Changes in Earth's Radiation Budget Since 2000 Observed by CERES

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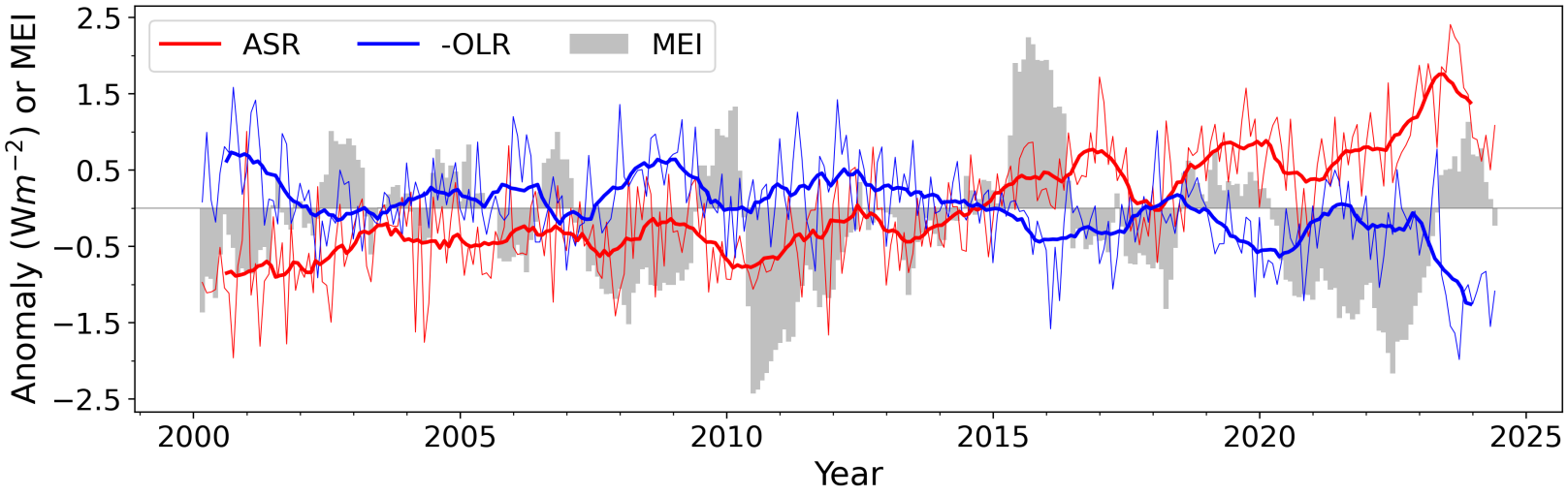
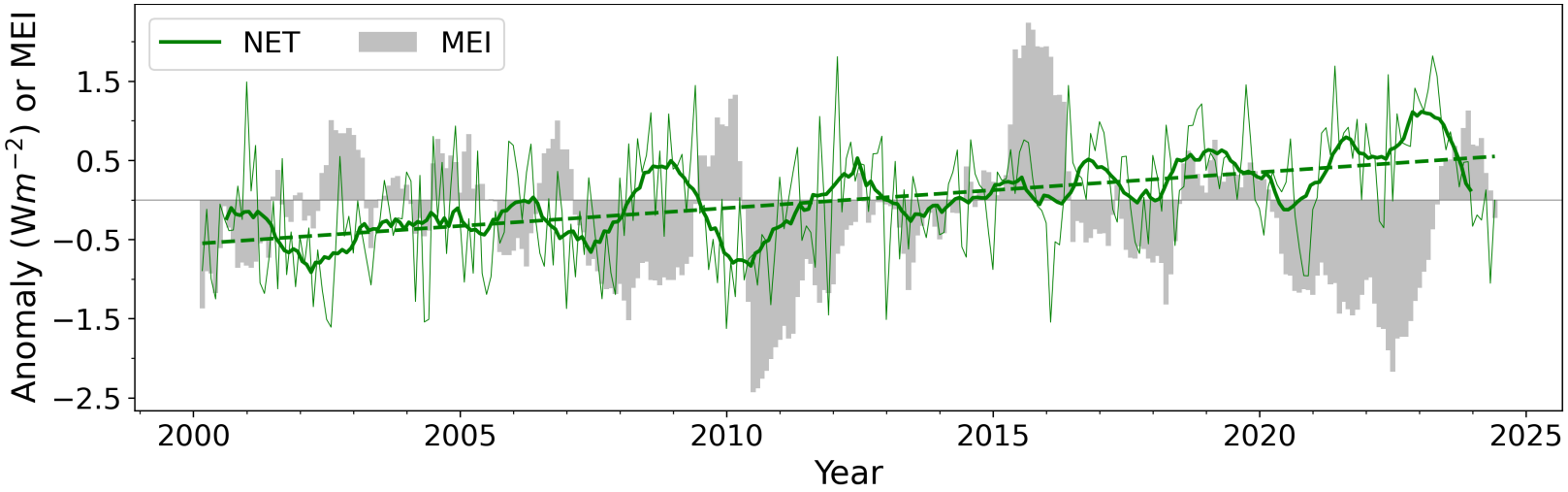
NASA Langley Research Center, Hampton, VA

American Geophysical Union Fall Meeting, December 12, 2024, Washington, DC

Global Mean All-Sky TOA Flux Anomalies (CERES EBAF Ed4.2; 03/2000–06/2024)





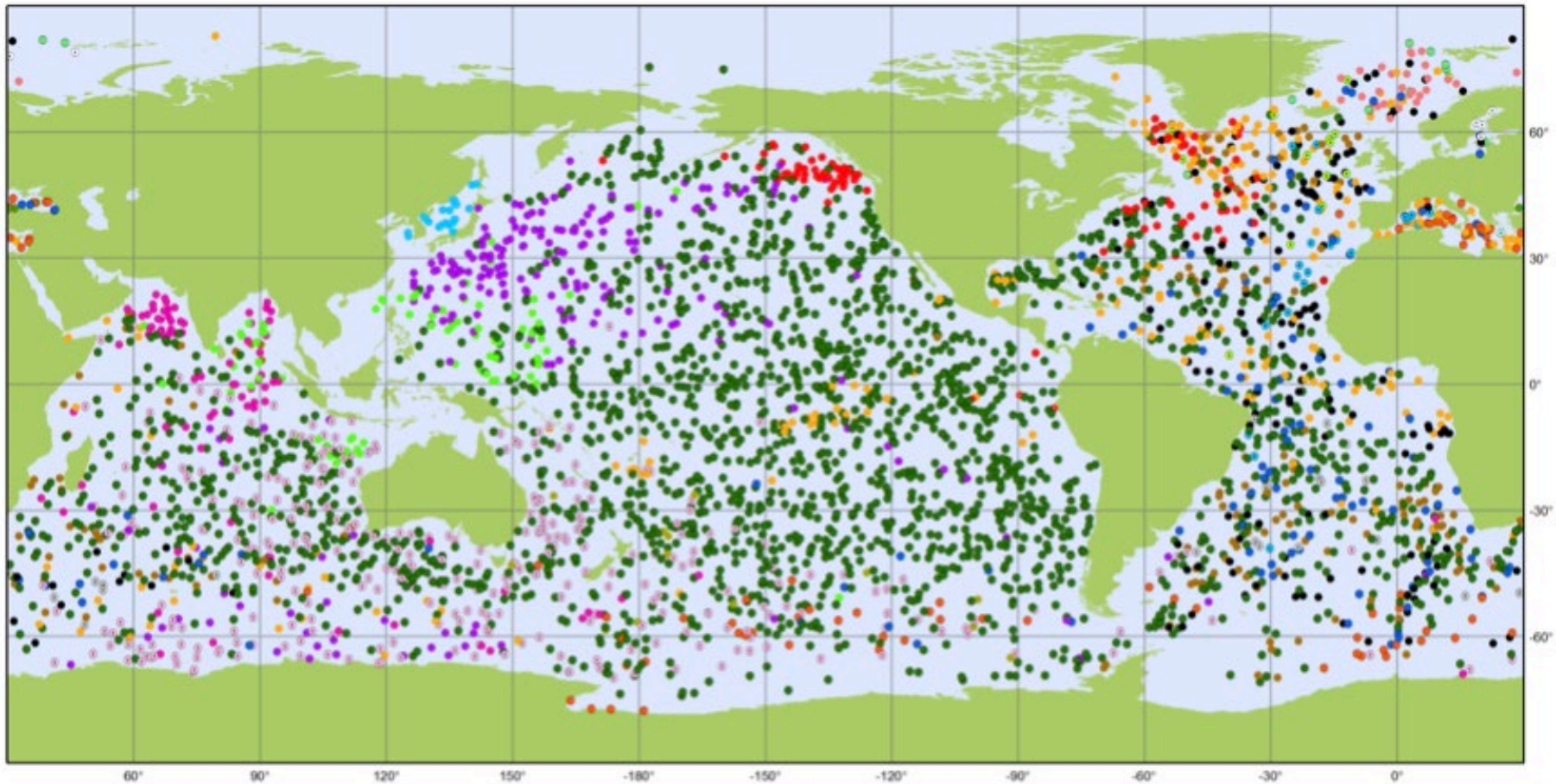
Trends (Wm^{-2} per decade; 2.5-97.5% CI)

