A Multi-model Operational Air Pollution Forecast System for China

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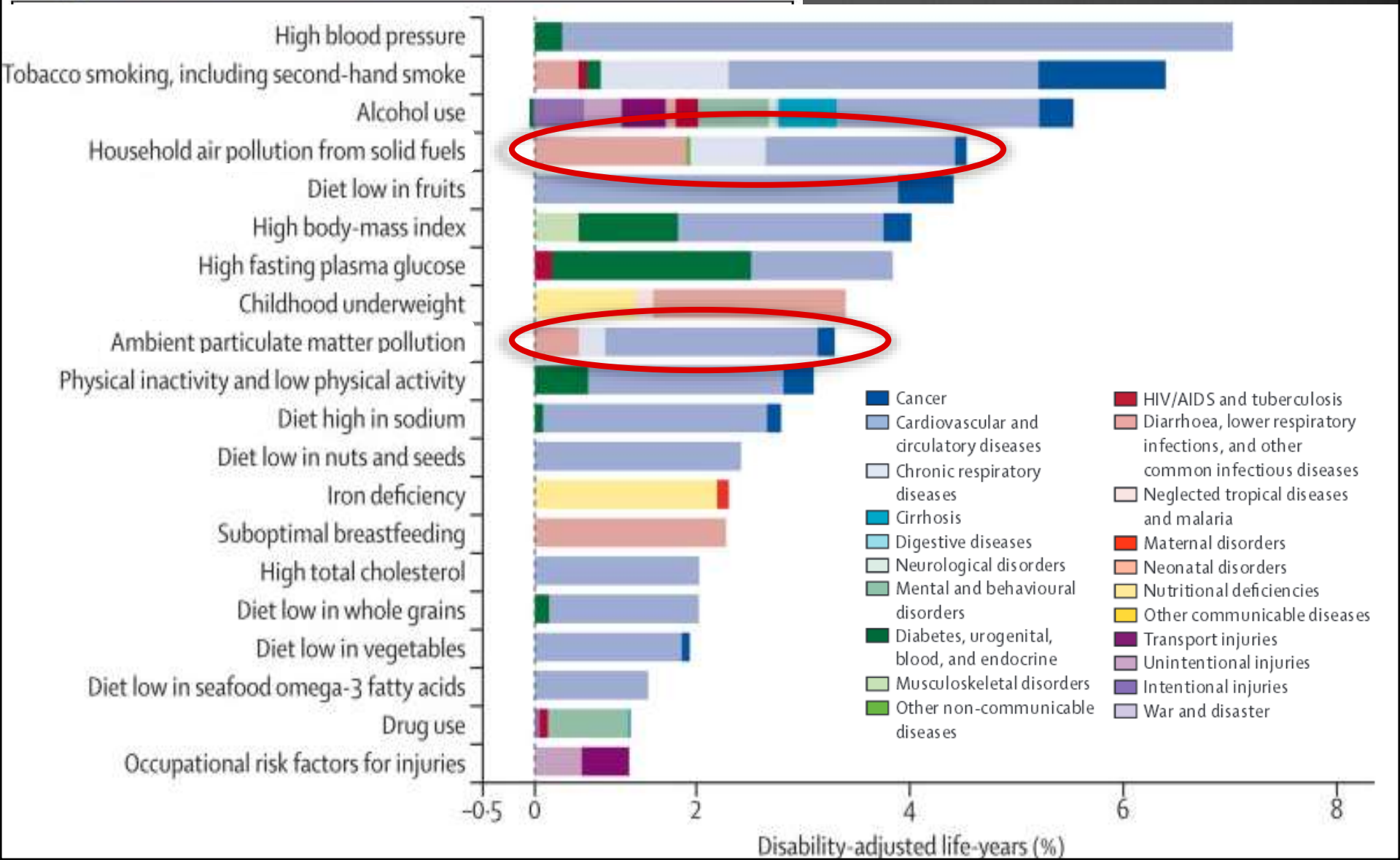
1.
Introduction

Economic growth has not been without environmental consequences

Health Burdon of Global Air Pollution is Enormous

(7+ million premature deaths due to air pollution per year !!)



How to address the Problem

1. Long-Term Action: Mitigation

→ Reduction in emissions, transformation of the economy and of change in the way of Life.

2. Short-term Action: Avoiding acute air pollution episodes

→ The need of air quality forecasts

3. Adaptation: Changing people's routine

→ The need for high resolution (individual) forecasts

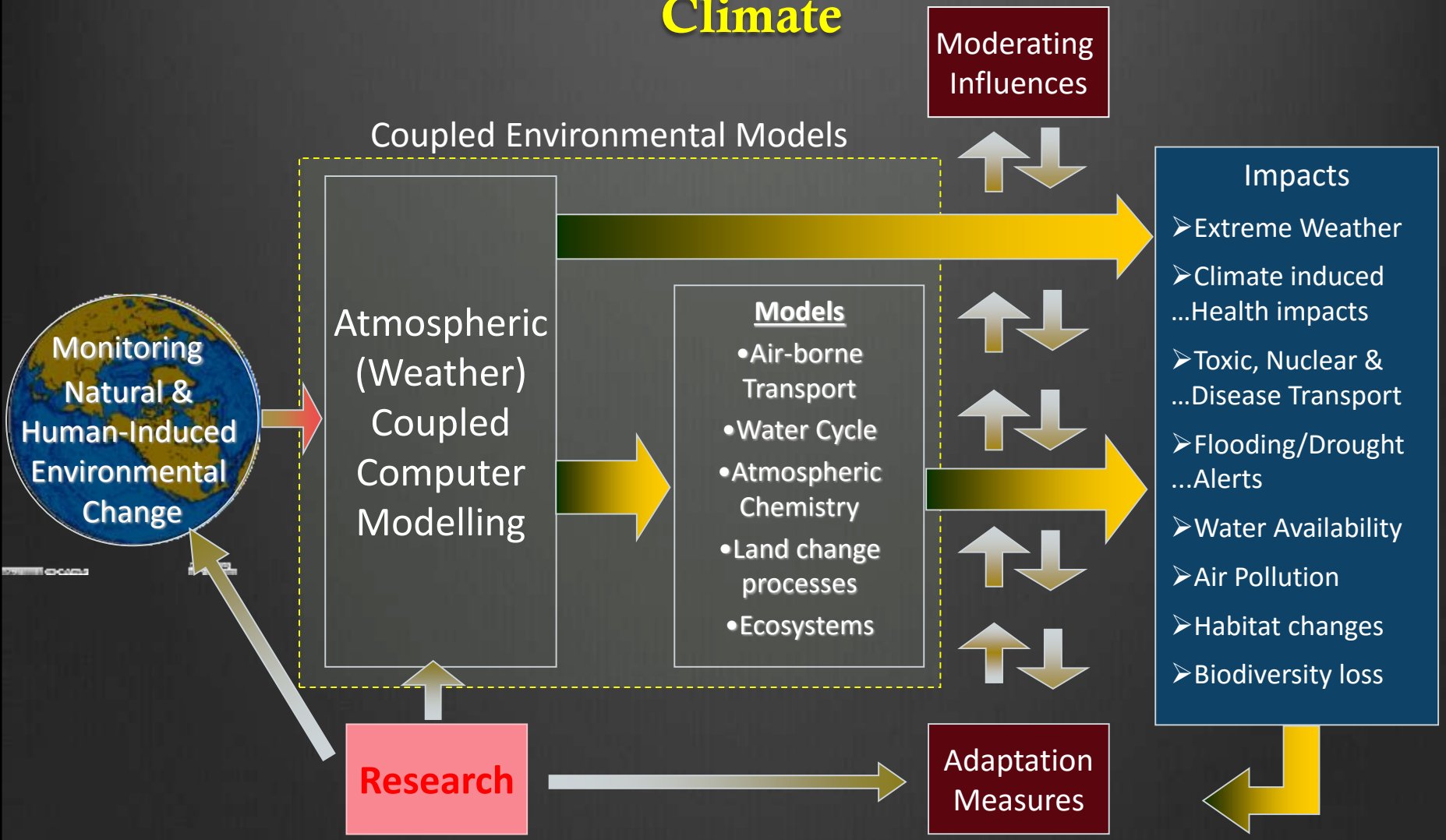
2.
Avoiding Severe Air Pollution Episodes

From "Meteorological Weather" to "Chemical Weather" Environmental Forecasts

Chemical Weather forecasts are 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

Overarching Research Need: Improve Prediction Capabilities via Incorporating/Integrating Composition, Weather and Climate



Across Relevant Temporal and Spatial Scales

From Greg Carmichael

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)

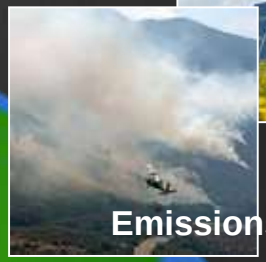
3.
Global Air Quality Forecasts (CAMS)

