Recent Variations in EEI, SST & Clouds

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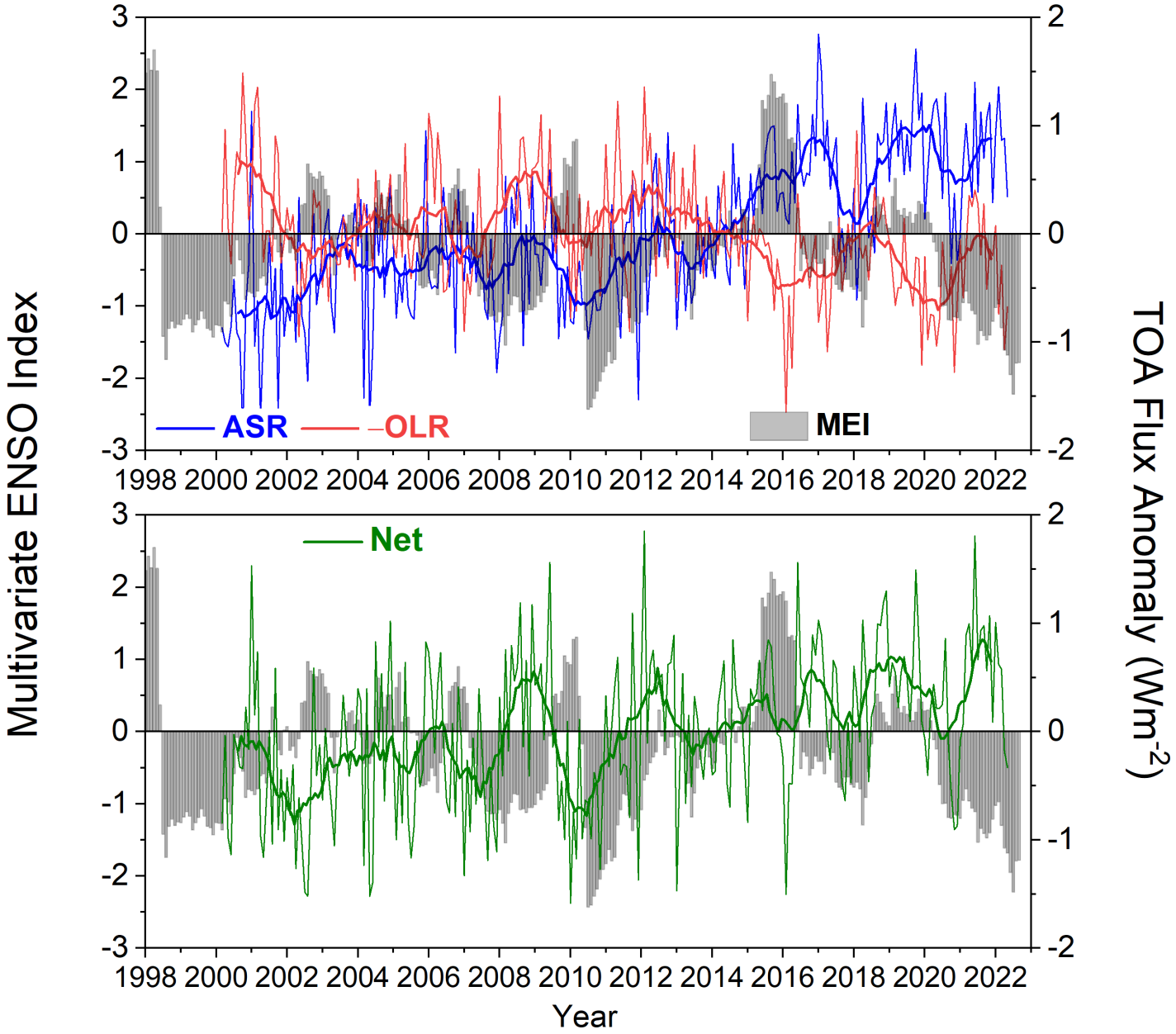
Acknowledgements: Tyler J. Thorsen, Fred G. Rose, Seiji Kato, John Lyman, Greg Johnson, Sueng-Hee Ham, Michael Mayer

2022 ERB Workshop, October 12-14, 2022, Hamburg, Germany

Global Mean All-Sky TOA Flux Anomalies & Multivariate ENSO Index
(CERES EBAF Ed4.2; 03/2000–05/2022)



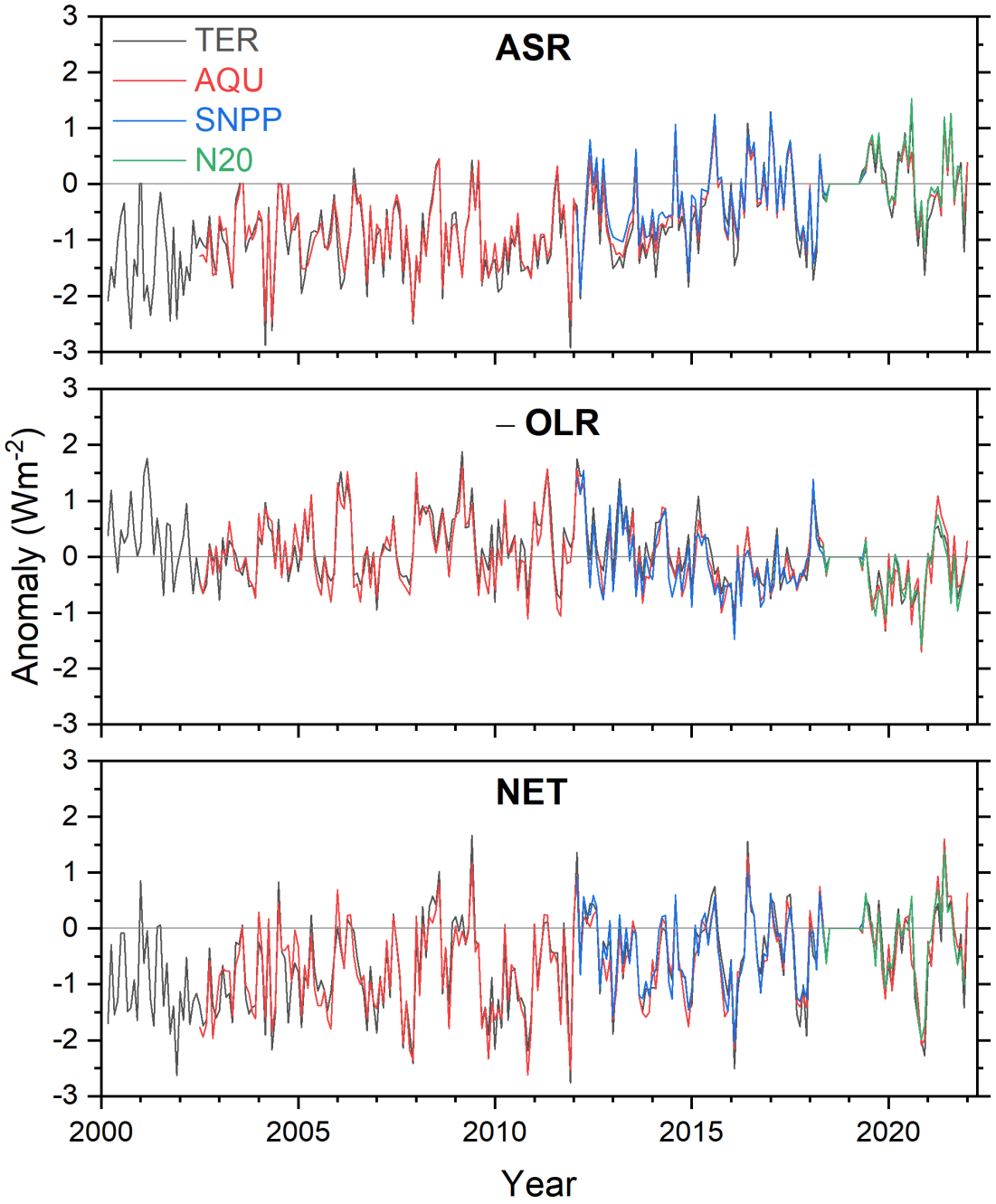
EBAF Trends (03/2000-05/2022)

ASR: 0.70 ± 0.20 Wm^{-2} per decade

LW: -0.28 ± 0.20 Wm^{-2} per decade

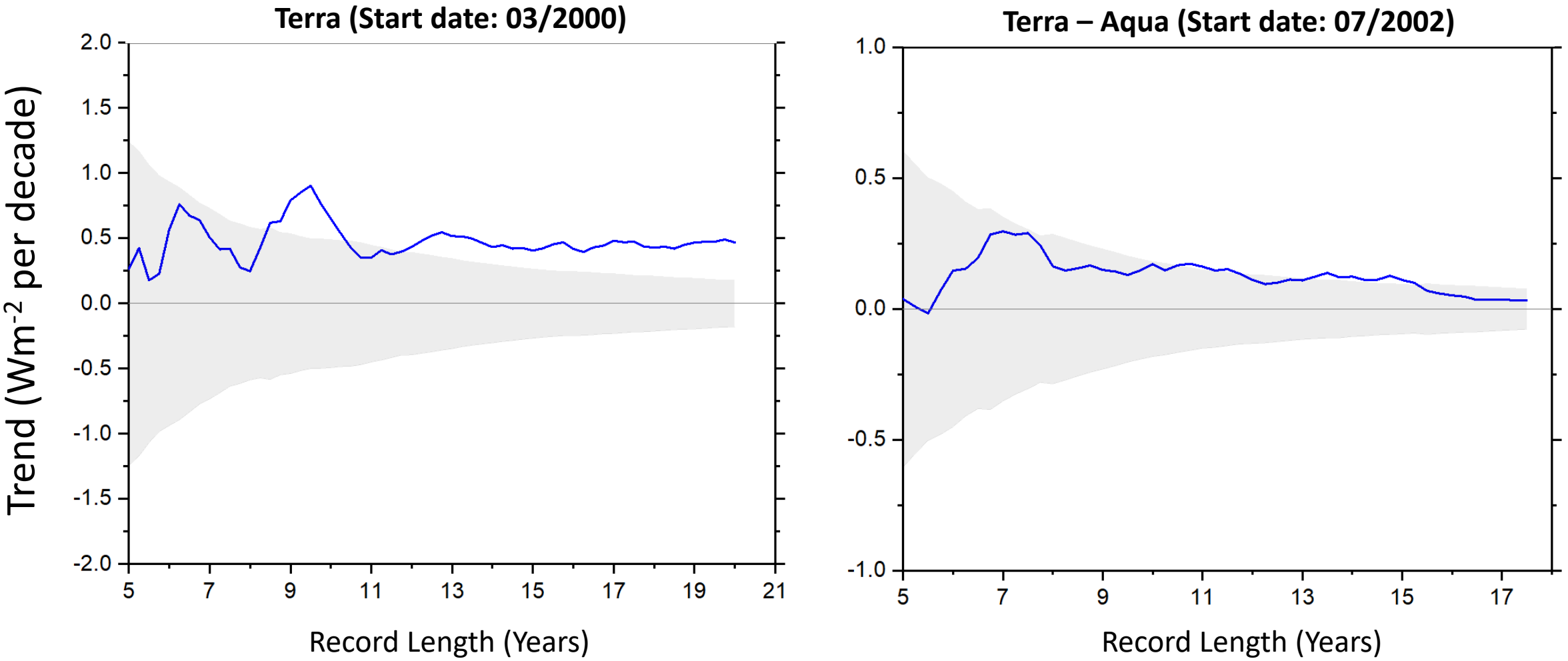
NET: 0.42 ± 0.19 Wm^{-2} per decade

Global Mean All-Sky TOA Flux Monthly Anomalies (03/2000-01/2022; Climatology: 05/2018—06/2019)



- Based upon CERES SSF1deg products (no GEO)
- NET monthly anomalies consistent to 0.3 Wm^{-2} (1σ)
- No evidence of CERES instrument drift

