Technical description of the high-resolution air mass transformation model at KNMI

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KNMI

Contents

Abstract

This report contains a technical description of the high resolution Air Mass Transformation (AMT)-model, which has been recently developed at KNMI. The AMT-model is intended for short range weather forecasts of the temperature and humidity profile, the structure of the boundary layer, the boundary layer height and the amount of boundary layer clouds. As such the model consists of a one-dimensional multi-layer boundary layer model, which is advected from a source region to a receptor point by trajectories The trajectories are calculated within a limited area model.The initial profiles for temperature and humidity are obtained from observed radiosondes.

In this report the several parts and subprograms of the model are described and documented. The implementation of the model on the KNMI computer systems is discussed as well.

1. Introduction

This report contains a technical description of the multi-layer Air Mass Transformation (AMT) model, which has been developed at KNMI (Holtslag et al 1990). The model is intended for short-range weather forecasting of atmospheric boundary layer properties. The dataflow necessary to run the model, the basic parts of the physics of the model and the way the results are presented, is described.

On basis of predicted trajectories a source area of the air can be determined. In the source area, representative radiosondes are selected automatically for composing the initial profile. The Atmosferic Boundary Layer (ABL) is transformed along the trajectory through the exchange of heat and water vapour with the earth's surface.
The tendencies are calculated with a one-dimensional model. Over land the surface fluxes are determined by the energy balance method (Holtslag and Van Ulden 1983). Over sea, the surface temperatures (SST) are used for the calculation of the surface fluxes with the profile method (Holtslag et al 1990).

In section 2 the model subroutines are described. The dataflow is given and the system dependent routines of the model are discussed. In section 3 we describe how the initial profile is constructed. Subsequently we discuss in section 4 how the trajectory data are treated and how the extraction of the sea surface temperatures (SST) takes place. In section 5 the physical routines are discussed on basis of a flowchart. In section 6 the model's output is discussed. The model result is presented as a prognostic temperature and humidity profile in a so-called θ_s-p diagram (see Fig 5 on p15). The printed output consists of intermediate profiles of θ and q and some boundary layer parameters such as Obukhov length, boundary layer height, friction velocity and heat- and moisture fluxes.

The actual implementation of the model is summarised in the appendices. In Appendix 1 a list of subroutines with an explanation of their functions is given.
In Appendix 2 the variables of the main program are listed and the boundary layer routines are described. Finally in Appendix 3, the reader will find instructions for running this model on a Unisys-computer and on a (MS-DOS based) personal computer.

2. Flowchart of the main program

Fig. 1 summarizes the flowchart of the AMT model. The main program controls the collection of data, the calculations and the presentation of the model results. Within the dotted lines on the flowchart, the system dependent of the Unisys computer are found.
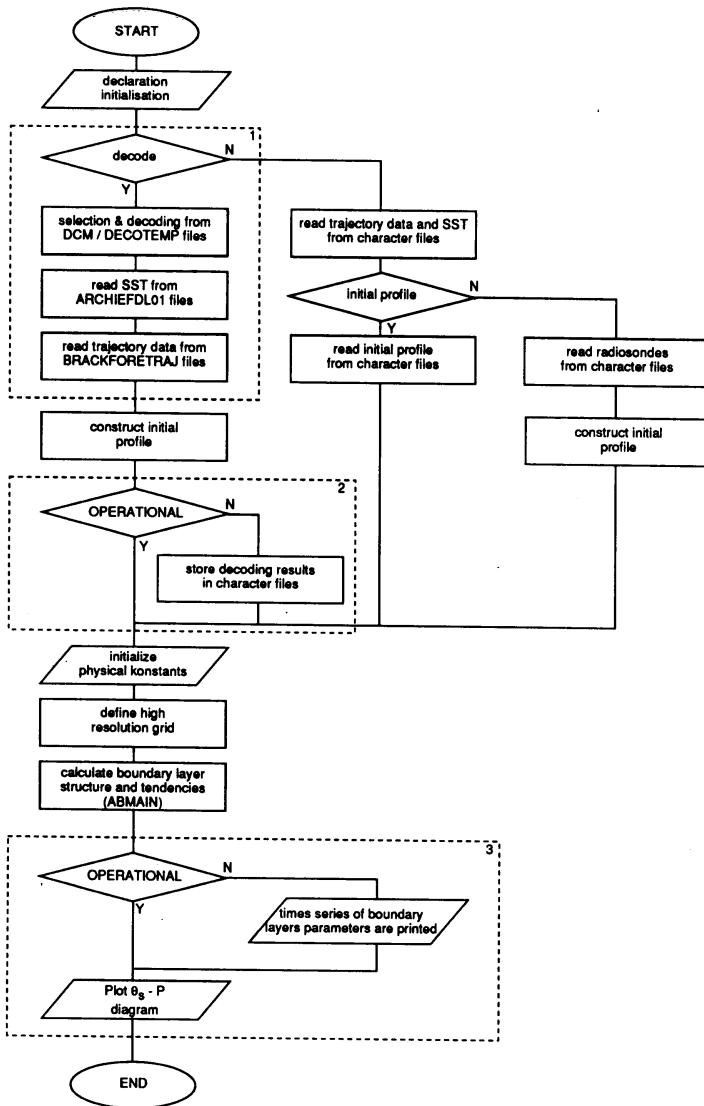

Fig. 1 Flowchart Main program

In block 1 the retrieval of data from KNMI's database is carried out. After selection of representative radiosondes in the source area (see 3.1), the radiosondes are decoded from the DCM/DECOTEMP files using the GETOBS library. The sea surface temperatures (SST) are read from an ARCHIEFDL01 file and an ALGOL subroutine (GSST) is used to extract the necessary data.

The trajectories are read from BRACKFORETRAJ files. Alternatively to block 1, the input data can be read from already available character files.

In block 2 the result of the data retrieval and the construction of the initial profile is stored in character files (only in the research mode). These data files can be used for subsequently running the program. In block 3 the system dependent routines for plotting and printing are found.

