SPECIAL PROJECT PROGRESS REPORT

Reporting year	2017/2018
Project Title:	Copernicus Atmospheric Monitoring Service – Air Quality and Composition – Regional Component (CAMS_50)
Computer Project Account:	SP DEFRIU
Principal Investigator(s):	Hendrik Elbern
Affiliation:	Rhenish Institute for Environmental Research at the University of Cologne (RIUUK)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Vincent Henry Peuch
Start date of the project:	January 2018
Expected end date:	December 2020

Computer resources allocated/used for the current year and the previous one

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	2,800,000	2,600,000	3,500,000	1,250,000
Data storage capacity	(Gbytes)	4,500	6,300	7,500	3,100

Summary of project objectives

Copernicus Atmosphere Monitoring Service (CAMS, atmosphere.copernicus.eu) is establishing the core global and regional atmospheric environmental service delivered as a component of Europe's Copernicus program. The service provides continuous data and information on atmospheric composition. The service describes the current situation, forecasts the situation a few days ahead, and analyses consistently retrospective data records for recent years. CAMS has been developed to support policymakers, business and citizens with enhanced atmospheric environmental information. These services, which achieved an operational status in 2015, are the result of more than ten years of pilot and active research projects (PROMOTE, GEMS, MACC (I-III)). The Rhenish Institute for Environmental Research at the University of Cologne (RIUUK) plays an active role in sub-project CAMS_50, which is the regional air quality component of CAMS.

Summary of problems encountered

None

Summary of results of the current year (from July of previous year to June of current year)

The delivery of the European-scale air quality data within CAMS_50 is based upon a geographically distributed ensemble of 7 individual models under the lead of Meteo France. RIUUK provides a member of this ensemble with its comprehensive chemistry transport model EURAD-IM (Elbern et al., 2007). Three data streams are provided:

- on a daily basis, hourly analyses for the previous day and forecasts up to + 96 h;
- with a delay of a few weeks (in order to maximise the number of observations) interim re-analyses are produced daily with systems frozen in their configuration of January 1st every year;
- with a delay of up to 2 years (due to the delay in getting fully validated data), re-analyses are processed with frozen systems, which are only updated every few years.

An important component of CAMS 50 is the further development of the individual air quality forecast models and of the data assimilation systems. Subject of this progress report are the further developments of EURAD-IM in the frame of CAMS_50 during the reporting period from July 2017 to June 2018.

Assimilation of IAGOS data (O_3, NO_2, CO)

In-service Aircraft for a Global Observing System (IAGOS) is a European Research Infrastructure for global observations of atmospheric composition from commercial aircraft. In order to provide optimal information, two complementary systems have been implemented, (i) IAGOS-CORE providing global coverage on a day-to-day basis of key observables and (ii) IAGOS-CARIBIC providing a more in-depth and complex set of observations with lesser geographical and temporal coverage.

IAGOS-CORE cooperates with several airlines for quasi-continuous measurements of trace gases, aerosol and cloud particles from a fleet of long-haul passenger aircraft. Each aircraft is equipped with the IAGOS-CORE rack which contains all necessary provisions for installing fully automated instruments for the measurement of ozone, carbon monoxide, humidity (ICH) and cloud particles (BCP). For the second instrument several options have been developed: measurements of total odd nitrogen (NOy), nitrogen oxides (NOx), aerosol, or greenhouse gases (CO2 and CH4). Only one option can be installed at a time in a given aircraft. By November 2016, seven aircraft are flying with the IAGOS-CORE installation.

One AIRBUS A340-600 operated by Lufthansa carries provisions for operation of the IAGOS-CARIBIC Flying Laboratory, a modified cargo container with state-of-the-art instruments for in-situ and remote sensing measurements and provisions for the collection of whole air and aerosol samples. In-situ measurements include ozone, water vapor, cloud water/ice, carbon monoxide, carbon dioxide, methane, nitrogen oxides, mercury, aerosol, soot, volatile organic compounds, and optical measurements of sulfur dioxide and formaldehyde. Operation of the container is discontinuous with 10-12 deployments per year, each for four consecutive long-haul flights.

