BSC's contribution to CAMS and associated activities

Carlos Pérez García-Pando

Atmospheric Composition Group
Department of Earth Sciences
Barcelona Supercomputing Center (BSC)

Santander, 19 March 2019

Workshop on Copernicus climate change and atmosphere monitoring services

Contributions to CAMS

Associated Developments & Activities

CAMS-50 **Regional production**	Development of a multiscale modeling and forecasting systems MONARCH, SDS-WAS, CALIOPE, ICAP
CAMS-81 **Global & regional emissions**	Development of top down and bottom up emission inventories and models HERMES
CAMS-43 **Global aerosol aspects**	Model data assimilation LETKF DA system
CAMS-84 **Global & regional a posteriori validation**	Model Evaluation BSC model evaluation tool
CAMS-95 **AsSISt: Aircraft Support & Maintenance Services**	Development of *user-oriented* services for a variety of socio-economic sectors InDust, DustClim, SOLWATT

CAMS-50 phase II: Regional production

Inputs
Global products
Regional emissions
In situ observations

7 operational AQ models

CHIMERE EMEP EURAD-IM LOTOS-EUROS

MATCH MOCAGE SILAM

1 ENSEMBLE model

ENSEMBLE Median (N=7)

How? Median of the individual results for each grid-cell
Why? Reliable, robust, performing

→ **to be used in priority**

Users

Copernicus — Europe's eyes on Earth
European Commission
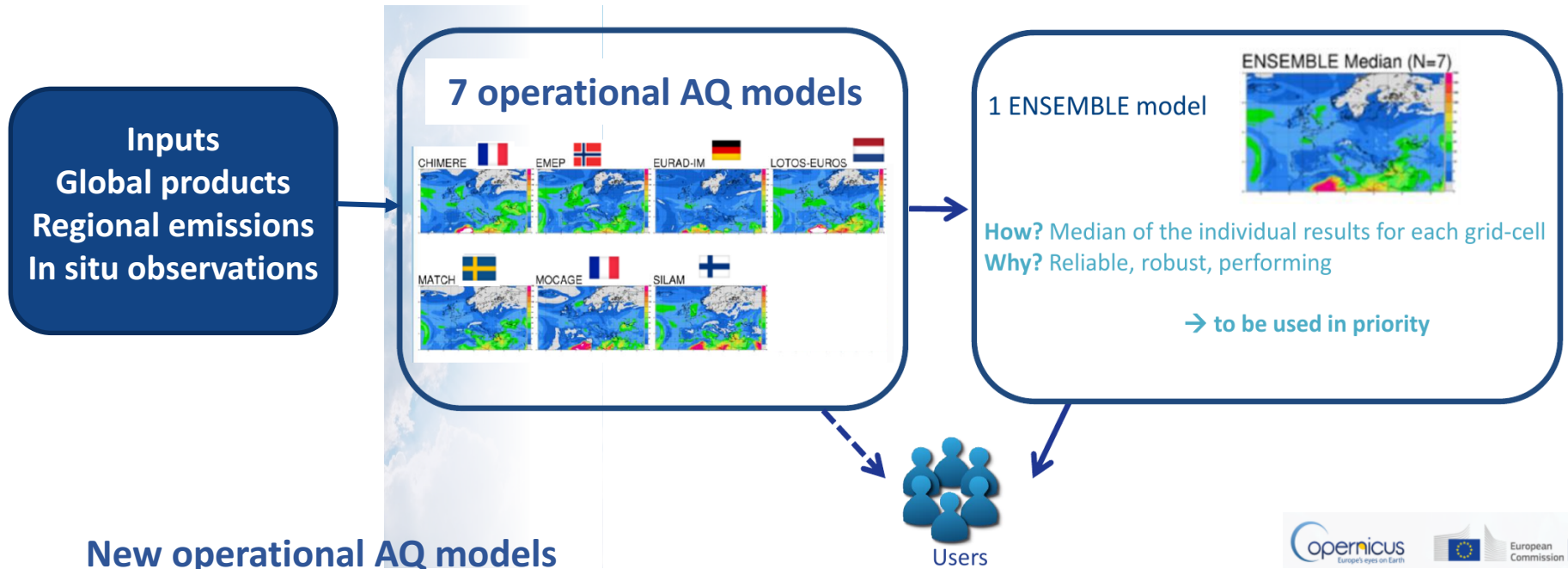
New operational AQ models

DEHM (AARHUS University)
GEM-AQ (IEP)

New candidates AQ models

MINNI (ENEA)
MONARCH (BSC)

Products

- NRT Individual & Ensemble 4-Day Forecasts
- NRT Individual & Ensemble Analyses (DD-1)
- NRT Validation & Statistics products
- Reanalyses (2014-2017)

# MONARCH: <u>M</u>ultiscale <u>O</u>nline <u>N</u>on-hydrostatic <u>A</u>tmosphere <u>CH</u>emistry model

· *Multiscale*: global to regional (up to 1km) scales allowed

· Fully *on-line* coupling: weather-chemistry feedback processes allowed

· Enhancement with a *data assimilation* system and machine learning techniques

Dust module is known as **NMMB/BSC-Dust**
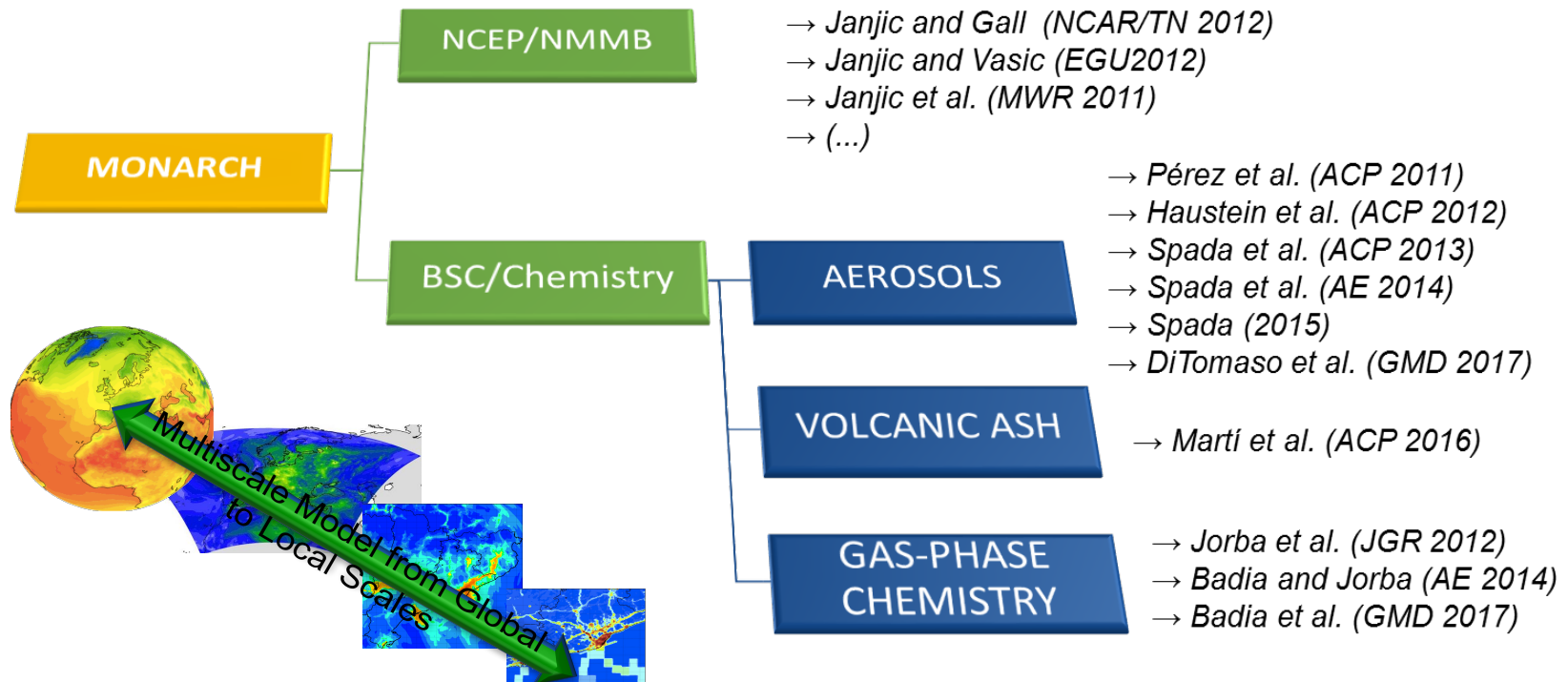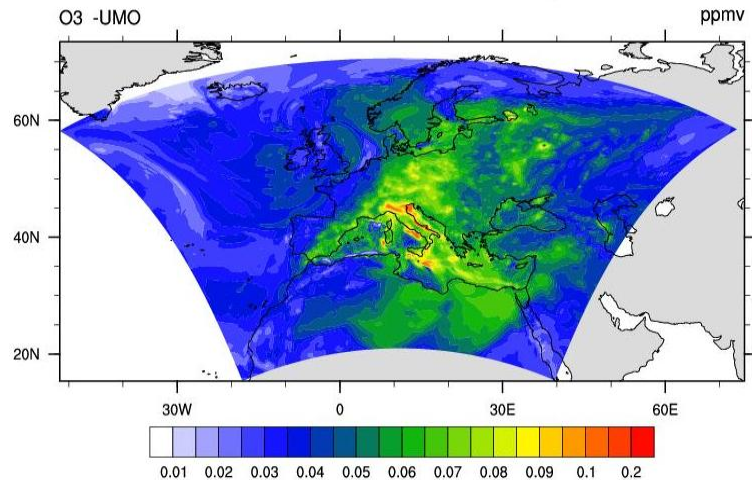
MONARCH forecasts

