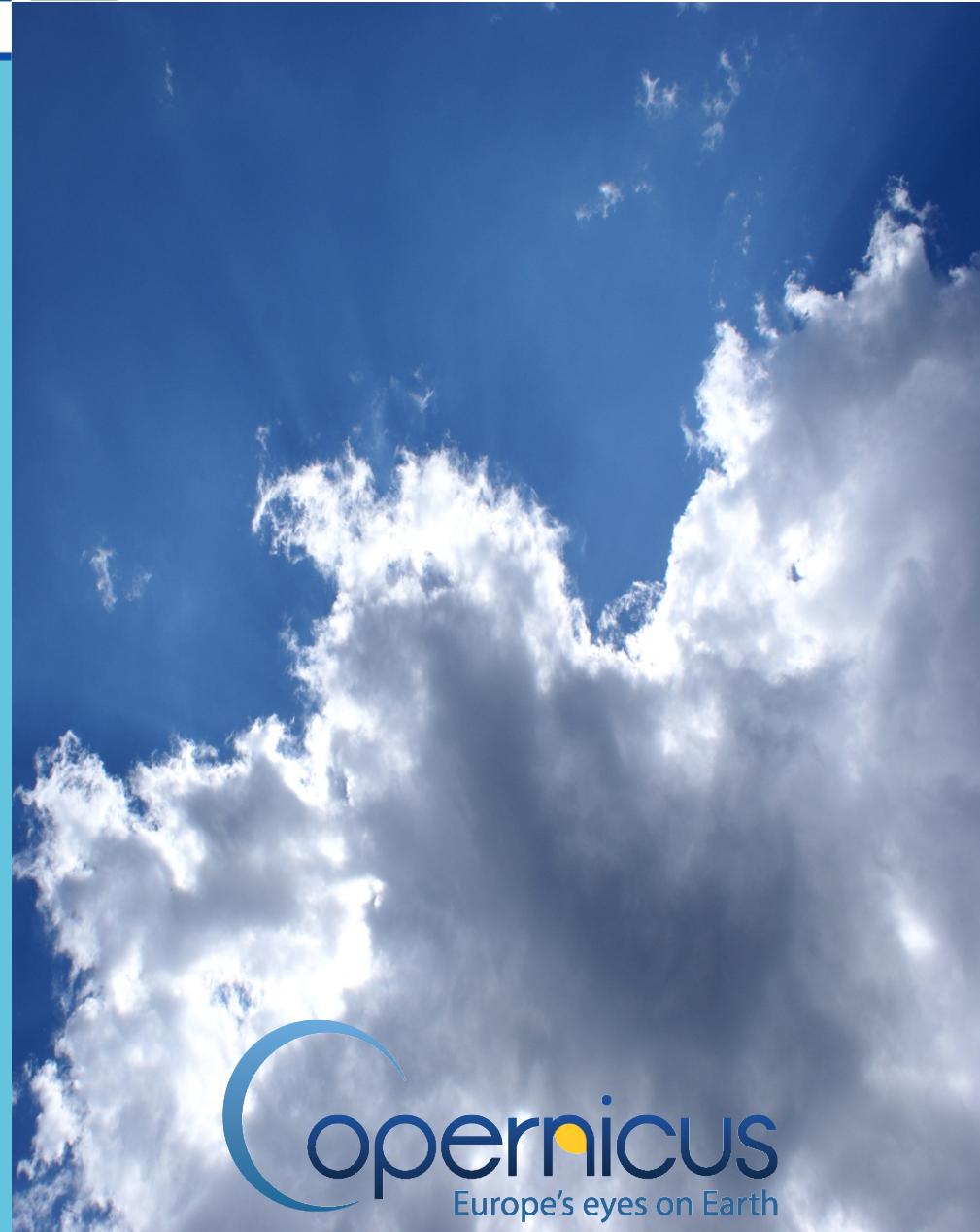
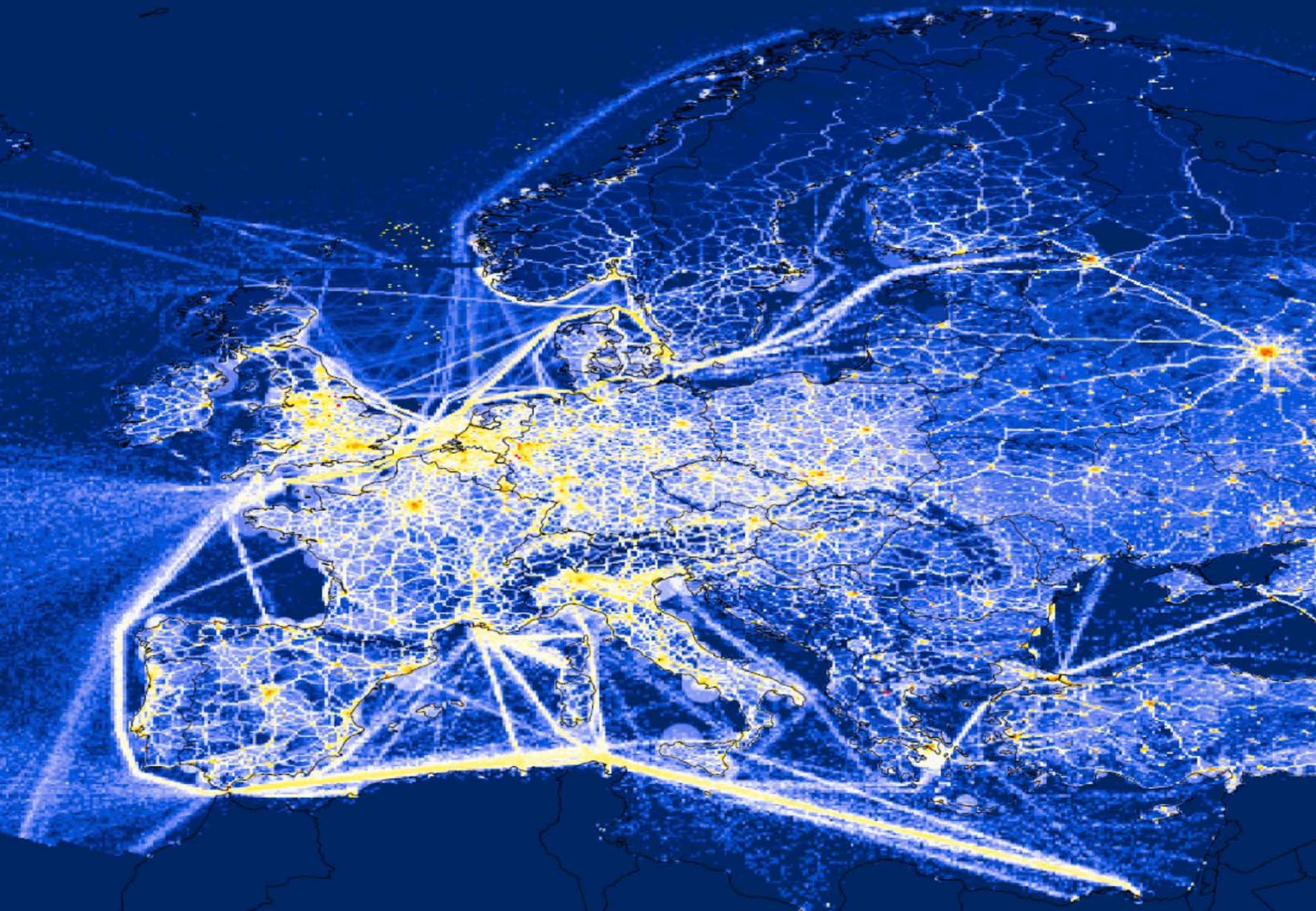




Air quality forecasting in Europe

Richard Engelen
ECMWF



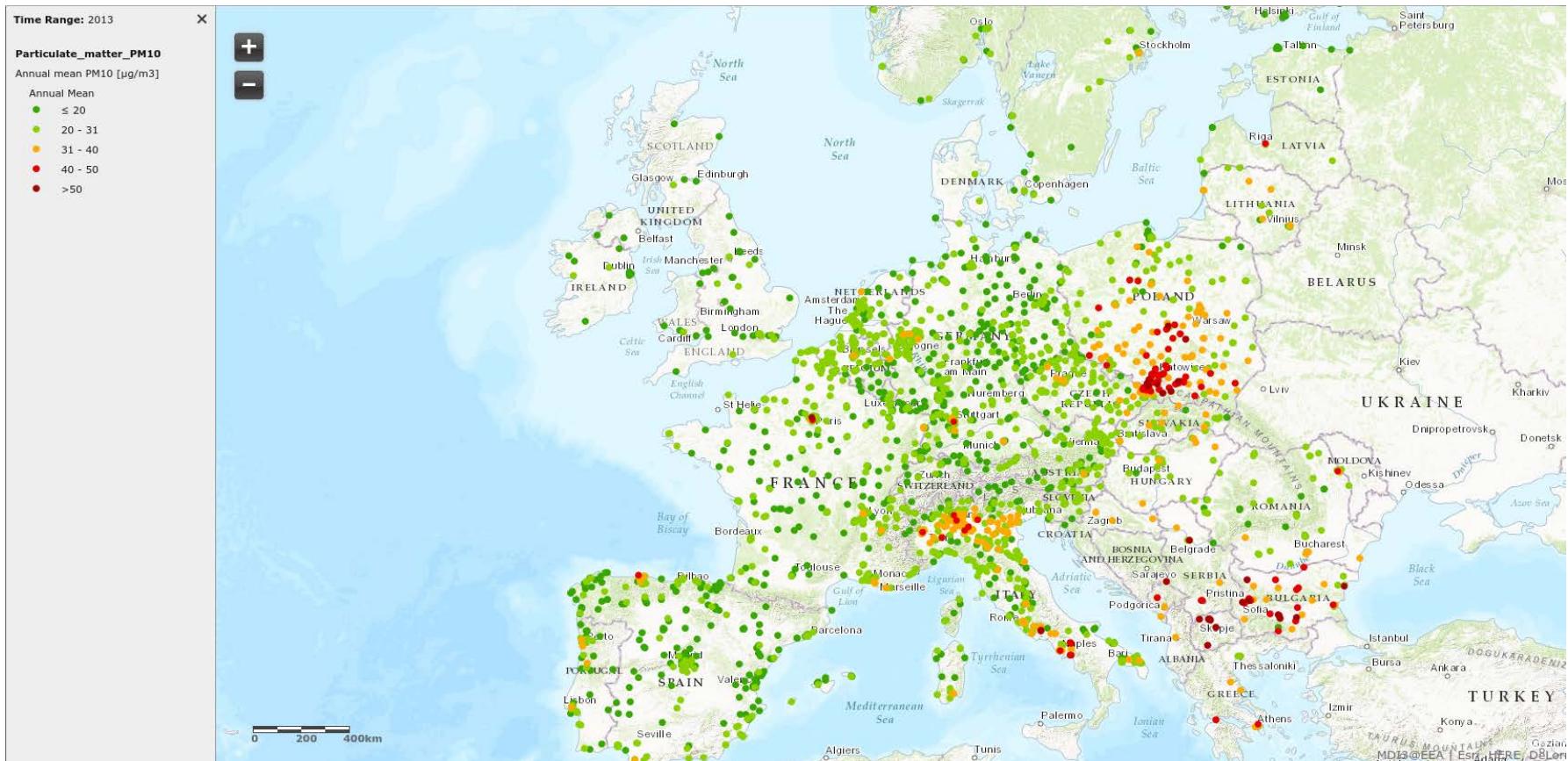


- **Introduction**
Using European Collaboration to forecast air quality
- **Copernicus Atmosphere Monitoring Service**
From satellite observation to air quality forecast
- **The global view**
Using NWP principles for atmospheric composition forecasting
- **The regional view**
Seven know more than one
- **Applications**
How is the information being used

European Air Quality Directive

- Sets targets for exposure levels of different pollutants that EU member states have to comply with
- Member states have to monitor air quality with prescribed standards and report to the European Commission
- Modelling may be used for monitoring purposes to reduce the number of measurement stations by up to 50%
- There is the possibility to discount natural sources of pollution when assessing compliance against limit values

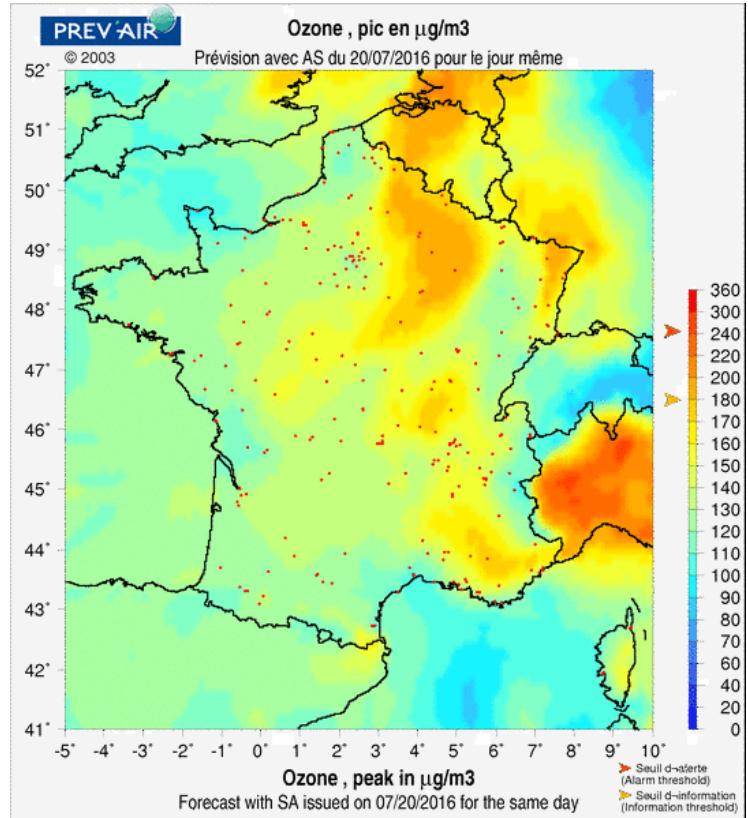
Regulatory Observations



Annual mean PM10
concentrations for 2013

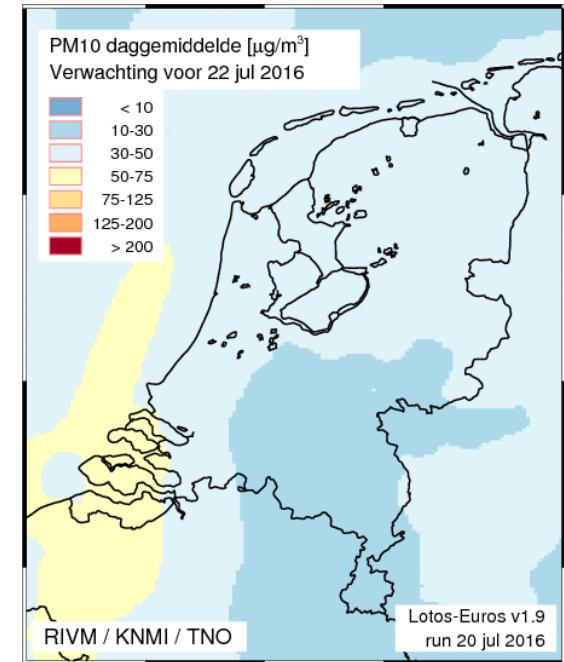
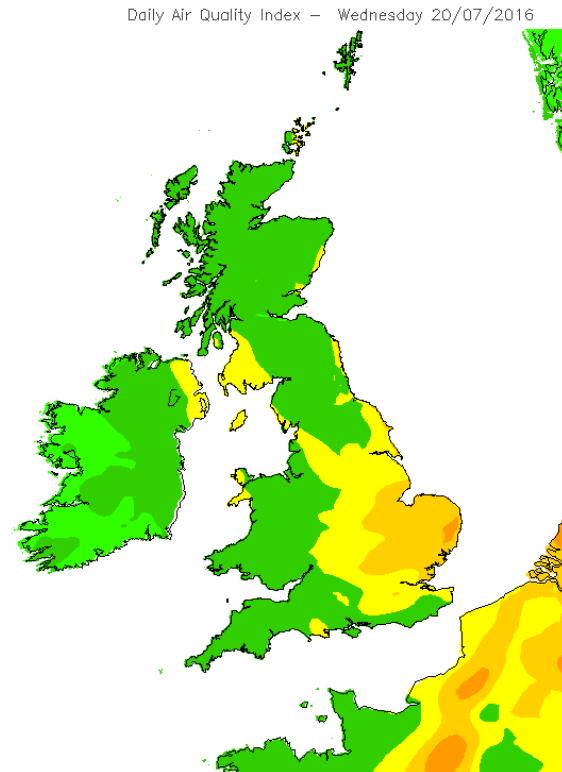
European Environment Agency





France

United Kingdom



Netherlands

CONSIDERING the importance for the **European economy** of a considerable improvement in medium-range weather forecasts;

CONSIDERING that the scientific and technical research carried out for this purpose will provide a **valuable stimulus to the development of meteorology in Europe**;

CONSIDERING that the improvement of medium-range weather forecasts will **contribute to the protection and safety of the population**;

CONSIDERING that, to achieve these objectives, **resources on a scale exceeding those normally practicable at national level are needed**;

CONSIDERING the importance that the establishment of such a centre can have for the **development of European industry** in the field of data processing,

HAVE DECIDED to establish a European Centre for Medium-Range Weather Forecasts

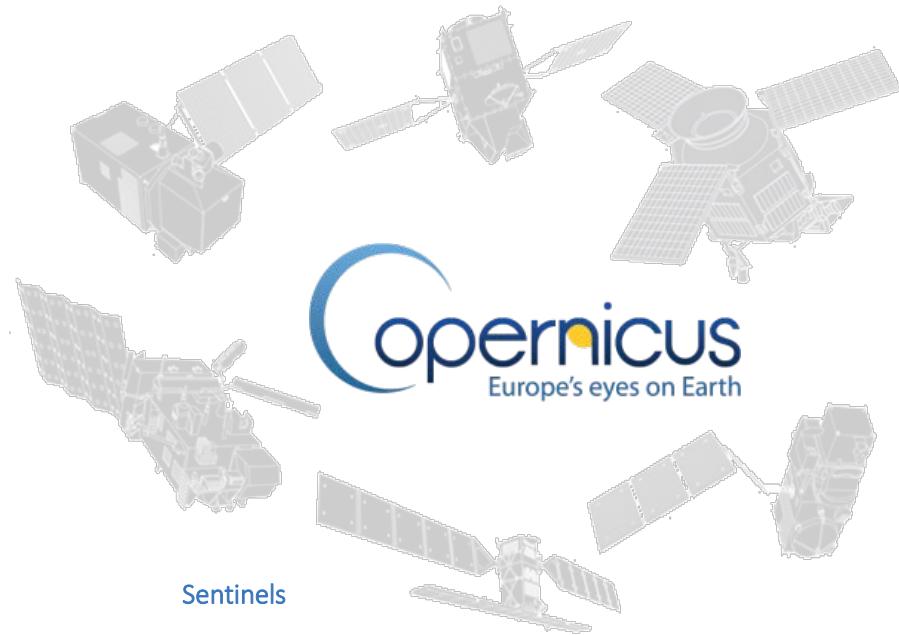
Can we apply the same concept to air quality forecasting in Europe?



