WALTER DI NICOLANTONIO - *SINOPIAE TEAM*

NEREUS International Conference
BARI, *February 27th, 2014*

MULTI-SCALE MONITORING OF ANTHROPOGENIC EFFECTS ON AIR QUALITY AND CLIMATE CHANGE IN LOMBARDY REGION

sinopiæ

RegioneLombardia

SPACE SYSTEMS

Overview

- SINOPIAE Objectives, Team and Role in the project

- Satellite, ground-based and modelling data: a multi-scale and multi-source synergistic use for environmental indicator assessment
  - Lombardy-Northern Italy Air Quality monitoring: PM and NO2
  - Garda Lake Water Quality: desert dust deposition effects
  - Aerosol direct effects evaluation on climate at regional scale

- Remote Sensing of Energy dispersion in urban scenarios

- Perspectives from next satellites and conclusion

- ***S I N O P I A E ?***

DECRETO N. 7128 DEL 29 LUGLIO 2011

RegioneLombardia

Sistema prototipale multi-sorgente **IN**tegrante tecniche di **O**sservazione multis**P**ettrale da satellite, aeromobile e a terra per il monitoraggio multi-scala della variazione di **I**ndicatori Ambientali legata ai costituenti **A**tmosferici e dispersione **E**nergetica

From the classical antiquity and the Middle Ages, ***sinopia*** is a "*prototype*" design for painting a picture

SINOPIAE is a prototype system fusing multispectral satellite, aircraft and ground-based observations for monitoring environmental indicators affected by atmospheric constituents variability and energy dispersion

SINOPIAE objectives

- **Remotely Piloted Aircraft System (RPAS) exploitation**

  - Design and development of a thermo-optical multisensor payload, integration on RPAS for thermal parameters monitoring at urban scale;

  - Iperspectral sensors integration on RPAS: atmospheric parameter monitoring & remote sensing of atmospheric optical parameters;

- **Atmospheric constituents monitoring on the basis of multi-source data fusion (A)**

  satellite observations, ground-based measurements, meteo and CTM simulations

- **Environmental Indicators (B)**

  algorithms develop. for the identification of cause-effect relationships between meteo-atmospheric parameters and environmental indicators on areas characterized by different anthropic pressures: thermal dispersion of buildings in urban areas, water quality, snow and ice surfaces;

- **Modeling tools (C)**

  estimating aerosol direct radiative forcing and energetic and emissions scenarios as a function of pollutants concentration and spatial distribution in urban areas;

- **Prototype modular system (SW)** equipped with external interfaces, data archiving functions, and by integrating each single sw module (as A,B,C)

SINOPIAE Team → role in the project (1/2)

OHB CGS company leader in Europe for aerospatial systems integration together with design and development of sw infrastructures and operat. services.

→ Algorithms and data processing for the monitoring of air quality in terms of PM and gases concentrations at the ground on the basis of satellite observations. Design, Test and Integration of the whole SINOPIAE sw system.

Aermatica (sme) Design, manufacturing, production and commercialization of small RPA with the corresponding Ground Control Systems.

→ Integration on a UAV of a thermo-optical payload leading to a ready-to-use systems, use of the system in dedicated field campaigns both for energetic efficiency and air quality monitoring.

TerrAria s.r.l. (sme) has a strong background in complex modeling systems, achieved and exploited in several applied research projects.

→ WRF-Chem model tuning and simulations of pollutants concentration transport, diffusion and chemico-physical processes over the domain of the project.

SINOPIAE Team → role in the project (2/2)

Research institution dedicated to methods and technologies for acquisition and analysis of images and data from remote sensing platforms for env. monitoring.

→ Algorithm and data analysis for monitoring and estimating water quality and study of the exchanges process between atmosphere and waters.

has a strong background in spectroscopy, radiometry, proximal sensing sensor, and atmospheric aerosol chemistry and physics.

→ Monitoring of the atmospheric pollution with estimates of the effects on the snow-ice remote surfaces reflectance properties.

POLITECNICO DI MILANO participates to SINOPIAE with 3 depts: Science and Technologies of the Building Environment, Electronic and Information, and Aerospace Engineering

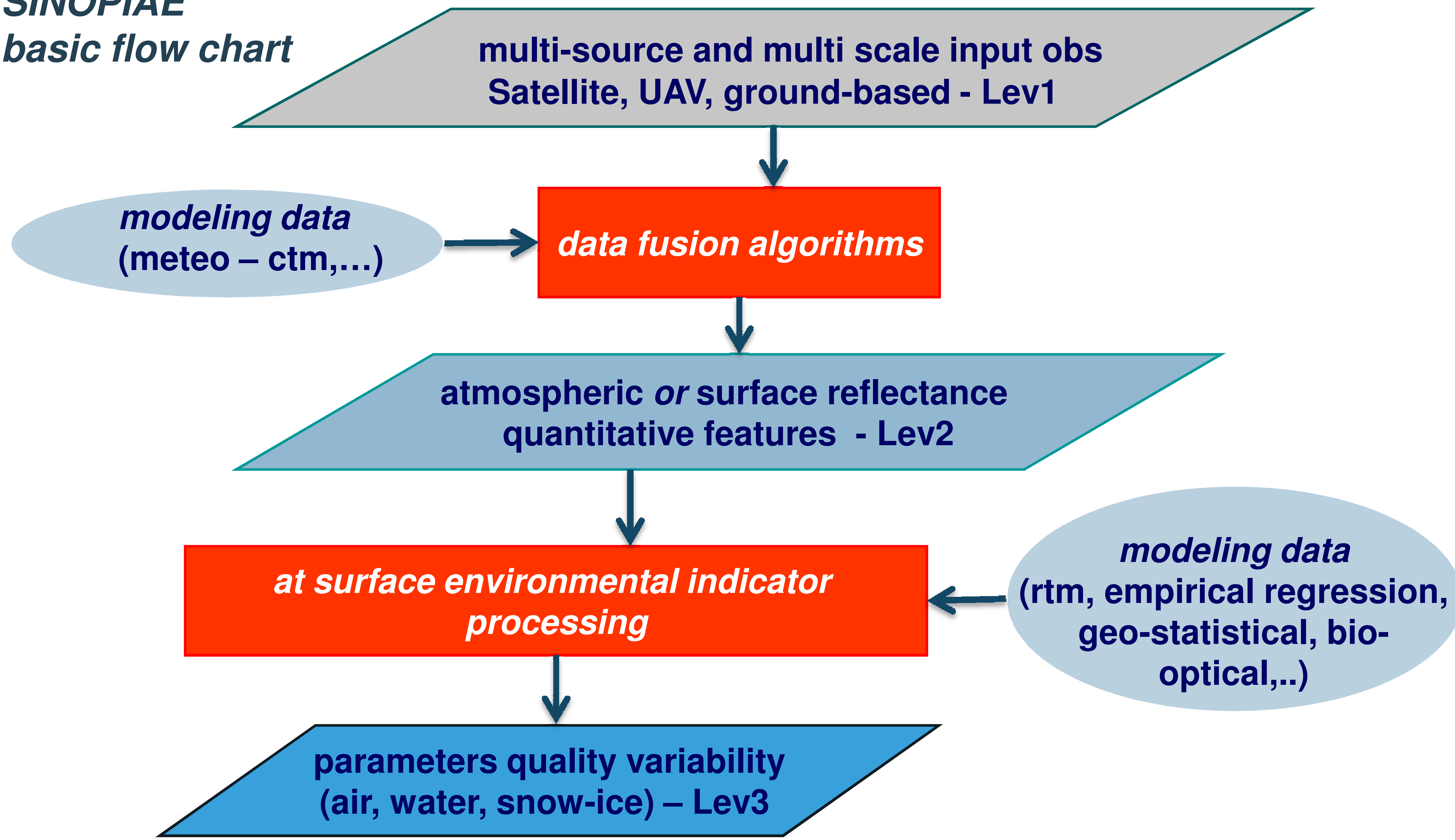
→ Modeling of the thermic dispersion at the district and urban scale, monitoring and mapping of energetic efficiency of the urban areas.

(sme) know-how on the technology for termal cameras and their integration.

→ manufacturing of embedded system with FPGA technology for images acquisition and on line integration with analysis instruments.

Satellite, ground-based and modeling data: multi-scale and multi-source inputs synergistic use

SINOPIAE basic flow chart

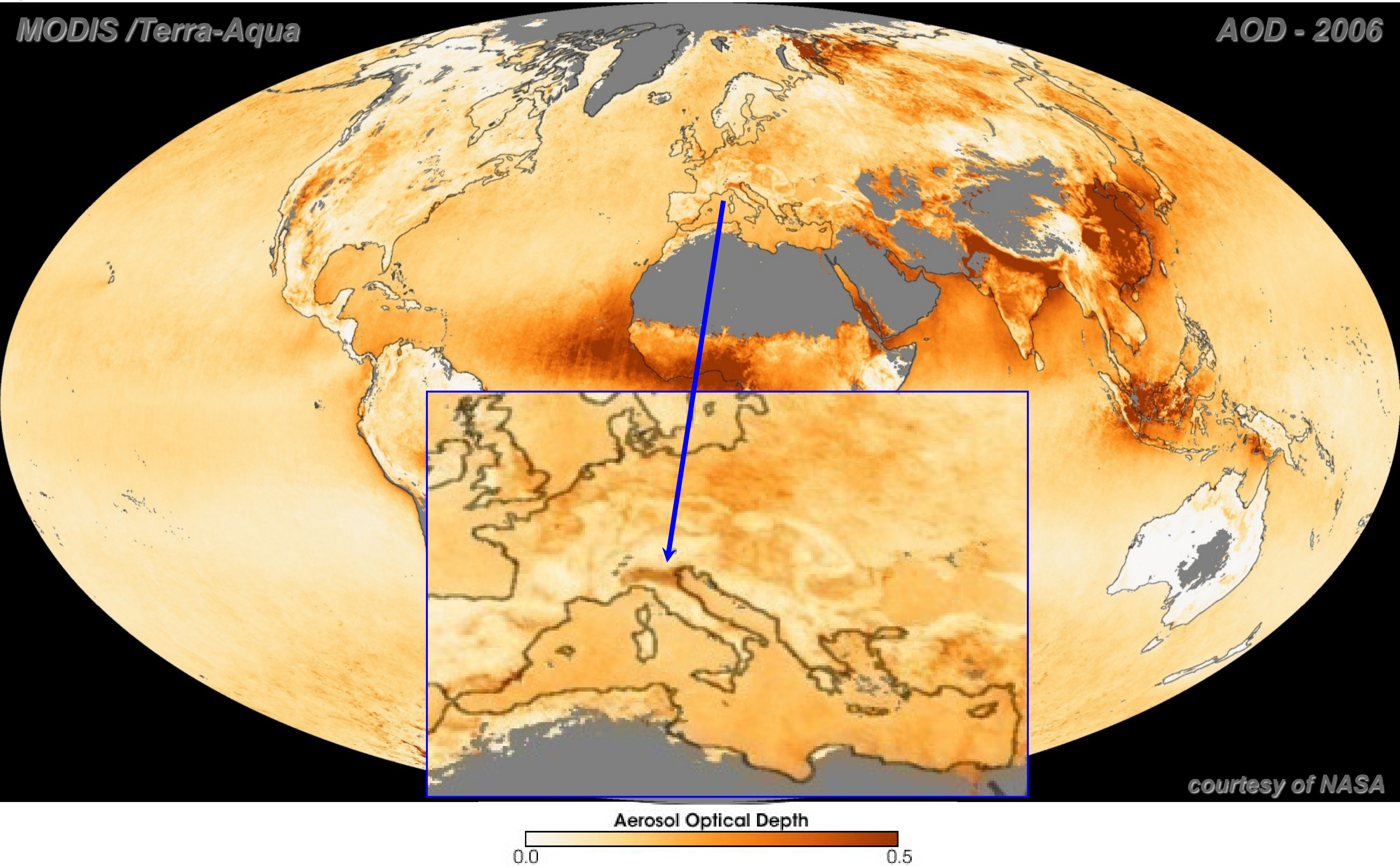


Satellite, ground-based and modeling data: multi-scale and multi-source inputs synergistic use

