REanalysis of the TROpospheric chemical composition over the past 40 years
A long-term modelling study of tropospheric chemistry

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Work Package 4

RETRO planning document

Long-term simulations of atmospheric composition

Deliverable D4.1

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1. Introduction

In RETRO we will exploit and synthesize a wide range of available, but under-utilised, measurements of tropospheric composition using state-of-the-art modelling tools that are becoming available within Europe. In this project, we will perform the first comprehensive global long-term tropospheric chemistry integrations covering a time period of 4 decades in order to both reproduce and understand the trends and variability of the tropospheric chemical composition. These simulations are made possible by the availability of the consistent meteorological reanalysis dataset, covering the last 40 years, currently being produced at the European Centre for Medium Range Weather Forecast (ERA-40, ECMWF). Our use of the ERA-40 will be the first major exploitation of that data set for atmospheric composition studies and will make a significant European contribution to investigations of global change.

Work package 4, lead by LSCE, covers the actual reanalysis of the tropospheric chemical composition over the last 40 years. This study will require substantial efforts to prepare the necessary data sets and to run the models for such a long period. The results will be evaluated while they are being produced, they will be interpreted in light of the observational data collected in WP2 and in terms of emission trends derived in WP1, and they will be processed for public dissemination and use in the assessment part of the project (WP5).

In this planning document, we provide a description of the simulations to be performed, the participating models and model configuration, the role of each WP partner, and the list of input data needed to run the models. The long-term chemical reanalysis is a complex task which requires active communication between the individual work packages. Therefore this document extends beyond WP4 and also provides an overview of the model simulations to be perfomed within other RETRO Work Packages closely connected to WP4. In particular, Work Package 3, lead by UCamb, aims at characterising the performance of all models participating in this study and at investigating the sensitivity of the models in response to individual factors contributing to the changes in pollutant and greenhouse gas concentrations. Work Package 5, lead by UiO, consists of three major parts: radiative forcing calculations and analysis, scenario calculations to assess potential changes of tropospheric chemical composition and radiative forcing in the future, and evaluation of past and future control measures.

2. Participating models

Five state-of-the-art global models will be used in the framework of RETRO. Three of these models are off-line Chemistry-Transport-Models (CTMs) and read the needed meteorological fields directly from input files. These models are **CTM2** from UiO, **TM3(5)** from KNMI and **pTOMCAT** from UCamb. The two other models are General Circulation Models (GCMs) coupled on-line to chemistry and aerosol models. **MOZECH** from MPG-IMET and **LMDz-INCA** from LSCE. In Annex 1, we provide a description of most model features including the format of input and output files as submitted by the various groups. Table 1 summarizes the general features of this survey conducted during the first 5 months of the RETRO project. All the models will be used for a full or subset simulation of the ERA40 period (section 5). In addition to that, they will also be used for benchmark and sensitivity simulations within WP3 or for impact studies within WP5 (section 3).

These global models have horizontal resolutions of 1.8°-3.75° in longitude and 1.8°-2.8° in latitude. They include 19-60 vertical levels. The chemical schemes range from simple methane oxidation schemes to full NMHC chemistry. Two of the models also include a full suite of aerosols. The total number of tracers range from 27 up to 86. Most of these models have already participated to model inter-comparison exercises and evaluation against measurements in the framework of the POET and TRADE-OFF European projects. It should be kept in mind that based on the current model simulations we anticipate that a full ERA40 simulation will require per model a total of **120-480 days CPU** on local workstations for the CTMs or **80-500 days CPU** for the participating GCMs on supercomputers. In addition to that a 40 year simulation generates **1680-3160 GB** of data for each model.

Table 1. Participating models general features.

	MOZECH	LMDz-INCA	TM3/5	pTOMCAT	CTM2
Participants	MPG-IMET S. Rast M. Schulz T. Diehl	LSCE D. Hauglustaine Y. Balkanski M. Schulz	KNMI T. van Noije P. van Velthoven	UCamb N. Savage J. Pyle	UiO J. Sundet M. Gauss A. Grini
Resolution (Min, Max)	2.8x2.8 L19 1.8x1.8 L31	3.75x2.5 L19 2.25x1.8 L50	2.5x2.5 L31 3.0x2.0 L60	2.8x2.8 L31	2.8x2.8 L60
Total nb species (tracers)	65 (63) or 93 (91)	75 (73) or 89 (87)	37 (22)	43 (27)	61 (51)4
Chem. scheme (reactions)	NMHC (135) Aerosols	NMHC (332) Aerosols	NMHC (95) Sulphur aerosols	NMHC (131)	NMHC (140) Aerosols
Advection **Convection** **Boundary Layer** **CPU (Wallclock) 1year**	Lin+Rood (or SL) Tiedtke ECHAM (300 h)	Van-Leer Tiedtke LMDz 35-48h	Slopes (Prather) Tiedtke Holtslag+Boville 288h	Ptrather Tiedtke Holtslag+Boville 72h	Prather CTM2 Holtslag 200 h
Output files (size) 1 year	NetCDF (63 GB)	NetCDF (42 GB)	HDF	NetCDF (79 GB)	NetCDF (50GB)
Biogenic emissions	--	Guenther et al. [1995] or biosphere model	--	None	--
Lightning emissions	Interactive	Interactive	Interactive	Interactive	Interactive
2 key references	--	*Hauglustaine et al.* [2003] *Brunner et al.* [2003]	--	*Law et al.* [1998] *Stockwell et al.* [1999]	--

3. Input data sets

3.1 Emissions

Emissions of ozone precursors gases (fossil fuel and industry, biogenic, biomass burning) and of aerosols for the simulated 40-year period will be provided directly from workpackage 1 to the participating models. Existing reconstructions (e.g. based on IPCC TAR) of longer-lived greenhouse gases (CO_2, CH_4, N_2O, and CFCs) concentrations over the considered period will also be used to constrain the surface concentration of these gases in the GCMs/CTMs and for the radiative forcing calculations. These emissions and how they will be prepared are described in detail in the RETRO internal report on emissions D1-1 and only a brief summary will be provided here.

3.1.1 Natural emissions

a. Oceanic emissions

While oceanic emissions are generally small compared to present-day terrestrial sources, they may have a sizeable impact on the global budgets of a number of ozone and aerosol precursors, such as DMS, C_2H_4, C_3H_6, acetone, halogens, and possibly CO and H_2. Given the scarcity of new data sets available to improve the knowledge about these processes, the efforts within RETRO will focus on the comparison of existing inventories. A common standard for the long-term simulations will be used. Responsibility: MPI-BGC and LSCE (WP1).

b. Volcanic emissions

Volcanic emissions are of importance predominantly for the global sulphur cycle. These emissions will be prepared based on a climatological data set of volcanic sulphur emissions available at MPG-IMET and augmented by literature information on major volcanic eruptions. Responsibility: MPG-IMET (WP1).

c. Biogenic emissions

The current state-of-the-art for modelling emissions of isoprene, terpenes, and other volatile organic compounds (VOCs) from terrestrial vegetation is *Guenther et al.* [1995]. The release of these compounds is very much species dependent and mainly controlled by the living biomass density, the leaf temperature, and the photosynthetically active radiation (PAR). An interactive emission algorithm has been developed and implemented in several chemistry transport models participating to RETRO (see Table 1). These emissions will be compared with the inventory prepared by *Guenther et al.* [1995] and its latest updates [*Guenther*, personal communication]. Based on these various models, a monthly mean inventory will be prepared. This work will be extended to the NO soil emissions following a similar approach and the previous work by *Yienger and Levy* [1995]. Responsibility: MPI-BGC, MPG-IMET, LSCE (WP1).

d. Dust and sea-salt emissions

A major part of the interannual variability of the source of sea-salt and dust comes from changing wind fields driven by the evolution of climate, as illustrated by Figure 1 which shows the simulated evolution of dust aerosol optical depth over a 10 year period. The dust and sea-salt aerosols source described respectively by *Balkanski et al.* [2003] and *Schulz et al.* [2003] have been implemented in the LMDz-INCA and MOZECH general circulation models. These sources will be used for a reference simulation of the ERA40 period. Responsibility: LSCE (WP1).

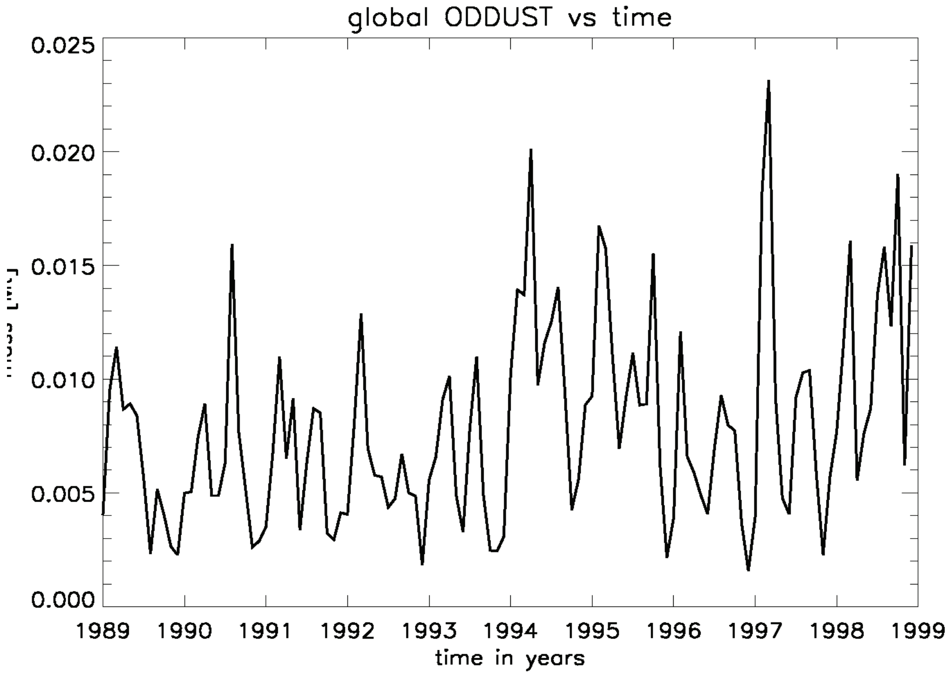


Figure 1: Time serie of global dust aerosol optical depth simulated with the LMDz-INCA model. This figure illustrates the impact of meteorological fields variability (10m wind speed for soil mobilization as well as precipitation for scavenging efficiency) on the global dust load in the atmosphere over a 10 year simulation using ERA15 and OD meteorological data.

e. Lightning emissions

The production of NO from lightning flashes is still a major uncertainty in the global budget of nitrogen oxides in the atmosphere. The models participating to RETRO use the parameterization proposed by *Price and Rind* [1992] to estimate the lightning flashes based on the occurrence of convection in the model and the cloud top height. For the purposes of the RETRO project, we have adopted a target value of 5 TgN/yr emitted on a global and annual mean basis for the year of 1997. The models will constrain their parameterization to provide the reference emission for the benchmark simulation 1997 and held the parameters constant for the long-term simulations in order to account for the inter-annual variability. The lightning flashes simulated by the models will be evaluated for the reference year against satellite measurements of lightning flashes occurrence by the LIS and OTD instruments. Responsibility: All participants.

f. natural methane emissions

Within RETRO we will not attempt to improve current estimates of natural wetlands methane emissions. Instead interpolated measurements of near-surface concentrations will be used in the models as boundary conditions. For the 1990's, such a data set has been already compiled during the course of the POET project. This data set will be adopted and extended to earlier years. Responsibility: All participants.

3.1.2 Biomass burning emissions

Emission sources from biomass burning may be organized into in-situ burning of vegetation and combustion of waste biomass and fuel wood. The fire behaviour is dependent on the ecosystem and on the prevailing meteorological conditions. For the purpose of the RETRO project, the biomass burning emissions will be determined using nine ecosystem classes. Emissions from combustion of waste wood and fuel wood will be investigated using an inventory-based approach using available data. Emission trends of agricultural waste burning will be assessed using the EDGAR methodology and attempt to correlate satellite data and burnt areas, crops statistics and a relationship between crop yields and burnt material. A considerable research effort will be devoted to the estimate of vegetation-related fire emissions and their inter-annual variability and long-term trends. This work will be based on historical and satellite based data sets to estimate burnt areas, and on the regional fire model (reg-FIRM) coupled the dynamical vegetation model LPG. The inventory-type emissions from vegetation fires will then be calculated using the Global Wildfire Emission Model (GWEM). Responsibility: MPG-IMET, MPI-BGC, IICT (WP1).

3.1.3 Anthropogenic emissions

The RETRO activities with respect to fossil fuel emissions will be based on the available data sets from EDGAR 3.2 with the extensions to cover the 1990-2000 period prepared in the framework of the POET project. The historical emission data set will be based on EDGAR-HYDE [*van Aardenne et al*., 2001] and the TROTREP project. A particular attention will be devoted to the speciation of VOCs and on the seasonal and diurnal variations of the emissions. RETRO will concentrate on the following gaseous species: CO, NO_x, VOCs, and SO_2. Carbonaceous particles emissions will be derived from the CEPMEIP project. Aircraft emissions will be based on the datasets prepared within the TRADE-OFF project for present day emissions and modified using a simple scaling approach. Responsibility: TNO, MPG-IMET (WP1).

3.1.4 Emission file format and resolutions

Emission input files are prepared by each model based on various inventories (EDGAR, GEIA). These emissions are then combined and interpolated on the model grid. The participating models require NetCDF, HDF or ASCII input files. Within RETRO, in order to facilitate the exchange of data sets, the project has adopted a common data format. All emission data sets will be produced based on the NetCDF format with standard naming conventions and attributes based on the PRISM and ASSET projects as described in Appendix 1 of the RETRO internal report on emissions data sets.

A common categorization scheme will be used for each emission source and species. This categorization is largely based on the existing EDGAR scheme already used by the models. Emission data will be stored in separate files per species containing the different individual sources per sector or fuel type. The VOC speciation will be: C_2H_6, C_2H_4, C_3H_8, C_3H_6, acetone, formaldehyde, benzene, and 4 generic species *alkanes, alkenes, aromatics*, and *oxygenated* *compounds*. Biogenic emissions will be further reported for isoprene, α-pinene (for terpenes) and methanol. All emissions will have a common horizontal grid of 0.5°x0.5°. For aircraft emissions, the vertical interval chosen is 2,000 feet (610 m), as already adopted within the TRADE-OFF project. The temporal resolution will be monthly with diurnal and weekly patterns provided separately.

3.2 Meteorological data

The forty years of gridded meteorological data with 6-hour time resolution needed to perform the comprehensive atmospheric GCM/CTM simulations of this project constitute a huge amount of data. These data must be retrieved from the archive of the *European Centre for Medium Range Weather Forecast* (ECMWF), be processed or reformatted in order to be used as inputs to the various models. Furthermore, these data must be either stored on mirror sites at the partner institutions computing facilities or accessed through a DODS (Distributed Oceanic Dataset System) server which allow an efficient internet access to the whole data base or to a subset.

Some issues related to the use of stratospheric boundary conditions in tropospheric chemistry models based on ERA-40 will be addressed during the first phase of the project for the benchmark and sensitivity simulations (section 4). Preliminary results obtained by KNMI using the CTM TM3 are presented below. Although the robustness and generality of these results need further investigation, the conclusions drawn may be relevant to the other CTMs used in the RETRO project as well. In TM3 the stratospheric boundary condition for ozone is applied by imposing a zonal mean climatology (TOMS) through relaxation ('nudging') in the upper stratospheric layers. In the standard implementation this relaxation is restricted to levels above 50 hPa. The resulting Stratosphere-Troposphere Exchange (STE) flux values for ERA-15 meteorology as well as for operational data (OD) for various years are within (or very close to) the range of observational estimates (450-590 Tg/yr according to *Gettelman et al.* [1997]). For ERA-40, however, the corresponding STE fluxes for all years considered (including various years in the 1990s as well as the year 1974) are well above 1000 Tg/yr. We conjecture that this overestimation of the STE fluxes is due to the problem that the stratospheric winds in ERA-40 exhibit a much too strong residual (Brewer-Dobson) circulation. Further evidence for this is provided by the age of air simulations performed at the KNMI and illustrated in Figures 2 and 3.

