

Observations and modeling of aerosol and cloud properties  
for climate studies

Paris, France, 12-14 September 2011

# **The MACC/ECMWF aerosol analysis and forecast system: Some recent results**

J.-J. Morcrette, A. Benedetti, L. Jones, J.W. Kaiser, M. Razinger, M. Suttie  
M. Janiskova, O. Stiller, A.J. Simmons

ECMWF, Reading, UK

- ECMWF for its operational analyses and forecasts ingest gigabytes of observational data every day and produces weather forecast(s) of temperature, humidity, wind, ..
- Since 2006, with the EU FP7 **GEMS** then **MACC** projects, ECMWF has been producing experimental analyses and forecasts of the same meteorological parameters PLUS reactive gases, greenhouse gases, and aerosols. Near Real Time forecasts started in September 2008.
- This presentation **quickly** surveys some recent and ongoing work dedicated to **aerosols**:
  - Introduction
  - Prognostic aerosols in the IFS
  - Some aerosol events
  - On-going work

# MACC Daily Service Provision

<http://www.gmes-atmosphere.eu>

Monitoring atmospheric composition & climate

macc Monitoring atmospheric composition & climate

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**macc** - Monitoring Atmospheric Composition and Climate is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. MACC combines state-of-the-art atmospheric modelling with Earth observation data to provide information services covering European Air Quality, Global Atmospheric Composition, Climate, and UV and Solar Energy.

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 Pre-operational Ozone Verification On-line  
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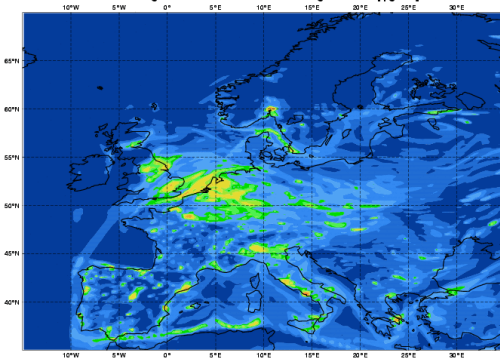
Health | Environment | Science Community | Citizen | Meteorology

MACC is a Collaborative Project (2009-2011) funded by the European Community under the 7th Framework Programme. It is coordinated by the European Centre for Medium-Range Weather Forecasts and operated by a 45-member consortium.

Air quality



Monday 22 March 2010 00UTC GEMS-RAQ Forecast t+000 VT: Monday 22 March 2010 00UTC  
 Model: LOTOS-EUROS Height level: Surface Parameter: Nitrogen Dioxide [ $\mu\text{g}/\text{m}^3$ ]

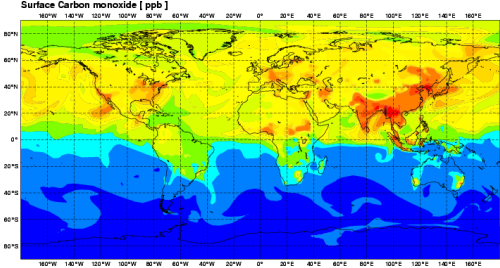


NO2

Global Pollution



Sunday 21 March 2010 00UTC MACC Forecast t+066 VT: Tuesday 23 March 2010 18UTC  
 Surface Carbon monoxide [ $\mu\text{g}/\text{m}^3$ ]

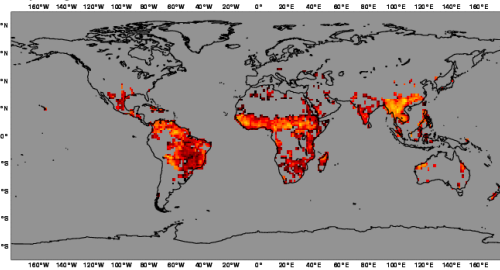


CO

Biomass burning



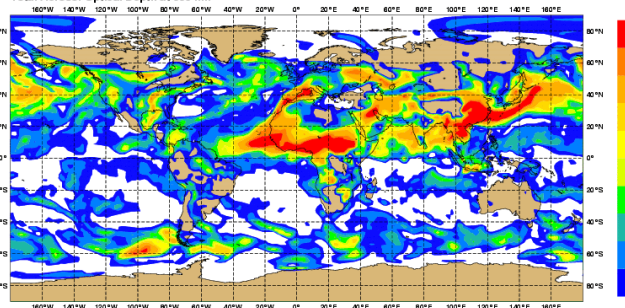
MACC Fire Intensity Products Wednesday 24 February 2010  
 Daily Average of Observed Fire Radiative Power [ $\text{nW}/\text{m}^2$ ]



Aerosol



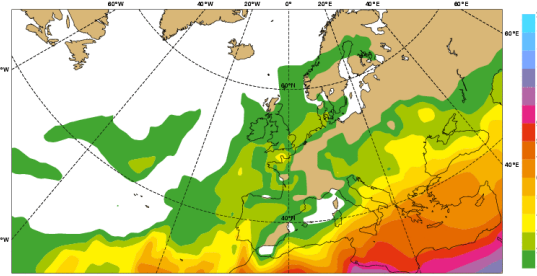
Sunday 21 March 2010 00UTC MACC Forecast t+003 VT: Sunday 21 March 2010 03UTC  
 Total Aerosol Optical Depth at 550 nm



UV index



Sunday 21 March 2010 00UTC MACC Forecast t+012 VT: Sunday 21 March 2010 12UTC  
 Total sky UV Index



NRT since September 2008

# Quick overview of the MACC/ECMWF aerosol analysis and forecasting (original) system

## Forward model

12 aerosol-related prognostic variables added to the existing prognostic variables (T, wind, q, O<sub>3</sub>, P<sub>s</sub>)

- \* 3 bins of sea-salt (0.03 – 0.5 – 0.9 – 20  $\mu\text{m}$ )
- \* 3 bins of dust (0.03 – 0.55 – 0.9 – 20  $\mu\text{m}$ )
- \* Black carbon (hydrophilic and –phobic)
- \* Organic carbon (hydrophilic and –phobic)
- \* SO<sub>2</sub> -> SO<sub>4</sub>

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 (SS, OM, BC, SU) and hygroscopicity (SS, OM, BC, SU).

Morcrette et al., 2009, JGR

## 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).

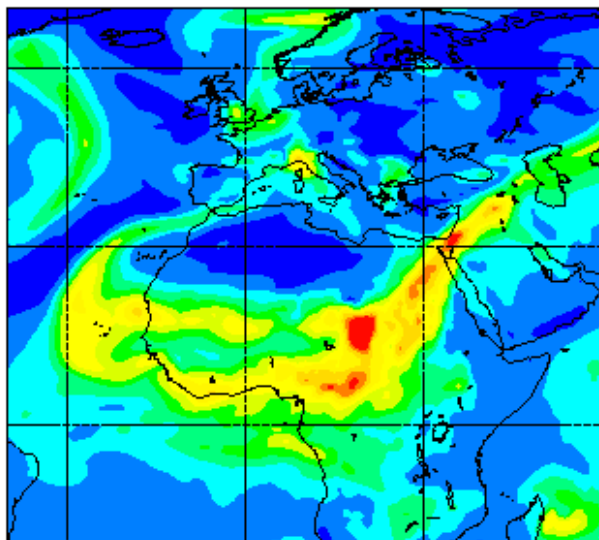
Assimilated observations are the **MODIS** Aerosol Optical Depths (AODs) at 550 nm over land and ocean. Observation errors are prescribed fixed values as a result of investigation to implement the variational bias correction (not active).

Benedetti et al., 2009, JGR

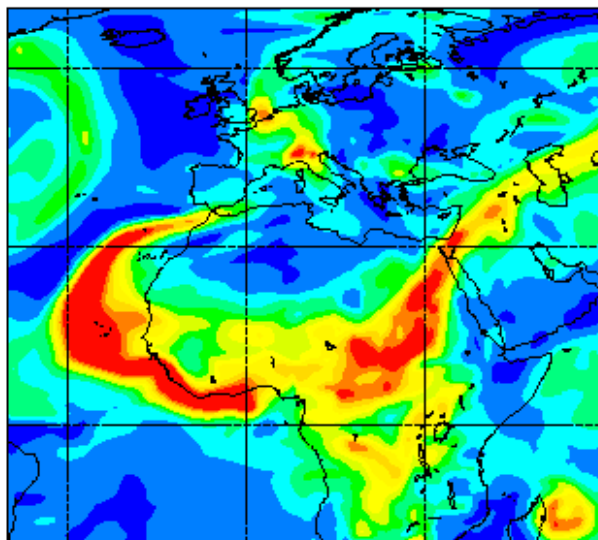
# Evaluation with MODIS/SEVERI and AERONET

## Saharan dust outbreak: 6 March 2004

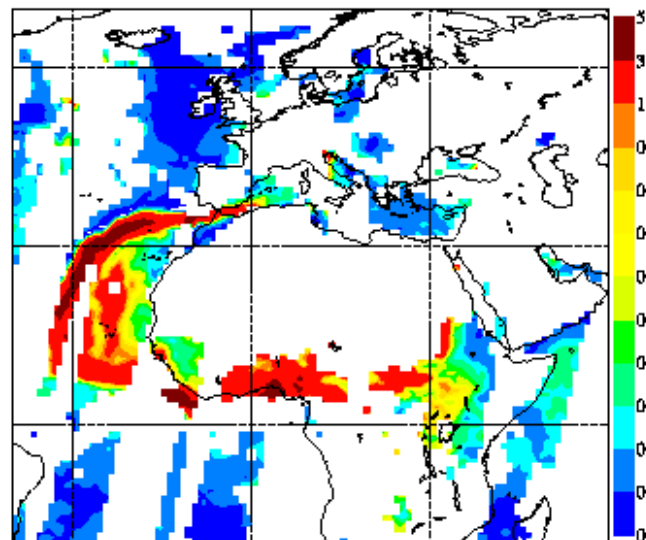
Model simulation



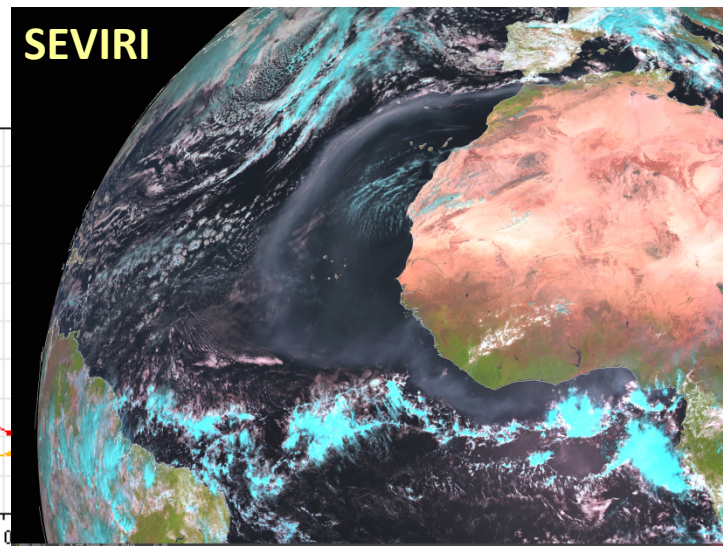
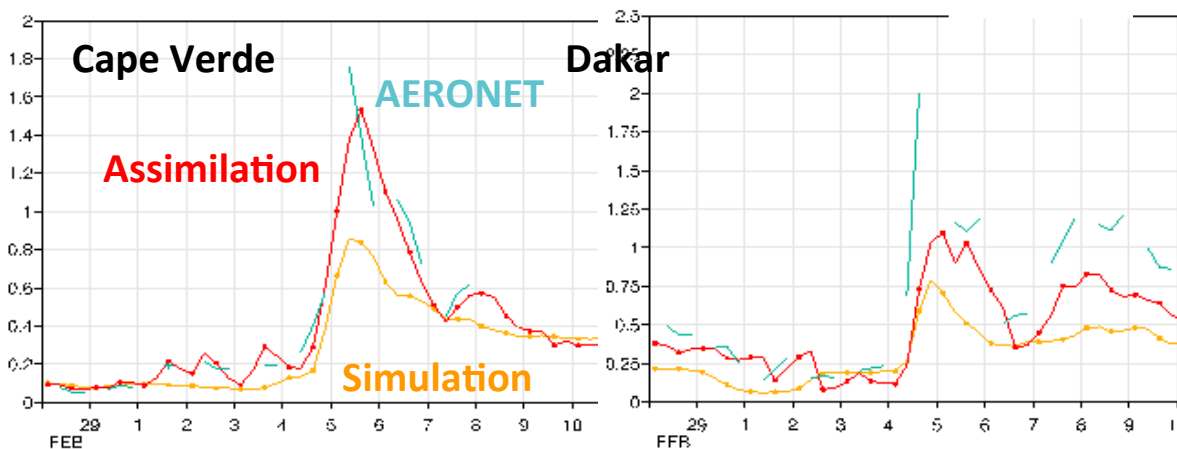
Assimilation



MODIS

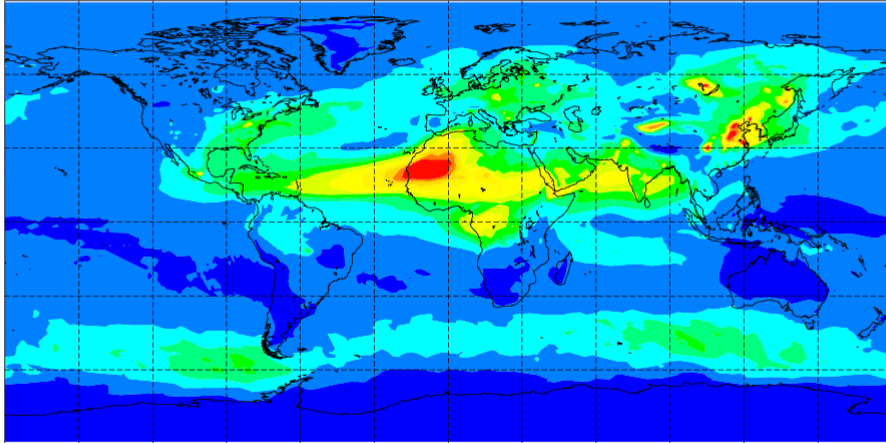


Aerosol optical depth at 550nm (upper)  
and 670/675nm (lower)

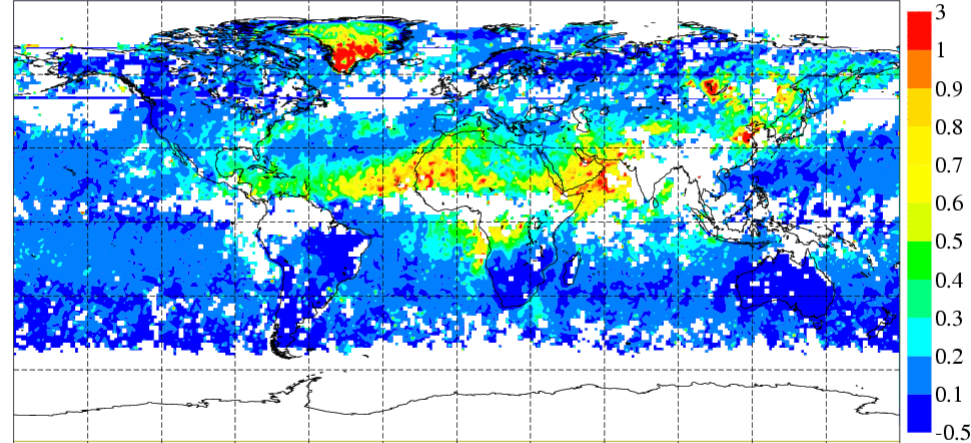


# Comparison of GEMS simulated and analysed aerosol optical depth with MODIS and MISR for July 2003

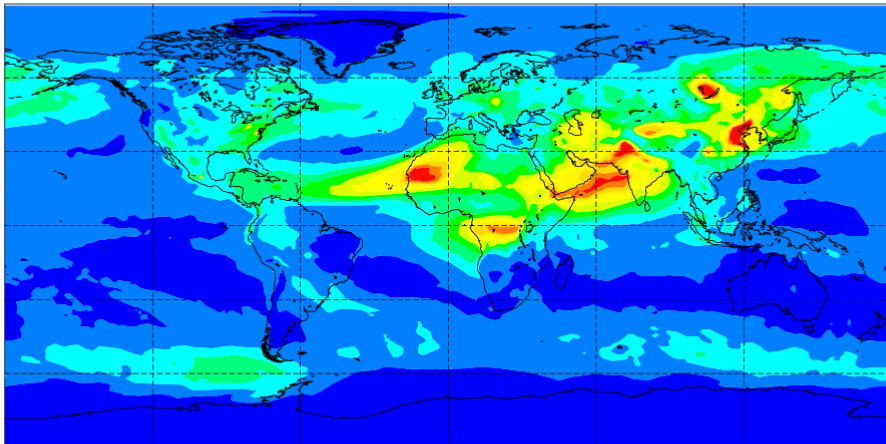
Aerosol Optical Depth at 550 nm from Unconstrained Model Run  
July 2003



