# Aerosol forecasting at UK Met Office

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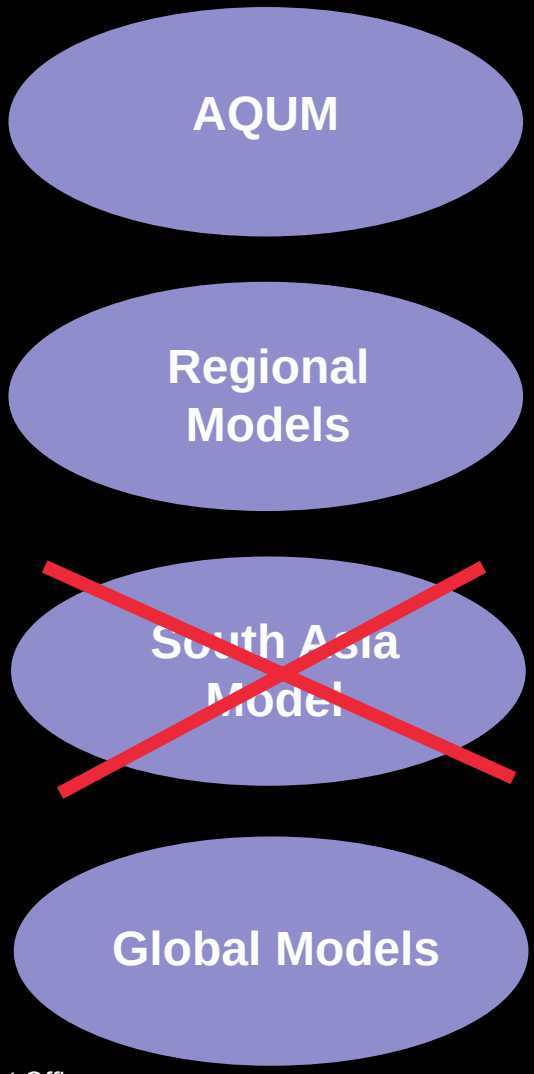
# Talk Overview

- Air quality forecasting update.
- Aerosol strategy for global NWP & where we are.
- Operational global dust forecasting and dust data assimilation progress.
- Application: Impact of aerosols on NWP forecasts
- Example of sensitivity of aerosol deposition to model changes
- Conclusions

# Aerosol forecasting across Met Office




- Air quality
- Visibility, PM forecasts

- Visibility using MURK

- Dust (6 bin Woodward scheme)

- Dust (2 bin)
- Visibility
- Improved NWP
- Climate prediction

**Most schemes using CLASSIC aerosol scheme → future move towards UKCA-MODE (simplified for NWP?)**


# Air Quality Forecasting

Paul Agnew

# New UK Daily AQ Index

- AQ Index changed from 1st January 2012
- Addition of $PM_{2.5}$ as a new component, alongside ozone, $NO_2$, $SO_2$, $PM_{10}$
- Introduction of $PM_{2.5}$ is already resulting in substantial number of UK exceedances
- Increases the importance of improved aerosol modelling and emission inventories

**Daily Air Quality Index**

The new bandings for the Daily Air quality Index are detailed in Table 1.

| Band | Index | Ozone<br>Running 8 hourly mean<br>µgm⁻³ | Nitrogen Dioxide<br>hourly mean<br>µgm⁻³ | Sulphur Dioxide<br>15 minute mean<br>µgm⁻³ | PM2.5 Particles<br>24 hour mean<br>µgm⁻³ | PM10 Particles<br>24 hour mean<br>µgm⁻³ |
|---|---|---|---|---|---|---|
| LOW | | | | | | |
| | 1 | 0-33 | 0-66 | 0-88 | 0-11 | 0-16 |
| | 2 | 34-66 | 67-133 | 89-176 | 12-23 | 17-33 |
| | 3 | 66-99 | 134-199 | 177-265 | 24-34 | 34-49 |
| MODERATE | | | | | | |
| | 4 | 100-120 | 200-267 | 266-354 | 35-41 | 50-58 |
| | 5 | 121-140 | 268-334 | 355-442 | 42-46 | 59-66 |
| | 6 | 141-160 | 335-399 | 443-531 | 47-52 | 67-74 |
| HIGH | | | | | | |
| | 7 | 161-187 | 400-467 | 532-708 | 53-58 | 75-83 |
| | 8 | 188-213 | 468-534 | 709-886 | 59-64 | 84-91 |
| | 9 | 214-239 | 535-599 | 887-1063 | 65-69 | 92-99 |
| VERY HIGH | | | | | | |
| | 10 | 240 or more | 600 or more | 1064 or more | 70 or more | 100 or more |

**Table 1: Daily Air Quality Index bands**

The new daily air quality index comes in three parts and includes additional advice for susceptible individuals, alongside advice for the general population:

A. Instructions on how the index should be used;

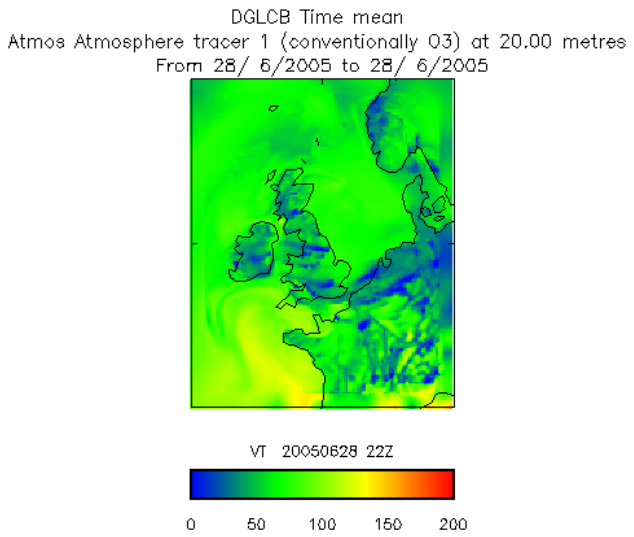
B. The short-term health effects of air pollution and action that can be taken to reduce impacts;

C. Health advice linked to each band to accompany the air quality index.

These are detailed below:

# On-line modelling with AQUM

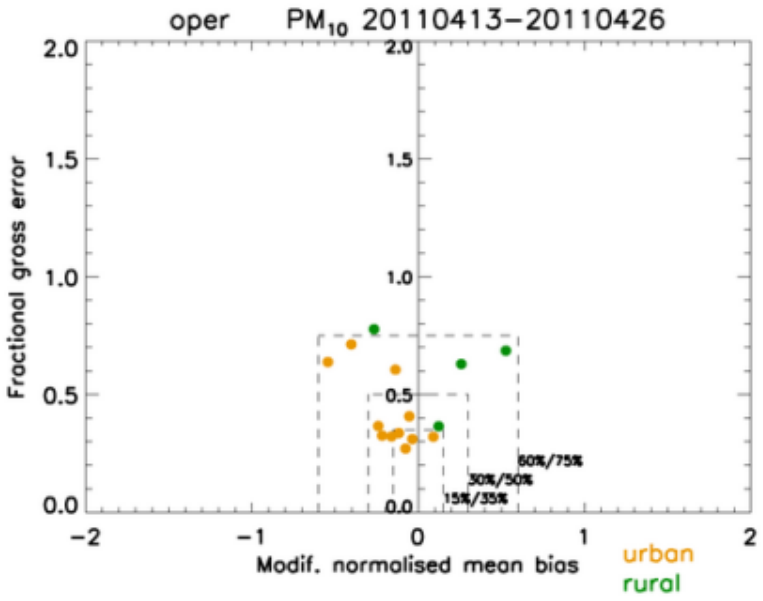
- AQ modelling in the UM offers advantages:
  - On-line modelling, which allows:
    - closer integration of meteorology and chemistry
  - Incorporation of lateral boundary fluxes from a global model
  - Potential for including feedbacks between composition and meteorology
    - Influence of composition on radiation, cloud physics and visibility forecasting

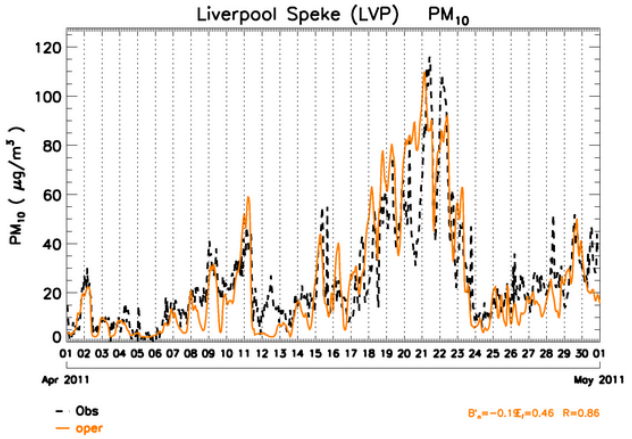



An ozone field from an AQUM case study

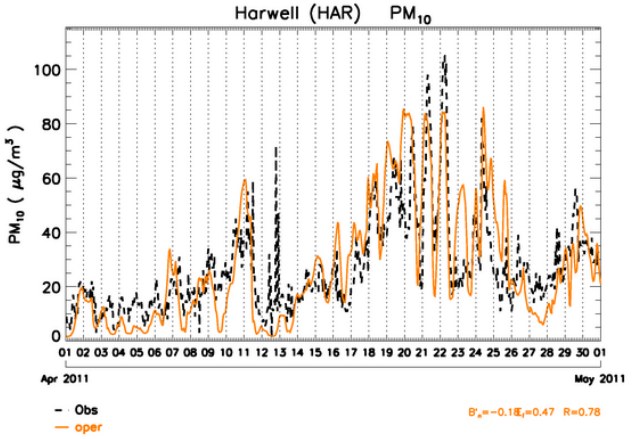
# UK PM Episode: April 2011

- Significant PM (and ozone) episode around Easter 2011



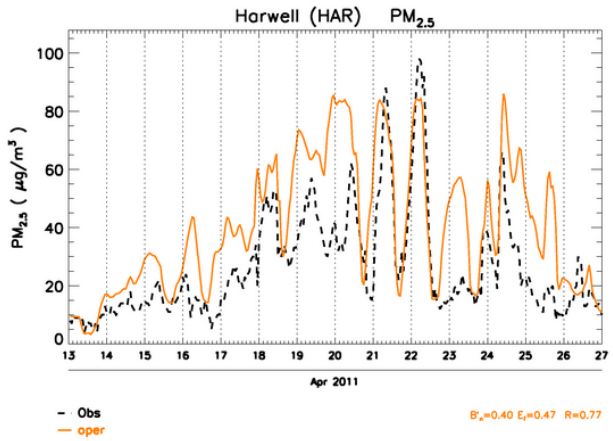



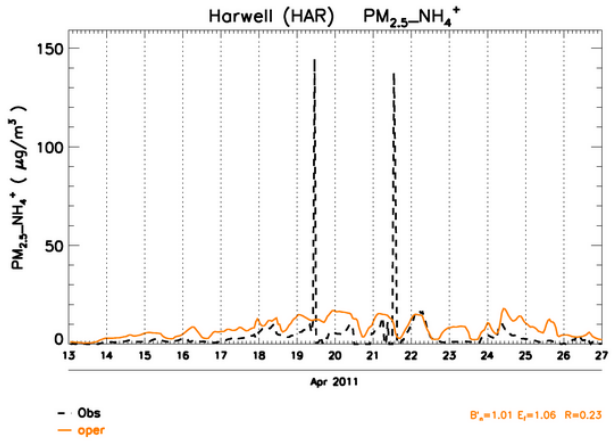

URBAN BACKGROUND [2.84° W, 53.35° N]

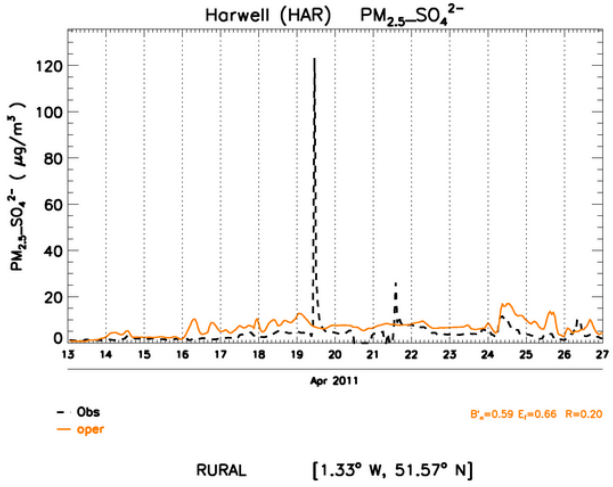


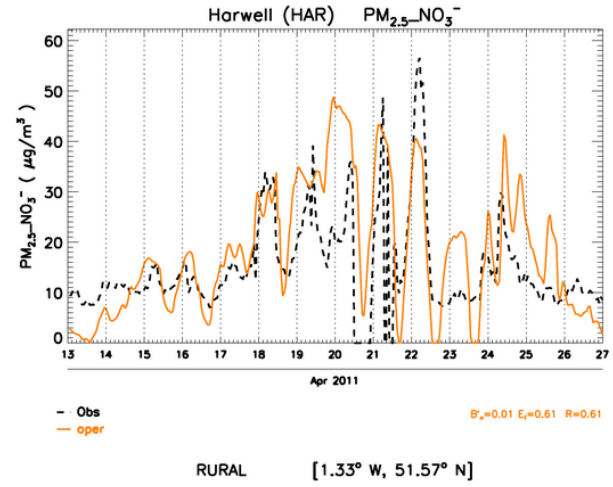

RURAL [1.33° W, 51.57° N]

