Surface Atmosphere Radiation Budget (SARB) working group update

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CERES Science team meeting

May 15-17, 2018

Langley Research Center, Hampton, VA

Work done after the fall 2017 CERES meeting

- Resolved cloud fraction issue
- Continue collaborating with GMAO in developing a new version of GEOS for Ed5 CERES products.
- Evaluated differences among snow/sea ice map products
- Started aerosol products comparison/evaluation for Ed5 (D. Rutan's talk).
- Estimated 2- and 4-stream model errors in diurnally averaged irradiances.
- Published EBAF-surface paper in journal of climate
- Extended Ed4 EBAF-surface through October 2017 (Ed4 SYN is available through October 2017).

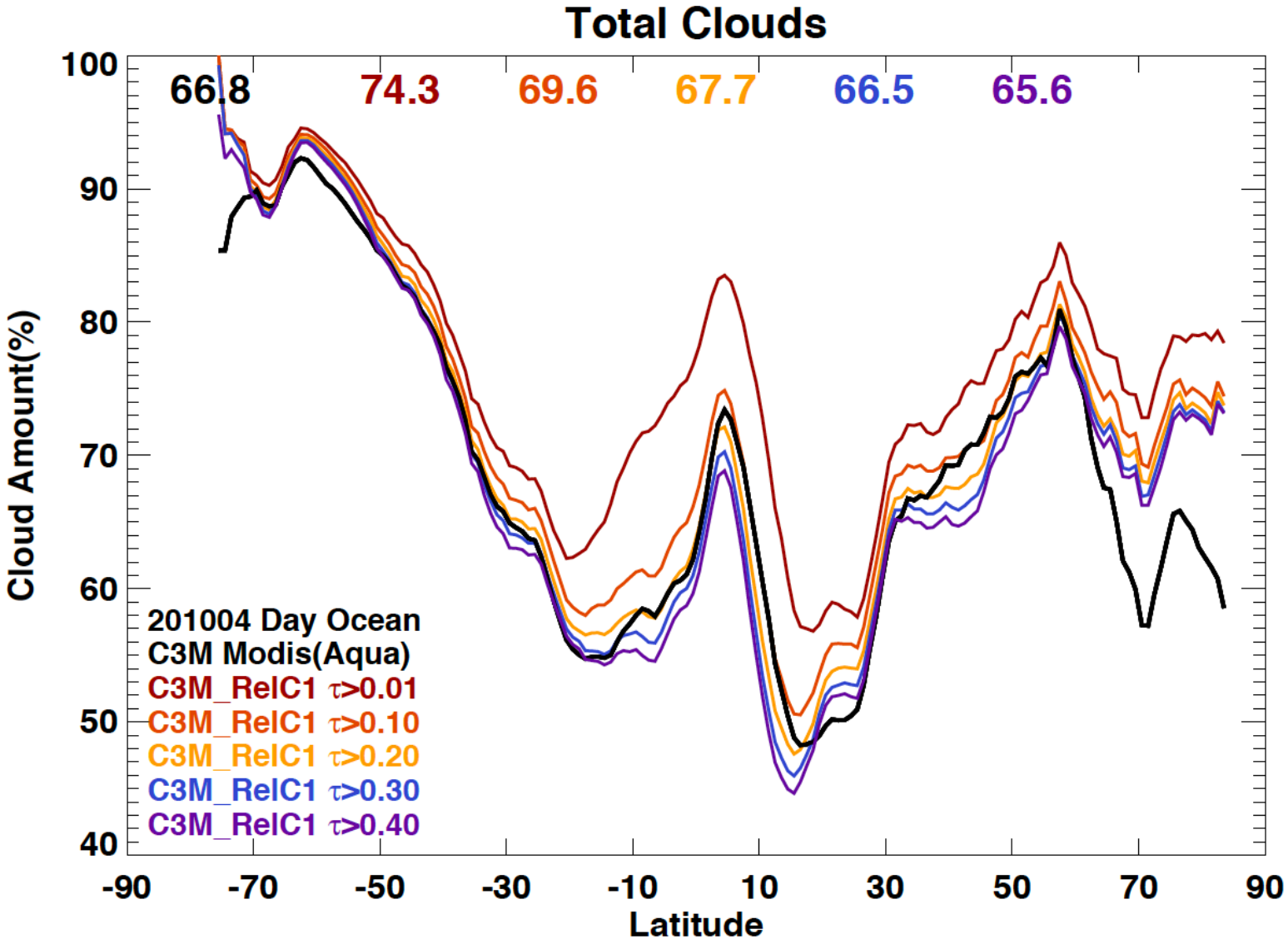
Cloud fraction issue

- Constructing vertical cloud profiles excluding layers within cloud optical thickness of 0.3 from the upper most cloud top
  - Objective is to derive cloud layers that MODIS should see
  - Because the CAD score stored in RelB1 CCCM is extracted from 5 km cloud profile product, CAD score for clouds detected by single shots is saved as a default value (127).
  - Cloud extinction coefficient vertical profiles for these clouds detected by single shots are 0.
  - As a consequence, these clouds are excluded from cloud layers

Revised cloud vertical profile construction

- Correct way to construct clouds with Version 3 CALIPSO product
  - Use VFM for cloud layers.
  - Extract CAD score from 1/3, 5, 20, and 80 Km cloud layer products
  - Identify clouds with CAD score greater than 70 using horizontal averaging from horizontal averaging 1/3, 5, 20, and 80 km.
- Revised approach
  - Layers above 4 km altitude (no change).
  - Layers below 4 km: No tau < 0.3 screening is applied and Include all clouds 70 < CAD <= 100 and = 127.
- Total cloud fraction (sum of 4 cloud types) derived from nadir view MODIS radiances agree with CALIPSO/CloudSat cloud fraction to within 0.01 (global monthly mean).

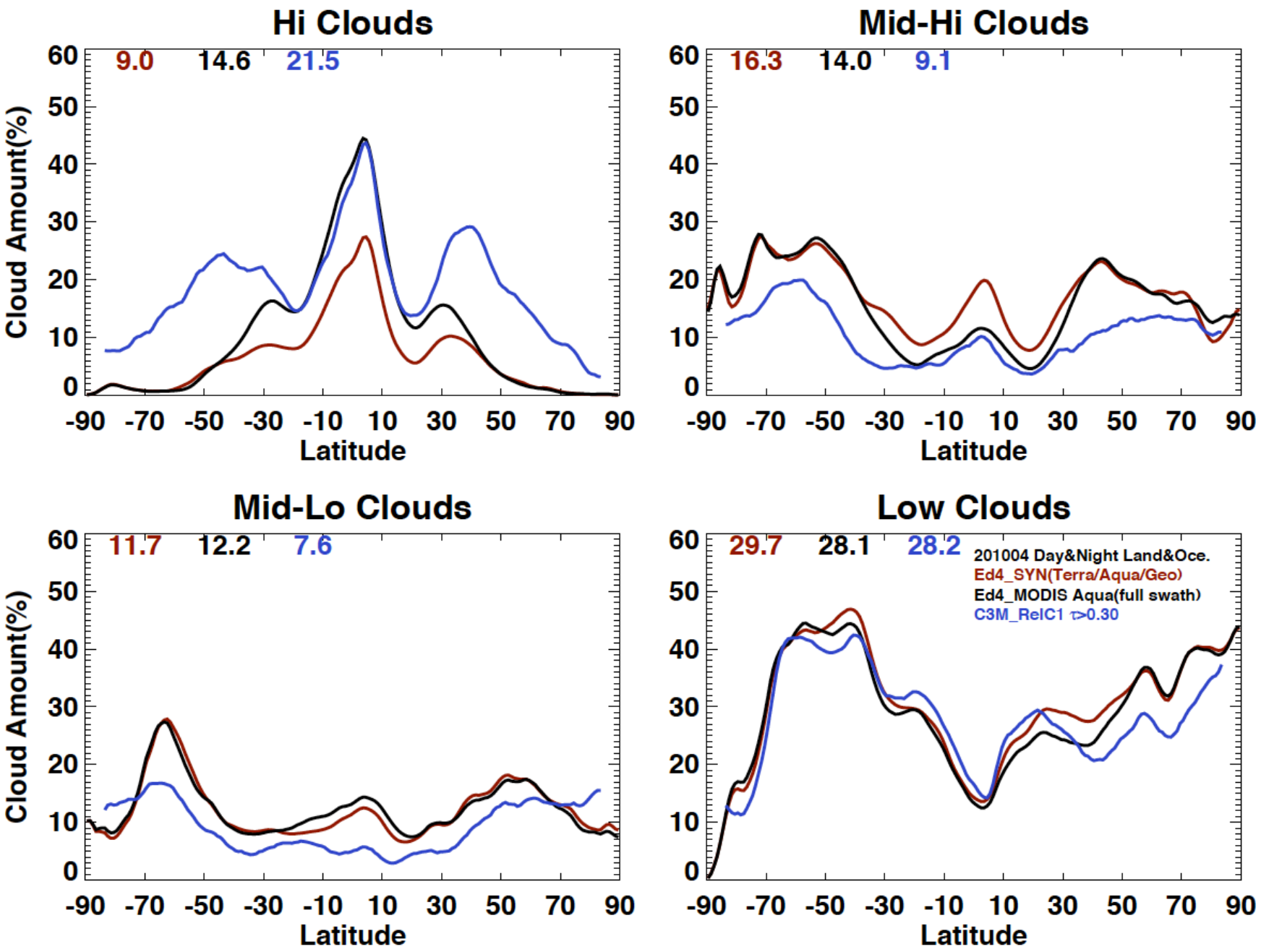
Zonal total cloud fraction comparison



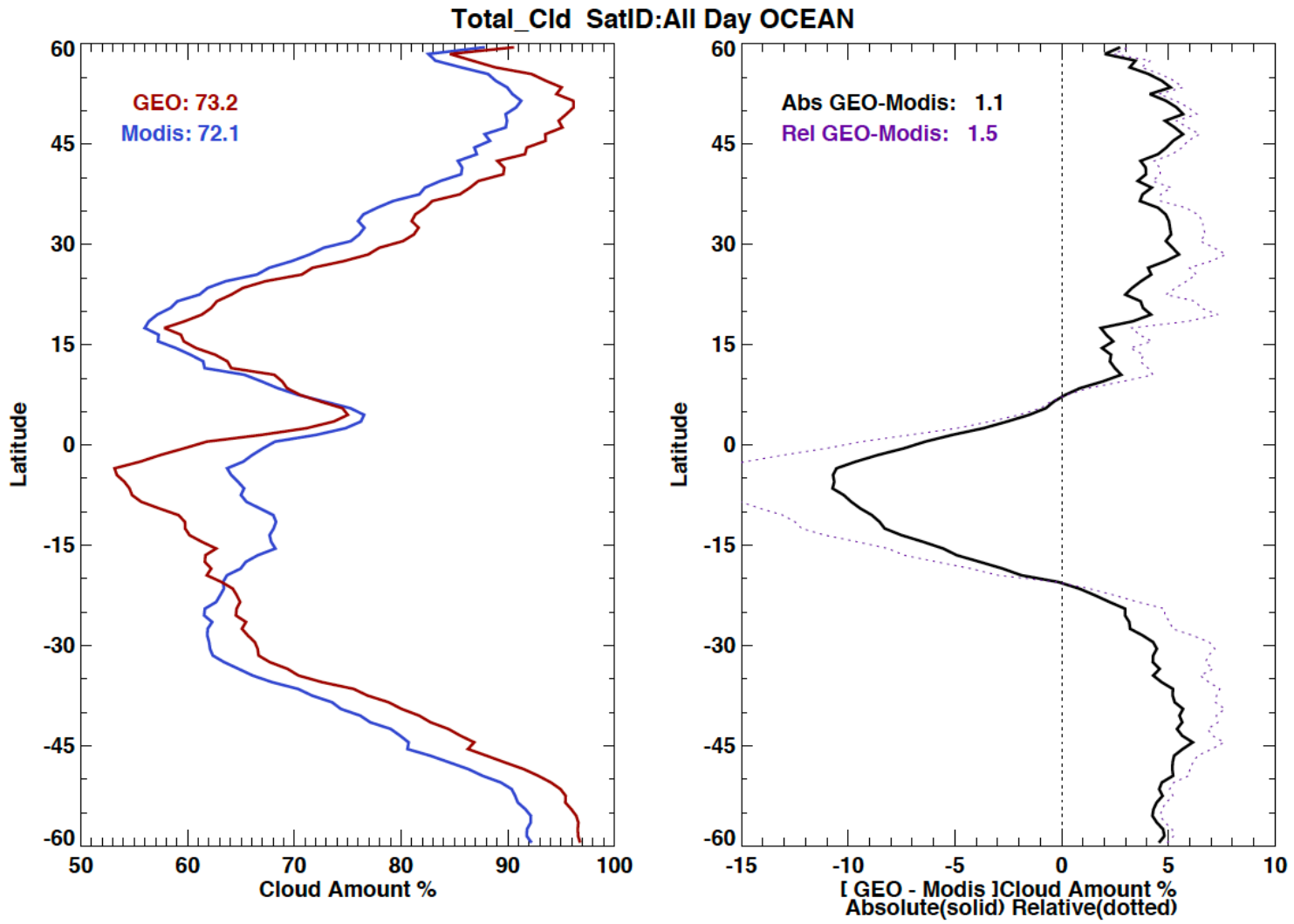
MODIS: Aqua, nadir view only
CALIPSO: different tau threshold to screen optically thin clouds

