Satellite versus GCM comparison of aerosol direct radiative forcing

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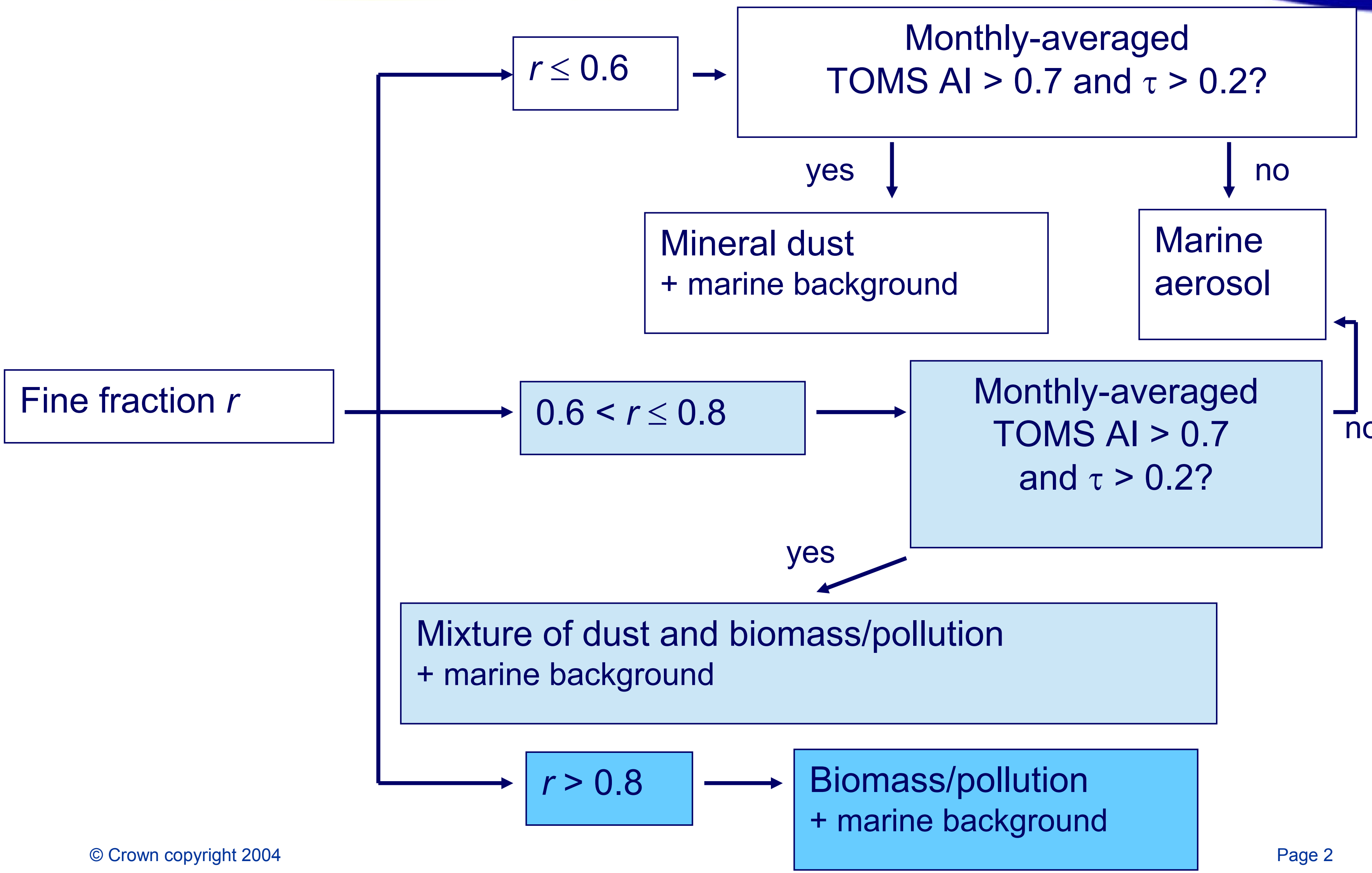
Presentation to AEROCOM meeting - Oslo - 15-17 June 2005

The MODIS algorithm over clear-sky oceans



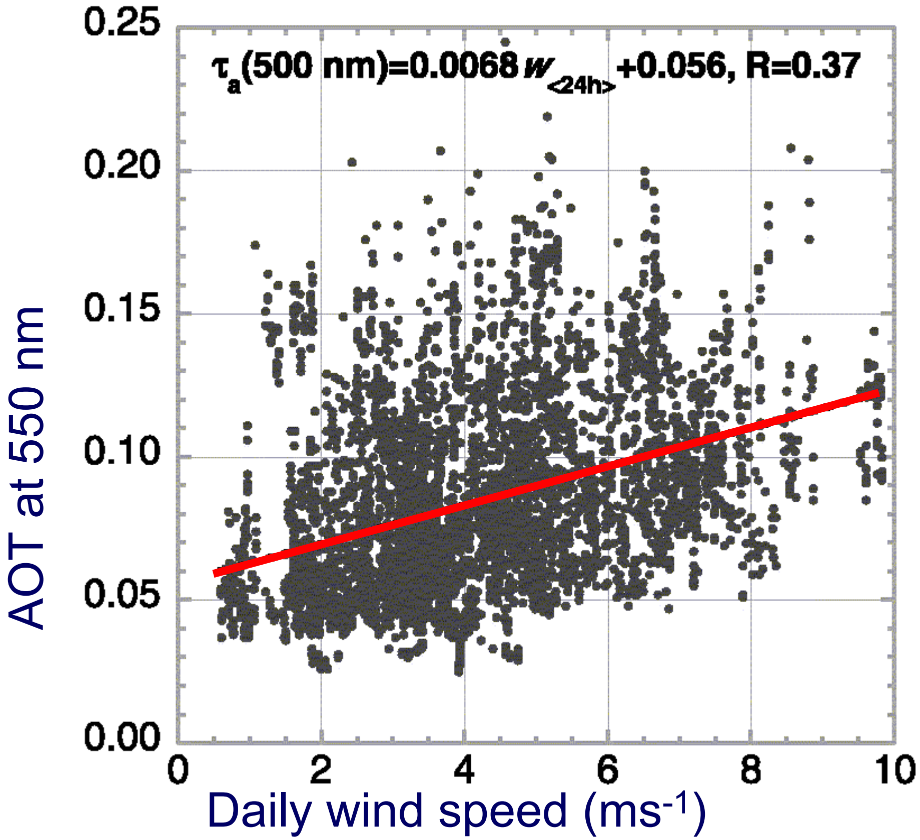
In-situ measurements of r

Measurements from the Met Office C-130
Osborne and Haywood, *Atmos. Res.*, 2004

Experiment	Aerosol type	*r*
SHADE	Mineral dust	0.67
SAFARI 2000	Aged biomass-burning (over ocean)	0.97
	Fresh biomass-burning (over land)	0.95
TARFOX	Industrial pollution	0.88
ACE-2	Industrial pollution, mixed with marine aerosol	0.60
---	Marine aerosol	0.16

