Variability in Hemispheric Top-of-Atmosphere Fluxes Observed by CERES

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Introduction

- Numerous studies have shown that the Northern and Southern Hemispheres reflect nearly the same amount of incident solar irradiance on an annual average.
  - True even though most landmasses and atmospheric aerosols reside in the Northern Hemisphere
- This has been a topic of intrigue over the past 50+ years.
- Here we examine temporal variations in this hemispheric symmetry during the CERES period.

Datasets

- **EBAF Ed4.2: 07/2000–06/2024**

Transition to NOAA-20:

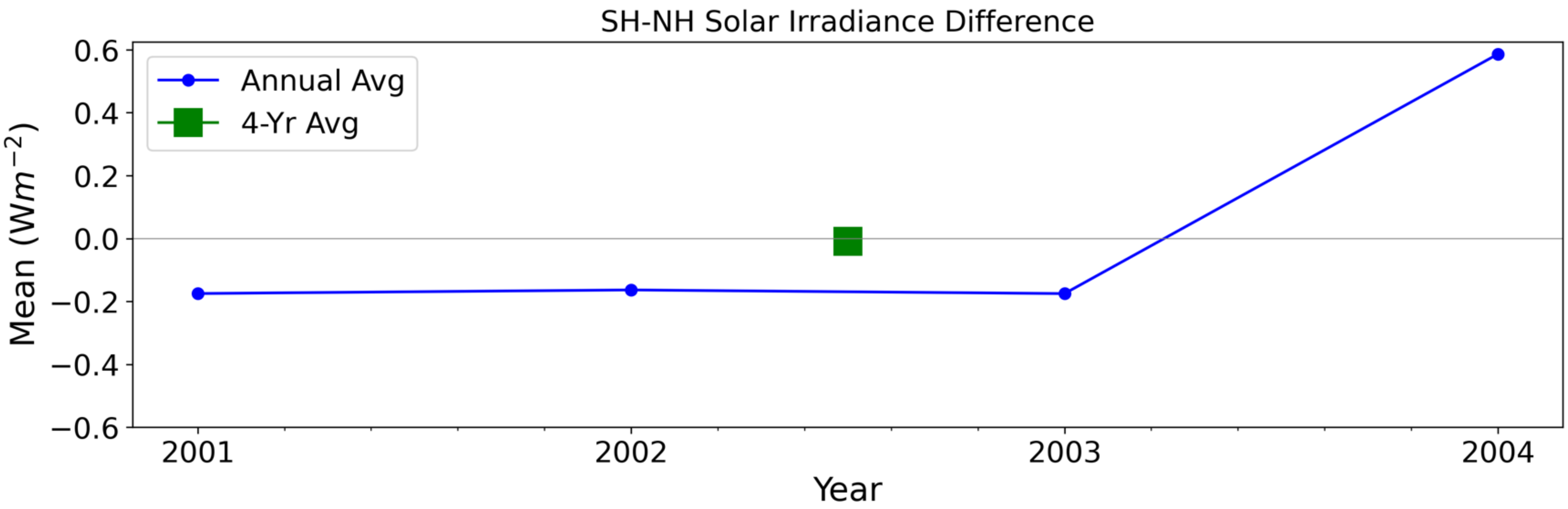
Terra-Only (03/2000-06/2002)	→	Terra+Aqua (07/2002-03/2022)	→	NOAA20 (04/2022-onwards)

  - Climatology of Terra-Only and NOAA20-Only fluxes and cloud properties are anchored to Terra+Aqua climatology using overlapping periods.

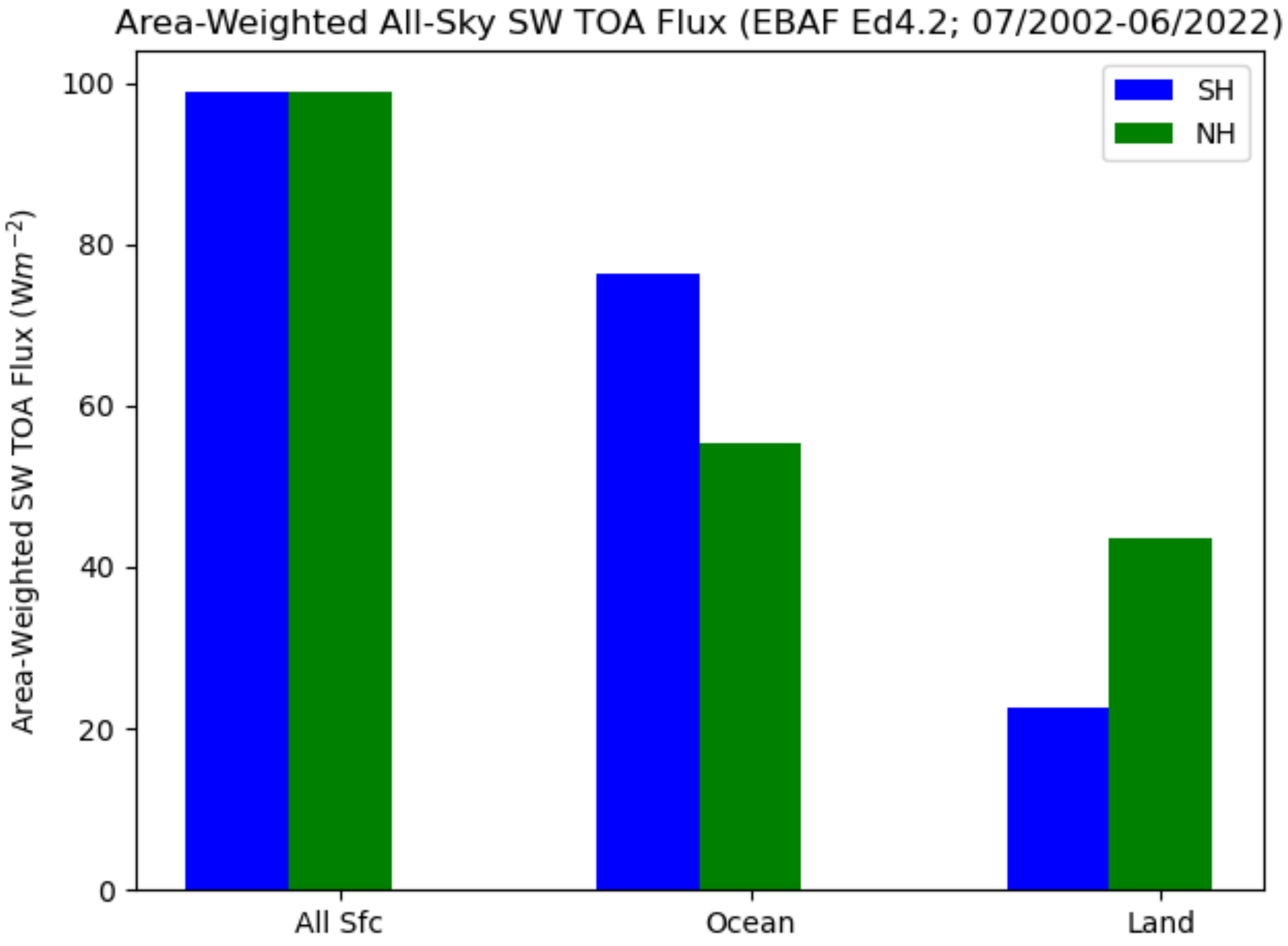
References:
Loeb et al., JCLIM, 2024 (TOA)
Kato et al., JCLIM, 2024 (SFC)

