WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Modelling Sand and Dust Storms

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WMO OMM
World Meteorological Organization
Organisation météorologique mondiale

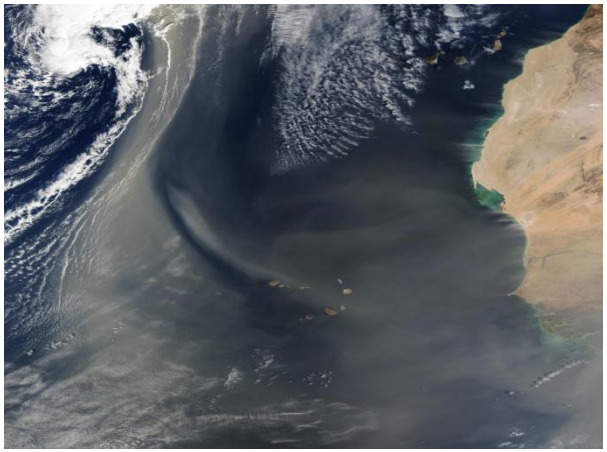
Dust cycle and associated processes

FAO Sand and dust storms (SDS): A transboundary issue of growing concern, watch the video
https://www.youtube.com/watch?v=RS_oJcqN1vo

Dust cycle and associated processes

Dust **transport** is a global phenomenon. However, **dust emission** is a threshold phenomenon, sporadic and spatially heterogeneous, that is locally controlled on small spatial and temporal scales.

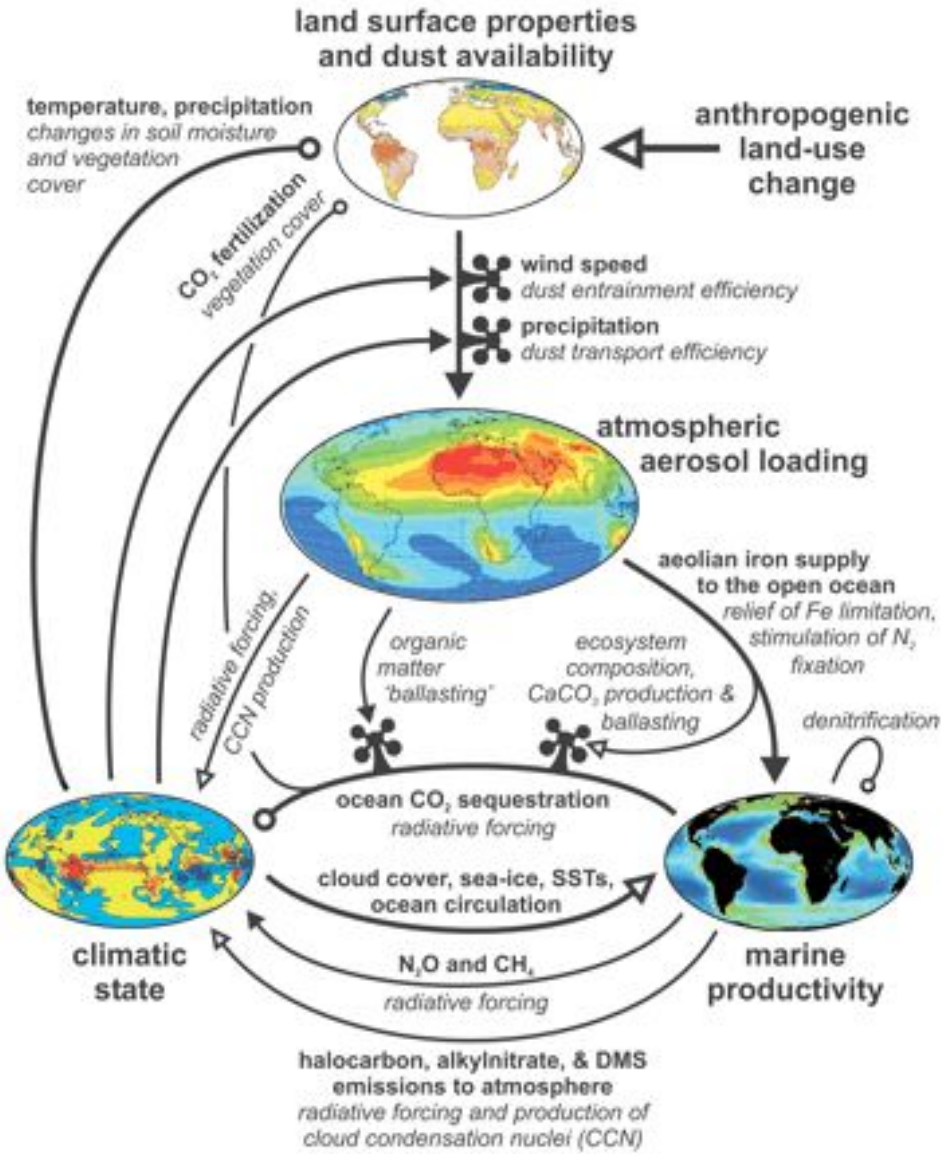
MODIS true colour composite image for March 2005 depicting a dust storm initiated at the Bodélé Depression (Chad Basin)



MODIS True color Western Africa – Altantic Ocean

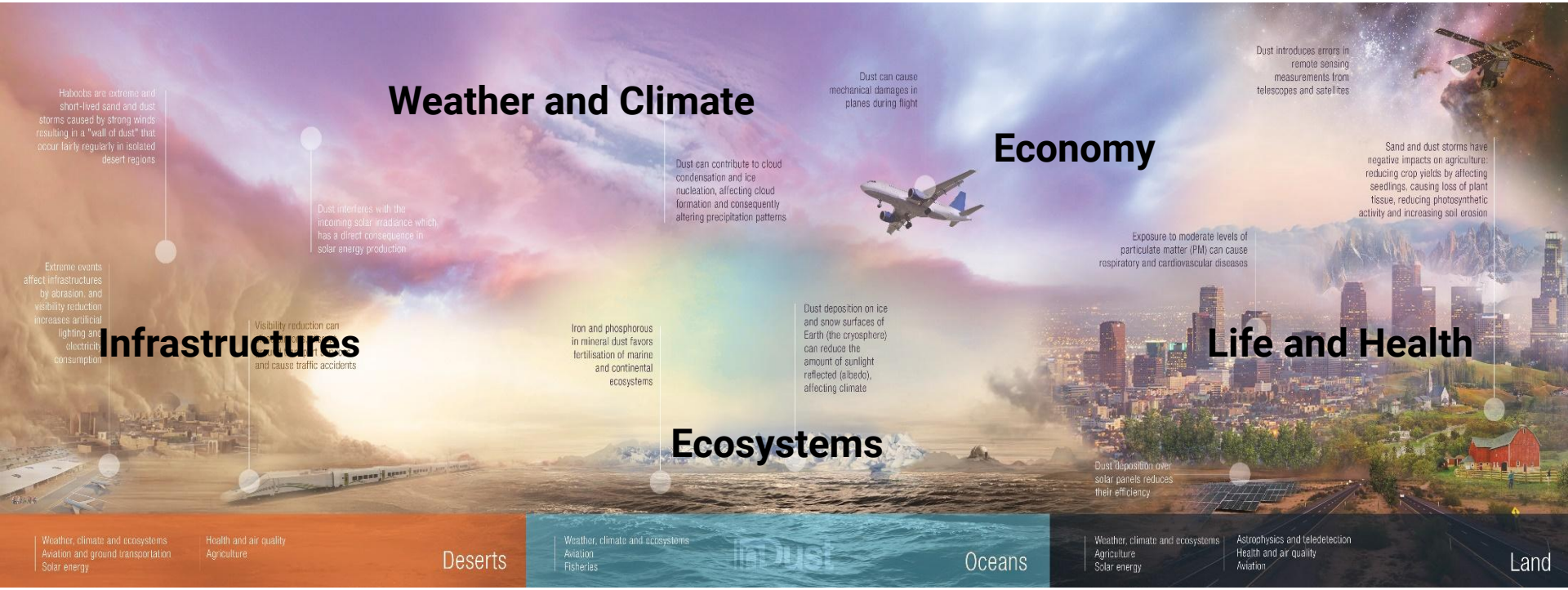
Dust emission, transport and deposition are sensitive to **surface wind speed** and precipitation, among other factors.

Sand and Dust Storms Impacts



(Jickells et al., 2005)

Sand and Dust Storms Impacts



inDust Leaflet available in www.cost-indust.eu/media-room

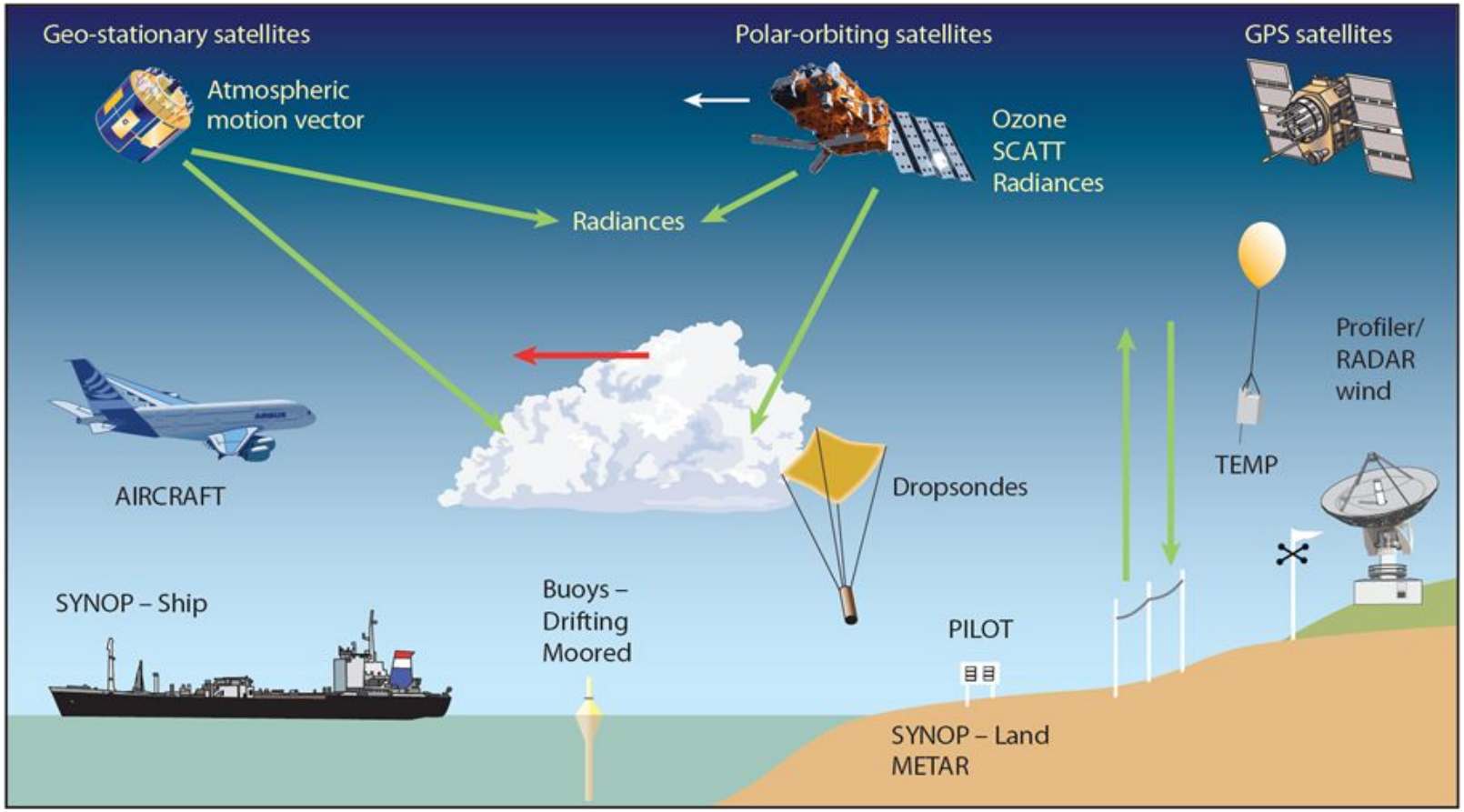
Sand and dust storms research

- Late **80's**:
  - First demonstration that SDS dynamic simulations are possible
- **90's**:
  - First satellite products capable to detect SDS
  - First successful daily SDS forecast test
  - First long-term daily SDS forecasts
- **2000's**:
  - Fast growth in dust observations and forecasting models
- **2010's**:
  - Fast growth in user-oriented applications

WE ARE **NOW** READY TO PROVIDE ADDED-VALUE DUST **INFORMATION** !