The marine aerosol background

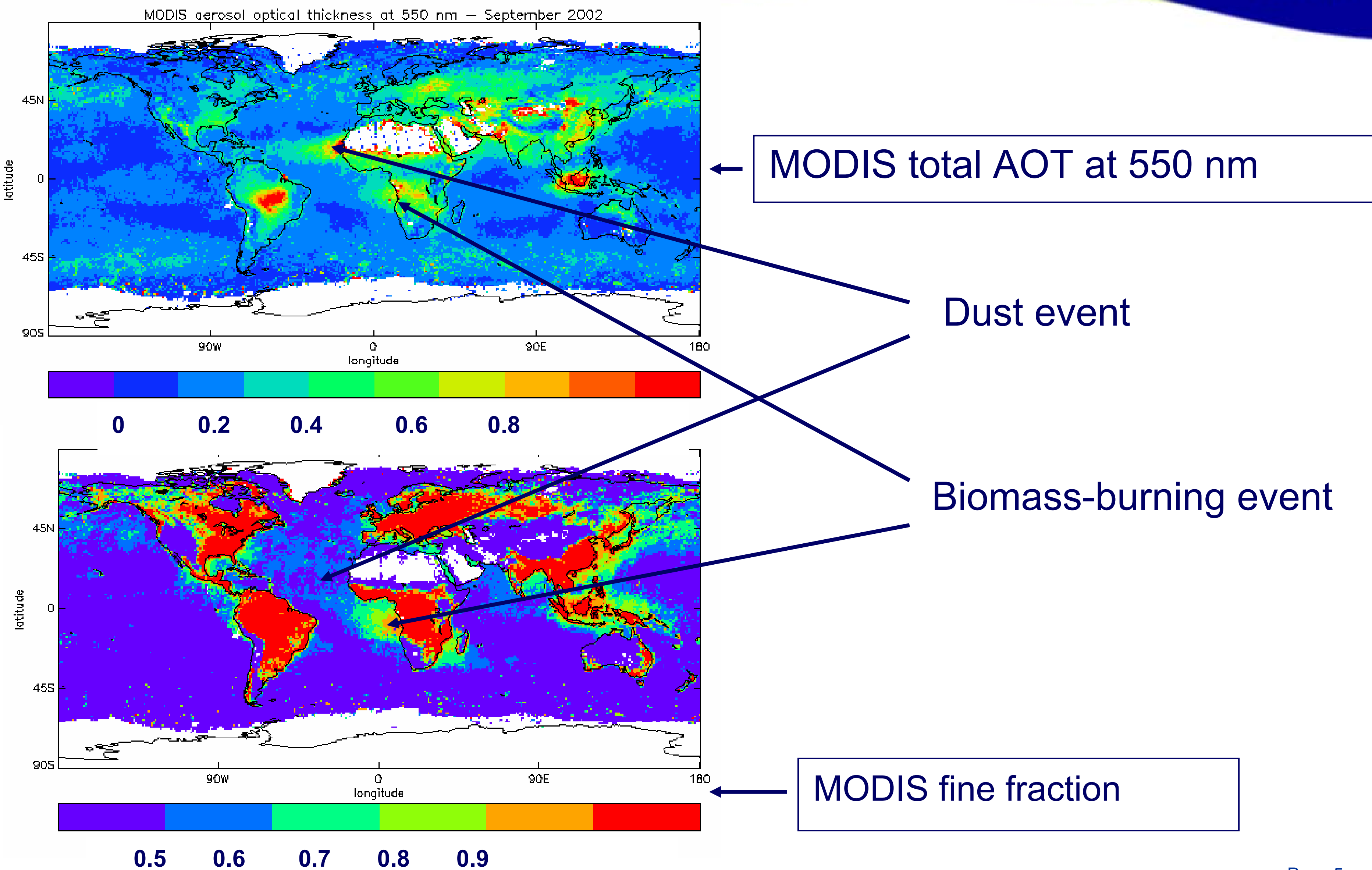
Get a *sensible* estimate of the marine aerosol OT when dust or biomass/pollution is identified.



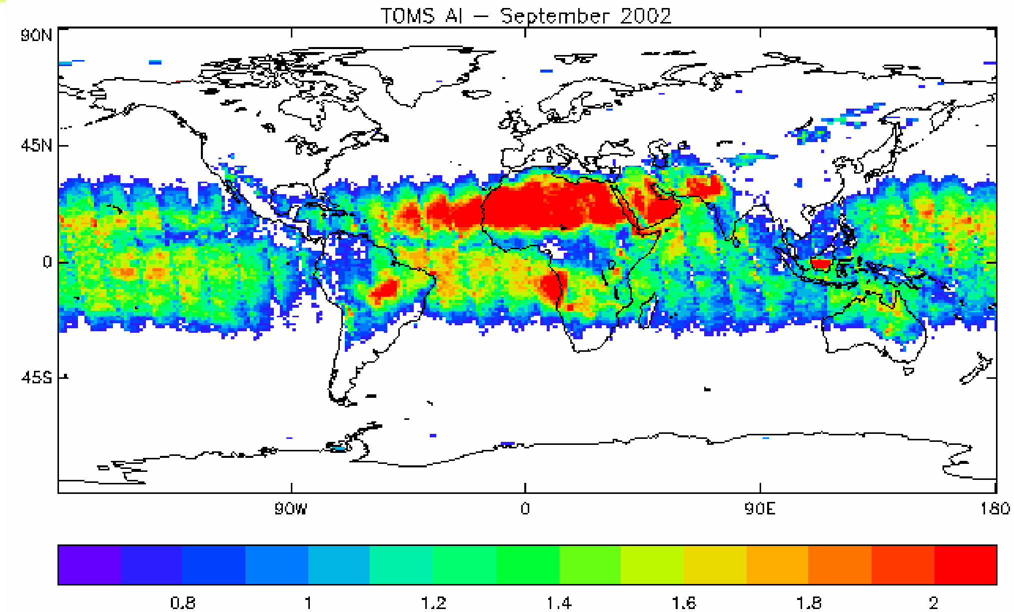
Linear relationship from Smirnov et al., *JGR, 2003*

In the algorithm, wind speeds are provided by SSM/I.

