European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs Meeting, Belgrade, 13 - 14 October 2015

organized by VINCA Institute and co-organized by Public Health Institute of Belgrade

hosted by Faculty of Mechanical Engineering, University of Belgrade

Action Start date: 16/05/2012 - Action End date: 30/04/2016

Year 4: 1 July 2015 - 30 April 2016 (*Ongoing Action*)

AIR-QUALITY MODELLING AT DIFFERENT SCALES

Camillo Silibello and many others

WG Member

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COST

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

COST is supported by the EU Framework Programme

European Science Foundation — ESF provides the COST Office through a European Commission contract

Scientific context and objectives in the Action

❑ Scientific context

Twofold potential for low-cost sensor technologies observations with respect to modelling:

- **The deployment of a large amount of sensors, to monitor the ambient air in urban, road traffic, rural or remote sites, permits *to evaluate the behaviour of dispersion models in different real-world situations*.**
- **The integration of model results and low-cost sensor technologies observations, by means of *data assimilation/fusion techniques*, permits to obtain more realistic air quality maps and to better estimate the exposure of population.**

❑ Objectives in the Action

ARIANET S.r.l. has developed and implemented:

- ***different modelling systems* that allow to investigate the processes affecting the air quality *from the local (street canyons) to the regional scale*.**
- ***QualeAria AQFS* (*http://www.qualearia.it/*) provides air quality forecasts over Europe and Italy. It can be used to support the planning of experimental campaigns.**

Current research activities of ARIANET

Models describing the dispersion and transport of air pollutants in the atmosphere can be distinguished on the:

✓ **spatial scale**

- global;
- regional-to-continental;

} ***Macroscale (characteristic lengths exceeding 1,000 km):*** *air flow is mainly associated with synoptic phenomena*

- local-to-regional;

} ***Mesoscale (characteristic lengths between 1 and 1000 km):*** *air flow depends on topographic (land/sea, mountain/valley breezes) and land use features*

- local;

} ***Microscale (characteristic lengths below 1 km):*** *air flow depends on surface characteristics (form of buildings, their orientation with regard to the wind direction,…)*

✓ **temporal scale** (episodic, long-term);

✓ **treatment of the transport equations** (Eulerian, Lagrangian) and **various processes** (chemistry, dry/wet deposition)

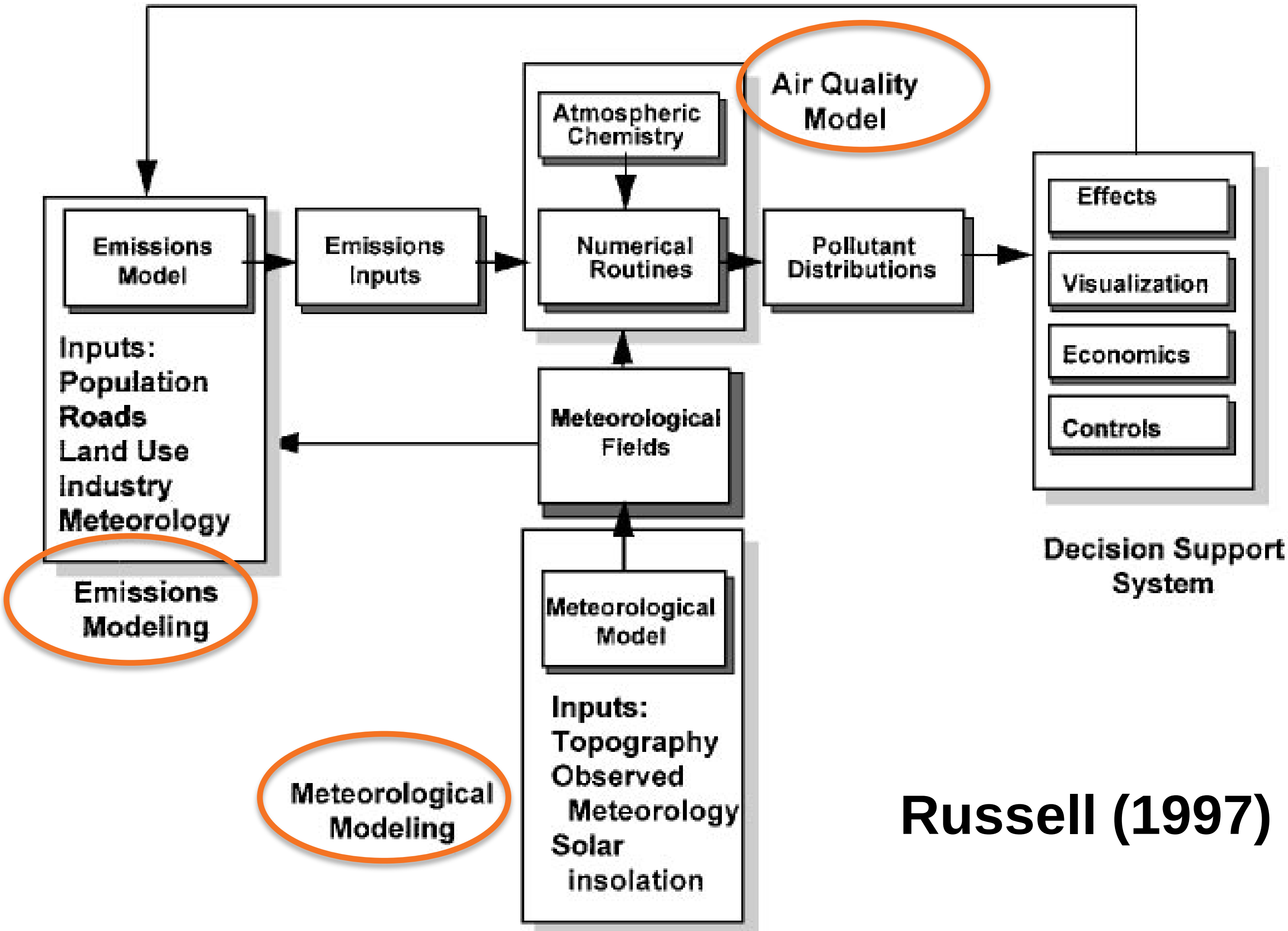
Current research activities of ARIANET

	Area of assessment		
Description	**Local/hotspot (1–1 000 m)**	**Urban/agglomerate (1–300 km)**	**Regional (25–10 000 km)**
Model type	Gaussian and non-Gaussian parameterised models Statistical models Obstacle-resolving fluid dynamical models Lagrangian particle models	Gaussian and non-Gaussian parameterised models Eulerian chemical transport models Lagrangian particle models	Eulerian chemical transport models Lagrangian chemical models
Meteorology	Local meteorological measurements Obstacle-resolving fluid dynamical models Diagnostic wind field models	Mesoscale meteorological models Localised meteorological measurements Diagnostic wind field models	Synoptic/mesoscale meteorological models
Chemistry	Parameterised or none	Ranging from none to comprehensive, depending on application	Comprehensive
Emission modelling	Bottom-up traffic emissions Source-specific emissions	Bottom-up and/or top-down emission modelling Emission process models	Top-down emission modelling Emission process models

The application of models under the European Union's Air Quality Directive: A technical reference guide. EEA Technical report No 10/2011.

Current research activities of ARIANET

Integrated modelling for air quality assessment

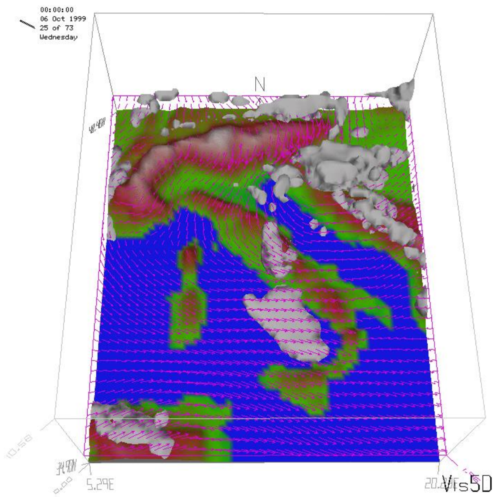


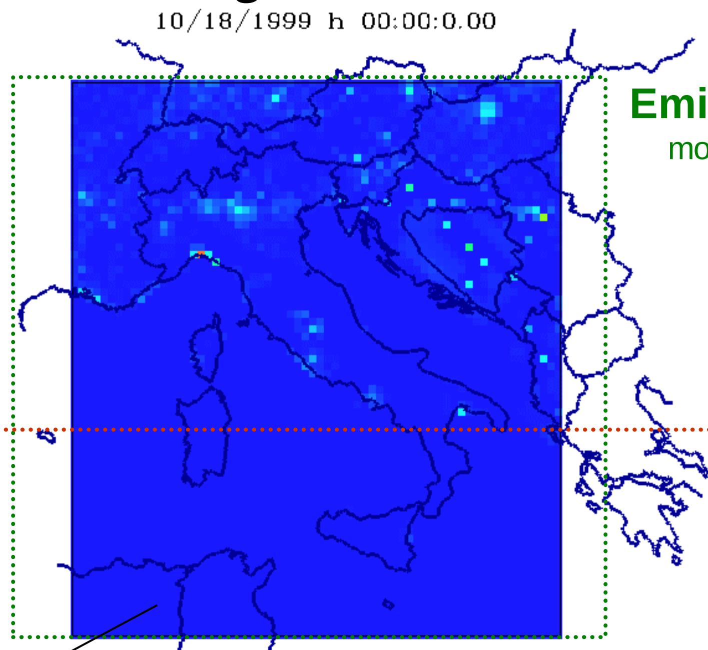
Russell (1997)

