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Atmospheric Chemistry and Physics Discussions

Reevaluation of Mineral aerosol radiative forcings suggests a better agreement with satellite and AERONET data

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Motivation: To understand effects of dust on climate
and how dust can influence weather forecasts we need
to have a correct representation of how absorbing dust is

Retrievals from satellite and from AERONET
sunphotometers indicate larger SSA than modellers
have assumed up to now

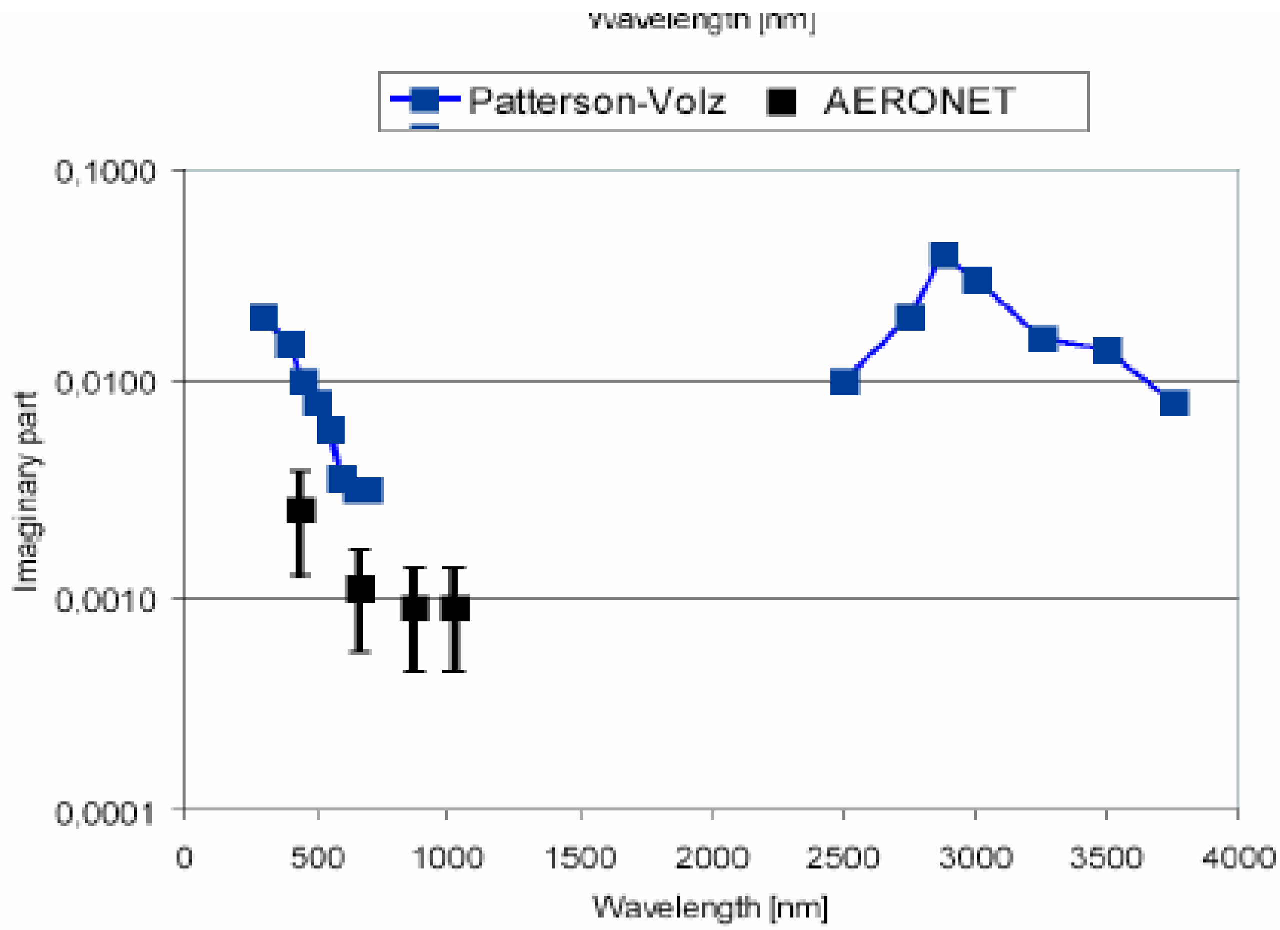
To understand these differences we recomputed
dust refractive index from the mineralogy of dust

