Ensemble Approach for European Air Quality Forecasting and its Usage

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Outline

- Scope and objectives
- The Integrated air quality platform
- Why apply a multi model ensemble?
- Evaluation
- Usage
- Summary and Outlook

Scope

- Integrated Air Quality Platform part of PROMOTE

- PROMOTE: ESA Project (Stage II, 2007-2009)
  www.gse-promote.org
- Mission: *to deliver the Atmosphere GMES Service Element a sustainable and reliable operational service to support informed decisions on the atmospheric policy issues of stratospheric ozone depletion, surface UV exposure, air quality and climate change.*
- More than 60 institutional users involved

Objectives

- Provision of air quality forecasts and analyses for Europe

Analyses

- Reporting on concentration levels and exceedances (e.g. State of the Environment by EEA)
- Contribution to implementation of EU air quality directives

Forecasting

- Raising awareness of people
- Early warning and alerting of people at risk
- Local model initialisation (boundary conditions)

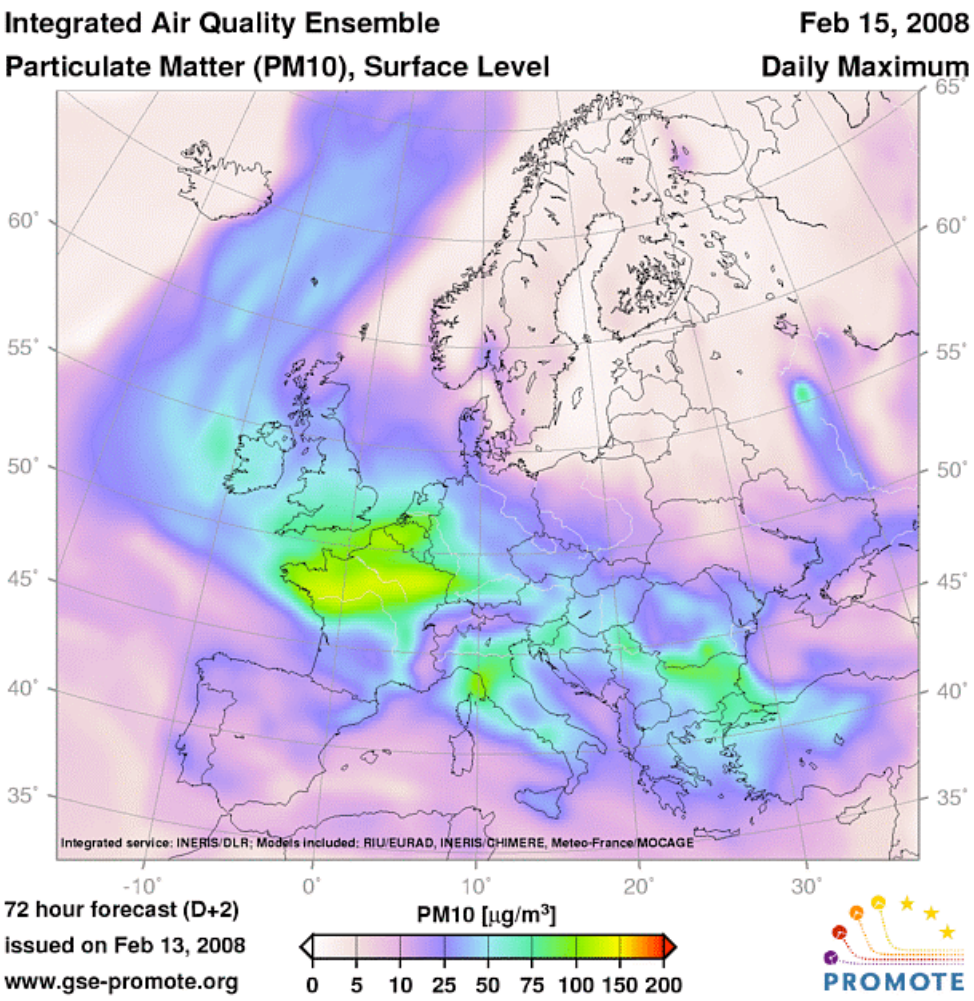
Integrated Air Quality Platform

- Focuses on air quality forecasts and analyses for regulatory pollutants O3, NO2 and PM10
- Acts as common European platform for ensemble forecasting and mapping
- Utilises observational data (in-situ and satellite-based)
- Considers operational constraints related to user's needs
- Disseminates results through an attractive web portal

  (Google Earth maps, movies…)

Integrated Air Quality Platform

- Forecasting capability: up to 72-hours
- Spatial discretization: 50x50km²
- Ensemble method: median approach built on 6 modelling systems



Ensembles

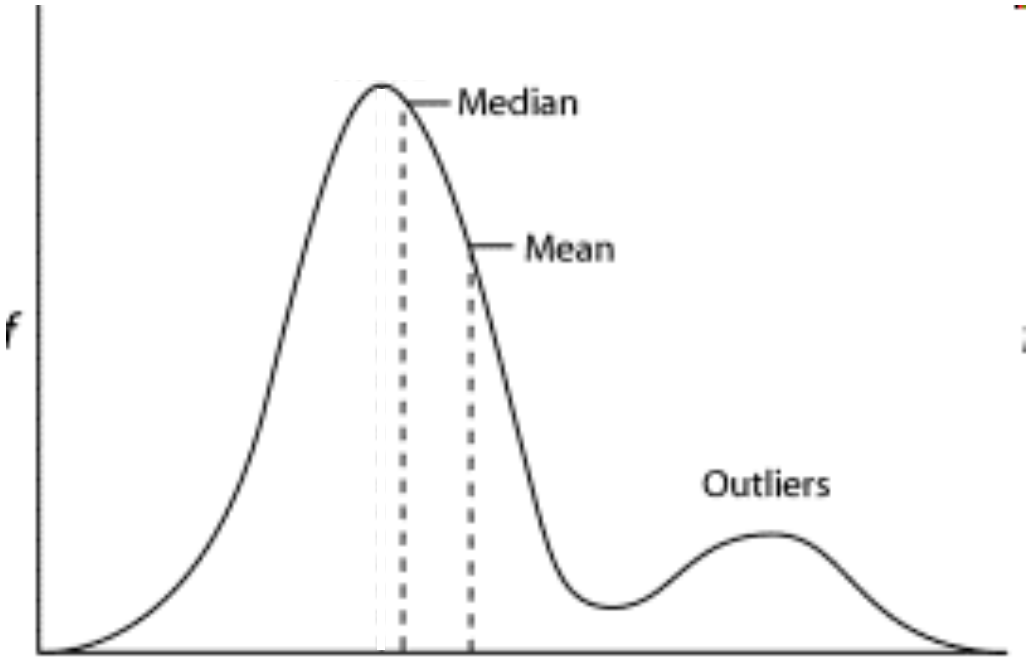
- “ensemble” French for “together” and “totality”
- Definition: estimation of the “true” physical or chemical state by combining several representations …

… of one model	…by several models
Single Model Ensemble	Multi Model Ensemble (Poor mans ensemble)
Toth and Kalnay (1993) perturbation of one system	Krishnamurti et al (1999) use of independent systems

- Aims at reducing the uncertainty by means of techniques designed to strategically sample the probability density function (Riccio et al. 2008)