Current research activities of ARIANET

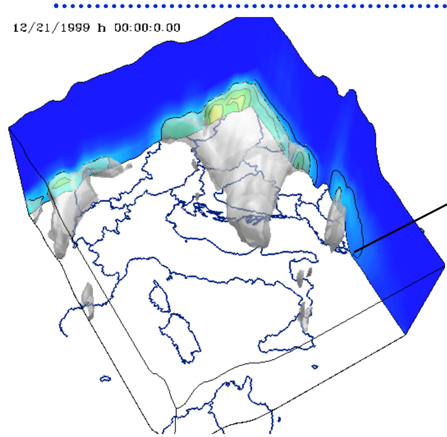
Air quality modelling

Meteorological
Modelling



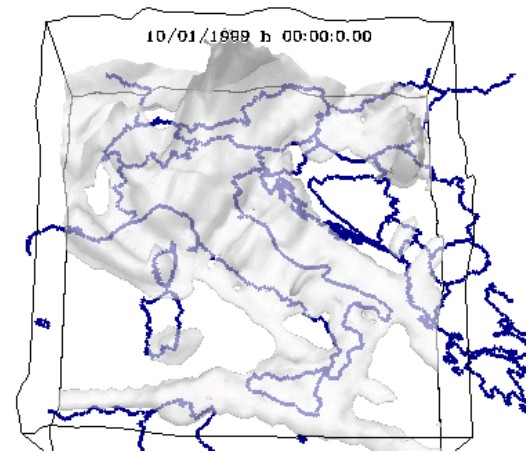


Emissions
modelling



AQ MODEL

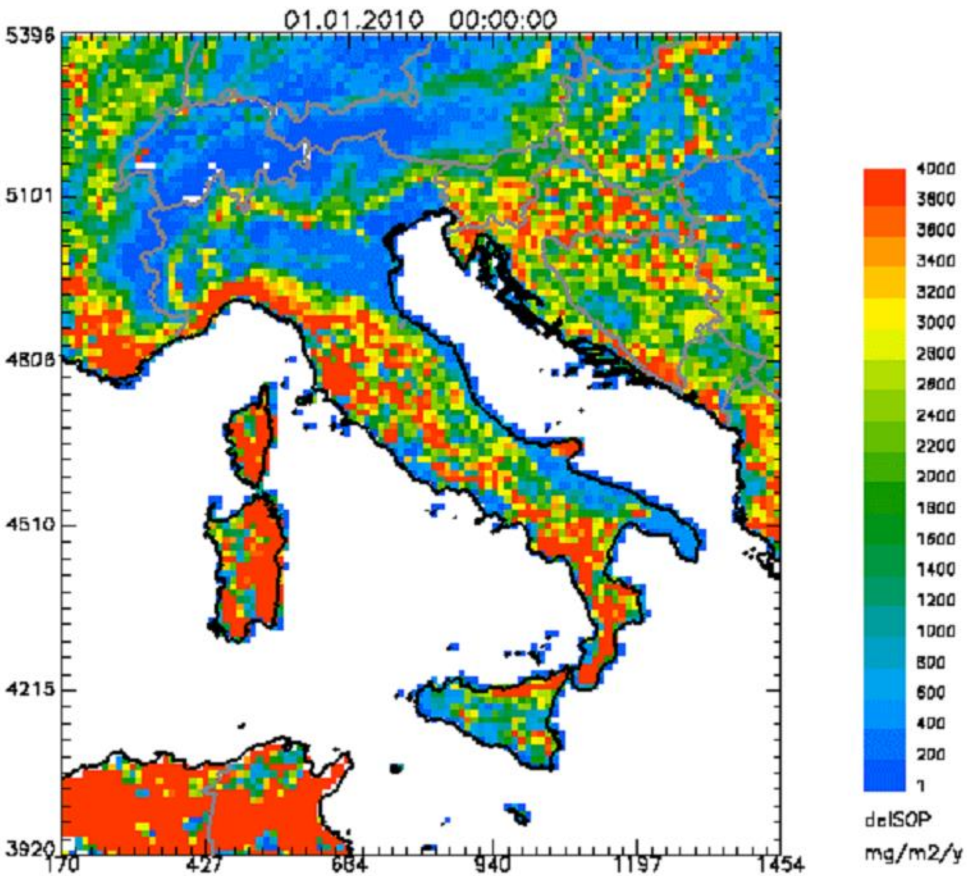
Visualization



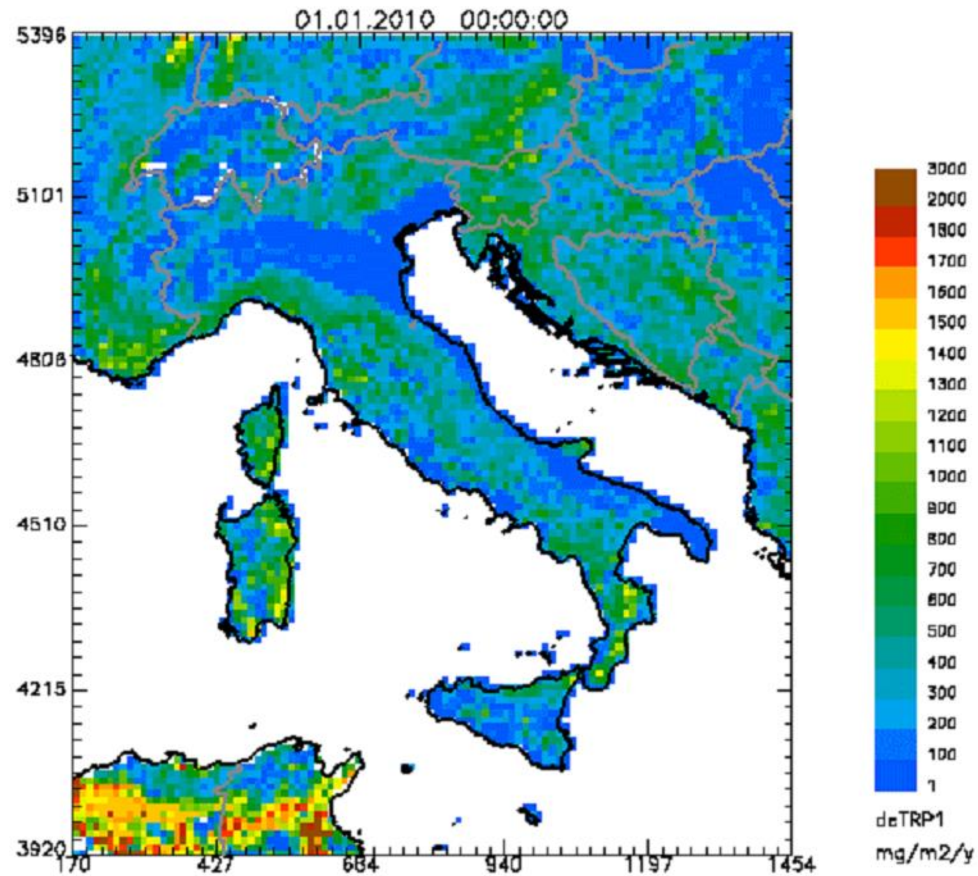
Boundary conditions

Current research activities of ARIANET

Natural emissions for CTM applications: VOCs from vegetation



Yearly Isoprene emission rates [mg m^{-2} y^{-1}]

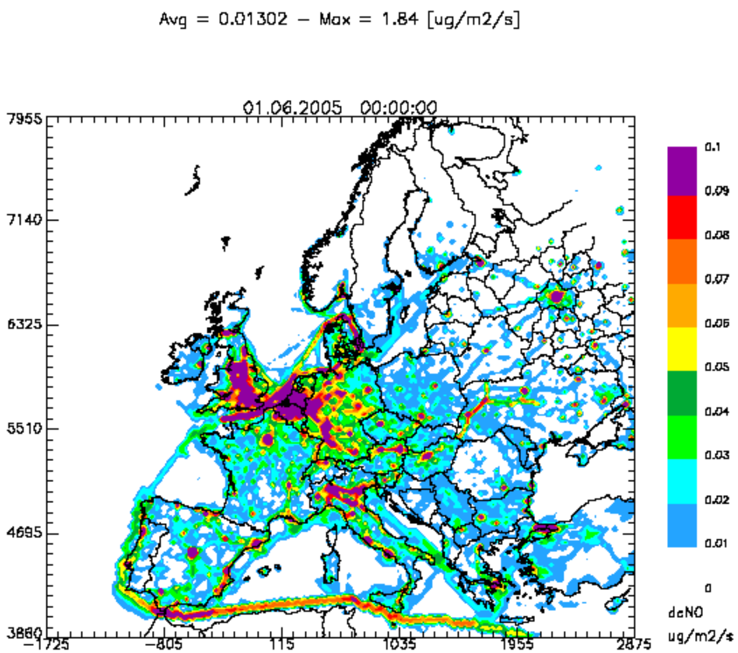


Yearly Monoterpenes emission rates [mg m^{-2} y^{-1}]