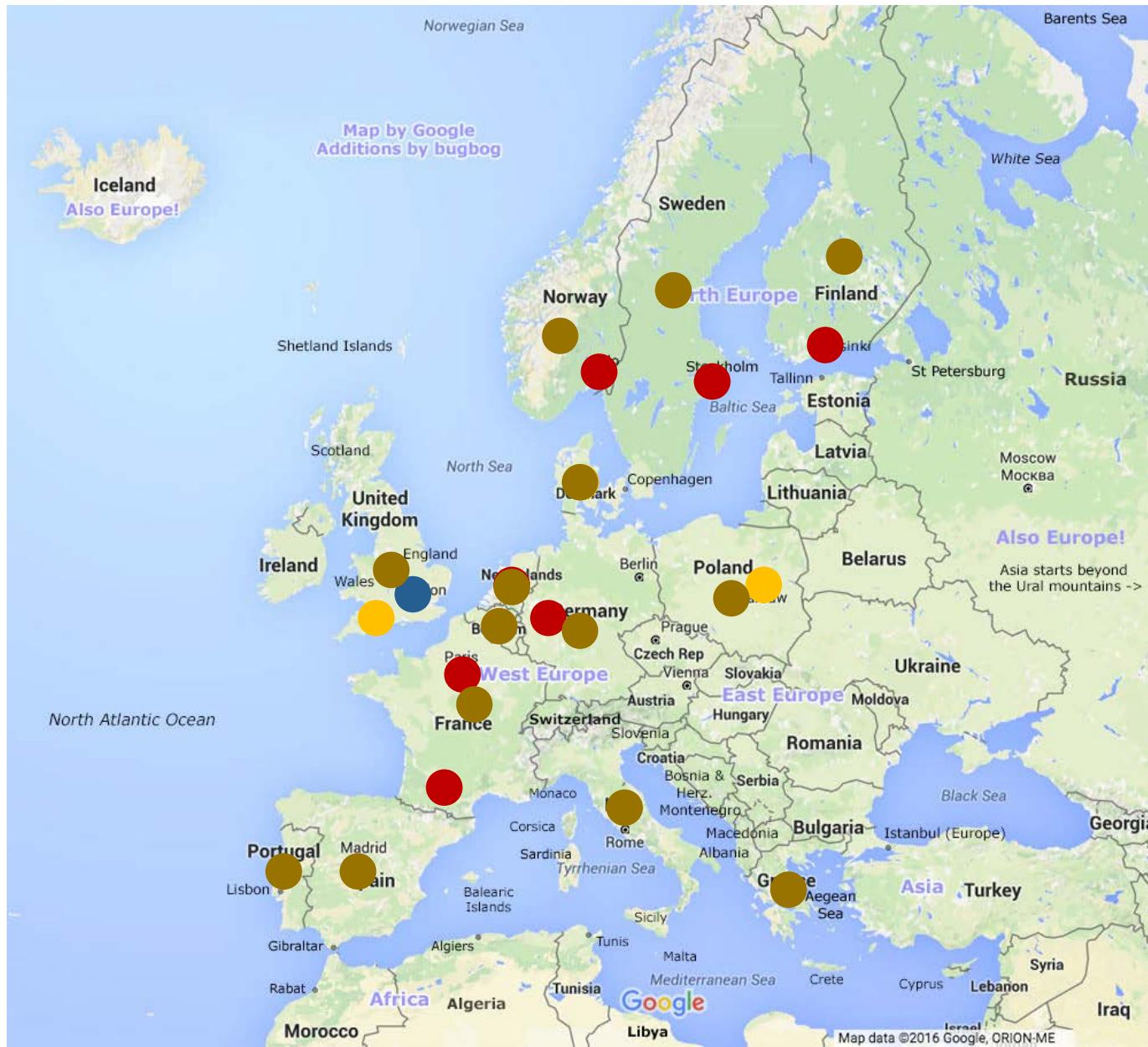
Copernicus Atmosphere Monitoring Service

Combine observations with state-of-the-art data assimilation and forecasting systems to provide air quality information on the global and regional scale.

Make optimal use of existing expertise and infrastructure in Europe.



European collaboration

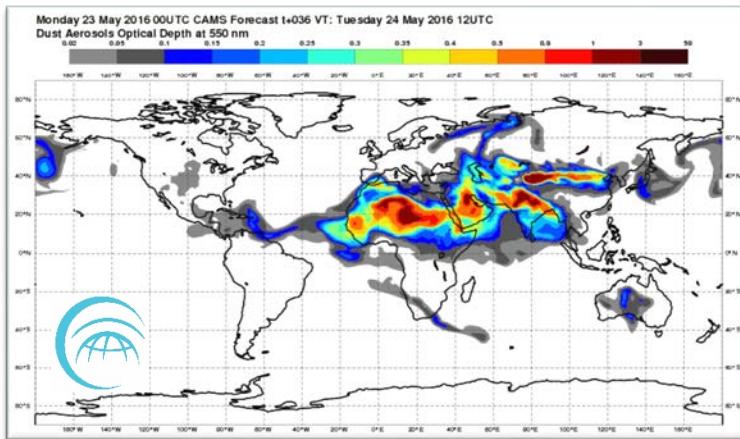
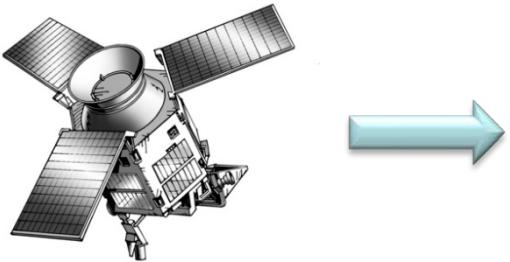


From satellite observation to air quality forecast

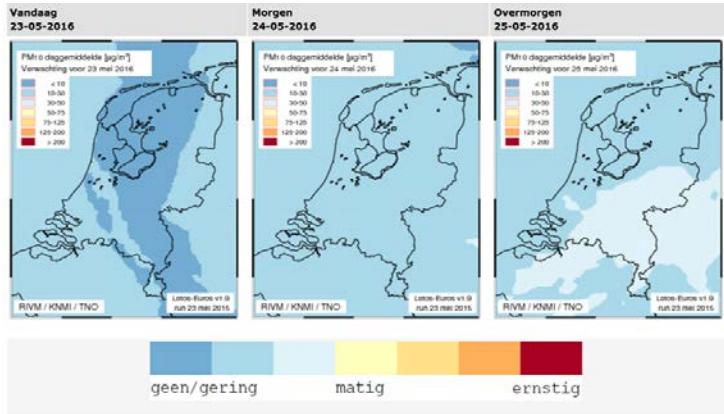
COPERNICUS ATMOSPHERE MONITORING SERVICE

CAMS IN A NUTSHELL

Space Agencies



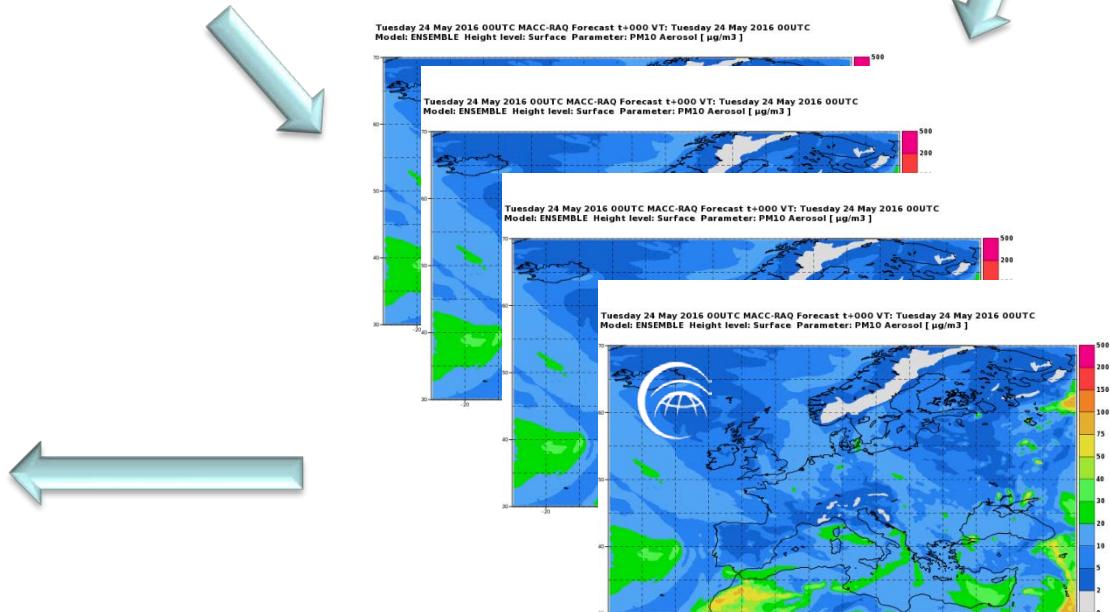
National scale

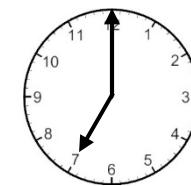
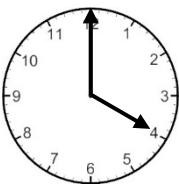
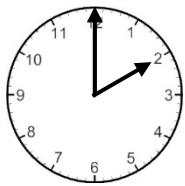


In-situ component



CAMS





Space

MOPITT observes
the atmosphere

NCAR

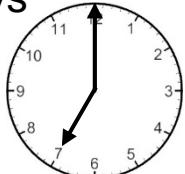
Retrieves carbon
monoxide
concentrations

ECMWF

Global data
assimilation and
forecast for the next 5
days

Anywhere

Daily AQ forecast for
Europe for the next 4
days



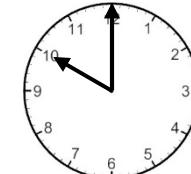
Meteo-France

Model ensemble
processing



7 regional centres

Regional air quality
forecast



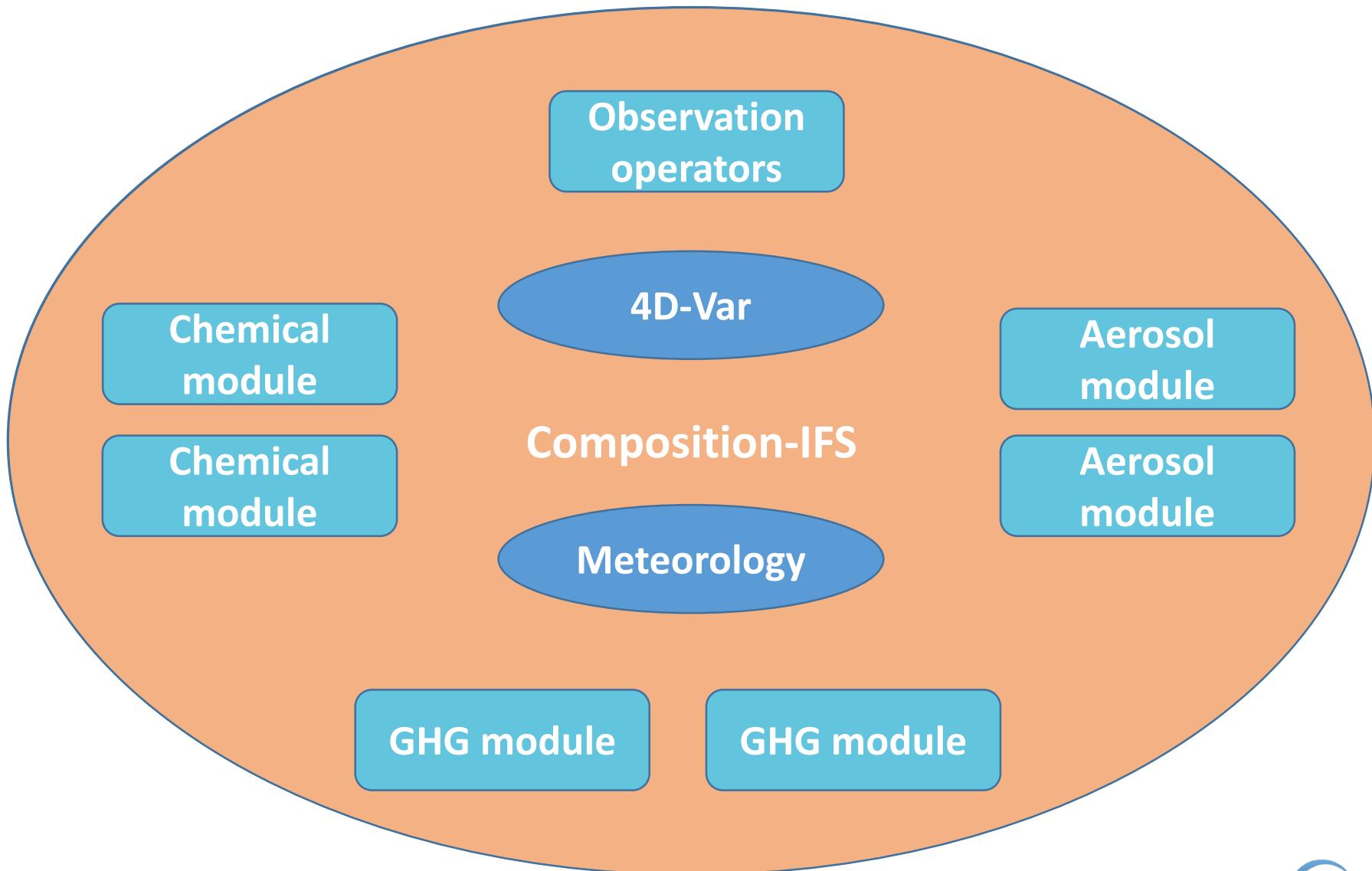
WHAT IS AVAILABLE?