In order to reduce as much as possible the impact of unrealistic stratospheric transport in ERA-40 on tropospheric chemistry simulation, it is necessary to reconsider the boundary conditions applied at the stratospheric side of the models. Below we propose a way to modify the ozone boundary condition in TM3; the other stratospheric boundary conditions may be reconsidered in a similar way. In a first attempt to improve the influx from the stratosphere, nudging of ozone concentrations was extended globally to levels above 100 hPa. The result is a significant reduction of the ozone flux from the stratosphere to the troposphere: for the year 1997 (ERA-40) the STE flux drops from 1040 Tg/yr to 690 Tg/yr. However, an unrealistic increase in ozone concentrations is still observed in the Upper Troposphere/Lower Stratosphere (UT/LS) over tropical Africa. The representation of STE is further improved if nudging is extended to lower levels (from 50 hPa to 100 hPa) only outside of the tropics. In that case the spurious effects over tropical Africa disappear and the STE ozone flux drops further to 610 Tg/yr. Although this value is still slightly above the range of observation estimates given above, it is sufficiently realistic for accurate and reliable simulations of tropospheric composition changes. We therefore conclude that, after careful reformulation of stratospheric boundary conditions, ERA-40 transport at about 100 hPa seems sufficiently accurate for tropospheric chemistry modelling.

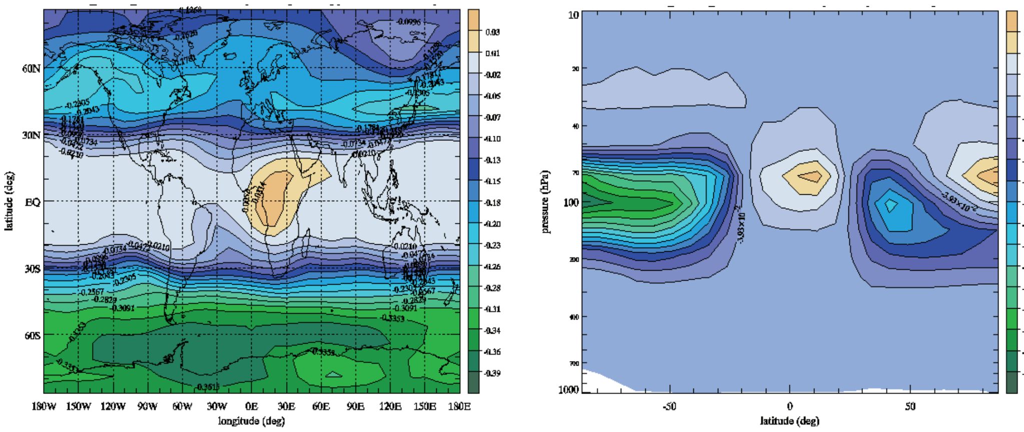


Figure 2: Simulation with the TM3 model of the impact of extending nudging globally to levels above 100 hPa on O3S (ozone from the stratosphere, ppmv) at 140 hPa (left) and on its zonal mean (right). Shown are the monthly mean values for Dec. 1997.

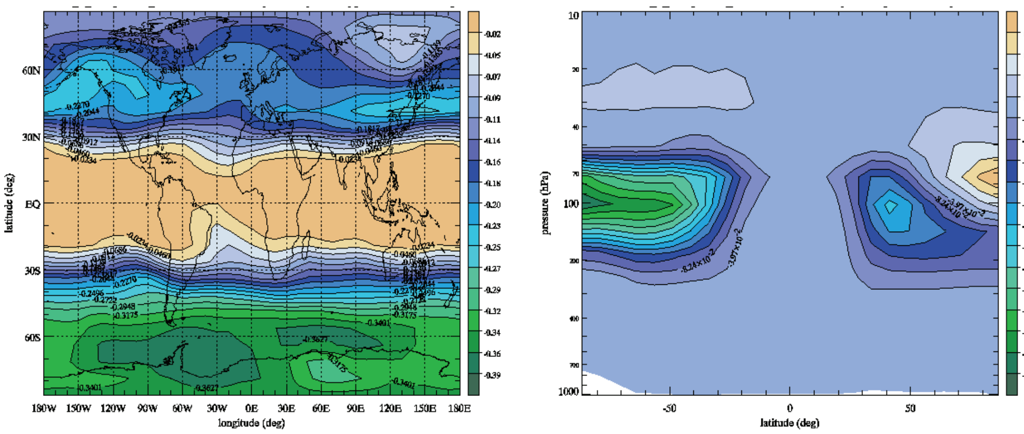
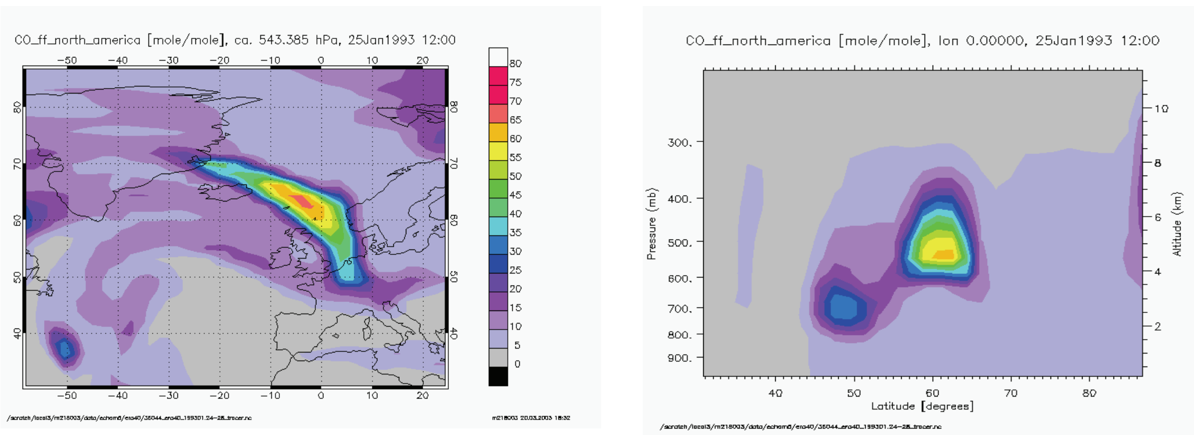


Figure 3: Simulation with the TM3 model of the impact of extending nudging to levels above 100 hPa except in the tropics (where nudging remains limited to levels above 50 hPa) on O3S (ppmv) at 140 hPa (left) and on its zonal mean (right). Shown are the monthly mean values for Dec. 1997.

Similar sensitivity tests have also been started at MPG-IMET in the case of carbon monoxide (CO) export from source regions (Fig. 4). These tests will be further analyzed during the first period of the project and performed with other participating models (section 4).



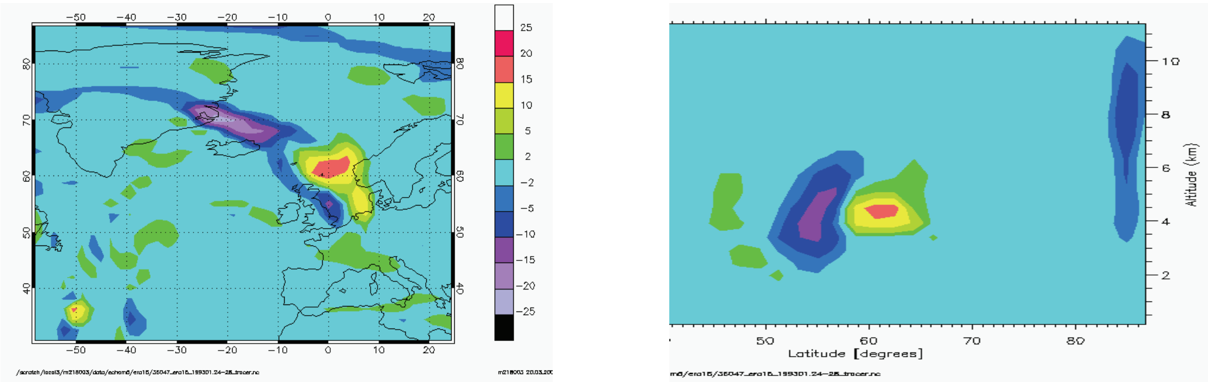


Figure 4: Long-range transport of Northern America fossil fuel CO by the MOZECH model for an episode in January 1993. Upper plots show the 500 hPa distribution of CO mixing ratio and cross section at 0W calculated based on the ERA40 meteorological fields. Bottom panels show the difference obtained when ERA15 meteorological input data are used.

As described in Appendix 1, all participating models will have their own access to ERA-40 data. The necessary meteorological data are prepared by each group in the model specific formats. Some of the groups have already prepared the needed meteorological input based on the first set of ERA-40 data already available. Table 2 provides a list of meteorological data needed to run the models for the RETRO simulations. Responsibility: all modeling groups.

Table 2. Meteorological fields needed to run RETRO GCMs and CTMs.

	MOZECH	LMDz-INCA	TM3	CTM2	TOMCAT
Temperature	X		X	X	X
Specific humidity			X	X	X
Geopotential height			X		
Wind vector (u, v)		X			
Wind divergence	X			X	X
Potential vorticity	X				X
Horizontal mass flux			X		
Convective mass flux			X	X	
Vertical diffusion			X		
LWC			X	X	
IWC			X	X	
Cloud fraction			X	X	
Cloud levels			X	X	
Large-scale precipitation			X	X	
Convective precipitation			X	X	
Aerodynamical resistance			X		
Friction velocity			X		
Temperature 2m			X		
Wind speed 10m		X			
Surface roughness			X		
Surface pressure	X	X	X		X

3.3 Stratospheric boundary conditions

There is presently no model available that is able to satisfactorily simulate chemistry and transport in both the troposphere and the stratosphere within one consistent framework and for the long term integrations envisaged within RETRO. Therefore, the tropospheric GCMs/CTMs employed in this project need to be supplied with stratospheric ozone column data and lower stratospheric ozone and nitrogen oxide (NO_y) concentrations in order to reproduce changes in the penetration of UV radiation into the troposphere and in the stratosphere-troposphere exchange of ozone and NO_y. In order to define the stratospheric boundary conditions for the tropospheric GCMs/CTMs, a data set of stratospheric column ozone and lower stratospheric ozone concentrations based on available satellite observations, inter- and extrapolated in order to yield a coarse resolution time series over the last four decades will be prepared.

The participating model have a top boundary in the pressure range 0.1-10 hPa. At the upper levels the participating models will need the following climatologies in order to fix or relax their concentrations in the stratosphere. The requested species are: **O_3, NO_x (=NO+NO_2), HNO_3, N_2O, N_2O_5, CH_4 and CO.** The fields should preferably be monthly extending from the tropopause level up to 0.1 hPa. Most of the models use 2D (latitude-altitude) fields. However, 3D fields would be preferable for major species as ozone or NO_x and HNO_3. The monthly climatologies will be interpolated linearly in time in each model to provide the fields at each time step. The format of the climatologies will be NetCDF. Responsibility: FMI..

4. Benchmarking and sensitivity studies

4.1 Benchmark simulations: 1997 and 2000

The simulation of year 1997 and 2000 will be performed as benchmark simulations. For these simulations, the surface emissions prepared in the POET project will be used in all participating models. The output fields from these test runs will be prepared according to the protocol set up for the long-term simulations (section 5). These simulations will serve as a consistency check of the model setup and output preparation and as a reference for model performance. The results of the 1997 simulations will be prepared before the RETRO second annual meeting (November 2003) and analyzed during the meeting. During the period November 2003-June 2004, these results will be summarized, rerun if necessary by some of the participants and extended to the year 2000. These runs will not only be used as benchmark to evaluate the model performances but also to evaluate ERA40 versus operational data and to analyze the impact of the El Nino and Northern Atlantic oscillations on chemical species. Responsibility: UCamb (WP3).

4. 2 Sensitivity simulations

In order to assess the relative importance of emissions and meteorology on the interannual variability of species, the models will perform several simulations of the 1990's period. In particular, this period will be run with (a) fixed emissions and varying meteorology, (b) fixed meteorology and varying emissions, and (c) fixed meteorology and emissions and varying stratospheric ozone. The results of these runs will also be compared to the full long-term simulations with changing emissions, meteorology and stratospheric ozone. Other model simulations will also be performed varying the model resolutions, chemical mechanisms or selected parameterizations (e.g., convection, washout). This work will be performed under Work Package 3. The definitive list of these runs will be defined at the RETRO second meeting in November 2003. Responsibility: UCamb (WP3).

Other simulations have also been suggested focusing on "policy relevant" issues. These simulations will be performed under Work Package 5. These runs will involve a look at future scenarios and possible alternative options which could have emerged in the past. Responsibility: UiO (WP5).

4.3 Tagged tracer simulations

In addition to the full simulations performed by the chemistry models, MPG-IMET will use the same meteorological data and the same emission data together with concentration fields of the OH radical from the comprehensive chemistry calculations to repeat the 40-year calculations with a tagged CO tracer model. The tagging technique allows for the distinction of the impact of various emission sources by type (fossil fuel combustion, biomass burning, or natural) and by region. The regions will be defined in communication with UiO and NILU in order to maximize the usefulness of these simulations for the evaluation of emission control strategies and cross boundary pollution transport within Workpackage 5. Responsibility: MPG-IMET.

Section 5 : Definition of model output
Version4, prepared on Jun., 2005
with additional stations (WDCGHG and CASTNET) and output (O3S, PV)
and revised section 5.1.3. (plotting)

This document reflects the results from the discussions among all RETRO modelling groups which took place during the ACCENT-IA3/IPCC meeting in Oslo on Jan. 18, 2005. The more detailed specifications contained here supersede all previous definitions.

5. Long-term simulations (ERA-40)

In this work package, 3 state-of-the-art chemistry transport models and 2 general circulation models coupled to a chemistry scheme (described in section 2) will perform comprehensive simulations of the troposphere over the last four decades (ERA-40 reanalysis period: 1957-present). All models will use the same emissions of precursors (section 3.1), meteorological input from ERA-40 data (section 3.2) and stratospheric boundary conditions (section 3.3). An important objective of this Work Package is to establish a best estimate of the tropospheric chemical composition trends and variability by combining the results from the individual models. At least one model will include speciation and processing of aerosol compounds over the full period, and all models will run with comprehensive tropospheric chemistry schemes which will be updated according to the latest available kinetic recommendations.

The long-term model runs will be performed chronologically in order to ensure consistency of the results. After completion of the 40-year runs, the model results will be processed and archived at a central location, and they will be combined to provide a best estimate of the tropospheric chemical composition and of aerosol loads over the last four decades. Analysis in terms of concentration trends and inter-annual variability of key constituents will be performed and evaluated through comparison with data collected under Work Package 2.

The following sub sections describe the output files that should be generated by all models participating in the RETRO project. At a minimum, all data files marked as “MANDATORY” must be delivered to the central archiving location (probably the Oslo ACCENT data server). Additional output (such as 3-hourly or 6-hourly concentration values, or 1-hourly surface ozone data) are desirable and should be stored at the individual participants’ archive for potential future analysis.

5.1.1 Gridded output

Output files are to be NetCDF (including time axis, description of grid by latitude, longitude, altitude, unit of parameter, and corresponding descriptor text (see also tables below). Please name the output files and parameters as given below. This is very important, so that we can identify the content of your files and do not need to adapt postprocessing tools to each individual model. The size of each file should be limited to 2GB. “Modelname” should contain a short acronym (no longer than 6 letters) to identify your model and indicate the experiment number or experiment ID. Use exactly one underscores “_” to separate the model acronym and the experiment number. Valid examples for the RETRO models would be:

- INCA_RETRO1

- MOZECH_36090
- TM4_V1
- UiO_V2
- PTOMCAT_V3

The results should be submitted on the model's native horizontal and vertical grid. The time dimension should always be marked as "unlimited" or "record" dimension in order to allow NCO operations to work swiftly.

Note: in contrast to the ACCENT-IA3/IPCC tables, the dimensions column includes the time dimension. Thus a spatial 3D field is marked as 4D, and a 2D surface field is marked as 3D.

FILE 1: Model horizontal grid definition (longitude, latitude, size of gridbox [m2]). For documentation purposes, please also include the native vertical grid definition from your model (hybrid level coefficients) and the formula used to calculate pressure.