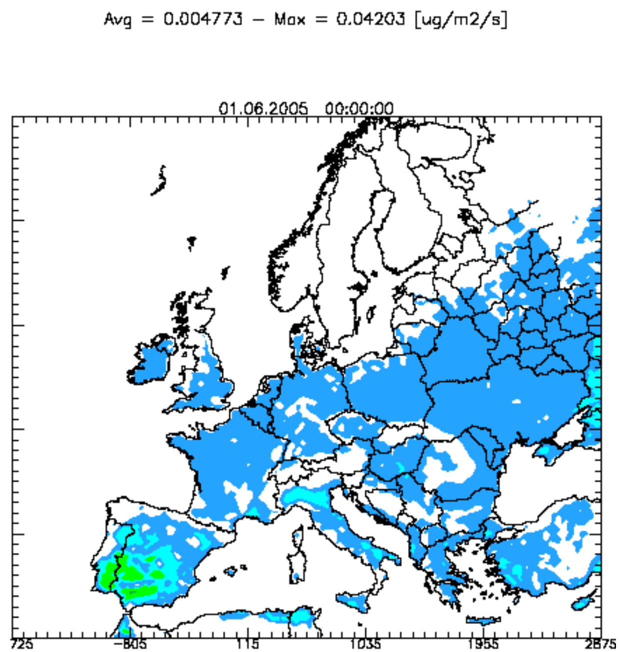
Current research activities of ARIANET

Natural emissions for CTM applications

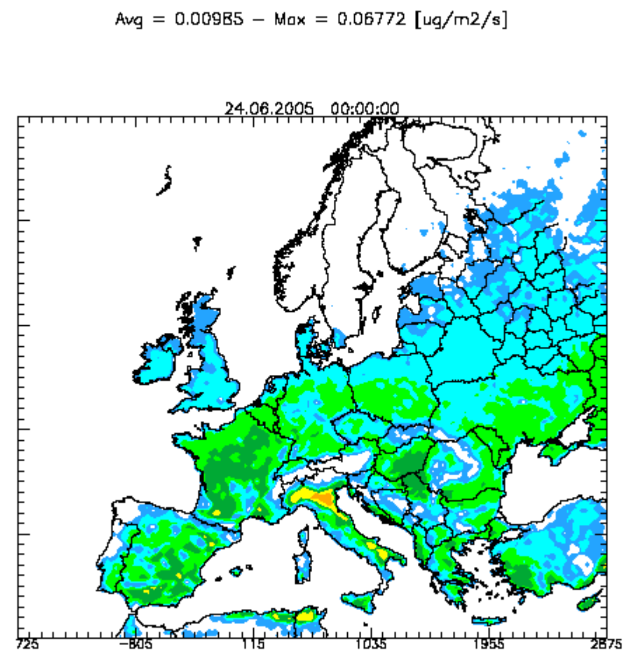
NO emission rates from soils (1 week average)



Anthropogenic



Natural, Spring

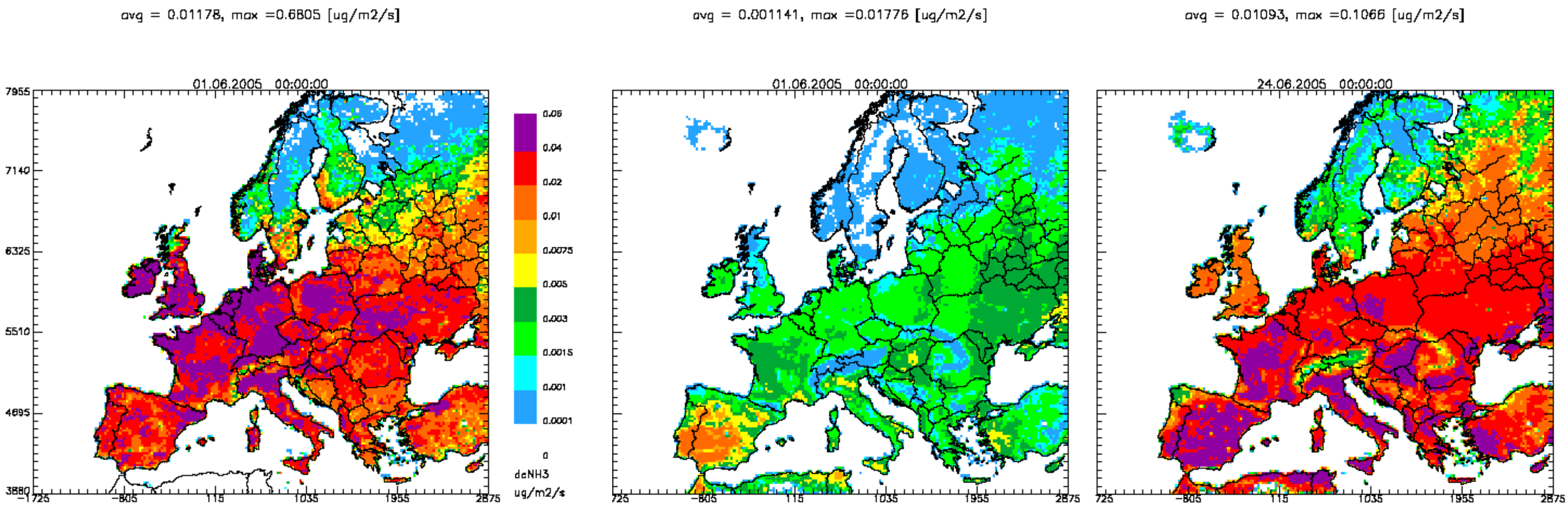


Natural, Summer

Current research activities of ARIANET

Natural emissions for CTM applications

NH_3 emission rates from vegetation and soils (1 week average)



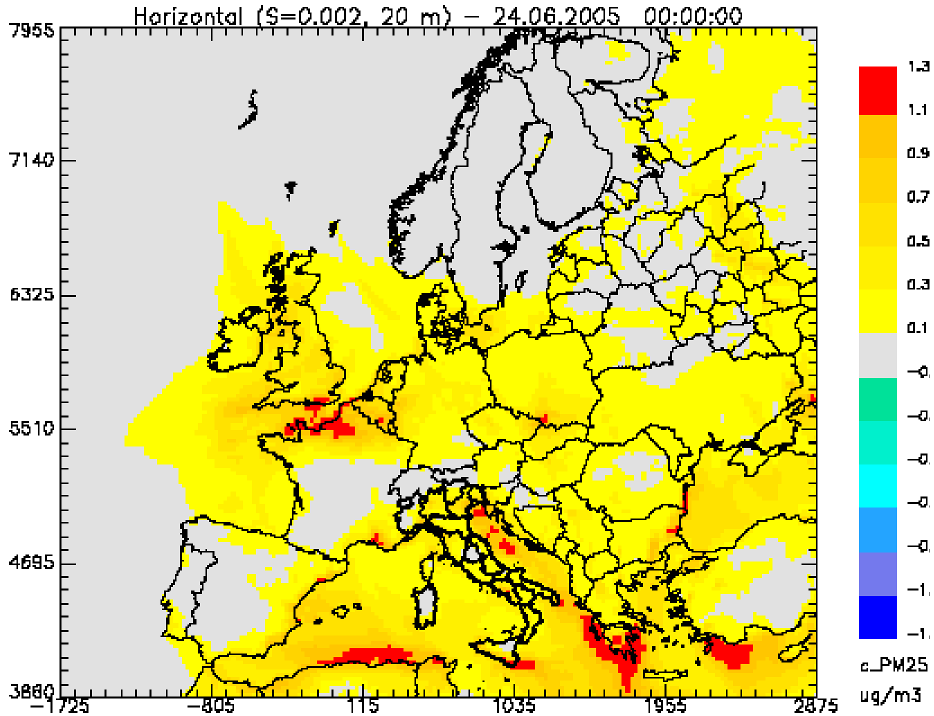
Anthropogenic | **Natural, Spring** | **Natural, Summer**

Current research activities of ARIANET

Natural emissions for CTM applications

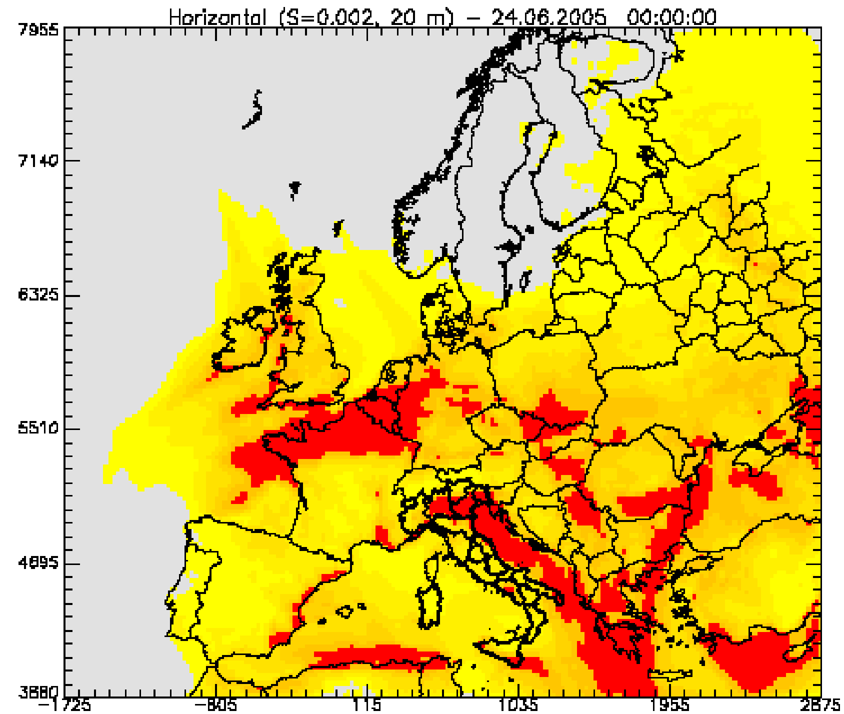
Impact on $PM_{2.5}$ concentrations (1 week average)

Min = −0.0007119 − Max = 2.537 [ug/m3]



NH_3 natural emissions only

Min = −8.34400e−006 − Max = 4.108 [ug/m3]

