Synergy of Satellite Radiation, Precipitation, and Other Meteorological Variable Observations for Global Mean Sea Surface Turbulent Heat Flux Estimation

Bing Lin

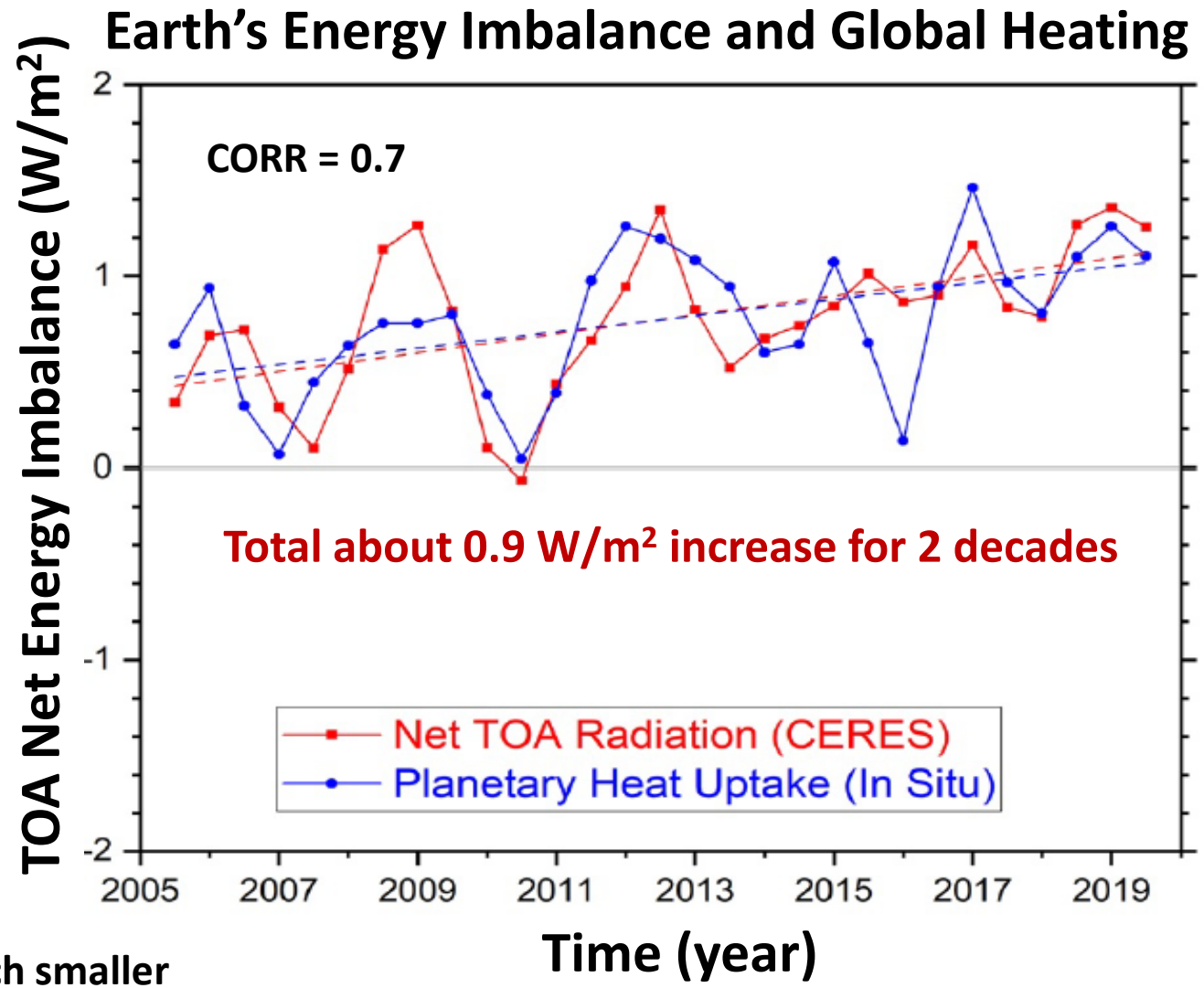
Science Directorate, NASA Langley Research Center

AMS 104th Annual Meeting

Baltimore, MD, January 29, 2024

Introduction

Loeb et al. (2021) found accelerated heating, mainly for the ocean, from both TOA net radiation and in-situ observations.



