The Modeling, Analysis and Prediction Initiative for Air Quality (MAP-AQ)

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Chinese students passing exams outside

with contributions from
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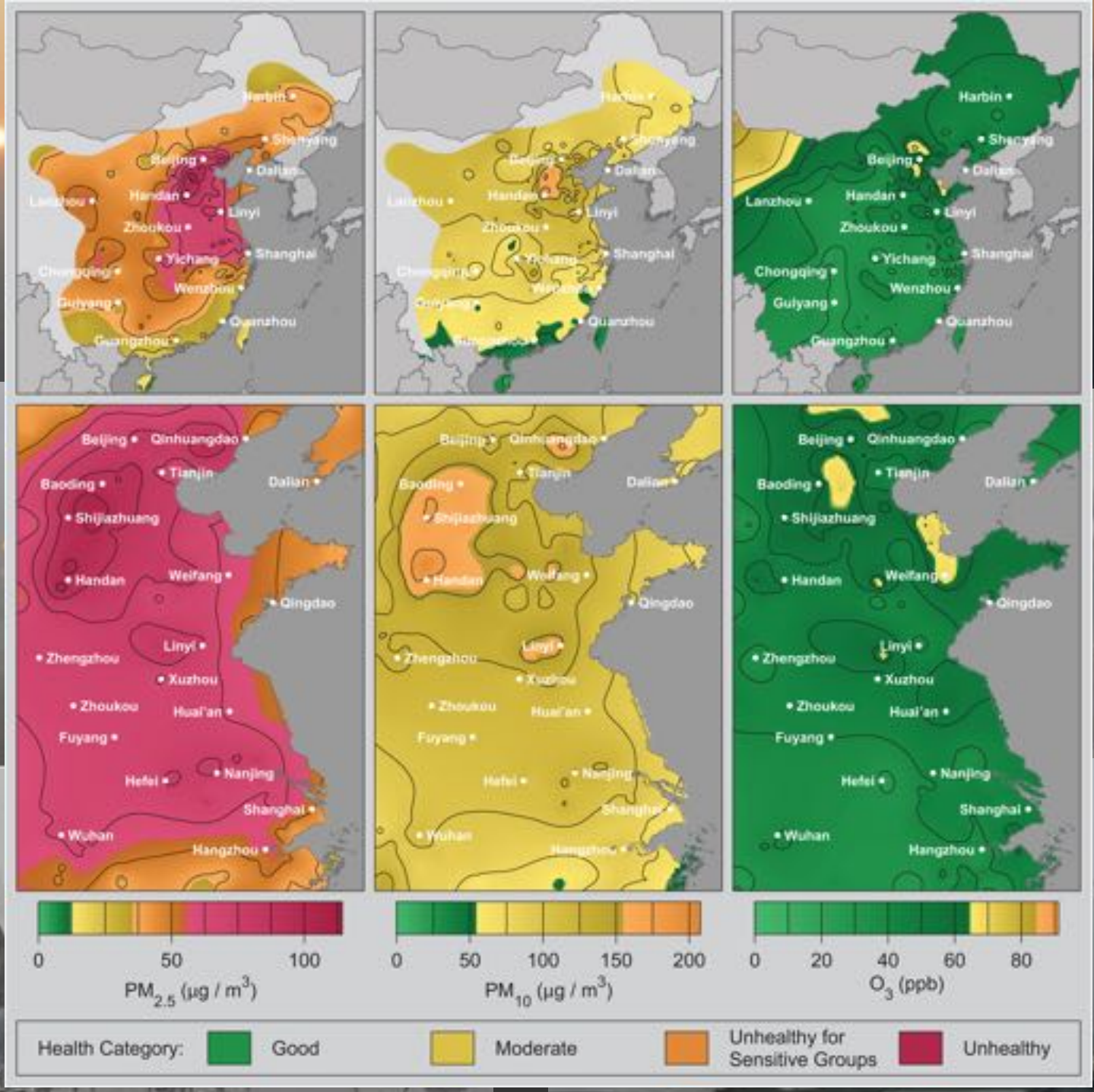
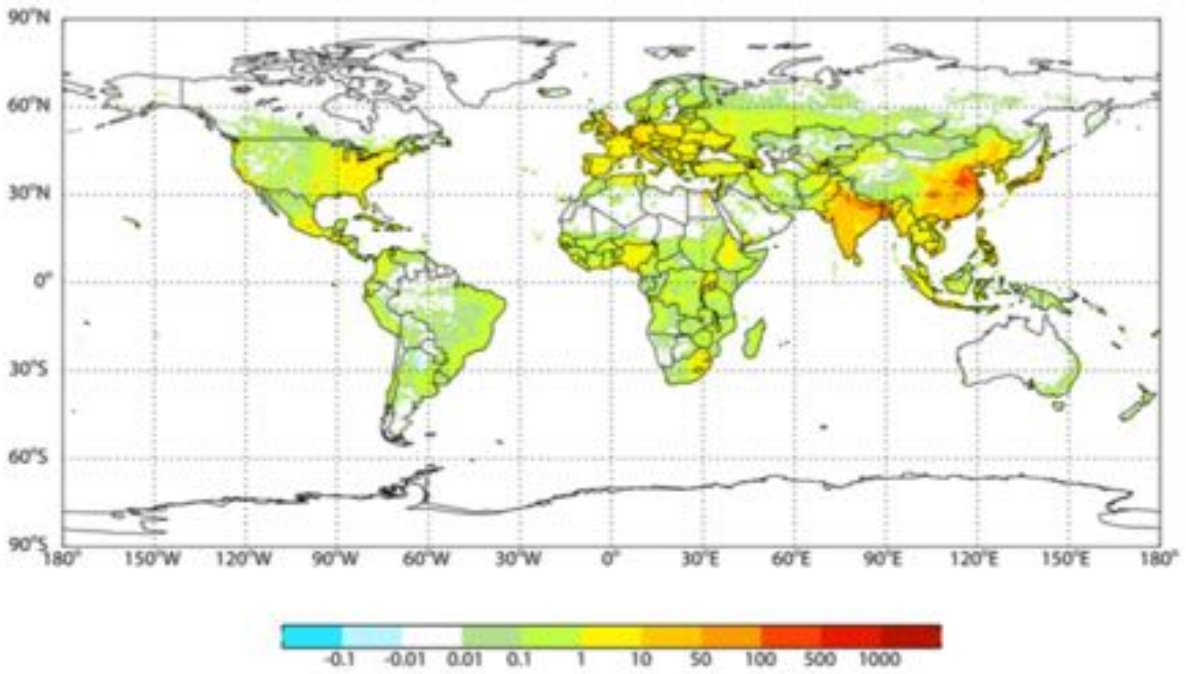
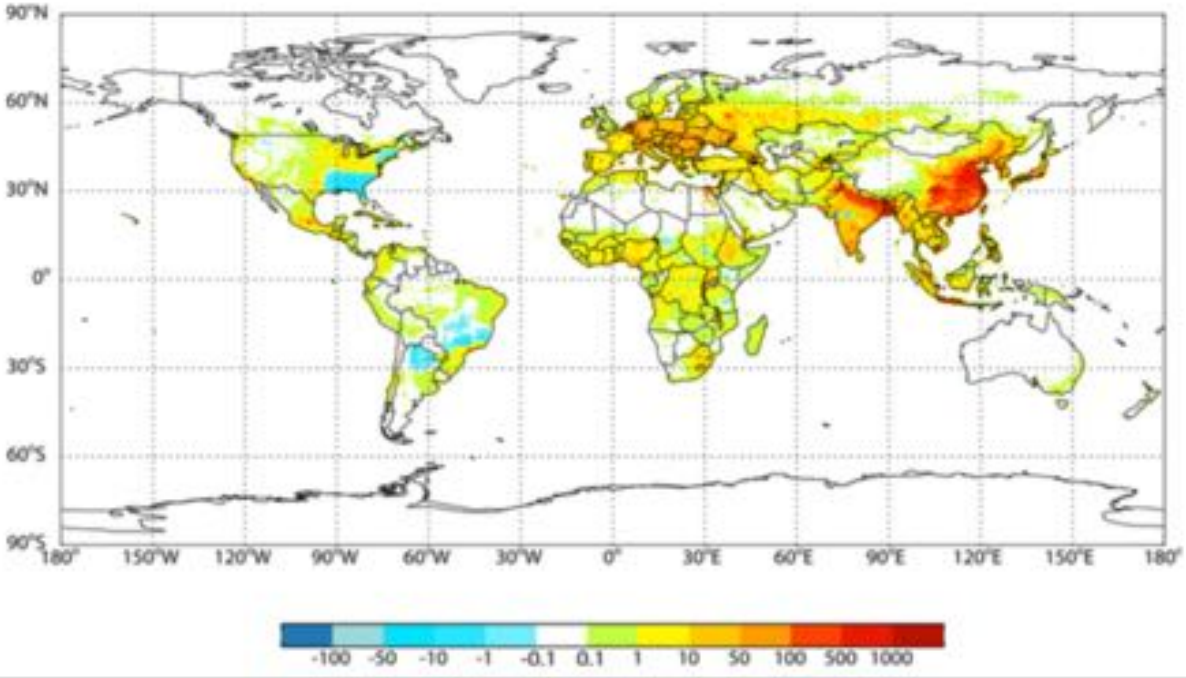

Harbin
Shenyang
Beijing
Dalian
Lanzhou
Handan
Linyi
Zhoukou
Yichang
Shanghai
Chongqing
Wenzhou
Guiyang
Quanzhou
Guangzhou
Qinhuangdao
Tianjin
Baoding
Shijiazhuang
Weifang
Qingdao
Zhengzhou
Xuzhou
Huai'an
Fuyang
Hefei
Nanjing
Wuhan
Hangzhou
0 50 100
PM2.5 (μg / m3)
0 50 100 150 200
PM10 (μg / m3)
0 20 40 60 80
O3 (ppb)
Health Category:
Good
Moderate
Unhealthy for Sensitive Groups
Unhealthy



Premature Deaths

(deaths year^{-1} (1000km^2)$^{-1}$)

Ozone

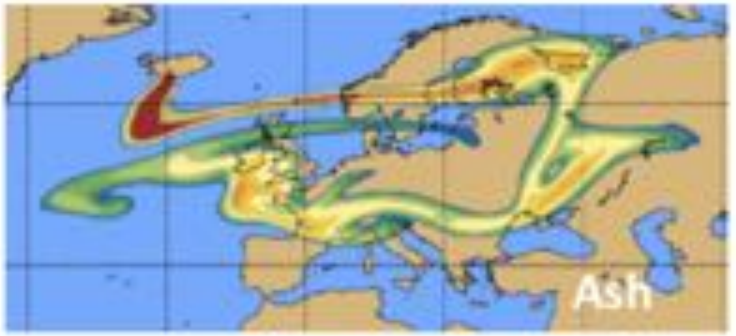


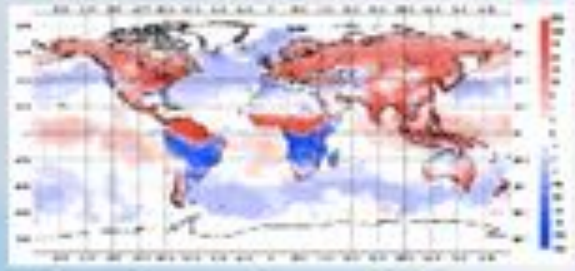
PM2.5

Avoiding Acute Air Pollution Episodes: Chemical Weather Forecasts

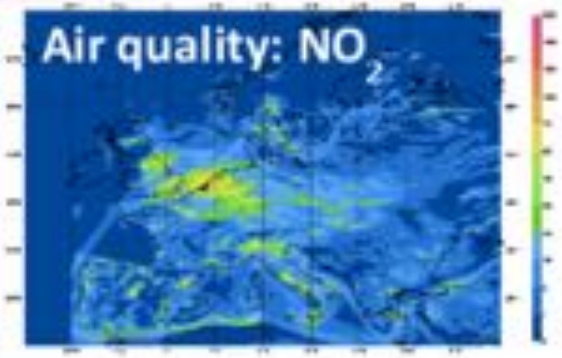
- Several Meteorological Services in the world expand their classic weather forecasts in a more comprehensive environmental forecasts that include "chemical weather" in addition to "physical weather".
- The forecasts of "chemical weather" are difficult to achieve because they depend on a diversity of factors that are not perfectly well established:
  - Weather patterns that are predicted (dynamics, cloudiness, precipitation)
  - Surface emission and deposition; boundary layer physics
  - Chemical and physical transformations
  - Initial and boundary conditions

The Super-Seamless Frontier: Environmental Prediction

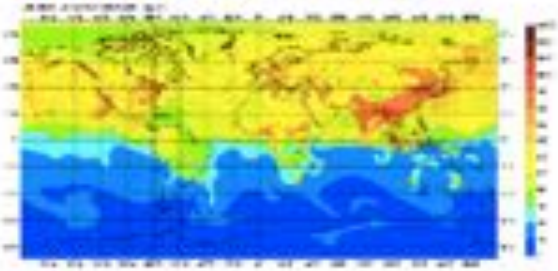


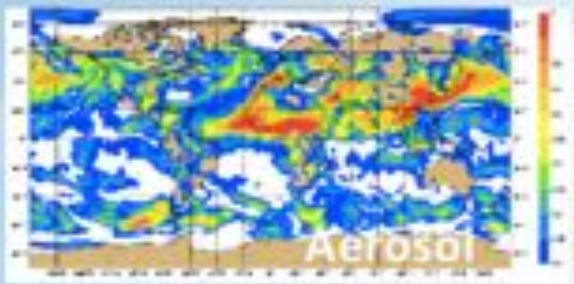


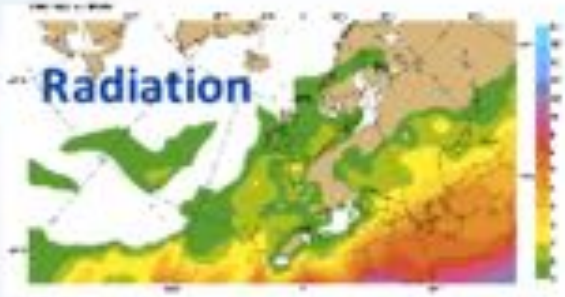
Flux inversions: CO_2

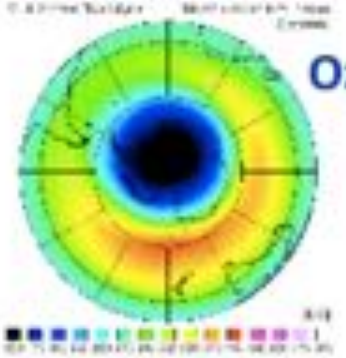


Global pollution: CO

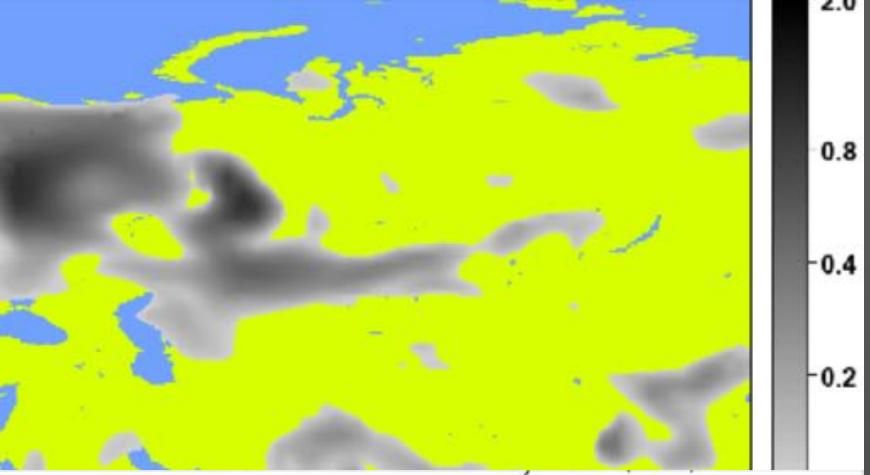


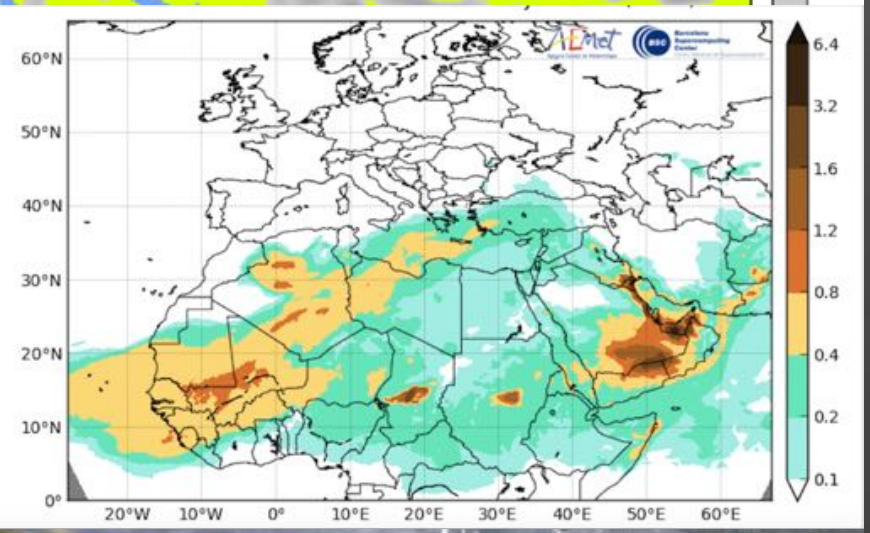






Ozone





Responses to Emergencies

Forecasting the evolution of extreme events such as the effects of

- wildfires,
- dust storms,
- urban spills
- chemical/nuclear accidents
- volcanic eruptions

