Regional and local air quality analyses and forecasting for Brasil by enlisting CAMS strategy?
Some ideas with EURAD-IM

H. Elbern, E. Friese, K. Kasradze, P. Franke, A.C. Lange, A. Vogel
Rheinisches Institut für Umweltforschung an der Universität zu Köln, und
IEK 8-FZ Jülich
Acknowledgement: results from MACC and CAMS partners including
Claire Granier, Hugo Denier van der Gon, Nicolas Huneeus, O. Boucher, F. Chevallier
Sebastien Massart, J. Flemming, V. Hujinen, A. Inness,
Frank Baier, Simon Chabrillat, Martin Schultz, Johannes Kaiser,
Samuel Remy, Ronan Paugam, Angela Benedetti
In collaboration with: Jean-Jacques Morcrette, Luke Jones,
Samuel Remy, and Miha Razinger

Contents

1. Introduction: legacy and incentive:
   „Daseinsvorsorge“, service for the public, providência a pró de existência

2. Scope of CAMS:

3. Regional air quality monitoring and forecast services

4. EURAD-IM CAMS implementation with downstream extensions

5. Validation

EURAD-IM's engagement in atmospheric constituent forecasting/monitoring

Copernicus production.

- Reference to project(s) and/or programme(s): Copernicus — The European Earth Observation Programme.
  See http://www.copernicus.eu/
- programme financed by European Union funds

Some key links to the CAMS atmosphere service

The Copernicus atmosphere service

https://www.copernicus.eu/en/services/atmosphere

How it is made available

https://www.ecmwf.int/en/about/what-we-do/environmental-services/copernicus-atmospher

The European regional models ensemble are with Meteo France

http://macc-raq-op.meteo.fr/index.php?category=ensemble&subensemble=hourly_ensemble

At RIU (now transferred to FZJ) we render a special presentation

http://db.eurad.uni-koeln.de/en/forecast/eurad-im.php

CAMS delivers the following operational services

In general: Products to support policy users, adding value to "raw" data products in order to deliver information products in a form adapted to policy applications and policy-relevant work

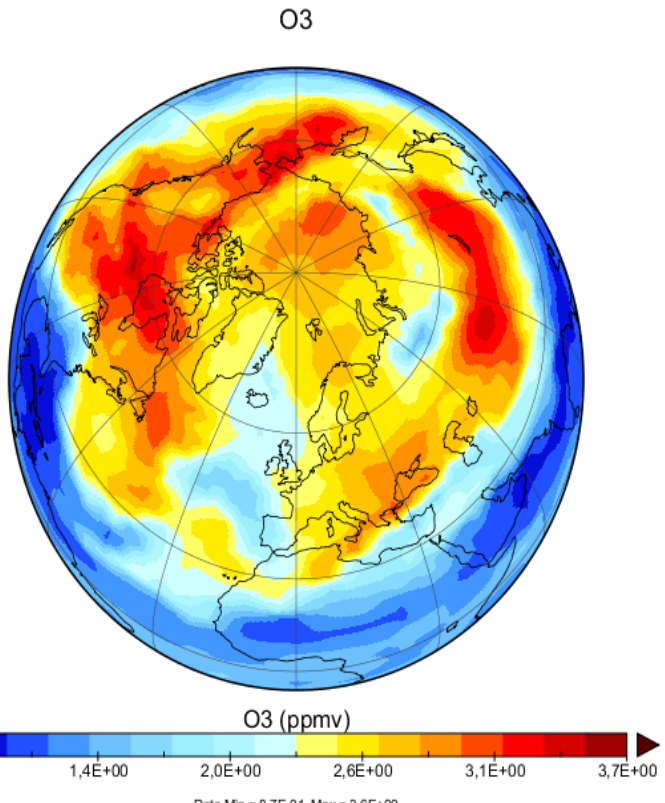
- Daily production of near-real-time analyses and forecasts of global atmospheric composition
- Reanalyses: consistent multi-annual global datasets of atmospheric composition
- Daily production of near-real-time **European air quality analyses and forecasts** with a multi-model ensemble system
- **Reanalyses** providing consistent annual datasets of European air quality
- Solar and UV radiation products supporting the planning, monitoring, and efficiency improvements of solar energy production and providing quantitative information on UV irradiance for downstream applications related to health and ecosystems
- Greenhouse gas surface flux inversions for CO_2, CH_4 and N_2O,
- Climate forcings from aerosols and long-lived (CO_2, CH_4) and shorter-lived (stratospheric and tropospheric ozone) agents
- Anthropogenic emissions for the global and European domains and global emissions from wildfires and biomass burning

CAMS service themes

- **Ozone Layer & Ultra-Violet Radiation**:
  - maintain and update the historical record of stratospheric ozone from 1979 until the present
  - provides forecasts of stratospheric ozone concentrations up to 5 days ahead,
  - 5-day forecasts of UV radiation
- **Air Quality & Atmospheric Composition**:
  - comprehensive global monitoring and forecasting system that estimates the state of the atmosphere on a daily basis,
  - combining information from models and observations, and it provides a daily 5-day forecast.
- **Climate forcing**:
  - CAMS near-real-time high resolution (16km) CO_2 forecast is available 3-hourly with a 5-day lead time.
  - CO_2 and CH_4 forecasts
- **Solar Radiation**:
  - both with the ultraviolet part of the spectrum having impact on human health and
  - with the visible solar spectrum being relevant for solar energy usage. Global and direct irradiances are provided for Europe, Africa, the Middle East and Asia providing the solar energy industry, the electricity sector, governments, and renewable energy organizations and institutions
- **Emissions & Surface Fluxes**:
  - compiles emission inventories that serve as input to the atmospheric chemistry-transport models.
  - estimates net fluxes of CO_2 and CH_4 at the Earth's surface using satellite and in-situ observations.
  - CAMS daily estimates emissions of aerosols, chemical species, and greenhouse gases from wild fires.

CAMS service theme
Ozone Layer & Ultra-Violet Radiation

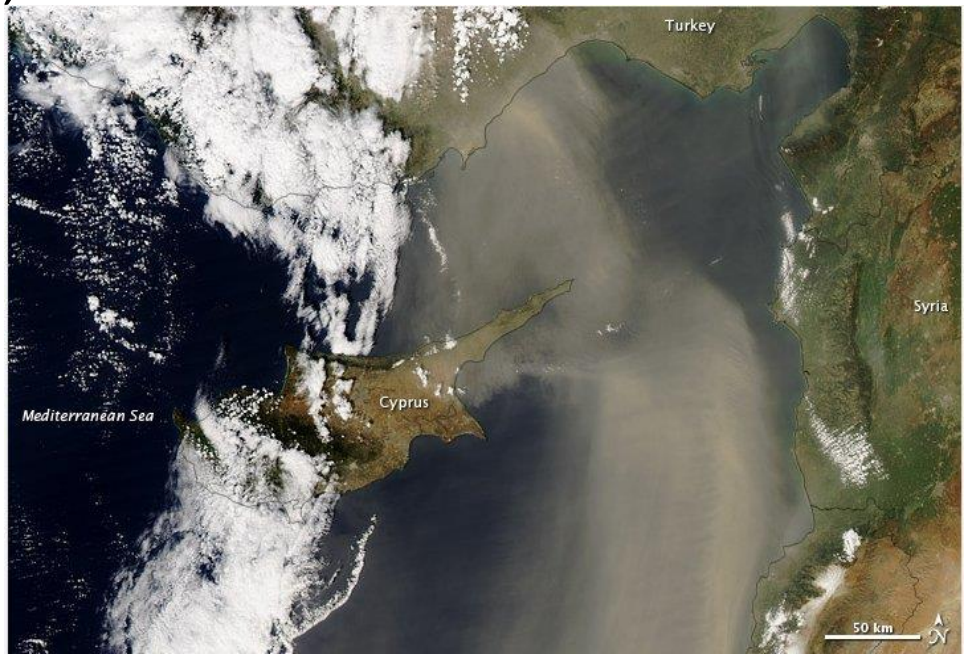
- provides services that maintain and update the historical record of stratospheric ozone using available satellite observations from 1979 until the present with a special focus on t
2012.
- provides forecasts of stratospheric ozone concentrations up to 5 days ahead, and
- provides 5-day forecasts of UV radiation taking into account the effect of ozone, clouds,
and aerosol particles



CAMS service theme
Solar Radiation

- considering both the ultraviolet part of the spectrum having impact on human health and with the visible solar spectrum being relevant for solar energy usage.

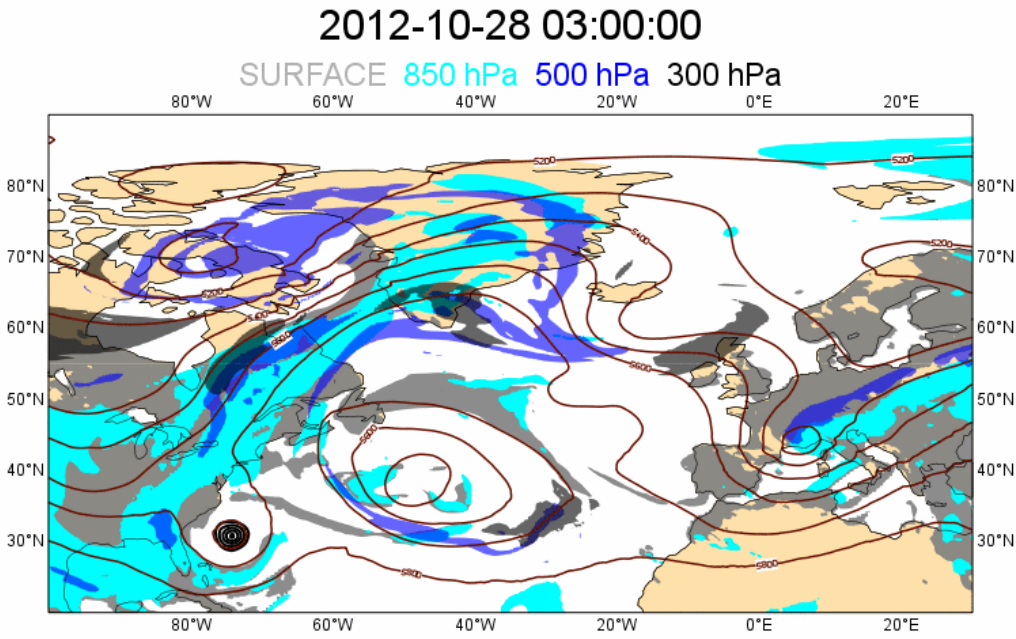
- Global and direct irradiances are provided for Europe, Africa, the Middle East and Asia providing the solar energy industry, the electricity sector, governments, and renewable energy organizations



CAMS service theme
Climate forcing

- CAMS near-real-time high resolution (16km) CO_2 forecast is available 3-hourly with a 5-day lead time.

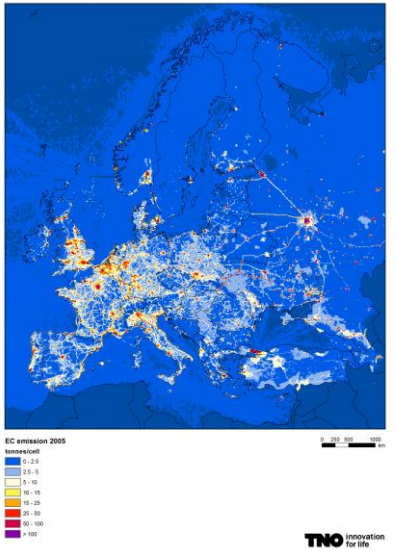
- for the InGOS/ICOS community - responsible for different insitu observing stations - on the availability of CO_2 and CH_4 forecasts

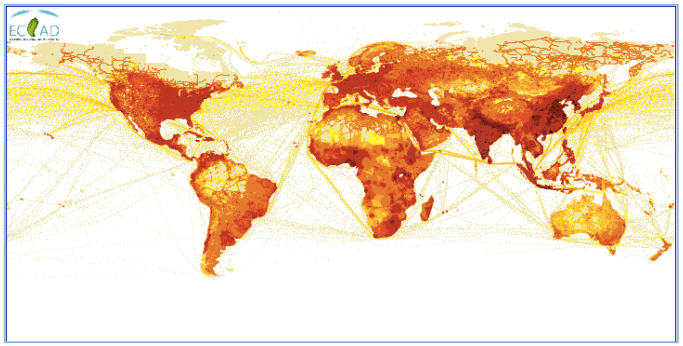


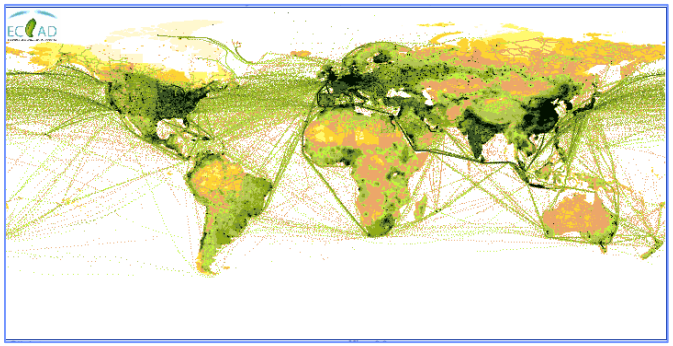
www.copernicus-atmosphere.eu/d/services/gac/verif/ghg/icos/icos_station_ts/

CAMS service theme
Emissions & Surface Fluxes

- compiles emission inventories that serve as input to the atmospheric chemistry-transport models,
- estimates net fluxes of CO_2 and CH_4 at the Earth's surface using satellite and in-situ observations,
- estimates emissions of aerosols, chemical species, and greenhouse gases from wild fires on a daily basis.



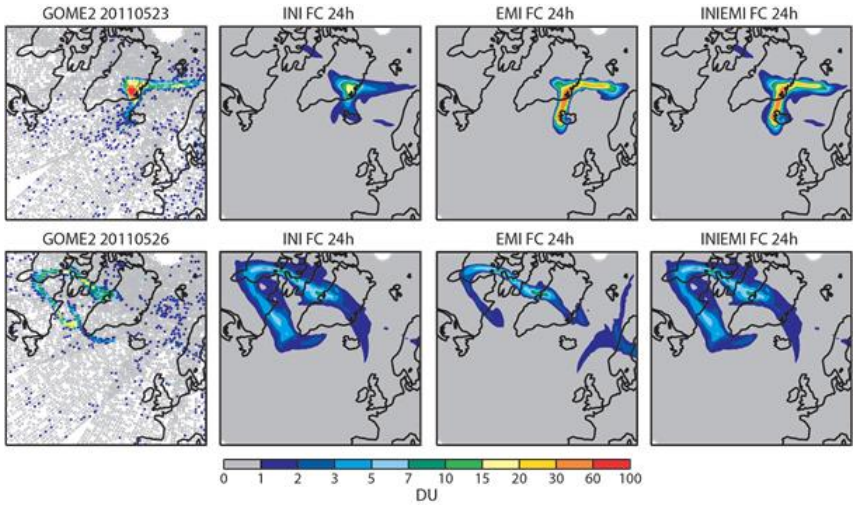




Focus here: CAMS service theme
Air Quality & Atmospheric Composition

A comprehensive global monitoring and forecasting system that

- estimates the state of the atmosphere on a daily basis, combining information from models and observations, and
- it provides a daily 5-day forecast.
- to provide the boundary conditions for an ensemble of more detailed regional air quality models, zooming in on the European domain and produce 4-day forecasts of air quality.



CAMS 50
Regional air quality monitoring and forecasting

- **operational** delivery of the European-scale air quality component of CAMS.
- based upon a geographically distributed ensemble of between 5 and 10 individual models, and
- a central processing function to **deliver three streams**:
  1. on a daily basis
     a) hourly analyses and
     b) forecasts up to + 96 h;
  2. with a **delay of a few weeks** (in order to maximise the number of observations) **interim re-analyses** will be produced daily
  3. with a **delay of up to 2 years** (due to the delay in getting fully validated data), **re-analyses** will be processed with frozen systems, which are only updated every few years.

