Impact of changes in diffuse radiation on the global land carbon sink

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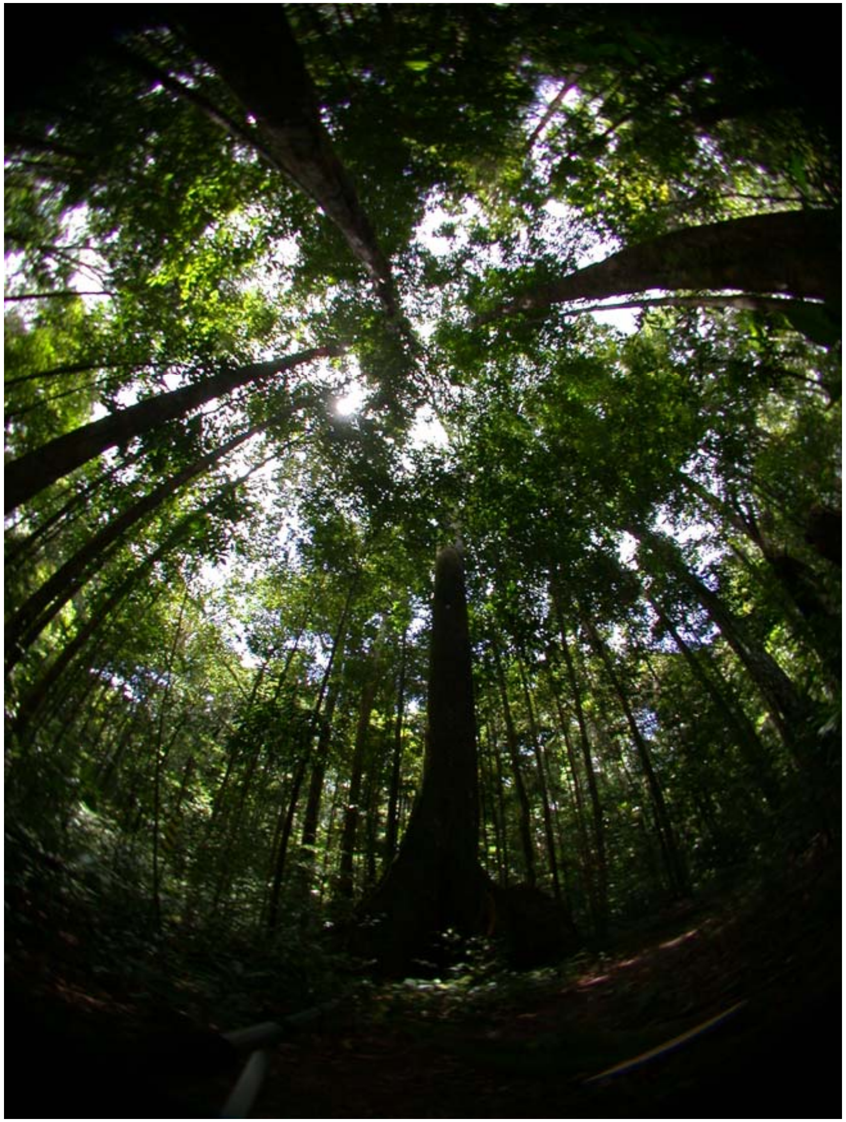
Nicolas Bellouin, Met Office Hadley Centre, 8 October 2008.

Authors

- Lina Mercado (Center for Ecology and Hydrology, Wallingford)
- Nicolas Bellouin, Stephen Sitch, Olivier Boucher (Met Office Hadley Centre, Exeter)
- Peter Cox (University of Exeter)

Aims

- Plant productivity increases with fraction of diffuse photosynthetically active radiation (PAR, 0.4→0.69 μm)
- This is due to a more uniform illumination of the canopy
- Is there an enhancement of the land carbon sink due to more efficient photosynthesis under increased diffuse fraction?
- What is the contribution of changes in aerosol loading during the 20th century and how will it evolve in the 21st?



Terminology

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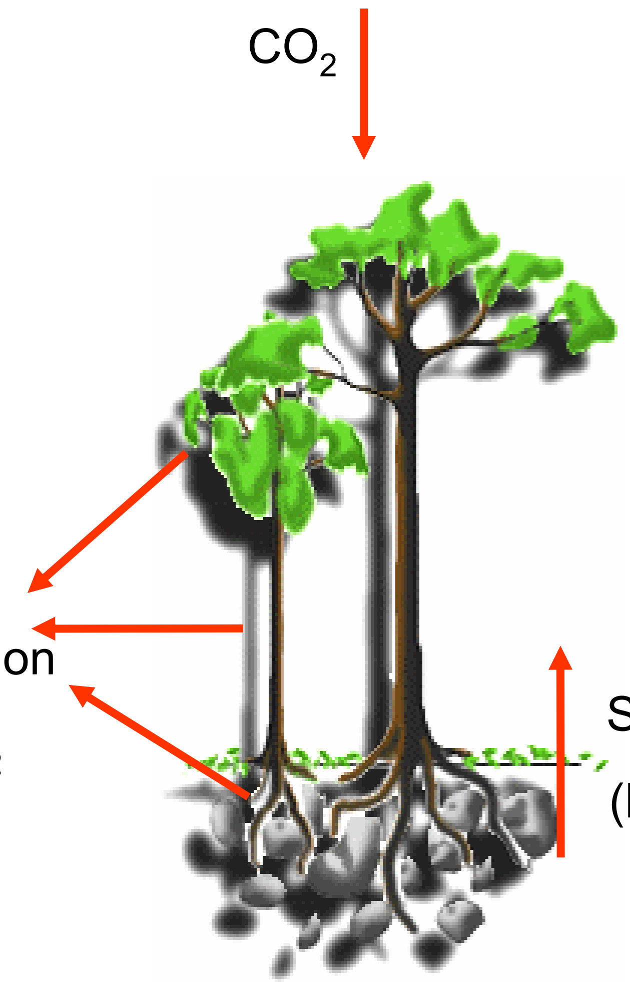


