CERES Science Team Meeting, May 14th-16th, 2024, Hampton, VA

CERES Cloud Radiative Swath (CRS) Update

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Collaboration with:

TISA Group: Joshua C. Wilkins, David Doelling and Pamela Mlynczak (TISA gridding for CRS1deg product)

Data Management: Walter Miller, Victor Sothcott, Joshua C. Wilkins, and Kathleen Dejwakh

ADM Group: Wenying Su (TOA fluxes)

Cloud group: Bill Smith Jr, Sunny Sun-Mack, and Ben Scarino (Cloud and skin temperature retrievals)

FLASHFLUX group: Paul Stackhouse (Parameterized surface fluxes in FLASHFLUX)

CRS Flux Algorithm

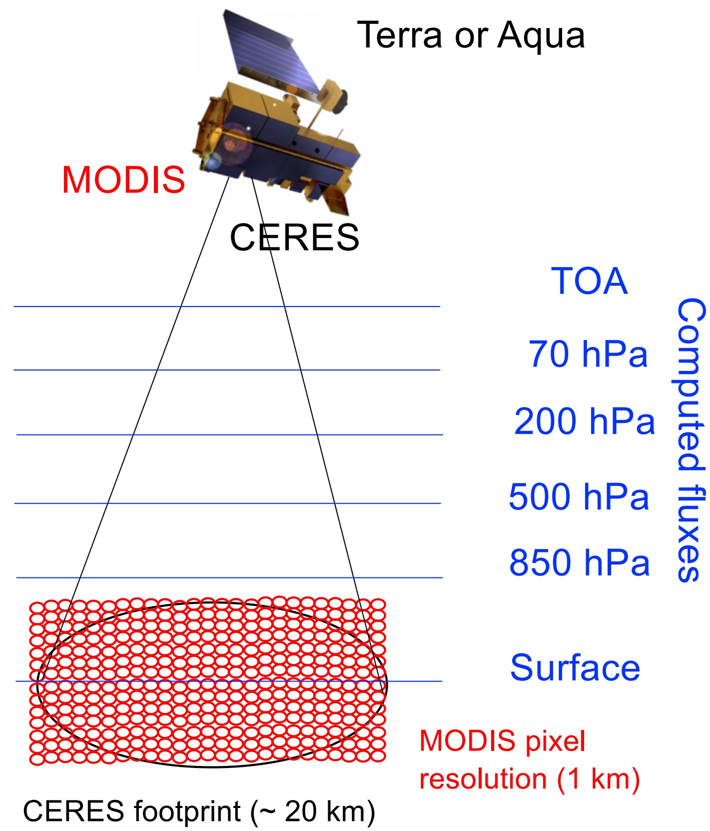
Inputs

Atmospheric Profiles	GMAO Reanalysis p(z), T(z), q(z), and O_3(z)
Surface	Surface Skin Temperature Surface Emissivity Surface Albedo
Clouds	MODIS Clouds
Aerosol	MODIS & CATM* Aerosol

Fu-Liou Radiative Transfer Model

Four Conditions:
- Total Sky (Aer + Cld)
- Clear Sky (Aer)
- No Aerosol (Cld)
- Pristine (-)

Computed Instantaneous Fluxes at 6 vertical levels for every CERES footprint



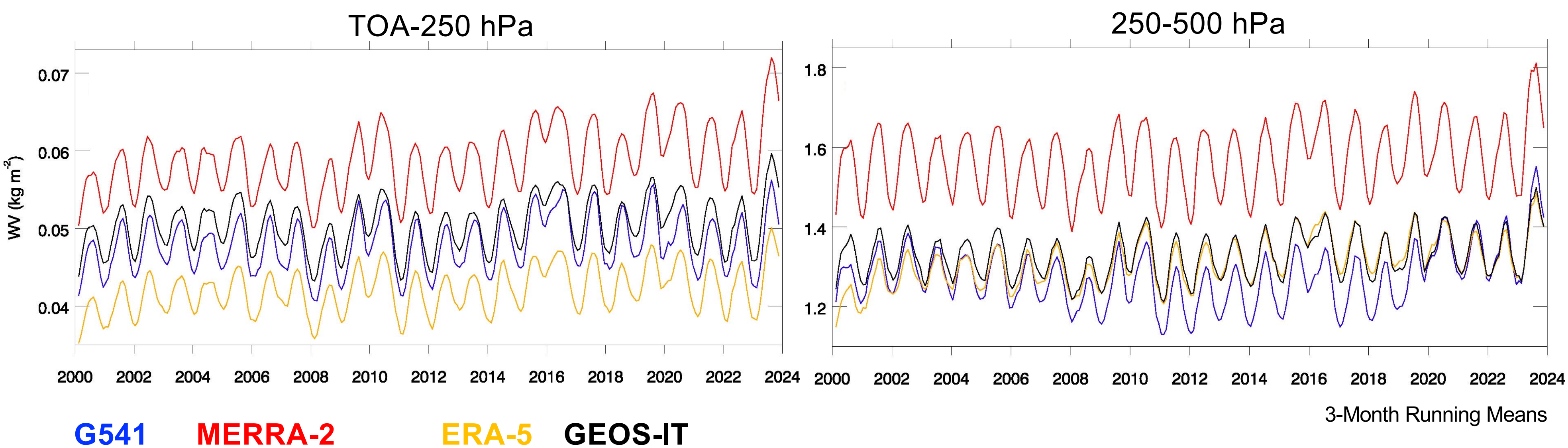
CATM : CERES Atmospheric Transport Model produced by CERES SARB group