Filename: modelname_griddef.nc, only one file needed

MANDATORY

What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Time	time	days since YYYY-01-01 HH:00:00	1D	only required if ps is given as monthly means = 12 values. Else optional containing 1 arbitrary value.
Gridbox area	gridbox_area	m^2	2D	
Hybrid level midlevel coefficients	hyam, hybm	none or Pa	1D	include formula, e.g. p=p0*hyam+ps*hybm
Hybrid level interface coefficients	hyai, hybi	none or Pa	1D	include formula, e.g. pi=p0*hyai+ps*hybi
reference pressure value	p0	Pa	0D	constant reference pressure value. Typically either 100000 Pa or 1 (if hyam and hyai are given in Pa)
surface pressure	ps	Pa	2D or 3D	include an annual average or climatological monthly mean surface pressure field in your model's resolution
(optional)	*geo_height*	*m*	*3D or 4D*	*same time resolution as surface*

geopotential height				*pressure (i.e. either annual average or monthly mean)*
(optional) potential vorticity	*pv*	*PVU*	*4D*	*monthly mean*

FILE2: 3D field of monthly Model pressure [Pa] and temperature [K].

Filename: modelname_TP_YEAR.nc , required for all years

MANDATORY for GCMs

○ What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01 HH:00:00	1D	12 values
Surface pressure	ps	Pa	3D	
Surface temperature	surface_temp	K	3D	
Temperature	temp	K	4D	
(optional) Pressure	*pressure*	*Pa*	*4D*	

FILE 3: 3D monthly mean fields for O_3, CO, CH_4, NO, NO_2, OH, H_2O, HNO3, PAN, CH_2O, Isoprene, and radon volume mixing ratios.

Filename: modelname_vmr_YEAR.nc required for all years.

MANDATORY

What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	

Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01 HH:00:00	1D	12 values
O_3	O3	vmr or mole/mole	4D	
CO	CO	ditto.	4D	
CH_4	CH4	ditto.	4D	
NO	NO	ditto.	4D	
NO_2	NO2	ditto.	4D	
OH	OH	ditto.	4D	
H_2O	H2O	ditto.	4D	
HNO_3	HNO3	ditto.	4D	
PAN	PAN	ditto.	4D	
CH_2O	CH2O	ditto.	4D	
Radon	Radon	ditto.	4D	

FILE 4: Daily 10:30 Local Time tropospheric columns

Filename: modelname_GOME_2D_YEAR.nc

MANDATORY beginning in 1995

Note: the troposphere diagnostics should be done as in ACCENT-IA3/IPCC using an ozone threshold of 150 ppb.

What	Name of Parameter	Unit	Dimension of field	Remark
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Time	time	days since YYYY-01-01 HH:00:00	1D	one time value per day (leap years 366 records, else 365 records)
Tropospheric column NO_2	NO2_col	molec/cm2	3D	
Tropospheric column Formaldehyde	CH2O _col	molec/cm2	3D	
Tropospheric column O_3	O3_col	molec/cm2	3D	
Tropospheric column CO	CO_col	molec/cm2	3D	for model comparison and potential use with MOPITT data

				only for 2000 onwards
(optional) Tropospheric column NO	*NO_col*	*molec/cm2*	*3D*	
(optional) Tropospheric column SO_2	*SO2_col*	*molec/cm2*	*3D*	

FILE 5: Daily 10:30 Local Time 3D fields

Filename: modelname_GOME_3D_YEAR.nc

RECOMMENDED from start for ozone, beginning in 1995 for NO2, formaldehyde, and CO (allows application of averaging kernels and ozone columns for UV calculations)

What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01 HH:00:00	1D	one time value per day (leap years 366 records, else 365 records)
NO_2	NO2_col	molec/cm2	4D	
CH_2O	CH2O _col	molec/cm2	4D	
O_3	O3_col	molec/cm2	4D	
CO	CO_col	molec/cm2	4D	for use with MOPITT data **only for 2000 onwards**

FILE 6: 2D monthly dry and wet deposition fields.

Separated for wet and dry deposition
Filename: modelname_depositions_YEAR.nc , required for all .

MANDATORY

What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Time	time	days since YYYY-01-01 HH:00:00	1D	12 values

O3 dry deposition	O3_ddep	gO3/m2/month	3D	
HNO3 dry deposition	HNO3_ddep	gN/m^2/month	3D	
HNO3 wet deposition	HNO3_wdep	gN/m^2/month	3D	
NO_y dry deposition	NOY_ddep	gN/m^2/month	3D	All oxidized N components (including NO_2,PAN,organic nitrates)
NO_y wet deposition	NOY_wdep	gN/m^2/month	3D	
(optional) NO2 dry deposition	*NO2_ddep*	*gN/m2/month*	*3D*	
(optional) H2O2 dry deposition	*H2O2_ddep*	*gH2O2/m2/month*	*3D*	
(optional) CH3OOH dry deposition	*CH3OOH_ddep*	*gCH3OOH/m2/month*	*3D*	
(optional) CH2O dry deposition	*CH2O_ddep*	*gCH2O/m2/month*	*3D*	
(optional) PAN dry deposition	*PAN_ddep*	*gN/m2/month*	*3D*	
(optional) CO dry deposition	*CO_ddep*	*gCO/m2/month*	*3D*	
(optional) NH_3 dry deposition	*NH3_ddep*	*g (N/m^2)/month*	*3D*	
(optional) NH_3 wet deposition	*NH3_wdep*	*g (N/m^2)/month*	*3D*	
(optional) NH_4 dry deposition	*NH4_ddep*	*g (N/m^2)/month*	*3D*	
(optional) NH_4 wet deposition	*NH4_wdep*	*g (N/m^2)/month*	*3D*	
(optional) SO_2 dry	*SO2_ddep*	*g (S/m^2)/month*	*3D*	

deposition				
(optional) SO_2 wet deposition	*SO2_wdep*	*g (S/m^2)/month*	*3D*	
(optional) SO_4 dry deposition	*SO4_ddep*	*g (S/m^2)/month*	*3D*	
(optional) SO_4 wet deposition	*SO4_wdep*	*g (S/m^2)/month*	*2D*	

FILE 7: monthly dry deposition velocity fields.

Separated for wet and dry deposition
Filename: modelname_depvels_YEAR.nc

OPTIONAL

What	***Name of Parameter***	***Unit***	***Dimension of field***	***Remark***
Longitude	*lon*	*degrees_east*	*1D*	
Latitude	*lat*	*degrees_north*	*1D*	
Time	*time*	*days since YYYY-01-01 HH:00:00*	*1D*	*12 values*
O3 dry deposition velocity	*O3_ddepvel*	*m/s*	*3D*	
ditto. for other species (recommended at least for NO2, HNO3, CO, CH2O)	*XXX_ddepvel*	*m/s*	*3D*	

FILE 8: 3D monthly mean field of the CH_4+OH destruction flux and OH number density.

Filename: modelname_ch4destruction_YEAR.nc, required for all years.

MANDATORY

What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01	1D	12 values

		HH:00:00		
OH density	OH_density	molecules/cm3	4D	
CH4+OH destruction flux	CH4_dest	g CH_4/month	4D	

FILE 9: Monthly ozone budgets including chemical production and destruction, stratospheric influx and surface deposition

Filename: modelname_ozonebudget_YEAR.nc , required for all years.

MANDATORY

Note: compute the 2D stratospheric O_3 influx following YOUR method (**i.e. flux through tropopause or nearby pressure surface**).

Note: contrary to ACCENT-IA3/IPCC, we will combine the 2D and 3D diagnostics in one file.

What	Name of Parameter	Unit	Dimension of field	Remark
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01 HH:00:00	1D	12 values
O3 chemical production	O3_prod	g O_3/month	4D	
O3 destruction	O3_dest	g O_3/month	4D	
O3 surface deposition	O3_ddep	g O3/month	3D	
O3 stratospheric influx	O3_flux	g O3/month	3D	

FILE 10: Interactive emission fluxes (biogenic VOC, lightning NO, dust, etc.)

Filename: modelname_emissions_YEAR.nc , required for all years.

MANDATORY

Note: biogenic emissions only needed if computed interactively in your model. You may also provide separate files, e.g. one for biogenic emissions, and one for lightning NO production.

What	Name of Parameter	Unit	Dimension of field	Remark
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Time	time	days since YYYY-01-01 HH:00:00	1D	12 values
biogenic isoprene emissions	ISOPRENE_emis	gC /m2/month	3D	multiply g(Isoprene) with factor 5
biogenic terpene emissions	TERPENES_emis	g C/m2/month	3D	if terpenes=a-pinene, multiply g(terpenes) with factor 10
column integrated NO production	NO_lightning	gN/m2/month	3D	
flash frequency	flash_frequency	flashes/s	3D	integrated number of flashes in grid box
dust emissions	dust_emis	g/month	3D	
sea salt emissions	seasalt_emis	g/month	3D	

5.1.2 Output for comparison with point observations (including vertical profiles e.g. from sondes)

Postprocessing of your 3-hour (or 6-hour) output should include the “station extraction”, where species mixing ratios are sampled at the geographical location and altitude of all stations from the following networks:

- CMDL (CO and surface ozone network) [beginning: 1977]
- EMEP [beginning: 1990]
- WOUDC and SHADOZ ozone sondes [beginning: 1957]
- MOZAIC airports [beginning: 1996]
- MAXDOAS sites [beginning: 1996]

Files from one network or measurement programme should be stored as annual data files in a subdirectory with lowercase network name (i.e. ‘cmdl’, ‘emep’, ‘woudc’, ‘shadoz’, ‘mozaic’, ‘maxdoas’). The filename convention is:
modelacronym_expid_YYYY_network_station_tracer.nc
The station codes vary from network to network as follows:

- CMDL: 3-letter uppercase station code (e.g. ALT for Alert)
- EMEP: 2-letter country code plus 2-digit station code (e.g. NO52 for Sandve in Norway)

- WOUDC and SHADOZ ozone sondes: 3-digit station code (e.g. 041 for Jungfraujoch)
- MOZAIC airports: 3-letter IATA airport code (e.g. BOS for Boston)
- MAXDOAS sites: 3-letter station code similar to CMDL

A detailed list of station codes and geographical coordinates is provided in the Annex.

An example filename may thus be:
MOZECH_36092_1990_cmdl_ALT_tracer.nc

The files should contain the instantaneous 3-hour (or 6-hour) mixing ratios of O3, NO2, NO, CO, and if possible also NOY (for MOZAIC), and CH4 (for CMDL). WOUDC, MOZAIC, and MAXDOAS files should contain all vertical model levels, CMDL and EMEP files have only one altitude, but should indicate the model level index that was extracted.

FILE-TYPE 11: Surface station data

Filename: modelacronym_expid_YEAR_network_stationcode_tracer.nc , required for all years as specified in table above.

MANDATORY

What	Name of Parameter	Unit	Dimension of field	Remark
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Time	time	days since YYYY-01-01 HH:00:00	1D	2920 values for normal year and 2928 values for leap-year (3-hourly output)
O_3	O3	vmr or mole/mole	1D	
CO	CO	ditto.	1D	
NO_2	NO2	ditto.	1D	
NO	NO	ditto.	1D	
CH_4	CH4	ditto.	1D	
NOY	NOY	ditto.	1D	
Strat O3	O3S	ditto.	1D	

FILE-TYPE 12: Profile data

Filename: modelacronym_expid_YEAR_network_stationcode_tracer.nc , required for all years as specified in table above.

MANDATORY

What	Name of Parameter	Unit	Dimension of field	Remark
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	

Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01 HH:00:00	1D	2920 values for normal year and 2928 values for leap-year (3-hourly output)
O_3	O3	vmr or mole/mole	1D	
CO	CO	ditto.	1D	
NO_2	NO2	ditto.	1D	
NO	NO	ditto.	1D	
CH_4	CH4	ditto.	1D	
NOY	NOY	ditto.	1D	
Strat O3	O3S	ditto.	1D	

FILE-TYPE 13: TRADEOFF campaign data

These files are generated using the TRADEOFF data extraction scheme and the TRADEOFF metadata-database.

Filename: modelacronym_expid_tradeoff_YEAR.nc , required for all years as specified in table above.

MANDATORY

What	**Name of Parameter**	**Unit**	**Dimension of field**	**Remark**
Longitude	lon	degrees_east	1D	
Latitude	lat	degrees_north	1D	
Level	lev	index or m	1D	level index or altitude (index from surface to top!)
Time	time	days since YYYY-01-01 HH:00:00	1D	2920 values for normal year and 2928 values for leap-year (3-hourly output)
O_3	O3	vmr or mole/mole	1D	
CO	CO	ditto.	1D	
NO_2	NO2	ditto.	1D	
NO	NO	ditto.	1D	
CH_4	CH4	ditto.	1D	
NOY	NOY	ditto.	1D	

5.1.3 Standard names for plotting

So that results can be easily viewed modellers must produce plots of all species for which monthly means are produced (see list above) using the standard IDL plotting tools produced by LSCE and MPI-M.

Standard definition of plots for input into RETRO interface

Plot size: width x height 400 x 300 px (approximately)
Forcing degrades the pictures in the interface

Plot type: .png or .gif (plots will all appear as .ps.png)

Plot name: the convention for naming plots will be included in the IDL routines soon:

V_S_P_Y_M_ST_TYP [TYP has first priority, then V and the following]

V_	**S_**	**P_**	**Y_**	**M_**	**ST_**	**TYP**
Model version and run number, or all five RETRO models compared to observations	species	Parameter	Year	Month	Station	Plot type
Must contain only one underscore					abbreviations ***(please use "short code" listed in annex 1)***	
ALL_CMDL ALL_EMEP ALL_GOME ALL_MOPITT ALL_MOZAIC ALL_SONDE ALL_TRADEOFF CAM_SONDE HELS_SONDE INCANMHC_15 INCANMHC_16 INCANMHC_17 MOZECH_36060 MOZECH_36061 MOZECH_36071 PTOMCAT_V2 PTOMCAT_V3 PTOMCAT_V4 PTOMCAT_V5 SONDE_INCANMHC SONDE_MOZECH	CH2O CO HNO3 ISOP METEO NO NO2 NOx O3 OH SO2	BUD BURD CONC DEP DRY EMI JVAL LOSS PROD P-L WET FLASH Q RH TEMP	1958 1959 1960 ….. 1997 1998 1999 2000 2001 58to59 60to69 70to79 80to89 90to99 00to02	AMJ JAS JFM OND YEAR 01 02 03 04 05 06 07 08 09 10 11 12	WORLD EMEP stations CMDL stations (for O3; for CO)	MAP250 MAP300 MAP500 MAP850 MAPCOL MAPSUR MAPZON PROFILE SCATTER SERIES TABLES TAYLOR

SONDE_PTOMCAT SONDE_TM SONDE_UIO TM_POETV1 TM_POETV2 UIO_V1						
Plot storage/ one directory per V name						

No underscores in the abbreviations, except for the model version which **must** include one underscore. Do carefully check upper/ lower cases: RETRO **is not** retro. No empty spaces in the complete name.
The table gives all possible abbreviations to be used. If these are not appropriate to name a plot (e.g., another species is introduced), please investigate with grodtmann@dkrz.de beforehand to include changes in the interface.

