Progress in CERES Clear-sky Aerosol Optical Thickness Dependent Shortwave ADM over Ocean

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1. Sort measured radiances into angular and wind speed bins \((w; \theta_0, \theta, \phi)\) and calculate mean radiances;

2. Calculate mean flux by integrating the mean radiances over all \(\theta\) and \(\phi\);

3. Define anisotropic factor;

4. Convert measured radiances to fluxes;
Aerosol in Ed.2 Clear-sky ADM over Ocean

• AOD is not directly accounted for in Ed.2 ADM;
• It is implicitly accounted for by a theoretical scale factor when radiances are converted to fluxes (Loeb et al., 2005).

\[ F = \frac{\pi I_O}{R \left( \frac{R_{I_0}^{th}}{R_{\hat{i}}^{th}} \right)} \]

• $R$ is the anisotropic factor for converting $\hat{i}$ at $(w, \theta_0, \theta$ and $\phi)$ to $F$;
• $R_{\hat{i}}^{th}$ is the theoretical anisotropic factor for $\hat{i}$;
• $R_{I_0}^{th}$ is the theoretical anisotropic factor for $I_0$.
How to quantify the performance of an ADM?

RMS of normalized radiance differences between ADM-prediction and observation

\[
RMS = \sqrt{\frac{1}{n} \sum \left( \frac{\hat{I}^i}{\langle \hat{I} \rangle} - \frac{I^i_o}{\langle I_o \rangle} \right)^2}
\]

\(\hat{I}^i\) is the radiance value of ADM at \((w, \theta_0, \theta \text{ and } \phi)\),

\(I^i_o\) is the radiance value of the theoretical model at \((w, \theta_0, \theta \text{ and } \phi)\),

\(\langle \rangle\) is the grid mean.
Where to improve?

Where to improve?

RMS in Ed.2 ADM

(Mar 2000 to May 2005, Terra RAP mode)

RMS is a function of AOD and aerosol type
1: AOD-classified ADM

2: AOD-and-type classified ADM
(two-model-minimal approach with MODIS bands 1 and 2)

3: AOD-and-type classified ADM
(AOD-fine-mode-fraction approach with MODIS bands 1 and 2)
1: AOD-classified ADM

Given a SSF, retrieve AOD based on an aerosol model

- 0-33% AOD bins
- 33-66% AOD bins
- 66-100% AOD bins
AOD retrieval - comparison with MODIS
AOD-classified ADM -- OPAC maritime-tropic model

Ed.2 ADM RMS

New ADM RMS
AOD-classified ADM -- OPAC maritime-tropic model
1: AOD-classified ADM

2: AOD-and-type-classified ADM
(two-model-minimal-retrieval-error approach with MODIS bands 1 and 2)

3: AOD-and-type-classified ADM
(AOD-fine-mode-fraction approach with MODIS bands 1 and 2)
Given a SSF, retrieve AODs for an aerosol model representing the fine mode aerosol and an aerosol model representing the coarse mode aerosol.

Compare two retrieval errors

Fine-mode-like aerosols
- 0-33% AOD bins
- 33-66% AOD bins
- 66-100% AOD bins

Coarse-mode-like aerosols
- 0-33% AOD bins
- 33-66% AOD bins
- 66-100% AOD bins
Aerosol classification

percentage of coarse-mode-like aerosols

( OPAC dust-urban model)

(MODIS bands 1-2, Ed.2 2000-2001 raps)
percentage of coarse-mode-like aerosols

(MODIS 1st-9th model)
AOD-and-type-classified ADM
(OPAC dust-urban model, two-model-minimal-retrieval-error approach)

Ed.2 ADM RMS

New ADM RMS
AOD-and-type-classified ADM

(OPAC dust-urban model, two-model-minimal-retrieval-error approach)

\[ \Delta RMS = -2.31\% \]

\[ \Delta F = -0.09 \text{w/m}^2 \]
AOD-and-type-classified ADM
(MODIS 1st-9th model, two-model-minimal-retrieval-error approach)

