Pyrogenic aerosol: current modelling capabilities in the Met Office

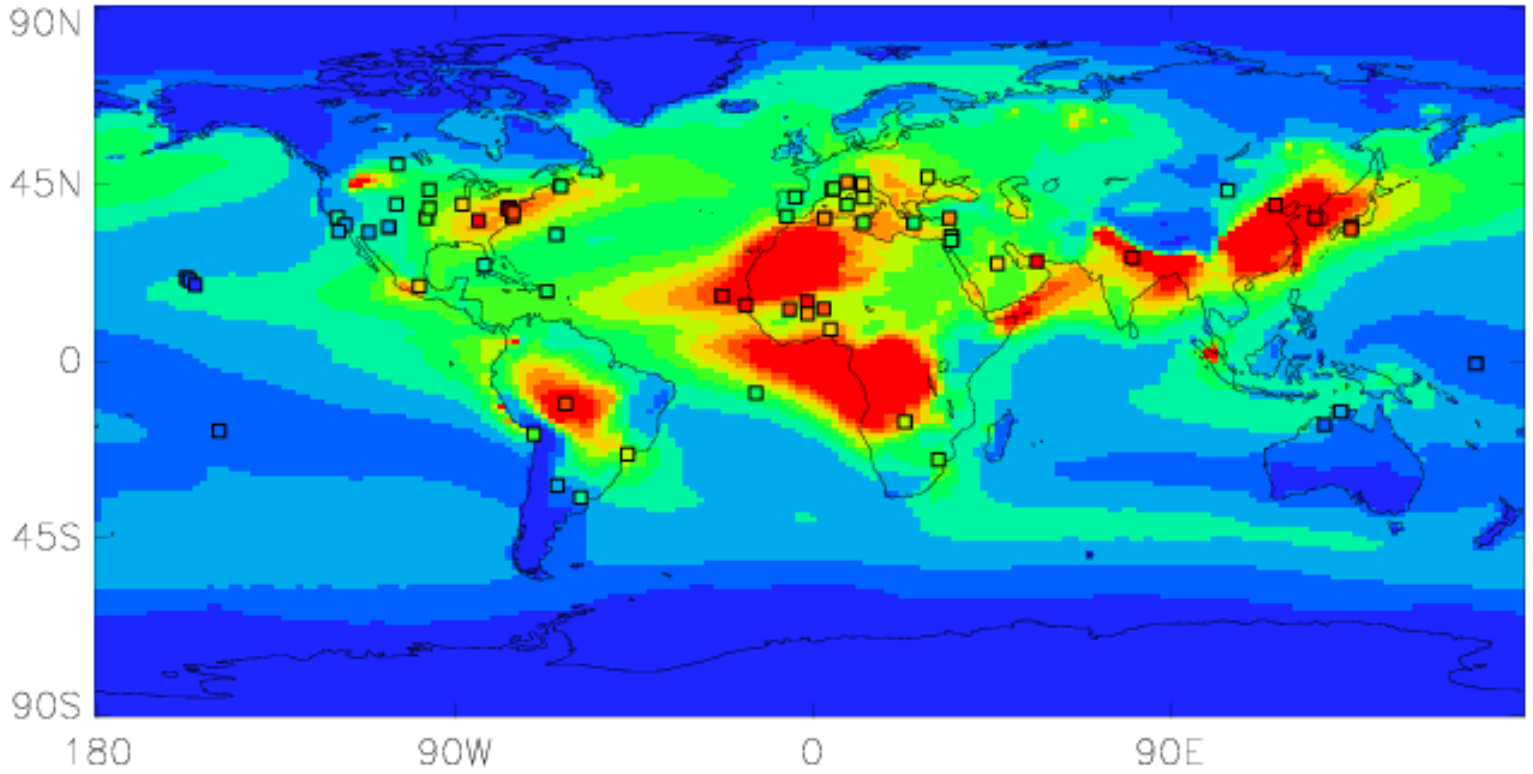
Jim Haywood, Nicolas Bellouin, Andy Jones, Olivier Boucher, Ben Johnson, Simon Osborne:

ESF exploratory workshop, Farnham, Sept 2009.

Current representation of aerosol in the Met Office global models:

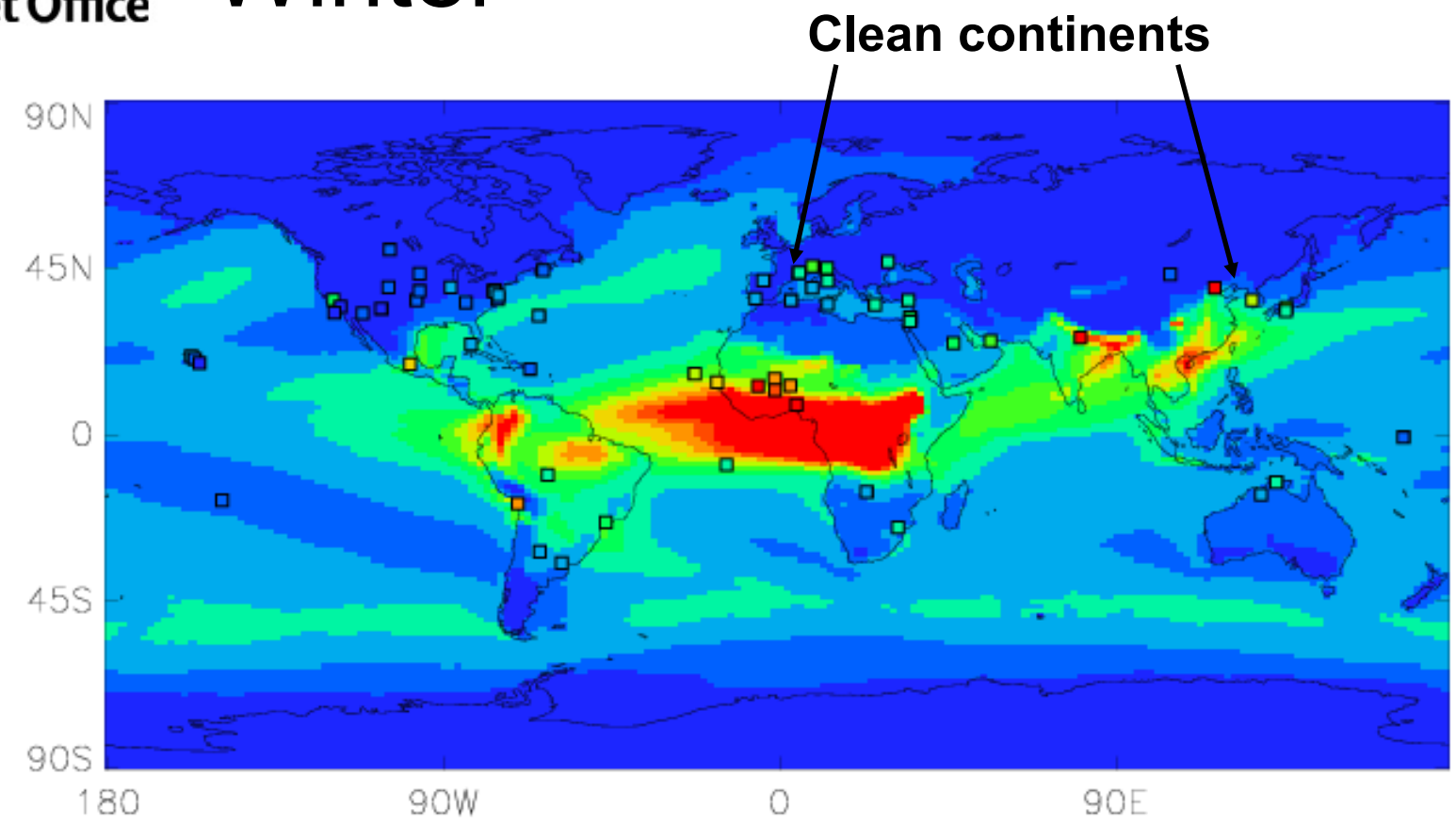
- **CLIMATE:**
  - **Sea-salt (film and jet modes)**
  - **Mineral dust (6-bins)**
  - **Sulphate (Aitken, accumulation, dissolved)**
  - **Fossil-fuel black carbon**
  - **Fossil-fuel organic carbon**
  - **Biogenic secondary organic carbon from isoprene emissions**
  - **Nitrate**
  - **Biomass burning aerosols.**
- **GLOBAL NWP: Aerosols in the global NWP model are (currently) very poor, but are being updated to climatological fields from the climate model version. Direct effect. No indirect effect.**

