Accounting for habitat-depth and seasonality effects on the $U_{37}^{K'}$ temperature proxy
Calibration and insights into model-data comparisons for the LGM

Vivien Bauer[1], William R. Gray[1], Joost De Vries[2], Masa Kageyama[1]

[1]Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA-CNRS-UVSQ, Gif-sur-Yvette, France; [2]BRIDGE University of Bristol, England

vivien.bauer@lsce.ipsl.fr

What's the Uk'37 proxy?

The $U_{37}^{K'}$, *index of di- and tri-unsaturated form of C_{37} alkenones produced by coccolithophores (cocco),* is one of the most widely used tools for **reconstructing** past **Sea Surface Temperatures** (*SST*).

$$U_{37}^{K'} = 0.033 \times T + 0.044 \qquad \textit{Müller et al. (1998)}$$

Still it has **significant biases** in **polar** and **tropical regions**, leading to a mismatch between $U_{37}^{K'}$*-derived SST* and *climate model reconstructions*. These may stem from the **assumption** that *coccolithophores* are related to **annual mean SSTs**.

Why this matters?

Constraining past climates such as the **Last Glacial Maximum** (*LGM*) is critical, since they provide major benchmarks to **reduce uncertainties** in model climate sensitivity and improve projections of future climate change.

Objectives

This project aims to revisit $U_{37}^{K'}$-based reconstructions by explicitly accounting for two key ecological factors: **seasonality** and **depth habitat** of *coccolithophores*. Thereby helping to resolve persistent model–data mismatches.

0. Methodology

I. New global estimates of coccolithophores biomass[1] (POC_{Cocco}) for 0-200 m.

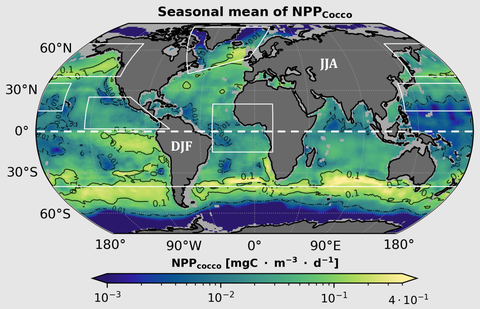
II. Estimation of Net Primary Production of coccolithophores[2] (NPP_{Cocco}).

$$NPP_{Cocco} = POC_{Cocco} \times \mu_{lim}$$

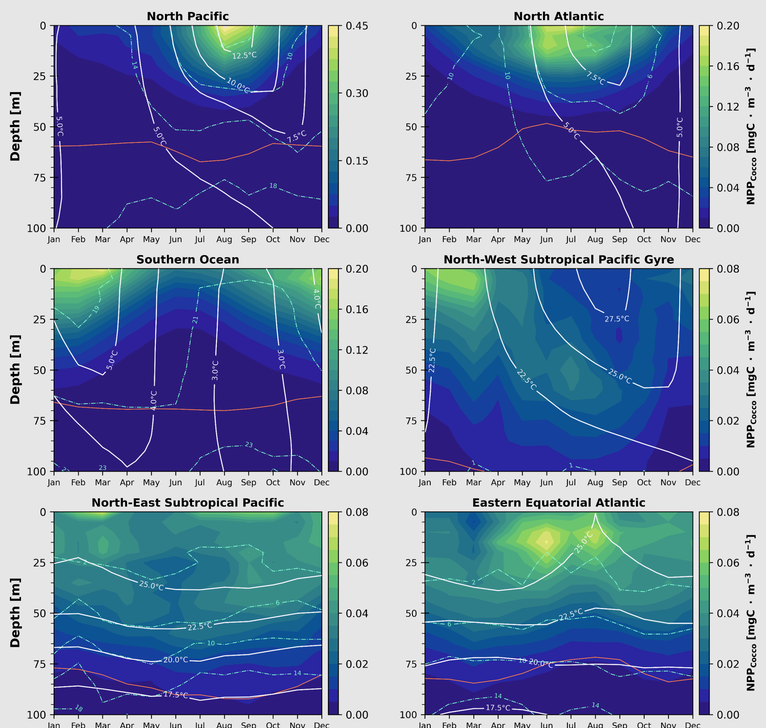
μ_{Tlim}[2] $\quad L_{light}$[3] $\quad L_{NO_3}$[4]

III. Seasonal and vertical weighting of temperatures[3] (T_W^{Cocco}) using NPP_{Cocco}.

1. NPP_{Cocco} distribution



Spatial and *temporal* **variability** jointly *control* NPP_{Cocco} distribution



2. Result: Habitat-weighted temperature

Polar regions:

