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BSC Update: MONARCH model

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Atmospheric Composition Group
Barcelona Supercomputing Center

7/06/2018

10th ICAP WG meeting - Exeter (UK)

Contents

Overview MONARCH model and updates on BSC forecast

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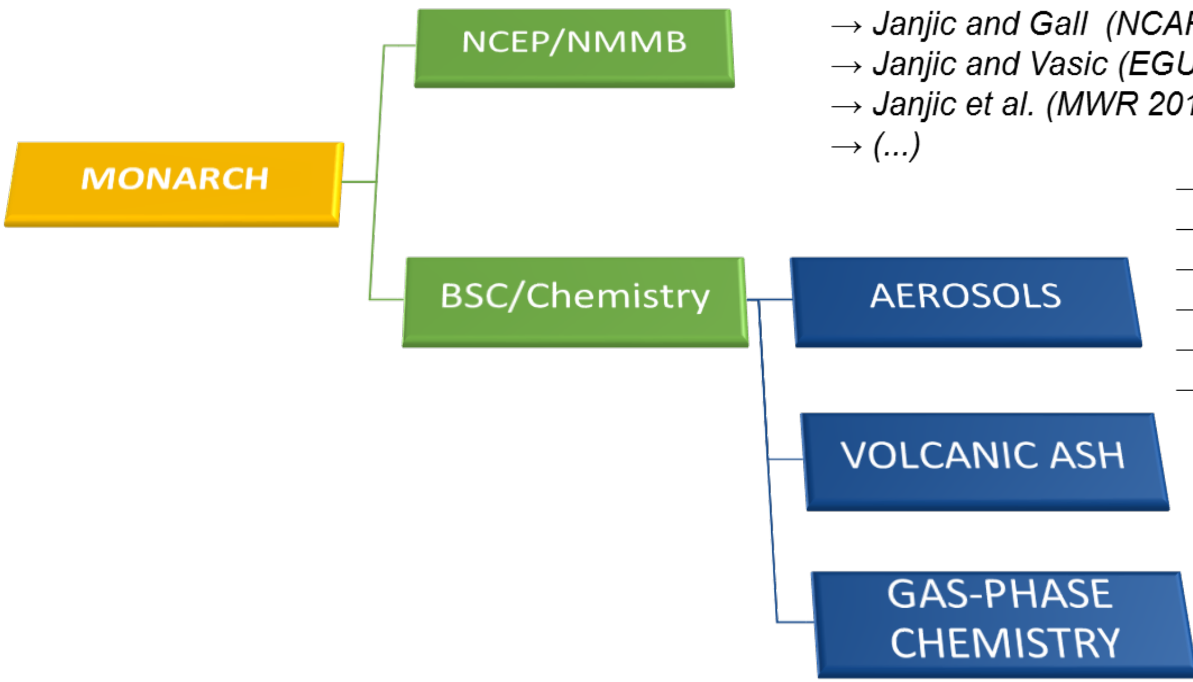
The MONARCH model

· ***Multiscale***: global to regional (up to 1km) scales allowed
· Fully ***on-line*** coupling: weather-chemistry feedback processes allowed
· Enhancement with a ***data assimilation*** system



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

AEROSOLS:
→ *Pérez et al. (ACP 2011)*
→ *Haustein et al. (ACP 2012)*
→ *Spada et al. (ACP 2013)*
→ *Spada et al. (AE 2014)*
→ *Spada (2015)*
→ *DiTomaso et al. (GMD 2017)*

VOLCANIC ASH:
→ *Martí et al. (ACP 2016)*

GAS-PHASE CHEMISTRY:
→ *Jorba et al. (JGR 2012)*
→ *Badia and Jorba (AE 2014)*
→ *Badia et al. (GMD 2017)*

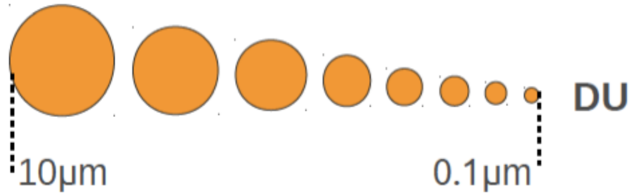
Dust module is known as **NMMB/BSC-Dust**

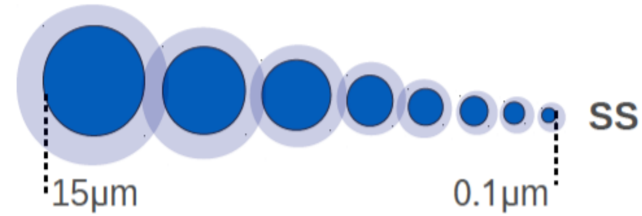
Aerosols

Sectional

dust (DU)

sea-salt (SS)





Bulk

Black Carbon (BC)

Organic Aerosols (OA)

Primary Organic Aerosols (POA)

Secondary organic aerosols (SOA)

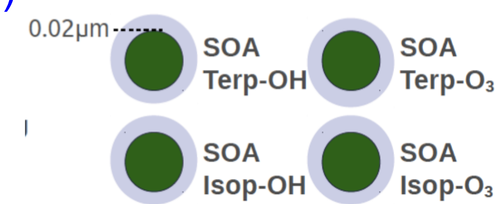
4 gaseous tracers (OH, O3, TERP, ISOP). Online emission (MEGAN)

4 aerosol-phase hydrophilic tracers

2-product scheme of Tsigaridis and Kanakidou (2007)

Oxidation by OH and O3 and gas-particle partitioning

Anthropogenic SOA from Toluene and Xylene under development



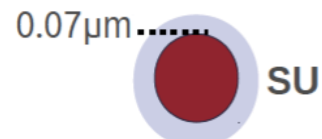
Sulfate (SU):

4 additional prognostic tracers (SO2, DMS, H2O2, H2SO4)

3 online or climatological oxidants (OH, O3, HO2)

gas-phase oxidation of SO2, DMS and H202 by OH

aqueous-phase oxidation by H202 and O3



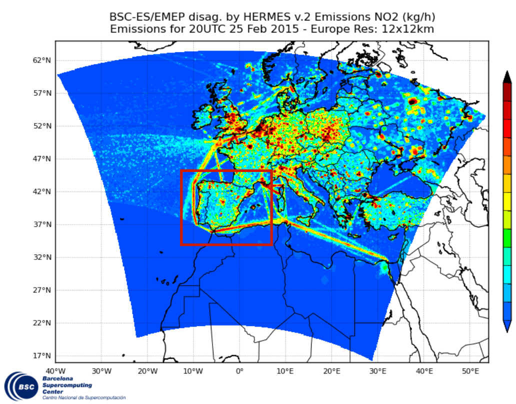
Nitrate (NO3) and Ammonium (NH4): as calculated by EQSAM thermodynamic equilibrium model but not evaluated yet

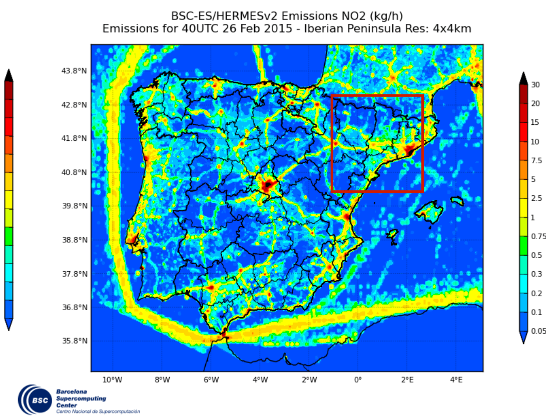
MONARCH - Emissions
HERMES 3.0: A multiscale emission modelling

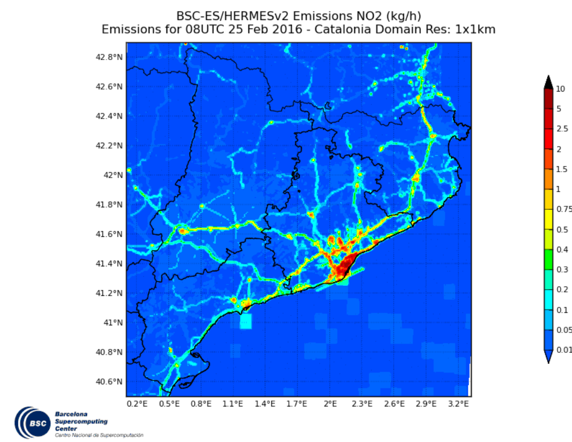
- A **stand-alone tool** for simulating **emissions** on a **user-defined grid for global, regional and urban** air quality models.

- Users can **select, combine and scale multiple inventories** through a flexible configuration file to obtain **hourly gridded emissions**.