The MODIS algorithm: MODIS data

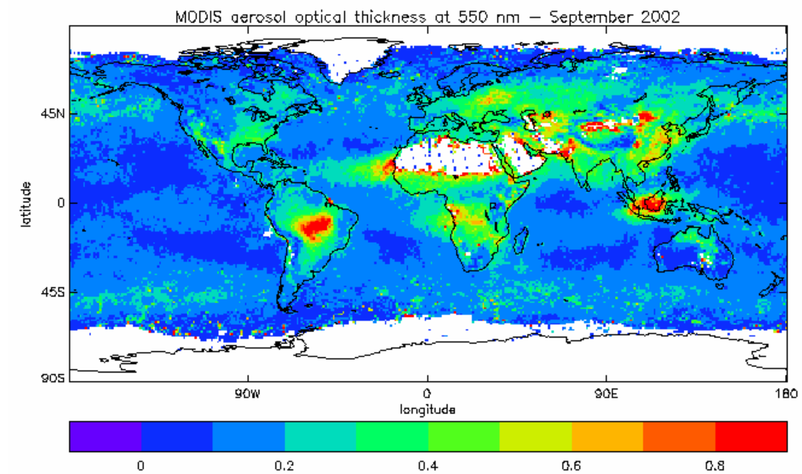


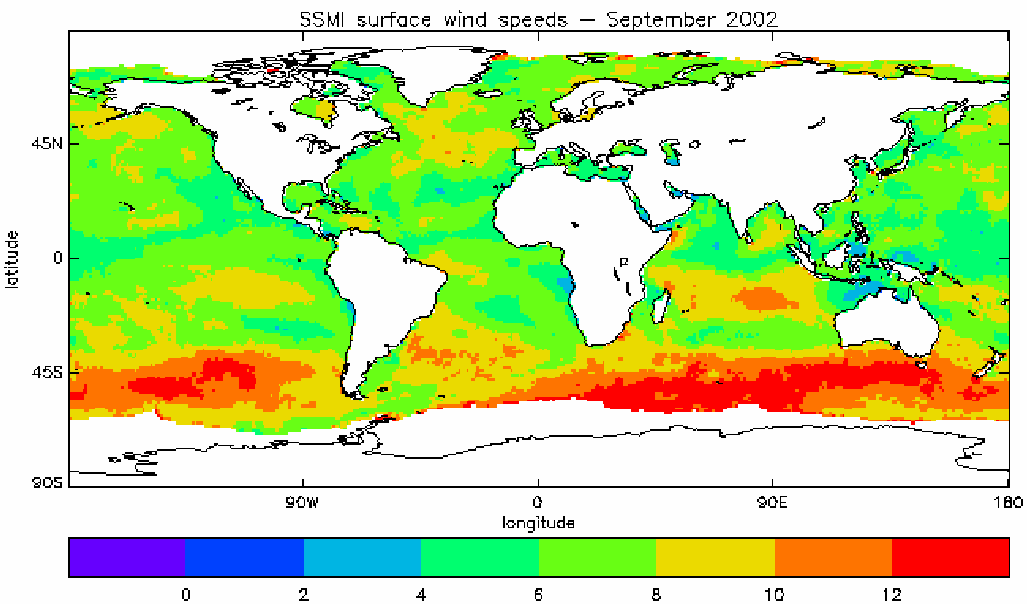
The MODIS algorithm: other input data



TOMS Aerosol Index

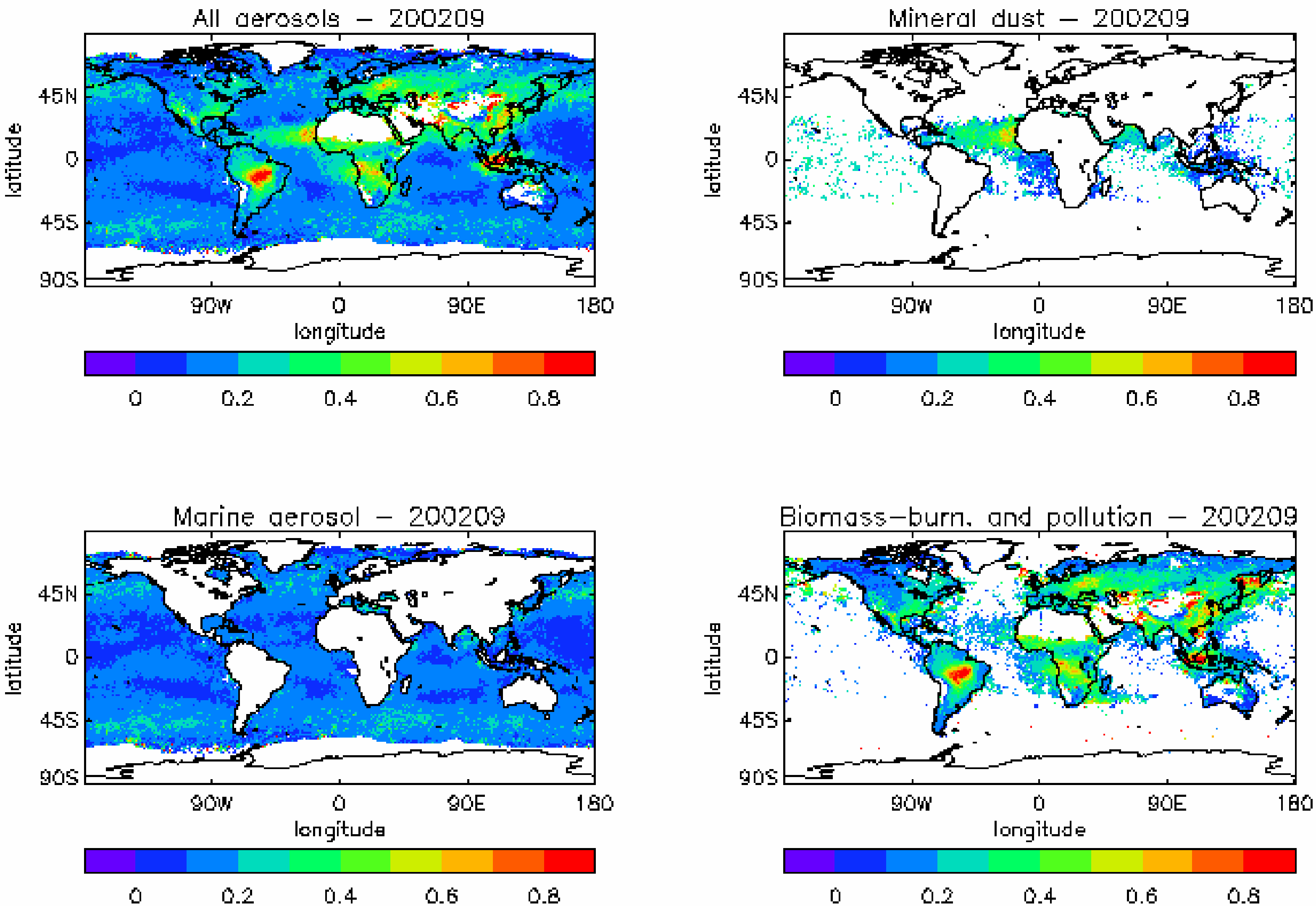
MODIS τ_{550}





SSM/I wind speeds

The MODIS algorithm: September 2002



From AOD to aerosol RF

Aerosol model:
- size distribution
- refractive index
(from AERONET)

Mie theory (24 λ)

$\tau(\lambda)$, $\omega_0(\lambda)$, $P(\Theta,\lambda)$

Aerosol optical thickness of a given aerosol type (from MODIS)

Radiative transfer code

Surface albedo (VIS & near IR)