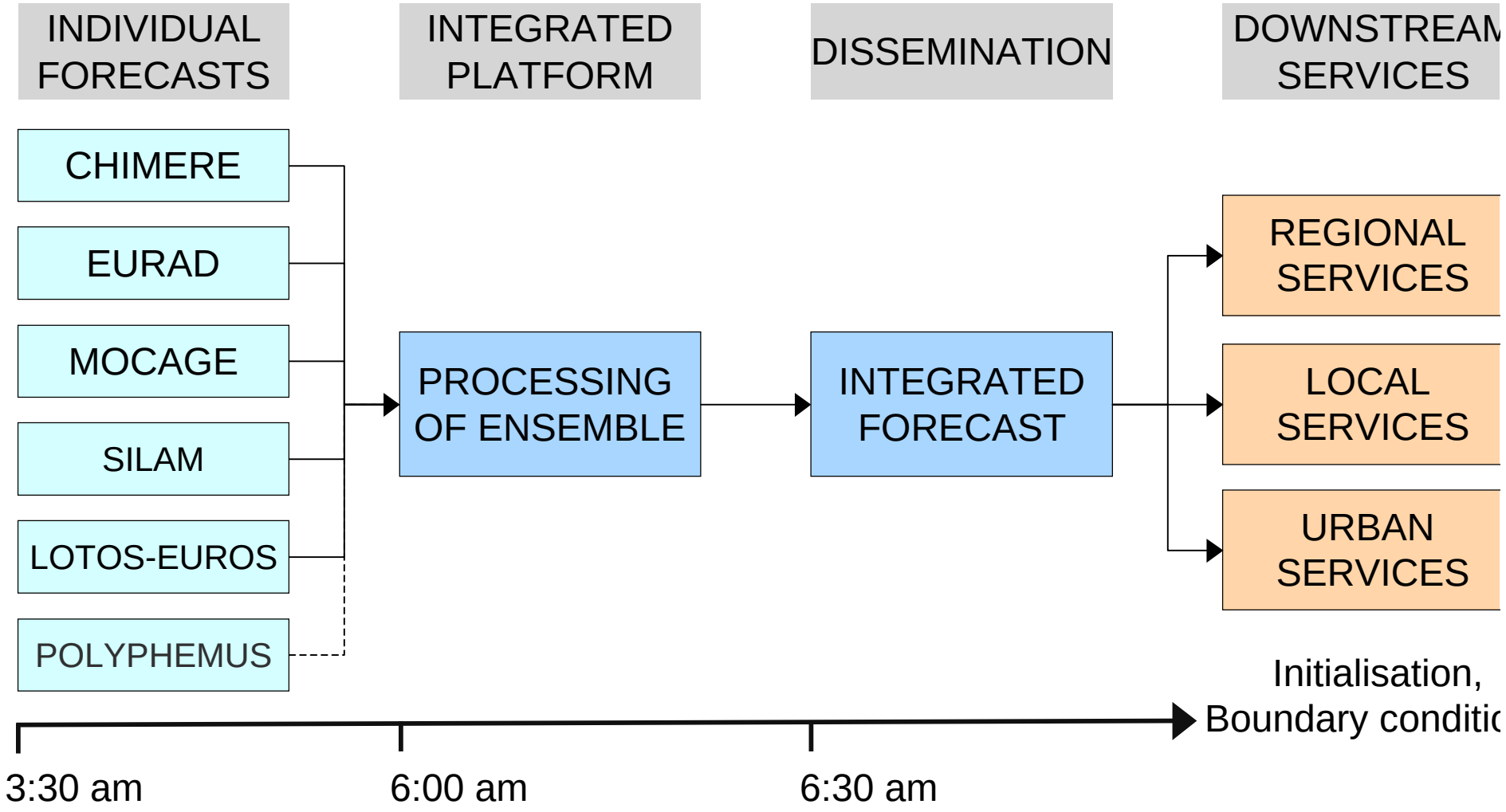
Ensembles

- Median approach

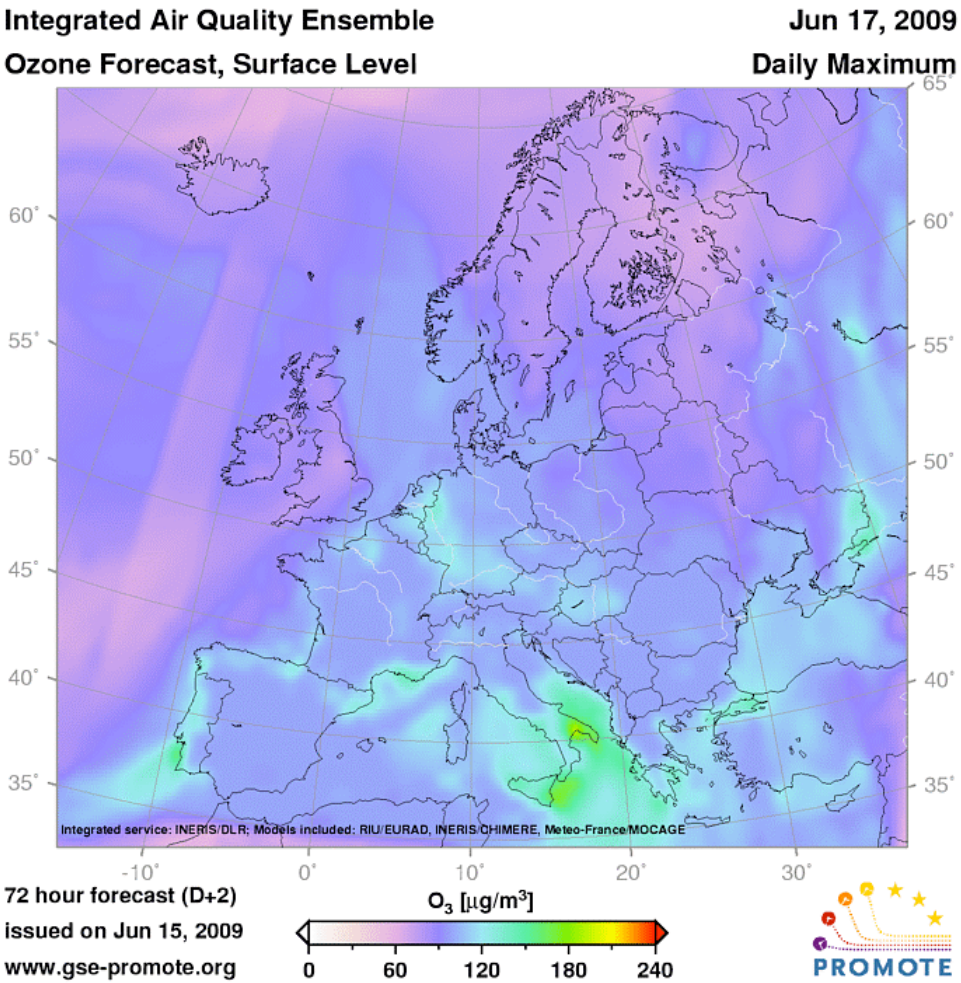


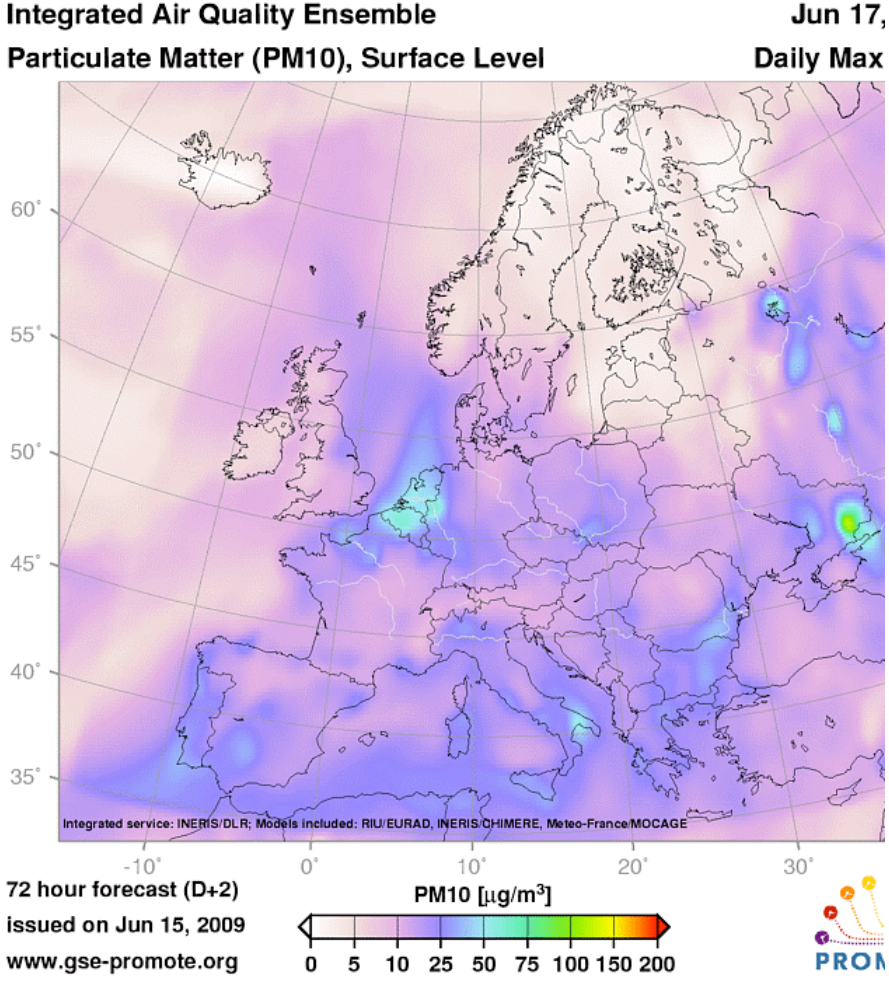
- Advantages:
  - Robust to outliers
  - Does not alter values

