

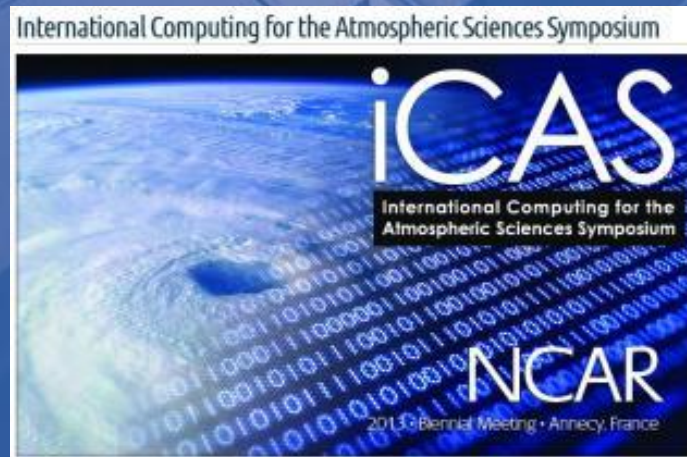


**Barcelona
Supercomputing
Center**

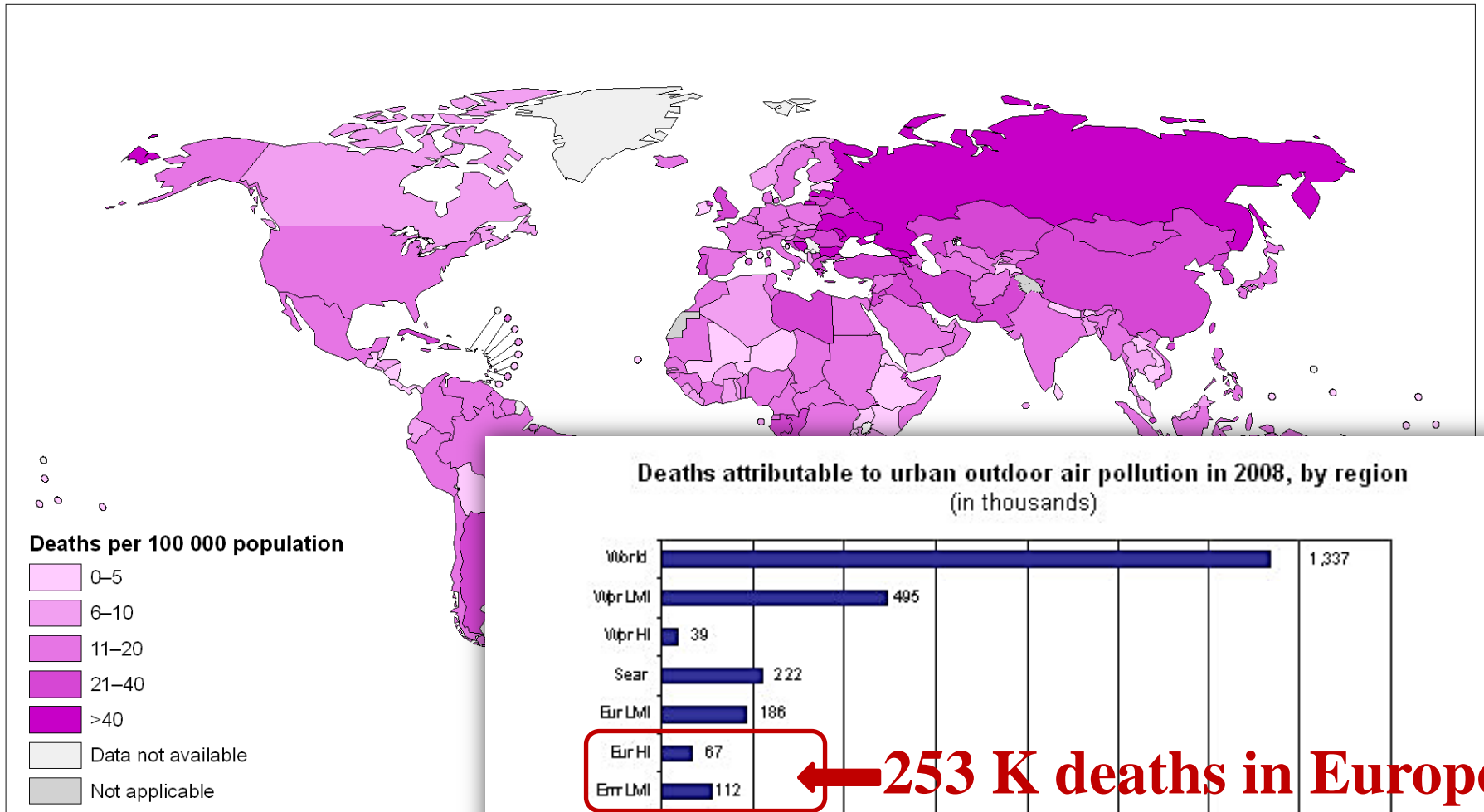
Centro Nacional de Supercomputación

Air Quality Forecasting Systems: Needs of Computational Resources and Database

Dr. José M^a Baldasano, Kim Serradell



Deaths attributable to outdoor air pollution, 2008

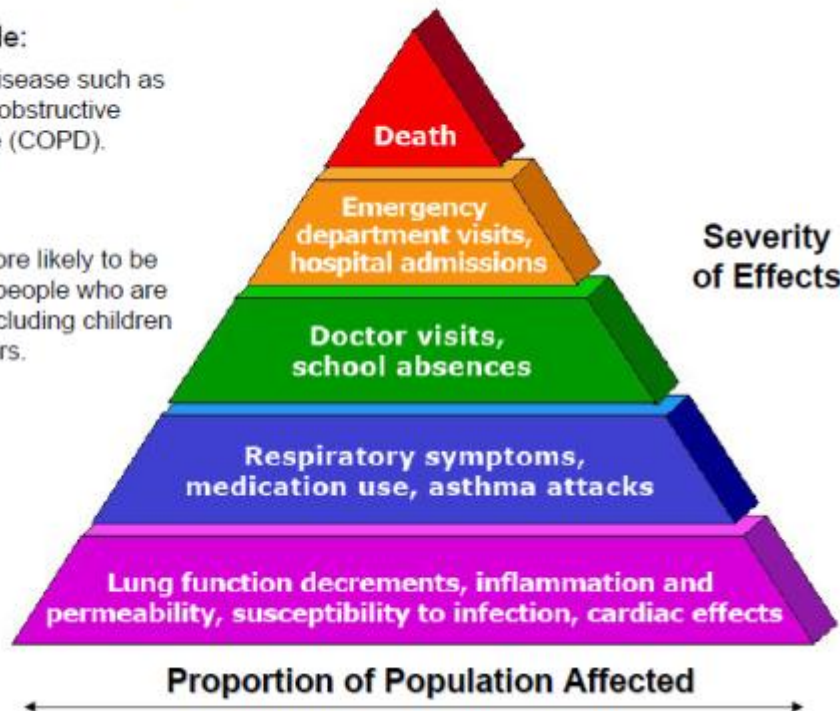


The boundaries and names shown and the designations used on this map do not represent the official position of the World Health Organization concerning the legal status of a country or concerning the delimitation of its frontiers or boundaries. Dotted lines on this map indicate areas where there may not yet be full agreement.

Health Impacts: "Pyramid of Effects"

At-risk groups include:

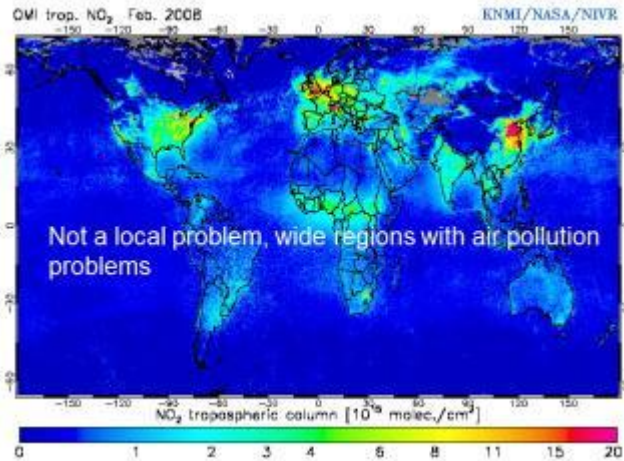
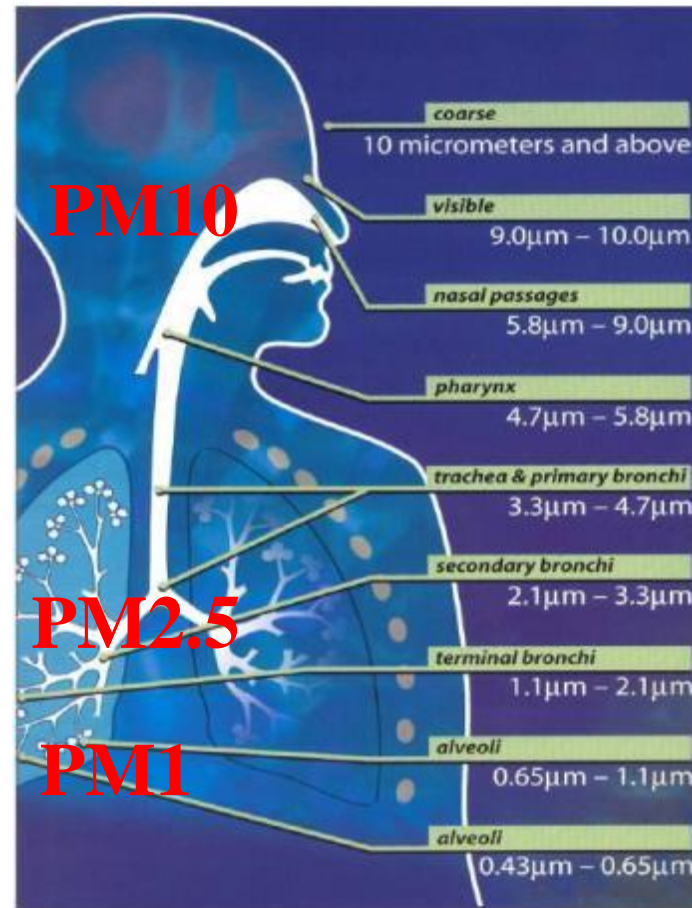
- People with lung disease such as asthma or chronic obstructive pulmonary disease (COPD).
- Children.
- Older adults.
- People who are more likely to be exposed, such as people who are active outdoors, including children and outdoor workers.