Ongoing Ed5 Development for the CRS Flux Algorithm

- Switching of the reanalysis (GEOS-5.4.1 → GEOS-IT), which is used for describing T(z) and q(z) profiles
- Flexible configuration of Fu-Liou radiative transfer model (Fred G. Rose)
- Updating gas absorption subroutine in Fu-Liou by including more gases and new band structure
- Updating surface albedo history (SAH) map using Ed5 IGBP and SSF CERES/MODIS (Tom Caldwell)
- Evaluation of the CRS algorithm using surface validation sites (David Rutan and Emily Monroe)
- New aerosol properties from CAM6 aerosol model (David Fillmore and Antonio Viudez-Mora; Wednesday afternoon talk)

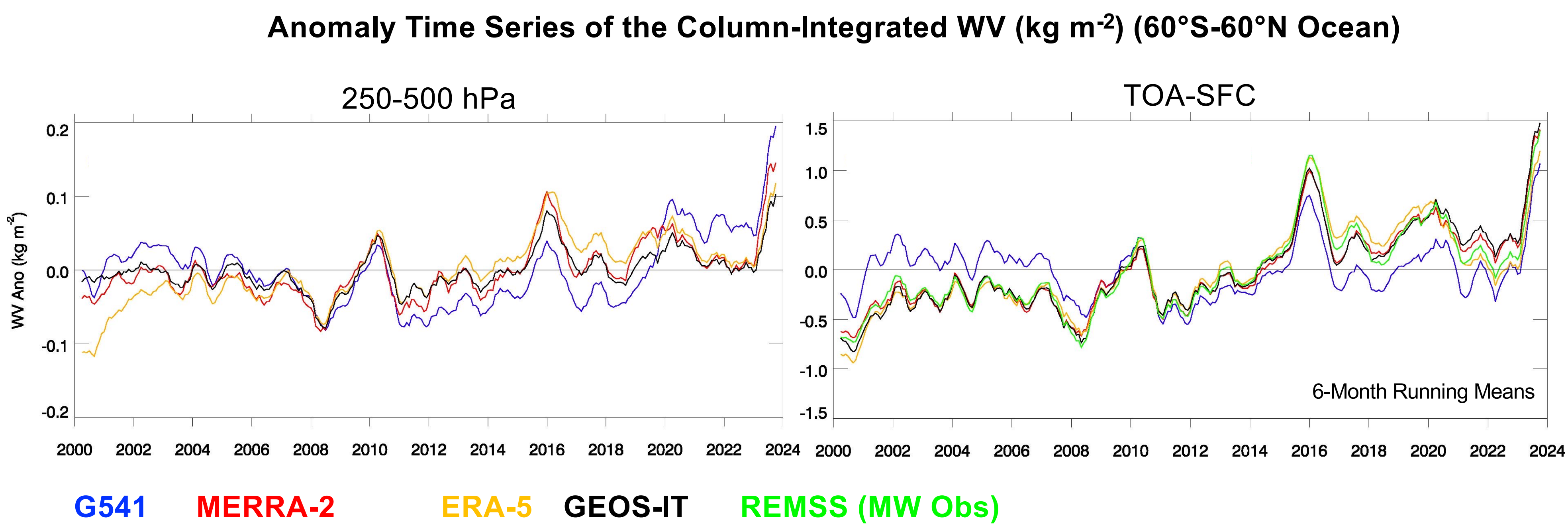
Better Upper-tropospheric Humidity (UTH) in GEOS-IT, compared to MERRA-2

Time Series of the Column-Integrated WV (kg m^{-2}) (60°S-60°N Ocean)



- UTH in GEOS-IT is lower than MERRA-2, which are closer to other AIRS satellite observations.
- GEOS-IT UTH is comparable to G541 UTH but with a better anomaly time series (next slide).

Better GEOS-IT WV Anomaly Time Series compared to GEOS-5.4.1



- MERRA-2, ERA-5 and GEOS-IT show quite consistent WV anomaly time series, while G541 is an outlier.
- However, after 2020, the PW anomaly time series of the three datasets (MERRA-2, ERA-5, and GEOS-IT) start to diverge, while Microwave observation (REMSS) is closest to ERA-5.
- **By using GEOS-IT T and q profiles, Ed5 LW flux time series will be improved, compared to the Ed4 LW flux time series from G541.**

Flexible Ed5 Fu-Liou Model with One Configuration File (Fred Rose)

- The Fu-Liou codes were significantly modified and reorganized, even though the core radiative transfer parts (2-stream or 4-stream solver) remain the same.
- The Ed5 Fu-Liou model uses a one configuration HDF file, which describes cloud/aerosol scattering parameters, narrow band structures, Rayleigh scattering, gas absorption, and surface albedo database.
- New gas absorption features will be considered include more gases and band structure flexibility (Thursday last talk by Ham in this meeting).

Static parameters

- Narrowband structure
- Incoming solar radiation database
- Rayleigh scattering coefficients
- Gas absorption CKD table
- Surface spectral model (Jin's snow and ocean models)
- Cloud scattering parameter database
- Aerosol scattering parameter database

→ One configuration file → Ed5 Fu-Liou Model

Without compilations of Fu-Liou codes, users can switch gas absorption CKD table, cloud/aerosol scattering parameters, and band structures through this configuration figure.