- T_W^{Cocco} **warmer** than *SSTs*

Productivity peaks near the surface (10-20 m) during summer/autumn

➢ *Indicates a **seasonally dominated** signal*

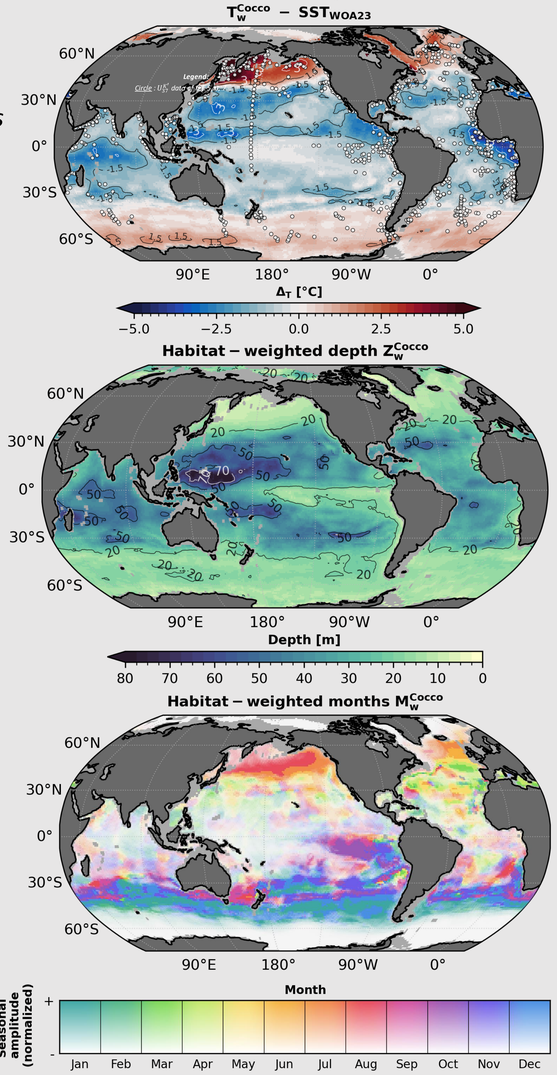
Tropical regions:

- T_W^{Cocco} **colder** than *SSTs*

Productivity extends deeper (>40 m), sampling cooler waters

➢ *Indicates a **depth-driven** signal*

Seasonality and Vertical-habitat co-modulate the T_W^{Cocco} signal



Takeaway

***$U^{K'}_{37}$ is not* a mean-annual surface signal**:

→ It reflects ***when*** (**seasonality**) and ***where*** (**habitat-depth**) coccolithophores thrive.

➔ **Rethinking** the *SST* assumption **reshapes how** we ***interpret* and *compare*** past ocean temperatures

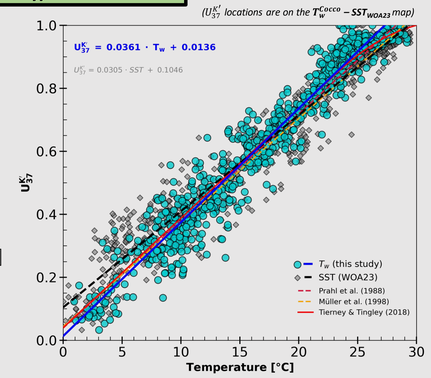
3. New calibration with T_W^{Cocco}

SST-based calibrations introduce **systematic biases**:

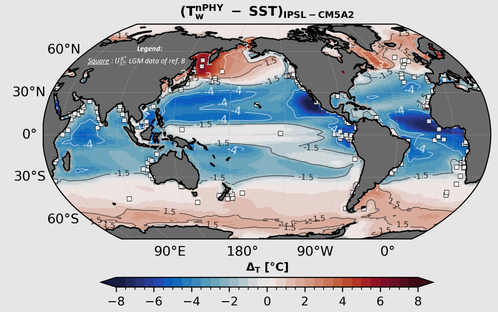
- **Too cold** at high latitude regions (*negative bias*)
- **Too warm** in subtropical to tropical regions (*positive bias*)

T_W^{Cocco} reduces these biases in $U_{37}^{K'}$ calibration

✓ ***Less bias*** *at both cold and warm ends*



4. Model-based evaluation (Pre-Industrial)

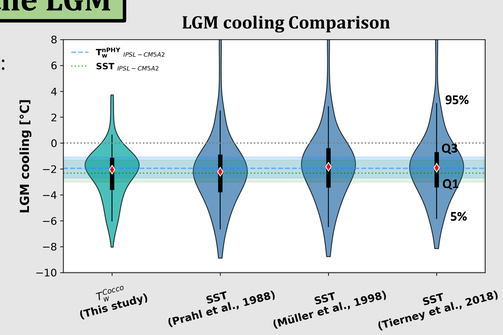


IPSL-CM5A2 results **reproduce** observed **habitat-driven** temperature **patterns**

5. Implication for the LGM

Using T_W^{Cocco}-based **calibration**:

Brings IPSL-CM5A2 LGM cooling into much **closer** alignment to $U_{37}^{K'}$-reconstructed temperatures



Takeaway

Accounting for **habitat-depth** and **seasonality** **improved agreement** between IPSL-CM5A2 and $U_{37}^{K'}$ reconstructions

➔ ***NPPc-weighted temperatures* yield more** reliable model–data comparisons ***than SST***

References:

1. De Vries et al., *in review*
2. Hopkins, J., & Balch, W. M. (2018)
3. MacIntyre et al. (2002)
4. Krumhardt et al. (2017)
5. Tierney, J. E., & Tingley, M. P. (2018)
6. Max, L. et al. (2020)
7. Hagemann, J. R. et al. (2023)
8. Tierney et al. (2020)

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