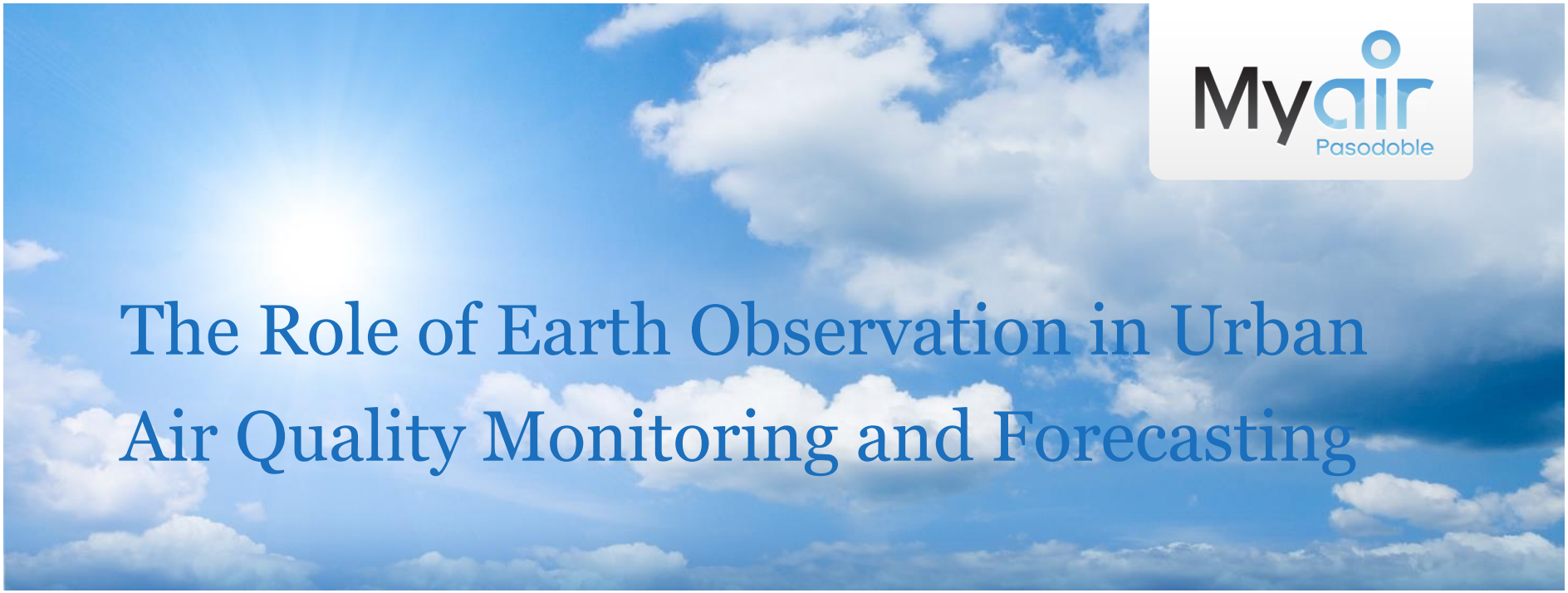

The Role of Earth Observation in Urban Air Quality Monitoring and Forecasting

Thilo Erbertseder*, D. Balis, C. Bergemann, L. Blyth, D. Carruthers, S. Choudrie, A. De Rudder, W. Di Nicolantonio, H. Elbern, H. Eskes, E. Friese, K. Ganev, T. Holzer-Popp, J. Kukkonen, O. Lesne, D. Melas, J. Meyer-Arnek, F. Prata, P. Sicard, N. Smeets, M. Sofiev, A. Stidworthy, R. Timmermans, N. Veldeman, H. Zelle and PASODOBLE consortium

*DLR Deutsches Zentrum für Luft- und Raumfahrt, thilo.erbertseder@dlr.de

Mediterranean City 2014

10-11 June 2014, Athens, Greece

Air pollution is a silent killer

- A large part of European citizens still lives in areas, mainly cities, with air pollution exceeding the levels defined by the European Directive (EEA, 2014).

- At current standards, healthcare costs associated with poor air quality are estimated to reach at least €189 billion/year by 2020 in Europe, EUROSTAT, 2012).

Sensitivity of Air Pollutants to Meteorological Variables

Variable	Ozone	Particulate Matter
Temperature	++	-
Stagnation	++	++
Wind speed	-	-
Mixing Depth	o	- -
Humidity	o	+
Cloud cover	-	-
Precipitiation	o	- -

Jacob and Winner, 2009

Climate Change, Air Pollution, Mediterranean Cities

Long term effects

- Various feedback mechanisms
- Less precipitation and higher temperature favor O3 and PM exceedances
- Increase in summertime ozone in urban areas by ~10 µg/m³ decade

Air pollution episodes

- Dust outbreaks and wildland fires will become more important PM sources, increasing natural contributions
- Heat waves linked with air pollution

→ EO can significantly contribute to monitor long term effects and air pollution episodes and minimize the error bars for radiative forcing estimates

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Copernicus AQ Downstream Project PASODOBLE

Development of 30 user-driven services for the regional and local air quality sector in Europe by combining EO data, in-situ data, numerical modelling and information technology for:

- Satellite-based compliance monitoring support
  for environmental agencies
- Forecasting and assessment support
  for agencies, authorities, citizens
- Health community support
  for people at risk, hospitals, pharmacies and doctors