← Episodic pollution



Chronic pollution





PERGAMON

Atmospheric Environment 35 Supplement No. 1 (2001) S91–S98

ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

Operational air pollution forecasts from European to local scale

Jørgen Brandt*, Jesper H. Christensen, Lise M. Frohn, Finn Palmgren, Ruwim Berkowicz, Zahari Zlatev

Department of Atmospheric Environment, National Environmental Research Institute, Frederiksborgvej 399, P.O. Box 358, DK-4000 Roskilde, Denmark

Received 3 May 2000; received in revised form 4 August 2000; accepted 14 August 2000

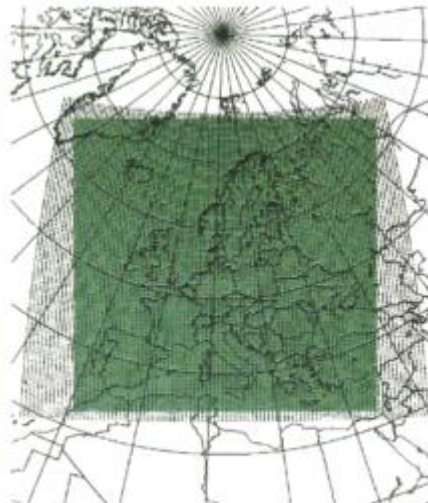
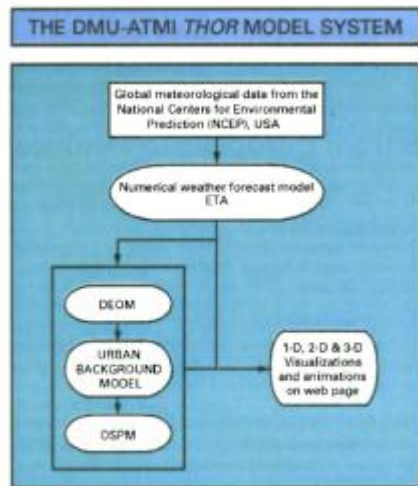


Fig. 1. A schematic diagram of the main modules and the data flow in the DMU-ATMI THOR air pollution forecast system (left figure). The model domains of the ETA model (dots) and the Danish Eulerian operation model (shaded square). The center of the domains is at NERI, Roskilde, Denmark (right figure).



Journal of Atmospheric Chemistry 42: 91–121, 2002.
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Comparison of Five Eulerian Air Pollution Forecasting Systems for the Summer of 1999 Using the German Ozone Monitoring Data

STEFAN TILMES¹, JØRGEN BRANDT², FRODE FLATØY³, ROBERT BERGSTRÖM⁴, JOHANNES FLEMMING⁵, JOAKIM LANGNER⁴, JESPER H. CHRISTENSEN², LISE M. FROHN², ØYSTEIN HOV³, INGO JACOBSEN^{1*}, EBERTHARD REIMER⁵, RAINER STERN⁵ and JÖRG ZIMMERMANN¹

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²National Environmental Research Institution (NERI), Frederiksborgvej 399, PO Box 358, DK-4000 Roskilde, Denmark

³Norwegian Institute for Air Research (NILU), PO Box 100, N-2027 Kjeller, Norway

⁴Swedish Meteorological and Hydrological Institute (SMHI), SE-601 76 Norrköping, Sweden

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(Received: 18 October 2000; in final form: 15 August 2001)

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STEFAN TILMES ET AL.

Table I. Summary of initial, boundary and input data for the five different air pollution forecast systems

| Input data | NERI | DWD | NILU | SMHI | FUB |
|-------------------------------------|---------------------------------------|---------------------------------------|--|---------------------------------------|---------------------------|
| Met. initial/ boundary data | NCEP | EM | ECMWF | ECMWF | DWD-GM |
| Met. model | ETA 39 km | LM | NORLAM | HIRLAM 44 km | DWD-EM |
| Emission data | EMEP + DK | IER | EMEP + GEIA (Bekovitz <i>et al.</i> , 1996) | EMEP | PROGNOS 94 |
| Chemical initial data | Restart from previous model run | Restart from previous model run | Restart from previous model run | Restart from previous model run | Measurements for ozone |
| Boundary conditions for ozone | Seasonal data | Seasonal data | Seasonal data | Seasonal data | Seasonal data |



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Historical evolution of NWP and AQM → future

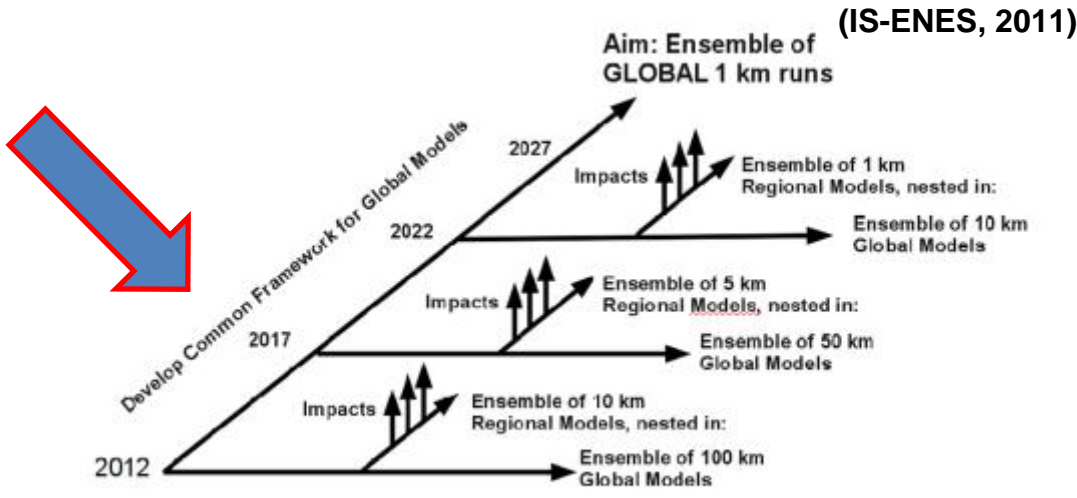
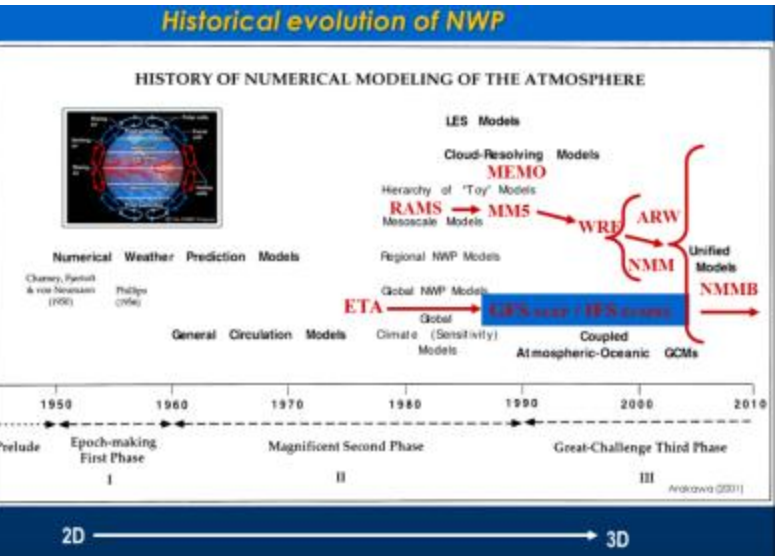


Figure 3: evolution diagram with global/regional models and resolution

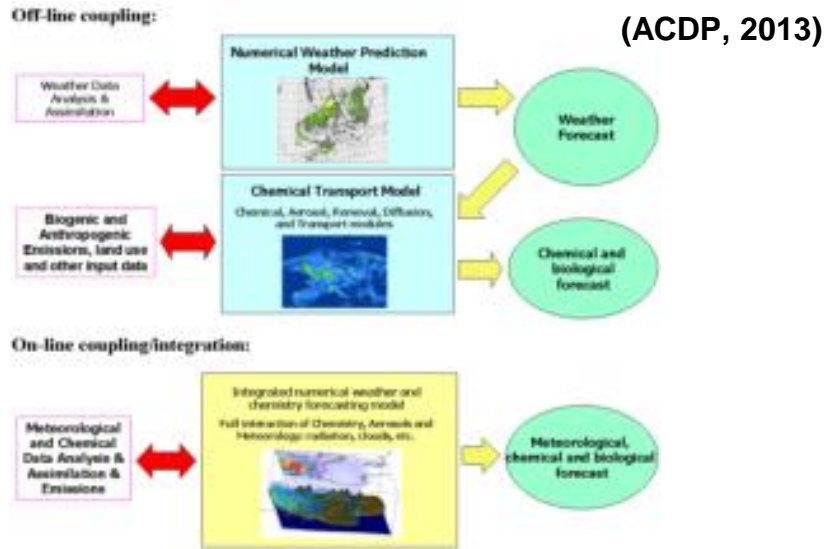
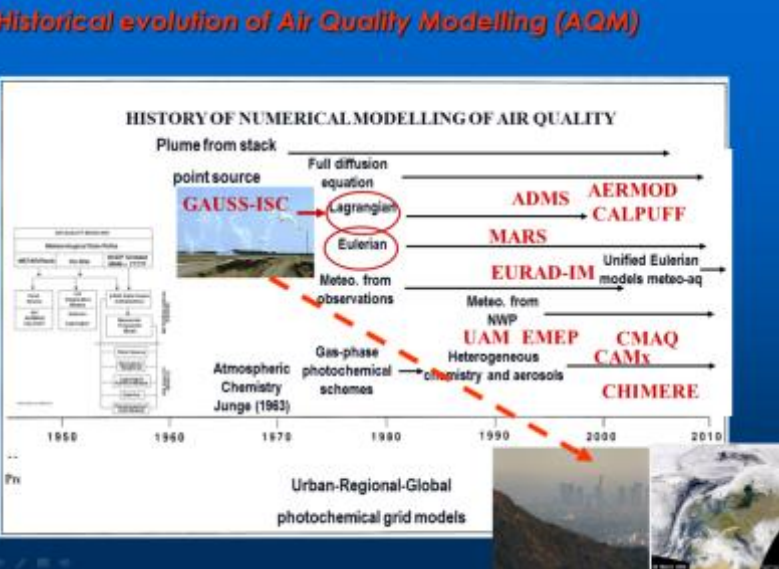


Figure 1: Schematic diagram of the off-line and on-line coupled NWP and ACT modelling approaches for CWE.