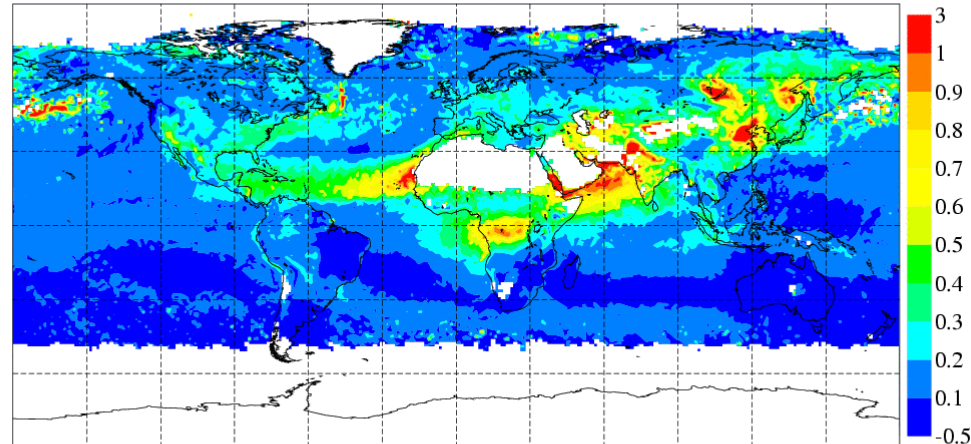
MISR Terra Aerosol Optical Depth at 557.5 nm [unitless]  
July 2003



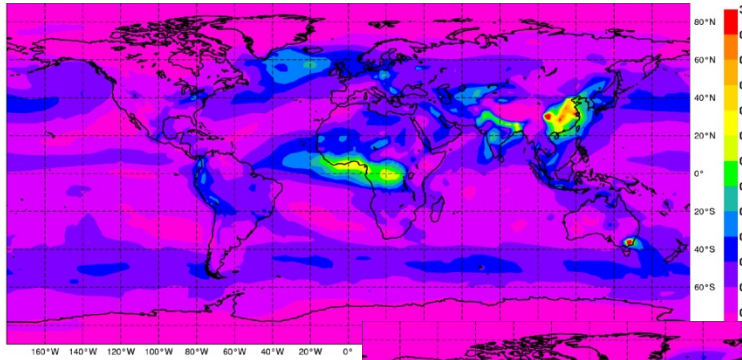
Aerosol Optical Depth at 550 nm for Reanalysis using MODIS AOD  
July 2003



MODIS Terra MOD08-M3.005 Aerosol Optical Depth at 550 nm [unitless]  
July 2003

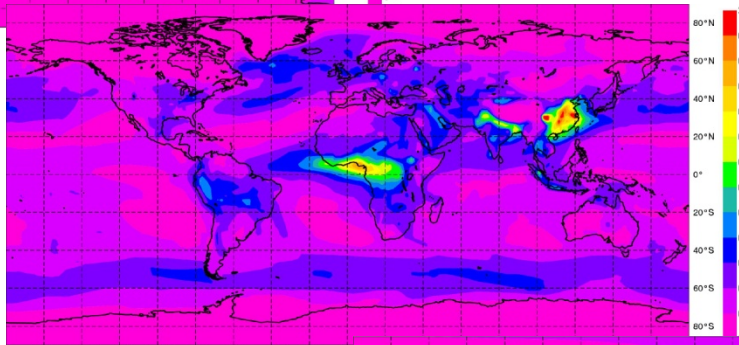


# Total aerosol optical depth

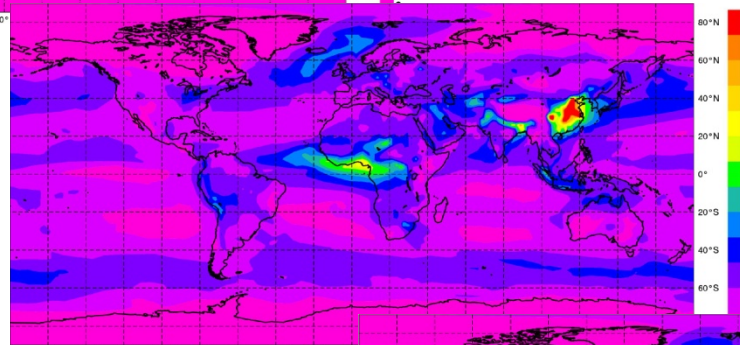


January 2003

- January 2003: increased AOD over south-eastern Australia as a result of bush fires

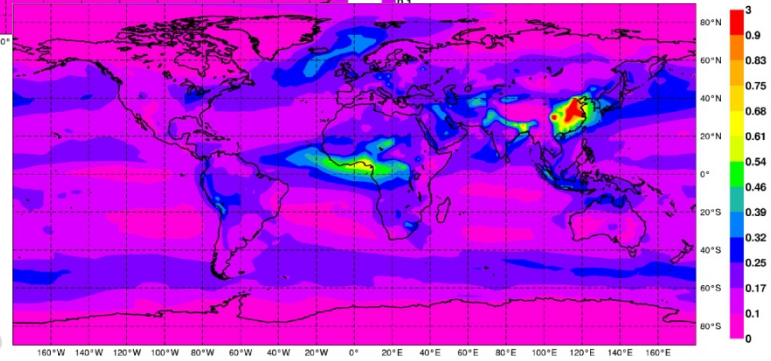


2004



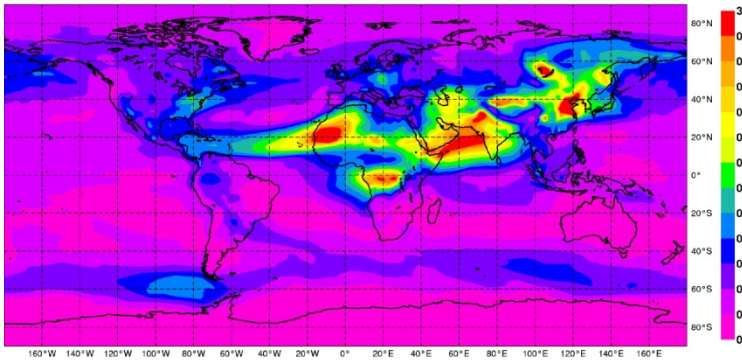
2005

- Low AOD-month with just a few hot spots (India, China and West Africa).
- Strip of large AOD at the foot of the Himalaya is a constant feature, due to trapped pollution coming from the Indian sub-continent.
- Large values of AOD with little seasonal and inter-annual variability over China, associated with anthropogenic pollution.
- Winter AOD maximum of varying inter-annual strength off the coast of West Africa at the Equator associated with biomass burning of the tropical savannah



2006

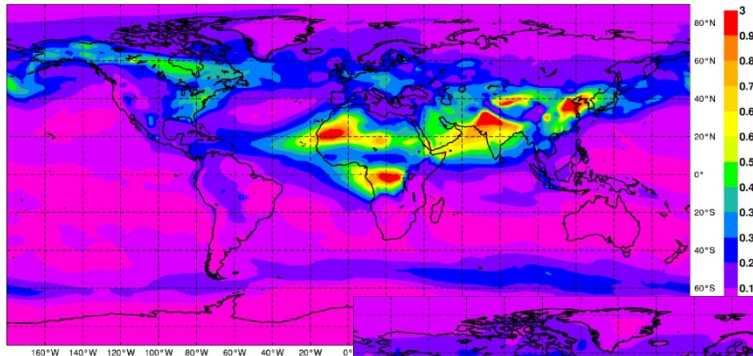
# Total aerosol optical depth



- July 2003: AOD maxima over Siberia associated with wild fires. This signature is also present in the CO field which is independently analyzed.

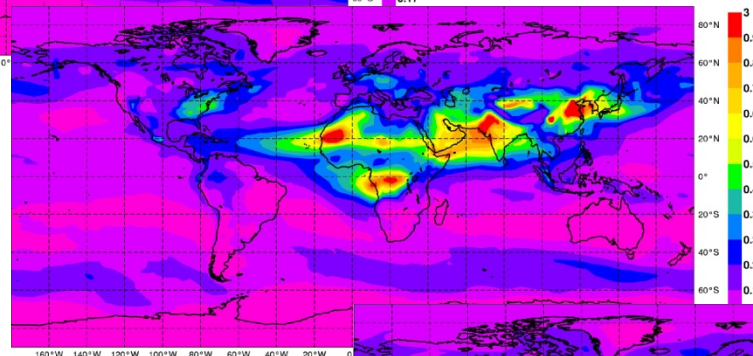
- July 2004: presence of a large aerosol load in the North-West of America connected with pollution transport from East Asia.

July 2003

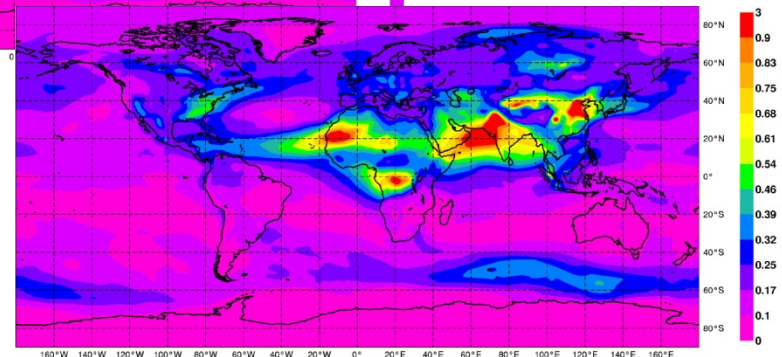


2004

2005



2006



- Biomass burning over West Africa and desert dust emissions from the Sahara are the main “constant” features
- Aerosol load in the Indian Ocean associated to strength of the monsoon
- The winter hemisphere usually presents larger values of AOD over the oceans connected to more intense circulation and increased production of maritime aerosols with inter-annual variability dependent on that of wind intensity at the ocean surface.



# Sydney dust storm, 23-09-09

BBC

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NEWS

LIVE BBC NEWS CHANNEL

News Front Page

Page last updated at 10:42 GMT, Wednesday, 23 September

## Desert dust storm chokes Sydney



Sydney's red dust has been blown from the outback

A large stretch of Australia's east coast, including the largest city Sydney, has been shrouded in red dust blown in from the desert outback.

Visibility in Sydney was so bad that flights were diverted and harbour ferry traffic disrupted.

ABC News

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Video

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## Dept admits error in air quality forecast

Posted 11 hours 54 minutes ago

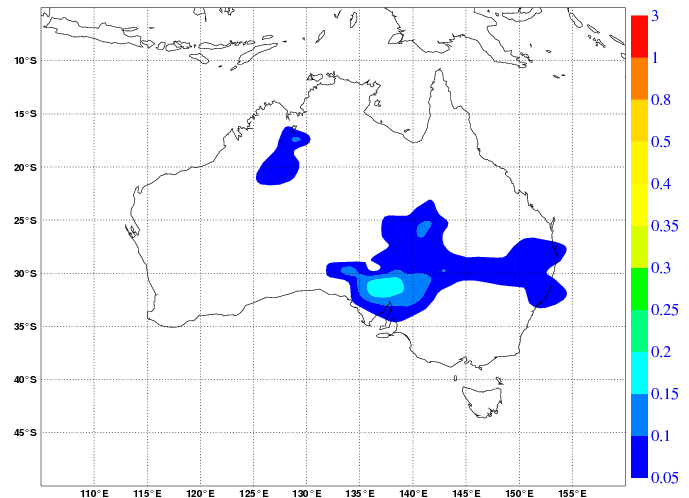
Updated 11 hours 51 minutes ago

The New South Wales Environment Department has admitted its forecast for air quality in Sydney today was wildly wrong after a dust storm prompted hundreds of emergency calls due to breathing difficulties.

Audio: Respiratory expert Dr Christine Jenkins speaks to ABC Local Radio (ABC News)

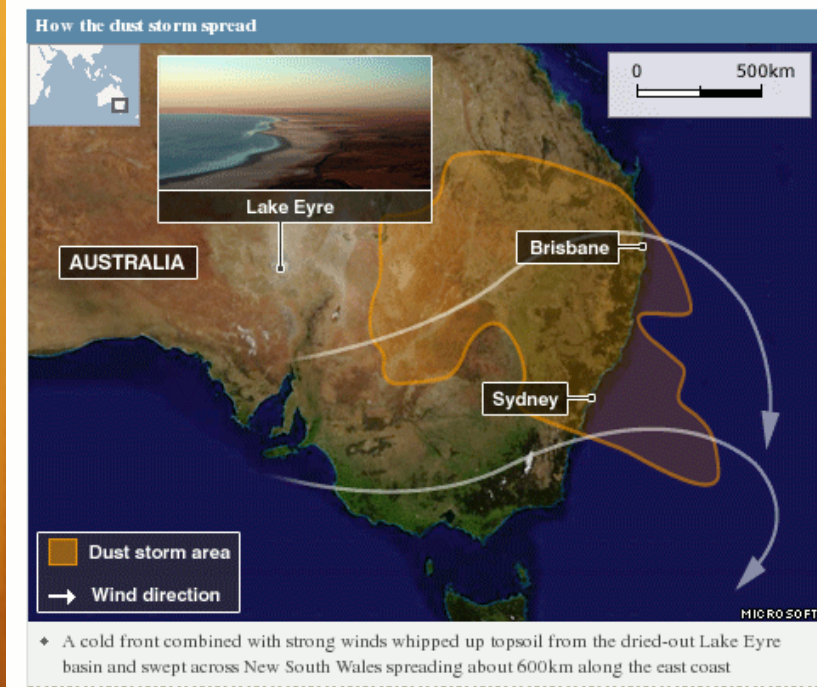
Until this morning, the department's website was forecasting conditions would be good.

