CAMS Reanalysis data documentation

Introduction

Here we document the CAMS reanalysis dataset, which, eventually, will cover the period January 2003 to near real time (NRT), though currently only data for the period 2003-2017 have been released. The CAMS reanalysis is the latest global reanalysis data set of atmospheric composition (AC) produced by the Copernicus Atmosphere Monitoring Service, consisting of 3-dimensional time-consistent AC fields, including aerosols, chemical species and greenhouse gases, though GHG fields will only be released early in 2019. The data set builds on the experience gained during the production of the earlier MACC reanalysis and CAMS interim reanalysis.

The CAMS reanalysis was produced using 4DVar data assimilation in CY42R1 of ECMWF's Integrated Forecast System (IFS), with 60 hybrid sigma /pressure (model) levels in the vertical, with the top level at 0.1 hPa. Atmospheric data are available on these levels and they are also interpolated to 25 pressure, 10 potential temperature and 1 potential vorticity level(s). "Surface or single level" data are also available.

Generally, the data are available at a sub-daily and monthly frequency and consist of analyses and 48h forecasts, initialised daily from analyses at 0 UTC.

The data are archived in the ECMWF data archive (MARS) and can be retrieved using the ECMWF Public Dataset service via the WebAPI (ECMWF Member State users can access the data using MARS directly, in the usual manner).

The IFS model and data assimilation system

The 4DVar data assimilation uses 12 hour assimilation windows from 09 UTC to 21 UTC and 21 UTC to 09 UTC.

The IFS model documentation for various model cycles can be found on https://www.ecmwf.int/en/forecasts/documentation-and-support/changes-ecmwf-model/ifs-documentation. The model used in the CAMS reanalysis includes several updates to the aerosol and chemistry modules on top of the standard CY42R1 release, which are listed below. Please note that 42r1 documentation is not available on the page, but the code for the earlier and later cycles is available for reference.

Aerosol model

- Updated aerosol optical properties, especially for organic matter (see Technical Memo 801 by Bozzo et al. 2017: "Implementation of a CAMS-based aerosol climatology in IFS").
- Bug fixes to sedimentation, which was unreasonably weak for some dust and sea-salt bins, with corresponding re-tuning of sea-salt scavenging.
- SO_2 dry deposition velocities updated to match those used in the chemistry scheme (from SUMO).
- New parametrisation of anthropogenic Secondary Organic Aerosol (SOA) production, proportional to non-biomass-burning CO emissions.
- More detailed SO_2 to sulfate aerosol conversion with dependence on temperature and relative humidity, and overall decrease in the conversion timescale especially at high latitudes.
- Increased sulfate dry deposition velocity over ocean.
- Mass fixer extended to aerosol species.
- Scaling of biomass-burning Black Carbon (BC) emissions using the ratio of BC AOD (CAMS interim reanalysis) / BC AOD (CAMS interim control run).
- 80% of SO_2 emissions are released in the two lowest model levels (as an update of tendencies) rather than at surface (fluxes)

Chemistry mechanism

The chemical mechanism of the IFS is an extended version of the Carbon Bond 2005 (CB05) chemical mechanism as implemented in CTM Transport Model 5 (TM5). In the CAMS reanalysis the model as documented in Flemming et al. (2015) and Flemming et al. (2017) is used with the following updates:

- Update of heterogeneous rate coefficients for N2O5 and HO2 based on clouds and aerosol
- Modification of photolysis rates by aerosol
- Dynamic tropopause definition based on T profile for coupling to stratosphere and tropospheric mass diagnostics

- Monthly mean VOC emissions calculated by the MEGAN model using MERRA reanalysed meteorology (Sindelarova et al., 2014) for all VOCs and for whole period 2003-2015 period.
- Bugfixes, in particular for diurnal cycle of dry deposition whose correction has decreased ozone dry deposition (about 15-20%)
- The version number for the chemistry scheme is CHEM_VER=15

Greenhouse Gases

The model configuration for greenhouse gases is based on the specification of the following components documented in the listed papers below:

- Emissions for CO2 are documented in Agusti-Panareda et al. (2014), Massart et al. (2016).
- Bias correction for CO2 ecosystem fluxes based on the Biogenic Flux Adjustment Scheme is documented by Agusti-Panareda et al. (2016)
- Emissions and loss rate for CH4 is documented in Massart et al. (2014)
- Mass fixer configuration for CO2 and CH4 is documented by Agusti-Panareda et al. (2017)

Emission datasets

The emissions datasets used to produce the CAMS reanalysis are listed in Table 1. They include the MACCity anthropogenic emission, GFAS fire emissions, MEGAN biogenic emissions and several GHG emission datasets.