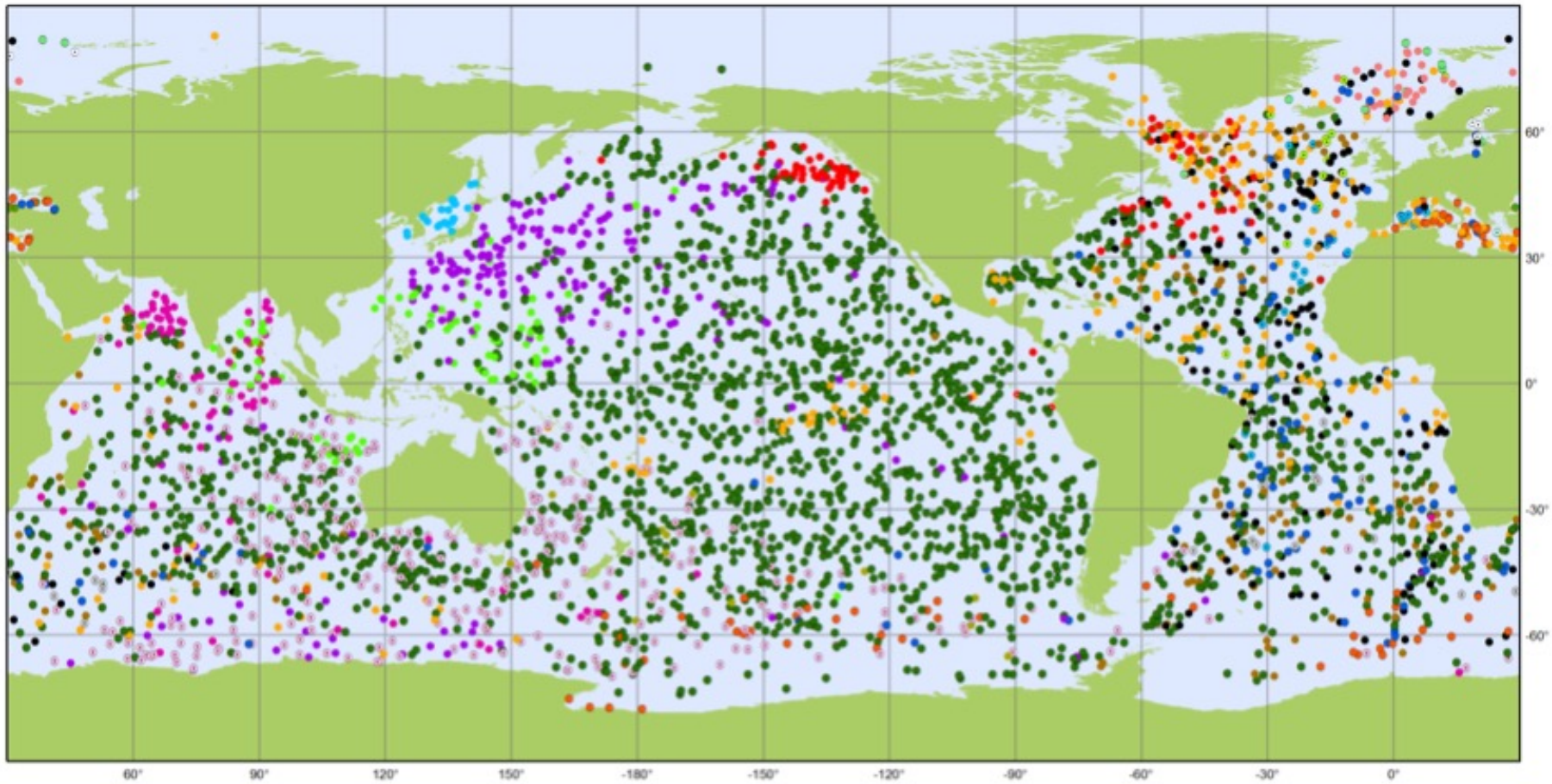
CERES Global Mean Net TOA Flux Trends vs Record Length



- Terra & Aqua net TOA flux trends are consistent to < 0.1 Wm^{-2} per decade for the full period

Loeb et al. JGR, 2022 (in press)

Argo Ocean Profiling Network



Argo

National contributions - 3918 Operational Floats

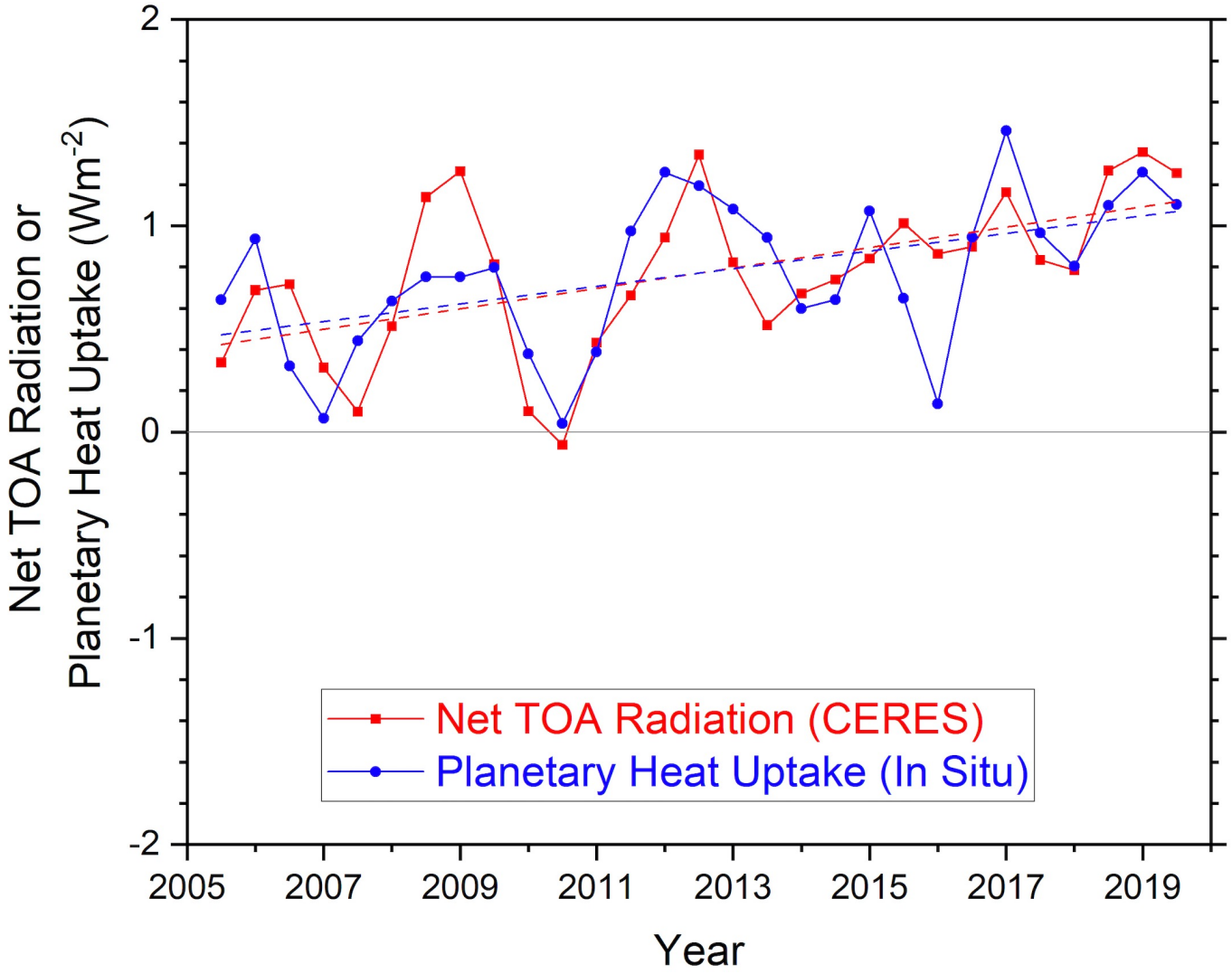
Latest location of operational floats (data distributed within the last 30 days)

February 2021

AUSTRALIA (327)	EUROPE (117)	GREECE (1)	JAPAN (219)	NEW ZEALAND (14)	KOREA, REPUBLIC OF (22)
BULGARIA (4)	FINLAND (7)	INDIA (87)	MEXICO (1)	NORWAY (31)	SPAIN (22)
CANADA (111)	FRANCE (242)	IRELAND (17)	MOROCCO (1)	PERU (3)	UK (170)
CHINA (85)	GERMANY (177)	ITALY (85)	NETHERLANDS (23)	POLAND (11)	USA (2142)

Generated by www.jcommops.org, 19/03/2021

Annual Mean Net TOA Radiation & In-Situ Planetary Heat Uptake (07/2005-06/2019)



- CERES Net radiation & In-Situ PHU show consistent increasing trends with good agreement in year-to-year variability.

Trend and Uncertainty (Wm^{-2} per decade; 5%-95% CI)

Trend : 0.50 ± 0.47

Trend Diff : 0.07 ± 0.29

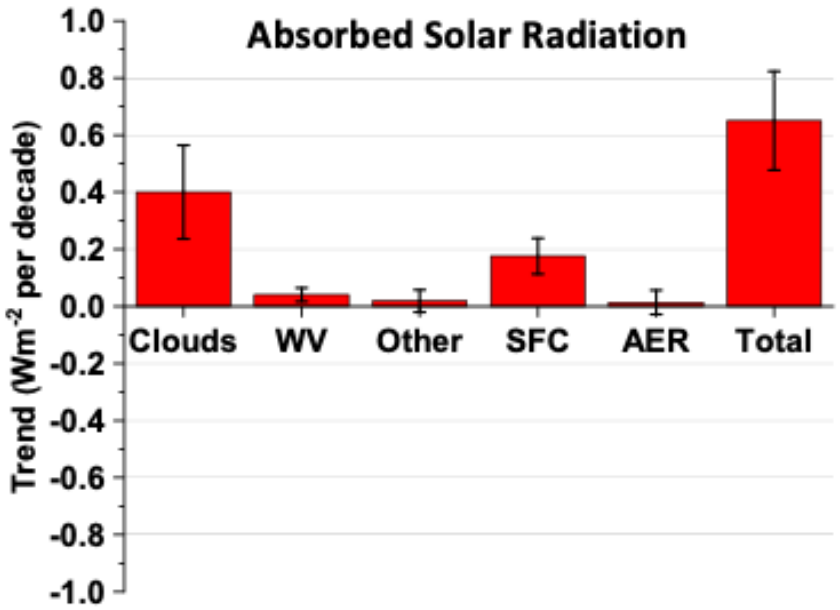
R^2 = 0.49

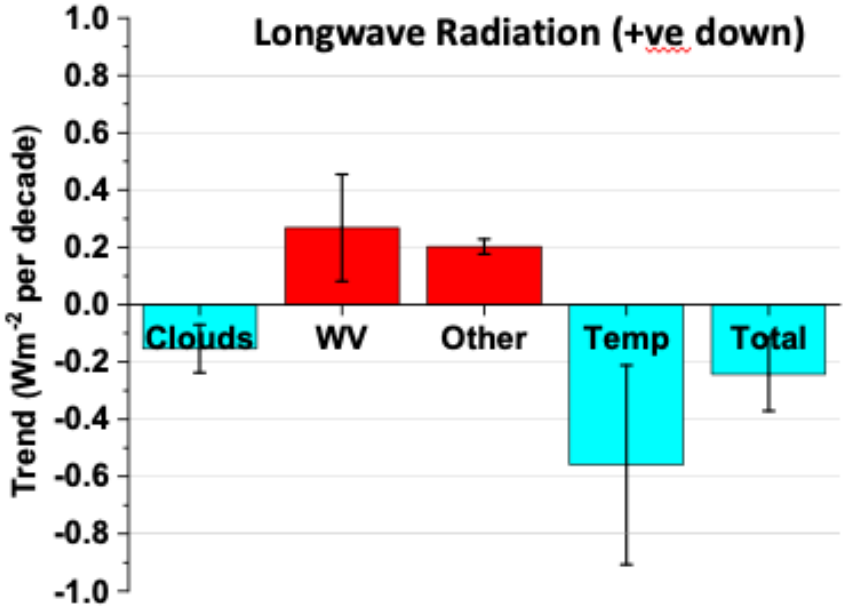
Note: CERES and Argo+Altimeter are anchored to an EEI of 0.76±0.1 Wm^{-2} for 2005-2020 based upon in-situ data.