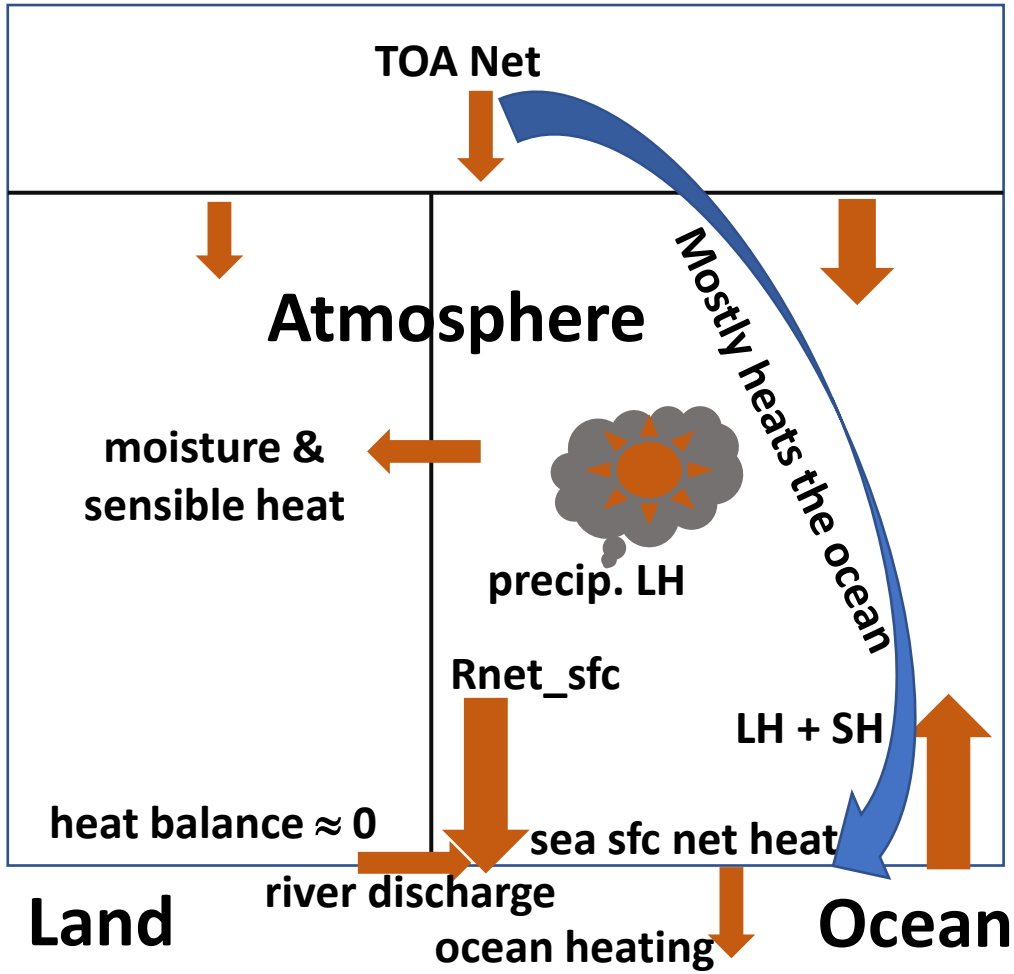
In-situ global net heat uptake: 0.77 ± 0.06 Wm^{-2}
Ocean: 0.62 ± 0.05; Deeper ocean: 0.062 ± 0.038
Land: 0.037 ± 0.004; Melting ice: 0.031 ± 0.006
Air T/q: 0.014 ± 0.009

much smaller

The trends of 0–2,000 m ocean and CERES TOA heat flux anomalies are is 0.43 ± 0.40 W m^{-2} $decade^{-1}$ and 0.50 ± 0.47 W m^{-2} $decade^{-1}$, respectively. (Loeb et al., GRL 2021)

Introduction (conti.)

Other energy cycle components of the climate system could have related variations due to the fundamental linkage among these components within the energy and water cycles, especially over oceans such as turbulent heat (TH) flux.

