Global shortwave aerosol direct radiative forcing from MODIS measurements for mineral dust, marine aerosol, biomass-burning and industrial pollution.

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The shortwave direct aerosol radiative forcing

What is needed?

1. The aerosol optical thickness for each type
2. The aerosol optical properties for each type
3. The surface albedo

Step 1

Get the optical thickness for mineral dust, marine aerosol and anthropogenic aerosols

Splitting the total aerosol optical thickness

Solve $\tau_{total} = \tau_{dust} + \tau_{marine} + \tau_{biomass/pollution}$

Help wanted!

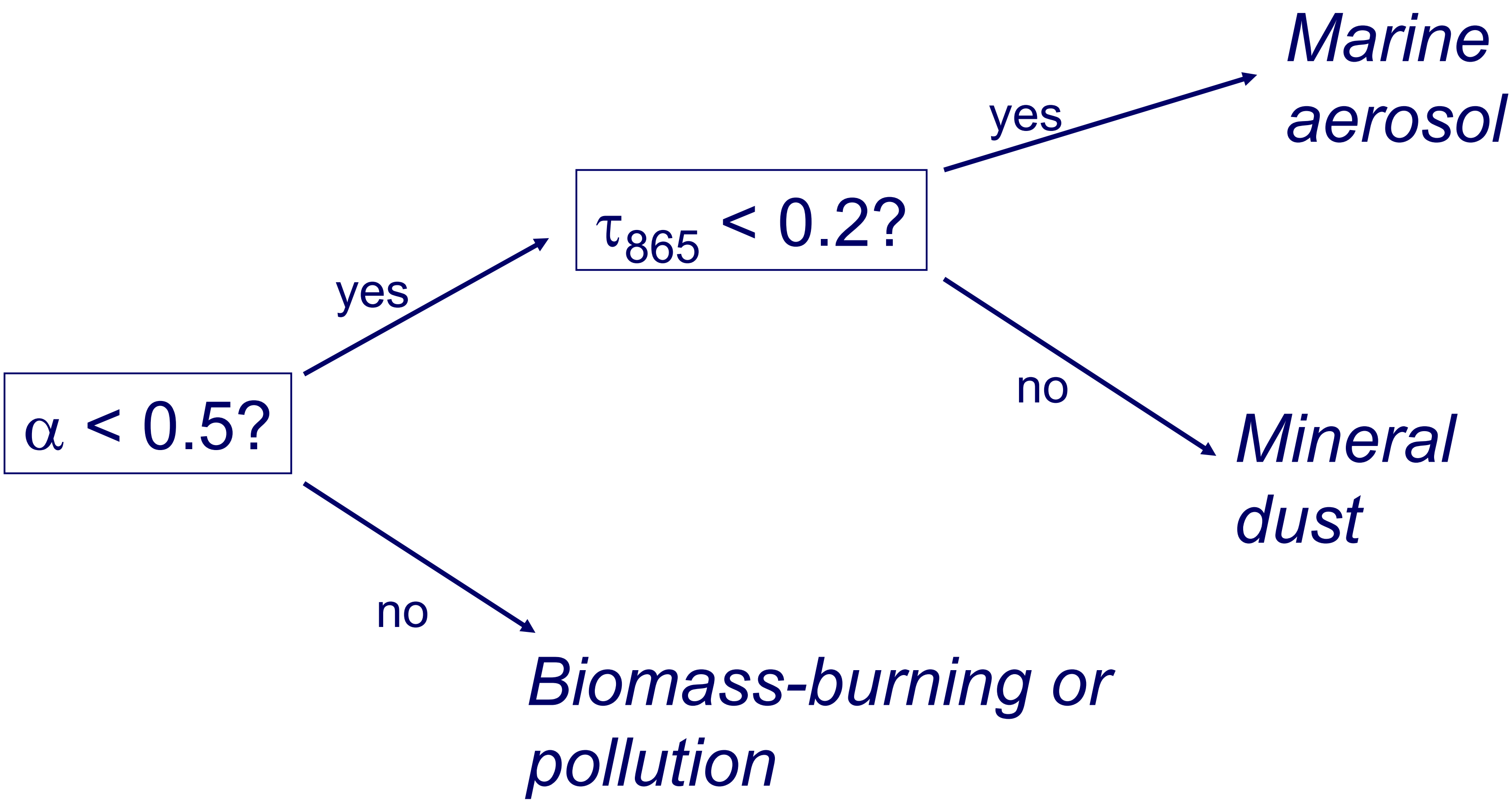
- Ångström exponent α
  spectral dependence of the extinction

