

# Estimating Energy Imbalance and the Global Water Cycle Across the Sea Surface

GEWEX Meeting, Sapporo, Japan

# 1. Estimation Framework

## Overview

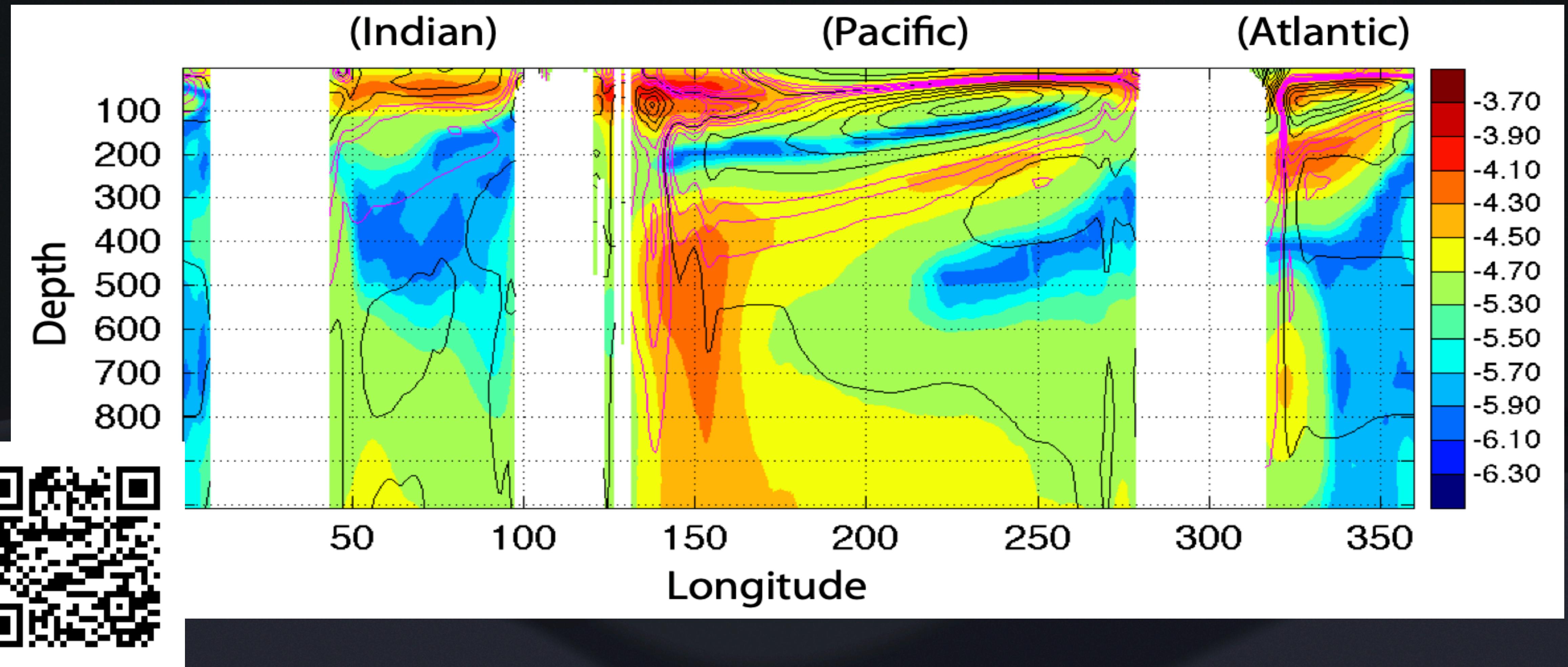
- **Ocean reanalysis** : ECCO (JPL) / OCCA (MIT)
- **Ocean model** : MITgcm & its adjoint, at 1 degree
- **Period** : 1992-2017 (ECCO4), 1980-present (OCCA2)
- **Data constraints** : temperature and salinity profiles from the field, multi-decadal satellite data record (SST, SSS, SLA, BP, sea-ice), atmospheric reanalysis for surface boundary conditions (*MERRA2 or ERA5 currently*), plus river runoff (*Fekete et al*)
- **Optimized parameters** : atmospheric state variables, surface wind stress, sub-grid scale mixing rates, meso-scale transport rates, initial ocean state

$$J(\mathbf{u}) = \sum_i \alpha_i \times \left( \mathbf{d}_i^T \mathbf{R}_i^{-1} \mathbf{d}_i \right) + \sum_j \beta_j \times \left( \mathbf{u}_j^T \mathbf{u}_j \right)$$
$$\mathbf{d}_i = \mathcal{P}(\mathbf{m}_i - \mathbf{o}_i),$$



