CERES TOA Flux Trends by Cloud Type

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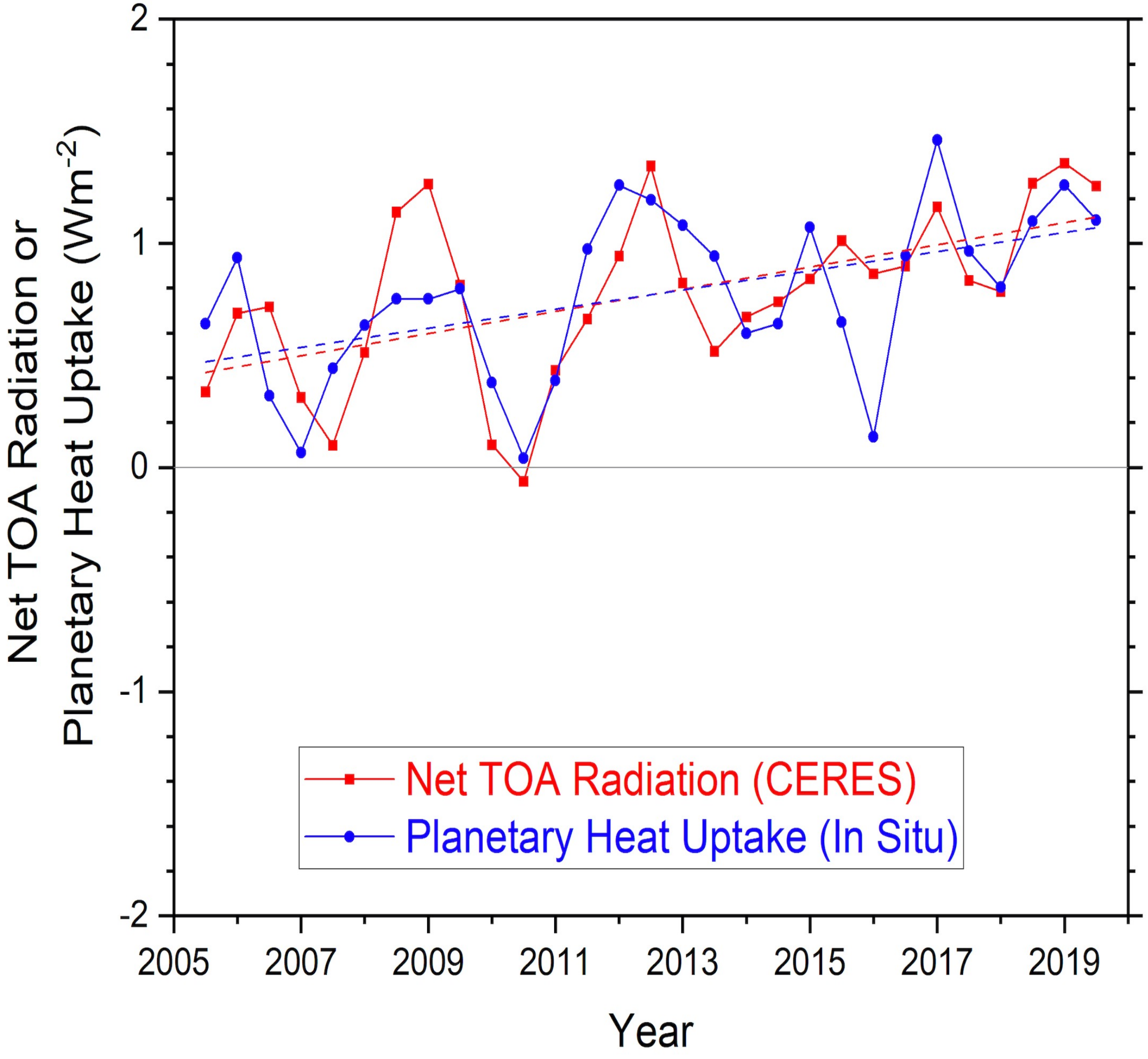
CERES Science Team Meeting, April 26-28, 2022