DARF ΔF
- instantaneous or daily-averaged
- at the TOA or surface

AERONET measurements of aerosol SSA

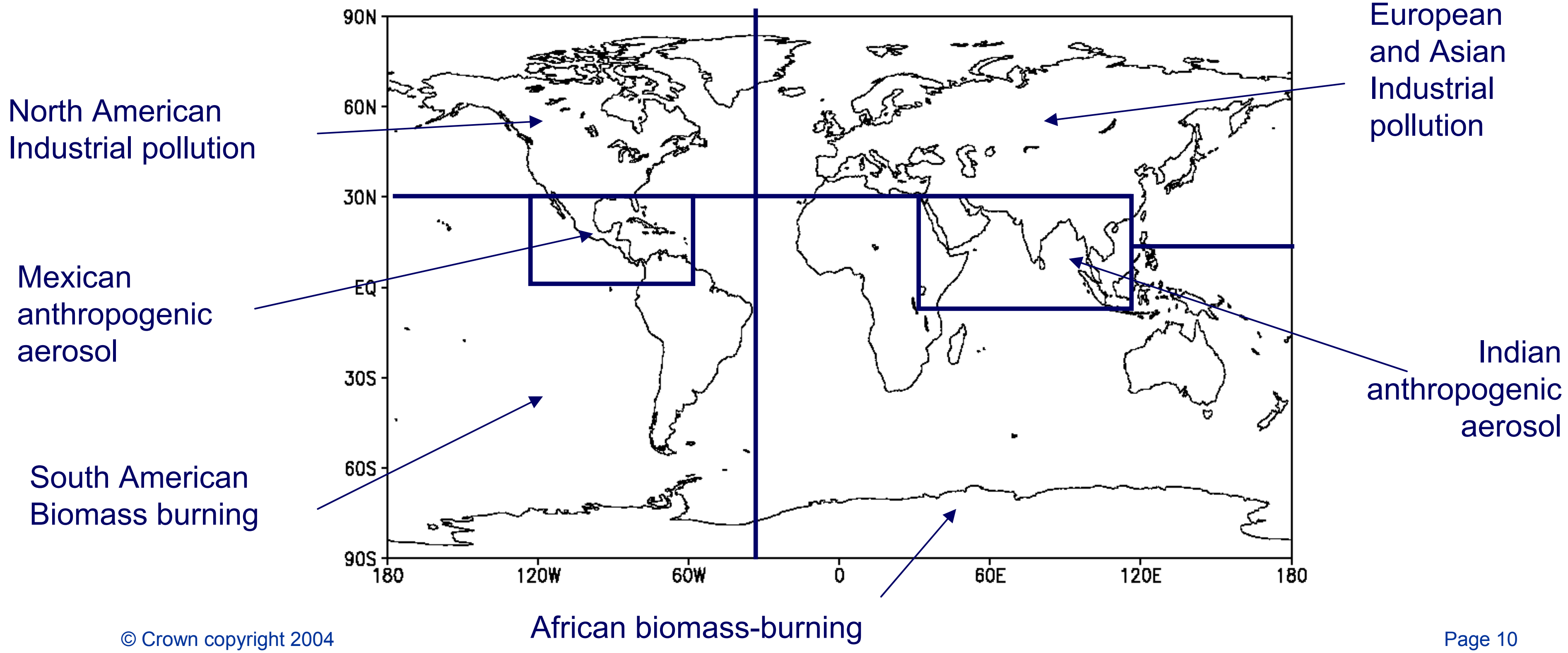
Aerosol optical properties

Aerosol	AERONET site	ω_0 at 550 nm
Dust	Cape Verde	0.97
Marine aerosol	Hawaii	0.98 **(0.99)**
Industrial pollution	Greenbelt, USA	0.97
Industrial pollution	Créteil, France	0.93
Industrial pollution, biomass-burning	Mexico City, Mexico	0.88
Industrial pollution, biomass-burning	Maldives (INDOEX)	0.89
Biomass-burning	Brazil	0.90
Biomass-burning	Zambia	0.86

Dubovik et al., *JAS*, 2002

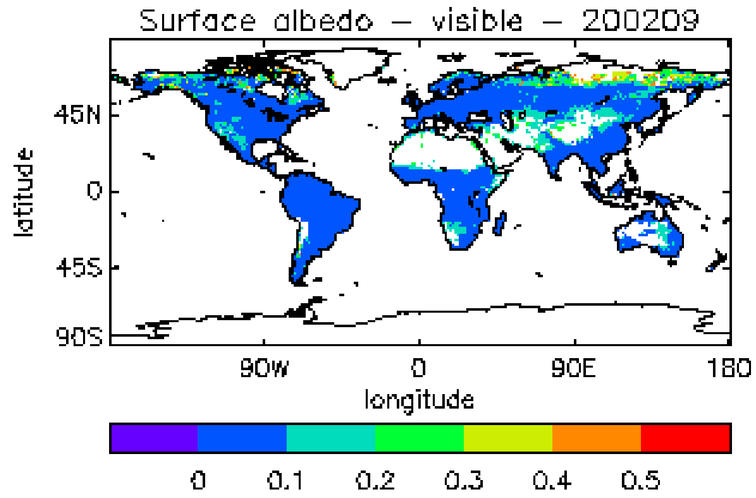
Properties of BB and pollution aerosols

- The optical thickness is derived in the same way for all biomass-burning and pollution aerosols.
- But optical properties differ according to geographic location, using regional boxes.

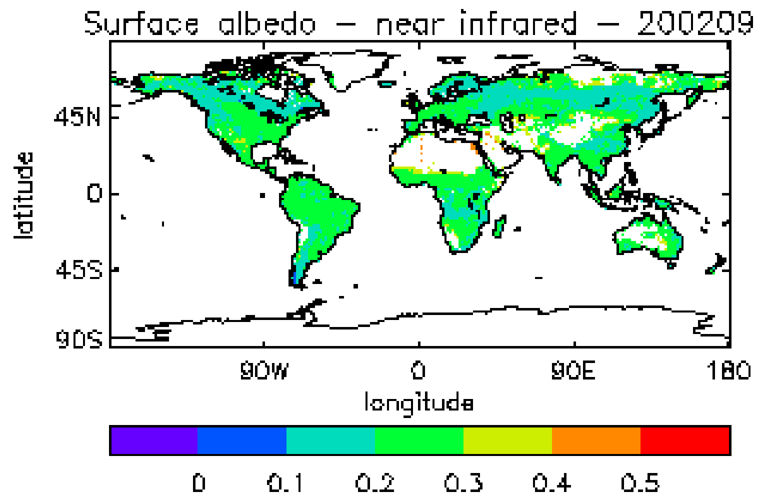


Surface albedo

Over ocean, the albedo is computed using *Cox and Munk* [1954]



Over land, the albedo is derived from MODIS measurements (products MOD43B3, *Schaaf et al.*, 2002) and corrected for aerosol effects.



Monte Carlo simulations

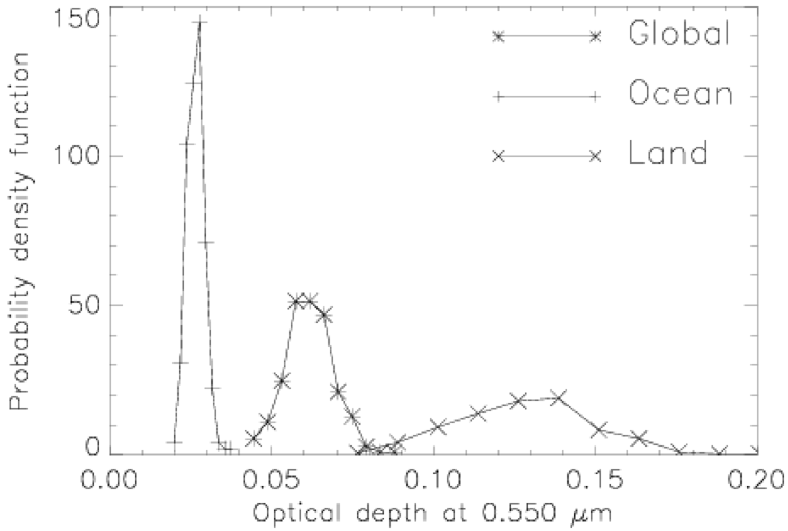
An ensemble of 250 simulations is carried out where

- local parameters are varied around their mean on a per pixel per day basis following normal distributions
  - land and ocean AOD according to documented errors in the retrievals (it is assumed there is no bias)
  - regional aerosol SSA (from AERONET)

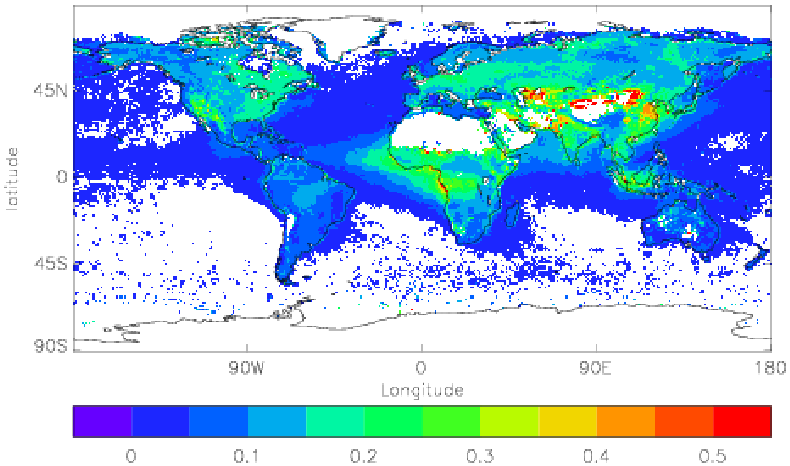
- global parameters are varied around their mean on a per simulation basis following normal distributions
  - threshold fine mode fractions (based on aircraft and AERONET data)
  - regional aerosol SSA (from AERONET)
  - anthropogenic fraction of land aerosol (from AEROCOM B/PRE)