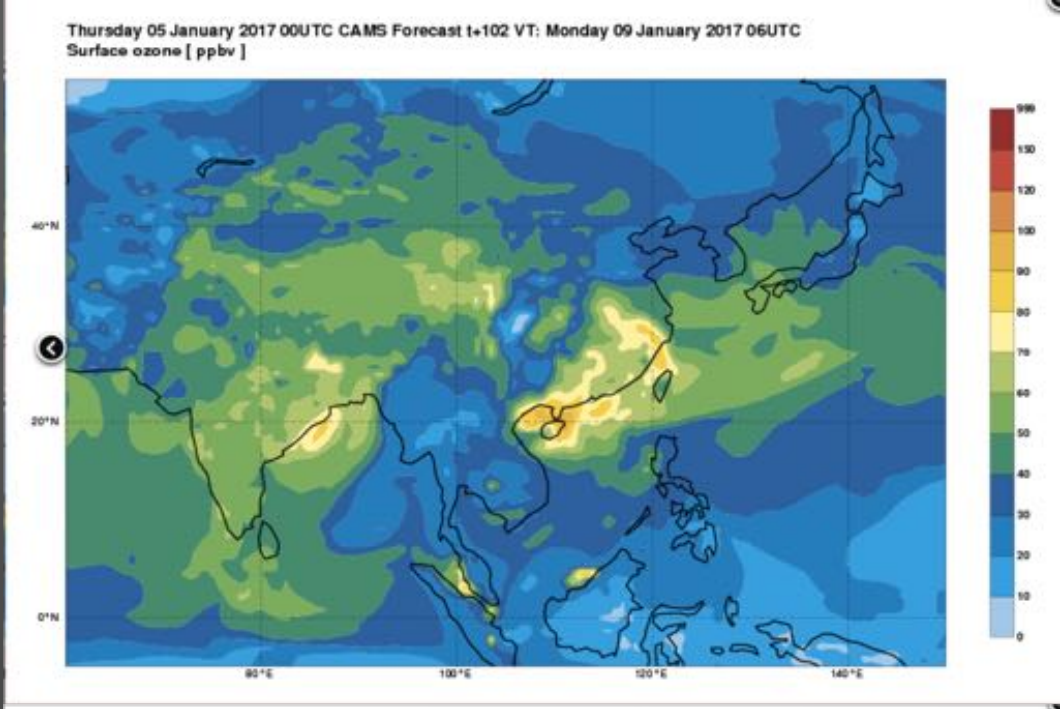
Operational Forecasting of Chemical Weather

- Modern Air Quality Forecasts are fundamentally based upon similar methodologies and tools as the ones successfully used for today's numerical weather predictions.
  - Numerical solution of dynamical/chemical equations
  - Initial and boundary conditions
  - Forcing factors (emissions, solar radiation
  - Data Assimilation to initialize the models
  - Model evaluation
  - Dissemination of information

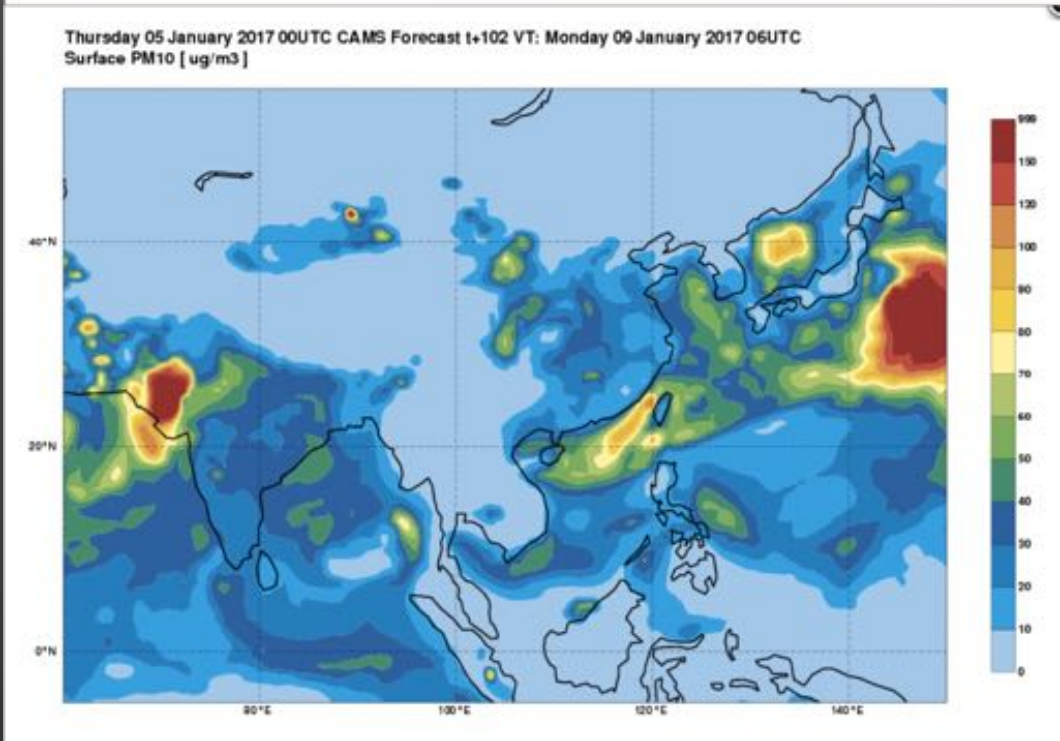
ECMWF CAMS Project

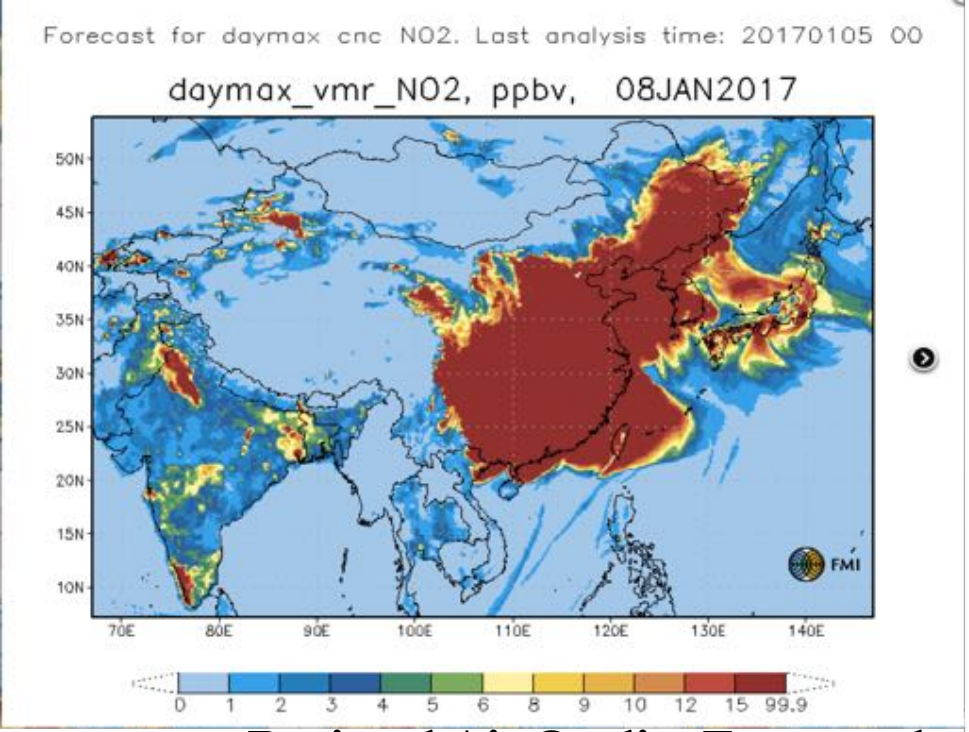
Global Chemical Weather Forecasts

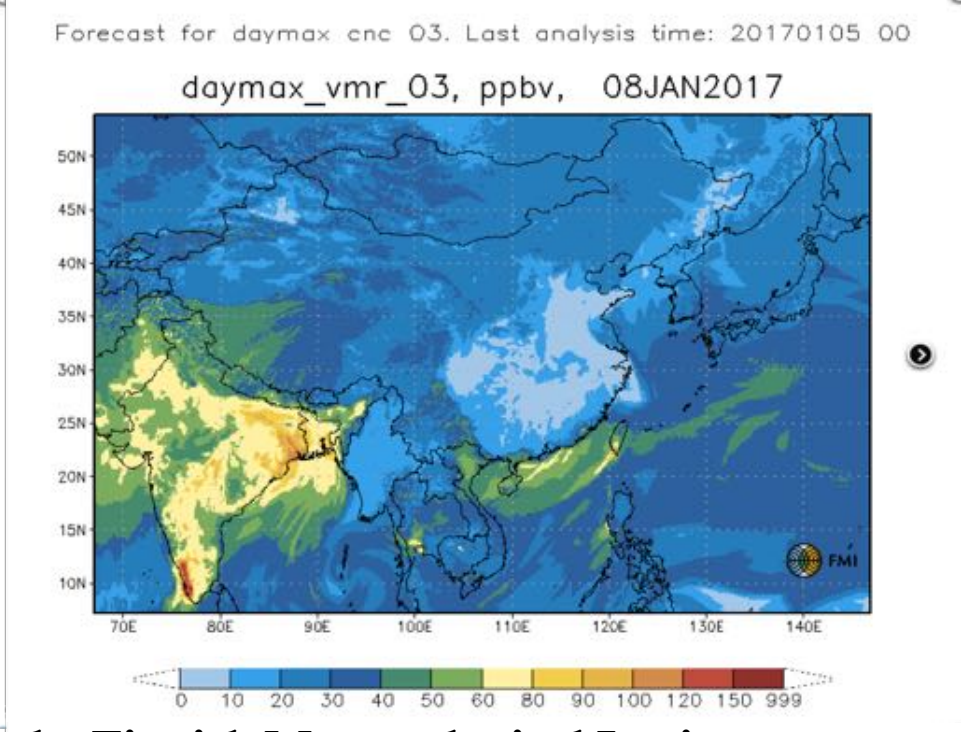
O_3



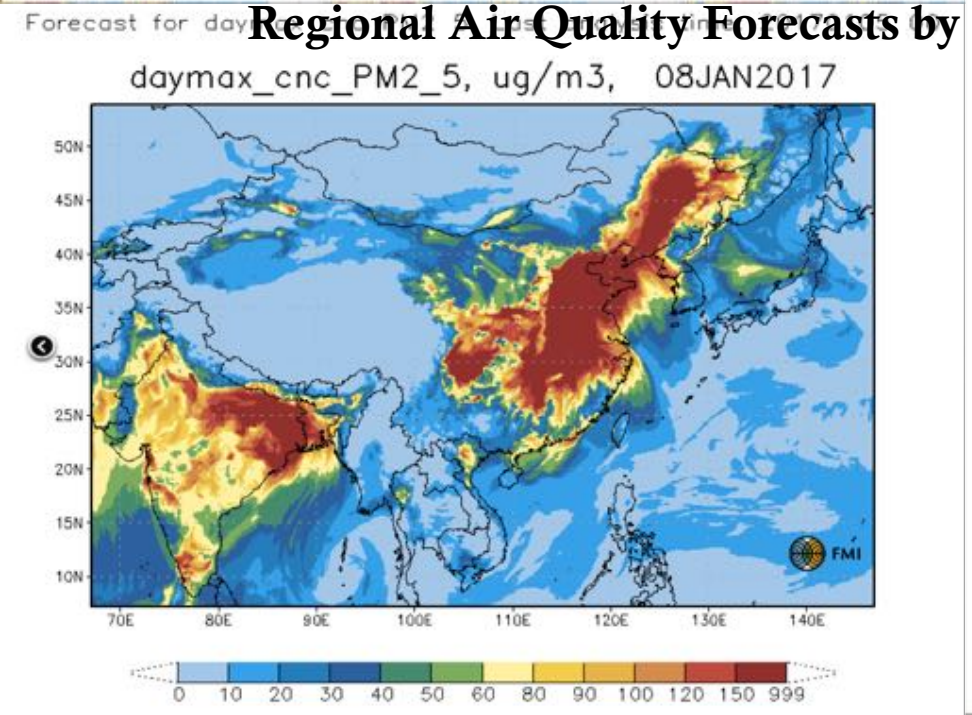
PM10

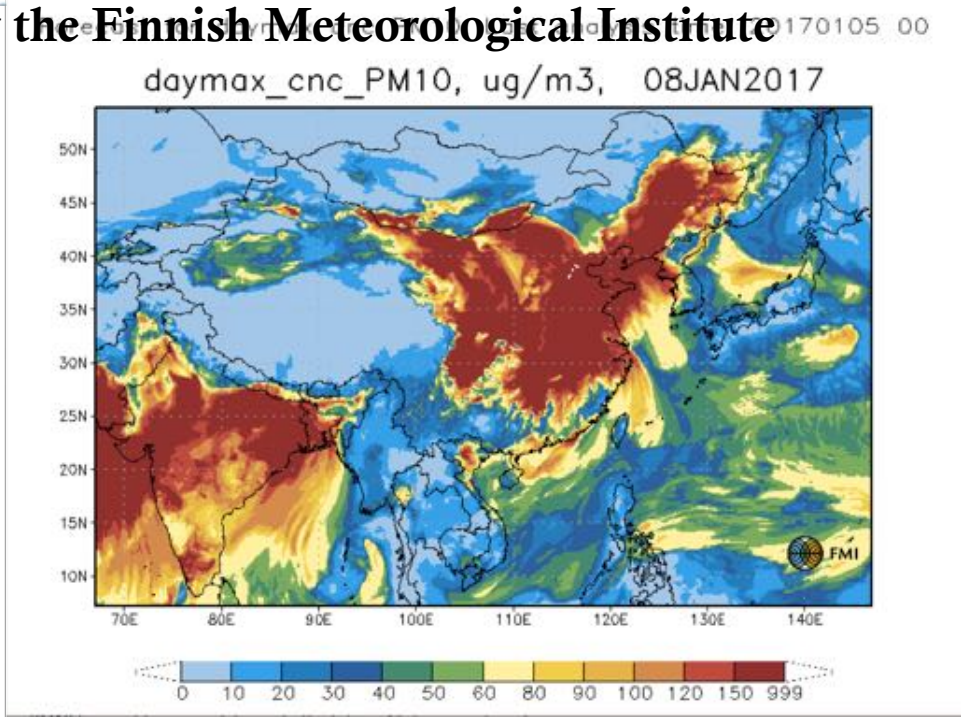






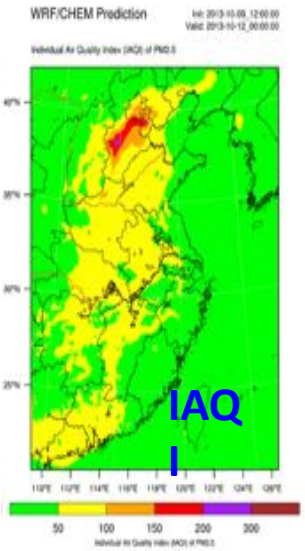
Regional Air Quality Forecasts by the Finnish Meteorological Institute