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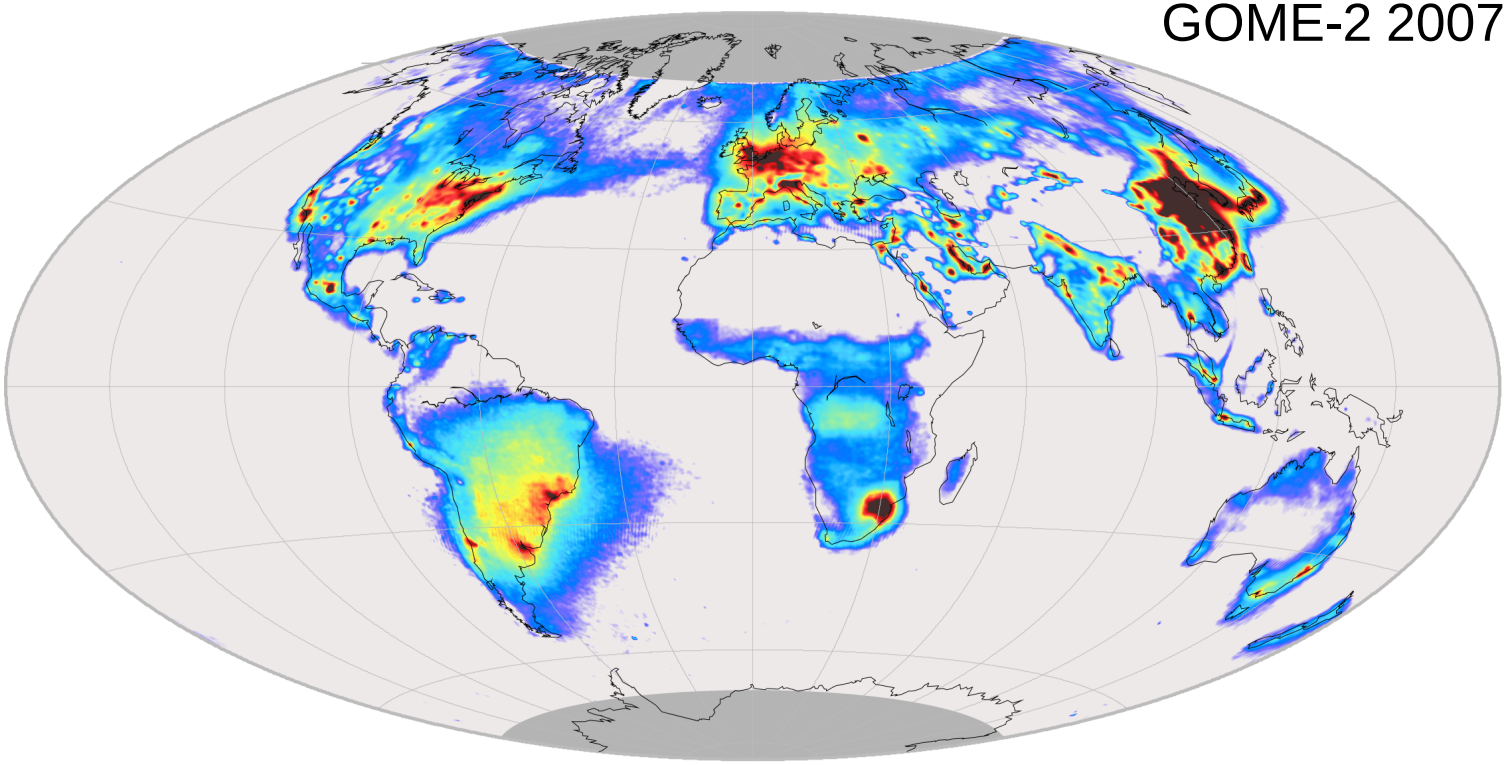
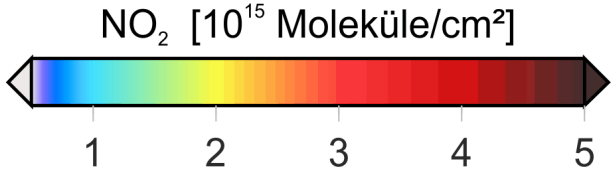
Tropospheric NO2 monitoring from space

GOME-2 2007-2013
Mean





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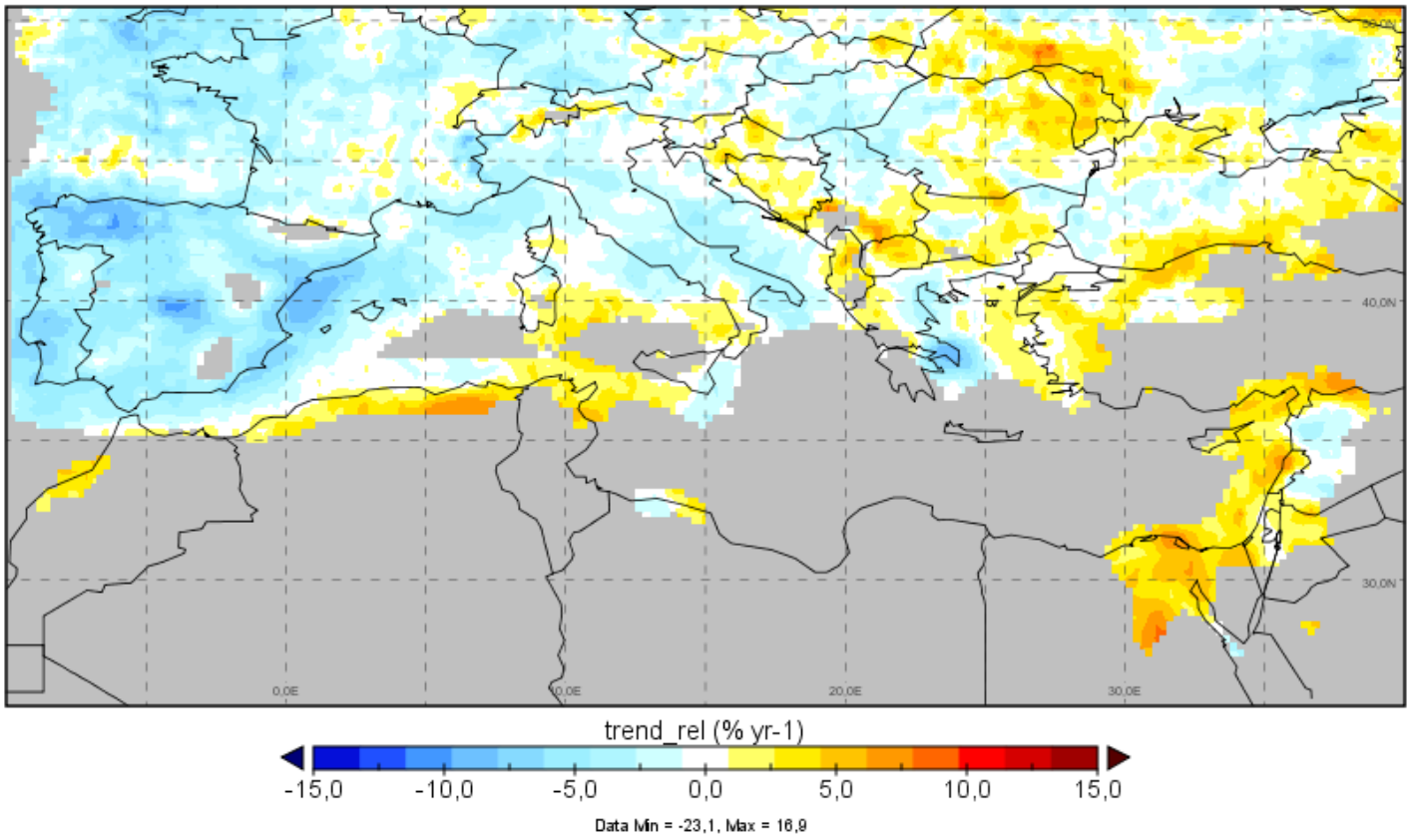
Tropospheric NO2 trends from space