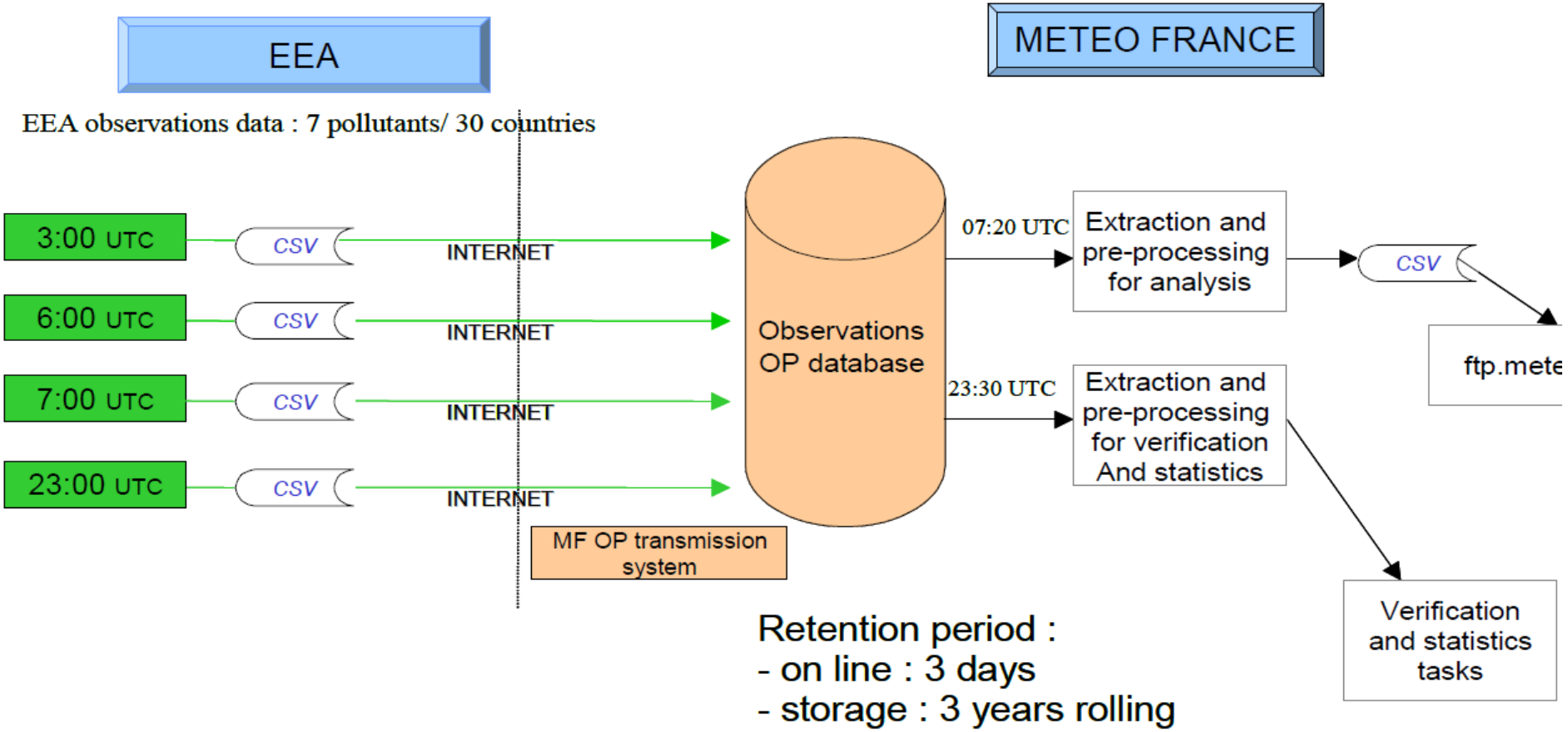
background requirements

- All the individual assimilation and forecast systems must be
  - mature, well validated and
  - operated by their main developers.
- a group of organisations with proven operational capabilities and track record in air quality assimilation and forecasting

Model characteristics on contract inception

Model	Operated and developed by	Horizontal resolution	Vertical levels	Assimilation	Observations assimilated (NRT)	Observations assimilated (reanalyses)
LOTOS-EUROS	KNMI-TNO	0.25°x0.125°	4 levels top at 300hPa	EnKF	stations (O_3)	Stations (O_3, PM10), OMI NO_2.
MATCH	SMHI	0.2°x0.2°	52 levels top at 300hPa	3D-Var	stations (O_3, CO, NO_2, PM10, PM2.5)	stations (O_3, CO, NO_2, PM10, PM2.5)
MOCAGE	METEO-FRANCE	0.2°x0.2°	47 levels top at 5 hPa	3D-Var	stations (O3, NO2)	stations (O3, NO2)
SILAM	FMI	0.1°x0.1°	8 levels top at 6.7 km	3D-VAR (all species but birch pollen) 4D-Var (birch)	stations (O3, NO2, SO2)	stations (O_3, NO_2, PM2.5, birch pollen)

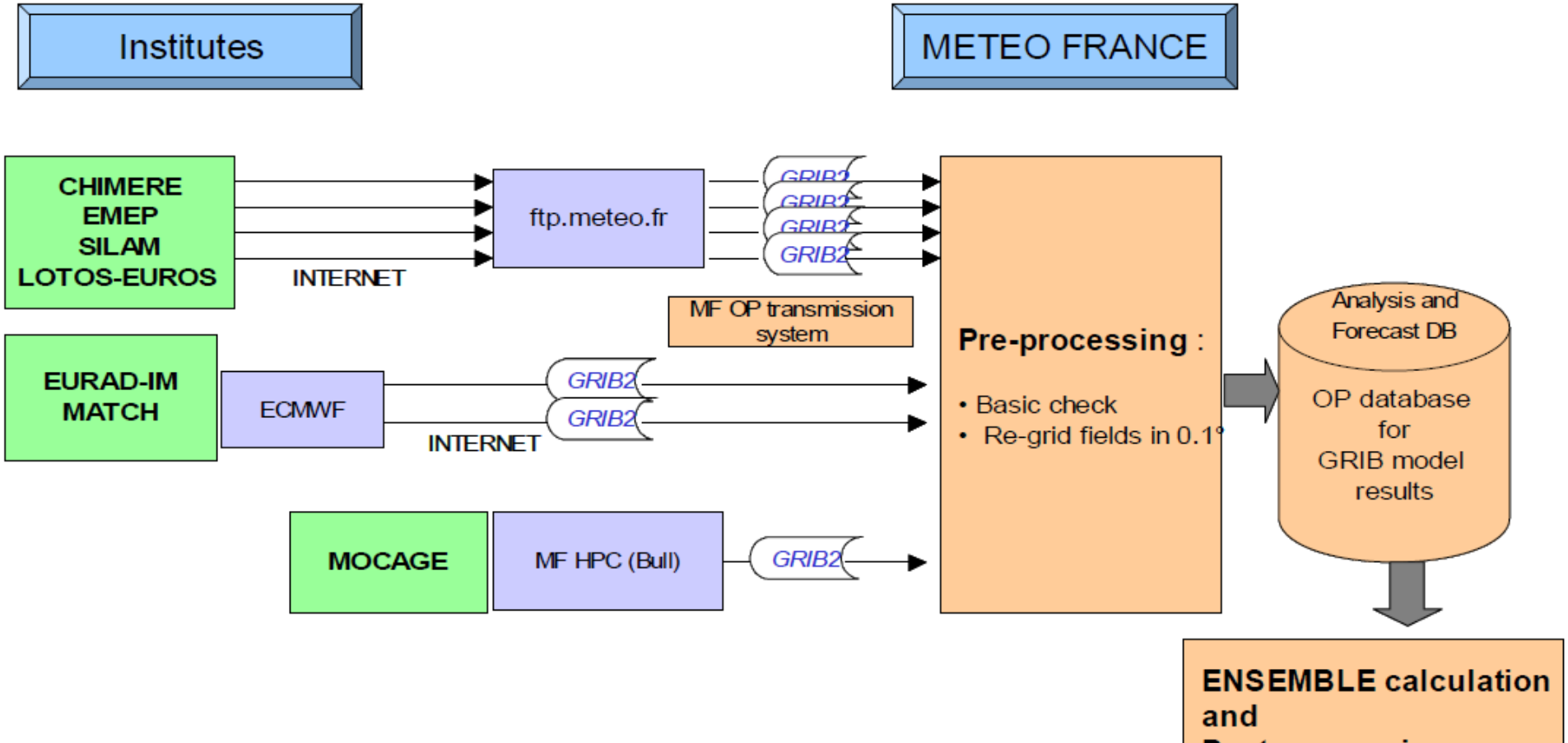
Data Acquisition



Description of individual productions

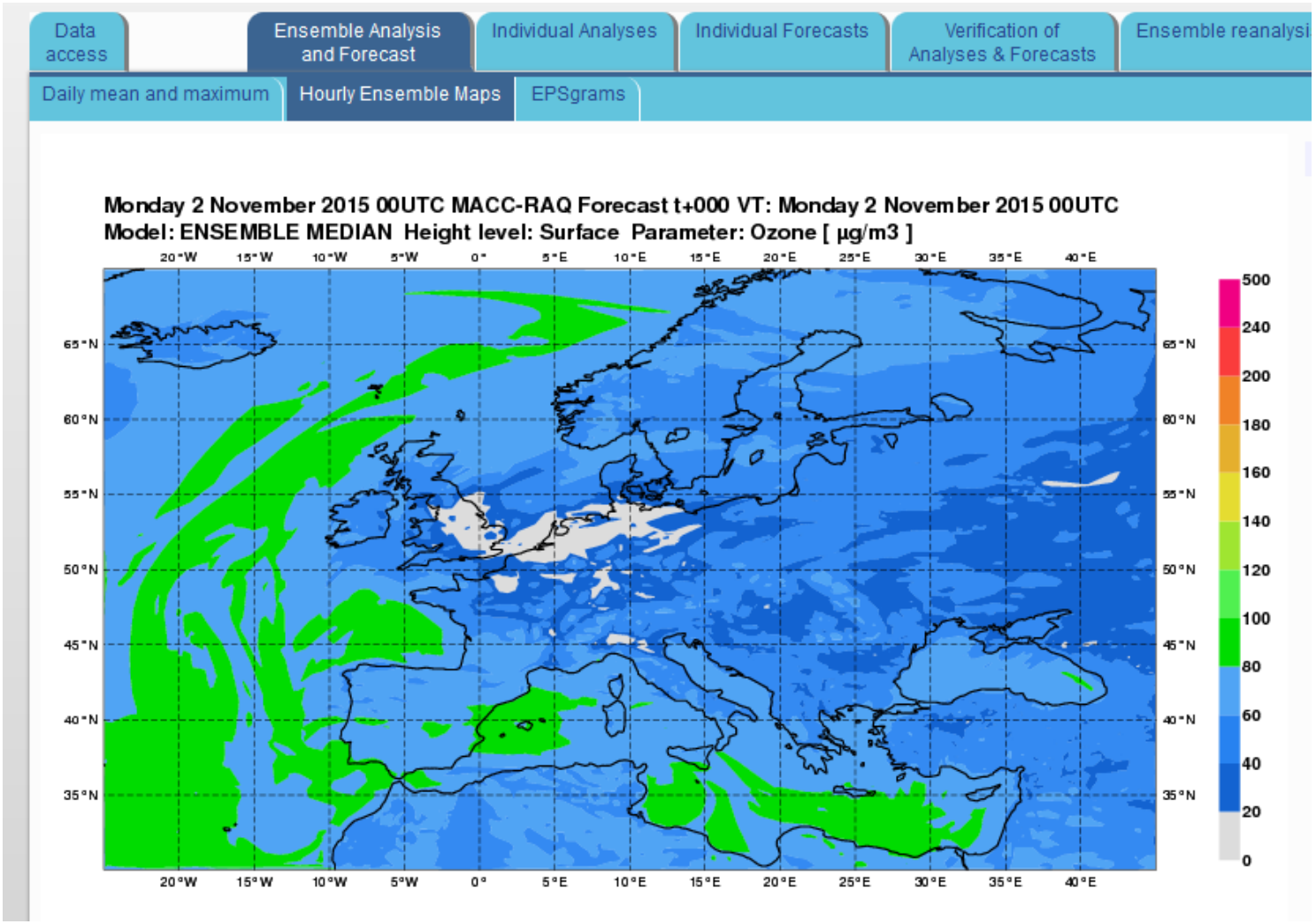
- **GRIB2** data format,
- eight vertical levels (surface, **50m, 250m, 500m, 1000m, 2000m, 3000m, and 5000m** above ground),
- parameters provided : **O_3, NO_2, NO, PM_{10}, $PM_{2.5}$, SO_2, CO, NH_3, PANs, NMVOC** and
- **birch pollen** for almost all models, **olive** and **grass** pollen provided at phase 2 and **ragweed** pollen is planned for phase 3.

Data flow of the daily regional production



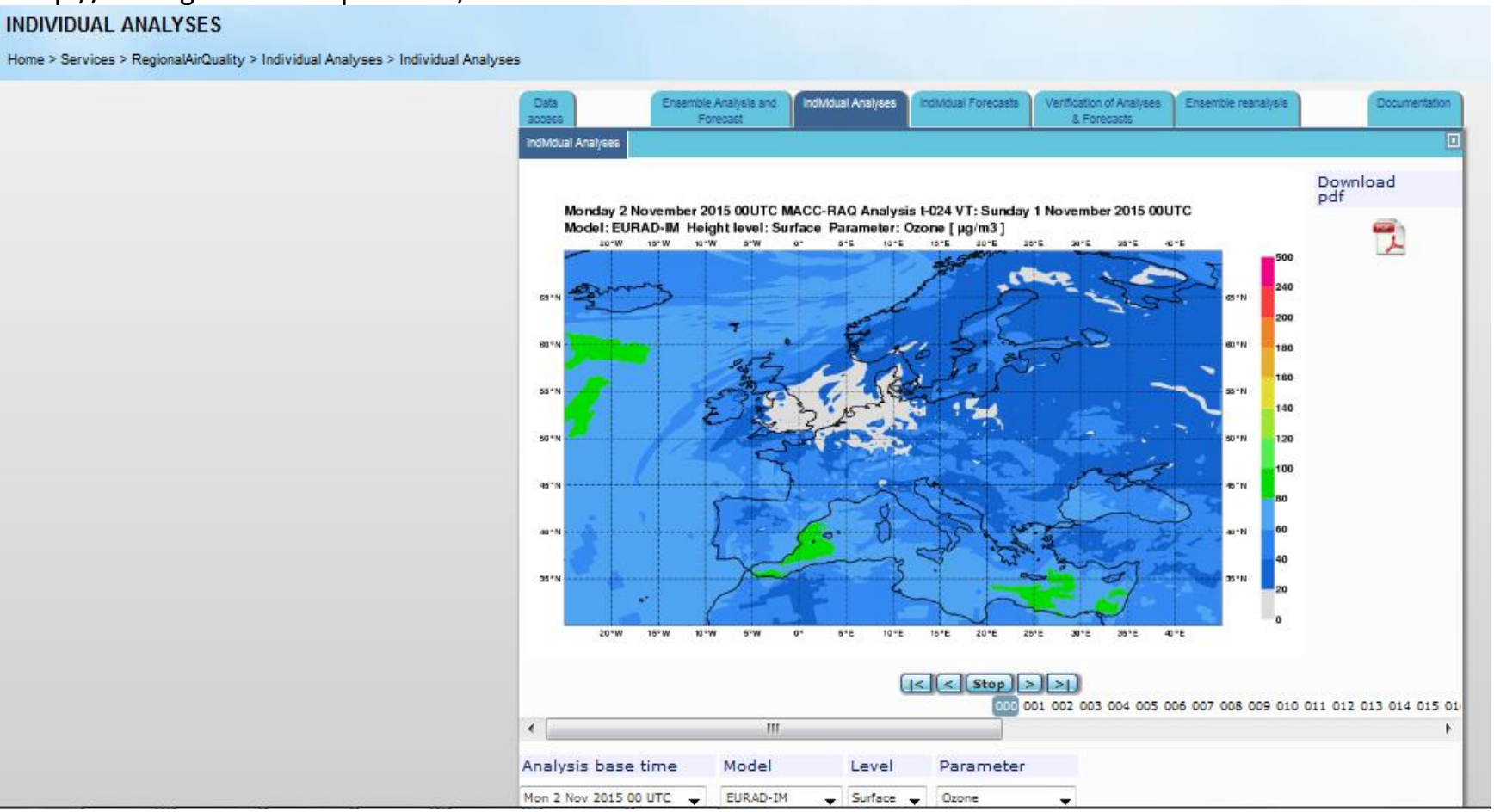
Web based product publication example: ensemble O_3