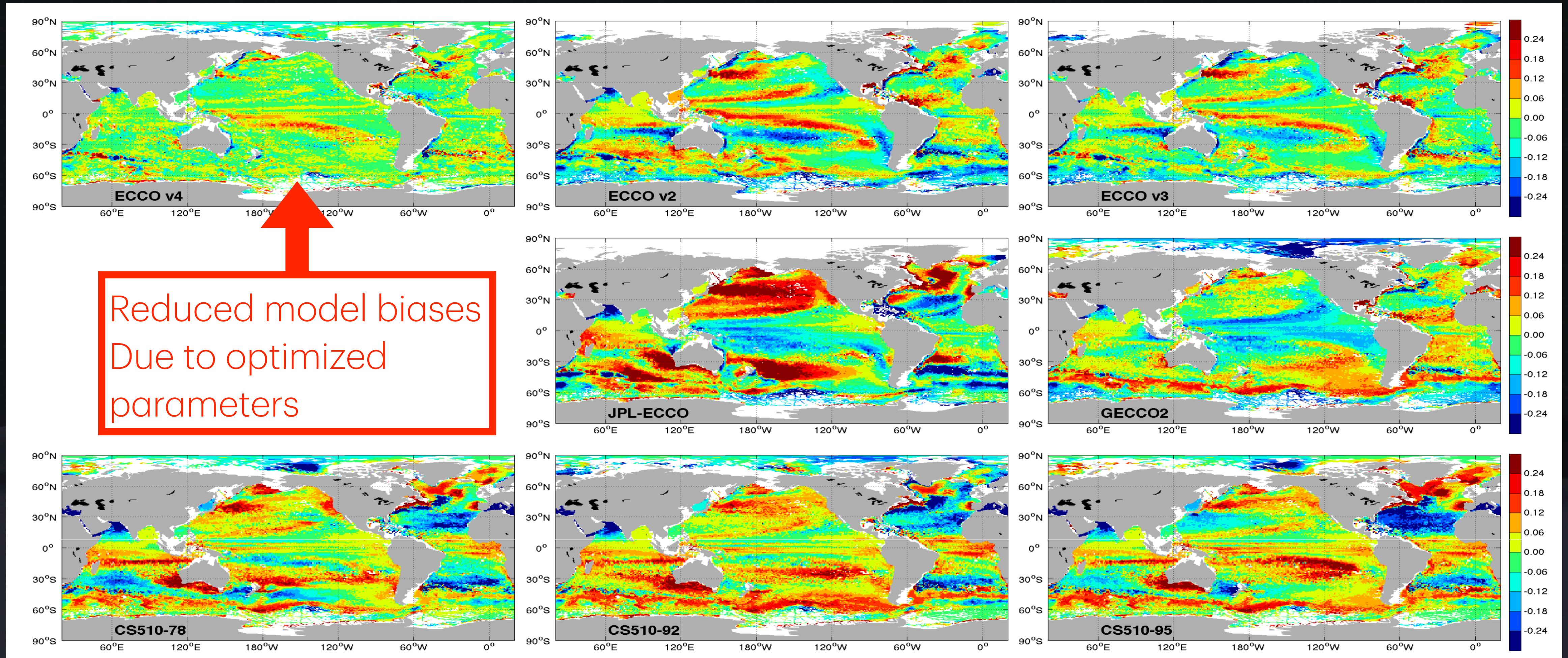
# 1. Estimation Framework

Optimizing Model Parameters, e.g. vertical mixing



# 1. Estimation Framework

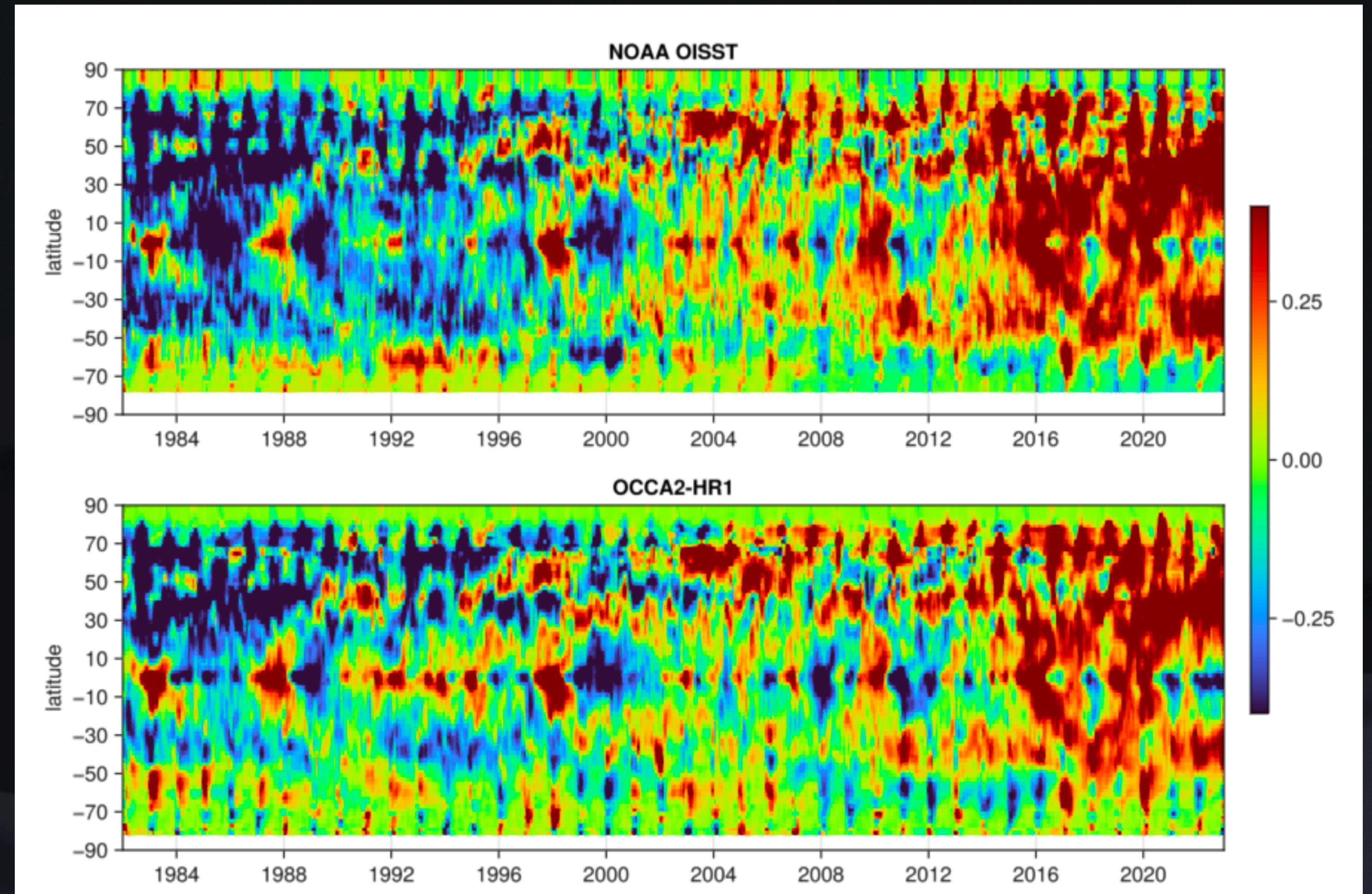
Improving Energy and Water Cycle, e.g. subsurface salinity



