www.bsc.es

Kuwait, February 2017

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Modeling and predicting the dust cycle at BSC

From R&D to operational forecast

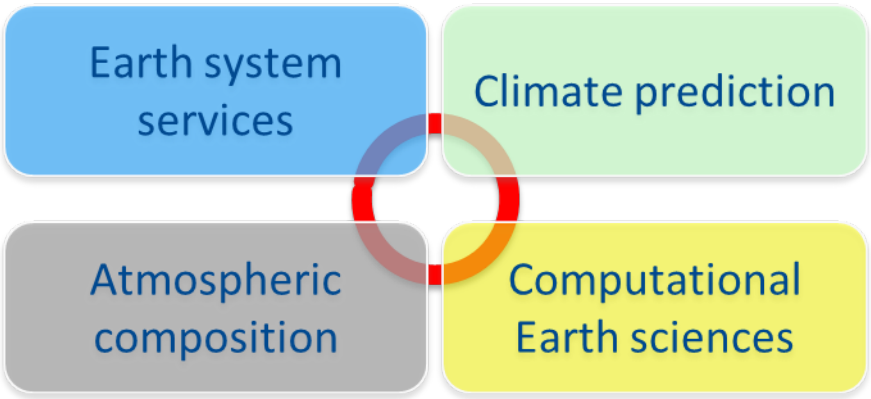
Carlos Pérez García-Pando (carlos.perez@bsc.es)

Barcelona Supercomputing Center

Barcelona Supercomputing Center
Centro Nacional de Supercomputación
EXCELENCIA SEVERO OCHOA

- Spanish National HPC facility
- Created in 2005: 450 employees
- Our mission
  - ✓ to provide ***infrastructure and supercomputing*** services to European scientists, and
  - ✓ to generate ***scientific knowledge and technology to transfer*** to business and society.

Earth Sciences Dpt. ⟹ ***Industry***

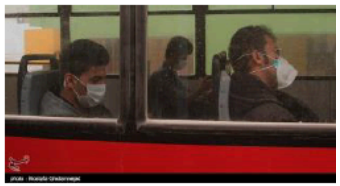


vodafone
fundación gasNatural fenosa
EnBW
WILKENS WEATHER TECHNOLOGIES WWT A Rockwell Collins Company
METEO SIM
IBM

BSC Dust Services

Applications

- **Solar energy**
  - Power forecasting
  - Mid-term maintenance planning
  - Site planning for new projects
- **Transportation**
  - (air) Visibility assessments for airlines and flight management
  - (ground) Transportation impacts
- **Health**
  - Early-warning system for people with respiratory problems
- **Agriculture/ Insurance**
  - Crop damage



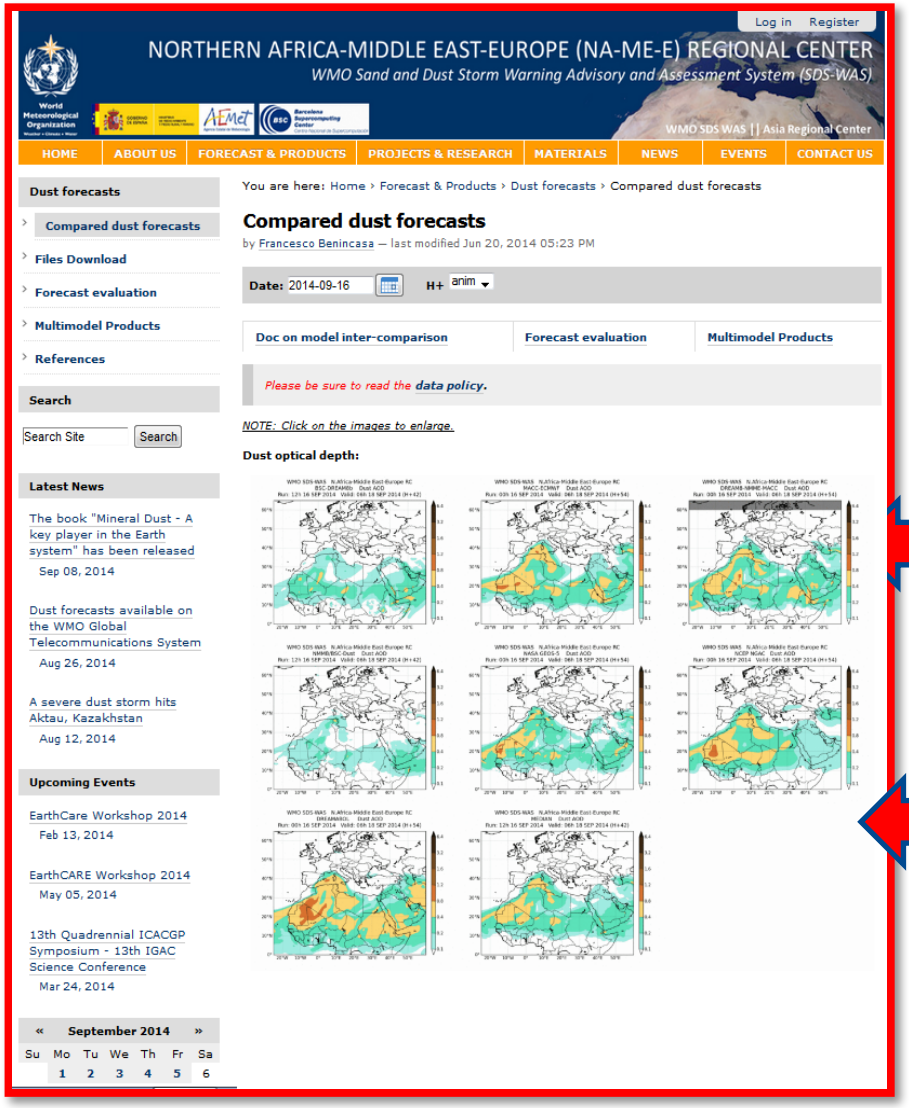
Contact us at:
info-services-es@bsc.es

BSC and AEMET are managing the WMO SDS-WAS NAMEE Regional Center (http://sds-was.aemet.es/) and the Barcelona Dust Forecast Center (http://dust.aemet.es/).

UNEP

WMO SDS-WAS programme

- Dust impacts have motivated the creation (in 2007) of WMO Sand and Dust Storm Warming Advisory and Assessment System (SDS-WAS) programme.