Relative Trend in %/year

GOME-2 2007-2013



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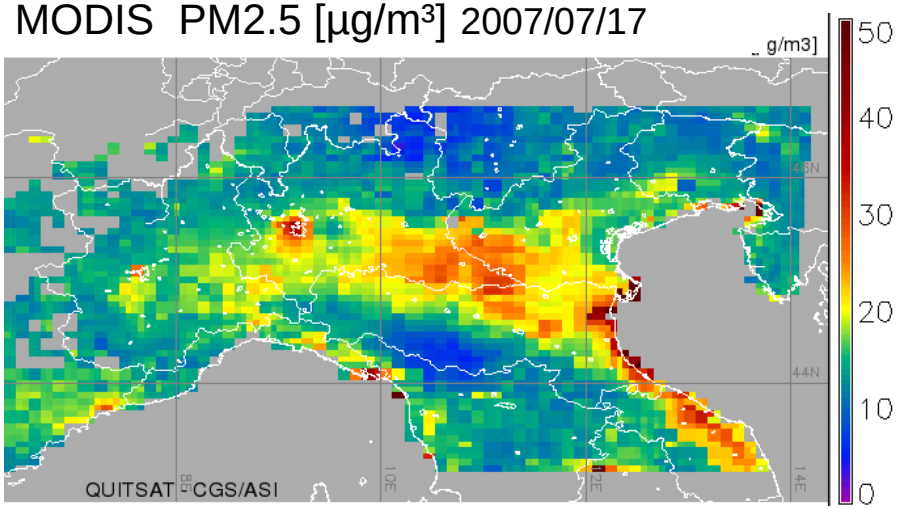
Urban Tropospheric NO2 Trends

City	Sensor	Period	Relative Trend [%/yr]
Athens	GOME-2	2007-2013	-8.36
	SCIA	2002-2012	-5.58
Thessaloniki	GOME-2	2007-2013	-2.16
	SCIA	2002-2012	-1.09

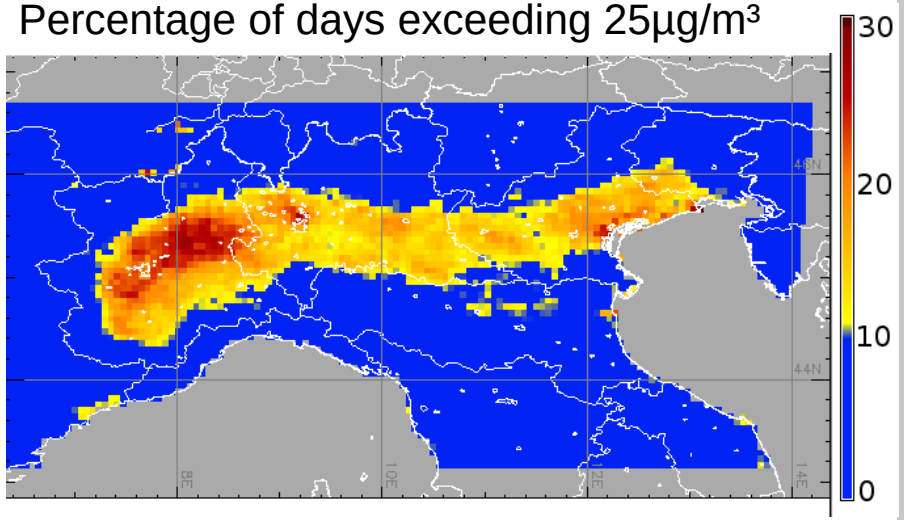
Satellite-based Compliance Monitoring of Partulate Matter

- Facilitate compliance reporting for environment agencies
- Establish satellite data complementary to in-situ data
- Help explain exceedances (local emissions/advected dust)

MODIS PM2.5 [µg/m³] 2007/07/17



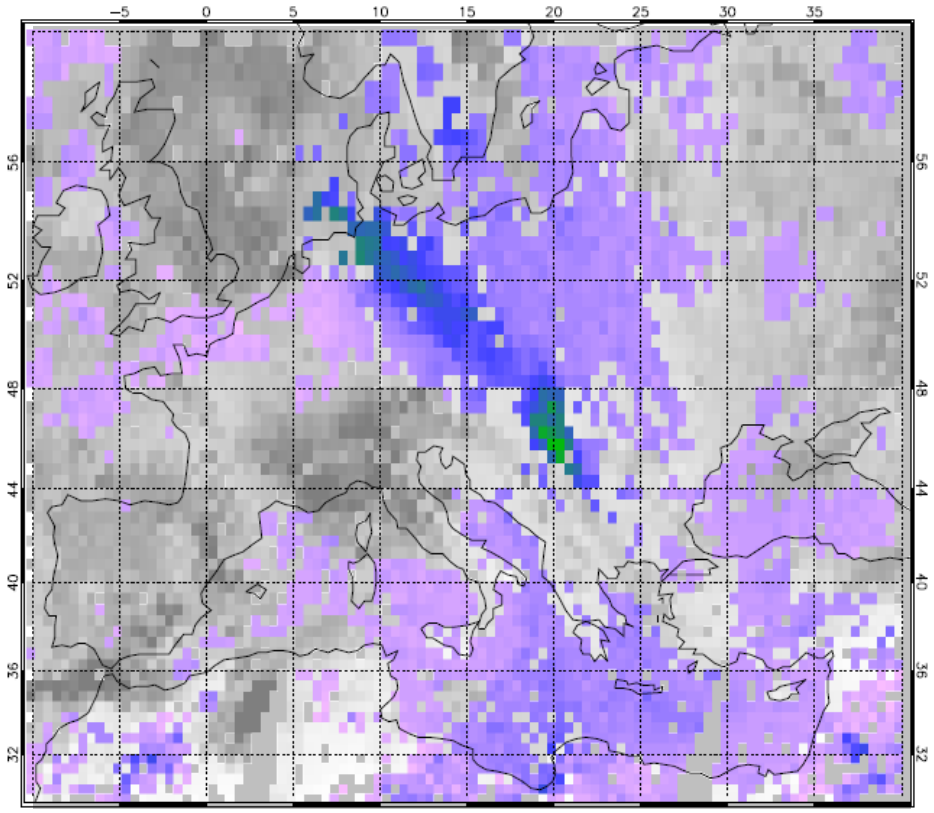
Percentage of days exceeding 25µg/m³



Bias Yearly Mean: PM10: 4µg/m³ PM2.5: 2.5µg/m³

Monitoring mineral dust outbreaks with IASI

helps explain exceedances in cities (local emissions/advected dust)