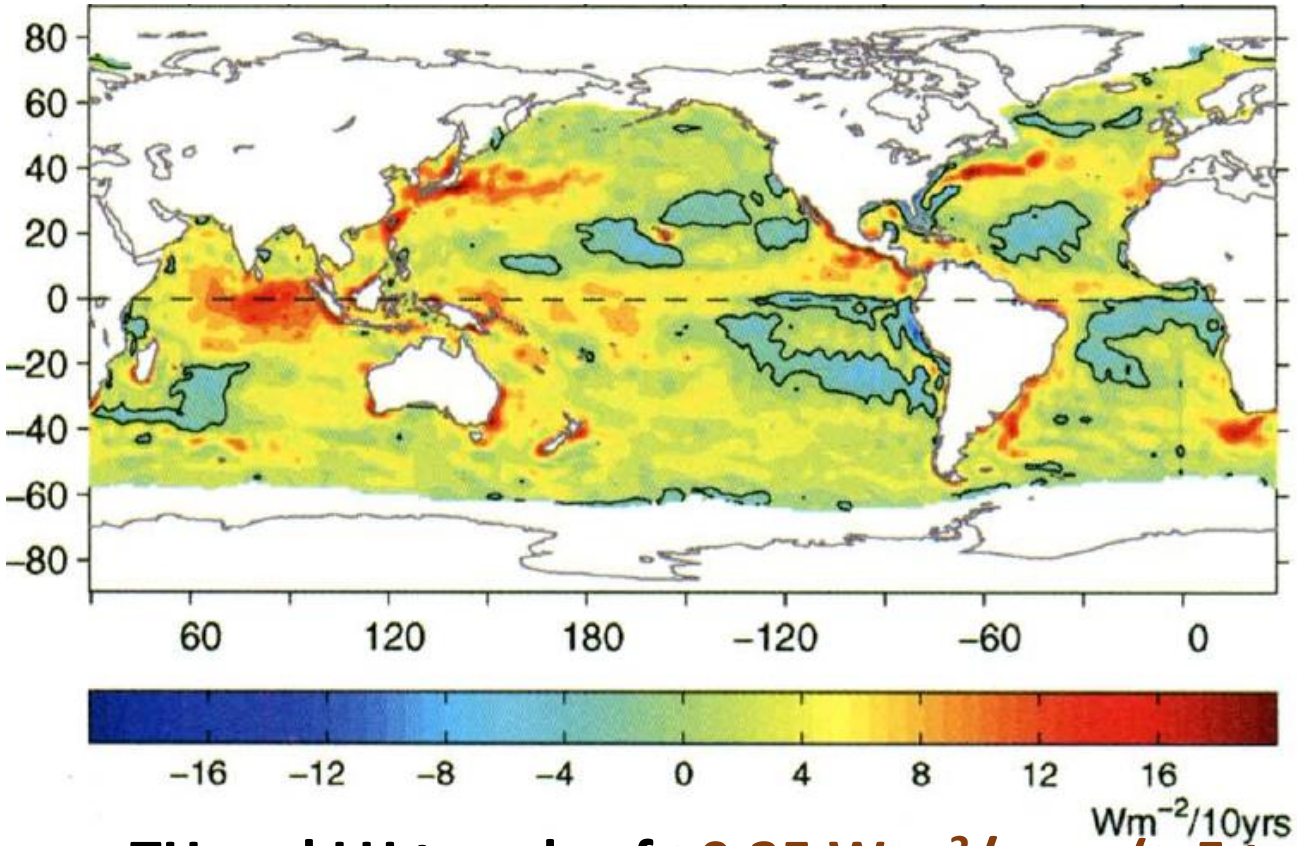


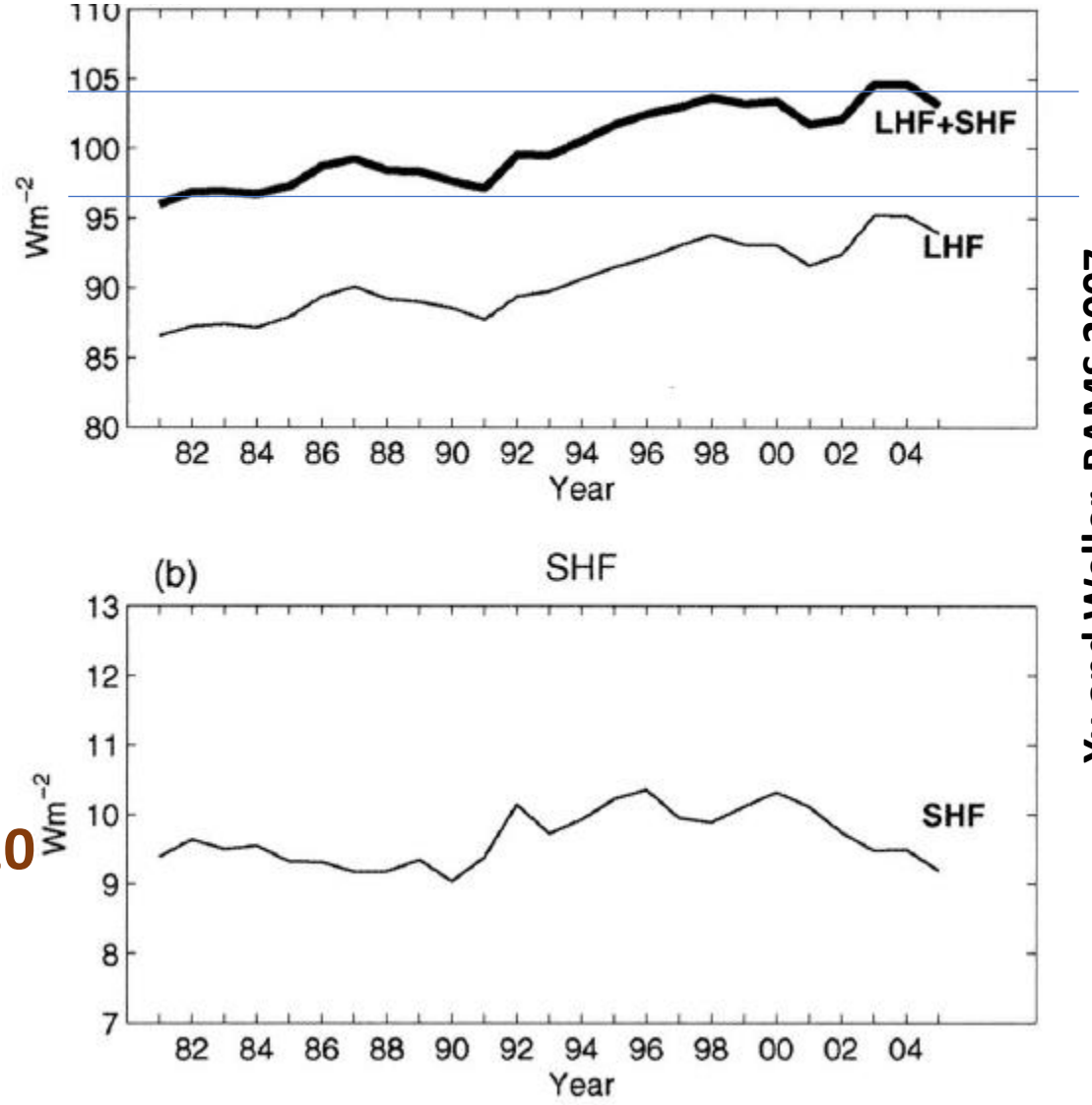
Rad, precip. latent, sfc latent, and sensible heats, and land-ocean heat exchange (transport)

Large differences for sea surface TH estimates

(Objectively Analyzed Air-sea Fluxes, OAFlux)

Annual mean systematic error could be about 7 W/m^2 or 8% (Cronin et al. FMS, 2019; Yu et al., JC, 2017)