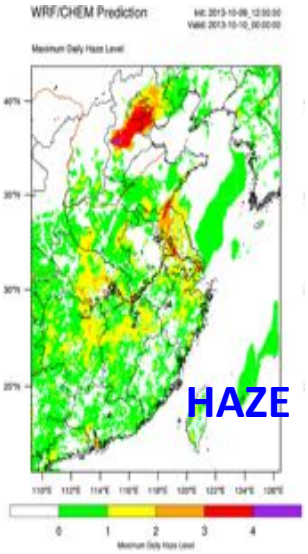


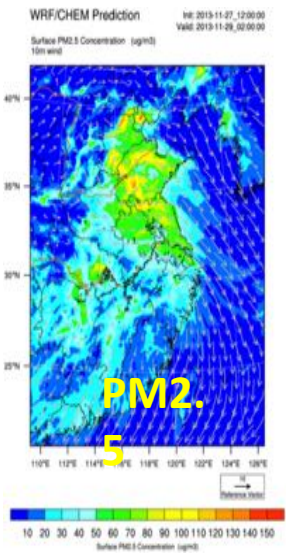


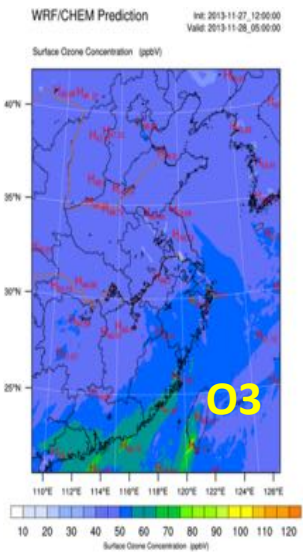
Forecasting Products by the SMB, China

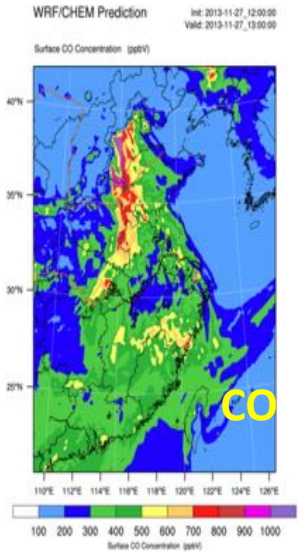
http://222.66.83.21:8086

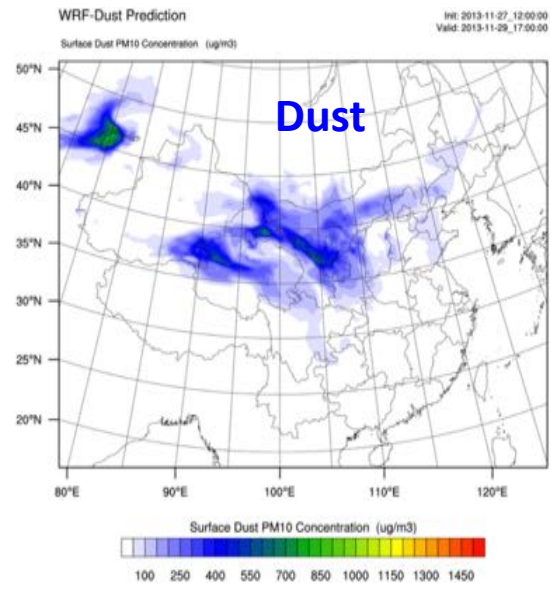


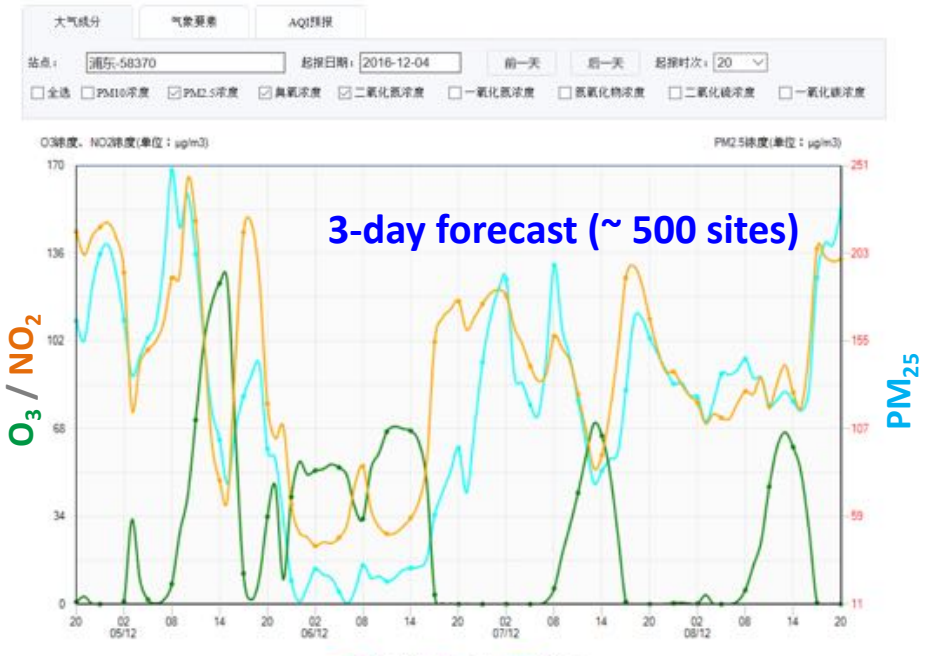




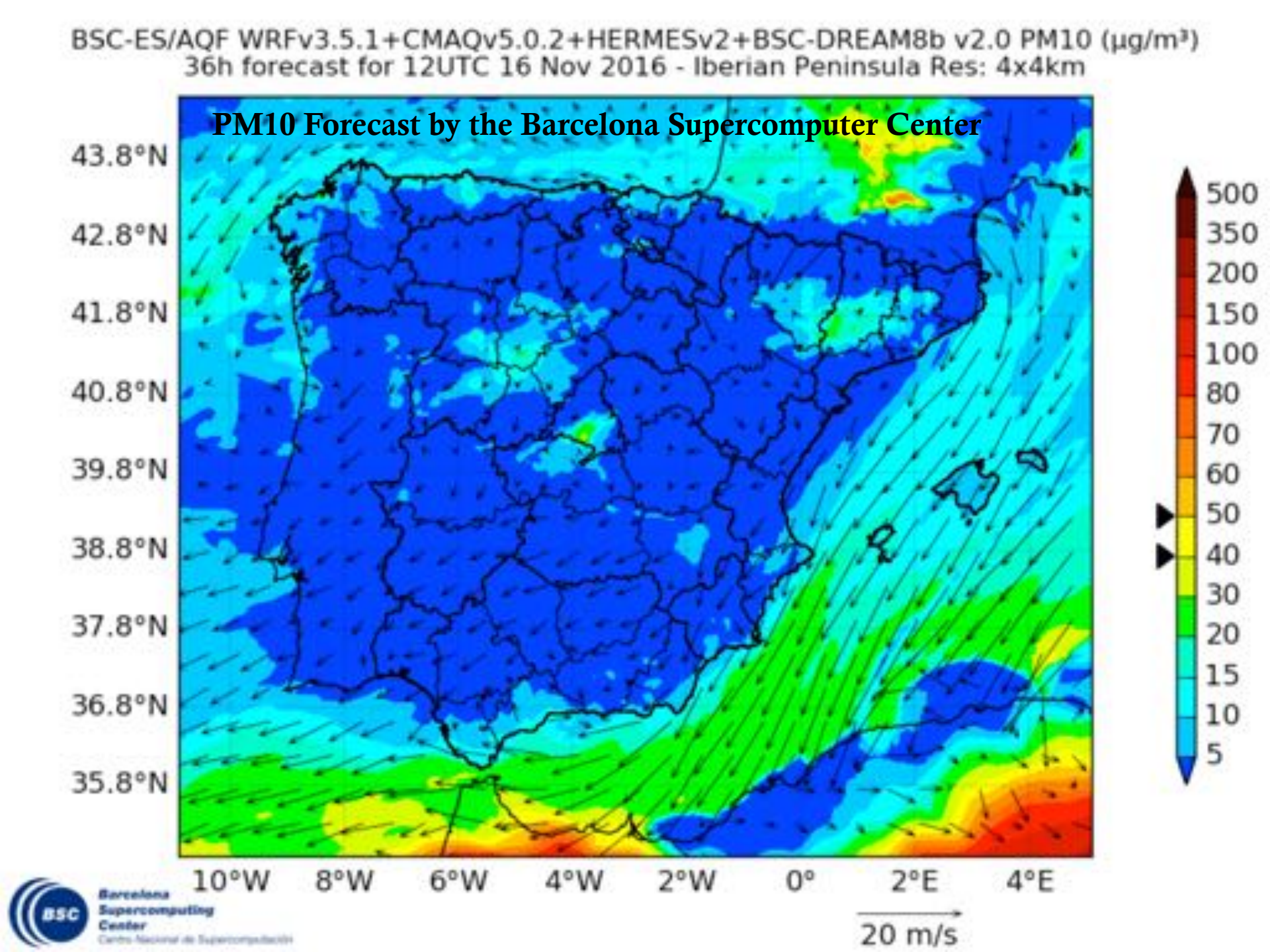


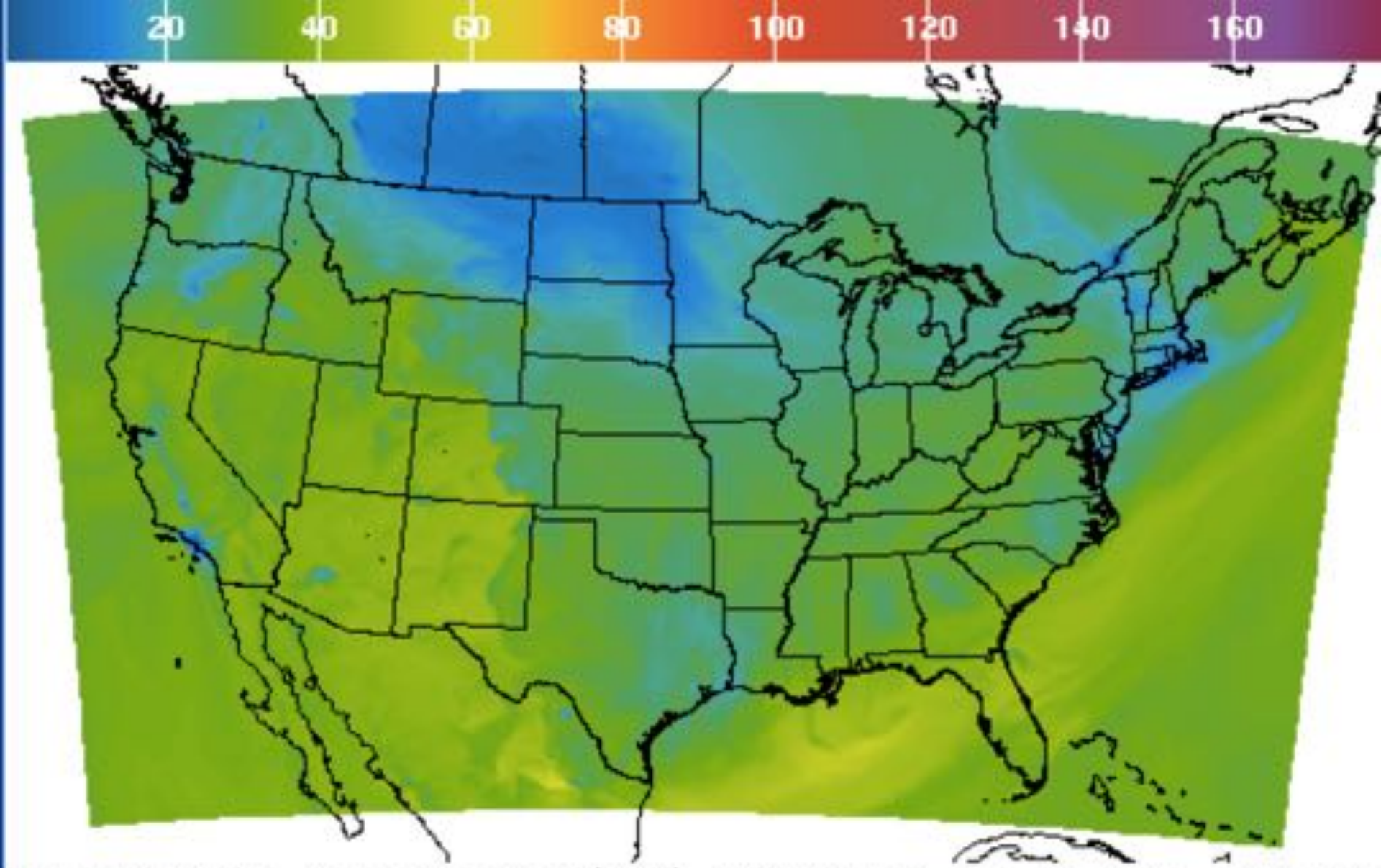






Ying Xie
SMB


BSC-ES/AQF WRFv3.5.1+CMAQv5.0.2+HERMESv2+BSC-DREAM8b v2.0 PM10 (µg/m³)
36h forecast for 12UTC 16 Nov 2016 - Iberian Peninsula Res: 4x4km
PM10 Forecast by the Barcelona Supercomputer Center
43.8°N
42.8°N
41.8°N
40.8°N
39.8°N
38.8°N
37.8°N
36.8°N
35.8°N
10°W
8°W
6°W
4°W
2°W
0°
2°E
4°E
500
350
200
150
100
80
70
60
50
40
30
20
15
10
5
20 m/s
Barcelona Supercomputing Center



1Hr Avg Ozone Concentration(PPB) Ending Wed Jan 04 2017 3PM EST

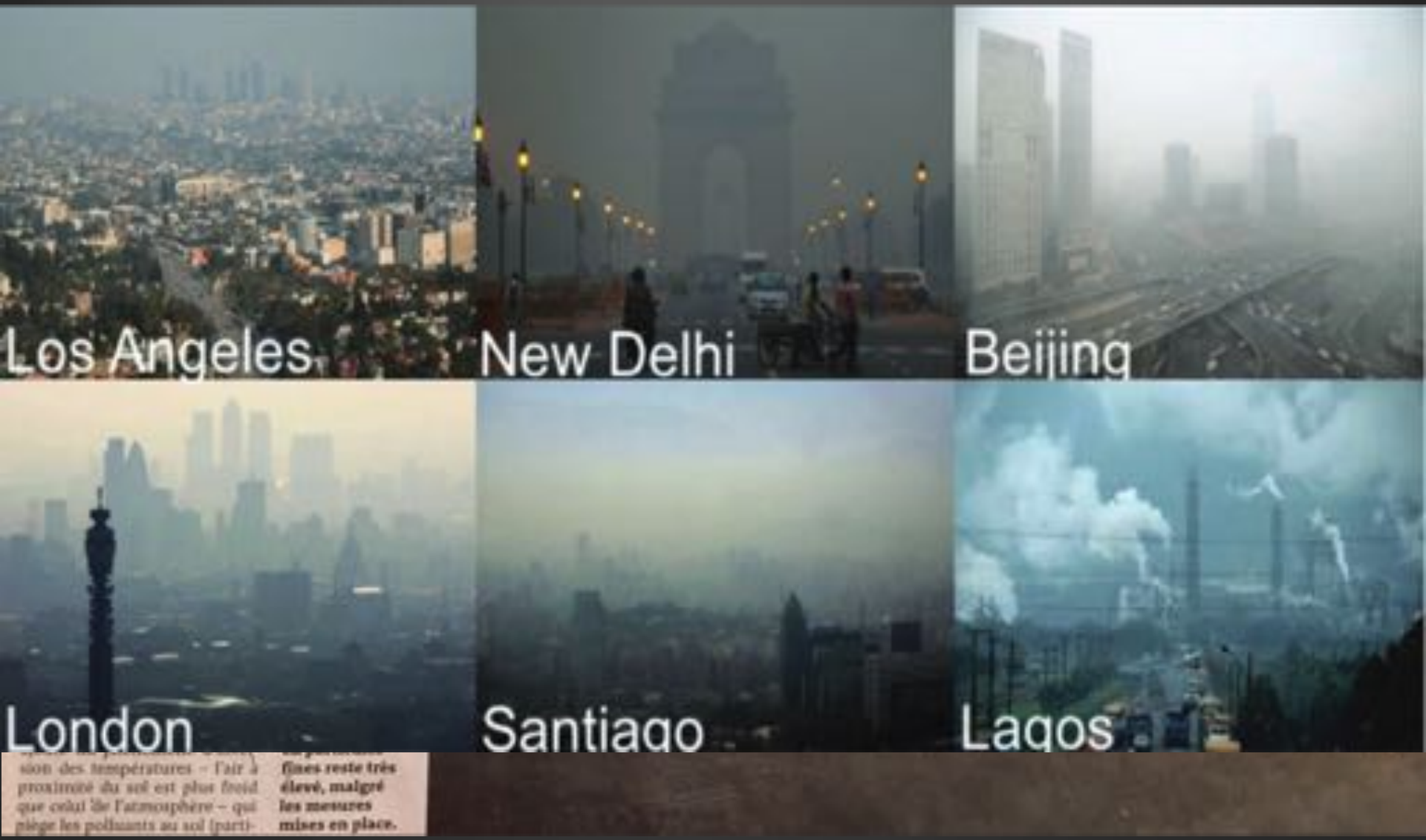
(Wed Jan 04 2017 20Z)

National Digital Guidance Database

12z model run Graphic created-Jan 04 11:46AM EST

2.
A New International Initiative: Monitoring, Analysis and Prediction of Air Quality MAP-AQ

Air Pollution affects all Continents,



Objectives of MAP-AQ

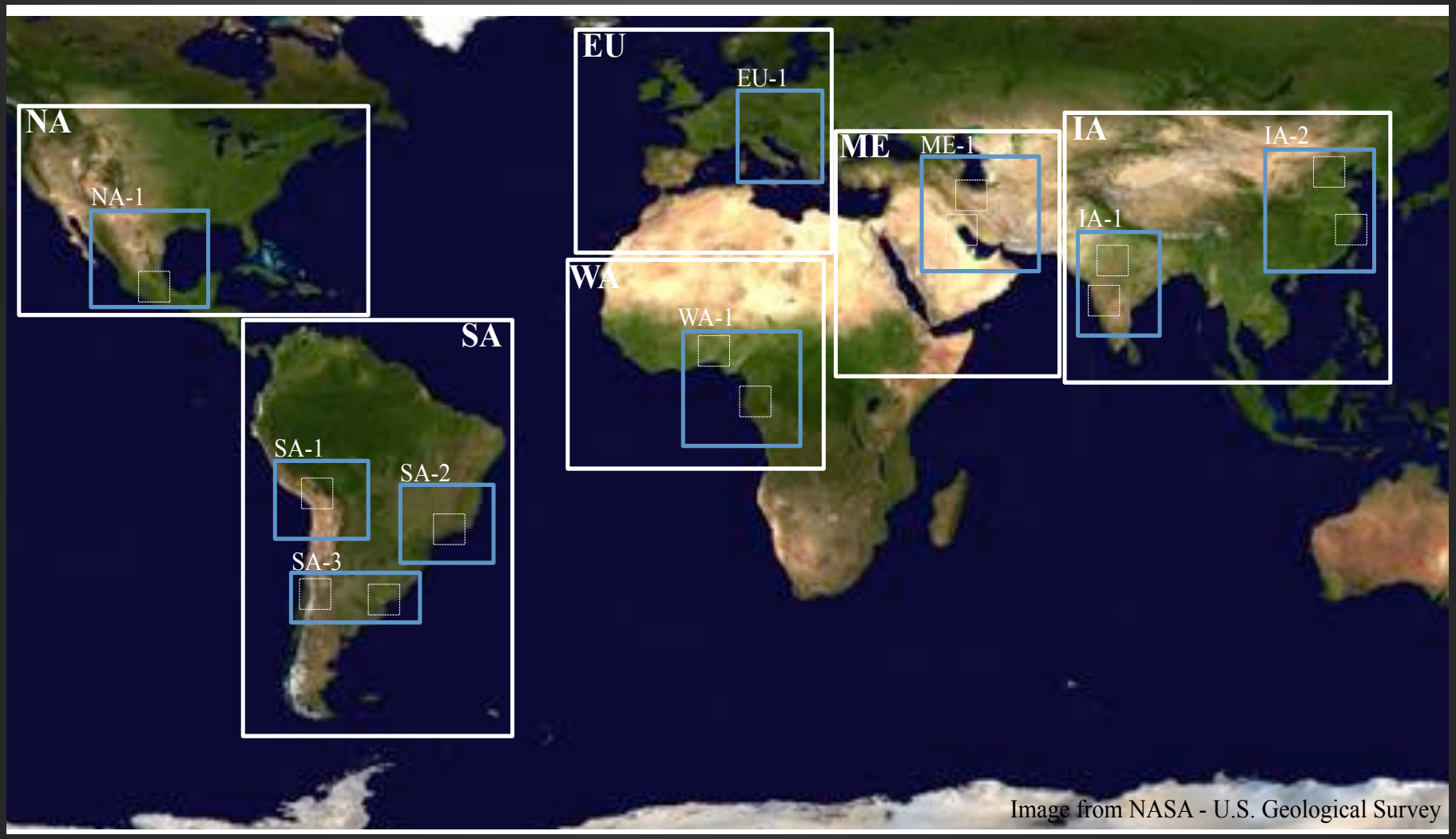
- To **develop a consortium of expert groups** that coordinates and enhances research and services with the purpose of mitigating air pollution, specifically in regions of the world with high concentrations of pollutants.
- To assimilate information provided by monitoring systems, specifically spacecraft, ground instruments and small sensor devices.
- To combine an ensemble of state-of-the-art multi-scale chemical transport models, high-resolution emission inventories, space observations and surface measurements to provide (near-real)-time forecasts of air pollution and its effects at the global to regional and local scales.