  ✓ *Spanish bottom-up emission inventory (street level emissions)*

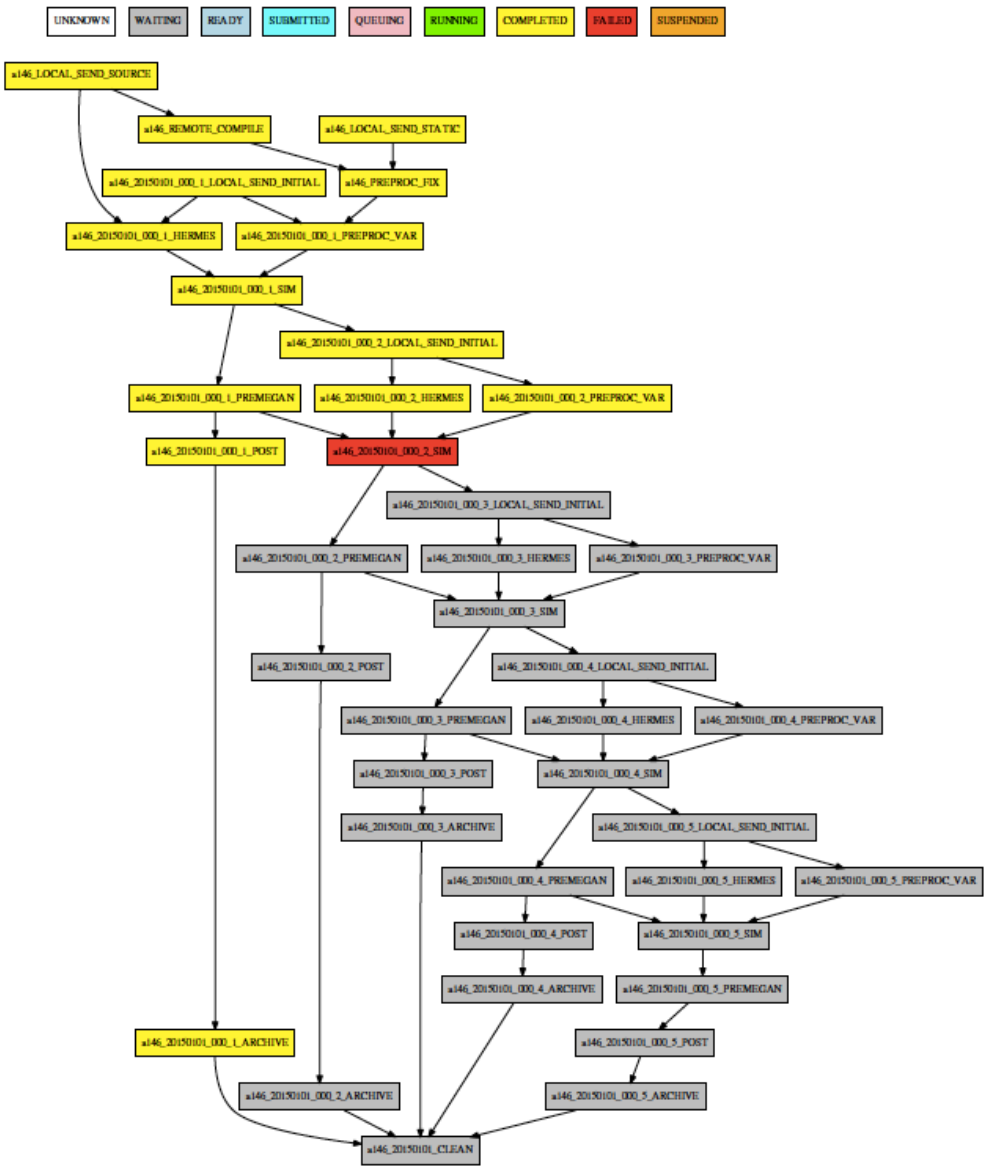






Guevara et al., in preparation

Autosubmit workflow manager



- Workflow manager developed at BSC
- Manages all the tasks associated to a model experiment
- Submits jobs in HPC systems and post-process results in local machine
- Flexible to configure and easy to modify dependencies
- Forecast systems of BSC ported to Autosubmit

BSC Current forecasts and plans

CURRENT FORECASTING – DEVELOPED/AVAILABLE – UNDER DEVELOPMENT - PLANNED

DOMAIN	GLOBAL (ICAP)	REGIONAL North Africa, Middle East and Europe (SDS-WAS)	REGIONAL Europe/Iberian Peninsula/Urban Areas (CALIOPE)
Model	MONARCH	MONARCH	CMAQ (DREAM for dust) MONARCH
Status	QO	O	O
Meteorology	Inline: NMMB	Inline: NMMB	Offline: WRF-ARW Inline: NMMB nesting
Resolution	1.4x1 deg ***0.7x0.5 deg***	0.1x0.1 deg 0.03x0.03 deg	0.1x0.1 / 0.04x0.04 / 0.01 x0.01
levels	24 48	40 60-70	30 60-70
DA	LETKF	LETKF	NA LETKF
Assimilated Obs	MODIS DT+DB (DU) MODIS DT+DB (ALL)	MODIS DT+DB (DU)	NA MODIS DT+DB (ALL)
Aerosol Species	***DU, SS, BC, POA, SOA bio,*** SOA anthro, ***SU***, NI	DU	CMAQ (AERO5) MONARCH aerosols
Gas phase chemistry	CBM-IV CB05 ONLINE and ***CLIMATOLOGY***		CB05 CB05
Emissions	***HERMES 3.0 (HTAP v2) MEGAN ONLINE***		EMEP, MEGAN / HERMES, MEGAN/ HERMES MEGAN
Bio. Burn. Emissions	***GFAS NRT***		NA NRT

Multiscale capability of MONARCH model

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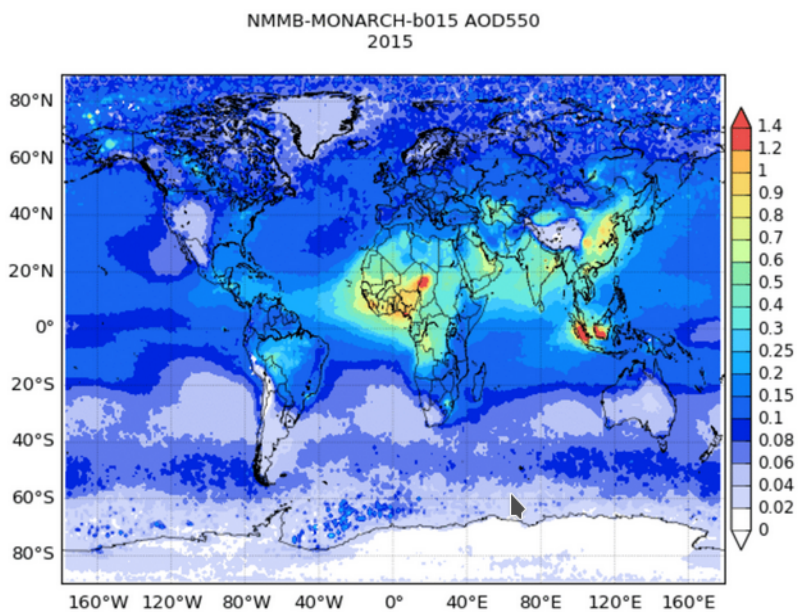
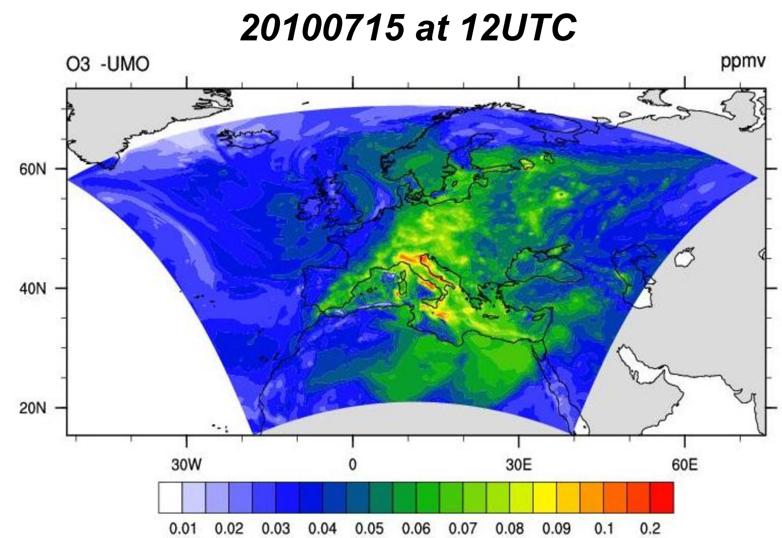
MONARCH - BSC forecasts

Global



- ✓ *MONARCH contributes to the* ***ICAP global forecast aerosol*** *multi-model ensemble* [*http://icap.atmos.und.edu*](http://icap.atmos.und.edu)

