Trends and variability in EEI and OHC

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CERES STM, October 18, 2023

Jet Propulsion Laboratory
California Institute of Technology

ABOUT PANELS ACTIVITIES EVENTS

GDAP CURRENT PROJECTS

WCRP GEWEX Data and Analysis Panel (GDAP) assessments

New Integrated Assessment on Earth's Energy Imbalance (EEI)

Leads: **Benoit Meyssignac** and **Tim Boyer**

Goals:

- GDAP assesses currently available EEI estimates from observations. Since the ocean stores more than 90% of the total planetary heat uptake, the EEI assessment focuses on **intercomparing estimates of the time rate of change of ocean heat content** (ocean heat uptake). This first EEI assessment will focus on:

  (a) Understanding the spread of global and regional ocean heat content and ocean heating rates among products.

  (b) Determining systematic errors that depend on assumptions, models, and combined observations.

  (c) Understanding the spread of uncertainties depending on the method and formulae used.

https://www.gewex.org/panels/gewex-data-and-analysis-panel/gdap-projects/

GEWEX-EEI: Objectives & science questions

https://sites.google.com/magellium.fr/eeiassessment/

Objectives:

- **Inter-comparison of EEI/OHC products with uncertainties, focusing on interannual to longer time scales.**
- Provide overview on available data records, meta data and evaluation results.
- Inform on common robust EEI variability present in all EEI records and identify and explain inconsistencies among data records.

Sciences questions:

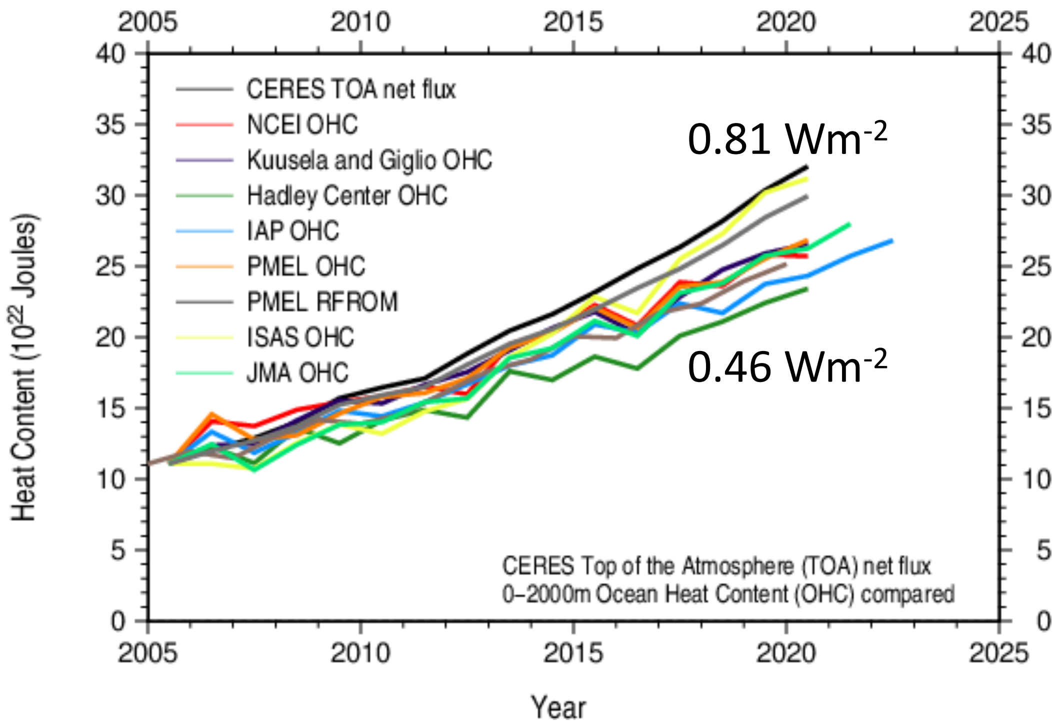
- What are the uncertainties in the observed mean and temporal change in EEI for each product?
- **How large are the differences in observed mean and temporal change across EEI/OHC products?**
- Do the OHU records exhibit areas/periods of distinct quality and how can differences and limitations be explained?
- What is the quality of OHU products in the lowermost part of the ocean? At high latitudes?
- How do OHC/EEI estimates compare between satellite, in situ and reanalysis/ocean state estimates?

GEWEX-EEI assessment

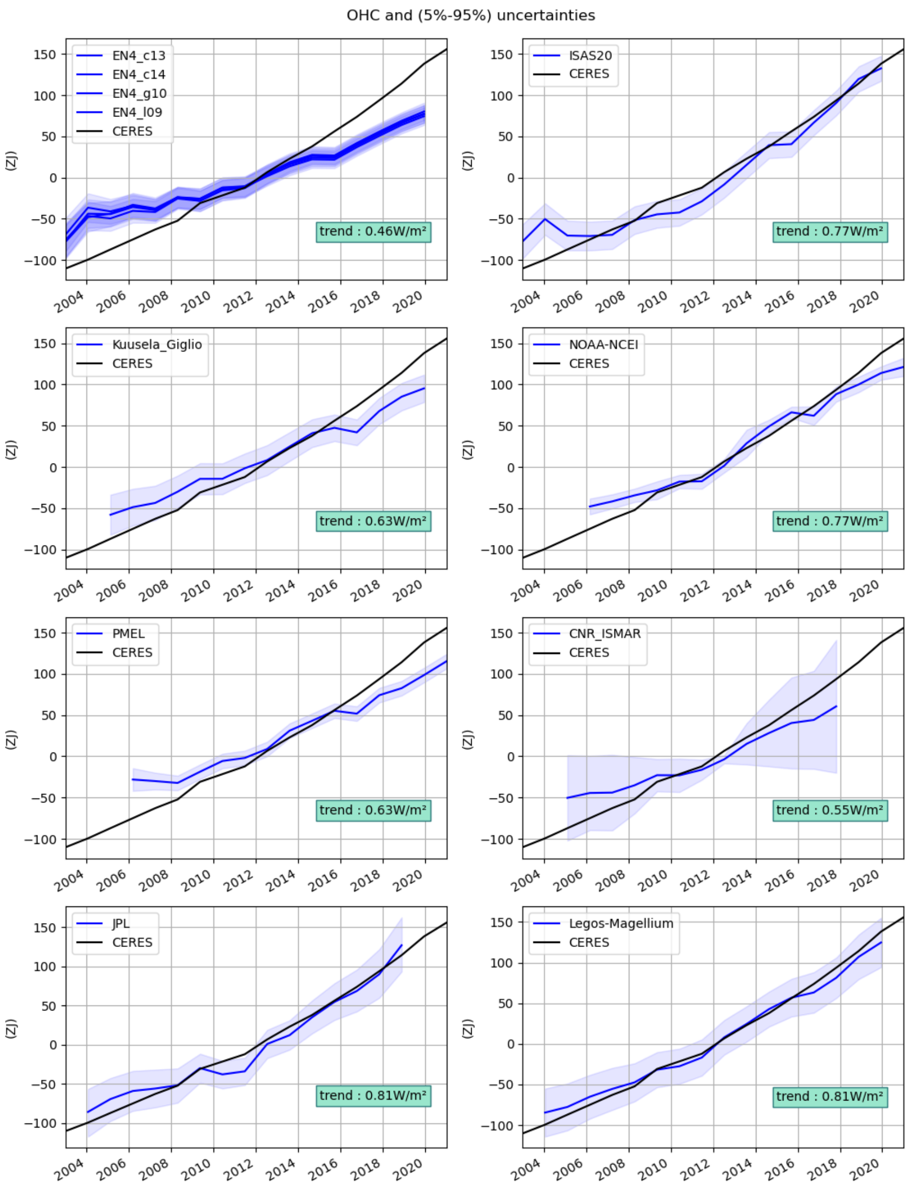
- **Substantial spread in annual global OHC estimates:**
  - Input data
  - Quality control
  - Mapping techniques

MapEval4OceanHeat: an objective assessment of mapping methods used to estimate ocean heat content change

  - Mask and coverage



T. Boyer



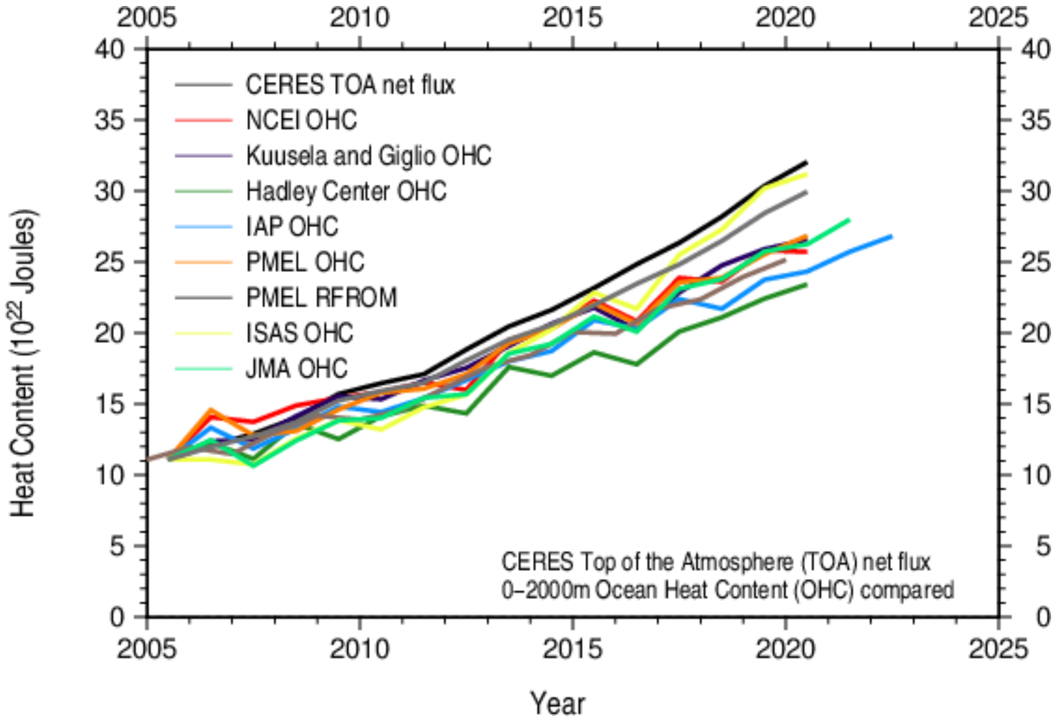
Satellite

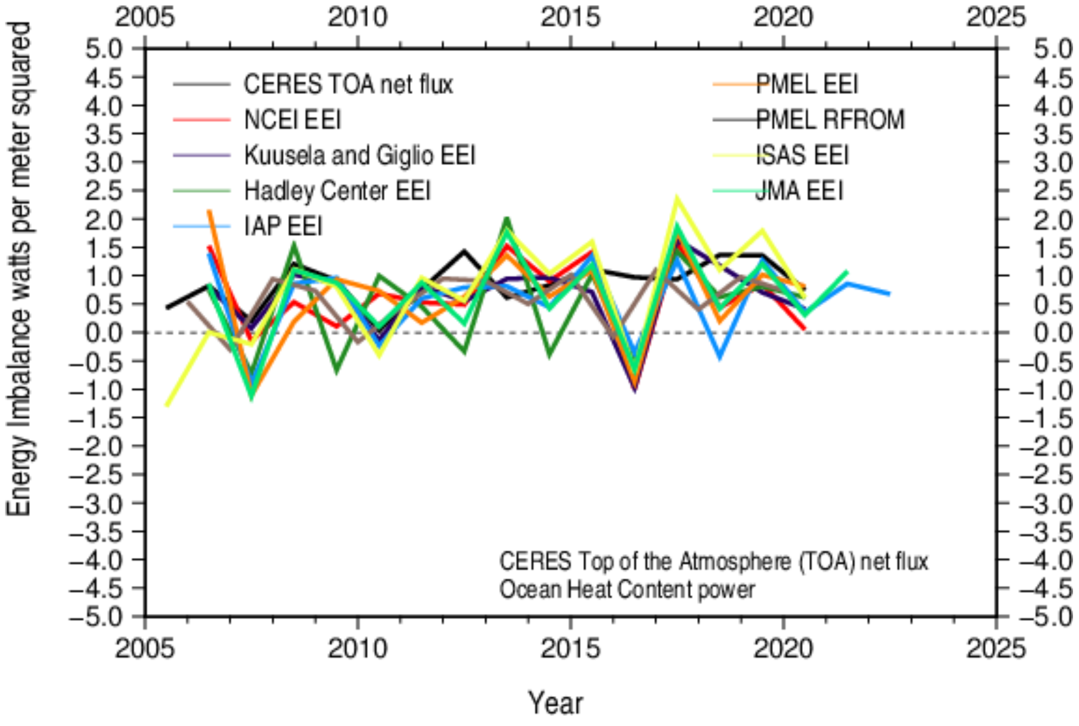
S. Fourest

GEWEX-EEI assessment

<u>**EEI variability compared to ocean heat uptake= dOHC/dt**</u>

Year-to year variability of ocean heat uptake from in-situ observations does not match too well with CERES EEI