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



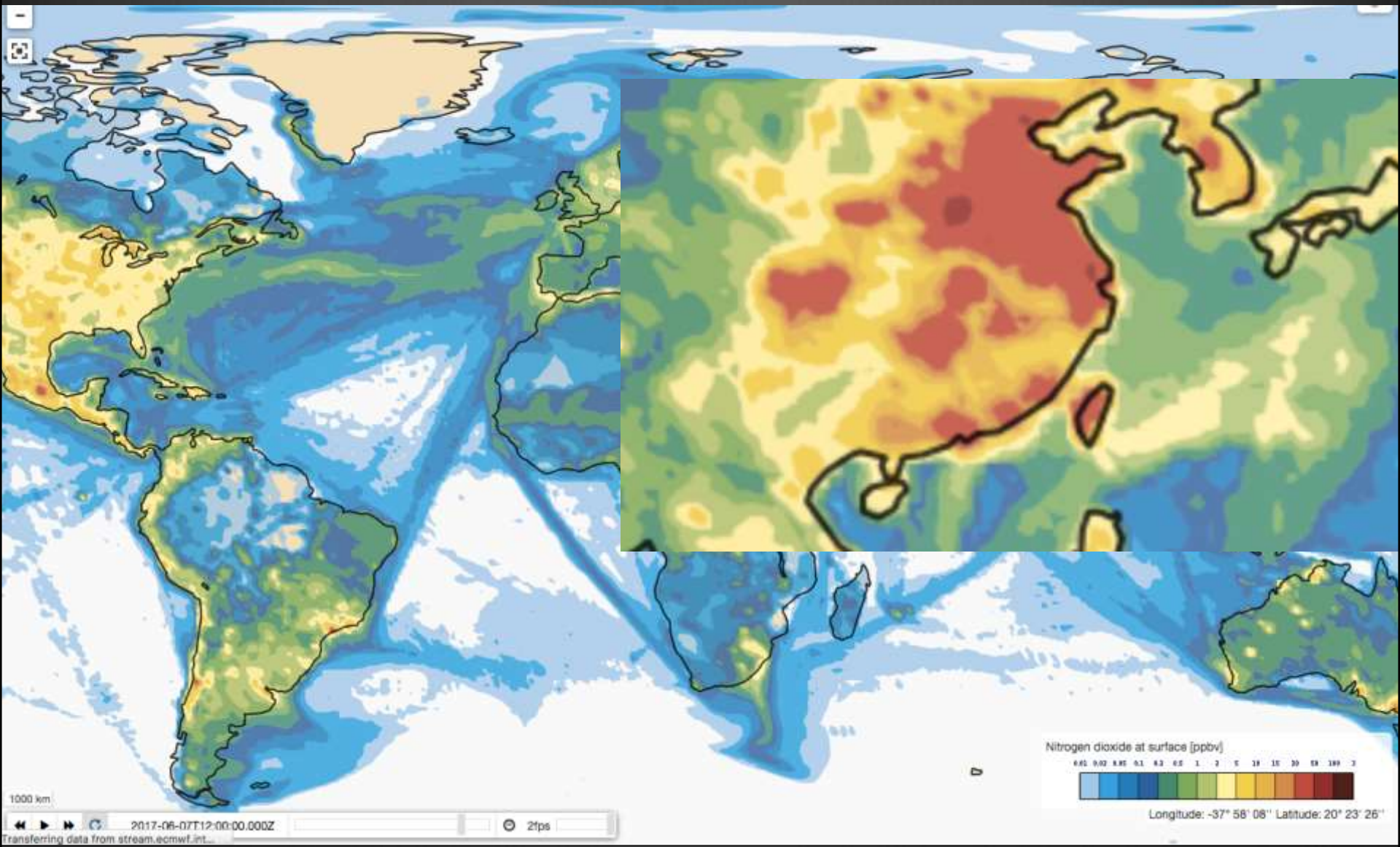
CAMS in three figures

280 million observations processed every 12 hours

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

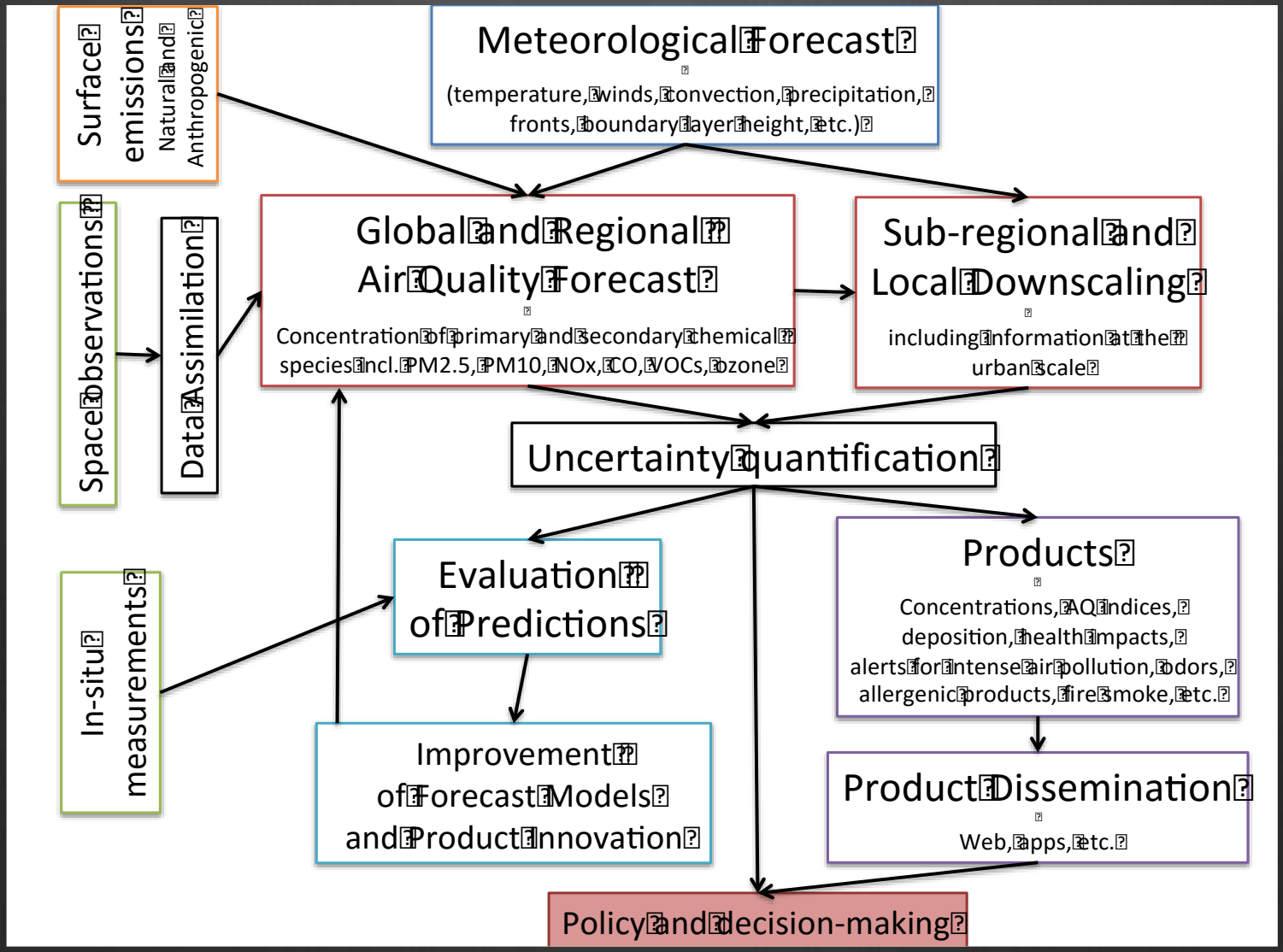
Delivers **everyday 14,000 maps** online

