CALIOPE: An operational air quality forecasting system for the Iberian Peninsula, Balearic Islands and Canary Islands

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Earth Science Department

The CALIOPE project: its objectives

- The CALIOPE project has as main objective to establish an air quality forecasting system for Spain coordinated by the Environment Spanish Ministry through funded project 441/2006/3-12.1, delivering air-quality related products useful to a wide range of users for reducing the impacts of air pollution on human health.

- A partnership of four research institutions composes the CALIOPE project: the Barcelona Supercomputing Center (BSC), the CIEMAT, the Earth Sciences Institute 'Jaume Almera' (IJA-CSIC) and the CEAM Foundation. This consortium will deal with both operational and scientific aspects related to air quality monitoring and forecasting.

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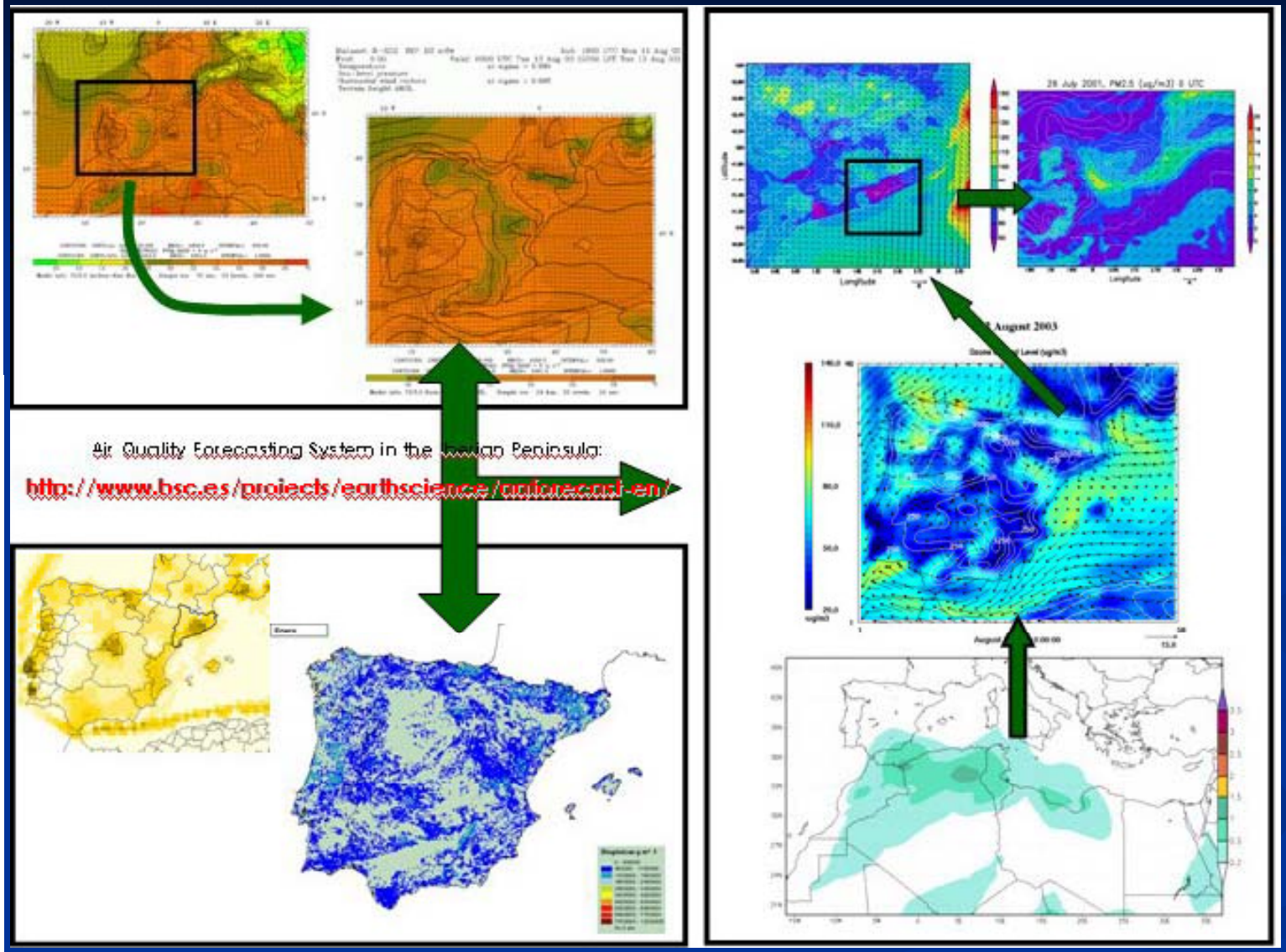

CALIOPE Air Quality Forecasting System

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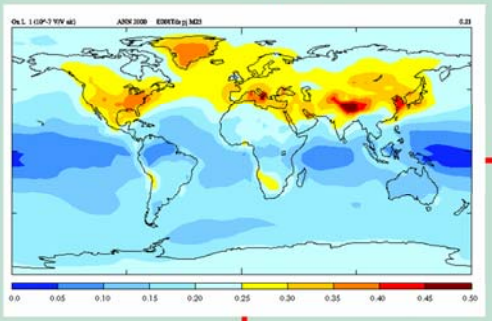
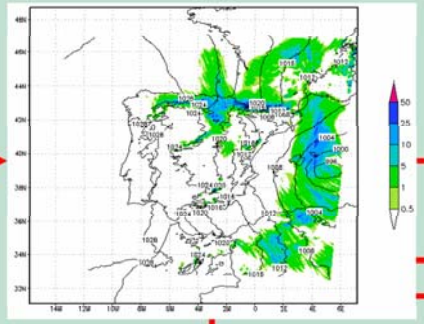
CALIOPE Air Quality Forecasting System

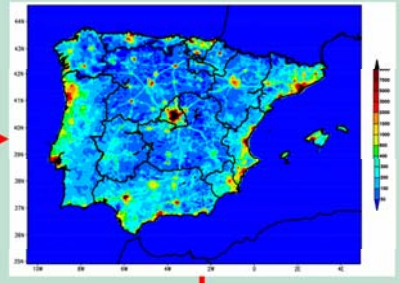
GLOBAL SIMULATIONS
Initial and boundary conditions

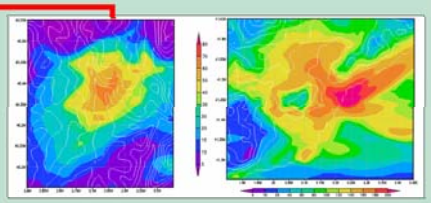


METEOROLOGICAL FORECAST FOR SPAIN
High resolution (4 km)

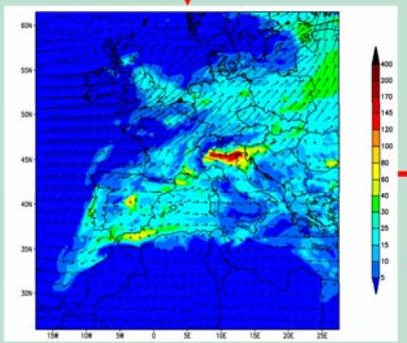


EMISSION MODEL
HERMES developed at BSC-CNS

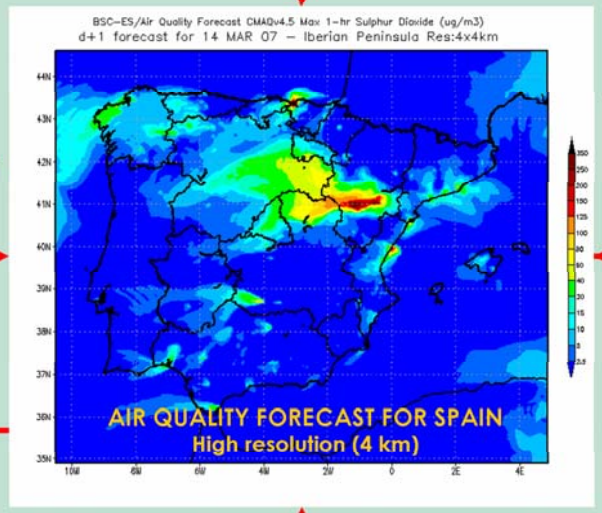


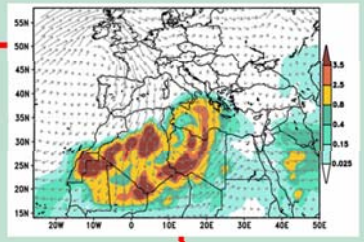


AIR QUALITY FORECAST FOR HOT-SPOTS REGIONS
Madrid and Barcelona (1 km)



EUROPEAN METEOROLOGICAL AND AIR QUALITY FORECAST
High resolution (12 km)

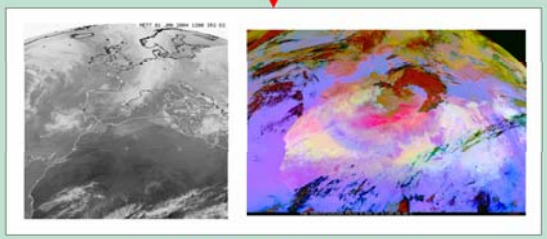




SAHARAN DUST OUBREAKS
Dust Regional Atmospheric Model (DREAM)

Quai-real time air quality data from stations

METEOROLOGICAL AND AIR QUALITY OBSERVATIONS
Dynamics and model evaluation



SATELLITE OBSERVATIONS
Surveillance and model verification

PARTICULATE MATTER OBSERVATIONS
Dynamics and model evaluation

CALIOPE Air Quality Forecasting System

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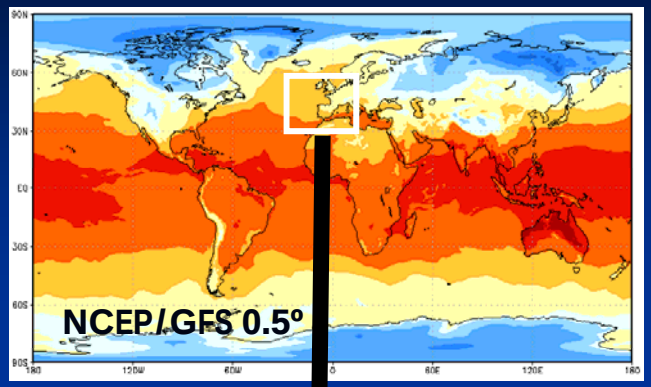
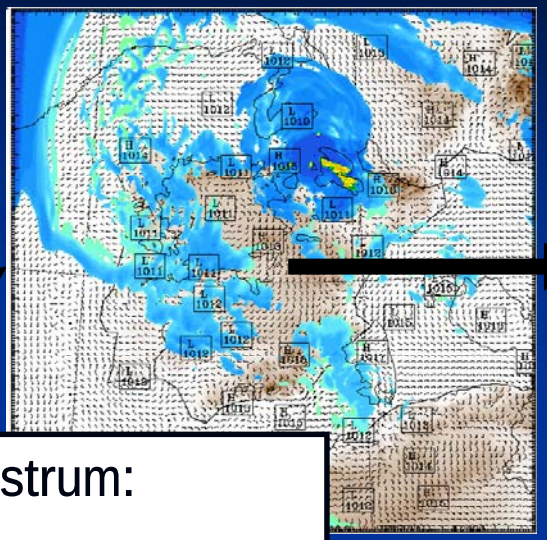


Iberian Peninsula 4 x 4 km



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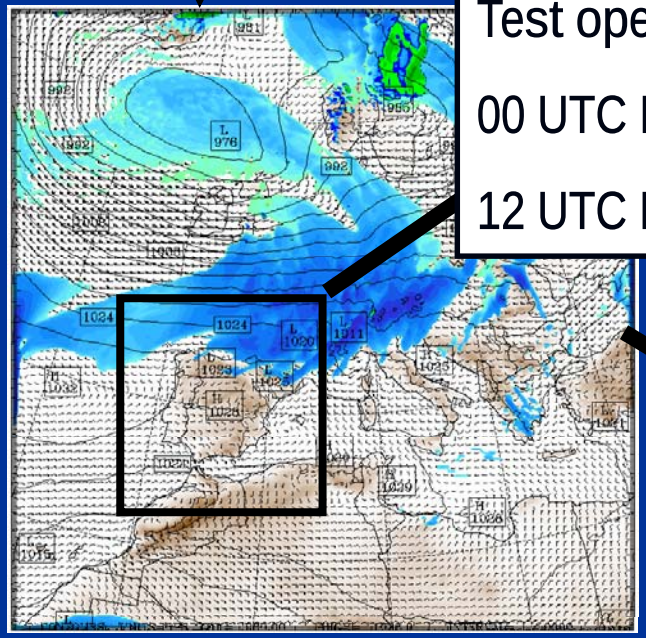

Europe 12 x 12 km

Test operations at MareNostrum:

00 UTC D+0, D+1 (disabled)

12 UTC D-1, D+0, D+1 (enabled)

WRFtoHERMES

INPUT – Emission model

CMAQ/MCIP

INPUT – Chemistry Transport Model

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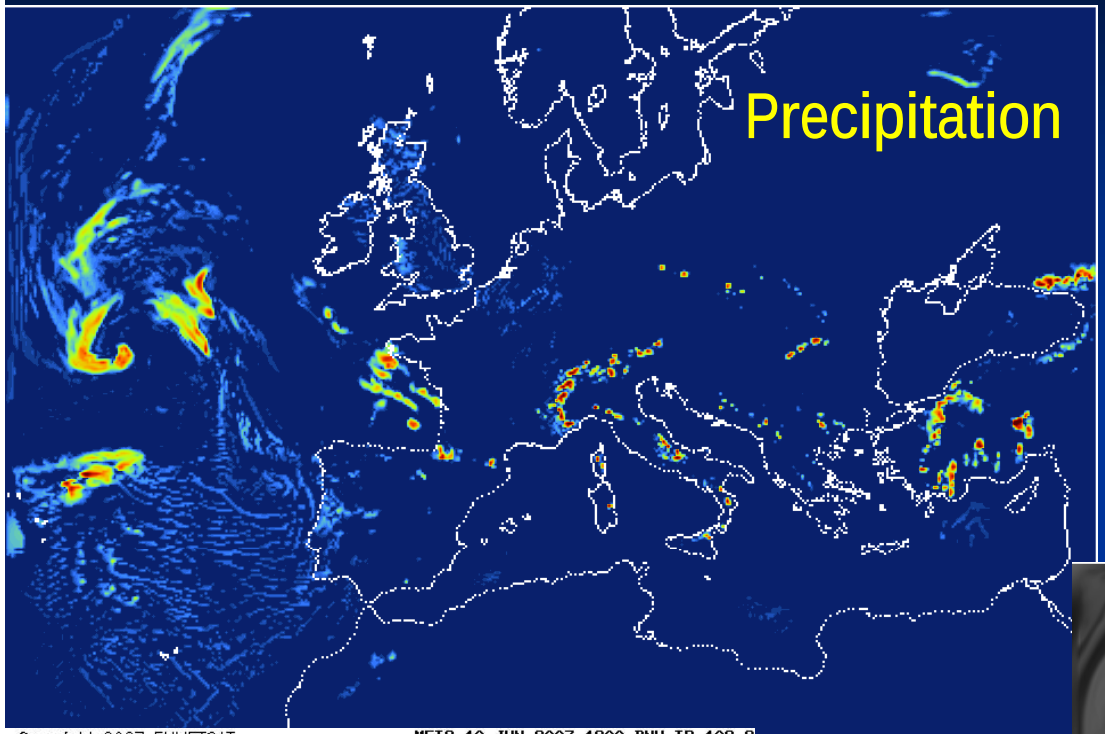
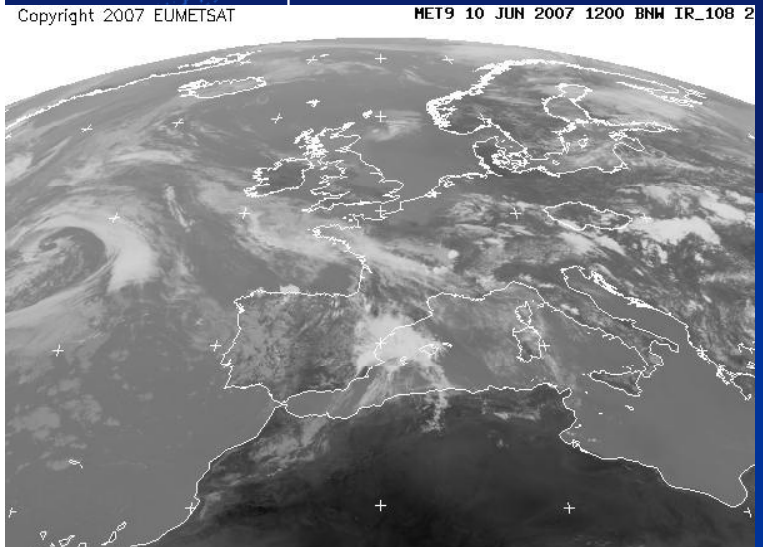
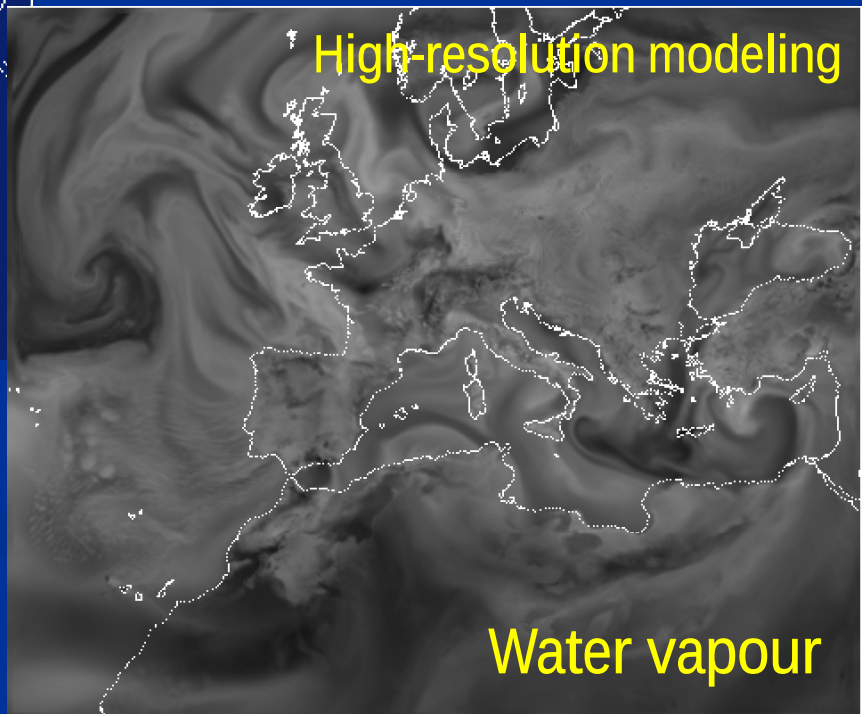
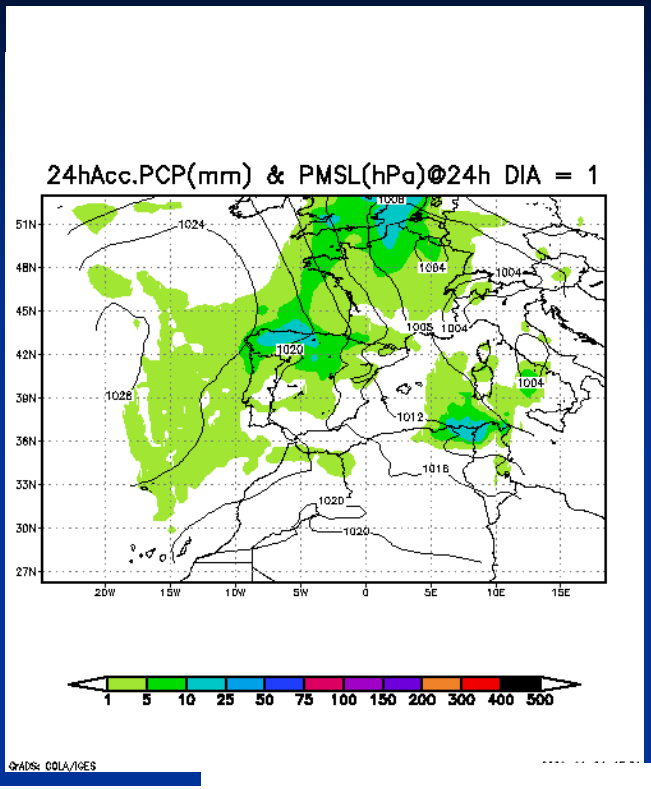


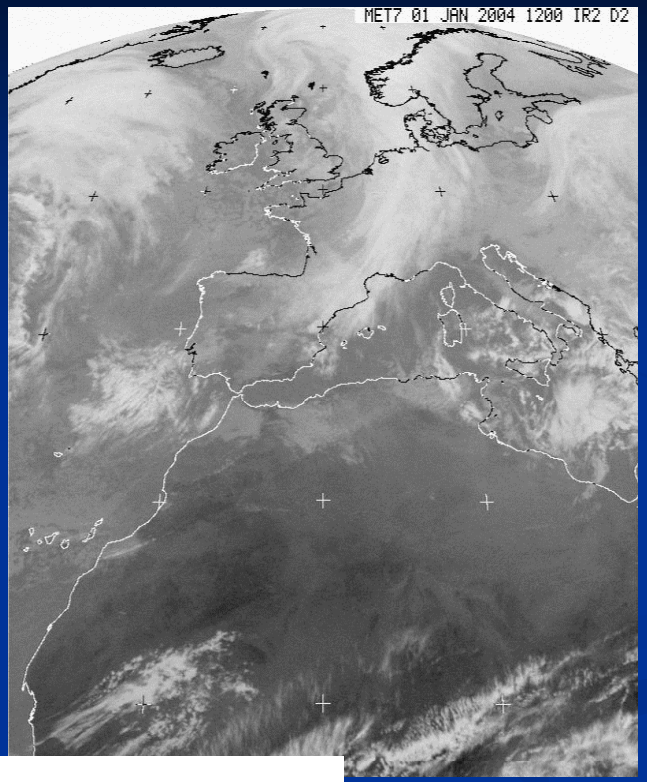
Enhancing spatial resolution – towards a new generation air quality modeling system

Resolution improved to 12 km for all Europe, 4 km for the Iberian peninsula, and 1 km for hot spot regions

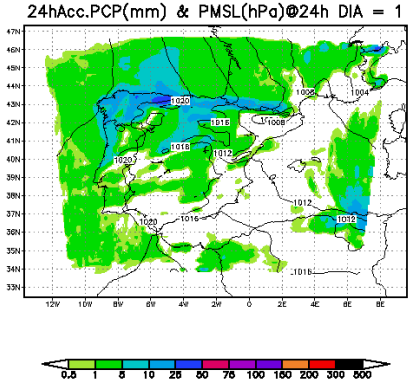


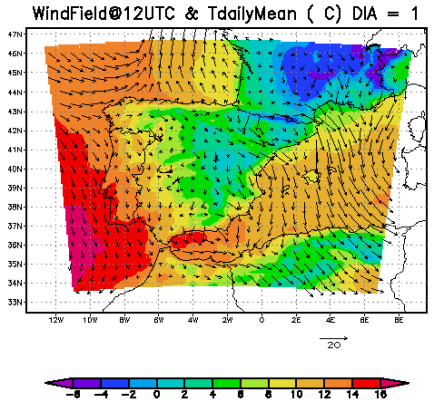


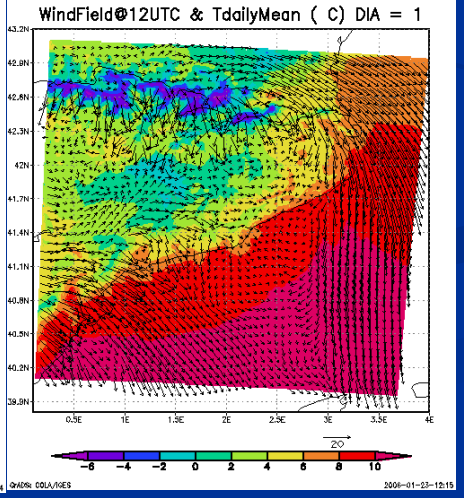




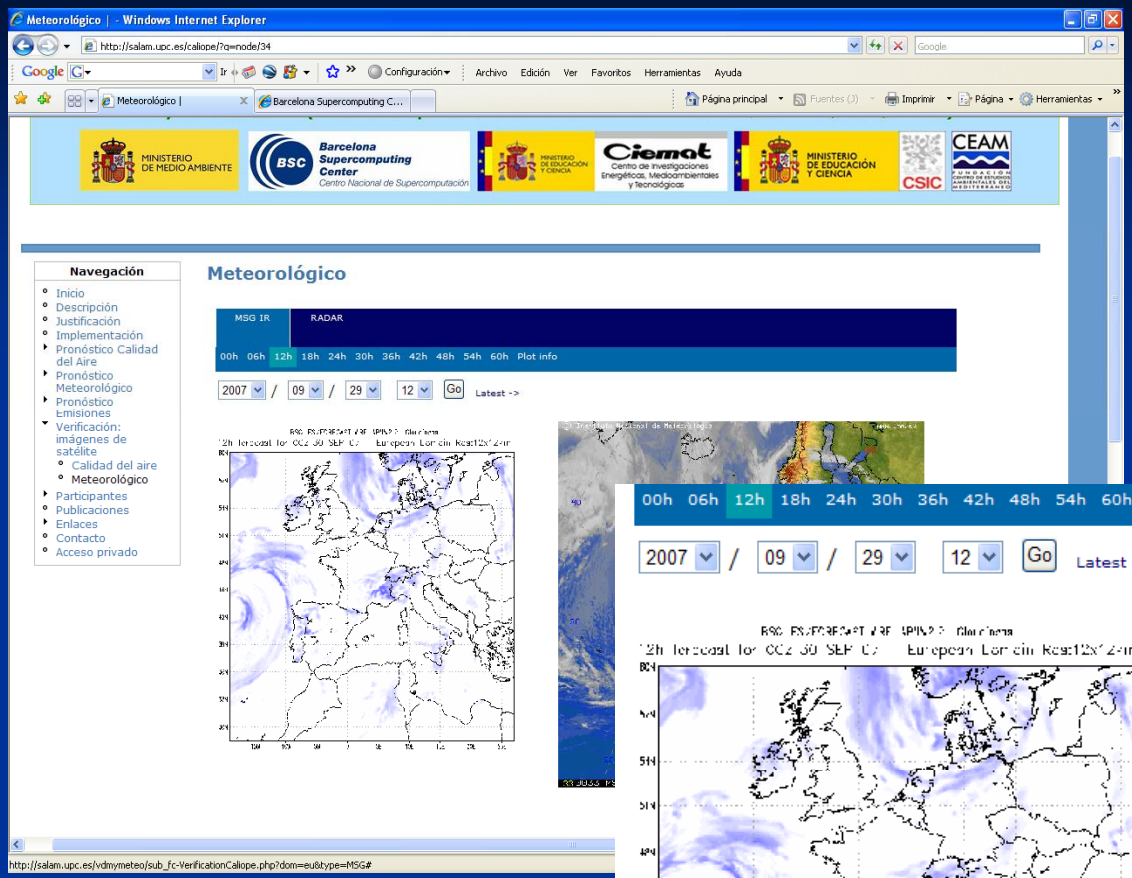
24-hr Precipitation + Average temperature + Surface wind field