- Fine fraction r
  fraction of the OT due to the accumulation-mode particles

- Surface wind speeds
  give a rough estimate of the marine aerosol OT

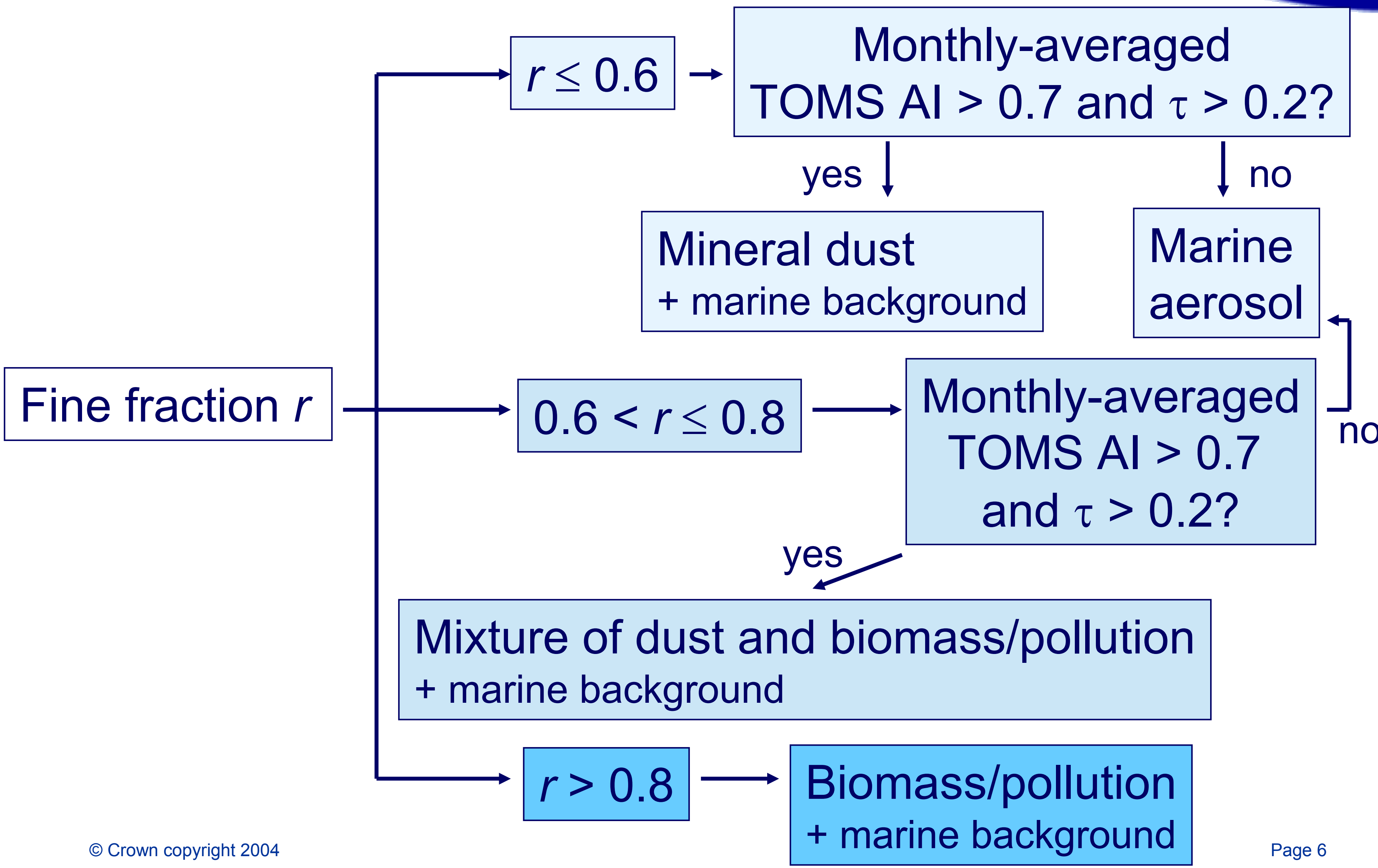
- TOMS aerosol index
  detects UV-absorbing aerosols (i.e. dust and biomass-burning)