« The objective of this programme is to improve the understanding of dust processes and dust prediction capabilities.

http://sds-was.aemet.es/

« WMO SDS-WAS programme has 2 regional nodes, which are managed in 2 regional centers (RC):

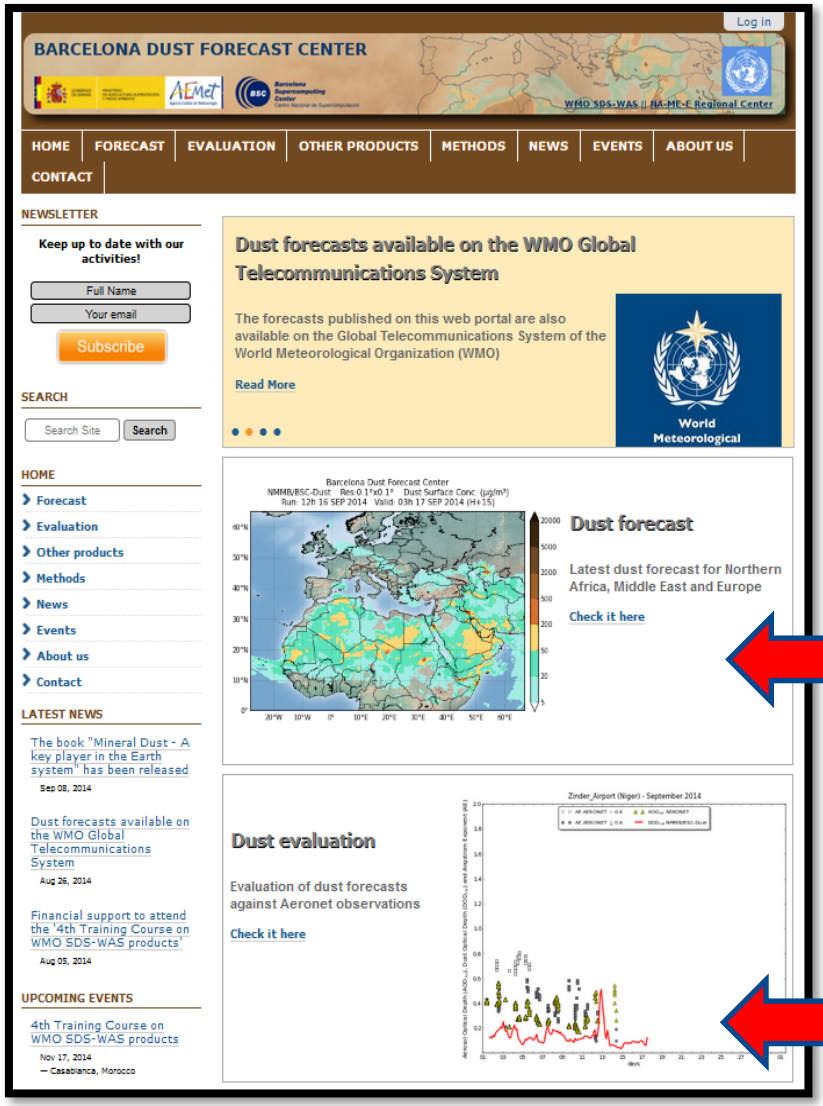
- **NAMEE RC:** AEMET-BSC, Barcelona
- **ASIA/Central Pacific RC:** China Meteorological Agency, Beijing

« WMO SDS-WAS NAMEE RC:

- **8 dust models** (e.g. NMMB/BSC-DUST, BSC-DREAM8b) → Dust forecast (DOD, Surf. Conc.)
- **NRT evaluation** (e.g. AERONET sun-photometers, MODIS)

Barcelona Supercomputing Center
Centro Nacional de Supercomputación
EXCELENCIA SEVERO OCHOA

WMO Barcelona Dust Forecast center (BDFC):



- It is the first specialized center for mineral dust prediction of the WMO
- NMMB/BSC-Dust model has been selected by WMO as dust model of reference for the dust forecast of this center *http://dust.aemet.es/*
- Dust forecast (NMMB/BSC-Dust):
  - **0.1ºx0.1º**
  - 72h (daily updated)
  - Various variables (e.g. DOD, Dust surf. Con.)
  - North Africa, Middle East, and Europe
- NRT, monthly, and seasonal evaluation:
  - AERONET sun-photometers (e.g. AOD, AE)

NMMB/BSC-Dust

NMMB/BSC-CTM

Nonhydrostatic Multiscale Model on the B-grid (NMMB)
meteo variables/parameters

→ *Janjic and Gall (NCAR/TN 2012)*
→ *Janjic and Vasic (EGU2012)*
→ *Janjic et al. (MWR 2011)*
→ *(...)*