Integrated Air Quality Platform

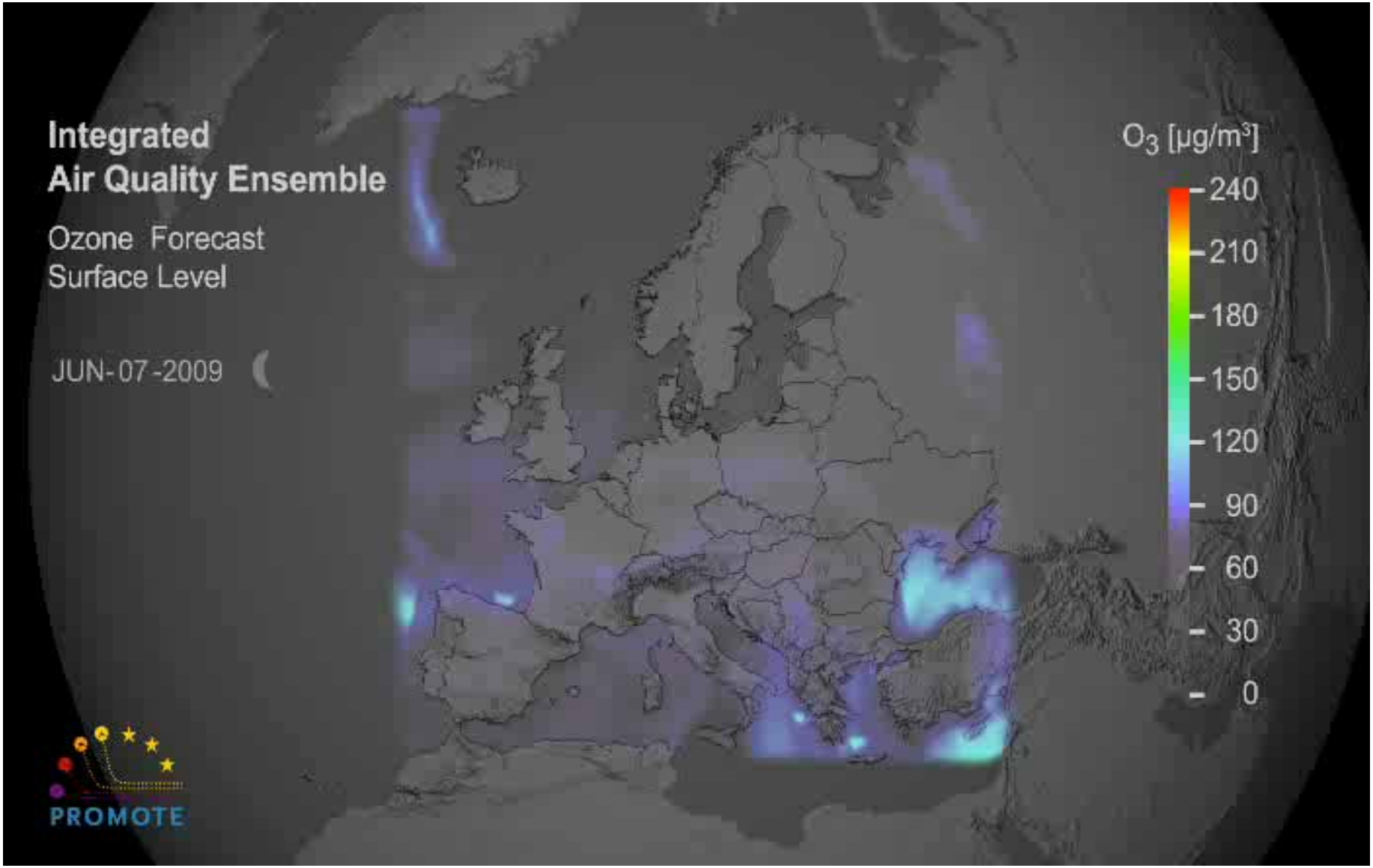


Currnet Forecasts





Service Results: Current PM 10 Forecast



Why apply a multi model ensemble?

- Robust (forecast available if one system fails)
- Scaleable (further system can be added easily)
- Reliable (reduced analysis and forecasting uncertainty)

Reduced Error Growth in Ensembles

Toth and Kalnay (1993): single model ensemble (NMC): perturbation of one system

Application of theoretical error growth Formulated by Lorenz (1982)

$$\frac{dv}{dt} = av(1 - v),$$

where y(t) is the forecast error at time t and a is the linear growth rate.

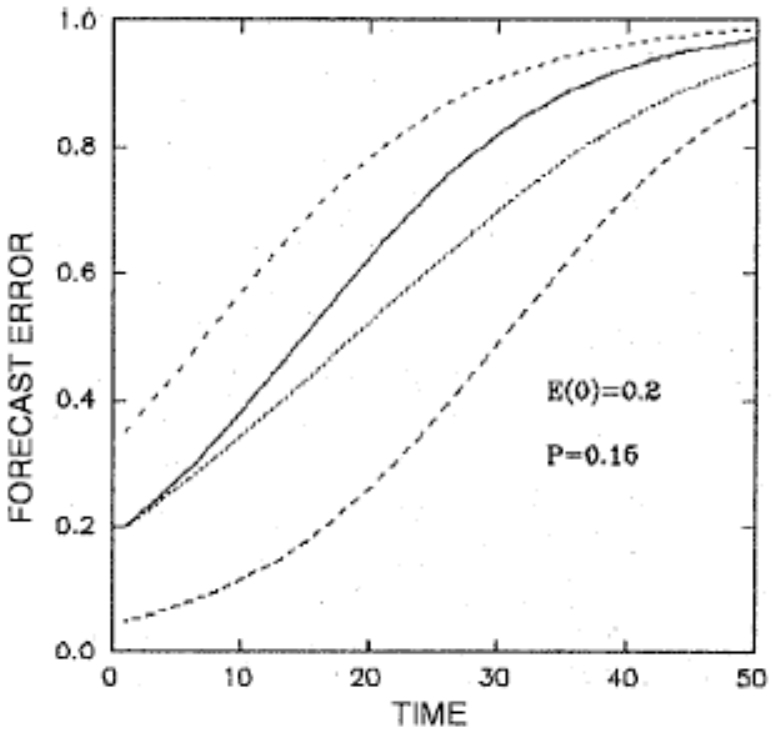
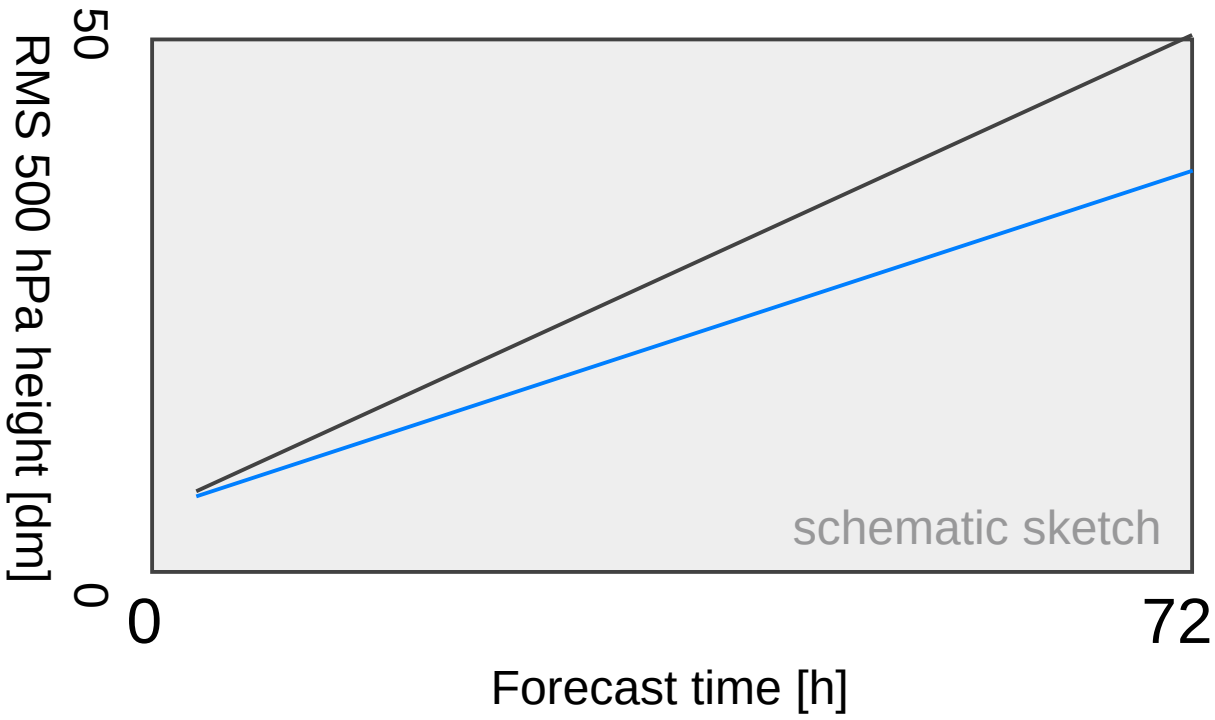


