Sharing not permitted

But my picture is here by the way!

The influence of the carbonate pump on the ocean carbon cycle – anthropogenic perturbations and natural air-sea carbon fluxes

Alban Planchat[1], Laurent Bopp[1] and Lester Kwiatkowski[2]

(alban.planchat@lmd.ipsl.fr)

[1]LMD-IPSL, CNRS, Ecole Normale Supérieure/PSL Res. Univ, Ecole Polytechnique, Sorbonne Université, Paris, 75005, France

[2]LOCEAN Laboratory, Sorbonne Université-CNRS-IRD-MNHN, Paris, 75005, France

EGU by train: share and exchange while taking care of the carbon footprint of research

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

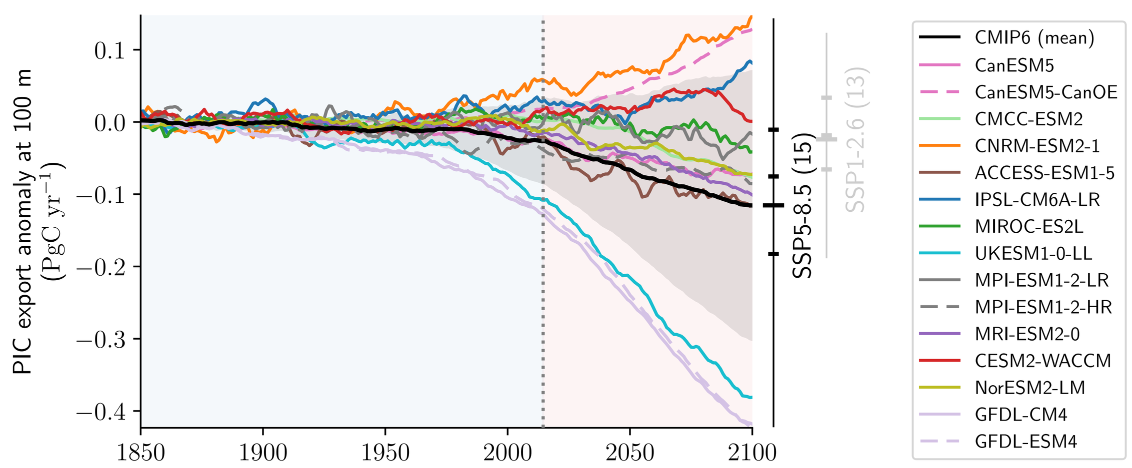
1. Anthropogenic perturbations

Planchat et al., *in prep*

METHODOLOGY

- **15 CMIP6 ESMs** processed up to 2100 (pre-industrial control, historical and SSP5-8.5 scenarios)
- **NEMO-PISCES** (marine biogeochemical model; Aumont et al., 2015) **sensitivity simulations** up to 2300 (historical and RCP-8.5 scenarios) to evaluate how a steady-state discrepancy, or a change in the carbonate pump magnitude, can impact the ocean carbon cycle in the Anthropocene Era.

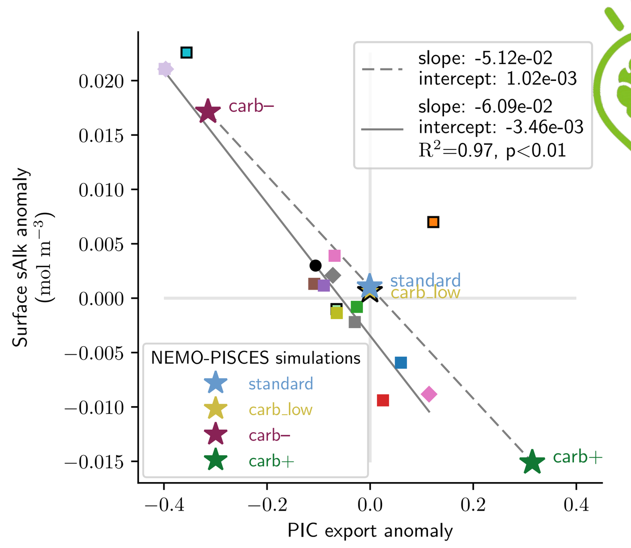
Particulate inorganic carbon (PIC) export projections diverge over the 21st century in CMIP6