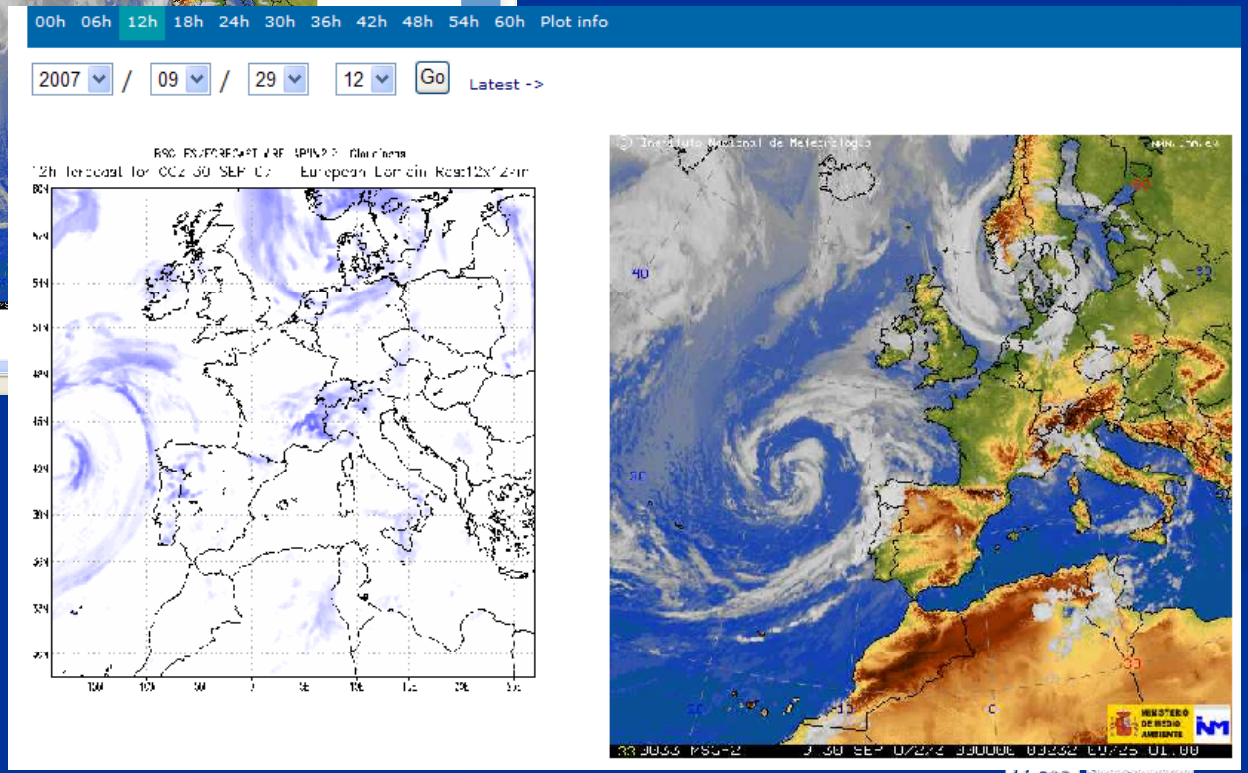






Operational meteorological validation: MSG IR





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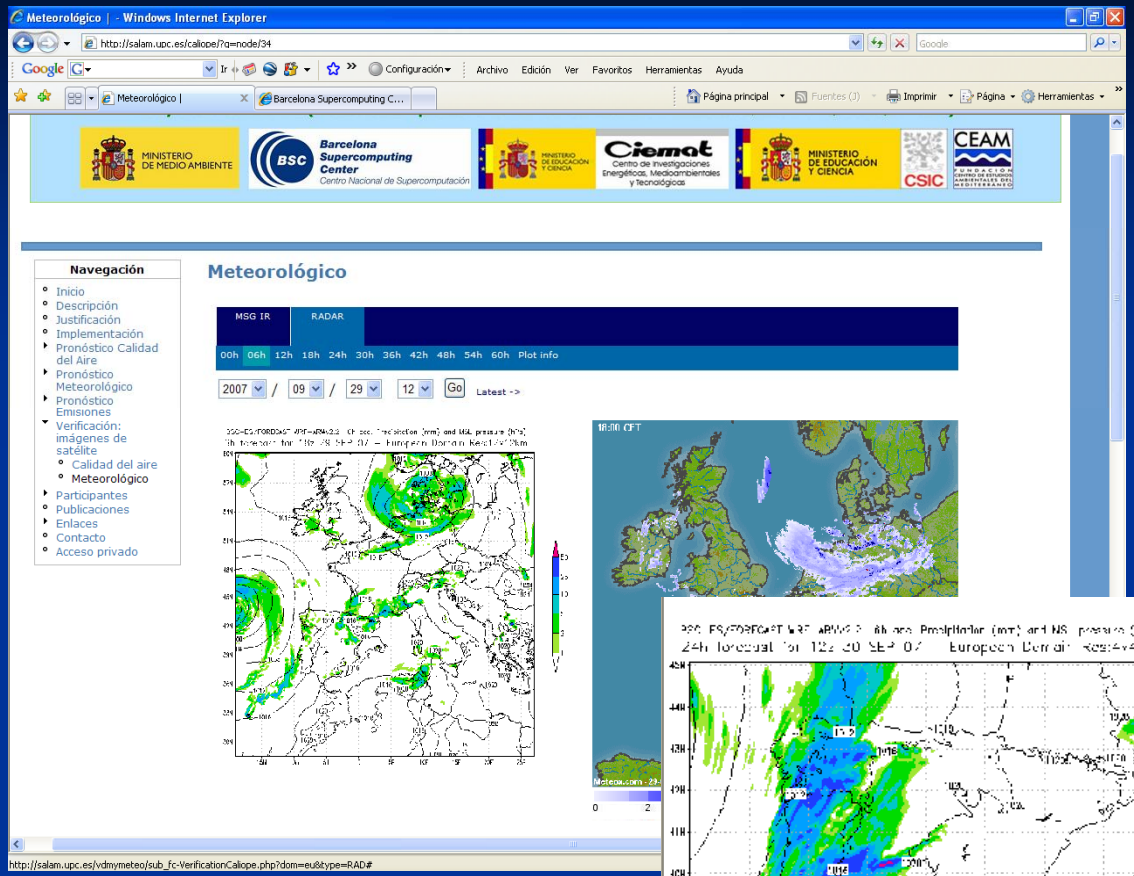
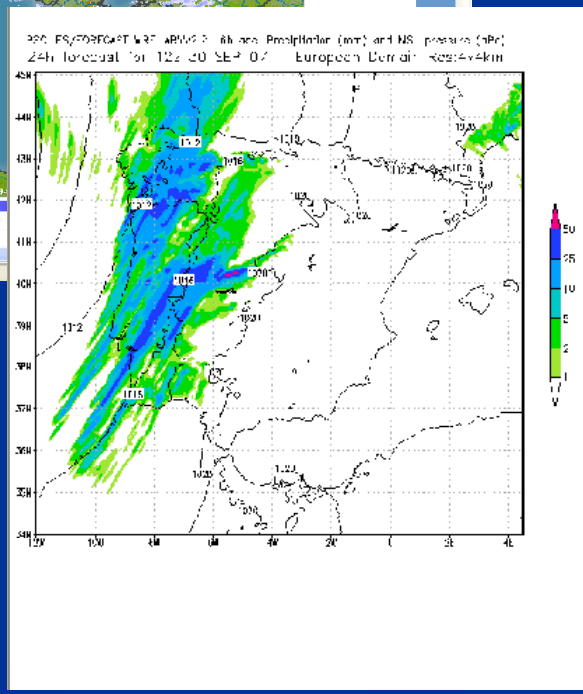
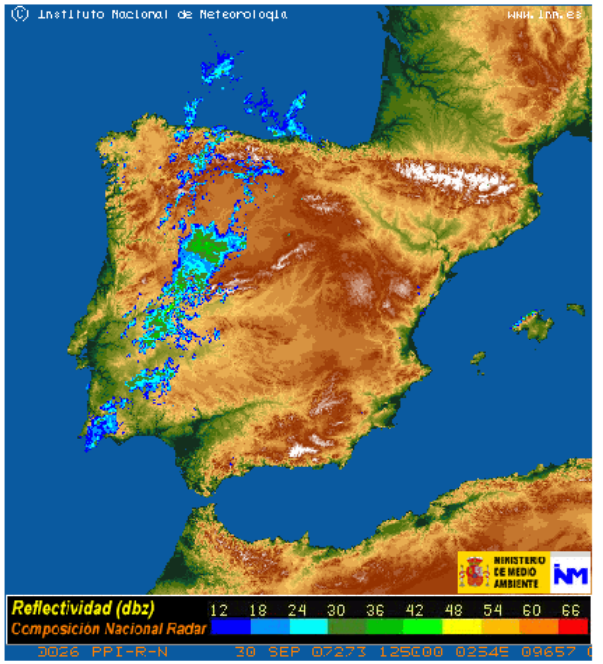
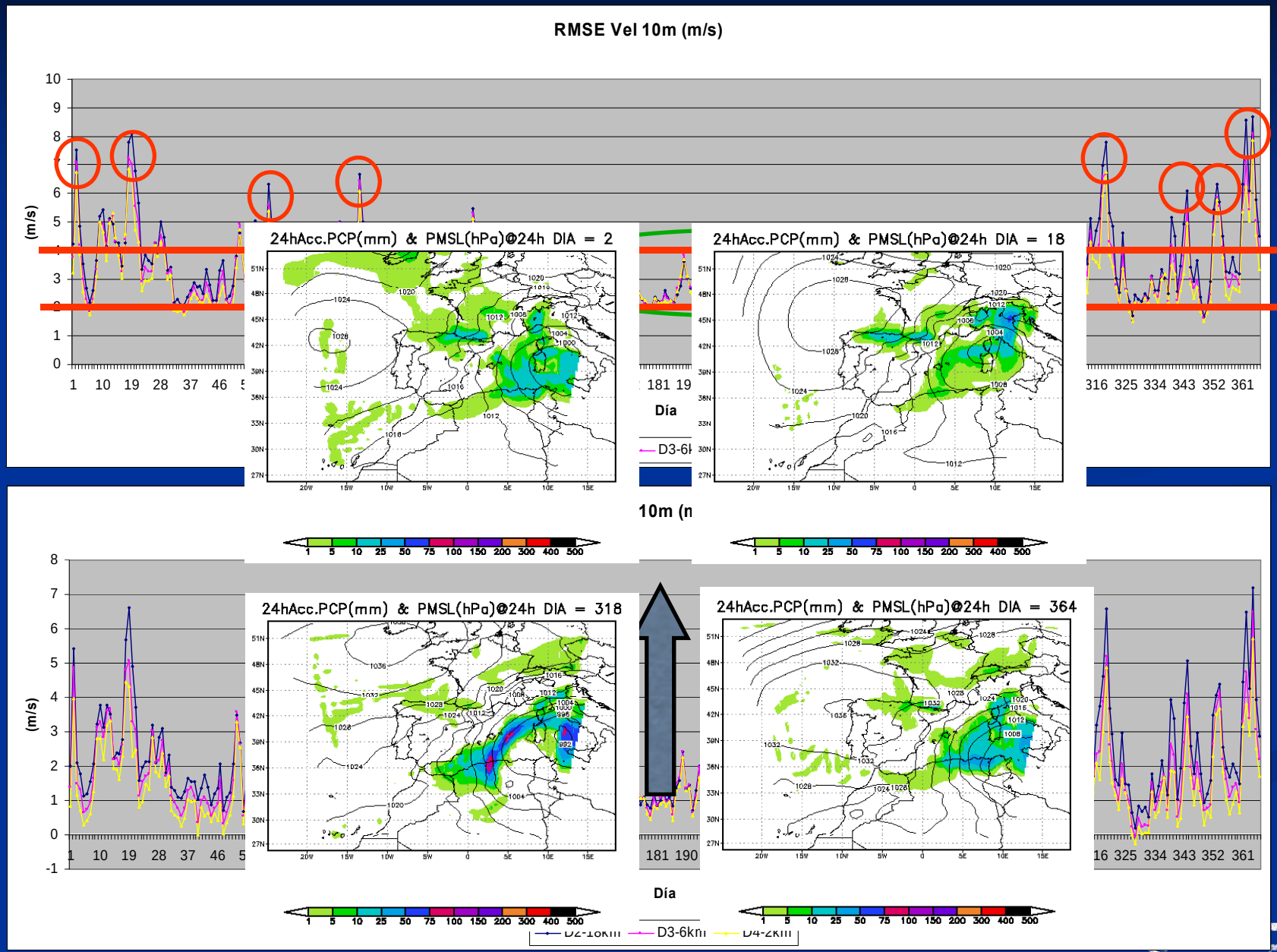
Operational meteorological validation: RADAR



