Atmospheric aerosol research at the U.K. Met Office Hadley Centre

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5th AeroCom Workshop 17-19 October 2006 Virginia Beach

Contents

The presentation covers the following sections

Aerosols in the improved HadGEM1

- Modelling
- Comparison against observations

- Observation-based estimates of the direct forcing
  - Differences between modelled and observation-derived direct forcing

Improved HadGEM1

- Hadley Centre Global Environmental Model vn1
- Based on the Unified Model vn6.1
  - Non-hydrostatic dynamical core
- Main improvements:
  - El Nino Southern Oscillation
  - Decreased North Hemis. summer warming bias
  - Improved aerosol representations
- Runs at N96L38 (1.25°x1.875°)
- 2 years/days for the coupled model on the NEC SX8
- No nudged or guided mode (own meteorology)

Aerosol modelling: SU, BB, BC

- Sulphate
  - Emissions from oxidised DMS, anthropogenic SO_2 and volcanic SO_2 (resp. Spiro *et al.* [1992] and Kettle *et al.* [1999], Smith [2004], and Andres and Kasgnoc [1998])
  - Oxidation of SO_2 by OH (dry) and H_2O_2 (wet)
  - Aitken, accumulation and dissolved modes with 5 intermodal processes
  - Hygroscopic growth from Fitzgerald [1975]

- Biomass-burning
  - Emissions from AeroCom [van der Werf 2003] into a fresh mode
  - Ageing into an aged mode with e-folding time of 6 hours
  - Increase of mass upon ageing to represent condensation of VOCs
  - Hygroscopic growth from Magi and Hobbs [2003]

- Black carbon
  - Emissions from Cooke *et al.* [1999] into a fresh mode
  - Ageing into an aged mode with e-folding time of 1 day

Aerosol modelling: SS, DU, SOA

- Sea salt
  - Number concentration from 10-m windspeed [O'Dowd 1997, 1999] for film and jet modes
  - Not transported
  - Hygroscopic growth from Fitzgerald [1975] and Tang *et al.* [1977]

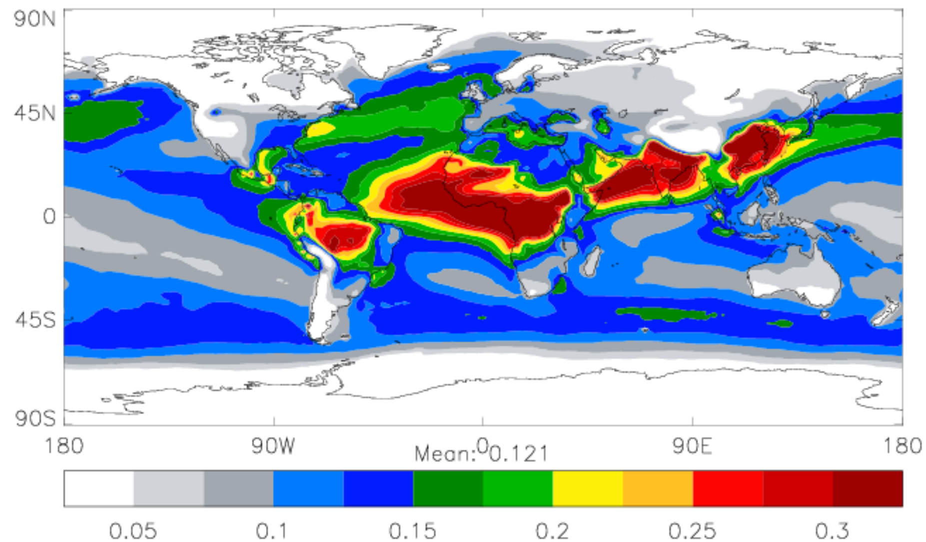
- Mineral dust
  - Sources from friction velocity, soil moisture, and vegetation [Woodward 2001]
  - 6 size bins from 0.03 to 30 μm

- Secondary organic aerosol
  - Non-interactive, monthly climatology from isoprene and terpene distributions (STOCHEM)
  - Size distributions from AERONET sites in Central Russia, refractive index from Lund-Myhre and Nielsen [2004], density from Bahreini *et al.* [2005]
  - Hygroscopic growth from Varutbangkul *et al.* [2006]

Aerosol burdens and optical depths

	Burden (mg m^{-2})		Optical depth (0.55 μm) in 2000	
Sulphate	3.7 [SO_4]	3.9 [1.8 – 5.3]	0.021	0.034 [0.015 – 0.051]
Biomass burning	2.4	3.7 [1.0 – 5.5]	0.017	0.024 [0.008 – 0.036]
Black carbon	0.5		0.003	
Sea salt	49.2	12.6 [4.8 – 25.8]	0.053	0.030 [0.020 – 0.067]
Mineral dust	13.4	39.1 [8.8 – 57.8]	0.019	0.032 [0.012 – 0.054]
Secondary organic	2.2	(n/a)	0.008	(n/a)
Total incl. SOA Total excl. SOA	71.4 69.2	56 [34 – 92]	0.121 0.113	0.127 [0.097 – 0.151]