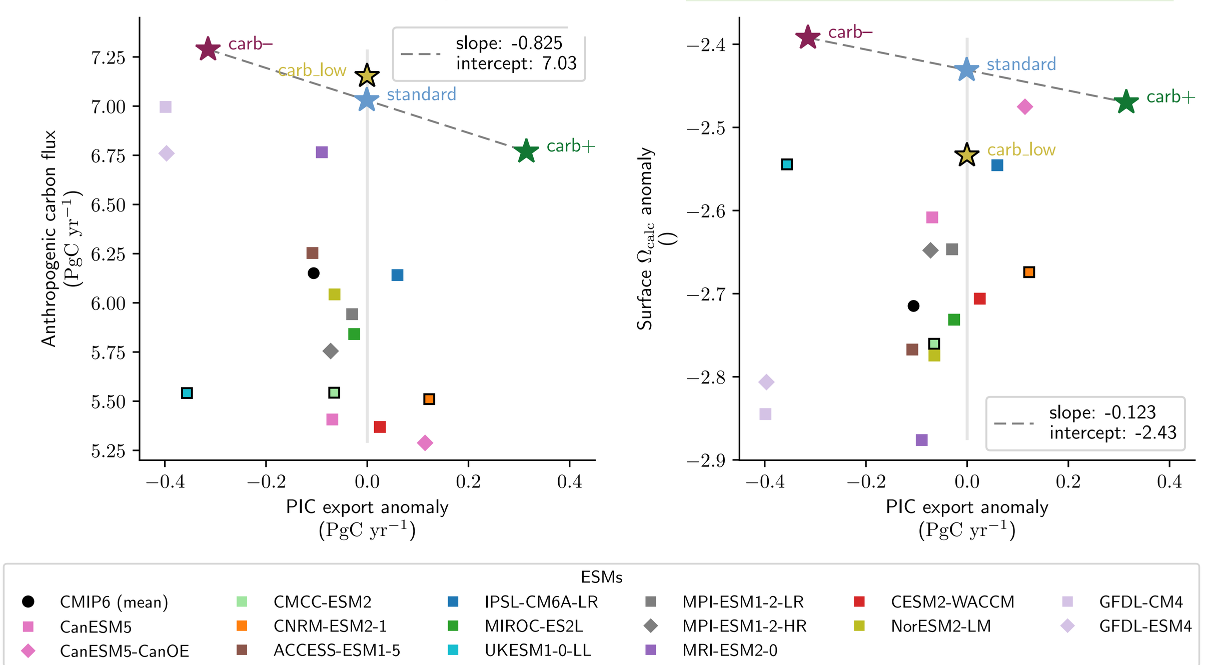
In fact, **PIC export appears dependent on particulate organic carbon (POC) export except for ESMs with a PIC production depending on the saturation state**, which show a major drop in PIC export by 2100 (UKESM1-0-LL and GFDL-CM4/ESM4).

The carbonate pump has a limited influence on the surface carbon cycle at a century and global scale

A 25 % decrease in the PIC export results, in a high-end estimate, in an increase by 4.0 % in the anthropogenic carbon flux (i.e. increased ocean carbon sink) and by 1.6 % in the surface ocean calcite saturation state (i.e. mitigated surface ocean acidification)