WMO Sand and Dust Storm Warning and Assessment System (SDS WAS) in cooperation with World Meteorological Organization (WMO)



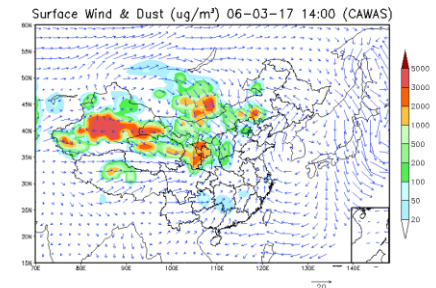
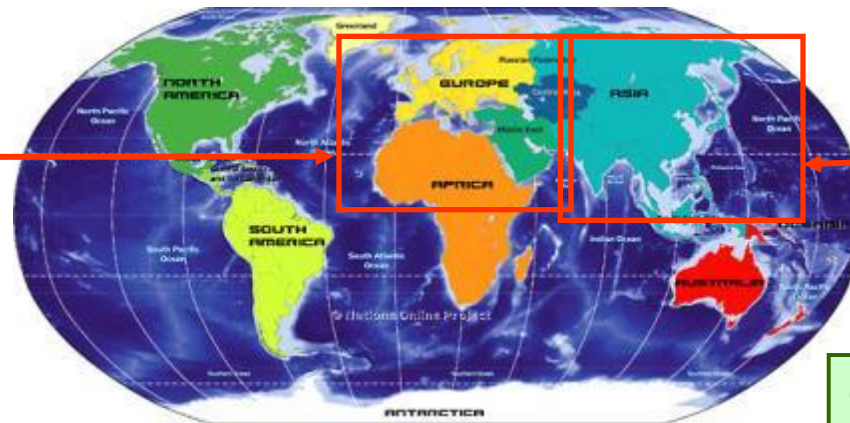
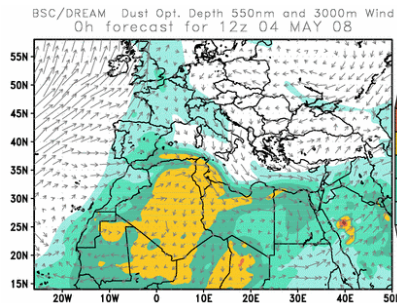
- To enhance the ability of participating countries to establish and improve systems for forecasting and warning to suppress the impact of Sand and Dust Storm

by

- Establishing a coordinated global network of Sand and Dust Storm forecasting centers delivering products useful to a wide range of users in understanding and reducing the impacts of SDS

North Africa, Middle East and Europe (<http://sds-was.aemet.es/>)

Asia



**BSC-CNS
AEMET, Spain**

**China Meteorological
Administration (CMA)**

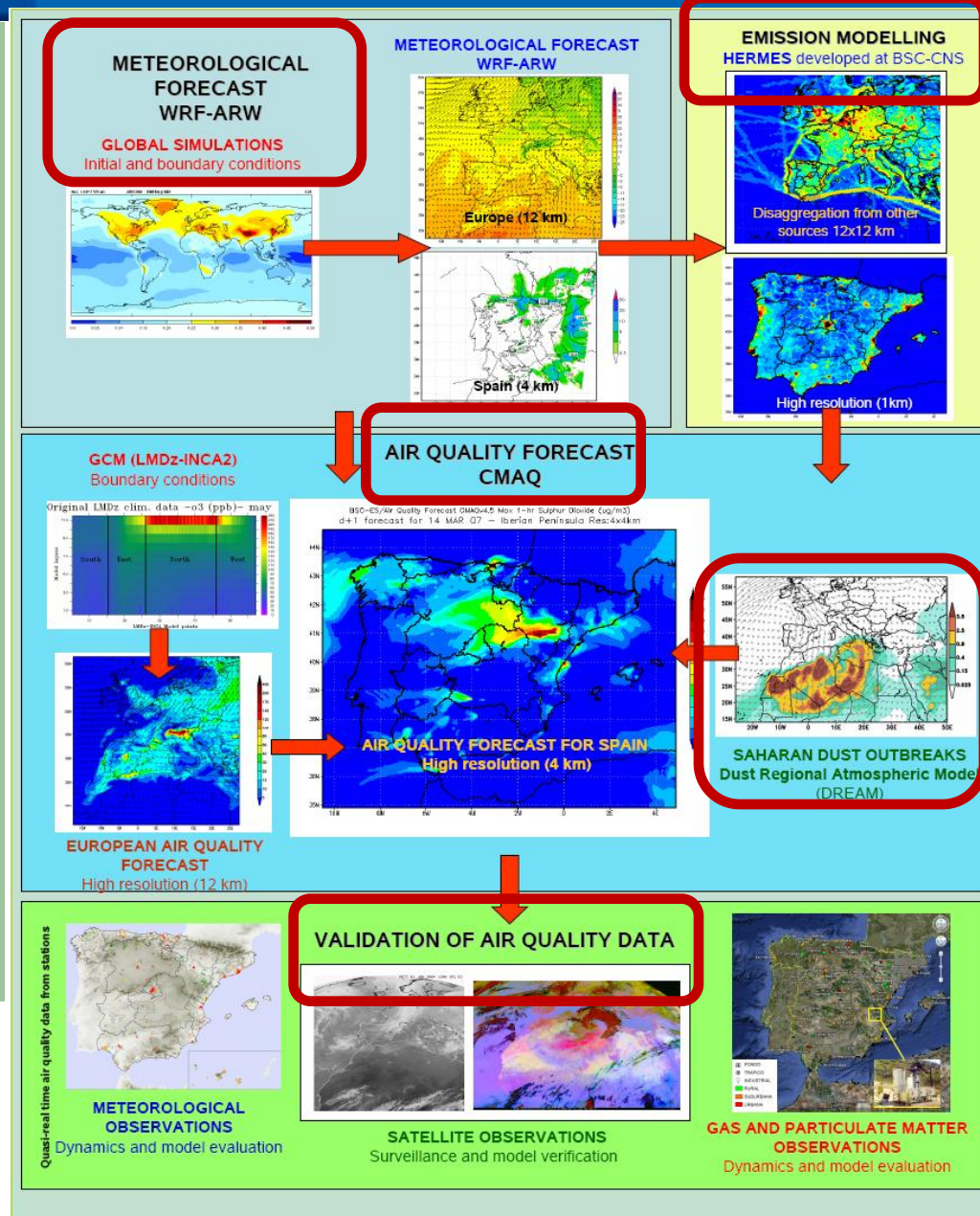
WMO REGIONAL CENTRES

CALIOPE Air Quality Forecasting System (www.bsc.es/caliope) → Cv3F

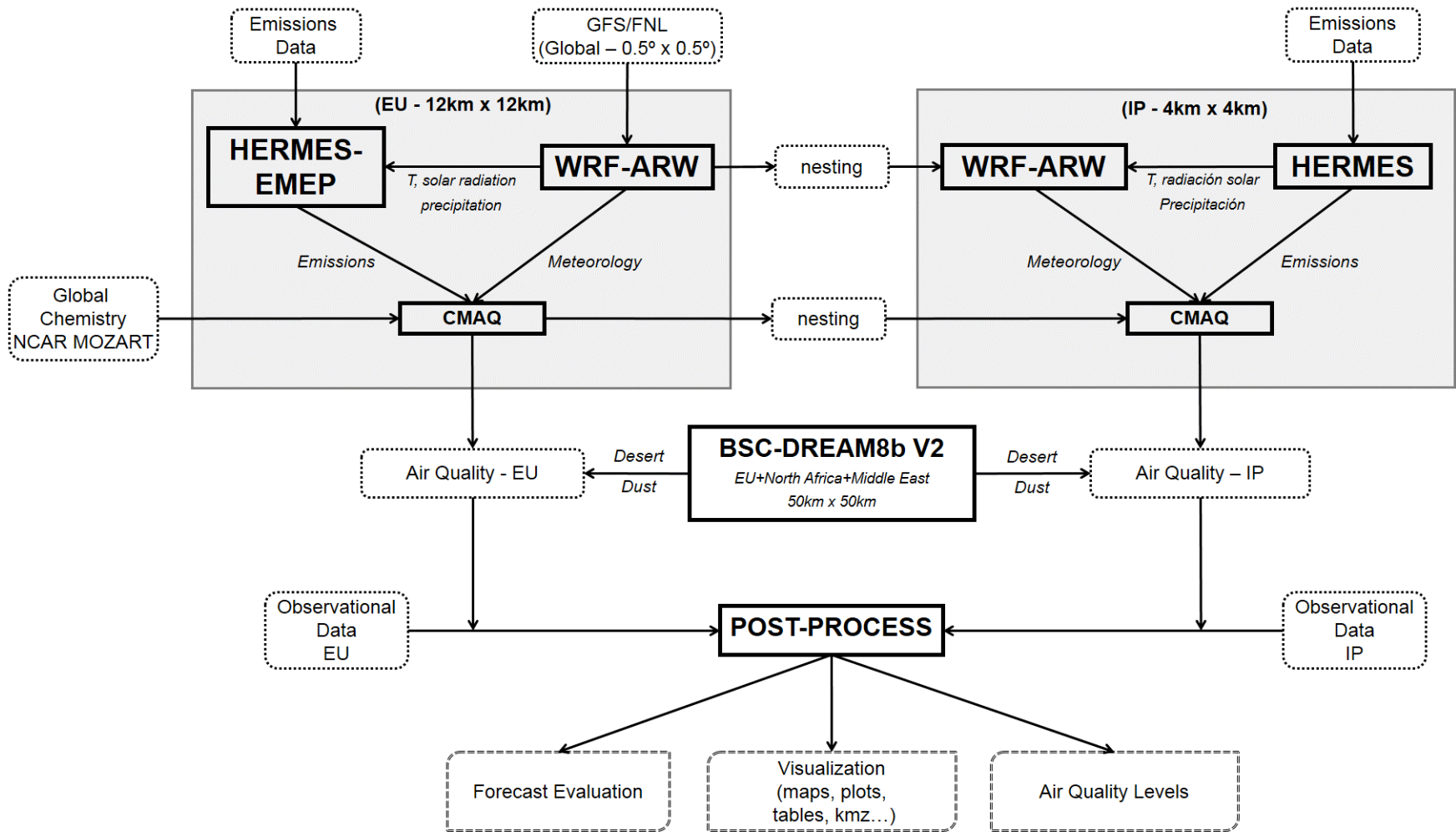
Spain: 4 km (399x399 grid cells), Europe: 12 km (480x400 grid cells)

