Non-Gaussian PDFs of TOA SW Flux from MISR and CERES

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(193? – 2022)

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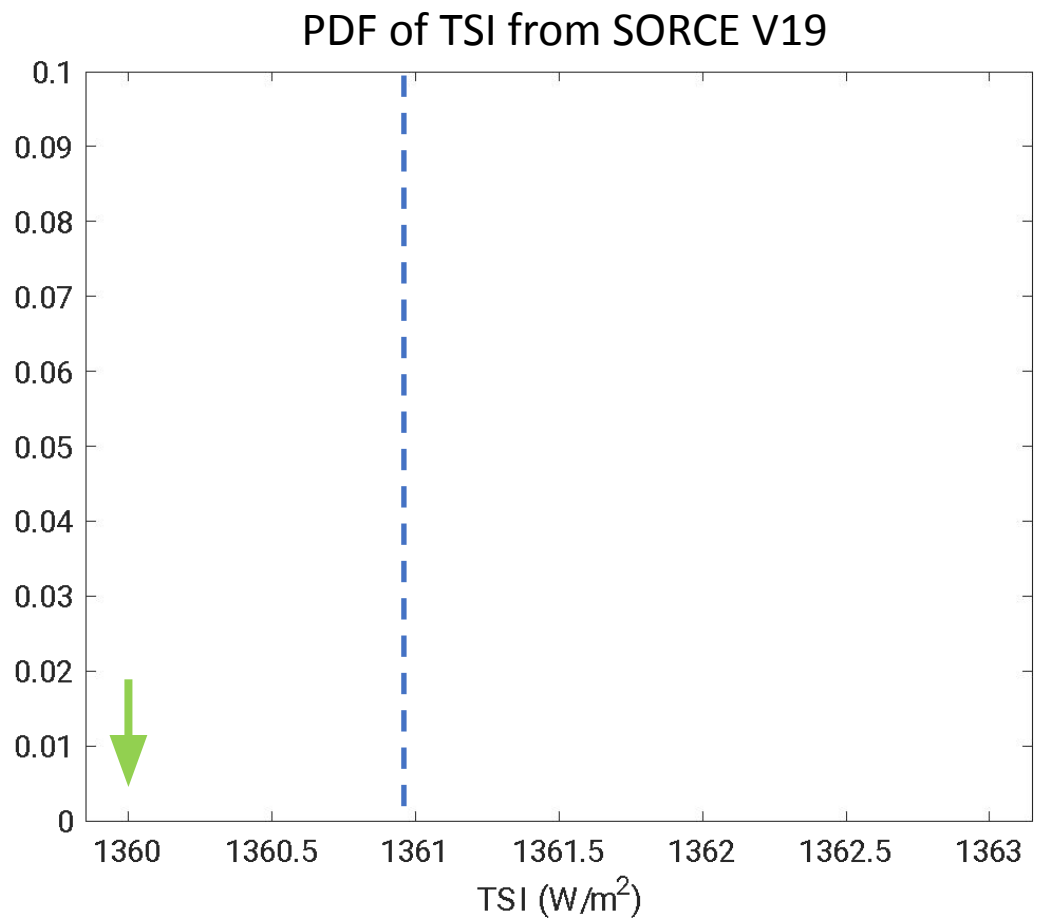
Acknowledgments : NASA Sun Climate Research

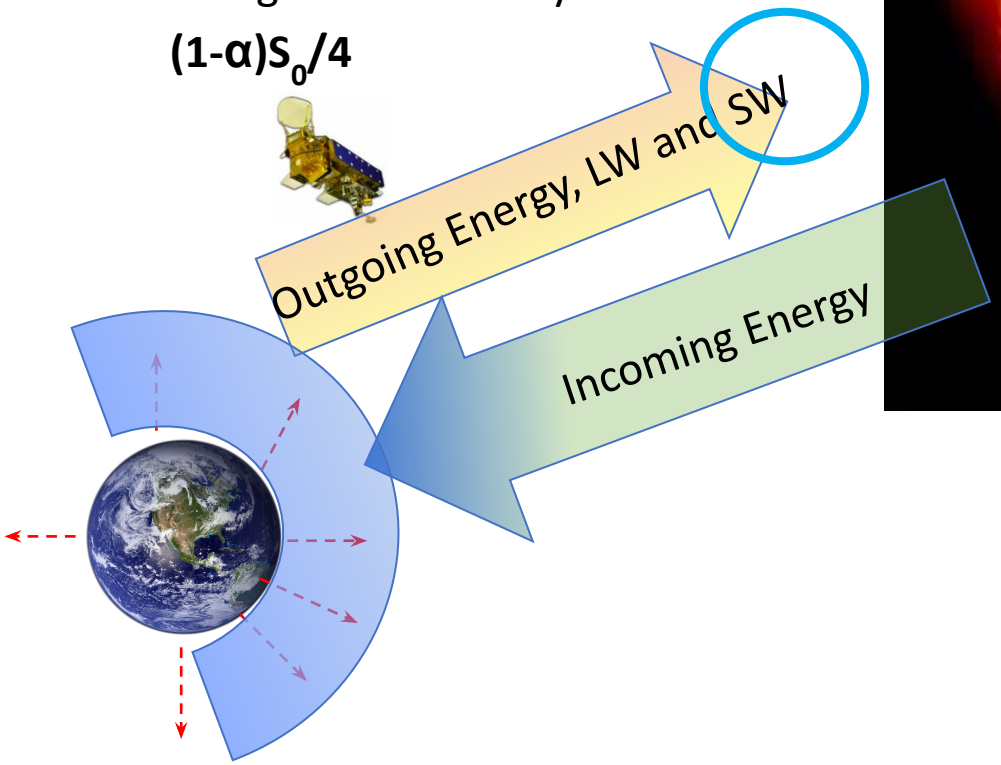
Gaussian distribution? Central limit theorem?

Mean value of total solar irradiance (TSI) during last two decades?



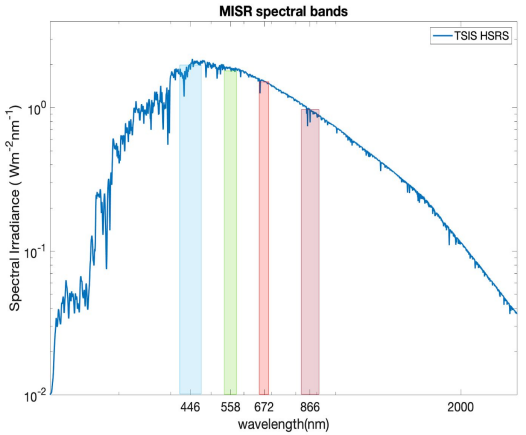
Top of the Atmosphere
Planetary albedo : $\alpha = SW/S_0$

Sun light absorbed by Earth
$(1-\alpha)S_0/4$



MISR and CERES TOA SW Flux Data

MISR (Multi-angle Imaging SpectroRadiometer) (**ATBD**)



- Near-simultaneous multi-angular measurements
- Narrow-to-broad band conversion (Sun et al., 2006)
- broad band albedo => SW Flux by S_0
- 275-m pixel
- Narrow (~400km) swath
- Scene type classification for albedo models (i.e., land, snow, ice, clouds): 1000's

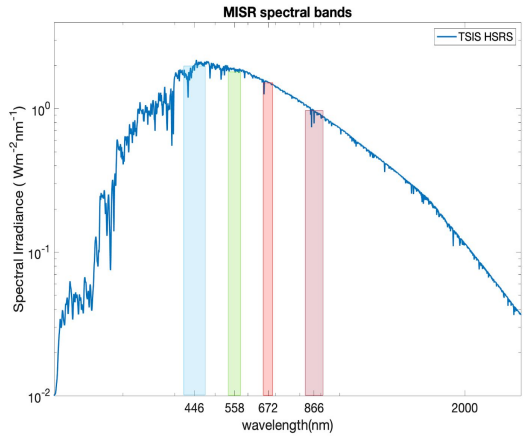
CERES (ATBD) : Single Scanner Footprint (SSF) product

- Climatological angular distribution models (ADMs)
- Direct broad-band SW flux divided
- 10-km pixel
- Wide (~3000km) swath
- Scene type classification for ADMs: 1000's

MISR and CERES TOA SW Flux Data

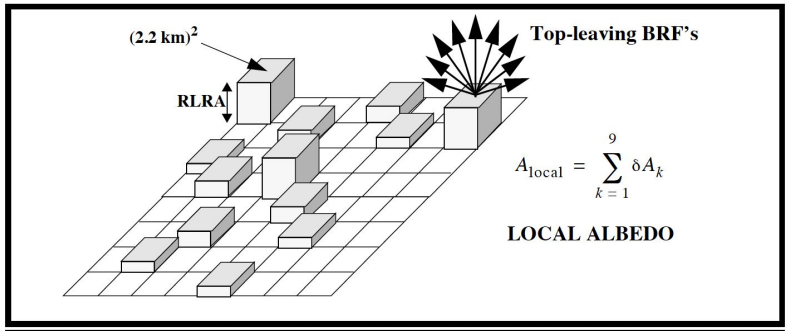
MISR (Multi-angle Imaging SpectroRadiometer) (**ATBD**)

- Near-simultaneous multi-angular measurements
- Narrow-to-broad band conversion (Sun et al., 2006)
- broad band albedo => SW Flux by S_0

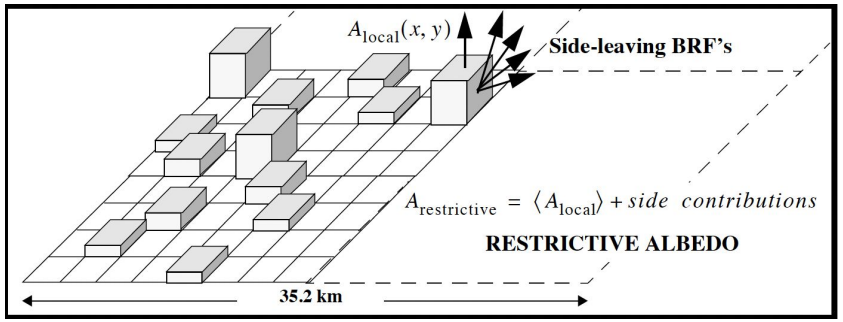


- 275-m pixel
- Narrow (~400km) swath
- Scene type classification for albedo models (i.e., land, snow, ice, clouds): 1000's