20090921 00UTC FC t+3 valid at 03UTC 20090921

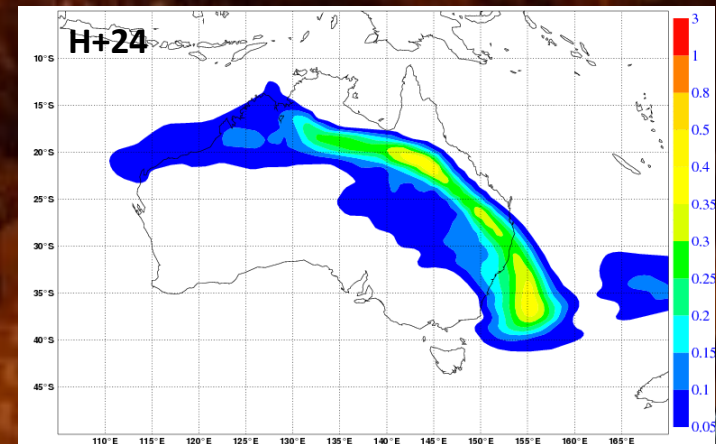
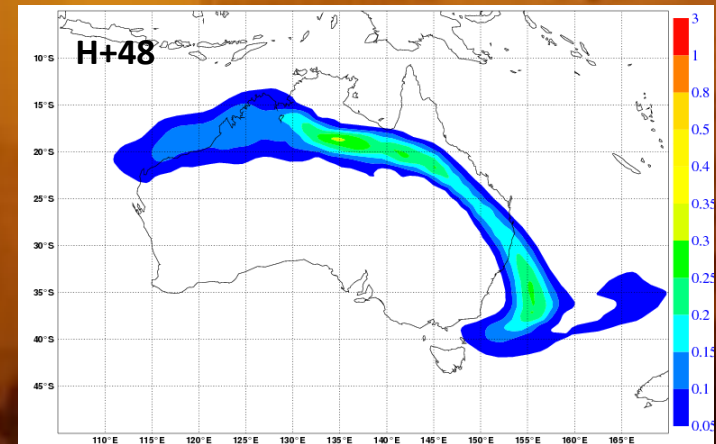
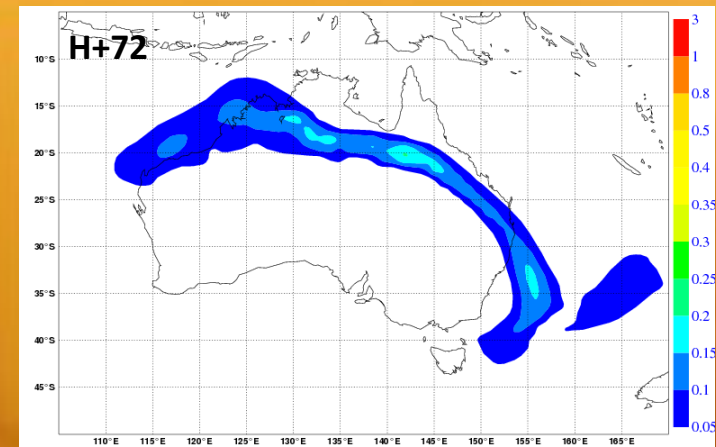
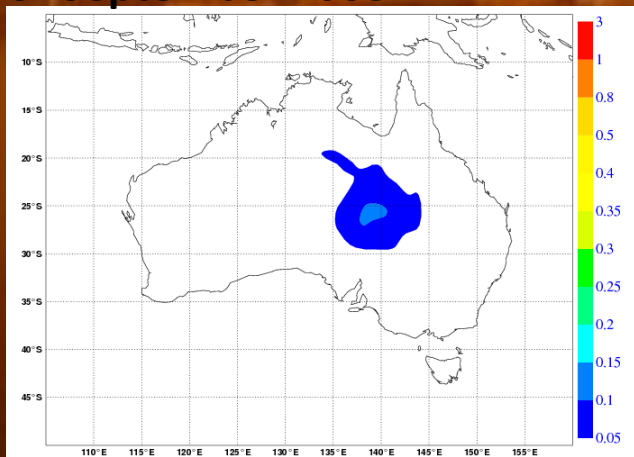


AFP

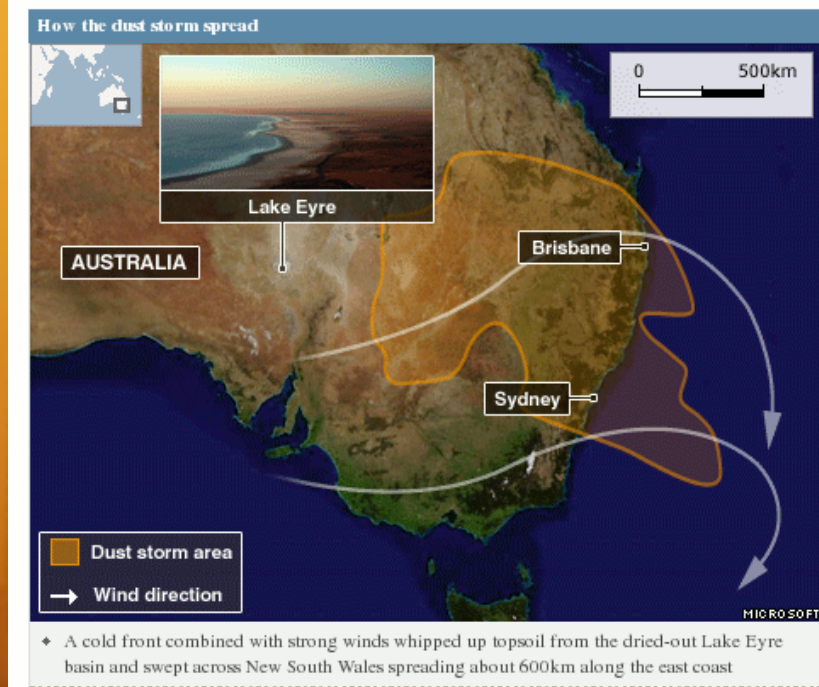
# Sydney dust storm, 23-09-09



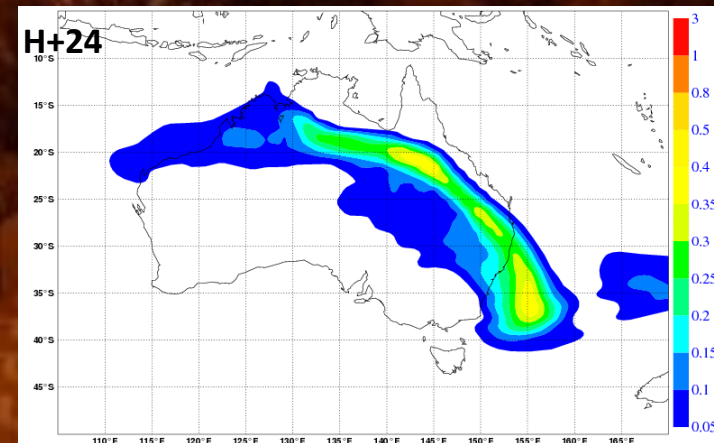
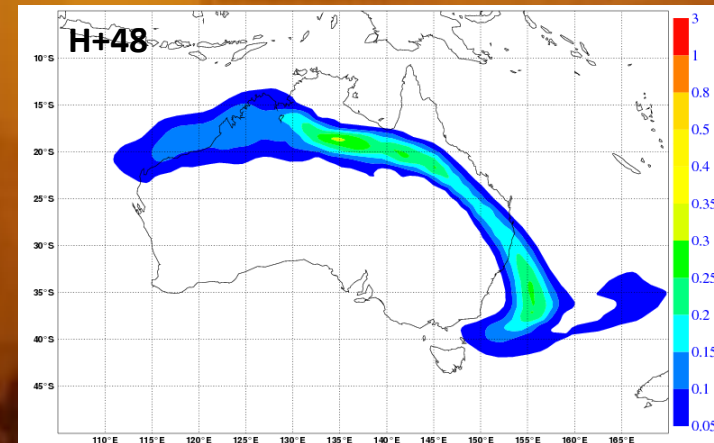
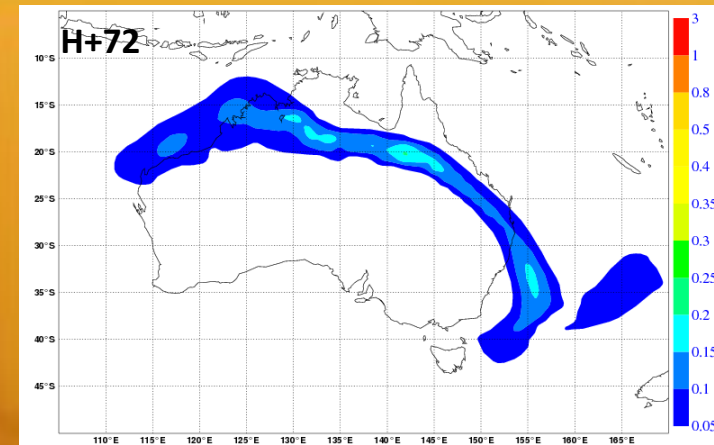
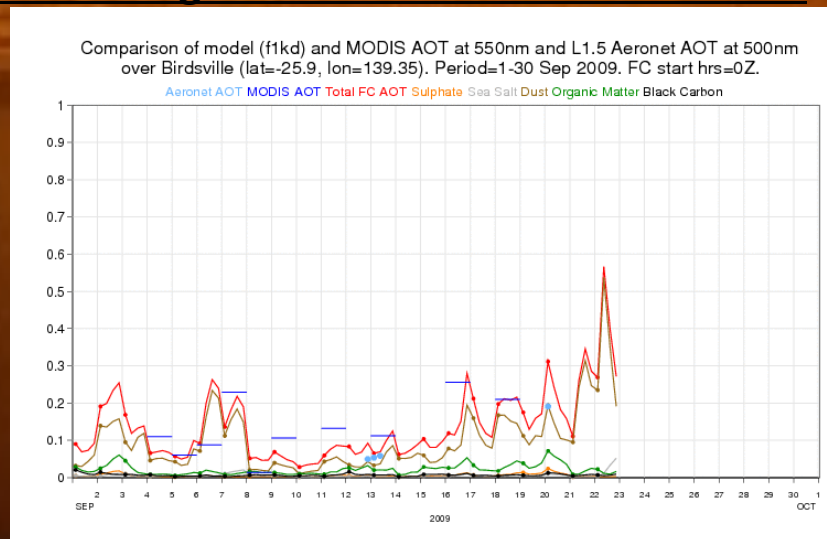
Aerosol optical depth for desert dust: monthly average for September 2008



# Sydney dust storm, 23-09-09



## Verification using AERONET data from Birdsville



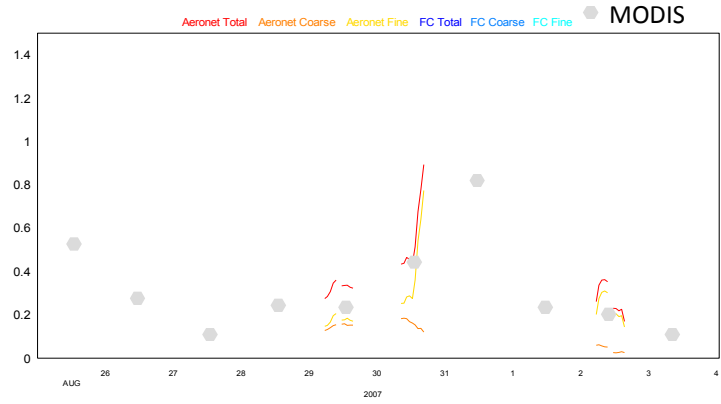
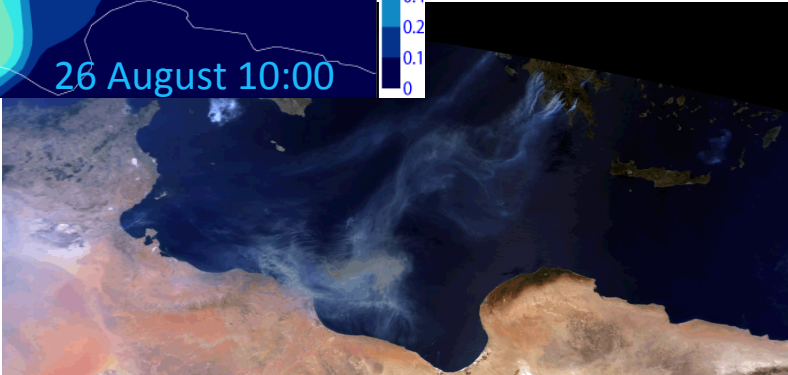
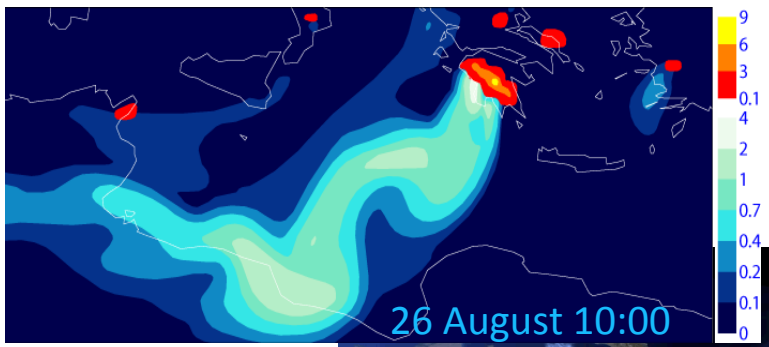
# Evaluation with SEVIRI - Case study: Fire emissions in August 2007



Observed Fire Radiative Power (from SEVIRI on Meteosat) is converted to emitted aerosol.

Run at 25km global resolution rather than 125km standard GEMS global resolution.

Joint work with FREEVAL project (M. Wooster, G. van der Werf, ...).



J.W. Kaiser et al., 2009

# Daily MACC forecasts: Eyjafjallajökull eruption

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**Area**

► Europe

N Hemisphere

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**Base time finder**

Forecast base times with forecast valid for the displayed valid time: **Sun 16 May 12UTC**

Sat 15 May 00UTC

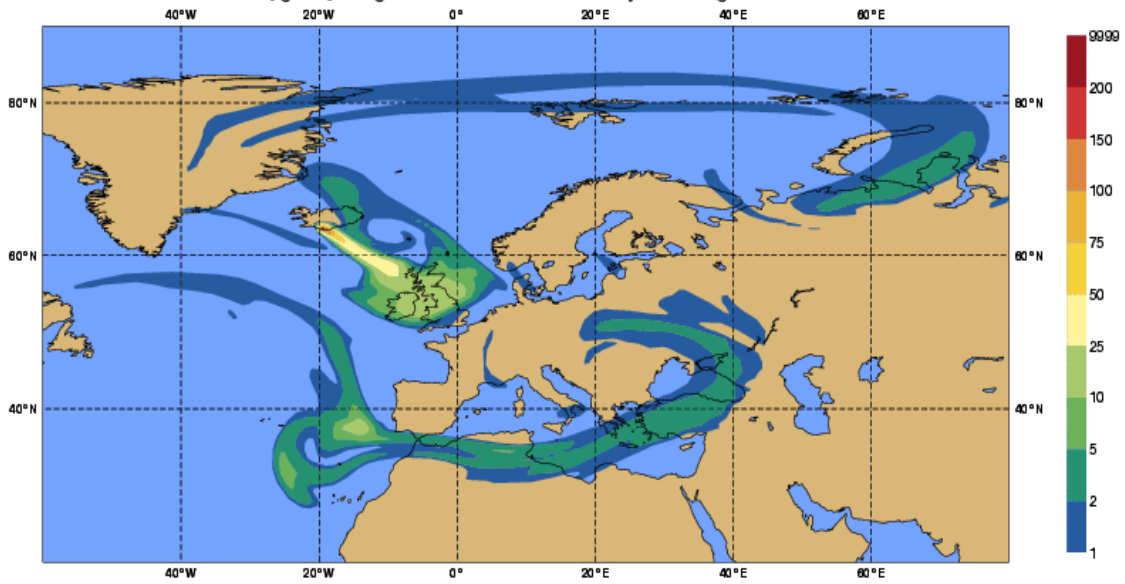
Open in new window

## Eyjafjallajökull Plume Forecasts

**Step (-> valid time)** **Forecast base time**

36 (Sun 16 May 2010 12UTC) Sat 15 May 2010 00UTC

MACC Eyjafjallajökull Plume Forecast for Sunday 16 May 2010 12 UTC  
Total column of ash tracer [ g/m<sup>2</sup> ] using London VAAC estimate of Injection height



**Show overview**

Area

Step (-> valid time)

Forecast base time

Base time finder

**Download...**

PDF (84 Kbytes)

Postscript (106.2 Kbytes)

The global MACC system at ECMWF provided daily 4-day forecasts of the plume **shape** based on basic assumptions for the injection height and mass.