Gross Primary Productivity

GPP = Photosynthesis + leaf respiration

Net Primary Productivity

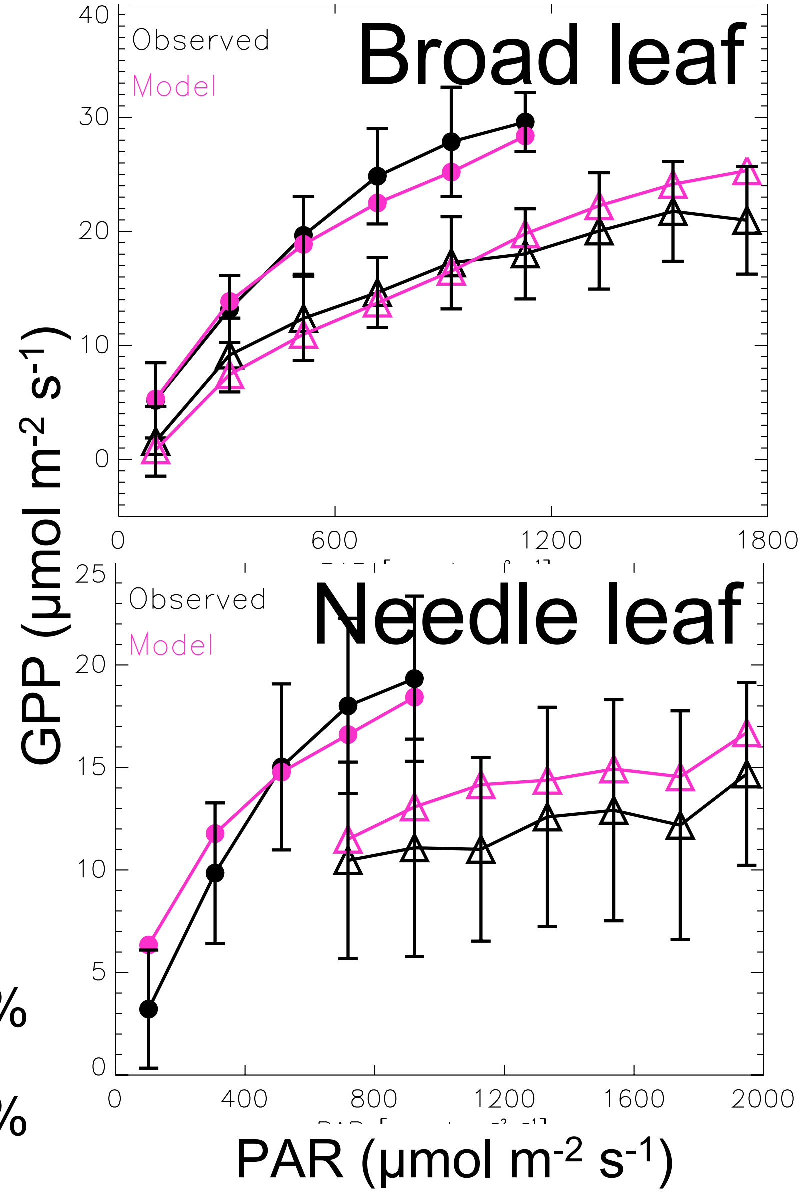
NPP = Photosynthesis – plant respiration

Net Ecosystem Exchange

NEE = NPP - RH

The soil and vegetation model

- Modified version of JULES
- Accounts for
  - Leaf area index and leaf angle distribution
  - Solar zenith angle, direct and diffuse radiation
  - Sun flecks (light-saturated portion of leaves)