Abbreviations used:
V_ : model version and run number (name corresponding to directory with specific comparisons)
'ALL_CMDL' => 'all five RETRO models compared to CMDL stations',
'ALL_EMEP' => 'all five RETRO models compared to EMEP stations',
'ALL_GOME' => 'all five RETRO models compared to GOME satellite data',
'ALL_MOPITT' => 'all five RETRO models compared to MOPITT satellite data',
'ALL_MOZAIC' => 'all five RETRO models compared to MOZAIC aircraft data',
'ALL_SONDE' => 'all five RETRO models compared to ozone sonde data',
'ALL_TRADEOFF' => 'all five RETRO models compared to TRADEOFF flighttrack data',
'CAM_SONDE' => '1997 model output compared to ozone sonde data',
'HELS_SONDE' => '1997-2001 model output compared to ozone sonde data',
'INCANMHC_15' => 'LMDz-INCA_NMHC run 15, usual INCA emissions, ERA40',
'INCANMHC_16' => 'LMDz-INCA_NMHC run 16, POET emissions, ERA40',
'INCANMHC_17' => 'LMDz-INCA_NMHC run 17, POET emissions, ERA15',
'MOZECH_36060' => 'MOZECH run 36060',
'MOZECH_36061' => 'MOZECH run 36061',
'MOZECH_36071' => 'MOZECH run 36071',
'PTOMCAT_V2' => 'p-TOMCAT version 2',
'PTOMCAT_V3' => 'p-TOMCAT version 3',
'PTOMCAT_V4' => 'p-TOMCAT version 4',
'PTOMCAT_V5' => 'p-TOMCAT version 5',
'SONDE_INCANMHC' => 'LMDz-INCA_NMHC compared to ozone sonde data',
'SONDE_MOZECH' => 'MOZECH compared to ozone sonde data',
'SONDE_PTOMCAT' => 'p-TOMCAT compared to ozone sonde data',
'SONDE_TM' => 'TM 3/5 compared to ozone sonde data',
'SONDE_UIO' => 'UiOslo CTM compared to ozone sonde data',
'TM_POETV1' => 'TM3/5 with POET emissions run 1',
'TM_POETV2' => 'TM3/5 with POET emissions run 2',
'UIO_V1' => 'UiOslo CTM version 1'

S_ : species
'CH2O' => 'formaldehyde',

'CO' => 'carbon monoxide',
'HNO3' => 'nitric acid',
'ISOP' => 'isoprene',
'METEO' => 'meteorological fields',
'NO' => 'nitrogen oxide',
'NO2' => 'nitrogen dioxide',
'NOx' => 'nitrogen oxides',
'O3' => 'ozone',
'OH' => 'hydroxyl radical,
'SO2' => 'sulphur dioxide'

P_ : parameter
'BUD' => 'budget',
'BURD' => 'column burden',
'CONC' => 'concentration',
'DEP' => 'total deposition',
'DRY' => 'dry deposition',
'EMI' => 'emission rate',
'FLASH' => 'NOx from lightning',
'JVAL' => 'photolysis rate',
'LOSS' => 'chemical loss term',
'PROD' => 'chemical production term',
'P-L' => 'ozone budget (PROD - LOSS)',
'Q' => 'specific humidity',
'RH' => 'relative humidity',
'TEMP' => 'temperature',
'VMR' => 'volume mixing ratio',
'WET' => 'wet deposition'

Y_ : year(s)
'58to59' => 'years 1958 to1959',
'60to69' => 'years 1960 to1969',
'70to79' => 'years 1970 to1979',
'80to89' => 'years 1980 to1989',
'90to99' => 'years 1990 to1999',
'00to02' => 'years 2000 to 2002',
'58to02' => 'years 1958 to2002'

M_ : month or period
'AMJ' => 'April-May-June',
'JAS' => 'July-August-September',
'JFM' => 'January-February-March',
'OND' => 'October-November-December',
'YEAR' => 'all months of a respective year',
'01' => 'January',
'02' => 'February',
'03' => 'March',
'04' => 'April',
'05' => 'May',
'06' => 'June',

'07' => 'July',
'08' => 'August',
'09' => 'September',
'10' => 'October',
'11' => 'November',
'12' => 'December'

ST_ : station or region name
'WORLD' => default for station (no explicit station)
stations: choose 'short code' from station list

TYP_ : plot type
'MAP250' => 'world map with concentration at 250 hPa',
'MAP300' => 'world map with concentration at 300 hPa',
'MAP500' => 'world map with concentration at 500 hPa',
'MAP850' => 'world map with concentration at 850 hPa',
'MAPCOL' => 'tropospheric columns',
'MAPSUR' => 'world map with concentration at surface level',
'PROFILE' => 'vertical profiles',
'SCATTER' => 'scatter plots',
'SERIES' => 'time series',
'TABLES' => 'budget tables',
'TAYLOR' => 'taylor plots',
'MAPZON' => 'zonal mean'

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Annex 1: Station lists

a) CMDL

Short Code	Code	Station name	Lat	Lon	Alt
ALT	CMDLALT	Alert	82 27 0 N	62 31 12 W	210
ASC	CMDLASC	Ascension Island	7 55 12 S	14 25 12 W	54
ASK	CMDLASK	Assekrem	23 10 48 N	5 25 12 E	2728
AZR	CMDLAZR	Terceira Island	38 46 12 N	27 22 48 W	40
BAL	CMDLBAL	Baltic Sea	55 25 12 N	17 4 12 E	28
BME	CMDLBME	St. Davids Head	32 22 12 N	64 39 0 W	30
BMW	CMDLBMW	Tudor Hill	32 16 12 N	64 52 48 W	30
BRW	CMDLBRW	Barrow	71 19 12 N	156 36 0 W	11
BSC	CMDLBSC	Black Sea	44 10 12 N	28 40 48 E	3
CBA	CMDLCBA	Cold Bay	55 12 0 N	162 43 12 W	25
CGO	CMDLCGO	Cape Grim	40 40 48 S	144 40 48 E	94
CHR	CMDLCHR	Christmas Island	1 42 0 N	157 10 12 W	3
CMO	CMDLCMO	Cape Meares	45 28 48 N	123 58 12 W	30
CRZ	CMDLCRZ	Crozet Island	46 27 0 S	51 51 0 E	120
EIC	CMDLEIC	Easter Island	27 9 0 S	109 27 0 W	50
GMI	CMDLGMI	Mariana Islands	13 25 48 N	144 46 48 E	6
GOZ	CMDLGOZ	Dwejra Point	36 3 0 N	14 10 48 E	30
HBA	CMDLHBA	Halley Station	75 34 48 S	26 30 0 W	33
HUN	CMDLHUN	Hegyhatsal	46 57 0 N	16 39 0 E	344
ICE	CMDLICE	Storhofdi	63 20 24 N	20 17 24 W	127
ITN	CMDLITN	Grifton	35 21 0 N	77 22 48 W	505
IZO	CMDLIZO	Tenerife	28 18 0 N	16 28 48 W	2360
KEY	CMDLKEY	Key Biscayne	25 40 12 N	80 12 0 W	3
KUM	CMDLKUM	Cape Kumukahi	19 31 12 N	154 49 12 W	3
KZD	CMDLKZD	Sary Taukum	44 27 0 N	75 34 12 E	412
KZM	CMDLKZM	Plateau Assy	43 15 0 N	77 52 48 E	2519
LEF	CMDLLEF	Park Falls	45 55 48 N	90 16 12 W	868
MBC	CMDLMBC	Mould Bay	76 15 0 N	119 21 0 W	58
MCM	CMDLMCM	McMurdo Station	77 49 48 S	166 36 0 E	11
MHD	CMDLMHD	Mace Head	53 19 48 N	9 54 0 W	25
MID	CMDLMID	Sand Island	28 12 36 N	177 22 48 W	7
MLO	CMDLMLO	Mauna Loa	19 31 48 N	155 34 48 W	3397
NMB	CMDLNMB	Gobabeb	23 34 48 S	15 1 48 E	461
NWR	CMDLNWR	Niwot Ridge	40 3 0 N	105 34 48 W	3475
PSA	CMDLPSA	Palmer Station	64 55 12 S	0 38 24 W	10
PTA	CMDLPTA	Point Arena	38 57 0 N	123 43 48 W	17
RPB	CMDLRPB	Ragged Point	13 10 12 N	59 25 48 W	45
SEY	CMDLSEY	Mahe Island	4 40 12 S	55 10 12 E	7
SHM	CMDLSHM	Shemya Island	52 43 12 N	174 6 0 E	40
SMO	CMDLSMO	Tutuila	14 14 24 S	170 34 12 W	42
SPO	CMDLSPO	South Pole	89 58 48 S	24 48 0 W	2810
STM	CMDLSTM	Ocean Station M	0 39 36 N	0 1 12 E	5
SUM	CMDLSUM	Summit	72 34 48 N	38 28 48 W	3238
SYO	CMDLSYO	Syowa Station	0 41 24 S	39 34 48 E	14
TAP	CMDLTAP	Tae-ahn Peninsula	36 43 48 N	126 7 48 E	20
TDF	CMDLTDF	Tierra Del Fuego	54 52 12 S	68 28 48 W	20

THD	CMDLTHD	Trinidad Head	41 3 0 N	124 9 0 W	107
UTA	CMDLUTA	Wendover	39 54 0 N	113 43 12 W	1320
UUM	CMDLUUM	Ulaan Uul	44 27 0 N	111 6 0 E	914
WIS	CMDLWIS	Sede Boker	31 7 48 N	34 52 48 E	400
WLG	CMDLWLG	Mt. Waliguan	36 17 24 N	100 54 0 E	3810
ZEP	CMDLZEP	Ny-Alesund	78 54 0 N	11 52 48 E	475
JFJ	GAW_JFJ	Jungfraujoch	47 24 36 N	10 54 0 E	2962
	WDCGELA	Experimental Lakes Area Canada	49 40 00 N	93 43 00 W	369
	WDCGSAT	Saturna	48 47 00 N	123 08 00 W	178
	WDCGALG	Algoma	47 20 00 N	84 23 00 W	411
	WDCGCHA	Chalk River	46 40 00 N	77 24 00 W	184
	WDCGKEJ	Kejimkujik	44 26 00 N	65 12 00 W	127
	WDCGPEN	Penhas Douradas	40 25 00 N	7 33 00 W	1380
	WDCGRYO	Ryori	39 20 00 N	141 49 00 E	260
	WDCGTKB	Tsukuba	36 30 00 N	140 08 00 E	25
	WDCGFUN	Funchal	32 39 00 N	16 53 00 W	58
	WDCGBAR	Baring Head	41 25 00 S	174 52 00 E	85
	TOR_KIS	Kislovodsk	43 42 00 N	42 42 00 E	2070
	NTL_NIC	Nicosia Cyprus	35 10 00 N	33 21 00 E	160
	IGACPIC	Pico Mountain Azores	38 28 13 N	28 24 15 W	2225

b) EMEP

Short Code	Code	Station name	Lat	Lon	Alt
AT02	AT0002R	Illmitz	47 46 0 N	16 46 0 E	117
AT03	AT0003R	Achenkirch	47 33 0 N	11 43 0 E	960
AT04	AT0004R	St. Koloman	47 39 0 N	13 12 0 E	851
AT05	AT0005R	Vorhegg	46 40 40 N	12 58 20 E	1020
AT30	AT0030R	Pillersdorf bei Retz	48 43 16 N	15 56 32 E	315
AT31	AT0031R	St. Leonhard	47 59 5 N	14 51 10 E	790
AT32	AT0032R	Sulzberg	47 31 45 N	9 55 36 E	1020
AT33	AT0033R	Stolzalpe bei Murau	47 7 45 N	14 12 14 E	1302
AT34	AT0034G	Sonnblick	47 3 16 N	12 57 30 E	3106
AT37	AT0037R	Zillertaler Alpen	47 8 13 N	11 52 12 E	1970
AT38	AT0038R	Gerlitzen	46 41 37 N	13 54 54 E	1895
AT40	AT0040R	Masenberg	47 20 53 N	15 52 56 E	1170
AT41	AT0041R	Haunsberg	47 58 23 N	13 0 58 E	730
AT42	AT0042R	Heidenreichstein	48 52 43 N	15 2 48 E	570
AT43	AT0043R	Forsthof	48 6 22 N	15 55 10 E	581
AT44	AT0044R	Graz Platte	47 6 47 N	15 28 14 E	651
AT45	AT0045R	Dunkelsteinerwald	48 22 16 N	15 32 48 E	320
AT46	AT0046R	Gänserndorf	48 20 5 N	16 43 50 E	161
AT47	AT0047R	Stixneusiedl	48 3 3 N	16 40 36 E	240
BE01	BE0001R	Offagne	49 52 40 N	5 12 13 E	430
BE32	BE0032R	Eupen	50 37 46 N	6 0 10 E	295
BE35	BE0035R	Vezin	50 30 12 N	4 59 22 E	160
CH02	CH0002R	Payerne	46 49 0 N	6 57 0 E	510
CH03	CH0003R	Tänikon	47 29 0 N	8 54 0 E	540
CH04	CH0004R	Chaumont	47 3 4 N	6 58 50 E	1130
CH05	CH0005R	Rigi	47 4 10 N	8 27 56 E	1030

CH31	CH0031R	Sion	46 13 0 N	7 20 0 E	480
CZ01	CZ0001R	Svratouch	49 44 0 N	16 2 0 E	737
CZ03	CZ0003R	Kosetice	49 35 0 N	15 5 0 E	534
DE01	DE0001R	Westerland	54 55 32 N	8 18 35 E	12
DE02	DE0002R	Langenbrügge	52 48 8 N	10 45 34 E	74
DE03	DE0003R	Schauinsland	47 54 53 N	7 54 31 E	1205
DE04	DE0004R	Deuselbach	49 45 53 N	7 3 7 E	480
DE05	DE0005R	Brotjacklriegel	48 49 10 N	13 13 9 E	1016
DE07	DE0007R	Neuglobsow	53 10 0 N	13 2 0 E	62
DE08	DE0008R	Schmücke	50 39 0 N	10 46 0 E	937
DE09	DE0009R	Zingst	54 26 0 N	12 44 0 E	1
DE11	DE0011R	Hohenwestedt	54 6 0 N	9 40 0 E	75
DE12	DE0012R	Bassum	52 51 0 N	8 42 0 E	52
DE14	DE0014R	Meinerzhagen	51 7 0 N	7 38 0 E	510
DE17	DE0017R	Ansbach	49 15 0 N	10 35 0 E	481
DE26	DE0026R	Ueckermünde	53 45 0 N	14 4 0 E	1
DE31	DE0031R	Wiesenburg	52 7 0 N	12 28 0 E	107
DE35	DE0035R	Lückendorf	50 50 0 N	14 46 0 E	490
DE38	DE0038R	Murnauer Moos	47 39 05 N	11 12 12 E	622
DE39	DE0039R	Aukrug	54 4 29 N	9 47 34 E	15
DE42	DE0042R	Öhringen	49 14 36 N	9 26 50 E	283
DK05	DK0005R	Keldsnor	54 44 0 N	10 44 0 E	10
DK31	DK0031R	Ulborg	56 17 0 N	8 26 0 E	10
DK32	DK0032R	Frederiksborg	55 58 0 N	12 20 0 E	10
DK41	DK0041R	Lille Valby	55 41 13 N	12 7 34 E	10
EE09	EE0009R	Lahemaa	59 30 0 N	25 54 0 E	32
EE11	EE0011R	Vilsandy	58 23 0 N	21 49 0 E	6
ES01	ES0001R	San Pablo de los Montes	39 32 52 N	4 20 55 W	917
ES02	ES0002R	Cartuja	37 12 0 N	3 36 0 W	720
ES03	ES0003R	Roquetas	40 49 14 N	0 29 29 E	44
ES04	ES0004R	Logroño	42 27 28 N	2 30 11 W	445
ES05	ES0005R	Noya	42 43 41 N	8 55 25 W	683
ES07	ES0007R	Víznar	37 14 0 N	3 32 0 W	1265
ES08	ES0008R	Niembro	43 26 32 N	4 51 1 W	134
ES09	ES0009R	Campisabalos	41 16 52 N	3 8 34 W	1360
ES10	ES0010R	Cabo de Creus	42 19 10 N	3 19 1 E	23
ES11	ES0011R	Barcarrola	38 28 33 N	6 55 22 W	393
ES12	ES0012R	Zarra	39 5 10 N	1 6 7 W	885
ES13	ES0013R	Penausende	41 17 0 N	5 52 0 W	985
ES14	ES0014R	Els Torms	41 24 0 N	0 43 0 E	470
ES15	ES0015R	Risco Llamo	39 31 0 N	4 21 0 W	1241
ES16	ES0016R	O Saviñao	43 13 52 N	7 41 59 W	506
FI04	FI0004R	Ähtari	62 32 0 N	24 13 18 E	162
FI09	FI0009R	Utö	59 46 45 N	21 22 38 E	7
FI17	FI0017R	Virolahti II	60 31 36 N	27 41 10 E	4
FI22	FI0022R	Oulanka	66 19 13 N	29 24 6 E	310
FI37	FI0037R	Ahtari II	62 35 0 N	24 11 0 E	180
FR08	FR0008R	Donon	48 30 0 N	7 8 0 E	775
FR09	FR0009R	Revin	49 54 0 N	4 38 0 E	390
FR10	FR0010R	Morvan	47 16 0 N	4 5 0 E	620
FR11	FR0011R	Bonnevaux	46 49 0 N	6 11 0 E	836
FR12	FR0012R	Iraty	43 2 0 N	1 5 0 W	1300
FR13	FR0013R	Peyrusse Vieille	43 22 29 N	0 6 16 E	236
FR14	FR0014R	Montandon	47 11 0 N	6 30 0 E	746
GB02	GB0002R	Eskdalemuir	55 18 47 N	3 12 15 W	243
GB06	GB0006R	Lough Navar	54 26 35 N	7 52 12 W	126