# PM speciation: importance of nitrate aerosol



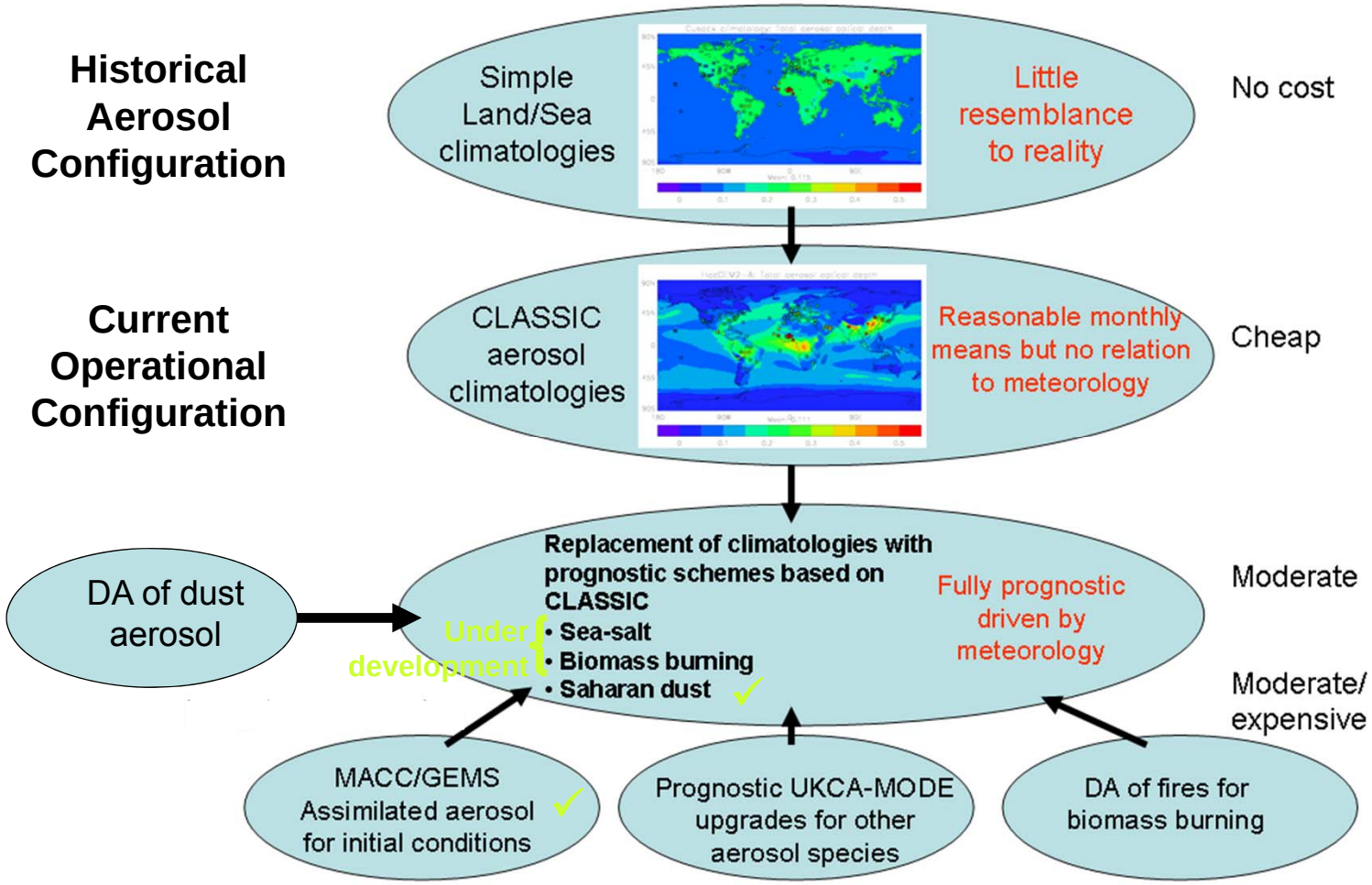



# Aerosols in global NWP forecasts

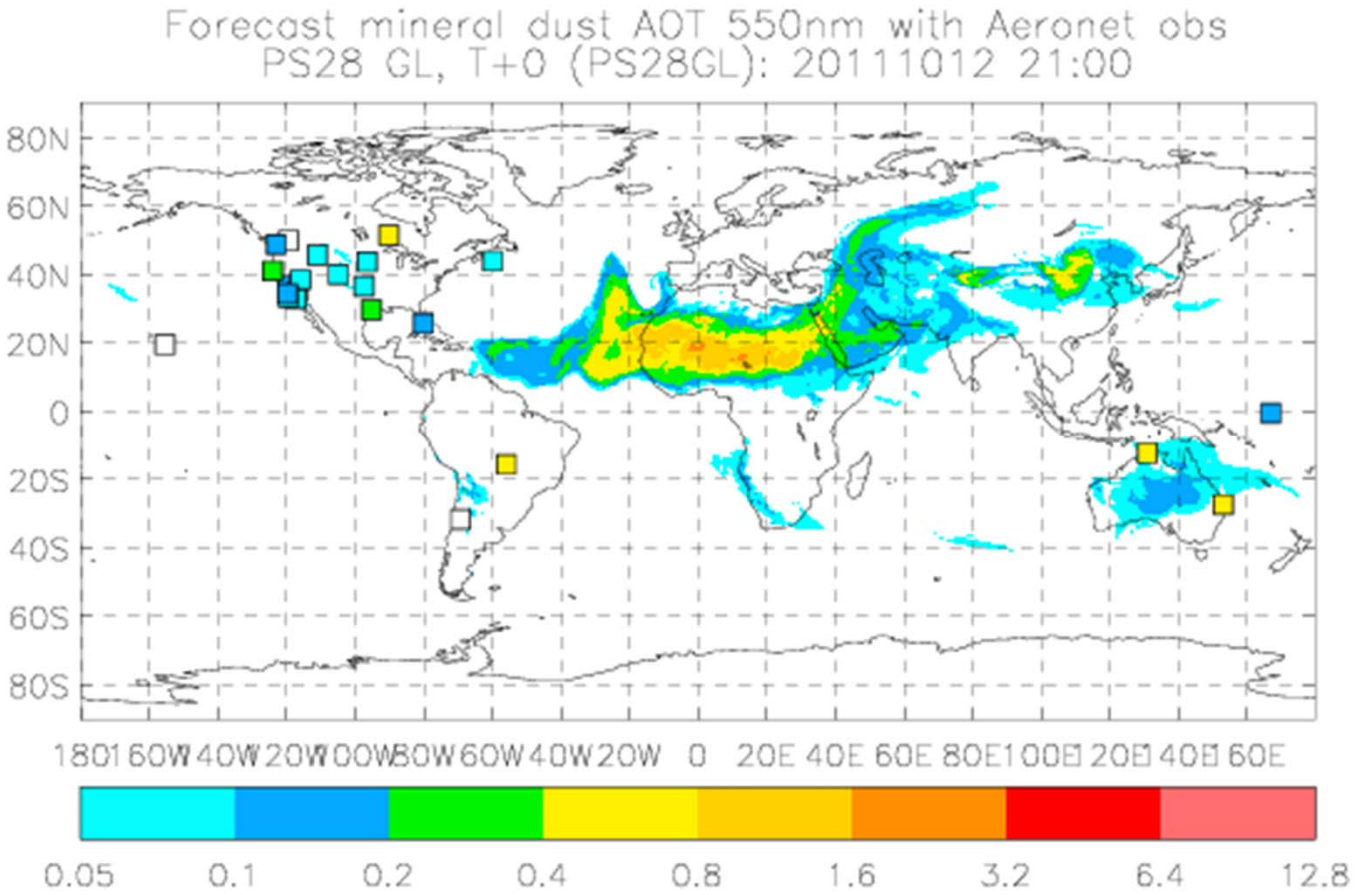
# Aerosol Strategy for NWP



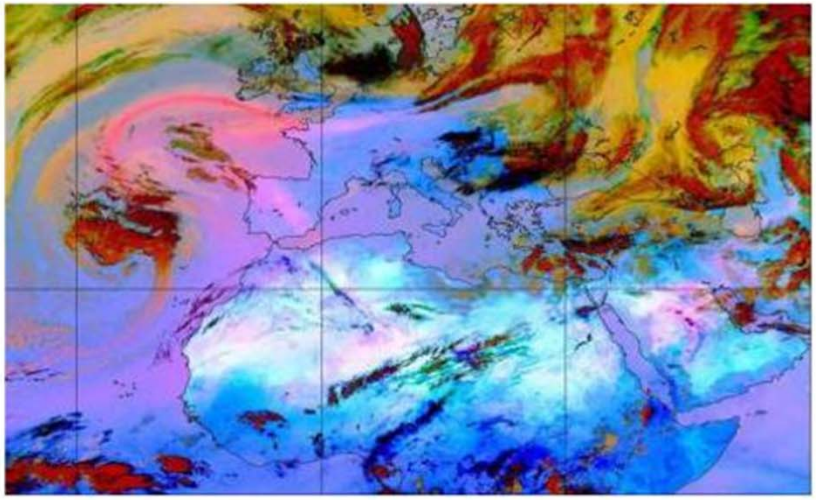
# Dust in the UM global NWP model

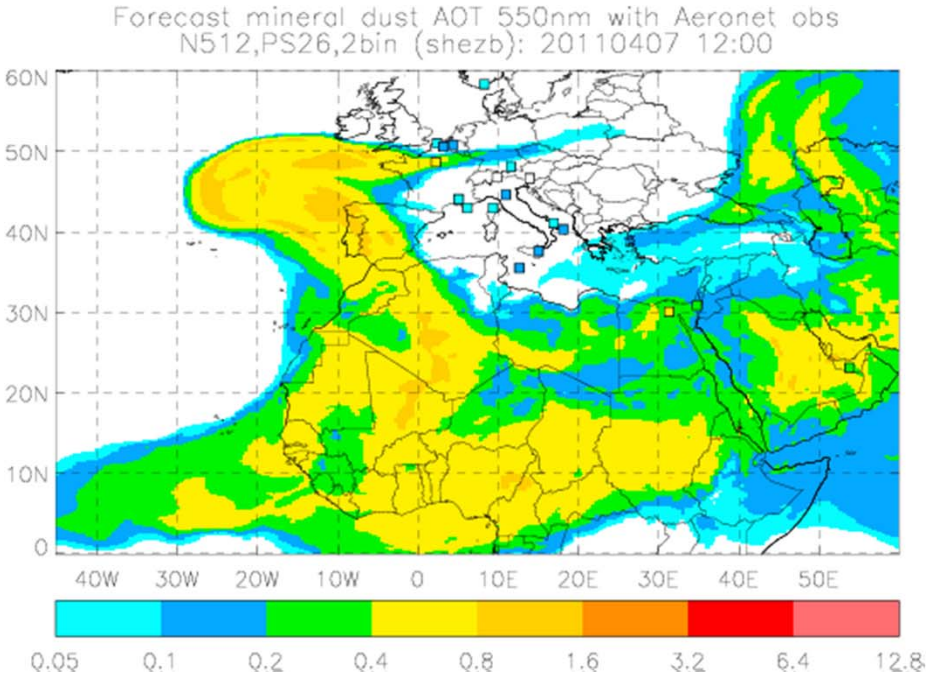
- Operational global dust forecasts out to 6 days are available from the Met Office global NWP model since July 2011 .
- Dust scheme is a simplified 2-bin version (0.1-2μm, 2-10μm) of the Woodward (2001,2011) scheme currently used in the HadGEM climate model.
- Current operational horizontal resolution is 25km, 70 vertical levels.
- Undergoes advection & deposition but is currently not interacting with radiation (comes from dust climatology)
- Operational data assimilation of dust observations expected in 2013.

# Global model dust in UM



# Global model dust in UM
## April 2011 Case Study





Met Office

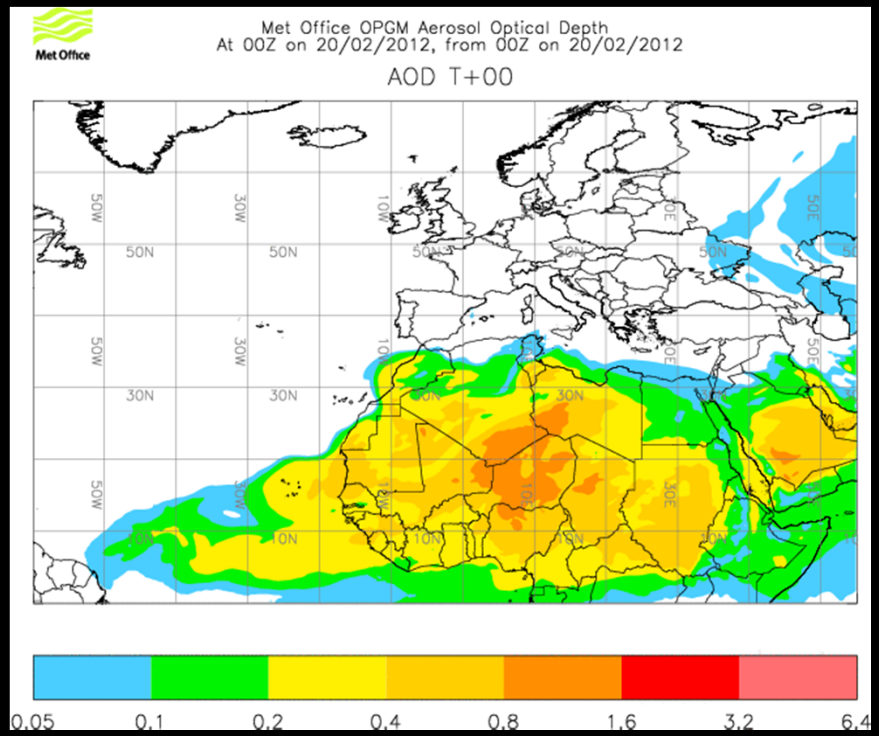
World Meteorological Organization

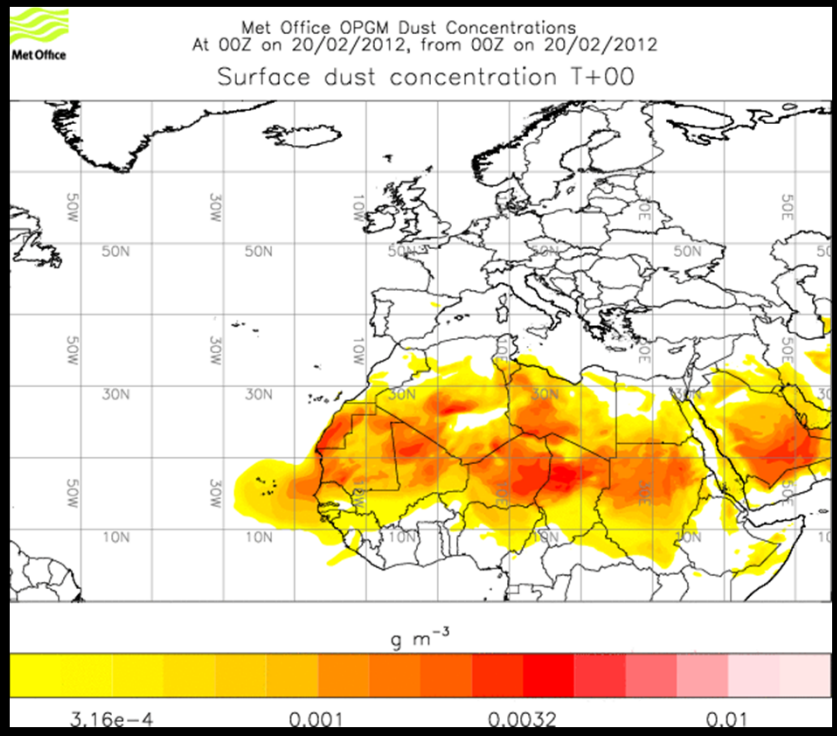
# NORTHERN AFRICA-MIDDLE EAST-EUROPE (NA-ME-E) REGIONAL CENTER

*WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS)*

WMO SDS WAS || Asia Regional Center

http://sds-was.aemet.es/forecast-products/dust-forecasts/index_html/u.k.-met-office