HadGEM2 and AERONET – Summer



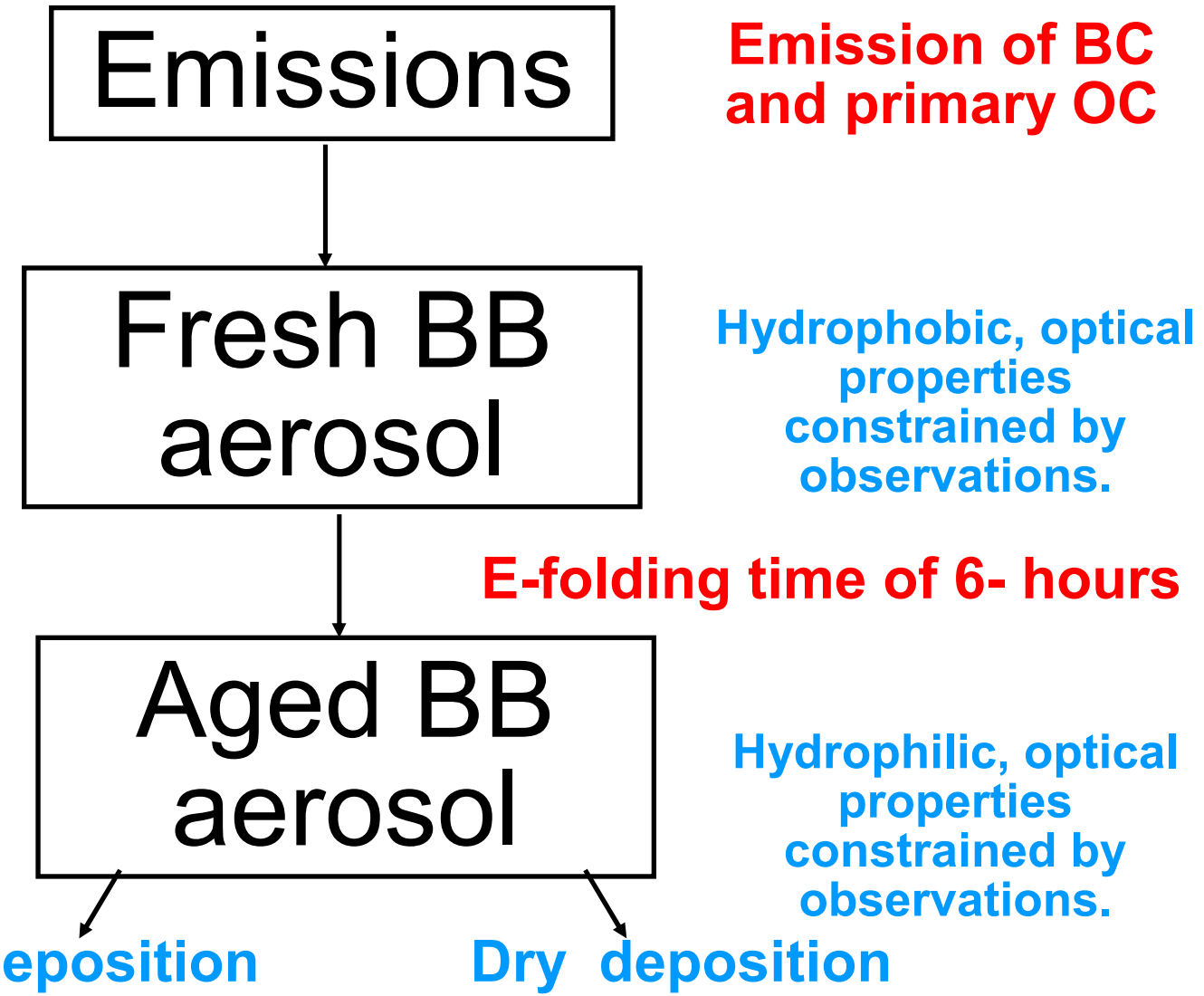
Pretty good simulation overall

HadGEM2 and AERONET – Winter



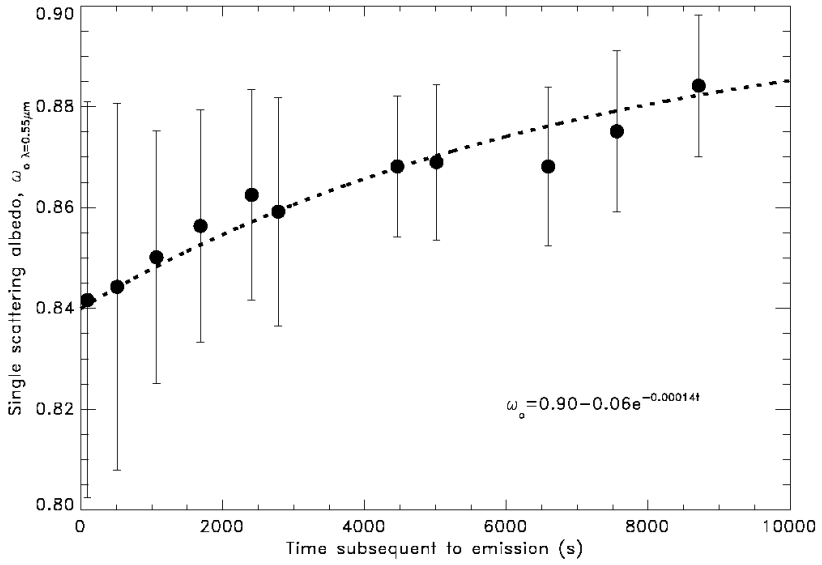
AOD at 0.44 μm

Biomass burning in the global climate version of the Unified Model:



1) Biomass burning fresh and aged aerosol size distributions and optical parameters are based on observations from SAFARI-2000.

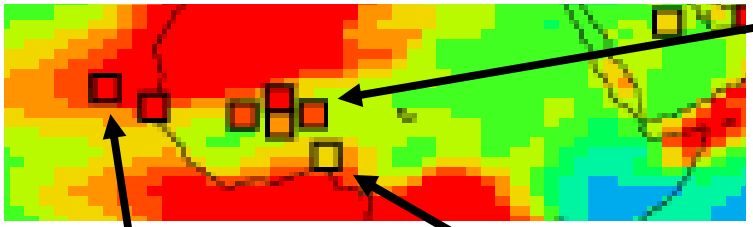
2) E-folding time parameterises observed increase in OC without the need for detailed gas phase chemistry.



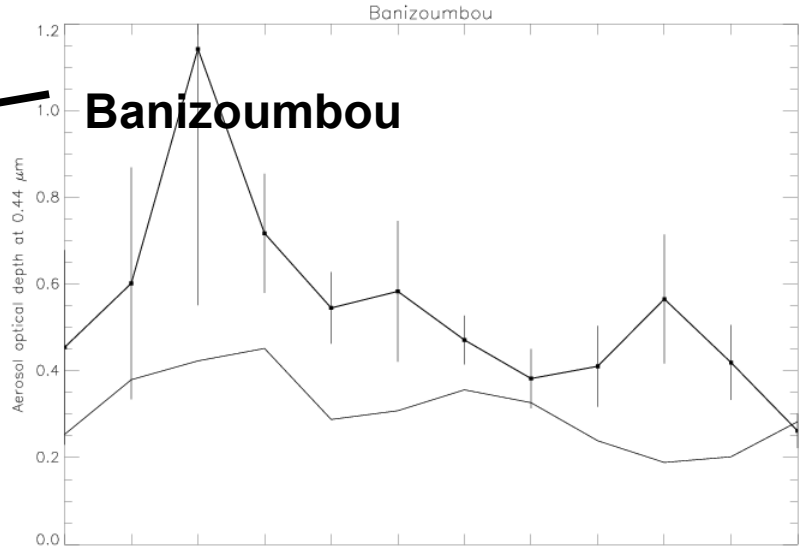
Less absorption/ particle as age increases

Raster pattern: Abel et al., 2003.
Lab studies: Grieshop et al, 2009;
Aircraft: Yokelson et al., 2009.

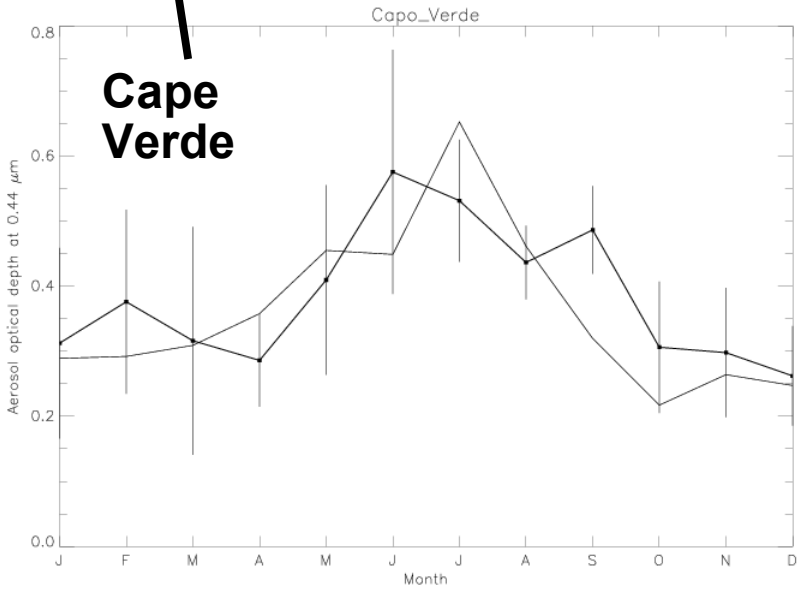
HadGEM2 and AERONET – Northern Africa (care – dust)



