NMMB/BSC-CTM updates

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ICAP Meeting, Maryland, 12 July 2016

NMMB/BSC-Chemical Transport Model

- Multiscale: regional to global scales
- On-line coupled aerosols and chemistry allowing consistency and feedbacks

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)*
→ *(...)*

NMMB/BSC-CTM

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. (in prep)*

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

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	NMMB/BSC-CTM	NMMB/BSC-CTM	CMAQ (DREAM for dust) NMMB/BSC-CTM
Status	QO	O	O
Meteorology	Inline: NMMB	Inline: NMMB nesting	Offline: WRF-ARW Inline: NMMB nesting
Resolution	1.4x1 0.7x0.5	0.1x0.1 0.03x0.03	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) BSC-CTM aerosols
Gas phase chemistry	CBM-IV CB05		CB05 CB05
Emissions	AEROCOM, MEGAN		EMEP, MEGAN / HERMES, MEGAN/ HERMES MEGAN
Bio. Burn. Emissions	AEROCOM NRT		NA NRT

Aerosols

Sectional

dust (DU)

sea-salt (SS)

Bulk

Black Carbon (BC)

Organic Aerosols (OA)

Primary Organic Aerosols (POA)

Secondary organic aerosols (SOA)

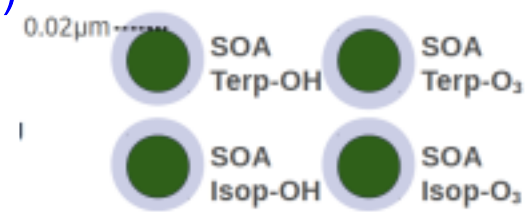
4 gaseous tracers (OH, O3, TERP, ISOP). Online emission (MEGAN)

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

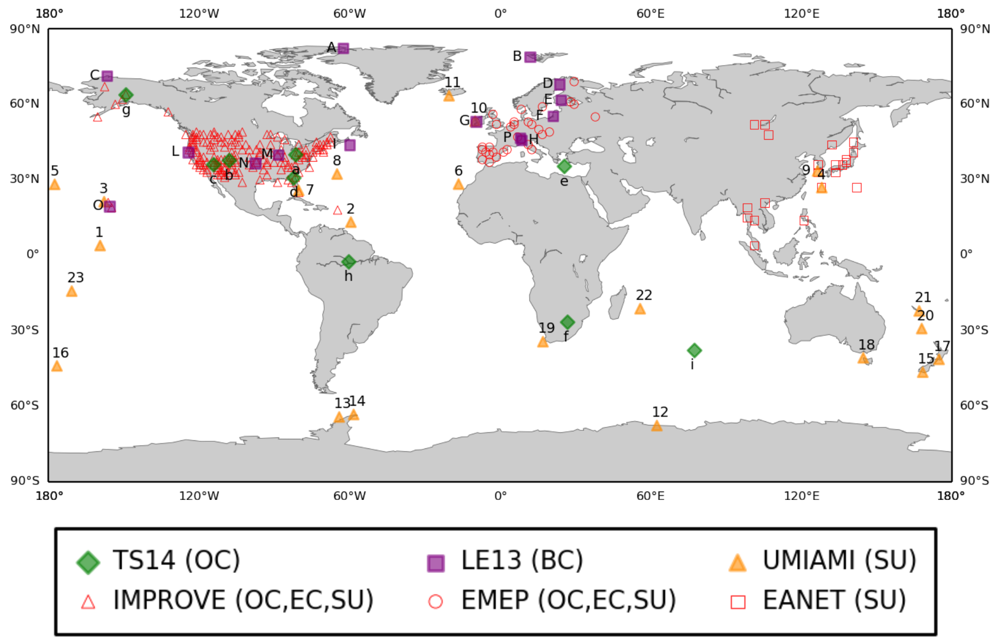
Aerosol Physics

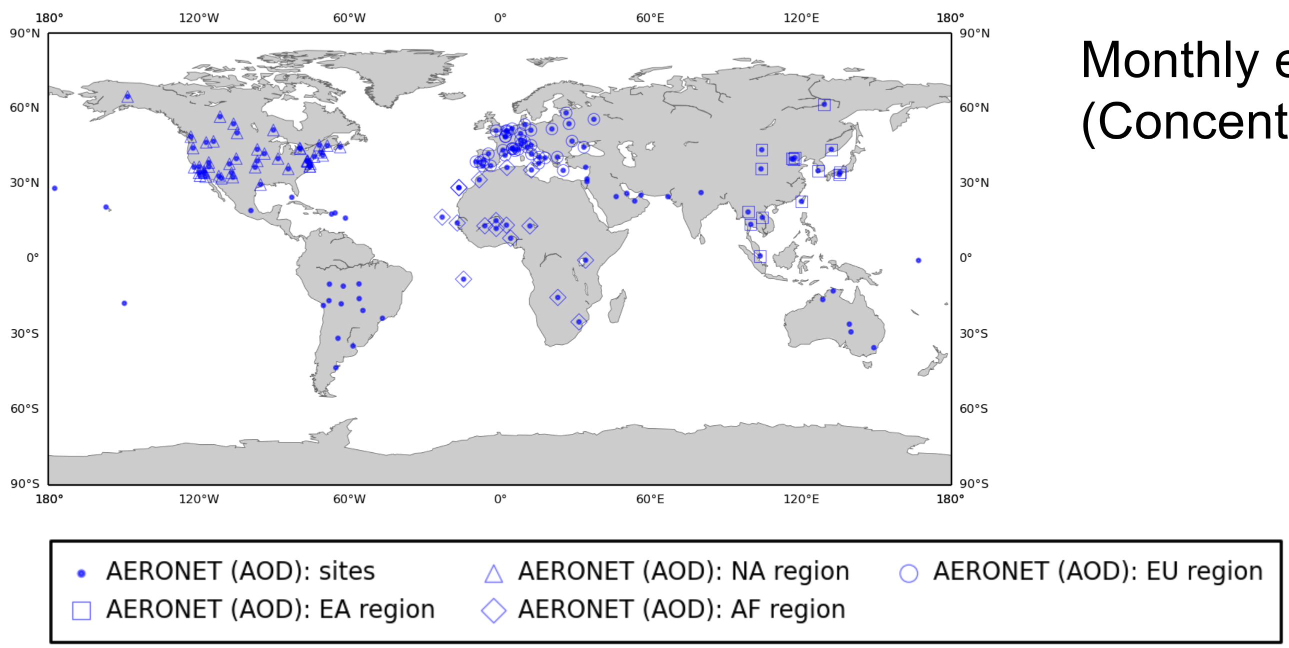
- Dry deposition: aerodynamic and surface resistance (Zhang et al., 2001)
- Gravitational settling: Stokes approximation, Cunningham correction factor. Both implicit and explicit upwind schemes available.
- In-cloud and below cloud scavenging from grid-scale (Ferrier Microphys.) and sub-grid scale (BMJ) 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

Gas-phase chemistry

- OH, O3, HO2: for aerosol calculations we can use online gas-phase simulations or off-line climatologies
- Carbon-bond CBM-IV and CB05 mechanisms implemented (Gery et al., 1989; Yarwood, 2005)
- Coupled with Fast-J photolysis scheme (Wild et al., 2000)
- Mechanism implemented through KPP kinetic pre-procesor (Damian et al., 2002)
- Implemented an EBI solver for CB05 as in CMAQ. Includes 51 chemical species and 156 reactions. Working version and thoroughly tested.
- Stratospheric ozone: linear model Cariolle and Teyssèdre (2007) or Monge-Sanz et al. (2011)

Spada et al. (GMD in prep)





5 yr global simulation (2002-2006)

Resolution 1x1.4

3-hr offline oxidants

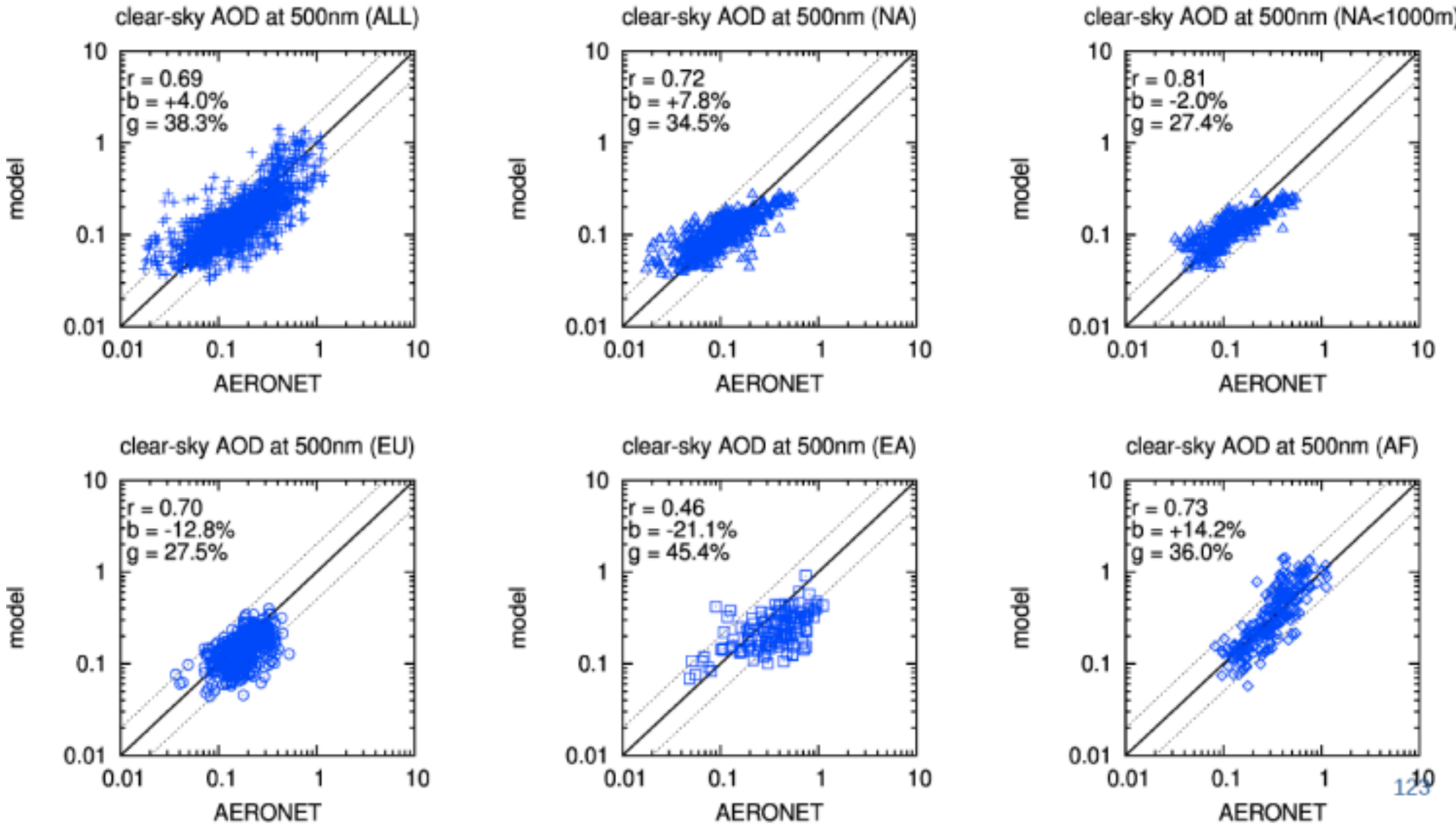
OA/OC=1.8

Monthly evaluation (Concentration, AOD)