http://www.gmes-atmosphere.eu/

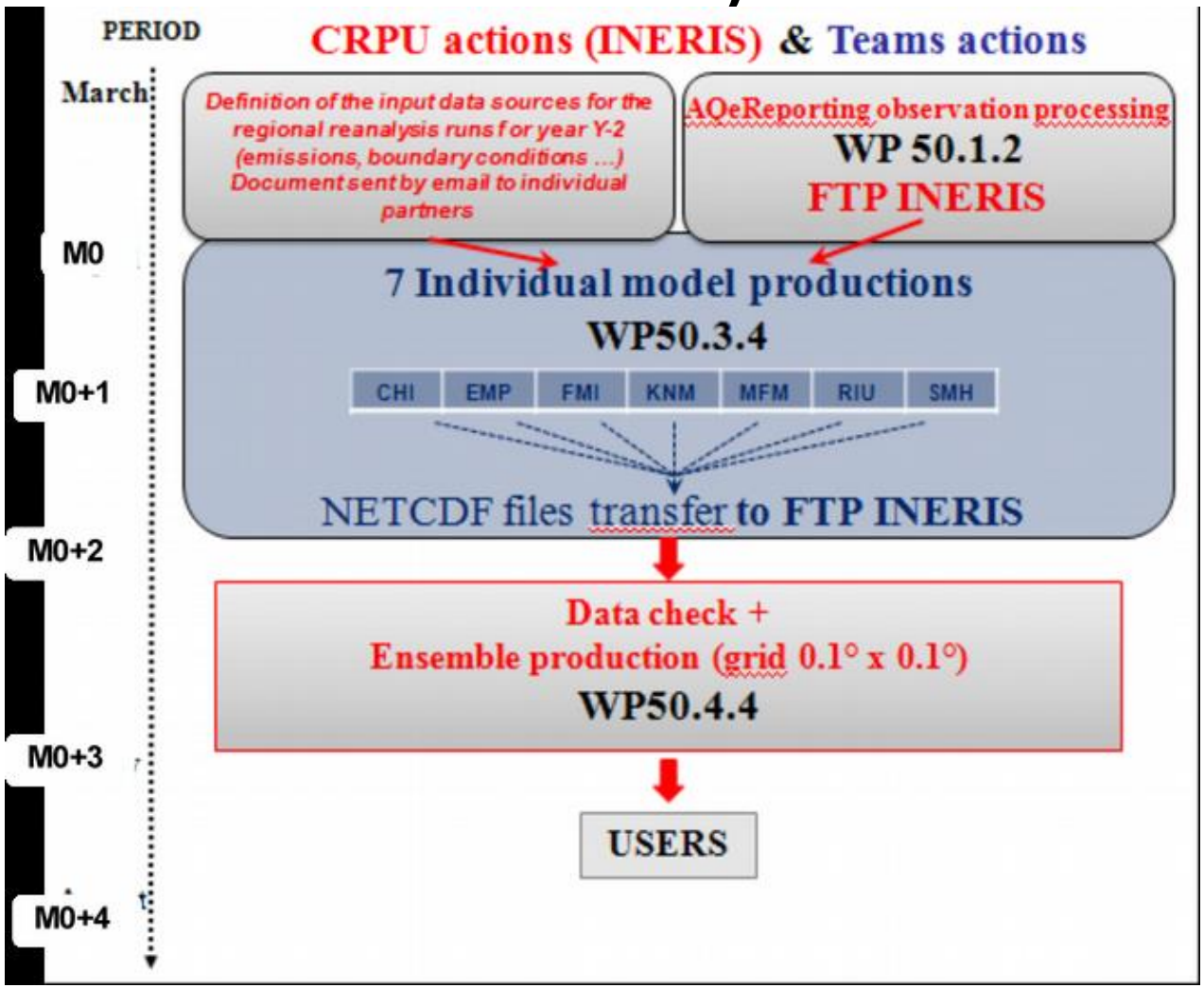


Web based product publication example: EURAD-IM O_3

http://www.gmes-atmosphere.eu/

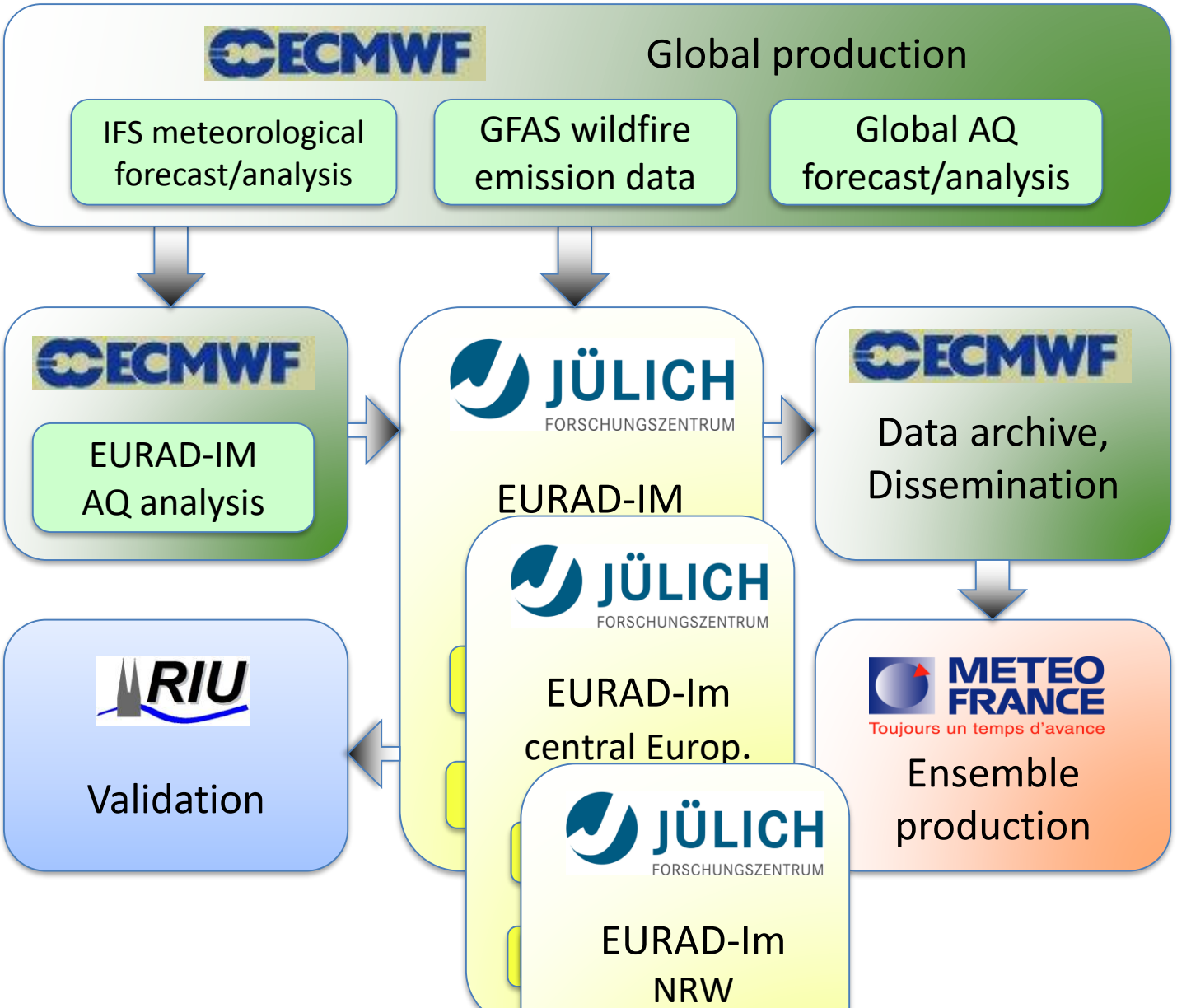


Reanalyses processing schedule (for observation database available in March)

