CERES Angular Distribution Model Working Group Report

Wenying Su
Wenying.Su-1@nasa.gov
NASA LaRC, Hampton VA

Joseph Corbett    Lusheng Liang
Zachary Eitzen    Sunny Sun-Mack
SSAI, Hampton VA

Erica Dolinar
Univ. of North Dakota
From radiance to flux: angular distribution models

- Sort observed radiances into angular bins over different scene types;
- Integrate radiance over all $\theta$ and $\phi$ to estimate the anisotropic factor for each scene type;
- Apply anisotropic factor to observed radiance to derive TOA flux;

$$R(\theta_0, \theta, \phi) = \frac{\pi \hat{I}(\theta_0, \theta, \phi)}{\int_0^{2\pi} \int_0^{\frac{\pi}{2}} \hat{I}(\theta_0, \theta, \phi) \cos \theta \sin \theta \, d\theta \, d\phi} = \frac{\pi \hat{I}(\theta_0, \theta, \phi)}{\hat{F}(\theta_0)}$$

$$F(\theta_0) = \frac{\pi I_o(\theta_0, \theta, \phi)}{R(\theta_0, \theta, \phi)}$$
Outline

• Theoretical aerosol dependent albedo directional models over clear ocean and their effects on 24-hour averaged fluxes;

• Comparison of different sea ice fraction datasets and their impact on cloud retrievals and flux inversions;
CERES directional model: albedo as a function of SZA

- CERES observations on TRMM were used to construct albedo directional models for different scene types;
- These directional models are used to convert instantaneous CERES shortwave fluxes to 24h-averaged fluxes;
- Over clear ocean, only one directional model was created;
- To test the sensitivity of the 24h-averaged flux to different clear-ocean directional models, a set of clear ocean directional models was generated for different wind speeds, aerosol types, and aerosol optical depths using Fu-Liou radiative transfer model;
- Surface albedo for these different cases were calculated using COART radiative transfer model;
Maritime/dust aerosols are more anisotropic than other aerosol types.
Directional models are also sensitive to wind speed and aerosol optical depth

- Clear-ocean directional model is more isotropic as wind speed increases: large sensitivity to wind speed;
- Dependence of clear-ocean directional model on aerosol optical depth is relatively small.
Daily gridded MATCH aerosol type and optical depth are used to determine the directional model.
Method

• For each grid box, the albedo directional model is determined based upon the daily MATCH aerosol composition and loading, and the wind speed:

\[ \alpha = \sum_{i=1}^{7} \frac{\alpha_i(\tau_i, ws)\tau_i}{\tau_i} \]

• The 24-hour averaged fluxes derived using the above aerosol and wind speed dependent directional models are compared with the 24-hour averaged fluxes derived using a single direction model:
  – Sea salt aerosols with optical depth of 0.12 for wind speed between 5 and 7 m/s;
  – Sea salt aerosols with optical depth of 0.12 for wind speed greater than 10 m/s;
  – Sulfate aerosols with optical depth of 0.12 for wind speed between 5 and 7 m/s;
Diurnally averaged clear-sky flux difference over ocean between aerosol-dependent and aerosol-independent directional models.
Wind speed distribution for July 2010
Comparison of directional models for two cases

<table>
<thead>
<tr>
<th></th>
<th>DM</th>
<th>Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aero</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>Sea-WS5</td>
<td>64.6</td>
<td></td>
</tr>
<tr>
<td>Sea-WS7</td>
<td>63.9</td>
<td></td>
</tr>
<tr>
<td>SO4-WS5</td>
<td>63.9</td>
<td></td>
</tr>
</tbody>
</table>
# Sea ice datasets

<table>
<thead>
<tr>
<th></th>
<th>NSIDC Near-Real time Snow and Ice Extent (NISE): used in Ed4</th>
<th>NSIDC/NOAA Climate Data Record of Passive Microwave Sea Ice Concentration (CDR)</th>
<th>Cloud Working Group Imager Clear sky snow/ice concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instrument/Radiances</strong></td>
<td>SSMI, SSMIS on DMSP F13 and F17 19.4, 37.0 GHz Tb - NESDIS</td>
<td>SSMI, SSMIS on DMSP F13 and F17 19.4, 37.0 GHz Tb - RSS</td>
<td>MODIS/VIIRS 0.6μm, 2.1μm (or 1.6μm), 11μm and 12μm</td>
</tr>
<tr>
<td><strong>Algorithm</strong></td>
<td>GSFC NASA Team</td>
<td>Combination of GSFC NASA Team and GSFC Bootstrap</td>
<td>Combination of thresholds</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>25 Km</td>
<td>25 Km</td>
<td>CERES footprint – clear sky portion only</td>
</tr>
<tr>
<td><strong>Quality Control</strong></td>
<td>Low Forward processing only</td>
<td>High Consistent algorithm over time series</td>
<td>High Consistent over time, possibly subject to MODIS drifts</td>
</tr>
</tbody>
</table>
CDR product has higher sea ice concentration than NSIDC

Sea Ice Concentration, August 2012

NSIDC Ed4A

CDR CDR-ICE

Diff CDR-ICE - Ed4A

Sea Ice Concentration Means: August 2002-2014, Ocean 60N-90N

- Ed4a
- CDR-ICE
Trends in August sea ice concentration show some difference

Sea Ice Concentration Trends

NSIDC Ed4A

CDR CDR-ICE

Diff CDR-ICE - Ed4A

\begin{align*}
\text{NSIDC Ed4A} & \quad \text{CDR CDR-ICE} & \quad \text{Diff CDR-ICE - Ed4A} \\
\end{align*}

\begin{align*}
\text{Sea Ice Concentration Trends} & \\
\text{NSIDC Ed4A} & \\
\text{CDR CDR-ICE} & \\
\text{Diff CDR-ICE - Ed4A} & \\
\end{align*}
Different sea ice data sets have very little impact on cloud fraction.
Effects on SW flux are also very small

SW TOA Flux, August 2012

NSIDC Ed4A

CDR CDR-ICE

Diff CDR-ICE - Ed4A

100 150 200 250 300

100 150 200 250 300

SW TOA Flux Means: August 2002-1014, Ocean 60N-90N

190 195 200 205 210 215


10/18/2016
Clear Area Normalised CWG Snow/Ice Concentration, August 2012

Ed4A

CDR-ICE

CDR-ICE - Ed4A

0 10 20 30 40 50 60 70 80 90 100

0 10 20 30 40 50 60 70 80 90 100

-10 -5 0 5 10

0 10 20 30 40 50 60 70 80 90 100

Clear Area Normalised CWG Snow/Ice

Sea Ice

Clear Area Normalised CWG Snow/Ice

Sea Ice

0 500 1000 1500 2000

0 500 1000 1500 2000

0 500 1000 1500 2000

0 500 1000 1500 2000
Summary

• Theoretical clear-ocean albedo directional models were calculated for different wind speed, aerosol types, and aerosol optical depths:
  – Monthly 24-hour averaged SW fluxes were calculated using the directional models selected based upon MATCH aerosol types and optical depths, and the GEOS wind speed;
  – Ignore the directional model’s sensitivity to aerosol type/optical depth and wind speed, can lead to errors in monthly 24-hour averaged SW fluxes (60S-60N) up to 0.4 Wm$^{-2}$.

• Investigated the effects of different sea ice data sets on cloud retrieval and flux inversion:
  – Although the CDR has higher ice concentration than the NSIDC ice data used in CERES data production, replacing NSIDC with CDR ice concentration has minimum effects on cloud and flux;
  – The imager based sea ice fraction agrees better with the CDR data.