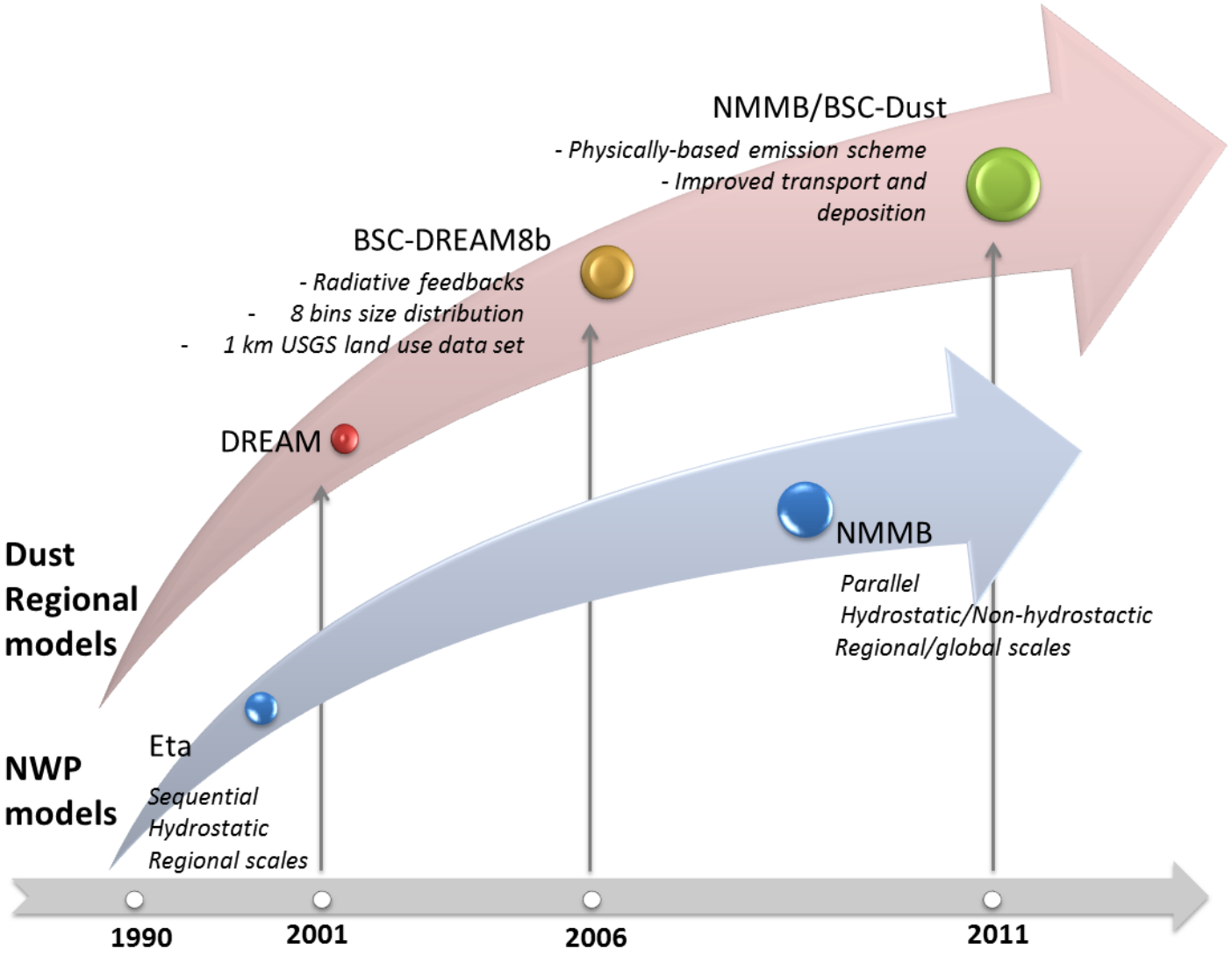
BSC Chemical Transport Model
(gas/aerosol variables: mass mixing ratios)

AEROSOLS
→ *Pérez et al. (ACP 2011)*
→ *Haustein et al. (ACP 2012)*
→ *Spada et al. (ACP 2013)*
→ *Spada et al. (AE 2014)*
→ *Spada et al. (GMD 2016 in prep)*

VOLCANIC ASH → *Martí et al. (2017)*

GAS-PHASE CHEMISTRY
→ *Jorba et al. (JGR 2012)*
→ *Badia and Jorba (AE 2014)*
→ *Badia et al. (GMDD 2016)*

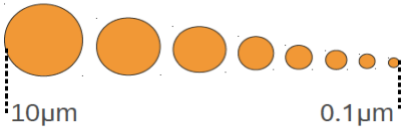
- NMMB/BSC-Dust model operational at BSC since 2012

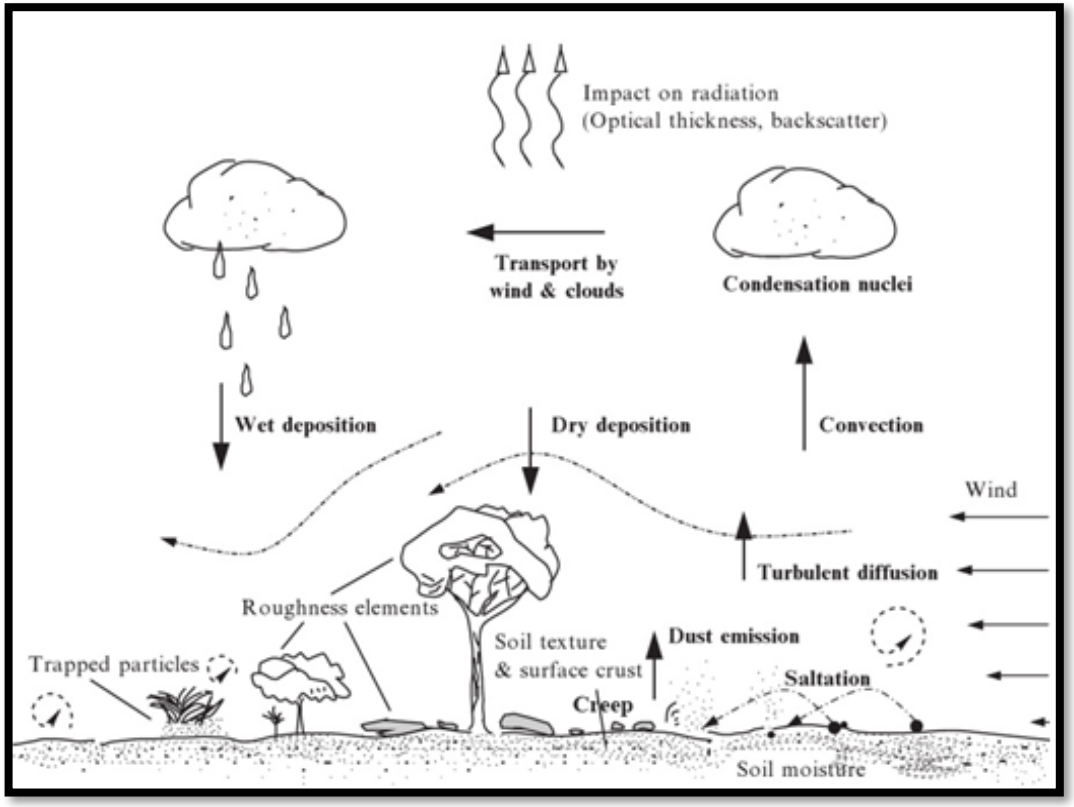


6

$$\frac{\partial C_k}{\partial t} = -u\frac{\partial C_k}{\partial x} - v\frac{\partial C_k}{\partial y} - w\frac{\partial C_k}{\partial z} - \nabla(K_H \nabla C_k) - \frac{\partial}{\partial z}\left(K_Z \frac{\partial C_k}{\partial x}\right) + \left(\frac{\partial C_k}{\partial t}\right) - \left(\frac{\partial C_k}{\partial t}\right)$$

Horizontal advection | **Vertical advection** | **Horizontal turbulent mixing** | **Vertical turbulent mixing** | **Emission** **Deposition**