Global

NMMB-MONARCH-b015 AOD550
2015
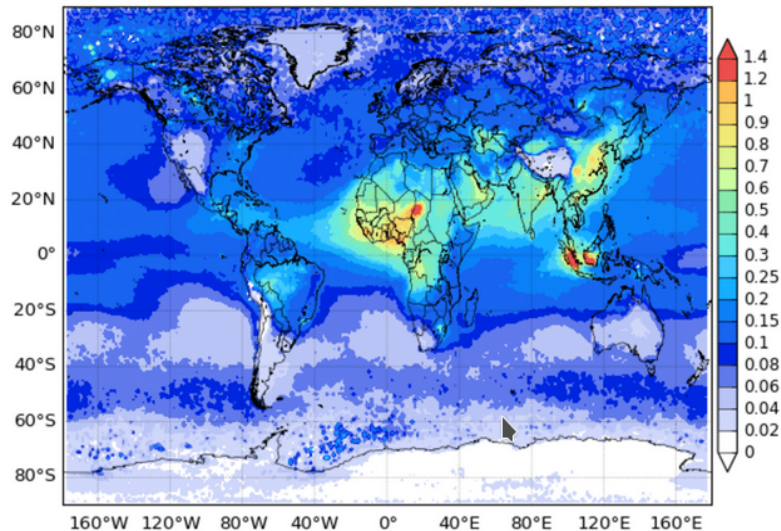
✓ *MONARCH contributes to the* **ICAP global forecast aerosol** *multi-model ensemble* *http://icap.atmos.und.edu*
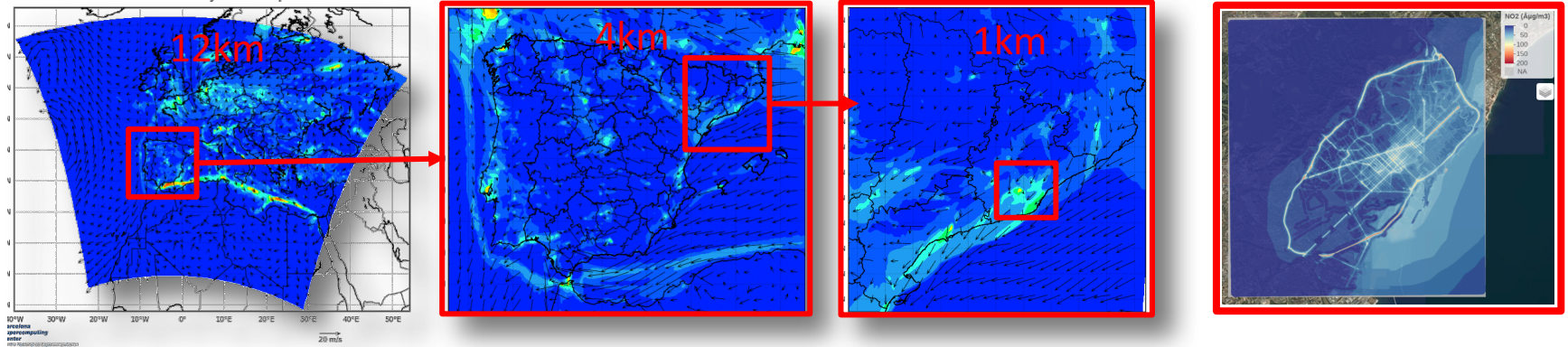
Regional

20100715 at 12UTC

✓ *Candidate model CAMS-50*
✓ *It will be implemented in*

CALIOPE (*www.bsc.es/caliope*)
AQ Forecast System for **EU** *and* **Spain**

And more products in: http://www.bsc.es/ess/

CALIdad del aire Operacional Para España (CALIOPE)
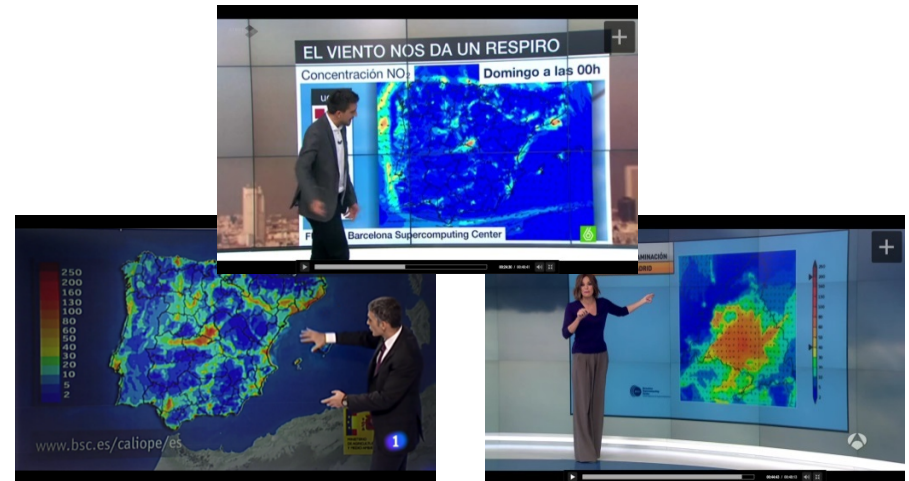

Multiscale models from regional to local scales

Web / App
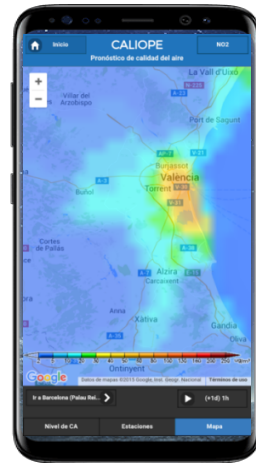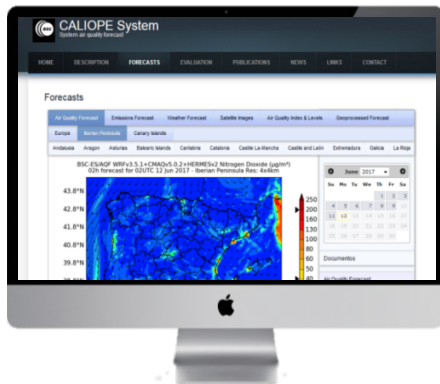
In the media