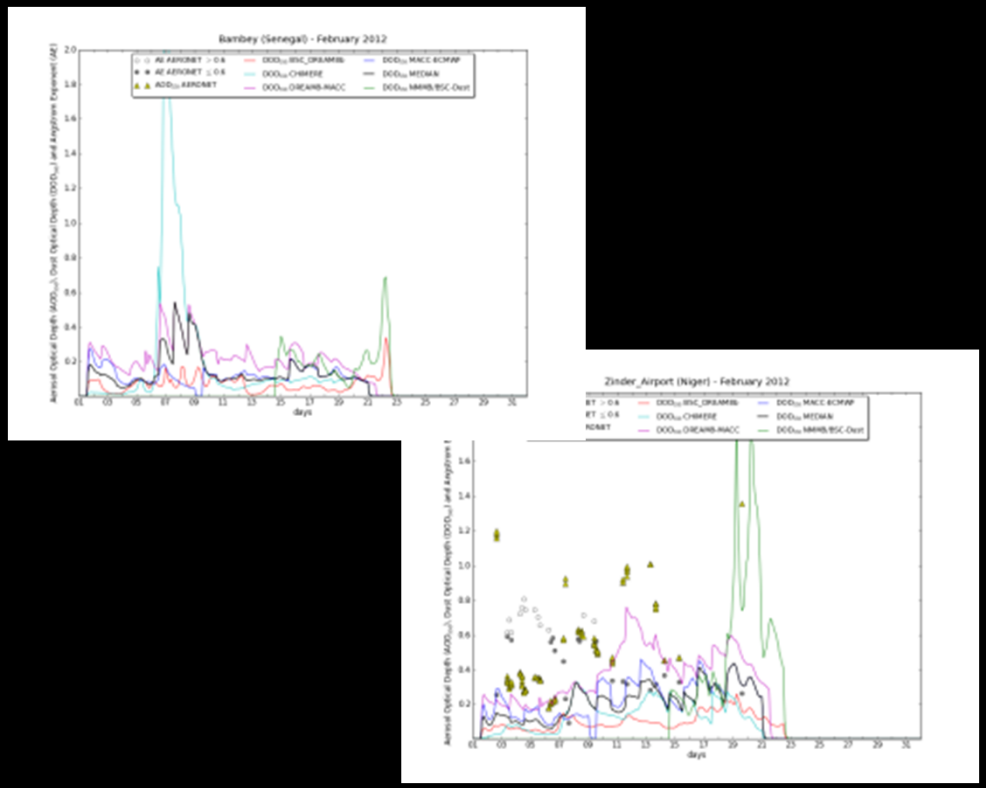

macc Monitoring atmospheric composition & climate

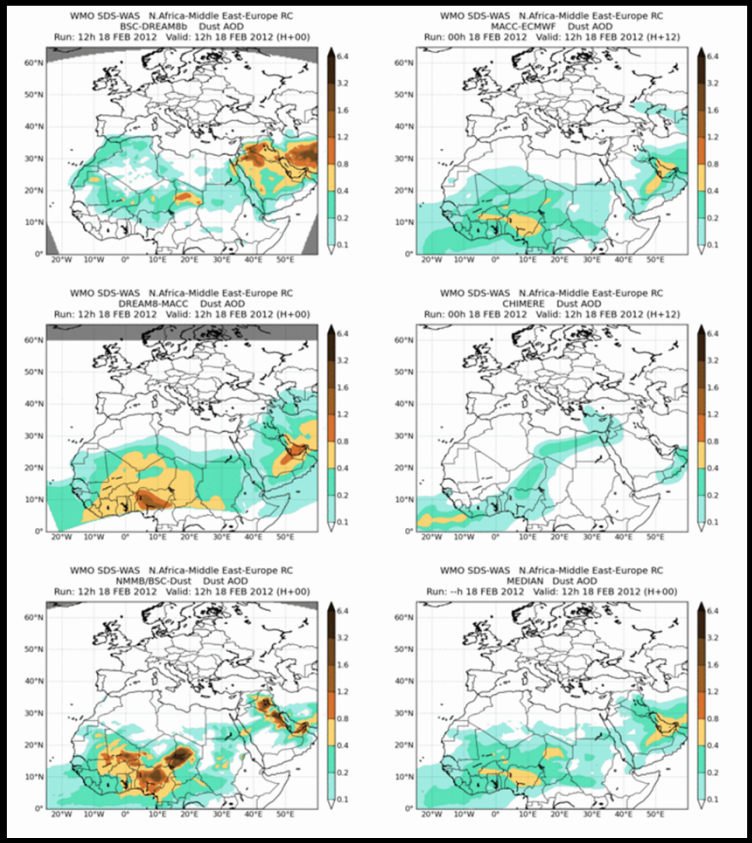
GMES

# WMO SDS-WAS (II)

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

- Participation in the routine evaluation and specific event model intercomparison with other SDS-WAS partners (including MACC dust forecasts)



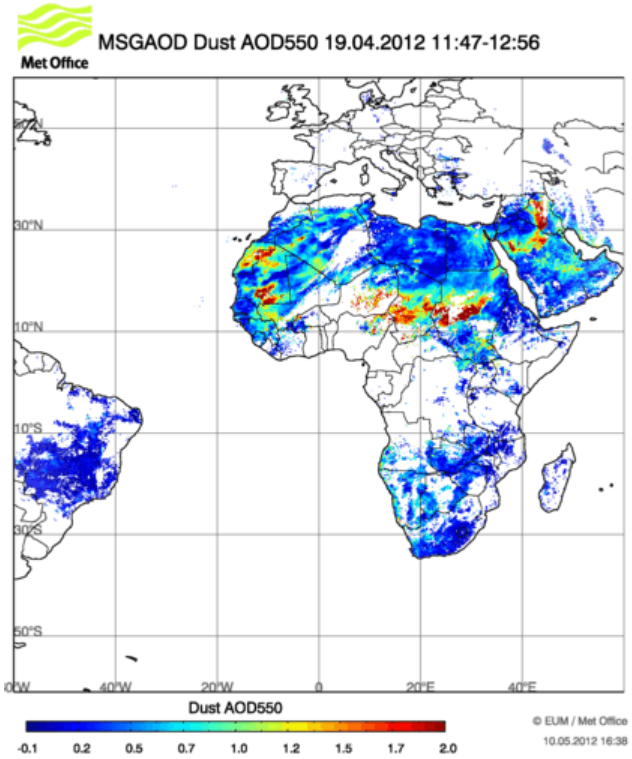
# Dust Data Assimilation Developments

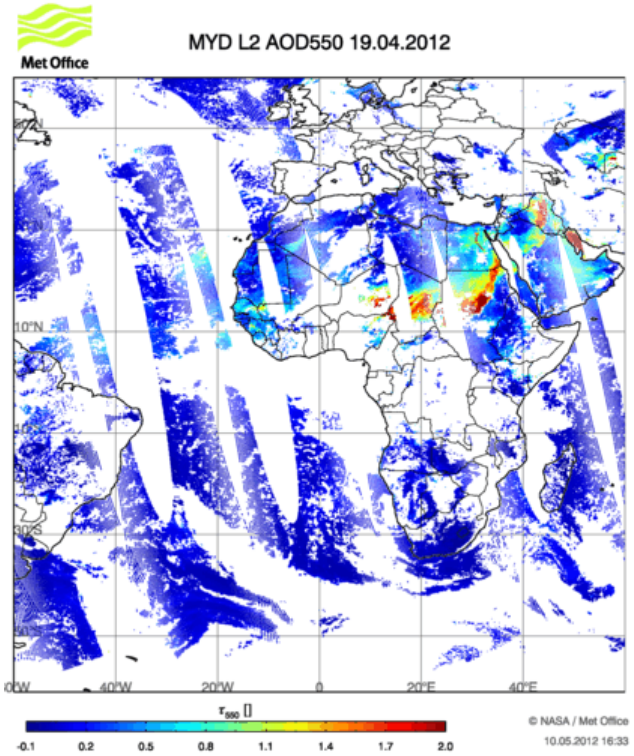
Bruce Ingleby, Yaswant Pradhan

# Recent progress

- **2009:** limited area 3D-Var version, short test with SEVIRI AOD
- **2011/12:** global 4D-Var version
  - code more generic/robust, MODIS processing added, minor improvements to AOD observation operator
  - forecast has two size bins, analysis uses total dust
  - new background error covariance statistics
- **2013** operational implementation of global 4D-Var planned

# Observations




SEVIRI retrieval:

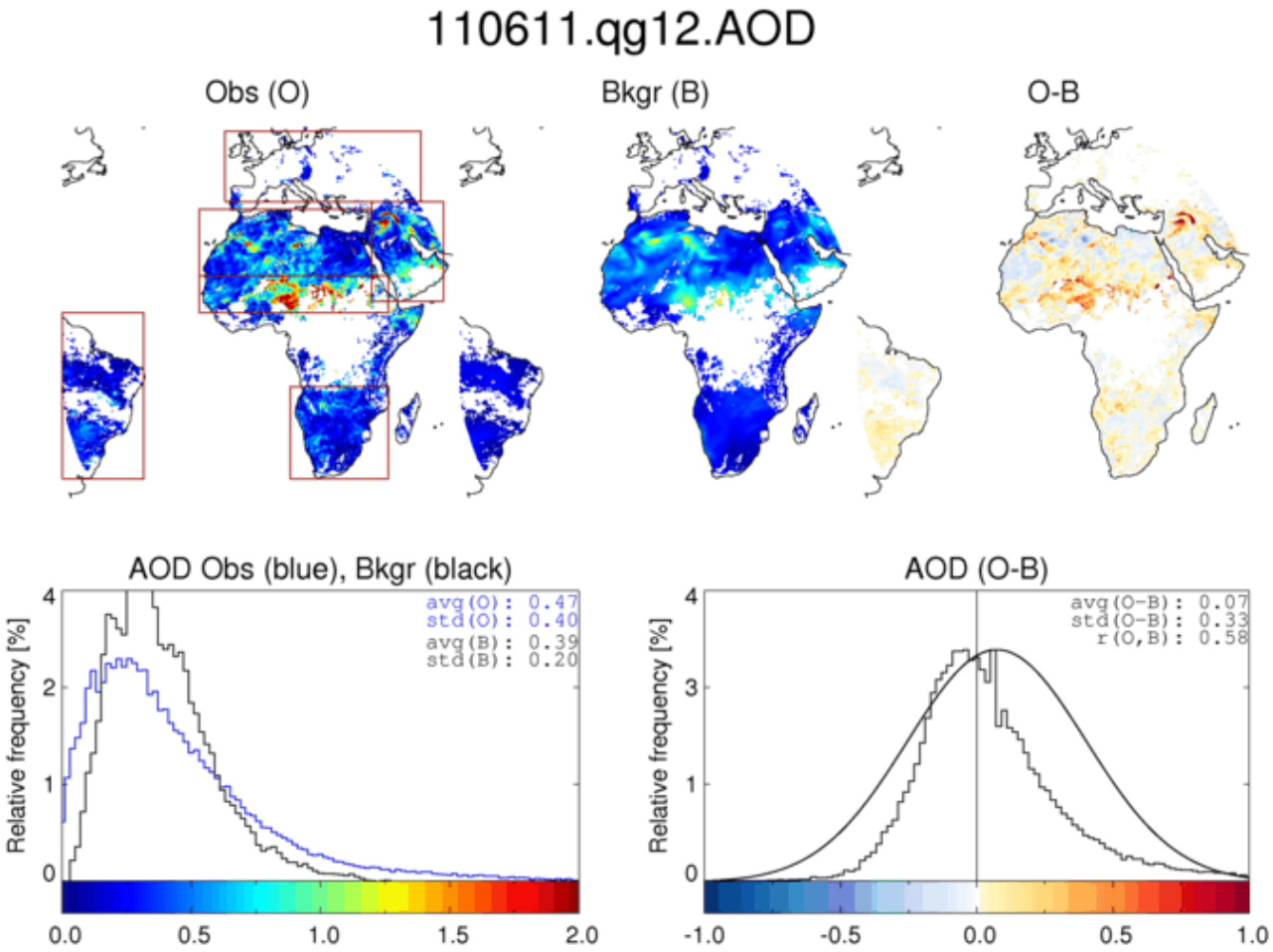
- Uses IR retrieval method (*Pradhan and Saunders, 2009; Brindley and Ignatov, 2006*)
- Accuracy degrades over non-arid surface, twilight period, night
- Observation error = 0.37

MODIS:

- merged standard AOD + “Deep Blue” algorithms

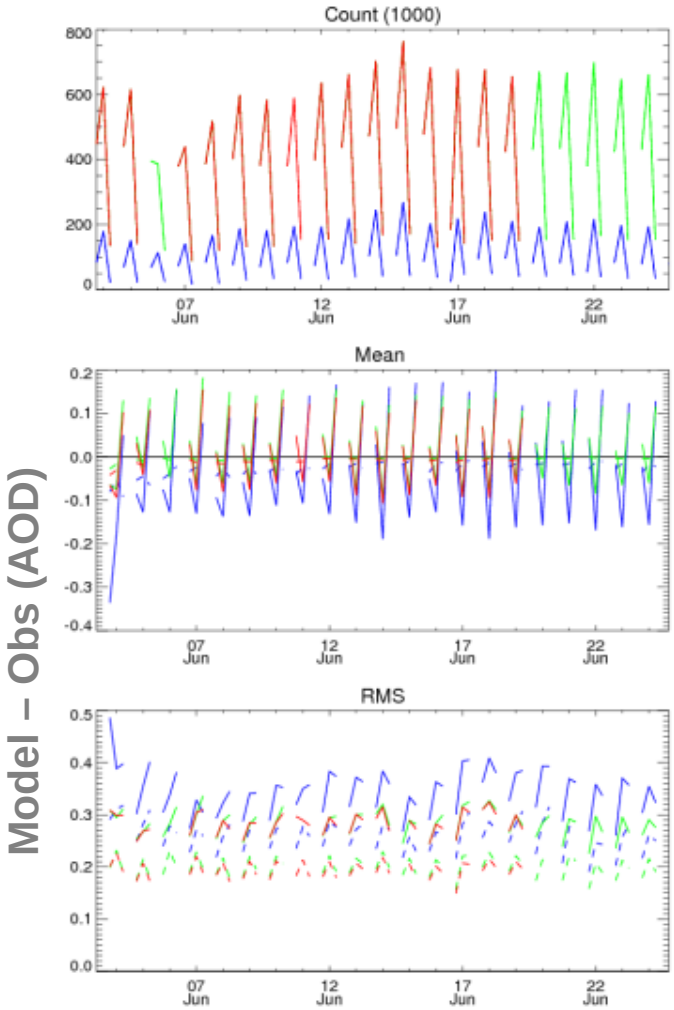
# Assimilation of SEVIRI AOD

## O-B Stats



# Assimilation of SEVIRI AOD

## Preliminary results

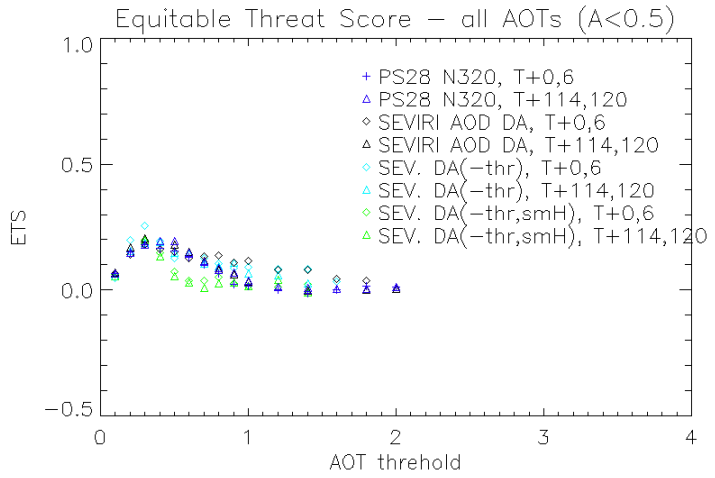



### Tuning different components

- **0.5 AOD threshold**
- **0.5 threshold removed**
- **0.5 threshold removed + smaller horizontal scale**

**Solid – Background**

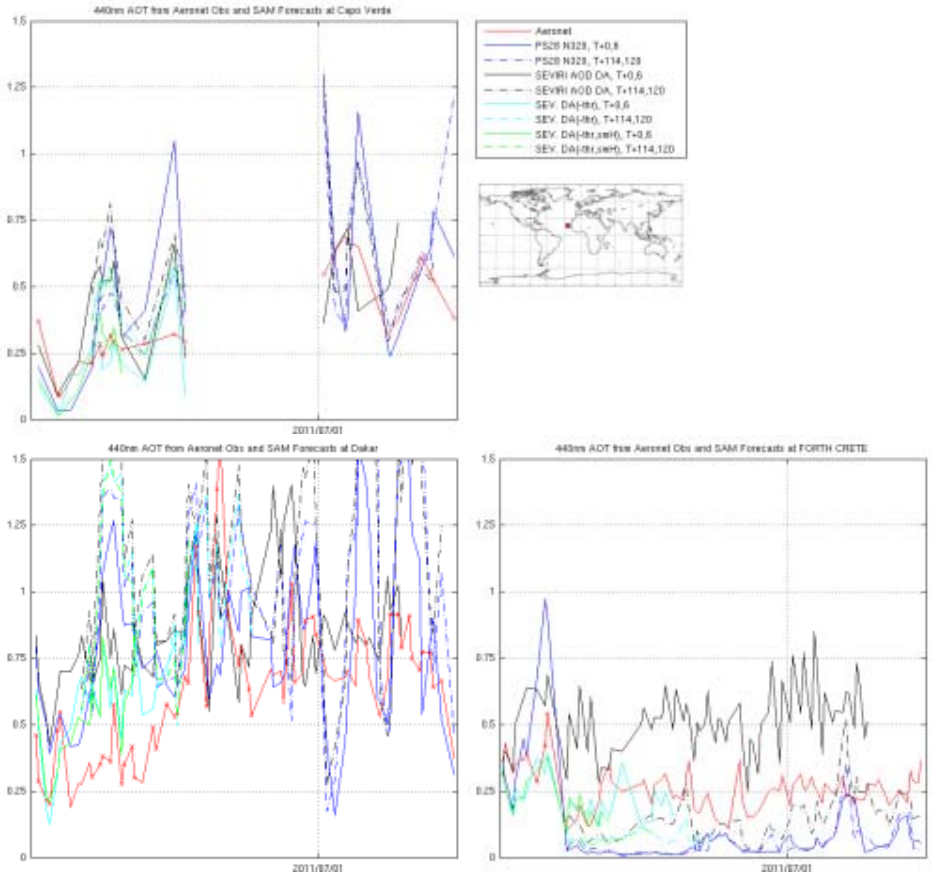
**Dash – Analysis**

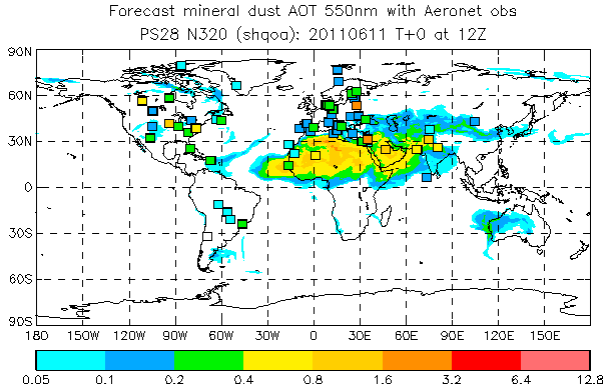


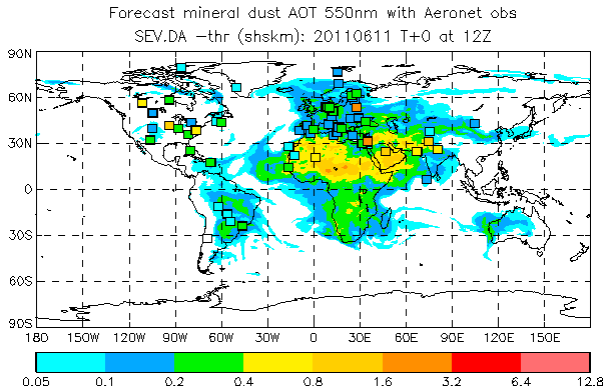

Looking at dust only events:
General incr. in skill at most AOD thresholds

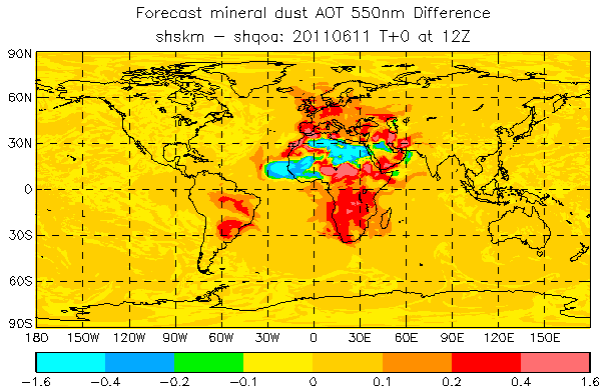
# Assimilation of SEVIRI AOD

## Comparison against AERONET



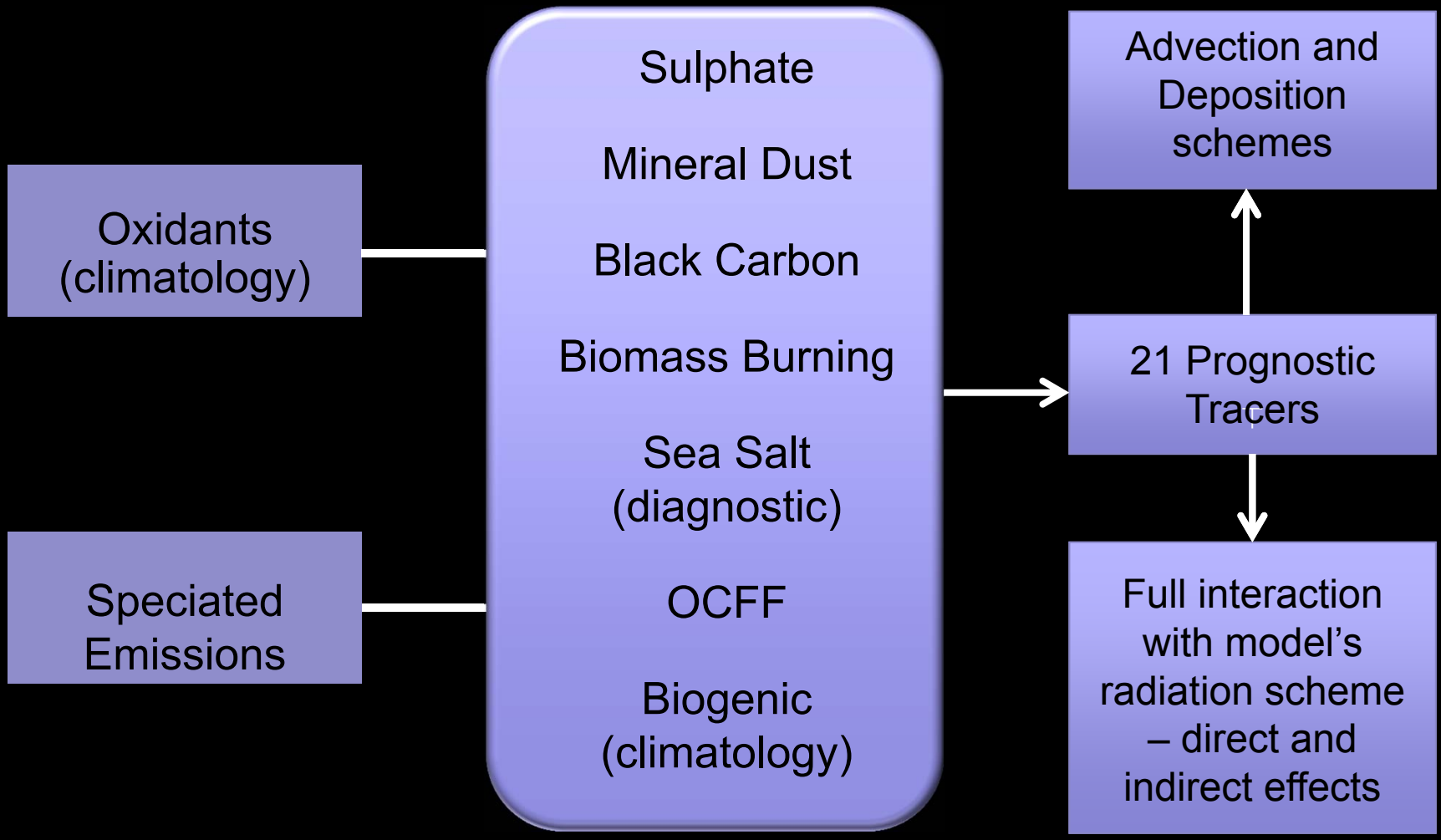



# Impact of fully prognostic aerosol in NWP forecasts

# CLASSIC Aerosol Scheme

Bellouin et al. (2011)



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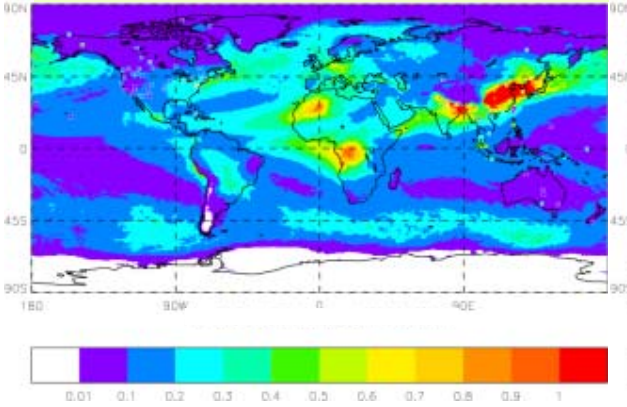
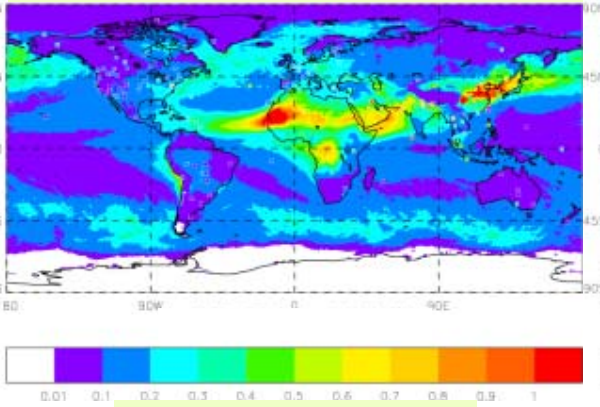
# CLASSIC aerosol simulations