FIG. 1. Example indicating the gain from esemble averaging in a one-dimensional example using Lorenz's error growth equation. The solid curve is the error of the control forecast, the dashed curves are the error of the perturbed forecasts, and the dotted curve is the error of the ensemble mean. Here, $E(0)$ is the initial error of the control forecast and P is the amplitude of the twin perturbations.

Reduced Error Growth in Ensembles



Single model ensemble (ECMWF)

Multi model ensemble (ECMWF, HIRLAM, COSMO, NCEP, UCAR)

→ Relative improvement of RMS of 15 % (for 72 h)

Bowler et al. 2008

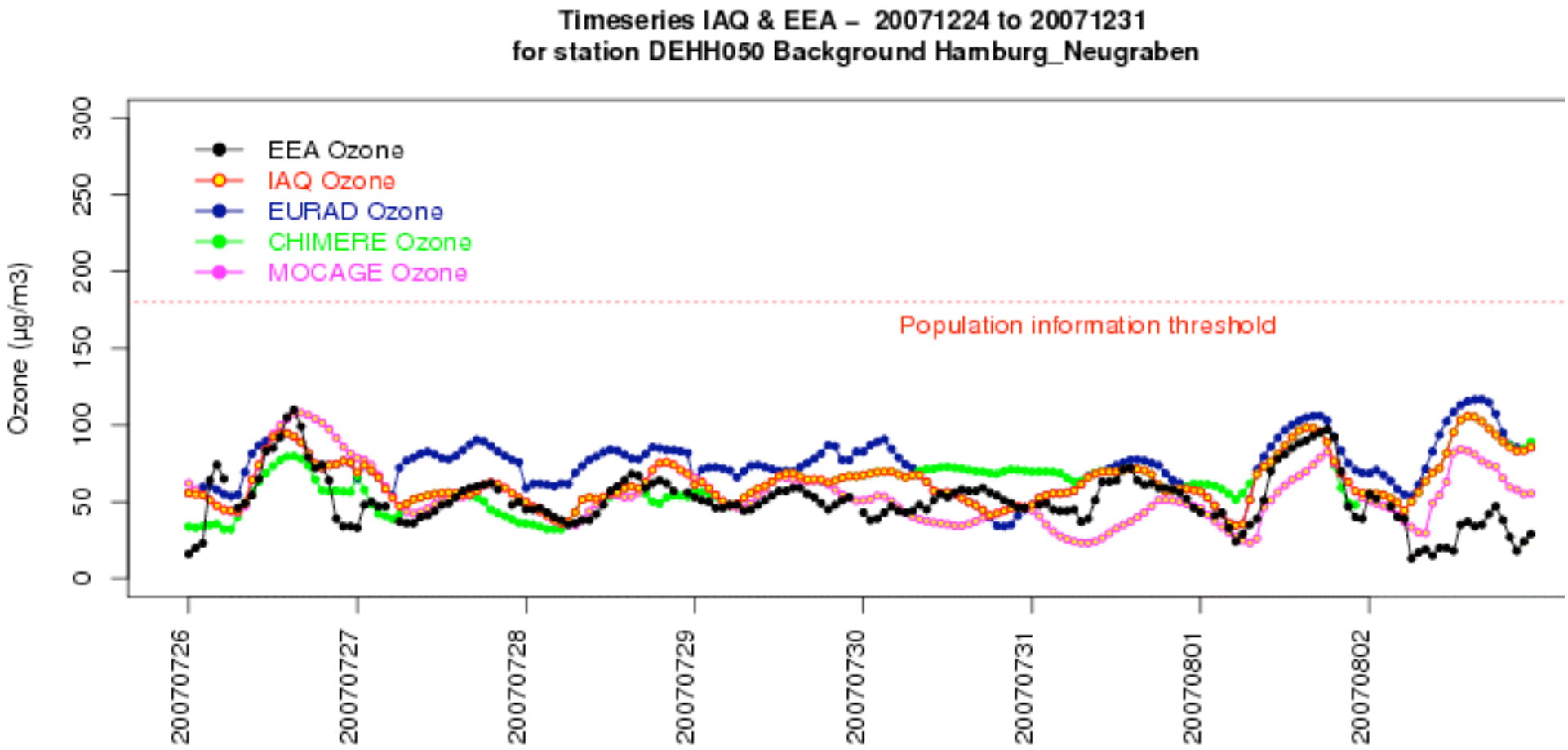
Evaluation

Evaluation strategy

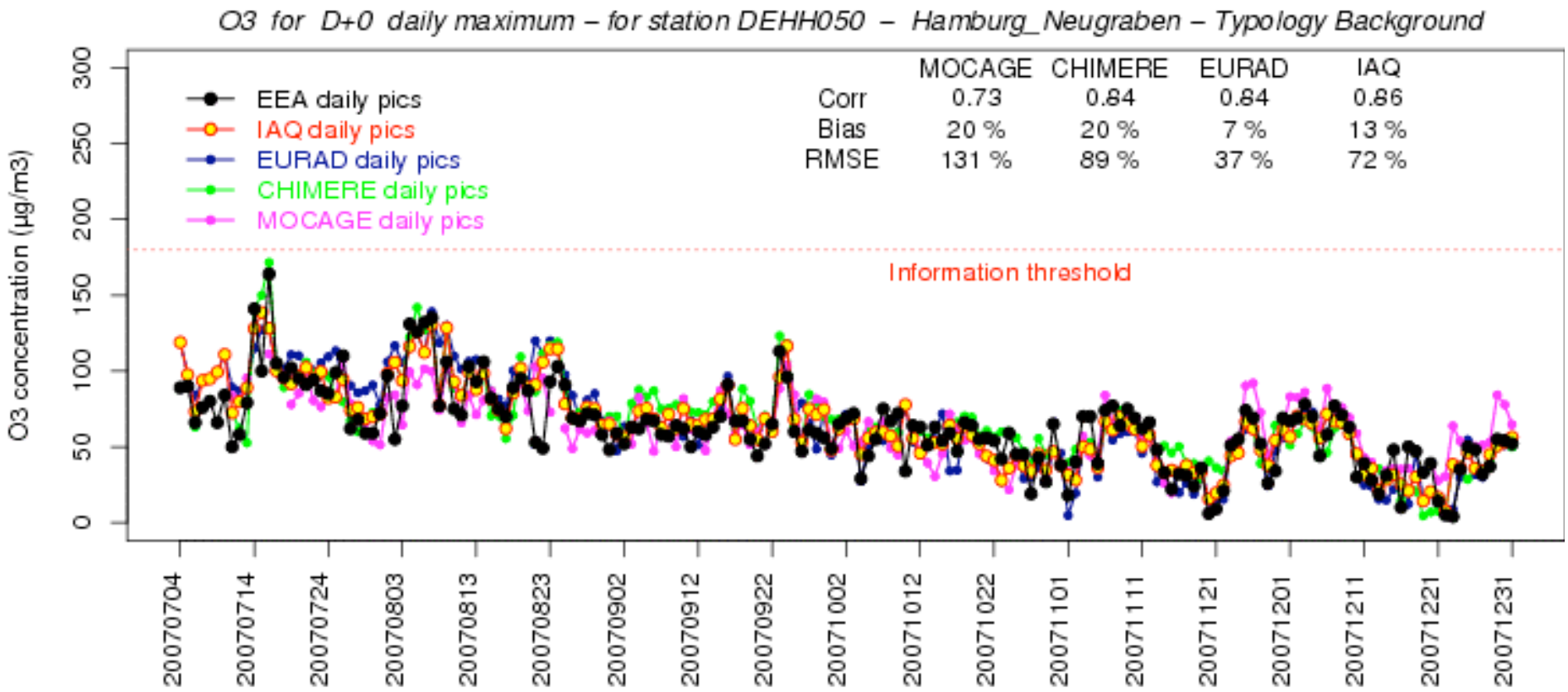
- Development of evaluation tools to assess the performance of the individual models as well as the ensemble in a consistent way
- Use of the EEA AirBase data
