OceanICU
Understanding Ocean Carbon

Will the ocean uptake of anthropogenic carbon dioxide (CO_2) continue primarily as an abiotic process?

6-March 2024

Host Richard Sanders
Panellists: Judith Hauck and Jamie Shutler

Co-funded by the European Union
UK Research and Innovation

This work was funded by the European Union under grant agreement no. 101083922 (OceanICU) and UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee [grant number 10054454, 10063673, 10064020, 10059241, 10079684, 10059012, 10048179]. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

OceanICU Webinar 4

Richard Sanders

MODERATOR

Coordinator of
the OceanICU project

MEET THE PANELLISTS

Prof. Jamie Shutler

Professor of Earth Observation and Climate, University of Exeter

Dr. Judith Hauck

Head of Helmholtz Young Investigator Group for Marine Carbon and Ecosystem Feedbacks in the Earth System (MarESys), and Deputy Head of Marine Biogeosciences at the Alfred Wegener Institute.

Welcome and Thank You for Joining Us Today

Agenda

- Brief Introduction
  Richard Sanders
- Panellist Presentations
  - Judith Hauck
  - Jamie Shutler:
- Questions and Answers

About Today's Format

This webinar is being video recorded

- Cameras & Microphones have been disabled
- Questions posted in the chat will not be included in the video recording so your name will not be displayed.

Questions and Answers

- Please use the chat function to ask any questions you have.
- Questions will be directed to the appropriate panellist by the moderator during the Q&A session.
- Questions & Answers covered during the session, along with any that we did not have time to respond to, will be posted in text form on the OceanICU website; a link will be sent to you in a post-webinar email communication.

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Contact: hello@ocean-icu.eu

Will the ocean uptake of anthropogenic carbon dioxide (CO_2) continue as primarily an abiotic process?

Judith Hauck

Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung

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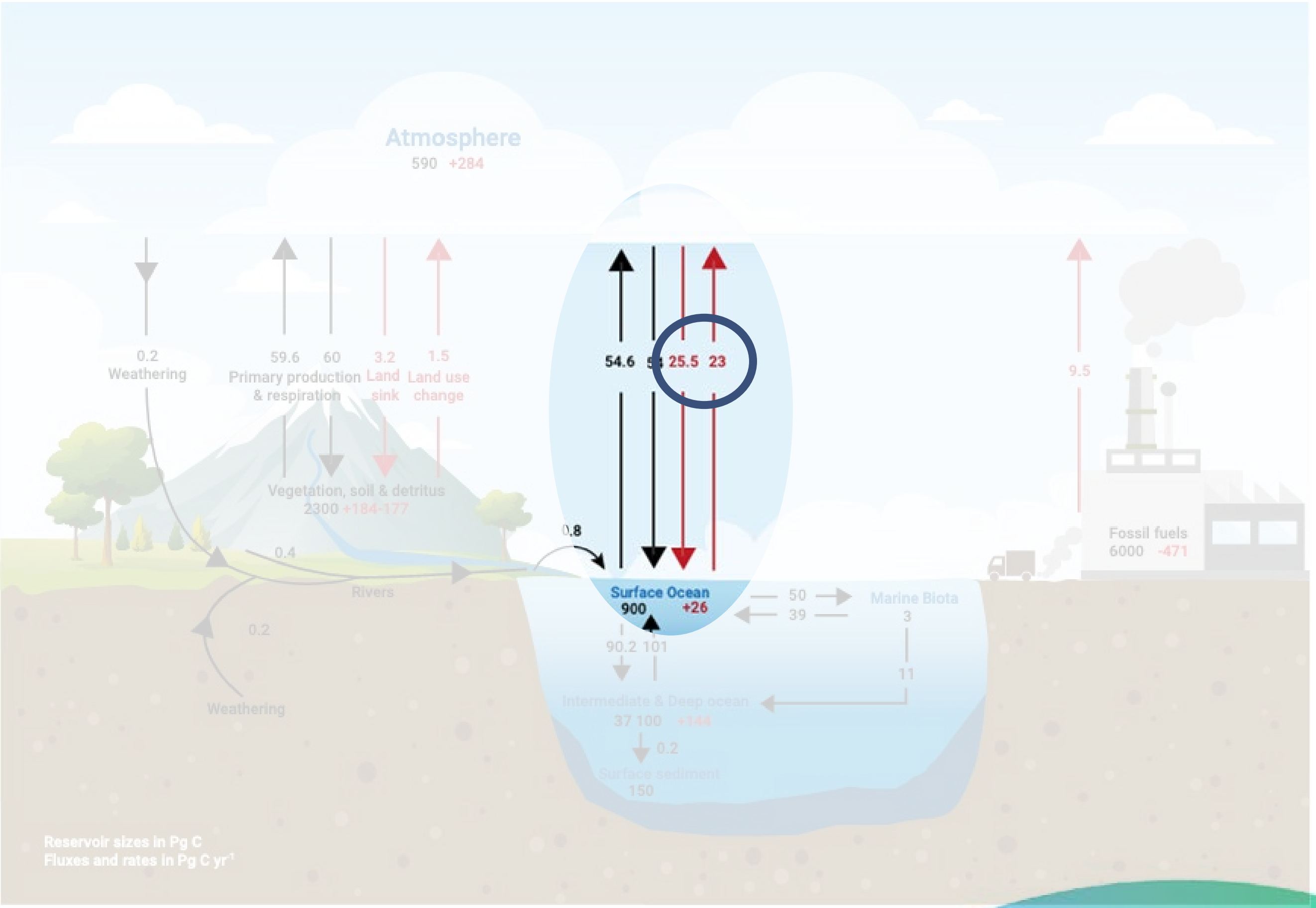
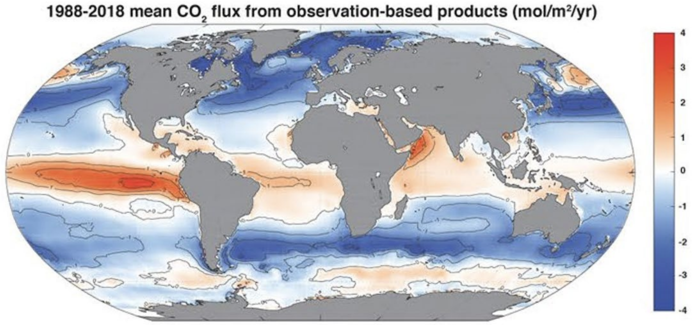
Unpacking the Question

1. Is the ocean uptake of anthropogenic CO_2 largely an abiotic process?
2. Will the abiotic uptake of anthropogenic CO_2 continue?
3. What is the role of biology for present-day ocean CO_2 uptake?
4. Will the role of biology for ocean CO_2 uptake change in the future?