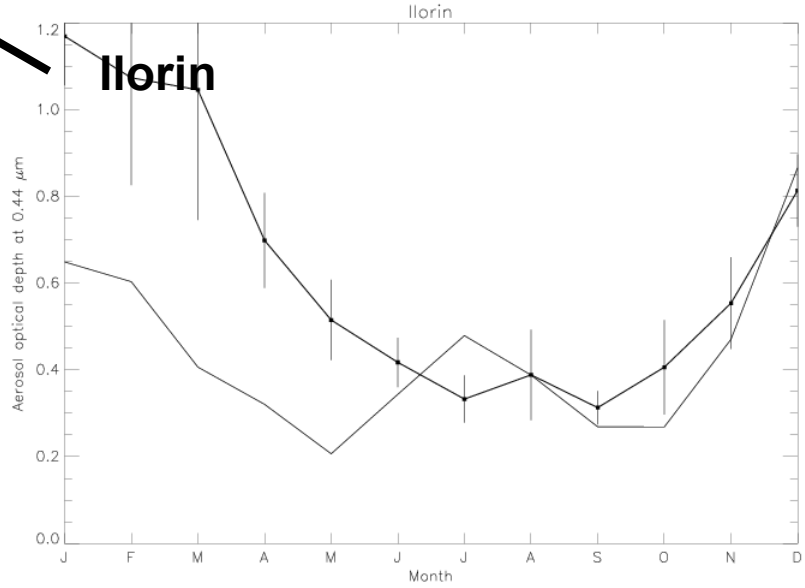
Banizoumbou



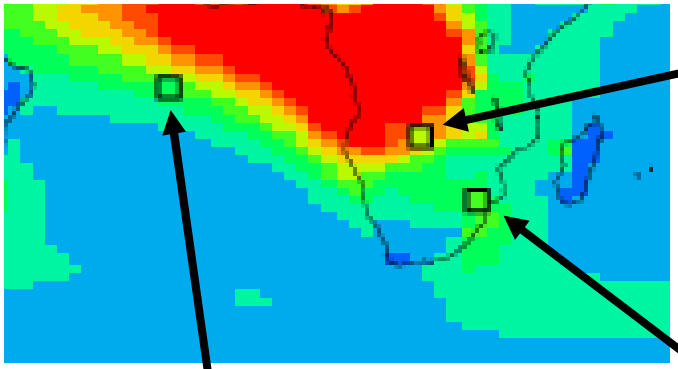
Cape Verde



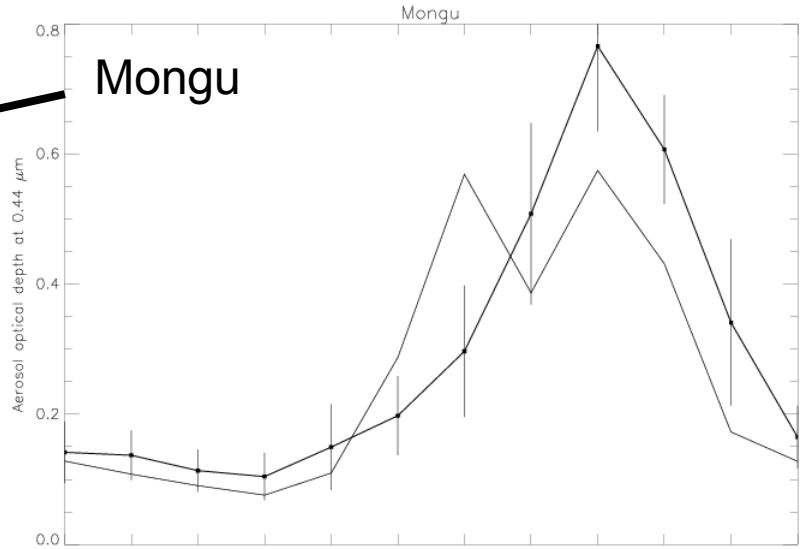
Ilorin



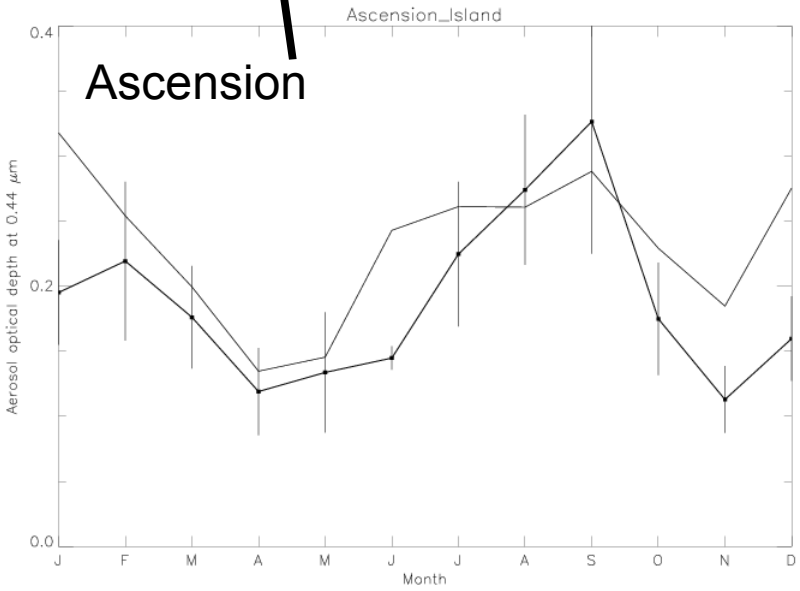
HadGEM2 and AERONET – Southern Africa



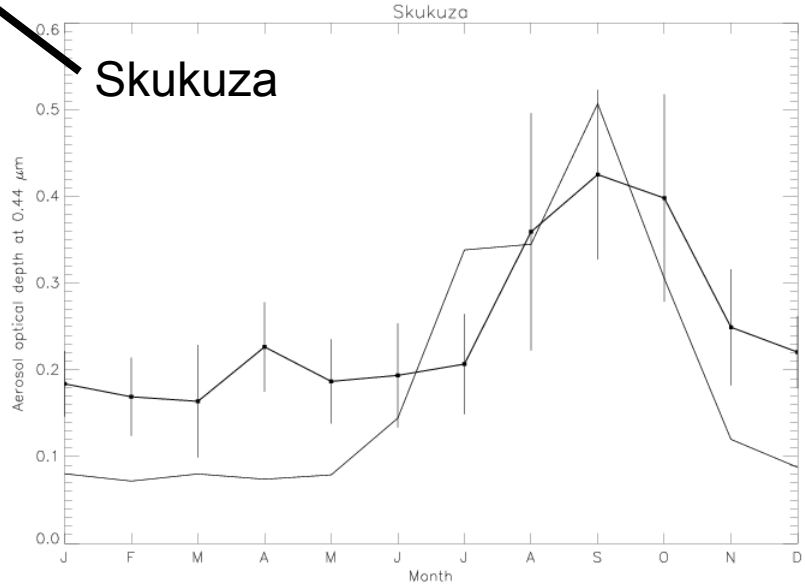
Mongu



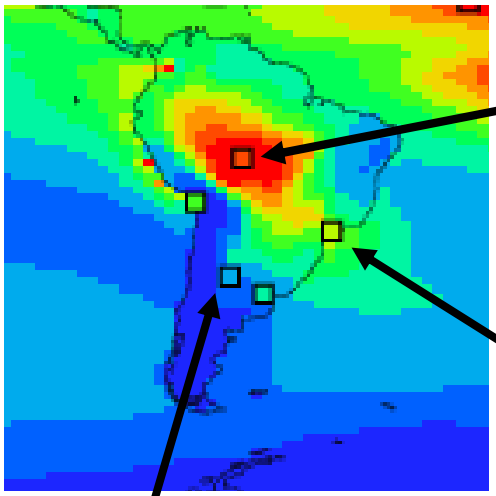
Ascension



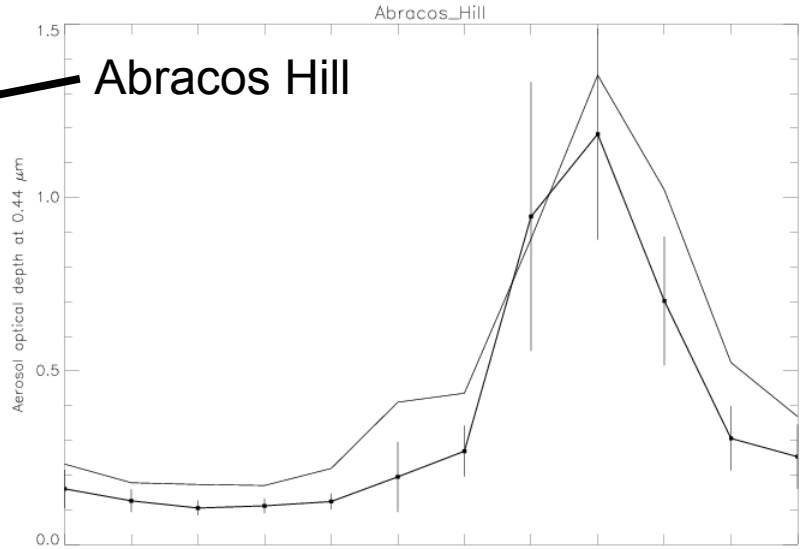
Skukuza



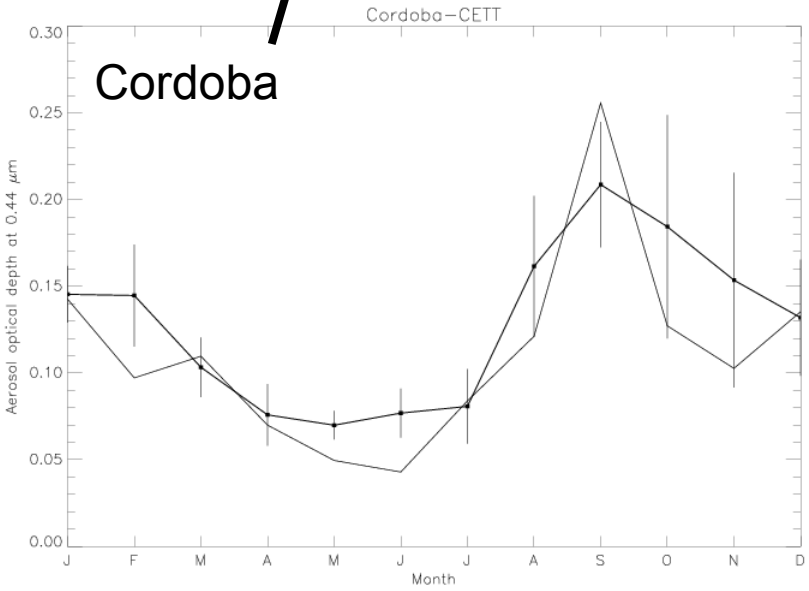
HadGEM2 and AERONET – South America



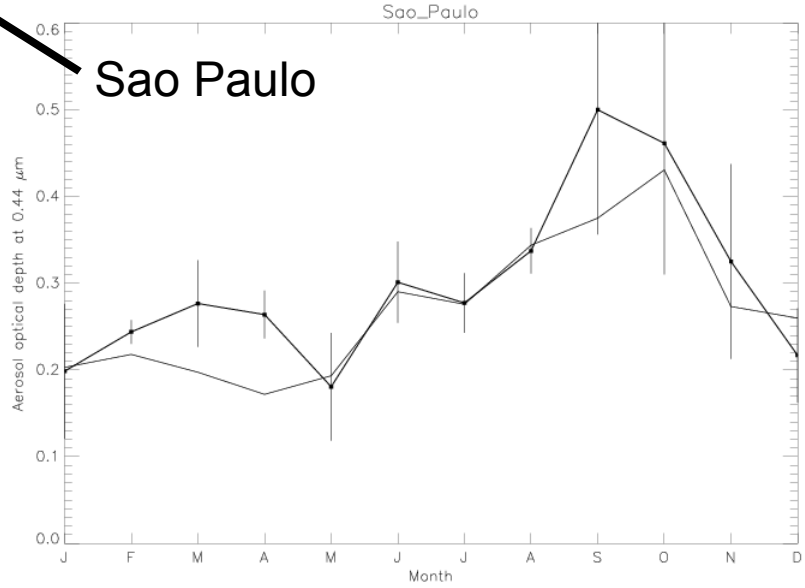
Abracos Hill



Cordoba

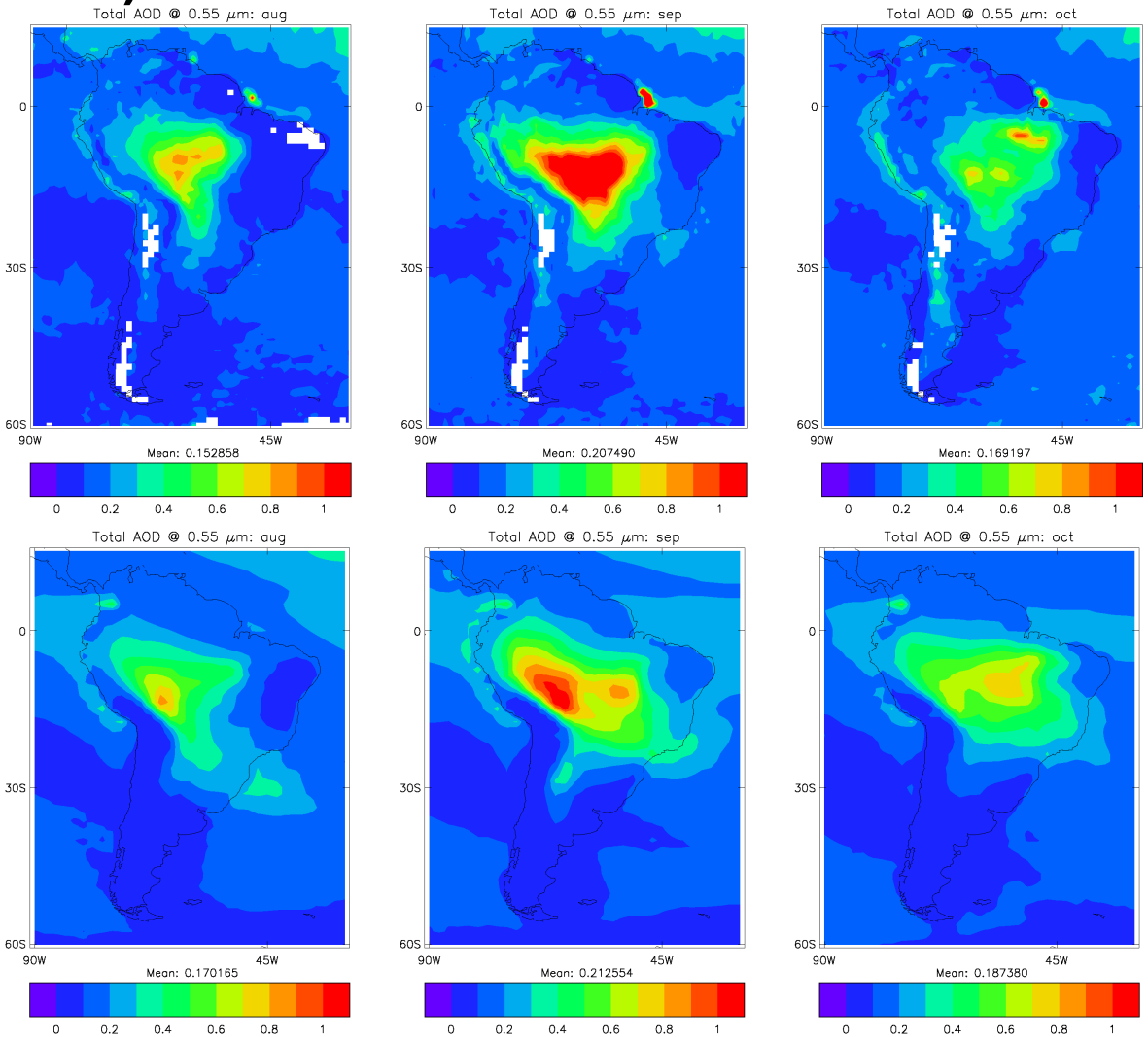


Sao Paulo

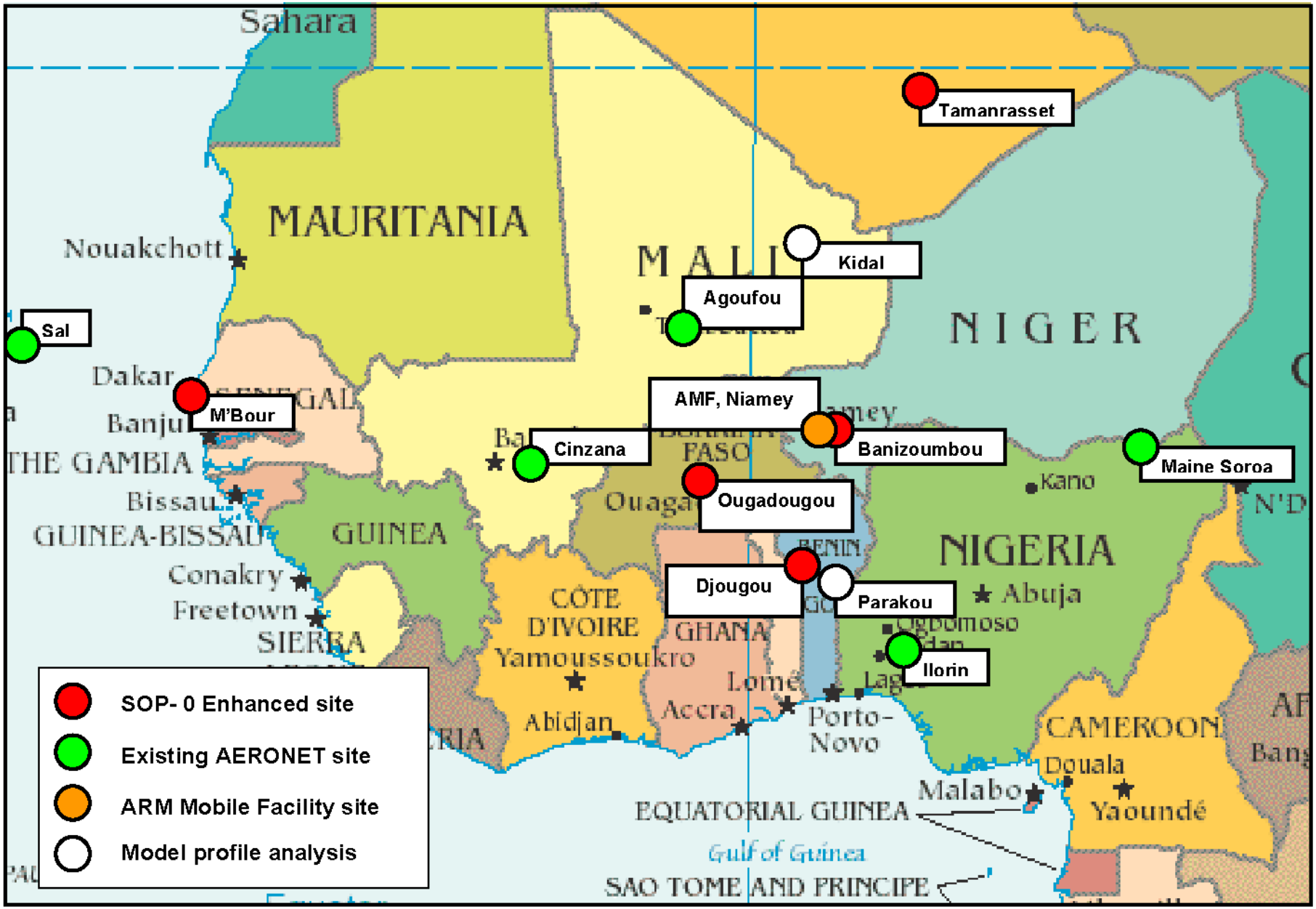