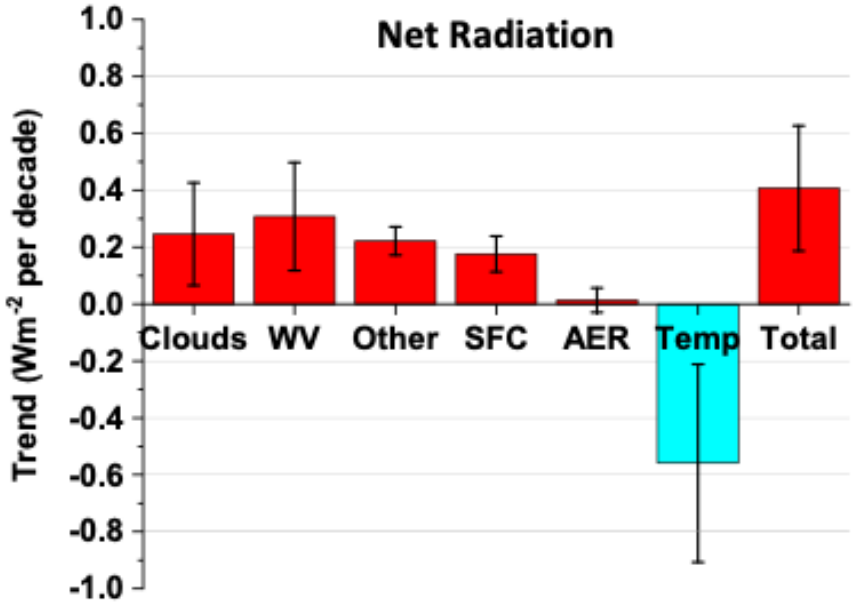
Satellite and in situ observations independently show an approximate doubling of Earth's Energy Imbalance (EEI) from mid-2005 to mid-2019

Loeb et al. (2021)

Global Mean Trends (09/2002-03/2020)

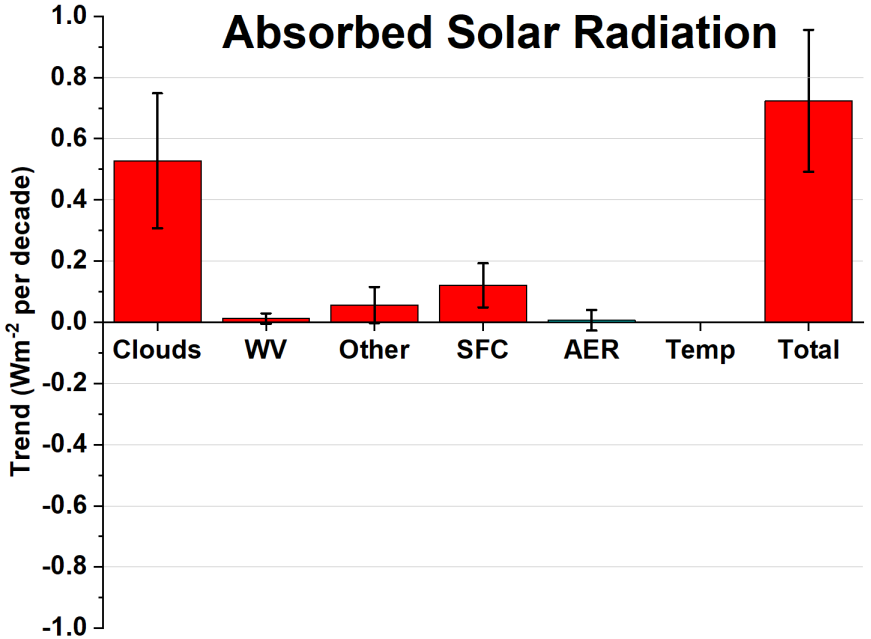


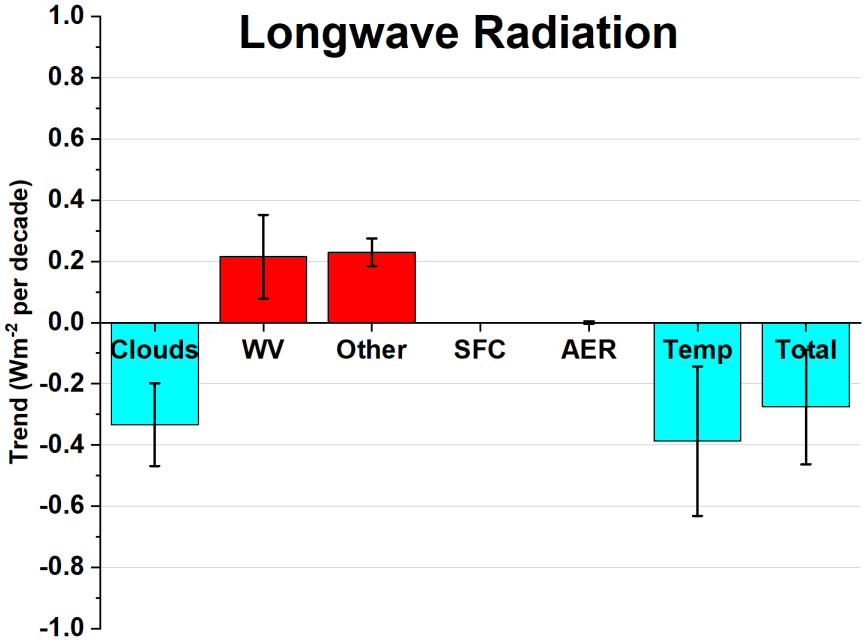


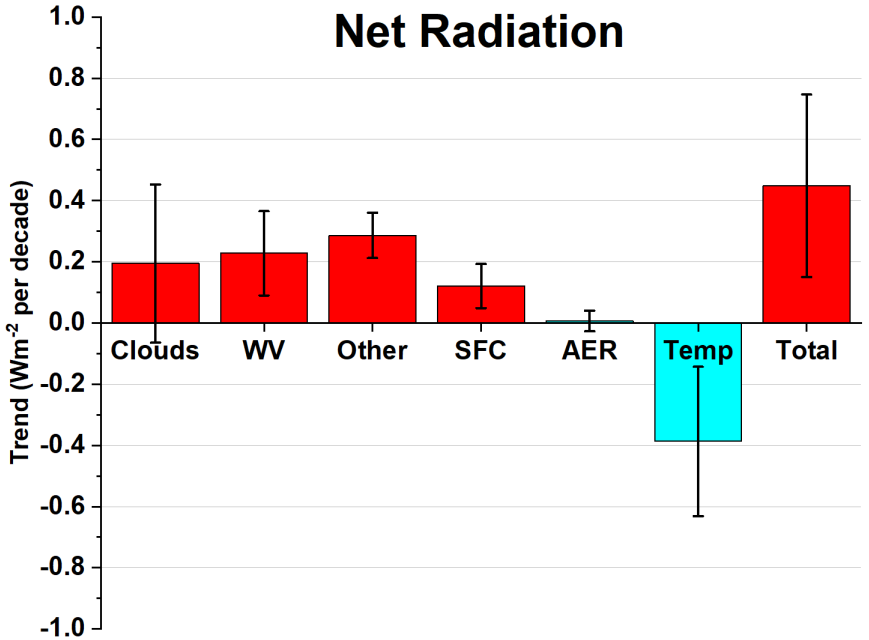


Combined changes in clouds, sea-ice, WV and trace gases exceed influence from temperature changes, resulting in a positive overall trend in net TOA flux.

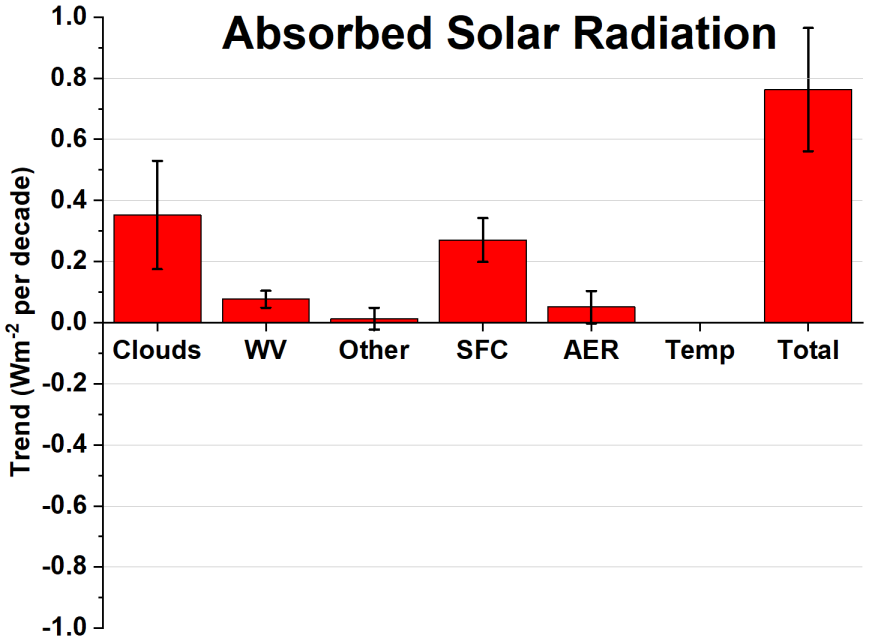
Trend Attribution (Jan-Dec; SH)

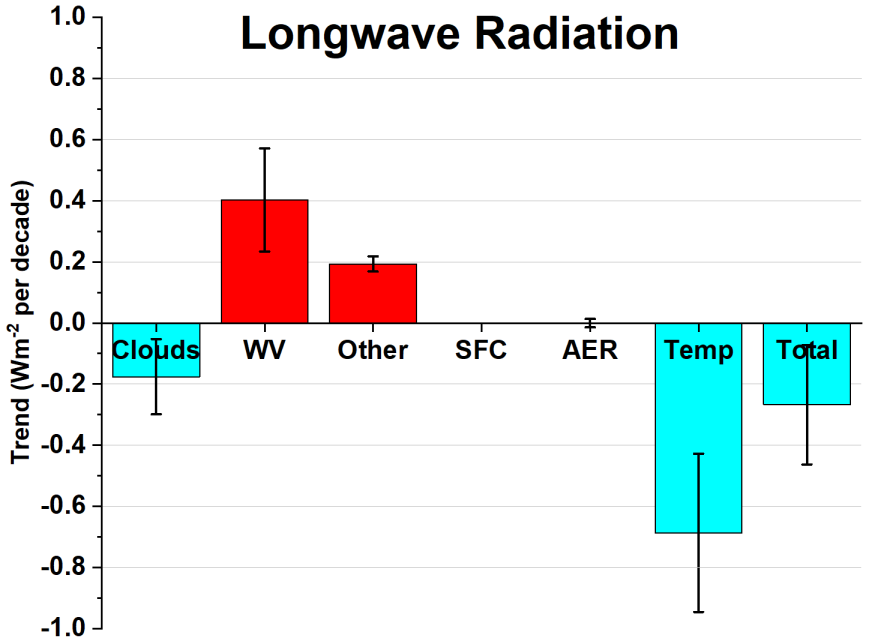


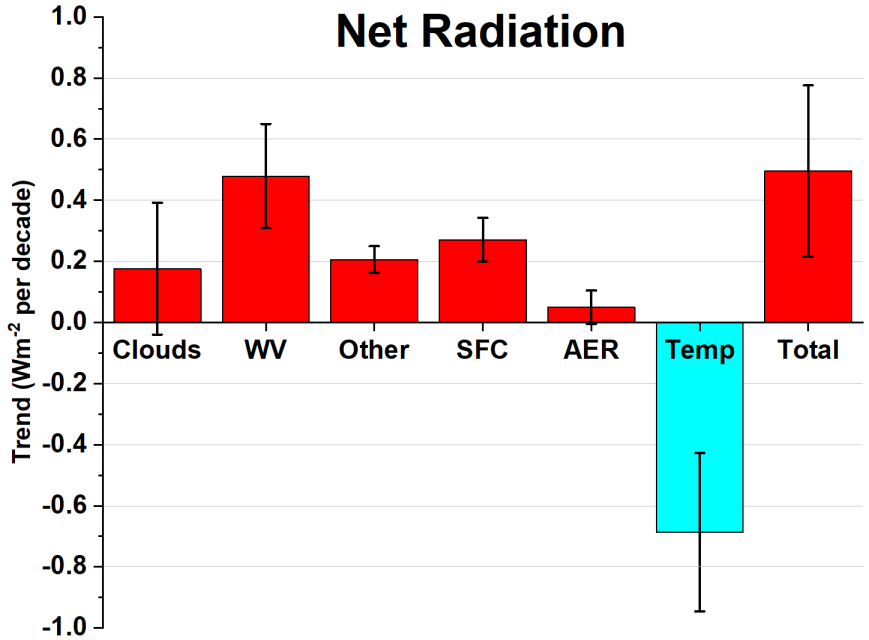




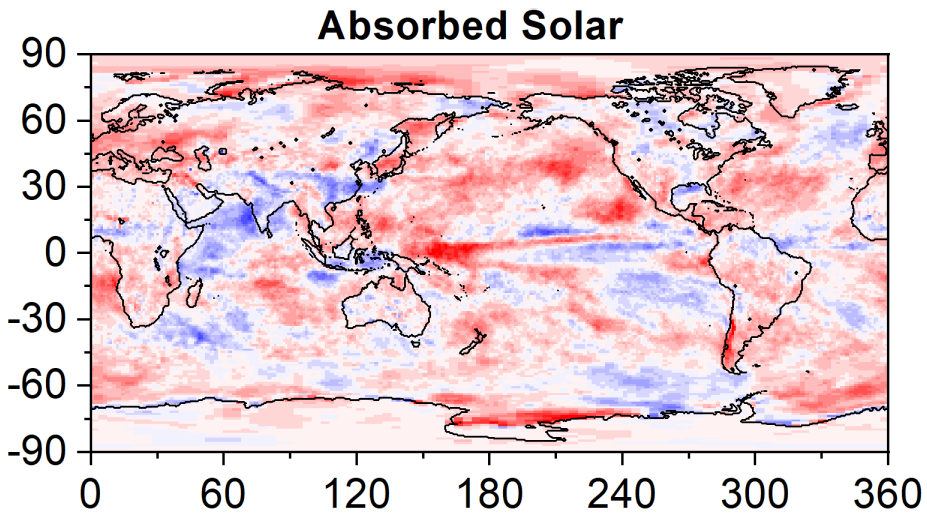
Trend Attribution (Jan-Dec; NH)