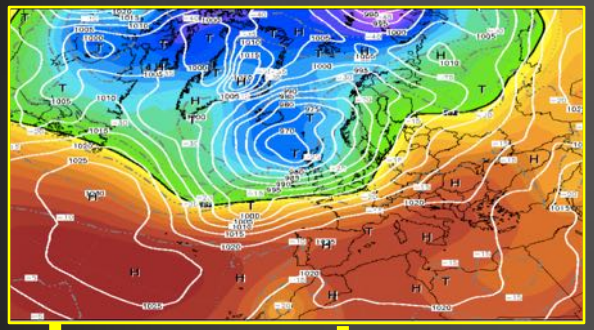
Objectives of MAP-AQ

- To implement **analysis and prediction systems** with **spatially downscaling capability**, specifically in low and middle-income countries.
- To **co-design and co-develop with users** and other stakeholders relevant products and services, and transfer air quality related information to the public.
- To organize **educational activities** in support of sustained capacity building.
- To **develop markets** for the products and services offered in different regions. (Private-Public partnerships)

MAP-AQ is an IGAC Emerging Activity and is encouraged by WMO as a support of the Global Atmospheric Watch (GAW)

Air Quality Forecasts in Different Regions of the World

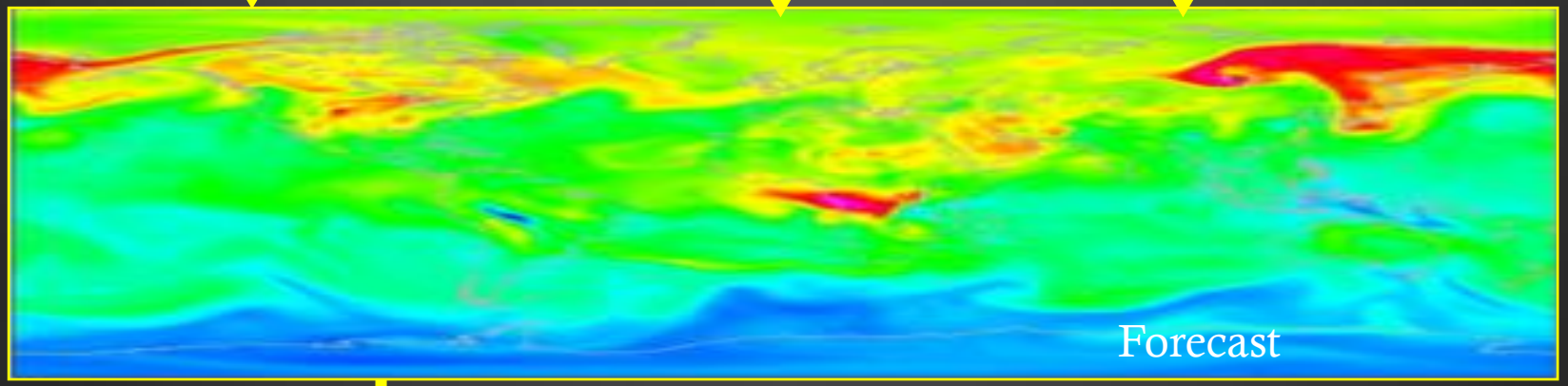




Weather Forecast

Emissions

Data Assimilation



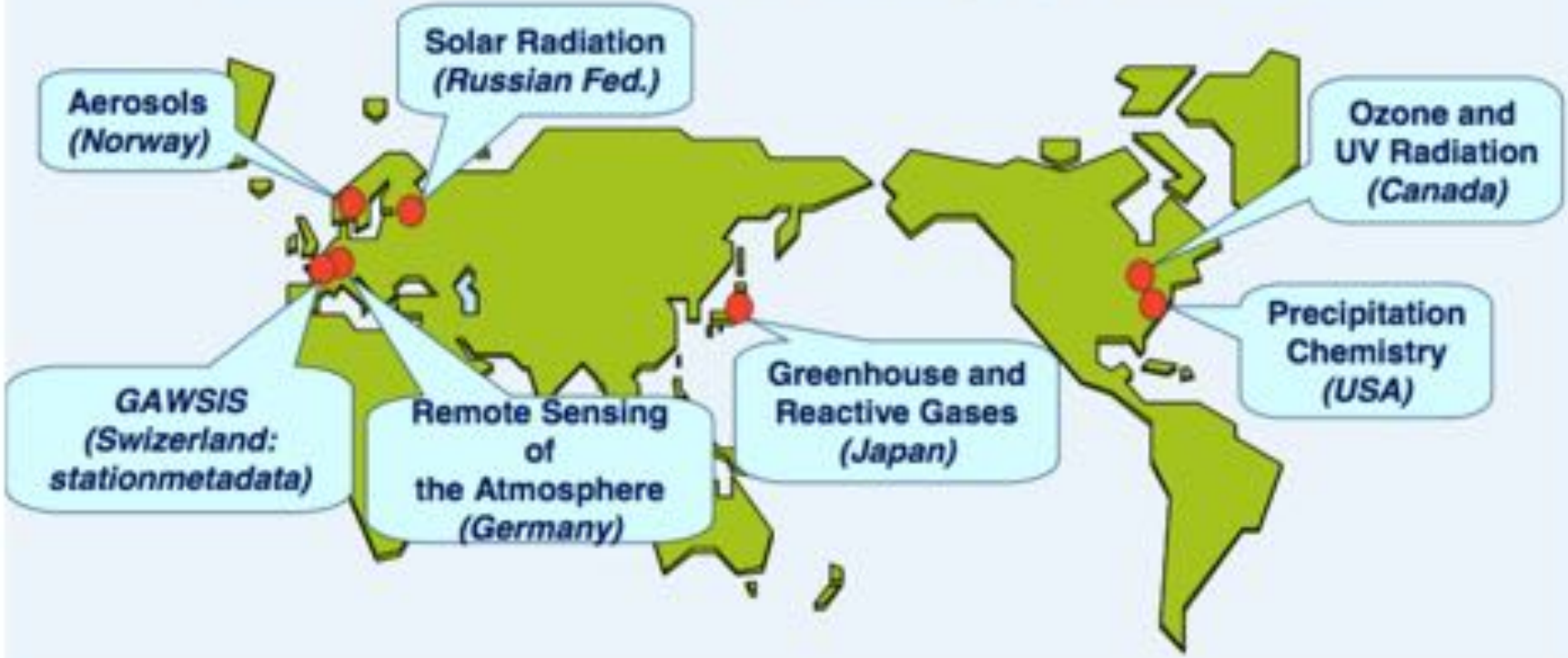
Forecast

Storage
Big Data
Management

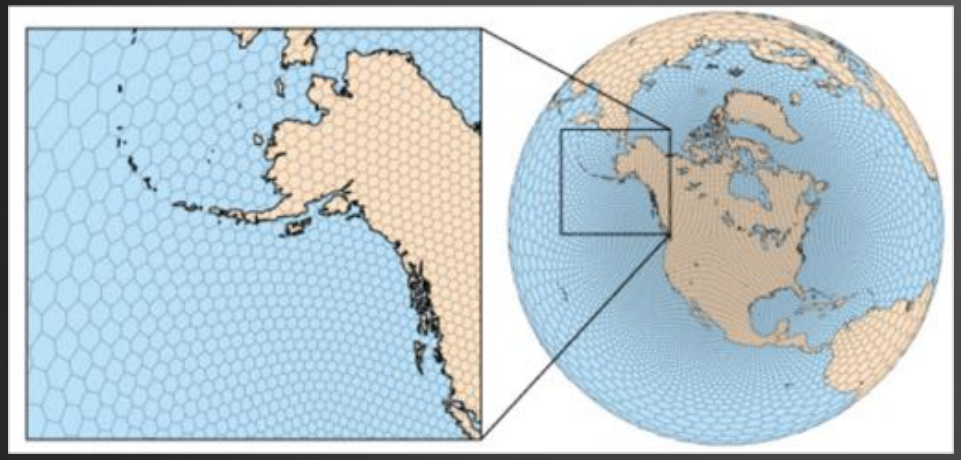
Community Emission Inventories and other Community Databases

World Meteorological Organization (WMO)
Global Atmosphere Watch (GAW)
World Data Centres

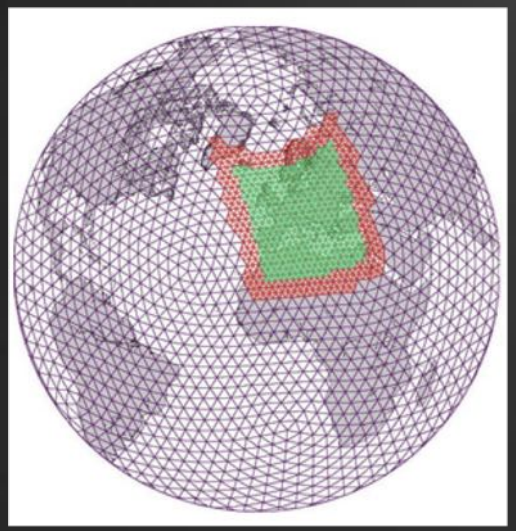
The WDCGG is one of the GAW World Data Centres, responsible for CO_2, CH_4, N_2O, Halocarbons, SF_6, Surface Ozone, CO, VOCs, NOx, SO_2, H_2, ^{85}Kr, ^{222}Rn, etc.

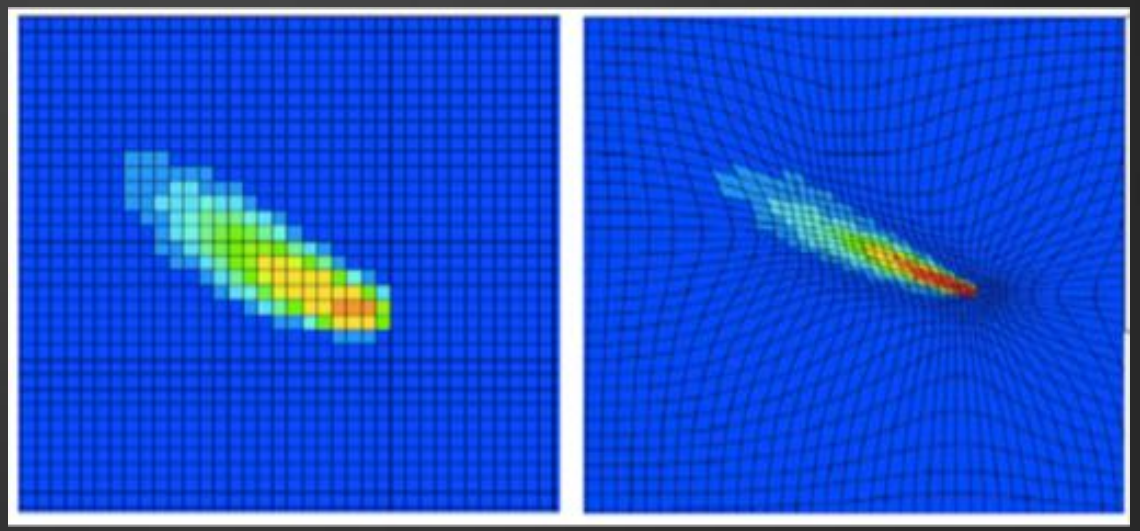


A New Generation of Community Prediction Models



- Global models such as MPAS or ICON with zooming capabilities to better resolve regional patterns or with dynamically evolving grids to better simulate the evolution of plumes





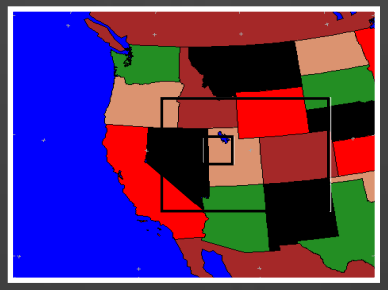
3.
Modeling Chemical Weather

A Spectrum of Coupled Scales

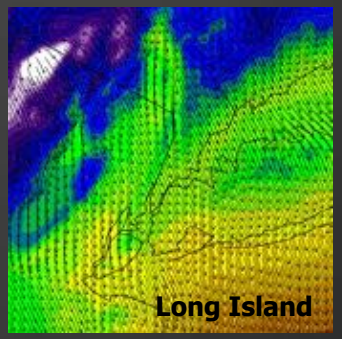
How do global and hemispheric patterns influence regional and local events?

