Energy Imbalance in the Sunlit Ocean Layer (SOL-EI)

ECCO annual meeting 2024

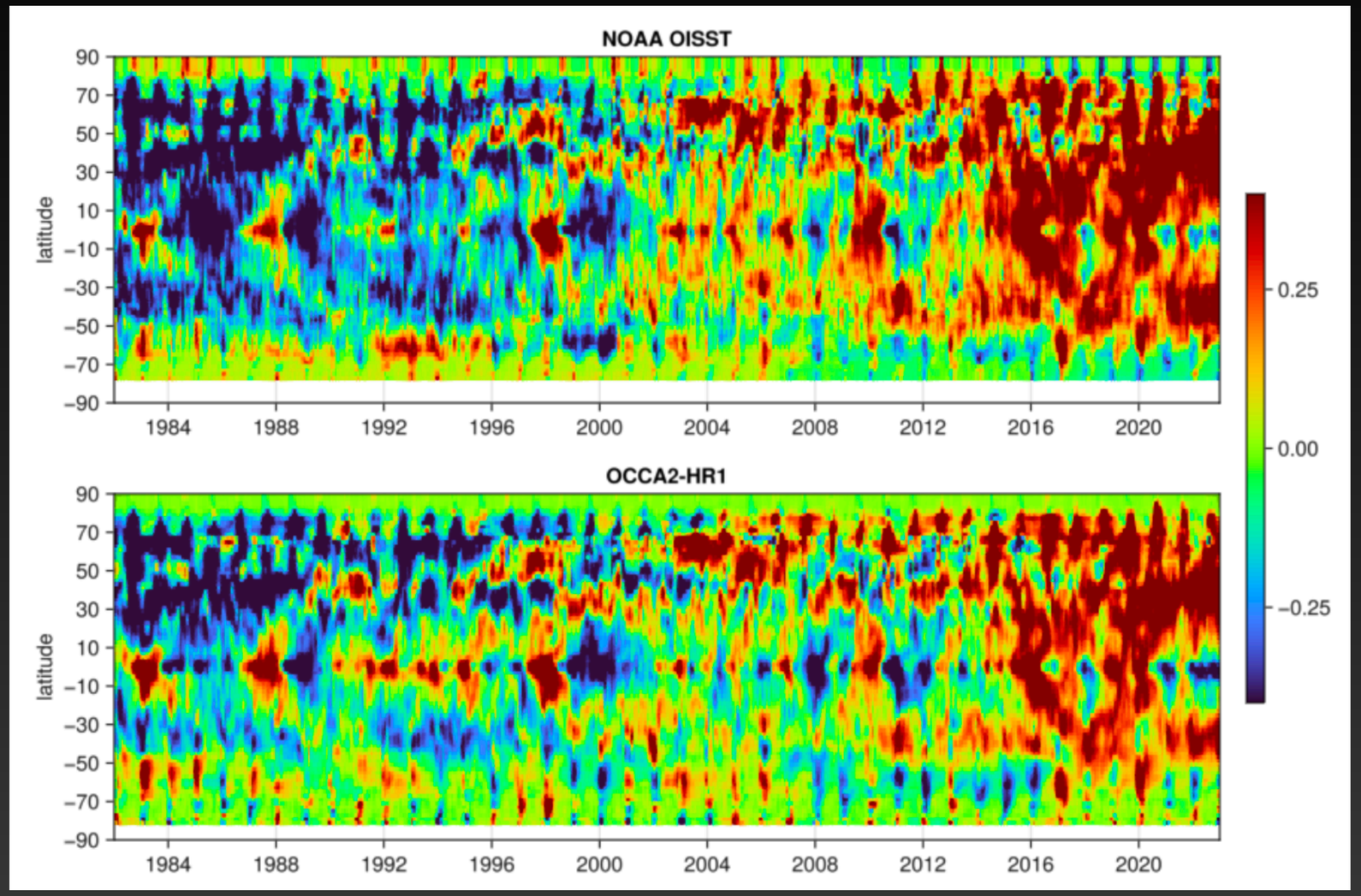
Gaël Forget

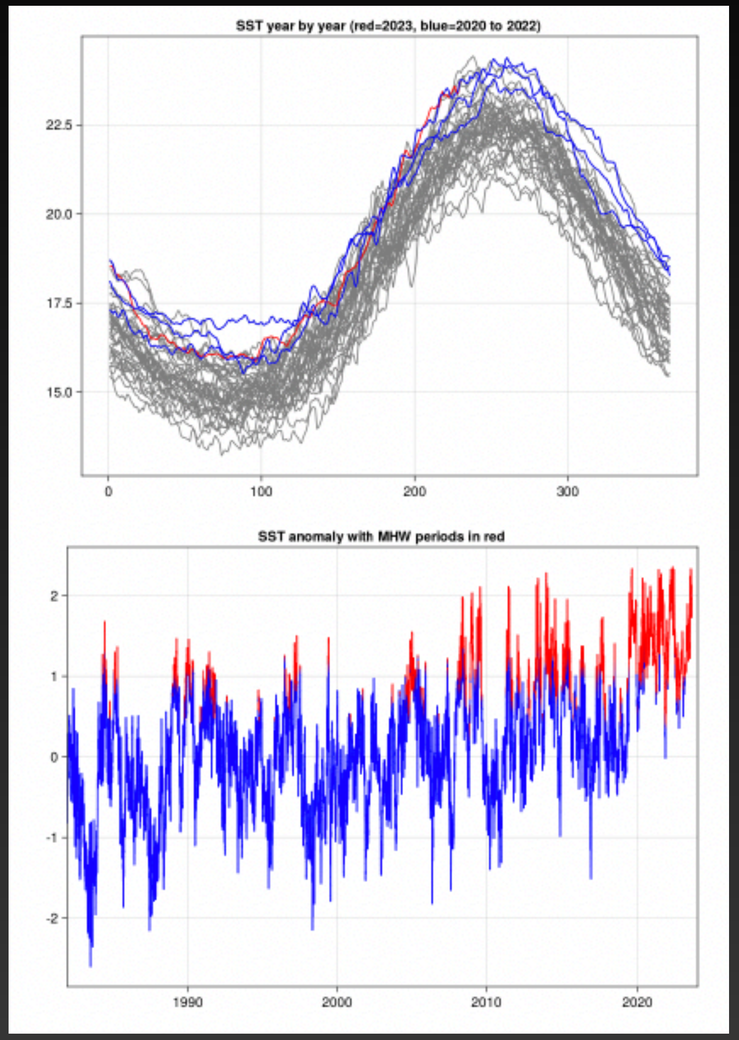
Austin TX, USA

2024/03/20

The Great Rise of Sea Surface Temperature

Leading Marine Heat Waves to New Heights

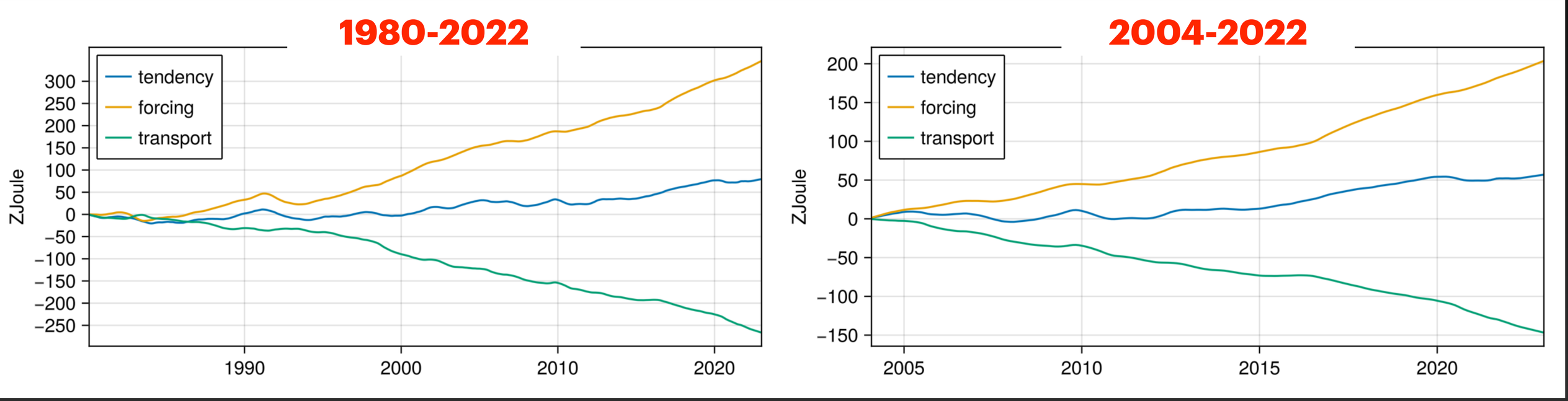




Forget 2024 (submitted)

Earth Energy Imbalance ≈ Ocean EI

And it is accumulating in the 0-200m layer



Sunlit Ocean Layer (0-200m) heat budget

Forget 2024 (submitted)

Objectives for Today

1. Zoom in on near-surface layer heat budget