- **Terra, Aqua SSF1deg Ed4.1: 07/2002–06/2022**

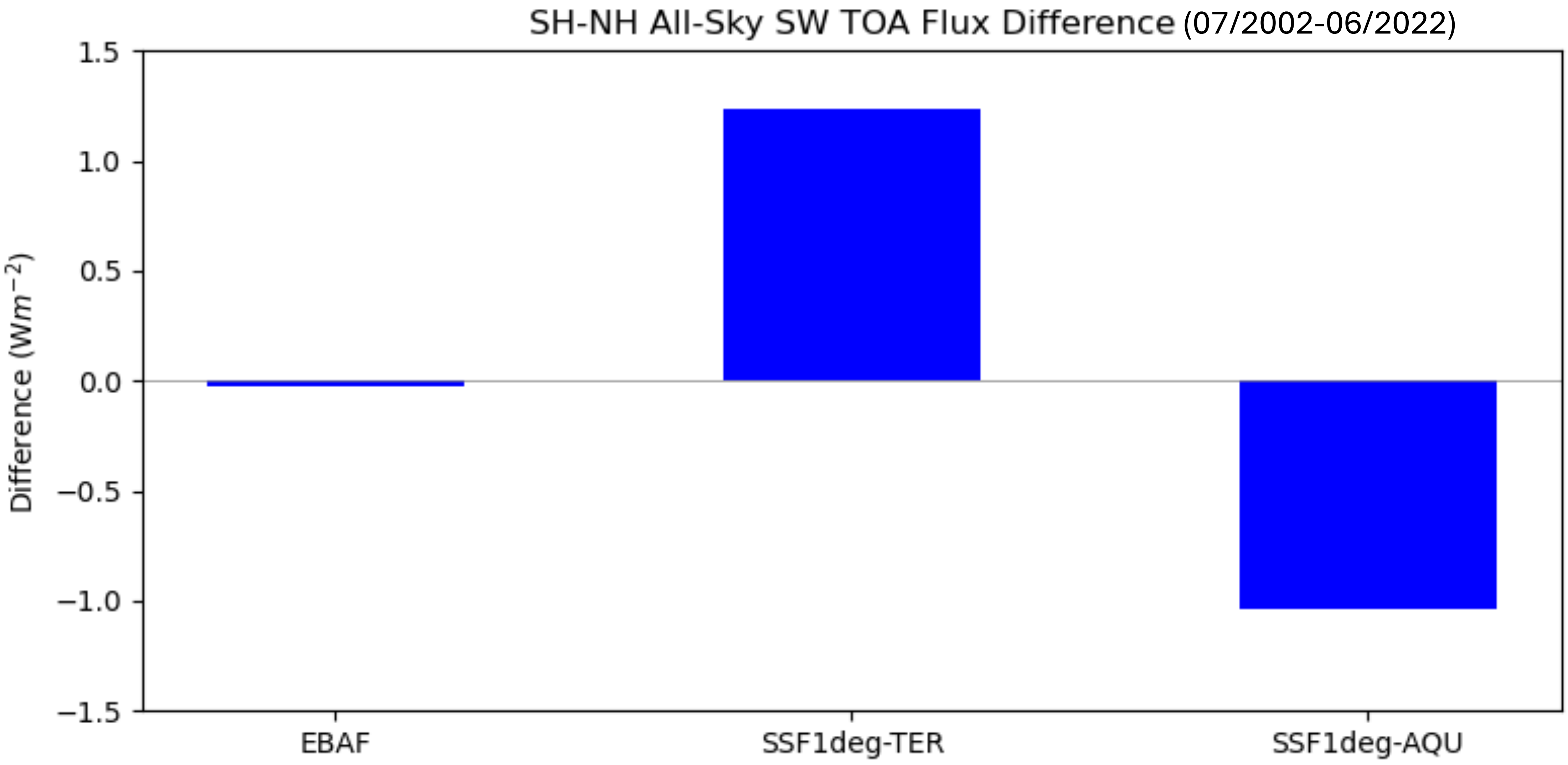
Leap Year Issue



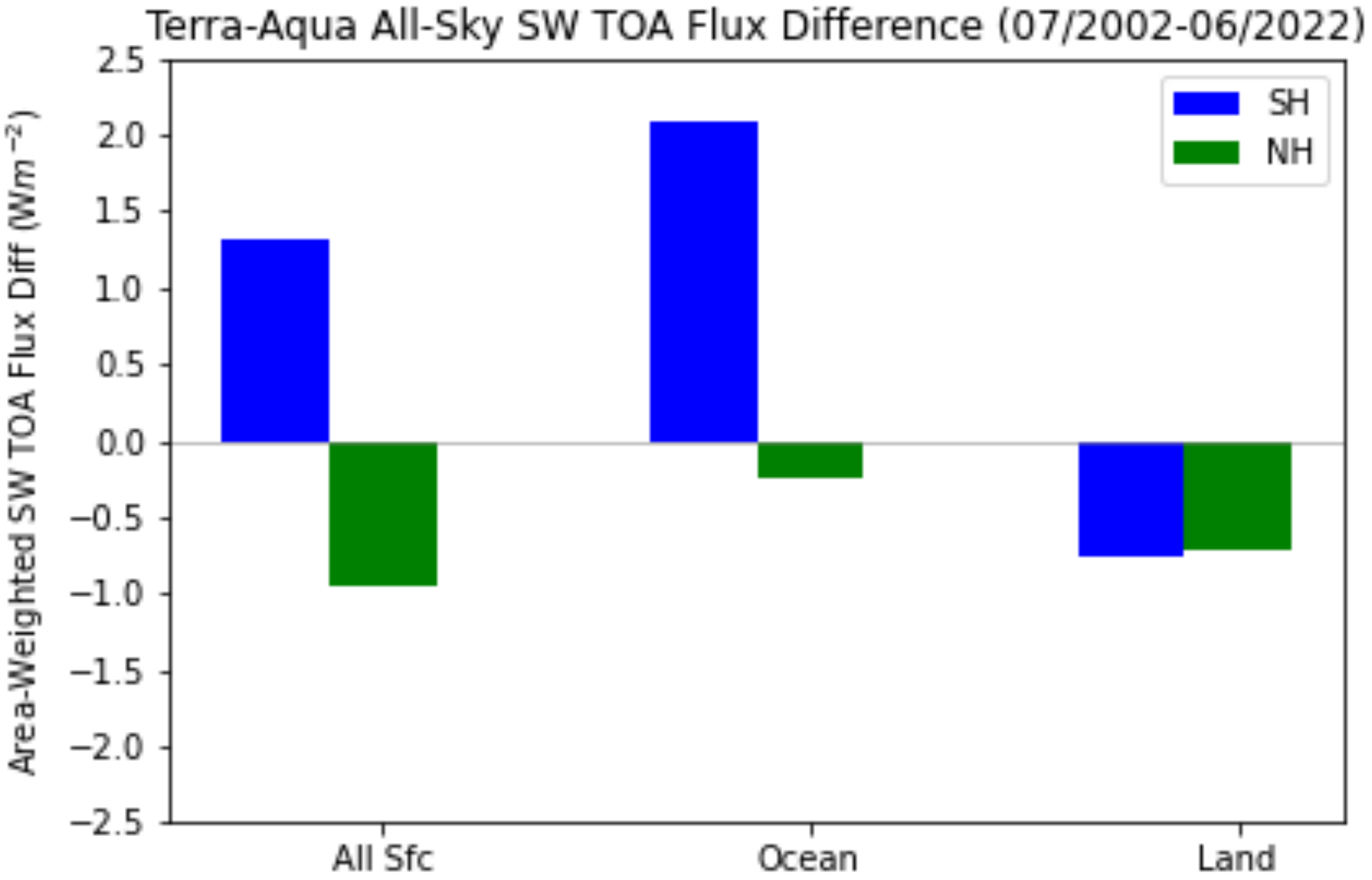
- Annual average TOA solar irradiance should be identical for the southern and northern hemispheres.
- But annual average SH–NH solar irradiance difference from CERES EBAF is nonzero. Why?
- A true year is 365.25 days, not 365 days. Leap year makes up for the difference.
  - ➢ Hemispheric difference in solar irradiance is only zero when you calculate a 4-year average.



- Hemispheric symmetry in all-sky SW TOA flux for all surface types.
- Hemispheric asymmetry over ocean+sea-ice ("ocean") and over land, desert, snow ("land")