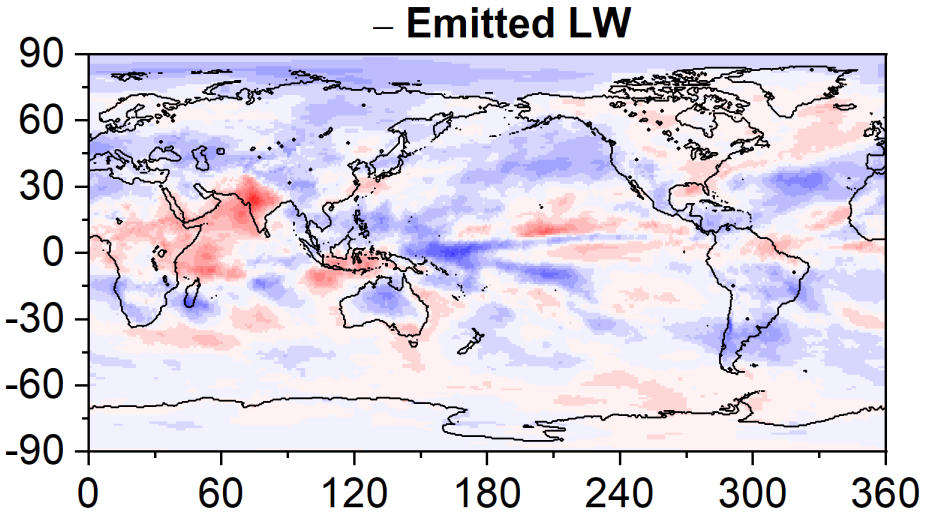


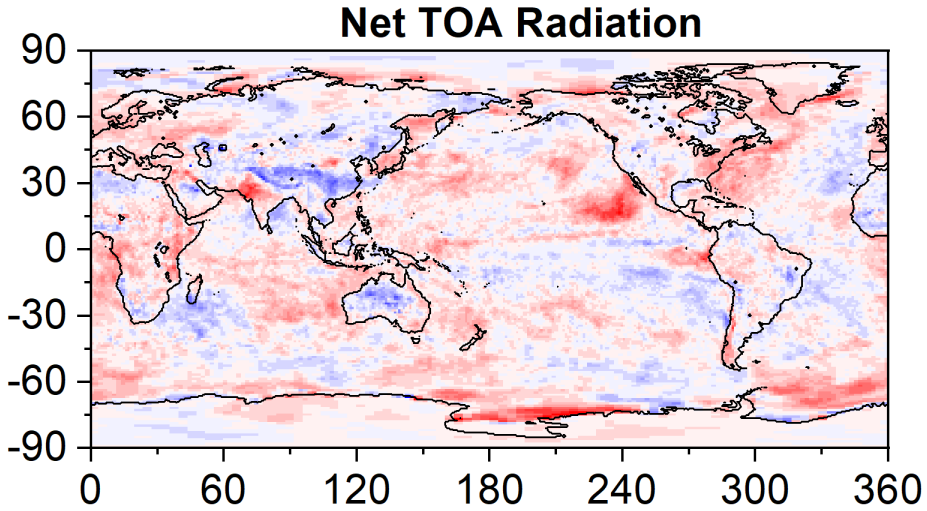


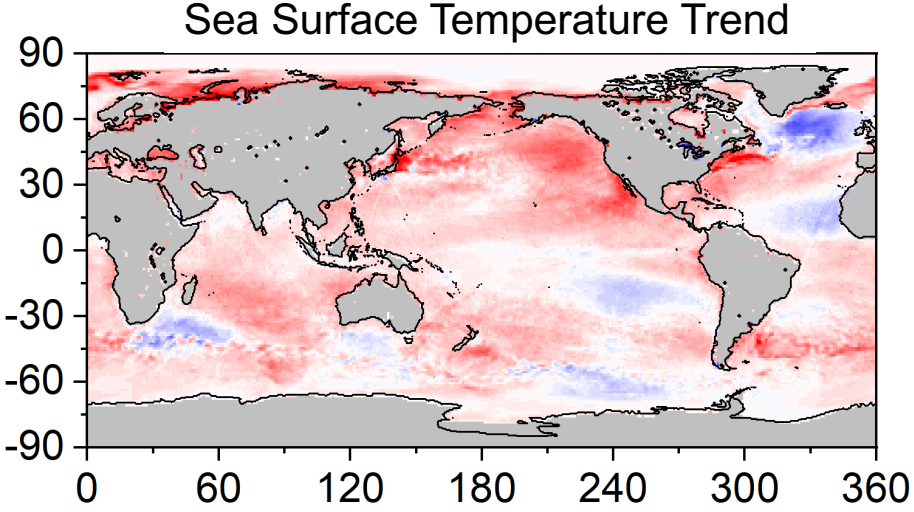


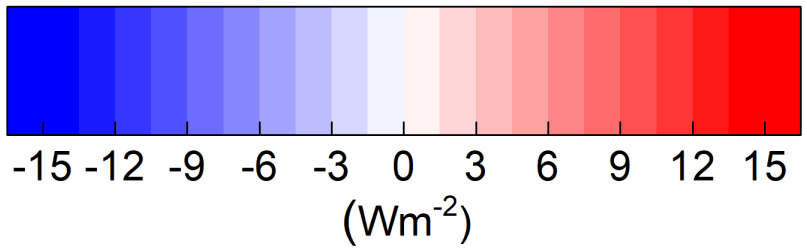
CERES TOA Radiation Changes & ERA5 SST Trend (03/2000 – 01/2022)

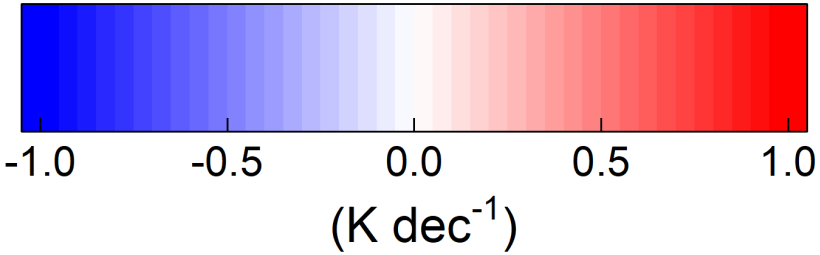




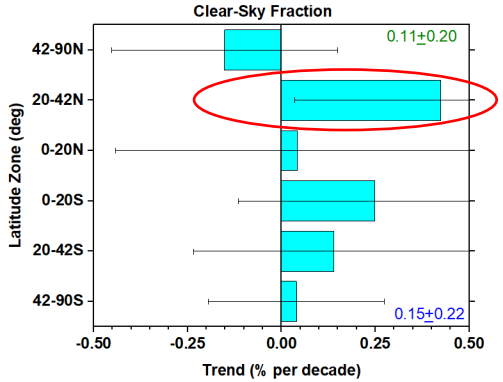


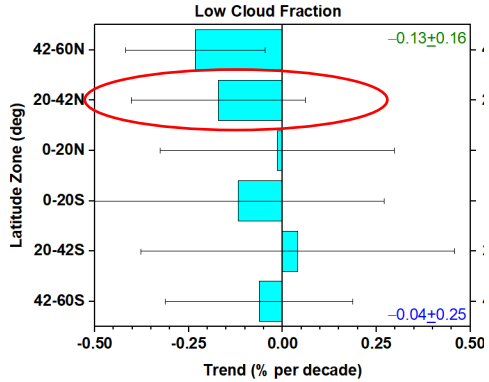


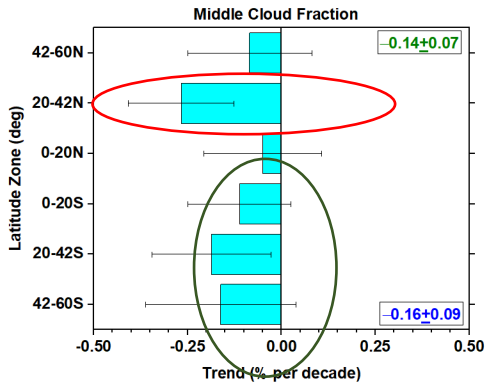


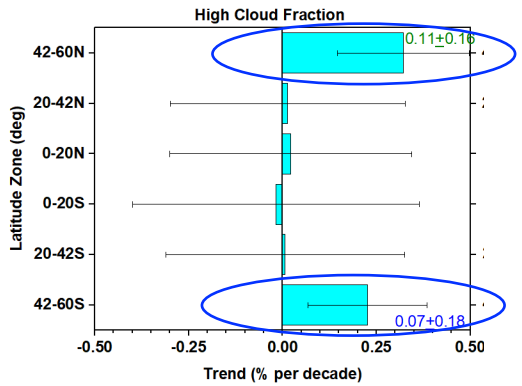


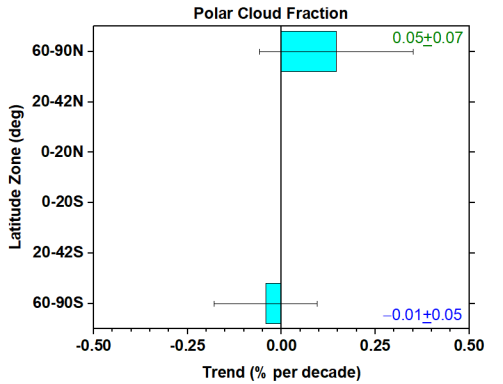
Trends in Clear/Cloud Fraction By Cloud Type (07/2002 – 12/2021)