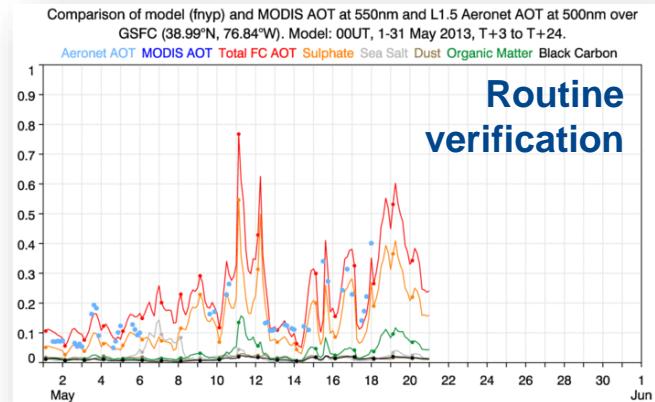
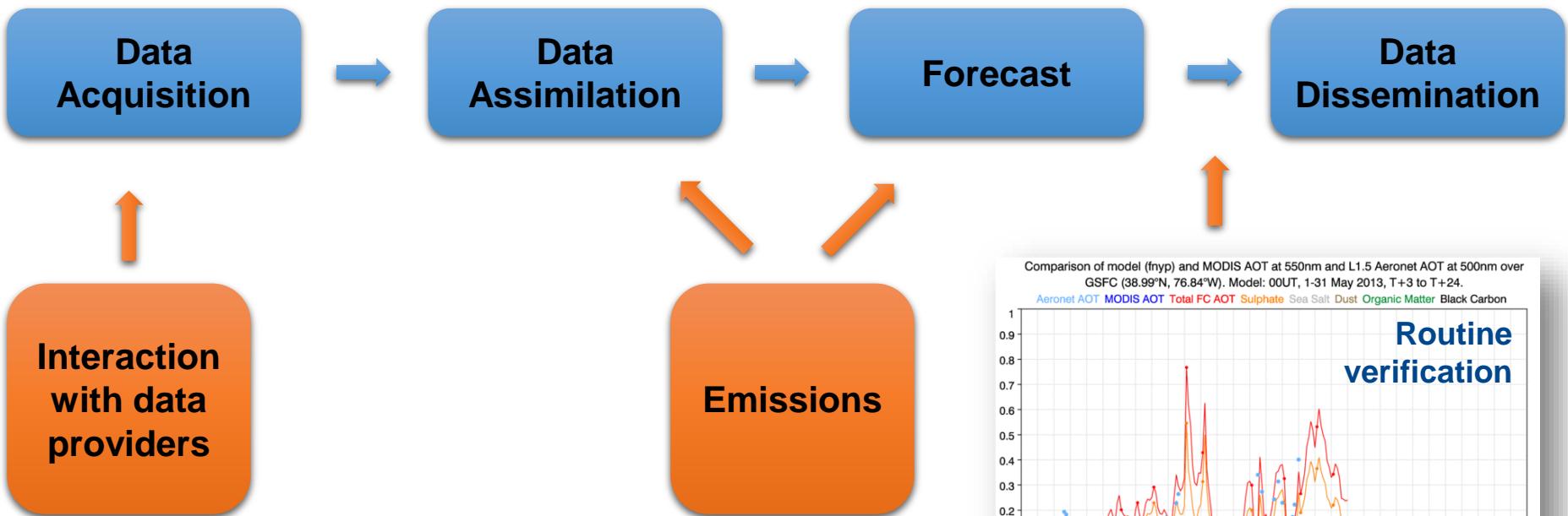
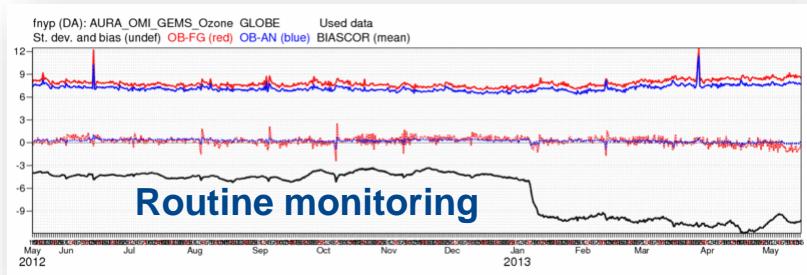
Portfolio	Product groups
A. Regional products	European AQ NRT analyses
	European AQ NRT forecasts
	European AQ interim reanalyses
	European AQ reanalyses
B. Global products (troposphere and stratosphere)	Global atmospheric composition NRT analyses
	Global atmospheric composition NRT forecasts
	Global atmospheric composition reanalyses
C. Supplementary products	Policy support products
	Solar radiation
	Greenhouse gas fluxes
	Climate forcings
D. Emissions products	Anthropogenic emissions
	Fire emissions

- Data
- Charts
- Policy reports
- Validation reports
- Documentation

Using NWP principles for atmospheric composition forecasting

THE GLOBAL ELEMENT

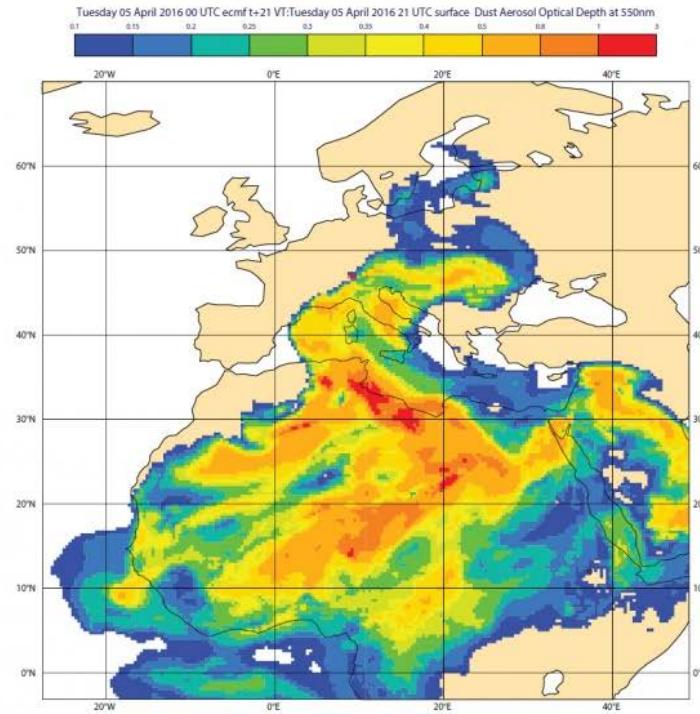
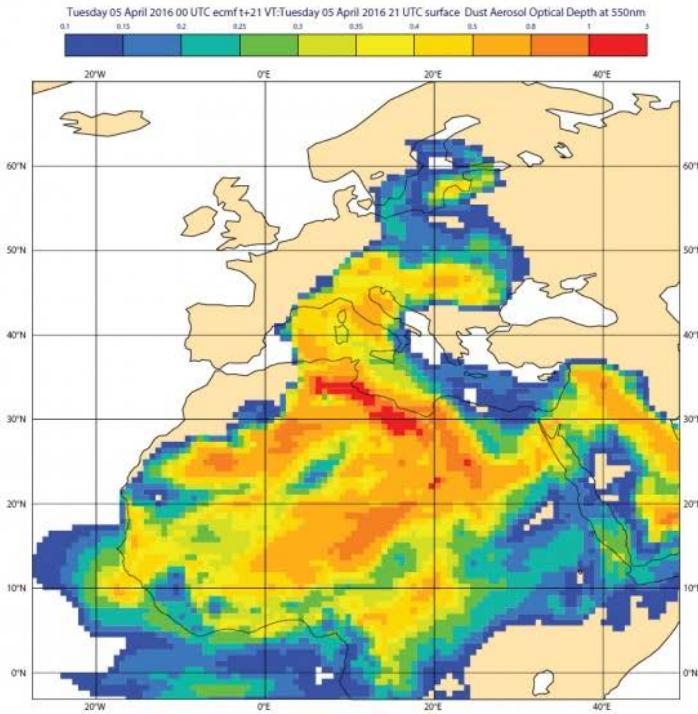




CURRENT STATUS

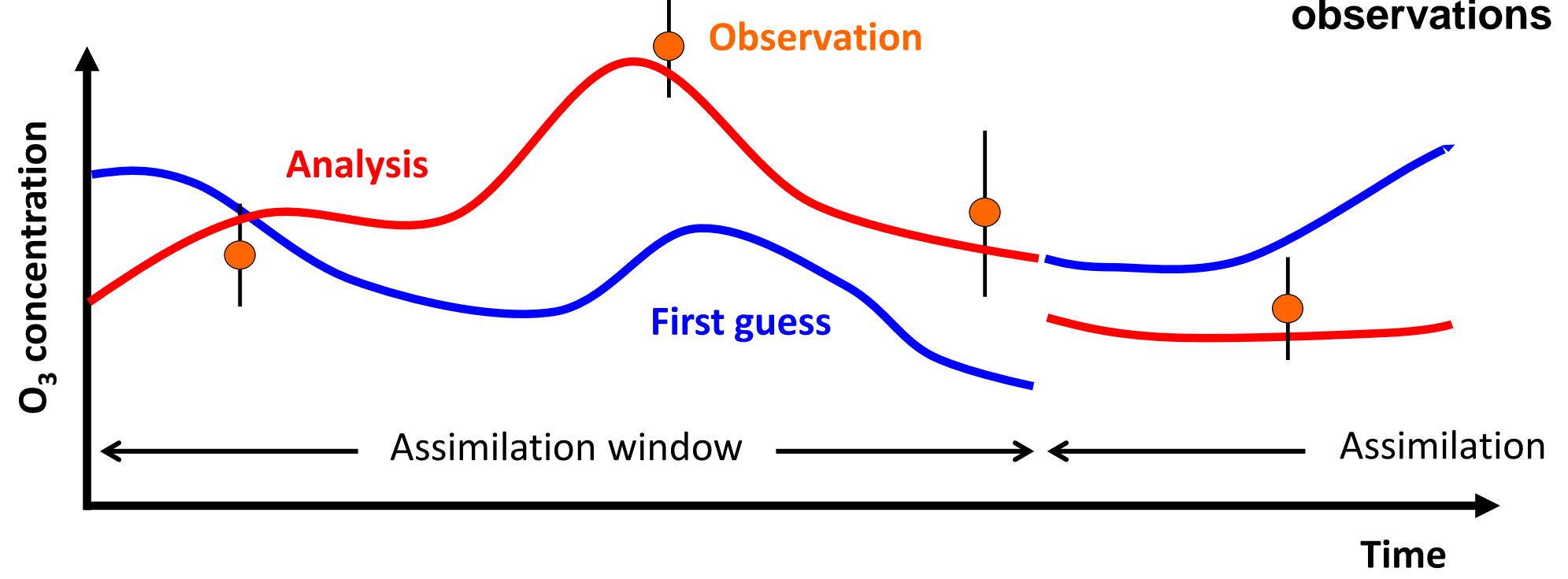


European
Commission

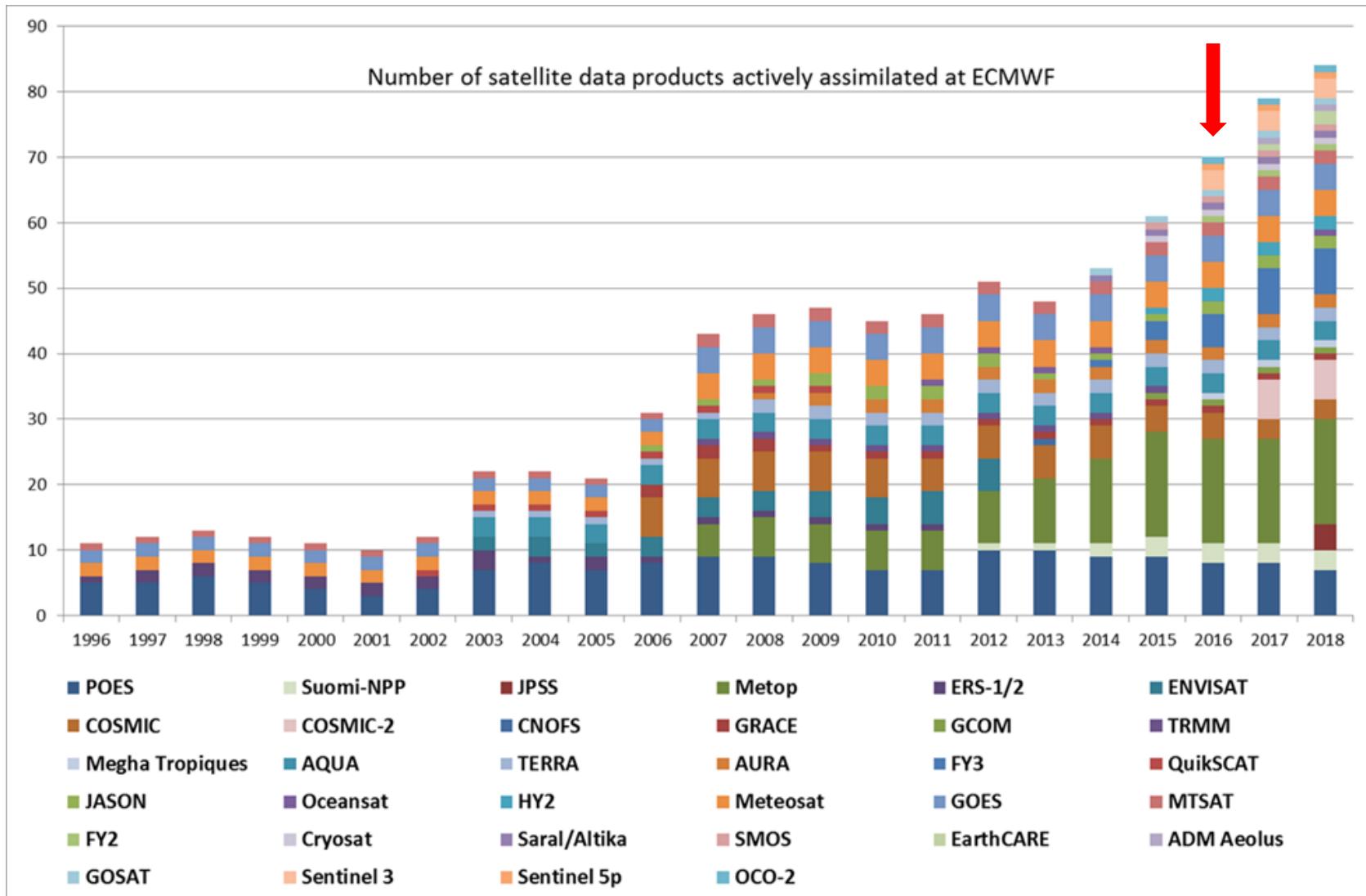


- 40 km horizontal resolution at 60 model levels
- Two 5-day forecasts per day
- Output species: O₃, CO, NO, NO₂, PAN, HNO₃, CH₂O, SO₂, CH₄, C₅H₈, C₂H₆, OH, C₃H₈, CO₂, aerosol (dust, sea salt, organic matter, black carbon, sulphates)
- TM5 chemical module – simple aerosol bin scheme – linearized stratospheric ozone

Data assimilation – combining model and observations

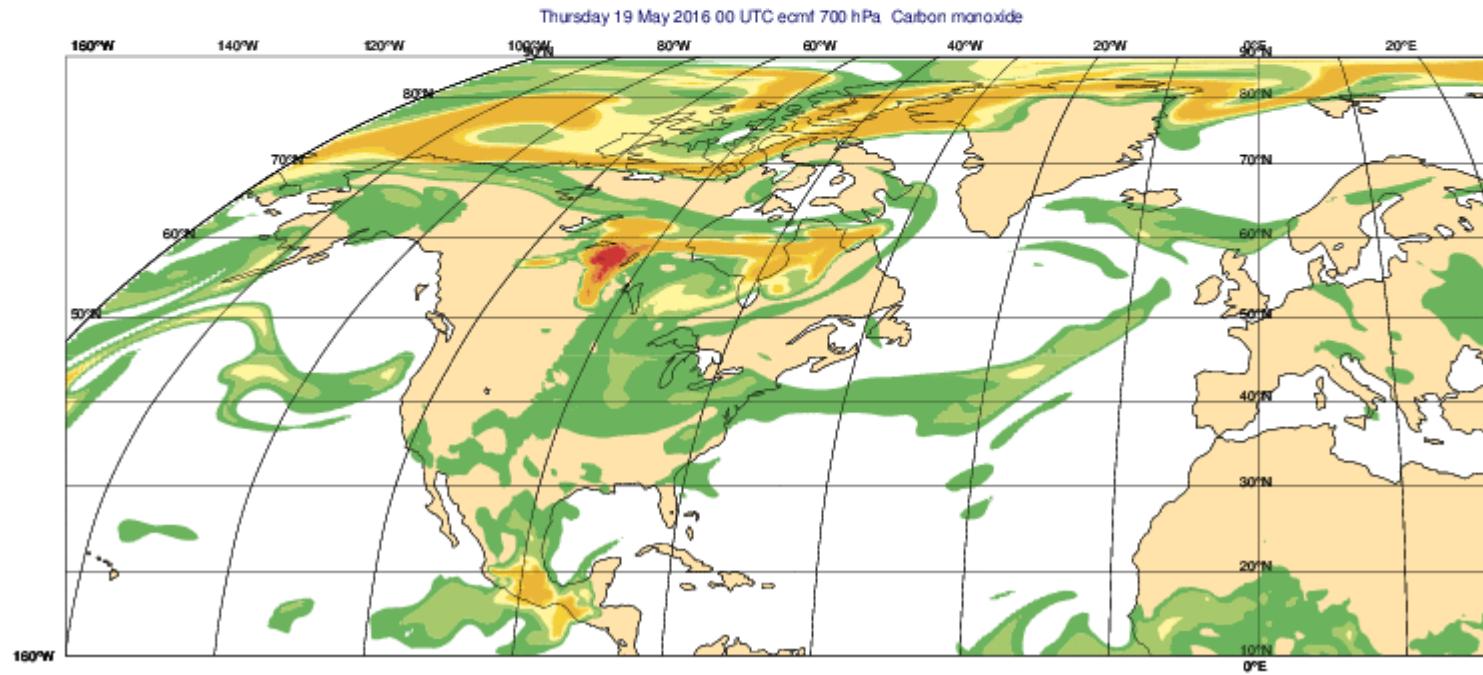


SATELLITE DATA USED



Species	Instruments
Global system	
O ₃	OMI, SBUV, GOME-2, MLS, OMPS, S5p
CO	IASI, MOPITT, S5p
NO ₂	OMI, GOME-2, S5p
SO ₂	OMI, GOME-2, S5p
Aerosol	MODIS, PMAp, VIIRS, S3
CO ₂	GOSAT, OCO-2
CH ₄	GOSAT, IASI, S5p
GFAS fire emissions	MODIS, GOES, SEVIRI, VIIRS