Ed.2 ADM RMS

New ADM RMS
AOD-and-type-classified ADM

(MODIS 1st-9th model, two-model-minimal-retrieval-error approach)
1: AOD-classified ADM

2: AOD-and-type-classified ADM
   (two-model-minimal-retrieval-error approach with MODIS bands 1 and 2)

3: AOD-and-type-classified ADM
   (AOD-fine-mode-fraction approach with MODIS bands 1 and 2)
3: AOD-and-type-classified ADM
AOD-fine-mode-fraction approach

Given a SSF, retrieve AOD and fine-mode fraction ($f$)

If $f < 0.5$

- **Fine-mode-like aerosols**
  - 0-33% AOD bins
  - 33-66% AOD bins
  - 66-100% AOD bins

- **Coarse-mode-like aerosols**
  - 0-33% AOD bins
  - 33-66% AOD bins
  - 66-100% AOD bins
Aerosol and fine-mode fraction retrieval

CERES (OPAC dust-urban model)
Fine mode fraction

MODIS
Fine mode fraction

AOD

(MODIS bands 1-2, Ed.2 2000-2001 raps)
Aerosol and fine-mode fraction retrieval

CERES (MODIS 1st-9th model)  MODIS

Fine mode fraction

AOD

(MODIS bands 1-2, Ed.2 2000-2001 raps)
AOD-and-type classified ADM

(OPAC dust-urban model, AOD-and-fine-mode-fraction approach)

Ed.2 ADM RMS

New ADM RMS
AOD-and-type classified ADM

(OPAC dust-urban model, AOD-and-fine-mode-fraction approach)

$\Delta RMS = -1.86\%$

New - Ed. 2

$\Delta F = -0.37 \text{w/m}^2$

$\Delta RMS (%)$

$\Delta F (\text{w/m}^2)$
AOD-and-type classified ADM

(MODIS 1st-9th model, AOD-and-fine-mode-fraction approach)
AOD-and-type classified ADM
(MODIS 1st-9th model, AOD-and-fine-mode-fraction approach)

$\Delta RMS = -1.83\%$

$\Delta F = -0.09 \text{ w/m}^2$

New - Ed. 2  \hspace{1cm} $\Delta RMS (\%)$

$\Delta F (\text{w/m}^2)$
Summary

<table>
<thead>
<tr>
<th>ADM</th>
<th>Ed.2 ADM RMS (%)</th>
<th>ΔRMS (%)</th>
<th>ΔF(w/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOD-classified</td>
<td>Three AOD-percentile bins</td>
<td>10.55</td>
<td>-2.00</td>
</tr>
<tr>
<td>AOD-and-type-classified (two-model-minimal-retrieval-error approach)</td>
<td>OPAC dust-urban model</td>
<td>10.55</td>
<td>-2.31</td>
</tr>
<tr>
<td></td>
<td>MODIS 1st-9th model</td>
<td>10.55</td>
<td>-2.09</td>
</tr>
<tr>
<td>AOD-and-type-classified (AOD-and-fine-mode-fraction approach)</td>
<td>OPAC dust-urban model</td>
<td>10.55</td>
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<td>MODIS 1st-9th model</td>
<td>10.55</td>
<td>-1.83</td>
</tr>
</tbody>
</table>

- The performance of AOD-classification ADM is nearly as good as the AOD-and-type-classified ADMs;
- As the performance of AOD-and-type-classified ADM, OPAC dust-urban model combination is better than MODIS 1st-9th model combination.
Future work

- The ADM performance with AOD-and-fine-mode-fraction approach could be better with a different fine-mode-fraction stratification.
- The ADM performance can be potentially improved with different MODIS aerosol model combinations.
- Examine ADM performances with Ed.4 cloud product and MODIS band 1-6 radiances.