Integrating models and observations for a better representation of the global dust cycle

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Model:
dust cycle simulated within CESM in different configurations, including with CAM4-BAM (sectional model with four bins 0.1-10 µm diameter)

Dust observations:

Table 2. Observational Datas Sets Used in This Work and Related Dust Properties for Comparison With the Two Models

Property	Feature	Data Set	Reference	Metric
AOD	Magnitude	AERONET	*Holben et al.* [1998]	AOD, annual average
AOD	Seasonality	AERONET	*Holben et al.* [1998]	AOD, monthly average
Column load	Size distribution	AERONET	*Dubovik and King* [2000]	Correlation for 1–10 μm range
Surface conc.	Magnitude	U. Miami	*Prospero et al.* [1998]	Concentration ($\mu g/m^3$), annual average
Surface conc.	Seasonality	U. Miami	*Prospero et al.* [1998]	Concentration ($\mu g/m^3$), monthly average
Deposition	Magnitude	This work	This work (Text S1)	Modern flux (mg/m^2 yr)
Deposition	Magnitude	This work	This work (Text S1)	LGM flux (mg/m^2 yr)
Deposition	Magnitude	This work	This work (Text S1)	Interglacial flux (mg/m^2 yr)
Deposition	Size distribution	This work	This work (Text S1)	Correlation for 1–10 μm range
Deposition	Provenance	This work	This work (Text S1 and Table S1)	Source apportionment

Albani et al. 2014 (JAMES)

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Improved dust representation in the Community Atmosphere Model

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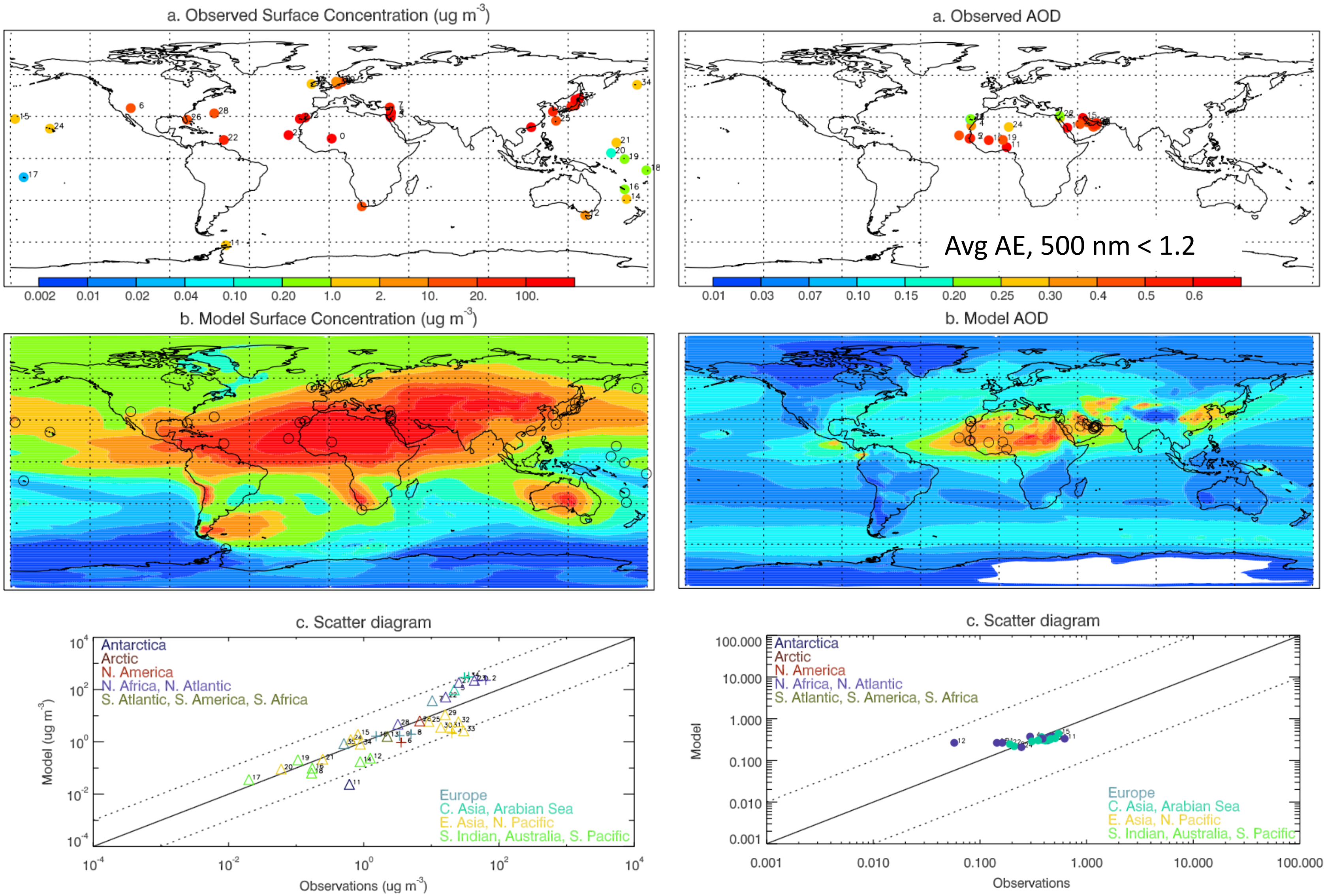
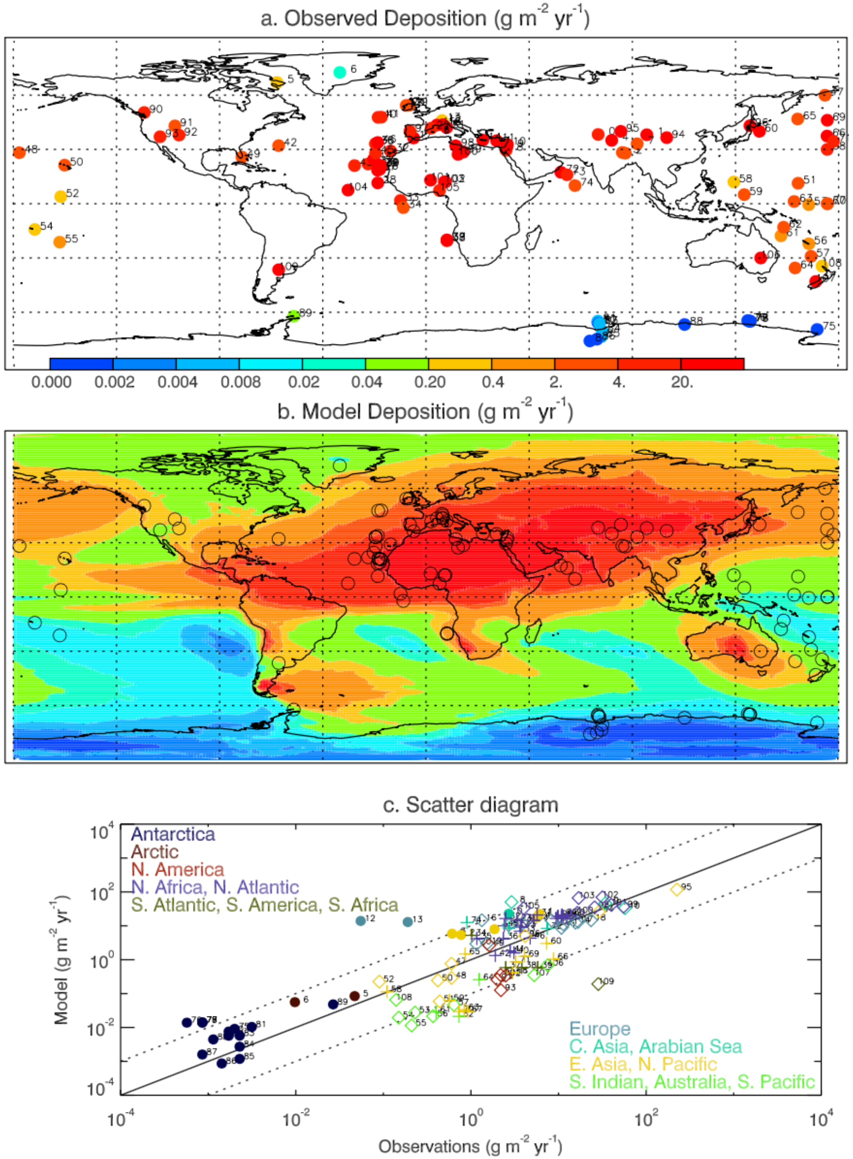
Key Points:
- Refined physical parameterizations of

