Aerosol forecast verification at ECMWF

Luke Jones
Angela Benedetti
ECMWF

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Quick overview of the MACC/ECMWF aerosol analysis and forecasting system

Forward model

12 aerosol-related prognostic variables:
* 3 bins of sea-salt (0.03 – 0.5 – 0.9 – 20 μm)
* 3 bins of dust (0.03 – 0.55 – 0.9 – 20 μm)
* Black carbon (hydrophilic and –phobic)
* Organic carbon (hydrophilic and –phobic)
* SO_2 -> SO_4

Physical processes include:

•emission sources (some of which updated in NRT, i.e.fires),
•horizontal and vertical advection by dynamics,
•vertical advection by vertical diffusion and convection
•aerosol specific parameterizations for dry deposition, sedimentation, wet deposition by large-scale and convective precipitation, and hygroscopicity (SS, OM, BC, SU)

Analysis

Integrated in the ECMWF incremental 4D-Var

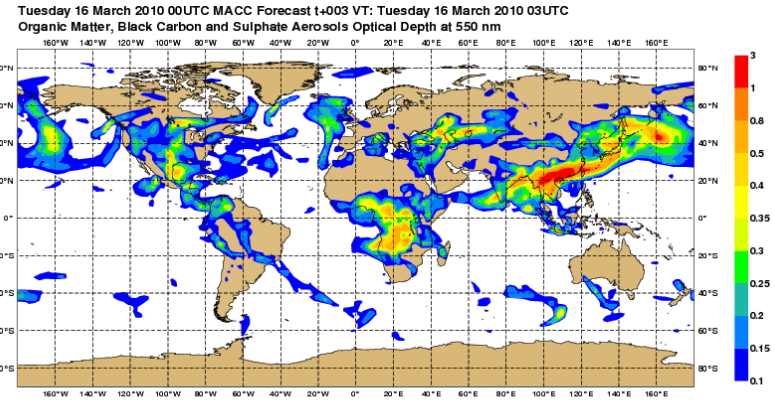
Control variable is formulated in terms of the total aerosol mixing ratio. Soon to come: fine and coarse mode. Increments in total mass are repartitioned into the single species according to their fractional contribution to the total.

Background error statistics have been computed using forecasts errors as in the NMC method (48h-24h forecast differences).

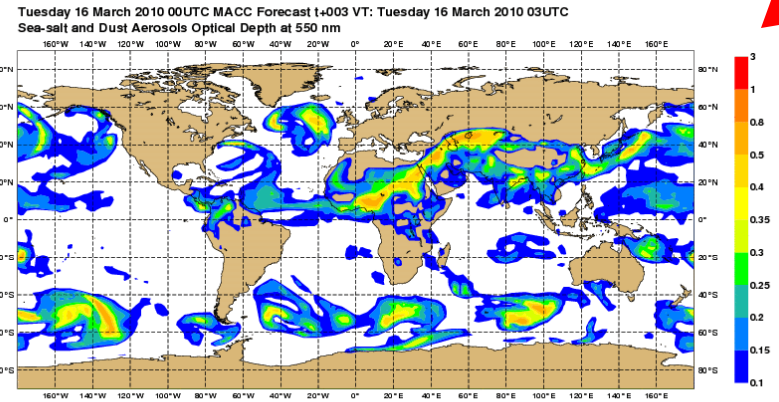
Assimilated observations are the MODIS Aerosol Optical Depths (AODs) at 550 nm over land and ocean. Observation errors are prescribed fixed values as a result of investigation to implement the variational bias correction (not active).