Global Scales

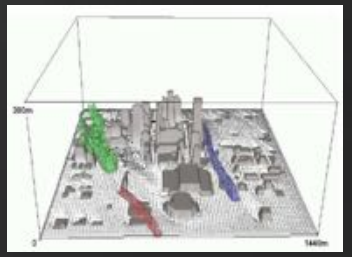
Continental Scales



Regional Scales



Local Scales



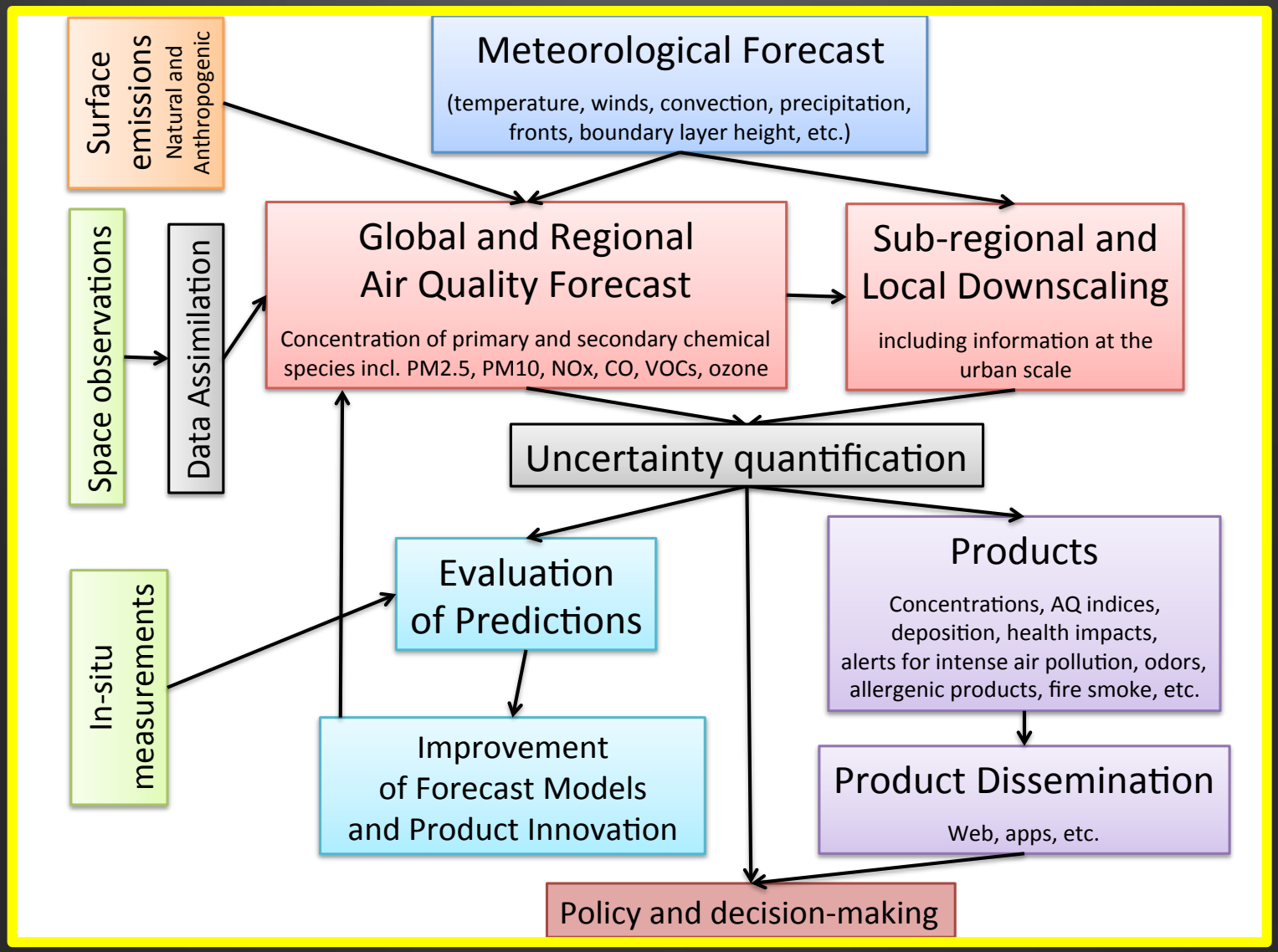
Urban Scales

Influences of local pollution sources on the regional and global scales

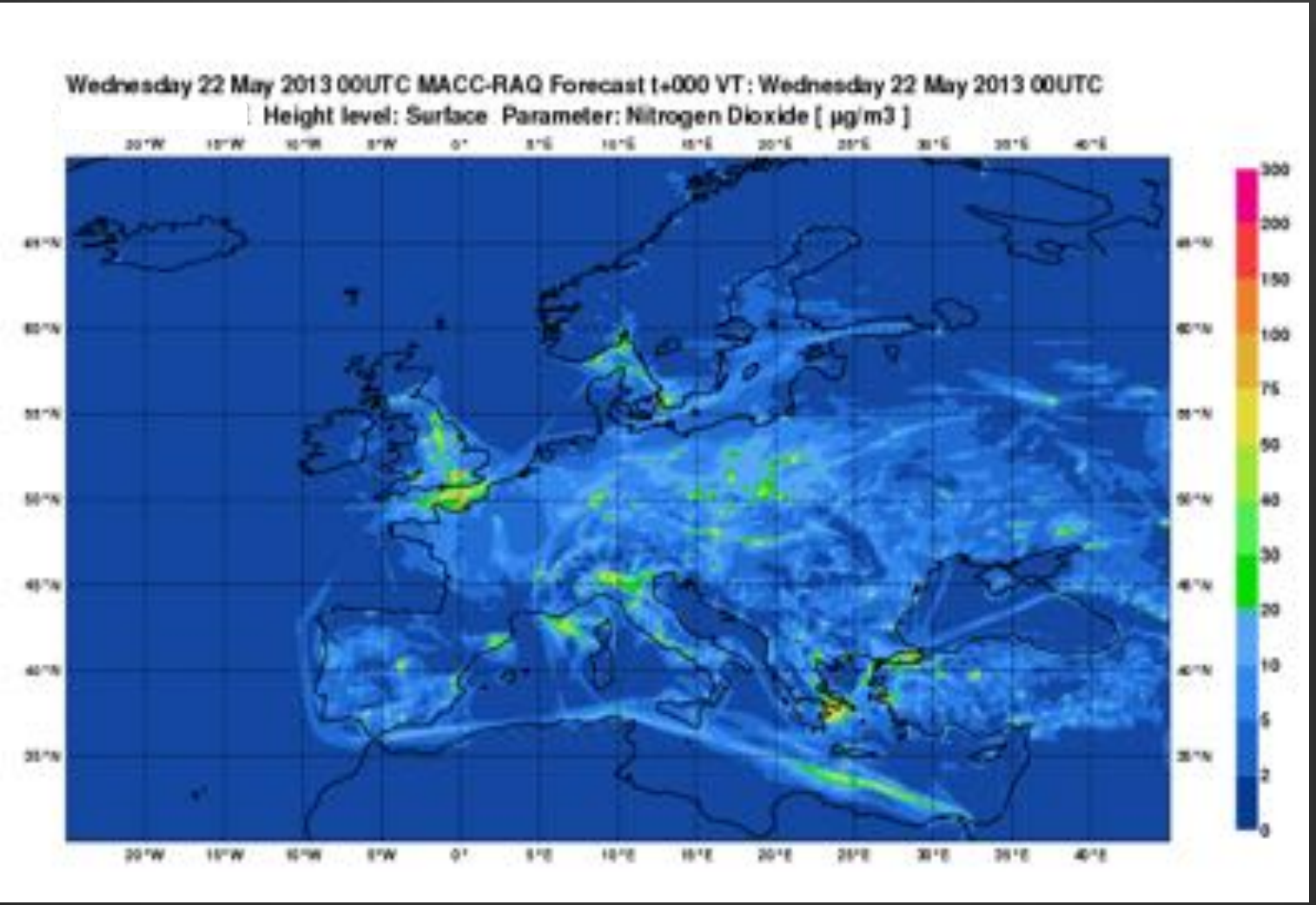
Modeling Challenges

- Comprehensiveness of the adopted chemical scheme
- Organic chemistry (i.e., isoprene oxidation)
- Aerosol formation and fate, wet chemistry (i.e., secondary organic aerosol)
- Treatment of large-scale advection at limited resolution
- Treatment of sub-grid chemical and transport processes (plumes, boundary layer ventilation, shallow and deep convection)
- Emissions, dry and wet deposition (e.g., multi-phase chemistry)
- Representation of natural variability and long-term trends (e.g., ozone)
- Model validation (lack of systematic observations)

Towards a Mosaic of Regional AQ Analysis and Forecast Systems

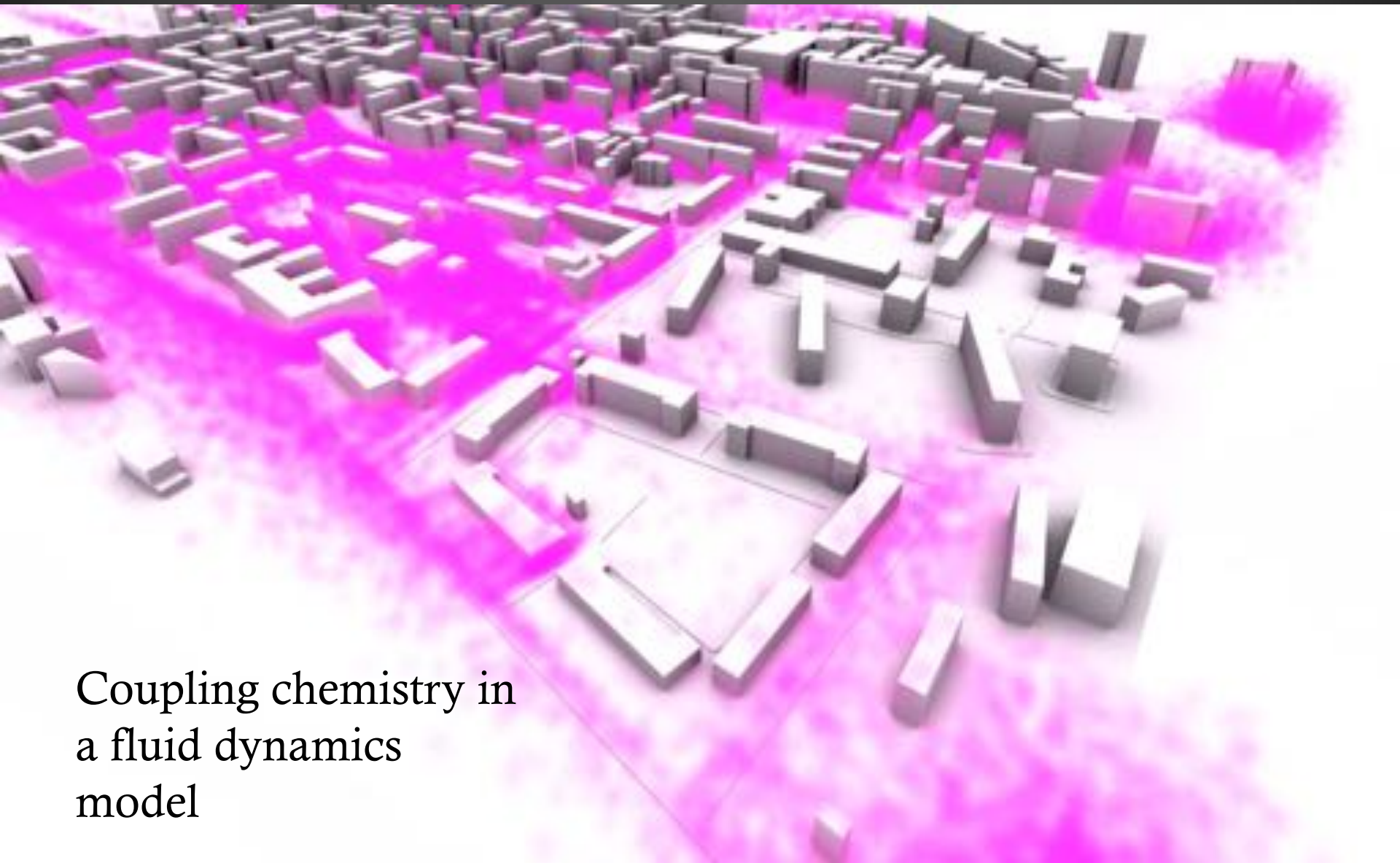


European Air Quality Forecasts in CAMS



NO_2

Downscaling to the City Block

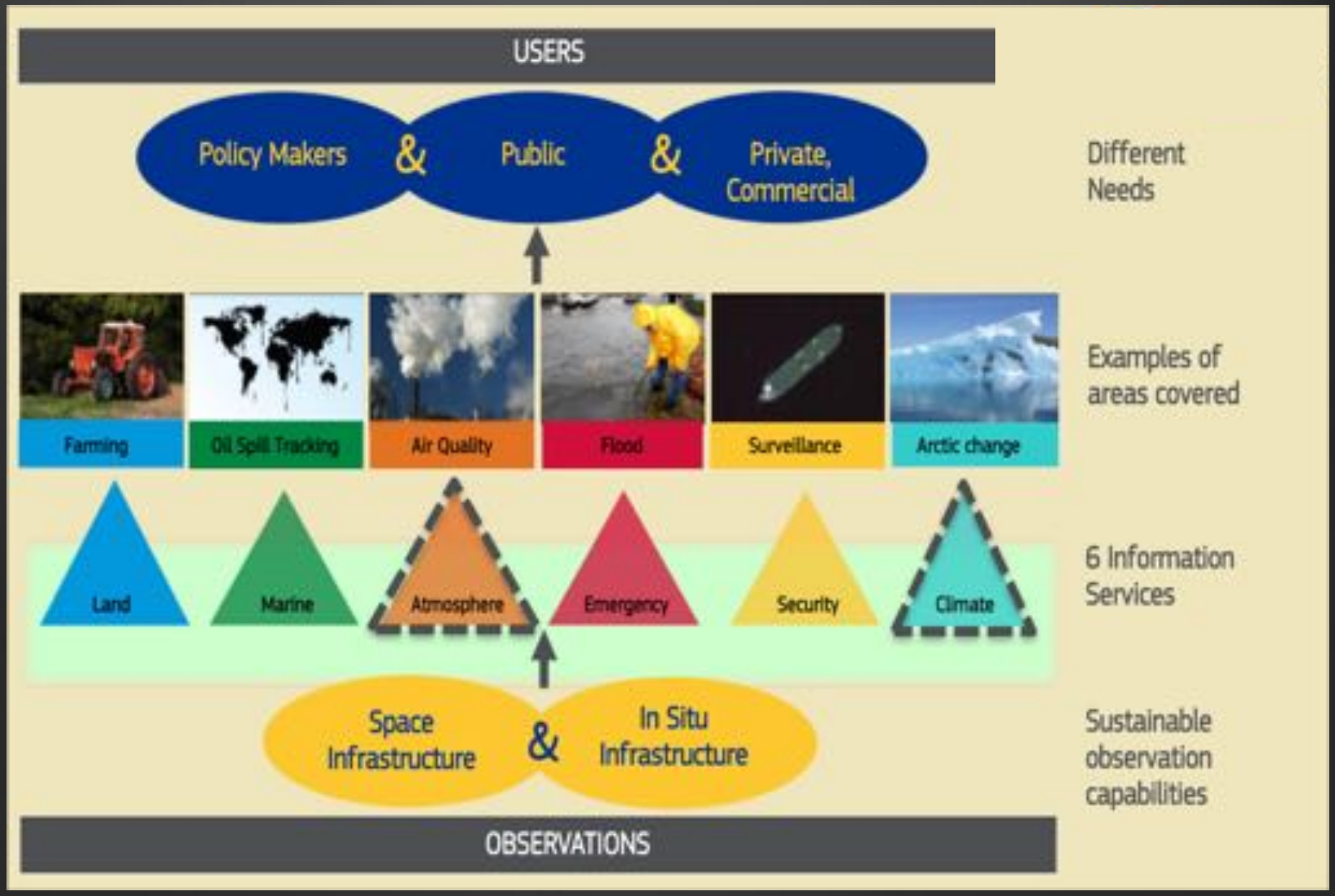


Coupling chemistry in a fluid dynamics model

3.
Air Quality Forecasts

The **Global** Scale

The Copernicus Project



Services
Led by ECMWF

From “Meteorological Weather” to “Chemical Weather” Environmental Forecasts

CAMS is fundamentally based upon similar methodologies and tools as the ones successfully used for today’s numerical weather predictions.

“The quiet revolution of Numerical Weather Prediction” Sept. 2015

The Copernicus Atmosphere Monitoring Service (CAMS)

Forecasts and informs on impacts

Detects emissions and estimate surface fluxes

Quantifies transport, removal and transformations of atmospheric constituents

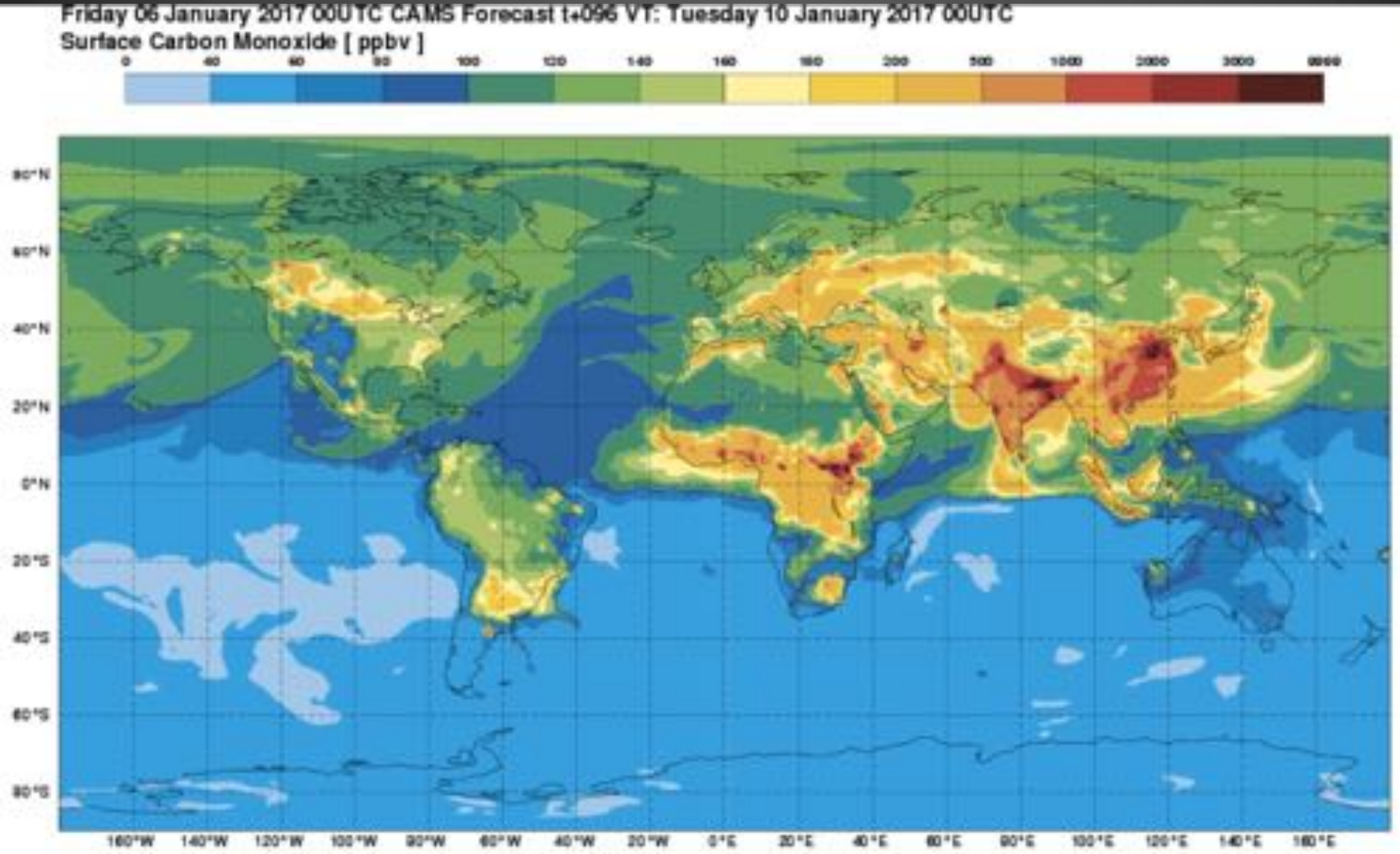
CAMS in three figures

280 million observations processed every 12 hours

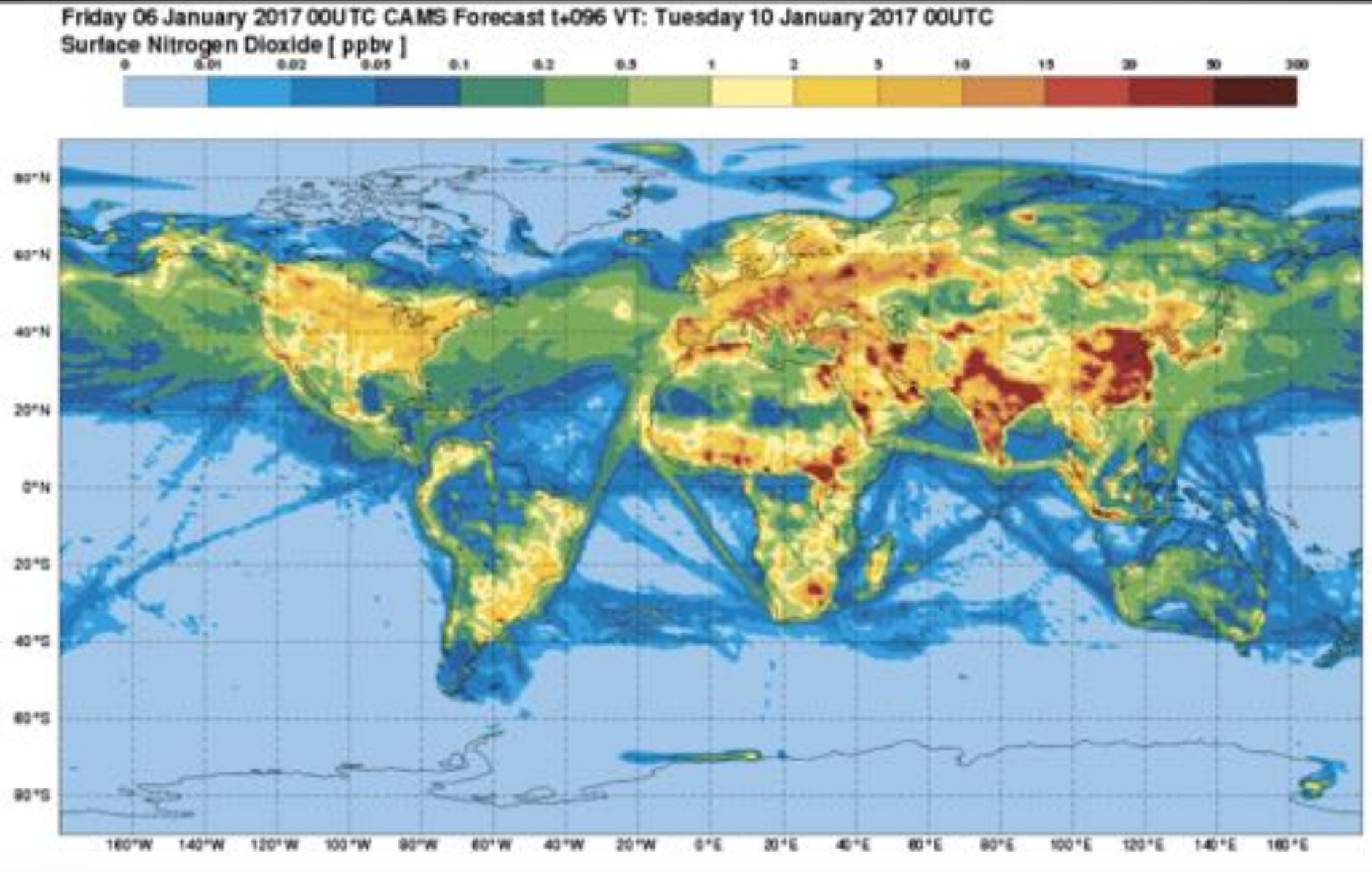
Data from **70 satellite instruments** are received and used

