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Recent EMEP MSC-W model development and evaluation with respect to PM:

Dust in focus

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14th TFMM meeting, Zagreb, 6-8 May 2013

Outline

- On-going works to improve PM calculations with the EMEP MSC-W model

- Evaluating PM10 dust modelling using EMEP intensive measurements June-July 2012:

  - Briefly about description of dust processes in the EMEP MSC-W model – main uncertainly sources
  - What does the first-ever evaluation of modelled dust with dust measurements at 13 EMEP sites show

- Main findings and outlook for model improvement with respect to dust calculations

Recent and on-going works to improve PM calculations in the EMEP MSC-W model

- A series of "technical" improvements to make the model more flexible (input/output, boundary conditions, grid/resolution) and robust (particularly important for SR calculations)

- Most important on-going works to evaluate and improve the model:
  - Model intercomparison and evaluation within EuroDelta-3
  - Model evaluation with extended data within Aerocom, including satellites, LIDAR
  - Improvement of NH3 (EU ECLAIRE) - dynamic NH3 emissions, NH3 compensation point (climate effects)
  - Implementation size-resolved aerosol (MAFOR)
  - Evaluation and improvement of dust calculations and improvement of coarse SIA

Why it is important for the model to be capable of accurately calculating dust

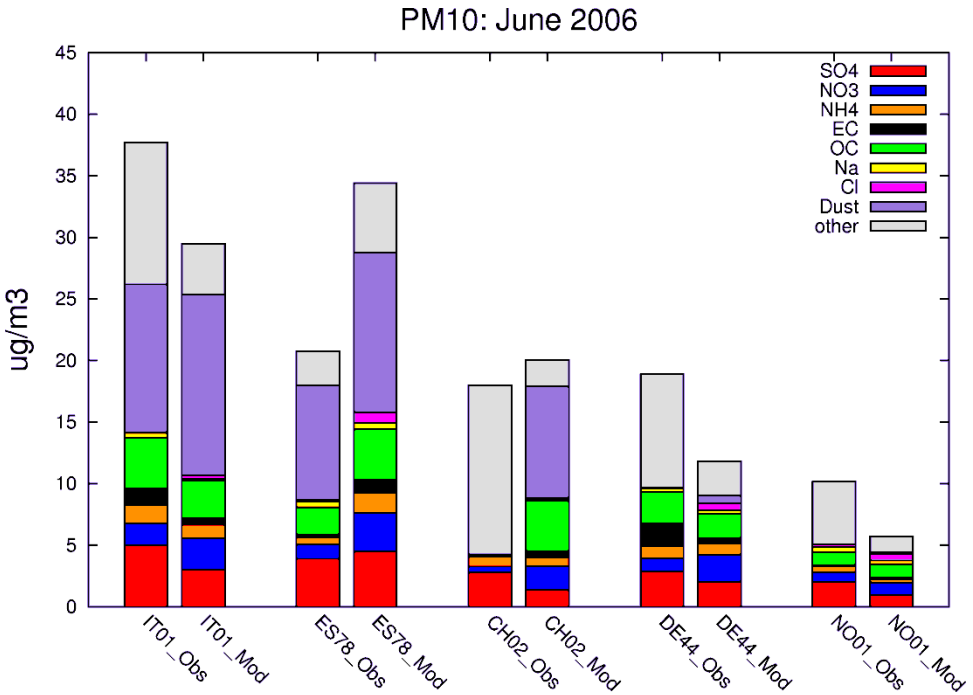
- To reproduce PM levels and episodes:
  * Important component of ambient PM all over Europe:
  * Saharan dust intrusions causes PM episodes, more frequent and severe in south European countries, but also others

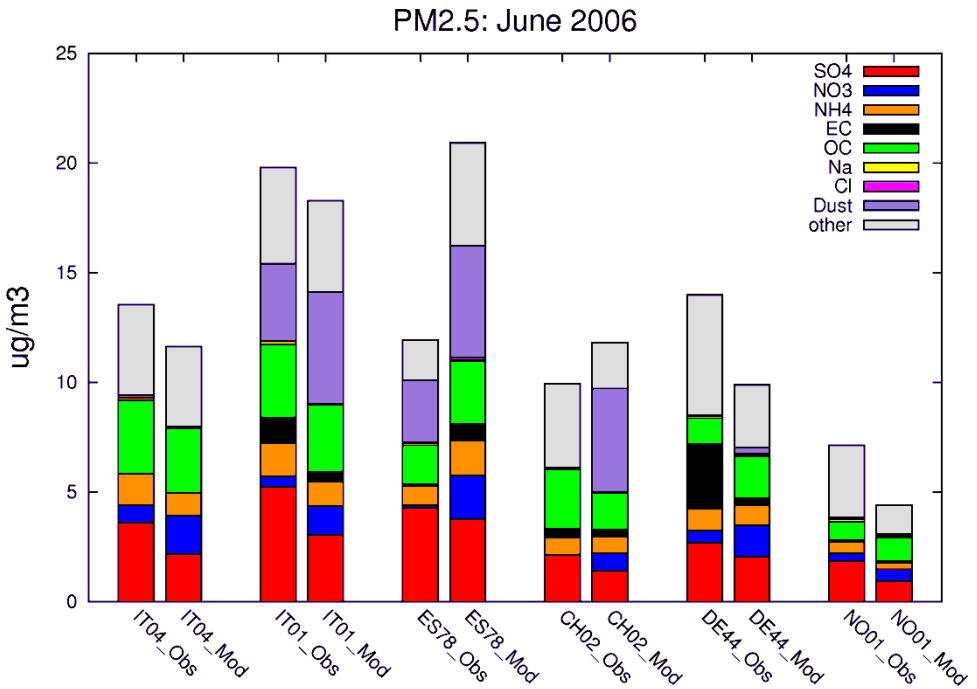
- For proper description of SIA (i.e. formation of coarse NO3 and SO4)

- To provide Base Cations deposition estimates for CCE (neutralizing effect to soil/water acidification)

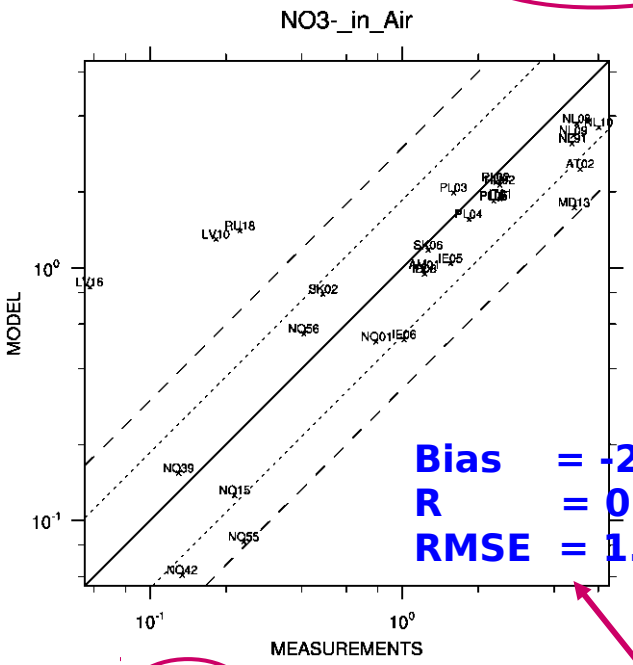
- To provide more accurate calculation of Radiative Forcing

PM10 and PM2.5 chemical composition in June 2006

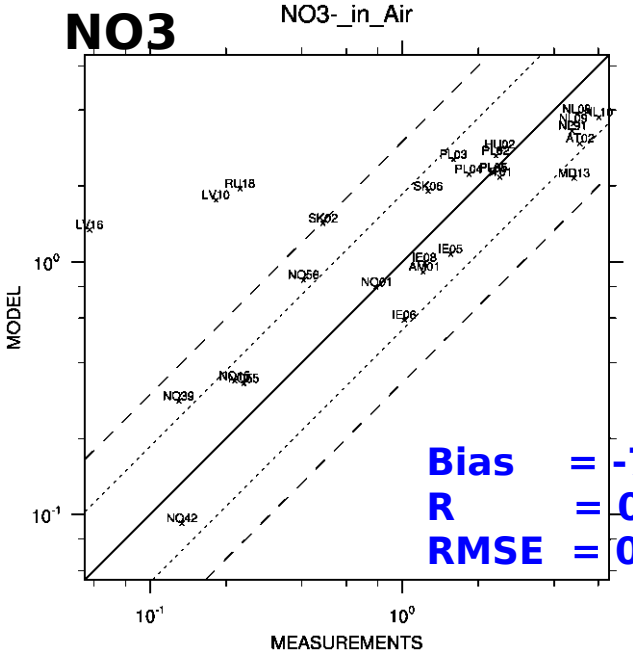


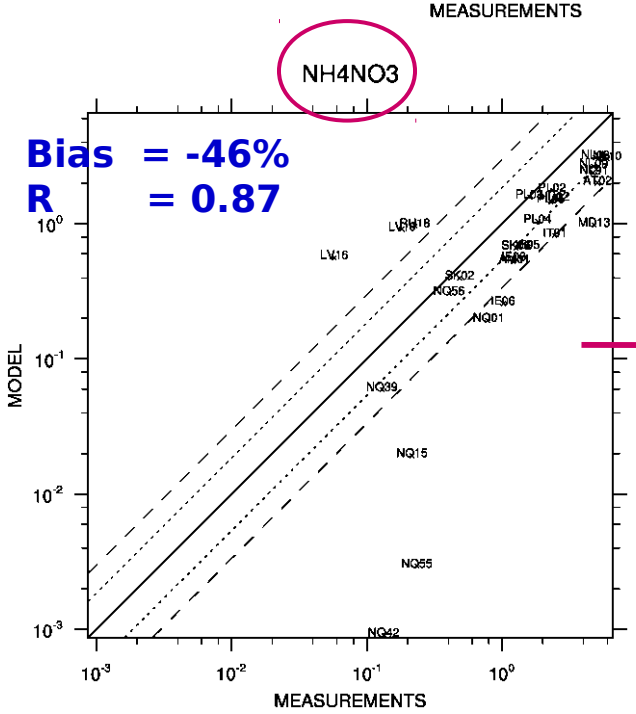


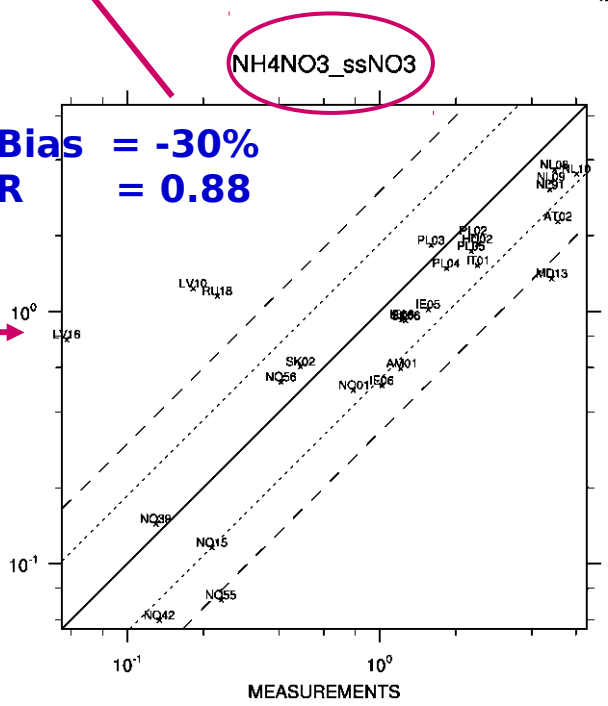
NO3 = fine NO3 + coar NO3 (on SS & dust)



