

# MACC-II NRT and REANALYSIS products

Angela Benedetti

*ECMWF*

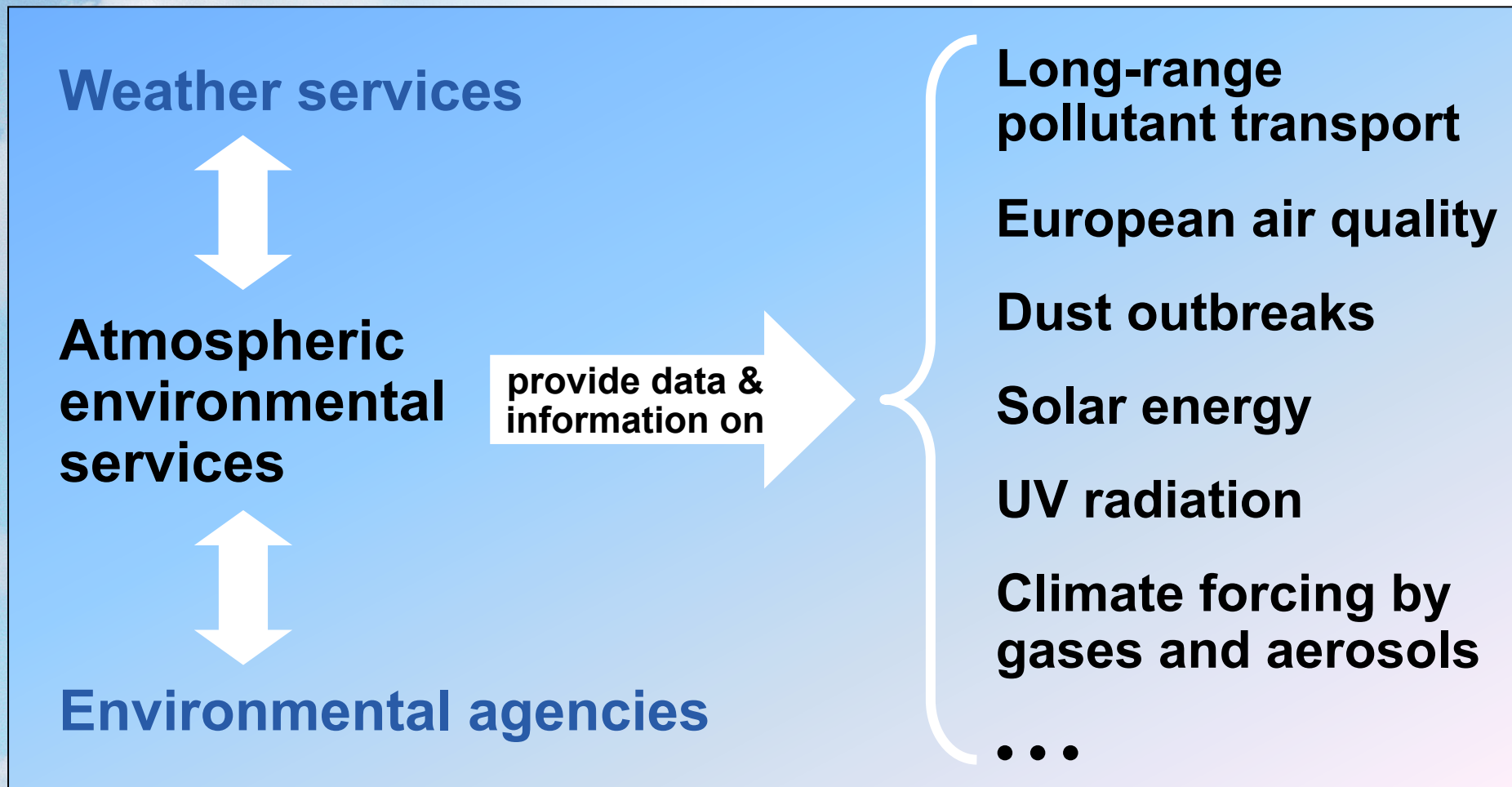
With contributions from:

**Anna Agusti-Panareda, Richard Engelen, Johannes Flemming, Antje Inness, Sebastien Massart and Jean-Jacques Morcrette**


















# Copernicus Services- Atmosphere

Services related to the chemical and particulate content of the atmosphere

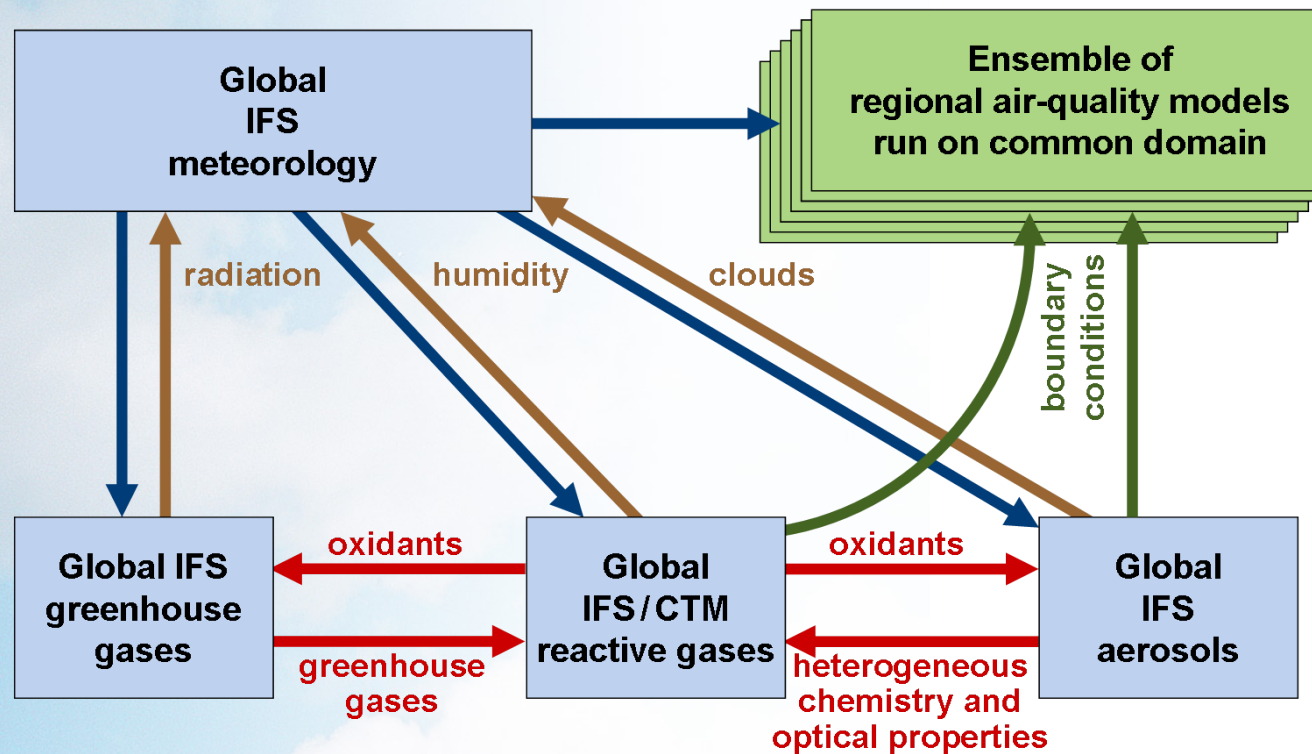


# Monitoring Atmospheric Composition and Climate- Interim Implementation

-  ● **36-partner Collaborative Project**, funded by European Union FP7
-  ● Started in November 2011 with expected completion in July 2014
-  ●
-  ●
-  ● Prototype for the operational Copernicus Atmospheric Service (follow-on of MACC project)
-  ●
-  ●
-  ●
-  ● **Providing air quality regional forecasts and global atmospheric composition** forecasts and reanalysis in support of Europe's air quality policies and health aspects
-  ●
-  ●
-  ●
-  ● All MACC-II data related to atmospheric composition are publicly available
-  ●
-  ●



# Global/regional system



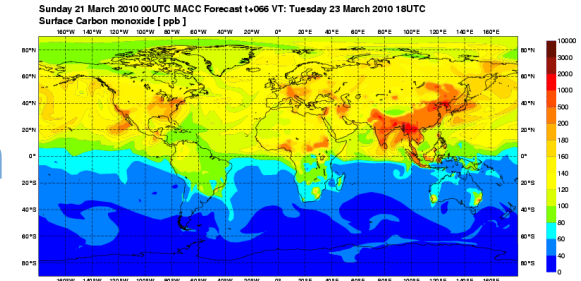
- The global system is based on the ECMWF Integrated Forecasting System (IFS), coupled to a global chemical transport model (CTM: MOZART, TM5 or MOCAGE)
- Regional ensemble comprises seven Chemical Transport Models run on a common European domain



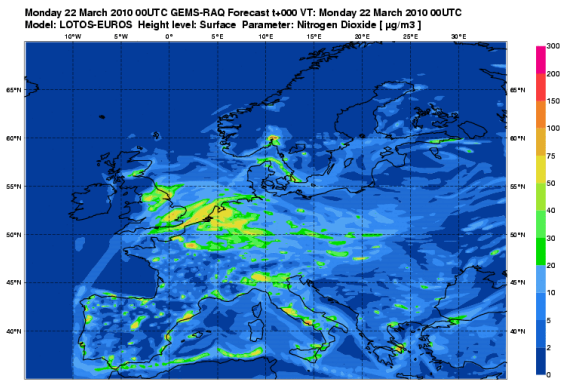
# MACC Daily (NRT) Service Provision



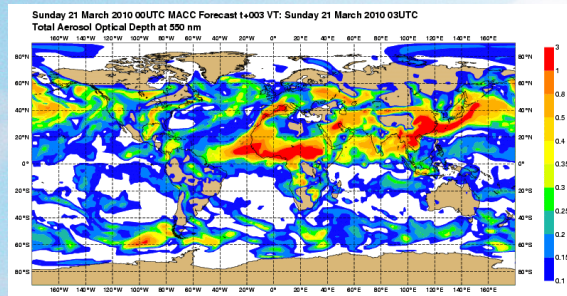
Global Pollution



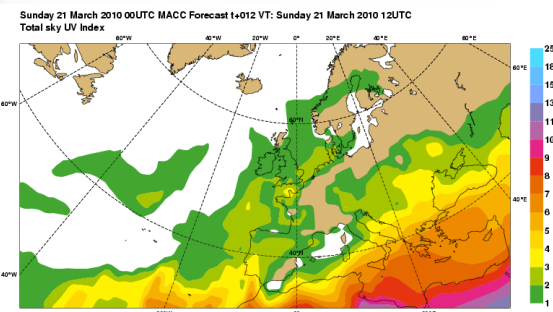
Air quality



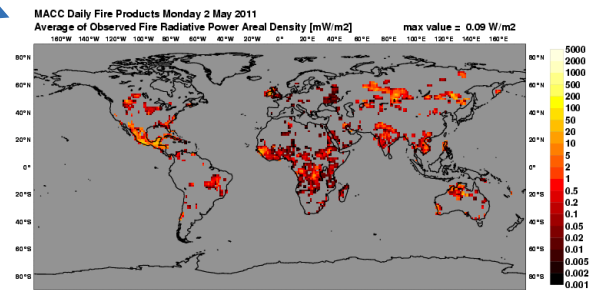
Aerosol



UV index



Fires



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

# MACC NRT Service Provision

## Ensemble of European Air-Quality forecasts

Monitoring atmospheric composition & climate

**macc** Monitoring atmospheric composition & climate

**gmes**

**METEO FRANCE**

HOME NEWS ABOUT THE PROJECT SERVICES DATA PRODUCTS DOCUMENTS EVENTS CONTACT US

Home > Services > RegionalAirQuality > Ensemble

ENSEMBLE EPSGRAMS HOURLY ENSEMBLE

Forecast base time: ALL 20130521

Tue 21 May 2013 00UTC

Day 0 Day 1 Day 2 Day 3

Model: ALL, Ensemble, CHIMERE, EMEP, EURAD, MATCH, MOCAGE, LOTOS-EUROS, SILAM

Parameter: Ozone, Nitrogen Dioxide, Sulfur Dioxide, Carbon monoxide, PM 10 aerosol, PM 2.5 aerosol, Birch Pollen in development

