Report for the year 2022 and future activities

SOLAS *'Belgium'*
compiled by: 'Gypens Nathalie'

This report has two parts:

- Part 1: *reporting of activities in the period of January 2022 - Jan/Feb 2023*
- Part 2: *reporting on planned activities for 2023 and 2024.*

The information provided will be used for reporting, fundraising, networking, strategic development and updating of the live web-based implementation plan. As much as possible, please indicate the specific SOLAS 2015-2025 Science Plan Themes addressed by each activity **or specify an overlap between Themes or Cross-Cutting Themes.**

1 Greenhouse gases and the oceans;
2 Air-sea interfaces and fluxes of mass and energy;
3 Atmospheric deposition and ocean biogeochemistry;
4 Interconnections between aerosols, clouds, and marine ecosystems;
5 Ocean biogeochemical control on atmospheric chemistry;
Integrated studies of high sensitivity systems;
Environmental impacts of geoengineering;
Science and society**.**

IMPORTANT*: This report should reflect the efforts of the SOLAS community in the* ***entire country*** *you are representing (all universities, institutes, lab, units, groups, cities).*

First things first…Please tell us what the IPO may do to help you in your current and future SOLAS activities. ?

PART 1 - Activities from January 2022 to Jan/Feb 2023

1. Scientific highlight

The land-to-ocean loops of the global carbon cycle

Carbon storage by the ocean and by the land is usually quantified separately, and does not fully take into account the land-to-ocean transport of carbon through inland waters, estuaries, tidal wetlands and continental shelf waters—the 'land-to-ocean aquatic continuum' (LOAC). Here we assess LOAC carbon cycling before the industrial period and perturbed by direct human interventions, including climate change. In our view of the global carbon cycle, the traditional 'long-range loop', which carries carbon from terrestrial ecosystems to the open ocean through rivers, is reinforced by two 'short-range loops' that carry carbon from terrestrial ecosystems to inland waters and from tidal wetlands to the open ocean. Using a mass-balance approach, we find that the pre-industrial uptake of atmospheric carbon dioxide by terrestrial ecosystems transferred to the ocean and outgassed back to the atmosphere amounts to 0.65 ± 0.30 petagrams of carbon per year (±2 sigma). Humans have accelerated the cycling of carbon between terrestrial ecosystems, inland waters and the atmosphere, and decreased the uptake of atmospheric carbon dioxide from tidal wetlands and submerged vegetation. Ignoring these changing LOAC carbon fluxes results in an overestimation of carbon storage in terrestrial ecosystems by 0.6 ± 0.4 petagrams of carbon per year, and an underestimation of sedimentary and oceanic carbon storage. We identify knowledge gaps that are key to reduce uncertainties in future assessments of LOAC fluxes.