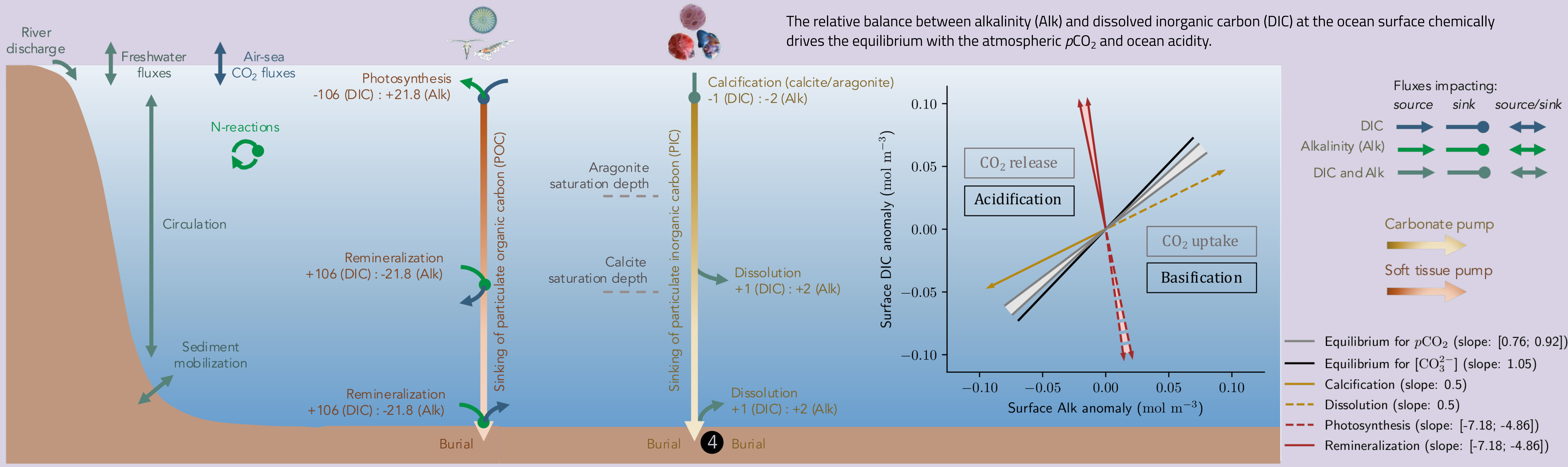
Surface salinity-normalized alkalinity (sAlk) time series could effectively be used to point, at first order, **to the trend in the carbonate pump** (Ilyina et al., 2009)



1. **The carbonate pump has limited influence on the global carbon cycle this century BUT** the $CaCO_3$ cycle could influence the global carbon cycle **in the long term with a dramatic shift in the vertical PIC dissolution pattern and strong regional variability**.

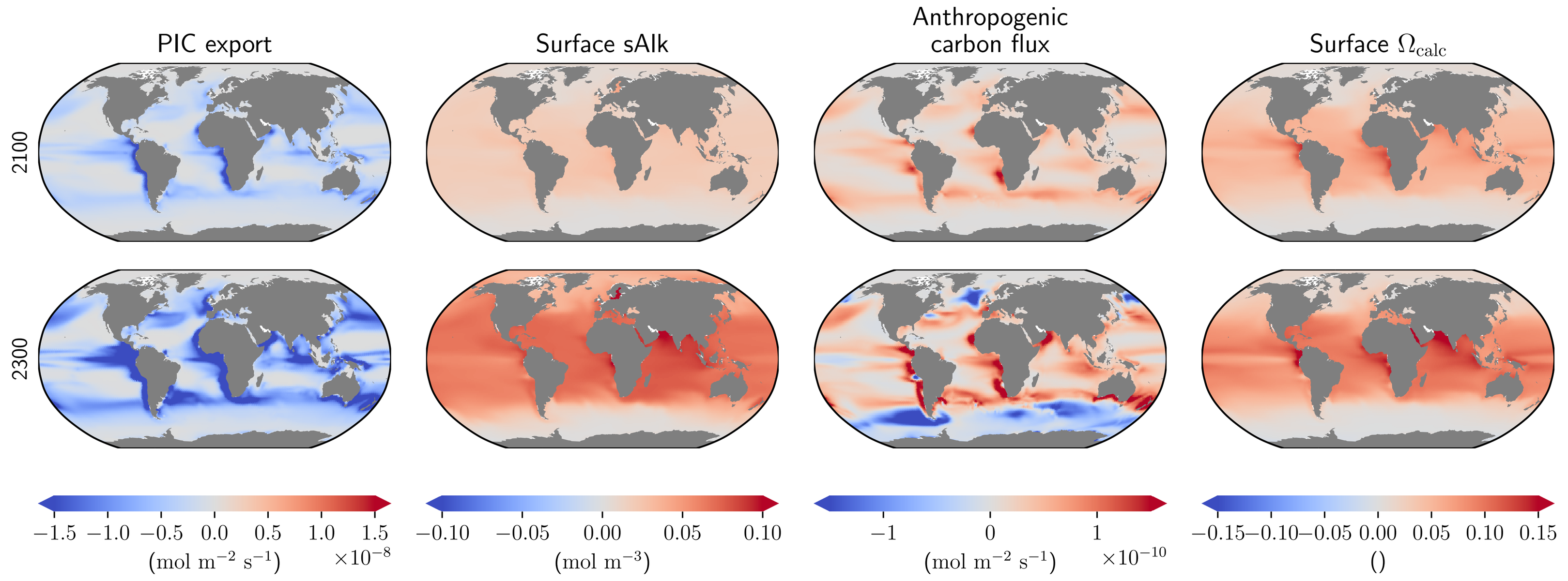
2. **The questioned drift in global alkalinity inventory at quasi-steady pre-industrial state** – with potentially an imbalance due to a greater PIC burial – **could increase the natural air-sea carbon flux and confine it in the Southern Ocean**.