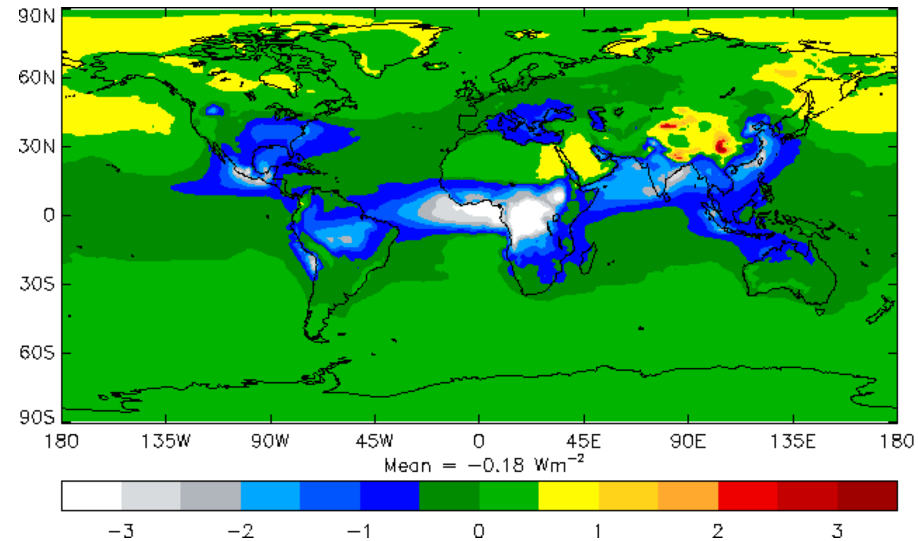
Total optical depth and forcings

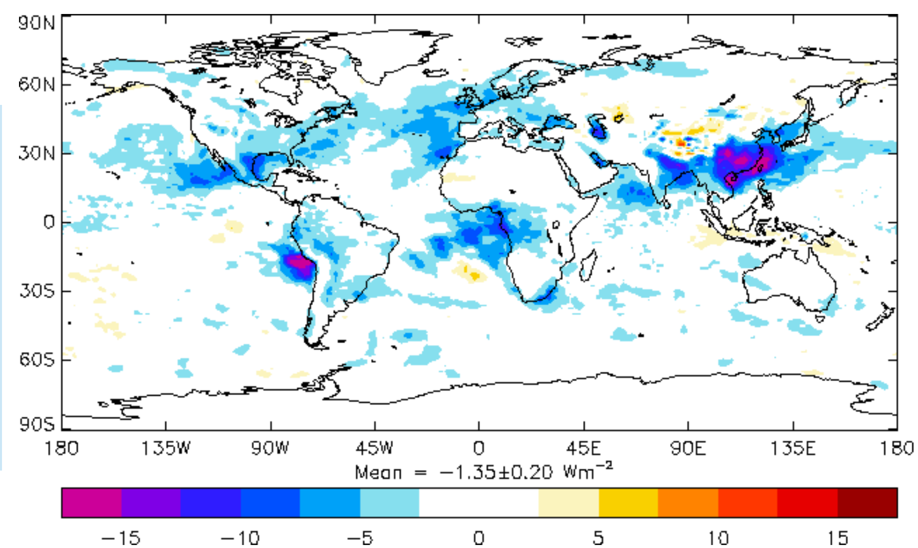


Optical depth at 0.55 µm

$\tau_{0.55}$ (present-day): 0.121
$\tau_{0.55}$ (pre-industrial): 0.093 (–0.028)

Forcing w.r.t. pre-industrial conditions (1860):
SW+LW Direct: –0.18 Wm^{-2}
SW+LW Direct and indirect: –1.35 Wm^{-2}