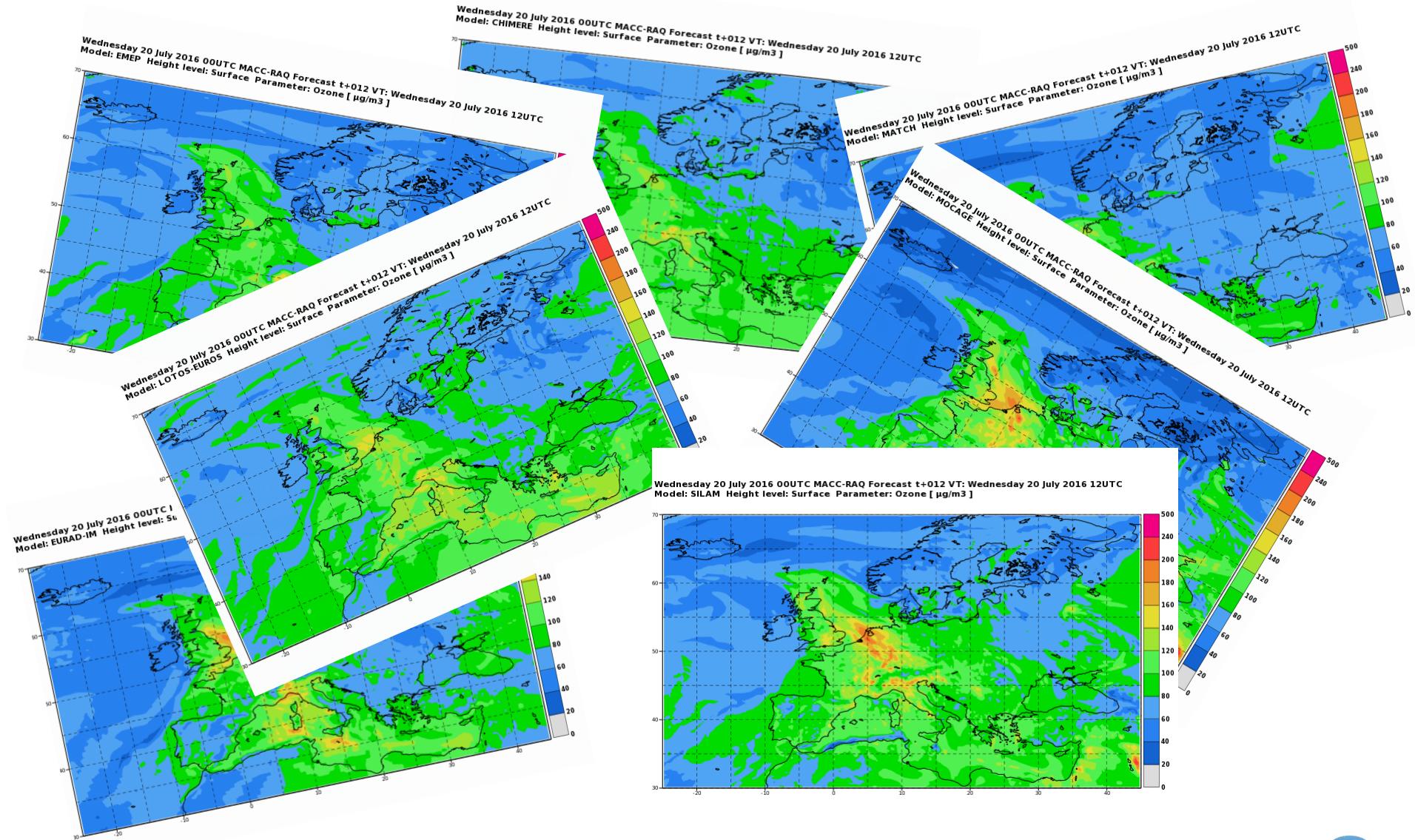
The global system is best suited to assimilate enormous amounts of satellite data and provide the long-range transport of key pollutants.



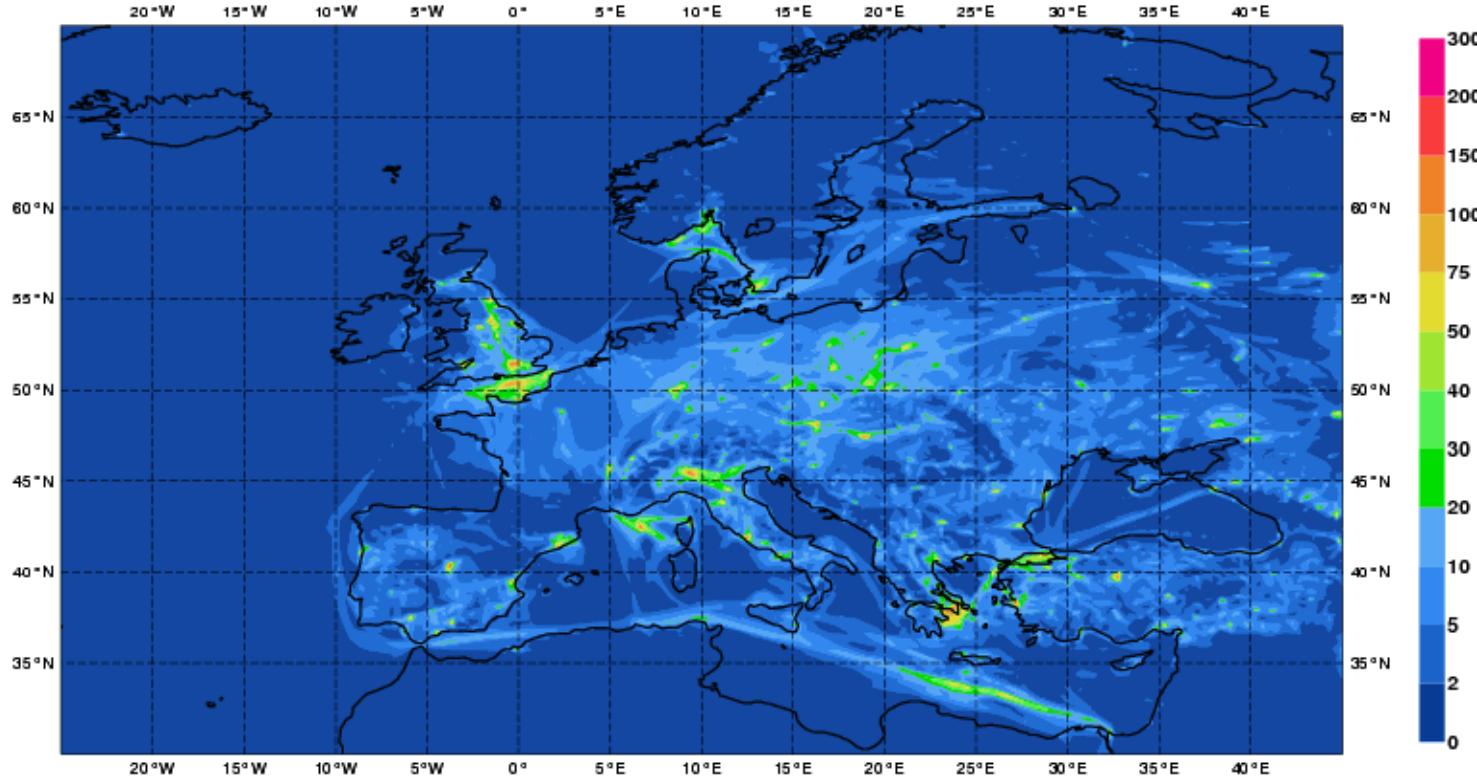
Seven know more than one

THE REGIONAL ELEMENT

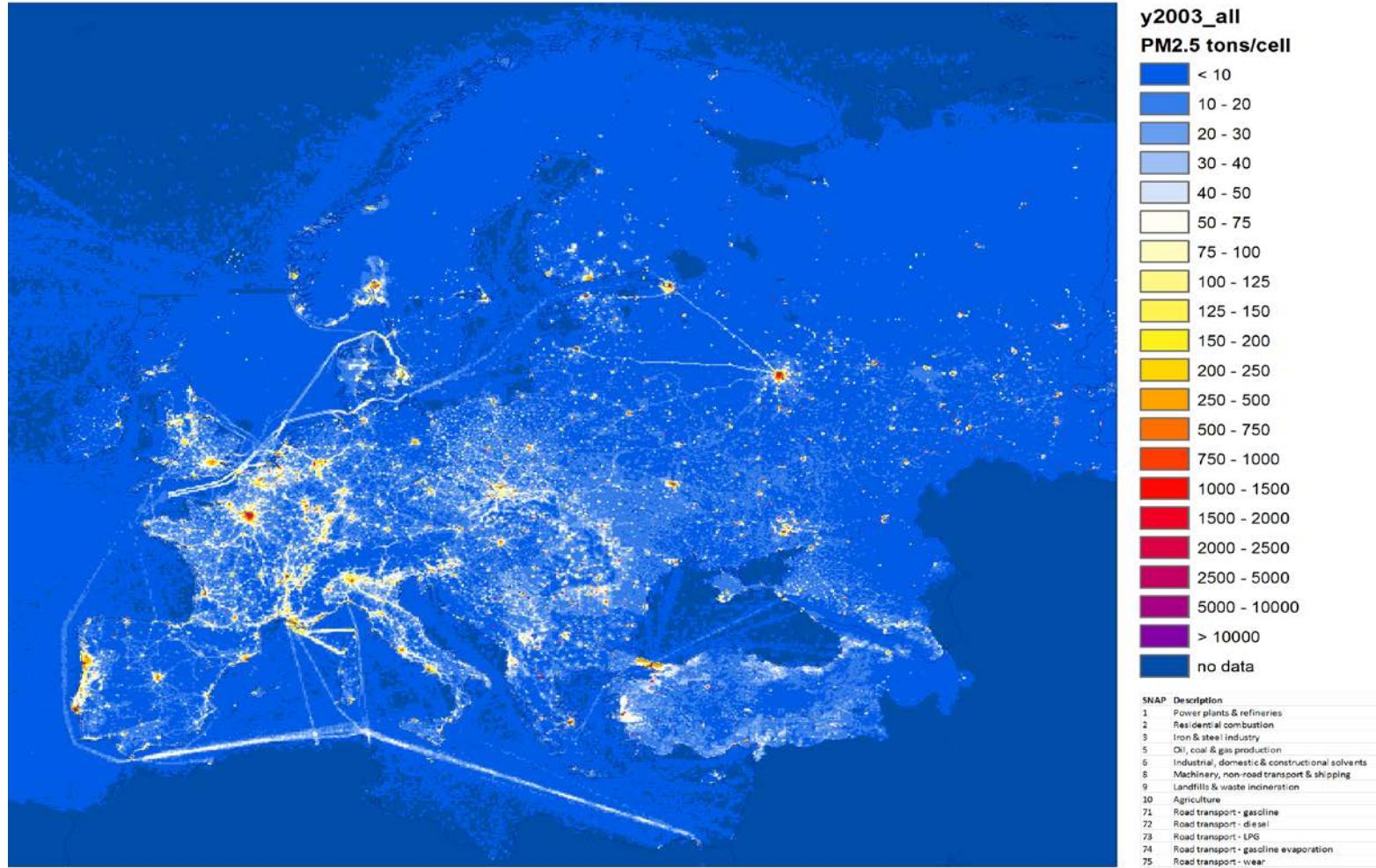
Why a model ensemble?



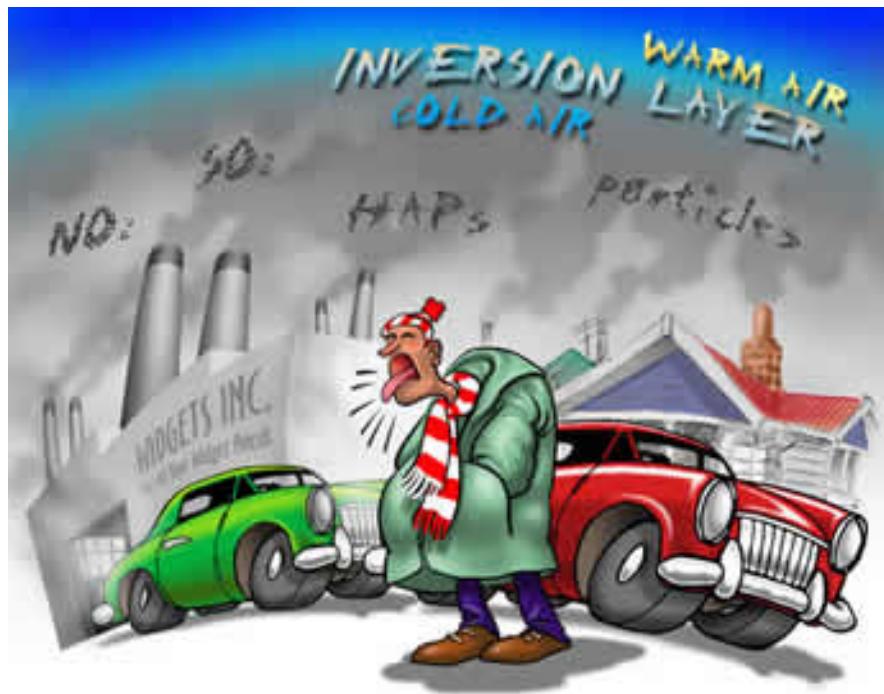
Wednesday 22 May 2013 00UTC MACC-RAQ Forecast t+000 VT: Wednesday 22 May 2013 00UTC
Height level: Surface Parameter: Nitrogen Dioxide [$\mu\text{g}/\text{m}^3$]



Modelling NO₂: what do you see?



All CAMS regional AQ models use the same emissions



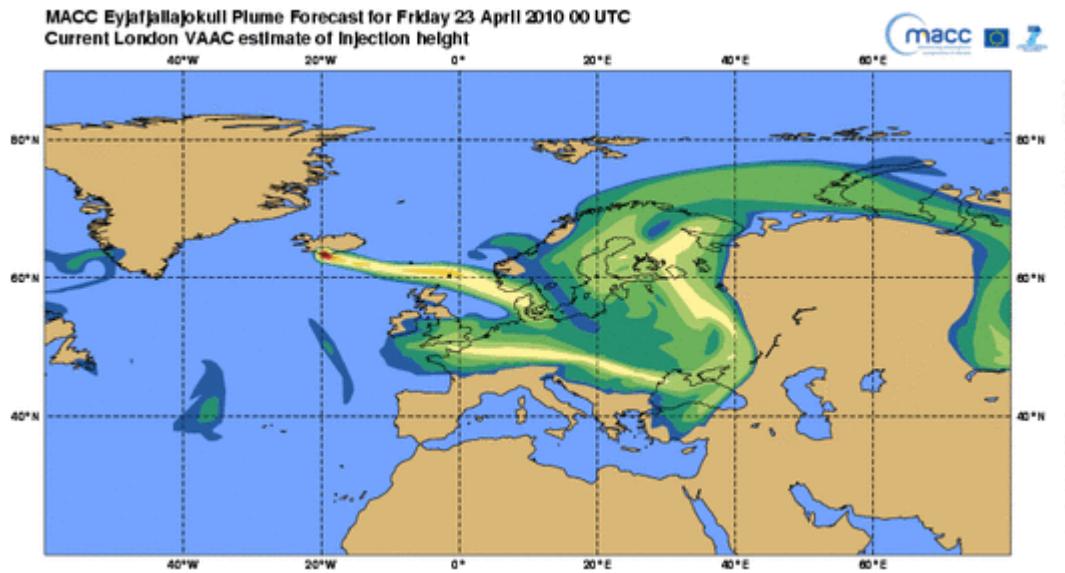
Winter smog
(PM, NO_x, SO₂...)



Photochemical smog
(O₃, PM...)

All CAMS regional models are driven by the same meteorological fields from the operational ECMWF NWP system.

