SPECIAL PROJECT PROGRESS REPORT

Reporting year 2016/2017

Project Title: Monitoring Atmospheric Composition and Climate - Phase 3 (MACC-III)

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-Henri Peuch

Start date of the project: July 2014

Expected end date: December 2017

Computer resources allocated/used for the current year and the previous one (if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	2,600,000	2,100,000	2,800,000	1,350,000
Data storage capacity	(Gbytes)	4,300	6,600	4,500	3,200

Summary of project objectives

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. CAMS 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. The Rhenish Institute for Environmental Research at the University of Cologne (RIUUK) plays an active role in sub-project CAMS50, which is the regional air quality component of CAMS.

Summary of problems encountered

None

Summary of results of the current year

The delivery of the European-scale air quality data in CAMS50 is based upon a geographically distributed ensemble of 7 individual air quality 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 in CAMS50:

- 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.

1. Further development of the EURAD-IM mineral dust forecast

In case of a Sahara dust outbreak towards Europe, mineral dust concentrations are probably under estimated by the EURAD-IM forecasting system. The aim of this activity was an improvement of the EURAD-IM skills in such situations. The impact of two measures on the EURAD-IM Sahara dust forecast has been investigated.

1.1 Activation of the EURAD-IM mineral dust emission module
DREAM (Nickovic et al., 2001) is used in the EURAD-IM CTM for the computation of the mineral dust emission source strength. Figure 1 shows a comparison of PM_{10} concentrations obtained from forecasts with EURAD-IM in the current operational configuration and with DREAM enabled.