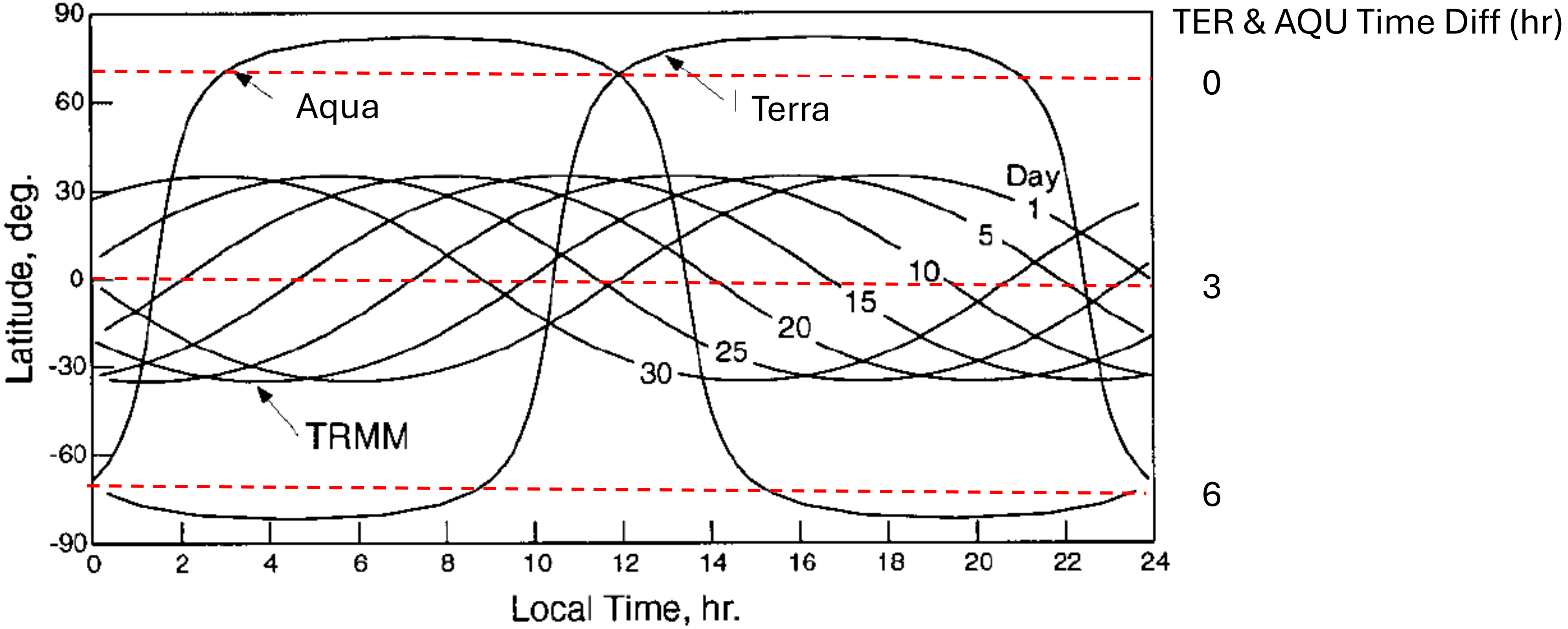


- Why is SH-NH SW flux difference positive for Terra and negative for Aqua?



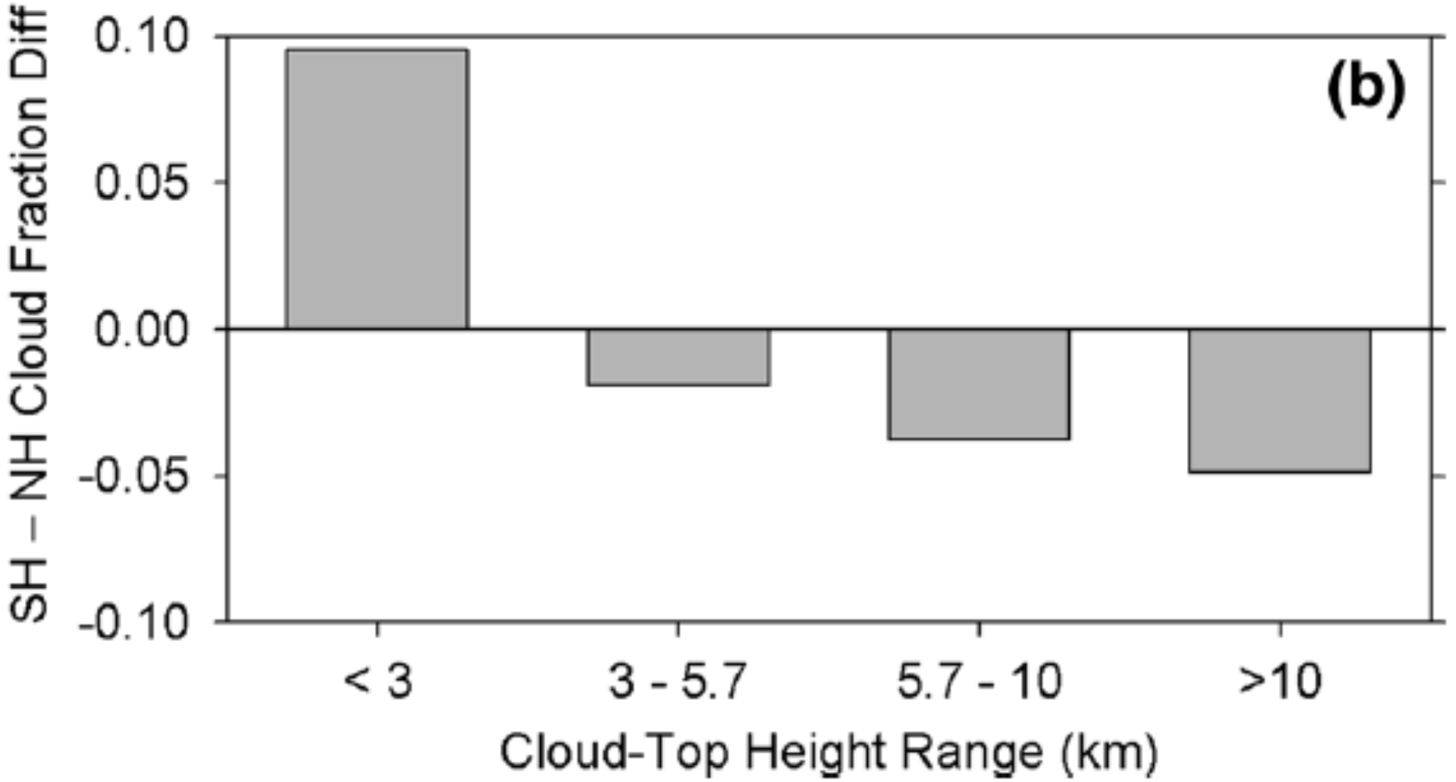
- Terra exceeds Aqua over SH ocean
- Aqua exceeds Terra over land

Temporal Coverage of Terra, Aqua and TRMM

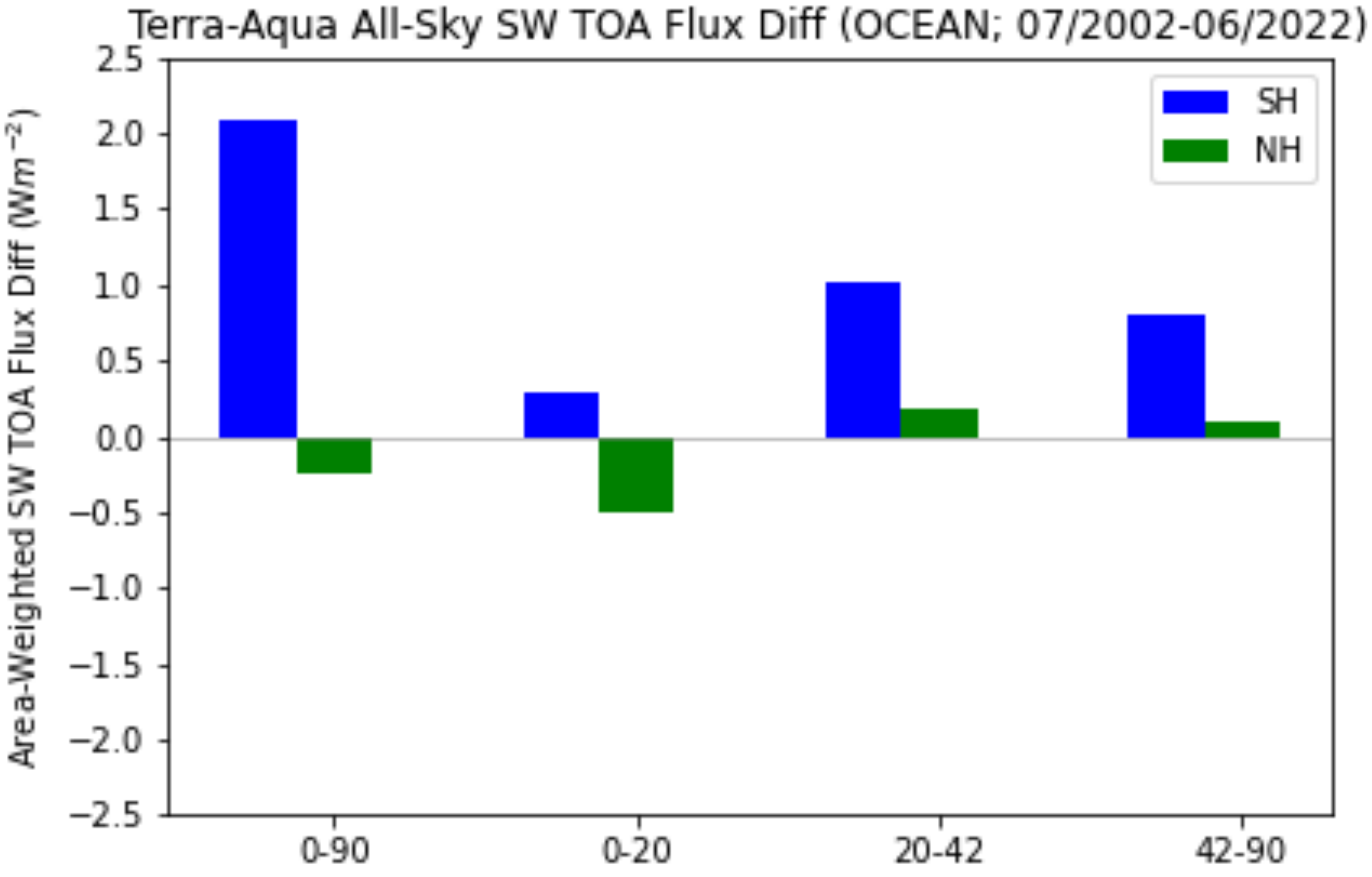


- Time separation between Terra and Aqua ground tracks is greater in SH than NH

SH–NH Difference in Cloud Fraction by Cloud-Top Heights (CALIPSO+Cloudsat)