Validation of the CRS Algorithm Using Polar Ground Measurements

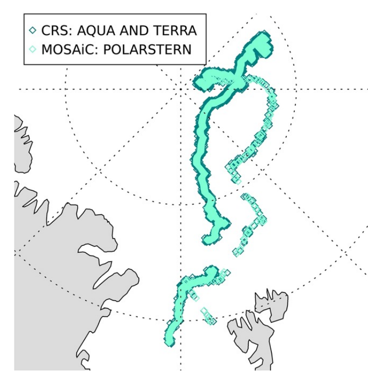
1. **Siple Dome over the West Antarctica: David Rutan**
   (Lat 81.65°S, Lon 148.81°W, Elevation 720 m, Dec 2019 to January 2020)
2. **MOSAiC Ship Campaign over the Arctic: Emily Monroe**
   (September 2019 to October 2020)

Siple Dome Site

https://www.usap-dc.org/view/dataset/601540

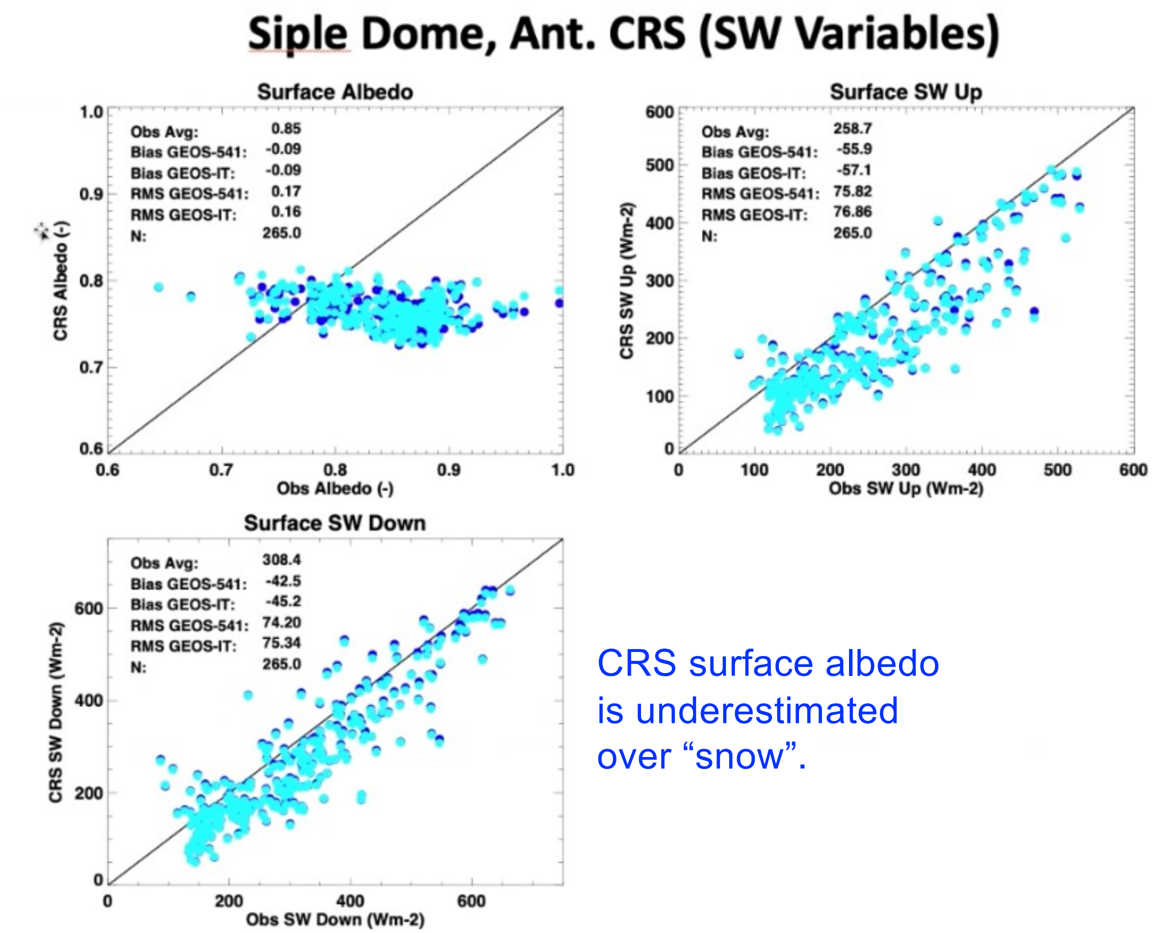
- **Validation of the CRS inputs**
  - Atmospheric T(z) and q(z) profiles
  - Skin temperatures
  - Surface albedos
  - Cloud masks and optical properties
- **Validation of the CRS outputs**
  - Surface fluxes
  - Surface albedos

MOSAiC Campaign



Comparison of SW Fluxes between CRS Calculations vs Siple Dome Ground Measurements

Ed4 CRS



CRS surface albedo is underestimated over “snow”.

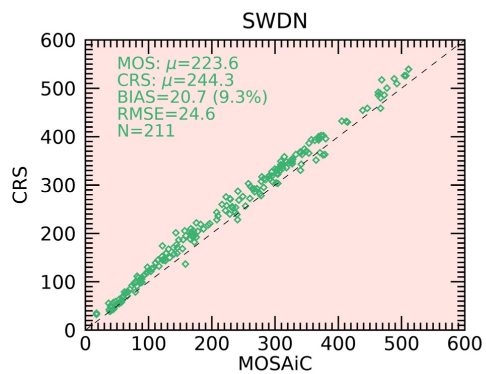
- Computed CRS surface downward fluxes are smaller than ground measured values. But for clear skies, better agreements are shown (not given here).
- CRS surface albedo values stays similar around 0.75 while the ground-measured values are between 0.7 and 1.0.
- The underestimation of the CRS surface albedo contributes to the underestimation of the CRS surface upward fluxes.
- Impact of the reanalysis dataset (GEOS-IT vs G541) on “SW” flux calculations is very small.