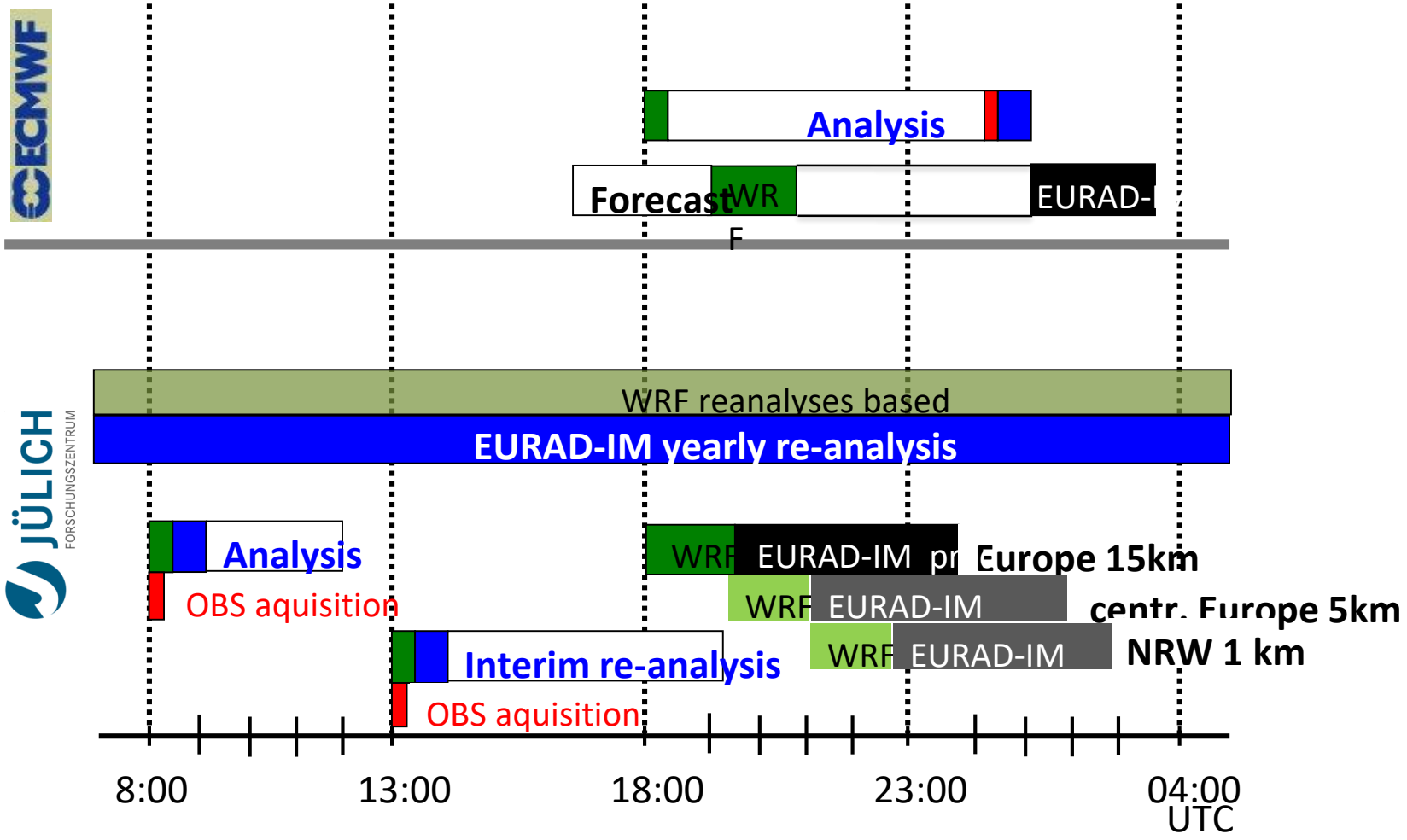


EURAD-IM CAMS-50 / Downstream Production Chain

EURAD-IM CAMS-50/Downstream Production at FZJ

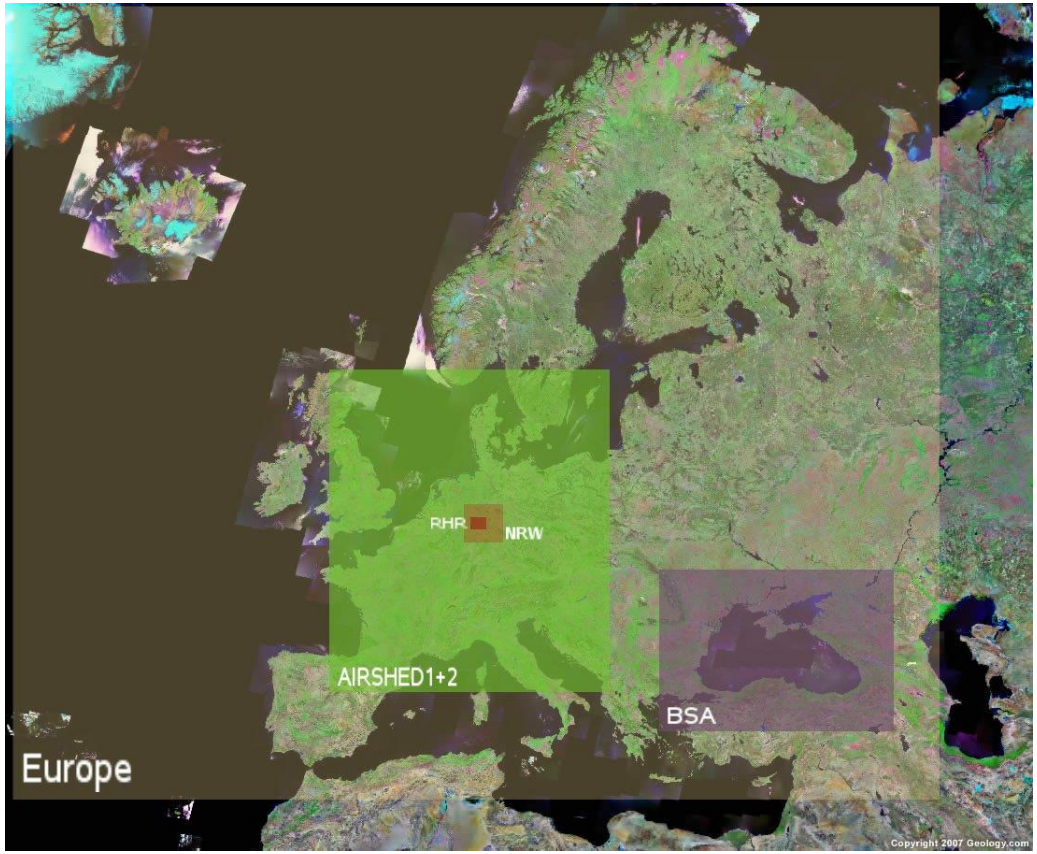


Daily time schedule of production

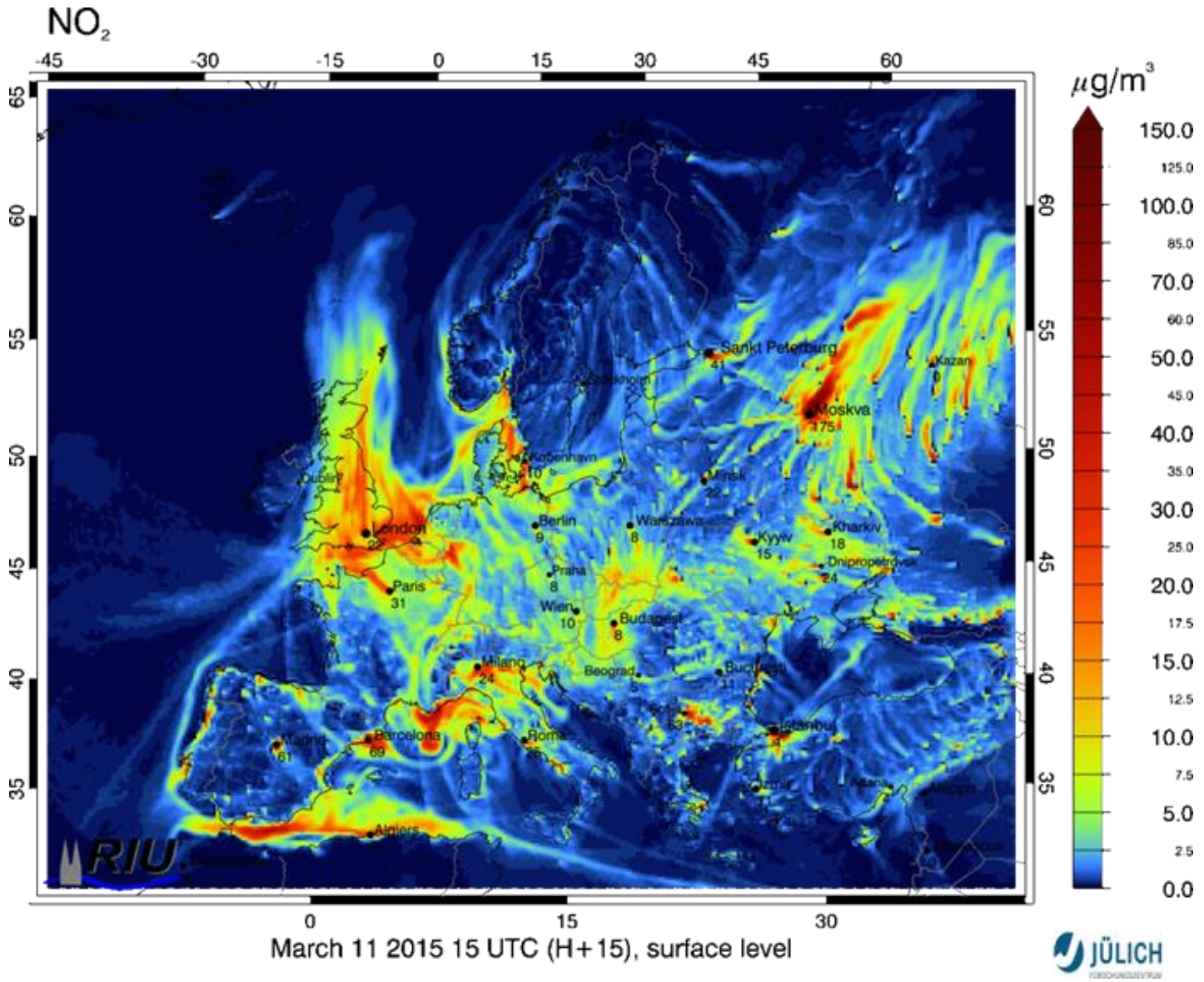


EURAD-IM Downstream AQ Services

- Regional scale (15 to 1 km resolution)
  - Central Europe (5km)
  - Black Sea Area (15km)
  - NRW (5km)
  - Ruhr-Rur Area (1km)
- Daily 96h air quality forecasts
- Daily air quality analyses of the previous day (hourly resolution)
- Web-based presentation and near-real-time verification
- User: Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen

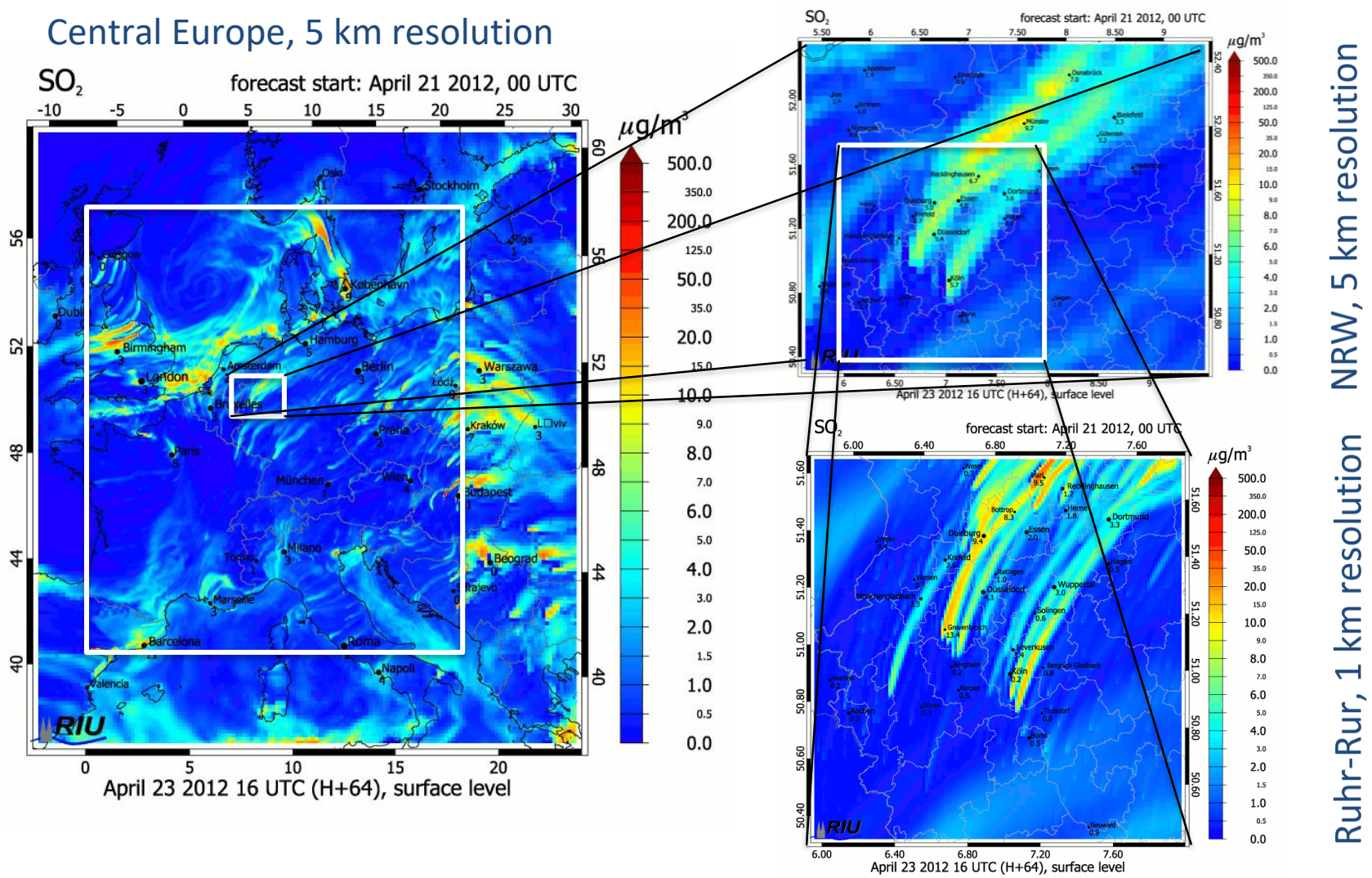


Forecast example of NO2



EURAD-IM Downstream AQ Service

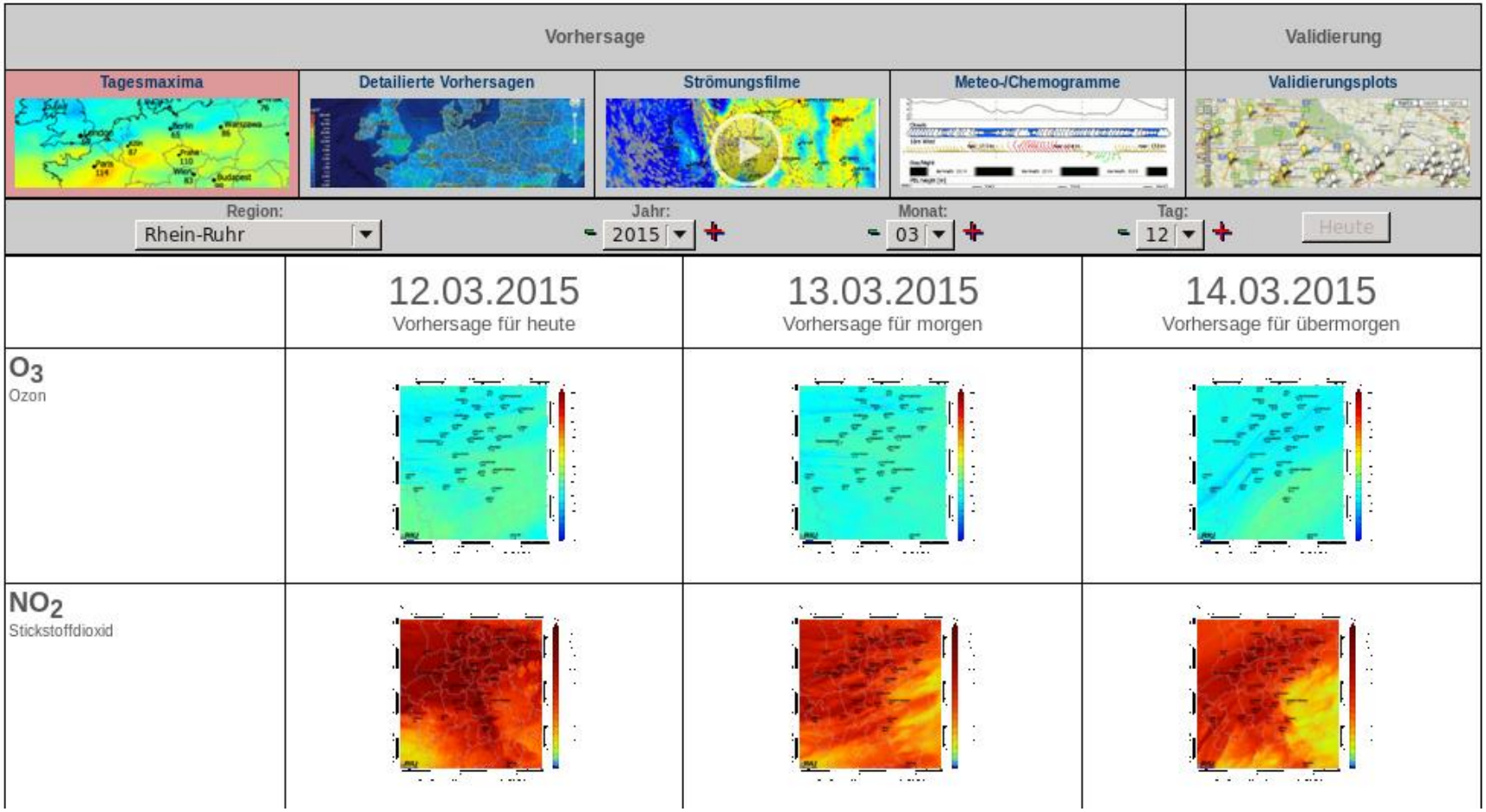
Example: SO2 forecast for the Ruhr-Rur-Area



EURAD-IM Downstream AQ Services

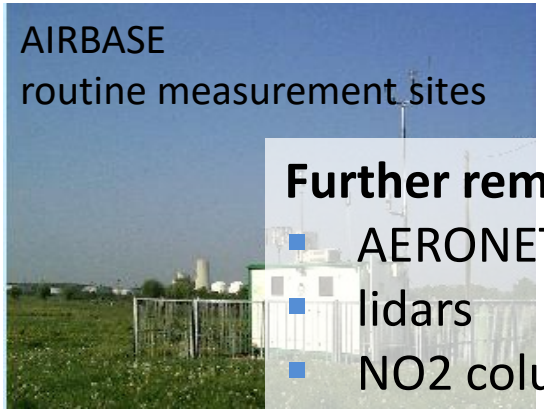
Web Based Product Publication

http://eurad.uni-koeln.de

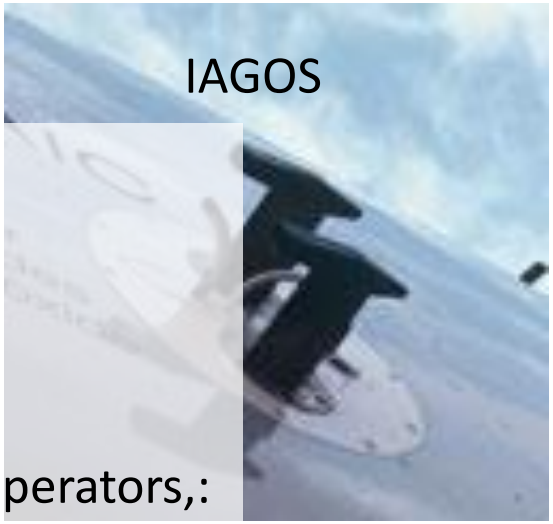


4. Examples for Data Assimilation with EURAD-IM in CAMS-50

Use of In Situ and Remote Sensing Data



In Situ

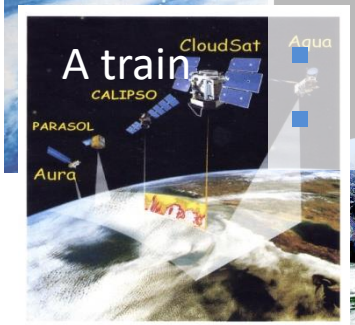


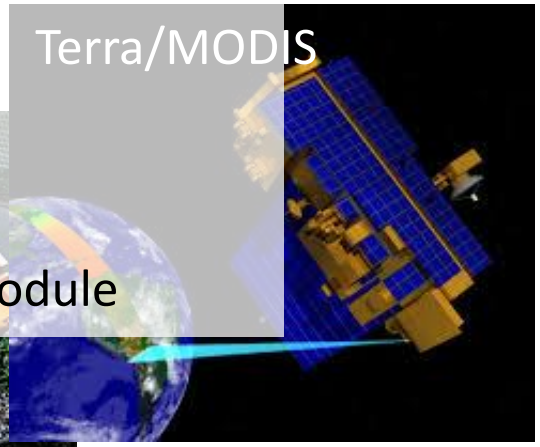
special stations: Jungfraujoch

Further remote sensing data

- AERONET
- lidars
- NO2 column data assimilation modules
- IASI O3 and CO data assimilation module
- integration of novel satellite observation operators,:
- IASI-GOME,
- SLSTR,
- Sentinels 1, 4, 5, 5p,
- VIIRS,
- OMPS
- MODIS, SEVIRI AOD data assimilation module