During the model development, the printing routines were used to create time series of relevant boundary layer parameters. The plot of a θ_s-p diagram is made on a Versatec electrostatic plotter. For plotting the plot library on the Unisys computer is used. Printing of the model results is done on the system printer of the Unisys mainframe.

3. The initial profile

3.1 Selection of radiosondes in the source area

The initial profile is constructed from representative radio sondes in the source area. Originally the radio-sondes were selected by the forecaster. However, in order to automate the process in the weather service, we have chosen to implement an algorithm which selects the radio-sondes automatically. The idea is that for each trajectory level three stations are chosen which are nearby to the begin positions of the trajectories at each level.

The selection algorithm starts with a random choice of three stations for each trajectory level.These three stations are written in an ascending sequence of distance. Subsequently we compare the selection with the contents of a database (SONDE) in which all presently available stations are listed and for each station we check if an alternative station exists with a shorter distance.The shortest distance to the begin position of the trajectory at respective levels gives the best choice. This method has disadvantages with regard to land-sea discontinuities.
When the trajectories start in northern France for example, it is possible that stations on the other side of the Channel will be selected. Possibly the procedure might need future updates.

After three stations are selected for each trajectory level, it may be possible that a station occurs more than once. If so, the additional occurence is rejected. Possible empty spots due to missing stations are filled with dummy values (99999). The database consists of stations of the part of the globe where the trajectories arriving in The Netherlands usually start. The database is built in a BLOCKDATA construction. Unfortunately not every station is available at the starting times 0000 and 1200 h.
The subroutine FILLSKP skips the stations when they are not available. The next list gives a survey of the stations influenced by SKIP(ok means available at that time).

number	code	00h00	12h00
38	7180	skip	ok
51	9486	skip	ok
59	10618	skip	skip
61	10771	skip	skip
86	16662	skip	ok
88	16754	skip	ok
97	26702	skip	skip

The data of the radiosonde stations are available in the DCM/DECOTEMP files. These files contain compact stored data which can be read with the GETOBS library. The selection of the stations is stored in the file SONDE&IMT/ISHIFT (Unisys) or SO&MM&DD.D&IMT (pc).

3.2 The construction of the initial profile

The subroutine ANALYSE, described by Remmers (1986), controls the composition of the initial profile. The initial profile represents in fact a tilted profile, because often the significant points are not above each other. This is caused by the trajectory levels starting at different positions. The observations by the radiosondes are normally presented in a temperature, dewpoint, pressure (T,Td,p) system. In the model these profiles are transformed to a potential temperature and specific humidity at a pressure level p where p is normalised by its surface value p_0 (θ, q, σ system). Here $\sigma=p/p_s$. The data from the selected radiosondes of the source area are checked for errors e.g., the pressure levels should be in a descending order. A point is rejected when the pressure increases with height. Subsequently the checked profiles and the begin positions of the trajectory levels are printed (Unisys) or written to a file AMTPRT.OUT (pc).

The distances between the start positions of the trajectory levels and the positions of the radiosondes are calculated. The minimum distance is set on 10 kilometers. The weight factors (which are inversely quadratic with the distance) are calculated and printed (Unisys) or written to the file AMTPRT.OUT (pc).

Subsequently p_s, θ_s and q_s are interpolated at the surface level of the initial profile. The pressure (p_s) is used to convert the interpolated surface σ-levels of the initial profile to the actual pressure levels. The analyzed profiles contain all the significant points of the nearby radiosonde stations. The accuracy of the analyzed profiles can never be larger than the accuracy of the observed radiosondes Therefore the number of signifant points in the θ- and q-profile is reduced. This is done in two steps. (Holtslag et al, 1990).

First, if at two adjecent significant σ-levels pressure, temperature and humidity differ by less than 3 mbar, 0.3 K and 0.2 g/kg respectively, the two significant levels are replaced by the lowest one. Second, at each significant level, the temperature is linearly interpolated between the temperature analyzed at the nearest and highest significant levels. The level with the largest deviation between interpolated and analyzed temperature is kept a significant level if the deviation exceeds 0.3 K. This procedure is repeated both below the newly defined significant point and above it, until all deviations are less than 0.3 K. Subsequently the procedure is repeated with the specific humidity where a tolerance of 0.2 g/kg is used. Finally the initial profile is printed (Unisys) and written to the files INTEMP&IMT/ISHIFT (Unisys) and PR&MM&DD.DIMT, AMTPRT.OUT (pc)

3.3 Interpolation to model levels

After the analysis is done the profiles of θ and q are transformed to the vertical grid of the model. Subroutine HYDRO uses a hydrostatic integration scheme to obtain the heights of the model points. The scheme assumes a linear variation of q with height between the model points .The profile is now interpolated to the model grid. Fig. 2 shows the model levels. The first model level is set at 10m. The resolution is 40m up to 300m, 50m up to 1000m, 100m up
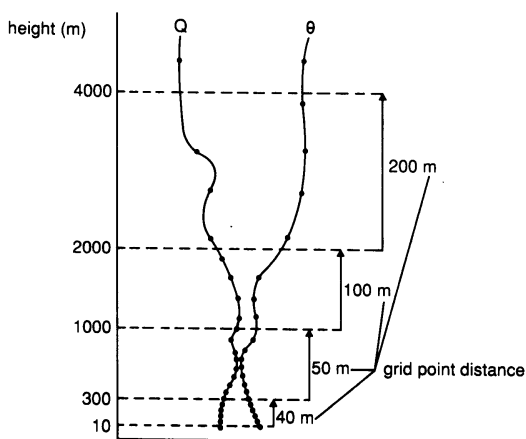