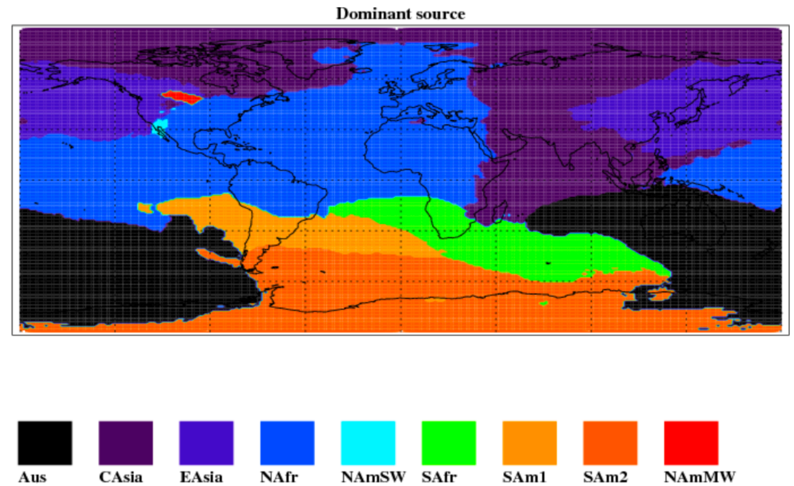
Climatological averages: surface concentrations and "dusty" AOD



Albani et al. 2014 (JAMES)

