A synergistic use of hyperspectral sounding and broadband radiometric observations from S-NPP and Aqua

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Fall 2020 NASA Sounder Science Team Meeting
October 05, 2020

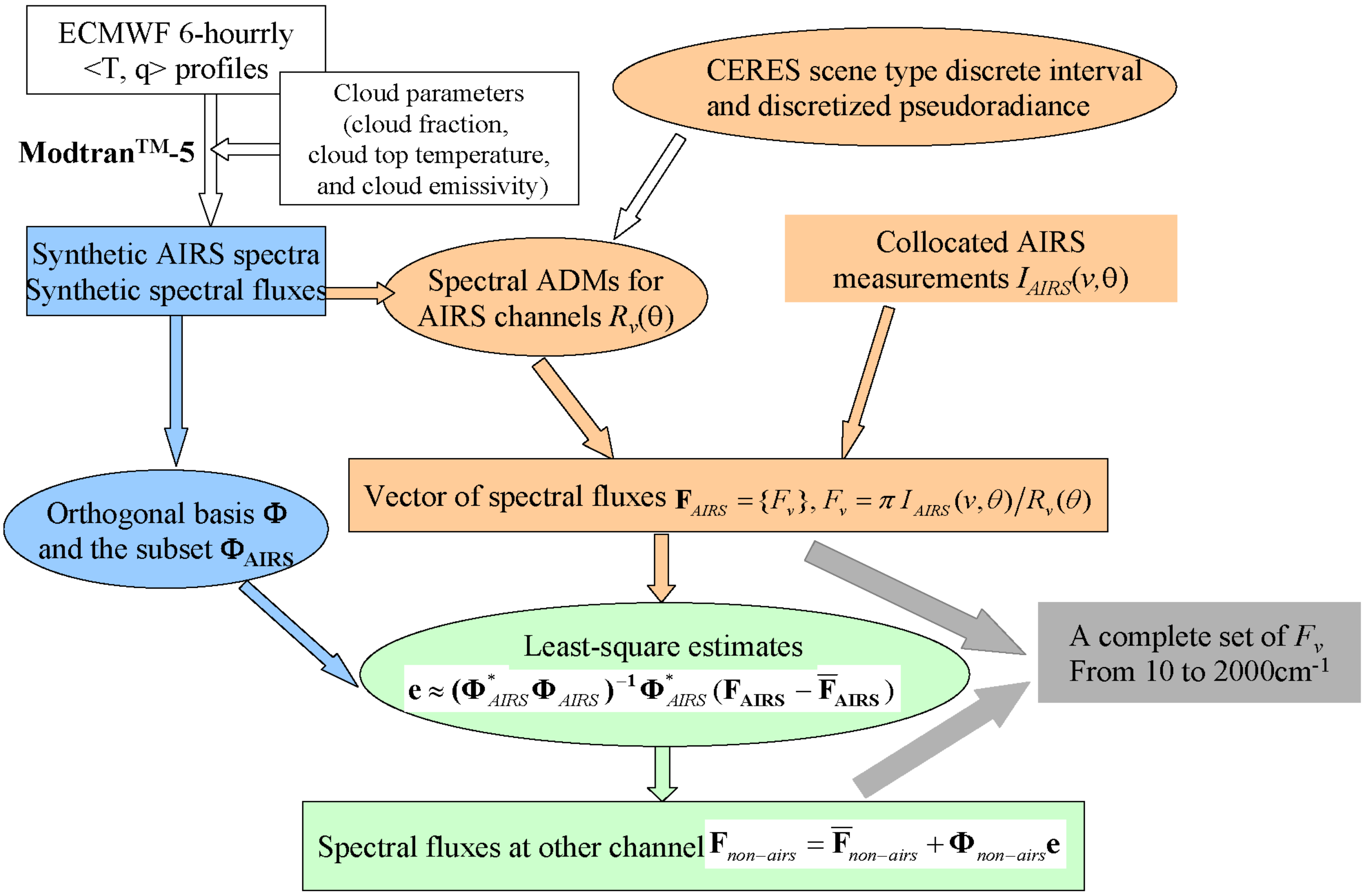
Acknowledgement: Terra/Aqua/S-NPP program and the CERES science team

- With AIRS and CERES on Aqua, we have showed the synergy between hyperspectral sounder and broadband radiometer
  - At flux level
    - LW spectral flux derived from the AIRS footprint using collocated scene type info from CERES-SSF
    - Good agreement with CERES OLR over multiple years and multiple scene types
  - At radiance level
    - Assess the CERES radiance stability over multiple years

Can we use the CrIS and CERES on S-NPP to show the same synergy, paving a road for future synergistic use of data from JPSS-1, JPSS-2?

On spectral flux

(Huang et al., 2008; 2010; 2014; Chen et al., 2013)



CERES flux and radiance are never used. Only scene-type info in the CERES SSF datasets.

Output: spectral flux at 10cm^{-1} intervals through the entire longwave spectral range

All collocated clear-sky observations in 2004 (80°S-80°N)

Surface Type	Daytime	Nighttime
	OLR_{AIRS_Huang}-OLR_{CERES} (Wm^{-2})	OLR_{AIRS_Huang}-OLR_{CERES} (Wm^{-2})
Forest	0.58±1.43	-0.42±1.41
Savannas	-0.03±2.52	0.68±1.50
Grasslands	0.19±2.61	0.63±1.65
Dark Desert	-0.71±2.85	0.36±1.74
Bright Desert	1.67±2.62	1.42±2.28
Ocean	1.09±1.55	0.90±1.26

Footprint statistics

(Chen et al., 2013)