NO3 = fine NO3f + ½ coar NO3







Na is calculated fairly well (Tsyro et al., ACP 2011)

Dust is difficult to verify, but is likely underestimated in C and N Europe

Dust production onset: U* > U*th

Threshold U^*_{th} – wind energy (drag) partitioning between erodible and non-erodible elements (Marticorena&Bergametti, 1995)

$$u_{*,th} = \frac{u_{*,sm}}{f_{eff}} f_w$$

$$f_{eff} = 1 - \left(\frac{\ln(z_0 / z_{0,s})}{\ln\left(0.35 (10/z_{0,s})^{0.8}\right)} \right)$$

$z_{0,s}$=Ds/30

Ds = 210 μm

Accounting for inhibition of dust generation by soil moisture:

$$f_w = \sqrt{\left(1 + 121 (w - w')^{0.68}\right)}$$

for *w > w'*,

Depends on sand content

Soil moisture Index from ECMWF is now used:

SMI = (SW - PWP) / (FC - PWP)

Wind gustiness (Beljaars 1994)

$$u = \kappa \sqrt{\left(u_{10^2} + (1.2w)^2\right)} \left(\ln \frac{z_{10}}{z_0} + \Phi \right)$$

(increase by surface roughness z0 due to saltation - Owen's effect)

Saltation flux (horizontal)

$$Q_{salt} = \frac{2.61 \cdot \rho_{air}}{g} \cdot U_3 \left(1 - \frac{U_{th}}{U}\right)\left(1 + \frac{U_{th}}{U}\right)^2$$

Vertical dust flux:

$$F_{DUST} = \alpha \cdot K_{\lim} \cdot Q_{salt} \cdot A_s$$

Sandblasting efficiency: α = 100.0 * exp(ln10 * (13.4 * clay - 6.0)) ! [m-1]

soil clay content changes flux by 3 orders of magnitude as 0.0 < fr_clay < 0.20

Constant values of α have been used in operational model

Soil erodibility: K_{lim} = 0.02 - 0.1 (based on measurements Gomes&Alfaro)

Restrictions: no dust from snow / frozen soil;
48h w/o precipitation (RH<85%);
< 10^{-8} -10^{-7} kg/m²/s

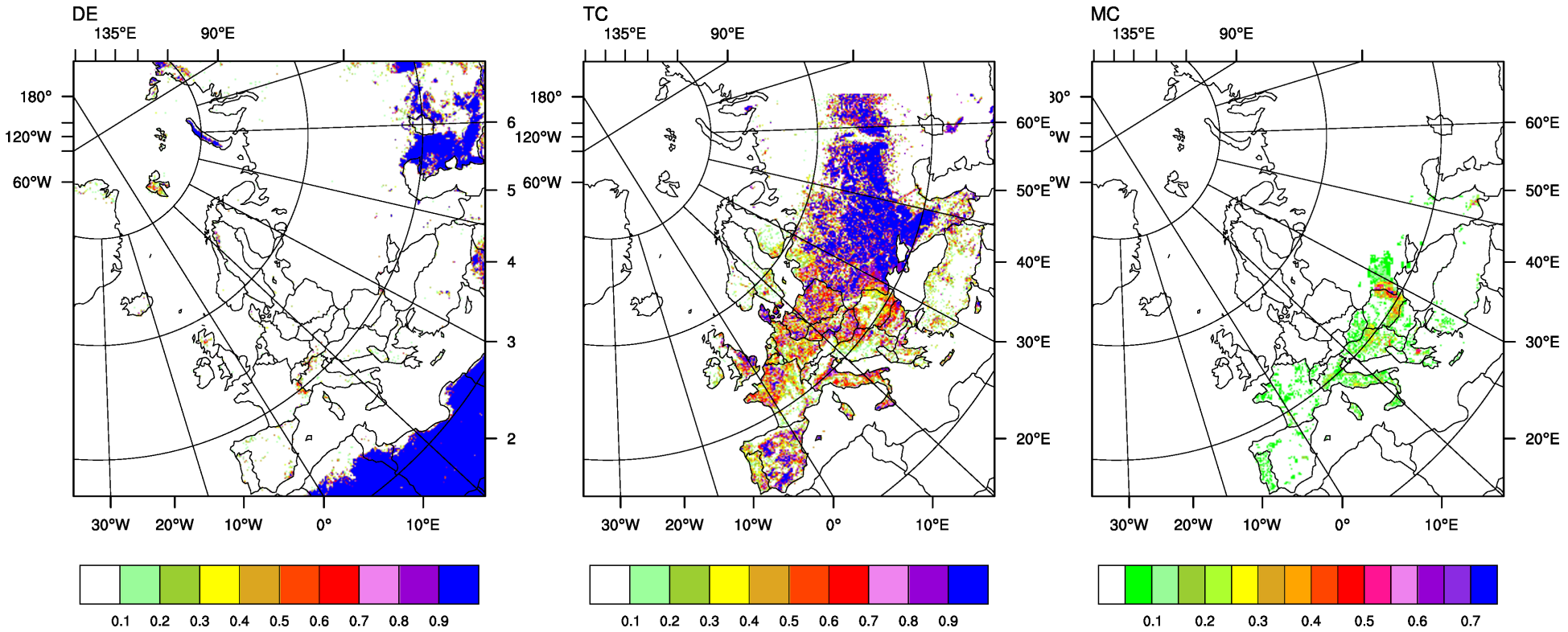
PM10 and PM2.5 fraction in total flux: Standard model: 5% - fine, 20% - coarse
Dependent on U* (Alfaro)

Erodible land-use types in the model

Desert &bare land

Temporal crops outside growth season 123-213 *)

Mediterranean crops outside growth season 123-237 *)

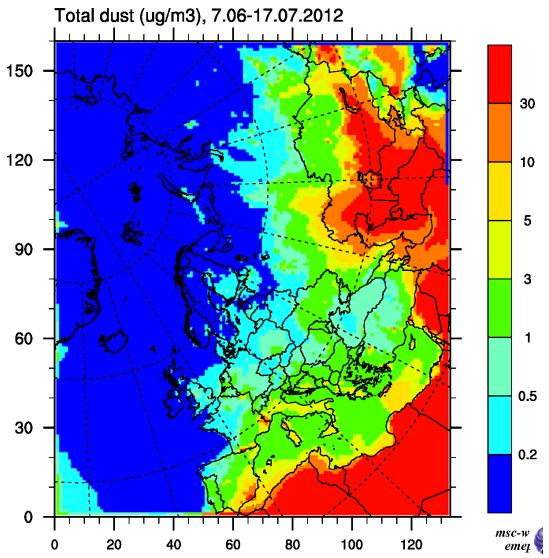


*) test for low dust production during growth season

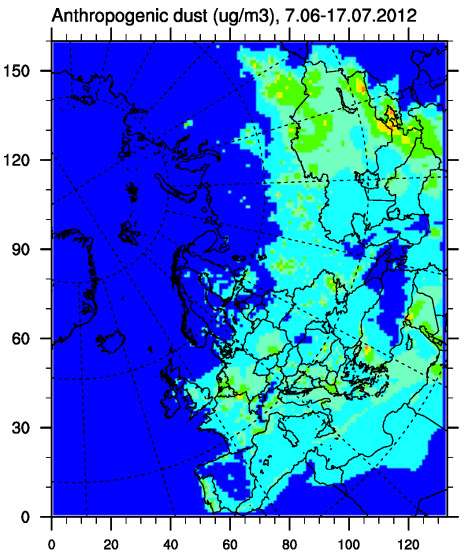
Saharan dust from boundary conditions (global CTM of UiO)

Model calculated dust concentrations:
average for 7 June- 17 July 2012

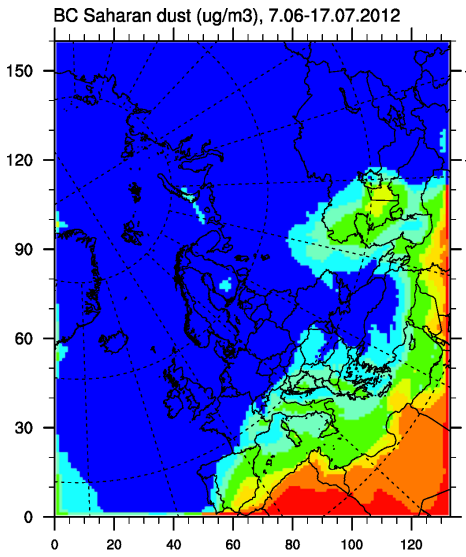
Total



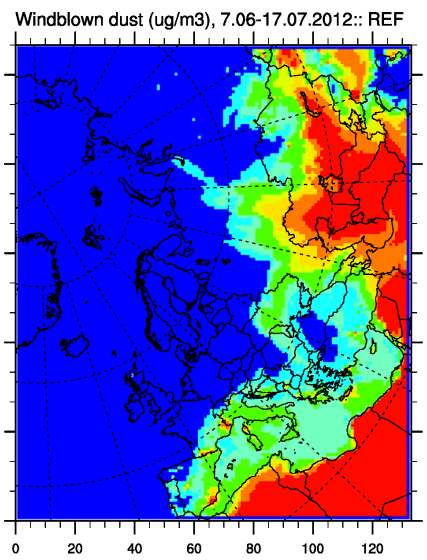
Anthropogenic



Saharan BCs



Windblown

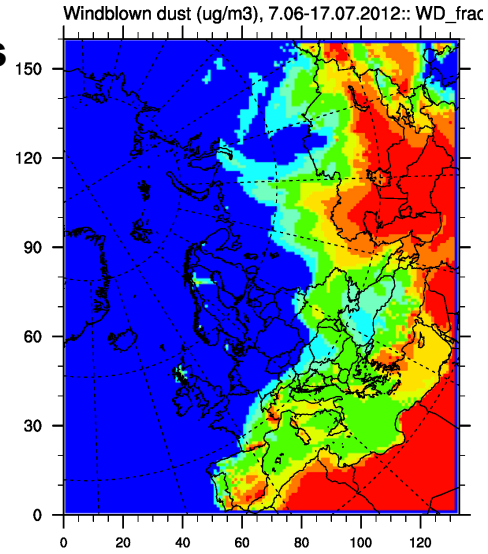


Windblown tests:

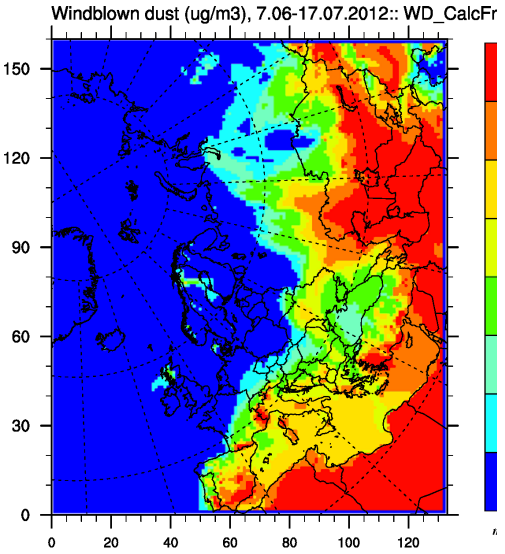
less wet scavenging+
some dust from crops

***) Road dust is very low**

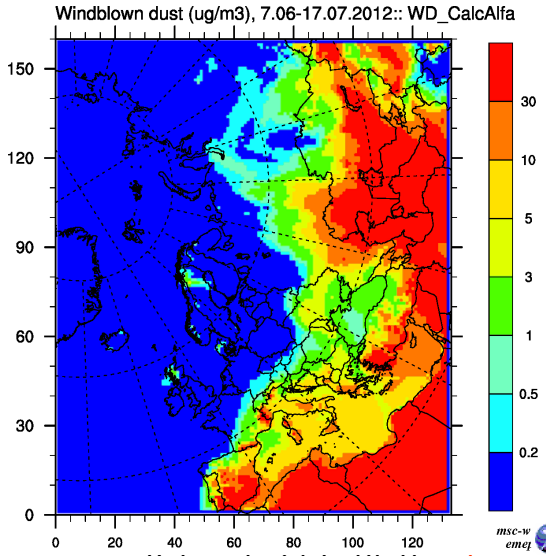
fin/coar frac.

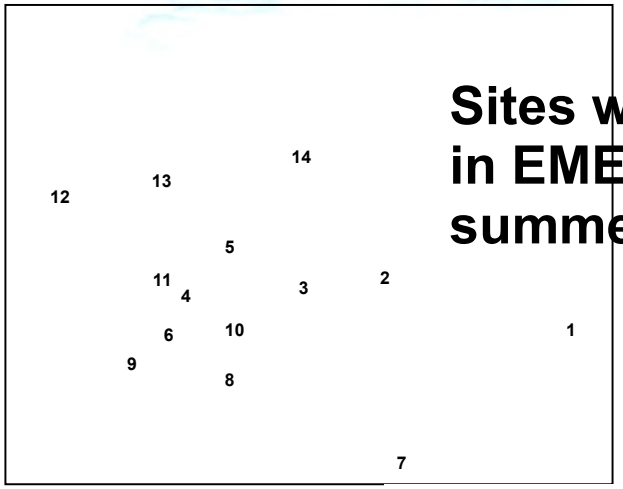


fin/coar frac (U*)



alfa=F(clay)





Sites with dust measurements in EMEP intensive period summer 2012

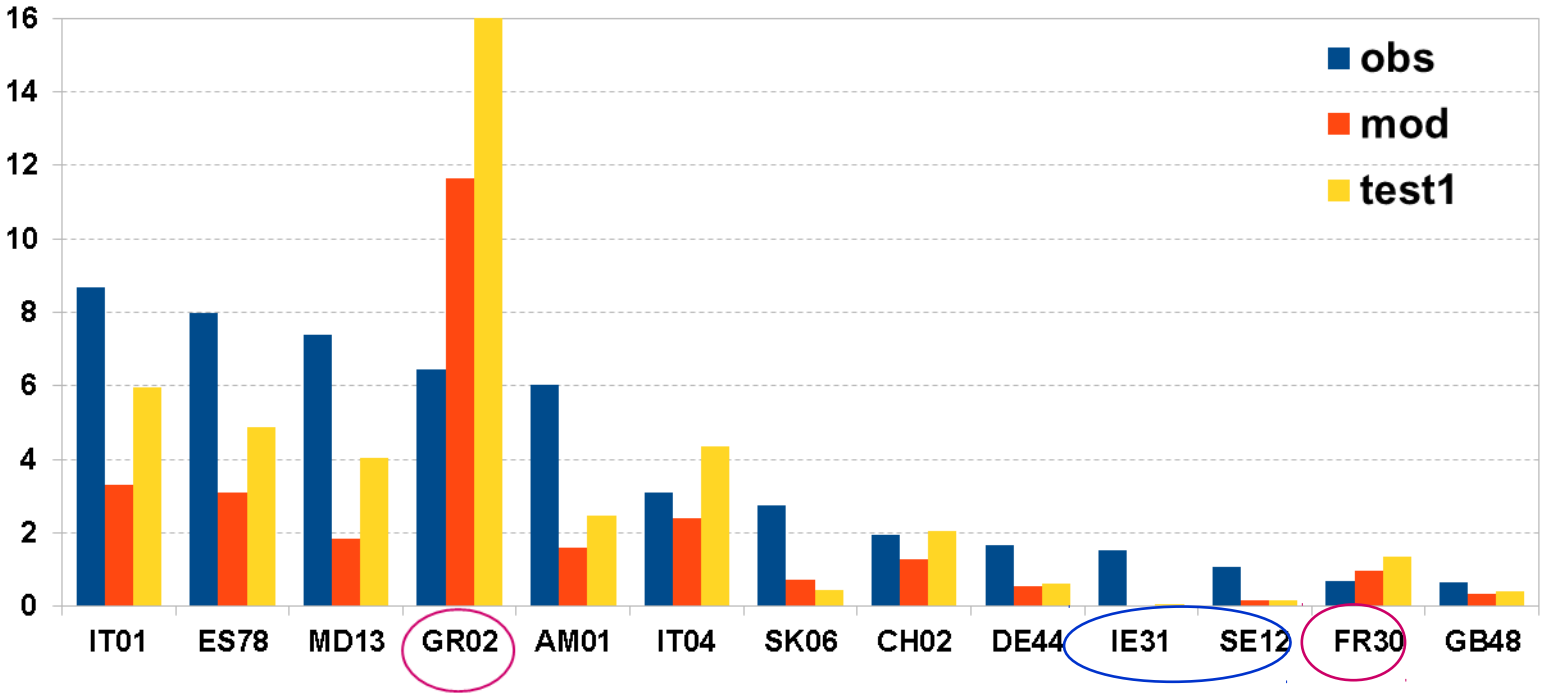
Average levels of background dust:

7 June- 17 July 2012

Notable:

Rather high dust levels, also at C. & N. European locations

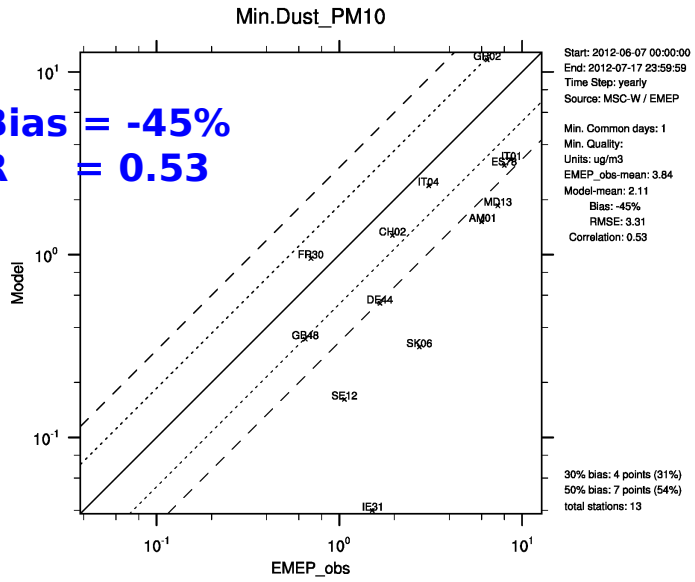
General model underestimation (with a few exceptions)



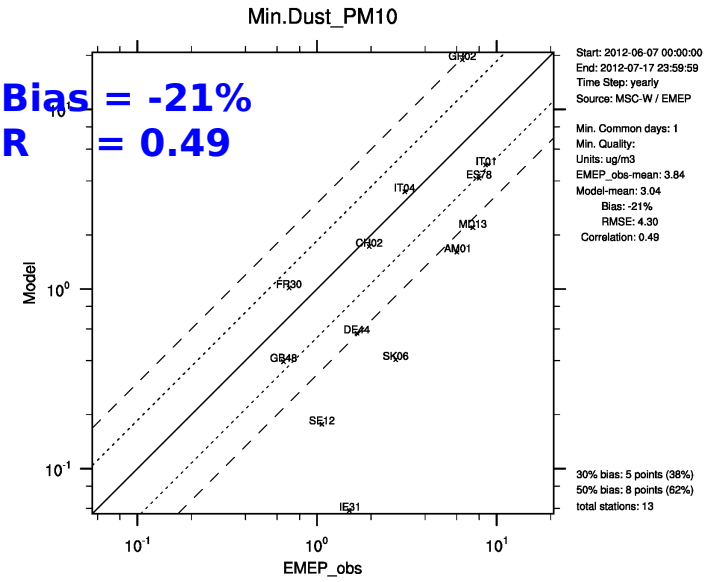
Min. Dust = Al_2O_3 + SiO_2 + Fe_2O_3 + TiO_2 + P_2O_5 + CaO + MgO + MnO + Na_2O_{crust} + K_2O