Climatological averages: dust deposition and provenance

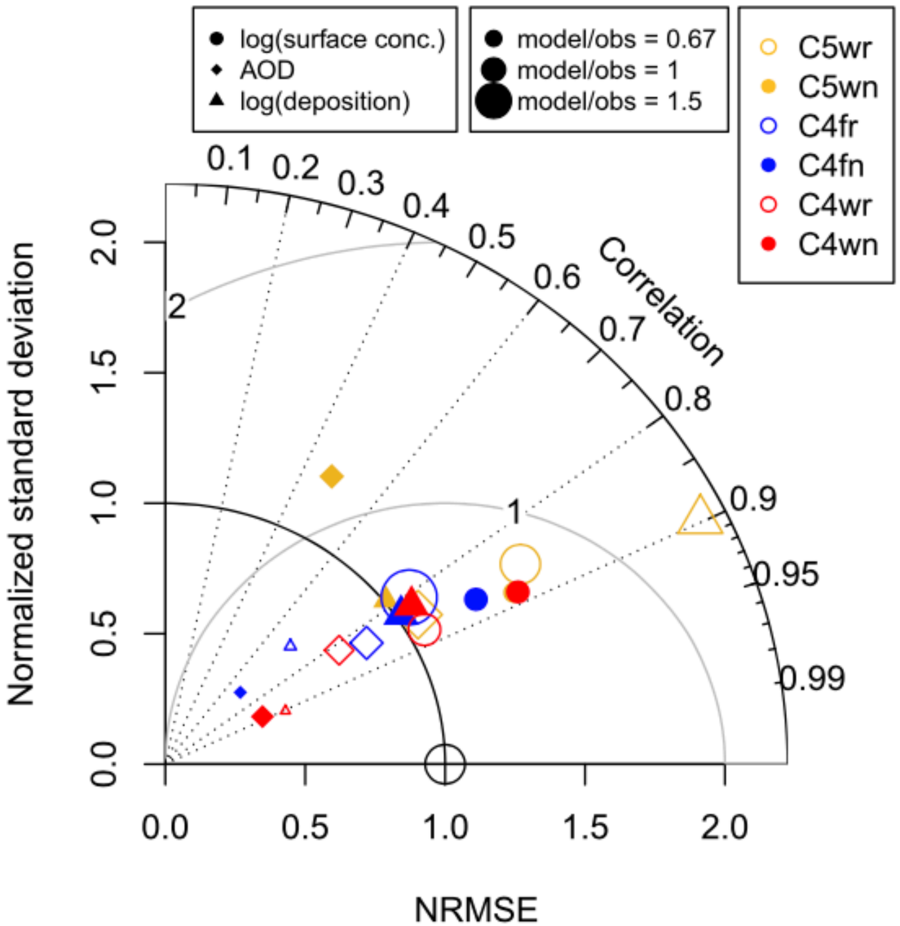




Site	Lat	Lon	Source interglacial / present	Source LGM	References Interglacial	References LGM
EDC	-75.1	123.35	Patagonia main source. Important also AUS/Puna.	Patagonia 95%, other either AUS or Puna Altiplano	Delmonte et al. 2007; Revel-Rolland et al. 2006; Delmonte et al. 2008A; Gaiero 2008; Marino et al. 2008; Gabrielli et al. 2010; Lanci et al. 2008; Vallelonga et al. 2010; De Deckker et al. 2010	Delmonte et al. 2008B and references therein
Vostok	-78.47	106.8	Patagonia main source. Important also AUS/Puna.	Patagonia 95%, other either AUS or Puna Altiplano	Delmonte et al. 2007; Revel-Rolland et al. 2006; Delmonte et al. 2008A; Gaiero 2008	Delmonte et al. 2008B and references therein
TALDICE	-72.82	159.18	Major local sources	Similar to EDC, Vostok; dominated by Patagonia	Delmonte et al. 2010B	Delmonte et al. 2010A
Berkner Island	-78.6	314.28	Patagonia + possible AUS. Local sources important contribution		Bory et al. 2010	
Law Dome	-66.72	113.2	Possibly Australia		Burn-Nunes et al. 2011	
GRIP	72.6	322.4	Gobi and Greenland, Canada major. Easia and NAF possible. Major dominating source EAsia	East(central) Asia. Alaska, Canada, Siberia cannot be ruled out as minor sources. Gobi-EAsia major sources	Burton et al. 2007; Bory et al. 2003B	Svensson et al. 2000; Burton et al. 2007
GISP2	72.6	322.4		East Asia		Biscaye et al. 1997
NGRIP	75.1	317.7	Taklamakan primary source. Tenegger, Mu Us, Gobi additional sources		Bory et al. 2003A; Bory et al. 2003B	
Dye3	64.65	315.39	Major dominating source Easia. Additional secondary source is NAF		Lupker et al. 2010; Bory et al. 2003B	

Albani et al. 2014 (JAMES)

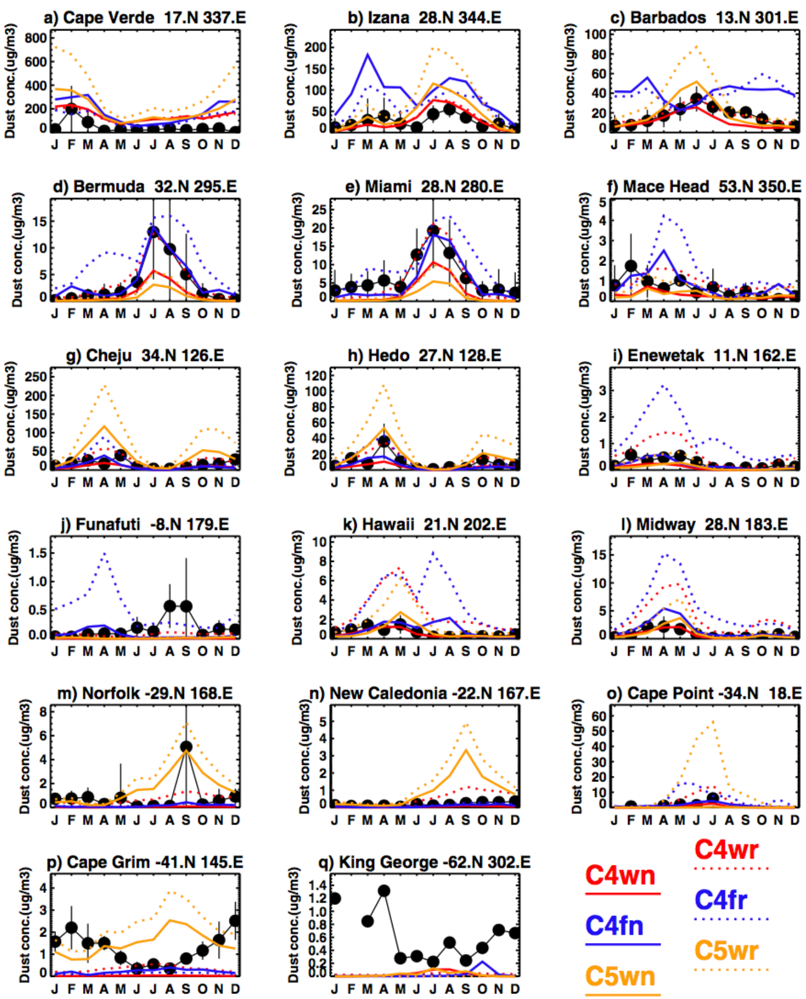
Climatological averages: overall comparison of different model setups