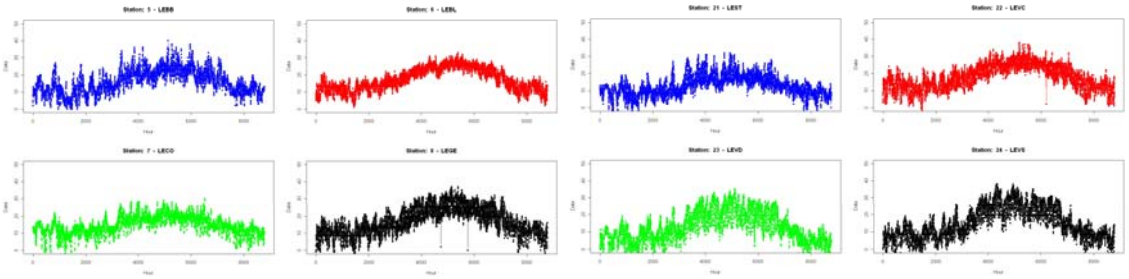




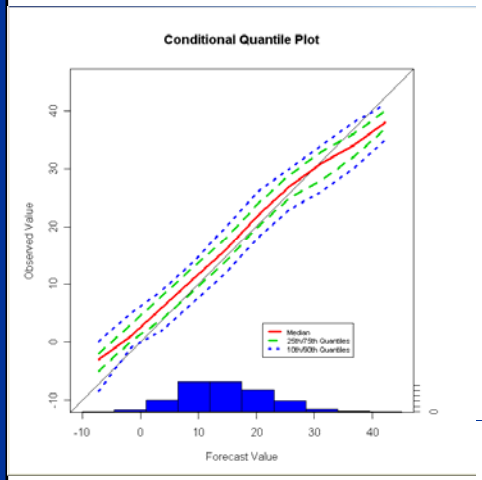

RMSE Vel 10m (m/s)
(m/s)
Día
24hAcc.PCP(mm) & PMSL(hPa)@24h DIA = 2
24hAcc.PCP(mm) & PMSL(hPa)@24h DIA = 18
24hAcc.PCP(mm) & PMSL(hPa)@24h DIA = 318
24hAcc.PCP(mm) & PMSL(hPa)@24h DIA = 364
D3-6km

Example: 2 m temperature

- QA/QC observations:

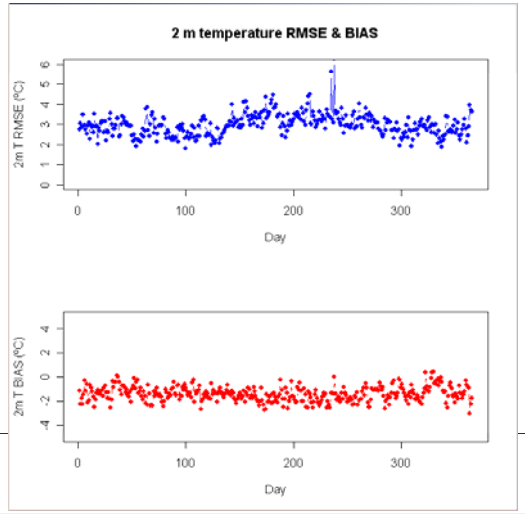


- Statistics and skill scores:




```
MAE                  =   2.389
ME                   =  -1.437
MSE                  =   9.173
MSE - baseline       =   56.01
MSE - persistence    =   25.33
SS  - baseline       =  0.8362
```

Temporal evolution:



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HERMES: High-Elective Resolution Modelling Emission System

Database information management

Biogenic emissions

- Land use map
- Emission factors and biomass
- Meteorological information (air temperature, solar radiation)

On road, ships and aircrafts traffic

- Roads (urban streets, roads, etc.), LTO cycles and ships routes
- Hourly, weekly and monthly profiles
- Distribution of the vehicles
- Velocity by road type
- Meteorological information (air temperature)
- Type of combustibles

Industry and electric generation

- Location (point/area)
- Production / electric generation
- Emission factors – energetic intensity
- Chimney height / diameter

Residential and commercial

- Density population map
- Combustibles consume
- Emission factors
- Solvent use
- Waste generation

Emission computation and speciation

BVOCs	NO_x, VOCs, CO, SO_2, particulate matter, CO_2, CH_4 and N_2O	NO_x, VOCs, CO, SO_2, particulate matter, CO_2, CH_4 and N_2O	NO_x, VOCs, CO, SO_2, particulate matter, CO_2, CH_4 and N_2O

Speciation

Management of the emission information

- Visualization and analysis of the results
- Management information tool

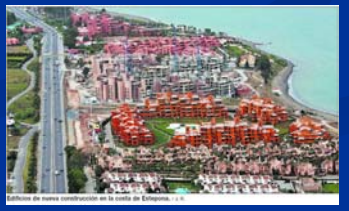
Management of emission data for air quality modelling

- Hourly aggregation of archives (4x4 km, 1x1 km grid size)
- Height desaggregation (vertical layers)
- Database resolution (1 - 4 km grid size)
- Generation of netCDF emission files







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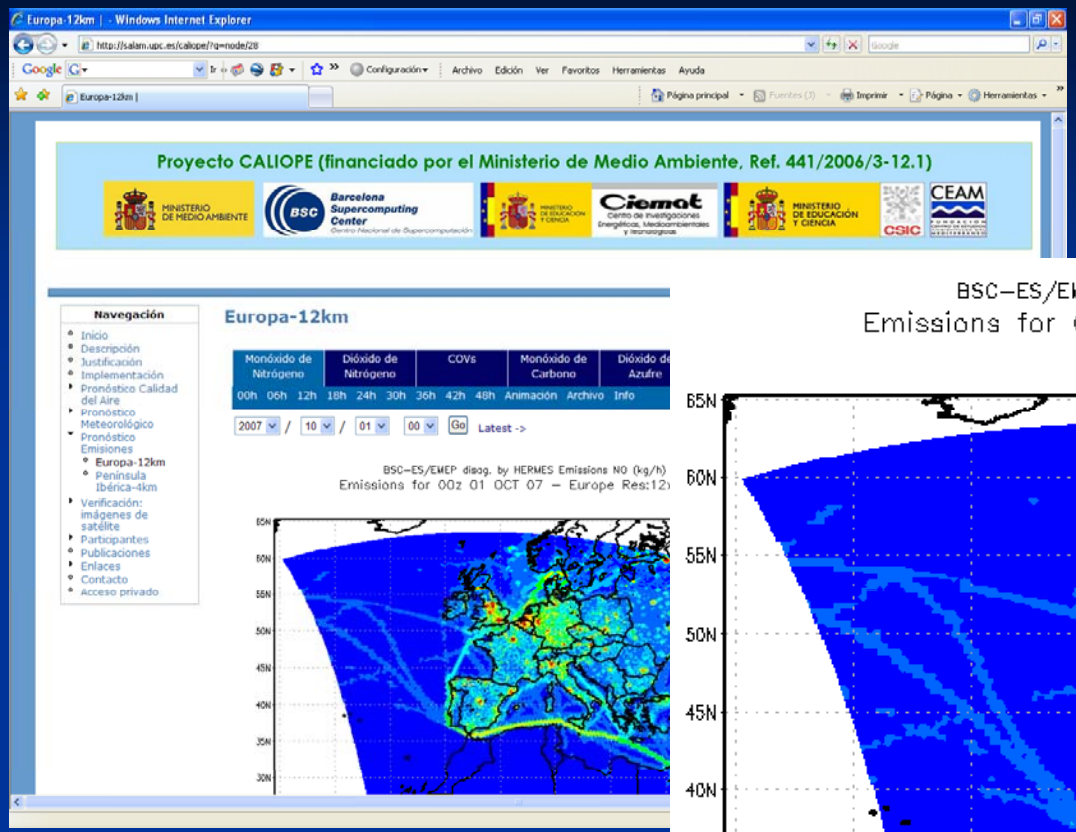
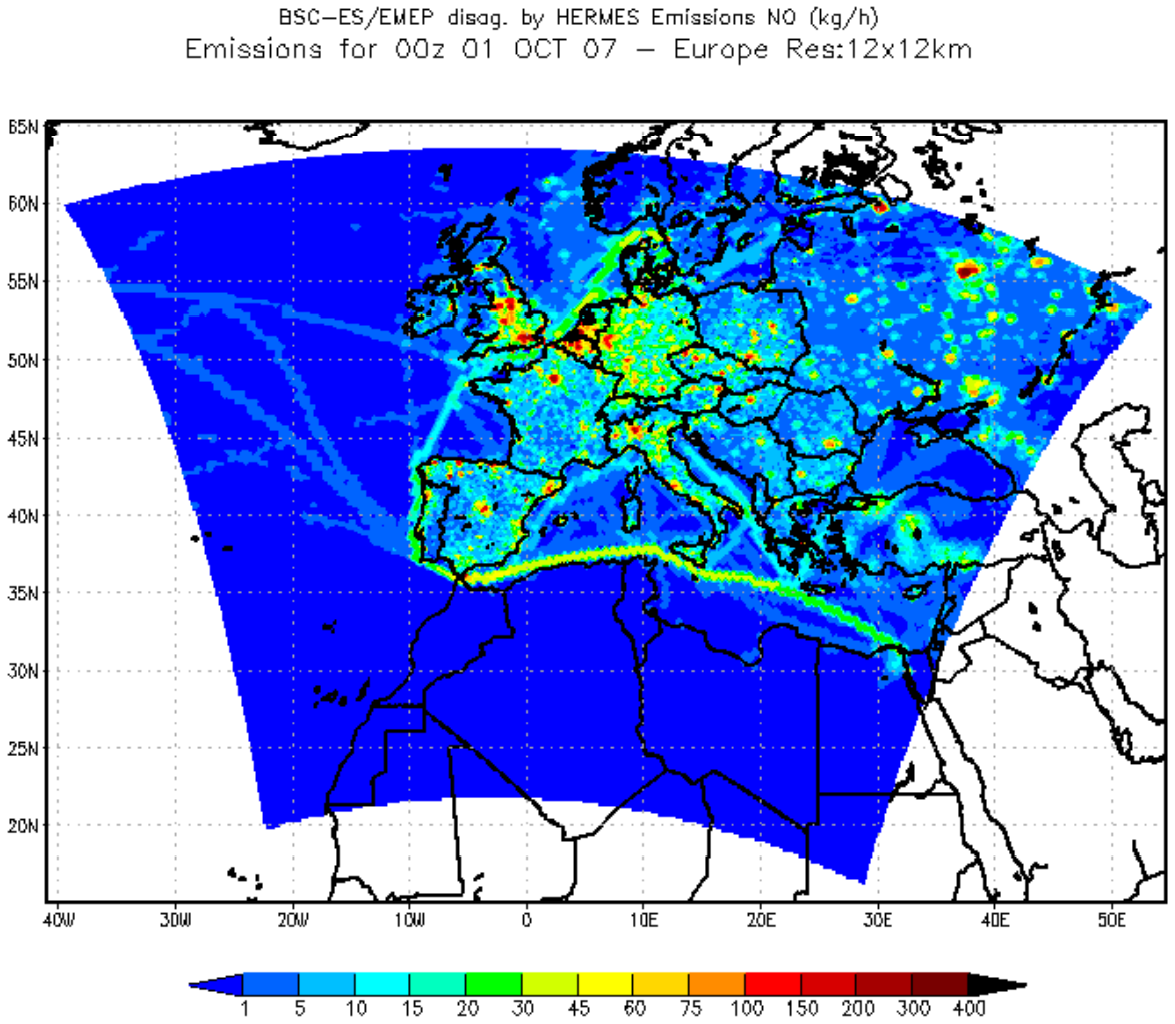
HERMES: Emissions for Europe, 12 km, disaggregated from EMEP (50 km), 01-02 October 2007, NO