Fig. 2 Definition of the modelgrid

to 2000m and finally 200m up to 4000m.As such we have 43 model levels. Above 4000m, model levels up to the pressure of the highest trajectory level are created at the location of significant points in the constructed initial profile.
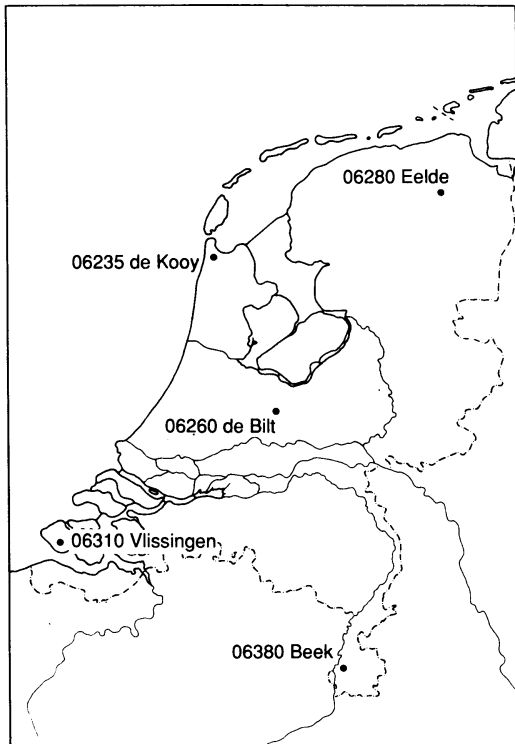
4. Trajectories and boundary conditions

Fig. 3 Arrival stations of trajectories

4.1 Trajectories

Forecasted and analyzed wind fields of the fine mesh limited area model of the United Kingdom Meteorological Office (UKMO) are used for the calculation of backward trajectories in time, starting from the receptor point to the source area. We receive bulletins (UK74,UK75) with trajectory data every 12 hours. The forecast times are 12, 24 and 36 hours ahead. The bulletins are transformed to datafiles, i.e.BRACKFORETRAJ files. These files contain five receptor points which are distributed throughout the Netherlands (Fig. 3).

The subroutine RTRAJ reads the wind speed and pressure data from the BRACKFORETRAJ files which are necessary to advect the profile.The trajectory data are given on four levels of which the end pressures are 500, 700, 850 and $0.975*P_s$mbar. Here P_s is the actual surface pressure. The latter trajectory is in fact held constant on a height of about 200m. The time interval between positions on the trajectory is 3 hours.

4.2 Cloud cover and final surface pressure

The lowest trajectory data contain additional information. Along the 975 mbar level also the cloud cover from the limited area model is available. Low level clouds and middle and high level clouds are given in octa's.
Since the ABL routines create boundary layer clouds, the model uses the clouds of middle and high levels as a boundary condition. The cloud cover is given with an interval of three hours. For presentation purposes the cloud cover data are converted to a two-hourly format with a simple linear interpolation algorithm.
In subroutine BLOCK the new position is determined by interpolation between the trajectory positions which are also given every 3 hours. The final surface pressure at the arrival point is obtained from the trajectory data. Finally the trajectory data (windspeed, cloud cover et cetera) are stored in files FORETRAJ12/ISHIFT (Unisys) or FC&MM& DD.D&IMT (pc).

4.3 Sea surface temperatures (SST)

To determine the surface fluxes over water it is important to know the sea surface temperatures.
In order to solve discontinuities at land-sea passages an accurate land-sea mask is needed. The land sea mask is defined in the BLOCK DATA construction LS. The horizontal resolution is about 20 km.In the file ARCHIEFDL1/JJMM the actual temperatures are stored. For the passage over sea, sea surface temperatures (SST) are necessary. These are derived from Offenbach's database. The land-sea mask is defined in the model. If a temperature is not available on a grid point, data from a climatological file EXTA/SST are taken instead.
The land-sea mask covers the North sea,the British Channel and the southern part of Scandinavia. It should be noted that GETSST is written in Algol and is linked to the main Fortran77 program.

5. The ABL routines

ABMAIN as shown in Fig. 1, is the marching scheme which controls the ABL processes. In Fig. 4 the flowchart of ABMAIN is shown. The scheme is divided in five parts, which are discussed separately below.
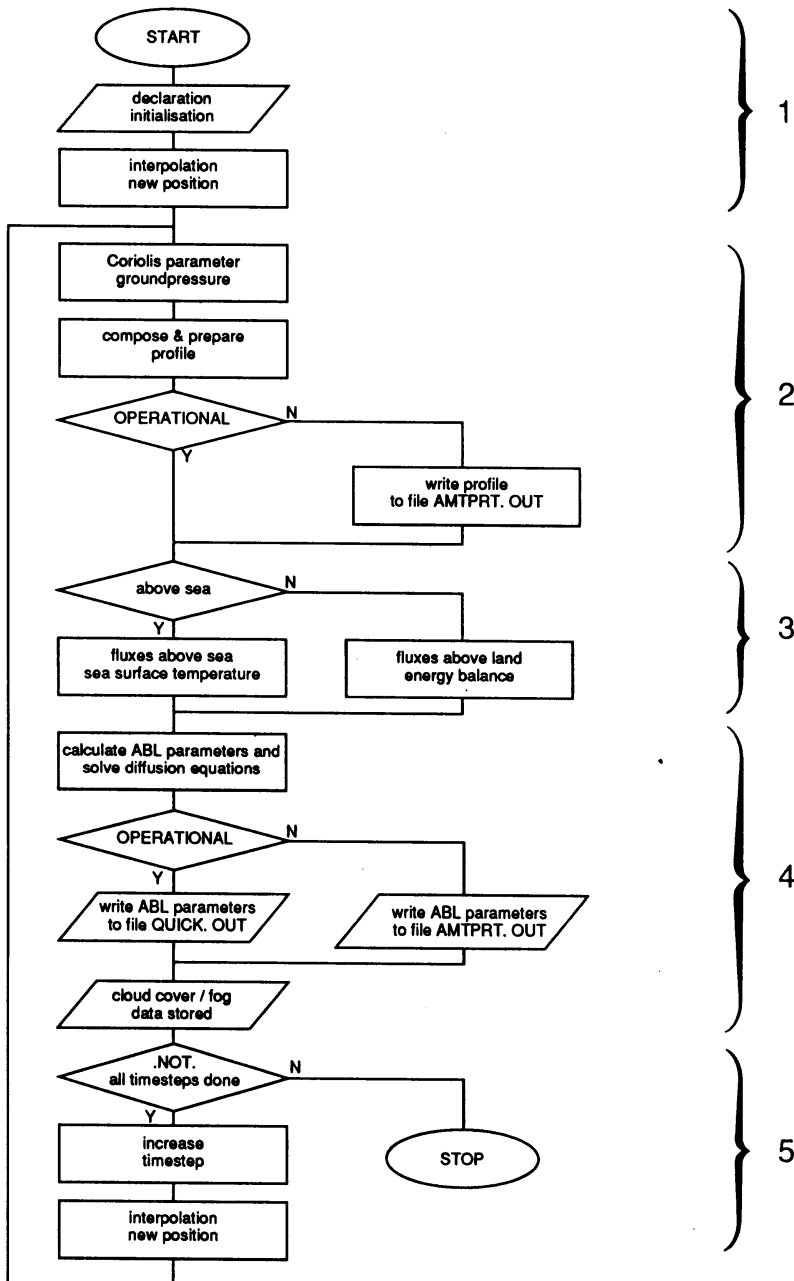
Fig. 4 Flowchart of ABMAIN