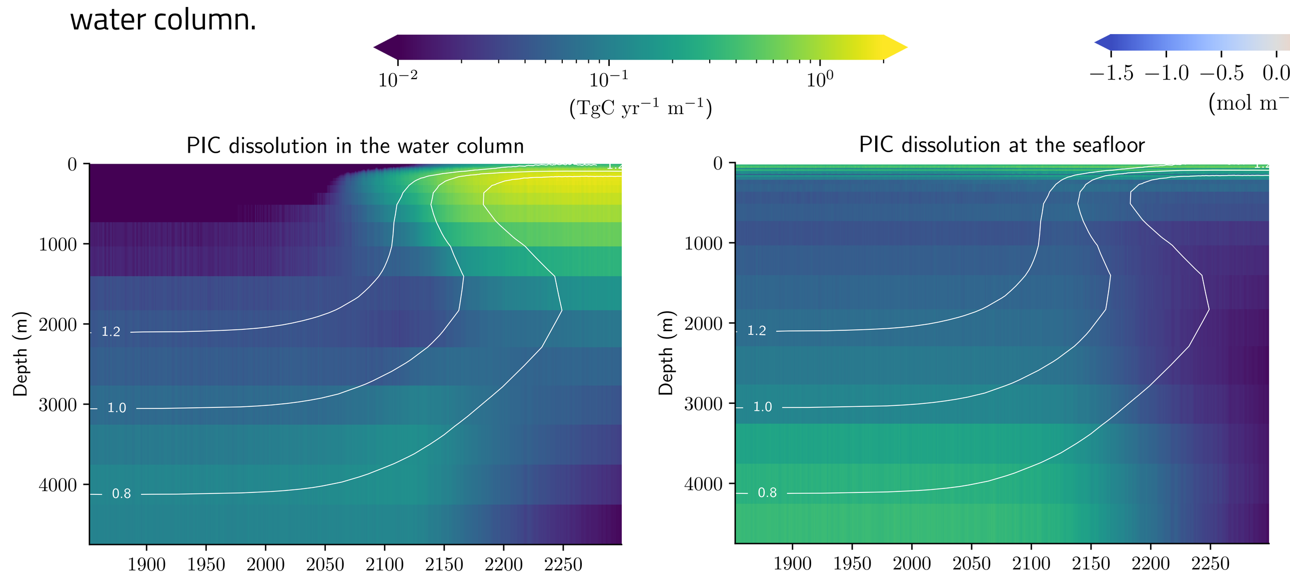
The relative balance between alkalinity (Alk) and dissolved inorganic carbon (DIC) at the ocean surface chemically drives the equilibrium with the atmospheric pCO_2 and ocean acidity.