GB13	GB0013R	Yarner Wood	50 35 47 N	3 42 47 W	119
GB14	GB0014R	High Muffles	54 20 4 N	0 48 27 W	267
GB15	GB0015R	Strath Vaich Dam	57 44 4 N	4 46 28 W	270
GB31	GB0031R	Aston Hill	52 30 14 N	3 1 59 W	370
GB32	GB0032R	Bottesford	52 55 46 N	0 48 55 W	32
GB33	GB0033R	Bush	55 51 31 N	3 12 18 W	180
GB34	GB0034R	Glazebury	53 27 31 N	2 27 59 W	21
GB35	GB0035R	Great Dun Fell	54 41 2 N	2 26 6 W	847
GB36	GB0036R	Harwell	51 34 23 N	1 19 0 W	137
GB37	GB0037R	Ladybower Res.	53 23 56 N	1 45 12 W	420
GB38	GB0038R	Lullington Heath	50 47 34 N	0 10 46 E	120
GB39	GB0039R	Sibton	52 17 38 N	1 27 47 E	46
GB41	GB0041R	Wharleycroft	54 36 9 N	2 28 6 W	206
GB43	GB0043R	Narberth	51 14 0 N	4 42 0 W	160
GB44	GB0044R	Somerton	51 13 52 N	3 2 53 W	55
GB45	GB0045R	Wicken Fen	52 17 54 N	0 17 34 W	5
GR01	GR0001R	Aliartos	38 22 0 N	23 5 0 E	110
GR02	GR0002R	Finokalia	35 30 0 N	26 10 0 E	0
GR03	GR0003R	Livadi	40 32 0 N	23 15 0 E	850
HU02	HU0002R	K-puszta	46 58 0 N	19 35 0 E	125
IE31	IE0031R	Mace Head	53 10 0 N	9 30 0 W	15
IT01	IT0001R	Montelibretti	42 6 0 N	12 38 0 E	48
IT04	IT0004R	Ispra	45 48 0 N	8 38 0 E	209
LT15	LT0015R	Preila	55 21 0 N	21 4 0 E	5
LV10	LV0010R	Rucava	56 13 0 N	21 13 0 E	5
MT01	MT0001R	Giordan lighthouse	36 6 0 N	14 12 0 E	160
NL02	NL0002R	Witteveen	52 48 49 N	6 40 11 E	17
NL09	NL0009R	Kollumerwaard	53 20 2 N	6 16 38 E	1
NL10	NL0010R	Vredepeel	51 32 28 N	5 51 13 E	28
NO01	NO0001R	Birkenes	58 23 0 N	8 15 0 E	190
NO15	NO0015R	Tustervatn	65 50 0 N	13 55 0 E	439
NO30	NO0030R	Jergul	69 27 0 N	24 36 0 E	255
NO39	NO0039R	Kårvatn	62 47 0 N	8 53 0 E	210
NO41	NO0041R	Osen	61 15 0 N	11 47 0 E	440
NO42	NO0042G	Spitsbergen, Zeppelinfjell	78 54 0 N	11 53 0 E	474
NO43	NO0043R	Prestebakke	59 0 0 N	11 32 0 E	160
NO44	NO0044R	Nordmoen	60 16 0 N	11 6 0 E	200
NO45	NO0045R	Jeløya	59 26 0 N	10 36 0 E	5
NO47	NO0047R	Svanvik	69 27 0 N	30 2 0 E	30
NO48	NO0048R	Voss	60 36 0 N	6 32 0 E	500
NO49	NO0049R	Valle	59 3 0 N	7 34 0 E	250
NO52	NO0052R	Sandve	59 12 0 N	5 12 0 E	15
NO55	NO0055R	Karasjok	69 28 0 N	25 13 0 E	333
NO56	NO0056R	Hurdal	60 22 0 N	11 4 0 E	300
PL02	PL0002R	Jarczew	51 49 0 N	21 59 0 E	180
PL03	PL0003R	Sniezka	50 44 0 N	15 44 0 E	1603
PL04	PL0004R	Leba	54 45 0 N	17 32 0 E	2
PL05	PL0005R	Diabla Gora	54 9 0 N	22 4 0 E	157
PT04	PT0004R	Monte Velho	38 5 0 N	8 48 0 W	43
RU01	RU0001R	Janiskoski	68 56 0 N	28 51 0 E	118
RU13	RU0013R	Pinega	64 42 0 N	43 24 0 E	28
RU16	RU0016R	Shepeljovo	59 58 0 N	29 7 0 E	4
RU18	RU0018R	Danki	54 54 0 N	37 48 0 E	150
SE02	SE0002R	Rörvik	57 25 0 N	11 56 0 E	10
SE11	SE0011R	Vavihill	56 1 0 N	13 9 0 E	175
SE12	SE0012R	Aspvreten	58 48 0 N	17 23 0 E	20

SE13	SE0013R	Esrange	67 53 0 N	21 4 0 E	475
SE32	SE0032R	Norra-Kvill	57 49 0 N	15 34 0 E	261
SE35	SE0035R	Vindeln	64 15 0 N	19 46 0 E	225
SE39	SE0039R	Grimsö	59 45 0 N	15 35 0 E	120
SI08	SI0008R	Iskrba	45 34 0 N	14 52 0 E	520
SI31	SI0031R	Zarodnje	46 25 43 N	15 0 12 E	770
SI32	SI0032R	Krvavec	46 17 58 N	14 32 19 E	1740
SI33	SI0033R	Kovk	46 7 43 N	15 6 50 E	600
SK02	SK0002R	Chopok	48 56 0 N	19 35 0 E	2008
SK04	SK0004R	Stará Lesná	49 9 0 N	20 17 0 E	808
SK06	SK0006R	Starina	49 3 0 N	22 16 0 E	345
SK07	SK0007R	Topolniky	47 57 36 N	17 51 38 E	113
TR01	TR0001R	Cubuk II	40 30 0 N	33 0 0 E	1169

c) MAXDOAS

Code =*Short Code*	Station name	Lat	Lon	Alt
ZEP	Ny-Alesund, Norway	78 54 0 N	11 52 48 E	475
SUM	Summit, Greenland	72 34 48 N	38 28 48 W	3238
BRE	Bremen, Germany	53 05 00 N	8 49 00 E	15
MER	Merida, Venezuela	8 12 00 N	71 06 00 W	15
NAI	Nairobi, Kenya	1 17 00 S	36 49 00 E	1662

d) Ozone Sondes

Short Code	Code	Station name	Lat	Lon	Alt
001	COG001	Leopoldville	04 18 00 S	15 33 00 E	450
002	DZA002	Tamanrasset	22 47 59 N	05 31 01 E	1377
003	KAZ003	Alma-Ata	43 13 58 N	76 55 58 E	847
004	IND004	Banaras	25 00 00 N	83 00 00 E	-1
005	RUS005	Dikson Island	73 30 00 N	80 13 58 E	18
006	IRQ006	Habbaniya	33 22 01 N	43 34 01 E	44
007	JPN007	Kagoshima	31 34 47 N	130 33 54 E	157
008	IND008	Kodaikanal	10 13 58 N	77 28 01 E	2343
009	IND009	Mount Abu	24 35 59 N	72 41 59 E	1220
010	IND010	New Delhi	28 39 00 N	77 13 01 E	220
011	PAK011	Quetta	30 06 36 N	66 34 11 E	1721
012	JPN012	Sapporo	43 03 35 N	141 19 53 E	19
013	IND013	Sprinagar	34 05 59 N	74 48 00 E	1586
014	JPN014	Tateno / Tsukuba	36 03 35 N	140 06 00 E	31
015	JPN015	Torishima	30 28 58 N	140 18 00 E	83
016	RUS016	Vladivostok	43 07 01 N	131 53 59 E	80
017	GBR017	Argentine Islands	65 15 00 S	64 31 01 W	10
018	CAN018	Alert	82 30 00 N	62 19 11 W	62
019	USA019	Bismarck	46 46 01 N	100 45 00 W	511
020	USA020	Caribou	46 52 01 N	68 01 47 W	192
021	CAN021	Edmonton / Stony Plain	53 33 00 N	114 05 59 W	766
022	USA022	Green Bay	44 28 58 N	88 07 58 W	209
023	CAN023	Moosonee	51 16 01 N	80 39 00 W	10
024	CAN024	Resolute	74 43 12 N	94 58 47 W	40

025	USA025	Washington	38 58 58 N	77 28 58 W	84
026	AUS026	Aspendale	38 01 47 S	145 06 00 E	1
027	AUS027	Brisbane	27 25 01 S	153 07 01 E	3
028	ATA028	Dumont D'urville	66 40 01 S	140 01 12 E	40
029	AUS029	Macquarie Island	54 30 00 S	158 58 01 E	6
030	JPN030	Minamitorishima / Marcus Is.	24 17 59 N	153 58 01 E	9
031	USA031	Mauna Loa	19 31 58 N	155 34 26 W	3405
032	NZL032	Wellington	41 16 58 S	174 46 01 E	126
033	GEO033	Abustumani	41 45 00 N	42 49 58 E	1600
034	DNK034	Aarhus	56 10 01 N	10 11 59 E	53
035	CHE035	Arosa	46 46 47 N	09 40 48 E	1840
036	GBR036	Camborne	50 13 01 N	05 19 11 W	88
037	RUS037	Elbrus Mt.	43 19 01 N	42 28 01 E	2100
038	ITA038	Cagliari/Elmas	39 15 00 N	09 03 00 E	240
039	GBR039	Eskdalemuir	55 19 01 N	03 12 00 W	242
040	FRA040	Haute Provence	43 55 58 N	05 41 59 E	674
041	CHE041	Jungfraujoch	47 00 00 N	08 00 00 E	3573
042	RUS042	St. Petersburg	59 58 01 N	30 17 59 E	74
043	GBR043	Lerwick	60 07 53 N	01 10 58 W	80
044	NOR044	Longyear	78 13 01 N	15 34 58 E	1
045	ITA045	Messina	38 11 59 N	15 33 00 E	51
046	NOR046	Murchison Bay	80 00 00 N	18 00 00 E	-1
047	ITA047	Naples	40 50 59 N	15 15 00 E	45
048	GBR048	Oxford	51 45 00 N	01 10 58 W	140
049	FRA049	Paris-Montsouris	48 49 01 N	02 19 58 E	76
050	DEU050	Potsdam	52 13 12 N	13 03 00 E	89
051	ISL051	Reykjavik	64 07 58 N	21 54 00 W	60
052	NOR052	Tromso	69 39 00 N	18 57 00 E	100
053	BEL053	Uccle	50 48 00 N	04 21 00 E	100
054	SWE054	Uppsala	59 50 59 N	17 31 01 E	15
055	ITA055	Vigna Di Valle	42 04 48 N	12 13 11 E	262
056	DEU056	Weissenau	47 46 01 N	09 34 58 E	445
057	GBR057	Halley Bay	73 31 01 S	26 43 58 W	31
058	USA058	Little America	78 00 00 S	162 00 00 W	44
060	DEU060	Dresden	51 07 01 N	13 40 58 E	246
061	COG061	Bunia Ruampara	01 30 00 N	30 12 57 E	1239
062	FRA062	Port Aux Francais	49 20 59 S	70 16 58 E	14
063	USA063	Fort Worth	32 49 58 N	97 03 00 W	176
064	USA064	Sterling	38 58 58 N	77 28 58 W	84
065	CAN065	Toronto	43 46 47 N	79 28 12 W	198
066	USA066	Fort Collins	40 34 01 N	105 04 01 W	1551
067	USA067	Boulder	40 01 47 N	105 15 00 W	1689
068	POL068	Belsk	51 50 24 N	20 47 24 E	180
069	ATA069	Hallett	72 19 01 S	170 13 01 E	5
070	FRA070	Mont Louis	42 30 00 N	02 07 58 E	1650
071	ZAF071	Pretoria	25 43 58 S	28 10 58 E	1369
072	ATA072	Byrd	80 01 47 S	119 31 01 W	1528
073	IND073	Ahmedabad	23 01 47 N	72 39 00 E	55
074	IND074	Varanasi	25 19 01 N	83 01 47 E	76
075	IND075	Dum Dum	22 39 00 N	88 26 59 E	27
076	CAN076	Goose Bay	53 18 00 N	60 21 36 W	40
077	CAN077	Churchill	58 45 00 N	94 04 11 W	35
079	USA079	Tallahassee	30 24 00 N	84 20 59 W	21
080	MDV080	Gan	00 40 58 S	73 09 00 E	2
081	ATA081	Base King Baudoin	70 25 58 S	24 19 01 E	38
082	PRT082	Lisbon	38 46 12 N	09 08 59 W	105

084	AUS084	Darwin	12 25 01 S	130 52 58 E	31
085	RUS085	Irkutsk	52 15 46 N	104 20 59 E	467
086	UKR086	Feodosija	45 01 58 N	35 22 58 E	26
087	UKR087	Kiev	50 24 00 N	30 27 00 E	121
088	ATA088	Mirny	66 33 00 S	93 00 00 E	30
089	NOR089	Ny Alesund	78 55 58 N	11 52 58 E	242
090	TKM090	Ashkhabad	37 58 01 N	58 19 58 E	227
091	ARG091	Buenos Aires	34 34 58 S	58 28 58 W	25
092	AUS092	Hobart	42 49 58 S	147 30 00 E	22
093	AUS093	Salisbury	34 43 01 S	138 38 59 E	1
094	AUS094	Woomera	30 57 00 S	136 30 57 E	146
095	TWN095	Taipei	25 01 12 N	121 28 30 E	25
096	CZE096	Hradec Kralove	50 10 58 N	15 49 58 E	285
097	FRA097	Magny-Les-hameaux	48 43 58 N	02 04 01 E	165
098	FRA098	Val Joyeaux	48 29 23 N	02 01 11 E	114
099	DEU099	Hohenpeissenberg	47 48 00 N	11 01 12 E	975
100	HUN100	Budapest-Lorinc	47 25 58 N	19 10 58 E	139
101	JPN101	Syowa	69 00 00 S	39 34 48 E	21
102	GBR102	Bracknell	51 22 47 N	00 46 47 W	70
103	USA103	Albuquerque	35 04 58 N	106 37 01 W	1575
104	USA104	Bedford	42 26 59 N	71 16 01 W	80
105	USA105	Fairbanks	64 49 01 N	147 52 01 W	138
106	USA106	Nashville	36 15 00 N	86 34 01 W	182
107	USA107	Wallops Island	37 53 52 N	75 28 58 W	13
108	USA108	Canton Island	02 45 35 S	171 41 59 W	3
109	USA109	Hilo	19 34 37 N	155 04 01 W	11
110	PER110	Huancayo	12 03 00 S	75 19 01 W	3313
111	ATA111	Amundsen-Scott	89 58 58 S	24 47 59 W	2810
112	RUS112	Bolshaya Elan	46 55 01 N	142 43 58 E	22
113	TJK113	Dushanbe	38 34 58 N	68 46 58 E	825
114	RUS114	Heiss Island	80 37 11 N	58 05 59 E	20
115	RUS115	Samara (Kuibyshev)	53 15 00 N	50 26 59 E	137
116	RUS116	Moscow	55 45 00 N	37 34 01 E	187
117	RUS117	Murmansk	68 58 01 N	33 03 00 E	46
118	RUS118	Nagaevo	59 34 58 N	150 46 58 E	118
119	UKR119	Odessa	46 28 58 N	30 37 58 E	42
120	RUS120	Omsk	54 55 58 N	73 24 00 E	119
121	LVA121	Riga	57 11 24 N	24 15 00 E	7
122	RUS122	Ekaterinburg	56 48 00 N	60 37 58 E	290
123	RUS123	Yakutsk	62 04 48 N	129 45 00 E	98
124	MEX124	Cerrillos	19 28 58 N	99 43 01 W	2640
125	DZA125	Columb-Bechar	31 37 48 N	02 15 00 W	806
127	USA127	Midland	31 55 58 N	102 11 59 W	872
128	KAZ128	Kararganda	49 48 00 N	73 07 58 E	553
129	RUS129	Pechora	65 07 01 N	57 05 59 E	61
130	RUS130	Petropavlovsk/Kamchatskii	52 58 01 N	158 45 00 E	78
131	CHL131	Puerto Montt	41 26 59 S	72 49 58 W	5
132	BGR132	Sofia	42 49 01 N	23 22 58 E	588
133	FLK133	Stanley	51 41 59 S	57 52 01 W	51
137	USA137	Topeka	39 04 01 N	95 37 58 W	270
138	NZL138	Christchurch	43 28 58 S	172 33 00 E	34
142	RUS142	Igarka	67 28 01 N	86 34 01 E	20
143	RUS143	Krasnoyarsk	56 00 00 N	92 52 58 E	137
144	RUS144	Markovo	64 40 58 N	170 25 01 E	22
145	RUS145	Olenek	68 30 00 N	112 25 58 E	127
147	KAZ147	Semipalatinsk	50 20 59 N	80 15 00 E	206