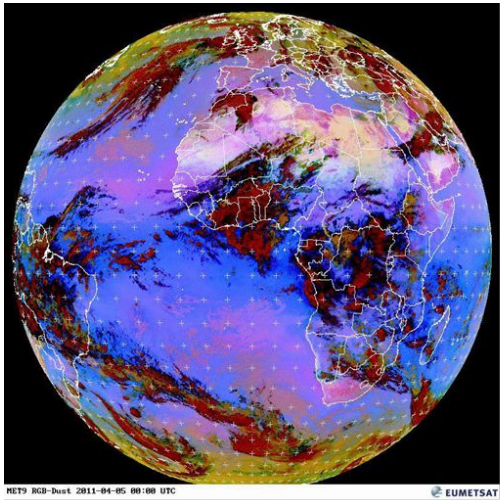
WMO OMM

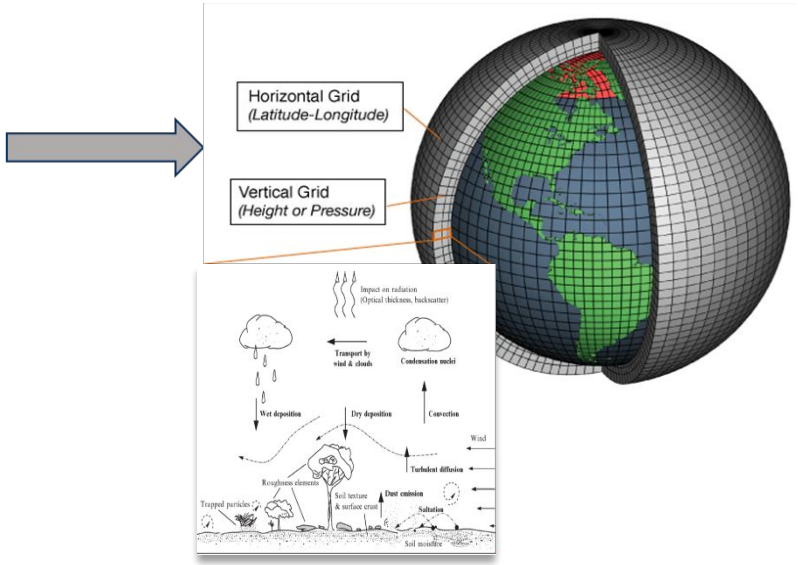
Observations



Desert dust models

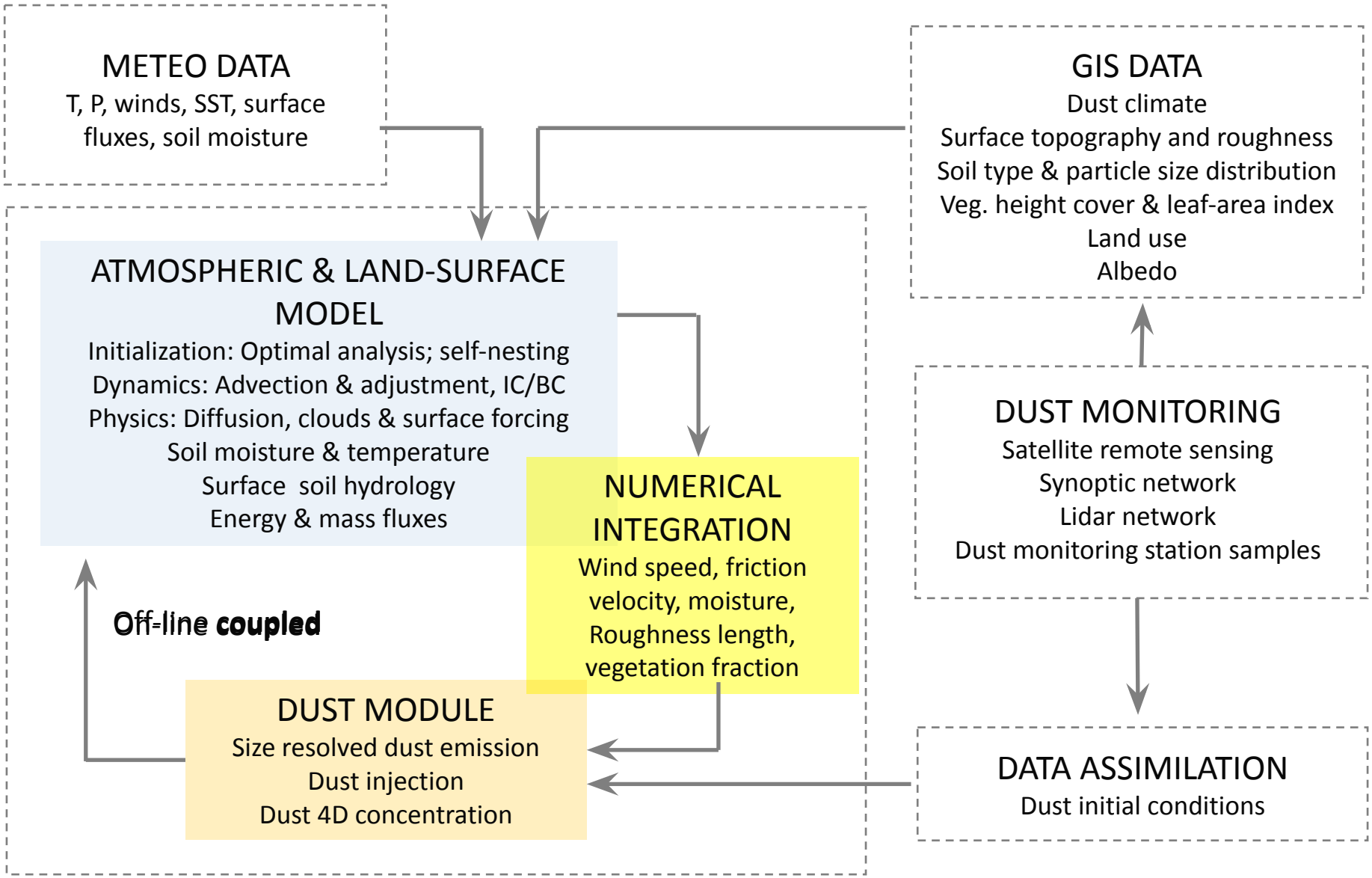
Desert dust models are a **mathematical representation** of atmospheric dust cycle.





- ✔ *To complement dust-related observations, filling the temporal and spatial gaps of the measurements.*
- ✔ *To help us to understand the dust processes and their interaction with climate and ecosystems.*
- ✔ *To predict the impact of dust used as **short-term forecasting tools** (3-5 days ahead) or **climate projections**.*

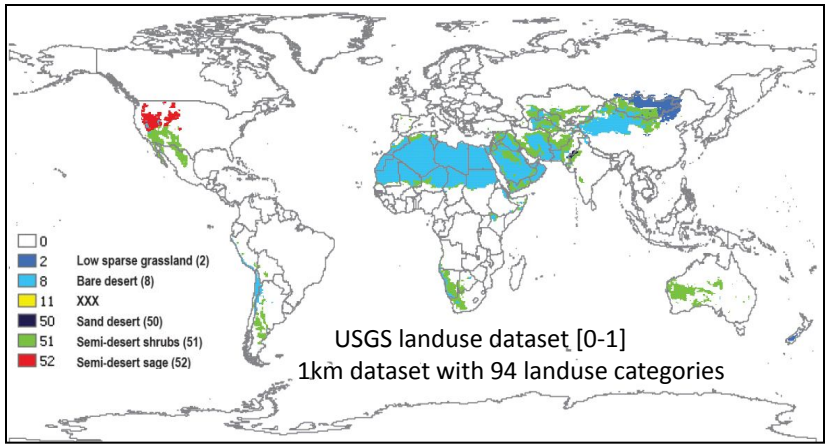
Desert dust models

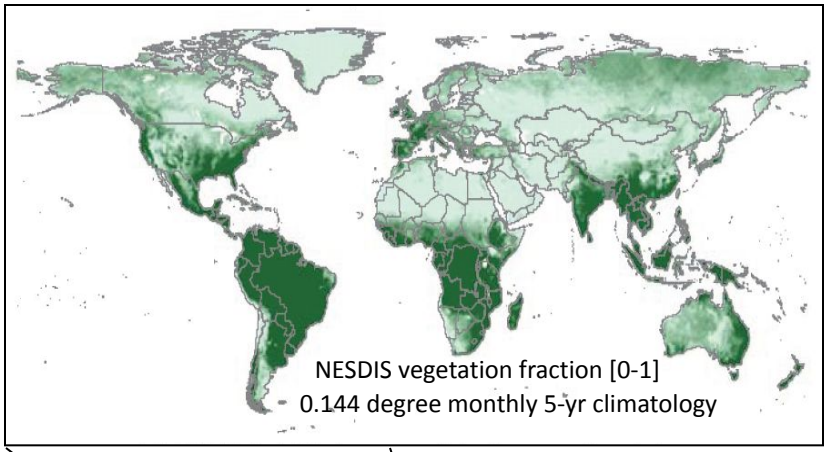


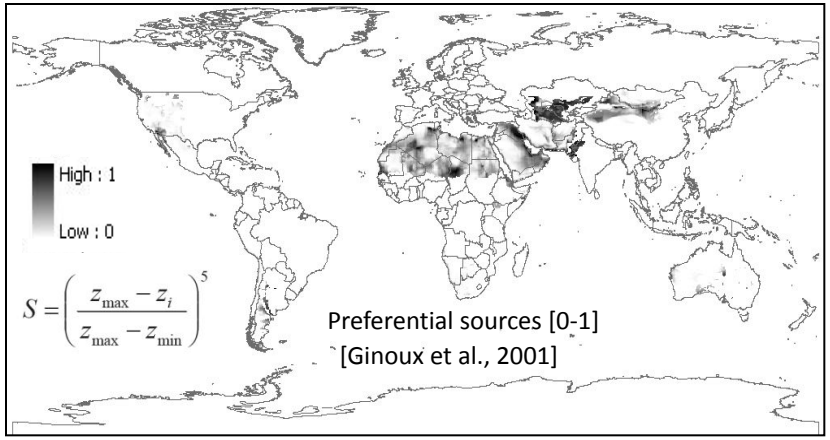
Desert dust model

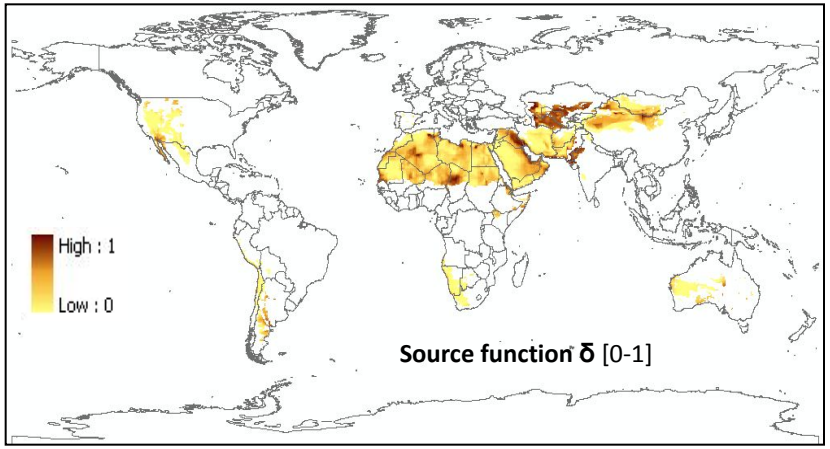
Desert dust source map

Example dust source function: MONARCH



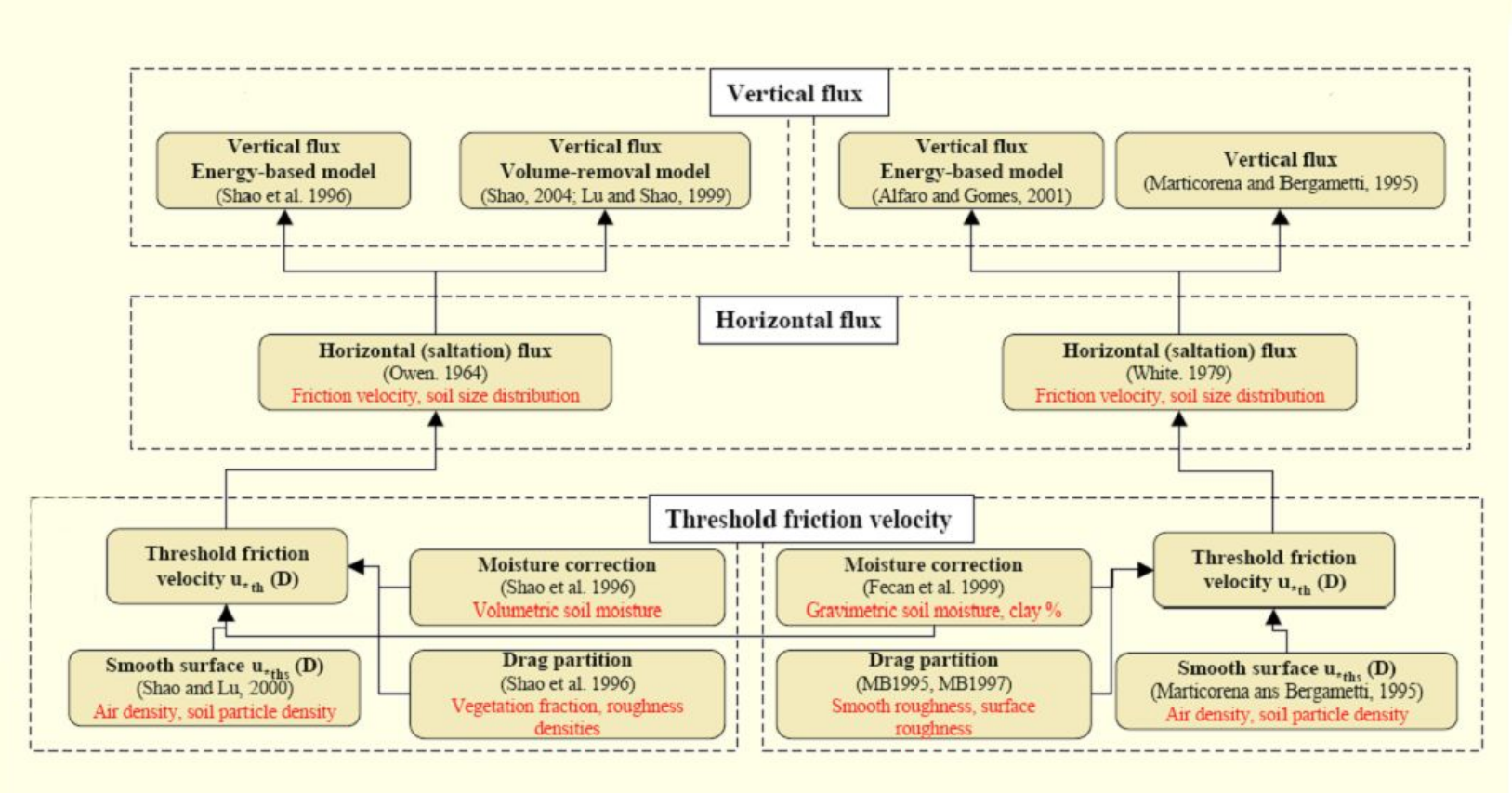






$$\delta = USGS \cdot PREF \cdot (1 - VEGFRAC) \cdot (1 - SnowCover)$$

Desert dust model
Dust emission schemes



Adapted from Darmenova et al, 2009

Dust emission schemes employ different parameterizations of the related physical processes, and require different input data.