ASR: 0.81 ± 0.21

–OLR: –0.36 ± 0.20

NET: 0.45 ± 0.18

Argo Ocean Profiling Network



Argo

National contributions - 3918 Operational Floats

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

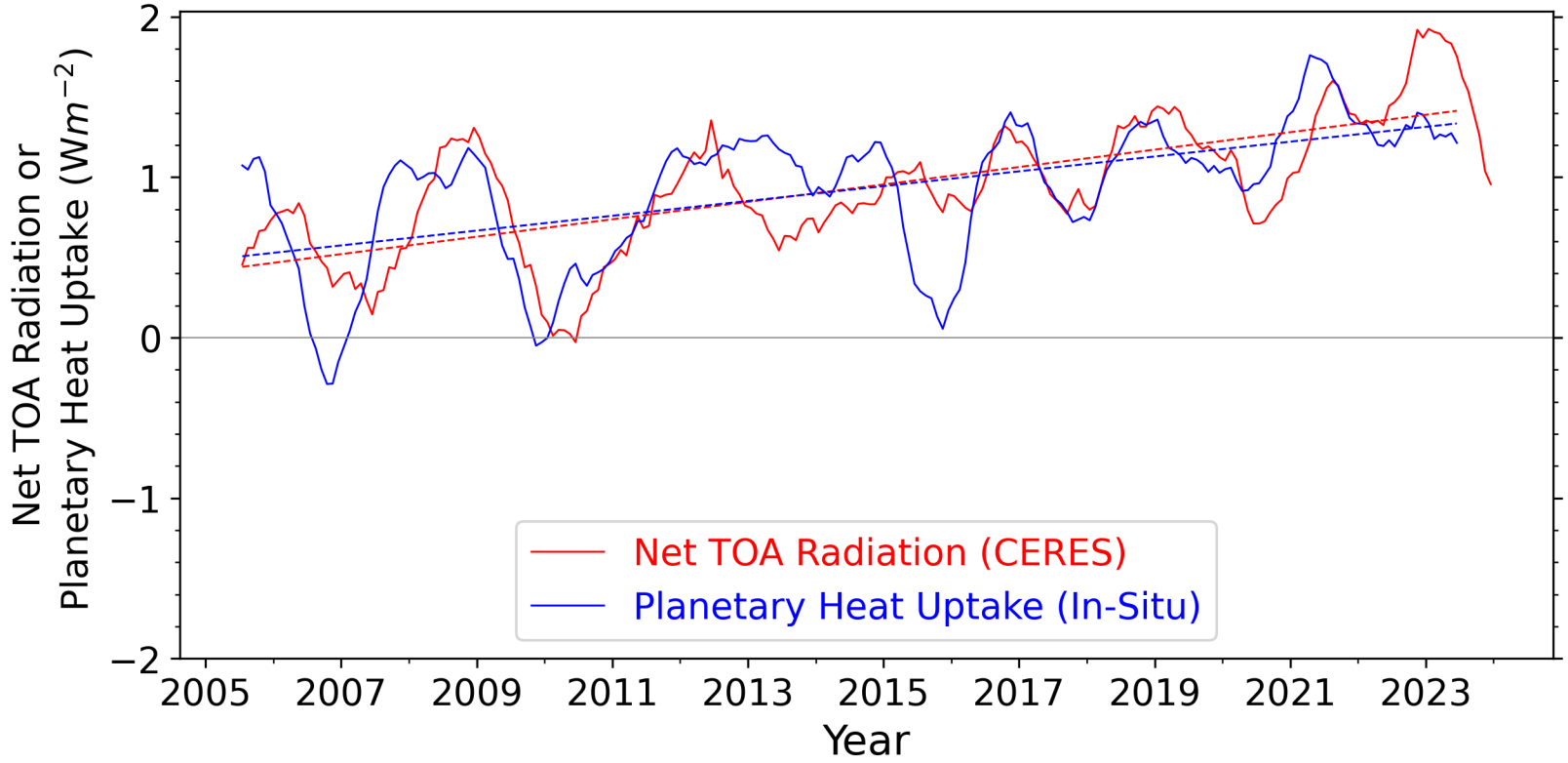
February 2021

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

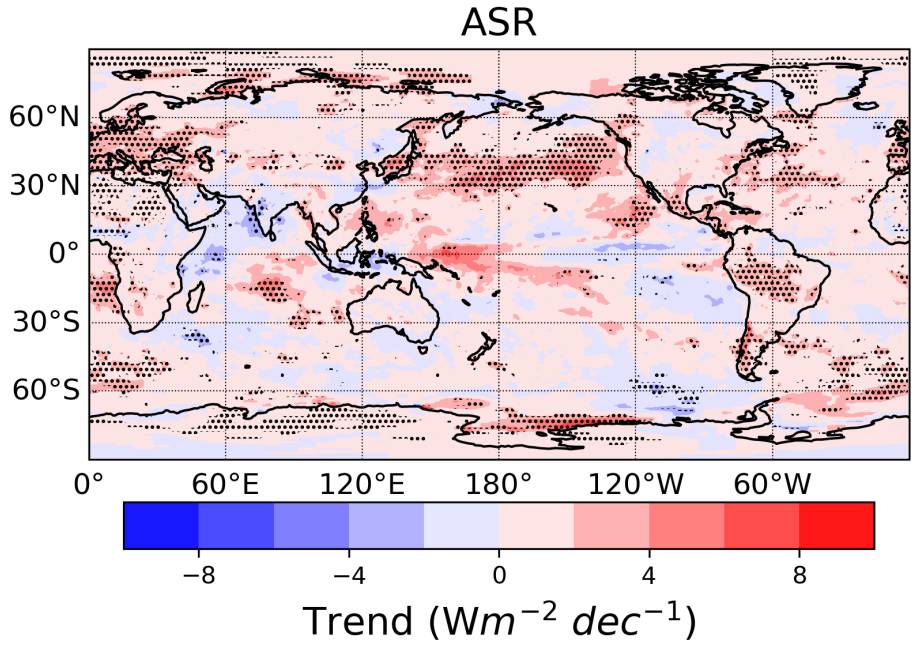
Annual Mean Net TOA Radiation & In-Situ Planetary Heat Uptake