Virtual Meeting

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

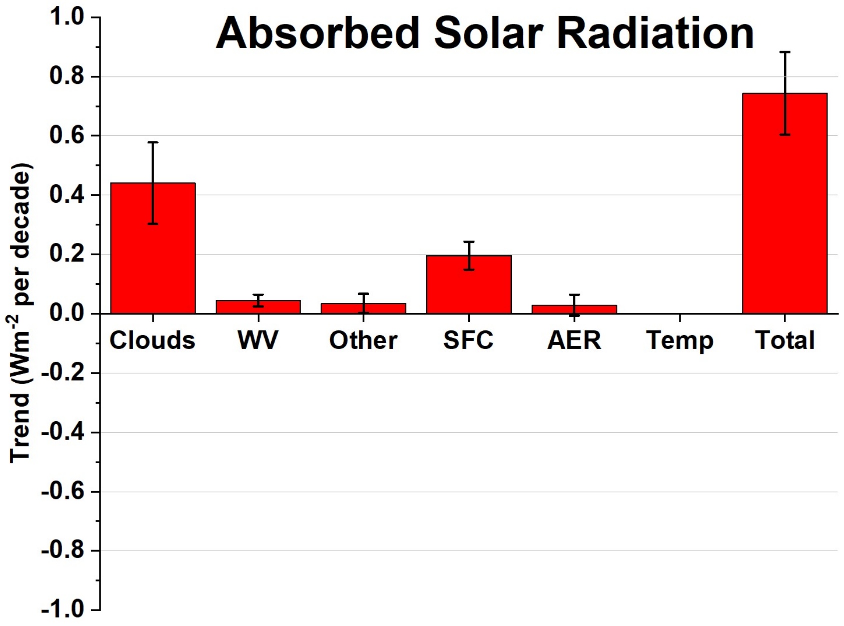
Trend Diff : 0.07 ± 0.29

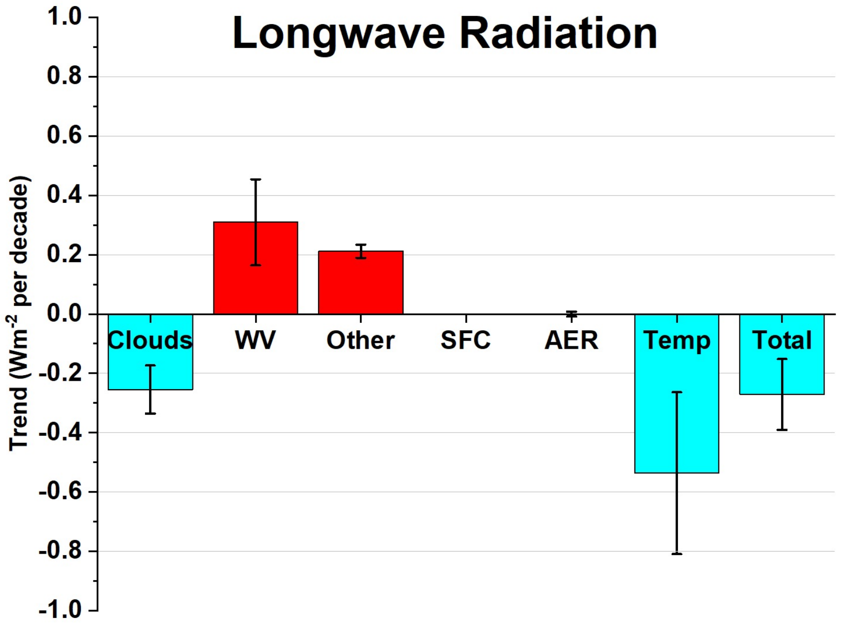
R^2 = 0.49

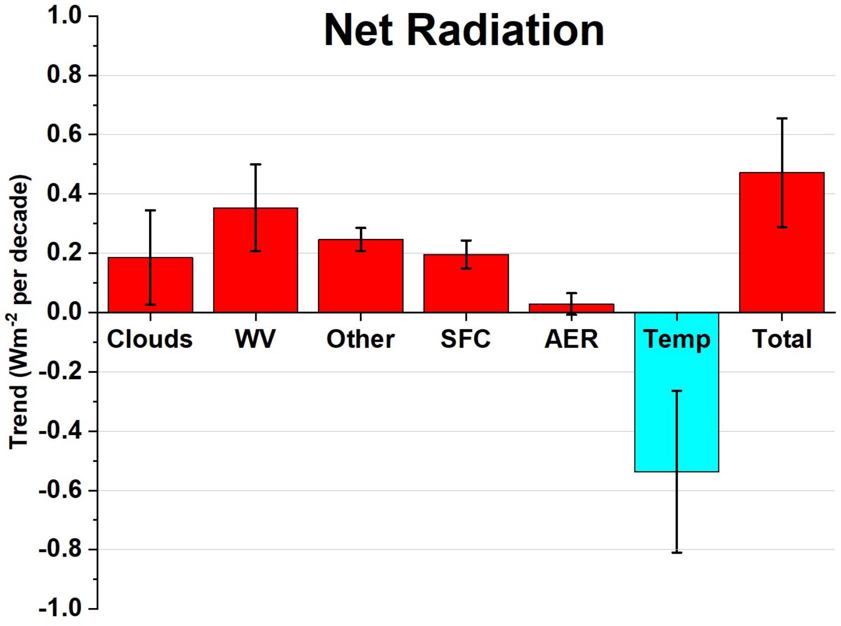
Note: CERES and Argo+Altimeter are anchored to an EEI of 0.76±0.1 Wm^{-2} for 2005-2020 based upon in-situ data.

Loeb et al. (GRL; 2021)