PDF of anthropogenic AOD

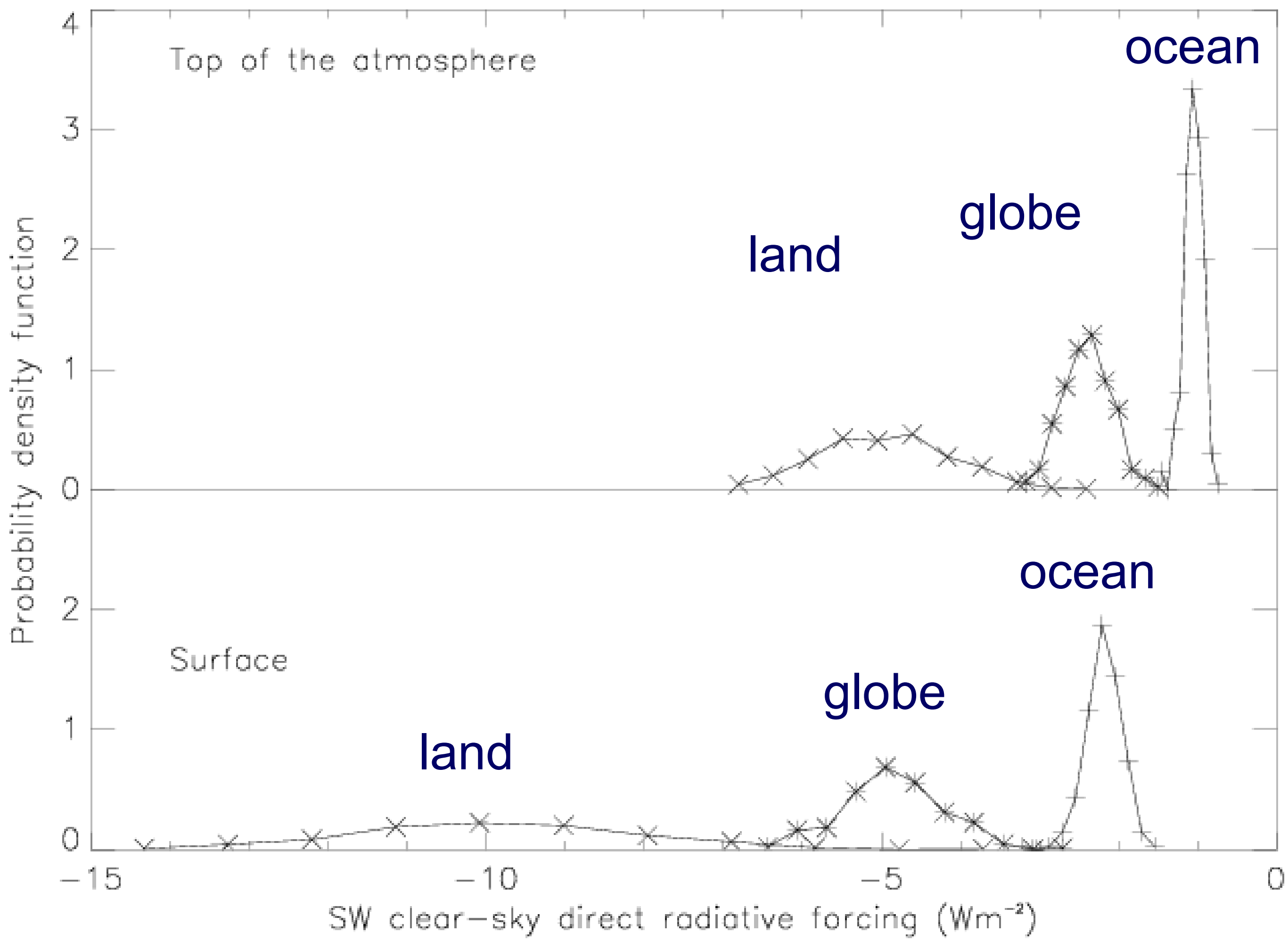
PDF of anthropogenic AOD



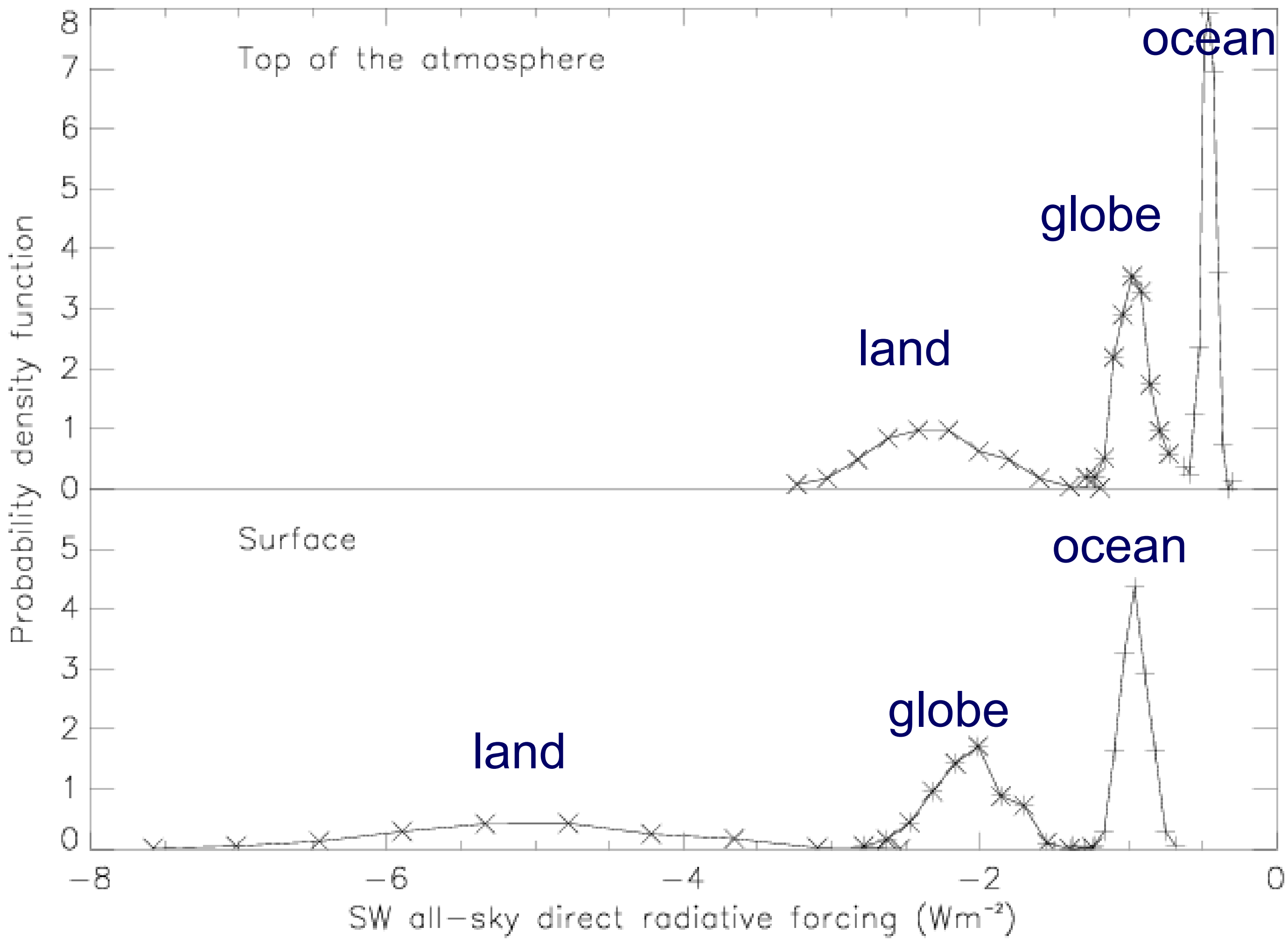
Average anthropogenic AOD



PDF of clear-sky aerosol direct radiative forcing



PDF of SW all-sky aerosol direct radiative forcing



Comparison LMDzt-LOA / MODIS

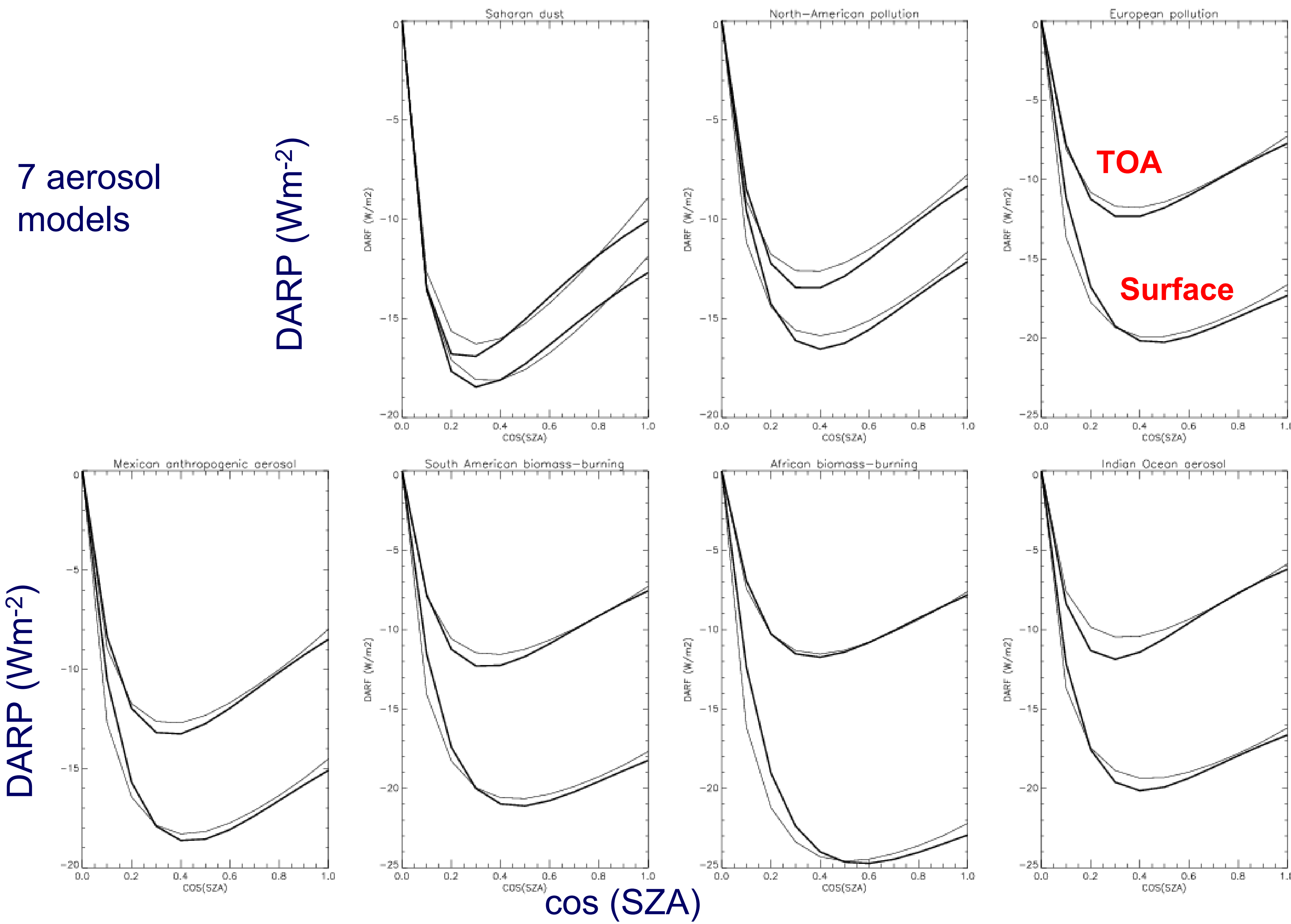
		LMDzt-LOA	MODIS	
Global	Extinction ant AOD	0.039	0.062	X1.6
	Absorption ant AOD	0.002	0.003	
	Single-scattering albedo	0.95	0.95	
	Clear-sky TOA DRF	-0.65	-2.40	X3.7
	All-sky TOA DRF	-0.25	-0.97	
Ocean	Extinction ant AOD	0.029	0.026	X0.9
	Absorption ant AOD	0.001	0.001	
	Single-scattering albedo	0.97	0.96	
	Clear-sky TOA DRF	-0.55	-1.05	X1.9
	All-sky TOA DRF	-0.16	-0.46	
Land	Extinction ant AOD	0.063	0.128	X2.0
	Absorption ant AOD	0.003	0.010	
	Single-scattering albedo	0.95	0.92	
	Clear-sky TOA DRF	-0.89	-4.95	X5.5
	All-sky TOA DRF	-0.48	-2.33	

Summary of satellite studies (from IPCC draft)