Cloud fraction comparison by cloud type (201004)

MODIS (full swath) tends to have more high and mid-high clouds and less mid-low and low clouds compared to CALIPSO/ CloudSat



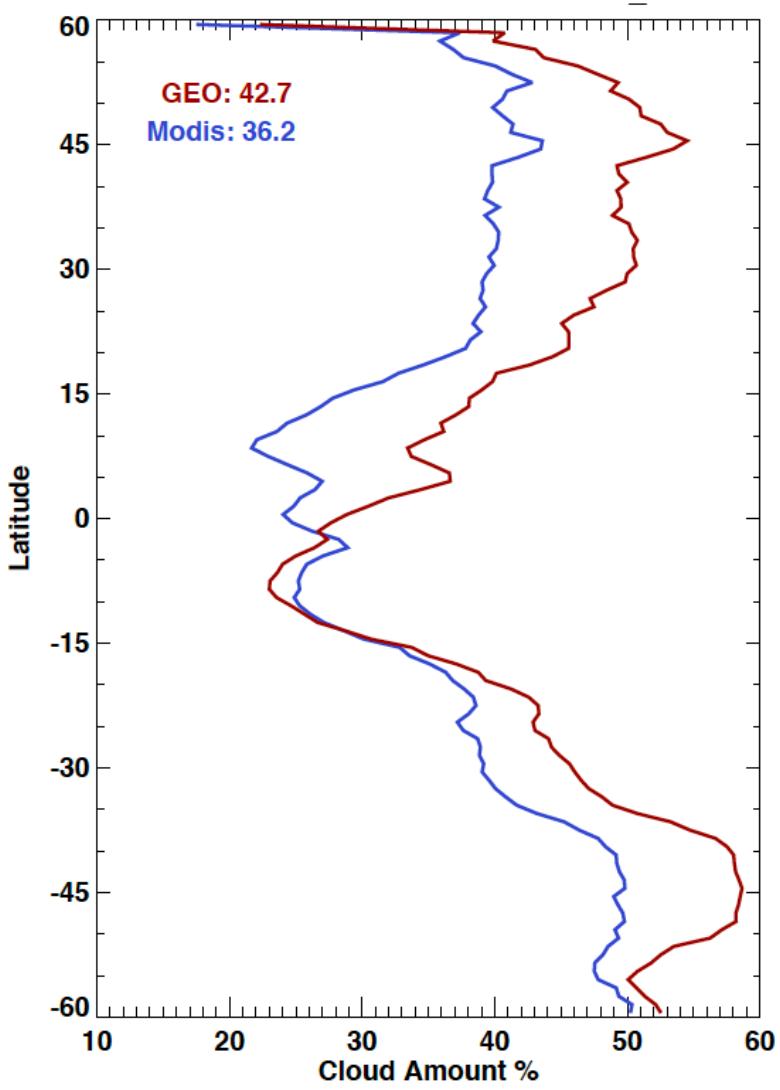
Cloud fraction comparison GEO vs. MODIS



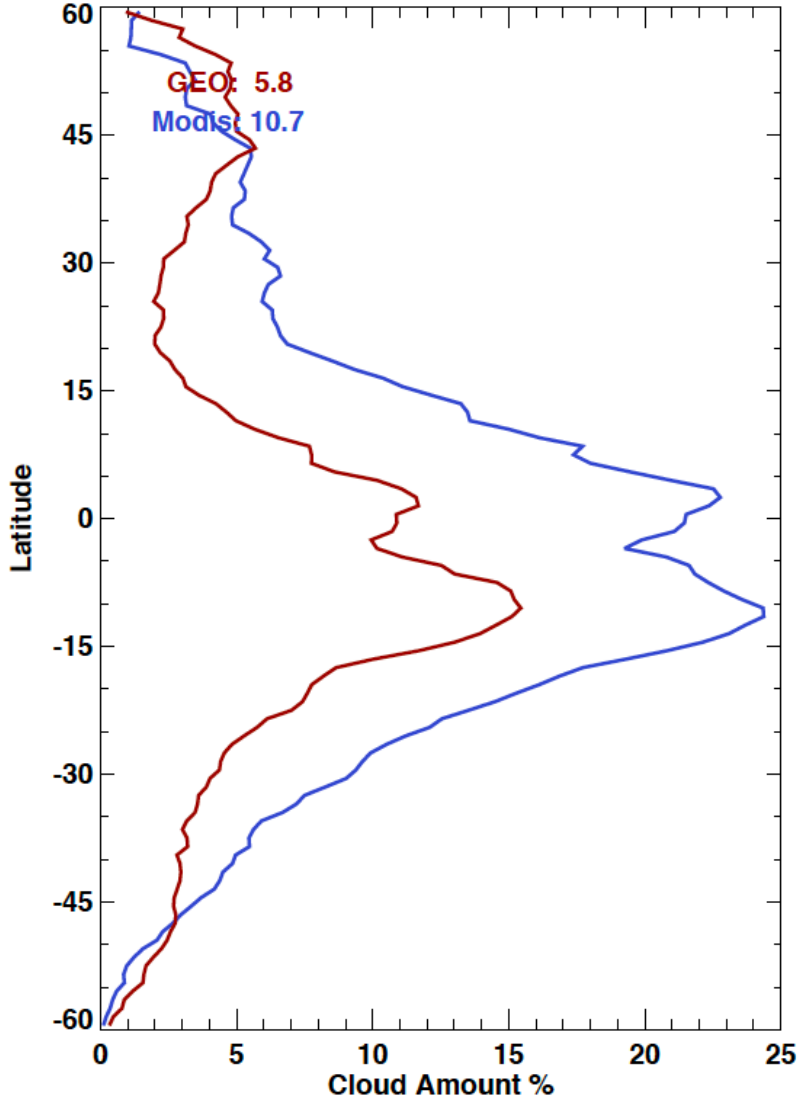
Compared with MODIS cloud fraction, GEO cloud fraction increases toward high latitude