The POLDER-1 algorithm over clear-sky oceans



Bellouin et al., *GRL*, 2003

The MODIS algorithm over clear-sky oceans



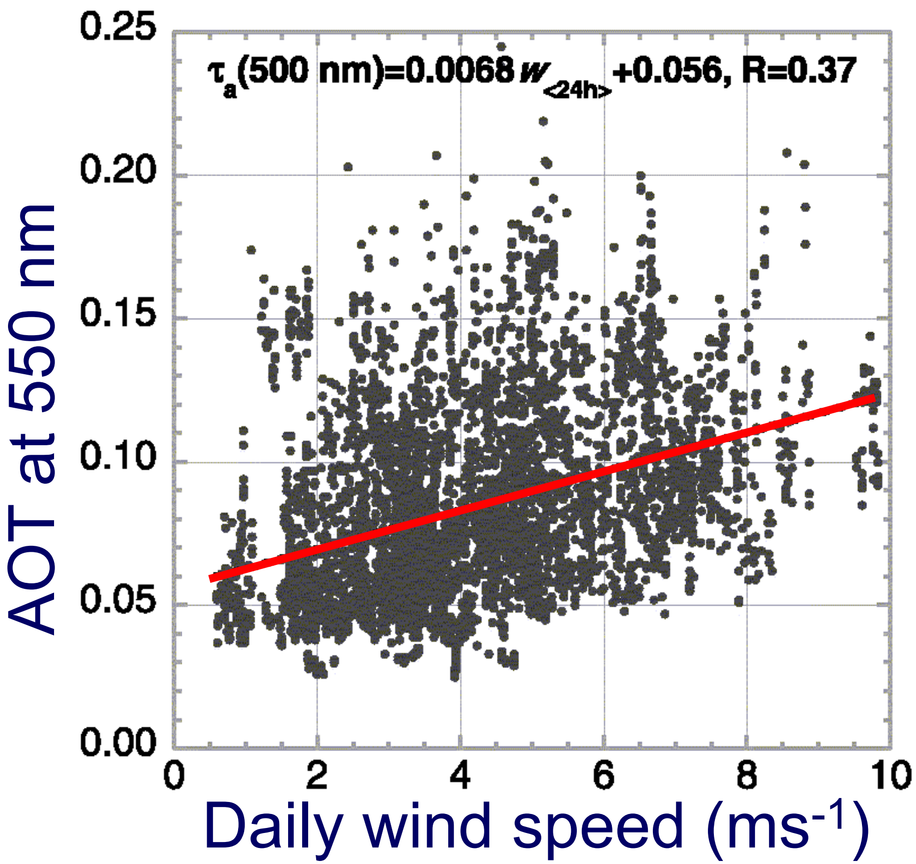
In-situ measurements of *r*

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

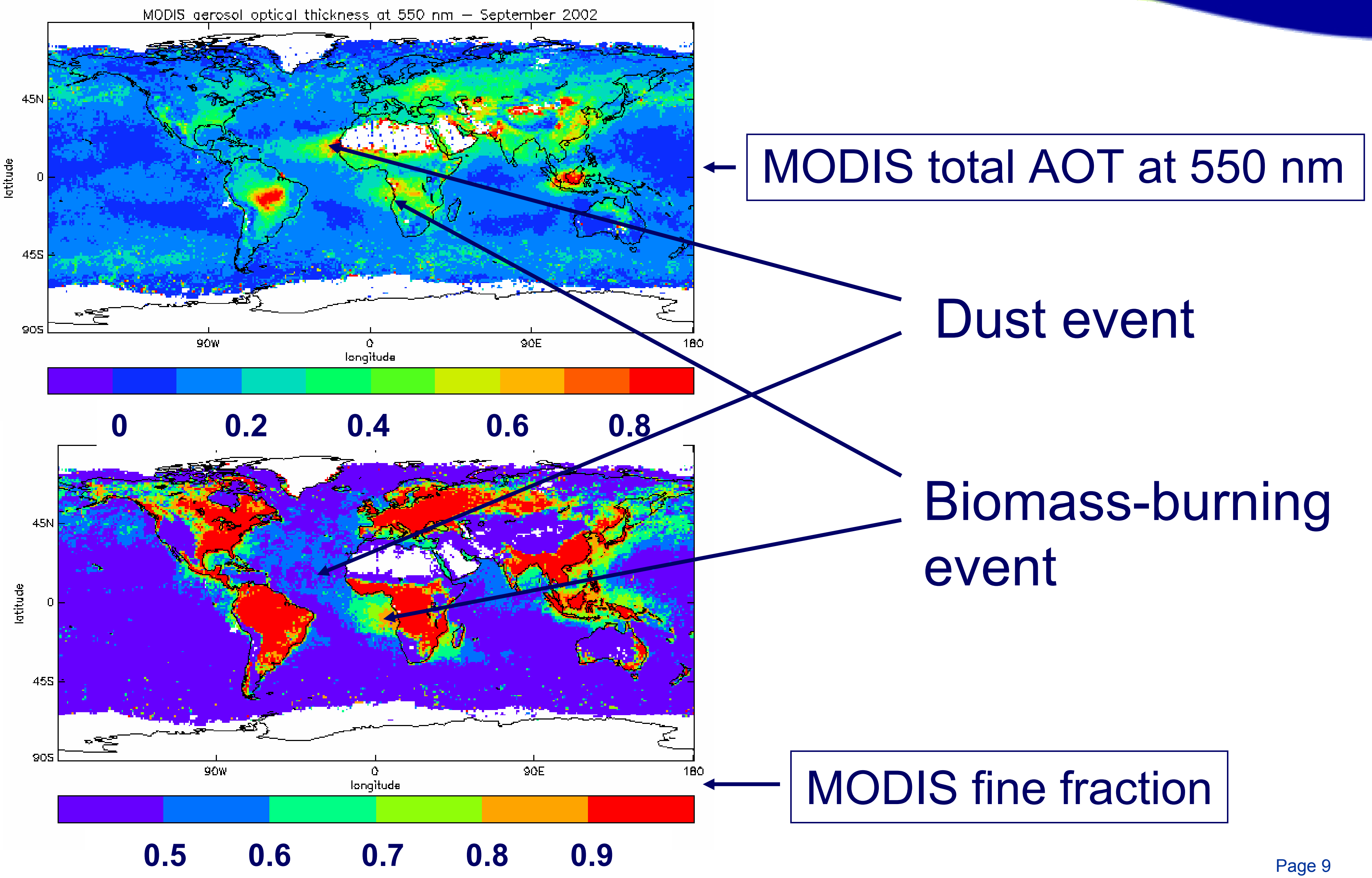
Get a *sensible* estimate of the marine aerosol OT when dust or biomass/pollution is identified.



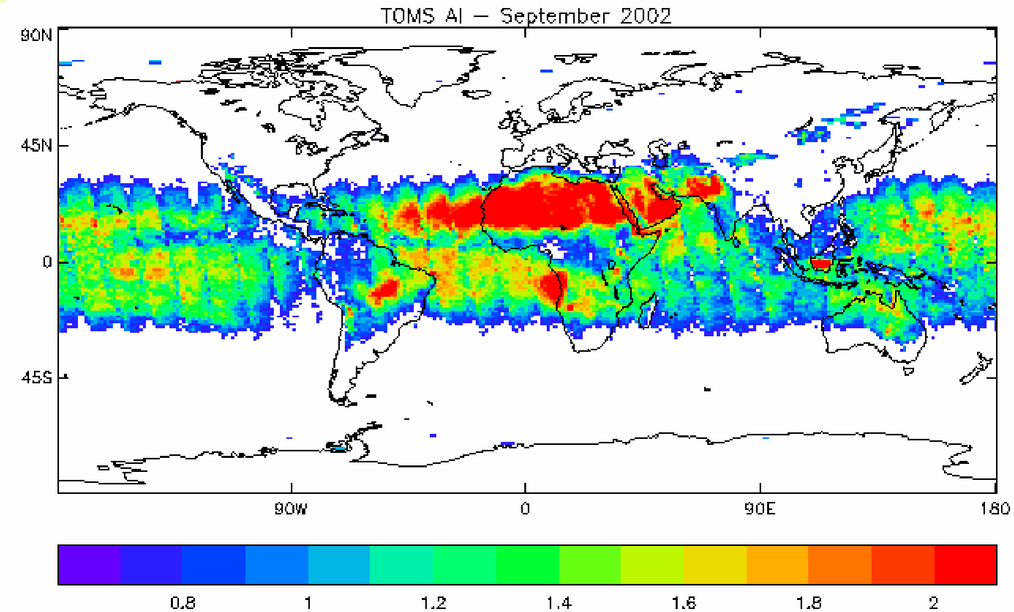
Linear relationship from Smirnov et al., *JGR, 2003*