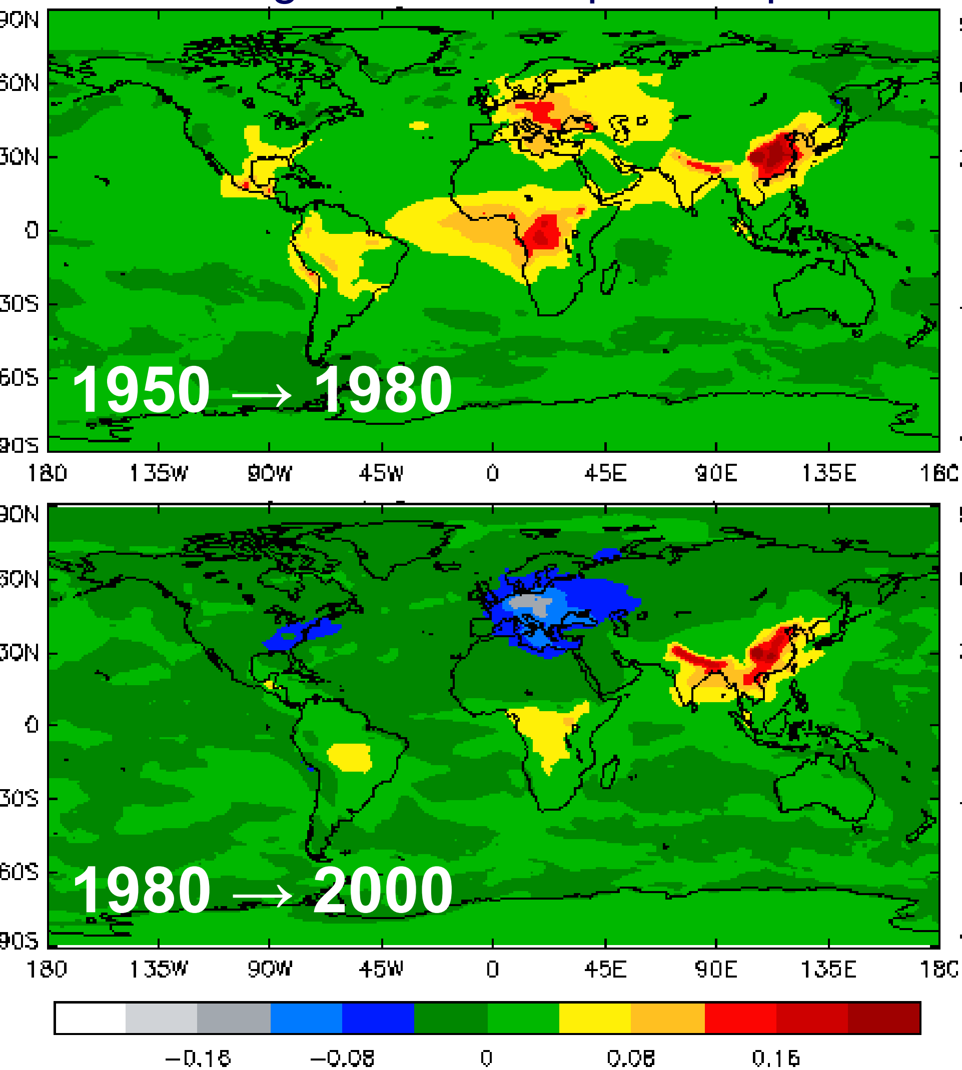




Direct (top) and total (bottom) RF

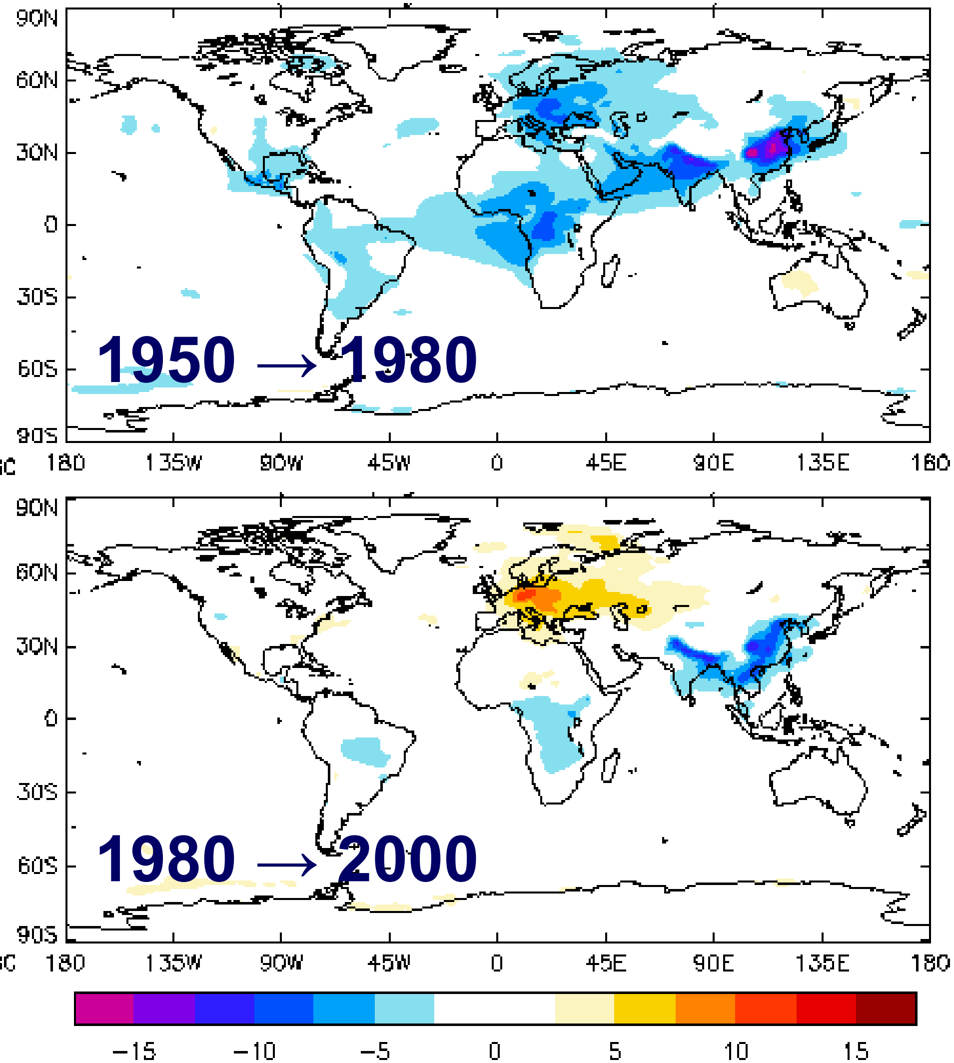
"Dimming" (in clear sky)