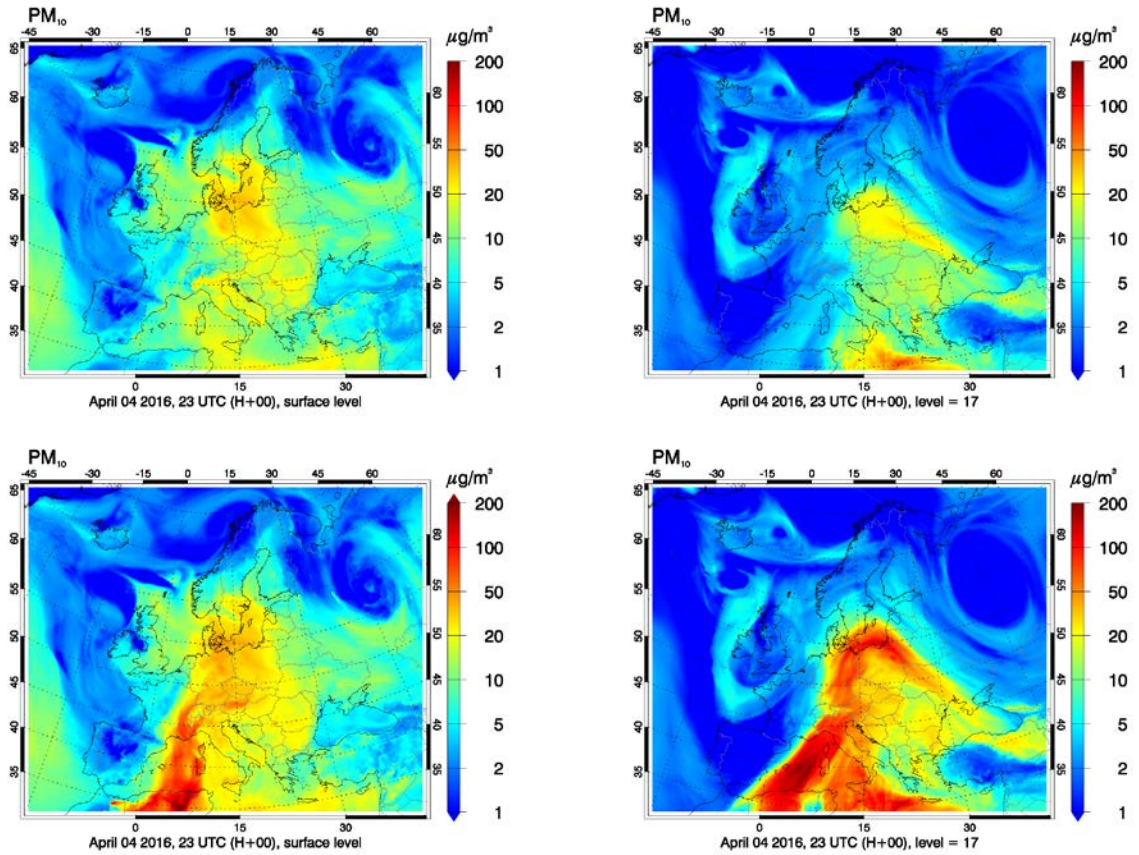

Figure 1: PM_{10} concentration at April 4, 2016. Upper panel: EURAD-IM forecast in the current operational configuration, lower panel: EURAD-IM forecast with the additional application of mineral dust emissions from DREAM. Left: surface level, right: level 17, approximately 3000 m height.

The performance of DREAM in EURAD-IM forecasts has been evaluated for two mineral dust episodes: from April 25 to Mai 7, 2013 and from March 29 to April 7, 2016. The evaluation shows that the application of DREAM significantly reduces the negative bias of EURAD-IM PM_{10} forecasts during mineral dust events, compared to the current operational configuration of the EURAD-IM forecast without mineral dust emissions from DREAM. This is depicted in terms of averaged PM_{10} and $PM_{2.5}$ time-series in Figures 2 and 3. At least for the period in 2013, $PM_{2.5}$ is less influenced by mineral dust events than PM_{10} in the model simulations. May be this is a result of the representation of mineral dust in the EURAD-IM CTM by coarse mode particles only. Due to the large-scale nature of mineral dust events, the application of DREAM could improve the aerosol forecast independent of station characteristics.

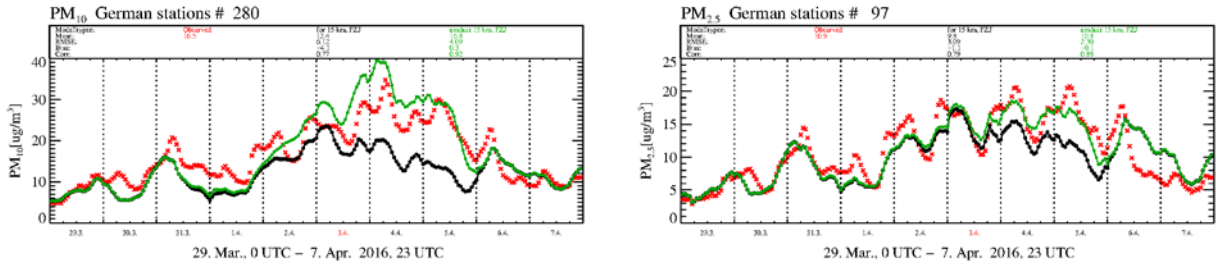

Figure 2: PM_{10} (left) and $PM_{2.5}$ time-series averaged over available stations from the German Umweltbundesamt for March 29 to April 7, 2016. Black: EURAD-IM forecast in the current operational configuration (aerosol boundary values from the global C-IFS forecast applied), green: EURAD-IM forecast with the additional application of mineral dust emissions from DREAM, red: observations.

1.2 Assimilation of MODIS AOD retrievals to improve PM forecasts

For the mineral dust episode from April 25 to Mai 7, 2013 the impact of an AOD analysis on the forecast performance has been investigated. For this episode the MODIS Aerosol Optical Depth Land and Ocean of MOD04 L2 retrieval from the Terra and Aqua satellites has been assimilated

with EURAD-IM in the configuration, which is currently used for the operational analysis (hourly 3d-var). Results from this analysis were taken as initial values for a forecast with mineral dust emissions from DREAM enabled. Generally, the application of initial values from the AOD analysis can further improve the EURAD-IM performance during mineral dust events (see Figure 3).