30 May 2008 MetOp/IASI
Horizontal Res 12km
Coverage twice daily

Comparison w/th AERONET
R=0.757
RMSD = 0.174
bias = +0.003
N = 190

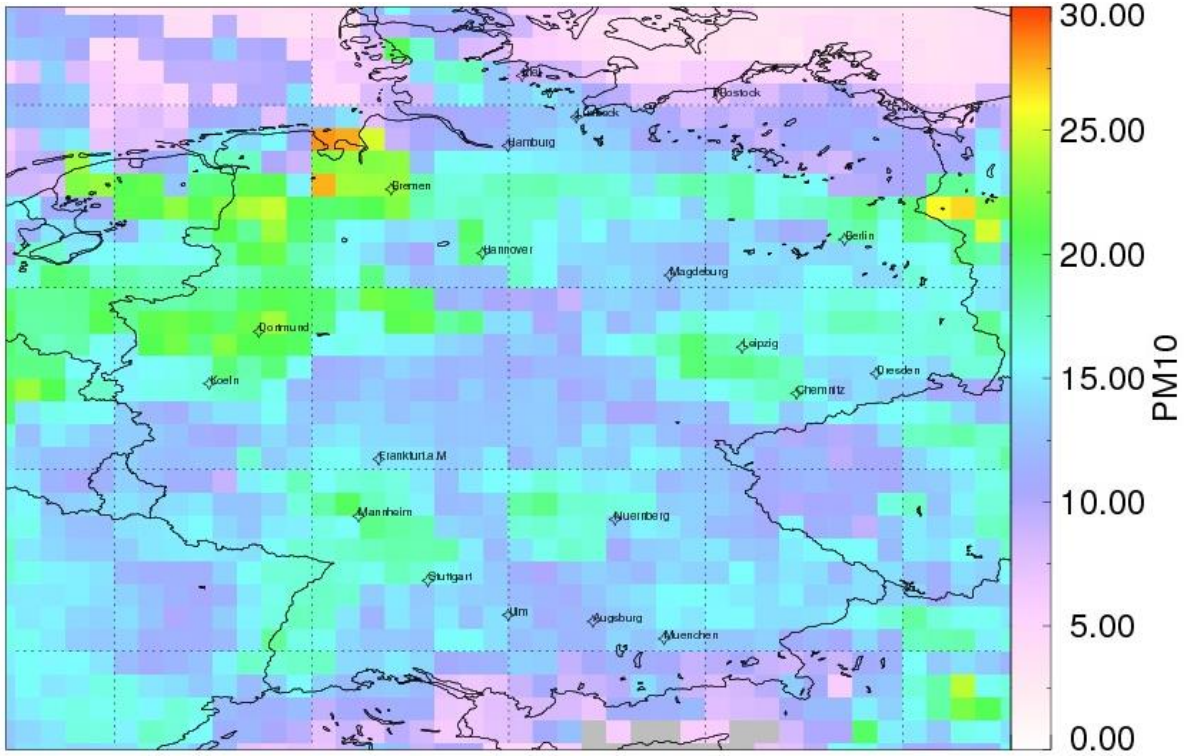
Mass [g/m²]

0.0 3.0 6.0 9.0 12.0

Klüser et al. , 2011, 2012

Separating Natural and Anthropogenic PM

Quantification of aerosol composition with SYNAER: soot, sea salt, min dust, sulfates and nitrates, biomass burning



ENIVSAT/SCIA/AATSR

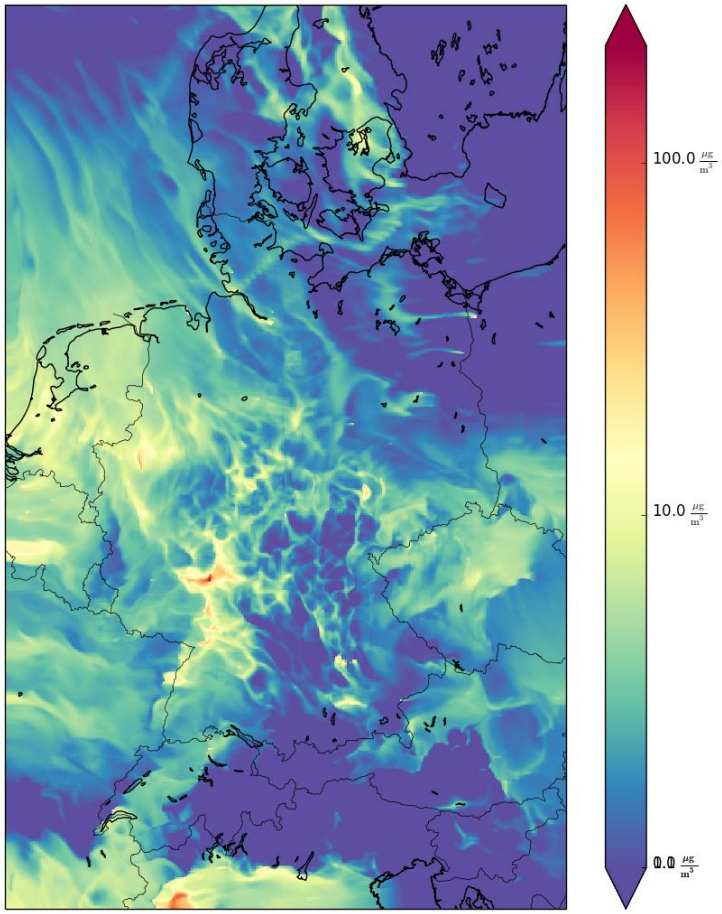
RMSE versus EMEP
$PM_{2.5}$: 4 µg/m^3
PM_{10} : 6µg/m^3
R=0.5

ESA Aerosol_CCI
→ CMUG

Holzer-Popp et al., 2011

Developments in Assessment and Forecasting

- Assimilation of in-situ + satellite data
- Improved emissions and resolution
- Integration of physical, chemical and biological weather
- Regional harmonisation
  - Nesting in Coperncius Atmosphere
  - Following FAIRMODE guidance
  - Quality Management / Validation
  - INSPIRE and ISO compliance
  - Interoperability (OGC)