In ABMAIN the time step of the printing process ITIME1, of the trajectory model ITIME2 and of the boundary layer model ITIME3 are initialized. Subroutine INTER obtains the interpolated values for position, pressure and velocity on the model grid points. The distinction between land and sea is defined in the BLOCKDATA LS which contains an accurate land-sea mask. INTER checks if a new position is above land or sea. The logical variable LOWATR becomes .TRUE. above sea and .FALSE. above land. The sea surface temperatures are derived from the ARCHIEFDL01

file. The interpolation of the cloud cover is done separately in a 2 hourly format(see section 4.2)

II

The main loop starts with calculating the Coriolis parameter for the given position.The surface pressure is linearly interpolated between the start surface pressure (composed from radiosondes) and the predicted surface pressure at the receptor point (derived from the trajectory data).After calculation of the surface fluxes and the boundary layer structure, the integration time step is completed by updating the pressure field and adjusting the vertical column to the new to the new surface pressure. As such the profiles are not allowed to rise above the 500 mbar level and to sink below the surface. Supersaturation is avoided by use of the subroutines SSHEAT and SVP. The height of the pressure levels is determined in HYDRO. The begin profile is written to AMTPRT.OUT(pc).

III

The logical variable LOWATR determines whether the air mass is above sea. Above land (LOWATR=.FALSE.) the surface fluxes are calculated with the energy balance method (Holtslag and Van Ulden, 1983). In this case cloud cover is needed.
The cloud cover is taken as a maximum of the cloud cover above the ABL and the boundary layer cloud cover from subroutine MLABL of the preceeding time step.
Over sea (LOWATR=.TRUE.) the sea surface temperatures are necessary for the flux calculation (Holtslag et al 1990). When, due to an error, the actual sea surface temperature is below 0 C, we take the temperature of the previous time step.
Above land the roughness length is specified as 0.1m. Above sea the roughness is dependent on the height of the waves. The Charnock relation is used to estimate the roughness length over sea. The drag coefficients are calculated by the surface similarity method (CDRAG). Subsequently the fluxes are calculated and also the Obukhov length (Holtslag et al,1990).
Special attention is given when the air mass passes from unstable conditions over land to stable conditions over sea. In that case the fluxes are calculated with a neutral approximation resulting in a smooth transition between land and sea.

IV

In this part the surface fluxes are transformed from kinematic units into energy units, which is done for printing these variables in FLXPRT and QUICK. In MLABL the boundary layer height is calculated. The equations of θ and q are solved. The new cloud cover of the ABL is calculated as well. To avoid oscillations of the calculated cloud cover and the net radiation, the ABL cloud cover is averaged with the cloud cover of the previous time step.
The subroutines FLXPRT and PROFIL (file AMTPRT.OUT)

and QUICK (file QUICK.OUT) are called. Relevant boundary layer variables are stored in files. Finally the cloud cover of the ABL and the 2m temperature are stored in FORCLD. These variables will appear in the θ_s-p diagram. Every 2 hours N_L and T_s are shown.

V

As long as the final time is not reached, ZTIME is increased with the time step. The interpolation variables are calculated. New position, and velocity, et cetera are known.

6. Presentation of results

6.1 Printer output

To diagnose the AMT process during the advection, special routines write data to files. These routines are FLXPRT,QUICK and PROFIL. They have often been used during the development of this model. FLXPRT gives the following output

SHIFT	MIN	USTAR	H	LE	VFLX	BOWEN	QNET	QSAT	VGEO
89021500	0	.384	54	118	62	45.8	9999.	3.7	11.8
SINZ	HABL	T2M	TW	N	PSURF	NCL	OBUKHOVL	RATIO	NEWSTAB
-.80	538	6.3	11.0	.00	1023	.81	-82.56	-6.5	2

SHIFT	= date time group
MIN	= minutes
USTAR	= friction velocity [m/s]
H	= sensible heat [mK/s]
LE	= latent heat [mK/s]
VFLX	= virtual heat [mK/s]
BOWEN	= Bowen ratio H/LE [ ]
QNET	= Net radiation [W/m2]
QSAT	= Saturated net radiation [W/m2]
VGEO	= wind on sigma level .975 [m/s]
SINZ	= sine of the sun height above local horizon [ ]
HABL	= height boundary layer [m]
T2M	= temperature on 2m height [C]
TW	= sea surface temperature [C]
N	= cloud cover on middle and higher levels (decimal) [ ]
PSURF	= surface pressure [mbar]
NCL	= cloud cover boundary layer (decimal) [ ]
OBUKHOVL	= OBUKHOV length [m]
RATIO	= ratio HABL/OBUKHOVL [ ]
NEWSTAB	= stable=1 unstable=2