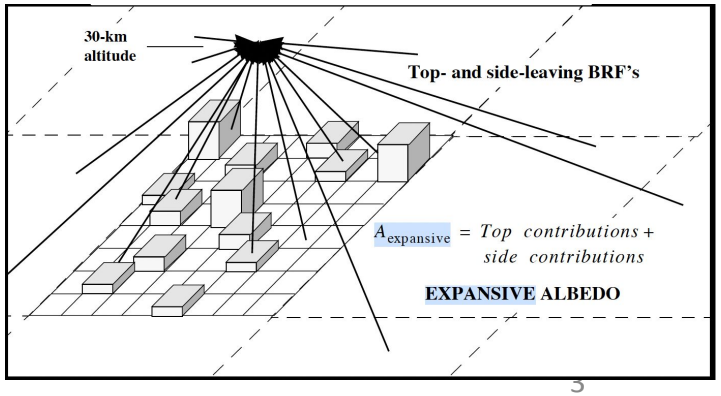
Local Albedo



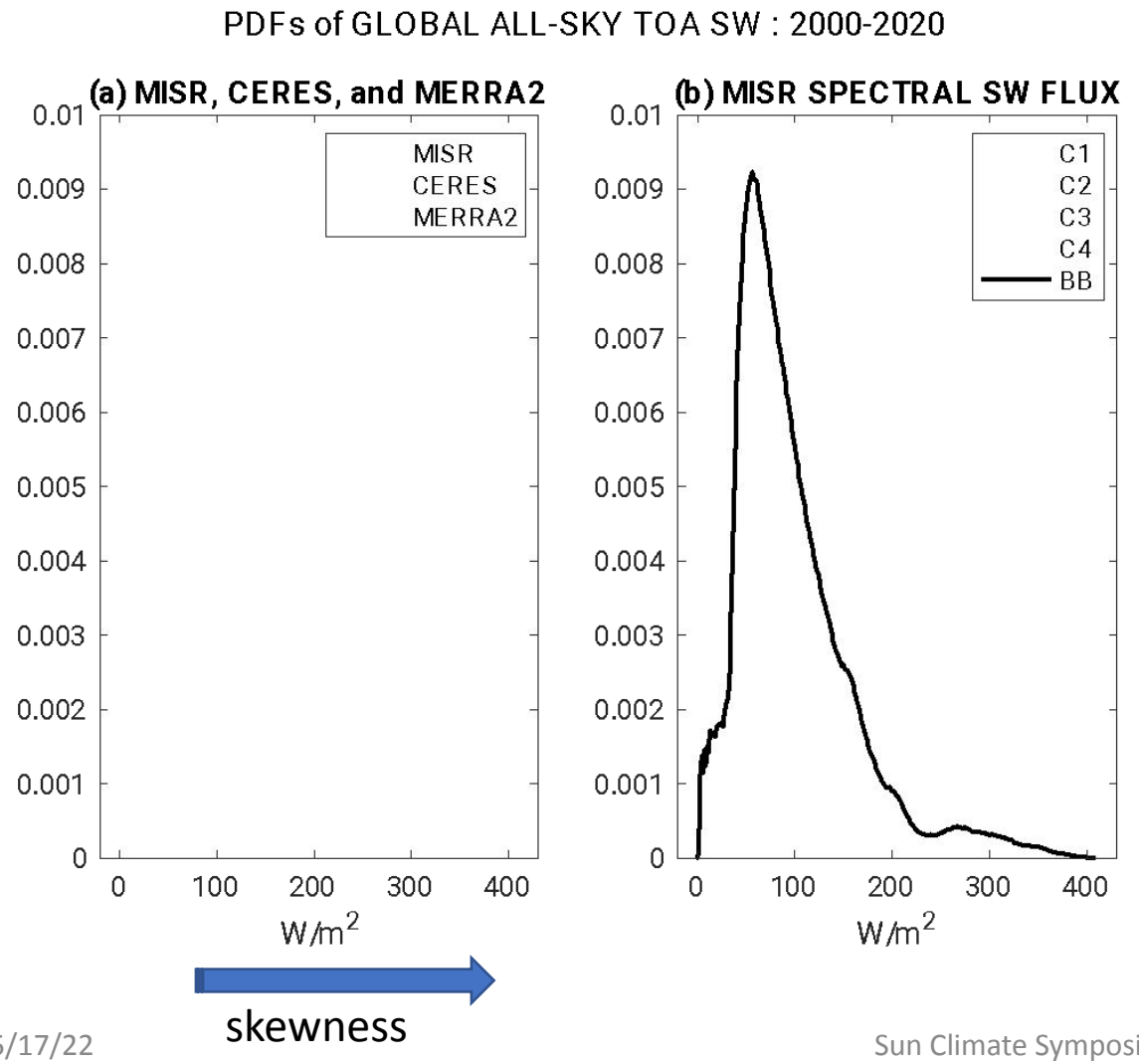
Restrictive Albedo



Expansive Albedo



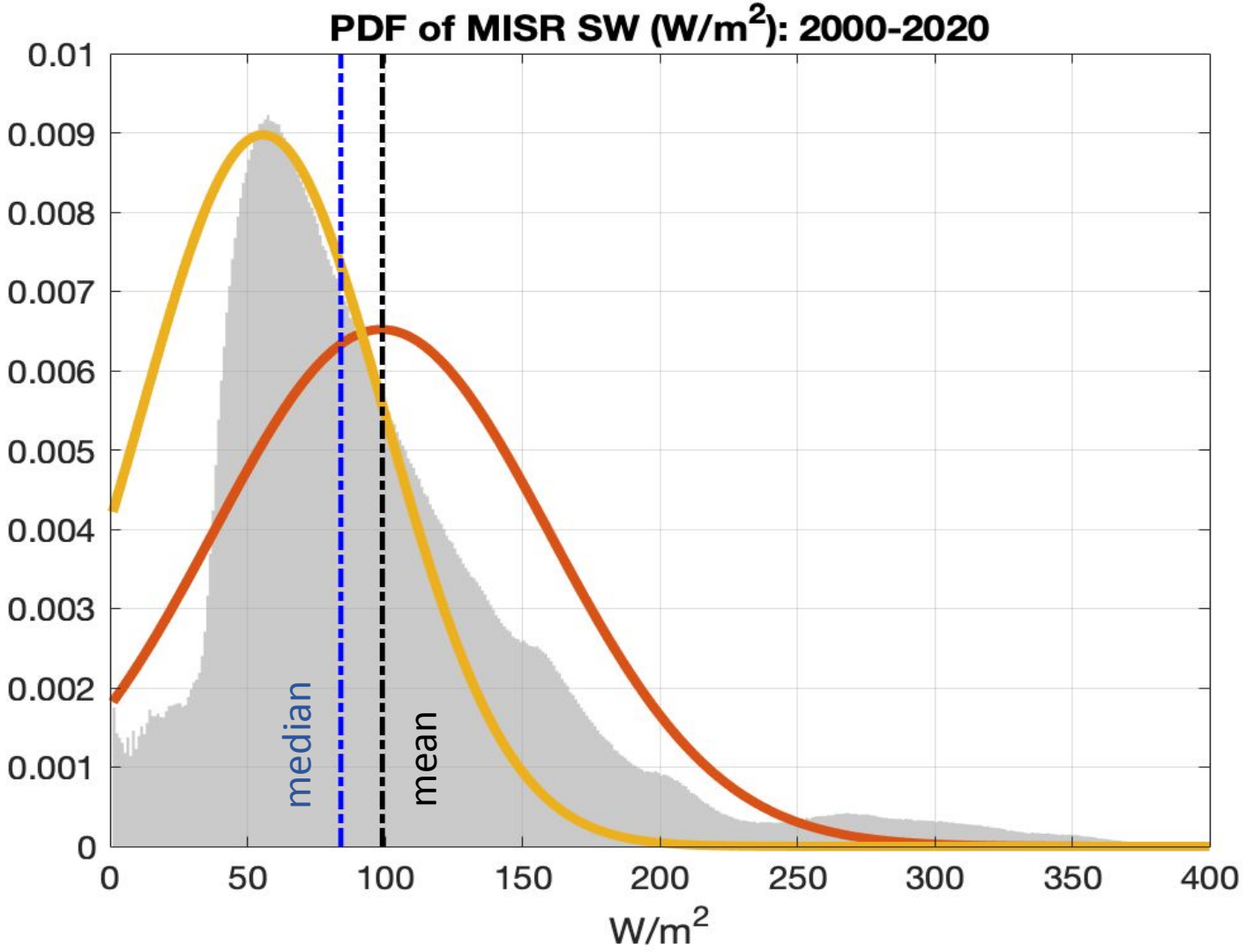
Skewness in the TOA SW distribution



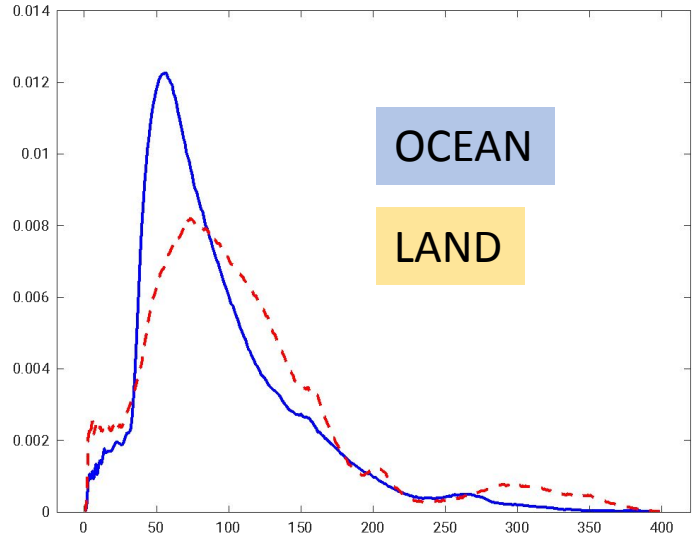
- Deviation from normal distribution
- Asymmetric from the maximum population
- Positive skewness more data on right side of the maximum population
- One major peak near 60W/m^2, MISR peak value is ~7W/m^2 less than that of CERES
- All four of MISR spectral SW flux are showing similar positive skewness

(Lee and Wu, 2022, JGR, in review)

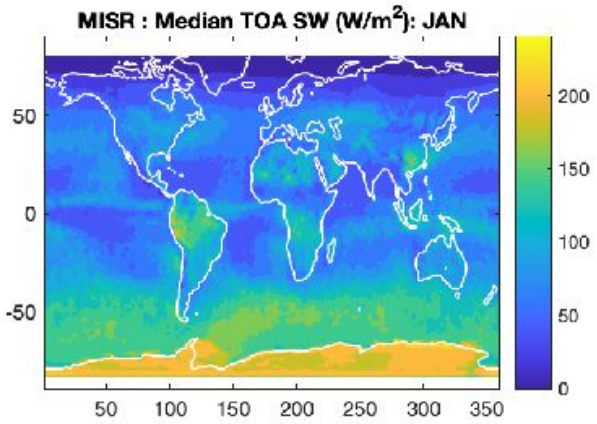
Implications of Non- Gaussian distribution?

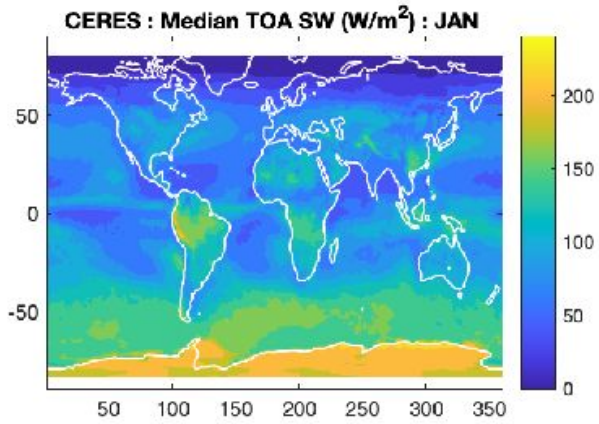


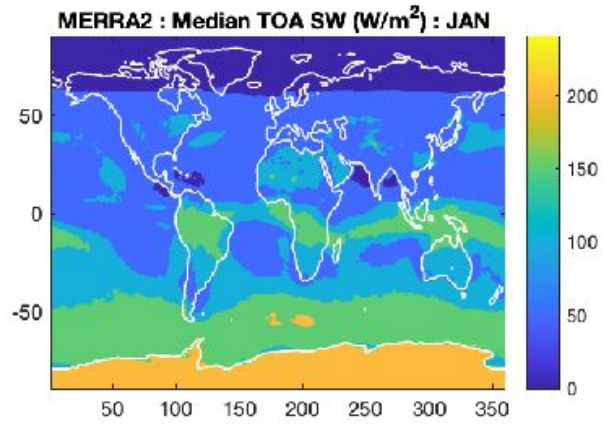
1. Deviations from mean
2. Outliers in high flux values above 300 W/m^2?

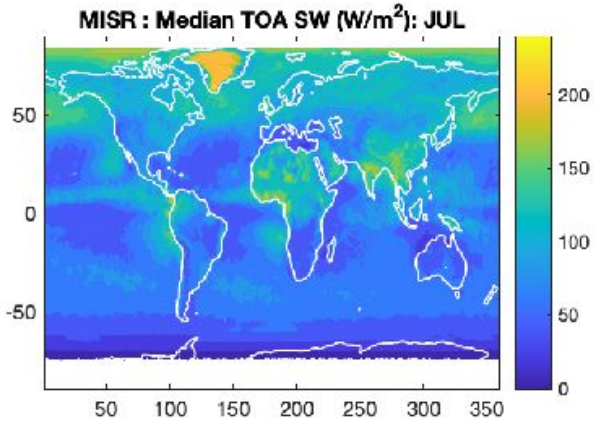


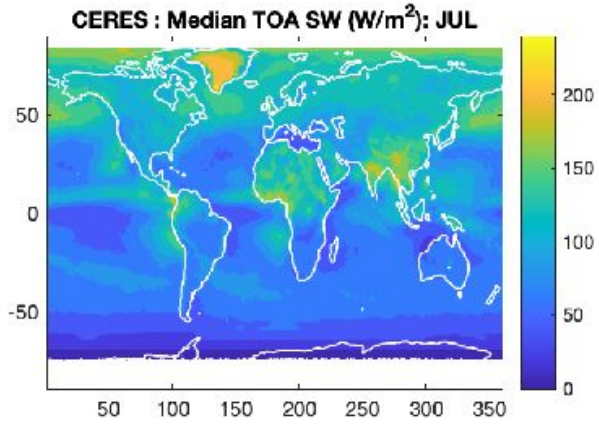
Median TOA SW flux (W/m^2) : MISR, CERES, and MERRA2