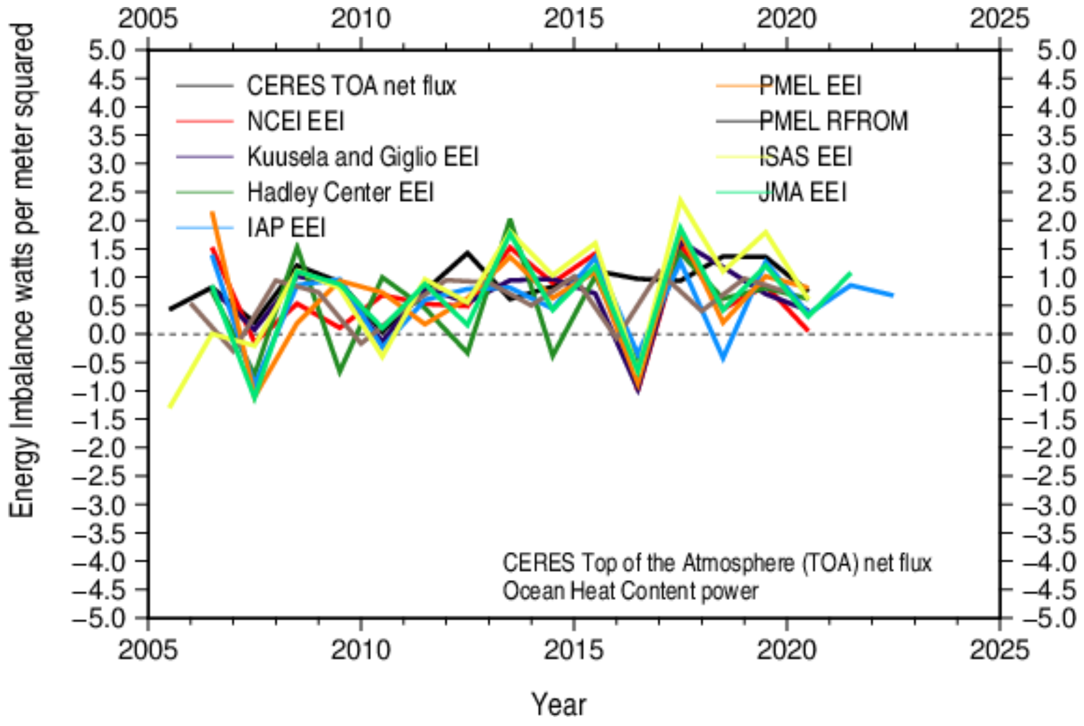


T. Boyer, NOAA

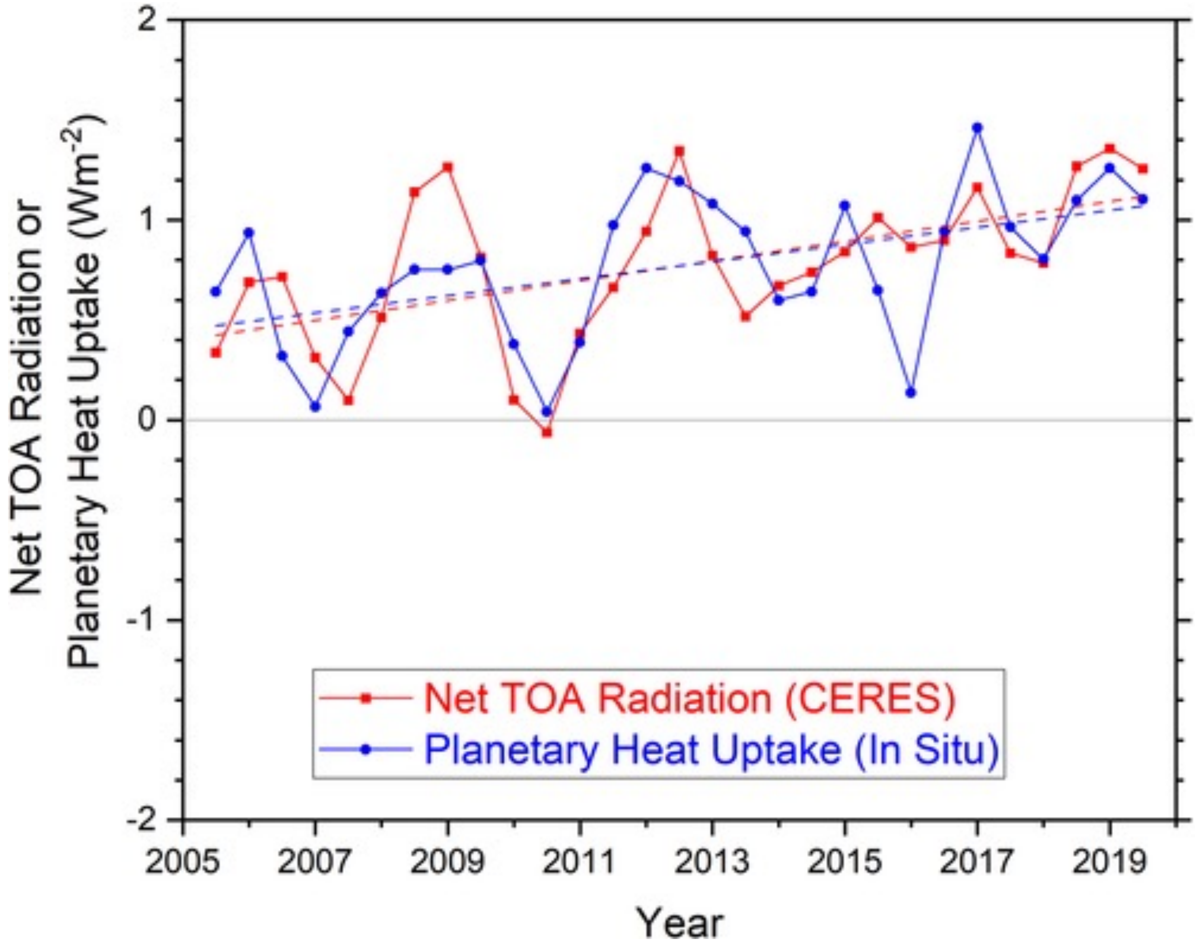
GEWEX-EEI assessment

Define and adopt best practices?

- Mapping and hybrid techniques?



BUT…
Very good agreement CERES EBAF EEI with in-situ + altimetry hybrid estimate



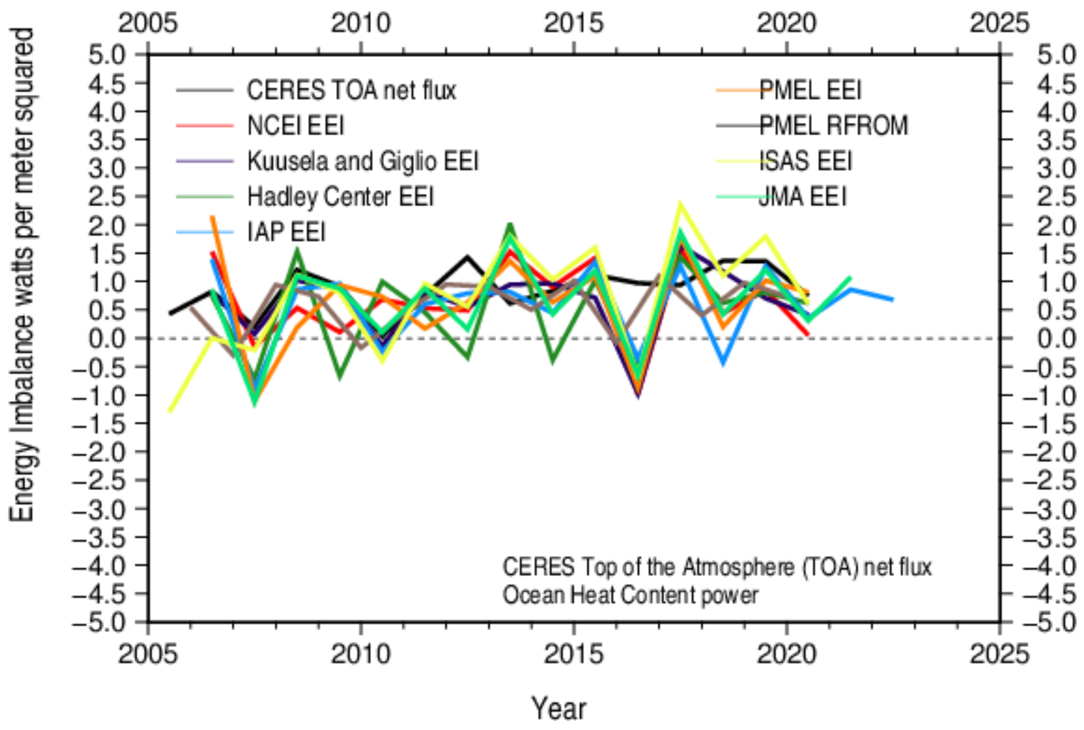
N. Loeb et al.: Satellite and Ocean Data Reveal Marked Increase in Earth's Heating Rate

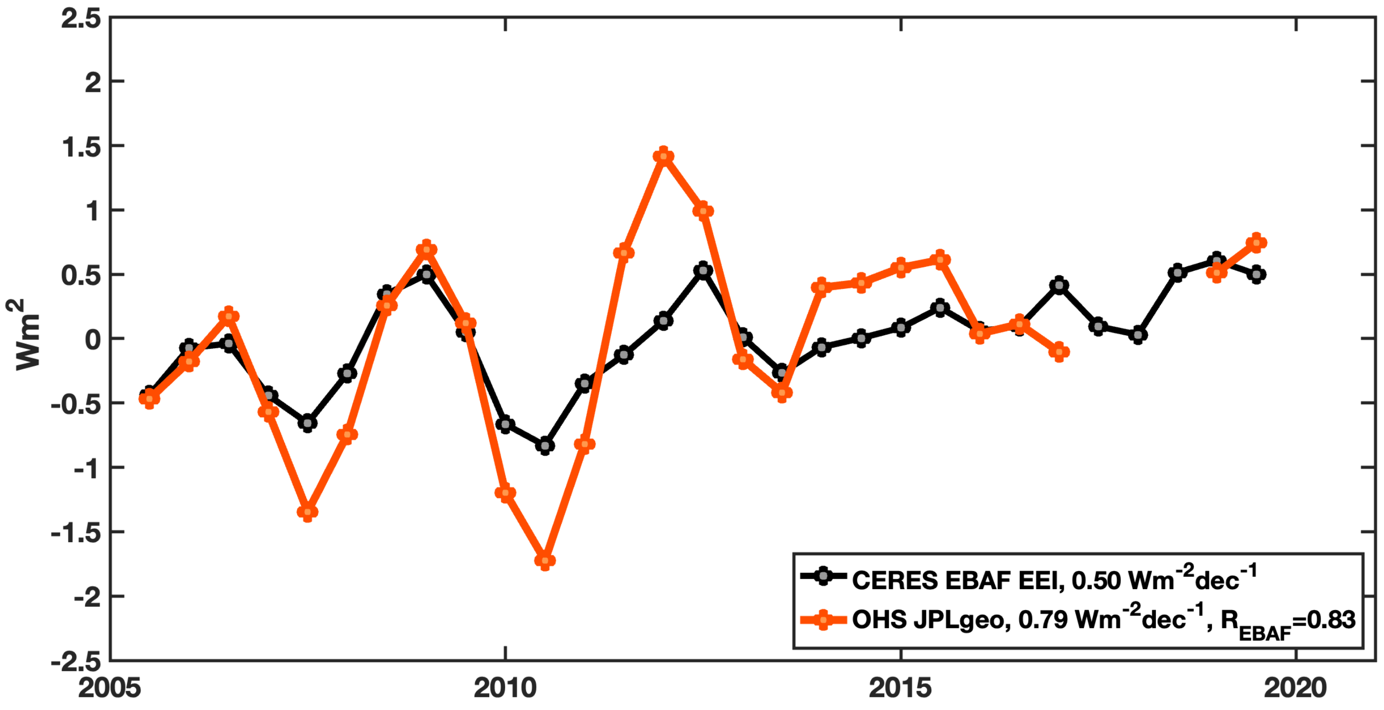
GEWEX-EEI assessment

Define and adopt best practices ?

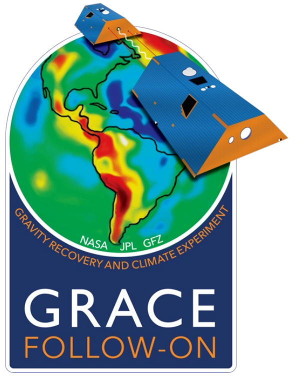
- Coverage & sampling

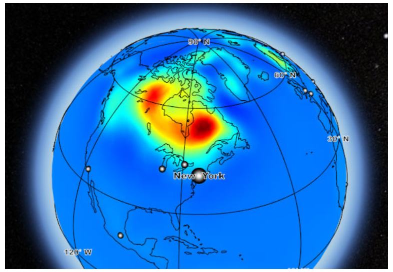
BUT…
Very good agreement CERES EBAF EEI with JPL geodetic ocean heat uptake.
Expansion efficiency: 0.5 Wm^{-2} / $mmyr^{-2}$





Global mean level budget

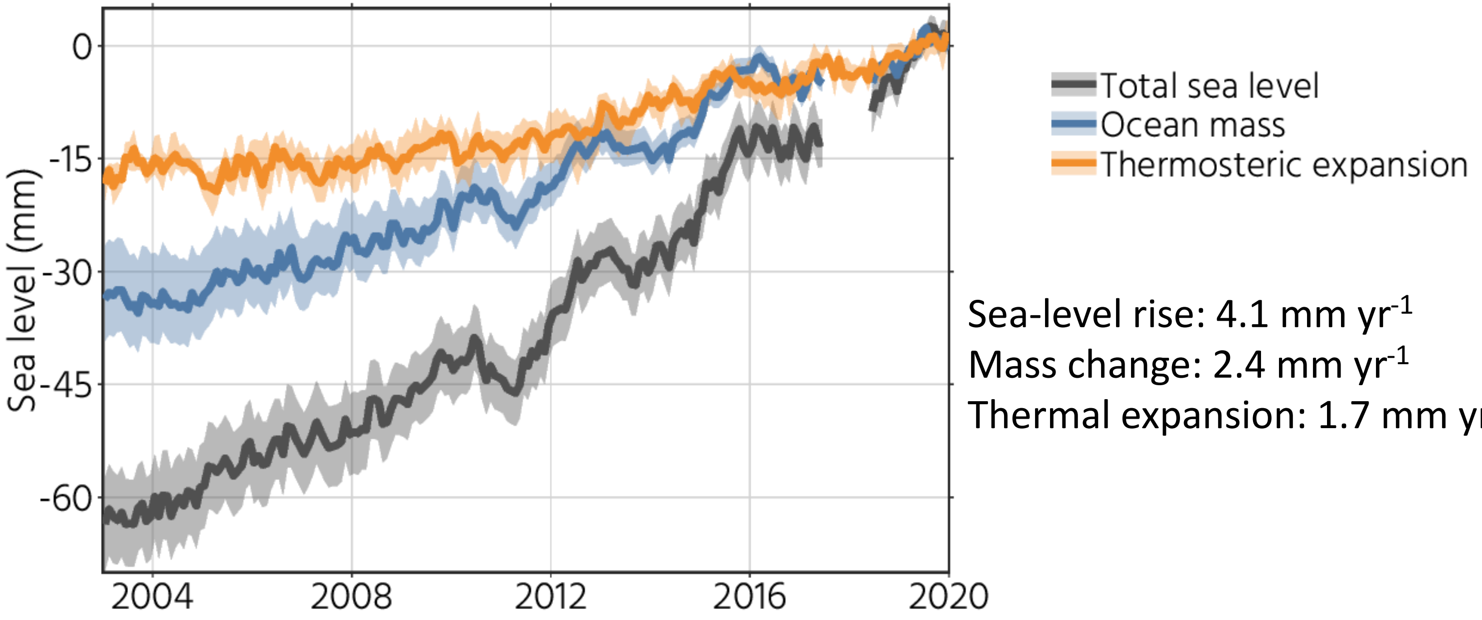




Total sea level change = Ocean mass change + Thermosteric change (+ geophysical corrections)

→ **Thermal expansion (thermosteric change) = Total sea level change – Ocean mass change (+ geo. corrections)**

Sea water's expansion efficiency of heat:
+1 $mmyr^{-1}$ change in thermosteric sea level equals **+0.5 Wm^{-2}** in ocean heat uptake!



Sea-level rise: 4.1 mm yr^{-1}
Mass change: 2.4 mm yr^{-1}
Thermal expansion: 1.7 mm yr^{-1}

GEWEX-EEI assessment

Define and adopt best practices ??