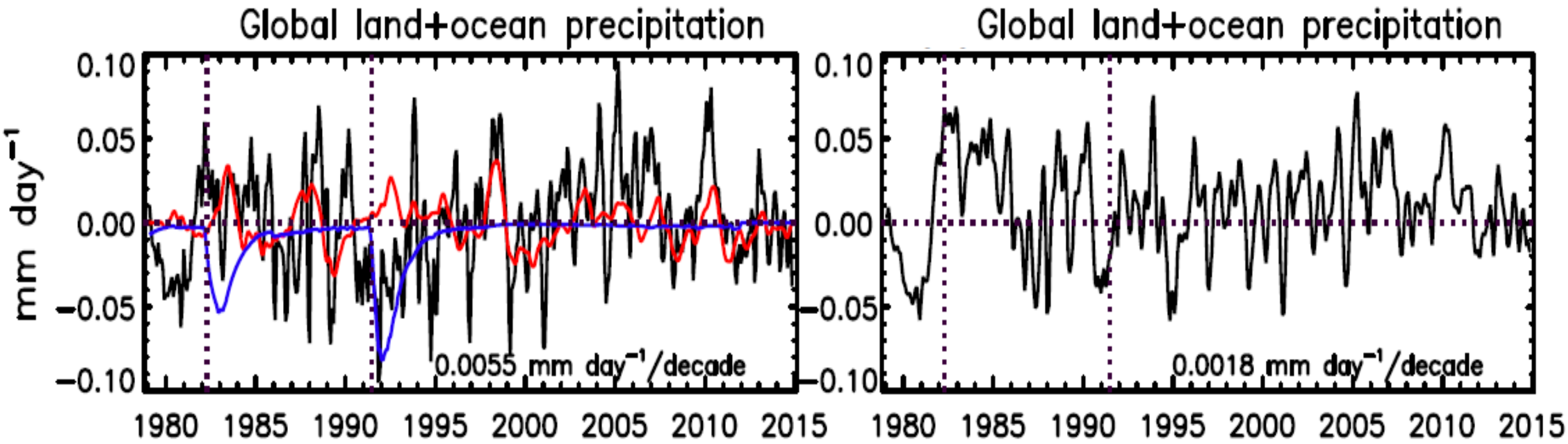
Yu and Weller, BAMS 2007

Large TH and LH trends of ~0.35 Wm^{-2}/year (~ 5 to 10 times bigger than that from radiation data) were found. Meteorological variables such as Δq, Ta, W, and turbulent transfer coefficients may be the key.

Introduction (conti.)

- Accelerated heating for the climate system, dominantly for the ocean, is found from TOA net radiation and in-situ observations.
- Other energy cycle components of the climate system could have related variations due to the fundamental linkage among these components within the energy cycle, especially over oceans.
- Surface TH estimates are largely different (~ 5 to 10 times bigger).
- This study tries to analyze ocean TH anomalies based on TOA radiation, precipitation and land-ocean heat transport estimates, along with sea surface Bowen ratios, for the 21st century. The sea surface latent heat is basically obtained from water cycle.
- Data: monthly CERES EBAF Ed4.1, GPCP V2.3, and OAFlux V3

Global Precipitation Time Series



Red : ENSO effect

Blue: volcano effect

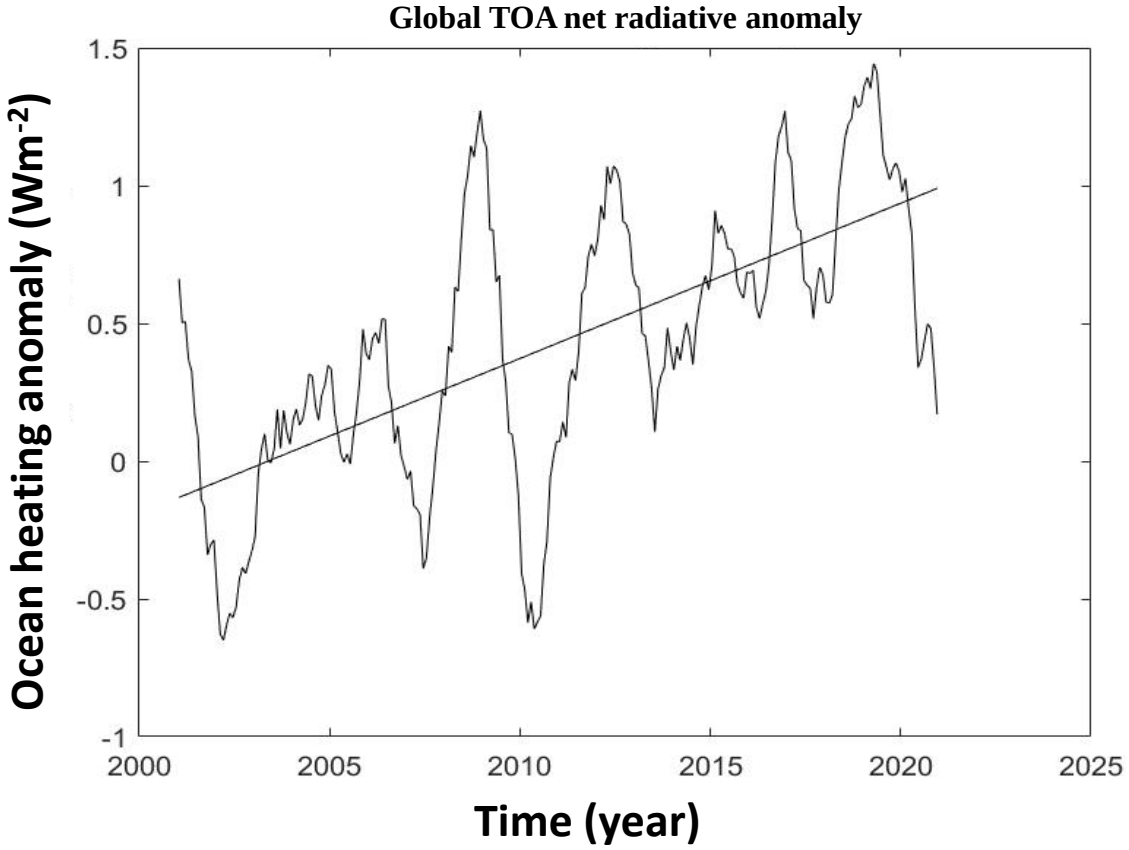
	Ocean	Land	Ocean + Land
Precipitation	2.89	2.24	2.69
Standard dev	0.29	0.16	0.25