1. Is the ocean uptake of anthropogenic CO_2 largely an abiotic process?





out of ocean

into ocean

The natural carbon cycle: Large fluxes into and out of the ocean

Anthropogenic CO_2 flux: Response to rising atmospheric CO_2

Net anthropogenic CO_2 uptake is a small residual of large background fluxes

Integrated ocean carbon research: a summary of ocean carbon research, and vision of coordinated ocean carbon research and observations for the next decade, IOC, Technical Series 158, 2021; Numbers: 2009-2018, Friedlingstein et al., 2019; map: Crisp et al., 2022

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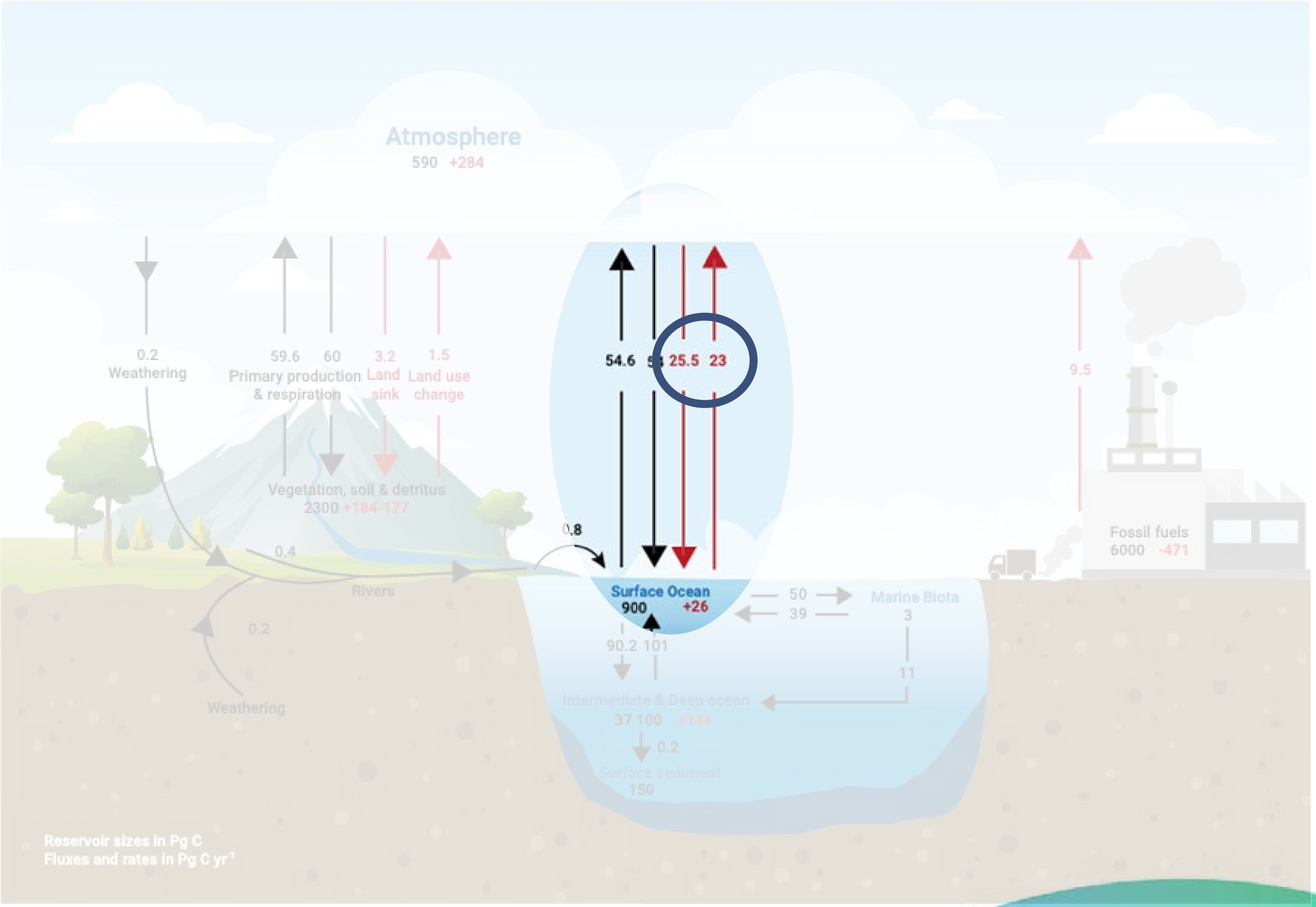

The natural carbon cycle is driven by biology, physics and chemistry

Anthropogenic CO_2 flux is an abiotic (physical-chemical) response to rising atmospheric CO_2