Change in aerosol optical depth



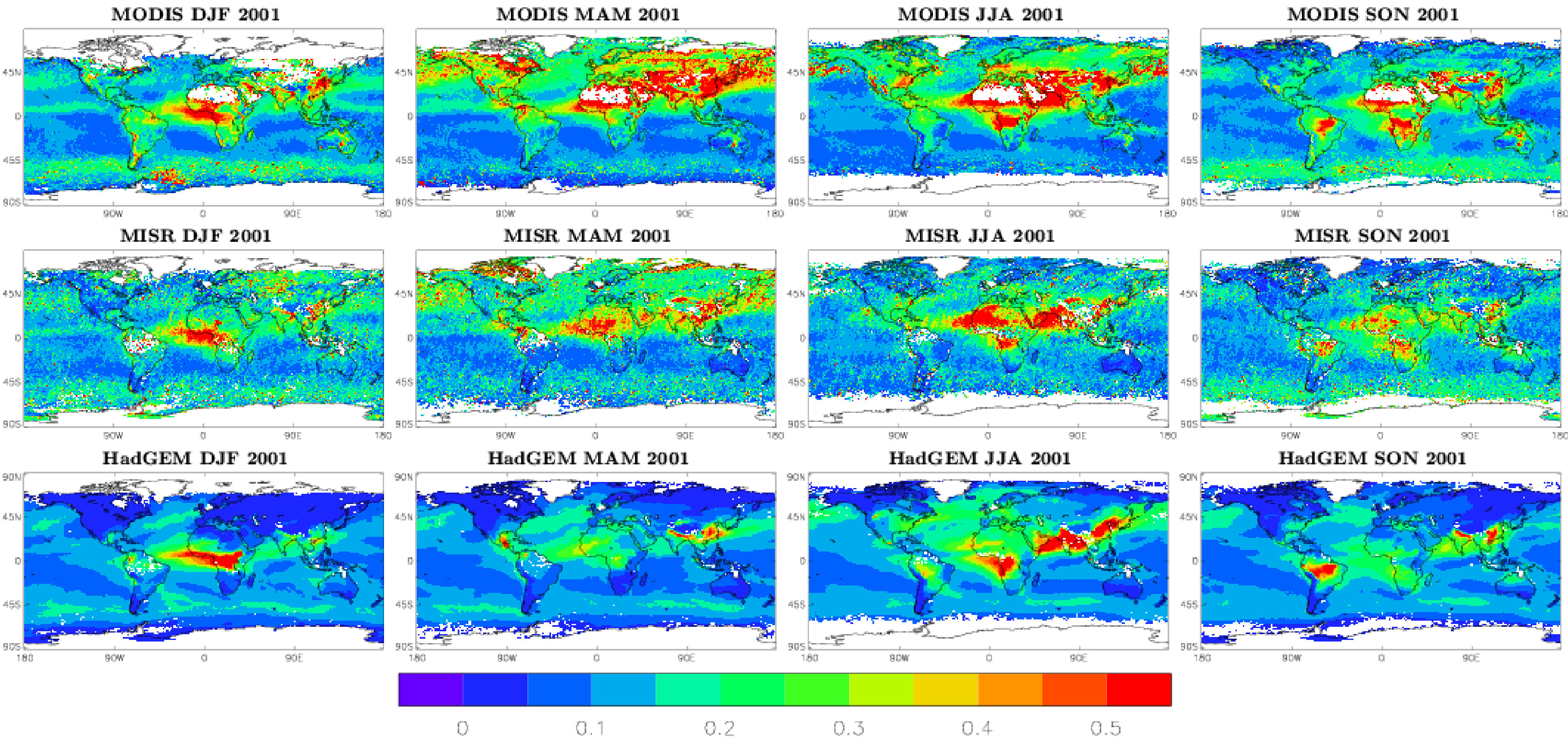
at 0.55 μm

Change in clear-sky shortwave flux at the surface



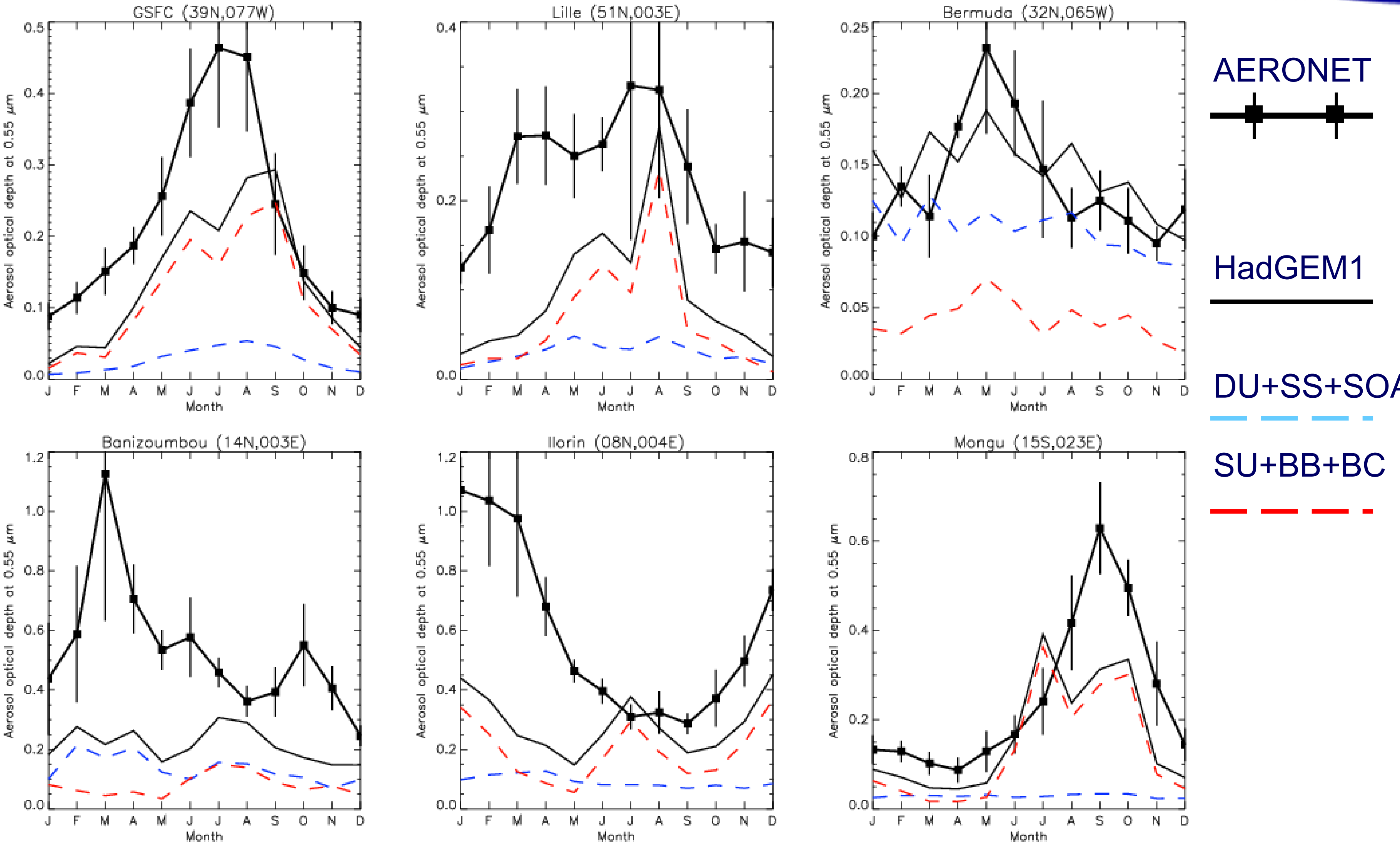