# 2. S.O.L. Energy Imbalance

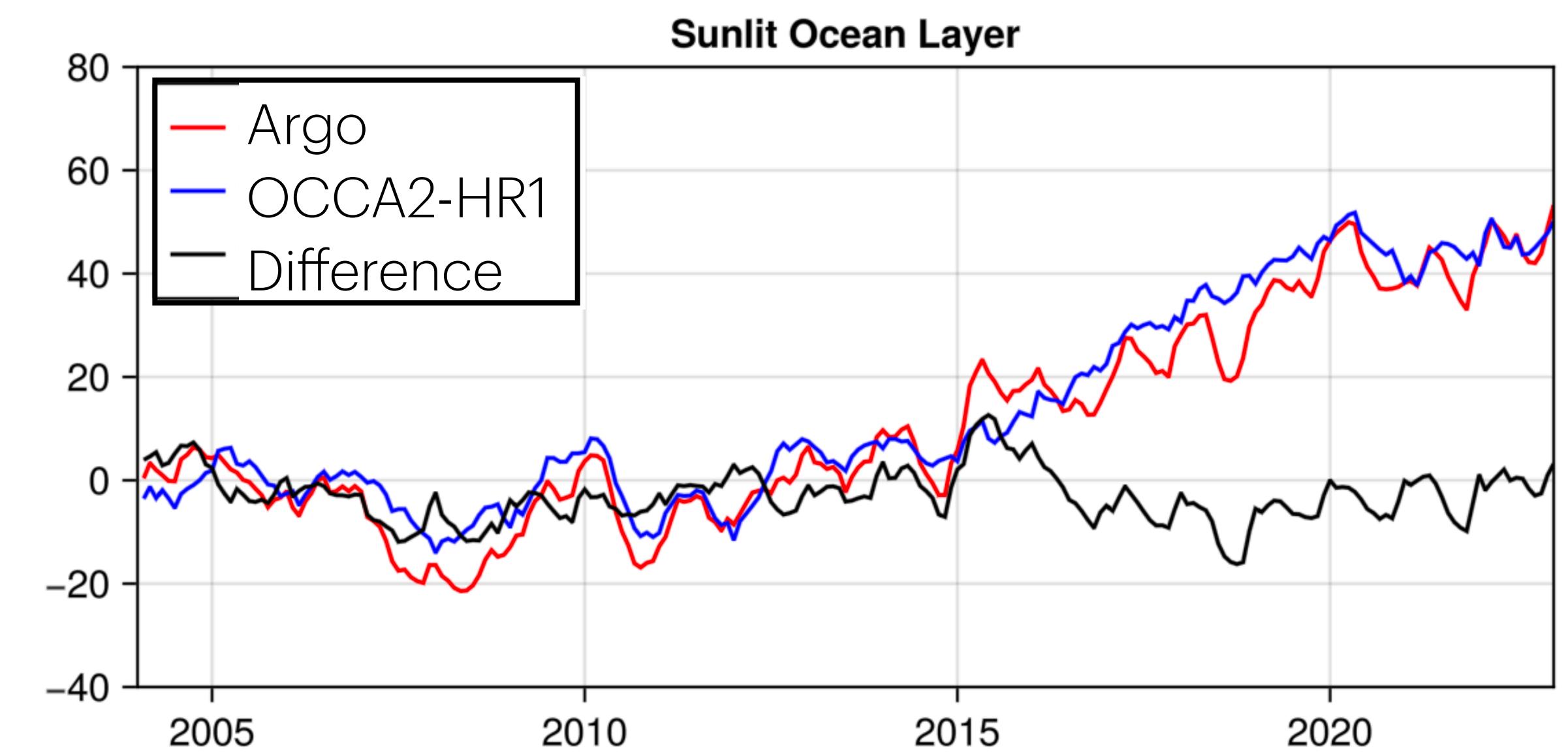