Field: Daily Mean, Daily Maximum

submit

Download pdf

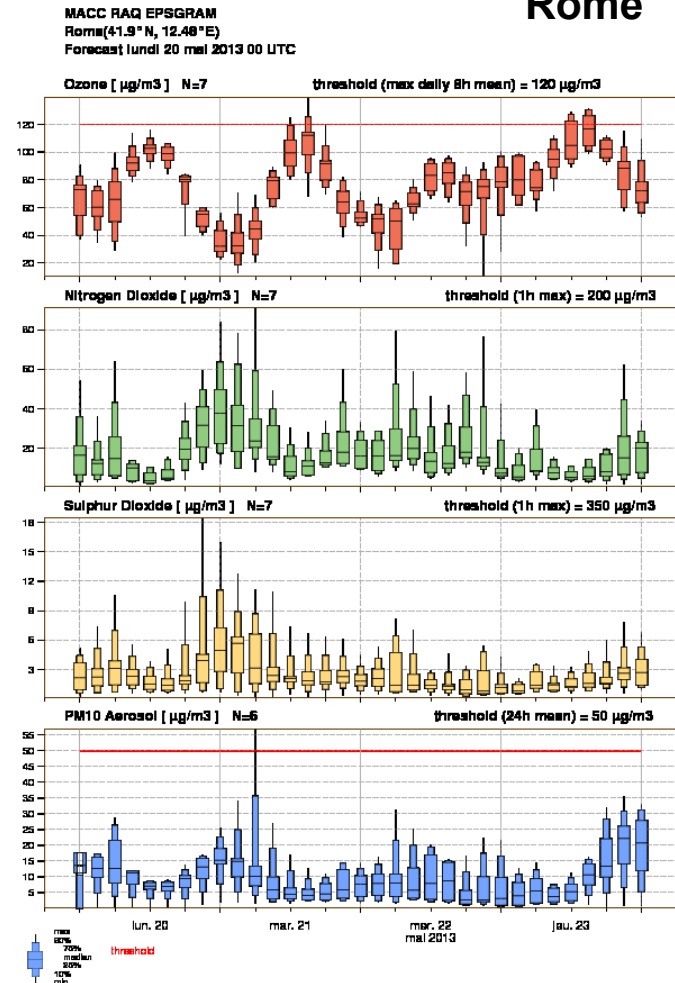
Tuesday 21 May 2013 00UTC MACC-RAQ Forecast D+0 VT: Tuesday 21 May 2013  
Surface Ozone Daily Mean [ $\mu\text{g}/\text{m}^3$ ]

EMEP SILAM LOTOS-EUROS MOCAGE

EURAD-IM MATCH ENSEMBLE MEDIAN (N=6)

- World-class air quality services for the European region, verified routinely
- Probabilistic “c-metograms” for the main European cities from the multi-model ensemble

### Rome

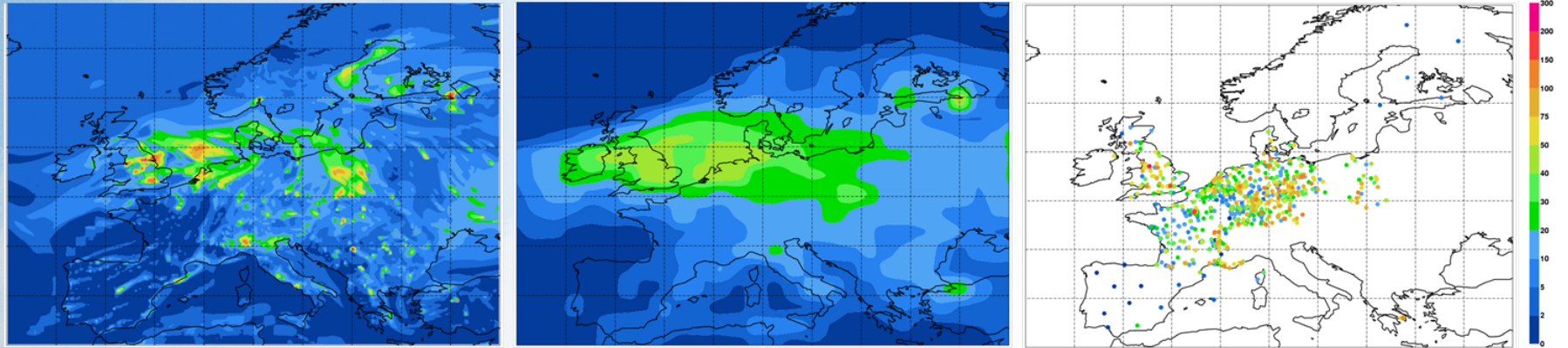


<http://www.gmes-atmosphere.eu>



# Forecasting European Air Quality

2-day nitrogen dioxide forecasts for 25 February 2010 from the MOCAGE regional model (left) and the coarser-resolution global model (middle) validated with observations (right).



**Regional Model**  
(national partner institutions)

**Global Model**  
(ECMWF)

**Observations**  
(Present: individual EU countries  
Future: EEA)

- MACC-II provides forecasts of European air quality from an ensemble of regional models.
- All forecasts are being validated with observations from the various European Union member states.
- The **Boundary Conditions** for reactive gases and aerosols are provided from the coupled global model run at ECMWF
- Boundary conditions for other region are freely available from this data server: [join.iek.fz-juelich.de/macc/](http://join.iek.fz-juelich.de/macc/)



Daily global 5-day forecasts and analyses of **reactive gases and aerosols** T255,L60 (~80km)

Daily global 5-day **CO<sub>2</sub>** forecasts  
T1279,L91 (~ 16km)

Forecast data  
available around  
22 UTC

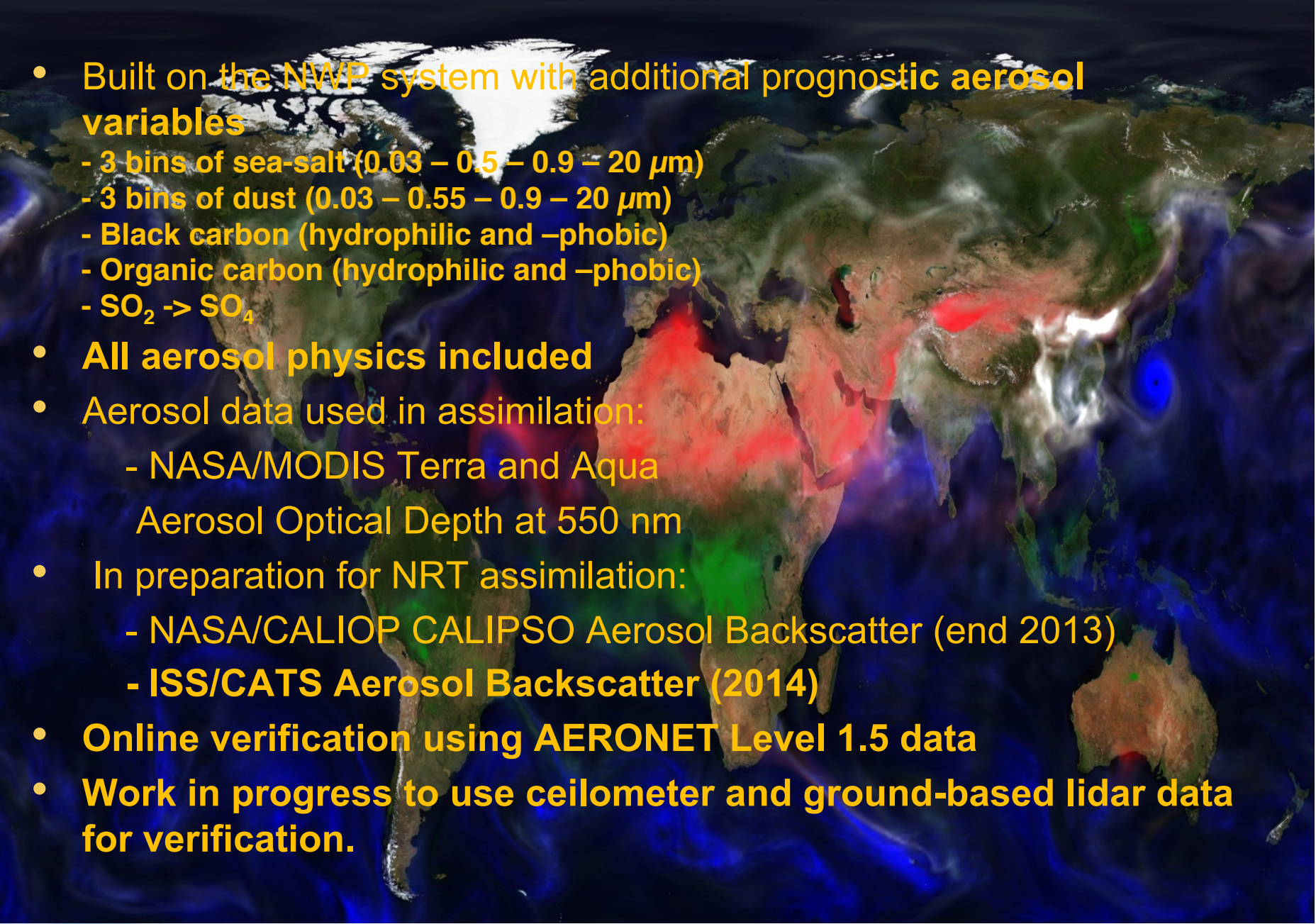
Daily global **fire emissions**  
from satellite data at  
0.1x0.1 res

Online verification and 3-  
monthly NRT validation  
reports

Data are publicly available on the  
MACC-II data server:  
<http://copernicus-atmosphere.eu/>



# Aerosol model

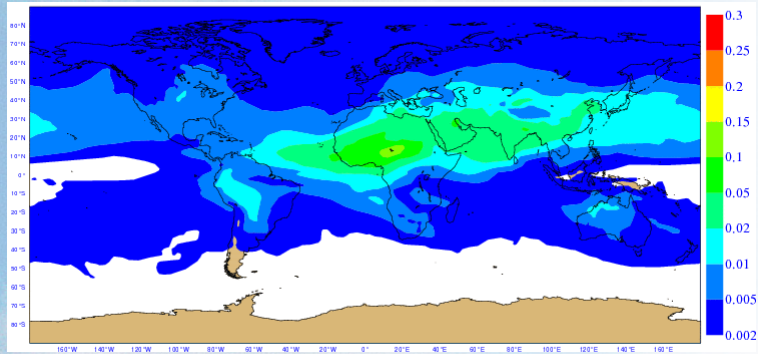
- Built on the NWP system with additional prognostic aerosol variables
    - 3 bins of sea-salt (0.03 – 0.5 – 0.9 – 20  $\mu\text{m}$ )
    - 3 bins of dust (0.03 – 0.55 – 0.9 – 20  $\mu\text{m}$ )
    - Black carbon (hydrophilic and -phobic)
    - Organic carbon (hydrophilic and -phobic)
    - $\text{SO}_2 \rightarrow \text{SO}_4$
  - All aerosol physics included
  - Aerosol data used in assimilation:
    - NASA/MODIS Terra and Aqua Aerosol Optical Depth at 550 nm
  - In preparation for NRT assimilation:
    - NASA/CALIOP CALIPSO Aerosol Backscatter (end 2013)
    - ISS/CATS Aerosol Backscatter (2014)
  - Online verification using AERONET Level 1.5 data
  - Work in progress to use ceilometer and ground-based lidar data for verification.
- 