Trend Attribution (Jan-Dec; Global) for 09/2002–03/2020

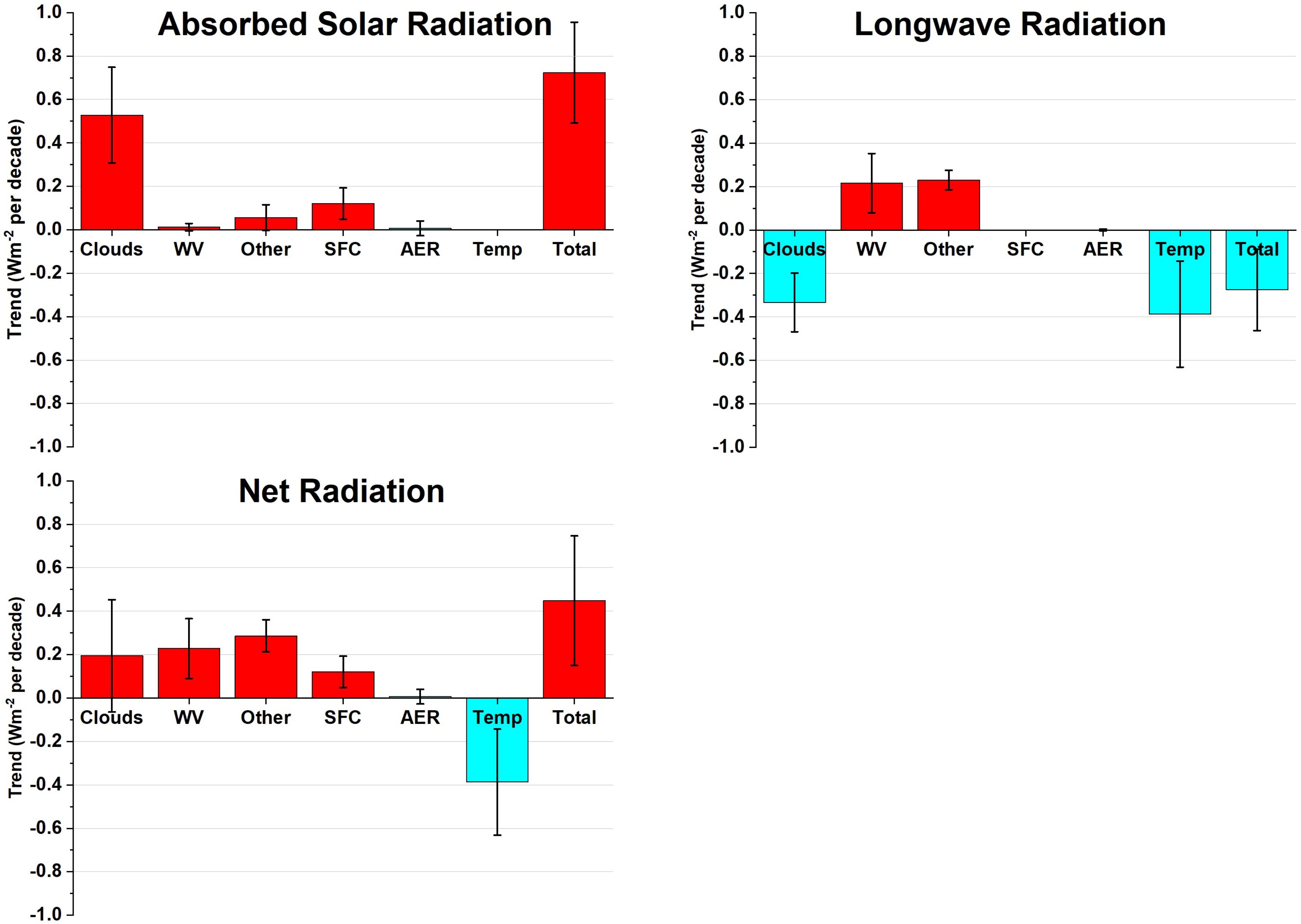




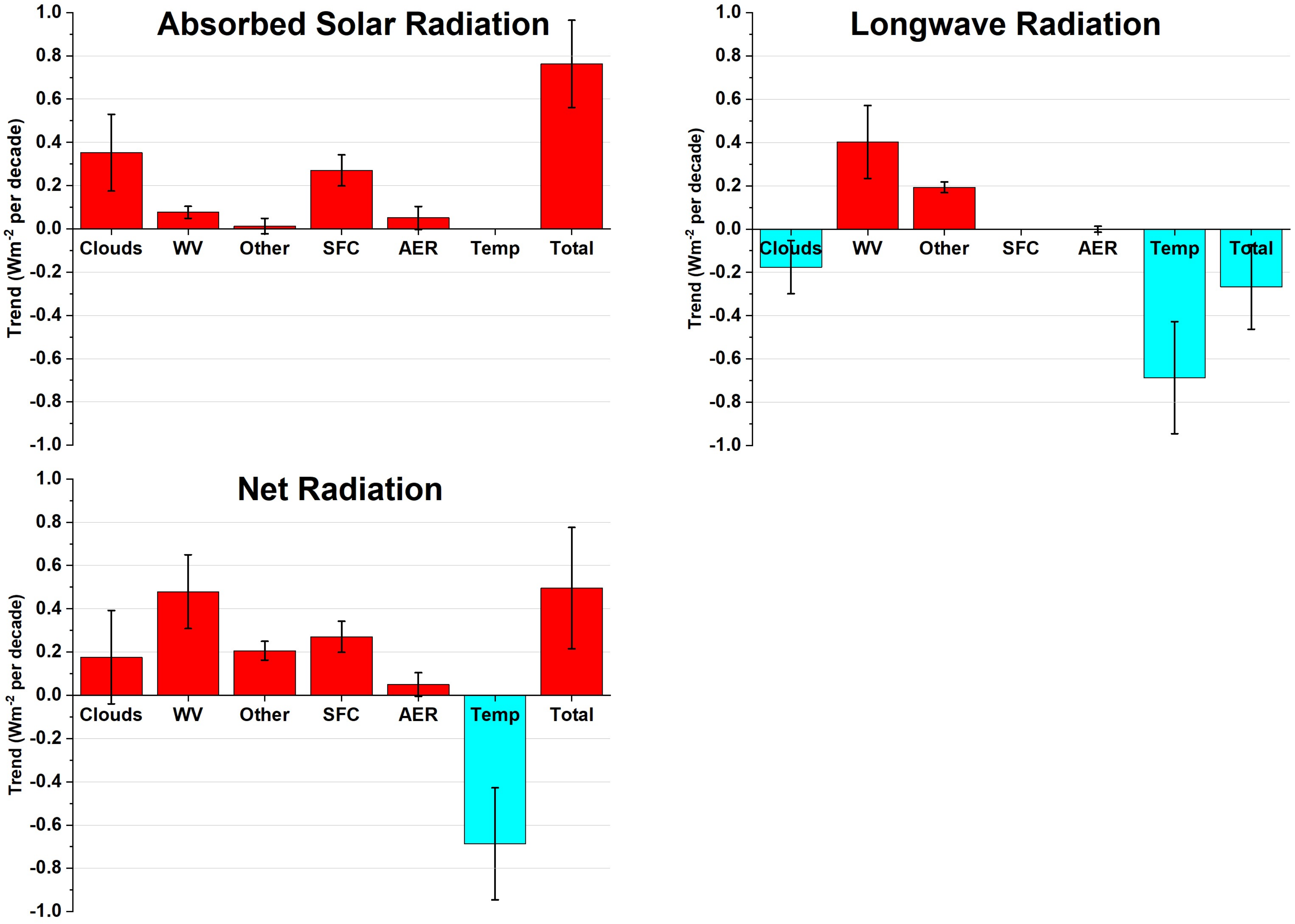


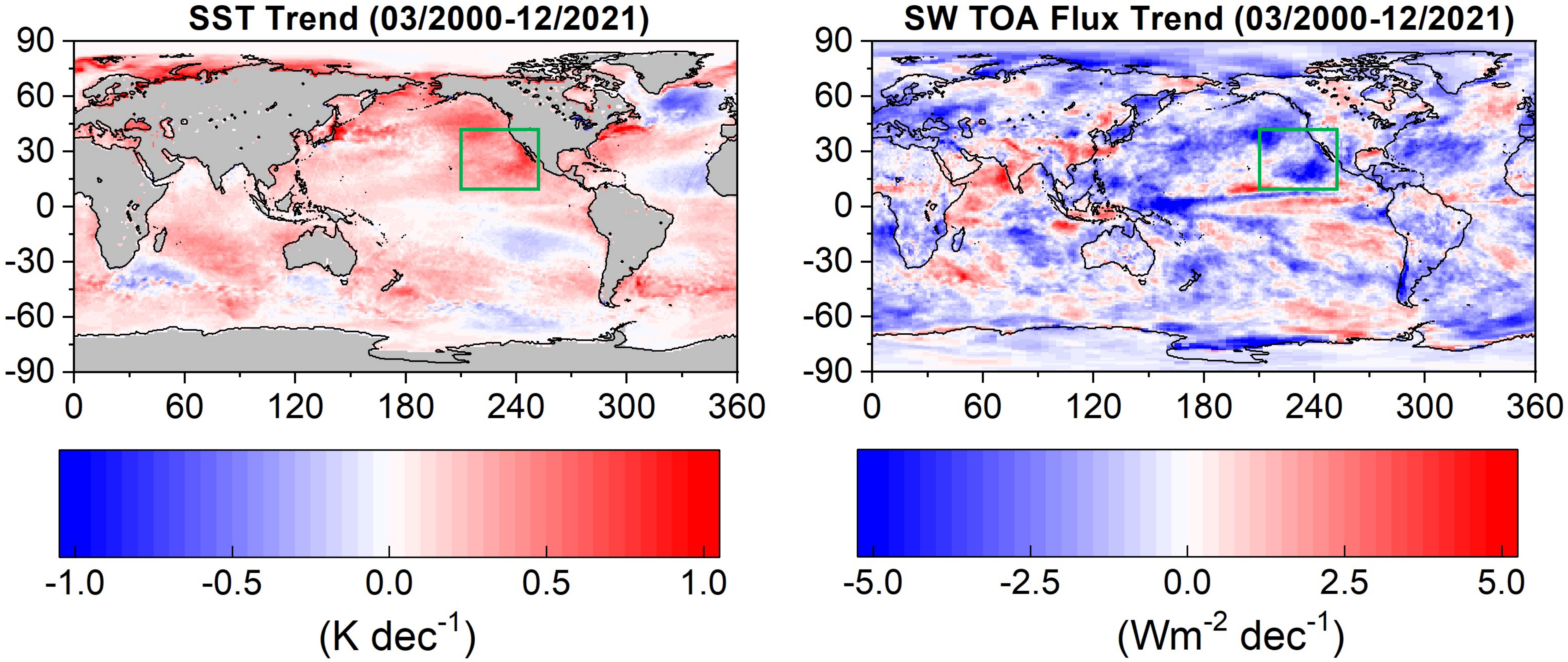
- ASR trend mainly due to cloud and surface albedo changes.
- Combined changes in clouds, sea-ice, WV and trace gases exceed influence from temperature changes, resulting in a positive overall trend in net TOA flux.