Cl is used to estimate sea salt Na, the rest of Na is Na_2Ocrust

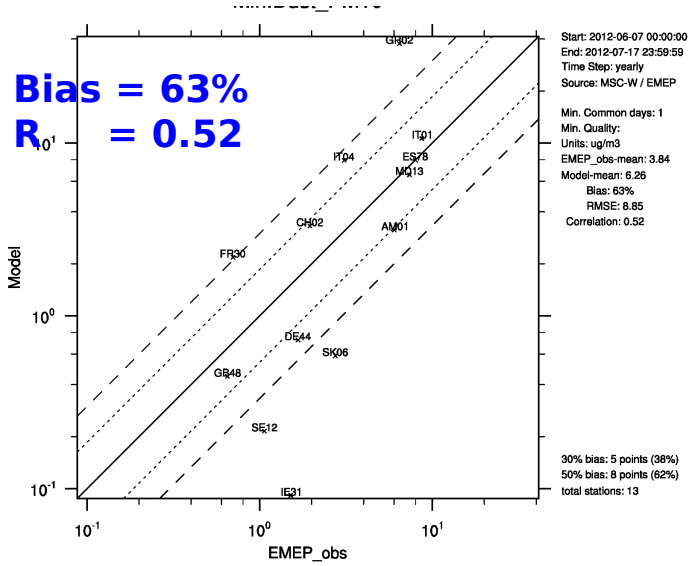
Operational



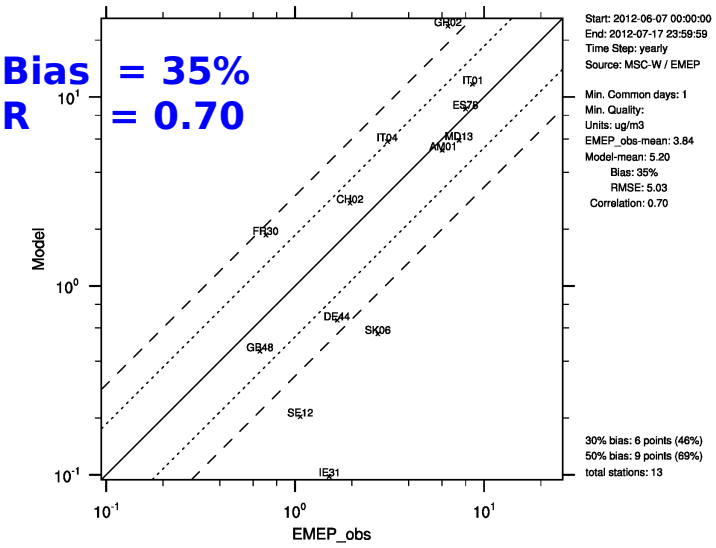
Decrease wet scavenging & some dust from crops



+ Fine/coarse fractions (u*)



+ Sandblasting (clay)



Tests:

Most improvement is due to Saharan dust, and for southern sites

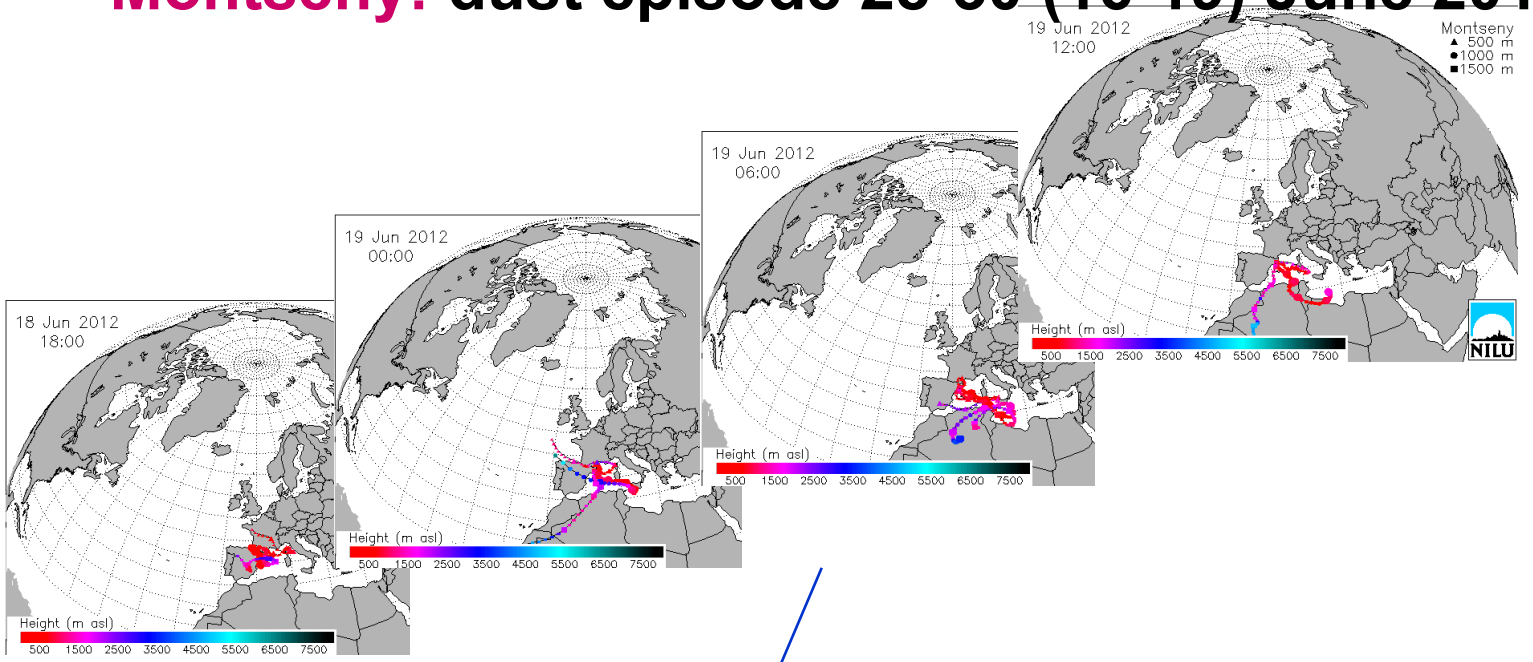
Far too little dust is calculated for the northern sites

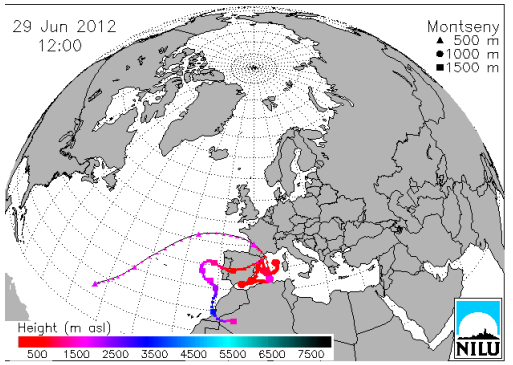
Looking closer at Dust episodes

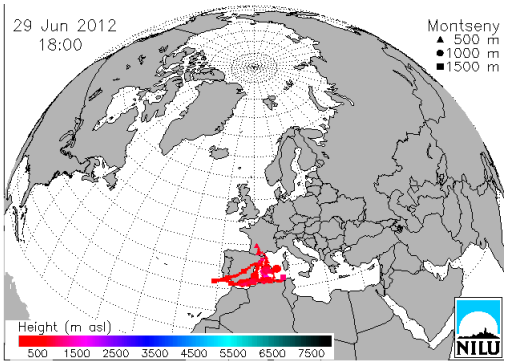
Saharan dust intrusions
in the model: due to boundary conditions and on-line generated dust in N. Africa

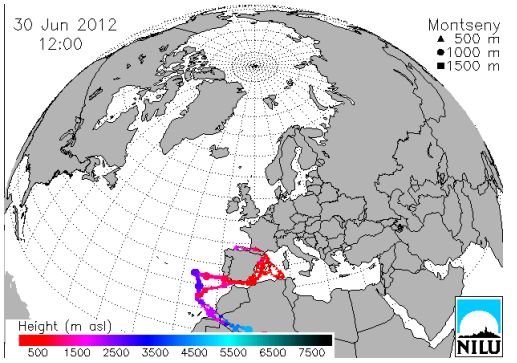
Anthropogenic PM and windblown dust from European soils

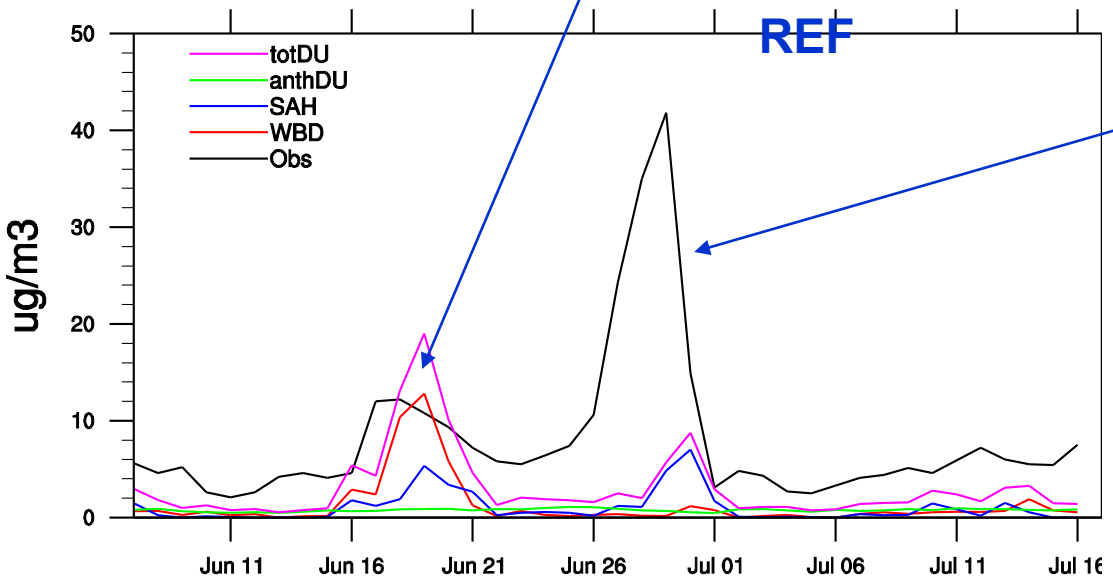
Montseny: dust episode 28-30 (16-19) June 2012