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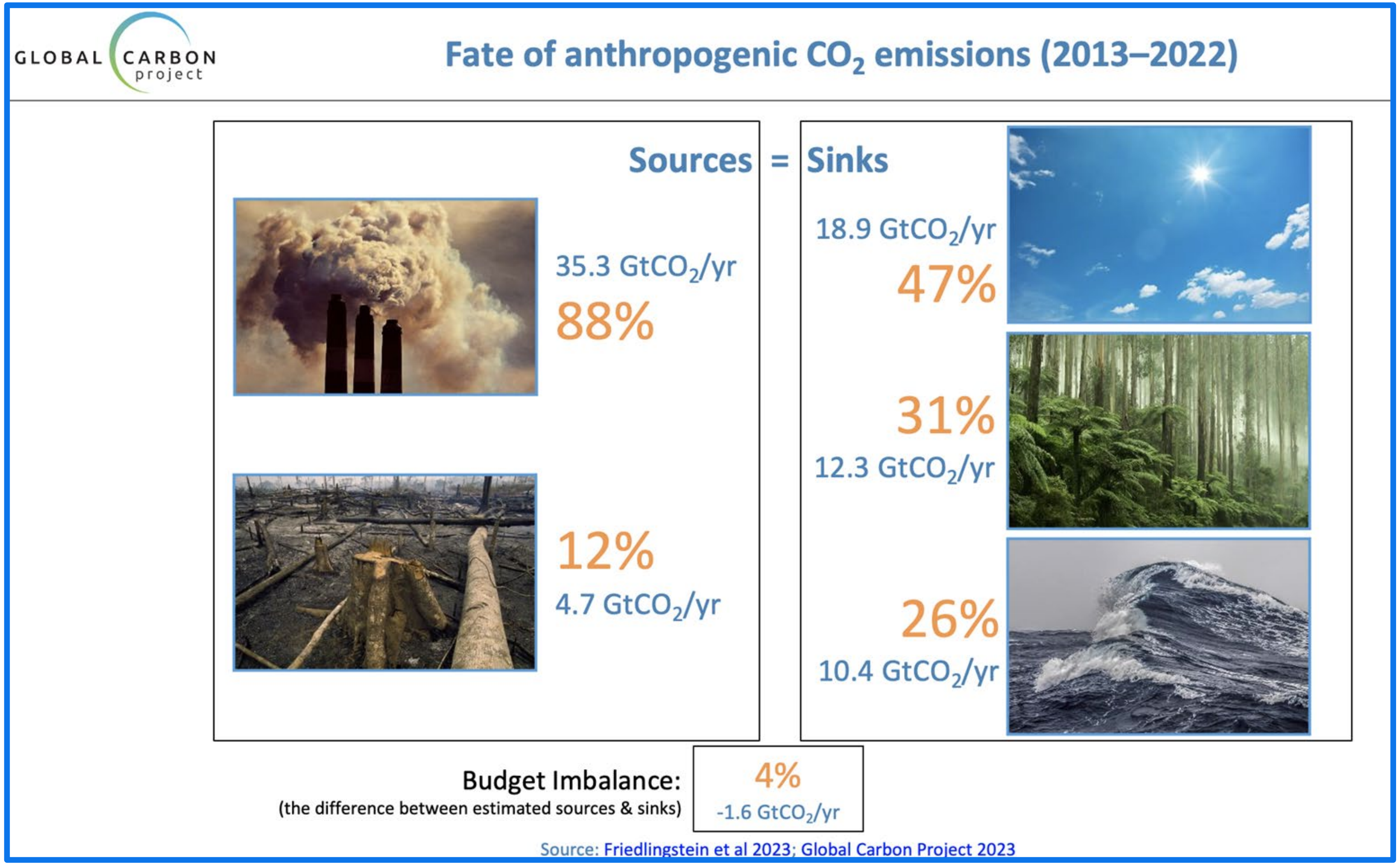
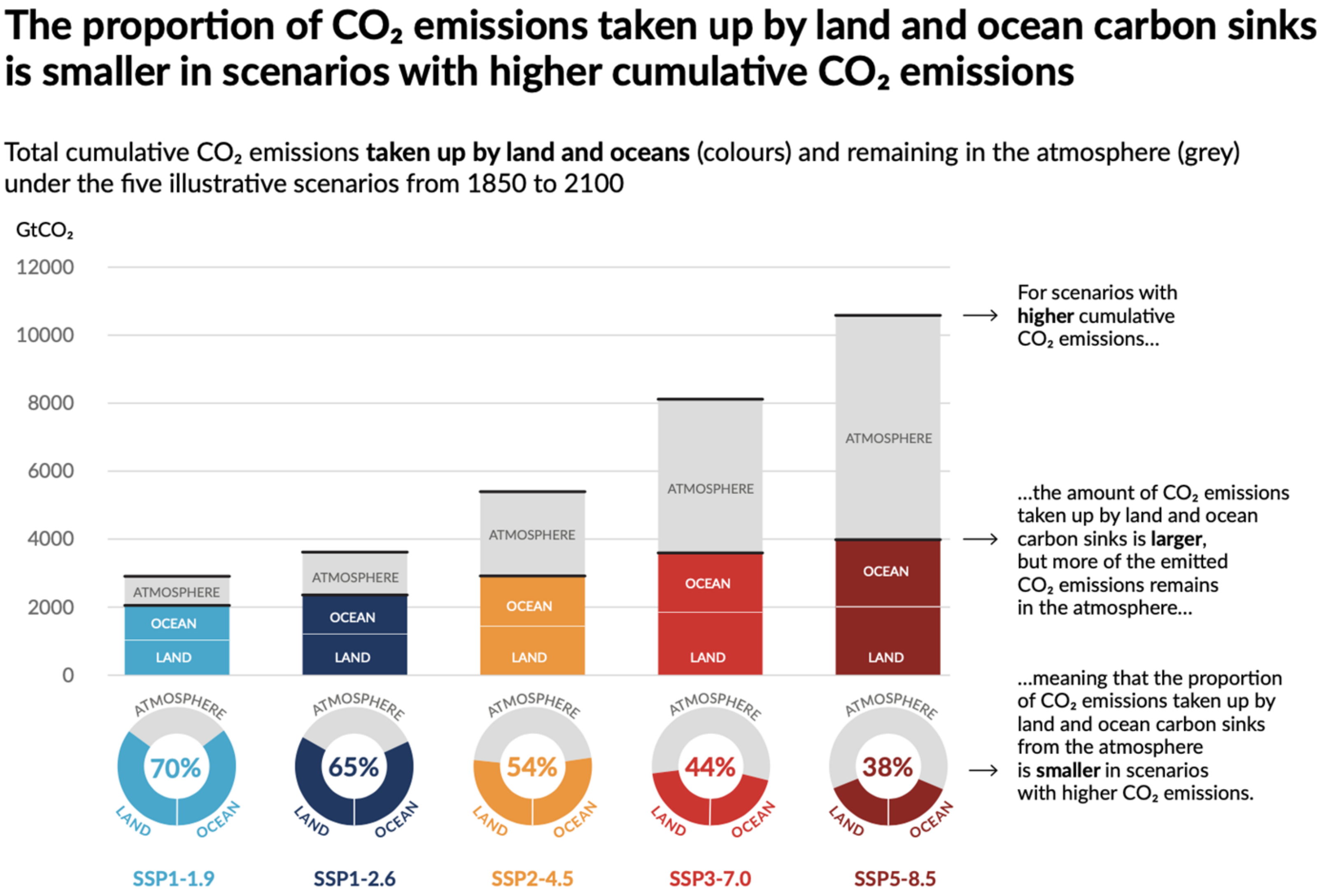