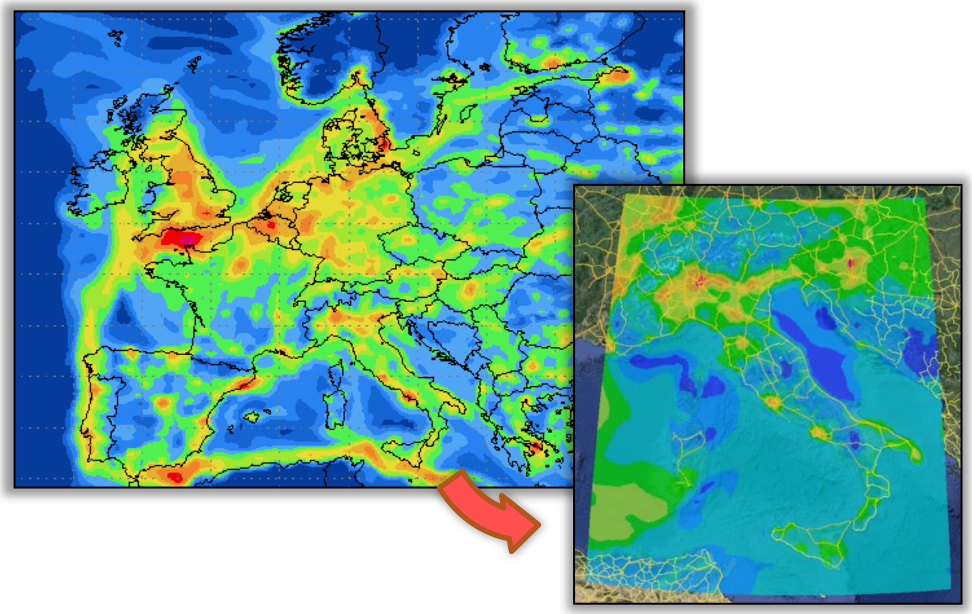


NH_3 and NO natural emissions

Current research activities of ARIANET

Chemical Weather Forecast over Europe and Italy (QualeAria)

- **Meteorological downscaling & air quality forecast**
- **Built from experience gained in: national project MINNI, EU research projects FUMAPEX and MEGAPOLI, COST Action ES0602-Chemical Weather**
- **Operational at ARIANET since 2007, continuously maintained and improved**
- **Results available on the web: http://www.qualearia.it/**
- **Daily data provided as boundary conditions to regional/urban forecast systems**
- **Accumulated data bases for off-line studies**

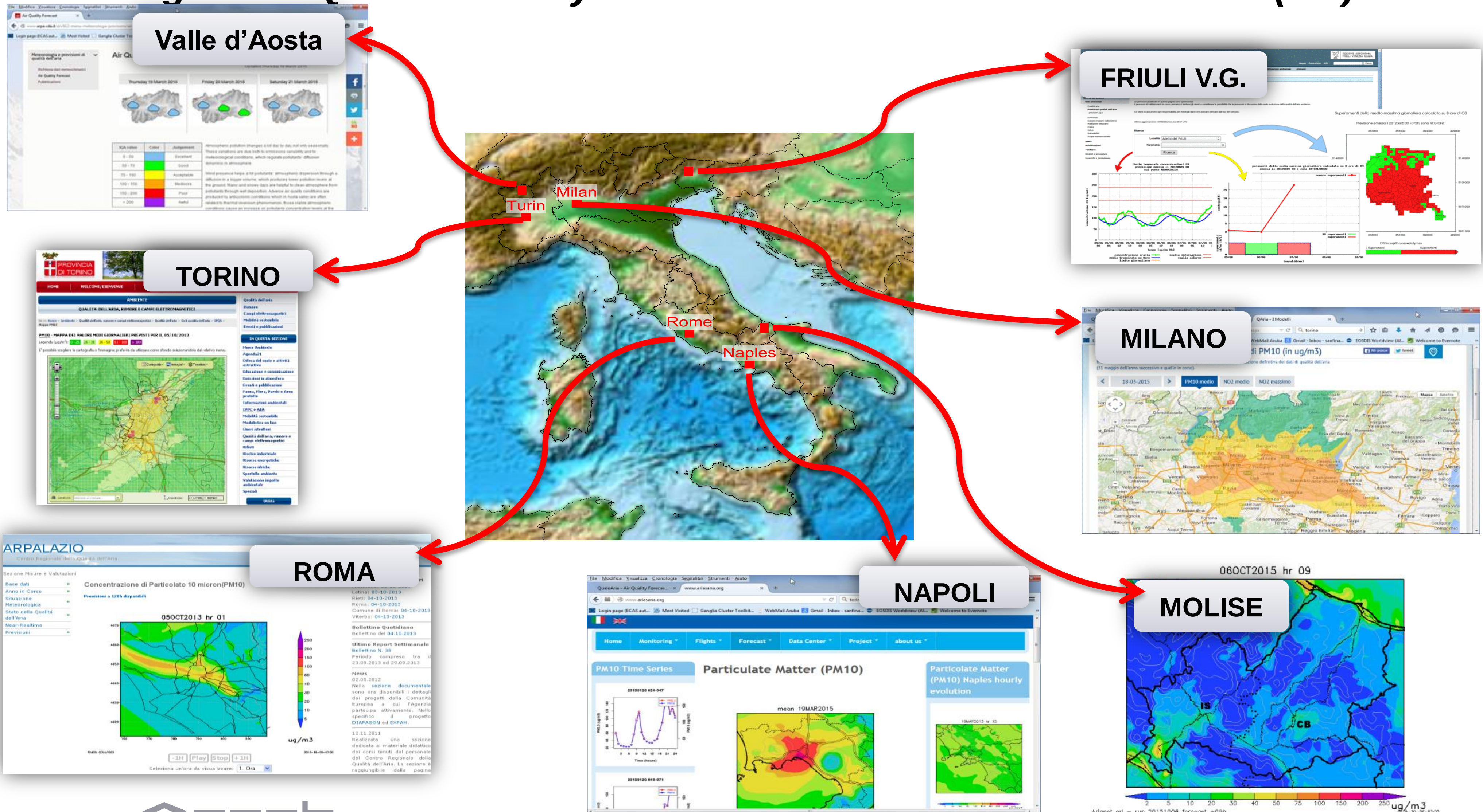


5 days forecast
2 nested domains **48 km** and **12 km** horizontal resolution (two-way nesting) **16 vertical layers** up to 10000 m.

Boundary conditions:
GFS, **United States weather service** (NCEP)
Global Air Quality forecast MACC-Copernicus (through *Forschungszentrum Jülich* data server)

Current research activities of ARIANET

Regional AQF and NRT systems based on ARIANET tools/data (BC)



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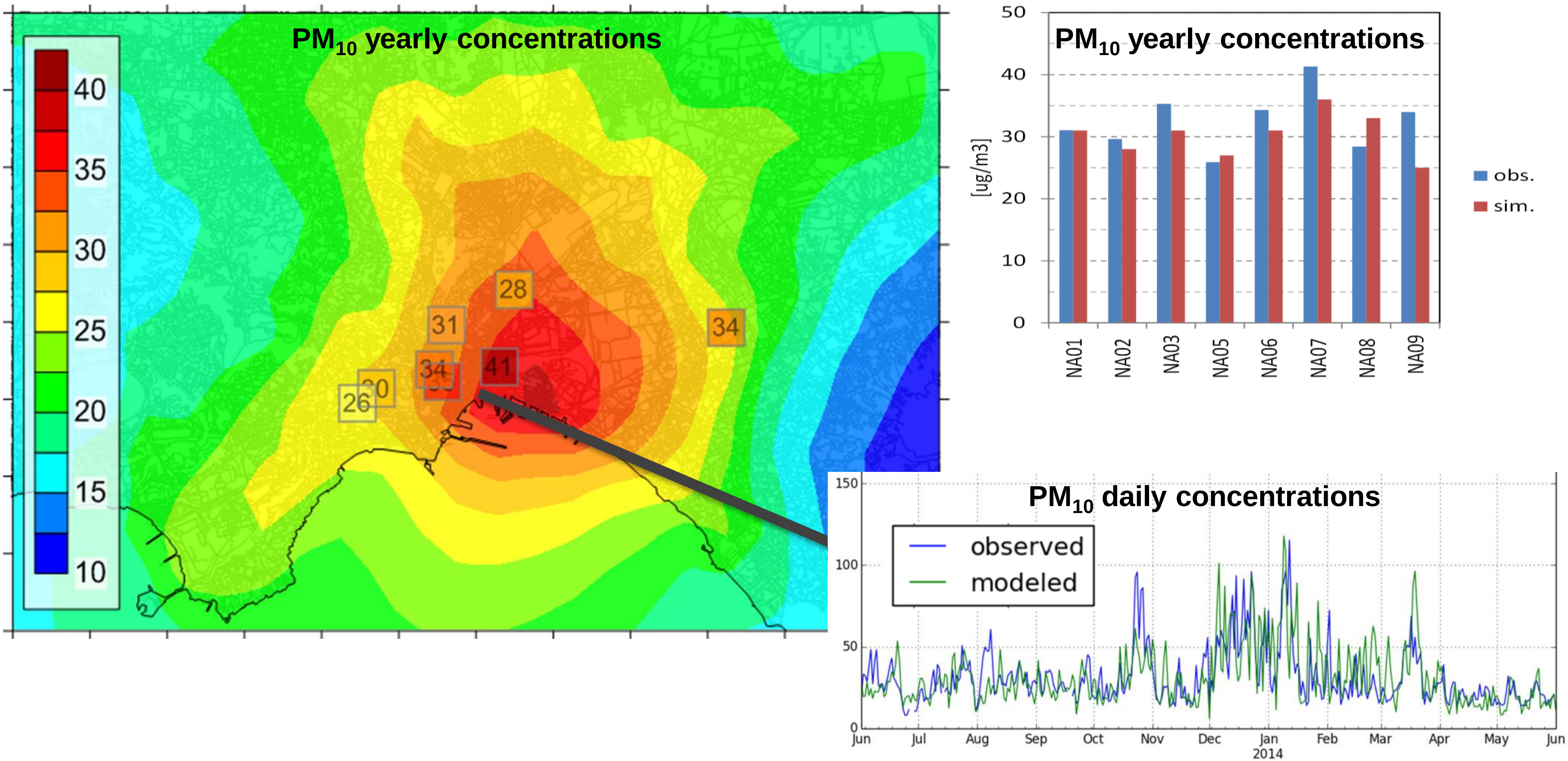
Urban/Agglomerate

Current research activities of ARIANET

Urban Air Quality assessment: Naples (Southern Italy) case study

Comparison of modelled and observed PM_{10} concentrations [µg/m³]