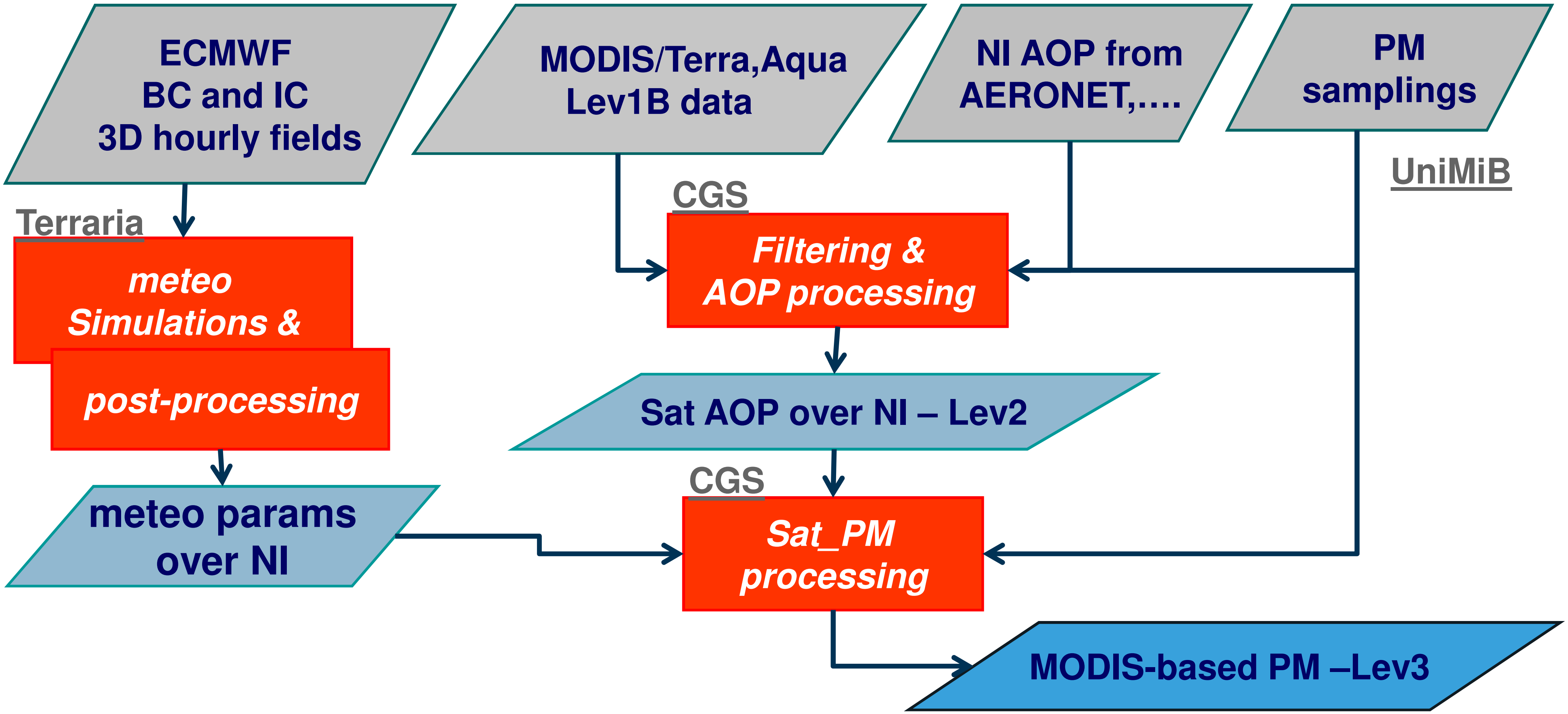
multi-source and multi scale input obs
Satellite, UAV, ground-based - Lev1

EO satellite sensors actually employed	PURPOSE
MODIS / Terra – Aqua 36 channel VIS/IR spectroradiometer expected lifetime up to 2014	multi-purposes imagery: atmosphere, land, ocean
OMI / Aura UV/VIS grating imaging spectrometer, 1560 channels expected lifetime up to 2014	ozone profile, trace gases and aerosols
MERIS / Envisat 15 channel VIS/NIR spectroradiometer flown since until April 2012	ocean colour, vegetation, aerosol
SEVIRI / MSG 12 channel VIS/IR Imager flying on operational programme expected lifetime up to 2022	multi-purposes imagery, clouds, winds, water vapour features

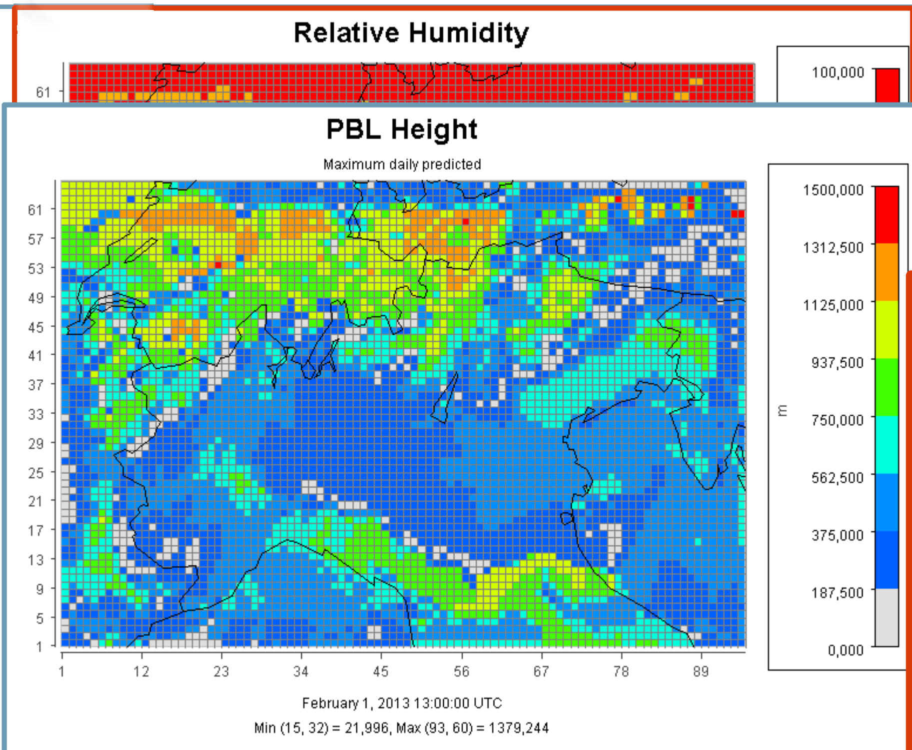
Aerosols & PM - Anthropogenic and/or natural



Lombardy-Northern Italy Air Quality monitoring: PM

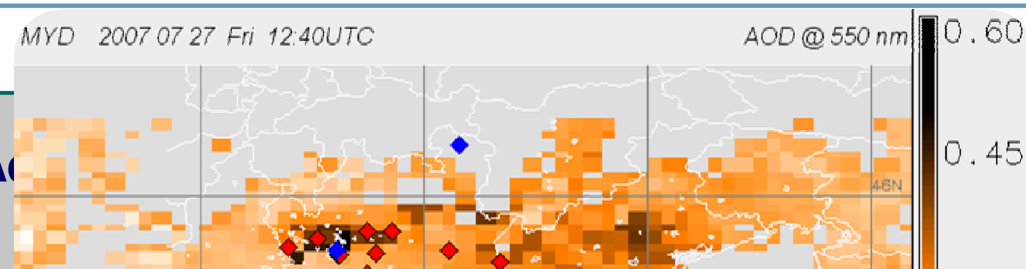


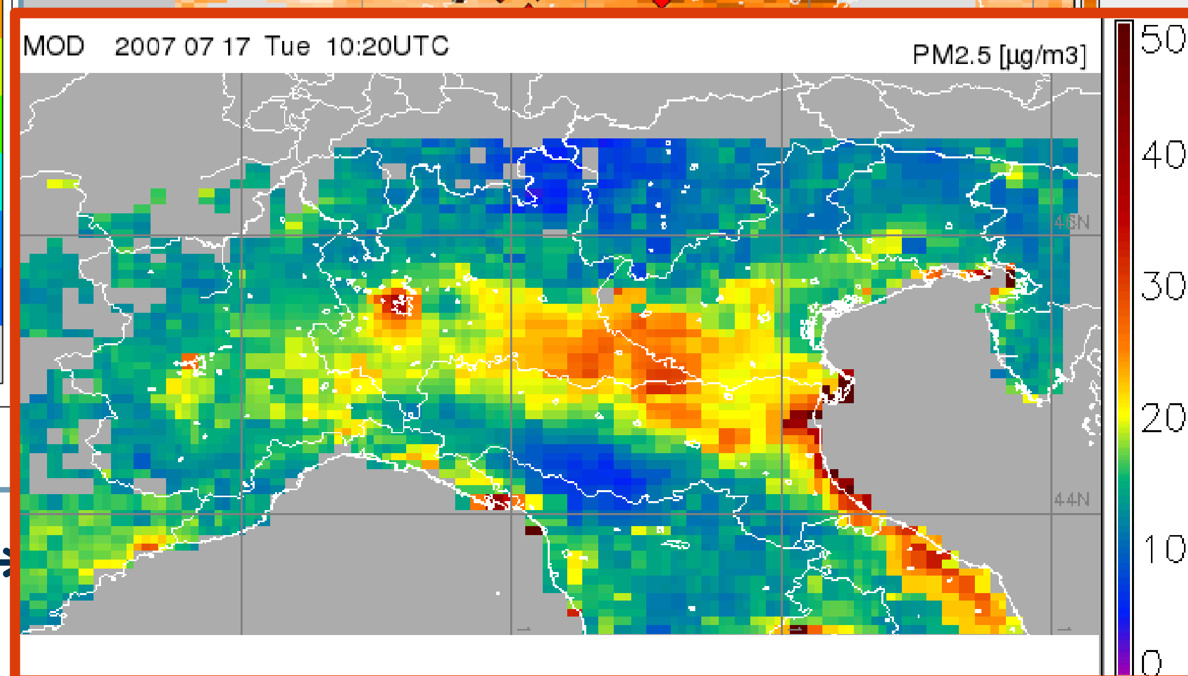
Lombardy-Northern Italy Air Quality monitoring: PM