- Dry deposition: aerodynamic and surface resistance (Zhang et al., 2001)
- Gravitational settling: Stokes approximation, Cunningham correction factor. Both implicit and explicit upwind schemes available.
- In-cloud and below cloud scavenging from grid-scale (Ferrier Microphys.) and sub-grid scale (BMJ) clouds
- Below cloud scavenging (directional interception, inertial impaction and Brownian diffusion)
- Vertical convective mixing follows the BMJ adjustment scheme (instead of a mass flux scheme)
- Radiation: RRTM SW/LW aerosol radiative feedback

- Dust emission scheme:

  - Horizontal flux (H) (White, 1979) ($u^* > u^*_{ths,i}$):

$$H = \delta \frac{\rho_{air}}{g} u^{*3} \sum_{i=1}^{4} \left(1 - \frac{u^*_{ths,i}}{u^*}\right)\left(1 - \frac{u^{*2}_{ths,i}}{u^{*2}}\right) s_i$$

  - Threshold friction velocity (u^*_{ths}) (Iversen and White, 1982; Marticorena and Bergametti, 1995; Fécan et al., 1999):

$$u^*_{ths} = u^*_{tsd}(D_s) \cdot f_h$$

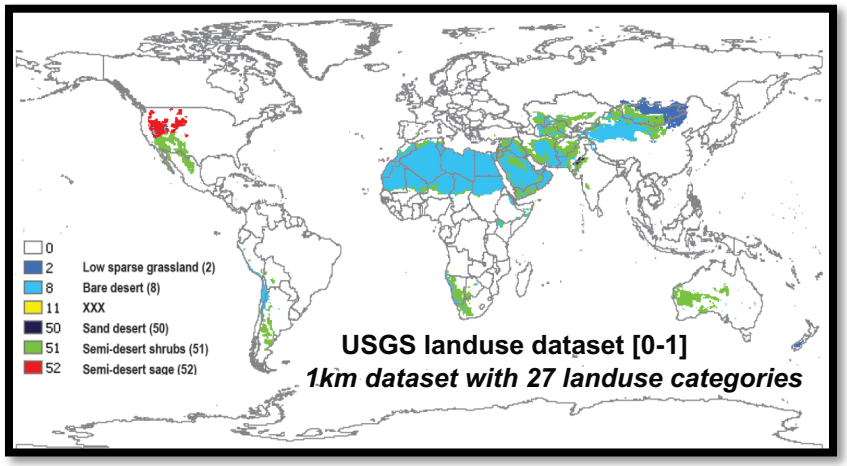
    - f_h= Mositure correction
    - $u^*_{tsd}(D_s) = u^*_{ths}$ in dry and smooth surfaces

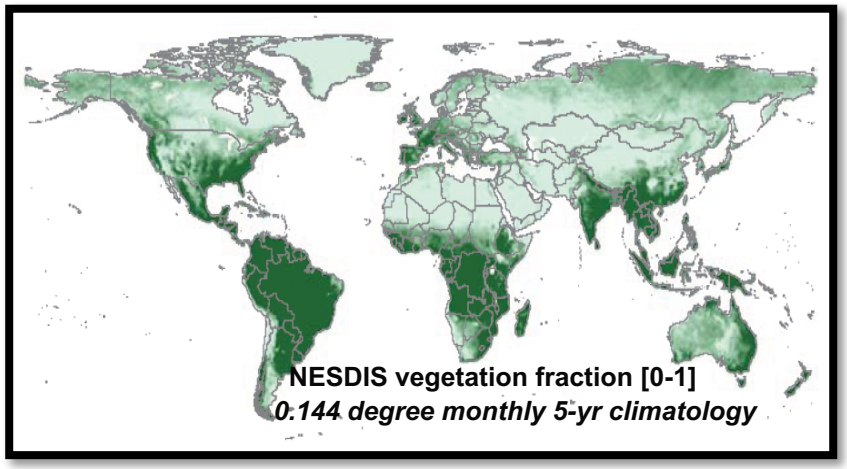
  - Vertical flux (F_k) (Shao et al., 1993; Marticonera and Bergametti, 1995; Tegen et al, 2002):

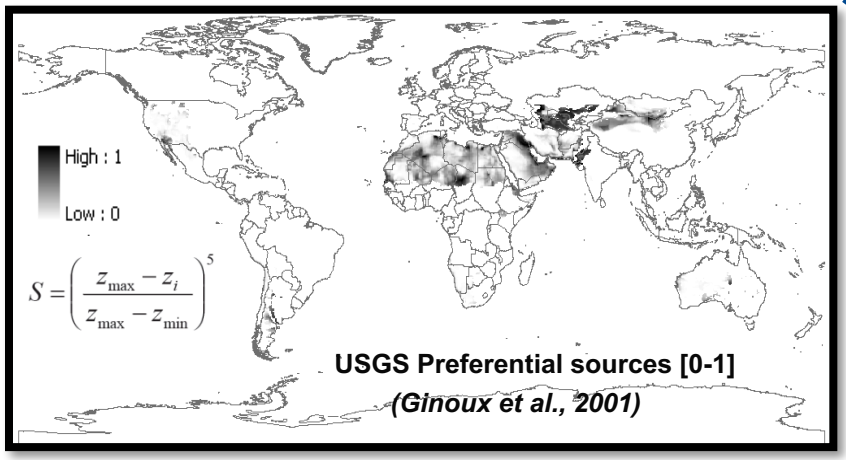
$$F_k \propto C \cdot \alpha \cdot H$$

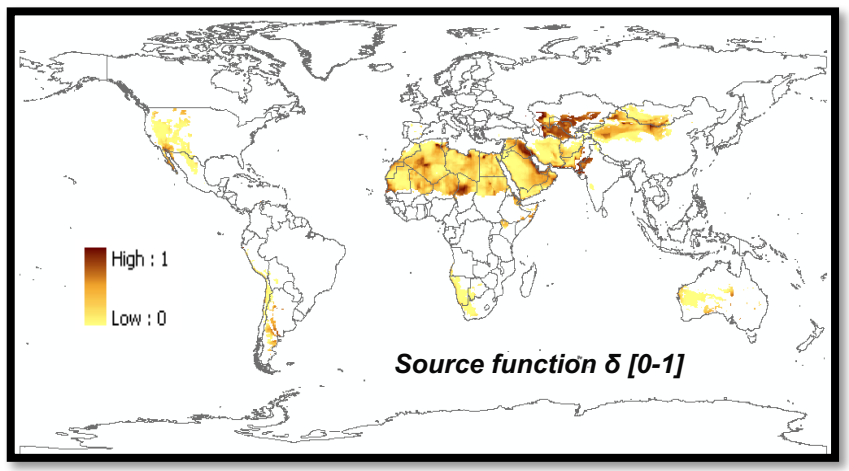
    - C = Calibration factor
    - α = The horizontal to vertical flux ratio (for each soil population)