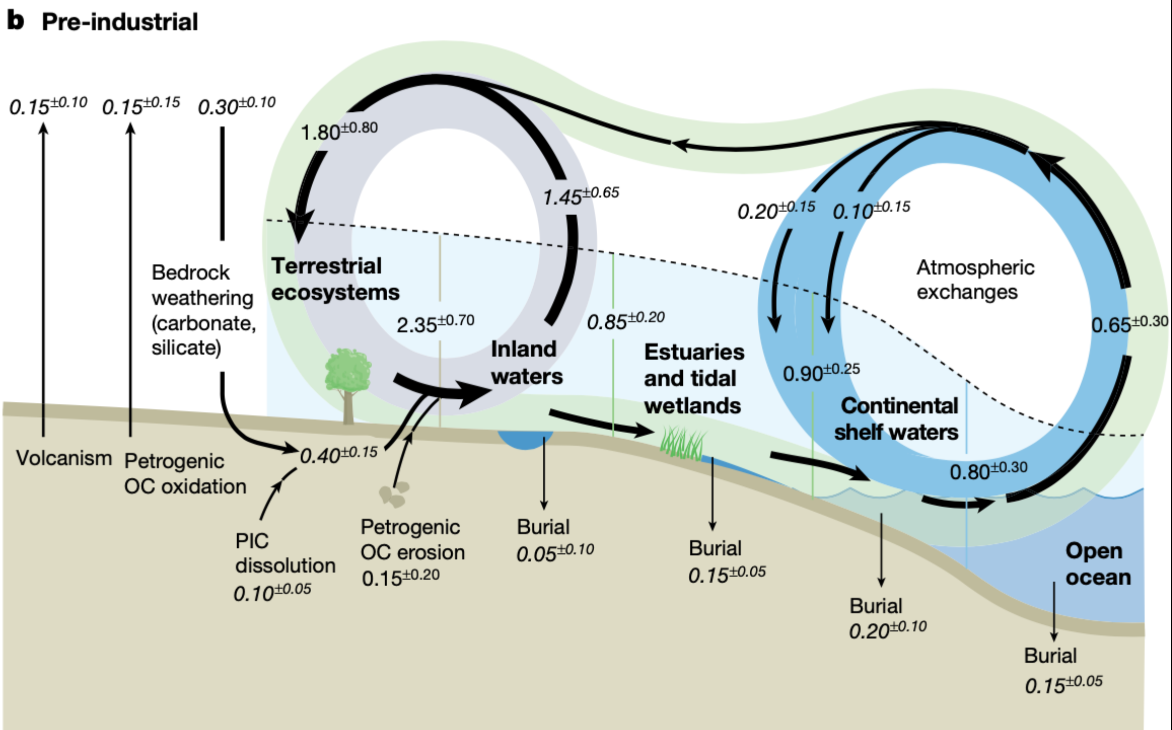

Figure 1: The global carbon budget with LOAC fluxes. b. The pre-industrial global carbon budget. All fluxes in italics are derived from bottom-up estimates; other fluxes were constrained from a mass balance. The units are PgC yr^{-1}. All fluxes have been rounded to ± 0.05 PgC yr^{-1}

Citation: Regnier P. et al. (2022) The land-to-ocean loops of the global carbon cycle. Nature, 603, 401–410.

A framework to evaluate and elucidate the driving mechanisms of coastal sea surface pCO_2 seasonality using an ocean general circulation model (MOM6-COBALT).

The temporal variability of the sea surface partial pressure of CO_2 (pCO_2) and the underlying processes driving this variability are poorly understood in the coastal ocean. In this study, we tailor an existing method that quantifies the effects of thermal changes, biological activity, ocean circulation and freshwater fluxes to examine seasonal pCO_2 changes in highly variable coastal environments. We first use the Modular Ocean Model version 6 (MOM6) and biogeochemical module Carbon Ocean Biogeochemistry And Lower Trophics version 2 (COBALTv2) at a half-degree resolution to simulate coastal CO_2 dynamics and evaluate them against pCO_2 from the Surface Ocean CO_2 Atlas database (SOCAT) and from the continuous coastal pCO_2 product generated from SOCAT by a two-step neuronal network interpolation method (coastal Self- organizing Map Feed-Forward neural Network SOM-FFN). The MOM6-COBALT model reproduces the observed spatiotemporal variability not only in pCO_2 but also in sea surface temperature, salinity and nutrients in most coastal environments, except in a few specific regions such as marginal seas. Based on this evaluation, we identify coastal regions of “high” and “medium” agreement between model and coastal SOM-FFN where the drivers of coastal pCO_2 seasonal changes can be examined with reasonable confidence. Second, we apply our decomposition method in three contrasted coastal regions: an eastern (US East Coast) and a western (the Californian Current) boundary current and a polar coastal region (the Norwegian Basin). Results show that differences in pCO_2 seasonality in the three regions are controlled by the balance between ocean circulation and biological and thermal changes. Circulation controls the pCO_2 seasonality in the Californian Current; biological activity controls pCO_2 in the Norwegian Basin; and the interplay between biological processes and thermal and circulation changes is key on the US East Coast. The refined approach presented here allows the attribution of pCO_2 changes with small residual biases in the coastal ocean, allowing for future work on the mechanisms controlling coastal air–sea CO_2 exchanges and how they are likely to be affected by future changes in sea surface temperature, hydrodynamics, and biological dynamics.