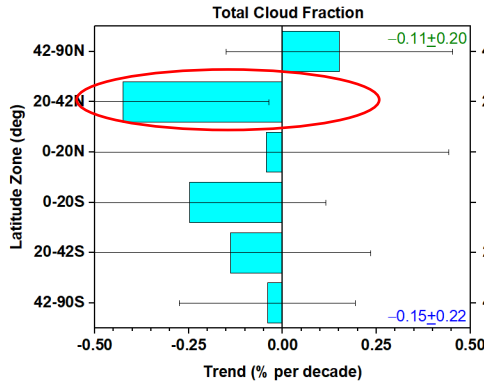






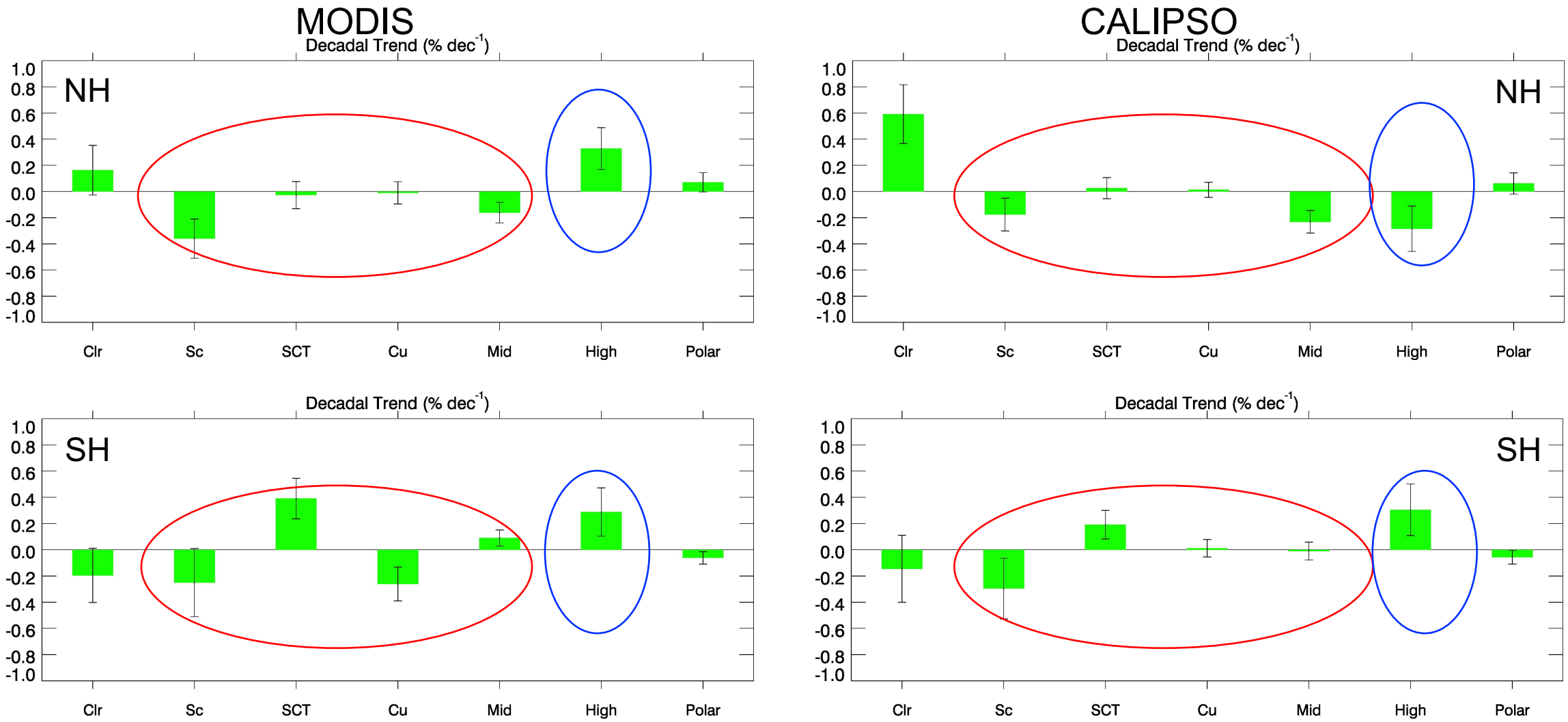






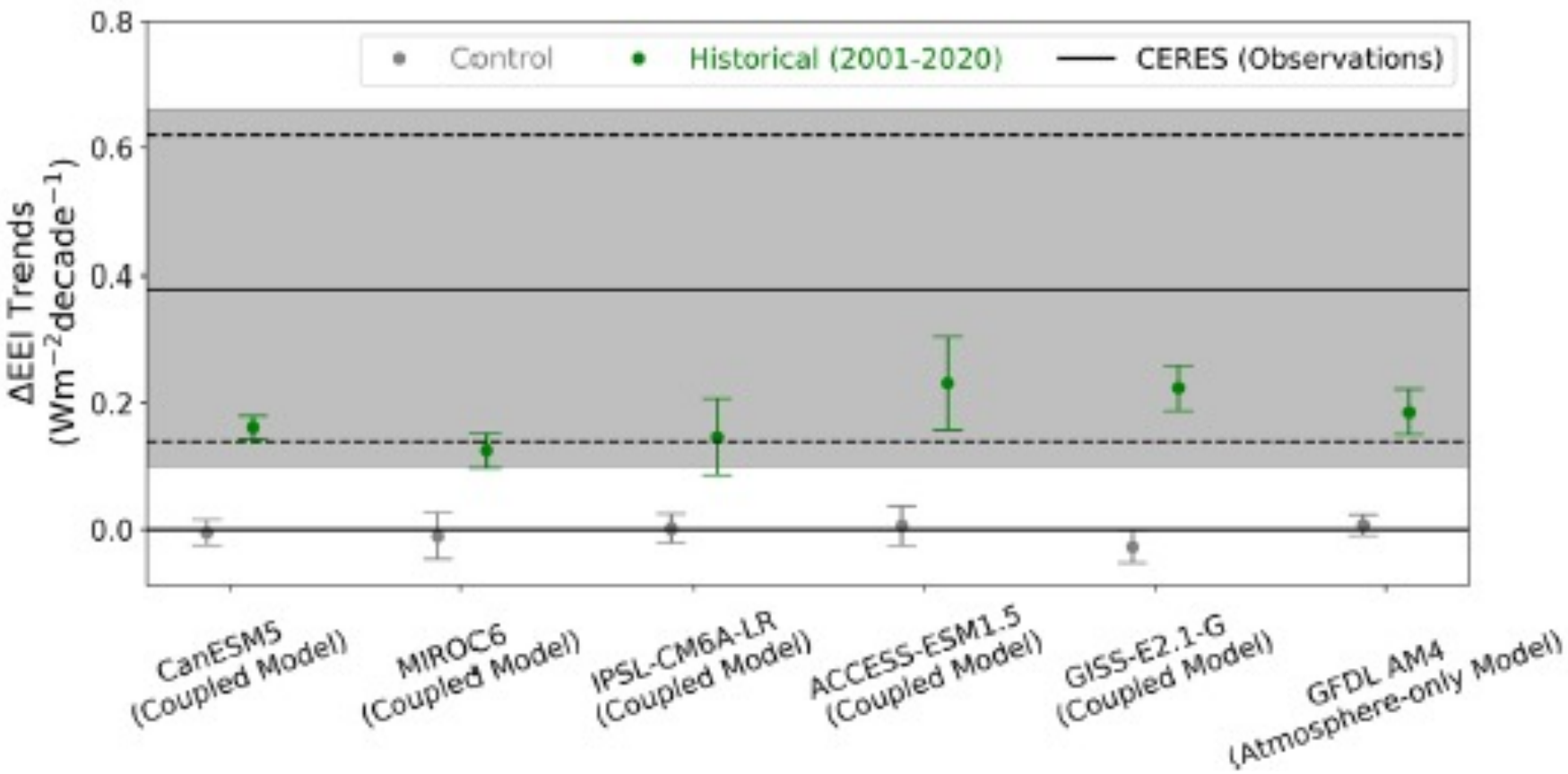
- Large increase in clear-sky fraction and decreases in low and middle cloud fraction in NH.
- Increase in high cloud fraction in NH and SH mid latitudes.
- Decrease in middle cloud fraction throughout SH.

Clear and Cloud Fraction Trends: MODIS and CALIPSO (2007-2017)



- Similar low and middle cloud trends in both hemispheres
- Consistent high cloud trends in SH but opposite in NH

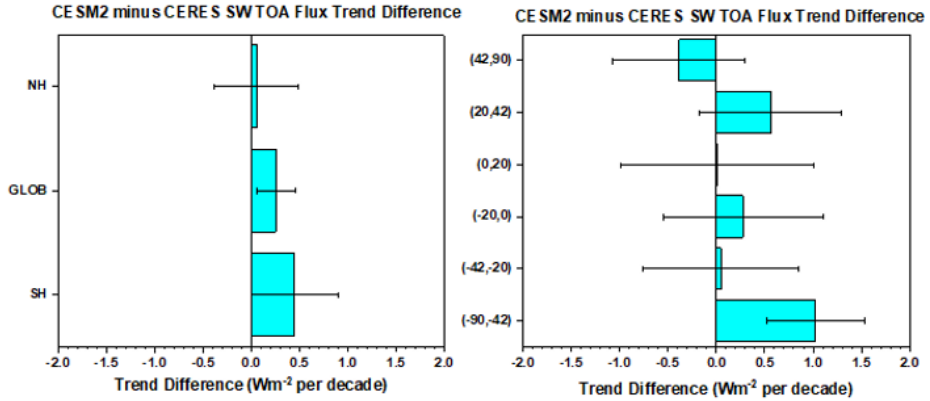
Global Mean Trend in Earth's Energy Imbalance (2001-2020): GCMs vs CERES

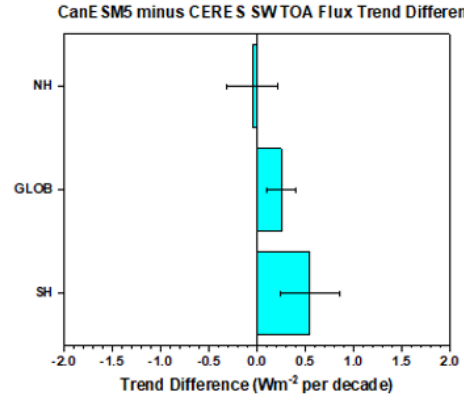


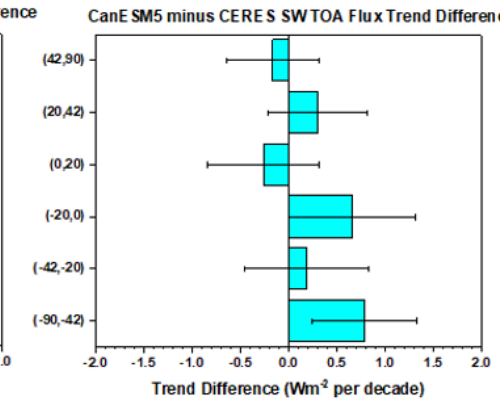
- The CERES EEI trend is exceptionally unlikely (<1% probability) to be explained by internal variability alone.
- Model simulations only fall within observational uncertainty when anthropogenic radiative forcing and the associated climate response are accounted for.
- Model EEI trends are in the lower range of the observed 95% confidence interval (dashed lines).

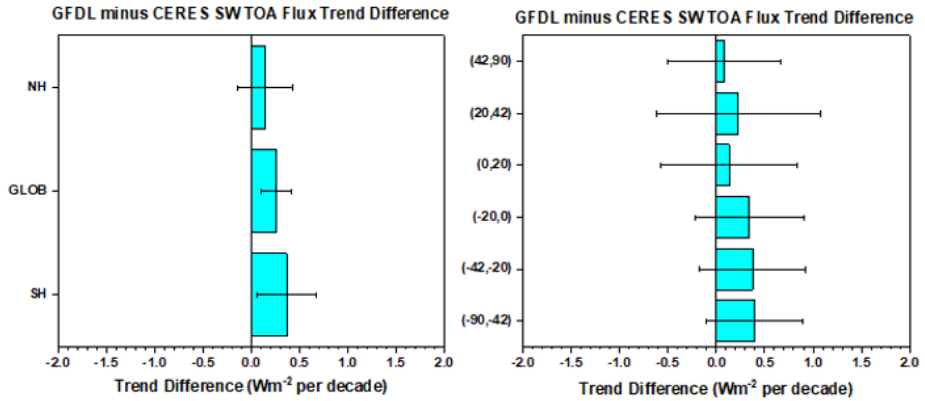
(Raghuraman et al., Nat. Comm., 2021)

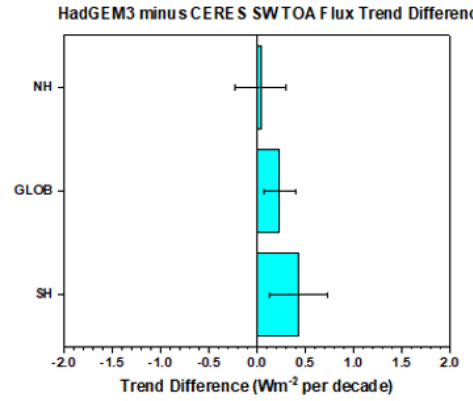
AMIP minus CERES SW TOA Flux Trends (03/2000-12/2017)