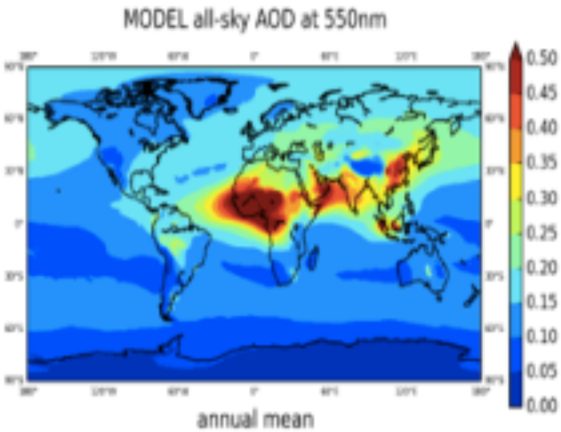
Spada et al. (GMD in prep) Emissions

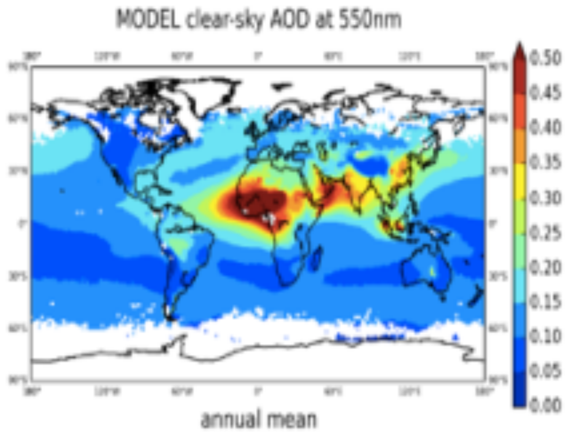
source	species	temp. res.	temp. range	reference	vert. height (m)
			off-line		
traffic	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	0–10
agric. waste	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	0–100
domestic	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	0–10
energy prod. plants	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	100–300
industrial plants	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	100–300
waste	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	100–300
ships	POA, BC, SO2	yearly	2002–2006	AEROCOM-ACCMIP	0–30
aircrafts	BC	yearly	2002–2006	AEROCOM-ACCMIP	25 levels interp. to model grid
grassland bb	POA, BC, SO2	monthly	2002–2006	AEROCOM-ACCMIP	IS4FIRES clim.
forest bb	POA, BC, SO2	monthly	2002–2006	AEROCOM-ACCMIP	IS4FIRES clim.
oceanic DMS	DMS	monthly	2000	MOZART	0–10
volcanos (non-erup.)	SO2	daily	2002–2006	AEROCOM-HC	upper 1/3 of volc. plume
			on-line		
biogenic	TERP, ISOP	online	–	MEGAN	0–10
desert dust	DU	online	–	Pérez et al. (2011)	surface layer
sea-salt	SS	online	–	Monahan et al. (1986)	0–10