- Coverage & sampling

BUT…
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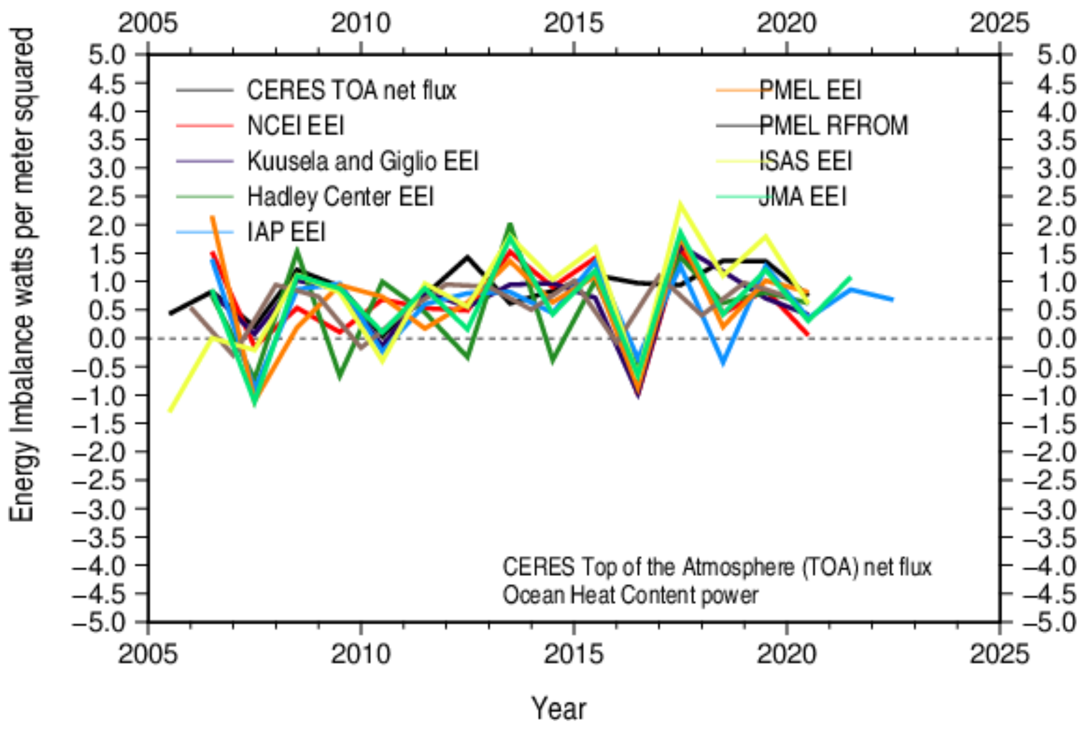
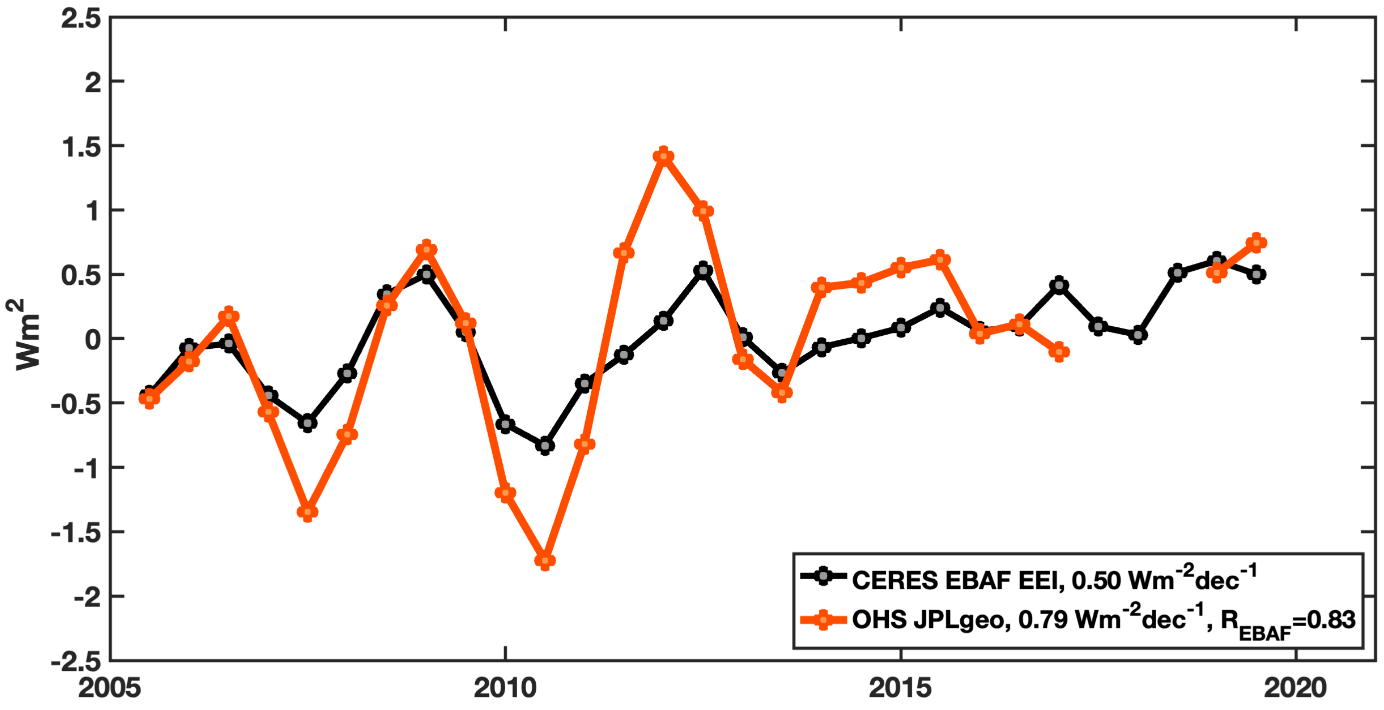
Expansion efficiency: 0.5 Wm^{-2} / $mmyr^{-2}$



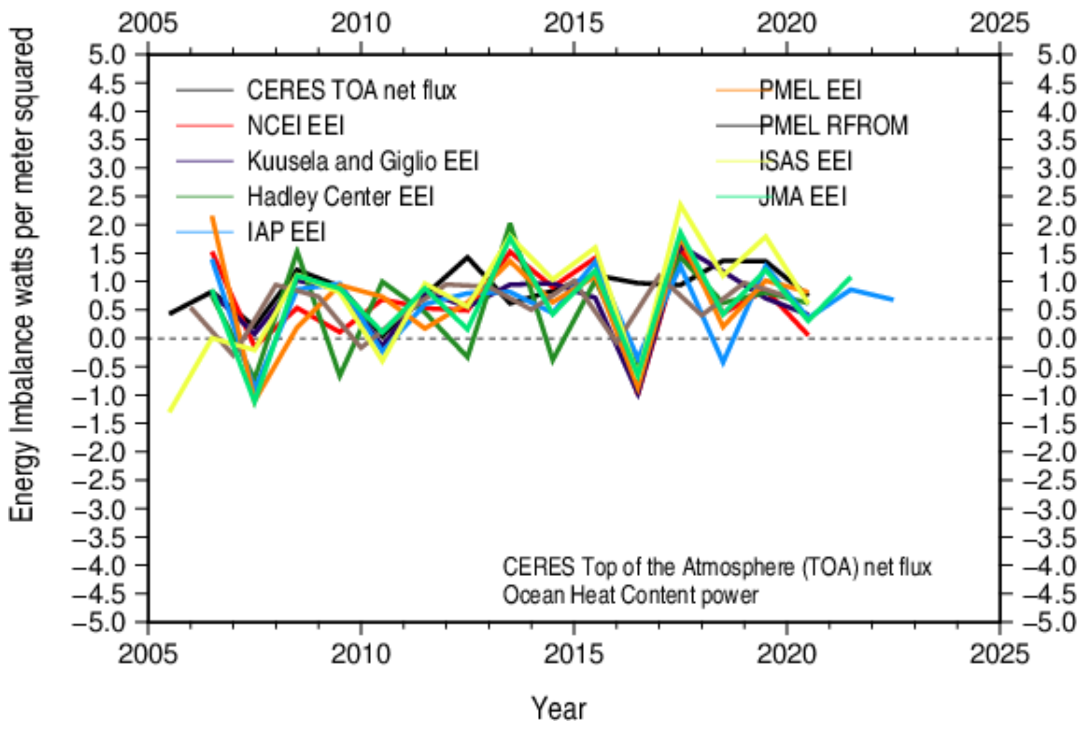


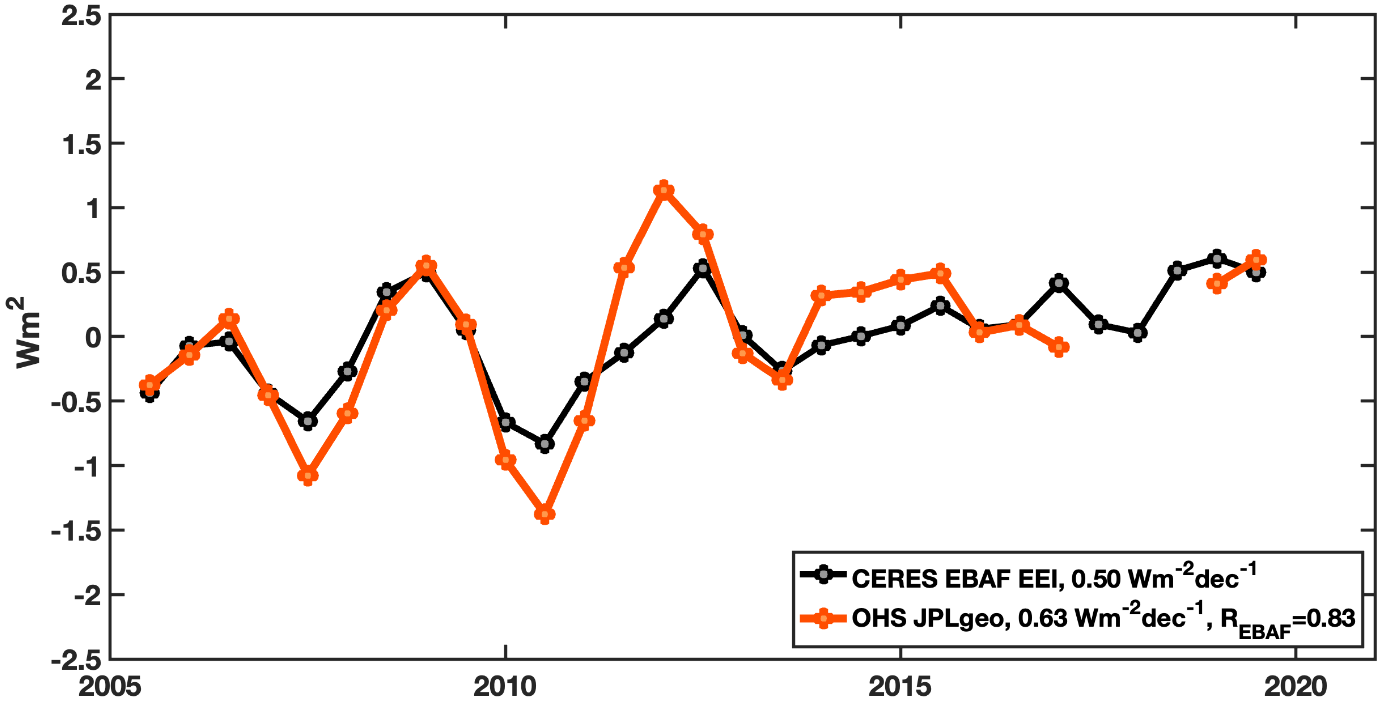
GEWEX-EEI assessment

Define and adopt best practices ??

- Coverage & sampling

BUT…
Very good agreement CERES EBAF EEI with JPL geodetic ocean heat uptake.
Expansion efficiency: 0.4 Wm^{-2} / mmyr^{-1}





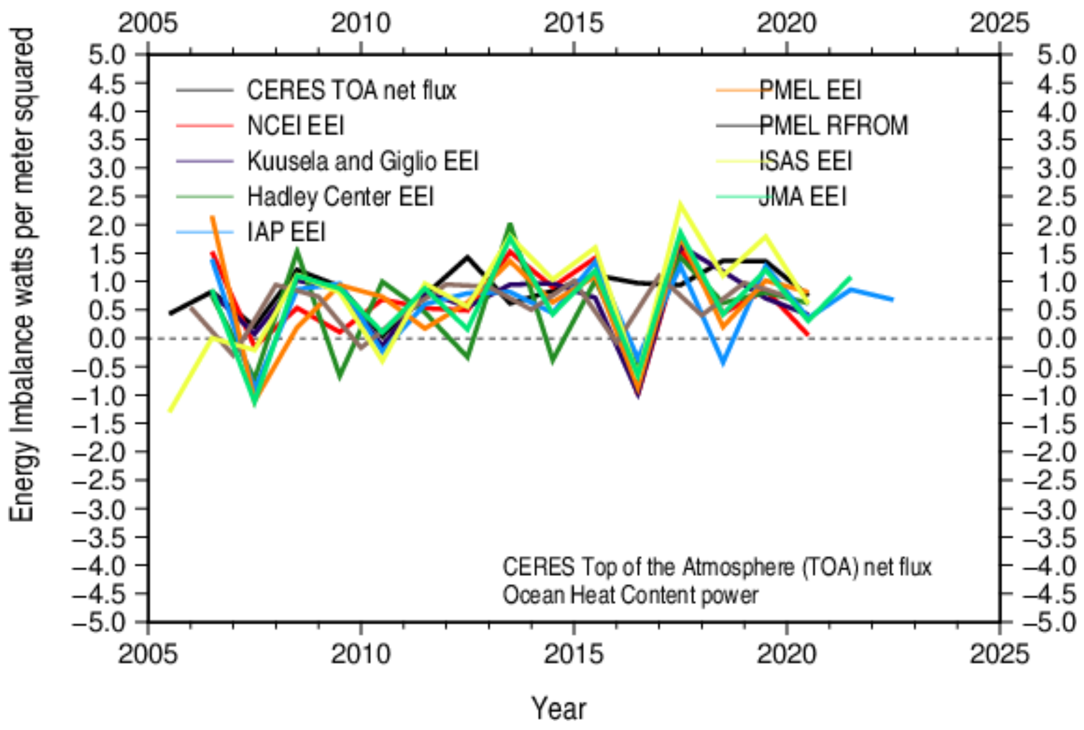
Expansion efficiency of heat acts as a scaling factor - requires further investigation. 0.4 has been used by other groups.

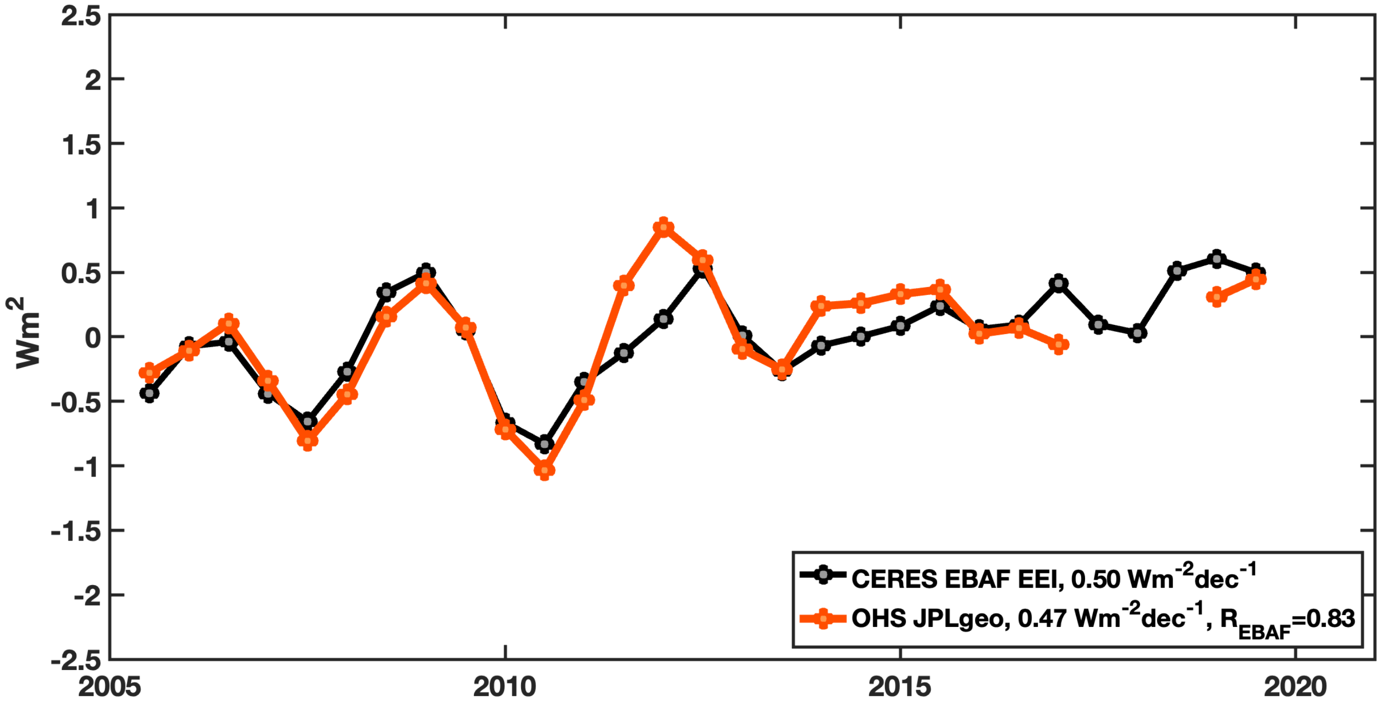
GEWEX-EEI assessment

Define and adopt best practices ??