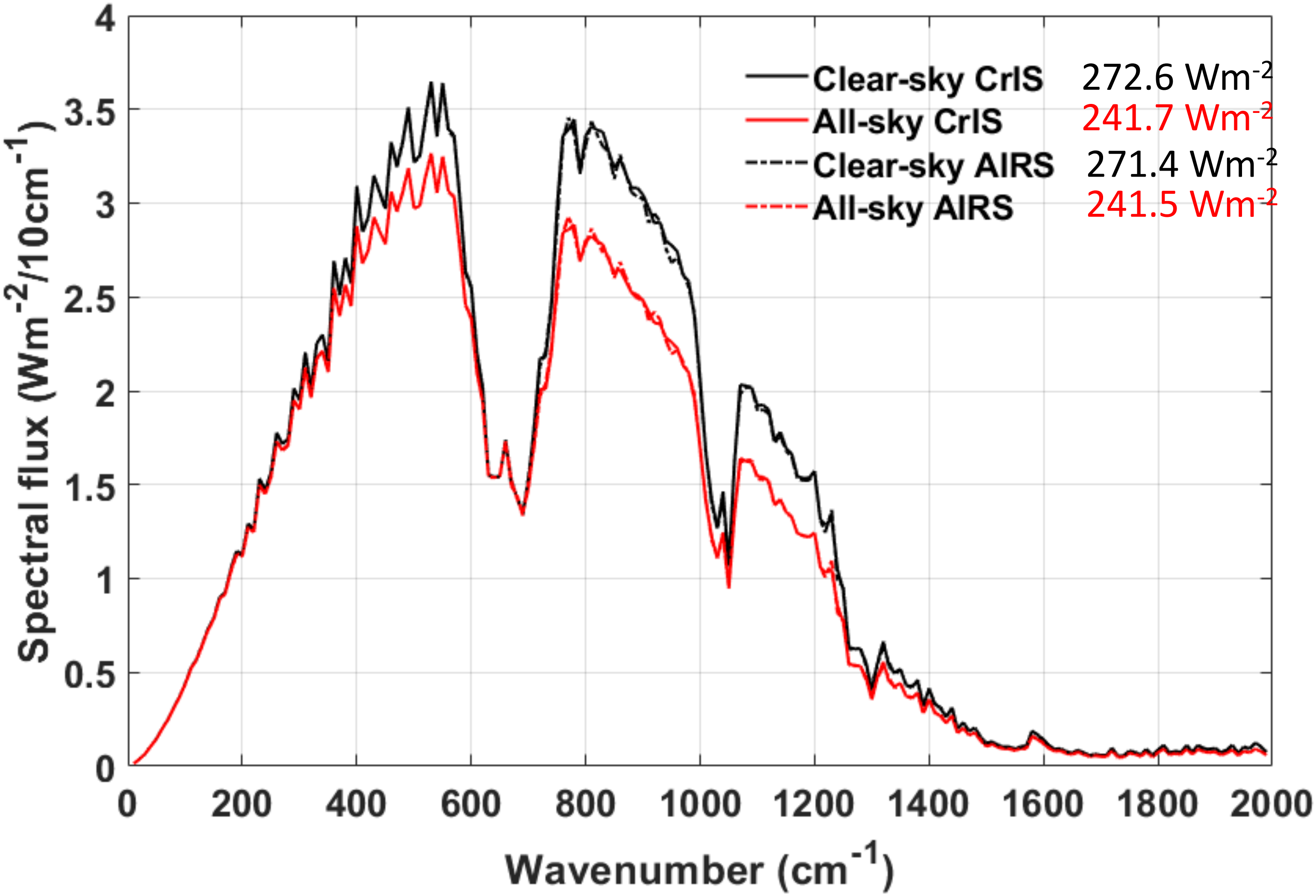
❑ AIRS

- Aboard Aqua with a 1:30 AM/PM equatorial crossing time
- A field of view 13.5 km (nadir)
- 2378 channels with a spectral resolving power ($\lambda / \Delta\lambda$) of 1200 from 650 to 2670 cm^{-1} (non-continuous coverage)
- Data collection from Sep 2002 to present
- *Stability: 0.002-0.003 K/yr in B.T.* (Aumann et al., 2019, GRL)
- Radiometric Uncertainty: 0.05-0.2K in B.T.

❑ CrIS

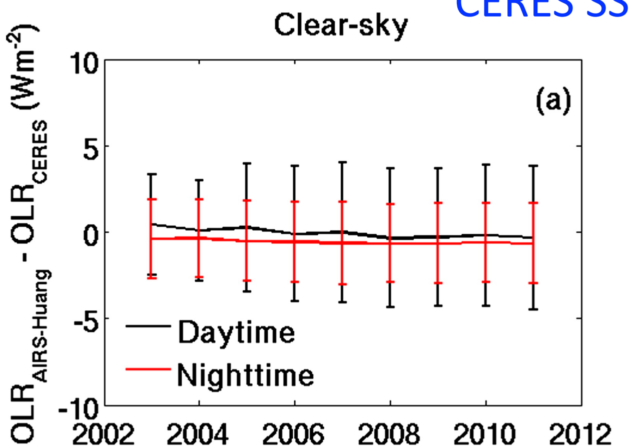
- Aboard Suomi-NPP with ~1:30 AM/PM equatorial crossing time
- 14-km nadir-view footprint
- 1305 channels over 3.92–4.64, 5.71–8.26, and 9.14–15.38 µm
- Data collection from Feb 2012 to present
- *Stability: 0.003-0.016 K/yr in B.T.* (Hepplewhite et al., 2019/2020)
- Radiometric Uncertainty: 0.03-0.2K in B.T.

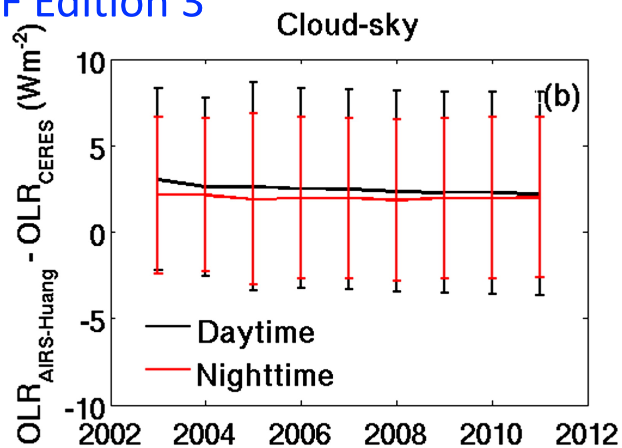
Multi-year-mean spectral flux from Aug. 2012 to Jul. 2018