Cloud fraction comparison by cloud type

Low clouds: daytime over ocean



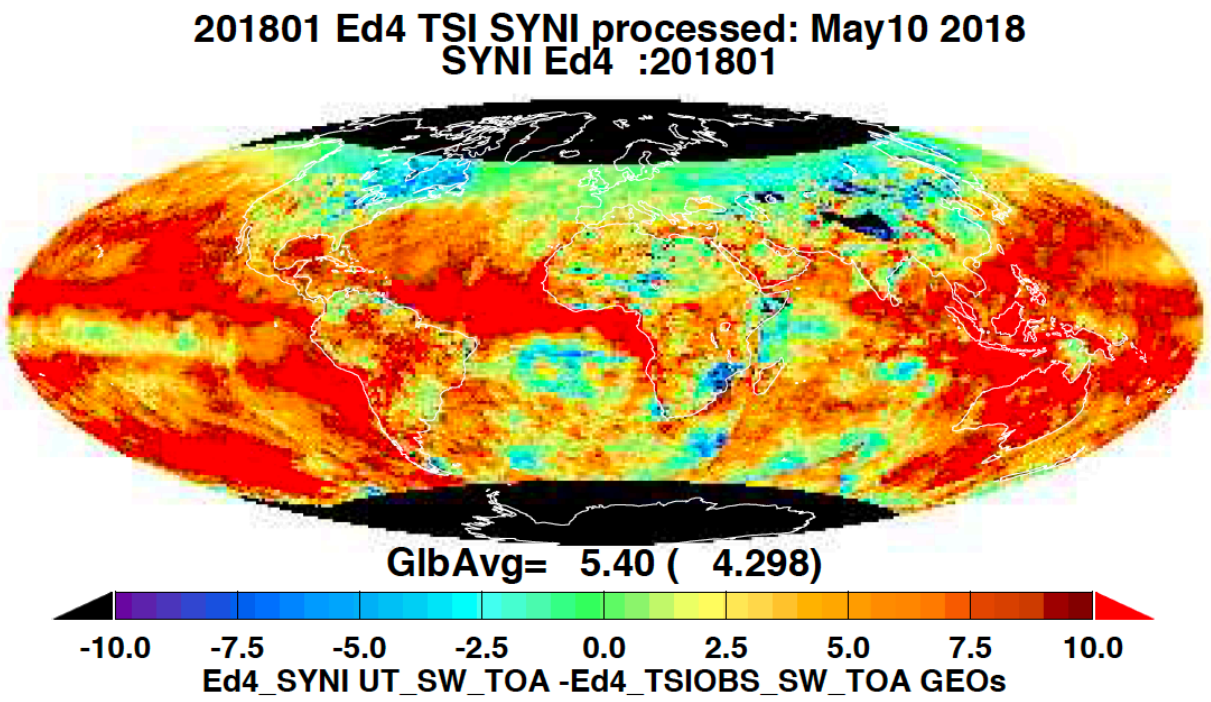
Hi clouds: daytime over ocean

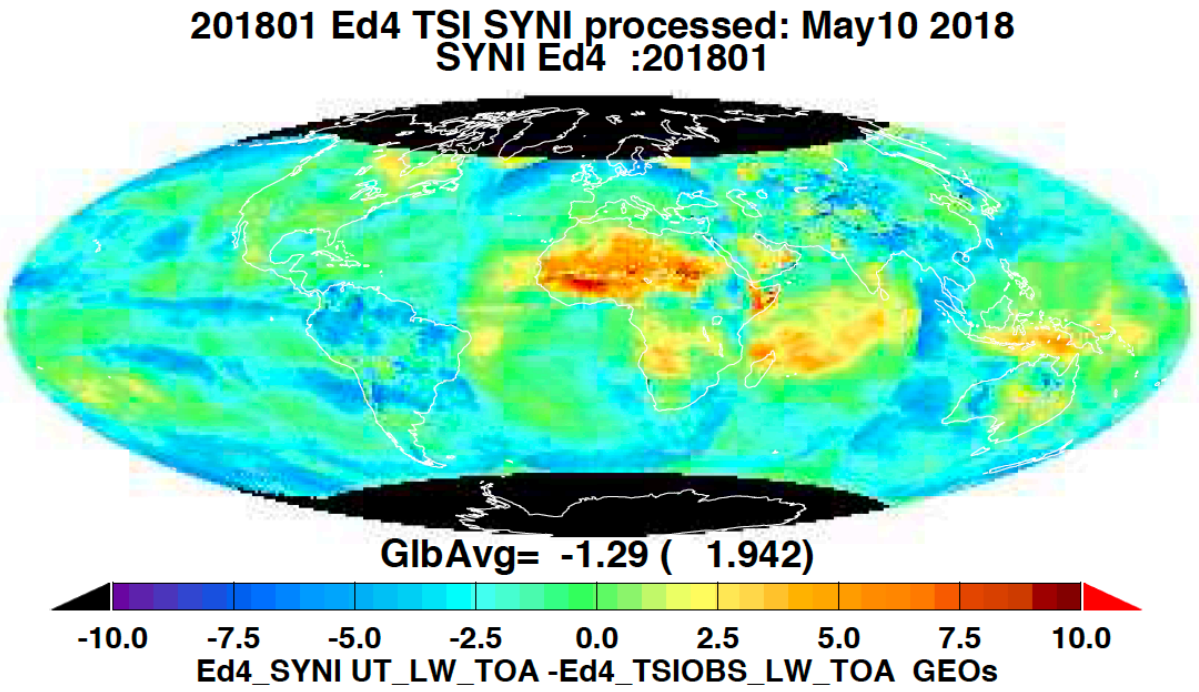


GEOs have less high-level clouds and more low-level clouds compared with MODIS

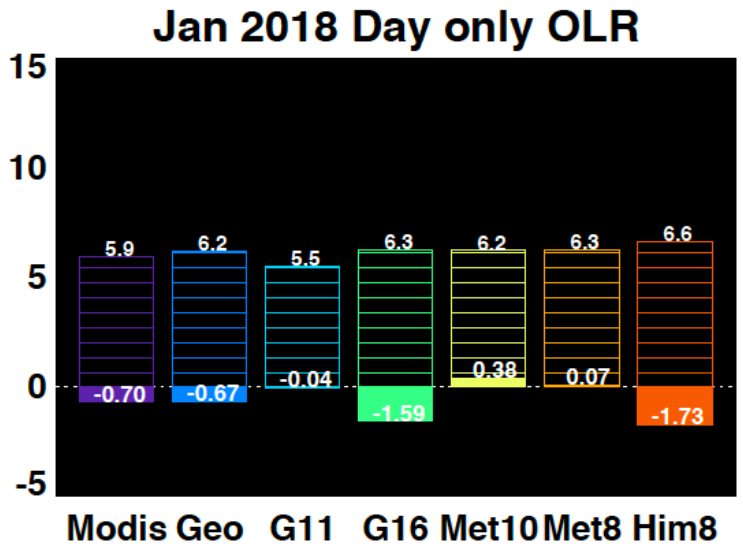
Edition 4.0 SYN with GOES16 clouds

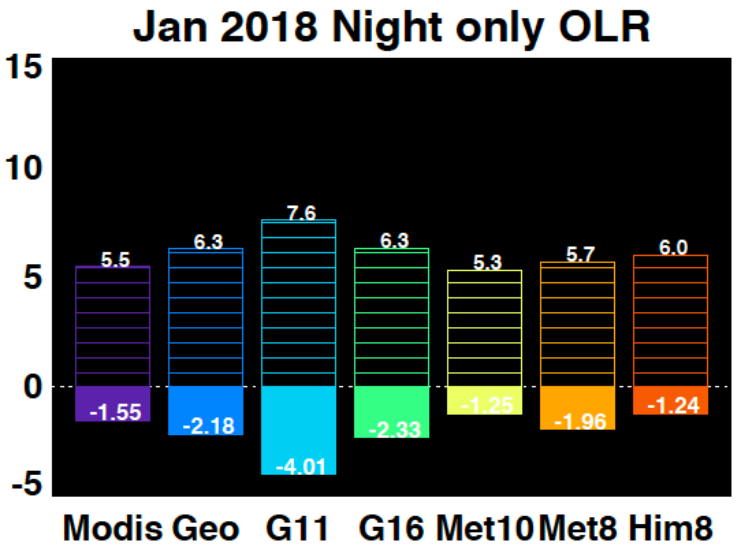
TOA irradiances

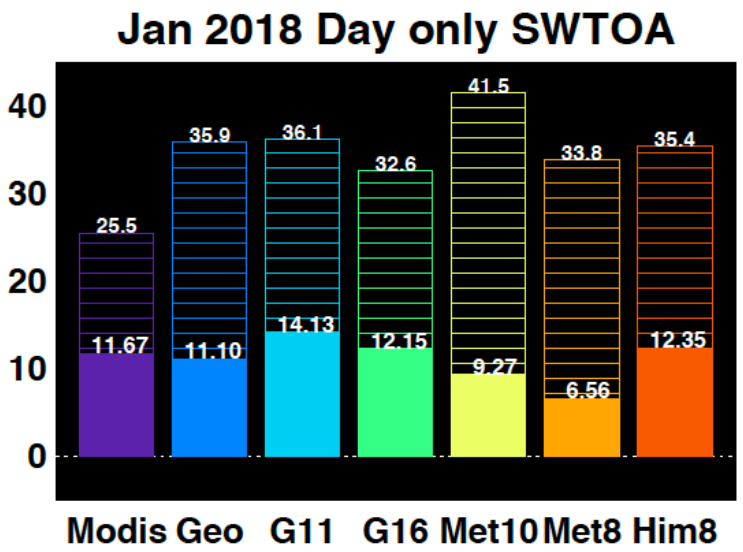




TOA irradiances

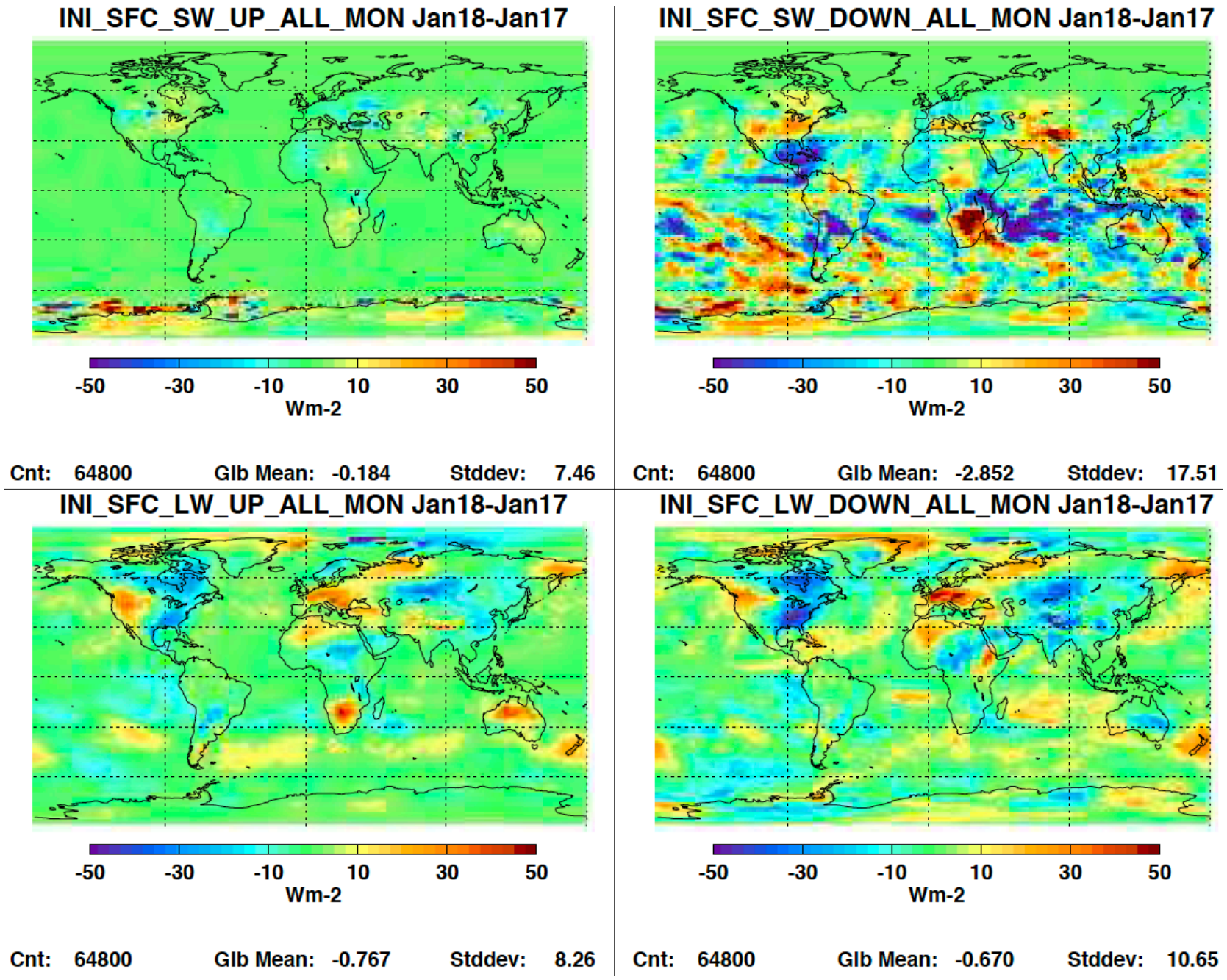






OLR bias of GOES-16 is similar to OLR bias of Himawari

Surface irradiances



GOES-16 summary

- The cloud code is frozen.
- Need to compare cloud properties from the approved code and V0 Himawari code.

GMAO collaboration: Evaluation of skin temperature over polar regions

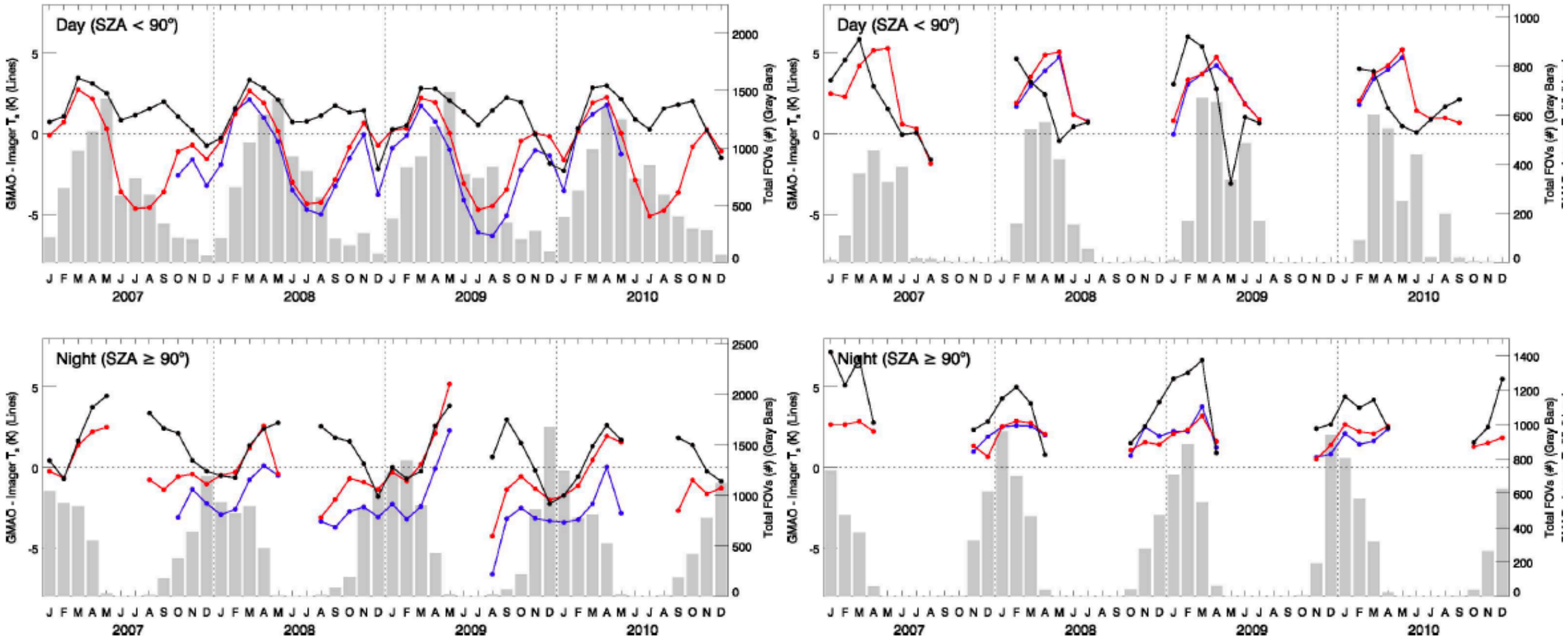
- Skin temperature comparison when CALIPSO/CloudSat detected clear-sky.
- Compare skin temperature derived from MODIS and skin temperature from GMAO reanalysis products
  - Clear-sky conditions are identified by CALIPSO and CloudSat
  - Skin temperatures from reanalysis products are sampled in the same way that clear-sky scenes are occurred