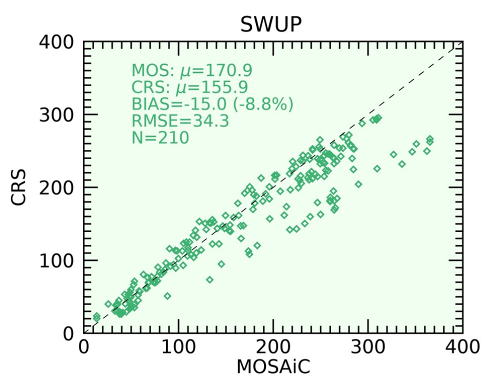
By David Rutan

Comparison of SW Fluxes between CRS Calculations versus MOSAiC Ship Campaign Measurements

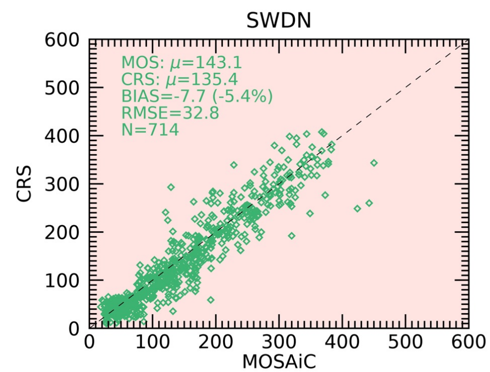
Ed4 CRS

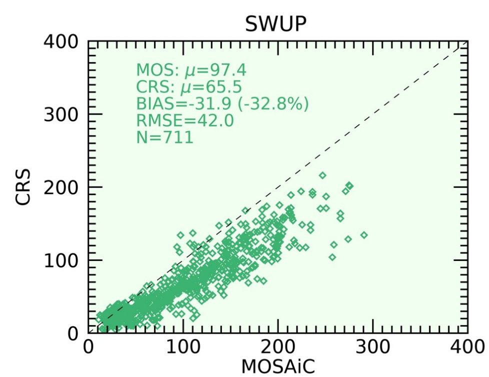
Clear (CF < 10%) according to CRS and MOSAiC





Overcast (CF > 90%) according to CRS and MOSAiC



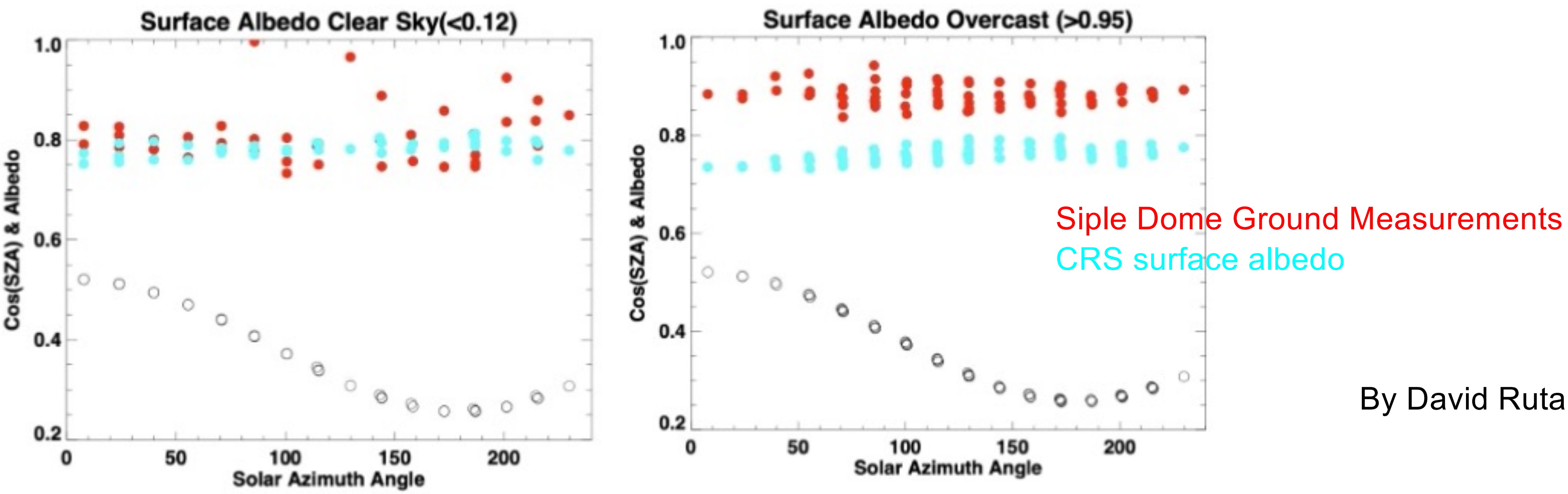


CRS surface albedo is underestimated over “sea ice”.

- Computed CRS SW surface downward fluxes are slightly larger than MOSAiC measurements for clear skies, and slightly smaller than MOSAiC for overcast skies. Generally good agreements.
- Computed CRS SW surface upward fluxes are smaller than MOSAiC values, and the differences are much larger for overcast skies, compared to clear skies. This indicates that the surface albedo is more significantly underestimated for cloudy skies.

By Emily Monroe (2023, Gordon Conference)

Validation of the CRS Snow Surface Broadband Albedo Using Siple Dome Ground Measurements