Modules

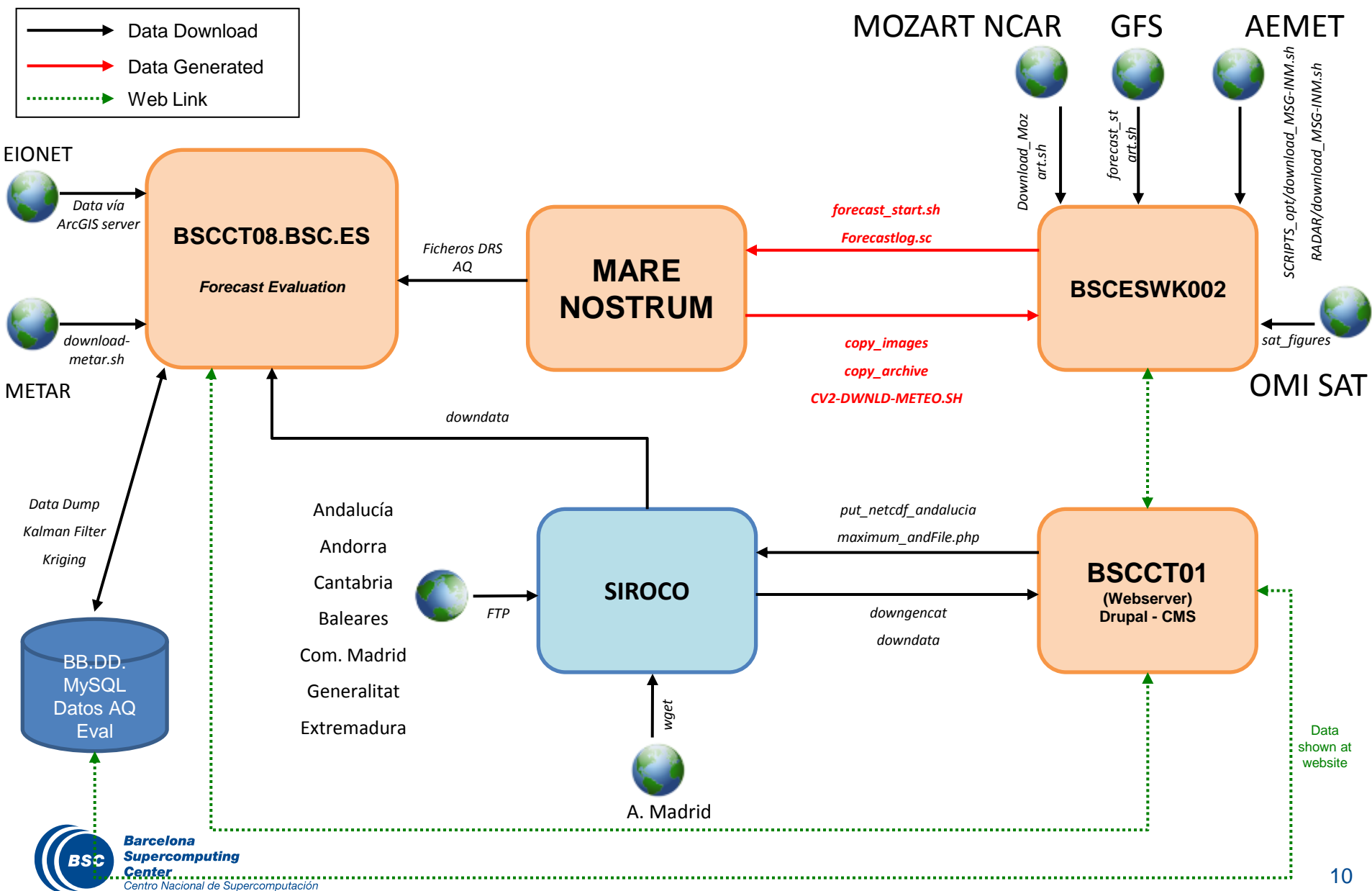
- Meteorology: **WRF-ARW**
v3.2.1, ibc: GFS (NCEP)
38 sigma levels; top of the atmosphere 50 hPa
- Emissions: **HERMES** v2
- Chemistry: **CMAQ-CTM** v5.0,
CBIV, Cloud chem. (aqu.),
Aerosol module (AERO4),
bc: LMDz-INCA model,
15sigma levels
- Mineral dust from Africa:
BSC-DREAM8b v2.0
- Post-processes by Kalman filter
- Evaluation: NRT-ground level observations, satellite, ozone sounds



Workflow



Hardware Topology (I)



Hardware Topology (II)

- ⌘ 5 machines involved
- ⌘ Receiving data from the outside is performed in a different network for safety reasons
- ⌘ Constant file transfers are critical for the system
- ⌘ MySQL databases used as data federation center for further analysis and visualization

BSC: MareNostrum supercomputer MNv3, December 2012

Nov2004 MNv1 → Nov2006 MNv2

- **Peak Performance of 1,1 Petaflops 100.8 TB of main memory**
- **Homogeneous Nodes**
 - 3,056 compute nodes
 - 2x Intel SandyBridge-EP E5-2670/1600 20M 8-core at 2.6 GHz
 - 8x4GB DDR3-1600 DIMMS (2GB/core)
- **Heterogeneous Nodes**
 - 42 heterogeneous compute nodes
 - 2x Intel SandyBridge-EP E5-2670/1600 20M 8-core at 2.6 GH
 - 2x Xeon Phi 5110 P
 - 8x8GB DDR3-1600 DIMMS (4GB/core)
- **2 PB of disk storage Interconnection networks:**
- **Infiniband FDR10**
- **Gigabit Ethernet**
- **Operating System: Linux - SuSe Distribution**

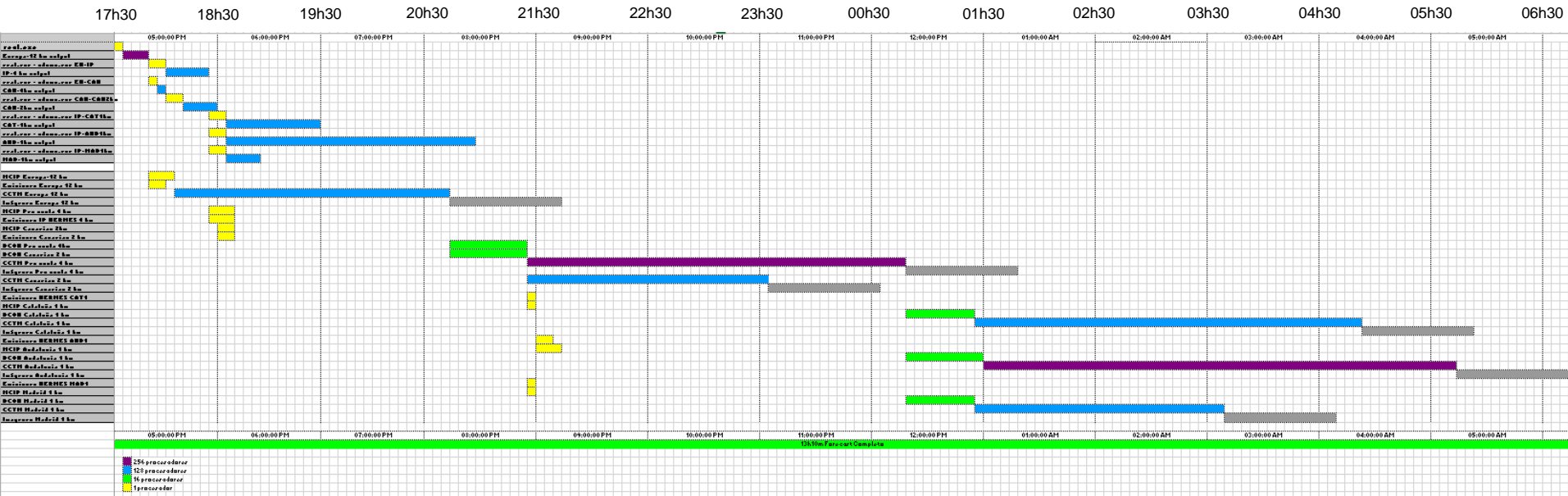


Expected time model output generation

| DOMAIN | RESOLUTION (km) | GRID POINTS | ENDING METEO GENERATION | ENDING AQ GENERATION |
|-------------------|-----------------|----------------|-------------------------|----------------------|
| Europe | 12 | 481 x 401 x 38 | 18h00 | 20h30 |
| Iberian Peninsula | 4 | 400 x 400 x 38 | 18h30 | 00h30 |
| Canary Islands | 2 | 305 x 205 x 38 | 18h45 | 23h30 |
| Andalucía | 1 | 669 x 361 x 38 | 20h45 | 05h30 |
| Cataluña | 1 | 299 x 279 x 38 | 20h00 | 05h00 |
| Madrid | 1 | 149 x 161 x 38 | 18h50 | 07h45 |

Timeline

Winter time



Approximate duration: 13h10m

44 major processes, corresponding to 6 domains calculation

Nested Domains (EU → IP, IP & → CAN AND, CAT, MAD), need to manage dependencies and waits via CSH script

Maximum consumption of 512 CPU's simultaneously, with a maximum of 256 per process