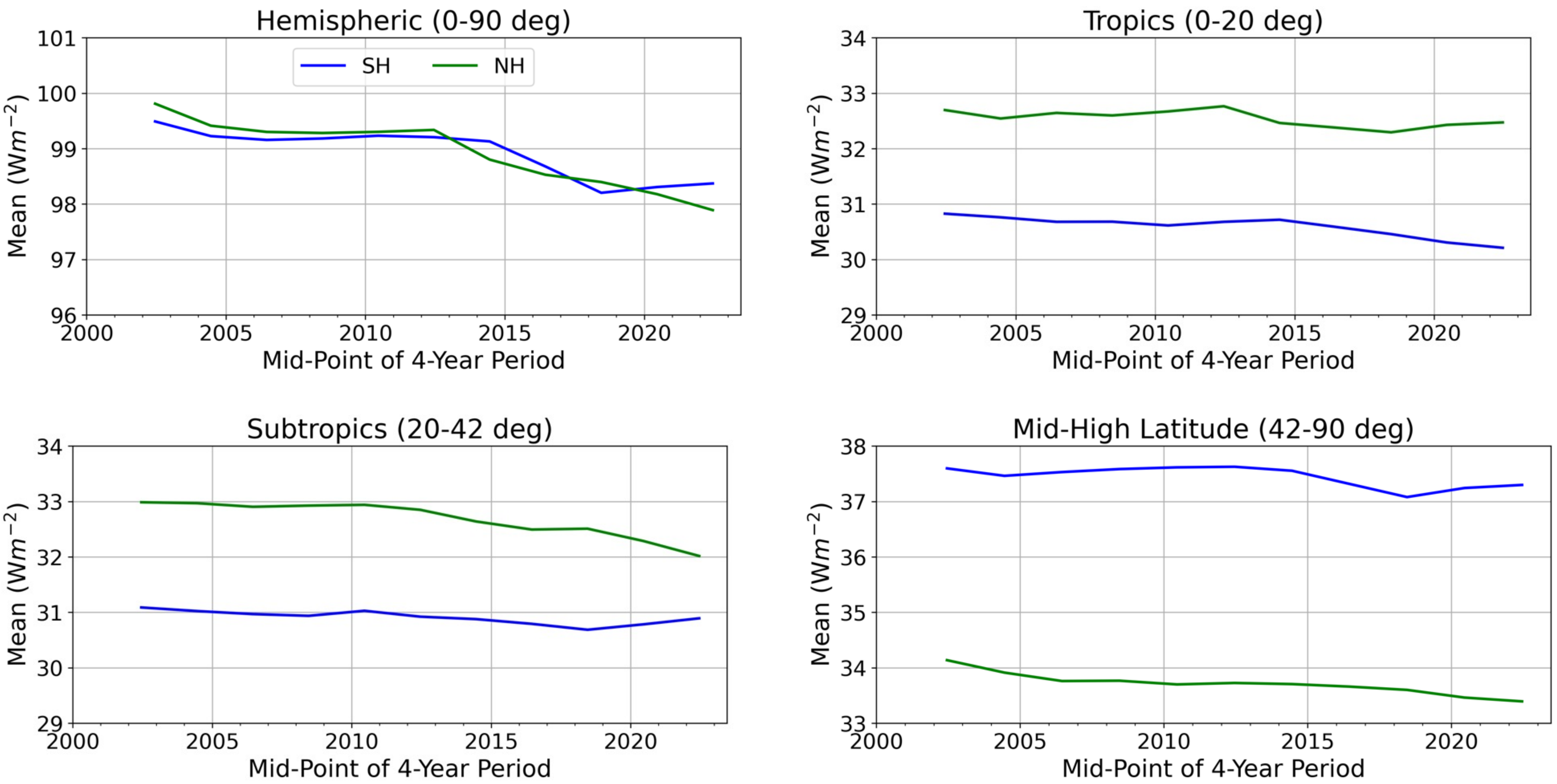


- More low cloud in SH than NH

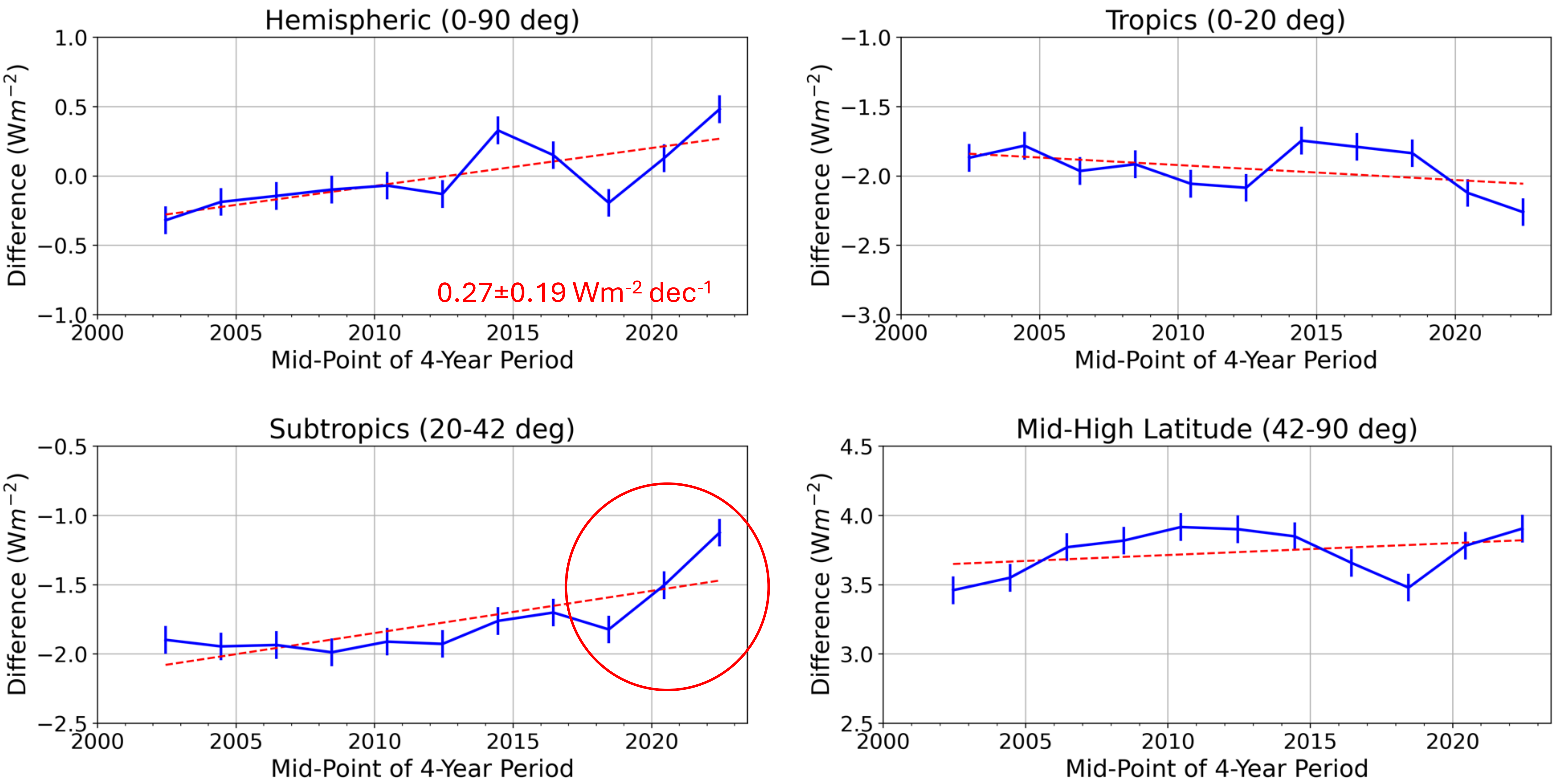


- Terra–Aqua SW TOA flux difference greatest in sub-tropics and mid-high latitudes, where low clouds are most abundant and orbit time difference is greater.