Source function





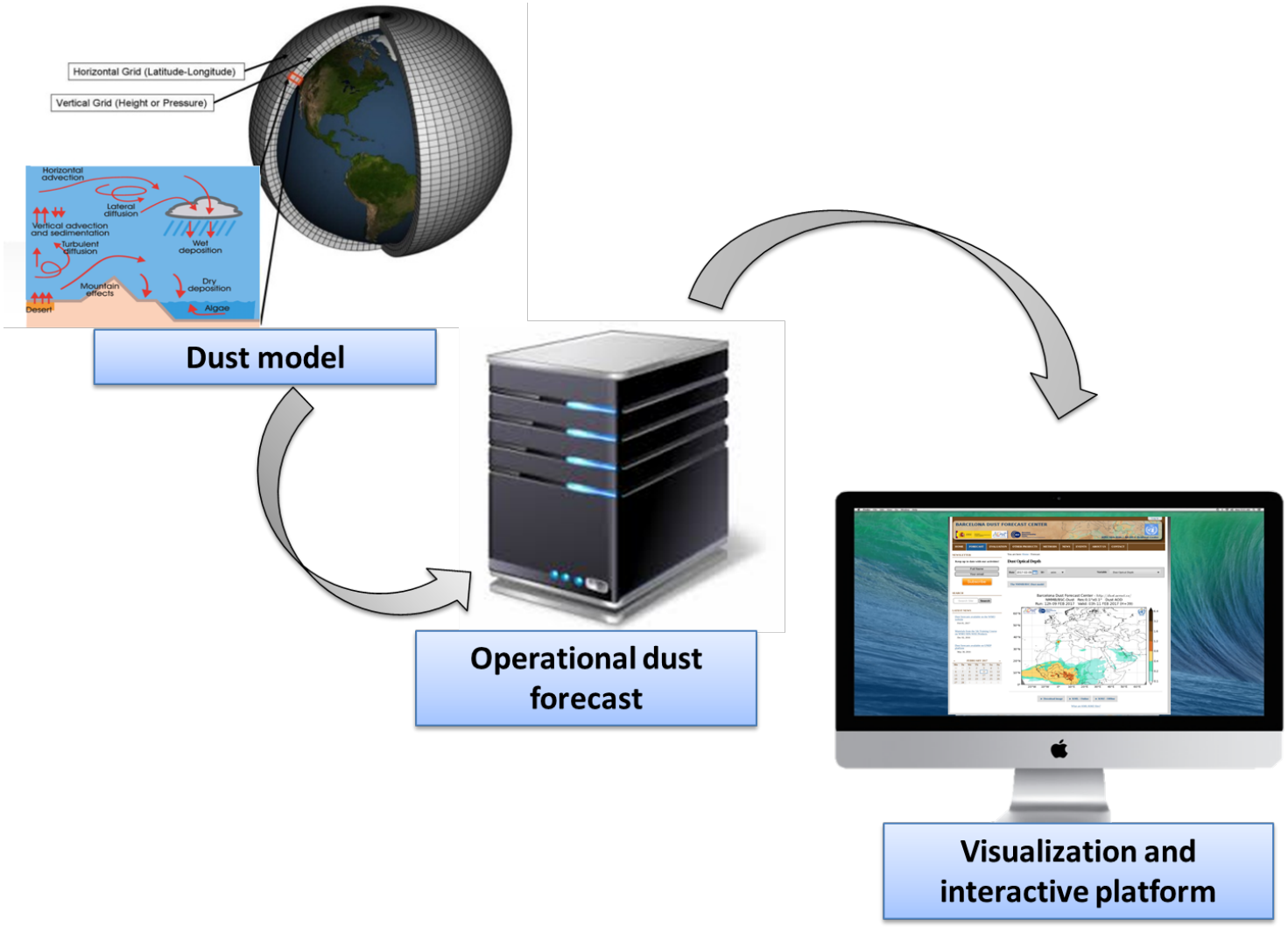




$$\delta = USGS \cdot PREF \cdot (1 - VEGFRAC) \cdot (1 - S)$$

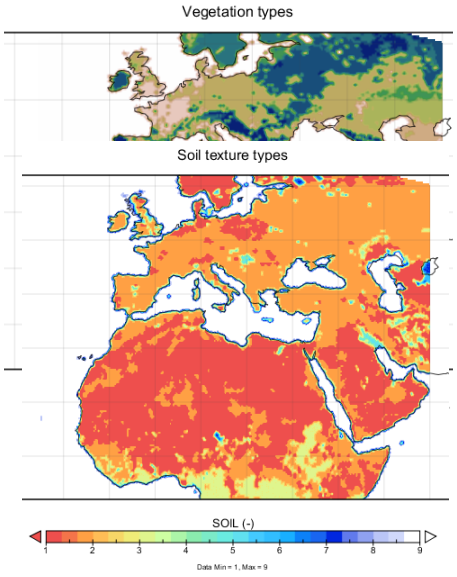
K-Dust project

OBJECTIVE: Development and implementation of a state-of-the-art **dust forecasting system** for Kuwait.



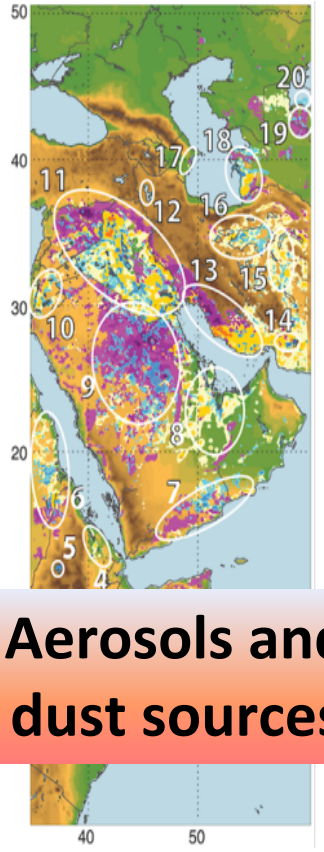
WP1 SDS characterization over Kuwait

- Task 1.1. Compilation of available dust information for the study region.
- Task 1.2. Aerosol characterization and identification of the desert dust sources.