Street Scale NO$_2$ modelling: Barcelona case

City morphology parameters: building height, street width, building density

Street scale NO$_x$ emissions from HERMESv3

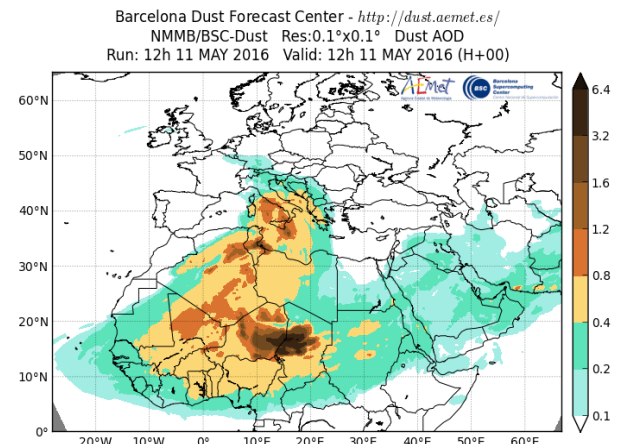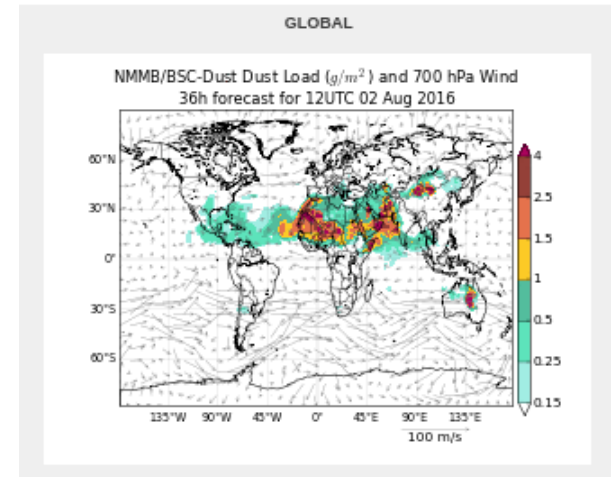Mesoscale – Street Canyon model coupling: NO$_2$ concentration

Mineral Dust Services at BSC

BSC dust operational forecast:

- Contribution to the SDS-WAS (regional) and ICAP (global) multi-model ensembles

WMO Dust Regional Centres:

- **Barcelona Dust Forecast Centre**. First specialized WMO Centre for mineral dust prediction. Started in 2014 - **Operational**
    - http://dust.aemet.es
    - @Dust_Barcelona

- Sand and Dust Storms Warning Advisory and Assessment System (**SDS-WAS**). North Africa, Middle East and Europe Regional Center. Started in 2010 – **Research**
    - http://sds-was.aemet.es

- Both WMO Regional Centres are jointly managed by BSC and AEMET

GLOBAL

NMMB/BSC-Dust Dust Load (g/m^2) and 700 hPa Wind
36h forecast for 12UTC 02 Aug 2016

Barcelona Dust Forecast Center - $http://dust.aemet.es/$
NMMB/BSC-Dust   Res:0.1°x0.1°   Dust AOD
Run: 12h 11 MAY 2016   Valid: 12h 11 MAY 2016 (H+00)

# Applying Machine learning in a forecast context

- Machine learning used to correct the MONARCH air quality forecasts based on previous observations and to better diagnose the forecast errors to improve the forecast system.

- Combination of random forests and neural networks to correct forecast biases using data from the previous weeks.

- Example for O3.

Observations
Model
Model after correction
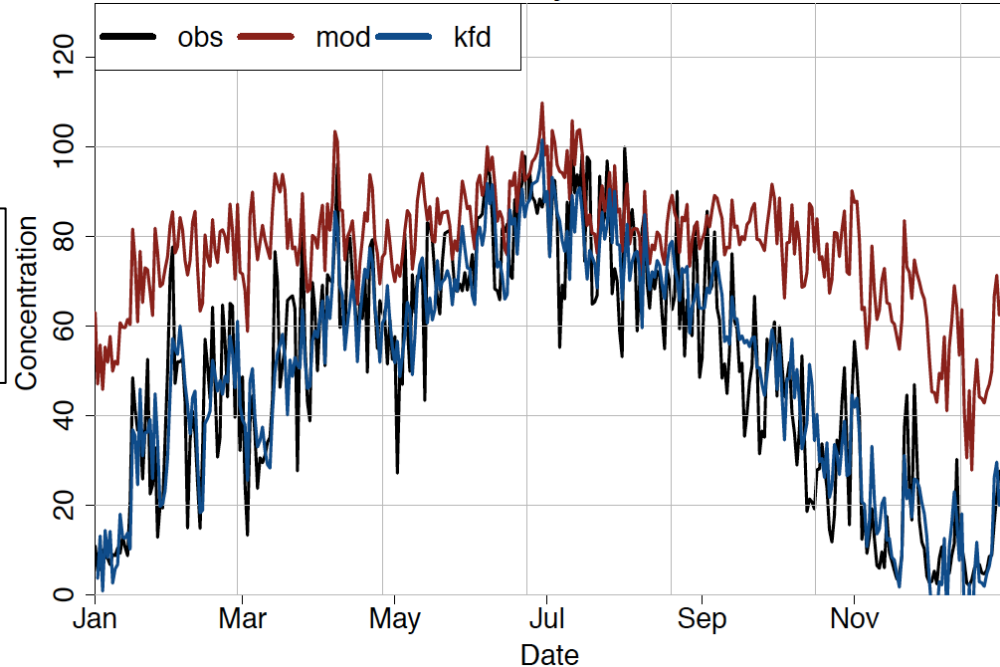
CAMS-81: global and regional emissions