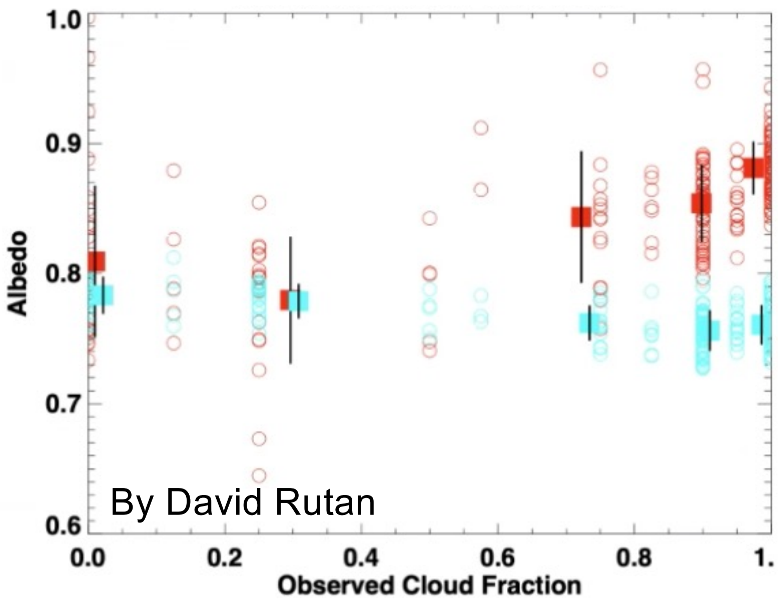
By David Rutan

- The CRS snow surface broadband (BB) albedo is comparable to the ground measurements for clear skies.
- The CRS snow surface BB albedo is significantly lower than the ground measurements for cloudy skies.
- The biases are not sensitive to the solar angles.
- Note that the ground measurements indicate a higher snow BB surface albedo for cloudy skies but the CRS does not.

Validation of the CRS Surface Broadband Albedo Using Ground Measurements

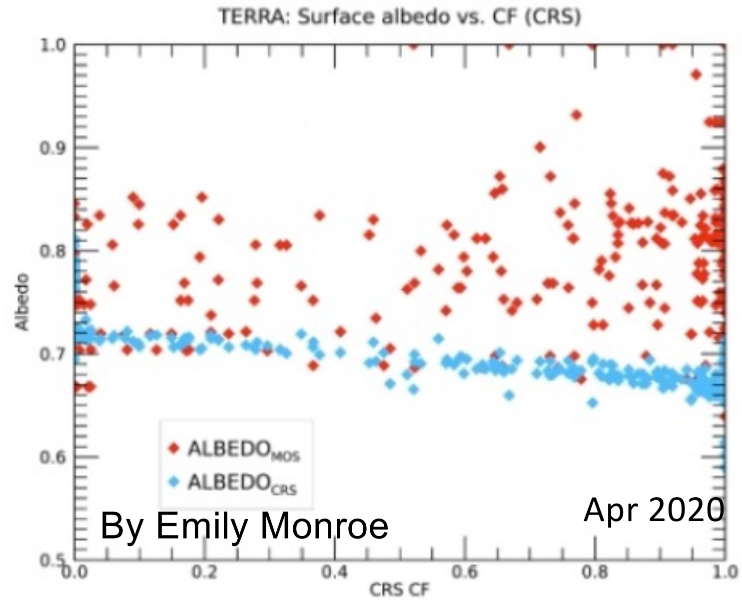
- CRS BB surface albedo is underestimated particularly for cloudy skies.
- Ground observation indicates increasing surface BB albedo with cloud fraction, but the CRS albedo does not increase with the cloud fraction.

Siple Dome (Snow Surface)



Siple Dome Ground Measurements
CRS surface albedo

MOSAiC (Sea Ice Surface)

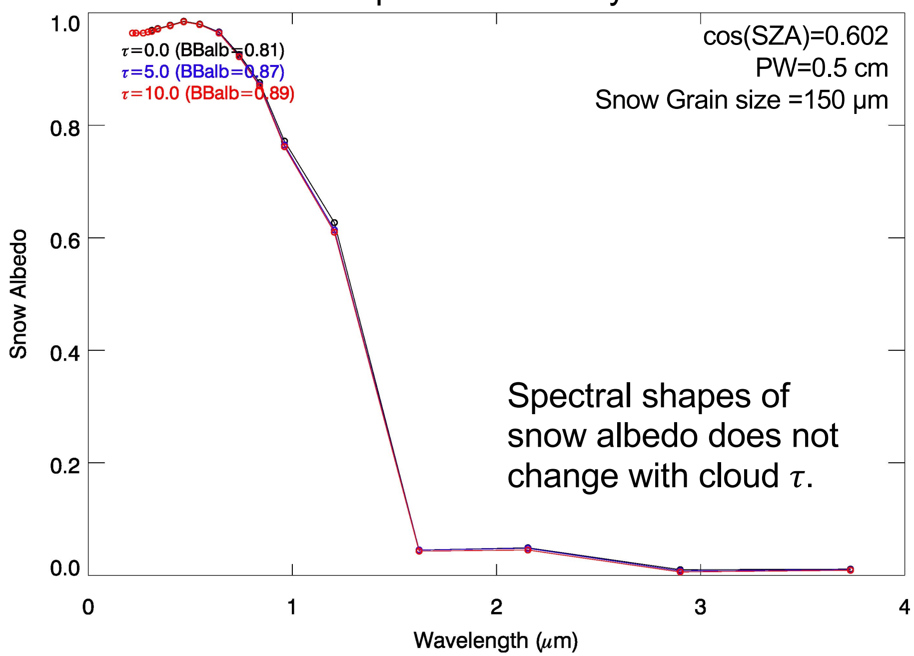


MOSAiC Ship Measurements
CRS surface albedo

Why does a higher snow BB Albedo occur for cloudy skies compared to clear skies?

- Spectral shapes of snow albedo remain similar with changing cloud τ (only changing into solar diffuse angle as τ increases).
- However, the BB snow albedo increase with cloud τ.
- This is because larger spectral weighting factors in the visible region for a larger cloud τ due to cloud absorption in the NIR region.