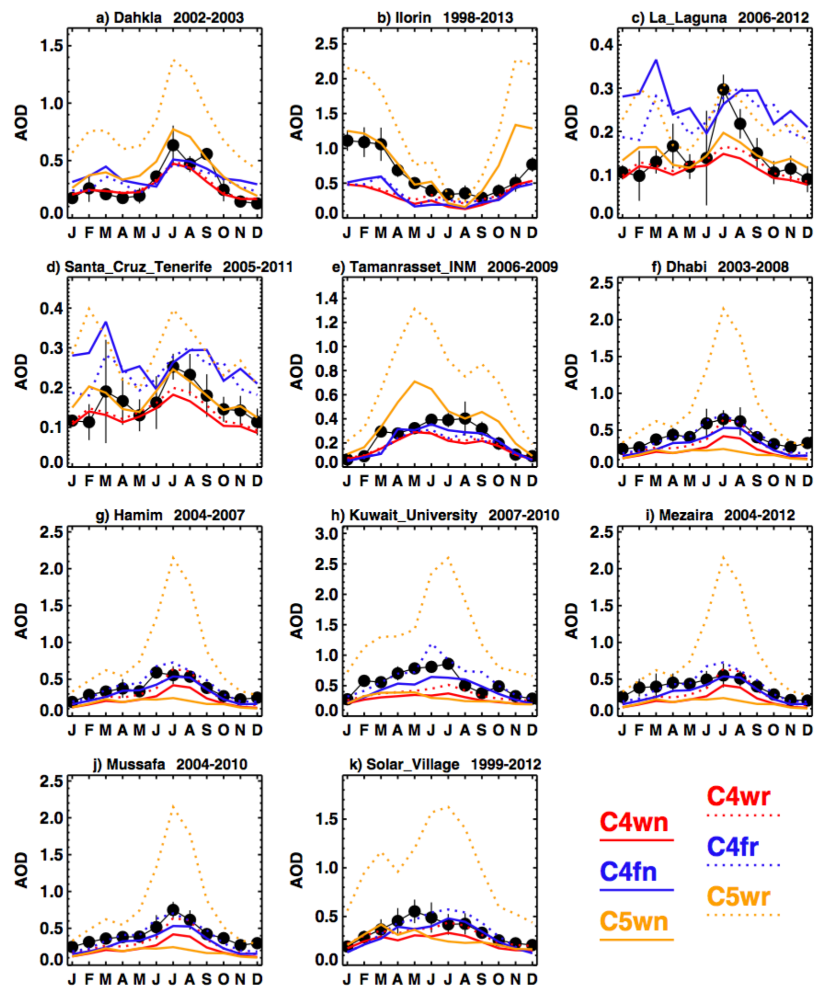


Difficulty in capturing all features at the same time (e.g. Huneeus et al., 2011)

Albani et al. 2014 (JAMES)

Comparing the seasonal cycle: surface concentration and AOD





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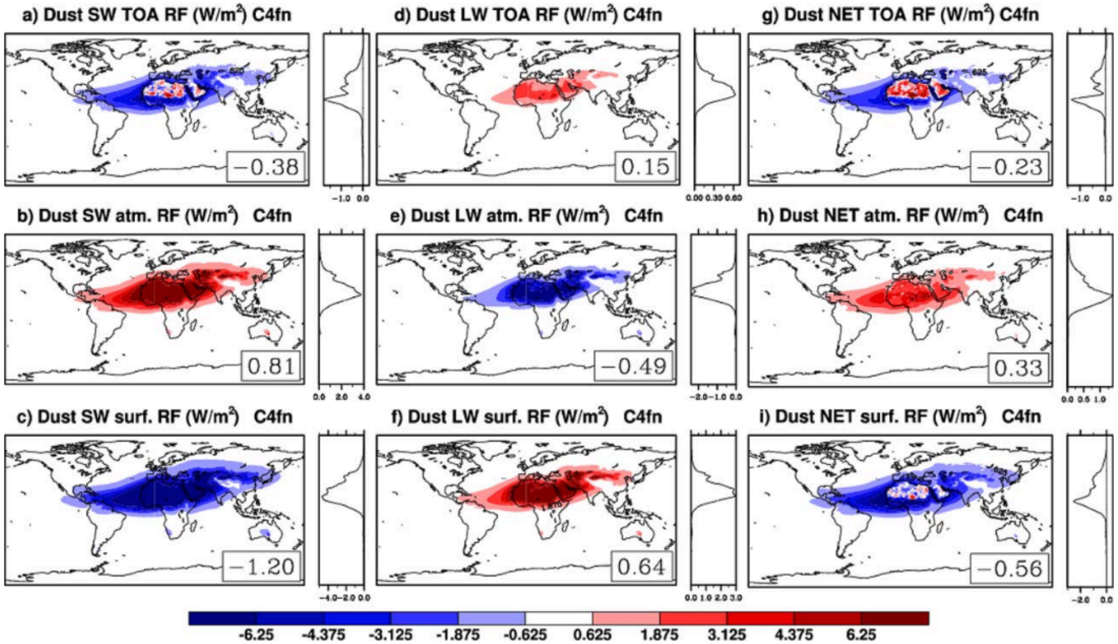
Dust direct Radiative Forcing