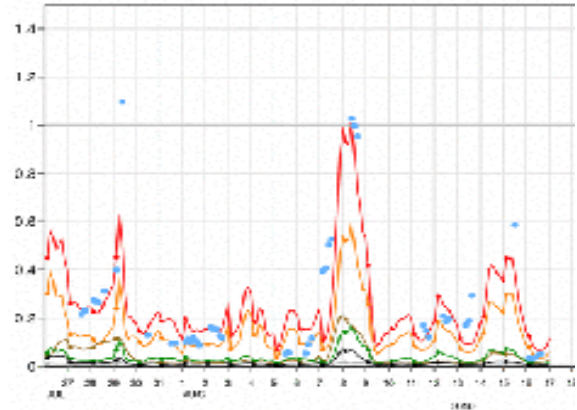
MACC is a Collaborative Project (2009-2011) funded by the European Union under the 7th Framework Programme. It is coordinated by the European Centre for Medium-Range Weather Forecasts and operated by a 45-member consortium.



# Russian fires, August 2010

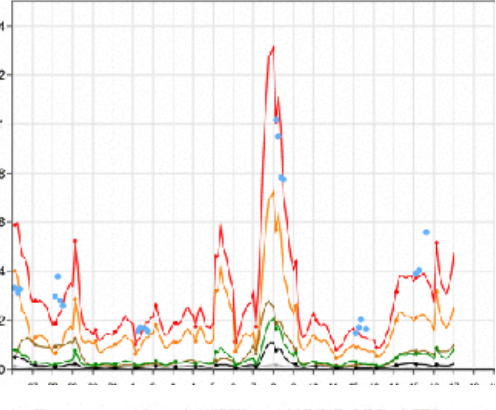
Comparison of model (I93I) and MODIS AOT at 550nm and Helsinki (60.2°N, 24.96°E). Model: 00UT, 26/07/2010

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust



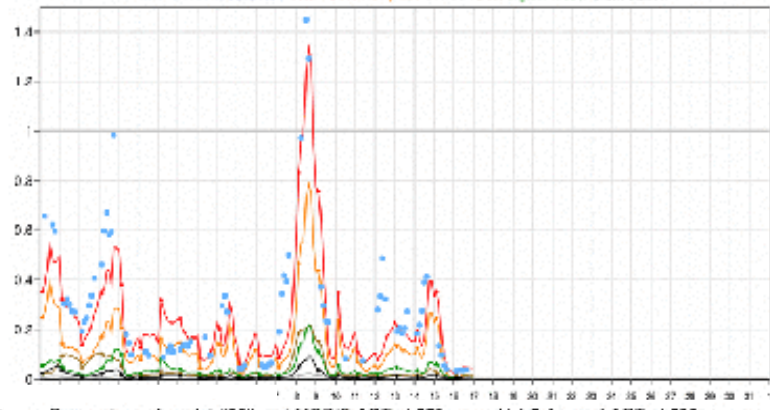
Comparison of model (I93I) and MODIS AOT at 550nm and Toraverre (58.28°N, 26.48°E). Model: 00UT, 26/07/2010

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust O



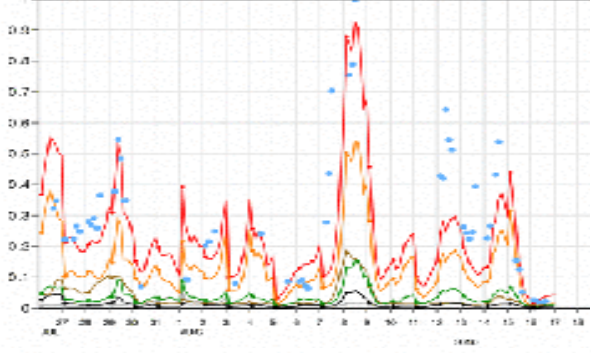
Comparison of model (I93I) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Kuopio (62.89°N, 27.63°E). Model: 00UT, 26/07/2010 - 31/08/2010, T+3 to T+24.

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust Organic Matter Black Carbon



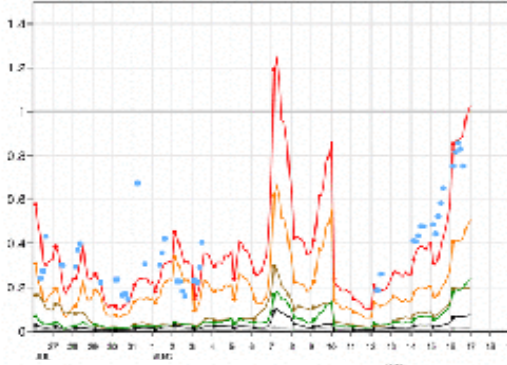
Comparison of model (I93I) and MODIS AOT at 550nm and Hyviala (61.85°N, 24.3°E). Model: 00UT, 26/07/2010

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust



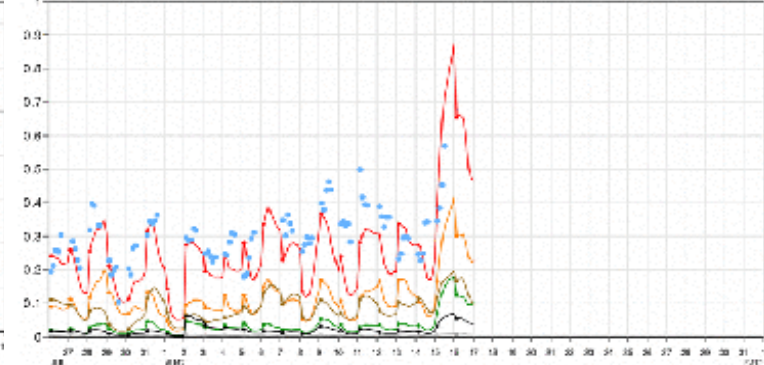
Comparison of model (I93I) and MODIS AOT at 550nm and Minsk (53.92°N, 27.8°E). Model: 00UT, 26/07/2010 -

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust O



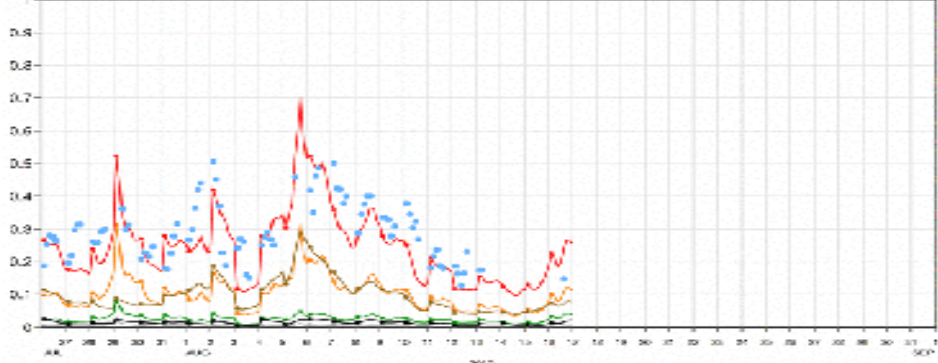
Comparison of model (I93I) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Sevastopol (44.62°N, 33.52°E). Model: 00UT, 26/07/2010 - 31/08/2010, T+3 to T+24.

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust Organic Matter Black Carbon



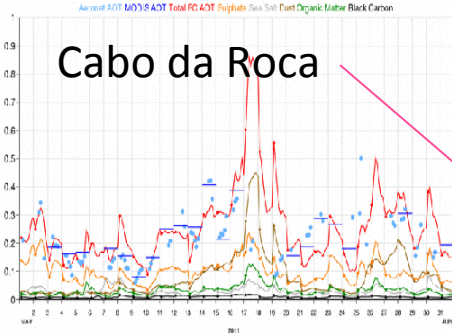
Comparison of model (I93I) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over TUBITAK\_UZAY\_Ankara (39.83°N, 32.78°E). Model: 00UT, 26/07/2010 - 31/08/2010, T+3 to T+24.

Aerosol AOT MODIS AOT Total FC AOT Sulfate Sea Salt Dust Organic Matter Black Carbon

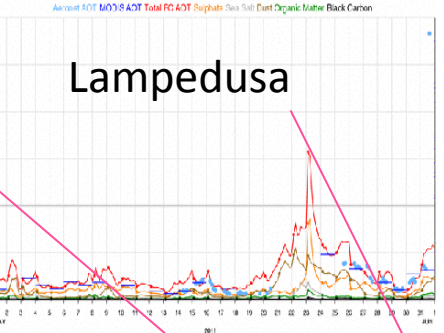


The MACC-AERosol system, assimilating MODIS tau550 allowed a very good description of the impact of the Russian fires In mid-August 2010 over North-Eastern Europe

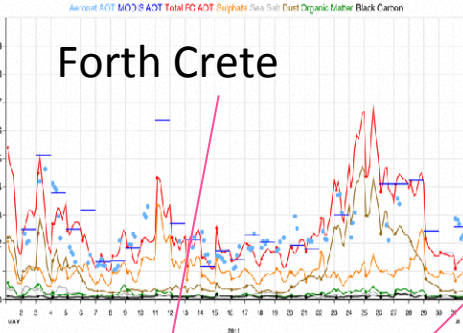
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Cabo\_da\_Roca (38.78°N, 9.5°W). Model: 00UT, 1-31 May 2011, T+3 to T+24.



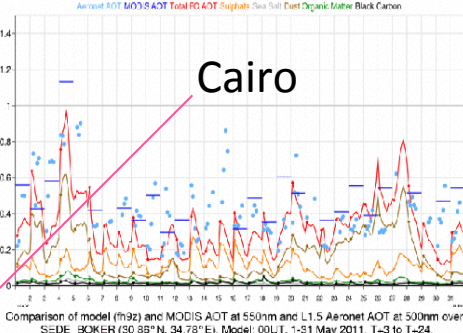
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Lampedusa (35.52°N, 12.63°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



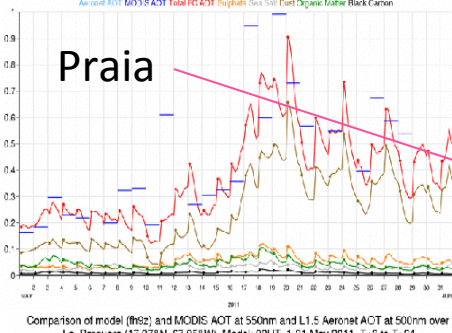
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over FORTH\_CRETE (35.33°N, 25.28°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



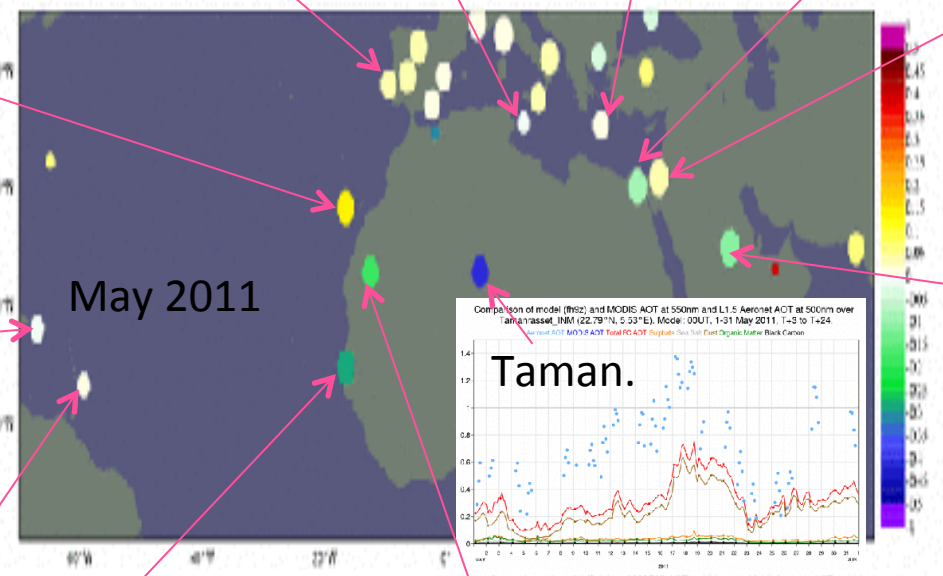
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Cairo\_EMA (30.08°N, 31.29°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



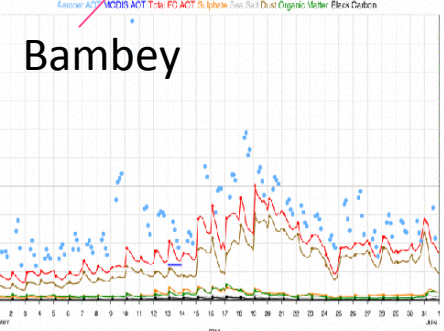
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Praia (14.95°N, 23.48°W). Model: 00UT, 1-31 May 2011, T+3 to T+24.



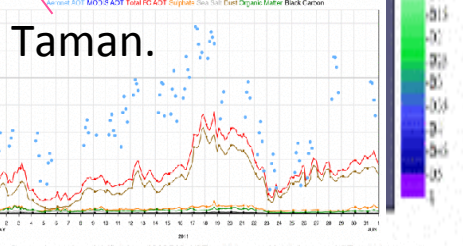
FC-OBS Bias. Model (fh9z) AOT at 550nm against L1.5 Aeronet AOT at 500nm  
Mean=-0.0275, Period=00Z-00Z 01-31 May 2011, FC start hrs=0, FCRS=T+3->24 by 3.



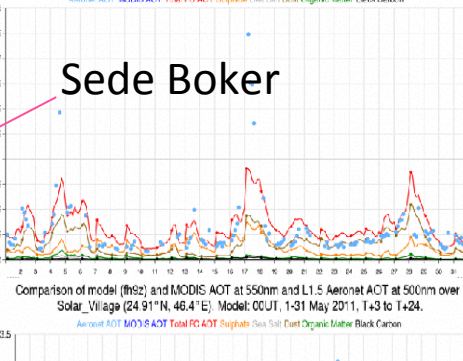
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Bambeý-ISRA (14.71°N, 18.48°W). Model: 00UT, 1-31 May 2011, T+3 to T+24.



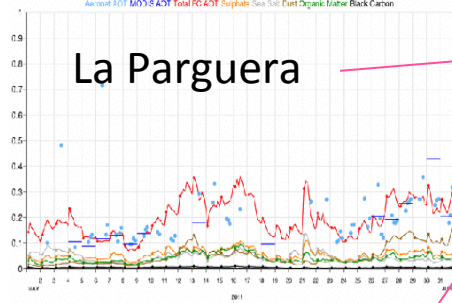
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Taman\_nasset\_INK (22.79°N, 5.33°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



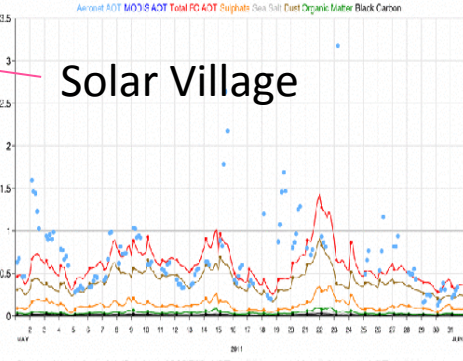
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over SEDE\_BOKER (30.88°N, 34.78°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



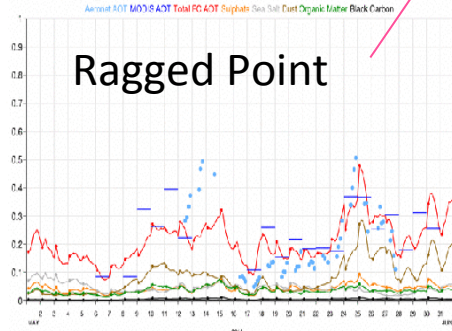
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over La\_Parguera (17.97°N, 67.03°W). Model: 00UT, 1-31 May 2011, T+5 to T-24.



