Training event on Atmospheric Composition Data Exploitation.

Sara Basart - sbasart@wmo.int

Day 2. Atmospheric Models

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani

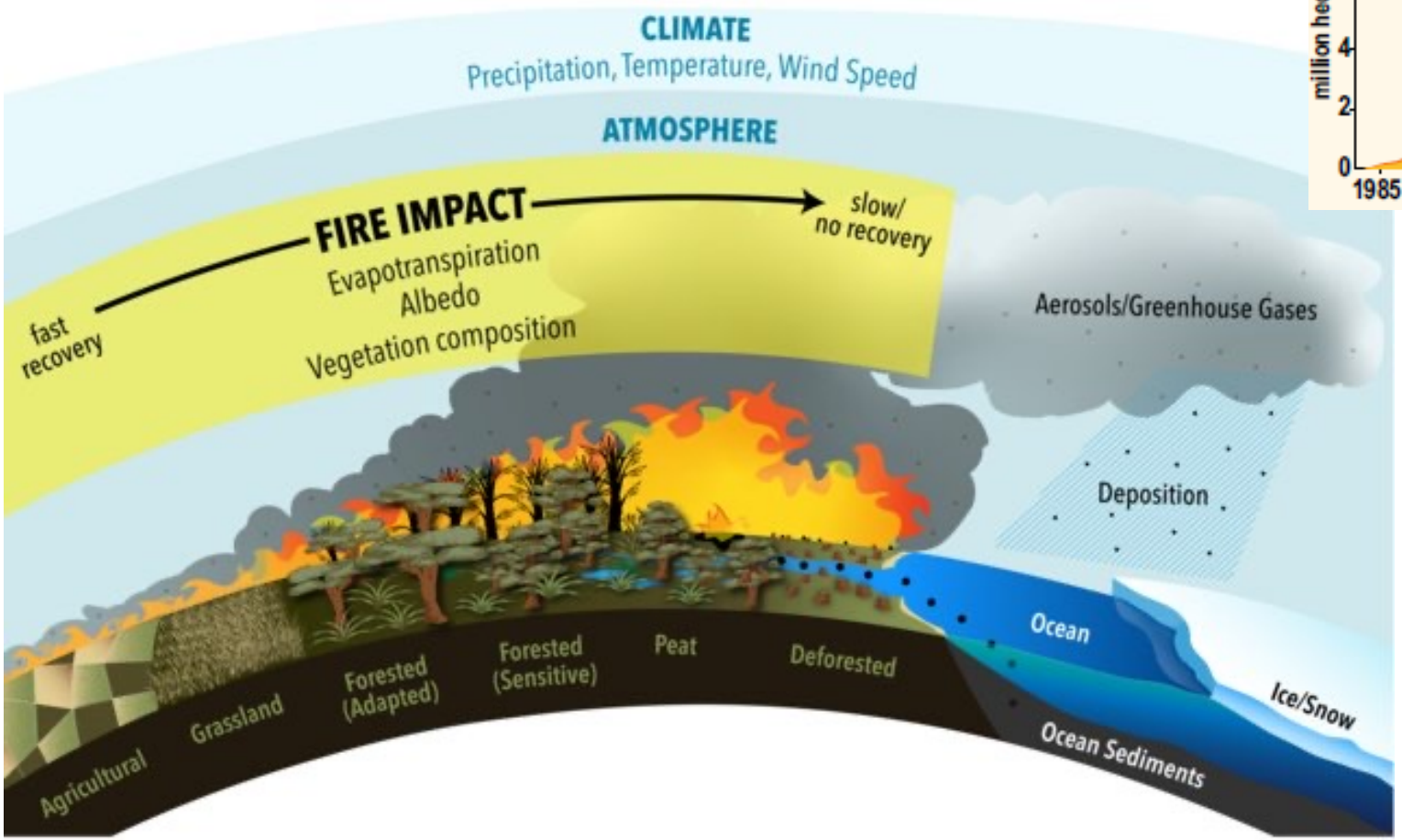
Training event on Atmospheric Composition Data Exploitation, 28-30 January 2025

Atmospheric Models: Basic concepts

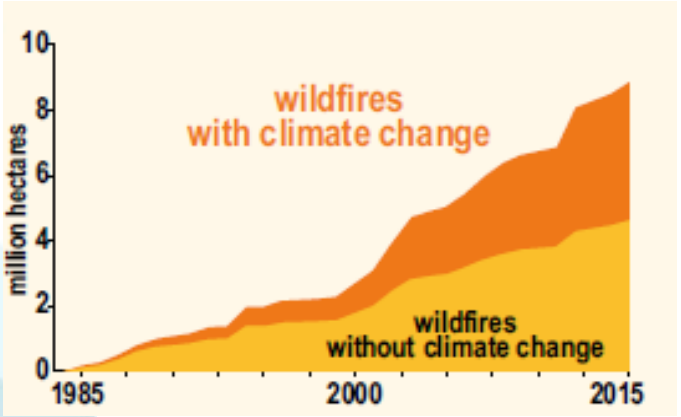
Sara Basart (sbasart@wmo.int)
Scientific Officer
Science and Innovation Department

WORLD
METEOROLOGICAL
ORGANIZATION

Atmospheric Composition on the Global context: Wildfires



(Lasslop et al., 2019)

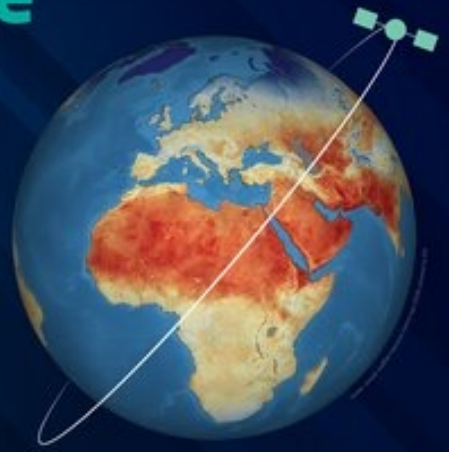


Lower emissions that would limit the global temperature increase to <2°C would reduce projected increases of global burned area to 30% to 35% and **projected increases of fire frequency to ~20%**.

(IPCC, 2021)

Weather versus Climate

The difference between weather and climate is a matter of time

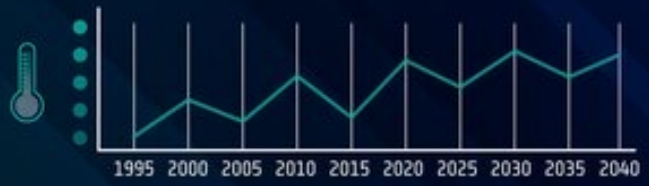


Weather

refers to short-term changes in the atmosphere.
It can change minute-to-minute, hour-to-hour and day-to-day

Climate

describes the average weather conditions in a specific area over a long period of time – 30 years or more



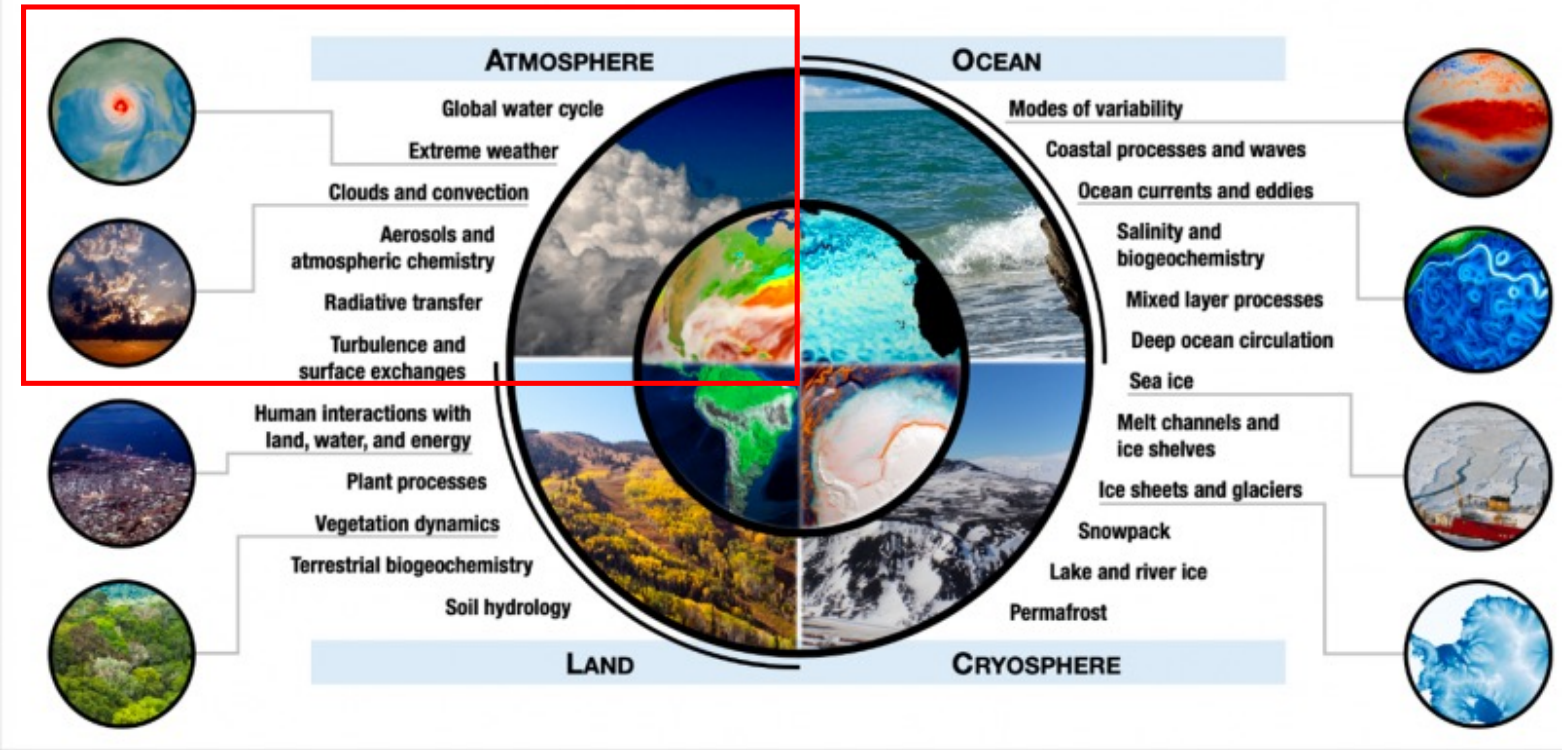
Satellites measure several aspects of Earth's weather as well as provide essential data over decades to monitor how our climate is changing