Remote Sensing

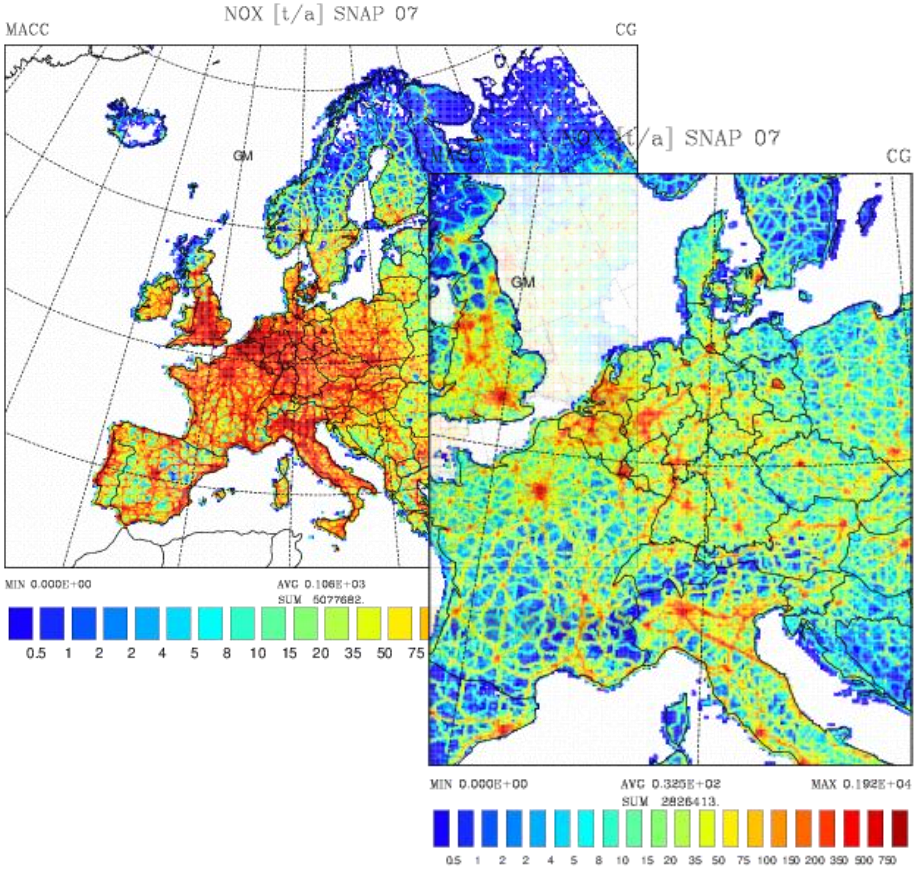




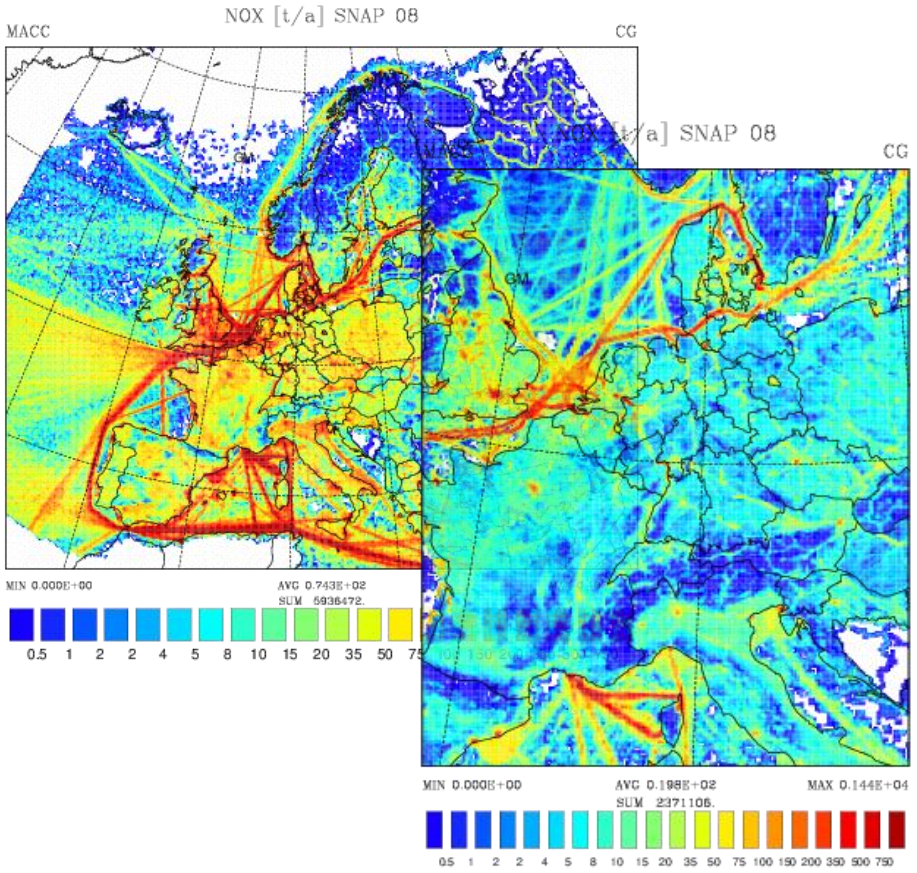
Examples from the TNO emission inventory 2009

NO_x 1/8° x 1/16°

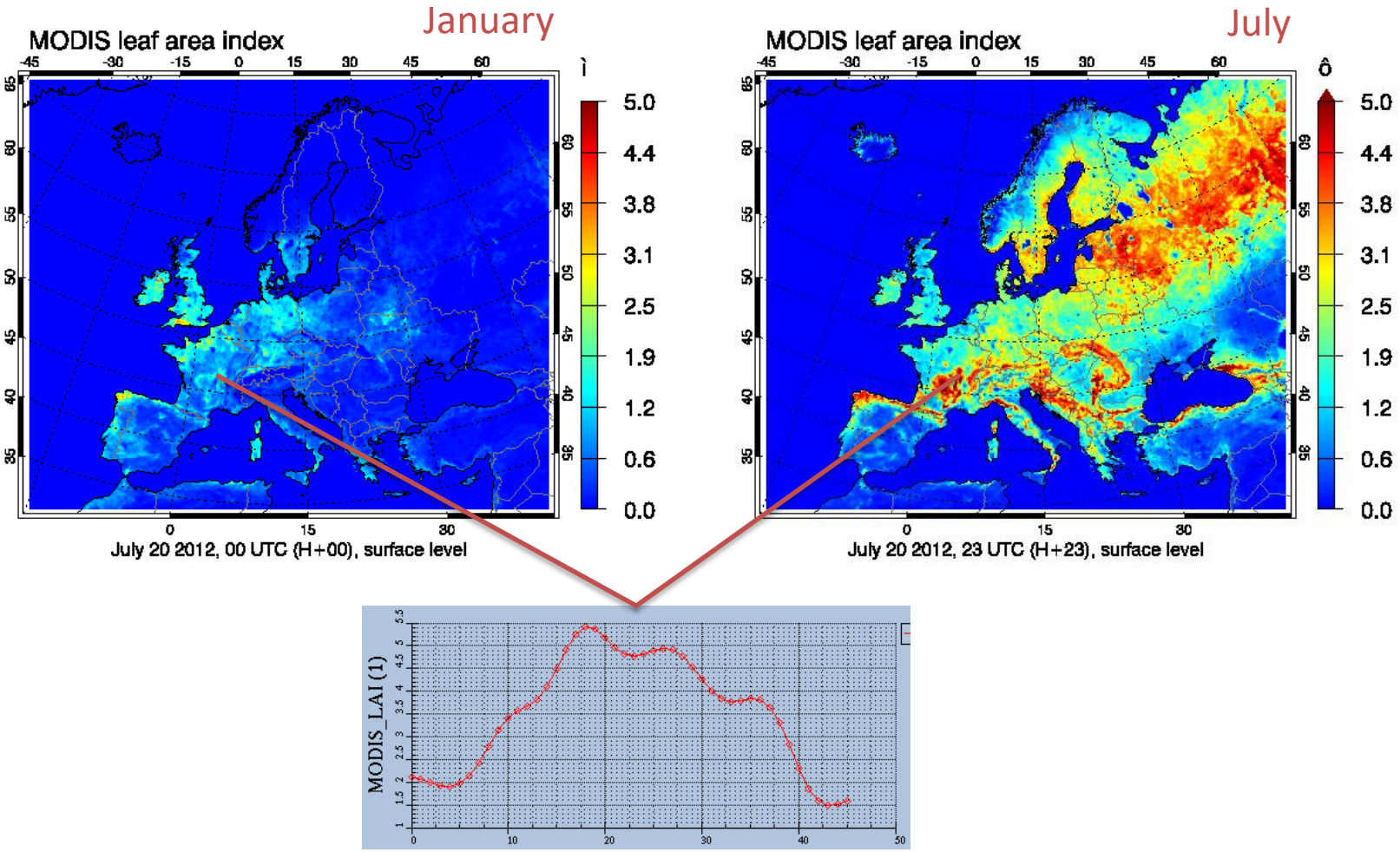
SNAP 07 Road Transport



SNAP 08 Other Mobile Sources



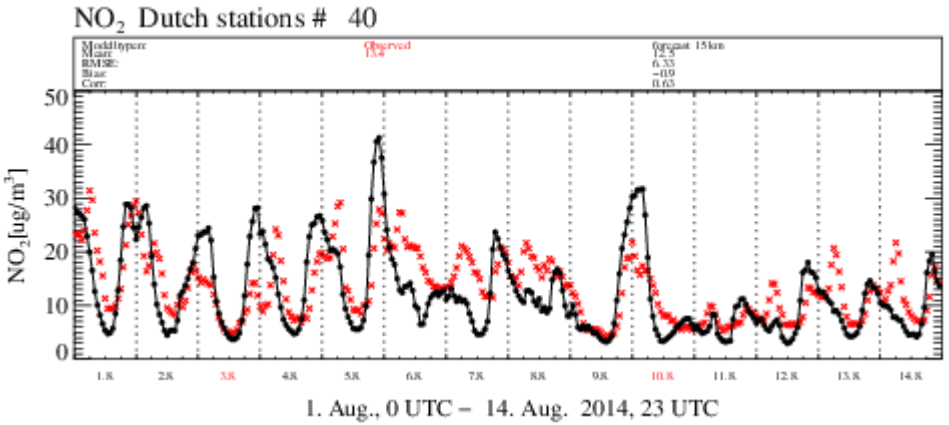
Incorporation of the MODIS 8-day Leaf Area Index Product



Forecast skills: impact of national emission inventories?

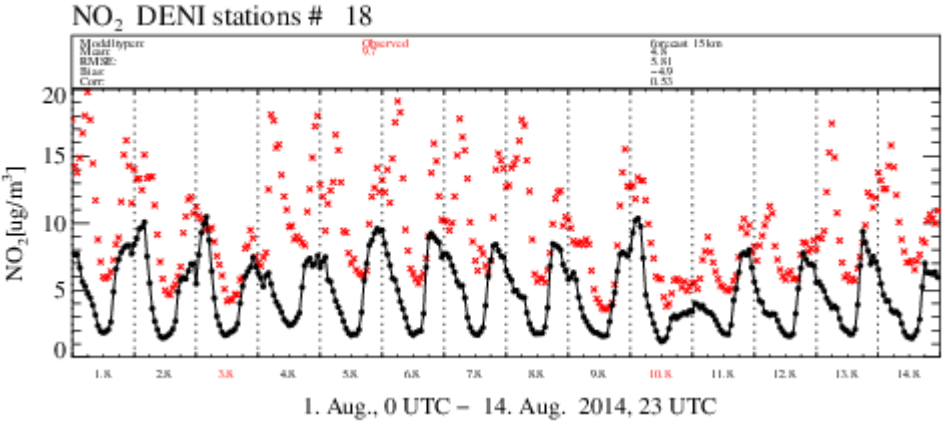
Typical NO_2 example compare Germany- The Netherlands

Netherlands

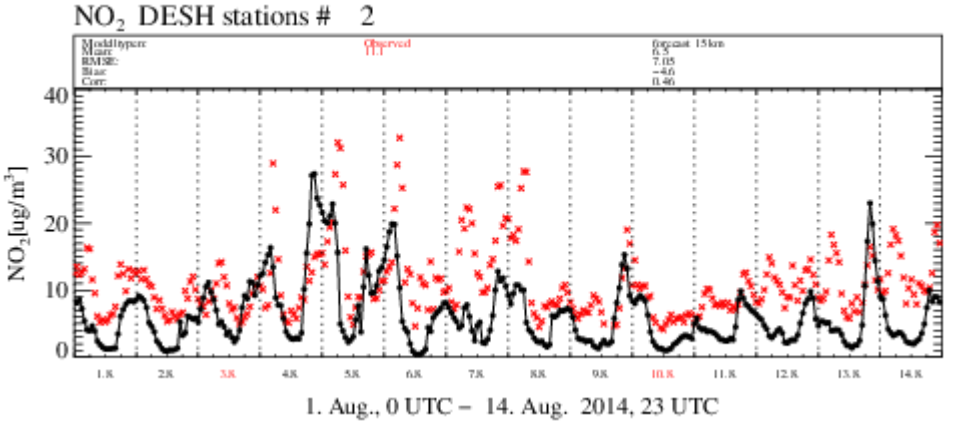


Germany (different emission assessment?)

Lower Saxony



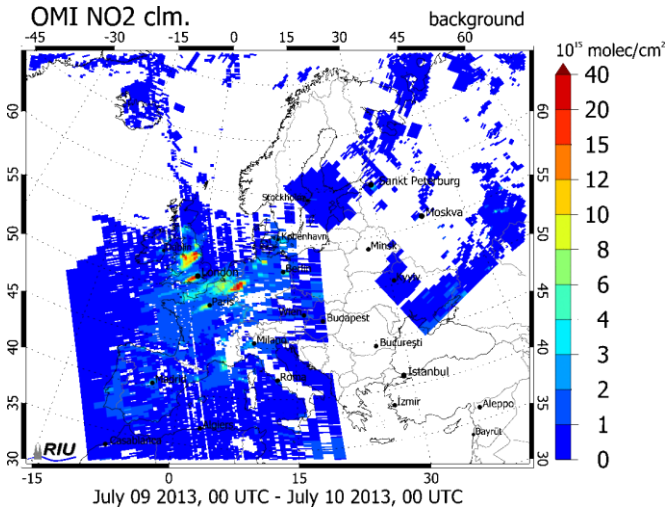
Schleswig-Holsatia

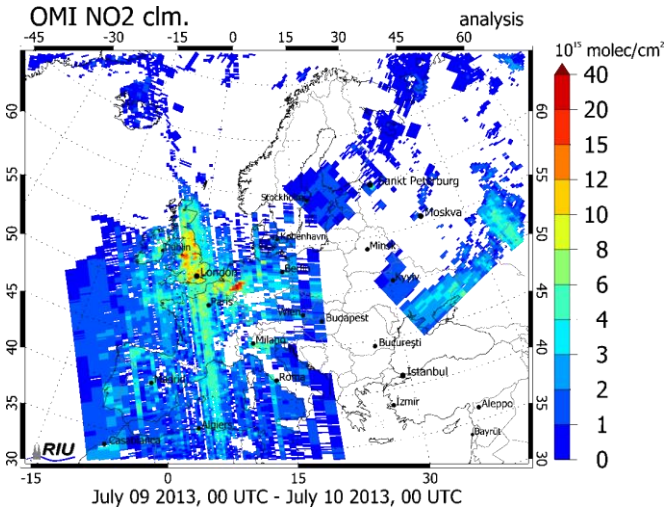


EURAD-IM MACC 3d-var EVA Re-Analysis for 2013

OMI NO_2 Column Retrievals for 9. July

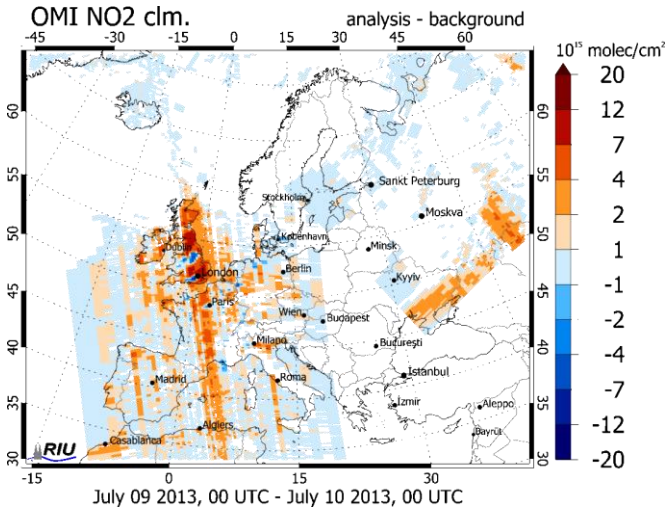
Background, H(x)