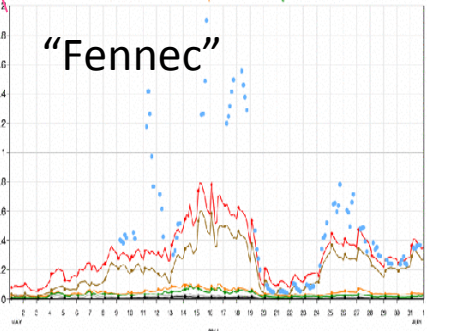
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Solar\_Village (24.91°N, 46.4°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



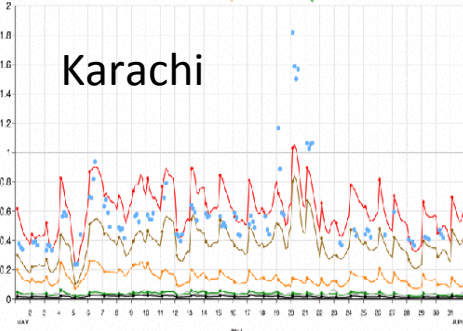
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Flagged\_Point (13.17°N, 59.43°W). Model: 00UT, 1-31 May 2011, T+5 to T-24.



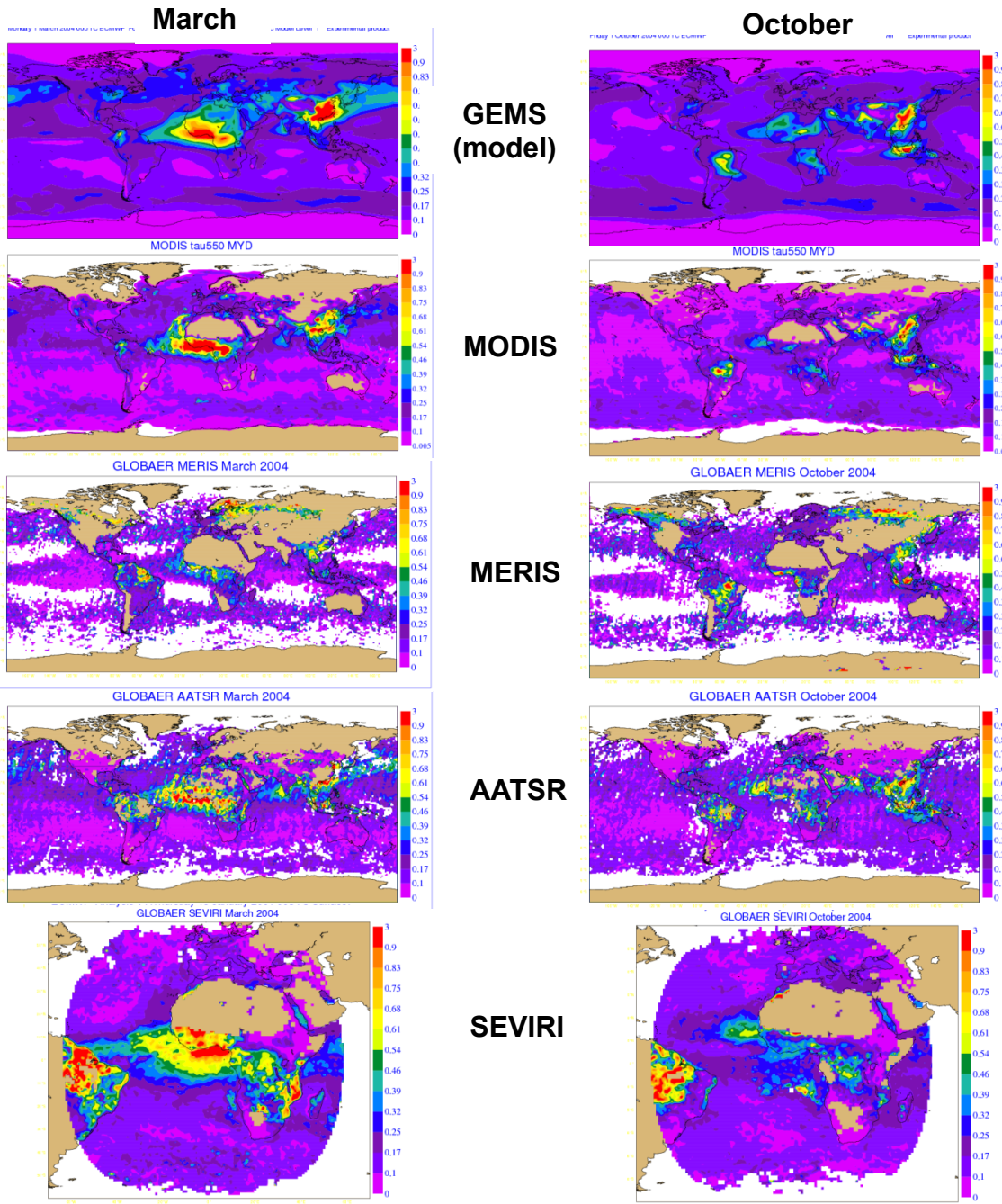
Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Zouerate-Fennec (22.75°N, 12.48°W). Model: 00UT, 1-31 May 2011, T+3 to T+24.



Comparison of model (fh9z) and MODIS AOT at 550nm and L1.5 Aeronet AOT at 500nm over Karachi (24.87°N, 67.03°E). Model: 00UT, 1-31 May 2011, T+3 to T+24.



# Validation of ESAGlobAEROSOL products: 550 nm Aerosol Optical Depths



-Large spread within the GlobAEROSOL product,

-MERIS presents the lowest values for the Saharian dust aerosols

-Large values over Brazil for SEVIRI (and MERIS) in March

-AATSR agrees the most of MODIS

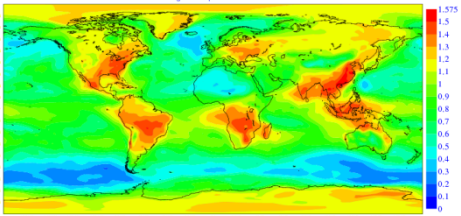
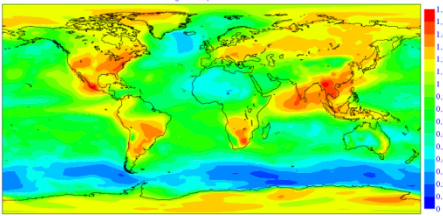


# Validation of ESA GlobAEROSOL products: 550-865 nm Angstrom exponents

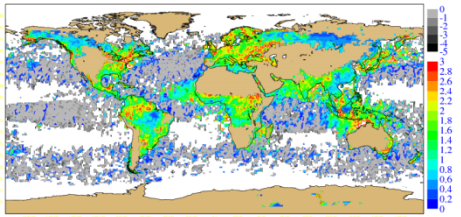
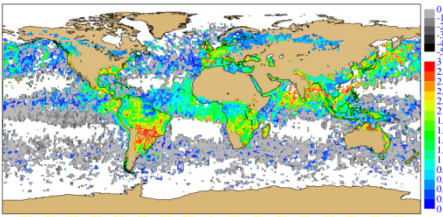
March

October

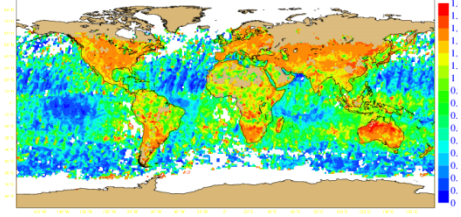
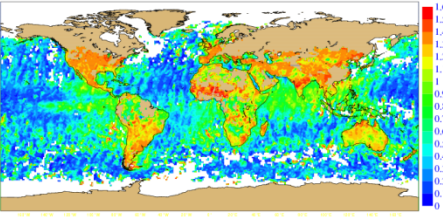
GEMS



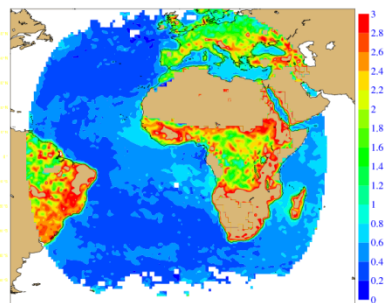
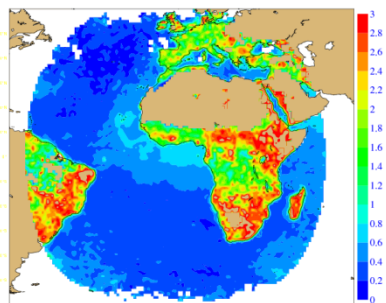
MERIS



AATSR



SEVIRI



-Land/sea discontinuity in regions where continuity is known to exist (off coast west-Sahara and central Africa)  
- Negative Angstrom exponent for MERIS

Good for assimilation?

→ Can we rely on quality control and on the use of obs. errors from the retrievals to “clean” the data?

→ Choice of SEVIRI to start with

# Assimilation of SEVIRI optical depths: 6hour-forecasts

3 Mar

4 Mar

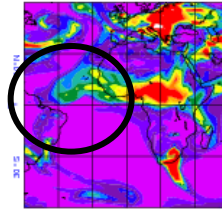
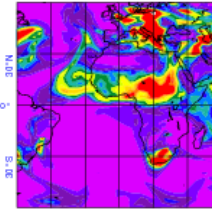
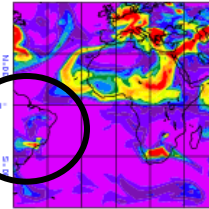
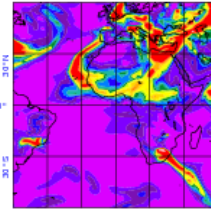
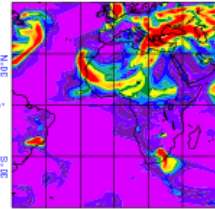
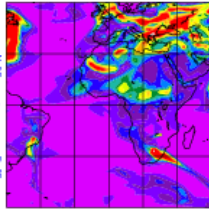
5 Mar

6 Mar

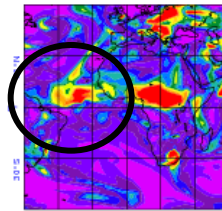
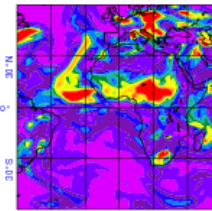
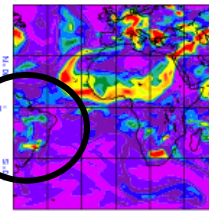
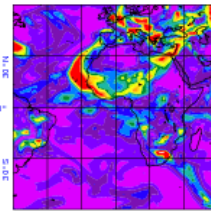
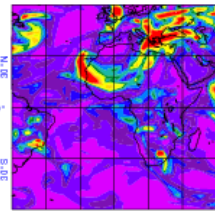
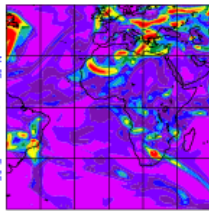
7 Mar

8 Mar

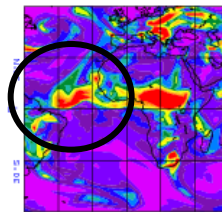
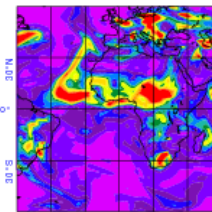
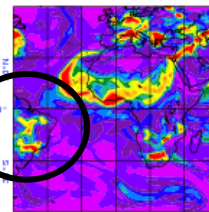
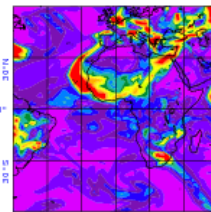
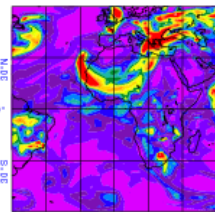
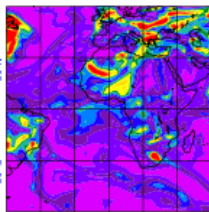
“free run”



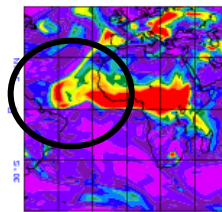
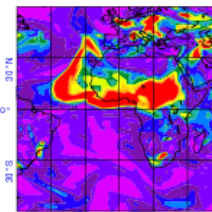
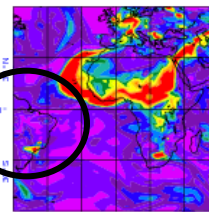
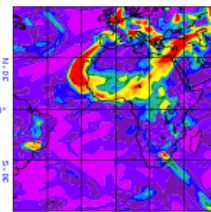
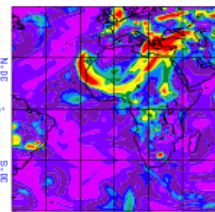
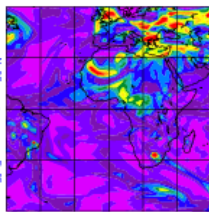
Seviri  
retrieval  
errors