Sistema CALIOPE

Pronóstico de la Calidad del Aire



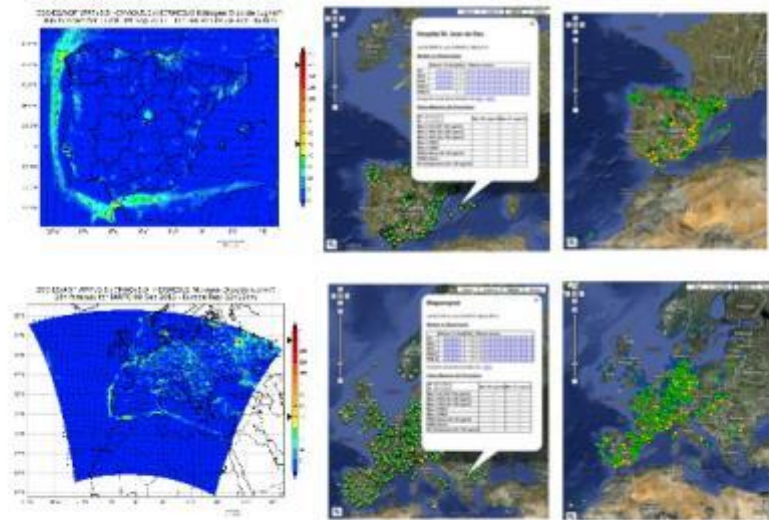
NAVIGATION

- Home
- Description
- Emissions Forecast
- Weather Forecast
- Air Quality Forecast
- Air Quality Index
- Air Quality Levels
- Forecast Evaluation
- Satellite pictures
- Links
- Publications
- About

System air quality forecast

Welcome to the forecast system of air quality operational Spain (CALIOPE) Department of Earth Sciences at the Barcelona Supercomputing Center - National Supercomputing Center (BSC-CNS), funded by the Ministry of Agriculture, Food and Environment (441/2006/3-12.1, and 157/PC08/3-12.0 A357/2007/2-12.1). The system provides operationally CALIOPE forecasting air quality for Europe and Spain in high spatial resolution through the HERMES model set, WRF-ARW, and BSC-DREAM8b CMAQ and executed in MareNostrum.

Air Quality Forecast - Forecast Evaluation - Air Quality Levels



Model Outputs Volume

| SYSTEM TOTAL | | |
|--------------|----------------|-------------------|
| | Daily (GB) | Total Annual (TB) |
| EU | 93.25 | 34 |
| IP | 78.701 | 29 |
| CAN | 30.917 | 11 |
| CAT | 32.861 | 12 |
| AND | 37.715 | 14 |
| MAD | 11.611 | 4 |
| METEO | 98.61 | 36 |
| HERMES | 68.4 | 25 |
| BSC-DREAM8b | 30.597 | 12 |
| Total | 482.662 | 177 |

| TOTAL DATABASE | | |
|----------------|--------------|---------------|
| | OBS_AQ | MAX_VALUES |
| # Registers | 466,238,998 | 3,119,142 |
| Physical Space | 90 GB | 832 MB |

- ⌘ The system generate about 483 Gb of data/day
- ⌘ Unable to store all this data: must have a restrictive policy storage and deletion
- ⌘ The data is stored in a database to facilitate further handling
- ⌘ The whole system generates more than 30,000 images/day

AQ Observations Data Volume

- Model results are evaluated at Near Real Time (NRT) with Air Quality observations from several AQ networks.
- Pollutants: O₃, NO₂, NO, SO₂, PM₁₀, PM₂₅, TOLUENE, BENZENE, XYLENE.
- 10 main AQ data providers: from EIONET (EEA) to regional government networks.

| Domain | # Stations |
|--------|------------|
| EU | 569 |
| IP | 402 |
| CAN | 44 |
| AND | 90 |
| CAT | 81 |
| MAD | 47 |

| Provider | Times per days | Number of files |
|-----------------------------|----------------|-----------------|
| EIONET (EEA) | 4 | 10 |
| Ayuntamiento Madrid | 1 | 1 |
| Comunidad Madrid | 1 | 1 |
| Junta Andalucía | 24 | 1 |
| Govern d'Andorra | 24 | 1 |
| Govern de les Illes Balears | 1 | 20 |
| Generalitat de Catalunya | 24 | 1101 |
| Gobierno Extremadura | 24 | 337 |
| Xunta de Galicia | 24 | 685 |

Pronóstico de la Calidad del Aire



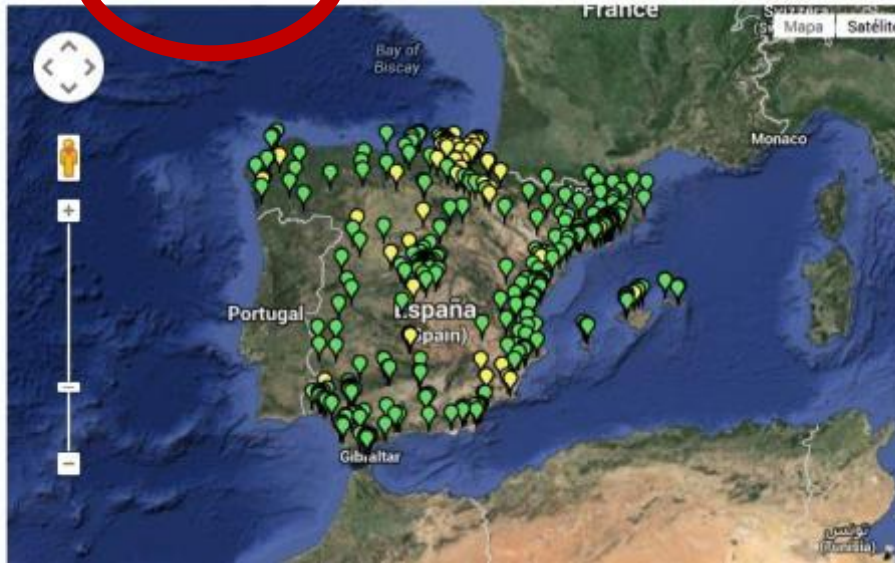
NAVIGATION

- Home
- Description
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- ▶ Weather Forecast
- ▶ Air Quality Forecast
- Air Quality Index
- ▶ Air Quality Levels
- Forecast Evaluation
- ▶ Satellite pictures
- Links
- Publications
- ▶ About

Forecast Evaluation

This section assesses the results of the forecast, hourly observations regarding measures across the different networks available, both air quality and meteorology. Additionally, for Spain by community shows the maximum values of the main pollutants for each of these stations.

| | | | | | |
|-----------------------------|-------------------------|-------------------------------------|-----------------------------|--------------|---------------|
| META-Verification | FCST PI Eval | FCST CAN Eval | FCST AND Eval | FCST EU Eval | FCST VERTICAL |
| Link to Map | Archive | Ficha de Evaluación | Información | | |



Actualmente se reciben datos de las siguientes instituciones:

- European Environment Agency
- Generalitat de Catalunya
- Gobierno de Cantabria
- Junta de Andalucía
- Gobierno de Canarias
- Comunidad de Madrid
- Ayuntamiento de Madrid
- Govern d'Andorra
- Govern de les Illes Balears
- Xunta de Galicia
- Gobierno de La Rioja
- Gobierno Extremadura
- Junta de Castilla y León

Los datos de calidad del aire utilizados en esta página son preliminares ya que no han sido validados y podrían cambiar tras su revisión (véanse los anteriores sitios web para obtener más información).

Los iconos verdes representan la existencia de datos de

Navegación

- o Inicio
- o Descripción
- o Implementación
- o Justificación
- ▶ Pronóstico Emisiones
- ▶ Pronóstico Meteorológico
- ▶ Pronóstico Calidad del Aire
- o Índice de calidad del Aire
- ▼ Evaluación del Pronóstico
 - ▼ Pronóstico por CCAA: y Andorra
 - o Andalucía
 - o Aragón
 - o Asturias
 - o Baleares
 - o Canarias
 - o Cantabria
 - o Castilla y La Mancha
 - o Castilla y León
 - o Cataluña
 - o Comunidad de Madrid
 - o Comunidad Valenciana
 - o Extremadura
 - o Galicia
 - o La Rioja
 - o Murcia
 - o Navarra
 - o País Vasco
 - o Andorra
 - ▶ Verificación: imágenes de satélite
 - ▶ Enlaces
 - o Publicaciones
 - ▶ Participantes

Comunidad de Madrid

Valores del Pronóstico, Lista de Estaciones de Comunidad de Madrid , 24h: 28/06/2011, 48h: 29/06/2011