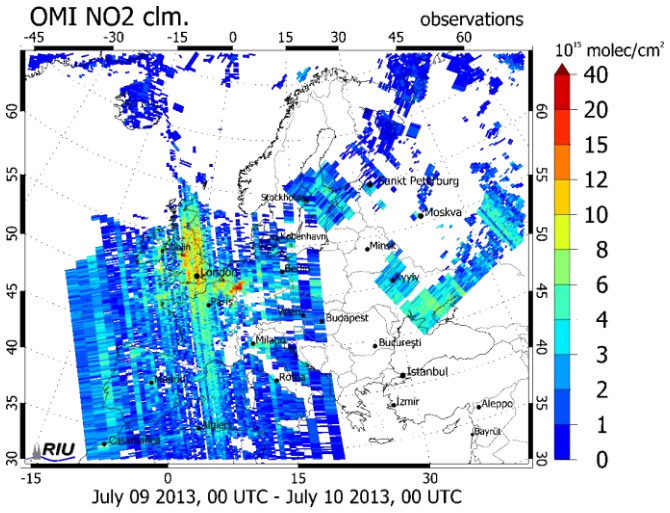




Analysis, H(x)

Analysis - background



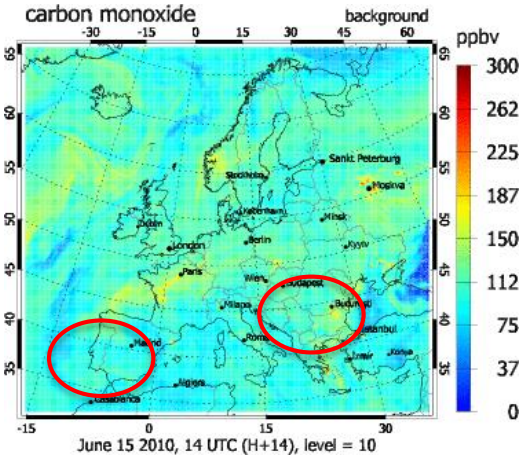


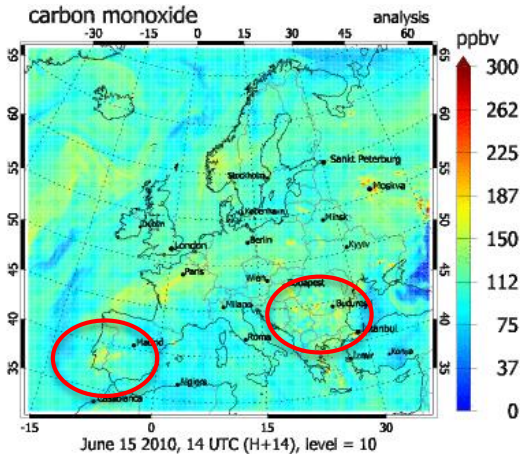
Observations, y

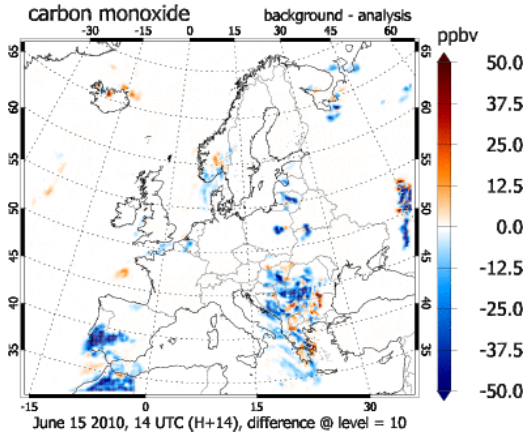
3d-var Assimilation of MOPITT CO Retrievals

background | analysis | background - analysis

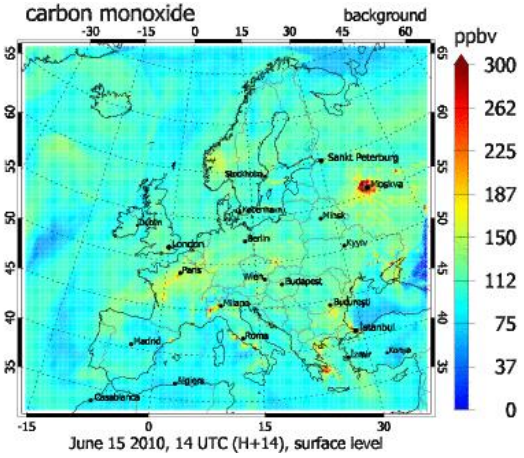
900 hPa, level 10

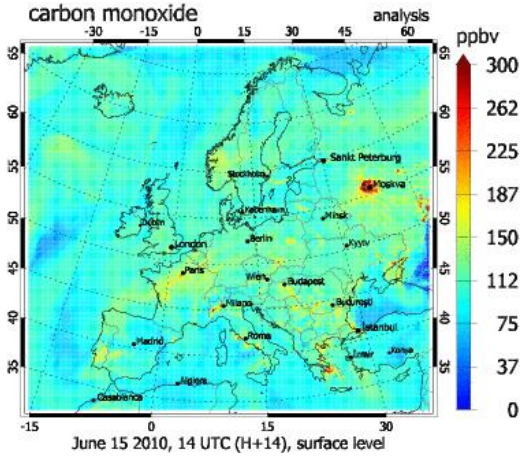


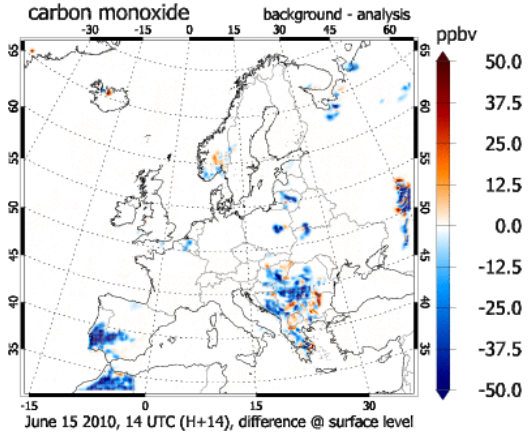




surface



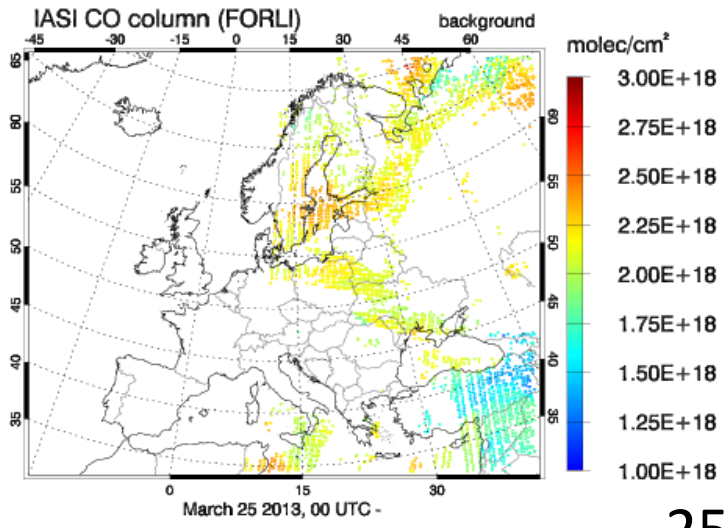




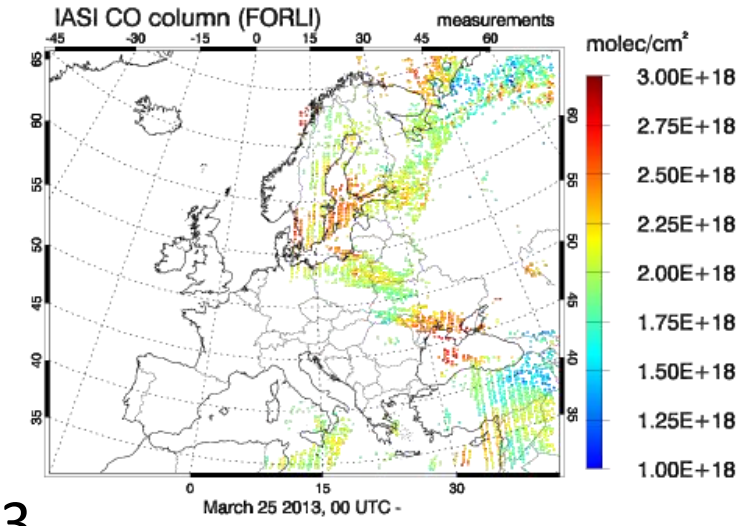
June 14, 2010, 14:00 UTC

IASI (FORLI) Data Assimilation: Total CO Columns

Background H(x)

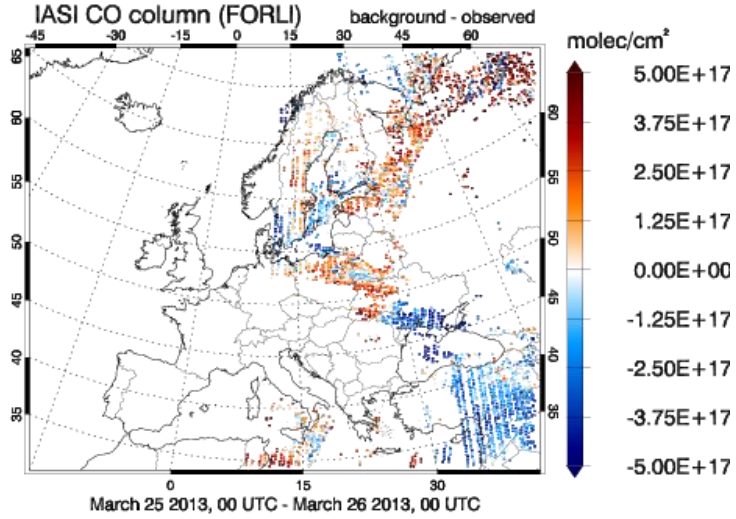


Observations, y

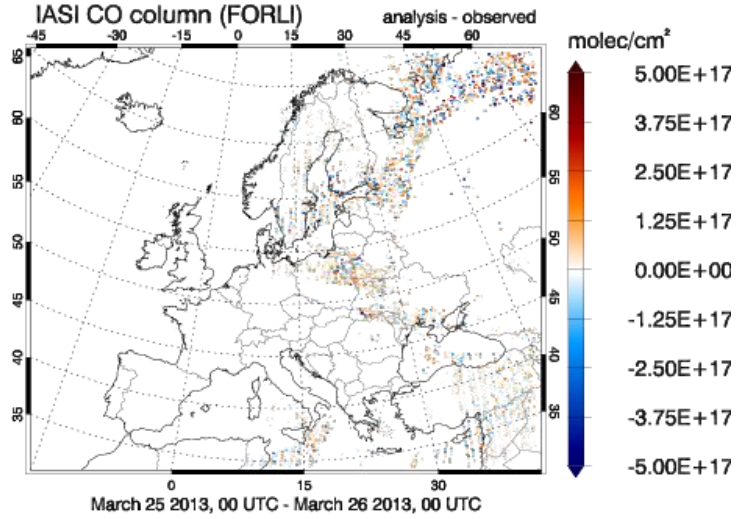


25.3.2013

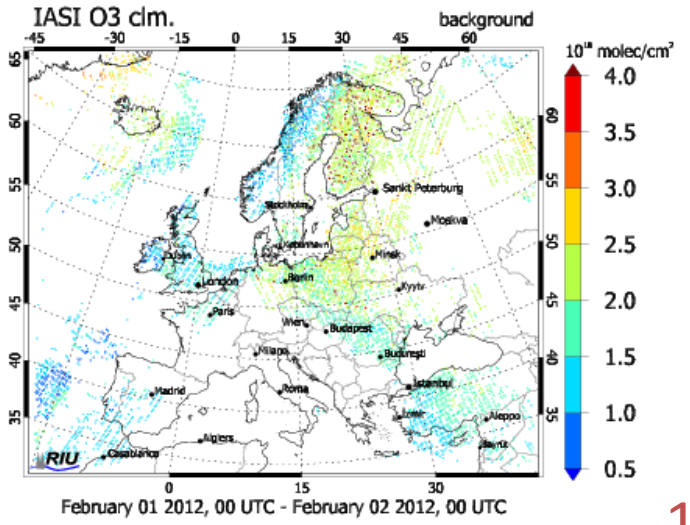
(BG H)(x) - y

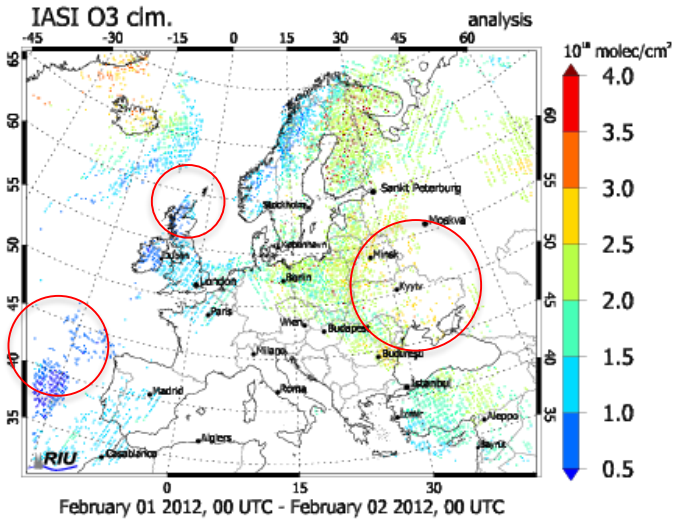


(AN H)(x) - y

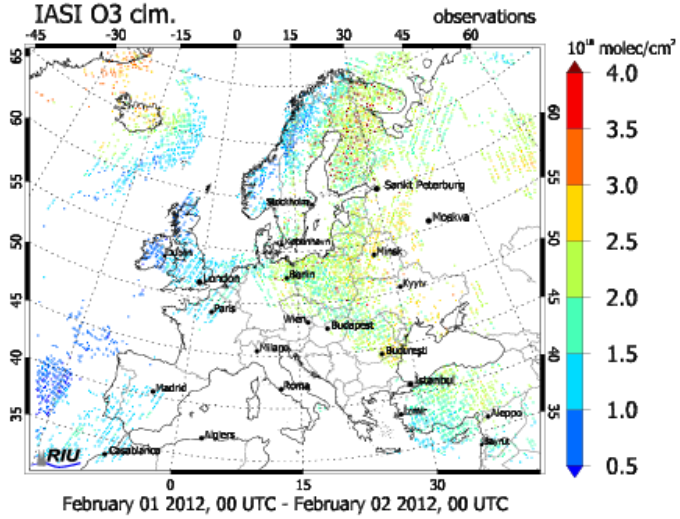


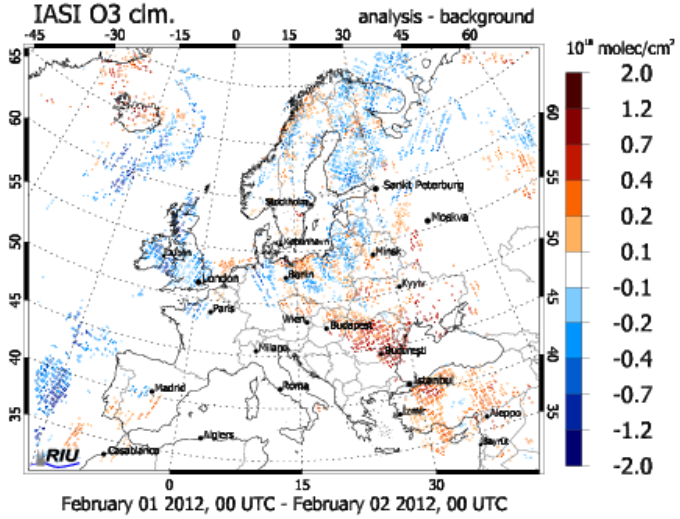
3d-var Assimilation of IASI Ozone Columns