Wm^{-2}

Comparison against satellite retrievals

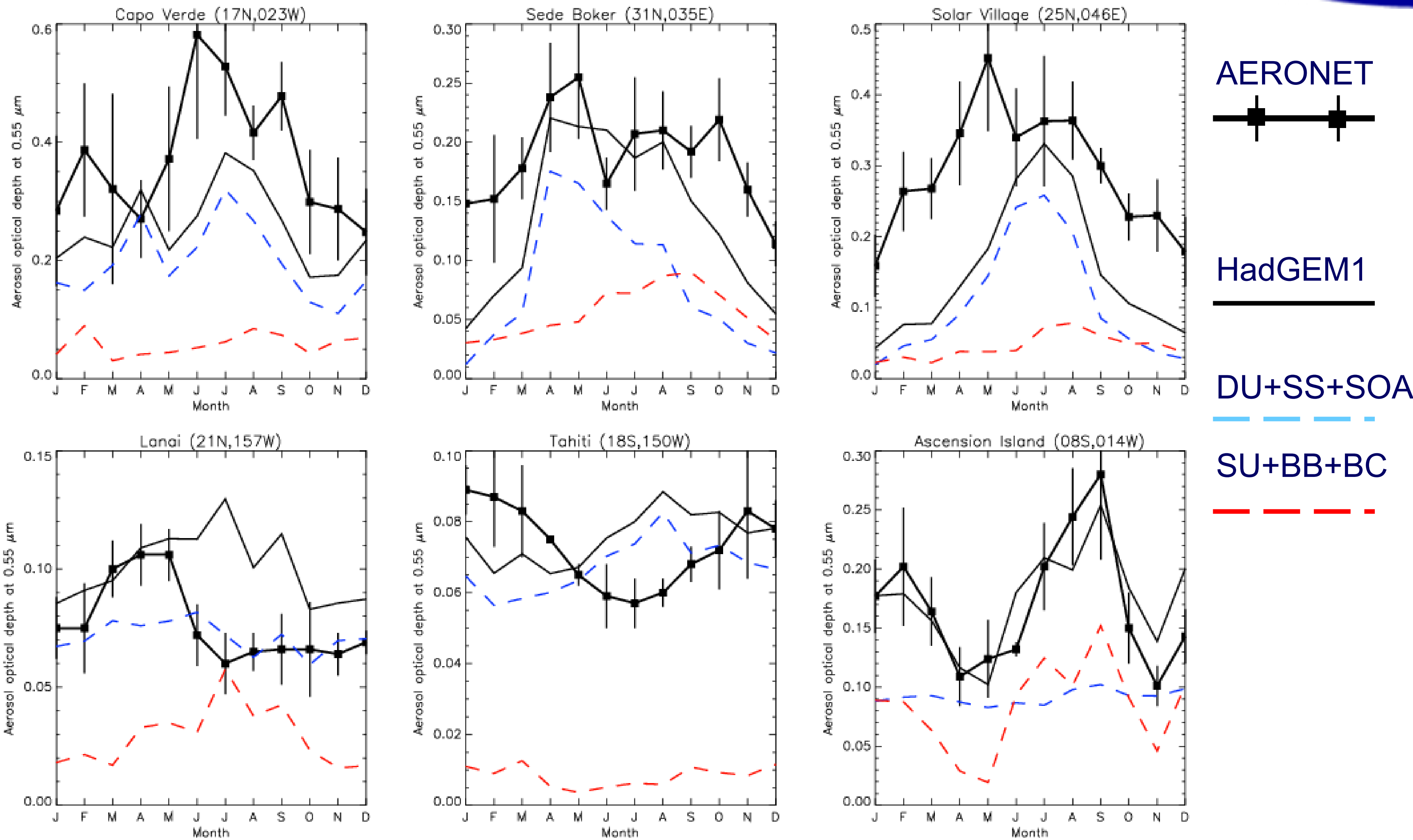


Optical depth at 0.55 μm

Comparison against AERONET climatology (1/2)