Urban/Agglomerate

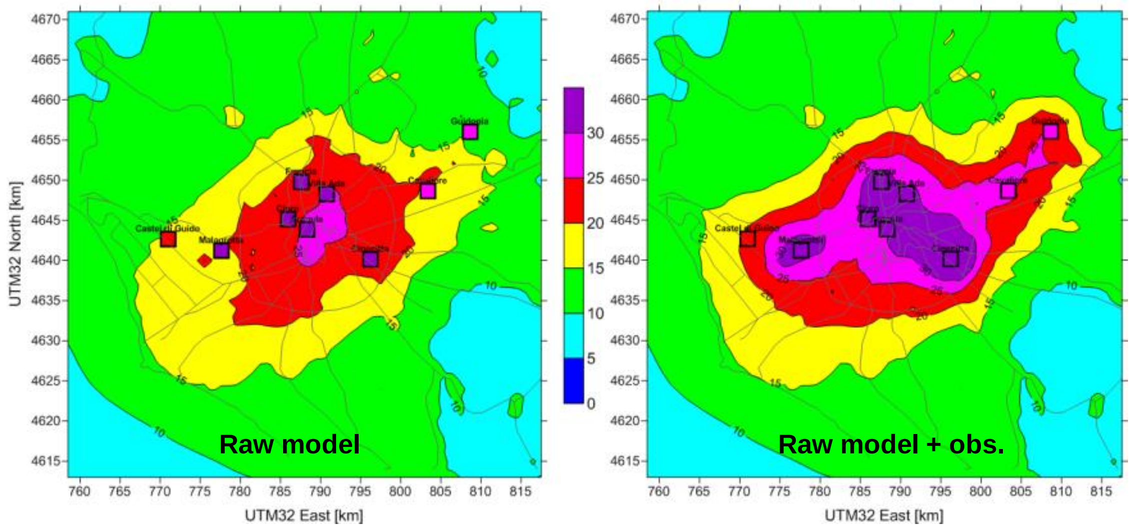
Current research activities of ARIANET

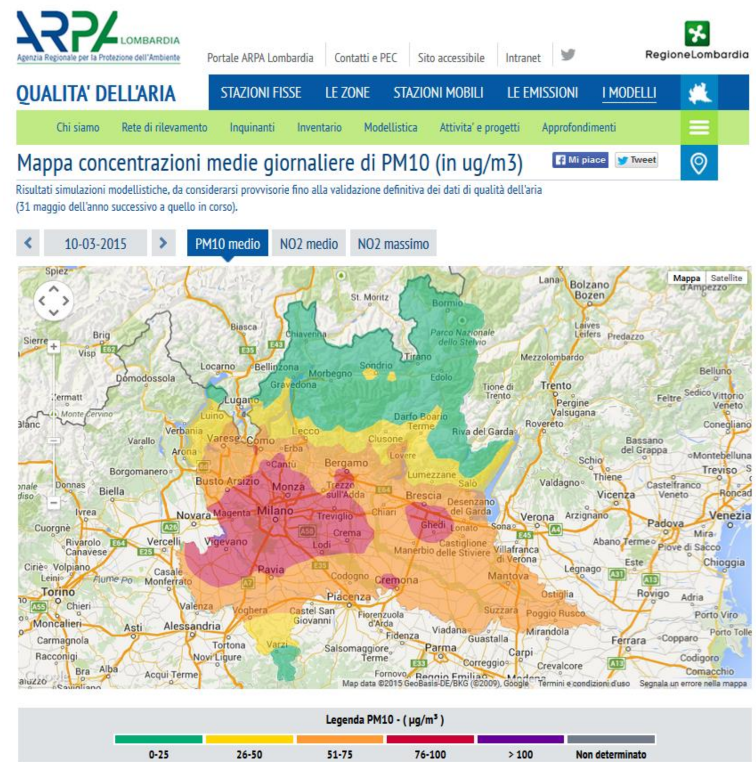
Data fusion & assimilation

The Lombardy Environmental Protection Agency uses past (yesterday) predicted concentration fields and observations to produce Near Real Time (NRT) air quality maps

Rome urban area

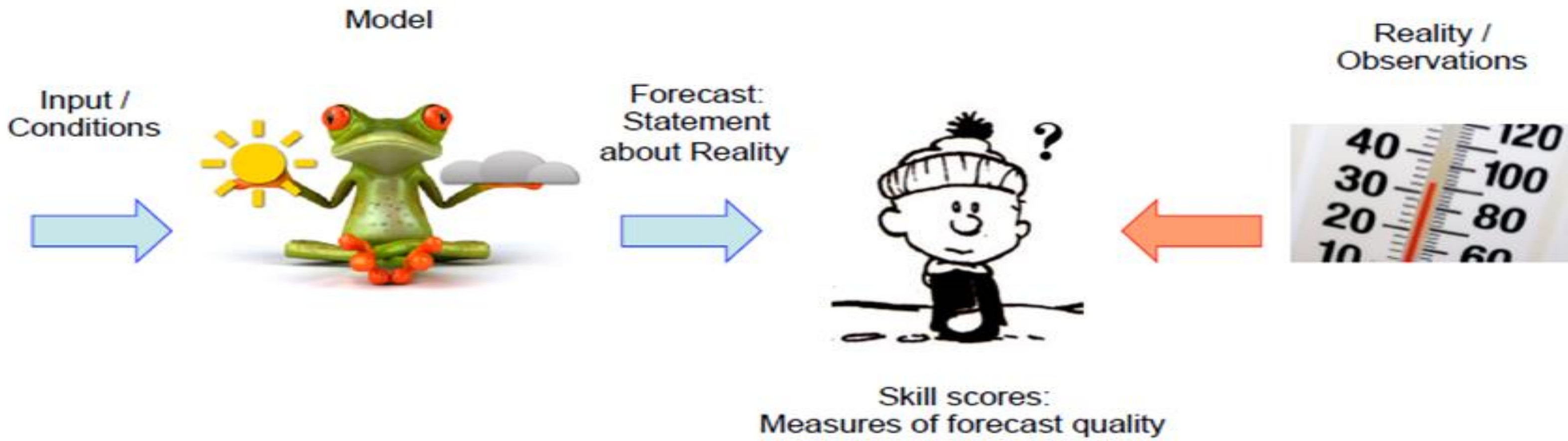
January 2012 - $PM_{2.5}$ Monthly averages [$\mu g\ m^{-3}$]

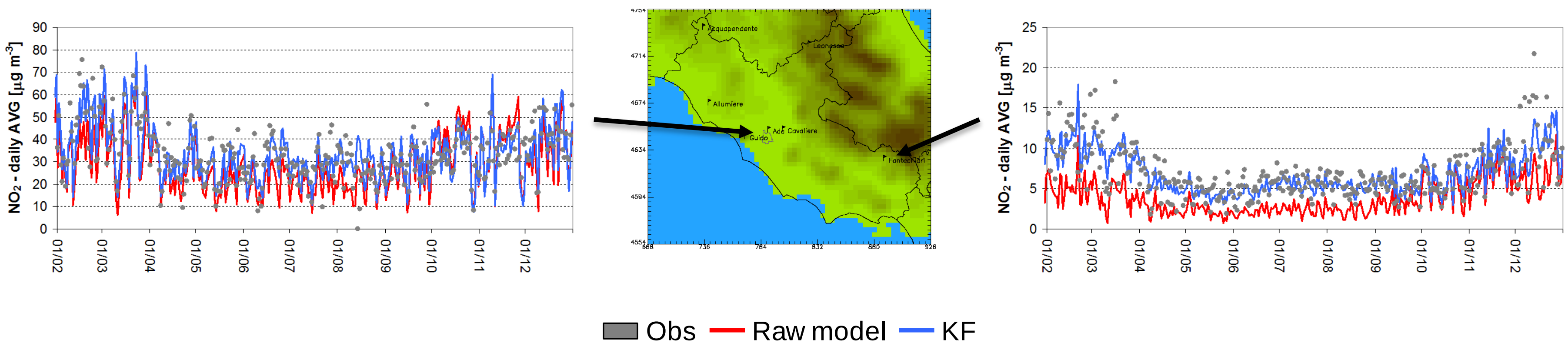




Current research activities of ARIANET

Forecast correction (Kalman filtering)