meteo params over NI

Terra,A[...] data



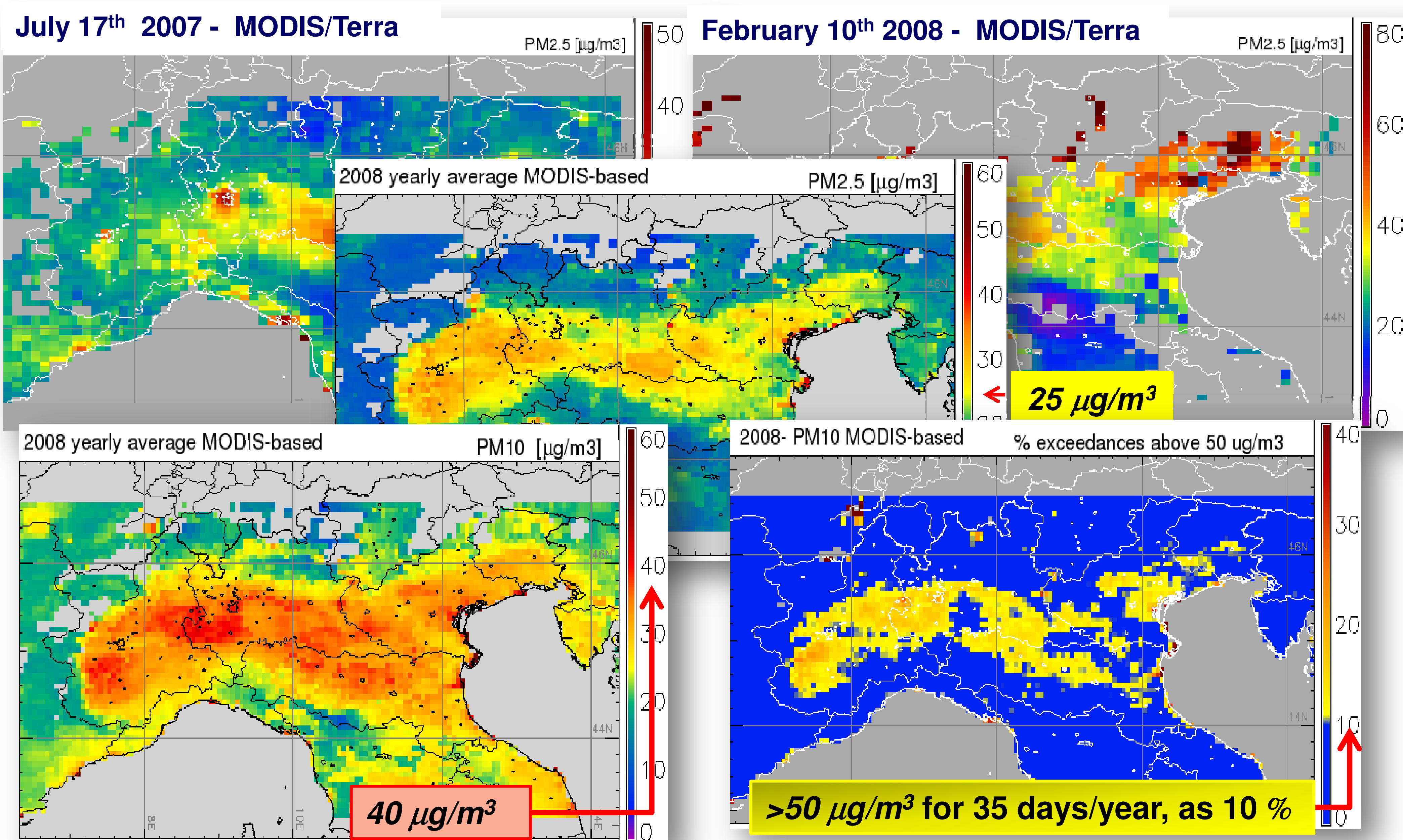


MODIS-based PM –Lev3

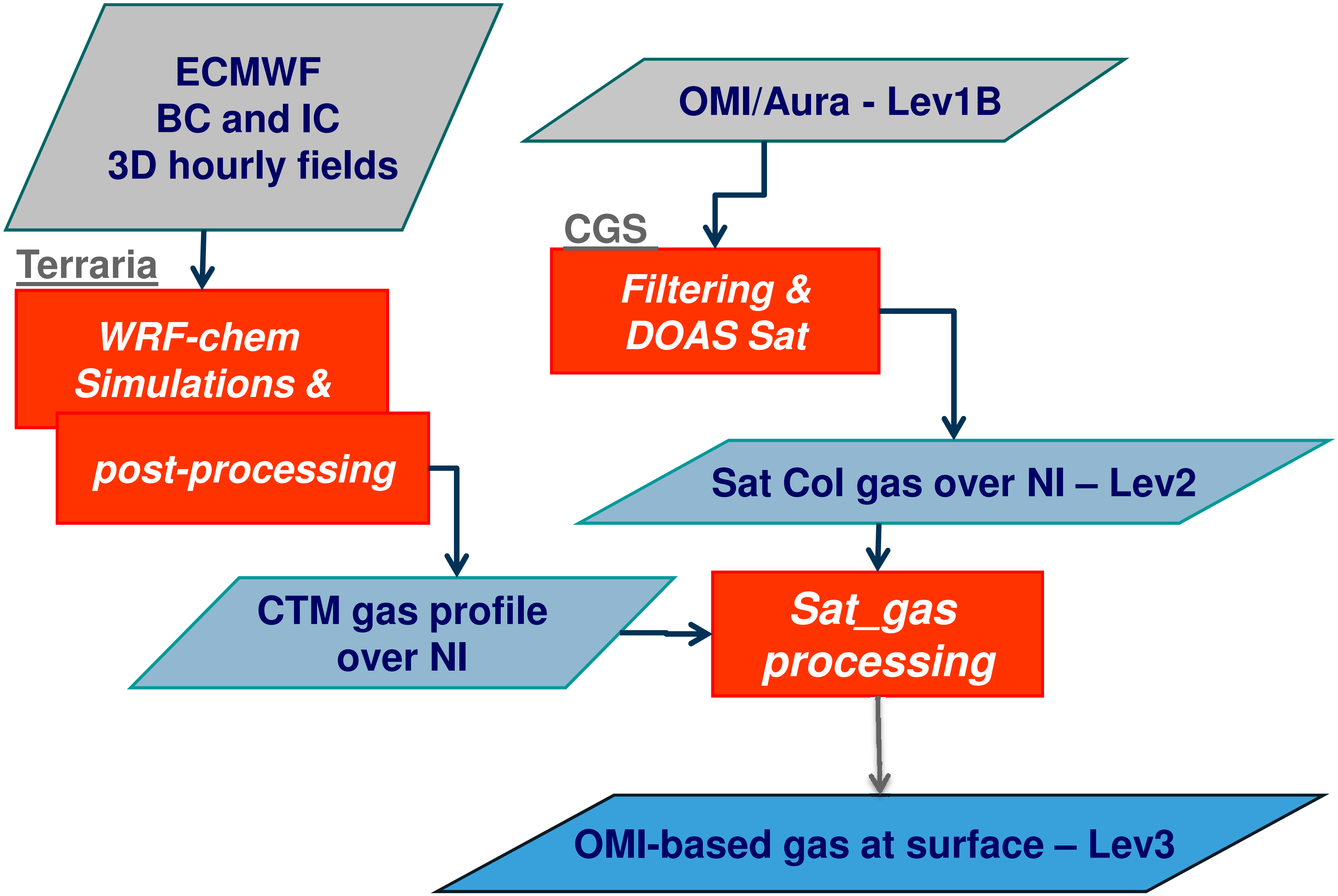
Useful research activities

- Corresponding PM samplings and other optical measurements (super-site concept)
- Increase the spatial resolution of satellite aerosol data and meteo and CTM models
- Integration of satellite-based and CTM data

NI Air Quality monitoring: PM satellite-based & EC Directive



Northern Italy Air Quality monitoring: NO2 satellite-based



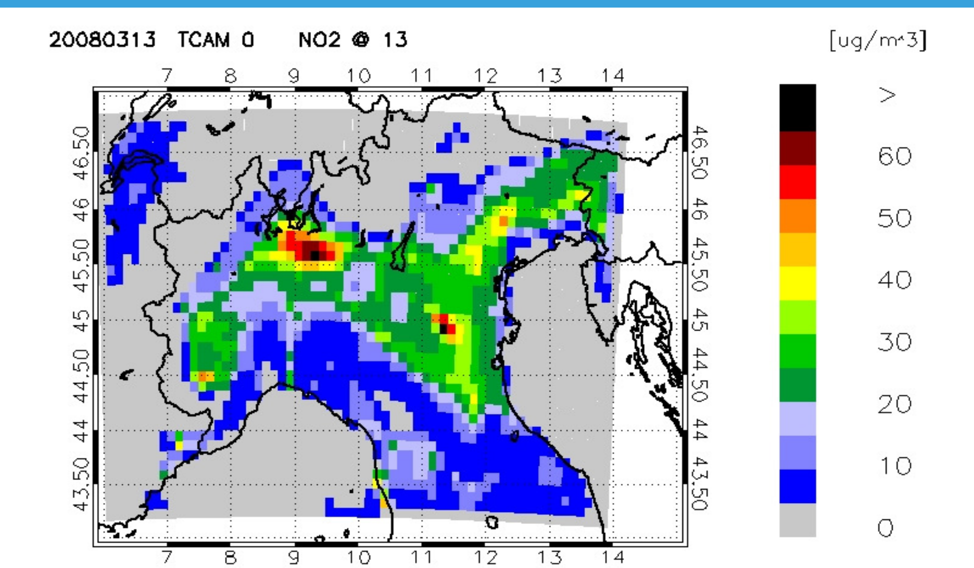
Northern Italy Air Quality monitoring: NO2 satellite-based