Arctic

G520 – Ed4
G541 – Ed4
MERRA2 – Ed4

Permanent snow

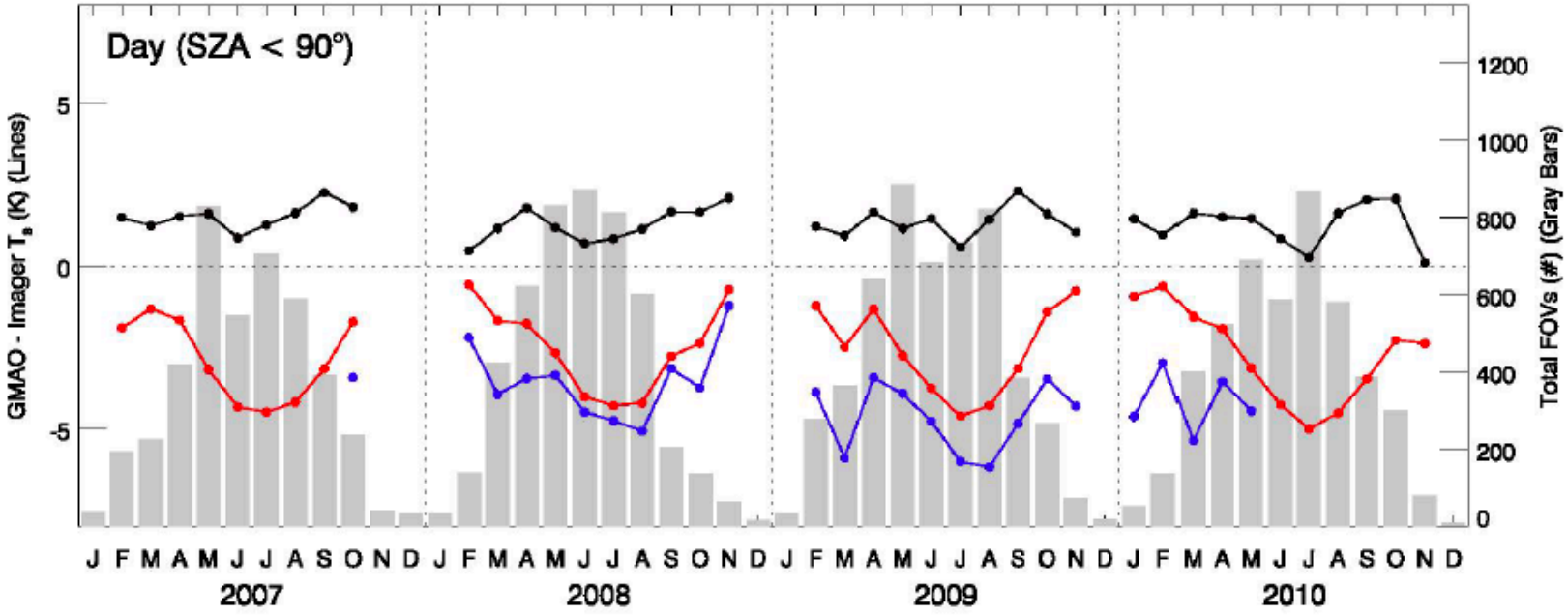
Sea ice



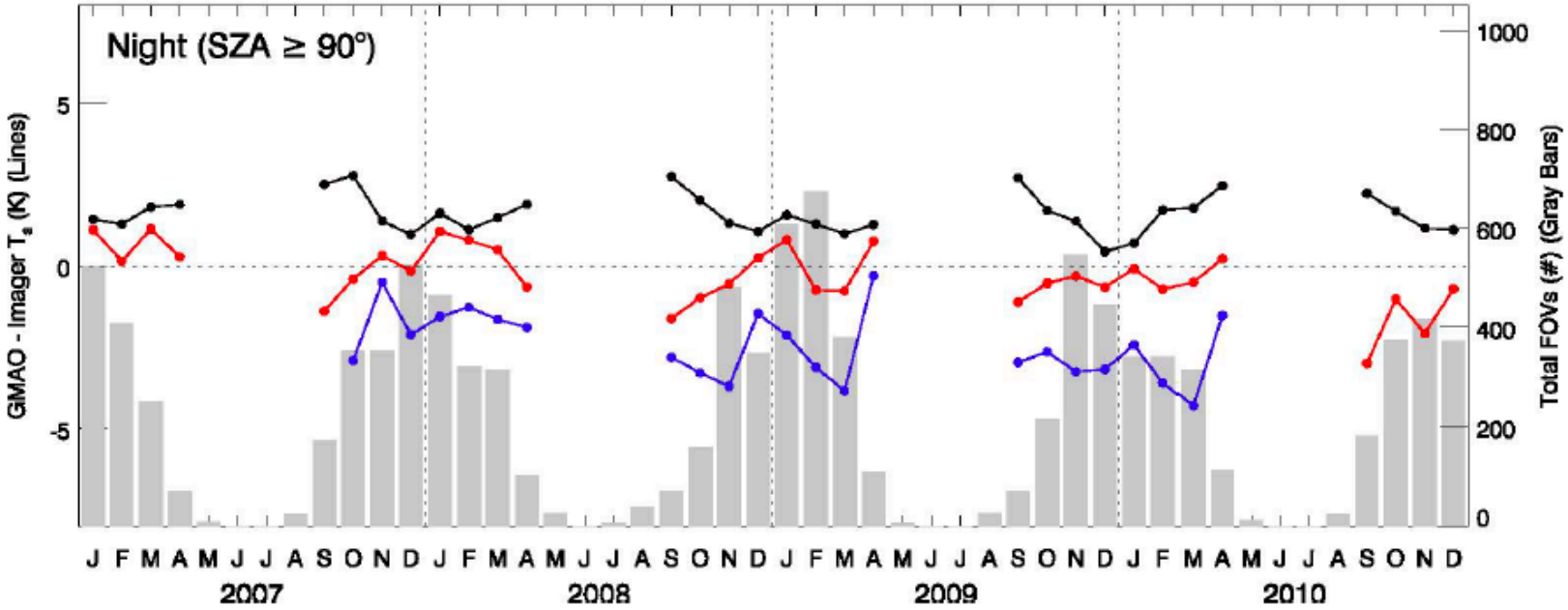
MERRA2 skin temperature over sea ice is high compared to retrieved temperature especially during night

Greenland

G520 – Ed4
G541 – Ed4
MERRA2 – Ed4



MERRA skin temperature is 1 to 2 degree higher than MODIS derived skin temperature



Antarctic

G520 – Ed4
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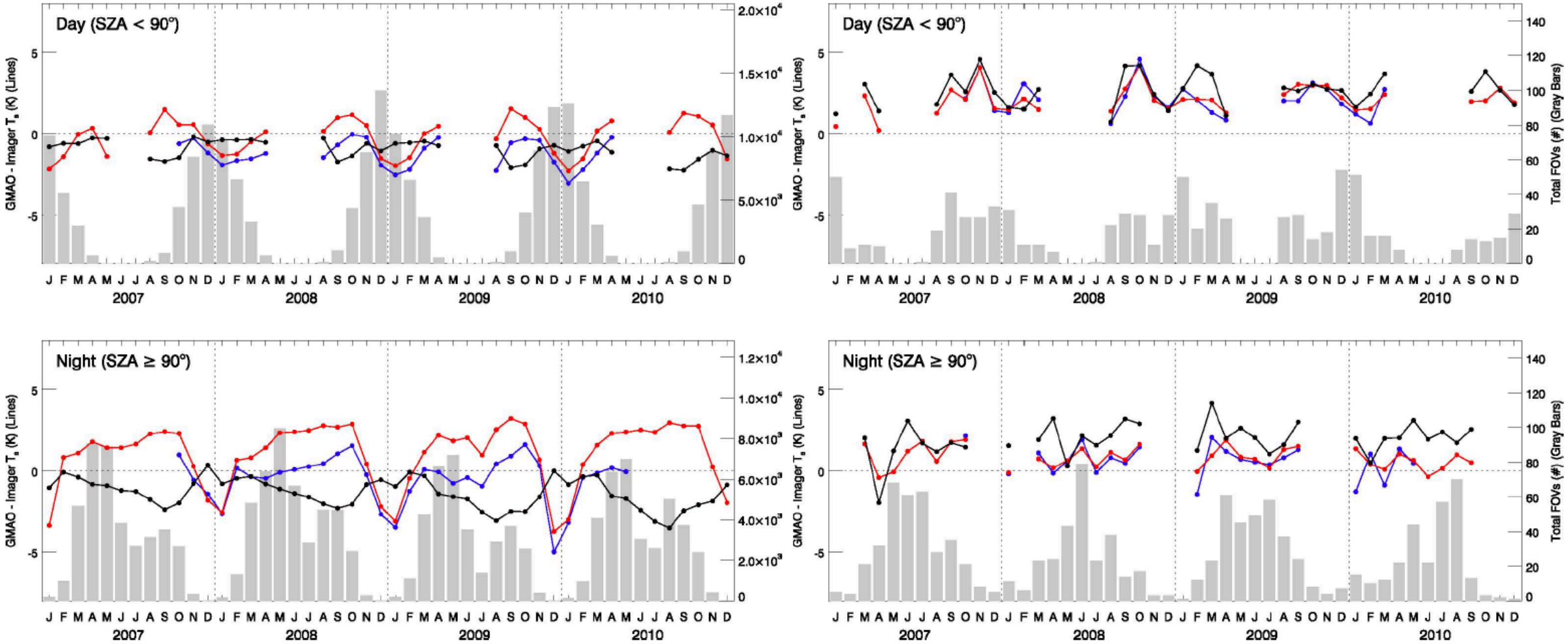
Permanent snow

Sea ice

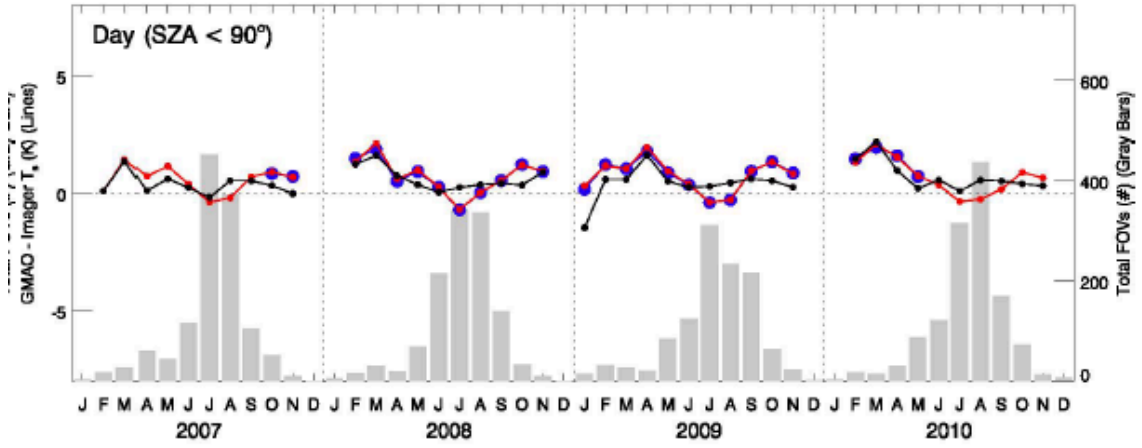


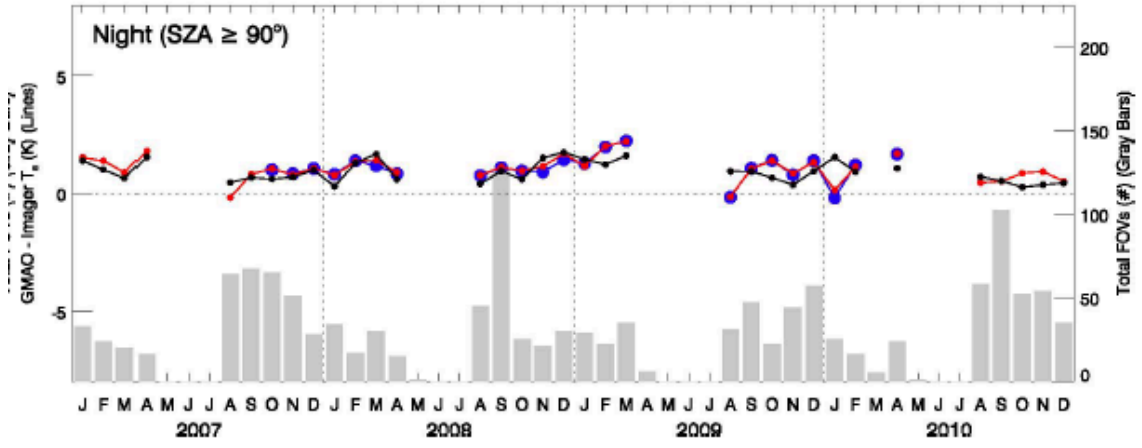
Sea ice skin temperature difference is consistent with the difference over Arctic
MERRS2 skin temperature over the Antarctica is less than the Ed4 skin temperature especially during night.
(Daytime permanent snow comes from coastal area)