Jin's Snow Spectral Model by Cloud τ



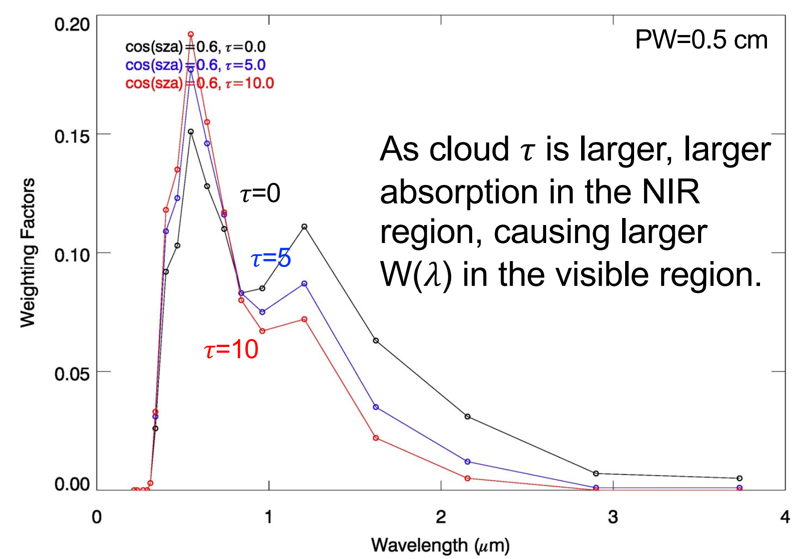
- Broadband albedo is a mean of spectral albedo weighted by a fraction of SW SFCDN:

$$\alpha_{BB} = \frac{\int_{\lambda_{min}}^{\lambda_{max}} F_{dn}(\lambda)\alpha(\lambda)d\lambda}{\int_{\lambda_{min}}^{\lambda_{max}} F_{dn}(\lambda)d\lambda}$$

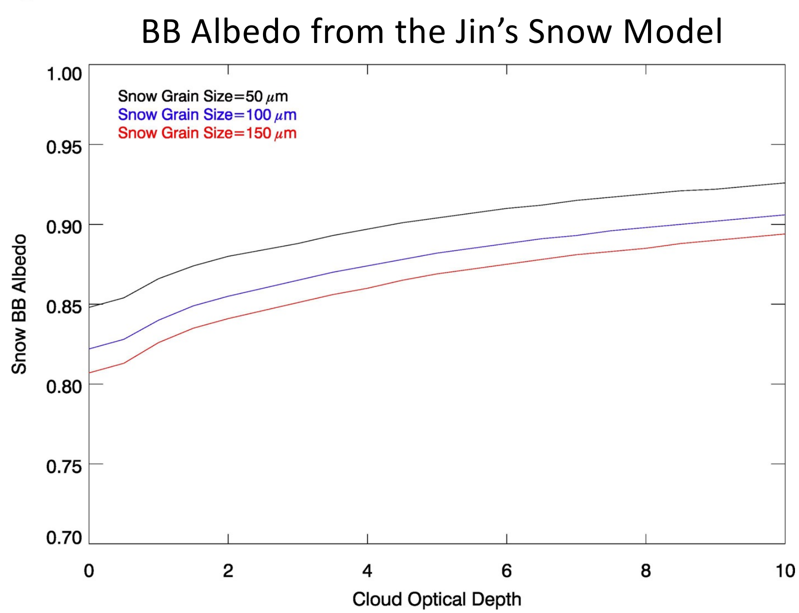
Weighting factor is "a fraction of SW SFCDN".

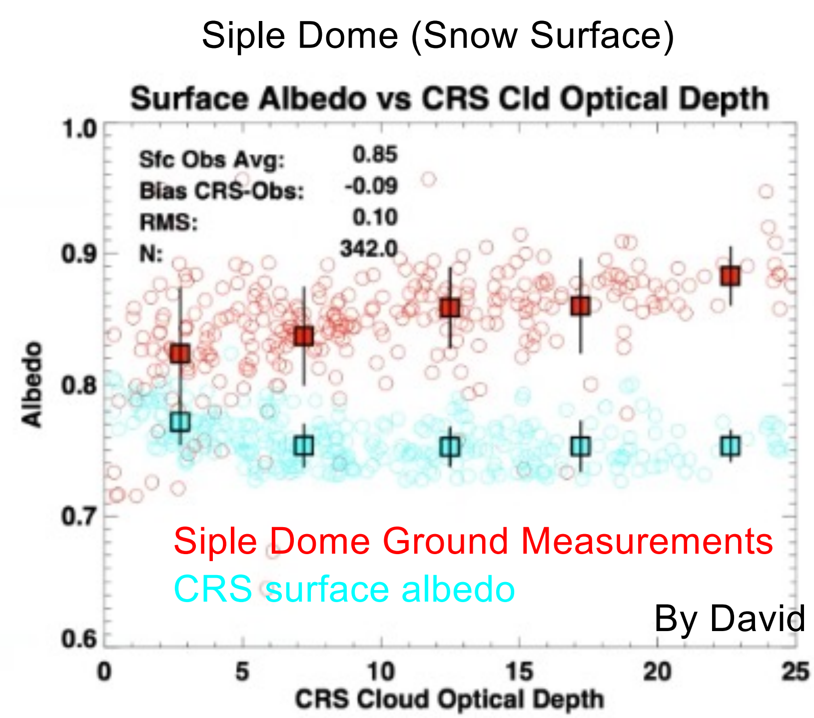
$$= \int_{\lambda_{min}}^{\lambda_{max}} w(\lambda)\alpha(\lambda)d\lambda$$

where $w(\lambda) = \frac{F_{dn}(\lambda)}{\int_{\lambda_{min}}^{\lambda_{max}} F_{dn}(\lambda)d\lambda}$



Why does a higher snow BB Albedo occur for cloudy skies compared to clear skies?