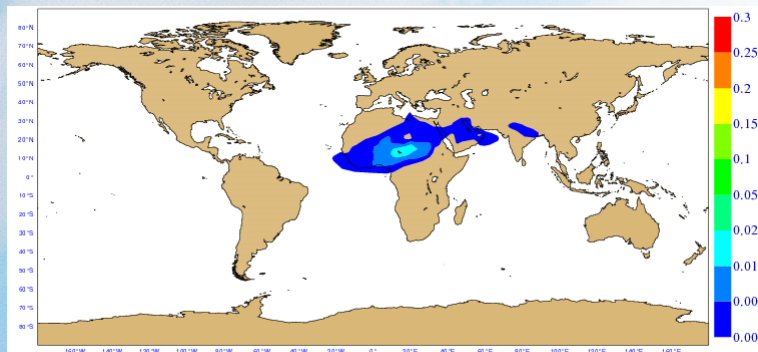
# Improvements in dust modelling

Jean-Jacques Morcrette

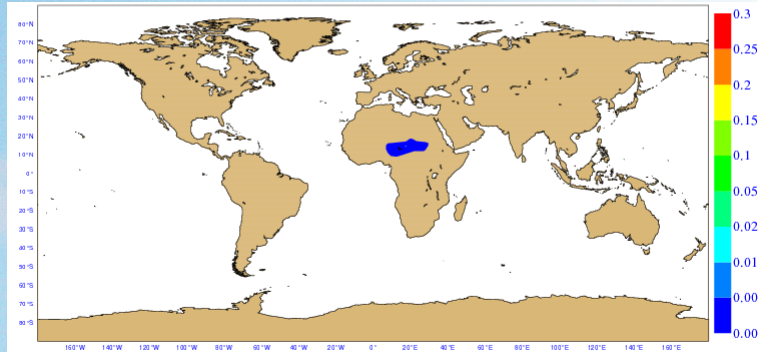
## MACC



Dust particles  
0.03-0.55  
microns

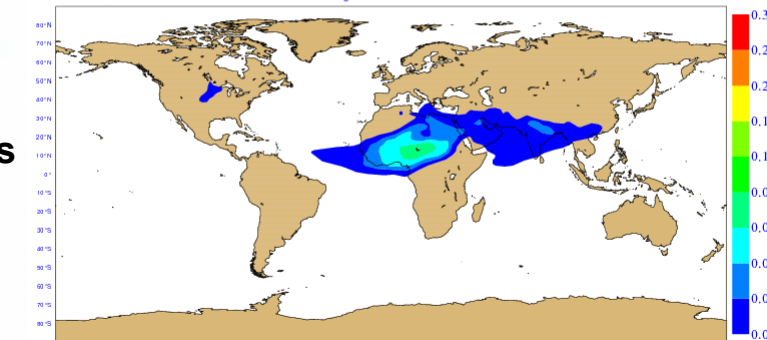
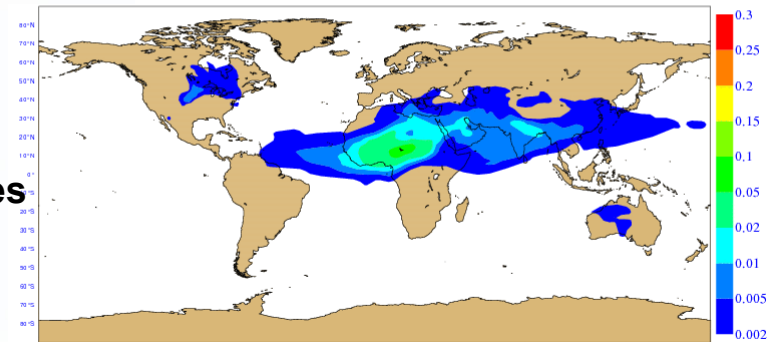
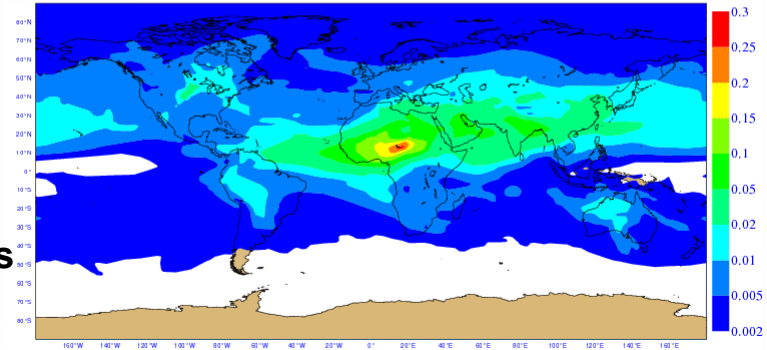


Dust particles  
0.55-0.9  
microns



Dust particles  
0.9-20  
microns

## MACC-II



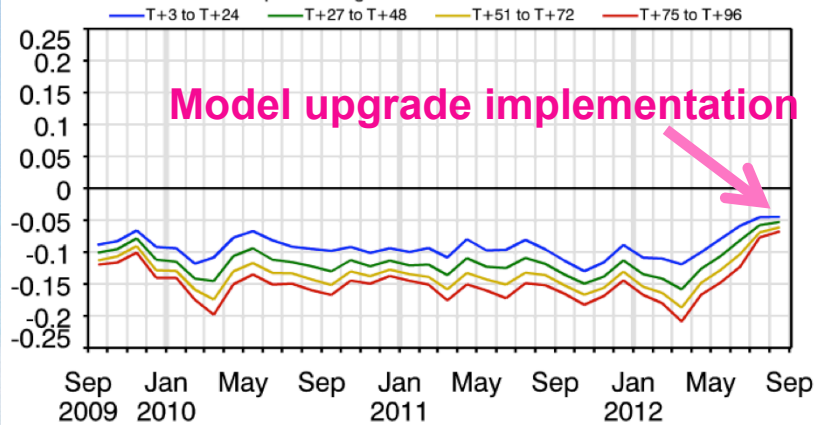
Original formulation: not enough coarse dust particles!  
Current formulation: more realistic dust distribution



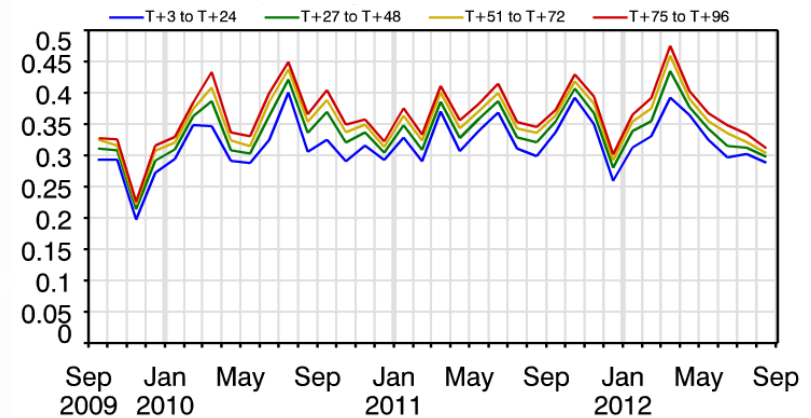
# AERONET verification showing model improvements

## Luke Jones & Jean-Jacques Morcrette

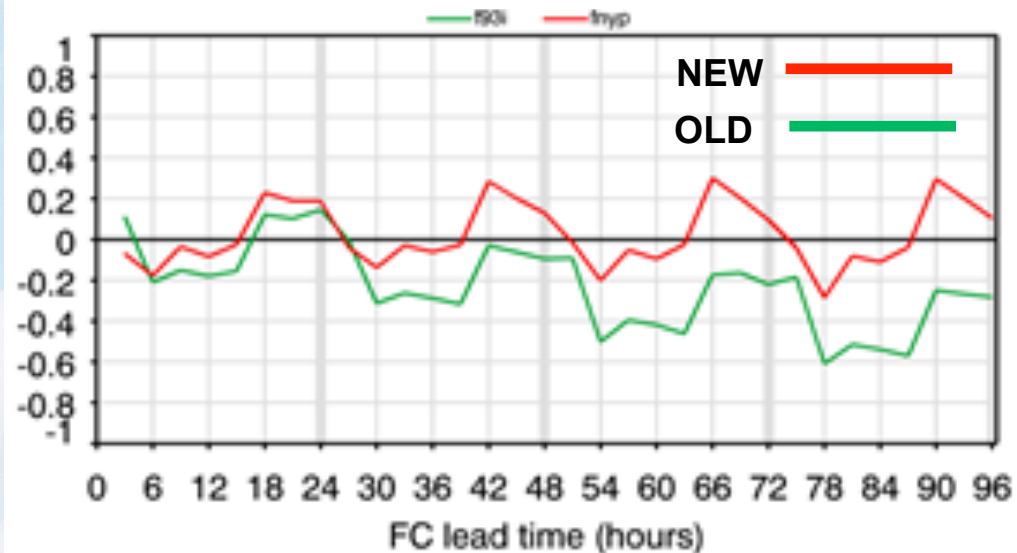
### Aerosol Optical Depth BIAS



### Aerosol Optical Depth RMS



### Aerosol Optical Depth NORMALIZED MEAN BIAS



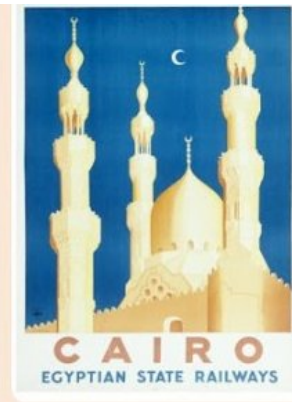
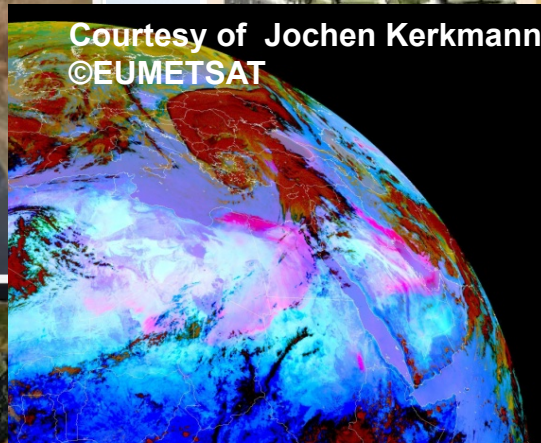
# Dust Storm on April 18 2012



Dust over the Nile delta from satellite imagery. Image courtesy of Chelys.