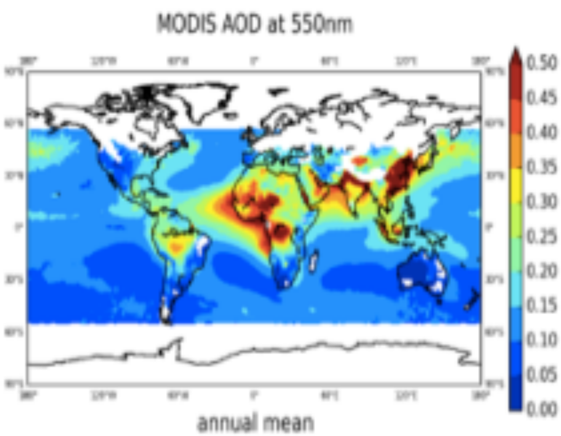
AERONET AOD at 550nm

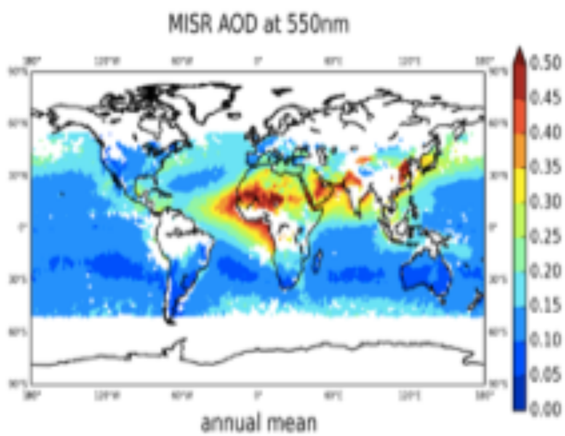


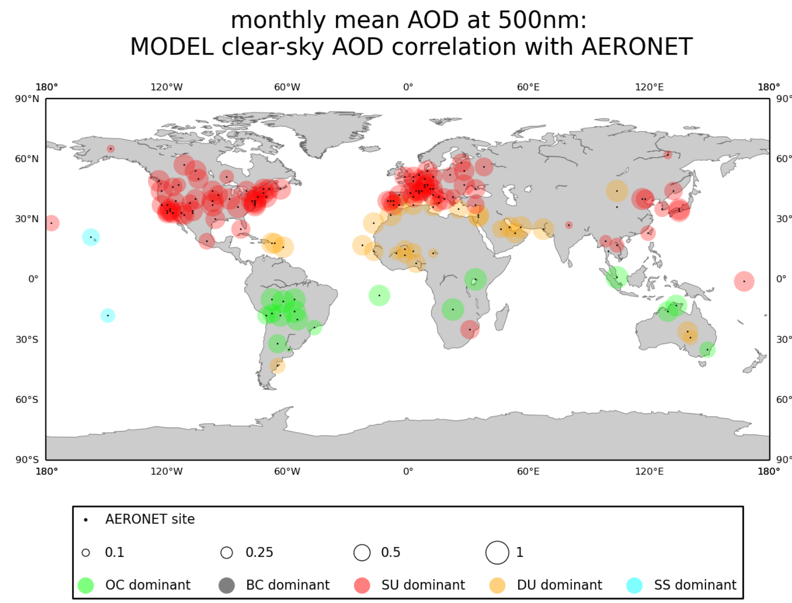
MODIS, MISR, AERONET

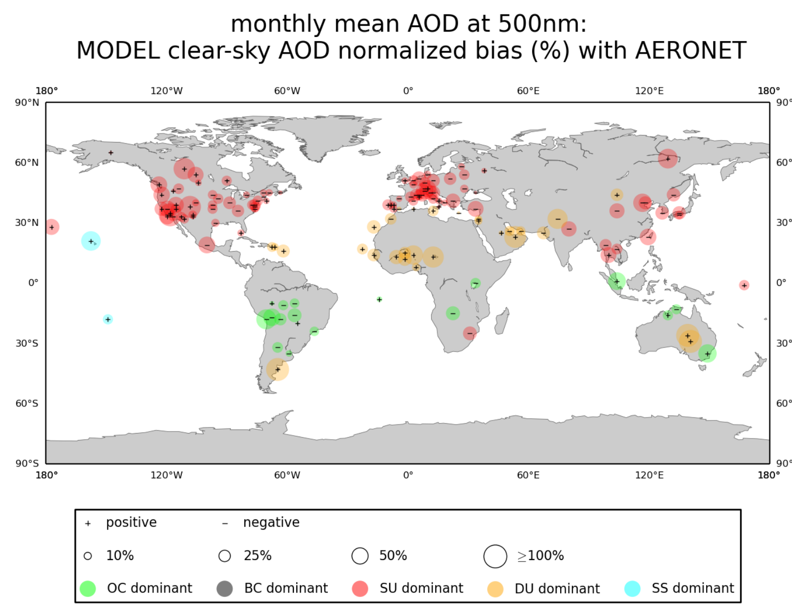




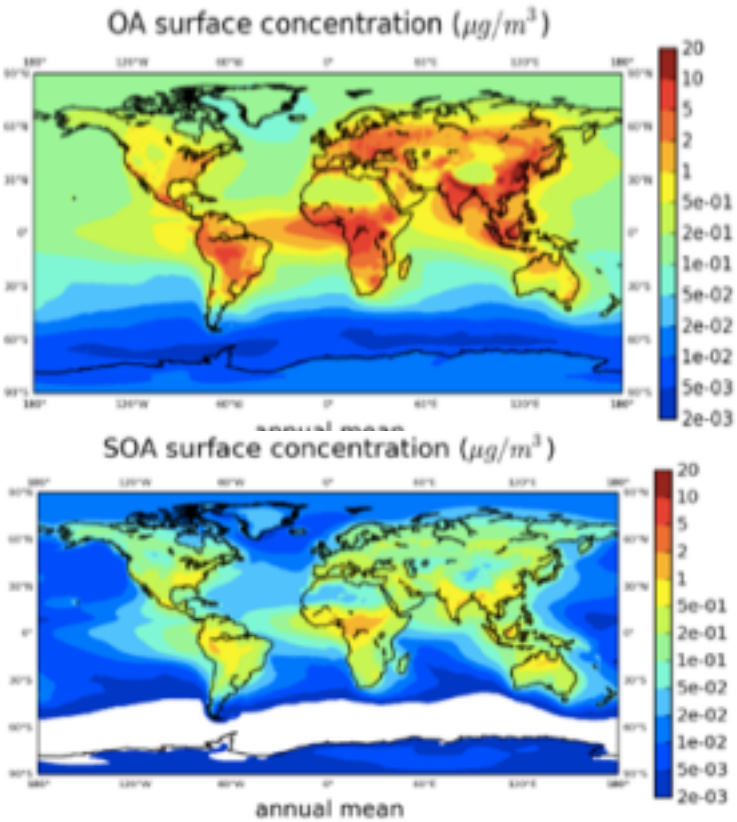


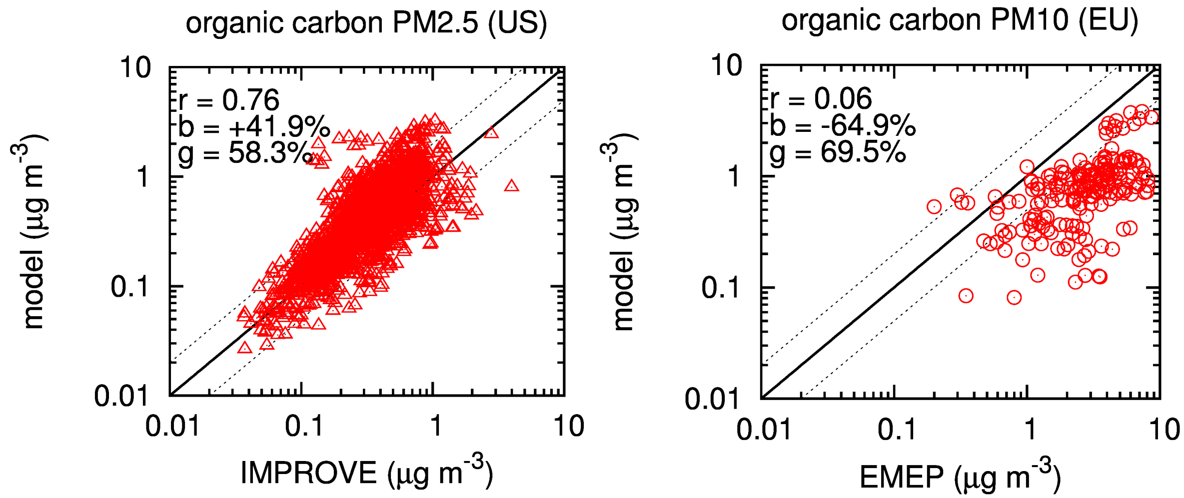






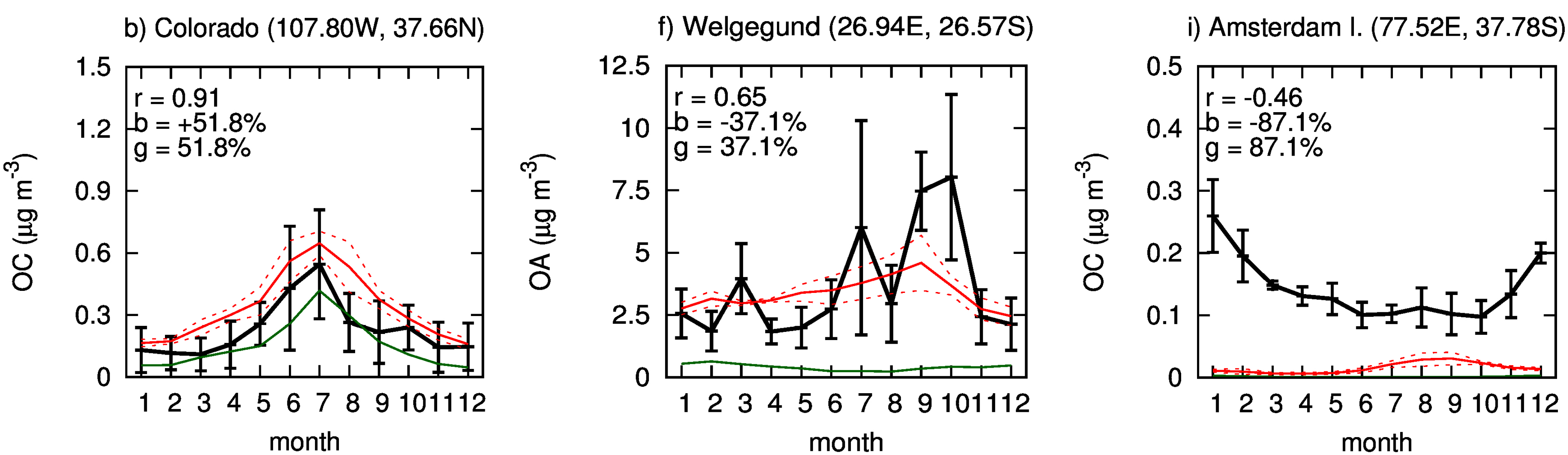
Organic Aerosol



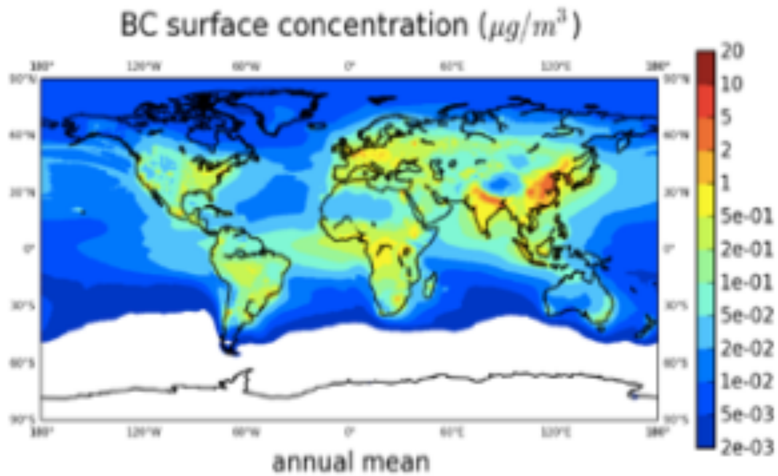


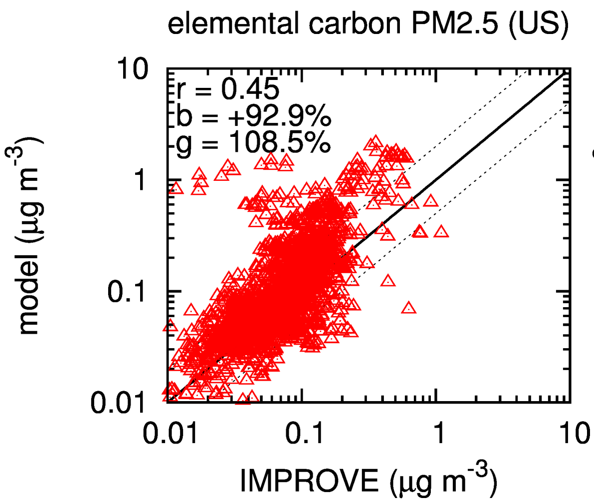
	AC-II median	BSC-CTM
r	0.47	0.76
RMSE	1.08	0.39

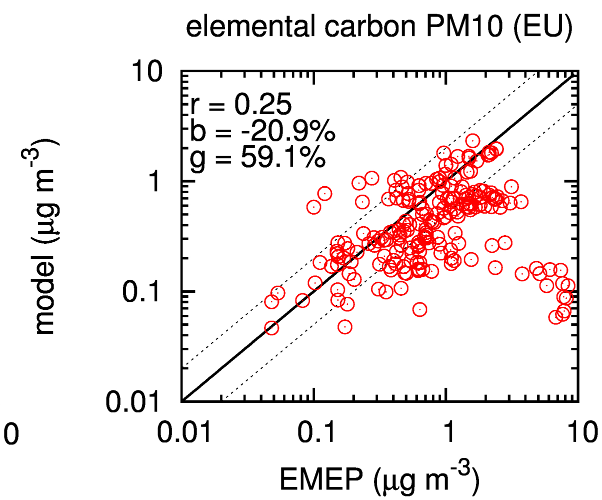
	AC-II median	BSC-CTM
r	0.12	0.06
RMSE	3.84	3.92



Black Carbon

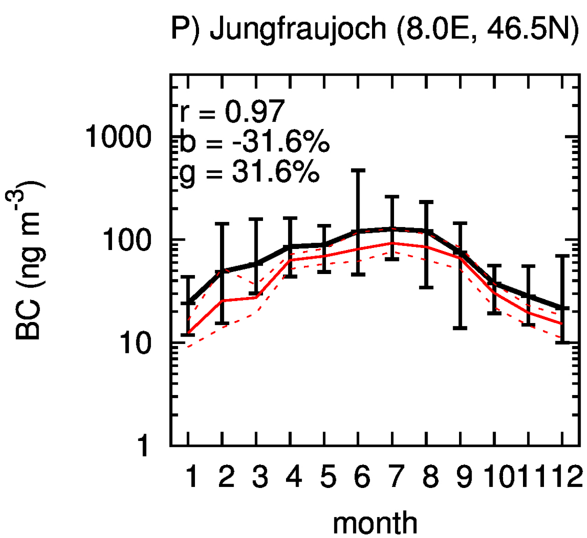


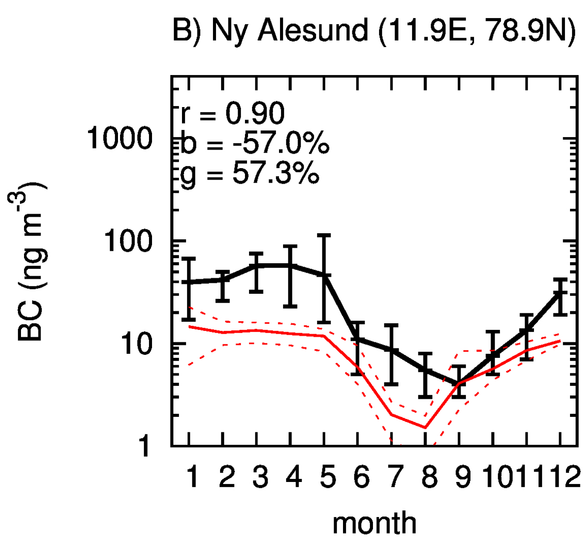


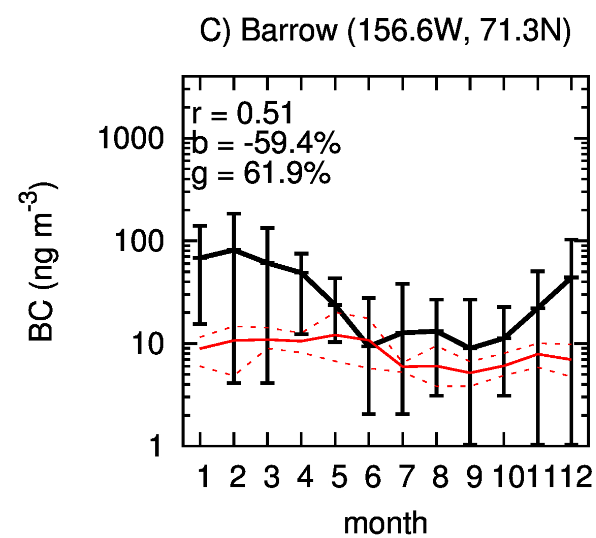


AC-II median

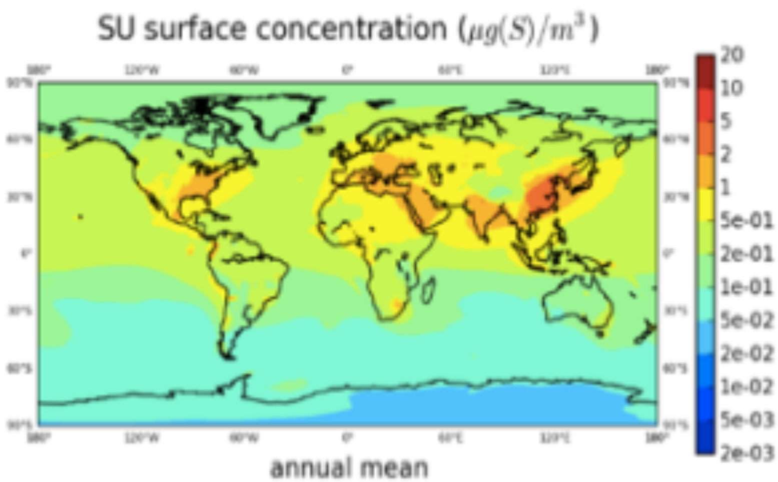
r -0.23

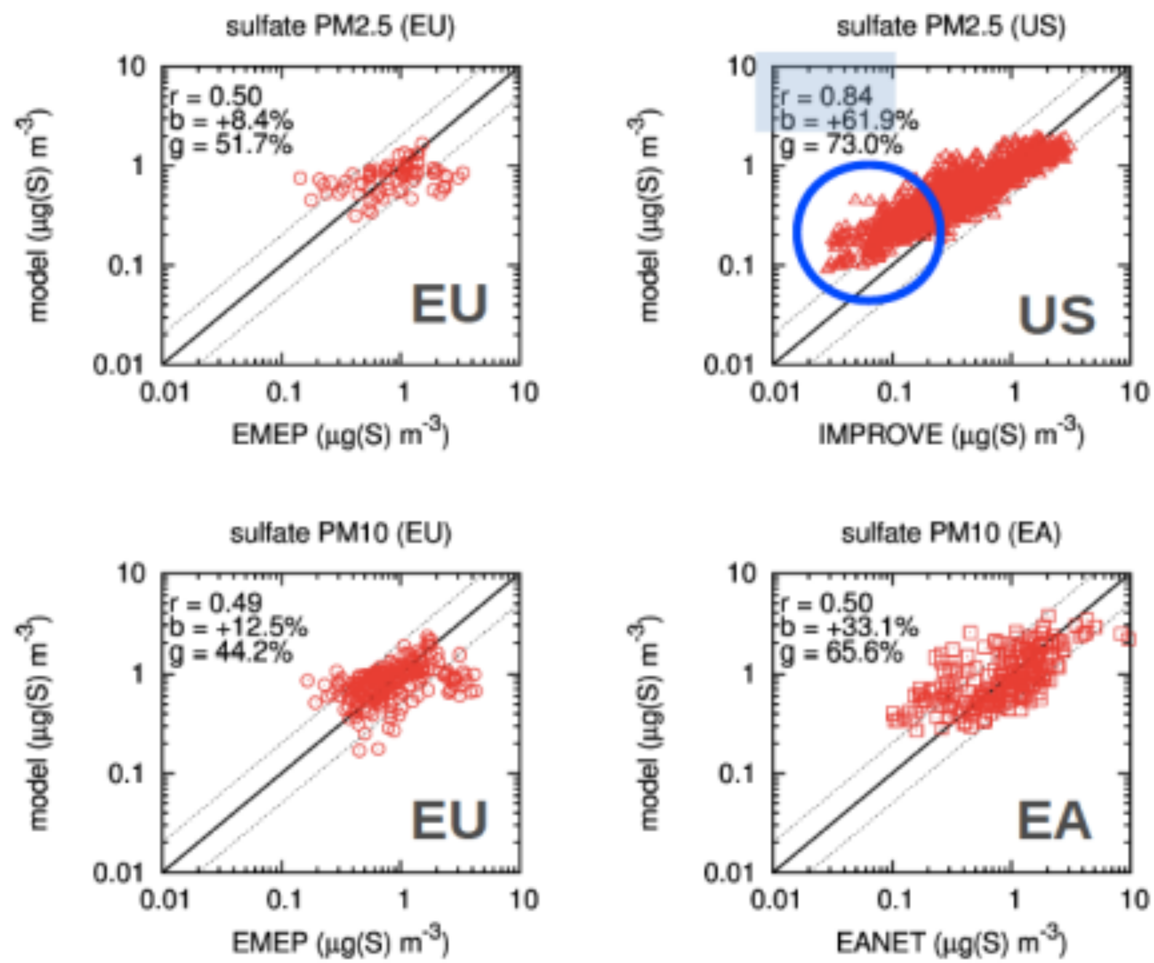






Sulfate

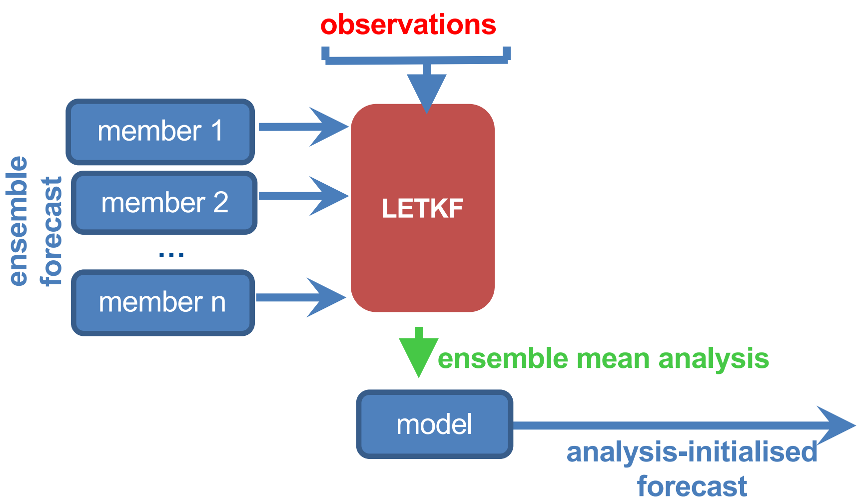

SU surface concentration ($\mu g(S)/m^3$)
annual mean
20
10
5
2
1
5e-01
2e-01
1e-01
5e-02
2e-02
1e-02
5e-03
2e-03