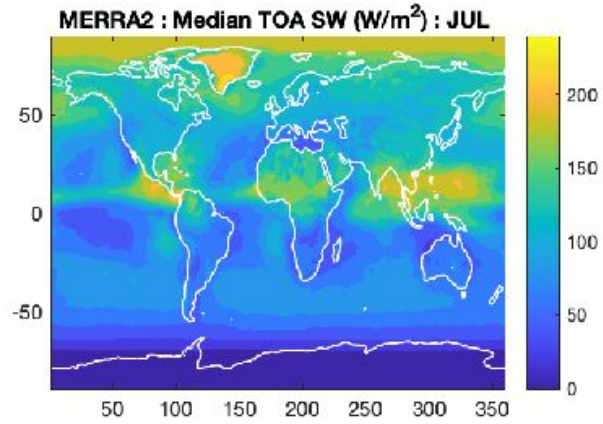


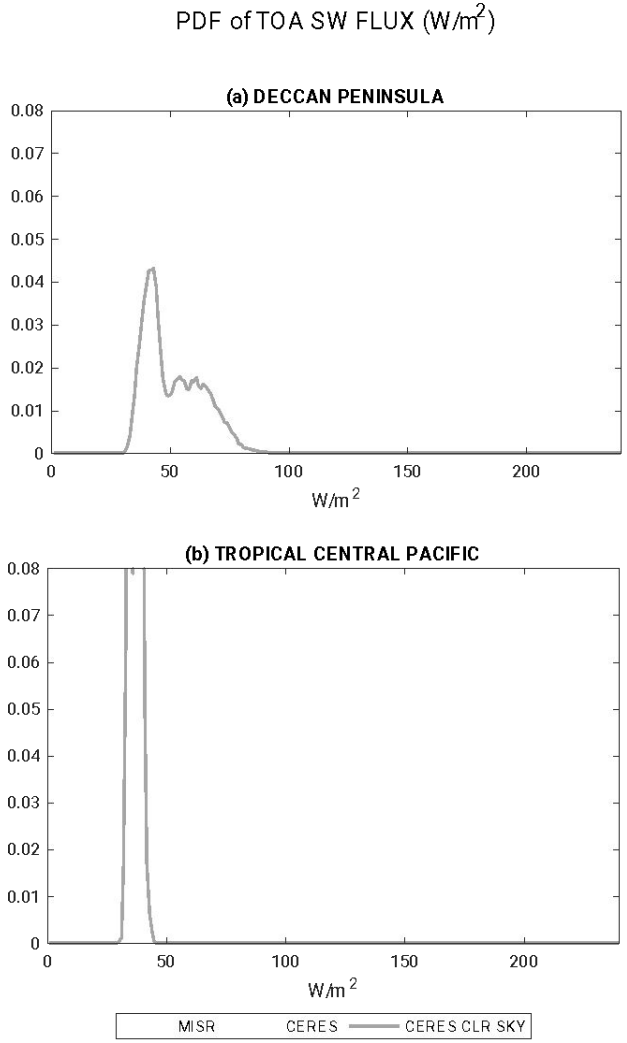


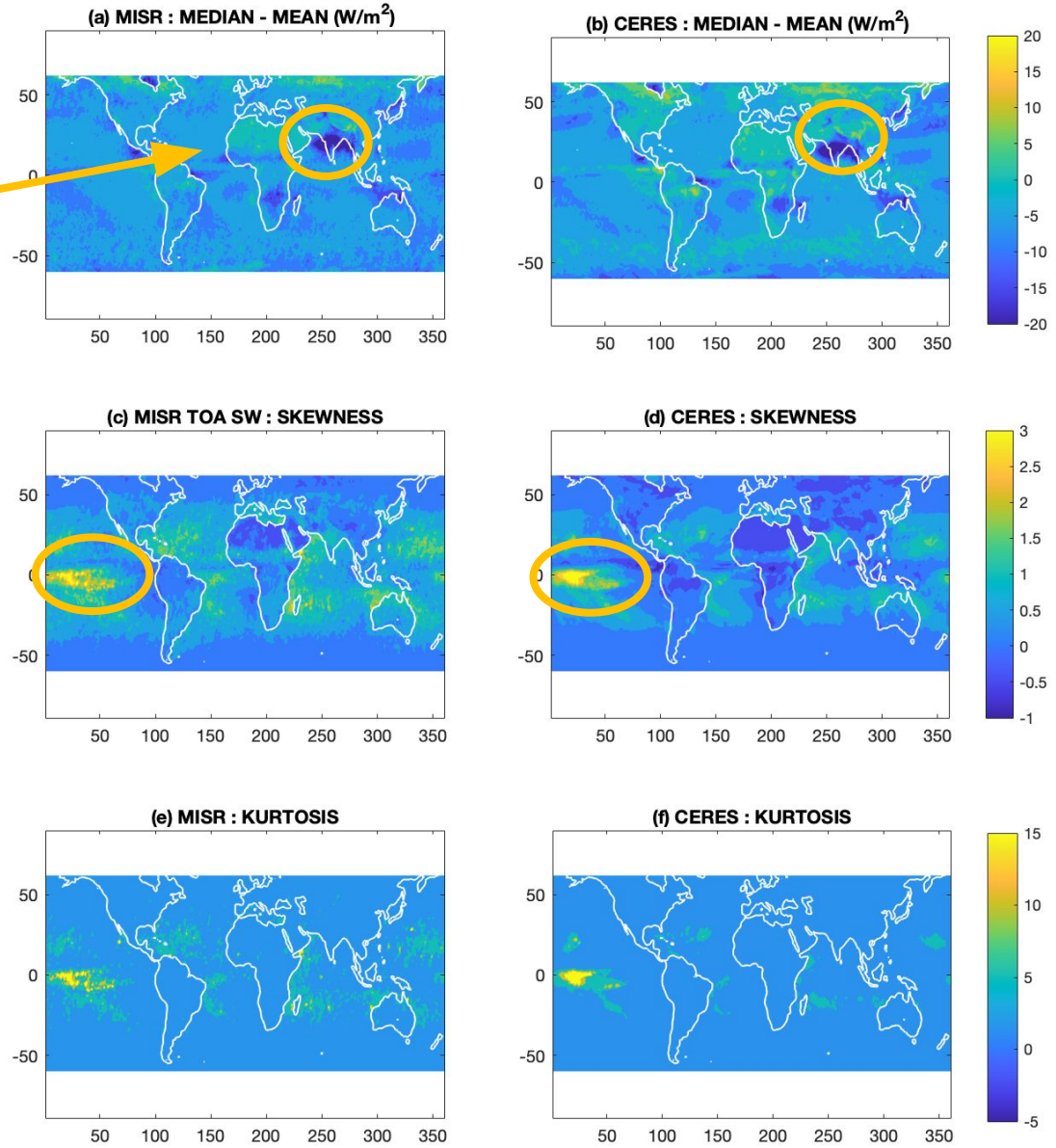




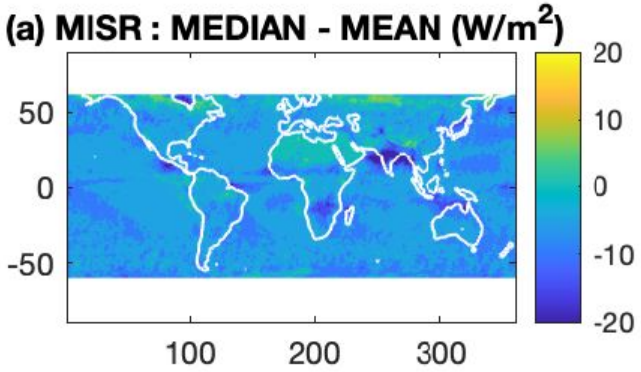


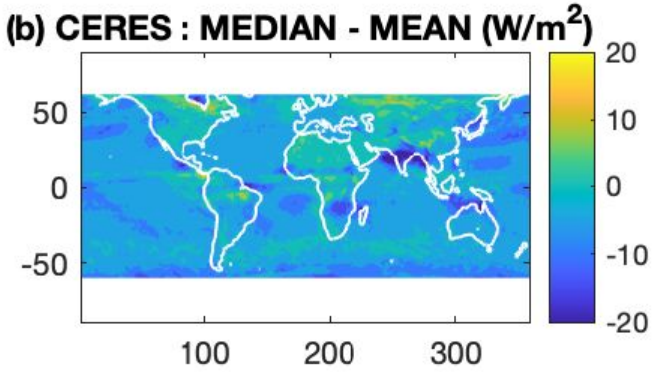


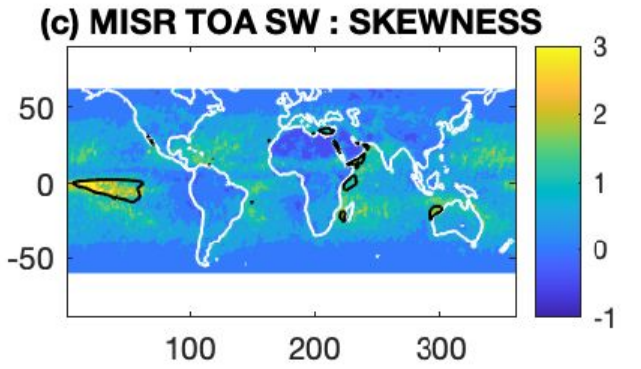


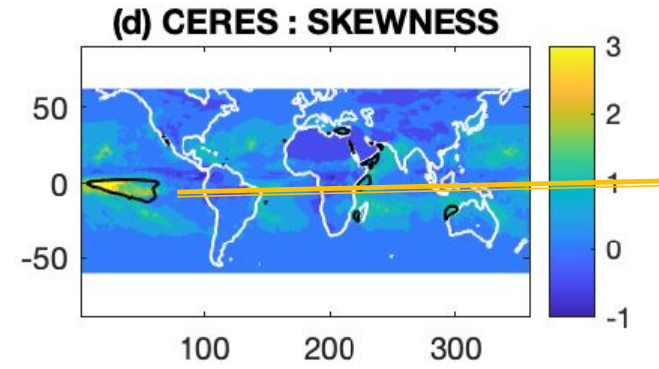


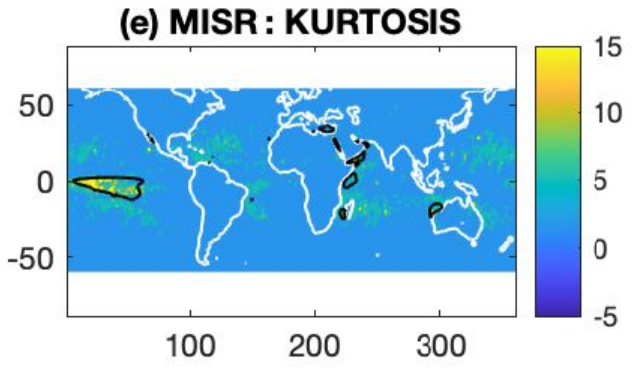
Where are the most skewed regions?