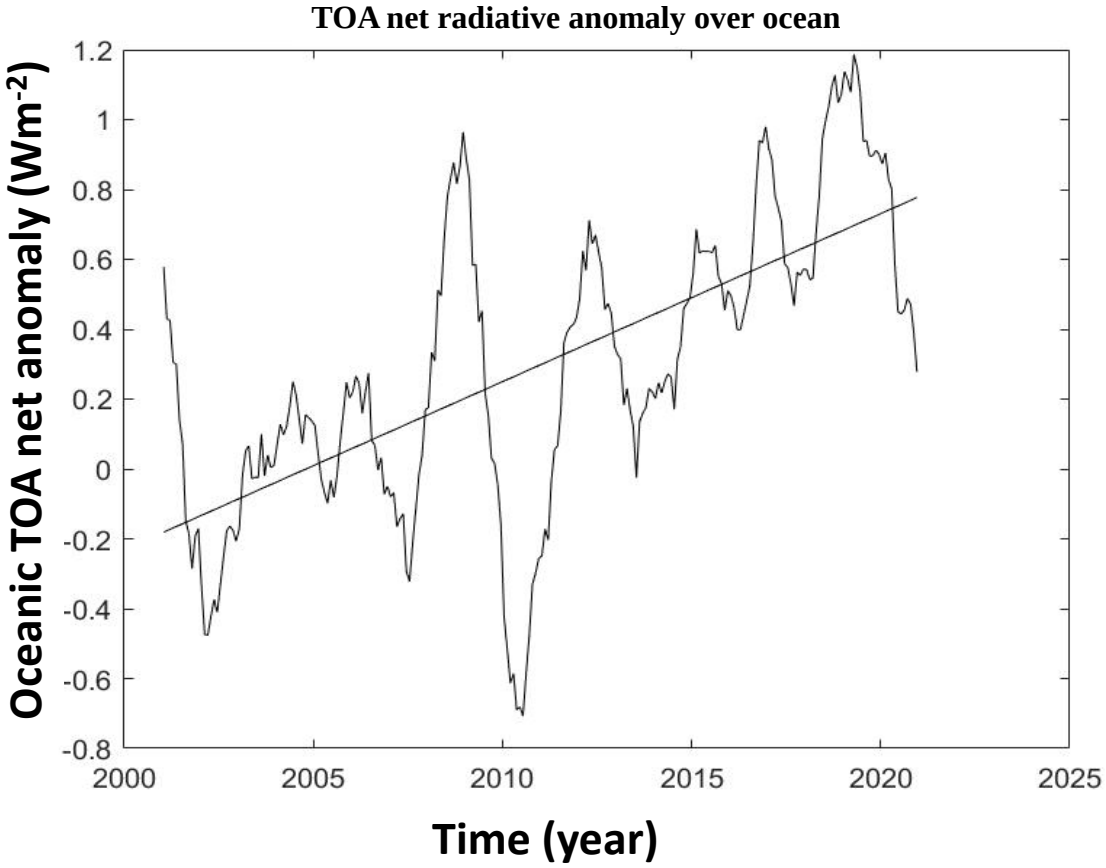
a very small insignificant trend

Adler et al., Surv Geophys, 2017: 3% lower than others (even lower than energy estimates)