sulfate PM2.5 (EU)
r = 0.50
b = +8.4%
g = 51.7%
EU
EMEP (µg(S) m^{-3})
model (µg(S) m^{-3})
sulfate PM2.5 (US)
r = 0.84
b = +61.9%
g = 73.0%
US
IMPROVE (µg(S) m^{-3})
sulfate PM10 (EU)
r = 0.49
b = +12.5%
g = 44.2%
EU
EMEP (µg(S) m^{-3})
sulfate PM10 (EA)
r = 0.50
b = +33.1%
g = 65.6%
EA
EANET (µg(S) m^{-3})

Dust data assimilation

(DiTomaso et al. (GMD submitted)

The NMMB/BSC-CTM is coupled with a with Local Ensemble Transform Kalman Filter (LETKF)



Updates:

- Creation of the ensemble: based on some of the uncertainties in the dust emission scheme

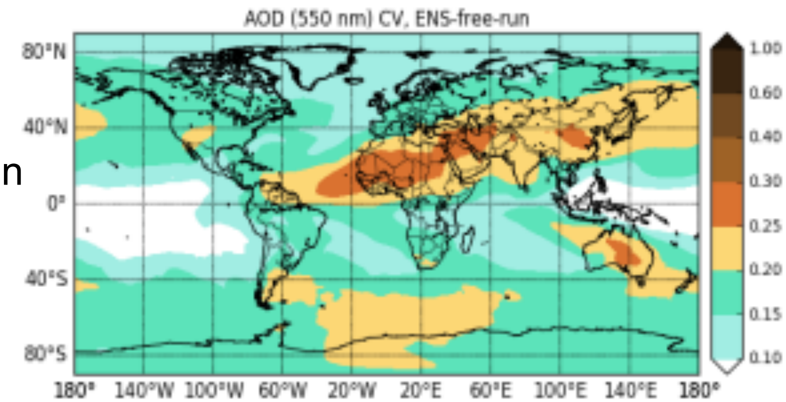
- validation of analysis and forecast with the new configuration

- MODIS Dark Target and Deep Blue

Spread of the Ensemble

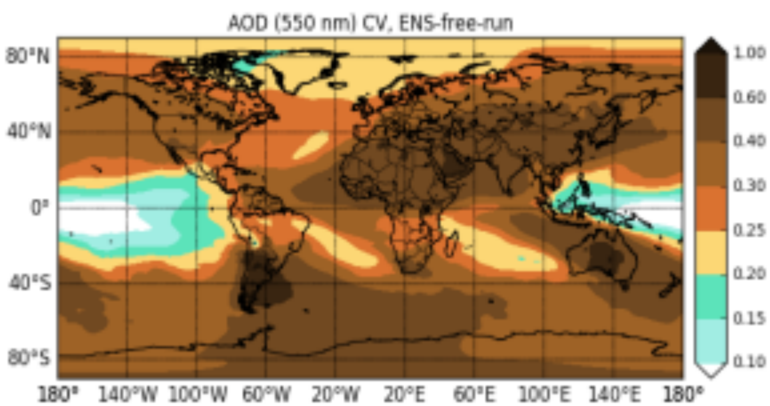
CV=coefficient of variation of the ensemble (=std/mean)

Free Run



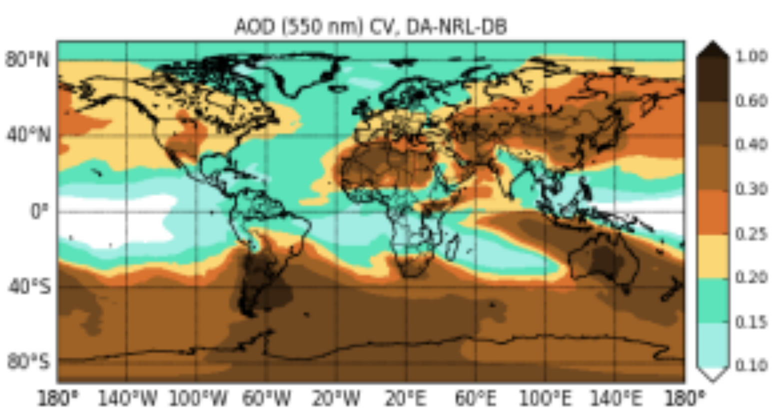
- Perturbing the vertical flux of dust in each of the eight dust bins
- (equivalent to perturbing the total vertical flux as well as the its size distribution at sources)
- Produces a reduced spread

Free Run



- Ensemble created perturbing the emitted mass vertical flux for each dust bin and also the threshold on the friction velocity
- (multiplicative random factor from a normal distribution with mean 1 and spread 0.4)
- Impact on the spread also outside source regions (spin-up period for the ensemble ensures propagation far away from sources)

DA Run



- Reduction of the ensemble spread generally where observations are present

First-guess and Analysis Departures

First-guess

Analysis

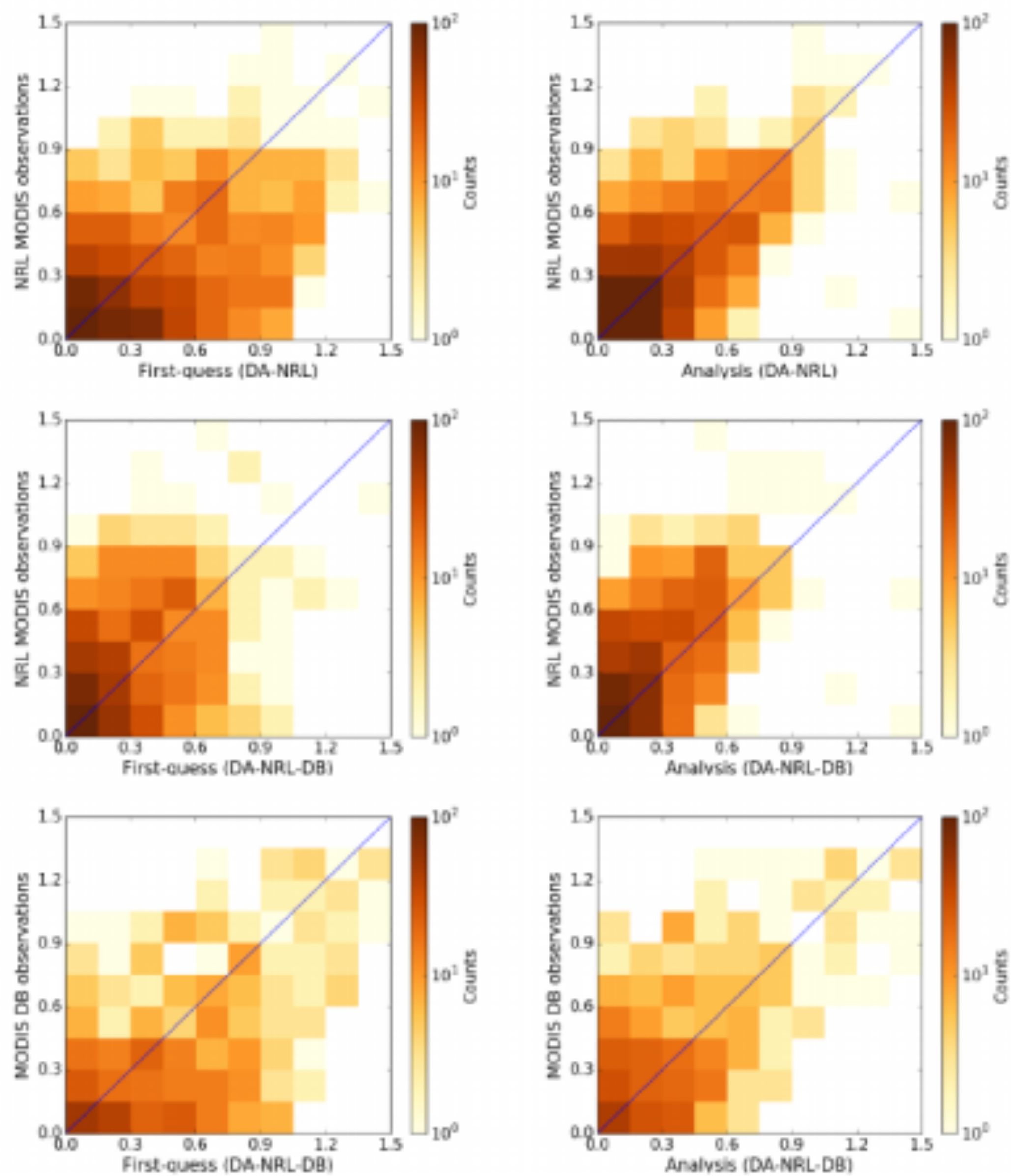
MODIS Dark Target (NRL)

Dark target assimilation experiment

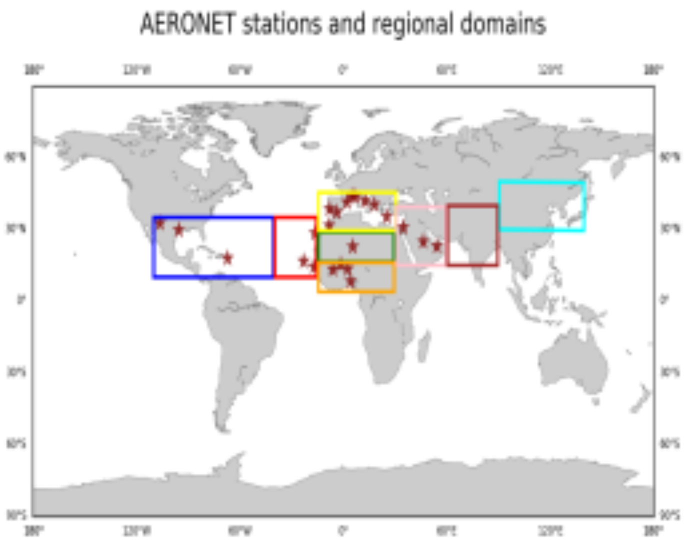
MODIS Dark Target (NRL)

MODIS Deep Blue

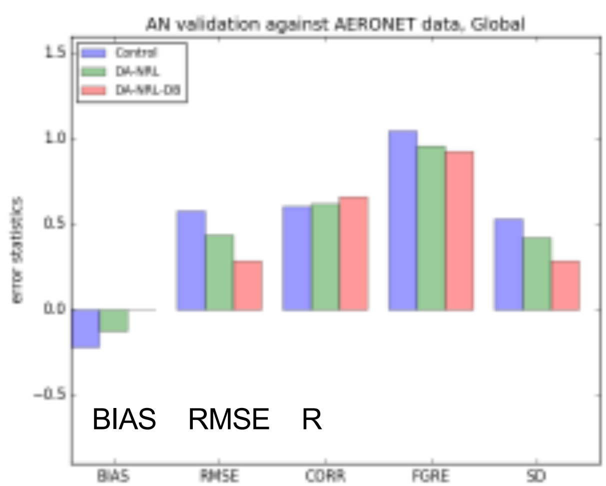
Dark Target + Deep Blue assimilation experiment