To provide **gridded distributions of annual anthropogenic (global and Europe) and natural emissions** and deliver **monthly, weekly and diurnal temporal profiles**.
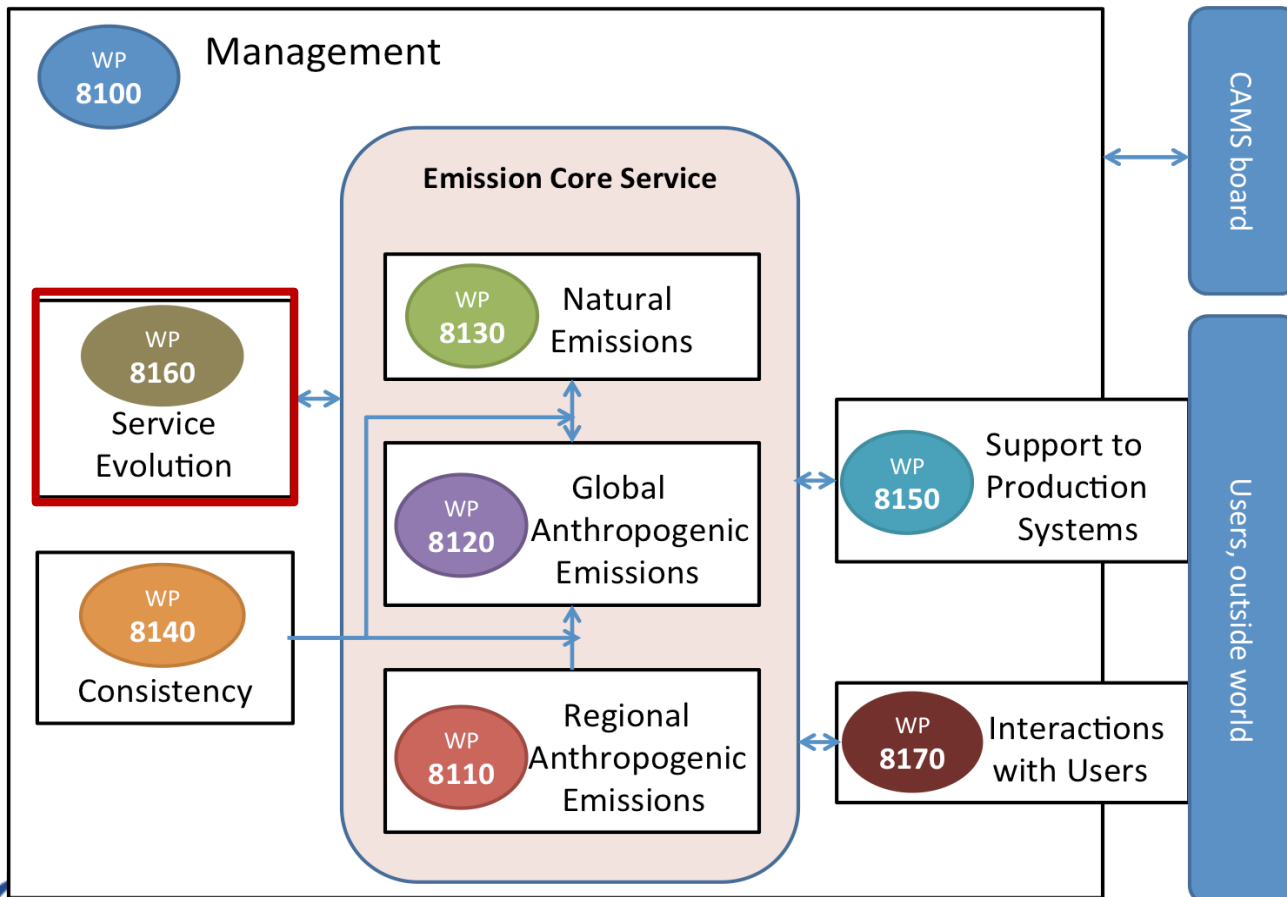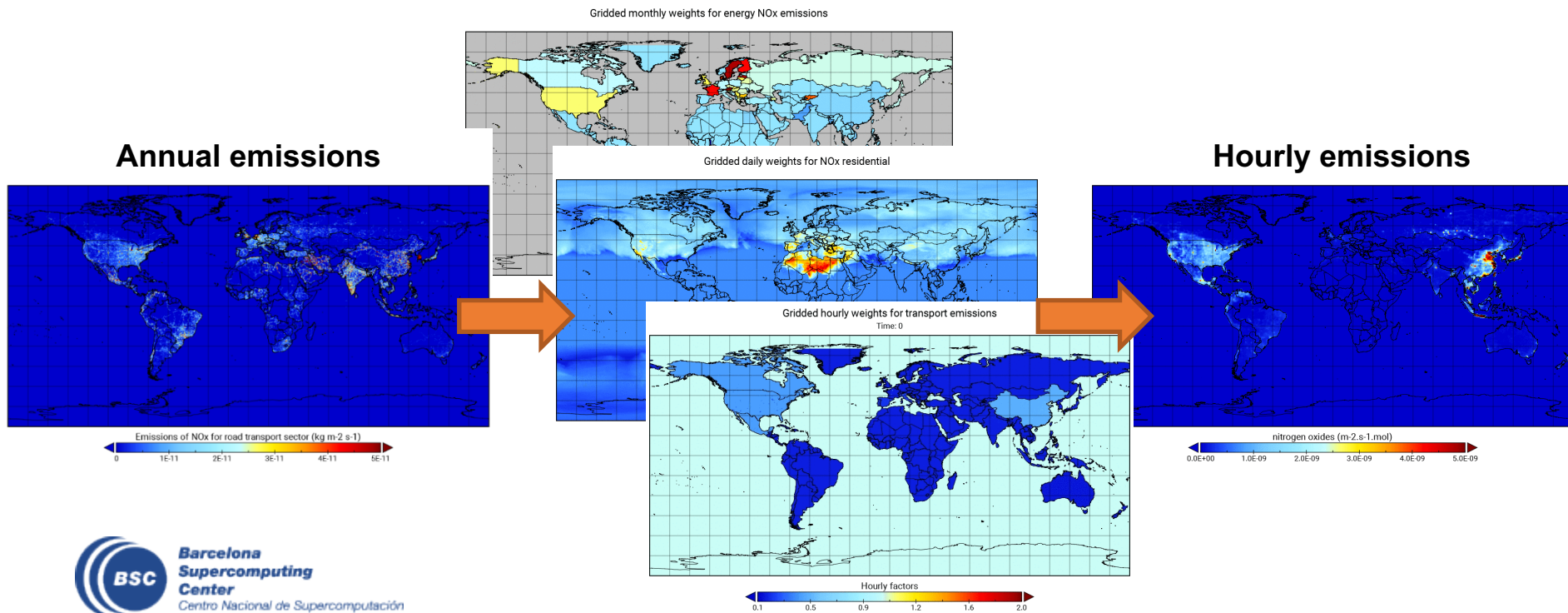
CAMS-81: new temporal profiles

Development of gridded temporal profiles that take into account differences across:

- Sources (energy and manufacturing industry, residential combustion, traffic and agriculture)
- Countries and regions (climatological and sociodemographic aspects)
- Pollutants (NO_x, CO, NMVOC, NH_3, SO_x, PM_{10}, $PM_{2.5}$, CO_2 and CH_4)

Monthly, daily, weekly and hourly profiles

Gridded monthly weights for energy NOx emissions

Annual emissions

Hourly emissions

Gridded daily weights for NOx residential

Gridded hourly weights for transport emissions
Time: 0

Emissions of NOx for road transport sector (kg m-2 s-1)

0   1E-11   2E-11   3E-11   4E-11   5E-11

nitrogen oxides (m-2.s-1.mol)

0.0E+00   1.0E-09   2.0E-09   3.0E-09   4.0E-09   5.0E-09

Hourly factors

0.1   0.5   0.9   1.2   1.6   2.0

HERMESv3

A python-based, open source, parallel and multiscale emission modelling framework that **processes and estimates gas and aerosol emissions** for use in atmospheric chemistry models.
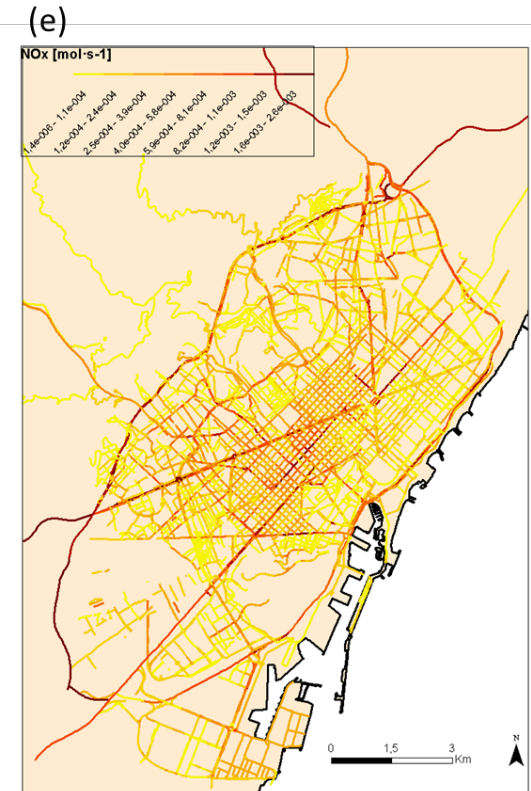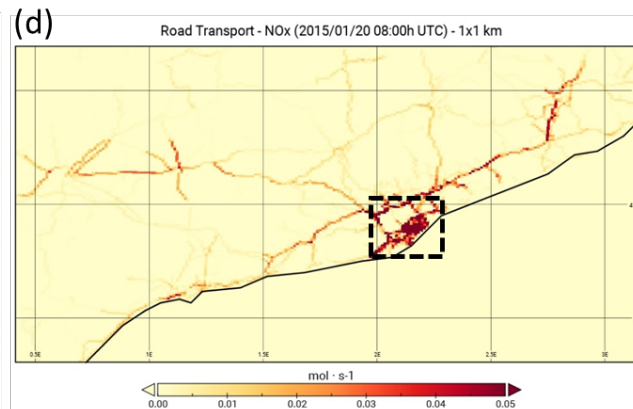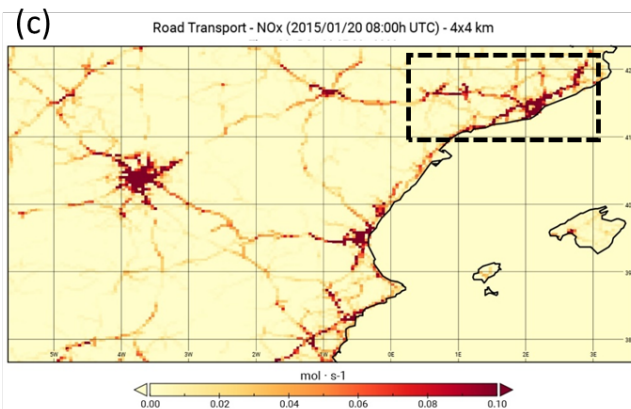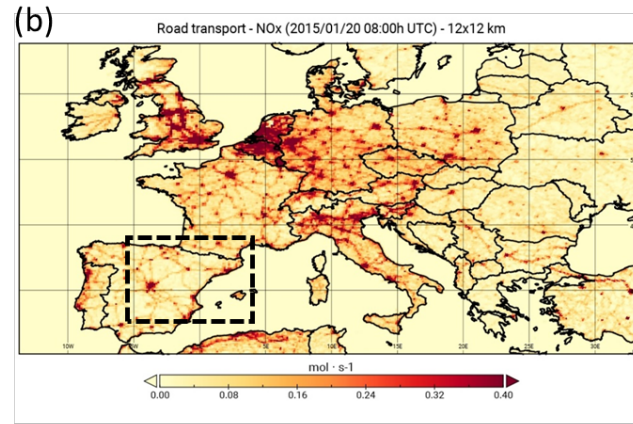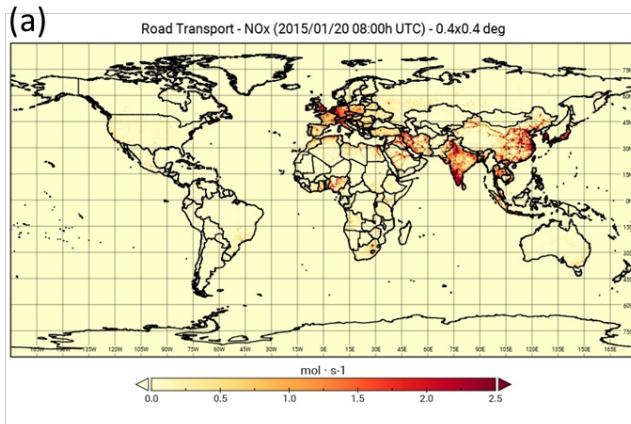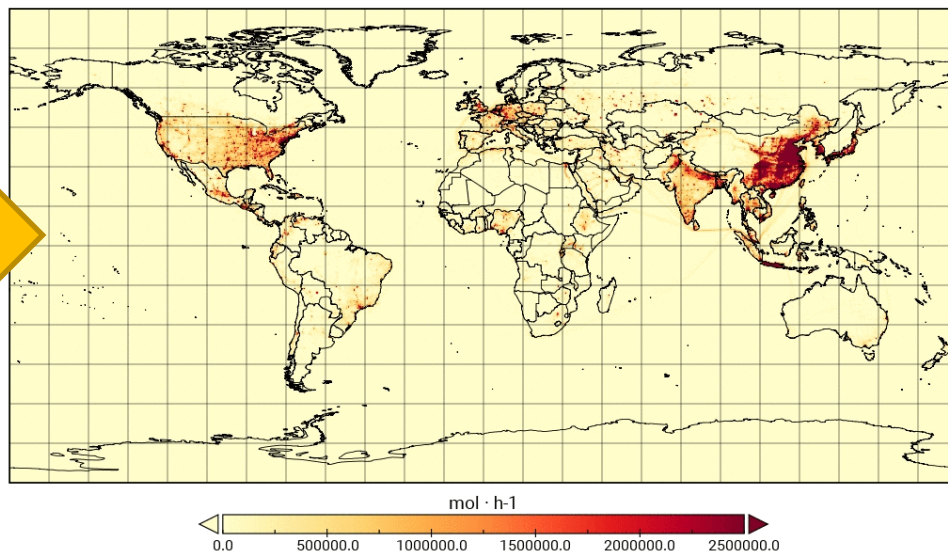
HERMESv3_GR: global-regional module