Reference	Instrument	Data analysed	Brief Description	Clear Sky DRE (ocean)	All Sky DRE (ocean)	Clear Sky DRF (ocean)	All Sky DRE (global)	All Sky DRF (global)
Bellouin et al. (2005)	MODIS/ TOMS/ SSMI	2001	MODIS fine and total τ_{aer} with TOMS AI and SSMI to discriminate dust from sea-salt.	-6.8±x.x	-2.6±	-1.2±	-2.6±	-1.0±
Kaufman et al. (2005)	MODIS	Aug 2001-Dec 2003	τ_{aer} from Remer et al (2005). Anthropogenic τ_{aer} from fine mode fraction.			-1.4±0.4		
Loeb and Manalo-Smith (2005)	CERES/ MODIS	Mar 2000 - Dec 2003	MODIS radiances and CERES angular distribution models used to estimate the direct radiative effect.	-3.8 to -5.5	-1.6to -2.0			
Remer et al. (2005)	MODIS	Aug 2001-Dec 2003		-5.7±0.4				
Zhang et al. (2004)	CERES/ MODIS			-5.3±1.7				
Bellouin et al (2003)	POLDER			-5.2				
Loeb and Kato (2002)	CERES/ VIRS		τ_{aer} from VIRS regressed against the top of the atmosphere CERES irradiance (35°N-35°S).	-4.6±1.0				
Chou et al. (2002)	SeaWiFs			-5.4				
Boucher and Tanré (2000)	POLDER			-5 to -6				