1.2.2012

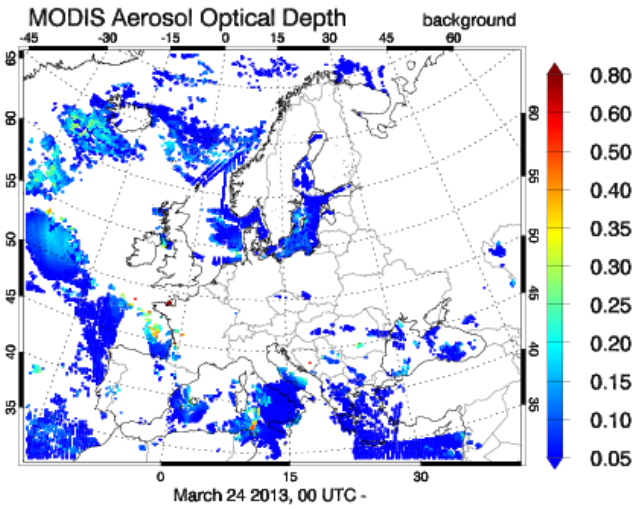


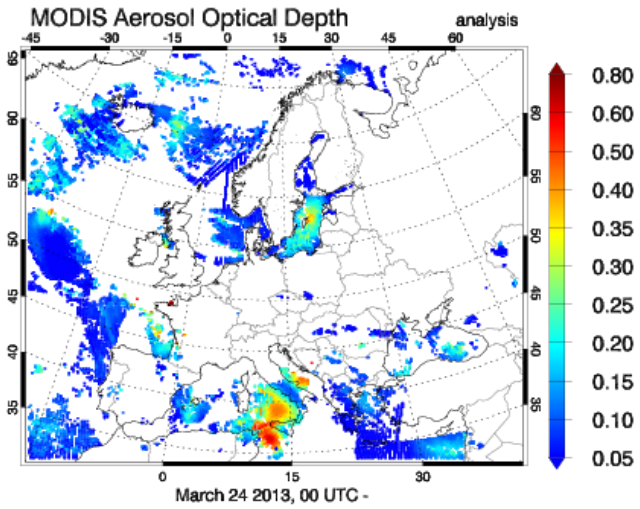


3d-var Assimilation of MODIS AOD Retrievals

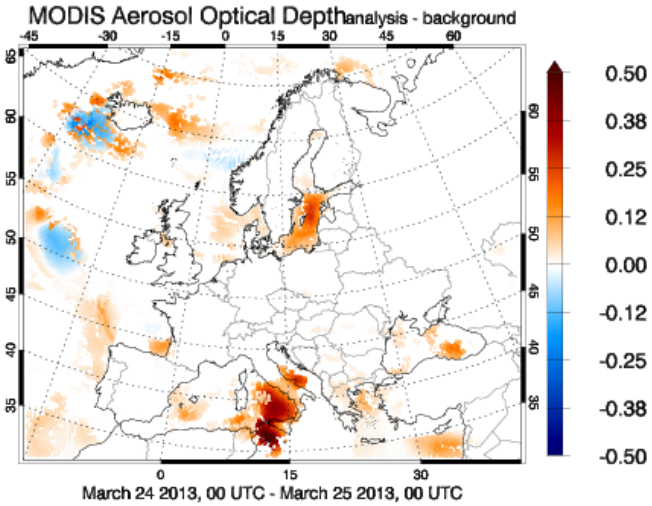
15 km model resolution, 24.3.2013

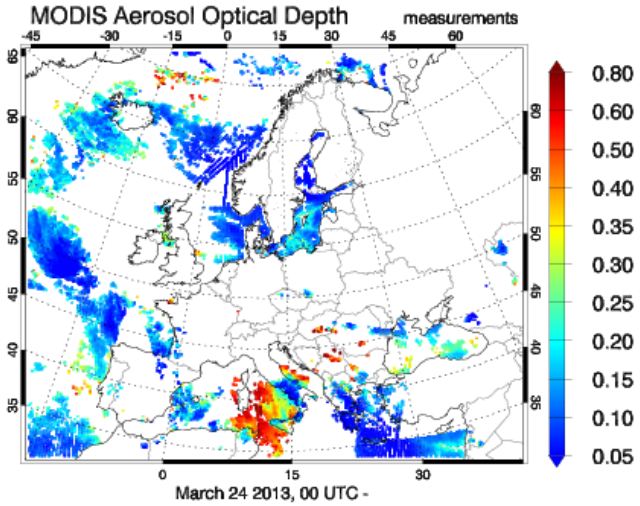
Background, H(x)





AN – BG H(x)





Analysis, H(x)

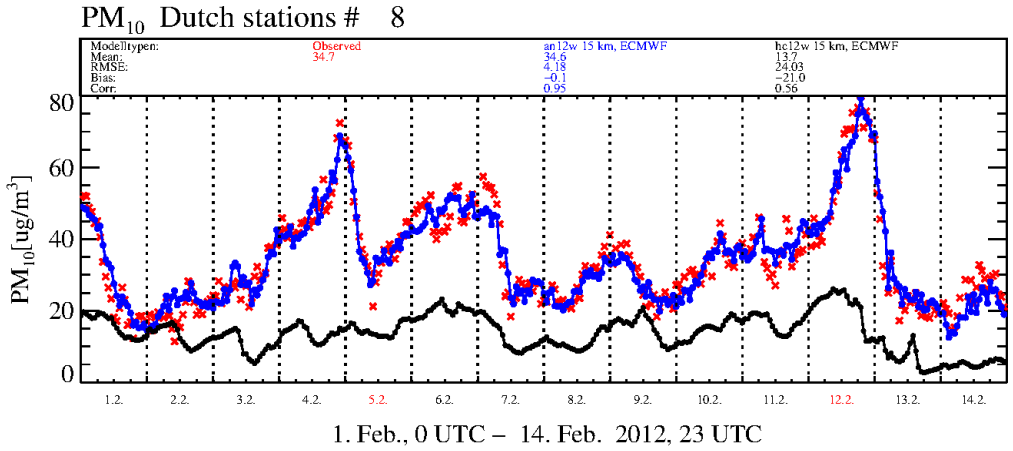
Observations, y

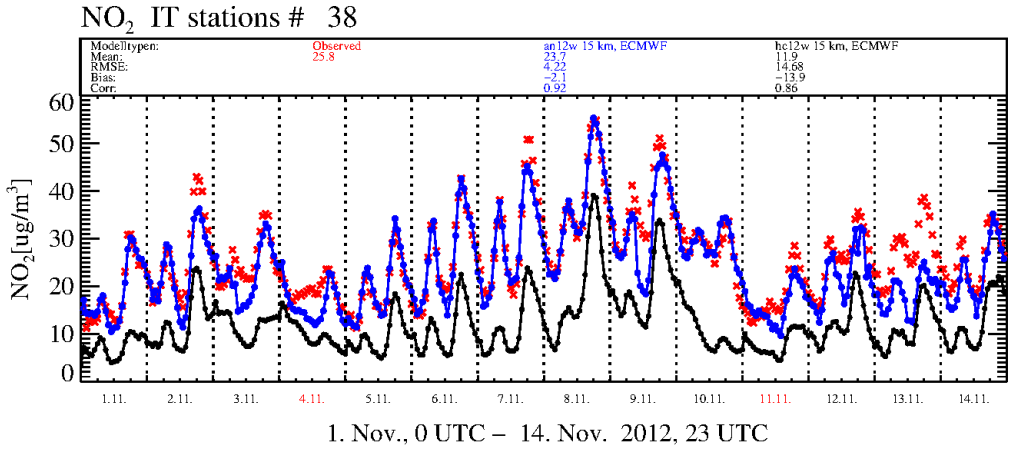
5. Validation of EURAD-IM CAMS-50 Analysis/Re-Analysis

EURAD-IM MACC EVA 3d-var Re-Analysis for 2012

Averaged Time-Series for AIRBASE Measurement Sites

(withheld from assimilation)





PM_{10} NL stations
1.2. – 14.2. 2012

Observations
Forecast
Analysis

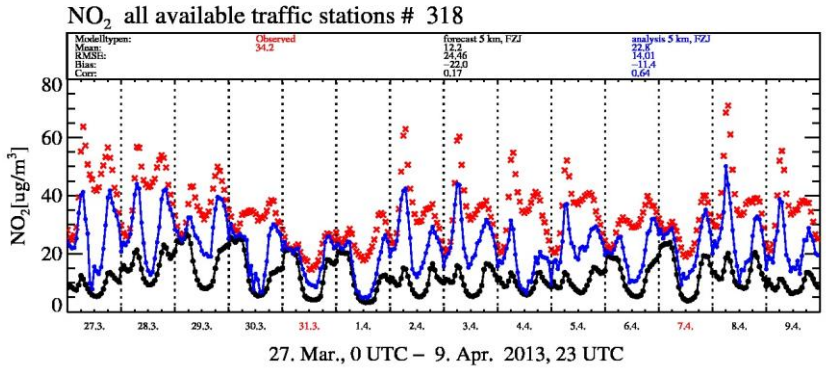
NO_2 IT stations
1.11. – 14.11.2012

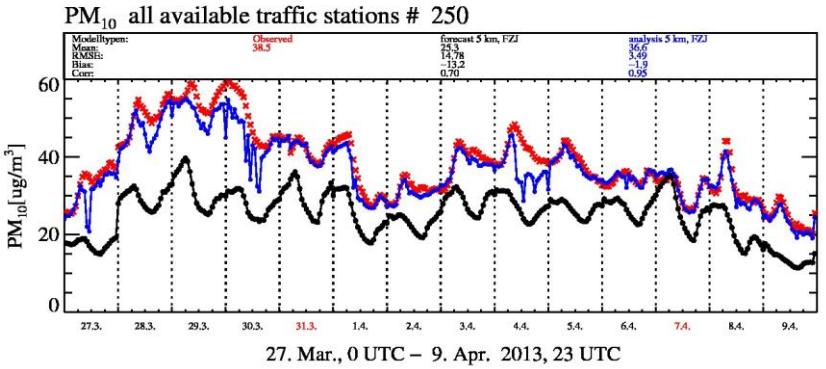
Good performance of the EURAD-IM airshed analysis even at traffic sites

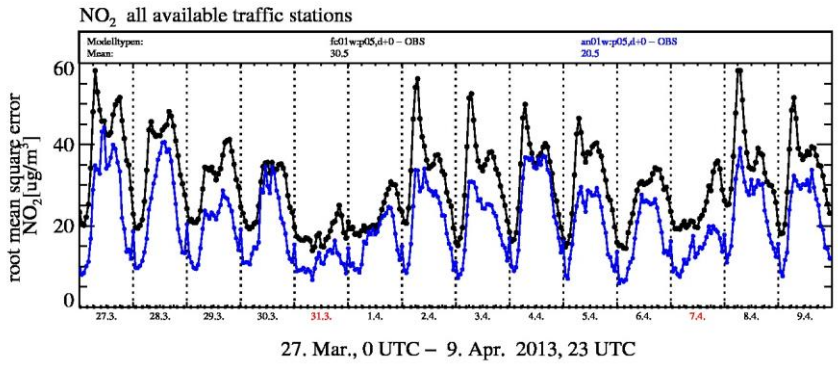
NO_2 PM_{10}

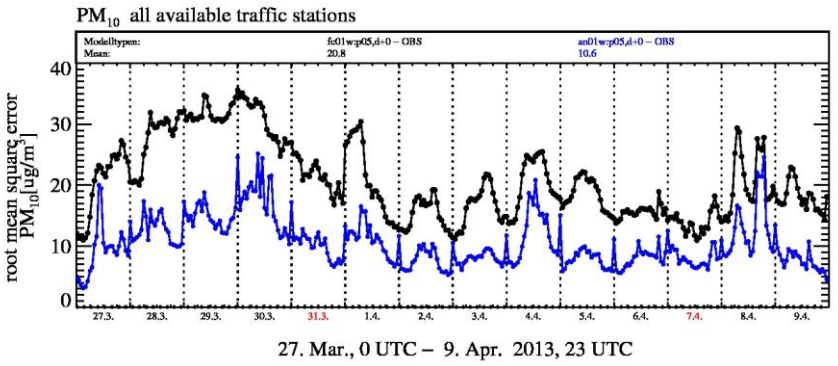
Averaged time-series from March 27 to April 9, 2013