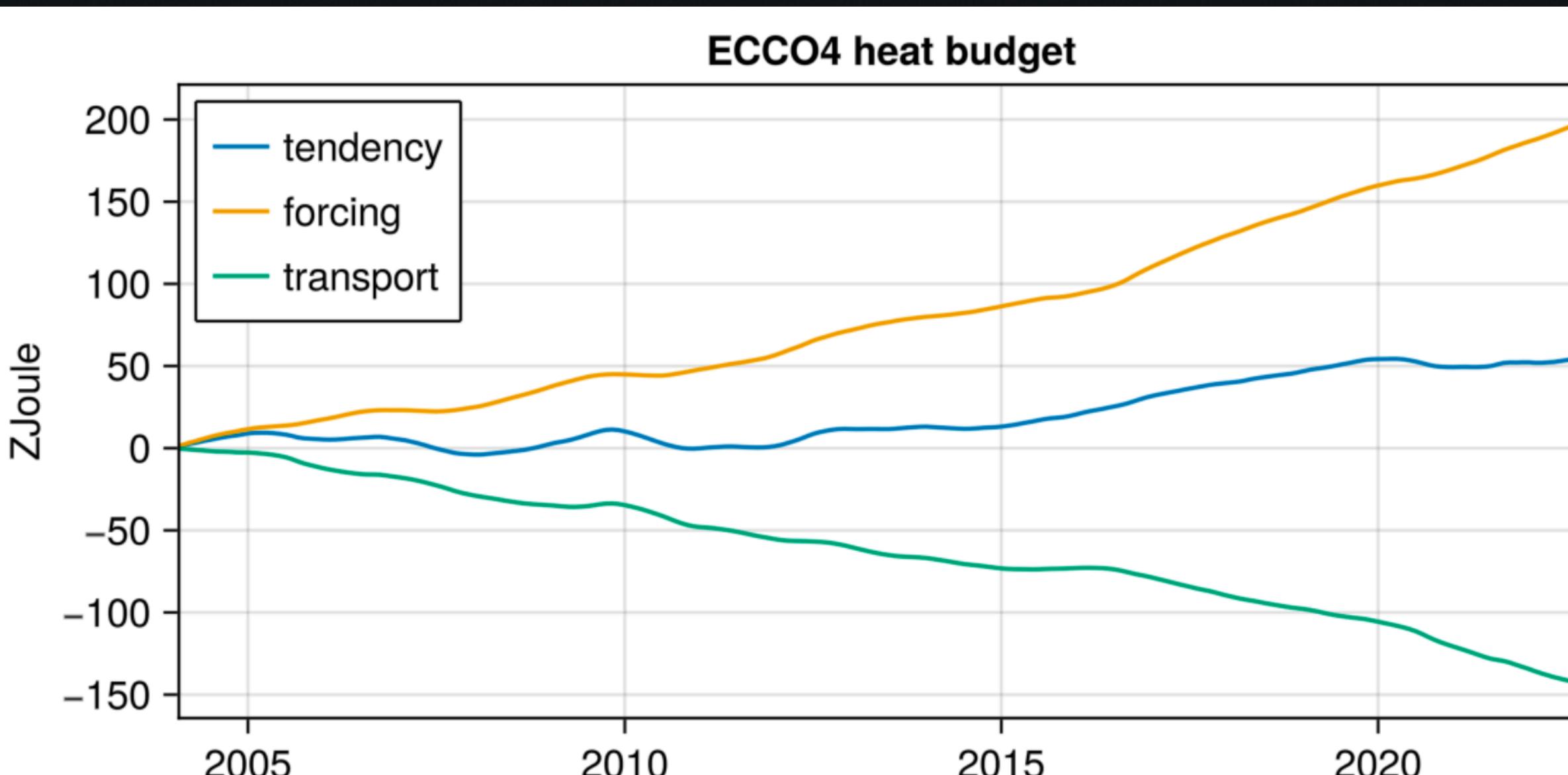
Sunlit Ocean Layer ~ 0-200m layer