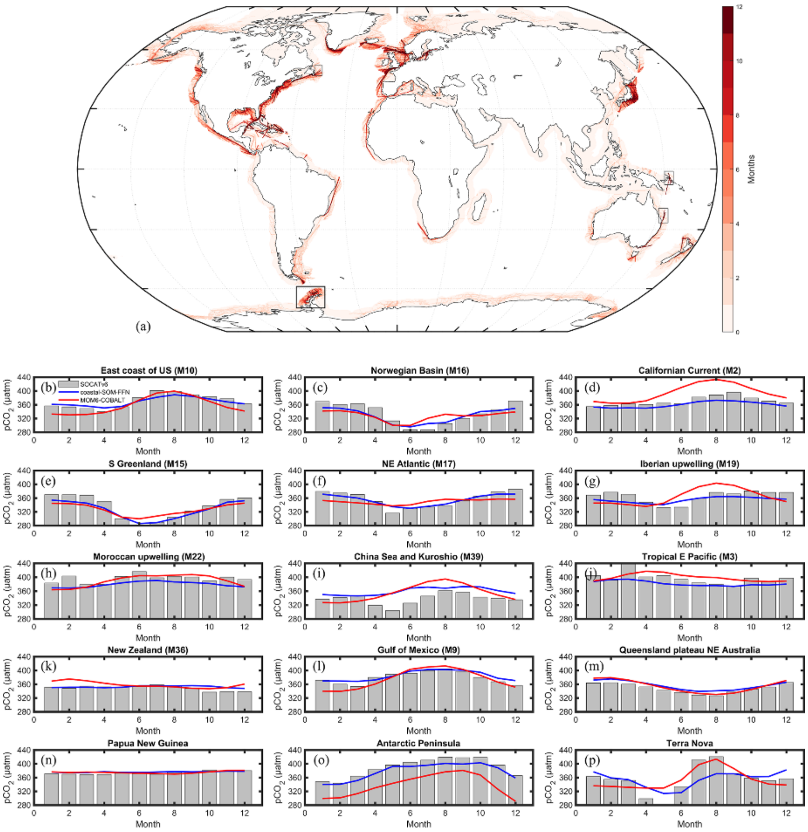

Figure 2: a) SOCATv6 temporal coverage evaluated as the number of months (1 to 12) where at least one pCO_2 measurement is available (see details in Sect. 2). Seasonal pCO_2 cycle (µatm) derived from SOCATv6 (bar in gray) and coastal SOM-FFN (in blue) and simulated by MOM6-COBALT (in red) for several MARCATS regions (b–l) and four coastal sites of smaller spatial extent than a MARCATS region (m–p). The location of the four coastal sites is represented by black boxes in panel (a). Month 1 corresponds to January. For consistency in the y axis between panels, the

value of 276 µatm is not represented in panel (p) for month 5 for the SOCATv6 data

Citation: Roobaert, A., Resplandy, L., Laruelle, G. G., Liao, E., and Regnier, P.: A framework to evaluate and elucidate the driving mechanisms of coastal sea surface pCO2 seasonality using an ocean general circulation model (MOM6-COBALT), Ocean Sci., 18, 67–88, https://doi.org/10.5194/os-18-67-2022, 2022.

2. Activities/main accomplishments in 2022 (e.g., projects; field campaigns; workshops and conferences; model and data intercomparisons; capacity building; international collaborations; contributions to int. assessments such as IPCC; collaborations with social sciences, humanities, medicine, economics and/or arts; interactions with policy makers, companies, and/or journalists and media).

- Organisation of the 53rd Ocean Liège Colloquium on ocean deoxygenation (Marilaure Grégoire - ULg). This event was sponsored by SOLAS with the support of 3 fellowships. A report has been sent to SOLAS.

- Horizon 2020 BRIDGE-BS project (2021-2025) where we have a task on the modelling of N2O air-sea fluxes (Marilaure Grégoire -ULg).

- Marine Copernicus Service, delivery of the air-sea CO2 flux in operational mode and reanalysis over the Black Sea (Marilaure Grégoire -ULg)

- Lead of the land-to-ocean greenhouse gas flux syntheses for RECCAP2, the Regional Carbon Cycle Assessment and Processes of the Global Carbon Project (GCP) (Pierre Regnier -ULB).

- Scientific Implementation Committee member for the global N_2O budget released by GCP and now coordination team member of the GCP CH_4 budget (focus on inland and coastal waters) (Pierre Regnier -ULB).

- Member of WCRP-CMIP7 (Coupled Model Intercomparison Project) Strategic Ensemble Group of the World Climate Research Programme (WCRP) (Pierre Regnier -ULB).

- ECV-Ice intercalibration of air-ice CO_2 fluxes and primary production in Cambridge Bay – Canada (May 2022) (François Fripiat -ULB).

3. Top 5 publications in 2022 (only PUBLISHED articles) and if any, weblinks to models, datasets, products, etc.

Belliard J-P, S Hernandez, S Temmerman, RH Suello, LE Dominguez-Granda, AM Rosado-Moncayo, JA Ramos-Veliz, RN Parra-Narera, KP Ramirez, G Govers, AV Borges & S Bouillon (2022). Carbon dynamics and CO_2 and CH_4 exchange in the mangrove dominated Guayas river delta, Ecuador, Estuarine, Coastal and Shelf Science, 267, 107766, https://doi.org/10.1016/j.ecss.2022.107766

Campbell, K., I. Matero, C. Bellas, T. Turpin-Jelfs, P. Anhaus, M. Graeve, F. Fripiat, M. Tranter, J.C. Landy, P. Sanchez-Baracaldo, E. Leu, C. Katlein, C.J. Mundy, S. Rysgaard, L. Tedesco, C. Haas, and M. Nicolaus (2022). Monitoring a changing Arctic: Recent advancements in the study of sea ice microbial communities. Ambio 51, 318-332. https://doi.org/10.1007/s13280-021-01658-z

Dai, M., Su, J., Zhao, Y., Hofmann, E., Cao, Z., Cai, W.-J., Gan, J., Lacroix, F., Laruelle, G. G., Meng, F., Müller, J. D., Regnier, P., Wang, G., & Wang, Z (2022). Carbon Fluxes in the Coastal Ocean: Synthesis, Boundary Processes and Future Trends. *Annual review of earth and planetary sciences*, 50(1). doi:10.1146/annurev-earth-032320-090746.