Forecast for NO_2 for 6 June 2017



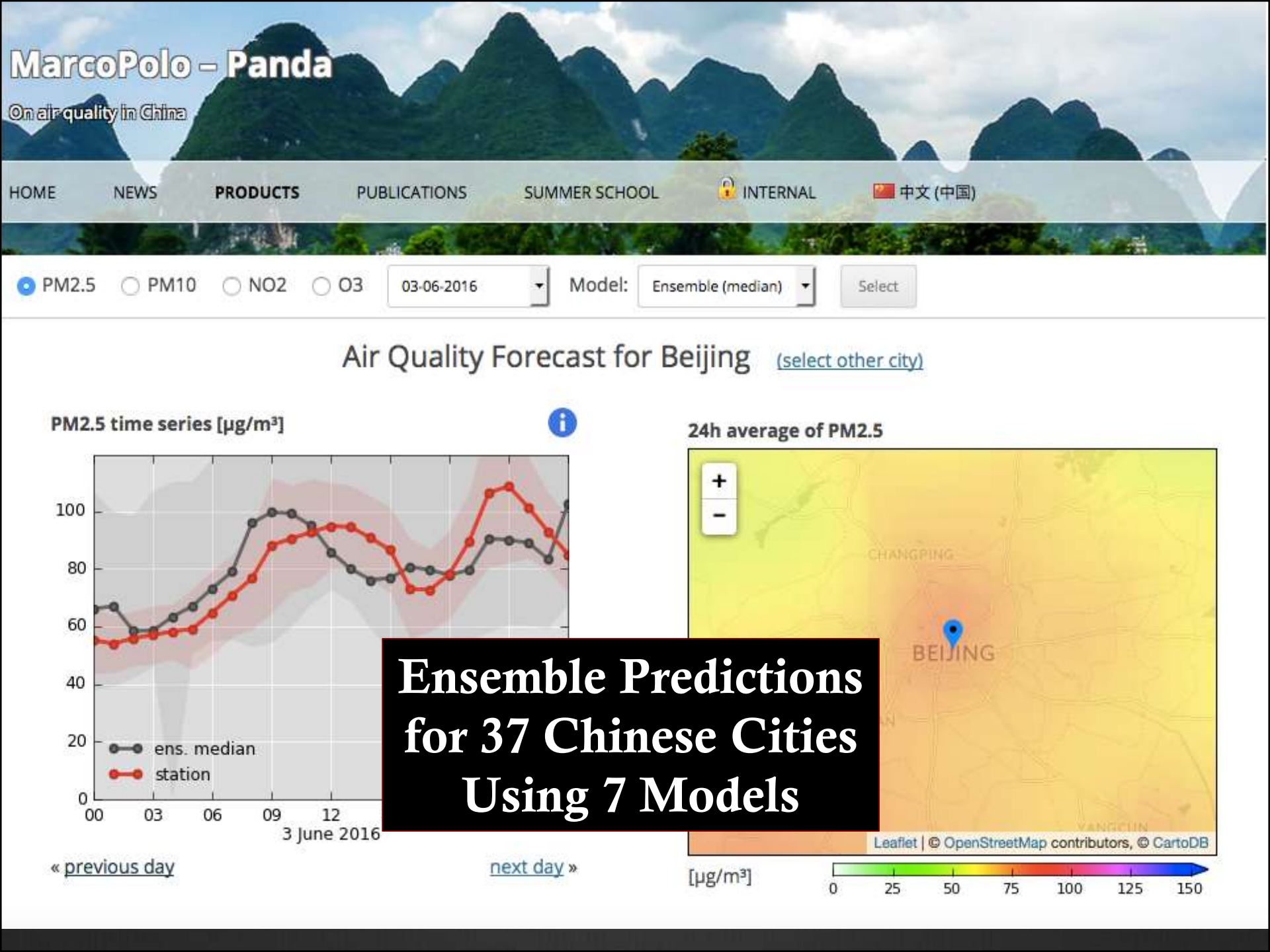
4.
Downscaling to Regional Level

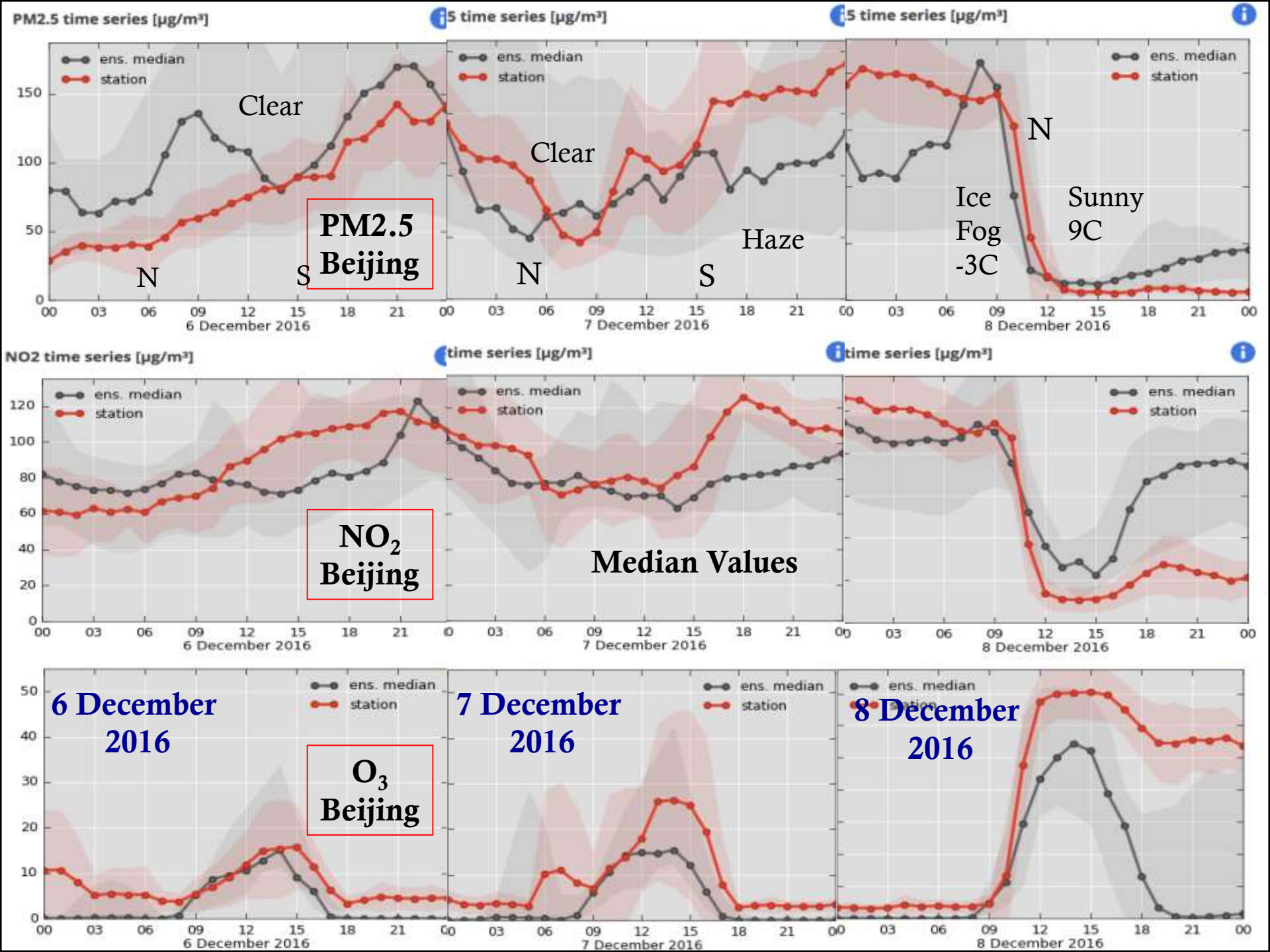
Towards a Mosaic of Regional AQ Analysis and Forecast Systems



An Ensemble Forecast involving 8 Models (Europe and in China)

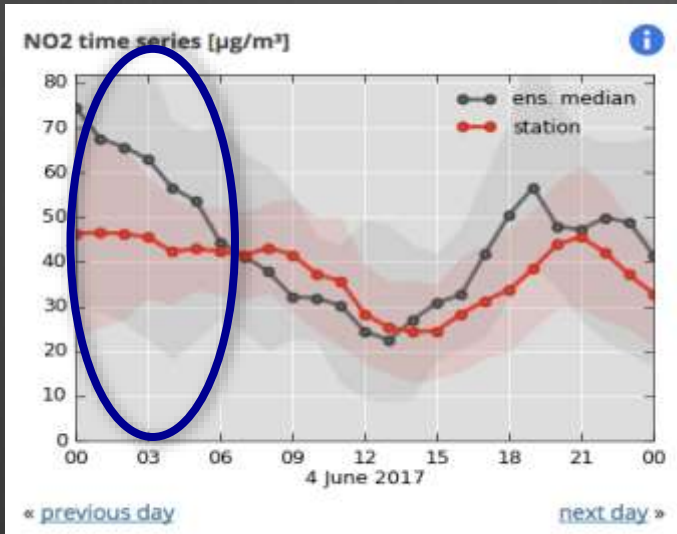
- **IFS** ECMWF/Copernicus
- **CHIMERE 2013** KNMI, The Netherlands
- **WRF-Chem-SCUEM** Shanghai Meteorological Service, China
- **WRF-Chem-MPI** Max Planck Institute for Meteorology, Germany
- **WRF-Chem NJU** Nanjing University, China
- **SILAM** Finnish Meteorological Institute, Finland
- **EMEP** Met-Norway, Norway
- **LOTOS-EUROS** TNO, The Netherlands

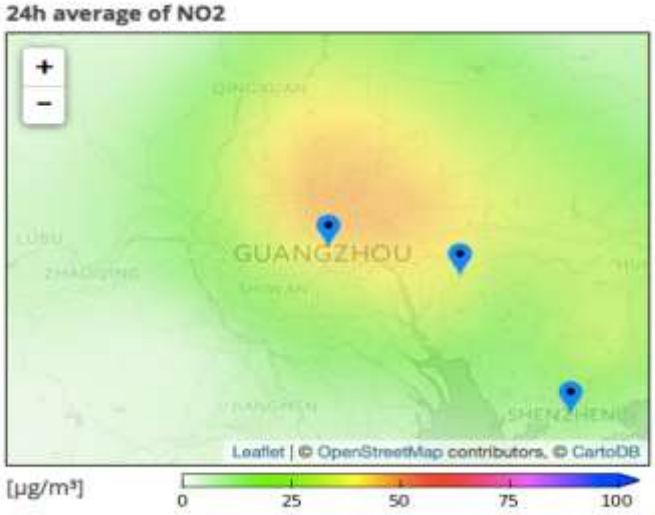

MarcoPolo – Panda
On air quality in China
HOME
NEWS
PRODUCTS
PUBLICATIONS
SUMMER SCHOOL
INTERNAL
中文 (中国)
PM2.5
PM10
NO2
O3
03-06-2016
Model:
Ensemble (median)
Select
Air Quality Forecast for Beijing
(select other city)
PM2.5 time series [µg/m³]
100
80
60
40
20
0
ens. median
station
00
03
06
09
12
3 June 2016
« previous day
next day »
24h average of PM2.5
CHANGPING
BEIJING
Leaflet | © OpenStreetMap contributors, © CartoDB
[µg/m³]
0
25
50
75
100
125
150
Ensemble Predictions
for 37 Chinese Cities
Using 7 Models