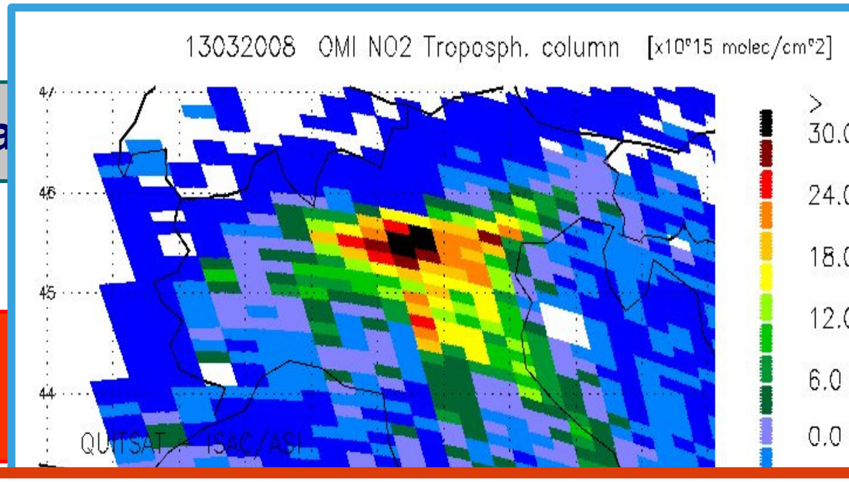
ECMWF
BC and IC
3D hourly fields

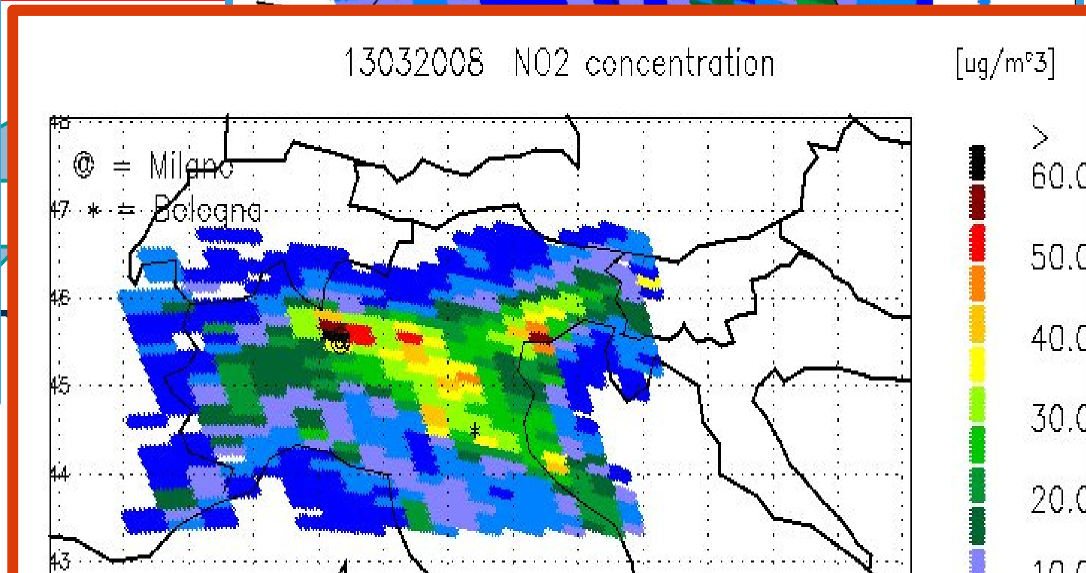
OMI/Aura

CGS

ltering &
OAS Sat

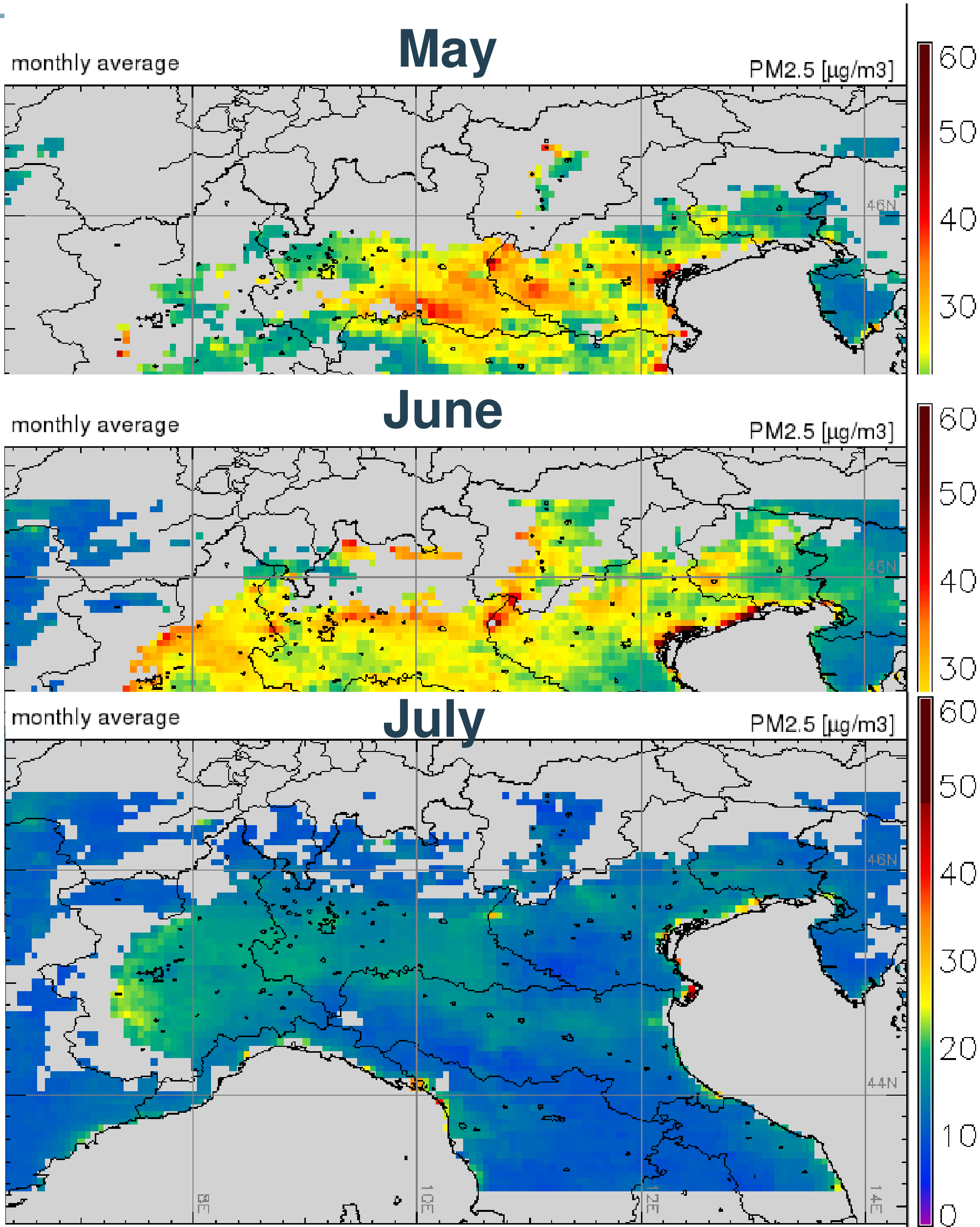


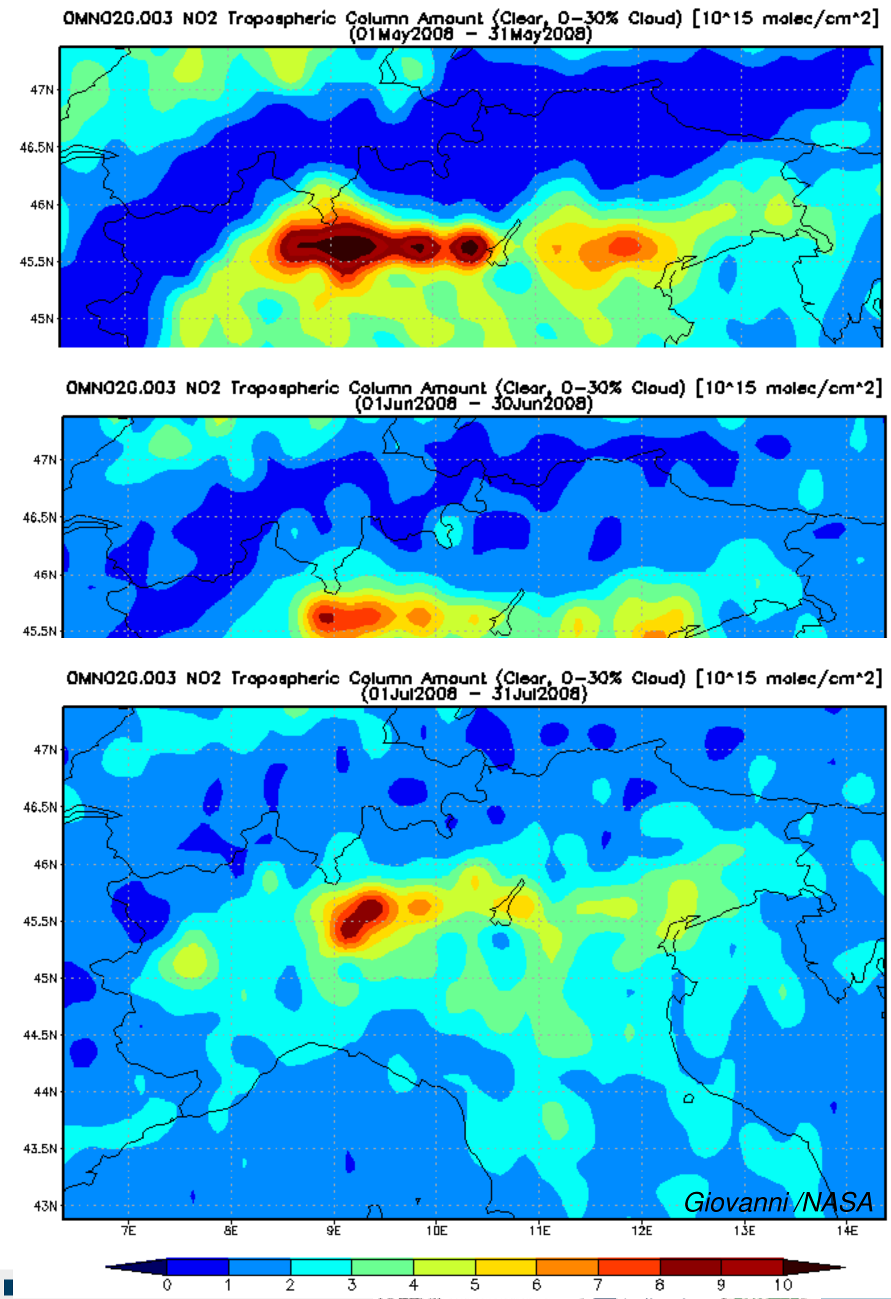




OMI-based gas at surface – Lev3

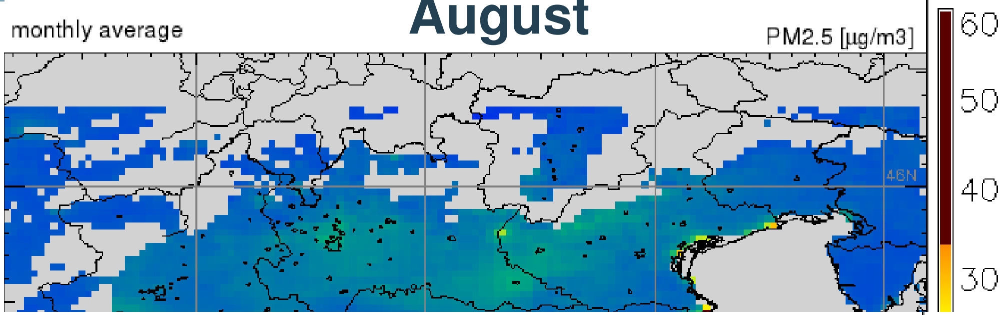
NI Air Quality monitoring: monthly PM & NO2 / 2008