Trend Attribution (Jan-Dec; SH) for 09/2002–03/2020



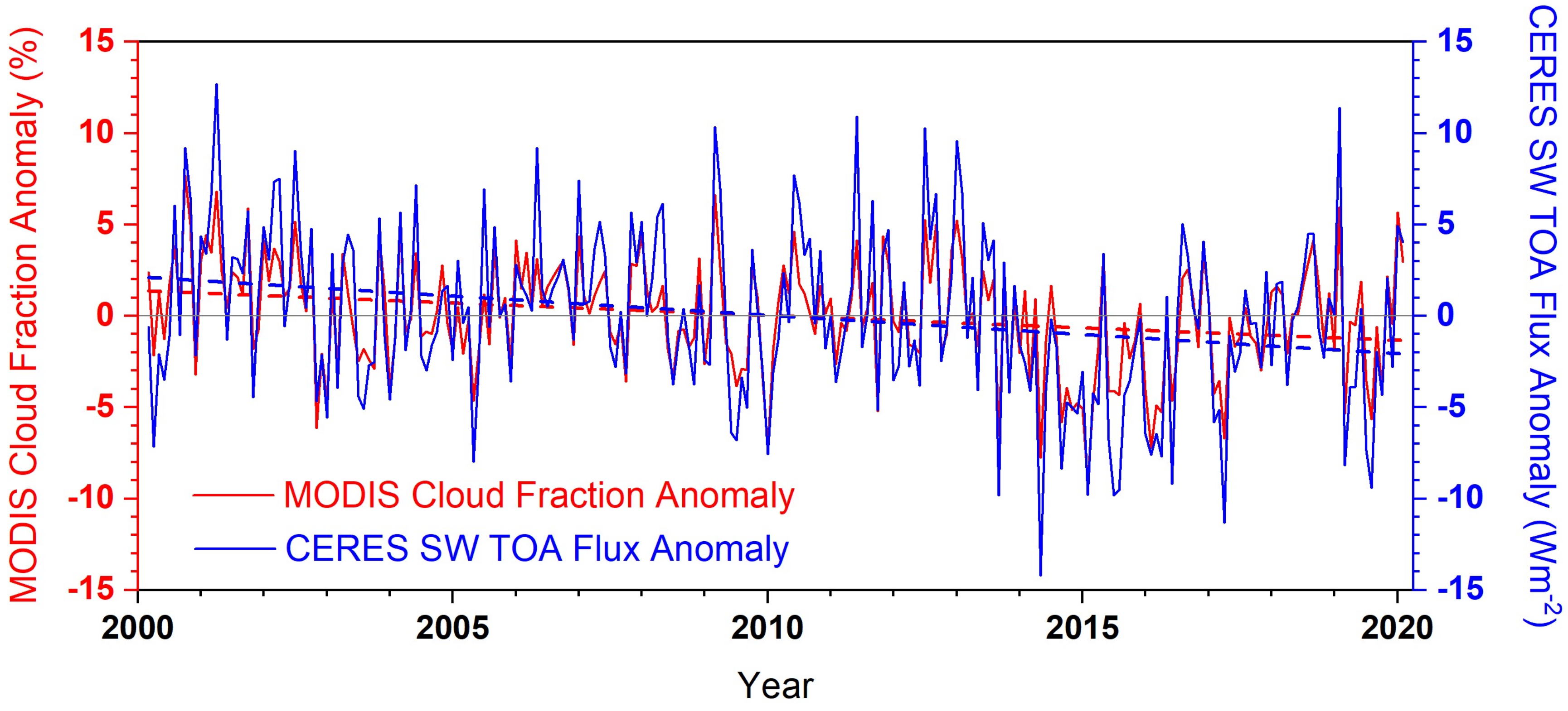
Trend Attribution (Jan-Dec; NH) for 09/2002–03/2020





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

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



Trends

MODIS Cld frac: -1.4 ± 1.1 %/decade

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

Figure S1 Anomalies in MODIS cloud fraction and CERES SW TOA flux for a region over the Eastern Pacific (10°-40°N, 150°-110°W) for 03/2000-02/2020.

Loeb et al. JGR, 2022 (in press)

Motivation for Study

Use the FluxbyCldType product to determine what cloud types contributed most to the cloud trends in each hemisphere

Methodology

1) Determine meteorology by cloud type:

- Read in meteorological variables (EIS, T_{skin}) in SSF1deg-daily for one month.
- Sort and average meteorology by cloud type categories in FluxbyCldTyp-daily files to produce monthly meteorology by cloud type (6 cloud optical depth, 7 cloud-top pressure).

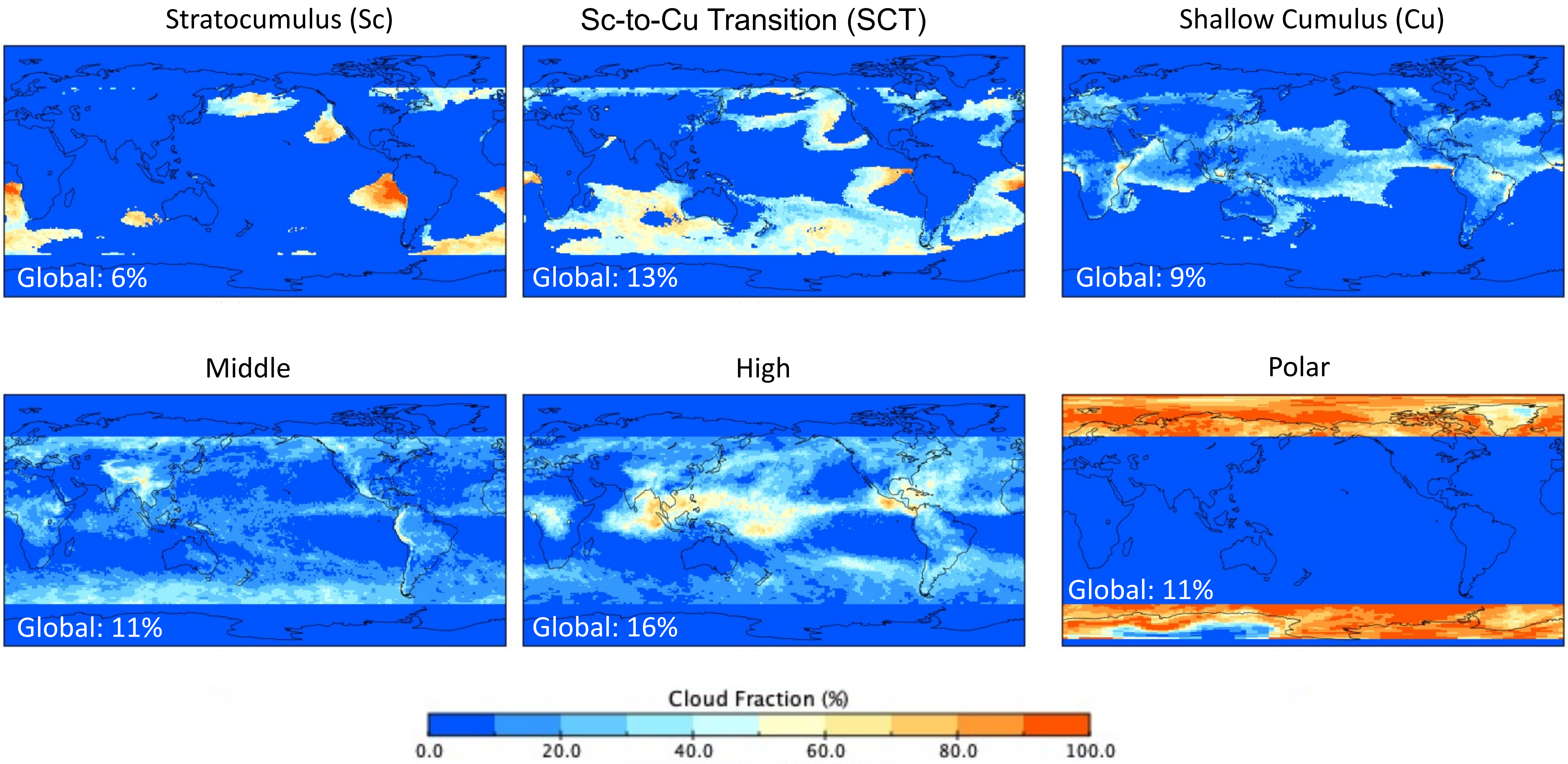
2) Determine flux by cloud class:

- Read in monthly meteorology by cloud type from step 1.
- For each gridbox, determine overall cloud fraction and mean SW TOA flux contribution for the following cloud classes:

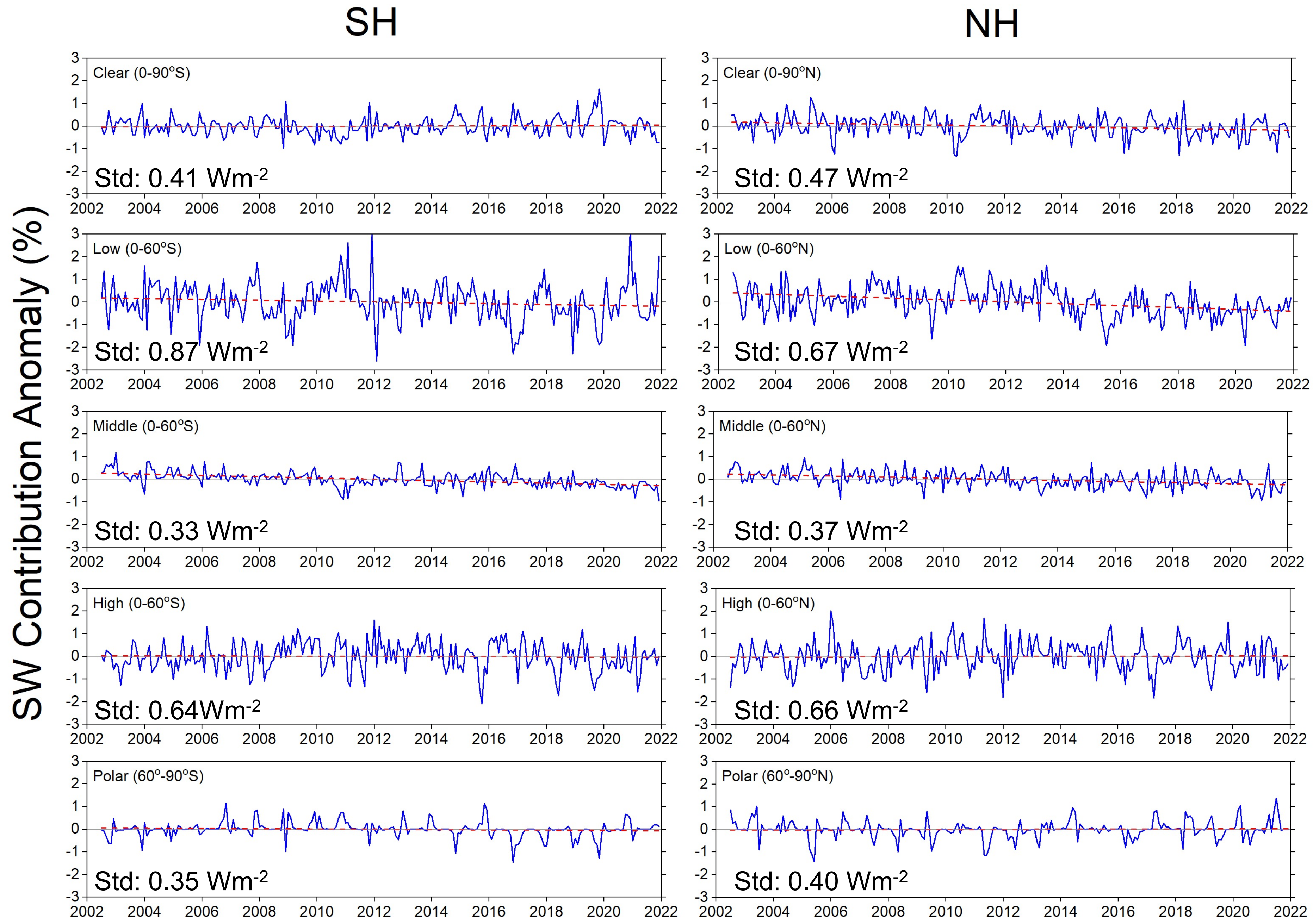
Cloud Class	Cloud Top Press (hPa)	EIS (K)	Latitude Range
Stratocumulus (Sc)	> 680	> 5	$\|\lambda\| < 60^\circ$
Stratocumulus-to-Cumulus Transition (SCT)	> 680	0 – 5	$\|\lambda\| < 60^\circ$
Shallow Cumulus (Cu)	> 680	< 5	$\|\lambda\| < 60^\circ$
Middle	440 – 680	–	$\|\lambda\| < 60^\circ$
High	< 440	–	$\|\lambda\| < 60^\circ$
Polar	–	–	$\|\lambda\| \geq 60^\circ$

- Determine anomalies and trends for each cloud class (07/2002-12/2021)