forecast analysis



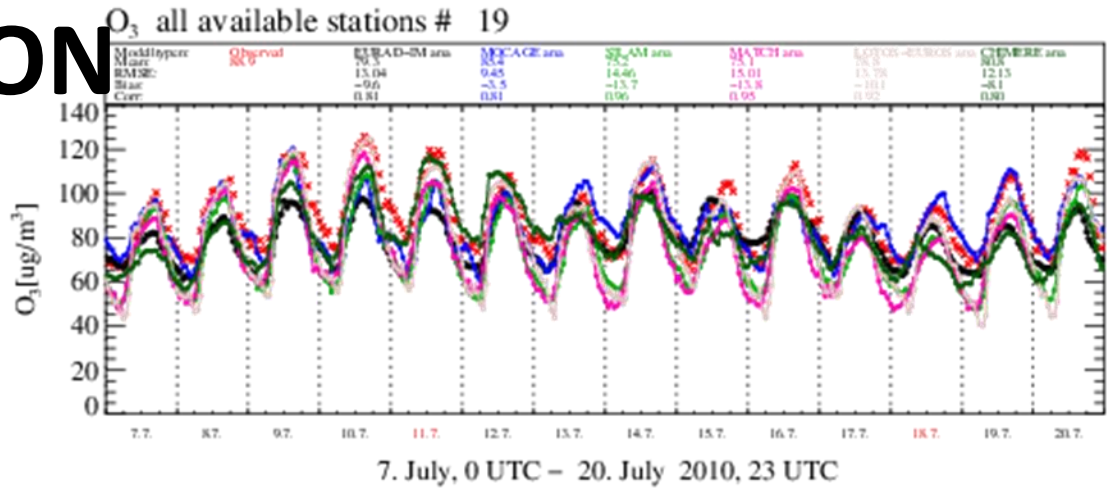




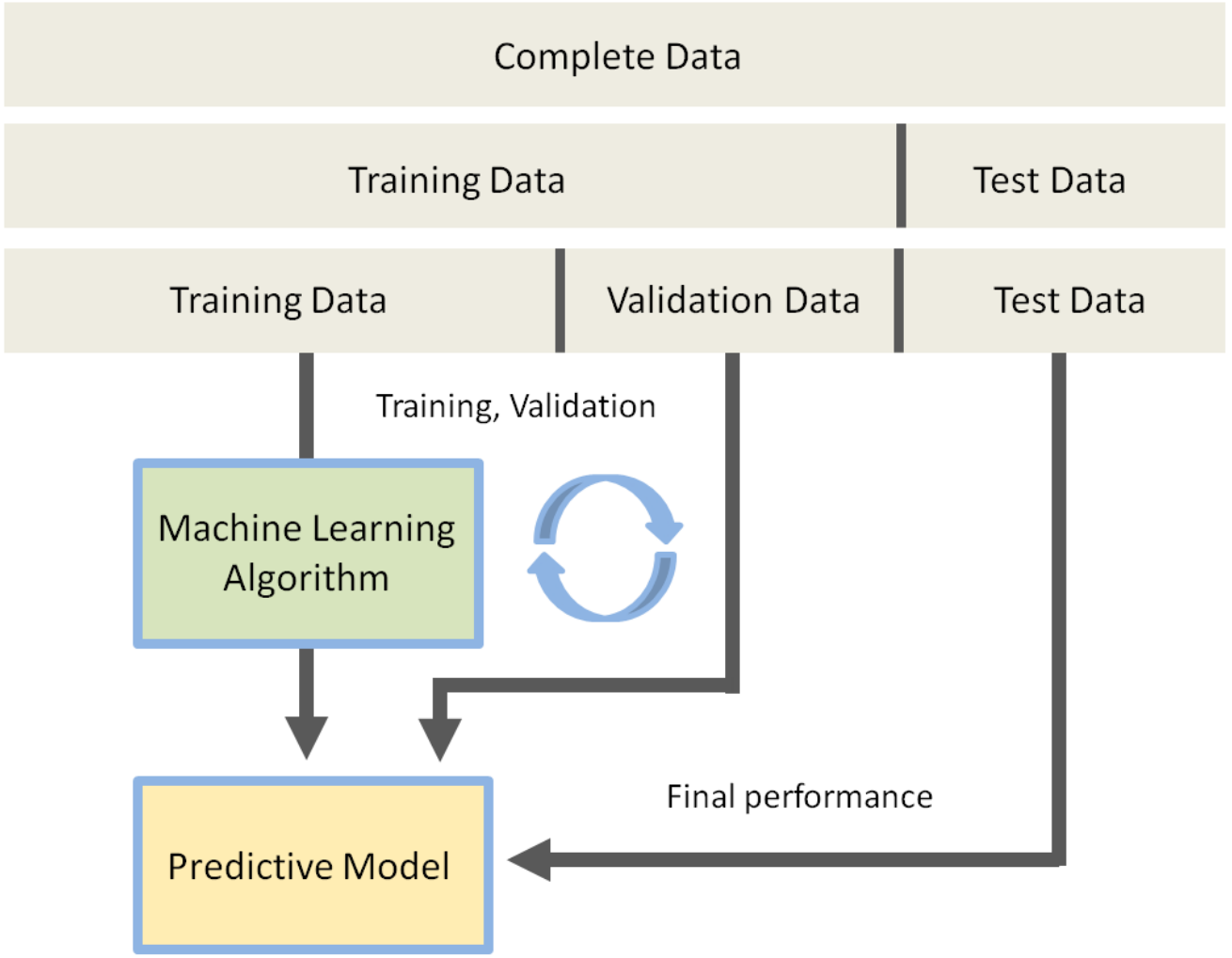


rmse time-series

5. VALIDATION

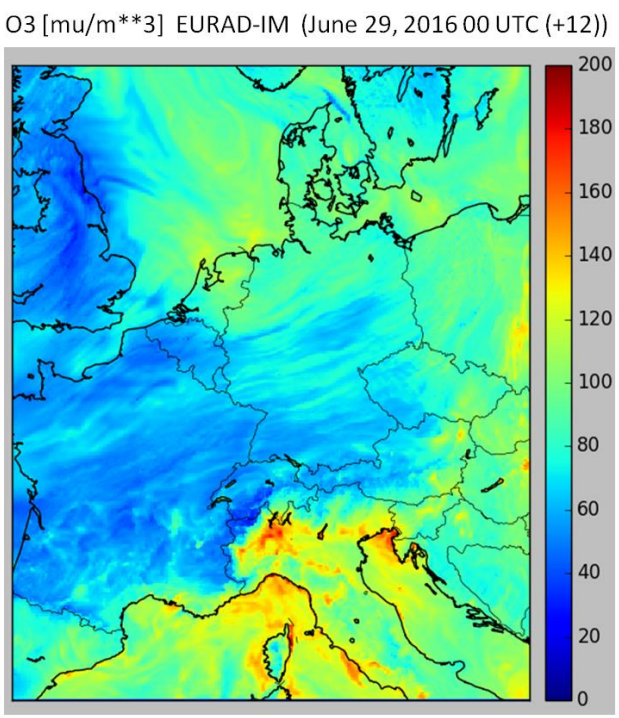


Model parameter optimisation and select learned models

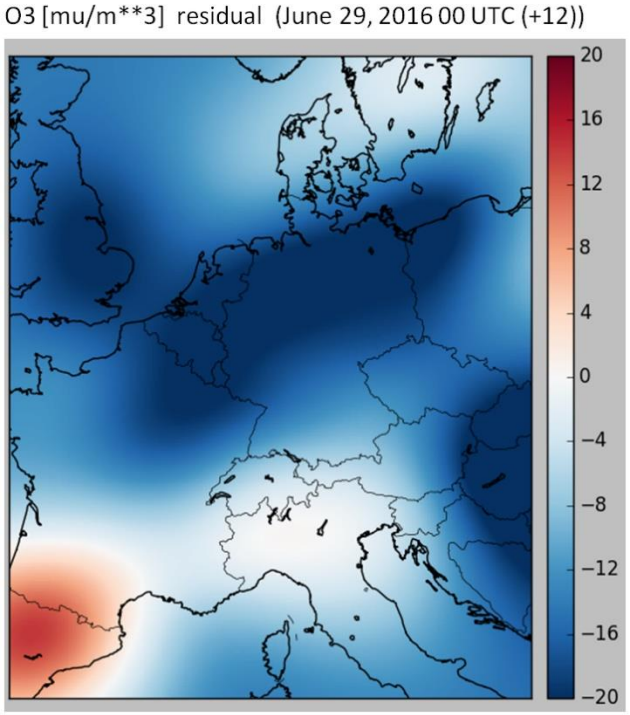


Bias correction by the hybrid method

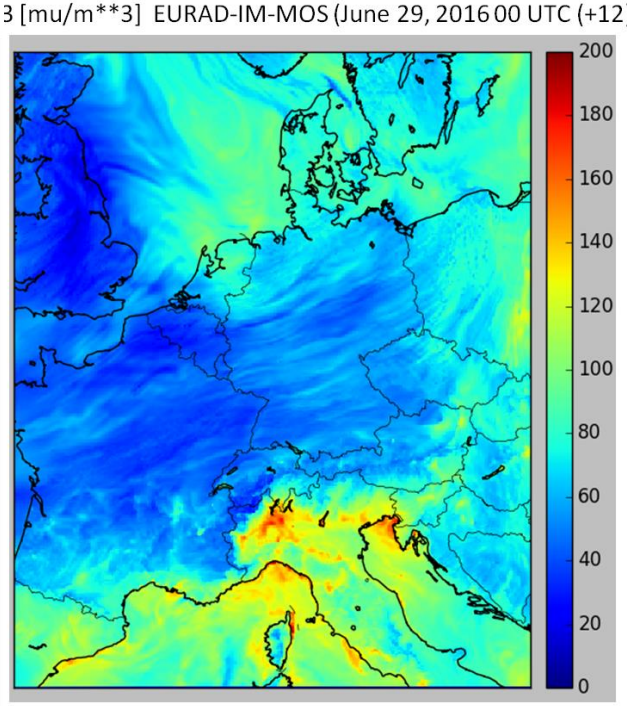
interpolated by Gaussian process regression (Kang et al. , 2008)



EURAD-IM surface O_3
5 km grid



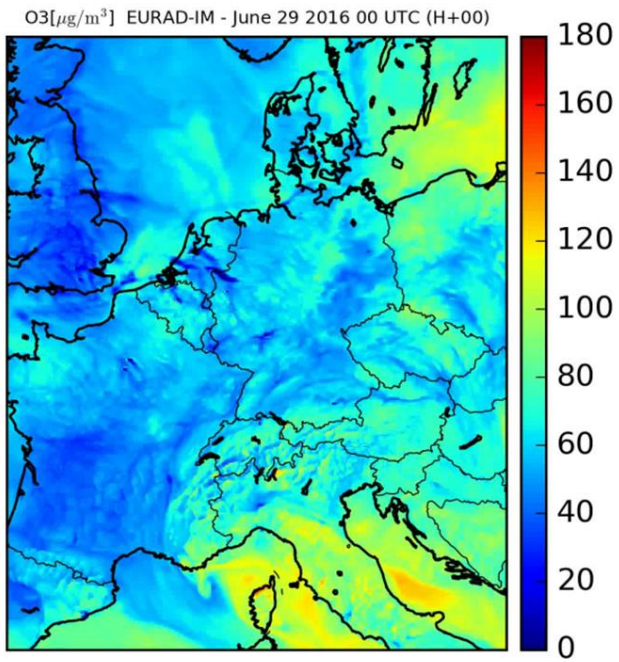
Bias correction term
interpolated by
Gaussian process regression



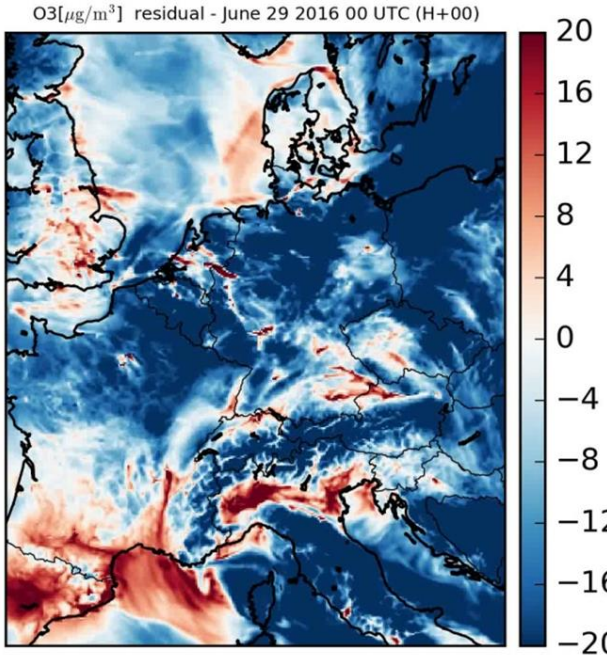
EURAD-IM surface O_3
corrected by bias correction

Bias correction by the hybrid method

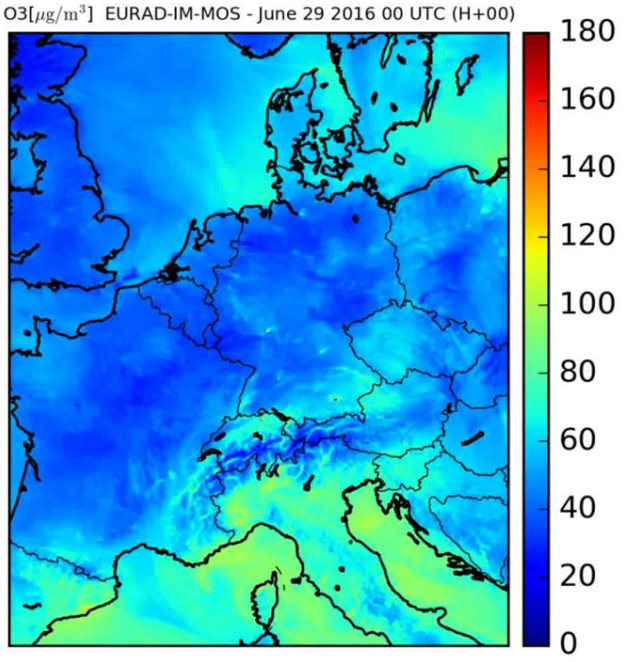
interpolated by ridge regression



EURAD-IM surface O_3
5 km grid



Bias correction term
interpolated by
ridge regression

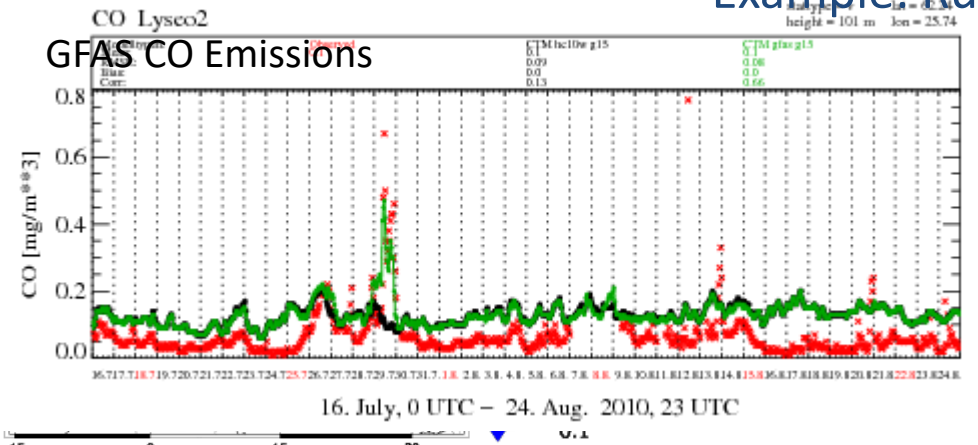


EURAD-IM surface O_3
corrected by bias correction

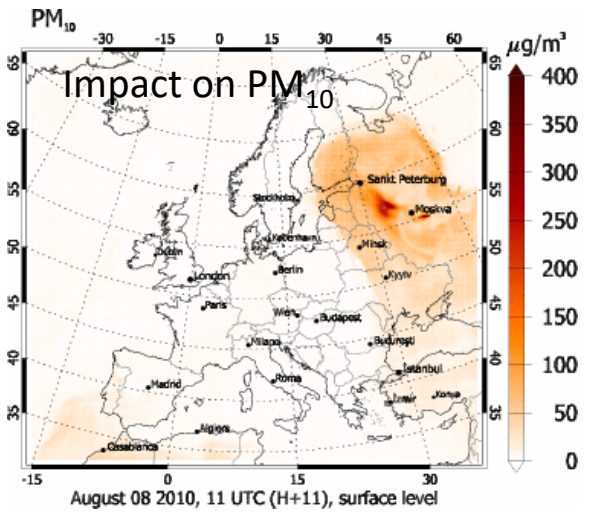
Fire Radiative Power Analysis from GFAS

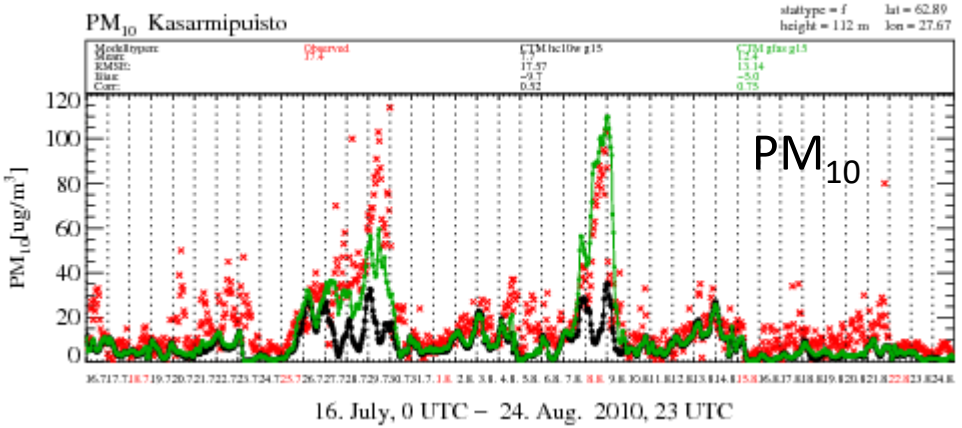
Example: Russian peat fires 2010

GFAS CO Emissions



CO





PM_{10}

- Observations
- EURAD-IM without GFAS emissions
- EURAD-IM with GFAS emissions

THANK YOU FOR YOUR ATTENTION