  - 1382 background stations for ozone
  - Period Jul to Dec 2007
  - Version 3.0

➔ Skill Analysis

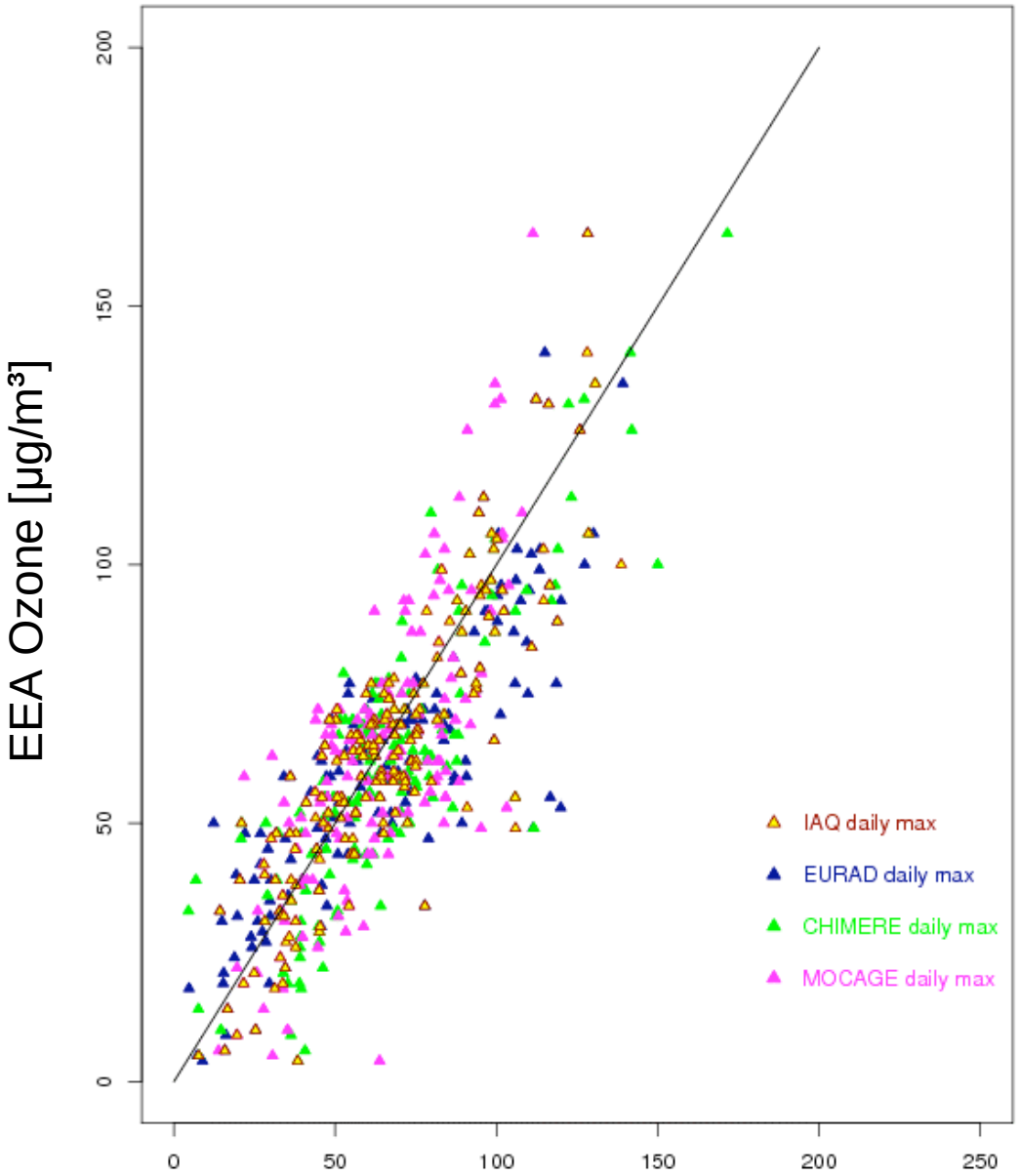
Comparison of Ozone Timeseries



Comparison of Daily Ozone Maxima



Comparison of Daily Ozone Maxima Correlations



Scatterplot IAQ vs EEA – 20070704 to 20071231
for station DEHH050 Background Hamburg_Neugra

	Corr with max
IAQ	0.86
EURAD	0.84
CHIMERE	0.84
MOCAGE	0.73

IAQ / Model Ozone [µg/m³]

Evaluation fo Daily Ozone Mean Values

Comparison to EEA AirBase data (V3.0)
1382 background stations, Jul to Dec 2007

Model / Ensemble	Correlation	Bias	RMSE
EURAD	0.72	9.82	19.80
CHIMERE	0.78	18.01	23.35
MOCAGE	0.64	15.02	22.94
IAQ	**0.78**	**11.02**	**19.59**

Evaluation of Daily Ozone Peak Values

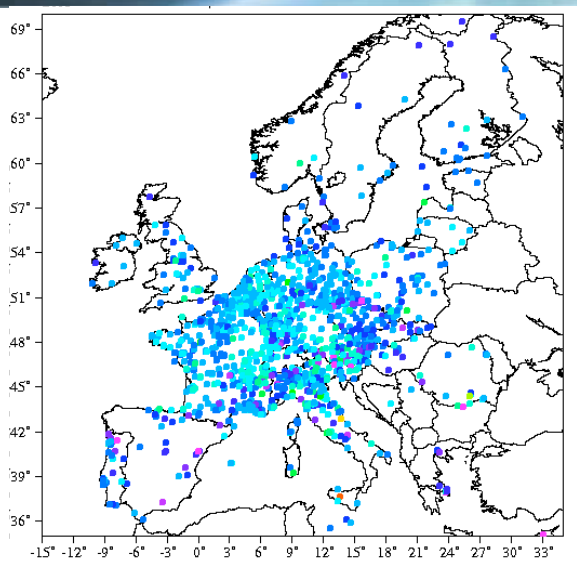
Comparison to EEA AirBase data (V3.0)
1382 background stations, Jul to Dec 2007