MACC NRT aerosol forecasts

“Anthropogenic”



“Natural”



http://www.gmes-atmosphere.eu

Verification

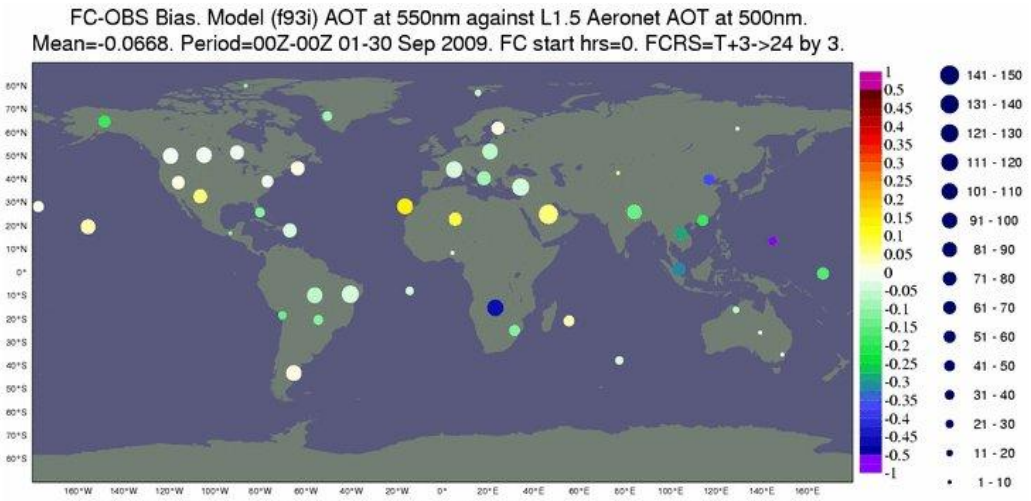
- Based on AERONET multi-wavelength Aerosol Optical Depths (AOD)
- Forecast fields are retrieved and interpolated to all known AERONET site locations using bi-linear interpolation.
- To obviate the problem of an uneven distribution of the AERONET sites around the globe, with a high density of stations in Europe and North America but far fewer in less developed regions and virtually none oceanic, an attempt is made to pick a sub-set of the sites by finding pairs of sites which are less than a critical distance apart (typically between 500km and 1000km) and rejecting the one which has fewer data at a given set of wavelengths over a given period.
- For NRT experiments the site-list is fixed. For reanalyses the list of selected sites needs to be a function of time to maintain data volume
- AERONET data is averaged over the number of hours between model output steps, and it is compared with the NRT forecast output at the given archiving time (every three hours)
- Time-series of bias (or mean error, F-O) and Root Mean Square Error ($\sqrt{\frac{1}{N}\sum_i (F_i - O_i)^2}$) are computed by averaging over the selected sites. Due to nature of AERONET the statistics are not always computed over the same number of sites (N is variable). The number of sites is plotted separately to check that the statistics are meaningful.

Plot type 1: Bias and RMSE maps

As a function of space, meaned over time

For multiple:

- months
- wavelengths
- areas



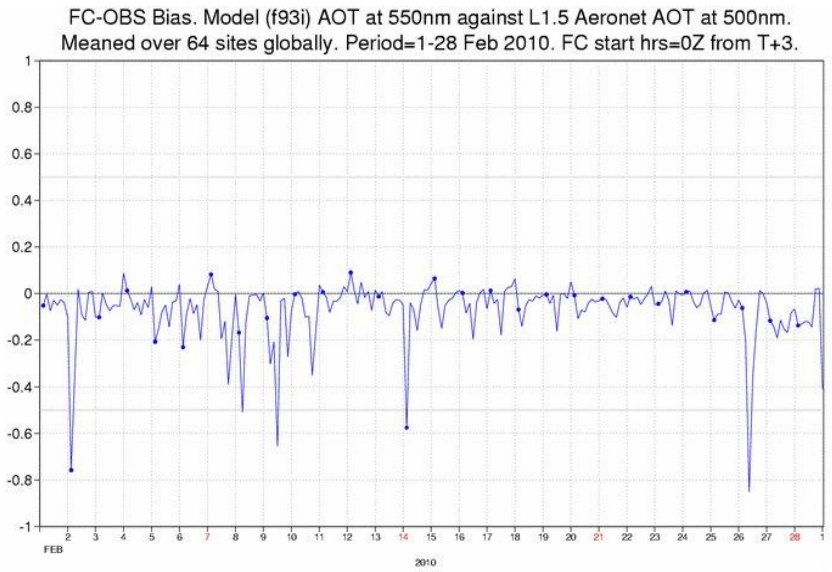
$$\frac{1}{N}\sum_i (F_i - O_i)$$

N is represented by the symbol-size

$$\sqrt{\frac{1}{N}\sum_i (F_i - O_i)^2}$$

Plot type 2: Bias and RMSE

As a function of time, meaned over space

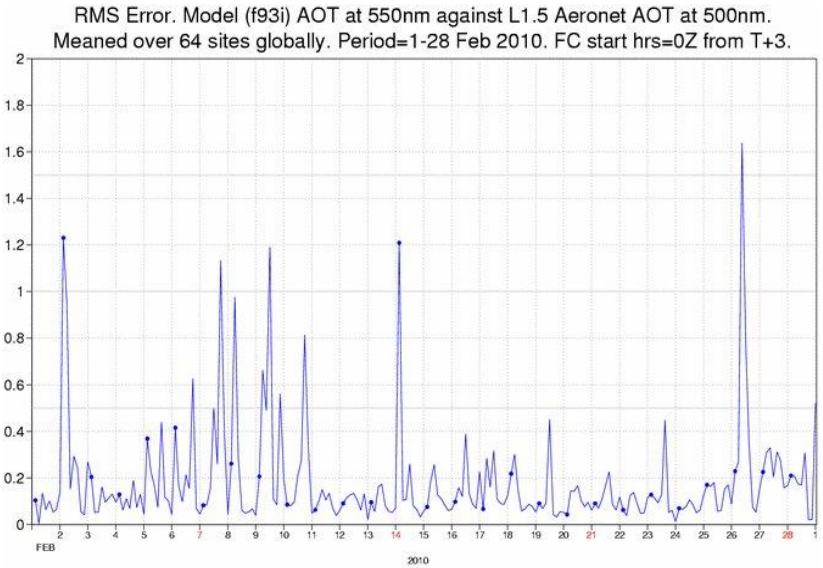


$$\frac{1}{N}\sum_i (F_i - O_i)$$

N is shown on a separate plot

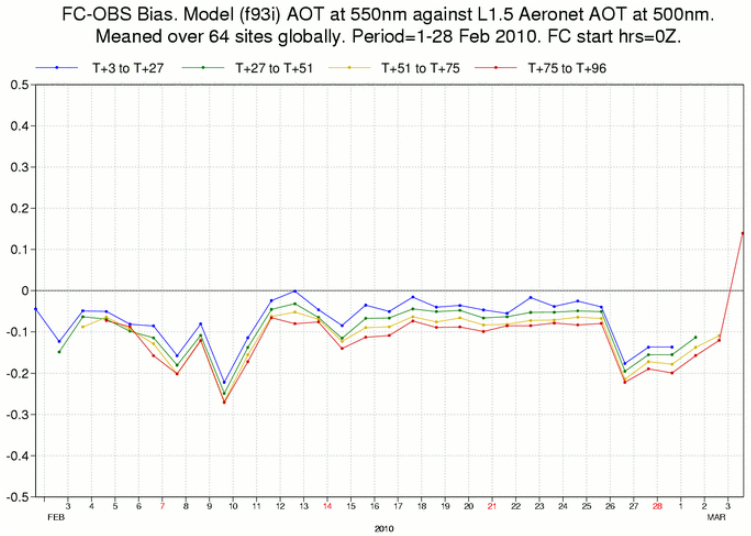
For multiple:

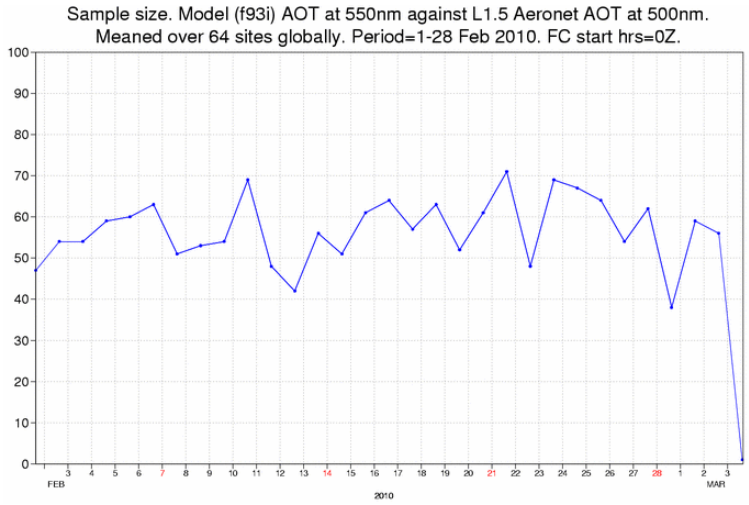
- months
- wavelengths
- areas

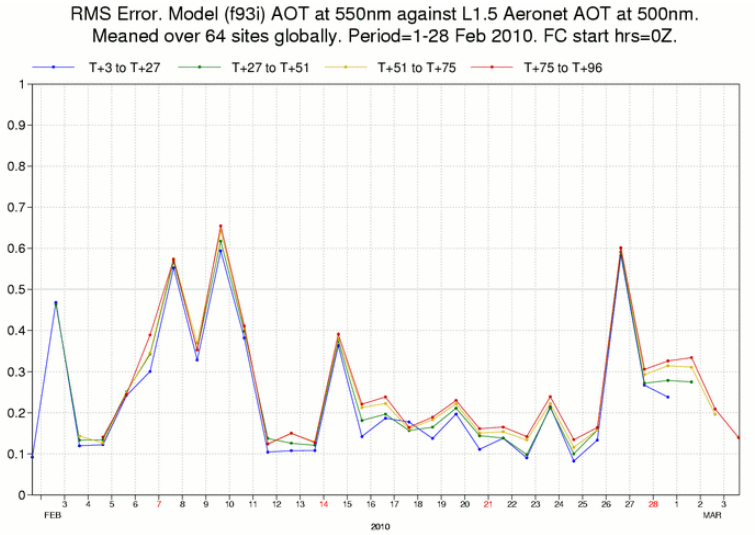


$$\sqrt{\frac{1}{N}\sum_i (F_i - O_i)^2}$$

Multiple forecast ranges & 24-hour meaning





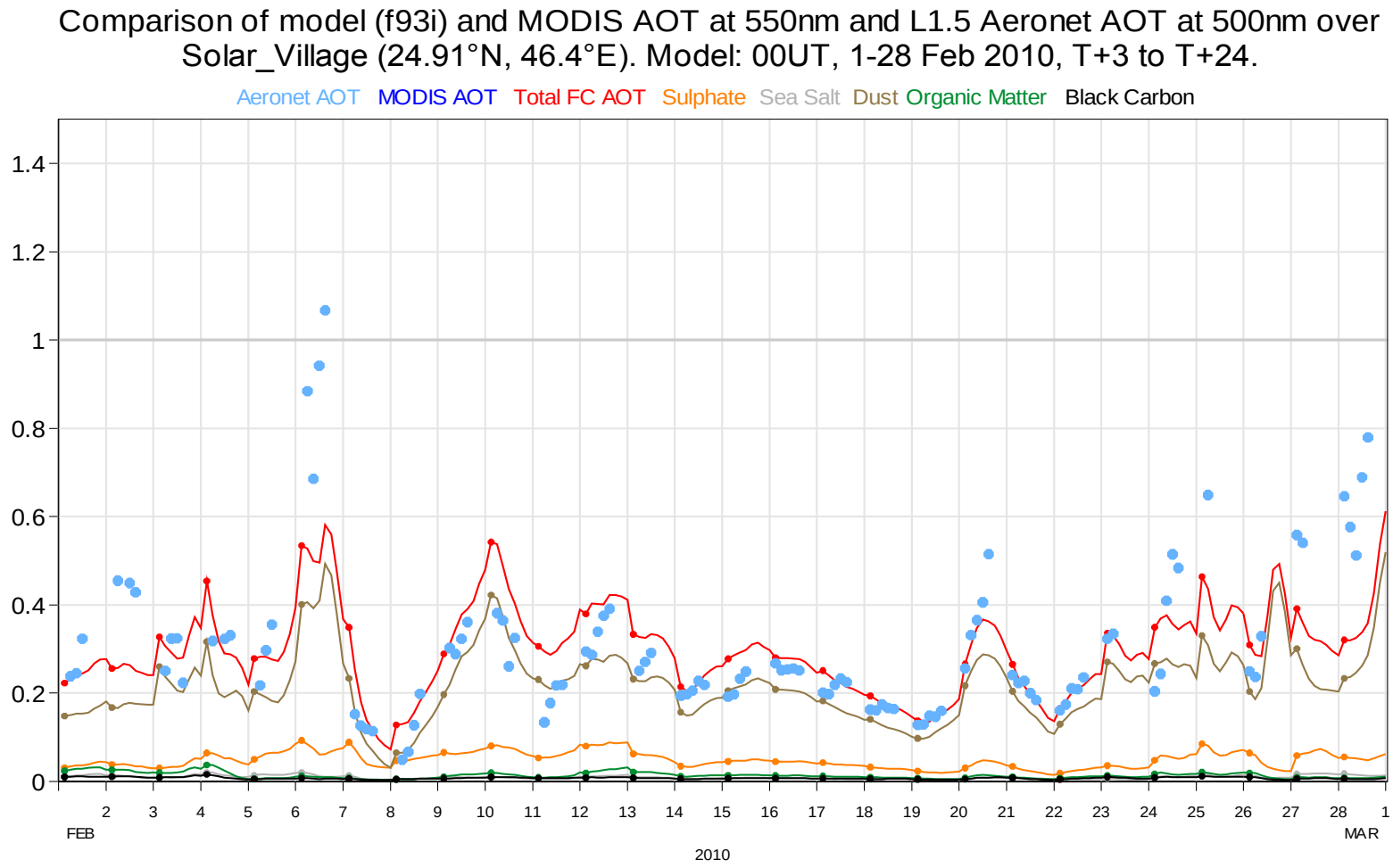


Day 1 Day 3

Day 2 Day 4