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

The MODIS algorithm: Data for September 2002

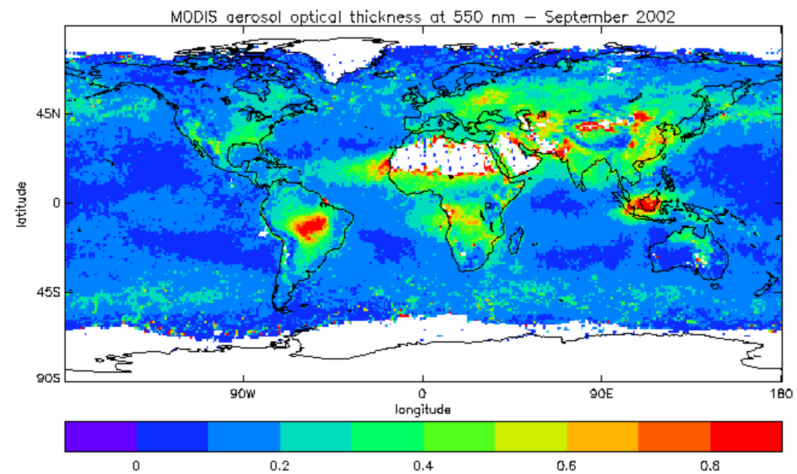


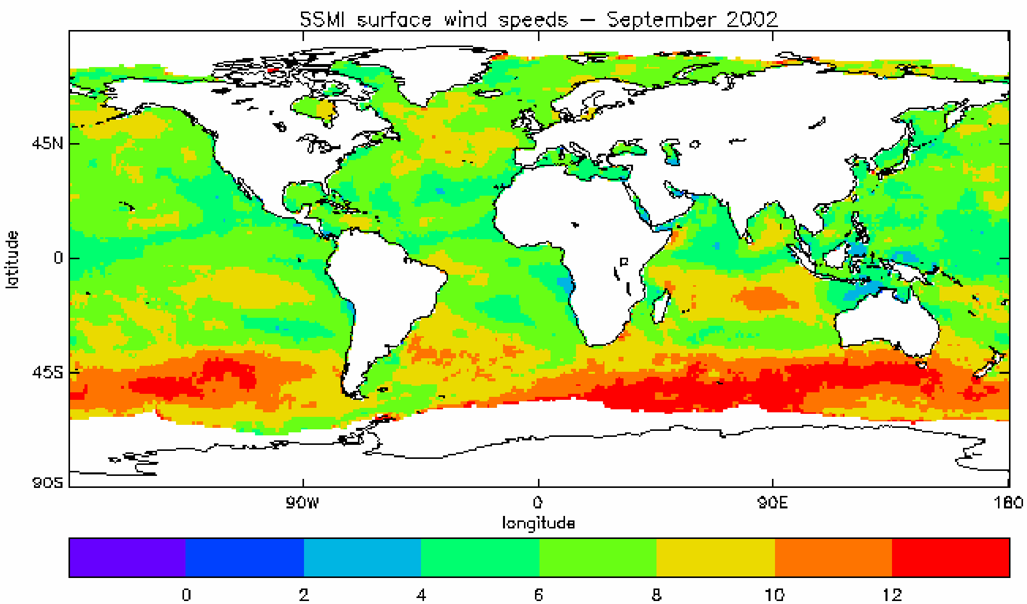
The MODIS algorithm: Data for September 2002