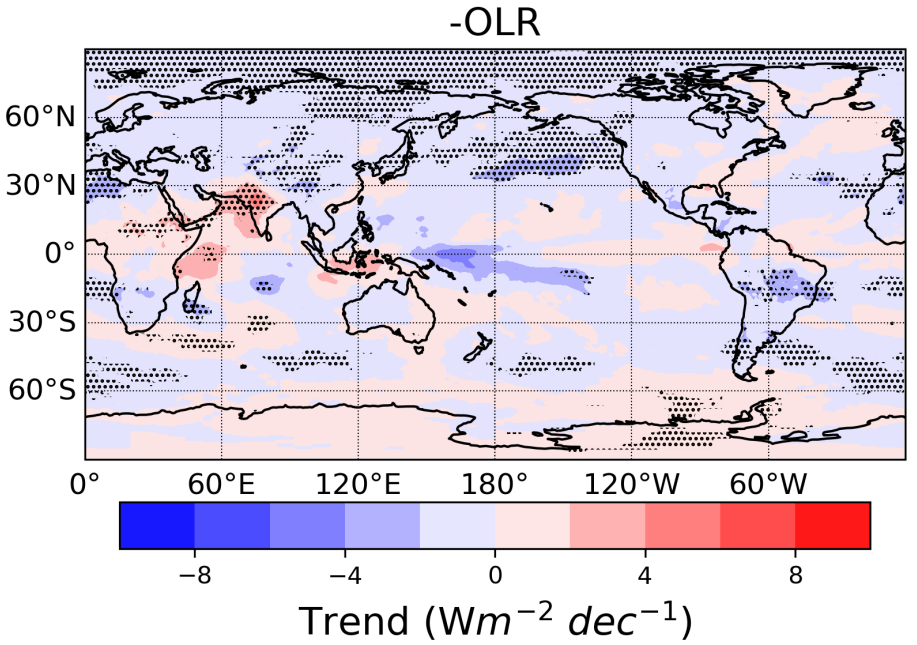
(CERES 02/2005-06/2024; In situ: 02/2005-12/2023)

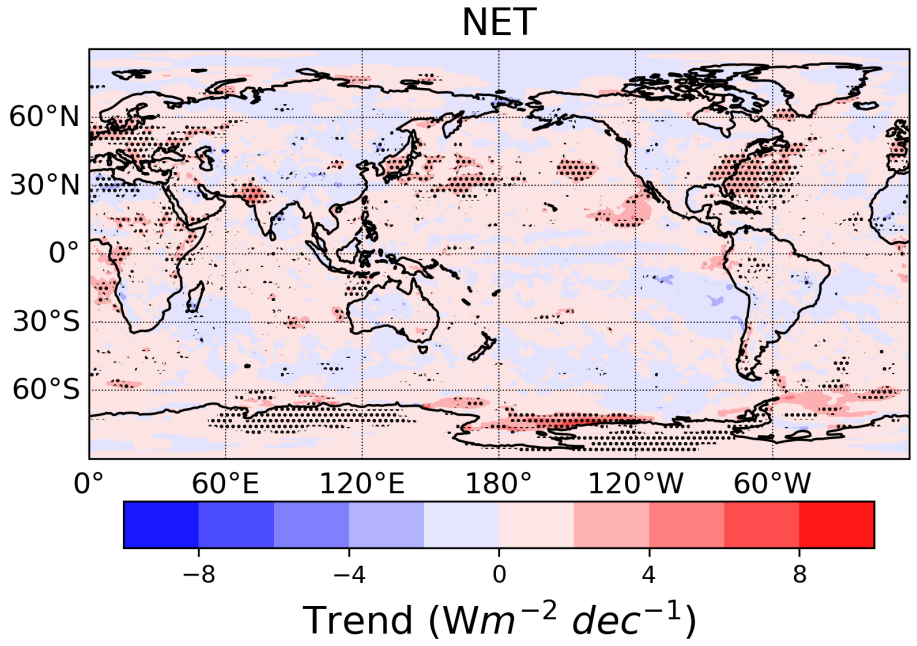


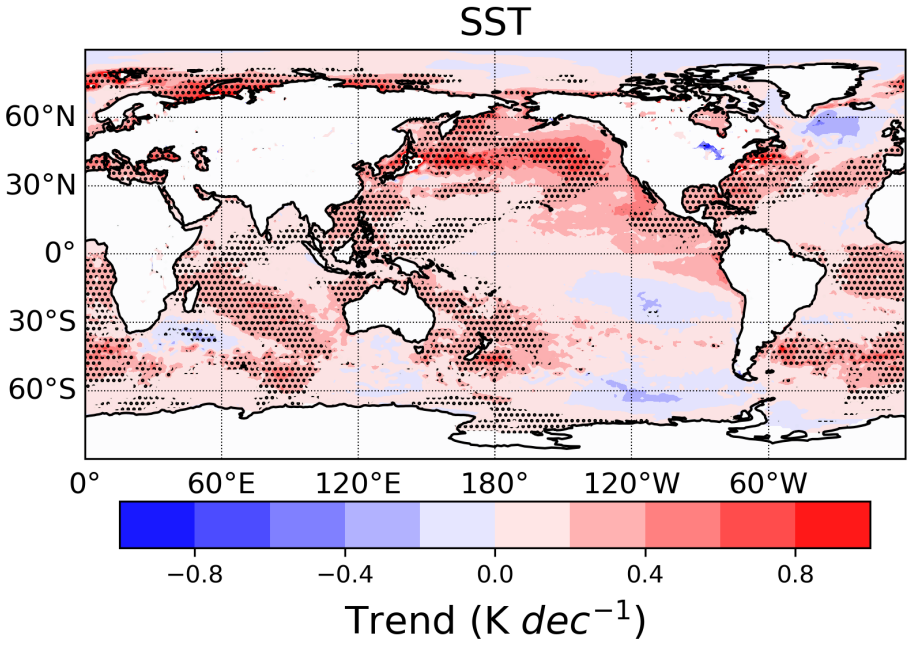
	Trend (Wm^{-2} dec^{-1}) 02/2005-12/2023
CERES EBAF Ed4.2	0.54 ± 0.28
In-Situ	0.46 ± 0.35
Difference	0.08 ± 0.30
R	0.68

Regional Trends in TOA Radiation and SST (03/2000–06/2024)