Multiple-year global comparisons: AIRS spectral OLR vs. CERES

CERES SSF Edition 3

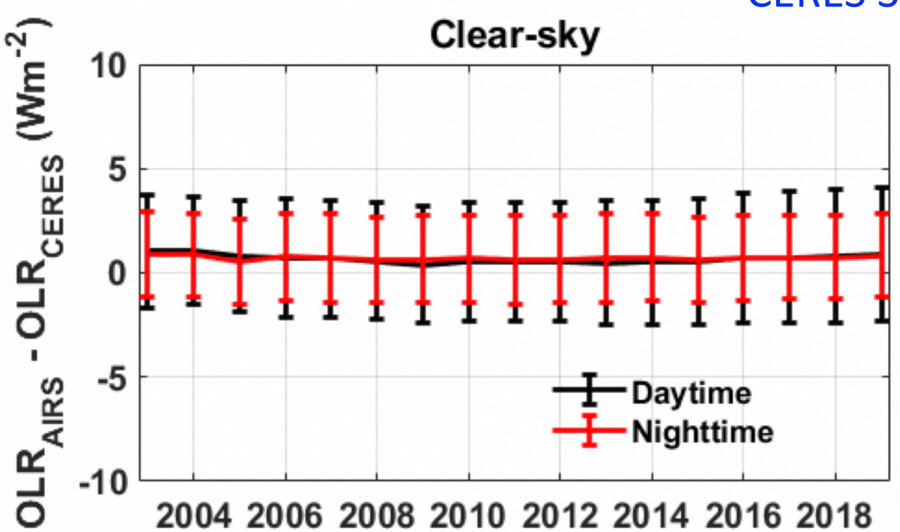


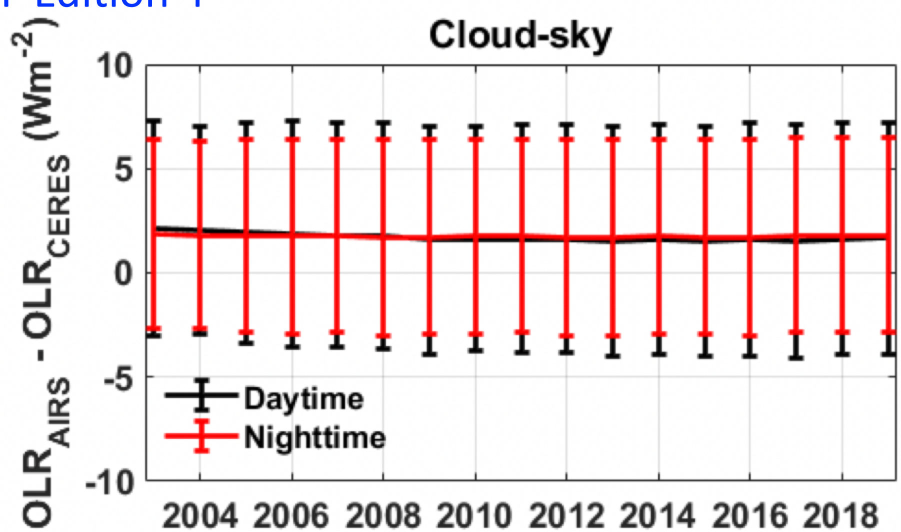


(Huang et al., 2014, J Climate)

Footprint statistics

CERES SSF Edition 4





Ed3 comparison

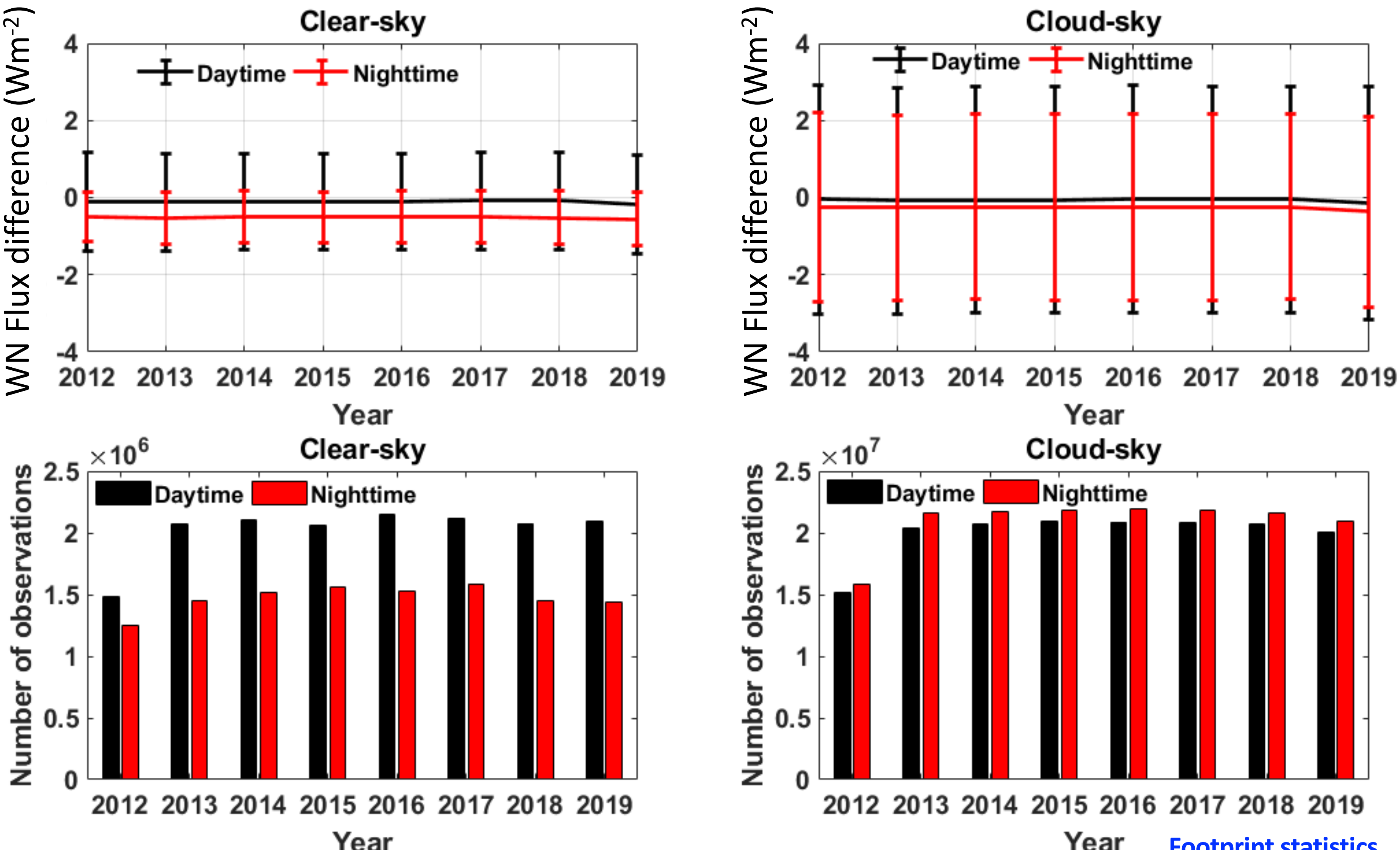
	Clear-sky	Cloudy-sky
Daytime	[-0.34, 0.42]	[2.20, 3.00]
Nighttime	[-0.67, -0.38]	[1.85, 2.12]

Ed4 comparison

	Clear-sky	Cloudy-sky
Daytime	[0.39, 1.07]	[1.48, 2.10]
Nighttime	[0.57, 0.89]	[1.69, 1.87]

WN-band Flux difference (CrIS – CERES)