The assimilation of O_3, CO, and NO_2 from IAGOS and IAGOS-CARIBIC has been implemented in EURAD-IM in CAMS 50 configuration. Figure 1 exemplary shows EURAD-IM model results and measurements of an IAGOS instrument onboard of an Airbus A340-313 for flights between Düsseldorf (DUS) and New York (EWR). Large differences between the O_3 background and observations at upper atmospheric levels are due to the initialisation of the model runs with climatological O_3 profiles. However, the assimilation was successful. The qualitative impact of the IAGOS data assimilation on O_3 model concentrations in the upper troposphere is depicted in Figure 2.

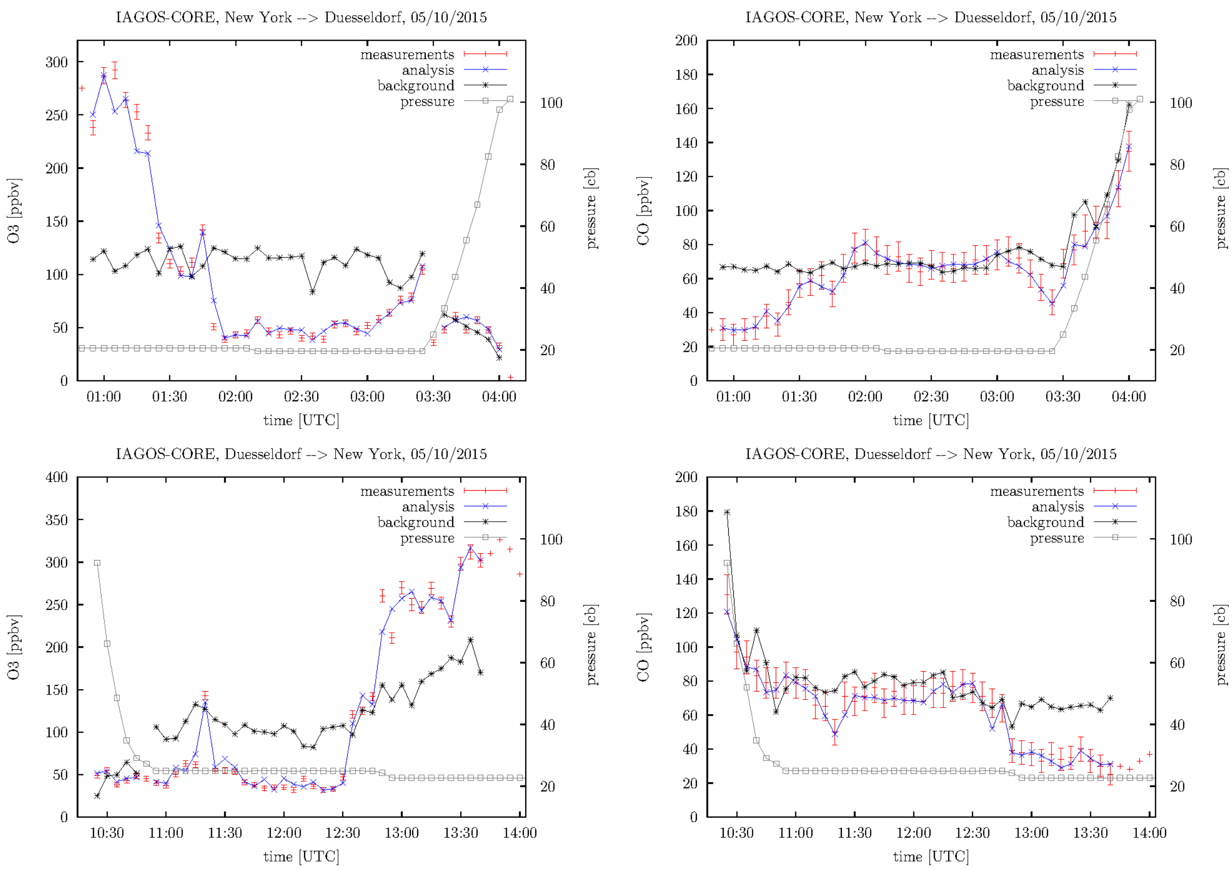


Figure 1: time-series of O_3 (left) and CO (right) for the flight of an Airbus A340-313 from New York (EWR) to Düsseldorf (DUS) (above) and for the flight back (below) on October 10, 2015. Black: EURAD-IM background run without any data assimilation, blue EURAD-IM analysis, red: IAGOS measurements of the air pollutants, grey: IAGOS pressure measurements.

