The Global Ocean Observing System

unesco Intergovernmental Oceanographic Commission

WORLD METEOROLOGICAL ORGANIZATION

UN environment United Nations Environment Programme

International Science Council

Session 3

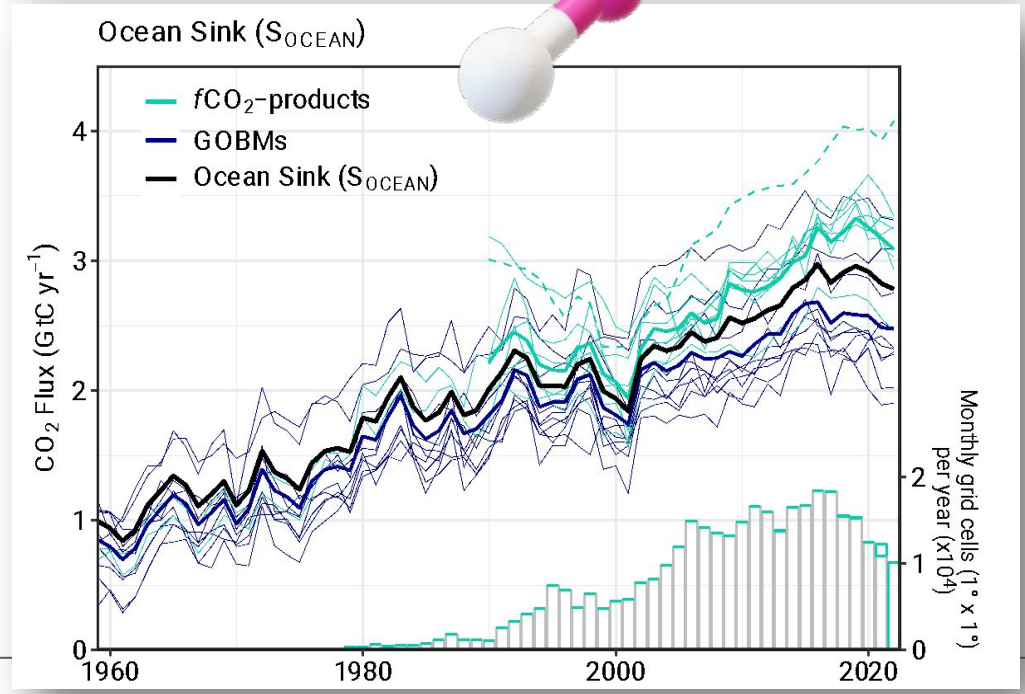
GOOS Carbon (and N_2O) Plan - response to mandates from our sponsors and community

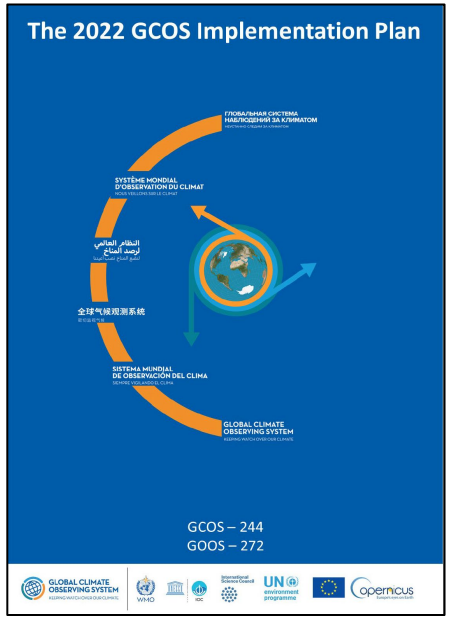
Visionary Discussion Session moderated by
Adrienne Sutton (BGC Panel co-Chair) and Maciej Telszewski (GOOS GMT)

Thirteenth GOOS Steering Committee Meeting [SC-13]
Barcelona 14th-17th April 2024

Goal: *Develop a coherent GOOS-wide Carbon and Nitrous Oxide Plan in response to mandates from our sponsors*