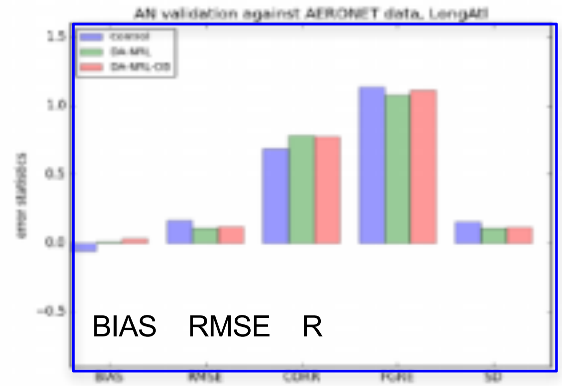
Analysis validation

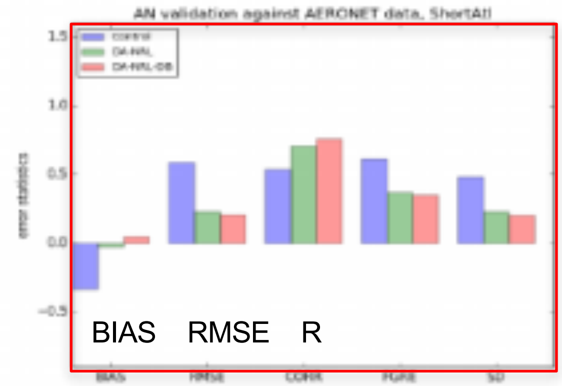


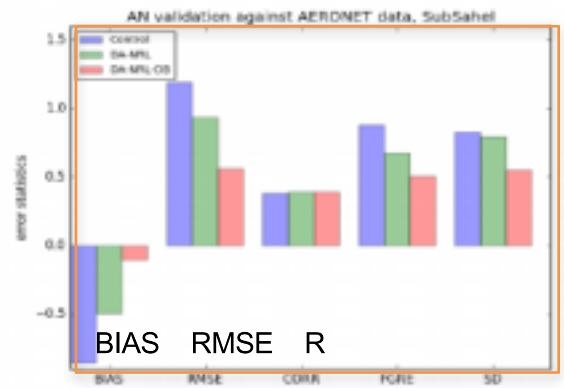
Global Scores

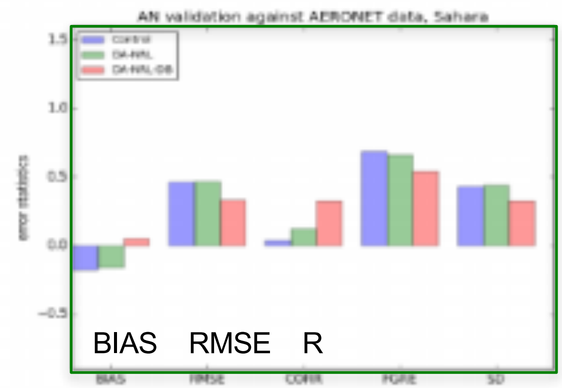


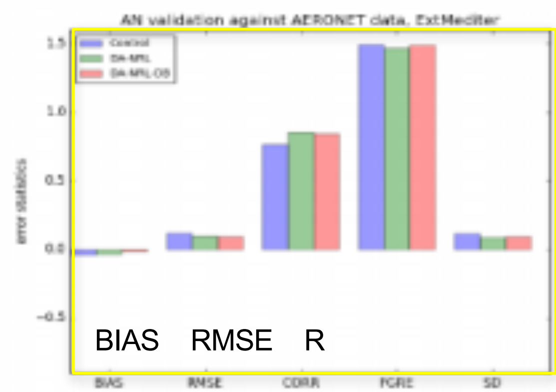
Regional Scores

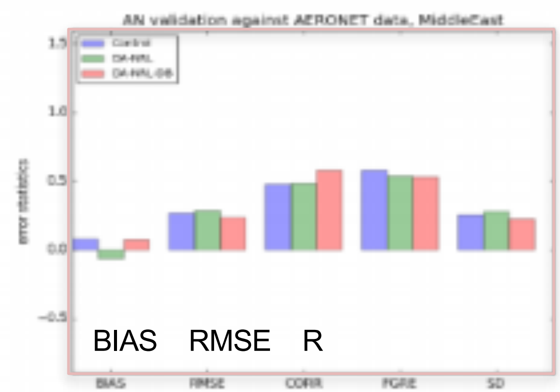






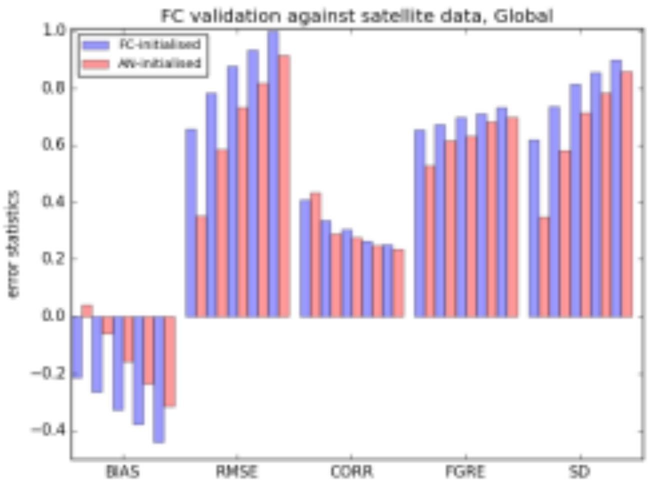






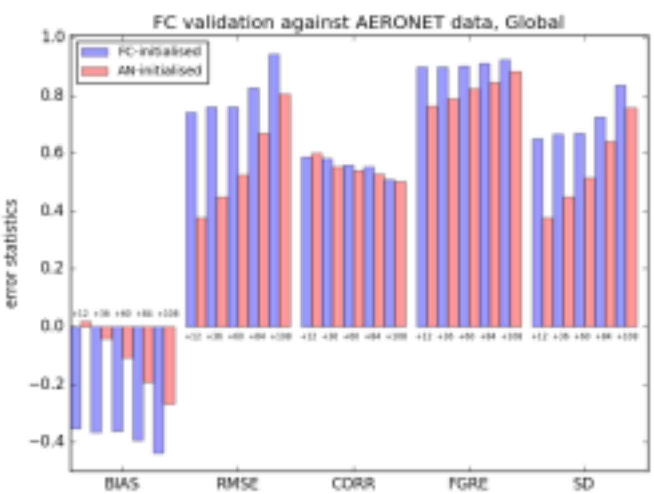
Forecast evaluation

Global Scores (satellite)



An analysis-initialized forecast performs better than a standard forecast almost everywhere in the first day of forecast,

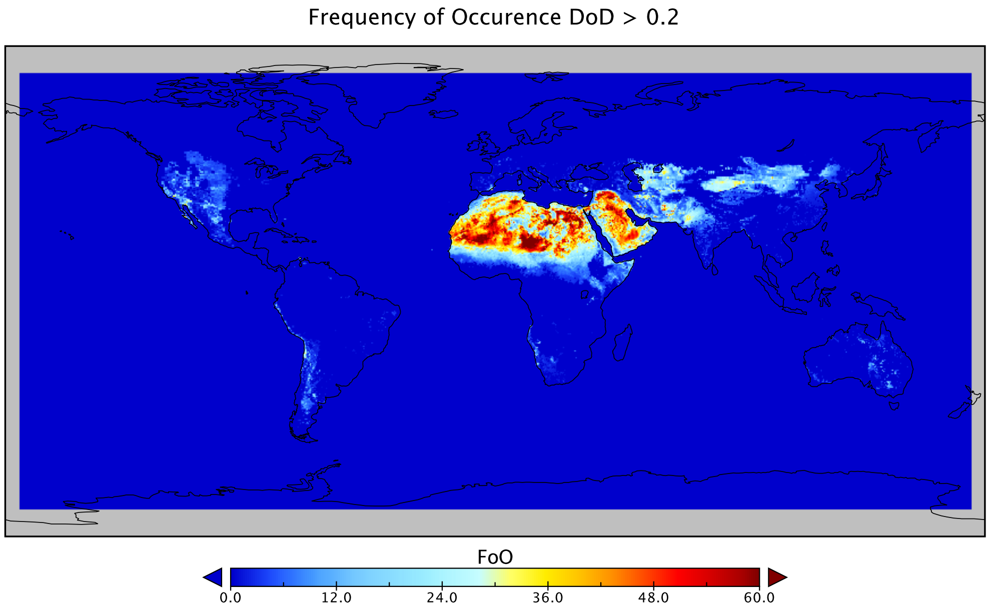
Global Scores (AERONET)

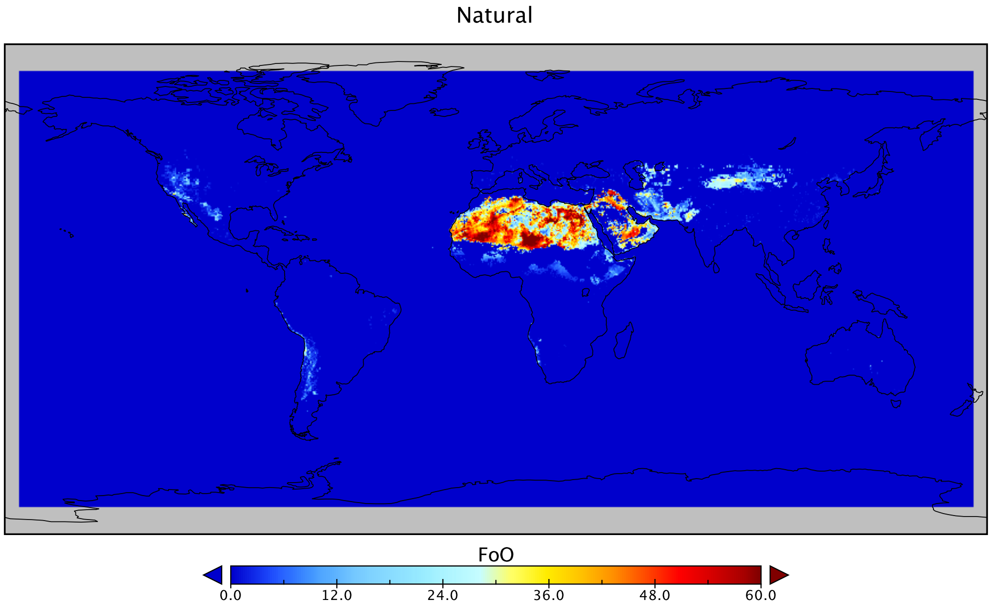


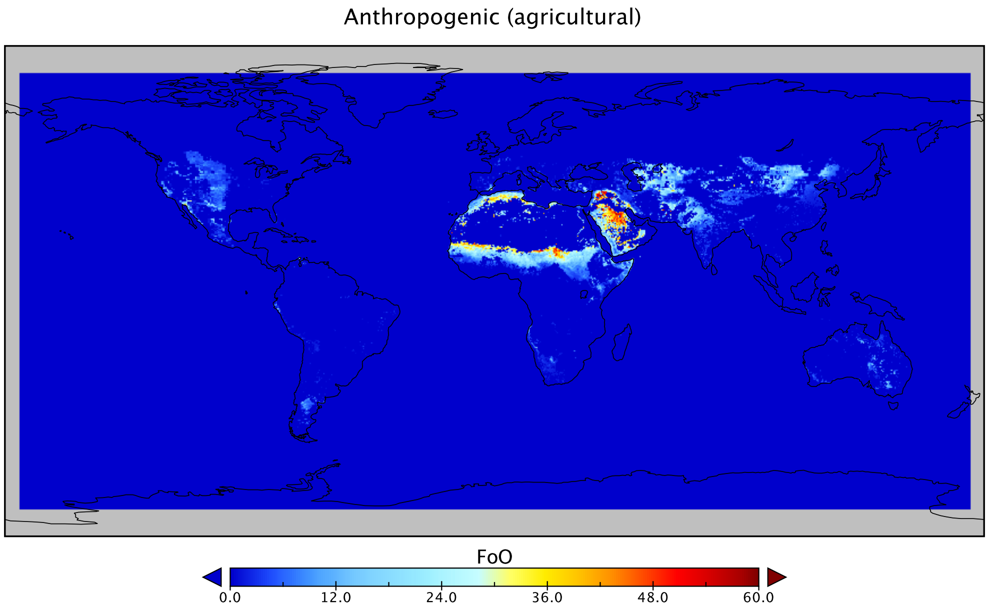
The positive impact of initialization in terms of departures from observations (but not in correlation) is kept for more than 4 days into the forecast.