- 2012 only includes Apr-Dec
- CERES FM5 Ed1

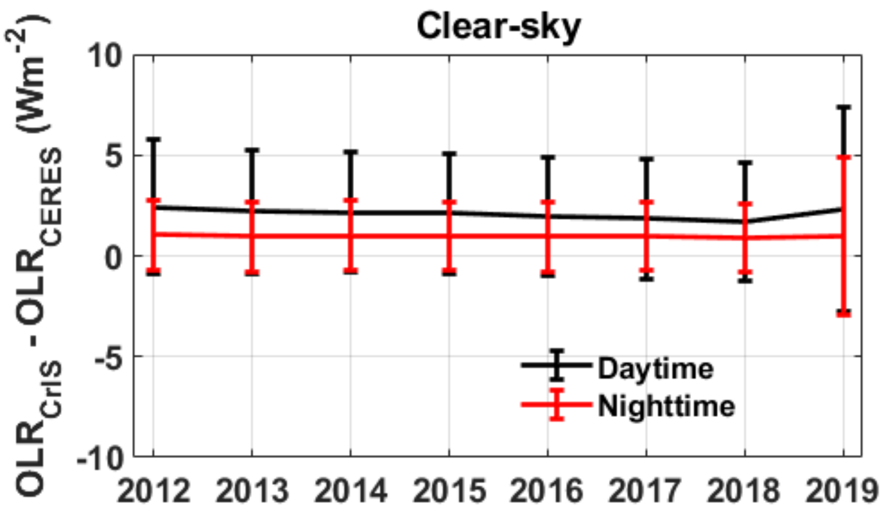


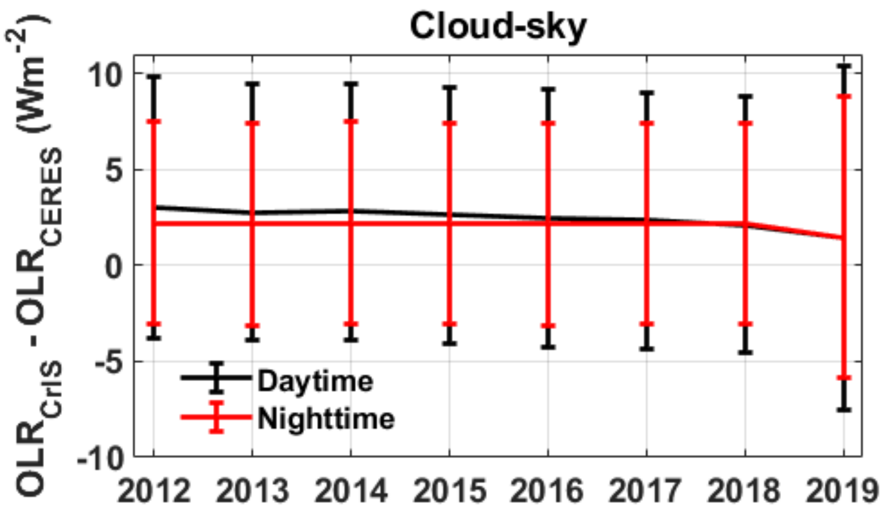
Footprint statistics

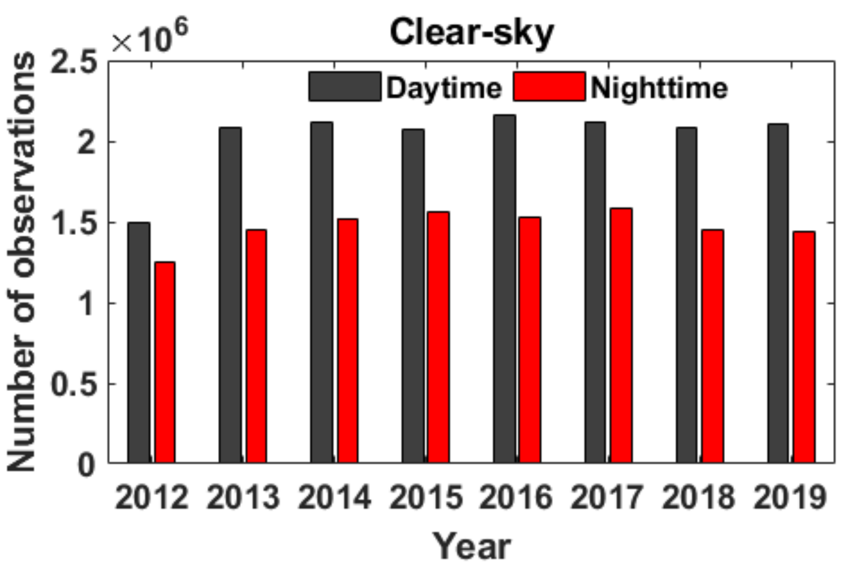
OLR difference (CrIS – CERES)

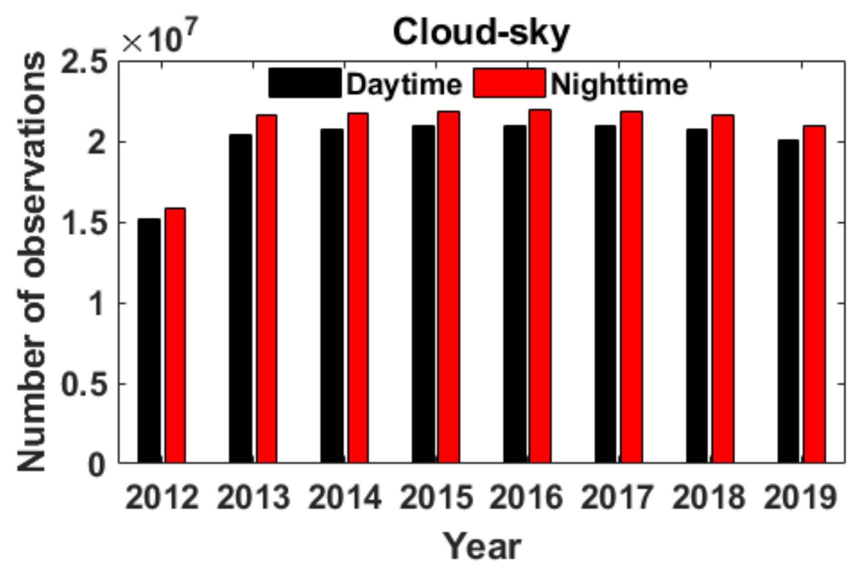
	Clear-sky	Cloudy-sky
Daytime	[1.71, 2.43]	[1.42, 3.02]
Nighttime	[0.88, 1.03]	[1.45, 2.23]

2012 only includes Apr-Dec
CERES FM5 Ed1
2019 error bar is large due to missing CrIS data