148	RUS148	Vitim	59 26 59 N	112 34 58 E	186
149	BOL149	Ovejuyo (La Paz)	16 31 01 S	68 01 58 W	3420
150	RUS150	Hanty Mansijsk	60 58 01 N	69 04 01 E	40
152	EGY152	Cairo	30 04 47 N	31 16 58 E	37
153	RUS153	Voronez	51 41 59 N	39 10 01 E	147
155	USA155	White Sands	32 22 58 N	106 28 58 W	1224
156	CHE156	Payerne	46 29 23 N	06 34 11 E	491
157	CHE157	Thalwil	46 49 01 N	08 27 17 E	515
158	MAR158	Casablanca	33 34 11 N	07 40 12 W	55
159	AUS159	Perth	31 55 01 S	115 56 59 E	2
163	USA163	Wilkes	66 15 00 S	110 31 01 E	12
164	USA164	Silver Hill	38 49 58 N	76 56 59 W	89
165	NOR165	Oslo	59 54 35 N	10 43 11 E	90
169	DEU169	Arkona	54 24 35 N	13 15 36 E	42
174	DEU174	Lindenberg	52 12 35 N	14 07 11 E	112
175	KEN175	Nairobi	01 16 01 S	36 48 00 E	1745
180	NZL180	Invercargill	46 25 11 S	168 18 57 E	1
181	DEU181	Berlin/Templehof	52 28 01 N	13 25 58 E	50
182	KAZ182	Aralskoe More	46 46 58 N	61 40 01 E	56
183	KAZ183	Atiray (Gurev)	47 01 47 N	51 50 59 E	-1
184	UKR184	Lwow	49 49 01 N	23 57 00 E	325
185	GEO185	Tbilisi	41 40 58 N	44 56 59 E	490
186	RUS186	Tiksi	71 34 58 N	128 55 01 E	8
187	IND187	Poona	18 31 58 N	73 50 59 E	559
189	NOR189	Svalbard Hornsund	77 00 00 N	15 33 00 E	11
190	JPN190	Naha	26 12 00 N	127 40 58 E	27
191	ASM191	Samoa	14 15 00 S	170 33 35 W	82
192	MEX192	Mexico City	19 19 58 N	99 10 58 W	2268
193	AUS193	Cairns	16 52 58 S	145 45 00 E	3
194	CAN194	Yorkton	51 15 46 N	102 28 01 W	504
195	GBR195	Sibton	51 30 00 N	00 07 01 W	50
197	FRA197	Biscarrosse/Sms	44 22 01 N	01 13 58 W	18
198	CAN198	Cold Lake	54 46 58 N	110 03 00 W	702
199	USA199	Barrow	71 19 01 N	156 36 00 W	11
200	BRA200	Cachoeira Paulista	22 40 58 S	45 00 00 W	573
201	ITA201	Sestola	44 13 12 N	10 46 12 E	1030
202	DEU202	Neuglobson	53 09 00 N	13 01 58 E	62
203	PAN203	Ft. Sherman	09 19 47 N	79 58 58 E	57
204	SHN204	St. Helena	15 55 58 S	05 38 59 W	460
205	IND205	Thivandrum	08 28 58 N	76 56 59 E	60
206	IND206	Bombay	19 07 01 N	72 50 59 E	145
207	SYC207	Mahe (Seychelles)	04 40 58 S	55 31 58 E	6
208	CHN208	Xianghe	39 58 29 N	116 22 11 E	80
209	CHN209	Kunming	25 01 47 N	102 40 58 E	1917
210	USA210	Palestine	31 47 59 N	95 43 01 W	121
213	ESP213	El Arenosillo	37 05 59 N	06 43 58 W	41
214	SGP214	Singapore	01 19 58 N	103 52 58 E	14
215	DEU215	Garmisch-Partenkir	47 28 58 N	11 04 01 E	740
216	THA216	Bangkok	13 40 01 N	100 36 43 E	53
217	USA217	Poker Flat	65 07 58 N	147 26 59 W	357
218	PHL218	Manila	14 37 58 N	121 49 58 E	61
219	BRA219	Natal	05 50 24 S	35 12 35 W	32
221	POL221	Legionowo	52 24 00 N	20 58 01 E	96
222	MOZ222	Maputo	25 58 01 S	32 35 59 E	70
223	MOZ223	Nampula	15 06 00 S	39 16 58 E	440
224	PER224	Chilca	12 30 00 S	76 48 00 W	-1

225	GUF225	Kourou	05 19 58 N	52 39 00 W	4
226	ROM226	Bucharest	44 28 58 N	26 07 58 E	100
227	USA227	Mcdonald Observatory	30 39 57 N	90 55 58 W	2081
228	CAN228	Gimli	50 37 58 N	97 03 00 W	228
229	PAN229	Albrook	08 58 58 N	79 33 00 W	66
230	AUS230	Cape Grim	40 40 58 S	144 40 58 E	94
231	USA231	Spokane	47 40 01 N	117 25 01 W	576
232	ATA232	Vernadsky / Faraday	65 15 00 S	64 16 12 W	7
233	ATA233	Marambio	64 13 58 S	56 43 01 W	196
234	PRI234	San Juan	18 28 58 N	66 07 58 W	17
235	USA235	Long View	32 30 00 N	94 45 00 W	103
236	ATG236	Coolidge Field	17 16 58 N	61 46 58 W	10
237	USA237	Great Falls	47 28 58 N	111 20 59 W	1118
238	USA238	Denver	39 46 01 N	104 52 58 W	1611
239	USA239	San Diego	32 26 59 N	117 06 36 W	124
241	CAN241	Saskatoon	52 06 36 N	106 42 35 W	530
242	CZE242	Praha	50 01 12 N	14 26 59 E	304
243	ITA243	Brindisi	40 39 00 N	17 57 00 E	5
244	USA244	Fresno	36 46 01 N	119 43 01 W	100
245	EGY245	Aswan	23 58 01 N	32 46 47 E	193
252	KOR252	Seoul	37 34 01 N	126 56 59 E	84
253	AUS253	Melbourne	37 48 00 S	144 58 01 E	125
254	AUS254	Laverton	37 52 01 S	144 45 00 E	21
255	USA255	Ainsworth (Airport)	42 34 58 N	100 00 00 W	789
256	NZL256	Lauder	45 01 47 S	169 40 58 E	370
257	CAN257	Vanscoy	52 11 59 N	107 18 00 W	510
259	DEU259	Zugspitze	47 15 00 N	11 00 00 E	-1
260	USA260	Table Mountain	34 13 47 N	117 24 36 W	2286
261	GRC261	Thessaloniki	40 31 12 N	22 58 12 E	50
262	FIN262	Sodankyla	67 20 05 N	26 30 18 E	179
265	ZAF265	Irene	25 33 35 S	28 11 16 E	1524
266	LTU266	Preila	55 19 58 N	21 13 01 E	3
267	GRL267	Sondrestrom	67 00 00 N	50 37 12 W	300
268	ATA268	Arrival Heights / Mcmurdo	77 49 53 S	166 40 04 E	250
269	GBR269	Strath Vaich	57 43 58 N	04 46 58 W	270
271	RUS271	Arhangelsk	64 34 58 N	40 30 00 E	-1
272	RUS272	Volgograd	48 34 58 N	45 43 01 E	-1
273	RUS273	Kotelnyj Island	76 00 00 N	137 53 59 E	-1
274	RUS274	Nikolaevsk-Na-amure	53 09 00 N	140 41 59 E	46
275	RUS275	Skovorodino	54 00 00 N	123 58 01 E	-1
276	RUS276	Tura	64 10 01 N	100 04 01 E	-1
277	RUS277	Cimljansk	47 43 58 N	42 15 00 E	64
278	TKM278	Cardzou	39 04 58 N	63 35 59 E	191
279	SWE279	Norrkoeping	58 34 48 N	16 09 00 E	43
280	ATA280	Novolasarevskaya / Forster	70 46 01 S	11 52 01 E	110
281	ATA281	Vostok	78 16 12 S	106 30 36 E	-1
282	RUS282	Kislovodsk	43 43 58 N	42 39 39 E	2070
284	SWE284	Vindeln	64 14 23 N	19 46 12 E	225
285	BGR285	Cape Kaliakra	43 22 01 N	28 28 01 E	59
286	BGR286	Primorsko	42 16 58 N	27 45 00 E	13
287	PRT287	Funchal (Madeira Is.)	32 38 23 N	16 53 23 W	49
288	PRT288	Penhas Douradas	40 25 01 N	07 33 00 W	1380
289	GBR289	Lullington Heath	52 00 00 N	00 30 00 E	50
290	CAN290	Saturna Island	48 46 47 N	123 07 48 W	178
291	CAN291	Asquith (Grandora)	52 08 23 N	107 03 35 W	519
293	GRC293	Athens	37 58 47 N	23 43 58 E	110

295	CHN295	Mt. Waliguan	36 17 13 N	100 53 52 E	3810
296	CAN296	London (Ontario)	43 00 36 N	81 16 12 W	100
297	ITA297	S.Pietro Capofiume	44 39 00 N	11 37 01 E	11
298	SYR298	Aleppo	36 08 23 N	37 05 59 E	502
300	ESP300	Iza╤a (Tenerife)	28 17 24 N	16 29 23 W	2367
301	ITA301	J.R.c. Ispra (Varese)	45 48 10 N	08 37 37 E	240
302	JPN302	Ryori	39 03 00 N	141 49 58 E	230
303	CAN303	Iqualuit	63 45 00 N	68 33 00 W	20
304	CHN304	Gonghe	36 16 01 N	100 37 11 E	-1
305	ITA305	Rome University	41 54 00 N	12 31 12 E	60
306	TWN306	Chengkung	23 05 59 N	121 21 53 E	10
307	RUS307	Obninsk	55 07 12 N	36 18 00 E	100
308	ESP308	Madrid	40 26 59 N	03 43 12 W	-1
311	CUB311	Havana	23 16 47 N	82 33 00 W	50
312	LTU312	Kaunas	54 31 12 N	23 32 24 E	77
314	ATA314	Belgrano Ii	77 52 01 S	34 37 58 W	255
315	CAN315	Eureka	80 02 24 N	86 10 30 W	315
316	NLD316	Debilt	52 05 59 N	05 10 53 E	9
317	NGA317	Lagos	06 36 00 N	03 19 58 E	10
318	IRL318	Valentia Observatory	51 55 48 N	10 15 00 W	14
319	CAN319	Montreal (Dorval)	45 28 47 N	73 45 00 W	31
320	CAN320	Winnipeg	49 54 00 N	97 14 23 W	239
321	CAN321	Halifax (Bedford)	44 42 00 N	63 36 36 W	50
322	MYS322	Petaling Jaya	03 05 59 N	101 39 00 E	46
323	ATA323	Neumayer	70 39 00 S	08 15 00 W	42
324	ITA324	Scott Base	77 48 00 S	165 36 00 E	22
325	CHN325	Linan	30 17 59 N	119 43 47 E	132
326	CHN326	Longfengshan	44 43 47 N	127 35 59 E	317
327	PRT327	Angra Do Heroismo (Terceica I)	38 39 28 N	27 13 19 W	74
328	COG328	Ascension Island	07 58 48 S	14 25 12 W	91
329	COG329	Brazzaville	04 16 47 S	15 15 00 E	314
330	VNM330	Hanoi	21 01 58 N	105 50 59 E	5
331	SVK331	Poprad-Ganovce	49 01 47 N	20 19 11 E	706
332	KOR332	Pohang	36 01 58 N	129 22 58 E	6
333	BRA333	Porto Nacional	10 48 00 S	48 24 00 W	240
334	BRA334	Cuiaba	15 36 00 S	56 05 59 W	990
335	NAM335	Etosha Pan	19 12 00 S	15 53 59 E	1100
336	IRN336	Isfahan	32 28 37 N	51 25 29 E	1550
338	CAN338	Bratts Lake (Regina)	50 12 18 N	104 42 18 W	592
339	ARG339	Ushuaia	54 50 59 S	68 18 28 W	7
340	ZAF340	Springbok	29 40 01 S	17 54 00 E	1006
341	USA341	Hanford	36 19 01 N	119 37 58 W	73
342	ARG342	Comodoro Rivadavia	45 46 58 S	67 30 00 W	43
343	URY343	Salto	31 23 42 S	57 58 12 W	31
344	HKG344	Hong Kong Observatory	22 18 36 N	114 10 11 E	66
345	THA345	Songkhla	07 11 59 N	100 35 59 E	13
346	ESP346	Murcia	38 00 10 N	01 10 09 W	69
347	KGZ347	Issyk-Kul	42 37 12 N	76 58 47 E	1640
348	TUR348	Ankara	39 56 59 N	32 52 58 E	891
349	CHN349	Lasha	29 24 00 N	91 01 47 E	3633
350	EST350	Tahkuse	58 31 12 N	24 56 23 E	23
351	URY351	King George Island	62 10 48 S	58 54 00 W	10
353	GBR353	Reading	51 26 59 N	00 55 47 W	66
354	BLR354	Minsk	53 49 58 N	27 28 08 E	240
355	USA355	Baton Rouge (La)	30 21 36 N	91 10 11 W	7