Ocean

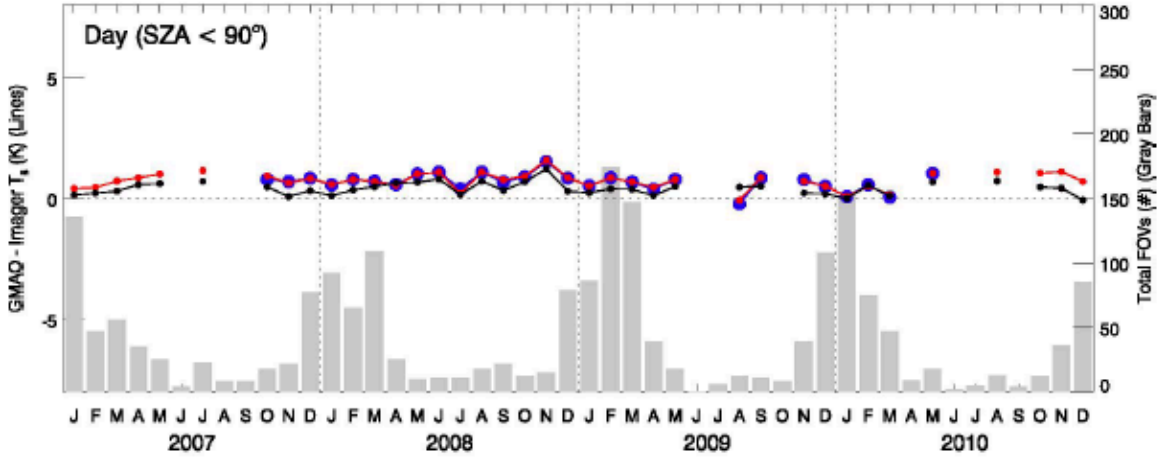
G520 – Ed4
G541 – Ed4
MERRA2 – Ed4

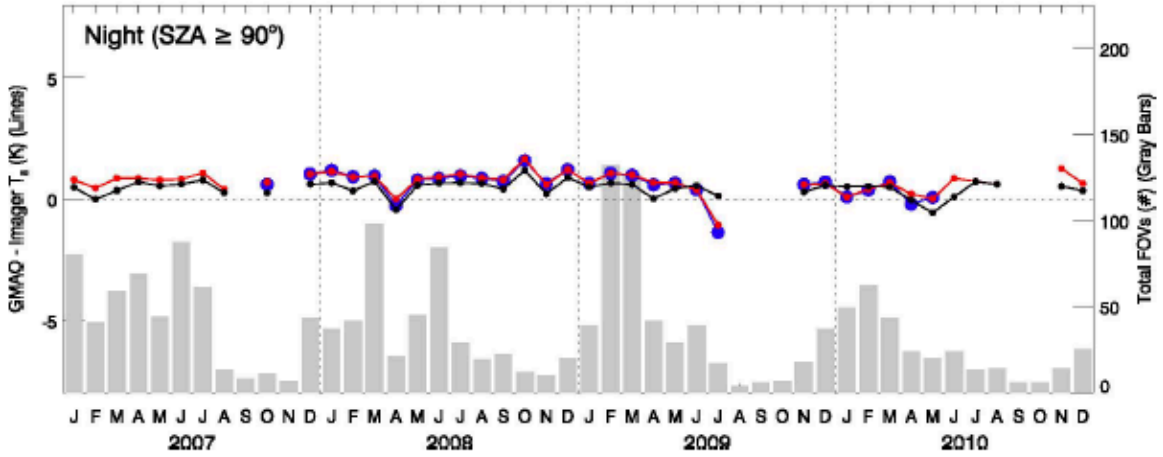
Arctic





Antarctic

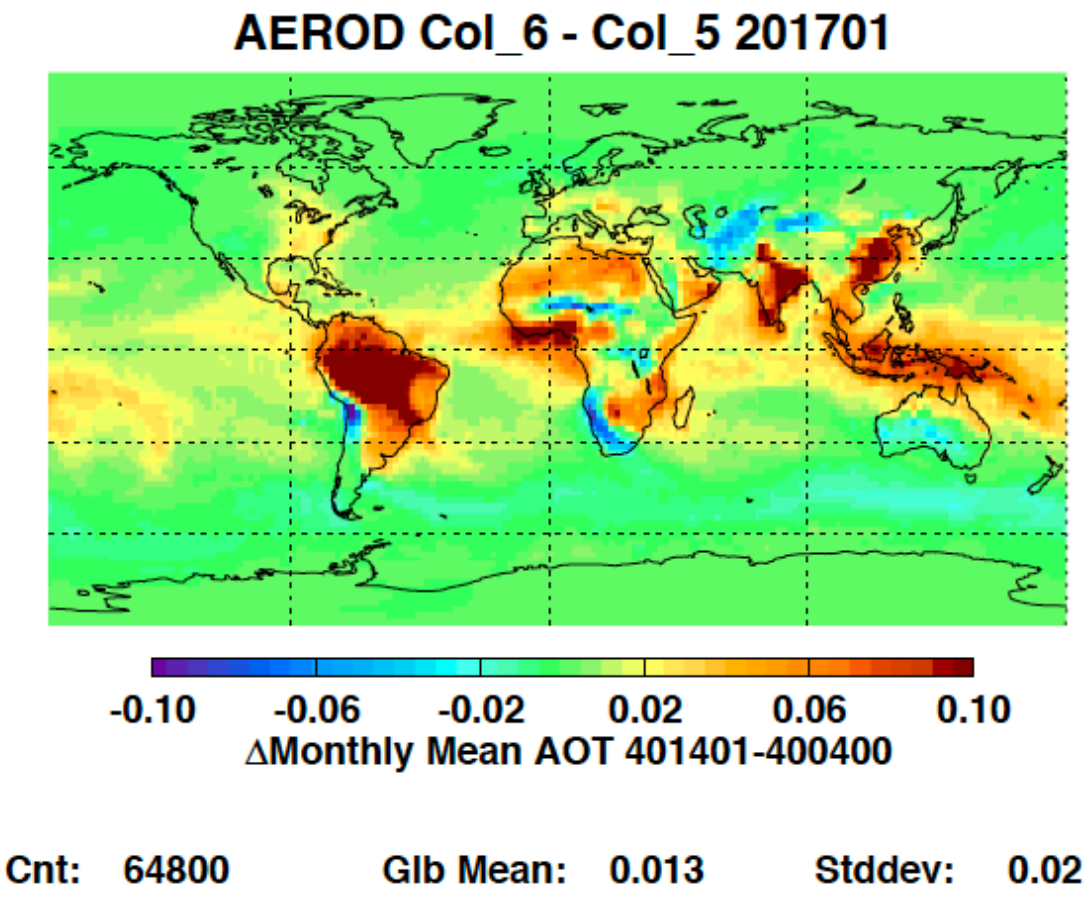


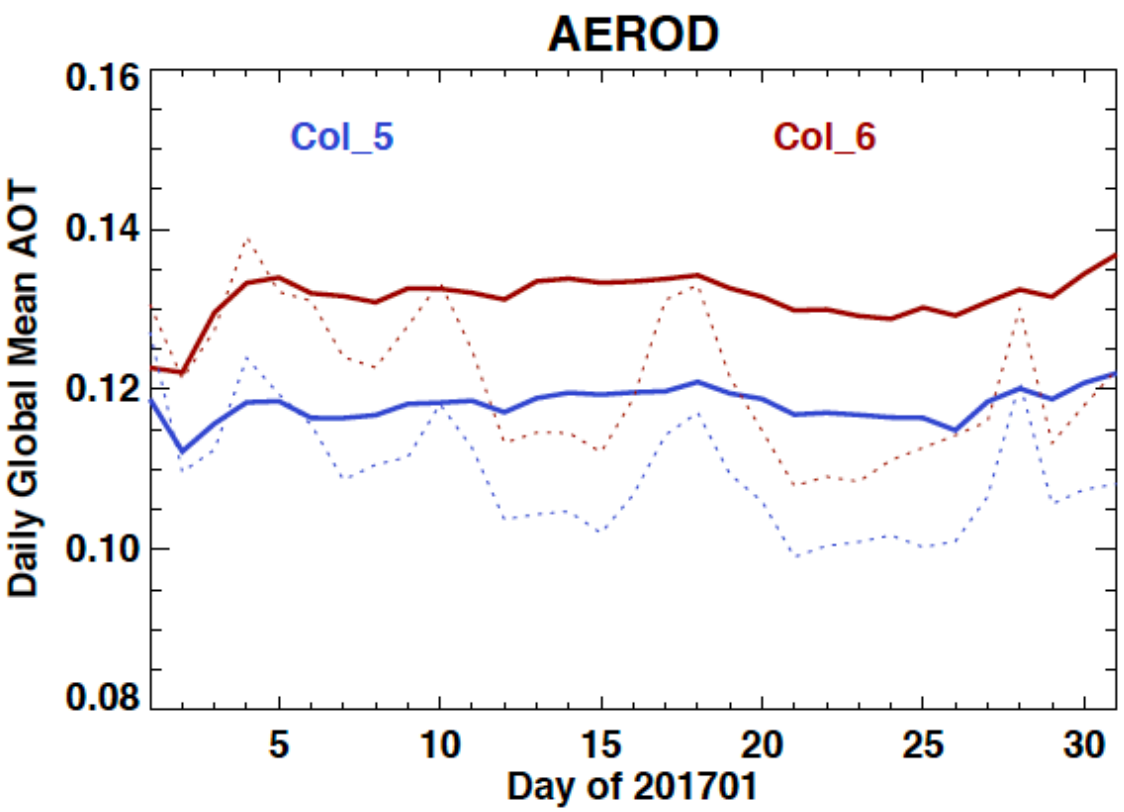


Summary of polar region skin temperature comparisons

- Arctic
  - MERRA2 skin temperature over sea ice is high compared to retrieved temperature especially during night
- Greenland
  - MERRA skin temperature is 1 to 2 degree higher than MODIS derived skin temperature
- Antarctic
  - Sea ice skin temperature difference is consistent with the difference over Arctic
- Antarctica
  - MERRS2 skin temperature is less than the Ed4 skin temperature especially during night.

MATCH aerosol optical thickness: C5 vs. C6





Ice map comparison

Walt Meier's sea ice map list

- Map produced by the NASA Team algorithm
  - most commonly used
  - http://nsidc.org/data/nsidc-0051, Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data
  - http://nsidc.org/data/nsidc-0081, Near-Real-Time DMSP SSM/I-SSMIS Daily Polar Gridded Sea Ice Concentrations
  - The second data set is a NRT version of the first one (i.e., the NRT is temporary until the first data is completed). This is the data that NSIDC cites (e.g., in announcing minimum extents, in browse images, etc.)
- Produced by the Bootstrap, and doesn't have a NRT version.
  - it tends to have more accurate concentration values over the ice pack during summer. Total extent values are very similar to the two other data sets above.
  - http://nsidc.org/data/nsidc-0079, Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS, Version 2
- combines both the NASA Team and Bootstrap.
  - No NRT (I think it's through 2013 now).
  - One possible advantage is that while the other products are in simply flat binary format, this is in NetCDF4.
  - There are actually a couple different concentration parameters in this product, similar but with subtle differences.
  - http://nsidc.org/data/g02202, NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 2

Four sea ice map products

- NASA (51)
- Bootstrap (79)
- NOAA CDR
  - Variable: seaice_conc_monthly_cdr
- NISE (used in Ed4 production)

What is available

Product name & NSIDC code	Brightness temperature NSIDC-0051	~~Near-Real-Time NSIDC-0081~~	Bootstrap NSIDC-0079	NOAA/NSIDC CDR G02202
Temporal coverage	26 October 1978 to 28 February 2017 (updated yearly)	~~1 January 2015 to 27 August 2017 (updated daily)~~	26 October 1978 to 31 December 2015 (updated 2015)	26 October 1978 to 31 May 2015
Format	Binary, text header and Byte data	~~Binary, text header and Byte data~~	Binary, no header, Short data	netCDF

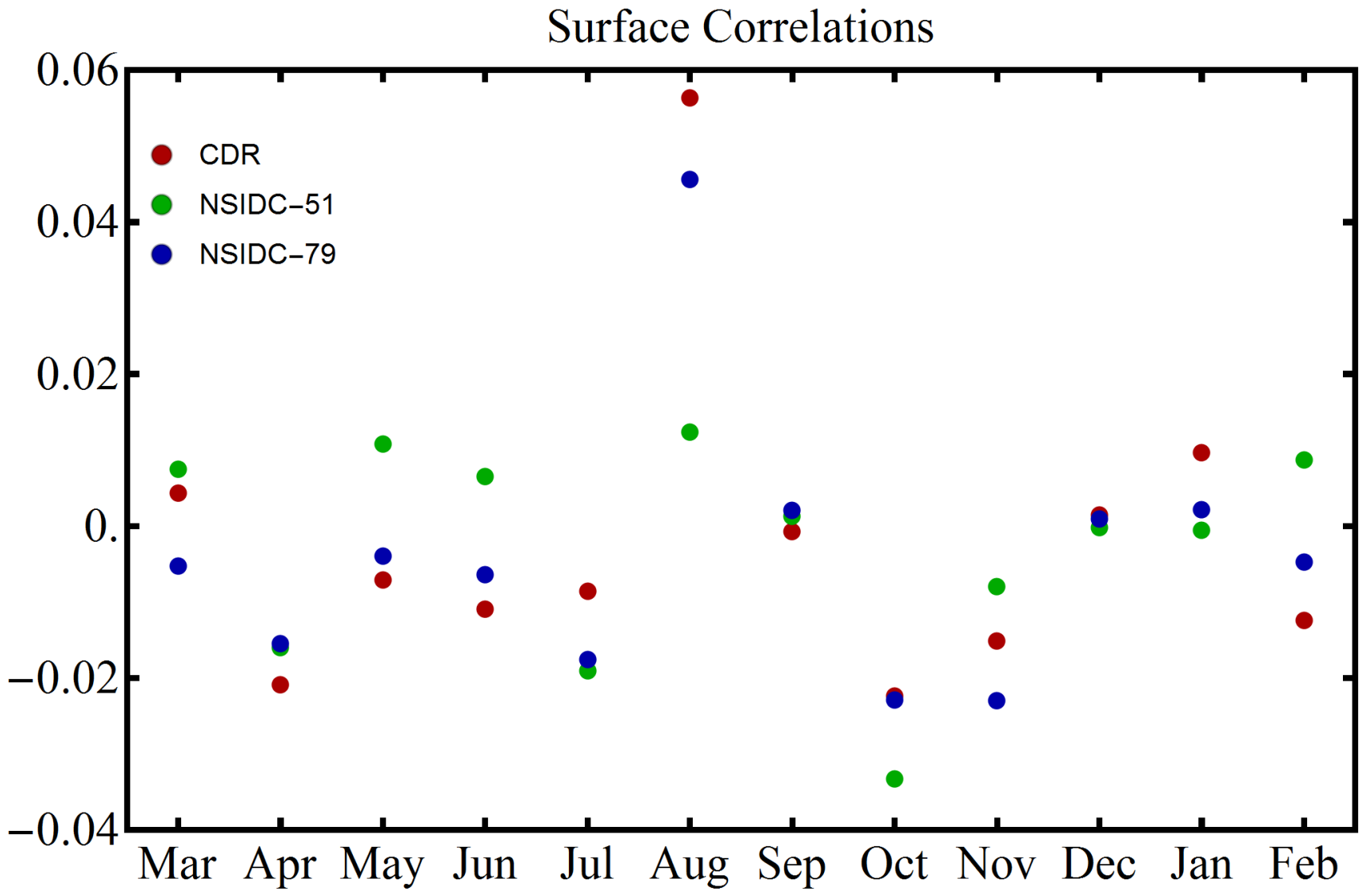
All products are available in daily and monthly versions.

