



Report on the WCRP & GCOS June 2023 Meeting, activities and GCOS assessment updates

The Earth cycles:

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Overview of Work from GCOS on Earth Cycles in the last 8 years

- Work on Earth Cycles is reflected in GCOS Implementation Plan 2016 with several Actions related to observational needs to close the carbon, energy and water cycles.
- This was discussed in a GCOS cross-panel meeting held in Marrakesh in 2019
- After that, three papers were prepared describing which the main gaps that hinder our understanding of the cycles are.
- A new ECV was proposed to better reflect the water cycles (terrestrial water storage, resp. Terrestrial Panel).
- 2022 GCOS IP has a section on The Earth Climate Cycles summarising the findings of the papers and an Action proposing to continue to periodically review observations of the Earth's energy, water, carbon cycles to identify gap.
- 2022 GCOS Steering Committee approves a Decision supporting the work on Earth Cycles and the organization of a workshop jointly with WCRP.



The 2022 GCOS Implementation Plan



GCOS – 244
GOOS – 272



WMO

IOC

ICSTC

environment

Action B10: Identify gaps in the climate observing system to monitor the global energy, water and carbon cycles

Activities	<ol style="list-style-type: none"> 1. Continue to periodically review observations of the Earth's energy, water, carbon cycles to identify gaps and areas of high uncertainty. 2. Review consistency of the underlying observations. 3. Develop plans to address the gaps identified in (1), if feasible.
Issue/Benefits	<p>This action will implement an objective approach to identifying gaps and major uncertainties in the global climate monitoring system.</p> <p>The energy, water and carbon cycles and their closure/imbalance are fundamental to understanding current climate state and change, and improved observations of the cycles will lead to improved climate projections and reduced model biases.</p>
Implementers	<p>From 1 to 3: GCOS, Research organizations, Funding agencies, WCRP.</p>
Means of Assessing Progress	<ol style="list-style-type: none"> 1. <ol style="list-style-type: none"> a) Periodic assessments of each cycle and its components at least as part of the Status Report (about every five years); b) Periodic reviews of suitability of existing ECV structure to monitor energy, water and carbon cycles at least as part of the Status Report. 2. Periodic assessment of consistency of the underlying ECVs. 3. Include plan to address the main issues for the next GCOS Implementation Plan.
Additional Details	<p>GCOS has reviewed how well the existing structure of ECVs monitors these cycles and their components. This has revealed significant gaps in observations and highlighted areas of highest uncertainty – this information will be used to guide developments and improvements to the observing system.</p> <p>Expert teams reviewing observations of the cycles will report on gaps and major uncertainties for inclusion in the next GCOS Status Report. They will develop plans to address these issues in subsequent Implementation Plans.</p> <p>See also Section 2.4 in this GCOS IP for more details and references.</p>
Links with other IP Actions	<p>This action indirectly links with many others but in particular with:</p> <ul style="list-style-type: none"> B3: Better EEI measurements. B4: In situ GHG observations. B8: Coordinate observations and data product development for ocean CO₂. C5: Activity 2 (estimation of aboveground biomass).

WCRP-GCOS June 2023 Paris Workshop



The overall aim of the workshop was to assess the current state of knowledge of the Earth's key cycles of water, carbon and energy, both with a view to identifying gaps in our understanding and in our observations. Review where community stands (survey)

- a. Global view
- b. Regional views

Specific aims for each cycle

1. Assess the **current state of knowledge of the cycle** as well as emerging changes in the cycle. Identify challenges from research (knowledge of processes) to modelling and observing system capabilities. Pay attention to:
 - i. Definition of systems to be closed, i.e. reservoir states, fluxes, dominant time scales.
 - ii. Stationarity of the cycle
 - iii. Processes involved that we do not understand
 - iv. Error considerations
 - v. Estimation and detection of trends.
 - vi. Possible attributions to climate change and other anthropogenic changes.
2. Identify key indicators for monitoring, measuring (observational needs) and modelling the cycle and indicate how they can be used in global assessment frameworks (IPCC, WMO, other). Take into account the WCRP Strategy and GCOS ECVs.
3. Identify **key processes** which require a better understanding to improve cycle monitoring or coupling to other cycles. What research is needed towards closing the budgets, bearing in mind that the budgets are not static, but are dynamic.