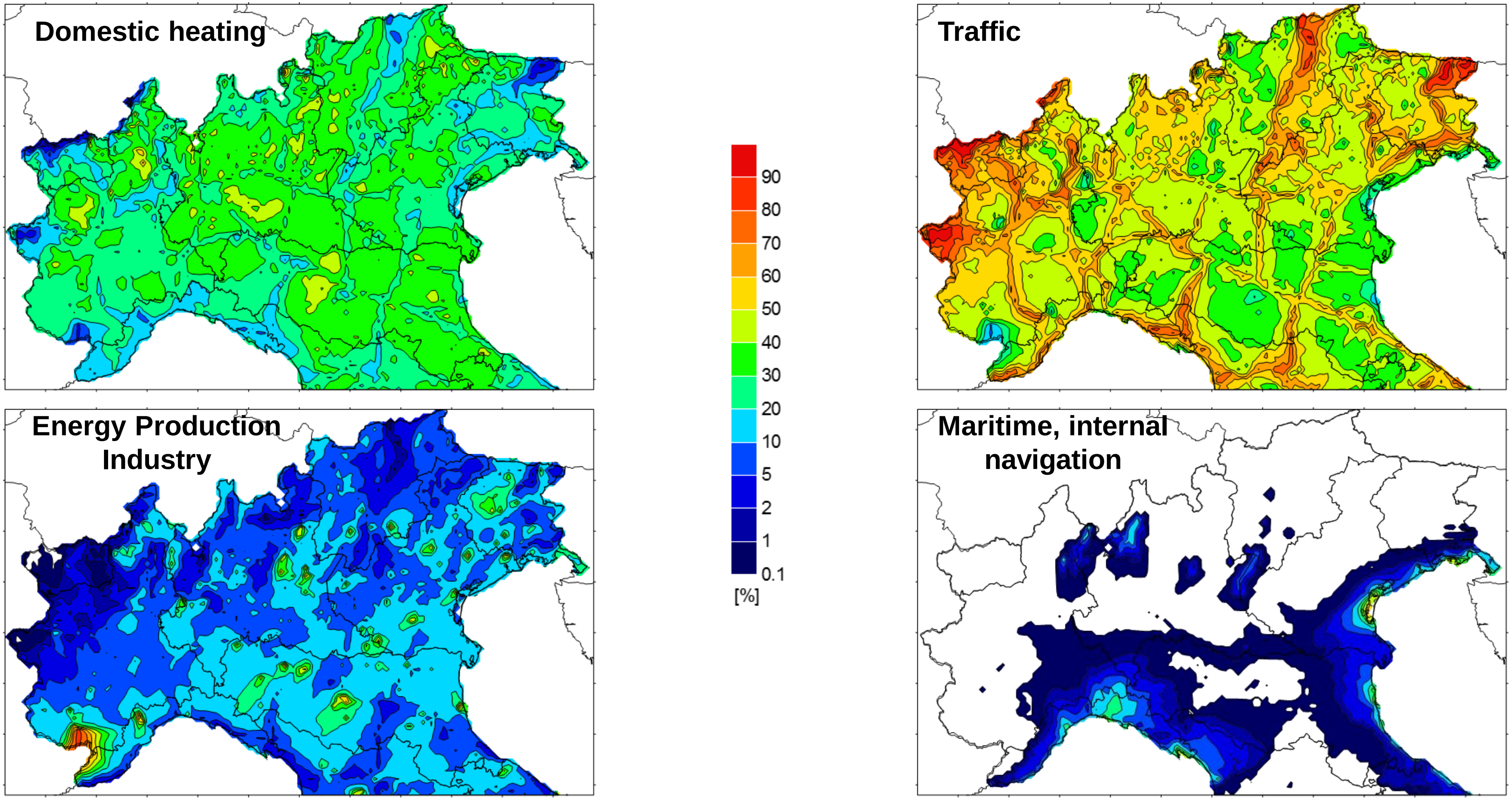




Bias-adjustment techniques, using recent past forecasts and observations, can be effectively applied to remove the systematic errors in predictions and improve the accuracy of air quality forecast systems (AQFS).

Current research activities of ARIANET

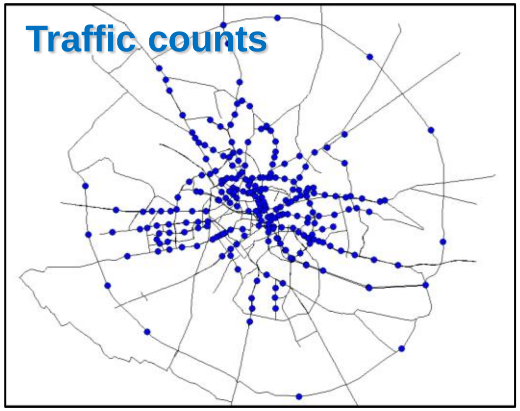
Source Apportionment: NO_2 contribution %



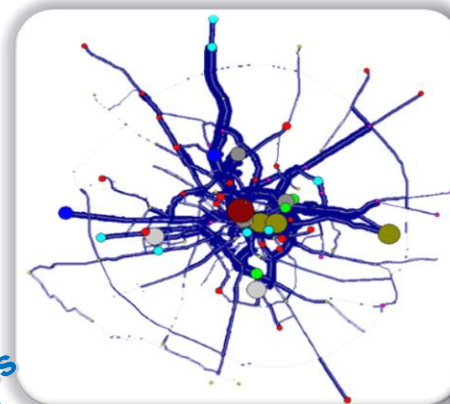
Urban/Agglomerate

Current research activities of ARIANET

Road traffic models



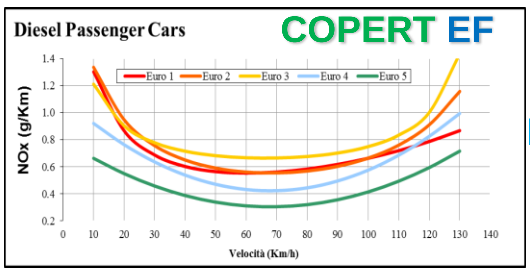
CARUSO
Traffic assignment model



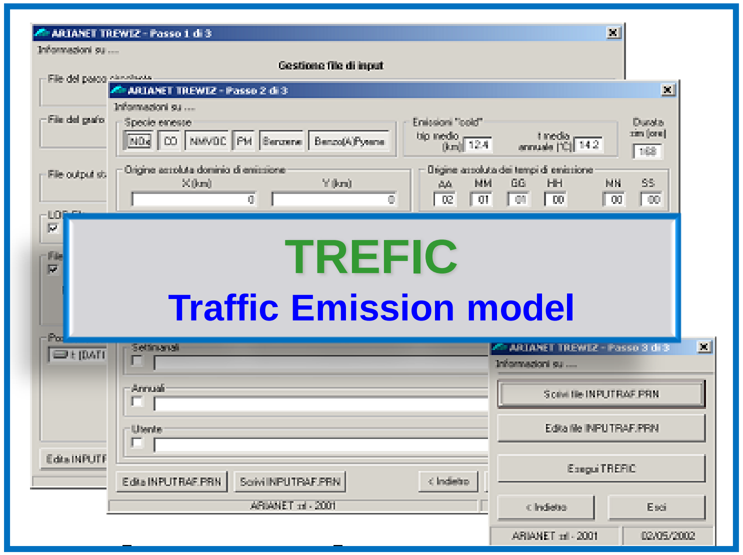
Traffic fluxes
Speed

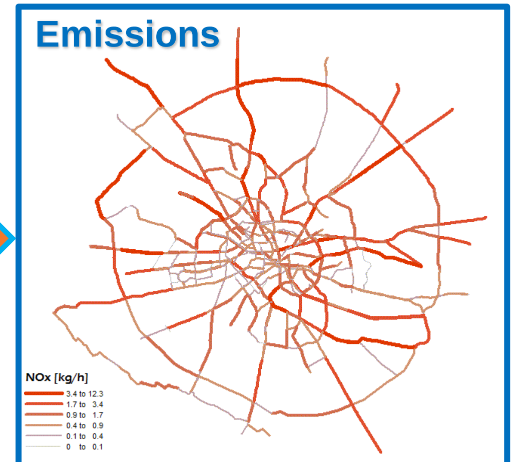
Autovetture benzina	499,466
Autovetture metano	634
Autovetture diesel	57,076
Autovetture GPL	15,147
Autocarri benzina	38,114
Autocarri metano	17
Autocarri GPL	178
Autocarri diesel	46,476
Autobus benzina	21
Autobus diesel	1,809
Motocicli benzina	38,215
Motocarri benzina	1,925
Totale veicoli immatricolati	699,078