The CAMS 50 geographical region of interest is temporally and spatially very sparsely covered by IAGOS measurement data. Nevertheless we intend to assimilate IAGOS data at least in the EURAD-IM validated re-analysis because IAGOS provides one of the rare in situ data sets, which is routinely available for upper atmospheric levels.

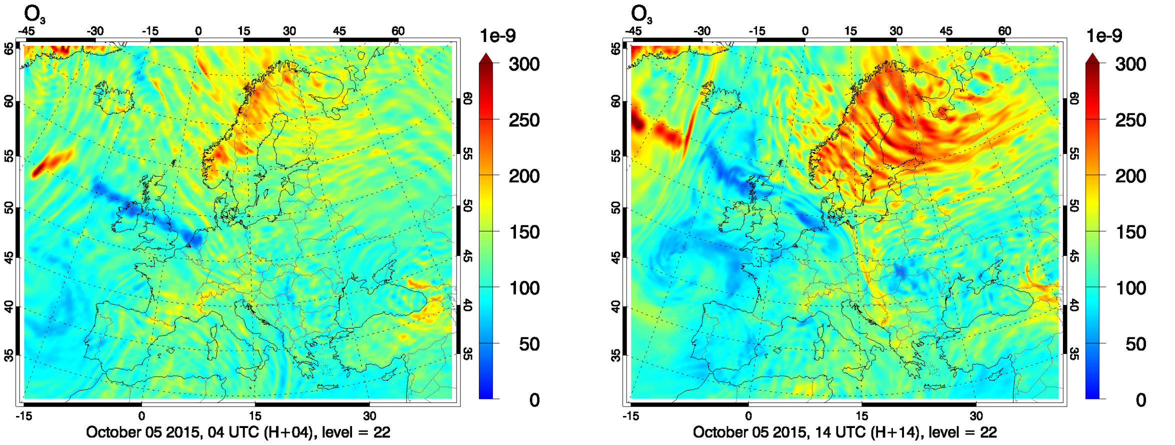


Figure 2: EURAD-IM O_3 analysis at flight level for the flight of an Airbus A340-313 from New York (EWR) to Düsseldorf (DUS) (left) and for the flight back (right) on October 10, 2015. The flight track intersects the western model boundary between 55° and 60° north. Concentrations significantly higher than the background concentration on the western part of the flight track and lower than the background on the eastern part of the flight track show the qualitative impact of the assimilation of IAGOS O_3 data.

Assimilation of SO_2 column retrievals from OMI and GOME-2

Atmospheric sulphur dioxide (SO_2) has significant impacts on the Earth atmosphere. Generated by natural (e.g. degassing and eruptions of volcanoes, sea spray) as well as anthropogenic sources (e.g. combustion processes), it forms sulphate aerosols that influence climate and weather, leads to acid deposition through formation of sulfuric acid and due to its toxicity it negatively affects human health, when present in high concentrations at surface. Monitoring and forecasting the dispersal of volcanic clouds during an eruption is also of importance for ensuring aviation safety. Overall, SO_2 and ash are likely to follow the same trajectory if emitted at similar injection heights. As SO_2 is the most easily detected species from space, SO_2 is often taken as a convenient indicator of the likely presence of ash.

In August 2014 a six-month lasting fissure eruption started related to the Bardarbunga volcano system on Iceland. The eruption was characterized by a significant release of sulphur dioxide (SO_2) into the lower troposphere. On September 21, 2014 several European measurement sides recorded extremely high SO_2 concentrations at ground level due to the remote transport of sulphur dioxide rich air from the Bardarbunga towards continental Europe.