Boundary conditions

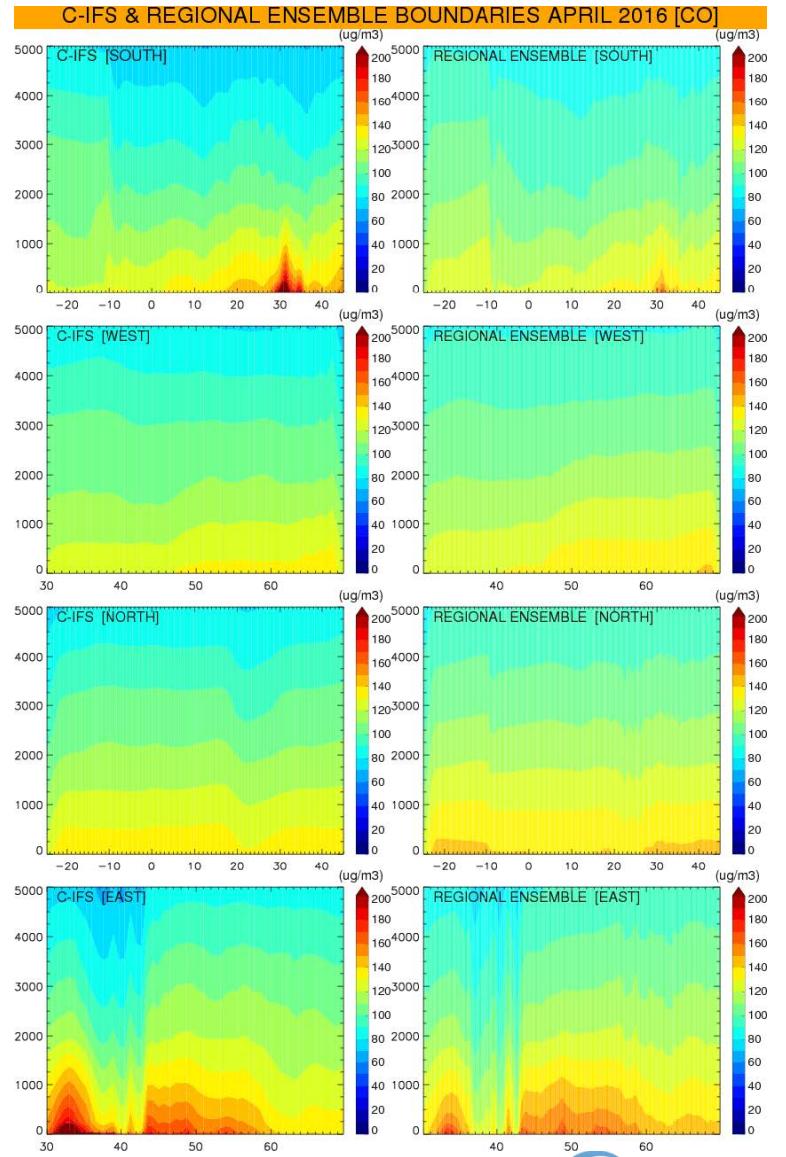
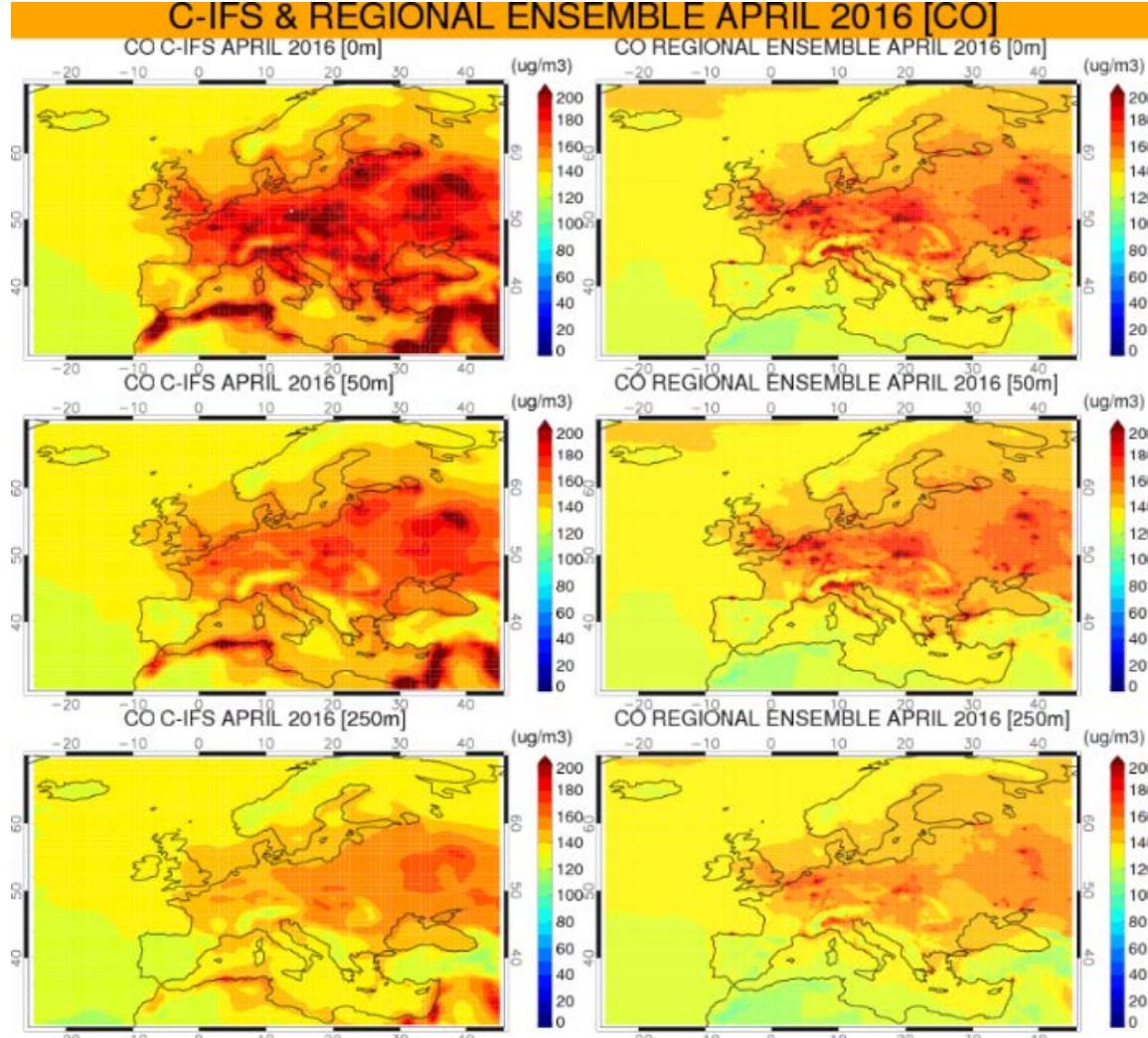


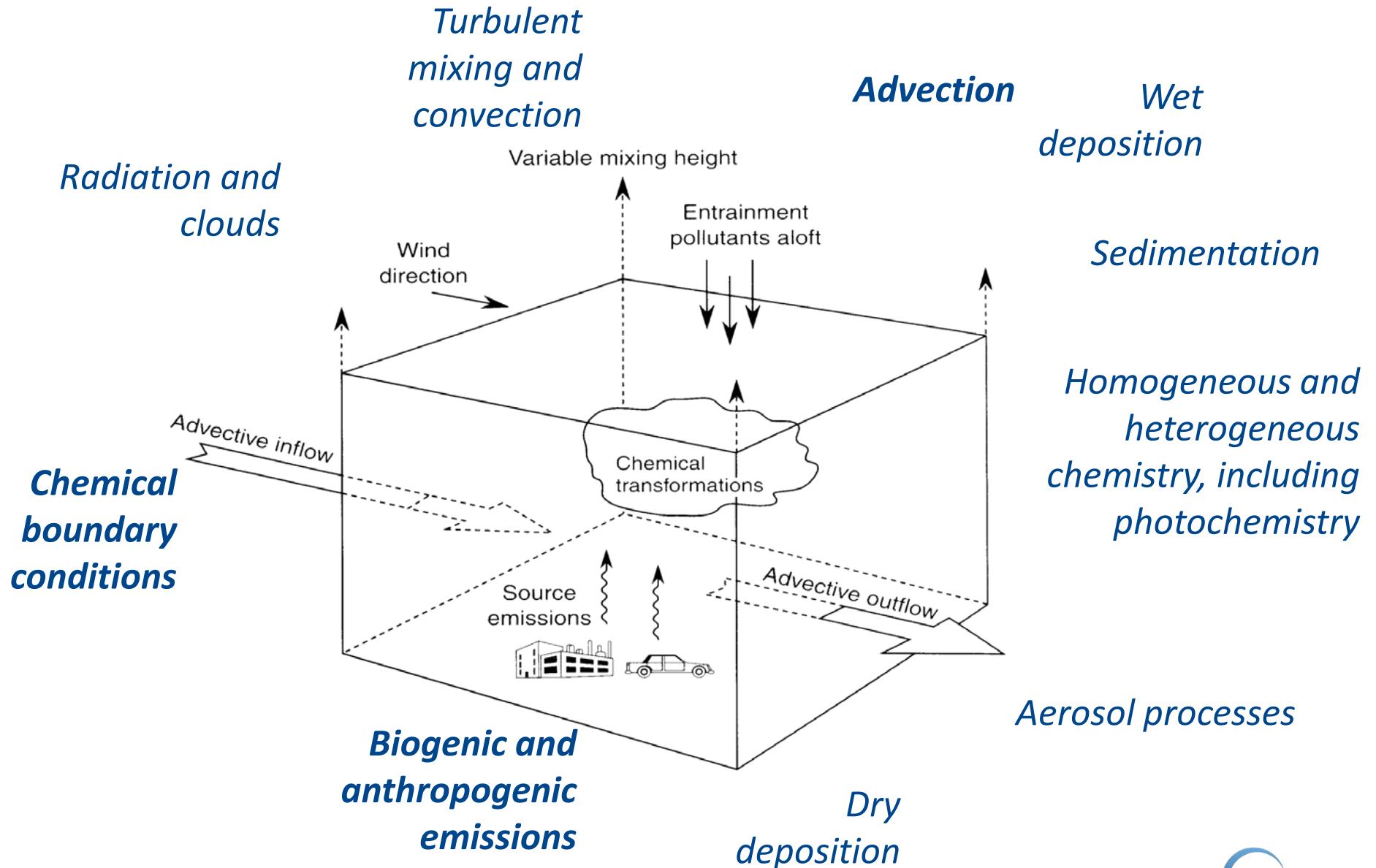
Everyone knows this!

Yet, among current regional air quality forecasting systems, chemical boundary conditions are prescribed by:

- a single value at the four interfaces (+top) for some pollutants, 0 for others (!)
- climatological values from global models, monthly or seasonal
- 3d distributions from larger-scale models corresponding to the actual dates (re-analyses, analyses or forecasts), still not a majority

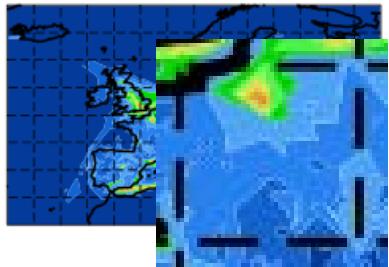
Boundary conditions



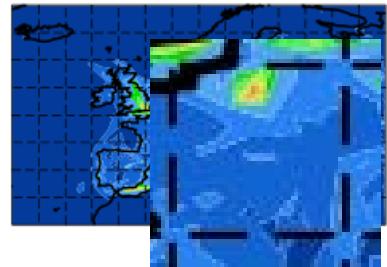


So we have constrained anthropogenic emissions, boundary conditions and meteorology...

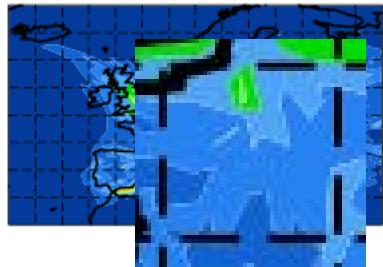
CHIMERE



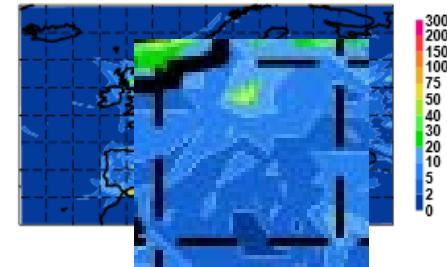
EMEP



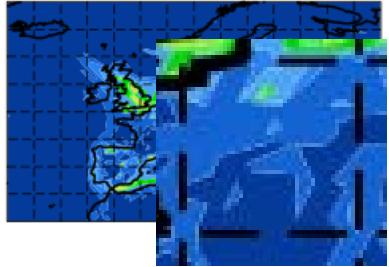
SILAM



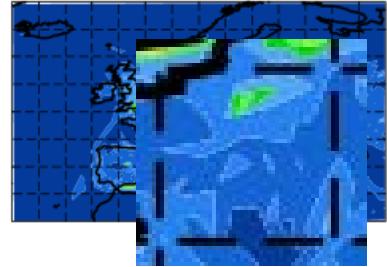
LOTOS-EUROS



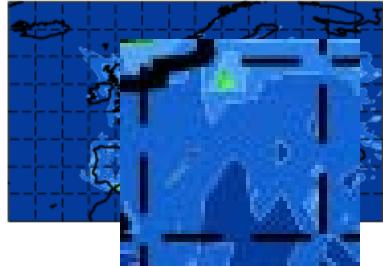
MOCAGE



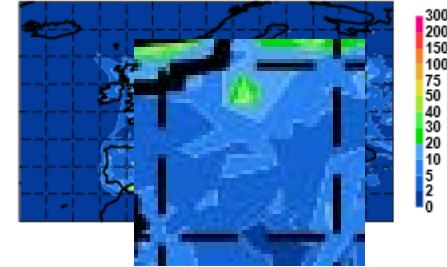
EURAD-IM



MATCH



ENSEMBLE MEDIAN (N=7)

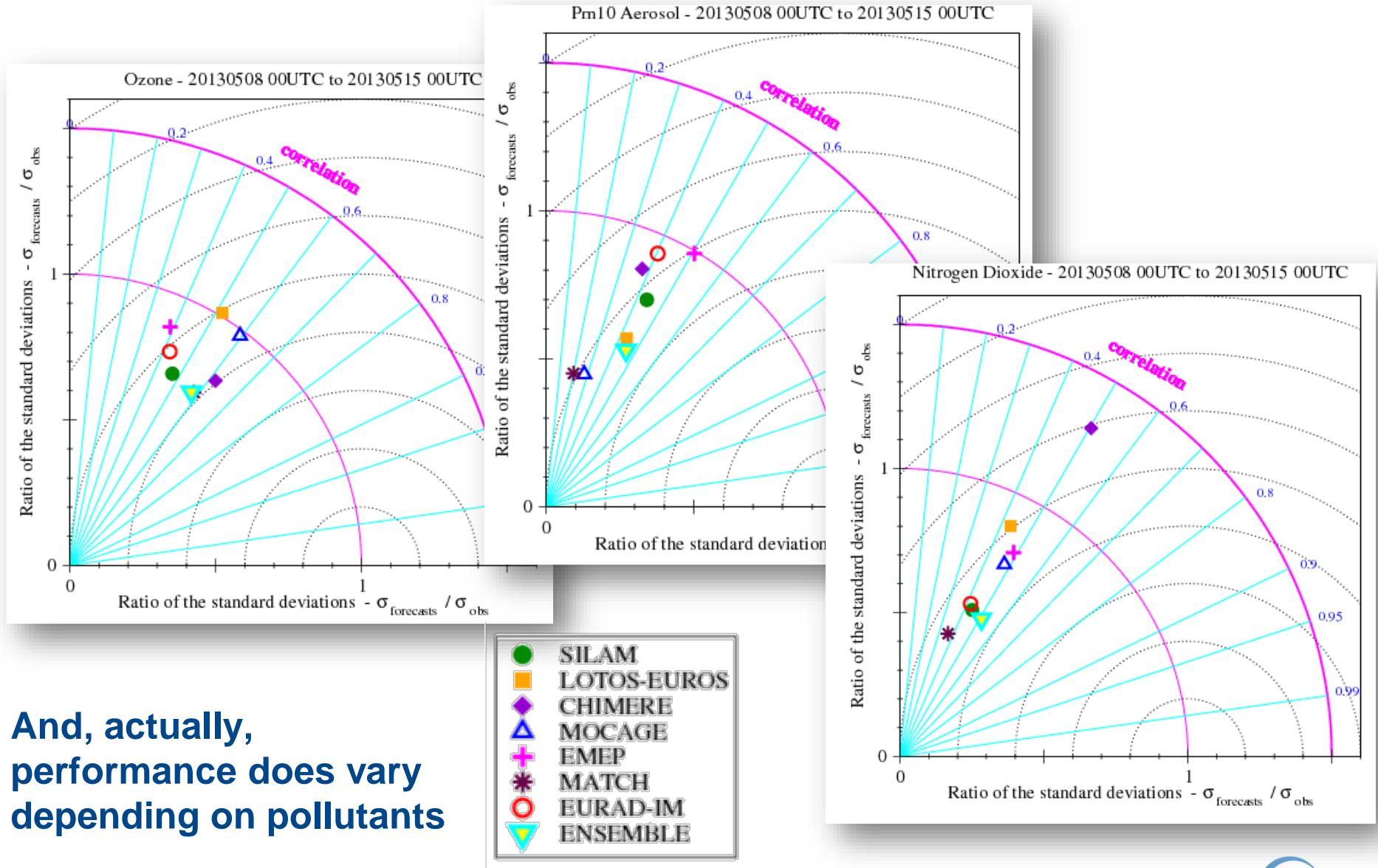


Are models all providing the “same” short-range forecast for NO₂?

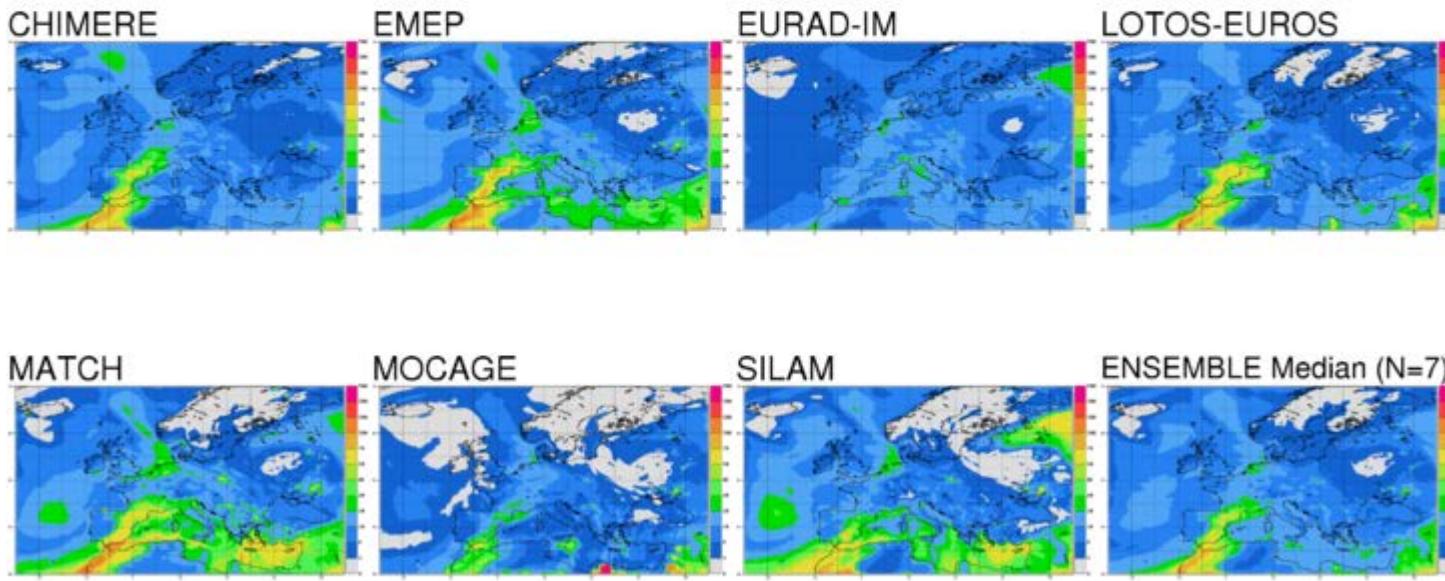
It is close... but not quite the same...