   ➡ ***0-200m, i.e. Sunlit Ocean Layer, ECCO4***

2. Check closed heat budget (HB) against Argo

   ➡ ***Add heat budget adjustment from Argo, OCCA2***

3. Subtract heat budget from reference period

   ➡ ***1981-2010 shows quasi-balanced HB from ECCO4***

4. Map out Energy Imbalance (EI) for past decade

   ➡ ***SOL-EI = Anomaly in SOL heat budget for 2013-2022***

5. Elucidate Interplay of Driving Processes

   ➡ ***net SOL-EI = EI uptake + EI export + Argo Adjustment***

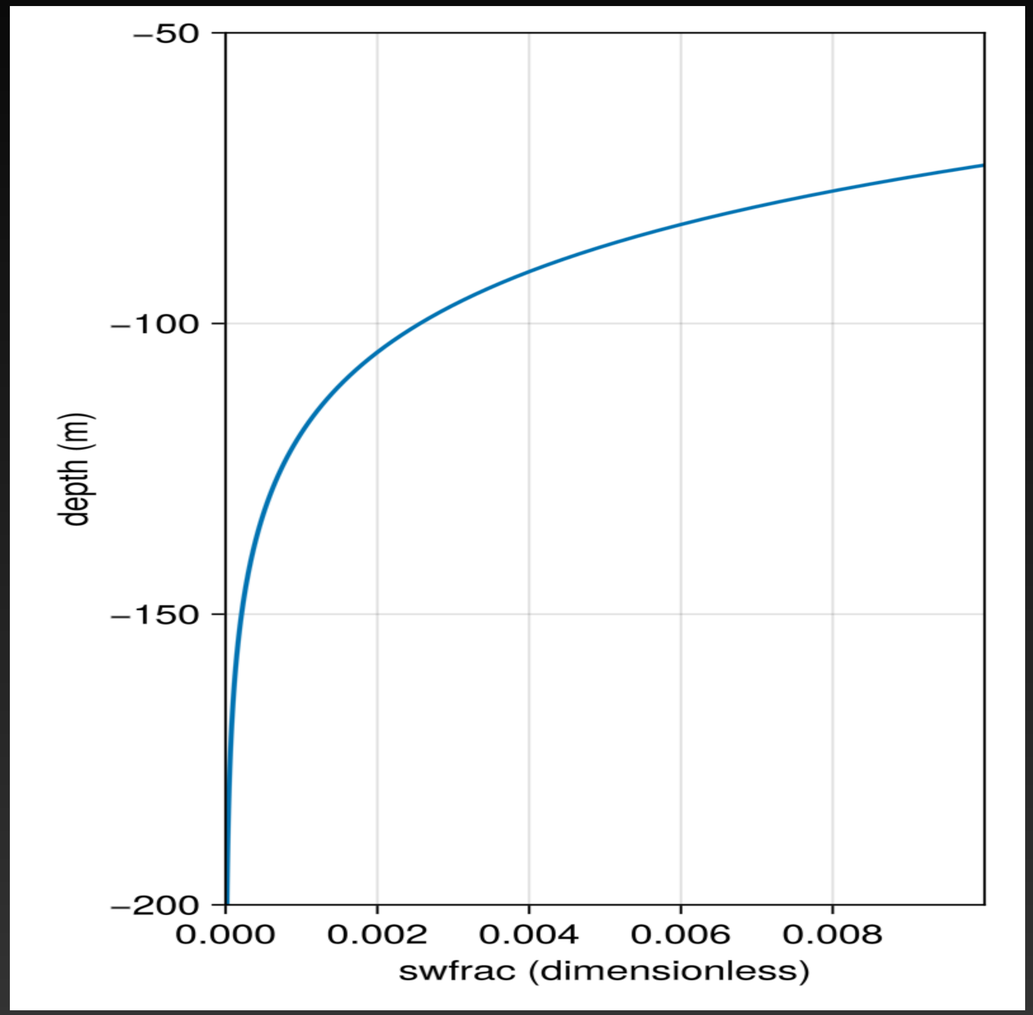
Forget 2024 (submitted)