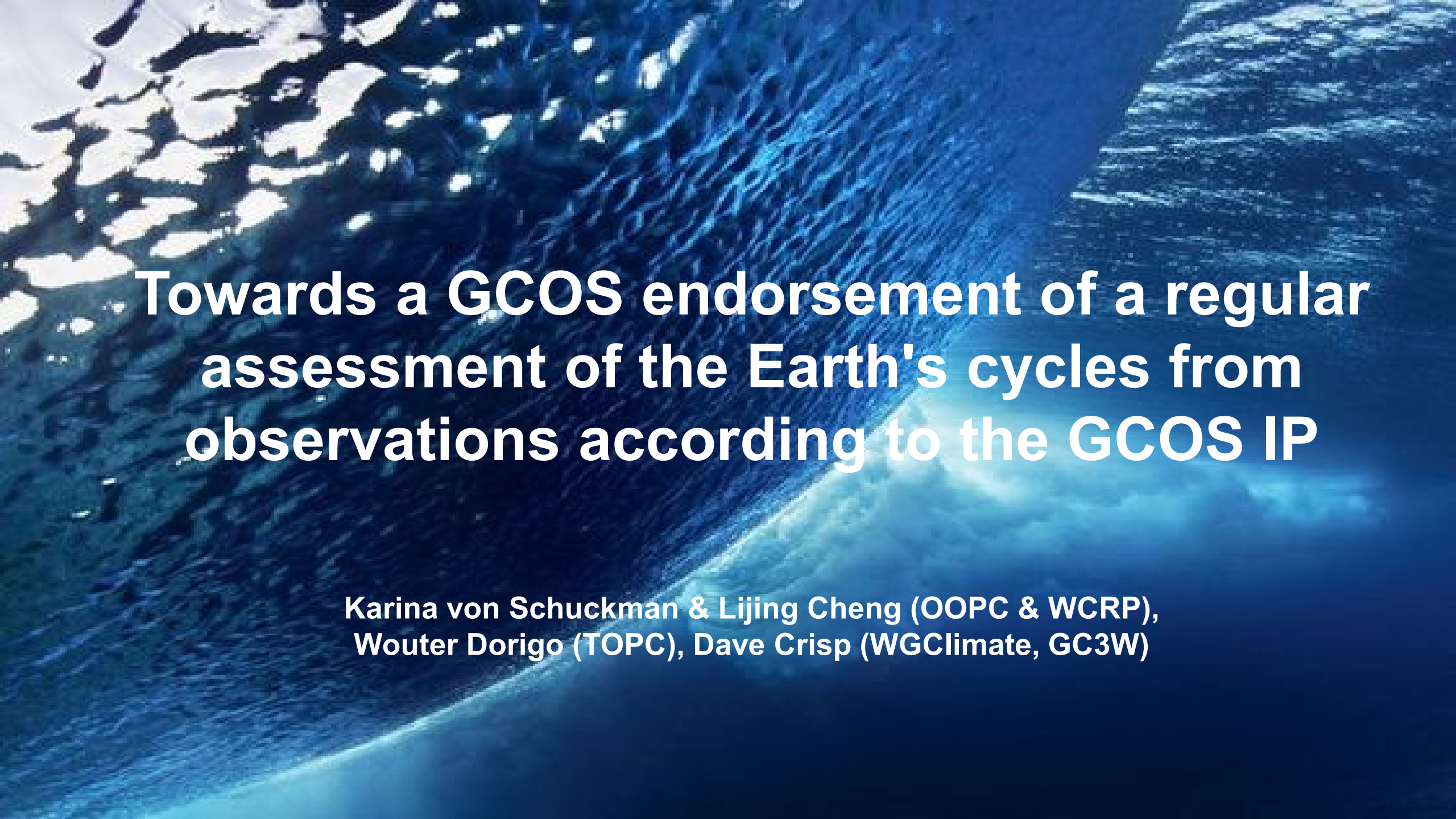
The workshop report & recommendations



PROCEDURES

A broad roadmap for GCOS-WCRP joint work coordinated by a joint GCOS-WCRP working group that will liaise with their respective expert groups (including the Global Carbon Project) and scientific communities.