## Jun/Jul 2009 N320L70 global NWP AOD

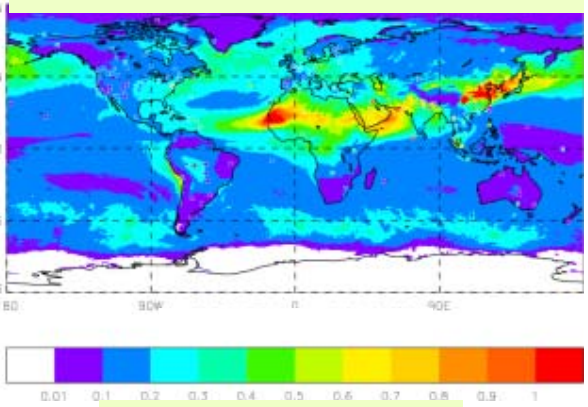
**Aerosol Climatology**



**CLASSIC Aerosol**

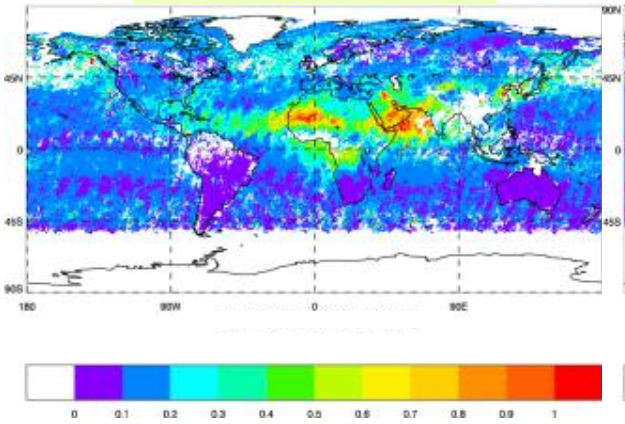


**INIT (GEMS) CLASSIC aerosol**

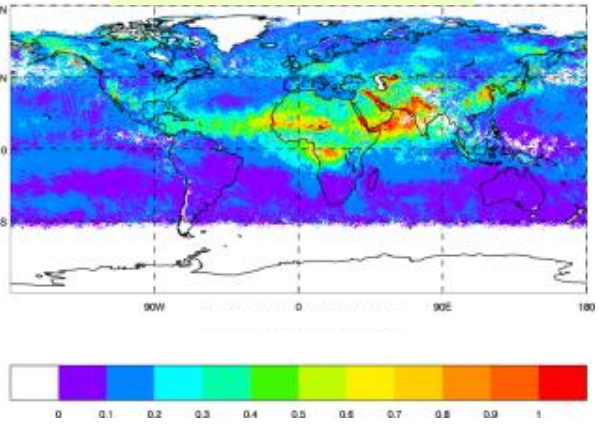


| Global Mean AOD | |
|---|---|
| Climatology: | 0.181 |
| CLASSIC: | 0.175 |
| INIT CLASSIC: | 0.197 |
| MISR: | 0.189 |
| MODIS: | 0.186 |

**MISR (555nm)**



**MODIS (550nm)**

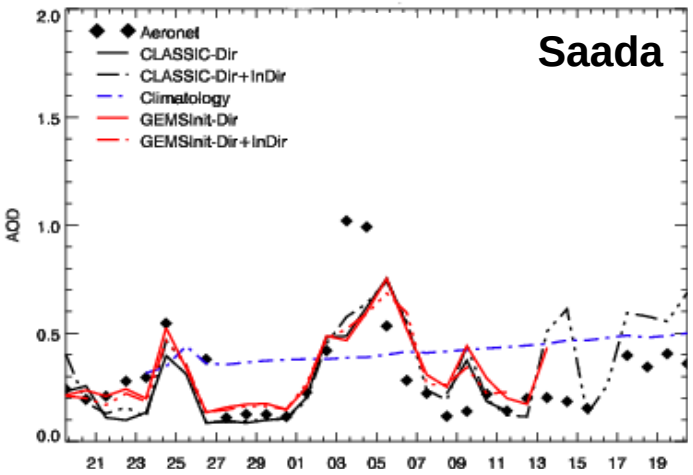


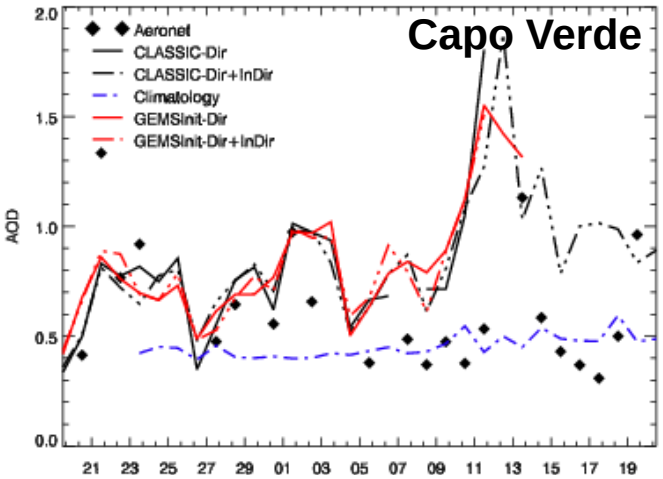
# AERONET Comparisons

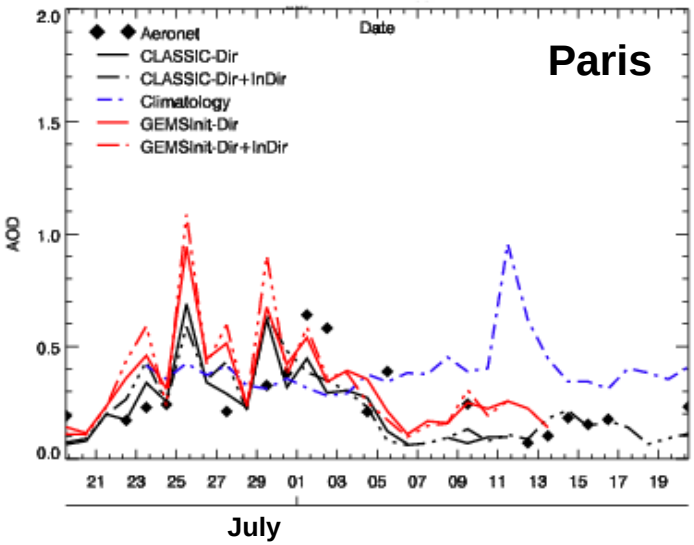
## Jun/Jul 2009 AOD (440nm) T+120

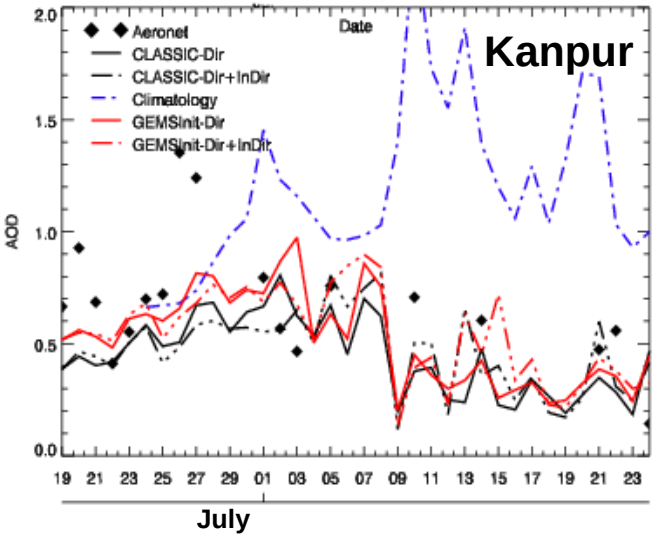
**Dust aerosol**

**Anthropogenic aerosol**



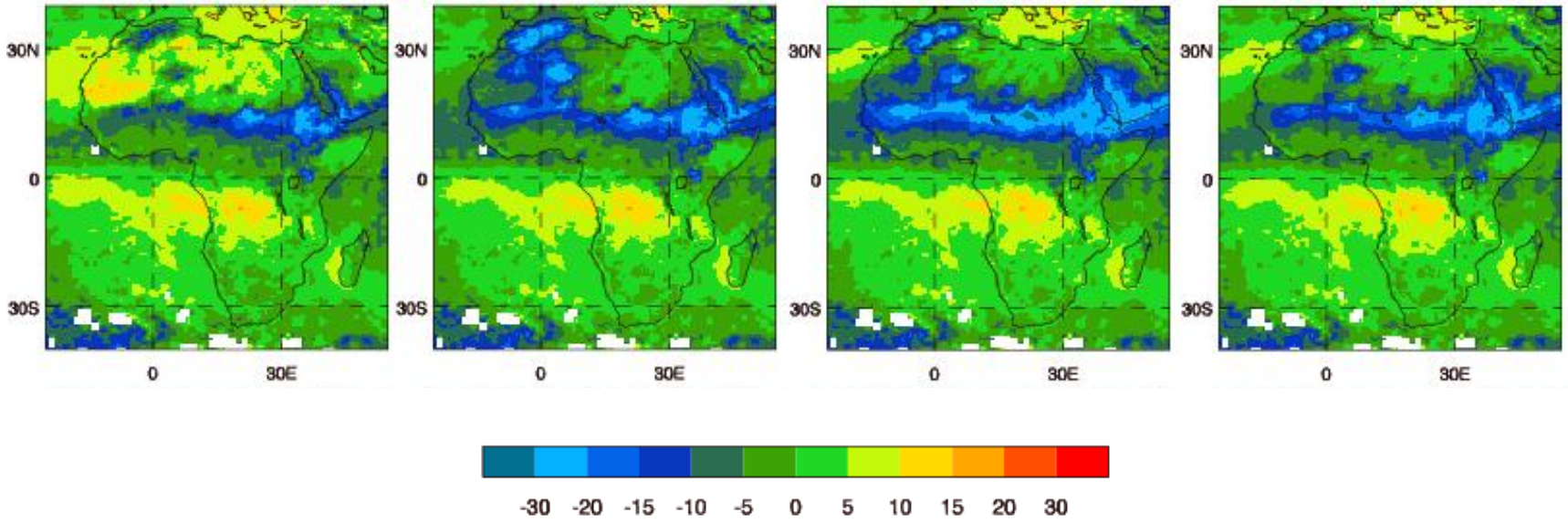



# Impact on radiation (I)

## Clear-sky OLR

| Control Error | Climatology Error | CLASSIC Aerosol Error | INIT CLASSIC Error |
|---|---|---|---|




Error is calculated relative to FLASHFlux Observations derived from CERES.



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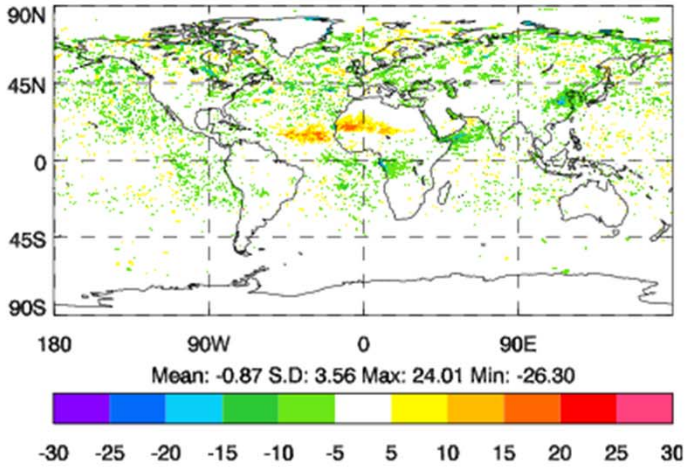
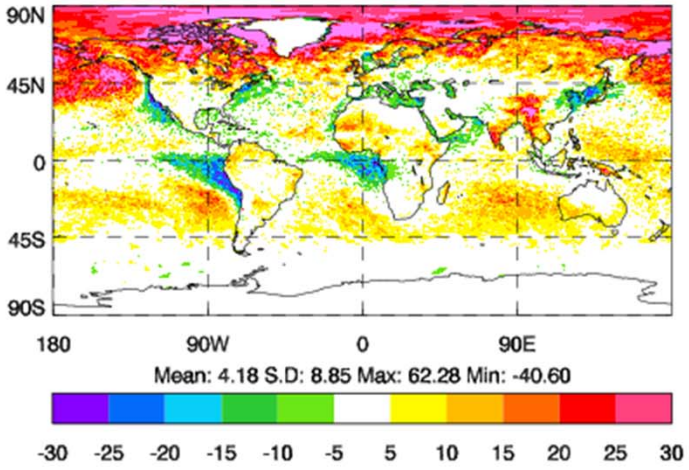
# Impacts on radiation (II)

Jun/Jul 2009 T+120

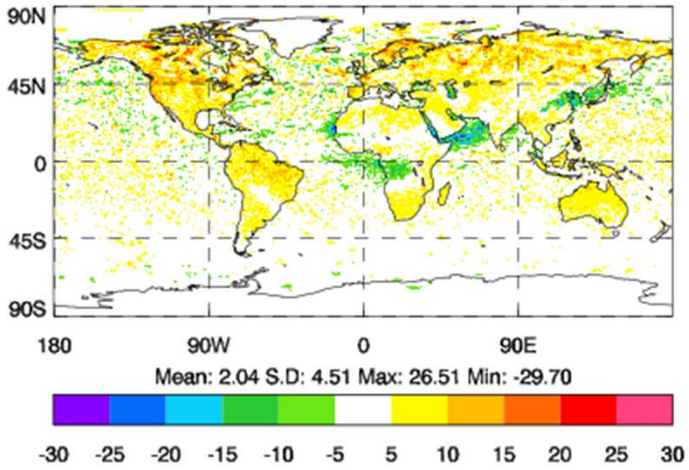
**Direct Effect** | **Direct & Indirect Effect**