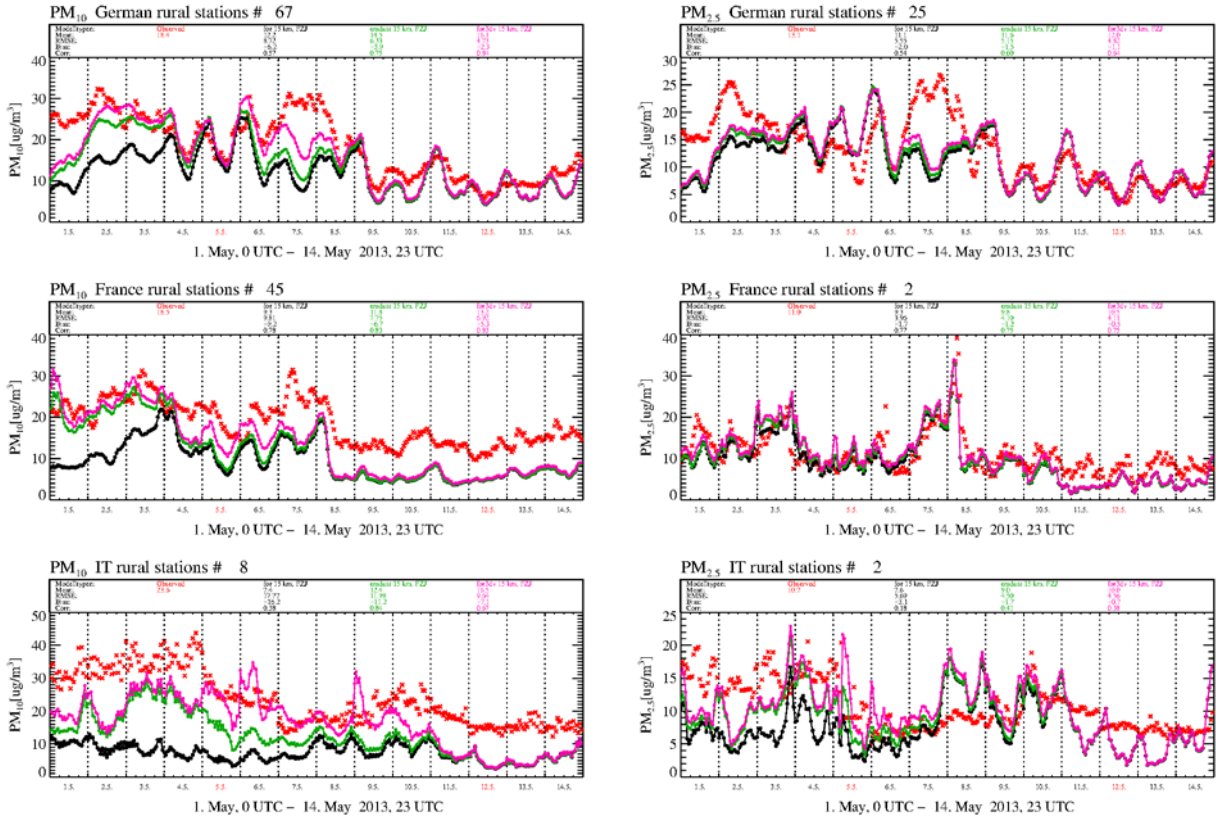

Figure 3: PM_{10} (left) and $PM_{2.5}$ time-series averaged over available stations from the eReporting database of the European Environmental Agency (EEA) for May 1 to May 14, 2013. Upper panel: German stations, middle panel: French stations, lower panel: Italian Stations. Black: EURAD-IM forecast in the current operational configuration (aerosol boundary values from the global C-IFS forecast applied), green: EURAD-IM forecast with the additional application of mineral dust emissions from DREAM, magenta: EURAD-IM forecast initialised with an AOD analysis, mineral dust emissions from DREAM applied, red: observations.