For more information, visit space for our climate:
www.esa.int/climate

Model types

Climate Models

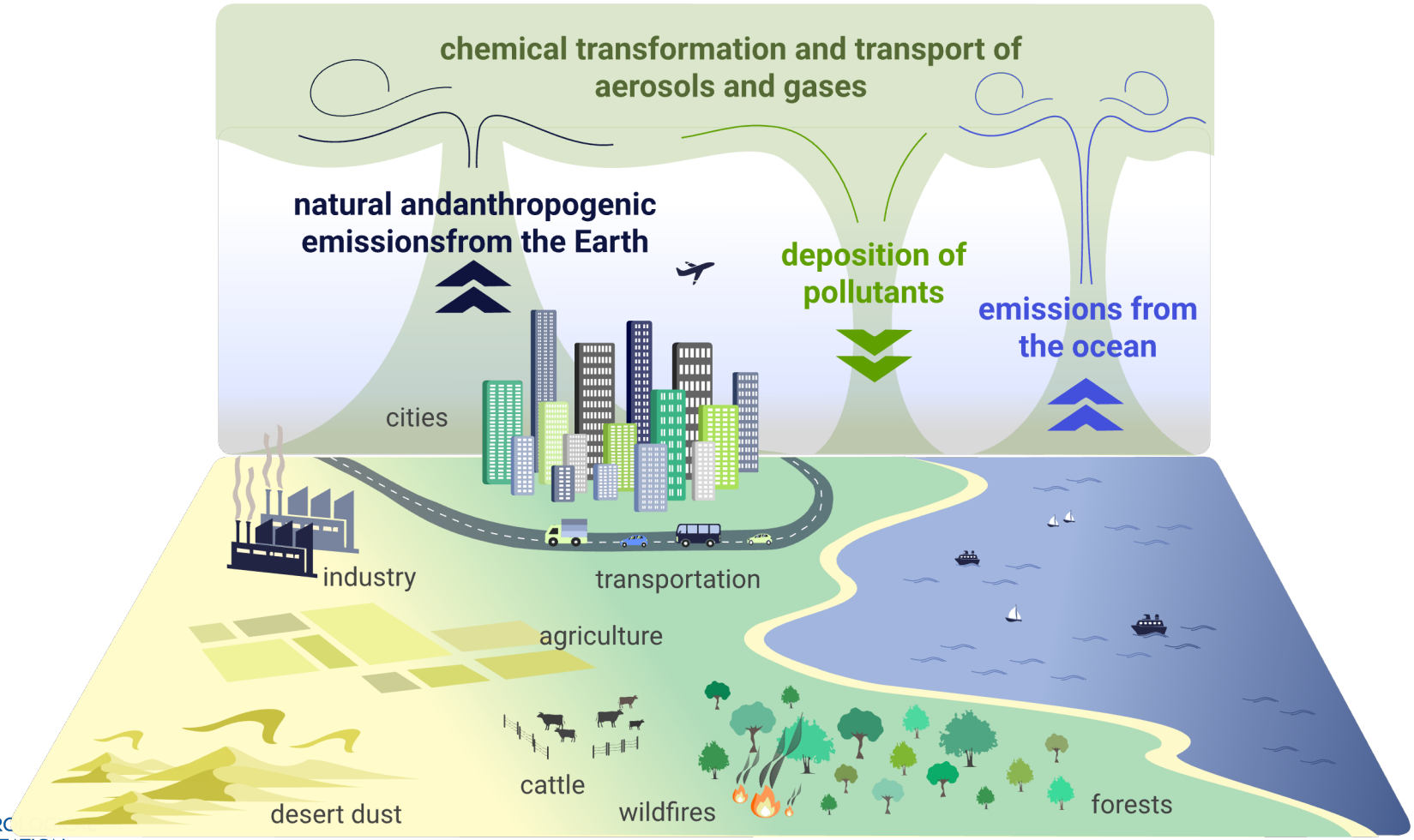
Atmospheric Models



WORLD METEOROLOGICAL ORGANIZATION

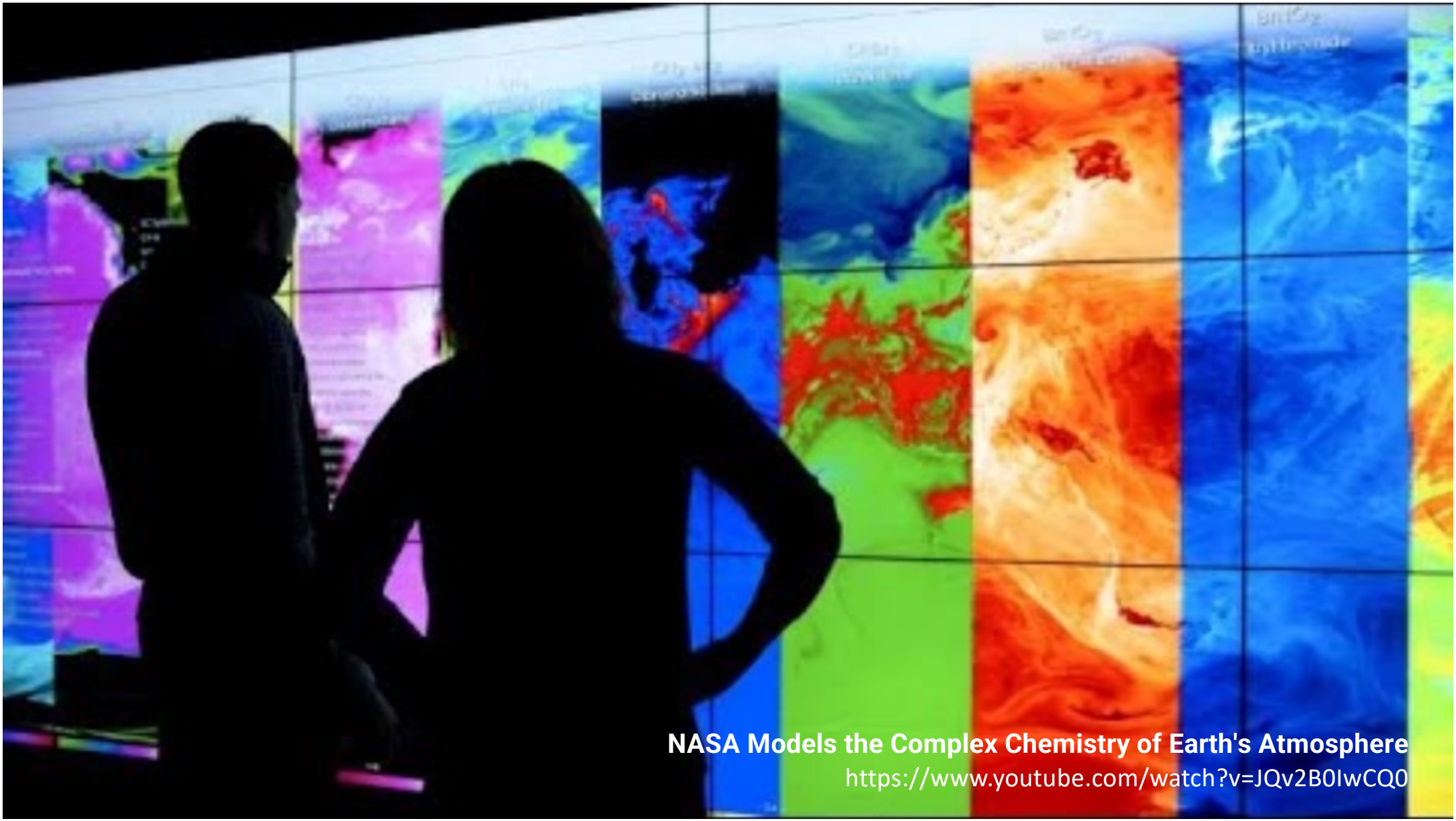
https://www.energy.gov/science/doe-explainsearth-system-and-climate-models

Atmospheric Composition models



WORLD METEOROLOGICAL ORGANIZATION

Source: https://caliope.bsc.es/

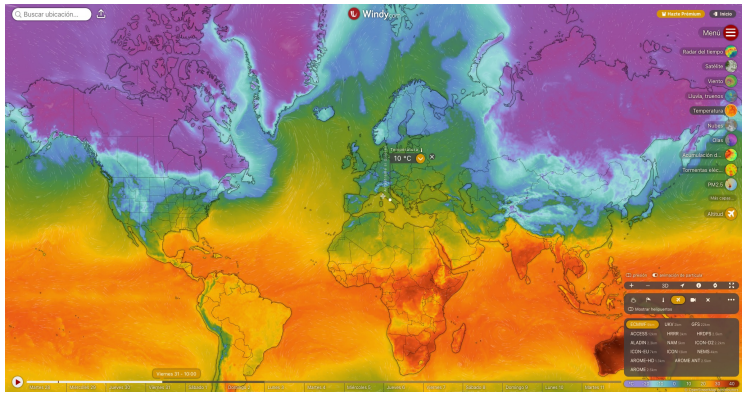


NASA Models the Complex Chemistry of Earth's Atmosphere

https://www.youtube.com/watch?v=JQv2B0IwCQ0

Atmospheric Composition models

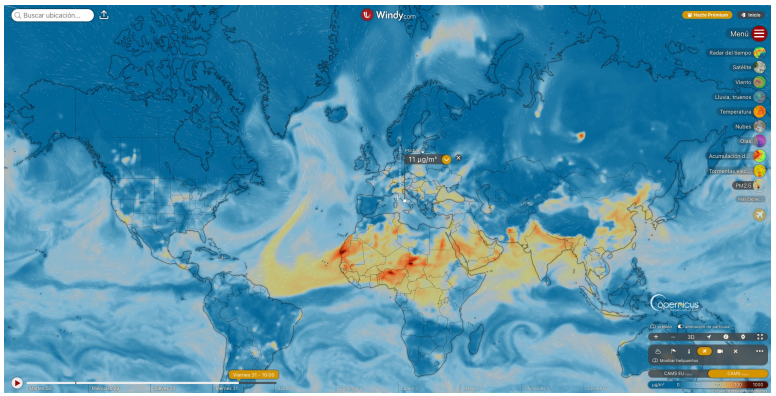
Atmosphere Monitoring Service
atmosphere.copernicus.eu