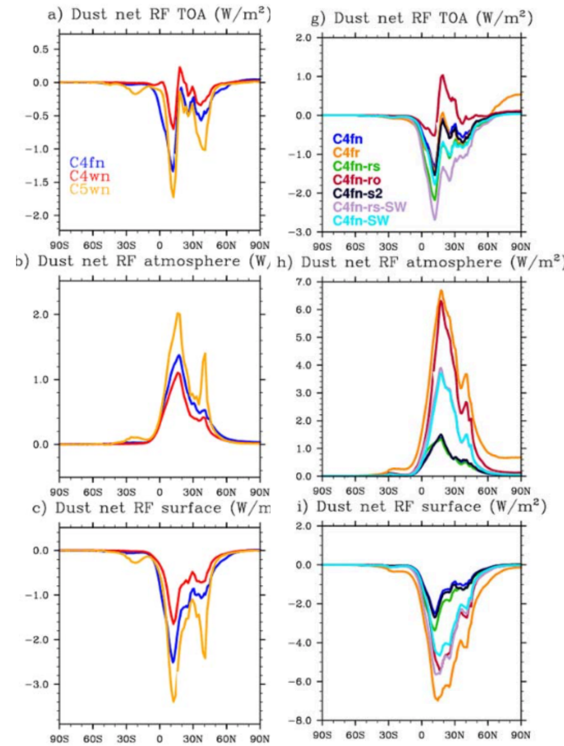
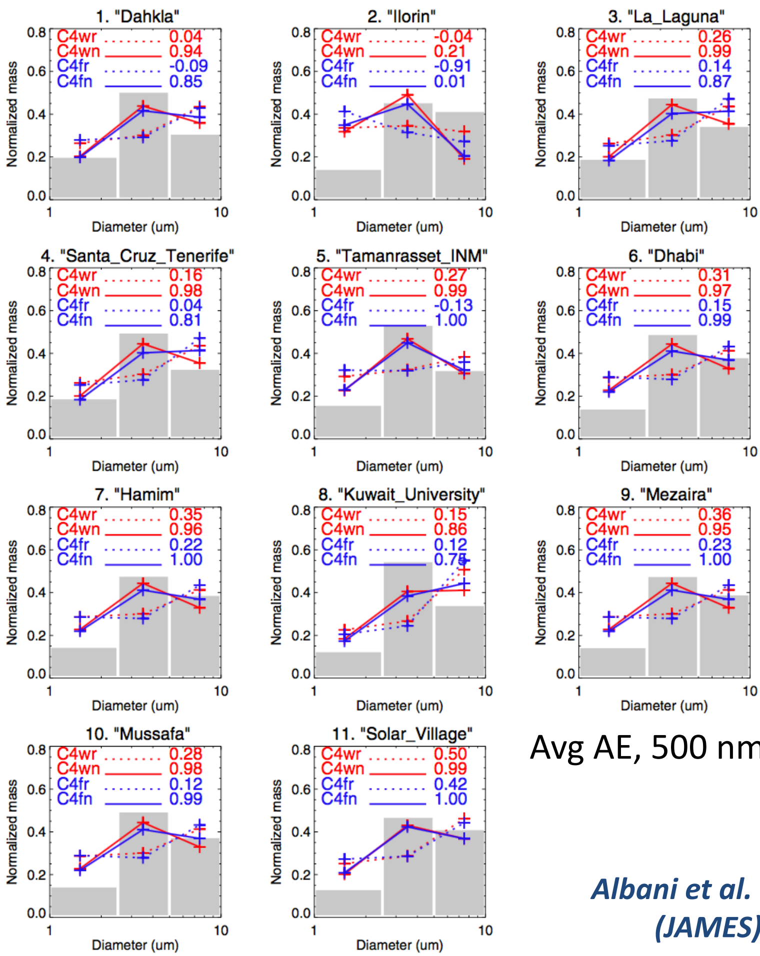


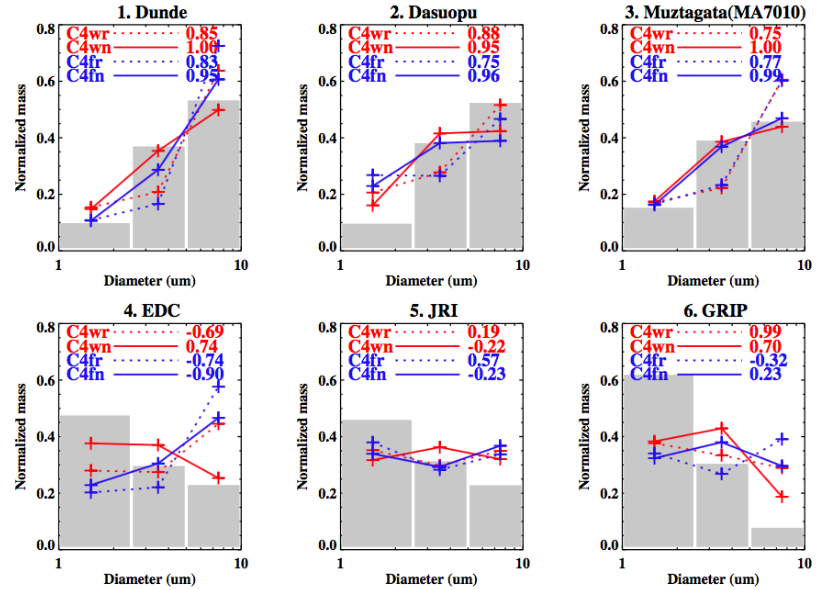
Table 6. Comparison of Observed and Modeled Net TOA Clear-Sky RF (W/m^2)