Model / Ensemble	Correlation	Bias	RMSE
EURAD	0.74	6.97	22.48
CHIMERE	0.83	9.05	19.35
MOCAGE	0.69	7.36	22.92
IAQ	**0.81**	**6.72**	**18.81**

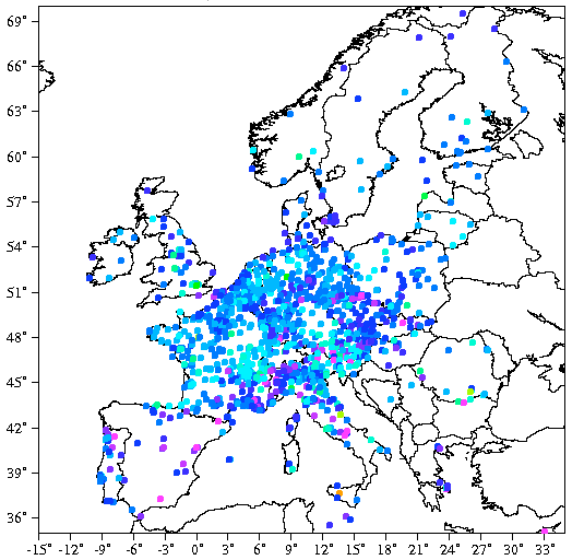
Evaluation of Systematic Errors in Ozone

- Daily maxima
- Jul to Dec 2007

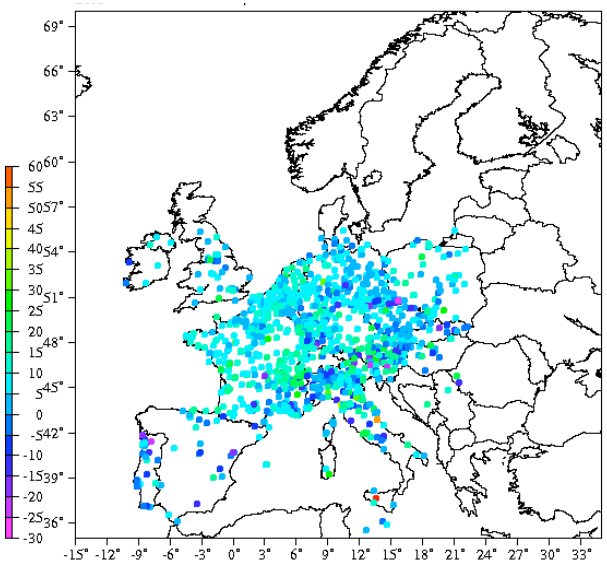
IAQ-AirBase



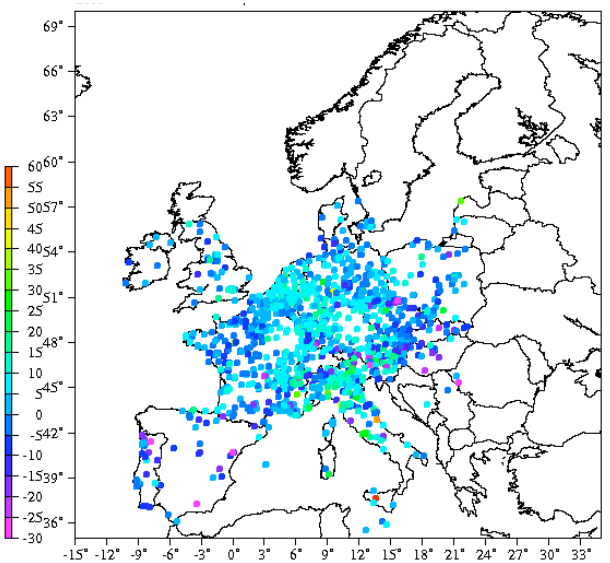
EURAD-AirBase



CHIMERE-AirBase



MOCAGE-AirBase

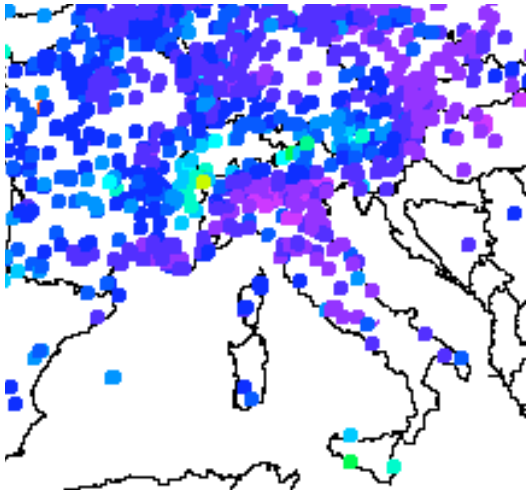


Ozone [µg/m³]

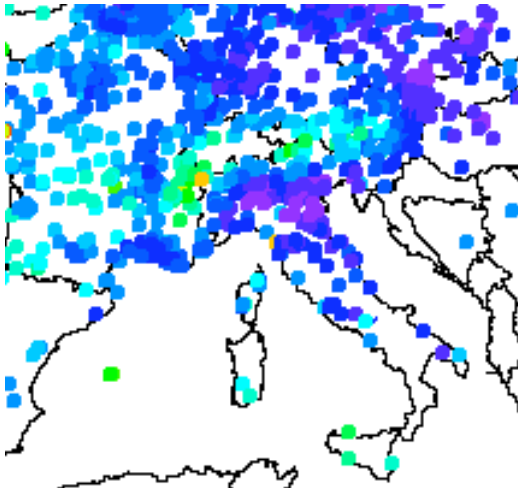
Evaluation of Correlation of Ozone

- Daily maxima
- Jul to Dec 2007

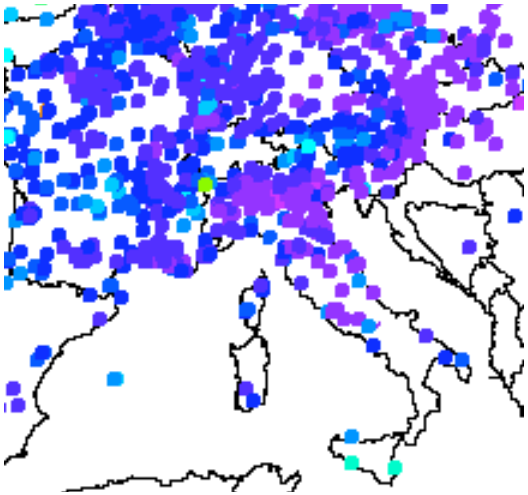
IAQ-AirBase



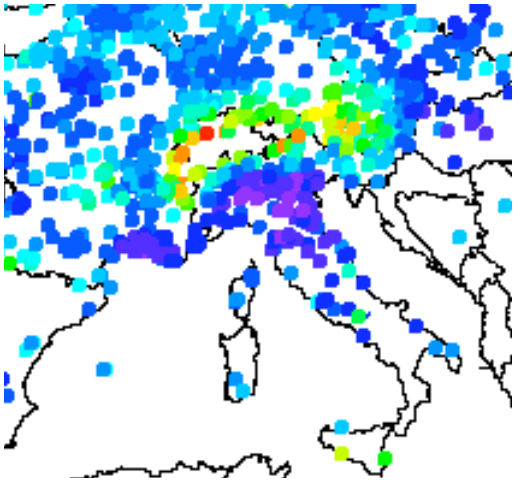
EURAD-AirBase



CHIMERE-AirBase



MOCAGE-AirBase



Application and Usage

Service Level Agreements (SLA)

- Data usage arranged by SLAs
- SLA is a formal negotiated contract between the user and the service provider(s)
- Stipulates the common understanding about the service, priorities, responsibilities, guarantees, and the level of service.
- Specifies the levels of availability, performance, operation and other relevant attributes of the service