POLYPHEMUS/DLR, NO2, 72h forecast

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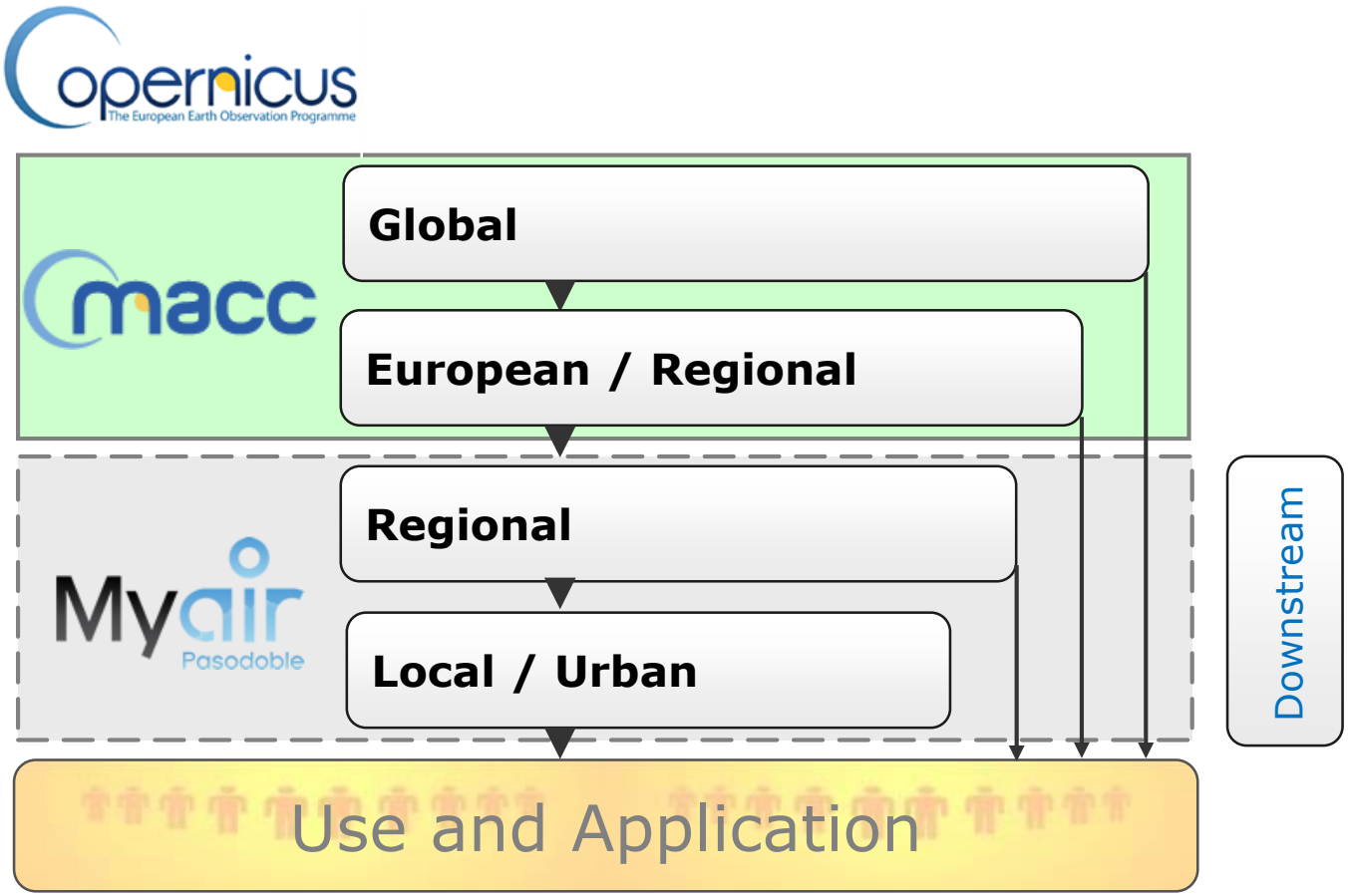
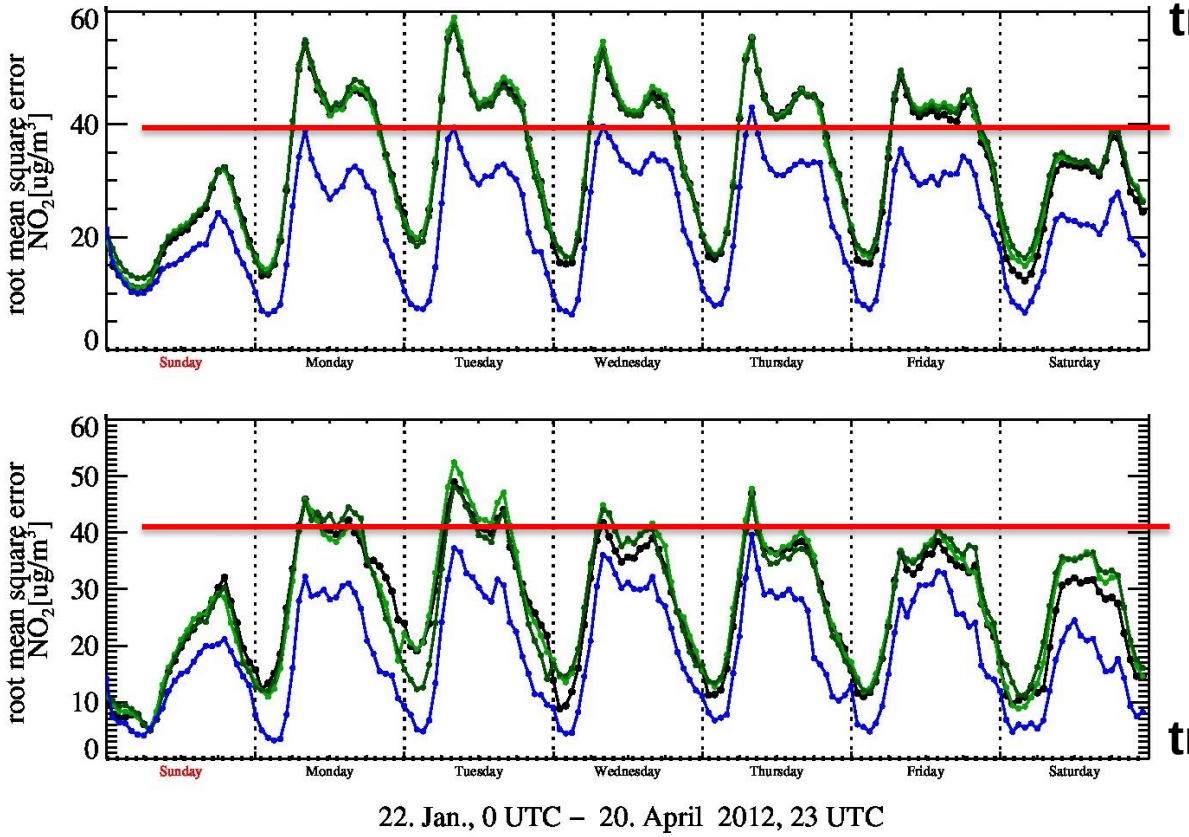
Coperncius Air Quality Service Chain



Forecasts/Analyses for Northrhine-Westfalia (EURAD-IM)

Time-series of NO2 **RMSE** weekly cycle, averaged over 4 months

-> Improvement with model resolution



traffic, 5 km resolution

forecast d+0

forecast d+1

forecast d+2

analysis

traffic, 1 km resolution

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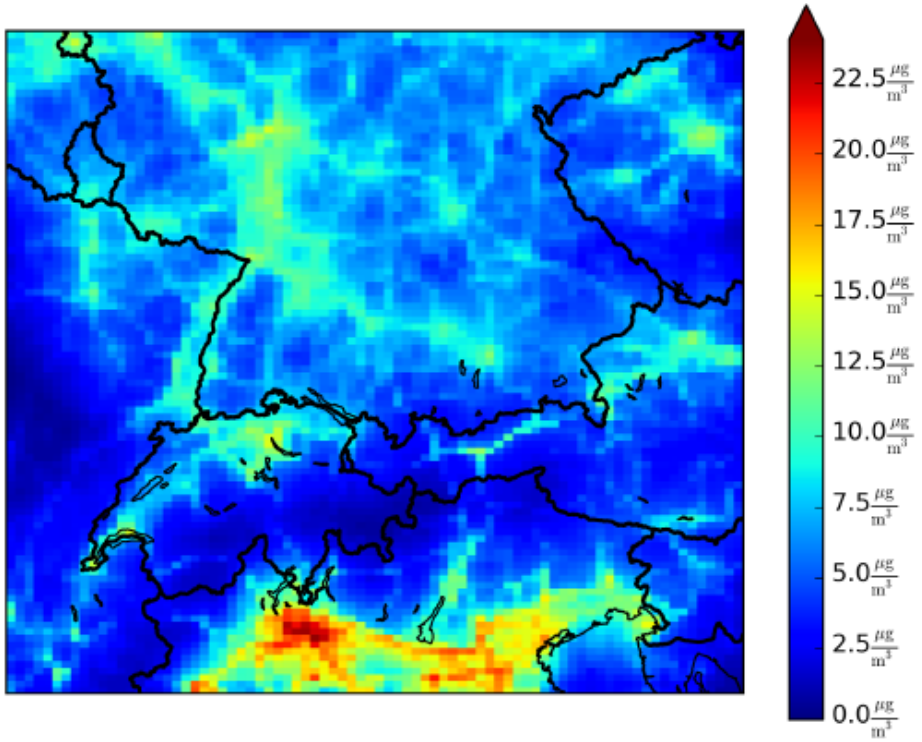
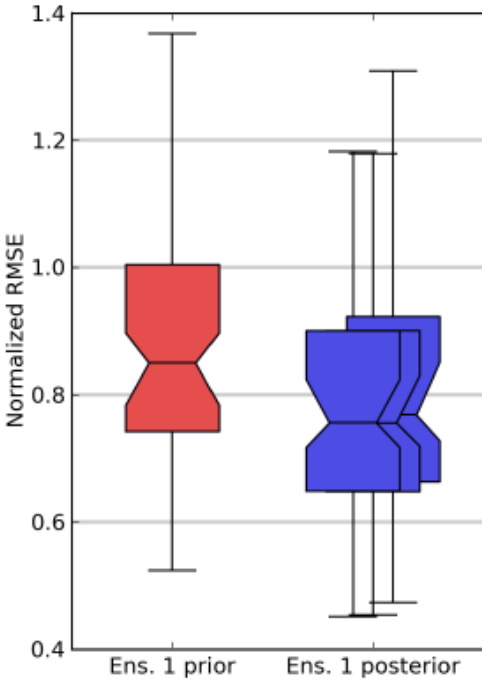
Ensemble Data Assimilation and Bayesian Filtering