3 satellite studies

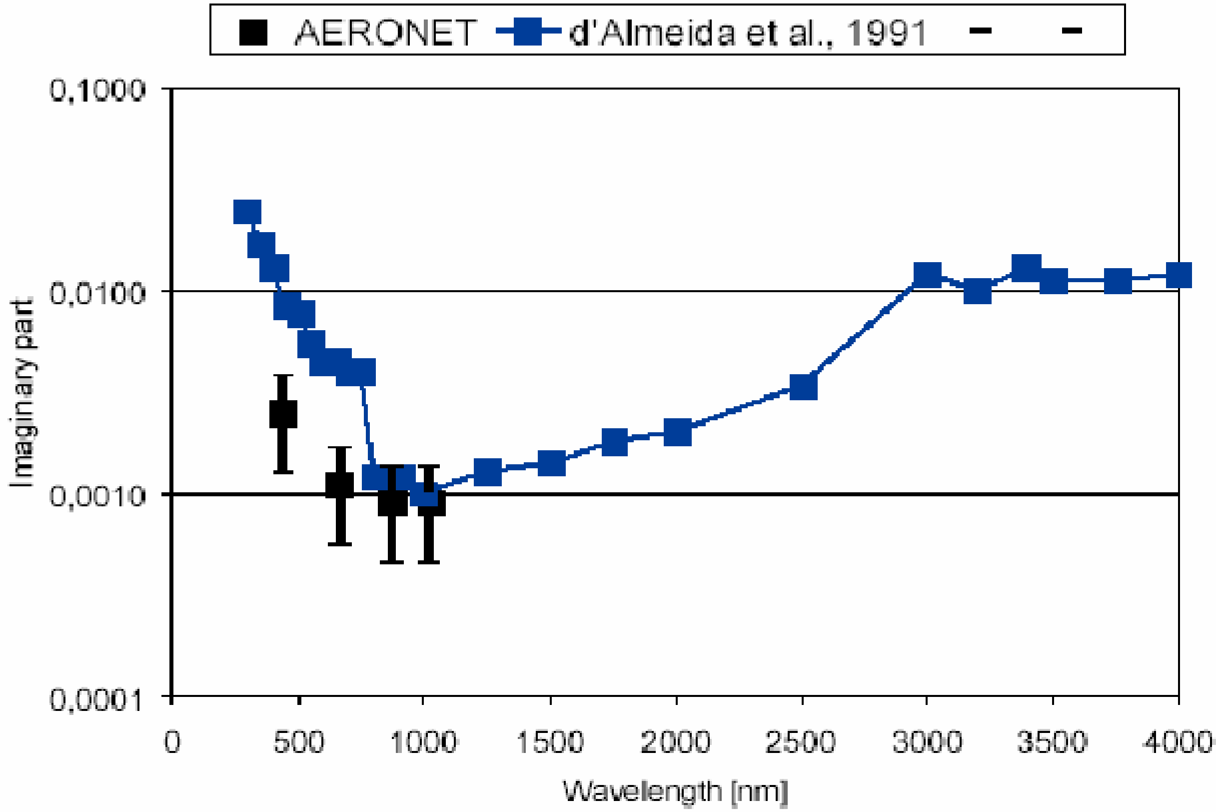
Kaufman et al. (2001) studied two dusty situations off the coast of Africa when optical depth reached 0.8 and 2.4 at 640 nm.
The imaginary part of the dust refractive index was varied for these two cases until it fitted the radiances. The increase in apparent reflectance consistent for the whole area of study suggested that dust is close to non-absorbing.

Moulin et al. (2001) needed to decrease the imaginarypart of mineral aerosol refractive index to match that the spectral reflectance measured from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) in dusty conditions

Haywood et al. (2003) looking at dust transported between Dakar (14.7 N, 17.
and Sal Island (16 N, 24 W) came up with the same conclusions.



Uncertainties are ±0.04 on the real part of the refractive index and 50% on the imaginary part [*Dubovik*, 2002 and personal communication].



AERONET
d'Almeida et al., 1991
0,1000
0,0100
0,0010
0,0001
Imaginary part
0
500
1000
1500
2000
2500
3000
3500
4000
Wavelength [nm]

Percentage (by VOL.) for the 6 minerals used to compute the refractive in

	S1a Central Hematite	S1b High Hematite	S1c Low Hematite
Hematite	1.5	2.7	0.9
Illlite	31.5	30.3	32.1
Quartz	14.0	14.0	14.0
Calcite	6.0	6.0	6.0
Kaolinite	24.0	24.0	24.0
Montmorillonite	23.0	23.0	23.0
Total	100.0	100.0	100.0

From the mineralogical database of Claquin et al. (1999)