Parameter	SW TOA JJA	LW TOA Sept	SW TOA JJA
Domain	N. Atlantic 15°N–25°N, 45°W–15°W	Sahara 15°N −35°N, 18°W–40°E	Sahara 15°N–35°N, 18°W–40°E
Reference	*Li et al.* [2004]	*Zhang and Christopher* [2003]	*Patadia et al.* [2009]
Obs.	−35 ± 3	15	~0 for Albedo of 0.40
C4fr	−31.7 ± 0.4		18.4 ± 0.4
C4fn	−34.5 ± 0.2	9.8 ± 0.6	3.1 ± 0.3
C4wr	−28.4 ± 0.7		19.9 ± 0.7
C4wn	−32.4 ± 0.8	9.2 ± 0.3	3.6 ± 0.4
C5wr	−21.4 ± 1.1	4.0 ± 0.3	11.9 ± 0.9
C5wn	−32.2 ± 1.0	5.0 ± 0.4	−1.1 ± 0.3
C4fn-ro	−24.36		30.05
C4fn-rs	−32.82	7.52	−0.56
C4fn-s2	−33.63	9.39	2.33

Albani et al. 2014 (JAMES)

Comparing dust particle size distributions: AERONET and ice cores





Avg AE, 500 nm < 0.8

Albani et al. 2014 (JAMES)

Simulations improved by changing:

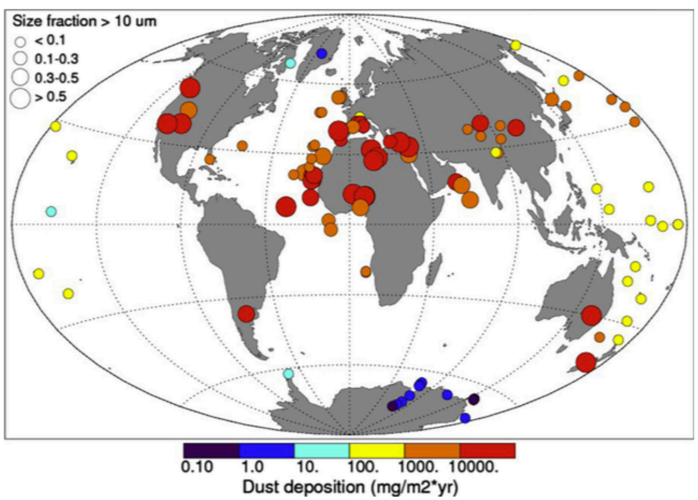
- Emission size distribution
- Large scale soil erodibility
- Wet scavenging
- Optical properties

Comparison with observationally-based size distributions suggests possible hints to simulated winds and/or scavenging parameterizations

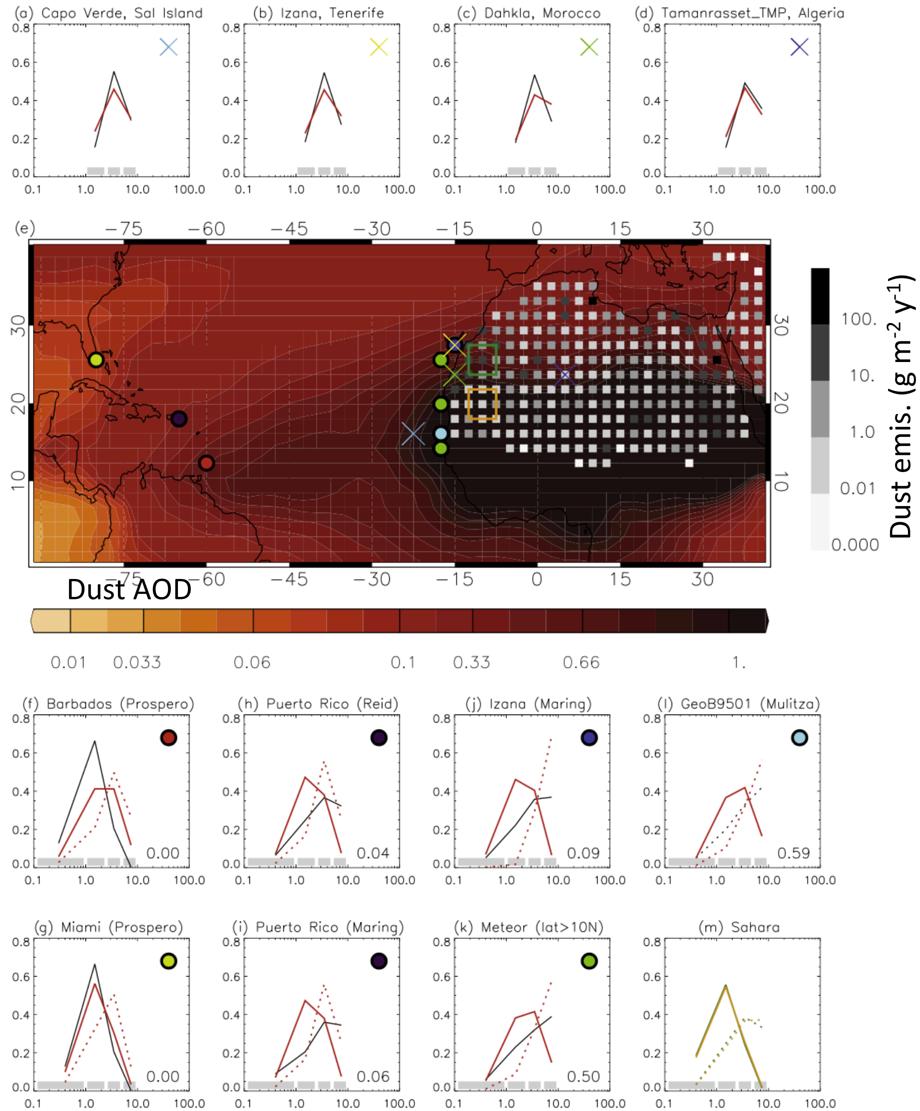
Value of constraining particle size distributions: magnitude of dust cycle