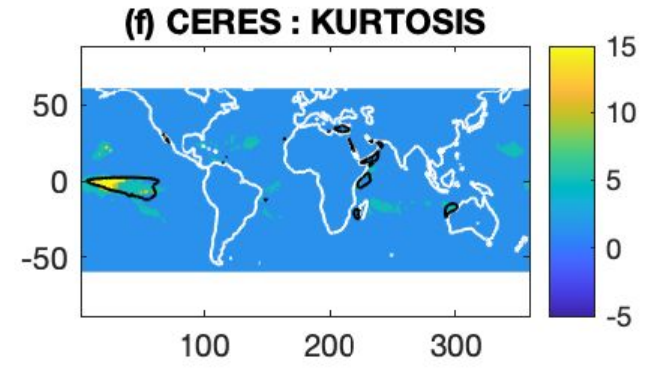












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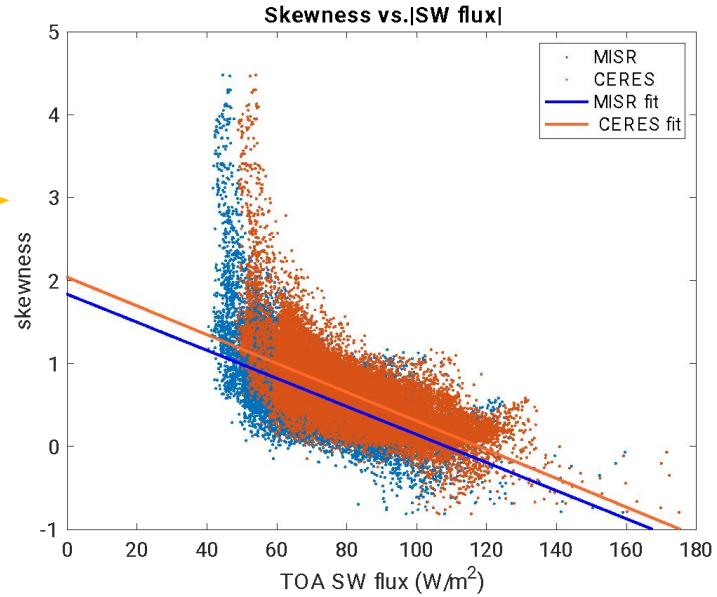
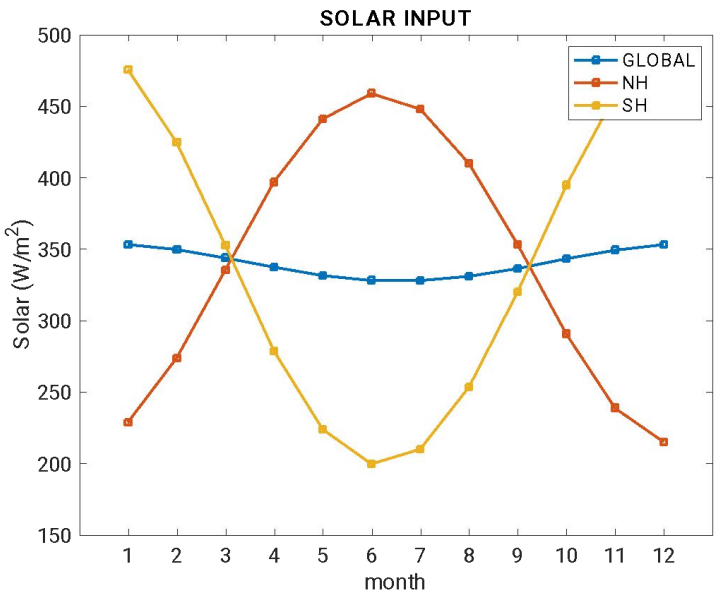
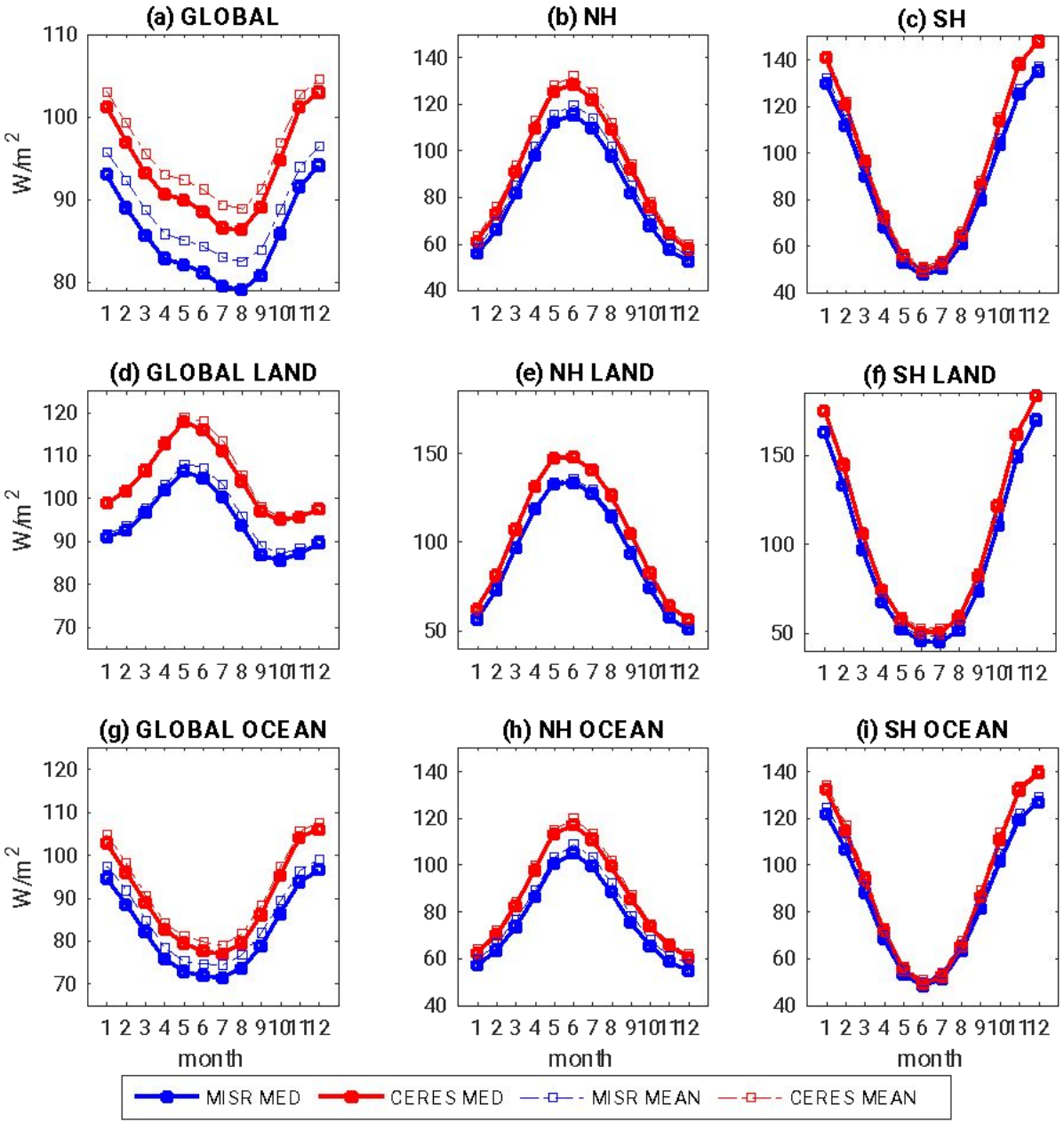
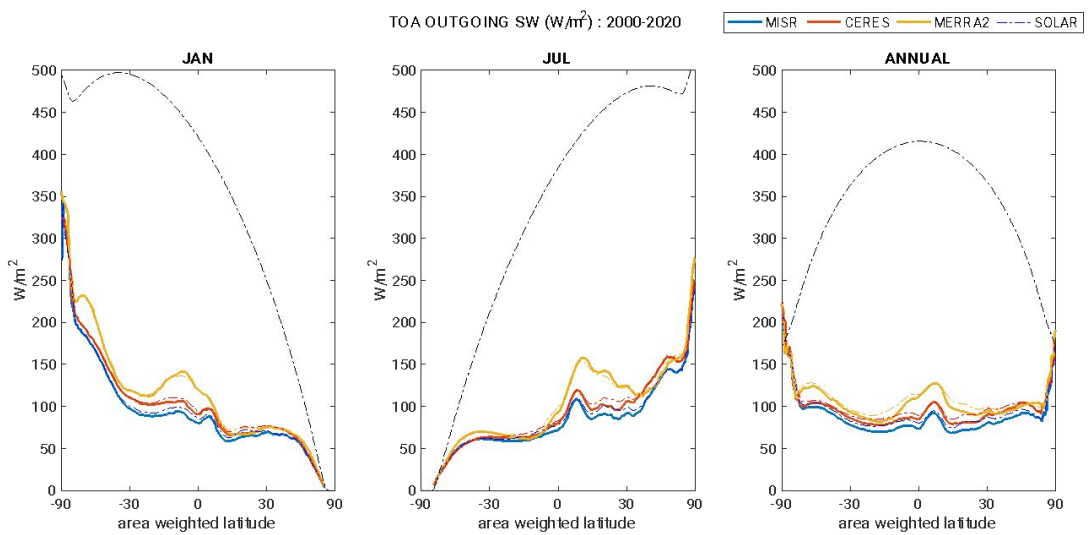


Seasonal variation of TOA SW (2000-2020)

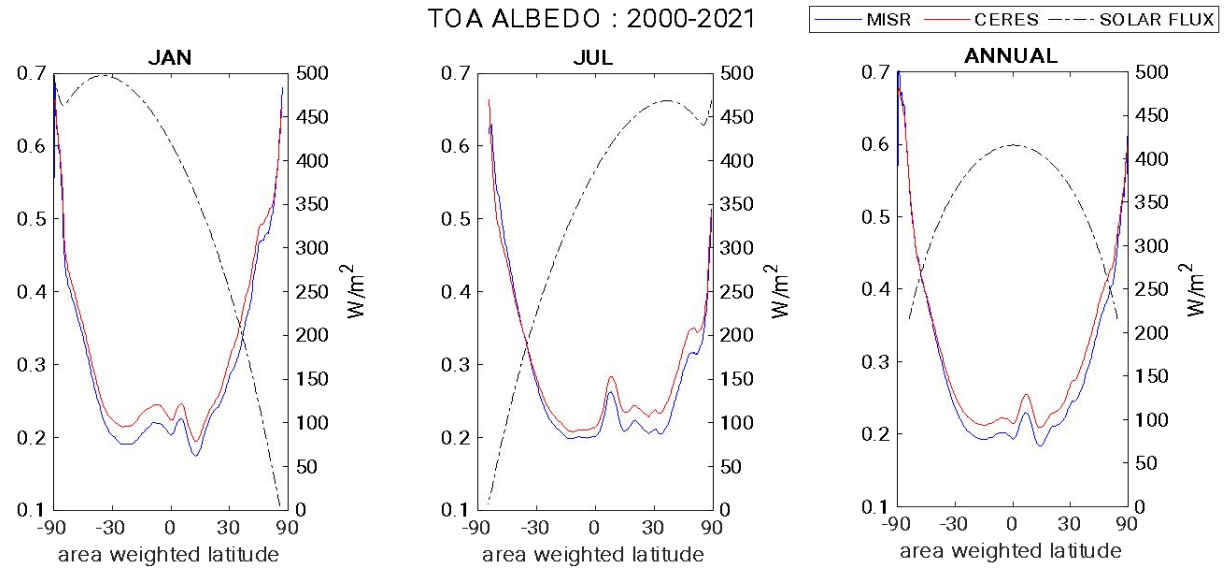




Seasonal Hemispheric Asymmetry in SW flux, albedo, and solar flux

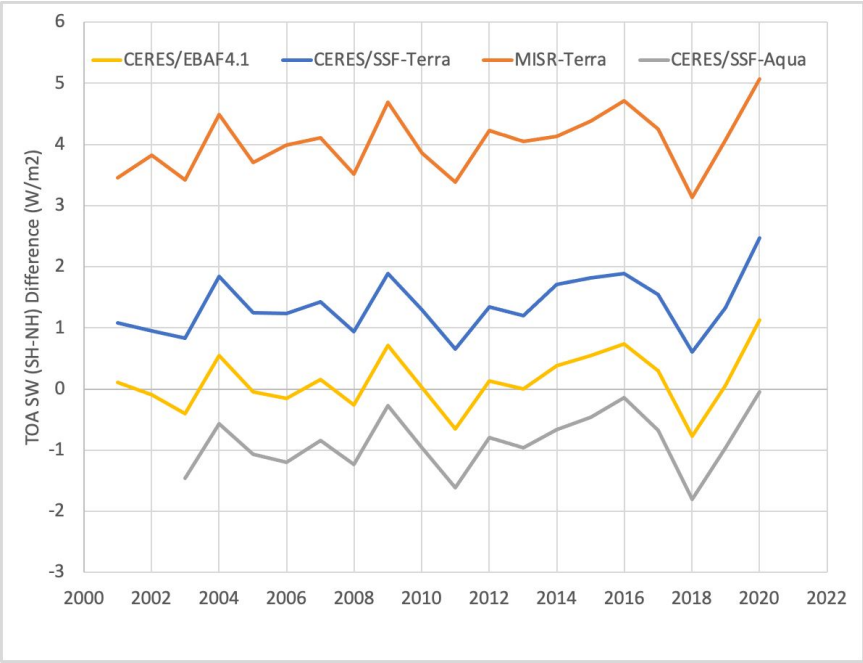


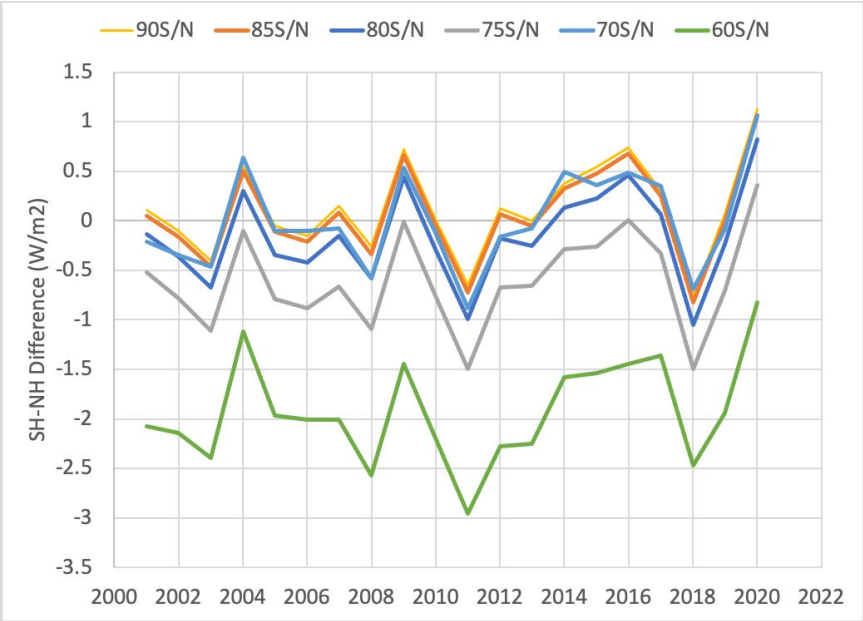
TOA SW flux (W/m2)



TOA albedo

TOA SW flux and albedo show greatest values in the high-latitude regions





Hemispheric Asymmetry? Symmetry?

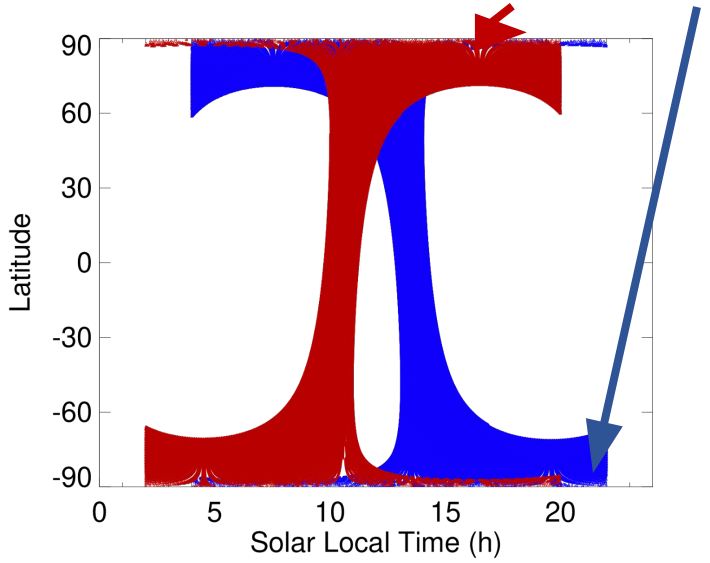
CERES Terra

CERES EBAF

CERES Aqua

- SH surface reflects less due to dark ocean.
- Hemispheric difference (SH-NH) of TOA SW is ~0, more clouds in the SH
- Terra, in 10:30 AM morning orbit, the marine stratocumulus in the SH overwhelms the surface effect

Local time coverage of Terra and Aqua



summary

- Should the PDFs be considered with caution in averaging TOA SW flux? Which distribution can well represent TOA SW flux?
- The PDFs may not be preserved but can change with time and location.
- Hemispheric asymmetry, the difference of SW between two hemispheres (SH – NH) is depending on the local time of measurement, and determination of diurnal cycle of the SW flux is critical.