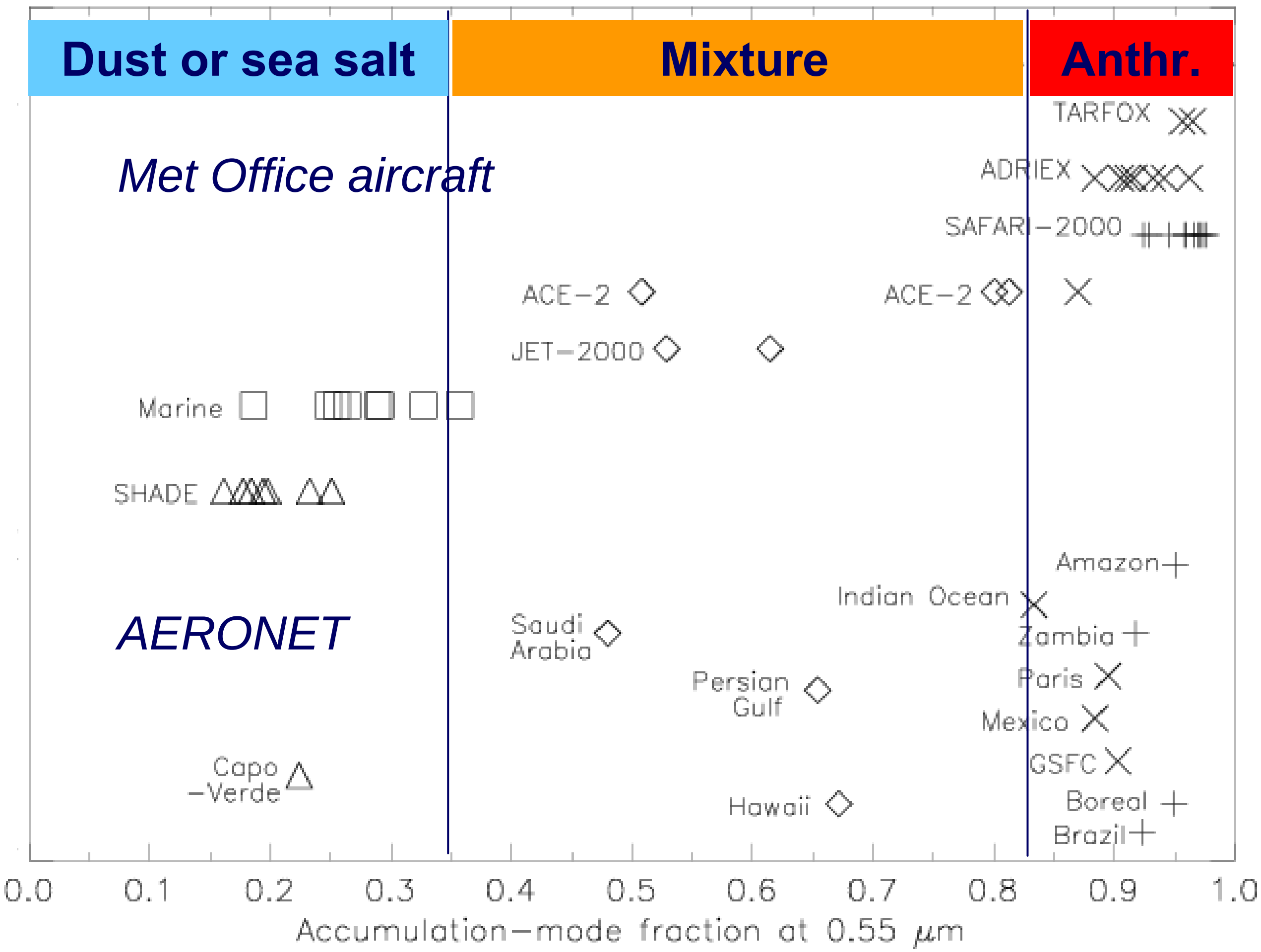


Comparison against AERONET climatology (2/2)



Observation-based estimates of the direct forcing

The accumulation-mode fraction