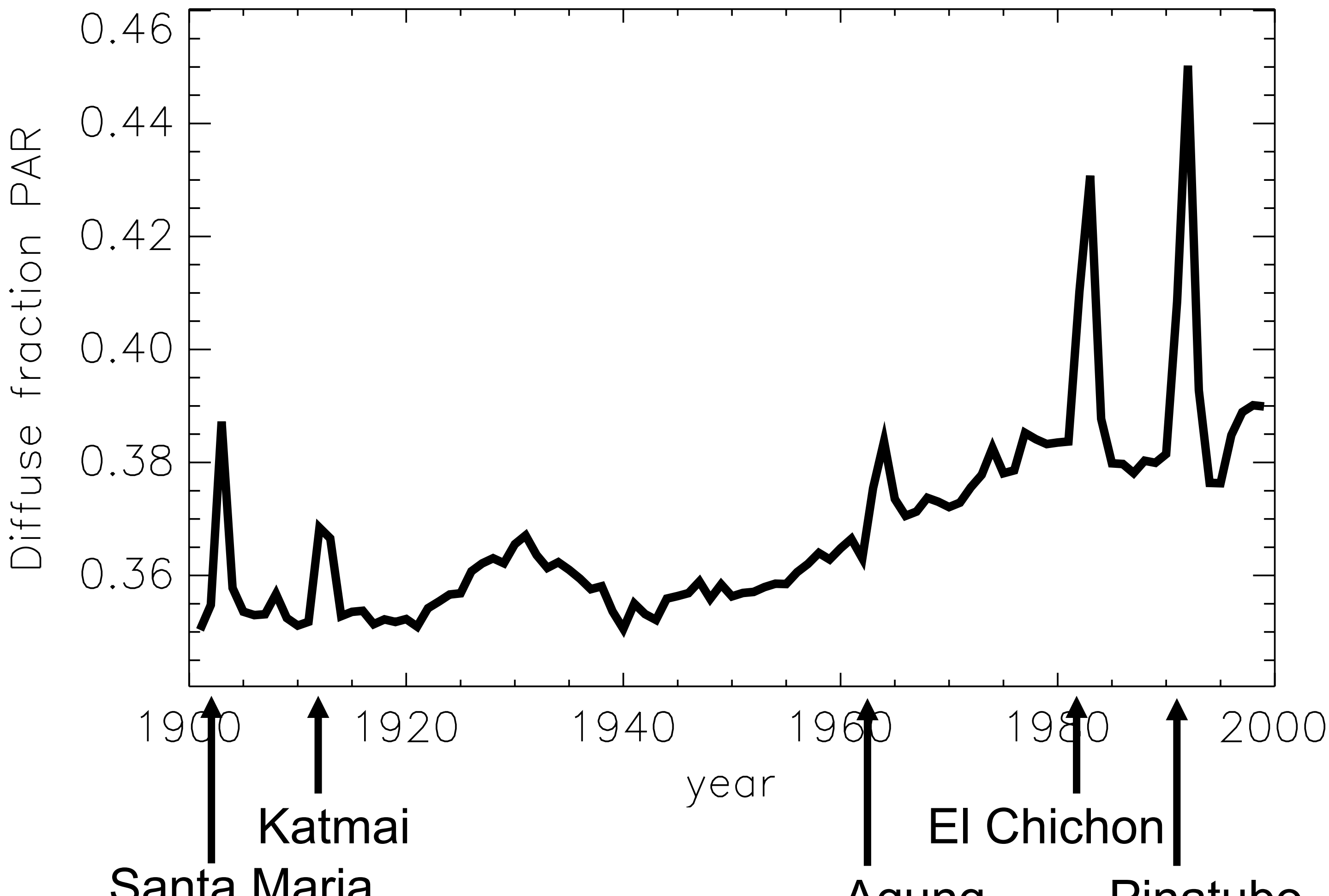
● Diffuse fraction ≥ 70%

△ Diffuse fraction ≤ 25%

Distributions for 20th century and radiative transfer

- Aerosols (2D, monthly)
  - SU, BB, FFBC, FFOC, DU, SOA from HadGEM2-A
  - Stratospheric from GISS dataset
- Cloud cover, temperature, precipitation from CRU dataset (2D, monthly)
- Radiative transfer provides clear-sky total, direct, diffuse downward PAR radiation as a function of tropospheric and stratospheric aerosols, SZA.