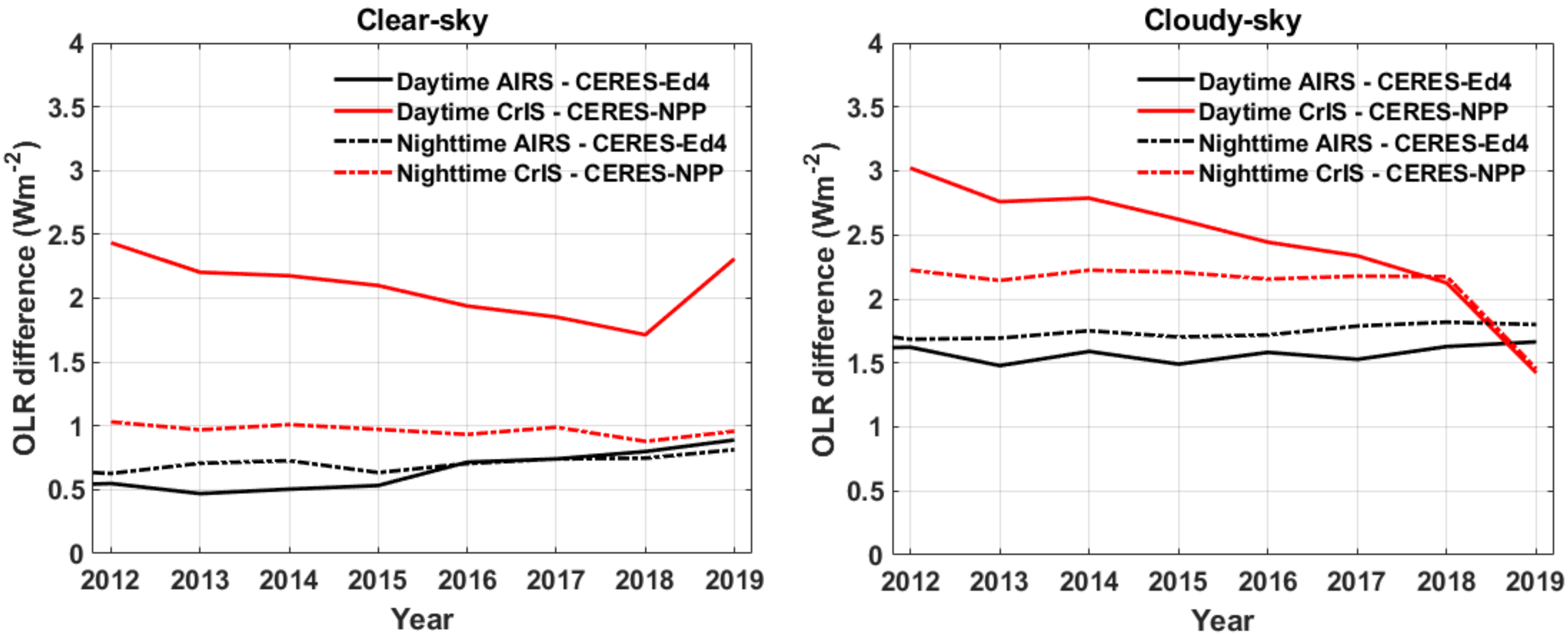






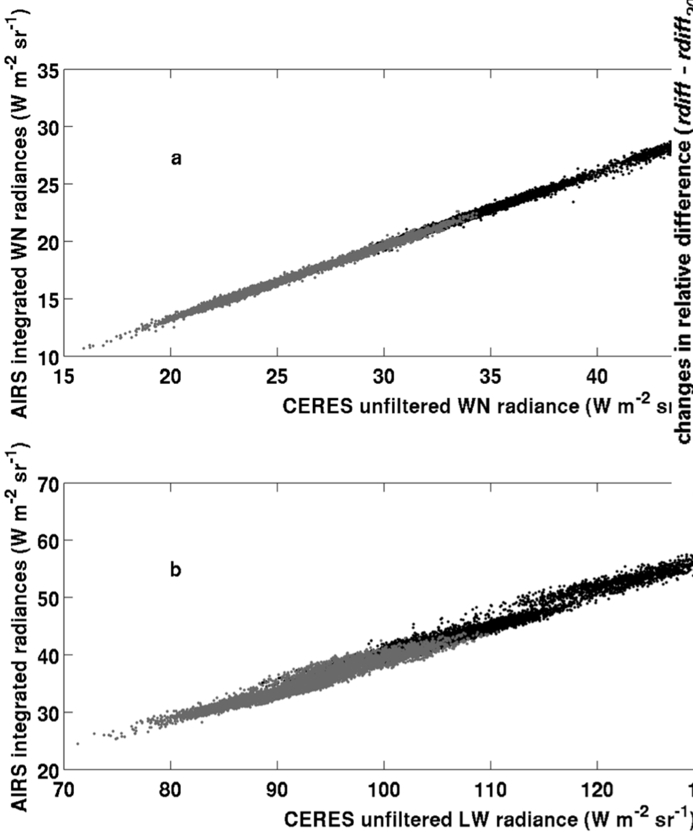


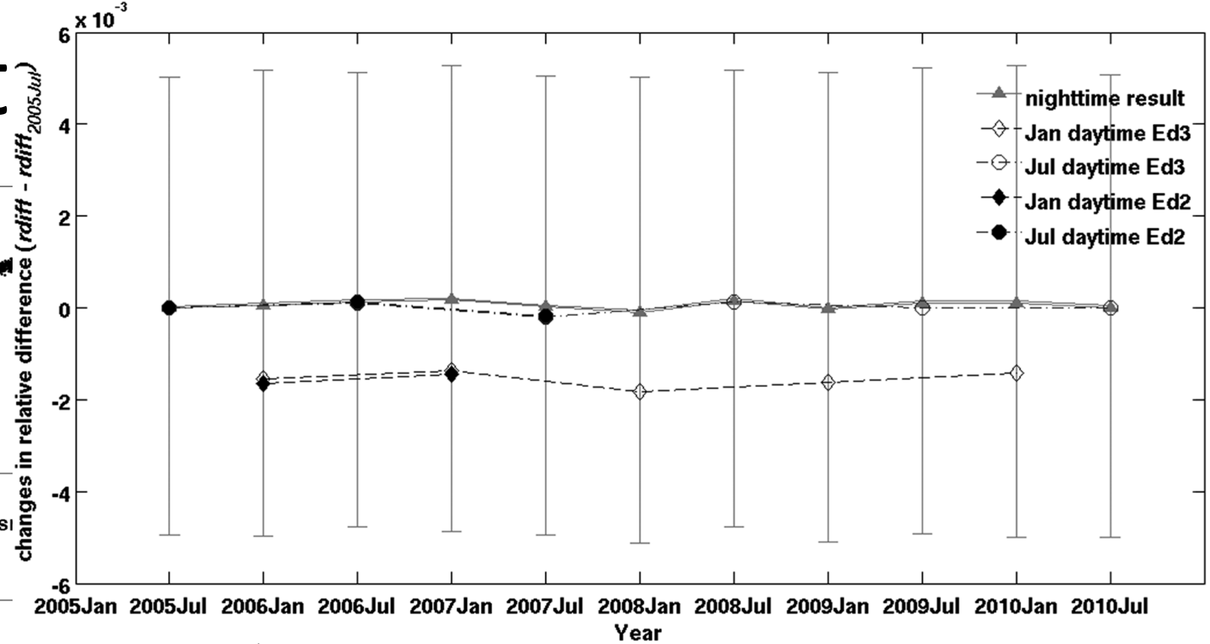
AIRS-CERES Ed4 on Aqua vs. CrIS – CERES Ed 1 on S-NPP