Farmer, J.R., T. Pico, O.M. Underwood, R. Cleveland Stout, J. Granger, T.M. Cronin, F. Fripiat, A. Martinez-Garcia, G.H. Haug, and D.M. Sigman (2022). The Bering Strait was flooded 10,000 years before the last Glacial Maximum. PNAS 120(1) e2206742119.

Martinez-Garcia, A., J. Jung, X.E. Ai, D.M. Sigman, A. Auderset, N.N. Duprey, A. Foreman, F. Fripiat, J. Leichliter, T. Ludecke, S. Moretti, and T. Wald (2022). Laboratory assessment of the impact of chemical oxidation, mineral dissolution, and heating on the nitrogen isotopic composition of fossil-bound organic matter. Geochemistry, Geophysics, Geosystems 23(8) e2022GC010396.

Regnier, P., Resplandy, L. L., Najjar, R. R., & Ciais, P (2022). The land-to-ocean loops of the global carbon cycle. *Nature*, 603(7901), 401-410. doi:10.1038/ s41586-021-04339-9.

Roobaert, A., Resplandy, L. L., Laruelle, G. G., Liao, E. E., & Regnier, P (2022). A framework to evaluate and elucidate the driving mechanisms of coastal sea surface pCO2 seasonality using an ocean general circulation model (MOM6-COBALT). *Ocean science*, 18, 67-88.

Zhang, H., Lauerwald, R., Ciais, P., Van Oost, K., Guenet, B., & Regnier, P (2022). Global changes alter the amount and composition of land carbon deliveries to European rivers and seas. *Communications Earth and Environment*, 3(1) doi:10.1038/s43247-022-00575-7.

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2022? If yes, who? How did you engage?

- ULiège is co-PI of the Global Ocean Oxygen Decade program. One of the targets of this program is the better quantification of ocean deoxygenation and hence the air-sea oxygen flux.
- BEPSII field school in Cambridge Bay (May 2022) (François Fripiat -ULB).

PART 2 - Planned activities for 2023 and 2024

1. Planned major national and international field studies and collaborative laboratory and modelling studies (incl. all information possible, dates, locations, teams, work, etc.).

2. Events like conferences, workshops, meetings, summer schools, capacity building etc. (incl. all information possible).

- Expected to have the 2024 IBIS meeting ("Isotopes in biogenic silica") in Belgium (F. Fripiat, ULB, and S. Opfergelt, UClouvain, as co-hosts).

- We are chair of an EMB working group on "Every second breath we take comes from the ocean". The Future science brief will be released during ASLO on June 8th. 2023 (Marilaure Grégoire -ULg).

- We will participate to a general public event on ocean deoxygenation organized at the Ixelles gallery in relation to the Ocean and Seas exhibition. This general public event will be part of a World Ocean Day wide event on ocean deoxygenation (Marilaure Grégoire -ULg).

- Part of the SC of the international summer school on ocean deoxygenation and acidification, November 2023, Chili (Marilaure Grégoire -ULg).

3. Funded national and international projects/activities underway.

2023-2029 - Green2Ice project (ERC Synergy Grant; F. Fripiat) "When was Greenland green? - Perspectives from basal ice and sediments from ice cores"

2023-2024 - ENGAGE project (FNRS; F. Fripiat) "Assessing the roles of the polar oceans on global biogeochemical cycles".

2023-2026 - STEREO project (FWB; F. Fripiat) "Southern Ocean's overturning circulation during ice ages"

2022-2023 - GENIAL project (FWB; F. Fripiat) "Gas concentrations and isotopes in the deepest part of the Antarctic and Greenland ice sheets: Environmental and paleoclimatic implications"

2022-2023 - AEROBIC project (FNRS; F. Fripiat) "Gas concentrations and isotopes in basal ice"

4. Plans / ideas for future national or international projects, programmes, proposals, etc. (please indicate the funding agencies and potential submission dates).

- HFSP research grant "trapped in ice" (Marcel Babin, Manu Prakash, Eric Maréchal, and F. Fripiat) – international collaboration (Belgium, USA, Canada, France) to study colonization processes in growing sea ice.

5. Engagements with other international projects, organisations, programmes, etc.

- BEPSII (Biogeochemical Exchange Processes at the Sea ice Interfaces) joint SOLAS-CLIC-IASC-SCAR working group
- CIce2Cloud (Coupling Ocean-Ice-Atmosphere processes from sea-ice biogeochemistry to areosols and clouds) SCOR working group
- ECVice (Essential Climate Variable for sea ice) SCOR working group
- National representatives of the IASC cryosphere and ocean working groups