TOMS Aerosol Index

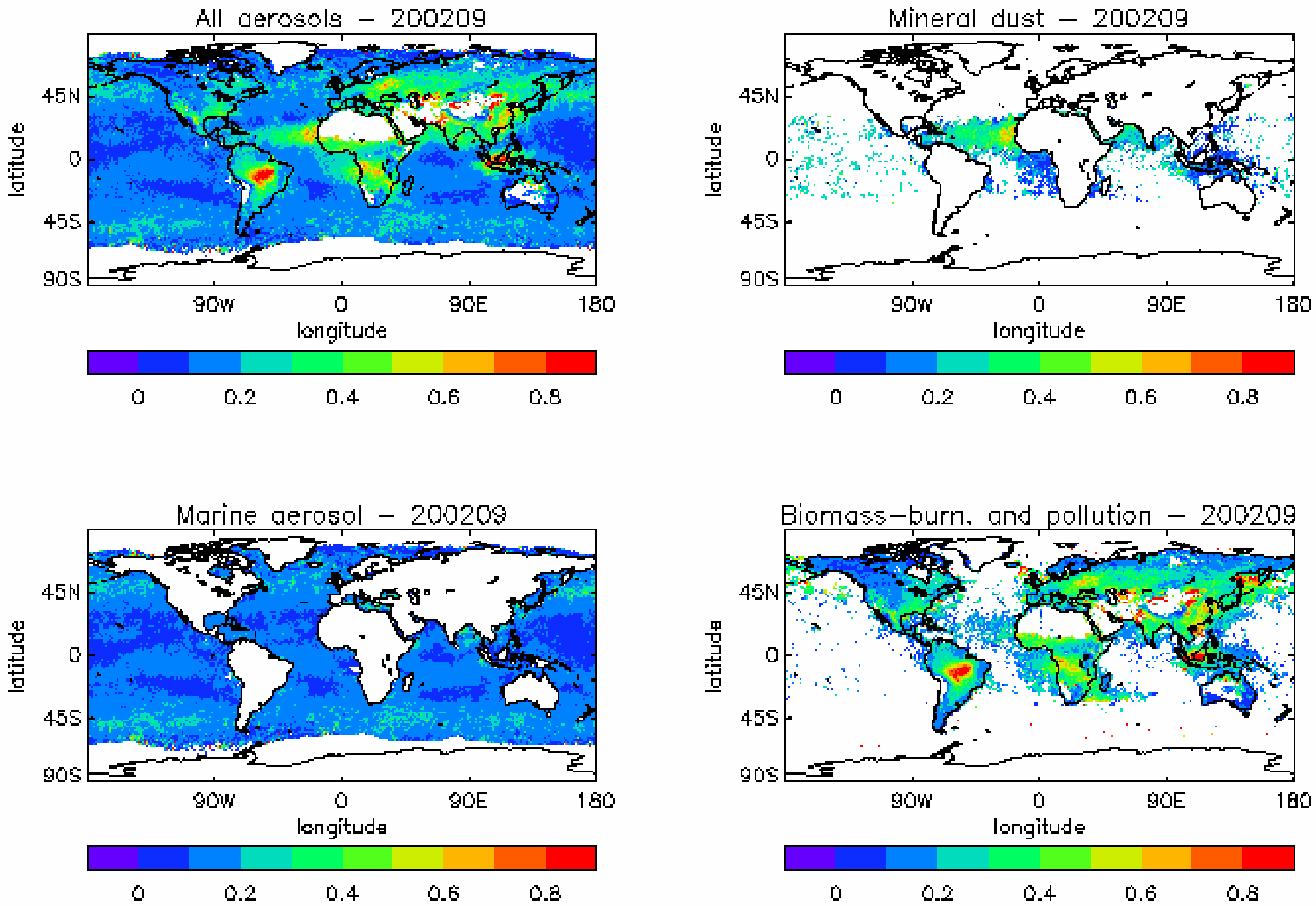
MODIS τ_{550}



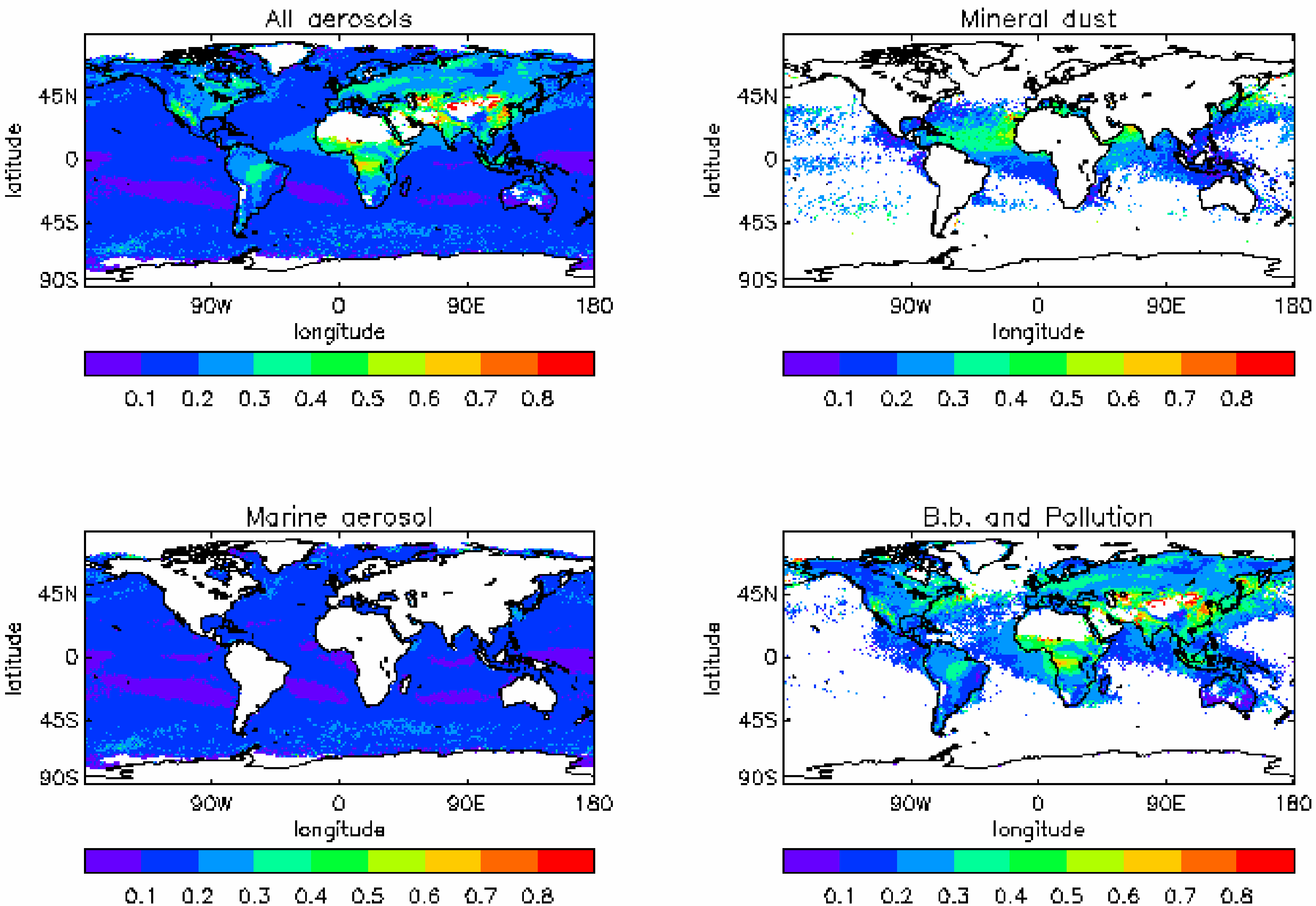


SSM/I wind speeds

The MODIS algorithm: Results for September 2002



Distributions of optical thicknesses for 2002



Step 2

Estimate the radiative forcing from the discriminated optical thicknesses

From the optical thickness to the radiative forcing

Aerosol model:
- size distribution
- refractive index

(from AERONET)