O3 RMSE deviation between posterior and prior distributions



NRMSE for O3 at verification stations

→Bayesian Filtering improves air pollution analysis

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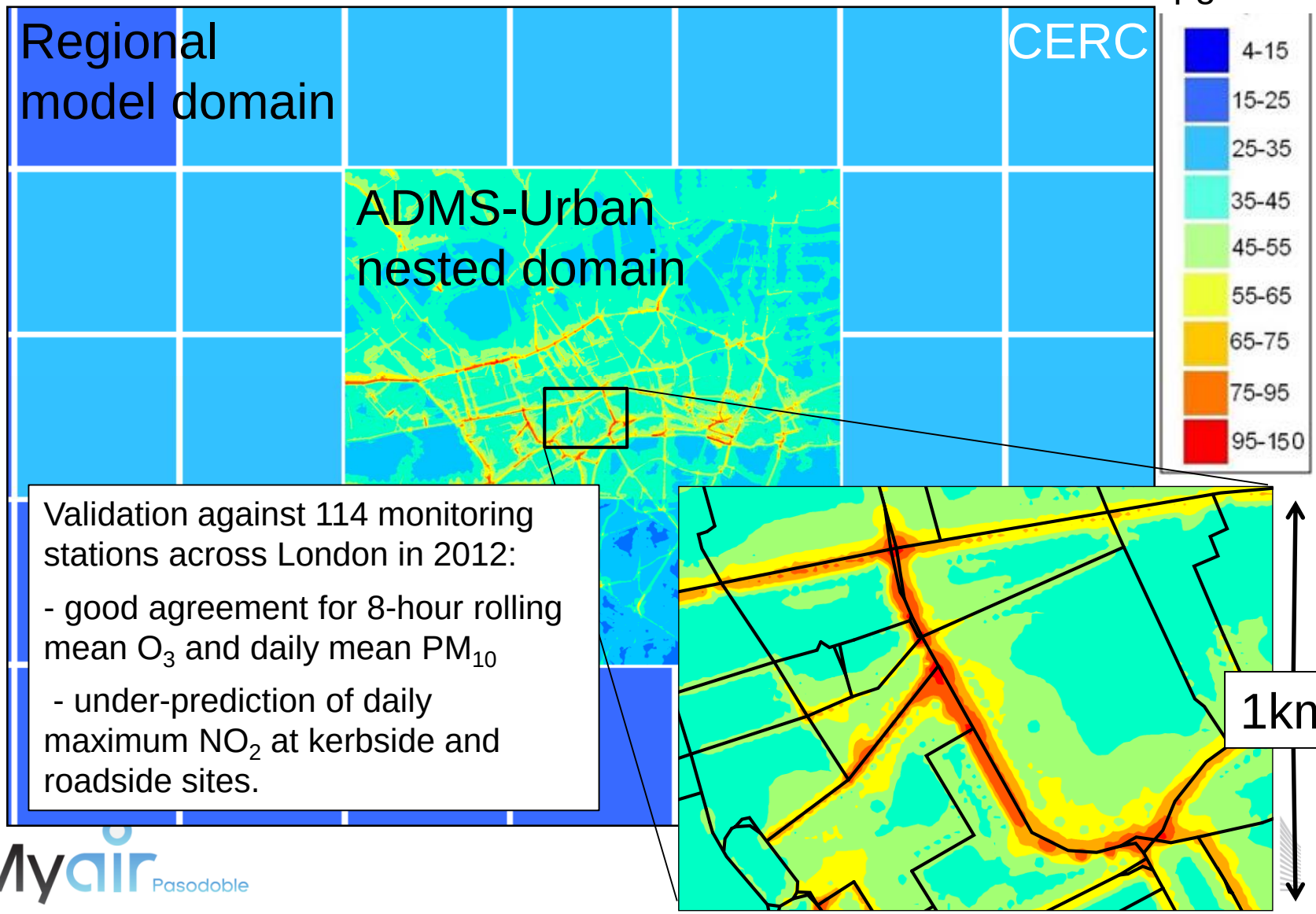
London: ADMS-Urban Operational 72 h Forecasts



Validation against 114 monitoring stations across London in 2012:

- good agreement for 8-hour rolling mean O_3 and daily mean PM_{10}
- under-prediction of daily maximum NO_2 at kerbside and roadside sites.

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Public Information for London Olympics 2012

Push service to >7.000 subscribers by Private Sector (CERC)