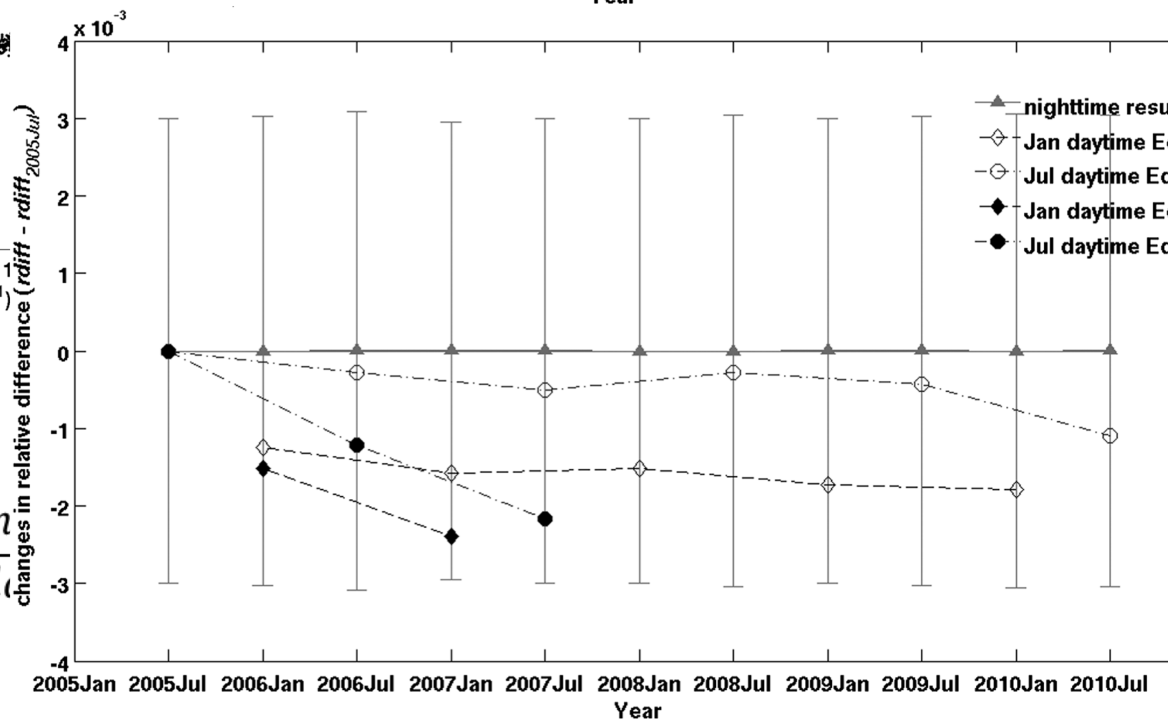


CERES is to start to produce Ed2 on S-NPP soon

On st







$$rdiff = \frac{I_{LW\_CERES}(daytim}{I_{est}(d}$$

(Huang et al., 2012)

On stability assessment

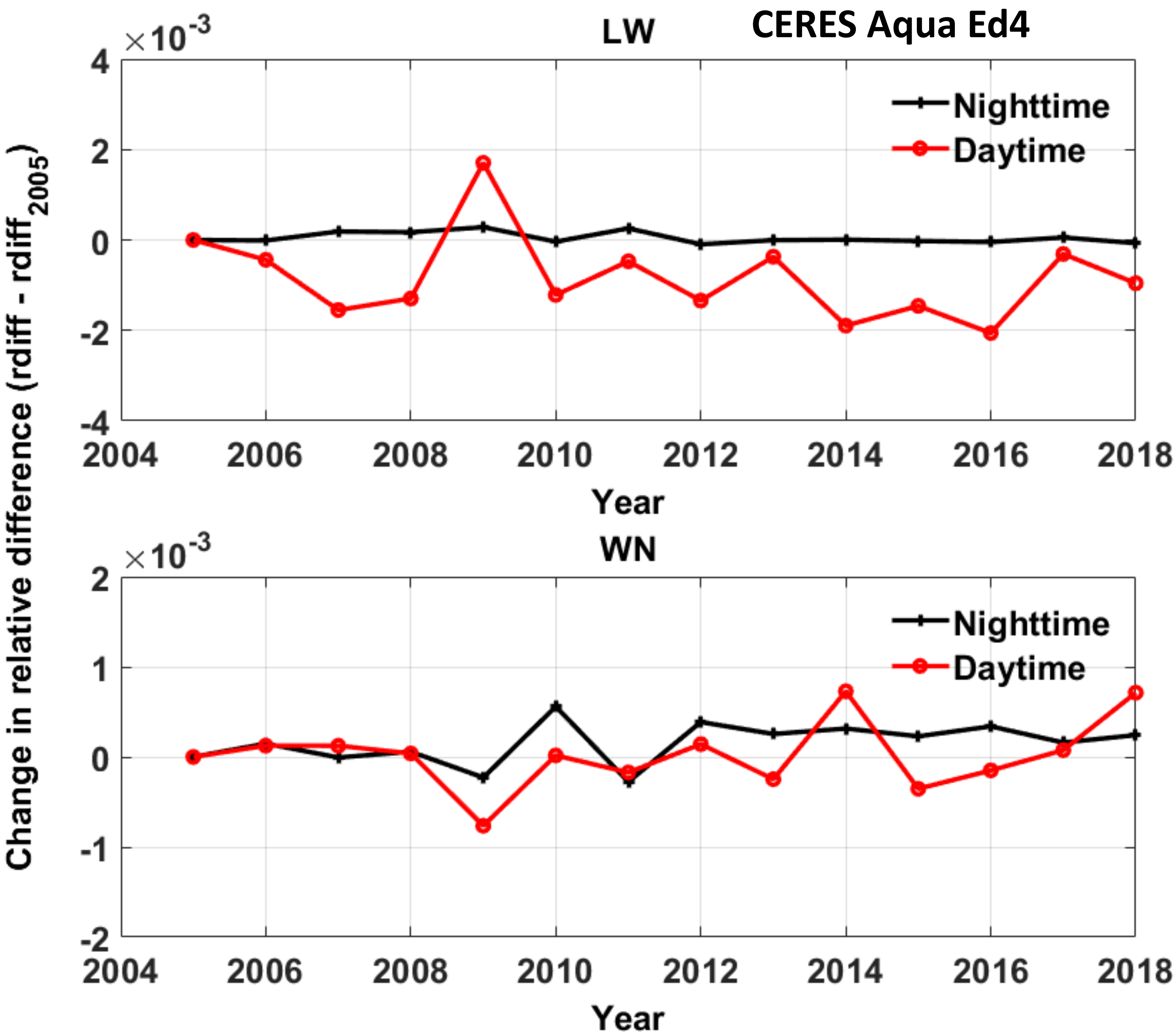
Following Huang et al. (2012, JTECH)

1) Do regression using nighttime CrIS (or AIRS) and CERES WN/LW radiance
2) Estimate CERES WN/LW daytime radiance using the regression coefficients from 1)
3) Estimate the relative difference for the daytime