0051 provide ice coverage over some lakes

Sea ice map

- Comparison of three ice map
- Correlation of monthly ice map difference and adjusted and unadjusted upward TOA and surface irradiances
- Adjusted clear-sky TOA and surface irradiances vs. sea ice extend difference from NISE (used in Ed4 process).

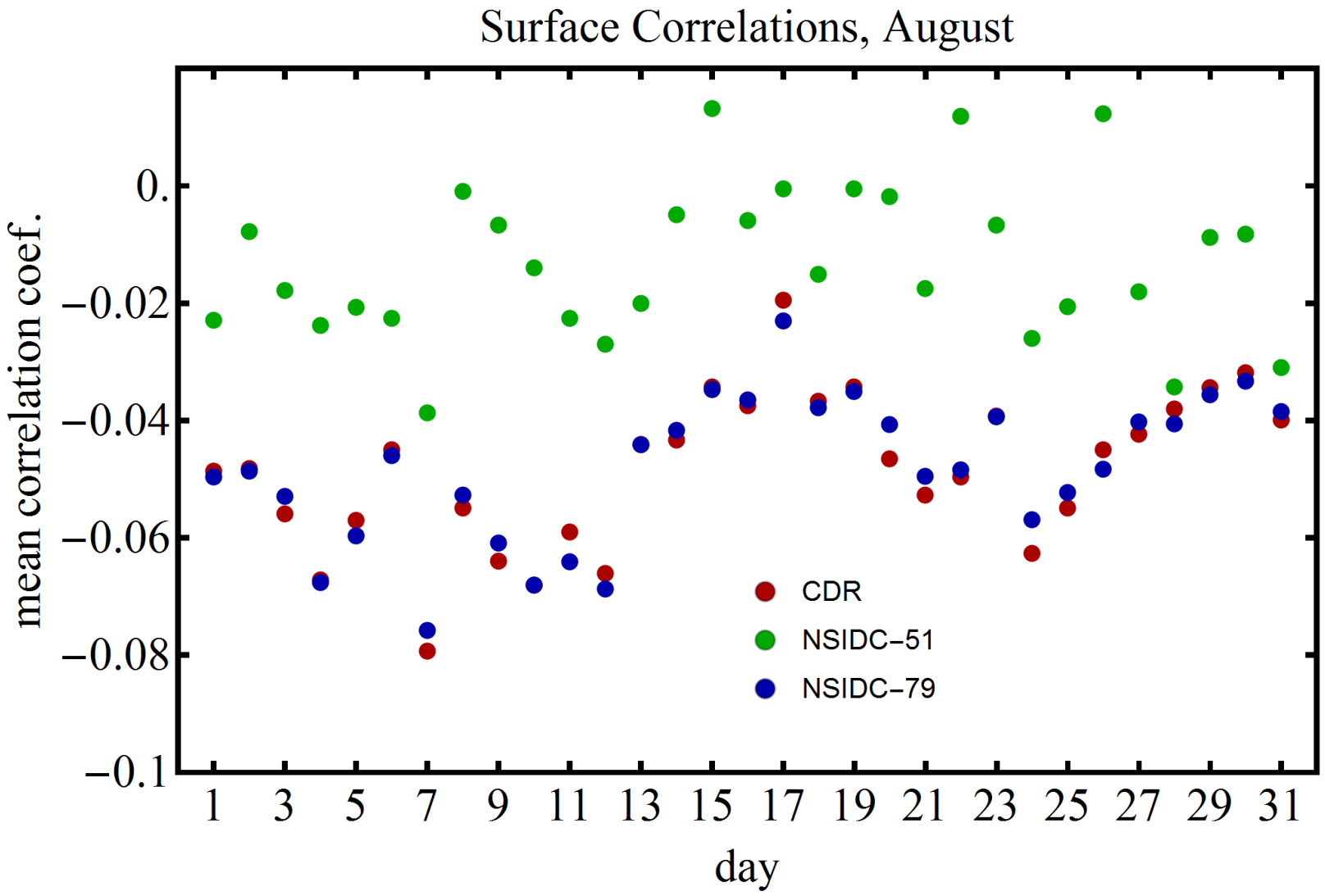
Average correlation coefficient: Monthly



No significant differences among products.

Recalculate correlation coefficient with daily differences and tune-untune from Ed4 SYN1deg-Day

Correlation coefficient: Daily



No significant differences among snow map products we evaluated

Bias error in diurnally averaged irradiance computed by Fu-Liou code

- 2-stream and 4-stream radiative transfer errors depend on solar zenith angle and cloud optical properties.
- Quantify the bias error in diurnally averaged TOA and surface shortwave irradiances computed by the Fu-Liou code using a Monte Carlo code.

Error in the diurnally averaged shortwave irradiances

- 780 3120 cases
  - Simulations to cover a global domain look up table of diurnal Solar zenith angle distributions,
  - Cloud, Surface and Atmosphere.

- 10 :: Cos(Sza)
  - (0.10 - 1.0 by 0.10)
- 3 :: Sfc Albedo f(Sza)
  - (Ocean-Jin, LAND crop , Snow)
- 13 :: Clear , Water Clouds (10um ,Top 3km, Base 2km) & ICE Cloud (60um , Top 10km , Base 8km)
  - Water and Ice each with Cld Taus (0.3 , 1.0 , 2.0 , 5.0, 10.0 , 50.0)
- 1 :: Aerosol Conditions
  - Pristine 0.0 , OCEAN Marine 0.1, Land continental 0.2, Desert Dust 0.4
- 2 :: Atmosphere (MLS, MLW)

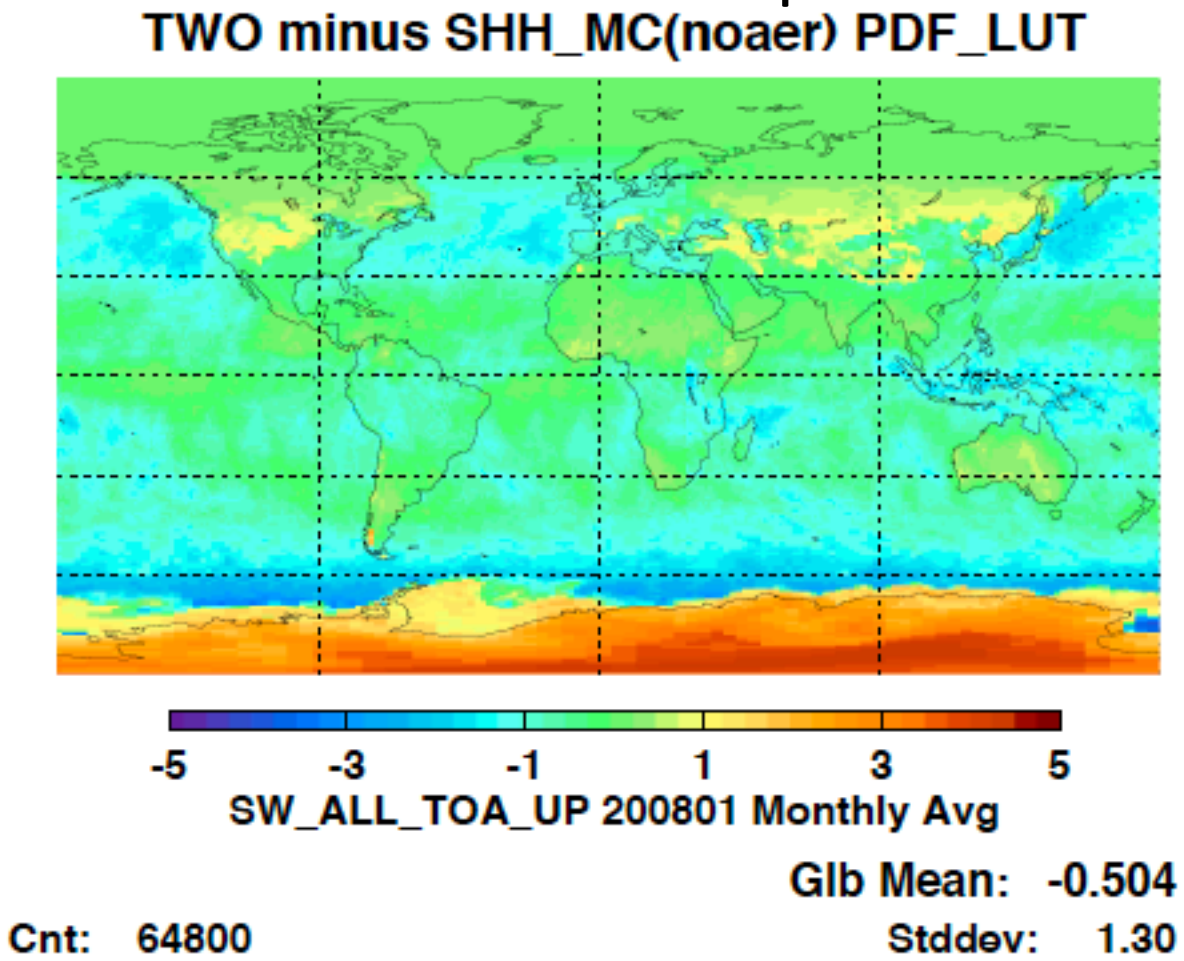
Syn1deg_Hour PDF's used to approximate all_sky regional hourly flux.

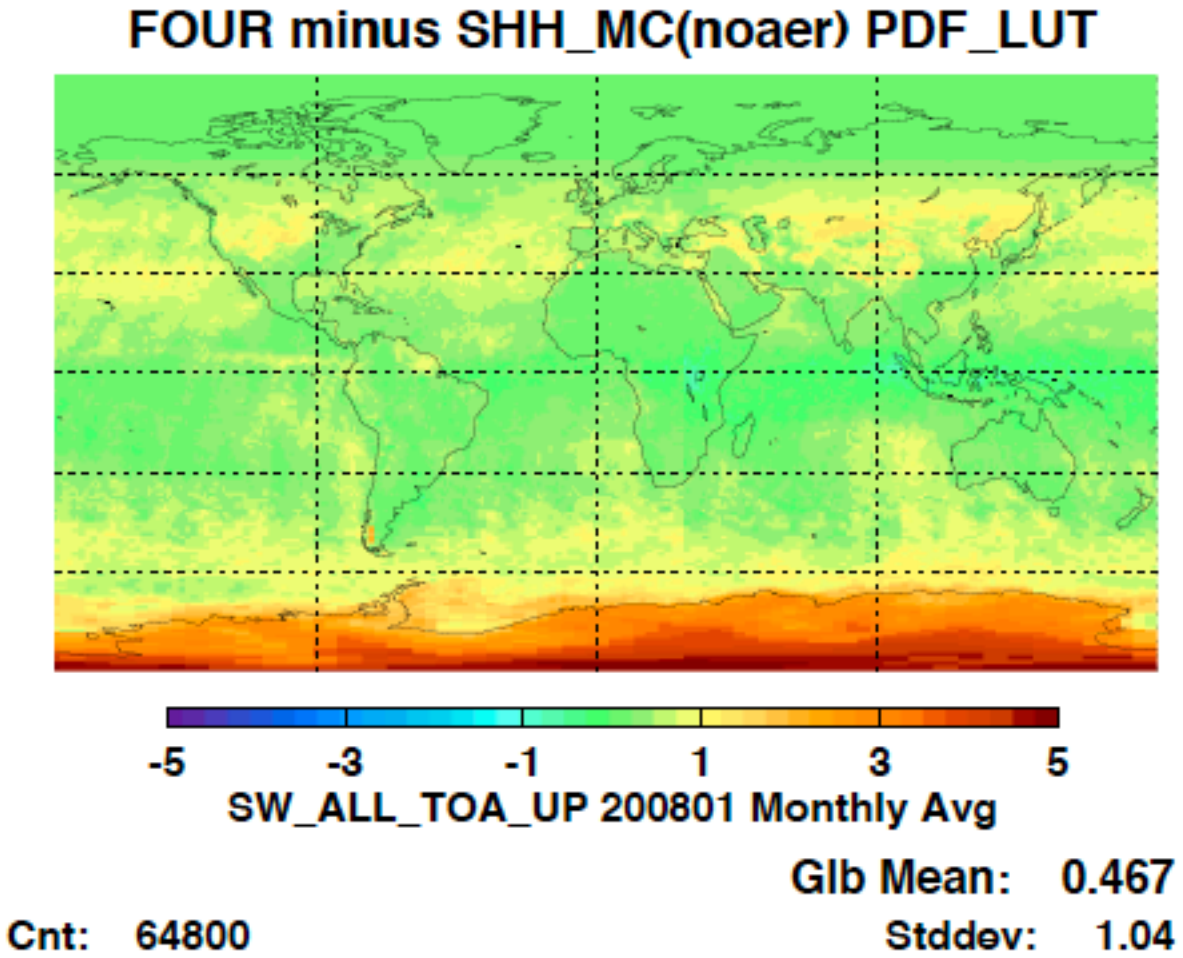
- Create Regional Hourly indexes of
  - 10 :SZA
  - 3 :Surface Type (Ocean , Land , Snow/Ice)
  - 13: Cloud (Ice ,Water , Cloud Optical depth)
  - 3: Aerosol(Ocean , Land tau<0.2 , Land tau>=0.2)
  - 2: Atmosphere(PW < 1cm , PW >=1cm)