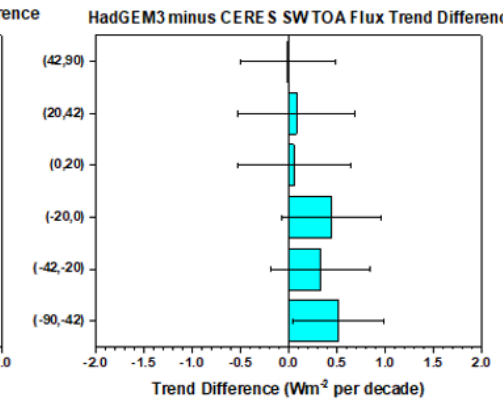


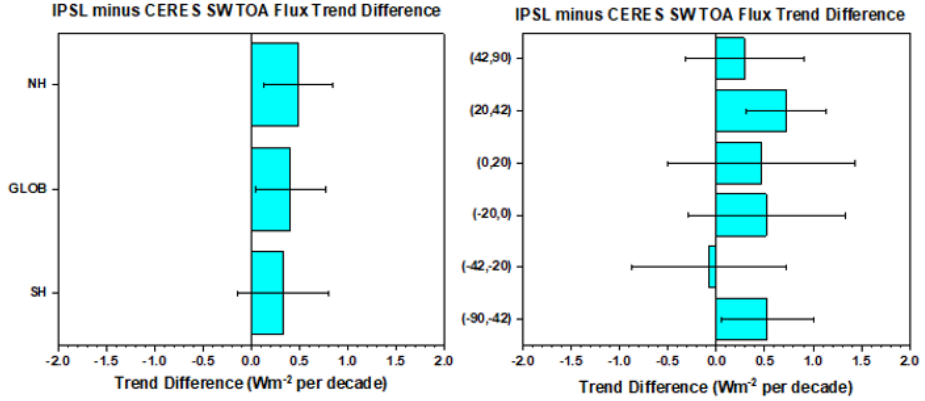


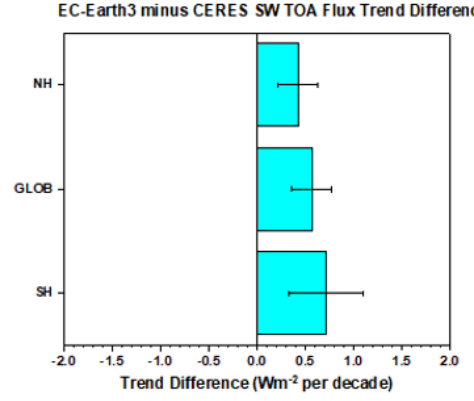


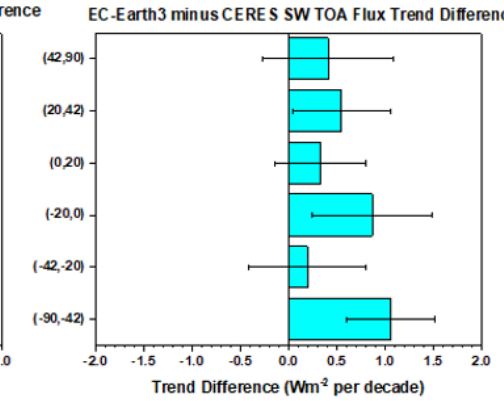




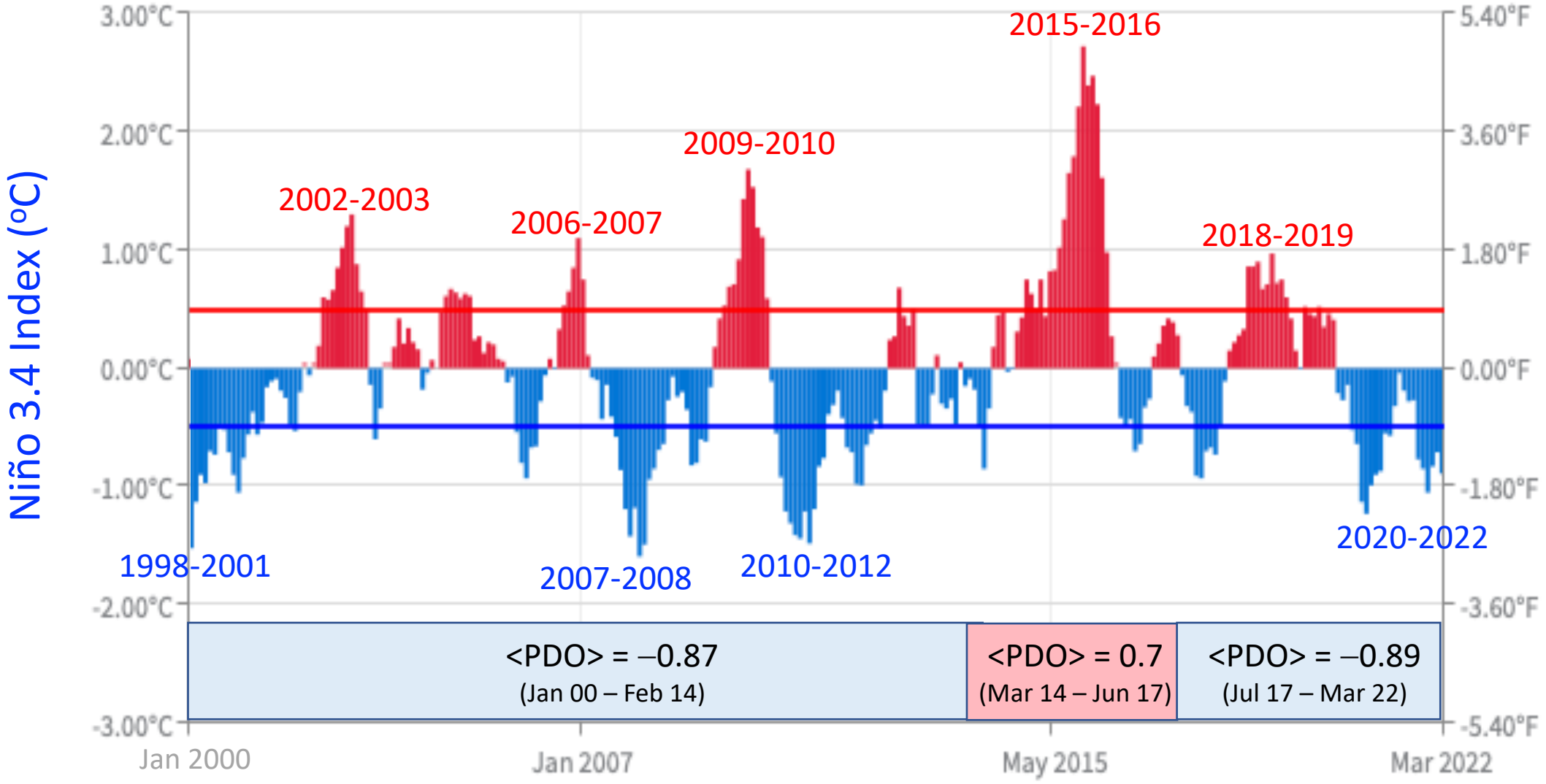




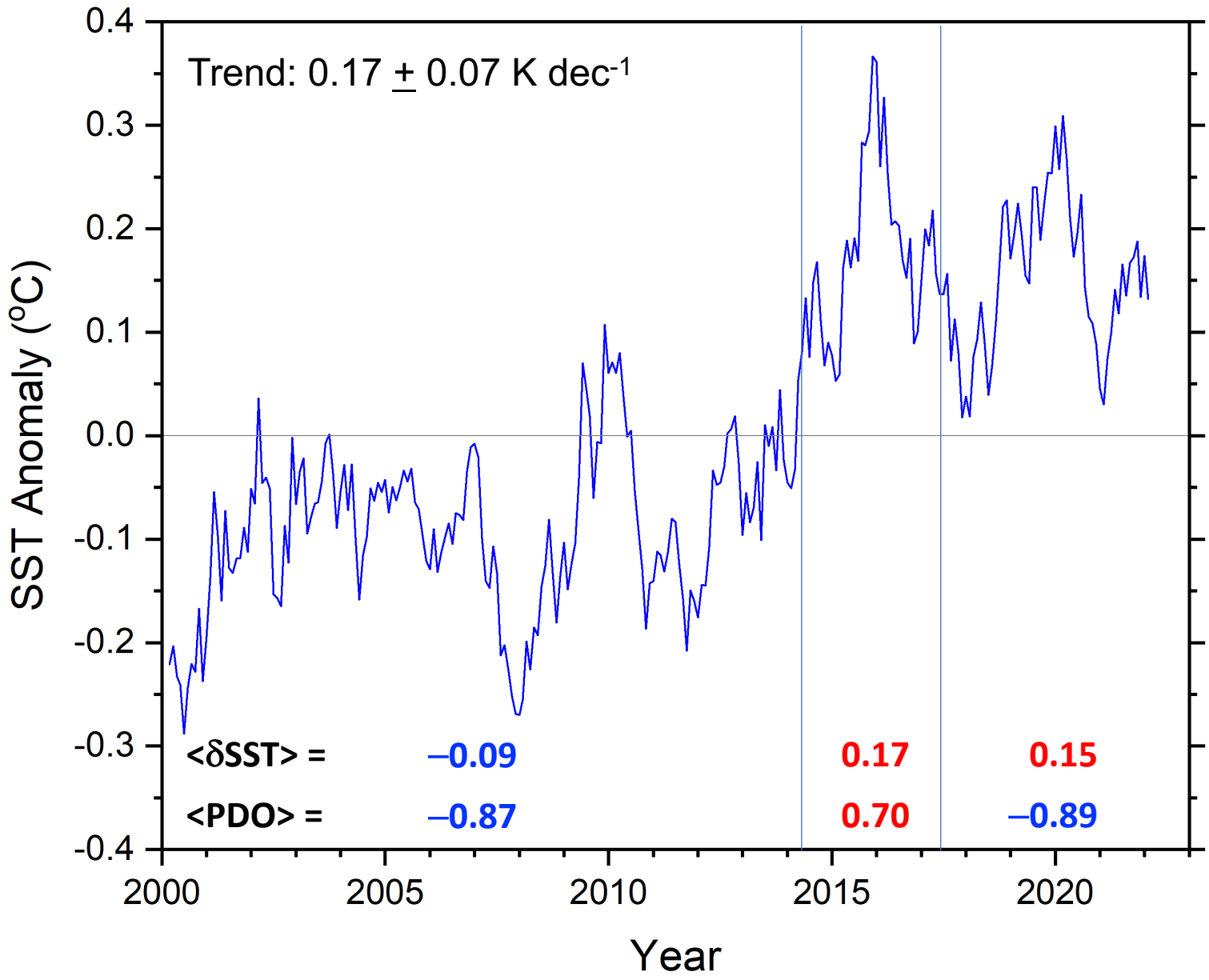




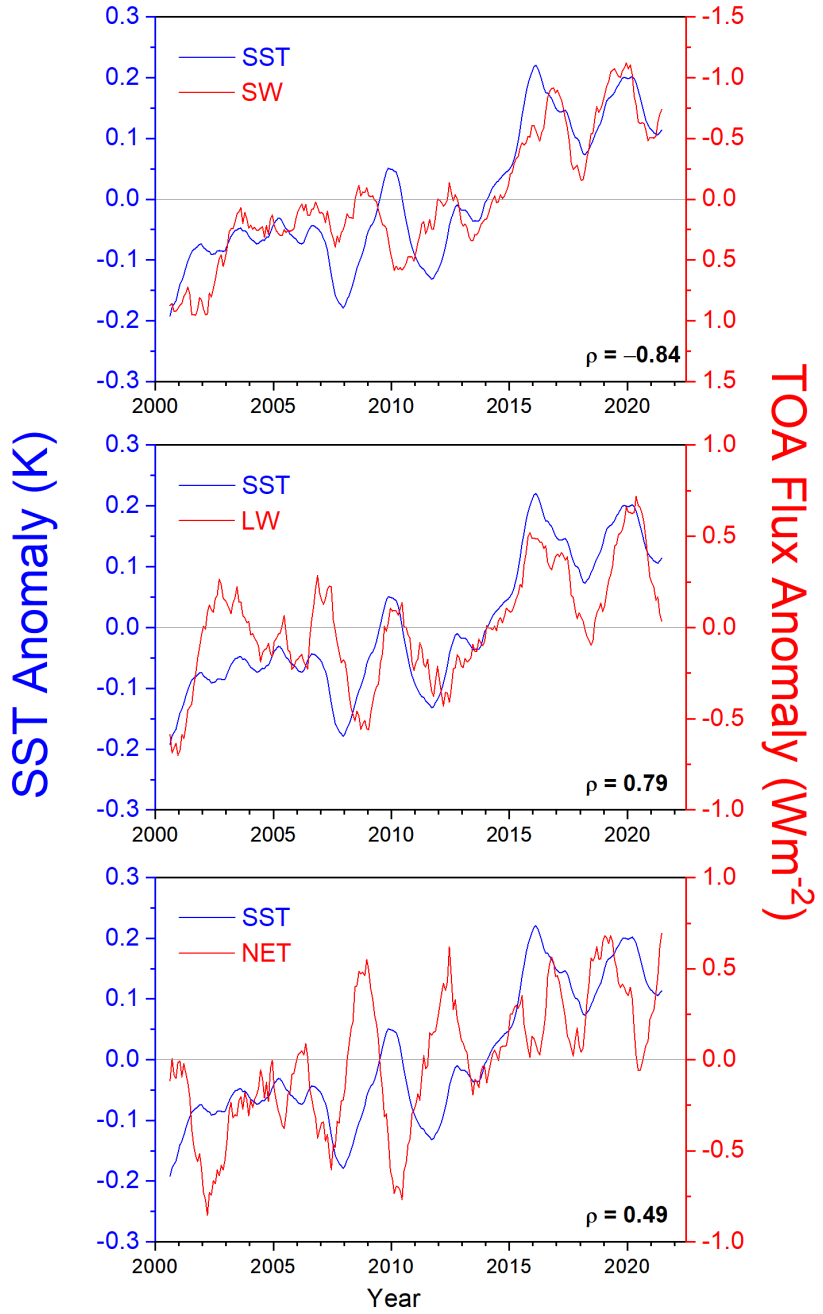
Niño 3.4 Index (ONI) Anomaly, PDO Index & δSST (01/2000 – 03/2022)



Global Mean SST Anomaly (03/2000-02/2022; HadSST.4.0.1.0)

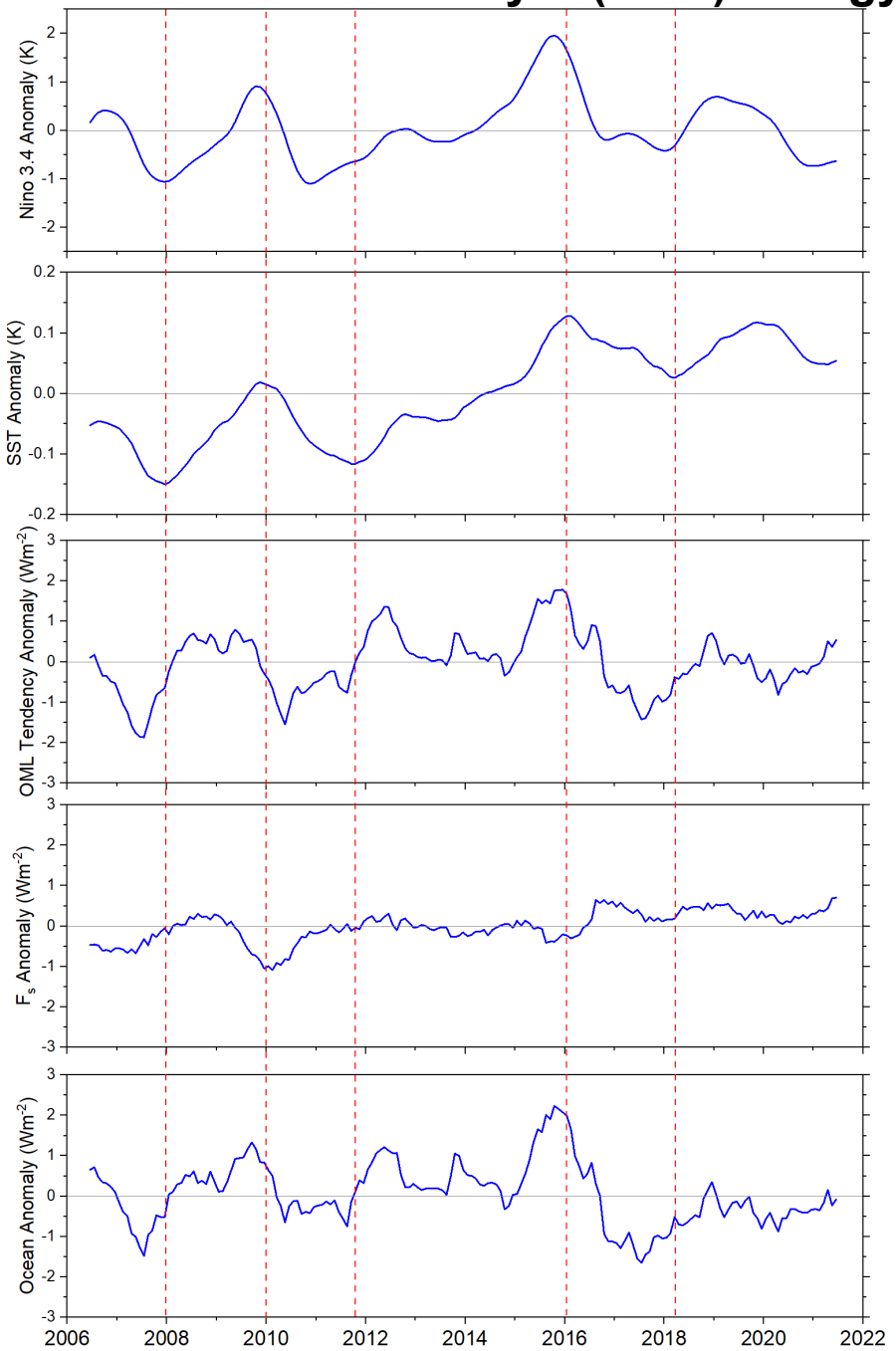


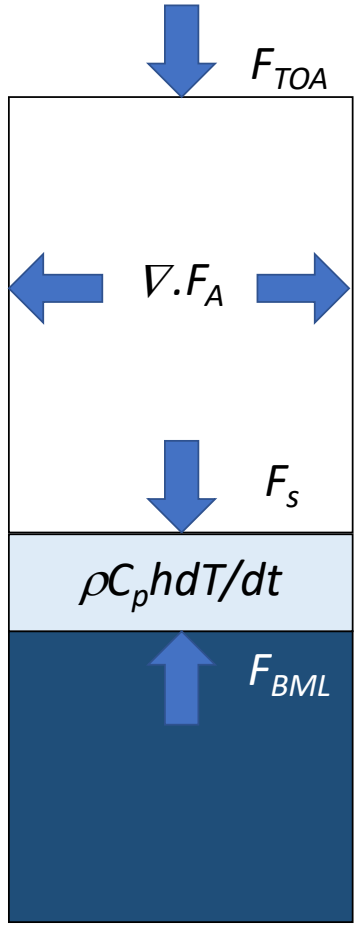
Global SST and TOA Flux Anomalies



Global Ocean Mixed Layer (OML) Energy Budget

Anomalies
Nino 3.4 (K)
SST (K)
OML Heat Content Tendency ($\rho C_p hdT/dt$; (Wm^{-2})
Surface Heat Flux (F_s) (Wm^{-2})
Ocean Heat Flux (F_{MBL}) (Wm^{-2})





Conclusions

- Satellite and in situ observations independently show an approximate doubling of Earth's Energy Imbalance (EEI) from mid-2005 to mid-2019.
- Marked decreases in clouds and sea-ice and increases in trace gases and water vapor combine to increase the rate of planetary heat uptake.
- Hemispheric symmetry in ASR trend.
  - Larger decrease in ASR trend due to cloud changes in SH compensated by larger decrease in ASR trend due to surface albedo changes in NH.
- Robust decreases in low and middle cloud amounts observed in both hemisphere.
- Four of seven CMIP6 AMIP model simulations show consistent ASR trends with CERES in NH, but none capture the observed ASR decrease in the SH.