- GCM provides total downward PAR as a function of cloud cover (regional, monthly). Assumed completely diffuse.

Changes in global, all-sky diffuse fraction



Impact of diffuse fraction variations: Volcanic eruptions

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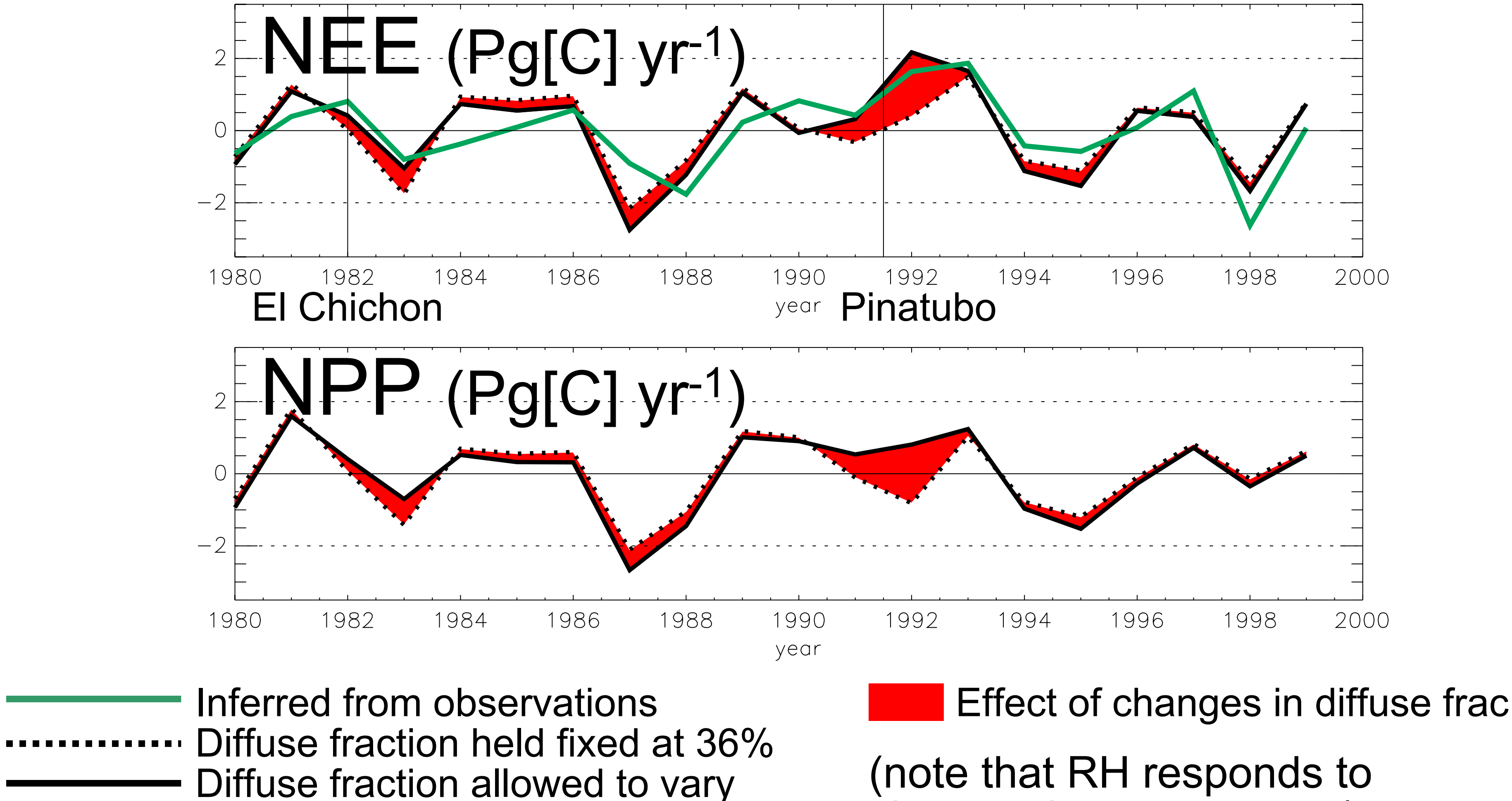
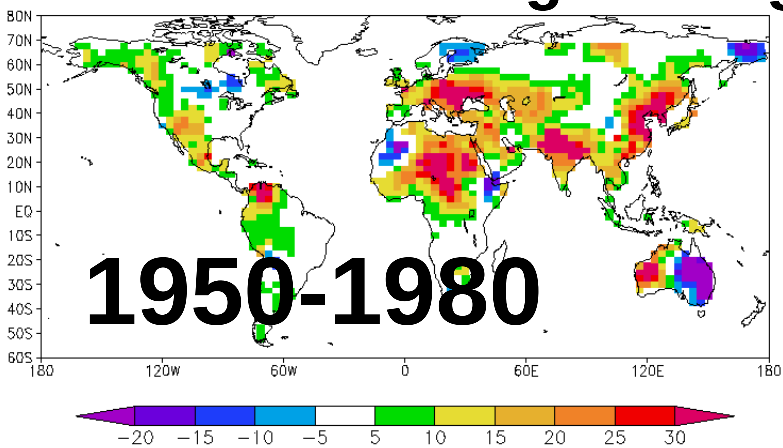
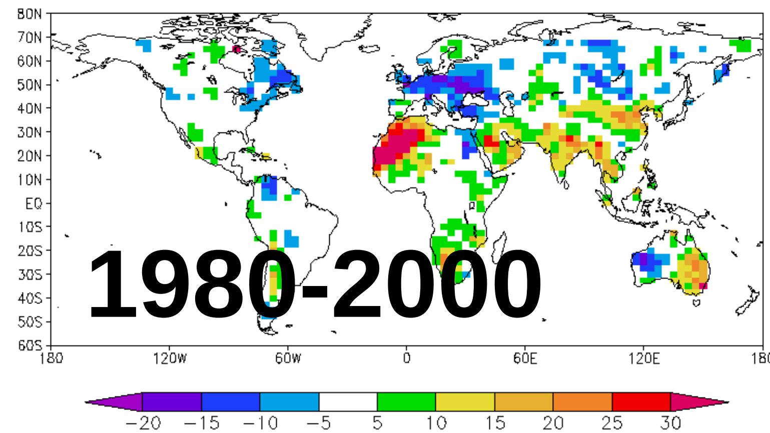


