Updates to the CERES SW Sea Ice ADMs

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NASA Langley

1)SSAI, 2)NASA Langley
From radiance to flux: angular distribution model

- 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;

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

\[
F(\theta_0) = \frac{\pi I_o(\theta_0, \theta, \phi)}{R(\theta_0, \theta, \phi)}
\]
Sea Ice

• Highly variable surface
  - First year ice vs multi-year ice, sea ice fraction, clouds vs sea ice

• Changes significantly during the course of a year
  - Snow covered -> melting snow -> melt ponds/bare ice -> open water
  - Large albedo changes for different types of sea ice

• High solar zenith angles

• Cloudy

• Need ADMs that can account for as much of the change as possible
Existing ADMs

- **Clear sky:**
  - based on sea ice fraction
  - For >99% sea ice cover: 2 ADMs based on surface brightness
    - Surface brightness for different regions specified by mean nadir MODIS 0.645µm band over 2000-2004.
    - ADM selected by matching the measured CERES radiance to the ADM radiance

- **Overcast:**
  - 4 ADMs based on surface brightness and cloud optical thickness (>10,<10)
  - Bright/dark ADM selected by matching the measured CERES radiance to the ADM radiance

- **Fractional cloud scenes:**
  - 25% cloud fraction and 25 % sea ice fraction bins
New approach

• Classify surface brightness using a band-differenced ratio that can be determined for each footprint.
• Classify scenes by surface brightness.
• For overcast scenes apply a linear fit in log (tau).
Classifying Sea Ice Surface Brightness

- Use the differenced ratio of clear-sky MODIS 0.469µm and 0.858µm bands

\[ \text{seaiceindex} = 1 - \frac{\rho_{0.47} - \rho_{0.86}}{\rho_{0.47} + \rho_{0.86}} \]

Rosel et al 2012, surface values
Sea Ice Index, Sea Ice Fraction and Reflectance

CERES Snow Ice Fraction and Sea Ice Index by VZA

\[
\begin{align*}
\theta &= 0 - 5 \\
\theta &= 25 - 30 \\
\theta &= 50 - 55
\end{align*}
\]

CERES Reflectance and Sea Ice Index by VZA

\[
\begin{align*}
\theta &= 0 - 5 \\
\theta &= 25 - 30 \\
\theta &= 50 - 55
\end{align*}
\]
Change in Sea Ice Index over melt season

- terra NOV 2002
- terra DEC 2002
- terra JAN 2003
- terra JUN 2003
- terra JUL 2003
- terra AUG 2003
Clear Sky

• 6 Sea ice fraction bins:
  – ≤1%, 1% - 25%, 25% - 50%, 50% - 75%, 75% - 99%, ≥99%

• For scenes with sea ice fraction >99%:
  – 3 sea ice index bins: ≤0.85, 0.85 – 0.935, >0.935
Normalize predicted and observed radiance

\[
\overline{I^o} = \frac{1}{n} \sum_{j=1}^{n} I^o_j \\
\overline{\hat{I}} = \frac{1}{n} \sum_{j=1}^{n} \hat{I}_j
\]

\[
RMS = \sqrt{\frac{1}{n} \sum_{j=1}^{n} \left( \frac{\hat{I}_j}{\overline{\hat{I}}} - \frac{I^o_j}{\overline{I^o}} \right)^2}
\]

- RMS error between normalized predicted radiance and normalized observed radiance is closely related to the ADM error

Observed radiance: \(I^o_j, \ j = 1, \ldots, n\)

Predicted radiance: \(\hat{I}_j, \ j = 1, \ldots, n\)
Results

Normalized radiance – predicted radiances difference

JUL 2003 Clear Sky

Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)

μ = 11.87%

MAY 2003 Clear Sky

Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)

μ = 7.23%

μ = 8.03%
MISR BB flux consistency

Distribution of MISR BB flux standard deviations
sza = 50 - 55

Distribution of MISR BB flux standard deviations
sza = 60 - 65

Distribution of MISR BB flux standard deviations
sza = 65 - 70

Distribution of MISR BB flux standard deviations
sza = 70 - 75
Partly Cloudy Scenes

• 4 cloud fraction bins:
  – 1% - 25%, 25% - 50%, 50% - 75%, 75% - 99%

• 2 log(tau) bins:
  – ≥1, <1

• 6 Sea ice fraction bins:
  – Sea ice fraction is calculated by assuming the footprint sea ice fraction is the same as the sea ice fraction in the clear portion.
  – ≤1%, 1% - 25%, 25% - 50%, 50% - 75%, 75% - 99%, ≥99%

• For scenes with sea ice fraction ≥99%:
  – 3 sea ice index bins: ≤0.85, 0.85 – 0.935, >0.935
Results

- normalized radiance differences

**JUL 2003 Partly Cloudy**

**Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)**

- $\mu = 15.89\%$
- $\mu = 22.91\%$

**MAY 2003 Partly Cloudy**

**Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)**

- $\mu = 11.50\%$
- $\mu = 12.84\%$
Overcast Scenes

Perform a linear fit between the mean reflectance in log tau bins of width 1 and log tau bin midpoint.
   - separate fits for:
     - water phase and ice phase clouds
     - 5 clear-sky sea ice index ranges (using a monthly map)
Create BRDFs for a range of log tau values and integrate to get albedo
Perform a linear fit between albedo and log tau to get the albedo dependence
Overcast Scenes

Perform a linear fit between the mean reflectance in log tau bins of width 1 and log tau bin midpoint.

- separate fits for:
  - water phase and ice phase clouds
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Create BRDFs for a range of log tau values and integrate to get albedo

Perform a linear fit between albedo and log tau to get the albedo dependence
Results – normalized radiance differences

JUL 2003 Over Cast

Ed4SSF (with Ed4ADM)  Ed4SSF (with updated Ed2ADM)

$\mu = 9.88\%$  $\mu = 9.86\%$
JUL 2003 Over Cast

Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)

$\mu = 9.88\%$

$\mu = 9.86\%$

MAY 2003 Over Cast

Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)

$\mu = 7.13\%$

$\mu = 6.39\%$
MISR BB flux consistency

Distribution of MISR BB flux standard deviations
sza = 55 - 60

Distribution of MISR BB flux standard deviations
sza = 60 - 65

Distribution of MISR BB flux standard deviations
sza = 65 - 70

Distribution of MISR BB flux standard deviations
sza = 70 - 75
Ed4SSF (with Ed4ADM)  Ed4SSF (with updated Ed2ADM)

\[ \mu = 9.65\% \quad \mu = 9.59\% \]

MAY 2003 All Sky

Ed4SSF (with Ed4ADM)  Ed4SSF (with updated Ed2ADM)

\[ \mu = 10.06\% \quad \mu = 11.37\% \]

NOV 2002 All Sky
Summary

• New ADMs have been developed for sea ice scenes.
• Main change is the use of a normalised band difference to quantify surface brightness.
• Use of a linear fit between reflectance and log (tau) is for overcast scenes.
• Results generally show an improvement over the existing ADMs.
Clear Sky ADMs

Principle Plane Anisotropy $\theta_0 = 70-75, \phi = 0-5, 175-180$

- Ed2 Dark
- Ed2 Bright
- Ed4 $\mathrm{sii} < 0.85$
- Ed4 $0.85 < \mathrm{sii} < 0.935$
- Ed4 $\mathrm{sii} > 0.935$

Anisotropic Factor vs. vza
Flux Changes: Ed4ADMs – Ed2ADMs