Mie theory, 24 λ

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

Surface albedo
(VIS & near IR)

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

radiative transfer code

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

Met Office

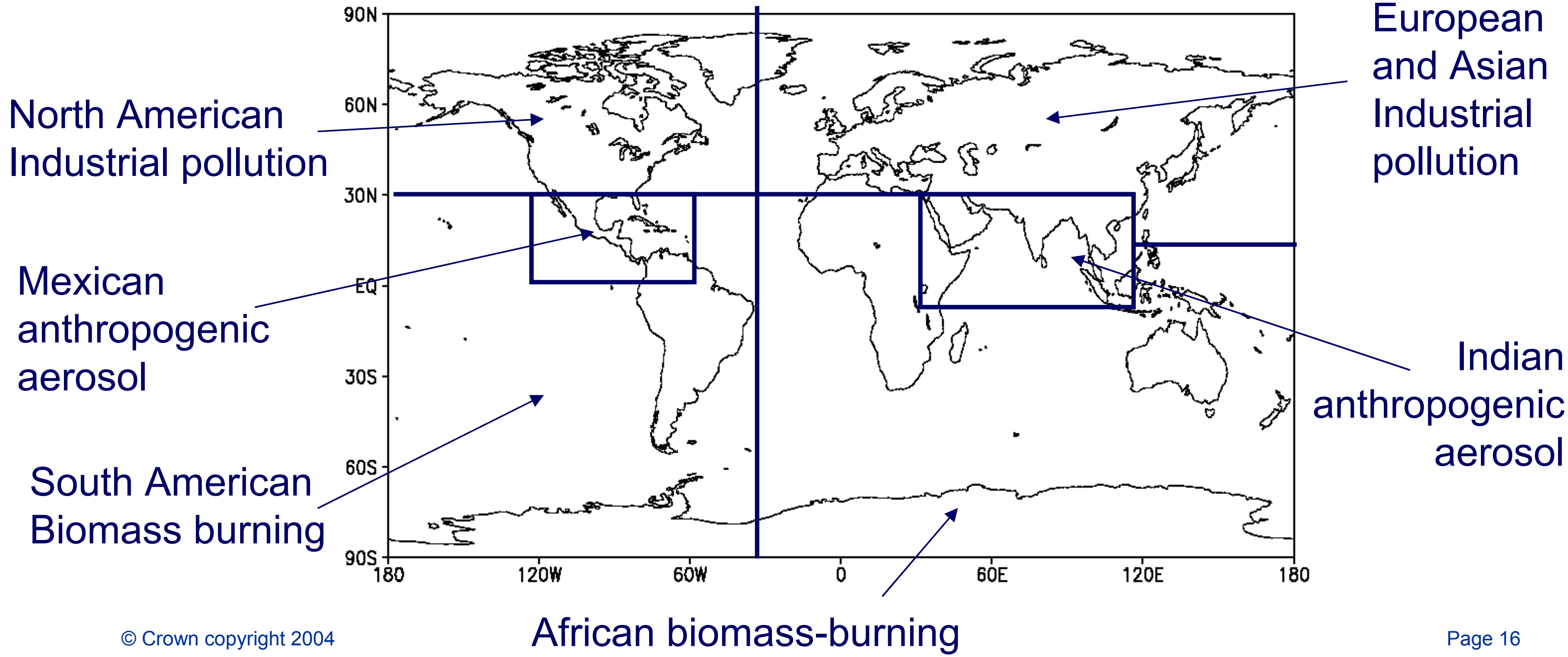
Aerosol optical properties

Dubovik et al., *JAS*, 2002

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

Biomass-burning and pollution properties

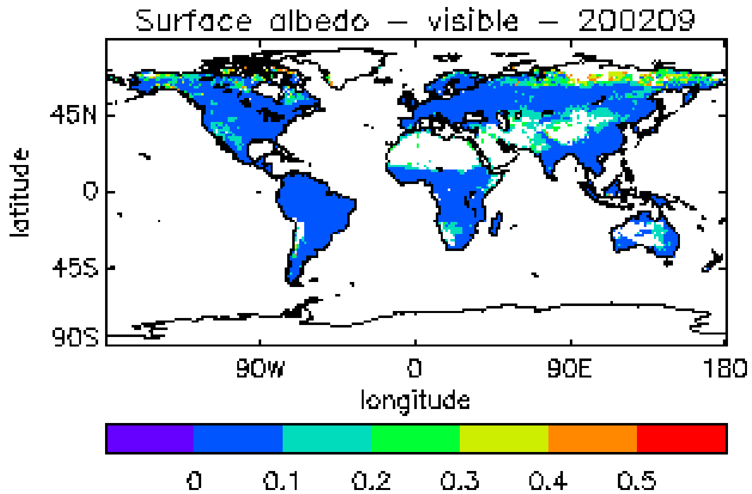
- The optical thickness is derived in the same way for all biomass-burning and pollution aerosols.
- But optical properties differ according to geographic location, using regional boxes.