Courtesy of Jochen Kerkmann  
©EUMETSAT



Wednesday, April 18, 2012

## #Sandstorm in #Cairo

We are having the worst sandstorm in Cairo today. It is the **Khamsin** in its official time after Easter. The storm started at 8:30 AM this morning. Suddenly we got this yellow color in the air.

Here is Tahrir square from short awhile ago .



Khamsin in Tahrir square "Kolena Khaled Said"



# MACC-II/ECMWF forecasts for April 18 2012

Graphycs by Miha Razinger

Saturday 14 April 2012 00UTC MACC Forecast t+108 VT: Wednesday 18 April 2012 12UTC  
Dust Aerosols Optical Depth at 550 nm

**Day 4**



Sunday 15 April 2012 00UTC MACC Forecast t+084 VT: Wednesday 18 April 2012 12UTC  
Dust Aerosols Optical Depth at 550 nm

**Day 3**



Monday 16 April 2012 00UTC MACC Forecast t+060 VT: Wednesday 18 April 2012 12UTC  
Dust Aerosols Optical Depth at 550 nm

**Day 2**



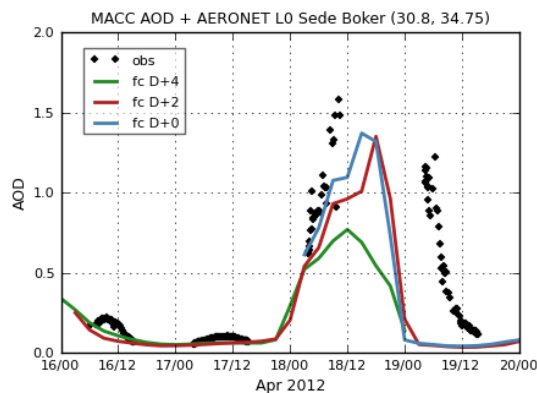
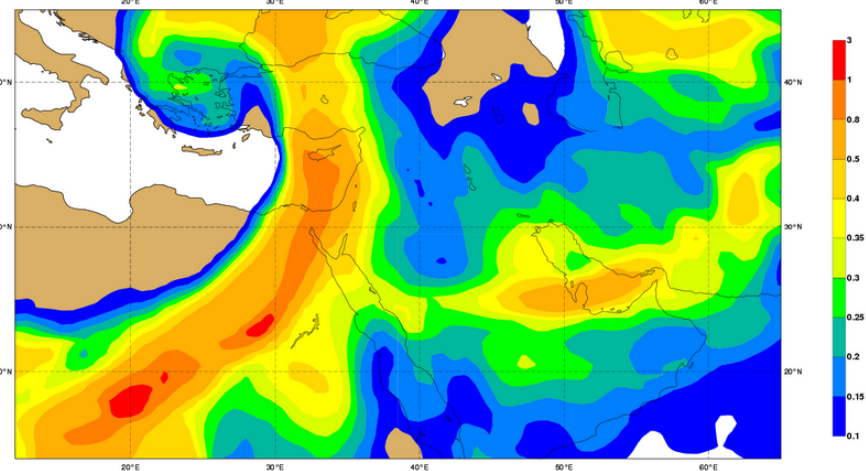
Tuesday 17 April 2012 00UTC MACC Forecast t+036 VT: Wednesday 18 April 2012 12UTC  
Dust Aerosols Optical Depth at 550 nm

**Day 1**



Wednesday 18 April 2012 00UTC MACC Forecast t+012 VT: Wednesday 18 April 2012 12UTC  
Dust Aerosols Optical Depth at 550 nm

**Day 0**

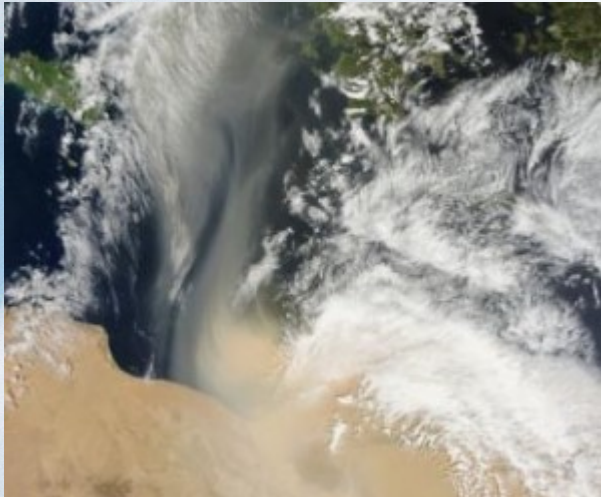


**AERONET verification at Sde Boker, Israel**

- Good skill of the model at the synoptic scale: storm predicted with 4 days of lead time!



# Dust Storms over the Mediterranean in April 2013



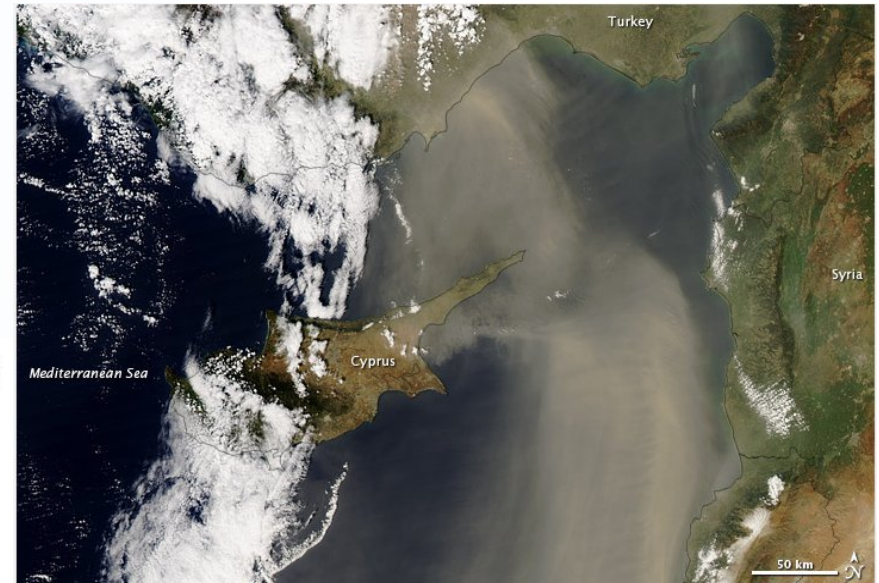
## Libyan dust storm hangs over Cyprus

1 April 2013

April 1, 2013 4 Comments

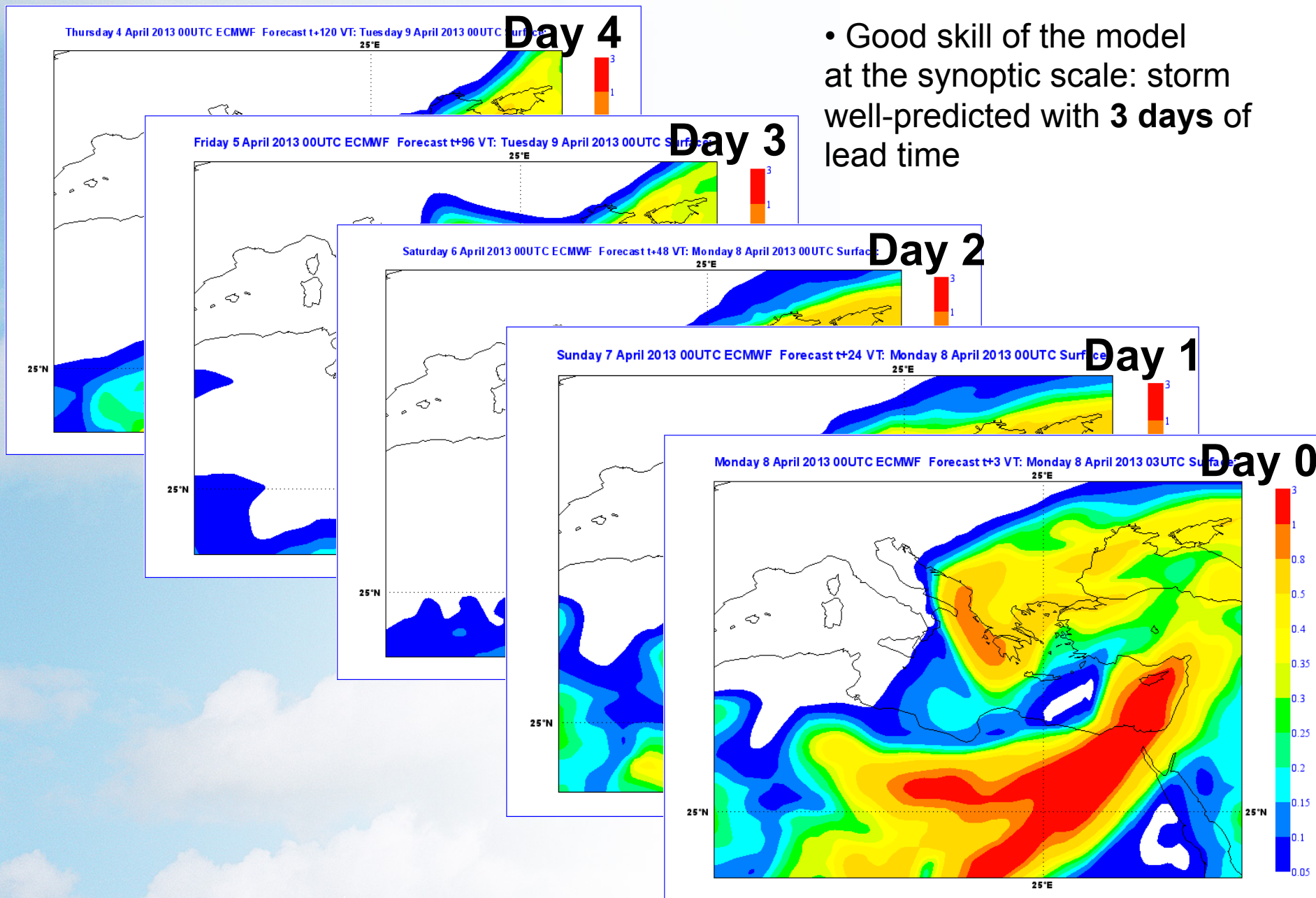


A cloud of fine dust was left hanging over Cyprus today. The air was very still and temperatures unseasonably high as a fine yellow dust, that could have been mistaken for mist, lurked over land and sea.