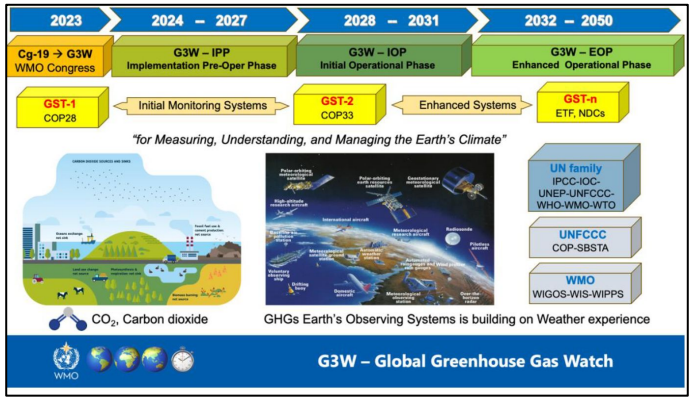
- **Setting the scene: overview of relevant mandates**
  - Unpacking the mandates driving the need for GOOS to have a carbon plan: GCOS IP 2022, WMO G3W IP 2024, IOC IOCR Report 2021
  - Draft zero of the table of content (ToC), mainly focused on general scope
  - Mode of operation (process and activities) and timeline
- **Reaction and input by the GOOS SC (non-exhaustive list)**
  - reaction to the need for such a plan, the proposed way of developing it, timeline and draft ToC
  - balance between focus on research (if any) and services
  - what are the key audiences for such a document
  - what are the key mechanisms that GOOS can target to trigger and/or enable implementation by the Member States
  - Is there a role for the Co-Design Carbon Exemplar in developing or implementing the GOOS Ocean Carbon Plan





GCOS IP 2022

Collects and documents the data needs for monitoring the climate system and for assessing the impacts of climate variability and change. Submitted every 5 years to the United Nations Framework Convention (UNFCCC) and is recognized by the Conference of the Parties (COP).



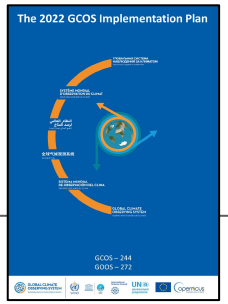
GGGW IP 2024

GGGW provides an integrated, operational framework in relation to GHG monitoring, striving to reduce the uncertainty in assessing the efficacy of climate action. Approved by WMO Congress and recognized by SBSTA59 at COP28. IP Requested by WMO Congress to allow Member States to facilitate actions required in 2024-2027

IOC IOCR WG 2021

The IOC-R addresses key issues in ocean carbon research through a combined strategy of investigative and observational goals around changing ocean carbon sink and impact that increasing CO2 levels have on ocean ecosystems. Reports to SBSTA and IOC Member States.