2. Development of pollen emission schemes for olive and grass

Olive and grass pollen emission schemes have been implemented in the EURAD-IM CTM. Pollen forecasts for birch, olive, and grass have been produced for the period January 1 to July 31, 2014. A preliminary validation of the results has shown that the grass pollen concentrations predicted by EURAD-IM were too high. The EURAD-IM pollen forecast has been re-calculated with correction terms applied on the grass pollen release rate, which depend on wind, temperature, and humidity. The application of the correction terms leads to considerably lower pollen concentrations, which are considered to be more realistic. Figure 4 shows mean olive and grass pollen concentrations in the near surface layer for May 2014.

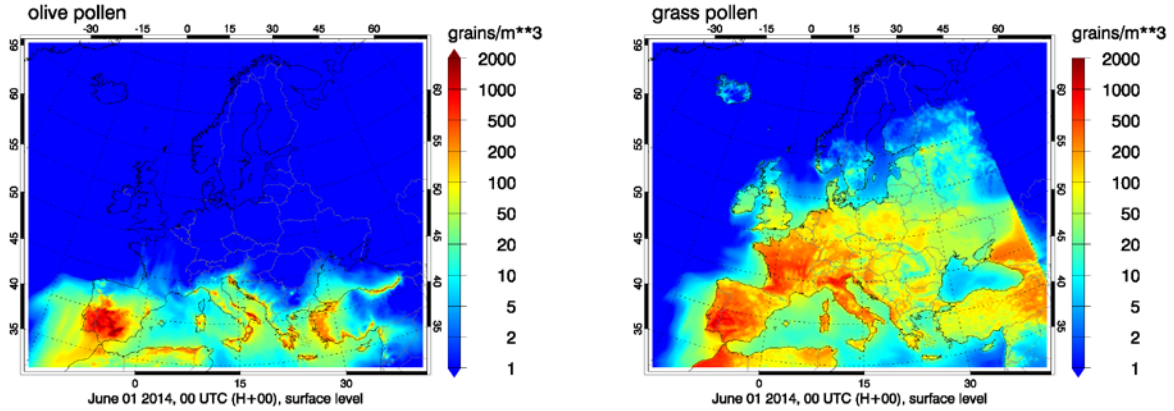

Figure 4: Monthly mean pollen concentrations in the near surface layer for May 2014 calculated with EURAD-IM. Left: olive, right: grass.

3. Assimilation of MODIS AOD and IASI CO data

MODIS AOD and IASI CO data have been assimilated with the EURAD-IM CTM. Assimilation results were independently validated with surface in situ observations. The MODIS Aerosol Optical Depth Land and Ocean of MOD04 L2 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. The analysis exhibits a considerable correction of EURAD-IM AOD values towards the observations. However, a more detailed investigation of the vertical aerosol distribution and of the aerosol size distribution obtained in the analysis is necessary. Figure 5 shows averaged time-series from an independent validation of the assimilation for PM**2:5** and PM**10** at surface in situ measurement sites.