Meteorological Model

Offline coupled

Online coupled



Chemistry Transport Model (CTM)

Emission Model

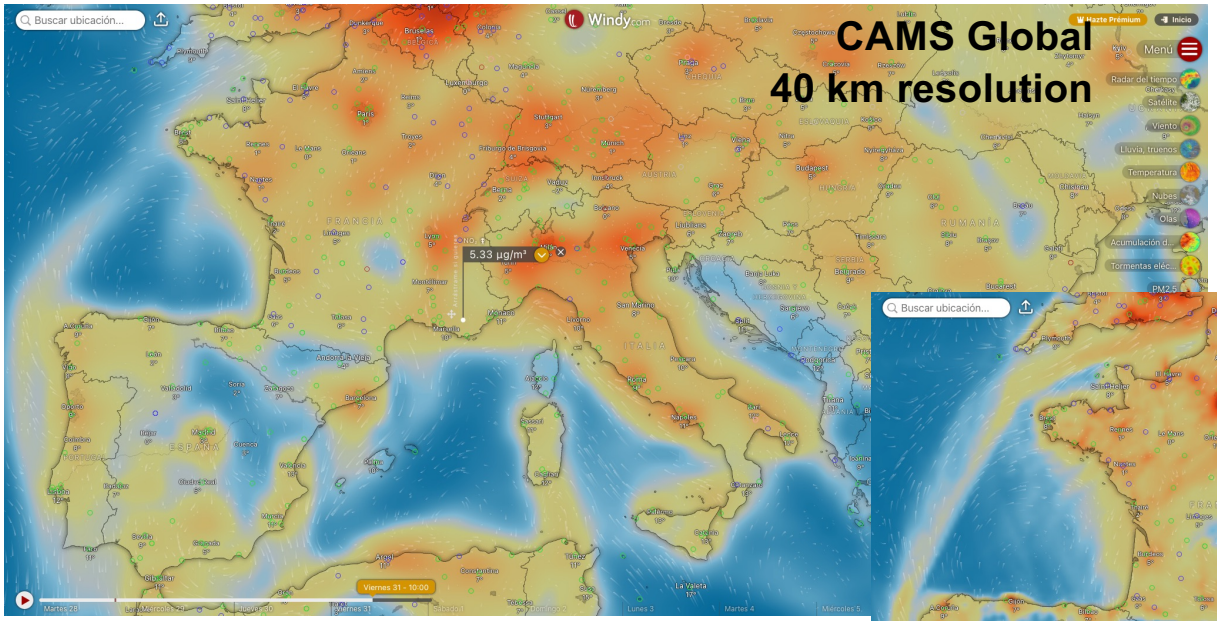
Emission Inventories

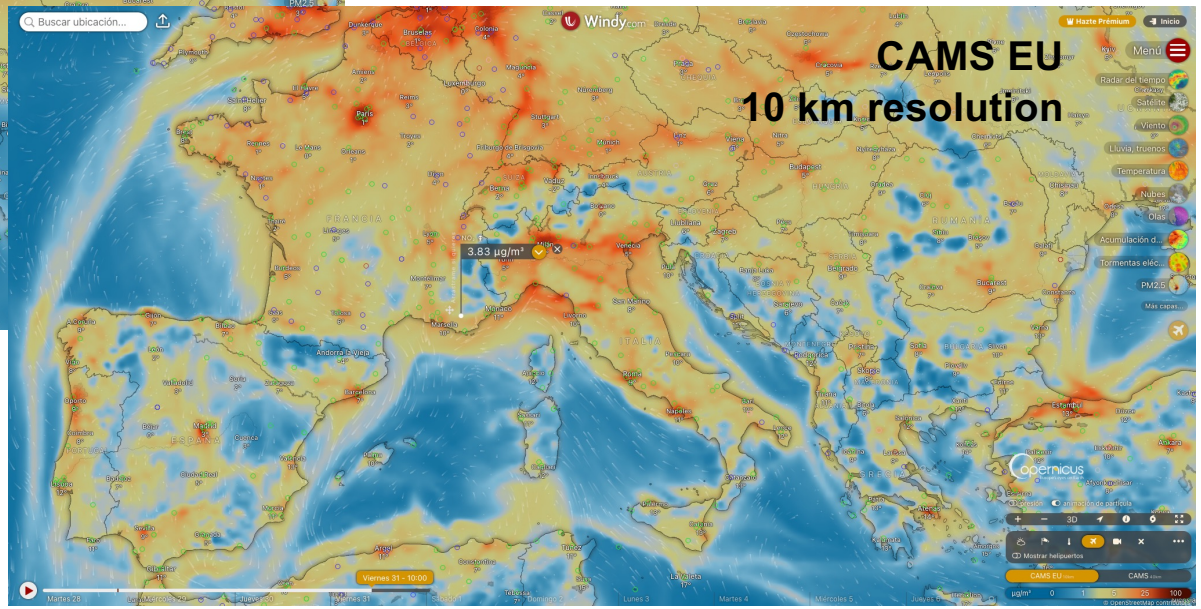
ATTENTION: SDS are modelled within the CTM based on meteorological paramenters and land conditions.

WORLD METEOROLOGICAL ORGANIZATION

CAMS Forecast image source https://www.windy.com/

Atmospheric Composition models: Global vs Regional





Atmosphere Monitoring Service
atmosphere.copernicus.eu

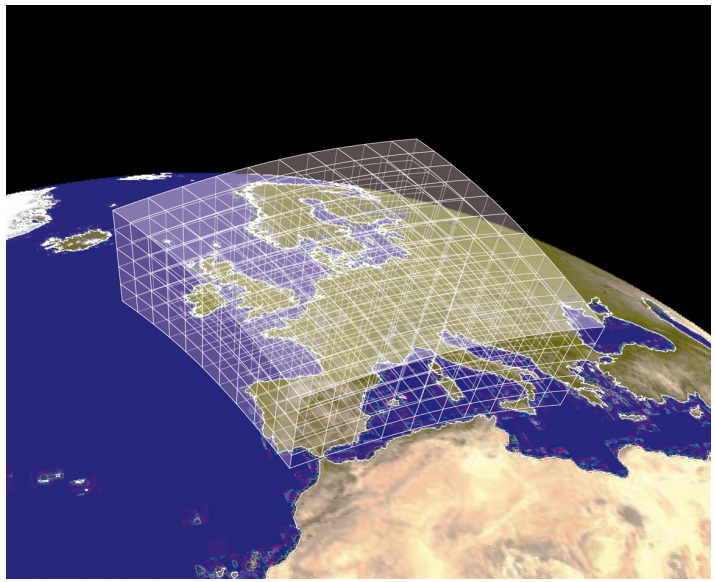
CAMS NO_2 forecasts
For 31 Jan 2025 at 10CET

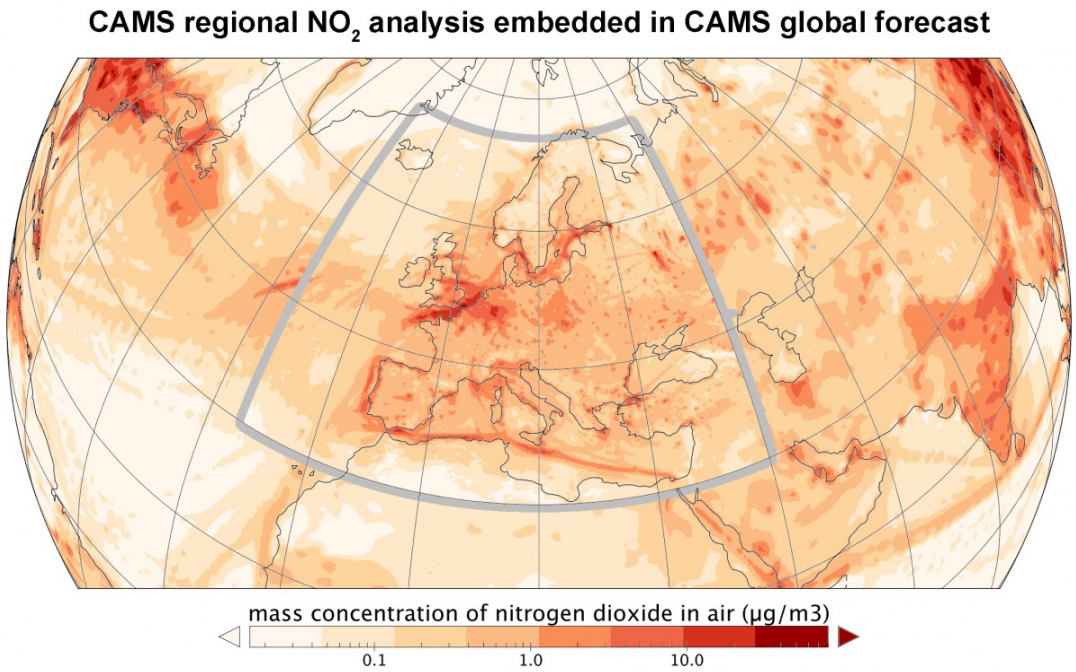
WORLD METEOROLOGICAL ORGANIZATION

Source https://www.windy.com/

Atmospheric Composition models: Global vs Regional

Global Forecasts are used as **Initial and Boundary conditions** by the Regional Forecasting Systems.