Land databases

Observations



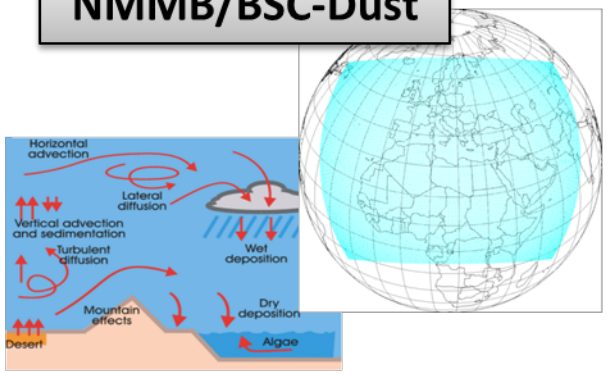
Aerosols and dust sources

WP2 Implementation of the dust forecasting-modelling system

- Task 2.1 HPC resource requirements.
- Task 2.2 Model configuration.
- Task 2.3 Model compilation and testing.
- Task 2.4 Improvement of the model performance.
- Task 2.5 Operational Implementation.
- Task 2.6 Data Management.
- Task 2.7 Visualization interface.

K-Dust project: WP2

NMMB/BSC-Dust



Task 2.2 Model configuration

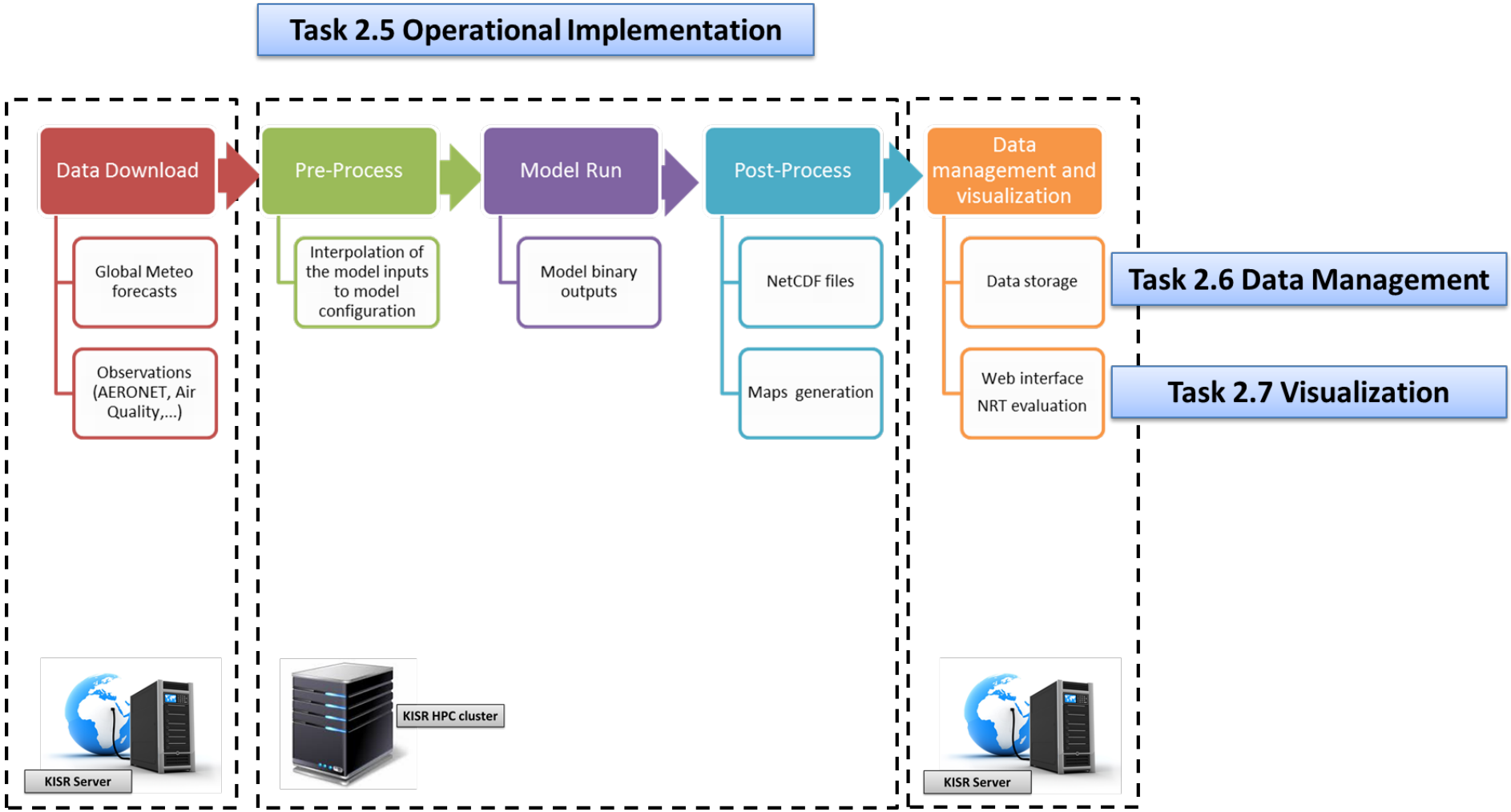
KISR HPC cluster

Task 2.1 HPC requirements

Task 2.3 Model compilation

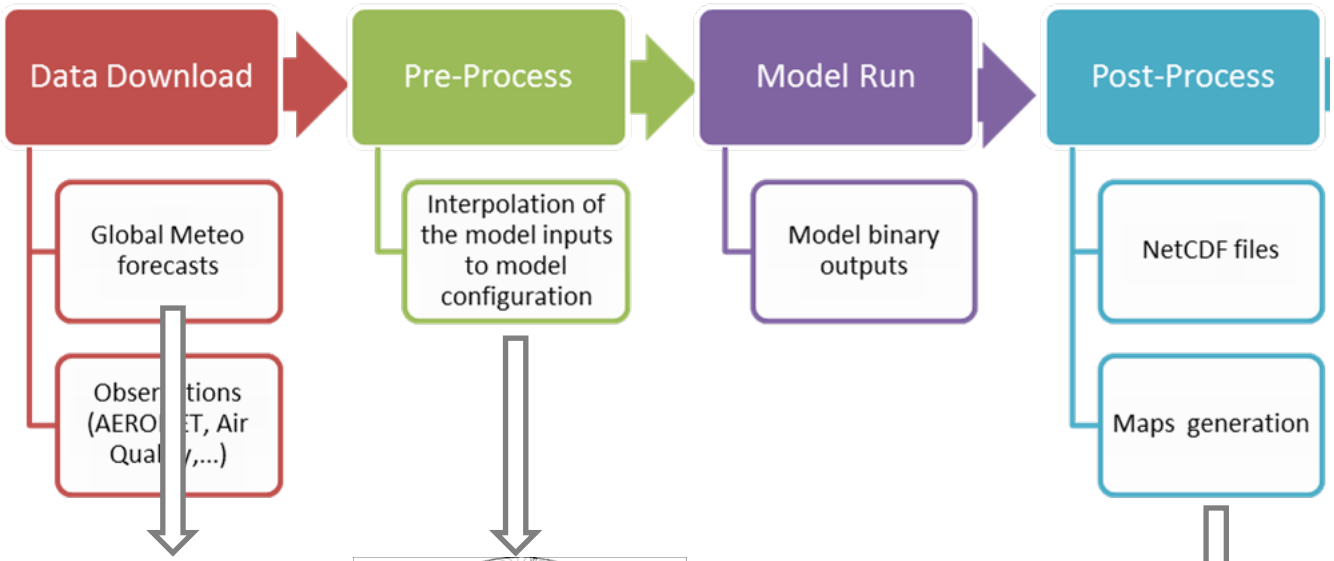
Task 2.4 Model performance

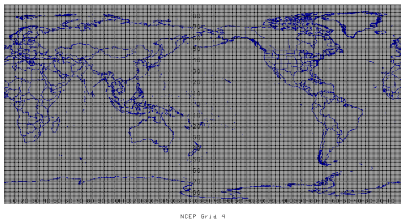
K-Dust project: WP2



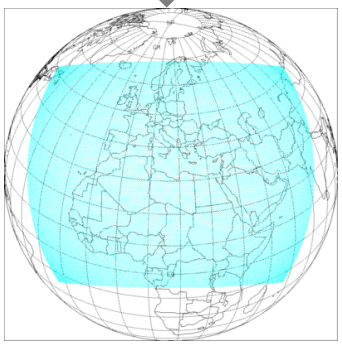
K-Dust project: WP2

Task 2.5 Operational Implementation

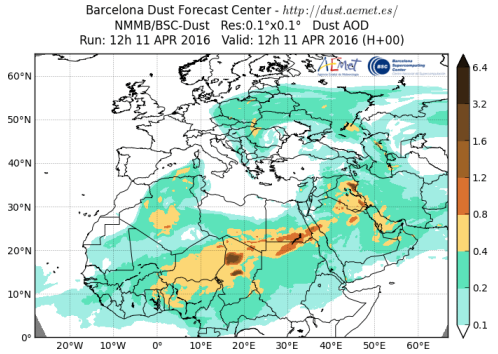




NCEP GFS Glob. Meteo grid



NMMB/BSC-Dust Regional grid



K-Dust project: WP2

Barcelona Supercomputing Center
Centro Nacional de Supercomputación
EXCELENCIA SEVERO OCHOA