Delivers **everyday 14,000 maps** online

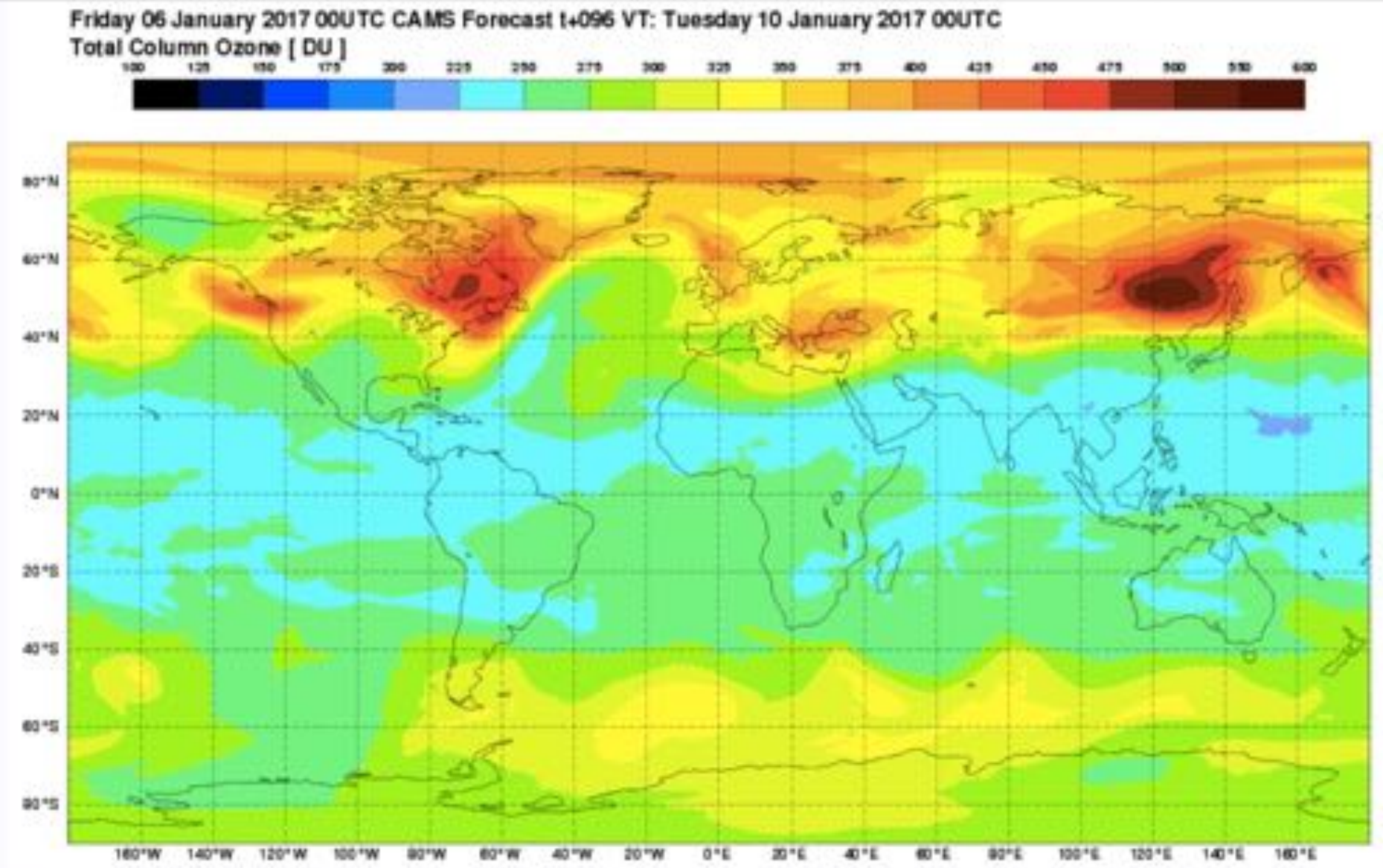
Forecast of Surface CO for 10 January 2017



Forecast for NO_2 on 10 January 2017



Forecast of Ozone Column for 10 January 2017

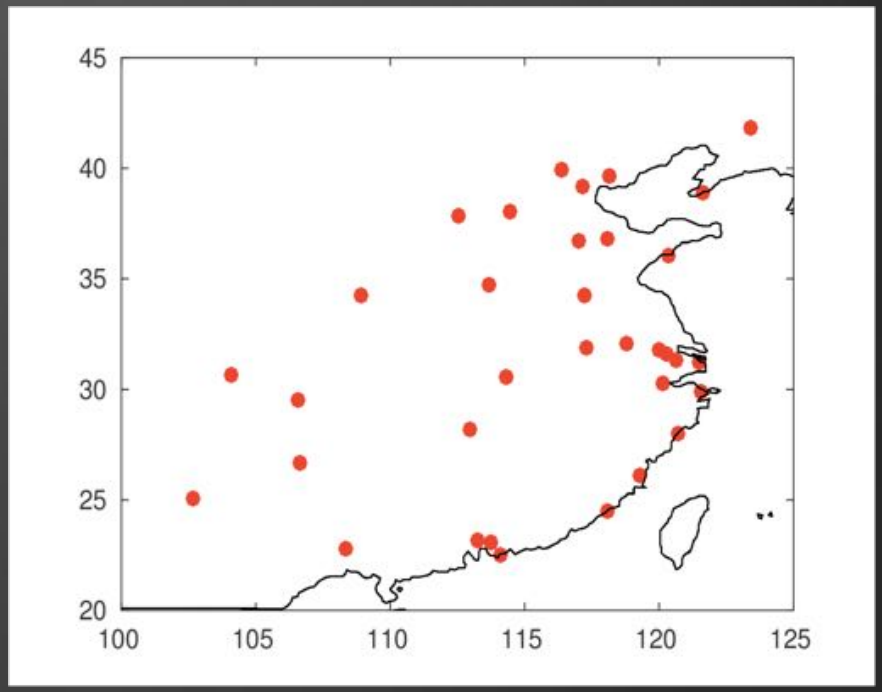


4.
Air Quality Forecasts

Downscaling to the Regional and Local Scales.

An Ensemble of 7 Models to Forecast Regional Air Quality near 34 Chinese Cities

1. ECMWF (C-IFS – Global, 40 km)
2. MPI-M (WRF-Chem, 20 km)
3. KNMI (CHIMERE, 25 km)
4. MET NORWAY (EMEP, 10 km)
5. SCUEM (WRF-Chem, 6 km)
6. FMI (SILAM, 25 km or 10 km)
7. TNO (LOTOS EUROS, 15 km)



The 34 Chinese Cities

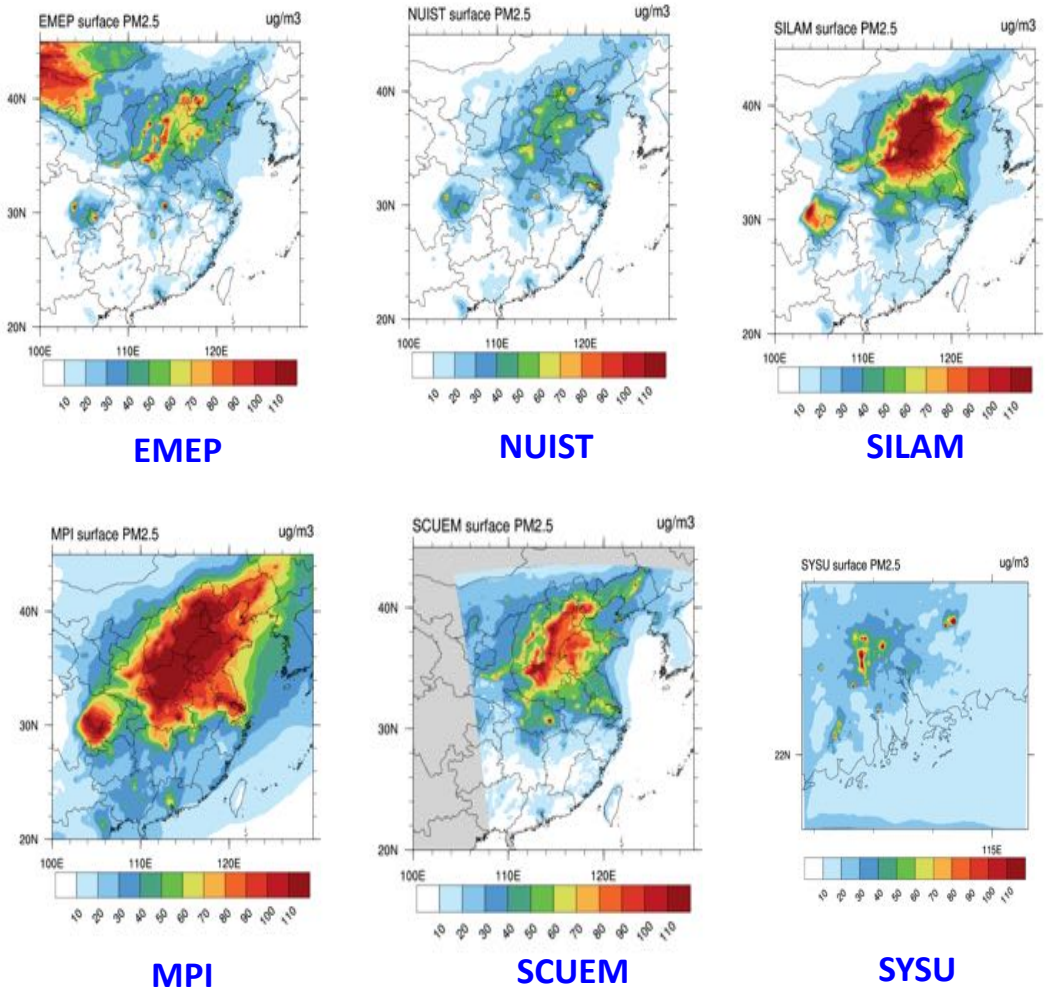
Emissions
Anthropogenic: MEIC, MACCity, HTAPv2
Biogenic: MEGAN Fires: FINN

Meteorology: ECMWF, NCEP

Chemical Downscaling and Model Intercomparison Exercise

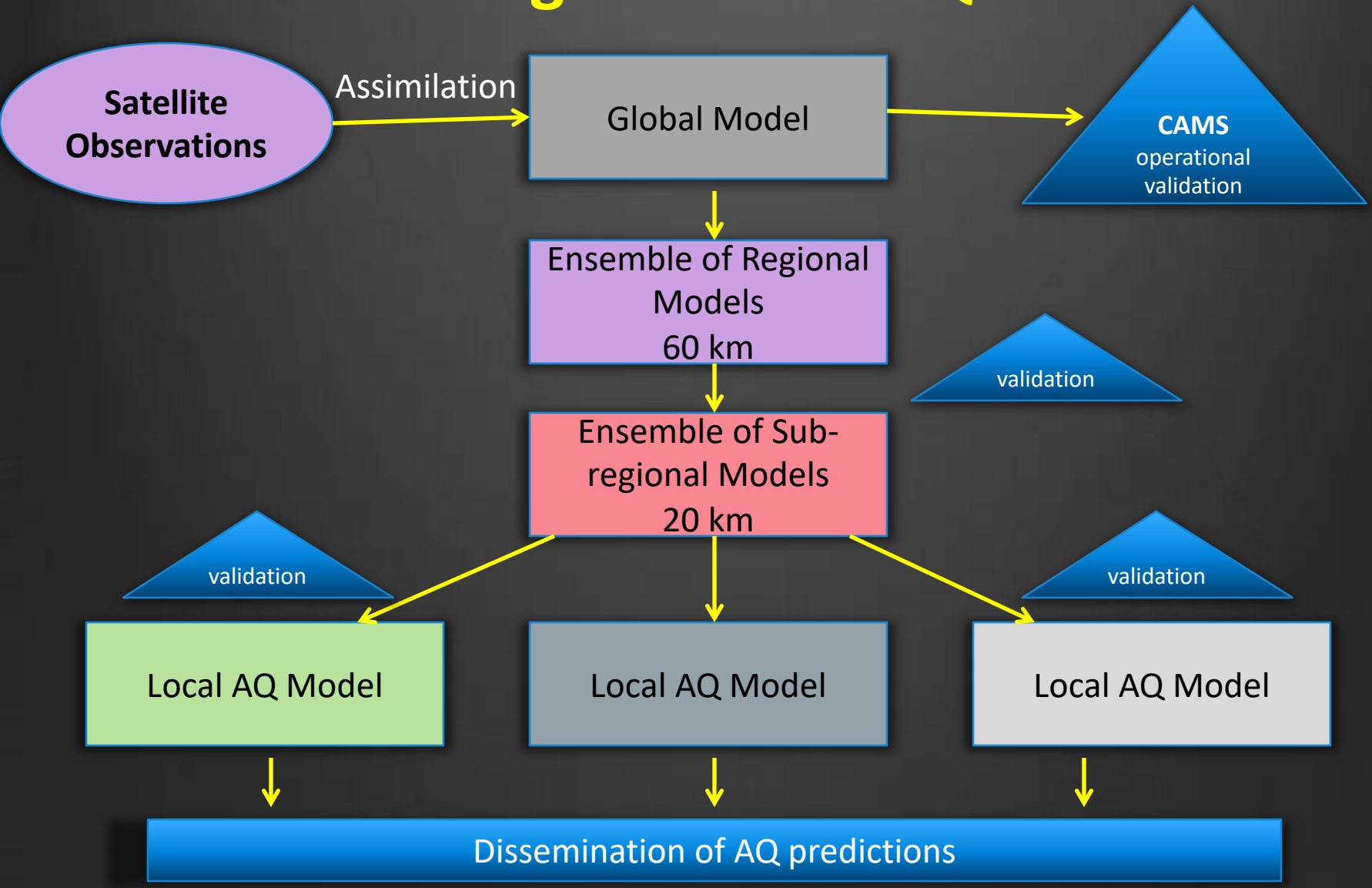
- **Three historical periods**
  - January and July 2010, July 2013
- **Participants**
  - MPI-M (WRF-Chem, 20 km)
  - MET NORWAY (EMEP, 0.1 degree)
  - SYSU (WRF-Chem, 3 km)
  - SCUEM (WRF-Chem, 6 km)
  - NUIST (CMAQ, 15 km)
  - FMI (SILAM, 0.1 degree)
- **C-IFS/ECMWF for chemical IC/BC**
- **Anthropogenic emissions**
  - January and July 2010: HTAPv2
  - January 2013: MEIC 2012 merged with HTAPv2
- **Evaluation ongoing and manuscripts under preparation by Bouarar et al.**