PM2.5 time series [µg/m³]
ens. median
station
Clear
N
S
PM2.5
Beijing
6 December 2016
Clear
Haze
7 December 2016
N
Ice
Fog
-3C
Sunny
9C
8 December 2016
NO2 time series [µg/m³]
NO2
Beijing
Median Values
6 December 2016
7 December 2016
8 December 2016
O3
Beijing

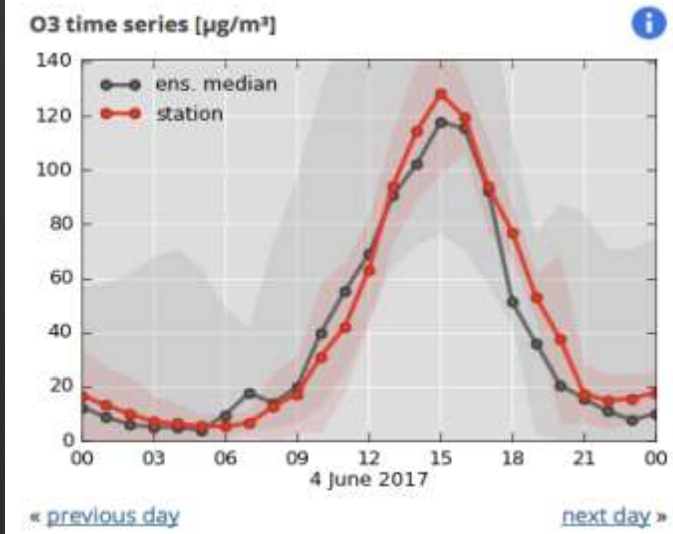
Median NO_2 and O_3
Guangzhou 4 June 2017

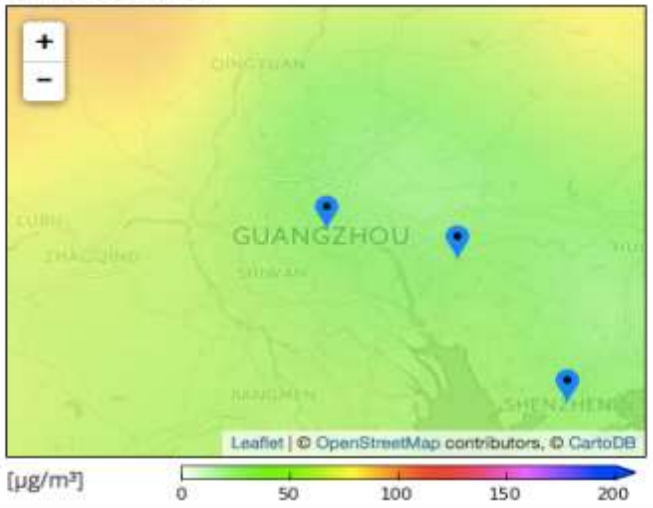
NO_2

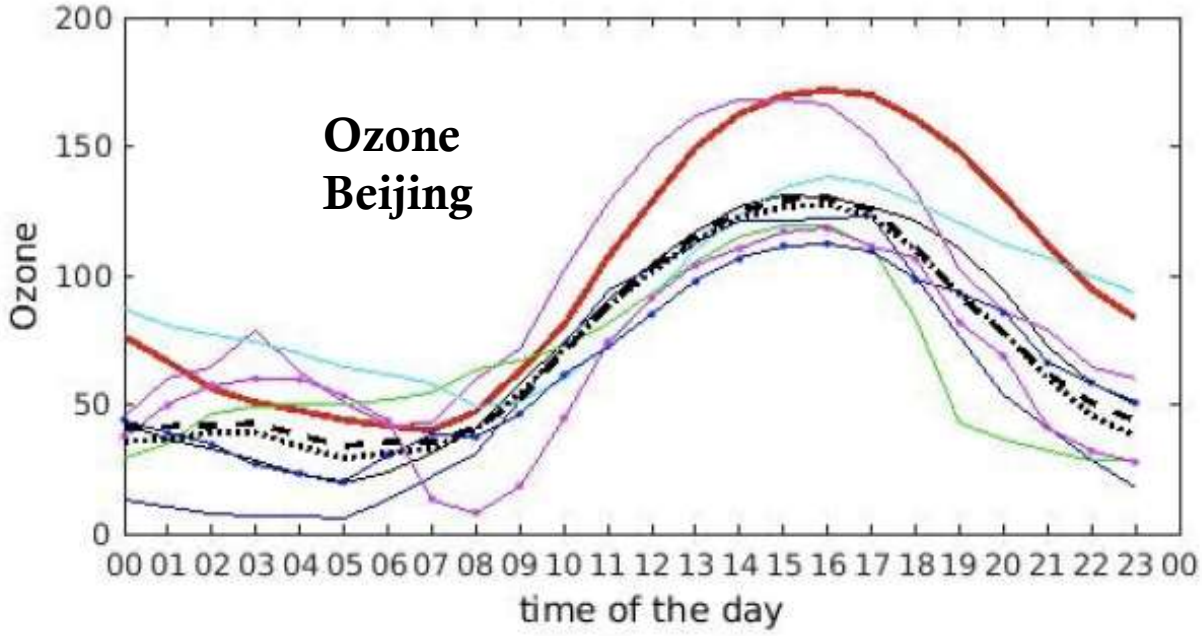


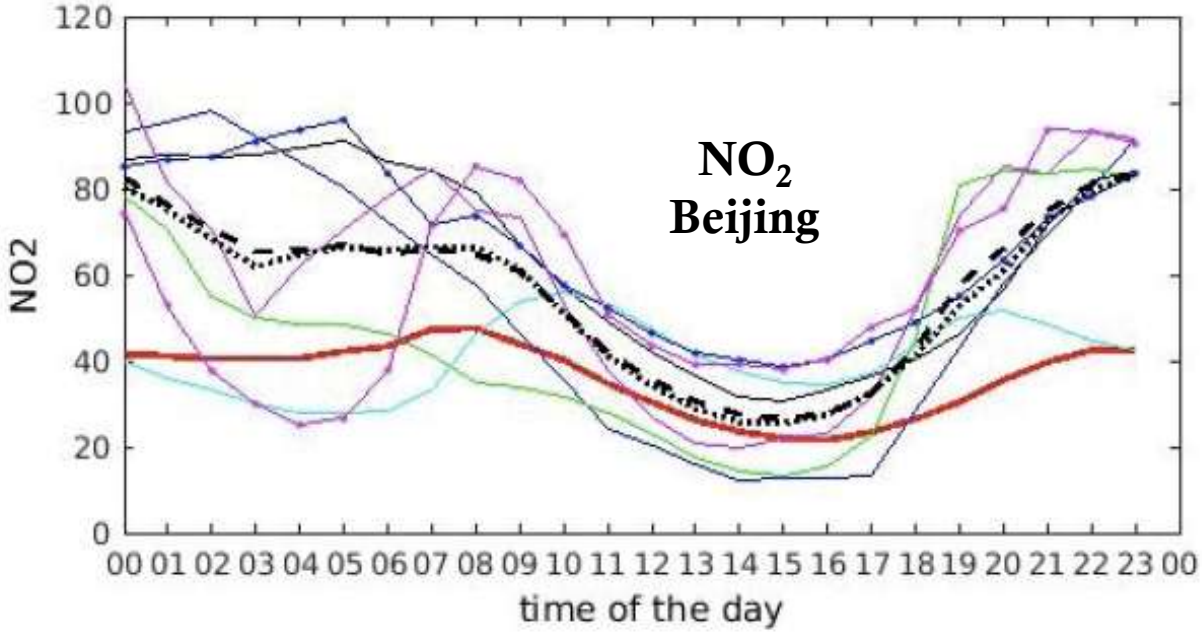


O_3

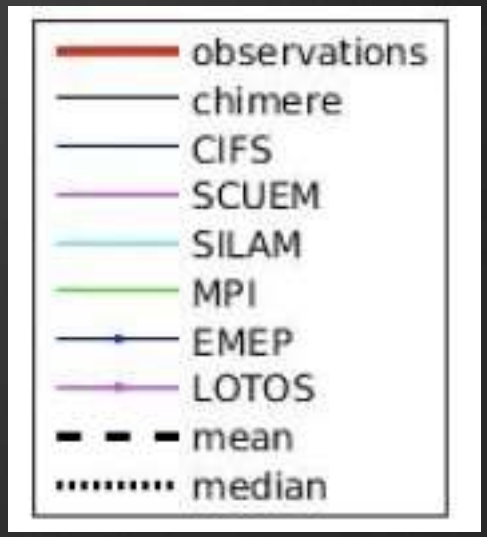






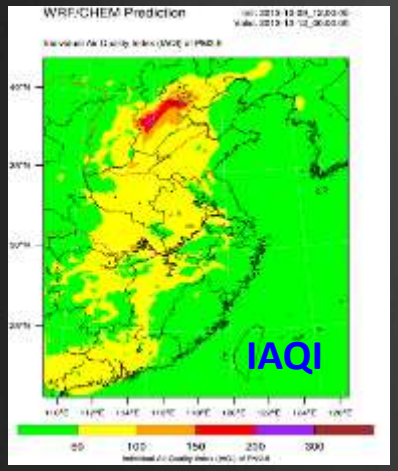


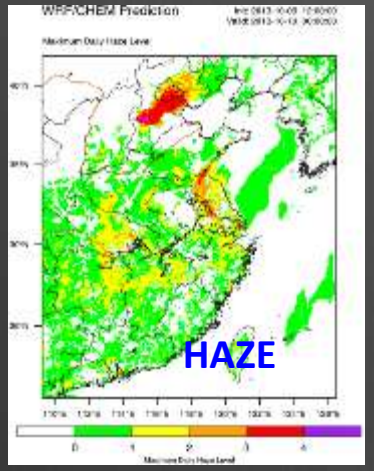
Comparison of the mean diurnal mean (April to July 2016) of the ozone and NO_2 concentration calculated by 7 models with the mean observation of the diurnal variation in **Beijing**