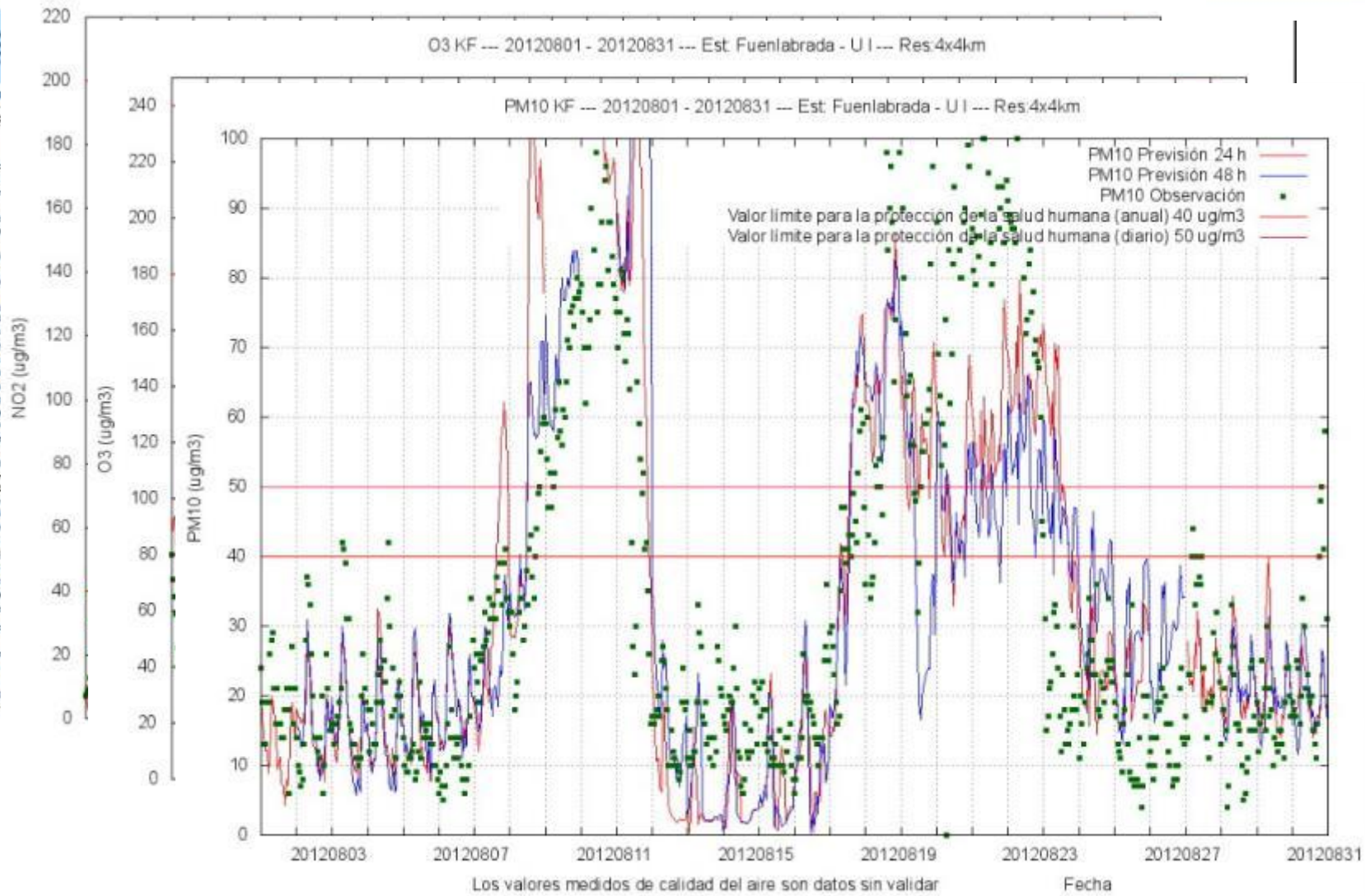
2011 / 06 / 28 HISTORICO

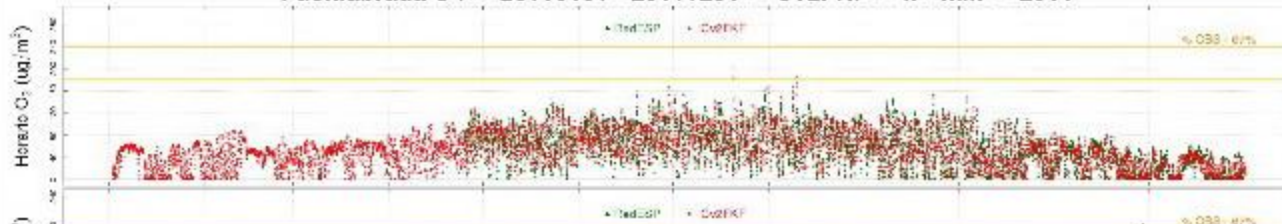
| Estación (Tipo, Emisión) | Datos de Observación | | | | | Max(ug/m3) | | | | | | | |
|--------------------------|----------------------|-----|-----|------|------|-------------------------|--------------------------|--------------------|------------|------------|---------------------------|-------------|----------------------|
| | O3 | NO2 | SO2 | PM10 | PM25 | Max h O3 (VL 180 ug/m3) | Max h NO2 (VL 200 ug/m3) | SO2 (VL 350 ug/m3) | Max h PM10 | Max h PM25 | PM10 Diario (VL 50 ug/m3) | PM25 Diario | 8h O3 (VL 120 ug/m3) |
| ALCALÁ DE HENARES U T | 24 | ✓ | ✓ | ✓ | ✓ | 136 | 57 | 3 | 91 | 24 | 58 | 13 | 125 |
| | | | | | | 85 | 46 | 5 | 65 | 24 | 44 | 17 | 79 |
| ALCOBENDAS U I | 24 | ✓ | ✓ | ✓ | ✓ | 143 | 85 | 5 | 81 | 24 | 52 | 14 | 131 |
| | | | | | | 113 | 28 | 3 | 67 | 26 | 45 | 18 | 85 |
| ALCORCÓN U F | 24 | ✓ | ✓ | ✓ | ✓ | 126 | 71 | 6 | 91 | 34 | 64 | 23 | 118 |
| | | | | | | 71 | 52 | 5 | 65 | 27 | 50 | 20 | 68 |
| ALGETE SU F | 24 | ✓ | ✓ | ✓ | ✓ | 164 | 32 | 3 | 93 | 39 | 63 | 26 | 145 |
| | | | | | | 129 | 10 | 3 | 66 | 25 | 43 | 17 | 96 |
| ARANJUEZ U F | 24 | ✓ | ✓ | ✓ | ✓ | 100 | 30 | 4 | 99 | 25 | 68 | 16 | 96 |
| | | | | | | 70 | 8 | 7 | 68 | 24 | 50 | 19 | 67 |
| ARGANDA DEL REY U I | 24 | ✓ | ✓ | ✓ | ✓ | 120 | 25 | 7 | 90 | 22 | 64 | 13 | 115 |
| | | | | | | 79 | 44 | 9 | 65 | 24 | 44 | 17 | 73 |
| ARTURO SORIA U T | 24 | ✓ | ✓ | ✓ | ✓ | 104 | 86 | 7 | 67 | 28 | 38 | 16 | 89 |
| | | | | | | 79 | 63 | 8 | 67 | 27 | 48 | 20 | 69 |
| AVDA. RAMON Y CAJAL U T | 24 | ✓ | ✓ | ✓ | ✓ | 90 | 130 | 6 | 63 | 25 | 39 | 16 | 74 |
| | | | | | | 90 | 66 | 8 | 67 | 28 | 48 | 20 | 72 |
| BARAJAS PUEBLO U T | 24 | ✓ | ✓ | ✓ | ✓ | 129 | 107 | 5 | 65 | 26 | 36 | 15 | 114 |
| | | | | | | 90 | 55 | 7 | 66 | 25 | 46 | 19 | 76 |
| BARRIO DEL PILAR U T | 24 | ✓ | ✓ | ✓ | ✓ | 114 | 138 | 5 | 61 | 24 | 38 | 16 | 103 |
| | | | | | | 104 | 58 | 6 | 66 | 25 | 47 | 19 | 76 |
| CASA DE CAMPO U F | 24 | ✓ | ✓ | ✓ | ✓ | 98 | 45 | 7 | 82 | 23 | 52 | 15 | 94 |
| | | | | | | 84 | 67 | 8 | 65 | 28 | 47 | 19 | 72 |
| CASTELLANA U T | 24 | ✓ | ✓ | ✓ | ✓ | 88 | 95 | 7 | 91 | 25 | 55 | 16 | 74 |
| | | | | | | 87 | 68 | 8 | 67 | 29 | 49 | 20 | 72 |
| COLLADO VILLALBA U T | 24 | ✓ | ✓ | ✓ | ✓ | 125 | 53 | 2 | 107 | 39 | 73 | 27 | 101 |
| | | | | | | 100 | 8 | 2 | 58 | 21 | 36 | 14 | 78 |
| COLMENAR VIEJO U T | 24 | ✓ | ✓ | ✓ | ✓ | 159 | 21 | 2 | 97 | 24 | 66 | 15 | 124 |
| | | | | | | 117 | 5 | 2 | 58 | 22 | 36 | 14 | 83 |
| COSLADA U T | 24 | ✓ | ✓ | ✓ | ✓ | 114 | 104 | 5 | 92 | 26 | 65 | 15 | 107 |
| | | | | | | 84 | 60 | 5 | 66 | 25 | 46 | 19 | 73 |
| CUATRO CAMINOS U T | 24 | ✓ | ✓ | ✓ | ✓ | 91 | 116 | 7 | 101 | 24 | 58 | 16 | 75 |
| | | | | | | 81 | 67 | 8 | 66 | 28 | 48 | 20 | 72 |

NO2 KF --- 20120801 - 20120831 --- Est: Fuenlabrada - U I --- Res: 4x4km

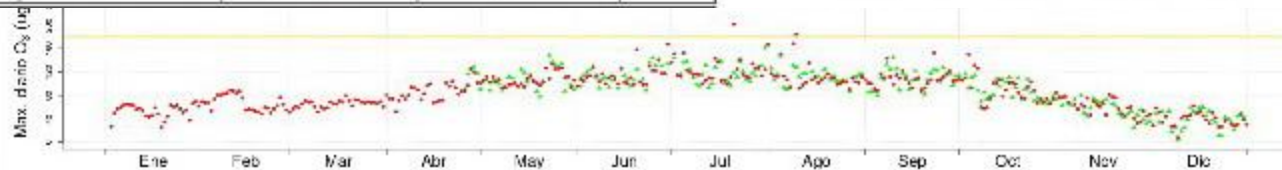
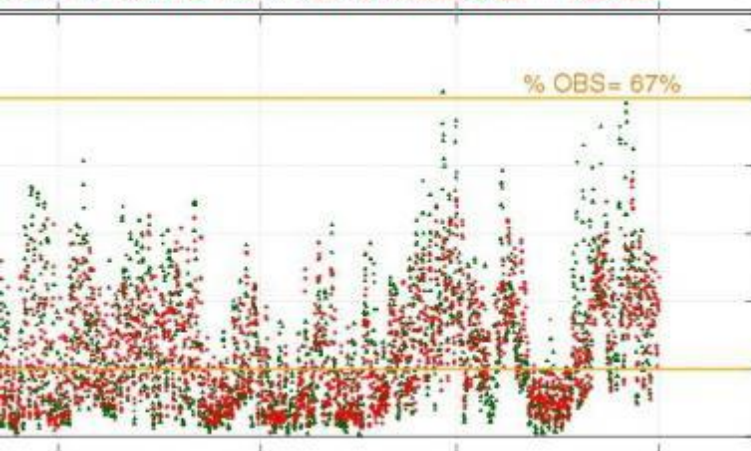
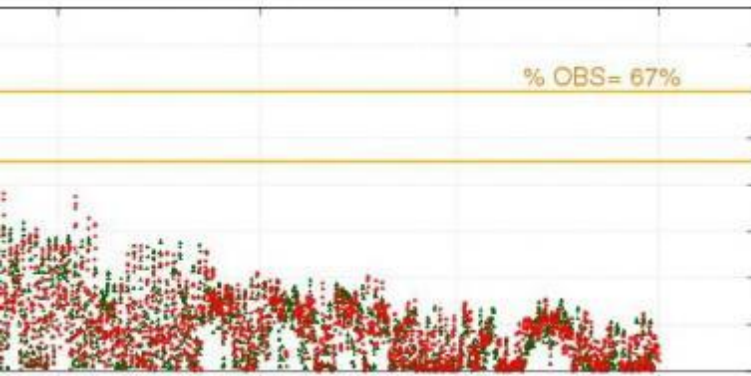
O3 KF --- 20120801 - 20120831 --- Est: Fuenlabrada - U I --- Res: 4x4km