Task 2.6 Data Management

KISR Server

MODEL OUTPUTS
NetCDF
Forecast maps

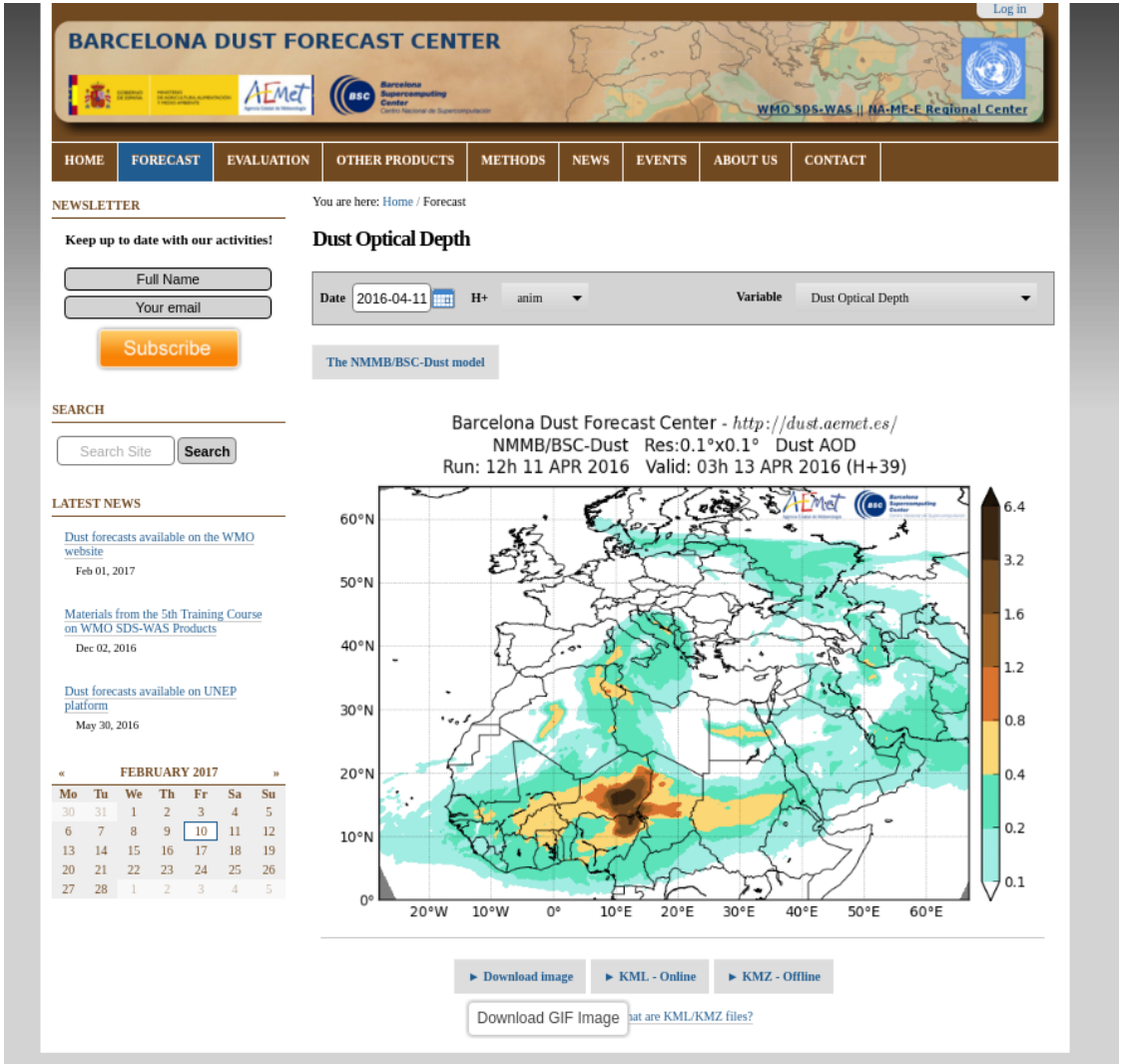
MODEL INPUTS
NCEP GFS

OBSERVATIONS
AERONET
AQ Kuwait…

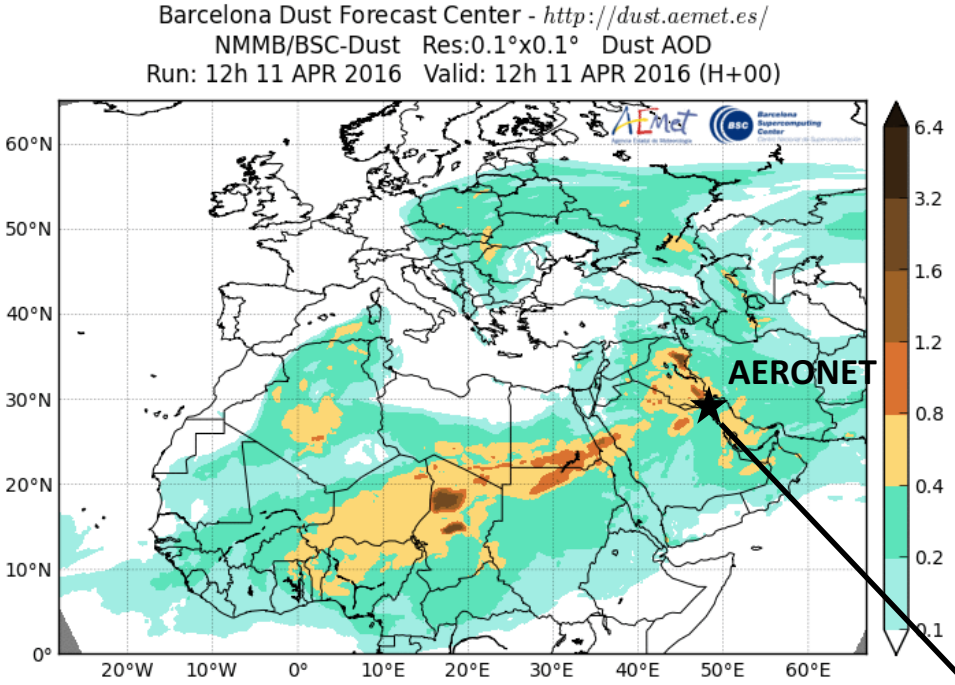
Others…
NRT evaluation

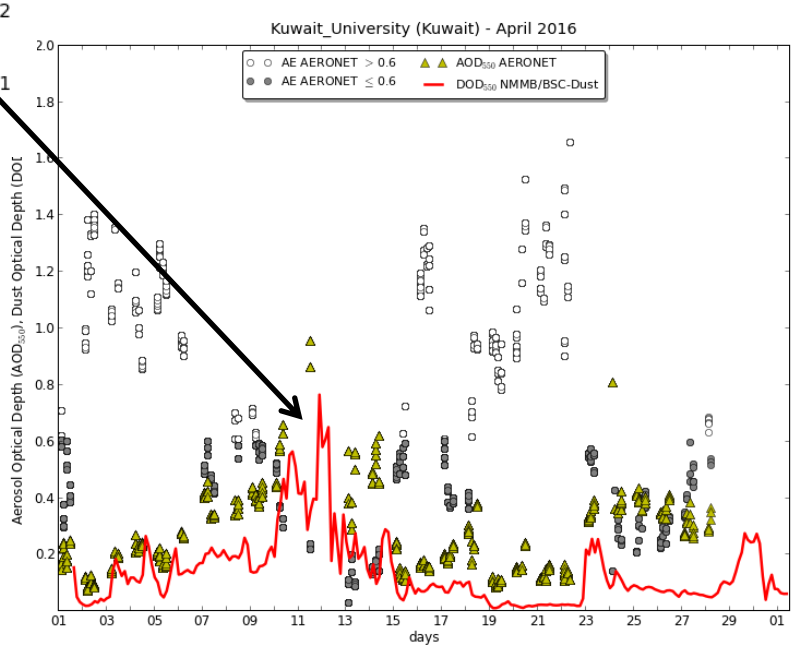
K-Dust project: WP2

Task 2.7 Visualization



K-Dust project: 11 April 2016





WP3 Capacity building and training

- Task 3.1. Dust forecasting skills and analysis of dust from observations.
  - Dust observations and forecasting models.
  - Manipulation of scientific formats

- Task 3.2. Implementation and maintenance of a dust forecasting system.
  - Compilation of the NMMB/BSC-Dust model.
  - Operational system: download input data, pre-processing, model execution and post-processing.
  - The NMMB/BSC-Dust model: parameterizations and main routines of the model code.
  - Data management (storage/archive) and web-interface.

K-Dust project

PROJECT:	Kuwait Dust Forecasting System					
Acronym	K-Dust					
Duration:	2 years					
	1st year			2nd year		
	Q1	Q2	Q3	Q4	Q5	Q6
WP1: Desert dust characterisation						
Task 1.1 Compilation of available information		M1.1		D1.1		
Task 1.2 Aerosol characterisation and desert sources indentification			D1.2			
WP2: Dust forecasting system						
Task 2.1 HPC resource requirements		M2.1	D2.1			
Task 2.2 Model configuration			M2.2			
Task 2.3 Model compilation and testing				M2.3		
Task 2.4 Improvement of the model performance				D2.2		
Task 2.5 Operational Implementation					M2.4	D2.3
Task 2.6 Data Management			M2.5		D2.3	
Task 2.7 Visualization interface						D2.5
WP3: Capacity building						
Task 3.1 Dust forecasting skills and observations	D3.1/M3.1	D3.2/M3.2				
Task 3.2 Implementation and maintainance of a dust forecasting system			D3.3/M3.3	D3.4/M3.4	D3.5/M3.5	D3.6/M3.6

www.bsc.es

Thank you!

Thanks to NASA AERONET, NASA MODIS, U.K. Met Office MSG, MSG EUMETSAT and EOSDIS World Viewer principal investigators and scientists for establishing and maintaining data used.

For further information please contact
carlos.perez@bsc.es