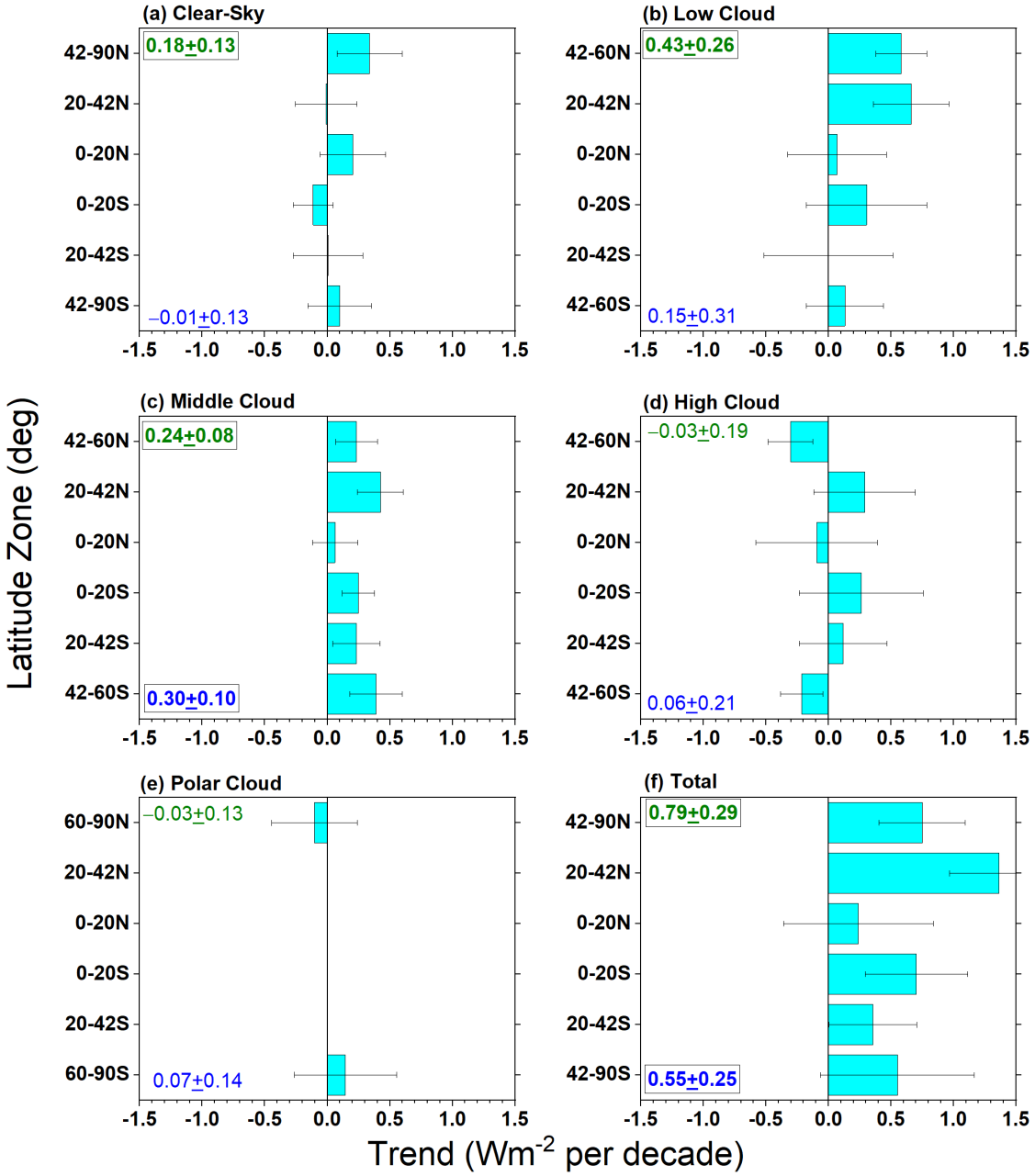








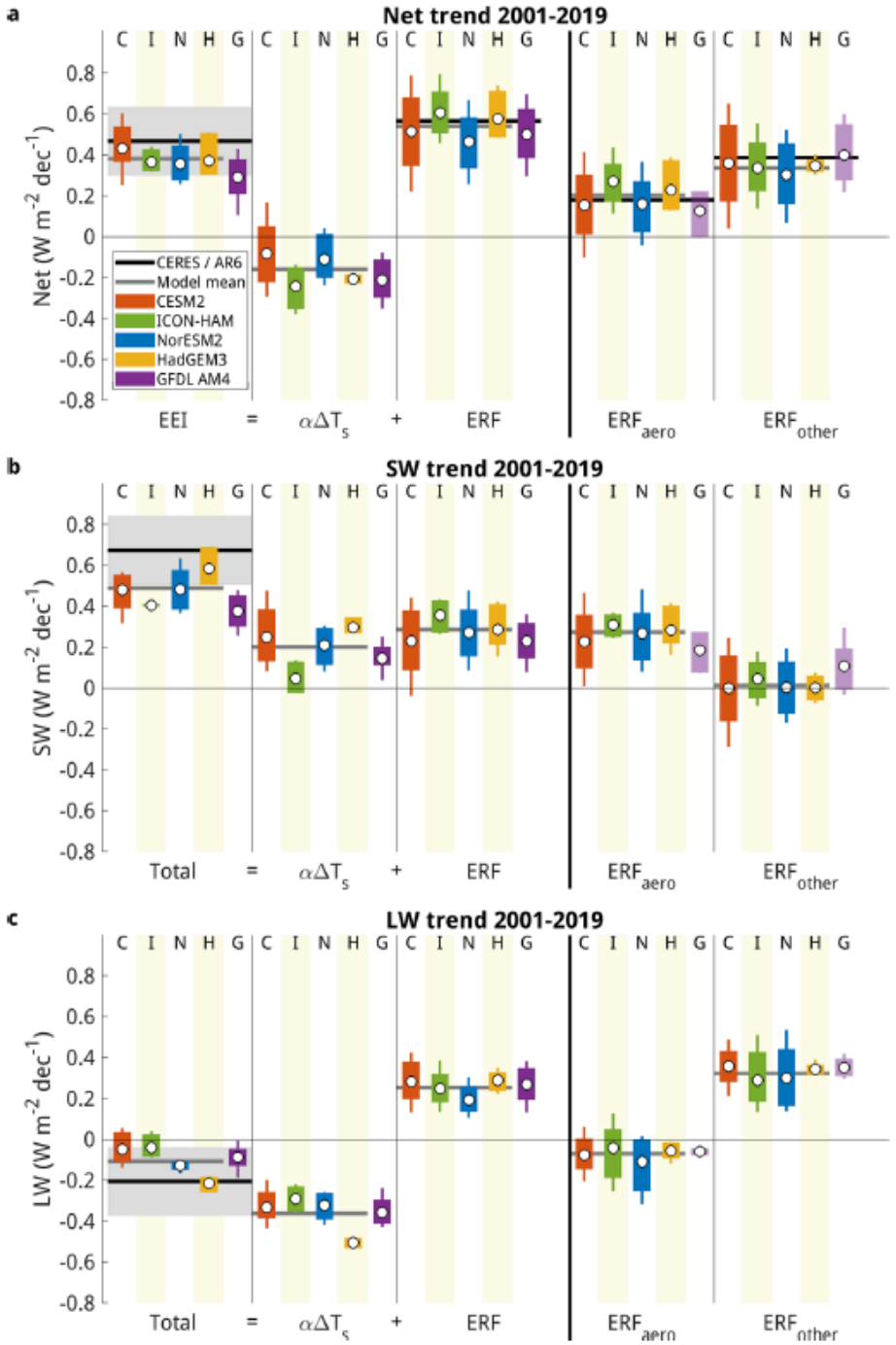
Zonal Mean Trends in □SW by Cloud Type (07/2002-12/2022)



Increase in –SW is associated with decreases in stratocumulus and middle cloud fraction and reflection in the Northern Hemisphere and decreases in middle cloud reflection in the Southern Hemisphere.