PM10 KF --- 20120801 - 20120831 --- Est: Fuenlabrada - U I --- Res: 4x4km





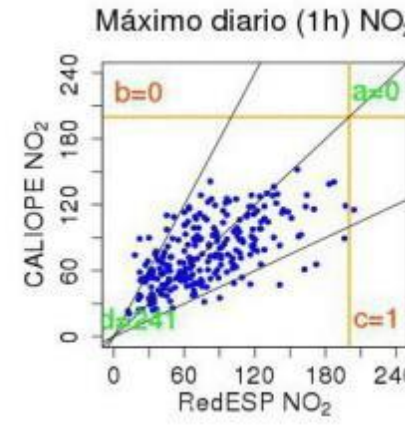
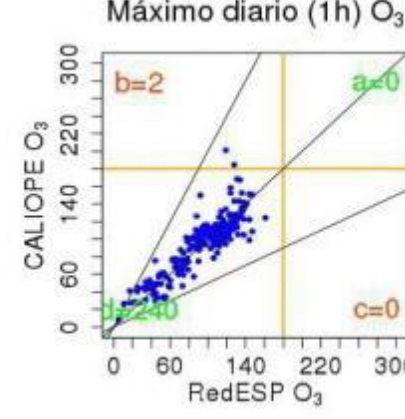
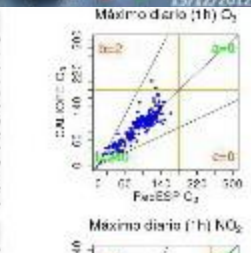
4km - 2011



| O ₃ | Obs media ug/m ³ | Mod media ug/m ³ | r | MB ug/m ³ | RMSE ug/m ³ | n |
|----------------|-----------------------------|-----------------------------|------|----------------------|------------------------|------|
| Anual | 57.3 | 58.5 | 0.84 | 1.2 | 19.8 | 5759 |
| Ene | - | - | - | - | - | - |
| Feb | - | - | - | - | - | - |
| Mar | - | - | - | - | - | - |
| Abr | 78.2 | 72.9 | 0.63 | -5.3 | 21.4 | 142 |
| May | 69.2 | 69.9 | 0.72 | 0.7 | 21.4 | 717 |
| Jun | 78.1 | 78.4 | 0.70 | 0.3 | 20.3 | 686 |
| Jul | 77.1 | 76.7 | 0.79 | -0.3 | 19.8 | 712 |
| Ago | 73.6 | 73.7 | 0.80 | 0.1 | 18.6 | 712 |
| Sep | 60.9 | 62.0 | 0.83 | 1.1 | 19.7 | 710 |
| Oct | 44.4 | 46.4 | 0.69 | 2.0 | 23.2 | 734 |
| Nov | 29.7 | 33.2 | 0.63 | 3.5 | 19.8 | 682 |
| Dic | 18.4 | 22.0 | 0.72 | 3.6 | 13.2 | 664 |

| NO ₂ | Obs media ug/m ³ | Mod media ug/m ³ | r | MB ug/m ³ | RMSE ug/m ³ | n |
|-----------------|-----------------------------|-----------------------------|------|----------------------|------------------------|------|
| Anual | 34.6 | 35.3 | 0.75 | 0.7 | 21.0 | 5762 |
| Ene | - | - | - | - | - | - |
| Feb | - | - | - | - | - | - |
| Mar | - | - | - | - | - | - |
| Abr | 27.9 | 30.8 | 0.69 | 2.9 | 18.1 | 142 |
| May | 23.4 | 30.6 | 0.55 | 7.2 | 21.5 | 717 |
| Jun | 22.6 | 26.1 | 0.45 | 3.5 | 21.2 | 686 |
| Jul | 22.4 | 23.4 | 0.61 | 1.0 | 16.1 | 712 |
| Ago | 21.2 | 21.4 | 0.69 | 0.1 | 14.0 | 713 |
| Sep | 36.8 | 32.1 | 0.73 | -4.8 | 23.5 | 711 |
| Oct | 46.8 | 49.1 | 0.75 | 2.3 | 22.2 | 734 |
| Nov | 47.7 | 43.9 | 0.83 | -3.8 | 21.2 | 682 |
| Dic | 58.6 | 58.3 | 0.72 | -0.2 | 26.3 | 665 |

| RedESP | Obs media ug/m ³ | Mod media ug/m ³ | r | MB ug/m ³ | RMSE ug/m ³ | n |
|--------|-----------------------------|-----------------------------|------|----------------------|------------------------|------|
| Anual | 57.3 | 58.5 | 0.84 | 1.2 | 19.8 | 5759 |
| Ene | - | - | - | - | - | - |
| Feb | - | - | - | - | - | - |
| Mar | - | - | - | - | - | - |
| Abr | 78.2 | 72.9 | 0.63 | -5.3 | 21.4 | 142 |
| May | 69.2 | 69.9 | 0.72 | 0.7 | 21.4 | 717 |
| Jun | 78.1 | 78.4 | 0.70 | 0.3 | 20.3 | 686 |
| Jul | 77.1 | 76.7 | 0.79 | -0.3 | 19.8 | 712 |
| Ago | 73.6 | 73.7 | 0.80 | 0.1 | 18.6 | 712 |
| Sep | 60.9 | 62.0 | 0.83 | 1.1 | 19.7 | 710 |
| Oct | 44.4 | 46.4 | 0.69 | 2.0 | 23.2 | 734 |
| Nov | 29.7 | 33.2 | 0.63 | 3.5 | 19.8 | 682 |
| Dic | 18.4 | 22.0 | 0.72 | 3.6 | 13.2 | 664 |



| RedESP | Obs media ug/m ³ | Mod media ug/m ³ | r | MB ug/m ³ | RMSE ug/m ³ | n |
|--------|-----------------------------|-----------------------------|------|----------------------|------------------------|------|
| Anual | 34.6 | 35.3 | 0.75 | 0.7 | 21.0 | 5762 |
| Ene | - | - | - | - | - | - |
| Feb | - | - | - | - | - | - |
| Mar | - | - | - | - | - | - |
| Abr | 27.9 | 30.8 | 0.69 | 2.9 | 18.1 | 142 |
| May | 23.4 | 30.6 | 0.55 | 7.2 | 21.5 | 717 |
| Jun | 22.6 | 26.1 | 0.45 | 3.5 | 21.2 | 686 |
| Jul | 22.4 | 23.4 | 0.61 | 1.0 | 16.1 | 712 |
| Ago | 21.2 | 21.4 | 0.69 | 0.1 | 14.0 | 713 |
| Sep | 36.8 | 32.1 | 0.73 | -4.8 | 23.5 | 711 |
| Oct | 46.8 | 49.1 | 0.75 | 2.3 | 22.2 | 734 |
| Nov | 47.7 | 43.9 | 0.83 | -3.8 | 21.2 | 682 |
| Dic | 58.6 | 58.3 | 0.72 | -0.2 | 26.3 | 665 |



Moving from 2km resolution to 1km

« Andalusia Domain

– WRF-AND2km

- 335 x 181 x 38 [230430] (256 cpu's, timestep = 12, runtime 17m)
- output size : 7,9 Gb

– WRF-AND1km

- 669 x 361 x 38 [9177342] (256 cpu's, timestep = 06, runtime 84m)
- output size: 34 Gb



Runtime Increase = **x4.9**

Output Increase = **x4.3**

« Issues regarding size outputs and time in a domain like this

- Size of 48 hours outputs of forecast of AND1km domain > 110 Gb
- Writing a shell logic to avoid writing all the species
 - First compute 24 hours then restart to compute following 24 hours.

Visualization (I)

- ⌘ Wide range of products available to the user.
 - ⌘ Displays need to be user friendly.
 - ⌘ High data quality and presentation.
 - ⌘ The products need to be well structured and organized.
 - ⌘ Archive is large and well organized
-
- ⌘ Areas for improvement:
 - Generating visual products is not sufficiently facing the user's demand.
 - The large amount of products generated → storage restrictive policies.
 - The large number of pictures generated consume a lot of computing resources and requires monitoring of processes to check that everything is correctly created.
 - A large number of tools used. System complexity and difficulty of installing all the necessary software.
 - The 3D view is not sufficiently exploited.