Model and MODIS

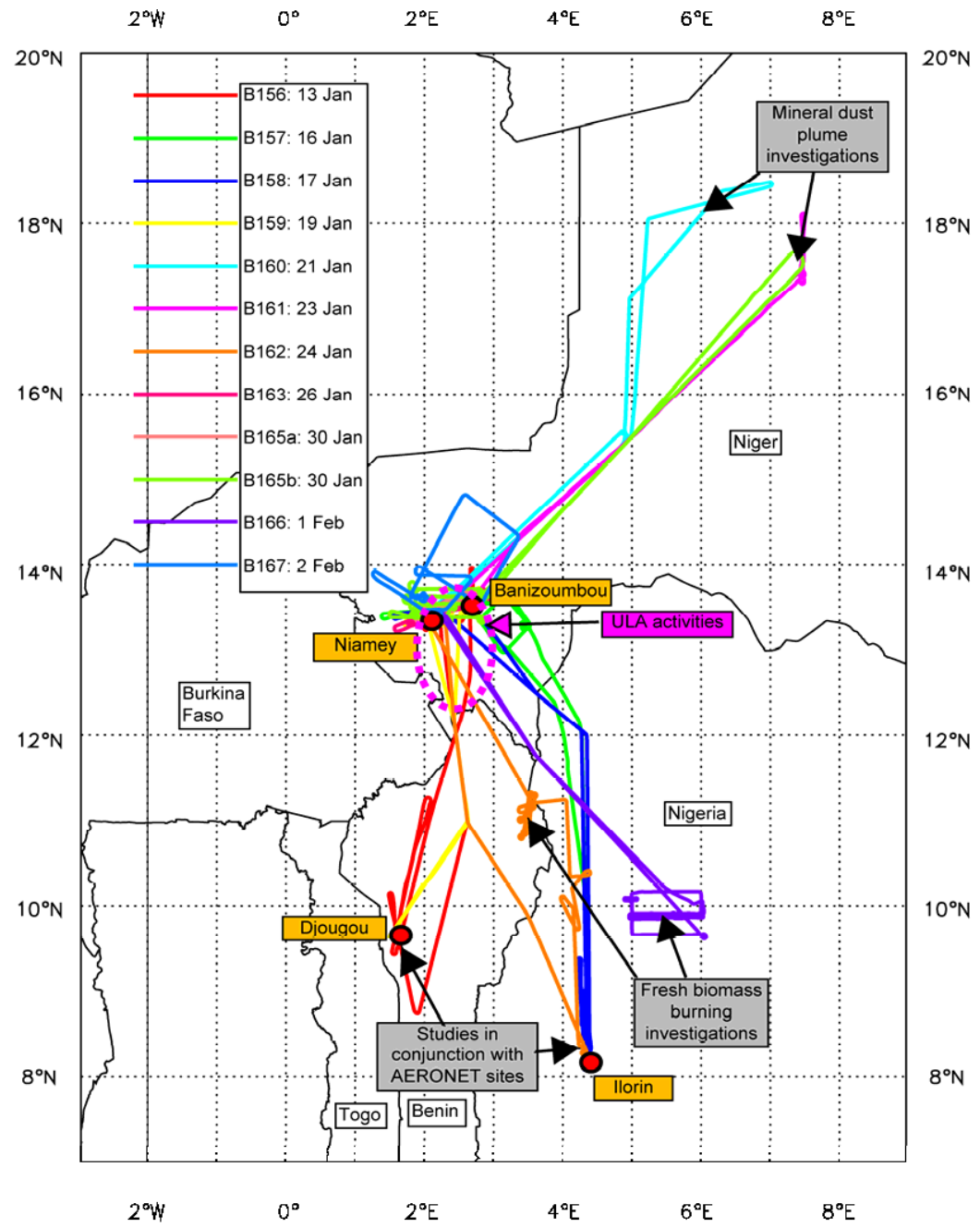
Q) Which one is which?

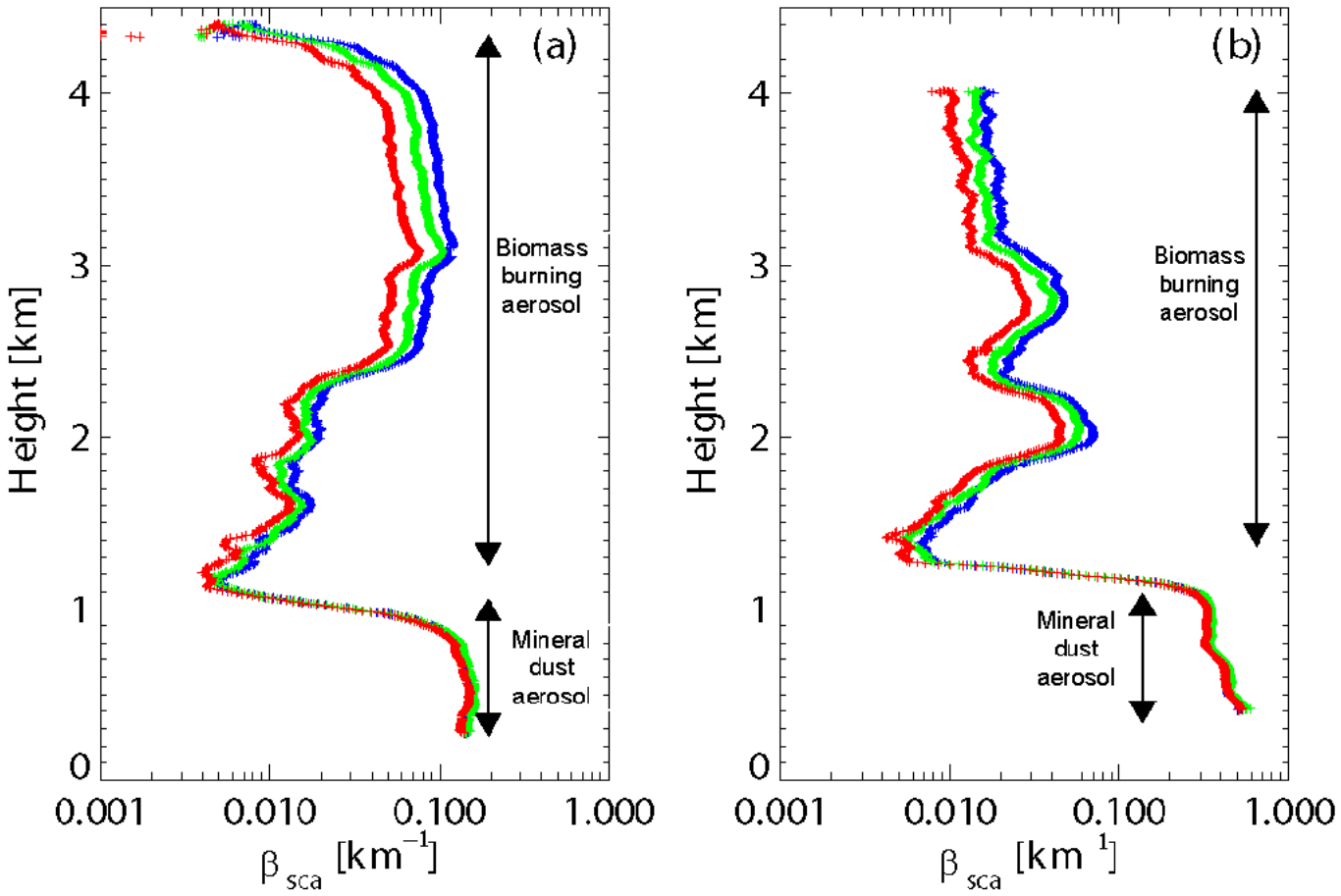


Showing the instrumented surface sites



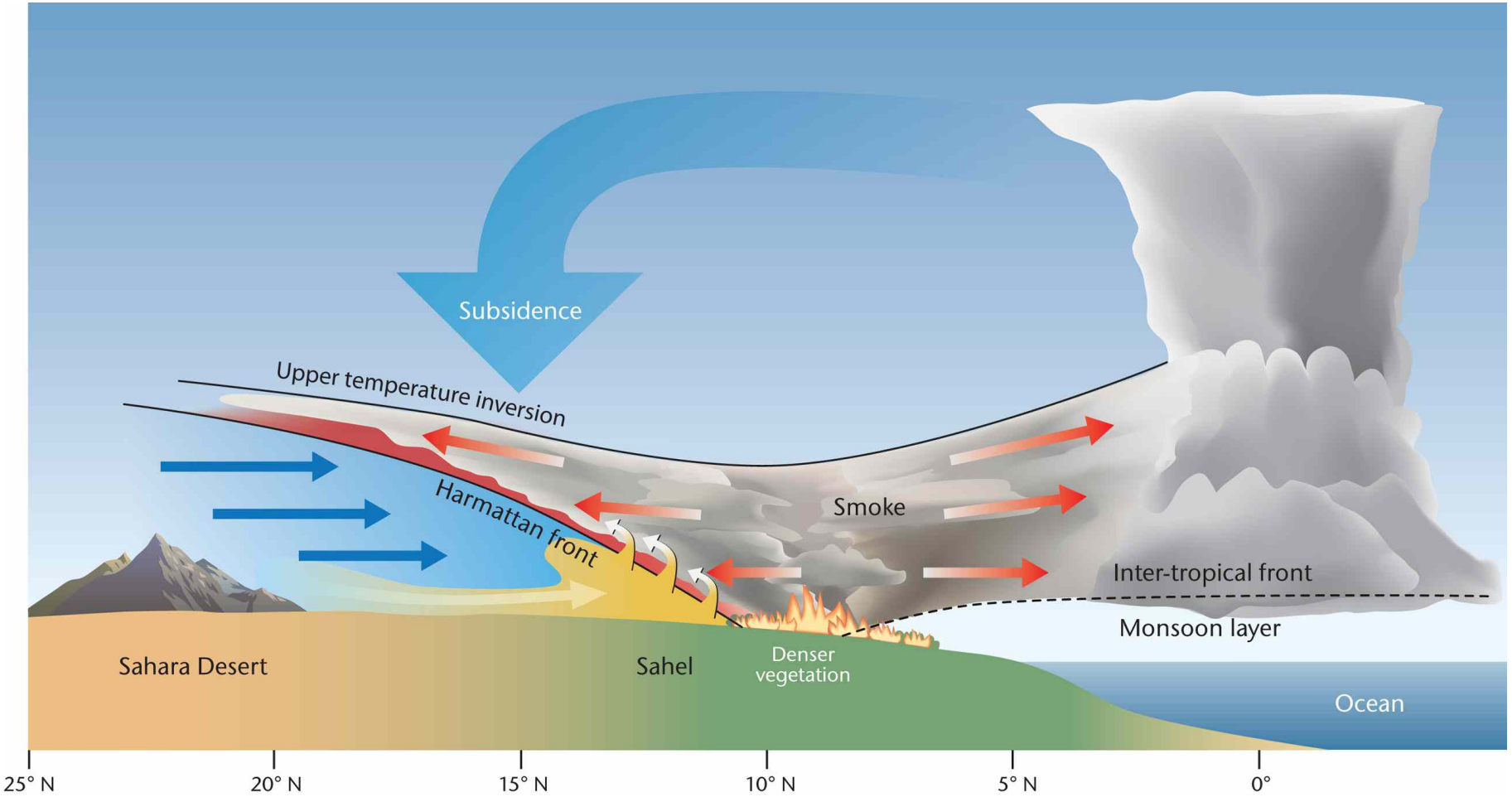
Aircraft operations during DABEX/ AMMA SOP0





Examples of the vertical profile of biomass burning overlying the mineral dust aerosol. The vertical profile of the biomass burning overlying the dust is driven by large scale dynamics rather than plume injection height

The aerosol transport picture:



Haywood et al, 2008

Example of the ‘Harmattan front’ approaching from the North East undercutting warmer moister air to the south.