By David Rutan

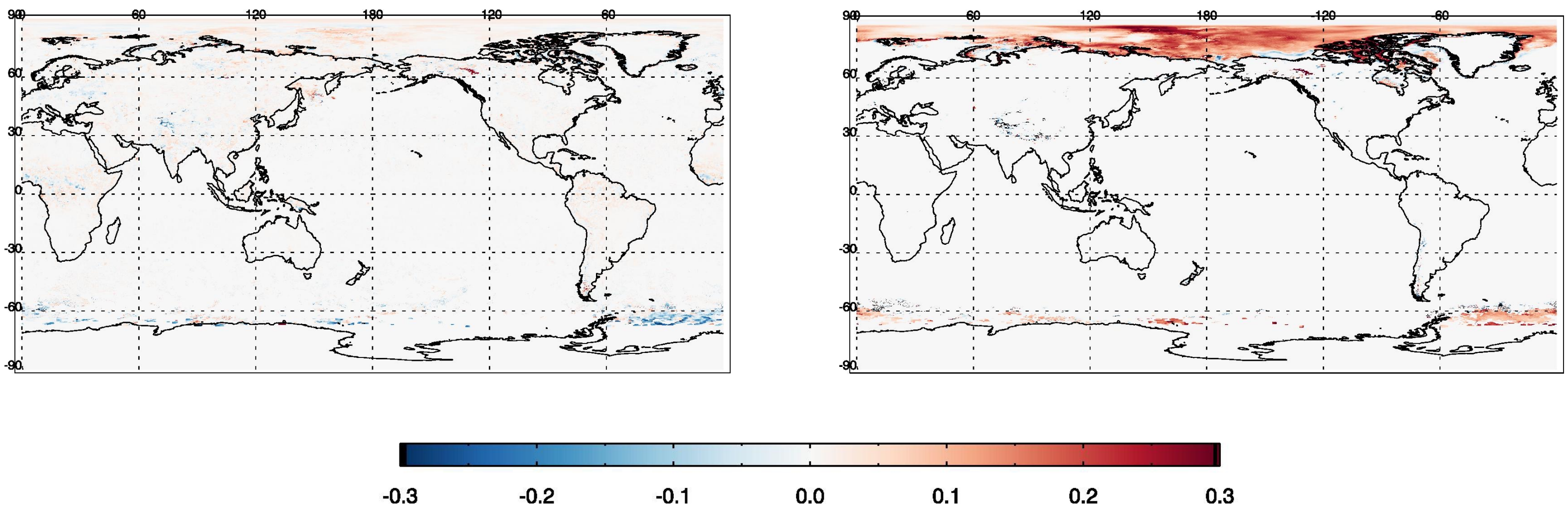
- While theoretical considerations and ground measurements indicate an increasing snow surface BB albedo with cloud optical depth.
- CRS snow BB albedo does not increase with cloud optical depth, and rather decreases.
- One of reason is to constraining process of snow spectral albedo from the SAH BB albedo, which only comes from clear-sky measurements.

Ed5 Surface Albedo History (SAH) Map

- Monthly clear-sky composites of broadband (BB) surface albedo based on CERES (clear) or MODIS (partly clear) TOA observations with atmospheric correction (e.g., PW).
- If there are not enough clear-sky cases for the grid, climatological SAH data fills the map.
- The BB albedo is affected by the cos(SZA), snow+ice fraction, and further adjustments are performed to the BB when used in the flux calculations at the actual footprints.
- Ed5 SAH surface BB albedo remains similar but the snow/ice fraction is increased, compared to Ed4.

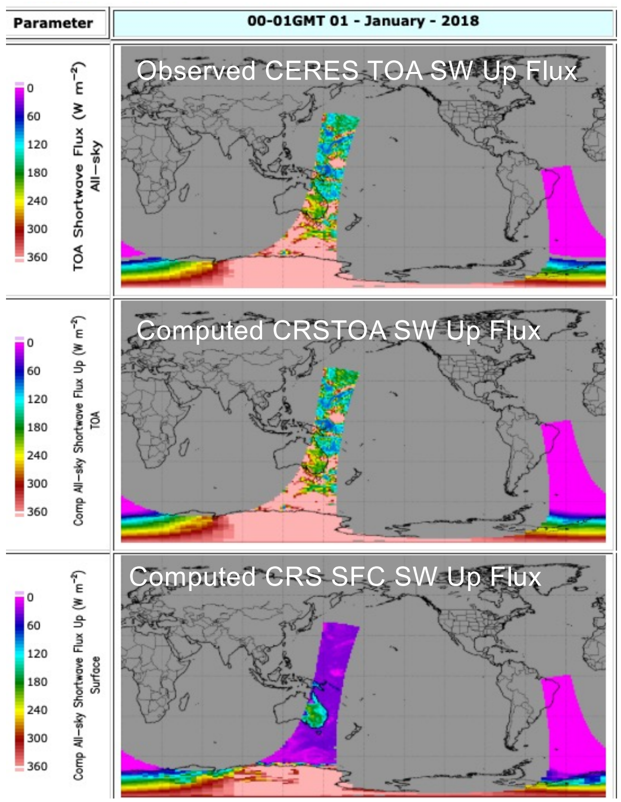
BB Albedo Changes (Ed4→Ed5)