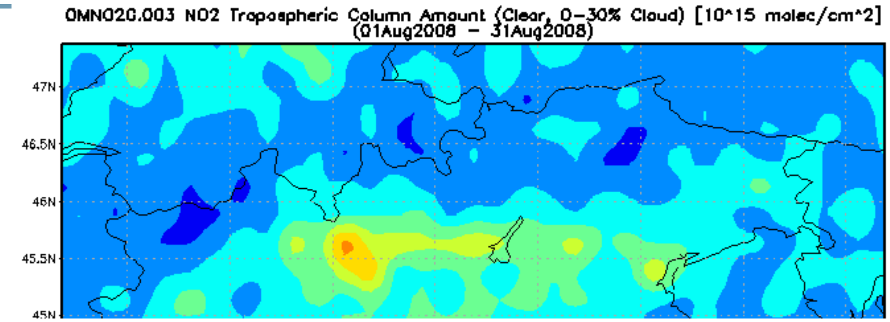




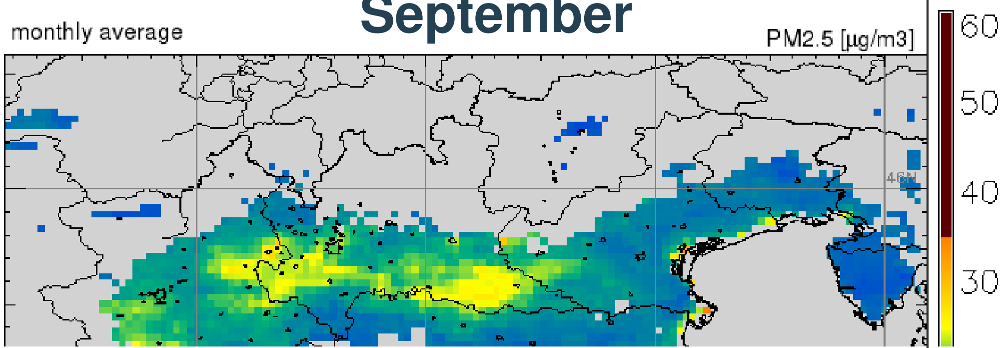
NI Air Quality monitoring: monthly PM & NO2 / 2008

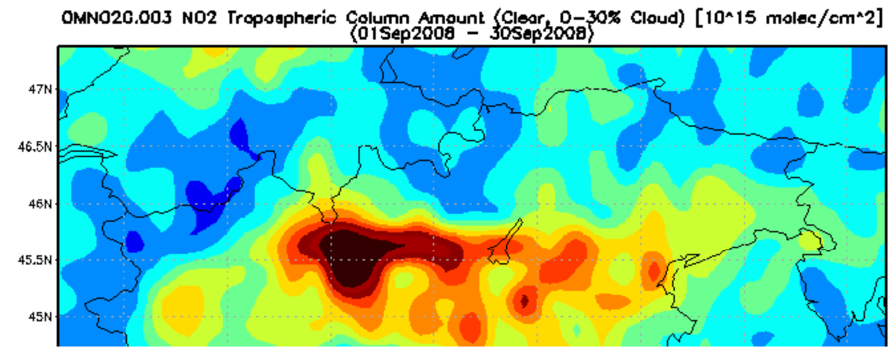
monthly average **August** PM2.5 [µg/m3]



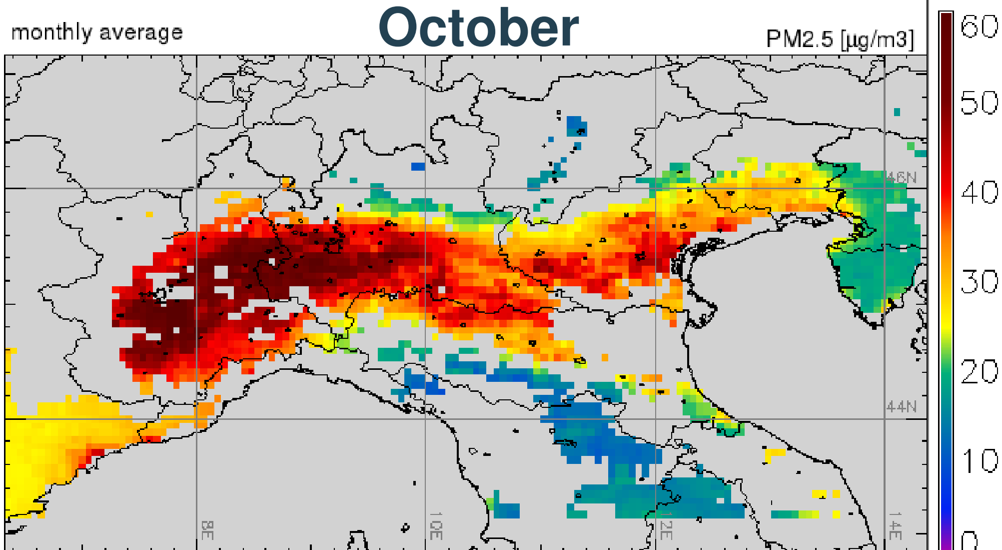


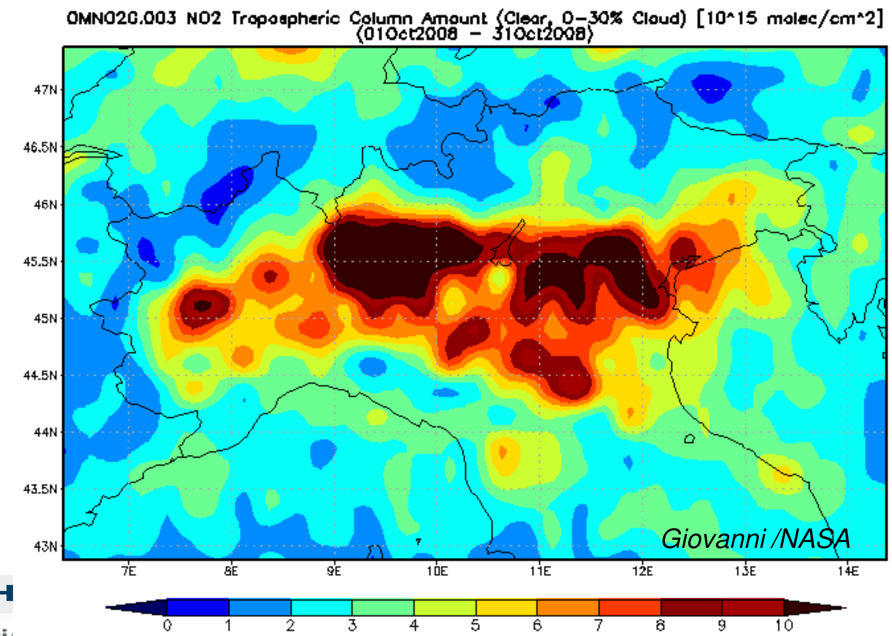
monthly average **September** PM2.5 [µg/m3]



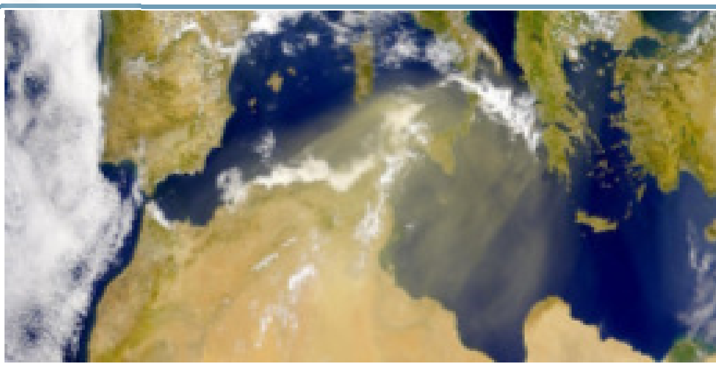


monthly average **October** PM2.5 [µg/m3]

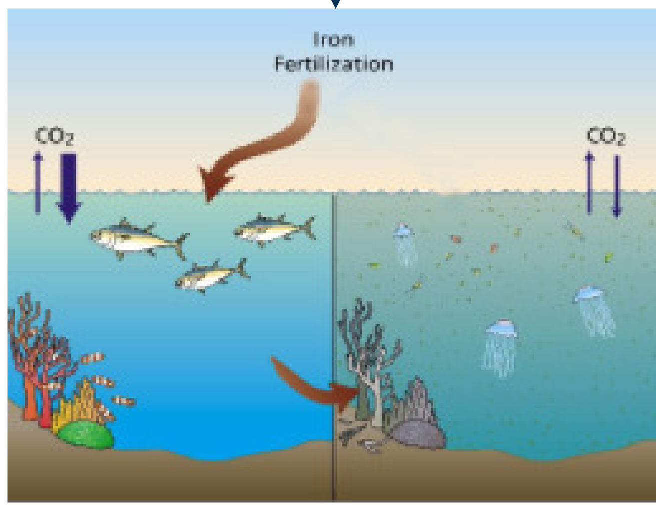




Garda Lake Water Quality: desert dust deposition effects



Saharan dust
(saharan sand rich
in trace metals)



Increase of nutrients thanks to trace metals in water and consequent phytoplankton development