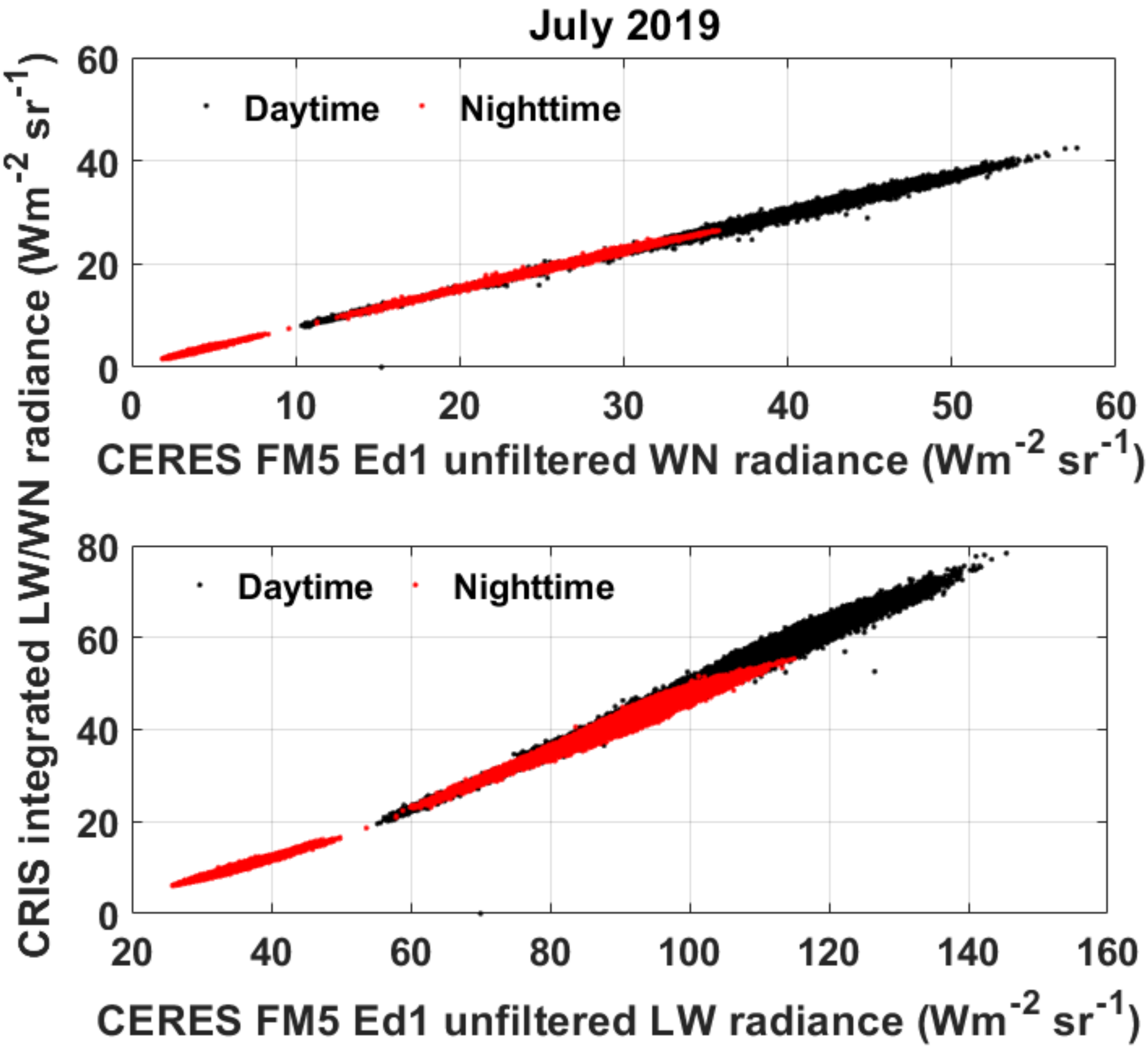
$$rdiff = \frac{I_{LW\_CERES}(daytime) - I_{est}(daytime)}{I_{est}(daytime)}$$

Premise: if daytime vs. nighttime has changes with time, rdiff should be able to tell

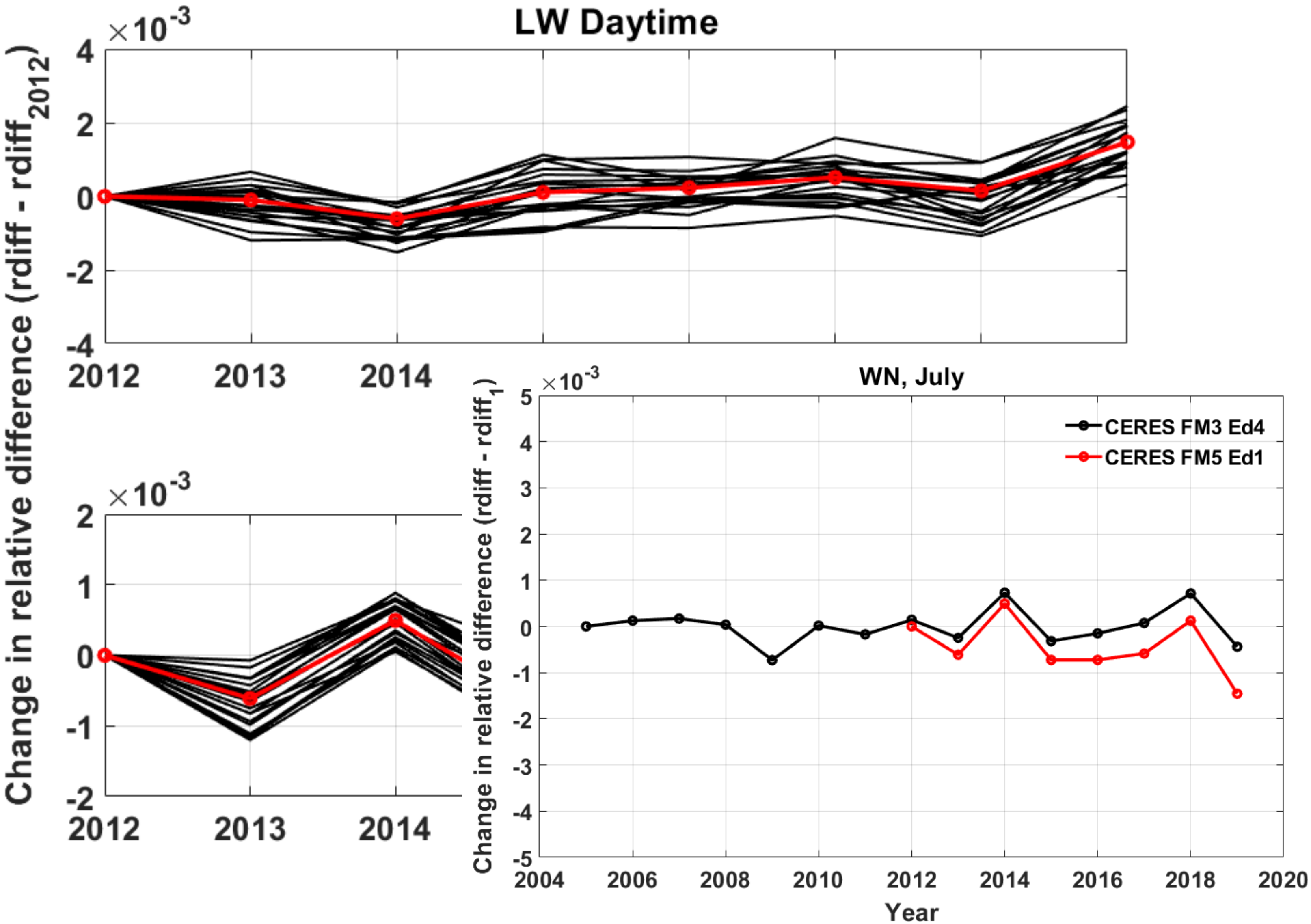
The shift of mean r_{diff} in Julies with respect to the mean r_{diff} of July 2005