**Dust plumes blew over the Mediterranean Sea in early April 2013. Thick plumes hovered off the coasts of Libya and Egypt on April 7 and spanned the sea's eastern shoreline the following day, reaching as far north as Turkey. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite captured these natural-color images on April 1 and April 8 .**

# MACC-II/ECMWF forecasts for April 8 2013

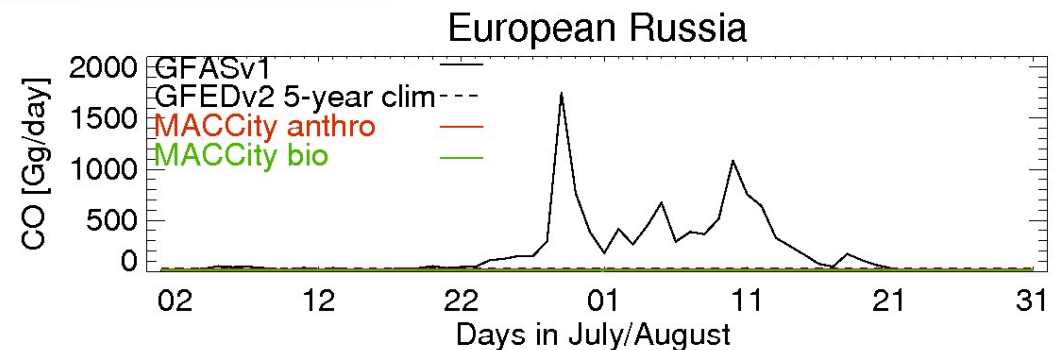
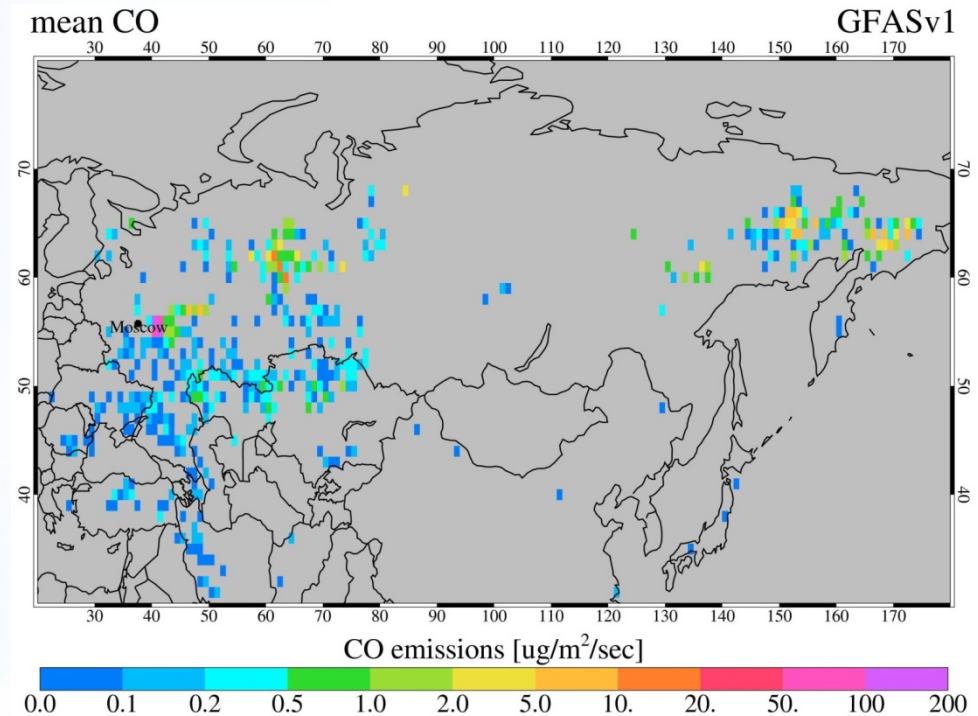




# NRT Fires emissions (GFAS)

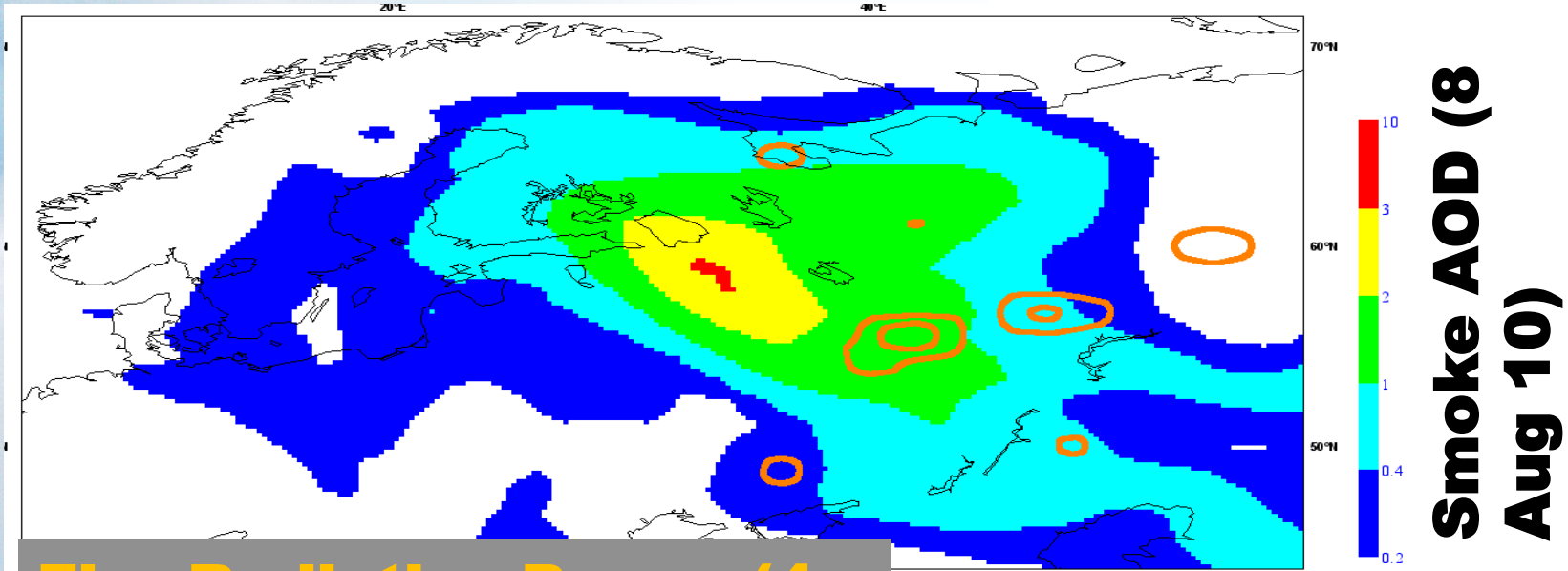
- Fire emissions are inferred from MODIS and SEVIRI Fire Radiative Power (FRP)
- **FRP allows Near Real Time estimate of fire emissions**
- **NRT fire emission improve AQ forecast**
- This dataset is also freely available

Credits: Johannes Kaiser

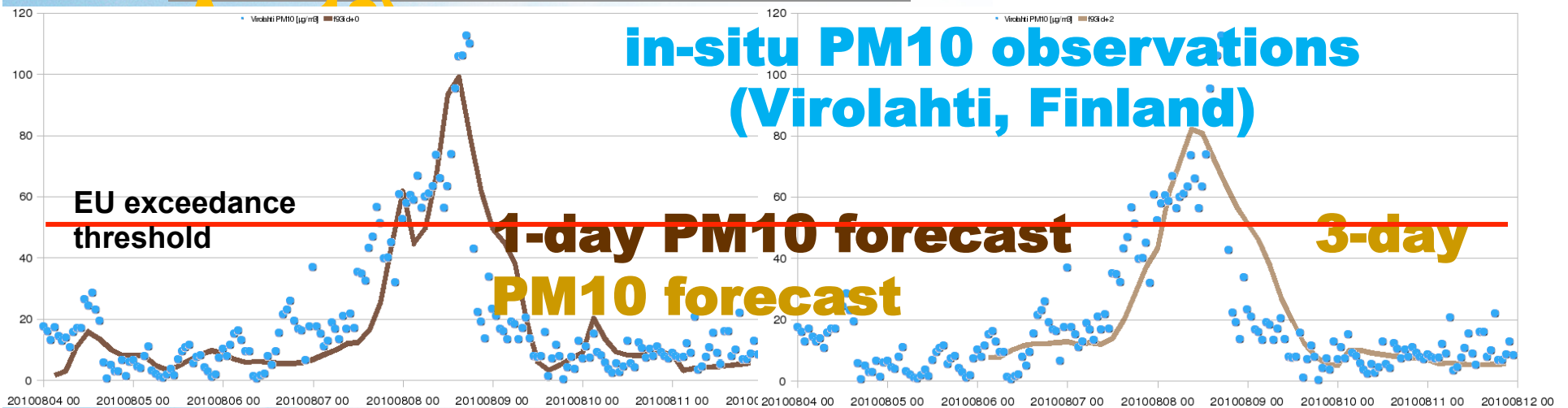




# Russian Smoke in Finland in 2010



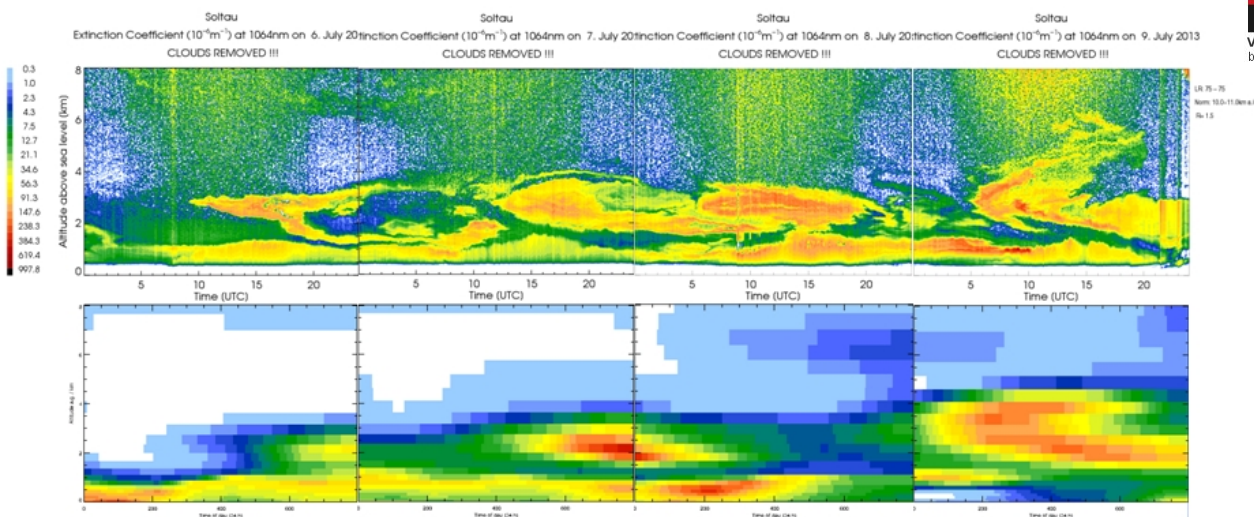
**Fire Radiative Power (4**



# Canadian Smoke in Europe July 2013

Comparison of Canadian forest fire plume seen by  
Ceilometers over Sołtau, North Germany  
6 – 9 July 2013

MACC-2D plot is **QUALITATIVE** and linear scale in contrast to ceiplot!!!  
Shall just show the reproduction of the plume structure



**Verification of MACC aerosol forecast with  
ceilometer data shows good performance for most  
plume occurrences  
(plots courtesy of Harald Flentje, DWD)**



Video 1. Maxime Duperré, traveling in a truck near Nemiscau, Quebec, took this video of one of the massive fires burning in Quebec this July.

## Canada's 2nd largest fire on record spreading smoke to Europe

Posted by Jim at Monday, July 15, 2013



By Dr. Jeff Masters  
13 July 2013



# Volcanic ash prediction activities

- Dedicated volcanic-ash prognostic variable
- SO<sub>2</sub> tracer simulations also performed
- Several cases investigated

## Volcanic plume (aerosols) off the coast of Iceland, 14 April 2010

Wednesday 14 April 2010 00UTC ECMWF Forecast 1+6 VT: Wednesday 14 April 2010 06UTC Model Level 52 Aerosol type 2 source/gain accumulated  
tkgp: Stohl et al's emission, 10-day FC from MACC analysis On 20100414 00UTC



**BBC NEWS ASIA-PACIFIC**

Home World UK England N.Ireland Scotland Wales Business Politics Health Education Entertainment & Arts

Africa Asia Europe Latin America Middle East US & Canada

21 June 2011 Last updated at 14:12

### Chile volcano ash causes renewed air chaos in Australia

Passengers at Sydney Airport frustrated by ash cloud delays

Australia's two major airports are facing up to 48 hours of disruption as the ash cloud from a Chilean volcano drifts across the south of the country.