Potential increase of chl-a concentration

Garda Lake Water Quality: method

MERIS/Envisat Lev1b

SEVIRI/MSG Lev1A

OMI/Aura Lev2

NI AERONET AOP

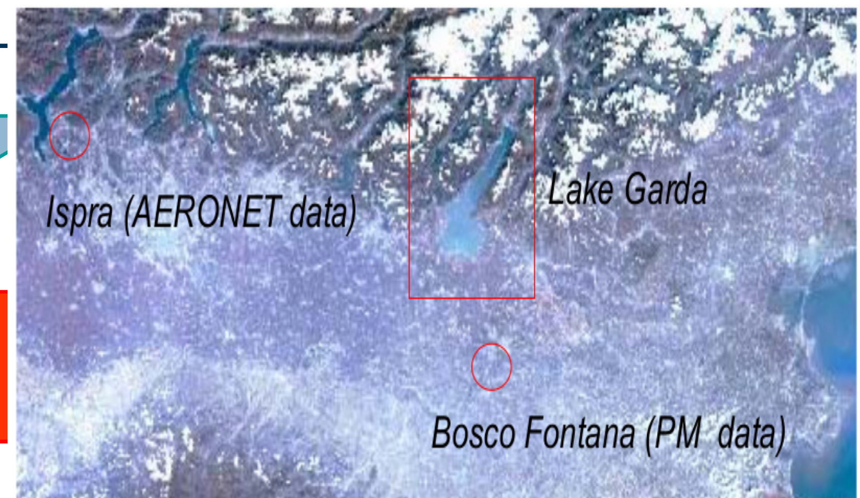
PM Samplings

SEVIRI BTD

OMI UV SSA Spectral check

Desert dust event identification

Radiometric, adiacency and atmospheric correction



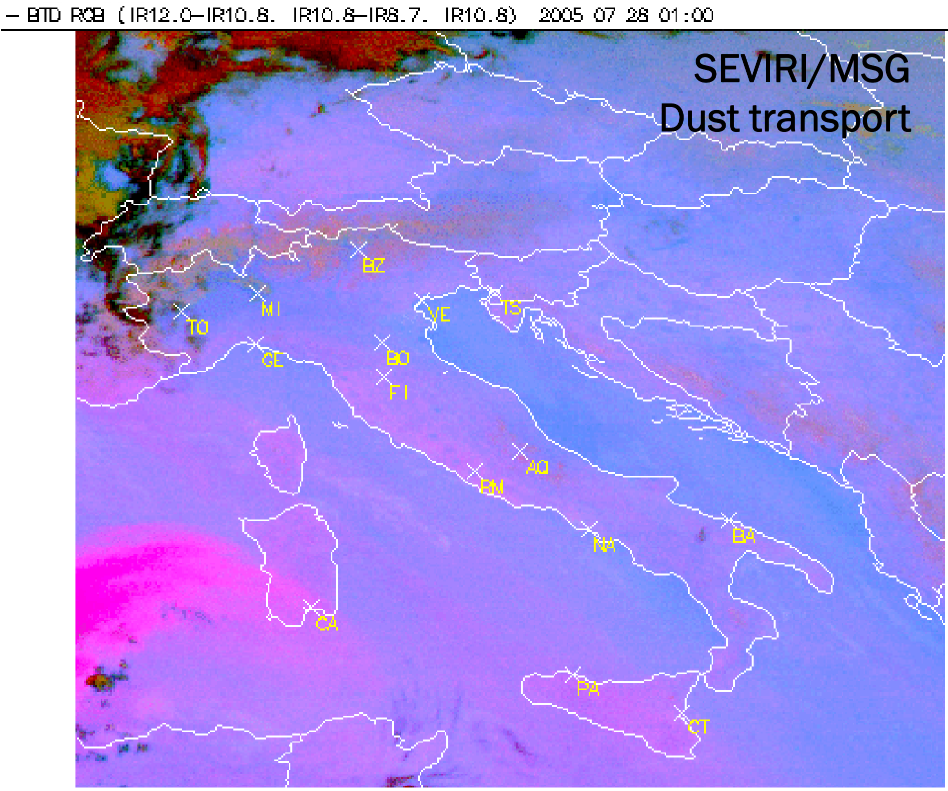
Water surface spectral reflectance

data from
bio-optical models

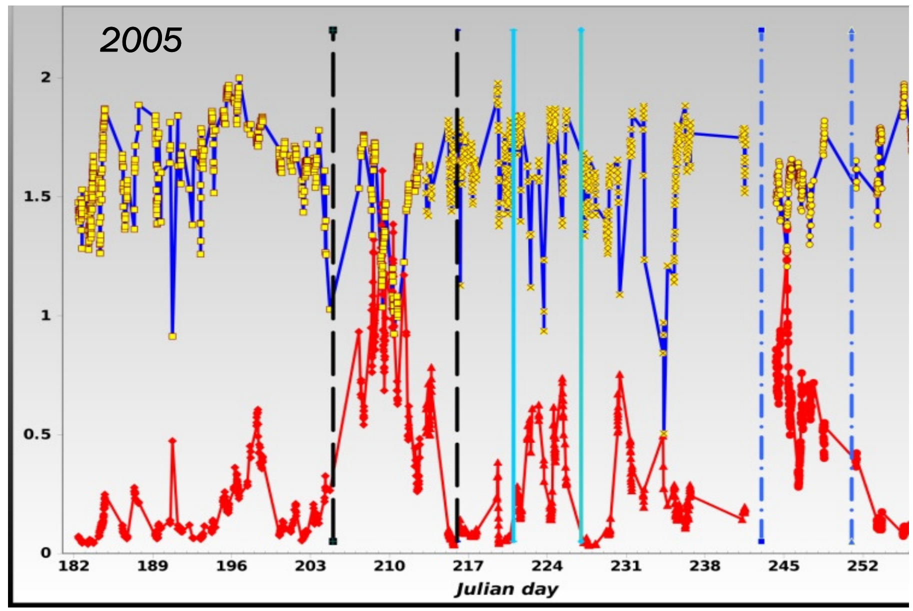
Water quality parameters

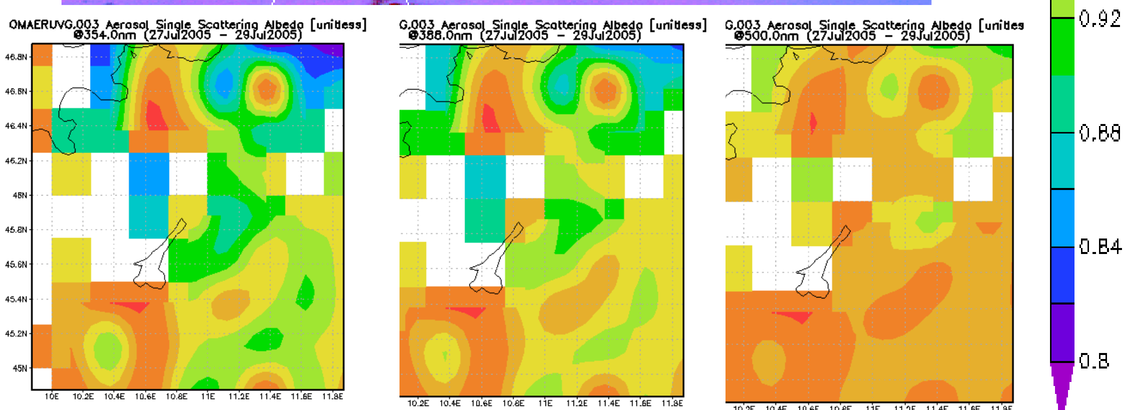
Garda Lake WQ: saharian dust event & deposition impact

Saharan dust event identification   2005 July 28 , DOY 210



AOD & *Angstrom parameter* - *Ispra (VA)*

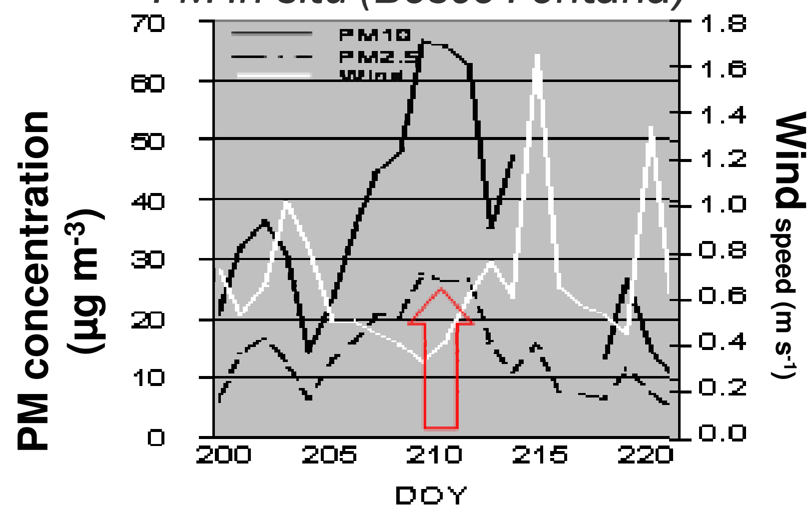




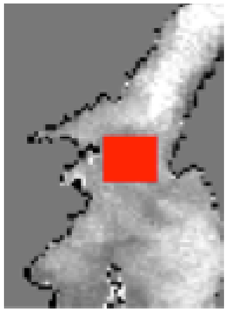
354 nm   388 nm   500 nm

OMI UV SSA: 27-29 July '05 : dust SSA increase with wavelength

PM in-situ (Bosco Fontana)

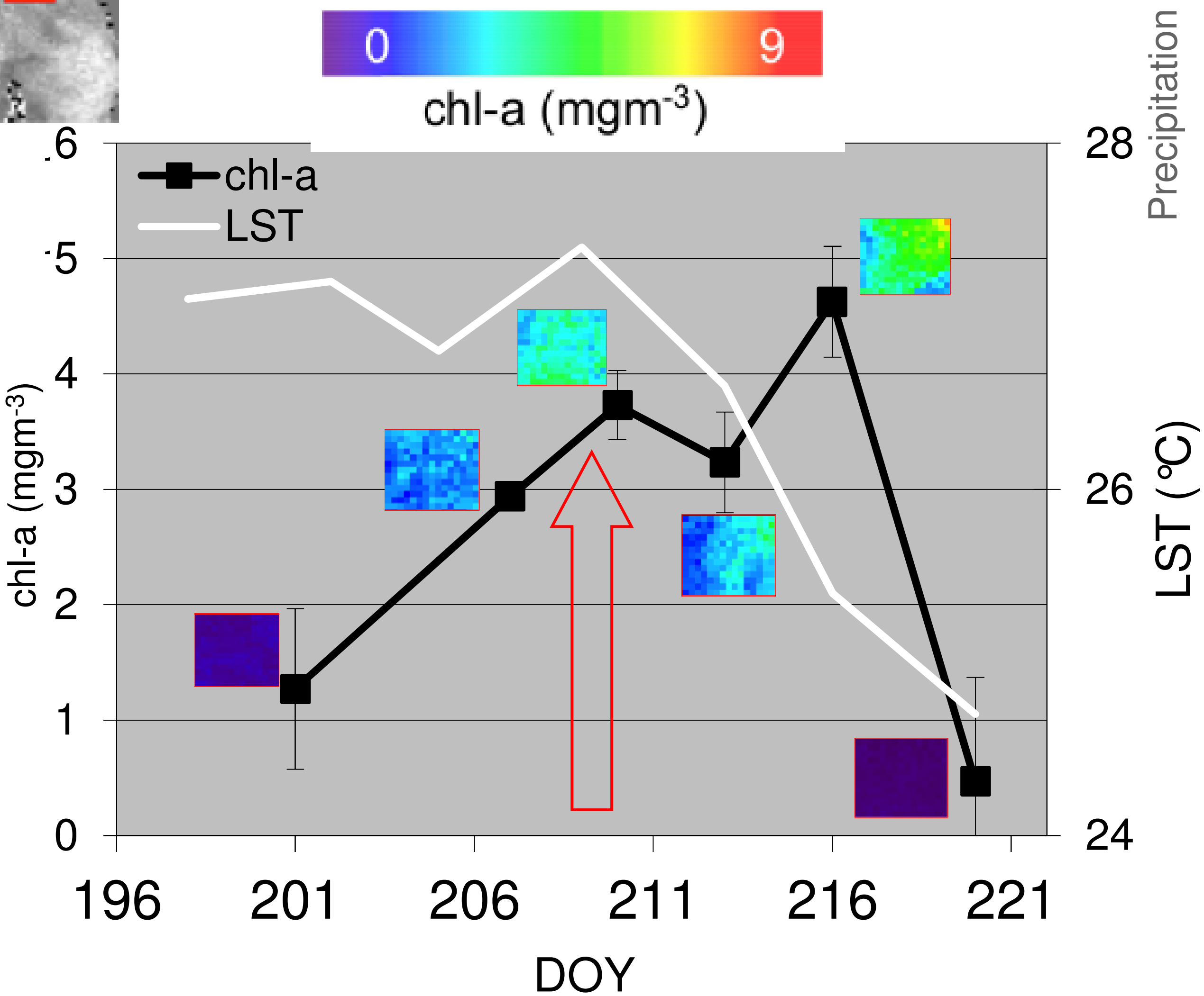


Garda Lake WQ: saharian dust event & deposition impact

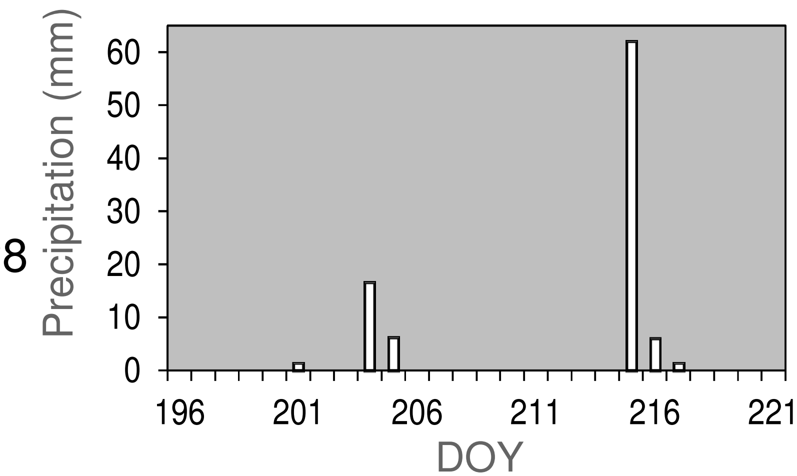


Saharan dust event 2005 July 28

Deposition impacts



precipitation



allows wet deposition and impacts water quality

Chl-a concentration: good agreement between in situ and MERIS estimation.