Bellouin *et al.* [2005]

Applied to MODIS (ocean):

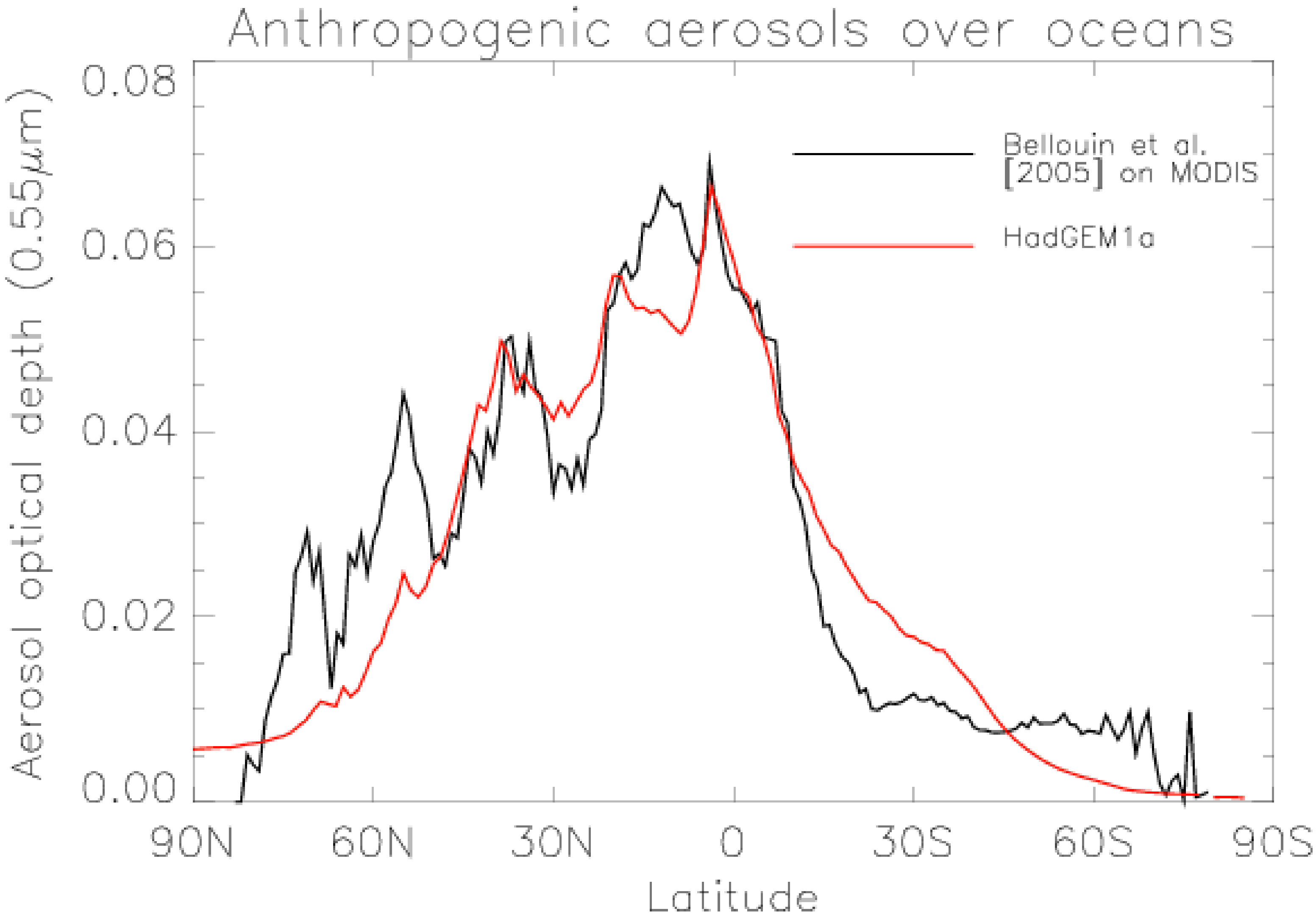
AMF > 0.83 ± 0.05
Industrial or biomass (from location)

