Absorbing aerosols above clouds: Getting hold of the direct aerosol effect

Karsten Peters\textsuperscript{1,2}, Johannes Quaas\textsuperscript{1}

\textsuperscript{1}Max Planck Institute for Meteorology, Hamburg
\textsuperscript{2}University of Hamburg, Hamburg

EGU General Assembly 2009, Session AS1.6
April 21, 2009
Outline

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August 13\textsuperscript{th}, 2006
Motivation • Data used • Applied Method • Results • Summary and Conclusions

Albedo enhancement

Albedo reduction
absorbing aerosols can lead to a reduction of the local planetary albedo (LPA) in cloudy scenes

Radiative forcing at TOA can exceed +10 Wm\(^{-2}\)

(Haywood and Shine, 1997; Liao and Seinfeld, 1998a,b; Keil and Haywood, 2003; Chand et al., 2009)
State of Science

- numerous numerical studies have been conducted
- analysis of satellite data only for case studies and/or short time periods

up to now, no analysis of measurements on a global scale is existent
<table>
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<th>Clouds</th>
<th>Aerosols</th>
<th>Radiation</th>
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<td><strong>MODIS</strong> (EOS Aqua)</td>
<td><strong>MODIS</strong></td>
<td><strong>CERES</strong> (EOS Aqua)</td>
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<td>- cloud fraction</td>
<td>- Aerosol optical depth</td>
<td>- shortwave local planetary albedo</td>
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<td>- cloud top temperature</td>
<td><strong>OMI</strong> (EOS Aura)</td>
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<td><strong>AMSR-E</strong> (EOS Aqua)</td>
<td>- UV-Aerosolindex</td>
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<td>- cloud liquid water path</td>
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**Spatial and temporal coverage**

0.25° x 0.25° over global oceans covering 2005 – 2006

**Restrictions applied**

solar zenith angle < 45°, OMI viewing angle < 30°
Cloudy sky LPA change with absorbing aerosol concentration

LPA depends on: 1) surface albedo
                2) cloud liquid water path (LWP)
                3) AOD (also influencing CDNC)

\[ \alpha = a_0 + a_1 (\text{LWP}) + a_2 \ln(\text{AOD}) \]

- UV-Al benchmarks are applied for sampling of absorbing aerosols
The OMI UV-AI

\[
\text{UV-AI} = -100 \cdot \left\{ \log_{10} \left( \frac{I_\lambda}{I_{\lambda_0}} \right)^{\text{meas}} - \log_{10} \left( \frac{I_\lambda}{I_{\lambda_0}} \right)^{\text{calc}} \right\}
\]

- measurements in the UV with \( \lambda = 342.5 \) and \( \lambda_0 = 388 \) nm

reduced effect of clouds and surface (Herman and Celarier, 1997)

Response of the UV-AI to particles in the atmosphere (Torres, 1998):

- \( > 0 \) for absorbing aerosols
- \( < 0 \) for scattering aerosols
- \( \approx 0 \) for clouds
Cloudy sky LPA changes with absorbing aerosol concentration

Regression coefficient calculations performed for:

- 10 Regions
- 5 UV-AI bins
  - all UV-AI values
  - UV-AI < 0
  - 0 < UV-AI < 0.7
  - 0.7 < UV-AI < 1
  - UV-AI > 1

Only scenes with 100% low cloud fraction are used
LPA dependence on cloud and surface properties

\[ \alpha = a_0 + a_1(LWP) + a_2 \ln(AOD) \]

Characteristic coefficient values

\( a_0 \): 0.03 – 0.33; surface albedo with no clouds and aerosols

\( a_1 \): 0.27 – 0.95; generally positive, very low uncertainty

reasonable values and low uncertainties for \( a_0 \) and \( a_1 \)

LPA in cloudy skies mainly determined by LWP
LPA dependence on aerosol properties

\[ \alpha = a_0 + a_1 (\text{LWP}) + a_2 \ln(\text{AOD}) \]
LPA dependence on aerosol properties

\[ \alpha = a_0 + a_1 (\text{LWP}) + a_2 \ln(\text{AOD}) \]
Radiative forcing calculations

Anthropogenic AOD Dataset supplied by Nicolas Bellouin (Hadley Centre, Met Office, Exeter, UK), as described in Bellouin et al., 2005
Regression Analysis

- relationship planetary albedo vs. aerosol optical depth in low-cloud scenes
  - mostly positive for scattering aerosols
    ( > aerosol indirect effect? )
  - gets (more) negative for absorbing aerosols
    ( > aerosol absorption above clouds)

Radiative forcing calculations

- follow seasonal cycle of absorbing aerosol emissions
  (e.g., biomass burning)
- global mean value
- forcing can exceed values of + 60 Wm\(^{-2}\) on small scales
- large uncertainties remain
Thanks for your attention