Smaller Y-scale here


July 2019
Daytime
Nighttime
0
20
40
60
0
10
20
30
40
50
60
CERES FM5 Ed1 unfiltered WN radiance (Wm-2 sr-1)
Daytime
Nighttime
0
20
40
60
80
20
40
60
80
100
120
140
160
CERES FM5 Ed1 unfiltered LW radiance (Wm-2 sr-1)
CRIS integrated LW/WN radiance (Wm-2 sr-1)

Daytime shift for CERES FM5 Ed1 (Julies)

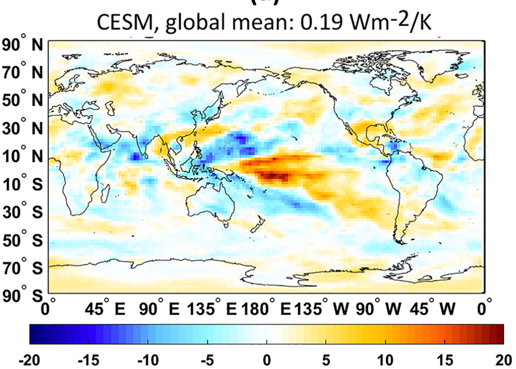


Red line is obtained using all data

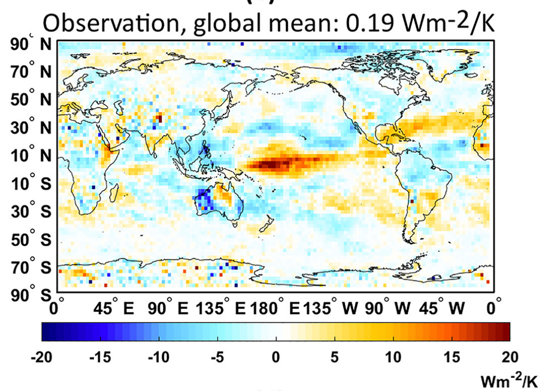
Black line: bootstrap with randomly chosen 50% data

Why bother with the WN band?

(a)

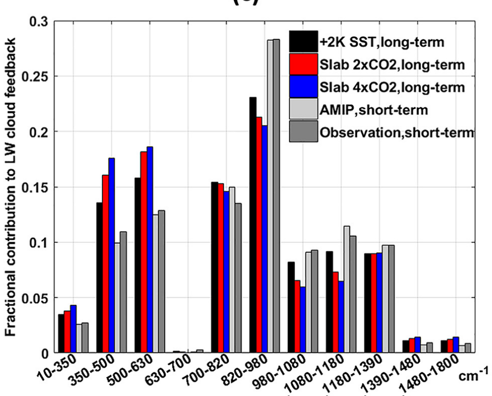


(b)



It can provide additional infect for cloud feedback vs. cloud change

(c)



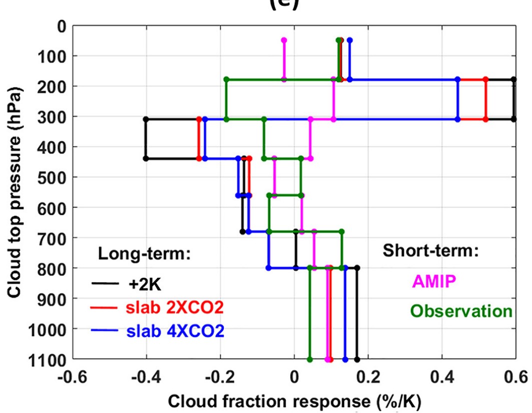
(d)

	Total fractional contribution from 10-630 cm^{-1} (far-IR)	Total fractional contribution from 820-1180 cm^{-1} (window)	LW broadband cloud radiative feedback (Wm^{-2}/K)
+2K SST	0.33	0.40	0.20
Slab 2xCO_2	0.38	0.35	0.18
Slab 4xCO_2	0.40	0.33	0.14
AMIP	0.25	0.49	0.19
Observation	0.26	0.48	0.19

Long-term change

Short-term (10yr+) fluctuation

(e)



Reference: Huang, X.L., X. H. Chen, Q. Yue, Band-by-band contributions to the longwave cloud radiative feedbacks, *Geophysical Research Letters*, 46, doi.org/10.1029/2019GL083466, 2019.

Conclusions and discussions

- Synergy exists between the CERES and hyperspectral observations
  - Agreements at both the radiances and flux are both reassuring the synergy
  - Collocated radiances can help assess CERES unfiltered radiance (window-band and longwave)
- Window-band flux from CERES is under-utilized.
  - Channel performances stable over the year
  - Flux is consistent with the ones from AIRS/CrIS

References

- **Huang, X.L.**, X. H. Chen, Q. Yue, Band-by-band contributions to the longwave cloud radiative feedbacks, *Geophysical Research Letters*, 46, doi.org/10.1029/2019GL083466, 2019.
- **Huang, X. L.**, X.H. Chen, G. L. Potter, L. Oreopoulos, J. N.S. Cole, D.M. Lee, N. G. Loeb, A global climatology of outgoing longwave spectral cloud radiative effect and associated effective cloud properties, *J. Climate*, 27, 7475-7492, doi:10.1175/JCLI-D-13-00663.1, 2014.
- Chen, X.H., **X.L. Huang**, X. Liu, Non-negligible effects of cloud vertical overlapping assumptions on longwave spectral fingerprinting studies, *JGR-Atmospheres*, 118, 7309-7320, doi:10.1002/jgrd.50562, 2013.
- **Huang, X.L.**, N. G. Loeb, H.W. Chuang, Assessing stability of CERES-FM3 daytime longwave unfiltered radiance with AIRS radiances, *Journal of Atmospheric and Oceanic Technology*, 29(3), 375-381, doi:10.1175/JTECH-D-11-00066.1, 2012.
- **Huang, X.L.**, N.G. Loeb, and W.Z. Yang, Spectrally resolved fluxes derived from collocated AIRS and CERES measurements and their application in model evaluation: 2. cloudy sky and band-by-band cloud radiative forcing over the tropical oceans, *JGR-Atmospheres*, 115, D21101, doi:10.1029/2010JD013932, 2010.
- **Huang, X.L.**,W.Z. Yang, N.G. Loeb, and V. Ramaswamy, Spectrally resolved fluxes derived from collocated AIRS and CERES measurements and their application in model evaluation: 1. clear sky over the tropical oceans, *JGR-Atmospheres*, 113, D09110, doi:10.1029/2007JD009219, 2008.

Thank You!