(note that RH responds to changes in temperature.)

Impact of diffuse fraction variations: global dimming

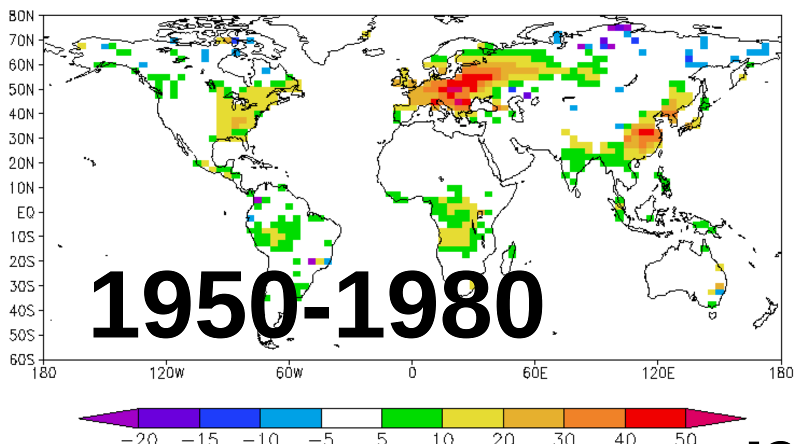
Percentage change in diffuse fraction

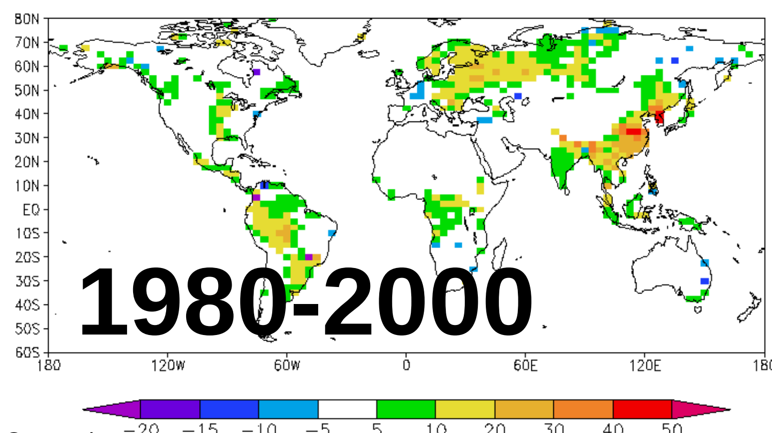




%

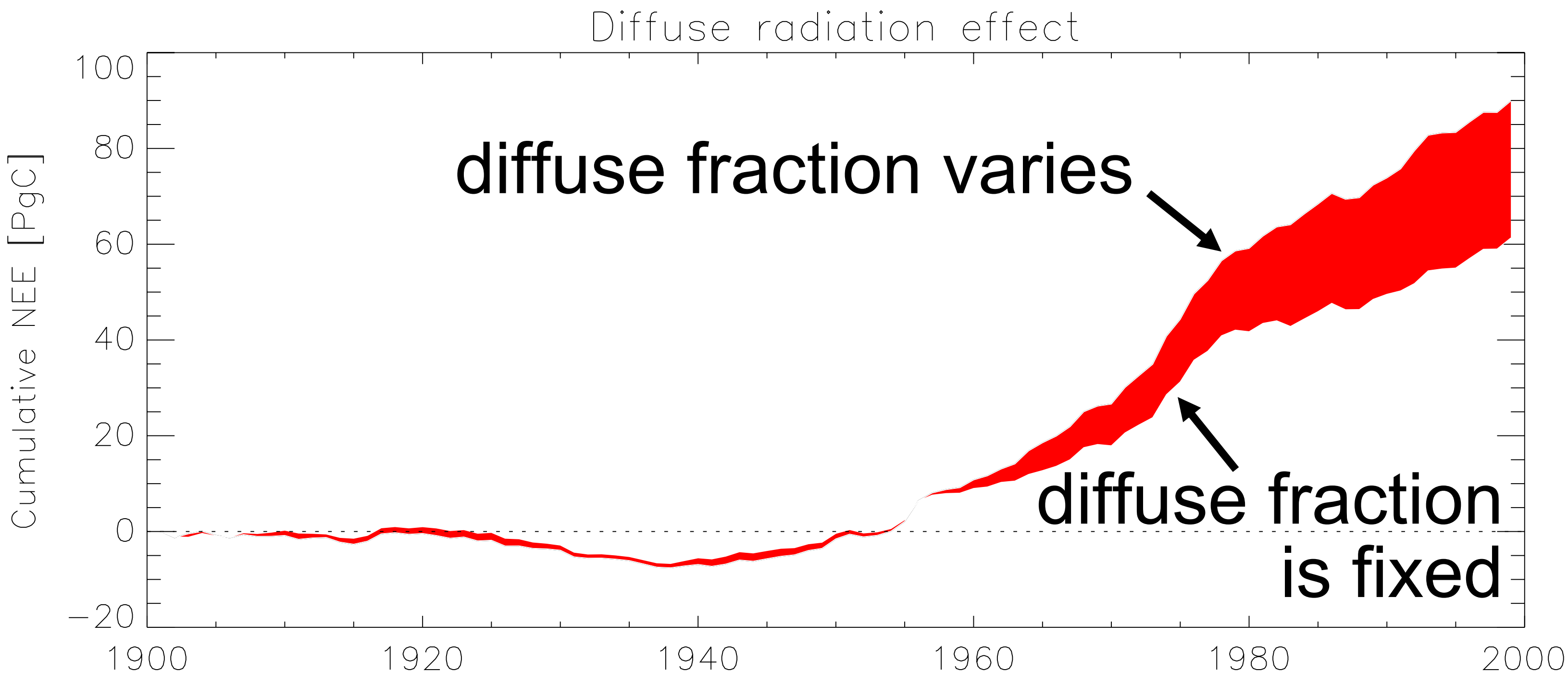
Contribution of diffuse frac variation to land carbon accum





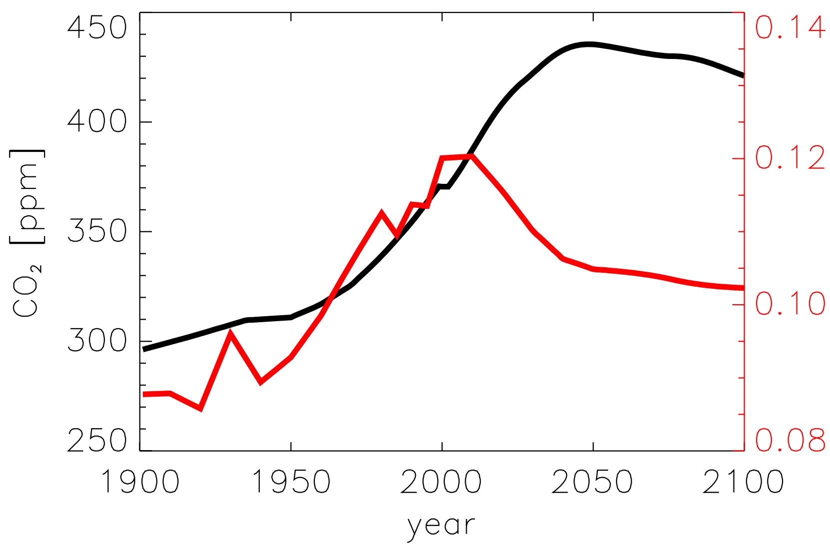
g[C]$m^{-2}yr^{-1}$

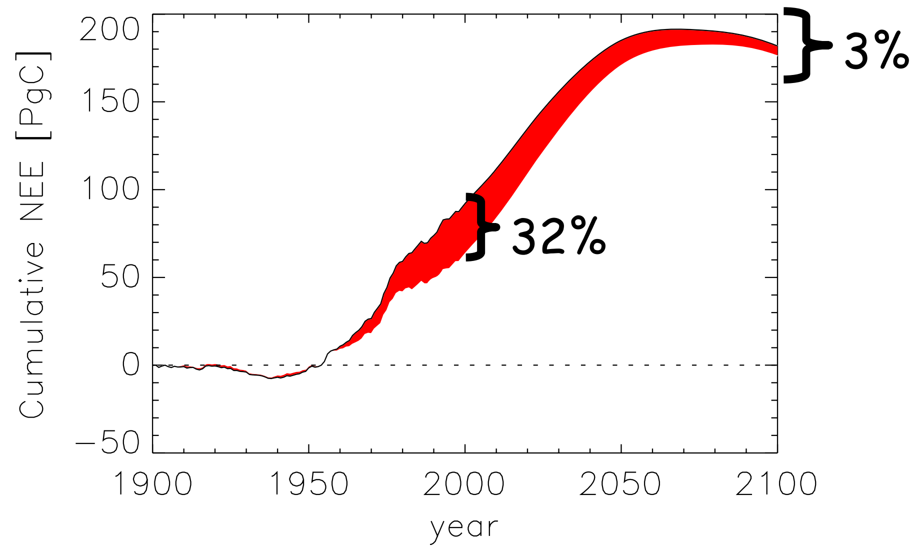
Impact of diffuse fraction variations: 20th century



32% of accumulated land carbon sink due to diffuse radiation effects on photosynthesis

Impact of diffuse fraction variations: 21st century





- Scenario ENSEMBLES A1B-450 (stabilisation at 450 ppmv CO_2 equiv)
- SU, FFBC, FFOC decreased
- DU, BB, stratospheric, cloud cover fixed at 2000 level

Summary

- The fertilisation effect of diffuse radiation contributes largely to the observed increase in land carbon sink after the Pinatubo eruption.
- Global dimming and brightening contributed to decrease and increase the land carbon sink, respectively.
- The diffuse radiation contribution to the land carbon sink will decrease under decreased aerosol emissions.