PROFIL gives the whole profile on a time step, as given here up to 210 m for example:

**** SHIFT= 89021500 ***** MINU= 5 SEA %= 0 LAND CLOUD %= 0

HGHT	PRES	TETA	TEMP	Q	RV	LAT	LNG	VX	VY	VW
10	1021	6.4	8.1	5.2	79	49.1	-5.1	9.7	6.8	-.0065
50	1016	6.4	7.7	5.1	79	49.1	-5.1	9.7	6.8	-.0065
90	1012	6.5	7.4	5.1	80	49.1	-5.1	9.7	6.8	-.0065
130	1007	6.6	7.1	5.1	81	49.1	-5.1	9.7	6.8	-.0065
170	1002	6.7	6.8	5.1	82	49.1	-5.1	9.7	6.8	-.0065
210	997	6.8	6.6	5.0	83	49.1	-5.1	9.7	6.8	-.0065

SHIFT	= date time group
MINU	= minutes
HGHT	= height [m]
PRES	= pressure [mbar]
TETA	= potential temperature [C]
TEMP	= temperature [C]
Q	= specific humidity [g/kg]
RV	= relative humidity [%]
LAT	= latitude [degrees]
LNG	= longitude [degrees]
VX	= velocity X-axis [m/s]
VY	= velocity Y-axis [m/s]
VW	= vertical movement [mbar/min]

SEA   = percentage of time above sea
LAND   = percentage of time above land and with clouds

SHIFT	MINU	LAT	LNG	PSURF	USTAR	HABL	T2M	TW	H	LE	NCL	N	RV1
89021500	0	49.10	-5.20	1023.	.38	538.	8.1	11.0	54.	118.	0.	6.	80.
89021500	5	49.12	-5.15	1023.	.38	599.	8.5	10.9	45.	111.	0.	6.	79.
89021500	10	49.13	-5.09	1023.	.38	612.	8.7	10.9	41.	108.	0.	5.	79.
89021500	15	49.15	-5.04	1023.	.39	622.	8.9	10.9	38.	107.	0.	5.	78.
89021500	20	49.17	-4.99	1022.	.39	631.	9.0	10.9	36.	106.	0.	5.	78.
89021500	25	49.18	-4.94	1022.	.39	638.	9.1	10.9	35.	106.	0.	5.	78.
89021500	30	49.20	-4.88	1022.	.40	643.	9.1	10.9	33.	105.	0.	6.	78.
89021500	35	49.22	-4.83	1022.	.40	648.	9.2	10.9	32.	104.	0.	6.	78.
89021500	40	49.23	-4.78	1022.	.40	652.	9.2	10.8	31.	104.	0.	6.	78.
89021500	45	49.25	-4.72	1022.	.41	655.	9.3	10.8	30.	104.	0.	6.	78.
89021500	50	49.27	-4.67	1022.	.41	659.	9.3	10.8	30.	103.	0.	6.	78.
89021500	55	49.28	-4.62	1022.	.41	664.	9.3	10.8	29.	103.	0.	6.	78.

It takes some time to write all data to the files. For a fast response it may be sufficient to use the subroutine QUICK only. The output of QUICK is as follows:

SHIFT   = date time group
MINU   = minutes
LAT   = latitude [degrees]
LNG   = longitude [degrees]
PSURF   = surface pressure [mbar]
USTAR   = friction velocity [m/s]
HABL   = boundary layer height [m]
T2M   = temperature at 2m height [C]
TW   = sea water temperature [C]
H   = sensible heat [mK/s]
LE   = latent heat [mK/s]
NCL   = boundary layer clouds [octa's]
N   = middle and high level clouds [octa's]
RV1   = relative humidity [%]
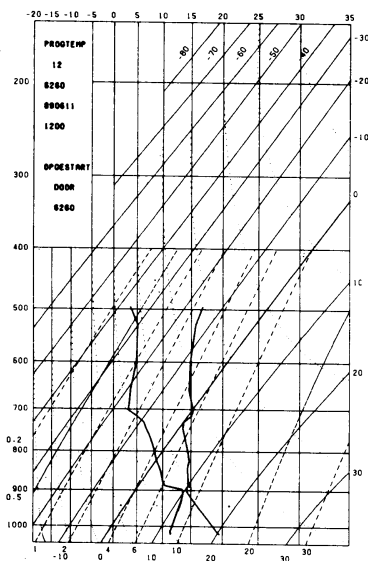
inputdata:

IIIII	GMT	n
3170	0	2
3322	2	1
3496	4	0
3774	6	0
3920	8	0
6260	10	0
6447	12	0

outputdata:

GMT	NL	TS
0	1-4	13.9
2	0	11.4
4	mist	11.0
6	1-4	15.5
8	0	18.2
10	5-8	19.7
12	5-8	20.6

Fig. 5 Presentation of modelresults in the weather room

6.2 The thermodynamic θ_s-P diagram

In the research mode each model run produces two plots. The begin and end profile are shown.
In operational use only the end profile is given. The model output is presented in a special KNMI diagram that is used to show a radiosonde observation (Fig. 5).
The vertical lines are moist-adiabats and the curved dotted lines are dry adiabats. The dashed line corresponds with the mixing ratio. The horizontal lines are the isobars. The sloping lines, labelled in degrees Celsius are isotherms. Additional data of the AMT model is shown on the right :

INPUTDATA:

IIIII : selected stations covering the source area of the trajectories
GMT: time step every two hours
N   : forecasted cloud cover in octa's on middle and high levels from large scale model

OUTPUTDATA:

The output data is gathered during the AMT run. Routine FORCLD is called every 2 hours in ABMAIN. Intermediate and final results are written in the arrays PTSFCA and PCLPBL. PTSFCA is a one dimensional array which contains the 2m temperatures. The presentation of the cloud cover is realised by the value of PCC (calculated in MLABL). PCC is the predicted low level cloud as a result of the turbulent mixing scheme in MLABL. The values of PCC are coded as follows:

PCC < 0.06   0
    <=0.57   1-4
    > 0.57   5-8

When the air mass is stable, fog is examined by calculating the relative humidity at the first model level. When the relative humidity is higher than 100% "mist" instead of 5-8 will be presented.