Why 200m depth?

Plotted : fraction of downward surface radiation that reaches a certain depth (typical parameterization)

Surface to 200m = SOL = simplest useful definition for Euphotic Layer

200m to sea floor = dark ocean layers



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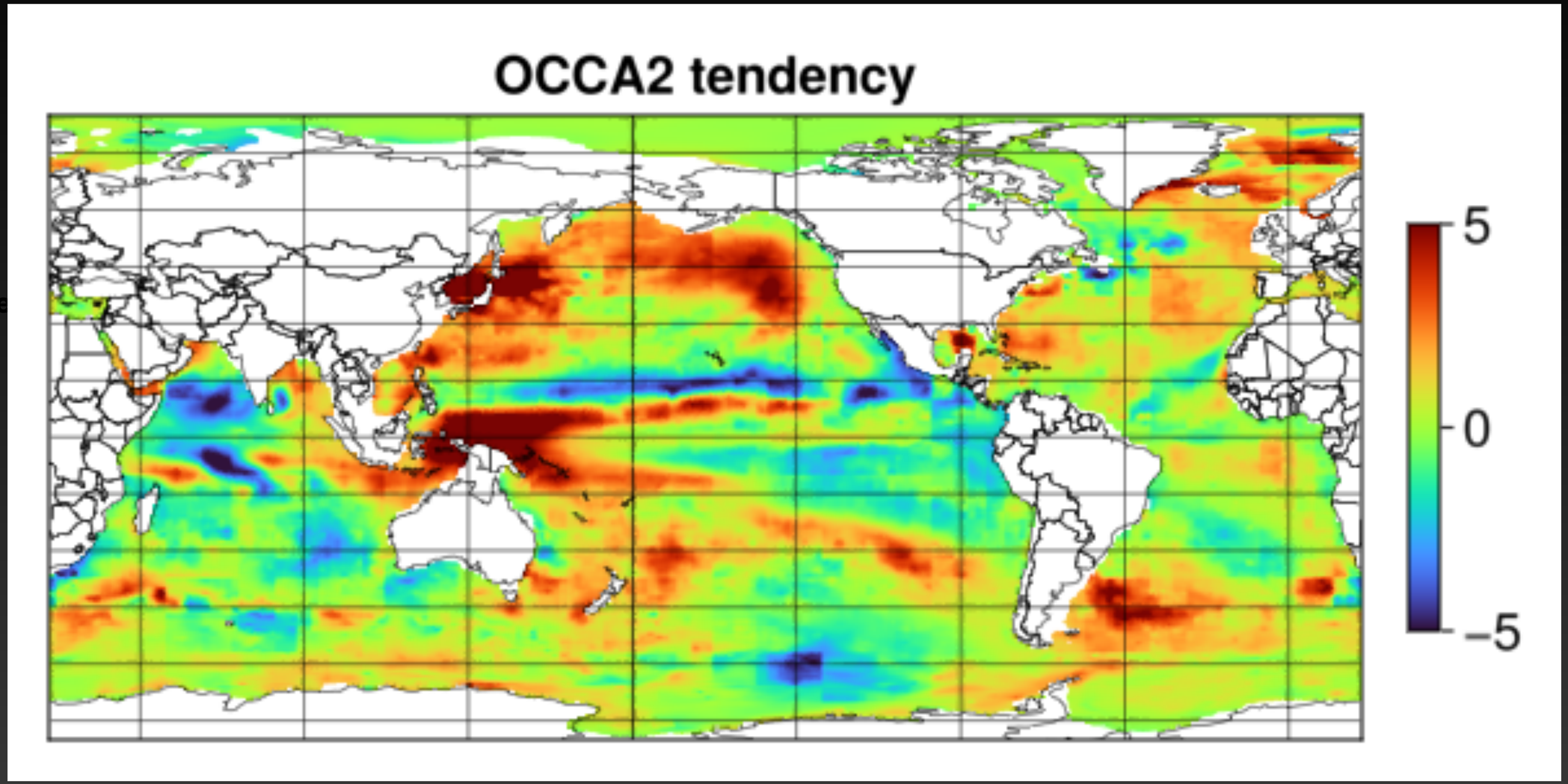
Mapping of net SOL-EI

