MACC Global air quality services – Technical Documentation

Olaf Stein, Martin Schultz, Forschungszentrum Jülich
Johannes Flemming, Antje Inness, Johannes Kaiser, Luke Jones, Angela Benedetti,
Jean-Jacques Morcrette, ECMWF Reading

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1. Service description

The MACC global air quality services consist of daily analysis and forecasts with the coupled MACC system IFS-MOZART with data assimilation of trace gas concentrations and aerosol properties as well as reanalysis products 2003-2010 with the same system using extended data assimilation. Data are made available as data products and graphical products from ECMWF (http://www.gmes-atmosphere.eu/services/gac/) and as netcdf files for use as boundary conditions in regional AQ models world-wide and for external analysis from Forschungszentrum Jülich (http://macc.icg.kfa-juelich.de:50080). Validation of aerosol optical depth, ozone, CO and NO_2 is carried out regularly using various independent in-situ and satellite data sets.

2. Model system

IFS

MACC's core global data assimilation and forecasting capabilities are being developed from those built by GEMS and incorporated within ECMWF's Integrated Forecasting System (IFS) software. The full scientific and technical documentation of this software is available online at http://www.ecmwf.int/research/ifsdocs . This documentation is updated at approximately two-to three-year intervals. Intermediate changes are documented at http://www.ecmwf.int/products/data/technical/model_id . Some further background to the development of the ECMWF forecasting system can be found at http://www.ecmwf.int/products/data/operational_system . The web gateway to the technical specification of IFS products, including the global greenhouse-gas, reactive-gas and aerosol products from MACC, is: http://www.ecmwf.int/products/data/technical . Among the information available from the links provided on this web page are specifications of the vertical resolutions of the available three-dimensional field products. The vertical representation of most of the initial MACC products is the 60-level resolution adopted for operations at ECMWF from October 1999 to January 2006, and used also for ECMWF's ERA-40 and ERA-Interim reanalyses. This and other possible vertical resolutions are specified at: http://www.ecmwf.int/products/data/technical/model_levels . The core MACC IFS products initially come from a T159 resolution spectral model employing a ~125km (N80) "reduced points" Gaussian grid as used for the ERA-40 reanalysis and specified at:

http://www.ecmwf.int/products/data/technical/gaussian . The resolution has increased during MACC to T255 with ~80km (N128) "reduced points" Gaussian grid as used for the ERA-Interim reanalysis and specified at the same address.
IFS products are coded using the WMO FM-92 GRIB edition 1 or edition 2 standards. Software for GRIB decoding, field interpolation and plotting can be obtained from: http://www.ecmwf.int/products/data/software . Much of this software is open source and downloadable free of charge. The local tables used in the GRIB code, which include variable names and specifications of units, are listed at:
http://www.ecmwf.int/services/archive/d/table/grib_table_2_versions . The table describing the additional IFS variables for which MACC has currently made provision is table number 210: http://www.ecmwf.int/services/archive/d/parameters/order=grib_parameter/table=210 . It should be noted that this table includes some variables (such as nitrous oxide and sodium hexafluoride) that are not provided, initially at least, by the standard MACC production systems. The set of variables describing the distribution of aerosols is dependent on the aerosol model adopted by MACC. The aerosol model is expected to change during MACC from that incorporated in GEMS to a new (UKCA-mode) model. Other new output fields (such as the maximum or minimum values of model variables occurring between model output times) may be added from time to time. User requests for specific additional model outputs will be considered, and met to the extent permitted by scientific, personnel-resource and computing constraints.
The standard meteorological IFS variables are described in table number 128:
http://www.ecmwf.int/services/archive/d/parameters/order=grib_parameter/table=128. The "Ozone" and "Total column ozone" variables defined in this table are the products of the highly parameterized ozone scheme incorporated in ECMWF's standard operational meteorological production, and must not be confused with the ozone variables produced by the interactive MACC reactive-gas component, which are defined in table number 210 where they are referred to as "GMES ozone" and "GMES Total column ozone". Both types of ozone variable may be produced by a single run of the IFS.
In addition to the chemical species available from the IFS, a much richer range of species is provided by the coupled CTM model MOZART used for the main production (see section 6). These species provided may be adjusted in response to user requirements.

IFS-aerosol

The current IFS aerosol module includes 12 prognostic variables (i.e., 11 aerosol mass mixing ratios and one precursor, SO2) and it is based on the system described in Morcrette et al (2008). It includes sources for sea salt and desert dust and a representation of sedimentation, and wet and dry deposition processes. The sedimentation scheme has been modified following developments by Tompkins (2005) while the wet and dry deposition schemes were adapted directly from the LMD model (Reddy et al, 2005). All aerosol species are treated as tracers in the IFS vertical diffusion and convection schemes and are advected by the semi-Lagrangian scheme, consistently with all other dynamical fields and tracers. Five types of tropospheric aerosols are included: sea salt, desert dust, organic matter, black carbon and sulphate aerosols. Stratospheric aerosols are not included in the current configuration.

Aerosols of natural origin such as sea salt and desert dust are represented via a three-bin formulation. Bin limits for sea salt are set at 0.03, 0.5, 5 and 20 μm and for desert dust at 0.03, 0.55 0.9 and 20 μm. This ensures that approximately 10, 20 and 70% of the total mass is included in the three respective bins. For organic matter and black carbon both the hydrophobic and the hydrophilic component are modelled. Sulphates are represented as one variable. There are no gaseous chemistry parameterizations for sulphate included in this version of the model which means that the model sulphate is only in the aerosol form. A parametric conversion of SO2 to SO4 is applied with a variable e-folding time which varies between 3 and 8 days as a function of latitude.

MOZART

The MOZART chemistry transport model in MACC is based on the MOZART3 model code (Kinnison et al. 2007) which itself is an extension of the troposphere model MOZART2 (Horowitz et al. 2003) to the stratosphere and mesosphere. Some features have been added from MOZART4 (Emmons et al. 2010), while others have been introduced with the MACC model version. The current version MOZART3.5 is the global chemistry transport model (CTM) as described in Kinnison et al. (2007) with the following general updates:

- resolution T106L60, time step 300 s
- reaction rates updated to JPL2006 (Sander et al. 2006)
- SOx/NH3/NH4 chemistry adapted from MOZART4 (Emmons et al. 2010)
- detailed isoprene degradation scheme as described in Pfister et al. (2008)
- flexible emission handling, split fire emissions / other emissions
- CF-compliant netcdf output

Updates concerning the stratospheric representation:

- zero-flux tracer conditions at upper boundary
- PSC parameterisation according to method (3) described in Kinnison et al. (2007)
- Updates in the photolysis look-up-table approach
- Local conservation of inorganic chlorine and bromine has been added
- Photolysis extended to solar zenith angles up to 97 degrees
- New sulphate surface area density input files provided from the CCMVal-2 project
- New approach to derive NAT surface area density (variable radius)
- Increased particle numbers from NAT and ice PSCs

In MACC the MOZART CTM is coupled to the ECMWF integrated forecast model (IFS) building the MOZART-IFS model system. For a coupled simulation both models are running in parallel and exchange several two- and three-dimensional fields every hour using the OASIS4 coupling software developed in the PRISM project (Valcke & Redler 2006): IFS provides meteorological data to MOZART as described in table 1. Data assimilation and transport of the MACC species O_3, CO, NO_x, HCHO, and SO_2 takes place in IFS, while the whole chemical system is calculated in MOZART. At exchange time MOZART provides updated tendency terms for chemistry, emission and deposition sources and sinks for the MACC species. IFS returns the updated mixing ratio fields for these species to MOZART. Currently the coupled reanalysis and forecast experiments run in the CTM-constrained mode, which means that the feedback of tracer concentrations is only done at the beginning of a new IFS forecast run, typically every 24 hours. In feedback-mode updated MACC tracer concentrations are provided to MOZART every hour. The coupled system is described in detail in Flemming et al. (2009).

3. Simulation catalogue

The main MACC products for global chemistry and aerosols consist of the MACC forecasts with IFS-MOZART available in near-realtime (experiment ID f93i) and the MACC reanalysis with IFS-MOZART for the years 2003-2010 (experiment ID fbov) both using extensive data assimilation of O3, CO, NO2, and aerosols. Forecasts without data assimilation and forecasts with IFS-TM5 as well as a MOZART reanalysis control simulation without data assimilation complete the MACC simulation catalogue.

Exp ID	Simulation type	Data assimilation	Model Configuration	Start Date	End Date
f93i	NRT forecast	yes	IFS-MOZART	20090901	ongoing
f1kd	NRT forecast	no	IFS-MOZART	20090601	20090929
f7kn	NRT forecast	no	IFS-MOZART	20090713	ongoing
f9nd	NRT-forecast	yes	IFS-TM5	20100223	ongoing
fbov	reanalysis	yes	IFS-MOZART	20021201	20101231
ffjt	reanalysis	yes	IFS-MOZART	20040625	20050630
mozart_sa	reanalysis control	no	MOZART	20030101	(20101231)

4. Data assimilation

The aerosol analysis system is described in Benedetti et al. (2009). It is integrated in the ECMWF incremental 4D-Var and uses the total aerosol mixing ratio as control variable. The increments in total aerosol mixing ratio are distributed to the single species according to the fractional contribution to the total mass. Background error statistics for the total aerosol mixing ratio have been computed with the NMC method which computes statistics for the 48-24h forecast differences and uses those as a proxy for the background (short-range forecast) error. Assimilated observations are the Aerosol Optical Depths at 550 nm from MODIS sensor on board of the Terra and Aqua satellites. Observations are assigned a fixed error which is larger over land than over ocean. In the NRT run (f93i) there is no account of observation bias, while in the reanalysis (fbov) a variational bias correction is applied to the MODIS data. The bias model is simply a global constant for the time being.
For the assimilation reactive gases such as the CTMs MOZART-3 and TM5 were coupled to the IFS using the OASIS4 coupler to model the chemical processes and to provide the IFS with chemical production and loss rates. The background error statistics for ECMWF ozone were also used for the assimilation of the GRG ozone as part of the coupled system. The background error statistics for the other species were calculated with the NMC method.
The assimilation experiments in MACC apply averaging kernels for CO observations and use the variational bias correction scheme for ozone observations.

NRT analysis f93i

Instrument	Satellite	Provider	Version	Species	Type	Period	Status
MLS	AURA	NASA	V02	O3	Profiles	20090901 -	Active
OMI	AURA	NASA	V883	O3	Total column	20090901 -	Active
SBUV	NOAA	NOAA	V8	O3	6 layer profiles	20090901 -	Active
SCIAMACHY	Envisat	KNMI		O3	Total column	20090916 -	Active
GOME-2	MetOp-A	Eumetsat/DLR	V003	O3	Total column	20090901 -	Passive
SEVIRI	MSG	Eumetsat		O3	Total column	20090901 -	Passive
IASI	MetOp-A	LATMOS		CO	Total column	20090901 -	Active
MOPITT	TERRA	NCAR	V4	CO	Total column	20100330 -	Passive
GOME-2	MetOp-A	Eumetsat/DLR	V003	NO2	Tropospheric column	20100714 -	Passive
OMI	AURA	KNMI	V883	NO2	Tropospheric column	20090913 -	Passive
SCIAMACHY	Envisat	BIRA		SO2	Total column	20090901 -	Passive
MODIS	AQUA	NASA	Col. 5	Aerosol	Total optical depth (AOD)	20090901-	Active
MODIS	TERRA	NASA	Col. 5	Aerosol	Total optical depth (AOD)	20090901-	Active

For information on system changes regarding the data assimilation, see the log at
http://www.gmes-atmosphere.eu/about/project_structure/global/g_idas/g_idas_2/log_f93i/

MACC reanalysis fbov

Instrument	Satellite	Provider	Version	Species	Type	Period	Status
GOME	ERS-2	RAL		O3	Profiles	20030101-20030531	Active
MIPAS	Envisat	ESA		O3	Profiles	20030127-20040326	Active
MLS	AURA	NASA	V02	O3	Profiles	20040808 -	Active
OMI	AURA	NASA	V003	O3	Total column	20041001 -	Active
SBUV	NOAA-16	NOAA	V8	O3	6 layer profiles	20040101 -	Active
SBUV	NOAA-17	NOAA	V8	O3	6 layer profiles	20030101 -	Active
SBUV	NOAA-18	NOAA	V8	O3	6 layer profiles	20050604 -	Active
SCIAMACHY	Envisat	KNMI		O3	Total column	20030101 -	Active
MOPITT	TERRA	NCAR	V4	CO	Total column	20030101 -	Active
OMI	AURA	KNMI	Col. 3	NO2	Tropospheric column	20041001 -	Passive
SCIAMACHY	Envisat	KNMI	V1.1	NO2	Tropospheric column	20030101 -	Active
OMI	AURA	NASA	V003	SO2	Total column	20040817 -	Passive
SCIAMACHY	Envisat	BIRA		SO2	Total column	20040104 -	Passive
OMI	AURA	NASA	V003	HCHO	Total column	20040827 -	Passive
SCIAMACHY	Envisat	BIRA	V2	HCHO	Total column	20030101 -	Passive
MODIS	AQUA	NASA	Col. 5	Aerosol	Total optical depth (AOD)	20030101-	Active
MODIS	TERRA	NASA	Col. 5	Aerosol	Total optical depth (AOD)	20030101-	Active

For information on system changes regarding the data assimilation, see the log at
http://www.gmes-atmosphere.eu/about/project_structure/global/g_idas/g_idas_2/log_fbov/

5. Input data

The following input data is needed for simulations with the MOZART model. Most of these are described in Kinnison et al. (2007) but some have been updated or modified for use in the MACC configuration.

Emissions:

Currently the following emissions are used for NRT forecasts:

- anthropogenic and natural emissions: GEMS emissions (RETRO/REAS, GEIA), monthly resolution (Schultz et al. 2007; Stein et al. 2011)
- fire emissions: GFEDv2 emissions with 8-day resolution derived from a climatology 2003-2007 (van der Werf et al. 2006)

For the reanalysis:

- anthropogenic and natural emissions: MACC D-EMIS (MACCity) in monthly resolution (Granier et al. 2011)
- fire emissions: A modification of GFEDv3 (van der Werf et al. 2010): Within each month and 0.5 deg grid cell the GFED3.0 emissions are redistributed to daily and 0.1 deg resolution according to gridded MODIS FRP observations (exp id fagg).

Beginning with cycle 37r3 the following modifications to the MOZART standard input file setting in t106lr resolution will be introduced:

- anthropogenic and natural emissions: MACC D-EMIS (MACCity) in monthly resolution with the following modification: CO traffic emissions are multiplied with a factor of 2.5 (Stein et al. 2011)

- fire emissions: GFASv1 NRT daily emissions (Kaiser et al. 2011, exp id ffxr), last day of analysis will be used for all forecast days (fallback option for missing data: GFASv1 climatology 2003-2010)

Dry deposition velocities:
A monthly climatology from a nudged ECHAM5/MOZ simulation 1999-2008 is deployed.

Lower boundary conditions:
Several longer-lived species and species only relevant for the stratosphere are prescribed as fixed monthly mean surface mixing ratios constrained by observations. The input data has been updated for future years with the ACCMIP scenario RCP8.5 to build a data set from 1850-2100.

Upper boundary conditions:
All tracers have been set to a zero-flux condition at the upper boundary of the model domain

Sulphate:

- sulphate: sulphate mixing ratio monthly climatology
- monthly means 1850-2100 of sulphate surface area density provided from the CCMVal-2 project

Photolysis:

- short wave cross sections for 60 photolysis species and 33 wavelength intervals derived from STUV, JPL06
- long wave cross sections for 62 pressure and temperature dependent photolysis species and 67 wavelength intervals derived from STUV, JPL06
- normalized actinic flux derived from TUV, 4-stream radiative transfer
- Time-dependent solar activity conditions 1948-2140, parameters for 2009-2140 created by repeating the last 4 cycles, daily
- Observation-based solar spectra from Woods & Rottman (2002) solar model (0-420nm)

For IFS-Aerosol the following emissions are provided:
Fire emissions:
- The reanalysis (fbov) uses version 0 of the Global Fire Assimilation System (GFASv0, Kaiser et al. 2009) from 2009 onwards. For 2003-2008, the reanalysis uses a modification of version 3.0 of the Global Fire Emission Database (GFED, van der Werf et al. 2010): Within each month and 0.5 deg grid cell the GFED3.0 emissions are redistributed to daily and 0.1 deg resolution according to the gridded MODIS FRP observations produced by GFAS.
- The NRT (f93i) production uses GFASv0 emissions with daily and T159 resolution.
- The next NRT production version will use GFASv1.0 emissions and will apply the aerosol enhancement factor recommended by Kaiser et al. 2011.

For natural aerosol, the sources are instead related to model parameters: both sea-salt and dust emission depends on the 10- wind, with sea-salt emission according to Schulz et al. (2004), and dust emission following Ginoux et al. (2001) with MODIS-UV-visible albedo, soil moisture, snow and amount of vegetation used to define the areas of potential dust emission.

Sources of other anthropogenic emissions are taken from SPEW (Speciated Particulate Emission Wizard) and EDGAR (Emission Database for Global Atmospheric Research) annual mean or monthly mean climatologies.

6. Output data

6.1 NRT data (IFS-MOZART)

The following chemistry and aerosol fields from the MACC NRT forecast (experiment ID f93i) are archived at ECMWF as 3-hourly instantaneous values for four days forecast each day since 20090901:

	IFS tracer	long name	units	GRIB code (Table 210)
1	GO3	GMES ozone	kg kg-1	203
2	CO	Carbon monoxide	kg kg-1	123
3	NOx	Nitriogen oxides	kg kg-1	129
4	CH4	Methane	kg kg-1	62
5	kCH4	Methane loss rate due to radical hydroxyl (OH)	s-1	71
6	HCHO	Formaldehyde	kg kg-1	124
7	SO2	sulfur dioxide	kg kg-1	122
8	AERMR01	Sea Salt Aerosol (0.03 - 0.5 um) Mixing Ratio	kg kg-1	1
9	AERMR02	Sea Salt Aerosol (0.5 - 5 um) Mixing Ratio	kg kg-1	2
10	AERMR03	Sea Salt Aerosol (5 - 20 um) Mixing Ratio	kg kg-1	3
11	AERMR04	Dust Aerosol (0.03 - 0.55 um) Mixing Ratio	kg kg-1	4
12	AERMR05	Dust Aerosol (0.55 - 0.9 um) Mixing Ratio	kg kg-1	5
13	AERMR06	Dust Aerosol (0.9 - 20 um) Mixing Ratio	kg kg-1	6
15	AERMR07	Hydrophobic Organic Matter Aerosol Mixing Ratio	kg kg-1	7
16	AERMR08	Hydrophilic Organic Matter Aerosol Mixing Ratio	kg kg-1	8
17	AERMR09	Hydrophobic Black Carbon Aerosol Mixing Ratio	kg kg-1	9
18	AERMR10	Hydrophilic Black Carbon Aerosol Mixing Ratio	kg kg-1	10
19	AERMR11	Sulphate Aerosol Mixing Ratio	kg kg-1	11
20	AERMR12	Aerosol type 12 mixing ratio	kg kg-1	12
21 … 28	AERGN01 … AERGN08	Aerosol type 1 … 8 source	kg m-2	16 … 23
29	AERLG	Aerosol large mode mixing ratio	kg kg-1	48
30 … 41	AERLS01 … AERLS12	Aerosol type 1 …12 sink	kg m-2	31 ... 42
42	AERDEP	Dust emission potential	kg s-2 m-5	52
43	TCSO2	Total column Sulphur dioxide	kg m-2	126
44	TCCO	Total column Carbon monoxide	kg m-2	127
45	TCHCHO	Total column Formaldehyde	kg m-2	128
46	TCNOX	Total Column Nitrogen Oxides	kg m-2	130
47	GTCO3	GMES Total column ozone	kg m-2	206
48	AOD550	Total Aerosol Optical Depth at 550nm		207
49	SSAOD550	Sea Salt Aerosol Optical Depth at 550nm		208
50	DUAOD550	Dust Aerosol Optical Depth at 550nm		209
51	OMAOD550	Organic Matter Aerosol Optical Depth at 550nm		210
52	BCAOD550	Black Carbon Aerosol Optical Depth at 550nm		211
53	SUAOD550	Sulphate Aerosol Optical Depth at 550nm		212
54	AOD469	Total Aerosol Optical Depth at 469nm		213
55	AOD670	Total Aerosol Optical Depth at 670nm		214
56	AOD865	Total Aerosol Optical Depth at 865nm		215
57	AOD1240	Total Aerosol Optical Depth at 1240nm		216

These fields are archived in GRIB2 format in the MARS archive:
http://www.ecmwf.int/services/archive/d/catalog/class=rd/expver=f93i/stream=oper/type=fc/levtype=ml/

Fields archived in Jülich:

	tracer	long name	units	source	quality
1	O3	ozone	mole mole-1	IFS	assimilated and validated
2	CO	carbon monoxide	mole mole-1	IFS	assimilated and validated
3	NO	nitric oxide	mole mole-1	MOZART	no validation
4	NO2	nitrogen dioxide	mole mole-1	MOZART	validated
5	NO3	nitrate radical	mole mole-1	MOZART	no validation
6	HNO3	nitric acid	mole mole-1	MOZART	no validation
7	CH4	methane	mole mole-1	MOZART	no validation
8	CH2O	formaldehyde	mole mole-1	MOZART	no validation
9	C2H6	ethane	mole mole-1	MOZART	no validation
10	GLYOXAL		mole mole-1	MOZART	no validation
11	PAN	peroxyacetylnitrate	mole mole-1	MOZART	no validation
12	ISOP	isoprene	mole mole-1	MOZART	no validation
13	C10H16	terpenes	mole mole-1	MOZART	no validation
14	SO2	sulfur dioxide	mole mole-1	MOZART	no validation
15	SO4	sulfate	mole mole-1	MOZART	no validation
16	DMS	dimethyl sulfide C2H4S	mole mole-1	MOZART	no validation
17	NH3	ammonia	mole mole-1	MOZART	no validation
18	NH4NO3	ammonium nitrate	mole mole-1	MOZART	no validation
19	DUST 1	dust (0.03-0.55 microns)	µg m-3	IFS	assimilated as total AOD and validated
20	DUST 2	dust (0.55-0.9 microns)	µg m-3	IFS	assimilated as total AOD and validated
21	DUST 3	dust (0.9-20 microns)	µg m-3	IFS	assimilated as total AOD and validated
22	SEASALT 1	sea salt (0.03-0.5 microns)	µg m-3	IFS	assimilated as total AOD and validated
23	SEASALT 2	sea salt (0.5-5 microns)	µg m-3	IFS	assimilated as total AOD and validated
24	SEASALT 3	sea salt (5-20 microns)	µg m-3	IFS	assimilated as total AOD and validated
25	BC	black carbon	µg m-3	IFS	assimilated as total AOD and validated
26	OC	organic matter	µg m-3	IFS	assimilated as total AOD and validated
27	NOy[1]	sum of reactive nitrogen	mole mole-1	MOZART	MOZAIC validation
28	OH	hydroxyl radical	mole mole-1	MOZART	no validation
29	PV	potential vorticity	PVU	MOZART	for MOZAIC validation
30	O3DDEP	ozone dry deposition flux	kg m-2 s-1	MOZART	diagnostic validation
31	LNOx	column-integrated lightning NOx emissions	kg m-2 s-1	MOZART	diagnostic validation

[1]NOy = NO + NO2 + NO3 + 2×N2O5 + HNO3 + HO2NO2 + ClOBO2 + BrONO2

These fields are saved as 3-hourly instantaneous values and stored “somewhere” at ECMWF with fast access. From the operational run these data will be copied to Jülich and stored as netcdf files every day and can be removed from ECMWF disks after successful transfer. For safety they should be archived for about one month (for example $TEMP etc.). Script chain currently split between scripts that run at ECMWF and scripts that run in Jülich. These need to be “merged” so that the entire chain leading to CF compliant netcdf files can be run at ECMWF.

6.2 Reanalysis

The variables stored in the ECMWF MARS archive are identical to those for the NRT forecasts. Each daily reanalysis run consists of an analysis and a 24 hour forecast from which 3-hourly fields can be retrieved covering the period 20021201-20101231: http://www.ecmwf.int/services/archive/d/catalog/class=rd/expver=fbov/stream=oper/type=fc/levtype=ml/

In addition MOZART 3-hourly instantaneous output for 40 species used for validation and scientific purposes is stored as netcdf files on the ecfs archive at ECMWF and can be accessed via the ecgate access at: ec:/ecgems/GEMS/mozart_out/fbov

7. Graphical products

7.1. ECMWF

Based on the main pre-operational streams the MACC project web site is providing a range of graphical products. The web site is based on ECMWF's plots publishing framework and offers easy navigation, animation and access to plots archive.

After the completion of each of the near-real-time model runs plots of daily analyses and forecasts up to 4 days of ozone and carbon monoxide from are produced and published. These plots include global and European total column maps and surface and pressure level concentrations and are available at http://www.gmes-atmosphere.eu/d/services/gac/nrt.

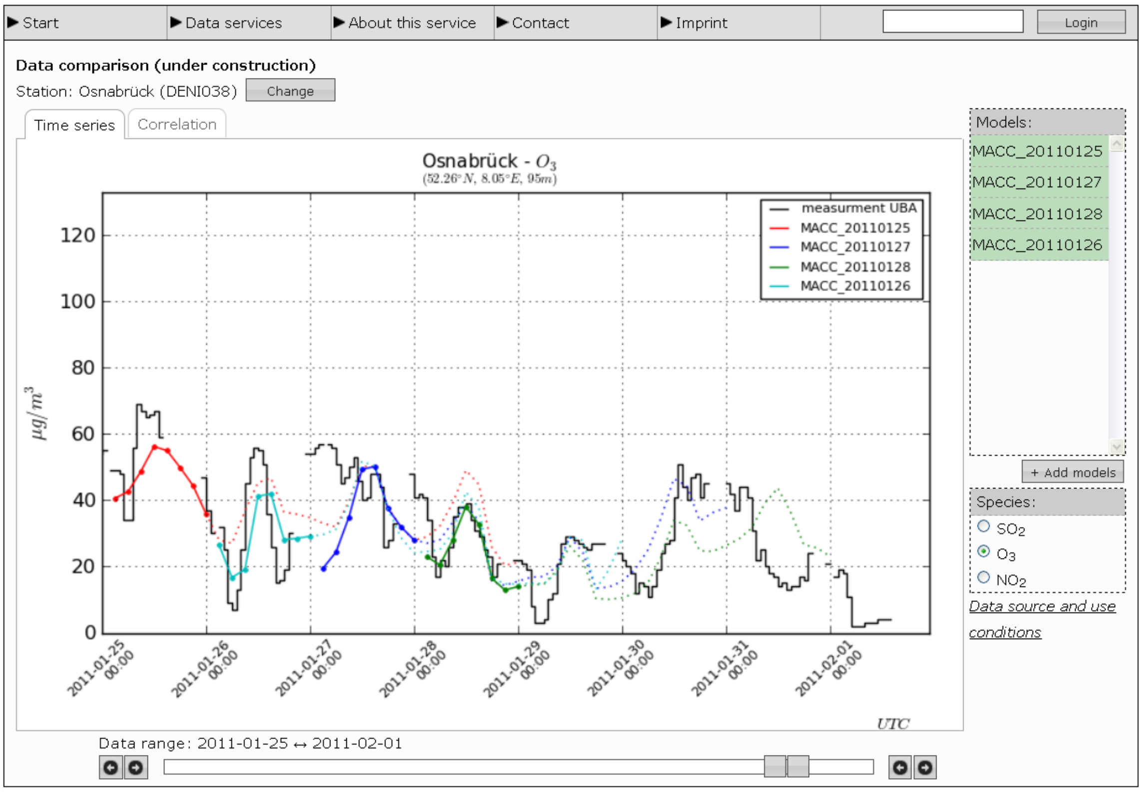
Results from the MACC reanalysis are available in form of monthly averaged fields of pressure level and surface concentrations and total columns of several chemical constituents including carbon dioxide, carbon monoxide, ozone, formaldehyde, methane, sulphur dioxide, nitrogen oxides and aerosols. There product are accessible at http://www.gmes-atmosphere.eu/d/services/gac/reanalysis/macc/ .

7.2. Field campaign support

The MACC project has provided support to the POLARCAT, HIPPO and FENNEC aircraft field campaigns by publishing near-real-time plots of atmospheric constituents on the MACC website at http://www.gmes-atmosphere.eu/services/science/campaign and http://www.gmes-atmosphere.eu/d/services/gac/fennec . These plots continue to be produced in anticipation of further observation campaigns and for general monitoring purposes. Produced are lat-lon pressure-level plots of chemical species and tracers, dust concentration and AOD, together with vertical cross-sections at chosen latitudes/longitudes for the multi-level fields.

3. Jülich graphical boundary condition service

Interactive access to the MACC data is provided via the MACC BCS web interface accessible at http://macc.icg.kfa-juelich.de:50080/ . The menu 'Data Access' can be used to open the MACC boundary condition data catalogue. By browsing the catalogue dates, geographic boundaries and variables can be selected and plotted using the interactive plotting capabilities. Finally, the model results can be compared to NRT observations. Currently only German station data from Umweltbundesamt are provided (see example below).



8. Validation

The near-real-time aerosol forecasts are verified daily against Aeronet observations and the plots are published on the MACC website at http://www.gmes-atmosphere.eu/d/services/gac/verif/aer/nrt. The plots show global bias and RMSE of AOD as a function of time and also forecast-versus-observed AOD for each site making up the global average.

The MACC tropospheric validation products for the reactive gases O_3, CO, and NO_2 are available from http://www.gmes-atmosphere.eu/services/gac/global_verification . These products comprise NRT validation of O_3 and CO with WMO GAW stations and NO2 tropospheric column validation with SCIAMACHY data. For the MACC reanalysis in addition to these products validation with MOZAIC airport profiles of O_3 and CO and evaluation against MOPITT CO data and surface CO and O_3 observations from EMEP and NOAA-GMD are available. Data from the MOZAIC successor IAGOS will be added for validation as soon as these data are available in NRT.

9. References

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