Chl-a increase is due to dust deposition

Direct aerosol-induced radiative forcing

- due to a variation in the content and optical properties of columnar particulate matter
- **evaluated** as **the net radiative flux change induced** at the tropopause or at the ToA (downwelling minus upwelling **F**net = **F** ↓ –**F** ↑)

→ Estimating the DARF effects on the Earth-atmosphere radiative balance

- at Top of Atmosphere **ΔF**(ToA) = **F**net – **F**∗ net

estimate of the instantaneous forcing induced at a certain time by aerosol particles

- at Bottom of Atmosphere **ΔF**BoA **= Φ**net – **Φ**∗ net

measure of the perturbation in the net flux reaching the surface induced by aerosols

- within the Atmosphere **ΔF**Atm **= ΔF**ToA – **ΔF**BoA

this term does not modify the net energy budget of the surface–atmosphere system redistributes energy internally and then affects temperature gradients and atmospheric circulation.

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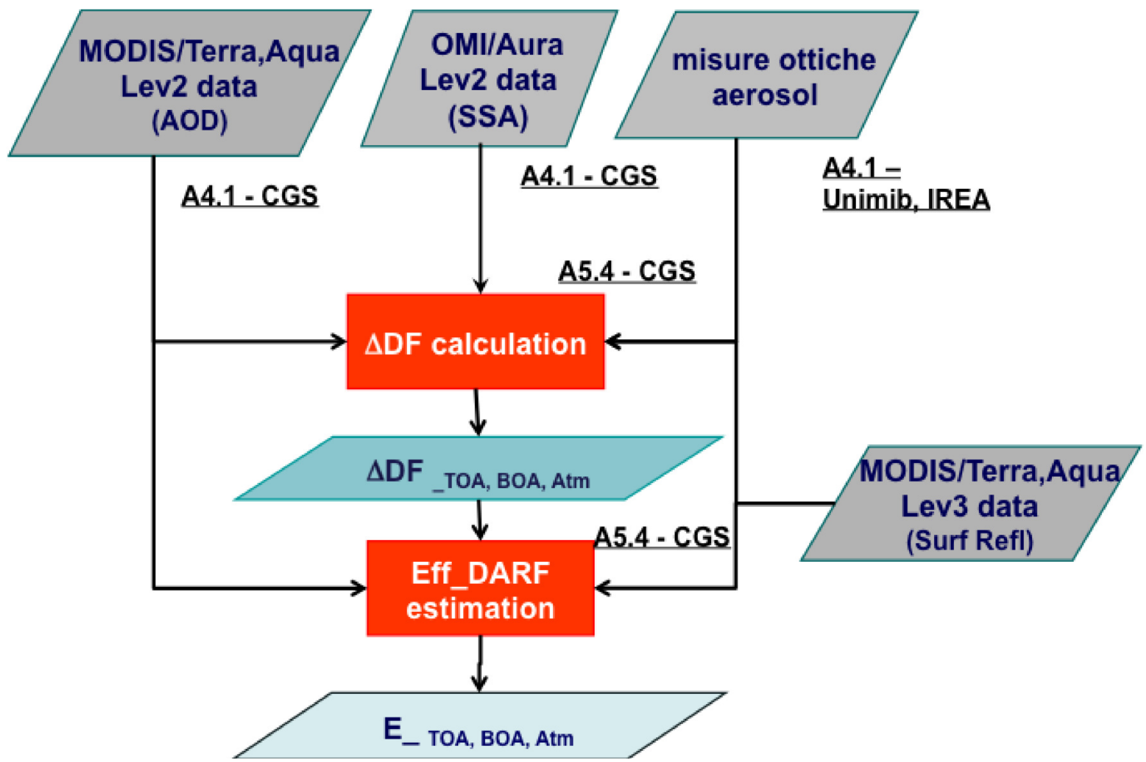
→ Estimating the DARF effects on the Earth-atmosphere radiative balance

- at Top of Atmosphere **ΔF**(ToA)

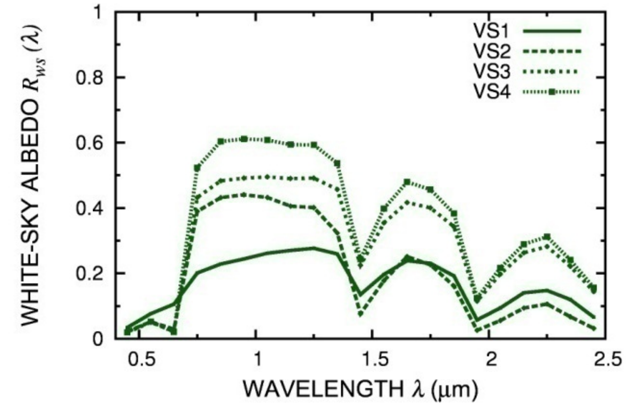
- at Bottom of Atmosphere **ΔF**BoA

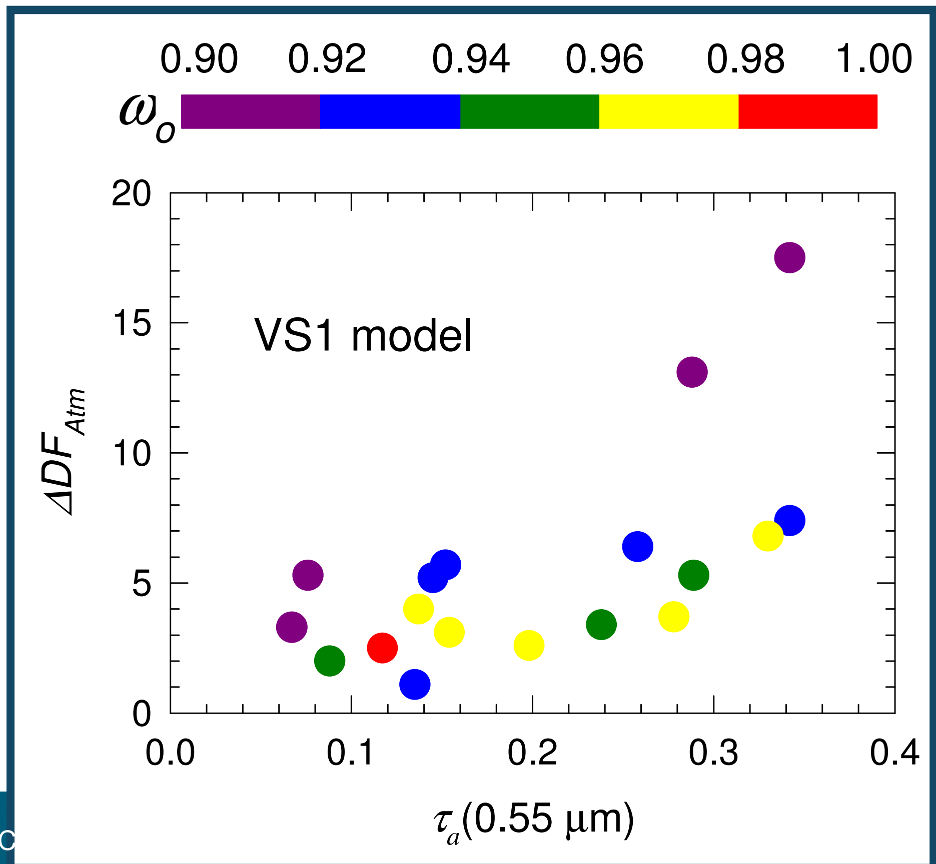
- within the Atmosphere **ΔF**Atm

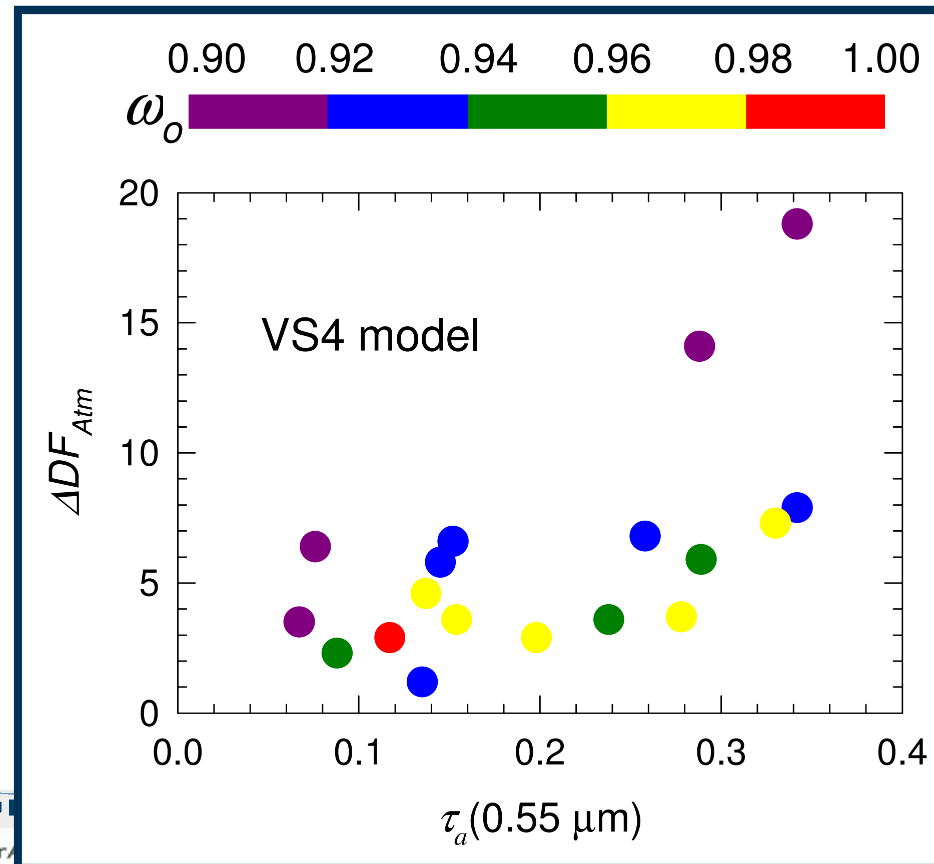


ΔFAtm

radiative transfer simulations (6S code) for different surface reflectance scenarios and for aerosol optical properties (AOD, Angstrom exponent, ssa) derived from filed measurements in the Po valley