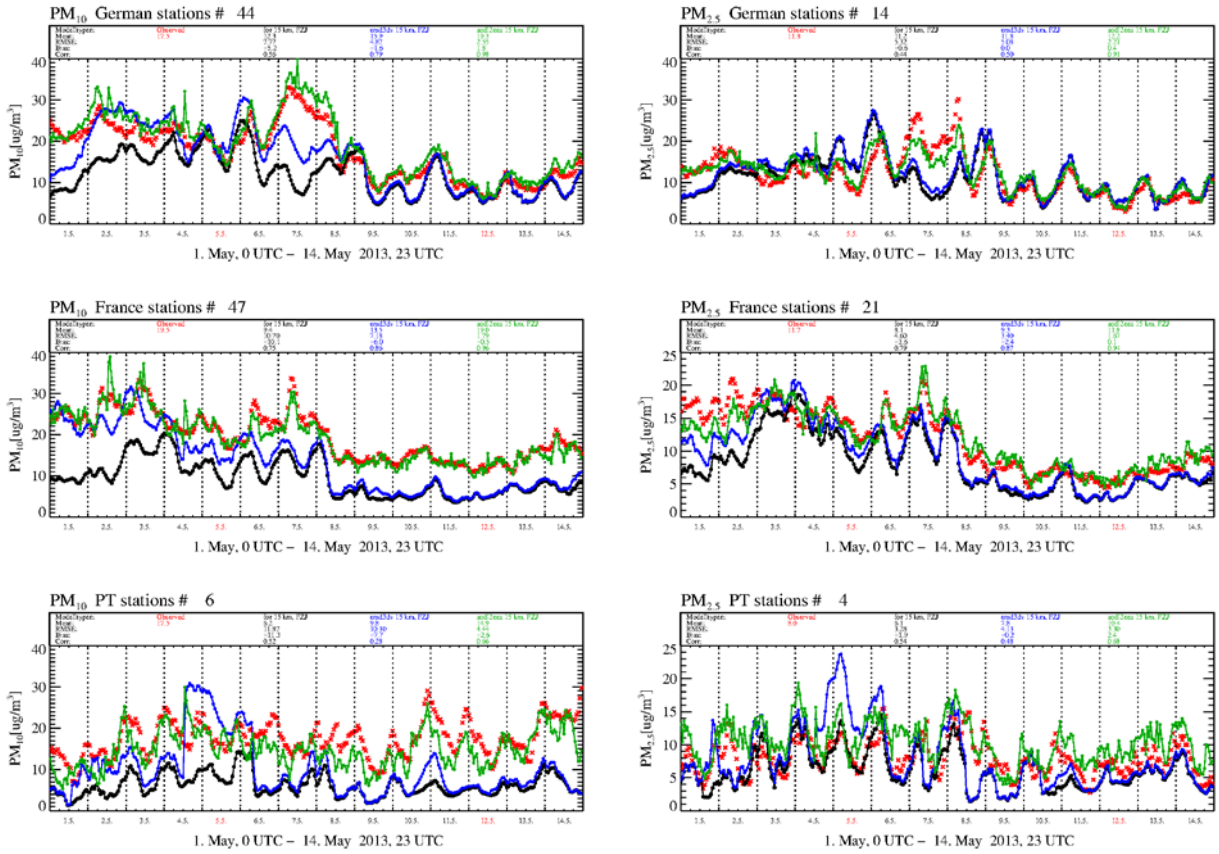

Figure 5: Averaged PM_{10} (left) and $PM_{2.5}$ (right) time-series for March 1 to 15, 2013. Upper panel: German stations, middle panel: French stations, lower panel: Portuguese stations. Black: EURAD-IM forecast without any data assimilation, blue: assimilation of MODIS AOD retrievals, green combined assimilation of MODIS AOD retrievals and surface in situ data from the eReporting database of the EEA, red: observations held back from assimilation.

LATMOS (Laboratoire Atmospheres, Milieux, Observations Spatiales) FORLI (Fast Optimal Retrievals on Layers for IASI) CO data retrieved from IASI has been assimilated for May 2013 with EURAD-IM in the configuration used for CAMS-50. The assimilation has been independently validated with surface in situ data from the eReporting database of the European Environmental Agency. Results are depicted in Figure 6 for the Period May 1 to 14, 2013. The large negative EURAD-IM CO bias in the near surface layer has been slightly decreased due to the assimilation of IASI CO column retrievals. In May 2013 most of the retrieval data was located over Eastern Europe. Because surface in situ CO measurements for this area are very sparse, the impact of IASI CO column assimilation on the near surface CO concentration is potentially under estimated in the time-series shown.