Local values can actually differ significantly: will there be high NO₂ in Paris?

Ensemble



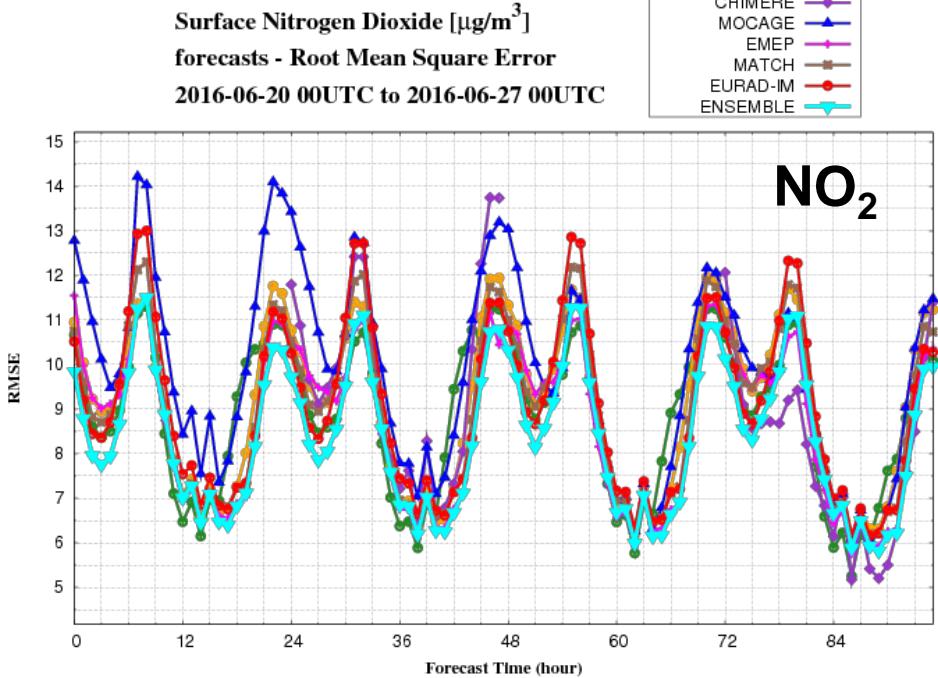
Thursday 21 July 2016 00UTC MACC-RAQ FORECAST D+0
Surface PM10 Aerosol Daily Mean [$\mu\text{g}/\text{m}^3$]



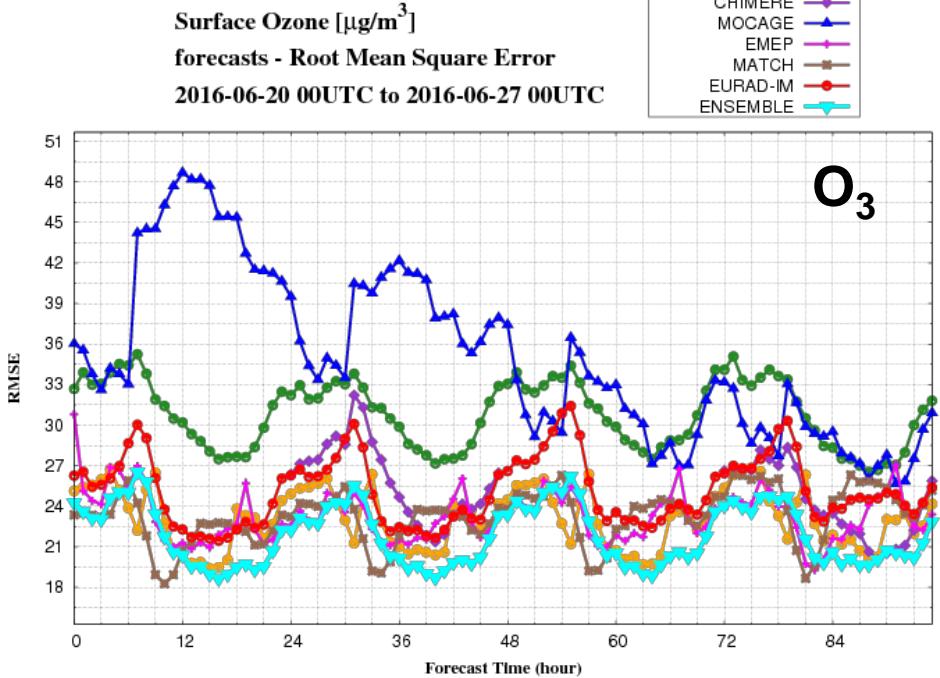
Much more spread between models than for other species. In general, negative biases are seen against observations (missing processes? Missing sources?...). Also issues with correctly using boundary conditions from global model.

Ensemble median

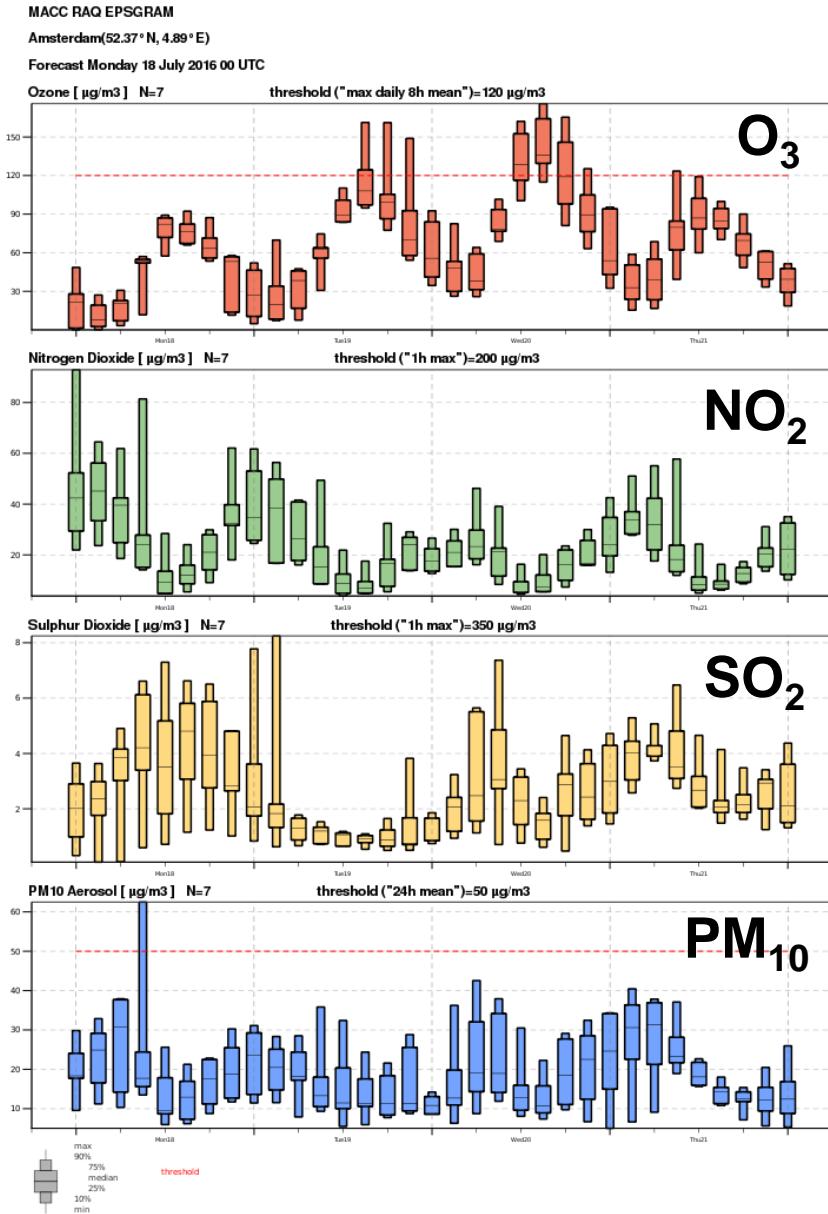
MACC RAQ - Verification - Europe



MACC RAQ - Verification - Europe



The ensemble median consistently outperforms any individual model!!!

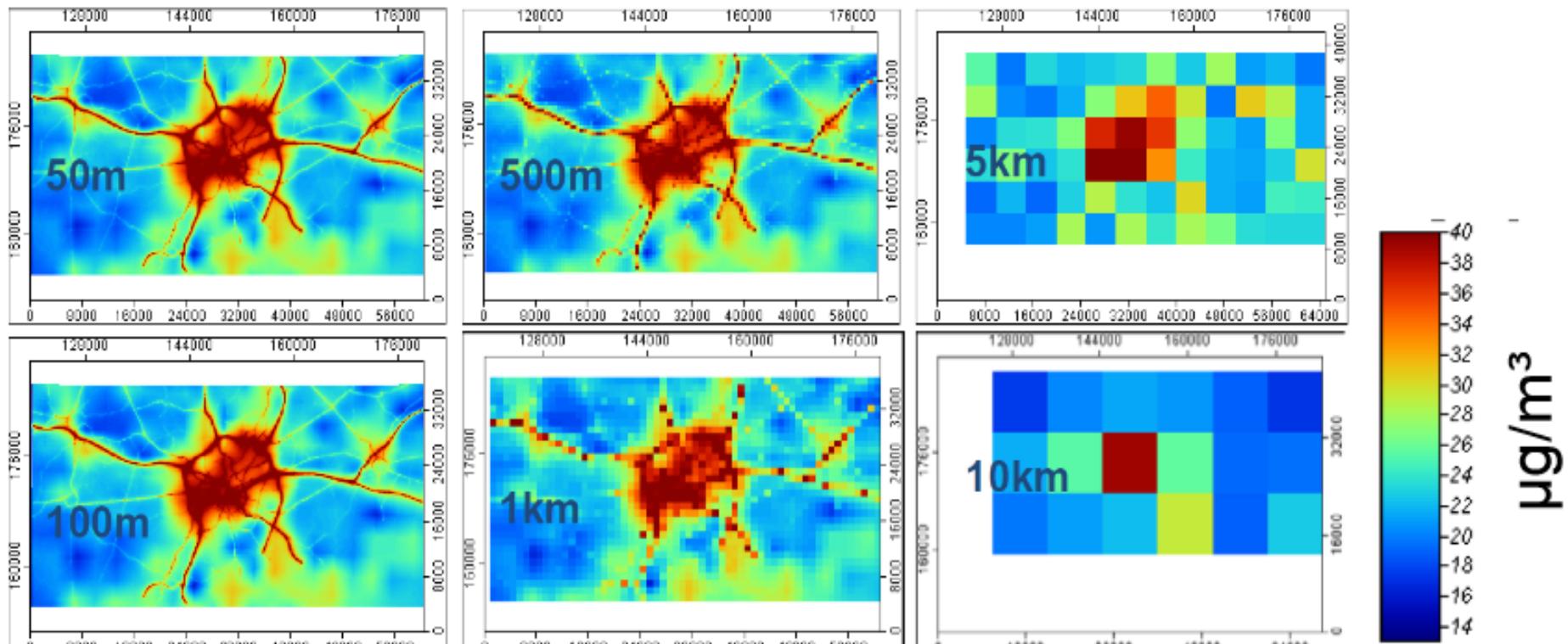


The ensemble spread also provides an indication of the uncertainty.

This is especially useful when values approach or overshoot regulatory thresholds.

Is it likely or is it just one model forecasting these high values?

Resolution seems to matter; so why do we get away with 10km resolution for the regional models?



NO₂ yearly mean 2007 Brussels

VITO, PASODOBLE



Islington Arsenal Urban Background station

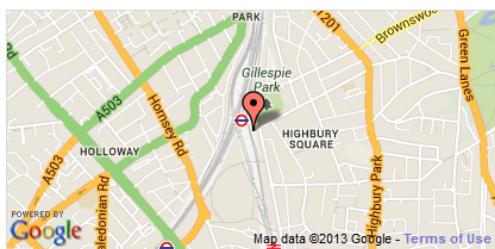


Address: Islington Ecology Centre, 191 Drayton Pk

Grid Ref: 531325, 186032

Latitude & Longitude: 51.557895000000, -0.106989000000

Click on the map to see the nearest street view (if available).



London Old Street Roadside station



Address: Old Street

Grid Ref: 532947, 182575

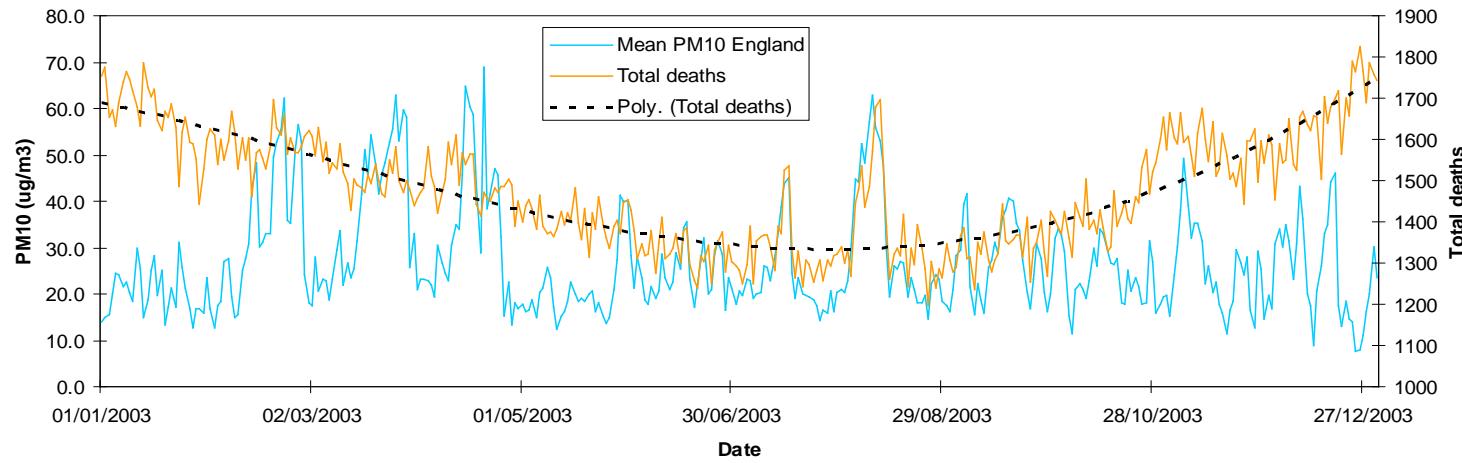
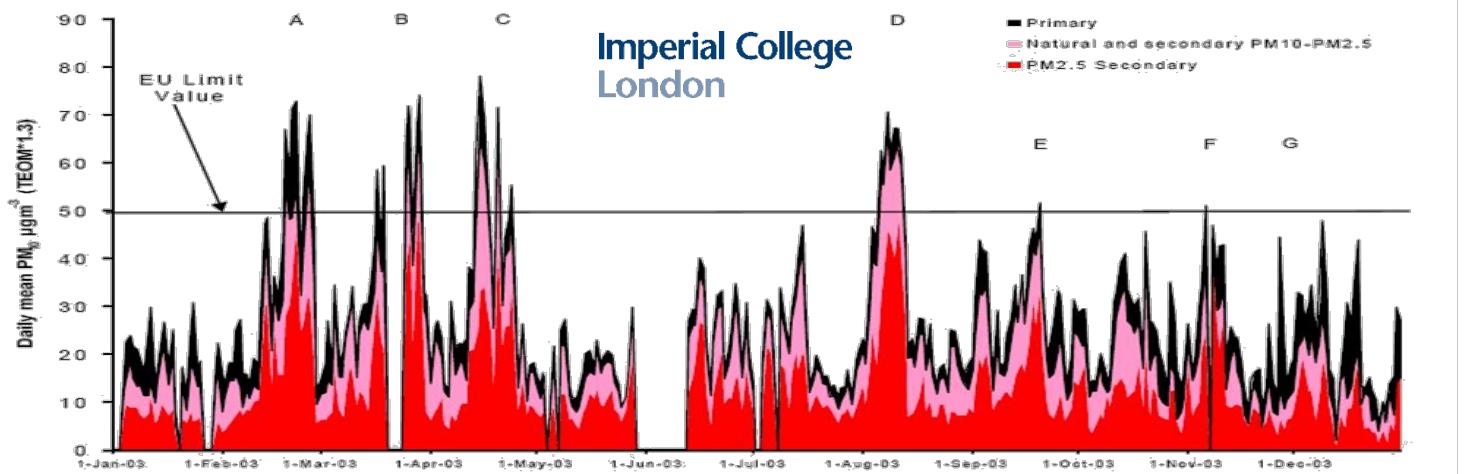
Latitude & Longitude: 51.526454000000, -0.084910000000

Click on the map to see the nearest street view (if available).