- Recent Acceleration in SST
- EEI accumulation in SOL
- Marine Heatwaves ...



# 2. S.O.L. Energy Imbalance

Global Heat Budget (0-200m)



A large Fraction of EEI goes through the SOL and gets stored below 200m

But recently EEI accumulating in the SOL more and more, leading to greater risk

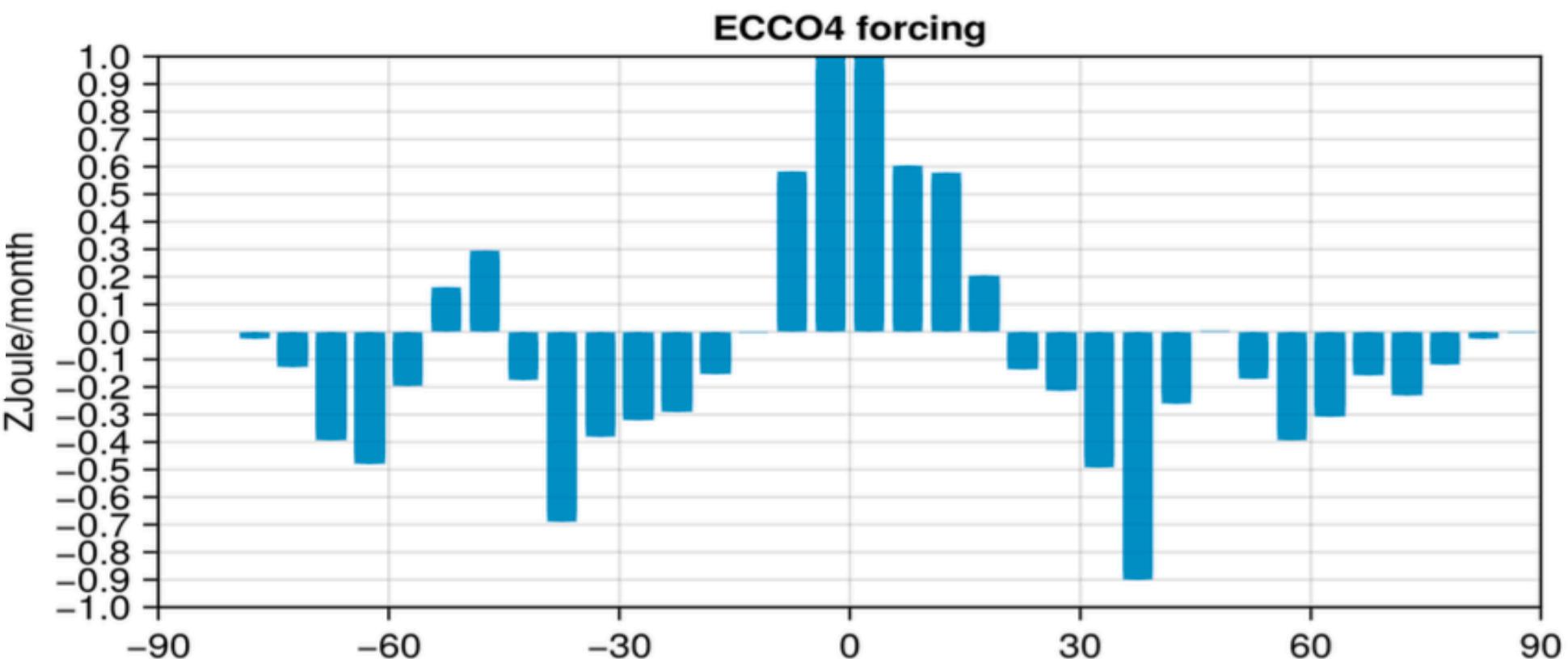
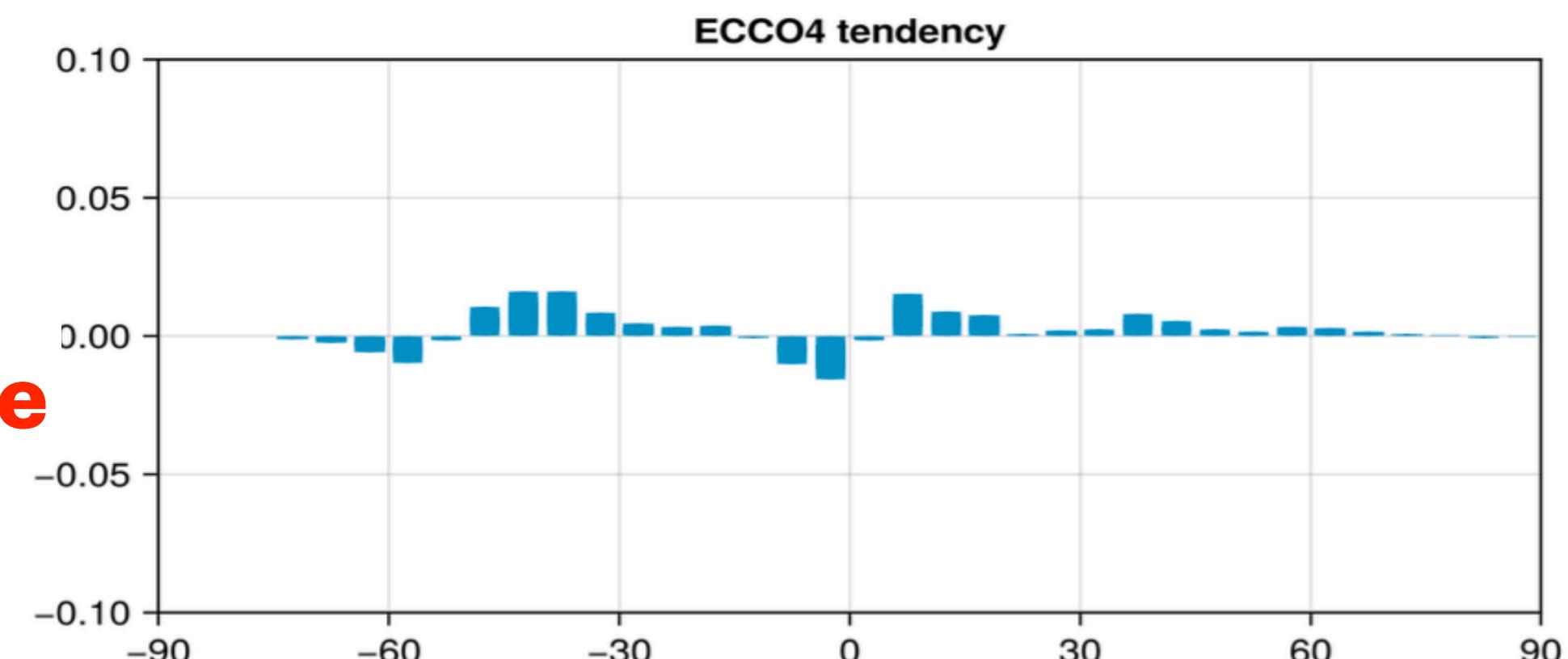
# 2. S.O.L. Energy Imbalance

Zonal Mean Heat Budget (0-200m)