95% of the surfaces of arid and semi-arid areas have hematite content > 0.9%

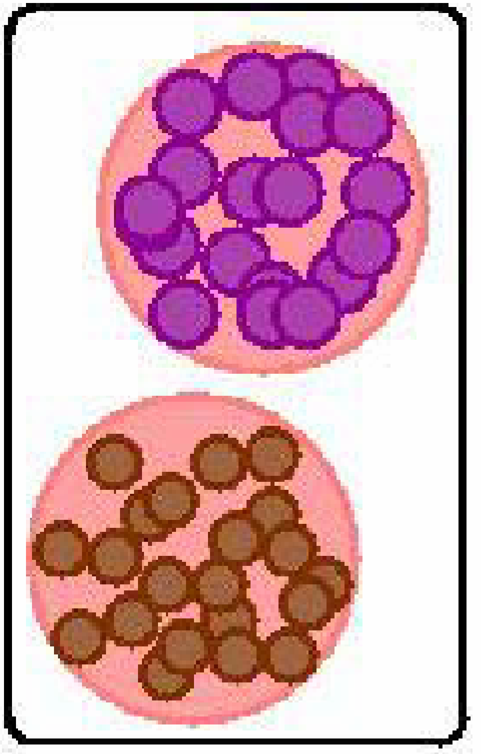
50% have hematite content > 1.5%

95% > 2.7%

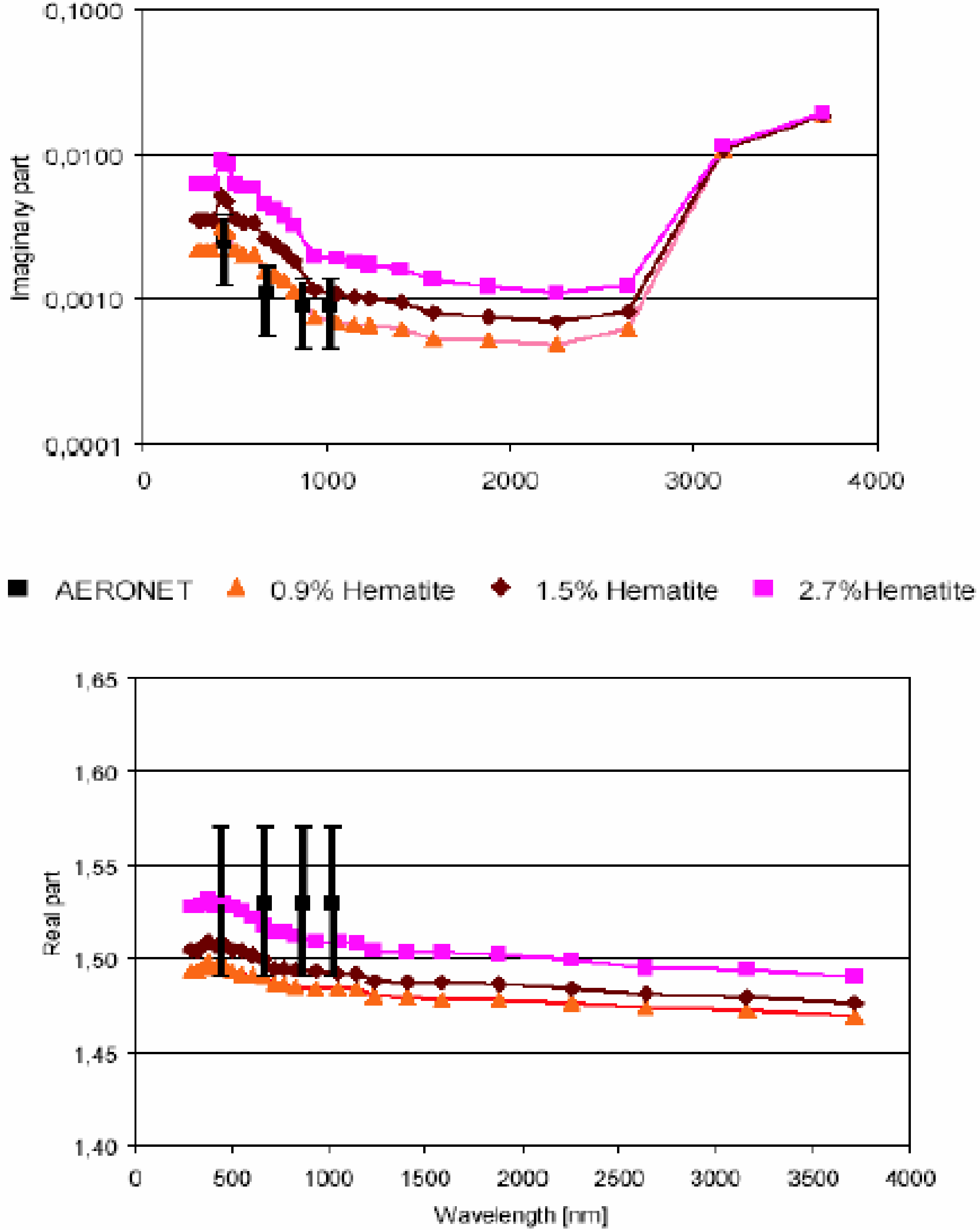
2 hypothesis were tested for mixtures:

-A refractive index computed as a volume weighted average

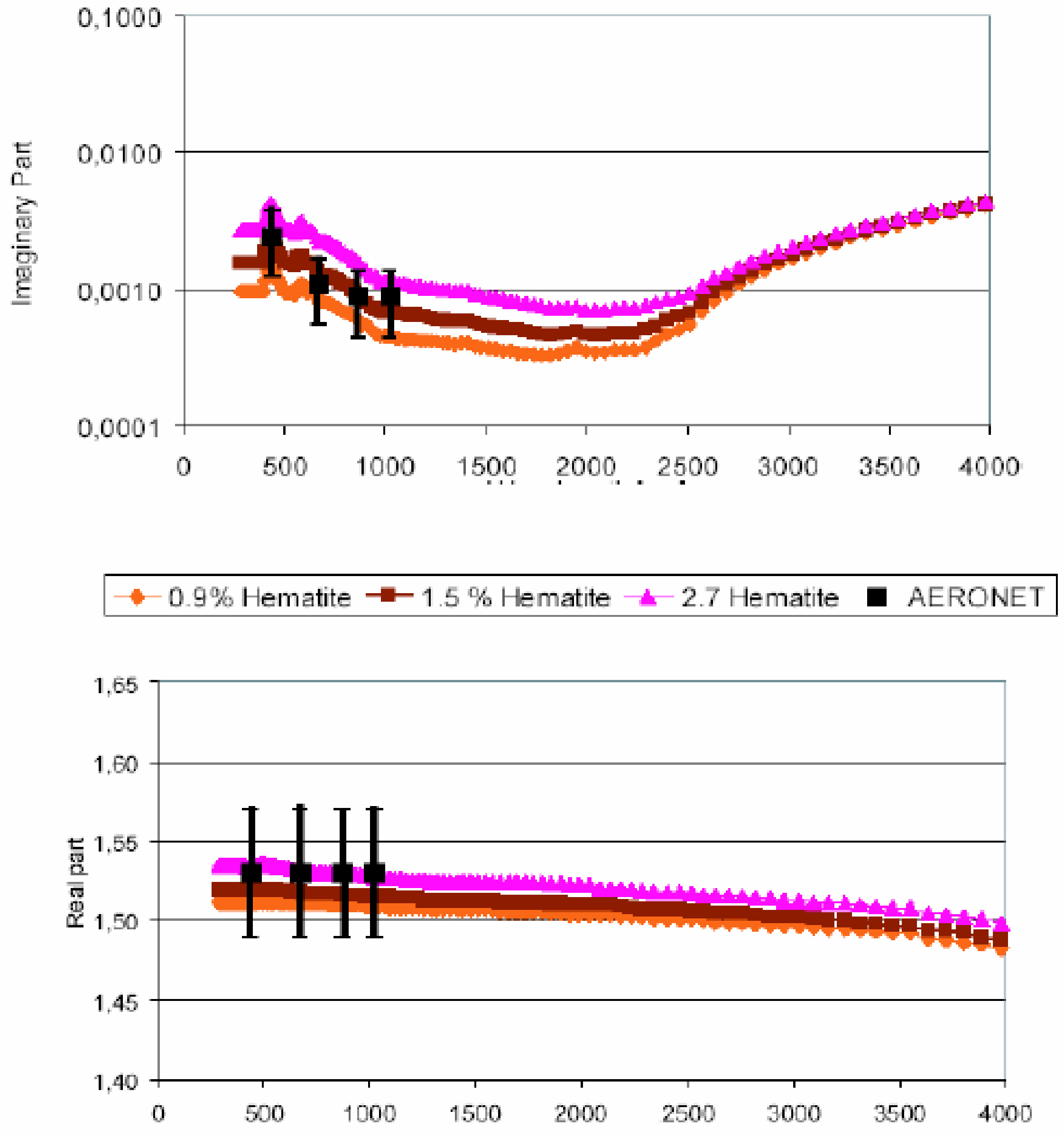
-a hypothesis of a mixture of minerals that are spherules embeded in hematite which allows to use the Maxwell-Garnett approximation