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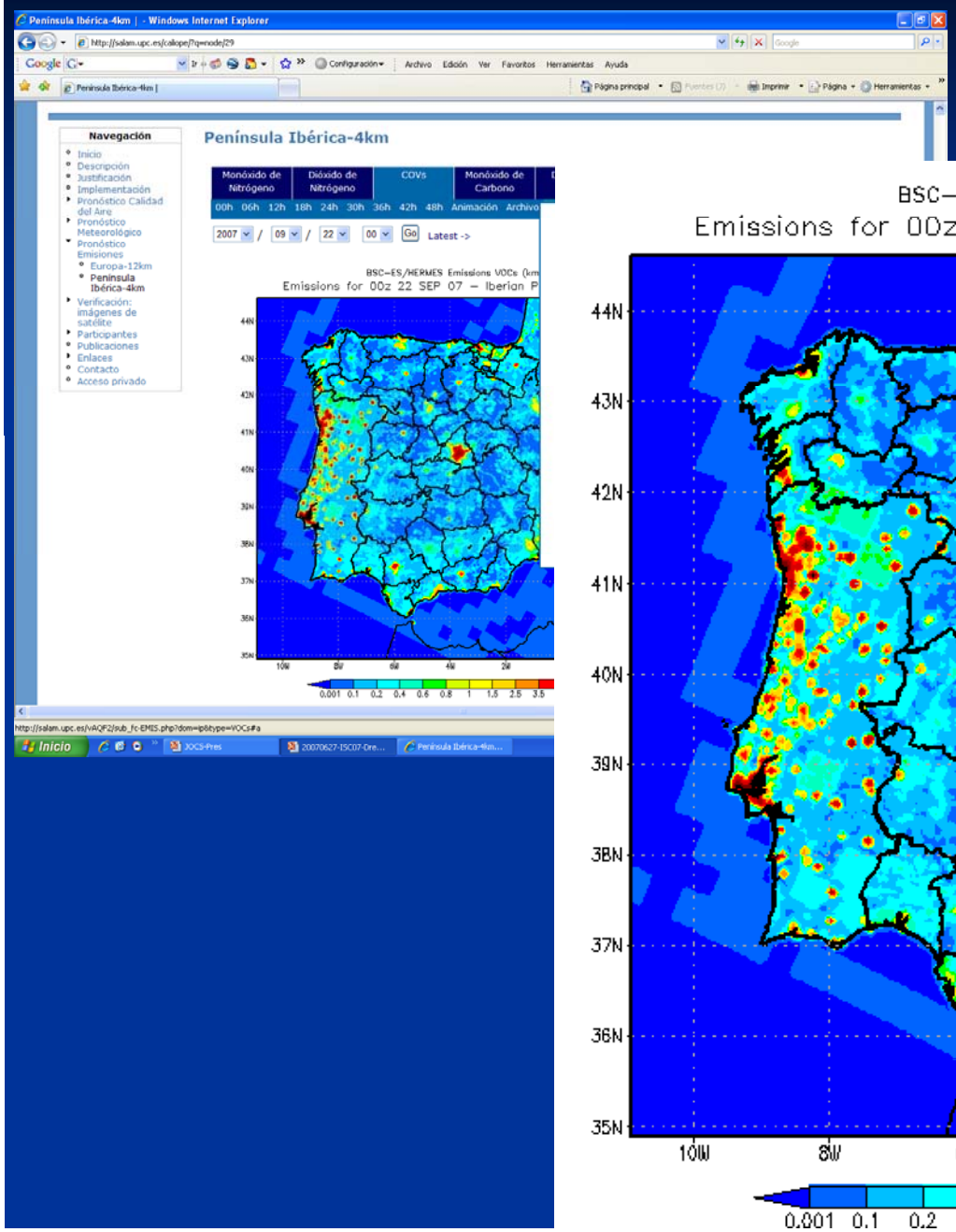
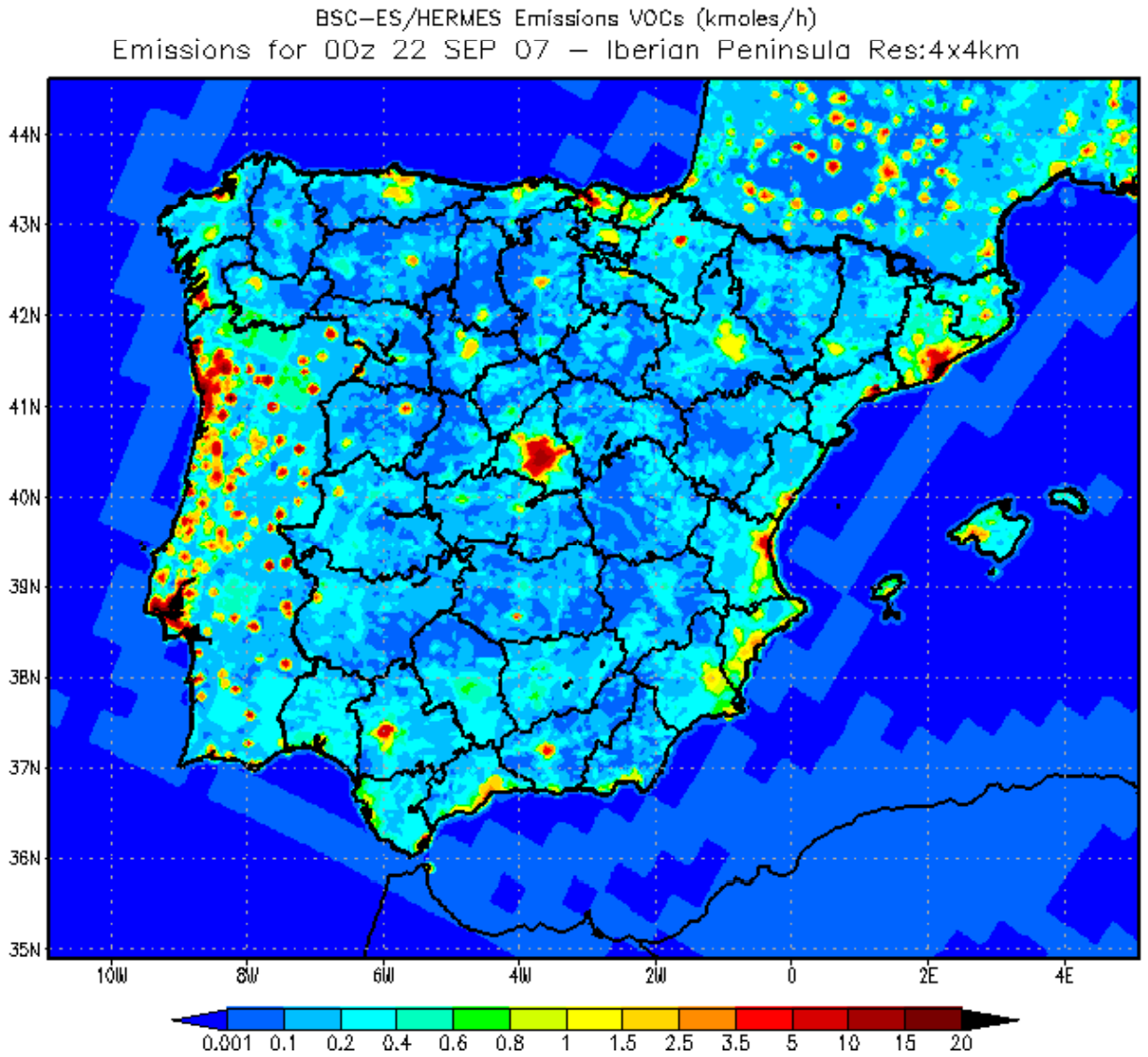
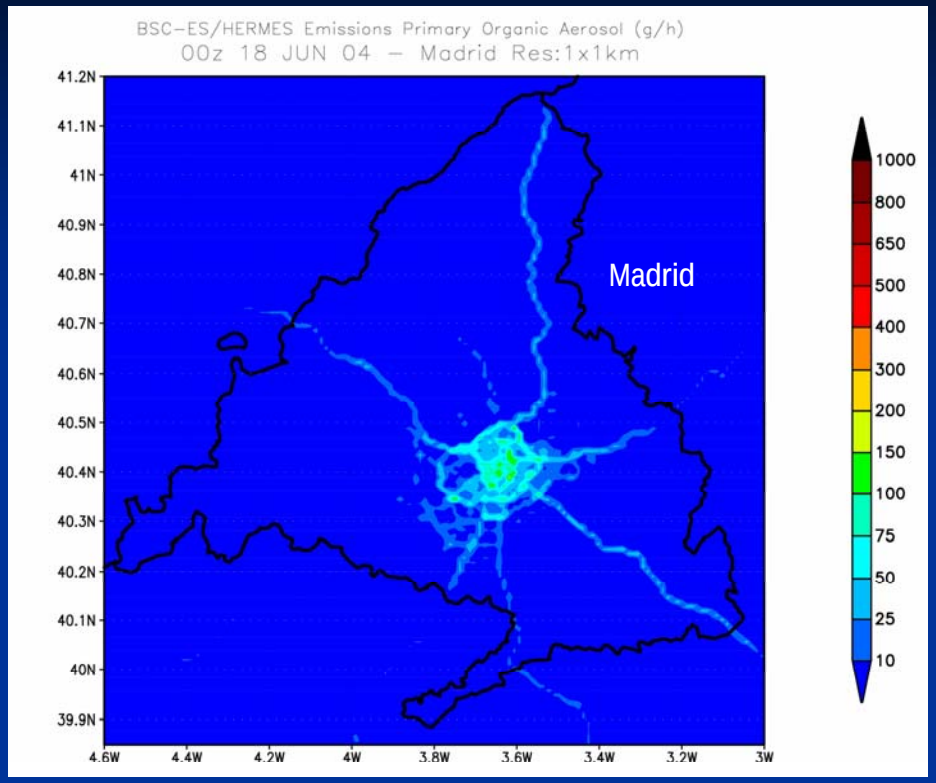
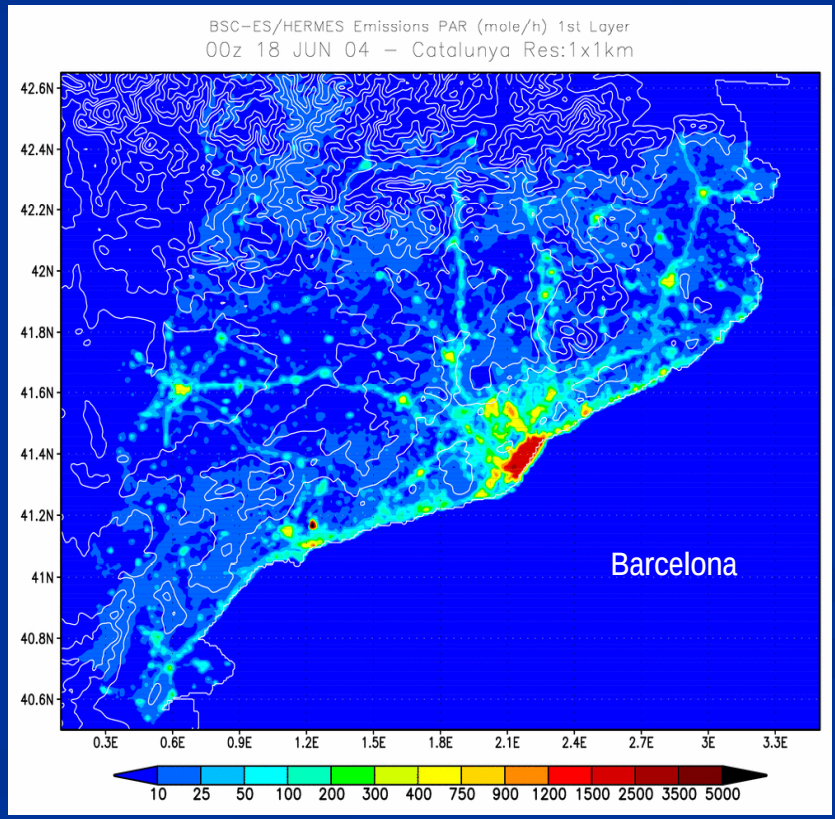
HERMES: Emissions for the Iberian Peninsula, 4 km, 01-02 October 2007, VOCs





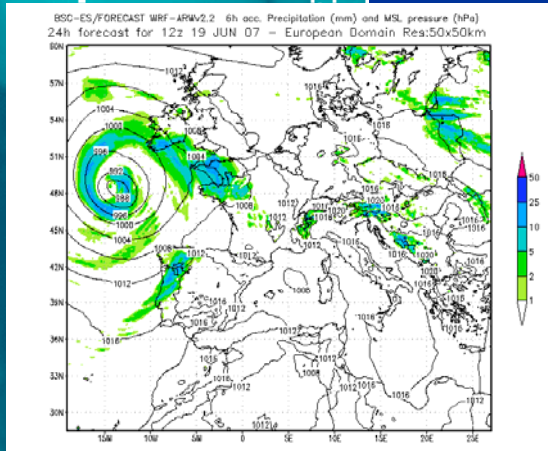


HERMES: Emissions for Madrid, 1 km, Primary Organic Aerosol (POA)