CERES EEI Trend Attribution

- CMIP6 AMIP Simulations
- Forcing-feedback framework

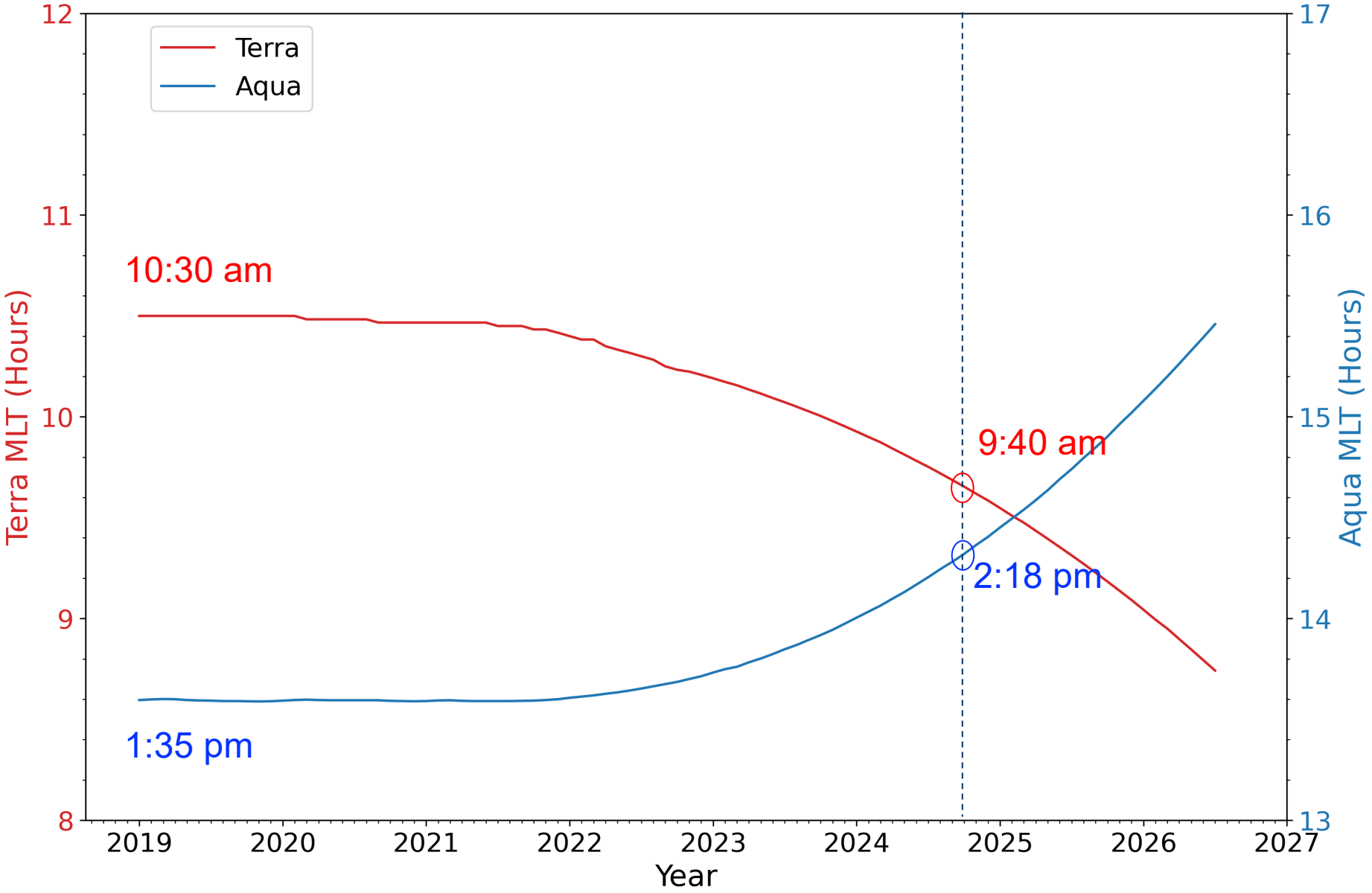


Key Points

- CMIP6 EEI trend consistent with CERES within uncertainty
- ERF contribution dominates (WMGG, aerosols)
- Large CERES ASR trend due to additive positive ERF and feedback contributions
- Models suggest large aerosol forcing
- Weaker OLR trend due to cancelation between positive ERF and negative feedback contributions

Hodnebrog et al., Nature Comm Earth & Environ, 2024

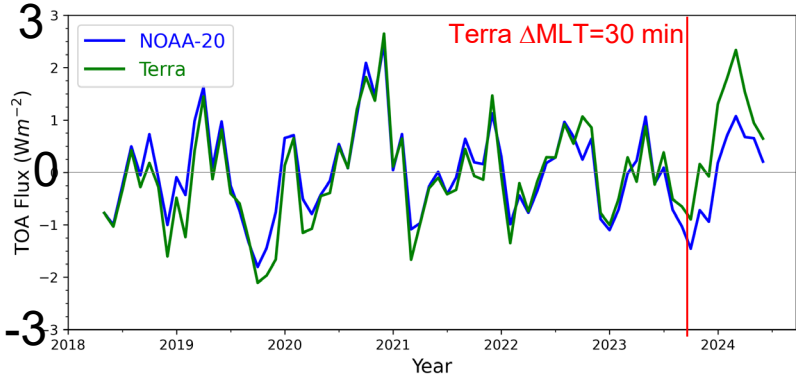
Terra and Aqua Mean Local Equatorial Crossing Times (MLTs)



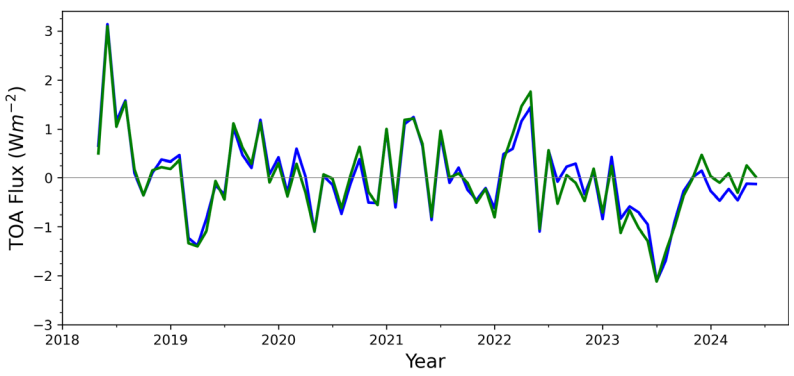
- **MLT updates available at: https://terra.nasa.gov & https://aqua.nasa.gov**

SW TOA Flux Anomalies for NOAA-20 (Fixed MLT) and Terra (Drifting MLT)