- Coverage & sampling

BUT…
Very good agreement CERES EBAF EEI with JPL geodetic ocean heat uptake.
Expansion efficiency: 0.3 Wm^{-2} / mmyr-2

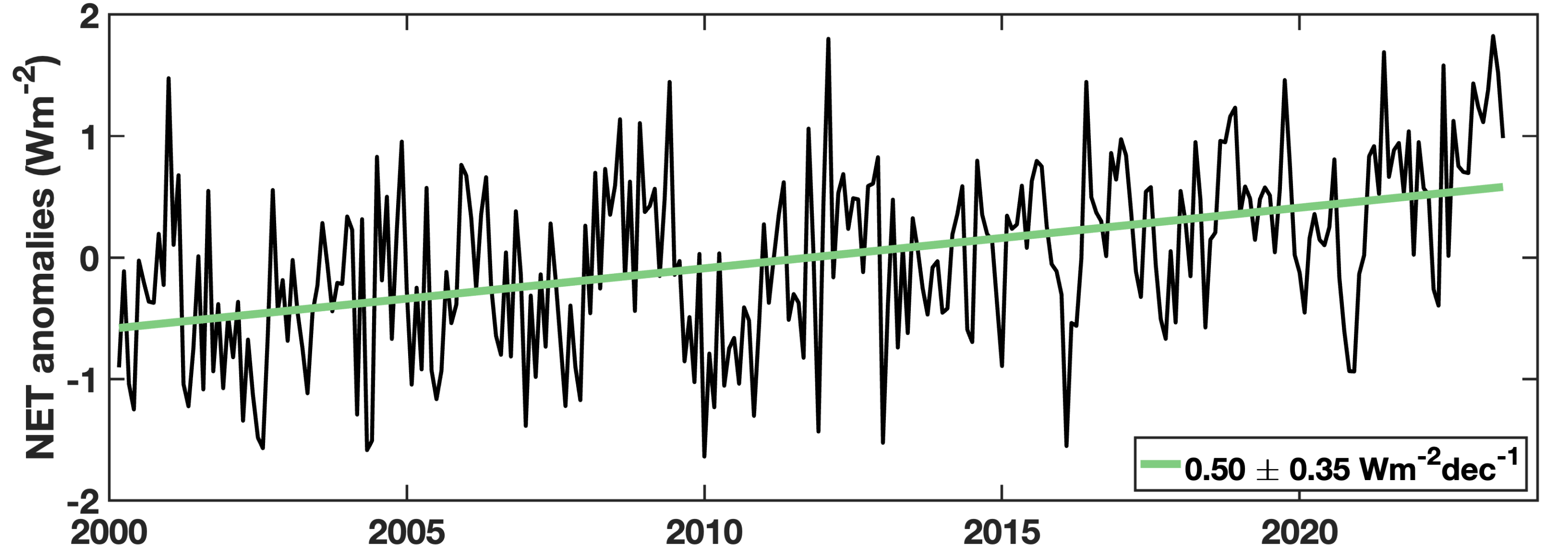




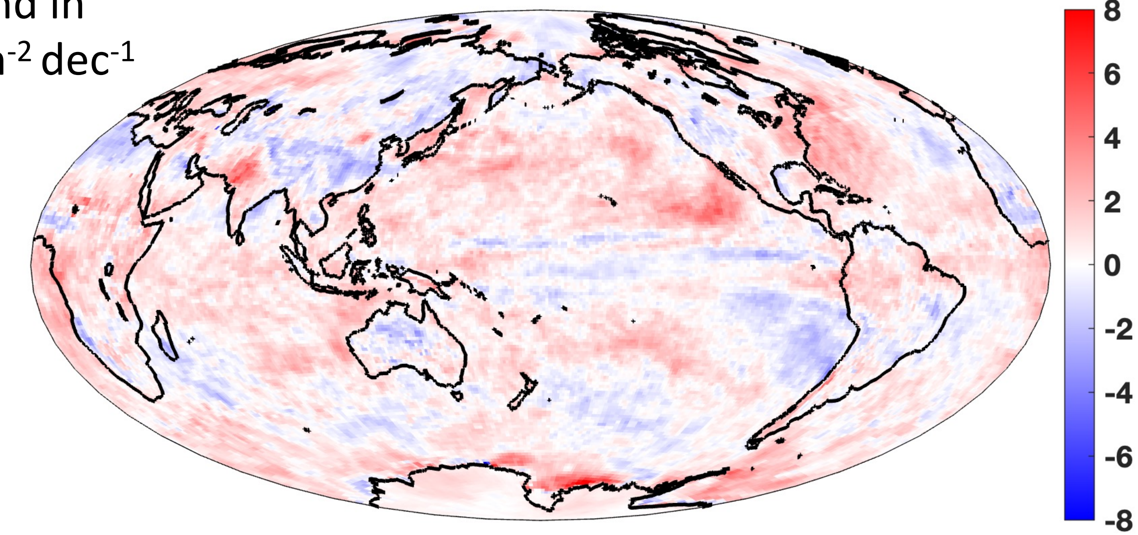
Expansion efficiency of heat acts as a scaling factor - requires further investigation. 0.3 is not sufficiently supported.