- Regional Hourly Total Cloud Fraction

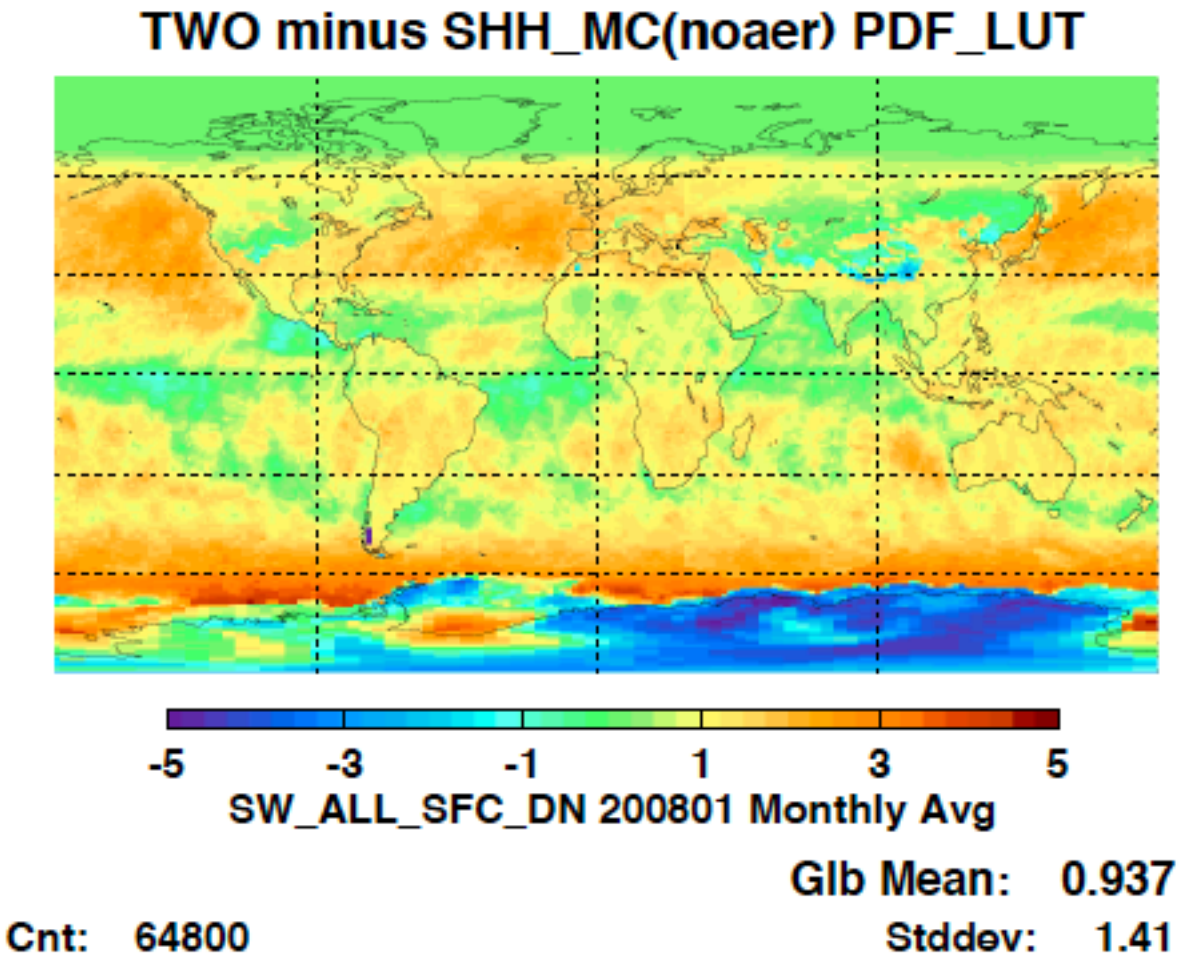
- Use Regional Hourly Indexes to Look-Up Flux simulations
- Use Overcast Sky and Clear Sky Flux simulation data set weighted using Regional/Hourly cloud fractions to give Regional Hourly All Sky flux

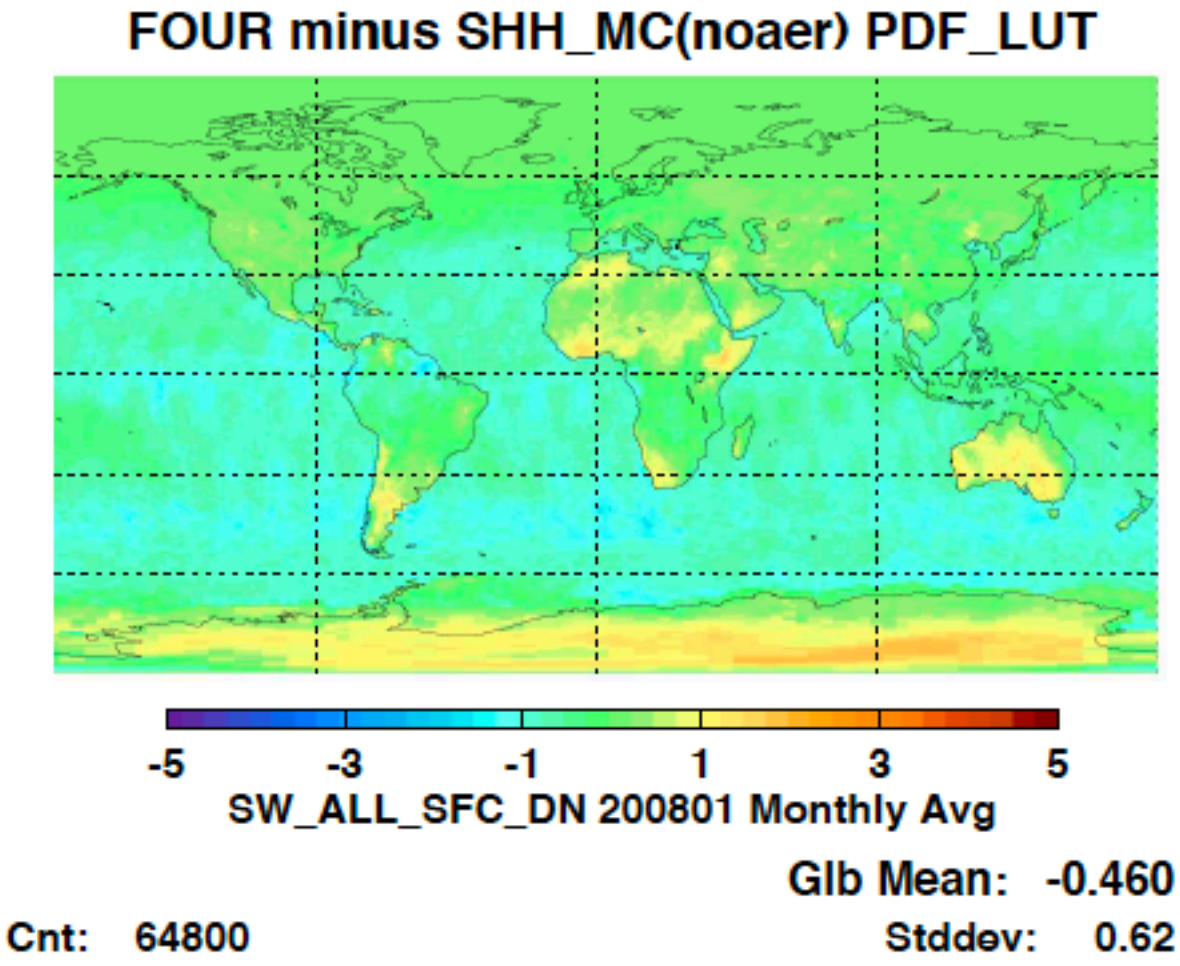
January 2008 case TOA shortwave upward irradiance comparison