UAV: Remotely Piloted Aircraft (RPA)

Advanced Sensors Integration:

- ➢ Customized I/R and visible sensor
- ➢ Air Quality Sensors
- ➢ Hyper spectral Sensors

350 – 1000 nm
1.5 nm FWHM
190 g

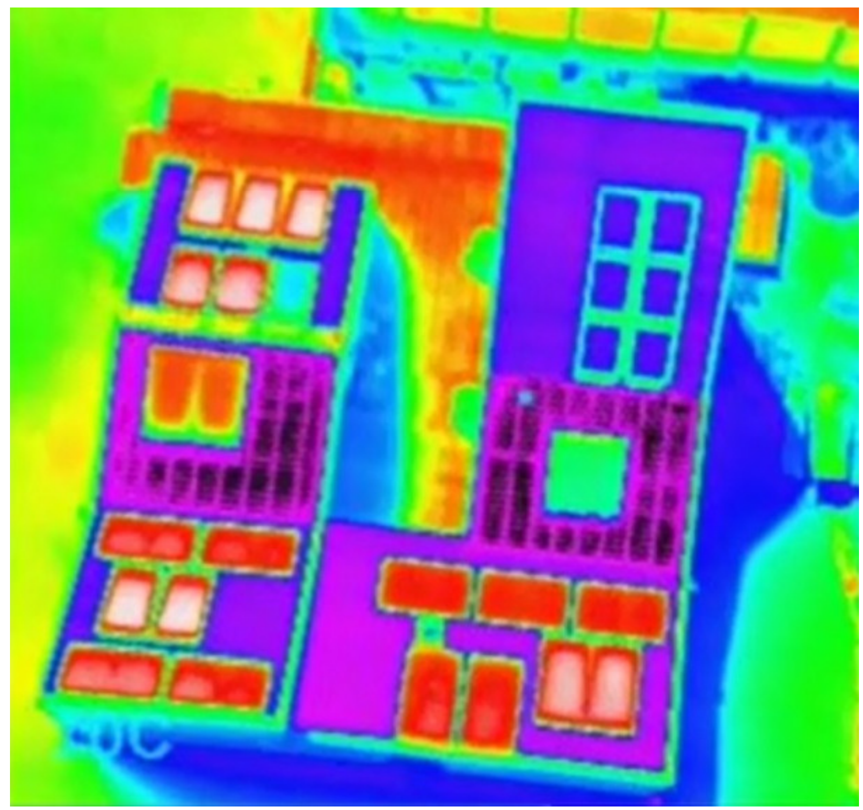
To gather experimental data of:

Energy Dispersion and Air Quality parameters

In Urban Scenarios, at High Altitude above sea level and over lake

Energy Characteristics of Buildings Monitoring

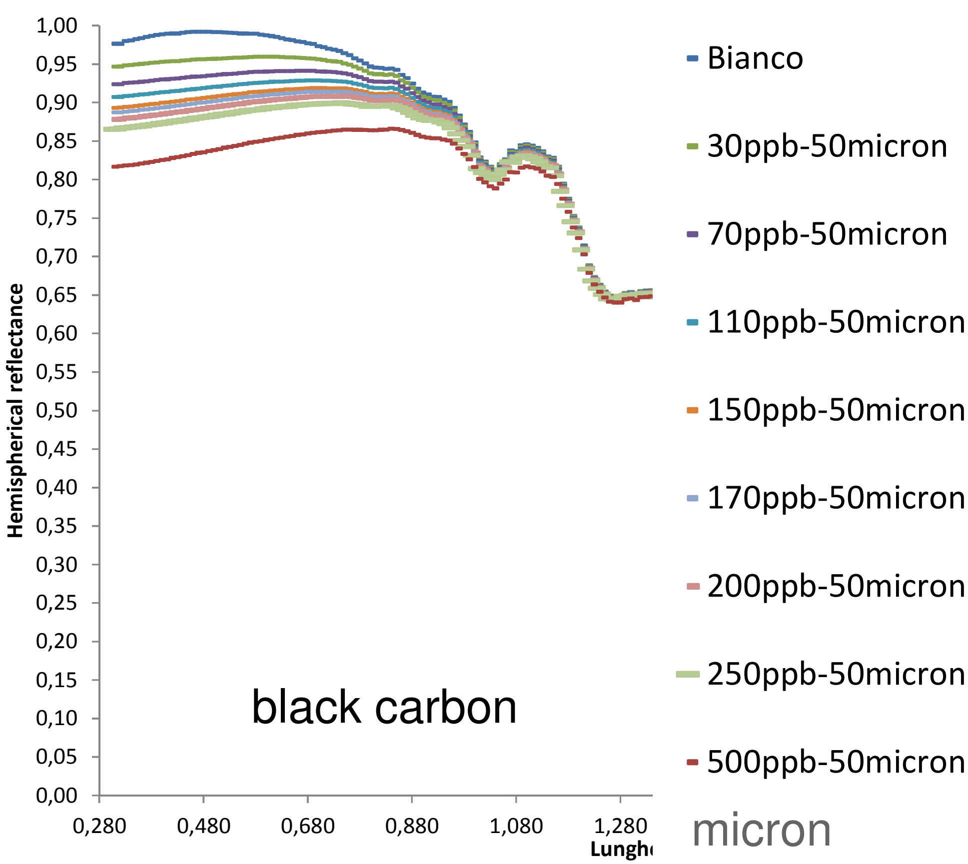
experimental data of **Energy Dispersion** in Urban Scenarios

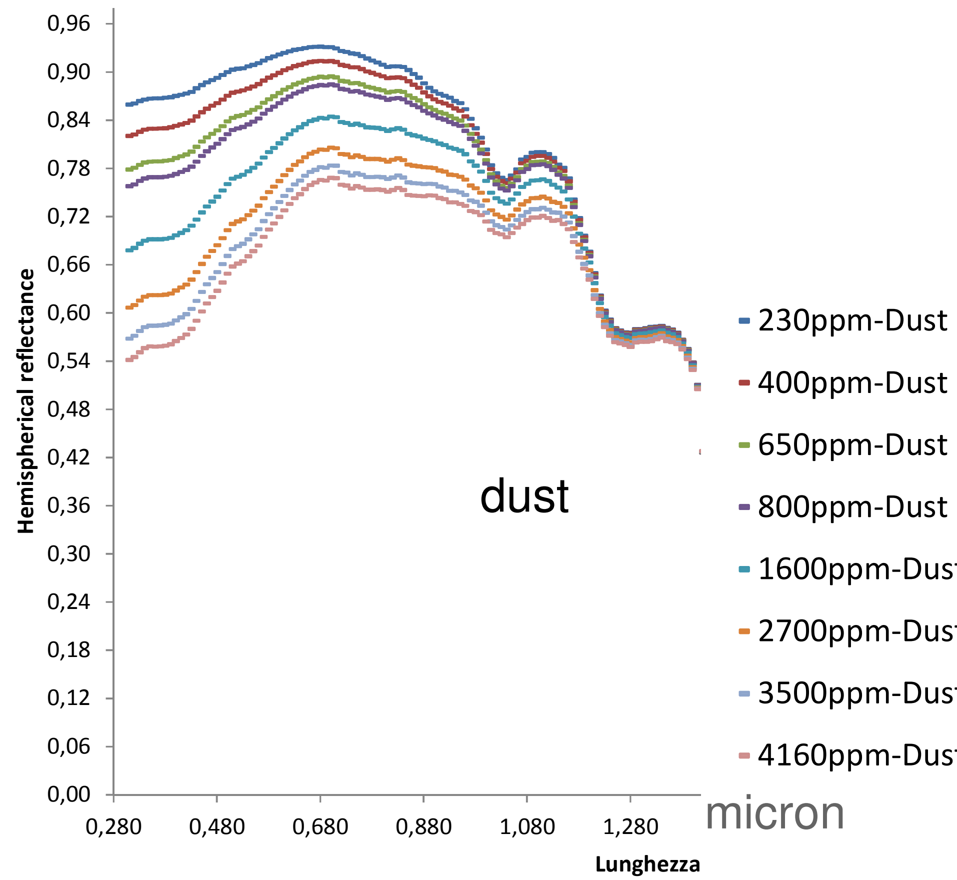


See also the Environmental & Sustainable session (Branka Cuca talk)

Variation in snow reflectance due to air pollutants deposition

Spectral (UV-VIS-NIR) behaviour of snow at changing surface impurities (RTM simulations with SNICAR model, *Flanner et al., 2007*)





Next satellites

future EO satellite sensors	PURPOSE
VIIRS / SUOMI-NPP (JPSS-1,-2)	multi-purposes imagery: atmosphere, land, ocean
22 channel VIS/IR radiometer imager, MODIS heritage Spatial res 275 m – 750 m at s.s.p Flying on SUOMI-NPP, expected lifetime up to 2029 on JPSS	
TROPOMI / Sentinel 5P	atmopsheric chemistry: trace gases and aerosol
UV/VIS grating spectrometer, OMI heritage Spatial res 7km at s.s.p Expected lifetime 2015-2021	
OLCI/ Sentinel-3A, 3B	ocean colour, vegetation, aerosol
21 channel VIS/NIR optical imager, MERIS heritage Spatial res 300 m Expected lifetime 2014-2022	
SLSTR / Sentinel-3A,3B	multi-purpose imagery: aerosol, clouds, and surface temperature
9 channel VIS/IR optical imager, AATSR heritage Spatial res 0.5 km, 1 km for TIR Expected lifetime 2014-2022	
UVN / Sentinel-4	frequent observation of trace gases and aerosol
UV VIS NIR grating spectrometer, OMI heritage Spatial res < 8km Expected lifetime 2021-2029 on board MTG-S1	

Conclusions and perspectives

- PM and NO2 satellite-based concentrations maps will be improved in terms of spatial resolution, 2 km and 6 km respectively.
- Water quality variability can be also conditioning by air quality and other factors (LST, water and atmospheric circulation, meteorological factor). The installation at Sirminione of a CIMEL sunphotometer will bring new information on dust deposition and water parameters
- The exploitation of RPA system will be demonstrated in different scenarios (urban, over lake, and at high altitude over not populated areas - snow-ice).

- In the future, algorithms tested in the frame of SINOPIAE project can be improved using new Sentinel satellites (mainly S3, S5P, S4)

Sinopiae will be a modular prototype monitoring system of environmental indicators. We know that a sufficient "condition" to well foreseen and then well mitigate the climate change effects is not handy.
Surely, the improvement of the observation capabilities, using independ sources of data, for better monitoring these effect is a necessary "condition" to better address forecasting system and, then, to decide for proper mitigation actions.

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THANK YOU FOR YOUR ATTENTION!

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