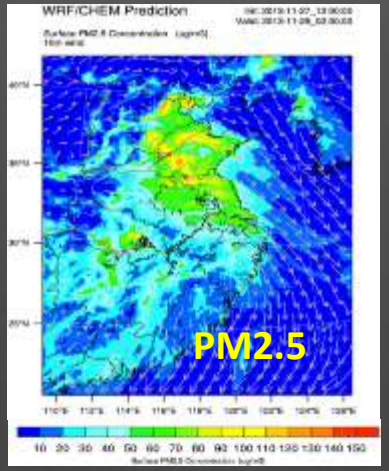


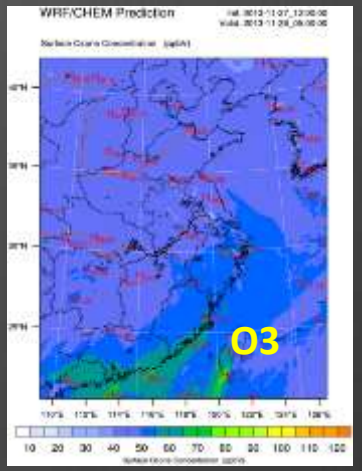
Forecasting Products by the SMS, China

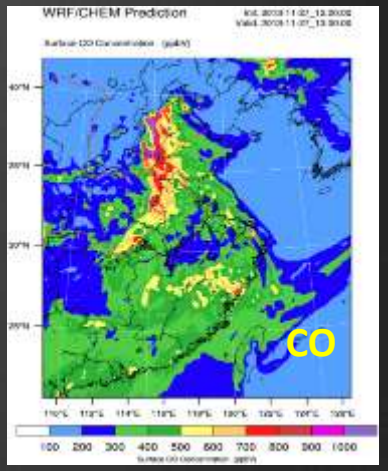
http://222.66.83.21:8086

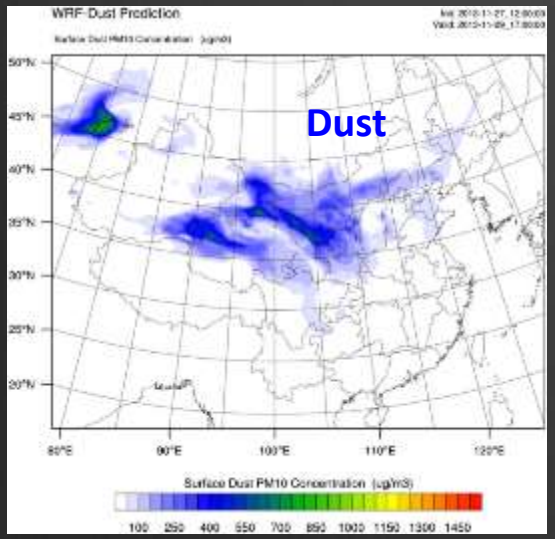


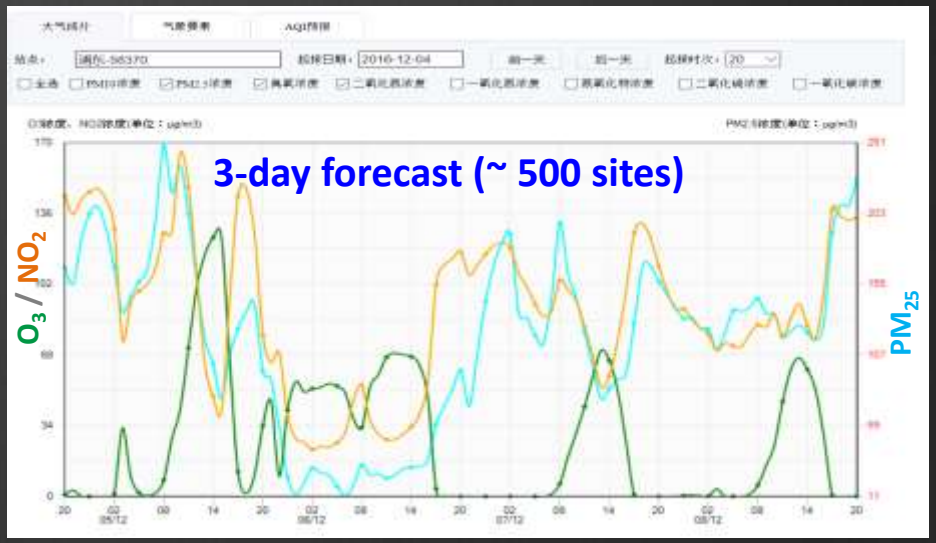








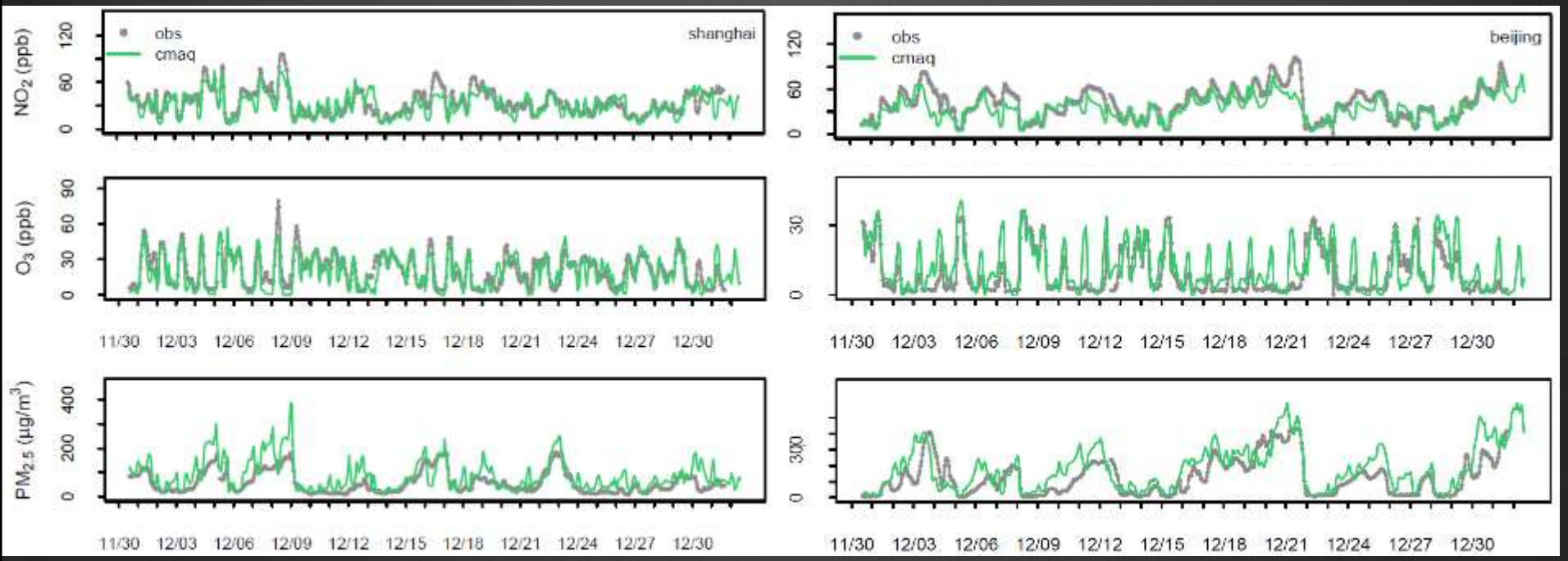




SMS Shanghai

Monthly results for Shanghai and Beijing by SMS, China

(December 2016)