- 1. Formulate the global integrals corresponding to the 12 continuity equations,** encompassing land, ocean, cryosphere, atmosphere and the 3 distinct cycles + a rigorous quantification of the uncertainties + systematic and random errors.
- 2. Describe in detail the procedures for submitting estimates** and the minimum requirements. These could be the first elements of a good practice guide.
- 3. To reduce systematic errors** GCOS/WCRP will provide a reference ocean/land/cryosphere mask. All integrals will need to be calculated using a **reference ocean/land/cryosphere mask and averaged over the annual cycle.**
- 4. Write a technical guide to define a common framework for how best to calculate the integral quantities and document the various types of errors.** Document known pitfalls. This should be part of a best practices guide.
- 5. Building on existing community activities, establish a scientific community (including early career scientists and experts from the Global South)** to evaluate the global integrals needed for closing the continuity equations + identifying observational gaps & process understanding is needed.
6. Seek funding opportunities

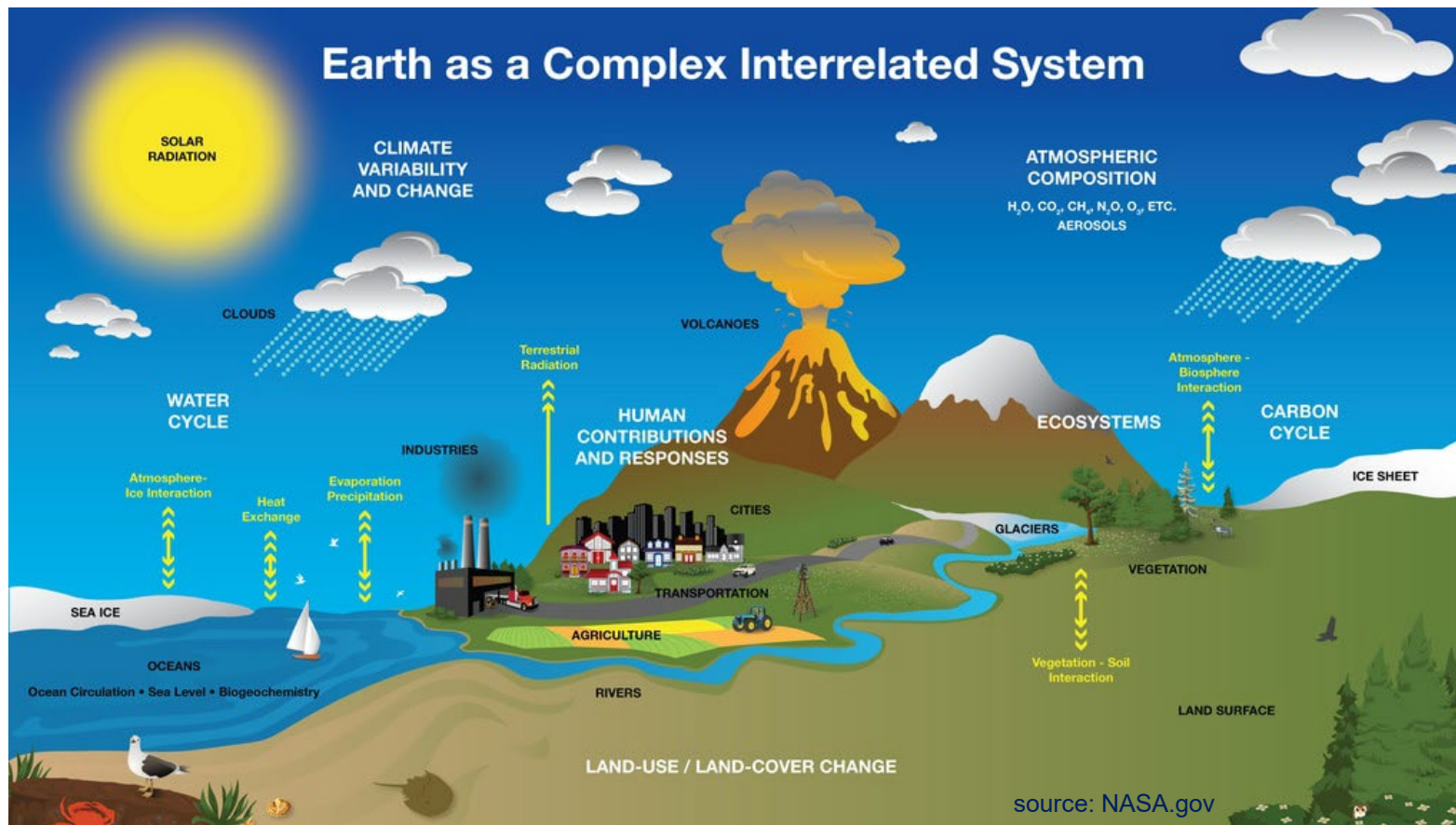
An aerial photograph of a mountain range with snow-covered peaks and a blue-tinted sky. The text is overlaid on the image.