Seviri  
errors=30%



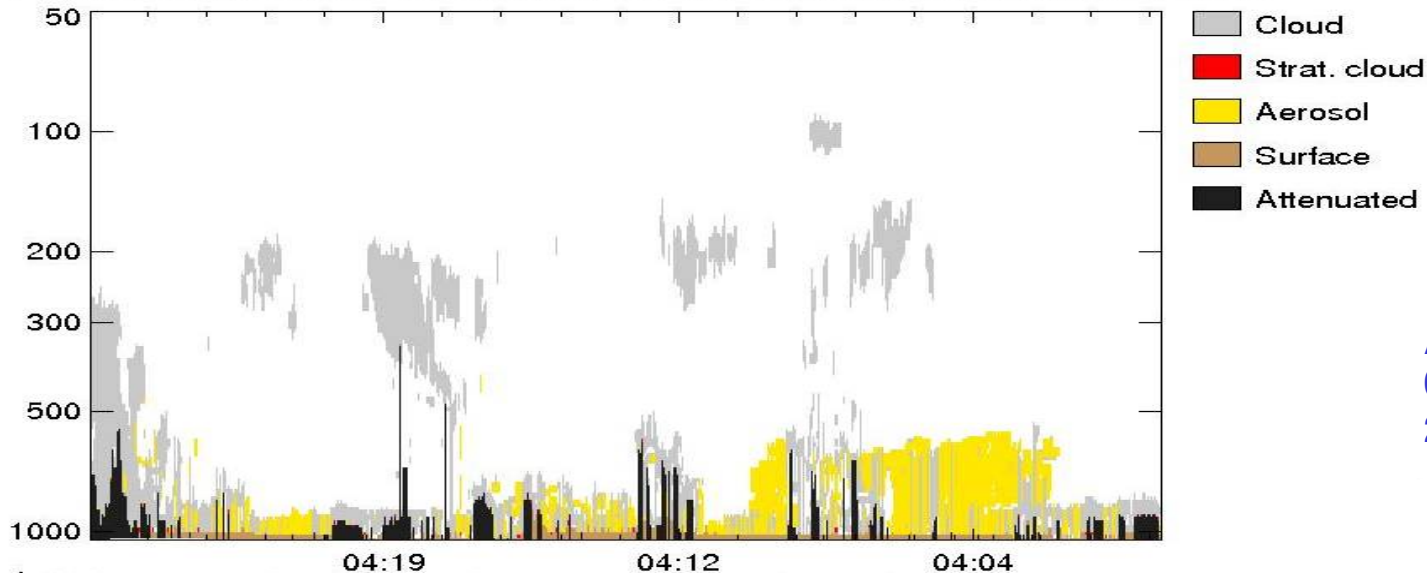
Modis



# Comparison of aerosol with CALIPSO cloud/aerosol mask

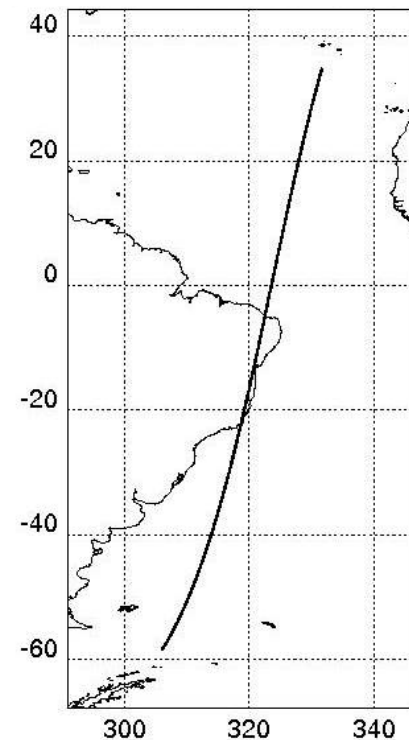
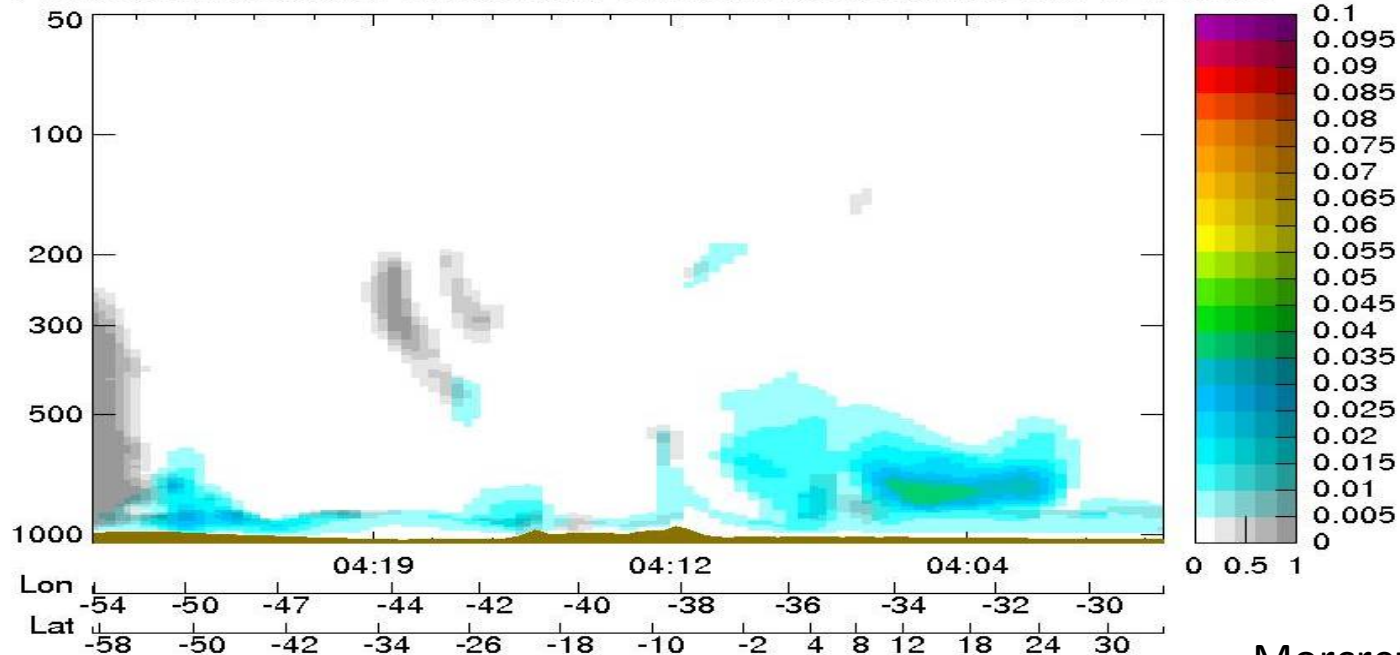
- Validation of aerosol parametrization
  - Comparison of model aerosol vertical profiles with CALIPSO cloud/aerosol mask

CALIPSO feature classification along 10733 km of A-Train orbit between 26/06/2007 04:00:12 and 26/06/2007 04:26:20

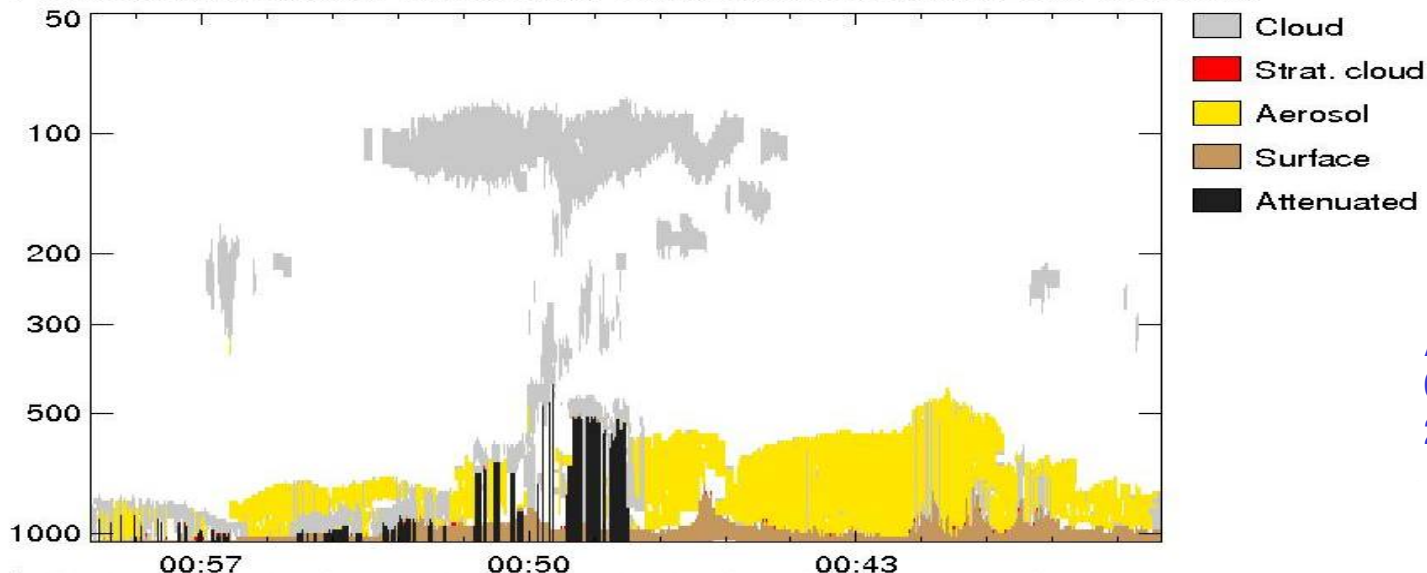


A-Train orbit between 04:00:12 and 04:26:20 26/06/2007

Model (eybt) aerosol amount and cloud fraction along 10657 km of A-Train orbit between 26/06/2007 04:00:02 and 26/06/2007 04:26:00

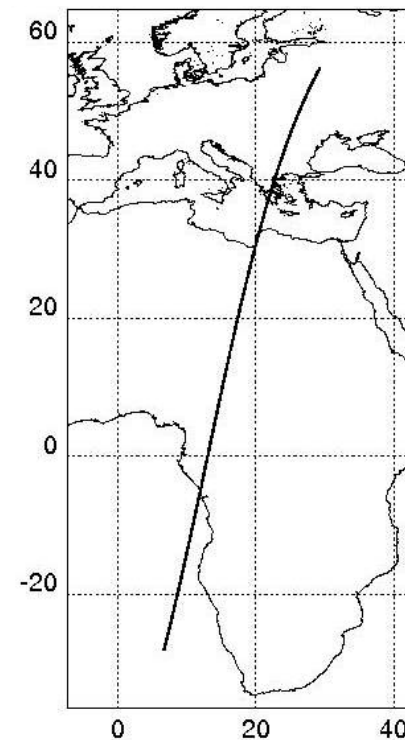
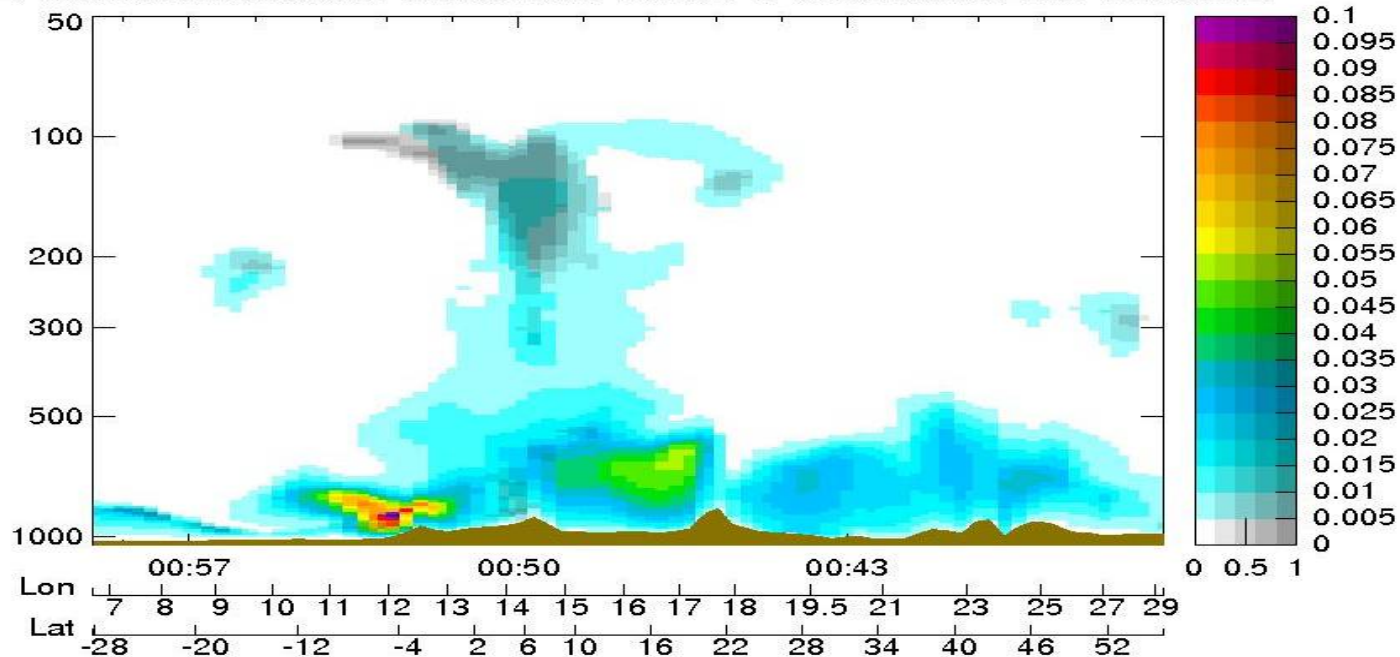


CALIPSO feature classification along 9670 km of A-Train orbit between 26/06/2007 00:36:29 and 26/06/2007 01:00:01



A-Train orbit between 00:36:29 and 01:00:01 26/06/2007

Model (eybt) aerosol amount and cloud fraction along 9625 km of A-Train orbit between 26/06/2007 00:36:17 and 26/06/2007 00:59:42



# Comparison of aerosol with CALIPSO cloud/aerosol mask:

## Conclusions

- From this limited set of comparisons, the vertical distribution of the model aerosols appears reasonable (although maybe issue with convective transport)
- Deficiencies are often linked to limited knowledge of emissions of anthropogenic aerosols
- On the model side, the absence of a plume model for emission (for OM, BC, and SU) is likely to limit the extent of the area over which these aerosols might be simulated.
- CALIPSO cloud/aerosol mask is aerosol or cloud, whether model results often show aerosols within cloud layers

# The lidar equation

$$LS(z, \lambda) = C_{LS}[\beta(\lambda)\omega(\lambda)\sigma(z, \lambda)] \exp\left[-2 \int_z^{z_{TOA}} \sigma(z', \lambda) dz'\right]$$

The lidar signal (LS) equation is given above, in which:

$\omega$  is the single scattering albedo,  $\beta$  is the phase function at  $180^\circ$ ,  $\sigma$  the extinction coefficient,  $C_{LS}$  a calibration coefficient,  $z$  the height and  $\lambda$  the wavelength.

Processes to be accounted for are: Rayleigh scattering, and depending on  $\lambda$ , gaseous absorption by  $O_3$ ,  $NO_2$ ,  $O_2$ ,  $CO_2$  ... and the absorption/scattering by aerosols in the observed volume and along the path.

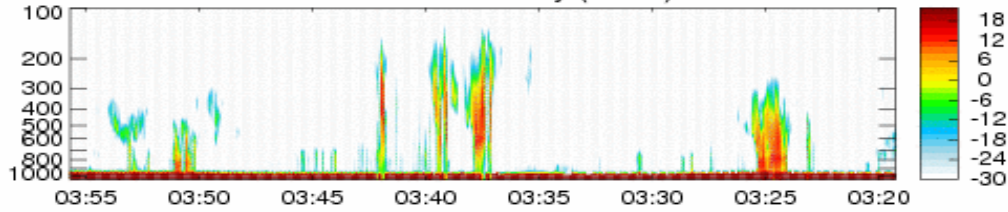
All relevant coefficients have been computed for the 11 aerosol types of the GEMS-AER configuration (SS3b, DU3b, 2OM, 2BC, 1SO4) using a standard Mie code.

The new model routine simulates the back-scattering coefficient of the GEMS aerosols (for a clear-sky atmosphere) observed by a lidar at 355 $\text{\$}$ , 532\* and 1064\* nm at TOA and surface (for comparison with EARLINET observations?)

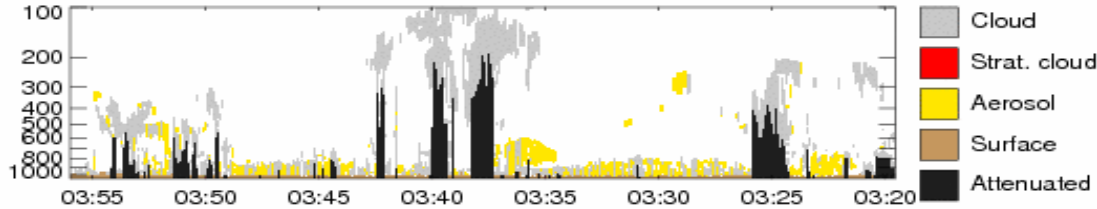
$\text{\$}$ : wavelength of future EarthCare lidar; \*: wavelengths of CALIPSO (practically only 532 nm); Lidars parts of EARLINET (European Aerosol Research Lidar Network) have data from the surface over various subsets of the three wavelengths.

Cross-sections along 14941 km of A-Train orbit between  
03:19 & 03:56 08/05/08 UT.