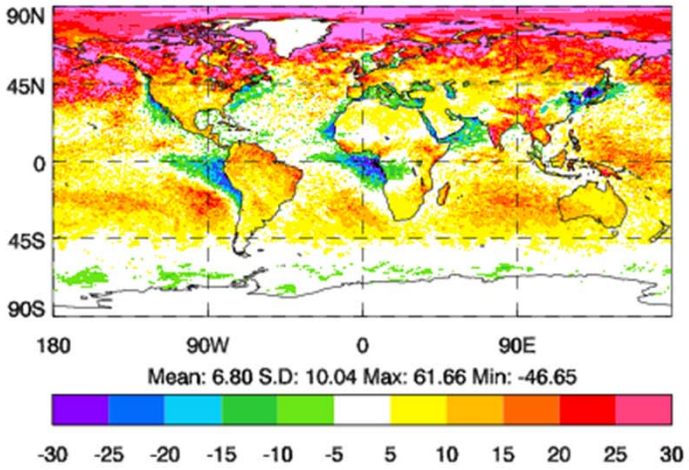
**TOA Net Radiation**




**Surface Net Radiation**



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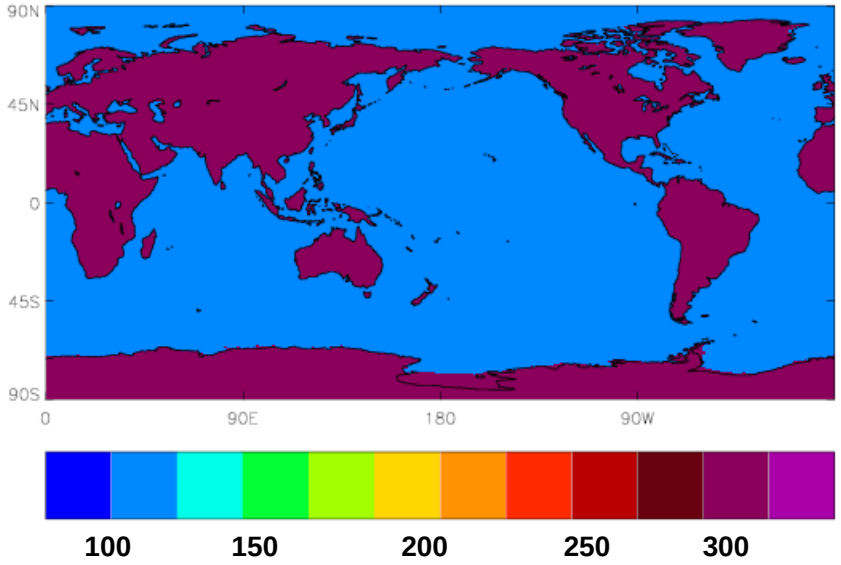
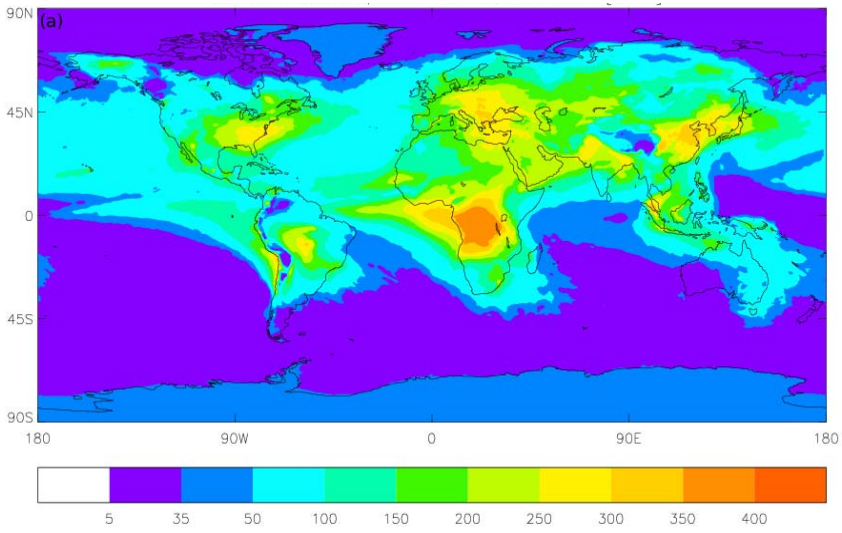
# Cloud droplet number

## Aerosol direct & indirect effects

**Operational Values**




**CLASSIC Aerosol**




Fixed values:
Land: 300 $cm^{-3}$
Ocean: 100 $cm^{-3}$

More realistic distribution of CDNC – much lower values (cleaner air) at high latitudes



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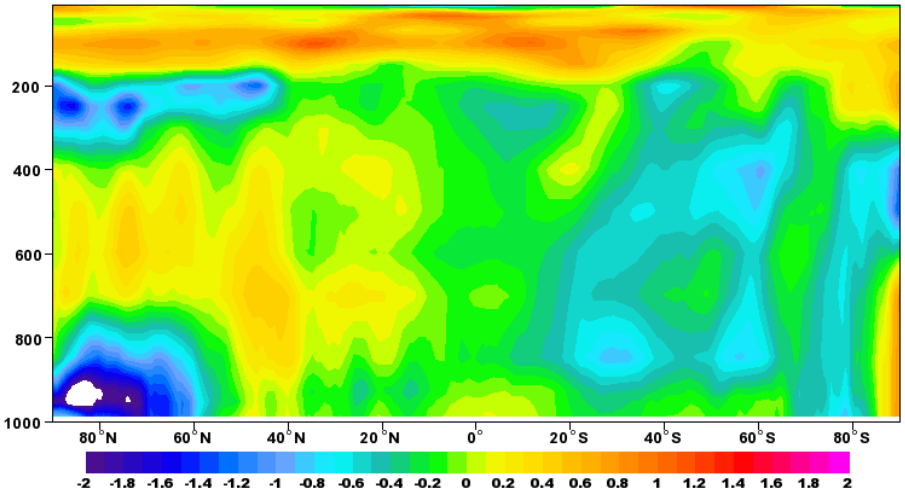
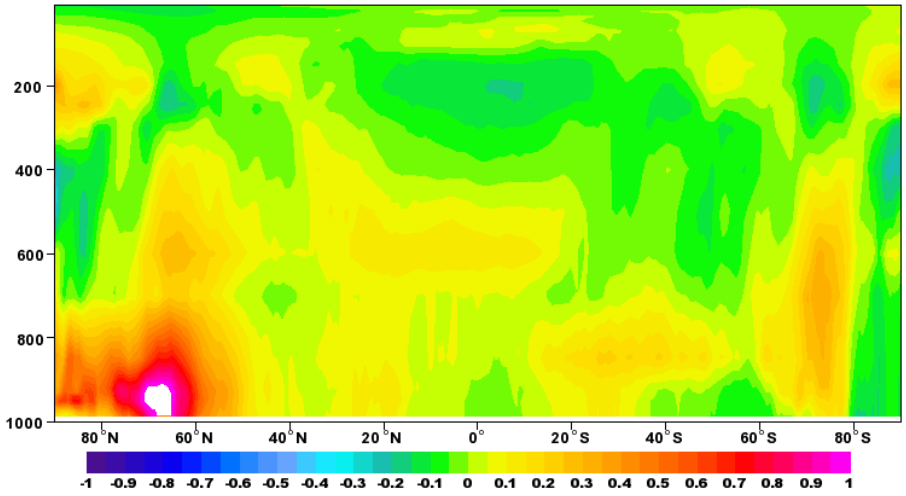
# Zonal Temperature T+120

Jun/Jul 2009




**Control Error (No aerosol)**




**CLASSIC Aerosol – CNTRL**

**Improvement in NH cold bias and in some regions of SH**

# Impact on monsoon flow

850hPa Winds

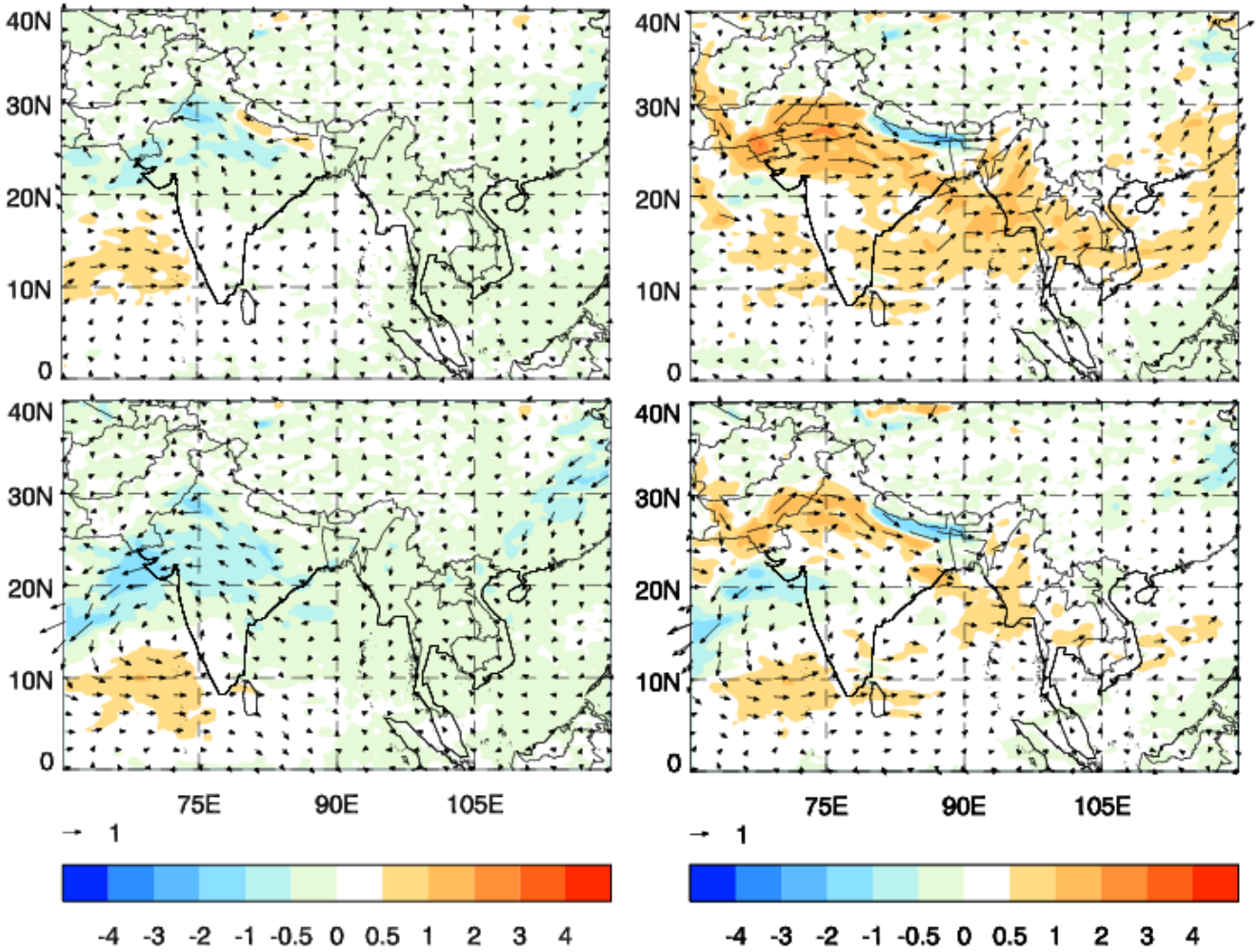
**All figures show Expt - Cntrl**

**Direct Effect**

**Direct & Indirect Effect**

**Initialised Direct Effect**

**Initialised Direct & Indirect Effect**



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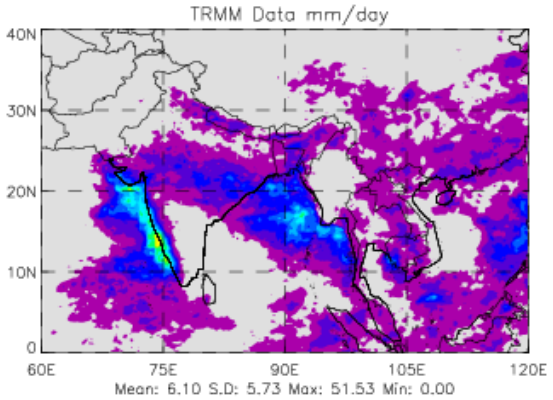
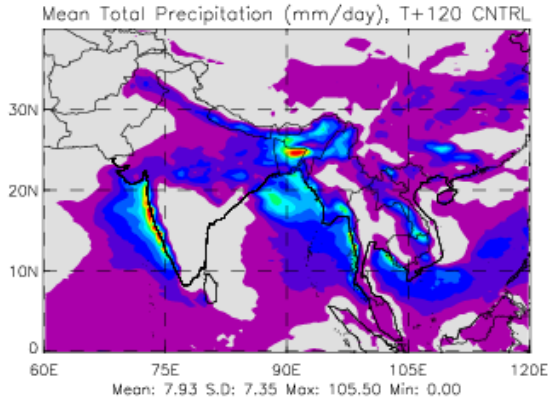
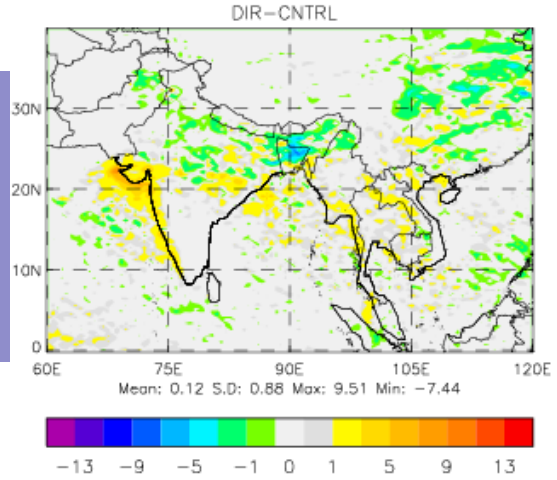
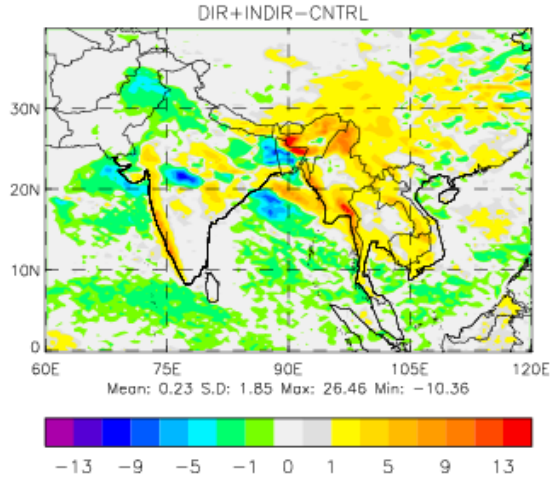
# Impact on total precipitation,

