Retrieving the effective radius of Saharan dust coarse mode from AIRS

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Introduction

- IPCC 2001: Radiative forcing of dust aerosol poorly known

- dust size: a key parameter for shortwave radiative forcing

- In-situ measurements show a high variability [Reid et al., 2003]

- present satellite retrievals from visible radiances not yet satisfactory (MODIS) [Lévy et al., 2003]

→ New approach: characterization of dust size from high resolution infrared measurements (AIRS)
Dust size distribution

Bimodal lognormal distribution
- accumulation mode: $r_a$, $\sigma_a$
- coarse mode: $r_c$, $\sigma_c$

$$n(r) = \frac{C}{r} \exp \left[ \frac{1}{2} \left( \frac{\log(r) - \log(r_m)}{\log(\sigma)} \right)^2 \right]$$

<table>
<thead>
<tr>
<th>Computations with Mie code</th>
<th>Visible (0.55 µm)</th>
<th>Infrared (10 µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOD acc / AOD coarse</td>
<td>1.0</td>
<td>0.08</td>
</tr>
</tbody>
</table>

- Advantage of the infrared: monomodal distribution (coarse mode: $r_c$, $\sigma_c$)

Exemple of bimodal aerosol size distribution (Dubovik et al., 2000)
Dust size distribution

Only one parameter is to be considered: coarse mode effective radius $r_e$

No effect of the width of the size distribution

Choice: $\sigma_c = 2.2$

$\sigma_c =$ geometric standard deviation

Normalized extinction vs Wavelength ($\mu$m)
Sensitivity study (1)

Difference between 2 AIRS channels
BT 177 (8.14 µm) – BT 165 (9.32 µm):

1. BT sensitive to atmospheric situation (temperature and gas profiles)
2. The impact of dust depends on the atmospheric situation

→ retrieving dust properties from infrared radiances first requires knowledge of the atmospheric situation
Signature of dust (BT clear – BT dust) for 324 AIRS channels:

→ Effect of dust optical depth and dust layer altitude: a few K
Sensitivity study (3)

- **Size**
  - $\Delta BT (3\mu m - 1\mu m)$
  - $500, 1000, 1500, 2000, 2500$ wavenumber

- **Shape**
  - $\Delta BT$ (spheroids-spheres)
  - $500, 1000, 1500, 2000, 2500, 3000$ wavenumber

$\rightarrow$ Effect of dust size and shape: a few tenths of K
Method: a 2-step process

**Step 1**
- 8 channels BTs
- Look-Up-Tables
- atmosphere (TIGR)
- + dust AOD (at 10 µm) + dust altitude

**Step 2**
- Channel 165 (1072.5 cm⁻¹)
- BT 165(re) calculated
- BT 165 observed

Pierangelo et al, ACP, 2004
Case study: Saharan dust over the Atlantic Ocean, April to June 2003

(Pierangelo et al., ACP, 2004)
Step 2: algorithm performance

60,000 simulations (changing atmospheric situation, dust AOD and altitude)
Conditions: AOD > 0.2, altitude > 1300 m
Estimate of the error for a single retrieval: 0.5 to 1.5 µm

→ Good performance of the algorithm over the 1-5 µm range
Comparison with AERONET

<table>
<thead>
<tr>
<th>coarse mode effective radius (µm)</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRS</td>
<td>2.02</td>
<td>2.27</td>
<td>2.14</td>
</tr>
<tr>
<td>AERONET (Capo-Verde)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spherical particles</td>
<td>1.67</td>
<td>1.78</td>
<td>1.67</td>
</tr>
<tr>
<td>non spherical particles</td>
<td>1.89</td>
<td>1.71</td>
<td>1.67</td>
</tr>
</tbody>
</table>

Possible reasons for discrepancies:
- only **2 to 5 days per month** for AERONET and AIRS (not the same!)
- AERONET: **day-time**, AIRS: **night-time**
- AERONET less sensitive to bigger particles (**size parameter** ≈ 15), may explain overestimation

→ Good agreement with climatological value (2.15 µm)  
[Tanré et al., 2001]
Results: comparison with GCM

**LMDz-INCA**: mass median diameter for a monomodal distribution

**AIRS**: effective radius for the coarse mode

- **East-west gradient**: preferential settling of big particles (2.4 to 2 µm)
- **AIRS sizes decrease more abruptly than LMDz-INCA**: accumulation mode less sensitive to dry deposition than coarse mode
- **30°N**: higher radius for both AIRS and LMDz-INCA
Conclusions

- New method to constrain dust size distribution
- First time that dust size is retrieved from infrared radiances
- Results for April to June 2003 in good agreement with in situ measurements
- Reduction of the coarse mode effective radius of dust particles with transport distance (2.4 to 2 µm)
- Geographical pattern in agreement with LMDz-INCA simulations

- Promising extension to IASI (higher spectral sampling)
- Possibility to retrieve other microphysical properties: dust aspect ratio, or composition (e.g. quartz content) could be retrieved with the same procedure?