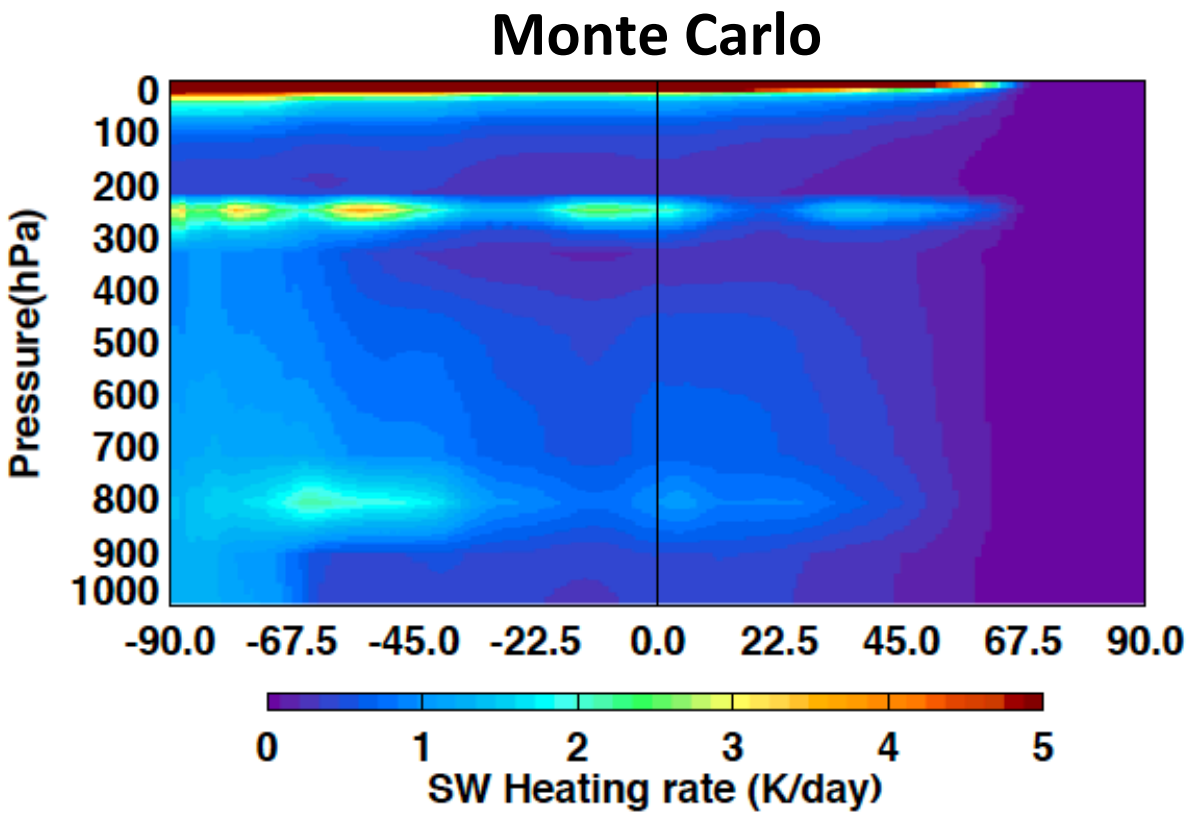


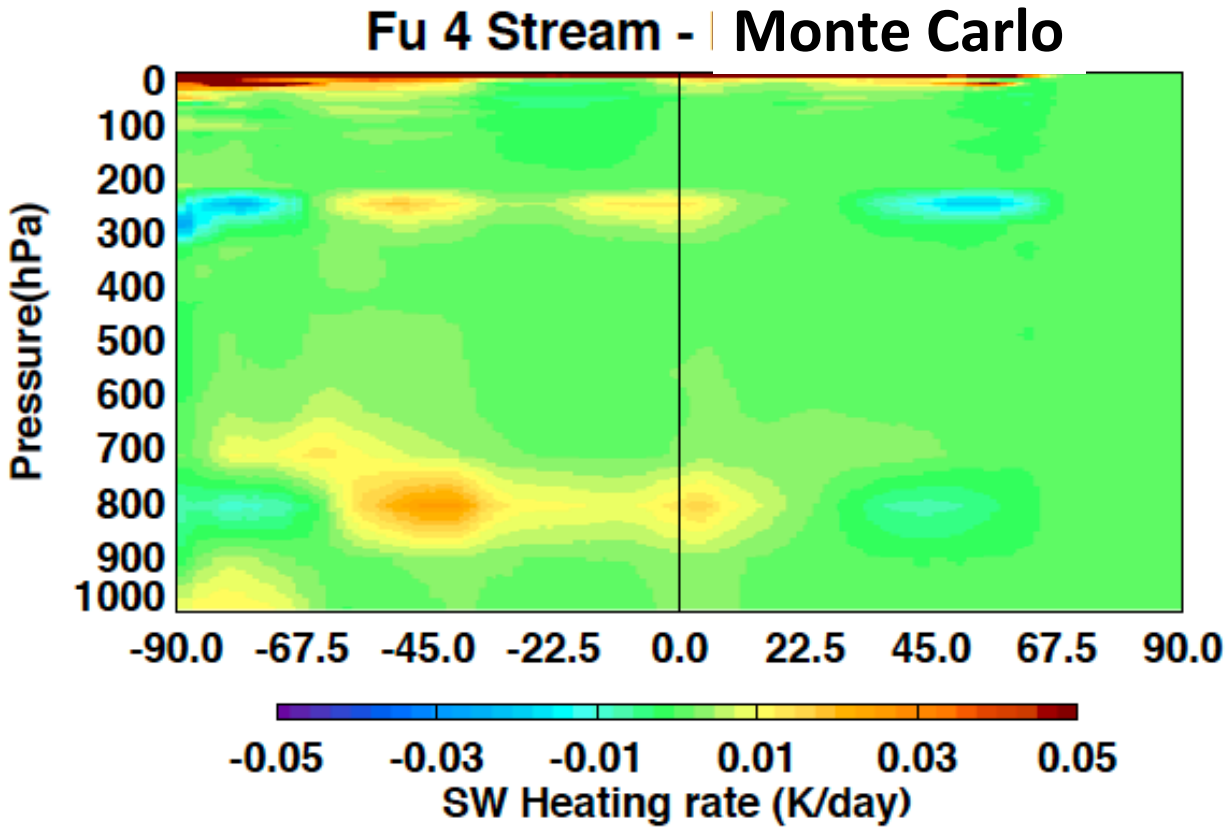
January 2008 case surface downward shortwave irradiance comparison





Shortwave heating rate difference





Plan for Edition 5

- Revise of Fu-Liou code
  - Longwave *k*-distribution
  - Use 3 by 3 cloud fraction-tau classification/ Gamma weighted two stream code
  - Vertical resolution near surface
- Apply bias correction to GEO cloud properties based on MODIS clouds
  - Outside MODIS overpass time is not straight forward (EOF approach?)
- Use a consistent phase function with the phase function used in GEO cloud retrievals
- Revise snow/sea ice spectral albedo
- New GEOS product
  - Apply temperature and humidity bias correction using mean spectral radiances (AIRS)
  - Use a high temporal and a spatial resolution in MOA
  - Use a native resolution of GEOS
  - Vertical interpolation of temperature and humidity near surface
  - HDF file

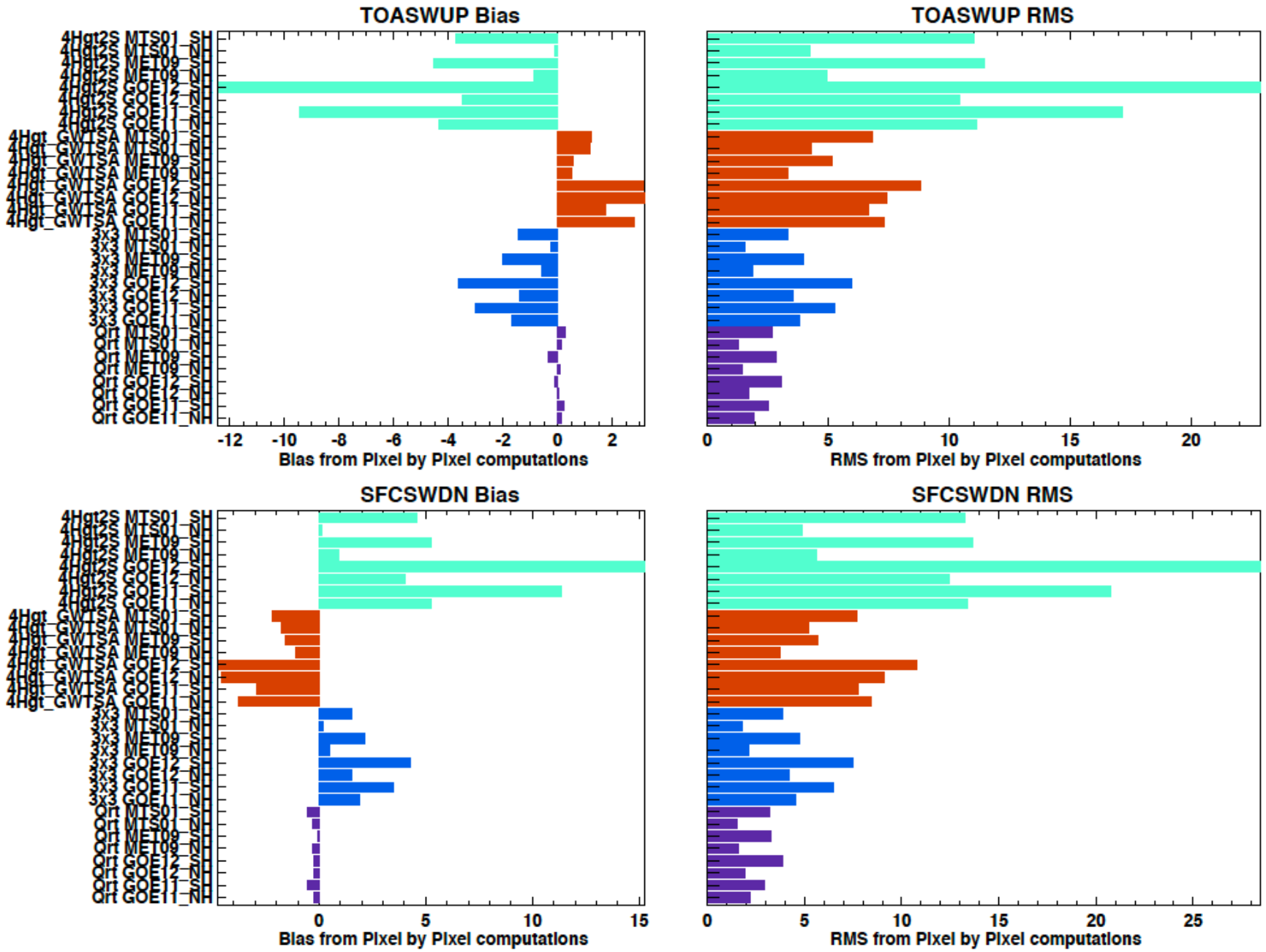
List of publications

- Kato, S., F. G. Rose, D. A. Rutan, T. J. Thorsen, N. G. Loeb, D. R. Doelling, X. Huang, W. L. Smith, W. Su, and S.-H. Ham, 2017: Surface irradiances of Edition 4.0 Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) data product, *J. Climate*, In press.
- Radkevich, A. 2018: A method of retrieving BRDF from surface-reflected radiance using decoupling of atmospheric radiative transfer and surface reflection, *Remote Sens.*, *10*(4), 591; https://doi.org/10.3390/rs10040591.
- Kato, S., F. G. Rose, S.-H. Ham, D. A. Rutan, A. Redkevich, T. E. Caldwell, S. Sun-Mack, W. F. Miller, and Y. Chen, 2018: Radiative heating rates computed with clouds derived from satellite-based passive and active sensors and their effects on generation of available potential energy, submitted to *J. Geophys Res*.
- Chen, X., X. Huang, X. Dong, B. Xi, E. K. Dolinar, N. G. Loeb, S. Kato, P. Stackhouse, M. G. Bosilovich, 2018: Using AIRS and ARM SGP clear-sky observations to evaluate meteorological reanalyses: a hyperspectral radiance closure approach submitted to *J. Geophys Res*.

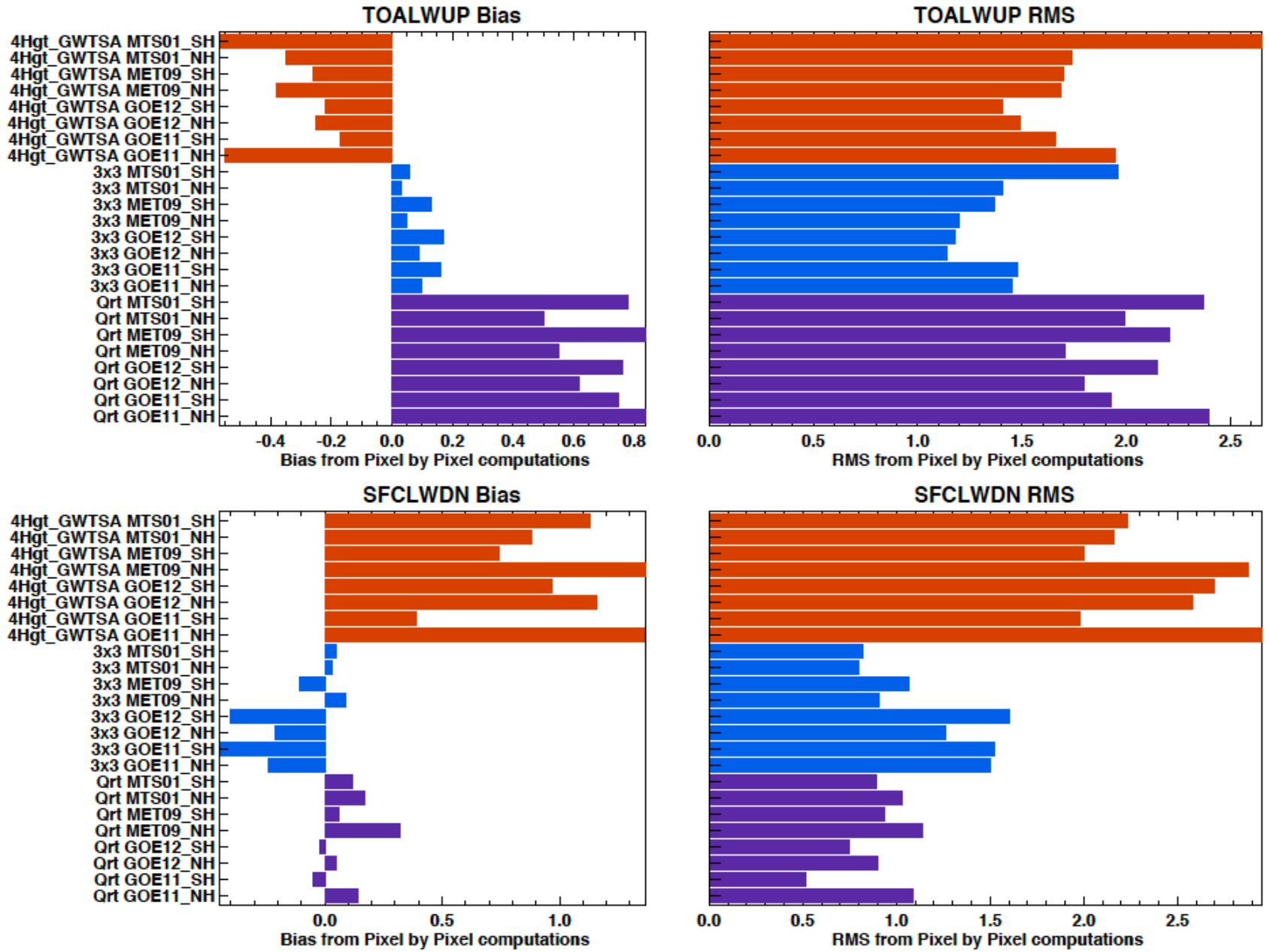
Back-ups

GWTSA horizontal inhomogeneity issue (working in progress)

Shortwave Bias and RMS compared to Pixel computations by satellite domain and computation mode Cloudy sky Statistics



Longwave Bias and RMS compared to Pixel computations by satellite domain and computation mode Cloudy sky Statistics



LW fingerprinting?