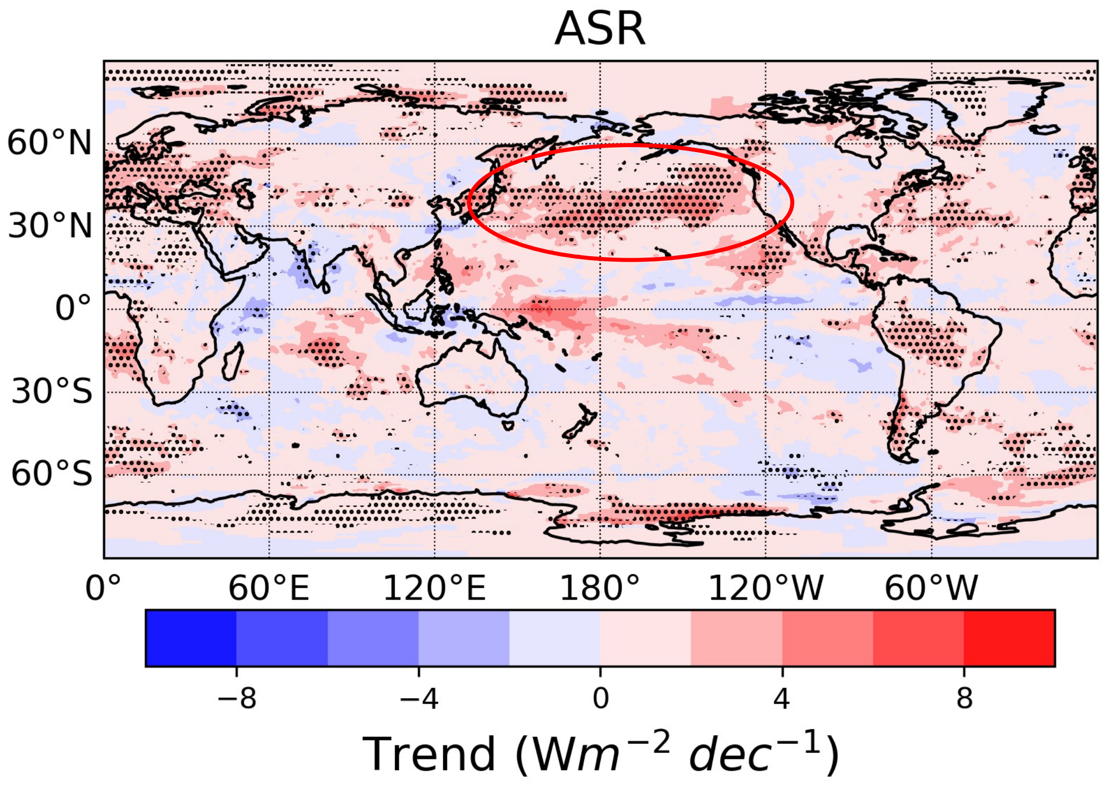
Area-Weighted All-Sky SW TOA Flux Averages (07/2000-06/2024)

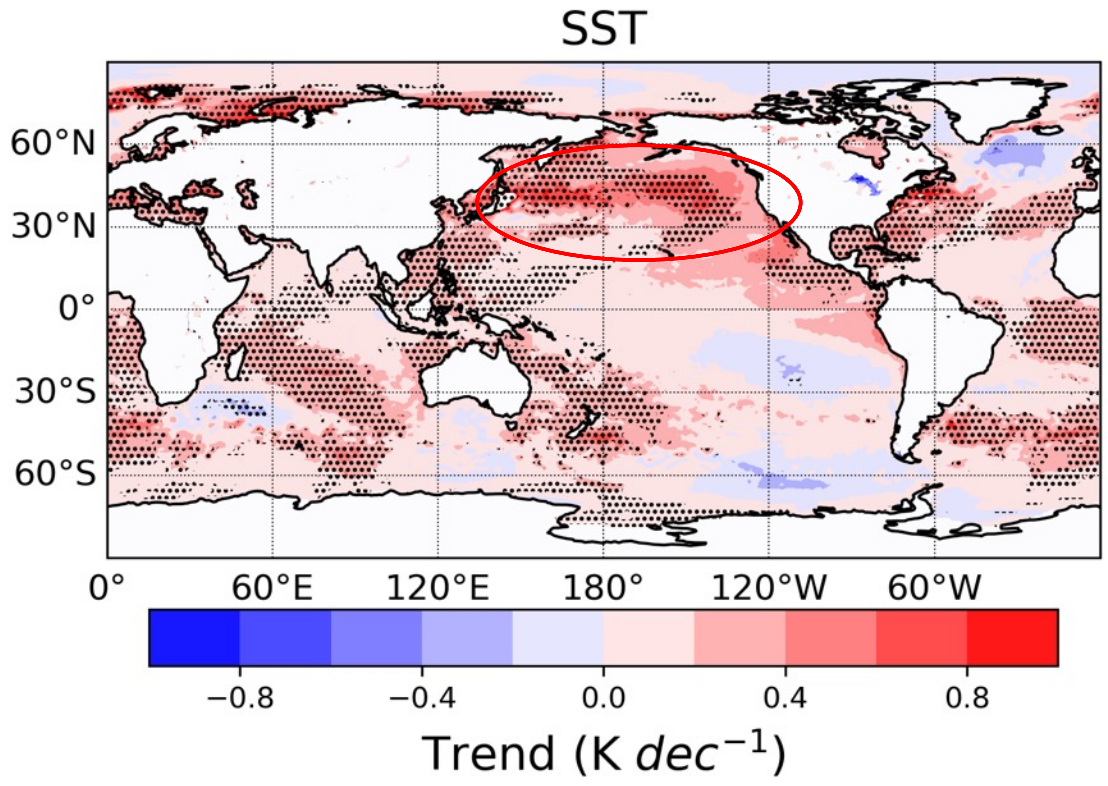


Area-Weighted All-Sky SW TOA Flux Differences (SH–NH) (07/2000-06/2024)