Global & Oceanic TOA Radiation Anomalies

ocean heating: total ~ 0.9 W/m^2 increase



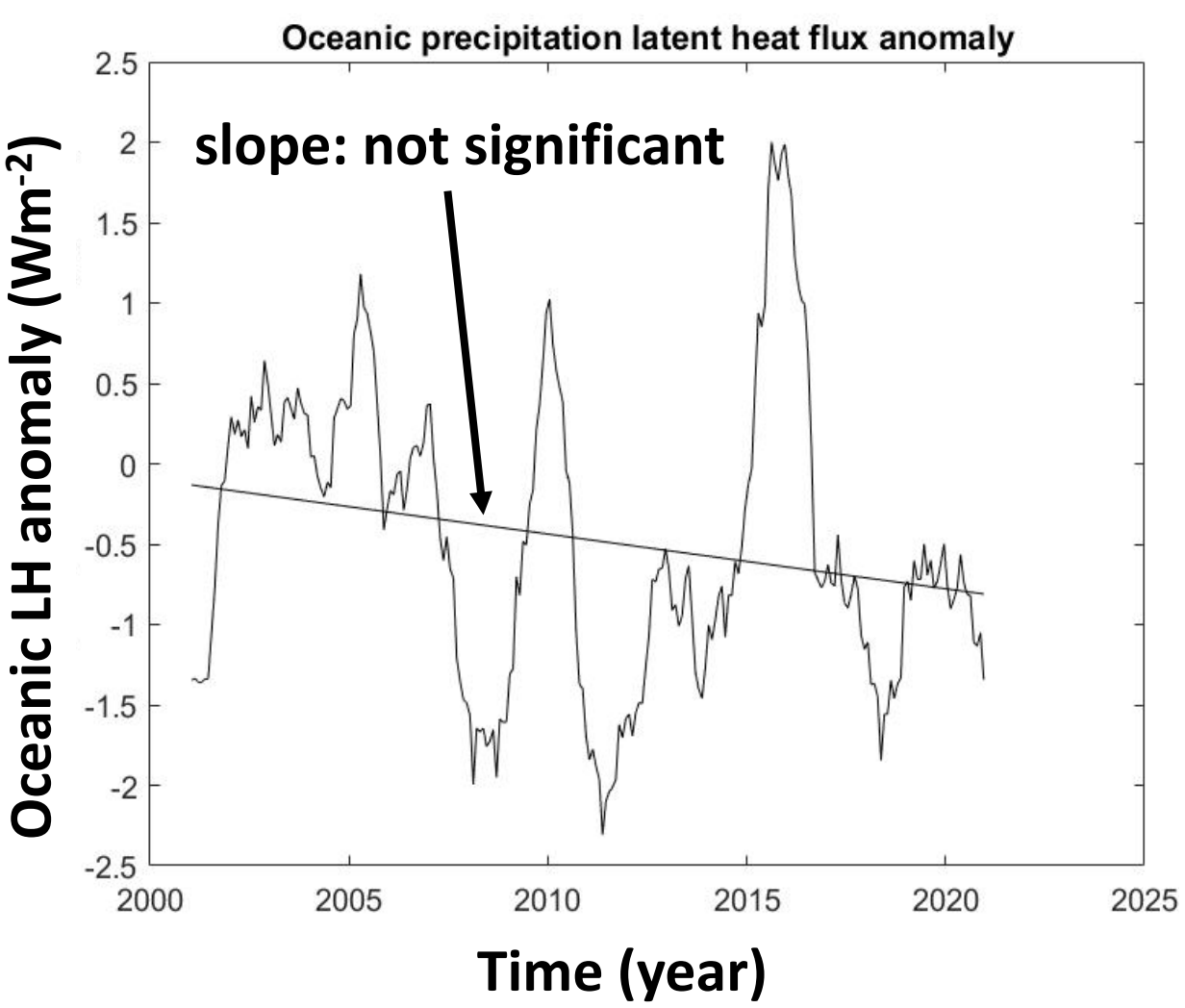


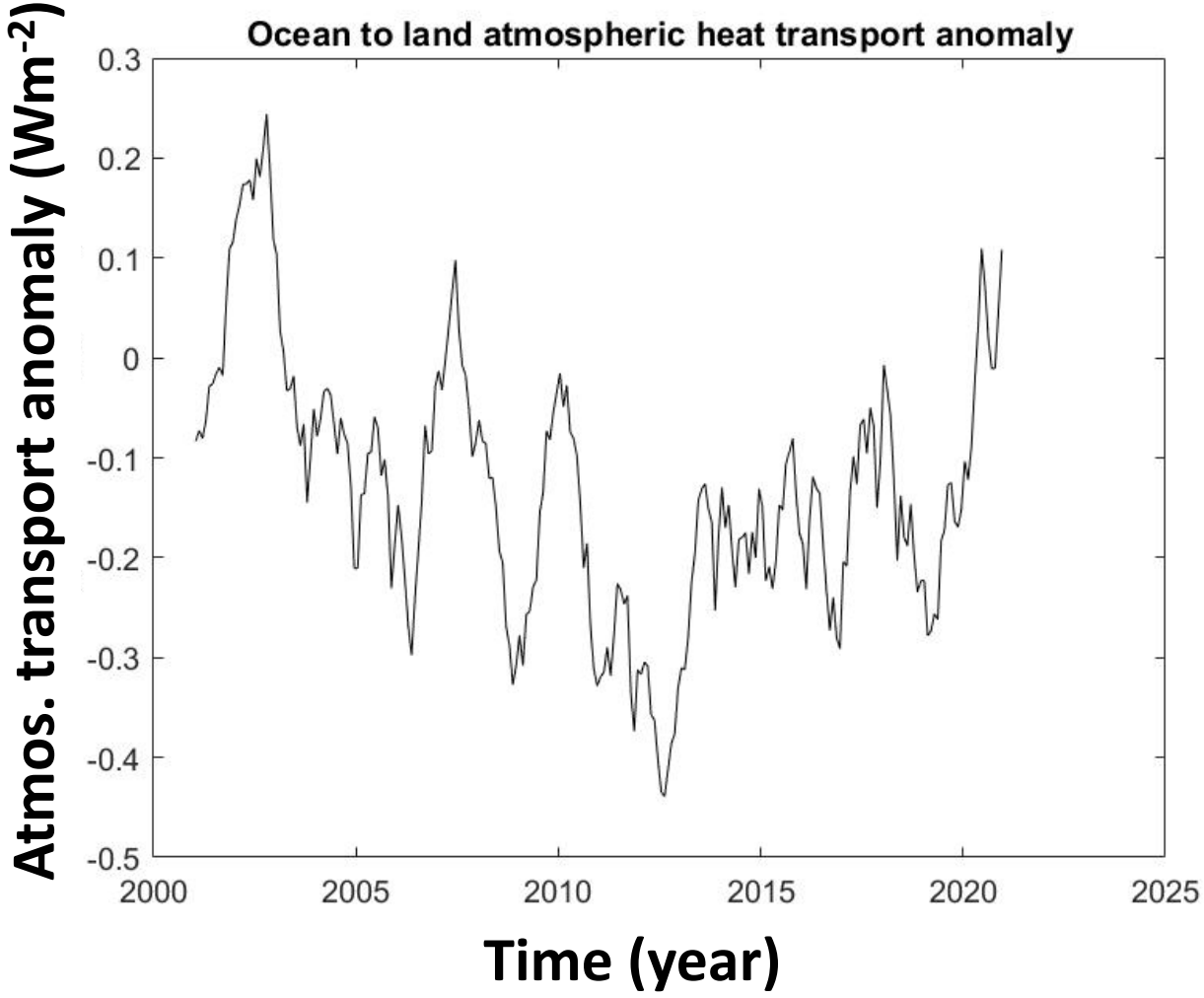
Global TOA net radiative anomaly: dominantly for heating oceans.

Oceanic TOA net anomaly: a component for ocean to land heat transport.