2013-2022 trend , converted to W/m2



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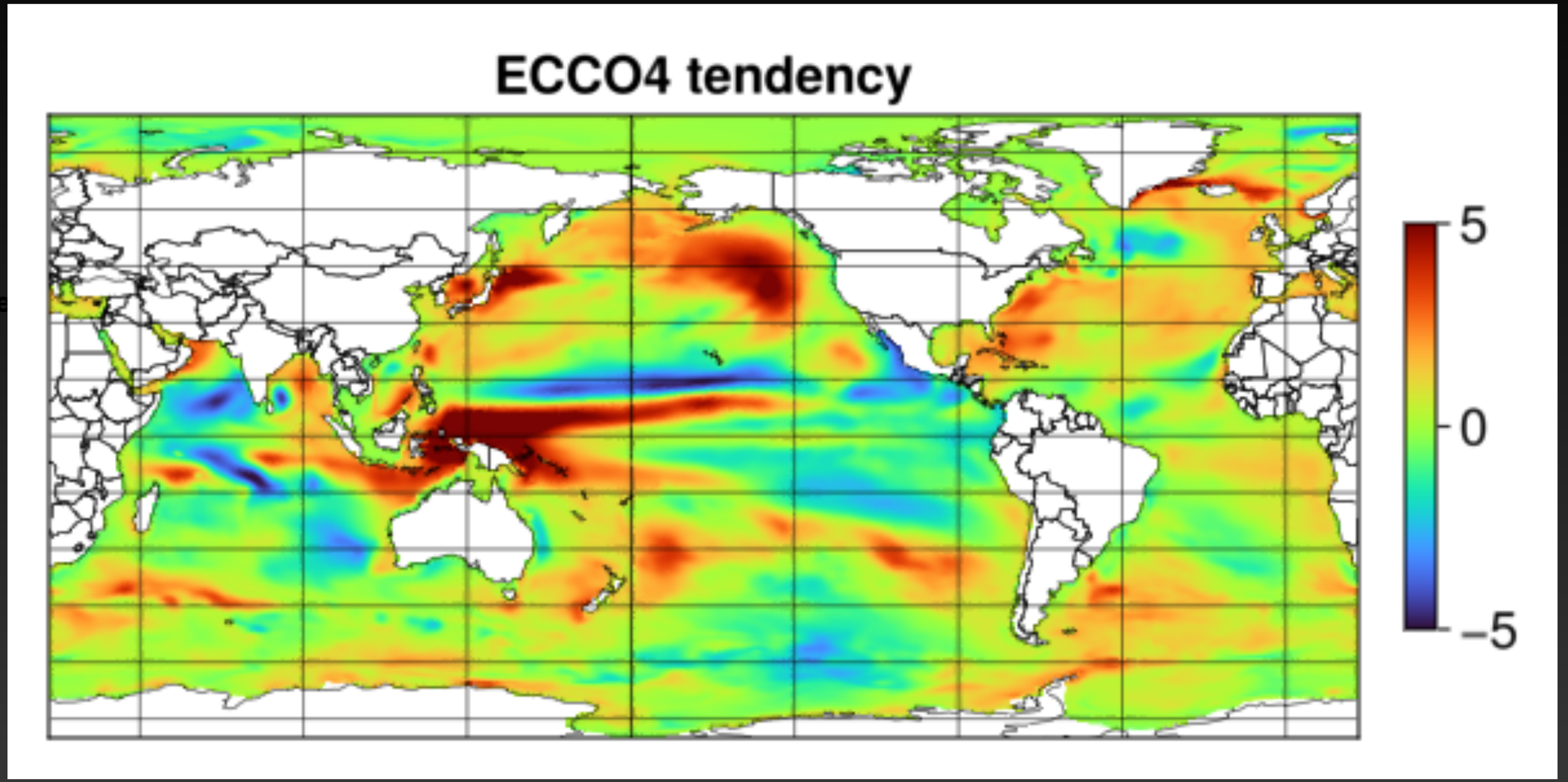
Mapping of net SOL-EI

From ECCO4 heat budget anomaly



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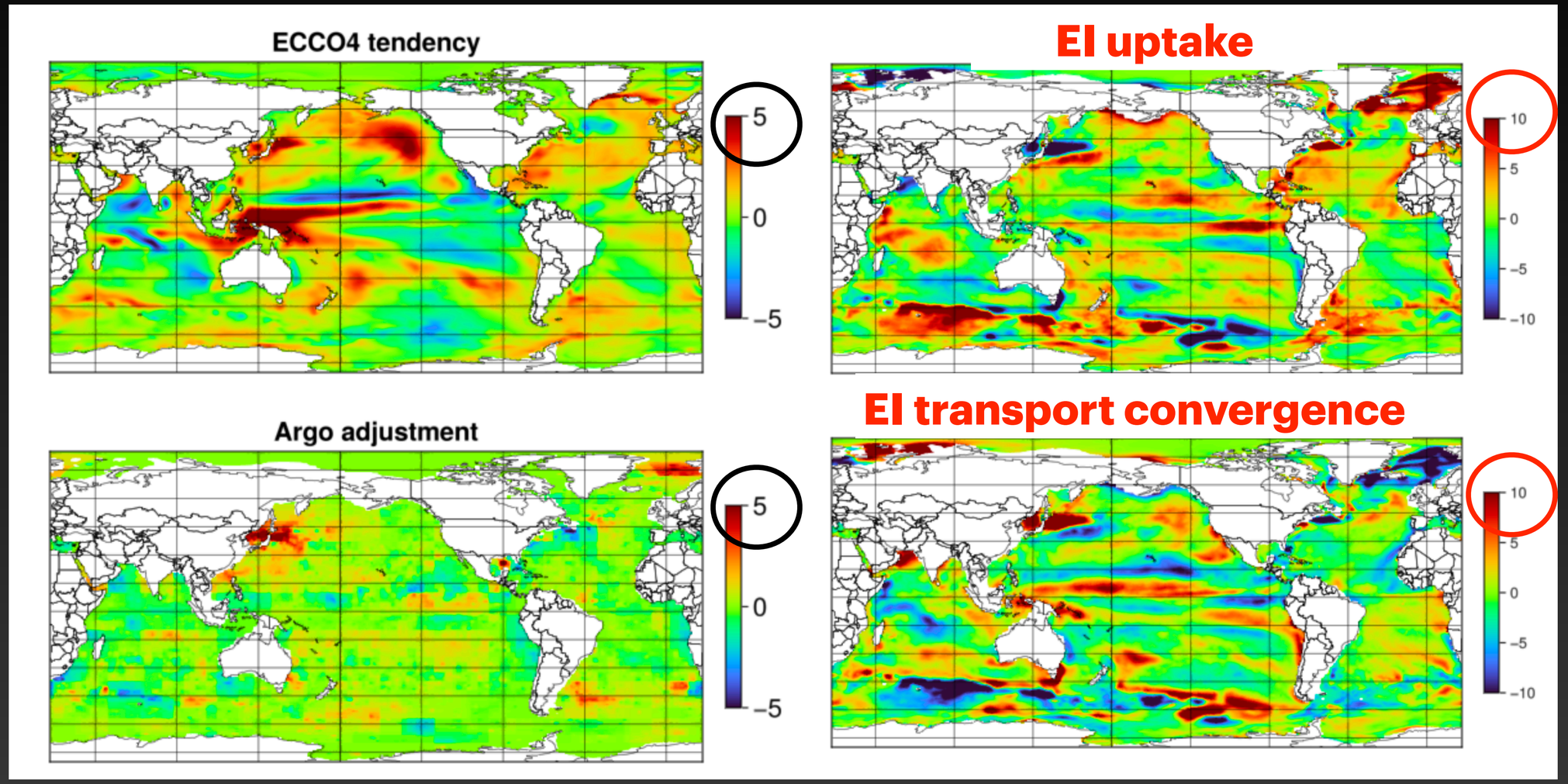
Mapping of SOL-EI budget