Vehicle fleet



EF

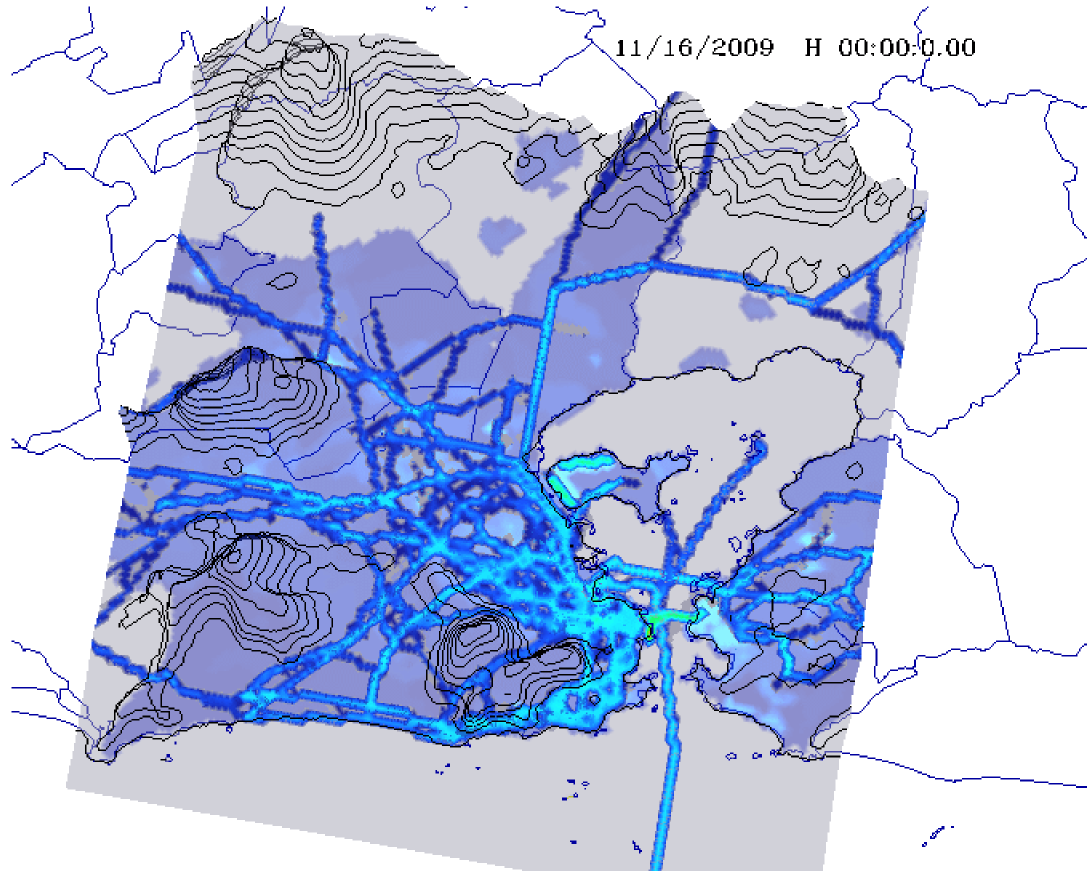




Current research activities of ARIANET

Impact Assessment: Rio de Janeiro road traffic emissions

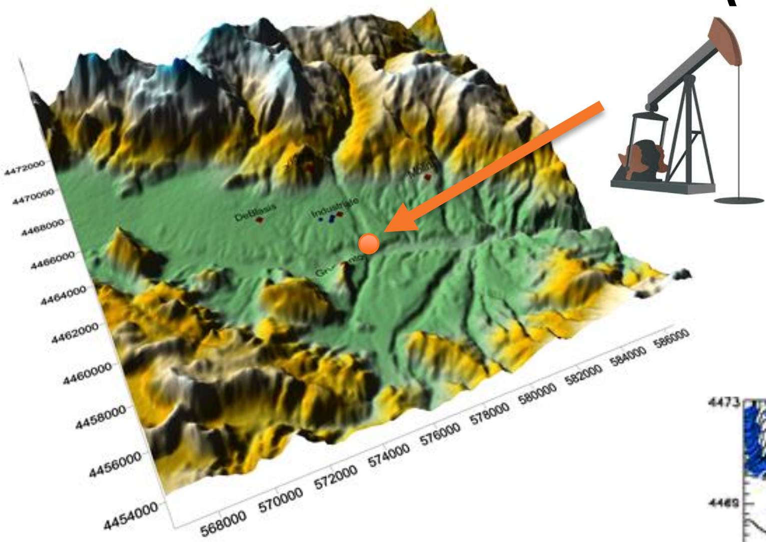
Time modulation



Urban/Agglomerate

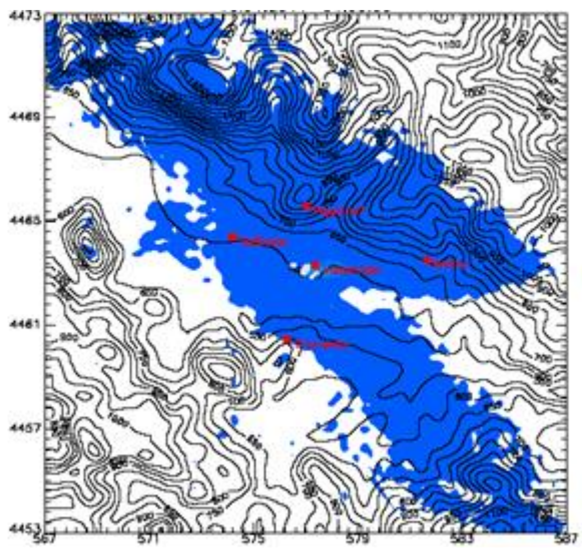
Current research activities of ARIANET

Emergency response system coupled with QualeAria (NRT and 48 h forecast)