Regional



- ✓ *BDFC and SDS-WAS dust forecast*
- ✓ *It will be operational at*

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

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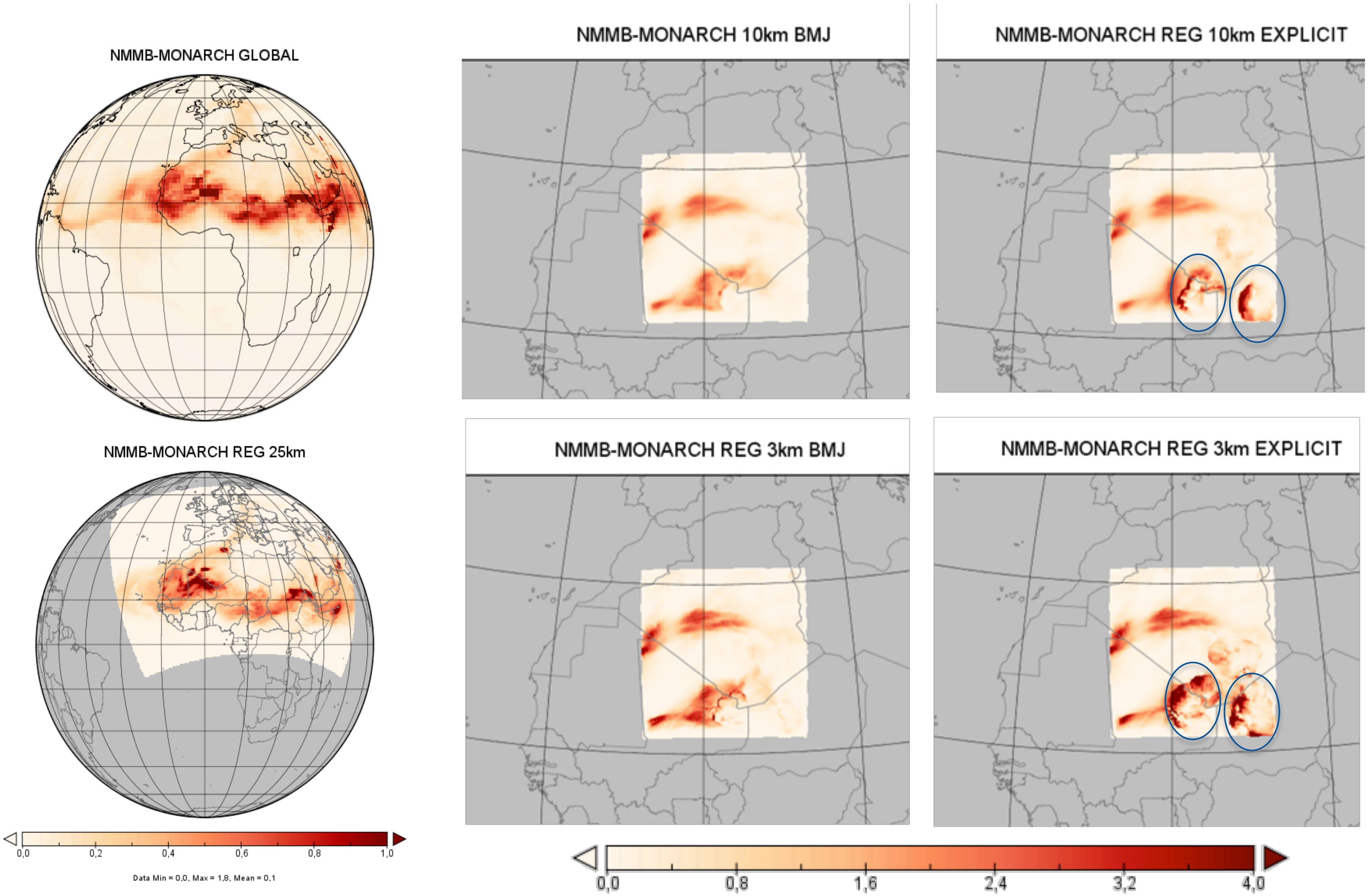
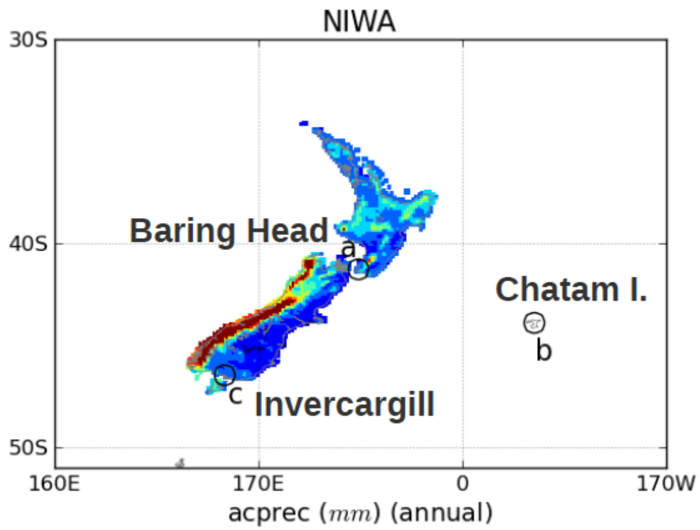
And more products in: http://www.bsc.es/ess/

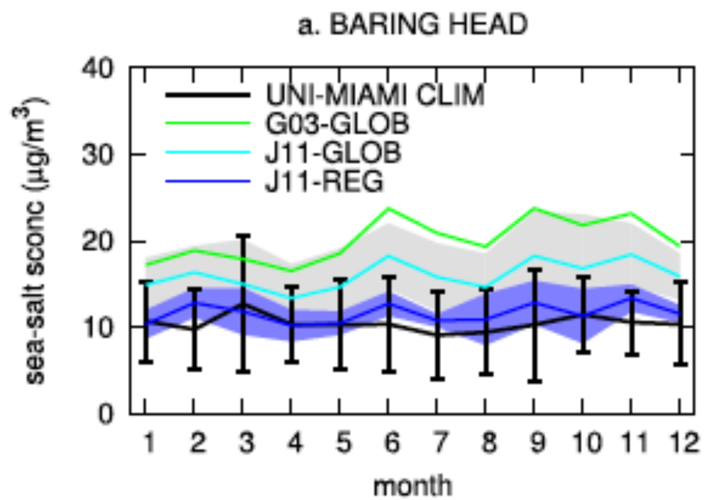
Mineral dust forecasting at wide range of spatial scales

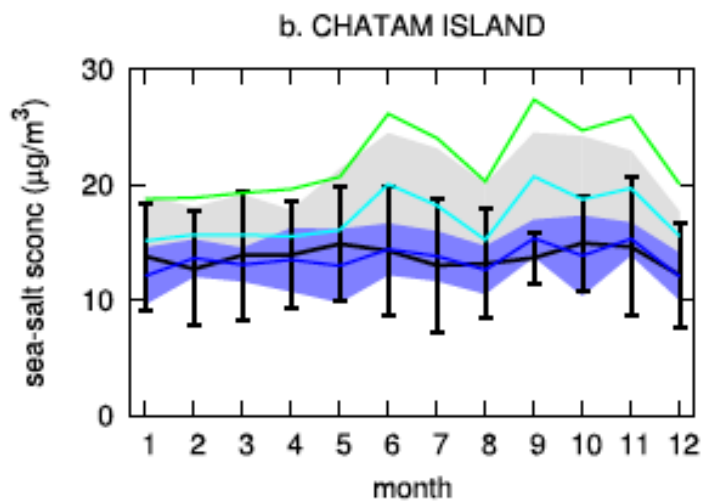


14 July 2011 at 18h – Haboob development

On the evaluation of global sea-salt aerosol models at coastal/orographic sites (Spada et al., 2015)

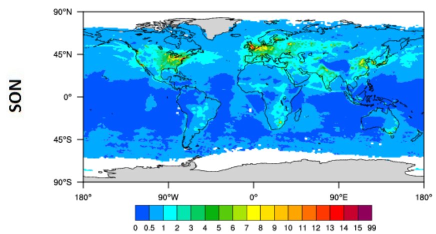






- Global run (1º x 1.4º, 2002.2006)
- Regional run (0.1º x 0.1º, 2002-2006)
- Two sea salt emission schemes:
  - ✓ *Gong (2003) function of wind speed*
  - ✓ *Jaeglé et al. (2011) function of wind speed and sst*

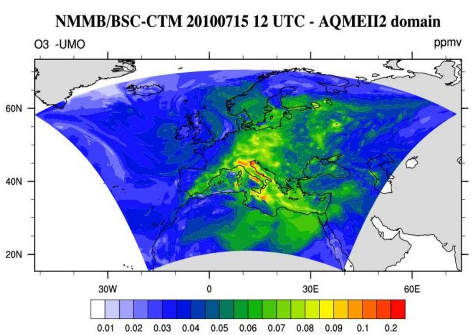
Impact of scales on surface ozone using full chemistry CB05