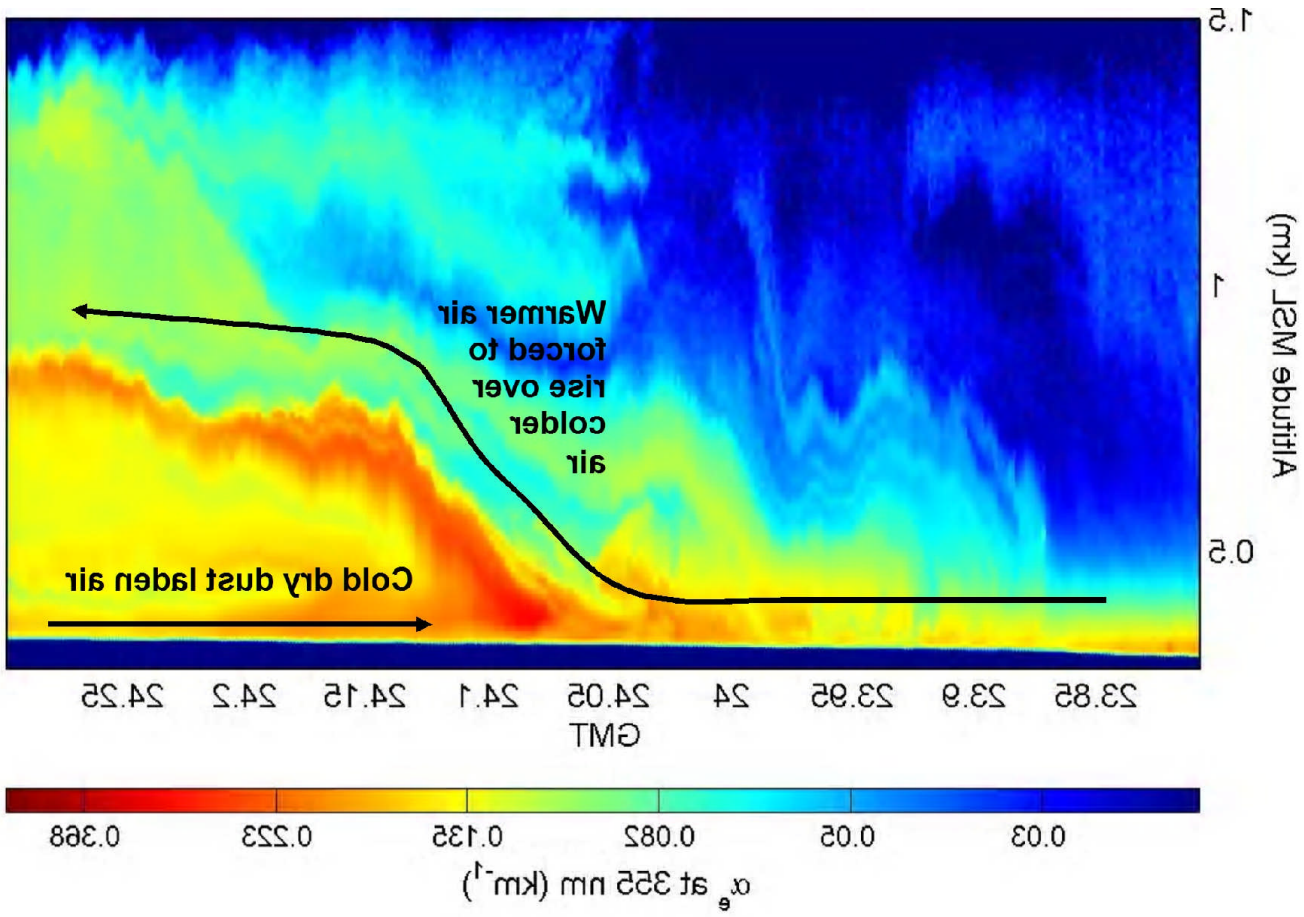
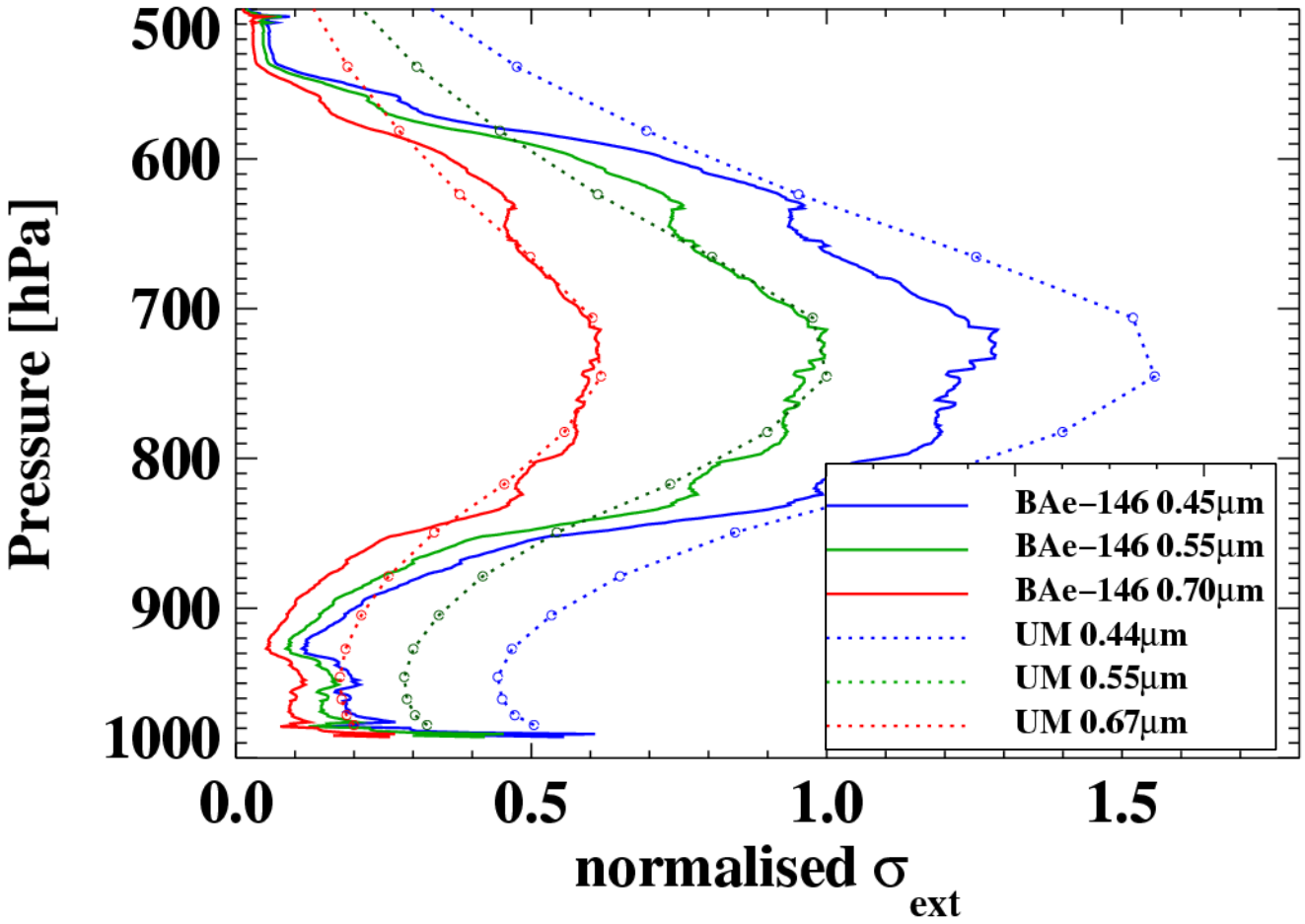


Figure 12. LALINA backscatter lidar image showing the progression of a dust front through Niamey during the 23rd-24th January. The lidar was sited at Niamey airport. α_e is the aerosol extinction in per km.

Do our current climate models represent the vertical profile accurately?

"Mean" biomass burning aerosol:



1) The altitude of the aerosol in the model is well represented.
2) The wavelength dependence of the scattering is good -> the effect on radiation is well represented.

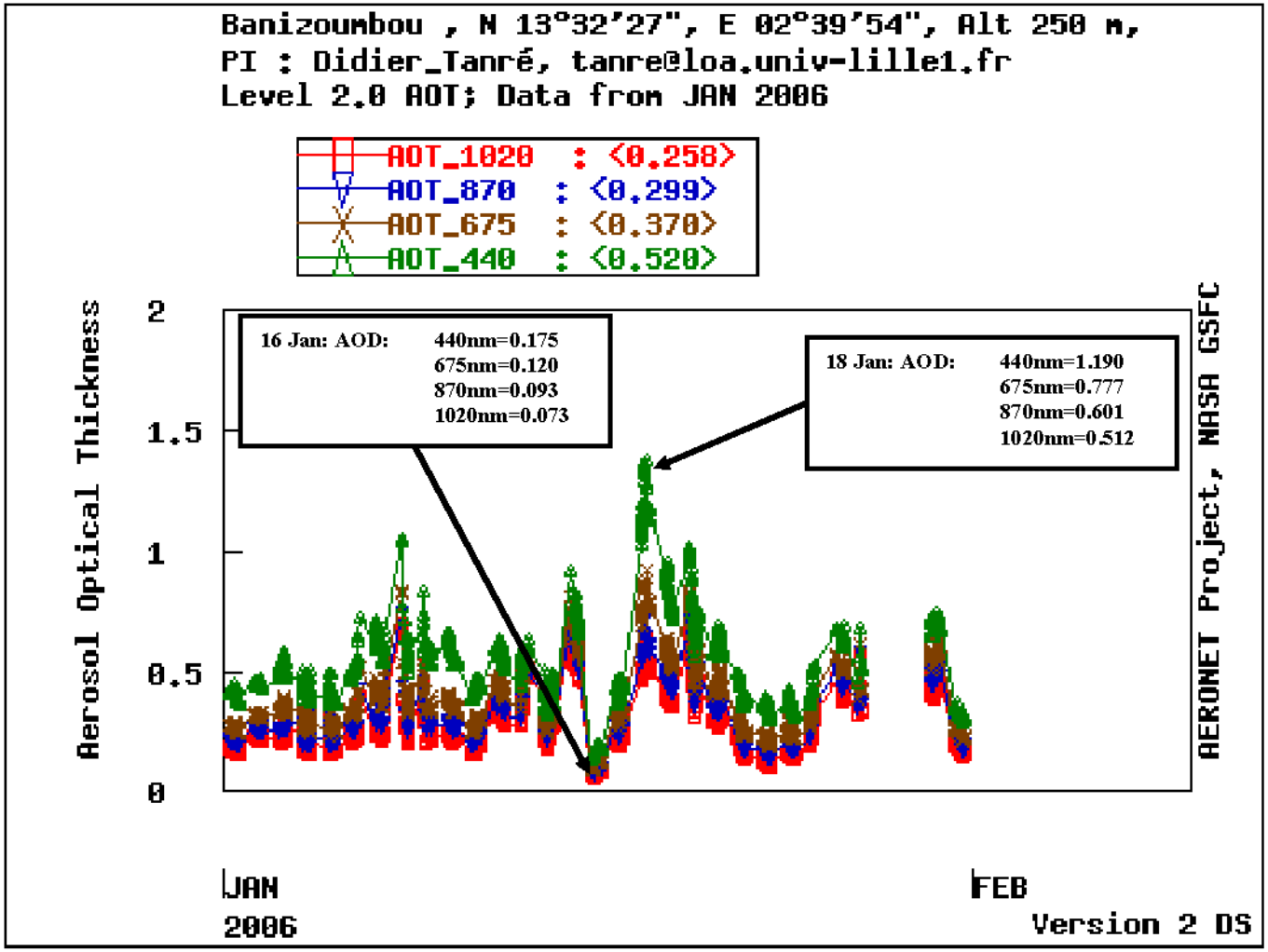
Monthly mean climatological values of the aerosol scattering from Niamey, Niger for January 2006.