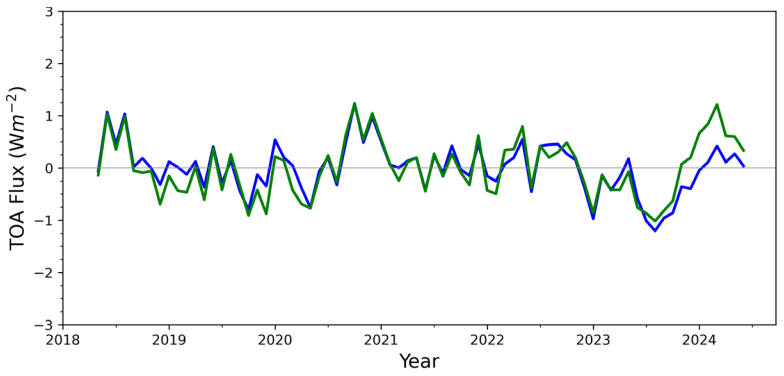
SH SW Anomalies



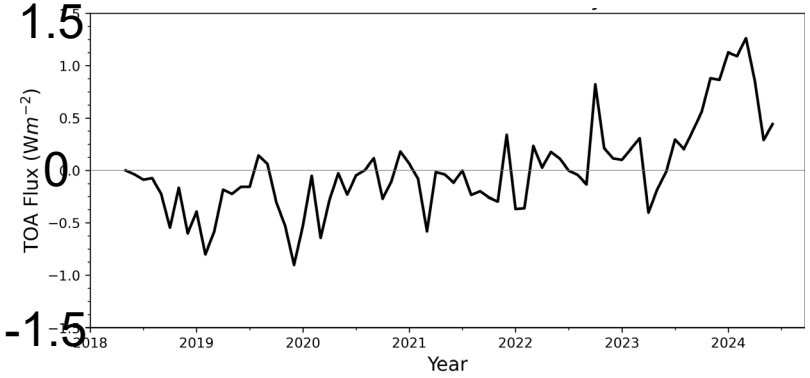
NH SW Anomalies



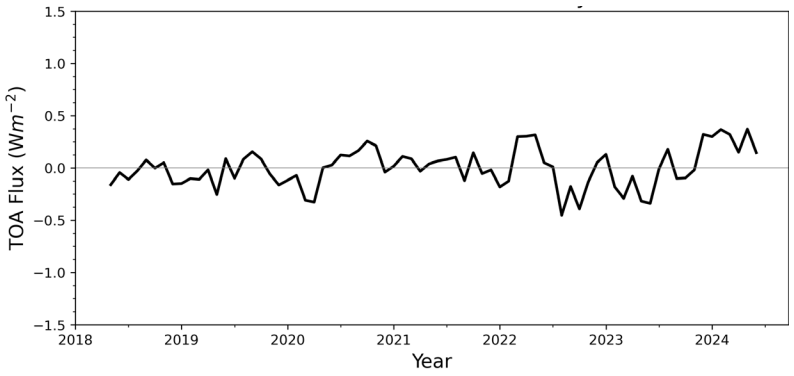
Global SW Anomalies



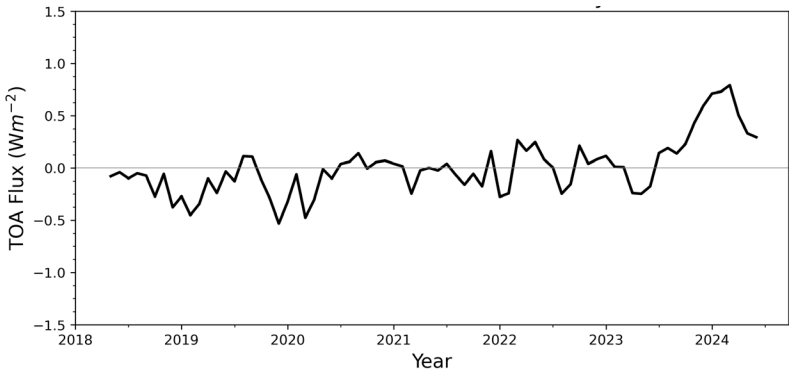
SH Ter-N20 SW Anomaly Diff



NH Ter-N20 SW Anomaly Diff

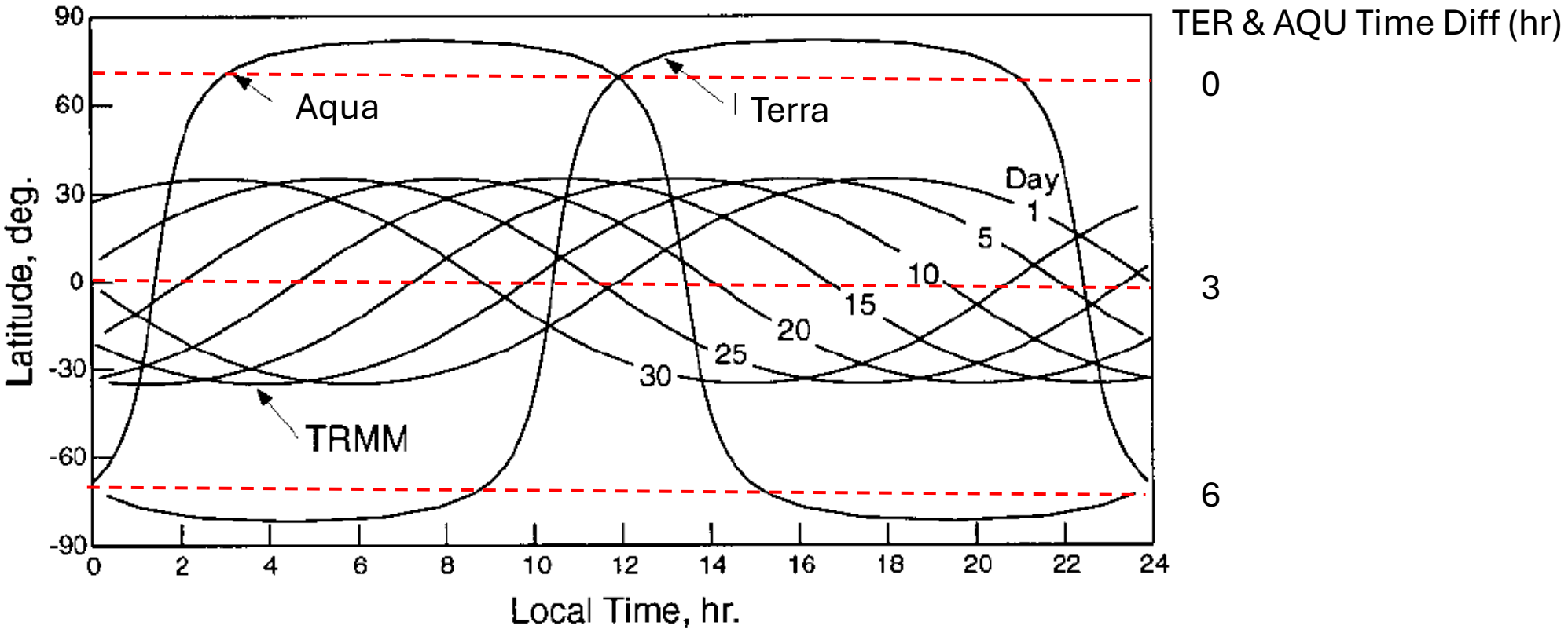


Global Ter-N20 SW Anomaly Diff



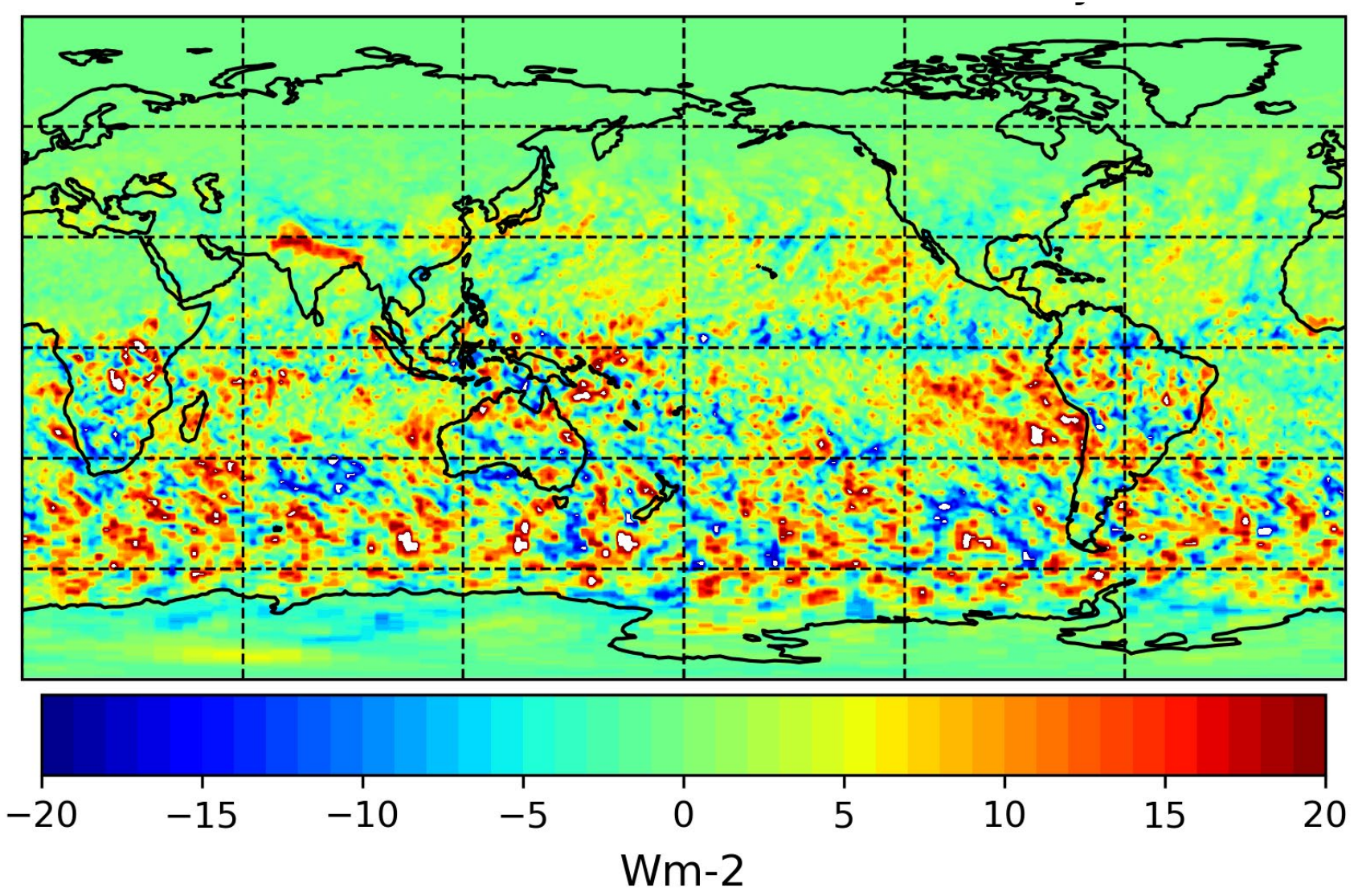
- Large Terra minus NOAA-20 SW anomaly difference in SH but not in NH. Why?