GMT : time step every two hours
N_L : cloud cover boundary layer clouds given in three categories: mist, 1-4, 5-8
T_s : 2m temperature in degrees Celsius

In the upper left corner other input parameters are shown
PROGTEMP : prognostic radiosonde
12 : forecast period of time span
6260 : arrival station code
890512 : date
1200 : arrival time
OPGESTART
DOOR : Station where the model has run
6260 :

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7. Final remarks

This report contains a technical description of the high resolution AMT-model at KNMI. It describes the collection of radiosondes in the source area, trajectories and boundary conditions (sea surface temperatures and cloud cover on middle and higher levels). On basis of a flowchart the atmospheric boundary layer routines are described. Model output is available in printed and plotted form. The printed output consists of time series of boundary layer parameters and intermediate profiles. The plotted output is given as a progtemp, which is presented in a so-called thermodynamic θ_s-p diagram.

This report can be read in addition to the scientific paper (Holtslag et al, 1990). It documents the implementation of the AMT-model on the current computer system. This report might be usefull for maintenance and for operating the model.

The AMT-model will be integrated within KNMI's Automatic Production Line (APL). As such the AMT-model will run on the CONVEX computer. Furthermore, trajectories will be calculated from wind fields of KNMI's Limited Area Model (LAM).

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Acknowledgements

Appendix I.

Subroutines

Subroutines which use system dependent libraries on the mainframe are not given in capital letters.

General routines

ABORT : stop program
CHNAME : link a filename to a device
QUEST : check if a specified file exists on a device
DAYNR : determines daynumber of a specified date
PAGE : lineprinter skips to the next page after 60 lines
bckupd : backupdate
DISTNC : distance between two points

General physical routines

THETA : normal temperature to potential temperature
TINVRT : potential temperature to normal temperature
SPCHUM : specific humidity from dew point and pressure
ES : saturation watervapour as function of tempera ture
QS : saturation specific humidity as function of pressure and temp.
S : slope of saturation humidity temperature as function of temp.
ZLV : specific latent heat
GAMGS : slope of saturation specific humidity

Sondes

ntempc : name tempcards
stemps : select temps
tempsw : get tempwords
closef : close tempfile
FILLA : reads profile on fixed levels (1000,850,700,500, 400, 300,250)
FILLB : reads profile on characteric points
BEWERK : decoding the PARRAY and filling the PCHAR and PTEMPS array
DECODE : routine which controls the decoding process using library subroutines (GETOBS) and fortran 77 routines
MAXMUM: rank number of a maximum in the array PH is determined
ZINTER : gets the KI-value at the height PSIGMA from observations
CHECK : data of the source-area profiles are checked
MAKDST : distances between starting points of the trajectories and the profiles are determined
PTOSIG : pressures are converted to sigma coordinates
WEGHTS : weight of a temp at height pzpres is calculated
SFCDAT : PSFCDT array is filled with interpolated values for pressure, potential temp. and humidity at ground level
MAKSGP : significant points are created by taking all characteric points
REDUC : significant points are reduced if pressure, pot, temperature differ too little

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TARCHV : begin profile is stored in the file INTEMP&IMT/ ISHIFT
SARCHV : radiosonde profiles are stored in the file SONDE &IMT/ISHIFT
ANALYSE: routine which controls the analysis process

Sea surface temperatures (SST)

getsst   : ALGOL procedure which fills FGRID with sea surface temperatures
GTEMP   : read GRID array from file SEATEMP&IMT/ISHIFT
RTEMP   : convert FGRID array to GRID array
STEMP   : store GRID array to file SEATEMP&IMT/ISHIFT

Trajectories

RTRAJ   : read trajectory data from file BRACKFORETRAJ &IMT/ISHIFT
PROTRA : processing of trajectory data
TRARCHV: relevant trajectory data of 06260 is stored in FORETRAJ&IMT/ISHIFT
GTRAJ   : get trajectorydata from FORETRAJ&IMT/ISHIFT

Interpolation

BLOCK   : help procedure for interpolation
STAP   : position and velocity on significant points are computed
COTRFM : transformation to MBW telescope grid
INTER   : the coordinates and velocities of significant points are obtained by interpolation in time and place
ZLNEAR : linear (inter/extra)-polation function
ST   : direct link between coordinates and MBW grid
TAKE   : check on point on MBW grid

Atmospheric Boundary layer (ABL)

HYDRO   : create height field from a hydrostatic integration assuming linear variation θ
INTER1 : interpolate initial profile to model levels
FORCLD : show forecasted cloud cover and surface temperature (2m)
FLXWAT : determines surfacefluxes above sea
FLXLA   : determines surfacefluxes above land
SVP   : calculates saturation vapor pressure and saturation specific humidity using a polynomial formula (Lowe and Fickes 1974)
LCL   : lifting condensation level and saturation point temperature
TDEW   : calculates dewpoint
SSHEAT : calculates the super saturation adjustment
CHACHA : fits piece wise linear function on one grid to piece wise linear function on another grid by least squares
MLABL   : boundary layer turbulent mixing scheme
FYSDAT : initialize physical constants in COMMON blocks

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INITGR   : preparation of initial profile for converting to model levels
ABMAIN : evolution of the boundary layer along the trajectories
SINUSZ : elevation of the sun
SONET   : calculation of the isotherm net radiation
CDRAG   : calculation of drag coefficients over land
ZOSEA   : calculation of the roughness length above sea
FPSIM   : stability correction of wind profile
FPSIH   : stability correction of temperature profile

Plot routines

MYPARA : help routine
PPLOT   : plot point in the radiosonde grid
NMBR   : plot value in the radiosonde grid
SY   : plot text in the radiosonde grid
PA   : help routine
TEMPFO : draw θ_s-p diagram
PLOTJE : routine which makes the complete plotter output
F   : help routine
G   : help routine
TD   : calculation dew point from specific humidity and temperature
PINTER : interpolate temperature on the plot