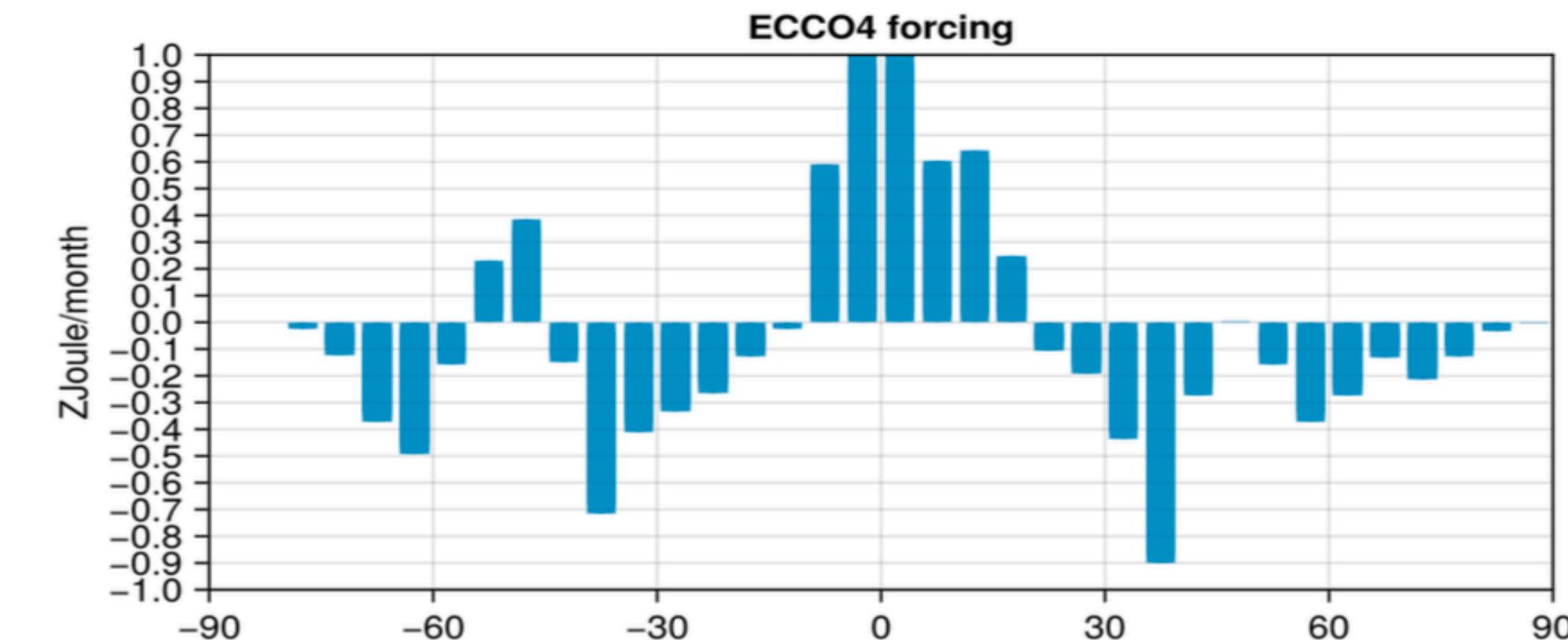
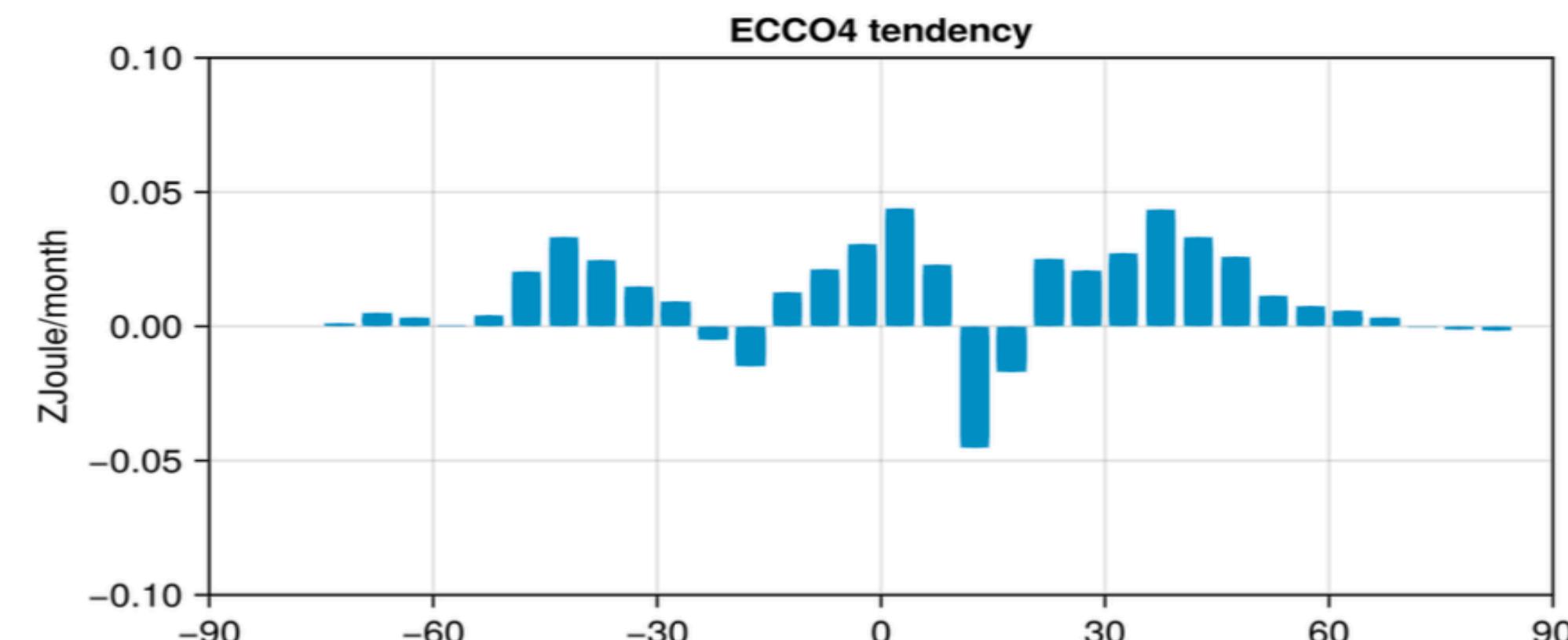
**Ocean Heat  
Content Change**