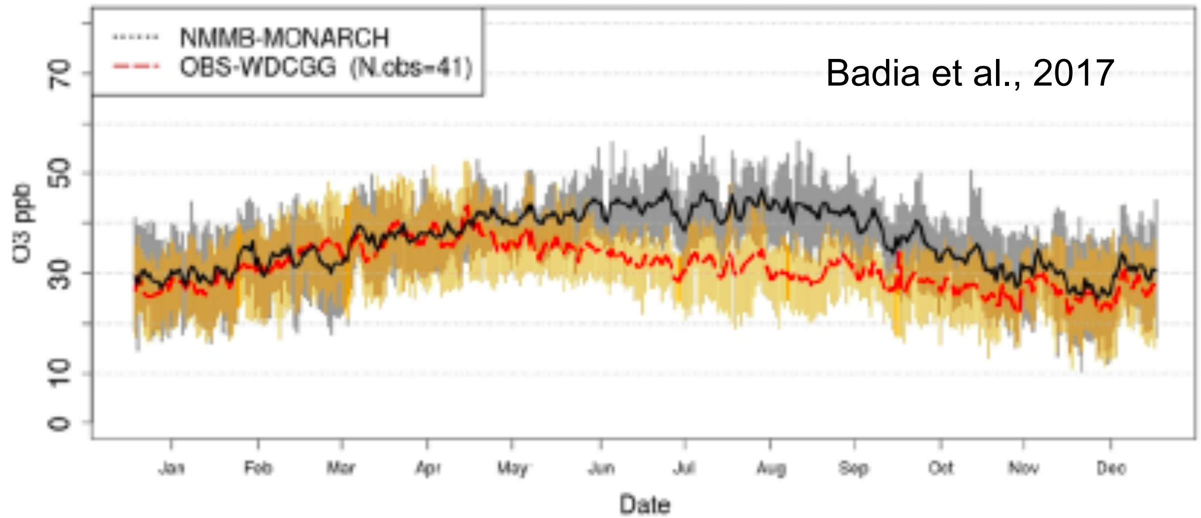


Global domain

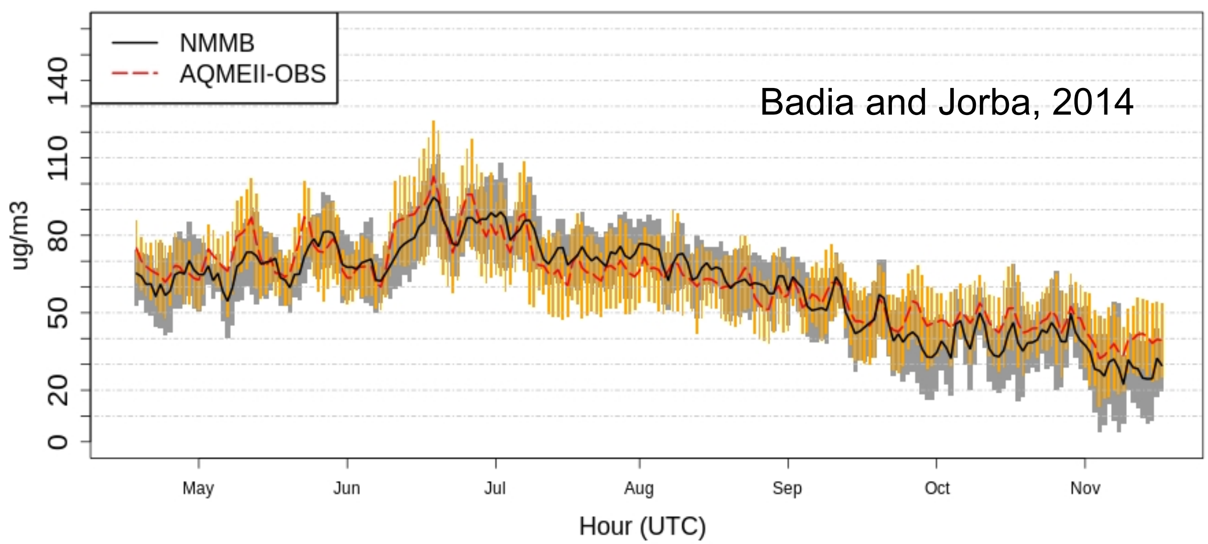
Same physics and chemistry

Regional domain





O3 -Daily mean concentration (ug/m3)- R=0.68 RMSE=20.2 MB=-2.2



Intensive optical properties evaluation

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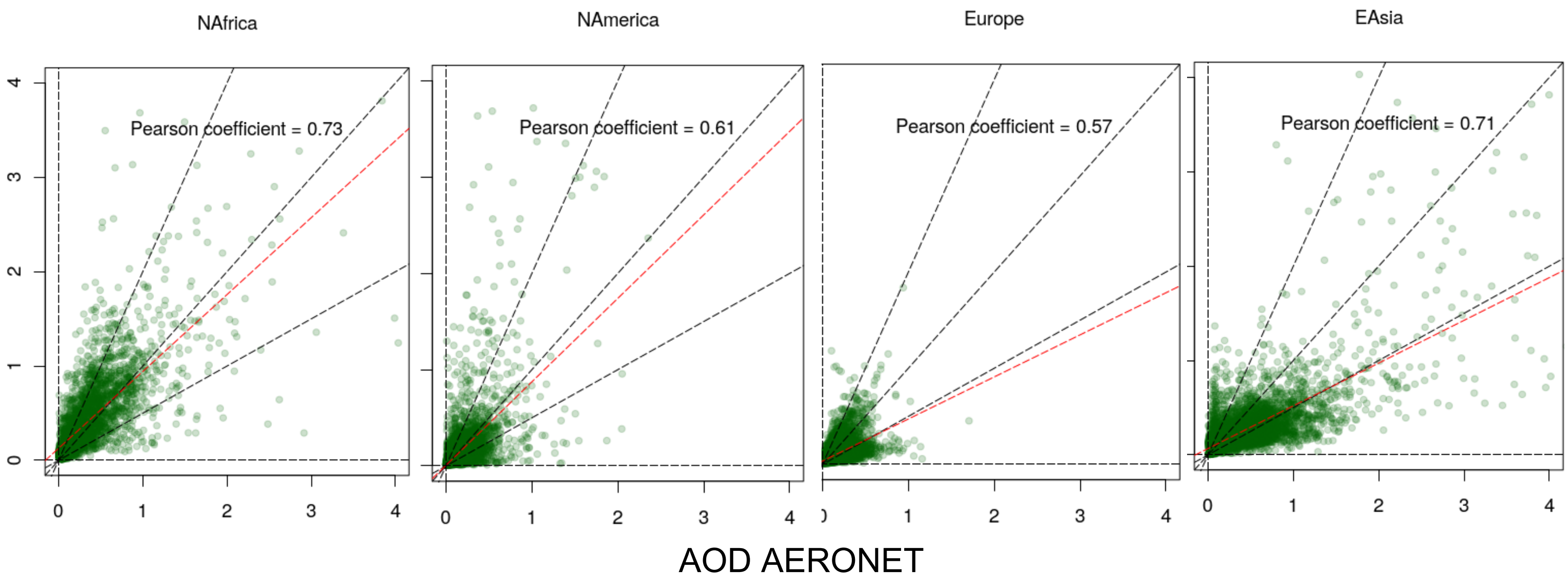
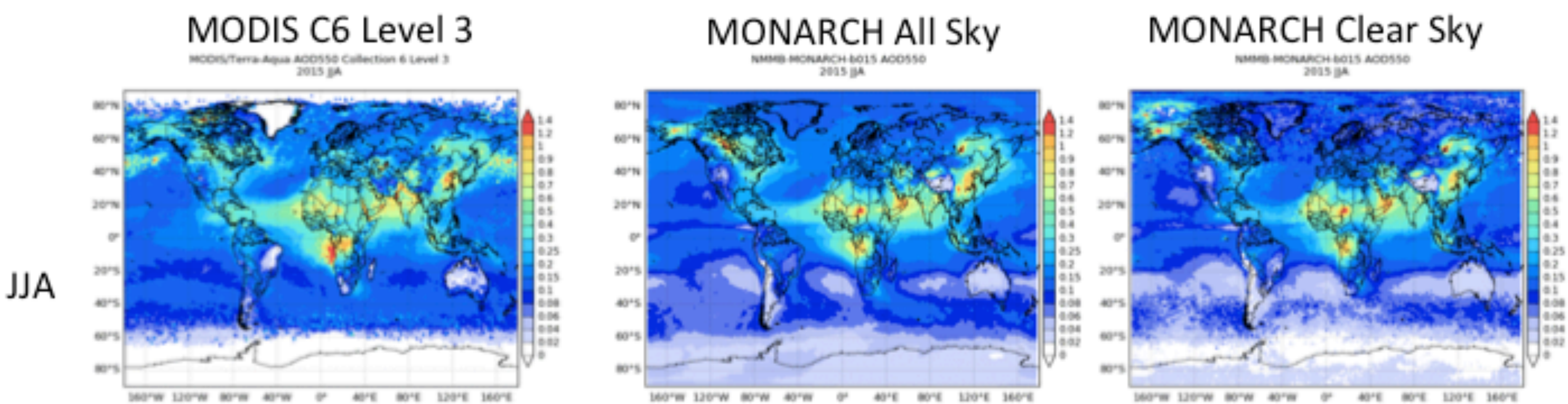
AOD evaluation: AERONET, MODIS





Aerosol intensive optical properties evaluation (Obiso, 2018)

CONTEXT AND OBJECTIVES

- Aerosol intensive optical properties: few and uncertain model evaluations [1,2,3,4]
- **Evaluation of full online aerosol-radiation coupling in NMMB-MONARCH**
- **Single scattering albedo** (ω) and **asymmetry factor** (g) against observations
- Impact of **new refractive indexes** on model performance

- MONARCH Global aerosol parameterization: 5 major aerosols
- Optical properties of aerosols in radiation from OPAC database

- **Global domain simulations**: *lon* x *lat* = 1.4ºx1.0º and 48 vertical layers
- 5-years period (**2012-2016**): spinup (1 year) and meteo initialization (24h, FNL)

1.Myhre et al. [2013a]; 2.Lacagnina et al. [2015]; 3.Takemura et al. [2002]; 4.Curci et al. [2015]

Updating microphysics (PTB case) [1]:

New refractive indexes at ~0.550 μm from recent literature

	DU [2]	SS [3]	POM [4] (anthropogenic)	BrC [5,6] (biom. burn.)	SOA [7,8] (biog. prec.)	BC [9]	SU [10]
n_r [1]	1.53 ↓ 1.531 (~)	1.5 ↓ 1.557 (+3.8%)	1.53 ↓ 1.501 (-1.9%)	1.53 ↓ 1.535 (~)	1.53 ↓ 1.486 (-2.9%)	1.75 ↓ 1.85 (+5.7%)	1.43 ↓ 1.546 (+8.1%)
n_i [1]	0.0055 ↓ 0.0025 (-54.5%)	0.00000001 ↓ 0.00000001 (~)	0.006 ↓ 0.00000001 (~ -100%)	0.006 ↓ 0.03 (+400%)	0.006 ↓ 0.000025 (~ -100%)	0.44 ↓ 0.71 (+61.4%)	0.00000001 ↓ 0.00000001 (~)

DU → ω ▲ g ▼ (coarse)

SS → τ ▲ (fine) g ▼

POM, SOA → τ ▼ ω ▲ g ▲

SU → τ ▲ g ▼

1.Hansen and Travis [1974]; 2.Denjean et al. [2016]; 3.Irshad et al. [2009]; 4.Shepherd et al. [2017]; 5.Tang et al. [2016]
6.Kirchstetter et al. [2004]; 7.Nakayama et al. [2012]; 8.Liu et al. [2013]; 9.Bond and Bergstrom [2006]; 10.Freedman et al. [2009]

Observations of τ, ω, g

Sun-photometers **AERONET** Version 2.0 [1,2]

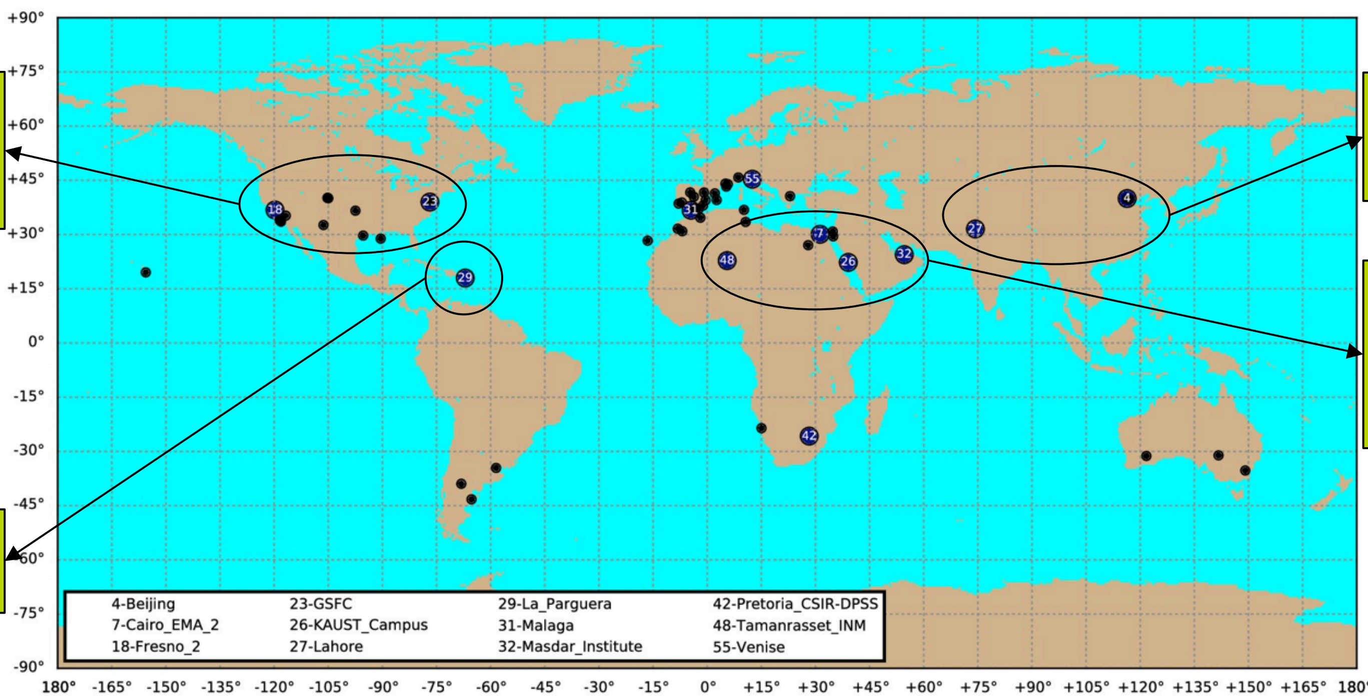
- Screened Level 1.5: Level 2 quality without optical depth filter: τ_{440} > 0.4 [3]
- 59 stations (full set): 20 data (daily τ, ω, g at 0.550 μm) per month (2012-2016)
- 12 stations (subset): i) observed τ, ii) dominant species, iii) geographical distribution

Fresno_2
GSFC

urban/ anthropogenic

La_Parguera

coastal



Beijing
Lahore

large urban

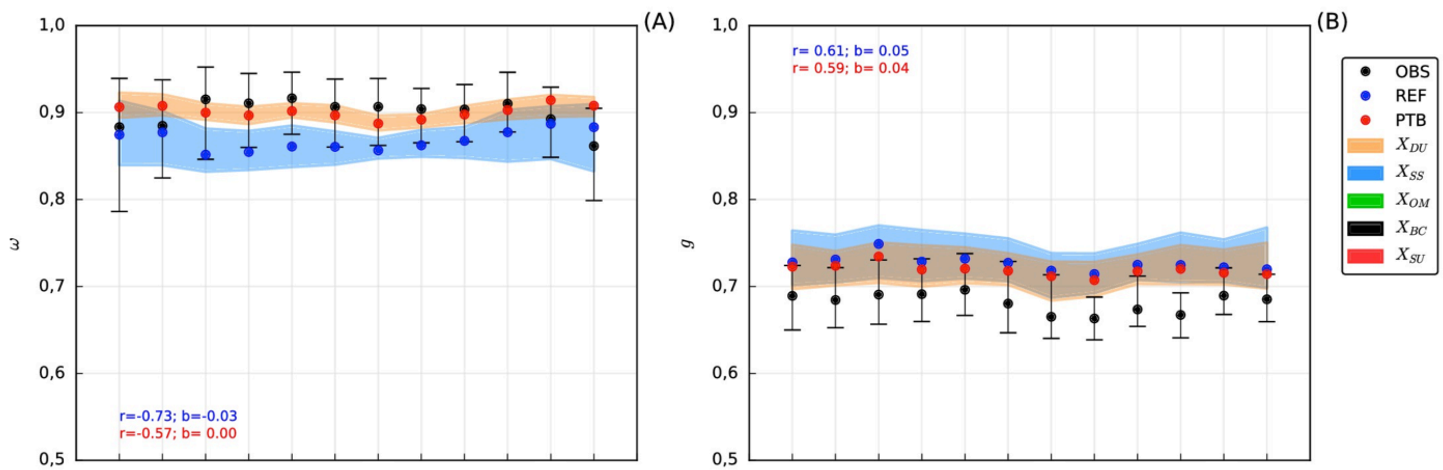
Cairo_EMA_2
KAUST_Campus
Masdar_Institute
Tamanrasset_INM

deserts/urban

1.Holben et al. [1998]; 2.Holben et al. [2006]; 3.Li et al. [2014]