2013-2022 minus 1981-2010



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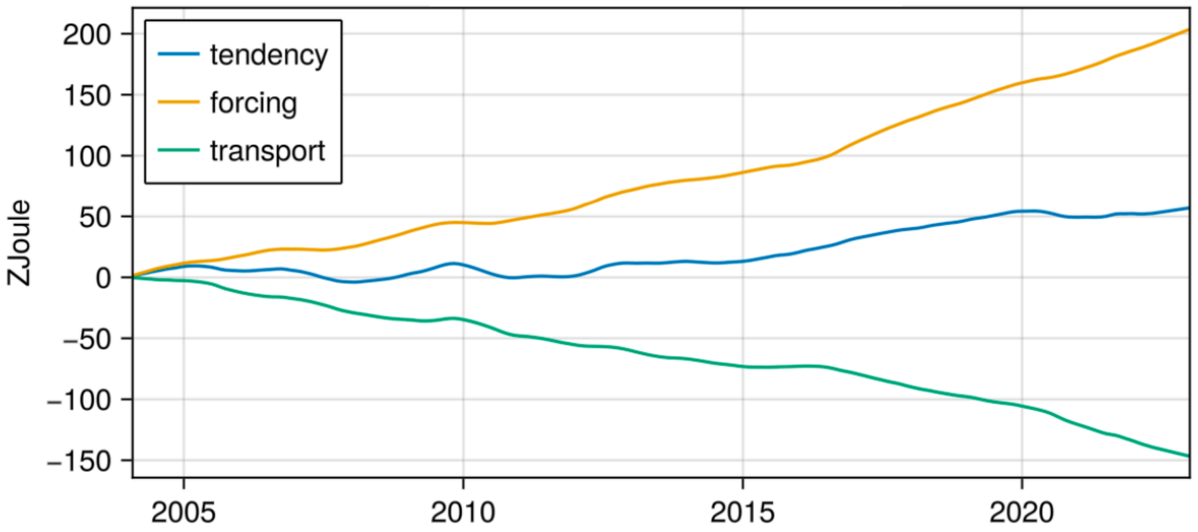
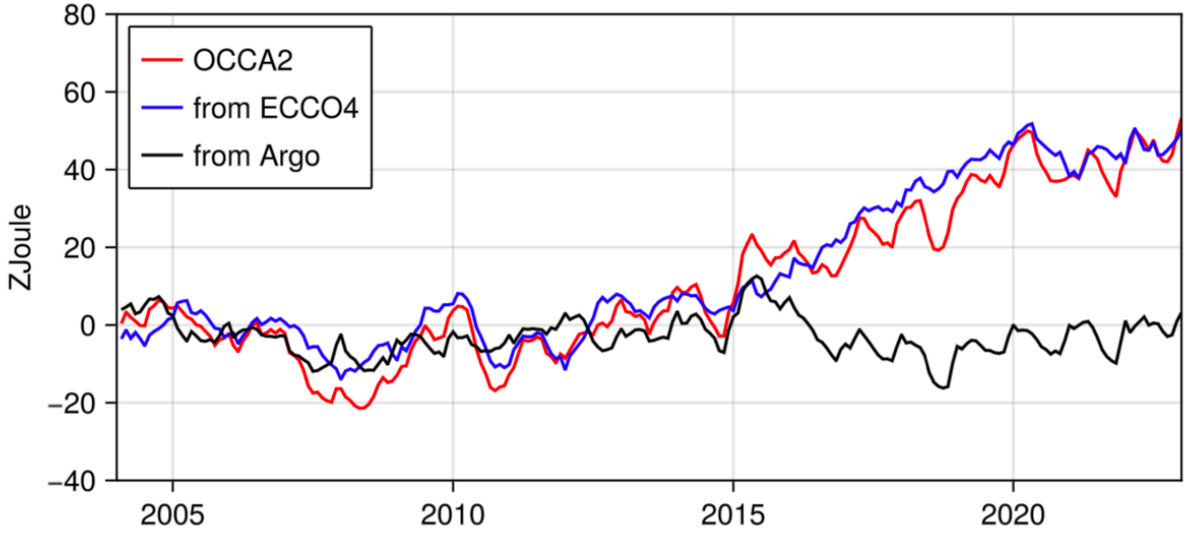
Recent 10X increase in SOL-EI