Monthly averages $PM_{2.5}$ concentrations for July 2010



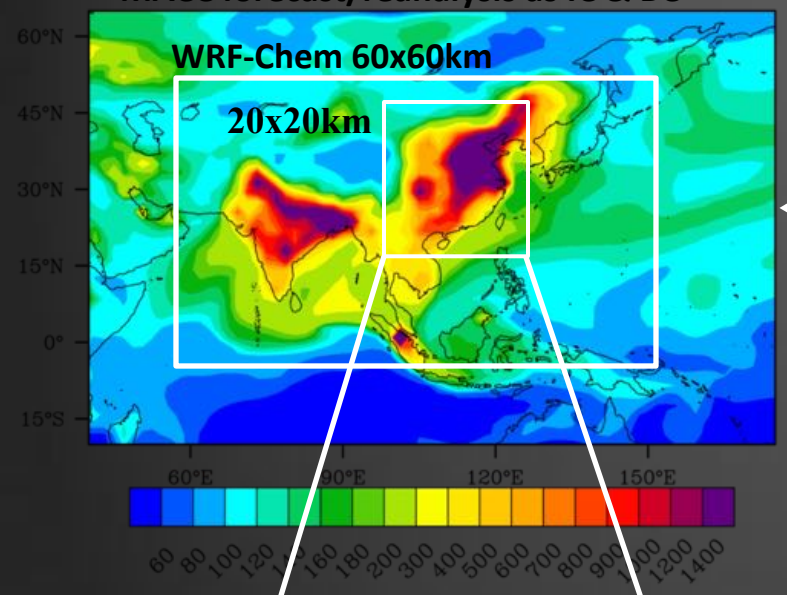
From Ying Xie, SMB

The EU Panda MarcoPolo Approach: Downscaling for China AQ Forecasts



Downscaling to Regional Scale in Asia

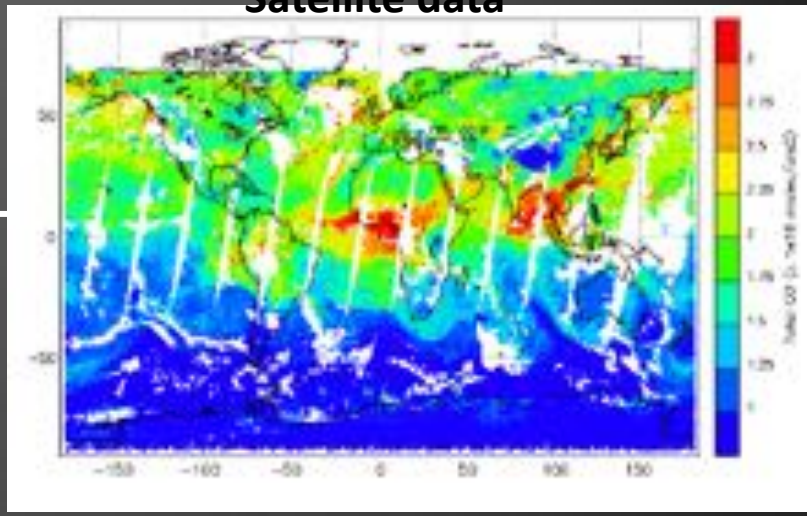
MACC forecast/reanalysis as IC & BC



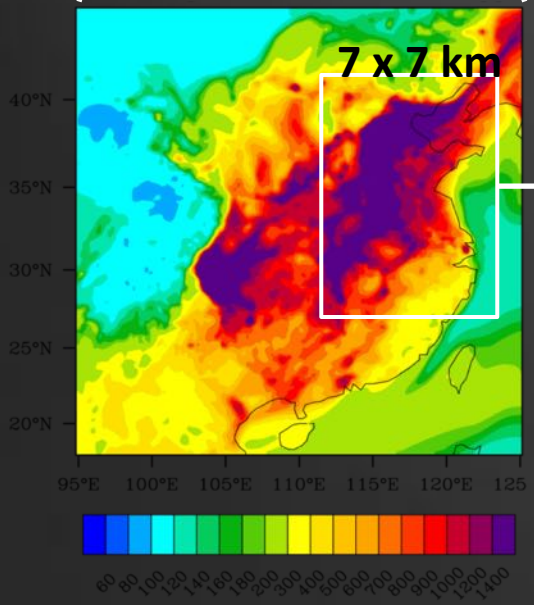
Assimilation

in CAMS

Satellite data

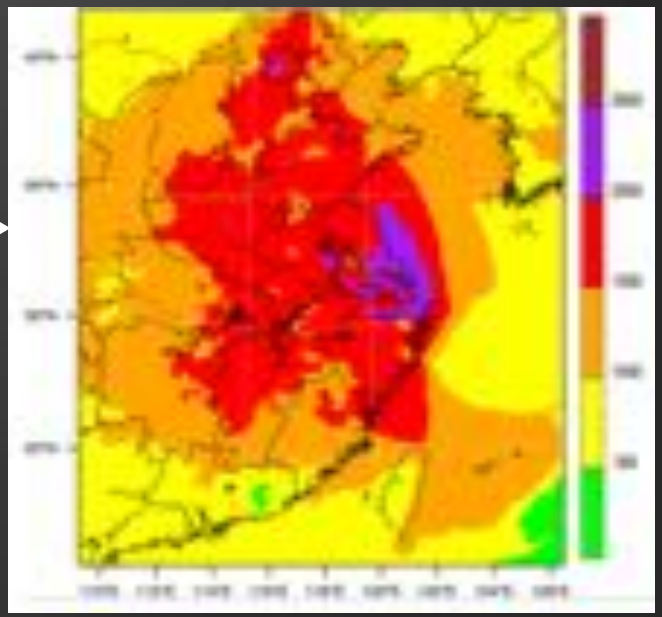


WRF-Chem prediction
20x20km



Air Quality Index (AQI)

WRF-Chem prediction
AQI



Automatic Forecasting System at MPI-M: Operation Steps

(DKRZ, Hamburg, Germany)

6pm (LT)

NCEP GFS

Meteo. Forecasts

10pm (LT)

6h WRF Meteo spinup

10pm (LT)

Chem. BC: ECMWF CAMS

Chemical Forecasts

00:00 (LT)

3 days WRF-Chem forecast

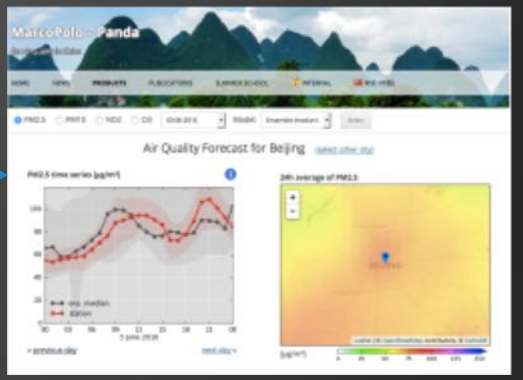
Chem. IC: Day -1 Forecast

HTAPv2 FINN Emissions

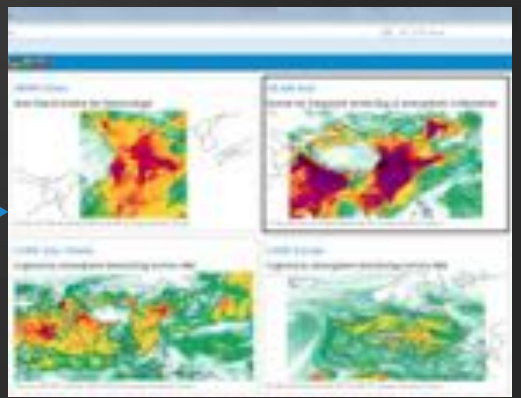
Dissemination

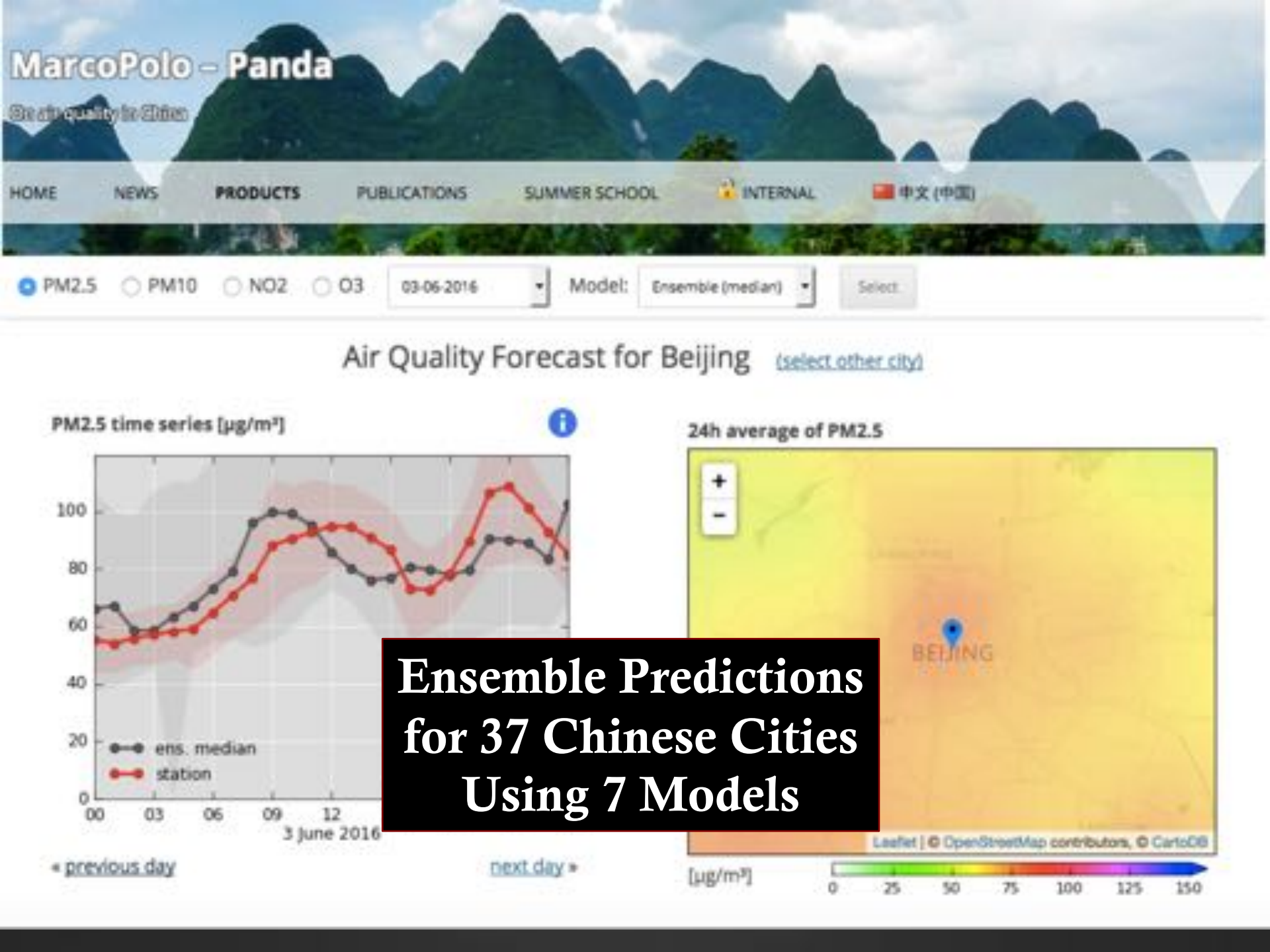
KNMI

www.marcopolo-penda.eu

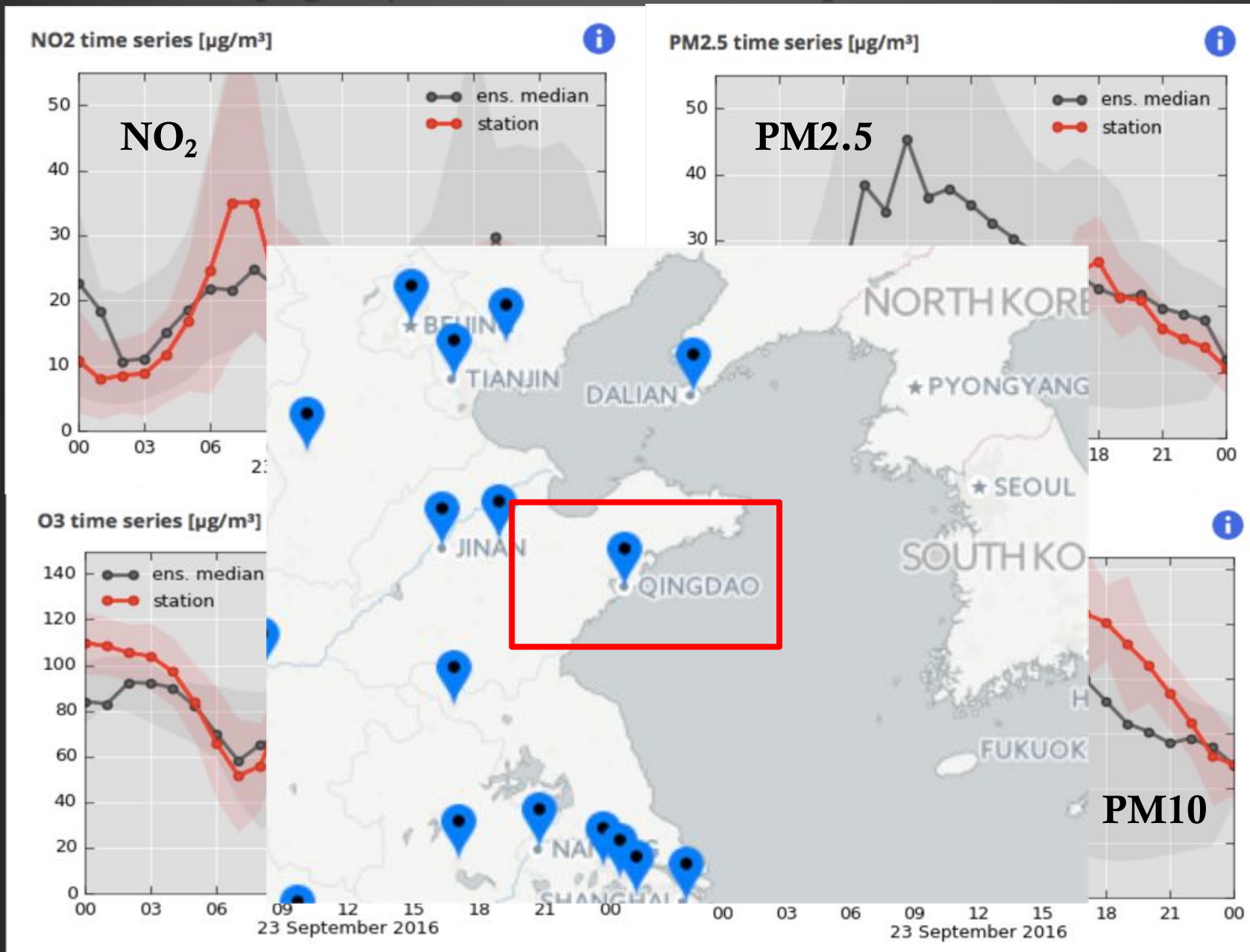


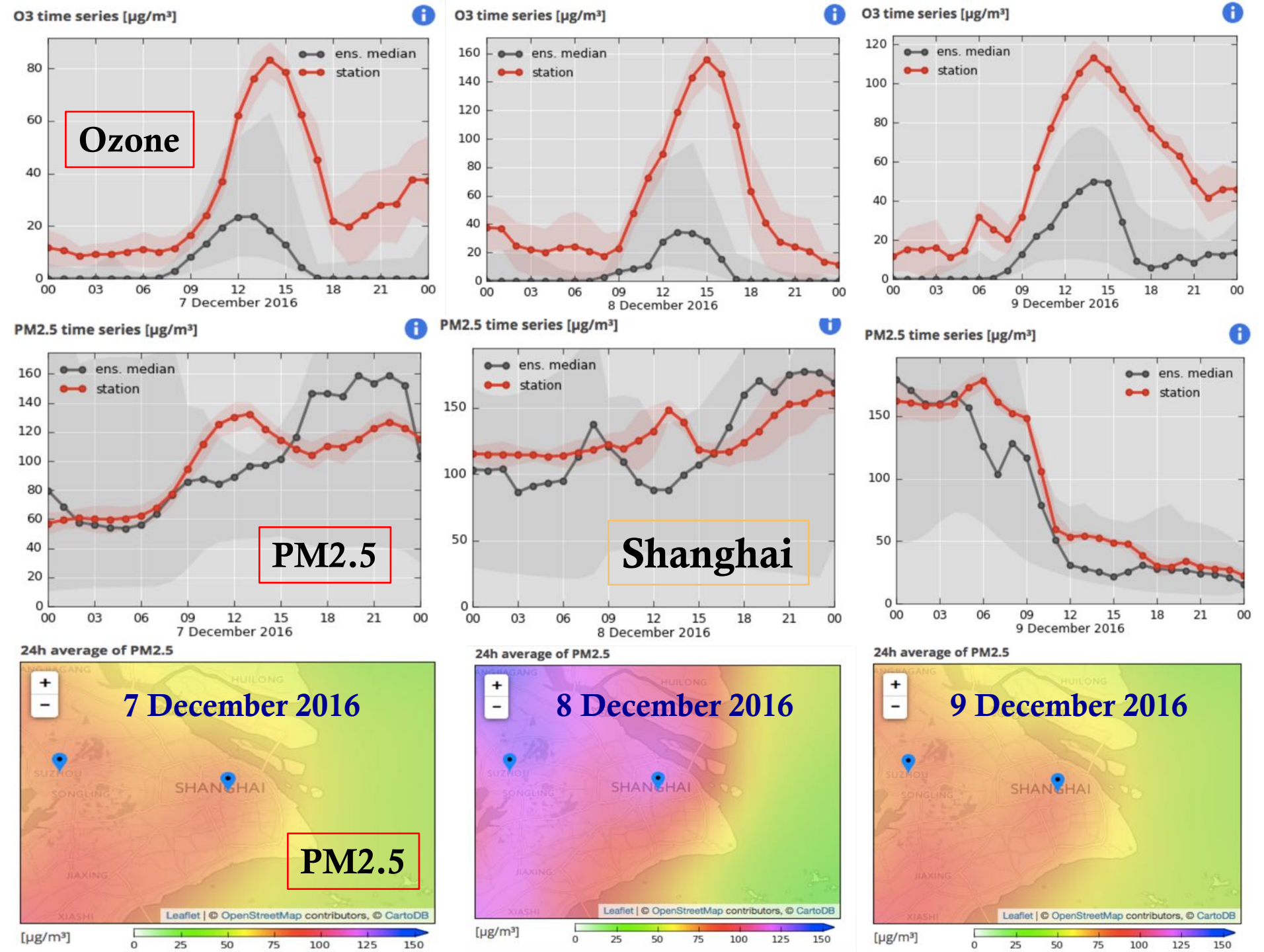
aqicn.org/forecast



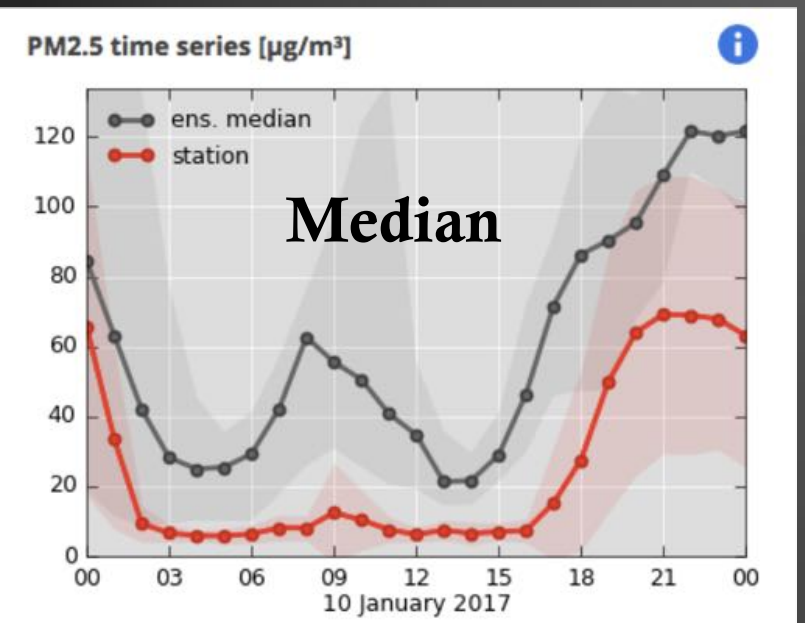

MarcoPolo – Panda
HOME
NEWS
PRODUCTS
PUBLICATIONS
SUMMER SCHOOL
INTERNAL
PM2.5
PM10
NO2
O3
03-06-2016
Model:
Ensemble (median)
Select
Air Quality Forecast for Beijing
(select other city)
PM2.5 time series [µg/m³]
ens. median
station
3 June 2016
« previous day
next day »
24h average of PM2.5
BEIJING
Leaflet | © OpenStreetMap contributors, © CartoDB
[µg/m³]
0
25
50
75
100
125
150
Ensemble Predictions
for 37 Chinese Cities
Using 7 Models