Printing routines

OUTPRT : the initial profile is printed
FLXPRT : fluxes,cloud covers during the run are printed
PRWGHT : distances and weights are printed
QUICK   : quick response output in file AMTOUT&IMT/ISHIFT
INPRT   : inputdata of trajectories and radiosounds are printed
PROFIL   : profiles of θ,T ,q and rv are printed
OUT   : data written to plotfile

Appendix II.
Description of variables
Mainprogram and
ABMAIN

Logicals

LOSOND	.TRUE.	use SO file (radiosondes of the source area)
	.FALSE.	use PR file (initial profile)
LODONE	.TRUE.	datafile is read succesfully
	.FALSE.	datafile is not read succesfully
LFOPER	.TRUE.	intermediate results written to AMTPRT.OUT
	.FALSE.	no extra data is stored

Character arrays

CHARACTER*48 LS   (0:80)   string array which contains the accurate land/sea mask

Integer

INRO	maximum number of selected radiosondes source area
ISHIFT	date time group
ISTAT	arrival station (De Bilt,De Kooy,Vlissingen, Eelde, Beek)
ISTART	station where the model runs
IMAX	number of points of the composed begin profile
IMT	timespan 12,24,36
ITEND	forecast period in minutes
IOLSTB	stability parameter 1=unstable 2=stable
IDEV2	unit number logfile AMTLOG.OUT
IDEV4	.. .. AMTPRT.OUT
IDEV6	.. .. screen
IDEV7	.. .. ST file (pc) or SEATEMP file (Unisys)
IDEV8	.. .. SO file (pc) or SONDE file (Unisys)
IDEV9	.. .. PR file (pc) or INTEMP file (Unisys)
IDEV10	.. .. PLOT.OUT
IDEV11	.. .. TR file (pc) or FORETRAJ file (Unisys)
IDEV14	.. .. QUICK.OUT (pc) or QUICK file (Unisys)

IIIIII(1:10)   array with the selected radiosondes source area

real

ZWTIME	time above sea as percentage of total time
ZCLAND	time above land with cloudcover as percentage of total time
ZHGEO	geostrophic wind (wind at first modellayer)
ZPSURF	surface pressure
ZTSURF	temperature at 2m
ZPDB(0:18)	ZPDB(0)=begin pressure
	ZPDB(1)=end pressure trajectories
ZTSFCA(0:18)	2m temperature along the trajectory every 2 hours
ZTLPBL(0:18)	cloud cover boundary layer along trajectory every 2 hours

ZCLOUD(0:18)	cloud cover from TR trajectory file. This array was usedto store the pre-described values of the meteorologists
ZTRLNG(0:18,4)	longitude trajectory at 4 levels
ZTRLAT(0:18,4)	latitude trajectory at 4 levels
ZTRP(0:18,4)	actual pressure trajectory at 4 levels
ZTRVX(0:18,4)	speed x-direction
ZTRVY(0:18,4)	speed y-direction
ZTRVW(0:18,4)	speed z-direction
ZTRAJ(4,0:3)	startpressure, longitude, latitude, end pressure
ZTEMPS(10,3)	stationcode, longitude, latitude
ZTSFCDT(3)	surface pressure,θ and q of the initial profile
ZSGNPT(0:300,3)	initial profile pressure,θ,q without ground level
ZCHAR(10,0:30,3)	all data of radiosondes in one matrix
ZHP(100)	profile of pressure converted to model levels
ZHTETA(100)	profile of pot. temperature converted to model levels
ZHQ(100)	profile of specific humidity converted to model levels
ZHZ(100)	profile of corresponding heights
GRID(0:38,0:32)	matrix which contains the coded seawatertemperatures
FGRID(0:1286)	matrix GRID converted to one array

common blocks

BLOCKN   LS
BLOCKS   GRID

Subroutine ABMAIN

logicals

LOWATR	.TRUE.	Air mass is above water
	.FALSE.	Air mass is above land
LOFRST	.TRUE.	First time through marching scheme
	.FALSE.	Other times
LOSEA	Helpvariable for transitions from land to sea integer	
J	index variable of array	
ITBLOK	counts ZPTRAJ time steps (3 hours ITIME1)	
ITBLOM	counts PCLOUD time steps (2 hours ITIME3)	
IHOUR	current time in elapsed hours (MOD (KSHIFT, 100))	
IMINU	current time in elapsed minutes	
INWSTB	stability parameter	
ILINE	linepointer AMTPRT.OUT	
ILIN	linepointer QUICK.OUT	
IFLAG	helpvariable to make sure soundings stays under 400 mb	
JM	index variable of array	

INDEX   index variable in the arrays PCLPBL and
            PTSFCA
IBKUPD   function which updates the date time group
ITIME1   timestep trajectory model 180 min
ITIME2   timestep boundary layer model 10 min
ITIME3   timestep cloud cover interpolation 120 min

real

ZTIME   counts prognose time
ZTFRAK   counts the fraction of time of the trajectories
ZTFRAM   counts the fraction of time of the cloudvover
ZRDOLD   helpvariable (ZRDOLD=ZNTRAD)
ZSINLD   helpvariable (ZSINLD=ZSINZ)
ZPDB   endpressure trajectories
ZHTABS   absolute temperature first level
ZTETAF   heat flux
ZQFLUX   moisture flux
ZVIRFX   virtual flux
ZUSTAR   friction velocity
ZCL   maximum of pre-described ZCLT and forcasted
            ZCC by MLABL
ZCLT   pre-described cloud cover
ZWATER   sea surface temperature
ZSINZ   sine of sun's height
ZNRDAY   day number
ZNTRAD   isotherm net radiation
ZHABL   boundary layer height
ZWAT0   helpvariable sea surface temperature
ZHF   Coriolis parameter
ZT1   helpvariable surface temperature (PTSURF)
ZCDRAG   dragcoefficient
ZOBKHW   Obukhov length
ZPTRAJ   start pressure (PPSURF)
ZPSOLD   helpvariable surface pressure
ZPINIT   start pressure (PPSURF)
ZZOS   surface roughness
ZTFOUT   helpvariable heat flux
ZQFOUT   helpvariable moisture flux
ZVFOUT   helpvariable virtual flux
ZCCOLD   helpvariable cloud cover boundary layer
ZCCNEW   helpvariable cloud cover boundary layer
ZCC   cloud cover boundary layer
ZOSEA   function
ZLNEAR   function
ZPFACT   (PHP/100.)**RCP
ZTN
ZQSN   helpvariables prevention occurence super-
            saturation
ZESN
ZBETA   coefficient for fluxes at nighttime
ZALFA   coefficient for evaporation
ZDENS   see ZTFOUT calculation kinematic units to ener-
            gy units