356	USA356	Big Bend (Castolon)	29 07 48 N	103 31 12 W	670
357	USA357	Bondville (Il)	40 03 00 N	88 22 11 W	213
358	USA358	Nunn (Co)	40 47 24 N	104 45 36 W	1641
359	USA359	Davis (Ca)	38 31 47 N	121 45 36 W	18
360	USA360	Pellston (Mi)	45 33 35 N	84 40 11 W	238
361	USA361	Holtville (Ca)	32 48 35 N	115 26 24 W	-18
362	USA362	Poplar (Mt)	48 18 35 N	105 05 59 W	634
363	USA363	Geneva (Ny)	42 52 47 N	77 01 47 W	218
364	USA364	Grand Canyon	36 03 35 N	112 10 48 W	2073
365	USA365	Grand Rapids (Mn)	47 10 48 N	93 31 47 W	390
366	USA366	Griffin (Ga)	33 10 48 N	84 24 36 W	270
367	USA367	Las Cruces (Nm)	32 37 12 N	106 44 23 W	1317
368	USA368	Dancy (Wi)	44 42 35 N	89 46 12 W	381
369	USA369	Logan (Ut)	41 40 11 N	111 54 00 W	1368
370	USA370	Mead (Ne)	41 07 47 N	96 28 47 W	353
371	USA371	Oxford (Oh)	39 31 47 N	84 43 12 W	286
372	USA372	Presque Isle (Me)	46 40 48 N	68 02 24 W	144
373	USA373	Pullman (Wa)	46 45 00 N	117 10 48 W	804
374	USA374	Burlington (Vt)	44 31 47 N	72 51 36 W	408
375	USA375	Wye (Md)	38 55 11 N	76 09 00 W	5
376	EGY376	Mrsa Matrouh	31 19 47 N	27 13 12 E	35
387	USA387	Everglades	25 23 23 N	80 40 48 W	2
394	AUS394	Broadmeadows	37 41 29 S	144 56 48 E	108
398	HKG398	Hong Kong University	22 16 30 N	114 11 59 E	113
399	ARG399	Ushuaia Ii	54 49 11 S	68 19 11 W	30
400	ATA400	Maitri	70 27 35 S	11 26 59 E	330
401	ESP401	Santa Cruz	28 25 12 N	16 15 36 W	36
404	FIN404	Jokioinen	60 48 35 N	23 30 00 E	103
409	EGY409	Hurghada	27 16 47 N	33 45 00 E	7
410	ARM410	Amberd	40 22 47 N	44 15 00 E	2070
412	LUX412	Diekirch	49 52 12 N	06 10 12 E	218
418	USA418	Huntsville	35 16 47 N	86 34 48 W	196
419	FRA419	Bordeaux	44 50 24 N	00 31 47 W	73
420	USA420	Beltsville (Md)	39 01 12 N	76 56 59 W	64
421	USA421	Billings (Ok)	36 37 12 N	97 30 00 W	317
422	USA422	Starkville (Ms)	33 28 12 N	88 46 47 W	85
423	USA423	Steamboat Springs (Co)	40 26 59 N	106 43 47 W	3220
424	USA424	Table Mountain (Co)	40 10 48 N	105 16 47 W	1689
425	USA425	West Lafayette (In)	40 28 47 N	86 59 23 W	216
426	ARG426	San Julian	49 18 00 S	67 45 18 W	62
427	ATA427	Doctor Sobral	81 04 01 S	40 30 00 W	100
429	PER429	Marcapomacocha	11 23 59 S	76 19 11 W	4479
432	PYF432	Papeete (Tahiti)	18 00 00 S	149 00 00 W	2
434	ECU434	San Cristobal	00 55 11 S	89 35 59 W	8
435	SUR435	Paramaribo	05 48 36 N	55 12 35 W	22
436	REU436	La Reunion Island	21 04 30 S	55 28 47 E	24
437	IDN437	Watukosek (Java)	07 34 11 S	112 38 59 E	50
438	FJI438	Suva (Fiji)	18 07 48 S	178 18 54 E	6
439	MDV439	Kaashidhoo	05 00 00 N	73 30 00 E	1
441	CHL441	Easter Island	27 10 12 S	109 25 11 W	62
442	ARG442	Pilar	31 39 35 S	63 52 58 W	338
443	MYS443	Sepang Airport	02 43 48 N	101 41 59 E	17
444	KOR444	Cheju	33 30 00 N	126 30 00 E	300
445	USA445	Trinidad Head	40 48 00 N	124 09 36 W	0
447	USA447	Goddard	38 59 23 N	76 49 58 W	100
448	KEN448	Malindi	02 59 23 S	40 11 24 E	-6

450	ATA450	Davis	68 34 37 S	77 58 22 E	16
452	MNG452	Sainshand	45 00 00 N	110 00 00 E	940
453	NOR453	Dombas	62 05 59 N	09 06 00 E	659
454	ATA454	San Martin	68 07 48 S	67 05 59 W	30
455	MDA455	Kishinev	47 00 00 N	28 48 57 E	202
459	GRL459	Scoresbysund	70 30 00 N	22 00 00 W	51
460	GRL460	Thule	76 31 47 N	68 44 23 W	57
461	USA461	Raleigh (Nc)	35 43 44 N	78 40 48 W	124
462	USA462	Seguin (Tx)	29 34 15 N	97 59 34 W	172
467	BWA467	Maun	19 58 47 S	23 25 48 E	950

e) MOZAIC Airports

CODE ***=Short Code***	Station name	Lat	Lon	Alt(m)
NRT	Tokyo, Japan	35 33 8 N	139 46 47 E	8
FRA	Frankfurt, Germany	50 1 35 N	8 32 35 E	113
JFK	New York, USA	40 38 23 N	73 46 44 W	4
BRU	Brussels, Belgium	50 54 5 N	4 29 4 E	58
VIE	Vienna, Austria	48 6 37 N	16 34 11 E	190
ORD	Chicago, USA	41 58 43 N	87 54 17 W	204
DFW	Dallas, USA	32 53 49 N	97 02 17 W	185
LAX	Los Angeles, USA	33 56 33 N	118 24 29 W	38
MUC	Muenchen, Germany	48 21 14 N	11 47 10 E	453
CDG	Paris, France	49 0 46 N	2 33 0 E	109
DEL	New Delhi, India	28 33 59 N	77 6 11 E	233
IAD	Washington, USA	38 56 40 N	77 27 21 W	95
LOS	Lagos, Nigeria	6 34 39 N	3 19 16 E	35
THR	Tehran, Iran	35 41 21 N	51 18 48 E	1208
TLV	Tel Aviv, Israel	32 0 34 N	34 52 37 E	49
BOS	Boston, USA	42 21 52 N	71 0 19 E	6
OSA	Osaka, Japan	34 47 8 N	135 26 18 E	15
ATL	Atlanta, USA	33 38 26 N	84 25 37 W	313
DXB	Dubai, United Emirates	25 15 18 N	55 21 52 E	10
MAA	Madras, India	12 59 40 N	80 10 50 E	16
THF	Berlin, Germany	52 28 23 N	13 24 14 E	51
IAH	Houston, USA	29 59 04 N	95 20 29 W	30
YVR	Vancouver, Canada	49 11 42 N	123 10 55 W	4
CAI	Cairo, Egypt	30 07 19 N	31 24 20 E	116
CCS	Caracars, Venzuela	10 29 06 N	66 50 37 W	835
DLA	Douala, Cameroon	4 00 22 N	9 43 10 E	10
RUH	Riyadh, Saudi Arabia	24 57 28 N	46 41 56 E	625
COO	Cotonou, Benin	6 21 25 N	2 23 4 E	6
YYZ	Toronto, Canada	43 40 38 N	79 37 50 W	173
JNB	Johannesburg, S.Africa	26 08 21 S	28 14 46 E	1694
ABJ	Abidjan, Ivory Coast	5 15 41 N	3 55 35 W	6
DEN	Denver, USA	39 51 42 N	104 40 23 W	1655

f) CASTNET

Code	Station name	Lat	Lon	Alt(m)
cABT147	Abington	41 50 24 N	72 0 36 W	209

cACA416	Acadia NP	44 22 37 N	68 15 39 W	158
cALC188	Alabama-Coushatta	30 25 15 N	94 24 16 W	101
cALH157	Alhambra	38 52 8 N	89 37 22 W	164
cANA115	Ann Arbor	42 24 59 N	83 54 7 W	267
cANL146	Argonne NL	41 42 0 N	87 59 23 W	229
cARE128	Arendtsville	39 55 23 N	77 18 28 W	269
cASH135	Ashland	46 36 14 N	68 24 48 W	235
cBBE401	Big Bend NP	29 18 7 N	103 10 37 W	1052
cBEL116	Beltsville	39 1 42 N	76 49 1 W	46
cBFT142	Beaufort	34 53 5 N	76 37 13 W	2
cBVL130	Bondville	40 3 6 N	88 22 20 W	212
cBWR139	Blackwater NWR	38 26 42 N	76 6 41 W	4
cCAD150	Caddo Valley	34 10 46 N	93 5 55 W	71
cCAN407	Canyonlands NP	38 27 29 N	109 49 15 W	1814
cCAT175	Claryville	41 56 31 N	74 33 7 W	765
cCDR119	Cedar Creek	38 52 46 N	80 50 51 W	234
cCDZ171	Cadiz	36 47 2 N	87 50 59 W	189
cCDZ571	Cadiz Aerosol	36 47 2 N	87 50 59 W	189
cCHA467	Chiricahua NM	32 0 33 N	109 23 21 W	1570
cCHE185	Cherokee Nation	35 45 2 N	94 40 12 W	299
cCKT136	Crockett	37 55 17 N	83 3 58 W	455
cCND125	Candor	35 15 47 N	79 50 11 W	198
cCNT169	Centennial	41 21 51 N	106 14 23 W	3178
cCON186	Converse Station	34 11 38 N	116 54 46 W	1837
cCOW137	Coweeta	35 3 38 N	83 25 49 W	686
cCTH110	Connecticut Hill	42 24 2 N	76 39 13 W	501
cCVL151	Coffeeville	34 0 9 N	89 47 56 W	134
cDCP114	Deer Creek	39 38 9 N	83 15 37 W	267
cDEN417	Denali NP	63 43 32 N	148 57 47 W	661
cDEV412	Death Valley NM	36 30 33 N	116 50 53 W	125
cEGB181	Egbert	44 13 55 N	79 46 52 W	251
cESP127	Edgar Evins	36 2 19 N	85 43 59 W	302
cEVE419	Everglades NP	25 23 27 N	80 40 50 W	2
cGAS153	Georgia Station	33 10 43 N	84 24 18 W	270
cGLR468	Glacier NP	48 30 37 N	113 59 44 W	976
cGRB411	Great Basin NP	39 0 19 N	114 12 56 W	2060
cGRC474	Grand Canyon NP	36 3 34 N	112 10 55 W	2073
cGRS420	Great Smoky NP - Look Rock	35 37 59 N	83 56 31 W	793
cGTH161	Gothic	38 57 23 N	106 59 8 W	2926
cHOW132	Howland	45 12 56 N	68 42 29 W	69
cHOX148	Hoxeyville	44 10 51 N	85 44 20 W	305
cHVT424	Hawaii Volcanoes NP	19 25 10 N	155 14 24 W	1199
cHWF187	Huntington Wildlife Forest	43 58 23 N	74 13 23 W	502
cIRL141	Indian River Lagoon	27 50 57 N	80 27 19 W	2
cJOT403	Joshua Tree NM	34 4 17 N	116 23 26 W	1244
cKEF112	Kane Exp. Forest	41 35 52 N	78 46 2 W	622
cKNZ184	Konza Prairie	39 6 7 N	96 36 34 W	348
cKVA428	Kobuk Valley National Park	67 10 50 N	157 53 30 W	88
cLAV410	Lassen Volcanic NP	40 32 25 N	121 34 35 W	1756
cLCW121	Lilley C. Woods	37 7 48 N	82 59 23 W	335
cLIV573	Livonia Aerosol	38 32 4 N	86 15 38 W	299
cLRL117	Laurel Hill	39 59 16 N	79 15 5 W	615
cLYE145	Lye Brook	43 3 3 N	73 3 41 W	730
cLYK123	Lykens	40 55 2 N	82 59 53 W	303

cMAC426	Mammoth Cave NP	37 16 50 N	86 15 50 W	236
cMCK131	Mackville	37 42 16 N	85 2 54 W	353
cMEV405	Mesa Verde NP	37 11 53 N	108 29 25 W	2165
cMKG113	M.K. Goddard	41 25 37 N	80 8 42 W	384
cMOR409	Mount Rainier NP	46 45 29 N	122 7 19 W	421
cNCS415	North Cascades NP	48 32 22 N	121 26 20 W	109
cOLY421	Olympic NP	48 5 50 N	123 25 32 W	125
cONL102	Oak Ridge	35 57 36 N	84 17 24 W	180
cOXF122	Oxford	39 31 57 N	84 43 42 W	284
cPAR107	Parsons	39 5 25 N	79 39 42 W	510
cPBF129	Perryville	37 40 47 N	84 58 11 W	279
cPED108	Prince Edward	37 9 55 N	78 18 24 W	150
cPET427	Petrified Forest	34 52 30 N	109 58 9 W	1723
cPIN414	Pinnacles NM	36 29 5 N	121 9 20 W	335
cPND165	Pinedale	42 55 43 N	109 47 16 W	2388
cPNF126	Cranberry	36 6 20 N	82 2 43 W	1219
cPOF425	Poker Flats, Yukon Flats NM	65 7 4 N	147 25 59 W	495
cPRK134	Perkinstown	45 12 23 N	90 35 48 W	472
cPSU106	Penn State	40 43 14 N	77 55 54 W	378
cQAK172	Quaker City	39 56 34 N	81 20 14 W	372
cRCK163	Reynolds Creek	43 12 36 N	116 45 0 W	1198
cROM406	Rocky Mtn NP	40 16 40 N	105 32 43 W	2743
cRTP101	Res. Triangle Pk.	35 54 35 N	78 52 47 W	94
cSAL133	Salamonie Reservoir	40 48 57 N	85 39 39 W	250
cSAV164	Saval Ranch	41 17 23 N	115 51 35 W	1873
cSCR180	Scotia Range	40 47 18 N	77 56 47 W	376
cSEK402	Sequoia NP - Lookout Pt	36 25 45 N	118 45 45 W	1225
cSHN418	Shenandoah NP - Big Meadows	38 31 23 N	78 26 4 W	1073
cSIK570	Sikes	32 3 26 N	92 26 7 W	68
cSND152	Sand Mountain	34 17 19 N	85 58 11 W	352
cSPD111	Speedwell	36 28 11 N	83 49 36 W	361
cSTK138	Stockton	42 17 12 N	89 59 58 W	274
cSUM156	Sumatra	30 6 37 N	84 59 25 W	14
cTHR422	Theodore Roosevelt NP	46 53 40 N	103 22 40 W	850
cUIN162	Uinta	40 32 59 N	110 19 11 W	2500
cUVL124	Unionville	43 36 49 N	83 21 32 W	201
cVII423	Virgin Islands NP - Lind Pt	18 20 11 N	64 47 47 W	80
cVIN140	Vincennes	38 44 26 N	87 29 7 W	134
cVOY413	Voyageurs NP	48 24 46 N	92 49 45 W	429
cVPI120	Horton Station	37 19 46 N	80 33 28 W	920
cWEL149	Wellston	44 13 29 N	85 49 11 W	295
cWFM105	Whiteface Mountain	44 23 24 N	73 51 35 W	570
cWNC429	Wind Cave National Park	43 34 59 N	103 35 59 W	1300
cWPA103	West Point A	41 21 0 N	74 2 59 W	203
cWSP144	Wash. Crossing	40 18 45 N	74 52 22 W	61
cWST109	Woodstock	43 56 42 N	71 42 2 W	258
cYEL408	Yellowstone NP	44 33 34 N	110 24 2 W	2400
cYOS404	Yosemite NP - Turtleback Dome	37 42 47 N	119 42 21 W	1605
cHAR999	Harvard Forest	52 54 00 N	72 18 00 W	340

Annex 2: Questionnaire to modellers

Questionnaire for the preparation of a planning document for RETRO 40-year reanalysis simulations (D.4.1)

In order to prepare a planning document to be used for ERA40 simulations within WP4 we need to collect information for each participating model. The collected information will then be summarized at our first annual meeting and will serve as a link with other WP in order to ensure that the input data needed to run the models are being prepared and will be made available for our simulations. As a reminder participants to WP4 are MPI, KNMI, UiO and LSCE. However, other groups participating to other WPs (i.e., WP3) may join the effort in order to ensure continuity between WPs and all the RETRO models. Other groups preparing the emission data, the observations, the ERA40 reanalysis are also welcome to provide any suggestion or input comment on this task.