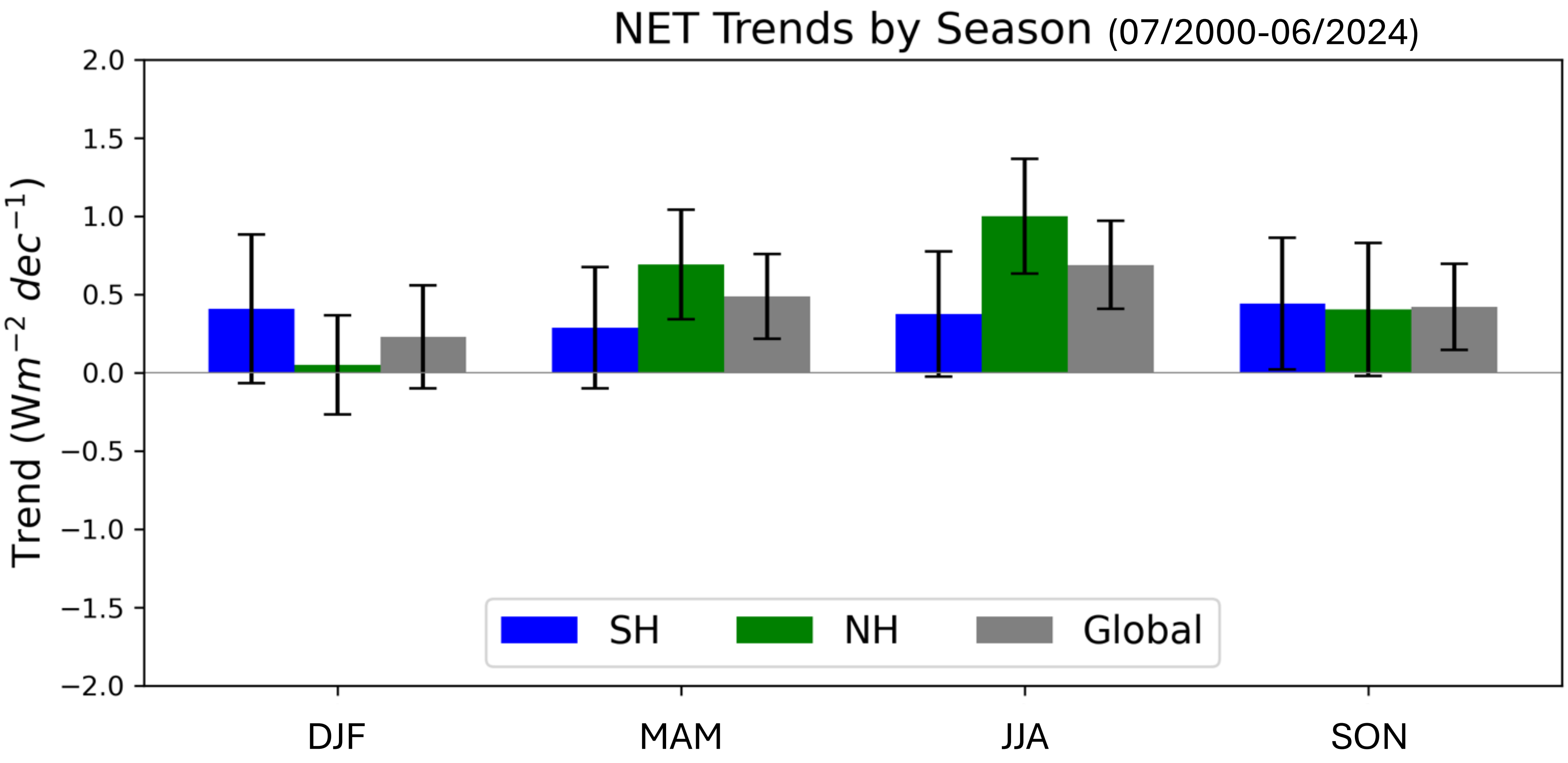


Regional Trends in TOA Radiation and SST (03/2000–06/2024)

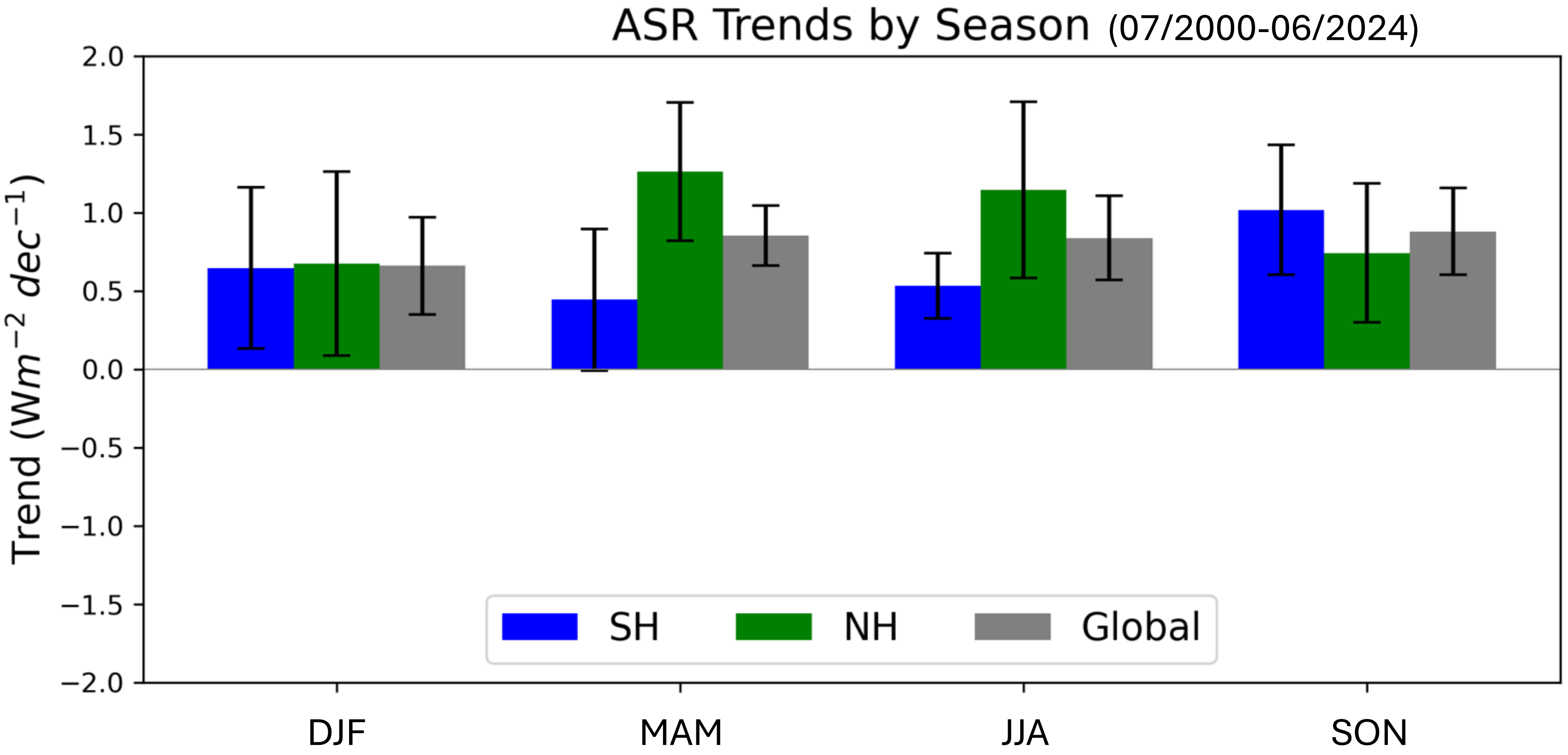




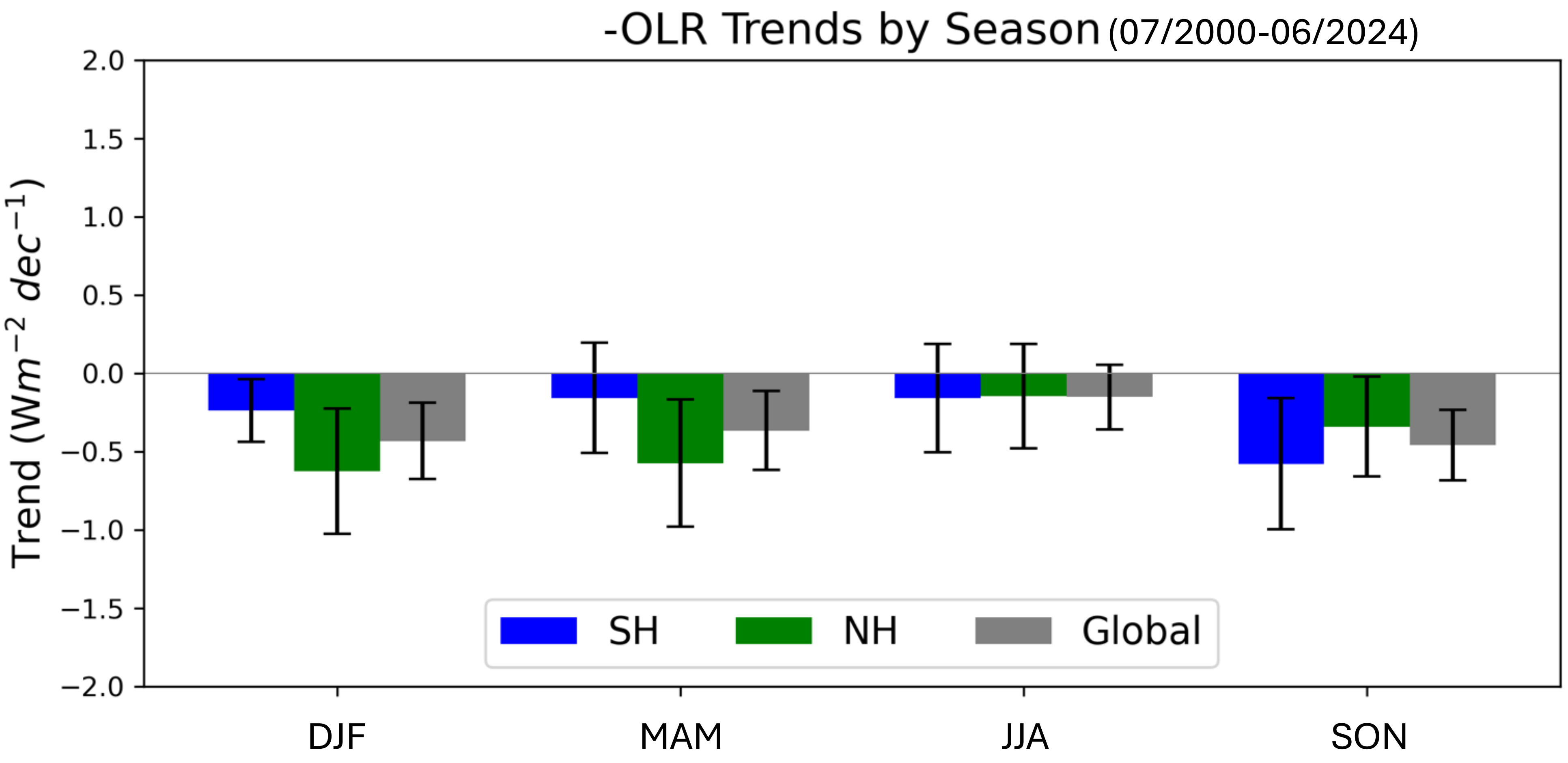
- ASR trends in NH subtropics coincide with trends in SST, particularly over Pacific Ocean