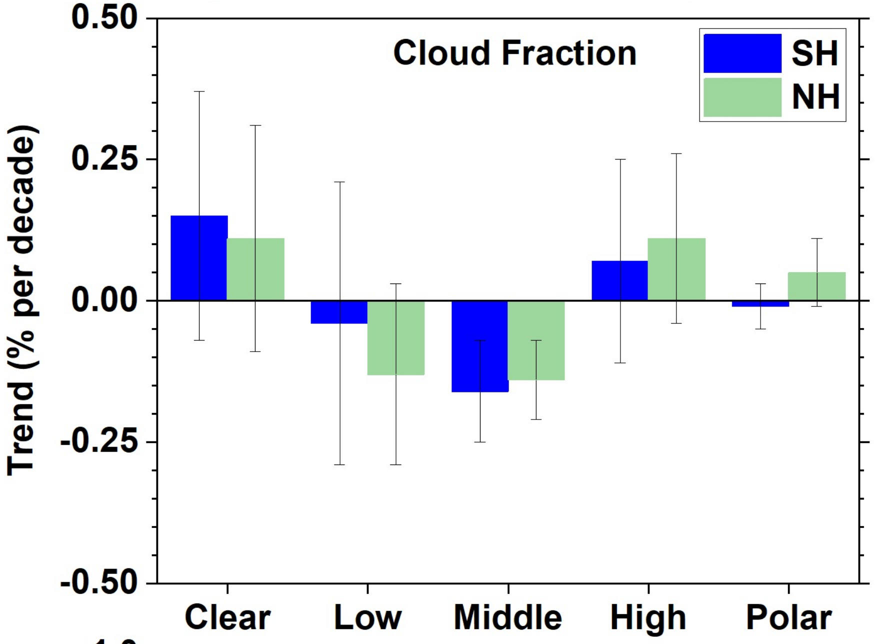
Cloud Fraction by Cloud Class (September 2002)



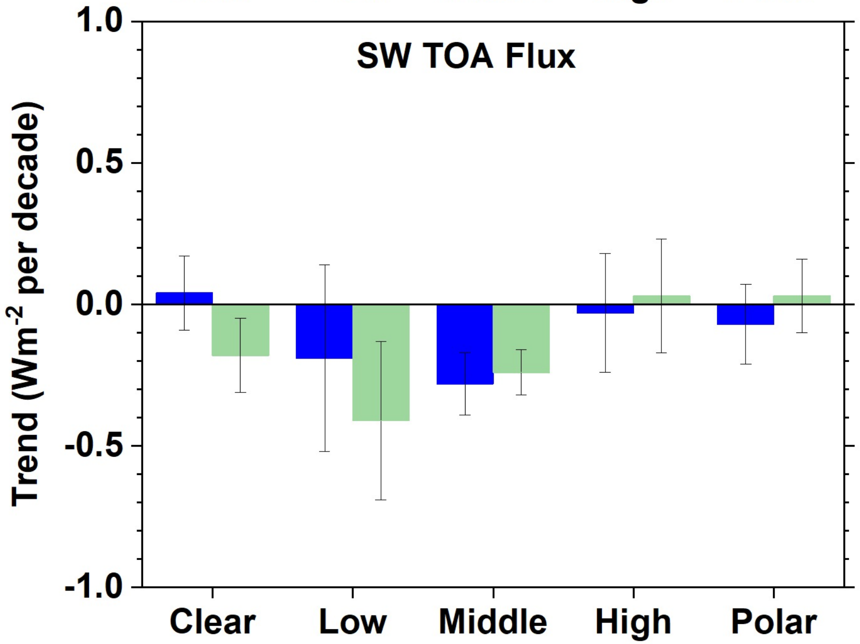
SW Contribution to Hemispheric Anomalies



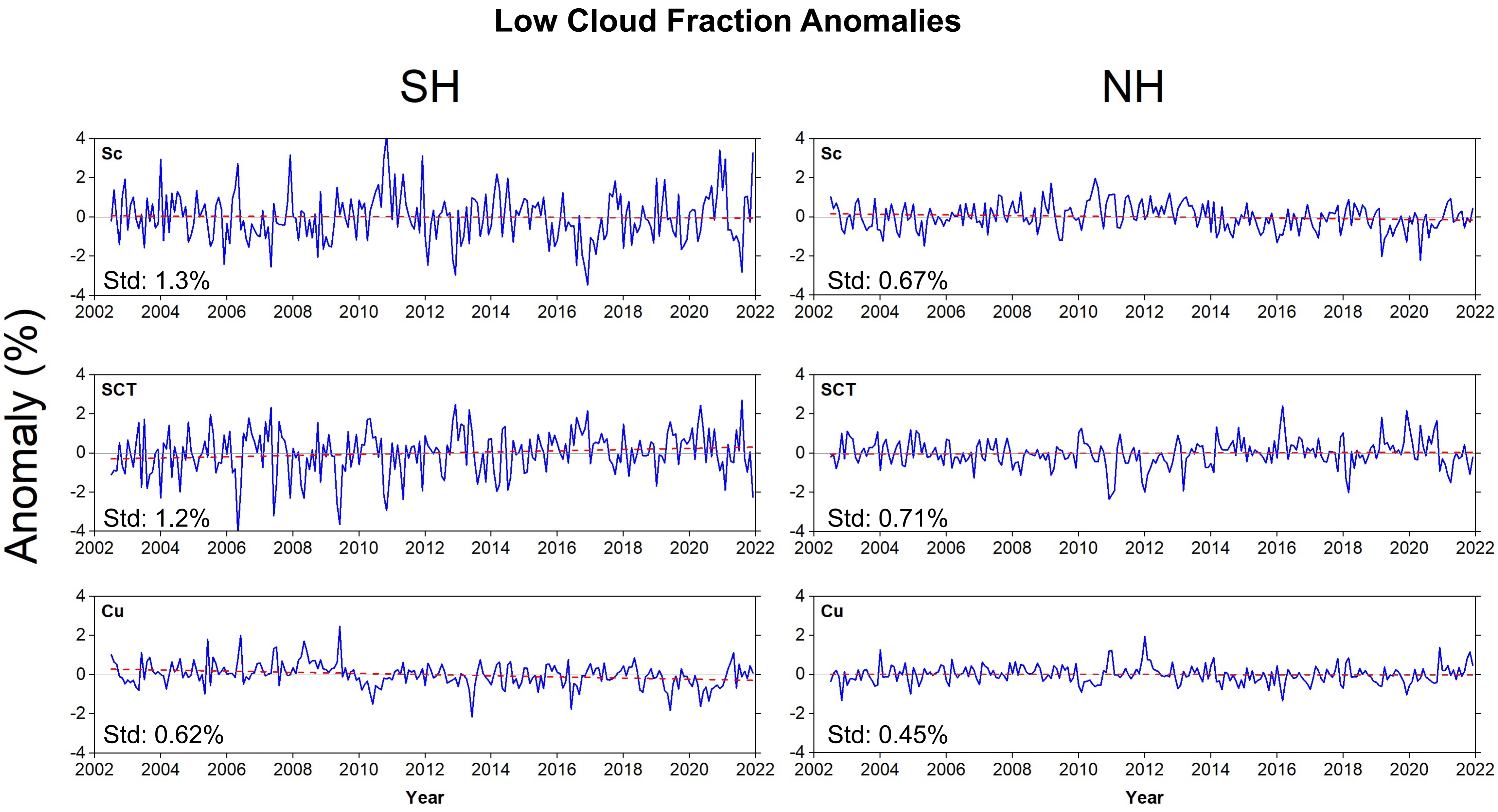
Trends in Cloud Fraction & SW TOA Flux (07/2002– 12/2021)