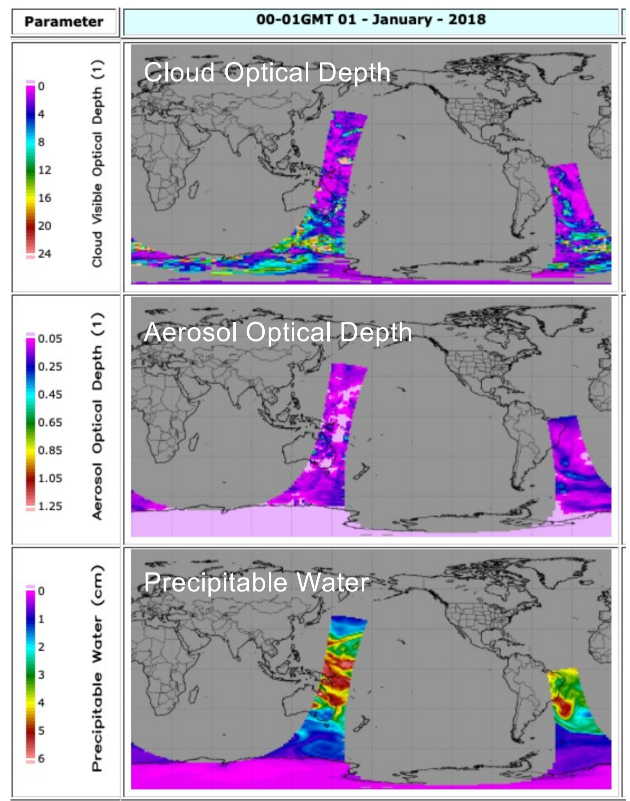
Snow+Seaice Fraction Changes (Ed4→Ed5)



Ed4 CRS1deg Release (March 2024) (TISA & DMT Group)

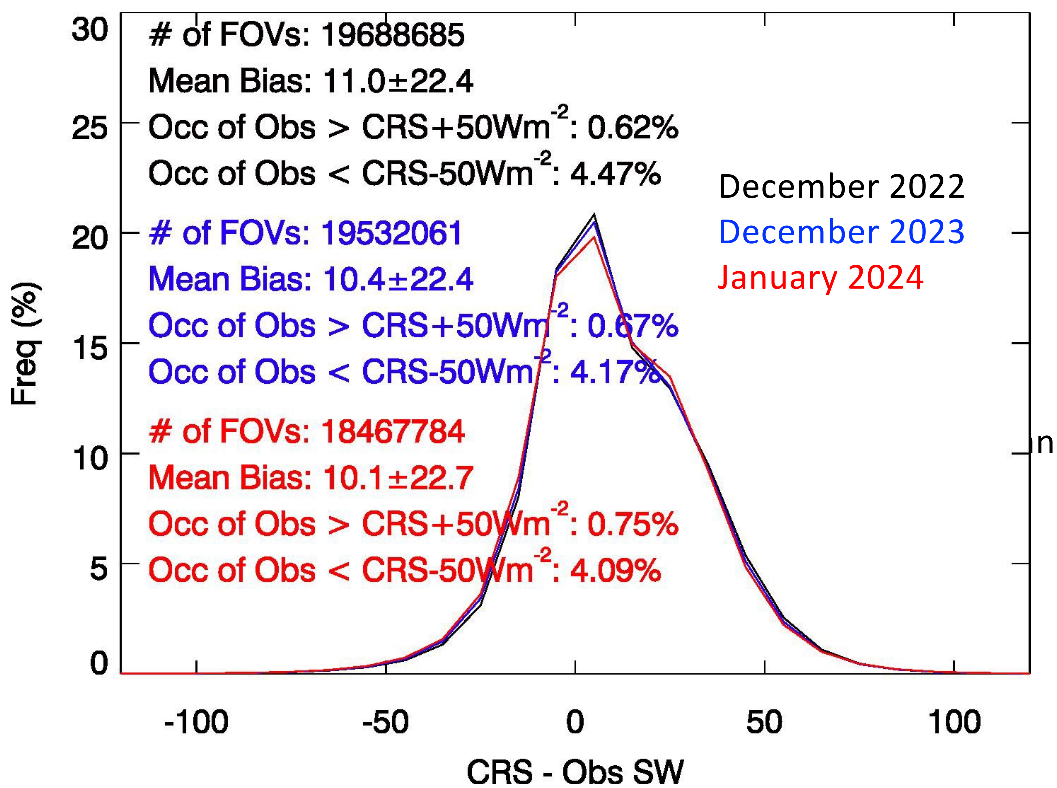
- Available for 2018-2022 in the CERES ordering tool (https://ceres.larc.nasa.gov/data/) or ASDC (https://asdc.larc.nasa.gov).
- Hourly grided (1°) **instantaneous** (Terra or Aqua times) computed fluxes and RT inputs, which can be compared with other climate or satellite datasets





Application of the CRS Flux Algorithm to Monitor FM6 SW Channel

- There was possibility that FM6 on NOAA-20 started to experience more frequent SW spikes starting November 2023.
- To monitor the performance of FM6, computed CRS TOA SW fluxes were compared with FM6 observed fluxes whether the SW spikes occur more frequently over time.
- The CRS flux is computed using MODIS aerosol/clouds and GMAO T(z) & q(z), and independent from the CERES observations over ocean.
- The probability density functions of the differences (calculated minus observed SW) are nearly identical for the two months, i.e., December 2022 (before the possible anomaly) and December 2024 (after the possible anomaly).



Summary

- By using GEOS-IT temperature and humidity profiles from product, better time series of the computed LW fluxes are expected, compared to those from GEOS-5.4.1.
- The new Ed5 Fu-Liou model will have more flexibility of the band structure, clouds and aerosol properties, compared to the Ed4 Fu-Liou model.
- Comparison of the CRS surface SW fluxes with ground measurements at polar regions indicates that the CRS surface albedo is overestimated over snow or sea ice regions, particularly for cloudy skies. These are likely related to the constraining method we are using based on the broadband observations (SAH map).
- Terra/Aqua CRS1deg-1Hour Ed4 product was released in March 2024, for five-year periods (2018-2022).
- The CRS flux algorithm can be used to monitor sensor changes of CERES instruments by comparing computed with measured fluxes.

Thank you for your attention!

Please contact to seung-hee.ham@nasa.gov if you have any questions.