Back-ups

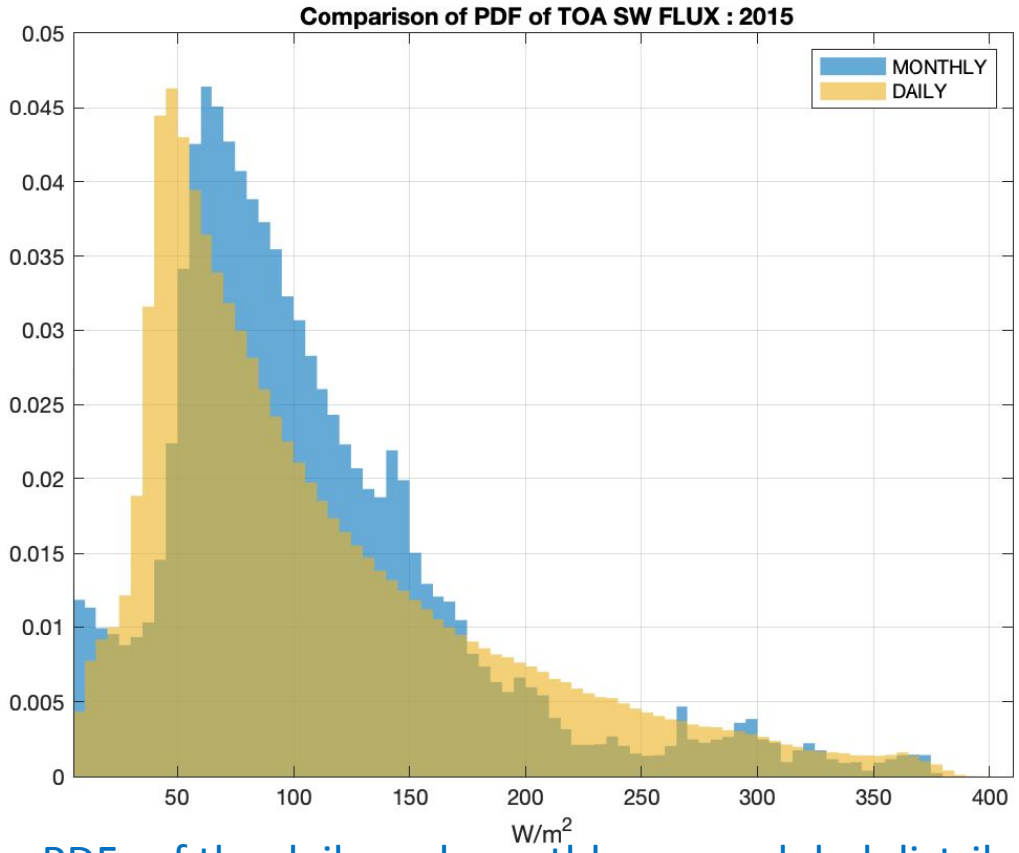
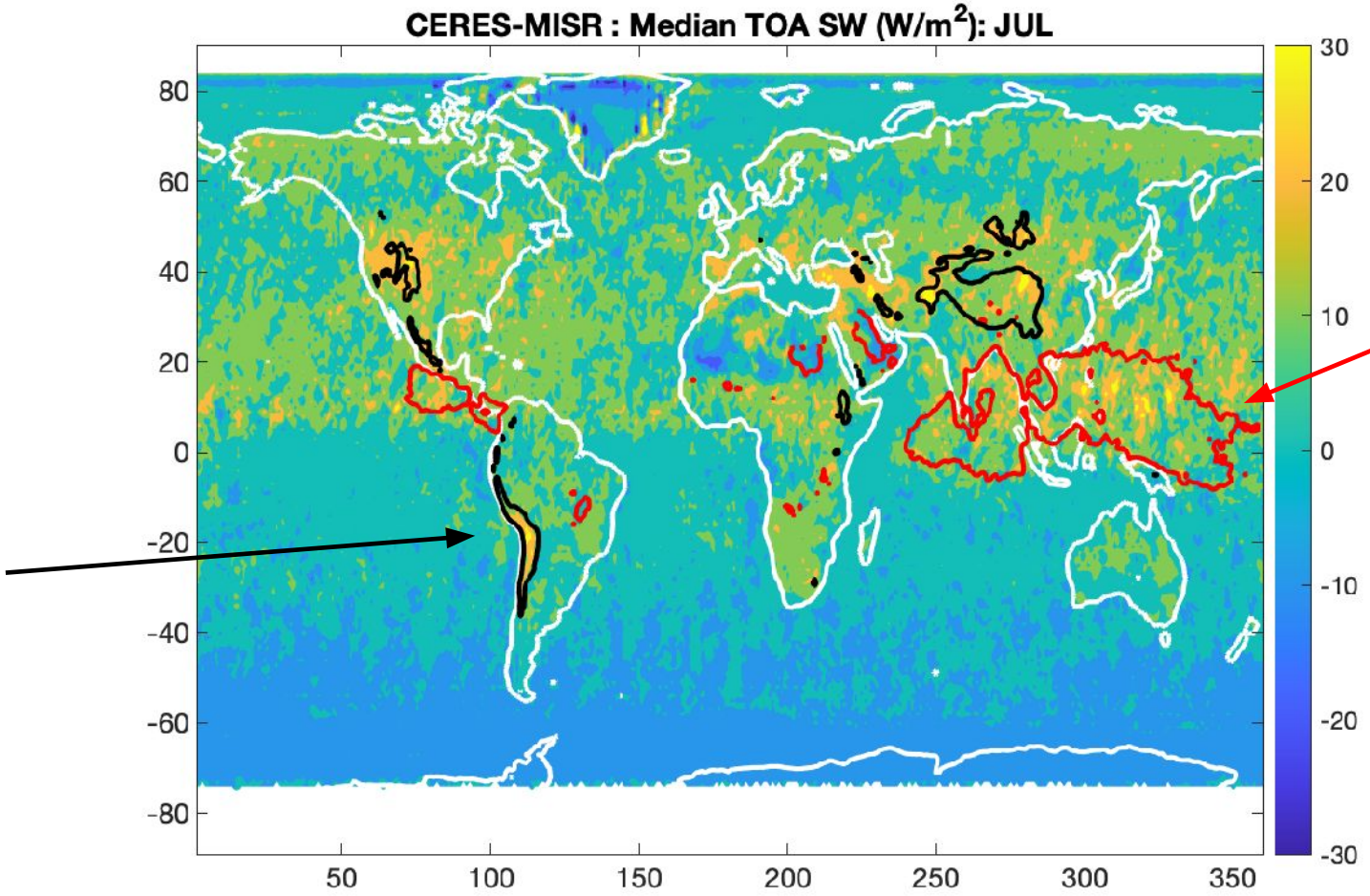


Figure. PDFs of the daily and monthly mean global distribution of all-sky broadband TOA SW Flux (W/m^2) measured from CERES during 2015. The daily data has 365 temporal samples and monthly data has 12 temporal samples for each at each 1° by 1° grids. The bin size is 5 W/m^2, and the total integration of the area under each PDF is normalized to be one.