….. So we’re in pretty decent shape with the climate model for biomass burning for monthly means.

Demonstration of the temporal variation of aerosols and their impact on atmospheric radiation

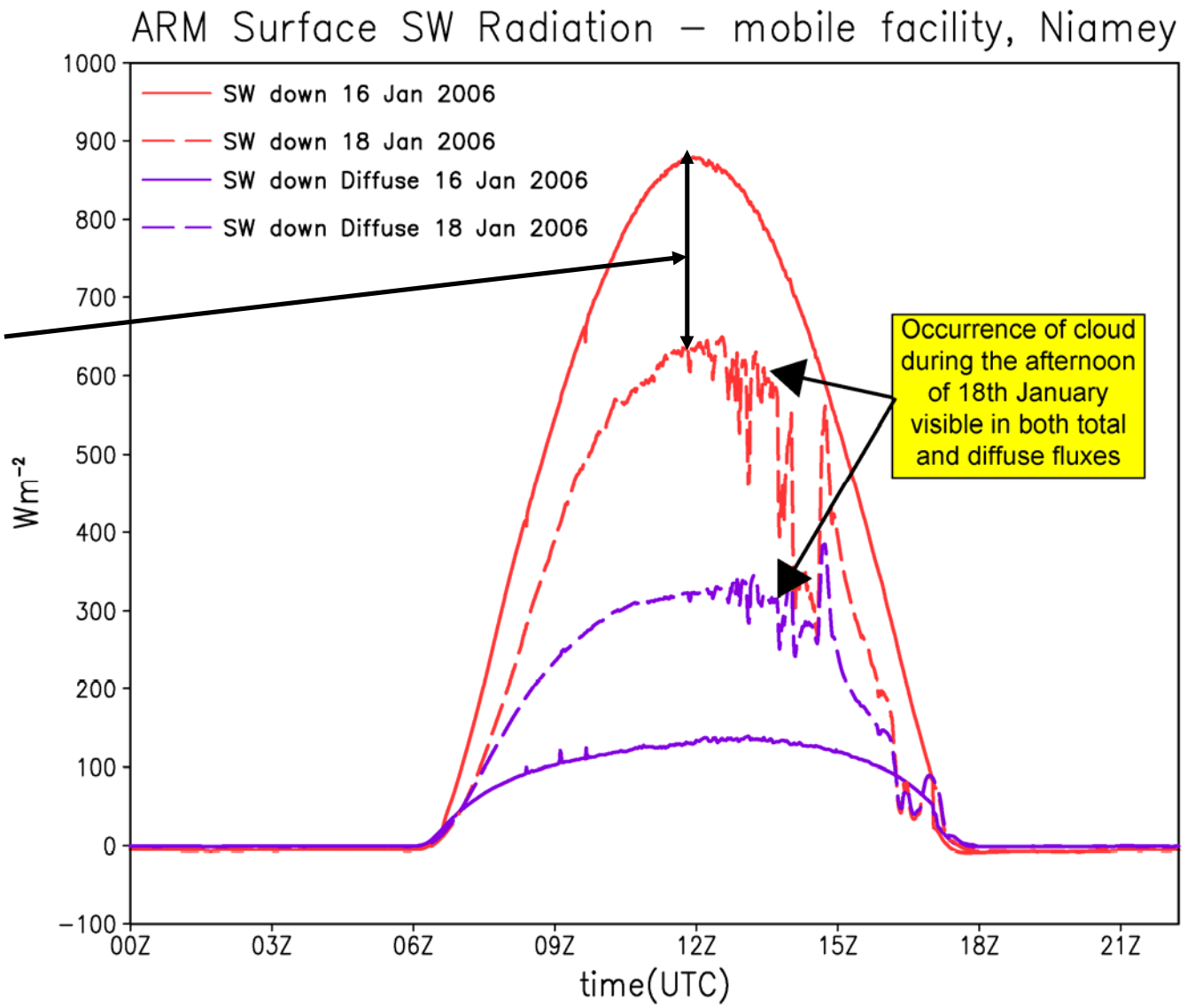
Clean day vs turbid day

(dust & biomass burning aerosols)

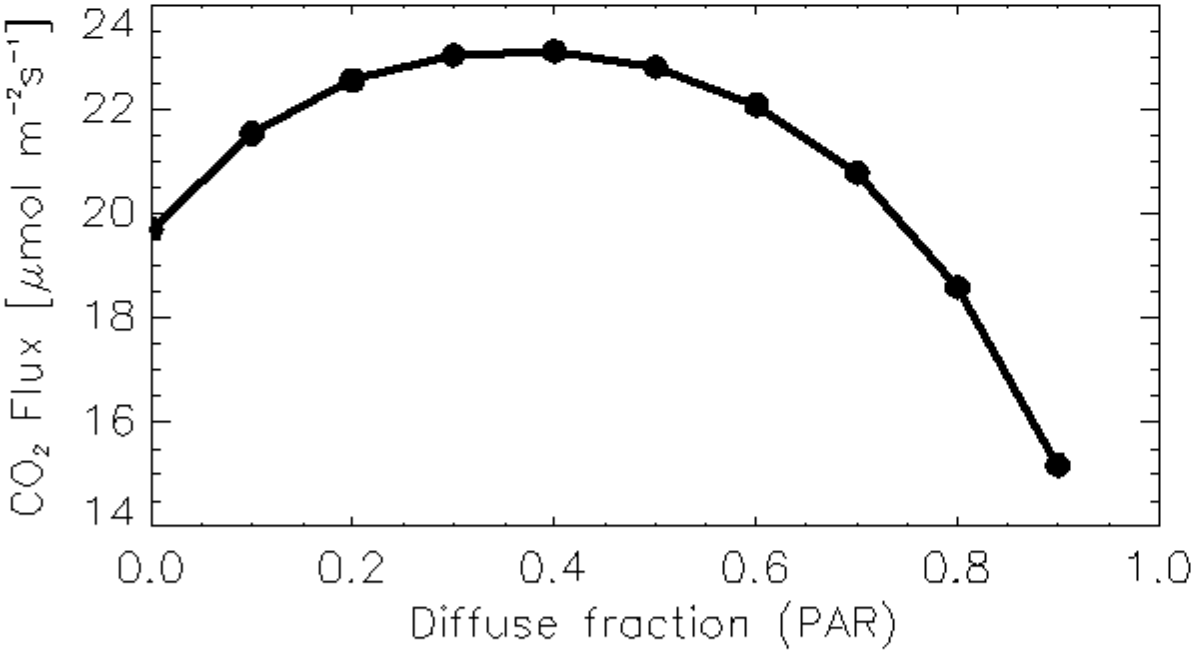


Demonstration of the temporal variation of aerosols and their impact on atmospheric radiation

Reduction in mid-day solar flux by >250Wm^{-2}

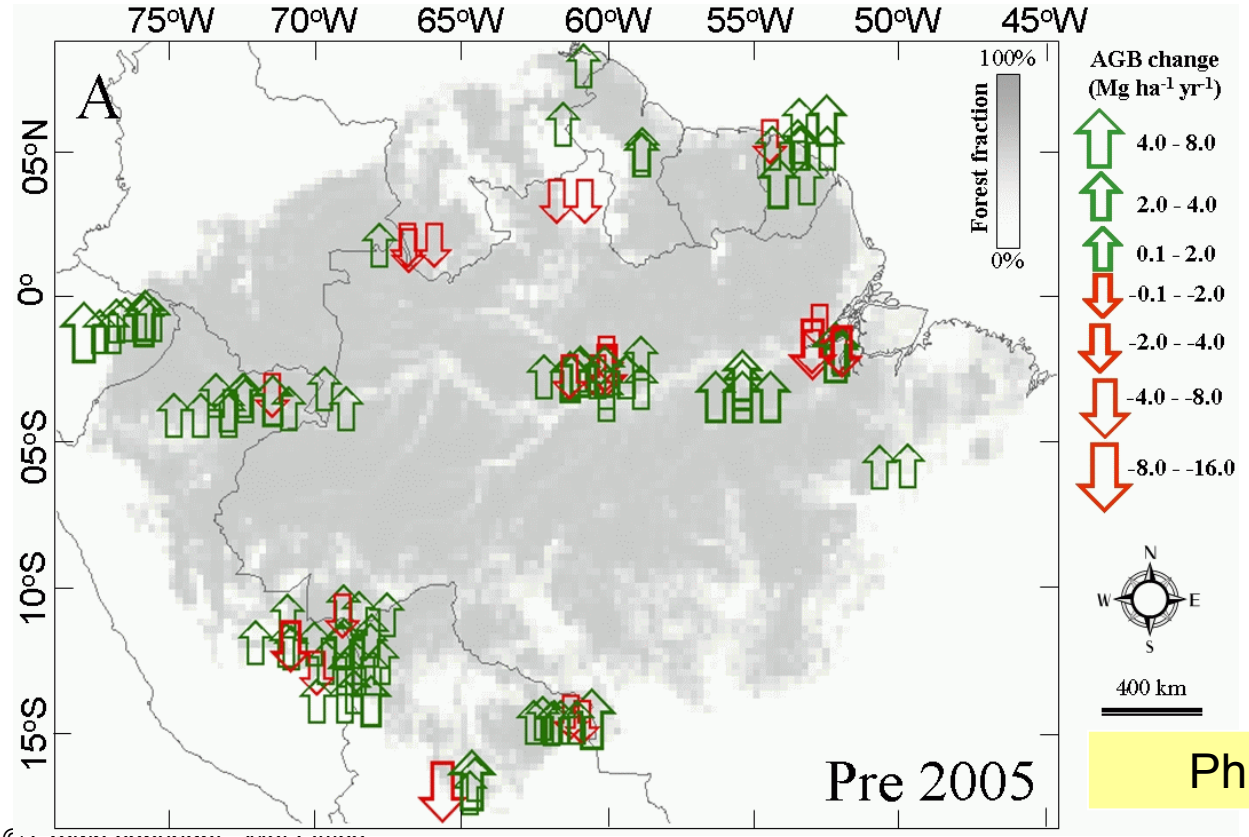


The reduction of photosynthetically active radiation may be countered by the increase in plant net primary productivity under diffuse radiation



GPP weighted by incoming radiation as a function of diffuse fraction (Mercado et al, Nature, 2009)

Primary productivity appears to be increasing in the Amazon ….