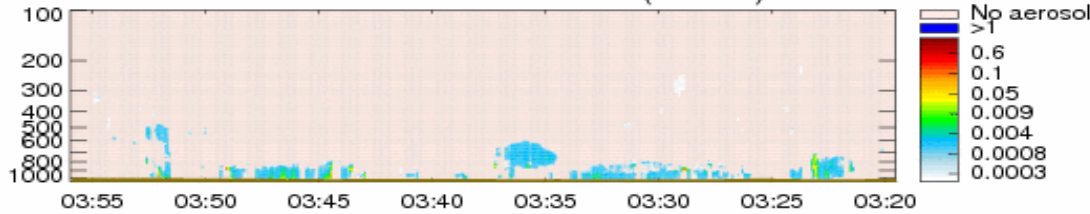
CloudSat reflectivity (dBZe)



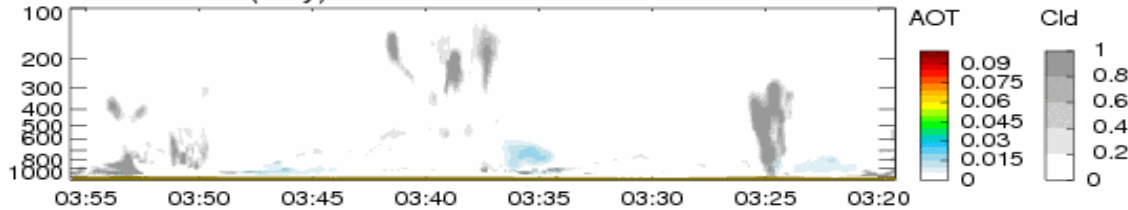
CALIPSO feature classification



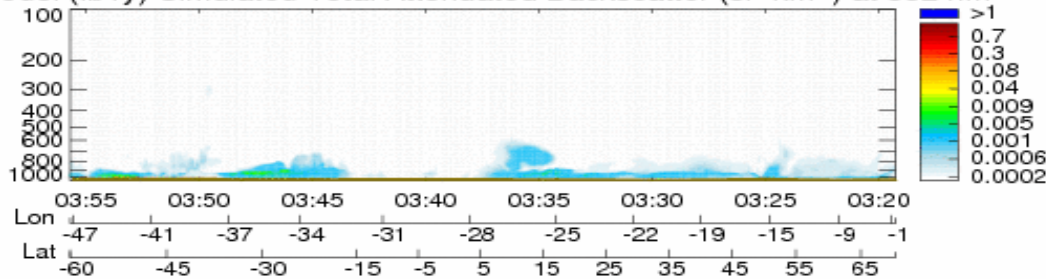
CALIPSO Aerosol Backscatter Coefficient ( $\text{sr}^{-1}\text{km}^{-1}$ ) at 532 nm



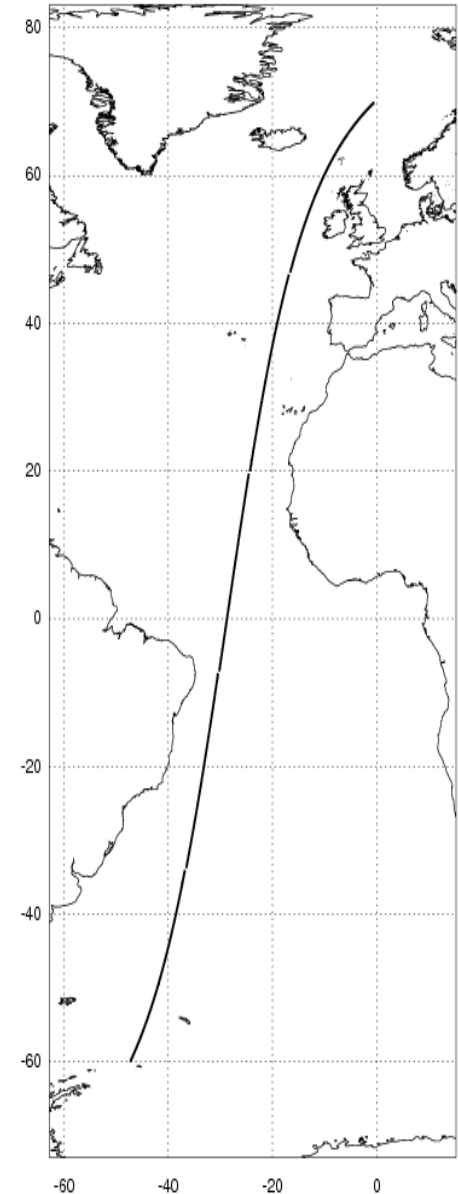
Model (fb1y) aerosol amount and cloud fraction



Model (fb1y) Simulated Total Attenuated Backscatter ( $\text{sr}^{-1}\text{km}^{-1}$ ) at 532 nm



A-Train orbit between  
03:19 & 03:56 08/05/08 UT



Graphics by Luke Jones



# 1D-Var for CALIPSO aerosol observations

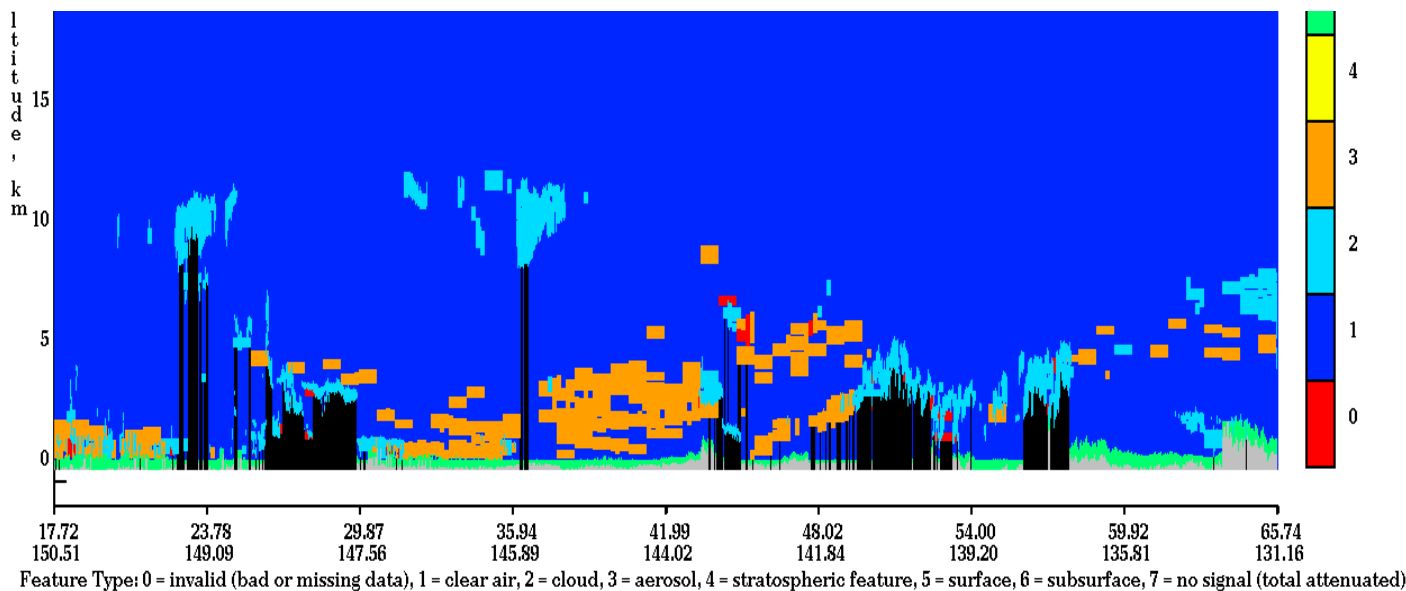
## Janiskova, Stiller, 2010

- assimilation of CALIPSO backscatter data restricted to updating only the aerosol fields, other fields left unchanged by the analysis procedure
- 11 aerosol species represented in the forecast model, but only one observed field to be assimilated

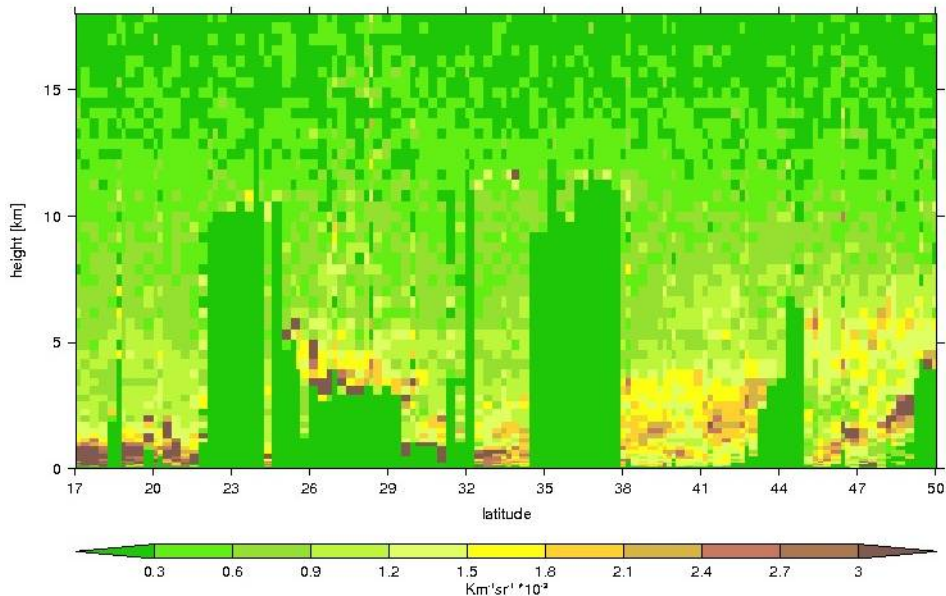


- only the total mixing ratio is incremented and the fractional contribution of each species is kept constant at the value given by the model background  
*(Benedetti et al. 2009)*

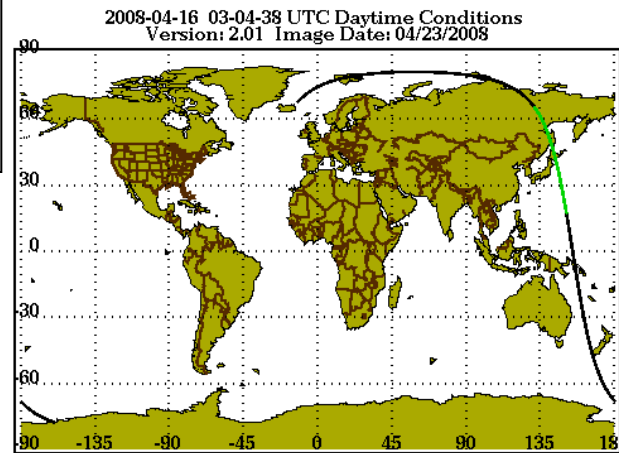
# CALIPSO observations and cloud screening



back scatter, observations



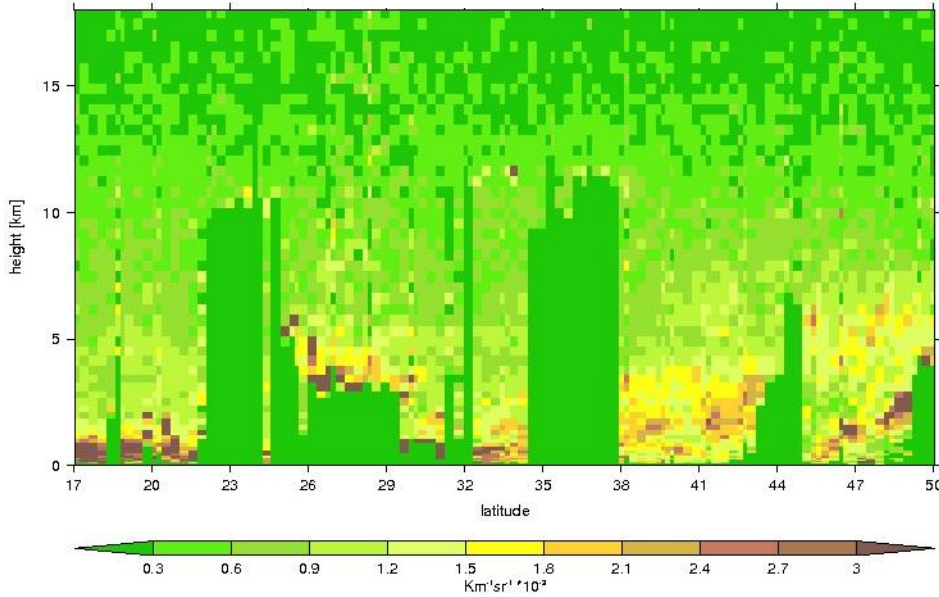
Cloud screening:  
5km  
product



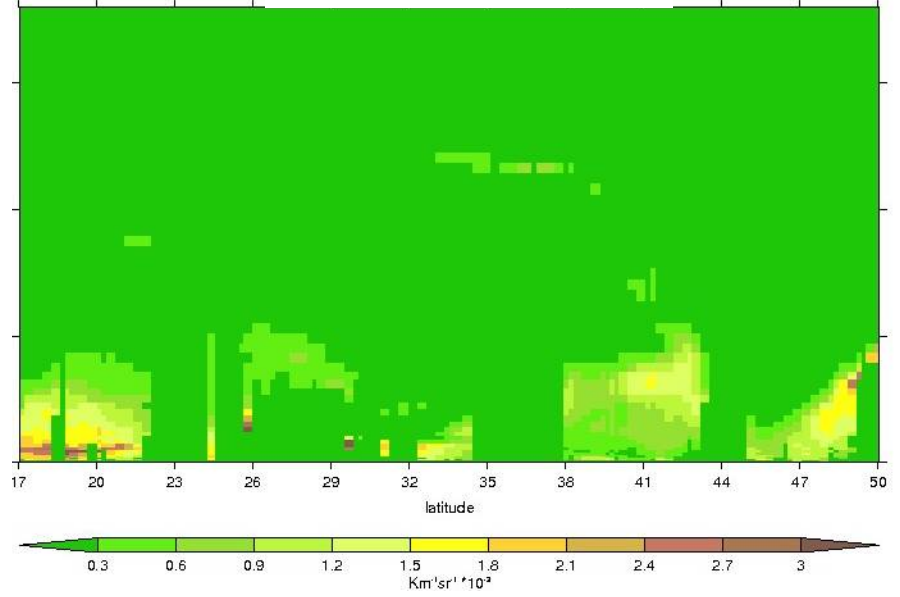
Case 20080416

# 1D-Var for CALIPSO aerosol observations – FG vs. AN

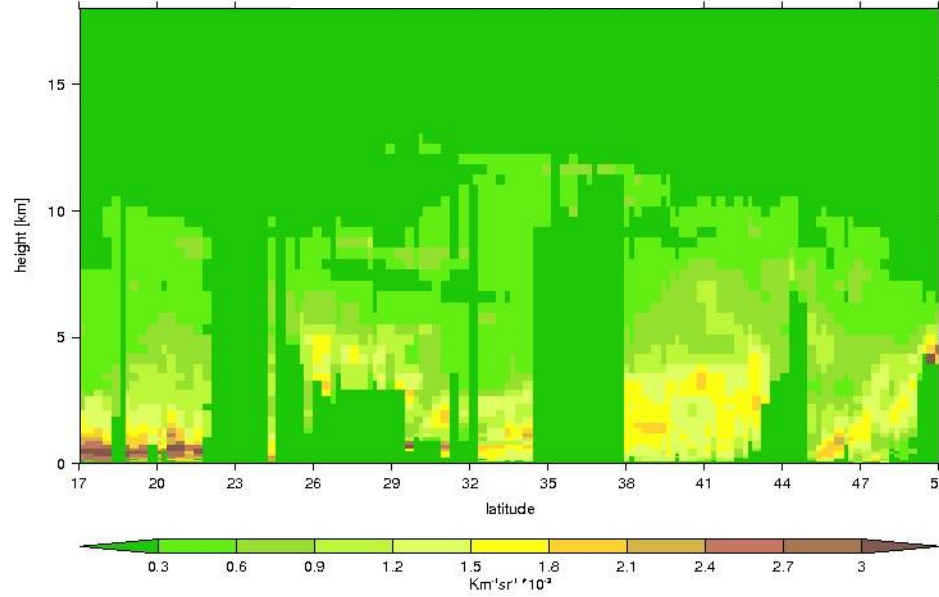
## backscatter – OBS



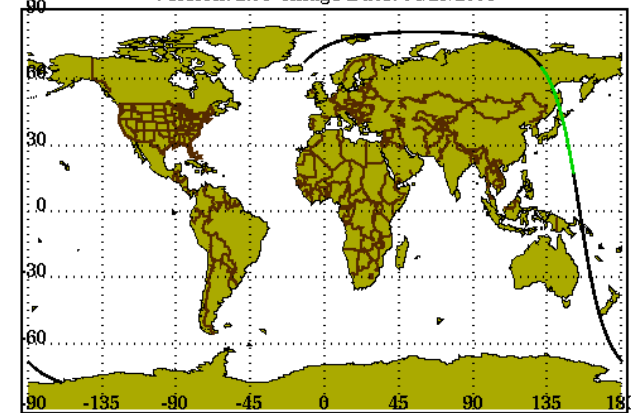
## backscatter – FG



## backscatter – AN



2008-04-16 03-04-38 UTC Daytime Conditions  
Version: 2.01 Image Date: 04/23/2008