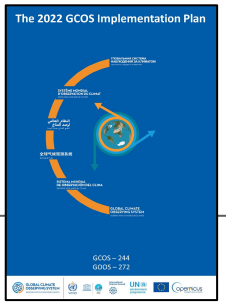
Theme	Actions	Implementing Bodies											
		WMO	NMHS	Space agencies	GOOS	Reanalysis Centers	Global Data Centers	Research organizations	National Agencies	Parties to UNFCCC	Academia	Funding Agencies	GCOS
A: ENSURING SUSTAINABILITY	A1. Ensure necessary levels of long-term funding support for in situ networks, from observations to data delivery	x	x					x			x	x	x
	A2. Address gaps in satellite observations likely to occur in the near future			x									
	A3. Prepare follow-on plans for critical satellite missions			x									
B: FILLING DATA GAPS	B1. Development of reference networks (in situ and satellite Fiducial Reference Measurement (FRM) programs)	x	x	x				x				x	x
	B2. Development and implementation of the Global Basic Observing Network (GBON)	x	x		x								x
	B3. New Earth observing satellite missions to fill gaps in the observing systems			x									
	B4. Expand surface and in situ monitoring of trace gas composition and aerosol properties		x					x	x			x	
	B5. Implementing global hydrological networks	x	x	x			x						
	B6. Expand and build a fully integrated global ocean observing system		x	x	x			x	x		x		
	B7. Augmenting ship-based hydrography and fixed-point observations with biological and biogeochemical parameters				x			x					
	B8. Coordinate observations and data product development for ocean CO_2 and N_2O	x			x			x	x				
	B9. Improve estimates of latent and sensible heat fluxes and wind stress		x	x	x			x			x		
	B10. Identify gaps in the climate observing system to monitor the global energy, water and carbon cycles							x				x	x
C: IMPROVING DATA QUALITY, AVAILABILITY AND UTILITY, INCLUDING REPROCESSING	C1. Develop monitoring standards, guidance and best practices for each ECV	x		x	x								x
	C2. General improvements to satellite data processing methods			x				x			x		
	C3. General improvements to in situ data products for all ECVs		x					x			x		
	C4. New and improved reanalysis products			x		x					x		
	C5. ECV-specific satellite data processing method improvements			x		x							
D: MANAGING DATA	D1. Define governance and requirements for Global Climate Data Centres	x					x						x
	D2. Ensure Global Data Centres exist for all in situ observations of ECVs	x	x		x				x			x	x
	D3. Improving discovery and access to data and metadata in Global Data Centres						x					x	x
	D4. Create a facility to access co-located in situ cal/val observations and satellite data for quality assurance of satellite products	x	x	x				x					
	D5. Undertake additional in situ data rescue activities	x	x							x		x	x
E: ENGAGING WITH COUNTRIES	E1. Foster regional engagement in GCOS	x			x					x			x
	E2. Promote national engagement in GCOS		x							x	x		x
	E3. Enhance support to national climate observations									x		x	x
F: OTHER EMERGING NEEDS	F1. Responding to user needs for higher resolution, real time data	x	x	x				x			x		x
	F2. Improved ECV satellite observations in polar regions			x				x			x		
	F3. Improve monitoring of coastal and Exclusive Economic Zones		x	x	x			x			x		
	F4. Improve climate monitoring of urban areas	x	x					x	x		x		x
	F5. Develop an Integrated Operational Global GHG Monitoring System	x		x				x	x		x		x



Action B8: Coordinate observations and data product development for ocean CO_2 and N_2O	
Activities	1. Develop a strategy and implementation plan to operationalize the data production and delivery of surface ocean CO_2 information. 2. Coordinate the existing nitrous oxide (N_2O) ocean observations into a harmonised network.

Action D2: Ensure Global Climate Data Centres exist for all in situ observations of ECVs	
Activities	1. Identify ECVs for which adequate global centres do not exist or are insufficiently supported and facilitate and support the creation or improvement of global data centres for these ECVs. 2. Promote regional data centres, their interoperability, where possible, synchronisation of their data holdings, and the provision of data in their archives to global data centres.

Action F5: Develop an Integrated Operational Global GHG Monitoring System	
Activities	The overall aim here is to develop an integrated operational global greenhouse gas monitoring infrastructure. The first steps are: 1. Design and start to implement a comprehensive global set of surface-based observations of CO_2, CH_4 and N_2O concentrations routinely exchanged in near-real time suitable for monitoring GHG fluxes.



Action O1: Create an exhaustive inventory of existing surface based GHGs measurements.

Action O3: Develop a roadmap for longer-term GHG observing activities.

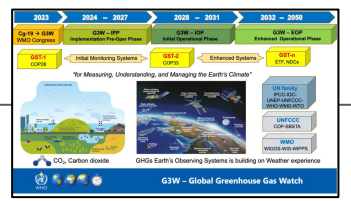
Action O8: Formalize and enhance a sustained surface ocean CO_2 observational network.

Action O9: Deliver routine global gridded products of air-sea CO_2 flux.

Action D2: Data management life cycle stage 2; Getting observational data from providers to operational centres for assimilation

The activities under this action include:

- Define architecture and systems needed to find, access and transfer quality-controlled data from providers to model ingest using FAIR principles in an optimized and automated manner.
- Define a list of targeted contributing observational datasets (timeliness, quality flag) from each domain (atmospheric GHG, SOCAT, satellite...) from the measurement sites or regional centres.
- Determine applicability, deficiencies and any needed improvements to WIS2.0 to provide means of data discovery and transport for an optimized model input data aggregation system.