GEMS aerosol products

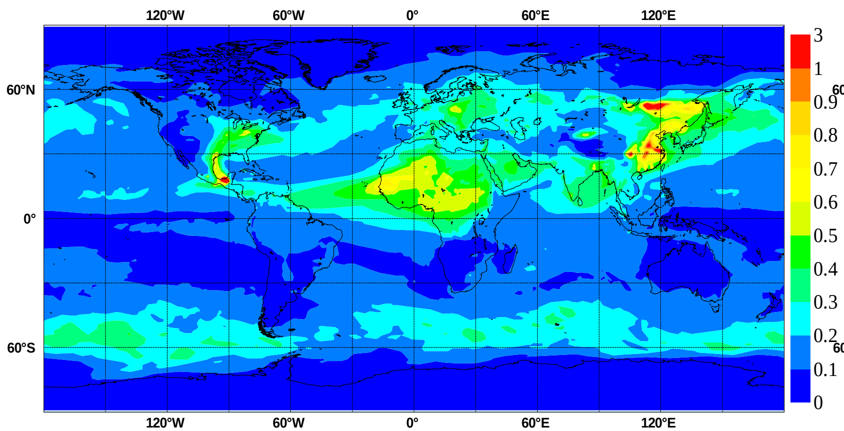
GEMS → MACC → GMES (Kopernikus) Atmospheric Service

- GHG, GRG, aerosols, air quality
- Aerosol model with the ECMWF IFS framework (12 variables*, emissions, transformation, sinks)
- 4D-VAR assimilation of MODIS data (1 variable: total AOD)
- Near-real-time forecast (with and without DA)
- Re-analysis for 2003-2008 (with DA)

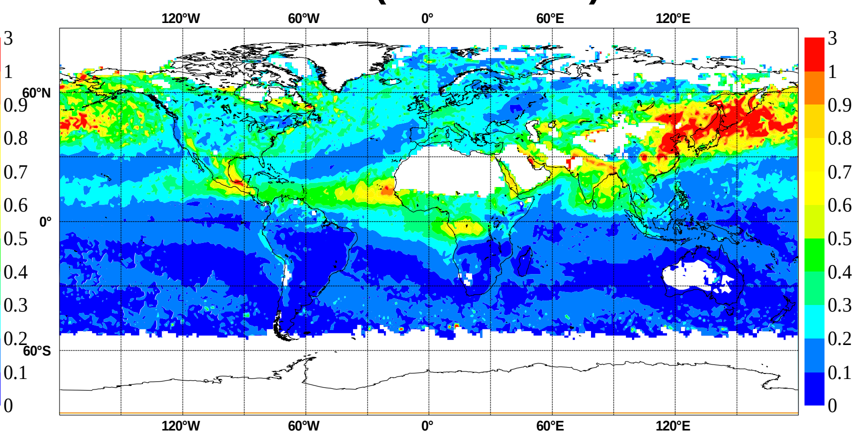
* 1SU, 1DMS+SO_2, 2OC, 2BC, 3DU, 3SS

GEMS: Comparisons with MODIS and MISR optical depth for May 2003

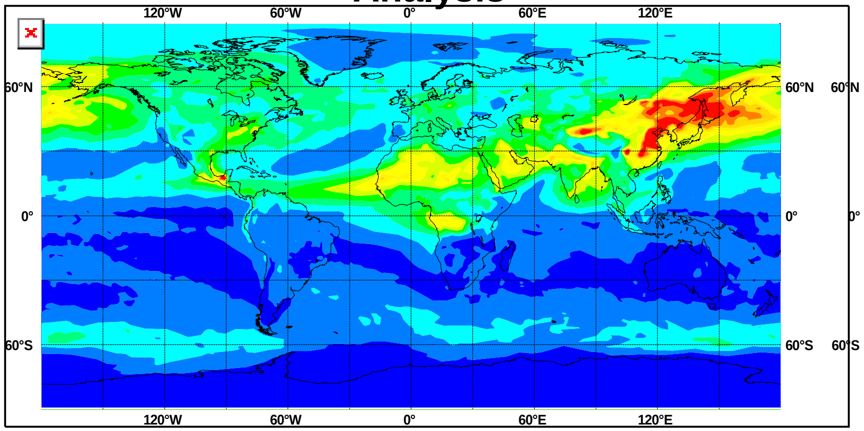
Free-running model



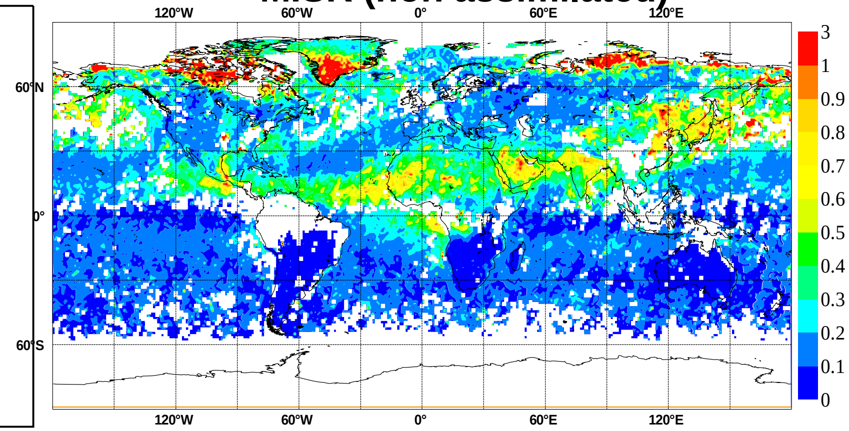
MODIS (assimilated)



