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

Samuel Albani ¹
Natalie Mahowald ², Yves Balkanski ¹

¹ LSCE/IPSL, France
² Cornell University, USA

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 708119.
**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>
<thead>
<tr>
<th>Property</th>
<th>Feature</th>
<th>Data Set</th>
<th>Reference</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOD</td>
<td>Magnitude</td>
<td>AERONET</td>
<td>Holben et al. [1998]</td>
<td>AOD, annual average</td>
</tr>
<tr>
<td>AOD</td>
<td>Seasonality</td>
<td>AERONET</td>
<td>Holben et al. [1998]</td>
<td>AOD, monthly average</td>
</tr>
<tr>
<td>Column load</td>
<td>Size distribution</td>
<td>AERONET</td>
<td>Dubovik and King [2000]</td>
<td>Correlation for 1–10 μm range</td>
</tr>
<tr>
<td>Surface conc.</td>
<td>Magnitude</td>
<td>U. Miami</td>
<td>Prospero et al. [1998]</td>
<td>Concentration (μg/m³), annual average</td>
</tr>
<tr>
<td>Surface conc.</td>
<td>Seasonality</td>
<td>U. Miami</td>
<td>Prospero et al. [1998]</td>
<td>Concentration (μg/m³), monthly average</td>
</tr>
<tr>
<td>Deposition</td>
<td>Magnitude</td>
<td>This work</td>
<td>This work (Text S1)</td>
<td>Modern flux (mg/m² yr)</td>
</tr>
<tr>
<td>Deposition</td>
<td>Magnitude</td>
<td>This work</td>
<td>This work (Text S1)</td>
<td>LGM flux (mg/m² yr)</td>
</tr>
<tr>
<td>Deposition</td>
<td>Size distribution</td>
<td>This work</td>
<td>This work (Text S1)</td>
<td>Interglacial flux (mg/m² yr)</td>
</tr>
<tr>
<td>Deposition</td>
<td>Provenance</td>
<td>This work</td>
<td>This work (Text S1 and Table S1)</td>
<td>Source apportionment</td>
</tr>
</tbody>
</table>

*Albani et al. 2014 (JAMES)*
Climatological averages: surface concentrations and “dusty” AOD

a. Observed Surface Concentration (µg m⁻³)
b. Model Surface Concentration (µg m⁻³)

a. Observed AOD
b. Model AOD

Avg AE, 500 nm < 1.2

Albani et al. 2014 (JAMES)
Climatological averages: dust deposition and provenance

### Site Details

**Site**
- **EDC**
  - **Lat**: -75.1
  - **Lon**: 123.35
  - Source: Patagonia main source. Important also AUS/Puna.
  - References: Delmonte et al. 2007; Revel-Rolland et al. 2006; Delmonte et al. 2008A; Gabriele et al. 2010; Lenci et al. 2008; Vallelonga et al. 2010; De Deckker et al. 2010
  - Inter-glacial: Patagonia 95%, other either AUS or Puna Altiplano
  - LGM: Patagonia 95%, other either AUS or Puna Altiplano

**Vostok**
- **Lat**: -78.47
  - **Lon**: 106.8
  - Source: Patagonia main source. Important also AUS/Puna.
  - References: Delmonte et al. 2007; Revel-Rolland et al. 2006; Delmonte et al. 2008A; Gabriele et al. 2010; Delmonte et al. 2008B and references therein

**TALDICE**
- **Lat**: -72.82
  - **Lon**: 159.18
  - Source: Major local sources.
  - References: Similar to EDC, Vostok; dominated by Patagonia

**Berkner Island**
- **Lat**: -78.6
  - **Lon**: 134.28
  - Source: Patagonia + possible AUS. Local sources important contribution.
  - References: Bory et al. 2010

**Law Dome**
- **Lat**: -66.72
  - **Lon**: 113.2
  - Source: Possibly Australia.
  - References: Burn-Nunes et al. 2011

**GRIP**
- **Lat**: 72.6
  - **Lon**: 322.4
  - Source: Gobi and Greenland, Canada major. East and NAF possible. Major dominating source EAsia.
  - References: Burton et al. 2007; Bory et al. 2003B

**GISP2**
- **Lat**: 72.6
  - **Lon**: 322.4
  - Source: East Asia.
  - References: Biscaye et al. 1997

**NGRIP**
- **Lat**: 75.1
  - **Lon**: 317.7
  - Source: Taklamakan primary source. Tenegger, Mu Us, Gobi additional sources.
  - References: Bory et al. 2003A; Bory et al. 2003B

**Dye3**
- **Lat**: 64.65
  - **Lon**: 115.39
  - Source: Major dominating source EAsia. Additional secondary source is NAF.
  - References: 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

Albani et al. 2014 (JAMES)
Dust direct Radiative Forcing

Albani et al. 2014 (JAMES)
Comparing dust particle size distributions: AERONET and ice cores

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

Albani et al. 2014 (JAMES)

Avg AE, 500 nm < 0.8
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.)

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

- 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

*Mahowald 2011 (Science)*
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).

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)

Kageyama et al. in press (GMD)
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