation and discharge data for the Elbe floods of summer 2002), verification results and anything you may care to suggest or contribute.