Qantas and Virgin have cancelled all flights into and out of Sydney and Melbourne. Adelaide airport has been shut and Canberra flights also hit.

Last week, tens of thousands of people were stranded as airlines grounded flights, and now the ash has returned.

**Related Stories**

- Unwelcome return for Chilean ash
- Qantas cancels flights over ash
- Chile volcano wreaks fresh havoc



**MACC-II is pioneering the use of operational data assimilation to provide additional information on the development of volcanic ash plumes.**

# ICAP and WMO-SDS multi-model ensembles

## International Cooperative for Aerosol Prediction

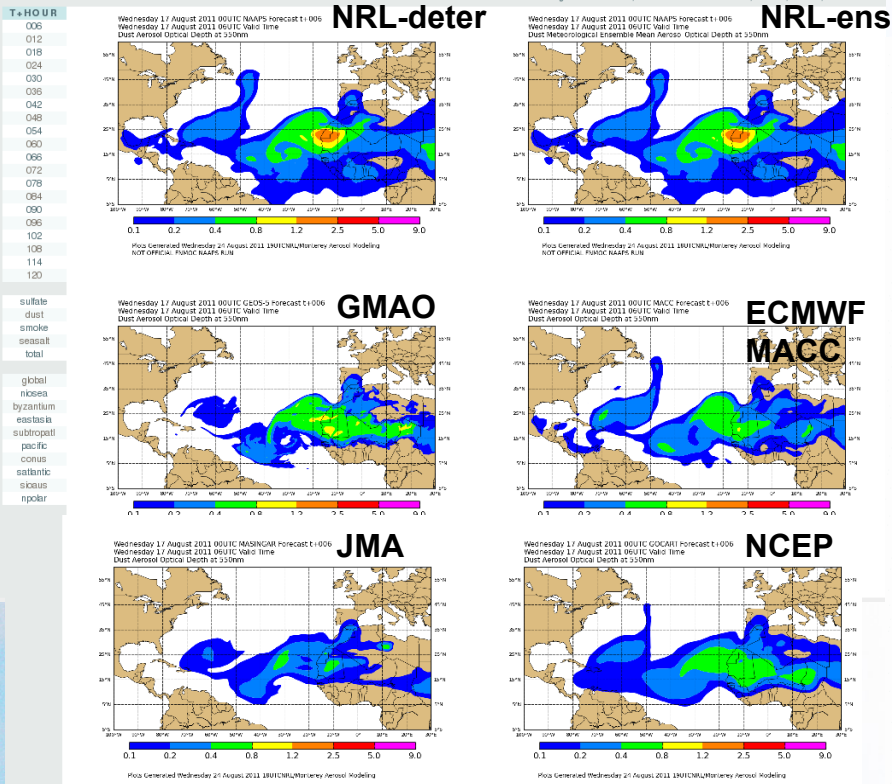
Link will go public at the end of 2013



NRL Monterey NAAPS Forecast

This page is an official U.S. Navy site and is intended as an internal research and development testbed. Products should not be treated as operational forecasting tools!  
 NOT OFFICIAL FNMOC NAAPS Privacy Policy Disclaimer  
 Marine Meteorology Division (Code 7500)  
 U.S. Navy Navy Recruiting Navy FOIA ONR

Main Listing / NAAPS Subtropical Atlantic Dust Aerosol Optical Depth Comparison Archive



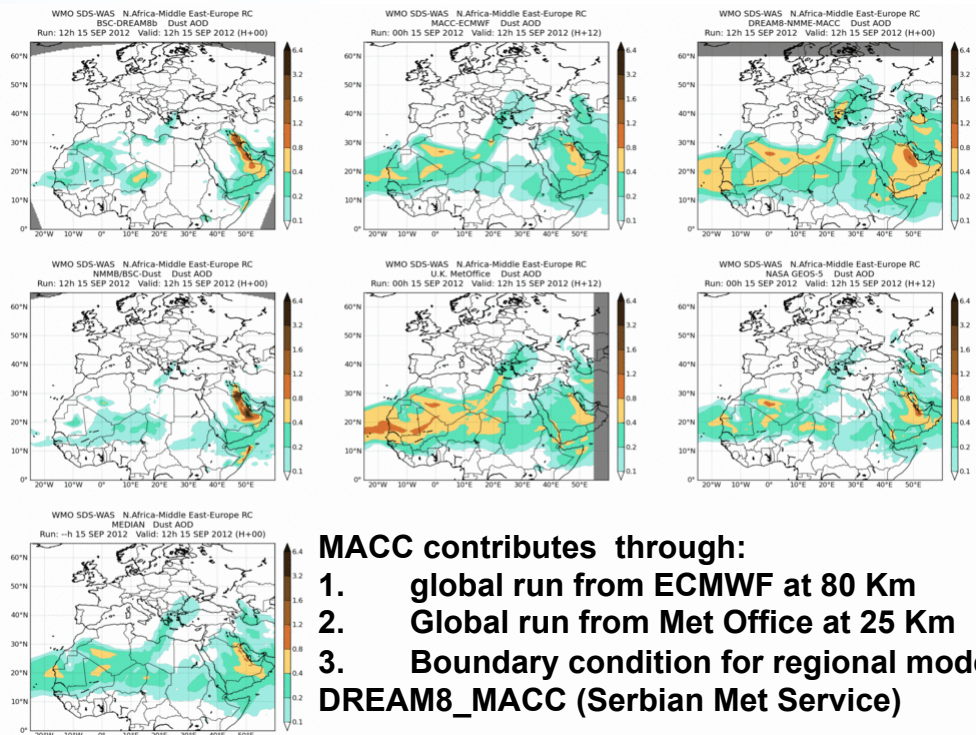
Graphics by:  
Walter Sessions, NRL

## WMO Sand and Dust Storm Warning Advisory and Assessment System

Northern Africa-Middle East-Europe Regional Centre

Public link:

<http://sds-was.aemet.es/forecast-products/dust-forecasts/compared-dust-forecasts>



MACC contributes through:

1. global run from ECMWF at 80 Km
2. Global run from Met Office at 25 Km
3. Boundary condition for regional model DREAM8\_MACC (Serbian Met Service)

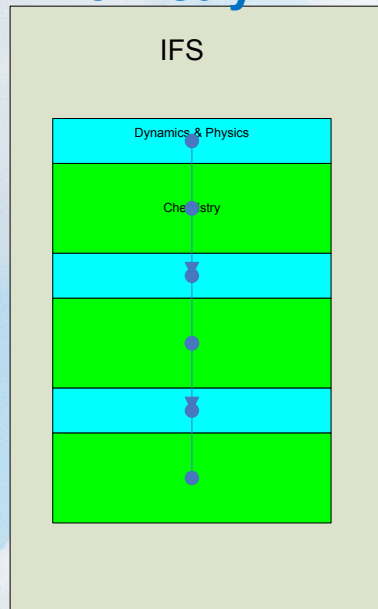
Graphics by:  
Francesco Benincasa, BSC



# Reactive Gases developments

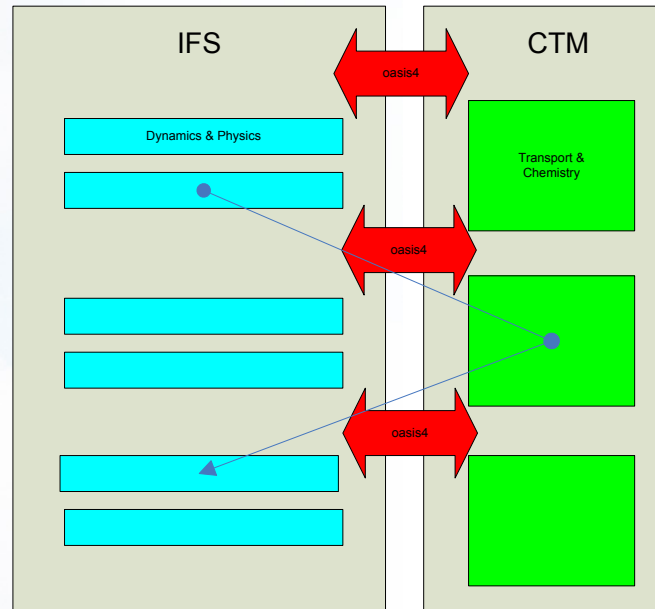
- MACC NRT analysis and reanalysis use “Coupled system”: MOZART CTM coupled to IFS
- Chemistry is now being integrated into the IFS: **C-IFS model**

## C-IFS On-line Integration of Chemistry in IFS



Integrated System  
Feedback: fast  
Flexibility: low

## Coupled System IFS- MOZART3 / TM5



● Feedback Flow →

Coupled System  
Feedback: slow  
Flexibility: high

**C-IFS is  
10 x more  
efficient than  
Coupled  
System** 21

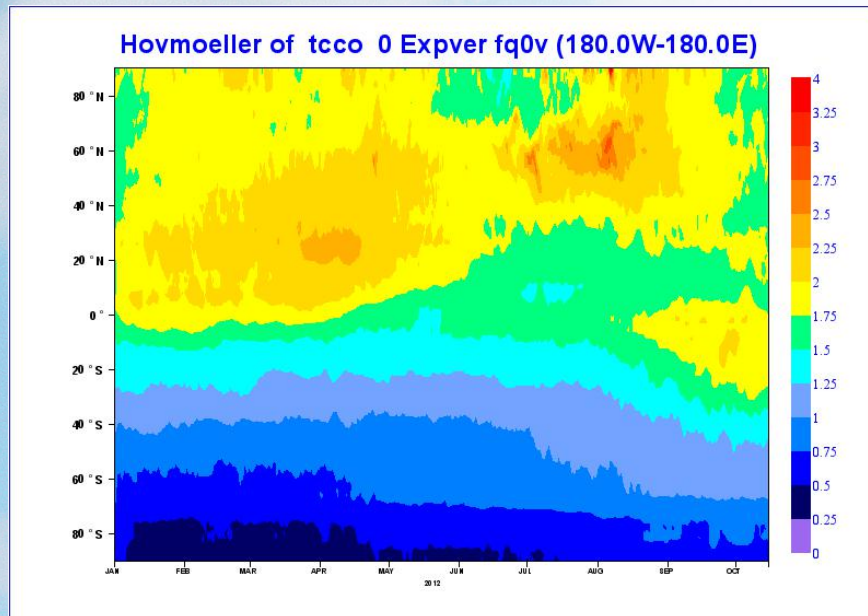
# C-IFS data assimilation experiments

- C-IFS DA experiment run for 2012, assimilating O3 and CO
- TM5 chemistry scheme
- Emissions: MACCity, GFAS