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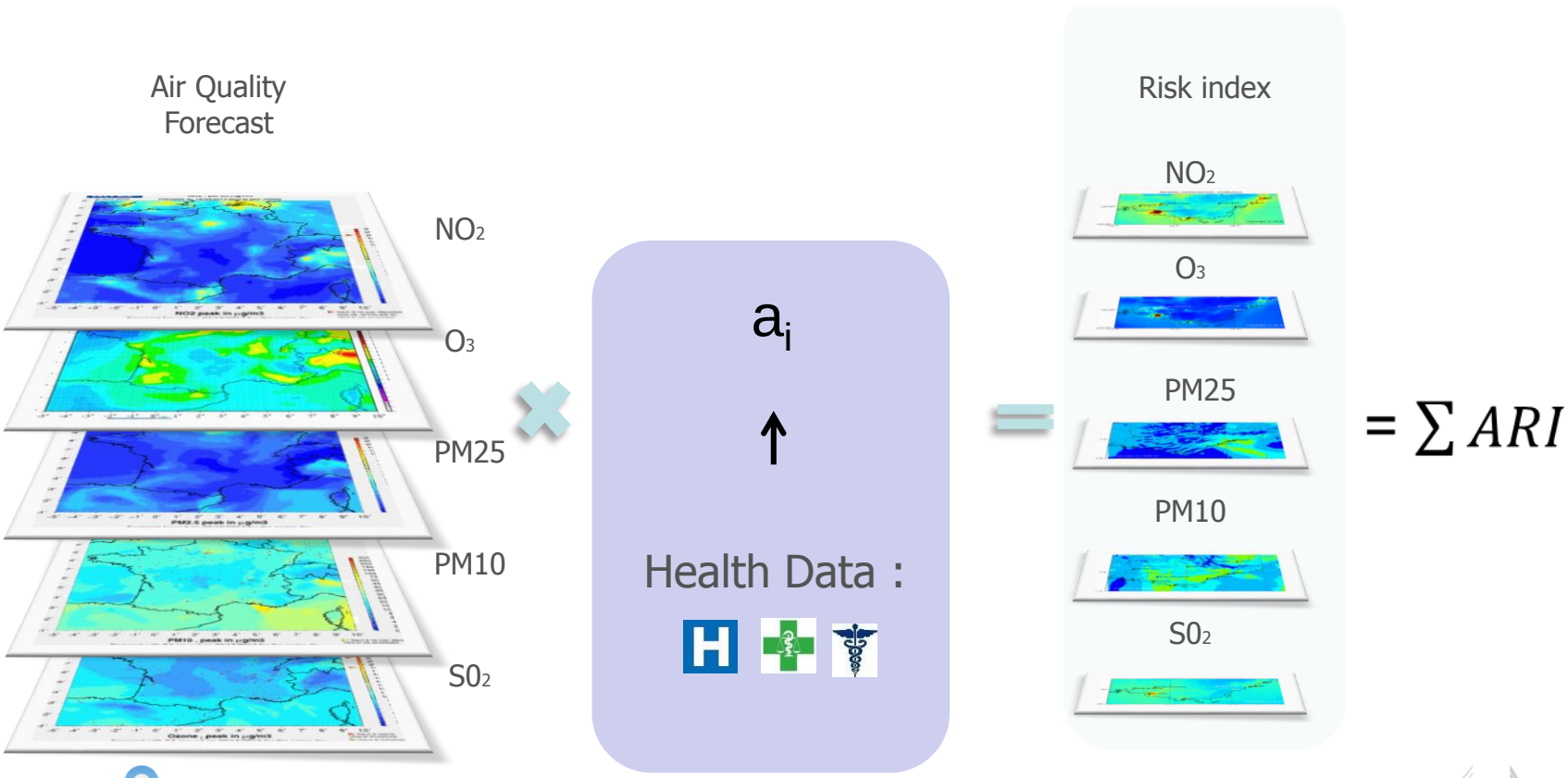
Aggregate Risk Index

Assessment of additive effects of short-term exposure to mixture of air pollutants for different pathologies:

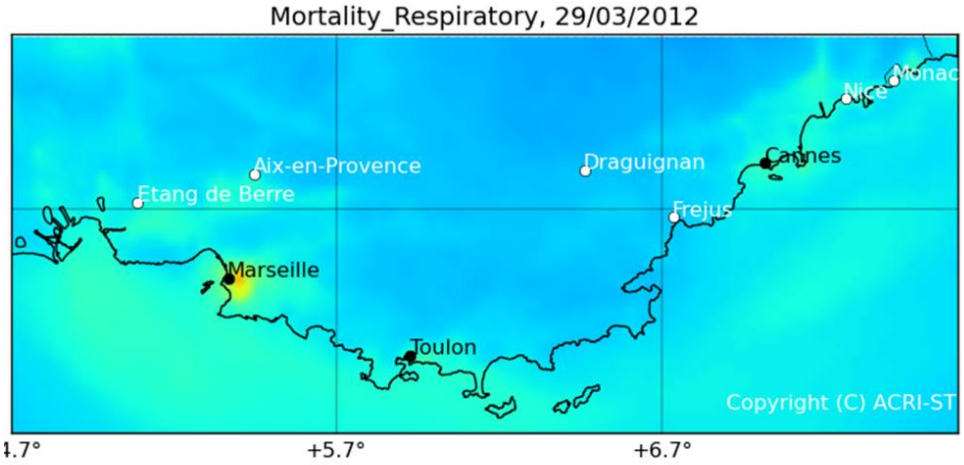
$$ARI = a_{O3} * C_{O3} + a_{NO2} * C_{NO2} + a_{SO2} * C_{SO2} + a_{PM2.5} * C_{PM2.5} + a_{PM10} * C_{PM10}$$



Sicard et al., 2011, 2012

Agreggate Risk Index Forecasts

- Development of ARI accounting for multiple exposure impacts
- Forecasts enable communication of health risk for different pathologies and sensitive groups to take precautionary action
- Demonstrators in Athens, Thessaloniki and South of France



Aggregate Risk Index

0	1	2	3	4	5	6	7	8	9	10	11

Enjoy your usual outdoor activities.

Follow your doctor´s advice for exercise.

Consider reducing strenuous physical outdoor activities, or reschedule to times when index is lower.

Follow your doctor´s advice for exercise.

Reduce physical exertion outdoors and particularly if you exerperience symptoms.

Follow your doctor´s usual advice. People with asthma may need their reliever inhaler more often. If symptoms persist seek medical advice.

Health Warning of emergency conditions. Avoid physical activities.