Analysis



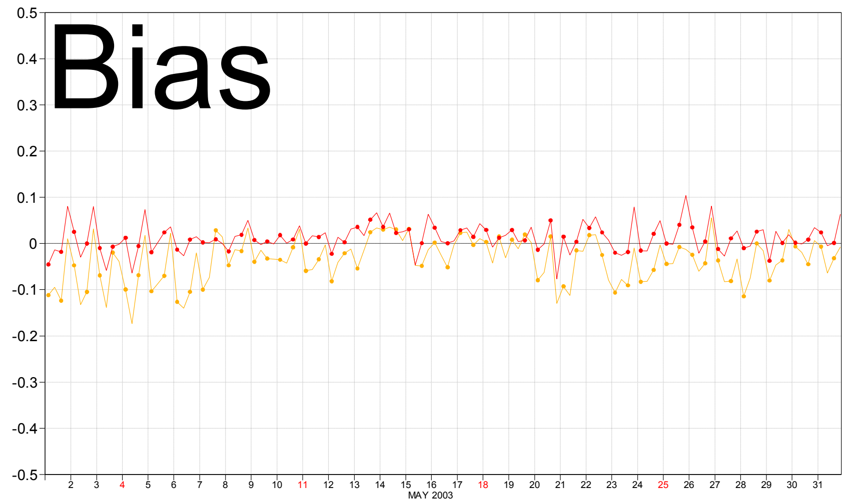
MISR (non assimilated)



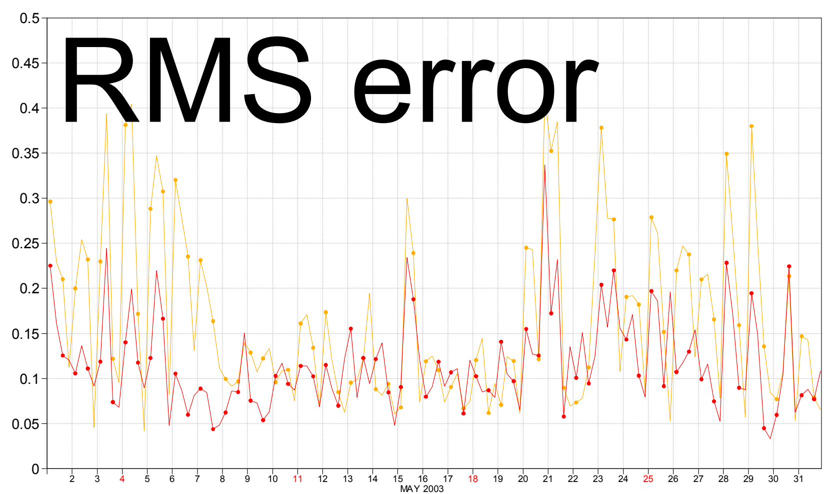
Courtesy: Jean-Jacques Morcrette and Angela Benedetti, CEPMMT, 2008.

Comparisons with AERONET independent data (May 2003)

FC-OBS Bias. Model AOT at 550nm against L2.0 Aeronet AOT at 500nm.
Meaned over 41 sites globally. Period=1-31 May 2003. FC start hrs=00,12Z.



RMS Error. Model AOT at 550nm against L2.0 Aeronet AOT at 500nm.
Meaned over 41 sites globally. Period=1-31 May 2003. FC start hrs=00,12Z.



Analysis

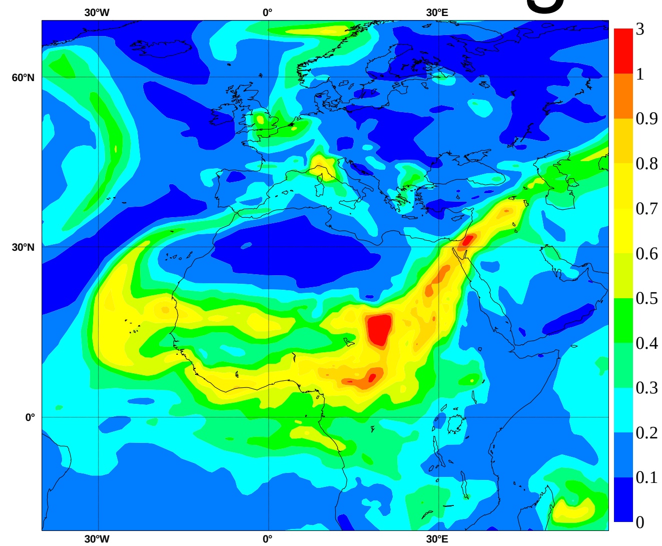
Free-running forecast

Analysis shows lower bias and lower RMS wrt AERONET optical depths than free-running model

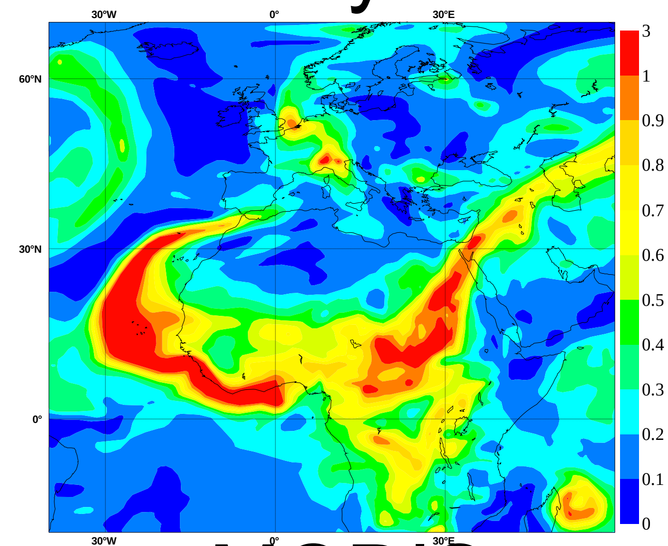
Courtesy: Angela Benedetti, CEPMMT, 2008.