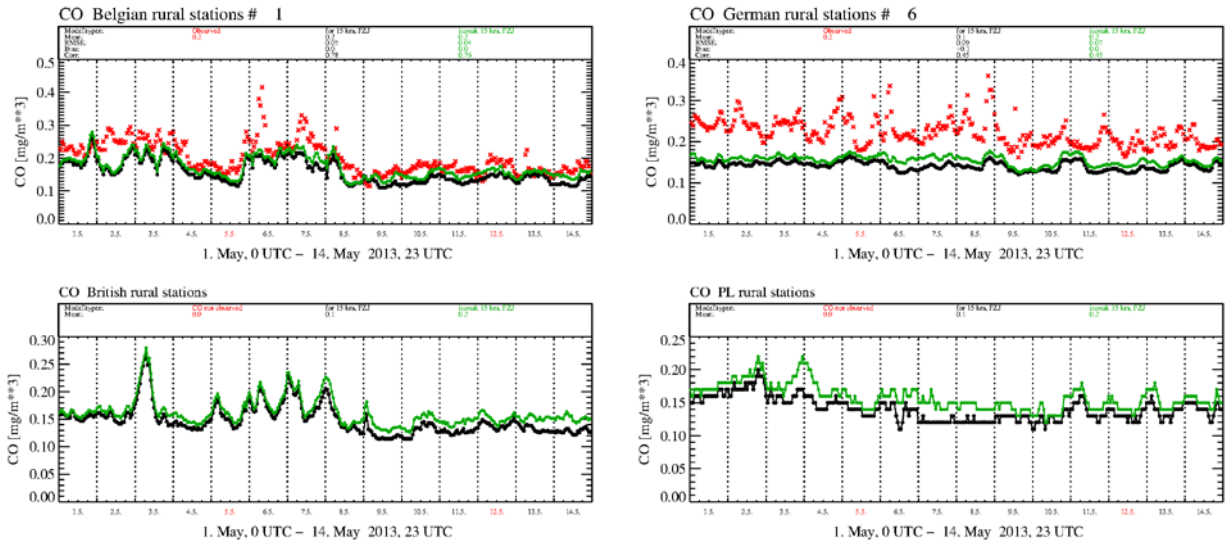

Figure 6: CO time-series averaged over all available background stations from the eReporting database of the European Environmental Agency (EEA) for May 1 to May 14, 2013. Upper left: Belgian stations, upper right: German stations, lower left: UK Stations, lower right: Polish stations. Black: EURAD-IM forecast without any data assimilation, green: EURAD-IM analysis of LATMOS FORLI CO column retrievals, red: observations.

4. Validated assessment of air quality in Europe

An important aim of CAMS 50 is the yearly production of air quality assessment reports for Europe. The state and the evolution of background concentrations of air pollutants in Europe are described in these reports. Validated observation and modelling data are combined in re-analysed maps and numerical _elds, to propose the best available representation of air pollutant concentration fields for a spatial resolution of 0.1 deg. Validated assessment reports from CAMS 50 are based upon an ensemble of models hosted at seven centres in Europe including RIUUK. During the accounting period the 2014 air quality re-analysis and the 2016 interim re-analysis have been completed. The observation data assimilated in the 2014 re-analysis consists of surface in situ data for the pollutants O_3, NO_2, PM_{10}, and $PM_{2.5}$, the troposhperic NO_2 column content retrieved from the OMI and GOME-2 instruments on the Aura and MetOp satellites provided by KNMI, and CO profile data retrieved from the MOPITT instrument onboard of the Terra satellite provided by UCAR/NASA. Intermittent 3d-var data assimilation has been applied. 30% of surface in situ background stations were held back from assimilation to allow for an independent validation of the assimilation results. Figure 7 exemplary shows scatter plots of the daily maximum O_3 concentrations for several European countries.