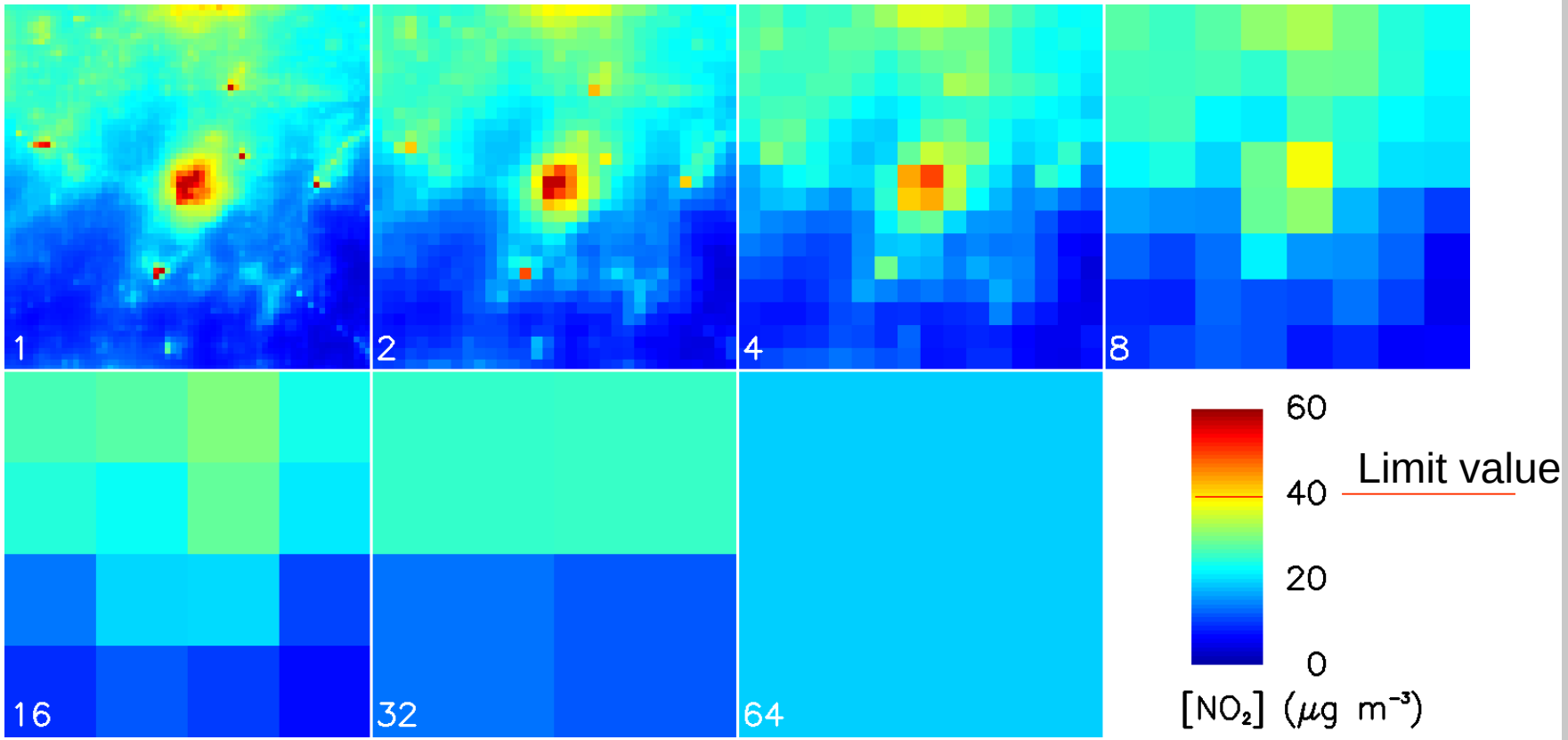
Follow your doctor´s usual advice. People with asthma may need their reliever inhaler more often.

Air Quality Monitoring and Forecasting Services…

… play a key role in Climate Change Adaption by:

- Raising public awareness
- Advising people at risk to take precautionary actions
- Informing hospitals, pharmacies and doctors on upcoming episodes
- Providing information to stakeholders and policy makers
- Enabling the monitoring of mitigation plans
- Facilitating daily working practise and reporting

Need for considering Urban Scales – Brussels NO2 2005



MACC ENS PROMOTE IAQ

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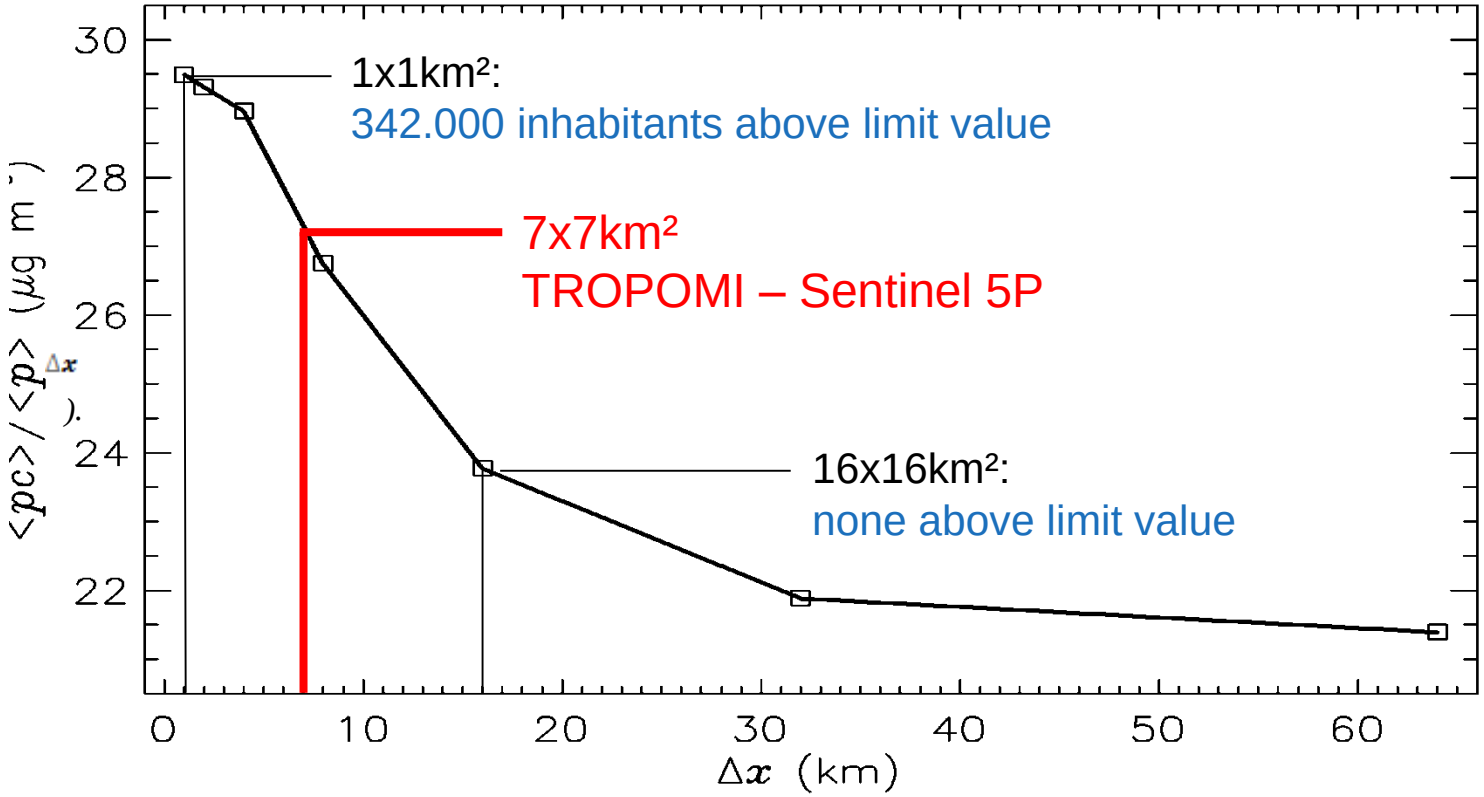
Need for considering local scales - Brussels



Population density weighted concentration (i.e., exposure) for a 64 × 64 km2 sub-domain, as a function of spatial resolution

Summary and Outlook

- EO can significantly contribute to monitor long term trends and air pollution episodes and minimize error bars to estimate radiative forcing
- Current instruments mainly designed for stratospheric O3 monitoring, but outcome already impressive (NO2, O3, PM+, SO2, CO, NH3) columns
- Sentinel-3, -4, -5 and -5P will offer unprecendted possibilites for urban air pollution monitoring (GEO, Horiz Res. Below 10x10km²)
- We should strive for a combined and complementary use of EO data, in-situ data and numerical modelling
- Long time series and sustainable data provision is essential
- Copernicus framework important, but downstream services essential to bridge the gap to local stakeholders and the citizen
- Commitment to stakeholder involvement essential

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