UPDATES on DUST (Pérez García-Pando et al., in prep)
(Through NOAA – NGGPS program)

Natural and anthropogenic sources based
On MODIS DB (Ginoux et al., 2012)







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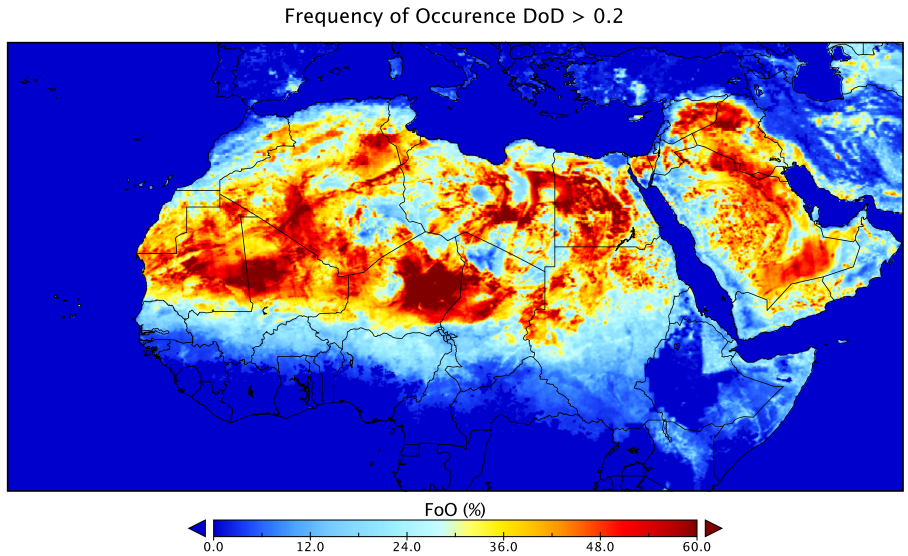
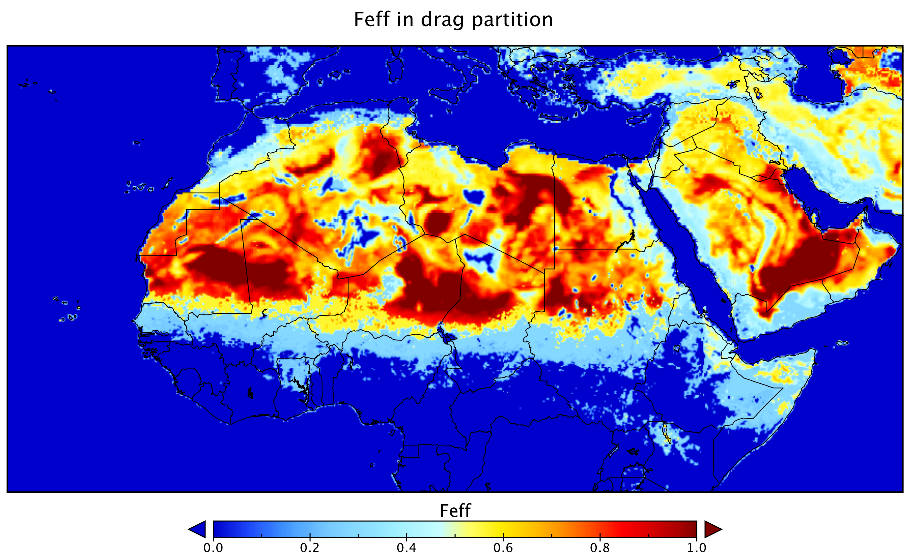




- Testing 3 emission schemes with drag partition:

NMMB original (~Maticorena based scheme)
GOCART scheme
New Kok scheme (Kok et al., 2014)

$$U^*t = \frac{U^*ts}{feff} \qquad feff = 1 - \frac{\ln\left(z0 / z0s\right)}{\ln\left(0.7 (X / z0s)^{0.8}\right)}$$

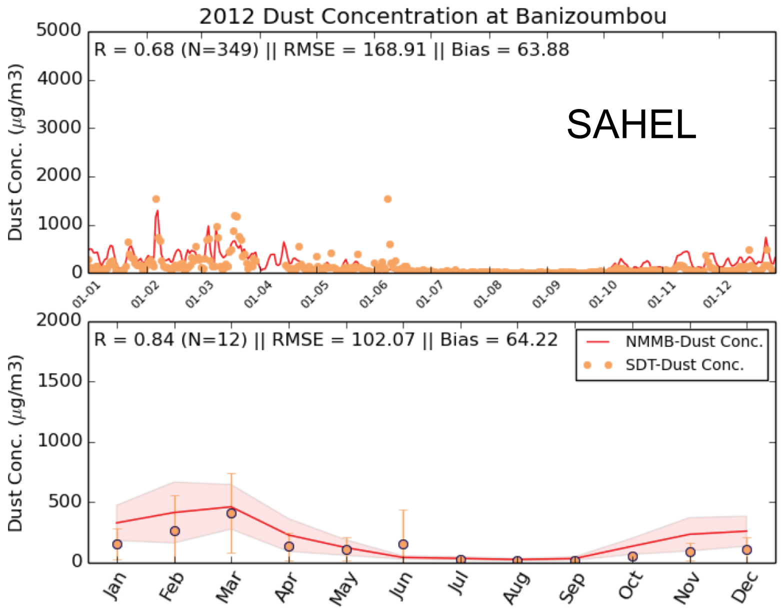
z0 based on satellite static roughness + monthly vegetation (LAI) from MODIS

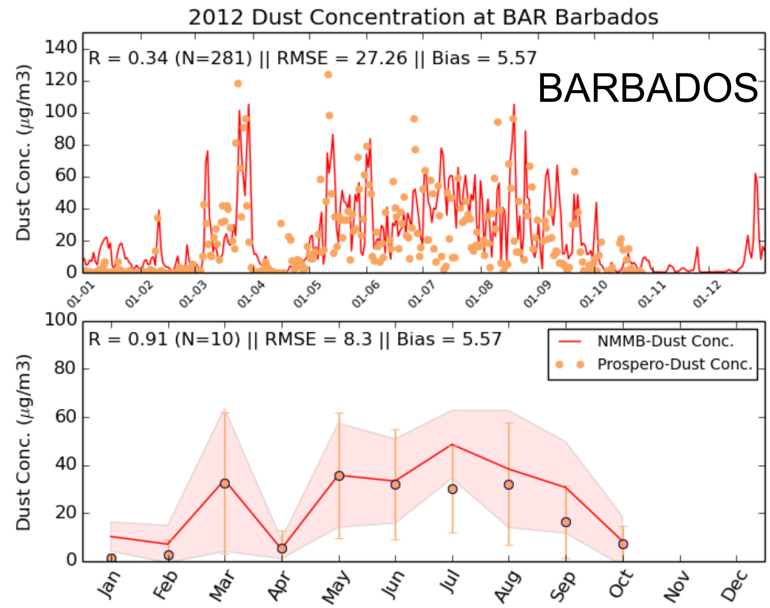
- Additional Model updates:

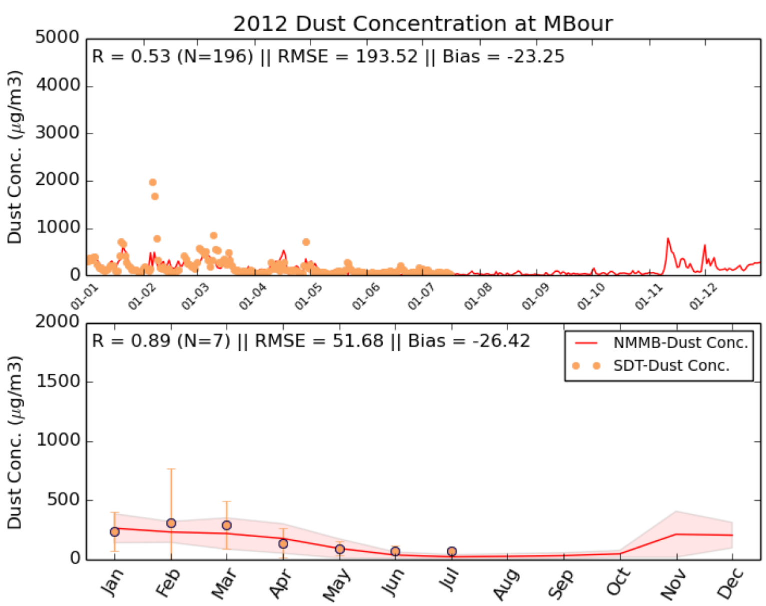
Emitted size distribution
Sedimentation and dry deposition
Mass fixer
Tuning wet deposition
Tuning dependence of threshold to soil humidity

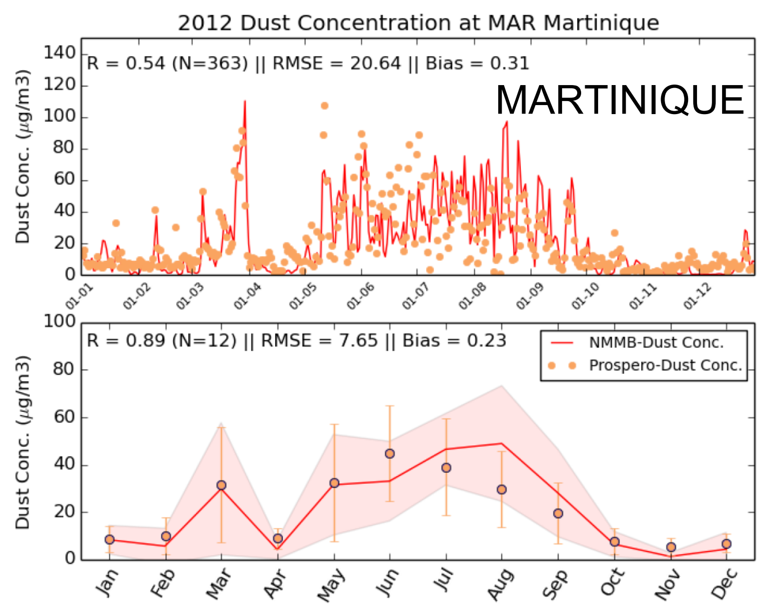
UPDATES on DUST (Pérez García-Pando et al., in prep)

(Through NOAA – NGGPS program)