Results: Impact of new refractive indexes

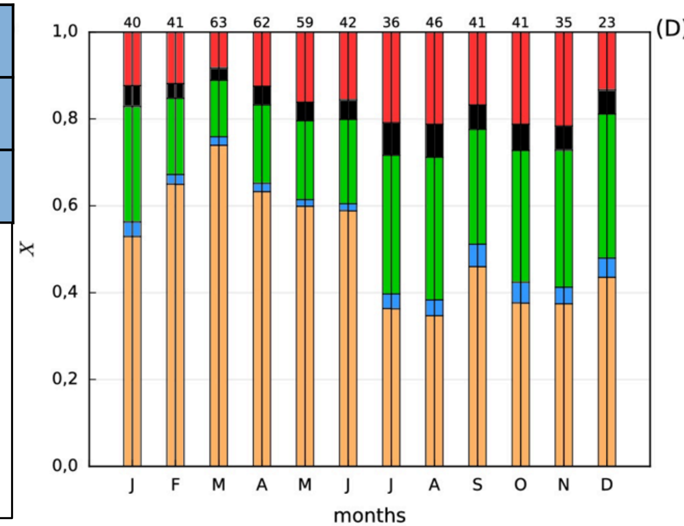
7-Cairo_EMA_2



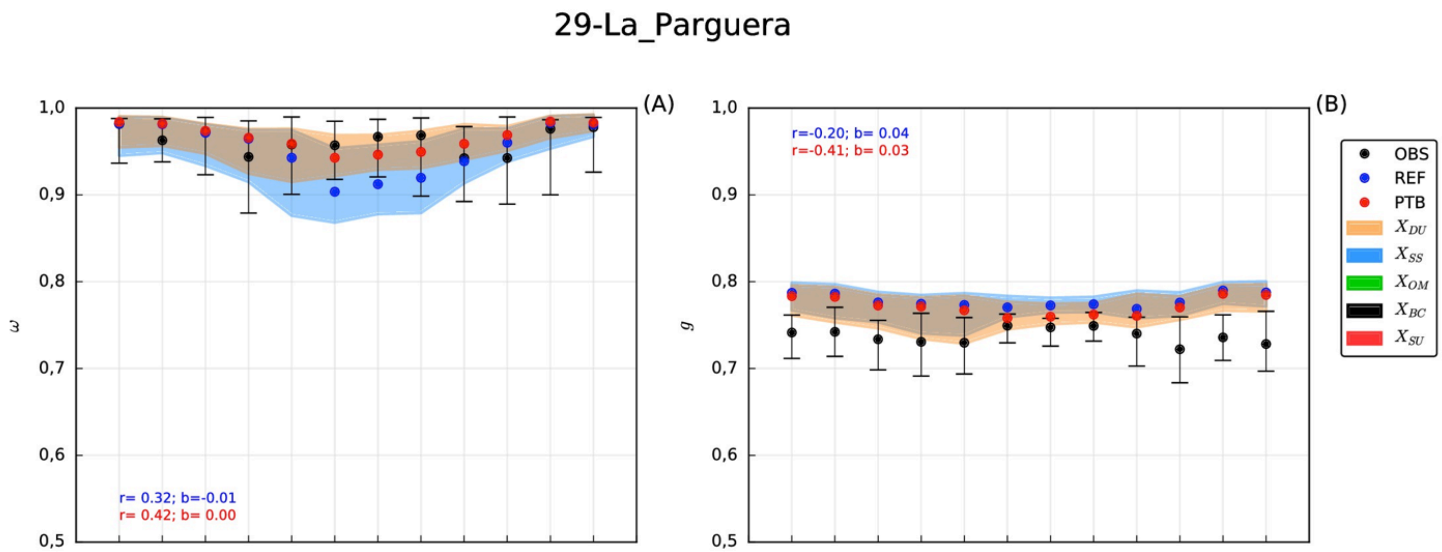
	ω	g
corr. variation	+0.16	-0.02
bias variation	+0.03	-0.01

New refractive index for DU and SS

- Strong ω increases ↔ DU peaks
- Slight g decreases ↔ DU peaks
- Further g reduction → more fine DU?



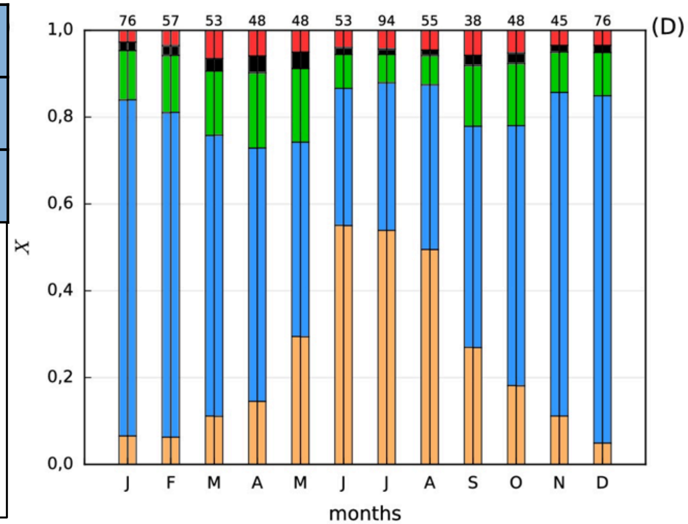
Results: Impact of new refractive indexes



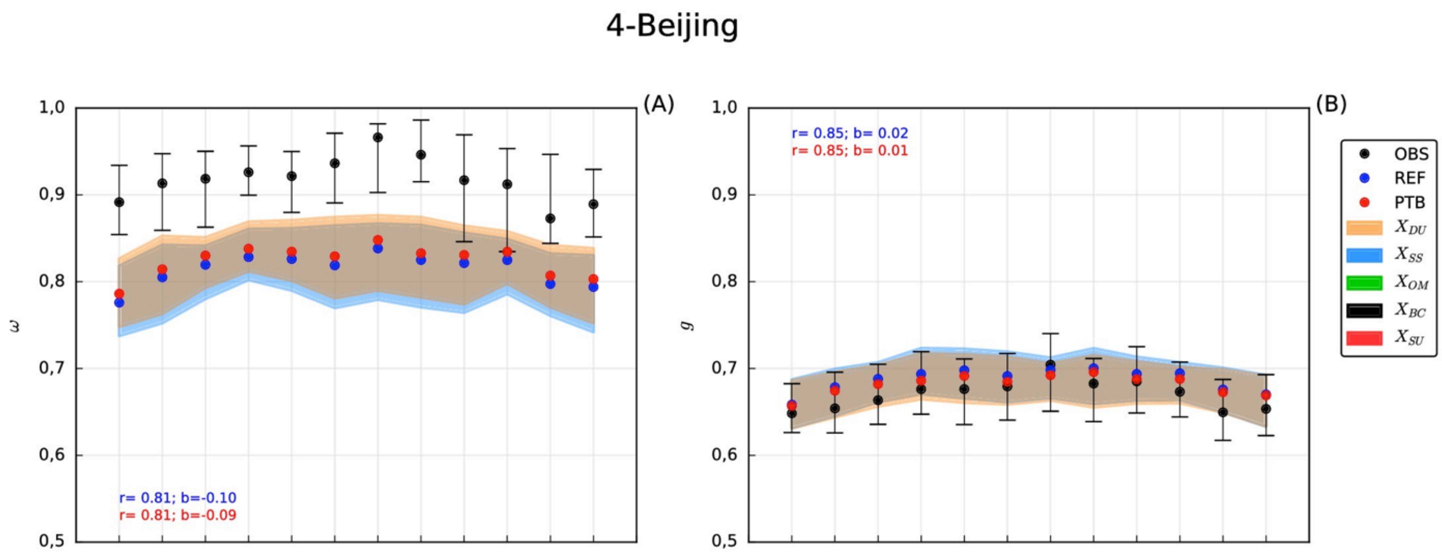
	ω	g
corr. variation	+0.10	-0.21
bias variation	+0.01	-0.01

New refractive index for DU and SS

- Stronger ω/g variations ↔ summer DU
- Negligible ω/g variations due to SS
- Further g reduction → more fine species?



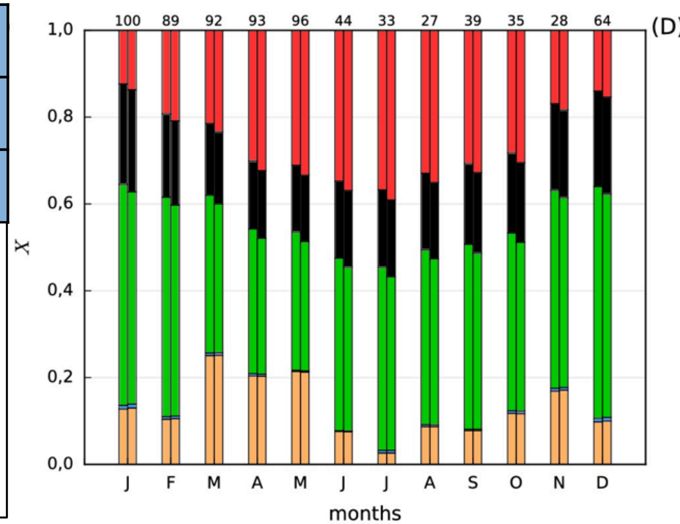
Results: Impact of new refractive indexes



	ω	g
corr. variation	0	0
bias variation	+0.01	-0.01

New refractive index for OM and SU

- Slight ω increases ↔ OM+SU changes
- Slight g decreases ↔ SU changes
- Stronger ω increases → less BC?



Data assimilation work

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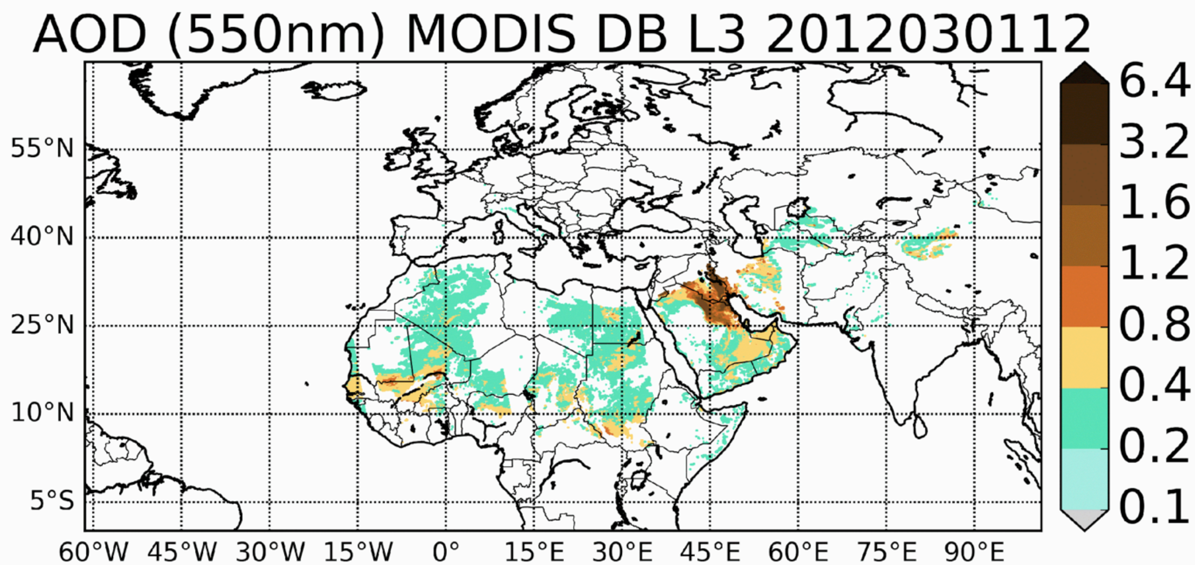
Produce a **high resolution dust reanalysis** for Northern Africa, Middle East and Europe covering the satellite era of quantitative aerosol information, and develop **dust-related services** tailored to specific socio-economic sectors.