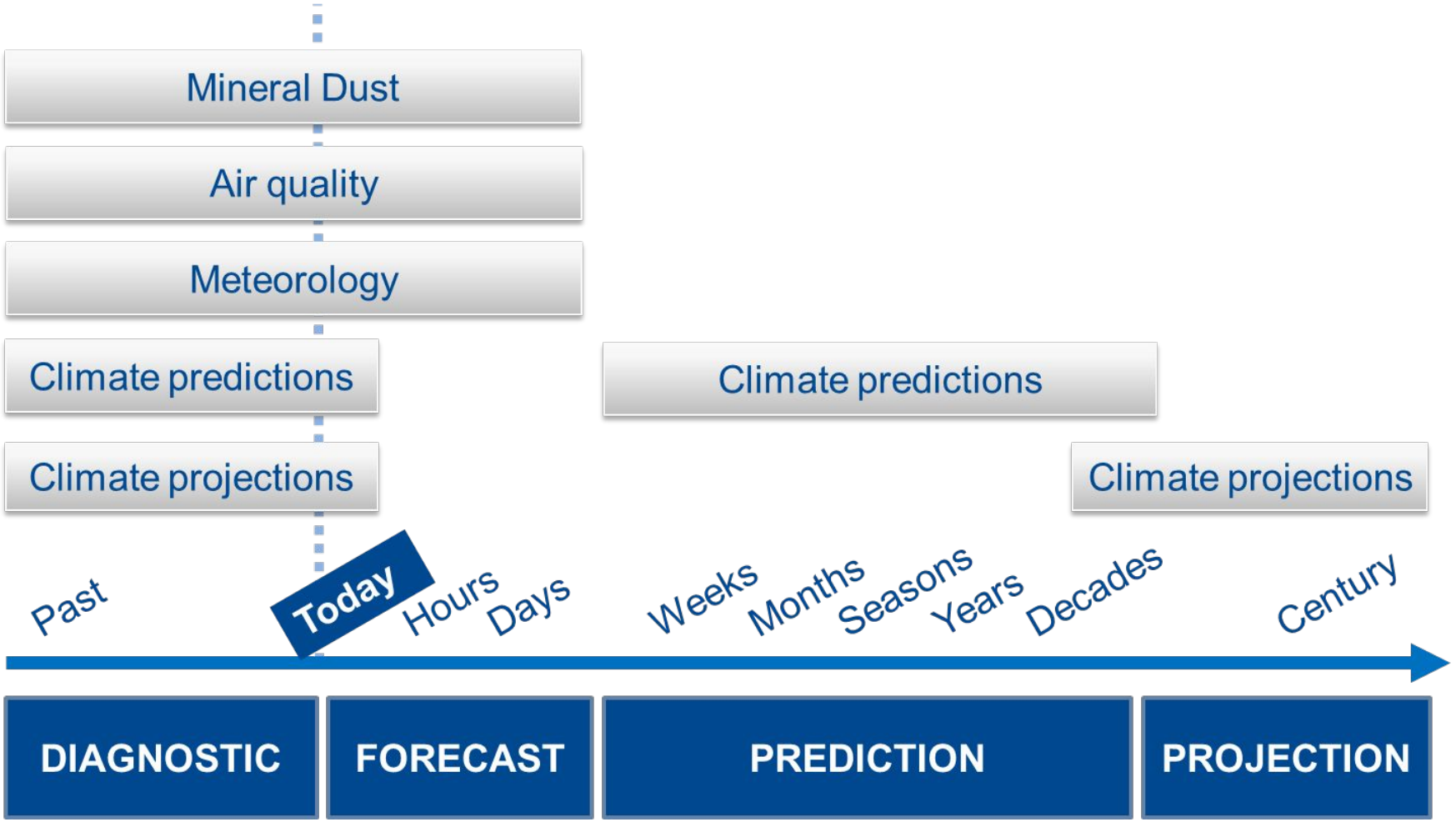
Desert dust models

Desert dust do **not** take account dust **resuspension** and other mineral dust emissions connected with human activities

Kathmandu, Nepal, March 2017

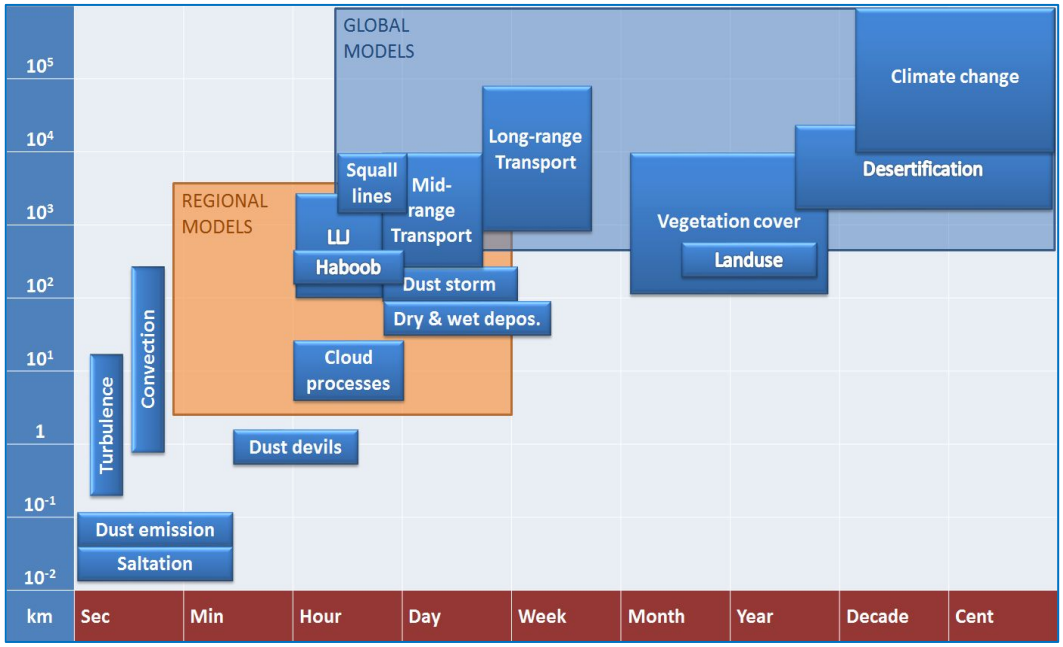
Desert dust models

Modelling scales



Courtesy Albert Soret, BSC

Desert dust models

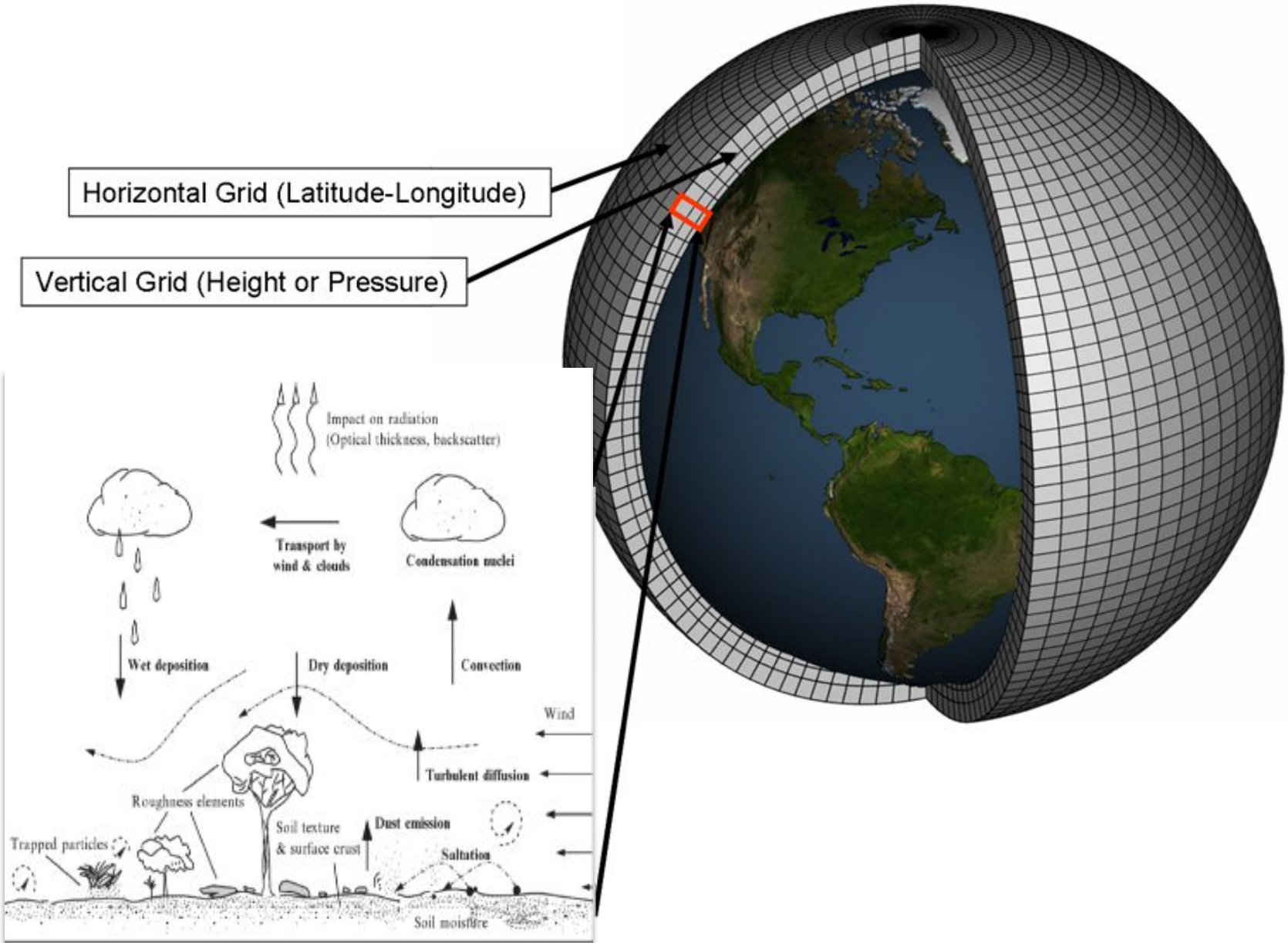


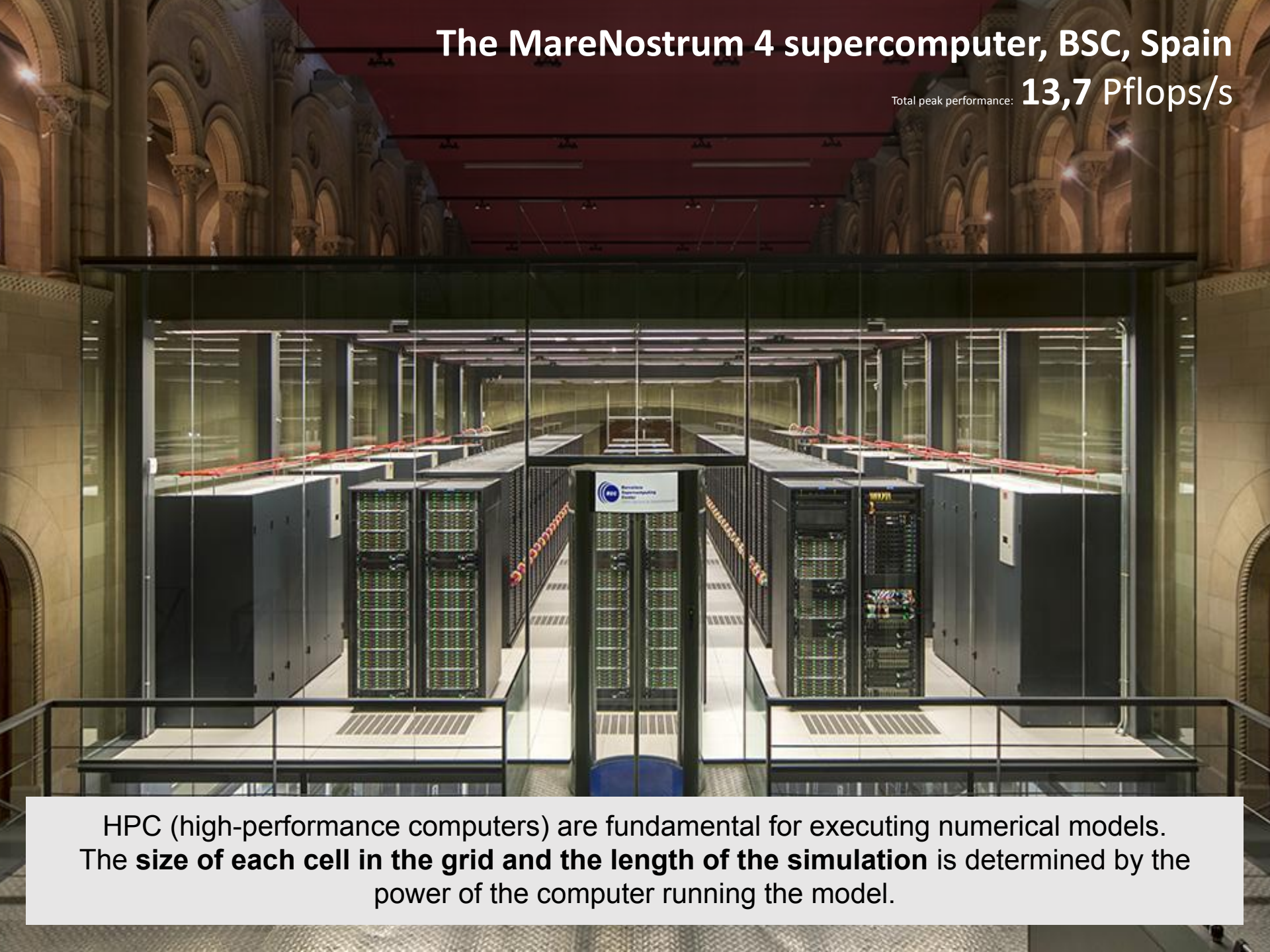
- Dust processes span over five orders of magnitude in space and time. **Dust transport** is a global phenomenon. However, **dust emission** is a threshold phenomenon, sporadic and spatially heterogeneous, that is locally controlled on small spatial and temporal scales.
- To correctly describe and quantify the dust cycle, one needs to understand equally well local-scale processes such as saltation and entrainment of individual dust particles as well as large-scale phenomena such as mid- and long-range transport.

Accurate representation of dust sources and sinks is critical for providing realistic magnitudes and patterns of atmospheric dust fields.

Adapted from Shao (2011)

Desert dust models

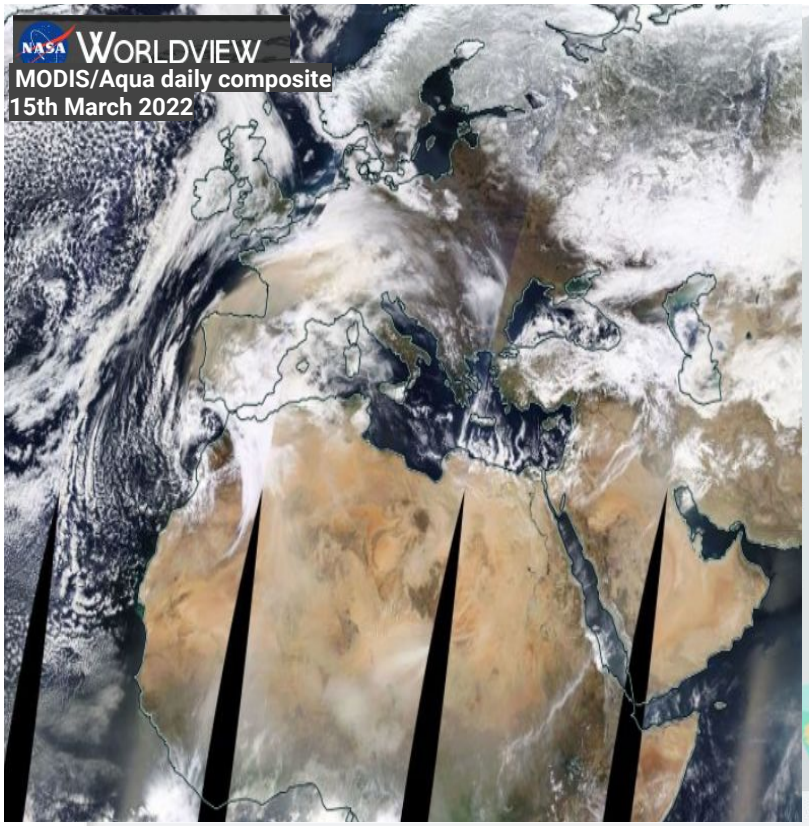


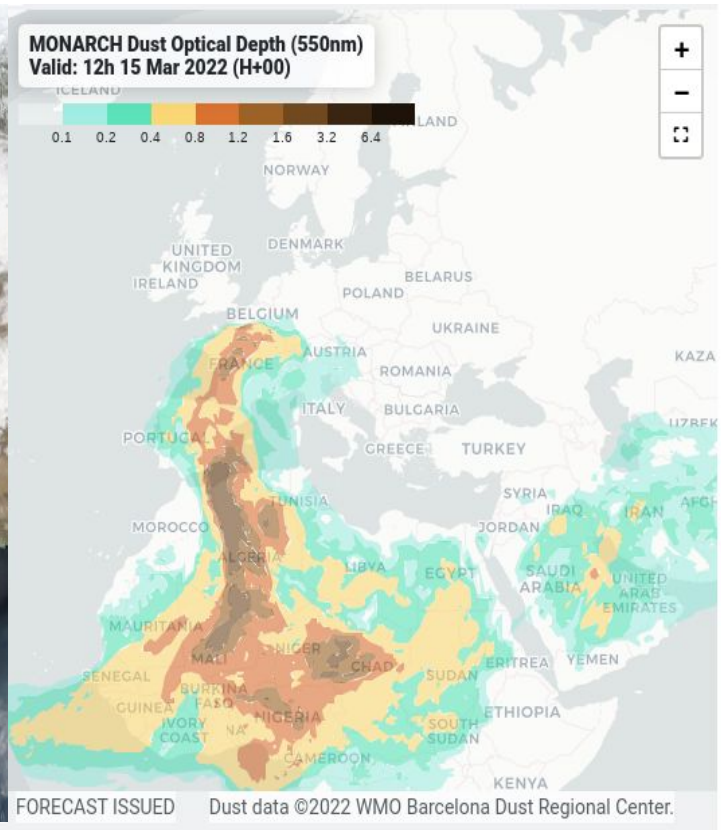


HPC (high-performance computers) are fundamental for executing numerical models. The **size of each cell in the grid and the length of the simulation** is determined by the power of the computer running the model.