The effect of climate change and ocean acidification on the $CaCO_3$ cycle could impact the global carbon cycle beyond 2100

For our standard simulation with NEMO-PISCES (historical+RCP-8.5), we point **a dramatic shift in the vertical PIC dissolution pattern**. From a mostly deep ocean dissolution, especially at the seafloor, **around 2100**, the dissolution shifts in the shallow waters and in the water column.





Heightened effects of carbonate pump anomalies post 2100 with strong regional variability for the anthropogenic carbon flux due to the upwelling of deep waters in the Southern Ocean impacted by the change in the carbonate pump magnitude (e.g. for the simulation with a constrained decrease in the carbonate pump relative to our standard simulation).

References

Aumont, O., Orr, J. C., Monfray, P., Ludwig, W., Amiotte-Suchet, P., & Probst, J. L. (2001). Riverine-driven interhemispheric transport of carbon. *Global Biogeochemical Cycles*, *15*(2), 393-405.

Aumont, O., Éthé, C., Tagliabue, A., Bopp, L., & Gehlen, M. (2015). PISCES-v2: an ocean biogeochemical model for carbon and ecosystem studies. *Geoscientific Model Development Discussions*, *8*(2), 1375-1509.

Cartapanis, O., Galbraith, E. D., Bianchi, D., & Jaccard, S. L. (2018). Carbon burial in deep-sea sediment and implications for oceanic inventories of carbon and alkalinity over the last glacial cycle. *Climate of the Past*, *14*(11), 1819-1850.

Friedlingstein, P., O'sullivan, M., Jones, M. W., Andrew, R. M., Gregor, L., Hauck, J., ... & Zheng, B. (2022). Global carbon budget 2022. *Earth System Science Data*, *14*(11), 4811-4900.

Ilyina, T., Zeebe, R. E., Maier-Reimer, E., & Heinze, C. (2009). Early detection of ocean acidification effects on marine calcification. *Global Biogeochemical Cycles*, *23*(1).

Planchat, A., Kwiatkowski, L., Bopp, L., Torres, O., Christian, J. R., Butenschön, M., ... & Stock, C. (2023). The representation of alkalinity and the carbonate pump from CMIP5 to CMIP6 Earth system models and implications for the carbon cycle. *Biogeosciences*, *20*(7), 1195-1257.

Resplandy, L., Keeling, R. F., Rödenbeck, C., Stephens, B. B., Khatiwala, S., Rodgers, K. B., ... & Tans, P. P. (2018). Revision of global carbon fluxes based on a reassessment of oceanic and riverine carbon transport. *Nature Geoscience*, *11*(7), 504-509.