Gome-2 and OMI SO_2 total column retrievals have been assimilated hourly with the 3d-var technique for the period September 18 to 22, 2014. EURAD-IM has been used in CAMS_50 configuration. Results for September 21, 2014 are depicted in Figure 3 for the Gome-2 satellite instrument. For this analysis SO_2 concentration retrievals with a center of mass altitude of 2.5 km were used for the assimilation procedure due to the low elevation height of the vent (~700 m asl) and relatively low plume heights of the effusive eruption. The analysis exhibits a considerable correction of EURAD-IM SO_2 values towards the observations. However, a more detailed investigation of the vertical SO_2 distribution obtained in the analysis is necessary.

The assimilation of SO_2 vertical column concentration retrievals from GOME-2 and OMI show on the first sight a capability to improve EURAD-IM performance at least in case of volcanic eruption. Because the applied SO_2 column concentration retrievals from GOME-2 as well as from OMI are available in near real time, they could be useful for the EURAD-IM analysis as well as interim re-analysis.

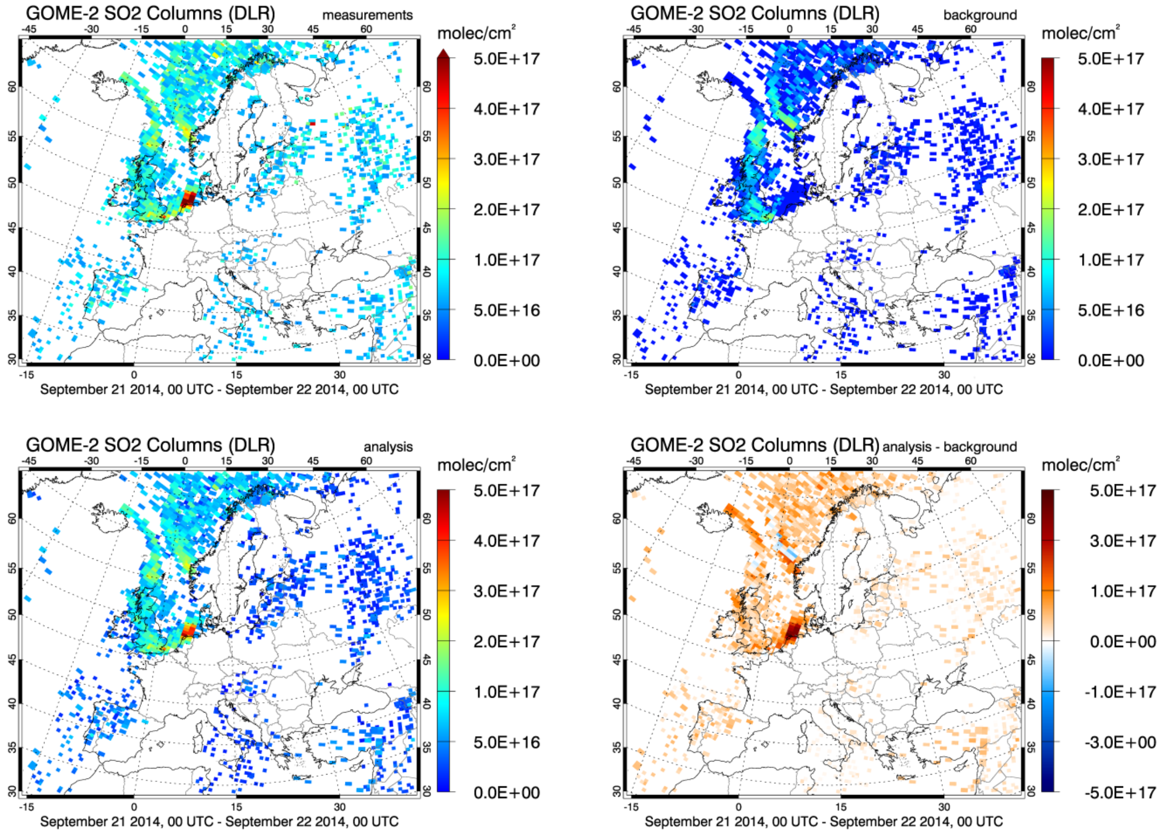
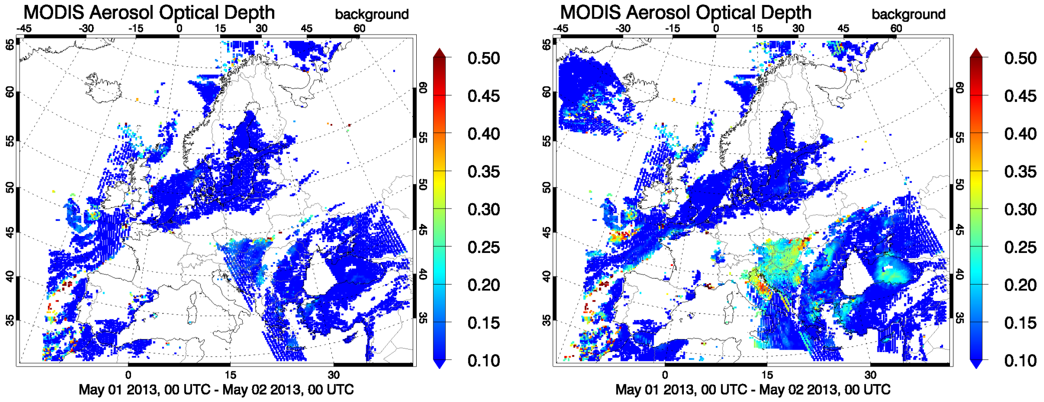