Over the past decade

2004-2022



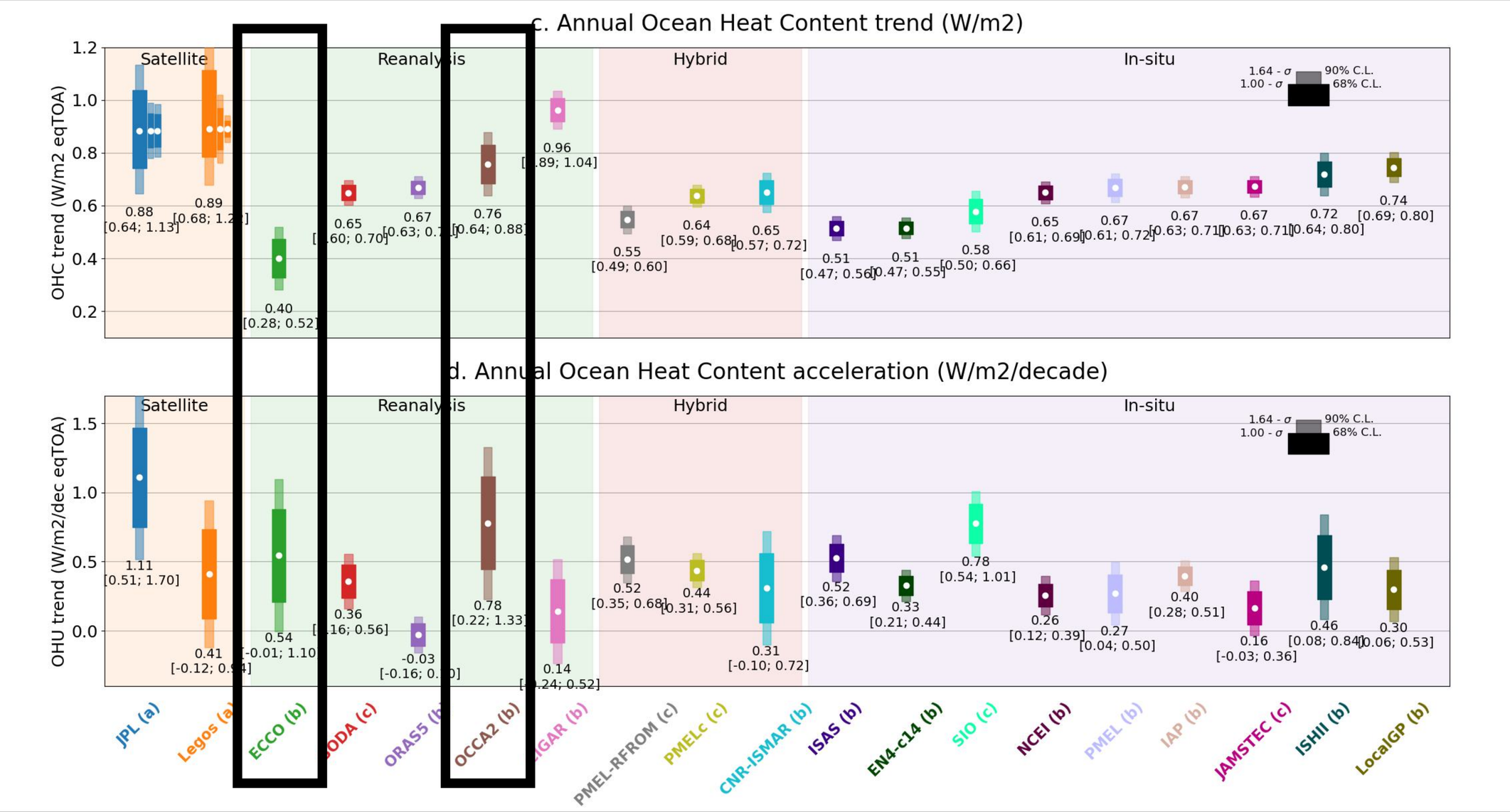
2004-2022



0.34 ZJ/year *(2004-2012)* → **4.7 ZJ/year** *(2013-2022)*

Forget 2024 (submitted)

Ocean Heat Content (trend, acceleration)



Hakuba et al 2024 (in press)