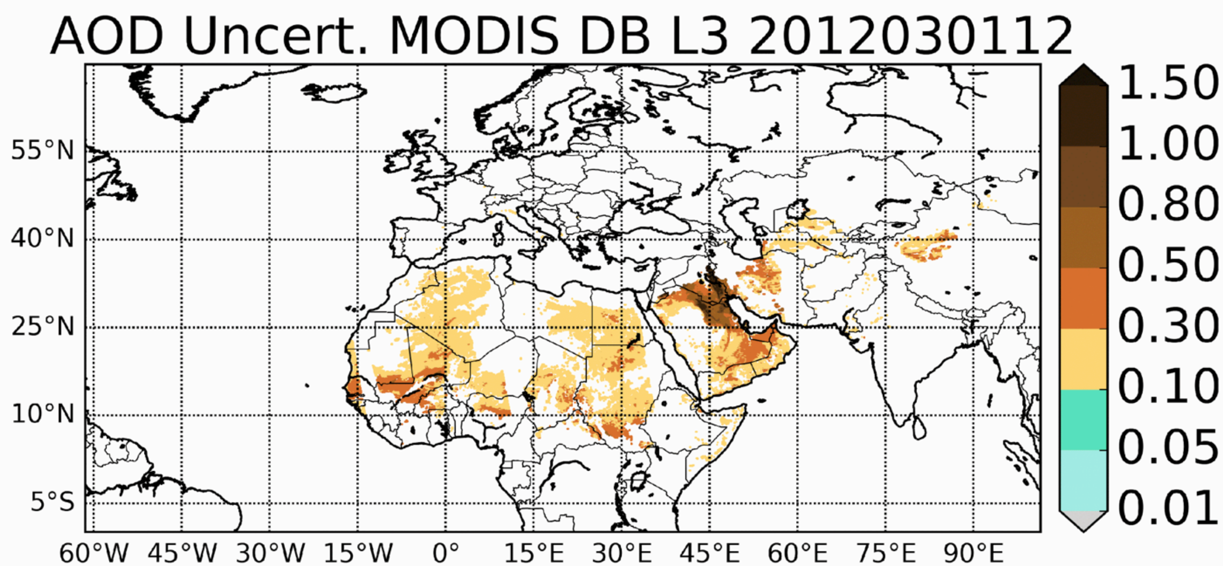
PI: Sara Basart
Period: 2017-2020

First test simulations: assimilated obs

MODIS Deep Blue, L2 C6

- *AE, ω filter, coarse AOD retrieval*
- *highest quality flag* (Ginoux et al., 2012; Pu & Ginoux 2017)
- *uncertainty model based on Sayer et al., 2014*





First test simulations: monthly analyses

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Year 2012

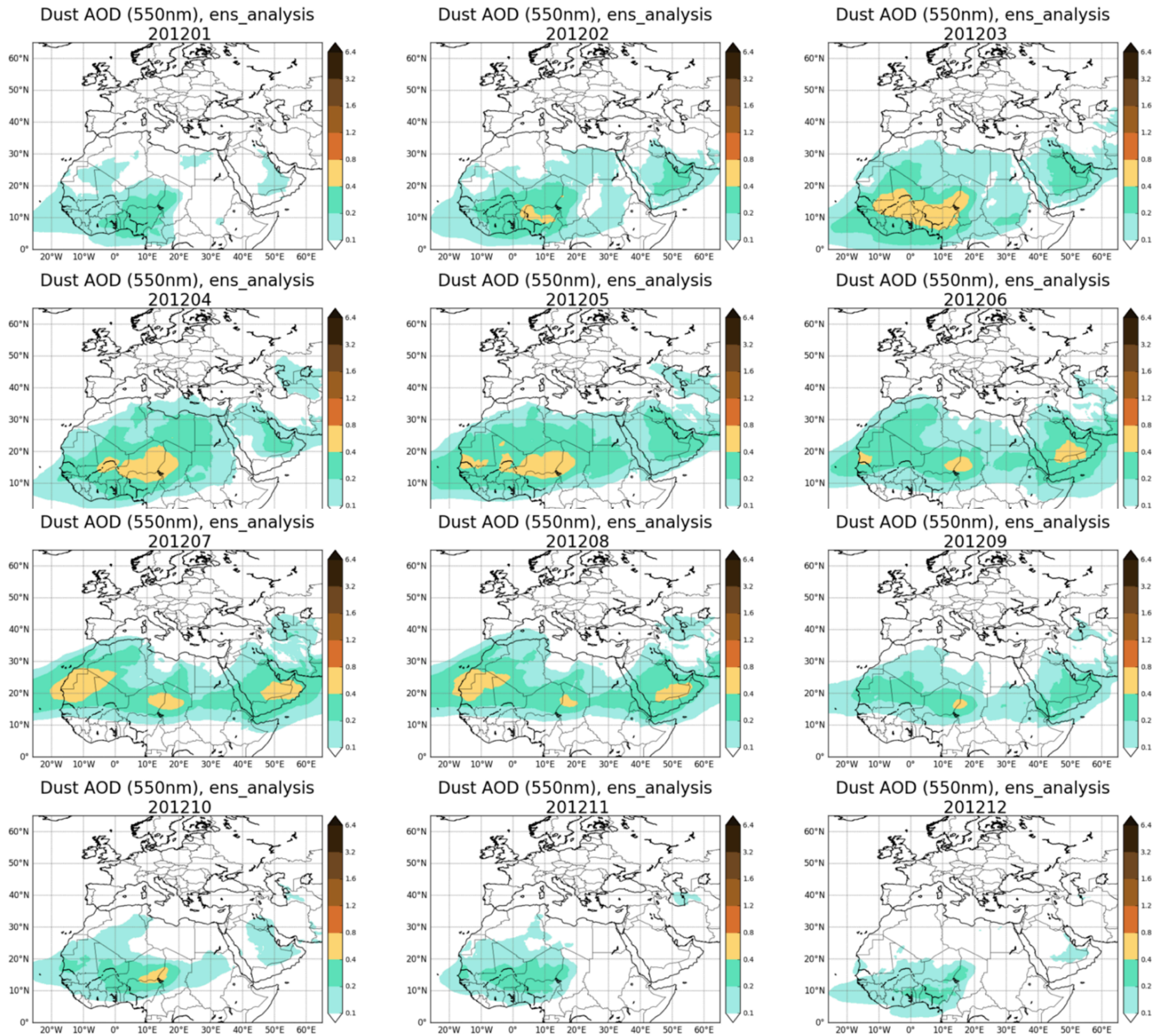
Resolution 0.1º

Next tasks:

- close-to-optimal configuration for the ensemble

- tuning of DA parameters

- treatment of the observations.



Aerosol_cci project

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IMARS DLR

LMD LMD

MAPIR BIRA-IASB aeronomie·be

ULB ULB UNIVERSITÉ LIBRE DE BRUXELLES

IASI dust AOD

- observations available day time and night time
- over ocean and over land (desert)
- 10 µm: detection of dust aerosol coarse mode (infrared wavelengths and ''V'' shaped depression of the Brightness Temperature)
- pixel level uncertainty

2006	2012	2018	2021	2028	2035
IASI/ Metop-A	IASI/ Metop-B	IASI/ Metop-	IASI-NG/ Metop-SG	IASI-NG/ MetopSG-B	IASI-NG/ MetopSG-C