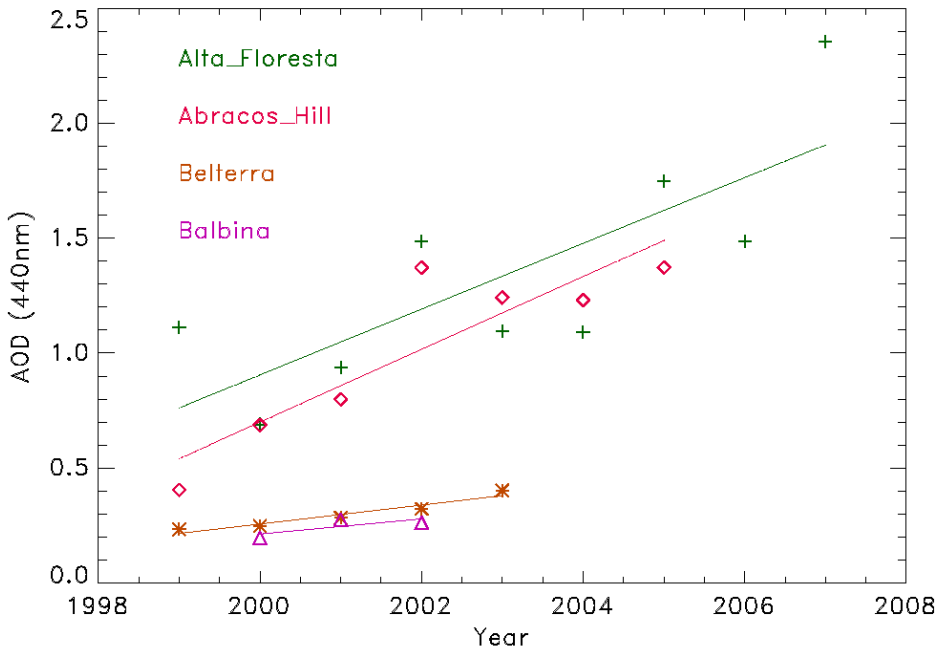


Is this due to CO2 fertilisation?

Is it due to aerosols?

Phillips et al. 2009 *Science*

Is there any sign of significant trends that indicate increased diffuse fraction over the Amazon?



The trends in AOD are strong over the south of the region where trend >0.1/year

This will increase the diffuse fraction of radiation

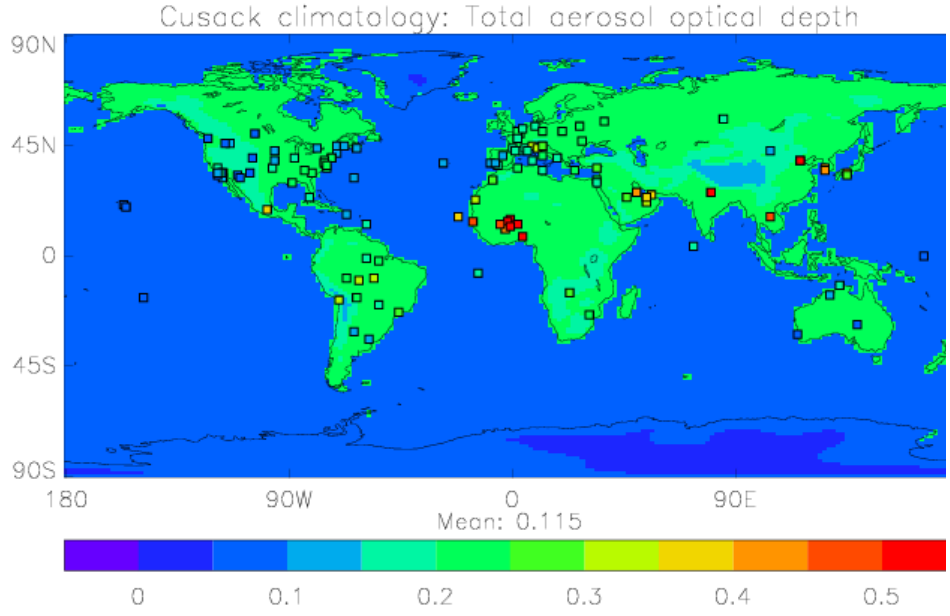
Data from September (~max of biomass burning) from AERONET stations

Conclusions

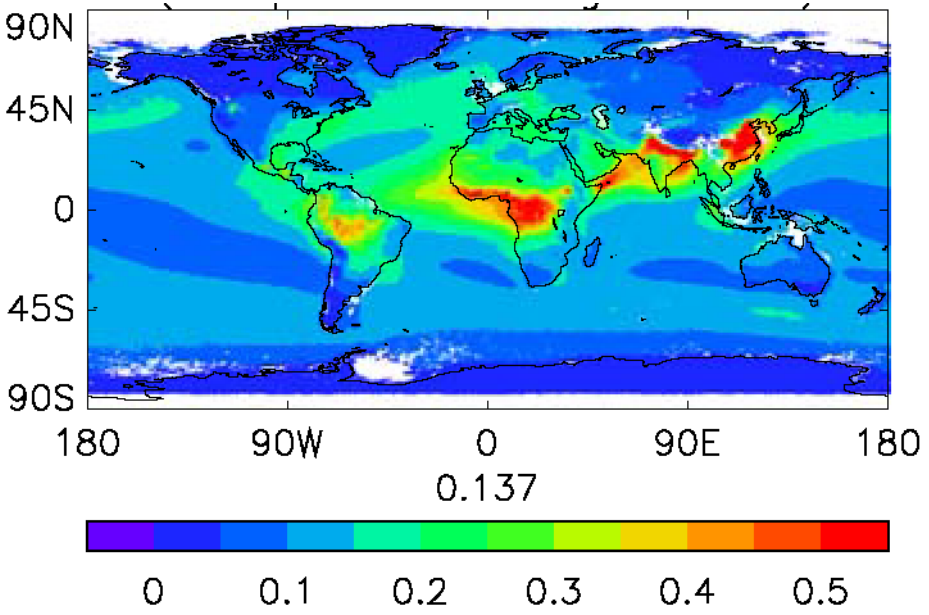
- **Aerosol monthly mean optical depth appears well represented in the climate model despite its simplicity.**
- **Biomass burning optical depth seems reasonable in the monthly means**
- **Biomass burning aerosol optical properties are constrained by observations and therefore reasonable**
- **The impact of biomass burning aerosol upon atmospheric radiation appears reasonable.**
- **We plan to include the potential impact of the reduction in PAR and the increase in diffuse fraction on vegetation productivity.**
- **The biomass burning scheme is simple and cheap (3 tracers) which means that we could adapt it easily to global NWP modelling …….**

Future plans: Global NWP Model

Current Model!



Annual mean climatologies from HADGEM2



Global NWP developments:

Marine/Continental.

↓

Speciated aerosol climatologies.

Still no temporal variability.

↓

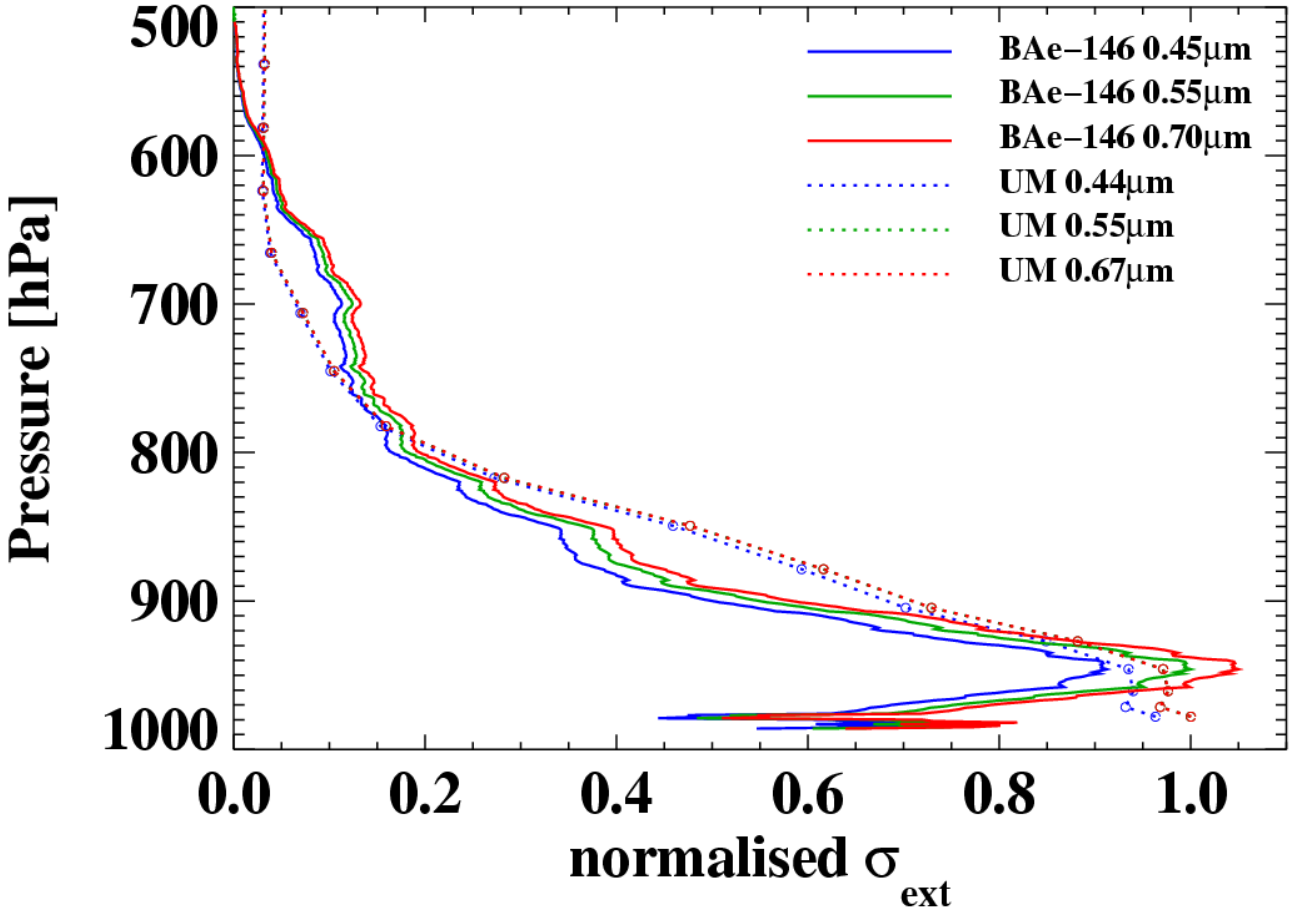
Prognostic sea salt, dust, BB

(either through our own modelling or through the GEMS/MACC project)

Additional material

Do our current climate models represent the vertical profile accurately?

"Mean" mineral dust aerosol:



1) **The altitude of the aerosol in the model is well represented.**
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Monthly mean climatological values of the aerosol scattering from Niamey, Niger for January 2006.

Current representation of aerosol in the Met Office models:

- **CLIMATE:** Biomass burning smoke is explicitly represented in the climate model version of the Unified Model. Direct effects and indirect effects are represented.
- **GLOBAL NWP:** Aerosols in the global NWP model are (currently) very poor, but are being updated to climatological fields from the climate model version. Direct effect. No indirect effect.
- **MESOSCALE MODEL:** Aerosols in the mesoscale model (12km resolution) are represented by UKCA chemistry coupled to the CLASSIC aerosol scheme from the climate model. Used for Air Quality (with plans for including visibility forecasts). No direct or indirect effect.
- **HIGH RESOLUTION MODELS:** Aerosols in the higher resolution (12km, UK4km, UK1.5km model) are represented by a single "MURK" aerosol intending to represent sulphate, nitrate and volatile organic carbon aerosol. Used for visibility forecasts. Data assimilation of visibility. No direct or indirect effects.