Figure 3: SO_2 total column concentrations at September 21, 2014. Upper left: Gome-2 SO_2 total column concentration retrieval, Upper right: EURAD-IM forecast, lower left: EURAD-IM analysis, lower right: analysis minus forecast.

Assimilation of MODIS AOD data over land

The MODIS *AOD 550 Dark Target Deep Blue Combined* retrieval from the Terra and Aqua satellites has been assimilated hourly with the 3d-var technique for the period April 25 to Mai 7, 2013. EURAD-IM has been used in the configuration currently used for the operational CAMS_50 analysis. Results are depicted in Figure 4. The analysis exhibits a considerable correction of EURAD-IM AOD values towards the observations. Compared to the assimilation of the Dark Target retrieval alone (*Aerosol Optical Depth Land and Ocean* retrieval) larger areas with high aerosol content are covered. However, the operational implementation of the MODIS AOD data assimilation depends on an independent validation with surface in situ observations over an extended period.



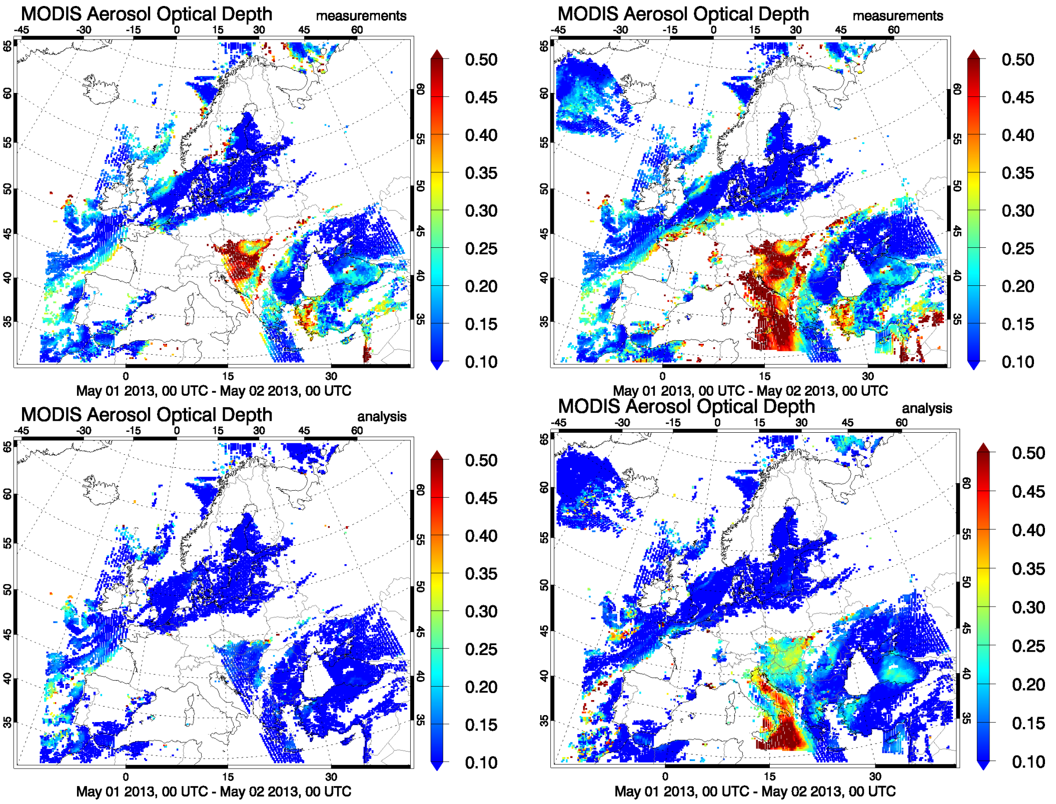


Figure 4: MODIS Aerosol Optical Depth Land and Ocean (left) and AOD 550 Dark Target Deep Blue Combined (right) retrievals from the Terra and Aqua satellites for May 1, 2013. Top: model equivalent of the EURAD-IM forecast, middle: MODIS measurements, bottom: model equivalent of the EURAD-IM analysis.