This is abiotic CO_2 uptake

2. Will the abiotic uptake of anthropogenic CO_2 continue?



Abiotic CO_2 uptake will continue as long as atmospheric CO_2 continues to rise.

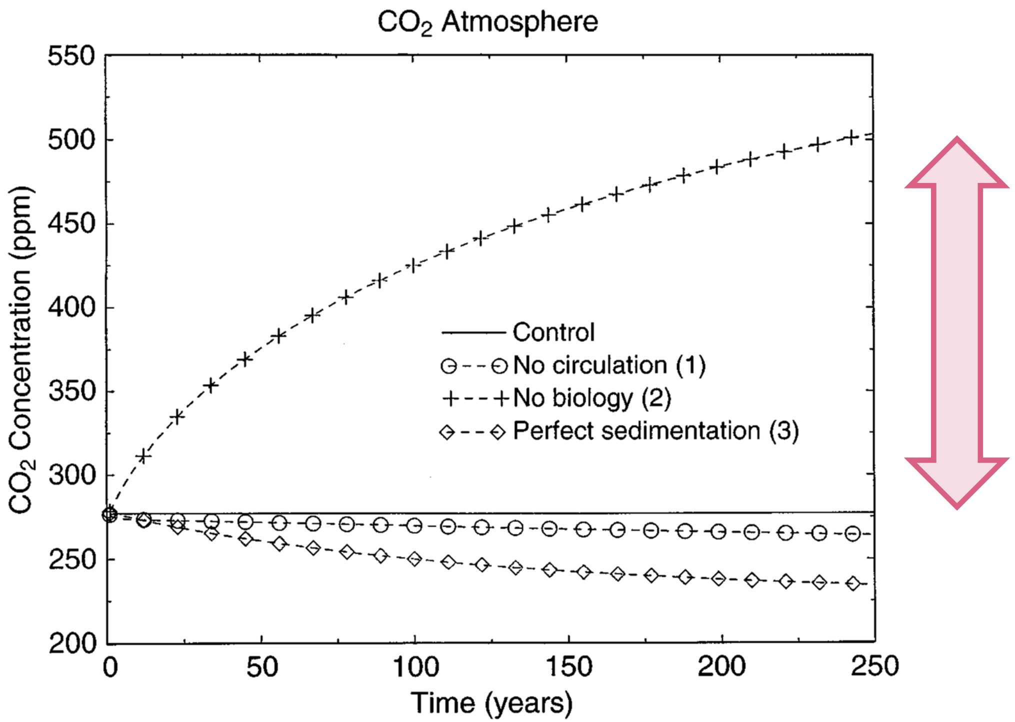
The total amount of CO_2 taken up is larger in high-emission scenarios.

But a larger share of CO_2 emissions remains in the atmosphere in high-emission scenarios.

IPCC AR6

3. What is the role of biology for ~~present-day~~ ocean CO_2 uptake?

pre-industrial



Reduces **'background' atmospheric CO_2** by ~200 ppm

Probably an **overestimate by a factor of 2** as it neglects the feedback by the land (new data coming!)

Maier-Reimer et al., 1996; Oschlies, 2009

4. Will the role of biology for ocean CO_2 uptake change in the future?

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Possible (we know from paleo-evidence that this has happened in the past)

Possible mechanisms:

1. Changing chemical state (carbonate chemistry, reduced buffer factor)
2. Changing physical state (stratification)
3. Changing biological fluxes (e.g., Henson et al., 2022, Nat. Geosciences)

Crisp et al., 2022, Reviews of Geophysics
Galbraith & Skinner, 2020, Annual Review of Marine Science

4. Will the role of biology for ocean CO_2 uptake change in the future?

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1. Changing chemical state (carbonate chemistry, reduced buffer factor)