Modelling and Observations

Model Evaluation and Data Assimilation





Assessing the model uncertainty and identifying missing processes thanks to model **evaluation**

Improved dust and aerosol forecasting products through the **assimilation** of satellite retrievals

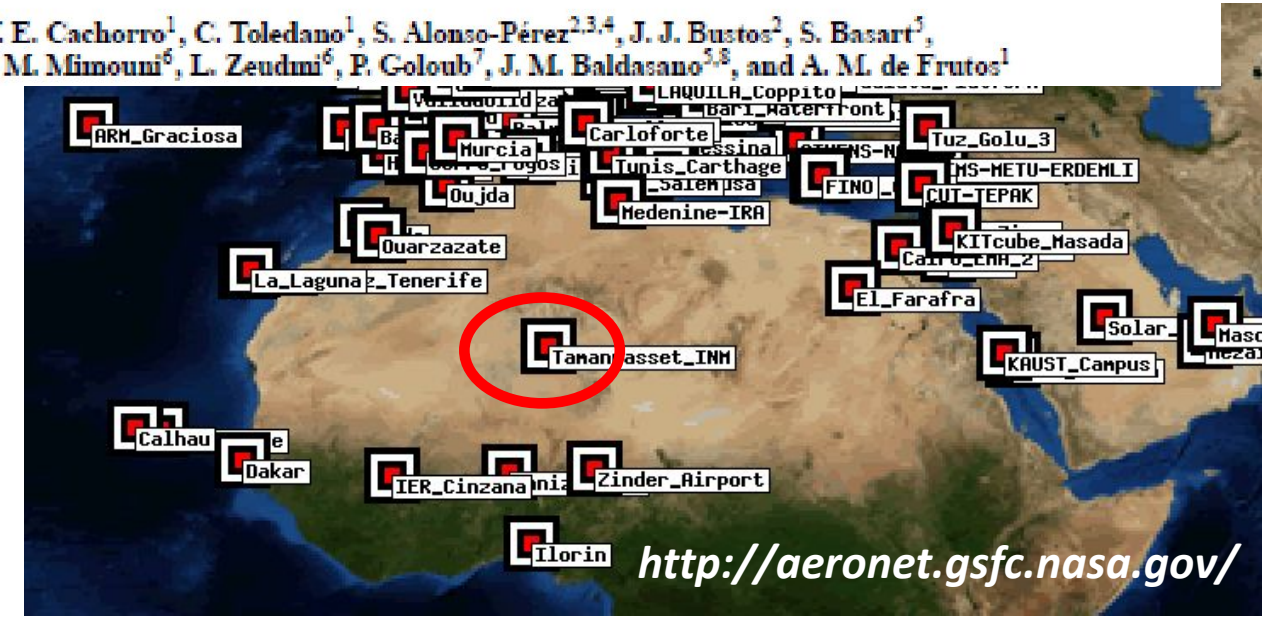
Desert dust models

Atmos. Chem. Phys., 14, 11753–11773, 2014
www.atmos-chem-phys.net/14/11753/2014/
doi:10.5194/acp-14-11753-2014

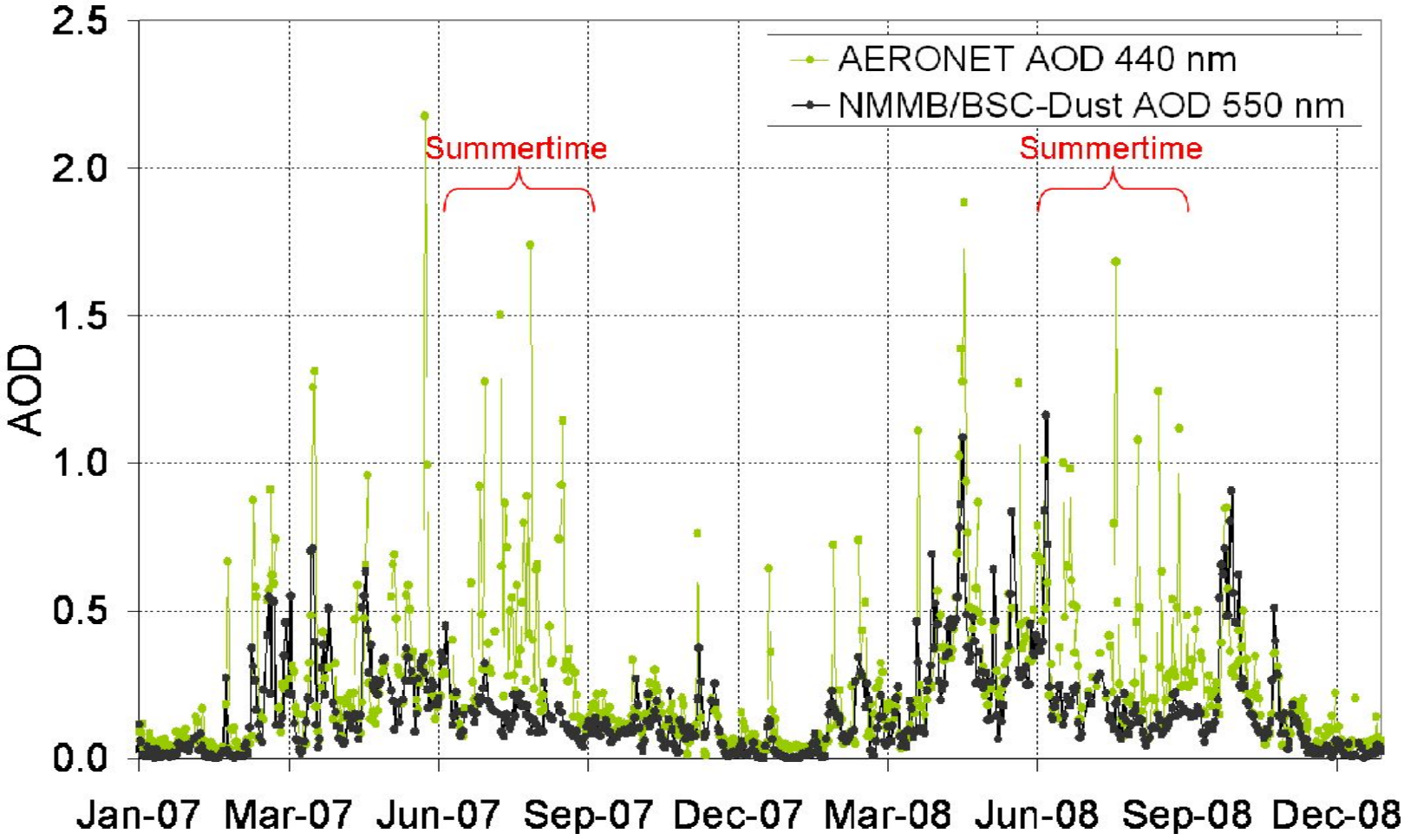
Atmospheric Chemistry and Physics
Open Access

Aerosol characterization at the Saharan AERONET site Tamanrasset

C. Guirado[1,2], E. Cuevas[2], V. E. Cachorro[1], C. Toledano[1], S. Alonso-Pérez[2,3,4], J. J. Bustos[2], S. Basart[3], P. M. Romero[3], C. Camino[2], M. Mimouni[6], L. Zeudmi[6], P. Goloub[7], J. M. Baldasano[5,8], and A. M. de Frutos[1]



Desert dust models

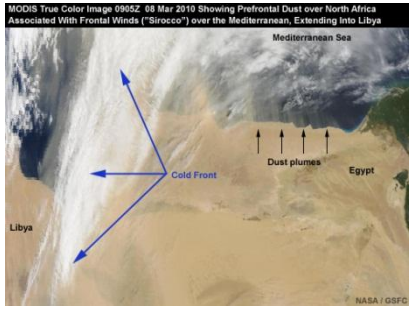


Extracted from Guirado et al. (2014, ACP)

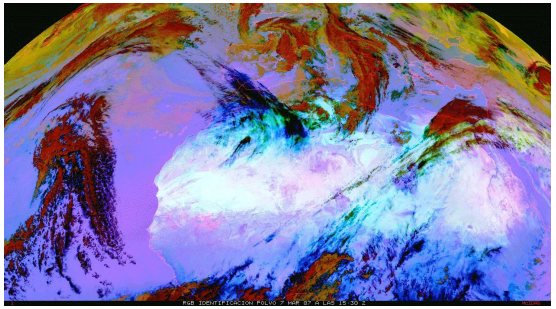
Dust cycle and associated processes

Sand and Dust Storms typologies

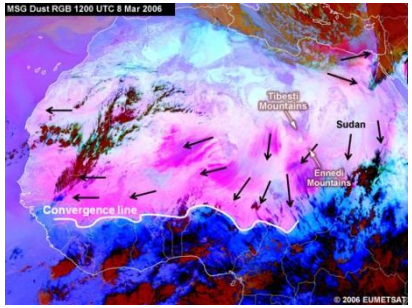
Synoptic dust storms (large scale weather systems)



Pre-frontal winds

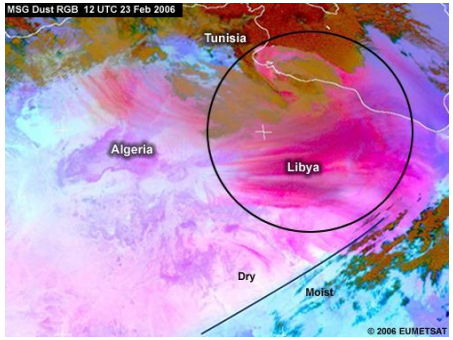


Post-frontal winds

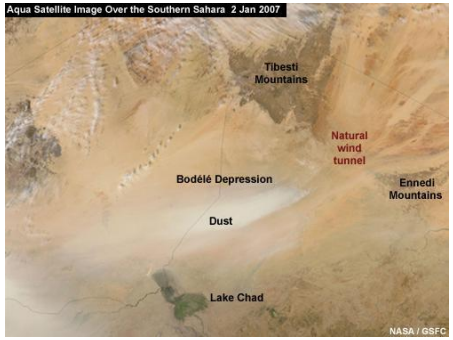


Large-scale trade winds

Mesoscale dust storms



Downslope winds

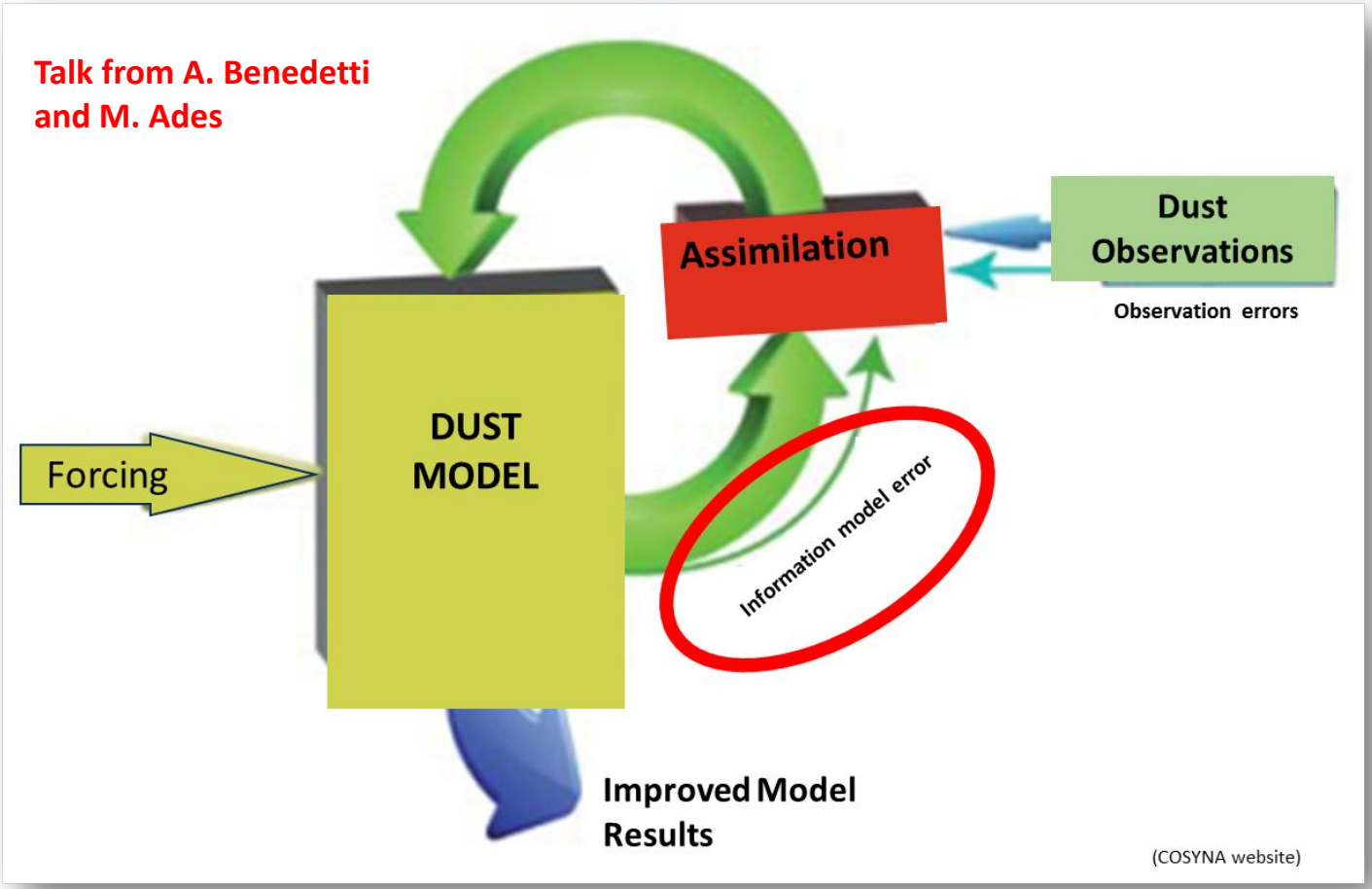


Gap flow

Dust devils

Haboobs

Data assimilation



- Obtaining the "best" estimate of current atmospheric dust conditions (**analysis**)
- Creation of data sets describing the recent history of dust in the atmosphere (**reanalysis**)