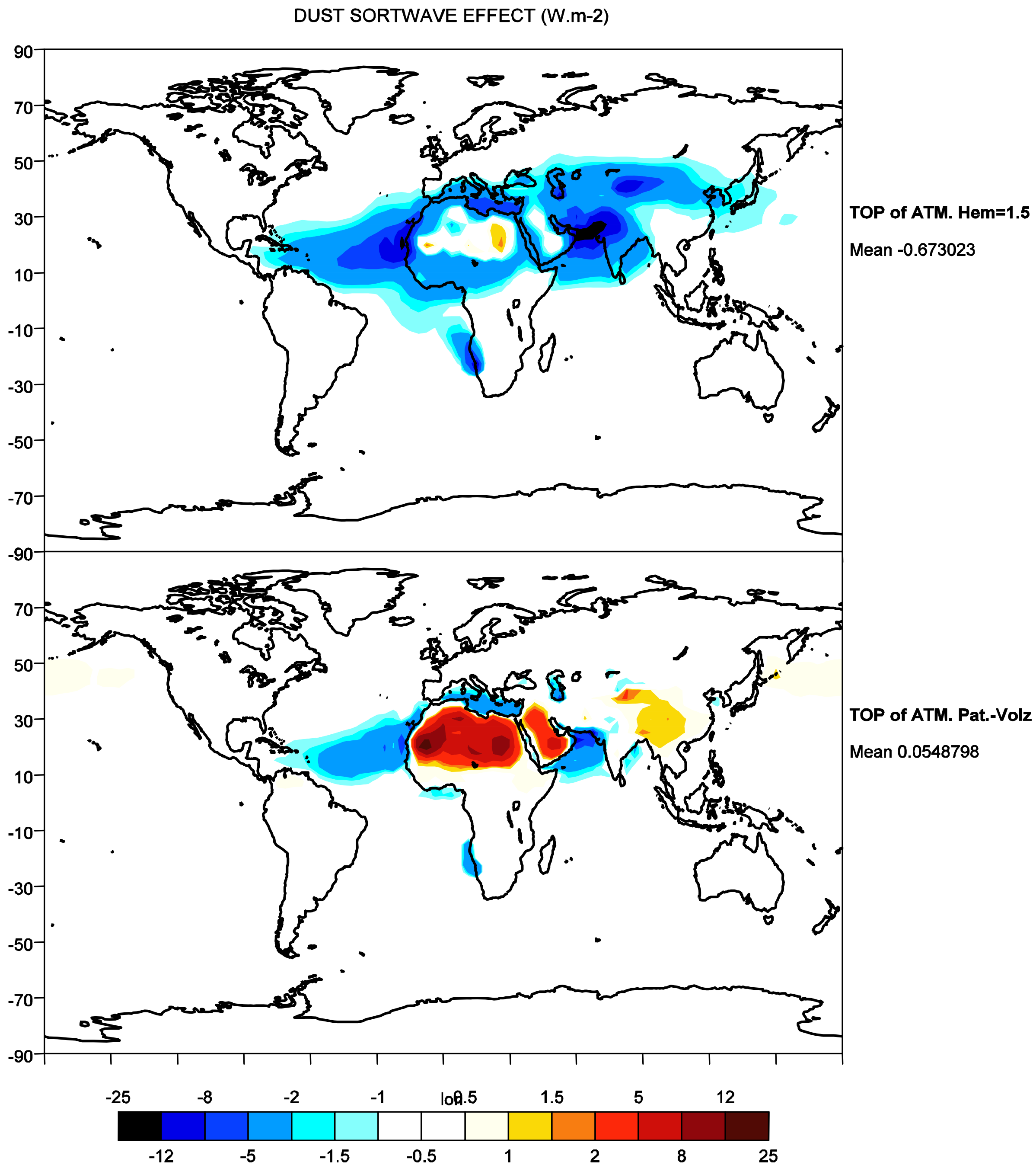


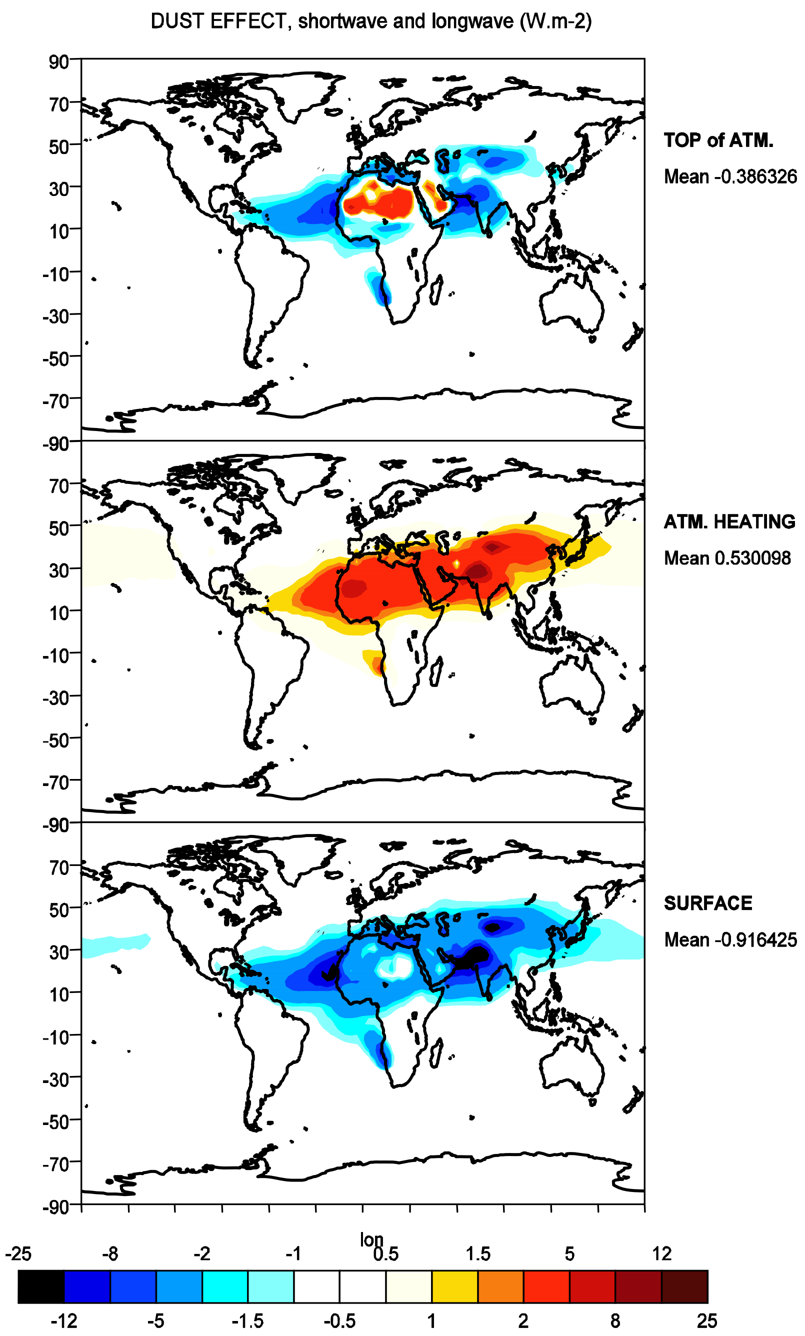
Refractive index for the volume weighed average