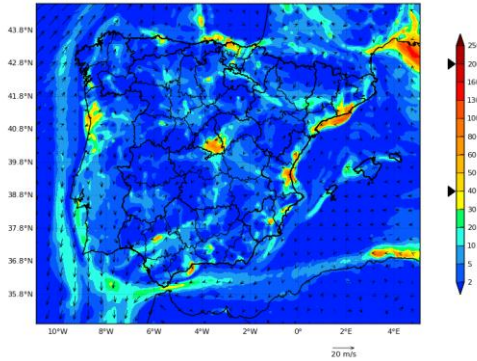
Visualization (II): Tools used

| | Process | Tool | Web Site |
|------------------------------|--------------|--|--|
| MAPS 2D | AQ/EMIS | The Grid Analysis and Display System (GrADS) | www.iges.org/grads/ |
| | | MapGenerator | |
| | | Matplotlib | www.matplotlib.org/ |
| | | PyGrADS | opengrads.org/wiki/index.php?title=PyGrADS_Interactive_Shell |
| | METEO | ImageMagick | www.imagemagick.org |
| | | The Grid Analysis and Display System (GrADS) | www.iges.org/grads/ |
| KMZ | Imágenes | The Grid Analysis and Display System (GrADS) | www.iges.org/grads/ |
| | | ImageMagick | www.imagemagick.org |
| | KML | Script en Bash Shell | |
| TEMPORAL SERIES / STATISTICS | Series | GNU PLOT | www.gnuplot.info/ |
| | | ImageMagick | www.imagemagick.org |
| | Estadísticos | R | www.r-project.org/ |
| | | Librerías Cairo | cairographics.org/ |
| | | ImageMagick | www.imagemagick.org |
| WEB | CMS | Drupal | drupal.org/ |
| | Maps | Google Maps API v2 | developers.google.com/maps/documentation/business/guide |

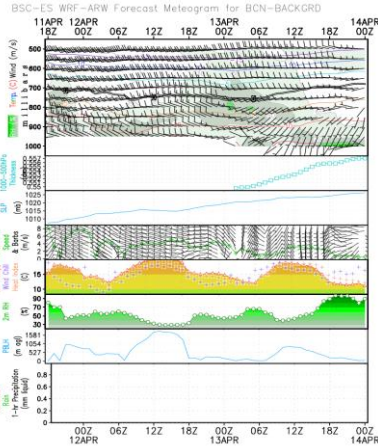
Visualization (III)

Examples

BSC-ES/AQF ARWv3.2+CMAQv5.0+HERMESv2 Nitrogen Dioxide ($\mu\text{g}/\text{m}^3$)
00h forecast for 00UTC 16 Apr 2013 - Iberian Peninsula Res: 4x4km

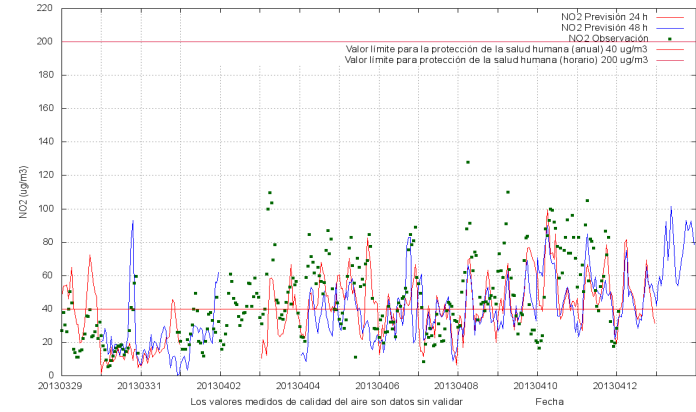


MAP AQ 2D

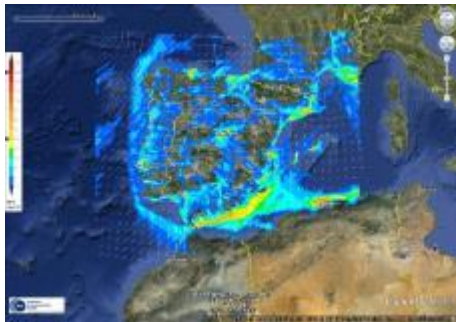


METEO Products

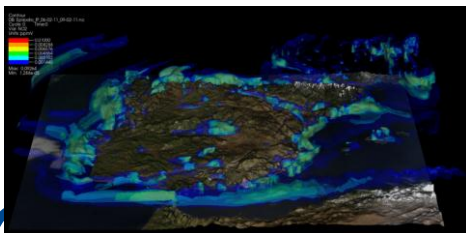
NO2 KF --- 20130329 - 20130412 --- Est. Barcelona (Gràcia St. Gervasi) - UT --- Res: 4x4km



Temporal Series AQ



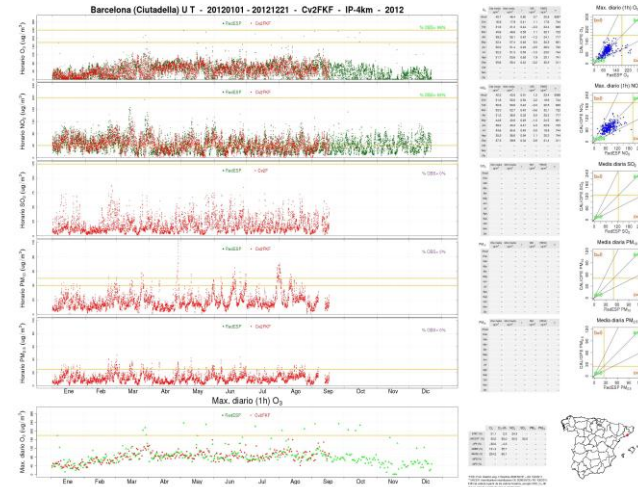
KMZ



3D



WEB



Statistics

Table 1: Statistics of the air quality forecast system in the frame of the CALIOPE project. Log from 20090101 to 20130909.

| Total logs | Percentage of <i>domains</i> completely simulated | | | | | | | |
|------------|---|-------|-------|-------|-------|-------|-------|--------------------------------|
| | % NaN/NCAGT | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Since Jan 1 st , 09 |
| 1586 | 35.4% | 69.1% | 75.5% | 91.4% | 95.0% | 98.0% | 93.6% | 88.1% |

Notes: NaN - Not a Number; NCAGT - netCDF subroutine retrieving numeric attribute (both machine-related causes of crash)

Table 2: Percentage of days successfully per domain simulated. WRF, CMAQ and HERMES models.

| WRF-ARW | | | | |
|---------|-------|-------|------------|-------|
| EU | IP | CAN | BCN-CAT | AND |
| 99.4% | 99.7% | 99.9% | dumfrwbcn% | 99.9% |

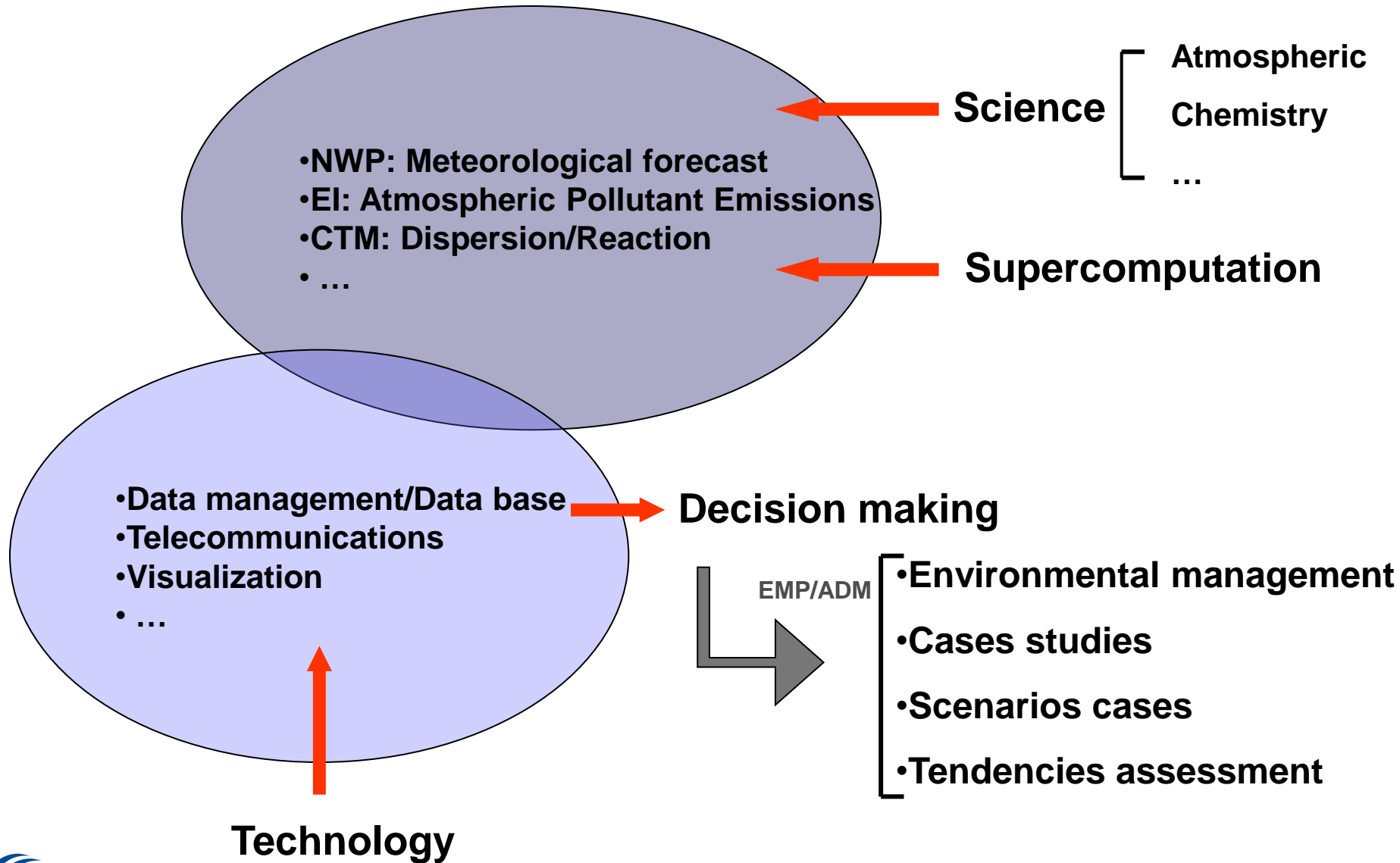
| CMAQ-CCTM | | | | |
|-----------|-------|-------|---------|-------|
| EU | IP | CAN | BCN-CAT | AND |
| 92.3% | 88.5% | 87.8% | dumbcn% | 89.4% |

| HERMES 2004 & V2.2 | | | | |
|--------------------|-------|-------|------------|-------|
| EU | IP | CAN | BCN-CAT | AND |
| 99.6% | 99.4% | 100.% | dumherbcn% | 100.% |

Notes: WRF-ARW: Advanced Weather Research and Forecasting model - version 3.0.1.1. CMAQ: Community Multiscale Air Quality modelling system - version 4.5. HERMES: High-Selective Resolution Modelling Emission System. CCTM: CMAQ Chemical Transport Model output.

BSC-ES/AQF
Nitrogen dioxide
48h Forecast 10/10/2011

Air Quality Forecasting Systems (AQFS)



Thank you for your attention



jose.baldasano@bsc.es

<http://www.bsc.es/caliope>
<http://www.bsc.es/projects/earthscience/BSC-DREAM/>
<http://www.bsc.es/projects/earthscience/nmmbsc-dust-forecast>
<http://www.nrlmry.navy.mil/aerosol/icap.1087.php>
<http://sds-was.aemet.es/>