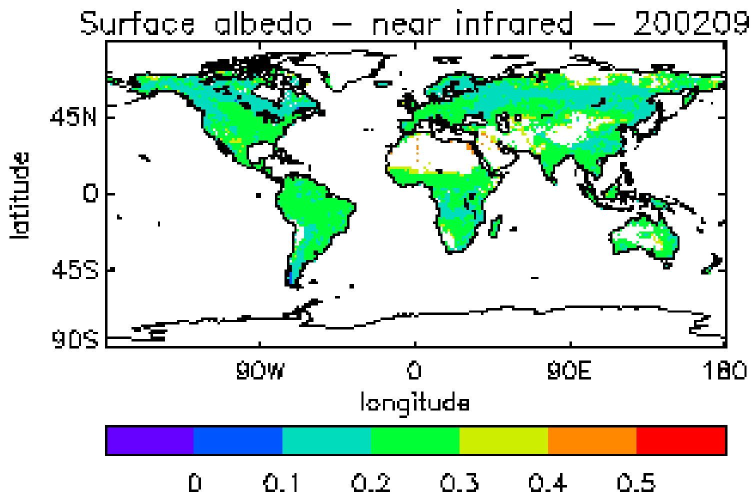


Surface albedo

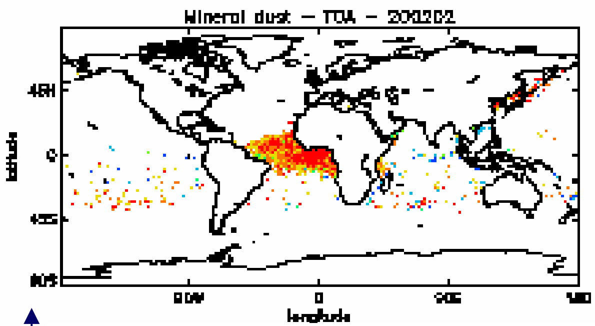
Over ocean, the albedo is computed using *Cox and Munk* [1954]

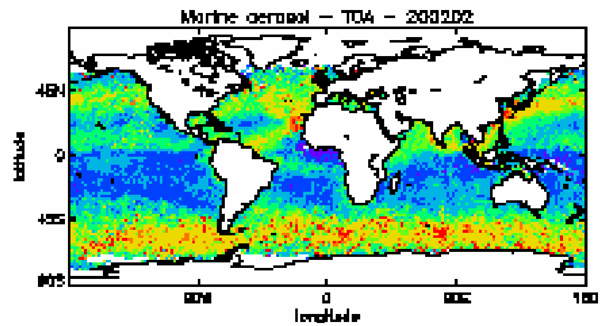
Over land, the albedo is derived from MODIS measurements (products MOD43B3, *Schaaf et al.*, 2002) and corrected for aerosol effects.

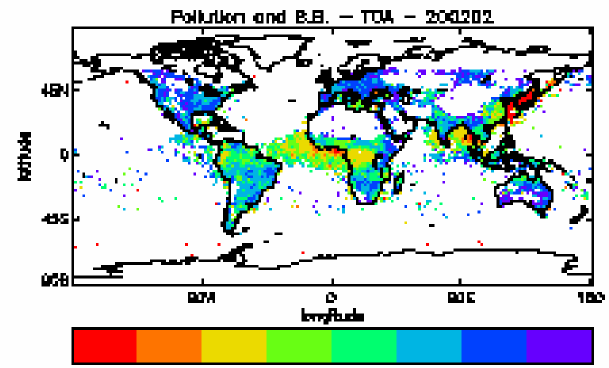




MODIS: Monthly average for February 2002





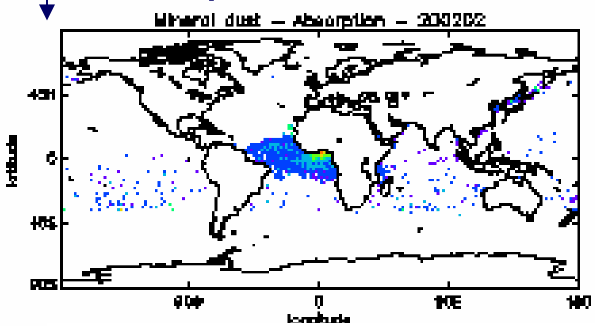


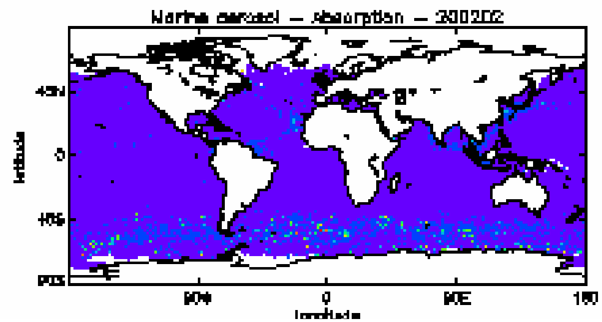
-20 -15 -10 -8 -6 -4 -2

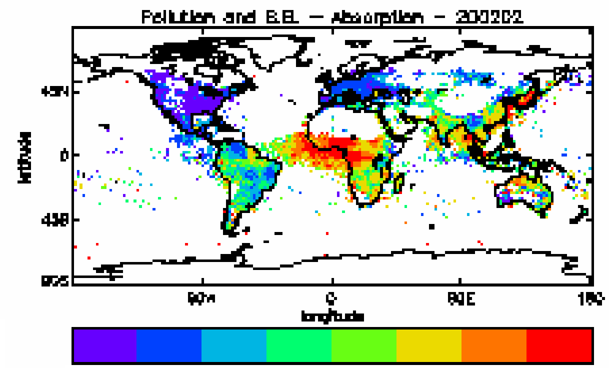
Top of atmosphere

Mineral dust   Marine aerosol   Biomass+Poll.