- Daily-meaned values more stable & meaningful
- Multiple forecast days superimposed
- Bias increases with forecast range
- Less noticeable on the RMS

Plot type 3: Single-site time-series



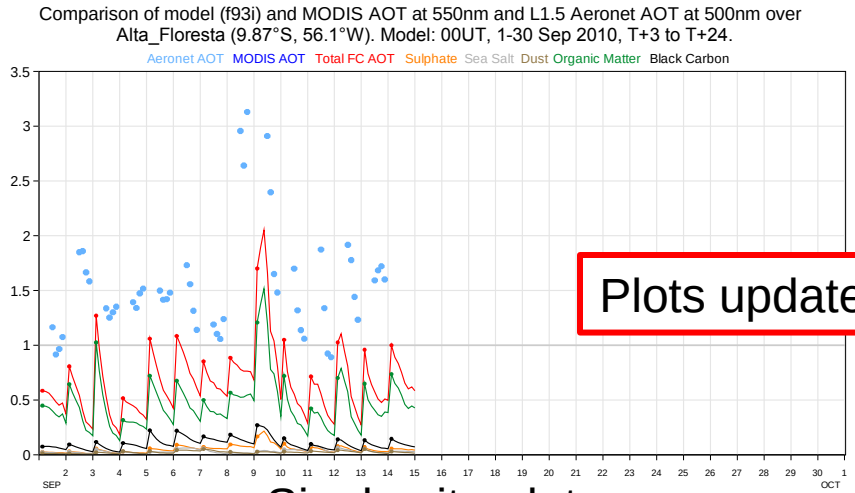
For multiple: sites, months, wavelengths