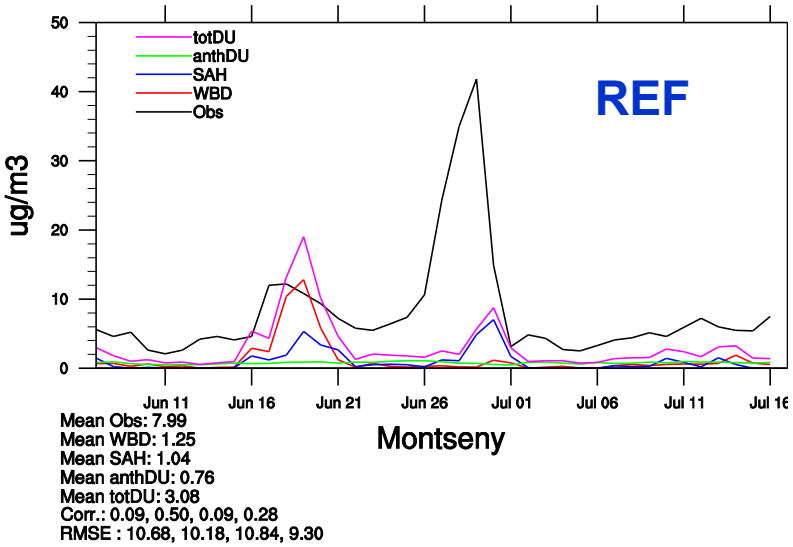


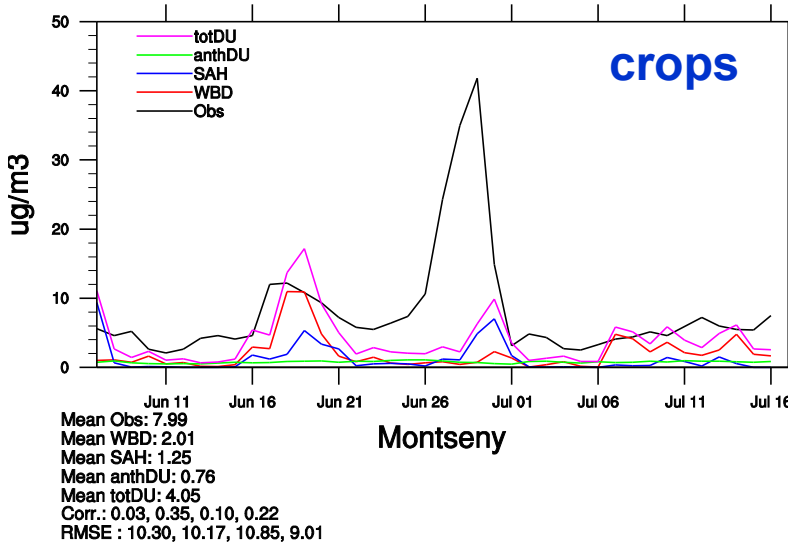


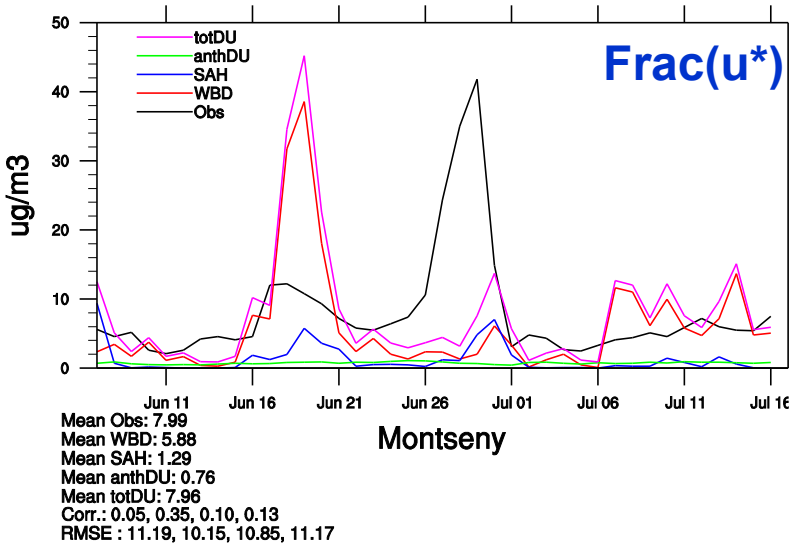


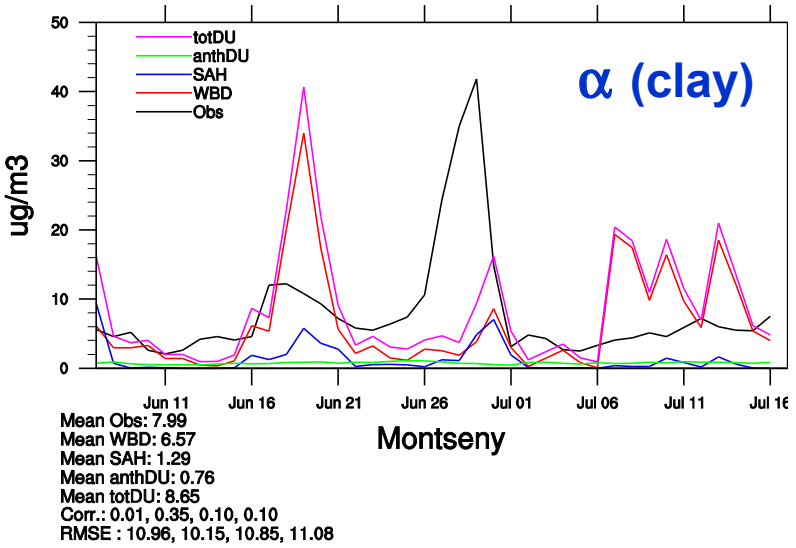
Mean Obs: 7.99
Mean WBD: 1.25
Mean SAH: 1.04
Mean anthDU: 0.76
Mean totDU: 3.08
Corr.: 0.09, 0.50, 0.09, 0.28
RMSE : 10.68, 10.18, 10.84, 9.30

Tests of the dust module: can the model manage the Saharan dust episode at Montseny



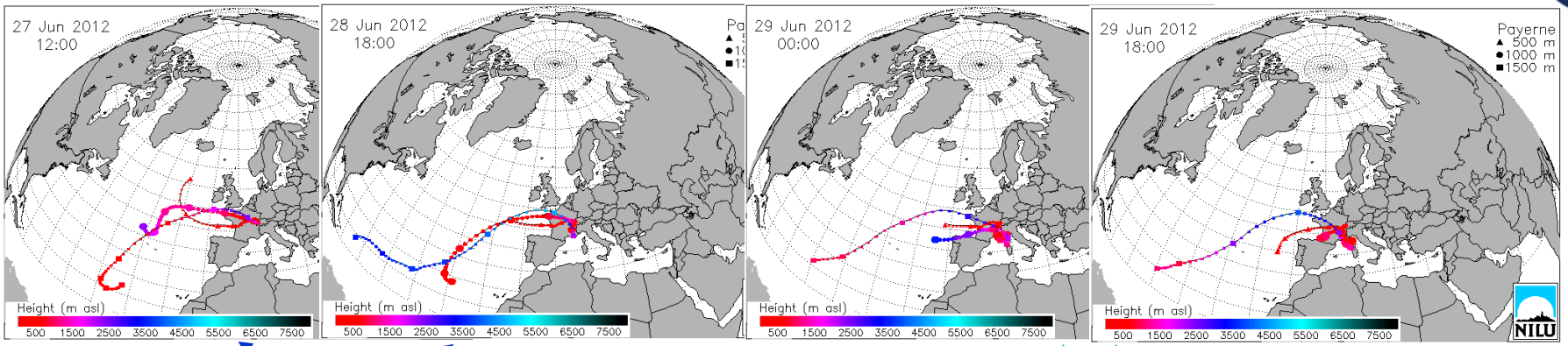


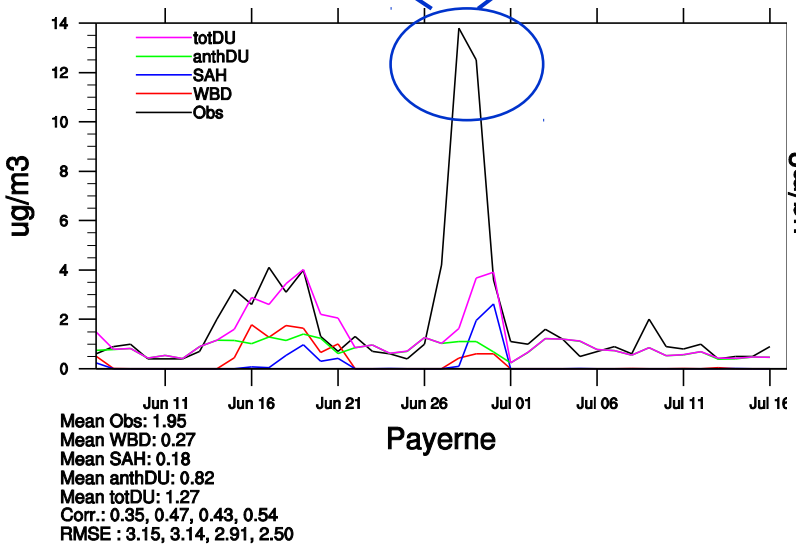




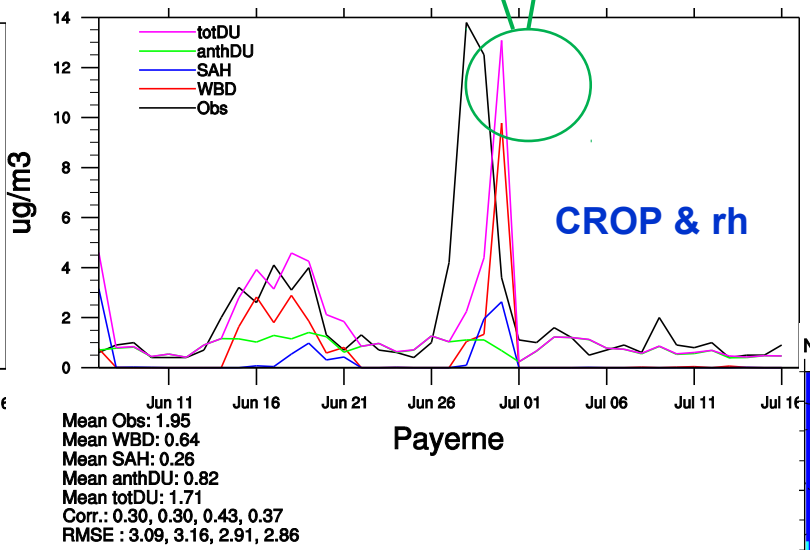
The boundary conditions used for the regional model calculations are not good enough

Payerne: dust episode 28-29 June 2012

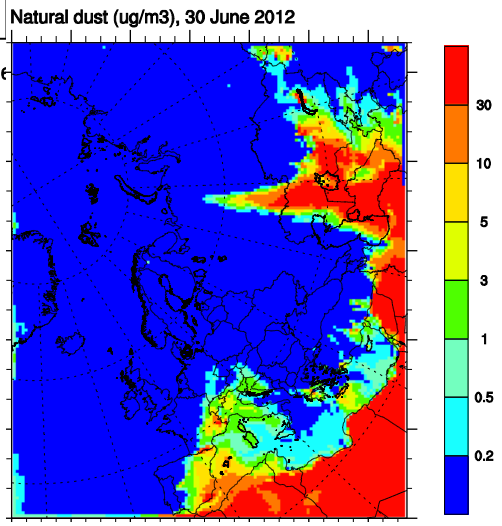




Mean Obs: 1.95
Mean WBD: 0.27
Mean SAH: 0.18
Mean anthDU: 0.82
Mean totDU: 1.27
Corr.: 0.35, 0.47, 0.43, 0.54
RMSE : 3.15, 3.14, 2.91, 2.50