Take Away Message

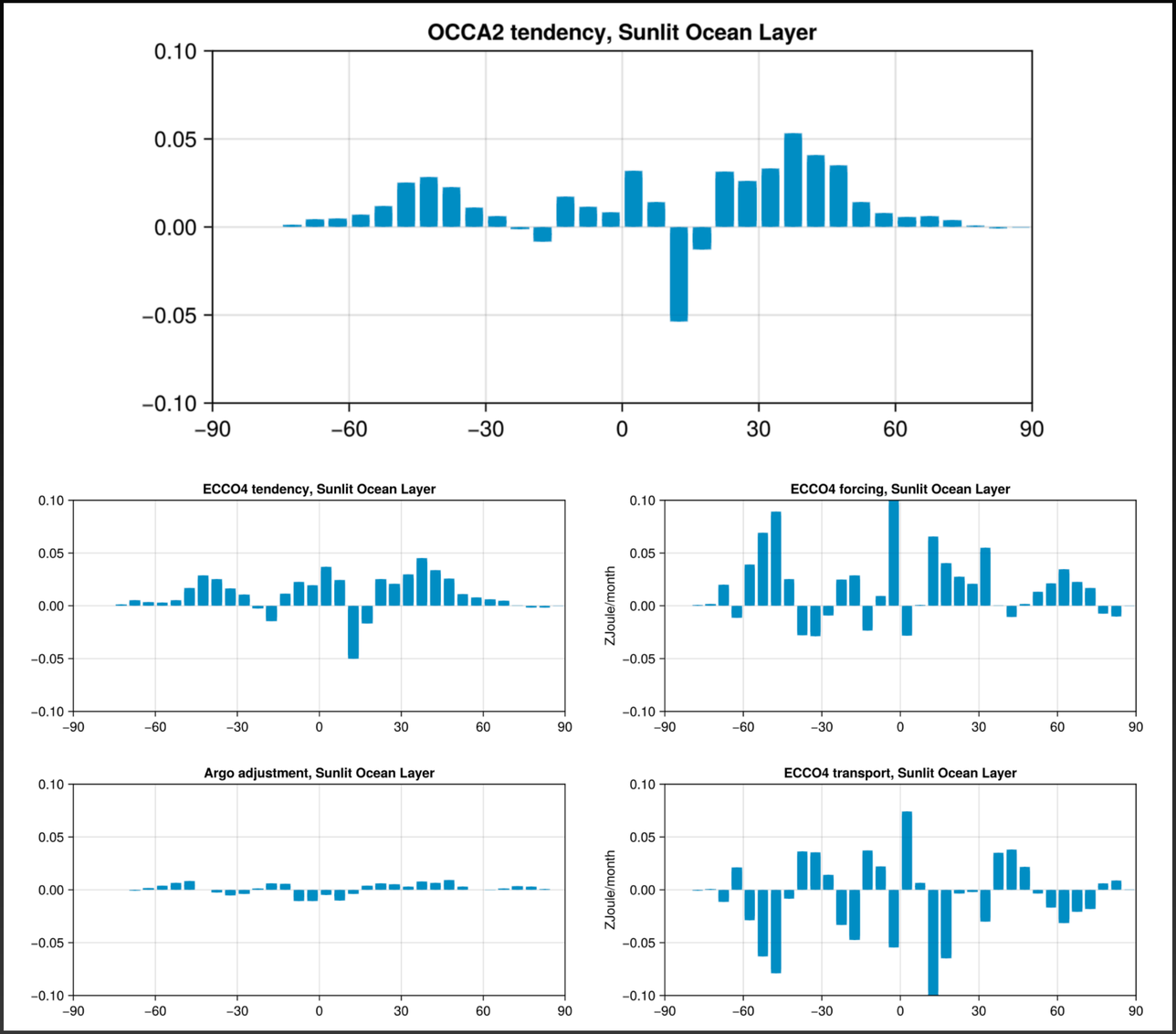
- The SOL is accumulating Earth's EI; 43% of total EEI storage over 2013-2022
- **SOL-EI recently increase by 10X from 0.34 ZJ/year to 4.7 ZJ/year**
- SOL-EI is a small imbalance between two large terms (uptake and export)
- Large variations (regional and temporal) in the interplay of processes
- Crucial to properly estimate (not back out) the anomalous transport term
- Now we have an operational definition and initial estimation for **SOL-EI = anomaly in ocean heat budgets over 0-200m, compared to the 1981-2010 climatology**

Preprint ... gforget@mit.edu , gaelforget.net

Extra slides

Mapping of regional EI budget

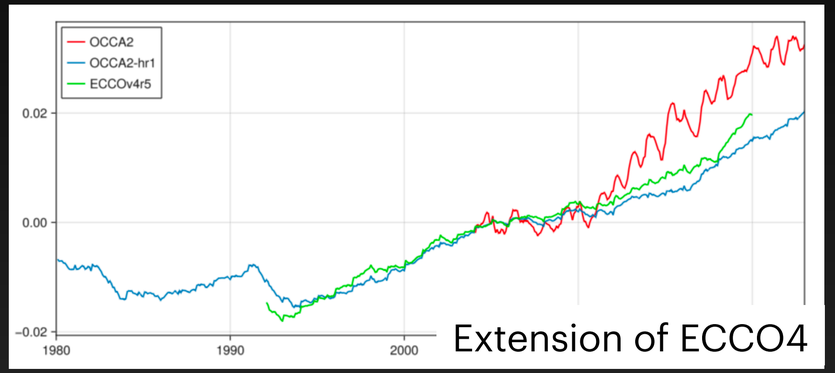
Degree K

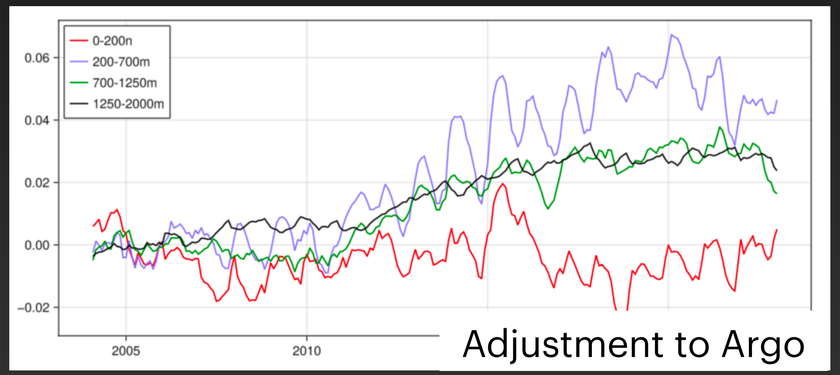


Forget 2024 (submitted)

Modeling Framework
An extension of ECCO4

1. Start from ECCO4 (release 2)
2. Diagnose forcing climatology (adjoint optimized)
3. Replace forcing with ERA5, and adjust to 2
4. Extend simulation to 1980-2023
   - Climatologically adjusted ERA5
   - Same initial conditions as ECCO4
   - Same adjoint-optimized parameters (Kd, Kgm, Kredi)
5. Compute adjustment to Argo by mapping out misfits