*Studies show: “boundary” or
“background” values are
essential!*

Air quality & health

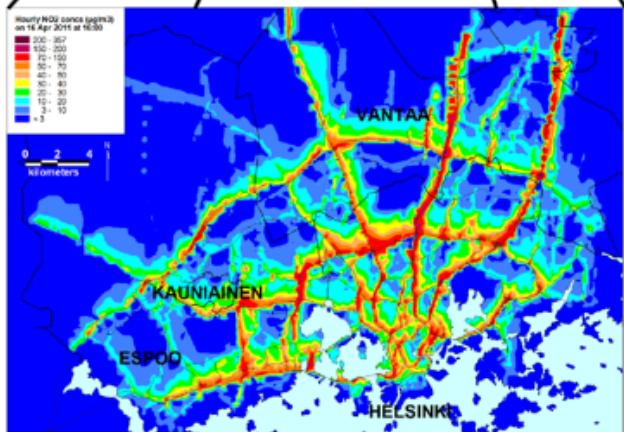
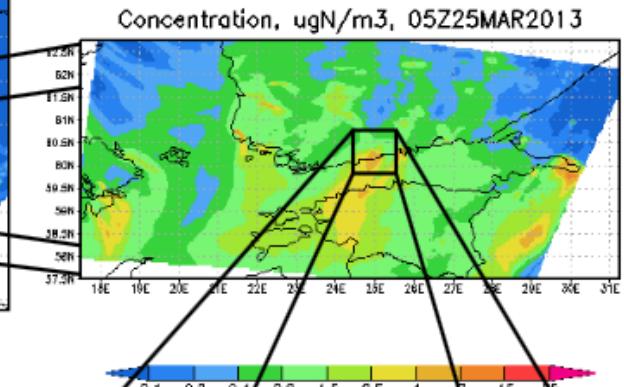
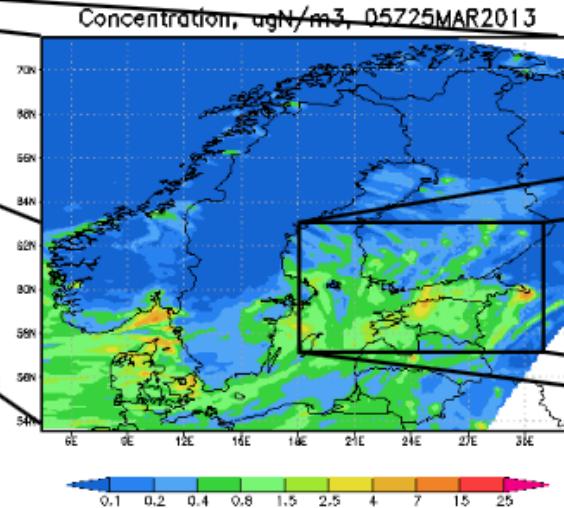
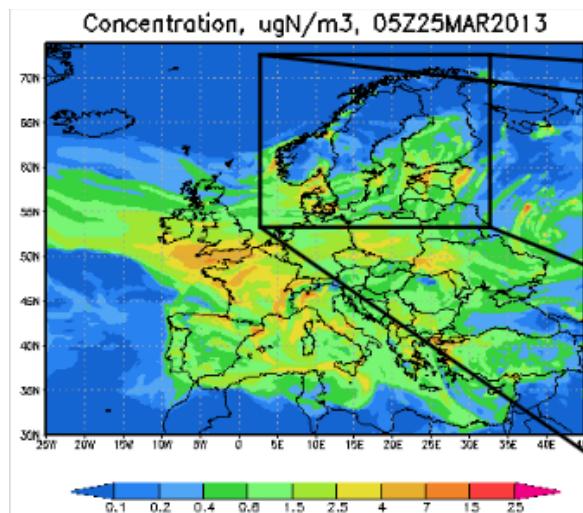


2003 : Central London (top), England (bottom)

The different factors (meteorology, pollutants...) need to be disentangled to target efficient policies.

Note: health does not only relate to concentrations of pollutants, but also to exposure of people (which is in turn the main justification for very high resolution).

Downscaling



CAMS (20km), Northern Europe (7km), Gulf of Finland (3km), Helsinki (Gaussian finite line source dispersion model).

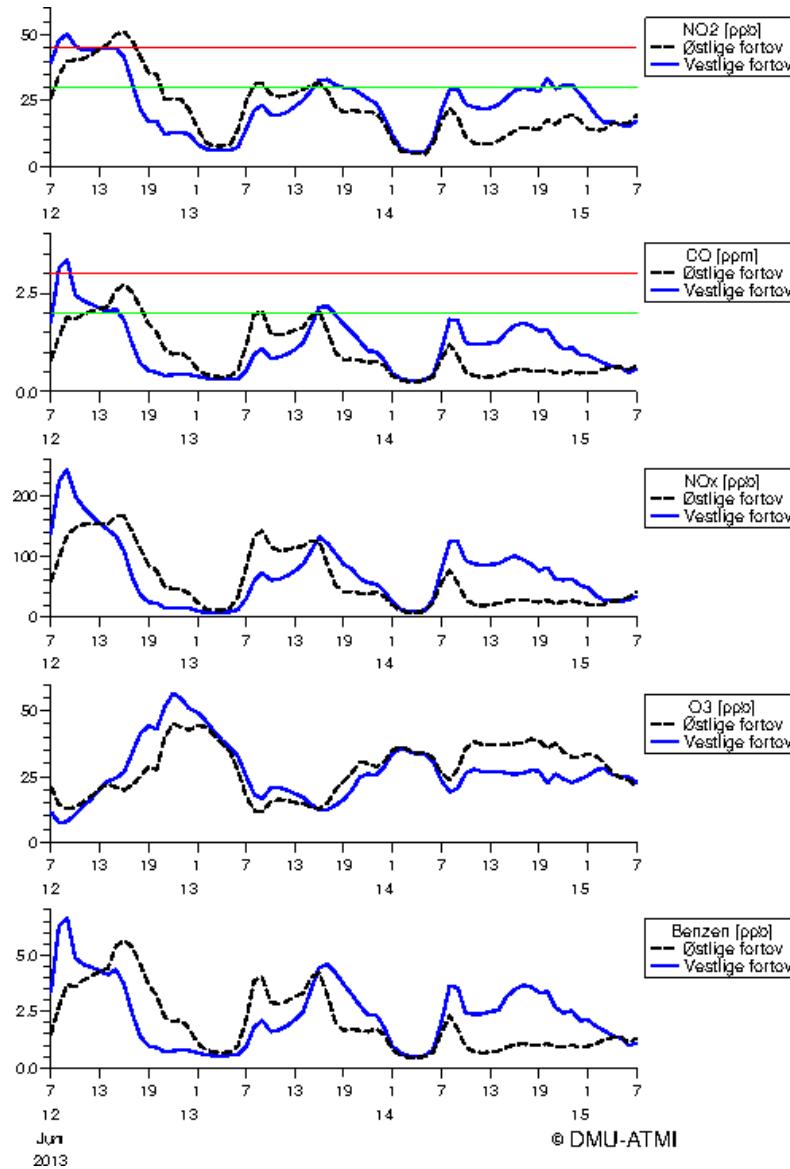
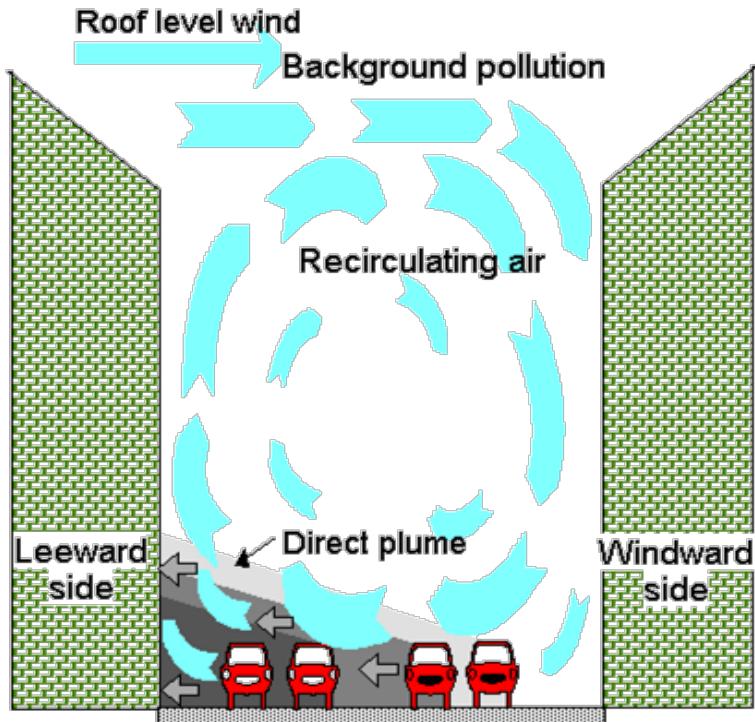
Where to stop?



European
Commission



Street canyon
modelling has been
already pioneering
in the early 1970s

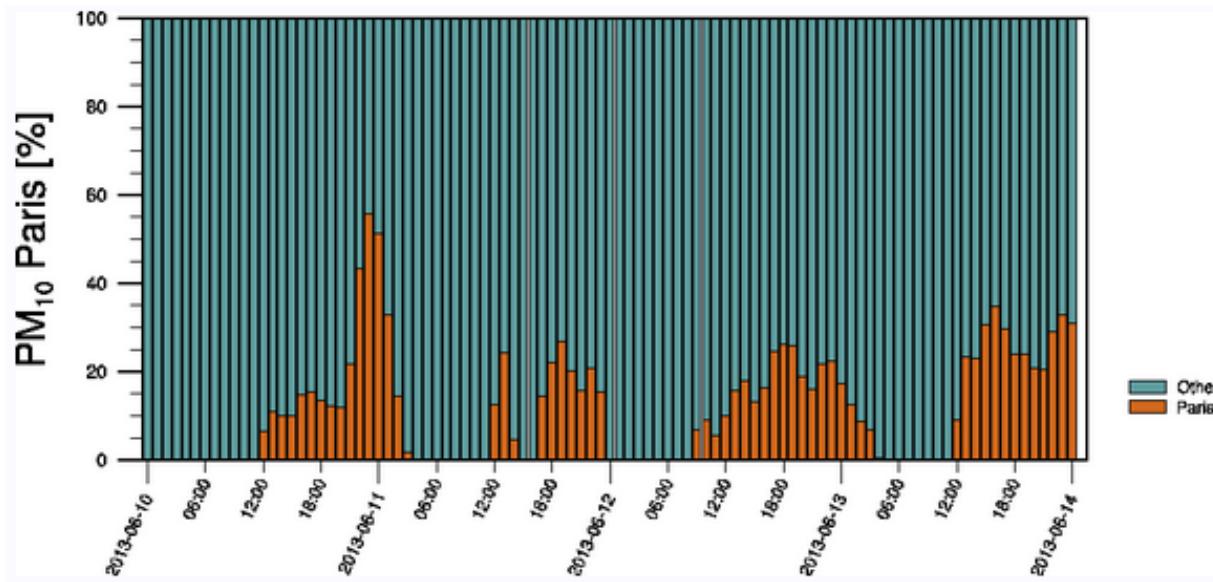


West / East side of Jagtvej (Copenhagen)

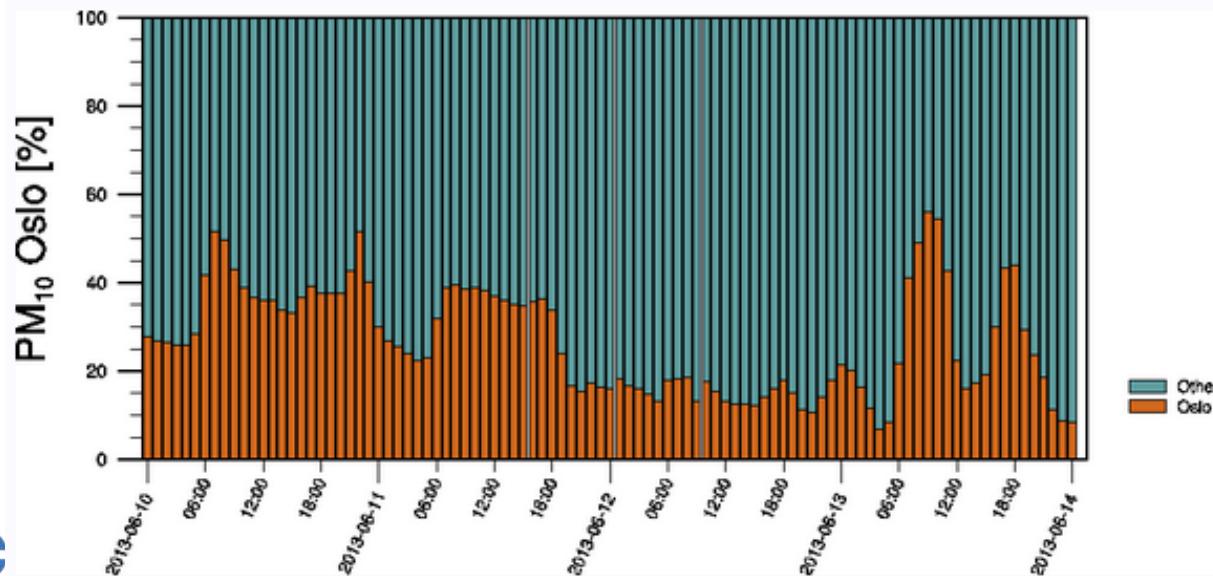


How is the information being used

APPLICATIONS



Local versus Imported PM₁₀

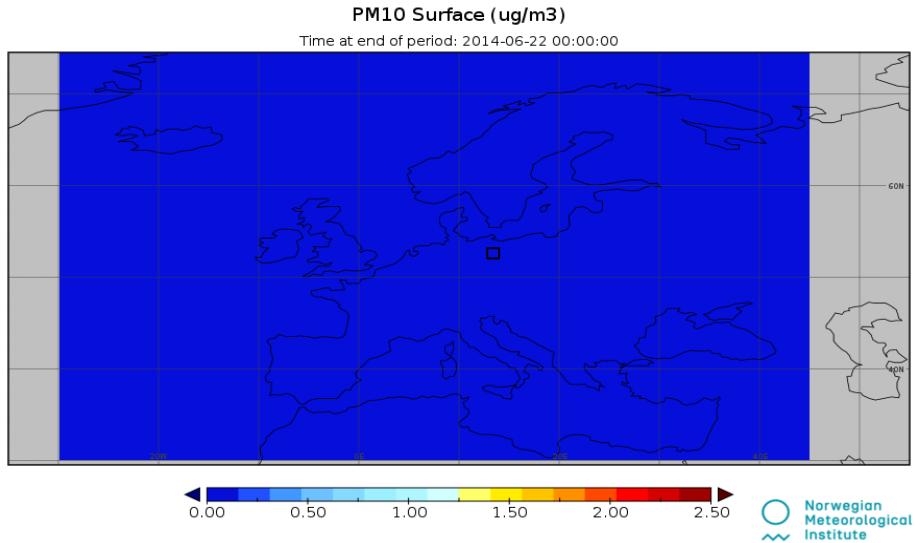
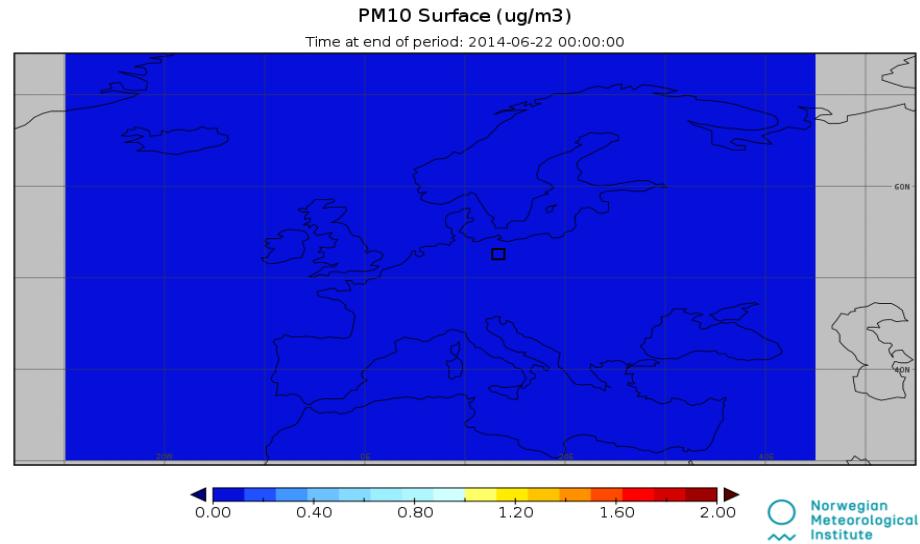
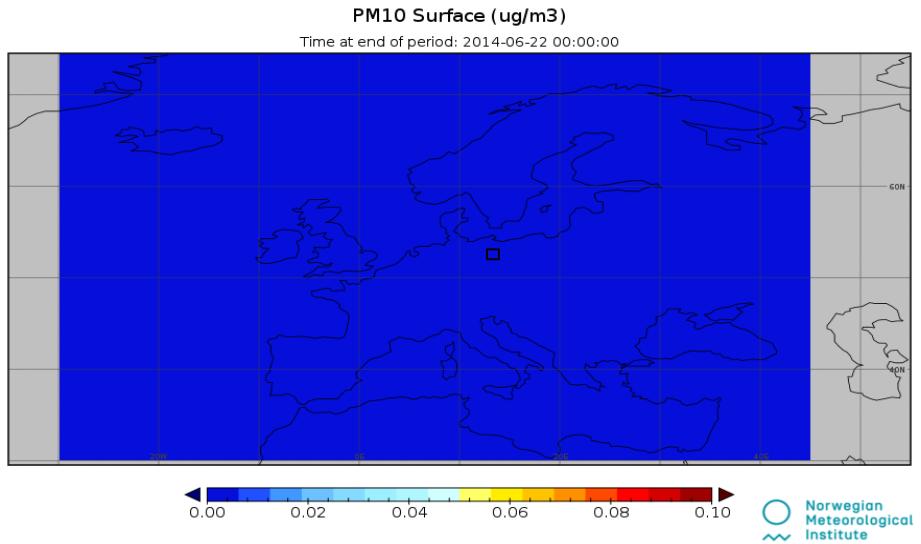


How much of the current pollution comes from within the city limits and can therefore be regulated by the local authorities?