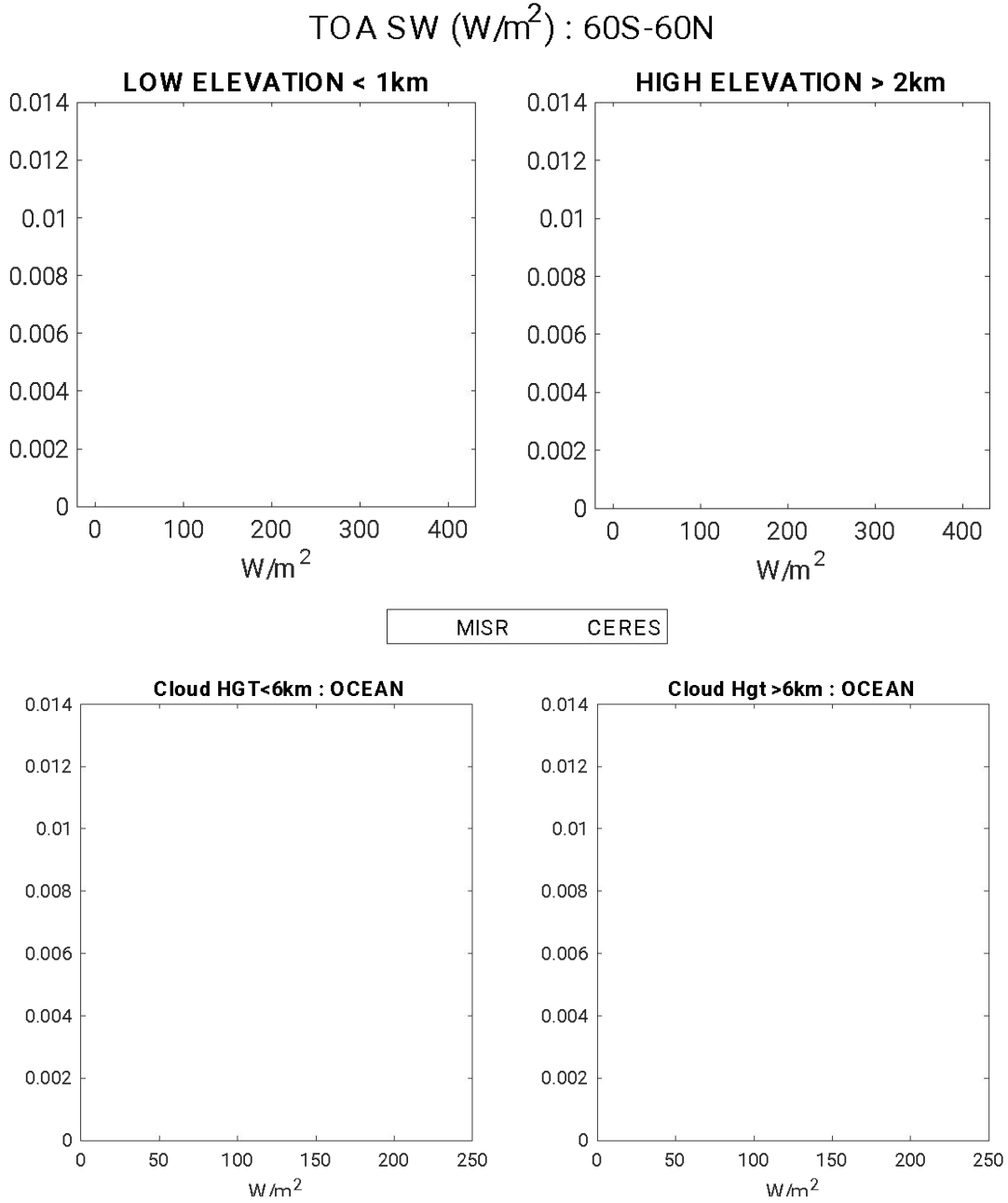
Difference between CERES - MISR



High Elevation Z>2km

HIgh Cloud region Cloud HGT > 9km

High vs. Low

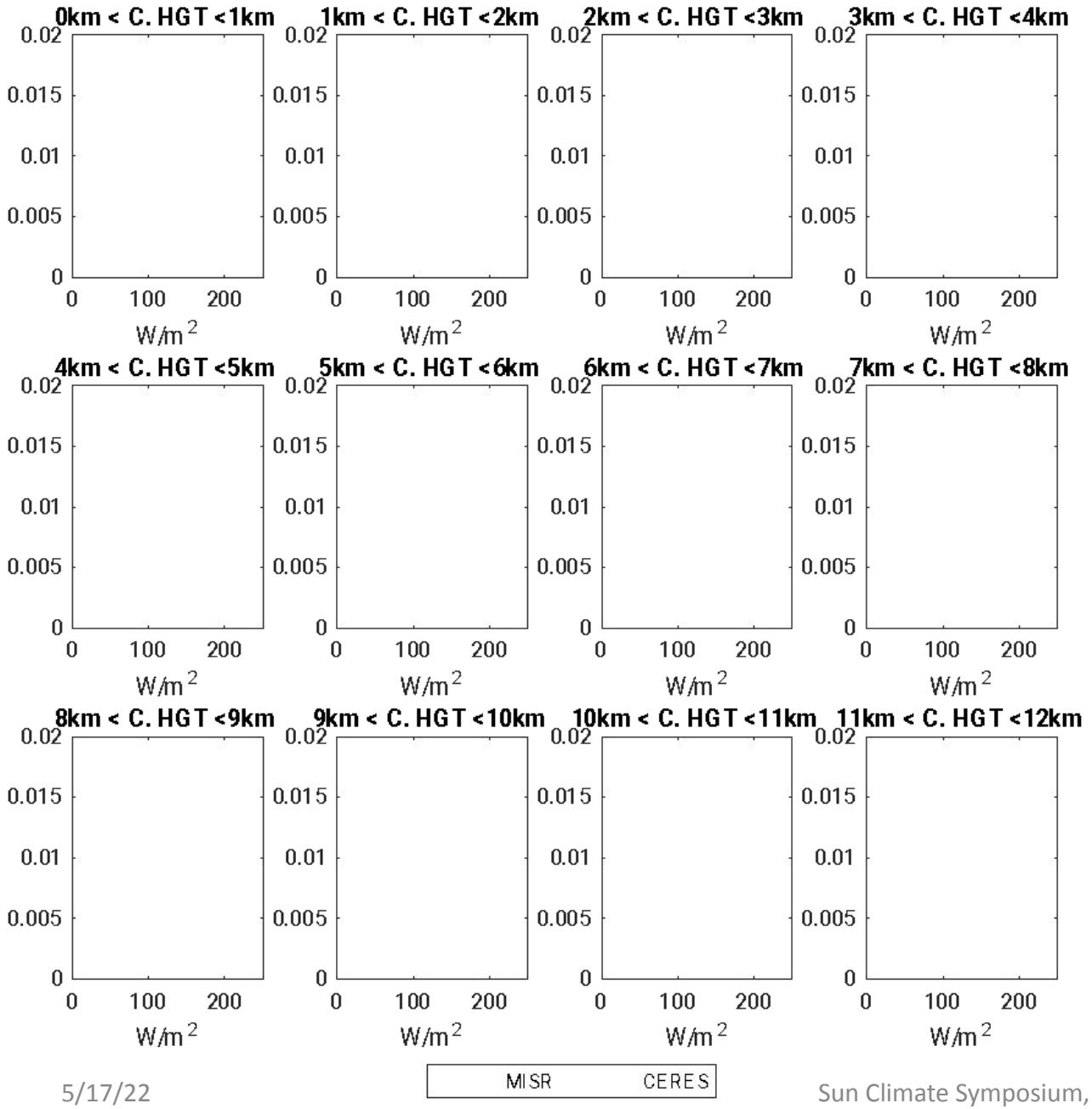


High Elevation

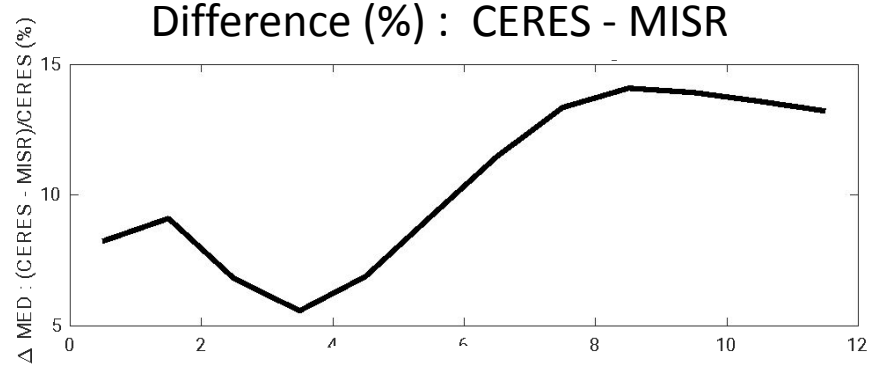
- Different anisotropy?
- 3D effects (Ham et al., 2017)?

High Clouds

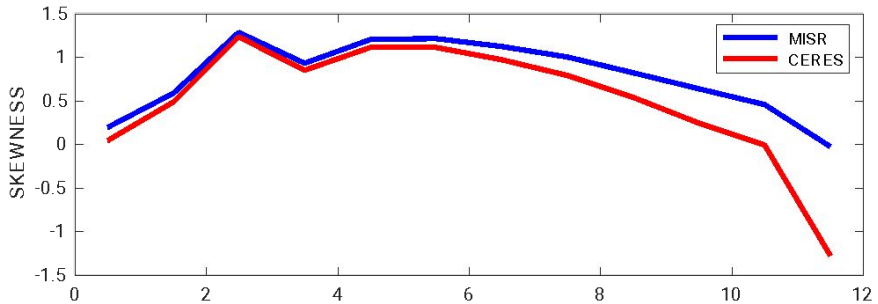
Cloud Height



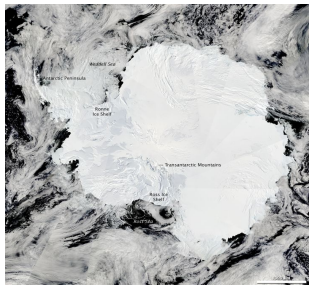
Difference (%) : CERES - MISR



Skewness



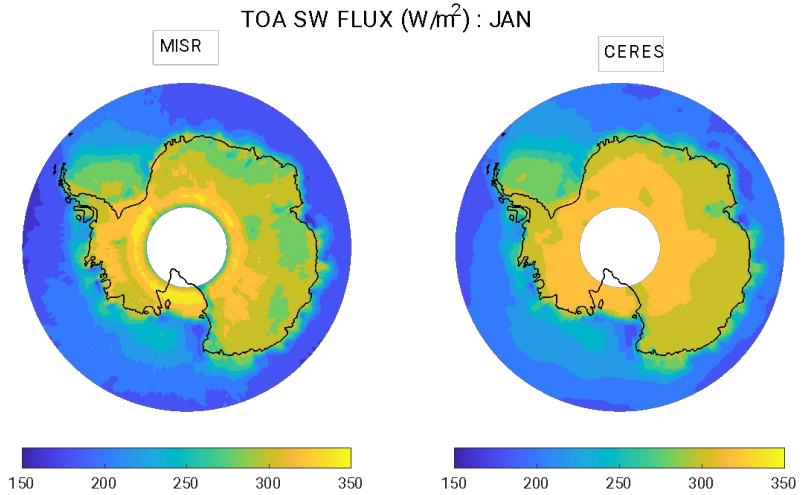
Cloud height (km)



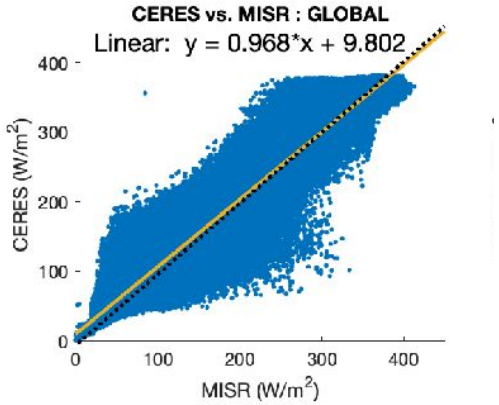
MODIS, Jan 30, 2009

Antarctic

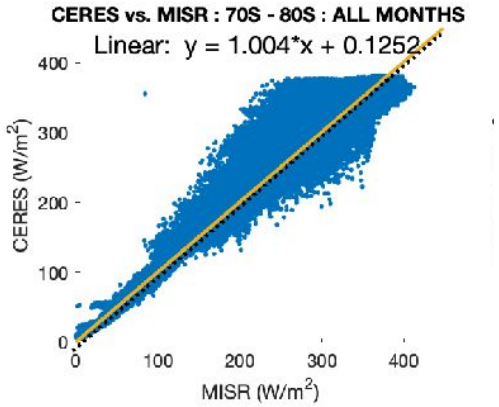
- Difference between two measurements are outstanding in Antarctica.
- CERES Flux shows saturated near 350 W/m^2 over Antarctica.