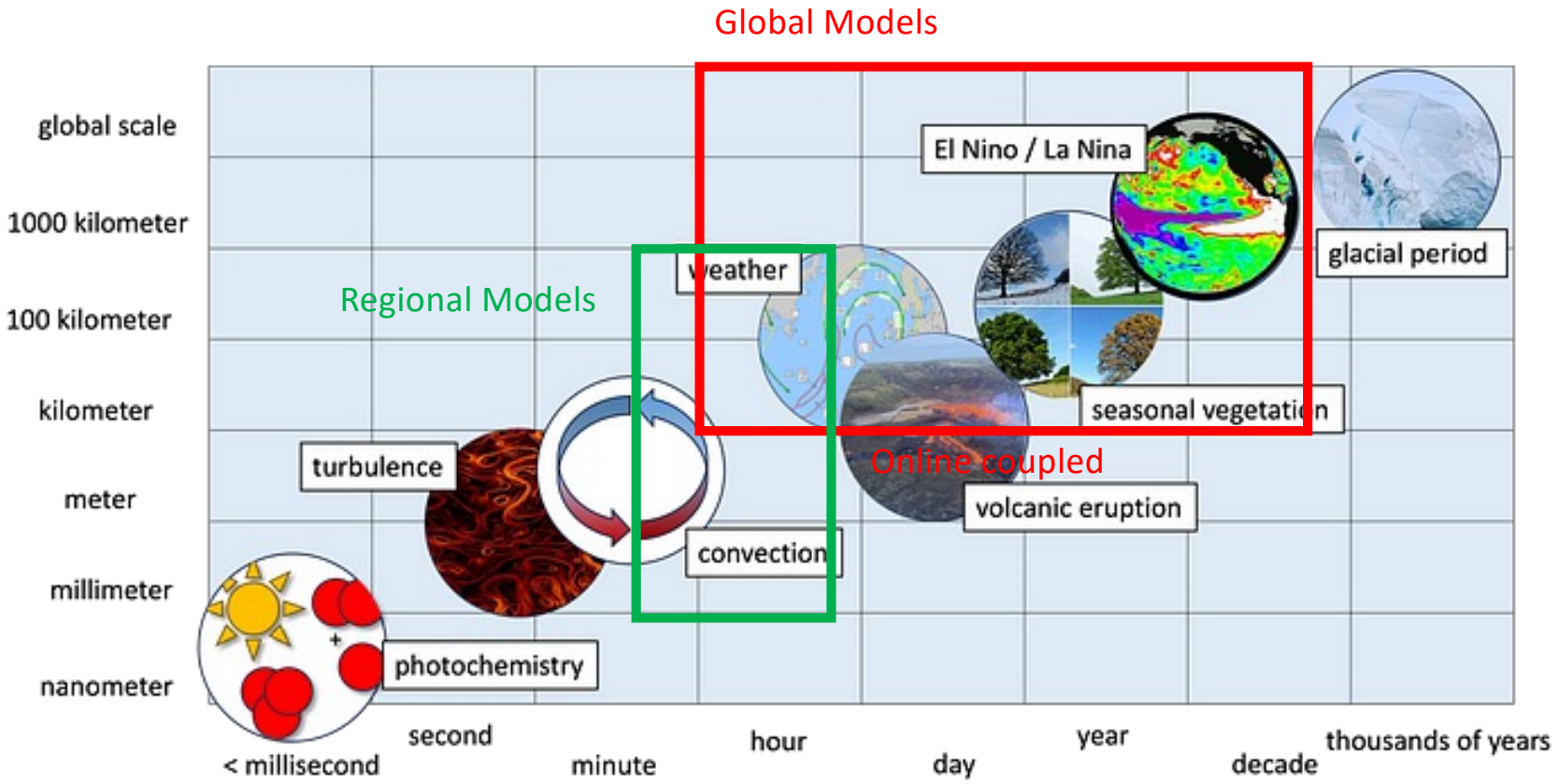


WORLD METEOROLOGICAL ORGANIZATION

Atmosphere Monitoring Service
atmosphere.copernicus.eu

https://atmosphere.copernicus.eu/copernicus-data-brings-pollution-forecasting-your-mobile-phone

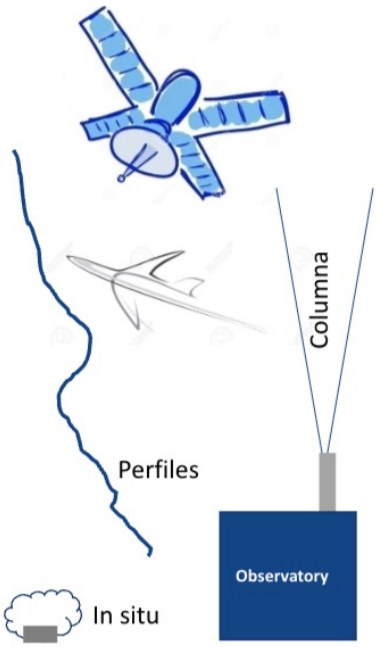
Atmospheric Composition models: Scales



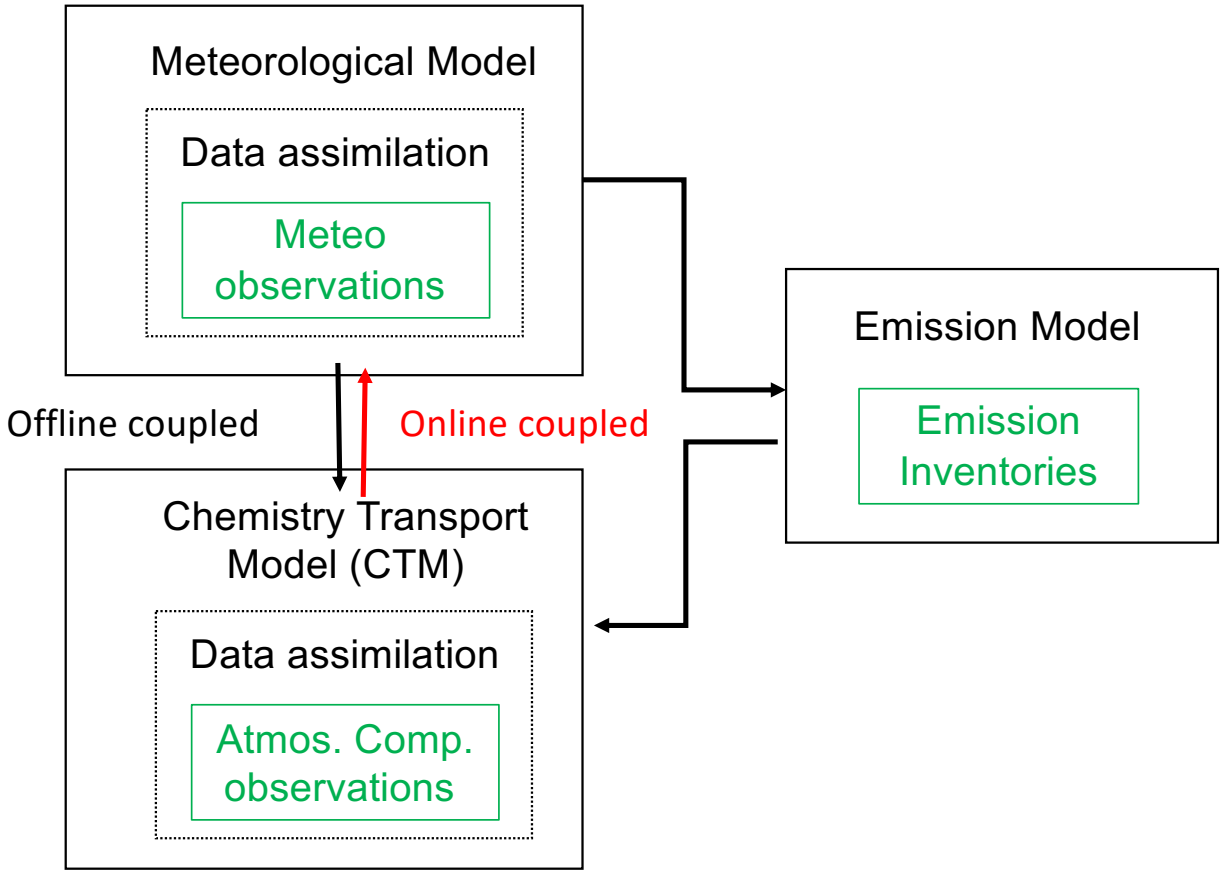
G. Inchingolo CC-BY-SA 4.0 / Aviation Weather Center Public Domain / Government of Iceland / J. Hagelüken CC-BY-SA 3.0 / G. Boz CC-BY-SA 3.0 | All Wikimedia Commons