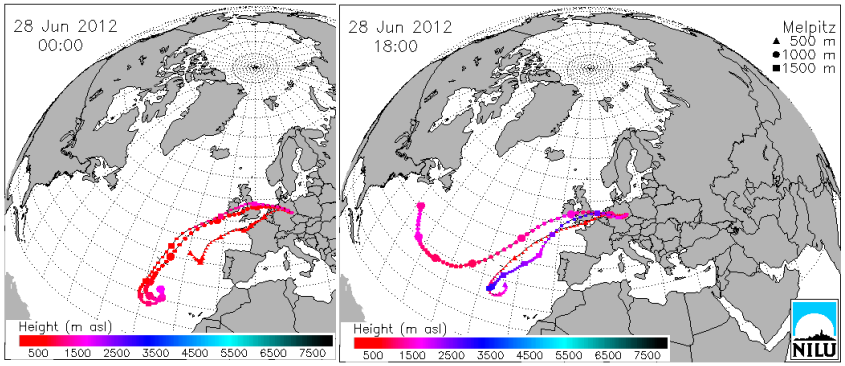


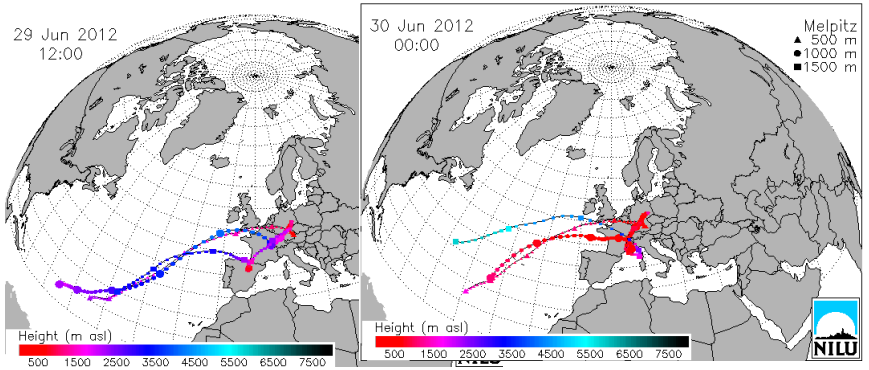
Mean Obs: 1.95
Mean WBD: 0.64
Mean SAH: 0.26
Mean anthDU: 0.82
Mean totDU: 1.71
Corr.: 0.30, 0.30, 0.43, 0.37
RMSE : 3.09, 3.16, 2.91, 2.86

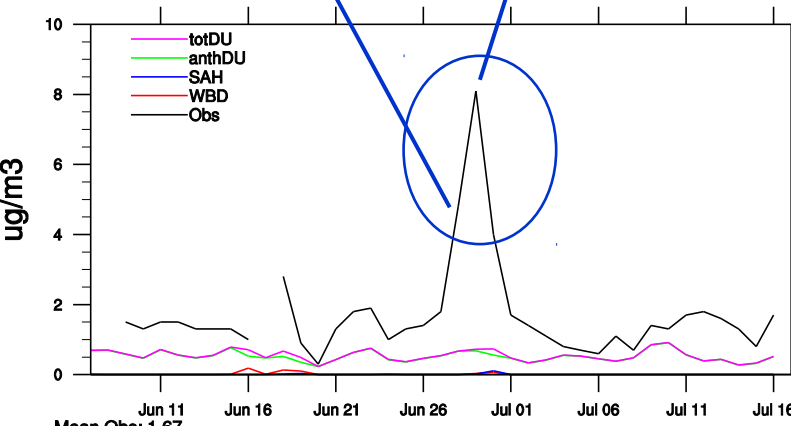


Standard:Saharan episode 1-2d delay, dust too low
Tests: OK dust max, still delay
Minor episode (from Spain-S.France): OK-ish

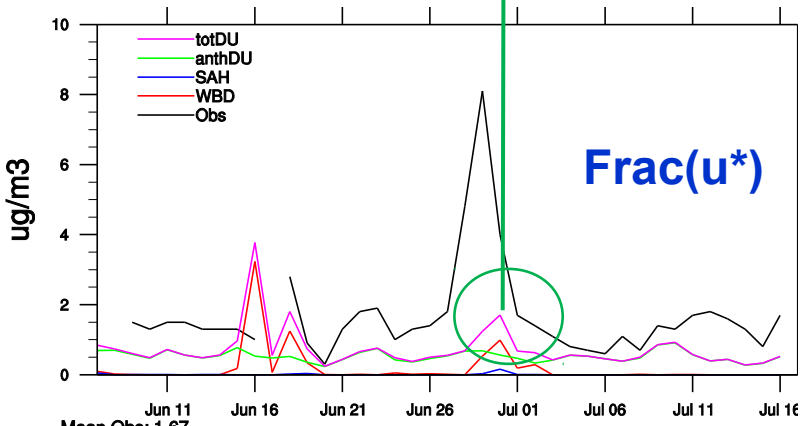
Melpitz: dust episode (28) 29 (30) June 2012



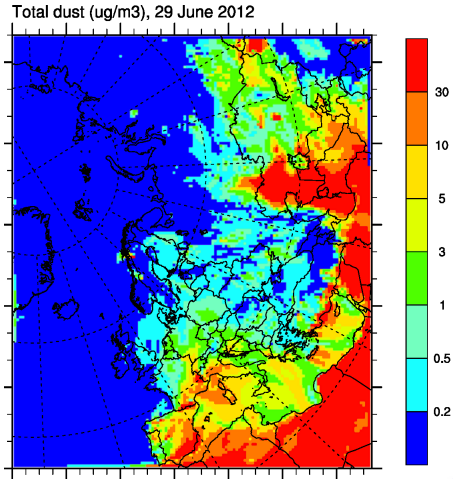




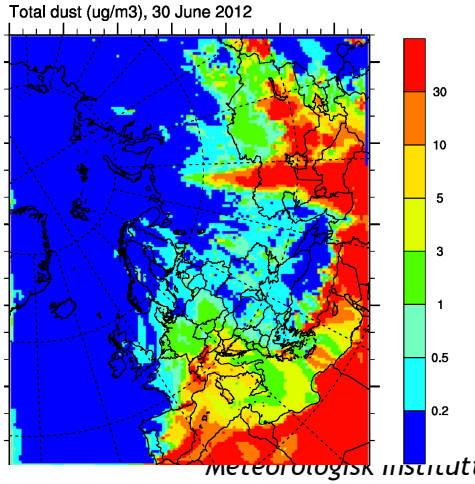
Mean Obs: 1.67
Mean WBD: 0.01
Mean SAH: 0.00
Mean anthDU: 0.52
Mean totDU: 0.54
Corr.: 0.14, 0.38, 0.33, 0.39
RMSE : 2.14, 2.14, 1.75, 1.72



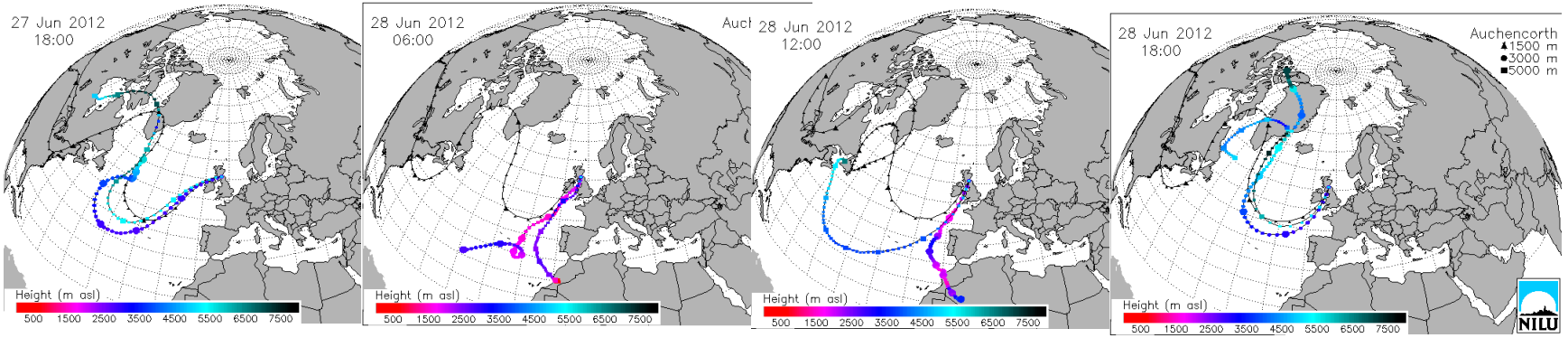
Mean Obs: 1.67
Mean WBD: 0.19
Mean SAH: 0.01
Mean anthDU: 0.52
Mean totDU: 0.72
Corr.: 0.15, 0.41, 0.33, 0.25
RMSE : 2.03, 2.14, 1.75, 1.64



Saharan episode is not predicted with the standard model, but with the test version:
- **one day delay,**
- **max dust too low**

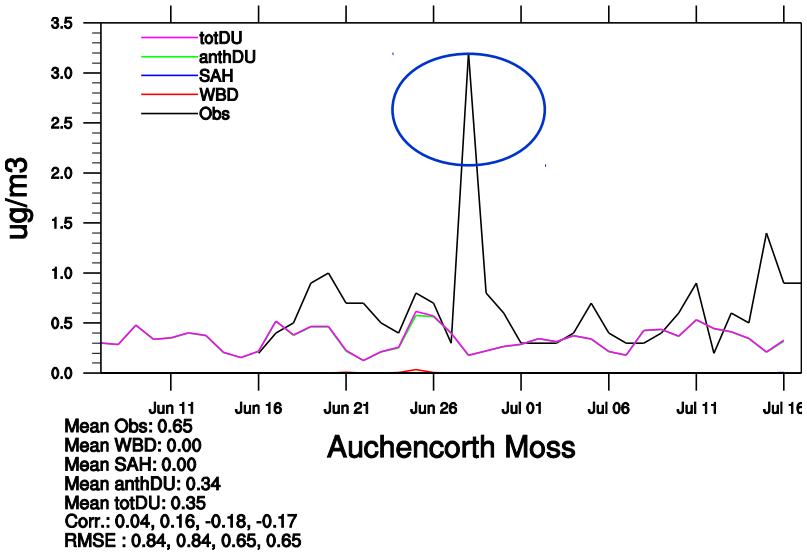


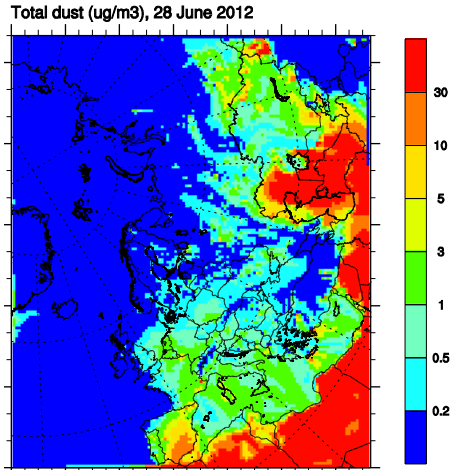
Auchencorth Moss: dust episode 28 June 2012