A **processing system** to calculate emissions through an automatic **combination of existing inventories** and user defined vertical, temporal and speciation profiles

Emission data library

HERMESv3_GR output

mol · h-1

- Combination of multiple up-to-date gridded emission inventories
- User defined destination working domain (conservative remapping)
- Application of country-specific scaling and masking factors
- Specific monthly, weekly and diurnal profiles per sector and pollutant
- Speciation profiles for multiple chemical mechanisms
- Available at the BSC git repository: https://earth.bsc.es/gitlab/es/hermesv3_gr

Guevara et al., 2019

HERMESv3_BU: bottom-up module

An **emission model** to estimate emissions at the **source level** combining state-of-the-art **bottom-up methods** with local activity and emission factors

Traffic flow data (vehicle counts and speed)
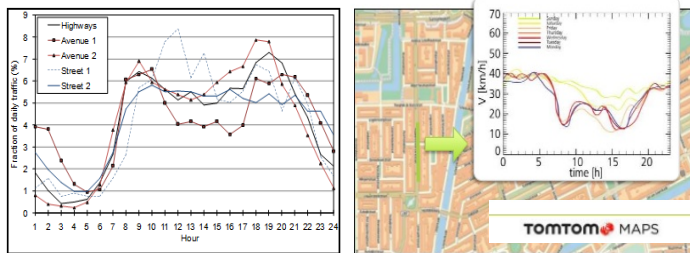
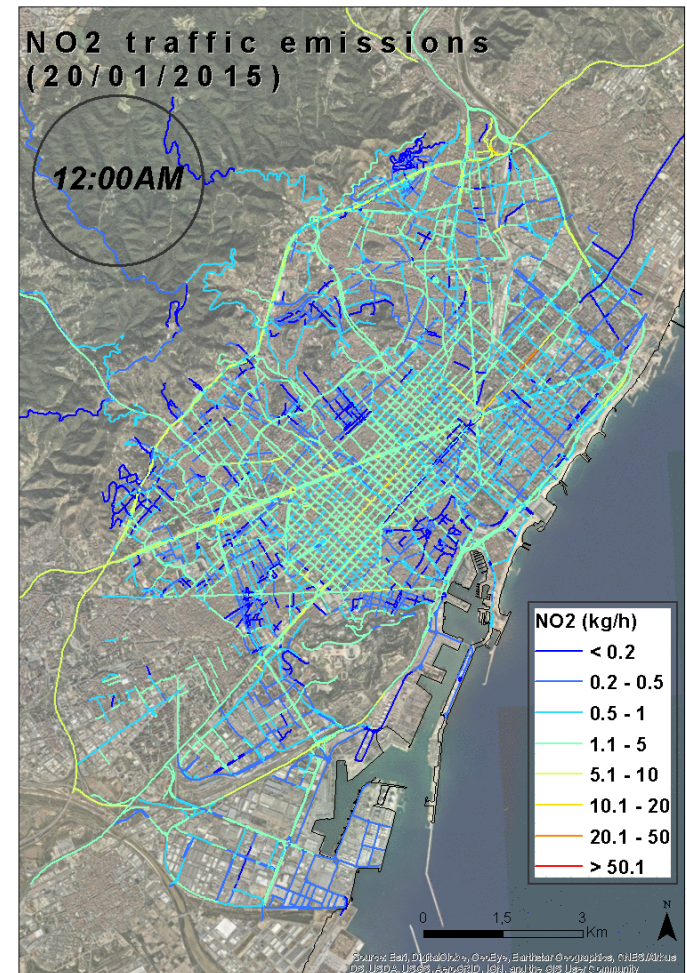**Vehicle fleet composition (traffic cameras)**

Emission factors (speed dependent)

+ resuspension
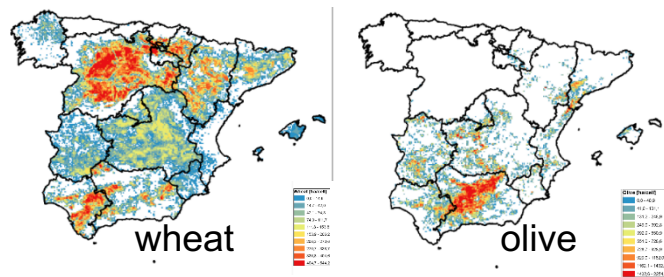(Amato et al., 2012)

Meteorological parameters

Temperature to account for variation in evaporative/cold-start emissions

HERMESv3_BU: bottom-up module

An **emission model** to estimate emissions at the **source level** combining state-of-the-art **bottom-up methods** with local activity and emission factors