- SW TOA flux changes track SST changes.
- Ocean vertical mixing appears to be main driver of global changes in SST.

Backup Slides

Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL092994

NASA CERES Spurious Calibration Drifts Corrected by Lunar Scans to Show the Sun Is not Increasing Global Warming and Allow Immediate CRF Detection

Grant Matthews[1]

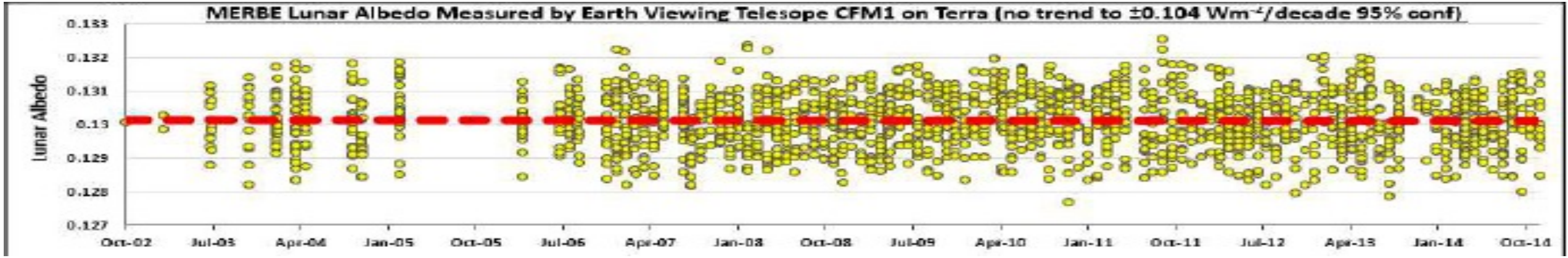
[1]Zedika Solutions LLC, Fort Wayne, IN, USA

Key Points:

- The Sun is not causing climate change and Cloud Radiative Forcing (CRF) signals can now be detected immediately
- Arctic heating is being balanced by reflectivity increases elsewhere
- The calibration accuracy of data is sufficient to detect uncertain cloud feedback signals immediately, rather than in decades

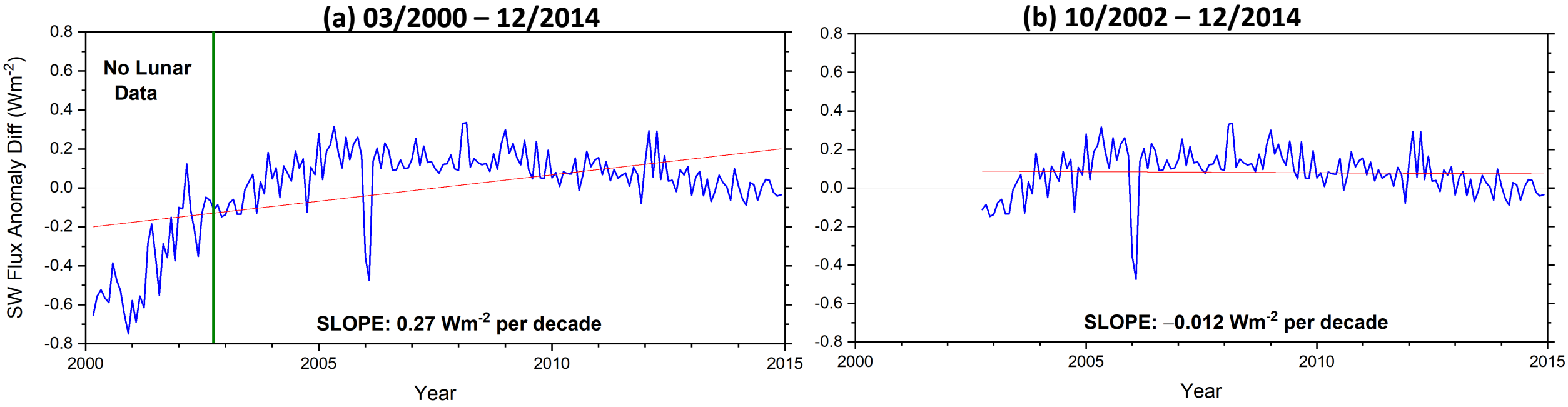
Correspondence to:

Abstract Orbital Earth Radiation Budget measurement comparisons to models, are critical for climate prediction confidence. Satellite systems must reduce calibration drifts for this purpose. NASA Clouds and the Earth's Radiant Energy System (CERES) measures Earth albedo reductions that if correct, would increase solar forcing and suggest greater sunlight absorption is driving much of recent temperature increases. Such results are presented, alongside those from the Moon and Earth Radiation