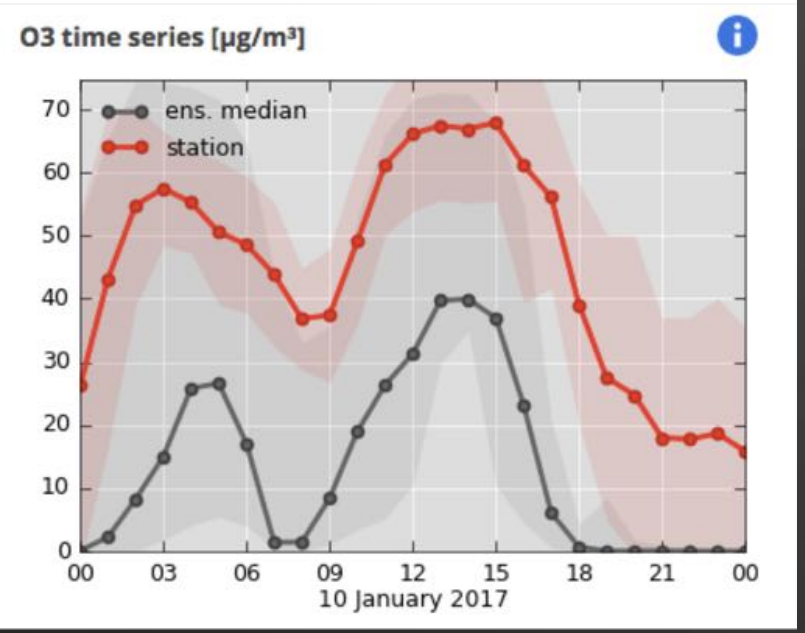
Median of 7 Predictive Models (black). Observation (red)
Qingdao, Yellow See Coast 23 September 2016

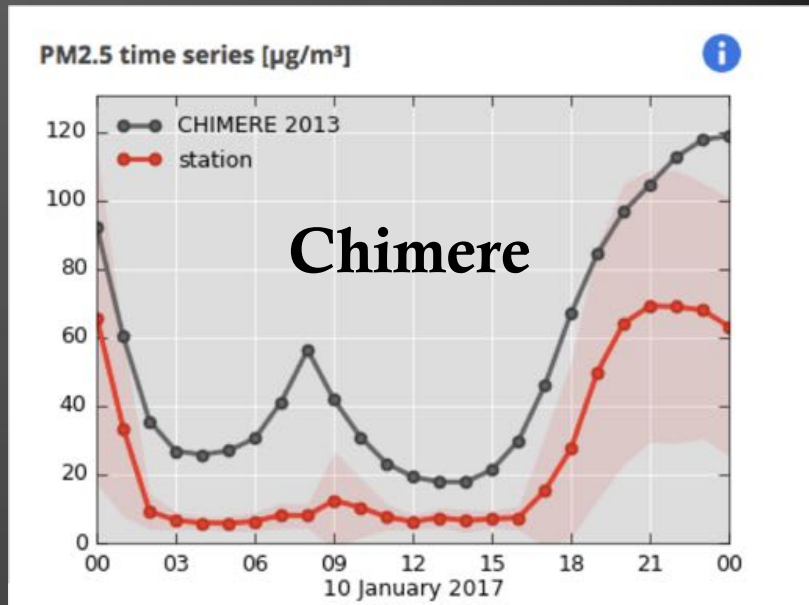


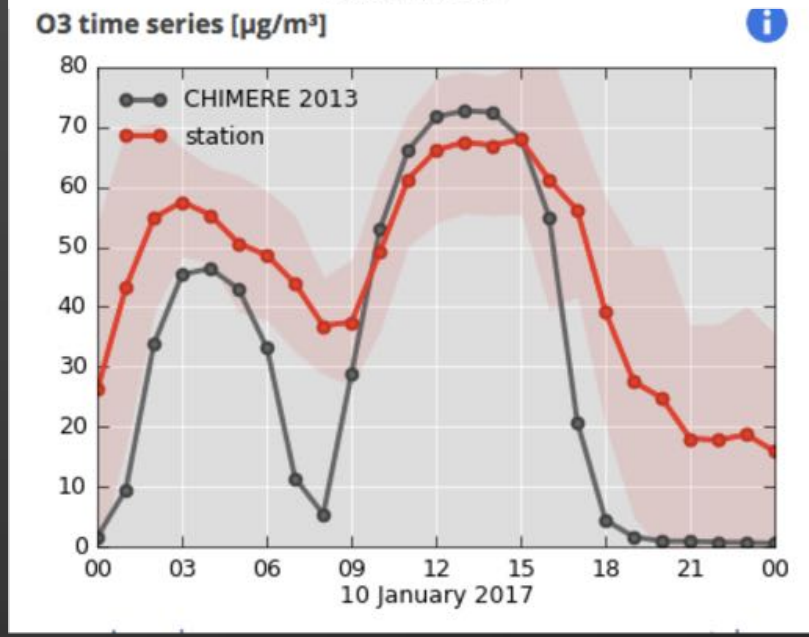

O3 time series [µg/m³]
ens. median
station
Ozone
7 December 2016
8 December 2016
9 December 2016
PM2.5 time series [µg/m³]
PM2.5
Shanghai
24h average of PM2.5
7 December 2016
8 December 2016
9 December 2016
PM2.5
SHANGHAI
SUZHOU
SONGLING
JIAXING
HUILONG
XIASHI
Leaflet | © OpenStreetMap contributors, © CartoDB
[µg/m³]
0 25 50 75 100 125 150

10 January 2017 Beijing





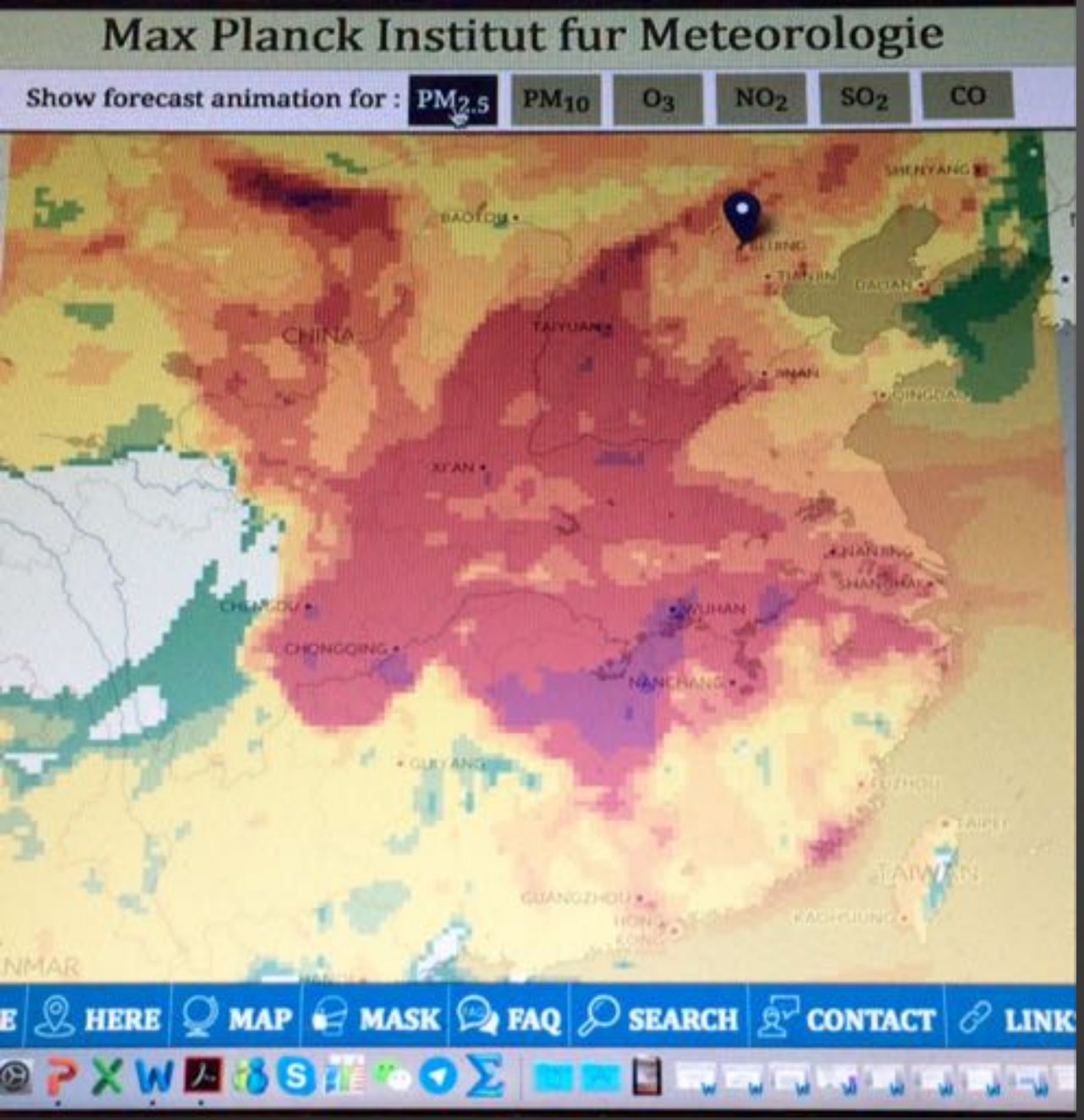




4.
Air Quality Forecasts

Dissemination
The Role of Local Start-Ups

Air Pollution in China
19 December 2016



Chemical Weather Forecast

Forecast for the period 27 October 2016 at 0.00 h to 29 October at 24:00

aqicn.org - world air quality

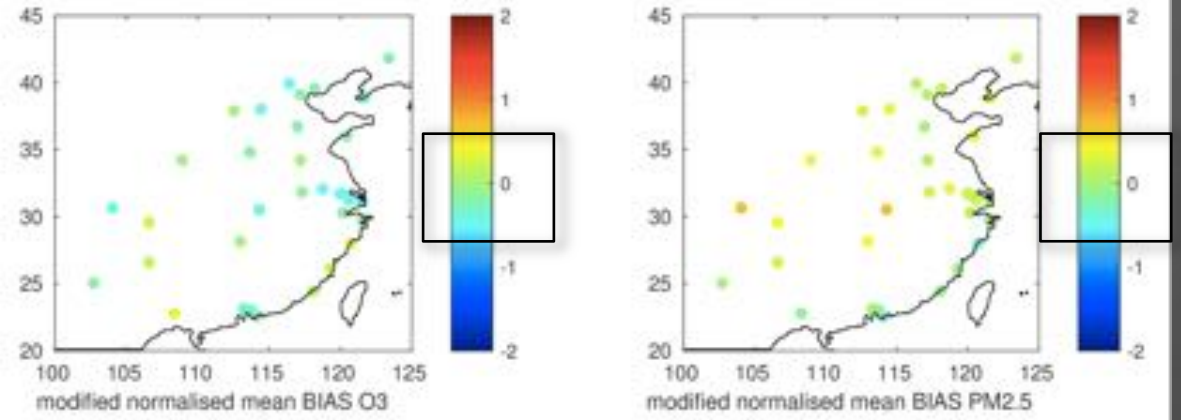
4.
Air Quality Forecasts

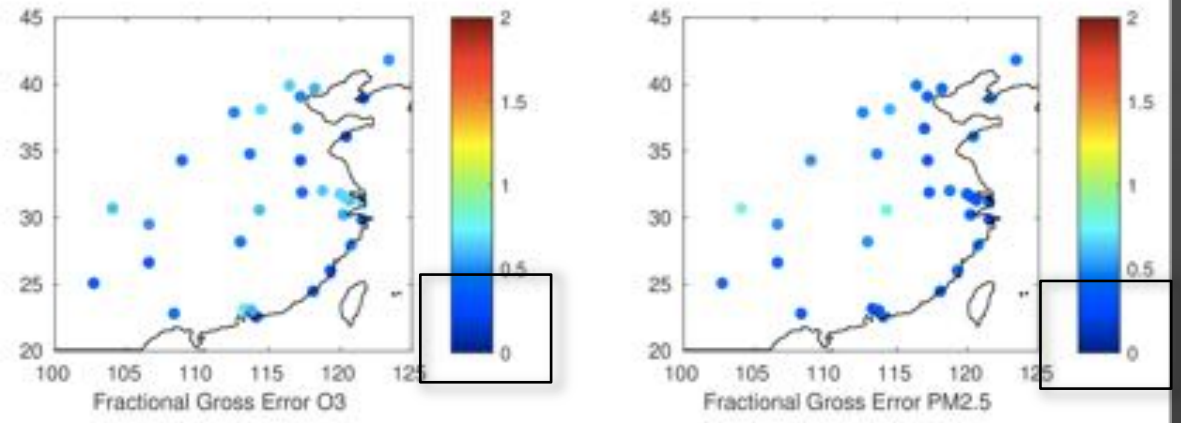
Evaluation of the Forecasts

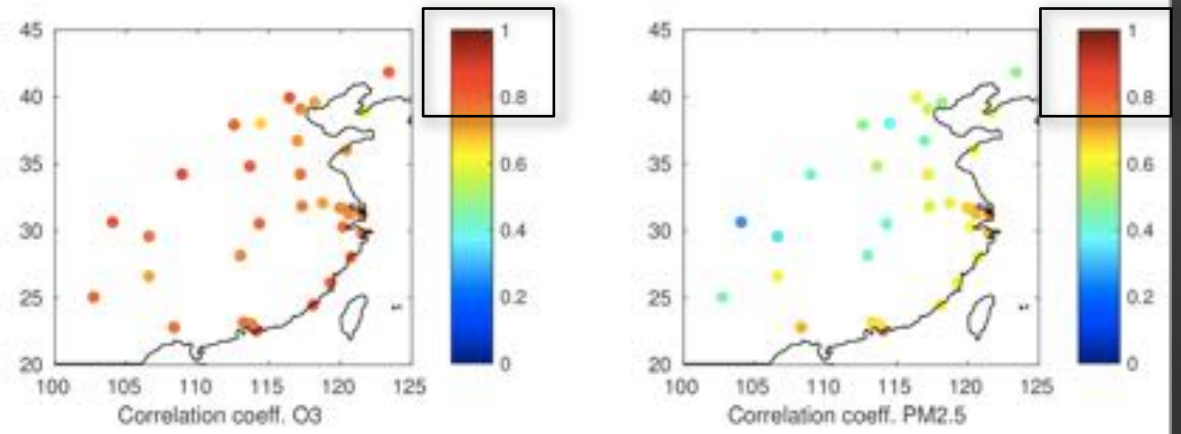
Ozone

Ensemble Median
1.April to 15.October 2016

PM2.5







Bias, Fractional Gross Error and Correlation coefficient (Ensemble Median) April to October 2016

$$MNMB = \frac{2}{N}\sum_{i=1}^{N}\frac{M_i - O_i}{M_i + O_i}$$

$$FGE = \frac{2}{N}\sum_{i=1}^{N}\left|\frac{M_i - O_i}{M_i + O_i}\right|$$

$$r = \frac{\sum_{i=1}^{N}\left(M_i - \bar{M}\right)\left(O_i - \bar{O}\right)}{\left[\sum_{i=1}^{N}\left(M_i - \bar{M}\right)^2\right]^{1/2}\left[\sum_{i=1}^{N}\left(O_i - \bar{O}\right)^2\right]^{1/2}}$$

Improvement of the forecasts

Outlook

- MAP-AQ is not a project. It is an umbrella under which several projects could develop in different parts of the world.
- We are currently establishing a rather broad MAP-AQ Implementation Group with representatives from all continents and different disciplines (research and service) to guide the development of the Programme
- We will also constitute a small Executive Board
- In addition to the existing White Paper, a paper presenting the objectives of MAP-AQ will soon be submitted to an international journal (Nature)
- MAP-AQ is an open structure. Everyone is invited to contribute.
- We now need to find ways to consolidate the initiative

Thank You