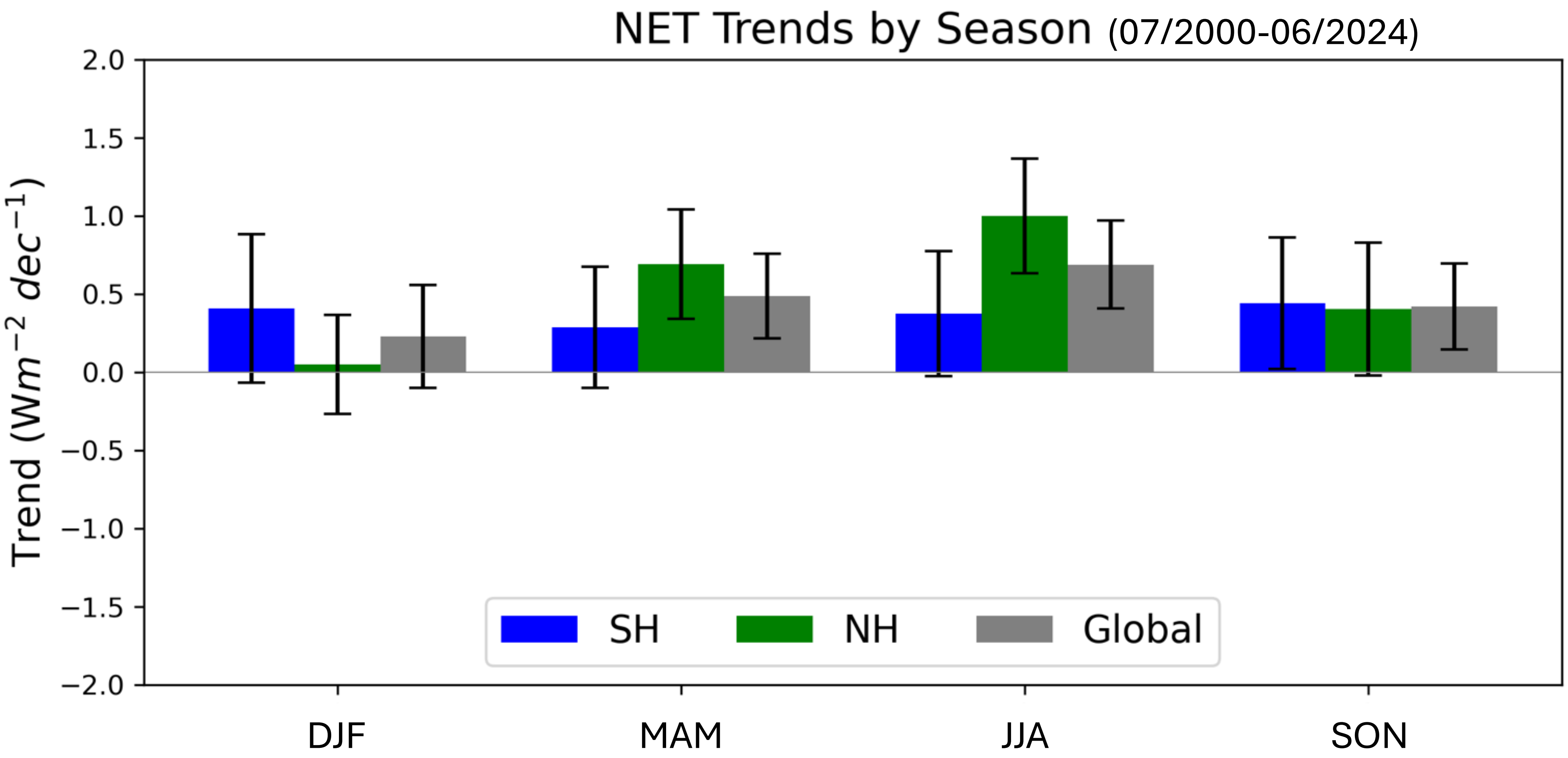
- Trends have strong annual cycle in NH but not in SH.



- Larger NH ASR trends during MAM and JJA.

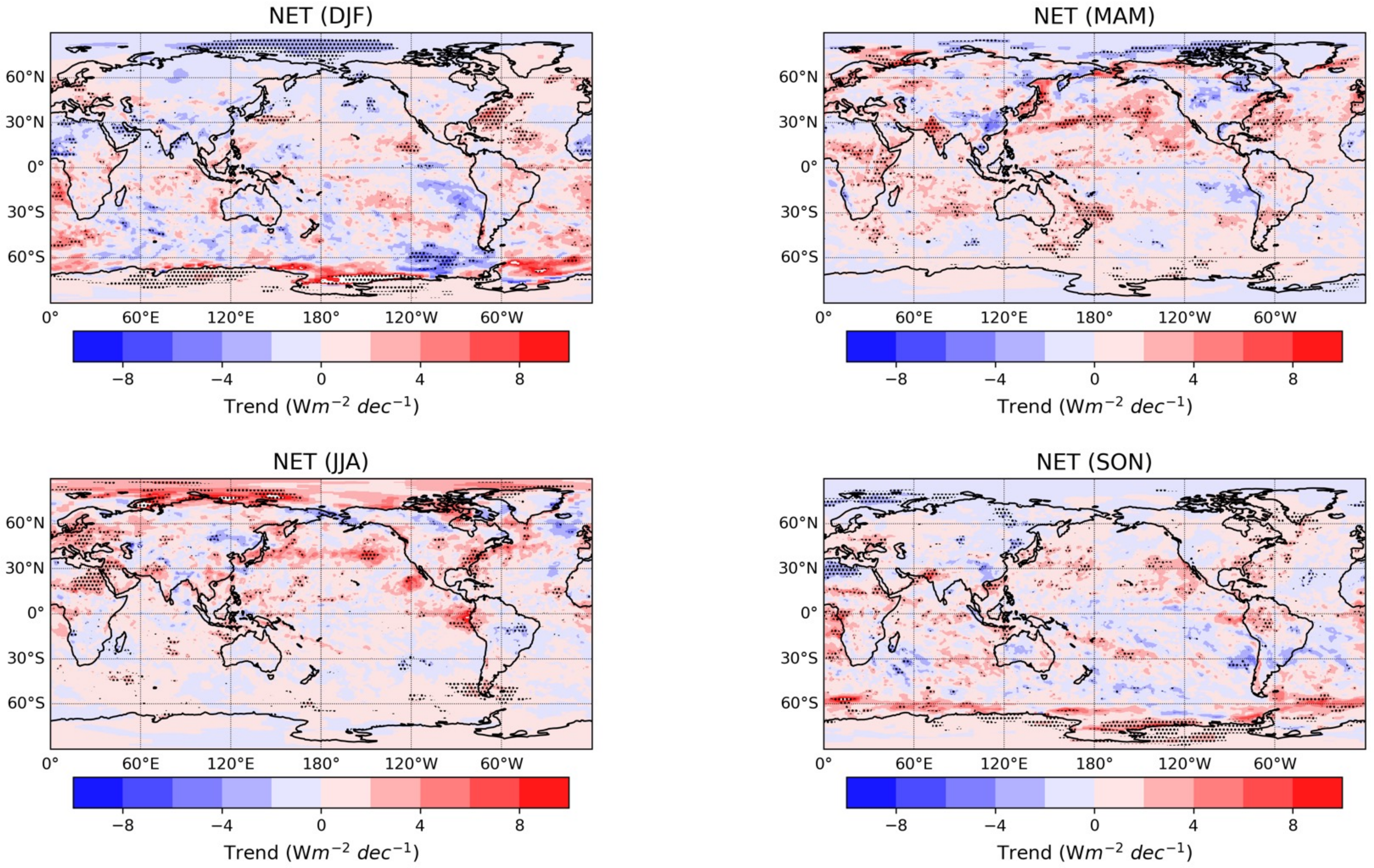


- OLR increase in NH most pronounced during DJF and MAM.