Policy applications



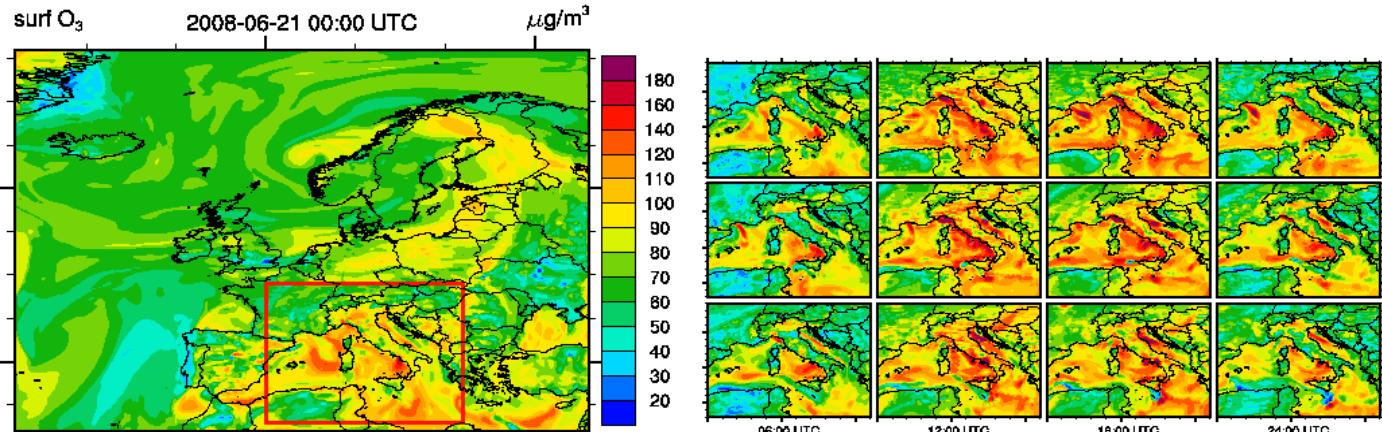
European
Commission



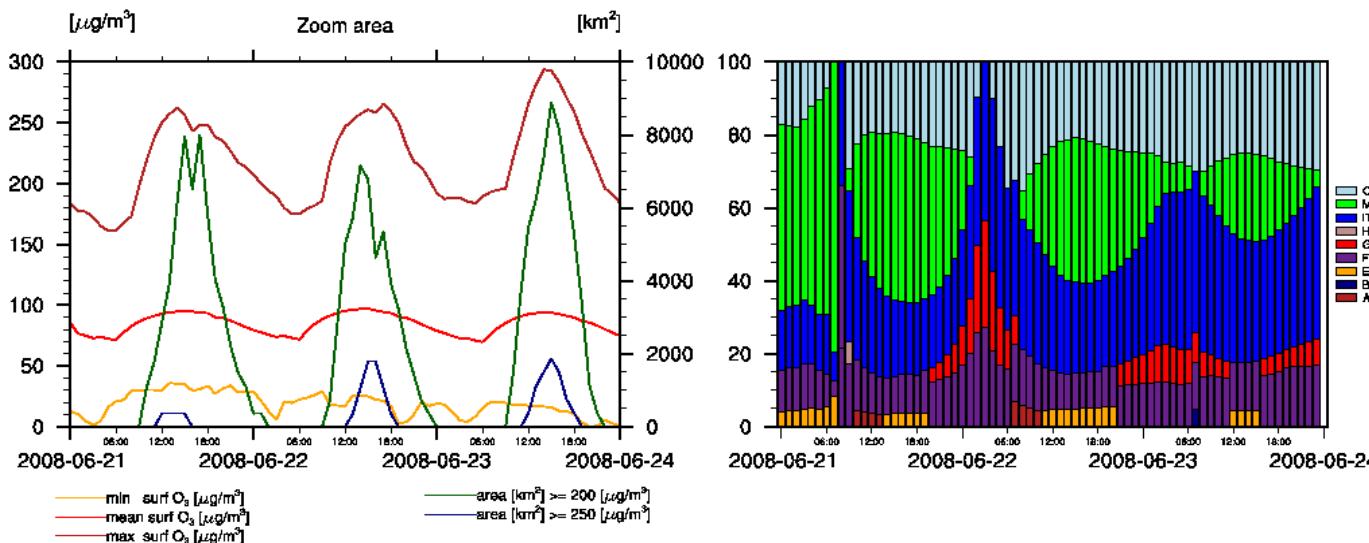
What is the impact over time of PM₁₀ emissions within the city, within Germany, and within Europe on the concentrations in Berlin?

Policy applications

3-day Forecast O₃ Episode

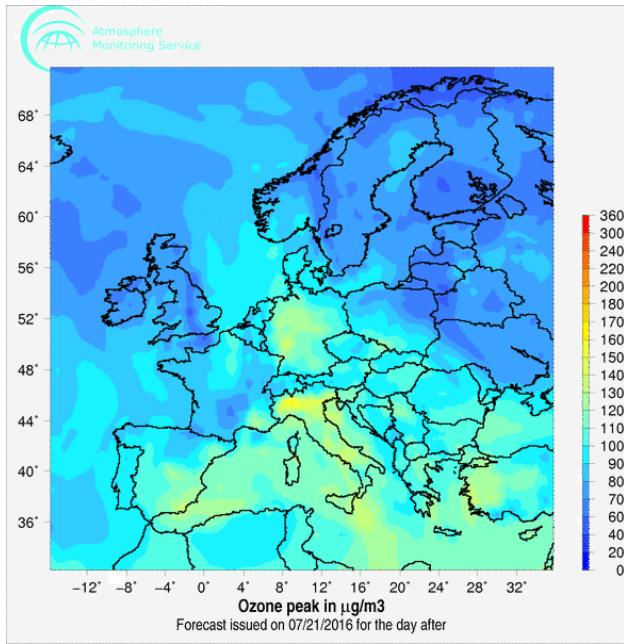


For specific pollution episodes, we can do this on a country scale.

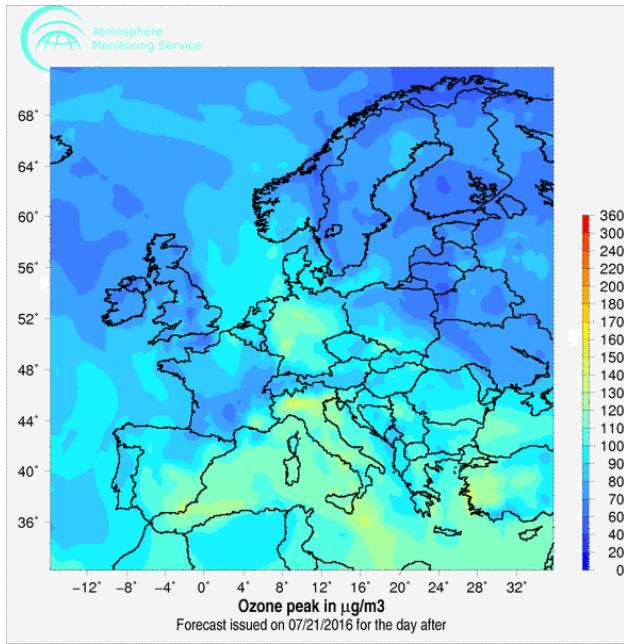


Country of origin:
Mediterranean
Italy
Hungary
Greece
France

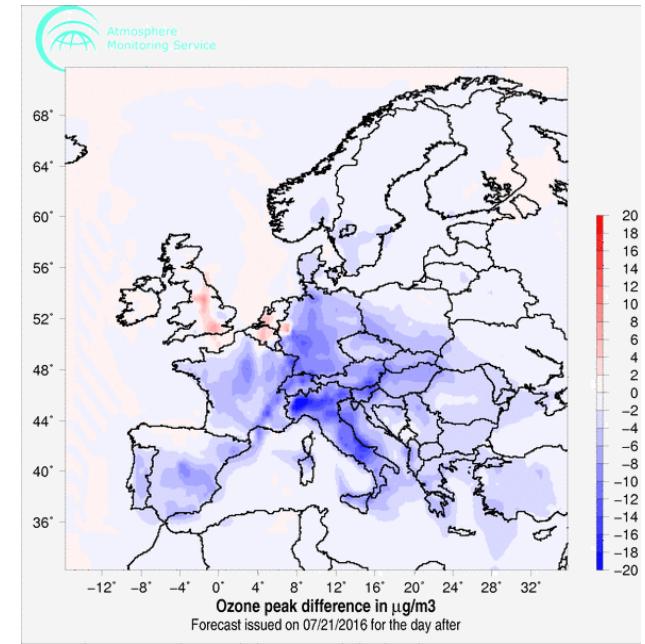
Policy applications



Normal



Reduced



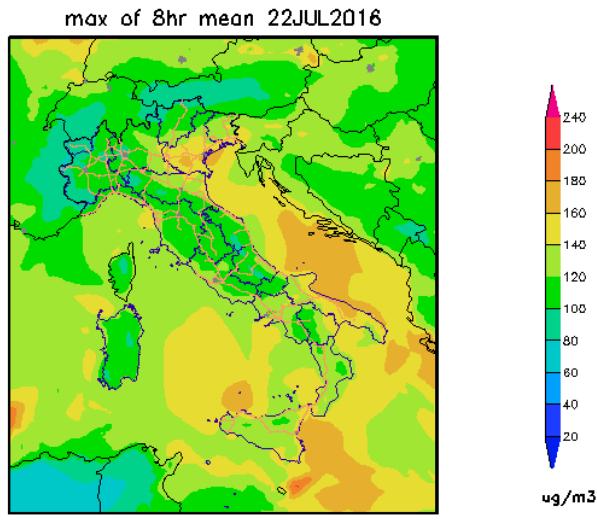
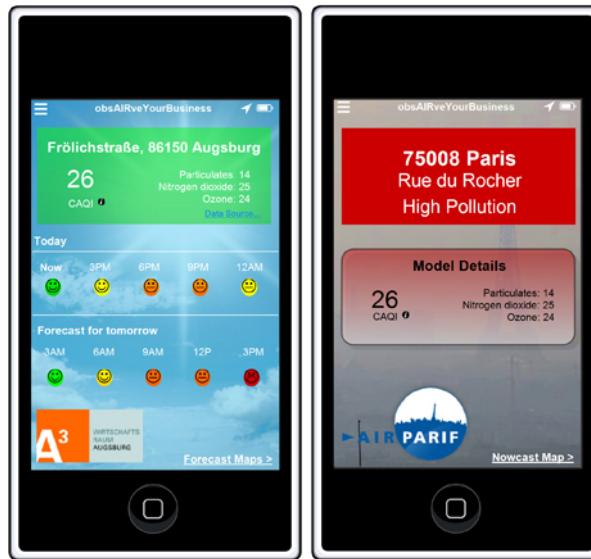
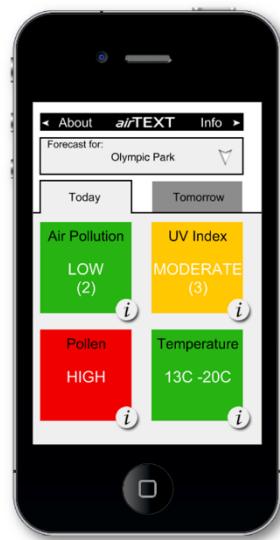
Difference

What happens to tomorrow's ozone values if we reduce road traffic emissions by 30% (cut traffic roughly in half)? Reduced species: NO_x, CO, NH₃, VOCs, SO₂, and PM.

Downstream applications



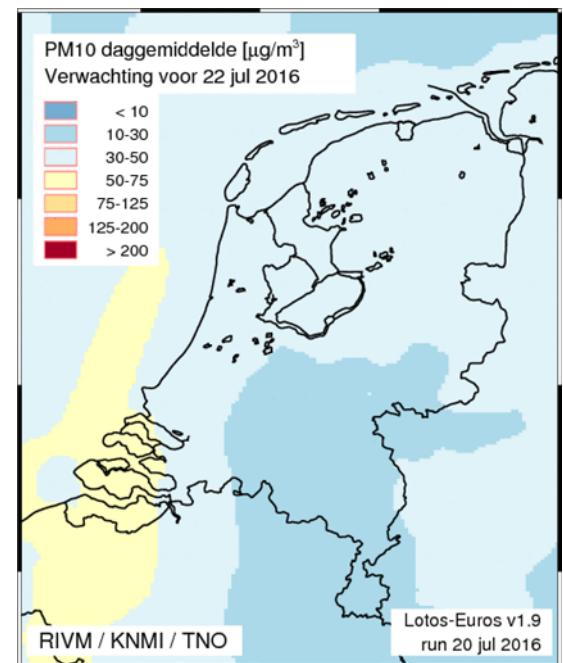
Copernicus wants to stimulate the downstream market.



Arianet ari - CC BY-NC-ND - o3 - run 20160722

2016-07-21-23:41

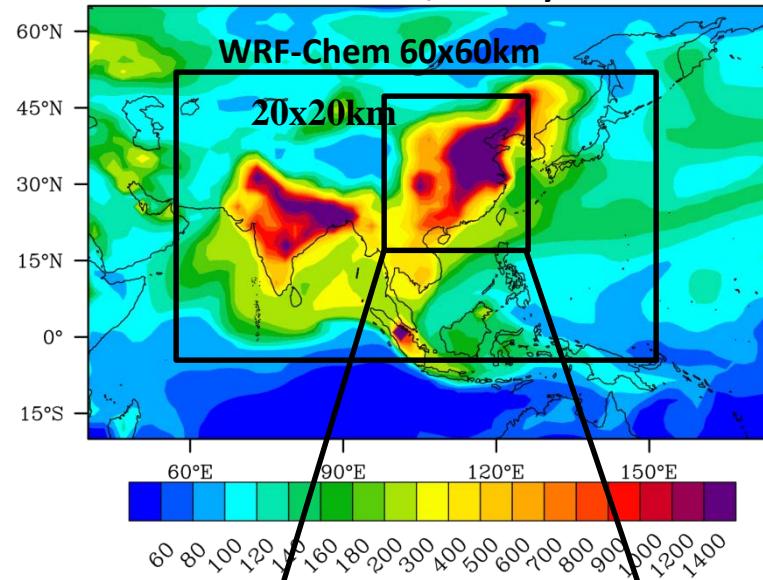
CAMS covers global and regional; the rest is up to national service providers and businesses.



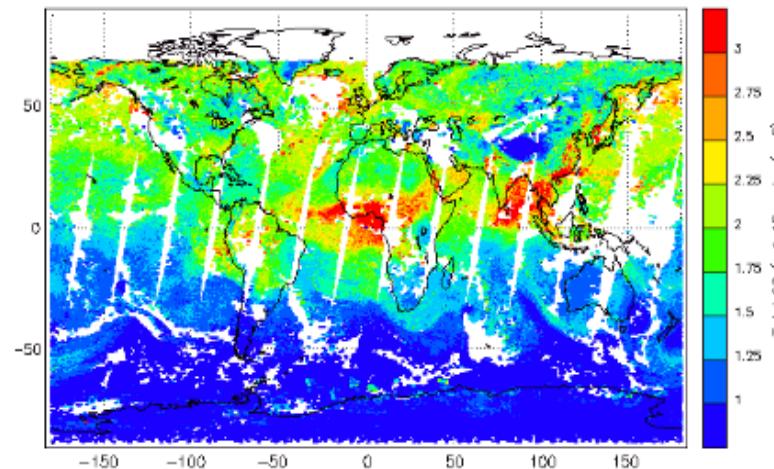
RIVM / KNMI / TNO

Lotos-Euros v1.9
run 20 jul 2016

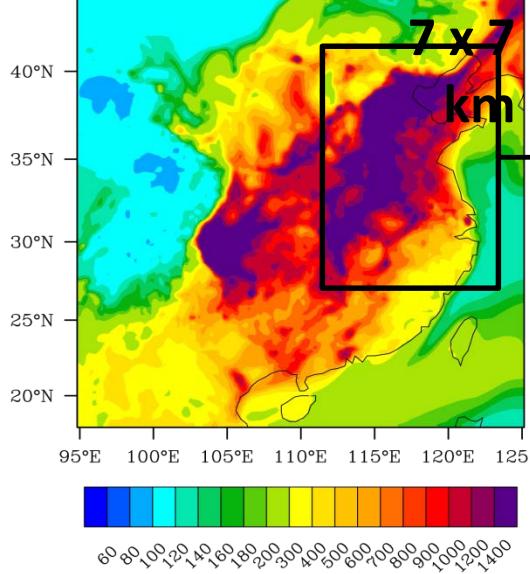
CAMS forecast/reanalysis as IC & BC



Satellite data

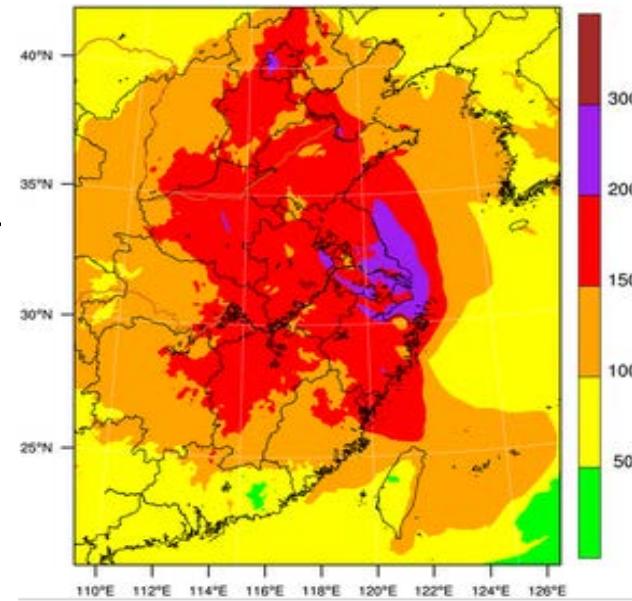


WRF-Chem prediction 20x20km



Air Quality Index (AQI)

WRF-Chem prediction AQI



Questions?