Absorption

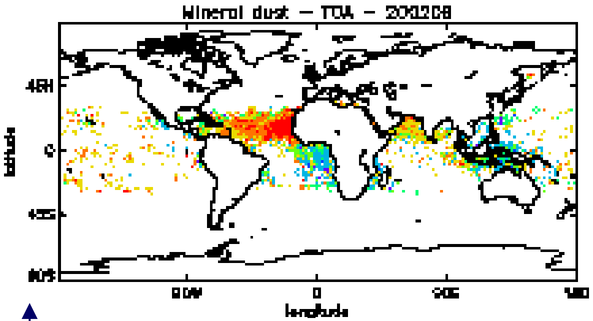


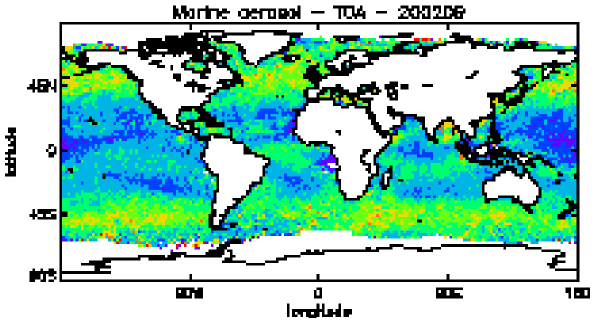


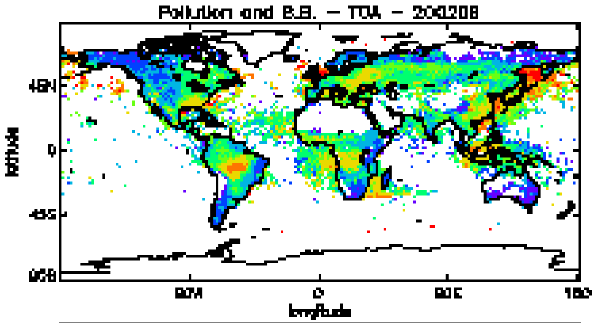


2 4 6 8 10 15 20

MODIS: Monthly averages for September 2002





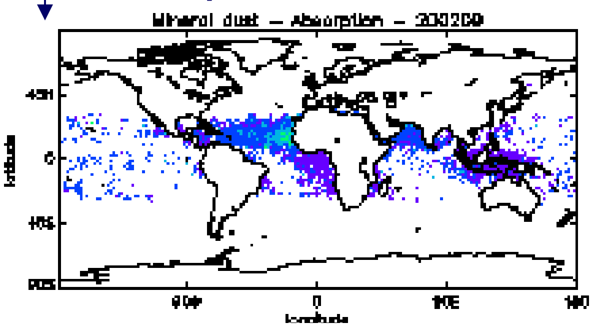


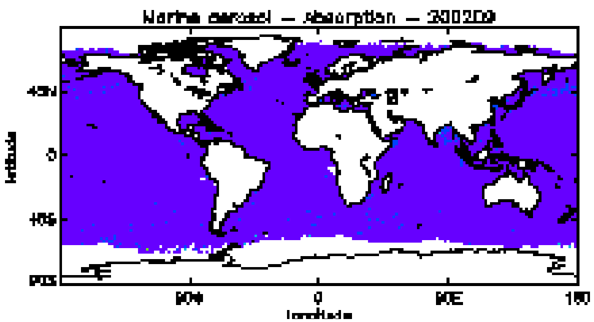
↑ Top of atmosphere

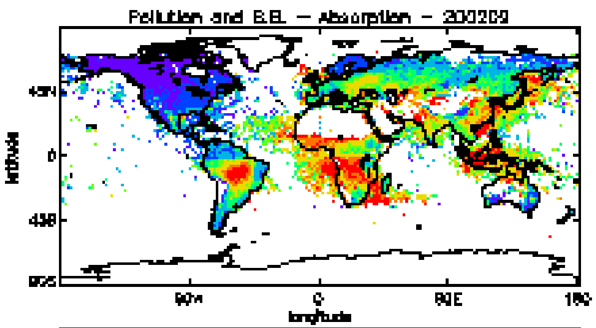
-20 -15 -10 -8 -6 -4 -2

Mineral dust   Marine aerosol   Biomass+Poll.

↓ Absorption







2 4 6 8 10 15 20

MODIS: Global clear-sky averages for 2002

Mineral dust	TOA (Wm^{-2})	Surface (Wm^{-2})	Abs. (Wm^{-2})	τ (550 nm)	E (Wm^{-2} / unit τ)
Global	-0.48	-0.57	0.09	0.009	-56
Ocean	-0.71	-0.85	0.14	0.013	-56
Marine aerosol					
Global	-3.61	-4.25	0.64	0.076	-47
Ocean	-5.35	-6.31	0.95	0.113	-47
bb + poll					
Global	-2.39	-5.43	3.04	0.093	-26
Ocean (+)	-0.52	-1.18	0.66	0.014	-37
Land (-)	-6.18	-14.06	7.88	0.255	-24

(+) lower bound of anthropogenic RF (-) upper bound of anthropogenic RF

Conclusion

- Our algorithm applied to MODIS data does a good job distributing the total optical thickness to mineral dust, marine aerosol, and biomass-burning and pollution aerosols.

- Choosing realistic aerosol properties from AERONET measurements improves the confidence in the estimated radiative forcings.

- Paper to be submitted soon.