Desert dust models

Main differences between dust models

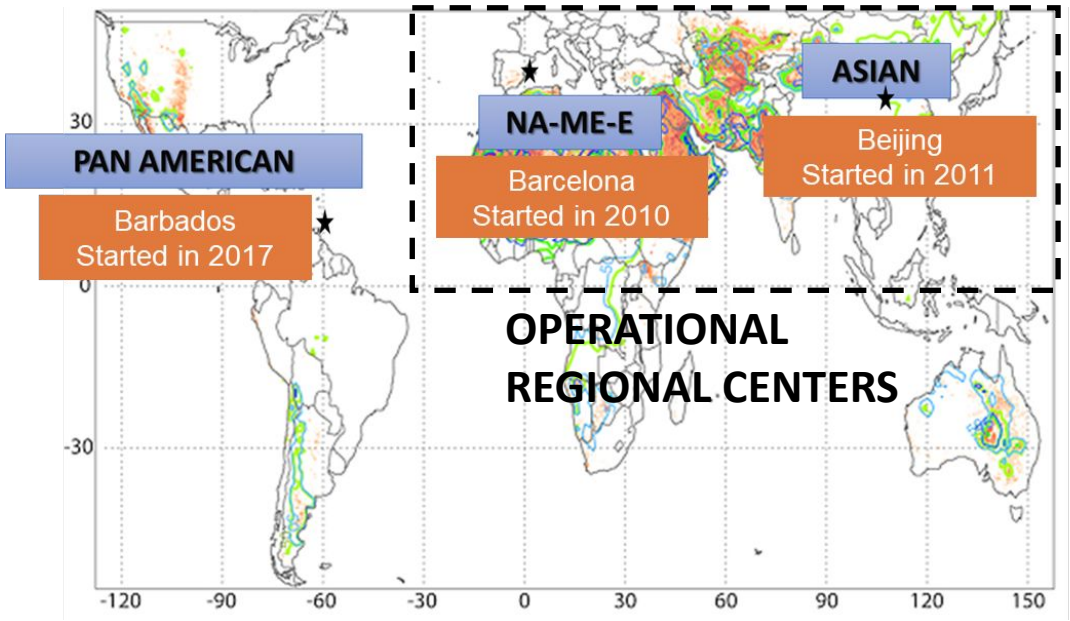
1. *Meteorological driver*
2. *Meteorological input files IBC*
3. *Emission scheme*
4. *Geographic-information database (source mask)*
5. *Land-surface scheme*
6. *Dry deposition scheme*
7. *Wet depositioon scheme*
8. *Spatio-temporal resolution*
9. *Data assimilation*
10. *….*

WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)

Objectives:

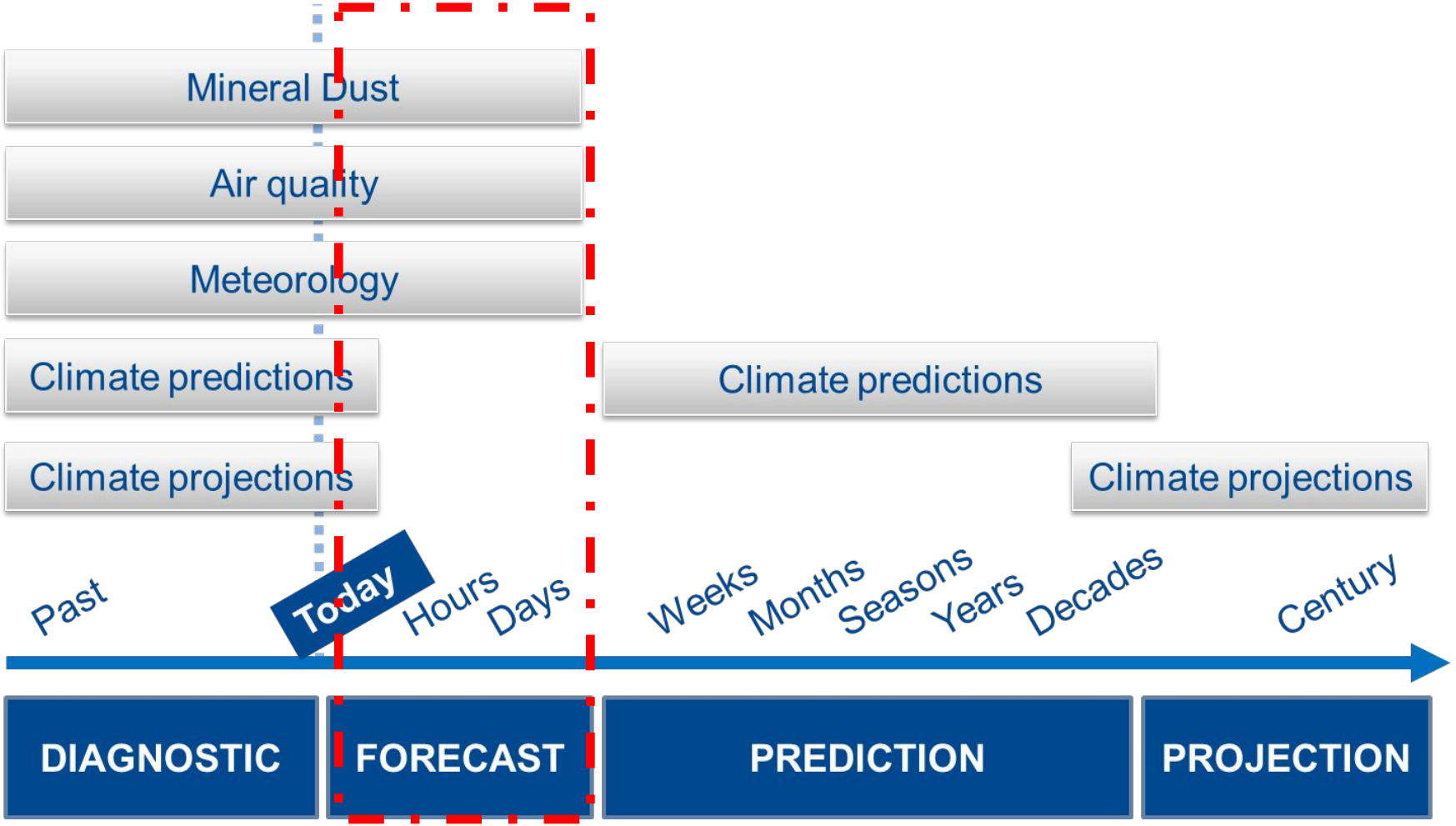
- Identify and improve **products to monitor and predict** dust by working with research and operational organizations, as well as with users.
- Facilitate **user access** to information.
- **Strengthen the capacity** of countries to use the observations, analysis and predictions provided by the WMO SDS-WAS.

Regional Nodes and Centers



Recently approved a GCC Node and under discussion WAsia Node

Modelling scales



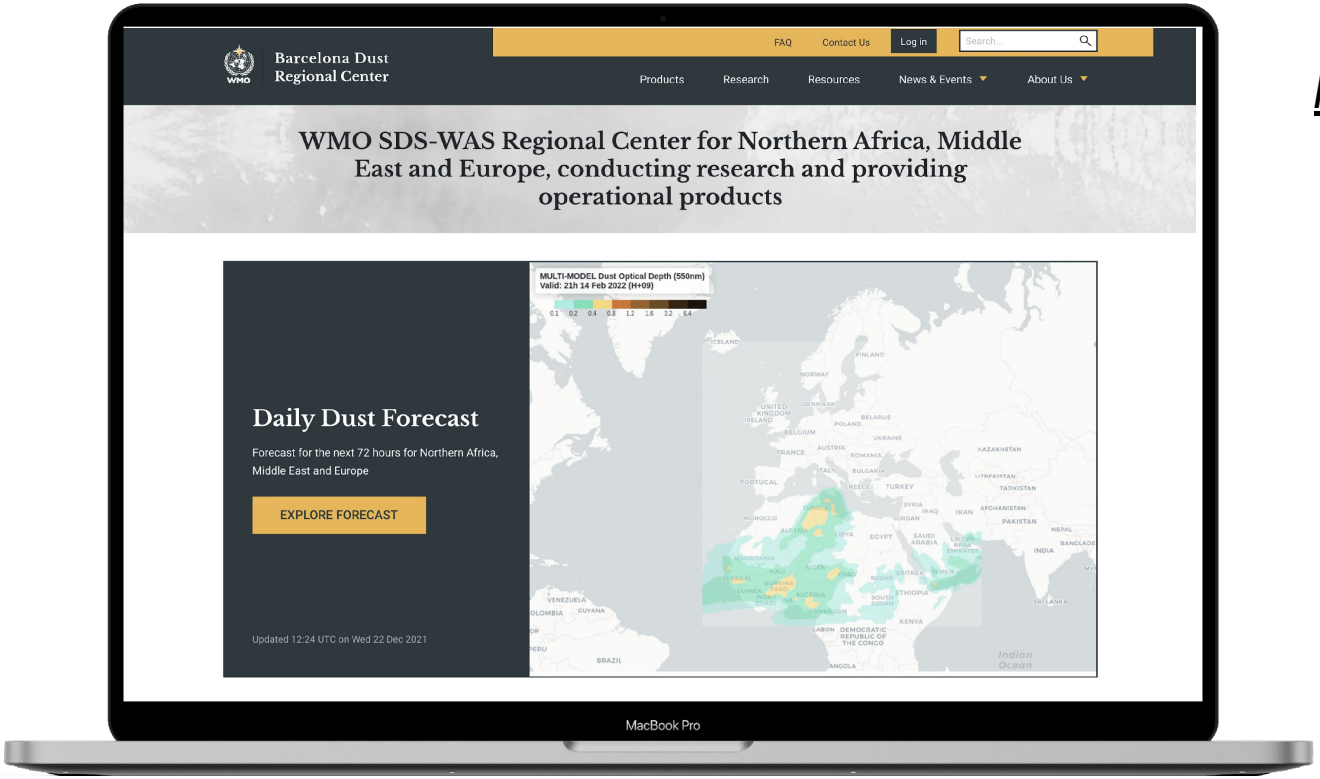
Short-term forecast

Courtesy Albert Soret, BSC

WMO Barcelona Dust Regional Center

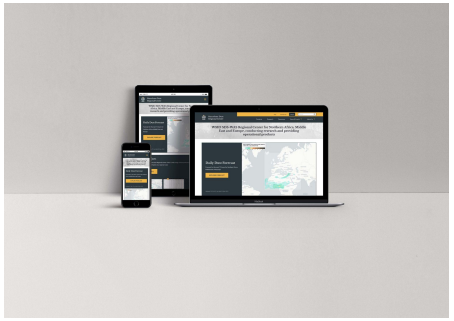
is coordinating the activities Northern Africa, the Middle East and Europe

New website launched in January 2022



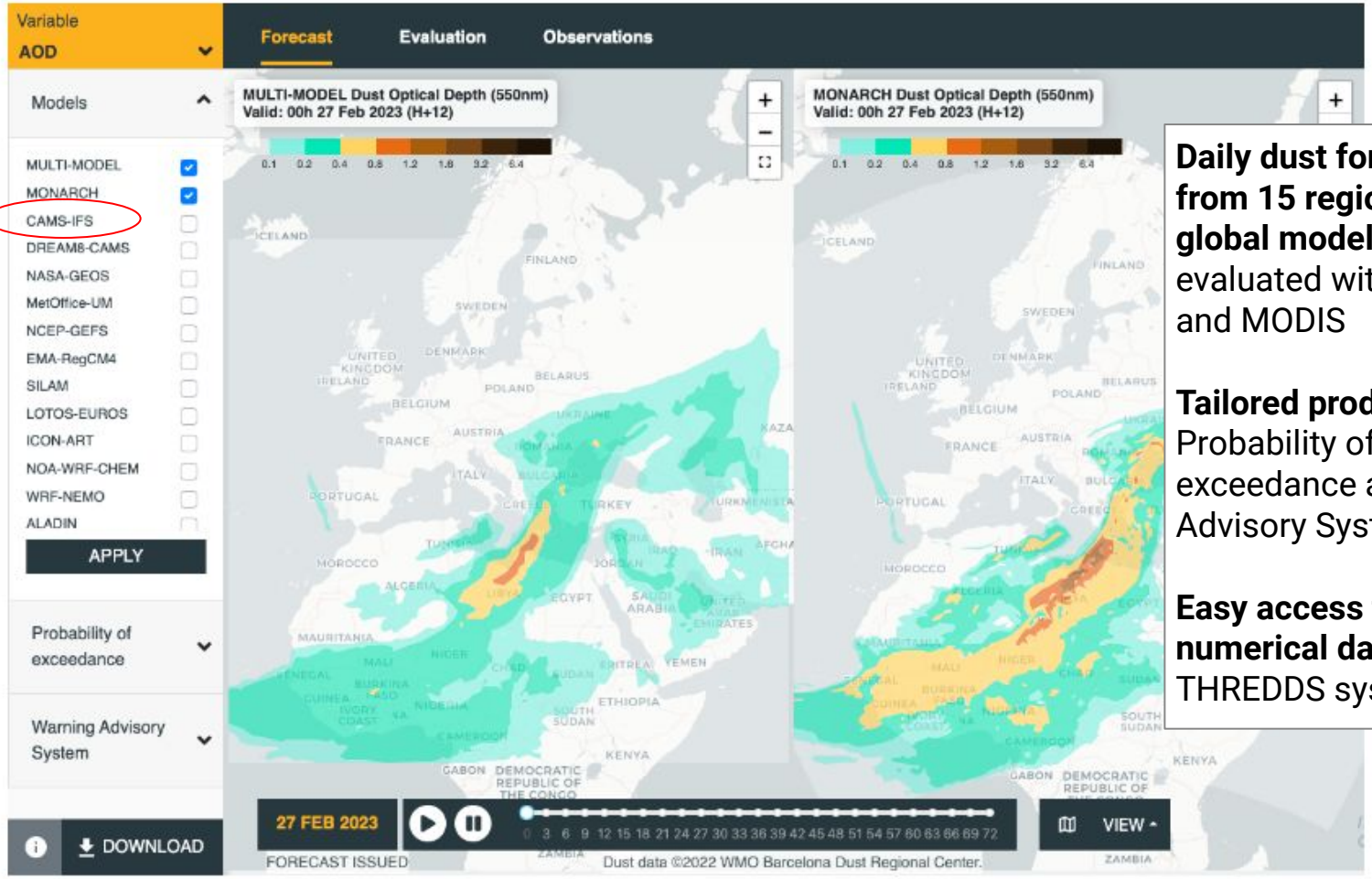
https://dust.aemet.es/
@Dust_Barcelona

Adapted for different devices



NOTE: *https://sds-was.aemet.es/ will decommissioned in next weeks*

Daily Dust Products



Daily dust forecasts from 15 regional and global models that are evaluated with AERONET and MODIS

Tailored products: Probability of exceedance and Warning Advisory System

Easy access to numerical data through a THREDDS system

https://dust.aemet.es/products/daily-dust-products

Talk from E. Werner

CAMS daily forecasts

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*.