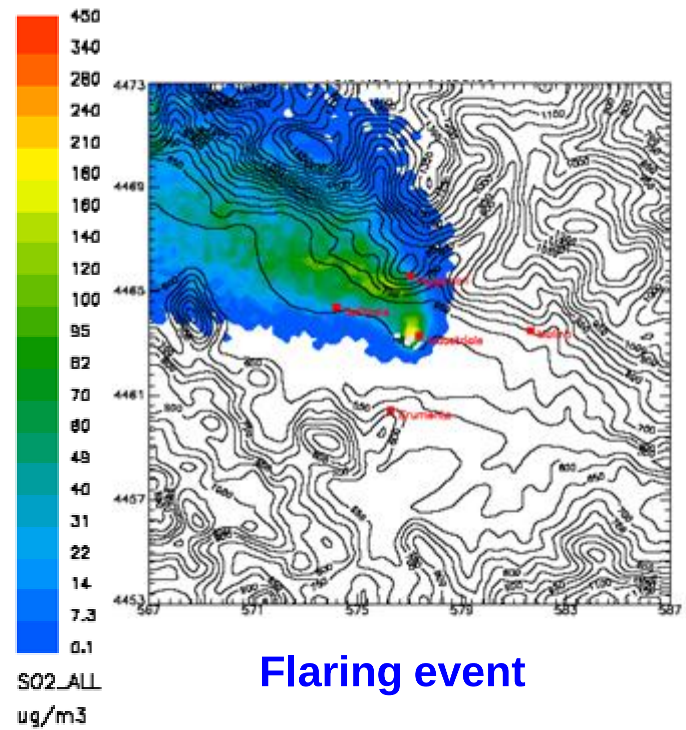


Target domain

SO_2 Maximum hourly concentrations [μg/m³]
Limit value 350 μg/m³



Normal management

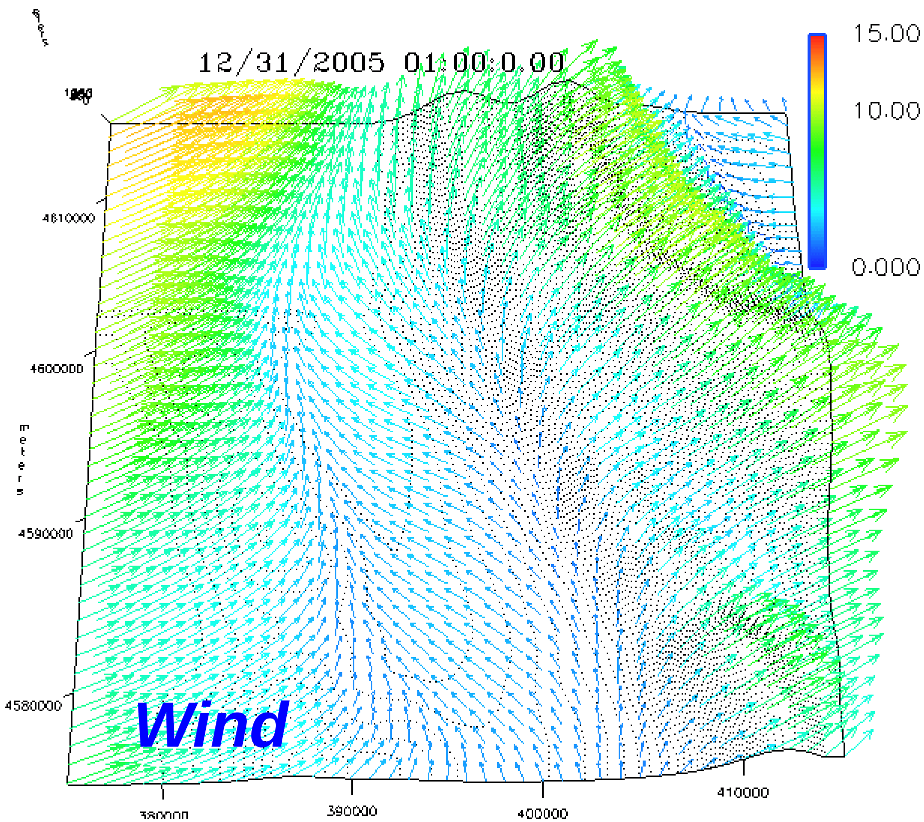


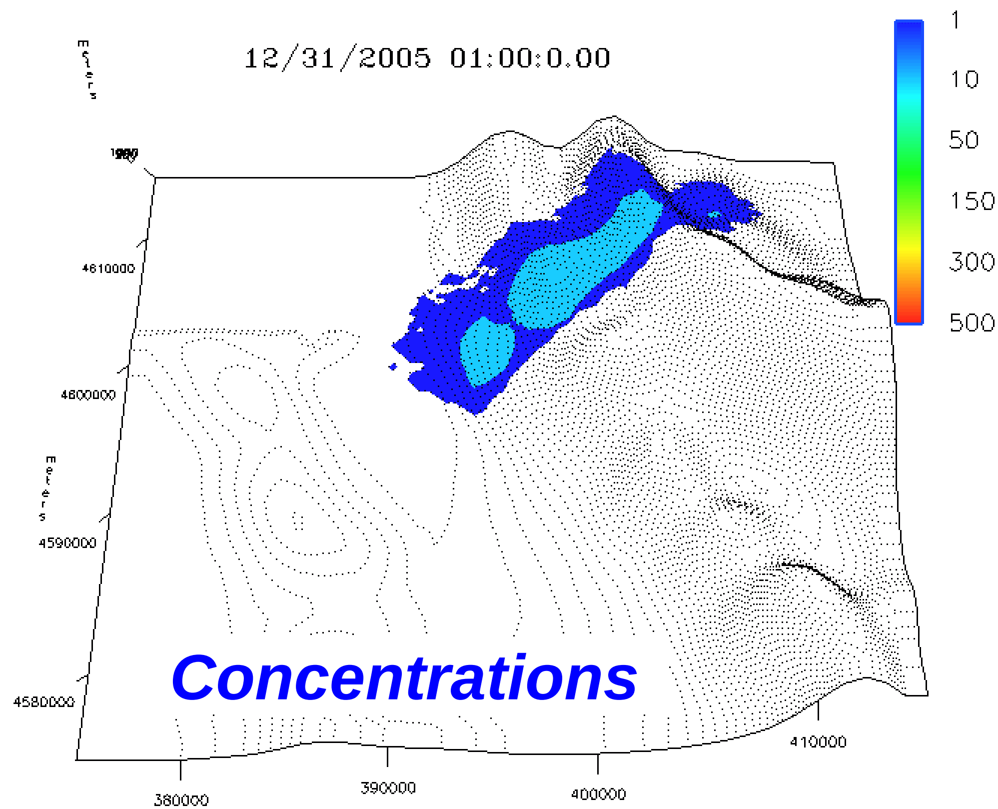
Flaring event

Local/hotspot

Current research activities of ARIANET

Impact Assessment: Fushe Kruje (Albania) cement factory expansion

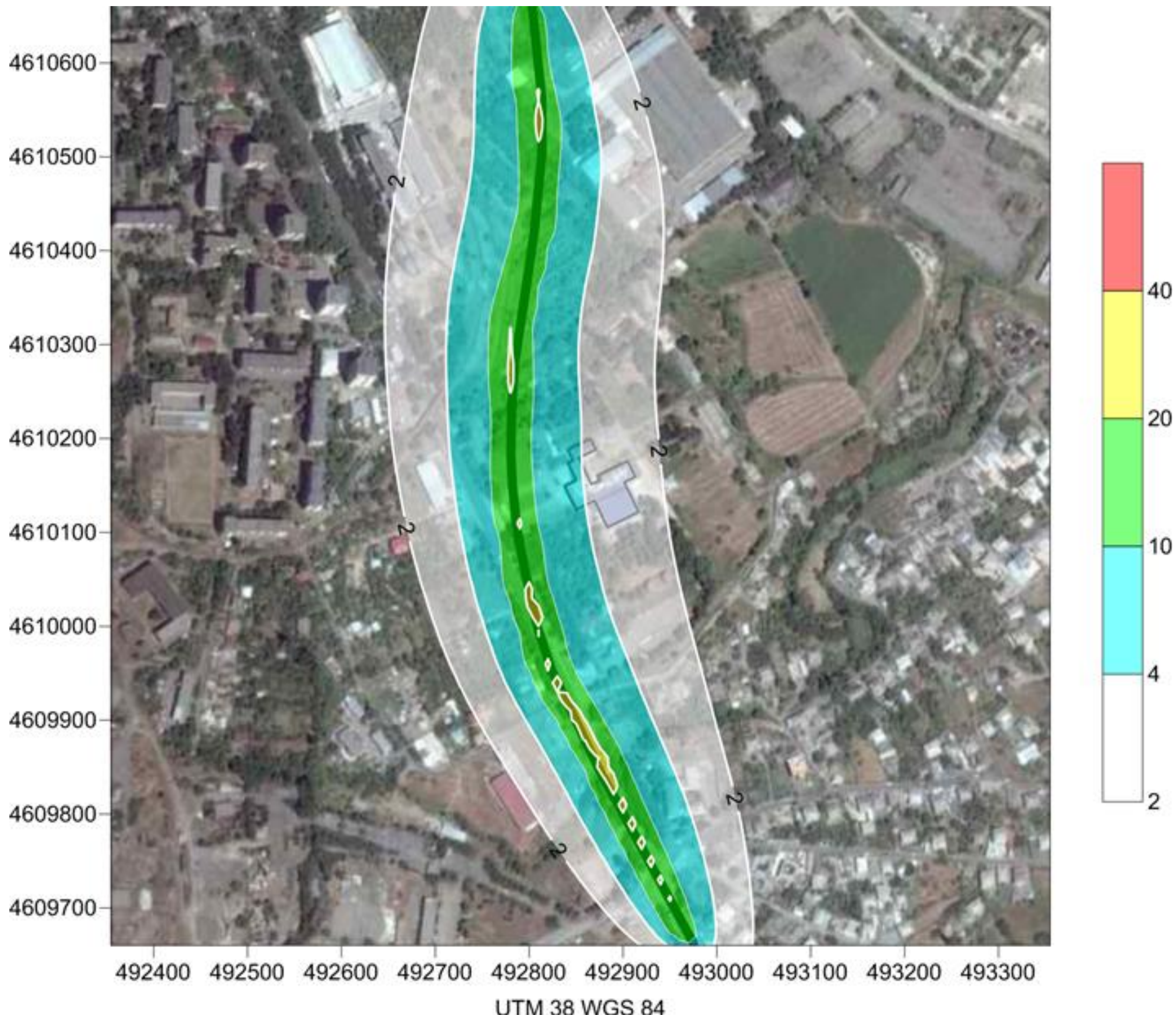




Local/hotspot

Current research activities of ARIANET

Environmental impact of a new highway in Georgia

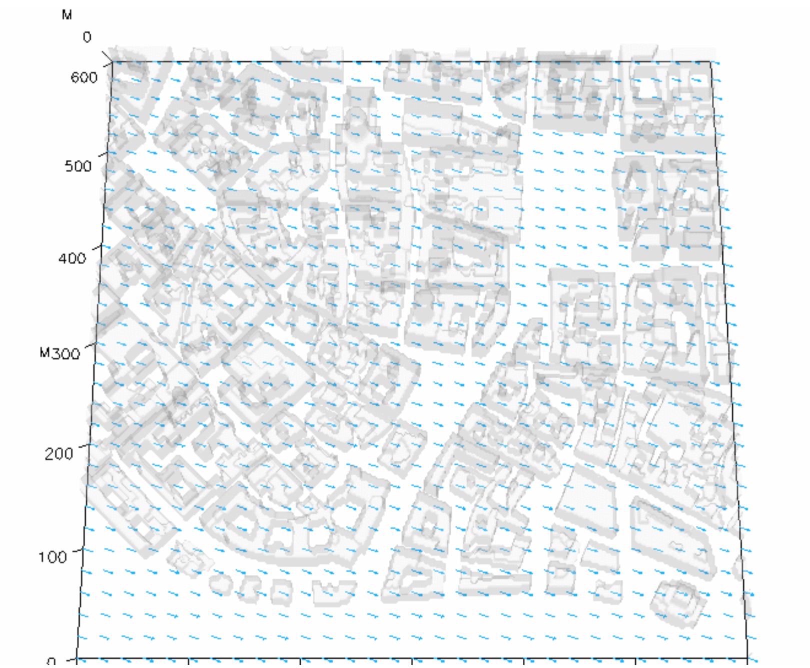


Local/hotspot

Current research activities of ARIANET

Micro scale simulation: flow

Obstacles ignored



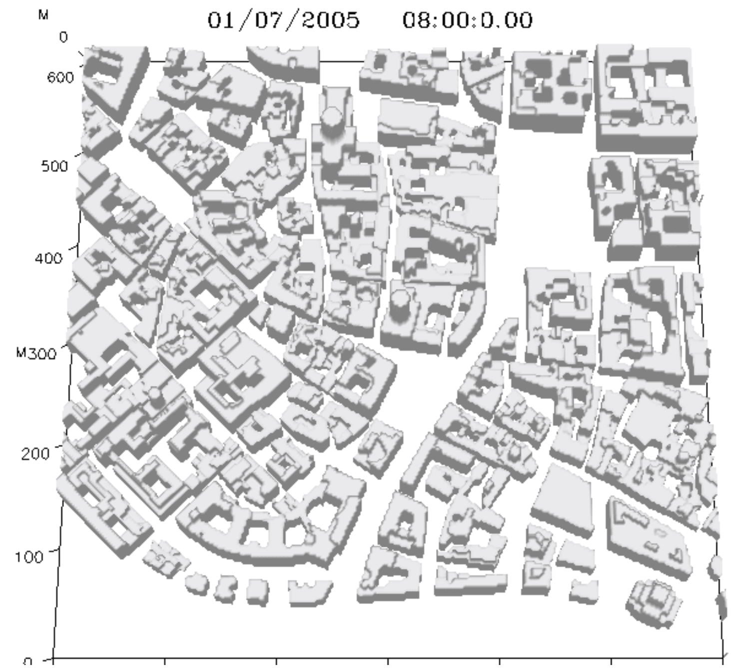
Obstacles considered

Current research activities of ARIANET

Micro scale simulation: concentration

Obstacles ignored

Obstacles considered



Local/hotspot

Research Facilities available for ARIANET

❑ Software modules

Developed by ARIANET and ARIA Technologies and public available:

- **Traffic assignment**: **CARUSO**;
- **Emissions**: COPERT, **TREFIC** (from road traffic), CollectER (database CORINAIR methodology), **EMMA** (prepare input for dispersion models from inventories); **EmEx** (inventory exploratory);
- **Meteorology**: prognostic models (RAMS, WRF, MERCURE), diagnostic models (**SWIFT/MINERVE,** CALMET), pre-processors (**SURF*Pro***, LAPS, UPP)
- **Dispersion models**: Gaussian (**IMPACT**, AERMOD, CALPUFF, OCD), Lagrangian particle (**SPRAY**), Chemical Transport (**FARM,** CHIMERE**),** CFD/microscale (FDS-SMV, ENVI-Met, **MSS)**
- **Visualization tools**: SAVI3D, **AVISU, …**

❑ HW facilities

2 Servers HPC Cluster (Intel/AMD Opteron Linux with 64 cores; Intel/AMD 2U QUAD OPTERON with 48 cores; + other devices (servers, PCs, …)

Suggested Priorities and R&I Needs for future research

- ✓ QualeAria AQFS is moving to ENEA HPC facilities. An improvement of the horizontal resolution is foreseen for the European and Italian domains;
- ✓ Application of “urban canopy models” (CFD, Lagrangian particle, LUR, …) to test their capability to simulate air quality within street canyons with a reasonable computational effort (comparison with low-cost sensors data);
- ✓ Urban canopy meteorological models (possible coupling of meteorological and transport/dispersion models)
- ✓ Local scale chemistry (e.g. NO to NO_2 conversion -EURO6 vehicles-, …)
- ✓ Low-cost sensors measuring tracers of specific sources may help to evaluate local/hotspot models, to identify uncertainties (flows, emissions) and improve models capabilities (emergency response, accidental releases, …)
- ✓ further tests and refinements of data fusion/assimilation techniques, also on urban & local scales, including data from distributed low-cost sensors
- ✓ improving source attribution methods at different scales, combining proper models and observational data

CONCLUSIONS

Main Achievements

- No single modelling approach to face with different air quality issues
- Air Quality Models of Different Complexities are used in many real-world operational and policy applications by/with public bodies and industries
- Different input data according to models requirements and complexities
- Data assimilation techniques:
  - lead to significant improvements in the geographical mapping of the pollutants and in the estimation of the health risk,
  - help to identify possible sources of uncertainties in model results and often highlight errors in observations

Thank you for your attention !