The spatial features of the global dust cycle and its magnitude (load, deposition, etc.) are tightly coupled to particle size distributions.

It's intuitive and offers the chance to more deeply understand the evolution of dust plumes.



Mahowald et al. 2014 (Aeol. Res.)



Value of constraining particle size distributions: impacts on radiative budget

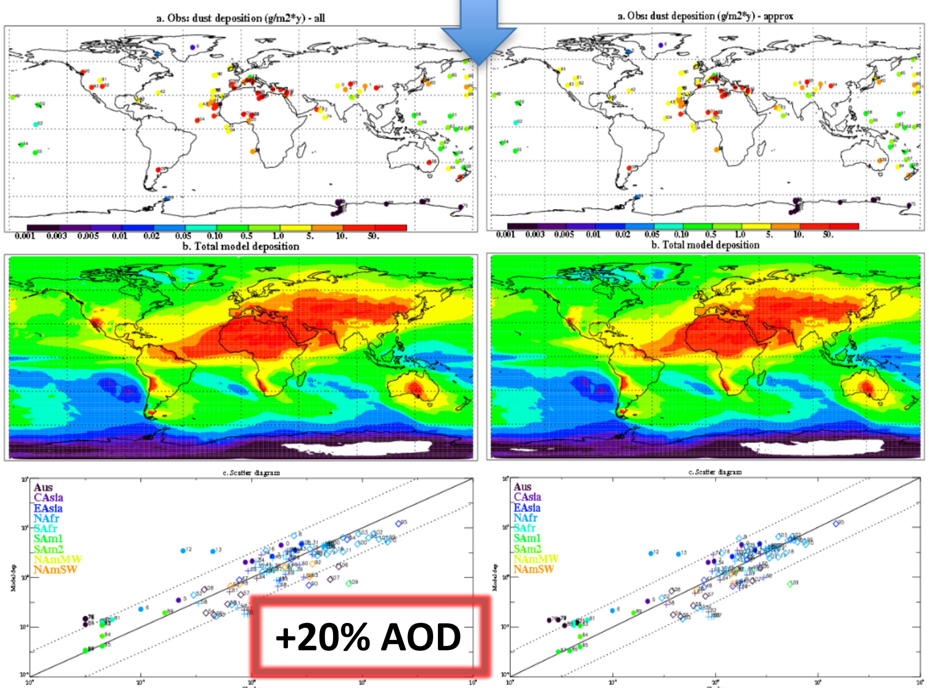
Test:

optimization algorithm on dust emission to match dust deposition from obs.:

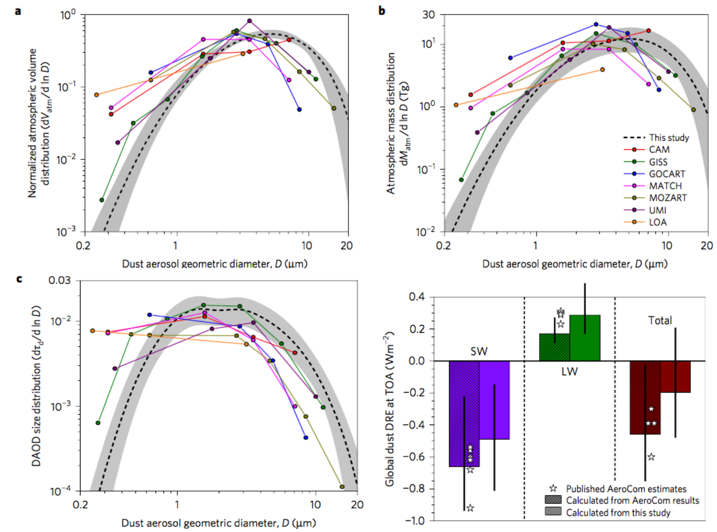
(a) bulk dust dep. Vs

(b) fine dust dep. - same size range as the model (<10 m diam.)

Bulk dust *Same size range*



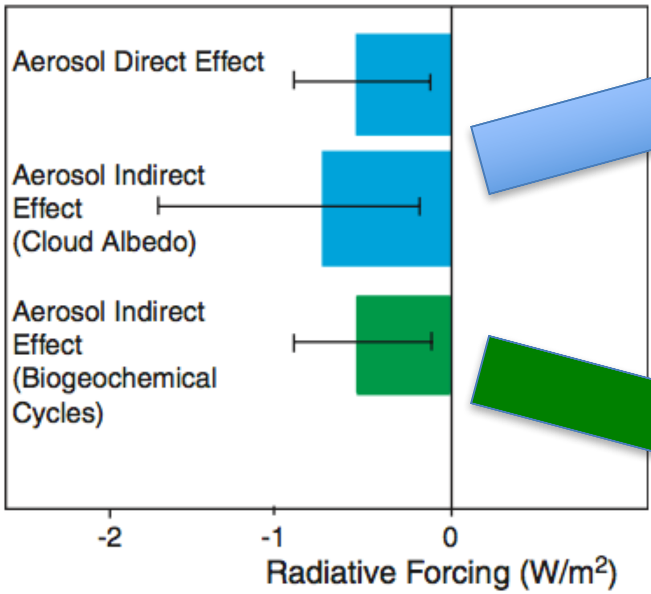
Albani et al. 2014 (JAMES)



Kok et al. 2017 (Nat. Geosci.)