Atmospheric Composition models: (Re)analysis

Observations

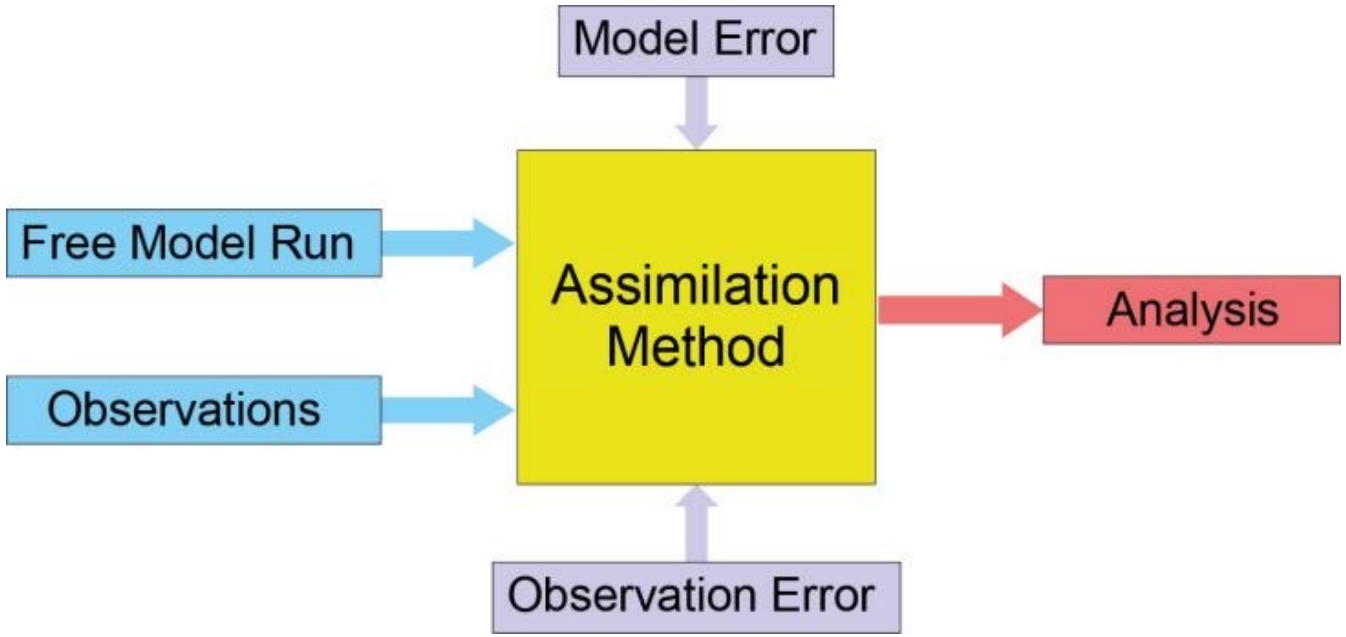


Scheme courtesy of L. Mona



WORLD METEOROLOGICAL ORGANIZATION

Atmospheric Composition models: (Re)analysis



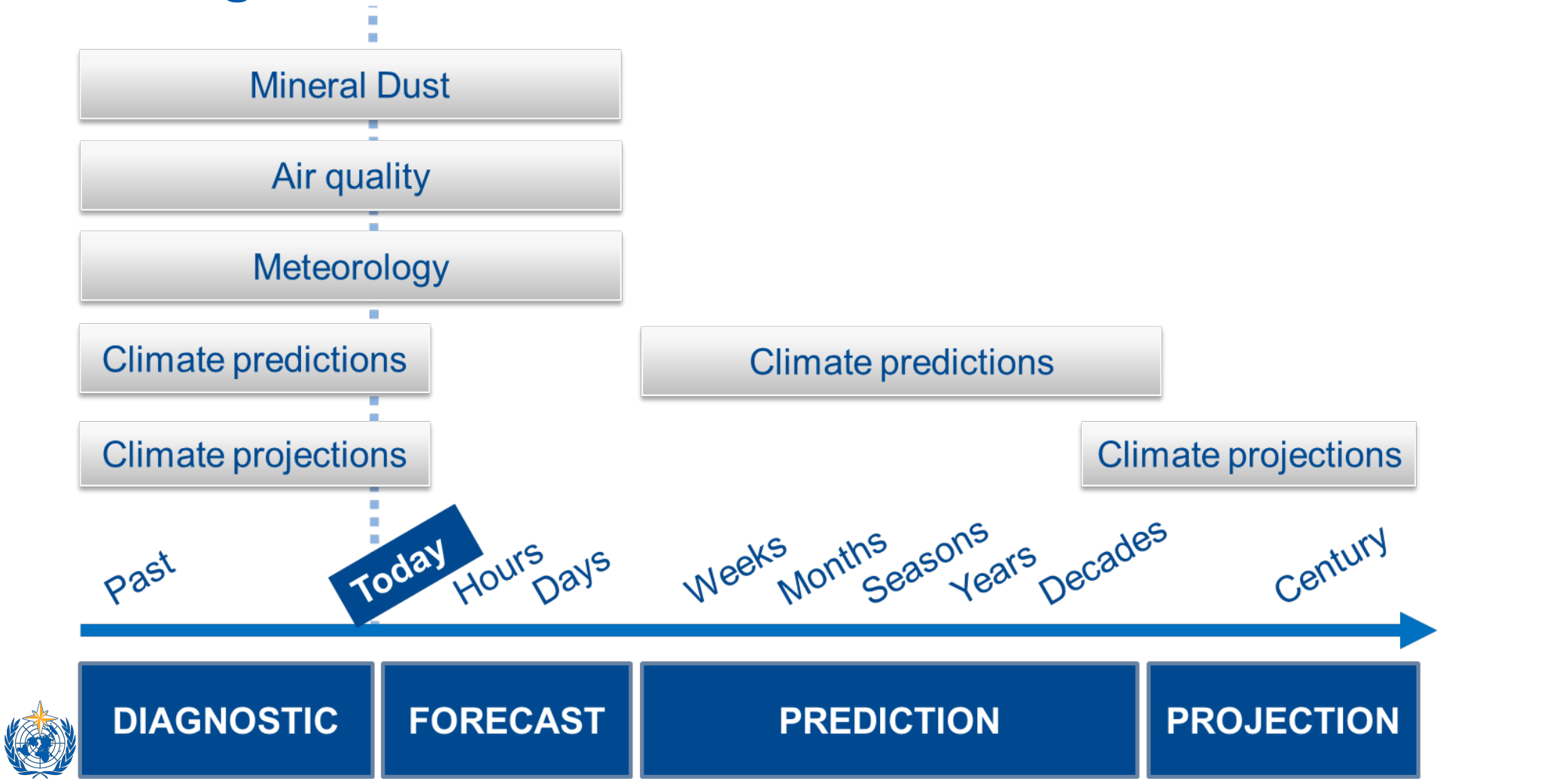
Analysis: Obtaining the "best" estimate of current atmospheric dust conditions

Reanalysis: Creation of data sets describing the recent history of dust in the atmosphere

WORLD METEOROLOGICAL ORGANIZATION

https://www.hereon.de/institutes/coastal_systems_analysis_modeling/hydrodynamics_data_assimilation/topics/data_assimilation/index.php.en

Modelling framework



Courtesy Albert Soret

Modelling framework

HPC (high-performance computers) are fundamental for executing numerical models. The **size of each cell in the grid and the length of the simulation** is determined by the power of the computer running the model.

The MareNostrum 5 supercomputer, Spain
It is a pre-exascale EuroHPC supercomputer
https://www.bsc.es/ca/marenostrum/marenostrum-5

WORLD METEOROLOGICAL ORGANIZATION

Why do we evaluate air quality models?

- **Accuracy & Reliability**:
  - Models need to predict pollutant concentrations with high accuracy.
- **Regulatory Compliance**:
  - Ensure models meet national and international air quality standards.

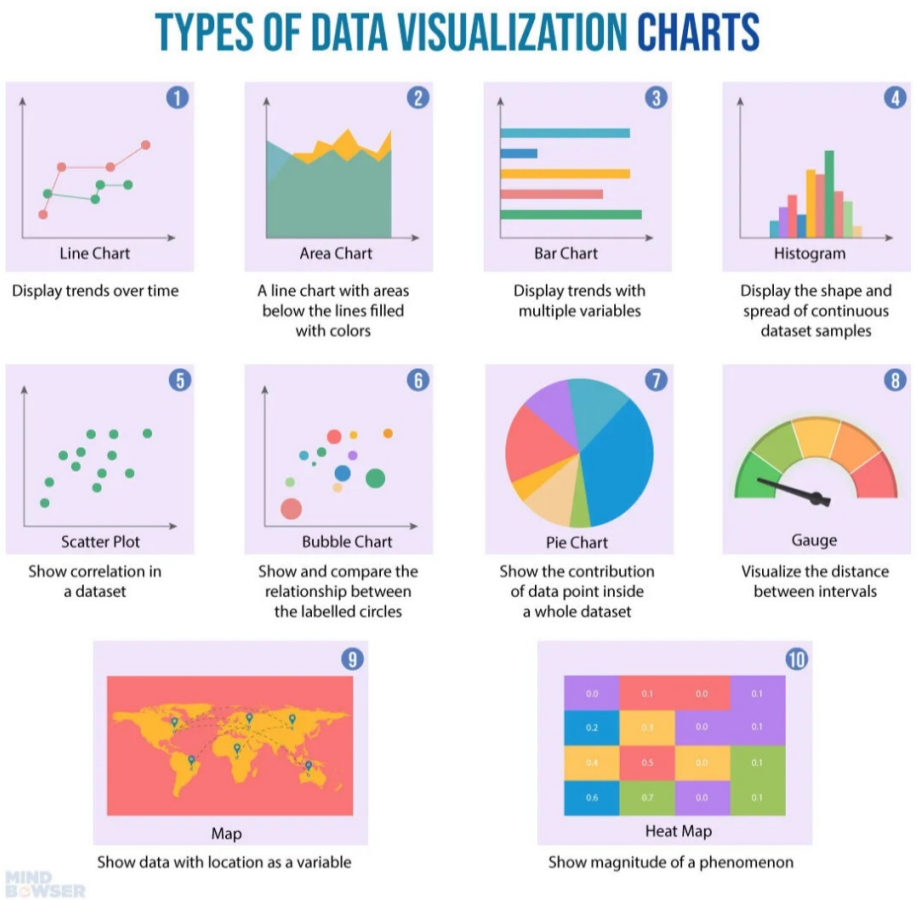
Key Steps in Model Evaluation

Comparison with Observations:

- Validate model output against measured air quality data (points: ground-based, gridded: satellite).

Statistical Performance Metrics:

- Categorical: Definition of categories by intensity
  - Contingency tables
- Continuous
  - Metrics like Mean Bias (MB), Root Mean Square Error (RMSE), and correlation coefficients.



VISUALISE THE RESULTS MATTERS!

WORLD METEOROLOGICAL ORGANIZATION

Barcelona Dust Regional Center

FAQ Contact Us Log in Search...