Assimilation of MOPITT CO NRT data

MOPITT CO data has been repeatedly assimilated in the EURAD-IM CAMS_50 re-analysis. Since 2017 MOPITT CO data is deployed in near-real time via the NASA LANCE system. This opportunity has been used to enable the assimilation of MOPITT CO profiles also for the EURAD-IM CAMS_50 analysis. The download of MOPITT data has been operationalised and the data was assimilated in EURAD-IM in its operational configuration for the Episode January 3 to 16, 2018. A reference run with EURAD-IM in CAMS_50 configuration was performed with the assimilation of CAMS NRT surface in situ data, OMI and GOME-2 NO_2 and SO_2 column retrievals and IASI CO partial columns. CO surface in situ observations were held back from assimilation for an independent validation. In a sensitivity run MOPITT CO profiles were additionally assimilated. Figure 5 shows assimilation results for January 12.

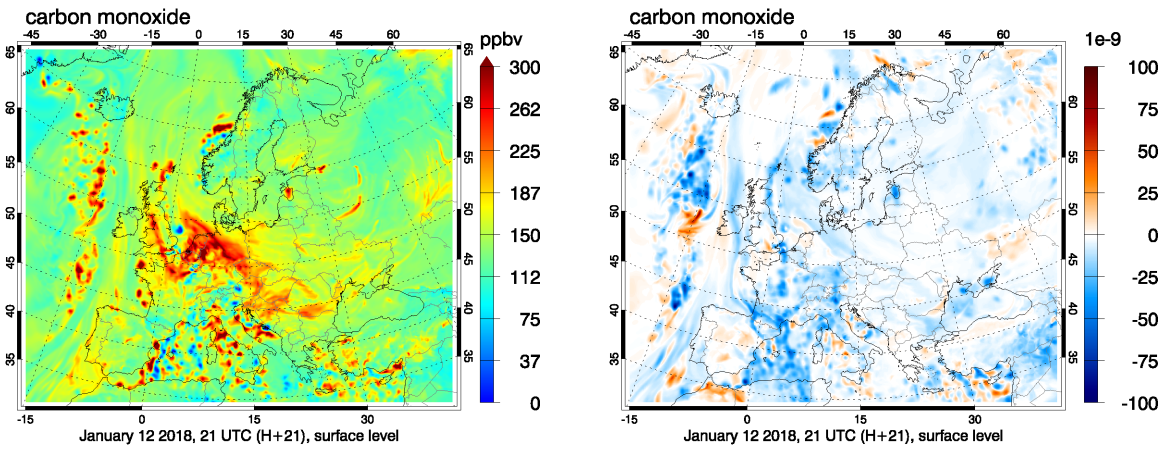


Figure 5: CO concentration in the lowest model layer over Europe for January 12, 2018 at 21:00 UTC. Left: EURAD-IM analysis in the current operational configuration (reference run). Right: difference between the reference run and a EURAD-IM analysis with the additional assimilation of MOPITT CO profiles.