**Net Air-Sea  
Heat Flux**

**1981:2010**



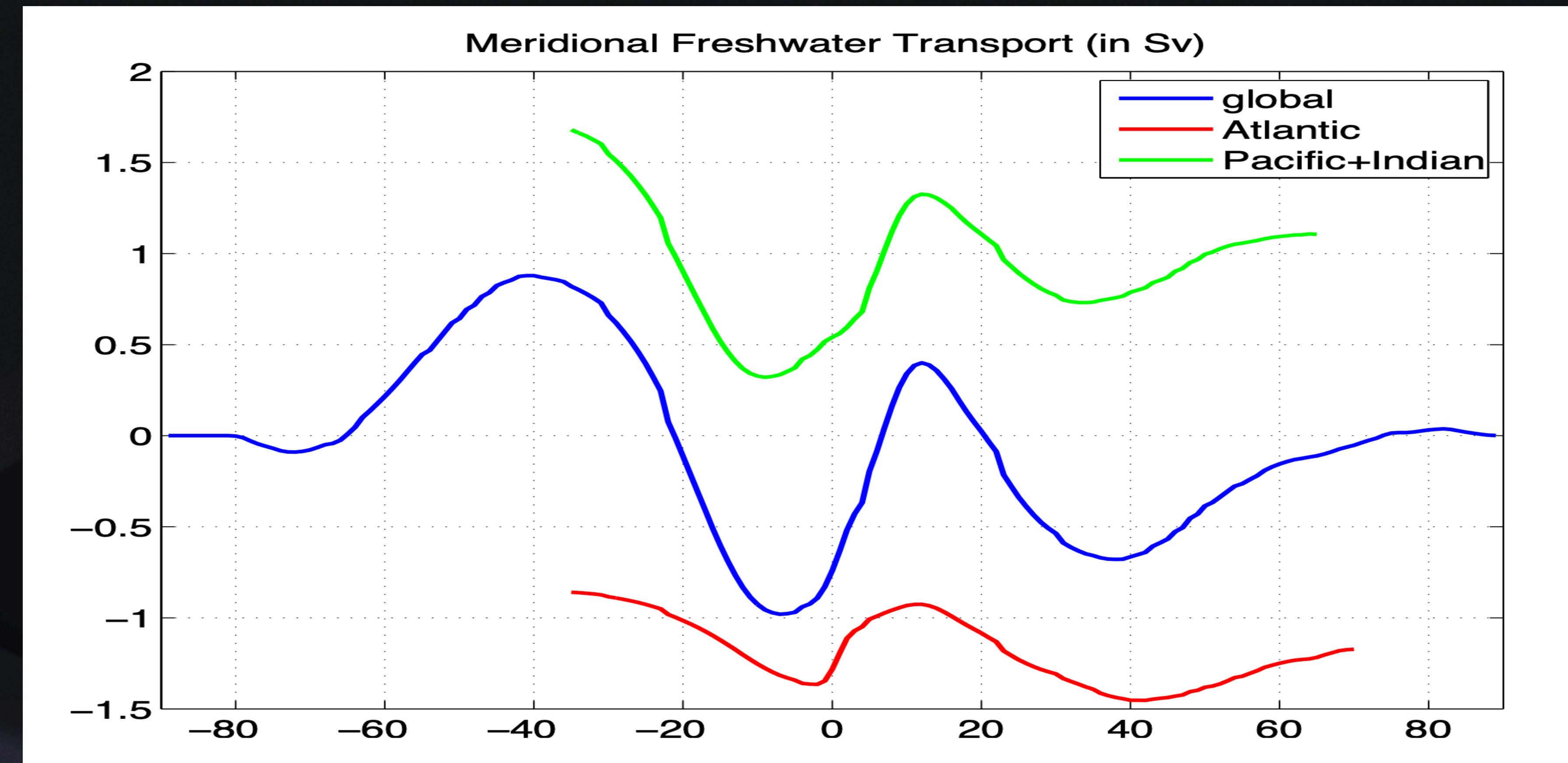
**2013:2022**



# 3. Global Ocean Water Cycle

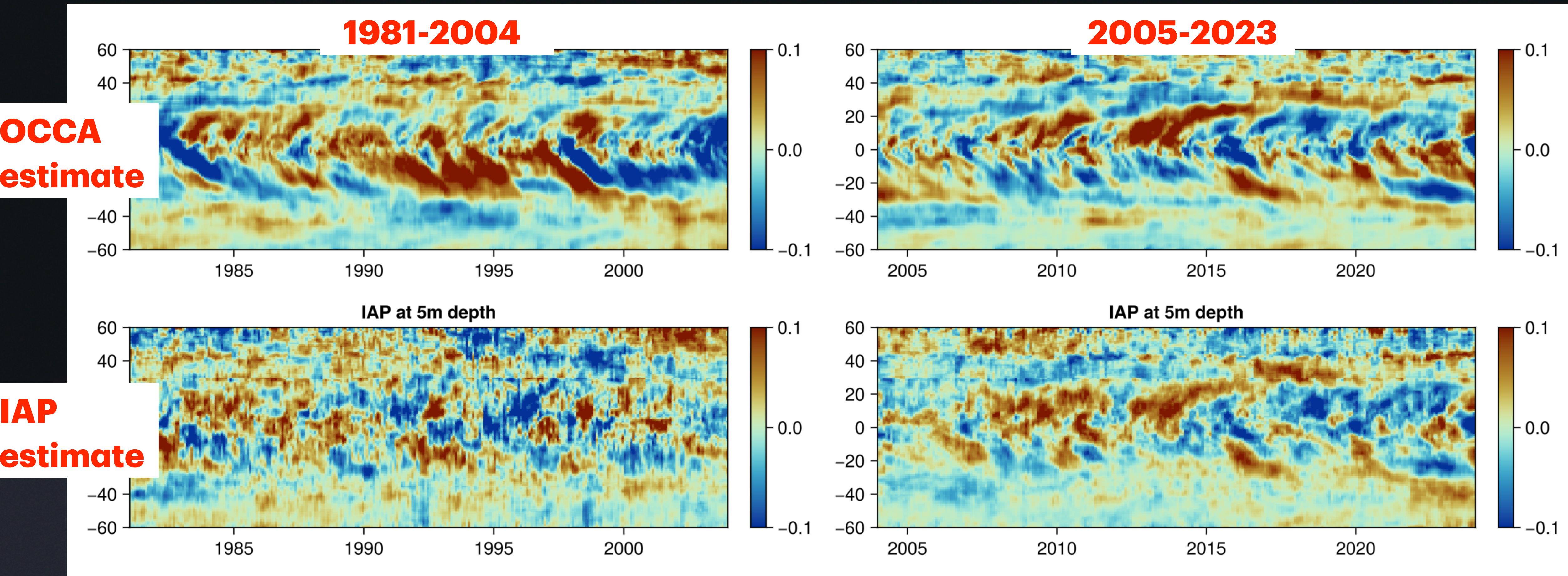
## Ocean Freshwater Transport

- Climatological mean
- Surface to Sea Floor
- For more on this :



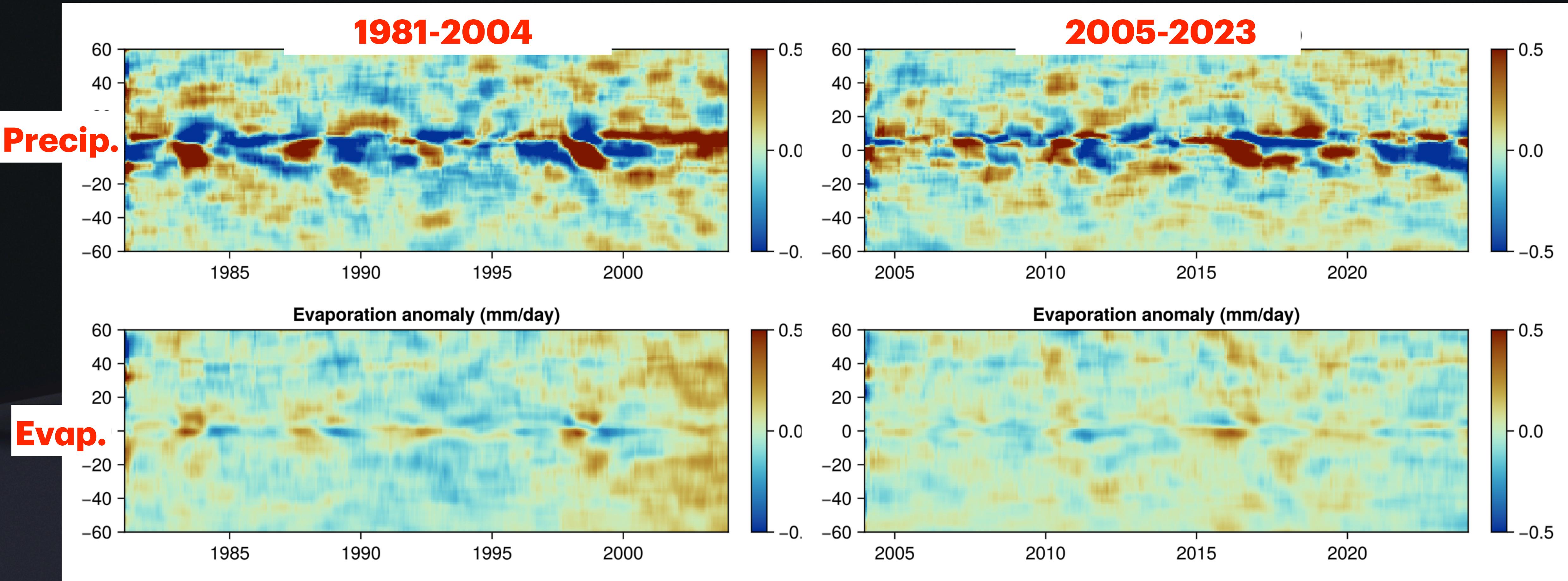
# 3. Global Ocean Water Cycle

## Salinity Variability near Sea Surface



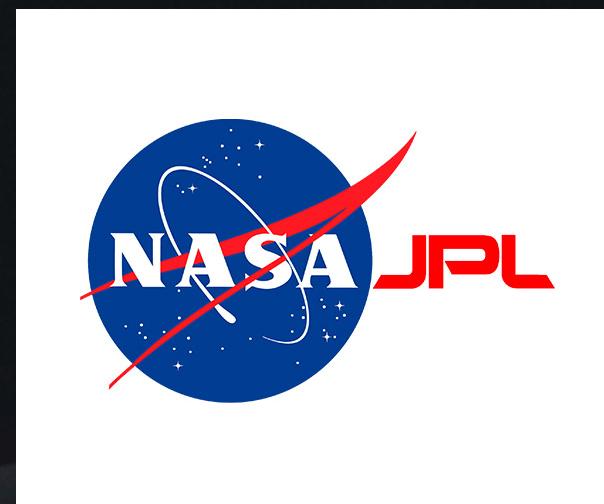
# 3. Global Ocean Water Cycle

## Precipitation and Evaporation Anomalies



# Conclusion

- EEI is accumulating just below the sea surface much more now than before
- Near surface salinity budget provides window into global water cycle
- Evaporation / latent heat flux rates are the great unknown



And collaborators at UTA, SIO, and beyond

**Data & Code Access**  
[earthdata.nasa.gov](http://earthdata.nasa.gov)  
[mitgcm.org](http://mitgcm.org)  
[ecco-group.org](http://ecco-group.org)

**New! Do it all in Julia**  
Climatology.jl  
MITgcm.jl  
ClimateModels.jl