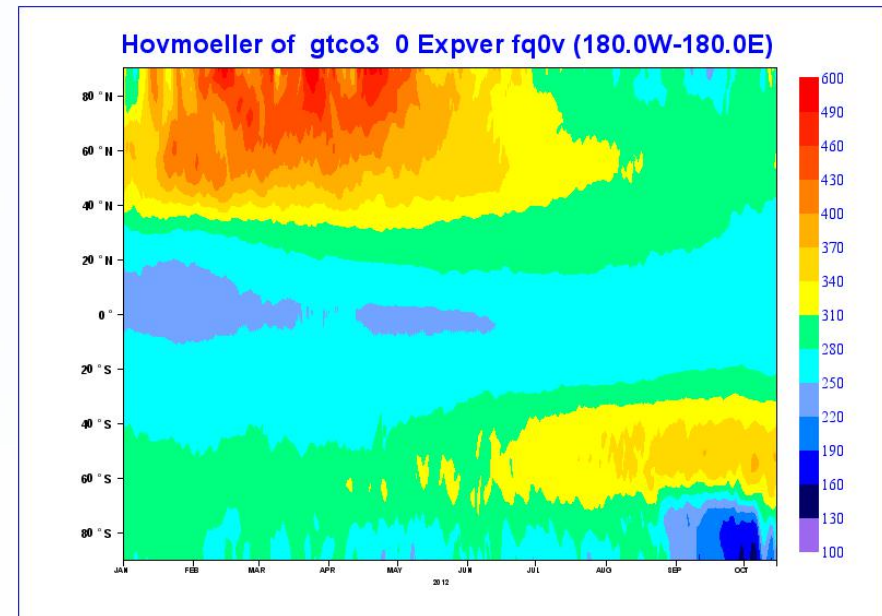
Antje Inness

## C-IFS analysis

CO



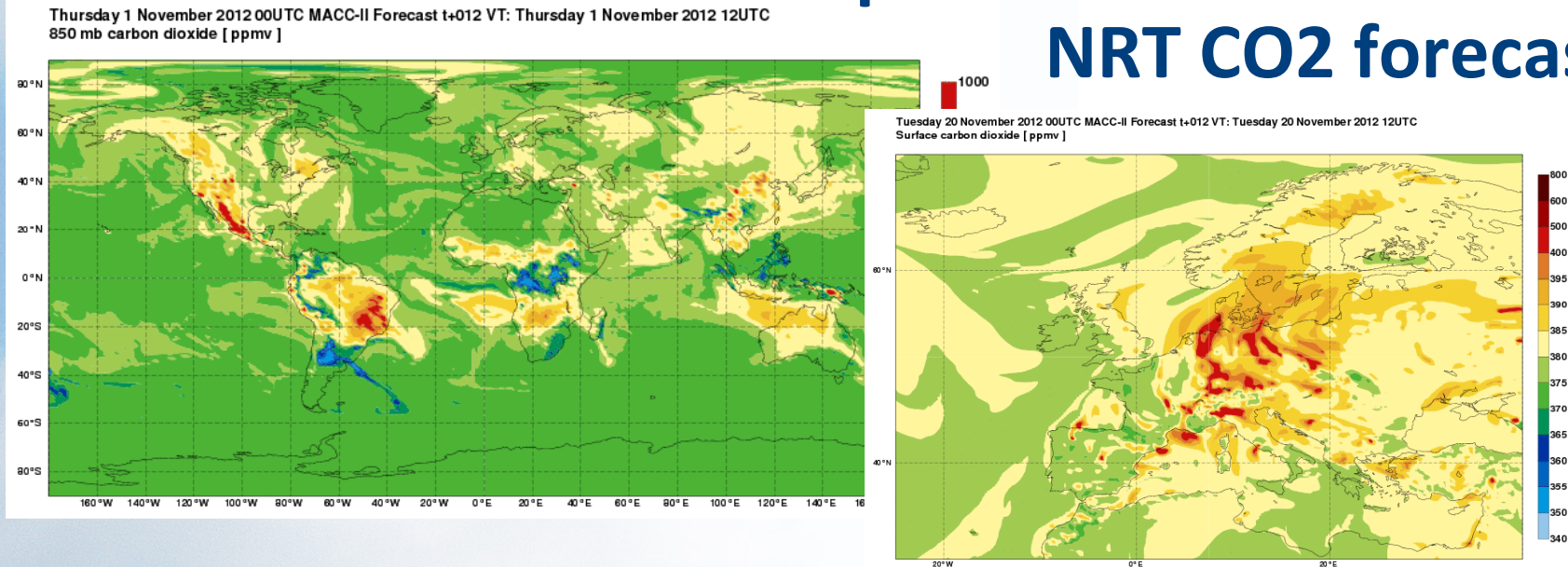
O3





# Greenhouse Gases developments:

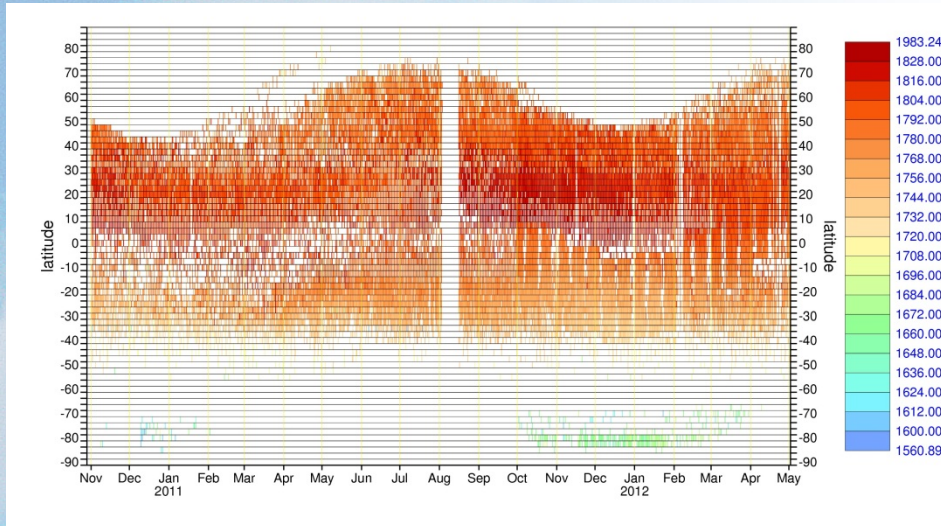
## NRT CO<sub>2</sub> forecast



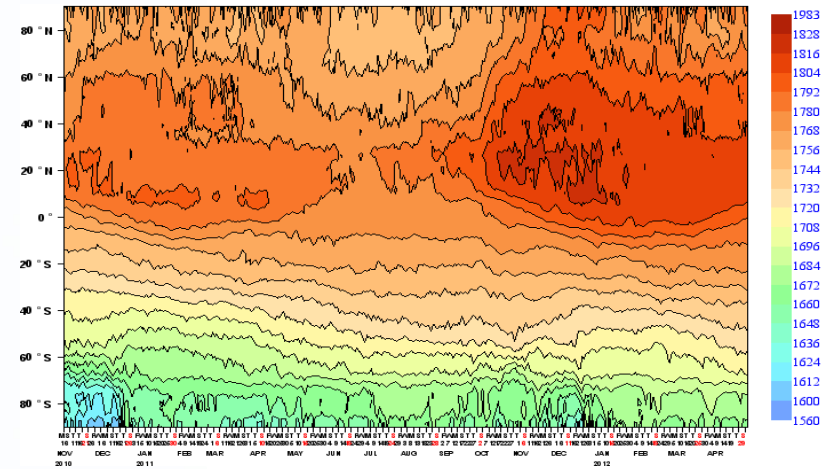
- With the CTESSEL land surface carbon model implemented in the IFS, we now have the capability to run CO<sub>2</sub> simulations at very high resolution (16km).
- 5-day forecasts are produced daily and validated against surface observations
- These NRT simulations are very useful to monitor and forecast the synoptic variability of CO<sub>2</sub>, which can be used to better interpret surface observations.
- Similar CH<sub>4</sub> forecasts in progress, expected at the end of 2013

# Greenhouse Gases: CH<sub>4</sub> Analysis

## TANSO-FTS/GOSAT obs



## CH<sub>4</sub> analysis



- **CH<sub>4</sub> analysis of satellite measurements with a 6 months delay since June 2009**
- **Assimilated data: SCIAMACHY/ENVISAT, IASI/METOP-A, TANSO-FTS/GOSAT**
- **Similar CO<sub>2</sub> analysis in progress**



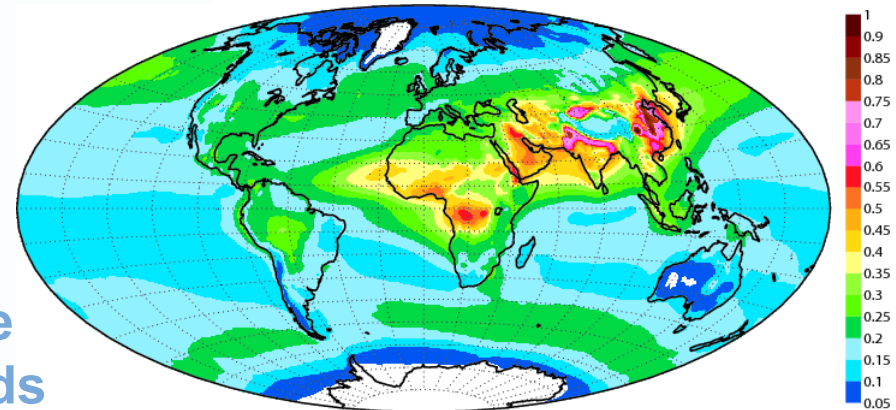
# MACC Retrospective Service Provision

Reanalysis of Atmospheric Composition (2003-2012)

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



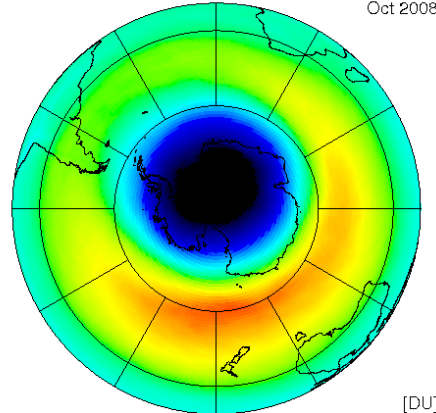
Aerosol Optical Depth



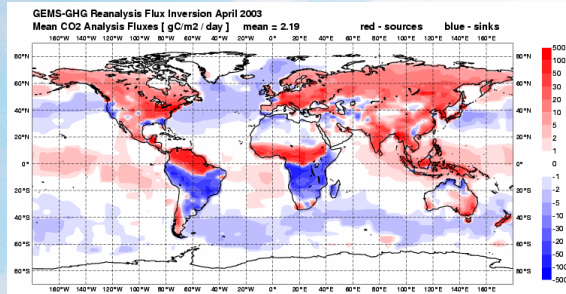
Ozone records

(30 years)

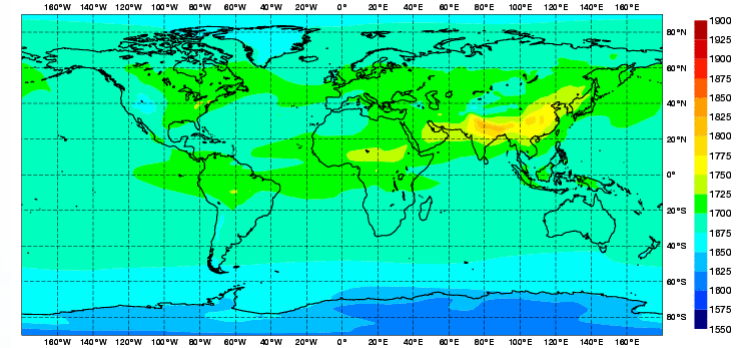
Multi Sensor Reanalysis Monthly mean total ozone Oct 2008