Crop-specific spatial distributions

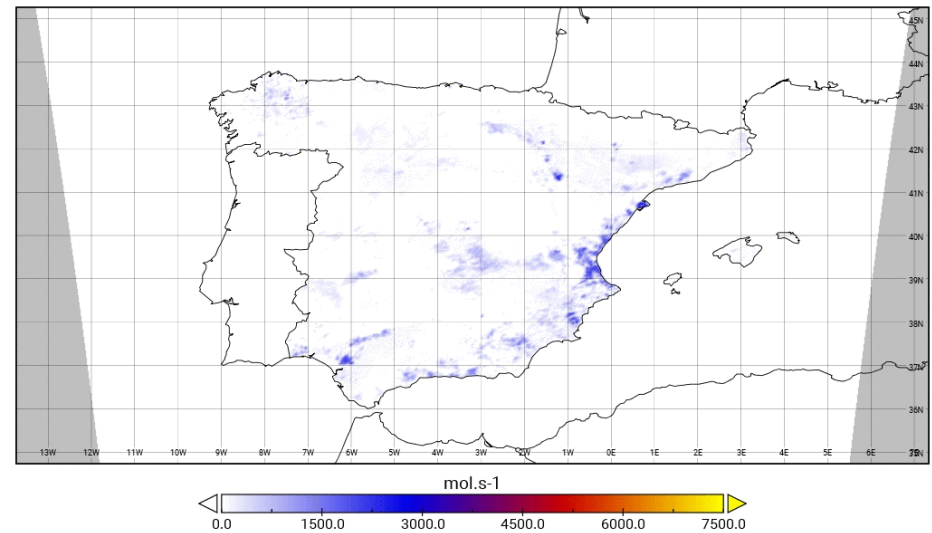wheat   olive

Soil properties (PH, cation exchange capacity)
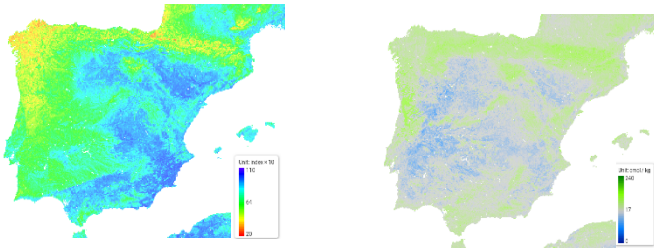
Crop-specific calendars and meteorology
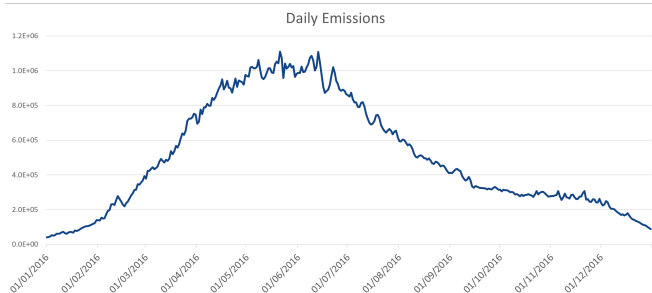
Fertilizer NH$_3$ daily emissions (Spain, 4x4km)

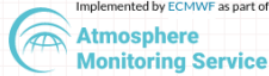mol.s-1

Guevara et al., 2019 in prep

CAMS-84: Global and regional a posteriori validation
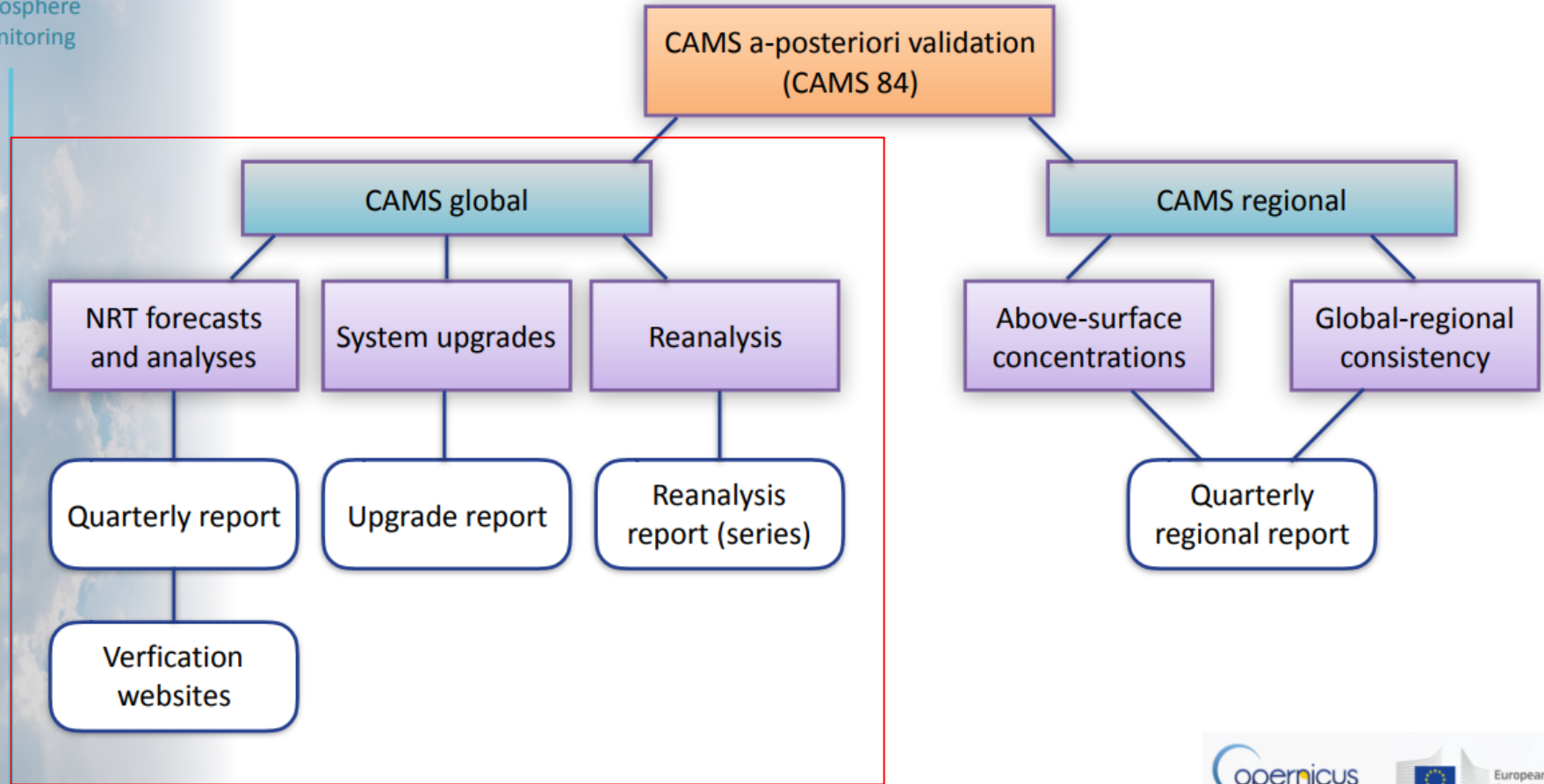
BSC's contribution focuses on the aerosols evaluation and particularly on the dust component

CAMS-84: Global and regional a posteriori validation

https://atmosphere.copernicus.eu/global-services

Implemented by ECMWF as part of The Copernicus Programme

Atmosphere Monitoring Service

News Events Press Tenders Help & support

DATA   ABOUT US   WHAT WE DO   SEARCH

European Commission | Copernicus Europe's eyes on Earth | IMPLEMENTED BY ECMWF | ✕ close

HELP & SUPPORT ▶ QUALITY ASSURANCE ▶ VALIDATION GLOBAL

Global Services

All the validation reports are available through the Copernicus website!

EVALUATION AND QUALITY ASSURANCE REPORTS   QUALITY MONITORING GRAPHICS

Evaluation and Quality Assurance reports

BSC also maintains the NRT of the global dust model through the WMO SDS-WAS

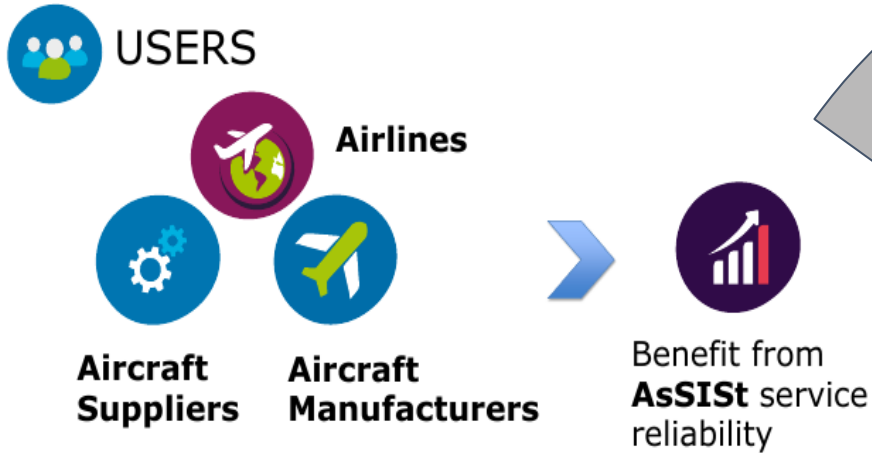### WMO Sand and Dust Storm Warning Advisory and Assessment System

The CAMS aerosol forecasts contribute to the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). The forecasts are verified with near-real time AERONET data. Evaluation metrics are available on a monthly and seasonal basis. A near-real time model comparison of contributing dust models is available.