Trends in EBAF TOA irradiances

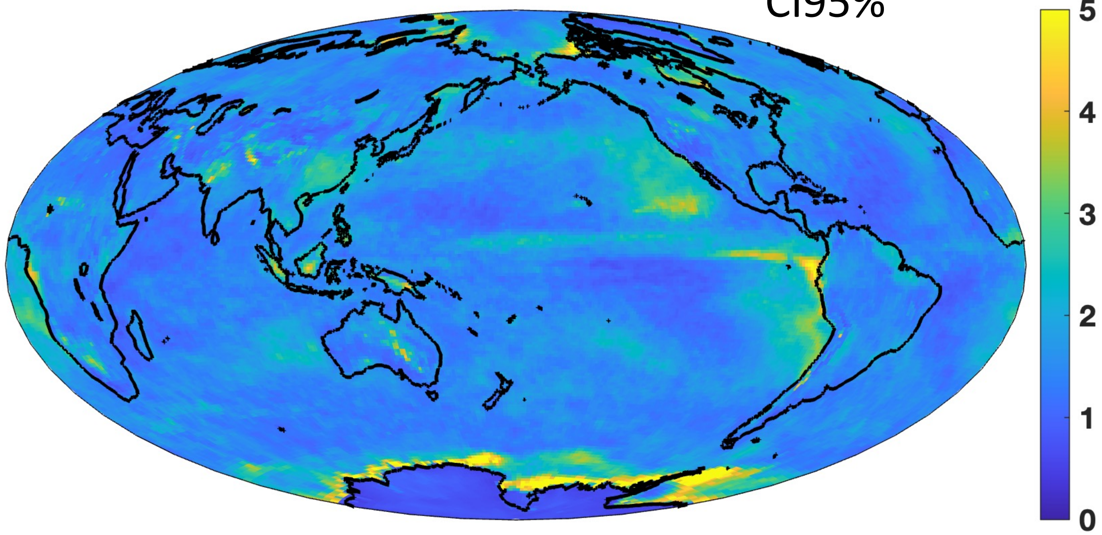
Net radiative flux



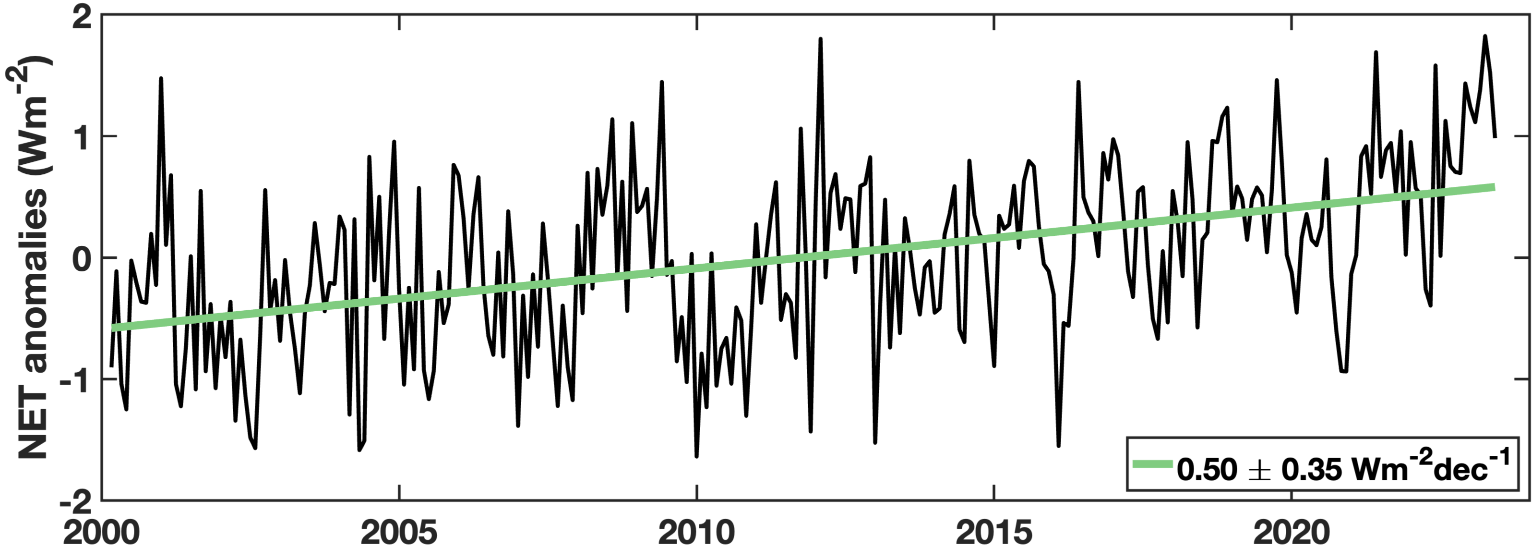
Trend in Wm^{-2} dec^{-1}



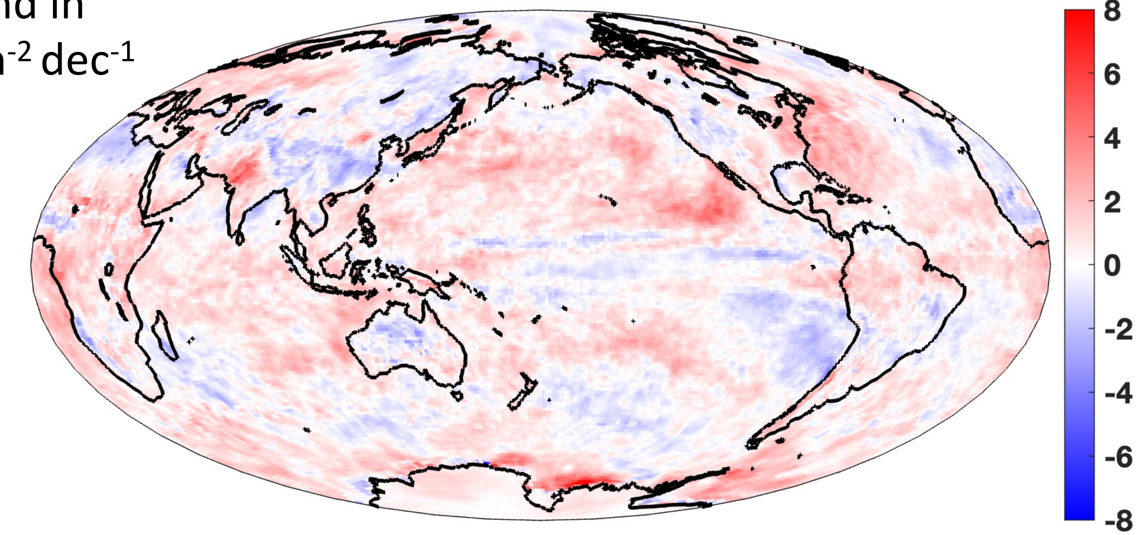
Trend uncertainty
CI95%



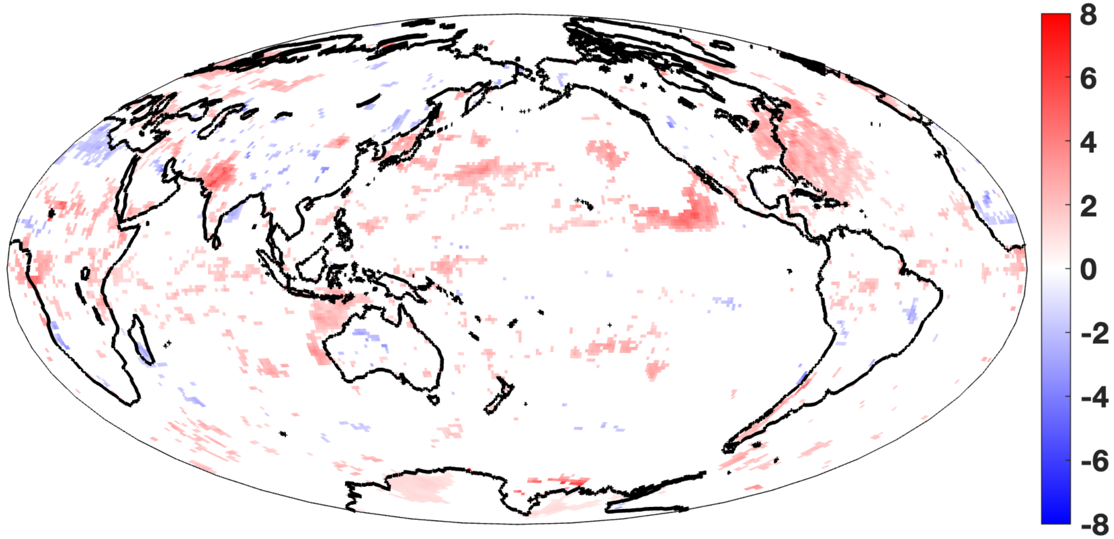
Net radiative flux



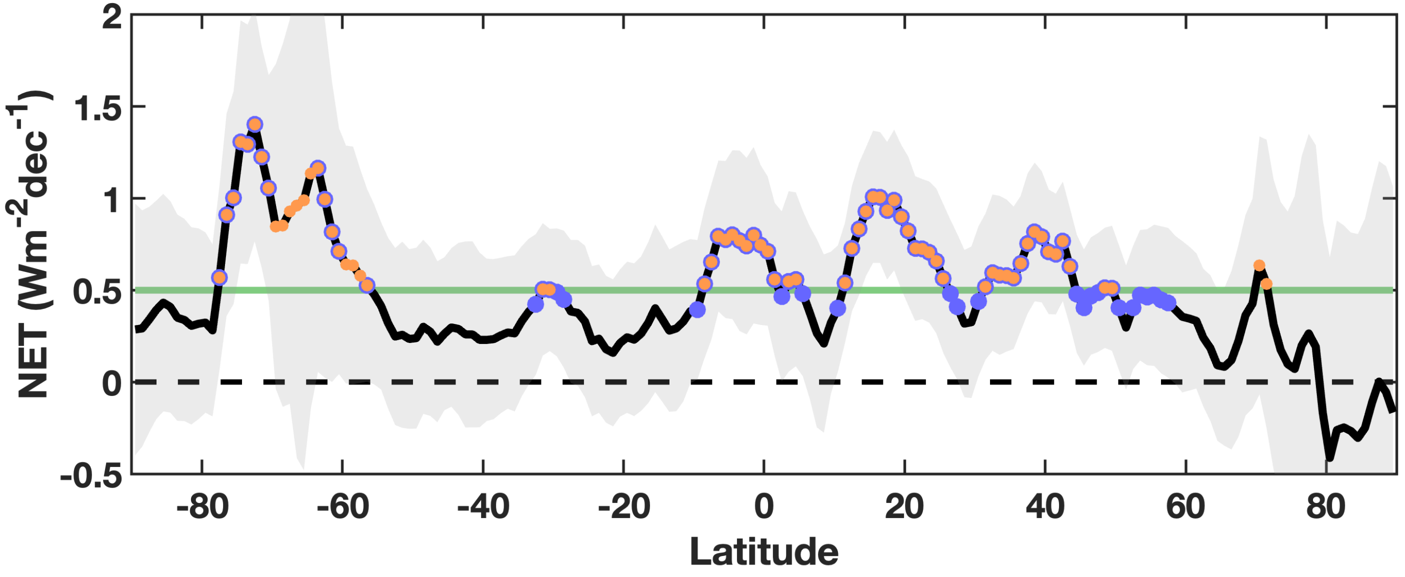
Trend in Wm^{-2} dec^{-1}

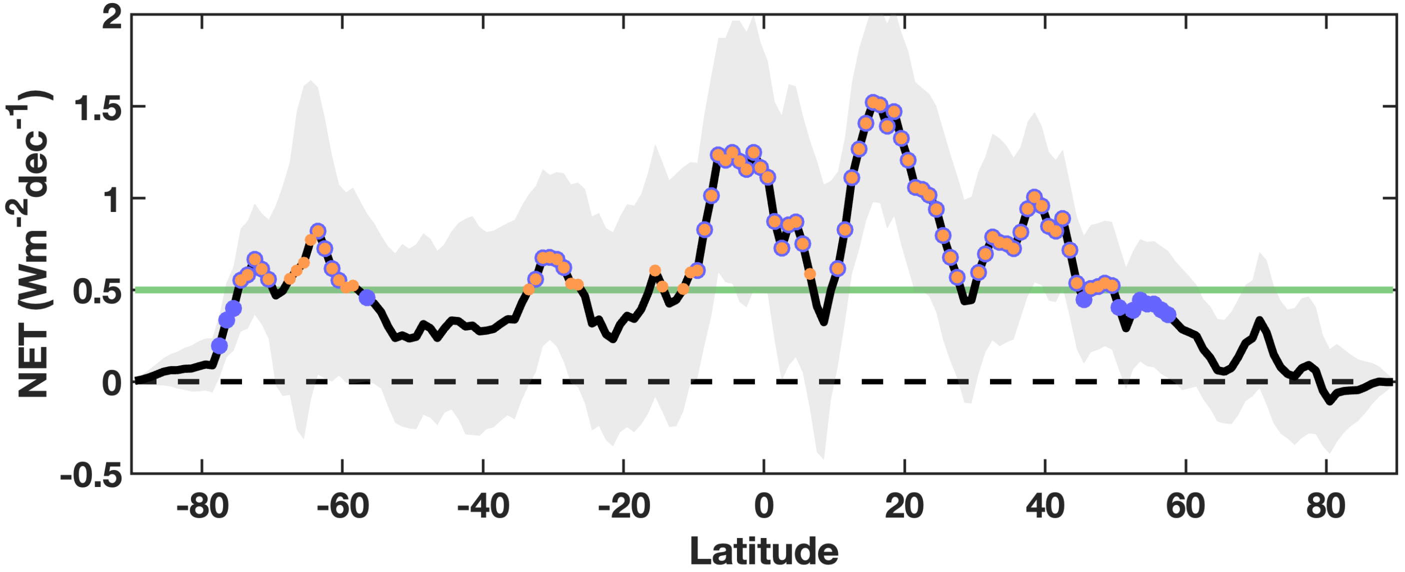


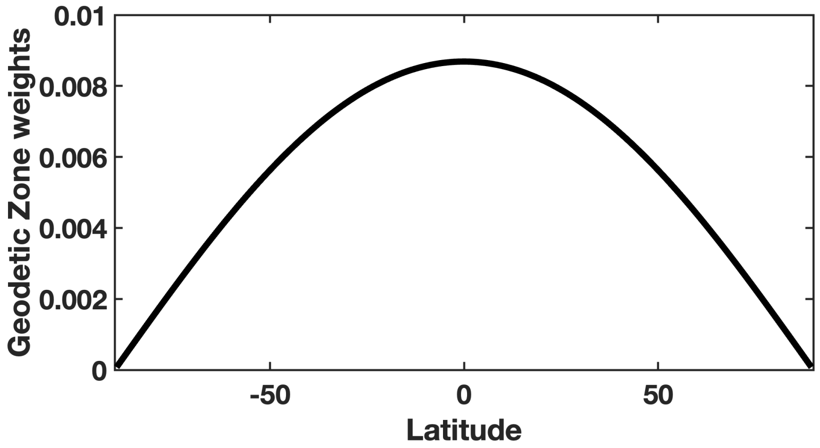
Trend uncertainty



Zonal trends in EBAF TOA irradiances

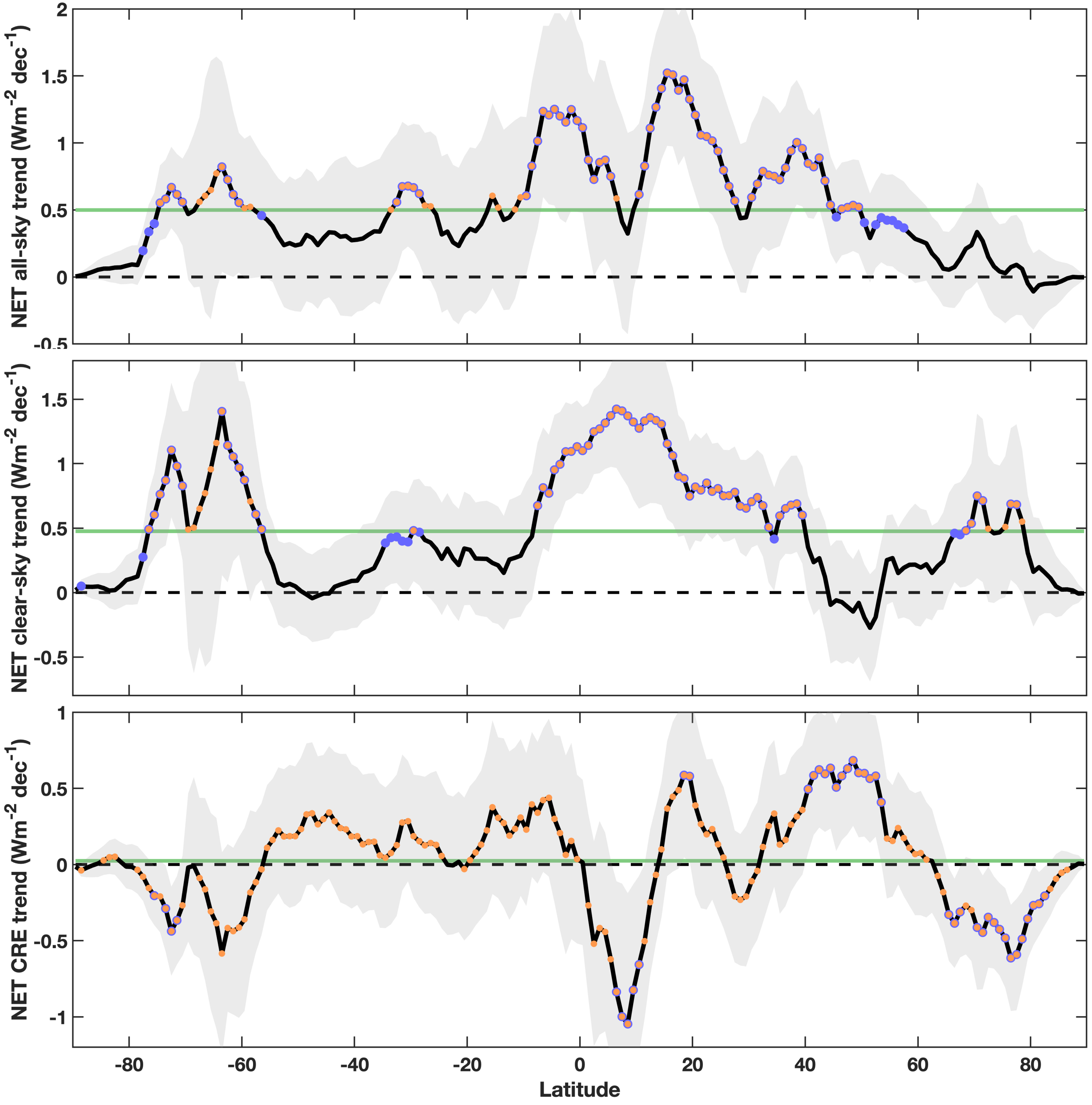






Area weighting so that arithmetic average of zonal trends is equal to global mean (green line).
- to allow direct comparison across latitudes and with global mean

Shading: trend plus/minus CI95%
Purple dots: trend is significant
Orange dots: trend magnitude exceeds global trend.



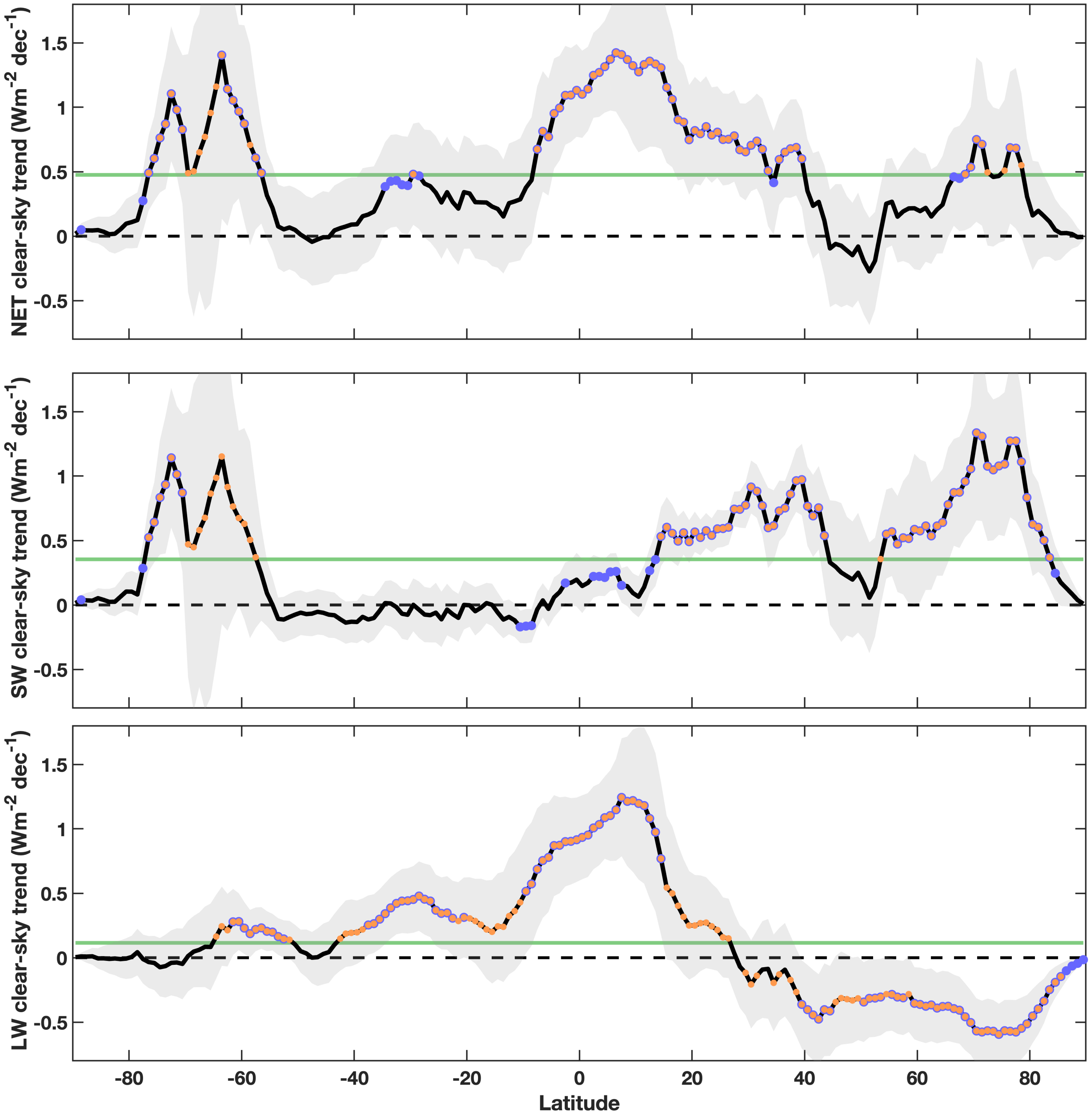
NET all-sky

- Zonal trends in all-sky NET are positive across all latitudes!
- Largest trends between 10S to 50N and 60S-70S

NET clear-sky

- Global clear-sky trend **is ~ all-sky trend**
- Positive almost everywhere.
- Largest in tropics and high latitudes

- NET CRE
- Global net CRE trend **is near-zero**
- Negative trends in NH deep tropics (ITCZ?) and at high latitudes
- (Partial) compensations of clear-sky trend at high lats (mostly NH) and deep tropical dip



NET clear-sky

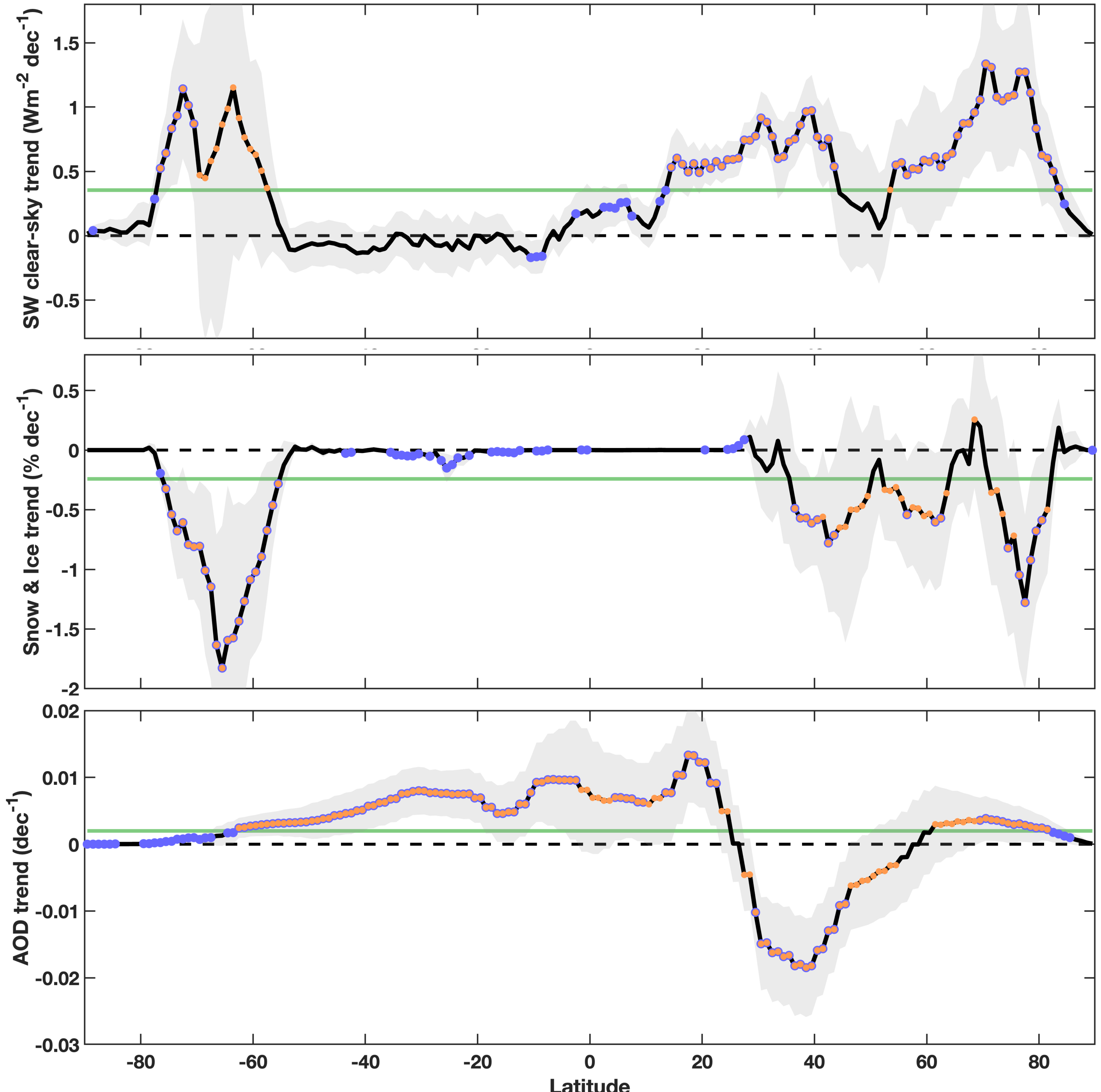
- Global clear-sky trend **is ~ all-sky trend**
- Positive almost everywhere.
- Largest in tropics and high latitudes

SW clear-sky

- Global SW clear-sky trend **is ~ all-sky trend**
- Positive almost everywhere.
- Largest at high lats and NH extra-top

LW clear-sky

- Global LW clear-sky trend **is near-zero**
- Positive southward of 30N and negative on NH
- Super greenhouse effect in tropics??
- NH warms faster?