NRT Verification on the Web

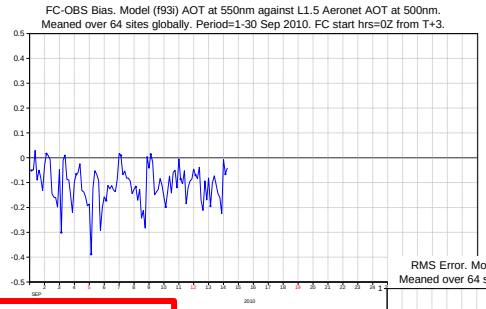
From the main web page **http://www.gmes-atmosphere.eu**

- Click on “Global atmospheric composition”
- Click on “Monitoring and Forecasting of Global Atmospheric Composition”
- Click on “aerosol verification plots” under the header “Verification”

Or go directly to **http://www.gmes-atmosphere.eu/d/services/gac/verif/aer/nrt**

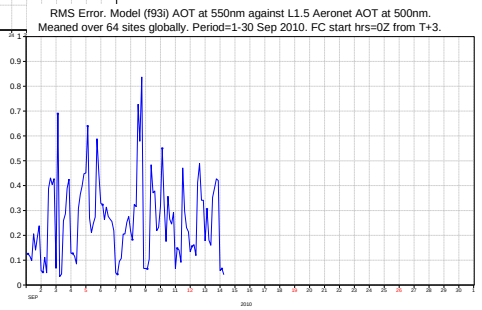


Single site plots



Time-series of bias over approx 64 uniformly-distributed AERONET stations.