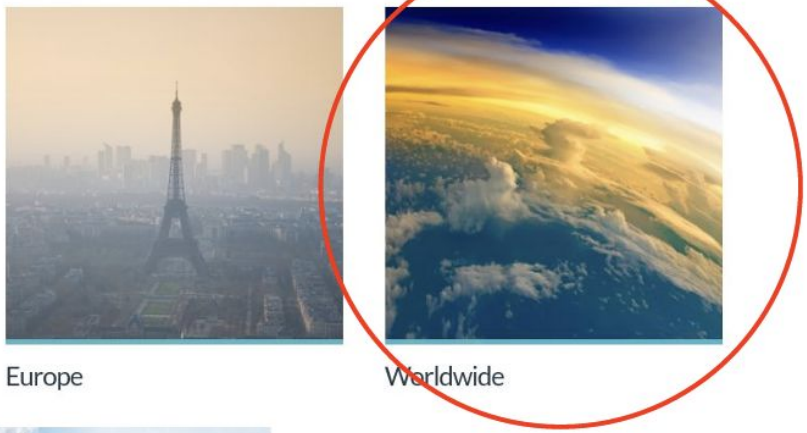
opernicus Europe's eyes on Earth | European Commission

CAMS daily forecasts

Atmosphere Monitoring

CAMS Products

Today's air quality forecasts



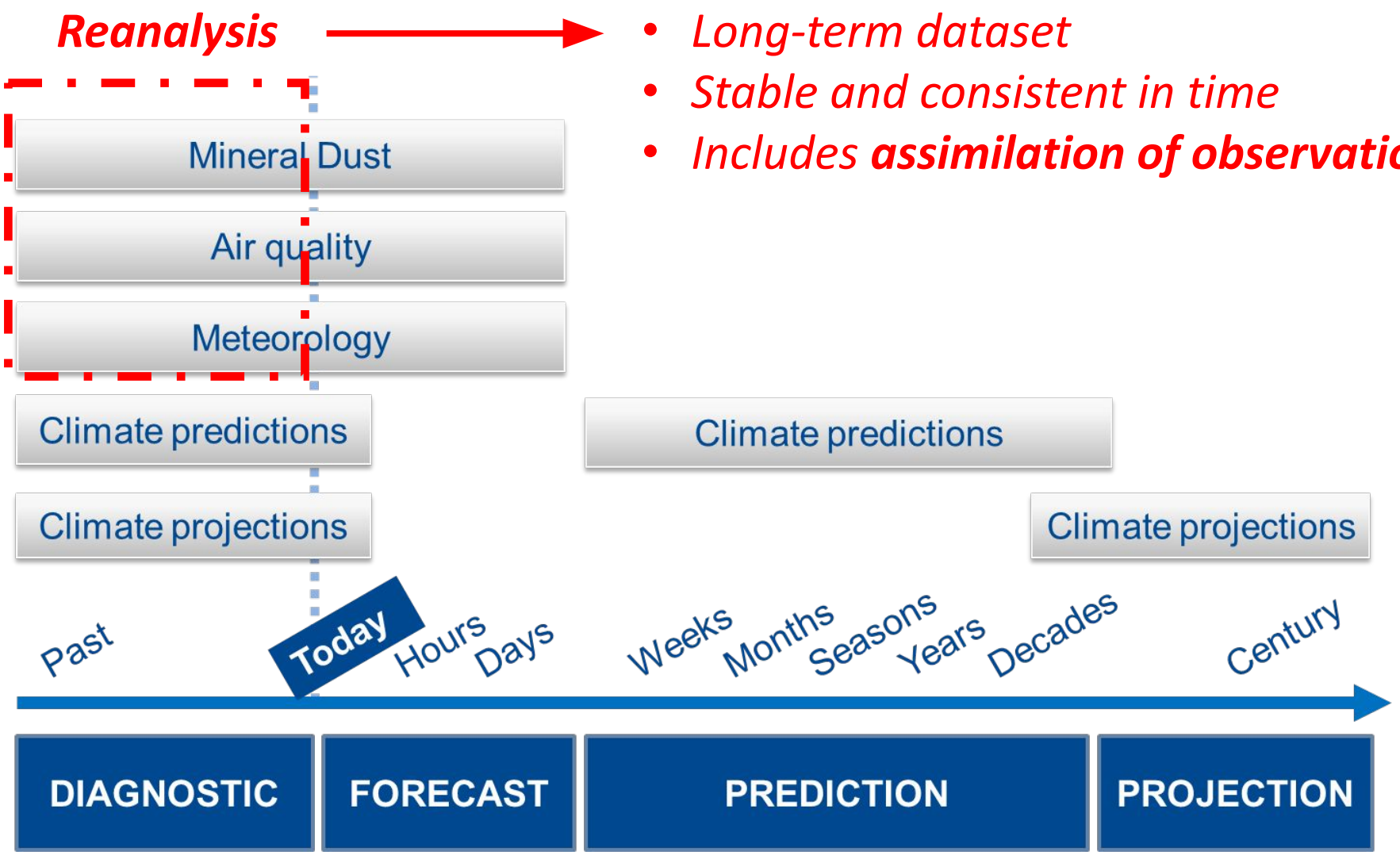
Talk from M. Ades

Catalogue of products:
https://atmosphere.copernicus.eu/catalogue#/

- The **global products** are provided by the ECMWF Integrated Forecast System (C-IFS).
- The services consist of
  - **Daily real-time analyses and forecasts**
    - Every day, CAMS provides five-day forecasts
  - **Reanalysis**, currently for the period 2003 - 2020.
    - It is updated every year.
- CAMS provides aerosols, atmospheric pollutants, greenhouse gases (CO2 and methane), stratospheric ozone and the UV-Index.
  - The global products cover both the troposphere and stratosphere
- CAMS global products are used
  - AQ daily forecasts (see Windy or Breezometer apps)
  - Initial and boundary conditions for operational regional AQ systems around the world
  - Impact assessment studies

Copernicus Europe's eyes on Earth
European Commission

Modelling scales

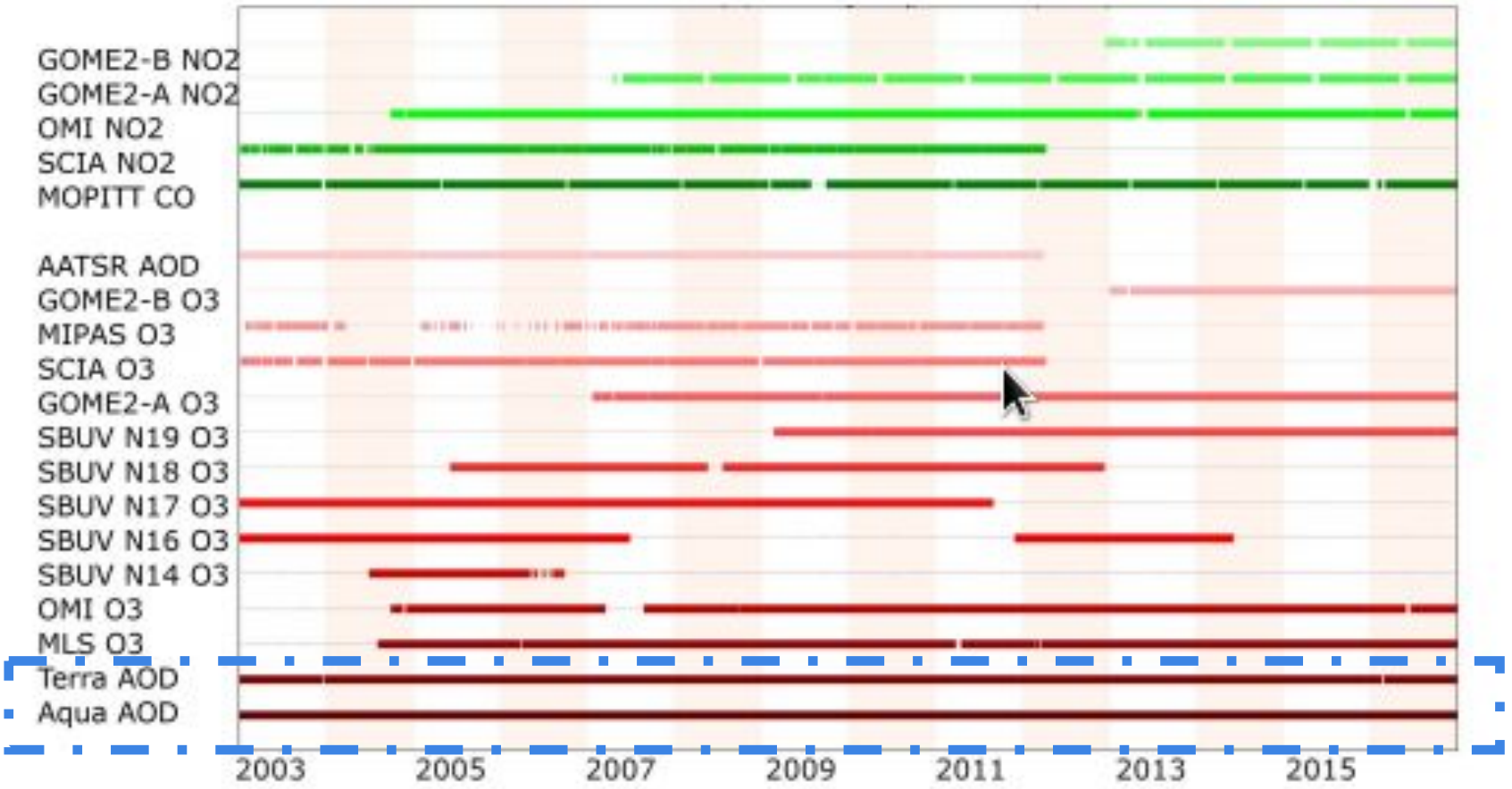


- *Long-term dataset*
- *Stable and consistent in time*
- *Includes **assimilation of observations***

Courtesy Albert Soret, BSC,

Global aerosol reanalysis: CAMS

Talk from M. Ades



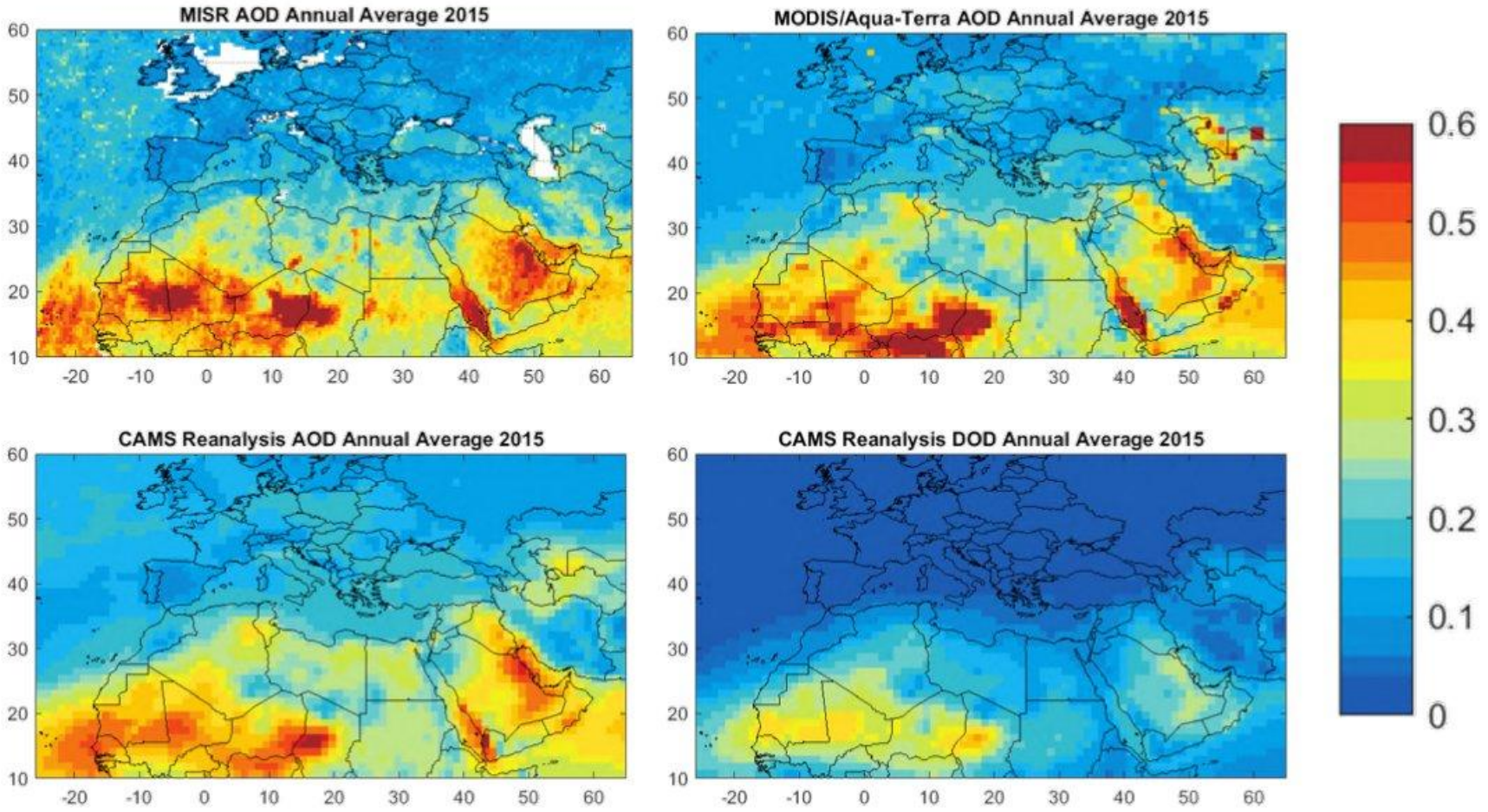
AEROSOLS

Atmosphere Monitoring Service
atmosphere.copernicus.eu

(Inness et al., 2019, ACP)

Global aerosol reanalysis: CAMS

Talk from M. Ades



Atmosphere Monitoring Service

atmosphere.copernicus.eu

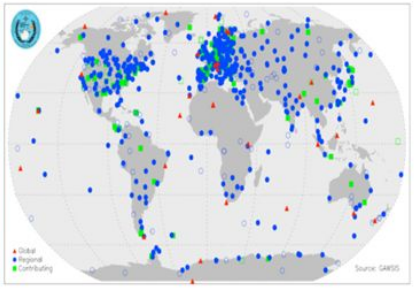
Courtesy CAMS2-82 Validation team

DustClim

ERA4CS European Research Area for Climate Services

Dust Storms Assessment for the development of user-oriented **Clim**ate Services in Northern Africa, Middle East and Europe

- SDS is a serious hazard for life, health, environment and economy
- Lack of dust observations (past trends and current conditions)



GOAL: Develop **dust-related services** to specific socio-economic sectors based on an advanced **dust reanalysis** for the NAMEE region

OBSERVATIONS: Our simulations, predictions and services are enhanced by/verified with an intensive use of in-situ and satellite filtered-dust observations