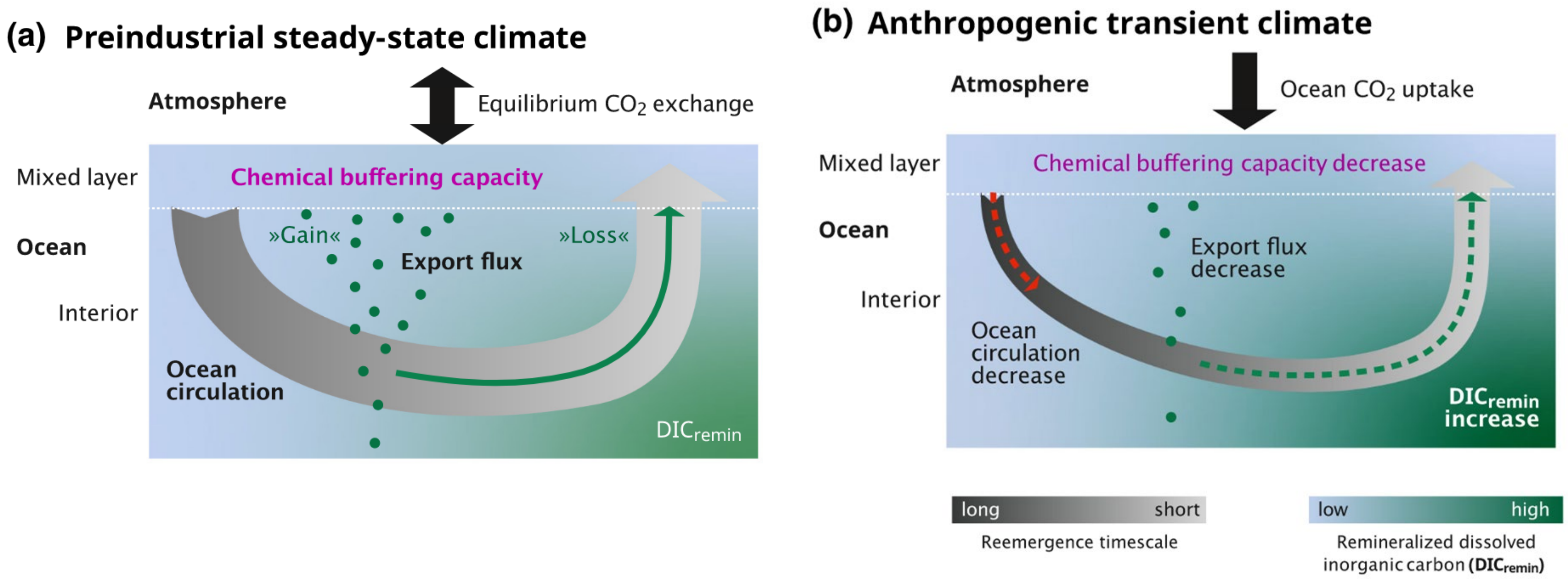
  - same **biological processes** lead to different **air-sea CO_2 flux**

- principles understood, hard to quantify, but likely secondary (<10%)

Hauck & Völker, 2015, GRL;
Fassbender et al., 2022,
Global Biogeochemical Cycles

4. Will the role of biology for ocean CO_2 uptake change in the future?

2. Changing physical state (stratification)



Frenger et al., 2023, Global Change Biology; Wilson et al., 2022, PNAS

Unpacking the Question

1. Is the ocean uptake of anthropogenic CO_2 largely an abiotic process? **Yes!**
2. Will the abiotic uptake of anthropogenic CO_2 continue? **Yes (as long as our emissions increase atmospheric CO_2)**
3. What is the role of biology for present-day ocean CO_2 uptake? **Without biology, atmospheric CO_2 would be ~100 ppm higher**
4. Will the role of biology for ocean CO_2 uptake change in the future? **Maybe. But human CO_2 emissions will remain the most important driver.**

Does biology (help) control the oceanic sink of carbon and could this change?

Jamie Shutler, University of Exeter, UK

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Importance of the ocean – over millions of years

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The three (natural) grand carbon stabilizers

Three grand stabilising feedback systems in the global biosphere.

All work on different time scales:

1. Atmospheric CO_2 thermostat.
2. Oxygen Homeostat
3. Oceans Calcium carbonate ($CaCO_3$) pH-stat.

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Weathering of igneous rocks, no biological influence, over hundreds of thousands of years

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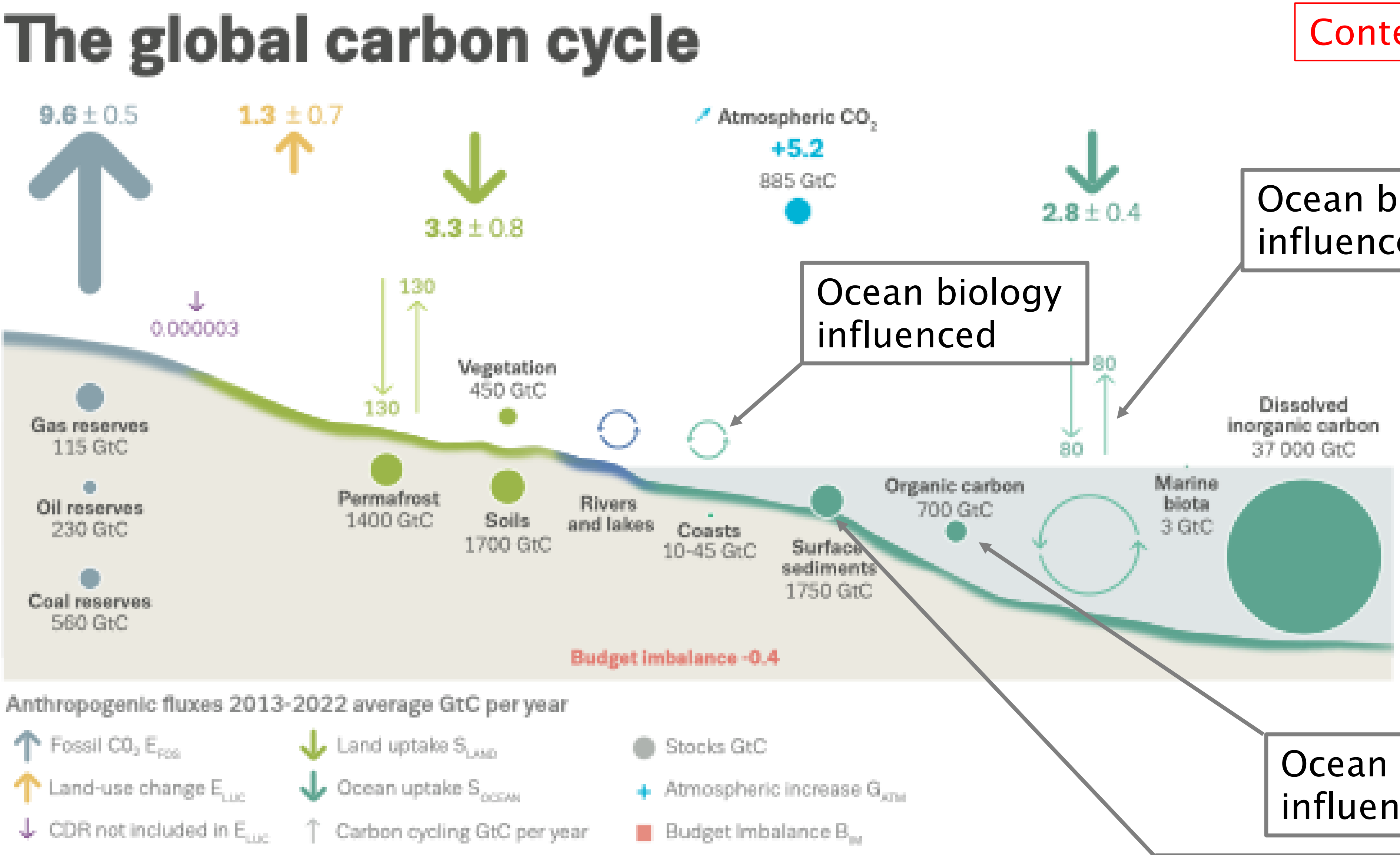
Weathering of igneous rocks, no biological influence, over hundreds of thousands of years