Aerosol_cci: IASI analyses

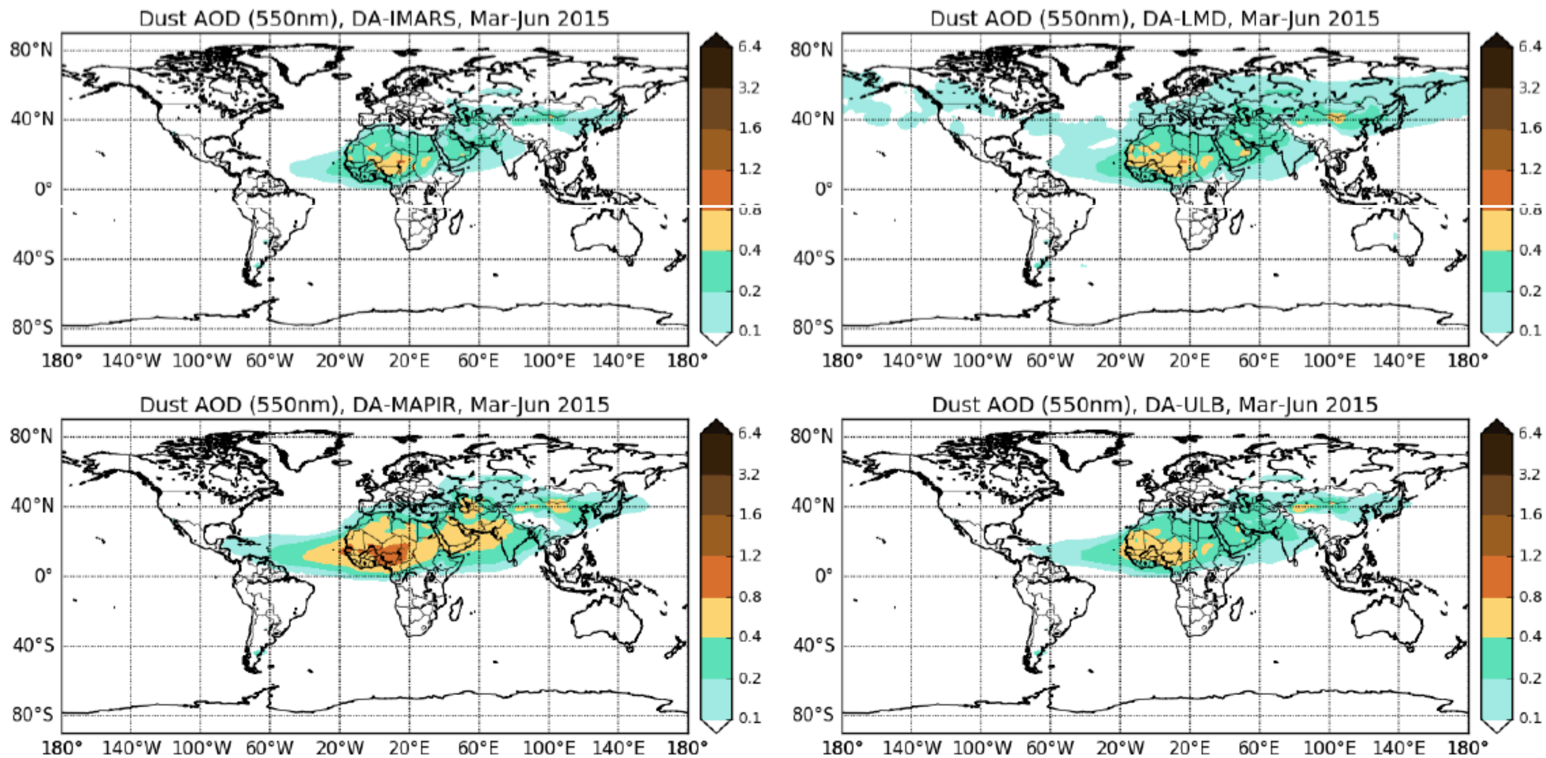
Updates: case study completed with the latest version of products provided by the retrieval teams and over an extended period (Mar-Jun 2015)

IMARS

LMD

MAPIR

ULB

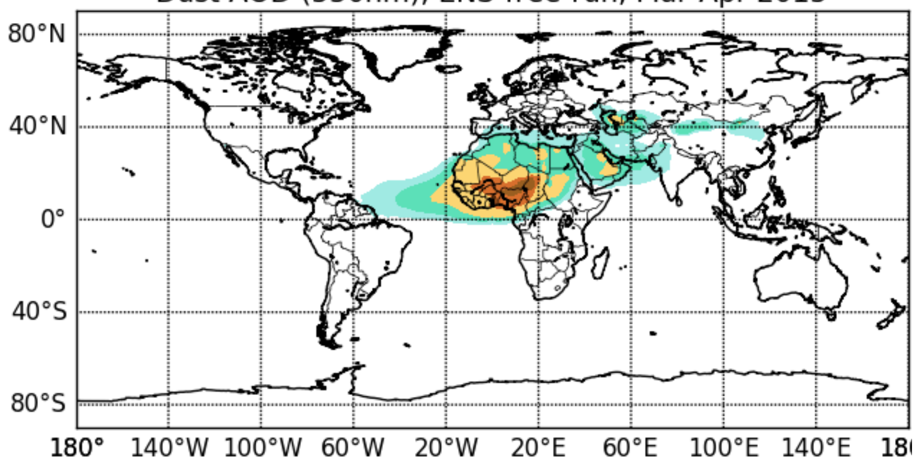


- Overall all the retrievals tend to produce an analysis that underestimates dust AOD (close to sources), with the exception of MAPIR;
- The assimilation of the IMARS product produces the least encouraging scores;
- The assimilation of LMD product is globally overall neutral (but with improvement in the correlation to AERONET in the Atlantic transport);
- Slightly reduced RMSE and higher correlation coefficients than the Control experiment are reported globally for the DA-MAPIR and DA-ULB experiments.

Exercise on observation uncertainty

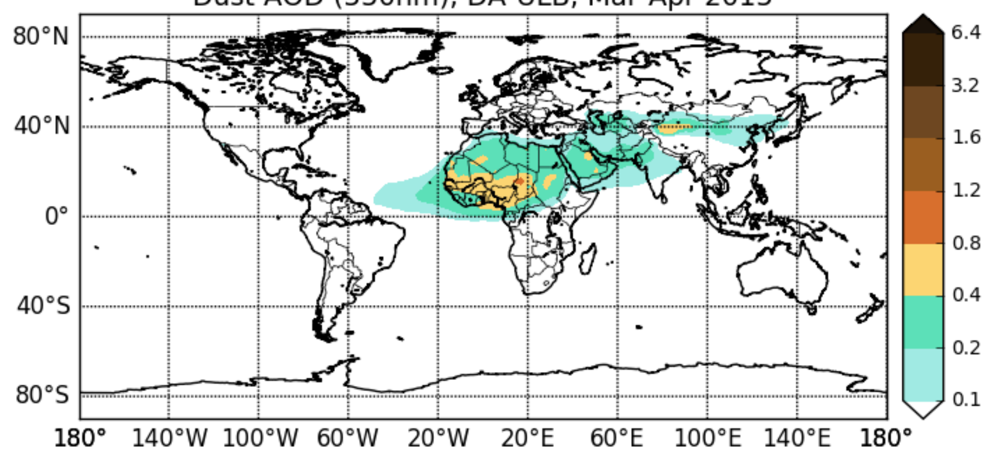
Free-run

Dust AOD (550nm), ENS-free-run, Mar-Apr 2015



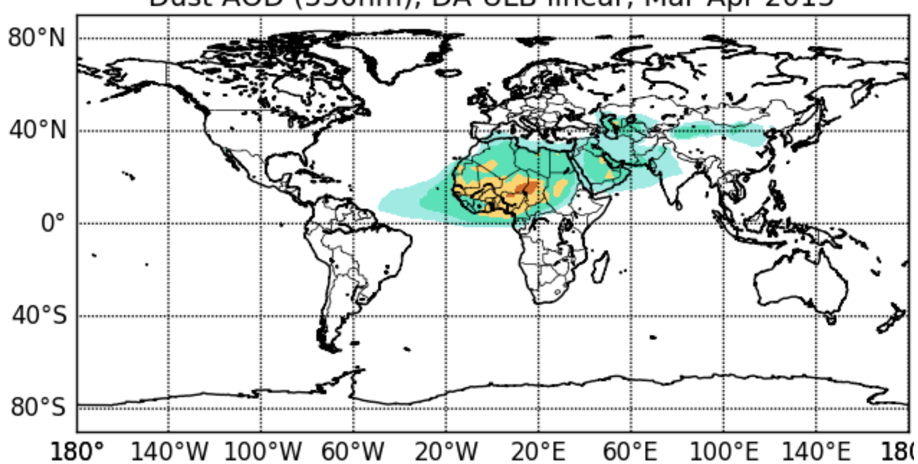
ULB AOD_unc

Dust AOD (550nm), DA-ULB, Mar-Apr 2015



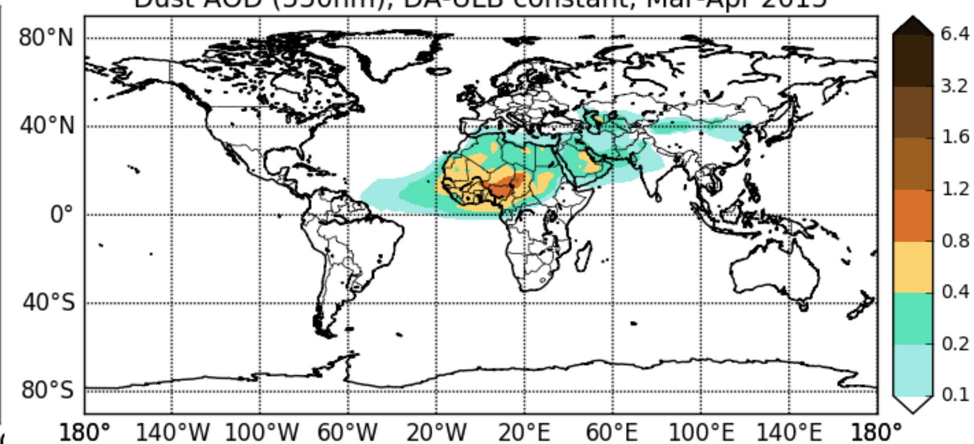
Linear: AOD_unc = 0.1 + 0.54 * AOD

Dust AOD (550nm), DA-ULB linear, Mar-Apr 2015



Constant: AOD_unc = 0.35

Dust AOD (550nm), DA-ULB constant, Mar-Apr 2015



- Relevant impact of the observation error characterization
- Further studies on the characterization of observation uncertainty for DA are needed

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Thank you!

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