Usage: AIRPARIF

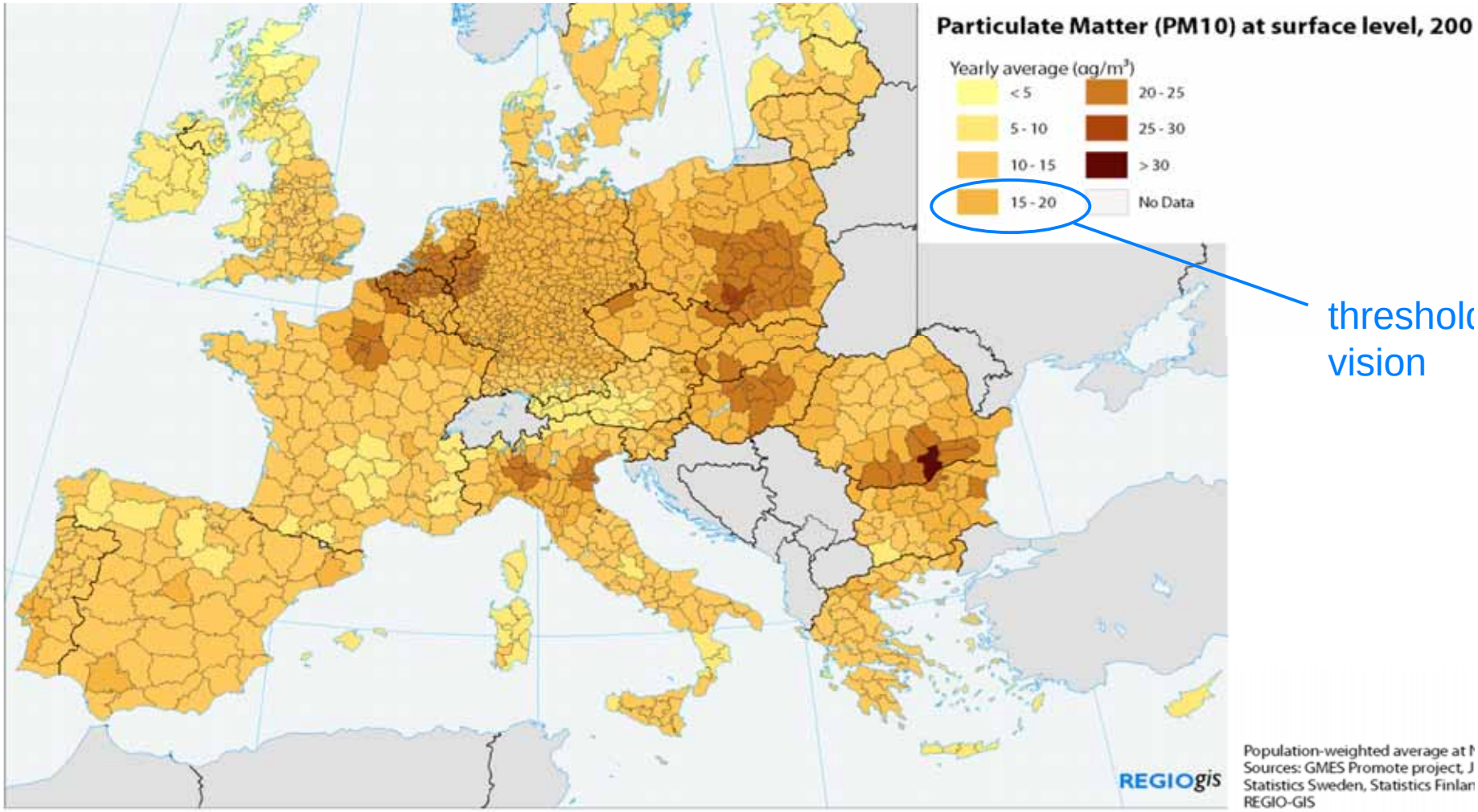
- AIRPARIF provides local air quality forecasts over the Paris Basin and Paris-Ile de France

„The numerical data issued from PROMOTE allows us to run more efficiently our own local air quality forecasting system, ESMERALDA. Indeed, PROMOTE gives us the relevant boundary conditions needed.“

„The integrated chain PROMOTE-ESMERALDA is the first example in France of an operational air quality forecasting system running from the regional scale to the local scale“

P. Lameloise (Director AIRPARIF)

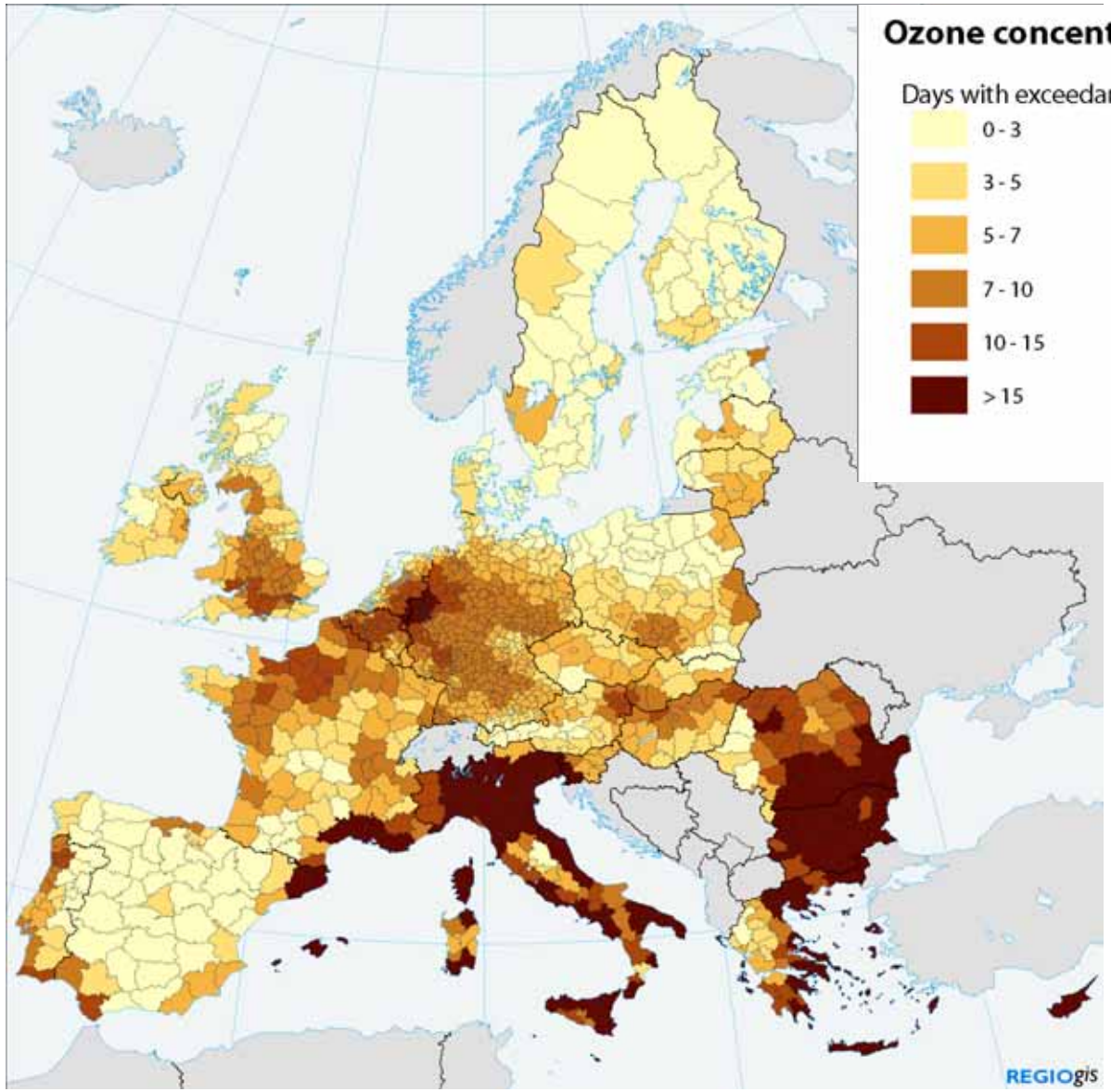
Usage: EU Regio-GIS PM10 Reporting



threshold
vision

Population-weighted average at N
Sources: GMES Promote project, J
Statistics Sweden, Statistics Finlan
REGIO-GIS

Usage: EU Regio-GIS O3 Exceedance Reporting



Days with ground-level ozone concentration above 12(
Population-weighted aggregated value at NUTS3 level.
Sources: GMES-Promote, Eurostat, JRC, REGIO-GIS