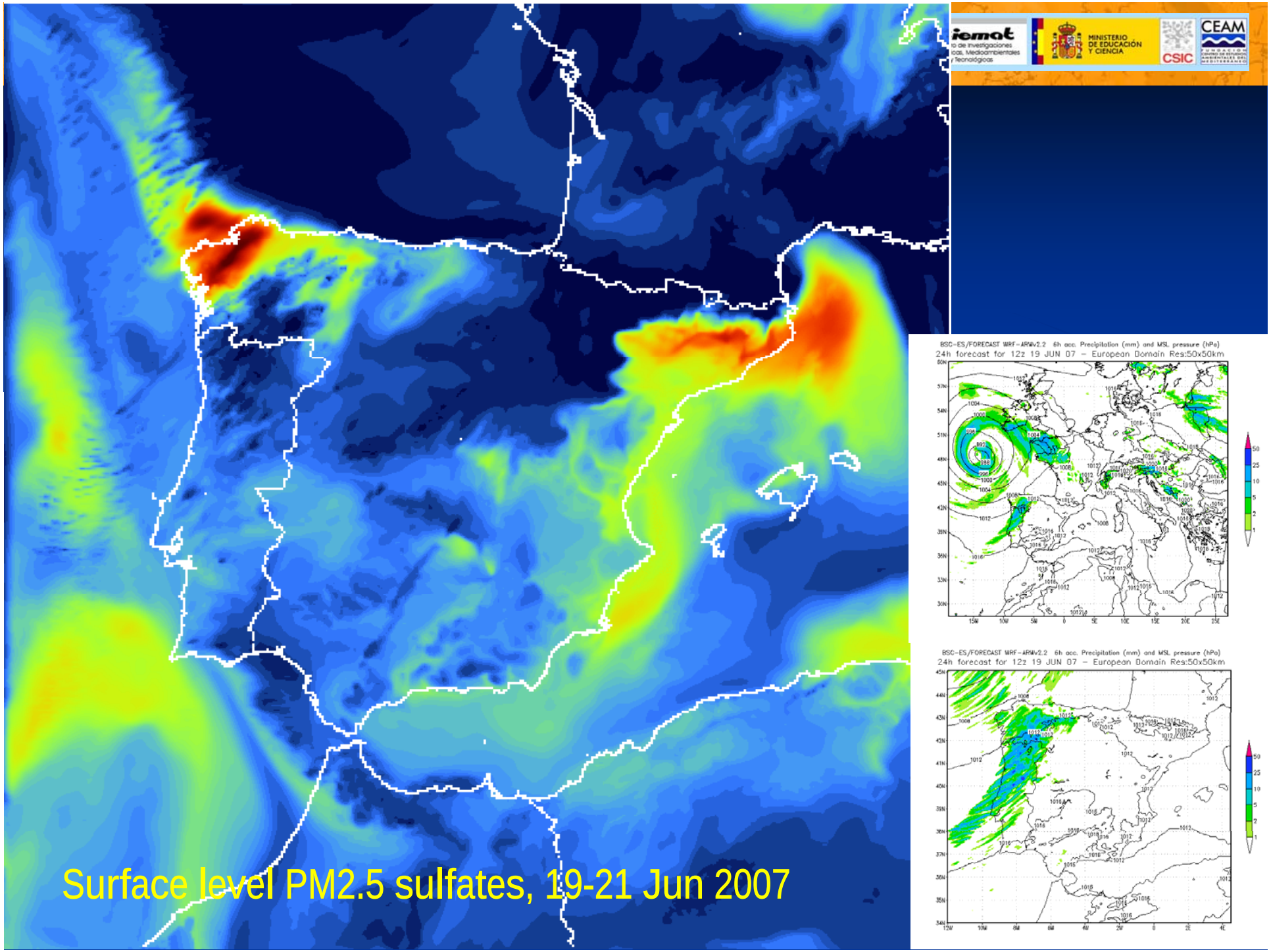


HERMES: Emissions for Catalonia, 1 km, Paraffin (PAR)

Resolution improved to 12 km for all Europe, 4 km for the Iberian peninsula, and 1 km for hot spot regions within MareNostrum Supercomputer



Surface tropospheric ozone, 18-21 Jun 2007


Surface level PM2.5 sulfates, 19-21 Jun 2007

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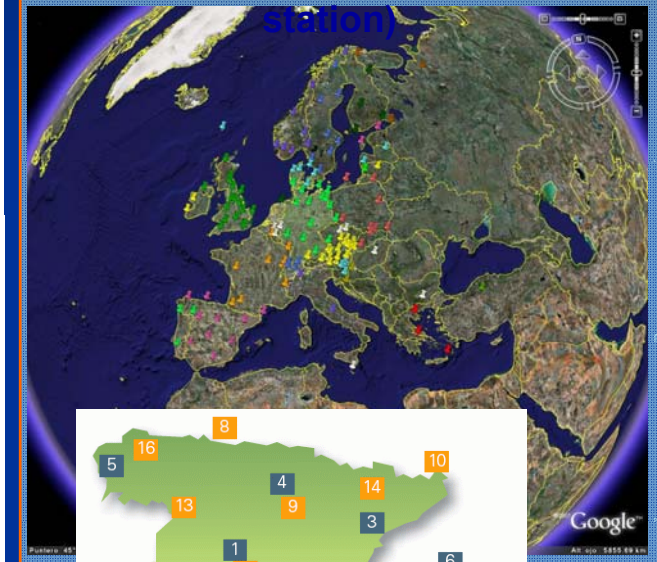
BSC-ES/FORECAST WRF-ARWv2.2 6h acc. Precipitation (mm) and MSL pressure (hPa)
24h forecast for 12z 19 JUN 07 – European Domain Res:50x50km

BSC-ES/FORECAST WRF-ARWv2.2 6h acc. Precipitation (mm) and MSL pressure (hPa)
24h forecast for 12z 19 JUN 07 – European Domain Res:50x50km

2004 validation data

EMEP DATA

(air quality data of background station)



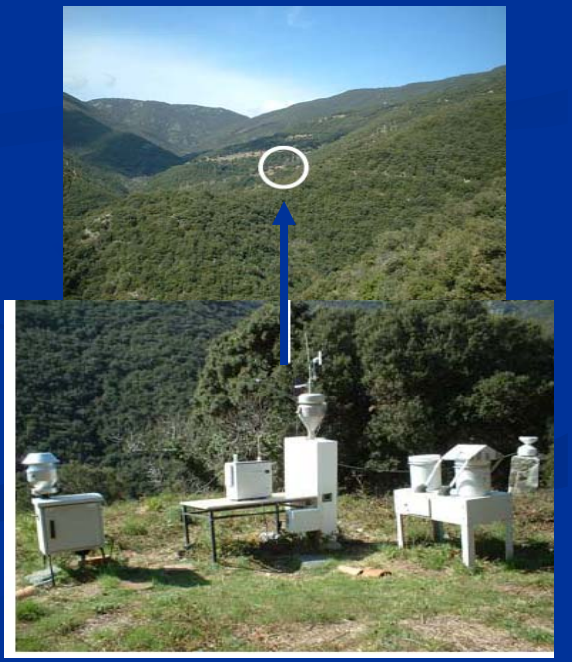
Víznar	ES7	3°28'28''W	37°14'18''N	1.230 m.
Niembro-Llanes	ES8	4°51'01''W	43°26'32''N	134 m.
Campisábalos	ES9	3°08'34''W	41°16'52''N	1.360 m.
Cabo de Creus	ES10	3°19'01''E	42°19'10''N	23 m.
Barcarrota	ES11	6°55'22''W	38°28'33''N	393 m.
Zarra	ES12	1°06'07''W	39°05'10''N	885 m.
Peñausende	ES13	5°52'17''W	41°17'20''N	865 m.
Els Torms	ES14	0°43'16''E	41°23'42''N	470 m.
Risco Llano	ES15	4°21'09''W	39°31'22''N	1.241 m.
O Saviñao	ES16	7°41'59''W	43°13'52''N	506 m.

CSIC DATA

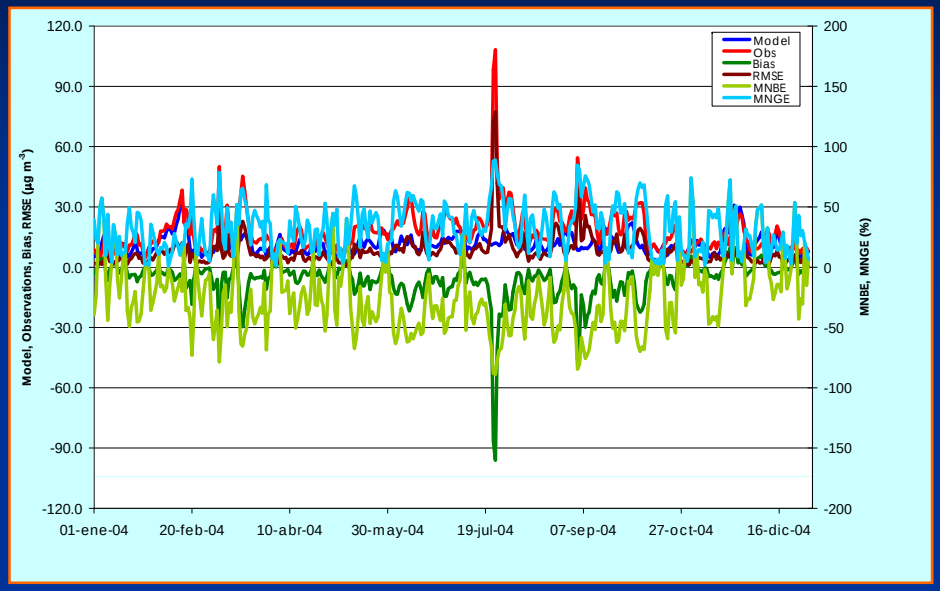
(levels and composition of particualte matter)

Air Quality data of Spanish networks

- Validation of the level of pollutant and composition of the particulate matter
- Validation of the spatial and temporal air quality
- Selección of representative station of air quality



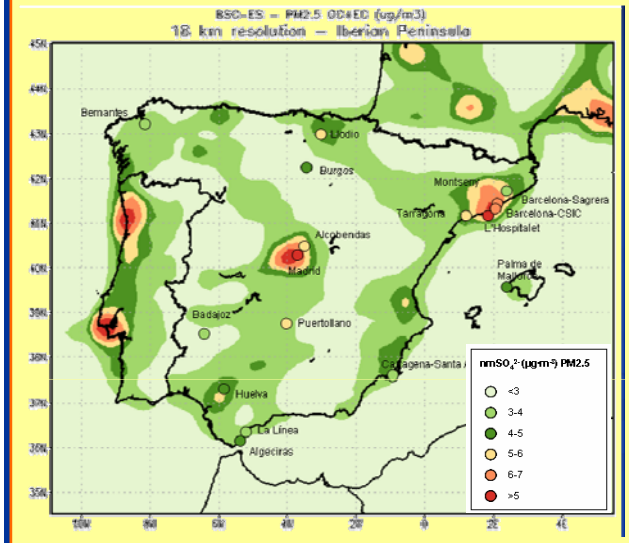
Cuantitative validation: parametres



European Directives

(1999/30/CE, 2002/3/CE)

The modelling results should meet the requeriments established in the Directive 1999/30/CE and 2002/3/CE on air quality pollutants (uncertainty in hourly values during daytime lower than 50%)



US EPA Guidelines

(1991, 2005)

Mean Normalized Bias Error
(tendency)