$T_{O2L} = R^{O}_{net\_TOA} - OH$; similar to left

Oceanic Precip. & Atmos. Heat Transport Anomalies





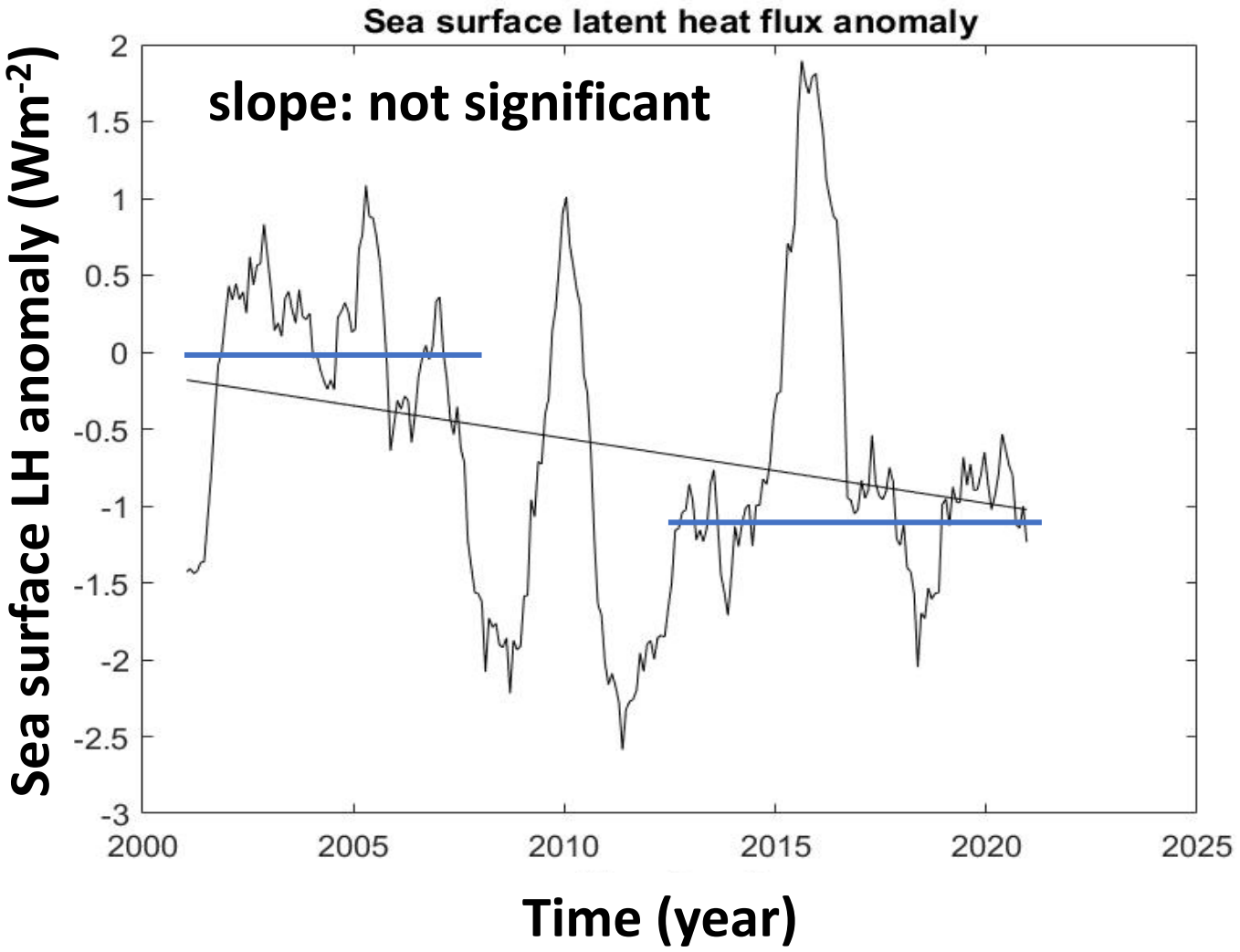
No significant trend, but big variability.

Indicating weaker transport? or Slower dynamics with warmer climate?

Sea surface LH Anomalies

beginning & ending phases?

large variability, bi-mode or oscillation?

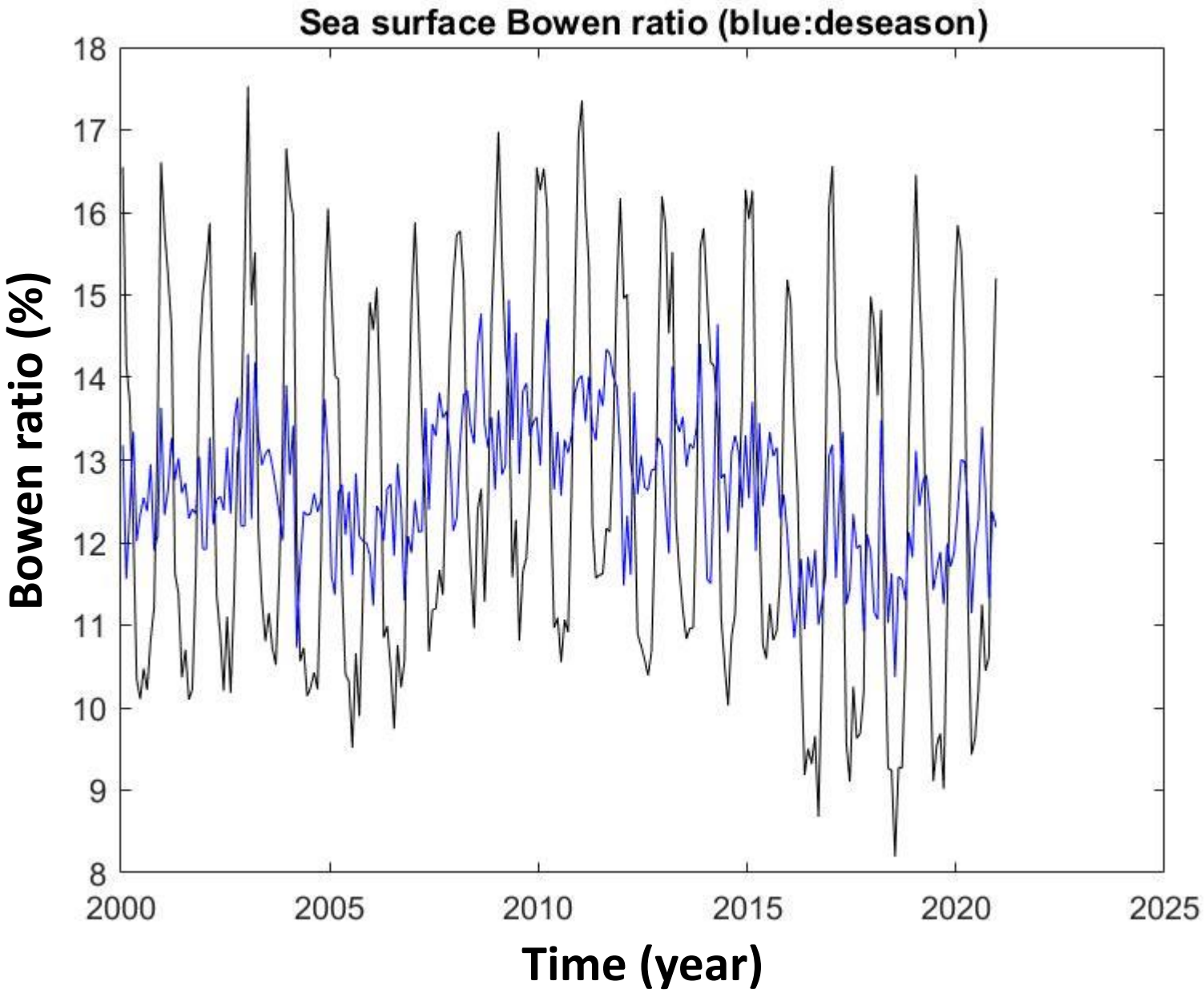


obtained from precipitation, along with transport, observations

decreased about 0.8 W/m^2 during the two decades

No clear trend is found for sea surface latent heat release anomalies during last two decades. However, variations are large. May in different modes.