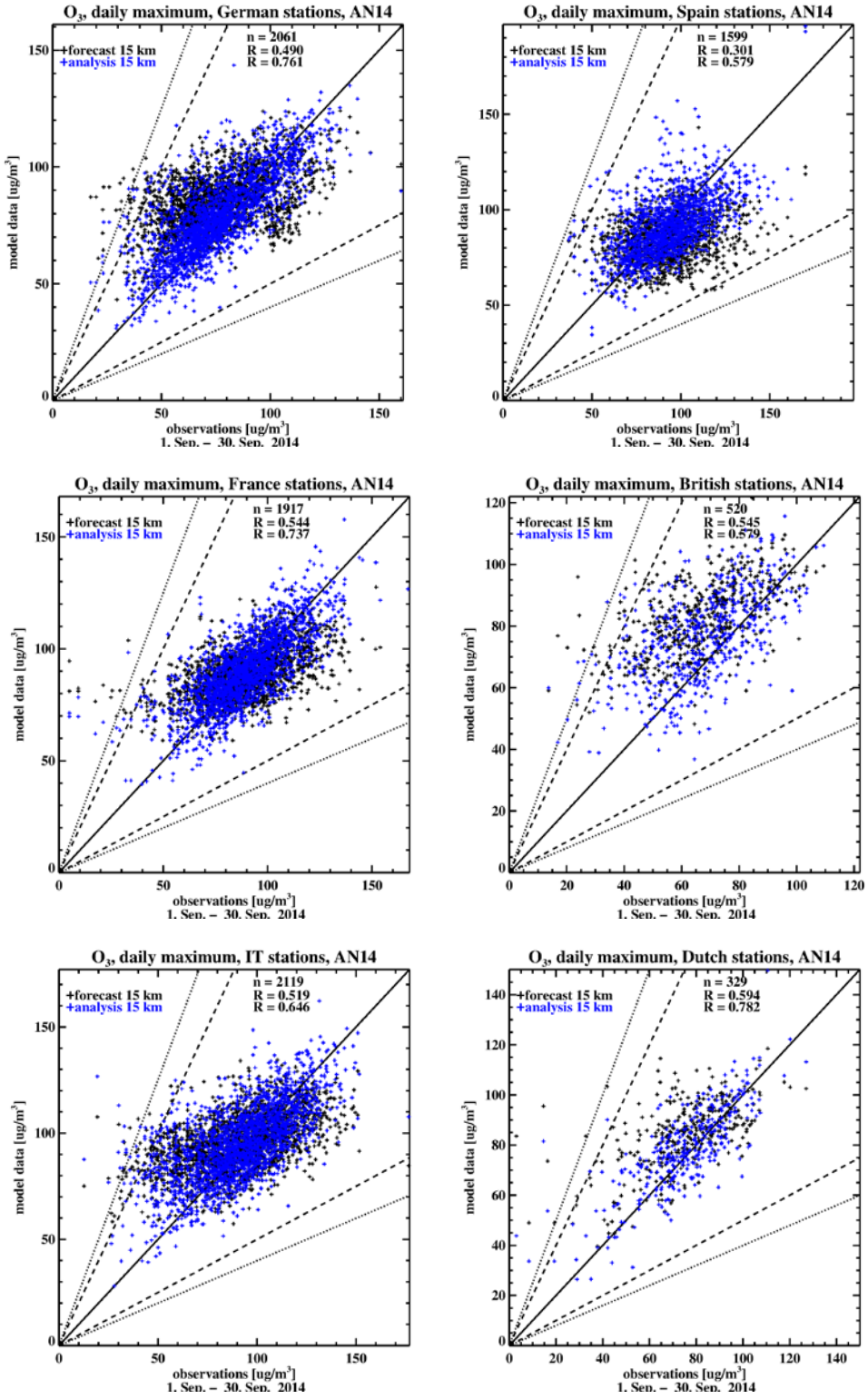

Figure 7: Scatter plots of the daily maximum O_3 concentration at stations withheld from assimilation for September 2014. Upper panel: Germany (left) and Spain (right), second Panel: France (left) and United Kingdom (right), third panel: Italy (left) and The Netherlands (left). Black: EURAD-IM background run, blue: EURAD-IM re-analysis.

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. Discuss., doi:10.5194/acp-2016-

1189, in review, 2017.

Summary of plans for the continuation of the project

Several actions are planned to improve the performance of EURAD-IM analyses above surface. EURAD-IM has established ability to assimilate in situ aircraft measurements. This ability will be applied to IAGOS (In-service Aircraft for a Global Observing System) measurements of O_3, CO, and NOx. Furthermore, the EURAD-IM system will be augmented by the 3d-var assimilation of SO_2 column retrievals. Near Real time SO_2 column retrievals are provided by the AURA/OMI and MetOp/GOME-2 instruments. In 2017 MOPITT CO data will be deployed in near-real time via the NASA LANCE system. This opportunity will be used to develop and assess the assimilation MOPITT CO retrievals also in EURAD-IM. The ability of EURAD-IM to assimilate MODIS AOD data will be further developed, with the aim to assimilate the MODIS AOD products over land.