- Increase in CLR fraction (SH & NH)
- Decreases in low and middle clouds (SH & NH)

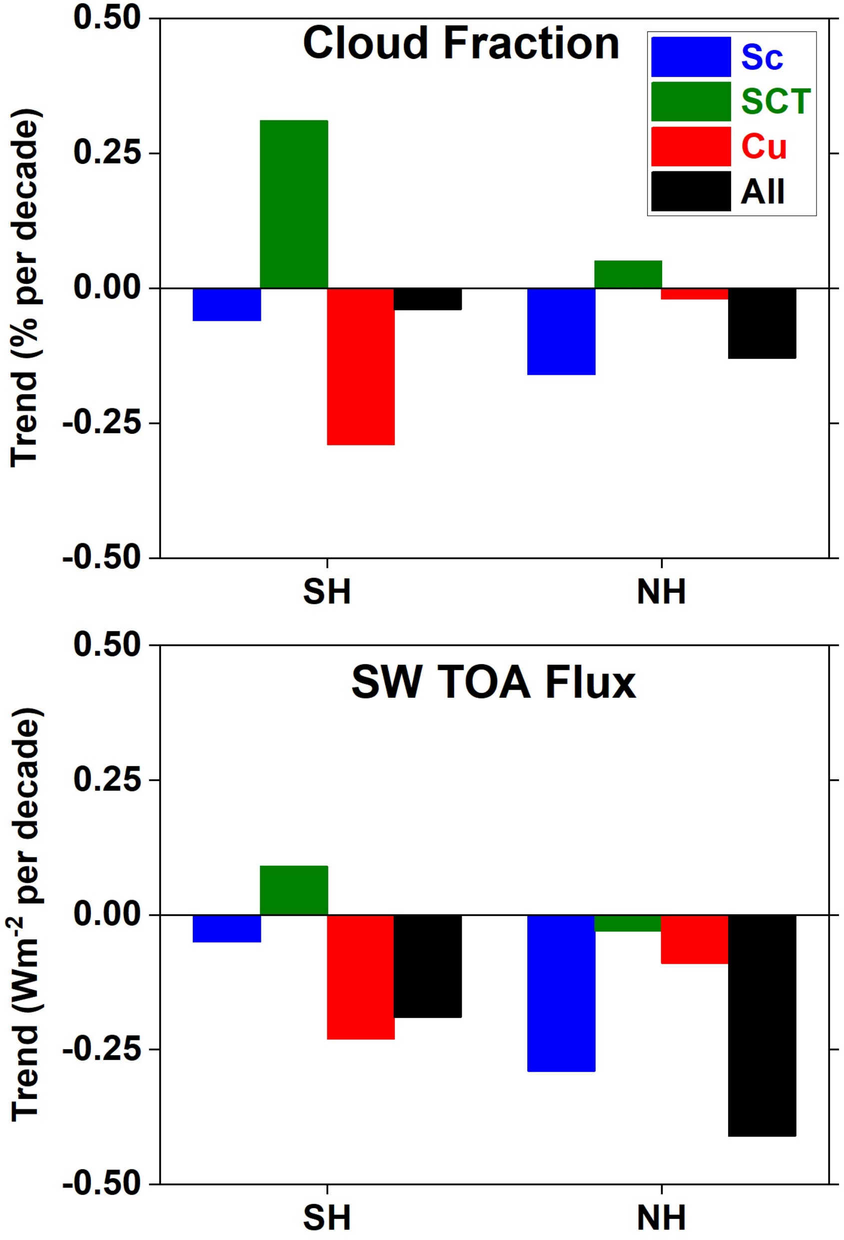


- NH CLR SW flux decrease due to decreases in sea-ice fraction and aerosols
- Middle cloud decreases are main reason for SW TOA flux changes in SH.
- Low cloud decreases are main reason for SW TOA flux changes in NH



Low Cloud Fraction Anomalies
SH
NH
Anomaly (%)
Sc
Std: 1.3%
Sc
Std: 0.67%
SCT
Std: 1.2%
SCT
Std: 0.71%
Cu
Std: 0.62%
Cu
Std: 0.45%
4
2
0
-2
-4
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
Year
Year

