CERES Angular Distribution Model
Working Group Report

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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:

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

• For each radiance measurement, first determine the scene type, then apply scene type dependent anisotropic factor to observed radiance to derive TOA flux:

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

• CERES NPP SW ADMs and their impact on inverted fluxes
• Rearchitect the shortwave inversion code, with a focus on snow/ice scene identification
• Merged LW surface emissivity datasets for Ed5
NPP CERES ADMs

- NPP FM5 started to collect RAPS data in fall of 2019.
- CERES instrument on NPP is in restricted biaxial scan since March 24, 2020, to avoid viewing the spacecraft antenna, and to minimize the instrument degradation.
  - For solar beta angle < 24°:
    Clock angle: 25° — 169°, cone angle: 0° — 64°
    Clock angle: 205° — 349°, cone angle: 0° — 64°
  - For solar beta angle ≥ 24°
    Clock angle: 25° — 180°, cone angle 0° — 64°
    Clock angle: 205° — 360°, cone angle 0° — 64°
Sample number comparison between NPP (20200324) and Aqua (20040324)

Aqua scan SZA: [20,30]  NPP scan SZA: [20,30]

Aqua scan SZA: [40,50]  NPP scan SZA: [40,50]

Aqua scan SZA: [60,70]  NPP scan SZA: [60,70]

Aqua scan SZA: [80,90]  NPP scan SZA: [80,90]
Developing NPP SW ADMs

- Using NPP FM5 Ed2A data from 201610-202207 to develop SW NPP ADMs using the Ed4 Terra/Aqua methodology.
- NPP fluxes inverted using NPP ADMs are compared with fluxes in NPP Ed2A product that used Ed4 Aqua ADMs.

SZA=40° Overcast with cloud optical depth of 10
Instantaneous NPP flux difference due to ADMs: NPP ADM-Aqua ADM

201601  $\Delta F = -1.36\, (w/m^2) \quad$ rms$= 2.28\, (w/m^2)$

201604  $\Delta F = -1.72\, (w/m^2) \quad$ rms$= 2.49\, (w/m^2)$

201607  $\Delta F =  0.65\, (w/m^2) \quad$ rms$= 2.26\, (w/m^2)$

201610  $\Delta F = -1.78\, (w/m^2) \quad$ rms$= 2.55\, (w/m^2)$
Direct Integration for SW Flux

- Construct two sets of regional (10° X 10°) all-sky ADMs by season (e.g. DJF, MAM, JJA, and SON) from
  - CERES measured radiances
    \[ I_0 \rightarrow F(\theta_0) = \frac{\pi I_0(\theta_0, \theta, \phi)}{R(\theta_0, \theta, \phi)} \]
  - ADM predicted radiances
    \[ \hat{I} \rightarrow R(\theta_0, \theta, \phi) = \frac{\pi \hat{I}(\theta_0, \theta, \phi)}{\hat{F}(\theta_0)} \]

- Both sets of regional all-sky ADMs have the same sampling
- Apply regional ADMs to cross track data of the middle month of the season to determine the fluxes
- Compare fluxes derived from these two sets of ADMs
Direct integration SW flux error for 2018 NPP FM5

- Flux errors are defined as the flux difference inverted from predicted radiance ADM and from observed radiance ADM
- Zonal mean flux errors from NPP ADMs are generally smaller than those from Aqua ADMs
- Global mean flux errors from NPP ADMs are smaller than those from Aqua ADMs by about 10-20%

05/09/2023
Rearchitect the shortwave inversion code
Snow ice variables used for inversion

- Scene identification relies on multiple variables, including imager- and microwave-based snow and ice fractions, and surface skin temperature from imager retrieval and reanalysis.
- When imager- and microwave-based snow and ice information contradict each other, surface skin temperature is used to aid scene identification.

![Graphs showing imager and microwave snow/ice fractions](image)

- Imager snow/ice > 0% with R = 0.967
- MW snow/ice > 0% with R = 0.962

- 3.6% > 280k
- 2.7% > 280k
A small percentage of footprints that were identified as sea ice and permanent snow by microwave have a surface temperature greater than 280 K.

A relatively large percentage of fresh snow footprints have surface temperature above 280 K.
Footprints with partial snow/ice cover are more likely to have surface temperature >280 K

- For footprints with snow/ice fraction between 1 and 25%, large percentage of them have surface temperature exceeds 280 K, especially over fresh snow.
100% snow/ice footprints almost all have surface temperature <280 K

- For footprints with snow/ice fraction of 100%, large percentage of them have surface temperature exceeds 280 K, especially over fresh snow.
Large percentage of fresh snow footprints with T>280K

- For 100% snow/ice fractions, 280 K is a good threshold indicating that the temperature is too warm for snow/ice.
- For smaller snow/ice fractions, significant percentage of footprints (especially fresh snow) have temperature greater than 280 K.
- Temperature threshold will be reevaluated for Ed5 (possibly snow/ice fraction-based thresholds).
Surface emissivity

- The LW and WN emissivity is an input for the cloudy-sky LW ADMs.
- For Edition 4 and earlier editions, a single value of emissivity was assigned to each IGBP type for both the LW and WN channels.
- For Edition 5, a merged surface emissivity database is developed from IASI data and from theoretical calculation:
  - Monthly climatology of surface emissivity based on 10 years of IASI hyperspectral data between 3.62 µm and 15.5 µm (Zhou et al. 2011, 2013)
  - Theoretical calculation based on Fresnel equations and the spectrally dependent indices of refraction for water, snow/ice, and desert (Huang et al. 2016)
Merged monthly surface emissivity dataset

- Surface emissivity values for the 12 Fu-Liou bands
- They are weighted to provide the broadband LW and WN emissivity values
- The spatial resolution of the merged dataset is 0.25° by 0.25°

Check surface type on IASI 0.25° × 0.25° grid

100% water?
Use Huang model for all 12 bands

land/water mixture?
Use IASI observations for all 12 bands

100% land?
vegetated according to Huang database?
Use IASI observations for all 12 bands

not vegetated?
Use Huang model for far-IR (bands 1-4), IASI for mid-IR (bands 5-12)
Emissivity difference between the merged dataset and the Ed.4 dataset

- Merged emissivity is significantly lower than that used in Edition 4 over water;
- Merged emissivity is slightly lower than that used in Edition 4 over most land areas;
- Merged emissivity is significantly higher than that used in Edition 4 over most desert regions.
Summary

• Developed a set of NPP CERES SW ADMs based on NPP CERES cross track and RAPS data and the VIIRS cloud properties for scene identification.

• Global monthly mean instantaneous NPP SW fluxes inverted from NPP ADMs can differ from those inverted from Aqua ADMs by more than 1.5 Wm$^{-2}$, with the regional fluxes differing by up to 10 Wm$^{-2}$. Large regional differences are mostly over snow/ice surface due to significant cloud property differences between VIIRS and MODIS.

• Results from direct integration indicate that global mean flux errors from NPP ADMs are smaller than those from Aqua ADMs by about 10-20%.

• Merged monthly surface emissivity based on IASI and theoretical calculation will be used for CERES Ed 5 processing. Merged emissivity is significantly lower over water and is significantly higher over most desert regions than that used in Edition 4.
Impact of surface emissivity on daytime LW flux inversion is small

- Bias is less than 0.1 Wm\(^{-2}\).
- RMS is less than 1.2 Wm\(^{-2}\).

January

April

July

October