Relationship of Sea Surface LH and SH Fluxes



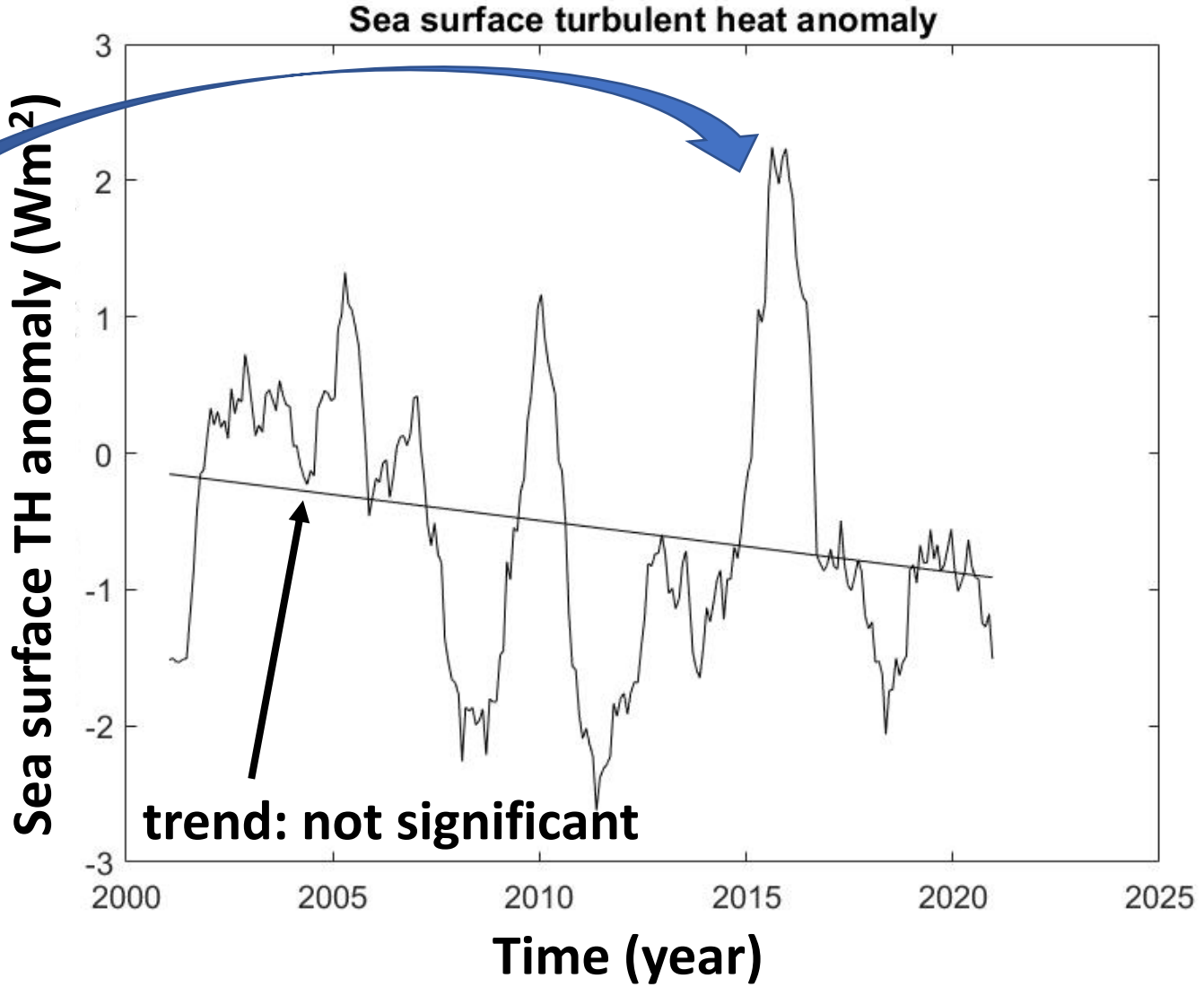
SH is about 12.5% of LH over oceans.

Based on this Bowen ratio & LH, TH can be estimated.

Sea surface TH estimated from precipitation

Caused by strong precip. anomaly

Certain system memory?



over ocean:

$TH = LH_P + LH_T + SH$

decreased about 0.7 W/m^2 during the two decades

Slow down atmospheric dynamics?

Sea surface TH flux anomalies estimated from global mean oceanic precipitation have similar variations as LH due to small transport & Bowen ratio variations.

Summary

- Global mean sea surface turbulent heat fluxes estimated from bulk formula may not be reliable for accessing decadal climate variations due to potential uncertainties of the formula and meteorological state variables.
- Atmospheric latent heat release over oceans estimated from precipitation observations does not show significant trends during the last two decades though the last decade values are lower than the previous ones. This could potentially indicate a slight slowdown of the atmospheric dynamics for a warmer climate.
- The magnitude of sea surface turbulent heat anomaly decreases estimated from energy balance is similar to radiation results, which may provide an alternate way for sea surface mean flux estimations.

Thank you!

Radiation data were obtained from the CERES ordering site (http://ceres.larc.nasa.gov/order_data.php).

GPCP global precipitation data were found from the NOAA ESRL/PSL site (https://psl.noaa.gov/).

Sea surface turbulent flux data were from OAFlux (http://oaflux.whoi.edu).