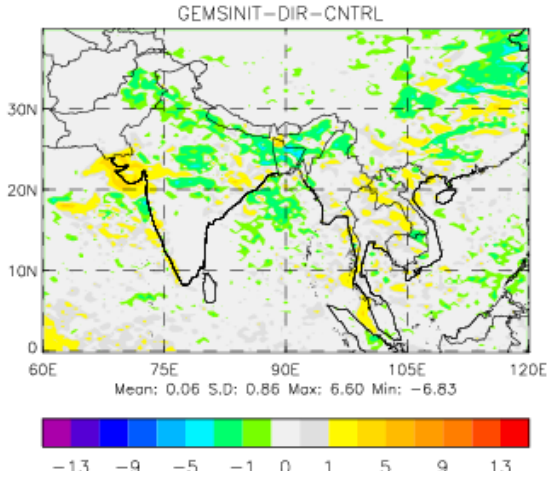
# T+120

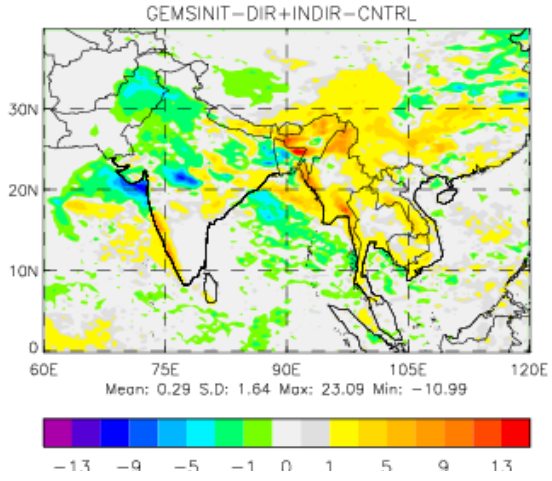


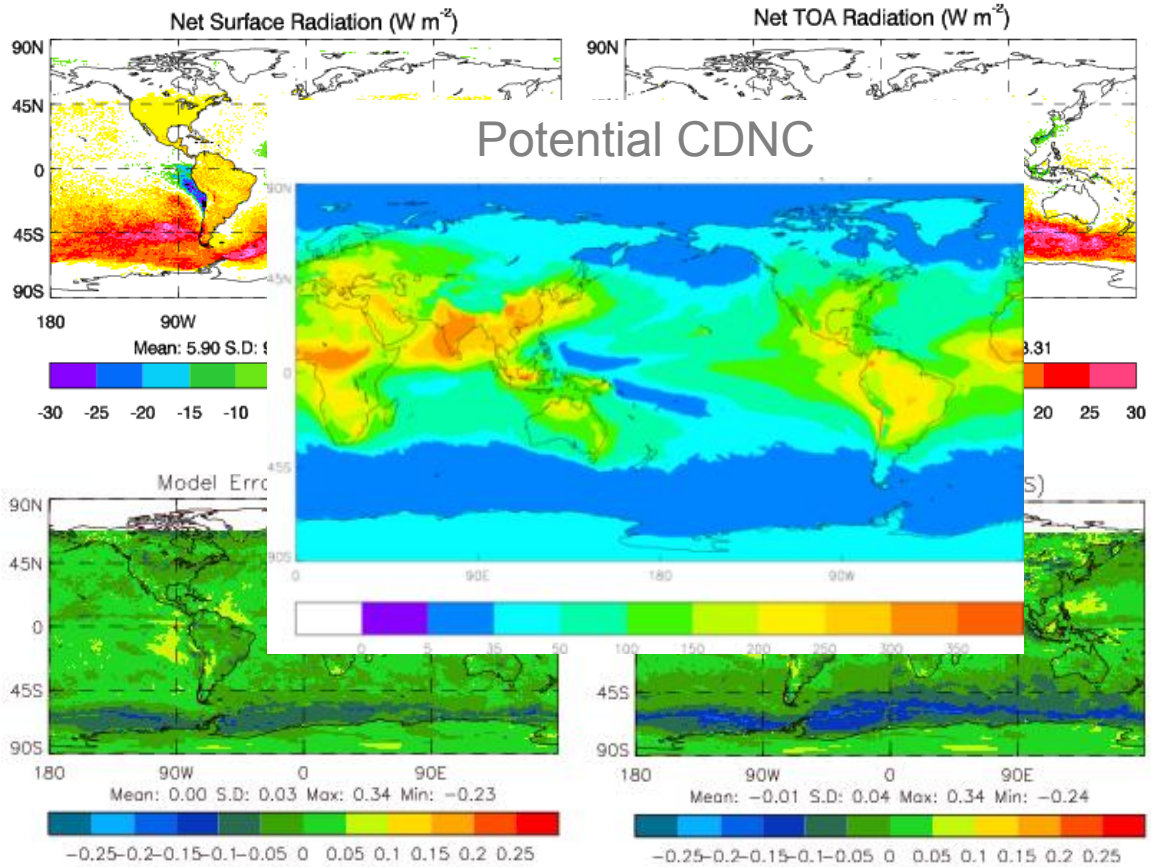



# Impact of aerosol on SO bias

## VOCALS: Oct/Nov 2008

- Significant warming found in the SO
- Increases in bias compared with CERES
- Linked to significant reduction in low level cloud – minimum CDNC values
- Currently evaluating role of sea salt and DMS in this region

**Expt (aerosol) – Cntrl (no aerosol)**




**CNTRL Albedo Error**

**Expt Albedo Error**



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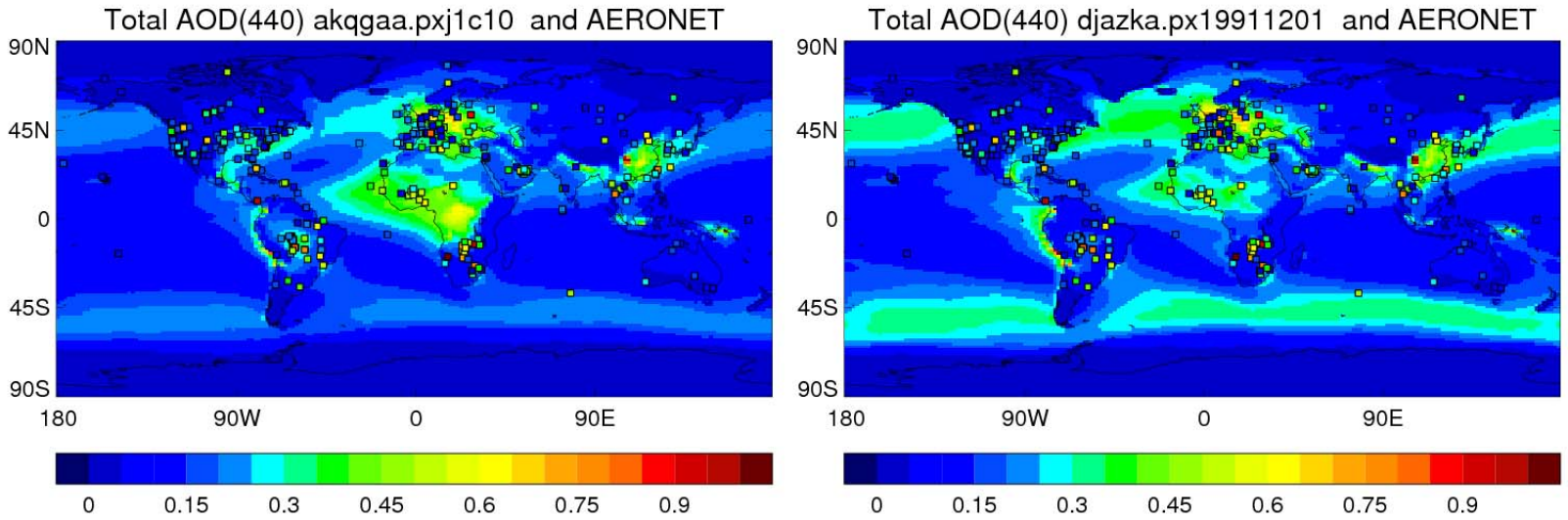
# Sensitivity of aerosol deposition schemes to model changes

# Aerosol deposition sensitivity

Latest climate model upgrade was found to have significant impact on CLASSIC aerosol




Among the land surface changes included in the upgrade is a particularly large increase in the heat to momentum roughness length ratios (z0H/z0M) for both BL and NL trees from 0.1 to 1.65 (observational finding).



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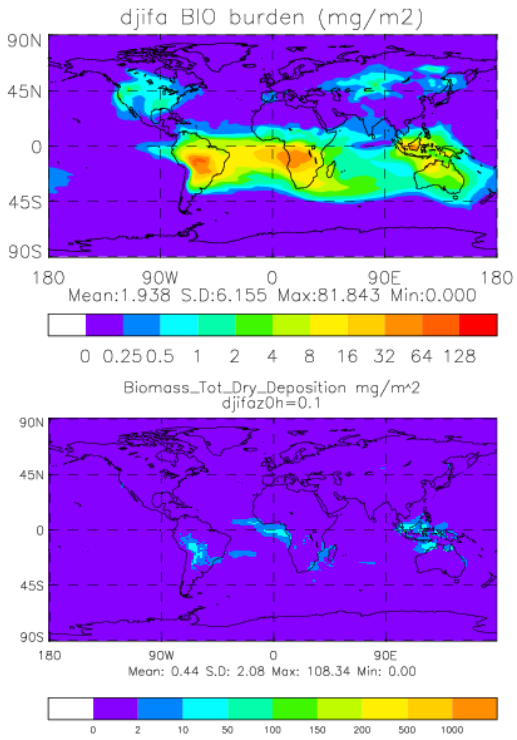
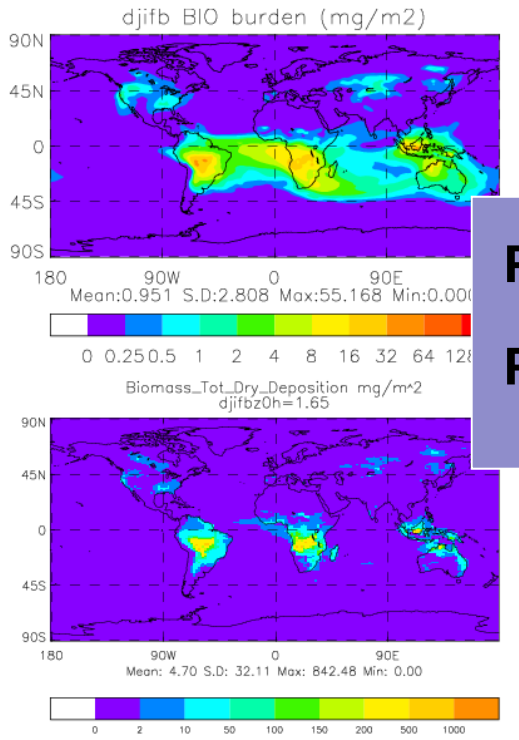
# Aerosol deposition sensitivity

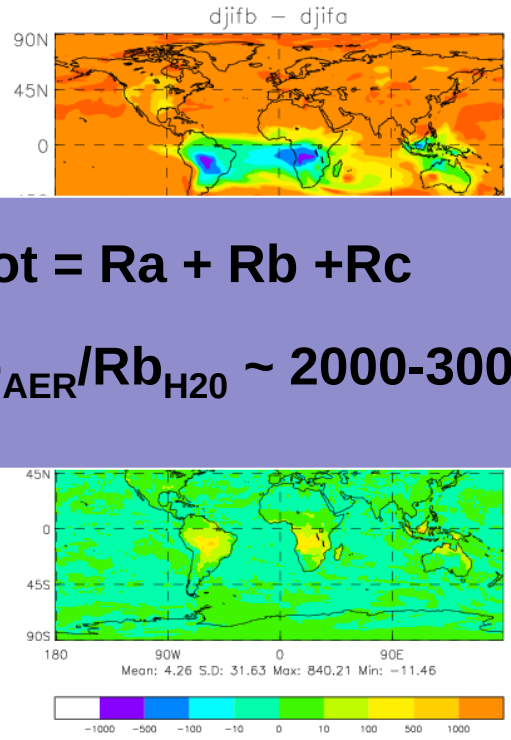
Predominant impact on biomass burning aerosol

**z0h/z0m=0.1**




**z0h/z0m=1.65**




**Rtot = Ra + Rb +Rc**

**$Rb_{AER}/Rb_{H20}$ ~ 2000-3000!**

Aerosol load reductions of approx 50%, 24%, 19%, 13%, and 0.06% were found for biomass, ocff, ffbc (soot), sulphate and dust respectively, dominated by an increase in the total dry deposition



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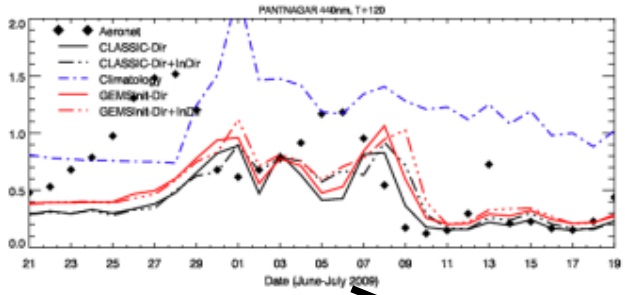
# Conclusions

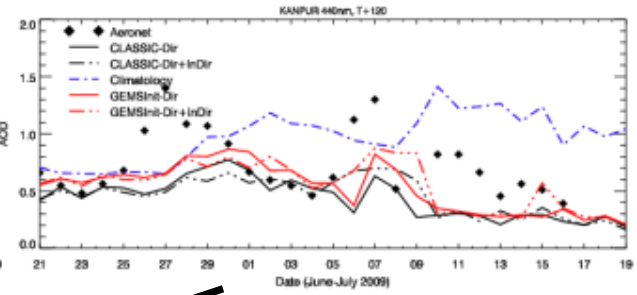
- New air quality index has led to significant increase in number of exceedances increasing of air quality modelling in the UK.
- AQUM now online model, 5 day forecasts – moving to full UKCA-mode in near future
- Dust now operational in global NWP model - verifying well against observations.
- Further dust developments under way during MACC II project
- Dust DA also progressing with additional observations; move from LAM 3D to global 4D VAR data assimilation. Planned implementation in 2013.
- Direct & indirect impacts of prognostic aerosol in NWP forecasts highlight importance of improved representation at these timescales