CO2 Flux Inversions



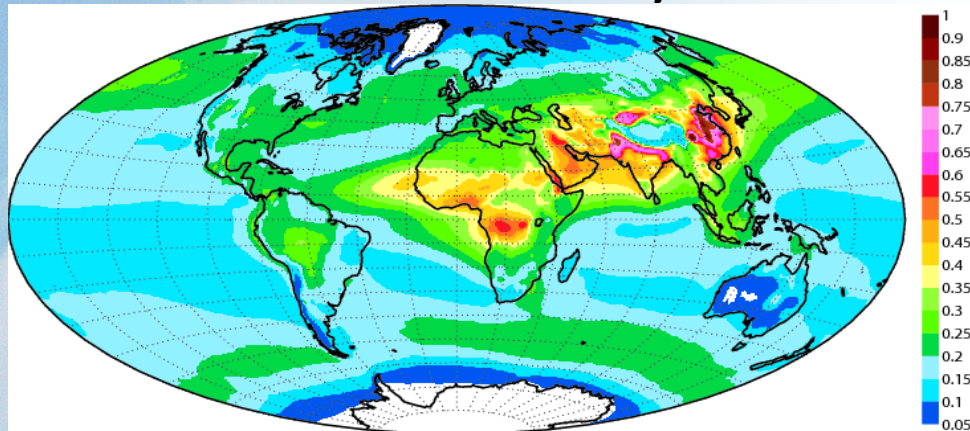
ECMWF/GEMS Reanalysis Global Monthly Mean August 2004 Mean Column CH4 Mixing Ratio [ ppb ]



# NOAA/BAMS

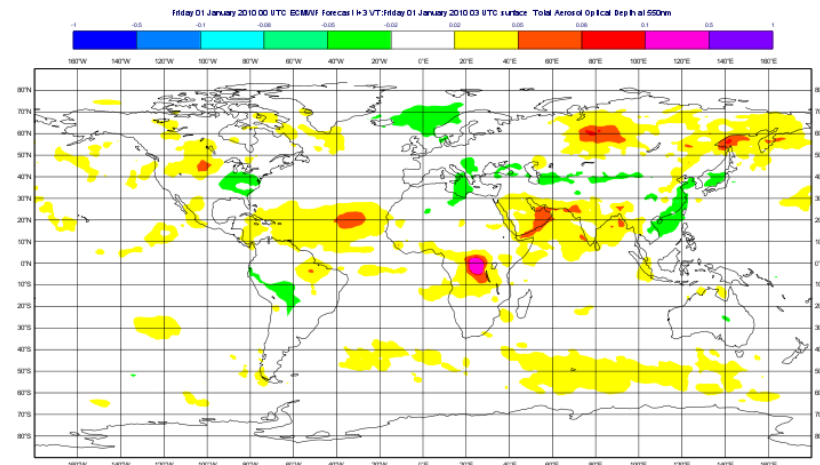
## Annual State of Climate Reports

Total Aerosol Optical Depth (2003-2010)  
from the MACC reanalysis

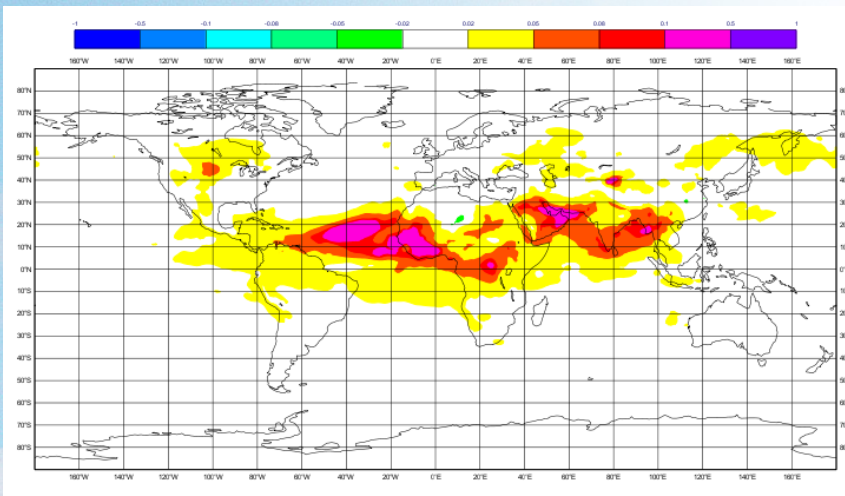


Benedetti, A., Jones, L. T., Inness, A., Kaiser, J. W., and Morcrette, J.-J., 2013: [Global climate] Aerosols [in "State of the Climate in 2012"]. Bull. Amer. Meteor. Soc., 94(8):S34–S36.

Total AOD anomaly for 2012  
with respect to 2003-2010



Dust aerosol anomaly for MAM 2012

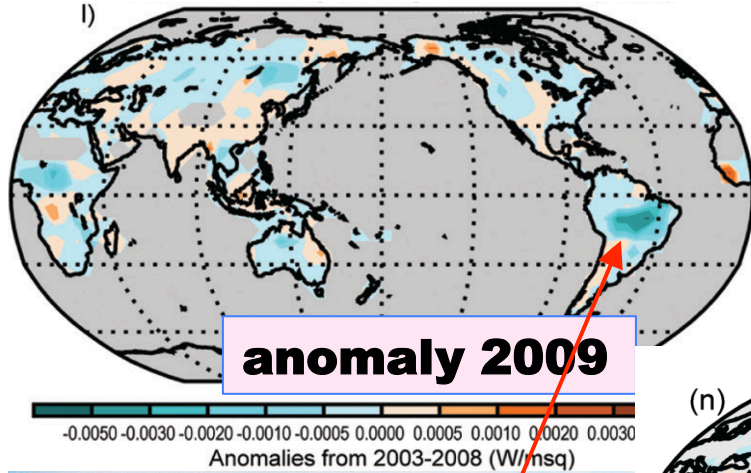


Very active Saharan dust season in Spring 2012, showing a large positive anomaly. This is also visible over the Atlantic in the total AOD annual anomaly

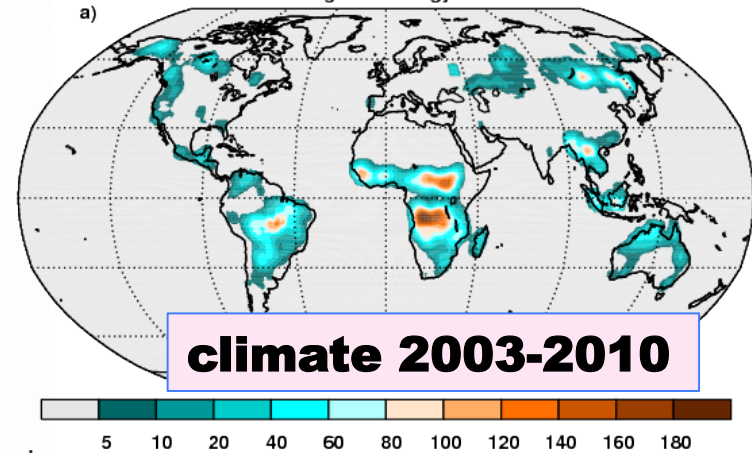


# Monitoring of ECV Fire Disturbance

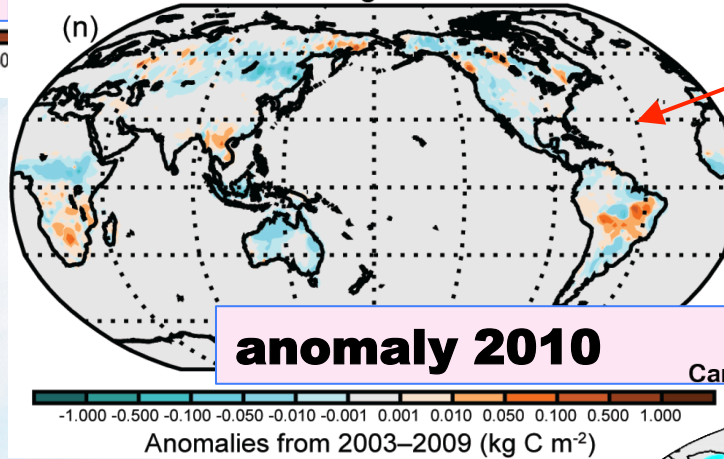
Biomass Burning (average fire radiative power)



Biomass Burning Climatology over 2003-2010



Biomass Burning Carbon Emission

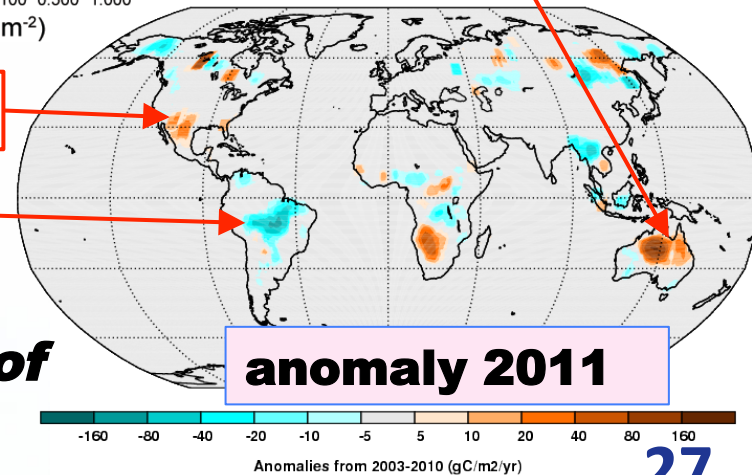


**SST anomaly in tropical N Atlantic**

**El Nino in late 2010, wet Feb/Mar 2011**

**hot and dry**

**reduced deforestation**



**Annual fire anomalies in NOAA's *State of the Climate* reports. [Kaiser et al. *BAMS* 2010,2011,2012]**

# MACC Reanalysis of Atmospheric Composition

- **Has been extended:** Period **2003-2012**
- O<sub>3</sub>, CO, NO<sub>x</sub>, HCHO, AER, CH<sub>4</sub> available from MACC data server <http://www.gmes-atmosphere.eu>
- Additional chemical species available. Please contact us for data access.
- Documentation:
  - Inness et al. (2013): The MACC reanalysis: an 8 yr data set of atmospheric composition, Atmos. Chem. Phys., 13, 4073-4109, doi:10.5194/acp-13-4073-2013.
  - Reanalysis validation reports:
    - [http://www.gmes-atmosphere.eu/services/gac/global\\_verification/validation\\_reports/](http://www.gmes-atmosphere.eu/services/gac/global_verification/validation_reports/)



# Forecast Product Users

User	Purpose	Means of access
MACC-II regional models	Boundary conditions for aerosol and reactive gases	MARS & ECFS
Other regional AQ models	Boundary conditions for aerosol and reactive gases	MARS & ECFS
Solar power companies	Aerosols	FTP
NWP centres	Fire emissions for aerosol & air quality forecasts	MARS & FTP
WMO Sand and Dust Storm service	Dust aerosol forecasts	MARS
Scientific field campaigns	Specific forecasts for flight planning	Web site, MARS, ECFS, & FTP

**All atmospheric composition products are freely available to users from public and private institutions/companies worldwide**



**More information about environmental monitoring activities at ECMWF and how to access the data can be found on:**



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



**For questions contact:**  
[info@copernicus-atmosphere.eu](mailto:info@copernicus-atmosphere.eu)