Section 3 Observing System – O (12)

- O1 – Observation inventory *(O2-O9, M4, M7, P1-P3, D2, R3)**
- O2 – Obs. standards & requirement *(O1, O3-O9, M4, D1, D2, R2)*
- O3 – Longer term Obs. *(O1, O2, O6, R2)*
- O4 – Surface-based Obs. design *(O1, O2, O6, O8, O9, M1, M3, P1-P3, R2)*
- O5 – Reference Network Development *(O1, O2, O7, M7, D1, D2)*
- O6 – Basic ("fit-for-purpose") network *(O1-O4, D1, D2)*
- O7 – RS & vertically-resolved Obs. *(O1, O2, O5, M7)*
- O8 – Ocean network design *(O1, O2, O4, O12, M3, D1, D2)*
- O9 – Gridded Air-Sea CO_2 flux *(O1, O2, O4, P1-P3, D1, D2)*
- O10 – Space-based Obs. with CEOS-CGMS, direct *(O11, O12, M3, M4, M7, P1-P3, D2, D4, R2, R3)*
- O11 – Space-based Obs. with CEOS-CGMS, indirect *(O10, O12, M4, M5, M7, P1-P4, D4, D5, R2, R3)*
- O12 – Space-based Obs. with CEOS-CGMS, future *(O8, O10, O11, M4, M5, M7, P1-P3, D4, R2, R3)*

Section 4 Modelling System– M (7)

- M1 – Modelling center & data *(M2-M7, O4, D3, D4)*
- M2 – Modelling center-documentation *(M1, M6, D3)*
- M3 – Continuous Operations (RRR) *(O4, O8, O10, M1, D2-D4, R2, R3, U2, U4)*
- M4 – Obs. acquisition and pre-processing *(O1, O2, O10 -O12, M1, D2, D4, R2)*
- M5 – Prior Implementation *(M1, O11, O12, P1-P4, D5-D7, R2, R3)*
- M6 – Production centers common approaches *(M1, M2, D3, D4, U1, U2, U4)*
- M7 – Modelling products Evaluation *(O1, O5, O7, O10-O12, M1, D2, D3, D5, R3, U1-U4)*

Section 5 Prior Information – P (4)

- P1 – Identify needs – CO_2 *(O1, O4, O9-O12, M5, D5-D7, R2, R3)*
- P2 – Identify needs – CH_4 *(O1, O4, O9-O12, M5, D5-D7, R2, R3)*
- P3 – Identify needs – N_2O *(O1, O4, O9-O12, M5, D5-D7, R2, R3)*
- P4 – Fluxes characterization *(O11, M5, D5-D7, R2, R3)*

Section 6 Data Management – D (7)

- D1 – Data from Raw to Exchange *(O2, O5, O6, O8, O9, D2, R2, R3)*
- D2 – Data from providers to assimilation *(O1, O2, O5, O6, O8-O10, M3, M4, M7, D1, D5)*
- D3 – Data for model intercomparisons *(M1-M3, M6, M7, U4)*
- D4 – Data discovery and distribution *(O10-O12, M1, M3, M4, M6, U1-U4)*
- D5 – Data repository for prior and fluxes *(O11, M5, M7, P1-P4, D2)*
- D6 – Definition of prior data providers *(M5, P1-P4)*
- D7 – Data policy for the repository of prior fluxes *(M5, P1-P4, U4)*

Section 7 R&D Needs – R (3)

- R1 – G3W R2O Task Team establishment *(R2, R3)*
- R2 – Advance Obs. & data exchange capabilities *(O2-O4, O10-O12, M3-M5, D1, P1-P4, R1, U1-U4)*
- R3 – Advance modelling and flux inversion capabilities *(O1, O10-O12, M3, M5, M7, P1-P4, D1, R1, U1-U4)*

Section 8 User Engagement & Uptake – U (4)

- U1 – Support the GST *(M6, M7, D4, R2, R3, U2, U4)*
- U2 – Guidance on regional products *(M3, M6, M7, D4, R2, R3, U1, U3, U4)*
- U3 – Establish relationship & pathway *(M7, D4, R2, R3, U2, U4)*
- U4 – Develop user interface guidelines *(M3, M6, M7, D3, D4, D7, R2, R3, U1-U3)*

Section 9 Capacity Building – C (5) *(Overarching)*

- C1 – Technical participation framework
- C2 – Continuously capacities evaluate
- C3 – Members' capacities in data use
- C4 – Capacity development programs for Member
- C5 – National capacities development

G3W Implementing bodies, actions and roles.

Institution or body	Actions	Role
Academic Institutions	O8, O9	As majority of the ocean observations is made by the academic institution, these institutions will play an important role in sustaining and extending these measurement programmes.
Global Ocean Observing System (GOOS)	D1, O8, O9, O11, O12, P1, P2, P3, R2	GOOS sets up the requirements for the ocean monitoring, defines Essential Ocean Variables and evaluates the status of the global observing network for ocean. GOOS provides recommendations on the need for sustainability and extension of these observing network. GOOS links broad community that is involved in ocean observations and research.
GOOS Secretariat	O1	GOOS secretariat will assist with the survey of the available greenhouse gas and related observations over/in the ocean.
IOC Secretariat	O1, O2, O3	IOC Secretariat will work with WMO Secretariat on the preparation of the observational survey, evaluation of the observational standards and available datasets and preparation of the workshop for the development of the long-term observations' strategy.
International Ocean Carbon Coordination Project (IOCCP)	O3, O8, O9	The IOCCP promotes the development of a global network of ocean carbon observations for research through technical coordination and communication

Financial O8: Ocean network design

Developing, running and expanding the surface ocean GHG observing system will require a coordinator (1 FTE) in IOCCP linked to GOOS and a technical coordinator (1 FTE) for SOCONET at OceanOPS.

National Ocean Research Agencies, Environmental and Climate Ministries, Academic Institutions, and National Meteorological Services need to take the financial commitment to run the sustained observing systems. Current committed funding for surface ocean GHG observations is approximately 8.1 M$ per year distributed across several nations. Estimates of near-term costs associated with support of existing and new observations, including initiating expansion to data-poor regions in the near-term, is approximately an additional 29 M$ per year distributed across all nations. This includes 9.2 M$ per year in capital investment for instrument updates, maintenance, and new instrumentation on existing platforms in addition to 25 FTE of new technical staff distributed across supporting nations to build capacity to fully operate new and existing measurements and quality control the data. Those investments are the highest priority in order to sustain critical observing infrastructure. Investment in research and development of approximately 4 M$ per year is needed to advance new techniques and GHG instruments, including support of early career researchers to grow the ocean GHG community. New autonomous surface ocean CO_2 platforms currently contributing data to SOCAT could be expanded to data-poor regions that OSEs have identified as major contributors to uncertainty in ocean CO_2 flux. An investment of 8 M$ per year in those measurements would make near-term progress and be adapted and deployed to other regions as OSEs assess observing impact.

Financial O9: Gridded Air-Sea CO_2 flux

The effort to run SOCAT has been estimated as 3 FTEs to develop and maintain software systems, support and troubleshoot the submission process, coordinate the annual release and to coordinate SOCAT of which approximately 1 FTE is committed. Innovating and developing SOCAT further will add another 2 FTE costs. Therefore, an extra 4 FTEs are needed.

MEMENTO also requires full time support (1 FTE) for database updates and maintenance, including for possible shared or leveraged infrastructure with SOCAT.

The SOCOM mapping exercise needs to be supported via National Ocean Research Agencies, Environmental and Climate Ministries, Academic Institutions, National Meteorological Services. Estimated costs to sustain efforts and conduct research to test optimal observing design is approximately 8 M$ per year across all nations.

WMO/IOC recommend that each National Ocean Research Agency or equivalent support a national contribution to this action that is consistent with and proportional to weather observing and forecasting contributions to address national needs and global assessments.

Co-convened by the IOC, the IOCCP/GOOS BGC, SOLAS, IMBeR, CLIVAR, and the GCP

- **Aimed at:**
  - Identification of critical knowledge gaps in the ocean carbon cycle
  - Identification of research activities in order to close this gaps
  - Bridging between science and policy: the UN Decade, the UNFCCC and its Paris Agreement, the IPCCC AR6 and subsequent AR's
  - Developing recommendations to be incorporated in implementation plans of convening organizations
- **The IOCR Structure**
  - Identification of global and regional research questions as well as specific societal and policy-relevant research questions
  - Identification of approaches to address Integrated Ocean Carbon Research in context of those questions
  - Development of recommendations for convening organizations and otherwise

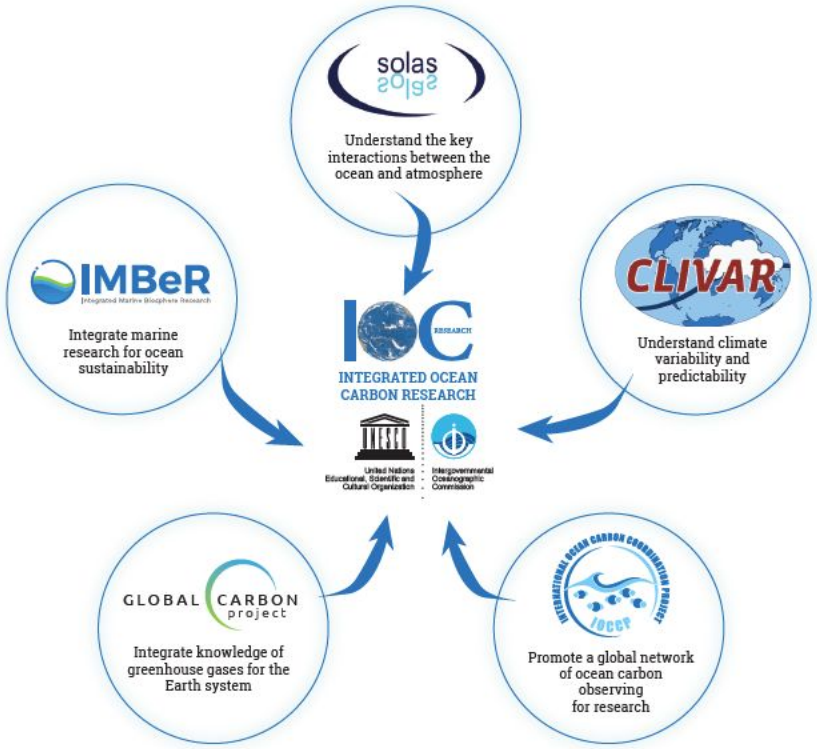
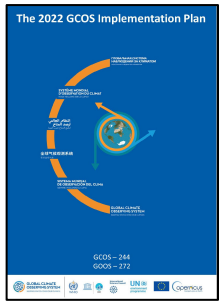
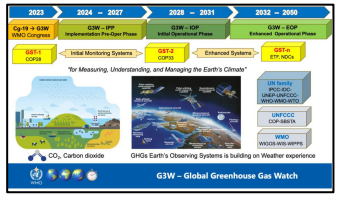


Figure 1. *The international global research and coordination programmes that contribute to IOC-R. Each programme has ocean carbon research, coordination, and assessment as part of its mission, and goals that will synergistically feed into IOC-R.*

General recommendations advocated by IOC WG on IOCR:

- Maintain and enhance sustained high-quality ocean carbon observations critical for quantifying the strength and variability of the ocean carbon sink.
- Co-design, properly fund, and operate carbon observing systems in cooperative ways through participating organizations and entities, including those of the private sector.
- Further utilize remote sensing for synoptic investigation of the ocean carbon cycle.
- Enhance the development and utilization of new technology with respect to sensors and platforms.
- Support best practices in measurements and data sharing and in quantifying uncertainty budgets.
- Accelerate the use of artificial intelligence in quantifying processes, patterns, and exchanges in the ocean carbon cycle.
- Enhance linkages between biogeochemistry and ecology as they pertain to the ocean carbon cycle.
- Integrate the land-ocean continuum more fully into global carbon cycle assessments and ESMs.
- Close important gaps in our knowledge through laboratory and field-based process studies, including properly scaled geoengineering studies, to elucidate mechanisms and contribute to model parameterization.
- Build reliable and comprehensive ocean carbon and biogeochemistry forecasting systems through enhanced synthesis products, modelling, and model-data fusion activities.
- Advance data assimilation activities in ocean carbon research.





GOOS Ocean Carbon and Nitrous Oxide Plan
(Implementation, Strategic or simply a Plan)
Draft 0 (20240412)

- **Executive Summary**
  - "This document will outline GOOS'es goals related to ocean carbon and nitrous oxide observing and describe the timeline for delivery of these goals through coordination, communication and implementation efforts over the next 3-5 years."

- **Introduction**
  - Motivation based on justification for the mandate documents
  - Motivation based on relevant elements of GOOS'es vision, mission and strategy
  - Description of usefulness of implementation of the Plan in supporting stakeholders (scientific community across GOOS elements, national and international efforts, funders of the ocean carbon observing system, others….)

- **Strategic approach**
  - Mandates
    - GCOS IP 2022
    - WMO G3W Implementation Plan 2024
    - IOC Integrated Ocean Carbon Research Report 2021
    - Other….?
  - Capacities and priorities across GOOS elements in the context of the mandates
    - Panels
    - OceanOPS
    - OCG
    - Networks
    - GRA's?
    - ETOOFS?
    - Partners: IODE, others?
  - Partnerships for implementation
  - Description of elements of mandates which are beyond GOOS'es capacity

- **Goals**
  - 4-5 Goals
    - 3-4 Objectives per goal
    - Each objective needs to have a clear description of action with timeline, named responsible GOOS element, measure of success

- **Conclusion and Next Steps**

Goals
Work around each goal focuses on gap analysis and development of 3-4 most pressing delivery objectives.

- Goal 1: Fill ocean carbon and nitrous oxide observational gaps
  - Synthesis of observing system design efforts (partnership?)
  - Critical domain gaps (e.g., ocean surface, coastal ocean, interface/exchange with seafloor)
  - Critical regional sampling gaps (e.g., Polar, Tropical Pacific, Indian Ocean, etc.)
  - Critical temporal sampling gaps (e.g., observations during winter)
  - Critical parameters gaps (e.g., co-located sampling, more holistic set of parameters on existing platforms)
  - Critical innovation and technological gaps (sensors, platforms)

- Goal 2: Provide useful climate information for modeling/forecasting, product development, mitigation, adaptation
  - Ocean carbon data management
    - Per network?
    - Per application? (e.g., ocean acidification, mCDR)
  - Existing and new data synthesis products
    - Per network (SOCAT, GLODAP, SPOTS)?
    - Per application (e.g., fluxes, storage)
    - More holistic?
  - Gaps filling efforts (e.g., Machine Learning)

- Goal 3: Sustain funding for observations and data management
  - Identification of infrastructural and personnel needs based on filling the gaps described in Goals 1 and 2
  - Identification of public and private stakeholders benefiting from filling those gaps
  - Identification of mechanisms allowing the stakeholders to invest in filling these gaps

- Goal 4: Develop optimal support structure for ocean carbon coordination efforts within GOOS
  - Existing structure
  - Specific coordination needs (within GOOS, across the community involved in delivering the GOOS Carbon Plan
  - Optimal structure

- **Mode of operation:**
  - Plan to be written as response to identified mandates and not beyond
  - A Task Team led by GOOS BGC Panel of limited size: volunteers primarily from GOOS elements (beyond if expertise needed)
  - Distributed responsibilities with agreed check-points and milestones (e.g. Trello board, dedicated teleconference calls, in-person workshop to gather wider input)
  - Dedicated GMT staff (consultant) hired to help coordinate
  - Description of limited number of specific, timeline'd objectives with final delivery within 3-5 years from publication of the Plan
  - Plan published/released around the UN Ocean Conference in June 2025
- **Reaction and input by the GOOS SC (potential discussion topics)**

1. *reaction to the need for such a plan, the proposed way of developing it, timeline and draft ToC*
2. *balance between focus on research (if any) and services*
3. *what are the key audiences for such a document*
4. *what are the key mechanisms that GOOS can target to trigger and/or enable implementation by the Member States*
5. *Is there a role for the Co-Design Carbon Exemplar in developing or implementing the GOOS Ocean Carbon Plan*

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Thank you

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