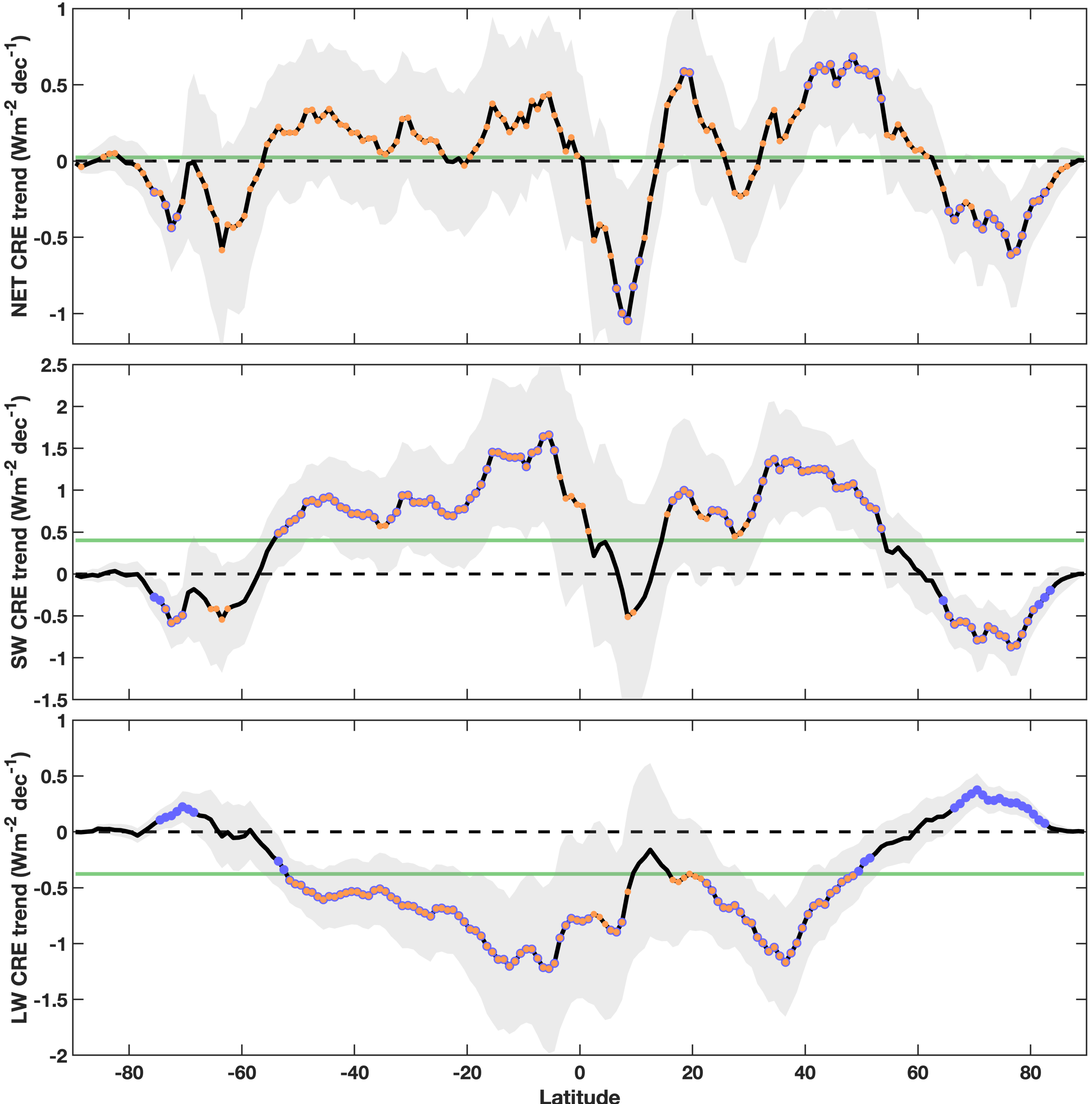


SW clear-sky

- Global SW clear-sky trend **is ~ all-sky trend**
- Positive almost everywhere.
- Largest at high lats and NH extra-top

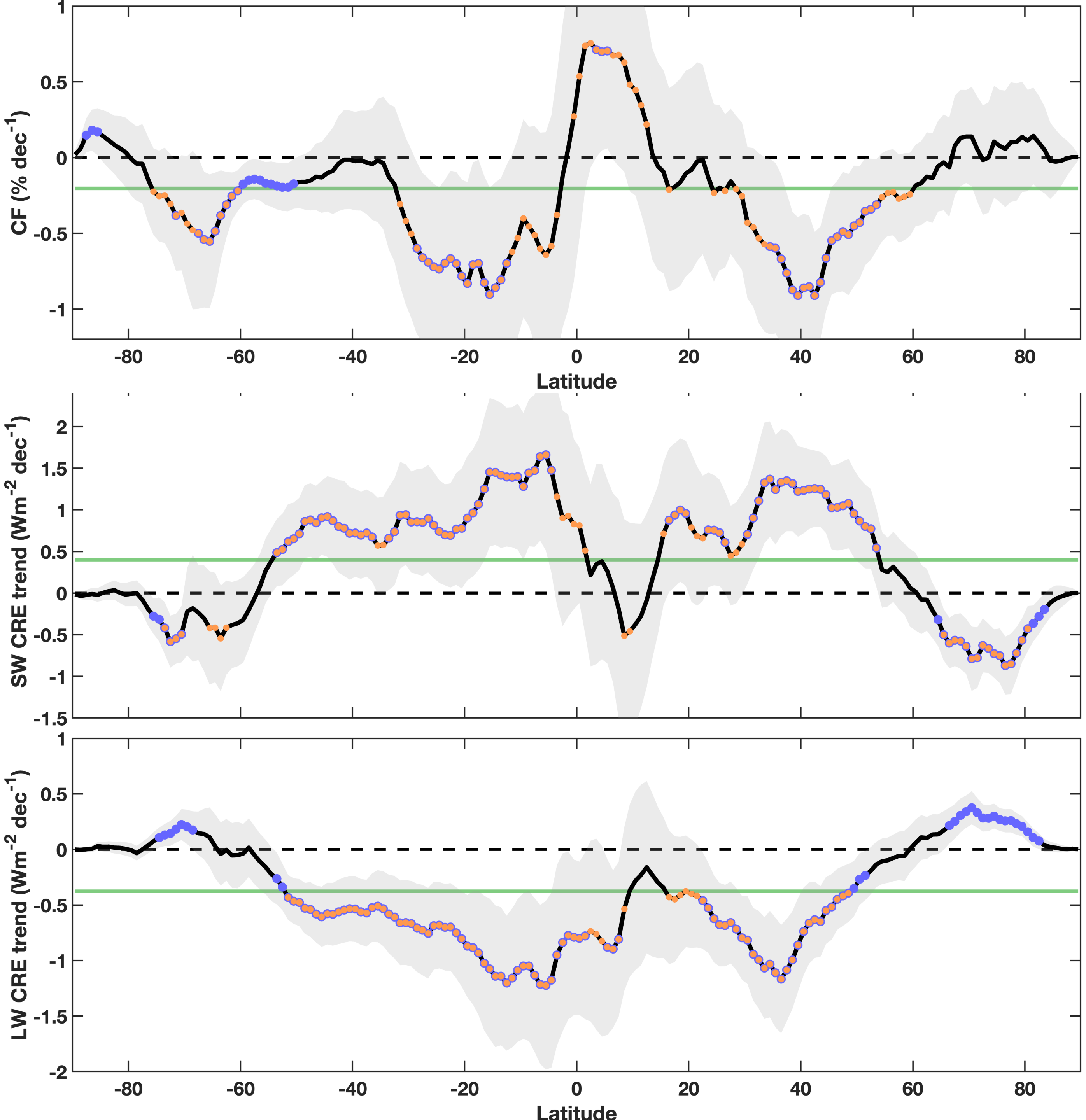
Ice and snow cover

AOD



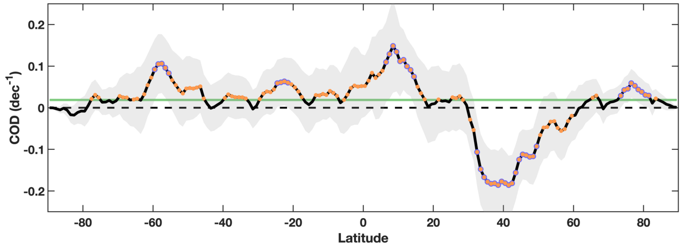
- NET CRE
- Global net CRE trend **is near-zero**
- Negative trends in NH deep tropics (ITCZ?) and at high latitudes
- Compensation of clear-sky trend at high lats (mostly NH) and deep tropical dip

- NET SW and LW CRE
- Global trends nearly compensate
- SW trends slightly more dominant, R w/Net CRE= 0.93; LW R= -0.69
- Deep tropical dip negative LW and SW add up, although LW not as deep.



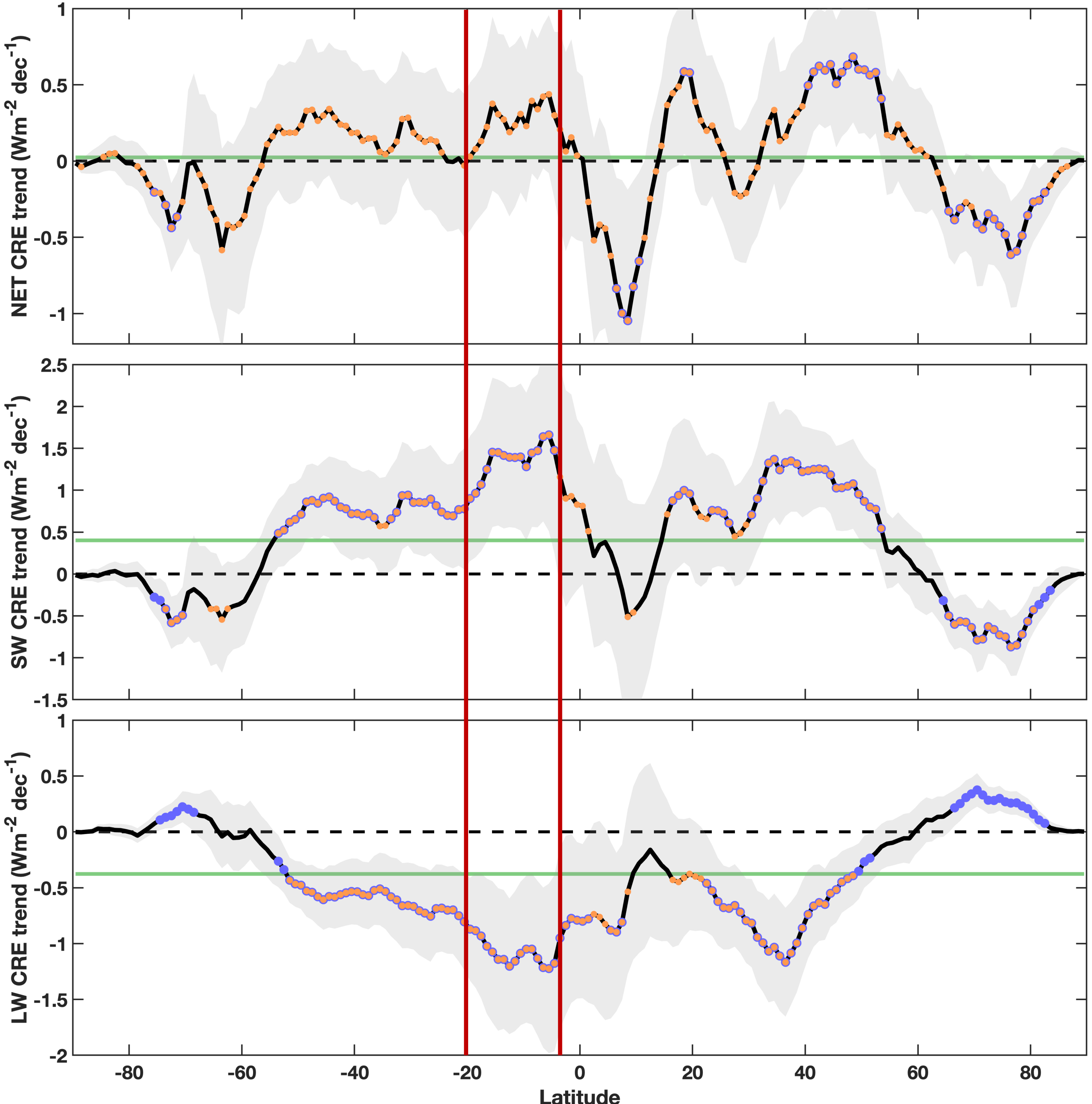
<u>Cloud fraction</u>

- Global negative trend
- Regions of decrease and increase match with CRE trends, except high lats?