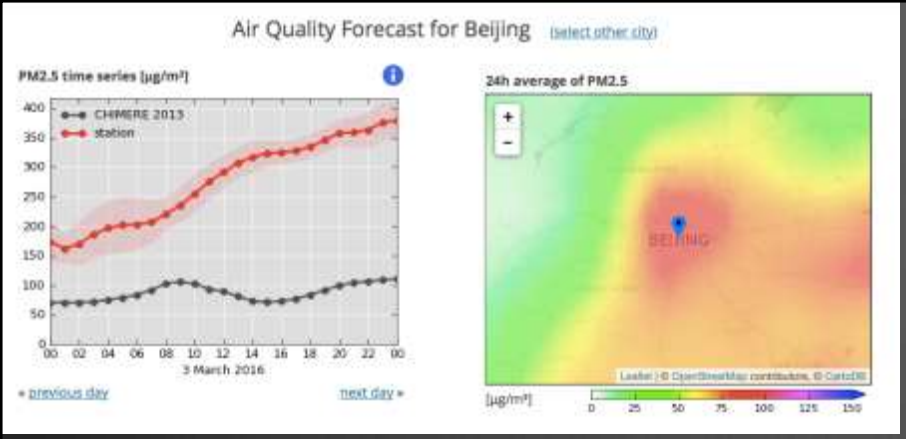
Shanghai

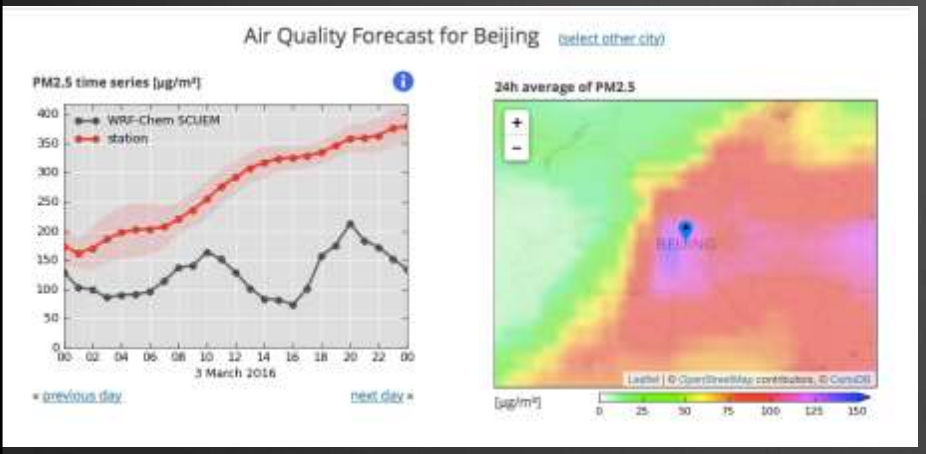
Beijing

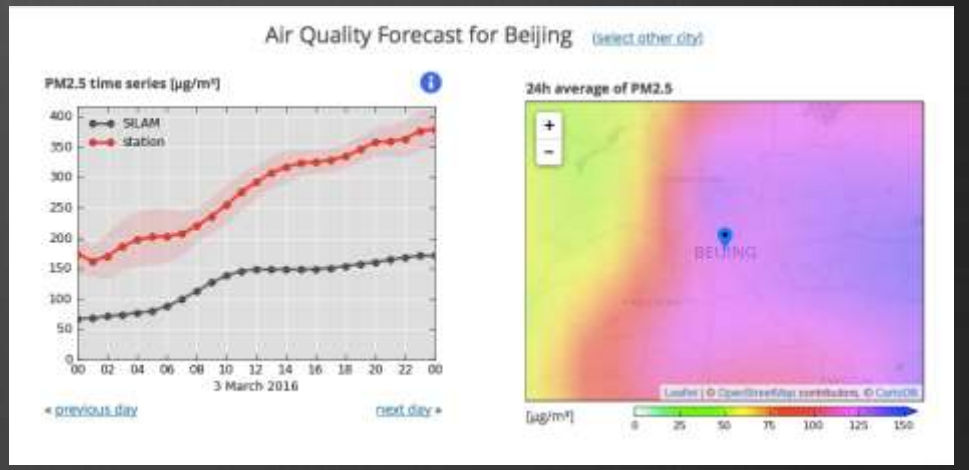
Ying Xie, SMS Shanghai

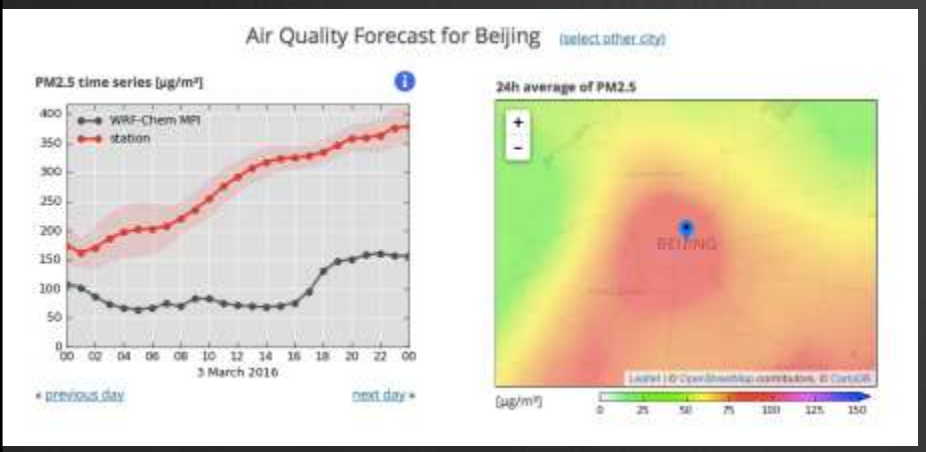
PM2.5
Beijing

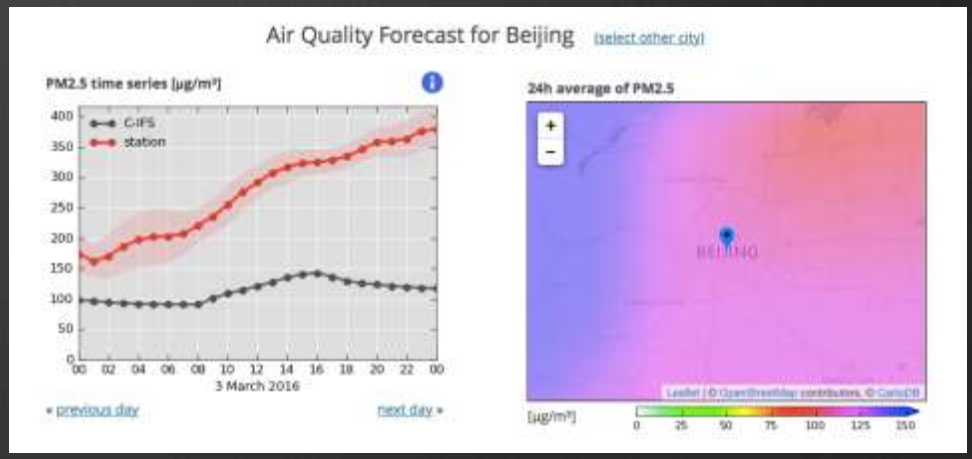
3 March 2016











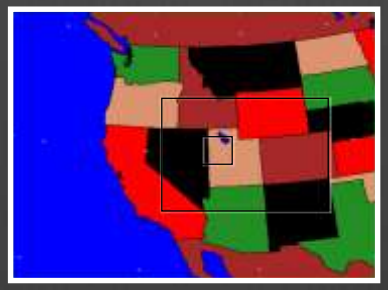
5.
Downscaling to urban and sub-urban levels

A Spectrum of Coupled Scales

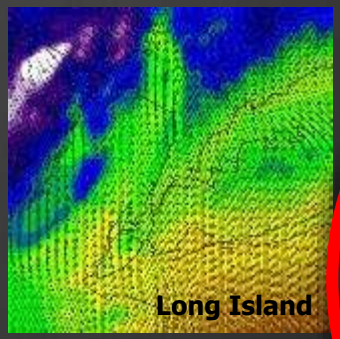
How do global and hemispheric patterns influence regional and local events?