## Case 20080416

# Summary of 1D-Var experiments for aerosol observations

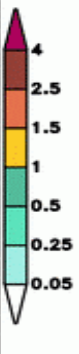
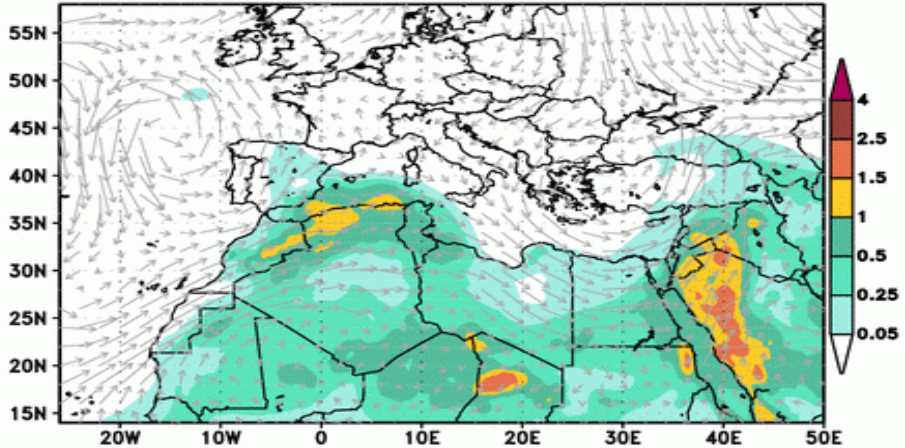
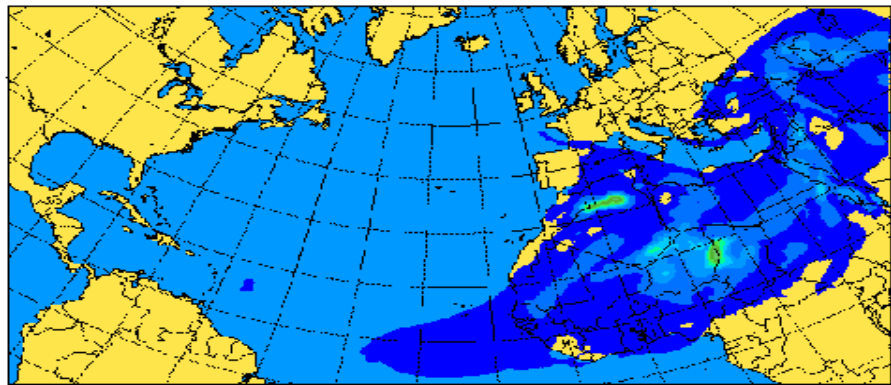
- A major technical and scientific development towards the assimilation of aerosol information from CALIPSO has been implemented
- **Main outcomes from 1D-Var experimentation:**
  - model equivalent aerosol observations are substantially driven towards CALIPSO backscatter data
  - model aerosols are strongly incremented
  - encouraging results suggest there is a potential of using these observations in the ECMWF aerosol system
  - GMES/MACC could also benefit from technical foundations laid by this project
  - further use in assimilation studies would require improved observation errors, more targeted cloud screening, ...
  - exciting perspectives for air quality monitoring and forecasting

# As a matter of conclusions

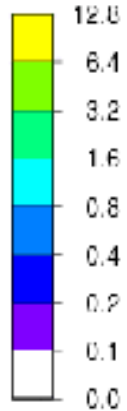
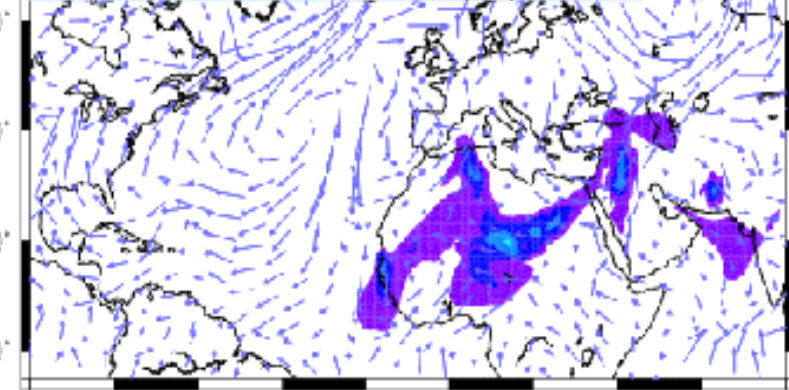
- Over the last six years, as part of first the GEMS, then the MACC projects, the development, validation and pre-operational provision of aerosol analyses and forecasts by the ECMWF IFS have relied heavily on the satellite data provided by MODIS and the surface measurements at the AERONET stations. MODIS fine mode tau550 is currently being tested for assimilation. CALIPSO backscatter measurements are the next measurements to be assimilated in the near future. SEVIRI is also considered for the future.
- Six years of aerosol daily analyses (2003-2008) followed by 3-day forecasts were produced by GEMS. Eight years of aerosol daily analyses (2003-2010) followed by 5-day forecasts are being repeated by MACC. All these are publicly available on request (EU FP project policy). Near real time analyses and forecasts have been produced daily since September 2008.
- These products are being refined through further aerosol and model developments, and will continue to depend on the near-real time provision of such satellite (and surface) measurements.
- A lot is going on in terms of “oper”, “pre-oper”, or “quasi-operational” aerosol modelling in various academic and operational meteorological institutions (WMO-SDS, ICAP).
- **Thank you**

# Present state of the prognostic aerosols in the ECMWF IFS

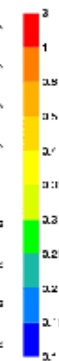
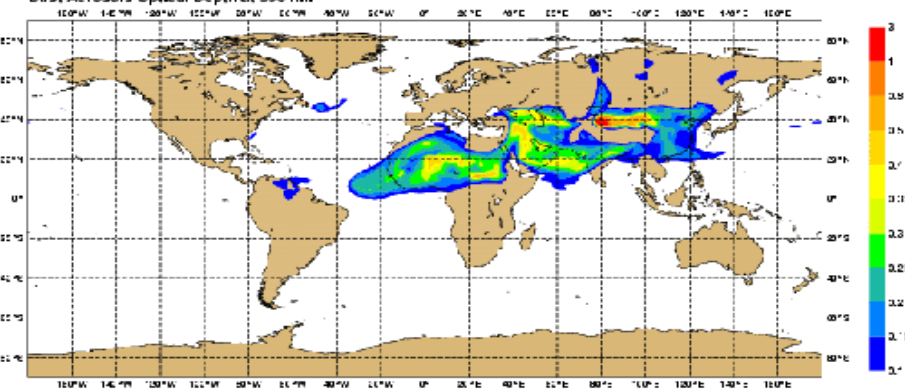
- Benedetti et al., 2009: JGR, 114, D13205
- Morcrette et al., 2008: GRL, 35, L24813
- Morcrette et al., 2009: JGR, 114, D06206
- Mangold et al., 2011: JGR, 116, D03302
- Kaiser et al., 2009: AIP CP, 1100
- Kaiser et al., 2010: BAMS, 91, SC2009
- Kaiser & Goldammer, 2010: BAMS, 91, SC2009
- Benedetti et al., 2011: BAMS, 92, SC2010
- Huneeus et al., 2011: ACPD



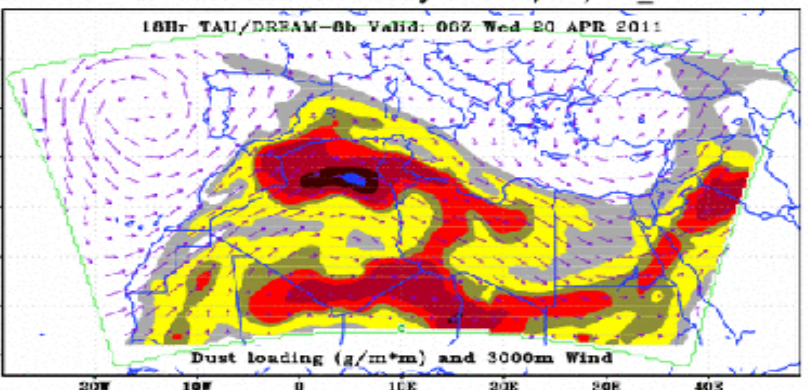
Dust aerosol optical thickness at 550 nm 11+0 2011-04-19



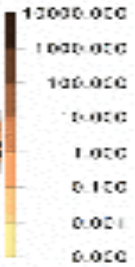
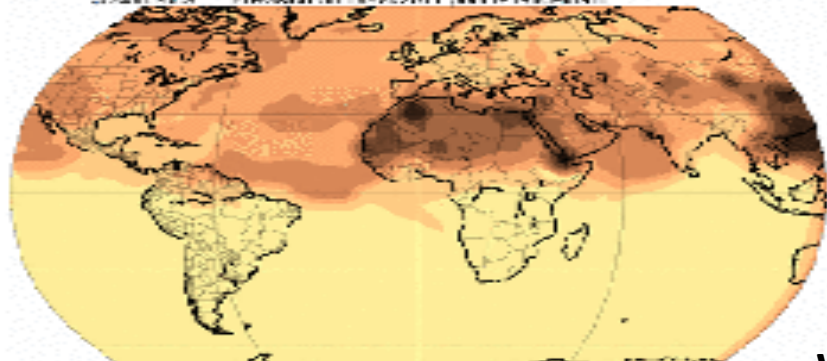
Monday 18 April 2011 00UTC MACC Forecast to 048 VT: Wednesday 20 April 2011 00UTC  
 Dust Aerosols Optical Depth at 550 nm



Desert Dust Forecast from 19/04/11\_12



PREYAR Desert Dust, µg/m³  
 04 April 2011

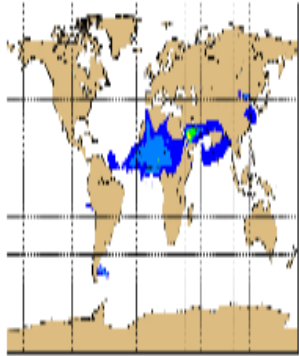


Desert Dust peak in µg/m³  
 Forecast for use on 04/19/2011 for the day after

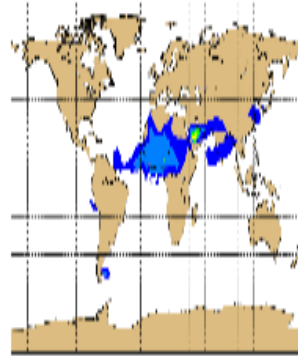
# International Comparison of Aerosol Prediction: NRL, NRL-EP, GMAO, CMWF, soon NCEP

Main Listing / NAAPS Global Dust Aerosol Optical Depth Comparison Archive

Modeling of monthly 2010 dust aerosol optical depth (AOD) over the globe using the NAAPS model

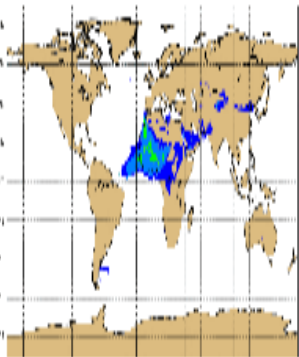


Modeling of monthly 2010 dust aerosol optical depth (AOD) over the globe using the NAAPS model



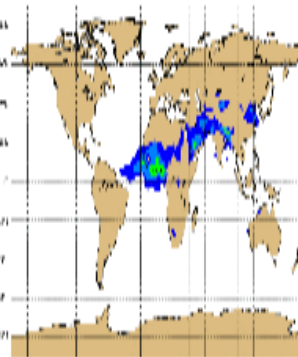
## Dust

Modeling of monthly 2010 dust aerosol optical depth (AOD) over the globe using the NAAPS model



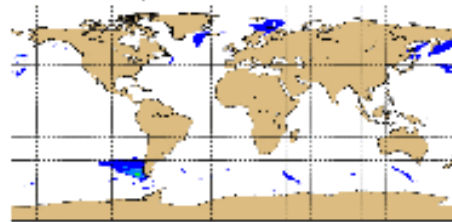
Legend for dust aerosol optical depth (AOD) ranging from 0.1 to 4.0.

Modeling of monthly 2010 dust aerosol optical depth (AOD) over the globe using the NAAPS model

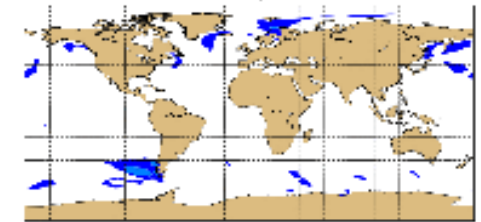


Legend for dust aerosol optical depth (AOD) ranging from 0.1 to 4.0.

Modeling of monthly 2010 dust aerosol optical depth (AOD) over the globe using the NAAPS model

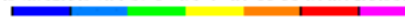
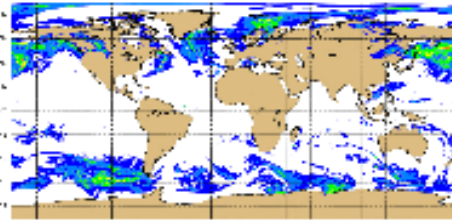


Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model



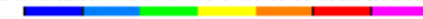
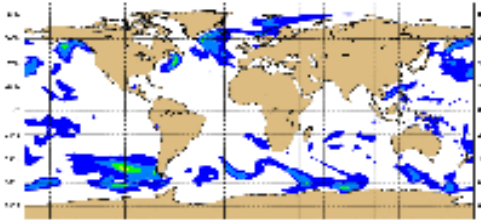
## Sea salt

Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model



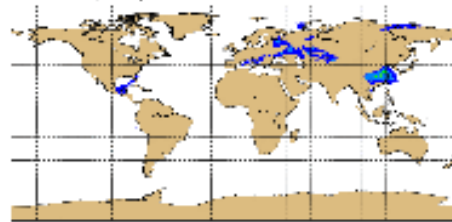
Legend for sulfate aerosol optical depth (AOD) ranging from 0.1 to 4.0.

Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model



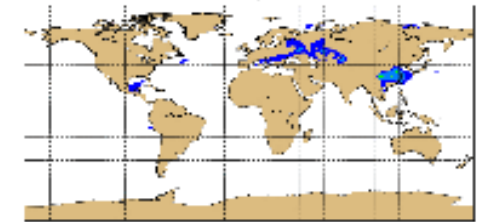
Legend for sulfate aerosol optical depth (AOD) ranging from 0.1 to 4.0.

Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model

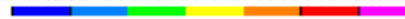
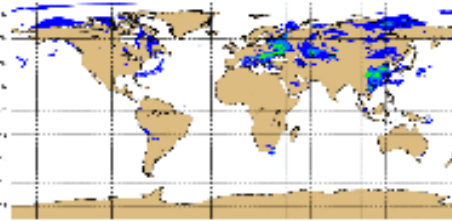


## Sulphate

Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model

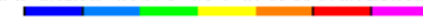
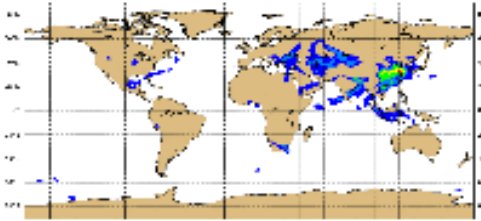


Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model



Legend for sulfate aerosol optical depth (AOD) ranging from 0.1 to 4.0.

Modeling of monthly 2010 sulfate aerosol optical depth (AOD) over the globe using the NAAPS model



Legend for sulfate aerosol optical depth (AOD) ranging from 0.1 to 4.0.