Photosynthesis in oceans, carbon is locked way as carbonate sediments, coal and other organic matter (timescale of 2 million years)

pH of ocean controlled by the cycling of $CaCO_3$ between sedimentary rocks and the ocean (eg limestone is $CaCO_3$ and was made by ocean plants).

As the ocean balances the $CaCO_3$ it controls its pH and the ocean's ability to sequester carbon (adjustment of pH occurs over a few thousand years)

Contemporary carbon cycle



Ocean biology influenced

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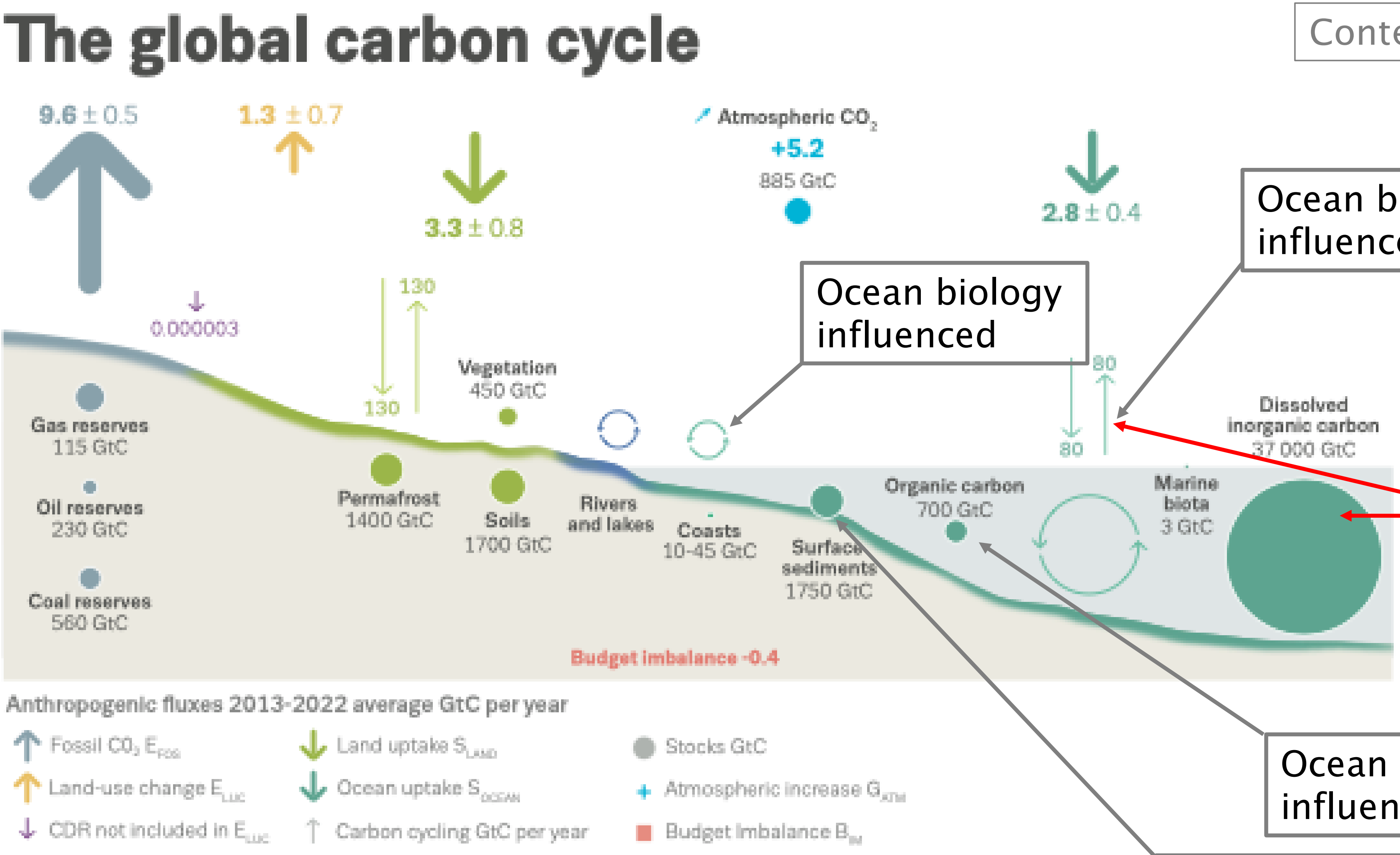
Friedlingstein *et al.*, (2023) The Global Carbon Budget 2023, *ESSD*

Contemporary carbon cycle



Ocean biology influenced

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How is biology enabling or supporting this ocean exchange and storage?