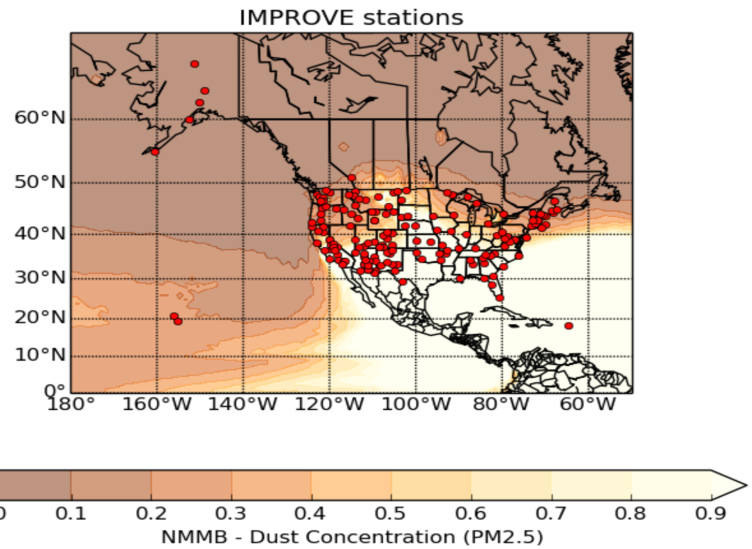


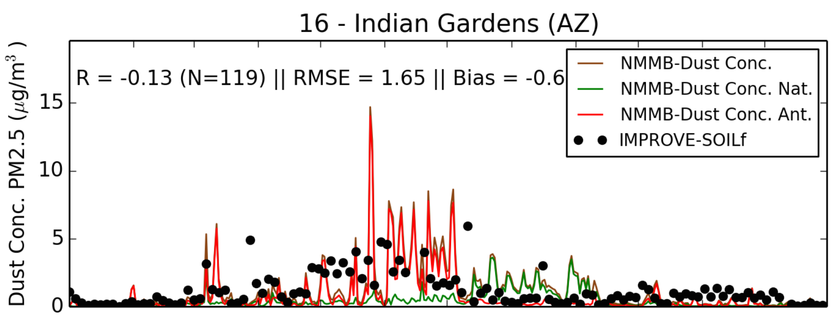


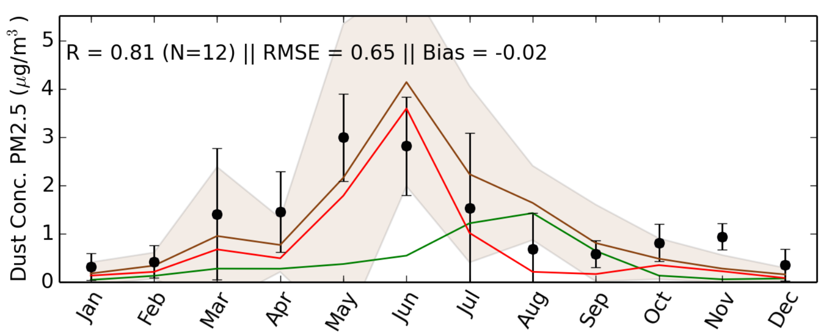


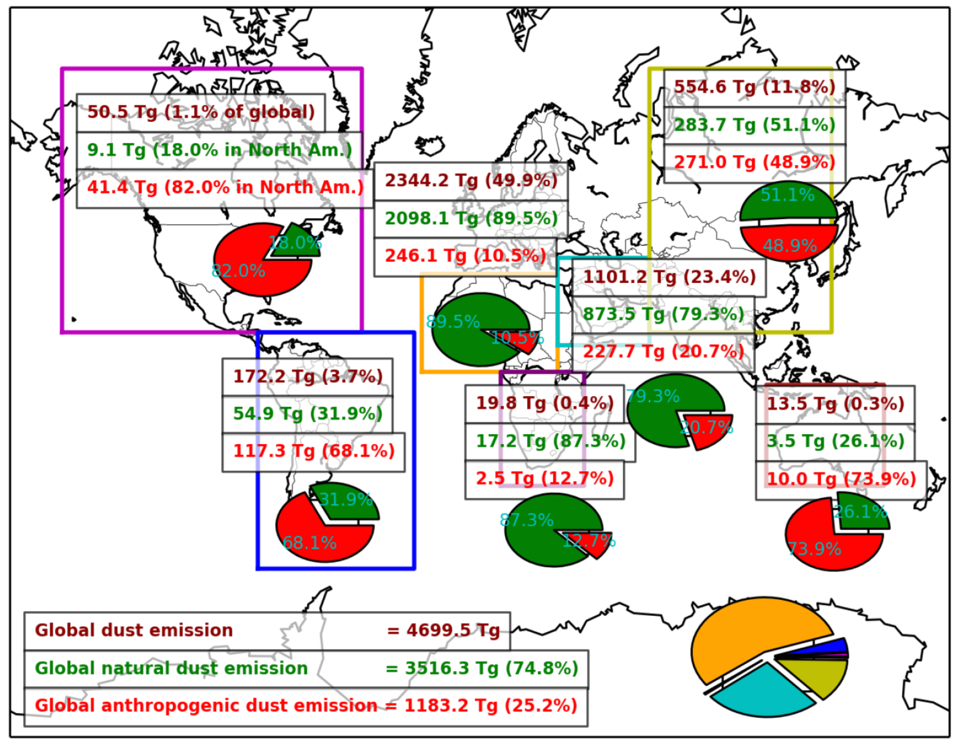
UPDATES on DUST (Pérez García-Pando et al., in prep)

(Through NOAA – NGGPS program)









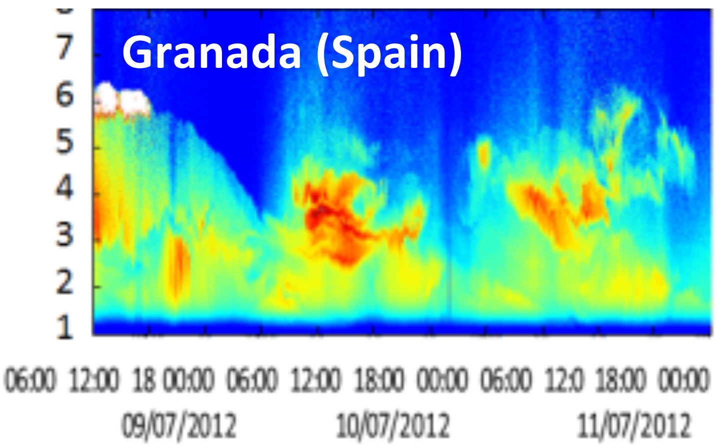
SDS-WAS: Dust Forecasts

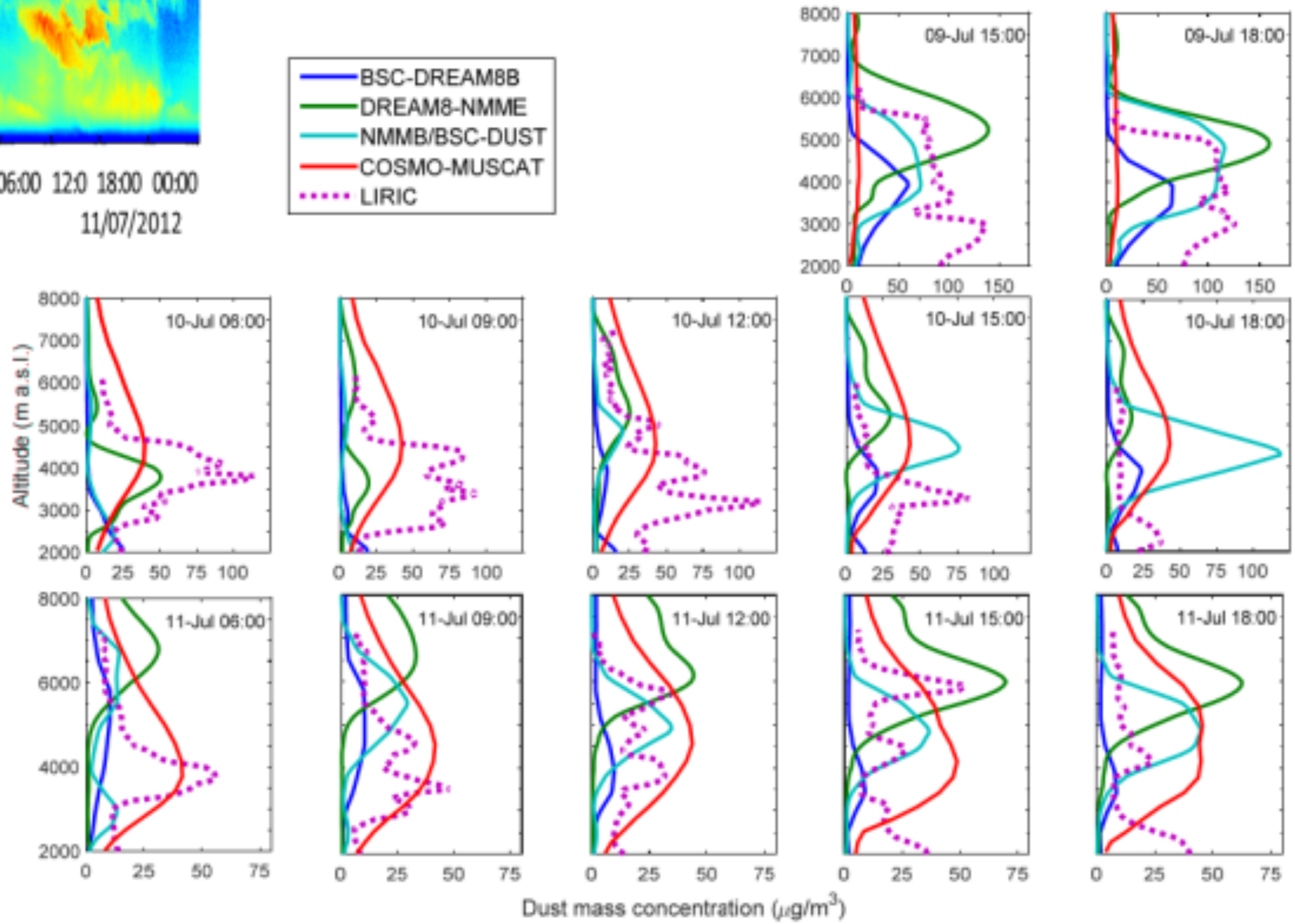
Dust prediction models provide 72 hours (at 3-hourly basis) of dust forecast (AOD at 550nm and surface concentration) covering the NAMEE region.

MODEL	RUN TIME	DOMAIN	DATA ASSIMILATION
BSC-DREAM8b v2.0	12	Regional	No
CHIMERE	00	Regional	No
LMDzT-INCA	00	Global	No
CAMS-ECMWF	00	Global	MODIS AOD
DREAM8-NMME	00	Regional	CAMS analysis
NMMB/BSC-Dust	12	Regional	No
MetUM	00	Global	MODIS AOD
GEOS-5	00	Global	MODIS reflectances
NGAC	00	Global	No
EMA REG CM4	12	Regional	No
DREAMABOL	12	Regional	No
NOA WRF-CHEM	12	Regional	No
FMI-SILAM	12	Global	No

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

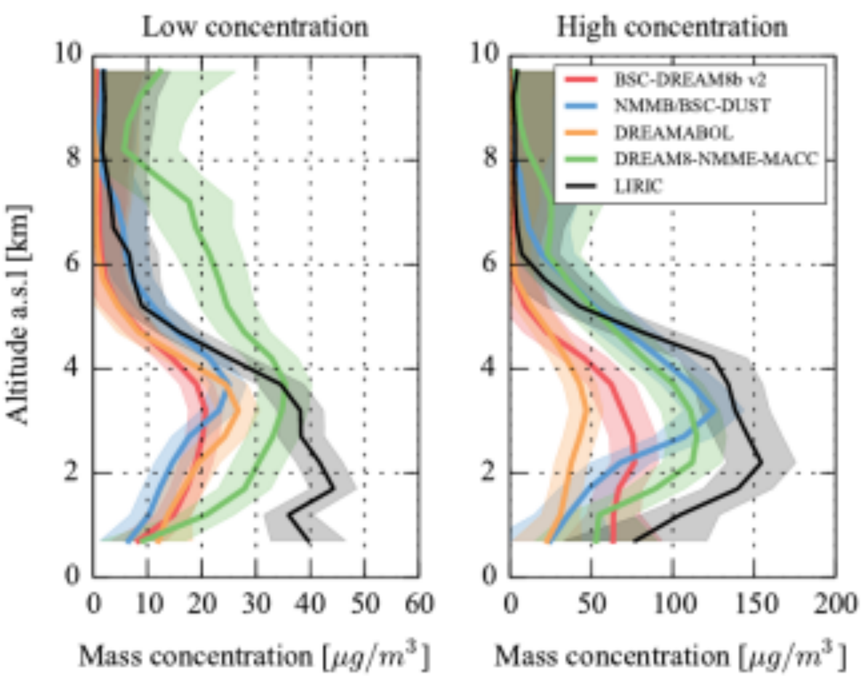
EARLINET: Charmex/EMEP intensive campaign July 2012