Products Research Resources News & Events About Us

Daily Dust Products

< BACK TO PRODUCTS

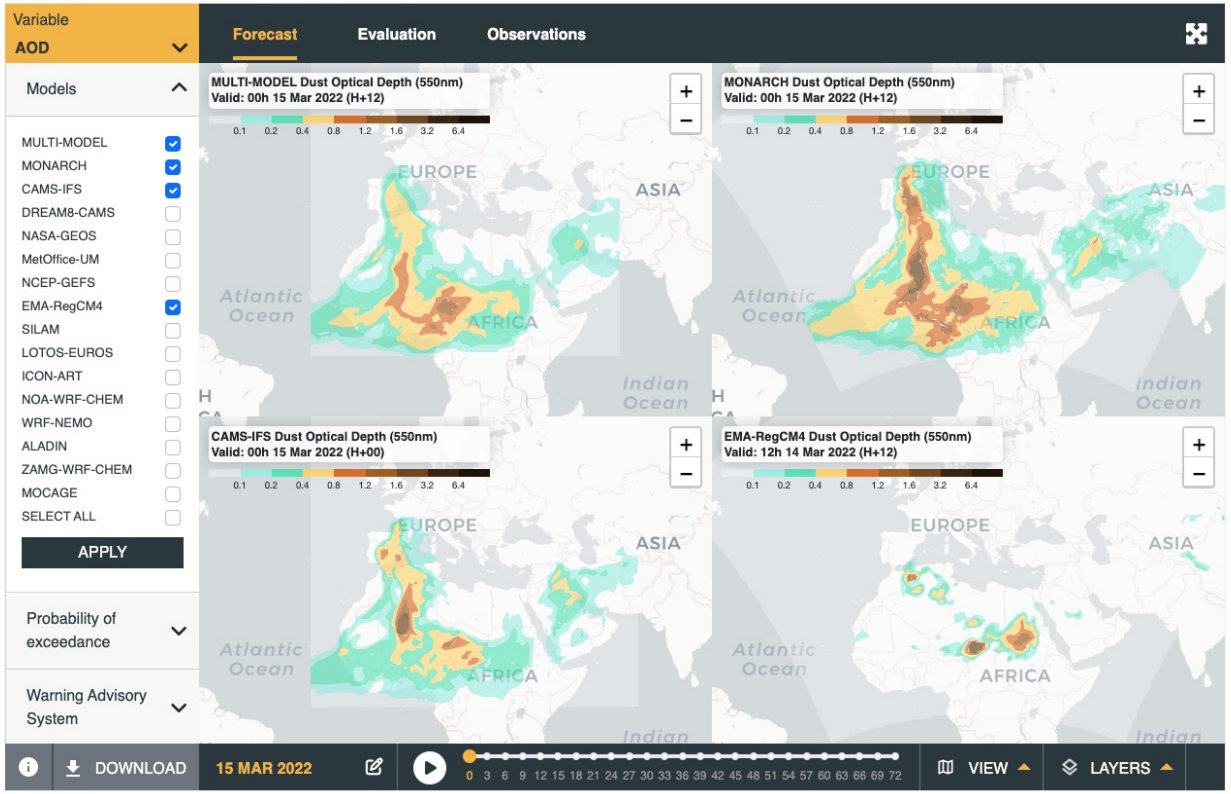
http://dust.aemet.es
@dust_barcelona

This interactive visualisation tool allows you to access dust forecasts from different numerical models and dust-related observational products. To find out how to interact with it, please watch the Video Tutorial or download the User Guide and read the Documentation. The Warning Advisory System has been developed thanks to the co-funding support of FEDER INTERREG MAC program and WMO-CREWS initiative.

Model intercomparisons

1. Promoting best practices and guidelines to be used by the international community

2. Development of probabilistic forecasts

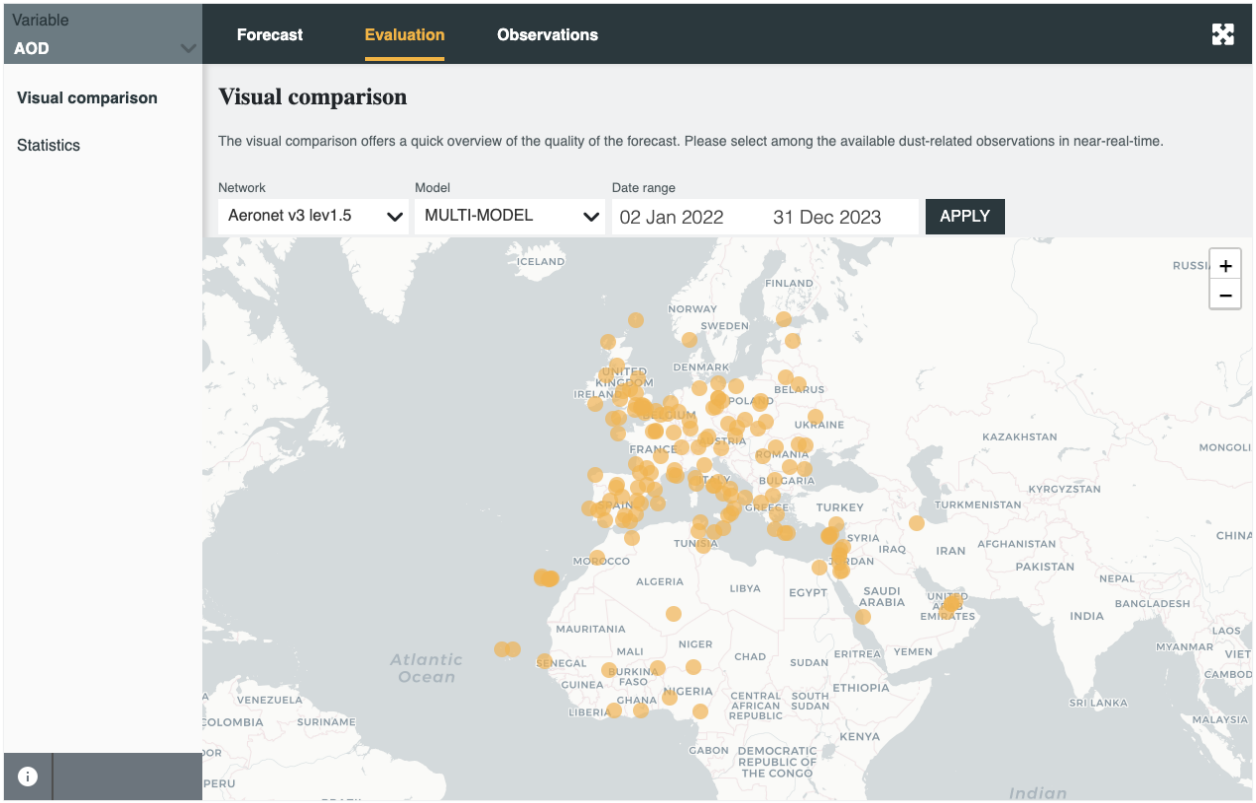


ONLY DUST

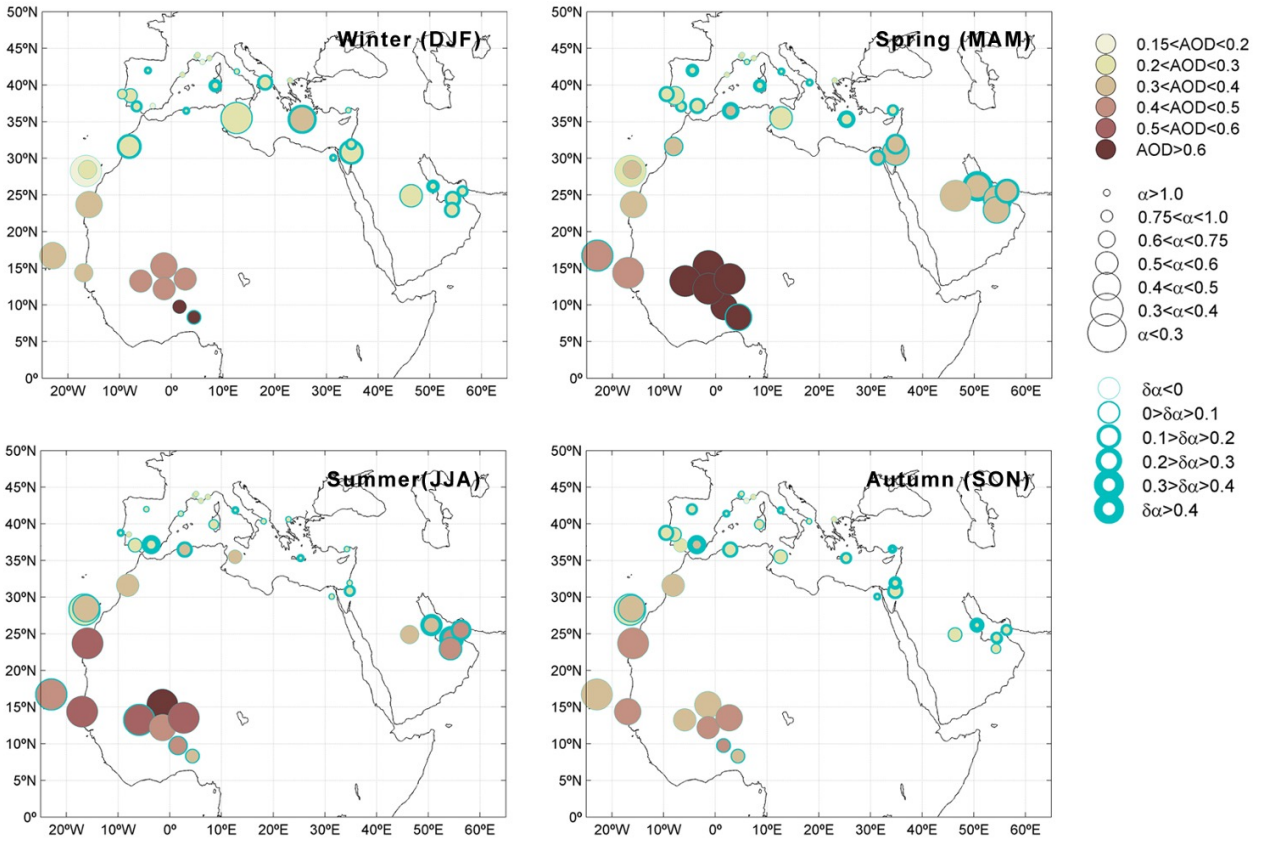
Daily Dust Products

< BACK TO PRODUCTS

This interactive visualisation tool allows you to access dust forecasts from different numerical models and dust-related observational products. To find out how to interact with it, please watch the Video Tutorial or download the User Guide and read the Documentation. The Warning Advisory System has been developed thanks to the co-funding support of FEDER INTERREG MAC program and WMO-CREWS initiative.