Global Scales

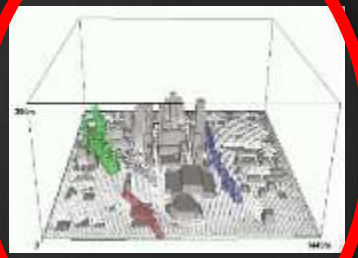
Continental Scales



Regional Scales



Local Scales



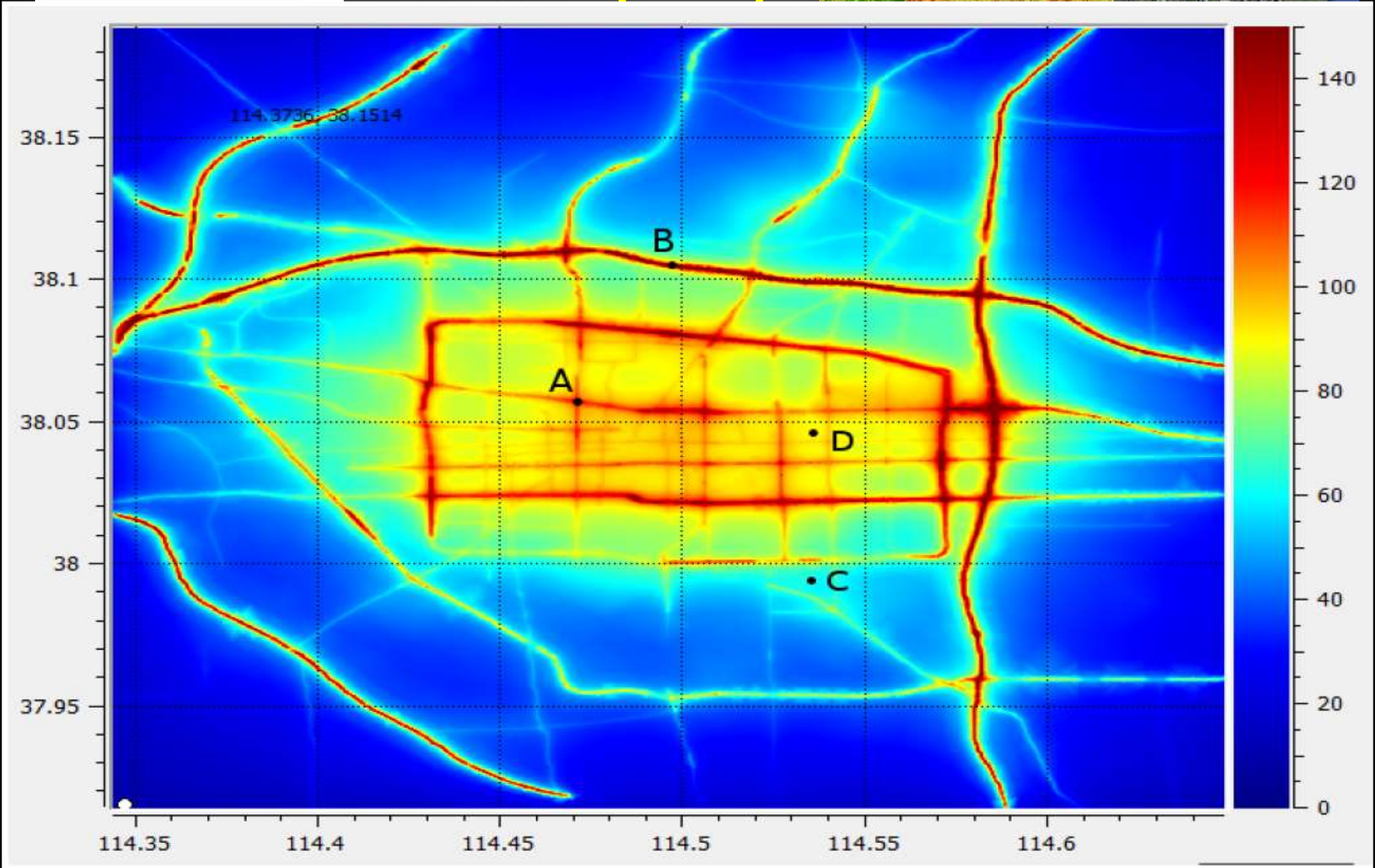
Urban Scales

Influences of local pollution sources on the regional and global scales

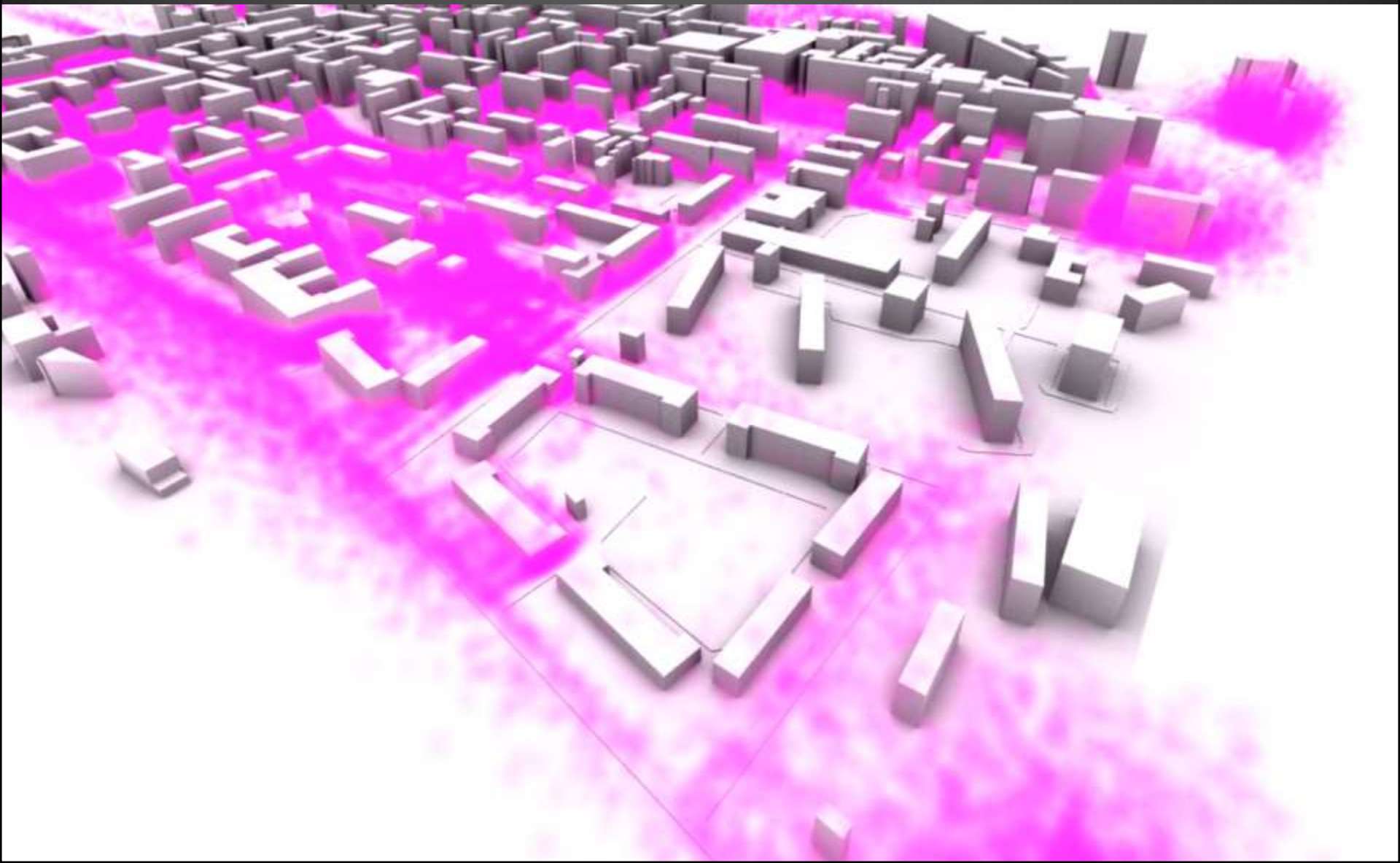
From Xuemei Wang

MEIC inventory

Downscaling Emissions (VITO)

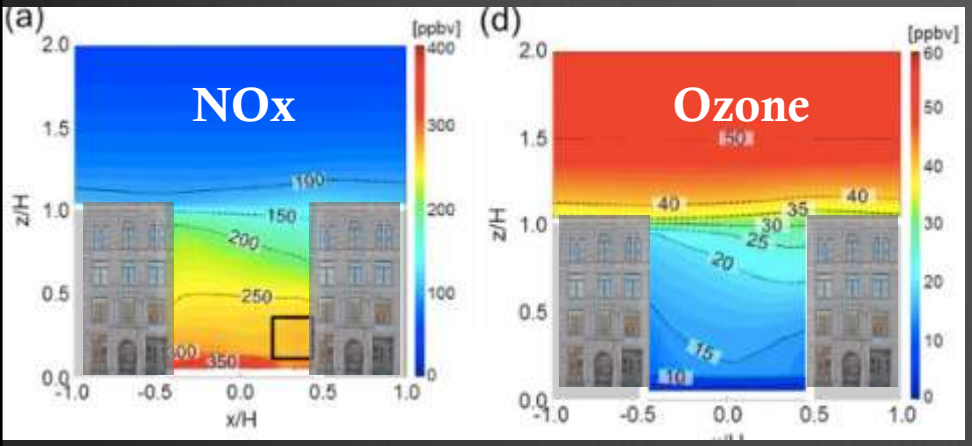


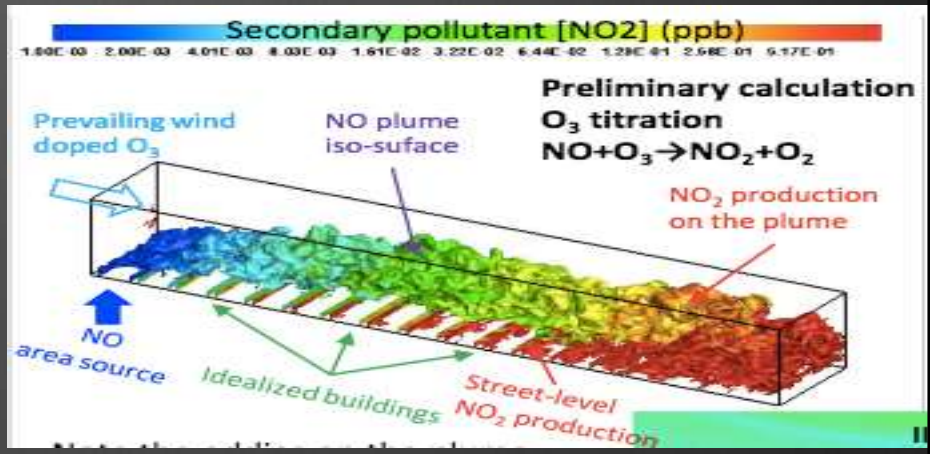
Downscaling to the City Block
Accounting for the Turbulent Flow



Downscaling Chemical Concentrations to sub-urban Scales

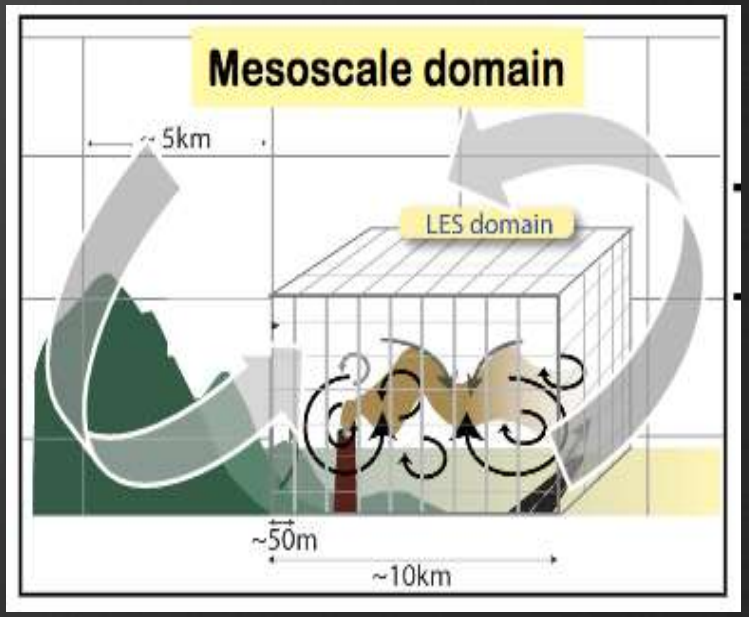
Large Eddy Simulations

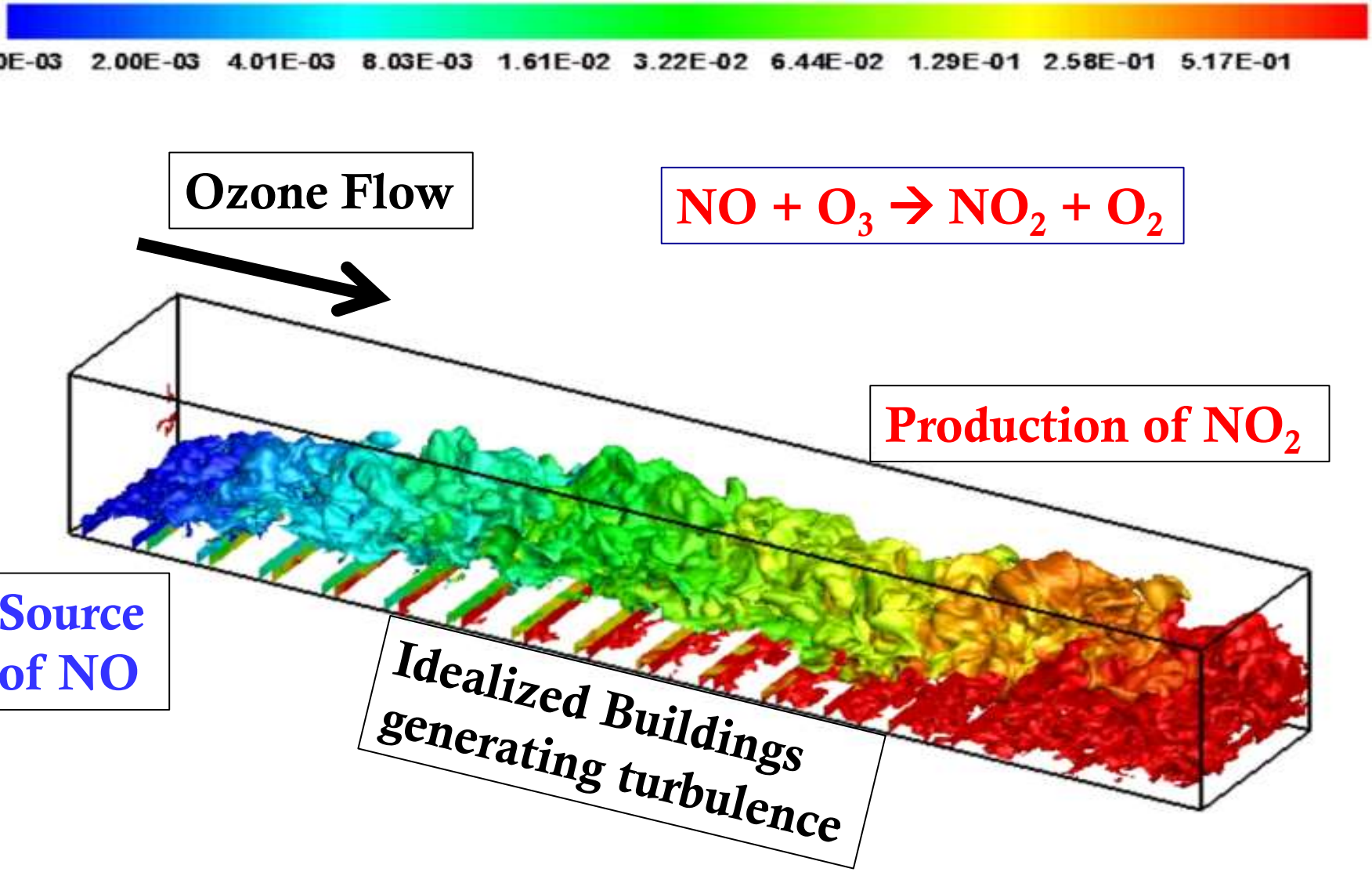




Locally emitted pollutants (e.g., NOx, VOCs) in street canyons interact chemically with background atmospheric species (e.g., ozone). Reaction rates are affected by **turbulence** mechanically and thermally generated in the urban canopy

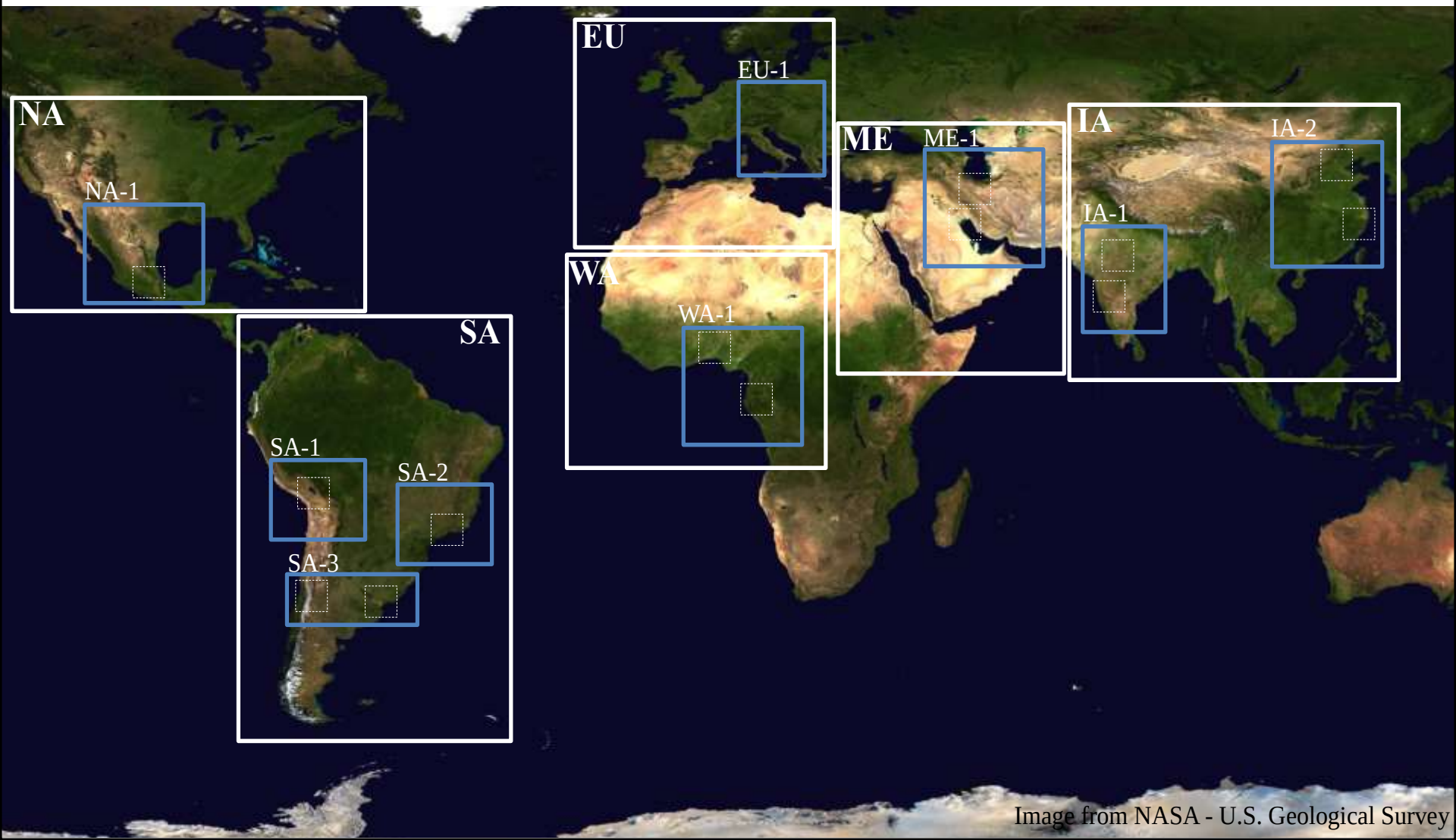
Large eddy simulation (LES) models coupled to regional mesoscale models (e.g., WRF) will be used to simulate the turbulent transport and chemical transformations of pollutants in the urban environment.




1.00E-03 2.00E-03 4.01E-03 8.03E-03 1.61E-02 3.22E-02 6.44E-02 1.29E-01 2.58E-01 5.17E-01
Ozone Flow
NO + O3 → NO2 + O2
Production of NO2
Source of NO
Idealized Buildings generating turbulence
Model of Chun-Ho Liu
Hong Kong University

6.
Future Directions

A Mozaic of Regional Approaches: The MAP-AQ Initiative



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

Thank You