Participating modelers and institute

Sebastian Rast, Martin Schultz, Thomas Diehl, Claire Granier
Max Planck Institute for Meteorology, Hamburg (MPG-IMET)

Didier Hauglustaine, Yves Balkanski, Michael Schulz
Laboratoire des Sciences du Climat et de l'Environnement (LSCE)

Twan P.C. van Noije, Peter F.J. van Velthoven
Royal Netherlands Meteorological Institute (KNMI)

Jostein K. Sundet, Michael Gauss, Alf Grini
Oslo, Dept. of Geophysics (UiO)

Prof J. Pyle, Nick Savage
University of Cambridge (UCamb)

Description of the models to be used for the RETRO simulations

Model name and type (GCM, CTM):
MOZECH: MOZART-2 chemistry implemented in ECHAM5; GCM
GCM with interactive chemistry and aerosol model: **LMDz-INCA**
Tracer Model, a CTM. Unless specified otherwise, the information below is based on version **TM3**. A new version (**TM5**) is currently being developed and will become available within a few months
Oslo CTM2 (CTM)
p-TOMCAT, CTM

Horizontal and vertical resolutions (upper boundary):
T63L31 (1.8°x1.8°) or T42L19 (2.8°x2.8°) depending on availability of computing facility, upper boundary in any case: 10hPa
96x72x19 (3.75°x2.5°), 4 hPa
2.5° x 2.5° and 31 levels up to 10 hPa. (For TM5 this would become 2° latitude x 3° longitude and up to 60 levels (up to 0.1 hPa) with zooming option up to 1° x 1° regionally.)
T42 (2.8x2.8) L60 (0.1 hPa)
2.8125 x 2.8125 degrees, 31 levels to 10hPa

Advection-convection-BL diffusion schemes:
Advection : Lin & Rood flux form or semi-lagrangian, convection : Tiedtke-Nordeng, BL : surface fluxes of momentum, heat, moisture, and chemical tracers derived from Monin-Obukhov theory. Within the BL and in the free atmosphere, turbulent transfer is based on a higher-order closure scheme (Brinkop and Roeckner, 1994). Surface fluxes are calculated separately in each grid box for the three surface types (land, water, ice)
Advection: Van-Leer second order, convection: Tiedtke, BL: local 2nd order closure
Advection : slopes/second-order moments schemes, convection scheme including entrainment and detrainment in updrafts and downdrafts from Tiedke [Mon. Wea. Rev. **117**, 1779-1800 (1989)], BL : stability-dependent vertical diffusion on the basis of Holtslag and Boville [J. Climate **6**, 1825-1842 (1993)] or Louis [Boundary Layer Meteorol. **79**, 187-2002 (1979)]
Advection: Prather second order moment, convection: massflux scheme, BL: Holtslag, K-eddy diffusion
Advection: Prather 2nd order, convection: Tiedtke, BL: Holtslag&Boville adapted from CCM2

Number of species (total and transported):
63 advected species. The aerosol model needs 28 additional tracers for selected periods
CH4_AER version: 73 advected species (75 total), NMHC version: 86 advected species (88 total)
37 species, of which 22 are transported
61/51
43 total, 27 transported

Complexity of chemical schemes (number of reactions, which NMHC included, which aerosol type included):
135 reactions including 33 photolysis reactions and 1 heterogeneous reaction OX (O_3, O^1D, O^3P), N_2O, N, NO, NO_2, NO_3, HNO_3, HO_2NO_2, N_2O_5, CH_4, CH_3O_2, CH_3OOH, CH_2O, CO, OH, HO_2, H_2O_2, C_3H_6, lumped higher unsaturated hydrocarbon species, ISOP, PO_2, CH_3CHO, POOH, CH_3CO_3, CH3COOOH, PAN, ONIT, C_2H_6, C_2H_4, C_4H_{10} (represents all higher

saturated hydrocarbon species), MPAN, $ISOPO_2$, MVK, MACR, $MACRO_2$, MACROOH, MCO_3, $C_2H_5O_2$, C_2H_5OOH, $C_{10}H_{16}$ (represents all terpenes), C_3H_8, $C_3H_7O_2$, C_3H_7OOH, CH_3COCH_3, ROOH, CH_3OH, C_2H_5OH, GLYALD, HYAC, EO_2, EO, HYDRALD, RO_2, CH_3COCHO, Rn, Pb, $ISOPNO_3$, ONITR, XO_2, XOOH, ISOPOOH, H_2, O_3S, O_3INERT.

CH4_AER version: 28 photolysis, 4 heterogeneous, 87 gas phase. 4 aqueous phase. NMHC version: 51 photolysis, 4 heterogeneous, 277 gas phase. Oxidation scheme of : C_2H_6, C_3H_8, C_2H_4, C_3H_6, C_2H_2, ALKEN, ALKAN, AROM, isoprene, terpenes. Aerosols: BC, OC, S, sea-salt, dust, 3 modes: accumulation, coarse, supercoarse.

95 reactions (24 photolysis, 67 thermal, including one heterogeneous reaction for the hydrolysis of N_2O_5 on cloud and aerosol, and 4 aqueous phase). The chemical scheme is based on a modified version of Carbon Bond Mechanism 4 (CBM-4) that describes the chemistry of CH_4-CO-NMHC-NO_x [Houweling, JGR **103**, 10673-10696 (1998)] as well as NH_x, DMS and SO_x. NMHC include PAR (paraffinic carbon atoms), OLE (olefinic carbon bonds), ETH (ethene), ALD2 (acetaldehyde and higher aldehydes), MGLY (methylglyoxal), ISOP (isoprene), C2O3 (peroxyacetyl radical), ROOH (lumped organic peroxides > C_1), ORGNIT (lumped alkyl nitrates), PAN (peroxyacetyl nitrate and higher PANs). Aerosols include ammoniumsulfate ($(NH_4)_2SO_4$)ammoniumbisulfate (NH_4HSO_4) and methane sulfonic acid (MSA)

120 thermal reactions, 20 Photolytic reactions. (CO), C2H4, C3H6, C3H8, C4H10, C6H14, M-Xylene, Acetone. Natural aerosols (sea salt, minerals – no chemical interactions), anthropogenic aerosols sulfur cycle, components

89 bimolecular, 15 termolecular, 27 photolysis, NMHC: ethane and propane, No aerosol at present

Stratosphere (interactive or not, type of boundary conditions, species constrained including their origin-2D model or climatology):

Passive stratosphere, concentrations of O_3 (HALOE), NO_x, HNO_3, N_2O_5, N_2O, CH_4, CO (2D model) fixed at two topmost model layers, relaxation towards observed/2D climatology in the lower stratosphere (10 days relax. time) down to the tropopause for all species but CO and CH_4, "O3S" tracer for diagnostics of strat-trop exchange

Interactive with O_3 relaxing towards climatologies (SBUV, SAGE2) or LINOZ above 380K

Interactive stratosphere, stratospheric boundary conditions applied to ozone, methane and nitric acid (HNO_3). At levels above 50 hPa stratospheric ozone is relaxed towards the zonal and monthly mean ozone column measurements by the Total Ozone Mapping Spectrometer (TOMS) using a vertical distribution from an ozone climatology representative for the 1980's [Fortuin and Kelder, JGR **103**, 31709-31734 (1998)]. The total ozone column above 10 hPa is prescribed. The 3D ozone variability in the stratosphere is maintained by simulated transport. Stratospheric reactions are not explicitly considered. To take into account the destruction of CH_4 by reactions with Cl and $O(^1D)$ below 10 hPa, an effective methane loss rate is applied (by scaling the reaction rate of CH_4 with OH with a factor larger than unity). The methane concentration at 10 hPa is nudged towards the monthly zonal mean HALOE/CLAES climatology. Similarly, the stratospheric nitric acid concentration is fixed by prescribing the HNO_3/O_3 ratio at 10 hPa on the basis of UARS measurements

Low resolution run (T21) with stratospheric and tropospheric chemistry packages OR SynOZ/LinOZ (here NO_y is scaled to ozone)

Passive stratosphere, concentrations of ozone, methane, NO_y overwritten at top level

CPU required for a 1 year simulation with this configuration (which platform):

MOZECH: about 300 wallclock-h per year (NEC, SX-6, 7CPU in parallel, dedicated queue). It should be possible to dramatically improve the performance

VPP5000: CH4_AER 35h CPU/year; NMHC 48h CPU/year
The system we have at our disposal is a 1024-CPU SGI Origin 3800. On a single CPU of this machine a 1-year simulation at the highest resolution takes about 12 days. Once the parallel code TM5 will be available, this would results in a significant speed-up.
IBM Regatta 690, 1 cpu, 200hours
~3 days on 32 CPUs SGI Origin 3800

Have you participated to the intercomparison exercise performed under the TRADEOFF or POET projects with this very model version:
MOZART-CTM is participating in POET. New mechanism including toluene as surrogate for aromatics (currently being tested at NCAR). Implementation of online version to be completed. Interactive link to aerosol module (HAM-M7).
TRADEOFF for gas phase chemistry, AEROCOM for aerosols
TM3 was used in the TRADEOFF project
POET project
Latest model version has not participated in POET or TRADEOFF intercomparisons. A serial version of the same code has participated in both.

Participation to the RETRO simulations

ERA-40 simulations (in full or for a specific period, please specify time window):
Full ERA-40 simulations
Full ERA-40
Full ERA-40
Time slice: 1950, 1960, 1970, transient run for 1980 - 2002
Full ERA-40

ERA-15 simulations (in full or for a specific period, please specify time window):
Individual years for comparison
Full ERA-15 as test and comparison
The full ERA-15 dataset has already been used as input in TM3 simulations [e.g. Lelieveld and Dentener, JGR **105**, 3531-3551 (2000); Dentener et al., Atmos. Chem. Phys. **3**, 73-88 (2003); Dentener et al., JGR submitted (2003)]
No
Individual years for comparison

Are you planning to run additional sensitivity experiments or colored tracers simulations (please specify):
Tagged CO tracer simulations (ECHAM) with ca. 30 CO tracers (14 regions with 2 categories each) – time extent yet to be specified. First experiments with ERA-15 and ERA-40 for 1993 completed.
Colored tracers for specific years (biomass burning CO)
To be discussed
yes (sensitivity, in particular for WP5)
Aim is to complete some of the experiments suggested

Meteorological input fields

All meteorological fields mandatory to run the model (2D and 3D):
MOZECH: T, rel. vorticity, divergence, surface pressure as spectral fields
u, v, T, ps
temperature, surface pressure, specific humidity, horizontal fluxes, convective fluxes, vertical diffusion, liquid water content, ice water content, cloud fraction, cloud levels, large-scale precipitation, convective precipitation, geopotential height, aerodynamic resistance, friction velocity, 2-m temperature, surface roughness length.
T, q, vorticity, divergence, cloud cover, rain fall, Cloud Liquid Water/Ice content, convective mass fluxes (four fields), all 75 2-d surface forecast data
Vorticity, divergence, temperature, absolute humidity, surface pressure

Input file format:
MOZECH: generic binary format, 4 files (about 0.4 GB per month for the four files)
NetCDF
HDF
GRIB WMO-92
Standard ECMWF

Do you have your own access to ERA15 and ERA40 data:
yes
yes
yes
yes (we will only use ERA-40)
yes

Do you apply any processing to the ECMWF data before use in the model (including interpolation on model grid):
Processing for MOZECH: data are extracted from MARS as T106L60, then horizontally and vertically interpolated – routines are operational
Interpolation (horizontal and vertical) and GRIB to NetCDF
Mass fluxes are computed from spectral fields of vorticity, divergence and surface pressure on the basis of a consistent scheme [Bregman et al., Atmos. Chem. Phys. Discuss. **2**, 1765-1790 (2002)], which avoids the use of interpolated wind fields. This scheme was not yet implemented in the ERA-15 simulations mentioned above. Other preprocessing is applied to generate the meteorological fields mentioned above
yes, make native format based on NetCDF
Analyses processed by own code

Any request from your side to have access to missing fields:
For assessing the impact of different input data into the assimilation scheme at ECMWF, it would be important to obtain results for at least 1 year in the 1990s using no satellite data
No
No
Noo
Our boundary layer scheme has been adapted from CCM2 and uses input files for ozone, sea surface temperature, deep soil climatological temperature and surface temperature. We only have data for these from 1979-1995 and so we need to update these

Emission input data

Please specify species emitted (in particular type of NMHC and aerosols):
Acetone, C_2H_4, C_2H_6, C_3H_6, C_3H_8, C_4H_{10} (lumped higher saturated carbon hydrates), CH_2O, CH_3OH, CH_4, CO, H_2, N_2O, NO_x (as NO), isoprene, terpenes
N_2O, CH_4, H_2, CO, NO_x (as NO), C_2H_6, C_3H_8, C_2H_4, C_3H_6, C_2H_2, ALKEN, ALKAN, AROM, isoprene, terpenes, acetone, CH_2O, methanol, SO_2, DMS, BC, OC, sea-salt, dust
Anthropogenic emissions for CO, NO_x, SO_2, NH_3, CH_4 and nonmethane volatile organic compounds (NMVOC) from Van Aardenne et al. [Global Biogeochem. Cycles **15**, 909-928 (2001)], who have extended the EDGAR 2.0 database for 1990 to the period 1890-1990. In addition GEIA emissions for SO_2 and NO_x, and for CO biogenic emissions from oceans and soils, isoprene monthly emissions, NMHC yearly emissions, GEIA volcanic emissions (non-eruptive, continuous degassing only), NO_x aircraft emissions, CH_4 emissions or surface concentrations, dimethylsulfide (DMS) ocean surface water concentrations, Spiro DMS/H_2S land emissions, seasonal distribution of biomass burning and ammonia natural emissions. Hydrocarbon emissions are translated into the corresponding CBM-4 elements (PAR, OLE, ETH, ALD2, MGLY and CH2O)
C_2H_4, C_3H_6, C_3H_8, C_4H_{10}, C_6H_{14}, M-Xylene, acetone. Natural aerosols are generated in the model.
Species emitted: NO_x,CH_4,CO,HCHO,C_2H_6,CH_3CHO,C_3H_8,$(CH_3)_2CO$

Format of the input file:
NetCDF
NetCDF for gas, ASCII for aerosols
ASCII or HDF
ASCII, NetCDF
For species with a seasonal cycle this contains 3 parameters per grid cell per month to give a smooth variation from the year. We have code to produce these files offline from input files at any resolution.

Interactive emissions needed in order to run ERA40(15) and not provided by your model (lightning, mineral dust, sea-salt, biogenics):
Biogenics read from file – perhaps possible to implement interactive scheme, lightning is treated interactively (Grewe et al, 2001; Price and Rind, 1993), aerosol model HAM-M7 will be used for episodes
Lightning, dust, sea-salt interactive. Biogenics are in progress.
Biofuels, biomass burning (NO_x from lightning calculated in the model)
Possibly biomass burning
No interactive emissions needed

Stratospheric conditions

Data needed in order to run the model over the ERA40(15) period (species, format, time resolution):

O_3, NO_x, HNO_3, N_2O, N_2O_5, CH_4, CO as 2D climatological fields at pressure levels comprising the tropopause. Netcdf format

Ozone. 3D monthly fields. Netcdf format

UARS and TOMS or GOME data for O_3, HNO_3 and CH_4. These data are already available, but do not cover the full period

None

O_3, NO_y and CH_4 are currently interpolated from 2D model data at 5 day intervals onto the top level of the model

Output format

Format of model output data:
Netcdf
NetcDF
HDF
NetCDF
NetCDF.

Resolution of output data:
ca. 1.8x1.8 deg., 31 vertical levels, monthly mean fields for about 30 species, fluxes, chemical prod. and loss rates, etc. 6-h "instantaneous" concentrations of key species (about 5; need to be defined)
3.75x2.5 degrees, 19 vertical levels, 24h averaged
2^o x 3^o and maximally 60 levels
To be completed
6 hourly

Amount of data generated for a one year simulation at this resolution:
ca 720 MB for monthly fields per year for 30 species; ca 14.2 GB for 6-h output of concentration of 5 species over one year. Meteorological data: About 18.3 MB per standard output set. These numbers are valid for the T63L31 model resolution.
24h averaged, 21 GB (chemistry) + 21 GB (climate)
User-dependent
50GB
79GB

Usual post-processing tools (e.g., budget calculations):
Calculation of net-ozone tendency, tropospheric columns of CO, NO_2, and ozone
nco, IDL (HIPHOP), fortran (budgets), FERRET
IDL (HIPHOP), GrADS
none – budgets etc. are done on-line
most done on line averaging etc done off line, ad-hoc basis depending on science required

Any other information or request you may have

We need to carefully specify the diagnostics we want to intercompare/archive and see how these can be implemented (e.g. some diagnostics can't be performed on averaged data). Input data sets which are climatological data currently, but could be replaced by time dependent data if available: Leaf area index, NPP, SST, vegetation type, stratospheric aerosol, stratospheric ozone column, solar radiation at top of atmosphere, sulfate aerosol concentration and surface area of sulfate aerosol particles. (indicate what is available or could be made available for RETRO).
Common tools for extraction and format (as TRADEOFF)