Understanding the observations
Aerosol typing – Example AERONET



Intensity
AOD 440 nm

Size
Angstrom Exponent
α(440,870 nm)

Mixture
Angstrom Exponent
Curvature
α(440,675nm)–
α(675,870nm)

(Basart et al., 2012)

WORLD METEOROLOGICAL ORGANIZATION

Barcelona Dust Regional Center

FAQ Contact Us Log in Search...

Products Research Resources News & Events About Us

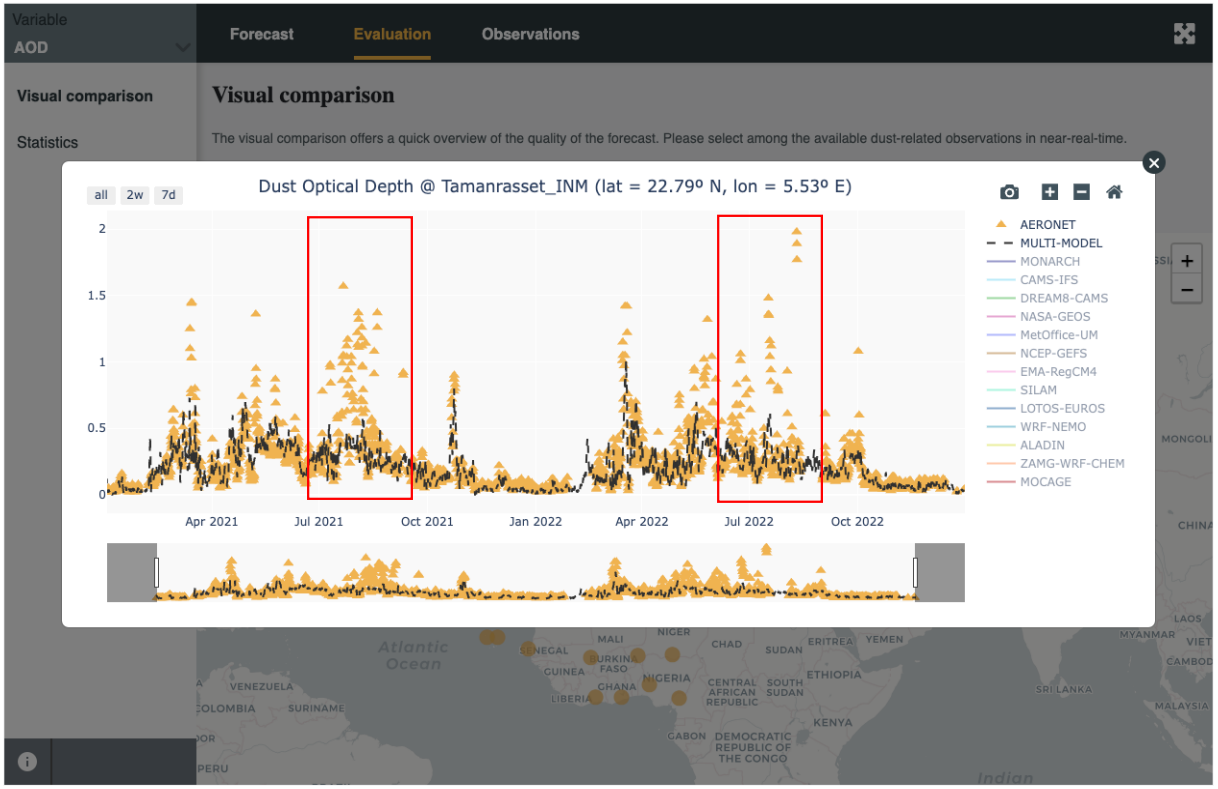
Daily Dust Products

< BACK TO PRODUCTS

http://dust.aemet.es
@dust_barcelona

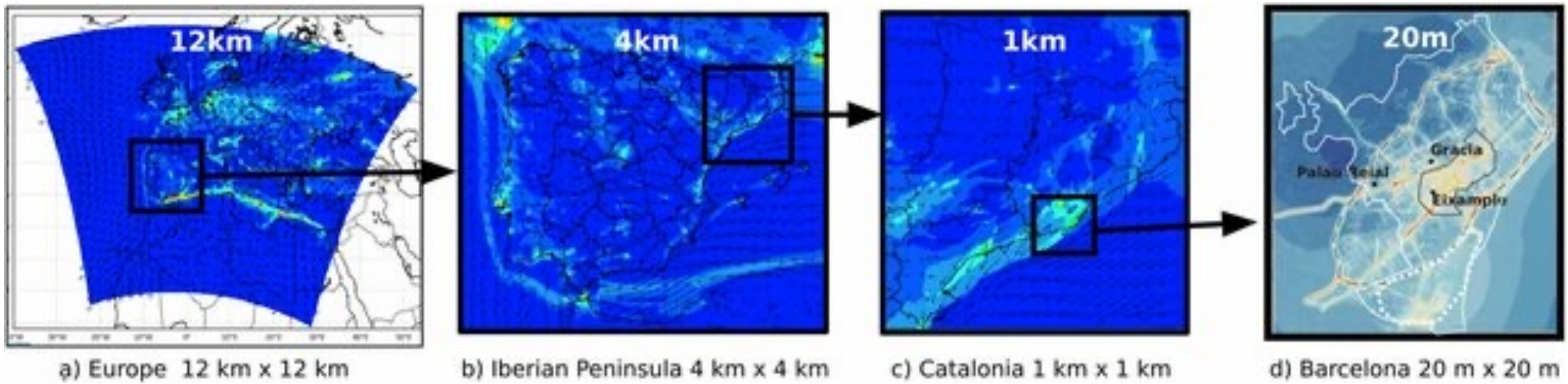
This interactive visualisation tool allows you to access dust forecasts from different numerical models and dust-related observational products. To find out how to interact with it, please watch the Video Tutorial or download the User Guide and read the Documentation. The Warning Advisory System has been developed thanks to the co-funding support of FEDER INTERREG MAC program and WMO-CREWS initiative.

Systematic underestimations in summer in Tamanrasset (Algeria)



ONLY DUST

Understanding the forecast | Spatial resolution
Example of NO2



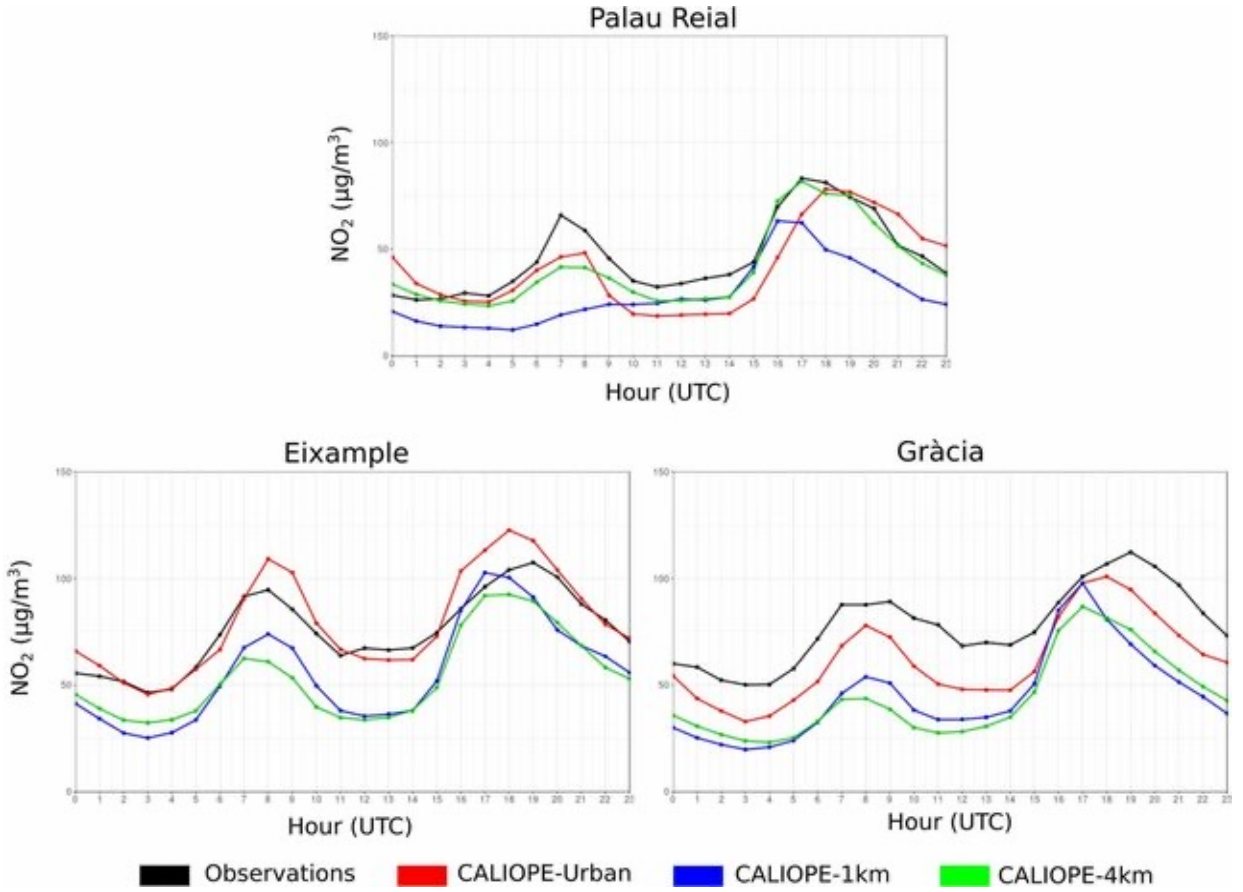
CALIOPE AQ forecasting system
Barcelona, Spain, 9-25 November 2017