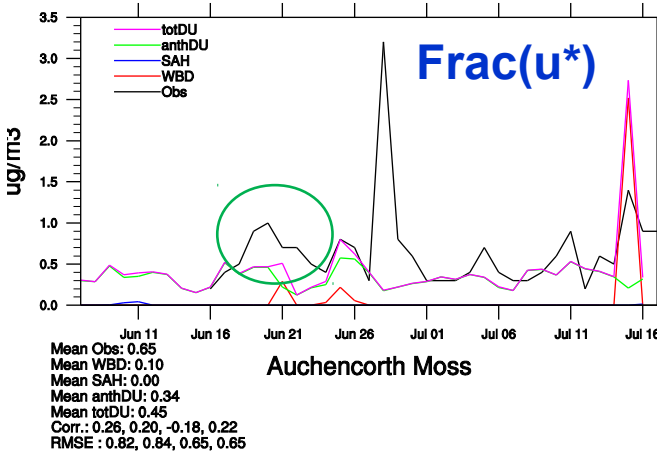


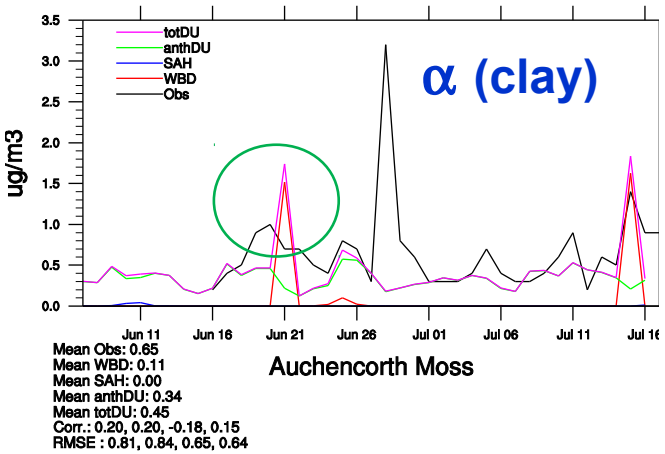
Sahara episode isn't predicted

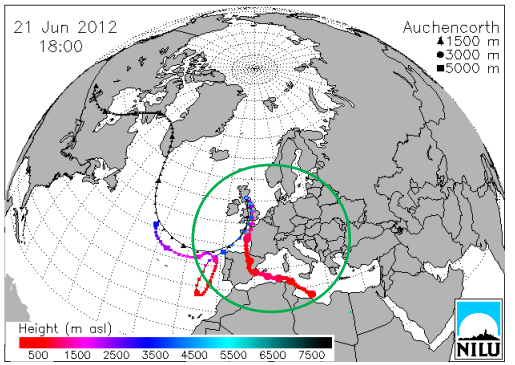
WBD episodes with test versions



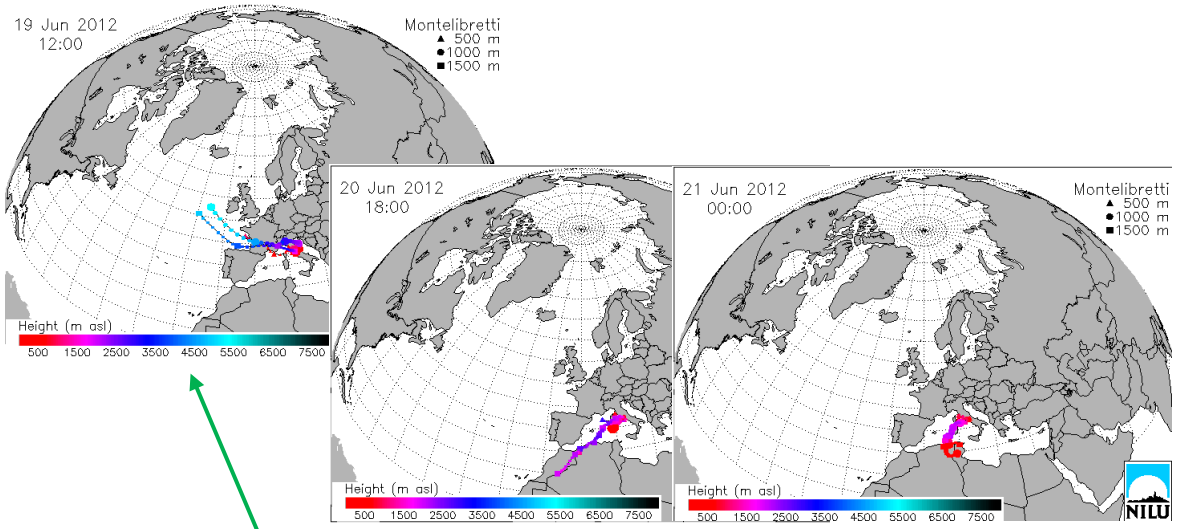


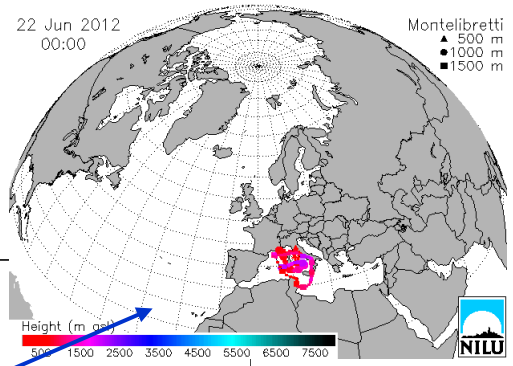


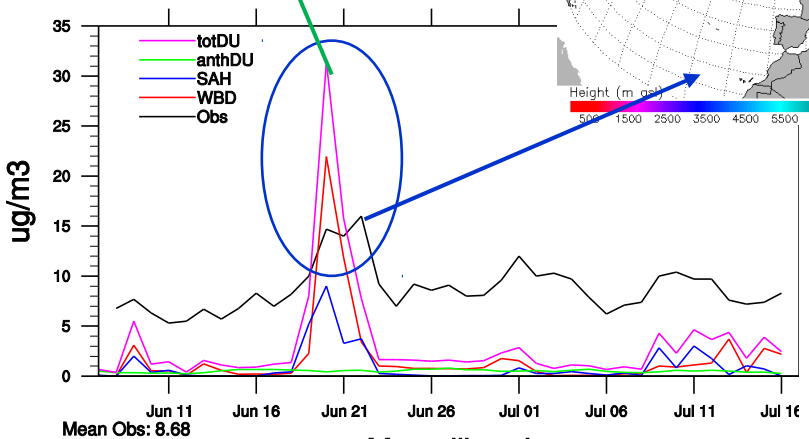




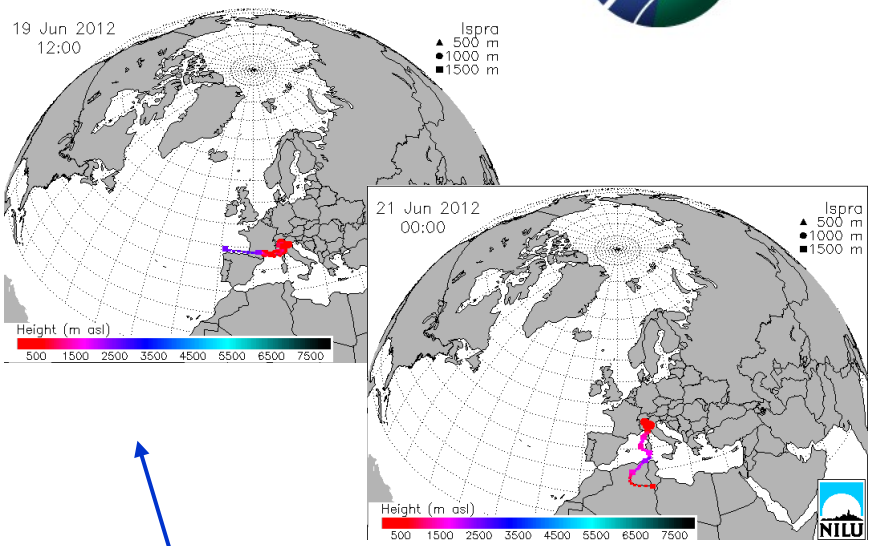
Montelibretti (20-22) and Ispra (19-20): dust episodes June 2012

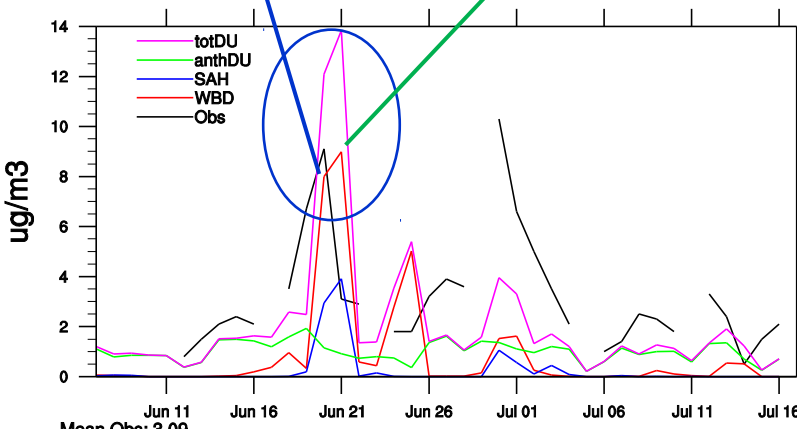






Mean Obs: 8.68
Mean WBD: 1.80
Mean SAH: 0.99
Mean anthDU: 0.50
Mean totDU: 3.30
Corr.: 0.61, 0.68, 0.27, 0.67
RMSE : 7.52, 7.89, 8.51, 6.80



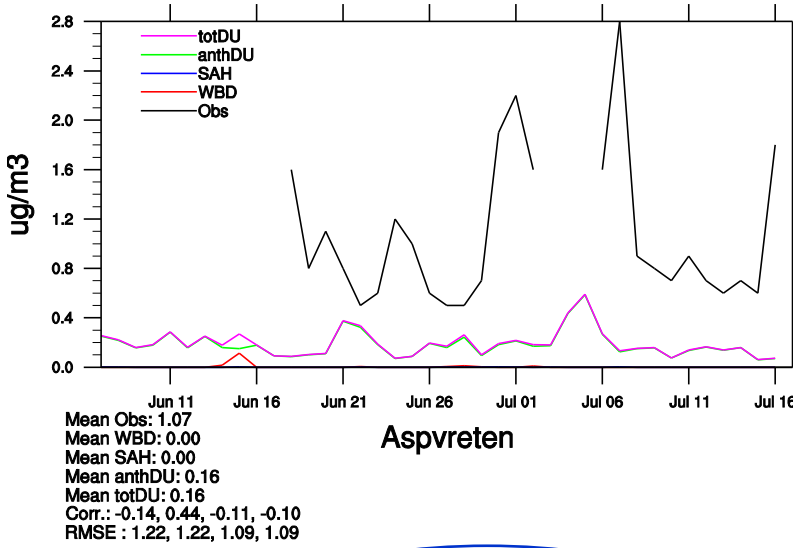


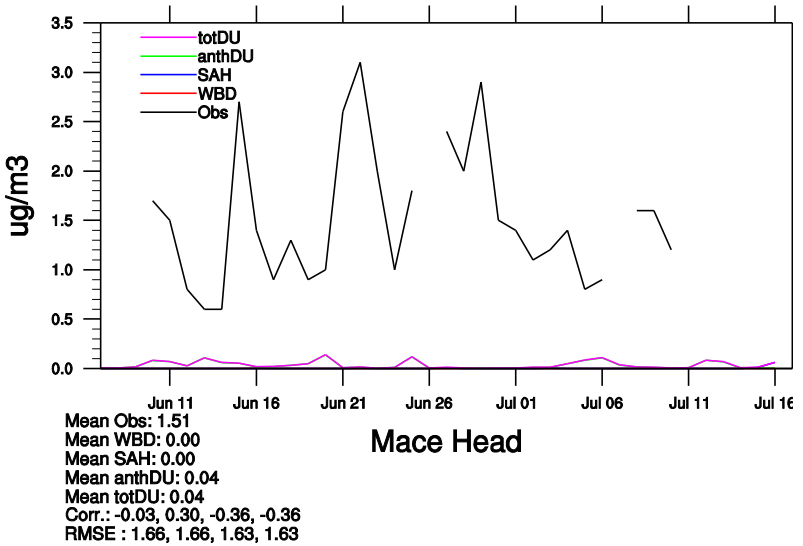
Mean Obs: 3.09
Mean WBD: 1.03
Mean SAH: 0.30
Mean anthDU: 1.04
Mean totDU: 2.38
Corr.: 0.35, 0.47, 0.47, 0.46
RMSE : 3.27, 3.43, 2.93, 2.89