Usage: EEA

- PROMOTE Air Quality Project (PAQ)
- Derivation of European Air Quality Index based on EEA network and IAQ data

Usage: EEA Air Quality Index

- AQ Index CAQI (CITEAIR Common Air Quality Index)
  http://www.airqualitynow.eu/

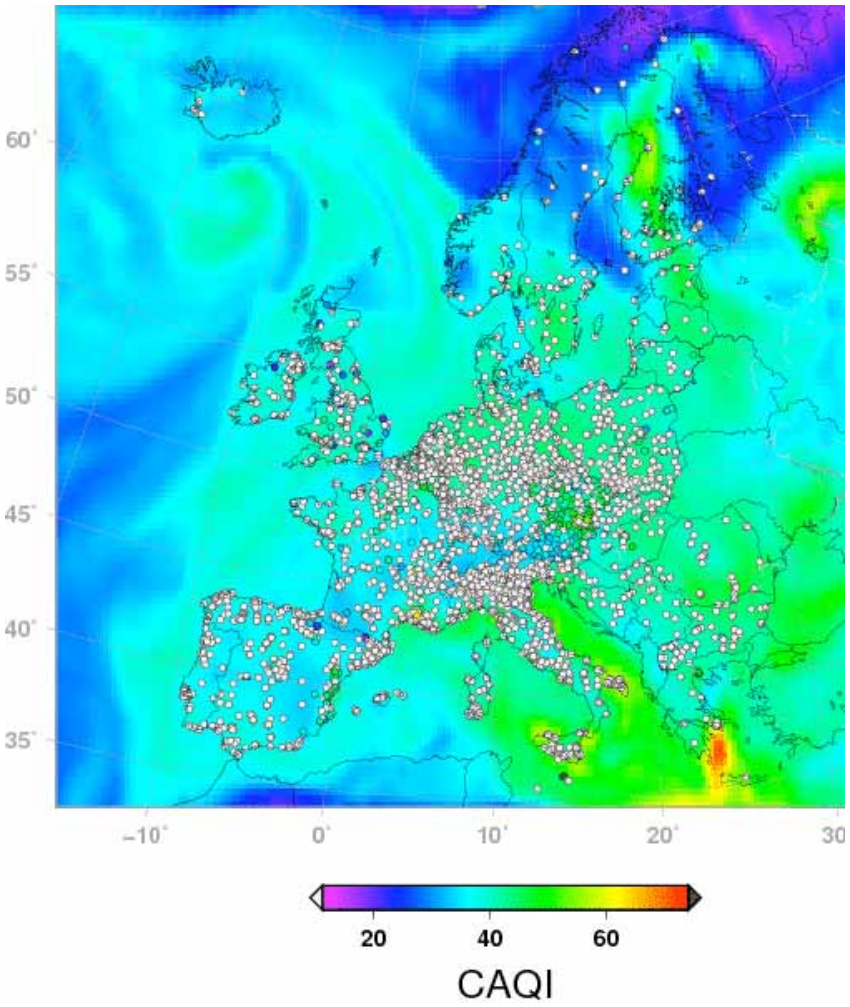
Index	Class	Traffic			City Background				
		NO_2	PM_{10}	CO	NO_2	PM_{10}	O_3	CO	SO_2
Very low	0	0	0	0	0	0	0	0	0
	25	50	25	5000	50	25	60	5000	50
Low	25	50	25	5000	50	25	60	5000	50
	50	100	50	7500	100	50	120	7500	100
Medium	50	100	50	7500	100	50	120	7500	100
	75	200	75	10000	200	75	180	10000	300
High	75	200	75	10000	200	75	180	10000	300
	100	400	100	20000	400	100	240	20000	500
Very High*	> 100	> 400	>100	>20000	> 400	>100	>240	>20000	>500

NO_2, O_3, SO_2:	hourly value / maximum hourly value in µg/m3
CO	8 hours moving average / maximum 8 hours moving average in µg/m3
PM_{10}	hourly value / maximum hourly value in µg/m3**

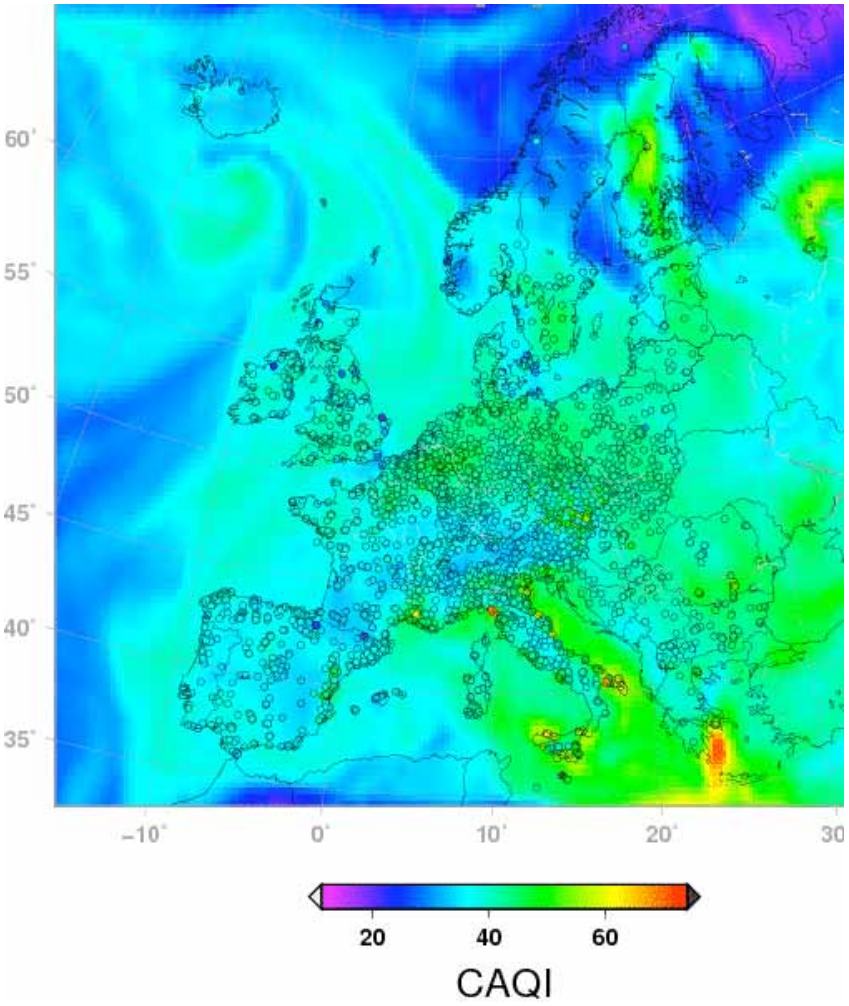
☞find the leading peak value (NO2, PM10 oder O3)
☞weight by class/value ratio

Usage: EEA Air Quality Index

available near-real time stations



near-real-time stations + IAQ



→ Improved index availability if IAQ is used additionally

Data access through web portal

- www.gse-promote.org → Air Quality → Integrated Air Quality
- Current Forecasts in netCDF format
- Movies and images on current forecasts
- Google Earth maps
- Data and Image archive hosted at WDC/RSAT
- User Guide
- Tools

Conclusion

- A lean, effective and efficient service has been set up to meet user needs
- Daily 72-hour ensemble forecasts of air pollutants are delivered for Europe
- A common ensemble platform has been established in cooperation with GEMS project regarding scientific aspects

- Validation with 1382 ground based stations of EEA confirmed: ensemble delivers improved forecasts compared to any single model.

Outlook

- Validation will be extended to 6 ensemble members (including SILAM, LOTOS-EUROS and POLYPHEMUS)
- Improvement of ensemble method envisaged (Bayesian Mean Approach, Riccio et al., 2008)

- Continuation in FP7 EC GMES projects MACC (Core) and PASODOBLE (Downstream)
- Basis for a sustainable service for GAS (GMES Atmosphere Service)
- Continuation for EEA PAQ project to derive a European Air Quality Index