real arrays

ZHLAT(1:100)	interpolated values latitude
ZHLNG(1:100)	interpolated values longitude
ZHVX(1:100)	interpolated values velocity x
ZHVY(1:100)	interpolated values velocity y
ZHP2P(1:100)	
ZH2TTA(1:100)	helpvariables calculation update pressure field
ZH2Q(1:100)	

Description of variables common blocks filled by FYSDAT

Block 1

AC1L,AC1W	constants for calculation of the net radiation
AC2L	constant fluxes over land
AC2W	constant fluxes over water
ACC1,ACC2,	
ACC3	correction terms
ACC4	cloud dependance net radiation
ASWINB	Swinbank constant
APLTRG	Paltridge constant
ASTEFA	Stefan Boltzmann
ASOLAR	Solar constant
AALBDO	albedo

Block 4

AKARM	Von Karmanconstant

Block 5

ACONST	temperature vapour pressure

Block 6

ACELS	absolute zero point

Block 7

API	pi
RGASS	gass constant dry air
CP	specific heat at constant pressure
G	gravity constant
ALLATH	latent heat

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Appendix III.
Instructions Unisys mainframe (non operational mode)

Prior to actually running the model the user must set up a control file.On the development computer a control file AMT/DATA can be changed. The contents of AMT/DATA is as follows:

1st record   ISHIFT,IMT,ZPDB,KSTAT,KSTART,PCLOUD
2nd record   KIIIII
3rd record   LODEC,LOSOND,LOPLOT,LFOPER

Originally the structure was designed to run the model interactively. For automatic running most of variables are initialized on dummy values.

ISHIFT	=	date time group
IMT	=	time span
ZPDB	=	expected end pressure arrival station
ISTAT	=	arrival station
ISTART	=	station where the model runs
ZCLOUD	=	cloud cover along trajectories
IIIIII	=	radiosondes source area
LODEC	= .TRUE.	decoding from DCMECOTEMP00 is done
	.FALSE.	data from SONDE&IMT/ISHIFT is used
LOSOND	= .TRUE.	initial profile is composed, ANALYSE is carried out
	.FALSE.	data from INTEMP&IMT/ISHIFT is used
LOPLOT	= .TRUE.	printer and plotter output is generated
	.FALSE.	printer and plotter output is suppressed
LFOPER	= .TRUE.	operational mode
	.FALSE.	the result of decoding is written to files (FORETRAJ, SONDE, SEATEMP and INTEMP)

The control file AMT/DATA can be edited under CANDE on the Unisys computer. When the file is saved with the correct data the job AMTML can be started.Before running, it is recommended to check if the operational files are available

OPER)ARCHIEFDL01/JJMM ON TEMP(PACK)
(OPER)BRACKFORETRAJ&IMT/ISHIFT ON TEMP(PACK)
(OPER)DCM/DECOTEMPHH/ISHIFT ON TEMP(PACK)

JJ	=	year (0-99)
MM	=	month(1-12)
IMT	=	timespan (12,24,36)
ISHIFT	=	date time group yymmddhh

For each day these files are available on TEMP(PACK). After three days the file are copied to tape. The operational data remains about three days available on TEMP(PACK).

IV. Instructions MS-DOS computer

Running the model

Type START to run the help program which fills the control file INDAT.DAT. The program asks for the date time group (yymmddhh), timespan (12,24,36), and the arrival station (6260,53772). Subsequently the user has to choose if the initial profile (TRUE) or the radiosondes (FALSE) are used. Then the program asked if AMTPRT.OUT (FALSE) or QUICK.OUT (TRUE) are filled.

The usage of the different radiosondes or the initial profile should give the same output. The initial profile is a result of the analysis part of the AMT-model. Using the initial profile costs less processor time. For research purposes it is recommended to create the file AMTPRT.OUT because all intermediate results are available. On the contrary the file QUICK.OUT contains less details but requires also less computing time and disk space. This option is ideal to see quickly what the model does.

To start the AMT-model type AMT. During the model run the time (hours and minutes from the beginning), temperature and dewpoint temperature are displayed.

Description of the input- and output files

The following input files are required:

TR&MONTH&DATE&HOUR.D&IMT = This file contains the velocities, positions, pressures and vertical movements for the trajectory arriving at the receptor point

SO&MONTH&DATE&HOUR.D&IMT = This file contains the radiosondes of the source area.

PR&MONTH&DATE&HOUR.D&IMT = This file contains the initial profile composed from the different radiosondes

ST&MONTH&DATE&HOUR.D&IMT = This file contains the sea surface temperatures for Western Europe

ISHIFT	= date time group yymmddhh
MONTH	= month of the year (1-12)
IMT	= timespan (12,24,36)
DATE	= day (0-31) of the month
HOUR	= hour (00 or 12)

Every model run generates the following output files:

AMTLOG.OUT = Data about the program flow and error messages are logged

PLOT.OUT = Profile of T and T_d as a function of pressure

Depending on the choice on the question in the program START the following files are created:

AMTPRT.OUT = Time series of the air mass are stored

QUICK.OUT = Most important parameters during the run are written to this file