Figure 6 depicts CO time series averaged over surface measurement sites held back from assimilation. The impact of the assimilation of MOPITT CO profiles on the assimilation results is very small. Potentially this is caused by the very cloudy weather condition over Europe in January 2018. However, the assimilation of NRT MOPITT CO profiles is ready for operational implementation.

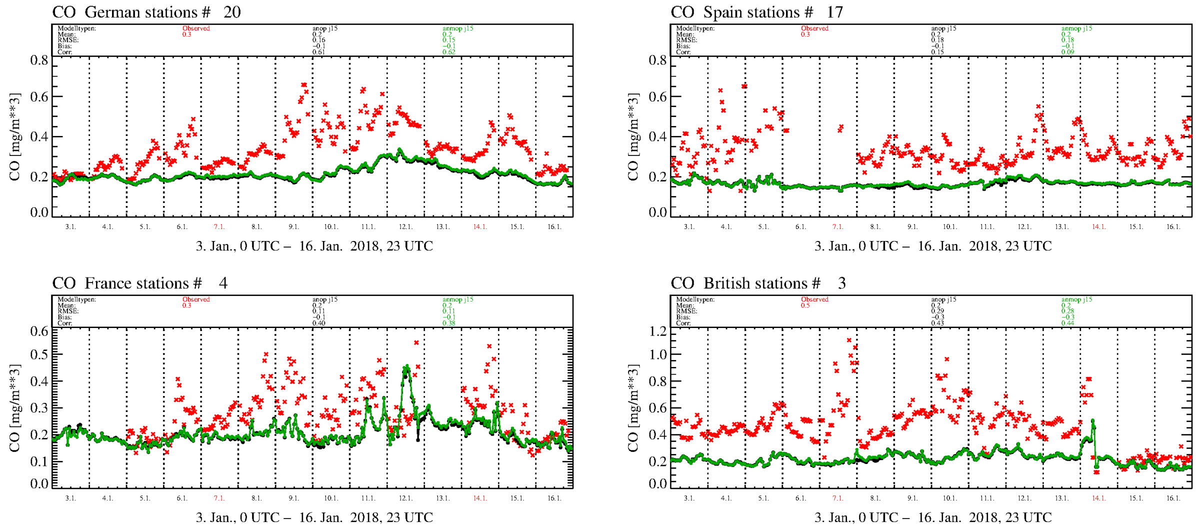


Figure 6: CO time-series for January 3 to 16, 2018 averaged over CAMS NRT surface in situ measurement sites in Germany (upper left), Spain (upper right), France (lower left), and United Kingdom (lower right). Black: EURAD-IM analysis in current operational configuration, green: analysis with additional assimilation of MOPITT CO profiles, red: measurements. All measurements were held back from assimilation.

List of publications/reports from the project with complete references

Sofiev, M., Ritenberga, O., Albertini, R., Arteta, J., Belmonte, J., Bonini, M., Celenk, S., Damialis, A., Douros, J., Elbern, H., Friese, E., Galan, C., Gilles, O., Hrga, I., Kouznetsov, R., Krajsek, K., Parmentier, J., Plu, M., Prank, M., Robertson, L., Steensen, B. M., Thibaudon, M., Segers, A., Stepanovich, B., Valdebenito, A. M., Vira, J., and Vokou, D.: Multi-model ensemble simulations of olive pollen distribution in Europe in 2014, Atmos. Chem. Phys., 17, 12341-12360, 2017.

Summary of plans for the continuation of the project

In October 2018 CAMS_50 will enter the second phase. The development activities in CAMS_50.II aim at the introduction of relevant evolutions into the regional air quality models in order to keep the regional production at the state of the art level of quality. New developments will be mostly driven by requirements of the ITT, user requirements, evolutions of the input data stream (IFS, boundary values, emission inventories), developments coming from own research and collaborations, and outcomes from the research and development component of CAMS (CAMS_61 ITT).