Case study: Saharan dust event (6th March 2004, 1200UTC)

Free-running



Analysis

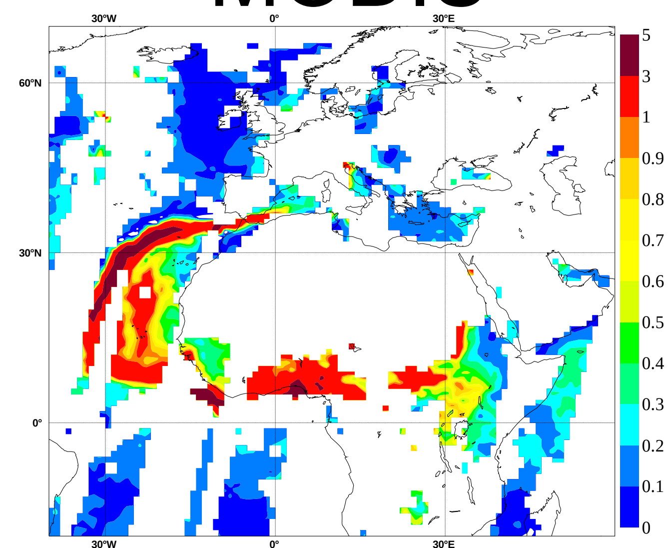


- **Comparison of AOD from the analysis and that from the free-running forecast shows larger values of AOD in agreement with (assimilated) MODIS data.**

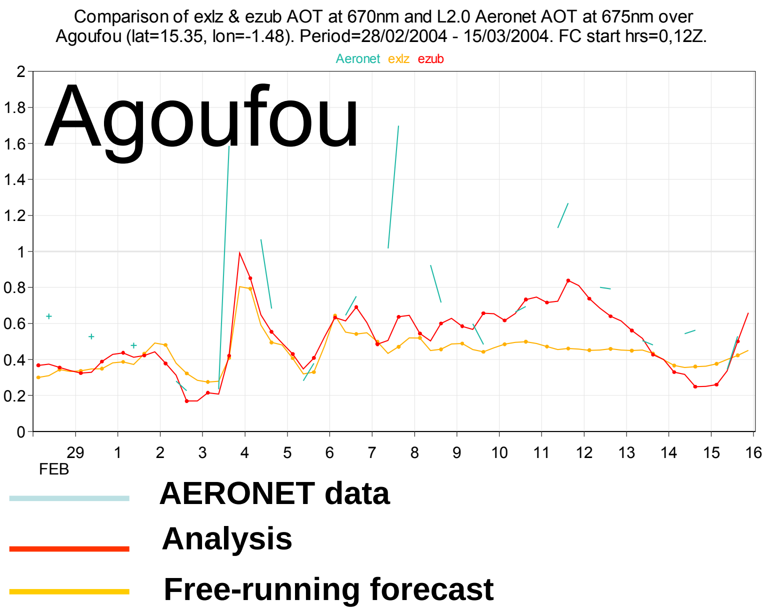
- **The shape of the dust outflow is well-represented also in the free-running forecast.**

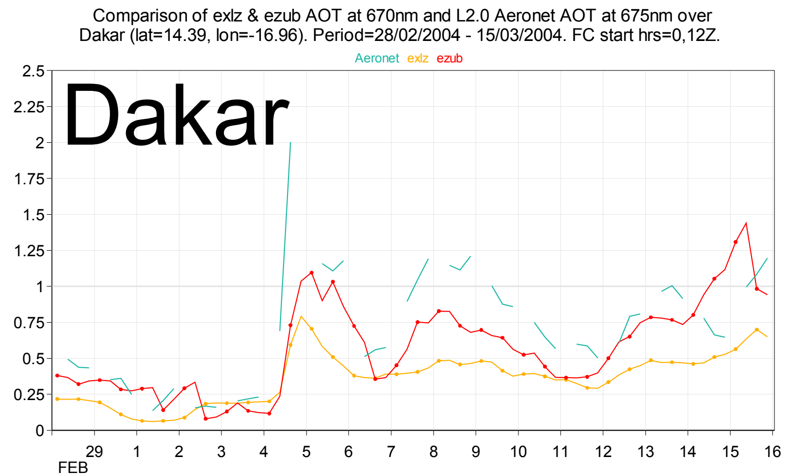
Courtesy: Angela Benedetti, CEPMMT, 2008.

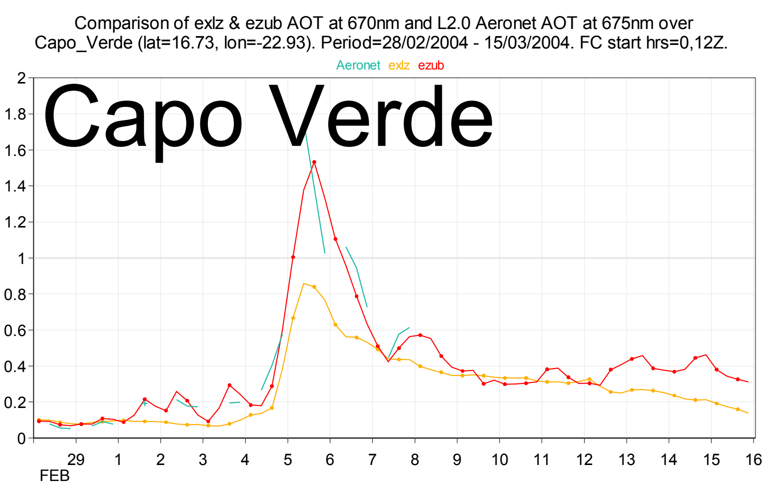
MODIS



Case study: Saharan dust event (March 2004)







- **Dust peaks are more pronounced in the analysis than in the free-running forecast, especially for the Cape Verde site, indicating a positive impact of the assimilation of MODIS aerosol optical depths on the forecast of the dust event.**

Courtesy: Angela Benedetti, CEPMMT, 2008.

Future work

- Assimilation of a second variable from MODIS: fine-mode fraction. Impact on speciation.

- Downstream products: monitoring of aerosol radiative forcings.

Met Office

Questions and answers

HadGEM2-A simulation of 20th-century aerosols