MNBE ±10-15%

Mean Normalized Gross Error

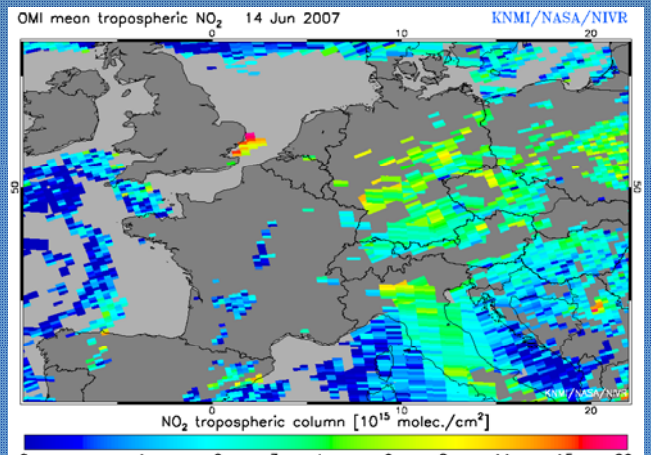
MNGE + 30-35%

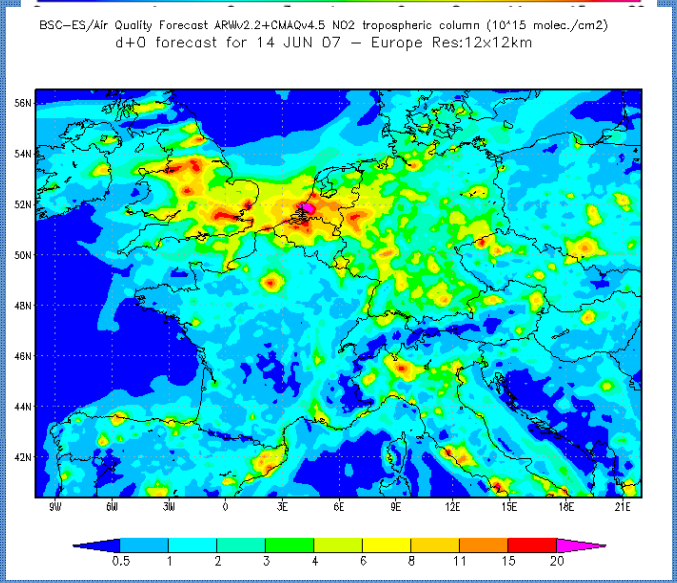
Unpaired Peak Accuracy

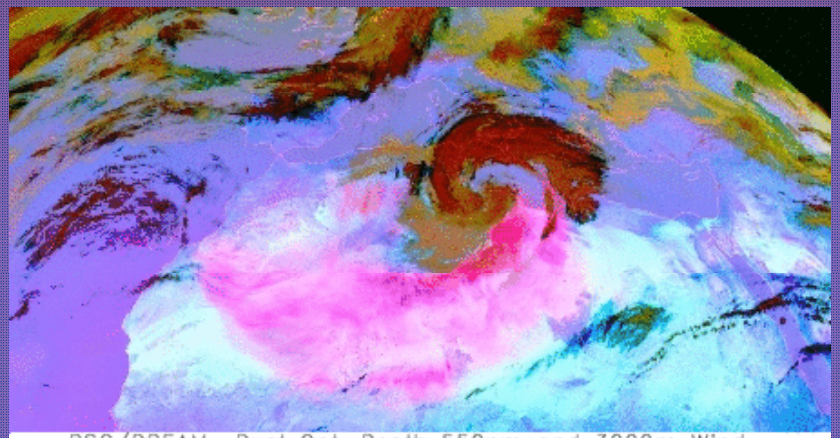
UPA ±15-20%

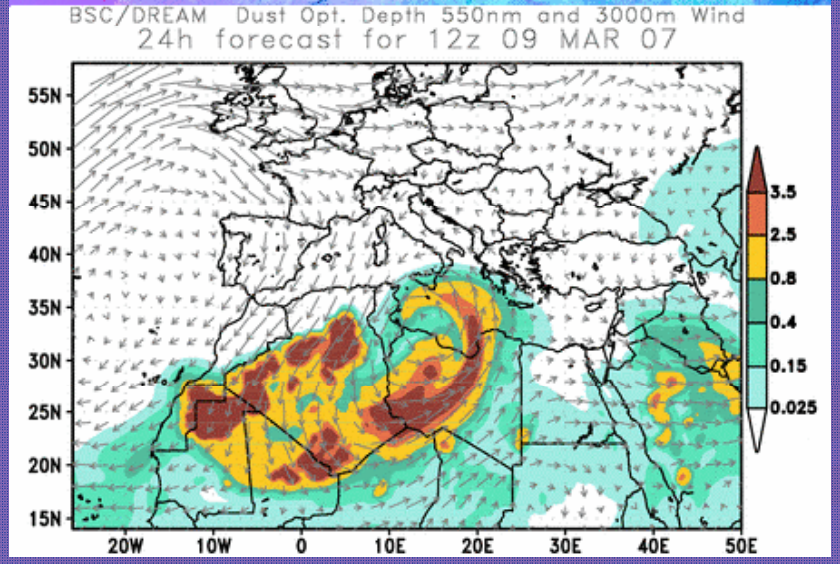
Qualititative validation

Comparation between OMI satellite and air quality modelling for NO_2









Comparation between MSG satelliteand dust load

Barcelona Supercomputing Center
Centro Nacional de Supercomputación
Earth Sciences

Diagnostic 2004

STEP 1

STUDIED DOMAIN

EUROPE-IBERIAN PENINSULA

STUDIED YEAR

2004

AIR QUALITY MODELLING

Meteorological model
WRF

Emission model
HERMES

Mineral dust model
DREAM

Chemical transport model
CMAQ

RESULTS

STEP 2

OBSERVATION

air quality, meteorological, particualte matter, satellite

RESULTS

1. Selection of the measurement locations
2. Interpretation of data from these notworks

VALIDATION

The European Directive 1999/30/EC defines as accuracy objective of 50 % for annual average

Uncertainty level

Capability of the model

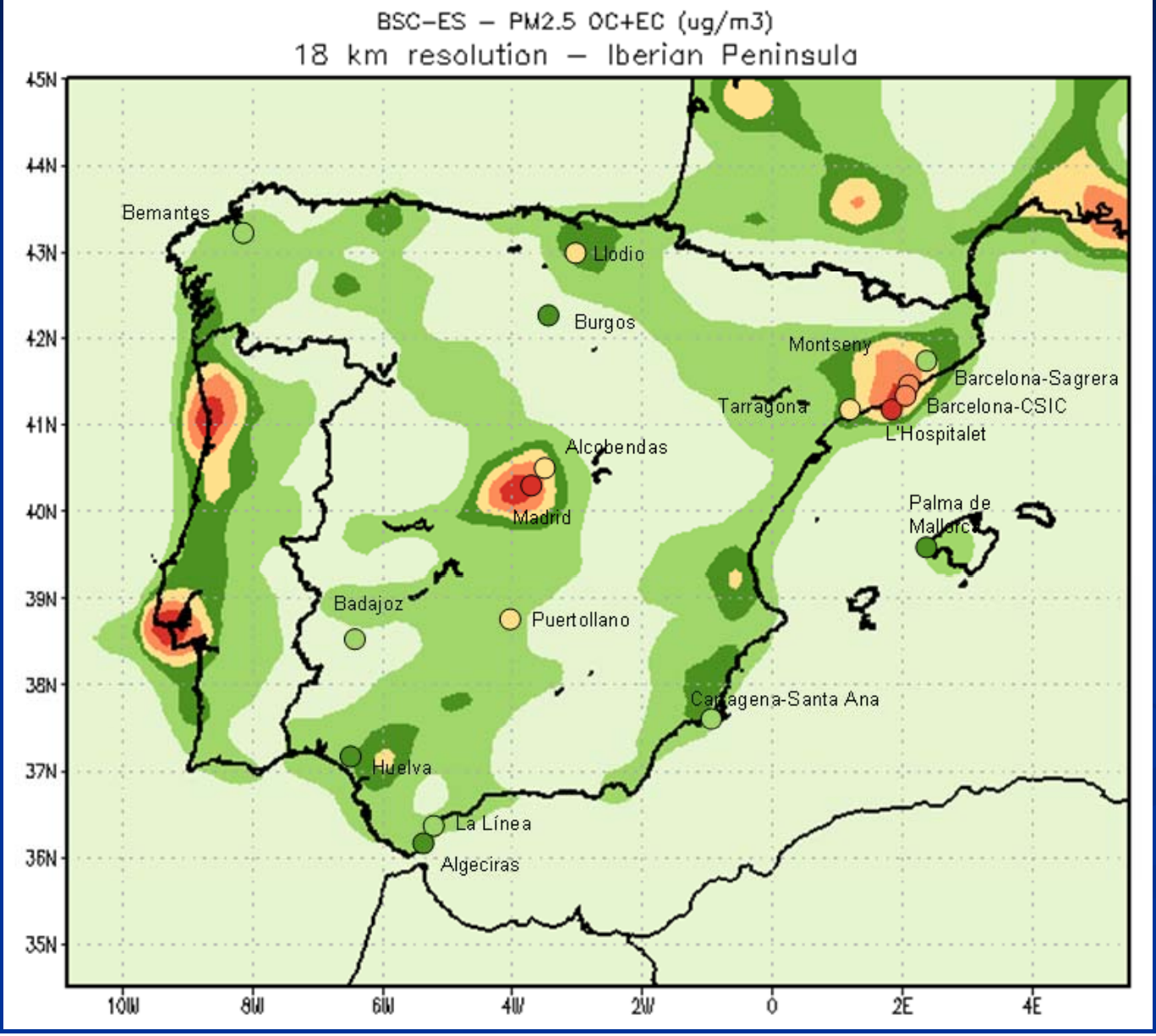
STEP 3

Determinig the dynamical patterns of pollution by particulate matter

Discriminate between anthropogenic and natural episodes of air polution

Decision-making for stabling policies set by air quality directives

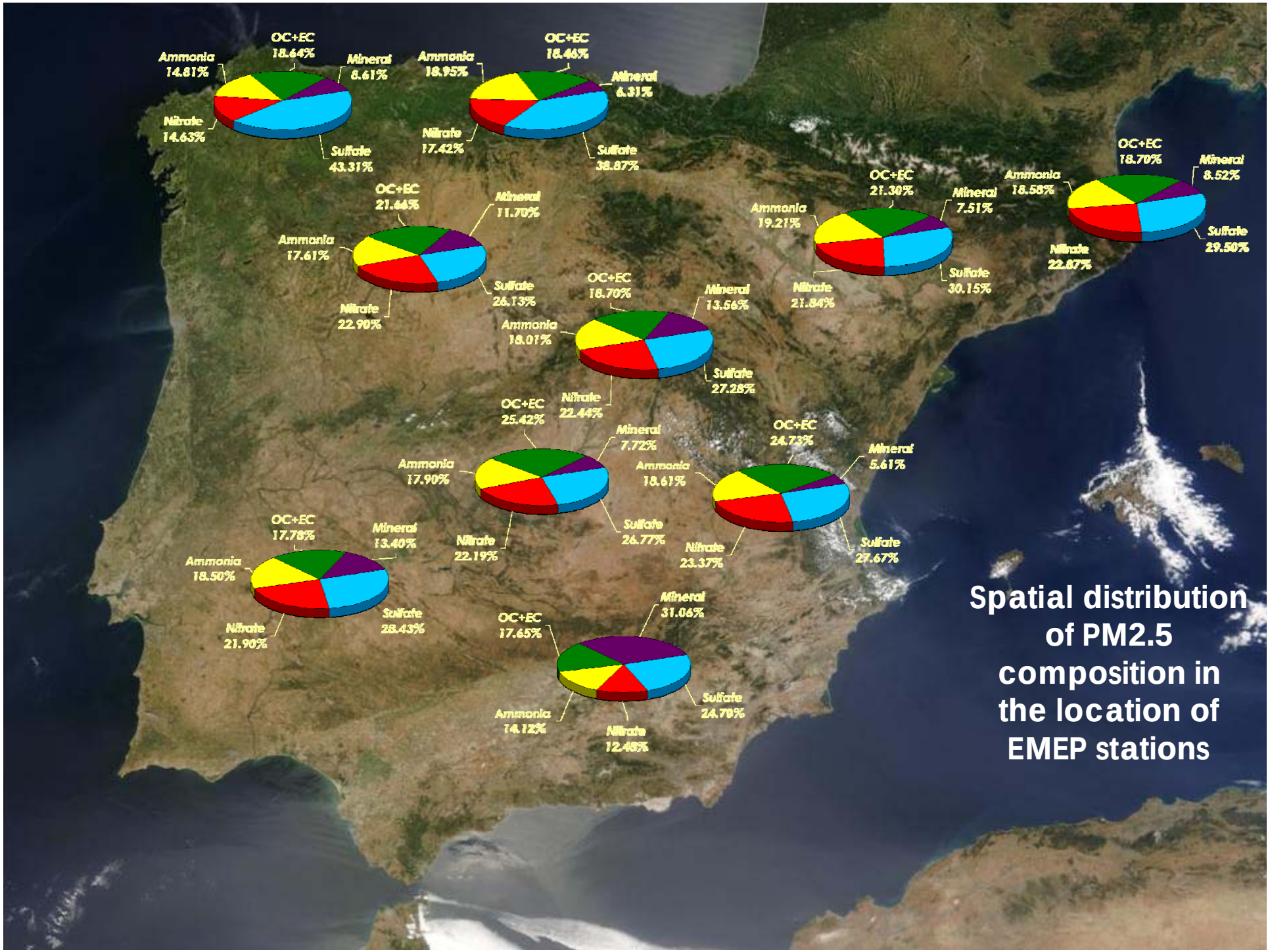
Distribution of OC+EC in the domain of study PM2.5