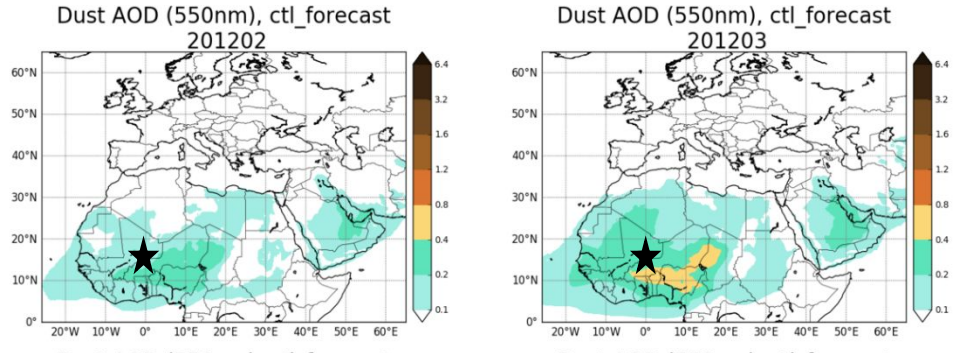
REANALISYS: Climatology (2007-2016) of sand and dust storms (SDS) in high spatial-temporal detail (10km, 3-hourly)

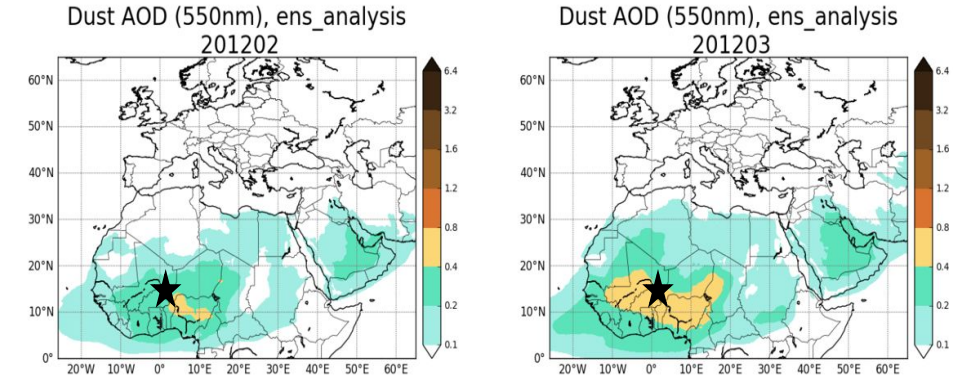
Dust-related Climate Services

BSC AEMet Agencia Estatal de Meteorología cnrs

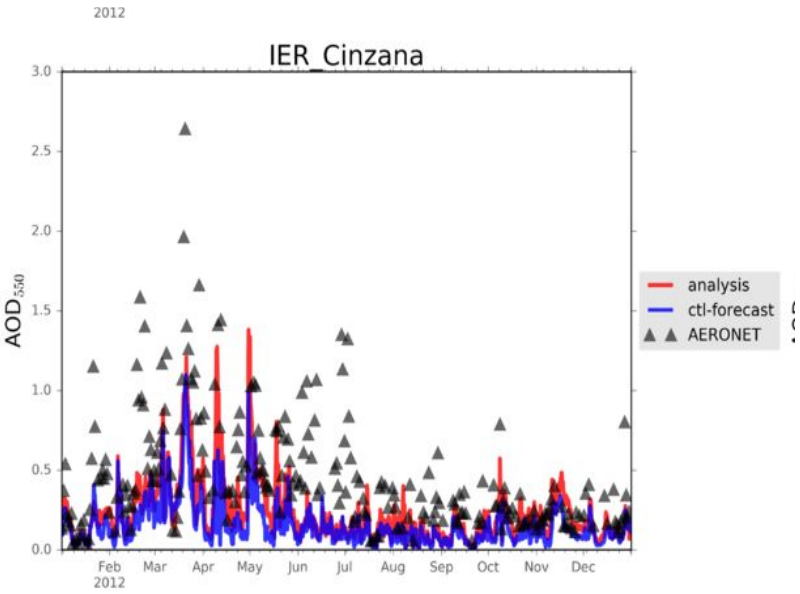
DustClim

ERA4CS European Research Area for Climate Services





Assimilating MODIS DOD Land product (Courtesy P. Ginoux, NOAA)

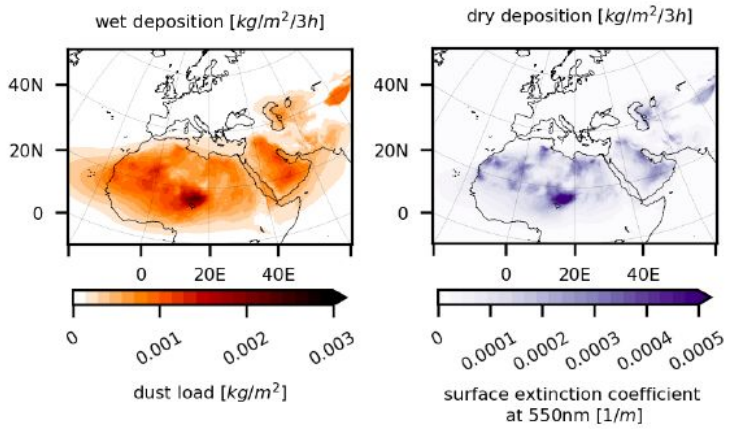


(Di Tomaso et al., 2022, ESSD)

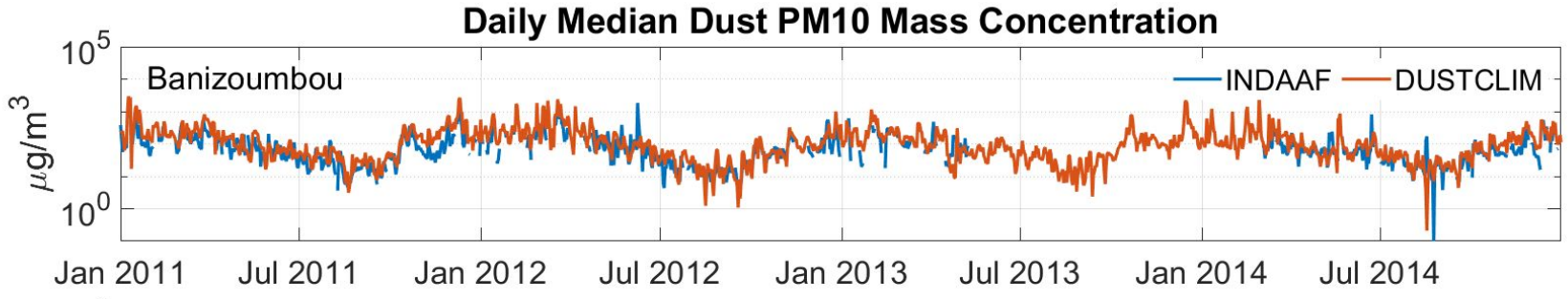
DustClim

ERA4CS European Research Area for Climate Services

Climatology (2007-2016) of sand and dust storms (SDS) in high spatial-temporal detail (10km, 3-hourly) based on an advance dust regional reanalysis using the **MONARCH** model



Detailed evaluation of key parameters: surface concentration, dust optical depth (total and coarse fractions), extinction, PM10, size distribution and deposition



Evaluation *results will help us to define the uncertainty of the reanalysis for a particular parameter. This is a fundamental step for the construction of the* ***SERVICES****.*

(Di Tomaso et al., 2022, ESSD)

DustClim

ERA4CS European Research Area for Climate Services

TAILORING PRODUCTS

WHAT: Identification of **impacts** and in ideas for **risk mitigation for a particular sector. This means that we need to understand their needs.**

AIR QUALITY: *Design of AQ Early warning systems, How much people is exposed to dust?*

AVIATION: *How much dust is needed to significantly damage gas turbine engines? Or to disturb operations?*

SOLAR: *How much dust is needed to significantly reduce solar production?*

HOW: Literature review and User engagement

BSC AEMet Agencia Estatal de Meteorología cnrs

Aviation portfolio

DUST IMPACTS

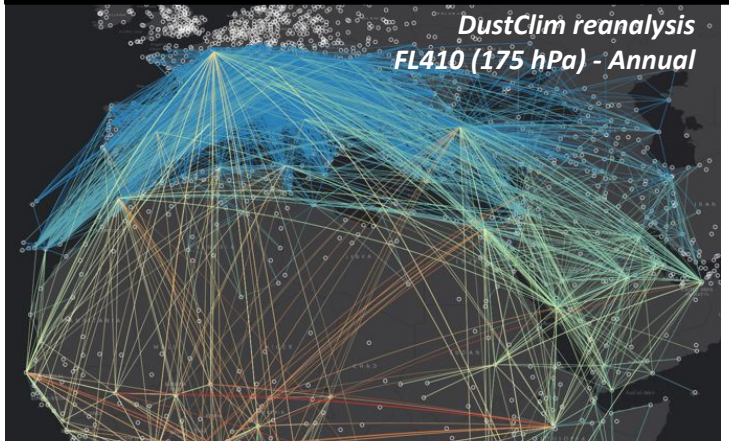
Mechanical problems

- Ice nucleation
- Dust melting in turbines
- Turbine abrasion

Reduction of visibility

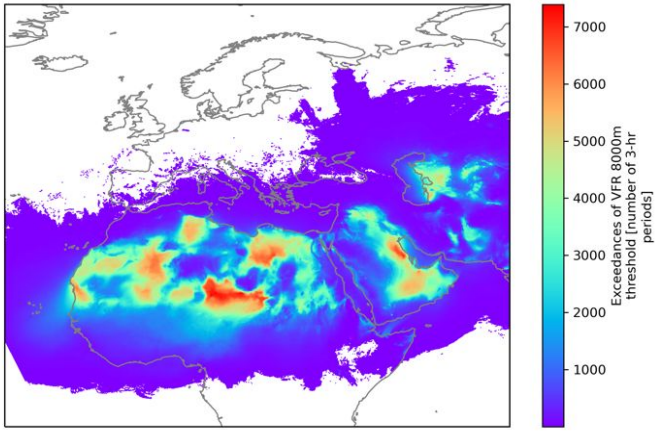
- Closing airports / Traffic management
  ⟶Rerouting and cancellations
- Disturbances in airport operations

AIRCRAFT SAFETY



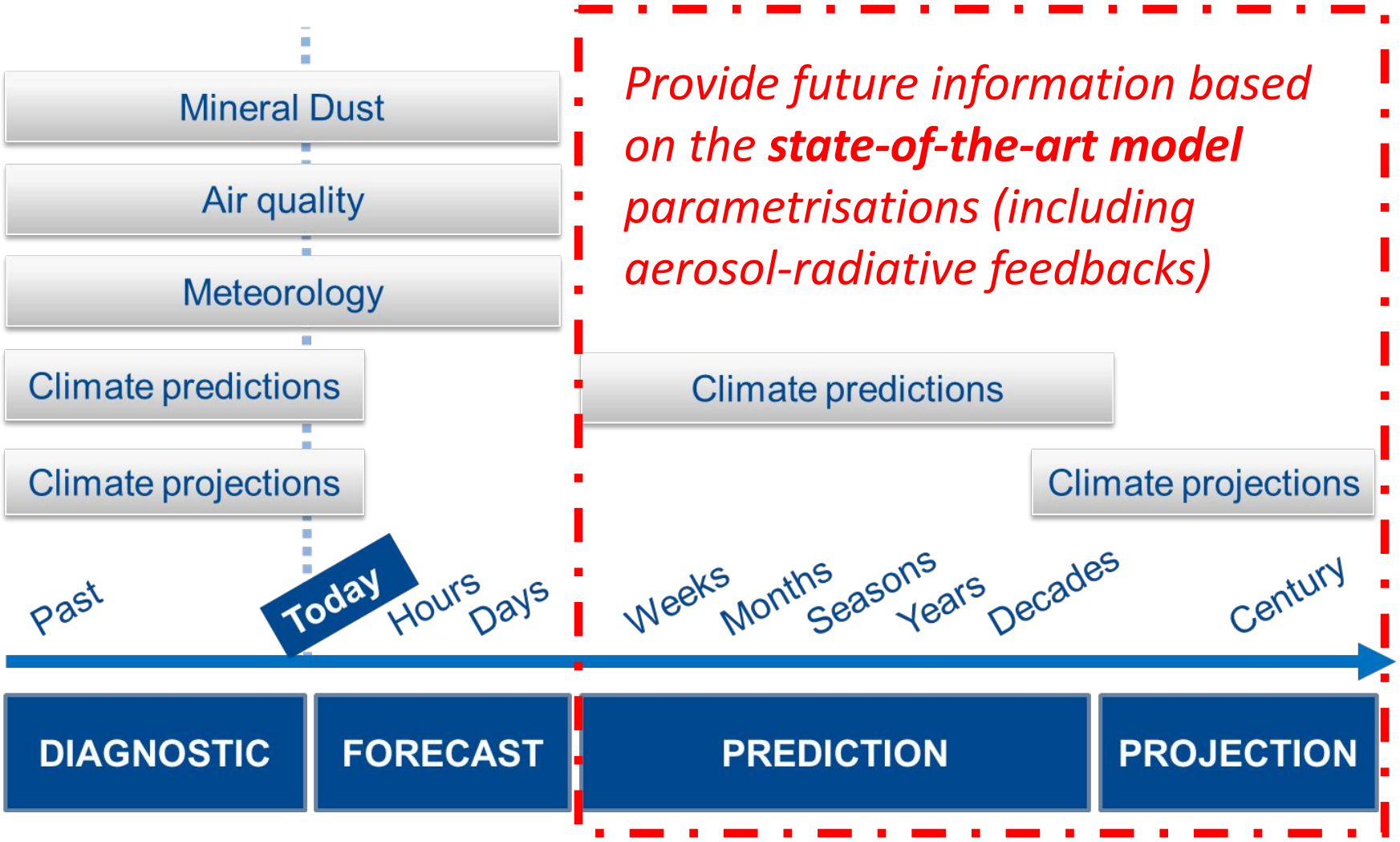
Aircraft Dust Exposure at Cruise level
Annual average (2007-2016)