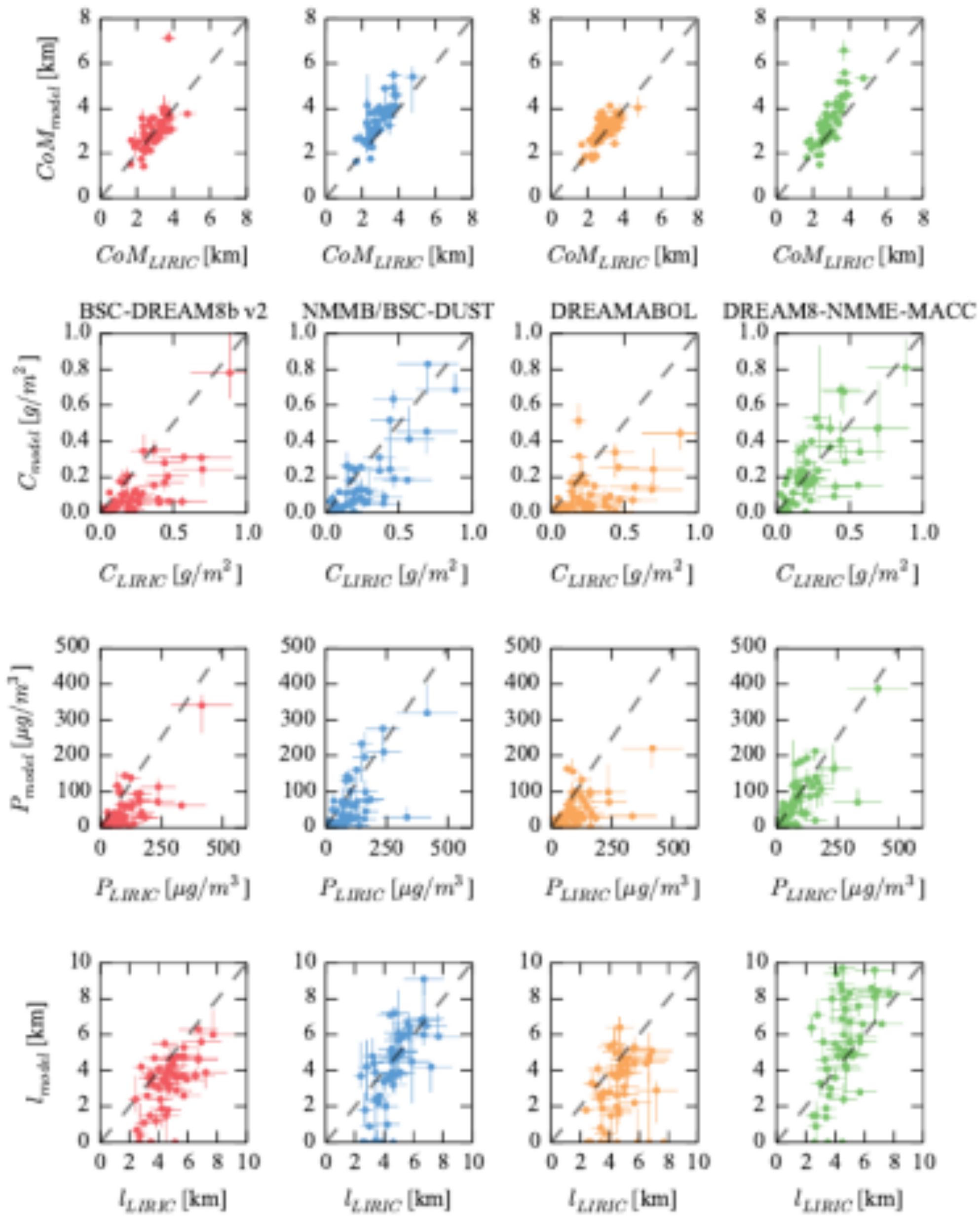




(Muñoz-Granados et al., ACP, 2016)

EARLINET vertical dust profiles: 2011-2013



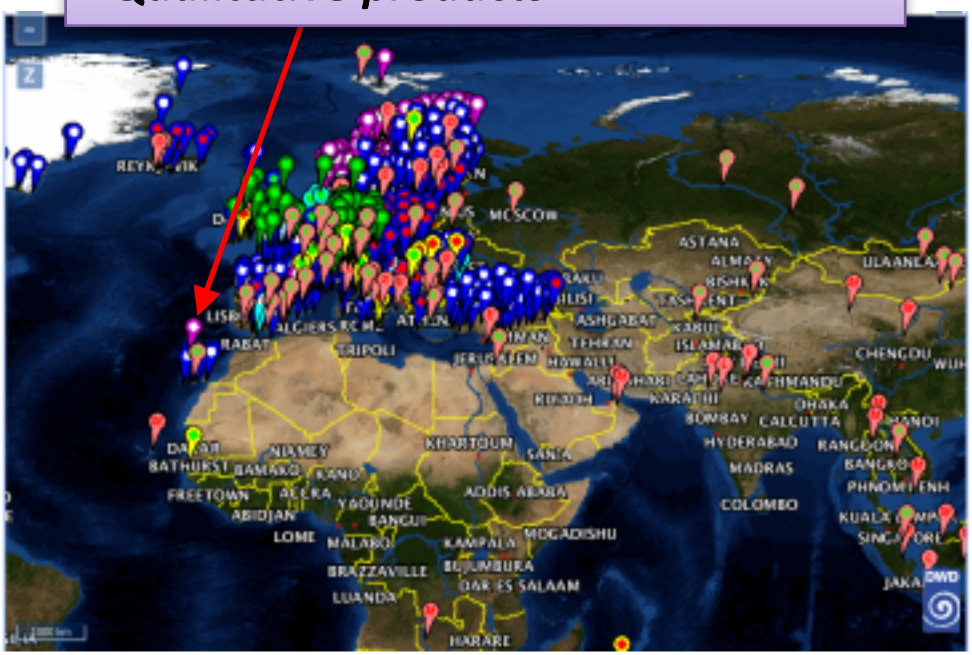


(Binietoglou et al., ATM, 2015)

SDS-WAS: NRT Vertical profiles - Tenerife and Dakar Pilot within ACTRIS-2 project

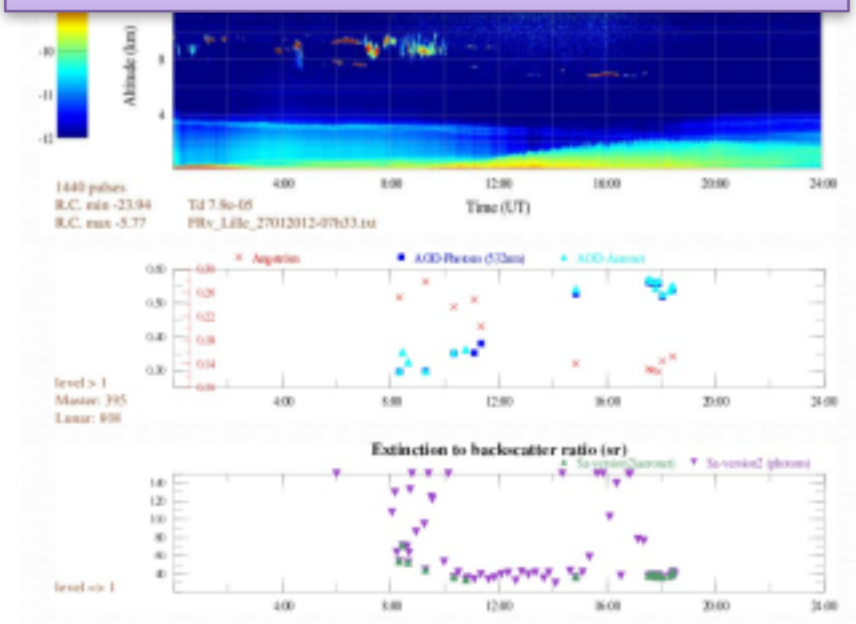
Ceilometer
Santa Cruz de Tenerife (Spain)

+ High density of stations
- Qualitative products



Lidar
M'Bour (Senegal)

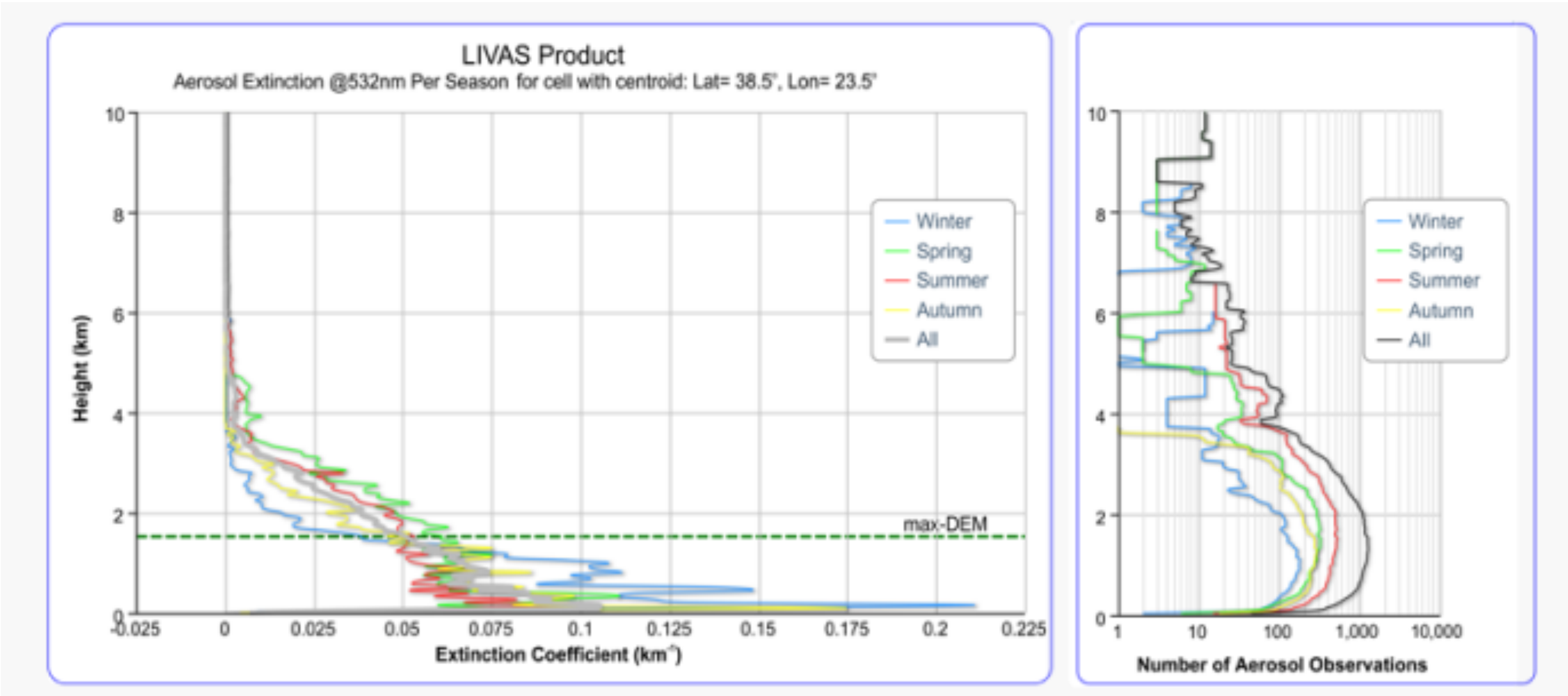
- Low number of stations
+ Quantitative products



http://sds-was.aemet.es/projects-research/evaluation-of-model-derived-dust-vertical-profiles

SDS-WAS : Obs. - Dust vertical product (Ongoing)

LIVAS catalogue includes a dust climatology based on 4 years (2008-2011) of CALIPSO data



http://lidar.space.noa.gr:8080/livas/

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

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	NMMB/BSC-CTM	NMMB/BSC-CTM	CMAQ (DREAM for dust) NMMB/BSC-CTM
Status	QO	O	O
Meteorology	Inline: NMMB	Inline: NMMB nesting	Offline: WRF-ARW Inline: NMMB nesting
Resolution	1.4x1 0.7x0.5	0.1x0.1 0.03x0.03	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) BSC-CTM aerosols
Gas phase chemistry	CBM-IV CB05		CB05 CB05
Emissions	AEROCOM, MEGAN		EMEP, MEGAN / HERMES, MEGAN/ HERMES MEGAN
Bio. Burn. Emissions	AEROCOM NRT		NA NRT