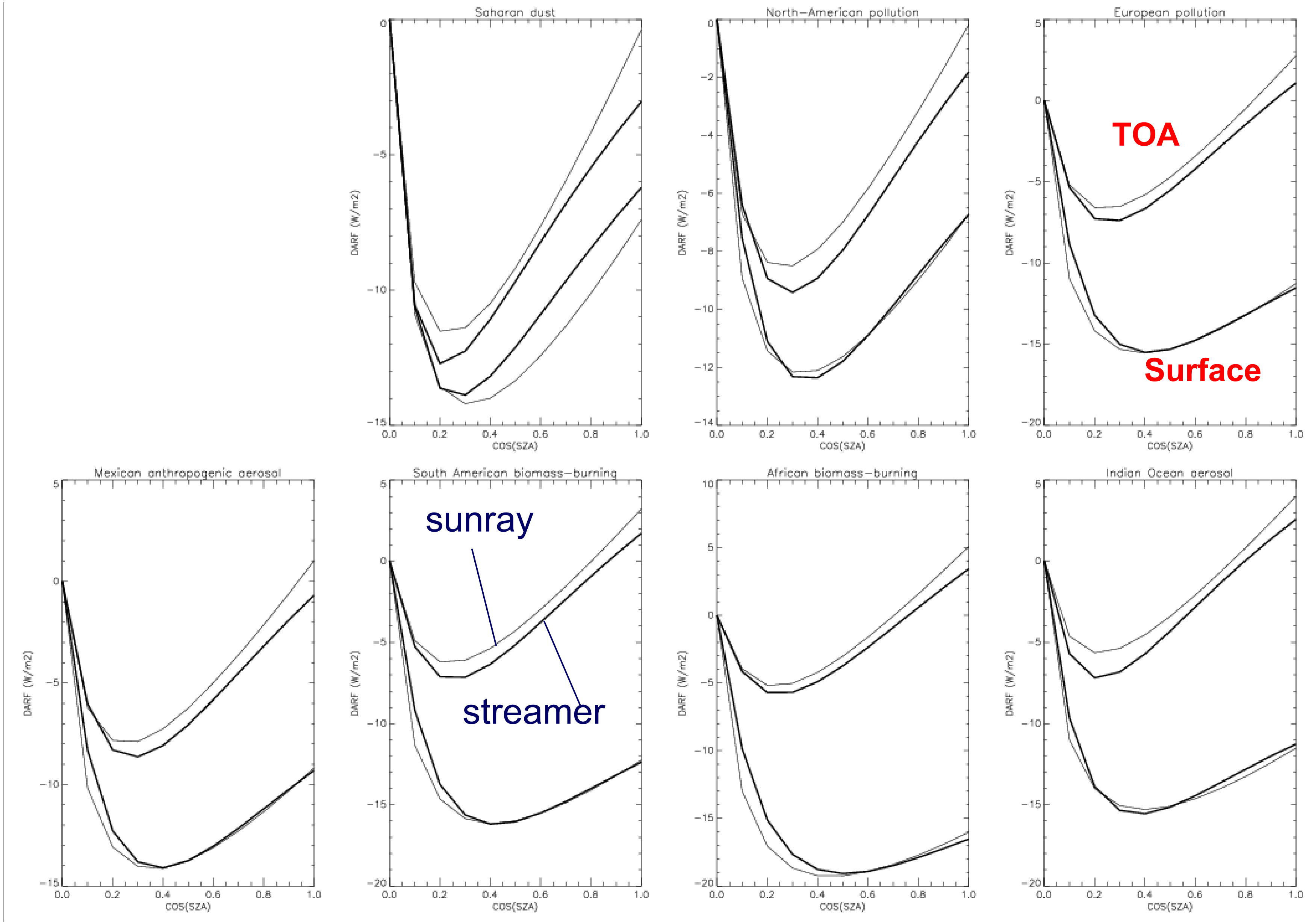
Shortwave 24-stream 24-waveband versus 2-stream 2-waveband RT codes
Aerosol optical depth = 0.1 Surface albedo = 0.0

7 aerosol models



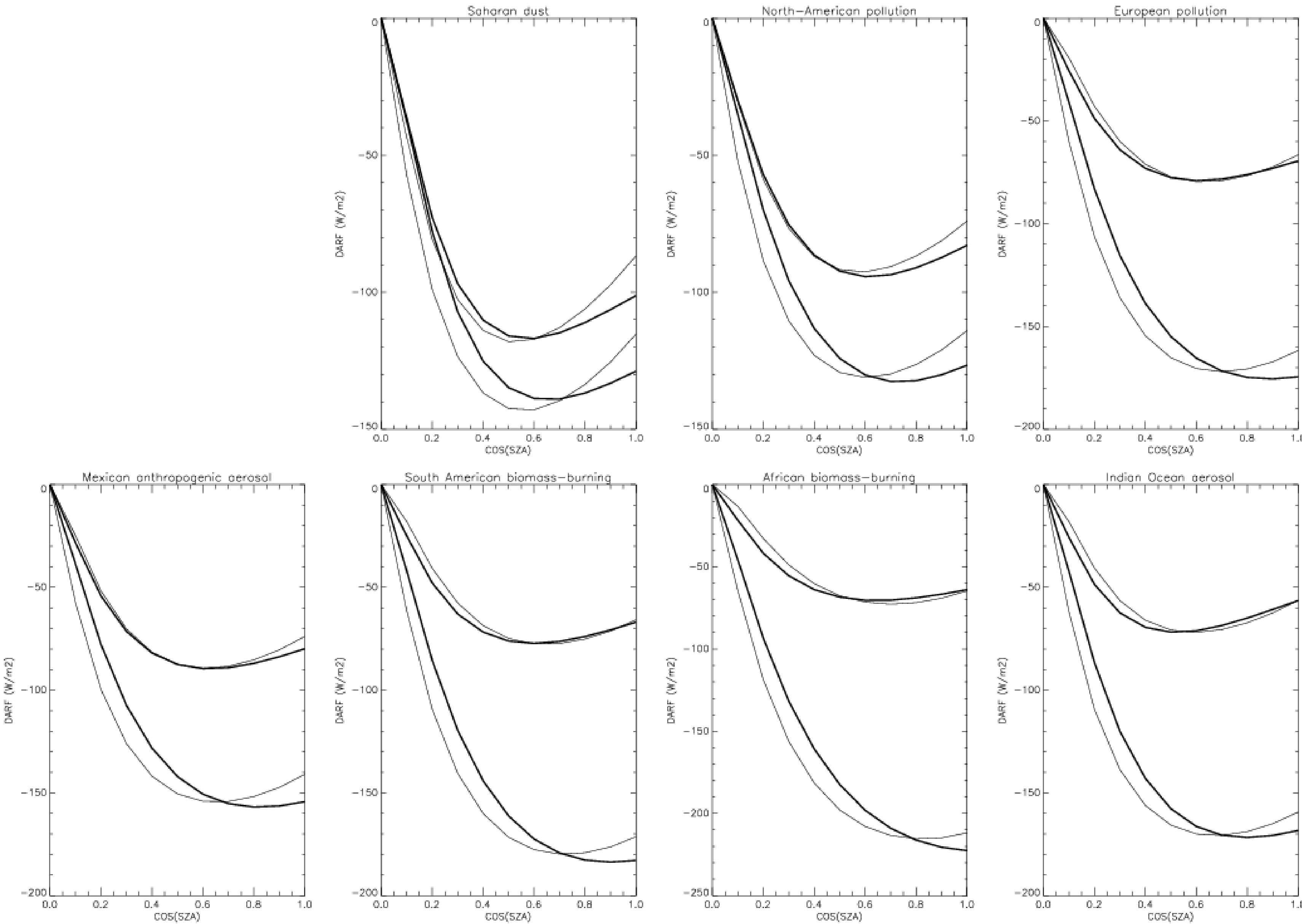
Broadband 24-stream 24-waveband versus 2-stream 2-waveband RT codes