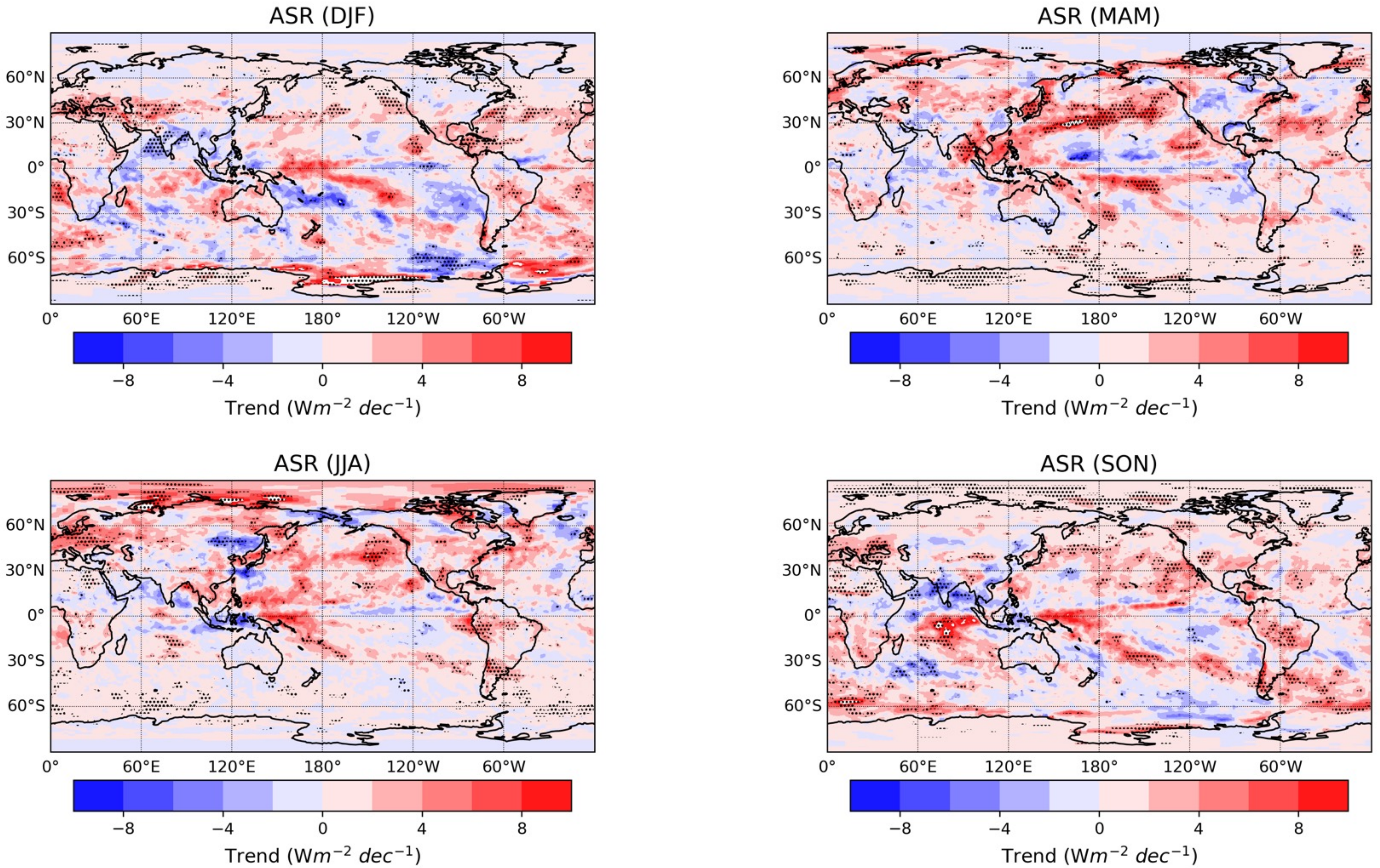


- Trends have strong annual cycle in NH but not in SH.

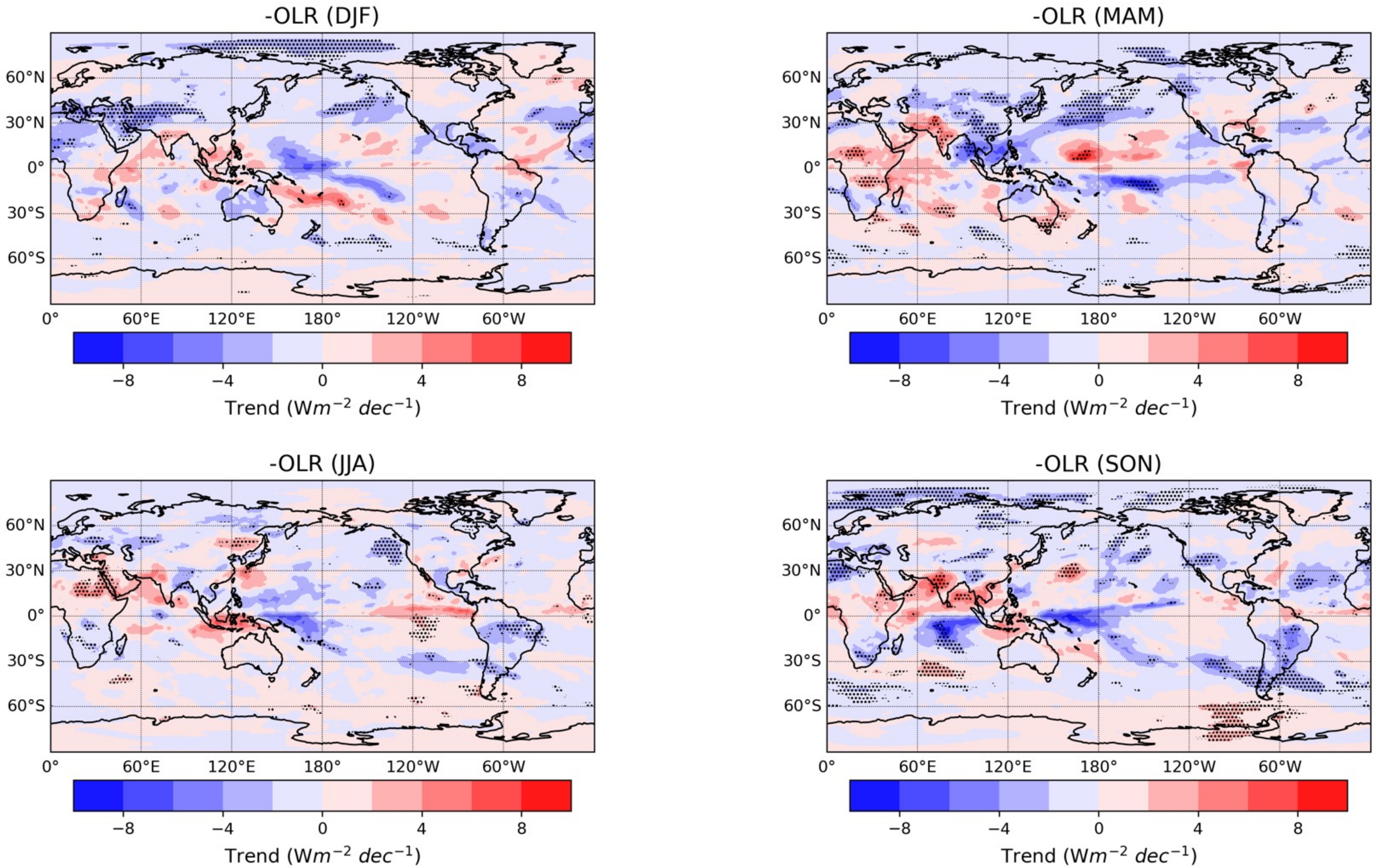
Regional Trends by Season in NET TOA Radiation (07/2000–06/2024)



Regional Trends by Season in ASR TOA Radiation (07/2000–06/2024)



Regional Trends by Season in –OLR TOA Radiation (07/2000–06/2024)



Conclusions

- **Hemispheric SW TOA flux difference depends upon satellite orbit**
  - SH–NH difference is 2.3 Wm^{-2} larger for Terra (morning) than Aqua (afternoon).

- **Hemispheric symmetry in SW TOA flux is associated with compensation between tropics, sub-tropics and mid-high latitudes**
  - NH > SH in tropics and subtropics
  - SH > NH in mid-high latitudes. Compensates for tropical and subtropical hemispheric differences

- **SH–NH SW TOA flux difference increases during CERES period by 0.27 Wm^{-2} dec^{-1}**
  - NH darkens faster than SH
  - Main driver is decreasing trend in the NH subtropics, especially in regions of elevated SSTs

- **Strong annual cycle in global net TOA flux trend driven by NH**
  - Significant trend in JJA, weak trend in DJF
  - Arctic: Notable trends in JJA (positive) and DJF (negative)

Backup

Regional Trends by Season in SST TOA Radiation (07/2000–06/2024)