AMF in [0.35, 0.83] ± 0.05
If TOMS detection, mixed dust and biomass
If not, sea salt

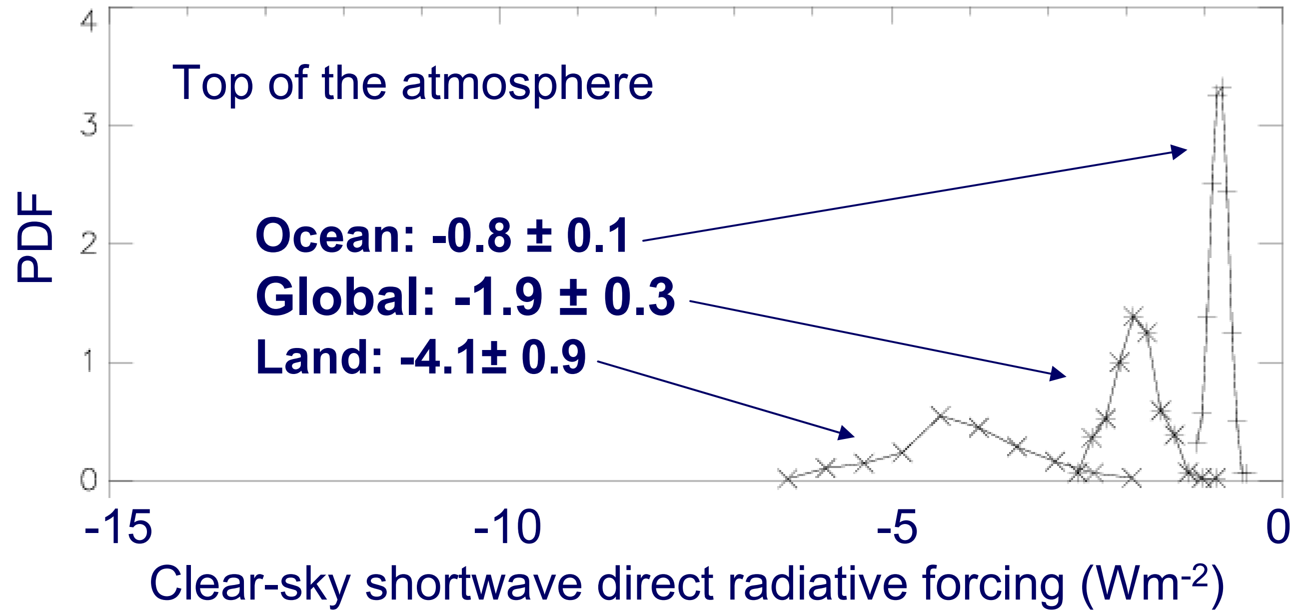
AMF < 0.35 ± 0.05
If TOMS detection, mineral dust
If not, sea salt

Over land, no AMF: replaced by anthropogenic fraction from AeroCom models

Anthropogenic aerosols over oceans



Observation-based and modelled direct forcings



Clear-sky DRF from AeroCom: –0.3 to –0.9 Wm^{-2} [Schulz *et al.* 2006]

Bellouin *et al.* [2005]: "*The DRF may be significantly larger than current model estimates*".

But: - Overestimated AOD over land from MODIS (cf. MISR)?

- Are we talking about the same thing?

Defining the direct forcing: impact

Met Office

Radiative perturbation (TOA): $\Delta F = F\uparrow_{reference} - F\uparrow_{perturbed}$

Over clear-sky oceans, shortwave only:

	Reference aerosols	Perturbed aerosols	MODIS		HadGEM	
			$\Delta\tau$	ΔF	$\Delta\tau$	ΔF
1	None	Present-day	0.143	-6.8	0.123	-4.1
1a	None	Anthrop.	0.028	-1.1	0.022	-0.6
2	Natural	Present-day	0.028	-0.8	0.022	-0.6
3	Pre-indus.	Present-day			0.018	-0.5

Bellouin *et al.* [2003] use (1), Bellouin *et al.* [2005] use (2), Schulz *et al.* [2006] use (3).

- MODIS 1a v. 2: Large differences due to relative vertical profiles
- MODIS 1a v. HadGEM: Optical depth, size distributions, optical properties, surface albedo, … Which is most significant?

Summary and things to come

- Aerosols are behaving well in the improved HadGEM1

- Next addition to the model: Fossil-fuel organic carbon aerosols

- UK Chemistry and Aerosol module
  - Interactive chemistry (including stratosphere)
  - M7-like aerosols

- Bellouin *et al.* [2006/7] on comparing modelled and observation-based direct radiative forcings

Questions & Answers