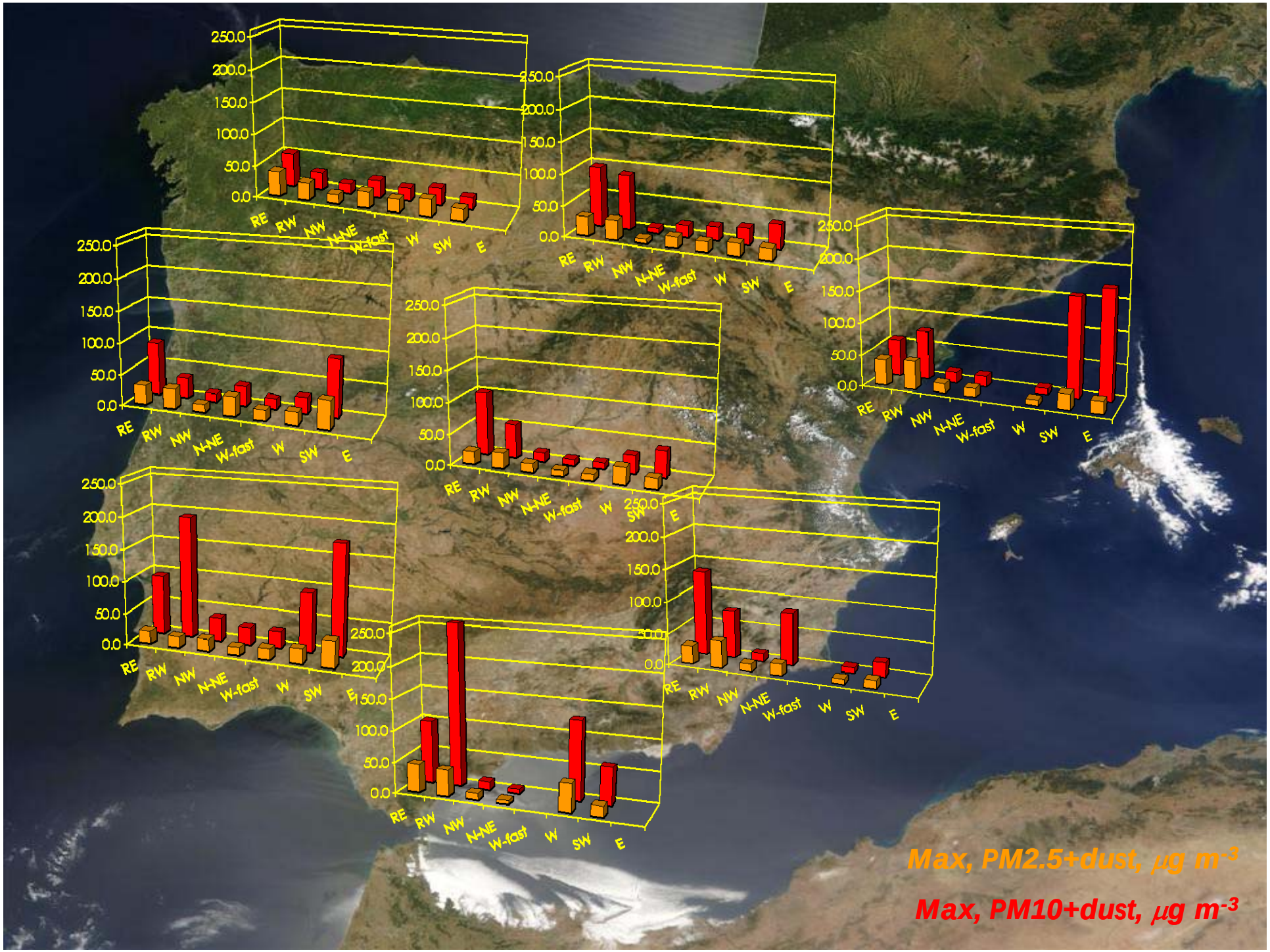


Station data taken from Querol et al. (2006), Atmospheric Particulate matter in Spain: levels, composition and source origin. Ed: CSIC and Ministerio de Medio Ambiente, Madrid, 39pp.

OC+EC ($\mu g \cdot m^{-3}$) PM2.5

- <3.0
- 3.0-5.0
- 5.0-7-0
- 7.0-10.0
- 10.0-15.0
- >15.0

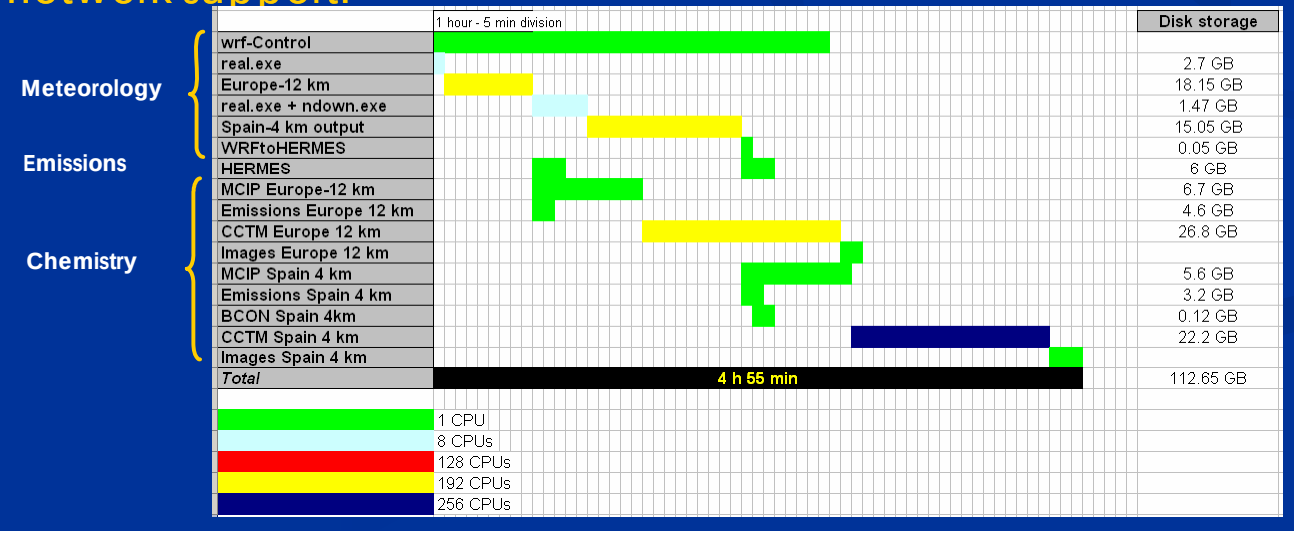

OC+EC 18.64%
Ammonia 14.81%
Mineral 8.61%
Nitrate 14.63%
Sulfate 43.31%
OC+EC 18.46%
Ammonia 18.95%
Mineral 6.31%
Nitrate 17.42%
Sulfate 38.87%
OC+EC 21.44%
Mineral 11.70%
Ammonia 17.61%
Sulfate 26.13%
Nitrate 22.90%
OC+EC 21.30%
Mineral 7.51%
Ammonia 19.21%
Nitrate 21.84%
Sulfate 30.15%
OC+EC 18.70%
Mineral 8.52%
Ammonia 18.58%
Sulfate 29.50%
Nitrate 22.87%
OC+EC 18.70%
Mineral 13.56%
Ammonia 18.01%
Sulfate 27.28%
Nitrate 22.44%
OC+EC 25.42%
Mineral 7.72%
Ammonia 17.90%
Sulfate 26.77%
Nitrate 22.19%
OC+EC 24.73%
Mineral 5.61%
Ammonia 18.61%
Nitrate 23.37%
Sulfate 27.67%
OC+EC 17.78%
Mineral 13.40%
Ammonia 18.50%
Sulfate 28.43%
Nitrate 21.90%
Mineral 31.06%
OC+EC 17.65%
Sulfate 24.79%
Ammonia 14.12%
Nitrate 12.48%
Spatial distribution of PM2.5 composition in the location of EMEP stations


250.0
200.0
150.0
100.0
50.0
0.0
RE
RW
NW
N-NE
W-fast
W
SW
E
Max, PM2.5+dust, μg m-3
Max, PM10+dust, μg m-3


14.8%
61.6%
1.6%
MNB (%) MNGE (%) UPA (%)
16.7%
45.1%
4.5%
MNB (%) MNGE (%) UPA (%)
1.1%
39.1%
-4.9%
MNB (%) MNGE (%) UPA (%)
-19.5%
38.3%
-15.2%
MNB (%) MNGE (%) UPA (%)
12.7%
52.2%
MNB (%) MNGE (%) UPA (%)
5.0%
45.3%
-0.8%
MNB (%) MNGE (%) UPA (%)
27.7%
61.8%
-34.8%
MNB (%) MNGE (%) UPA (%)
18.2%
45.7%
21.1%
MNB (%) MNGE (%) UPA (%)
40.3%
-33.8%
19.6%
-5.6%
MNB (%) MNGE (%) UPA (%)
PM2.5 evaluation against EMEP data

MareNostrum Supercomputer

- 10240 IBM Power PC 970MP processors at 2.3 GHz (dual processors).
- 20 TB Main Memory (4GB ECC 333 DDR memory per node).
- 94.21 Tflops (peak).
- 280 + 90 TB disk.
- 3 networks: Myrinet, Gigabit and 10/100 Ethernet
- Linux 2.6 cluster (SuSe).
- Diskless network support.



Conclusions

- The CALIOPE system will contribute to a deeper understanding of atmospheric processes and the dynamics of air pollutants in Europe, the Iberian Peninsula and the urban areas presenting exceedances of the thresholds set in the regulations for protecting the human health and the ecosystems.

- Also, it should be highlighted that this system is useful to complement the data obtained in the present networks of air quality measurements managed by regional and local authorities, and in certain experimental measurement campaigns or air quality studies performed both in urban or background areas.

- The model qualitative and quantitative evaluation studies performed so far for a reference year (2004) using data from observation networks and satellite information have outlined the good skills of the modelling system concerning the concentrations of gaseous pollutants and aerosols in Spain and Europe. The initial state of the system and the operational forecasts are available at

http://www.bsc.es/
http://salam.upc.es/caliope

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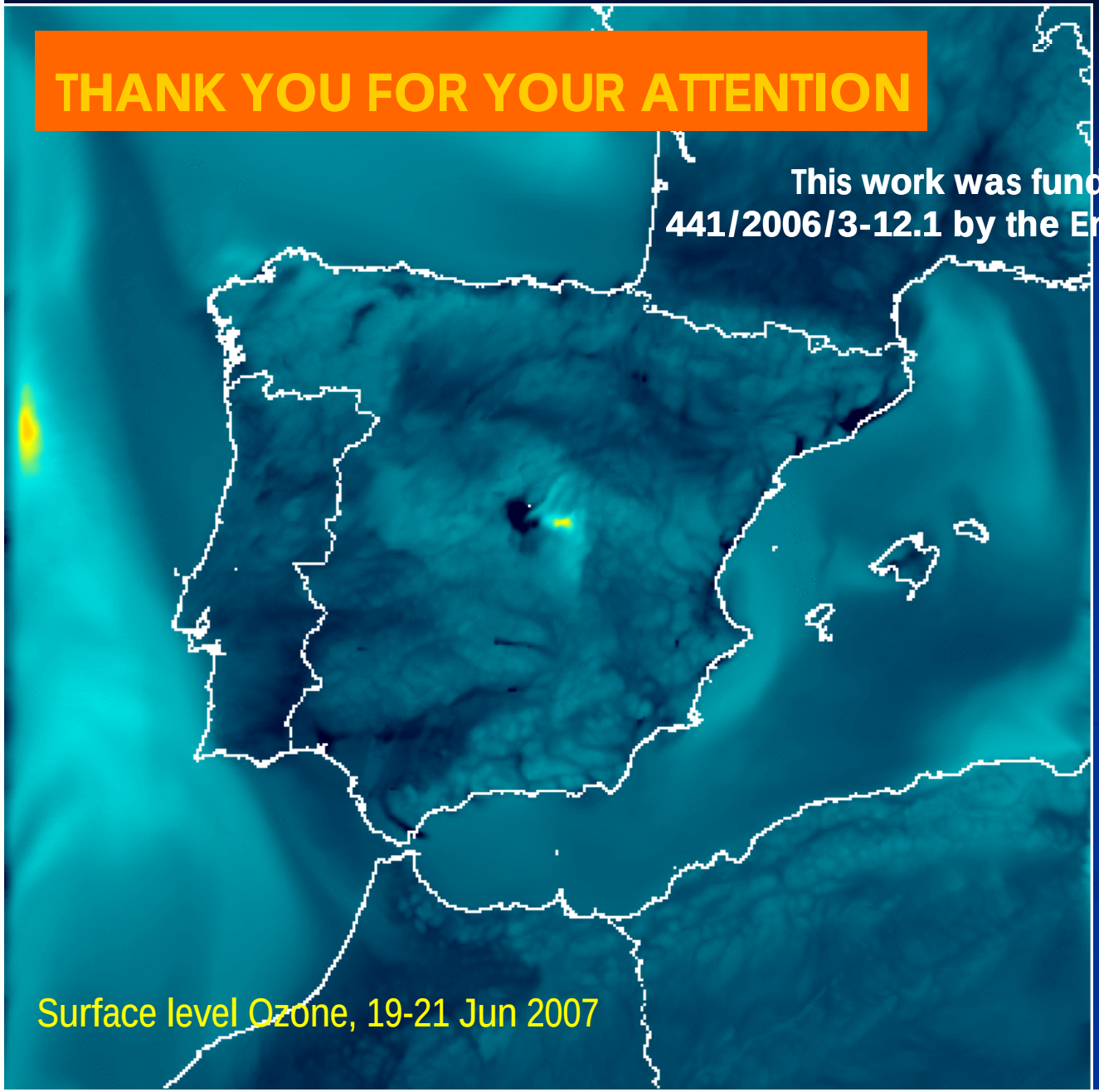
Earth Sciences

THANK YOU FOR YOUR ATTENTION



Surface level Ozone, 19-21 Jun 2007

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