Table 1: *Emission datasets used in the CAMS reanalysis*

Data set	Version/Period
MACCity anthropognic emissions	MACCity (trend: ACCMIP + RCP8.5) & CO emission upgrade Stein et al. (2014)
GFAS	v1.2: 20030101-
Dry deposition	Sumo dry deposition
VOC emissions	Monthly mean VOC emissions calculated by the MEGAN model using MERRA reanalysed meteorology (Sindelarova et al., 2014)
CO2 ocean fluxes	Takahashi et al. (2009) climatology
CO2 emissions from aviation	Based on ACCMIP NO emissions from aviation scaled to annual total CO2 from EDGAR aviation emissions.
CO2 ecosystem fluxes bias corrected with BFAS	Based on CHTESSEL (modelled online in C-IFS)
CO2 anthropogenic emissions	EDGARv4.2FT2010 (2003-2010)
CH4 wetland emissions	LPJ-HYMN climatology (Spanhi et al., 2011)
CH4 total emissions	based on EDGARv4.2FT2010 , LPJ-HYMN wetland climatology and other natural sources/sinks (2003-2010)
CH4 chemical sink	based on Bergamaschi et al. (2009) dataset
CH4 anthropogenic emissions	EDGARv4.2FT2010 (2003-2010)

Data organisation and access

The data is listed in ECMWF's public data catalogue. To access the data use the ECMWF Web API with 'dataset':'eac4'.

Users with access to MARS can also browse the data on the MARS catalogue under class=mc and expver=eac4.

Stream:

- oper: sub-daily
- mnth: synoptic monthly means
- moda:monthly means of daily means

Type:

- an: analyses
- fc: forecasts

Levtype:

- sfc: surface or single level
- pl: pressure levels
- pt: potential temperature levels
- pv: potential vorticity level
- ml: model levels

Spatial grid

The CAMS reanalysis data have a resolution of approximately 80 km. The data are available either as spectral coefficients with a triangular truncation of T255 or on a reduced Gaussian grid with a resolution of N128. These grids are so called "linear grids", sometimes referred to as TL255.

Temporal frequency

For sub-daily data for the CAMS reanalysis (stream=oper) the analyses (type=an) are available 3-hourly. The daily forecast, run from 0 UTC, has 3-hourly steps from 0 to 48 hours for the 3D model level and pressure level fields, and hourly steps from 0 to 48 hours for the surface fields.

Monthly means

Several parameters are also available as synoptic monthly means, for each particular time and forecast step (stream=mnth) and as monthly means of daily means, for the month as a whole (stream=moda).

Monthly means for analyses and instantaneous forecasts are created from data with a valid time in the month, between 00 and 23 UTC, which excludes the time 00 UTC on the first day of the following month. Monthly means for accumulations and mean rates are created from data with a forecast period falling within the month. For example, monthly means of daily means for accumulations and mean rates are created from contiguous data with forecast periods spanning from 00 UTC on the first day of the month to 00 UTC on the first day of the following month.

Data format

Model level fields are in GRIB2 format. All other fields are in GRIB1, unless otherwise indicated.

Level listings

Pressure levels: 1000/950/925/900/850/800/700/600/500/400/300/250/200/150/100/70/50/30/20/10/7/5/3/2/1

Potential temperature levels: 300/315/320/330/350/370/395/475/600/850

Potential vorticity level: 2000

Model levels: 1/to/60, which are described at https://www.ecmwf.int/en/forecasts/documentation-and-support/60-model-levels.

Parameter listings

The archive of available parameters can be browsed here.