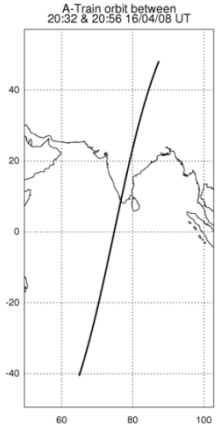
Plots updated daily

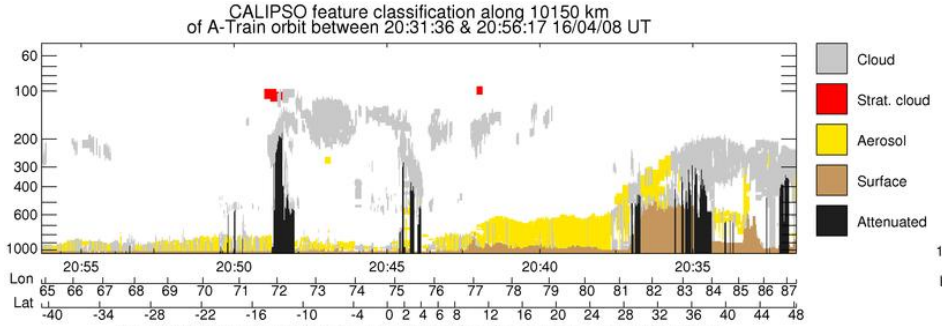


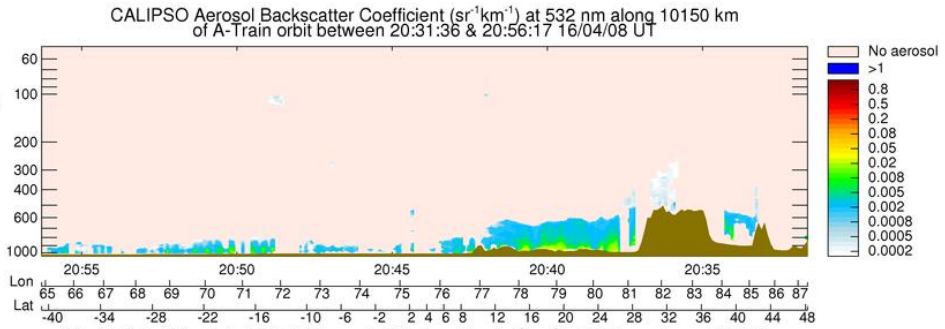
RMS

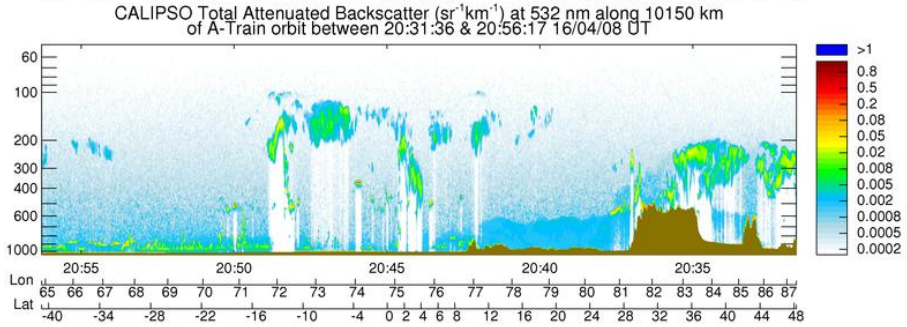
Aerosol verification with A-Train data

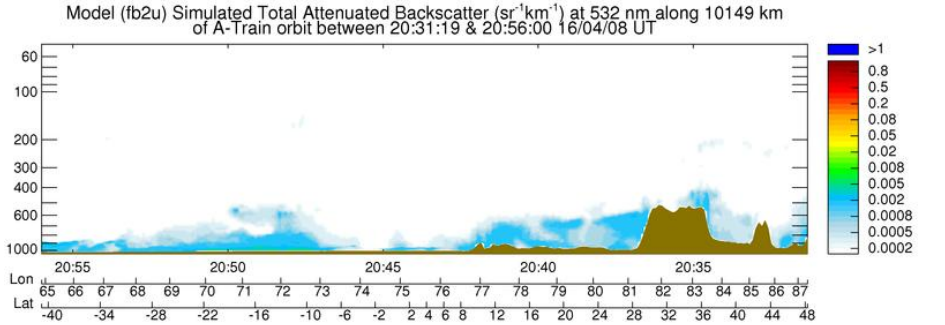
- Model now outputs simulated Aerosol Attenuated Backscatter
- Allows direct numerical comparison between CALIPSO & model – statistics can be computed
- What statistics? ~ on-going research
- Soon to come: new NRT level-1.5 CALIPSO product