WORLD METEOROLOGICAL ORGANIZATION

CAMS-95 AsSISt
Aircraft Support & Maintenance Services

USERS

Airlines

Aircraft Suppliers

Aircraft Manufacturers

Benefit from **AsSISt** service reliability

CAMS DATA

BSC

At parking position:
- Relative humidity and temperature
- SO2 Concentration
- Cl- deposit rate

En-route:
- Black carbon
- Sea salt
- Mineral dust
- Sulfates
- Organic biogenic
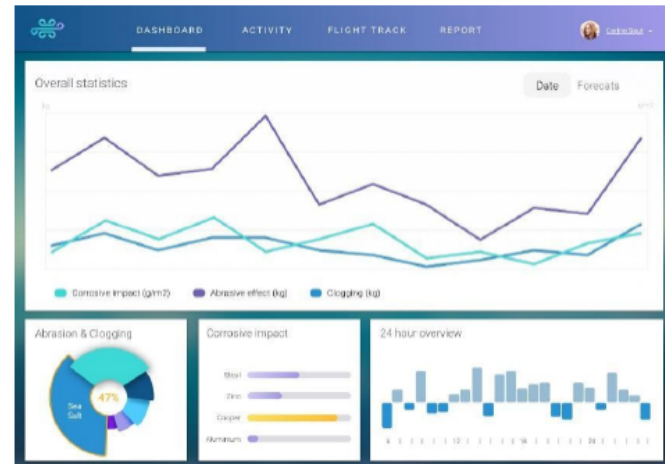
Evolution of indicators over time

Types of particles
Indicators by aircraft component

Capgemini   INERIS   Barcelona Supercomputing Center

AVIATION: Dust MONARCH model outputs (colour scale) vs airport and flight routes
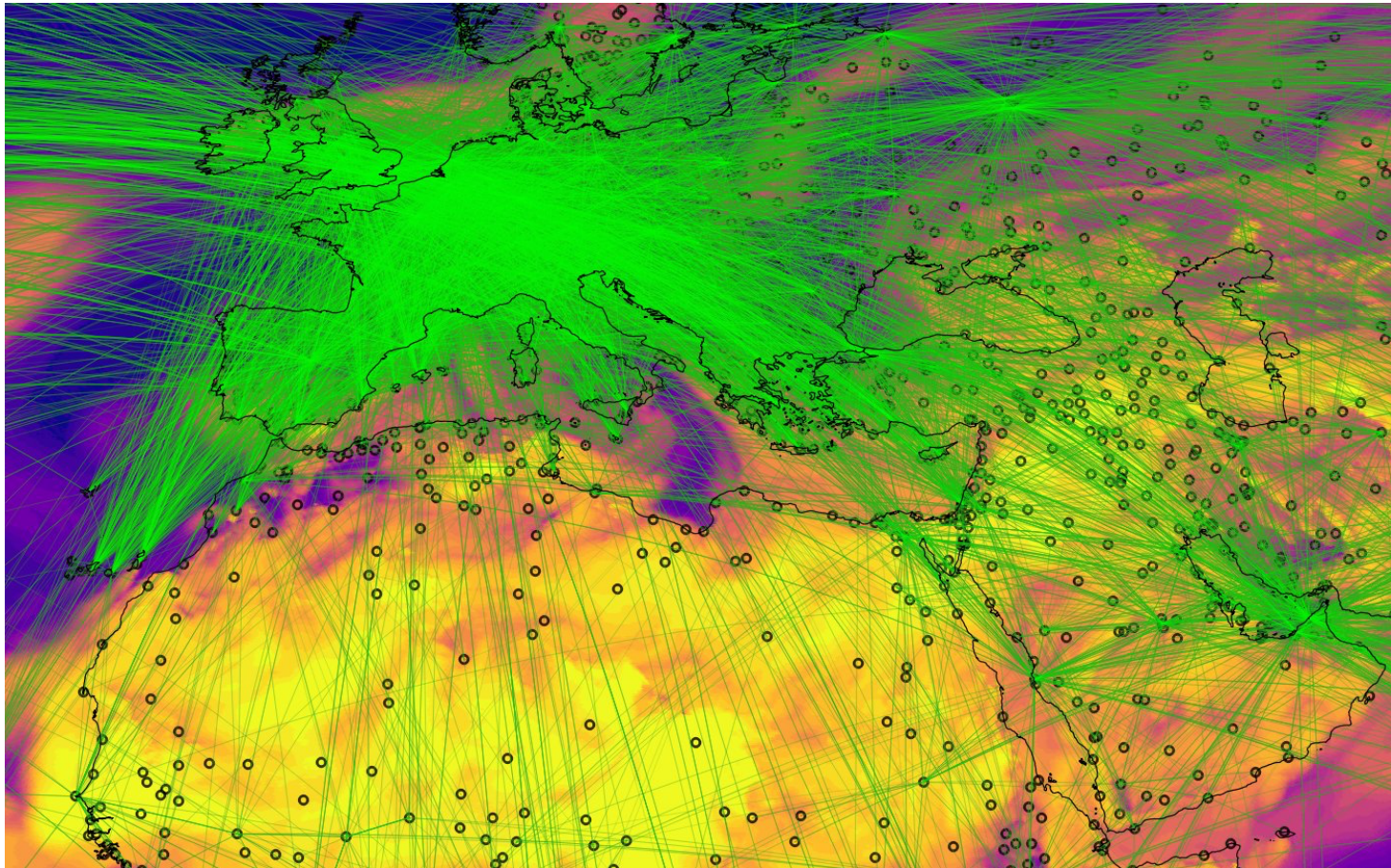
(Courtesy A. Votsis, FMI)

AIR QUALITY: Design of AQ Early warning systems – First tests based on NMMB-MONARCH simulations
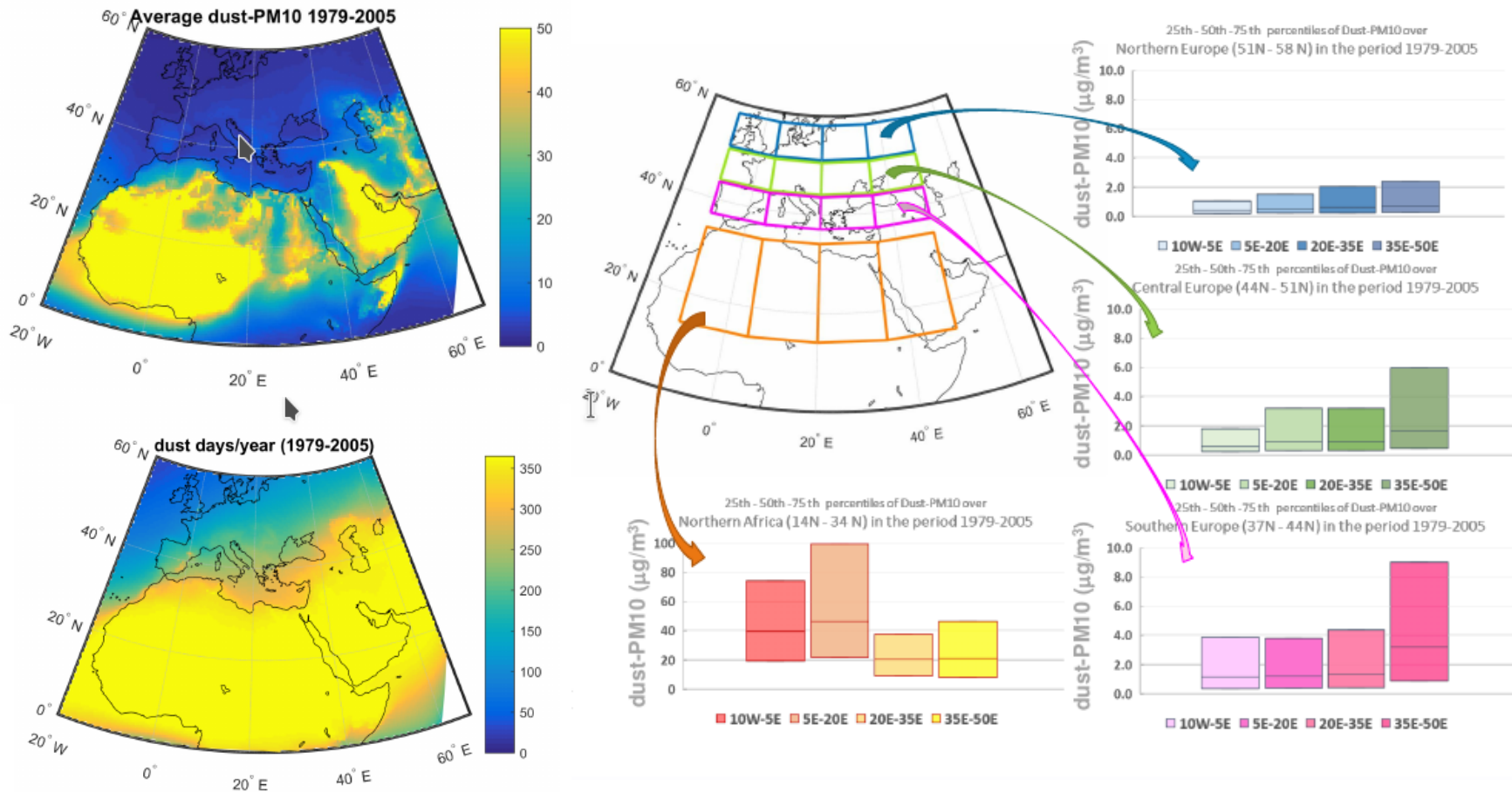
Number of days that exceed the EU limit of PM10 (i.e 50 µg/m3)