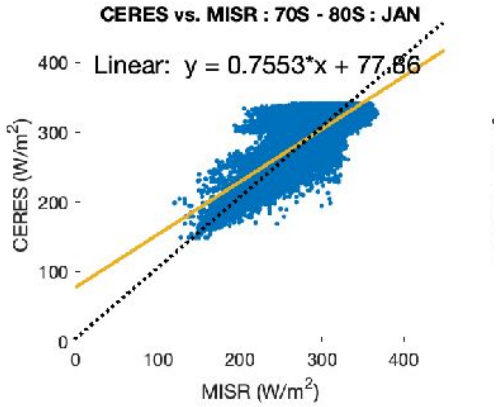
Global : all months



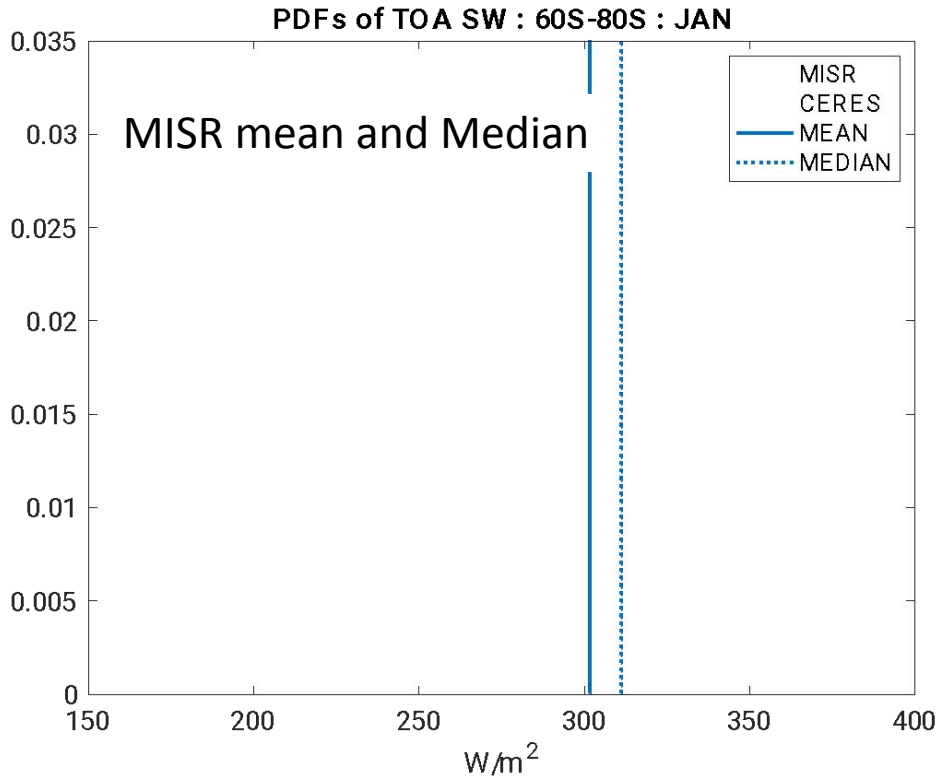
70S-80S : all months

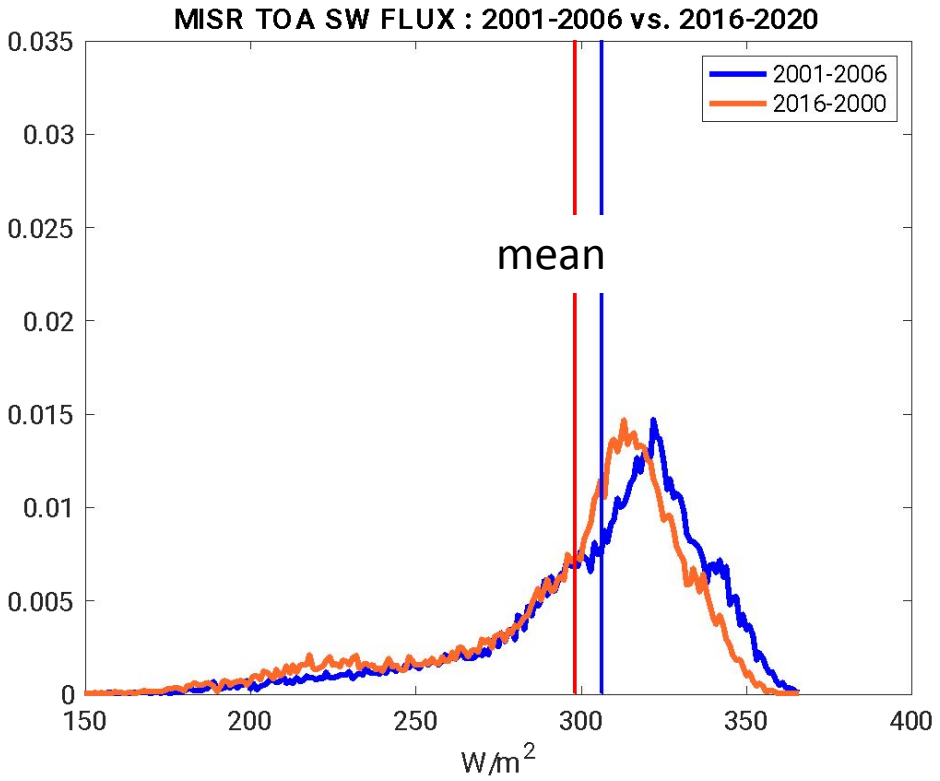


70S-80S : January

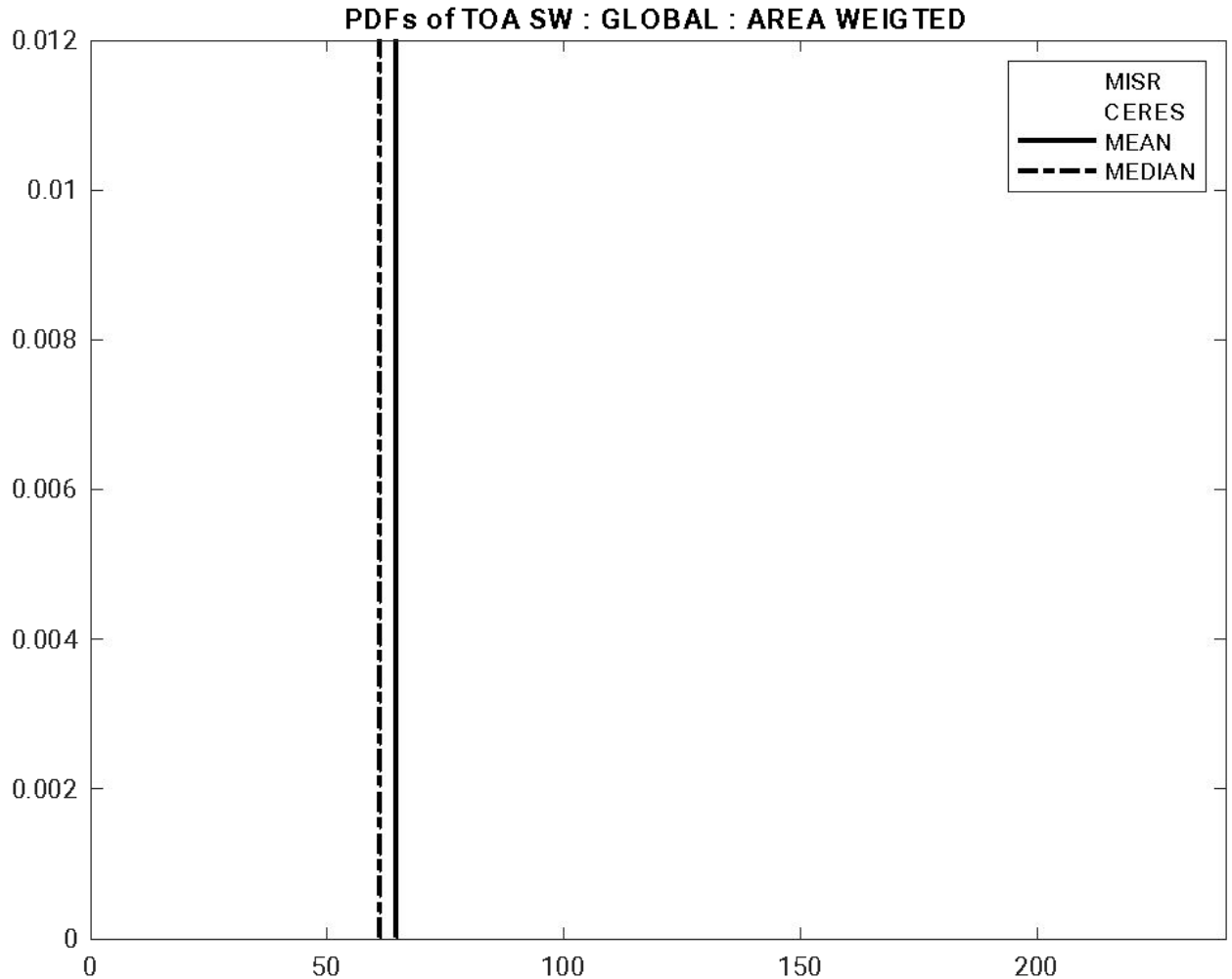


Antarctic : 70S-80S : JAN

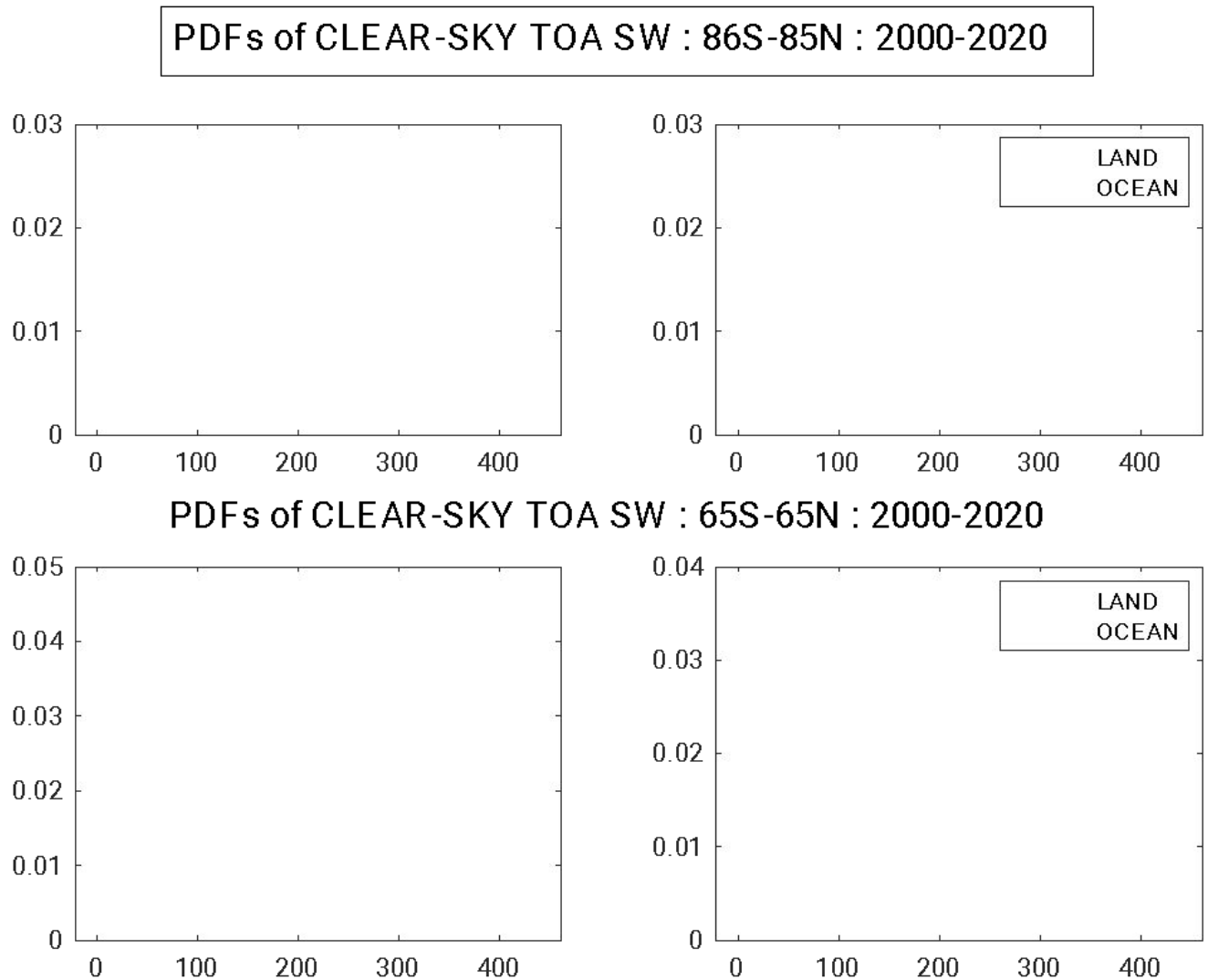


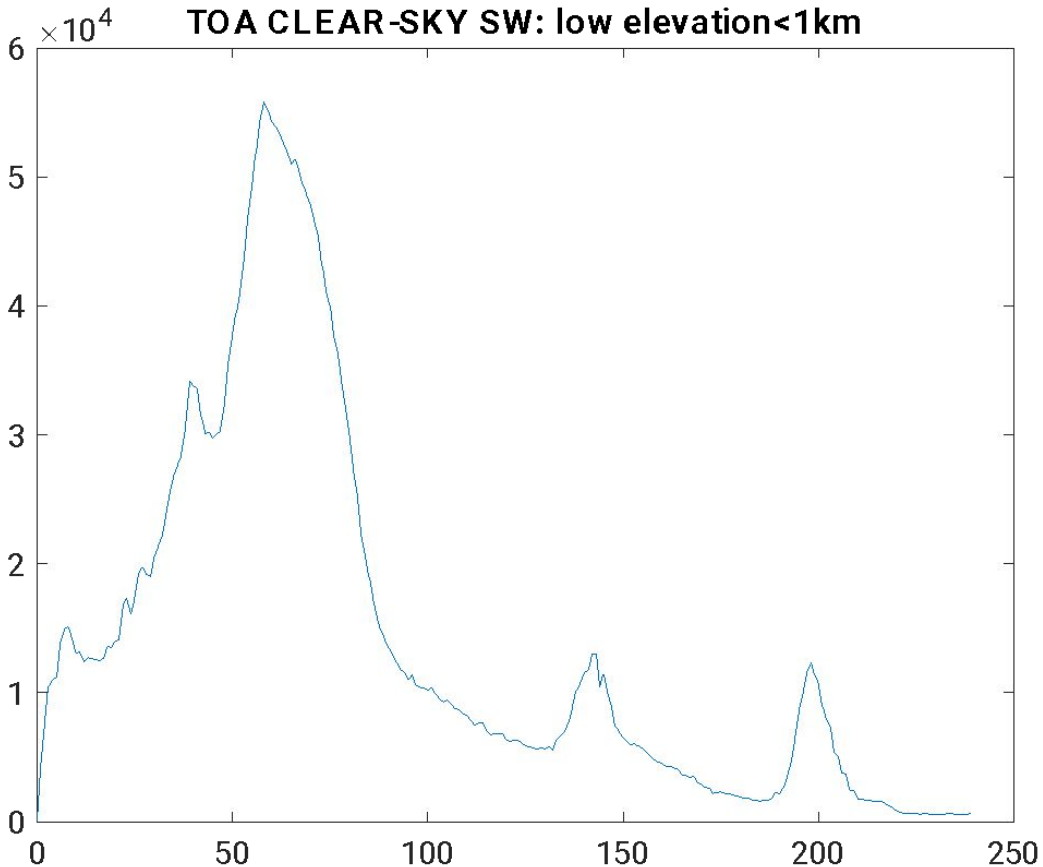


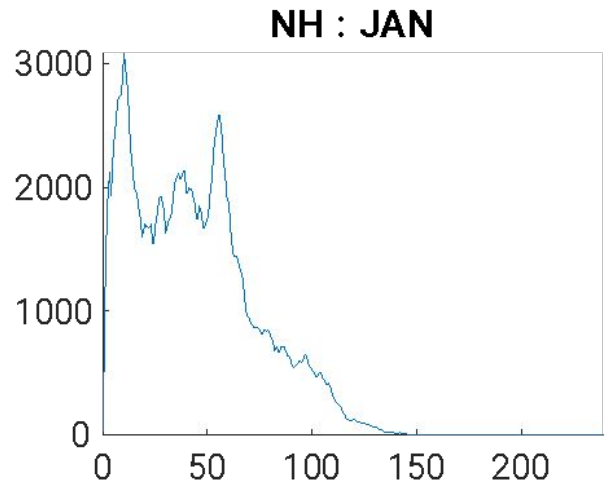
Extra slides

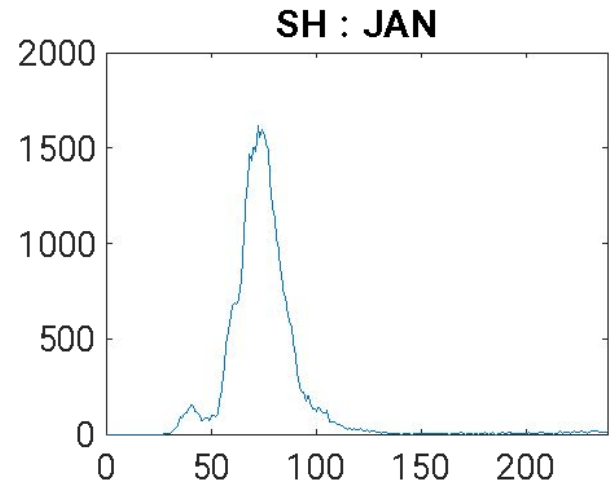


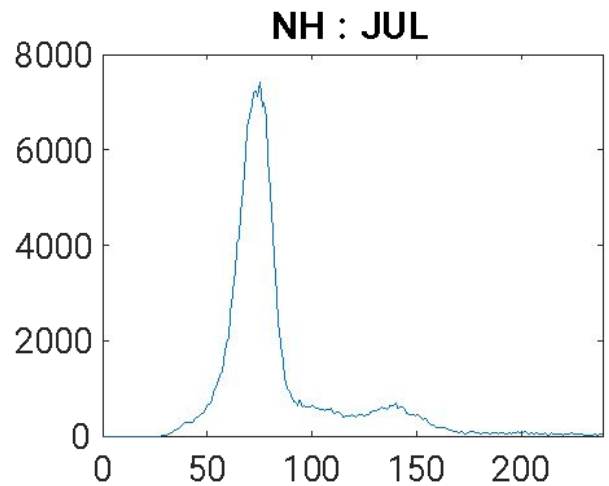
Clear Sky TOA SW flux : CERES

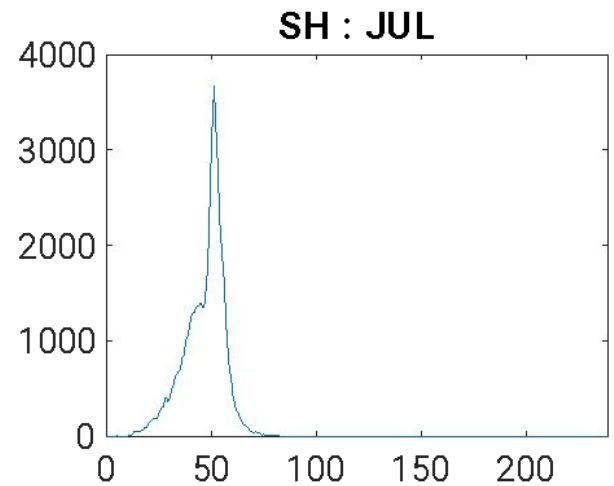



TOA CLEAR-SKY SW: low elevation<1km
×10^4
6
5
4
3
2
1
0
0
50
100
150
200
250

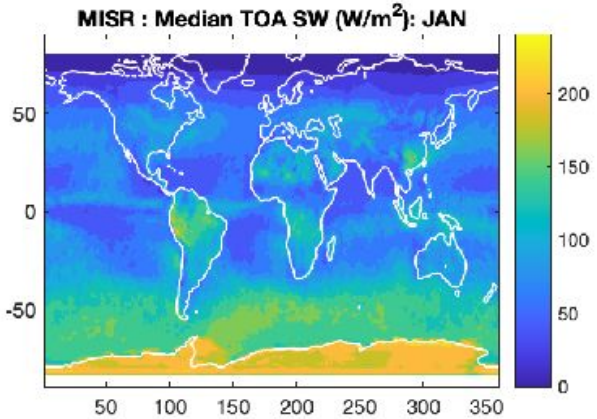

NH : JAN
3000
2000
1000
0
0
50
100
150
200

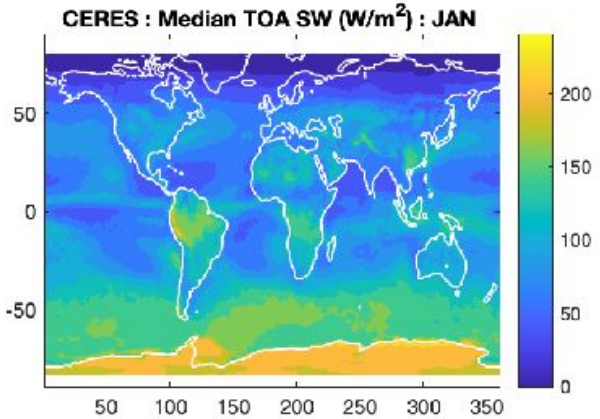

SH : JAN
2000
1500
1000
500
0
0
50
100
150
200

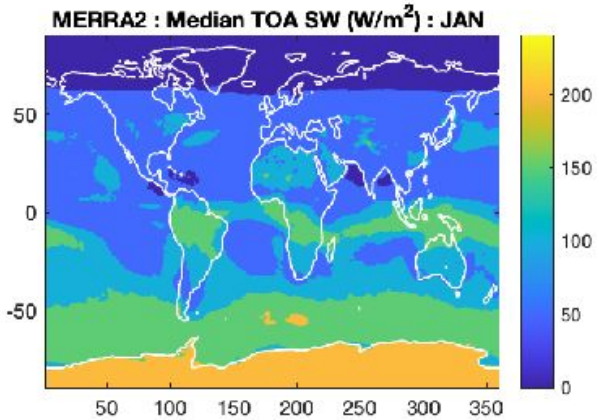

NH : JUL
8000
6000
4000
2000
0
0
50
100
150
200