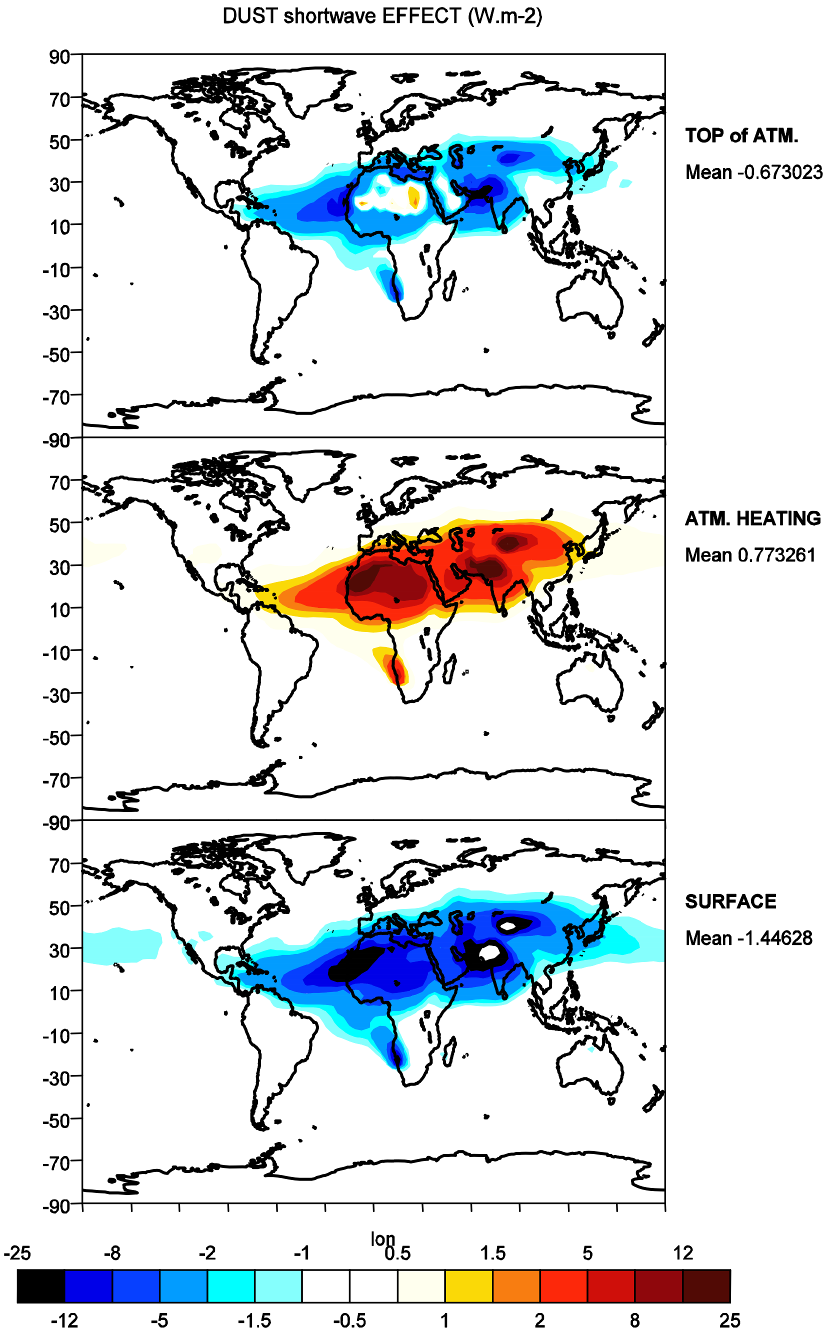
Refractive index for the Maxwell-Garnett approximation