<u>NET SW and LW CRE</u>

- Global trends nearly compensate
- SW negative trends prevail at high lats.
- Deep tropical dip negative LW and SW add up
- SW CRE more dominant, R w/Net CRE= 0.93; LW R= -0.69

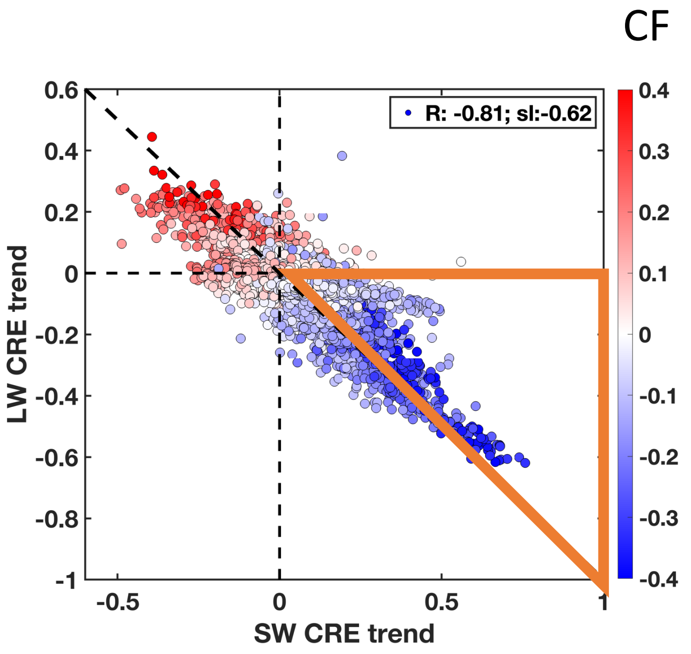


- <u>NET CRE</u>
- Global net CRE trend **is near-zero**
- Negative trends in NH deep tropics (ITCZ?) and at high latitudes
- Compensation of clear-sky trend at high lats (mostly NH) and deep tropical dip

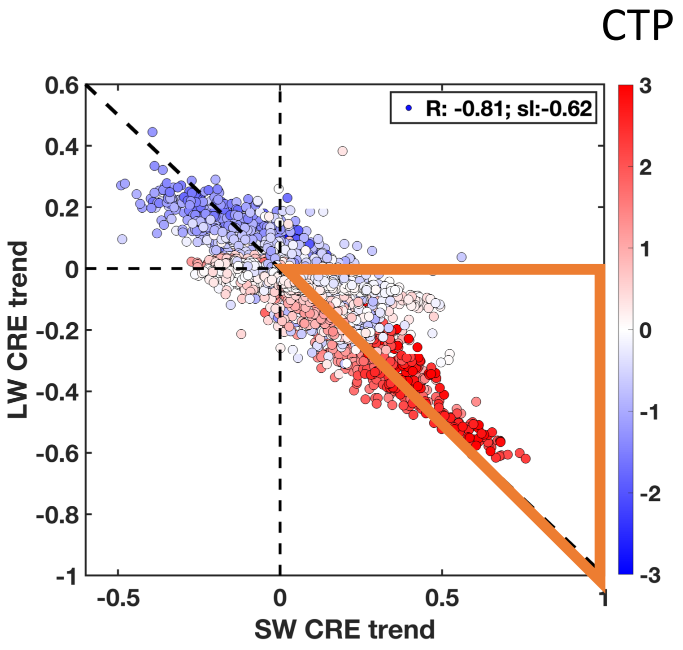
- <u>NET SW and LW CRE</u>
- Global trends nearly compensate
- SW negative trends prevail at high lats.
- Deep tropical dip negative LW and SW add up
- SW CRE more dominant, R w/Net CRE= 0.93; LW R= -0.69

Incomplete LW and SW CRE compensation between 5S-20S

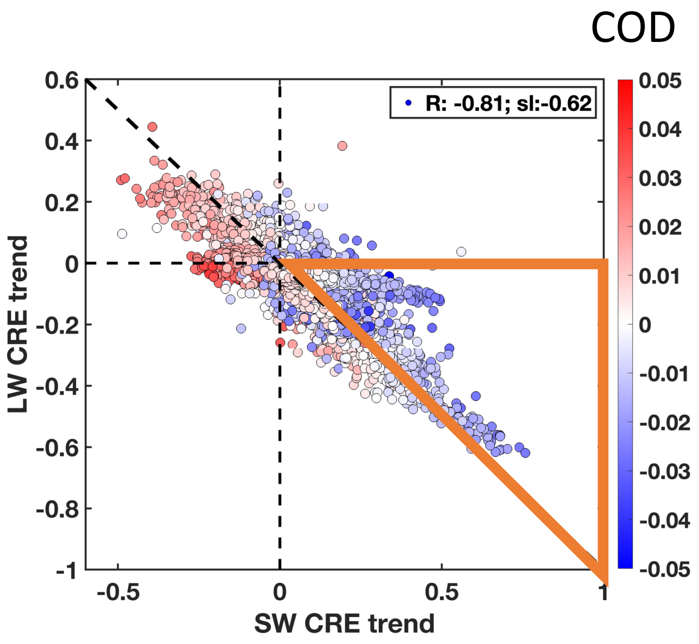
Positive regional SW CRE trends within zonal band > negative LW CRE trends



Fewer clouds



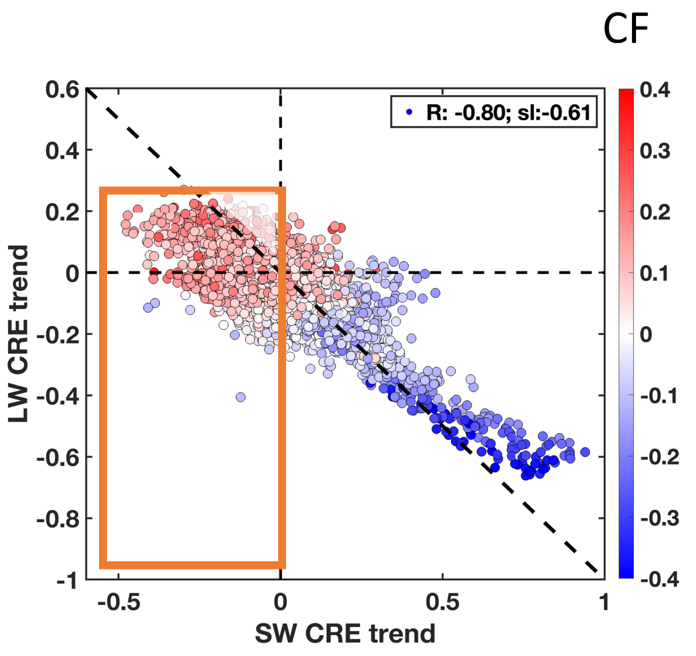
Lower clouds



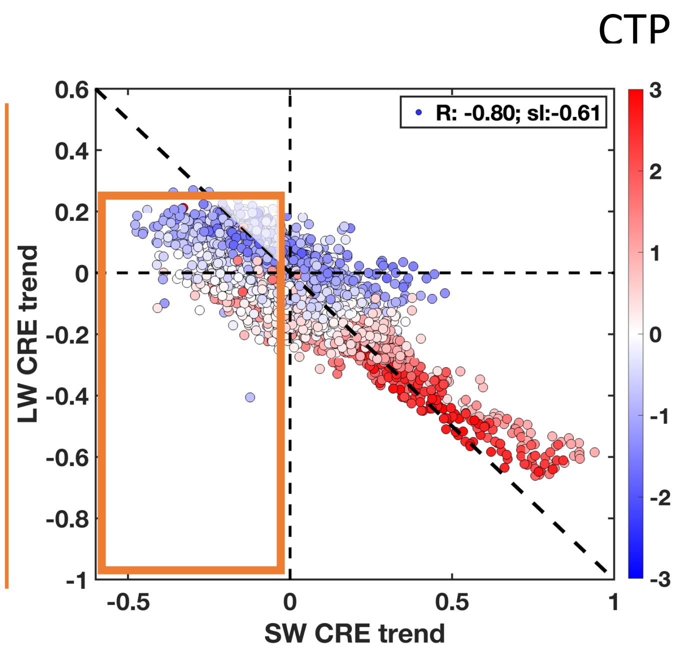
Thinner clouds

Incomplete LW and SW CRE compensation between 0-15N

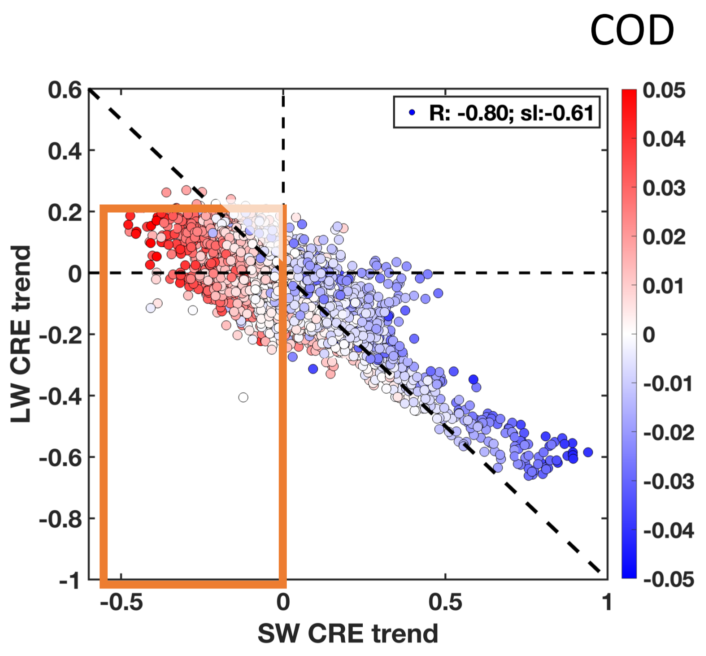
Negative SW CRE trends in deep tropical dip > positive LW CRE trends or add with negative LW CRE trend.