Low Cloud Trends by Type



SH: Weak overall low cloud change due to compensation between SCT and Cu

NH: Sc dominate the low cloud changes

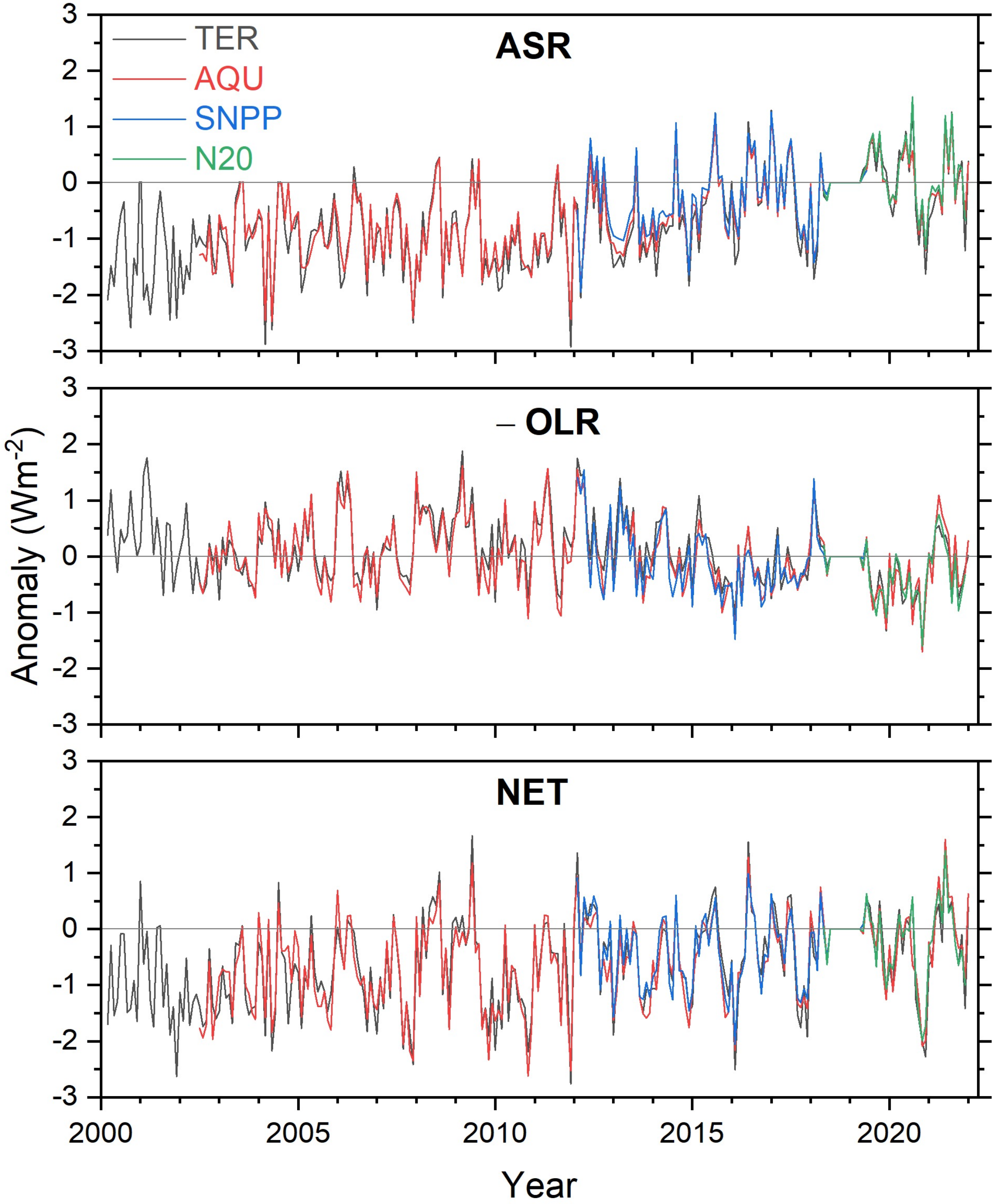
Summary

- Increase in clear area fraction in both hemispheres
- NH CLR SW flux decreases due to decreases in sea-ice fraction and aerosols
- Middle cloud decreases are main reason for SW TOA flux changes in SH.
- Low cloud decreases (mainly Sc) are main reason for SW TOA flux changes in NH

Next Steps

- Use the C3M data product to compare trends in cloud fraction from MODIS with those from active sensors (CALIPSO & CloudSat) for 2007-2017.
- Analyze active sensor data in a manner analogous to MODIS: examine cloud fraction for the clouds exposed to space (sort clouds according to top layer visible from space).

Global Mean All-Sky TOA Flux Anomalies (Relative to Climatology for 05/2018—06/2019)



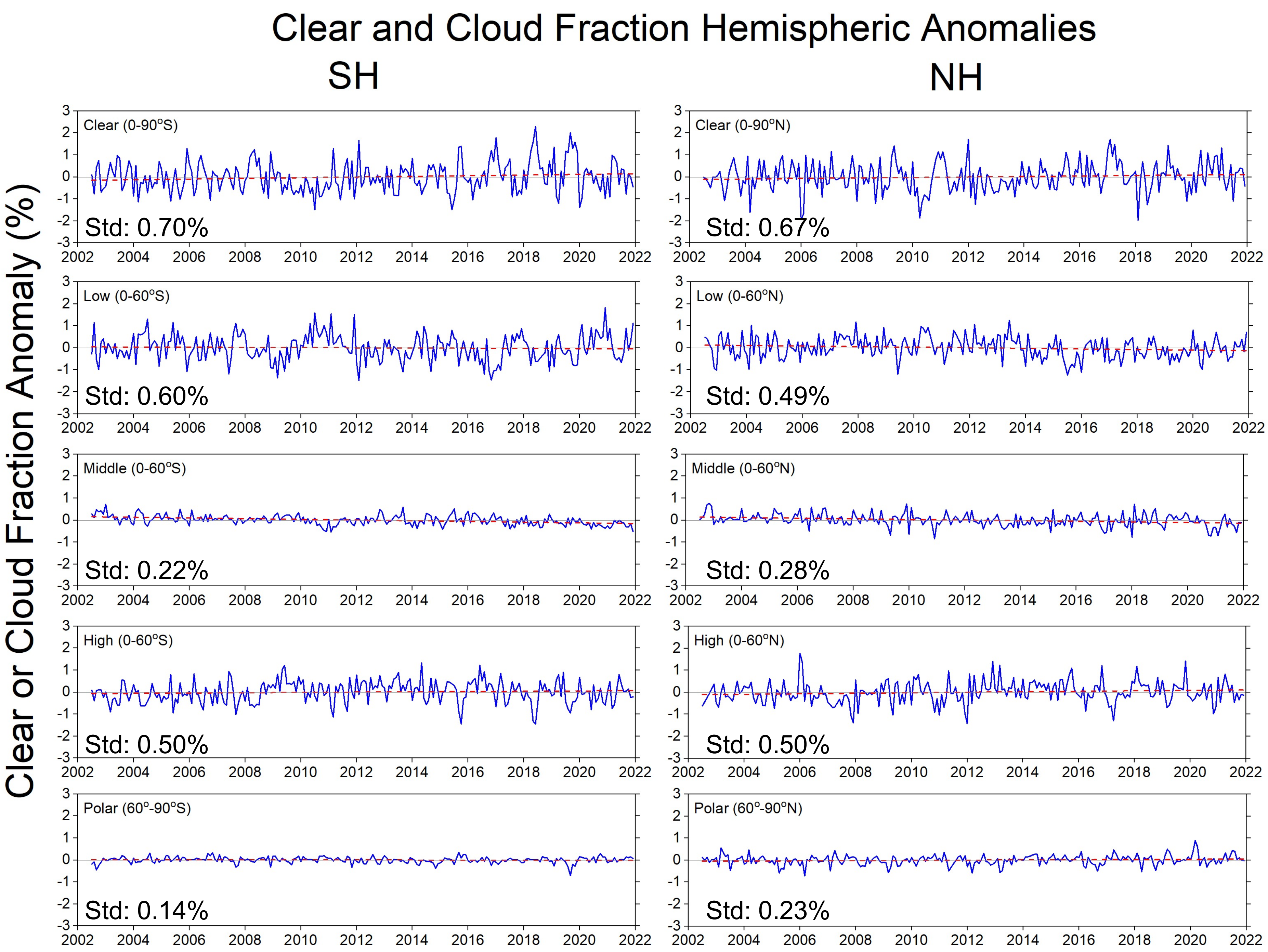
EBAF Trends (03/2000-01/2022)

0.69 ± 0.20 Wm^{-2} per decade

-0.27 ± 0.21 Wm^{-2} per decade

0.42 ± 0.20 Wm^{-2} per decade

- **Earth's heating rate increased markedly since 2000:**
  - **Avg EEI (03/2000—02/2005): 0.44 Wm^{-2}**
  - **Avg EEI (02/2017—01/2022): 1.14 Wm^{-2}**


Clear and Cloud Fraction Hemispheric Anomalies
SH
NH
Clear or Cloud Fraction Anomaly (%)
Clear (0-90°S)
Std: 0.70%
Clear (0-90°N)
Std: 0.67%
Low (0-60°S)
Std: 0.60%
Low (0-60°N)
Std: 0.49%
Middle (0-60°S)
Std: 0.22%
Middle (0-60°N)
Std: 0.28%
High (0-60°S)
Std: 0.50%
High (0-60°N)
Std: 0.50%
Polar (60°-90°S)
Std: 0.14%
Polar (60°-90°N)
Std: 0.23%

Low Cloud SW Flux Anomalies