Ocean biology influenced

Ocean biology influenced

Friedlingstein *et al.*, (2023) The Global Carbon Budget 2023, *ESSD*

Importance of the biology – alkalinity

Article | Open access | Published: 24 February 2024

Machine learning reveals regime shifts in future ocean carbon dioxide fluxes inter-annual variability

Damien Couespel, Jerry Tjiputra, Klaus Johannsen, Pradeebane Vaittinada Ayar & Bjørnar Jensen

Communications Earth & Environment **5**, Article number: 99 (2024) | Cite this article

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776 Accesses | 14 Altmetric | Metrics

- Surface concentration of dissolved inorganic carbon and alkalinity are critical drivers for determining ESM current and future estimates of the ocean sink.
- Alkalinity expected to become increasingly important with time (but is often poorly captured in ESMs).
- Biology modulates alkalinity and is changing e.g. coccolithophores are moving poleward.

Importance of the biology – the Southern Ocean (SO)

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RESEARCH ARTICLE | EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES |

Biogenic carbon pool production maintains the Southern Ocean carbon sink

Yibin Huang, Andrea J. Fassbender, and Seth M. Bushinsky Authors Info & Affiliations

Edited by Donald Canfield, Syddansk Universitet, Odense M, Denmark; received November 4, 2022; accepted March 29, 2023

April 26, 2023 | 120 (18) e2217909120 | https://doi.org/10.1073/pnas.2217909120

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Relative to an abiotic SO, organic carbon production enhances CO_2 uptake (to a lesser extent, inorganic biological production diminishes uptake).

Without organic carbon production, the SO would be a CO_2 source to the atmosphere (rather than providing 40% of the current oceanic sink).

Importance of the biology – Beyond the Southern Ocean

Biogeosciences, 19, 93–115, 2022
https://doi.org/10.5194/bg-19-93-2022

Biogeosciences Open Access EGU

Derivation of seawater pCO_2 from net community production identifies the South Atlantic Ocean as a CO_2 source

Daniel J. Ford[1,2], Gavin H. Tilstone[1], Jamie D. Shutler[2], and Vassilis Kitidis[1]

[1]Plymouth Marine Laboratory, Plymouth, UK
[2]College of Life and Environmental Sciences, University of Exeter, Penryn, UK

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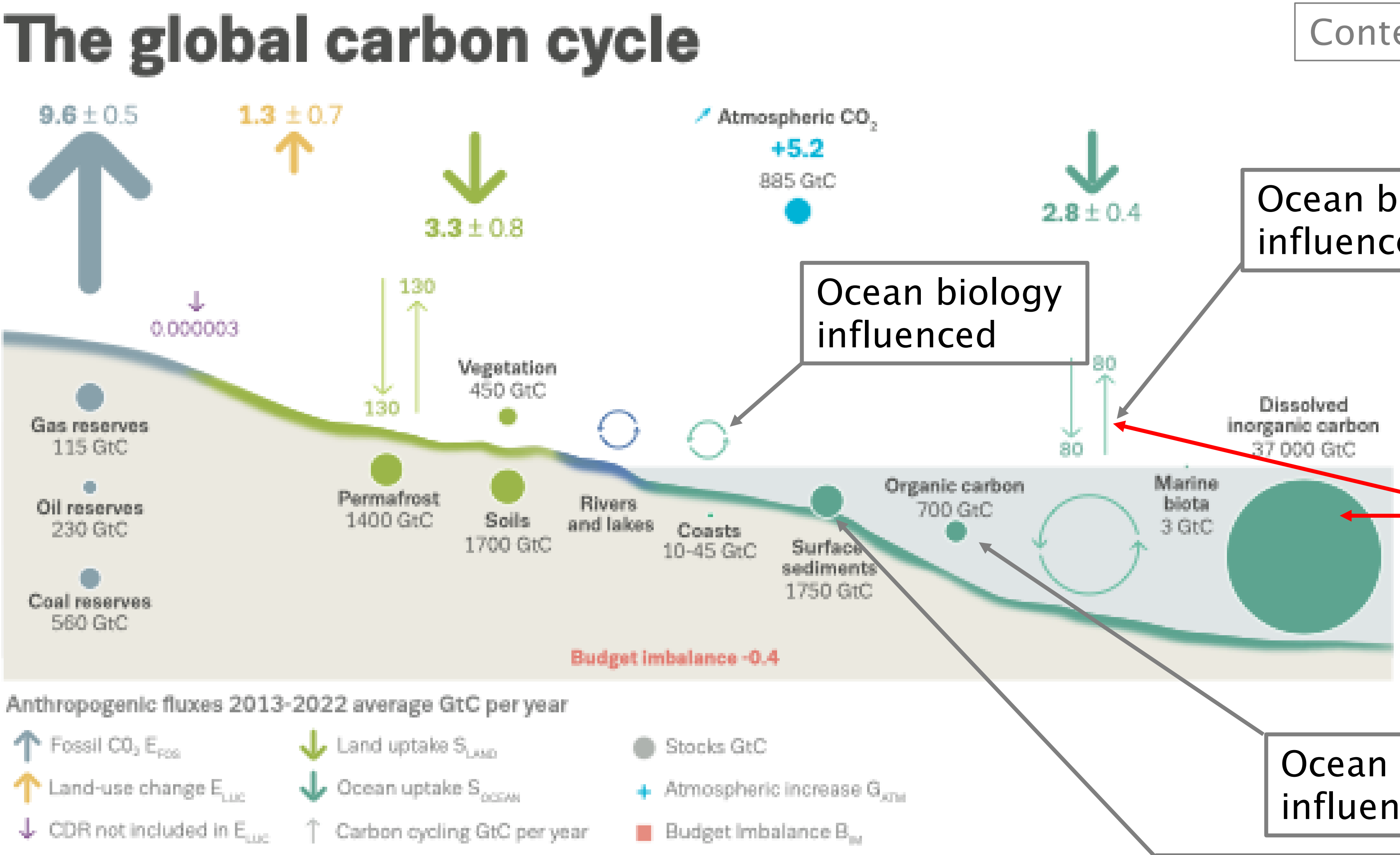
- We know that biological production alters the surface carbon uptake.
- Including this as a potential driver recreates the previously missing expected spatial structures and alters the direction of carbon flow.