One day shorter episode, max dust too high

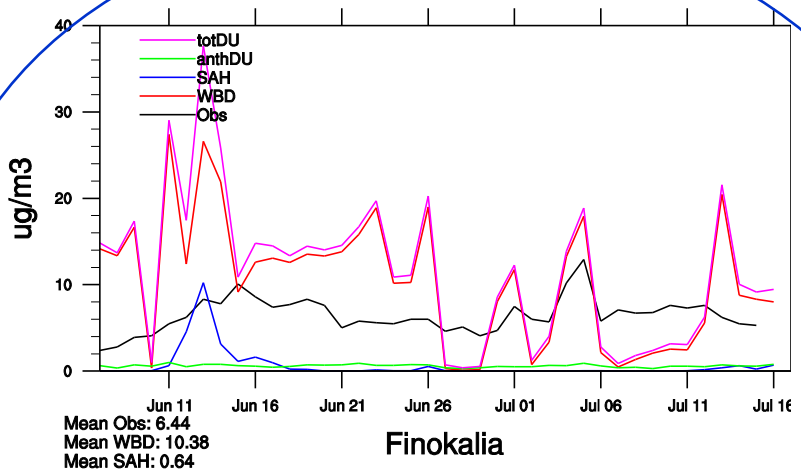
One day delay, max dust too high

No Saharan dust episodes – what are the sources????

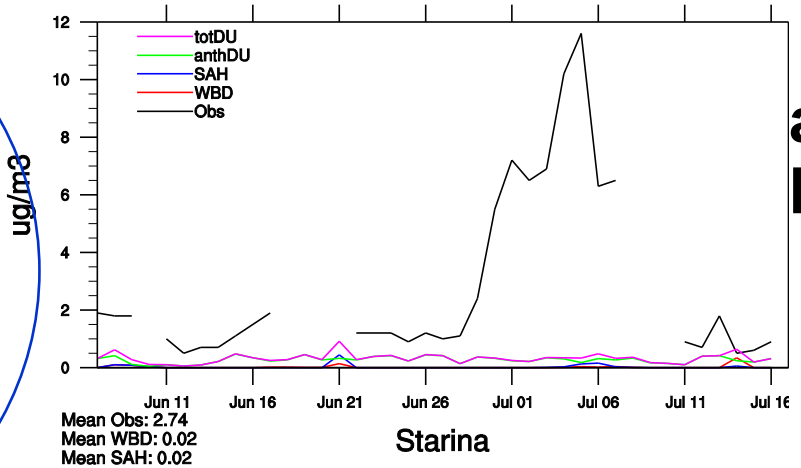




Far too low dust levels are calculated for N. Europe



Too high dust in the Mediterranean



and for C. Europe

The tests did not help!!

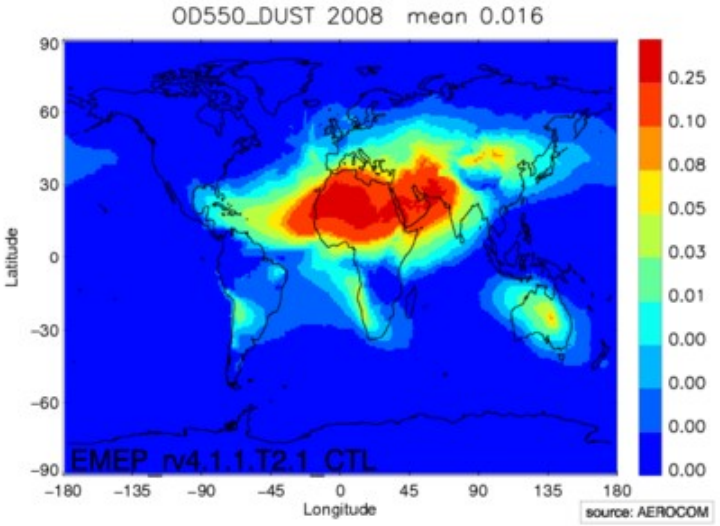
Findings:

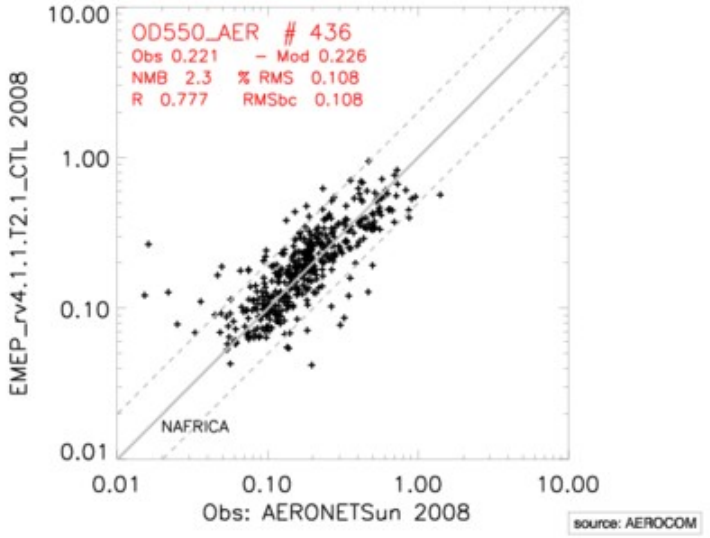
- By and large, the model under-predicts average observed dust levels in June-July 2012, with the exception of south European and elevated sites
- This can due to either underestimation of / failure to predict dust episodes or underestimation of the general background levels
- In general, the model seems to generate enough/too much dust from N. African and C. Asian deserts, but not from soils and roads across Europe... anthropogenic sources?
- The tests show that modification of dust generation scheme helps to increase (even too much) dust production from deserts, but not from agricultural soils, suggesting that different/modified approach should be applied for non-desert "dusty" soils

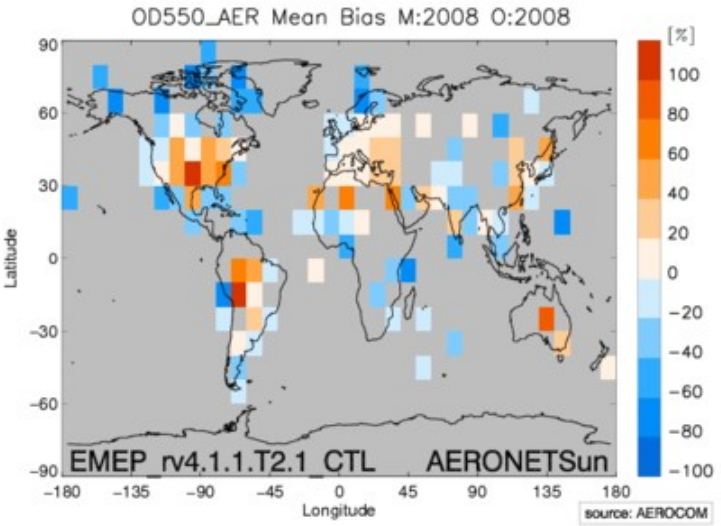
Findings:

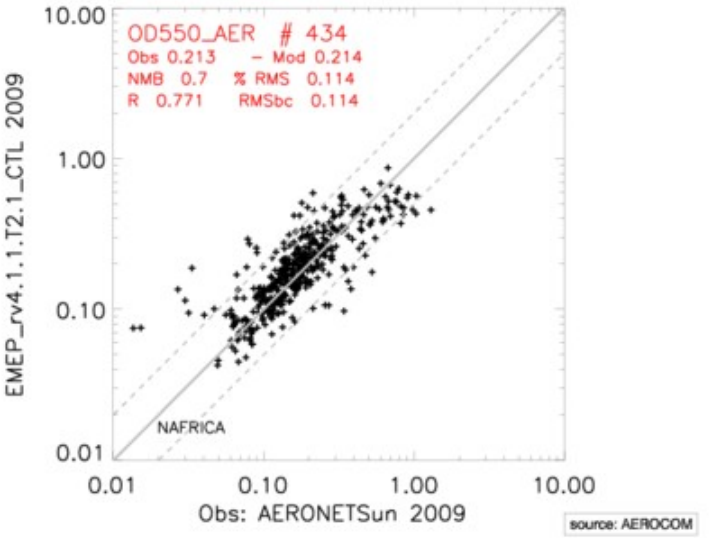
- The dust episode 28-30 June is captured by the model for Montseny, Payern and Melpitz (though 1-2 days delayed), but not for Auchencorth Moss
- For ES1778, CH0002 and DE0044, the dust peak concentrations are calculated however with variable accuracy (scheme modifications result in different effects for these sites)
- For GB0048, the trajectory analysis indicates Saharan dust transport over the N. Atlantic – the model fails to reproduce it due to its limited domain and apparently inaccurate boundary conditions – global/hemispheric model calculations are needed for adequate calculations of Saharan dust intrusion in Europe.
- Sub-grid land-use and meteorology (wind gusts) – would a finer resolution produce better results?

AOD from the EMEP MSC-W model compared with AERONET data (2008-09)









Final remarks and outlook

- Without reasonable description of dust, the model do not have much chance to accurately calculate PM10 (PM2.5)
- Present dust modelling is associated with rather large uncertainties and observational data is essential to constrain dust calculations
- Dust measurements from 2012 (and 3013) facilitate evaluation and testing the model and provide a basis for dust calculation improvements (do not forget coarse SIA!)
- Should investigate separately Saharan episodes on the one hand and anthropogenic, agricultural and road dust on the other – different processes

Do we have good enough data on anthropogenic (fugitive) dust emissions

- Additional information on the origin of measured dust would be very helpful

Thank you for your attention!