Temporal Coverage of Terra, Aqua and TRMM



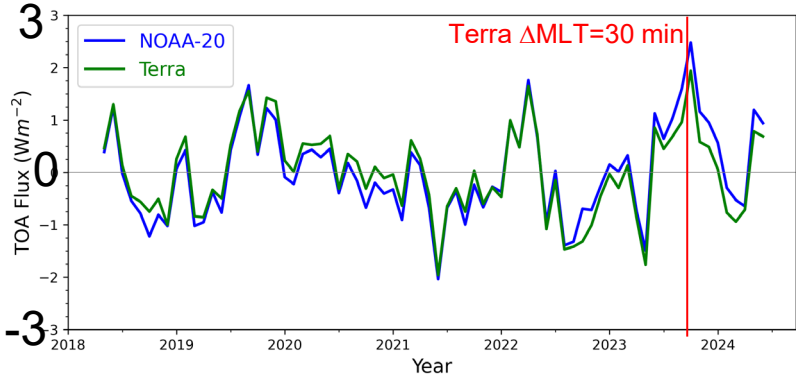
- Time separation between Terra and Aqua ground tracks is greater in SH than NH

Terra minus NOAA-20 SW TOA Flux Anomaly Difference (January 2024)

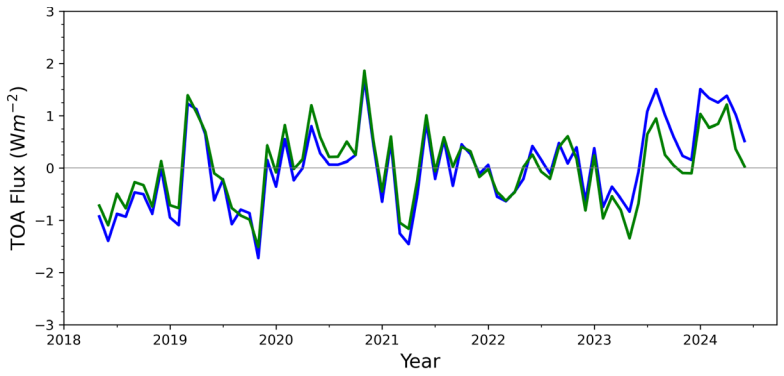


LW TOA Flux Anomalies for NOAA-20 (Fixed MLT) and Terra (Drifting MLT)