Contemporary carbon cycle

Ocean biology influenced

Ocean biology influenced

How is biology enabling or supporting this ocean exchange and storage?

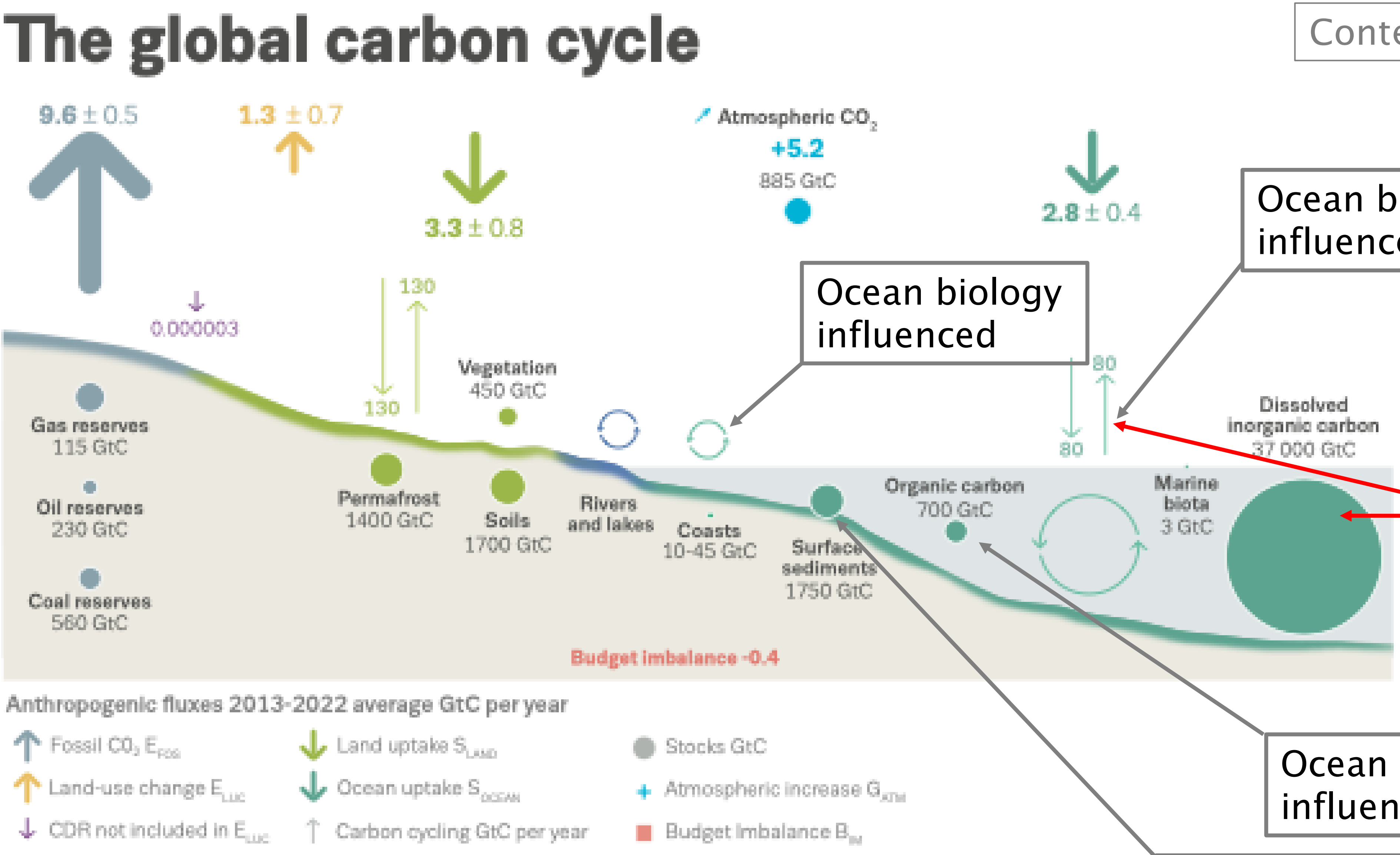
Ocean biology influenced

Ocean biology influenced

Examples:
Surface pCO_2
Alkalinity
Deposition

Friedlingstein *et al.*, (2023) The Global Carbon Budget 2023, *ESSD*

Contemporary carbon cycle



Ocean biology influenced

Ocean biology influenced

Does, or will, ocean biology enable continued uptake? (e.g., alkalinity, Southern Ocean biological organic and inorganic carbon).

Ocean biology influenced

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Friedlingstein *et al.*, (2023) The Global Carbon Budget 2023, *ESSD*

Conclusions

Biological processes have led to the conditions under which contemporary exchange occurs.

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Biology appears important for regional uptake e.g. the Southern Ocean.

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Along with atmospheric forcing, ocean chemistry, which can be altered and modulated by biology, will govern future uptake.

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Biology appears important for regional uptake e.g. the Southern Ocean.

Along with atmospheric forcing, ocean chemistry, which can be altered and modulated by biology, will govern future uptake.

It would seem difficult to ignore the potential role of biology for altering current and future ocean sink evolution.

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Or are you a citizen interested in climate change and its relationship with a sustainable blue future?

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Questions & Answers

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