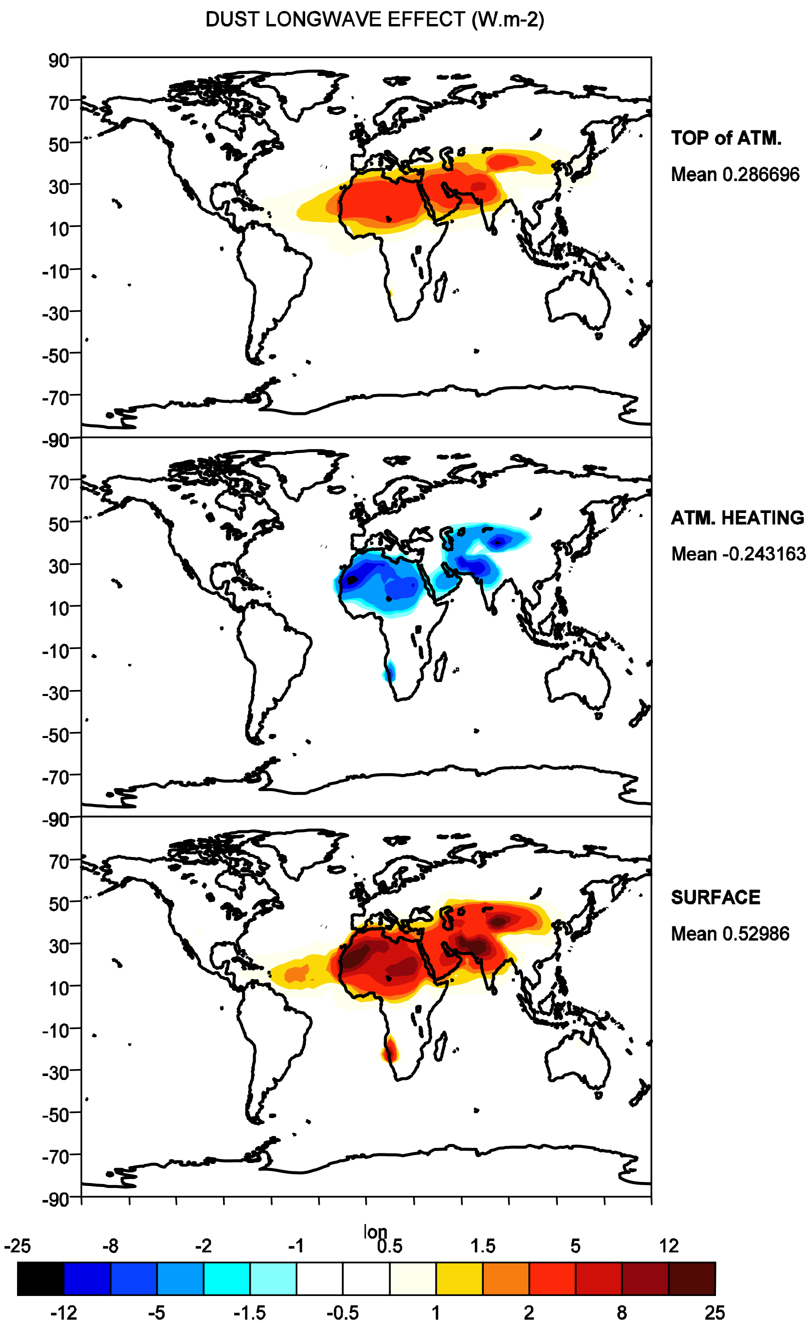

DUST SORTWAVE EFFECT (W.m-2)
90
70
50
30
10
-10
-30
-50
-70
-90
TOP of ATM. Hem=1.5
Mean -0.673023
TOP of ATM. Pat.-Volz
Mean 0.0548798
-25
-8
-2
-1
0.5
1.5
5
12
-12
-5
-1.5
-0.5
1
2
8
25

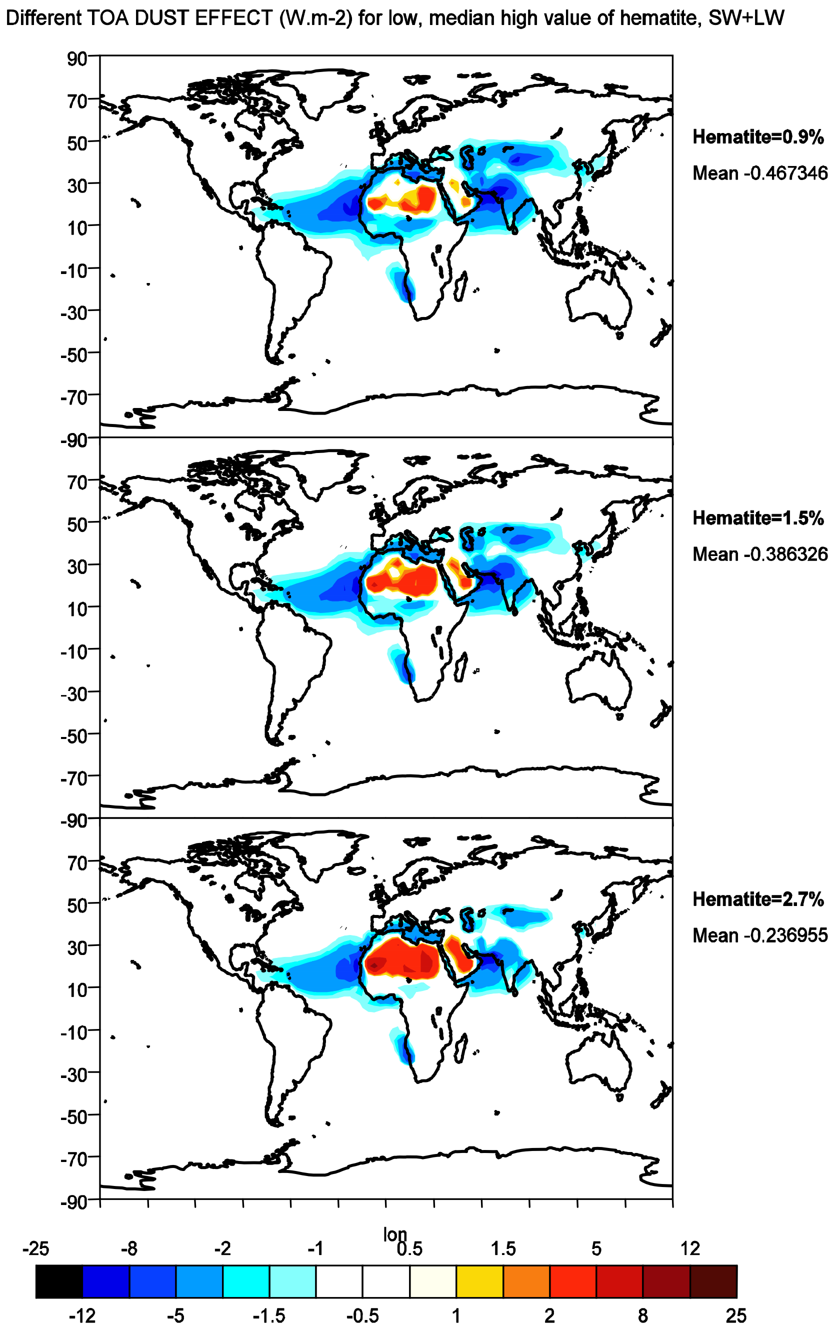


DUST EFFECT, shortwave and longwave (W.m-2)
TOP of ATM.
Mean -0.386326
ATM. HEATING
Mean 0.530098
SURFACE
Mean -0.916425
90
70
50
30
10
-10
-30
-50
-70
-90
lon
-25
-8
-2
-1
0.5
1.5
5
12
-12
-5
-1.5
-0.5
1
2
8
25