Global estimates based on AOD retrievals and assumptions on dust size distributions and optical properties suggest potentially large differences compared to earlier AeroCom results.

Value of constraining deposition: indirect effects on biogeochemistry



Mahowald 2011 (Science)

Mass, number, size distribution of atmospheric dust particles

Size-resolved optical properties

Potential as CCN and IN

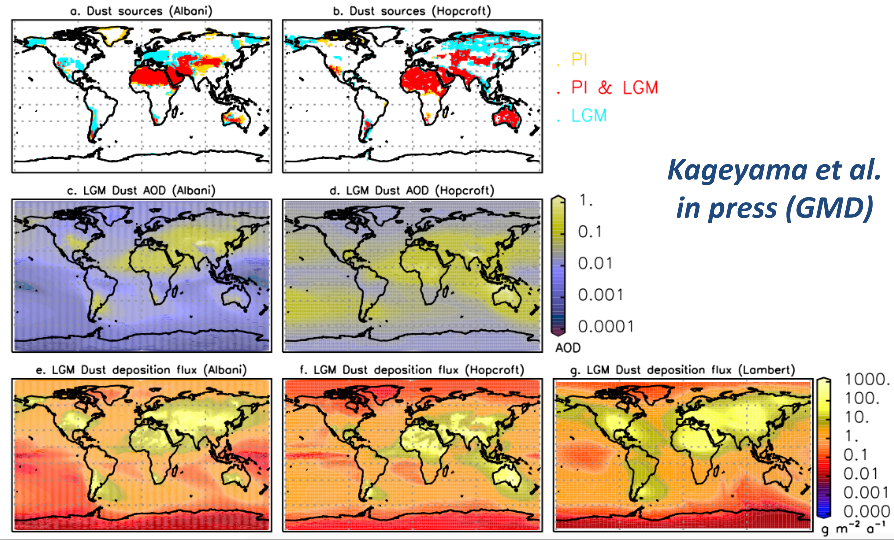
Mass, size distribution of dust deposition fluxes

Size-resolved mineralogical and elemental composition

Fertilization of land (P) and marine (Fe) ecosystems

Value of constraining deposition: link with paleoclimate

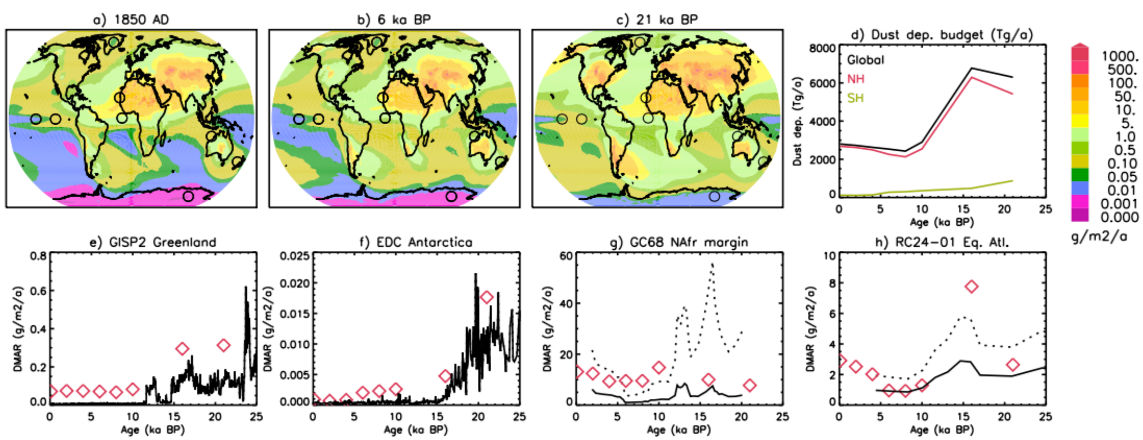
An interactive dust cycle is now an explicit possibility in CMIP6/PMIP4 experiments (Eyring et al., 2016; Kagayama et al., 2016).



Kageyama et al. in press (GMD)

Dust deposition is the variable that

- can be compared to paleoclimate observations and
- can be compared across climates in relation to observations



Albani et al. 2016 (GRL)

Take home messages

- Example of dust model data comparison
  - Multiple views (conc, AOD, dep) → difficult to constrain all
  - Average vs seasonal
  - Comparison with estimates of RF
  - Comparison with particle size distributions

- Value of evaluating particle size distributions
  - Better constrain magnitude (i.e. compare in the same size rage)
  - Better constrain spatial features (e.g. gradients) and proxy for potential "faulty" processes
  - Impact on radiation and clouds

- Value of evaluating dust deposition rates
  - Complementary view on the global dust cycle
  - Helpful to constrain spatial gradients in atmospheric burden and particle size distributions
  - Link with paleoclimate (CMIP6/PMIP4 experiments)
  - Indirect effects on biogeochemistry stem from deposition to the surface