More clouds



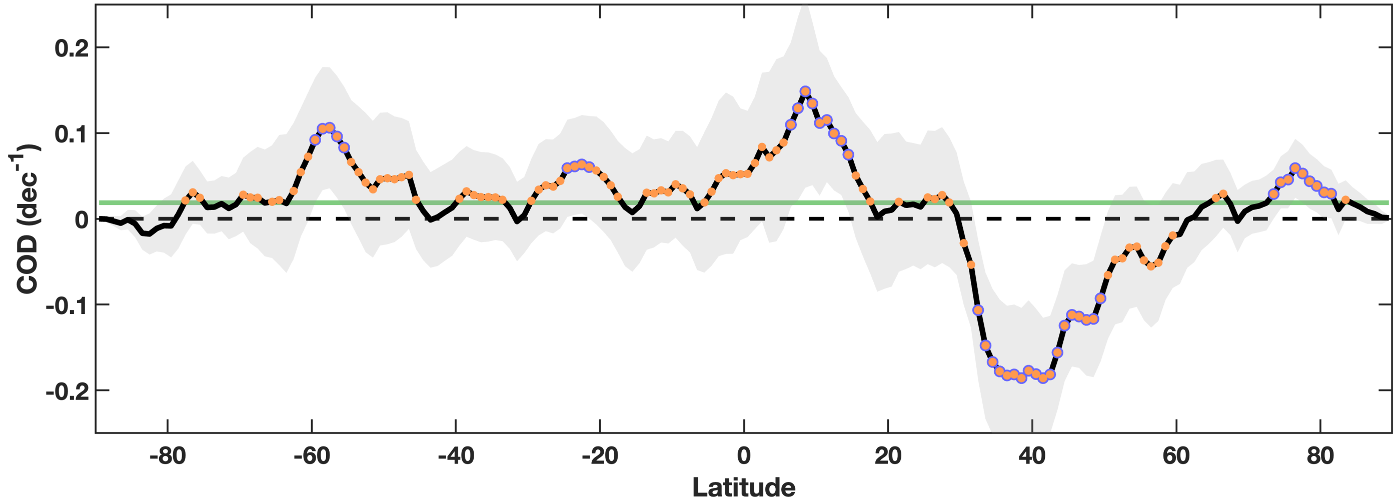
Higher clouds

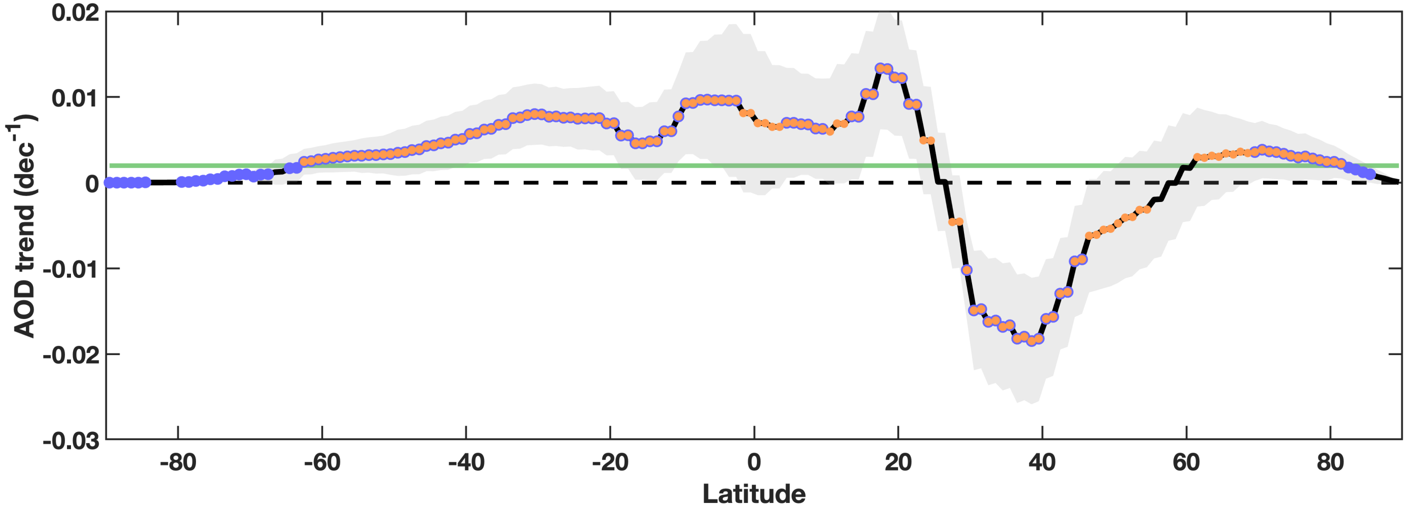


Thicker clouds

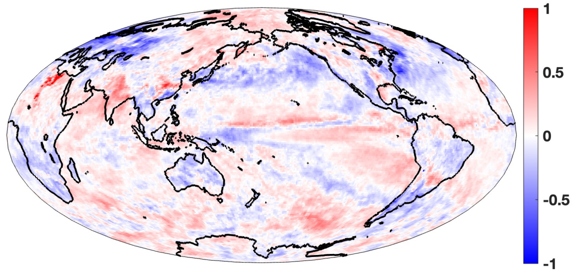
Note on AOD55 and COD trends

Zonal trends correlate at R=0.8

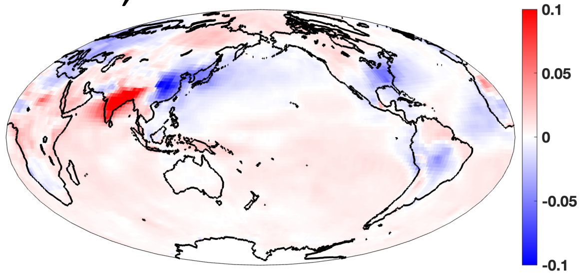




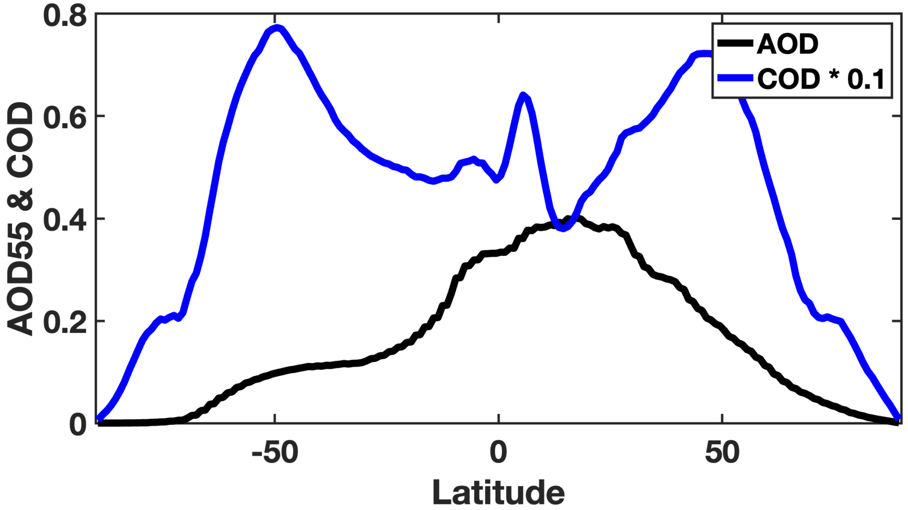
COD trend



AOD trend, R=0.27



Zonal averages



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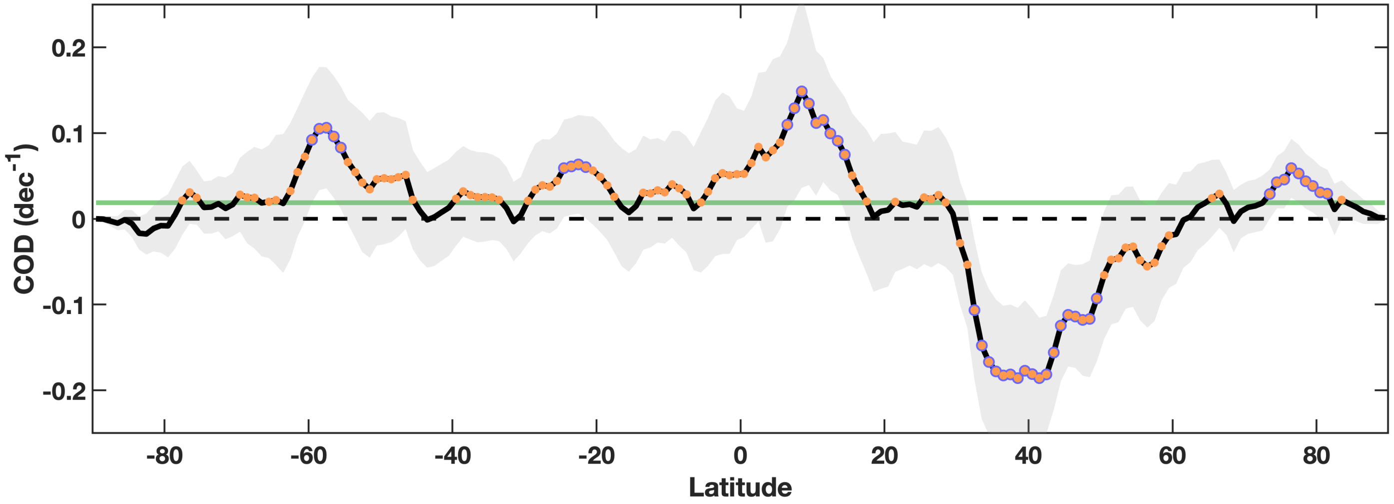
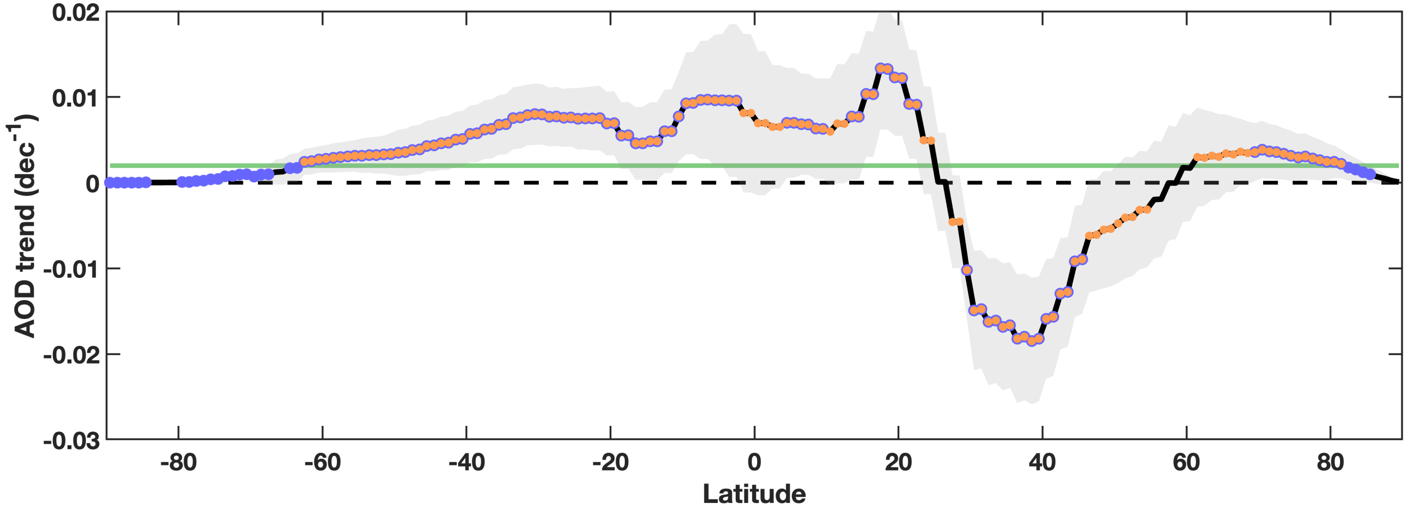
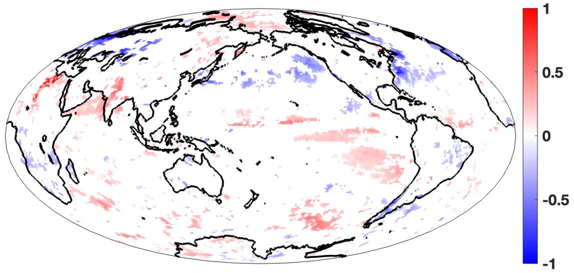
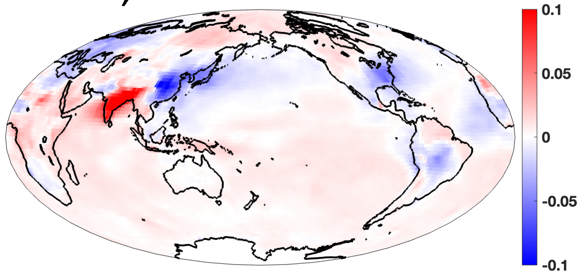




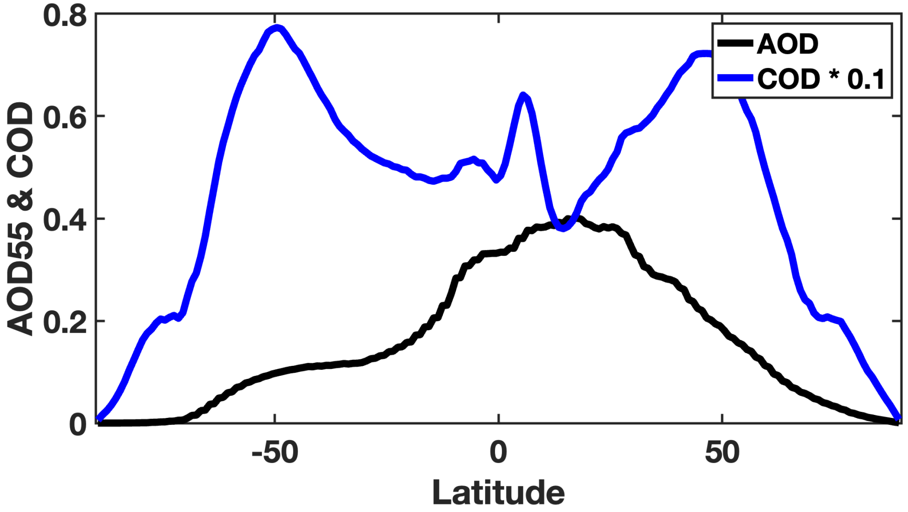
COD trend sig



AOD trend, R=0.47



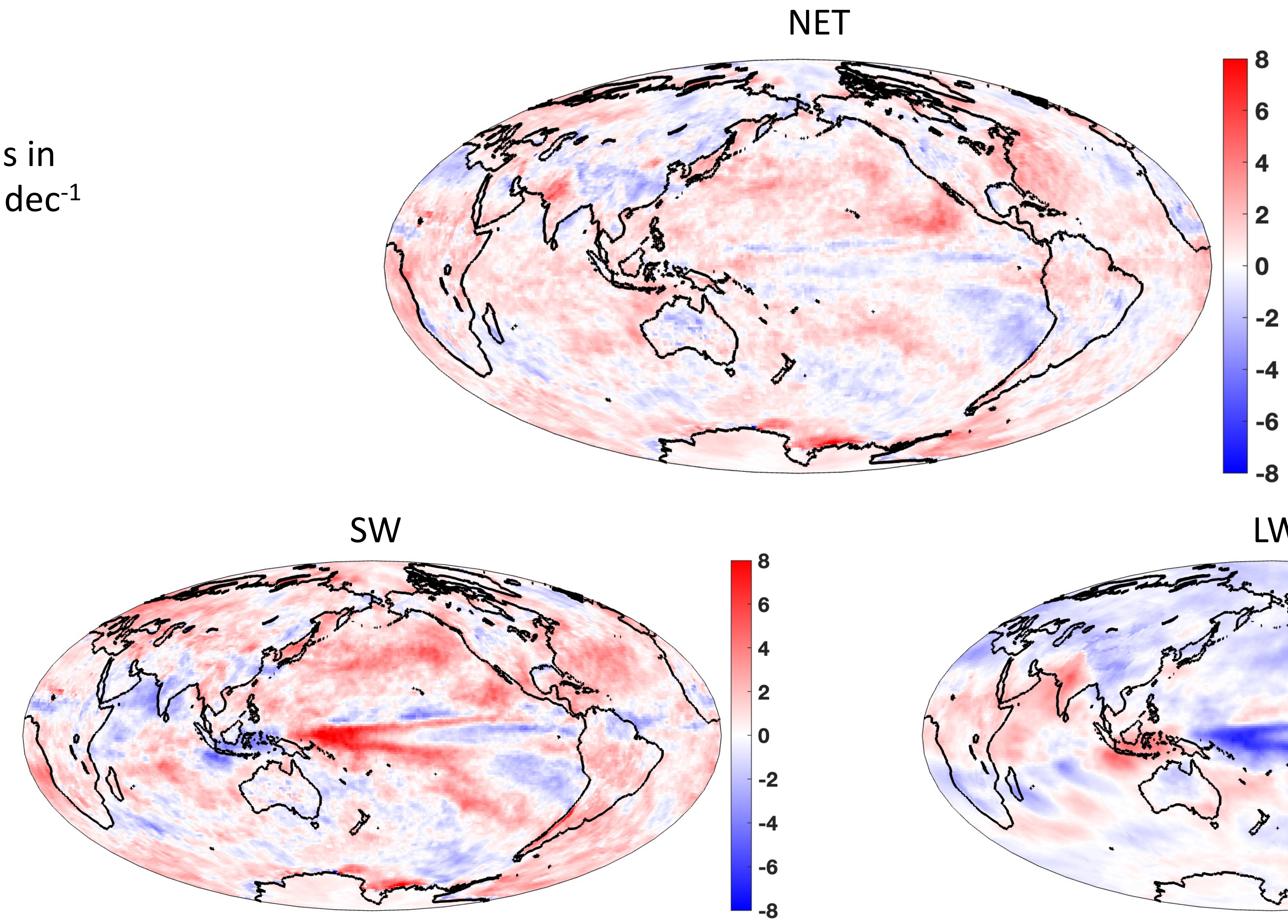
Zonal averages



Conclusions

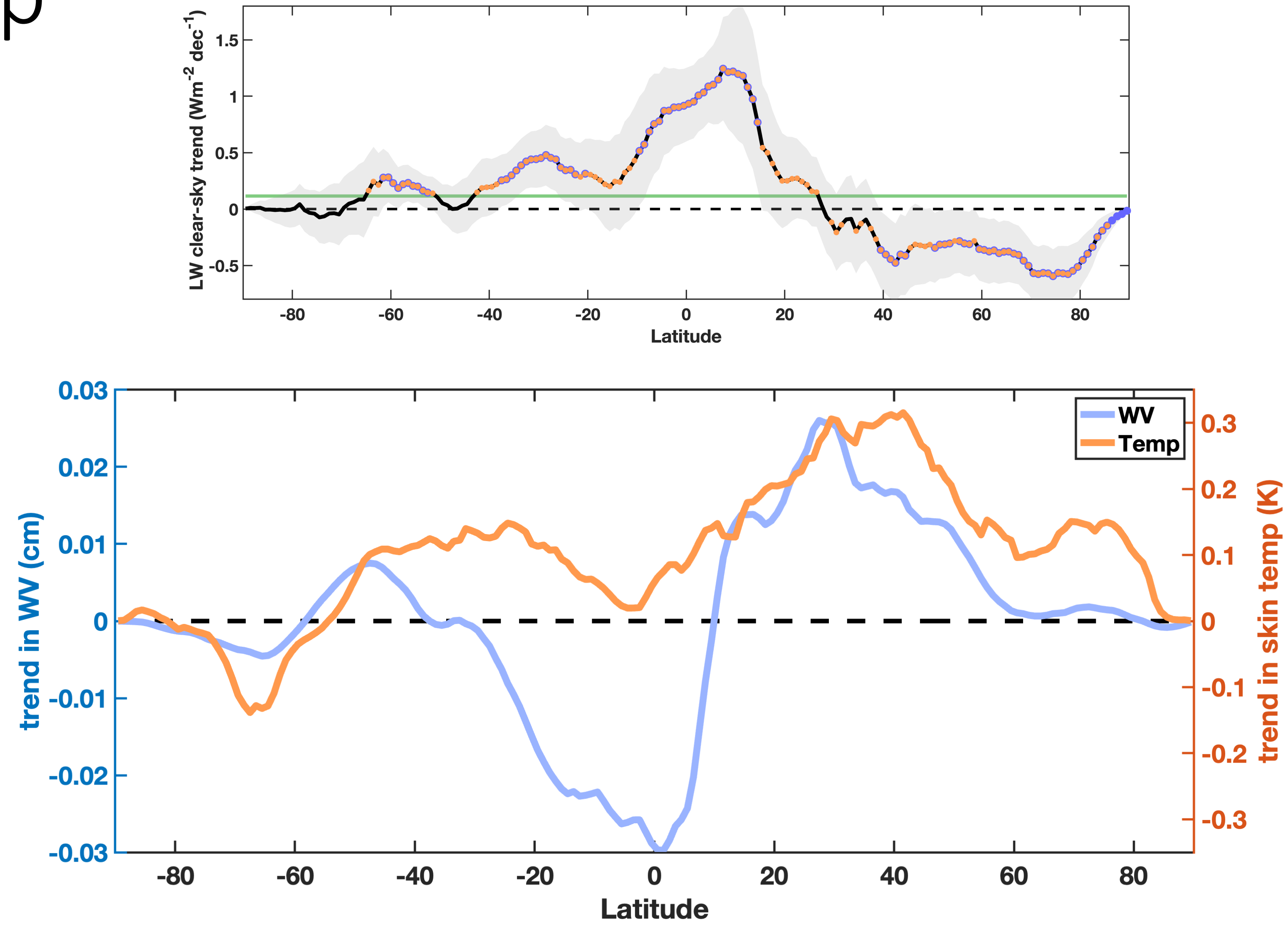
- GEWEX-DAP conducts EEI assessment with focus on ocean heat content and heating rate: Large spread in ocean heat uptake estimates due to: input data, mapping, coverage?
- Satellite-based and hybrid estimates agree best with EEI variability, but "scaling" with expansion efficiency requires investigation – more complete spatiotemporal sampling appears to be key.
- Zonal trends in EBAF fluxes reveal:
  - positive NET flux trends across all zones.
  - … largely a result of positive clear-sky NET and SW trend (snow and ice mostly? – requires surface and atmospheric contribution analysis)
  - … Partial compensation by CRE at high lats and deep tropical dip
  - SW and LW CRE nearly cancel globally and by latitude, slight dominance of positive SW CRE
  - Positive (negative) SW CRE "dominance" in tropics comes with fewer (more), lower (higher), and thinner (thicker) clouds – related to convective intensity?
- Zonal trends in COD and AOD show large correlation (indicative of cloud-aerosol interaction?) which is not as evident on the regional scale.

Trends in $Wm^{-2}\,dec^{-1}$



Positive indicates "absorbed" or "downward"

Backup



LW clear-sky trend (Wm^{-2} dec^{-1})
1.5
1
0.5
0
-0.5
-80
-60
-40
-20
0
20
40
60
80
Latitude
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
trend in WV (cm)
WV
Temp
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
trend in skin temp (K)
-80
-60
-40
-20
0
20
40
60
80
Latitude