TRAFFIC MANAGEMENT



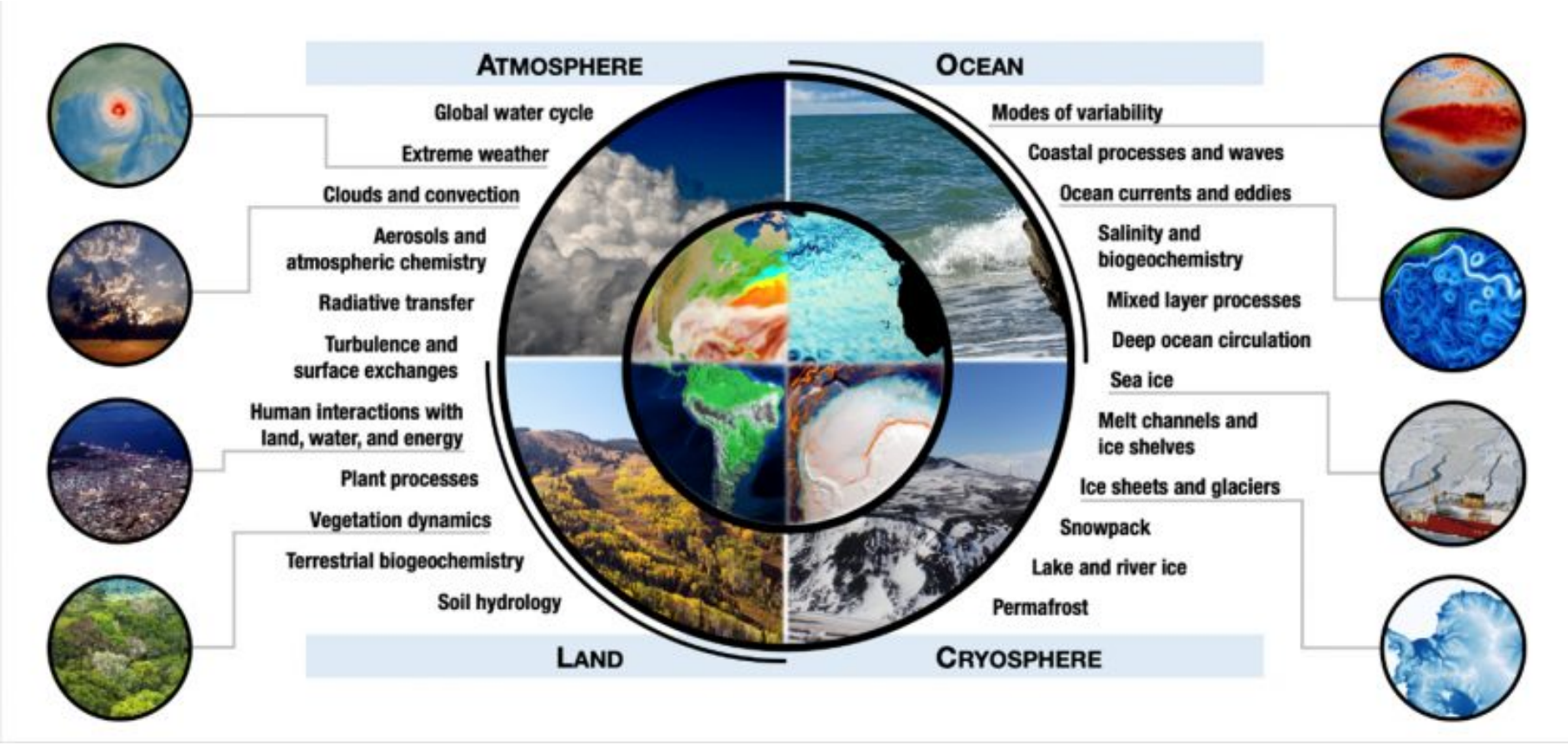
Probability of exceedance of Visual Flight rules (> 8km)
Annual probability (2007-2016)

Modelling scales



Courtesy Albert Soret, BSC,

Climate models vs Earth Systems



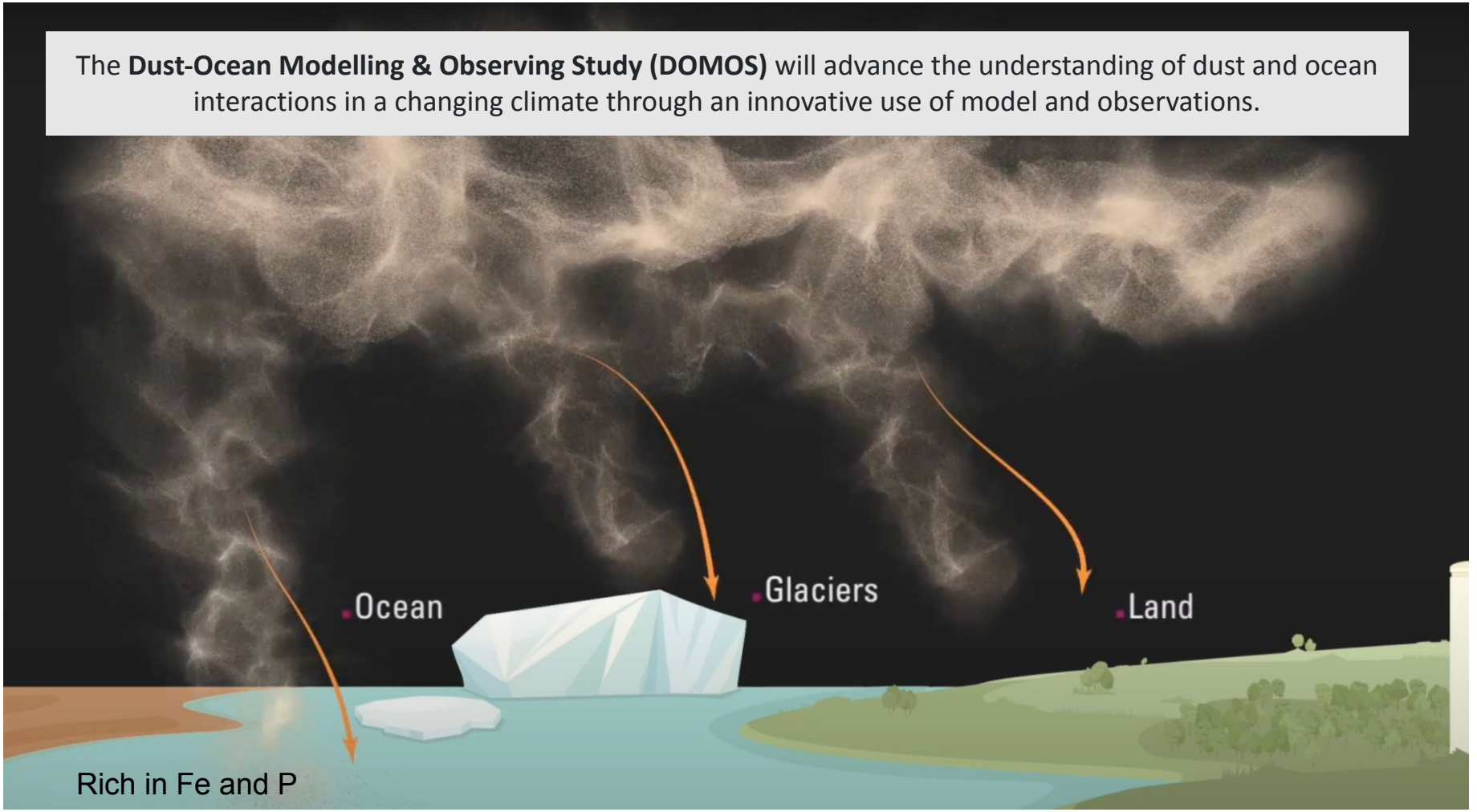
https://www.energy.gov/science/doe-explainsearth-system-and-climate-models

Climate is the long-term pattern of weather variables. Meanwhile, **Earth system models** include all the factors in climate models, but also can include the effect of human decisions, they are useful tools for planning things like infrastructure, energy production and use, and landscape use.

Talk from A. Benedetti

DOMOS

The **Dust-Ocean Modelling & Observing Study (DOMOS)** will advance the understanding of dust and ocean interactions in a changing climate through an innovative use of model and observations.

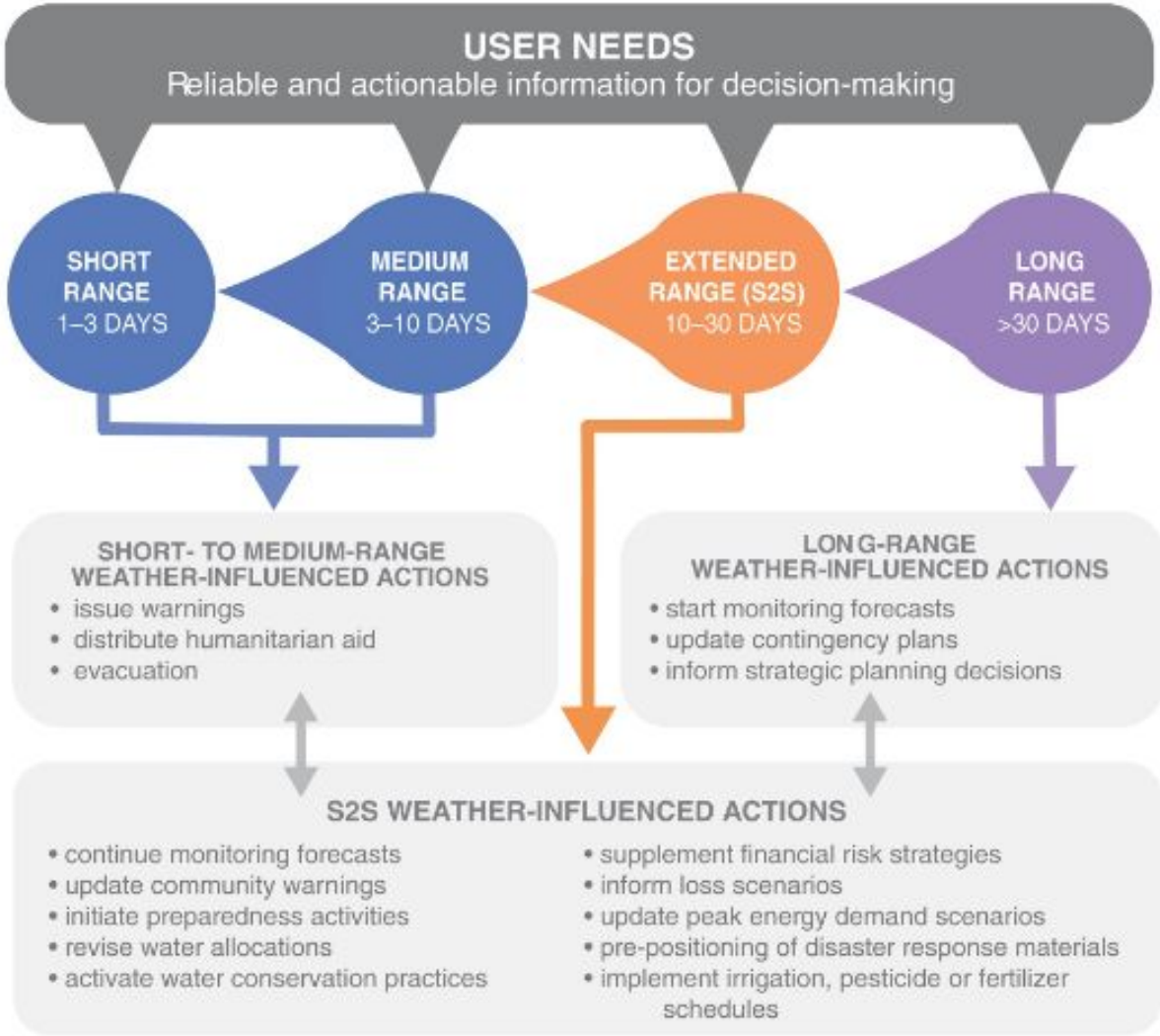


inDust

Dust and the Earth System
https://cost-indust.eu/media-room/gallery

Next: Sub-seasonal to Seasonal (S2S)

Research on adding aerosols!!



http://www.s2sprediction.net/

(White et al., RMETS, 2017)

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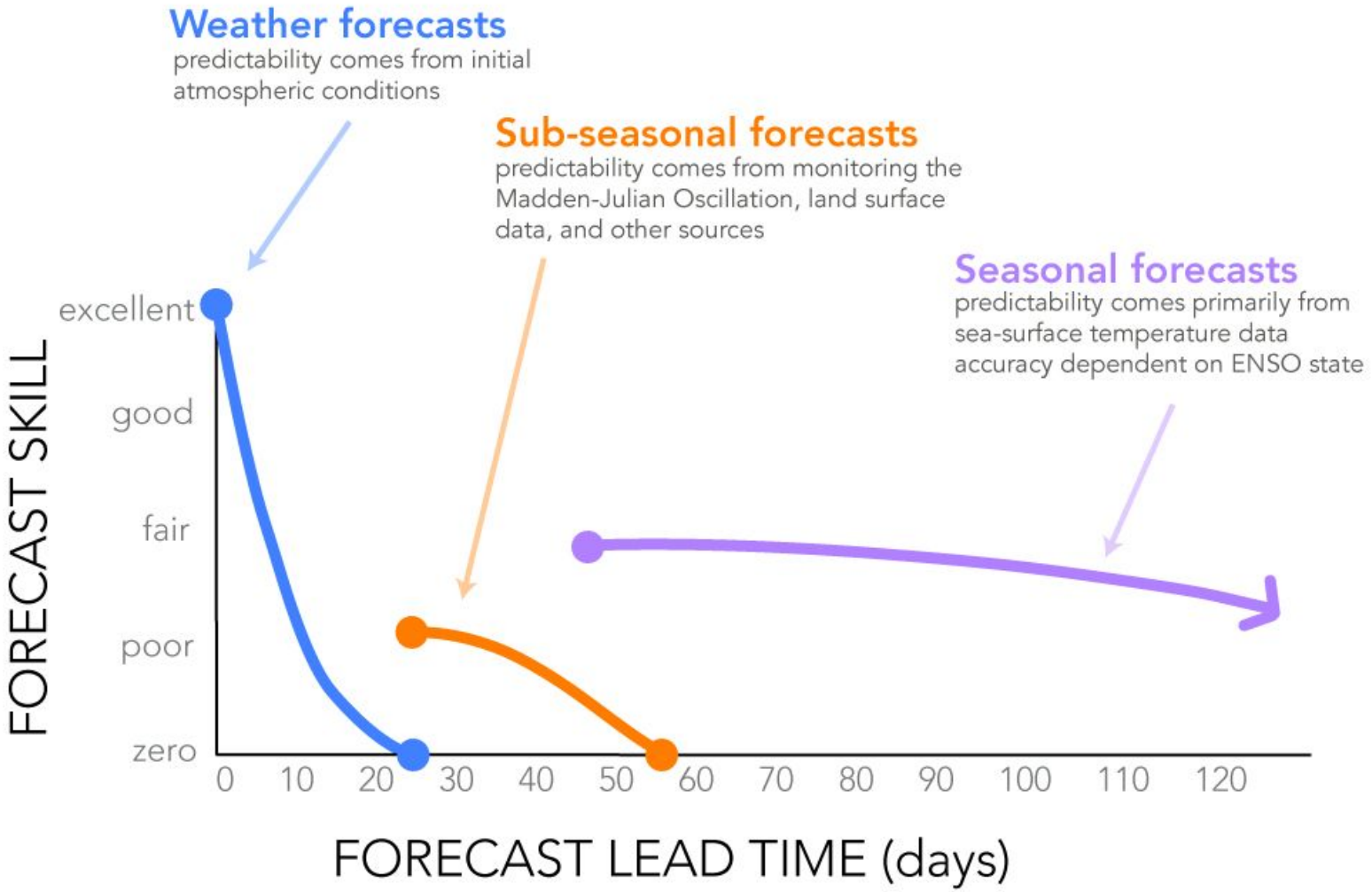
Research on adding aerosols!!



http://www.s2sprediction.net/

(White et al., RMETS, 2017)

Final remarks

- Desert dust models are fundamental tool
    - To complement dust-related observations, filling the temporal and spatial gaps of the measurements.
    - To help us to understand the dust processes and their interaction with climate and ecosystems.
    - To develop tailored products and services for users
- There are a variety of model run types that focus in different purposes
    - It’s important to define the time and spatial scales of your studies

Thank you

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WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

WMO OMM

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Organisation météorologique mondiale

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