Satellite Data

The atmospheric composition satellite retrievals used as input into the CAMS reanalysis are listed below. The following abbreviations are used in Table 1. TC: Total column, TRC: Tropospheric column, PROF: profiles, PC: Partial columns, ColAv: Column average mixing ratio, QR= quality flag given by data providers, SOE: Solar elevation, MODORO: Model orography, PRESS_RL= pressure at bottom of layer, LAT: Latitude.

Table 2: *Satellite retrievals of atmospheric composition that were assimilated in the CAMS reanalysis*

Parameter	Instrument	Satellite	Product	Period	Data provider/ Version	Blacklist Criteria (i.e. these data are not used)	Averaging kernels used
O3	SCIAMACHY	Envisat	TC	20020803-20120408	ESA, CCI (BIRA)	QR>0 SOE<6	no
O3	MIPAS	Envisat	PROF	20030127- 20040326 20050127-20120331	ESA, NRT ESA, CCI (KIT)	 QR>0 for CCI data	no
O3	MLS	Aura	PROF	20040803-20180312 NRT: 20180313-	NASA, V4	QR>0	no
O3	OMI	Aura	TC	KNMI reproc: 20041001-20150531 NRT:20150601-	KNMI/NASA, V003	QR>0 SOE<10	no
O3	GOME-2	Metop-A	TC	20070123-20121231 201301-201612 NRT:20170101-20181231	ESA, CCI (BIRA), fv0100 ESA, CCI (BIRA), fv0300	QR>0 SOE<10	no
O3	GOME-2	Metop-B	TC	201301-201612 NRT: 20170101-	ESA, CCI (BIRA), fv0300	QR>0 SOE<10	no

O3	SBUV/2	NOAA-14	PC 13L	200407-200609	NASA, v8.6	QR>0 SOE<6 MODORO > 1000. and PRESS_RL > 450.	no
O3	SBUV/2	NOAA-16	PC 13L PC 13L PC 21L	200301-200706 20111201-20130708 NRT: 20130709-201406	NASA, v8.6	QR>0 SOE<6 MODORO > 1000. and PRESS_RL > 450.	no
O3	SBUV/2	NOAA-17	PC 13L	200301-201108	NASA, v8.6	QR>0 SOE<6 MODORO > 1000. and PRESS_RL > 450.	no
O3	SBUV/2	NOAA-18	PC 13L	200507-201211	NASA, v8.6	QR>0 SOE<6 MODORO > 1000. and PRESS_RL > 450.	no
O3	SBUV/2	NOAA-19	PC 13L PC 21L	200903-20130708 NRT: 20130709-	NASA, v8.6	QR>0 SOE<6 MODORO > 1000. and PRESS_RL > 450.	no
CO	MOPITT	Terra	TC	20020101-20161231 NRT: 2017010-	NCAR, V6 (TIR)	LAT>65. LAT< -65 QR>0 Night time data over Greenland	yes
NO2	SCIAMACHY	Envisat	TRC	20030101-20101231 20110101-20120409	KNMI V1p KNMI V2	QR>0 SOE<6 LAT>60 LAT< -60	yes
NO2	OMI	Aura	TRC	20041001-20101231 20110101-20121231 NRT: 20130101 -	KNMI, COl3 KNMI, Domino KNMI NRT	QR>0 SOE<6 LAT>60 LAT< -60	yes
NO2	GOME-2	Metop-A	TRC	20070418-20171106 NRT:20171112-	AC SAF, GDP4.8	QR>0	yes
NO2	GOME-2	Metop-B	TRC	201301-20171106- NRT: 20171112-	AC SAF, GDP4.8	QR>0	yes
AOD	AATSR	Envisat	TC	20021201-20120331	ESA, CCI (Swansea)	abs(LAT)> 70	no
AOD	MODIS	Terra	TC	20021001-20161231 NRT: 20170101-	NASA, COl6	abs(LAT)> 70	no
AOD	MODIS	Aqua	TC	20021001-20161231 NRT: 20170101-	NASA, Col6	abs(LAT)> 70	no
CO2	SCIAMACHY	Envisat	ColAv	20030101-20120324	ESA CCI (Bremen)	QR>0	yes
CO2	IASI	Metop-A	ColAv	20070701-	LMD v8.0	MODORO > 6000	yes
CO2	IASI	Metop-B	ColAv	20130201-	LMD v4.0	MODORO > 6000	yes
CO2	Tanso	GOSAT	ColAv	20090601-	ESA CCI (SRON)	QR>0	yes
CH4	SCIAMACHY	Envisat	ColAv	20030108-20120408	ESA CCI (SRON) v7.0	MODORO > 6000 QR > 0	yes
CH4	IASI	MetoP-A	ColAv	20070701-	LMD V8.3	MODORO > 6000 LAT<-60. and LSMASK = land	yes
CH4	IASI	Metop-B	ColAv	20130201-	LMD V8.1	MODORO > 6000 LAT<-60. and LSMASK = land	yes
CH4	Tanso	GOSAT	ColAv	20090601-	ESA CCI (SRON)	QR > 0	yes

Validation reports

Validation Reports for the CAMS reanalysis can be found on the CAMS Quality Assurance website.

Guidelines

The following advice is intended to help users understand particular features of the CAMS reanalysis data:

- Users who want to use meteorological data only are advised to use the ERA5 meteorological reanalysis.
- CAMS data users please use the **'GEMS Ozone'** (param 210203) and **'Total Column GEMS Ozone'** (param 210206) fields. These are produced specifically for CAMS using the full tropospheric chemistry scheme, see also CAMS Global data: What is "GEMS ozone".

Known issues

At the time of writing (2017-11) we are aware of these issues with the CAMS reanalysis:

- Validation of AOD with Aeronet data has show there are some hot spots around outgassing volcanoes (in particular Mauna Loa and Mexico City) with high analysis AOD values that degrade the global average RMSE. If calculating global mean statistics it is advisable to exclude those two stations as unrepresentative. This is a side effect of model-resolution orography not resolving the height of the volcanoes that has been unmasked by recent enhancements to the SO2 oxidation scheme which improve aerosol on the global scale.
- During 2003 the ozone analysis has a degraded quality (bigger biases with respect to observations) in Arctic and Antarctic free troposphere because MIPAS and SCIAMACHY data of lower quality were assimilated.
- Between March-August 2004 no ozone profile data were available for assimilation. This affects the vertical structure of the ozone analysis and we see larger biases wrt ozone sondes, especially in the Antarctic.
- From 2013 onwards there is a larger seasonally varying bias in ozone in the free troposphere, particularly in the Arctic and Antarctic that is not seen in the control run. The reason for this bias is a change in the observing system, namely the change from 13-layer SBUV/2 data to 21-layer SBUV/2 data in July 2013 (see Table 2) that unfortunately has an impact on tropospheric ozone. A similar bias is seen in the NRT CAMS ozone analysis which also uses the 21-layer SBUV/2 data after 2013.
- During 2003 the seasonal cycle of the tropospheric column NO2 is not well represented because of the assimilation of SCIAMACHY NO2 data of degraded quality.
- The use of the NOx variable from the CAMS reanalysis (as well as from the CAMS interim re-analysis and the CAMS operational system) is not recommended. The user is advised to download NO and NO2 separately and to add them up. Please note that a conversion of the mass mixing ratios [kg/kg] to volume mixing rations / molar fractions [mol/mol] is needed to do this in a meaningful way.

This list will be updated as we become aware of further issues in the CAMS reanalysis.

How to cite the CAMS Reanalysis

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References

A reference paper is available from www.atmos-chem-phys.net/19/3515/2019/ and further CAMS reanalysis references will be available from the ECMWF e-Library in the future.

An ECMWF newsletter article '***The new CAMS global reanalysis of atmospheric composition***' is available from: https://www.ecmwf.int/node/18821

Mailing list

To be kept informed of the latest news associated to the CAMS Reanalysis products, you may subscribe to the CAMS Global Reanalysis mailing list.

Related articles

- CAMS Reanalysis data documentation
- Regional (European) CAMS data: Convert from GRIB2 to NetCDF
- CAMSiRA, the CAMS interim Reanalysis
- FTP access to CAMS GFAS data

- FTP access to CAMS global data