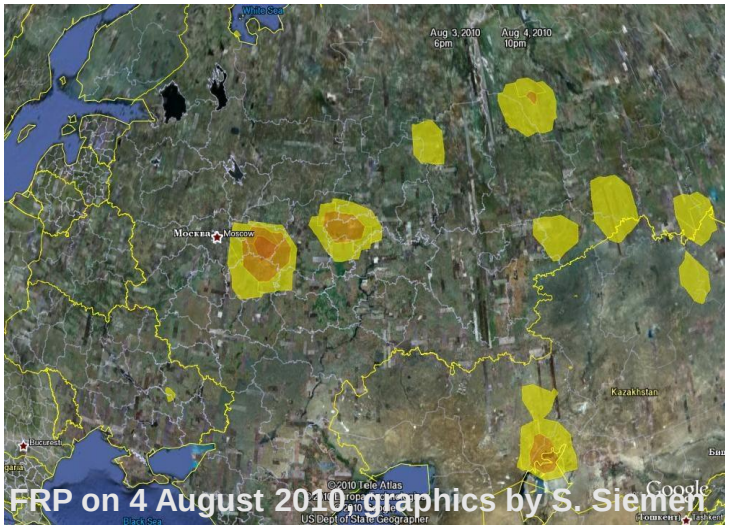






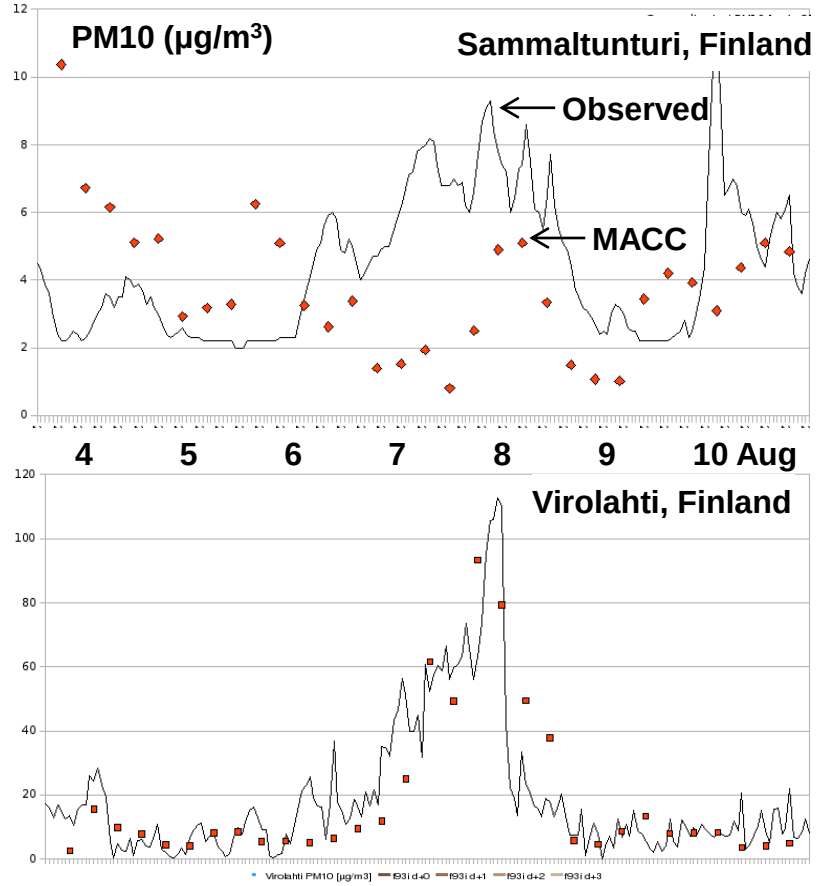
Aerosol verification with PM10

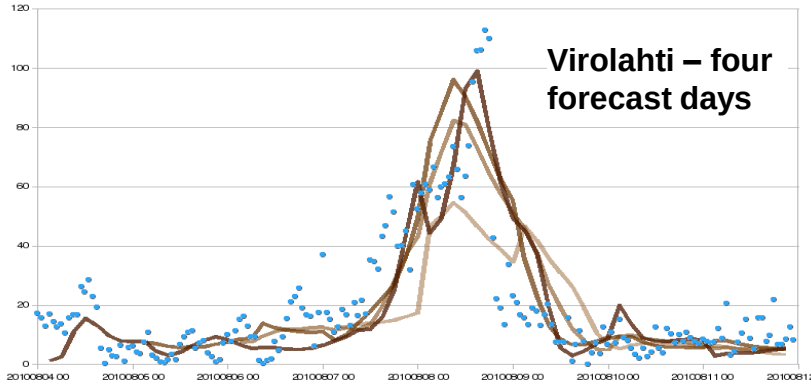
- Single case-study: 2010 fires in Russia



- Air-quality observations show high values over parts of Finland on 8 August (y-axis labels not public)
- MACC 0-96-hour forecasts predict the smoke plume overpass well
- Due to aerosol assimilation & fire source
- PM10 is a useful aerosol verification measure

graphics by M. Razinger





Summary and future plans

- Currently, all verification for the aerosol analysis/forecasts with the ECMWF/MACC system is based on INDEPENDENT observations of multi-wavelength AOD from AERONET and lidar backscattering from CALIPSO.

- Verification activities have benefitted greatly from the provision of near real-time data (AERONET typical data latency is 1 day, thanks to NASA/GSFC). Other teams dealing with aerosol observations are developing NRT data provision capabilities (i.e. CALIPSO, thanks to NASA/LaRC).

- Research data (level 2.0 AERONET, CALIPSO, ground-based lidars , GAW stations, other in-situ observations, aircraft and field experiments) is very valuable for R&D and model assessment, even if does not meet the NRT “requirements”

- Future plans to include also model-based verification – looking forward to the outcomes of today’s discussion!