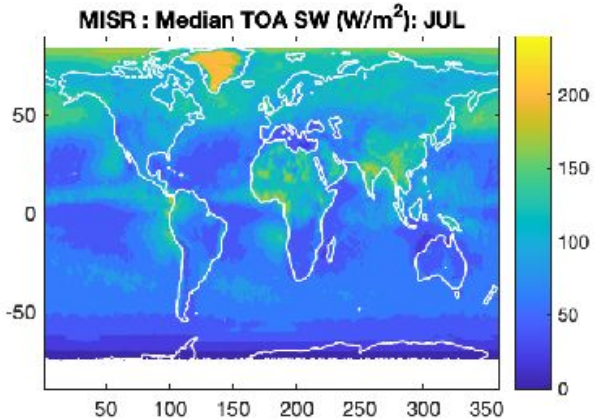

SH : JUL
4000
3000
2000
1000
0
0
50
100
150
200

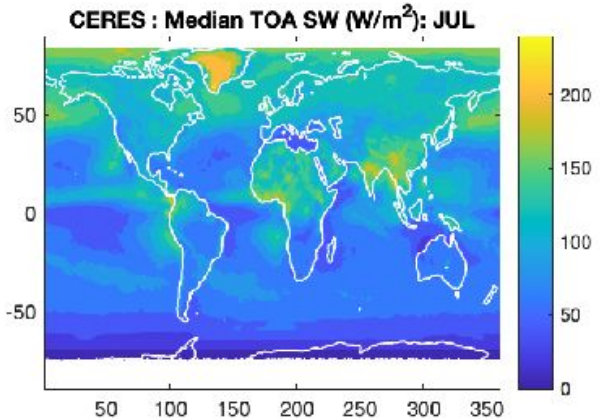
TOA SW Flux from MISR, CERES, and MERRA-2

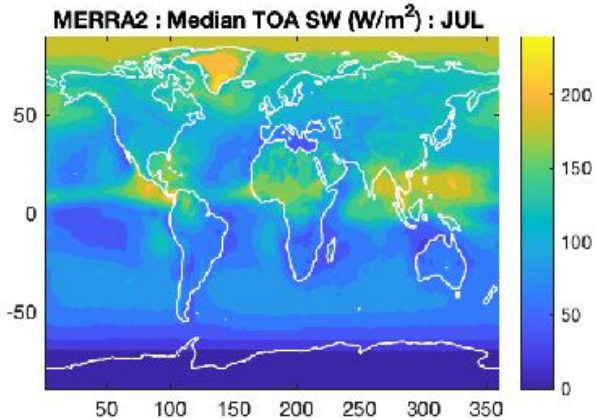




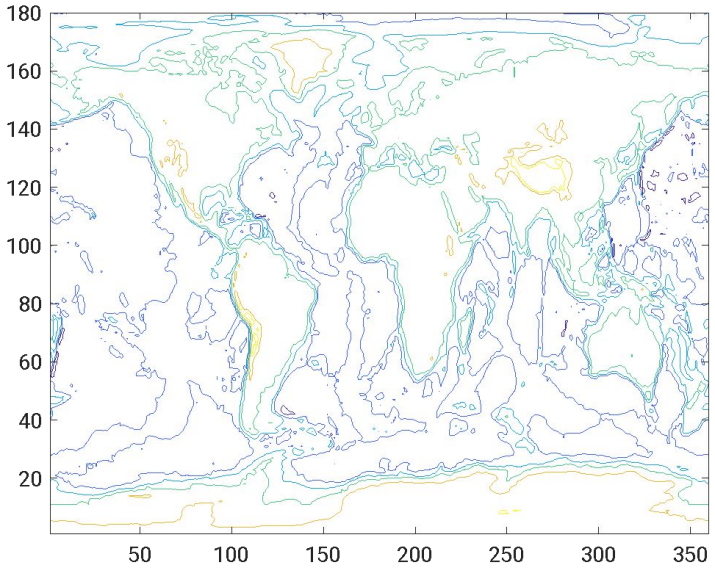


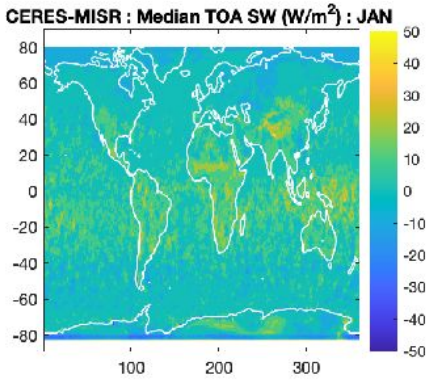


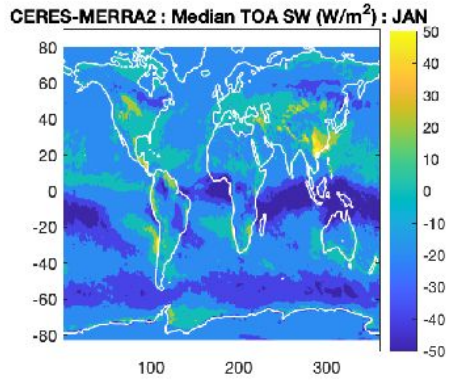


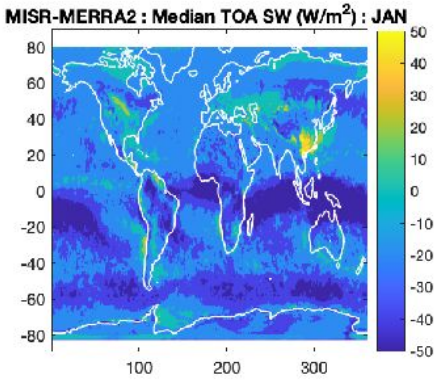


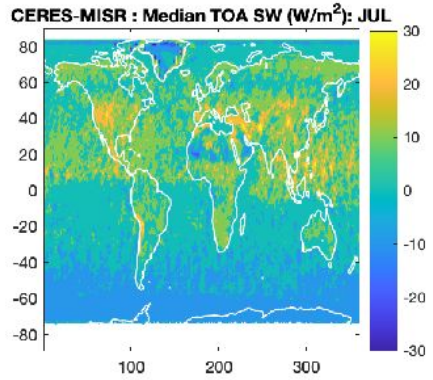
TOA SW Flux from MISR, CERES, and MERRA-2

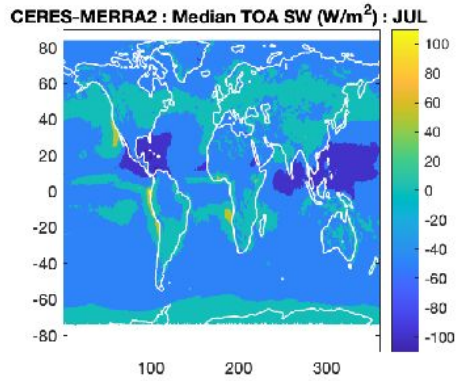


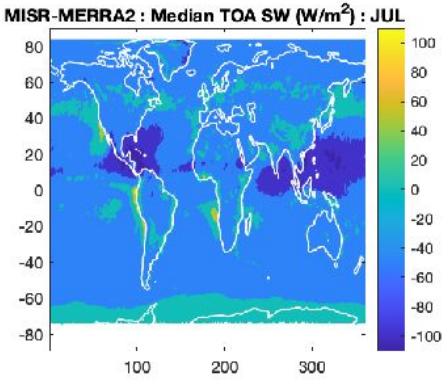


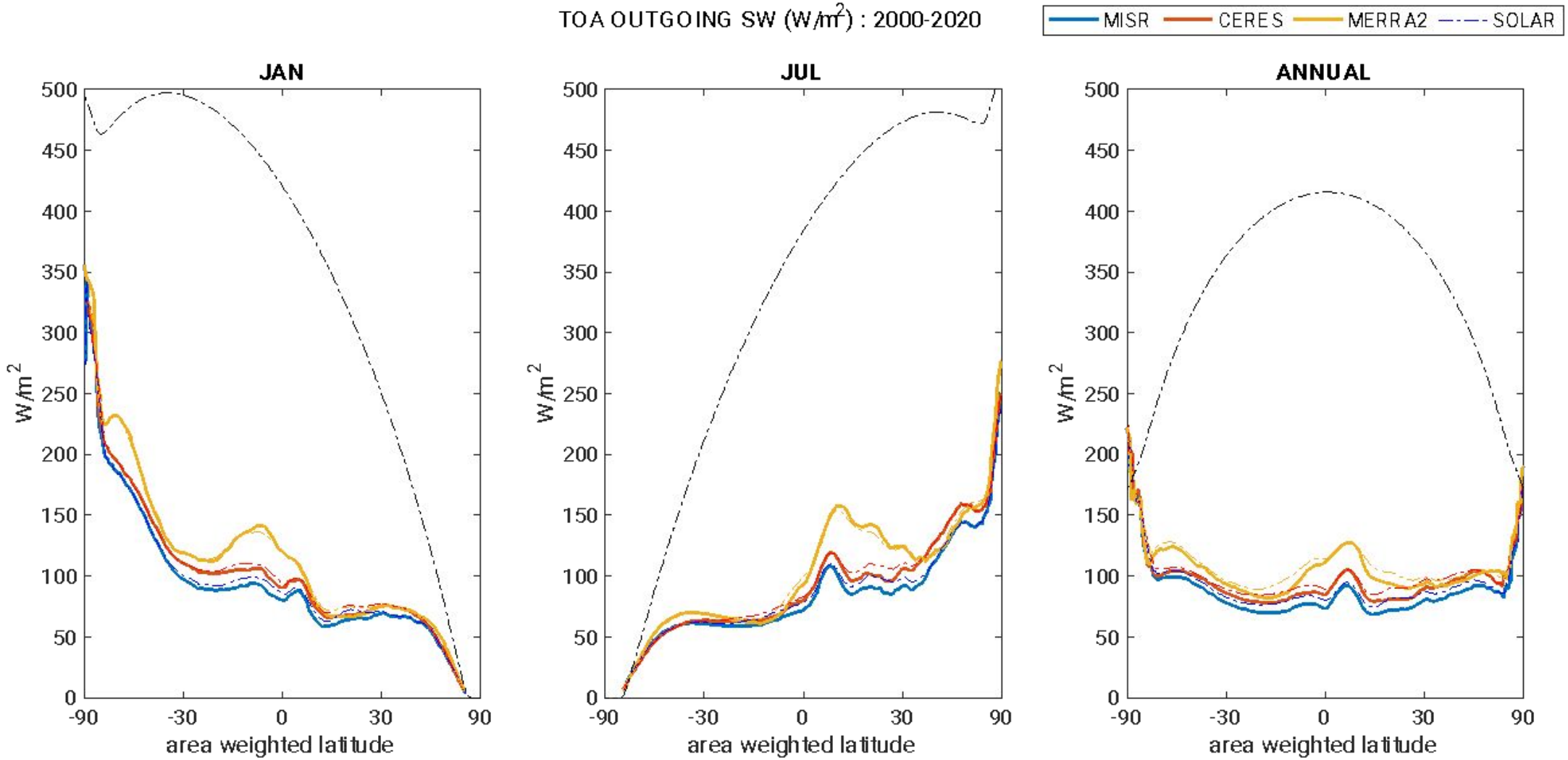











TOA OUTGOING SW (W/m^2) : 2000-2020
MISR
CERES
MERRA2
SOLAR
JAN
JUL
ANNUAL
W/m^2
area weighted latitude
-90
-30
0
30
90
0
50
100
150
200
250
300
350
400
450
500

MISR Spectral Albedos

Restrictive Albedo :

- In 4 channels
- Sampled from single region only
- Unobscured bidirectional reflection from top and side