WORLD METEOROLOGICAL ORGANIZATION

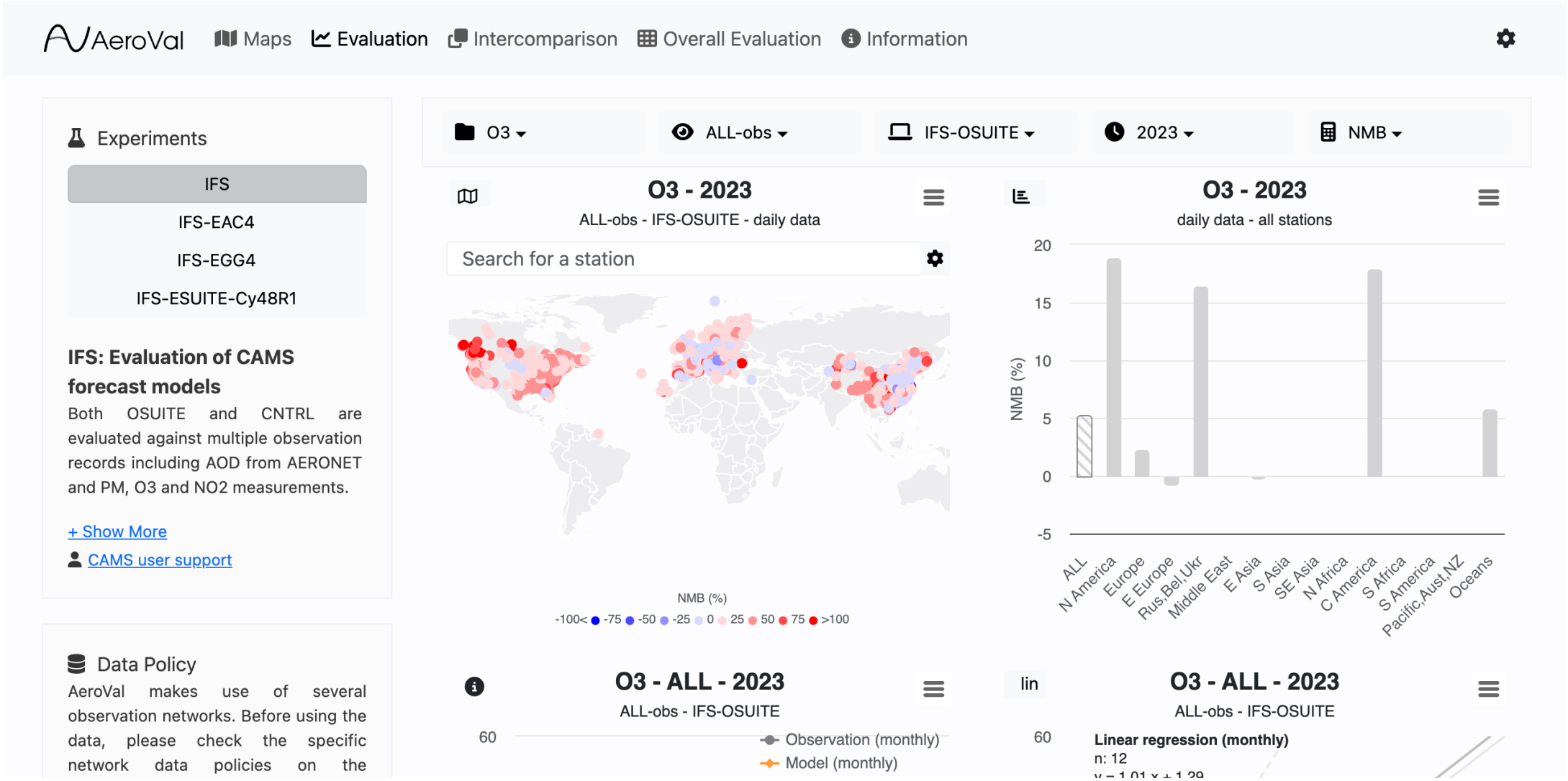
(Benavides et al., 2021)

Understanding the forecast | Representativity

CALIOPE AQ forecasting system
Barcelona, Spain, 9-25 November 2017



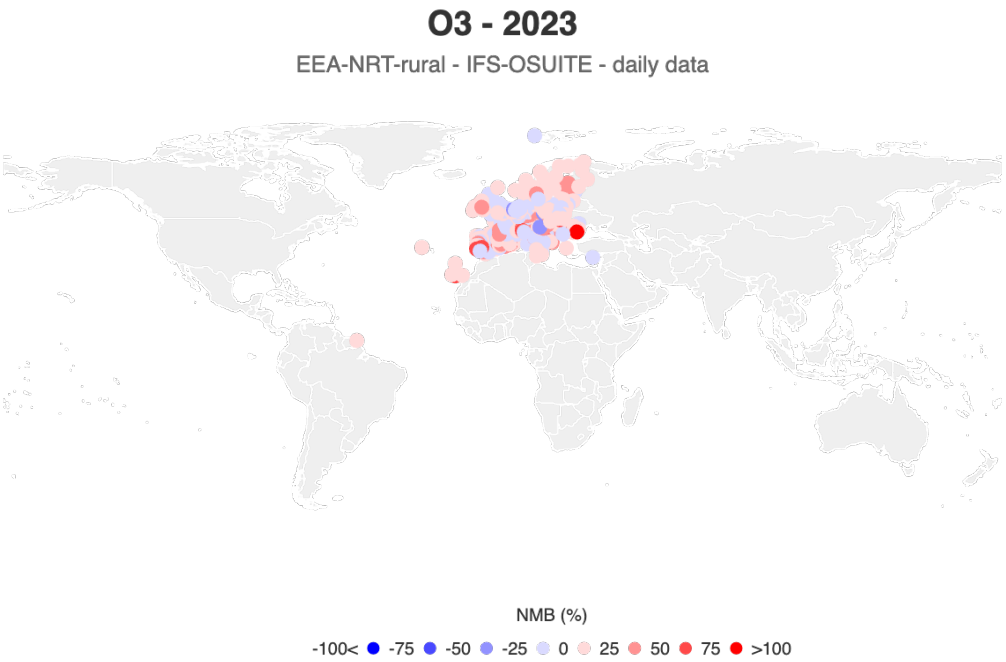
(Benavides et al., 2021)

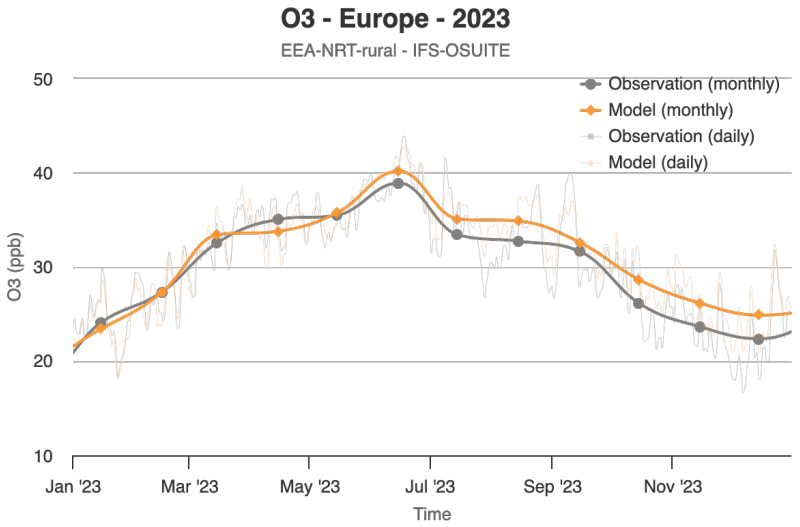


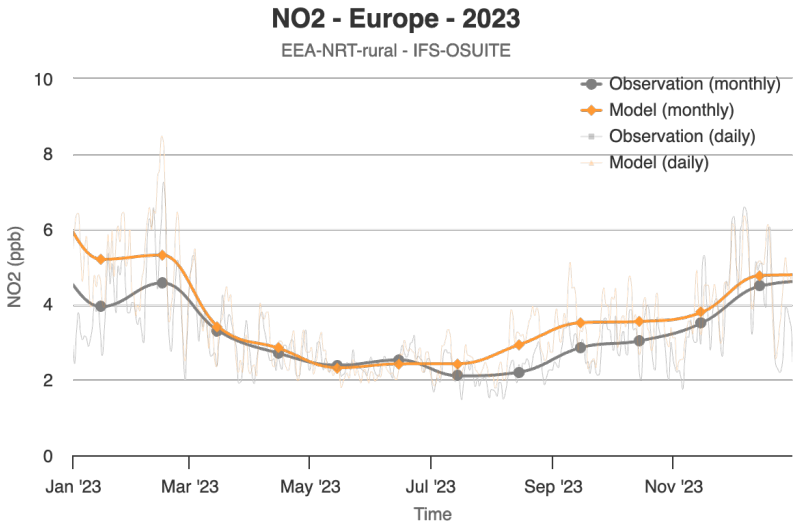
https://global-eqc-server.atmosphere.copernicus.eu/

Atmosphere Monitoring Service
atmosphere.copernicus.eu

Understanding the processes
NO_2 is the precussor of O_3







https://global-eqc-server.atmosphere.copernicus.eu/

Atmosphere Monitoring

Copernicus overview

Copernicus is the European Union's Earth observation programme, looking at our planet and its environment to benefit all European citizens.

It offers information services that draw from satellite Earth Observation and in-situ (non-space) data *as well as modelling products*.

Key Messages

- Understand your model
  - Be sure about the scales that you are considering in your configuration and the processes represented

- Compare oranges with oranges
  - Understand the spatial and temporal representativity of the stations or gridded datasets that you are using you comparisons
  - Comparison of the same parameter

WORLD METEOROLOGICAL ORGANIZATION

ITINERIS

THANKS!

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani