JPI OCEANS

Joint Programming Initiative
Healthy and Productive
Seas and Oceans

Ocean Carbon Capacities:

Identifying priorities for collaborative action

Joachim Harms
Vice Chair JPI Oceans Management Board | Project Managmenet Jülich, DE

21-22 October 2021, virtually

State of the Art for a Joint Action on Ocean Carbon Capacitiy

- We know that the topic is
  - Important
  - Very timely and
  - Of high scientific and political relevance

CO_2 Uptake
ca. 8.9 $GtCO_2/yr$
about 22 %

- We need to improve our information products, observing systems and the knowledge base for decision-making

- The workshop will give the opportunity to exchange the actual knowledge among experts, inform about important initiatives in this field and define future needed actions

- What we from the JPI Oceans perspective are looking for are
  - Relevant, exciting, scientific questions,
  - Clear, achievable, and scalable plans/actions (e.g. building on existing investments)
  - Broad authorship/participation

Update on progress

- 12 JPI Oceans participating countries, many scientific experts involved
- 8 Action Areas are identified sofar
  - North Sea
  - MedSea
  - Baltic Outflow
  - Open North Atlantic
  - Modelling
  - Blue Carbon
  - Observing system design/ infrastructure sharing
  - Negative Emission Technologies
- Liaison with existing initiatives (like GOOS, IOCCP, G7 FSOI, GOA-ON, …)
- Action Plan under development and to be presented here

What next?

- To get **information about the ocean carbon sink in near real time across the ocean** there is a need **for clarification** how the systems operate and what will happen to key pH sensitive components of the system

- Inform the public

- Formulate **policy advice** (what is the system doing now and how might it react in future)

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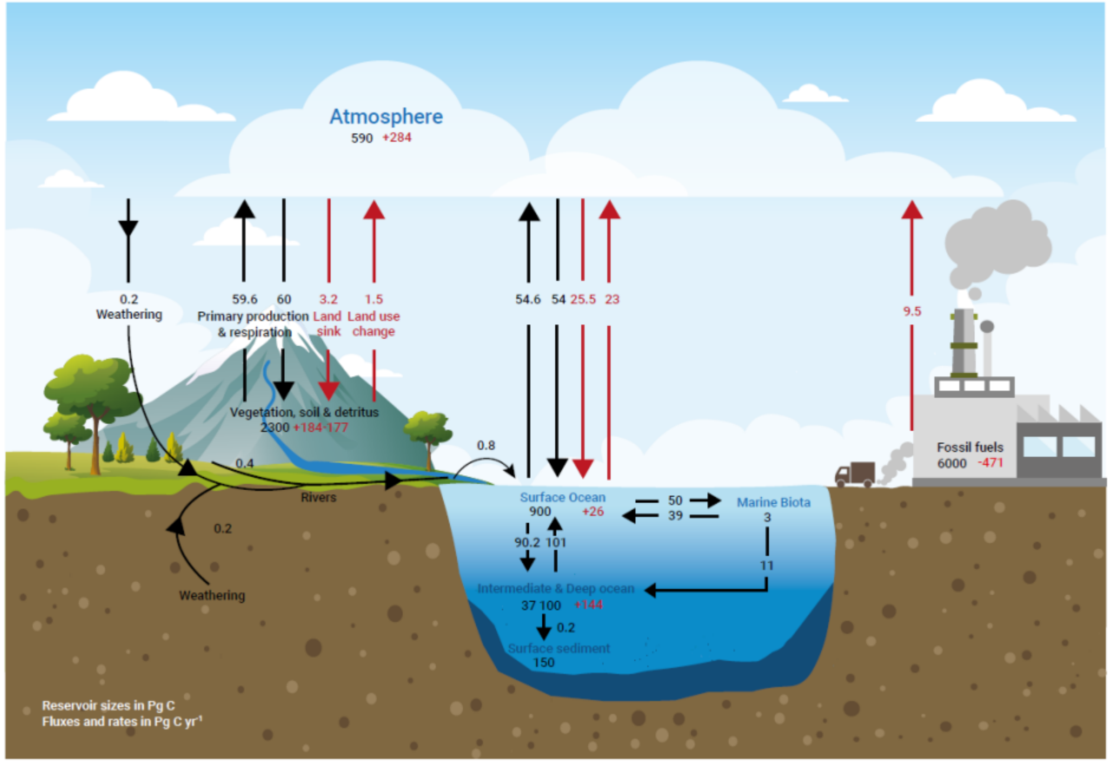
Introduction

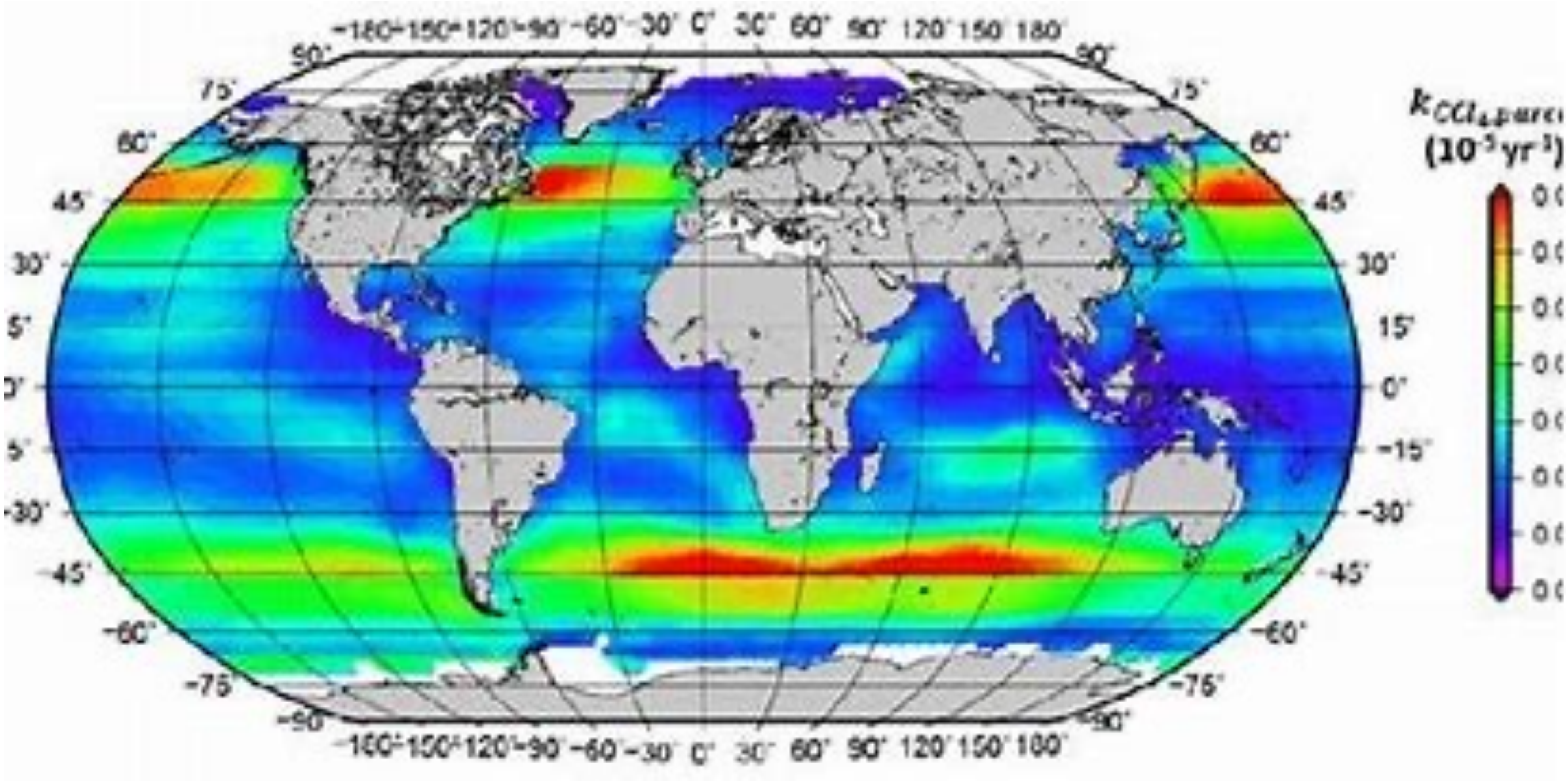
Richard Sanders, ICOS Ocean Thematic Centre

Net Uptake

- Has reversed natural role of ocean (in preindustrial times ocean was a sink)
- Drives Ocean Acidification
- Much smaller (ca 40 x) than the ‘natural C cycle’ of uptake and release, both around 100GT C/yr
- Small difference between two large numbers (uptake and release spatially and temporally decoupled)
  - Need lots of data to define it accurately
  - Still some uncertainty regarding the size of surface flux



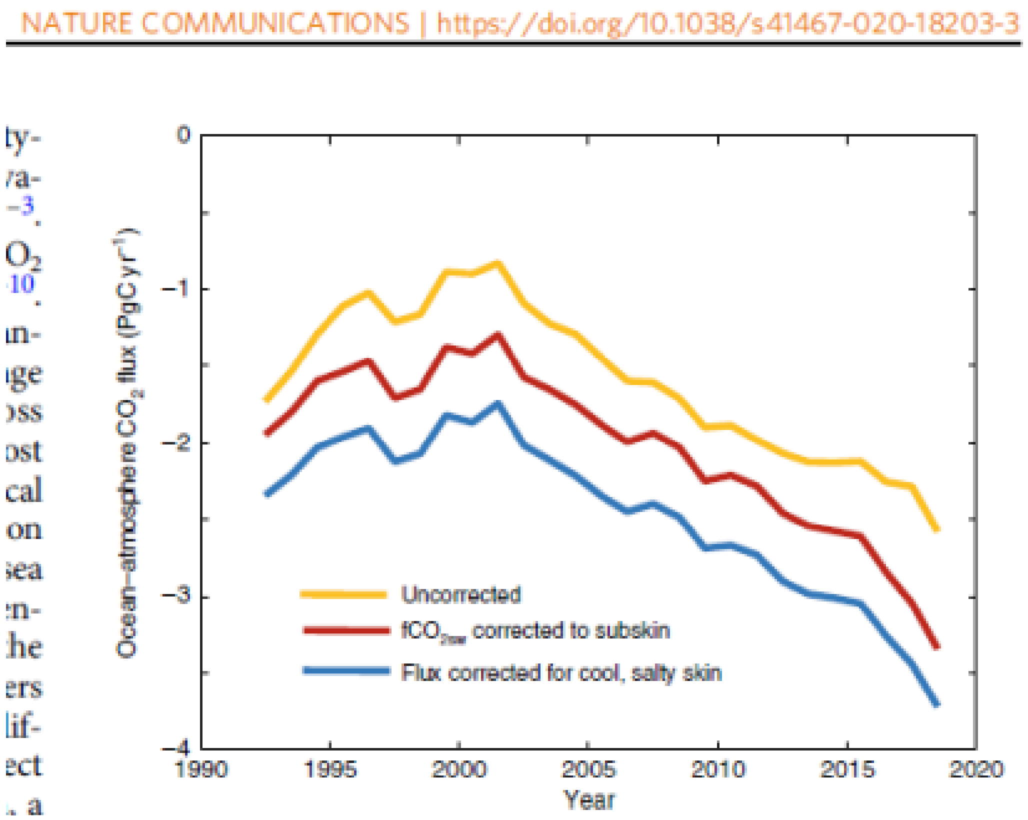
Spatial distribution of uptake



Some Uncertainty in sink strength – the skin effect

Near surface structure in surface ocean means that properties estimated at 5 m are not representative of surface

Calculation of flux accounting for this adds about 1GT C year uptake, occasionally doubling flux



Watson et al., 2021

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

Big Change coming: What happens when we reach net zero

- We do not know: the best estimates are highly variable
- Entire instrumental record acquired under period of rising CO_2
- At that point past performance becomes poor guide to future behaviour
- Performance at that time will govern post overshoot mitigation measures
- Crucial to have good observing system in place by then

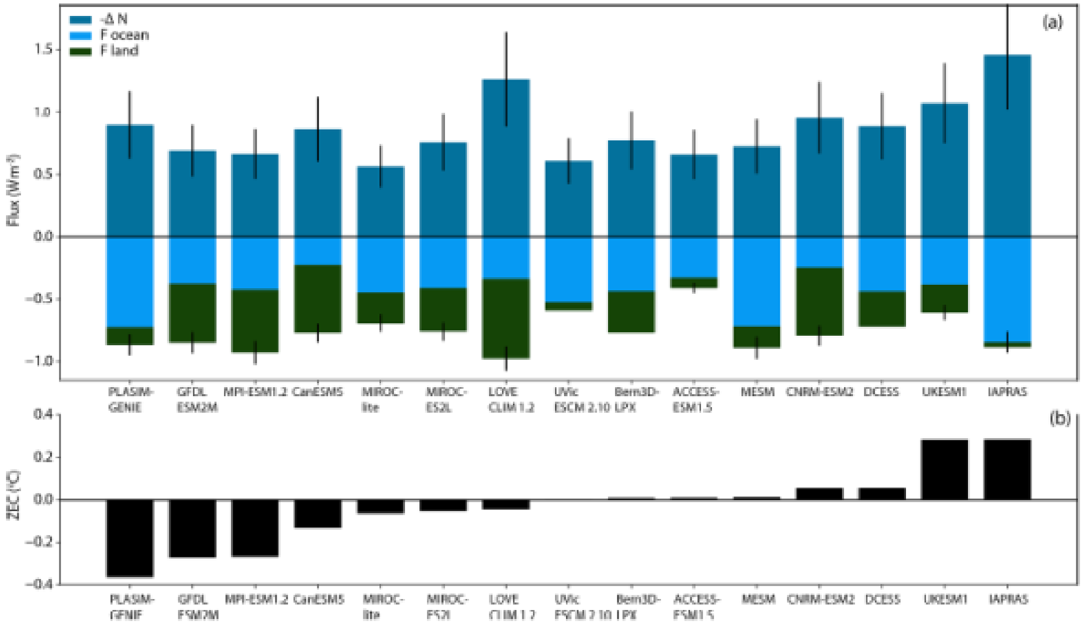


Figure 7. (a) Energy fluxes following cessation of CO_2 emissions for the 1000 PgC 1 % (A1) experiment. ΔN is the change in ocean heat uptake relative to the time that emissions ceased. A reduction in ocean heat uptake will cause climate warming, hence $-\Delta N$ is displayed. F_{ocean} is the change in radiative forcing caused by ocean carbon uptake, and F_{land} is the change in radiative forcing caused by terrestrial

Economic Value of Better Understanding and Observing

- The Ocean C sink is valuable; it defers and reduces mitigation and adaptation costs
- If it reduces these, costs will rise
- But what is the value of knowing more about it?
  - Allows quicker action in response to change
  - More precise adaptation measures
- Hard to quantify the economic value but some estimates available
  - Jin et al., (2020) suggest that the discounted net economic benefit of a putative 20-year scientific research program to narrow the range of uncertainty around the amount of carbon sequestered in the ocean is on the order of $0.5 trillion (USD)

In light of the above there is a strong shared view that Ocean Carbon Uptake is a priority research area

- Many initiatives and actors working in this field with slightly different foci (scale, mechanisms, impacts)
- State of Play before we move to our specific Action Areas
  - GOOS
  - G7 FSOI
  - IOCCP
  - IOCR-Report
  - Canadian initiative

- Action Areas developed within JPI Oceans expert teams focused on
  - What are the priorities?
  - Where is action needed?
  - What is the role of JPI?

Linking ocean carbon observation to effective climate targets

Anya M. Waite & Toste Tanhua
JPI Oceans

21 October 2021

The Global Ocean Observing System

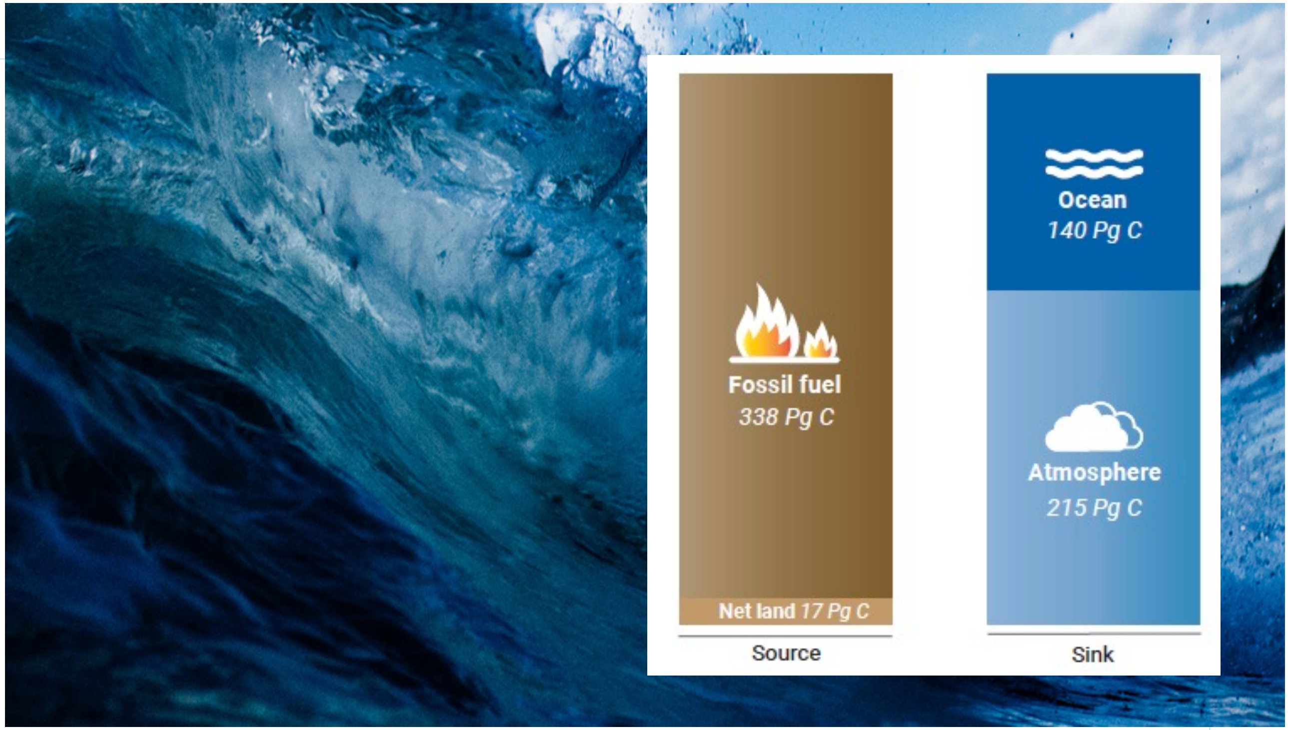
FRONTIER INSTITUTE

Linking ocean carbon observation to climate targets

Land-based emissions targets fail to recognize the ocean's carbon absorption:

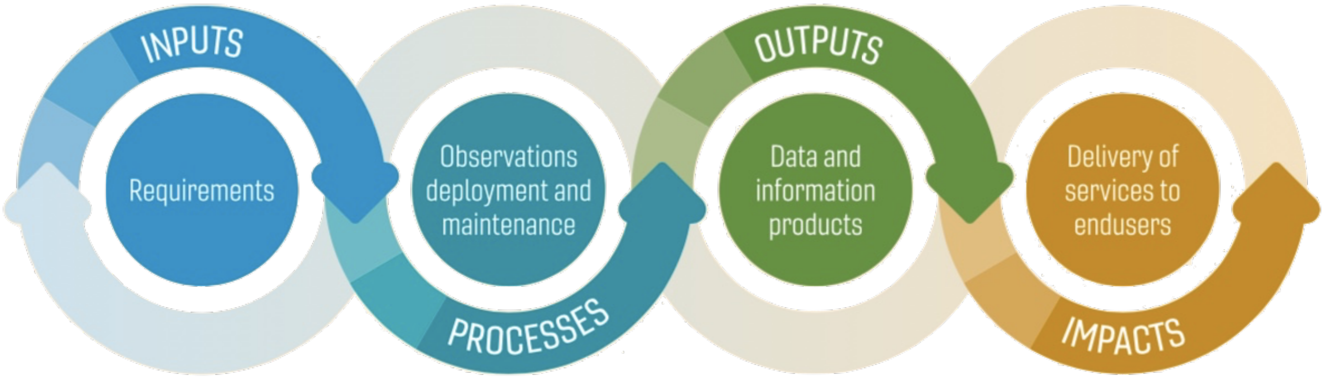
40% fossil fuel emissions ..

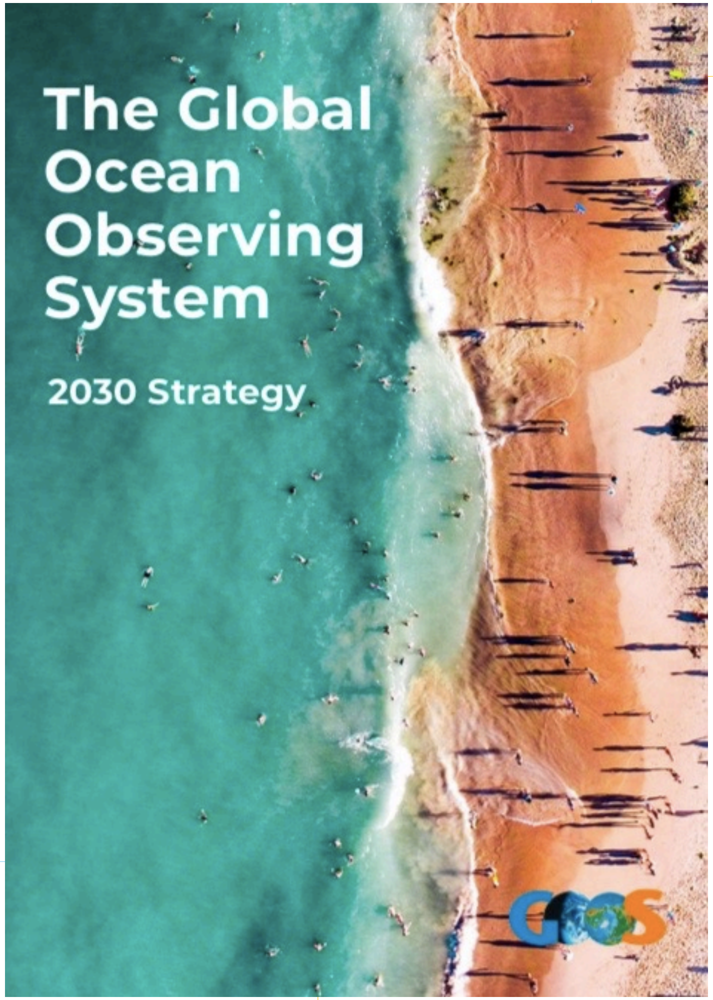
.. But will it continue?



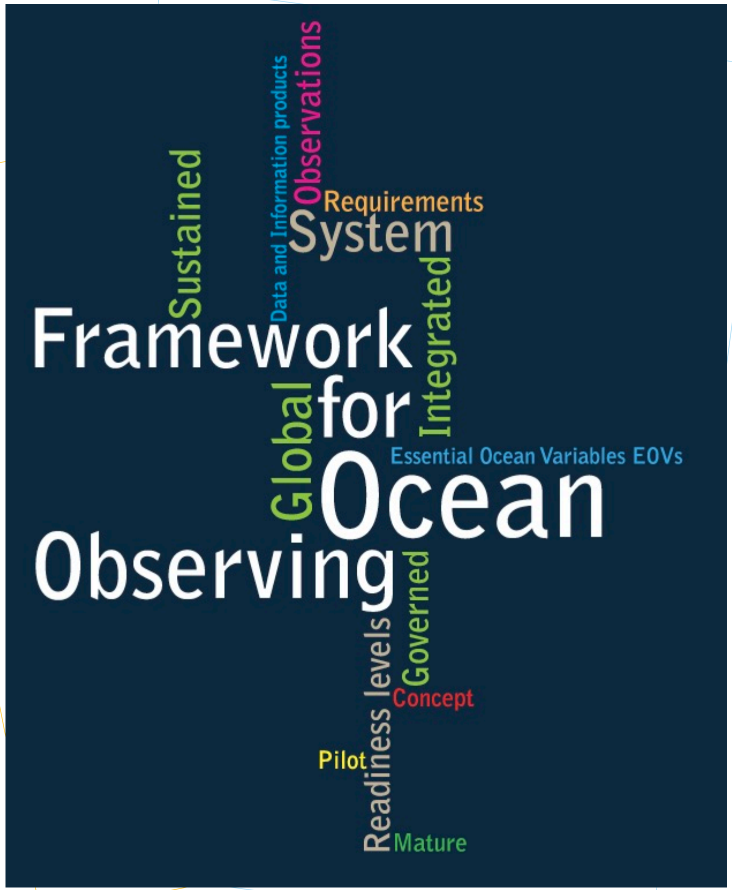
Linking ocean carbon observation to climate targets

The Global Ocean Observing System (GOOS) coordinates a long-term, sustained ocean observing system



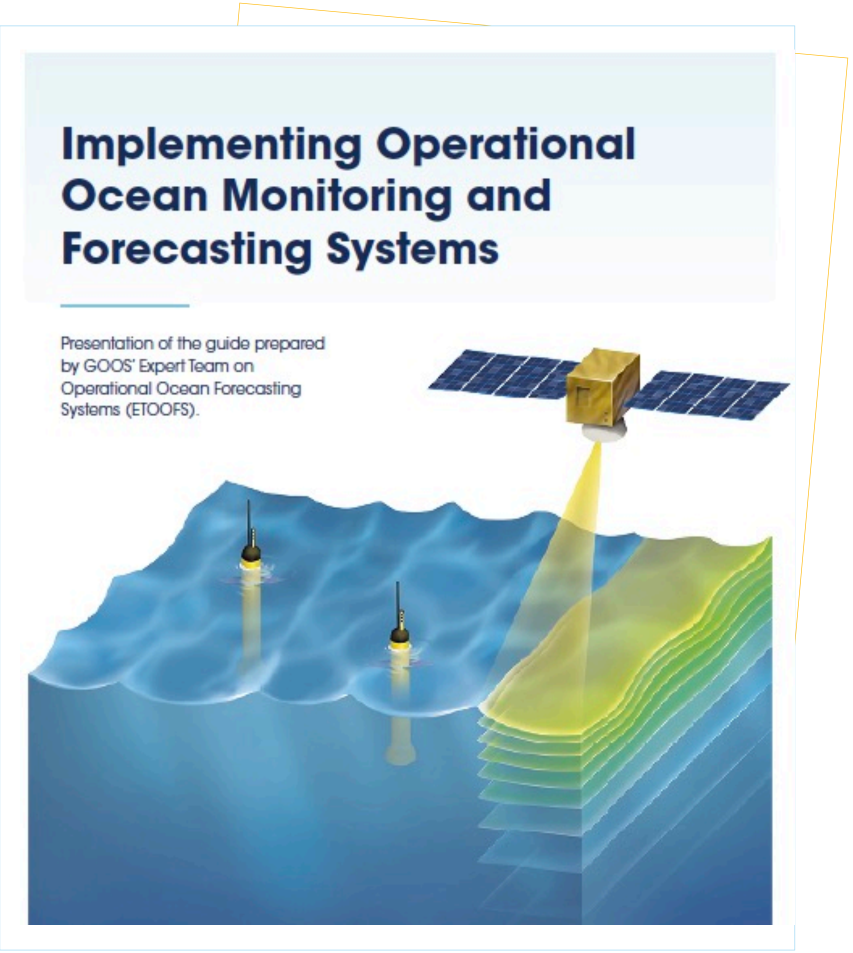


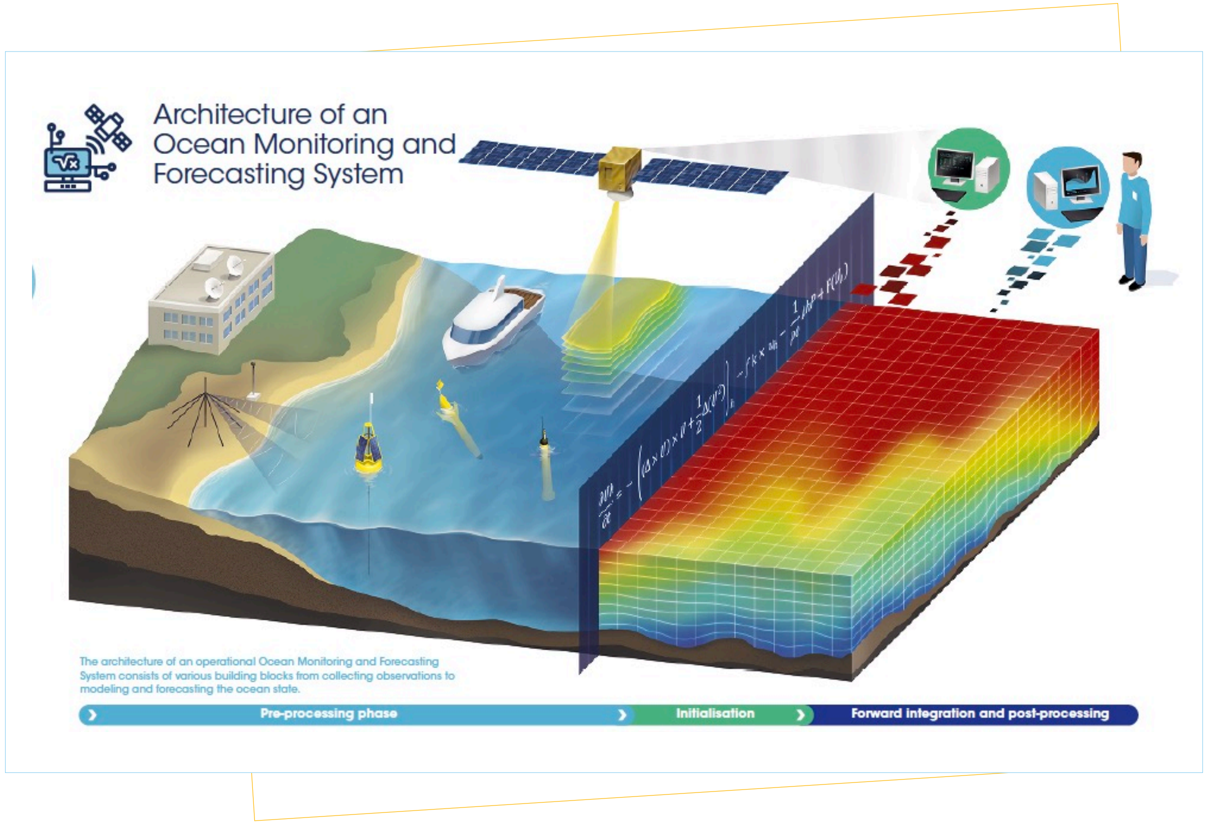
Linking ocean carbon observation to climate targets



The global community is mature and ready to act

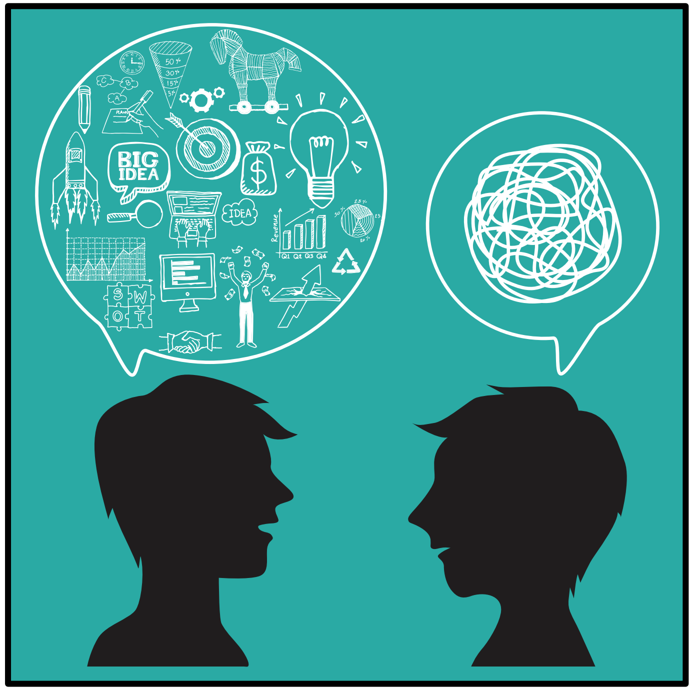
Linking ocean carbon observation to climate targets





Community is well prepared to
design sustained carbon observations

Linking ocean carbon observation to climate targets



Communicating the need for sustained carbon observations

.. to national governments and international policy makers

Policy Makers
Philanthropists
Governments
Foundations

THE OCEAN IS MISSING!

G7 Nature Compact
CoP26 Glasgow

Add the ocean to solve for net zero!

THE OCEAN IS MISSING!

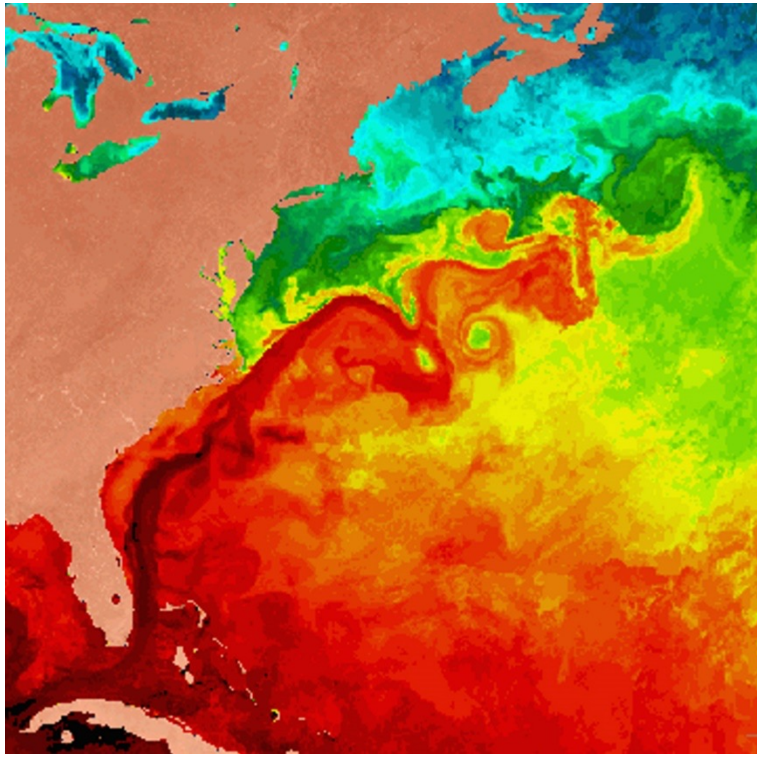
.. with North Atlantic as a global exemplar

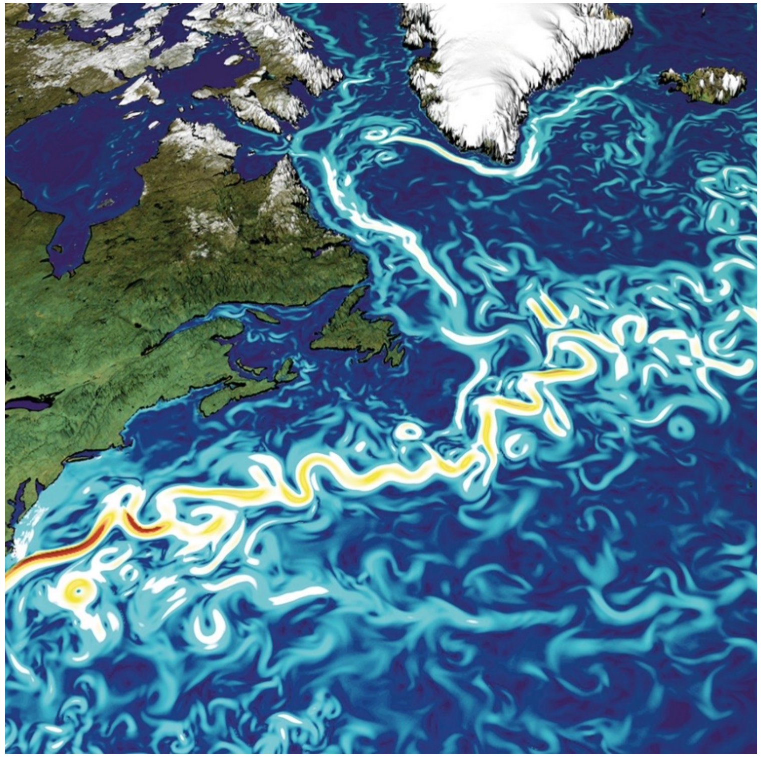

26

AN EXEMPLAR

North Atlantic Carbon Observatory

(NACO)





Linking ocean carbon observation to climate targets

Example:

Ocean innovation in CDR urgently needs an ocean baseline

Thank you. Questions or discussion?

Global Ocean Observing System

goosocean.org/join

Ocean Frontier Institute

OFI is a multidisciplinary, transnational hub for ocean research

Dr. Anya Waite

anya.waite@oceanfi.ca

The Global Ocean Observing System

FRONTIER INSTITUTE

Maria Hood

EU Office of the G7 Future of the Seas and Oceans Initiative Coordination Centre

The Surface Ocean CO_2 Monitoring Strategy is an activity that we are developing through the IOCCP (e.g., the GOOS biogeochemistry panel). For the IOCCP, this activity is being led by Richard Sanders giving us strong links to the JPI-Oceans carbon community.

This project is focusing on developing an internationally-agreed strategy and implementation plan for a surface CO_2 monitoring network. The idea for this came from discussions with several G7 national focal points who said they would like to fund surface CO_2 programmes but currently have no way of knowing if a particular proposal represents a contribution to the global network. The goal for this project is for us to establish this recognized global network to provide information to G7 governments (and others) that they need to make funding decisions.

The focus is on the 'how to' of the strategy for monitoring surface CO_2. It will not cover ocean interior carbon (but will be a complementary piece of the puzzle) and will not repeat the background science or justification sections of recent ocean carbon plans like the IOC-R.

This project in many ways represents 'low-hanging fruit' because many of the elements already exist. The strategy will build on existing observing requirements for surface CO_2 already developed through GOOS and GCOS, and updated for some aspects through SOCONET and OASIS. It will focus on how to develop an integrated multi-platform strategy that combines optimal use of networks and platforms including underway systems and moorings as well as making best use of BGC Argo, GO-SHIP, and combining the in situ data with satellite data and modelling capability.

And the strategy will build on existing foundations to establish the network and the International Mission Team (following the model used by the BGC Argo community)

- We already have the IOCCP to link to GOOS, GCOS, the GCP, and the wider ocean CO_2 observing community,
- we have SOCONET focused on reference networks for air-sea fluxes of CO_2 from multiple platforms (along with OASIS), and
- we have SOCAT as a long-standing pseudo-operational data centre.

What is missing is pulling all of these elements together into an implementation plan and establishing an International Mission Team to oversee it.

The end-game of this exercise at the end of 2 years is to have:

- an international mission team for the surface CO_2 network,
- a full-time coordinator as part of the OceanOPS Centre (located at IOCCP), and
- funding to support and operationalize the data centre / SOCAT management (staff + operating costs).

The next step of this activity is to develop an initial drafting team for the strategy and implementation plan (lead for IOCCP is Richard Sanders), and we will have a 1st planning meeting for this at the IOCCP SSG meeting at the end of November. In the 1st half of 2022, we will host an international workshop to get full community input into this process. We look forward to working with the JPI-Oceans community on this.

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Perspectives from IOCCP

Richard Sanders, ICOS Ocean Thematic Centre

What is IOCCP

- Promotes the development of scientific programmes and a global network of ocean carbon observations.
- Co-sponsored by the Intergovernmental Oceanographic Commission (IOC) and the Scientific Committee on Oceanic Research (SCOR),
- Coordinates ocean carbon activities
  - Ocean acidification,
  - Repeat hydrography,
  - Underway pCO_2,
  - Synthesis activities and data products
  - Standards and methods, instruments and sensors
- Expert Panel for Biogeochemistry for GOOS.
- Leading 'Surface Ocean CO_2 Task team'

The Standards Crisis

- Most Deep Ocean CO_2 observations and coastal OA observations are referenced to standards coming out of one lab in the US
- Deep Ocean observations key for 5 years studies and Argo calibrations
- The lead Investigator is close to retirement
- JPI Oceans Support could be critical

The world's only source of critical seawater samples could dry up

Scientist's retirement threatens to close lab key to climate and ocean studies

29 SEP 2021 · 3:05 PM · BY CAROLINE CATHERMAN

Carefully characterized seawater samples have been key to marine research. © 2009 SCRIPPS INSTITUTION OF OCEANOGRAPHY

SHARE:

Potential Solution

- Establish European Standard laboratory
- Europe already contains a laboratory making gas standards for atmospheric and oceanic observations
- A seawater chemistry laboratory would be a very natural complement

(https://www.icos-cal.eu/)

The Flask and Calibration Laboratory

Contact/Visit us ☛ (https://www.icos-cal.eu/fcl/contact)

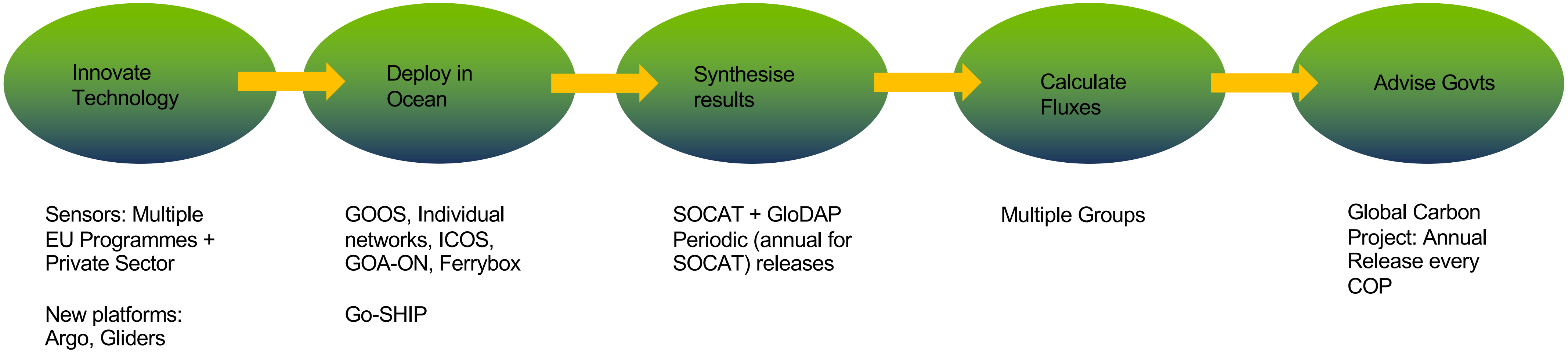
The Flask and Calibration Laboratory (FCL) is one of the Central Analytical Laboratories (https://www.icos-cal.eu/) of ICOS. It's hosted by the Max Planck Institute for Biogeochemistry (http://www.bgc-jena.mpg.de) in Jena.

Standard gases (https://www.icos-cal.eu/fcl/standard_gases)

- production of real air reference gases for ICOS stations
- initial conditioning of high pressure cylinders
- calibration of reference gases (CO_2, CH_4, N_2O, CO) relative to the established WMO scales (maintained by the Central Calibration Laboratory at NOAA-ESRL)
- provision of standard gases as temporary replacement sets for stations and for round robin intercomparisons

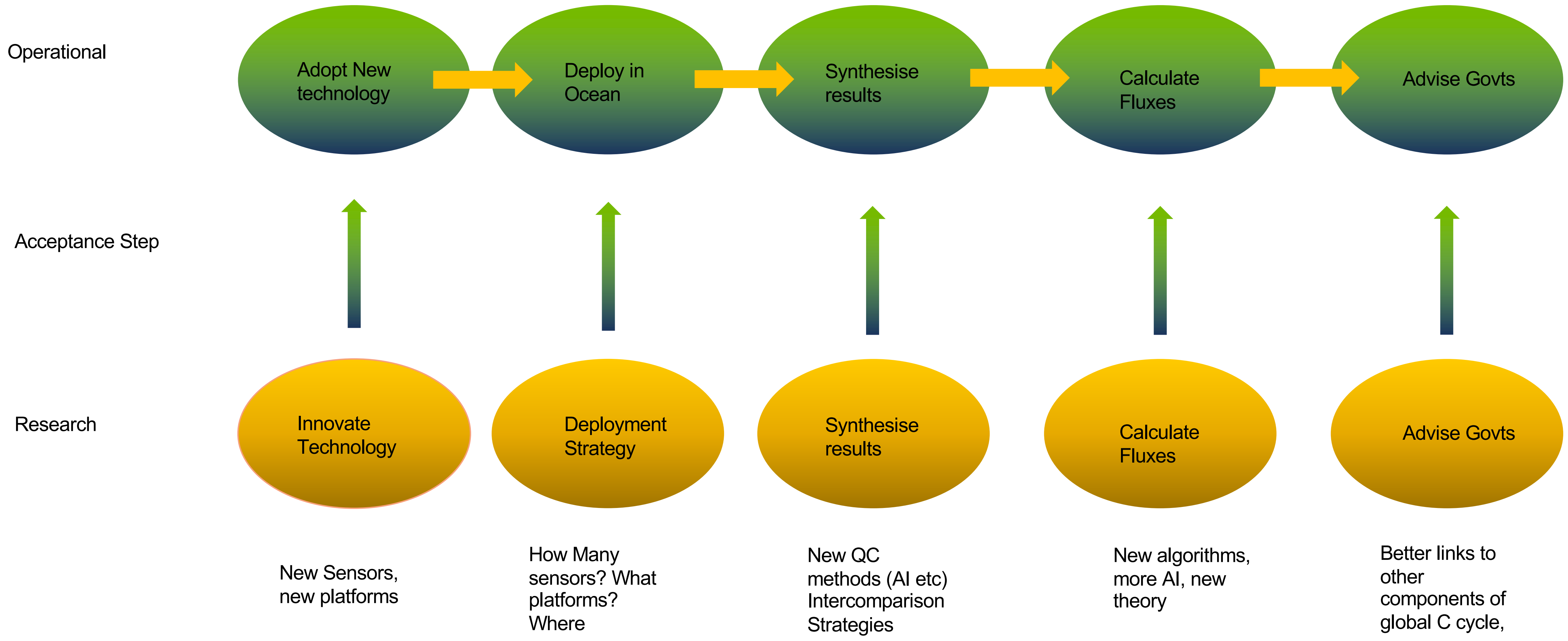
Surface Ocean CO_2 Task team

- Established Summer 2021
- Aim is to 'produce a surface pCO_2 monitoring strategy' that is internationally accepted so that individual countries can pick up key elements
- Concept of the 'Ocean Carbon Value Chain'



- Only as strong as its weakest link
- Currently some links frighteningly weak
- Many elements largely research funding based

Ambition for Value Chain?



Potential Actions

Link to JPI Oceans Action Area document on ‘Observing System Design/Infrastructure Sharing’

Small Scale

- Support JPI Oceans participation in G7 FSOI Surface Ocean CO_2 task team and task team activity more broadly
- Support meetings for exchange within networks of GOA-ON, ICOS and Ferrybox in Europe and links to Non-European networks in Pacific, Arctic and Southern Ocean

Medium Scale

- Support Ocean CO_2 reference material laboratory
- Stabilise value chain as it exists now (prioritise missing observations, possibly via the regional studies proposed here, data synthesis, GCP)

Large Scale

- Support transitional costs to create operational system and research as required
  - E.g. via an international, co-branded Ocean Decade, G7 FSOI, GOOS activity/project

The Need for Integrated Ocean Carbon Research in the JPI Oceans Initiative:

Reducing uncertainties of climate-ocean interactions and the ocean's buffering capacity for CO_2

Rik Wanninkhof
US National Oceanic and Atmospheric Administration, Miami, USA

"The Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) was established in 2011 as an intergovernmental platform, open to all EU Member States and Associated Countries who **invest in marine and maritime research**. By joining forces, JPI Oceans focuses on long-term collaboration between EU Member States, Associated Countries and international partners. "

Integrated Ocean Carbon Research

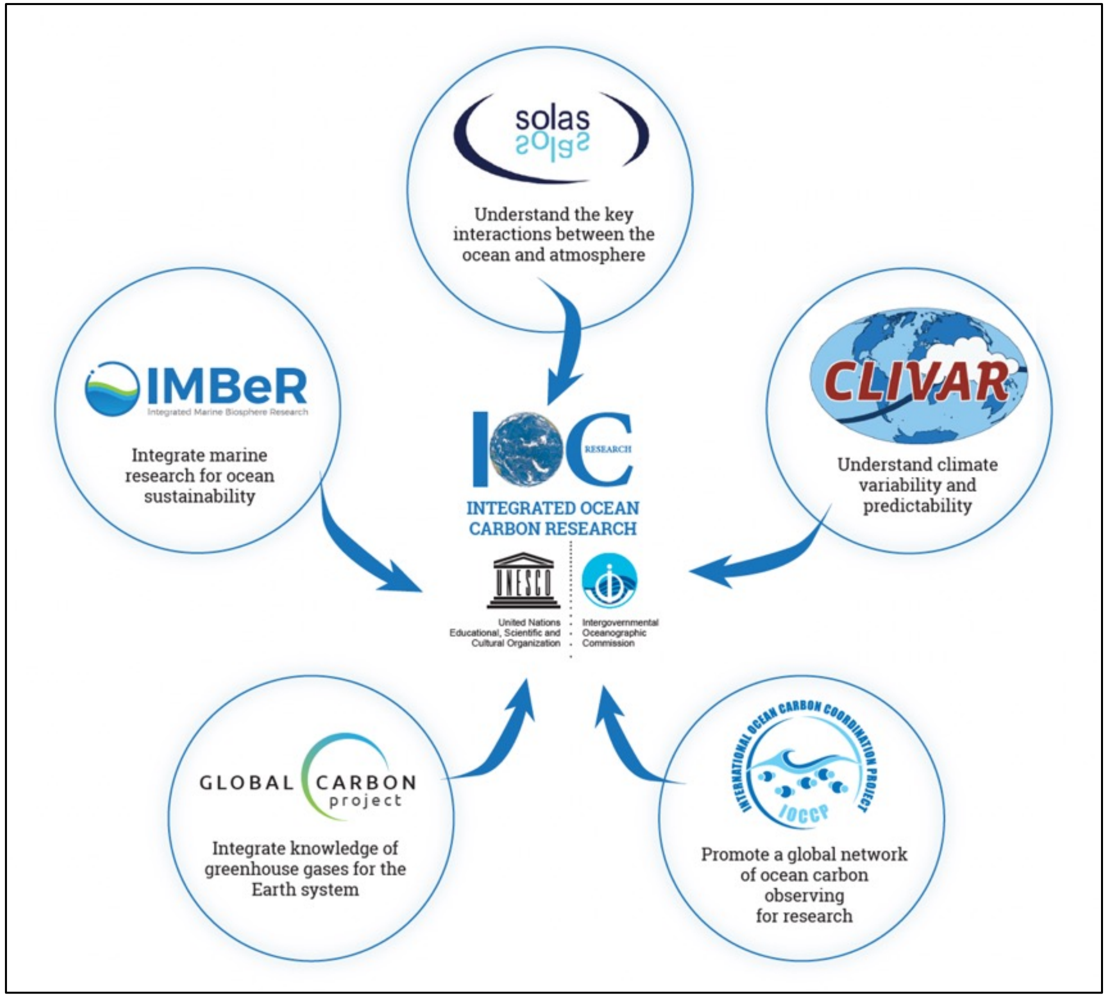
A Summary of Ocean Carbon Knowledge and a Vision for Coordinated Ocean Carbon Research and Observations for the Next Decade

- An effort by international science programs and [ocean] carbon scientists focusing on ocean carbon research needed in the next decade

- Led by the Intergovernmental Oceanographic Commission (IOC) to address climate and ocean health implications of the changing ocean carbon cycle in support of the United Nations Decade of Ocean Science for Sustainable Development

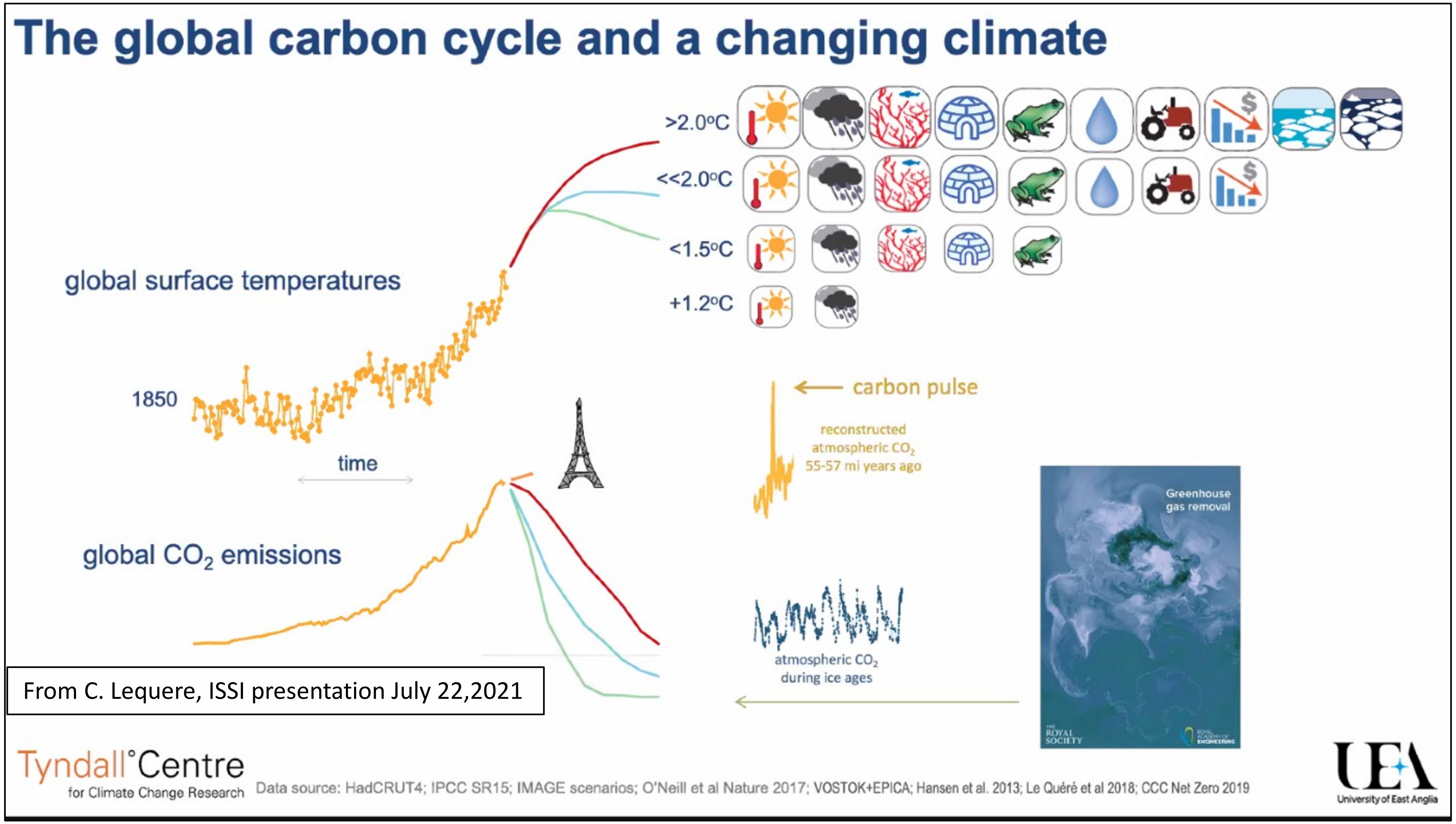
Organizational Justification and Need

- Various ocean carbon research endeavors are in different programs
- Synthesize the key questions being addressed by the partner organization
- Collaborate to facilitate implementation of ocean carbon research activities



Scientific Justification and Need

"Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future." Roger Revelle



From C. Lequere, ISSI presentation July 22,2021

In all scenarios we will be decreasing emissions faster in the future than we've increased them in the past

How will the ocean carbon cycle affect and be affected by this change in emissions?

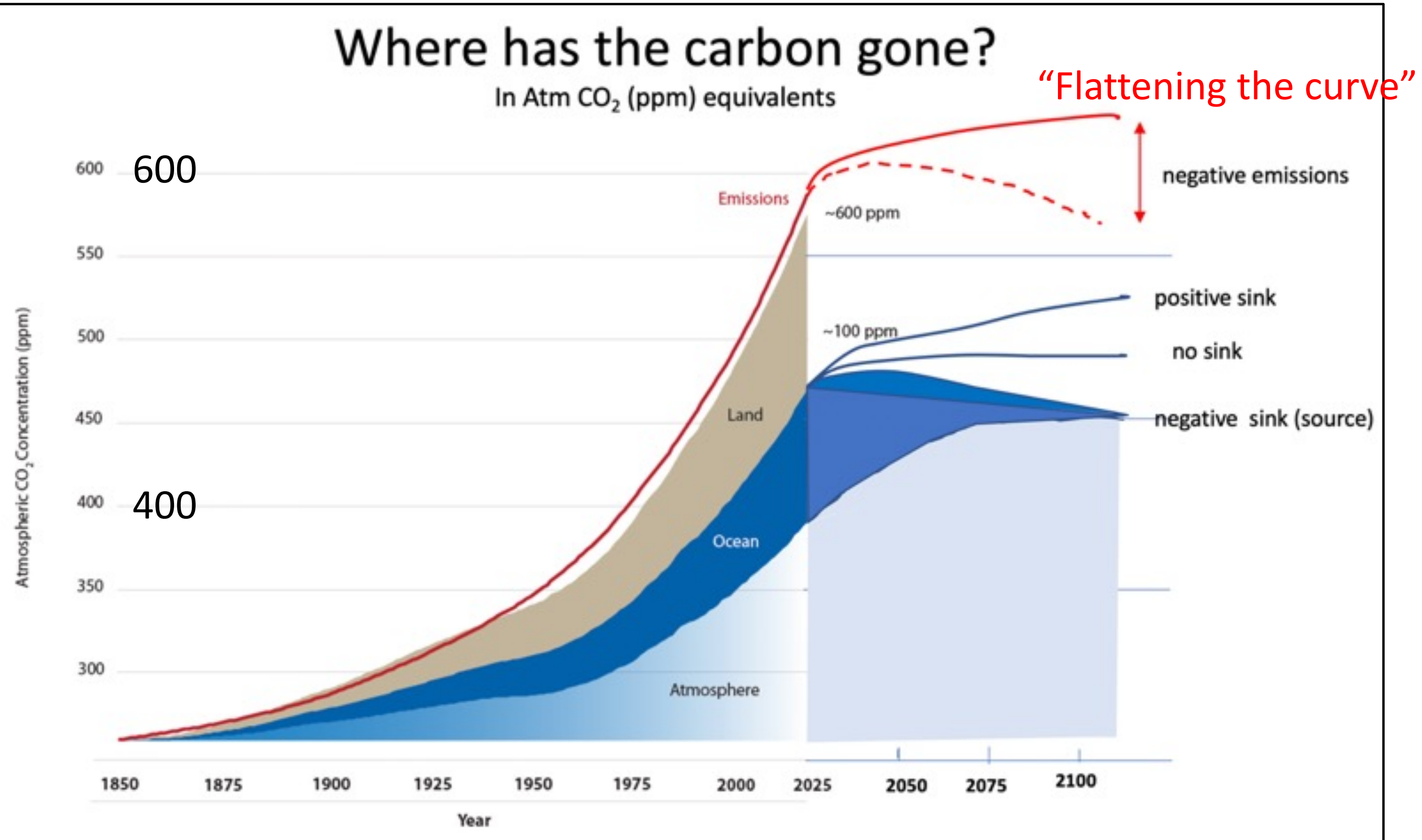


Figure 6. *Evolution of CO_2 emissions from fossil fuels and land-use change, in equivalent atmospheric CO_2 concentrations (top starred line), and their partitioning between the land, ocean, and atmosphere since 1850. Without the ocean and terrestrial sinks, the atmospheric trajectory would be the same as the emission trajectory. Hauck (pers. comm.) based on GCP data[6].*

Four overarching questions:

1. Will the ocean uptake of anthropogenic CO_2 continue as an abiotic process?

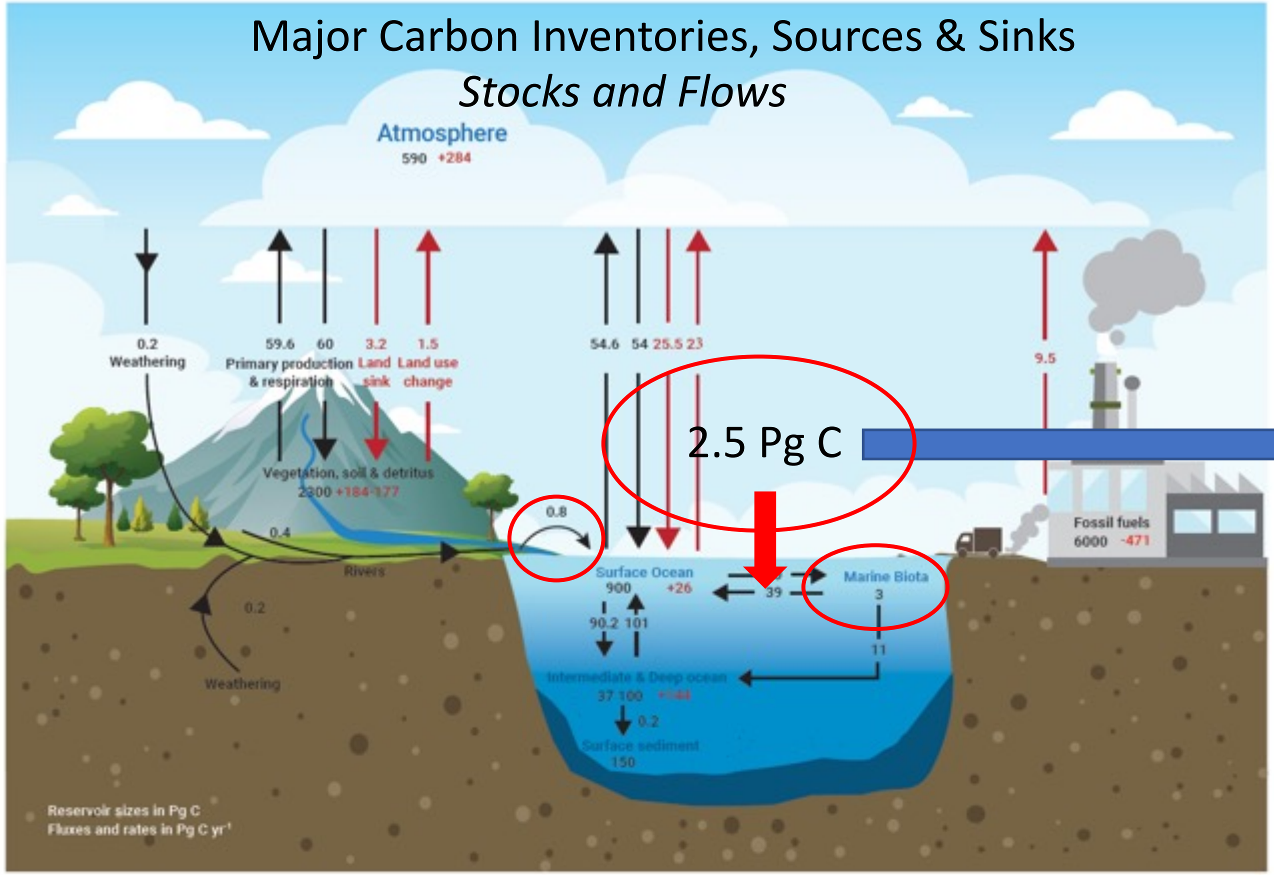
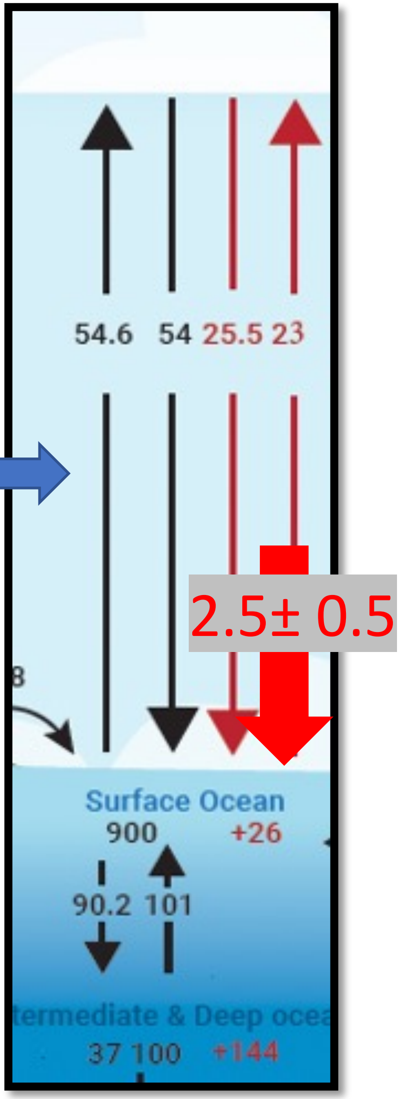


Figure 2 *Inventories of major carbon reservoirs and transport between the reservoirs of the global carbon cycle, estimated for the decade of 2010-2020. Black arrows and numbers indicate the natural carbon cycle and reservoirs, while red arrows and numbers indicate anthropogenic perturbations. The figure is adapted from Sarmiento and Gruber (2002)[3], with the permission of the American Institute of Physics, updated to the decade of 2009-2018 using values from Friedlingstein et al. (2019)[6]. Values outlined in light blue are updated values. Changes in natural fluxes between the ocean and atmosphere are based on a downward revision of the global gas average transfer velocity[7]. Uncertainties in values range from 10-50%.*



The ocean takes up 25 % of the anthropogenic CO_2; we would be ”lost without it” [or at least a bit warmer]

What we build on:
- Sustained ocean observations
- Modelling and Analysis
- New technology and platforms

What we need:
- Integrated Research incorporating modelling & analysis

Four overarching questions:

2. What is the role of biology in the ocean carbon cycle, and how is it changing?

- “The biological pump”-without it atmospheric CO_2 levels > 2 x greater
- Impacts of elevated CO_2 on marine biota: Ocean acidification

6 Pg C (Bar-on et al., 2018)

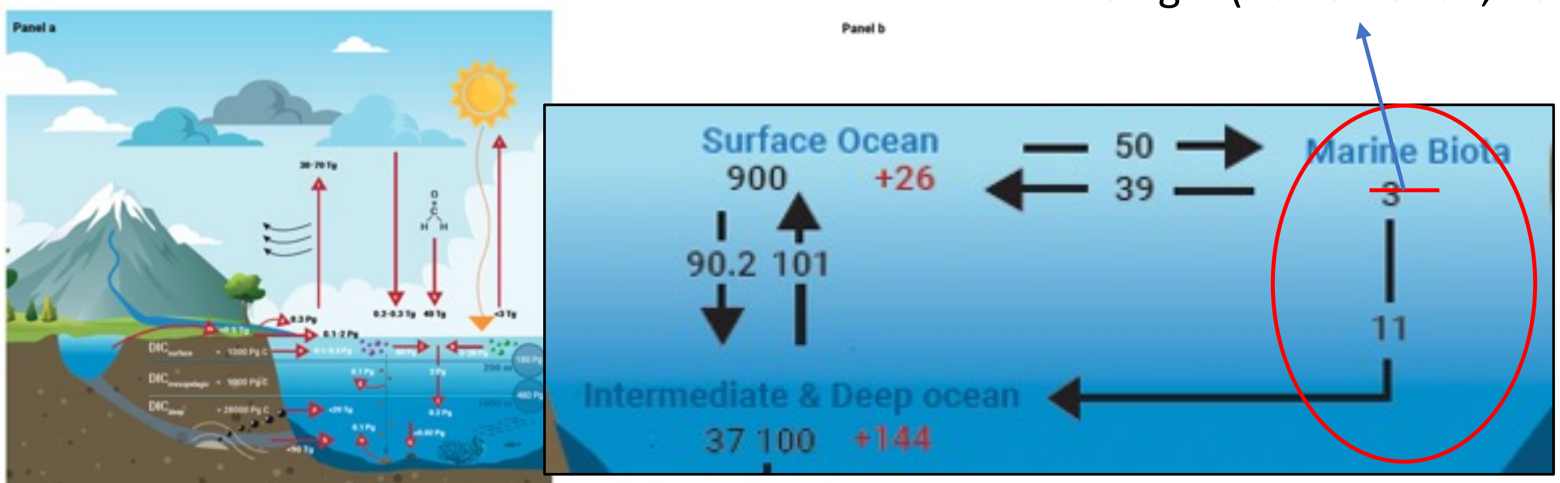


Figure 7. *Panel a depicts organic carbon fluxes and inventories in the ocean. Total dissolved inorganic carbon (DIC) is listed for the different reservoirs, as well as for a comparison of magnitudes. Note that values are provided in both Pg C and Tg C (1 Pg = 1000 Tg). Fluxes are per year. Panel b shows the estimated range of fluxes on a log scale, showing significant uncertainties in the size of organic stocks and fluxes. The organic carbon inventories and fluxes in the ocean are significantly less than the inorganic components, but their importance in the biological carbon cycle and the ocean's health, make these components of the ocean carbon cycle critical for active research (figure redrawn from Wagner et al., 2020[92]).*

What we build on:

-Incorporate biological sampling in observing schemes

What we need:

-Integrated research on living biota-organic carbon-inorganic carbon interactions

DOC: Total inventory ≈ 700; Surface ocean ≈30 Pg C

Four overarching questions:

3. What are the exchanges of carbon between the land-ocean-ice continuum and how are they evolving over time?

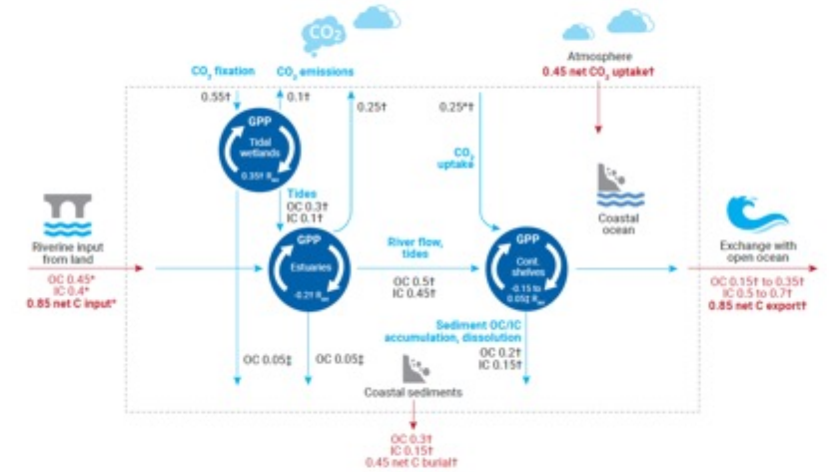
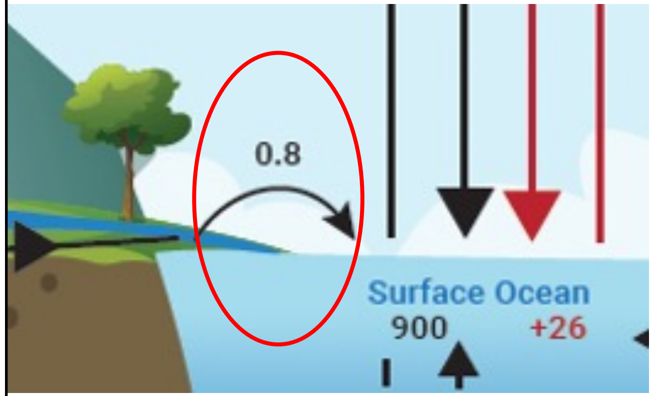


Figure 4. *Major transports and transformations of carbon in the land-ocean continuum in Pg C yr^{-1} rounded to ± 0.05 Pg C yr^{-1}. Values are from Bauer et al. (2013)[58] and differ from other investigations due to large uncertainties from undersampling and extrapolations. Typical uncertainties for carbon fluxes: * 95% certainty that the estimate is within 50% of the reported value; † 95% certainty that the estimate is within 100% of the reported value; ‡ uncertainty greater than 100%. OC is organic carbon, IC is inorganic carbon, GPP is gross primary production (GPP) and R_{AH} is total system respiration (A = autotrophic, H = heterotrophic). Figure adapted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature, Nature, The changing carbon cycle of the coastal ocean, Bauer et al., Copyright © 2013[58].*



- Impacts coastal ecosystems part of the socio-economic value of our EEZ
- The Arctic ice is melting

What we build on:
-Integration of coastal and open ocean carbon research
-Several Arctic Initiatives

What is needed:
-Stronger links with other disciplines; fisheries, aquaculture, energy industry

Four overarching questions:

4. How are humans altering the ocean carbon cycle and resulting feedbacks, including purposeful carbon dioxide removal (CDR)?

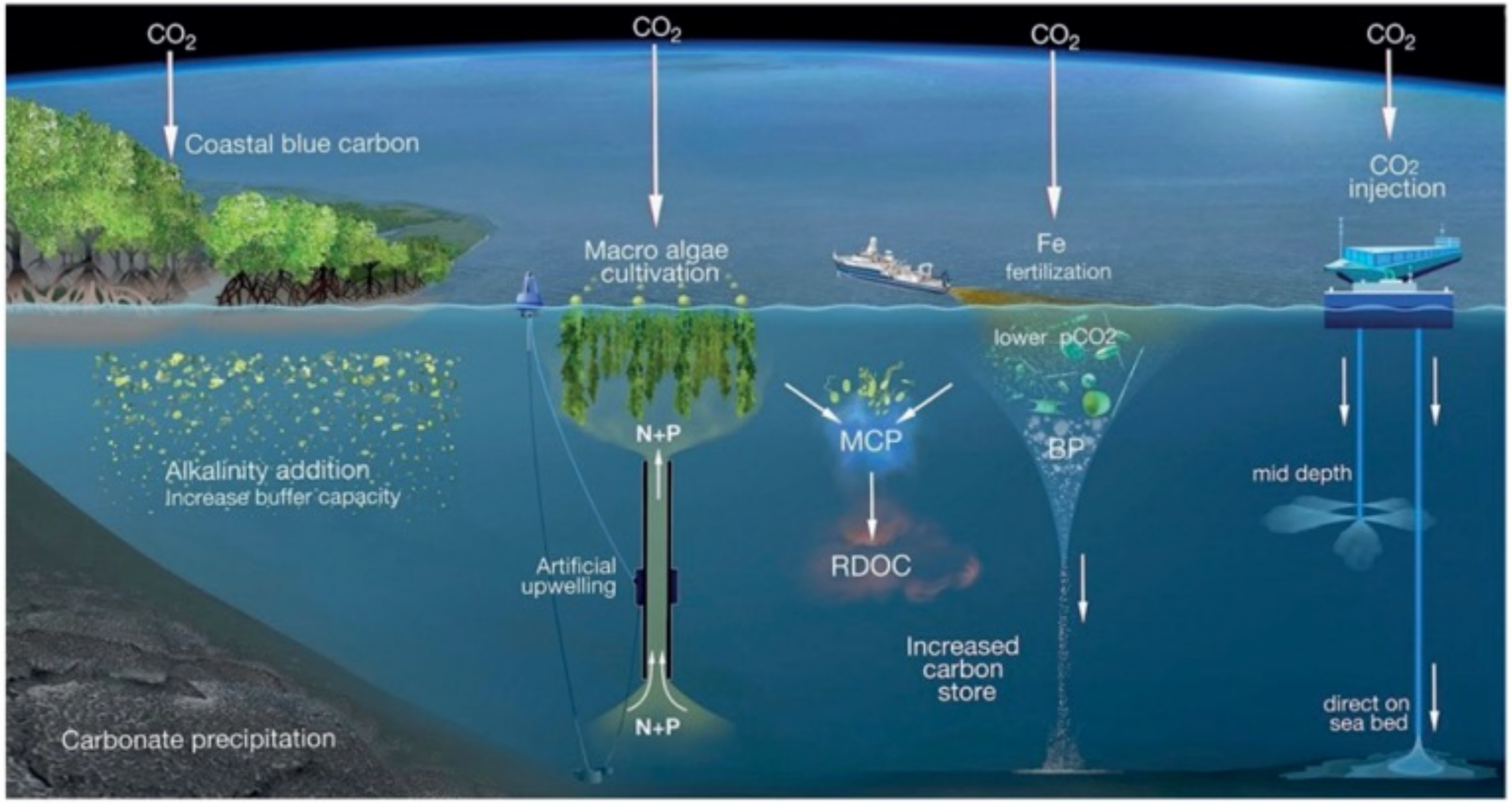


Figure 8. *A sampling of proposed marine ecoengineering and geoengineering approaches with description in the text. Figure is from N. Jiao pers. comm.*

What we build on:
Increased understanding and observations of the natural carbon cycle

What we need:
Use all avenues available to increase understanding
- Basic research
-Innovative ideas and careful assessment of the outcomes
-Process studies
- Modelling

- Need to understand the natural carbon system in order to understand its perturbation
- Need to determine the efficacy and impacts of M-CDR

We cannot reliably predict the future trajectory of carbon in the atmosphere without improved understanding of the ocean [carbon] system

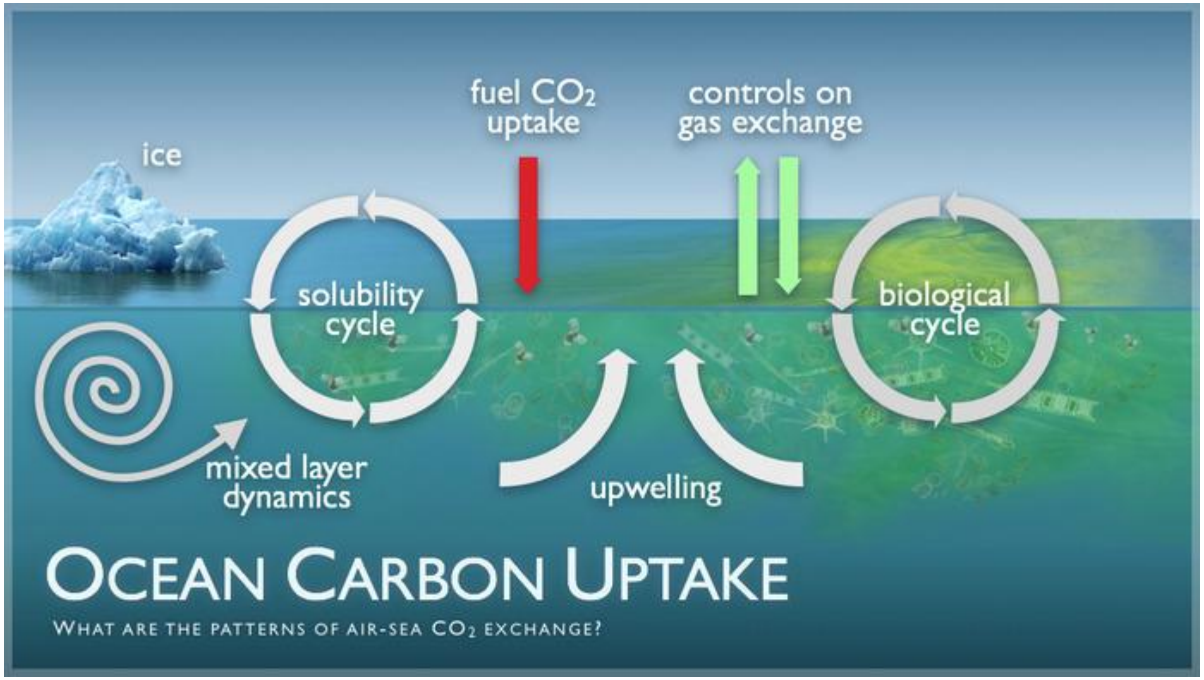
Integrated Ocean Carbon Research needs to play a central and enduring role in predicting this trajectory, its impacts on the ocean, and tradeoffs

Thank you for your attention

Canadian efforts: North Atlantic Biogeochemical Carbon Pump

JPI Oceans Scoping Workshop
'Ocean Carbon Capacities: Identifying priorities for collaborative action'

21 October 2021



https://www.pmel.noaa.gov/co2/file/Ocean+Carbon+Uptake+Image

Andrew Stewart
Fisheries and Oceans Canada

Drivers

G7 United Kingdom 2021

G7 2030 Nature Compact

(3E) Supporting the UN Decade of Ocean Science for Sustainable Development: endorsing the G7 Ocean Decade Navigation Plan to drive developments in transformational ocean science to protect and further our sustainable relationship with the ocean. As part of this work we will convene scientific and policy experts to discuss the carbon absorption function of the ocean, furthering targeted and effective ocean action.

The Commonwealth Blue Charter

World Ocean Day 2021 - The Blue Reset: Building resilient and equitable ocean-based economies post-COVID

Hon. Bernadette Jordan, Minister of Fisheries, Oceans and the Canadian Coast Guard

"Where there are gaps in knowledge, we need to continue to take action, to learn more, and to strive for a better tomorrow. Canada would like to convene leading scientific and technical experts in coming months to discuss scaling up knowledge and monitoring of the North Atlantic Biological Carbon Pump."

Scientific Workshop on the North Atlantic BGC Carbon Pump

Objectives:

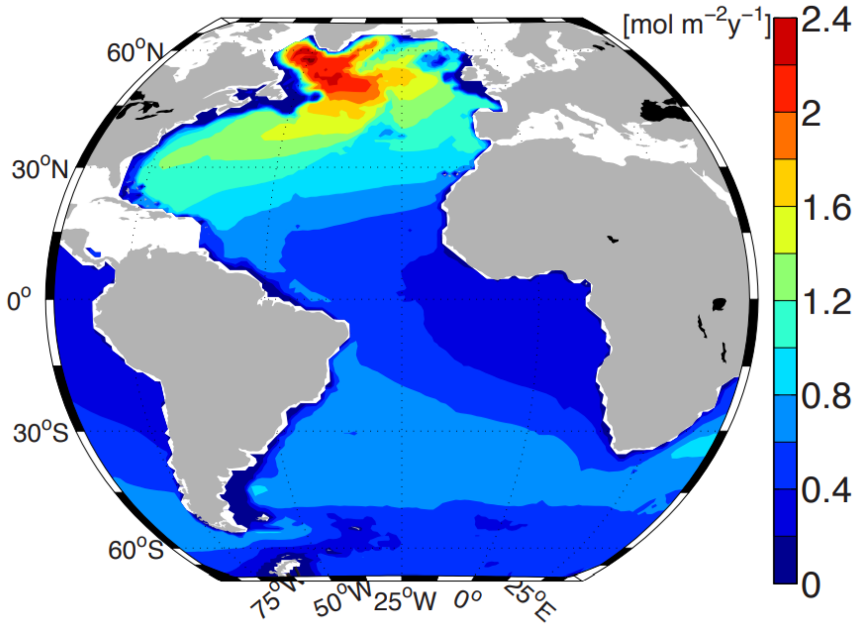
- Advance ministerial commitments
- Highlight the importance of unique environments in the carbon cycle, using the North Atlantic and its Arctic Gateways as an exemplar
- Discuss the need to observe these areas and ways by which we could observe them

Canada will convene a workshop:

- Scientific, technical and policy experts from G7 countries and beyond
- Discuss scaling up knowledge and monitoring of the North Atlantic Biogeochemical Carbon Pump (BCP)
- Tentative dates: virtual sessions on December 15 and 16, 2021

This workshop will emphasize the critical importance of understanding ocean carbon as our nations aim for "net-zero-carbon" and the extent to which we need to account for this key variable in global climate prediction.

Among all the oceans, North Atlantic Ocean is the most intense carbon sink on the planet, which accounts for approximately 30% of the global ocean CO2 uptake.



Storage rates of anthropogenic carbon ([mol m−2 y−1]) averaged over 1980–2005 for the Atlantic Ocean, doi:10.5194/bg-10-2169-2013 https://oceanrep.geomar.de/21469/1/bg-10-2169-2013.pdf

Scope of the Scientific Workshop

The purpose of this workshop is to identify the gaps and needs to better understand the North Atlantic Biogeochemical Carbon Pump with a global lens. The scope of the scientific workshop includes

- examine the North Atlantic Biogeochemical Carbon Pump as an exemplar looking through the global lens
- examine methodologies for quantifying, monitoring and modelling the carbon pump
- examine links to domestic and international activities already in place and planned
- find the knowledge and monitoring gaps in the North Atlantic Carbon Pump

Scientific Workshop –Questions?

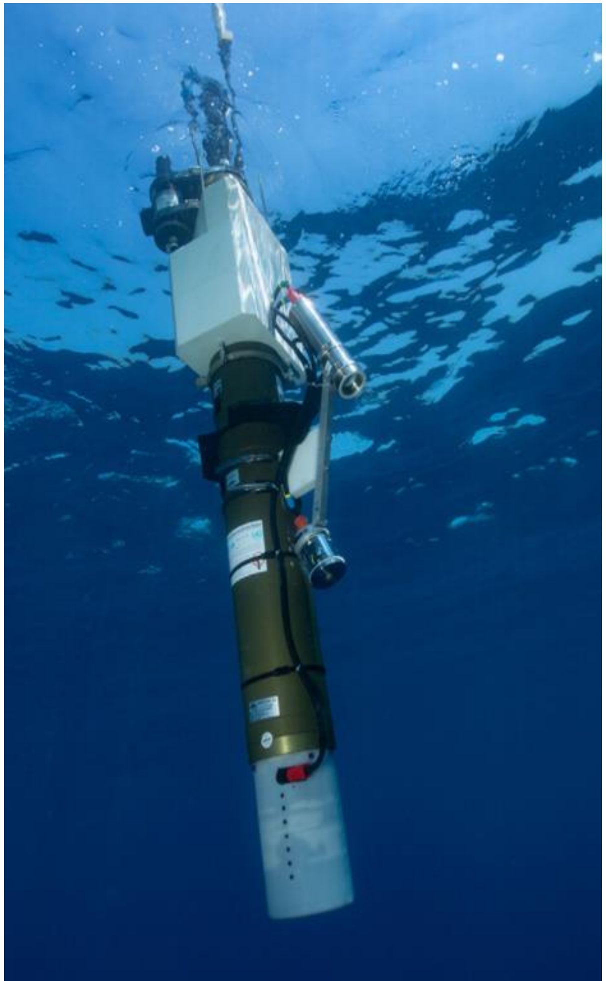
The workshop will include keynote speeches, breakout sessions and plenary sessions to discuss the questions related to

- Knowledge gaps – what do we still need to understand about how the North Atlantic carbon pump works, how it is changing, and how it is likely to change in the future?

- Monitoring, modeling and research - current availability of monitoring networks techniques; modeling capabilities, research activities, what and where are the gaps?

- Related activities - domestic and international activities currently underway and planned in the area which can be connected or contributed to, where and how the outcomes of this workshop can connect with other national, international activities.

- Science and policy linkages - how the science of carbon cycle and process links with/contribute to/drive policy-making.



https://phys.org/news/2020-02-carbon-sequestration-oceans-powered-fragmentation.html

Expected outcomes of the Scientific Workshop

- **Achieve a shared understanding** between ocean science, technical and policy experts on the oceanic carbon cycle and processes, unique areas of interest including the North Atlantic Biogeochemical Carbon Pump and critical implications for global health as ocean changes occur;

- **Clarity on the implications** of ocean change for climate targets and reinforce the need to continue global research to close **critical knowledge gaps**; and,

- **Raise the awareness of policymakers** as to the importance of science, research and monitoring of the North Atlantic carbon pump.

Next steps

- A report will be produced outlining the scientific findings of the workshop.
- The workshop is meant to be policy neutral, in that is not intended to lead to specific, targeted recommendations.
- The report will be made publicly available.

Overall Goal of Workshop

Richard Sanders

GOAL
‘To identify areas and actvities where JPI Oceans can work together, in small groups or collectively to support Ocean Carbon Research’

- Thus, the activities need to be
  - Excellent, relevant, achievable, and scalable
  - Link to other existing initiatives and actors
  - Broadly supported

- 3 Scoping Workshop Stages
  - ✅ External perspectives
  - JPI Oceans Task Team suggestions
  - Feedback and reflection from countries and general discussion

What is JPI Oceans?

- JPI Oceans is a **pan-European intergovernmental platform** aiming to increase efficiency and impact of research and innovation for sustainably healthy and productive seas and oceans.

- **National strategies** and priorities are the **main building blocks** of JPI Oceans.

- JPI Oceans supports national efforts by:
  - Coordinating initiatives
  - Aligning agendas
  - Increasing cost-efficiency and synergies

- **A high level of flexibility** is guaranteed by allowing member countries to participate on a case by case basis.

- JPI Oceans can **act fast** when it comes to identifying **emerging topics** and implementing related actions, thus achieving quick outcomes.

Genesis of the Action + Timeline

- Late 2020: Contacted JPI Oceans to request that they consider an ocean carbon capacities programme
- Nov 2020/early 2021: JPI Oceans management Board accepted this request and interested countries nominated experts to serve on organisation team of Scoping Workshop
- May 2021 onwards: Expert team discussions resulting in establishment of subgroups
- Now: Subgroups report preliminary ideas for action and seek feedback
- Next week: Integrate comments and revise Action Plan; submit to participating countries in this Joint Action
- Mid-November 2021: Deliver Action Plan to JPI Oceans Management Board and seek for decision on next steps and prioritized actions

How it will work: Short talks on various action areas

- Model Synthesis

- Negative Emission Technology / Carbon Dioxide Removal

- Geographical Areas
  - Open North Atlantic Ocean
  - Baltic Outflow
  - North Sea
  - Mediterranean Sea

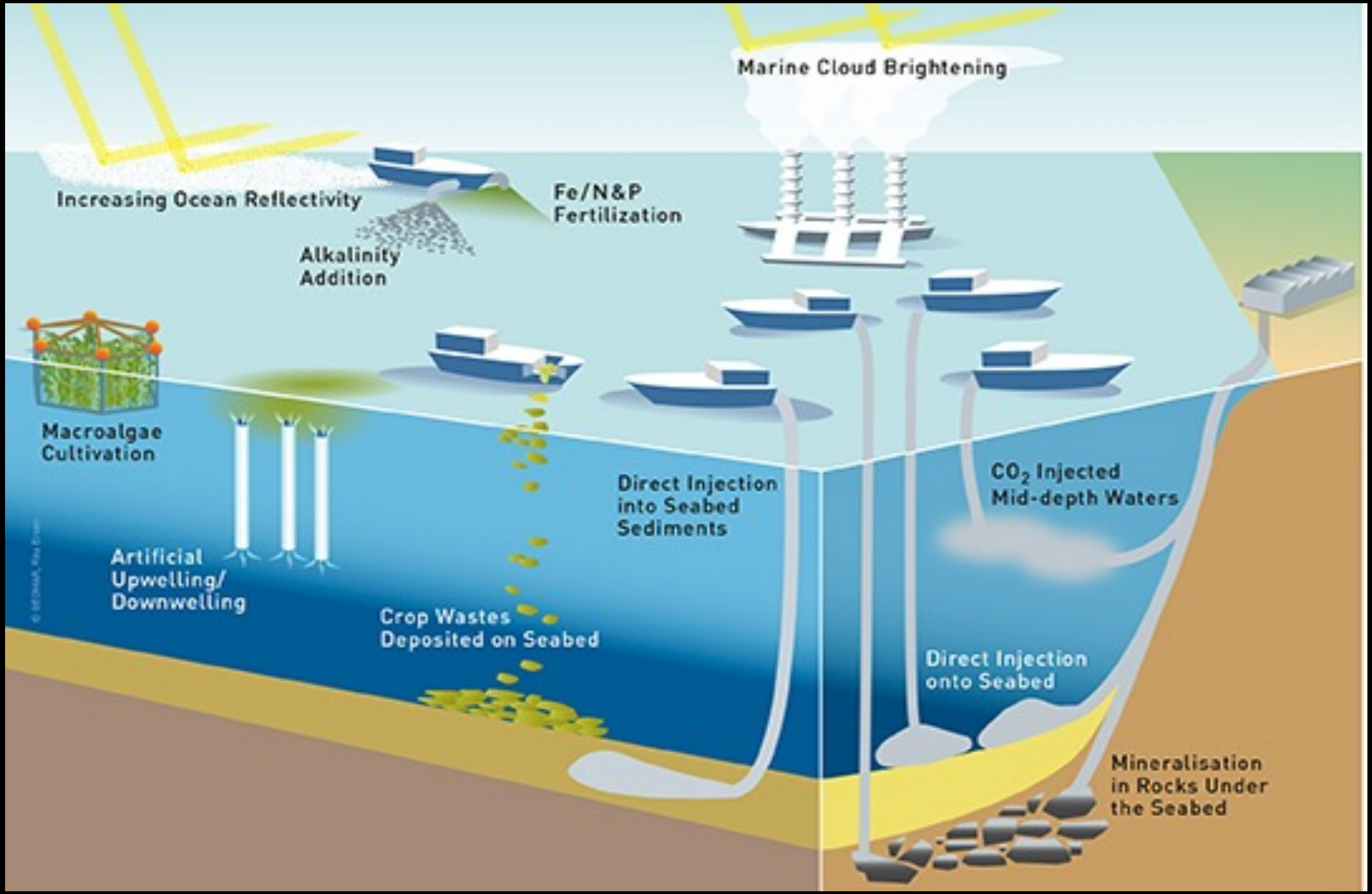
INVESTMENT LEVELS	Baltic Outflow - Kattegat-Skagerrak Carbon Transformation and Turnover	North Sea, Celtic Sea and Irish Sea Carbon observations and information mechanism	North Atlantic Ocean	Mediterranean Sea – Strengthening the assessment of the Ocean Carbon Sink and its Impact on Marine Ecosystems	Model Synthesis	Observing System Design	Negative Emissions Technology
Small scale	(~300 K€): Proper regional integration of observing networks	Optimize synergies between different observational communities (ESFRI/ERIC, RIs, regional and global initiatives with presence in the area).	Link North Atlantic efforts from JPI Oceans through to international context	Capacity development in Eastern MedSea and Southern regions certified material for oceanic CO_2 measurements Develop new technologies and common protocols for analyses	Support JPI Oceans engagement in international CO_2 modelling activities (eg comparison with BGC models as used in regional vs global configuration)	Intercomparison exercises and training workshops Support of reference materials platform	Workshop for experts to define the status of research and to develop a handling protocol for OAE, Annual training workshops
Medium scale	(~1,5 M€): PhD programme across participating countries + dedicated multi-disciplinary supersite monitoring activities	Design new campaigns using existing capacity (includes FTE support and cover the costs of campaigns and deployment of equipment and platforms)	Saildrone or other Autonomous surface vessel (ASV) missions with surface pCO_2 instrumentation, to assess gap-filling techniques and BGC-Argo floats: Dedicated cruise for float and SOOP evaluation	Extend sampling programmes or joint PhD studentships. Fill the spatial and temporal gaps	Targeted support to key elements of the value chain (improved merging of data and models; looking at air-surface-fluxes, ..)	Support stablish/improve r egion specific estimation algorithms for use in remote sensing based upscaling in different regions	Develop and test automatized injection systems using a global network of scientists Communication to environmental agencies and political decision makers to set the legal framework Large scale multi-national field experiment with long term monitoring

INVESTMENT LEVELS	Baltic Outflow - Kattegat-Skagerrak Carbon Transformation and Turnover	North Sea, Celtic Sea and Irish Sea Carbon observations and information mechanism	N Atlantic (Spain, Portugal, Iceland, Germany, Belgium, Denmark, Norway)	Mediterranean Spain, France, Greece, Italy, Lebanon, Turkey,	Model Synthesis	Observing System Design	Negative Emissions Technology
Large scale	(~5M€): Full carbon cycle study linking processes, modelling, and data synthesis	Full Carbon Cycle study; improvement of data management and modelling (including stronger relationship with industry)	Glider observations of transport between the shelf seas and the open North Atlantic	Development of new SOO lines Promote long term cooperation actions with non-Mediterranean institutions Establishment of a center able to produce and provide primary or secondary CRM with limited costs Establish new atmospheric CO_2 oceanic time-series stations	Transitional costs to support operationalising of value chain (use of models to define optimal future observing systems)	Establish pilot projects where the whole ocean C value chain can be brought together and create coordinated long-term & sustained effort by multiple countries and institutions	Install systems and monitor the effect of OAE

Finally

- Many Thanks to all those who gave their time to bringing this together
- Especial Thanks to Sandra and Thorsten

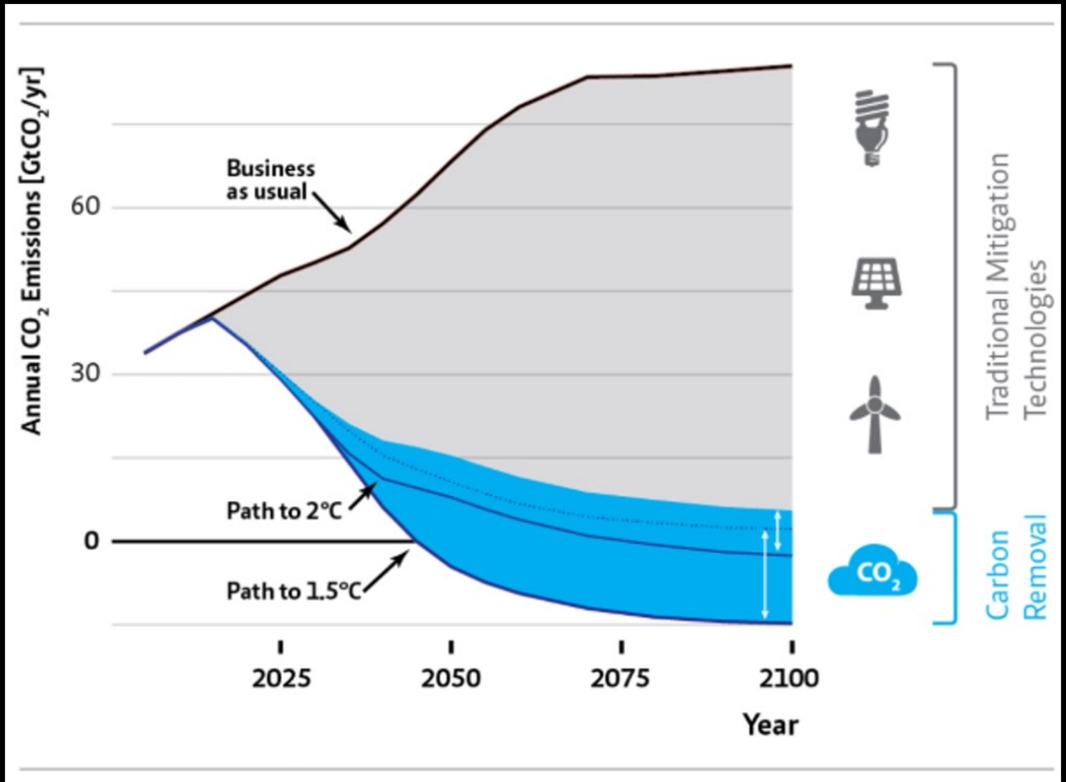
Ocean Negative Emission Technologies



Carolin Löscher
DIAS, Dept of Biology, University of Southern Denmark

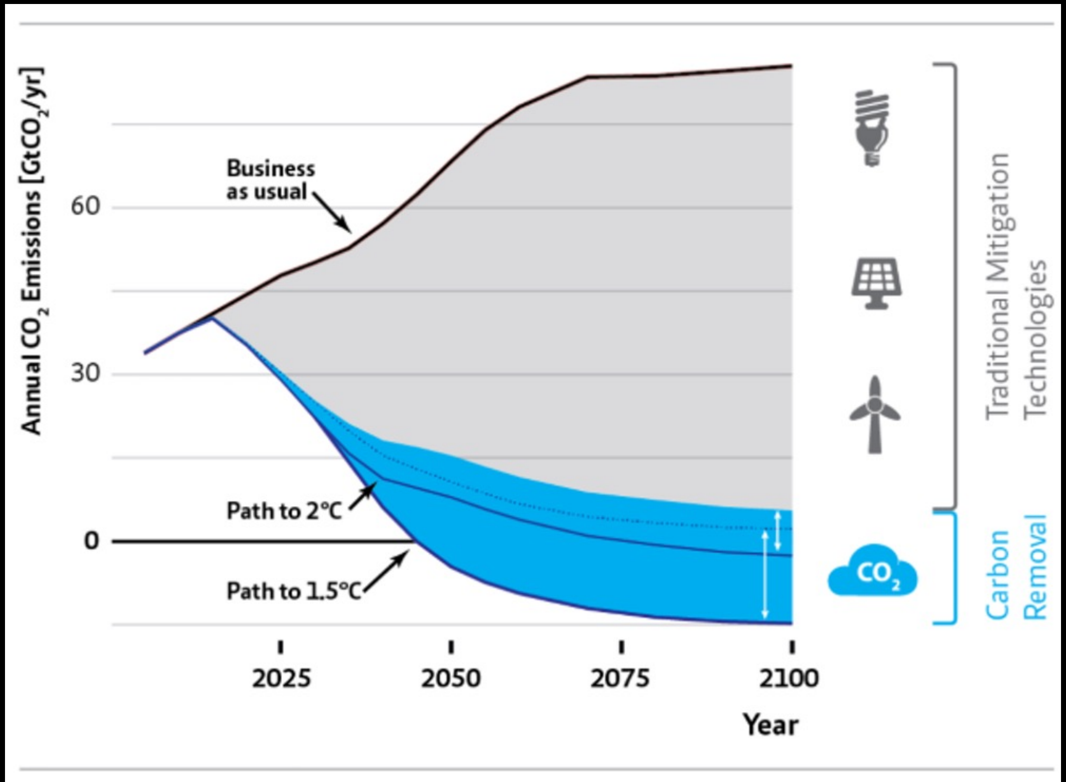
Climate change

Massive increase in CO_2 over the last 150 years
Temperature increase by 0.7 °C



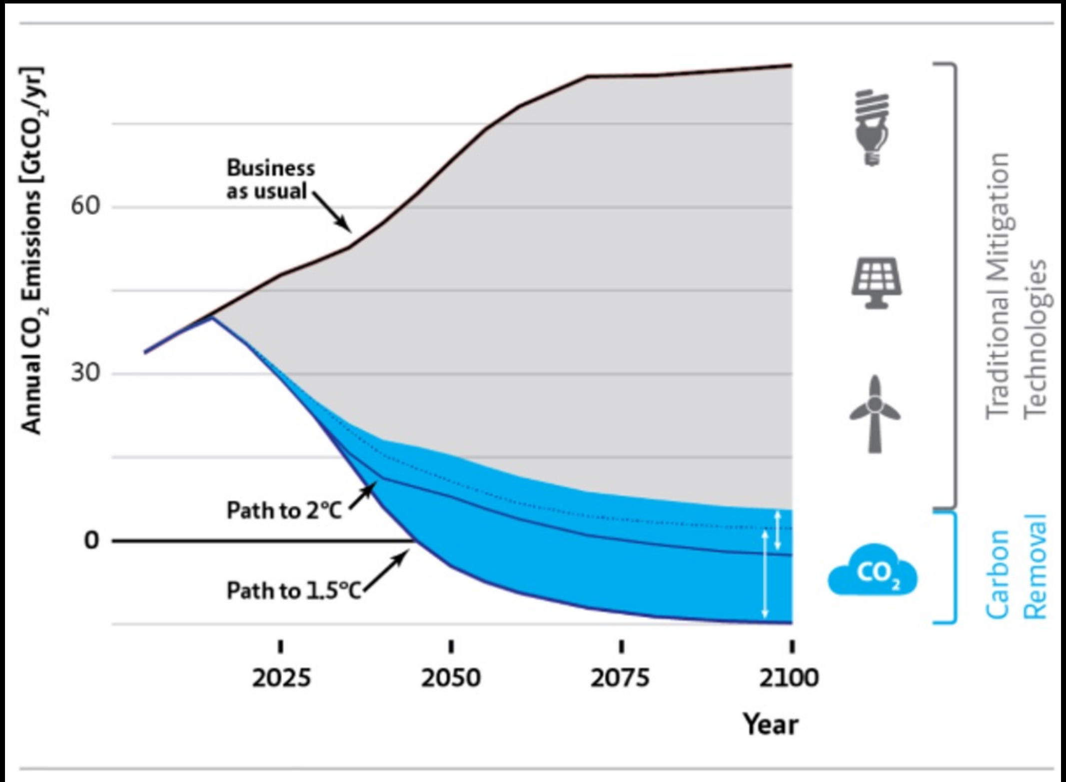
Climate change

Massive increase in CO_2 over the last 150 years
Temperature increase by 0.7 °C
2050: net zero CO_2 emissions



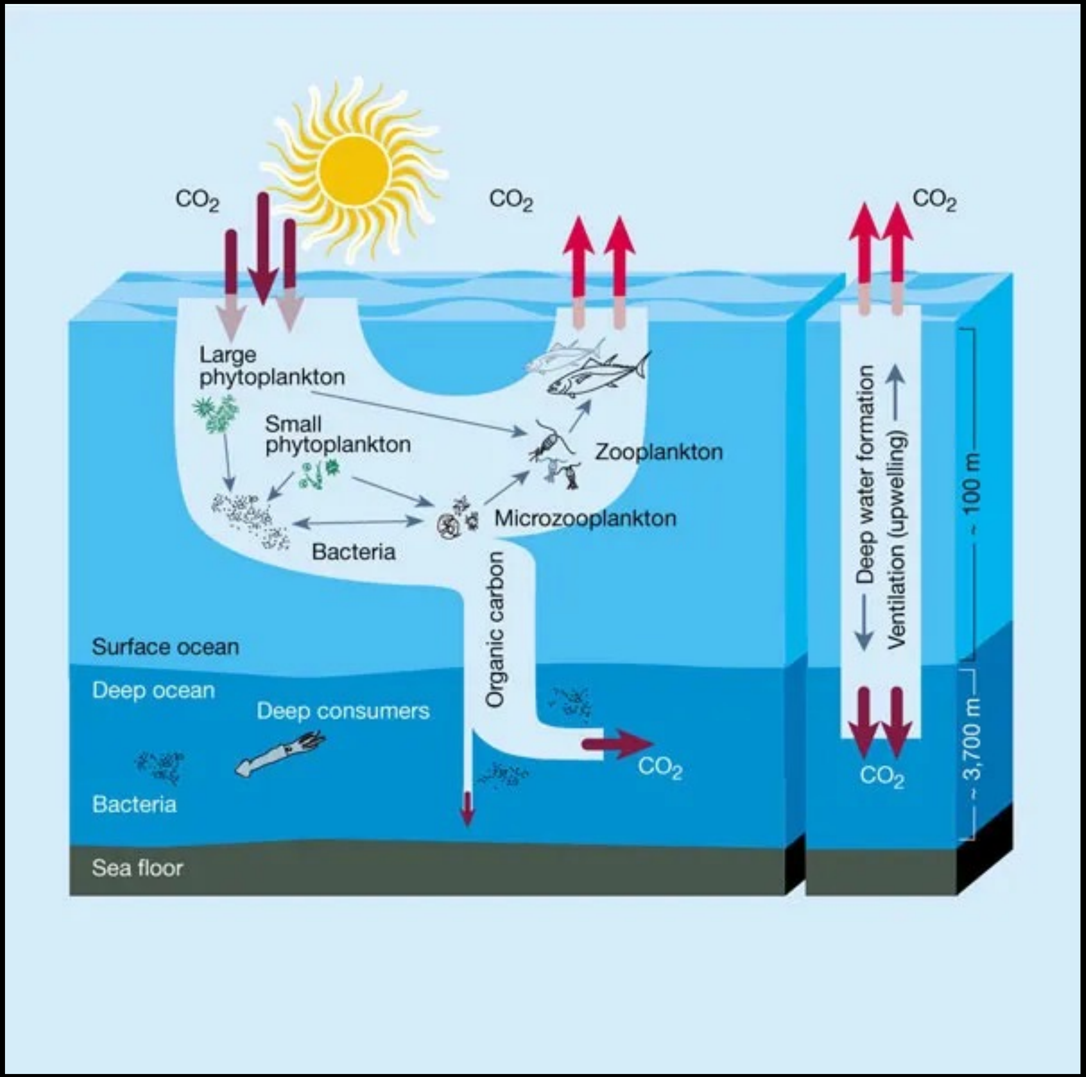
Climate change

Massive increase in CO_2 over the last 150 years
Temperature increase by 0.7 °C
2050: net zero CO_2 emissions
Active CO_2 removal needed



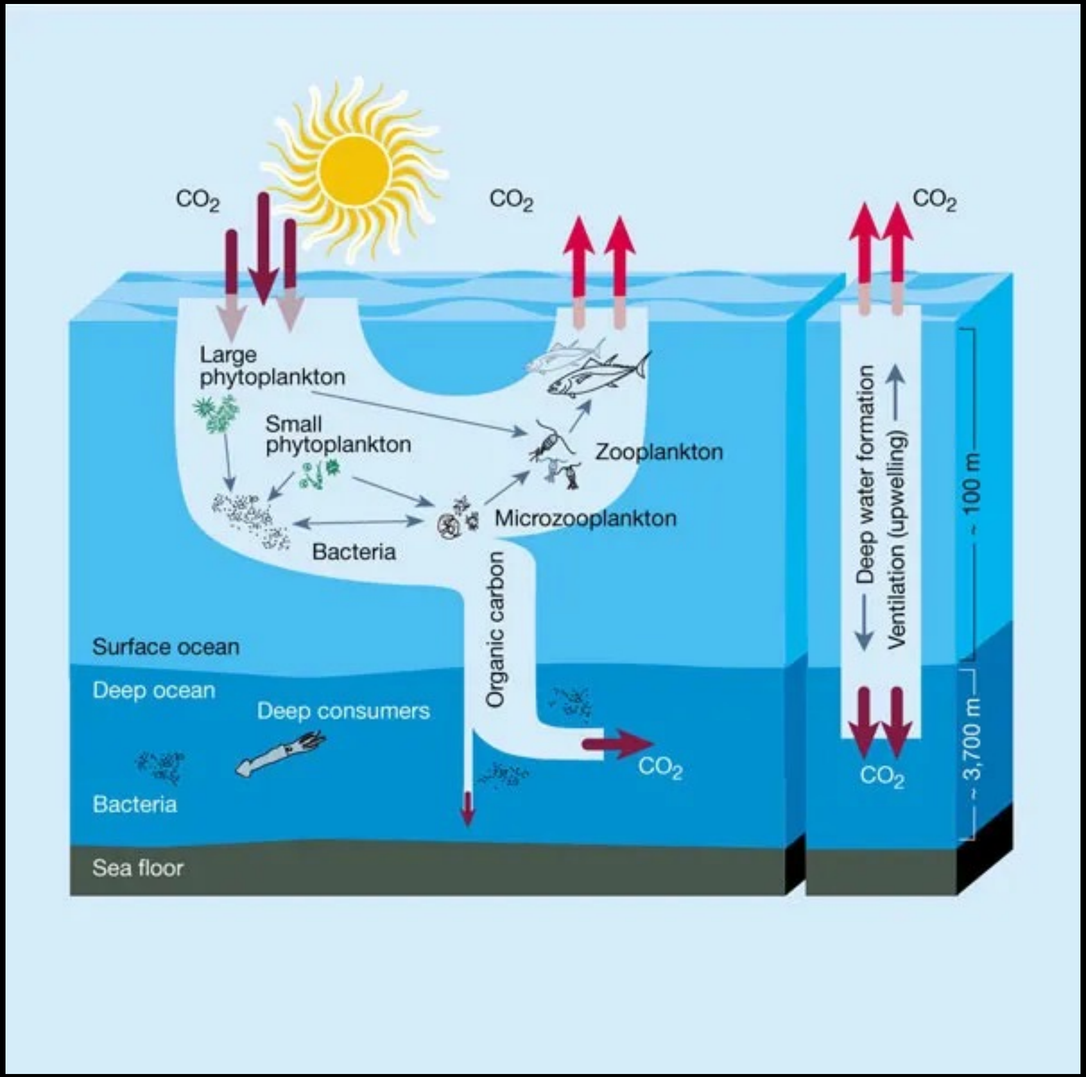
Climate change

25% of CO_2 taken up by the ocean: chemical dissolution and biological carbon pump



Climate change

25% of CO_2 taken up by the ocean: chemical dissolution and biological carbon pump
→ Ocean acidification

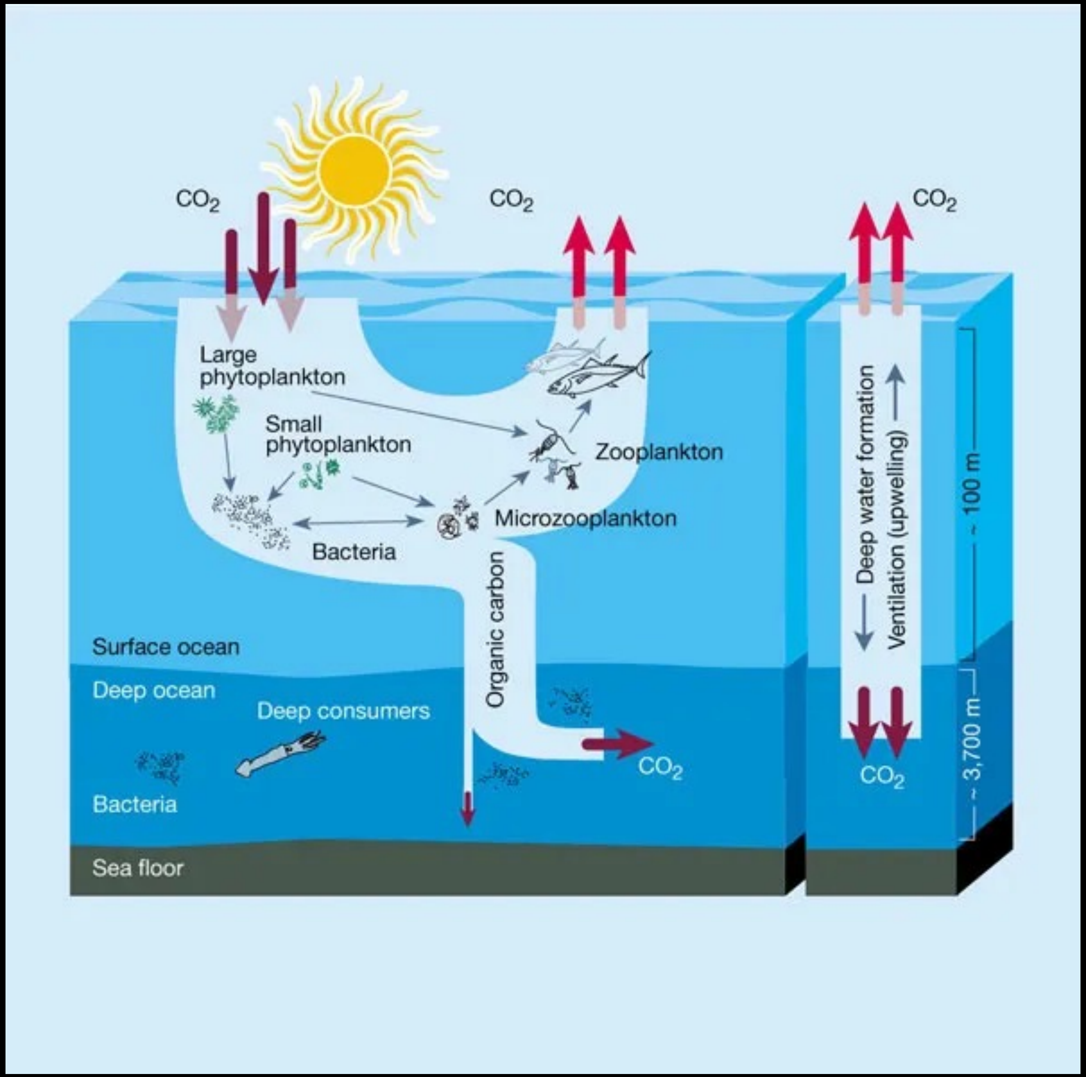


Climate change

25% of CO_2 taken up by the ocean: chemical dissolution and biological carbon pump

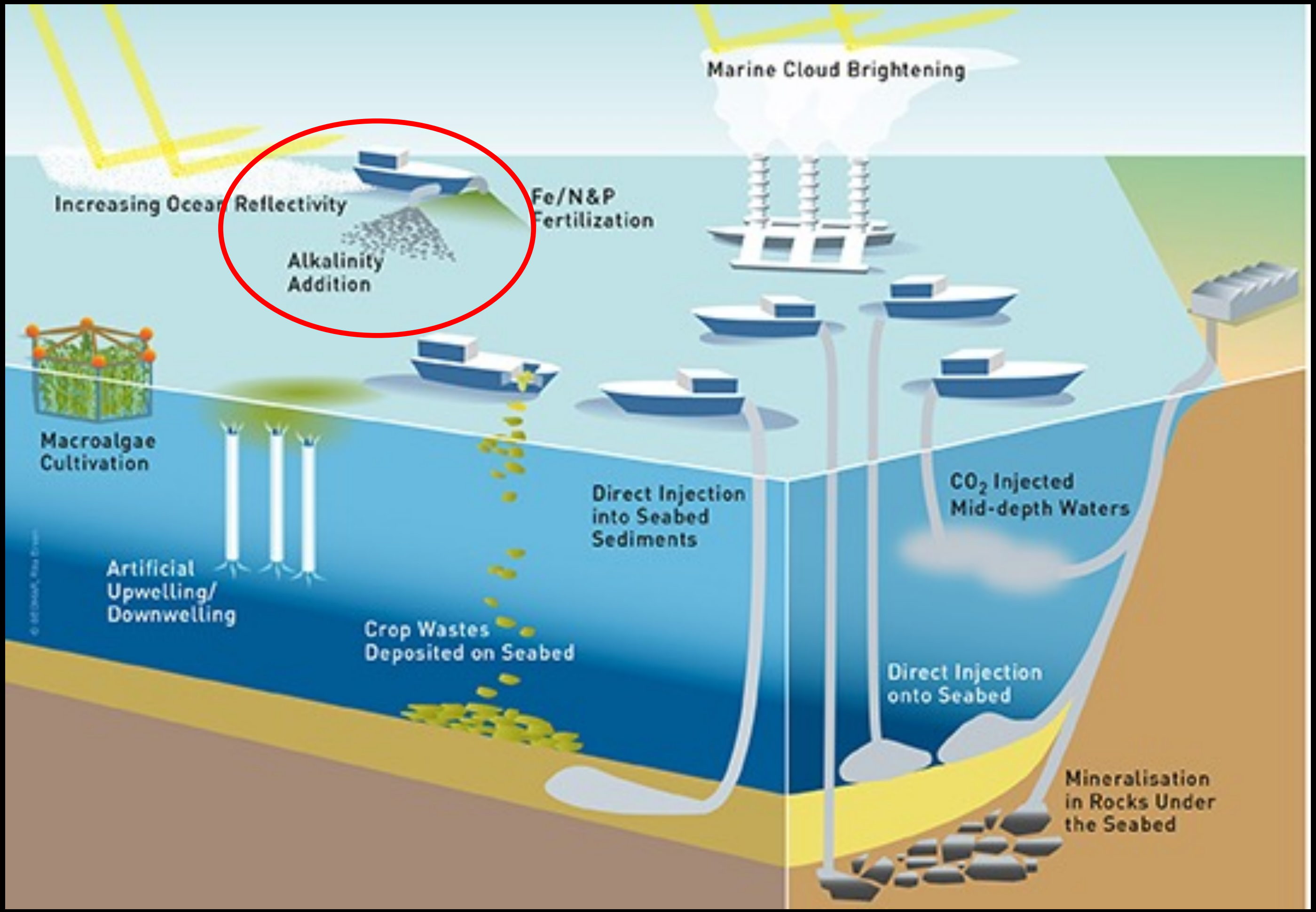
→ Ocean acidification

→ Loss in biodiversity



Possible solutions

Ocean Negative Emission Technologies

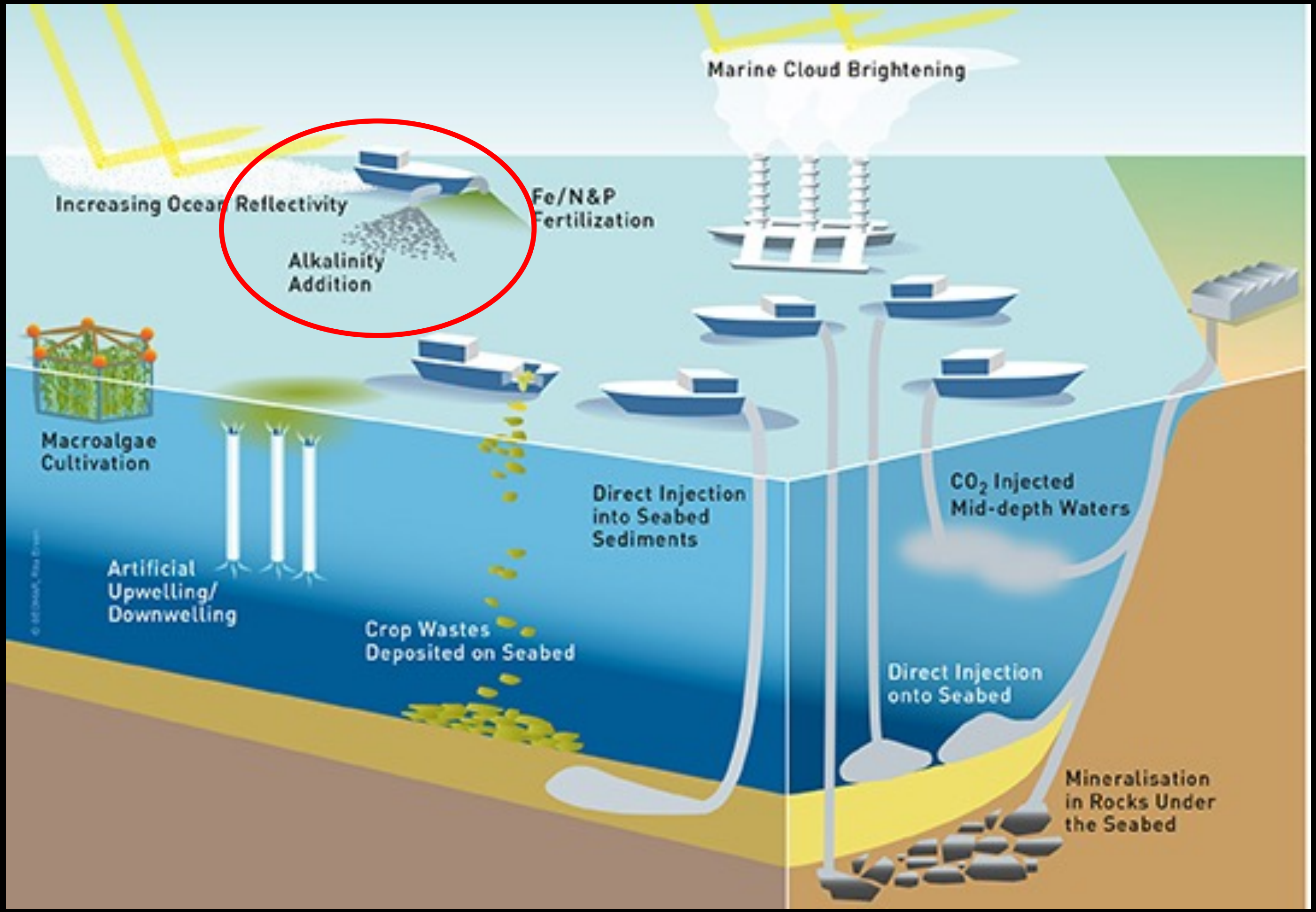


WMO

Possible solutions

Ocean Alkalinity Enhancement by mineral addition

- Promotes CO_2 uptake by chemical dissolution
- Prevents ocean acidification
- Protects primary producers



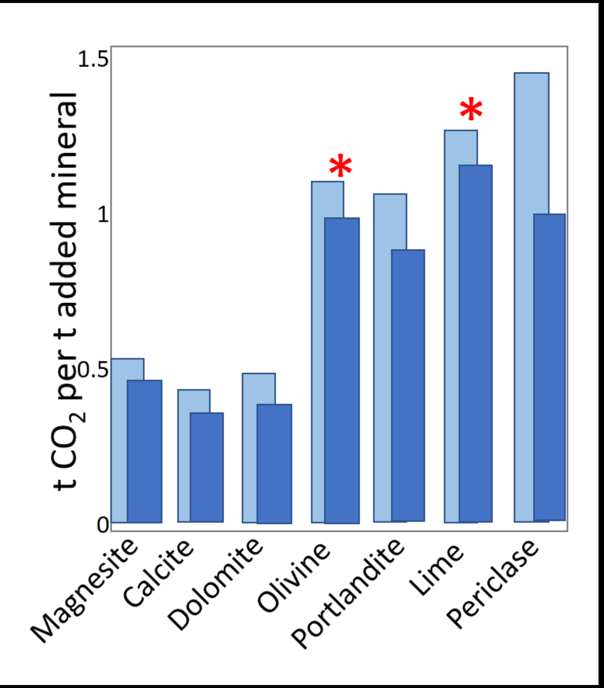
WMO

What do we know about OAE?

Research status was at:

Identification of suitable minerals

Model-based quantification of additions



What do we know about OAE?

Research status was at:

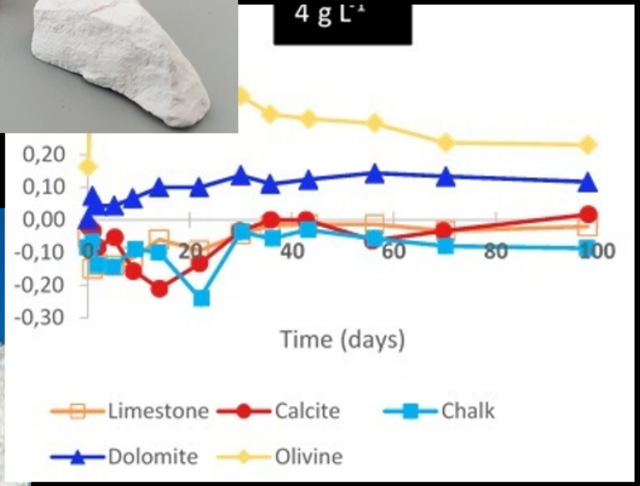
Identification of suitable minerals

Model-based quantification of additions

Gaps of knowledge:

Dissolution kinetics ?

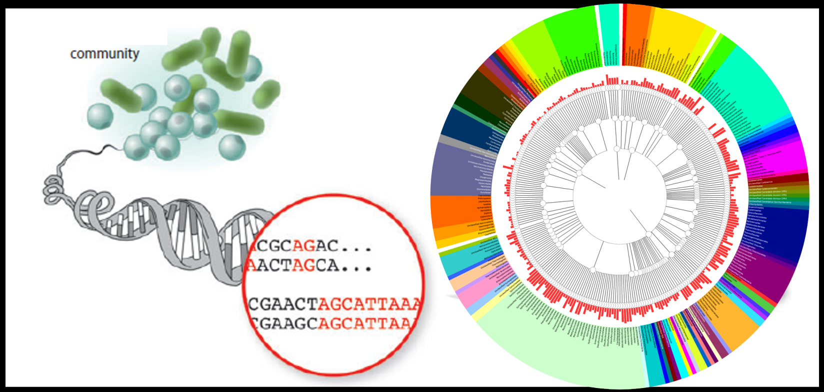
Effectiveness ?



What do we know about OAE?

Research status was at:
Identification of suitable minerals
Model-based quantification of additions

Gaps of knowledge:
Dissolution kinetics ?
Effectiveness ?
Side effects ?



What do we know about OAE?

Research status was at:

Identification of suitable minerals

Model-based quantification of additions

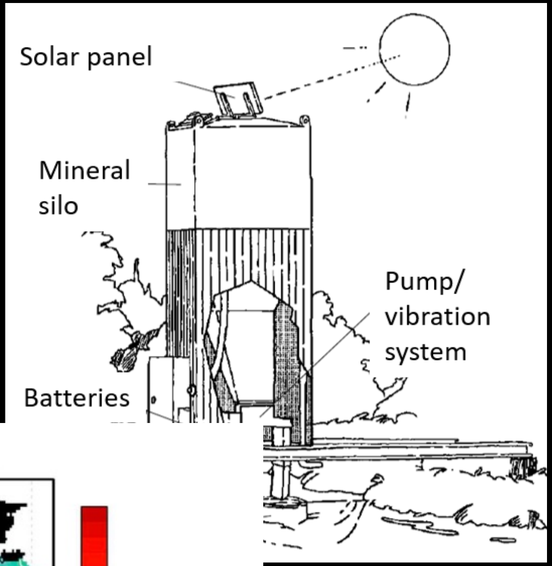
Gaps of knowledge:

Dissolution kinetics ?

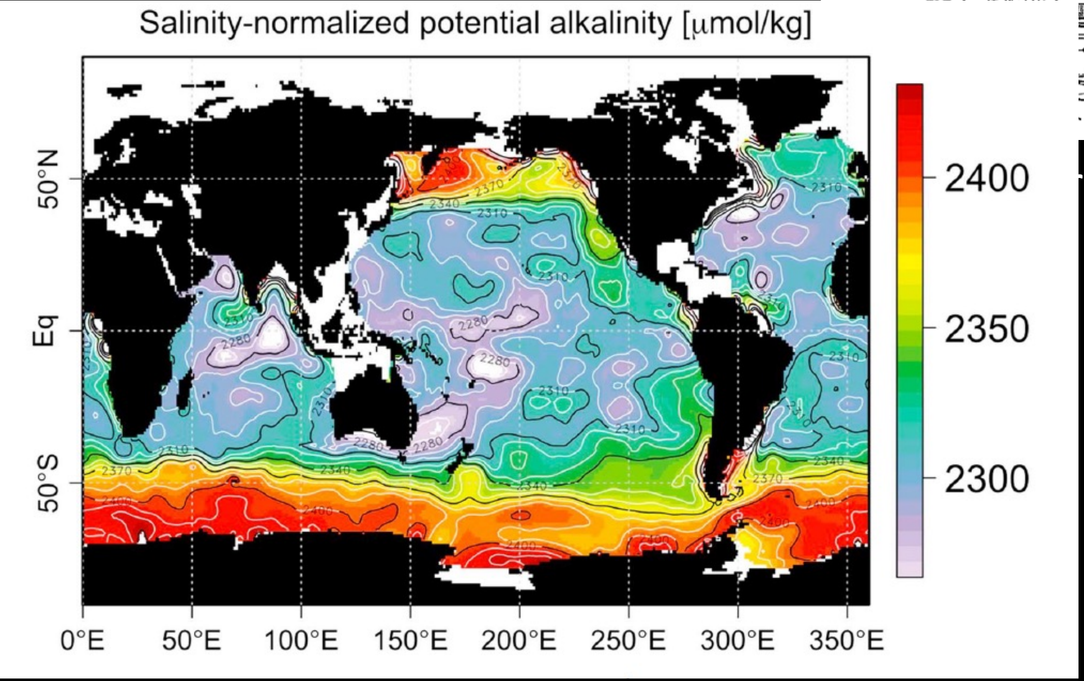
Effectiveness ?

Side effects ?

Applicability and upscaling ?



rdsverket, 2010



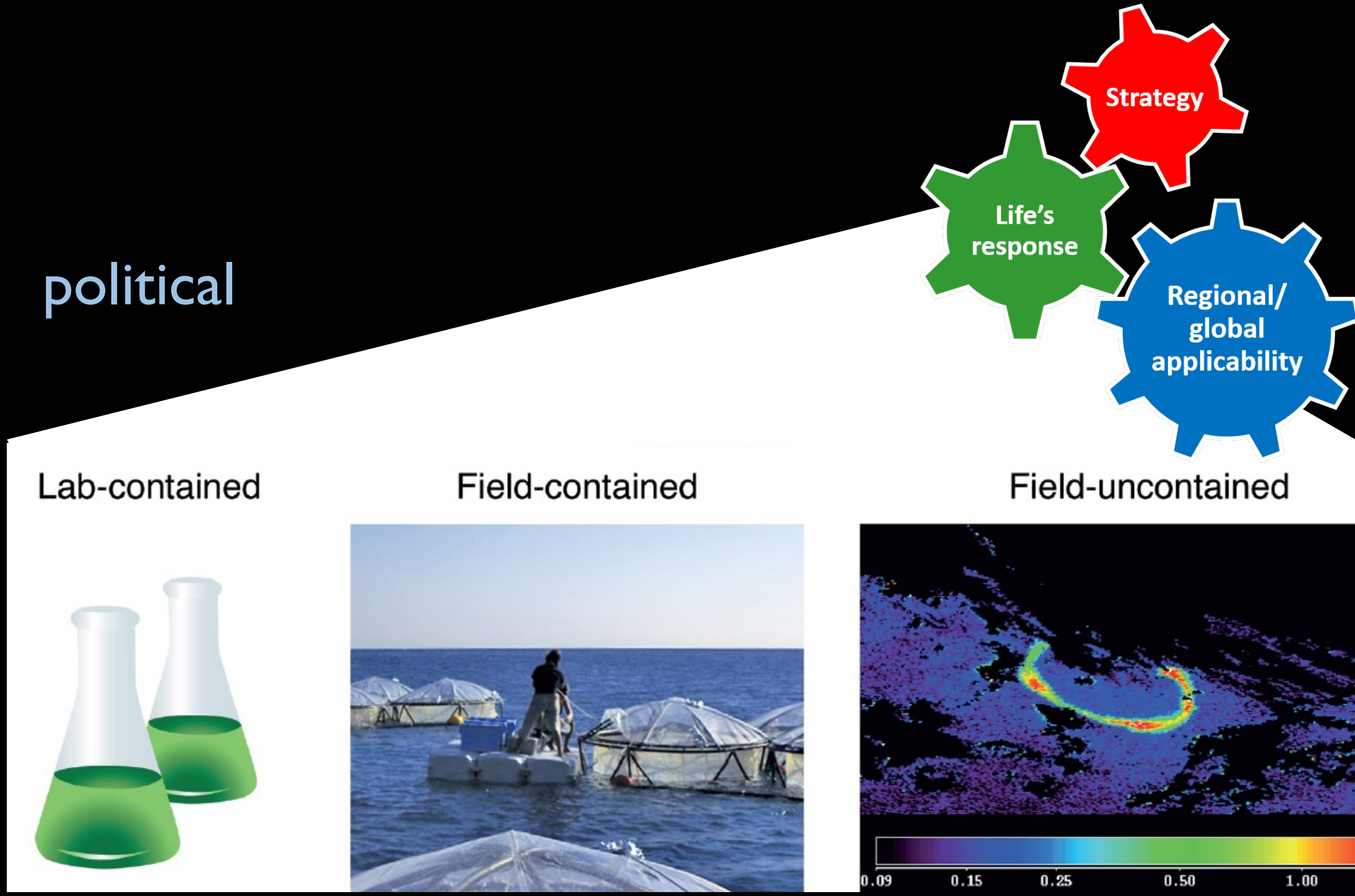
Renforth & Henderson, 2017

Status

Various projects investigate OAE

Shortcomings:

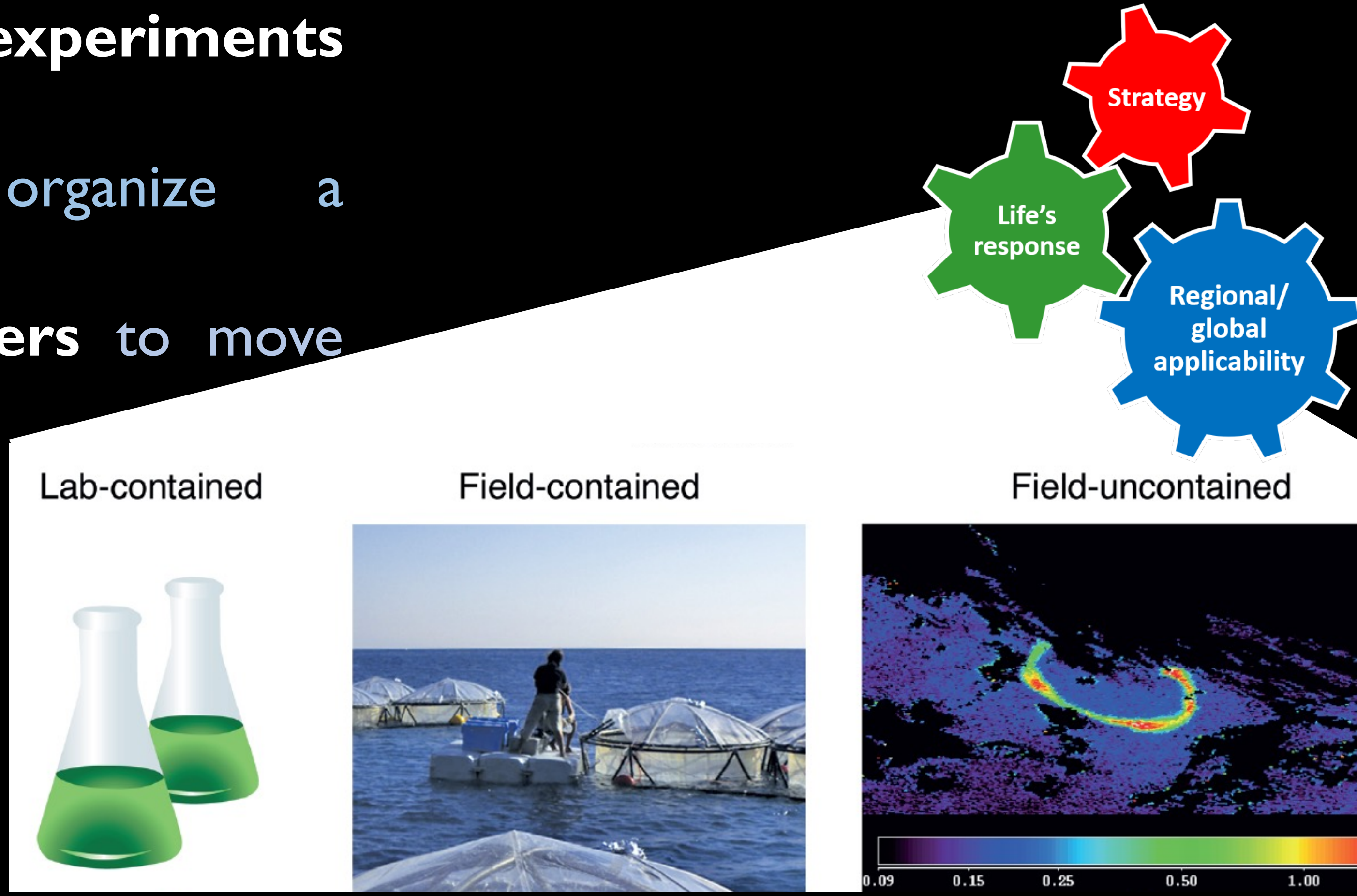
- No framework for communication
- Lack of coordination
- Limited understanding of legal and political framework for applicability



How to move forward?

Establishing a hub of experts

- to define a **guideline of best practice**,
- coordinate and plan **multinational experiments** for the most promising approaches,
- **install ONET-systems** and organize a **monitoring network**
- Invite **political advisors and lawyers** to move forward with the legal framework



OPEN NORTH ATLANTIC

JPI Oceans – ocean carbon capacities

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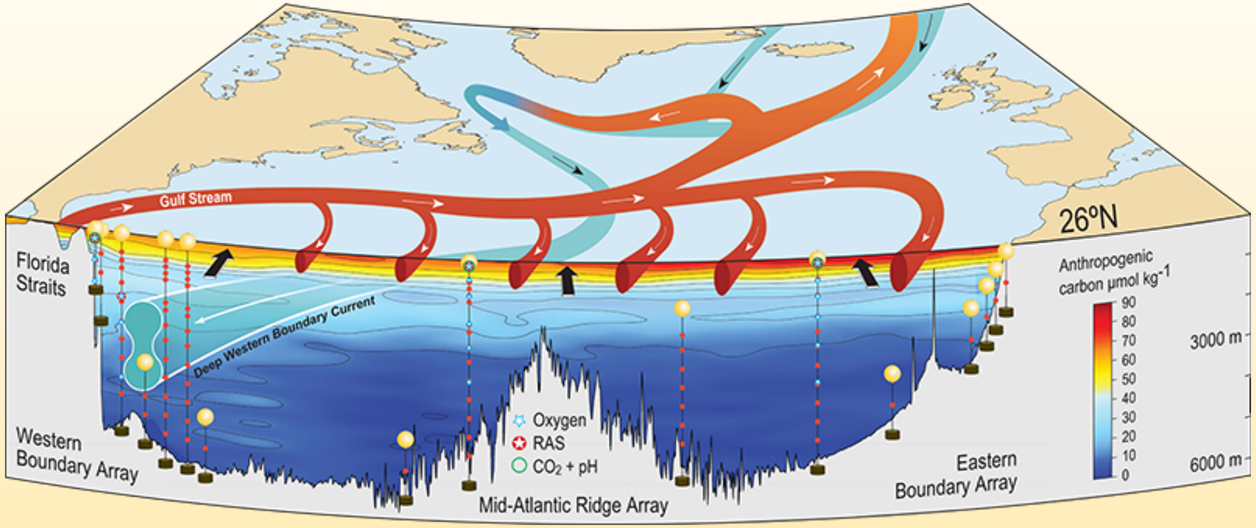
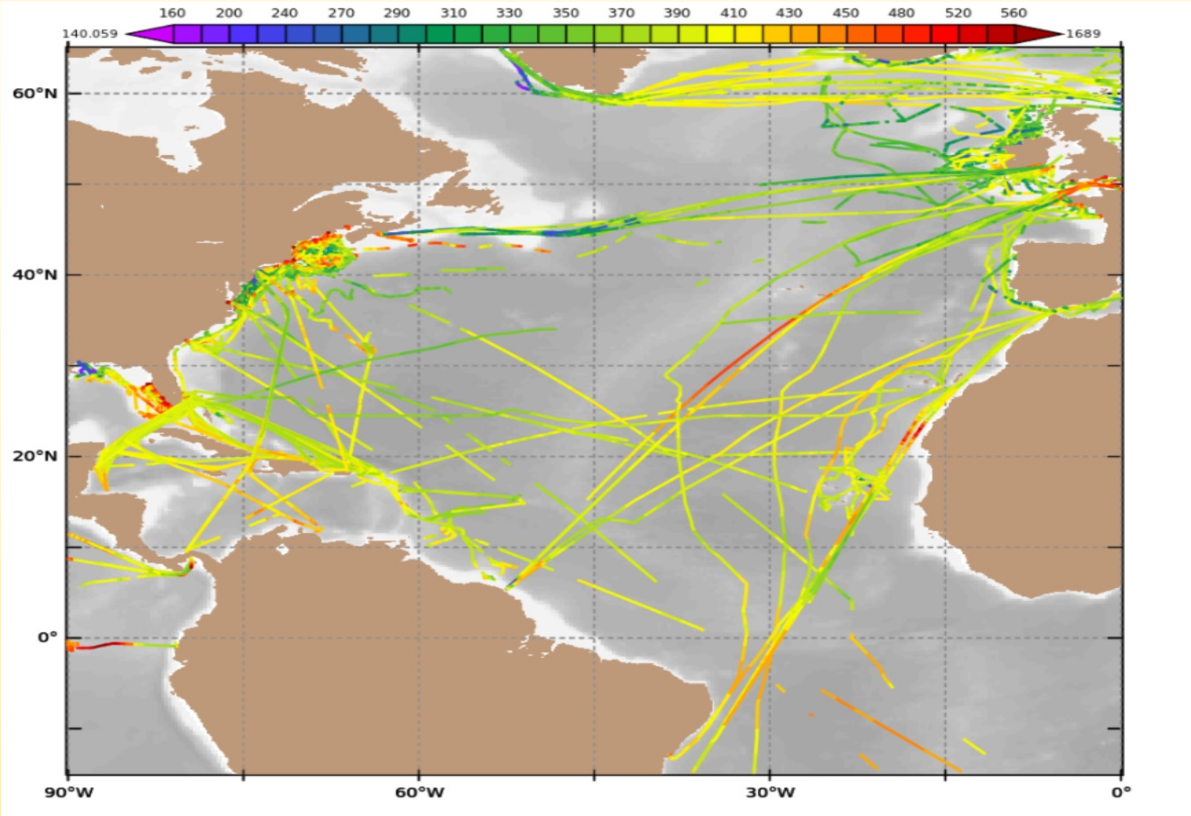
NORTH ATLANTIC CARBON BUDGET

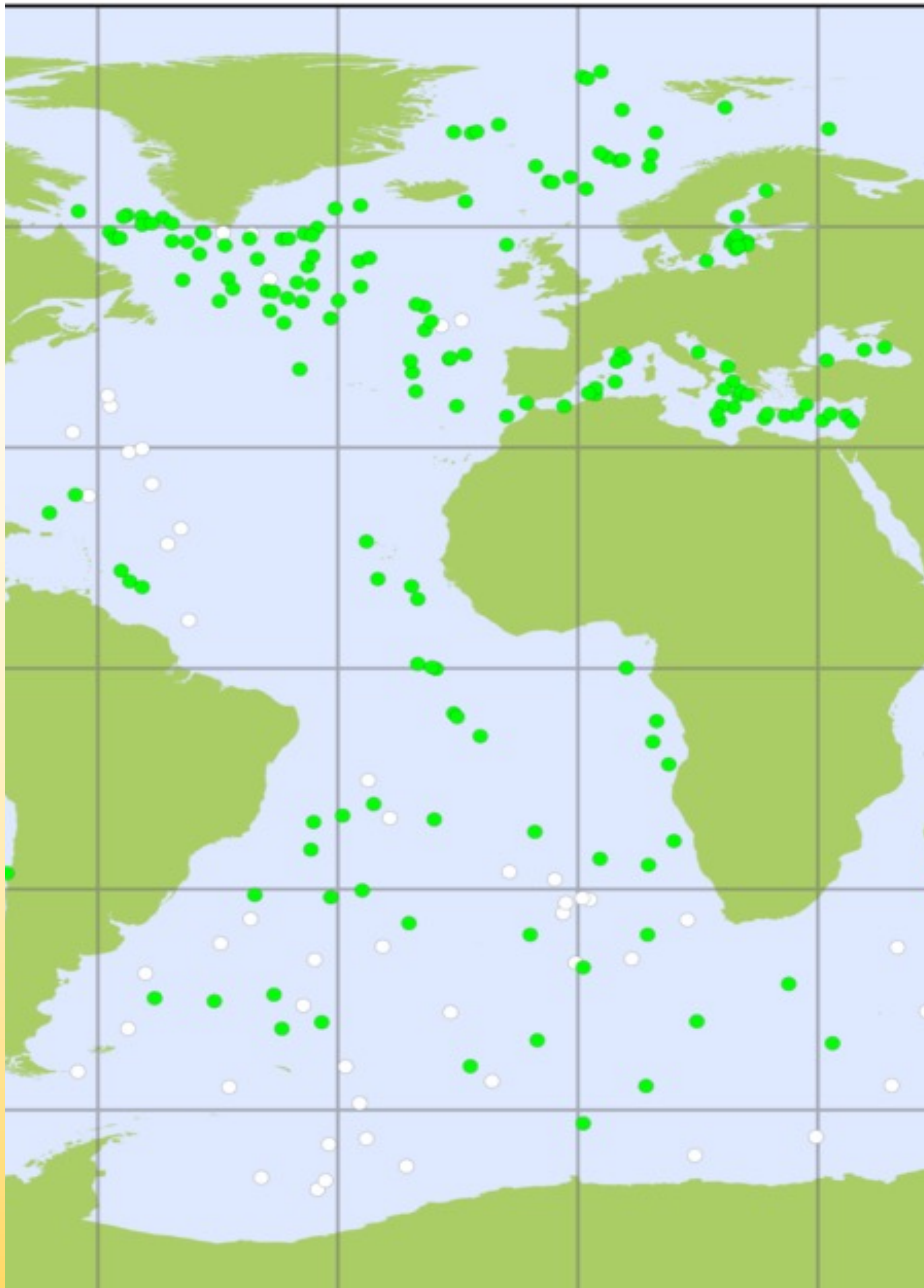
- Most intense ocean carbon sink region
- Large “natural”, pre-industrial sink
- Large anthropogenic sink
- Intense annual phytoplankton bloom
- AMOC is crucial to both natural and anthropogenic components:
- Observations suggest rapid increase in sink over the last 20 years – CMIP 5/6 models generally don’t capture this.
- Models suggest sink will asymptote over the course of this century.



ONGOING ACTIVITIES

- SOOP Lines
- Time series sites
- GO-SHIP hydrographic sections
- Biogeochemical Argo floats





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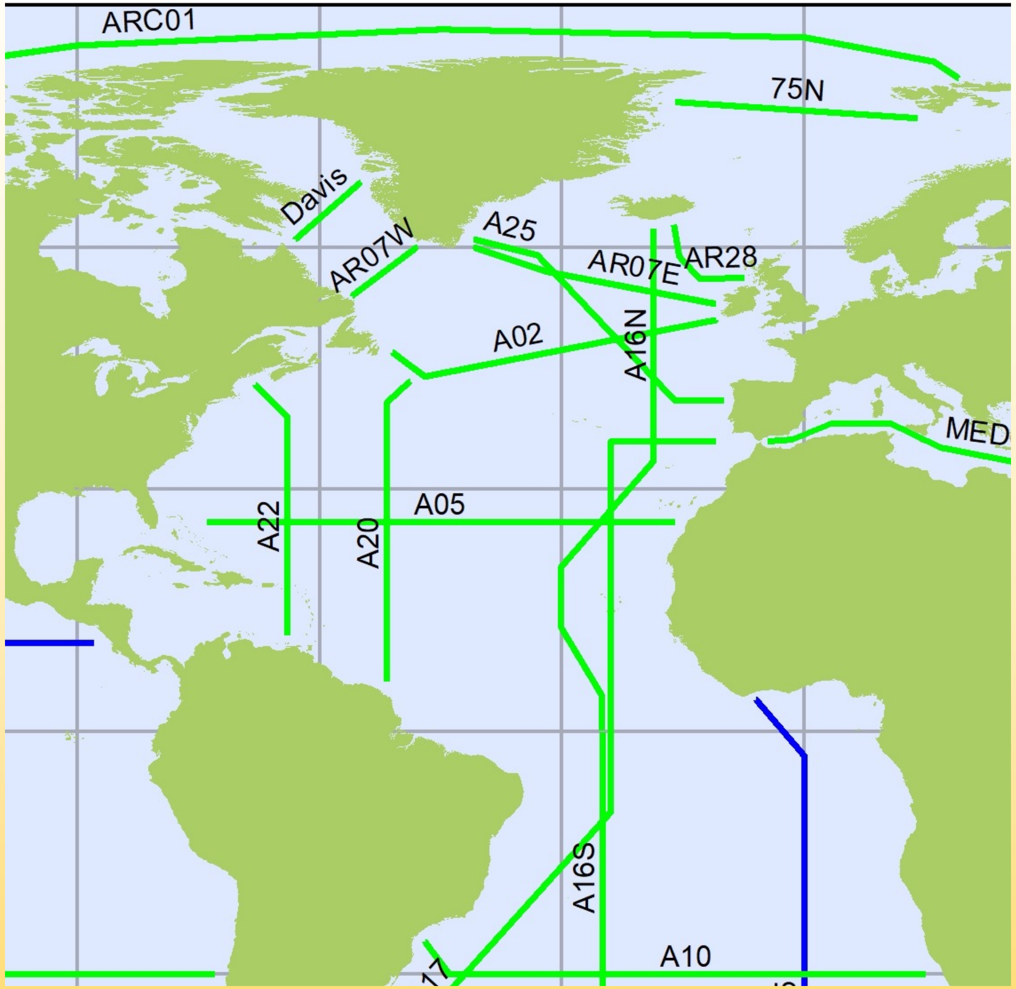


OTHER INITIATIVES

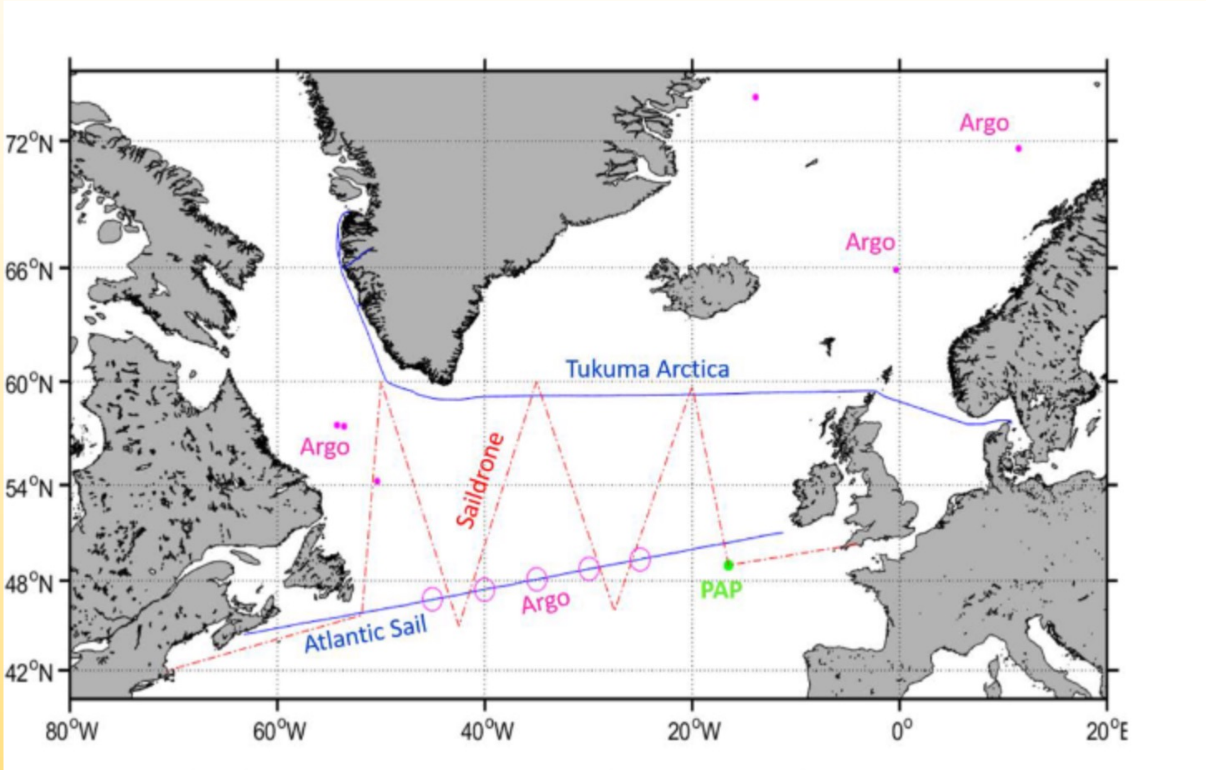
- G7 initiative on Future of the seas and oceans – Ocean carbon observing scoping document
- Canadian Initiative on the “North Atlantic Carbon Pump”
    - Convene a workshop (December) on uptake of carbon by the ocean, with North Atlantic and Arctic gateway as exemplars.
    - Part of a proposal for a North Atlantic Carbon observatory”:
    - https://oceanfrontierinstitute.com/ocean-carbon

GAPS

- Lack of **integration and interpretation** actions for the ongoing activities.
- Lack of **sustained funding**, e.g. UK-Caribbean SOOP line, some Spanish observation programs.
- **Geographical gaps:** Substantial regions not well covered by existing activities,
  - central temperate zone,
  - Eastern tropics,
  - upwelling regions of N. African coast.
- **models** do not capture well the trend of rapidly increasing sink for CO_2 seen in observations over the last 25 years in the N. Atlantic.
- **Solutions needed** to validate the BGC-Argo data.
- Inadequate study of **connections** between the surrounding shelf seas and the open North Atlantic

PROPOSAL 1

- **Saildrone or other Autonomous surface vessel (ASV) missions with surface pCO_2 instrumentation, to assess gap-filling techniques and BGC-Argo floats:**



- Validation of SOOP lines, Fixed Ocean stations (PAP)
- Validation of BGC-Argo floats

PROPOSAL 2

- **Dedicated research cruise(s) for validation/ evaluation of techniques**
  - Evaluation of new and existing methods across laboratories, groups
  - “Hunt” BGC floats and conduct co-located detailed hydrography

PROPOSAL 3

- **Observations of transport between the shelf seas and the open North Atlantic**
  - Where does the carbon taken up by the shelf seas go? We don’t know in detail.
  - Into the subsurface North Atlantic?
  - Or maybe deposited on shelf / slopes?
  - Use gliders, ASVs, research sections to map the transport.

PROPOSAL 4

- **Coordination workshop (Spring 2022?)**
  - It will be important to co-ordinate any JPI-sponsored action on the North Atlantic with:
    - G7 FSOI
    - Canadian initiative
    - Other actions in surrounding shelf and marginal seas.

Carbon transformation and turnover in Kattegat-Skagerrak

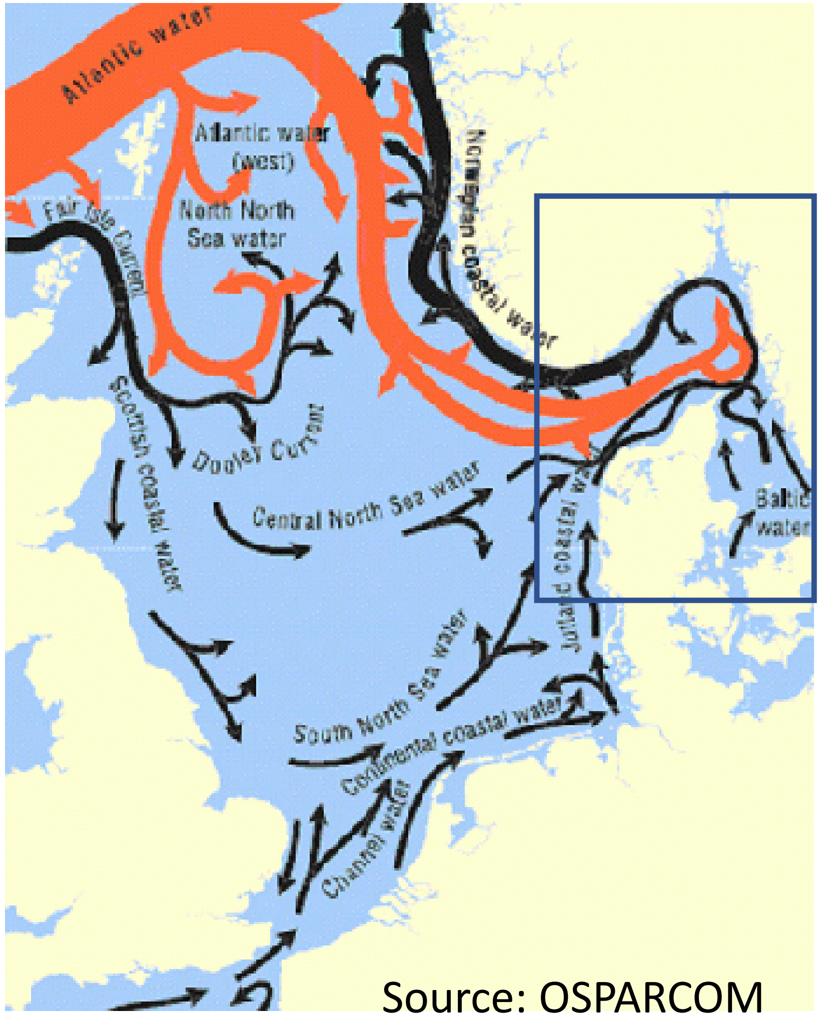
Jun She (DMI) and *Colin A. Stedmon (DTU), Denmark*

Lars Arneborg and Elin Almroth-Rosell (SMHI), Sweden

Richard Sanders (NORCE) and Erik Sandquist (UIB) Norway

Acknowledgement: *an external expert group from DK, NO and SE have contributed*

Study area



Source: OSPARCOM

- An area with very high ecosystem service economic value: blue energy, aqua-farming, fishery, shipping…
- An area with high impact of human pressure: increased algae bloom & hypoxia, reduction of eelgrass….
- An transition (estuary-like) area affected by Baltic outflow, North Sea/N.Atlantic inflow, river discharges with complex carbon sources and sinks

Importance of estuary carbon cycle

- Estuaries represent only 0.3% of the Earth's ocean-covered surface. However, estuaries emit 0.25 Pg C $year^{-1}$ of CO_2 to the atmosphere, roughly equivalent to the amount of CO_2 absorbed by continental shelves, and a similar order of magnitude as the amount of CO_2 absorbed by the open ocean (~1.5 Pg C $year^{-1}$) (Ward et al., 2017)

Facts

- Transport (Fluxes)
  - Baltic outflow:
    - DIC: 5.5TgC/y
    - DOC: 1.7 TgC/y
  - Local rivers:
    - TOC: 0.41 TgC/y
  - Air-sea carbon flux:
    - Skagerrak: 0.45 TgC/y
    - Ksttegat: uncertain
- Seasonal variability and long-term trend
  - Air-sea carbon flux seasonal variability
  - Baltic-Kattegat-Skagerrak areas show less trend than North Sea as an insreasing sink of CO2
  - Increased trend on organic carbon loads in the region, both from terristrial and Baltic
- Coastal water darkening

Transformation of carbon – a multi-scale process

- **Transformation of terrestrial organic carbon (tOC) in estuary-coastal continuum:**
  - High burial rate
  - High C:N ratio
  - Remineralization
  - POC dynamics
  - DOC dynamics: Microbial degradation, photo-oxidation, and dilution (Temperature-dependent processes)
- **Transformation of Baltic organic carbon (bOC) in offshore waters**
  - Low burial rate
  - Low C:N ratio
  - Biological pump
- **Transformation of tOC in offhore waters**

Surface carbon observations (pCO2/fCO2)

SOOP from ICOS, EuroGOOS FB, SOCAT database (new activities planned)

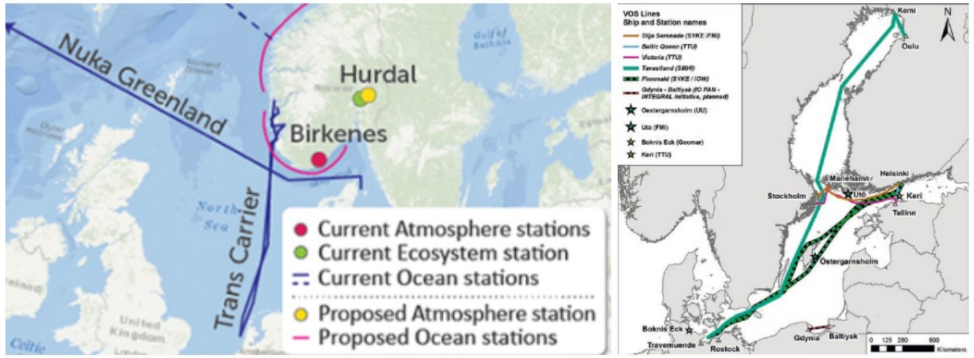
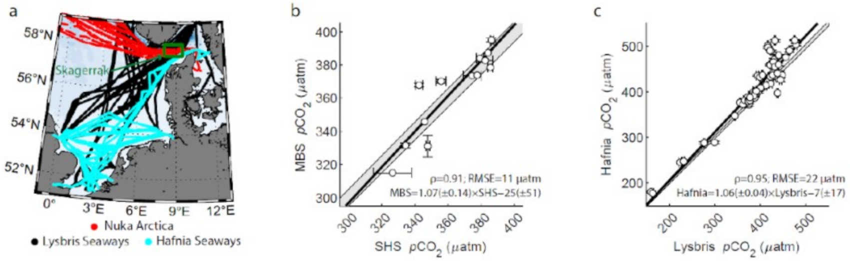
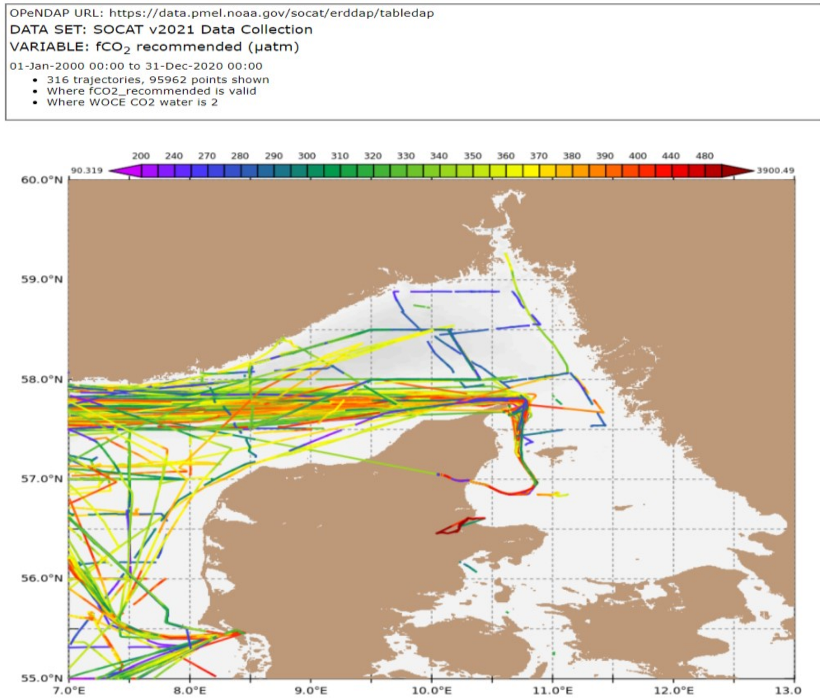


Fig. 2: ICOS SOOP lines in Baltic and North Sea

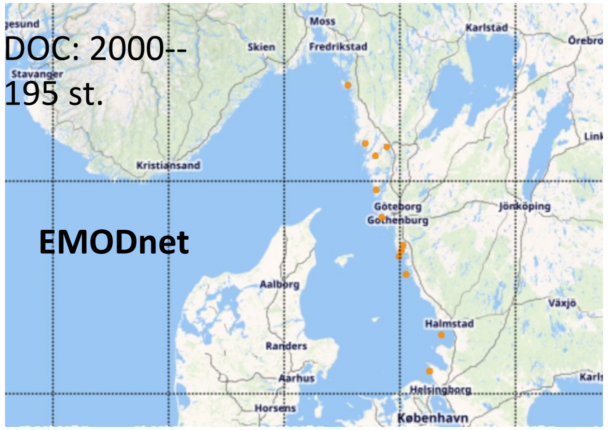


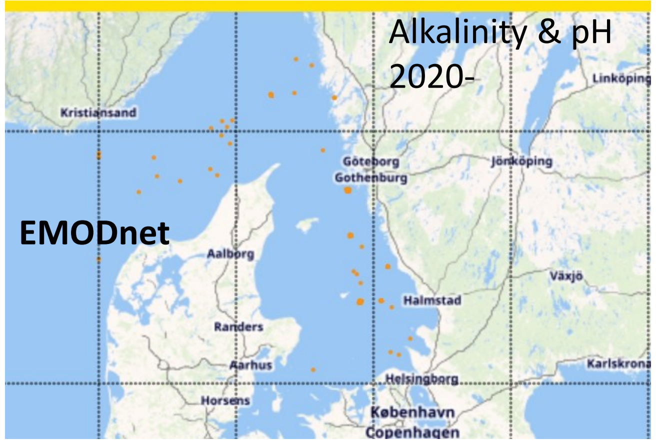
EuroGOOS Ferrybox measurements

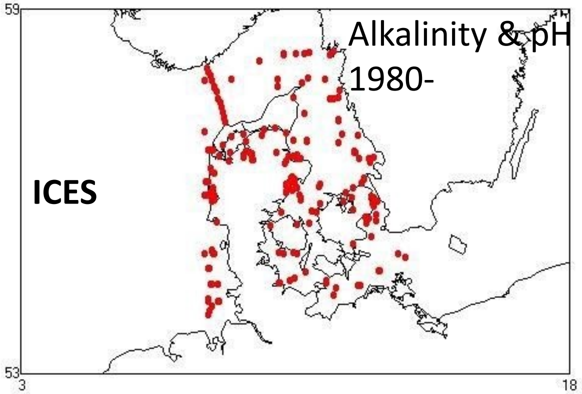


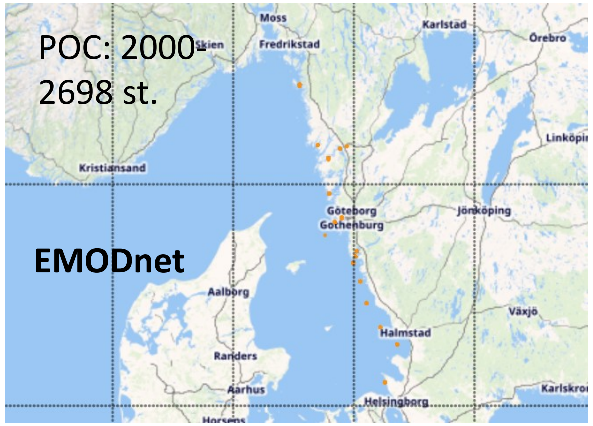
Carbon profile obsercations

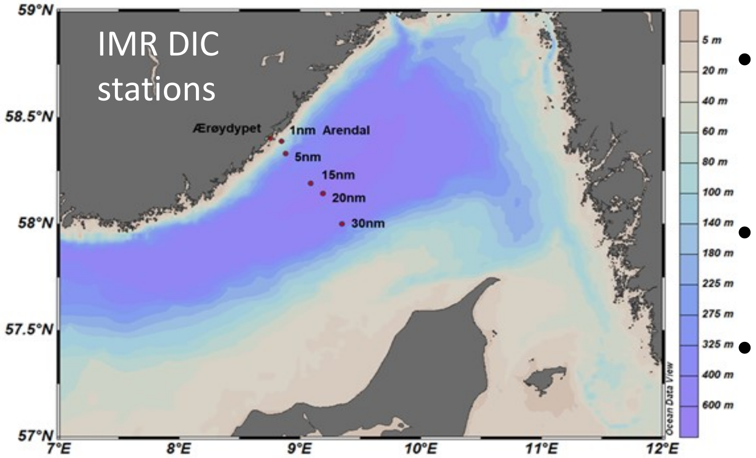
(Alkalinity/pH/DIC/DOC/POC, new activities planned)









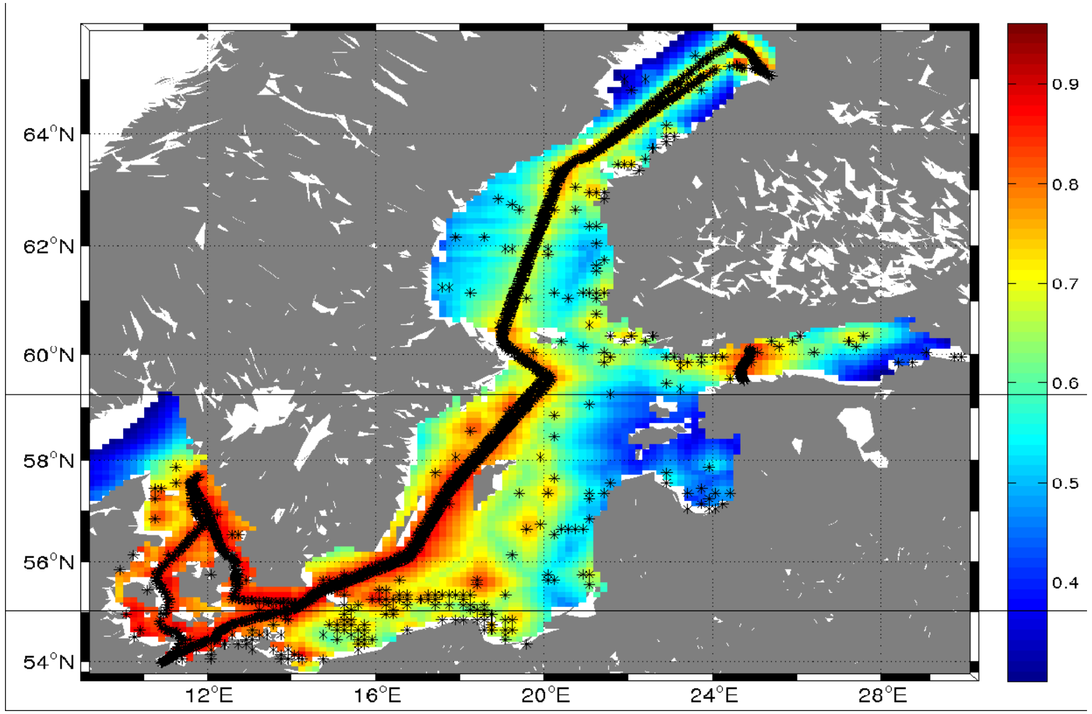


- Data Assembly centres (EMODnet Chemistry, ICES)
- National monitoring programs (DK-NO-SE)
- Other research data

Sampling strategy assessment and optimal design

- Use model as a proxy of observations, quantitative methods for assessing and optimizing observing networks have been developed in EU projects Optimal Design of Observational Networks (ODON), ECOOP, Operational Ecology (OPEC), JERICO and EMODnet CheckPoint.
- Similar methodology may be developed for carbon observations

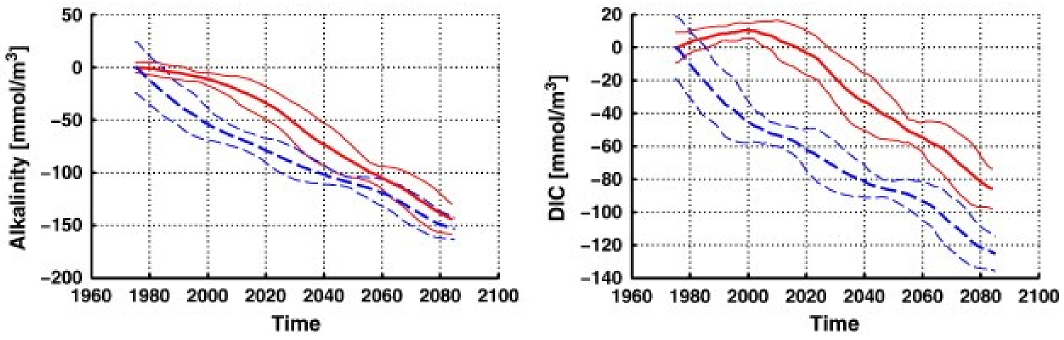
Effective coverage (in %) of chl-a data in the Baltic Sea



Carbon cycle modelling capacities

- **Carbon cycle processe modelling**
  - Kuznetsov and Neumann, 2012: TA & DIC as state variables; pH-pCO2 as diagnostic variables
  - Redtke et al. (2019): closing carbon cycle in the sediment
  - Fransner (2018) did stoichiometric flexible modelling in BFM, found it important for explaning air-sea CO2 flux seasonal variability
- **Modelling systems:**
  - Seamless inland water-estuary-coastal-open sea PHY-model HBM and BGC-model Flexsem
  - Baltic-North Sea model HBM-ERGOM; NEMO-ERGOM, NEMO-SCOBI, NEMO-BFM etc.

- Application examples:
  - Reconstructing the history:
    - ERGOM hindcast run 1961-2007
    - SCOBI/ERGOM reanalysis run 1993-2020
  - Projections
    - ERGOM Climate scenario runs
    - SCOBI climate scenario runs
  - Integrating carbon observations & model data to estimate Baltic net carbon fluxes to the North Sea



Source: Kuznetsov and Neumann, 2012.

Major gaps (non-exclusive)

- **Observation gaps**:
  - more direct pCO2 measurement in Kattegat
  - Vertical carbon flux measurements
  - POC/DOC/DIC profile measurements
  - Significant gas in estuary-coast continuum
- **Monitoring technology gaps**:
  - Tech. for measuring accurate vertical gas transfer coefficient
  - Tech. for measuring vertical carbon flux
- **Modelling gaps**:
  - POC & DOC dynamics in model
  - Seamless modelling for inland-estuary-coast-open sea carbon cycle
- **Knowledge gaps**:
  - Transformation and transportation processes in estuary-coast continuum are not clear
  - The seasonality and trend identified in air-sea CO2 fluxes, carbon sources and fluxes have not been explained
  - How different carbon sources (eg tOC, aged bOC) affect the CO2 sinks and sources, bacterial versus the primary production, biological pumping etc?
  - Processes related to vertical flux and bio-transformation esp. organic carbon related, are not clear.
  - Reasons and consequences of coastal water darkening
  - Impact of a warming ocean on key carbon cycle processes

Proposed activities

- *Small scale project on synergy analysis (~300 K€):*
  - *coordinate and integrate existing carbon observing networks*
  - *establish a common carbon database and identify data needs and gaps.*
  - *synergy analysis should quantify specific processes that are currently poorly resolved*

Proposed activities Cont.

- *Medium scale project on process study (~1.5M€):*
  - ***Focus**: filling knowledge gaps in some of the poorly resolved key processes in the carbon cycle by using an **integrated monitoring-modelling approach**.*
  - ***Process study**:*
    - *bioavailability, mixotrophy, quantifying carbon flux in estuary-coastal-open sea continuum especially vertical fluxes related to mineralization and sediment carbon burial.*
    - *Multi-disciplinary Supersite monitoring in the water and sediment will be dedicated to observe the targeted processes.*
    - *The carbon modelling capacity will be improved with using new observations and to improve our understanding on the full 3D picture of the carbon cycle.*

Proposed activities Cont.

- *Large scale project on regional carbon budget and transformation (~5M€):*
  - ***Rational**: this would cover large scale transformational investments which not only coordinate existing observation programs but with quantitative assessment and optimal design, integrate with modelling to help deliver regional carbon budgets for the present state as well as for scenarios of future change with considering mitigation measures and climate change.*
  - *Multiple carbon sinks/sources should be quantified for improved management measures in spatial planning and nutrient load management.*
  - *Impacts of the Kattegat-Skagerrak carbon cycle on the surrounding sea basins should be better understood.*
  - *These activities should be integrative with respect to knowledge generation and monitoring/modelling technology improvement but also to education (e.g. PhD School), management and outreach.*

Expected impact:

- *Improved understanding of* ***coastal/shelf carbon cycle*** *and its contribution to global carbon cycle*
- ***Filling key knowledge gaps in regional carbon cycle****, e.g., physical-biogeochemical coupling processes in in-land- water-estuary-coastal-open sea carbon exchange, organic carbon remineralization and vertical carbon flux quantification, impact of Baltic outflow in the regional carbon cycle.*
- ***Improved monitoring and modelling capacities*** *on organic and inorganic carbon cycle in coastal-estuary continuum, vertical carbon fluxes and carbon sedimentation*
- ***Improved carbon data management and fit-for-the-purpose monitoring network optimal design***
- *Improved knowledge and assessment on* ***national and regional carbon budgets****: air-sea CO_2 flux, blue carbon, Baltic carbon outflow, organic and inorganic carbon budget*
- *Contribution to* ***improved management measures*** *for e.g., nutrient load and eutrophication by resolving and quantifying how anthropogenic activities influence potential carbon sequestration by natural systems.*
- *Contribute to regional MPA network design by identifying environment and habitat areas with significant carbon sinks and correspondent management measures*
- *Contribute to international cooperation as a regional/national contribution to the UN Ocean Decade*

Thank you

North West Europe Seas Action
Carbon Observations

Gkritzalis T.[1]
Bakker D.C.E.[2], Becker M.[3], Berx B.[4],
Diaz P.[4], Findley H.S.[5], Greenwood N.[6], Hartman S.[7],
Helmuth T.[8], Humphreys M.[9], Kitidis V.[5], Macovei V.[8],
Mcintosh K.[4], Palmer M.[7], Ribas-Ribas M.[10], Schuster U.[11],
Shutler J.D.[11],Steinhof T.[12,13], van Dam B.[8], Voynova Y.G.[8] ,
McGovern E., Cronin M.

UK: [7]NOC, [5]PML, [2]UEA, [4]Marine Scotland, [11]UExeter, [6]CEFAS

NL: [9]NIOZ

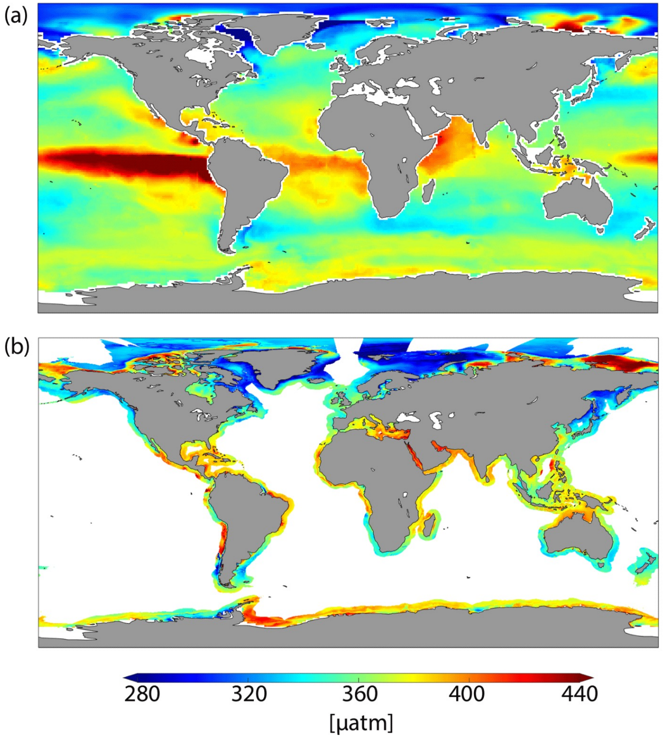
DE: [8]HEREON, [12]GEOMAR, [10]Universität Oldenburg (ICBM)

NO: [3]UiB, [13]NORCE

BE: [1]VLIZ

IRL: MI

Why the Coast?



pCO_2 conc. a: Open Ocean, b: coast
Landschützer et al., 2020

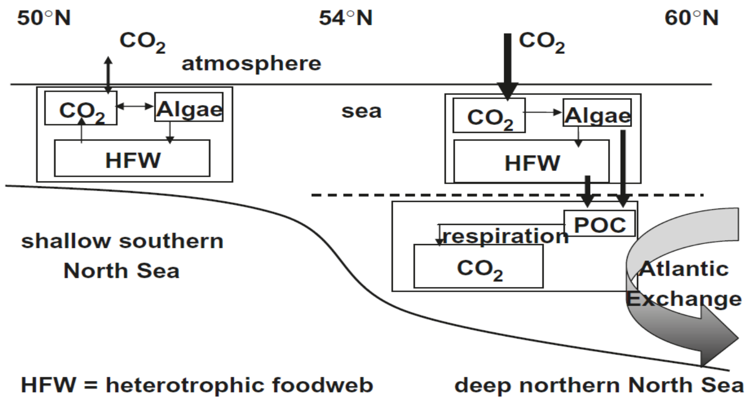
- $\Delta pCO_{2\ \mathrm{ampl.}}$ and F/m^2 much larger than open ocean (spatial – temporal) (Thomas et al., 2004, Laruelle et al., 2010)

- 14– 30 % of ocean primary productivity (Gattuso, et al., 1998)

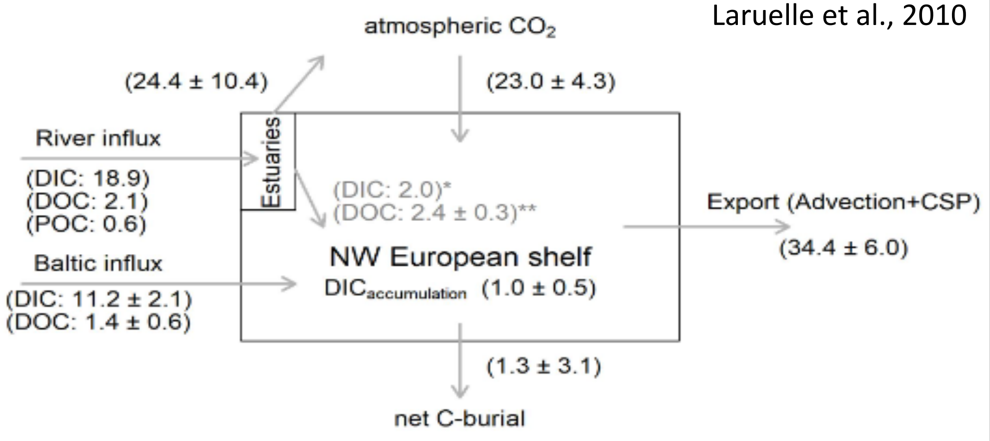
Why the North West Seas (North Sea, Irish Sea, Celtic Sea) Action?

Experience & Tools

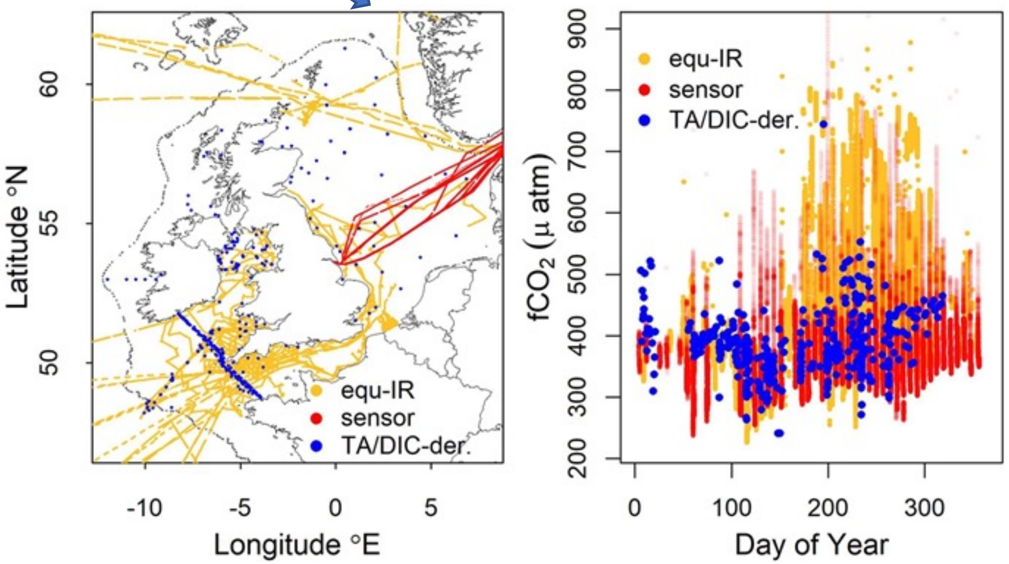
10% of Global
(-0.22 ± 1 Gt/y)
Laruelle et al., 2010



Thomas et al., 2004

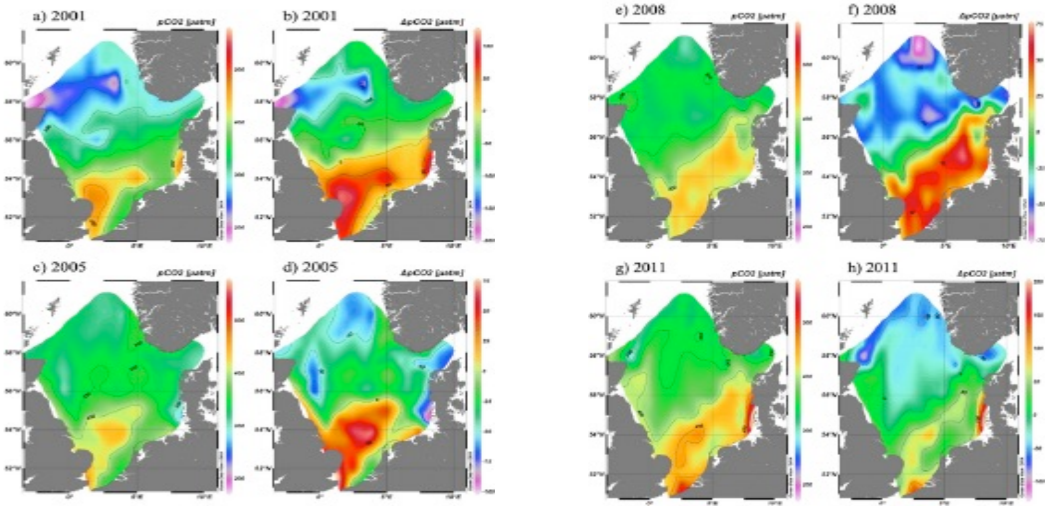


Kitidis et al. 2019 (units are TgC/y)

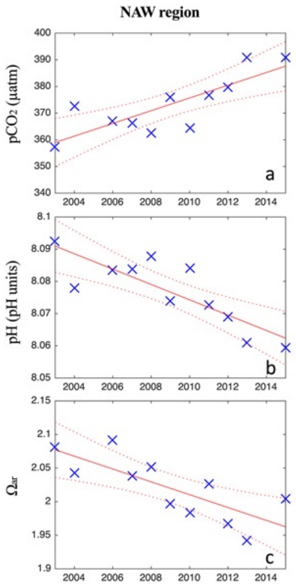


Why the North West Seas (North Sea, Irish Sea, Celtic Sea) Action?

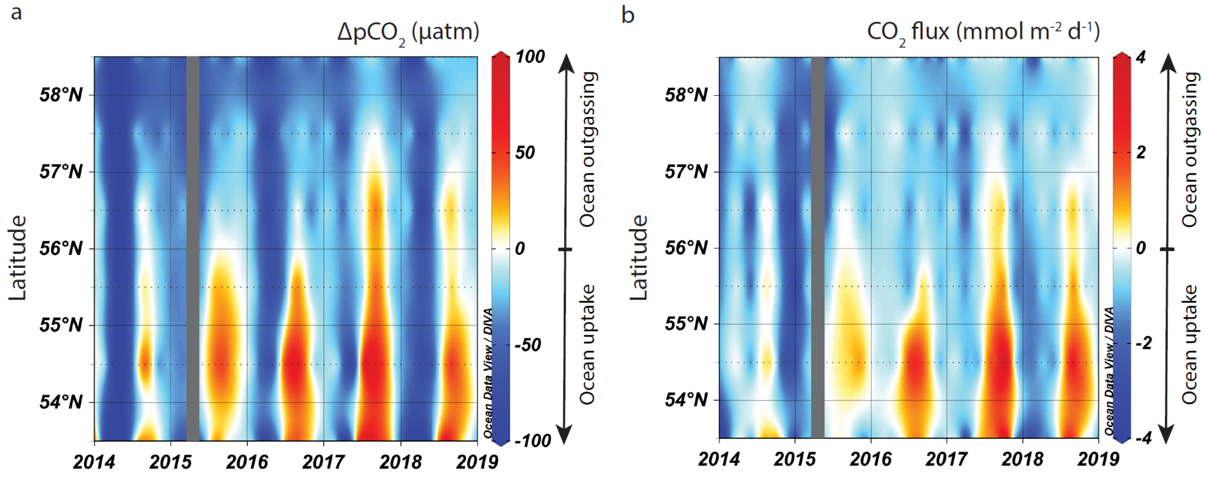
pCO2 and C-chemistry trends



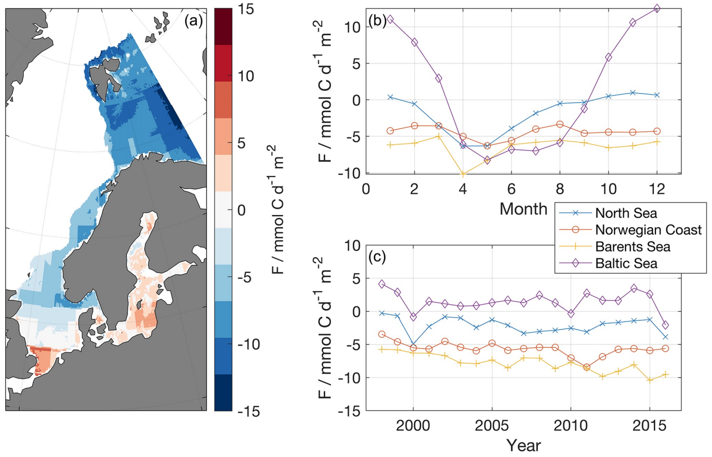
Clargo et al., 2015



Omar et al., 2021

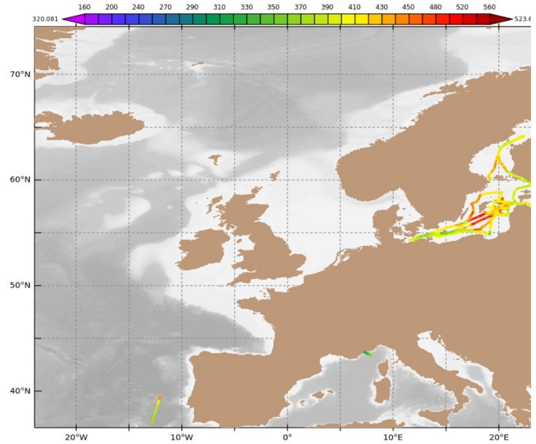


Macovei et al., 2021

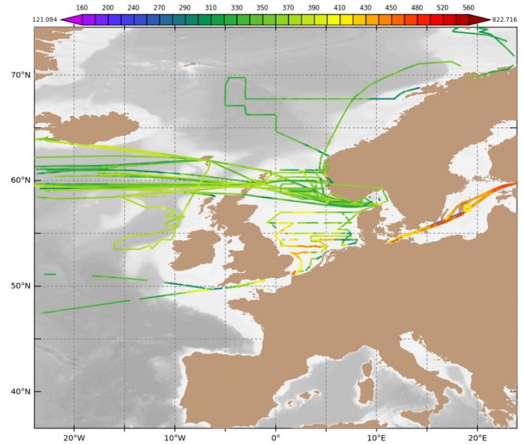


Becker et al., 2021

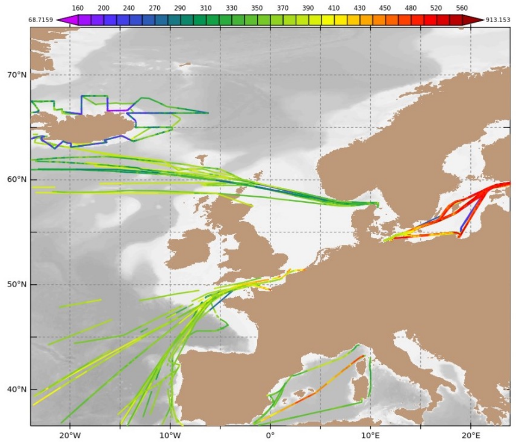
NWS Data through time (SOCAT)



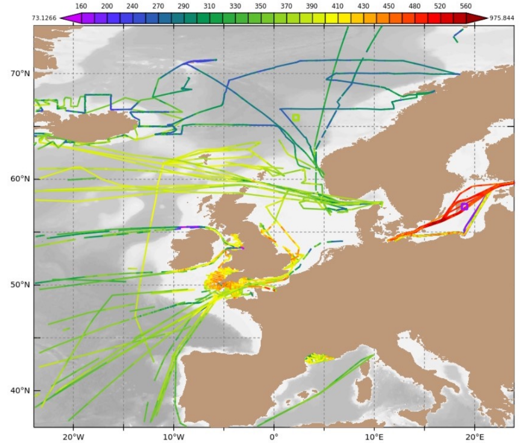
2000



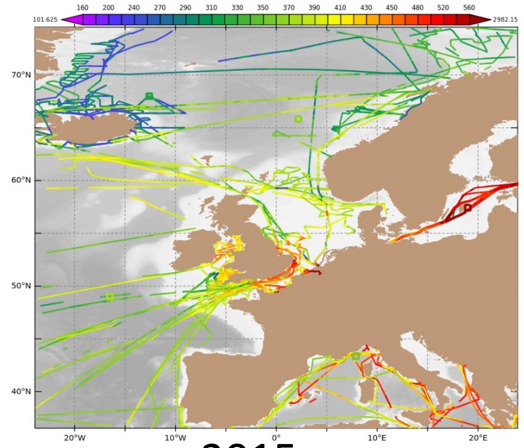
2005



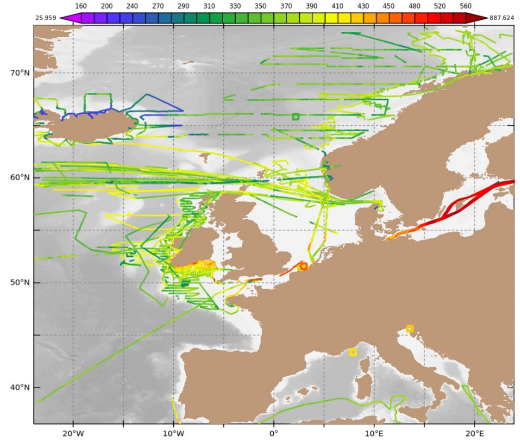
2010



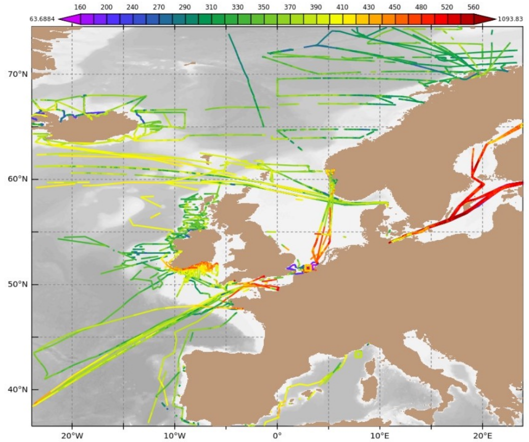
2012



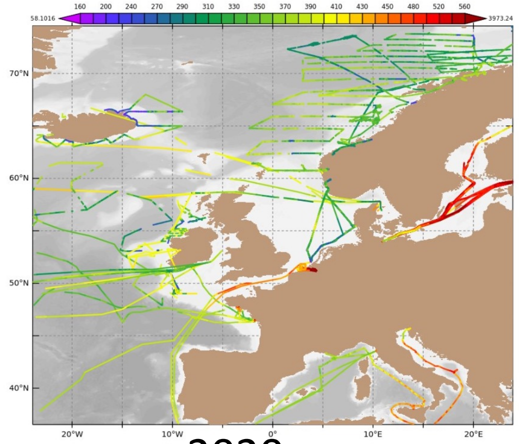
2015



2018



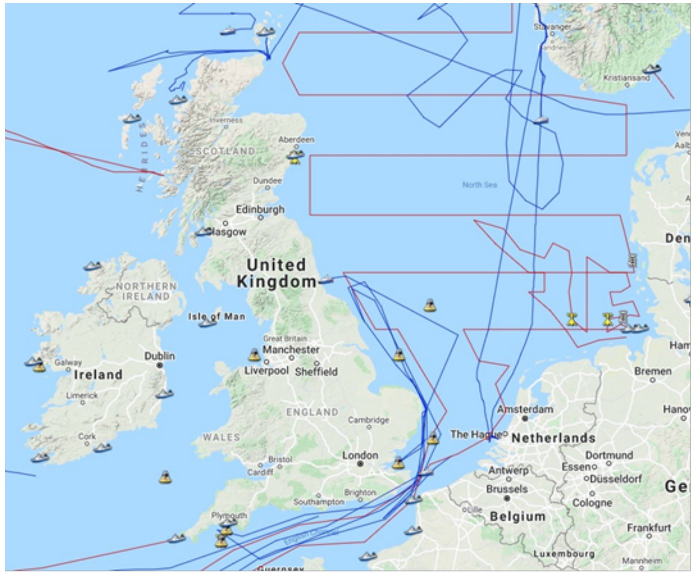
2019



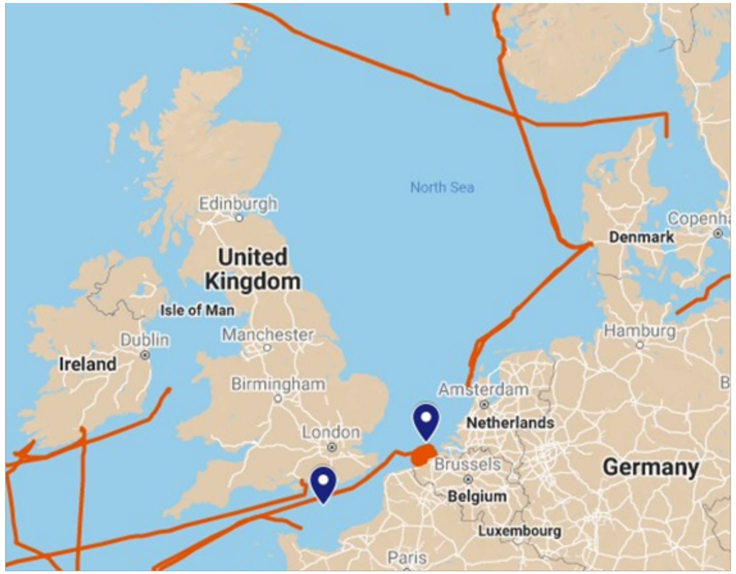
2020

Coverage is generally improving.
2020… ?

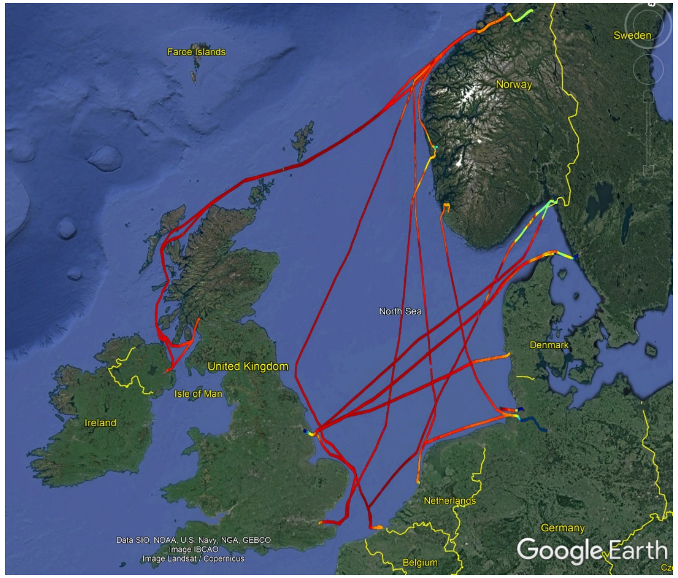
Capacity



GOA-ON Global Ocean Acidification Observing Network



ICOS Ocean Thematic Centre



FerryBox

ACTRIS AnaEE ARISE AQUACOSM DANUBIUS-RI DISSCO EISCAT elixir eLTER EMBRC EMPHASIS emso ERIC EPOS EUFAR
Euro Argo EUROCHAMP 2020 Eurofleets+ EuroGOOS HEMERA IAGOS ICOS INTERACT is-enes JERICO LifeWatch ERIC SeaDataNet SIOS

esa

NWS Action suggestions

- Is Existing Capacity adequate to provide the info required?

<u>Enhanced Support & commitment</u>

- Coordination & Network Design **<u>(Low)</u>**
- New targeted campaigns using available capacity and invest in people (PIs – pDocs – PhDs – Eng/Tech). Improve Data flow and Modelling capacity **<u>(Mid)</u>**
- Gap filling (observations, technology, personnel) **<u>(Significant)</u>**

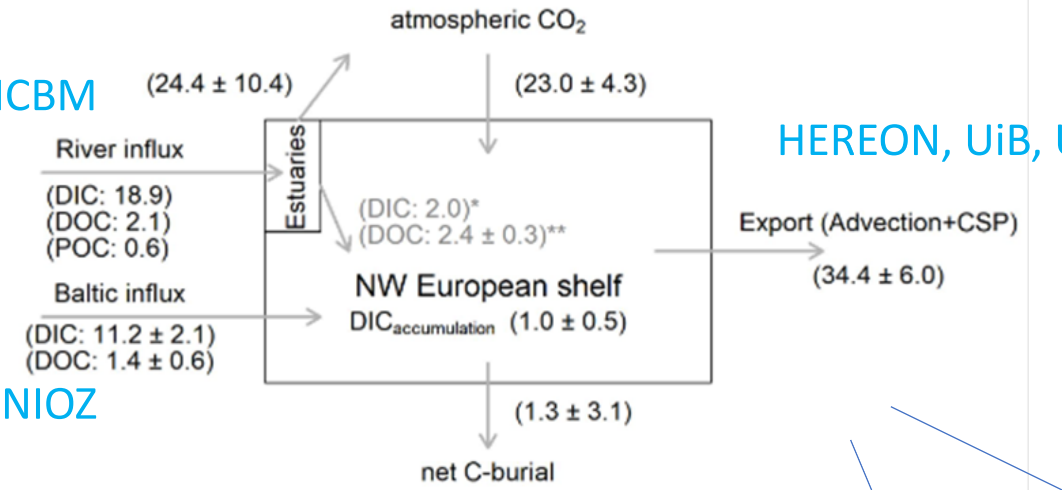
Proposed action and potential capability

All partners (UEA, UEx, UiB strong data/modelling capacity)

Flux-engine

MS, UiB, VLIZ, PML, ICBM

HEREON, UiB, UEx., MI, GEOMAR, NOC,



UiB, ICBM, HEREON, NIOZ

MS, CEFAS, ICBM

Links with Fisheries:
CEFAS, MS

OA: PML, NIOZ, UiB, HEREON, MS

Technology: NOC

Expected Impact

Ocean Acidification

Carbon Sink (mitigation efficiency) → National Policy and Actions

Eutrophication

Fisheries

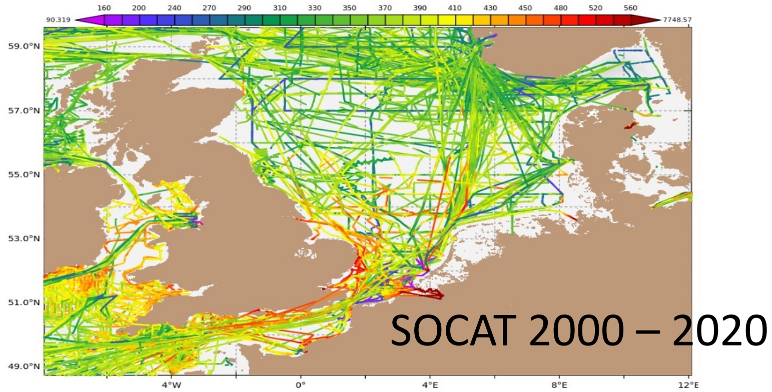
OSPAR COMMISSION

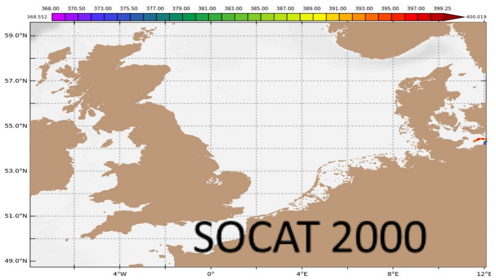
14 LIFE BELOW WATER

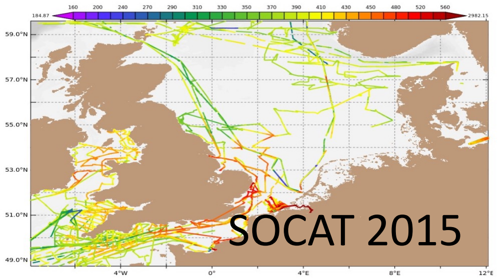
United Nations Climate Change

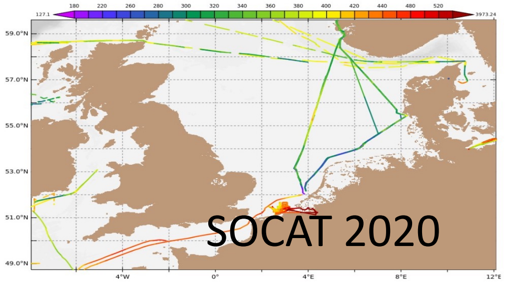
Challenges & Risks

- Time Series pCO_2 record in order to detect trends: 12 years (Keller et al. 2014)
- Depict trends from decadal variability : 25 years (McKinnley et al. 2011)
- Intermittent – non adequate funding







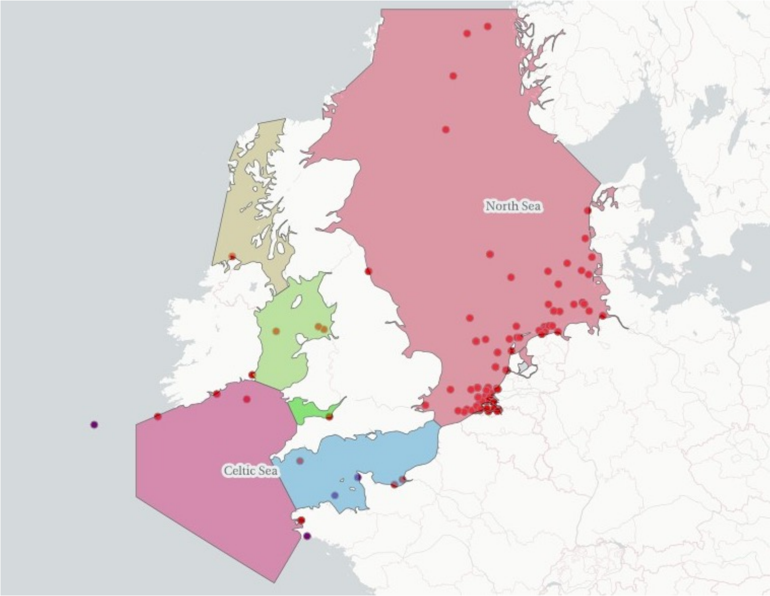


?

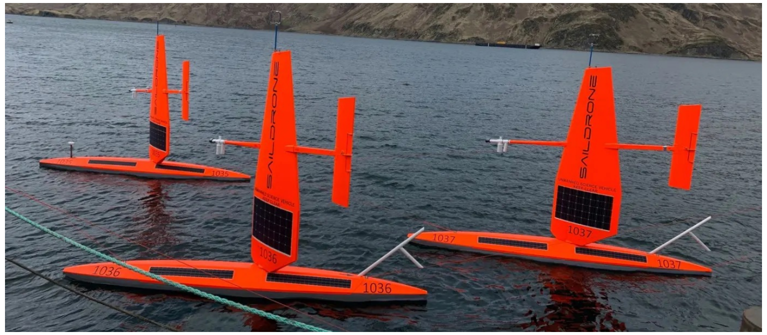
Strengths & opportunities

- Experience
- New technology is available
  - In situ platforms
  - Unmanned vehicles
  - Satellites
  - Modelling – NN – AI
- Upscaling – Global impact on coastal c-fluxes research
- Translation into policy

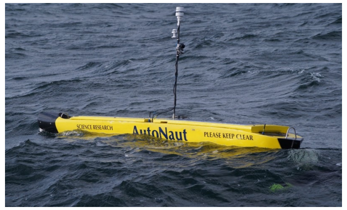
Prospects



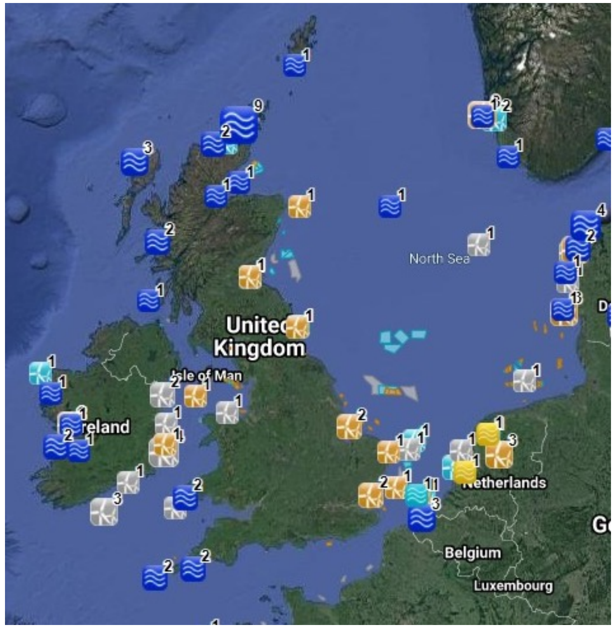
EMODNet Physics
107 Moorings – Gliders – Drifter over the past year



VLIZ (MRC)



Uni. Exeter (CaPASOS)



EMODNet Human activities

Link with other JPI Oceans C initiatives

- Link with other actions within this initiative
  - Baltic/Skagerak
  - North Atlantic

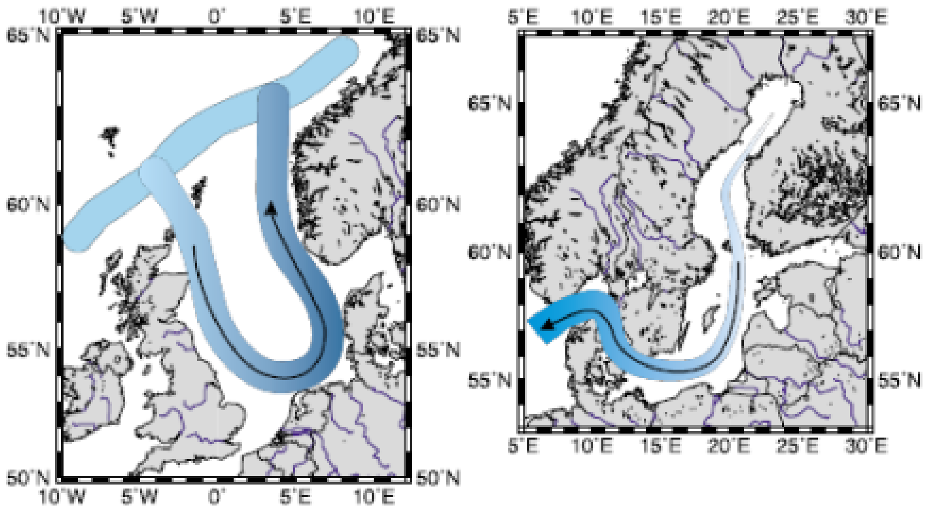
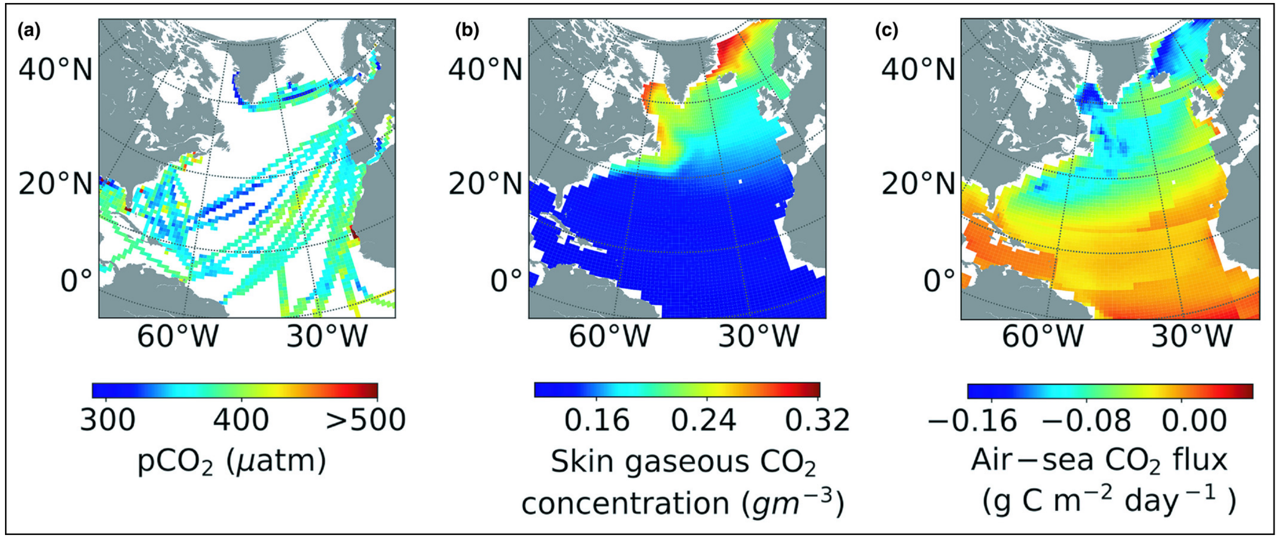


Fig. 5. Different operational modes of the continental shelf pump: the bypass pump in the North Sea (a) and the injection pump in the Baltic Sea (b).



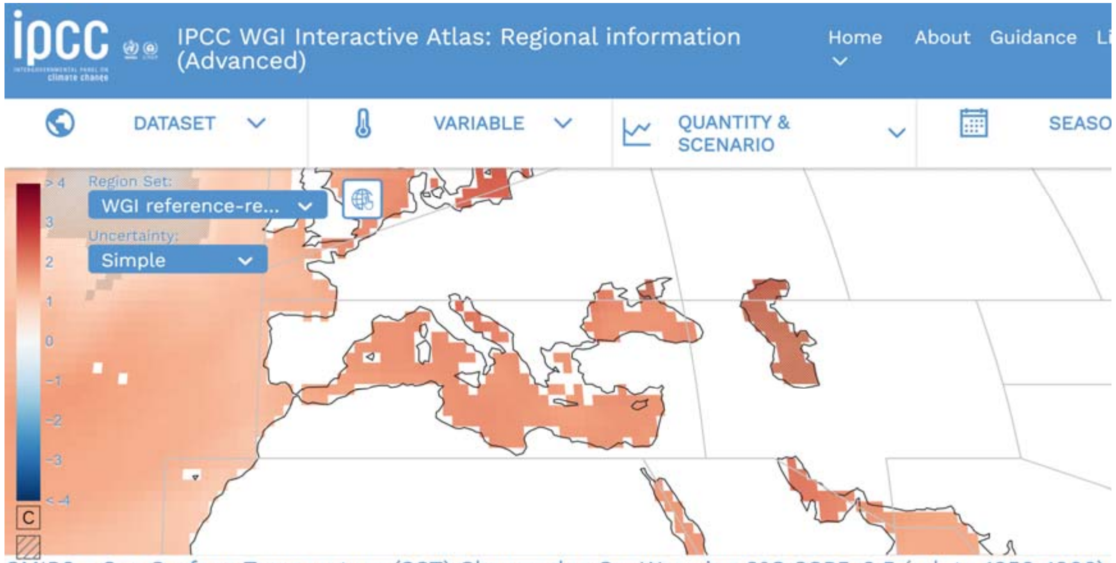
Observations and satellites in North Atlantic

Thomas et al. 2005

Shutler et al., 2020

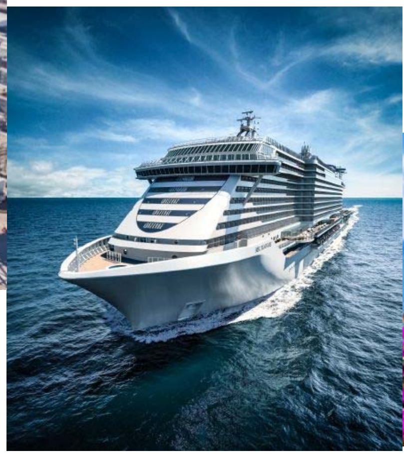

THANK YOU!!

The Mediterranean Sea



CMIP6 - Sea Surface Temperature (SST) Change deg C - Warming 2°C SSP5-8.5 (rel. to 1850-1900)

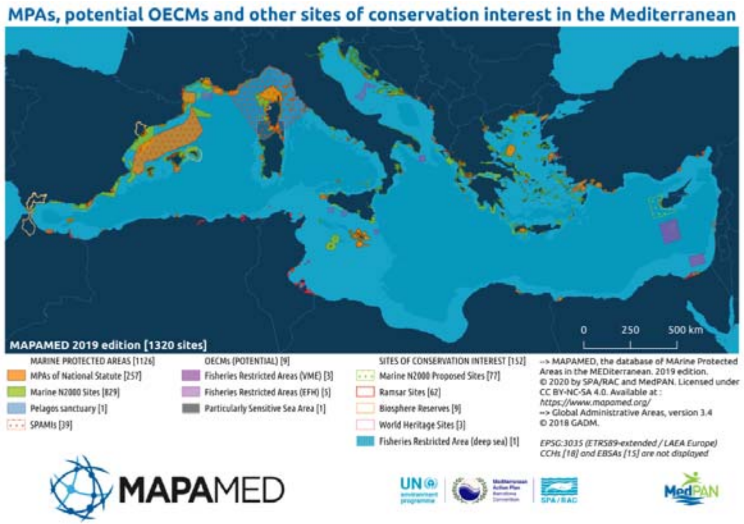
A hot spot of climate change: temperature increase, reduction of precipitations and extreme (and recurrent) events.

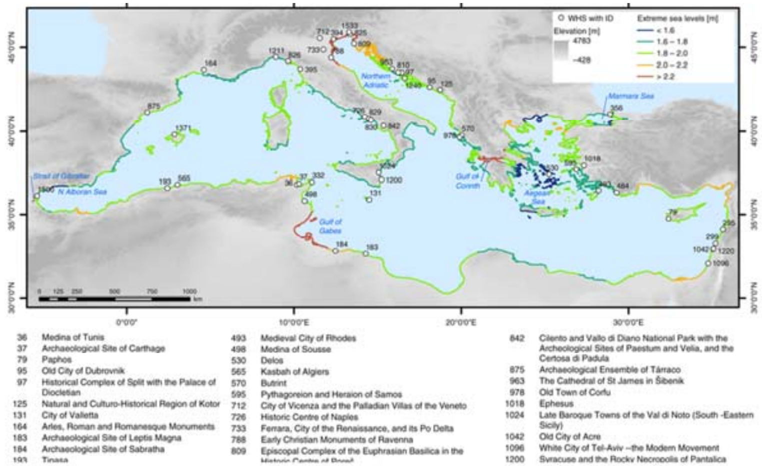


It hosts 30 % of global tourism and it is crossed by 25 % of global sea borne trades by volume and ¼ by oil traffic (450 ports and terminals, 2nd largest market for cruise ships)

Cultural diversity and geopolitical complexity: safety and security issues, coastal pressures and resources exploitation

Unique biodiversity: 400 UNESCO sites and 236 Marine Protected Areas

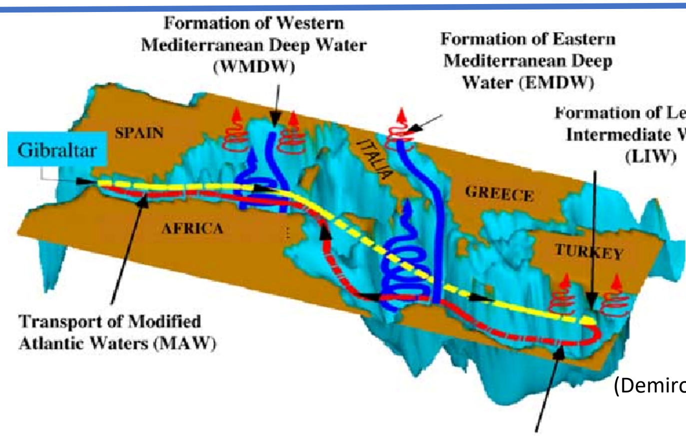




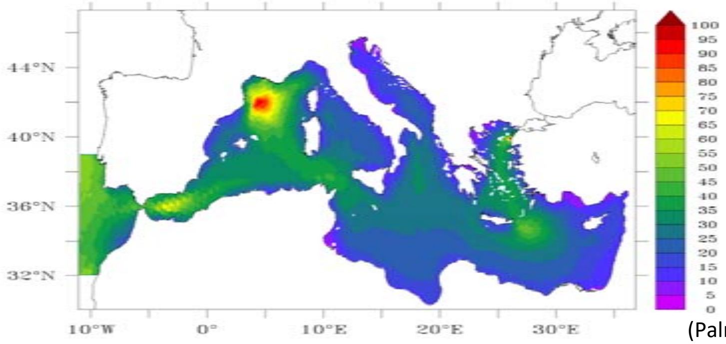
It is the only basin away from polar regions where open-ocean deep convection reaching the ocean bottom happens, despite its location in temperate latitudes.

It has been identified as an important region for anthropogenic carbon (C_{ANT}) storage where the column inventory can be much higher than in the Atlantic or Pacific oceans.

It is experiencing ocean acidification, even detectable in deep water masses, with major impact on biodiversity in iconic Mediterranean ecosystems



(Demirov & Pinardi 2007)

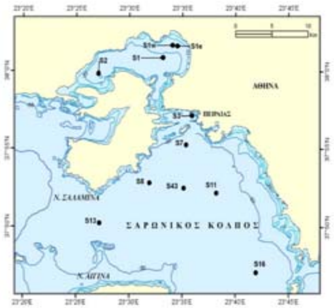


(Palmieri et al., 2015)

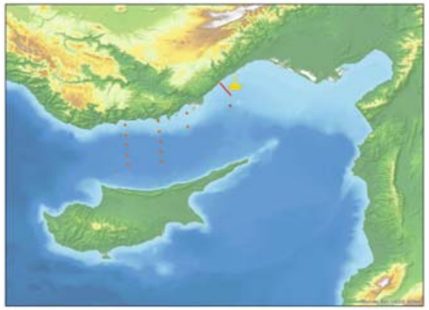
Existing OCC activities in the MedSea

Eastern Mediterranean

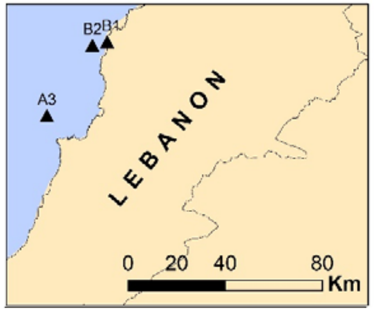
Greece

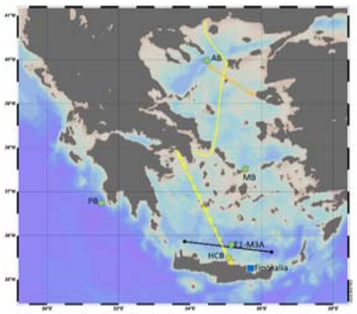


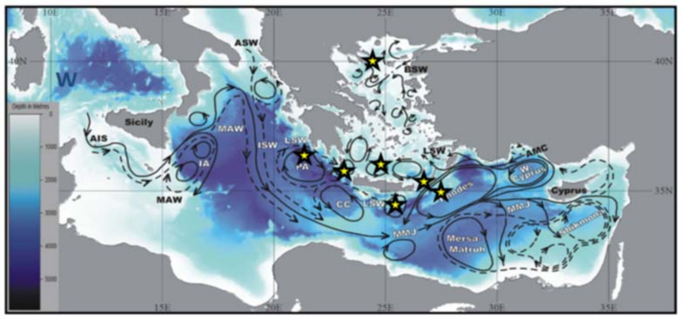
Turkey



Lebanon



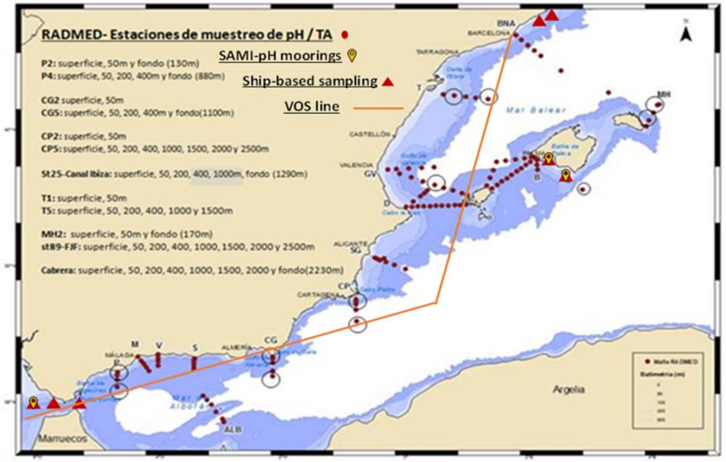




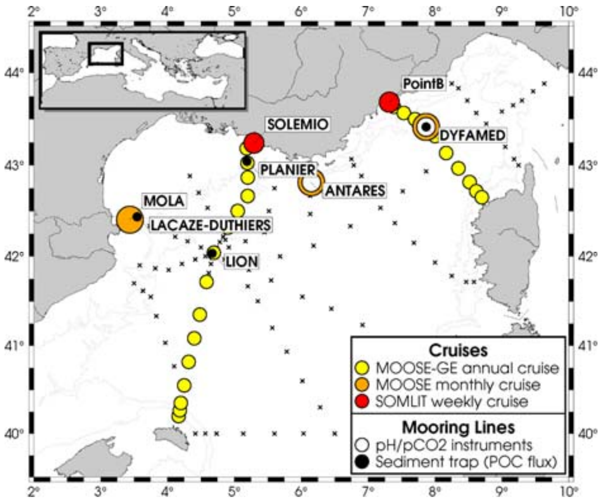
Existing OCC activities in the MedSea

Western Mediterranean

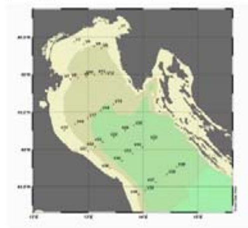
Spain



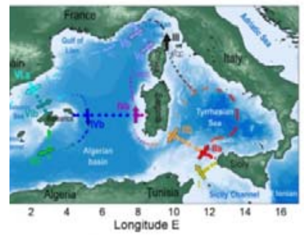
France



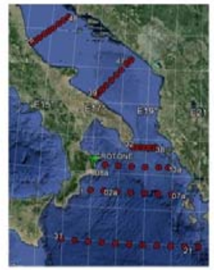
Italy



North and central Adriatic basins



Western basins

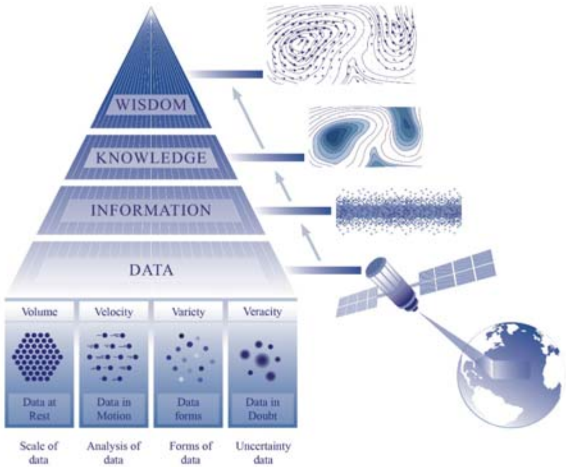


Southern Adriatic and Ionian basins

Western and central basins

ICOS Marine stations
Miramare-OGS
PALOMA-CNR ISMAR
E2M3A-OGS
W1M3A-CNR ISSIA
Atmospheric & marine station
Lampedusa –ENEA

GAPS



Knowledge:

Lack of support and underpinning actions, integration and interpretation of the ongoing activities. A better coordination will lead to improve the estimation of the C_{ANT} at the scale of the basin and sub-basins and solve the impact of meso and sub-meso scale processes on carbon biogeochemistry

Observations:

Acquisition of CO_2 variables should be expanded in undersampled geographic areas (e.g. central Mediterranean, Turkish and Lebanese seas etc)

Technology:

pH measurements from gliders and Argo floats equipped with pH sensors

Management:

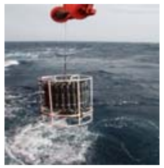
Data treatment (QC procedures) for real-time data acquisition

Products:

Acidification and anthropogenic indicators

IDEAS FOR ACTION



1. To promote capacity building in the Eastern MedSea and Southern regions to increase carbon measurements and to sustain observations. Establishment of a middle-long term advisory program connecting experienced researchers to less experienced researchers and students.

2. To establish common Best Practices and development of European capacity for Certified Material for oceanic CO_2 measurements.

3. Development of new technologies to expand observations in the MedSea (e.g surface unmanned vehicles SAILDRONE type)

4. Joint activities for the validation of data acquired on different platforms, as a key component for near real-time data-validation.

5. Intercalibration exercises.

6. Deep study of the economic impact of OA in the Mediterranean Sea.

Small scale investments

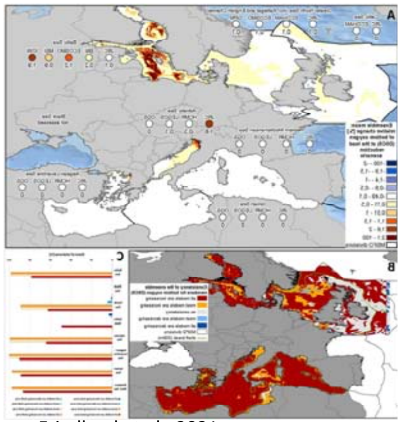
1. To extend sampling programmes or joint PhD studentships.

2. To fill the spatial and temporal gaps by performing repeated surveys with direct measurements of pCO_2 (and derived variables) in key areas and linking different ICOS stations. Surveys may be conducted by individual countries or jointly (e.g. VOS lines connecting different sub-basins and run by the two connected countries). Complemented by intercalibration exercises.

Large scale transformative investments

1. Development of SOOP lines for automated monitoring of Essential Oceanographic variables and CO_2 system supported at trans-national level through the JPI Ocean action in under-sampled areas of the Mediterranean Sea.
2. To promote long term cooperation actions with non-Mediterranean institutions (Black, North and Baltic Seas).
3. To establish a center to produce and provide Certified Reference Material (CRM) at European level and particularly for the MedSea community.
4. To launch a R&D program for funding small scale projects to support observations and projects in the SoUthern Mediterranean.
5. To establish new atmospheric CO_2 oceanic time-series stations.

IMPACT



Friedland et al., 2021

1. Enhancement of international cooperation.
2. Integration of the FOS in the ICOS (Integrated Carbon Observing System) network of stations, giving the capacity to provide accurate data to platforms (e.g Surface Ocean CO_2 Atlas).
3. Coupling between technological advances and remote sensing and instrumentation installed on the SOOP lines.
4. Expanding the capacity building would fill the gaps of knowledge in southern Mediterranean countries.
5. Increasing public awareness on the GHG emissions through the visualization of CO_2/pH measurement on board of passenger cruise ships
6. Knowledge transfer to other fields, including Climate Change studies and impacts on the MedSea
7. Data acquisition will improve the existing models for the basin, and create new models in not well-studied sub-basin, such as the South-Eastern Mediterranean.

INITIATIVES

G7
FUTURE OF THE SEAS & OCEANS INITIATIVE

The United Nations Decade of Ocean Science for Sustainable Development (2021-2030)

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

SUSTAINABLE DEVELOPMENT GOALS

glodap

futurearth
research for global sustainability

GOA-ON
Global Ocean Acidification Observing Network

SOCAT
SURFACE OCEAN CO2 ATLAS

GO-SHIP

Argo

ICOS
INTEGRATED CARBON OBSERVATION SYSTEM

EMODnet
European Marine Observation and Data Network

Copernicus
Europe's eyes on Earth

Copernicus Marine Service

GOOS

EOOS