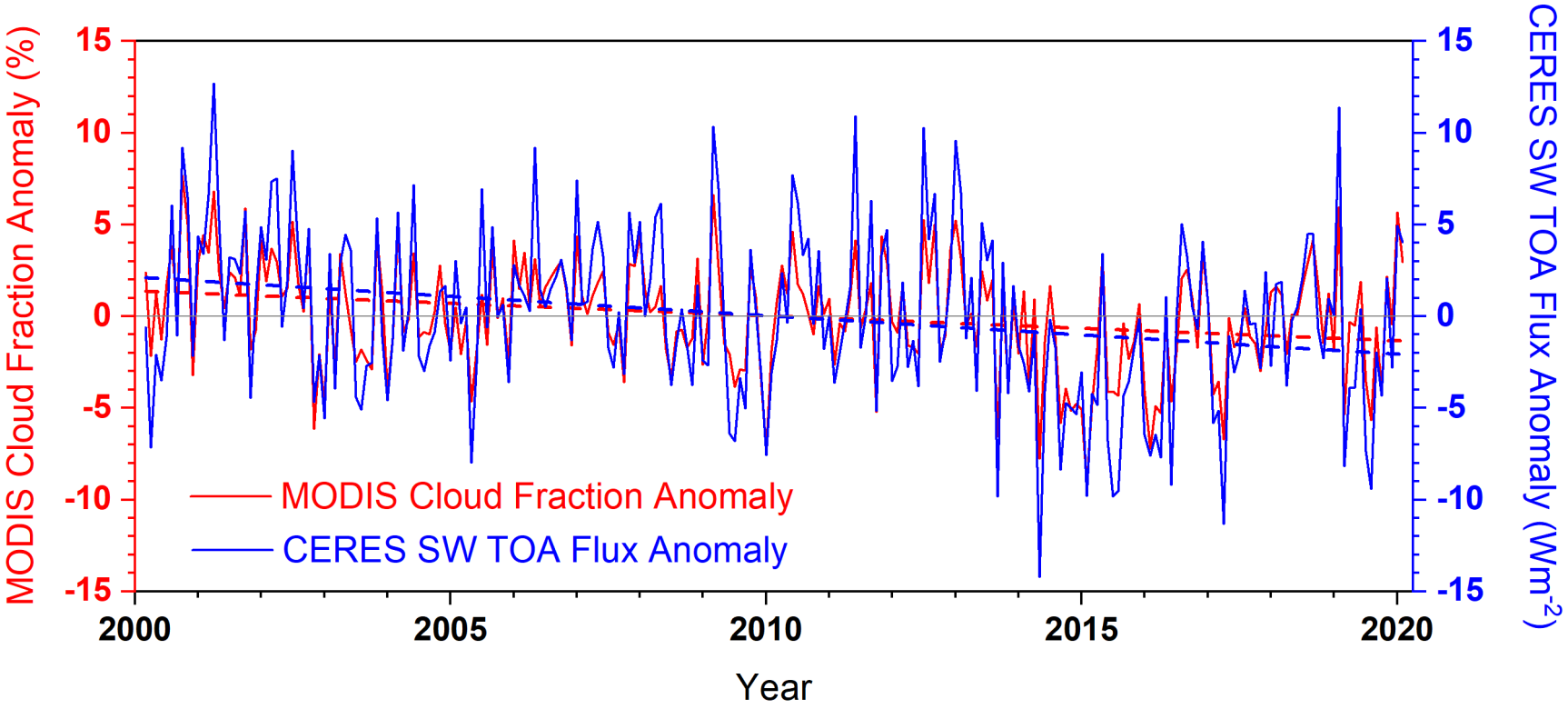
"Moon and Earth Radiation Budget Experiment (MERBE) uses constant lunar reflectivity for tracking and compensation of instrument telescope degradation, undetectable by CERES."

MERBE minus CERES_SSF1deg_Terra SW Flux Anomaly Difference



- **MERBE "corrects" the 15-year trend measured by CERES by making large adjustments during the period prior to CERES lunar scanning (Figure a).**
- **There is no trend difference between MERBE and CERES during the period after CERES lunar scanning began (Figure b).**
  - **MERBE lunar analysis confirms that CERES Terra is stable during the period when CERES lunar scans are available!**

MODIS Cloud Fraction and CERES SW TOA Flux Monthly Anomalies Over Eastern Pacific (10°-40°N, 150°-110°W) (March 2000 – February 2020)

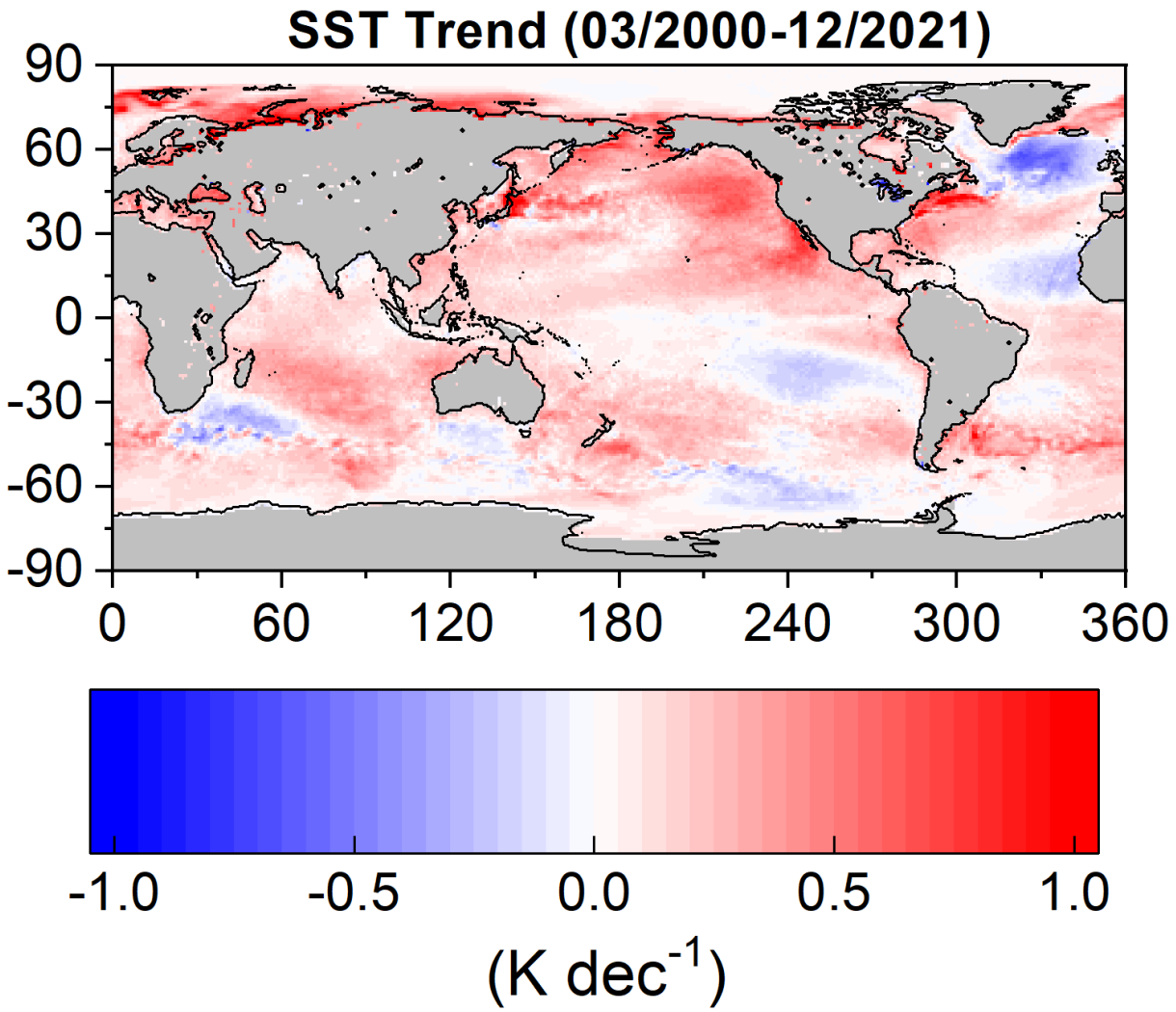


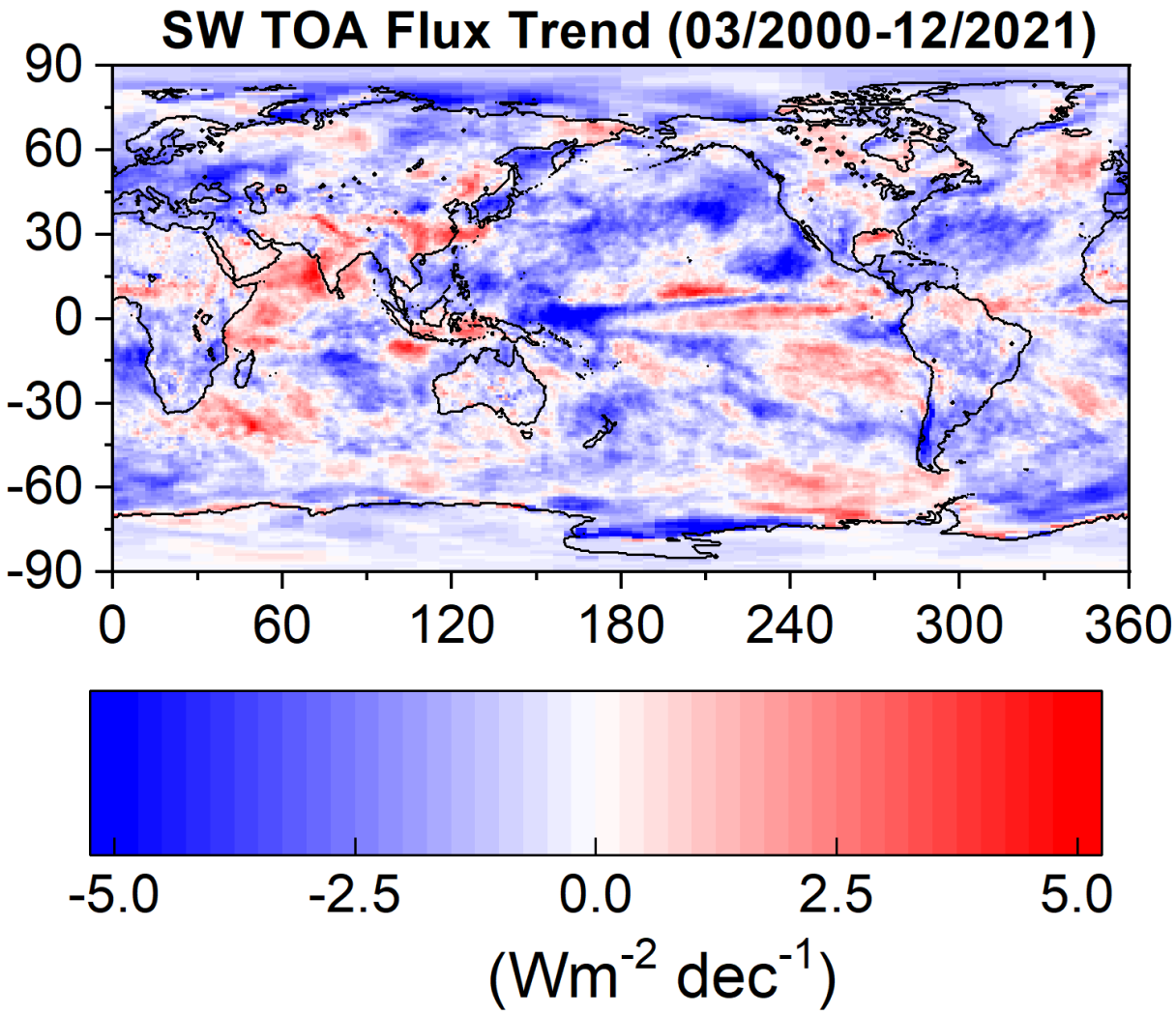
Trends

MODIS Cld frac: -1.4 ± 1.1 %/decade

CERES SW TOA: -2.1 ± 1.6 Wm^{-2}/decade

Loeb et al. JGR, 2022





- Negative reflected SW TOA flux trends often found in regions with positive SST trends