DUST shortwave EFFECT (W.m-2)
TOP of ATM.
Mean -0.673023
ATM. HEATING
Mean 0.773261
SURFACE
Mean -1.44628
90
70
50
30
10
-10
-30
-50
-70
-90
lon
-25
-8
-2
-1
0.5
1.5
5
12
-12
-5
-1.5
-0.5
1
2
8
25


DUST LONGWAVE EFFECT (W.m-2)
TOP of ATM.
Mean 0.286696
ATM. HEATING
Mean -0.243163
SURFACE
Mean 0.52986
90
70
50
30
10
-10
-30
-50
-70
-90
lon
-25
-12
-8
-5
-2
-1.5
-1
-0.5
0.5
1
1.5
2
5
8
12
25



Different TOA DUST EFFECT (W.m-2) for low, median high value of hematite, SW+LW
Hematite=0.9%
Mean -0.467346
Hematite=1.5%
Mean -0.386326
Hematite=2.7%
Mean -0.236955
90
70
50
30
10
-10
-30
-50
-70
-90
lon
-25
-8
-2
-1
0.5
1.5
5
12
-12
-5
-1.5
-0.5
1
2
8
25

Case	Load (mg m^{-2}) 0<D<1 μm	Load 1<D<10 μm	Total OD	SW TOA	LW TOA	SW+LW TOA	SW+LW SRF
			1.5% hematite internally mixes				
S1 simulation (this study)	4.0	36.2	0.031	–0.68	+0.29	–0.39	–0.92
			Refractive index Patterson-Volz				
S2 simulation (this study)	4.0	36.2	0.031	+0.05	+0.30	+0.35	–1.44
Tegen et al. (1996)	14.7	21.6	0.026	–0.39	+0.53	+0.14	–1.92
			*Refractive index from a range of measurements**				
Woodward (2001)	NA	NA	NA	–0.16	+0.23	+0.07	–0.82
			Refractive index from d'Almeida (1991)				
Myhre and Stordal (2001)	14.7	21.6	0.026	–0.61	+0.13	–0.48	NA
Same dust distribution as Tegen et al. (1996), same size distribution as Tegen and Lacis (1996)							

Clear-Sky Mineral Dust Radiative Efficiency ($Wm^{-2}\ \tau^{-1}$) Broadband Shortwave only.
All values are averaged diurnally.

	TOA	Surface	Ratio [SRF/TOA]	Heating*
Summer (JJA) over the Tropical Atlantic (15° N–25° N; 45° W–15° W)				
Li et al. (2004)	–35±3	–65±3	1.9	+30±4
S1b: 0.9% Hematite	–49	–65	1.3	+16
S1: 1.5% Hematite	–47	–69	1.5	+22
S1c: 2.7% Hematite	–45	–76	1.7	+32
S2: Patterson-Volz	–29	–88	3.0	+60
30 Sept. 2000 near Dakar (15N,17W) values reported in Anderson et al. (2005) The model gridbox averages over (16.85° W–13.1° W and 13.75° N–16.25° N)				
Haywood et al. (2003)	–24	–38	1.6	+12
S1b: 0.9% Hematite	–24	–48	2.0	+24
S1: 1.5% Hematite	–21	–51	2.4	+30
S1c: 2.7% Hematite	–16	–57	3.6	+41
S2: Patterson-Volz	+4	–70	–17.5	+74

The column heating ($W\ m^{-2}$) is computed as the difference between TOA and surface fluxes.

Single scattering albedo (at 550nm)

Patterson –Volz	External Mixture hem. Low/med./high	Internal Mixture idem
0.89	0.90/0.94/0.96	0.95/0.97/0.98

Case	SW	LW	SW+LW TOA	SW+LW SRF
Internal mixtures (this study)				
S1: 1.5% hematite	–0.68	+0.29	–0.39	–0.92
S1b: 0.9% hematite	–0.76	+0.29	–0.47	–0.81
S1c: 2.7% hematite	–0.53	+0.29	–0.24	–1.11
External mixtures (this study)				
S3: 1.5% hematite	–0.38	+0.32	–0.06	–1.01
S3b: 0.9% hematite	–0.53	+0.32	–0.21	–0.80
S3c: 2.7% hematite	–0.15	+0.32	+0.17	–1.33
External mixtures (Myrhe and Stordal, 2001)				
0.5% hematite	–1.14	+0.42	–0.72	NA
1.0% hematite	–1.08	+0.41	–0.66	NA
Sensitivity study with 2 modes (this study) 1st mode with MMD=2.5 μm for and 2nd mode MMD=5.0 μm at the source				
S4: 1.5% hematite	–0.78	+0.38	–0.40	–1.13

What have we learned?

The combination of satellite observations, AERONET retrieved refractive indices and mineralogy indicate that both SW and SW+LW TOA radiative perturbation by dust are negative.
We estimated from sensitivity studies the TOA perturbation (SW+LW) in the range from -0.17 to –0.47 W m^{-2}

The radiative forcing efficiency derived from satellite and airborne measurements could be used in AEROCOM to examine TOA, surface aerosol radiative fluxes as well as atmospheric column heating

AEROCOM news:

AERONET retrieved refractive indices are showing Higher values than in version 2. We will examine how if this changes The conclusions presented here.