Aerosol optical depth = 0.1 Surface albedo = 0.2

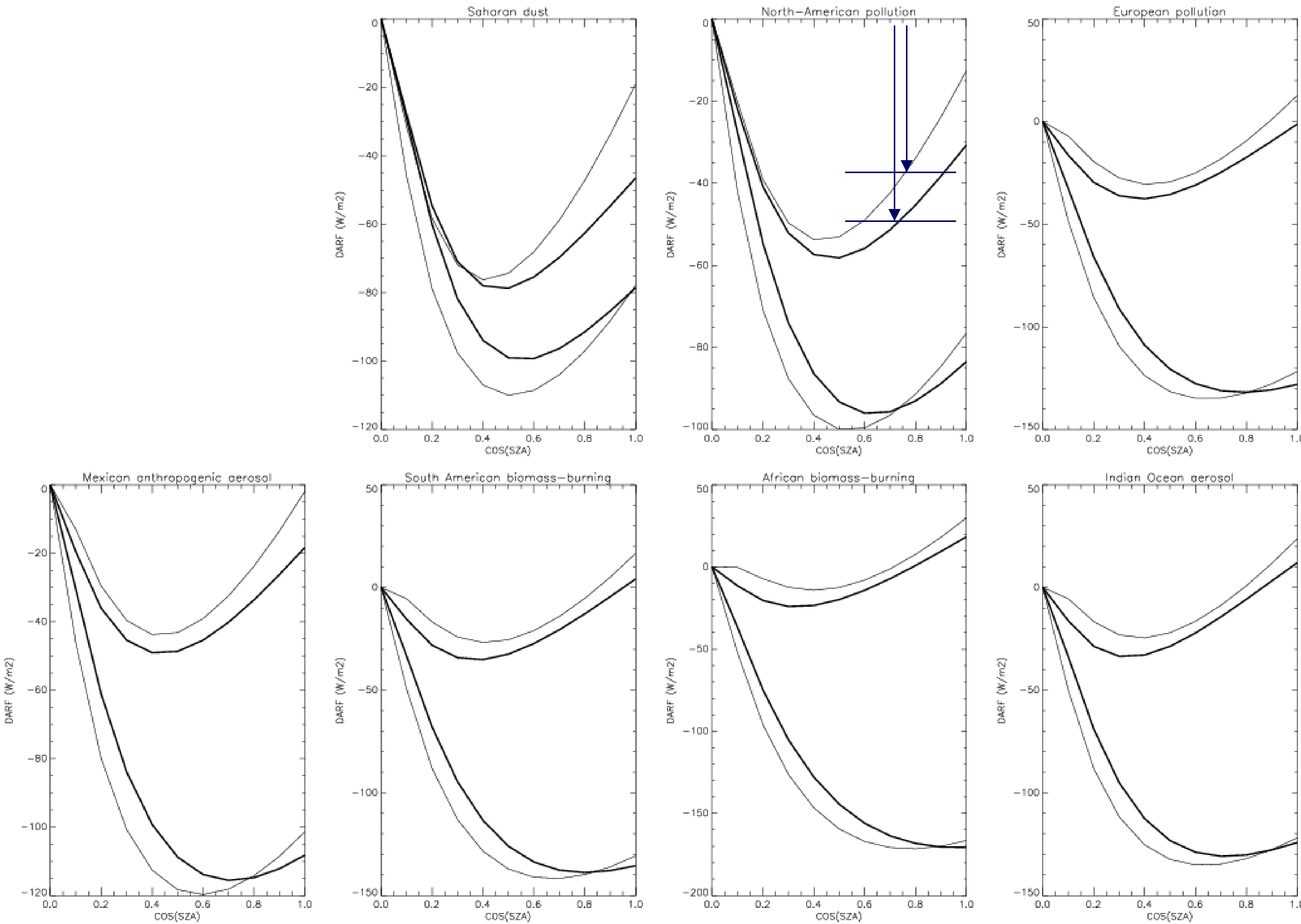


Broadband 24-stream 24-waveband versus 2-stream 2-waveband RT codes

Aerosol optical depth = 1.0 Surface albedo = 0.0



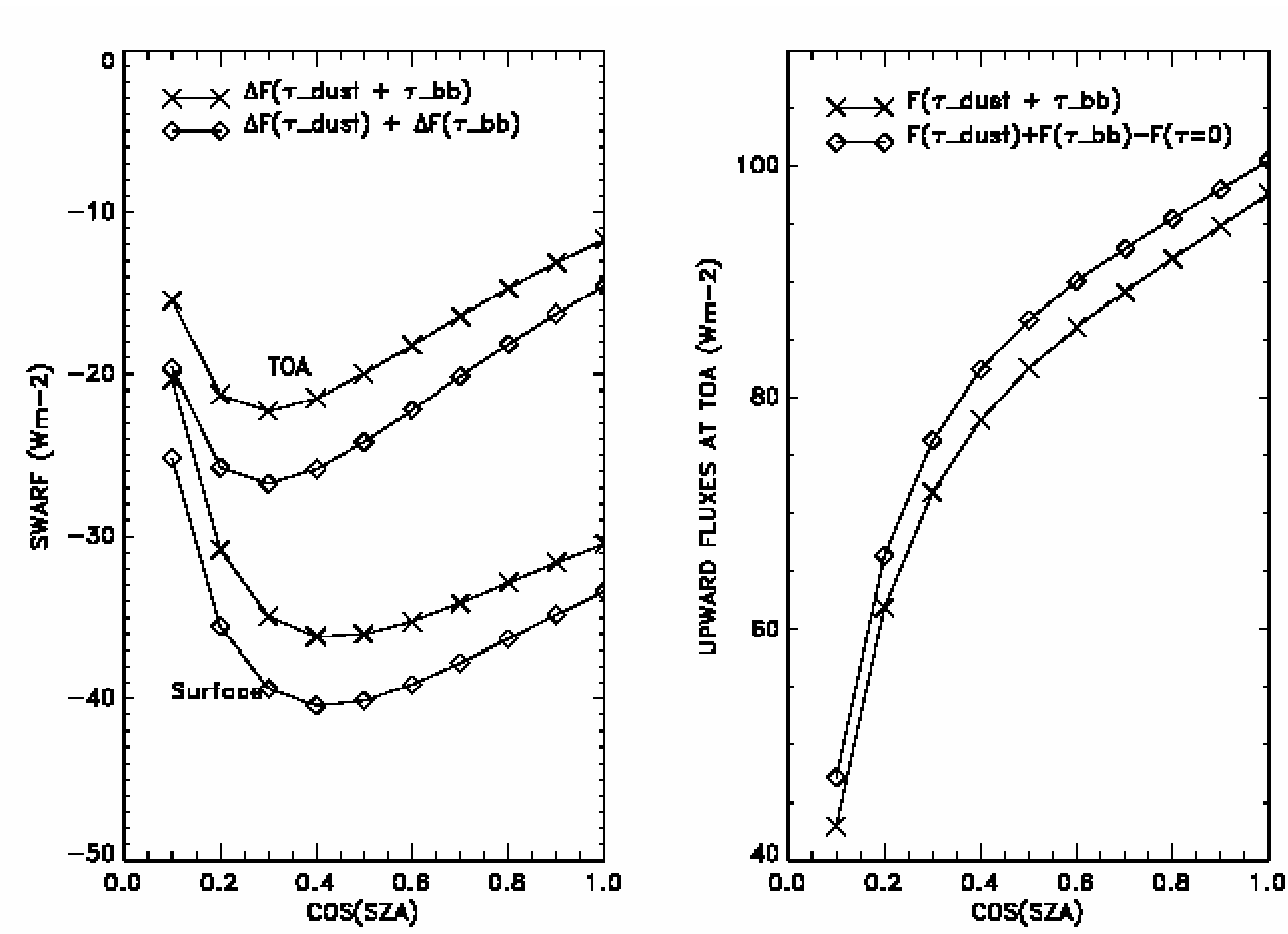
Broadband 24-stream 24-waveband versus 2-stream 2-waveband RT codes
Aerosol optical depth = 1.0 Surface albedo = 0.2



The direct aerosol RF is not as linear as we may think!

$DF_{dust} + DF_{bb} <> DF_{dust+bb}$

Implication is that $F_{dust+bb} - F_{bb} > F_{dust} - F_0$



Planned experiments to resolve the discrepancy

For Ocean and Land separately

- Different area weightings

-Use GCM albedo in MODIS calculations

-Test importance of spectral dependence of ocean albedo

-Use LUT generated by the GCM in the MODIS calculations

-Add a scattering layer in calculations of the STREAMER LUT