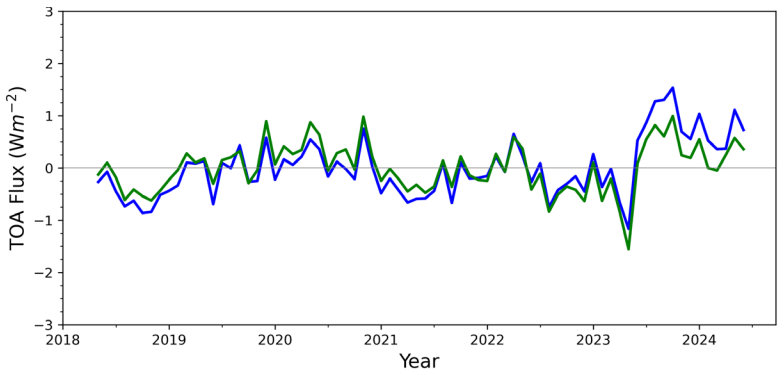
SH LW Anomalies



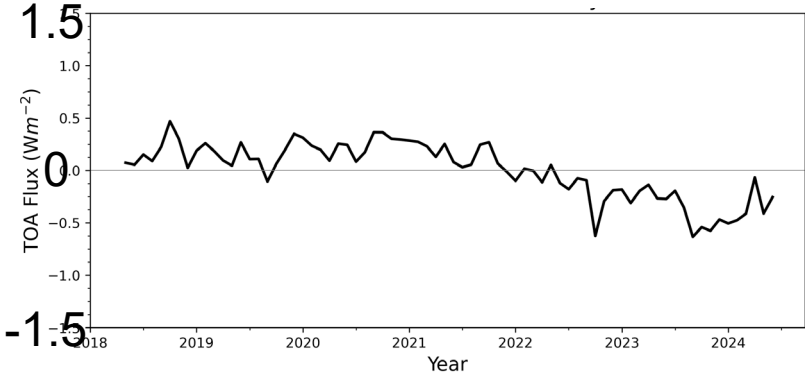
NH LW Anomalies



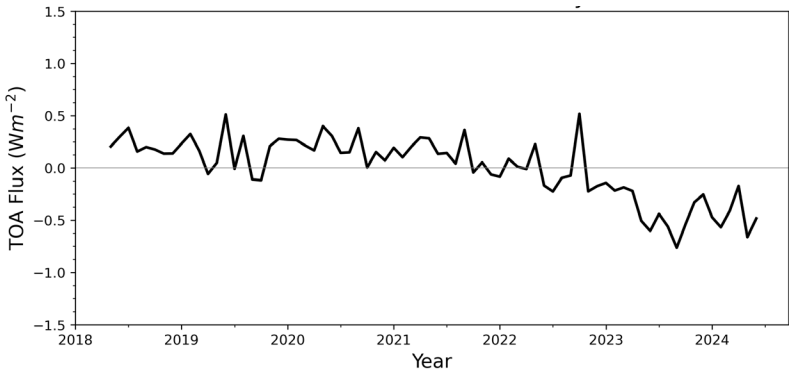
Global LW Anomalies



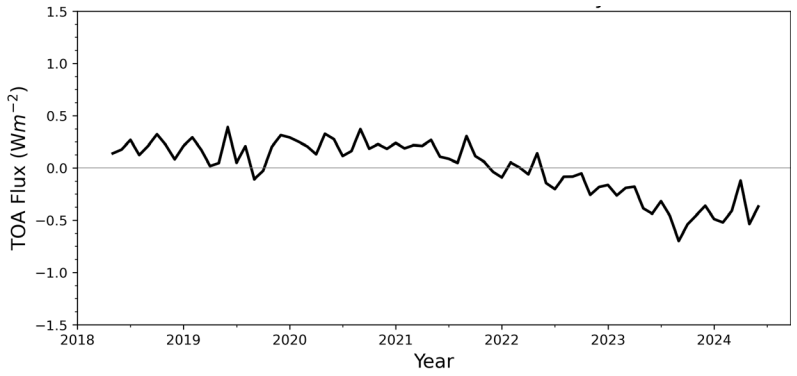
SH Ter-N20 LW Anomaly Diff



NH Ter-N20 LW Anomaly Diff

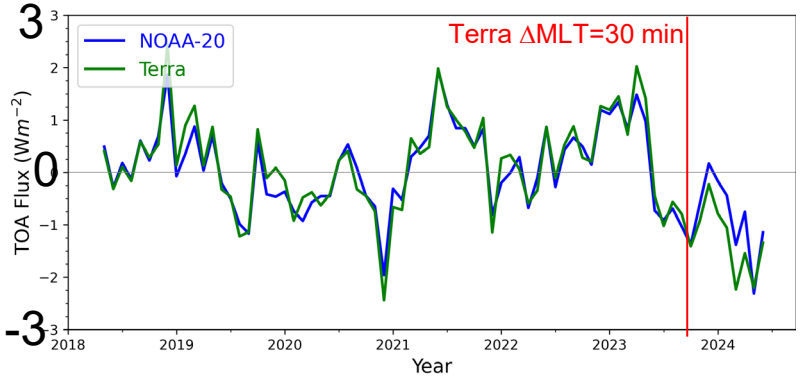


Global Ter-N20 LW Anomaly Diff

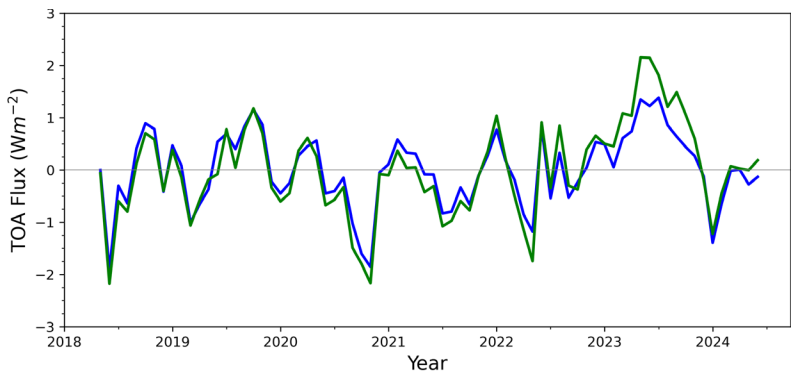


NET TOA Flux Anomalies for NOAA-20 (Fixed MLT) and Terra (Drifting MLT)

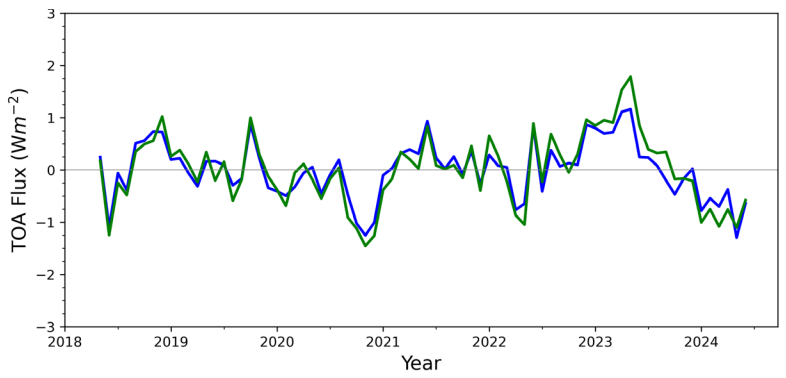
SH NET Anomalies



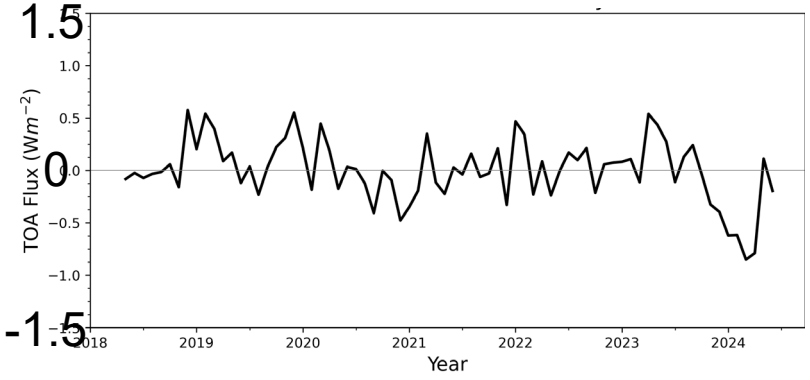
NH NET Anomalies



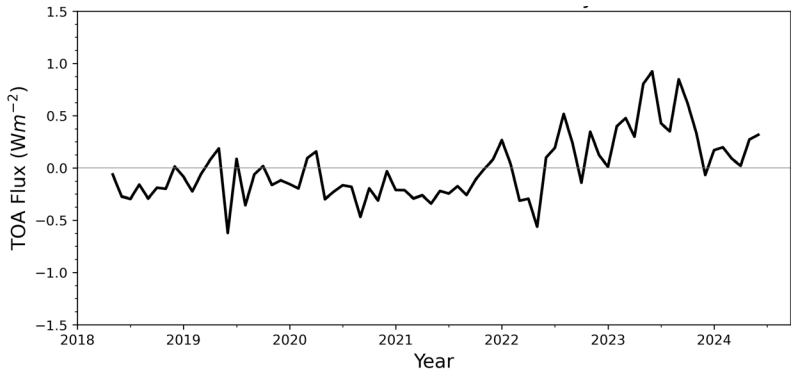
Global NET Anomalies



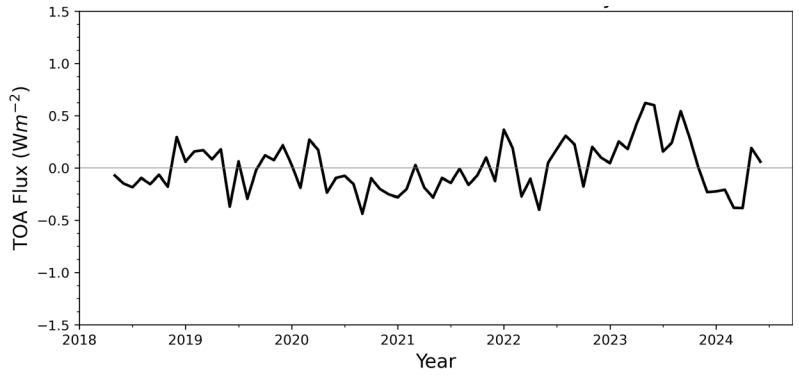
SH Ter-N20 NET Anomaly Diff



NH Ter-N20 NET Anomaly Diff



Global Ter-N20 NET Anomaly Diff



Conclusions

- The remarkable longevity of Terra (and Aqua) CERES has revealed an alarming doubling in Earth's energy imbalance.
  - Additional heating leads to further increases in ocean heating, snow & ice melt, sea level, global mean surface temperature and atmospheric moisture
- Attribution of these changes still an active area of research
  - Combined CERES & MODIS observations show key role of clouds
  - Climate model simulations also show increasing trend in EEI. Highlight important role of aerosol-cloud interactions
- Impact of Terra orbital drift clearly evident
  - Compared to fixed-MLT NOAA-20
  - Terra nicely captures diurnal cycle of marine low cloud in southern hemisphere