(Courtesy F. Barnaba, CNR-ISAC)

20

- **Soiling** → panels efficiency and water management

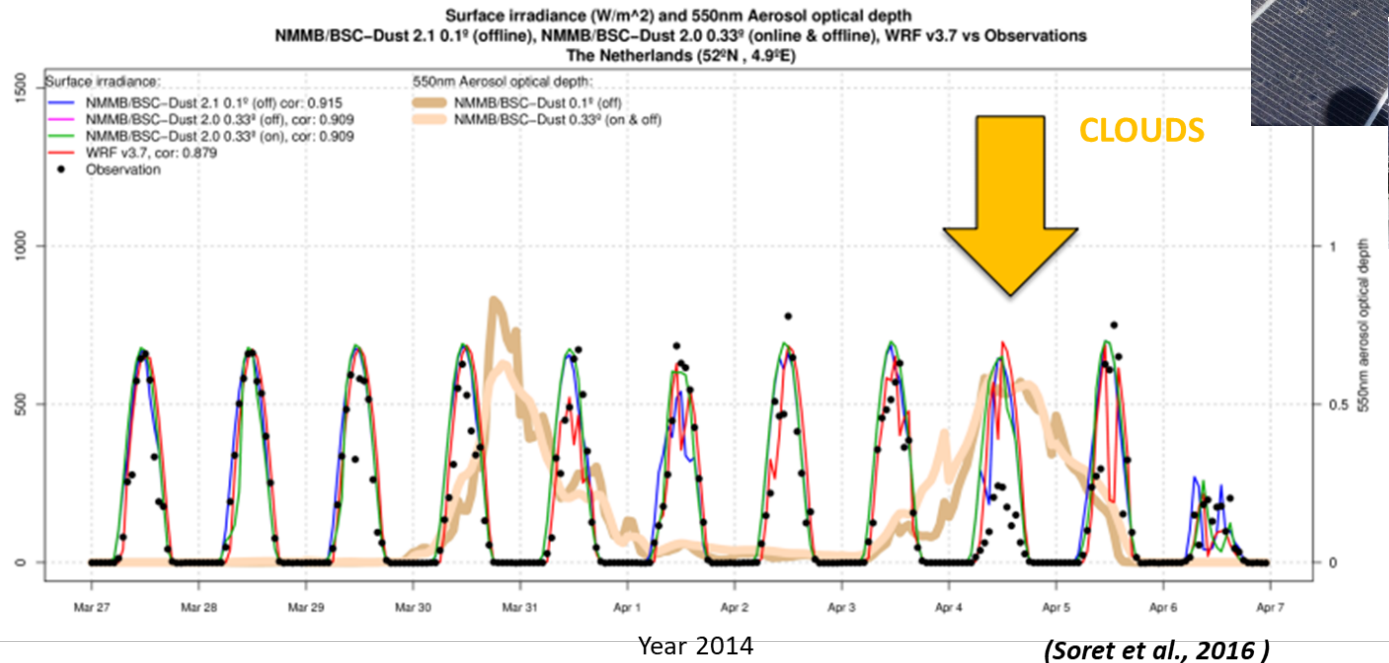- **Solar irradiance** → the presence of dust reduces the incoming **solar irradiance** through direct radiative effect

Surface irradiance (W/m^2) and 550nm Aerosol optical depth
NMMB/BSC-Dust 2.1 0.1º (offline), NMMB/BSC-Dust 2.0 0.33º (online & offline), WRF v3.7 vs Observations
The Netherlands (52ºN , 4.9ºE)

Surface irradiance:
NMMB/BSC-Dust 2.1 0.1º (off) cor: 0.915
NMMB/BSC-Dust 2.0 0.33º (off), cor: 0.909
NMMB/BSC-Dust 2.0 0.33º (on), cor: 0.909
WRF v3.7, cor: 0.879
Observation

550nm Aerosol optical depth:
NMMB/BSC-Dust 0.1º (off)
NMMB/BSC-Dust 0.33º (on & off)

CLOUDS

Year 2014

(Soret et al., 2016)

21

International Network to Encourage the Use of Monitoring and Forecasting Dust Products

COST Action CA16202

Chair: Sara Basart (Spain, sara.Basart@bsc.es)
**Vice-Chair:** Slobodan Nickovic (Serbia)

www.cost-indust.eu
Contact: cost-indust@bsc.es

cost
EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

**Barcelona
Supercomputing
Center**
Centro Nacional de Supercomputación

Our goals

- To establish a network involving research institutions, service providers and potential end users of information on airborne dust.

- To coordinate and harmonise the process of transferring dust observations and predictions to users (including researchers and stakeholders).

- To assist the diverse socio-economic sectors affected by the presence of high concentrations of airborne mineral dust.
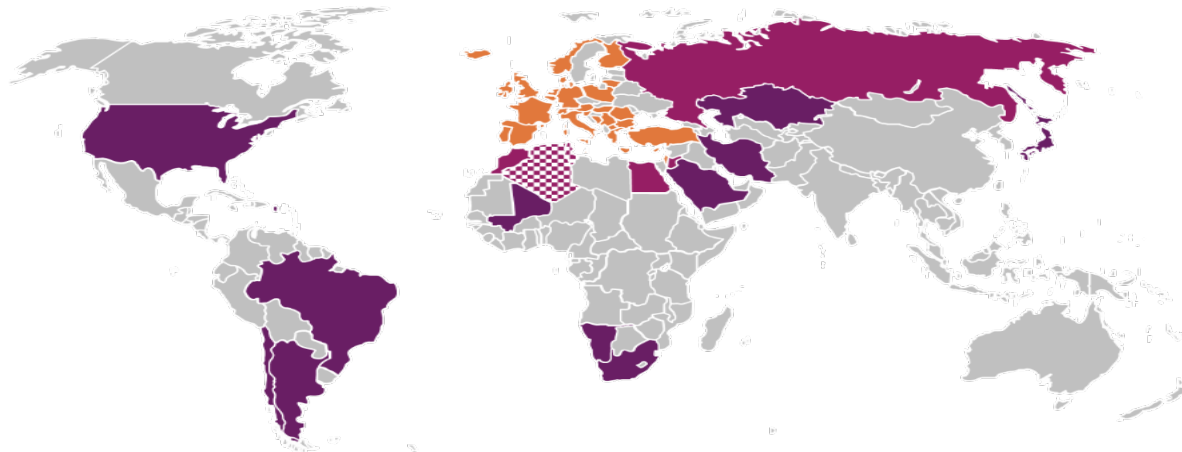
COST countries (in total 29)
Near-Neighbour Countries (Egypt, Jordan, Lebanon, Morocco, Russia, *Algeria*)
International Partner Countries
International organisation (WMO, *ECMWF*)

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Thanks!

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