# Questions and answers

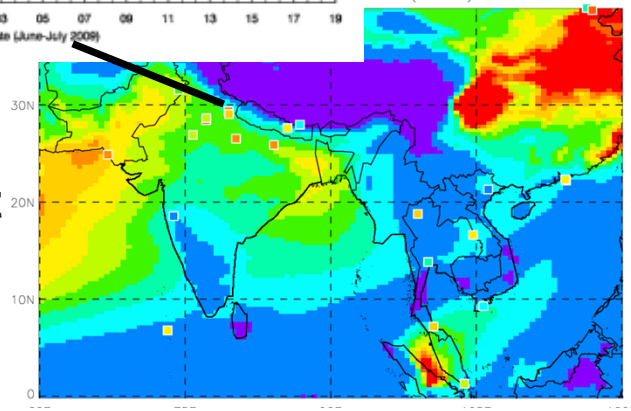
# sia during r

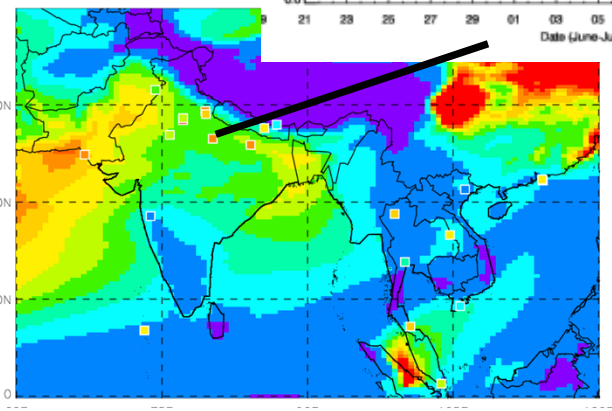
m 21st June – 20th J



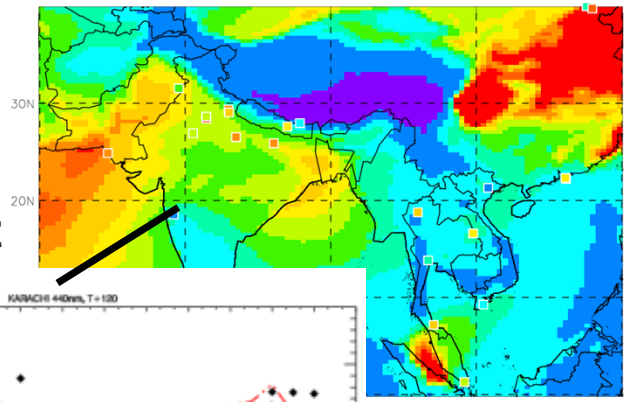

**Direct Effect**

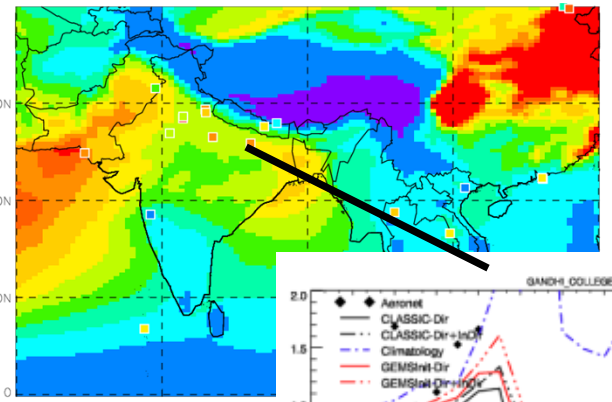


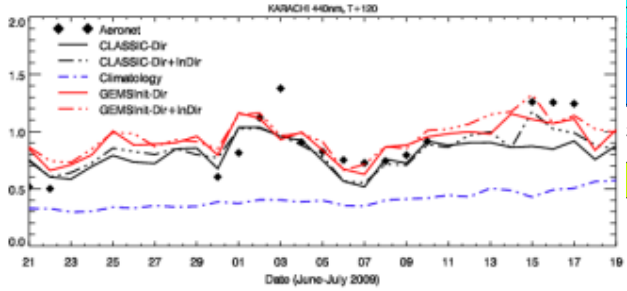

**Direct & Indirect Effect**

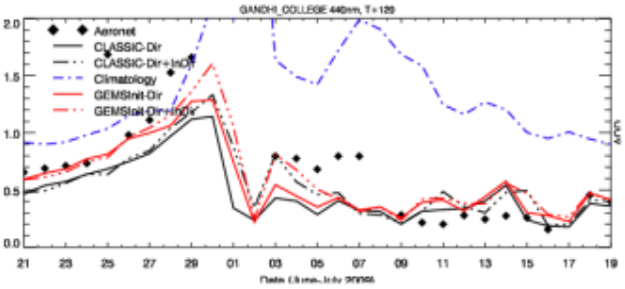
**Initialised Direct Effect**




**Initialised Direct & Indirect**



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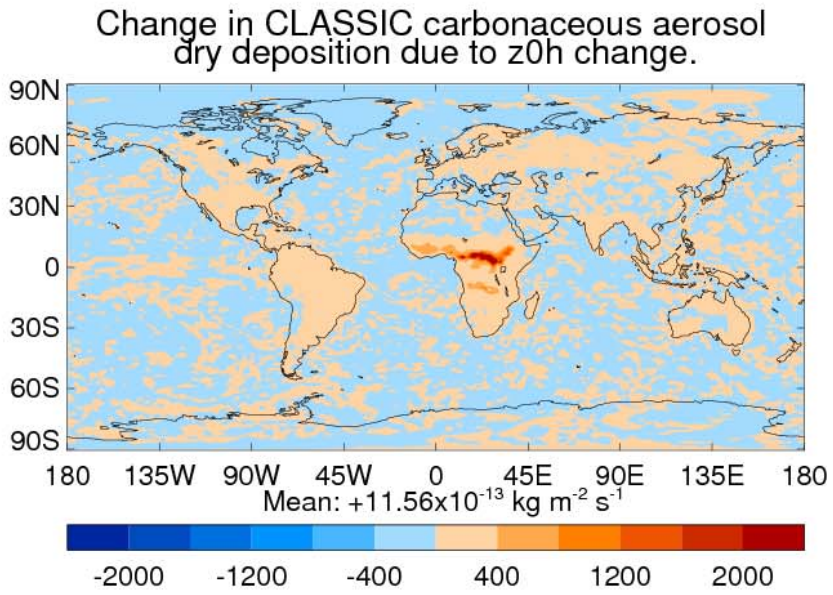
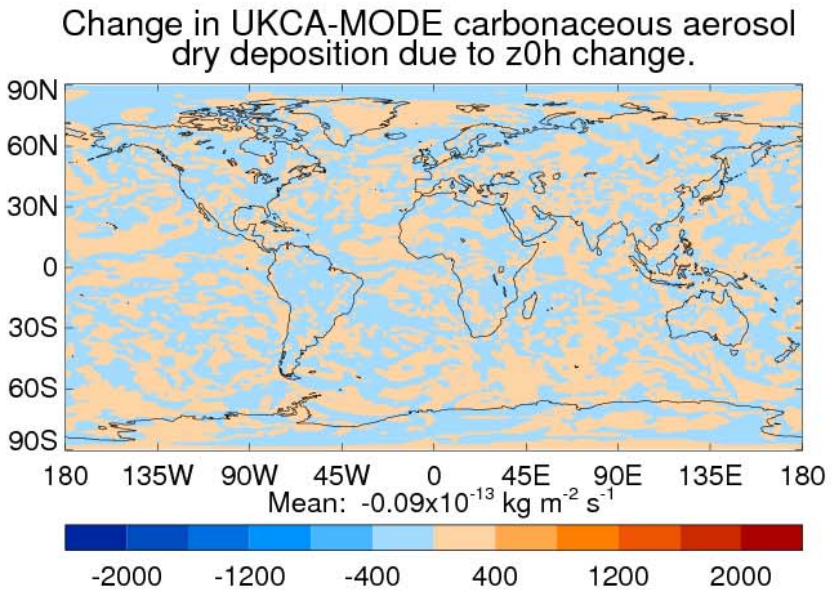
# Aerosol deposition sensitivity

## CLASSIC vs. UKCA-MODE



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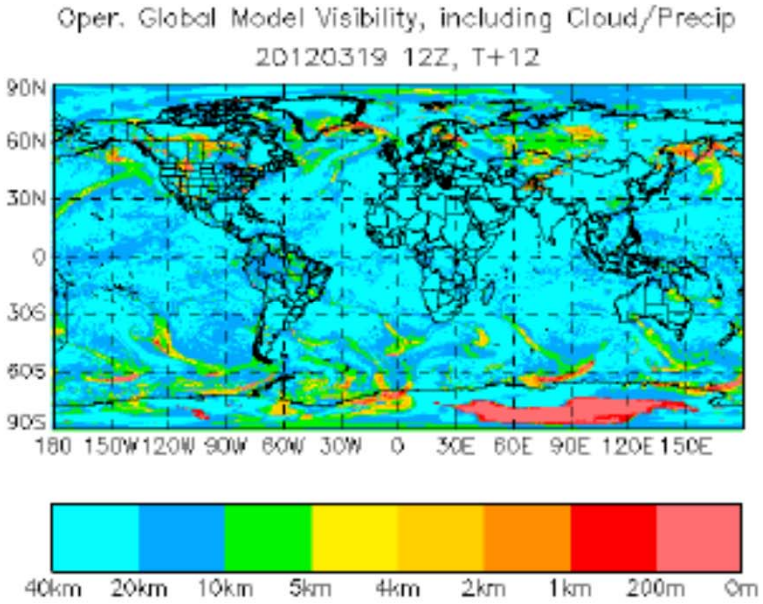
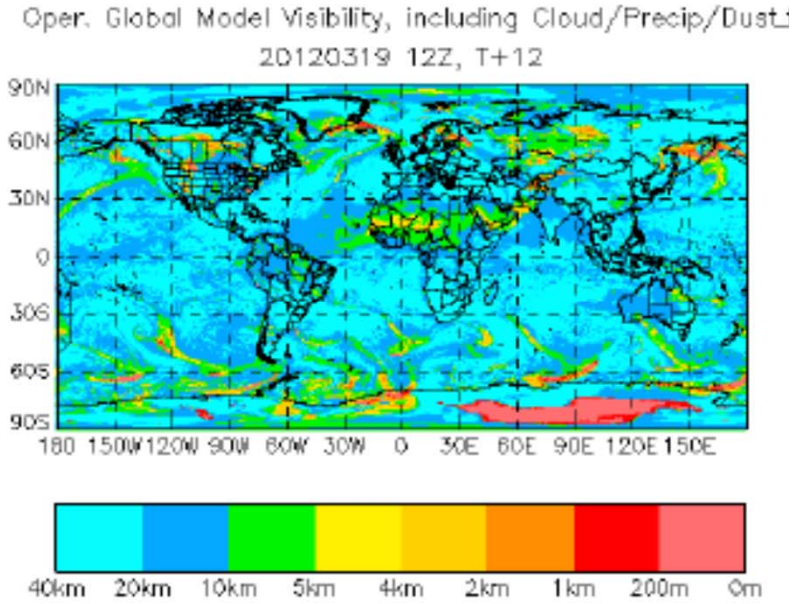
# Dust Model Developments

Malcolm Brooks, David Walters

# Visibility diagnostic

## Including the effects of dust



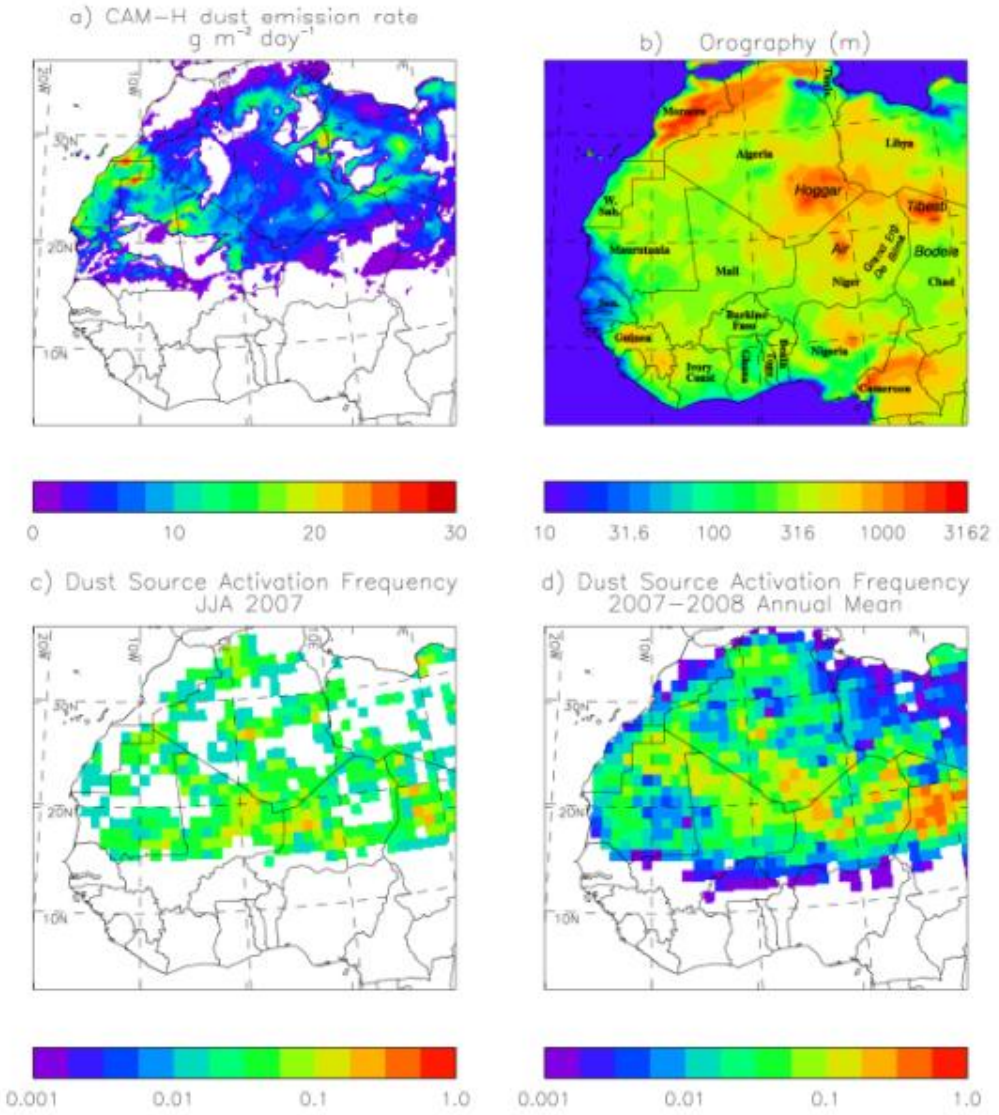



# Underway: Implementation of seasonal vegetation

Malcolm Brooks

Comparison of GERBILCAM emissions with obs:

- During the campaign the N-S dist. of emissions compares well (a vs. c)
- Vegetation in the model makes the N-S dist. constant in the model.
- N-S dist. varies in the obs
- In the real world, dust is emitted where vegetation is seasonal.



# Underway: Implementation of seasonal vegetation

Malcolm Brooks

Use the same bare soil fraction for dust emission that is seen in radiation