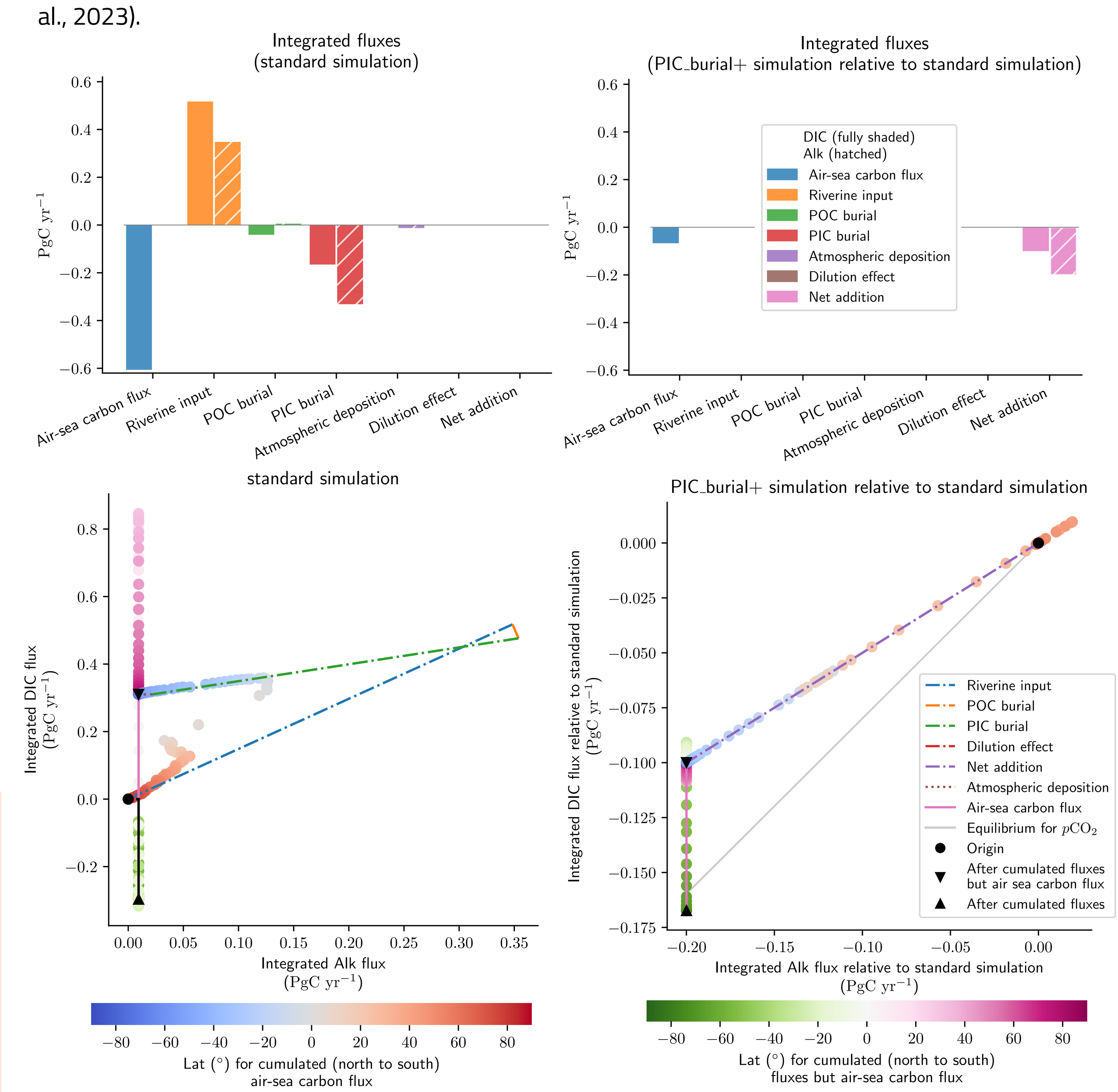
2. Natural air-sea carbon fluxes

METHODOLOGY

2500-year spin-up simulations run under pre-industrial conditions to assess the effect of a misrepresentation of the PIC burial, and a potential imbalanced global alkalinity inventory at quasi-steady pre-industrial state on the natural air-sea carbon fluxes.

An imbalance in the quasi-steady pre-industrial state of the global alkalinity inventory has the potential to increase the natural carbon outgassing

Constraining an imbalance of the global alkalinity inventory through a net PIC burial of 0.1 PgC yr^{-1} (PIC_burial+ simulation) **with a forced PIC burial in the deep Atlantic** of 0.2 PgC yr^{-1} **and a forced PIC dissolution in the deep Pacific** of 0.1 PgC yr^{-1}; Cartapanis et al., 2018) **increases the natural carbon outgassing towards the atmosphere** by 11.1 % (+0.07 PgC yr^{-1}). This increase is confined in the Southern Ocean, but at global scale, the surface alkalinity and DIC changes are very consistent with what a first approximation of an equilibrium with the atmospheric pCO_2 would suggest (Planchat et al., 2023).



Opening

Can we work at global scale, in a (Alk, DIC) diagram, to investigate changes in the global carbon cycle?

- **In a context of climate change and ocean acidification** to understand **what is missing in the models to improve their representation of the carbon cycle** and **what is missing in their estimate of the anthropogenic carbon sink** (Friedlingstein et al., 2022)
- **In a context of quasi-steady pre-industrial state** to understand **where the missing part of the natural carbon flux could come from** (Aumont et al., 2001; Resplandy et al., 2018)