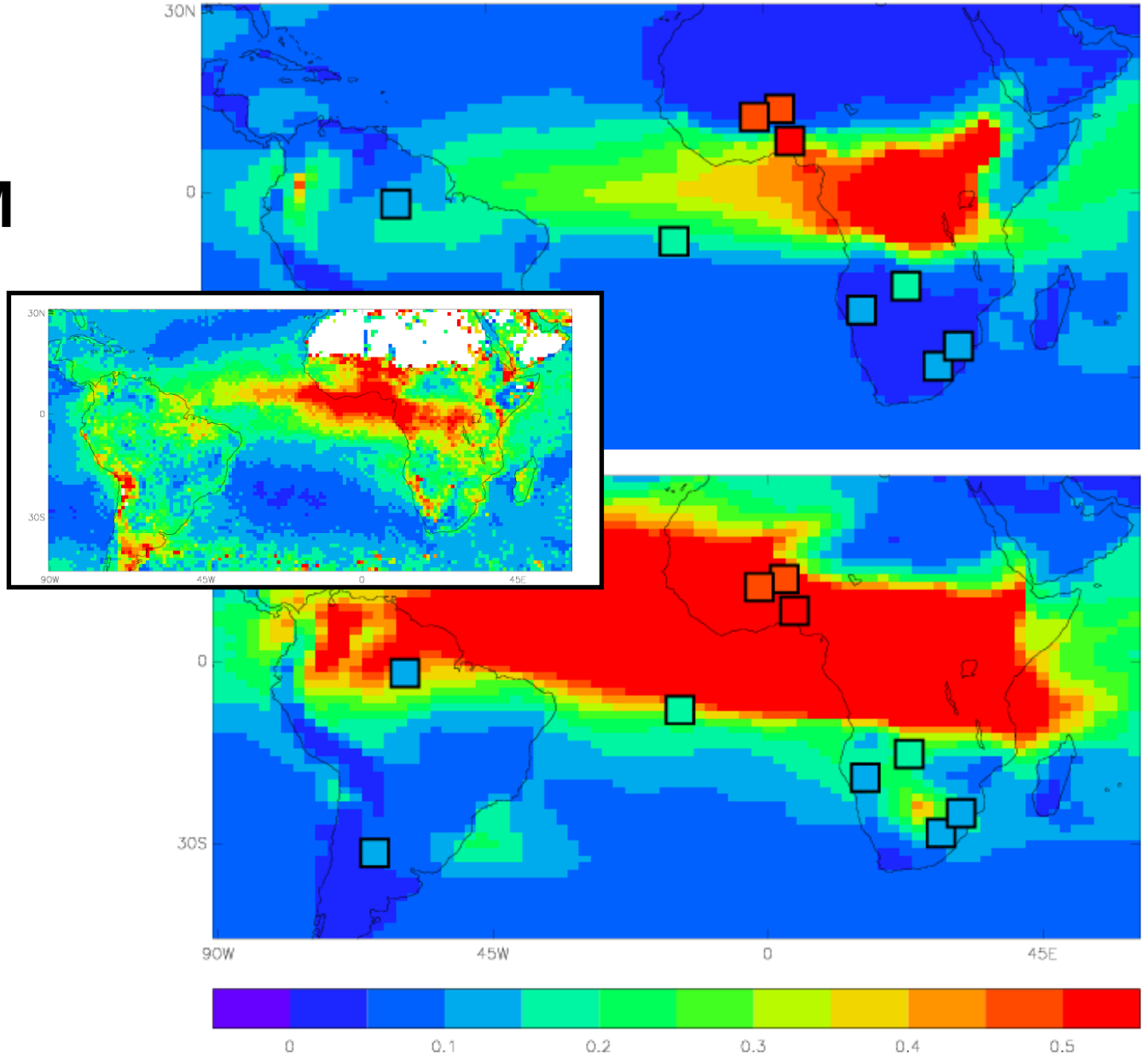
Can we get a reliable near-real time data set of emissions for use in the NWP model?

Met Office

AEROCOM

Jan

Nozawa



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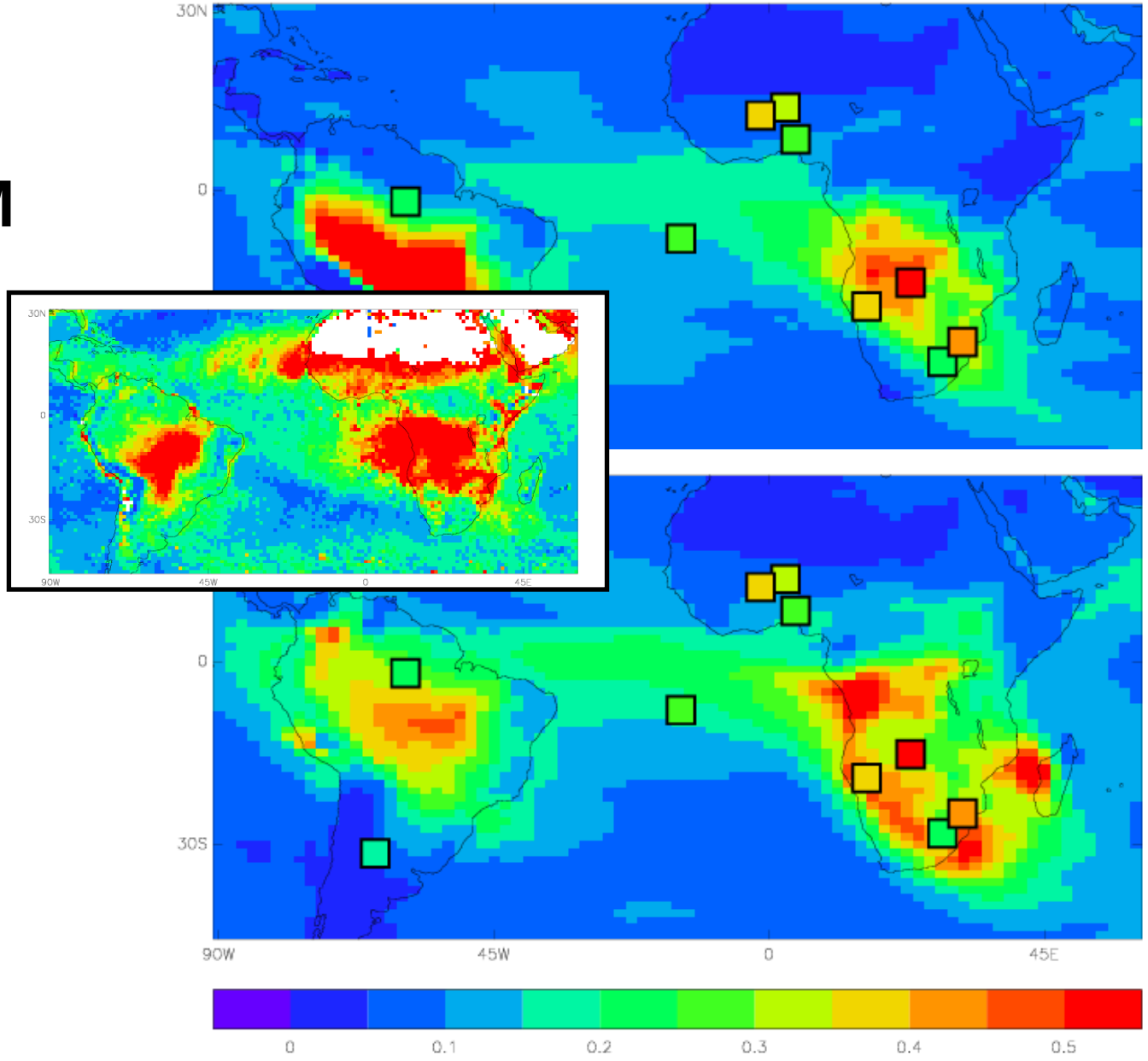
Met Office

AEROCOM

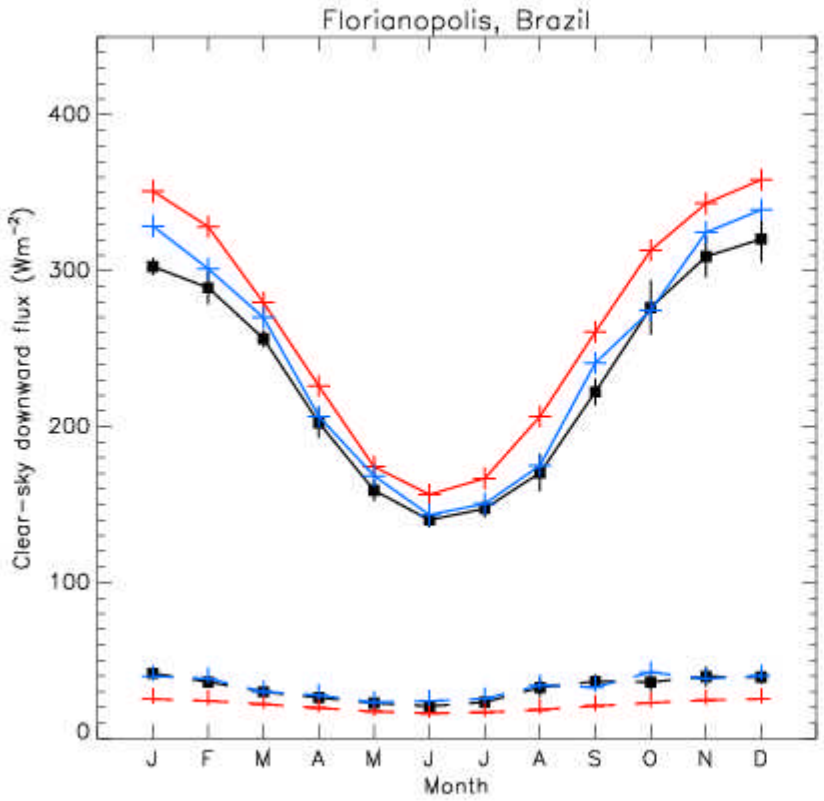
Sept

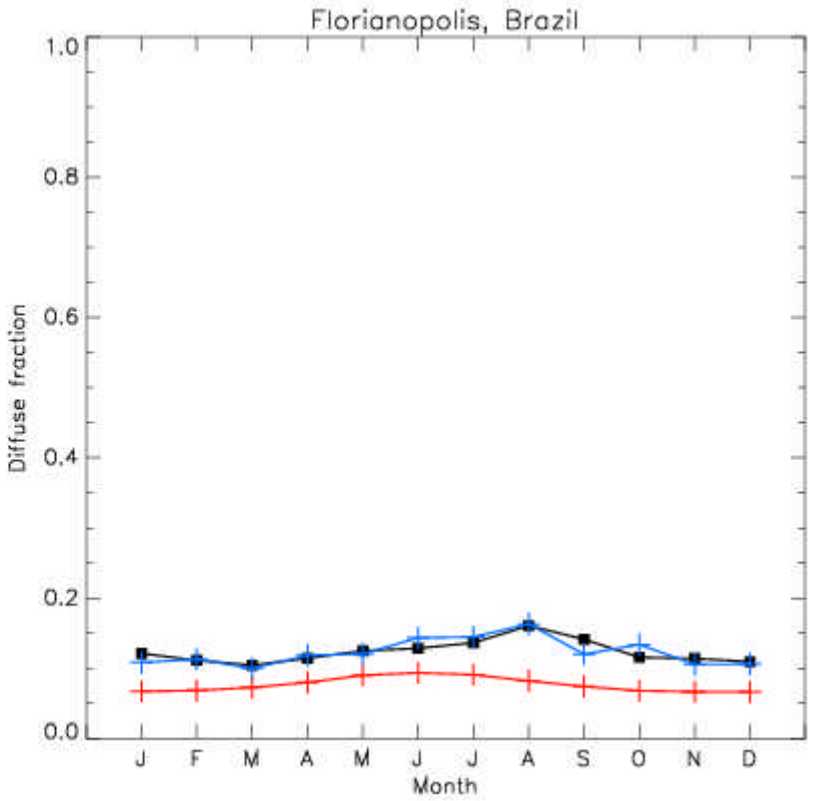
Nozawa



Radiative fluxes and diffuse fraction: BSRN

BSRN HadGEM2 No aerosols HadGEM2 aerosols





Collaboration with Kings College London (Martin Wooster).

SEVIRI – stable and well calibrated.

Extending to GOES satellites.