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State Estimates Fit to Argo

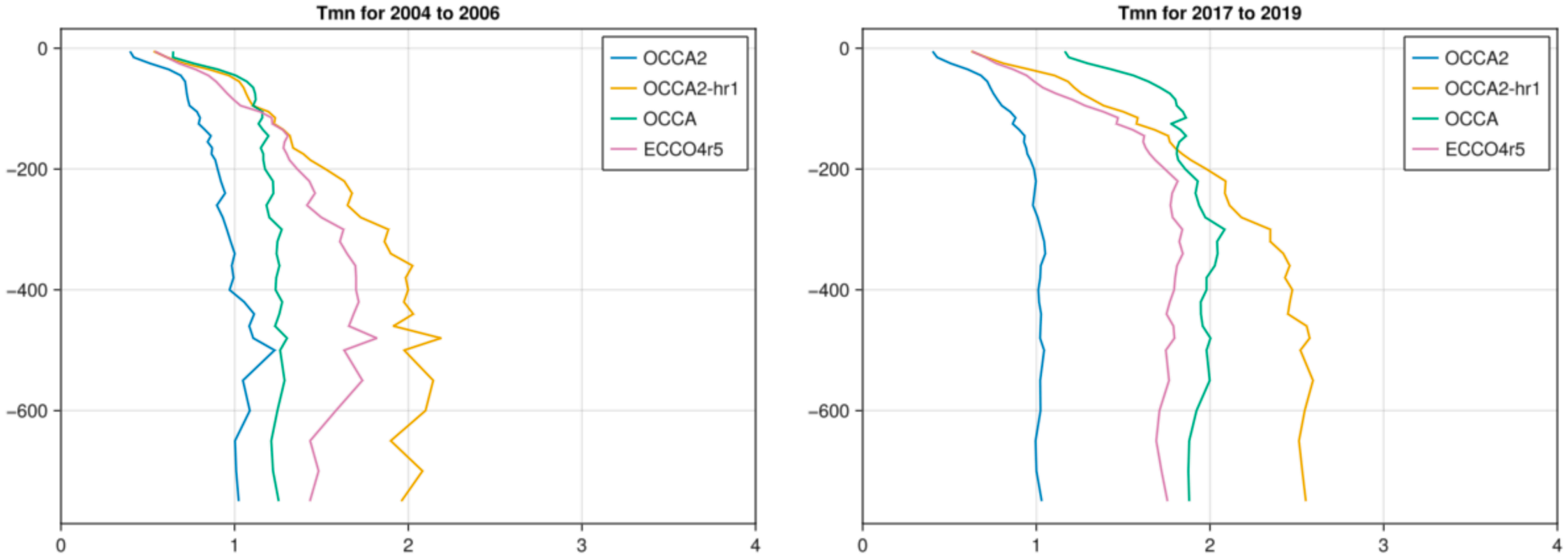

Fig. 9 Cost functions that measure misfits to Argo for different ocean state estimates. These sample mean values were computed over the global ocean for 2004-2006 (left) and 2017-2019 (right). In theory, they would be near 1 if a true optimum had been reached and error estimates were perfect.

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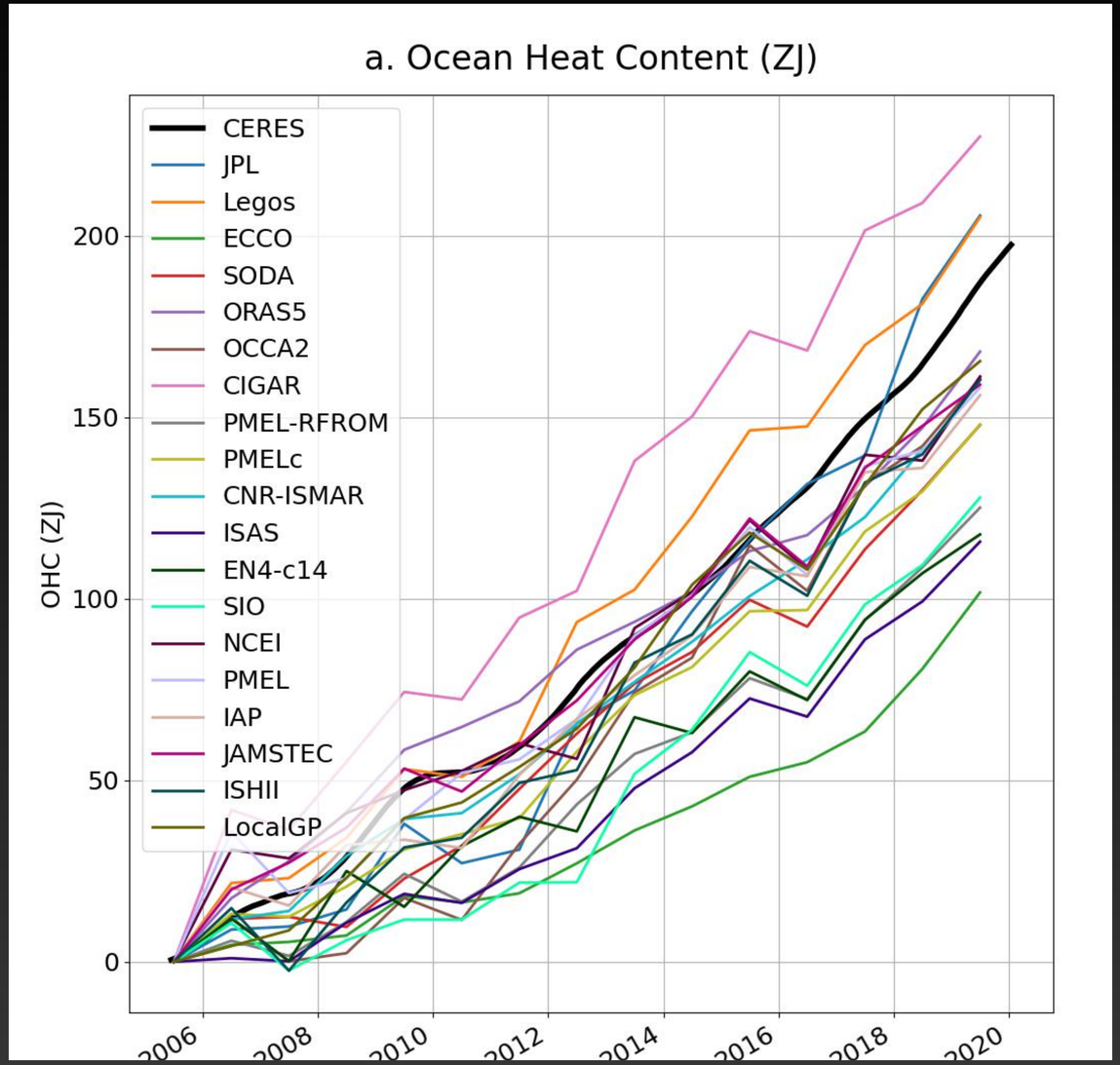
Ocean Heat Content (top to bottom)



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