Towards a GCOS endorsement of a regular assessment of the Earth's cycles from observations according to the GCOS IP

**Karina von Schuckman & Lijing Cheng (OOPC & WCRP),
Wouter Dorigo (TOPC), Dave Crisp (WGClimate, GC3W)**

Understanding, monitoring and predicting Earth system cycles ultimately relies on observations

EXPLAINER



Earth system cycles ...

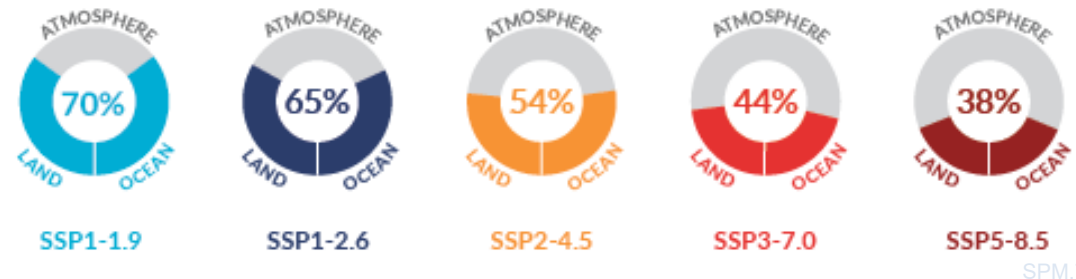
- **sustain life** on Earth through the transfer, exchange & storage of heat, water, carbon, ... **across all domains** - the atmosphere, ocean, land, cryosphere and biosphere.
- interactions are triggered and altered by **natural variations** of the climate system to maintain and balance the **life-sustaining natural rhythm** of the Earth system cycles.

Systematic climate observations across all domains are the **foundation for monitoring, understanding and predicting** Earth cycles natural rhythm, their underlying processes, and future evolutions are needed to close knowledge gaps.

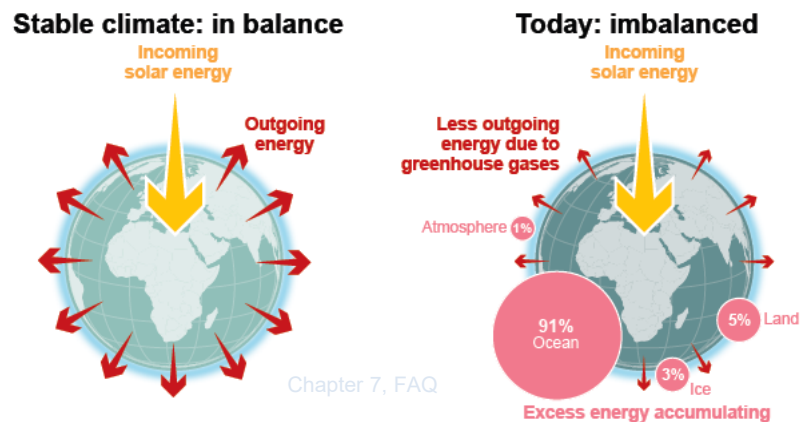
Long-term pressure from climate change affects the natural rhythm of all cycles across all domains.

EXPLAINER

Carbon & nitrogen cycles: Human activity has caused an accumulation of well-mixed GHG (CO₂: 47%, CH₄: 156%, N₂O: 23 %)*, altering land & ocean sink dynamics

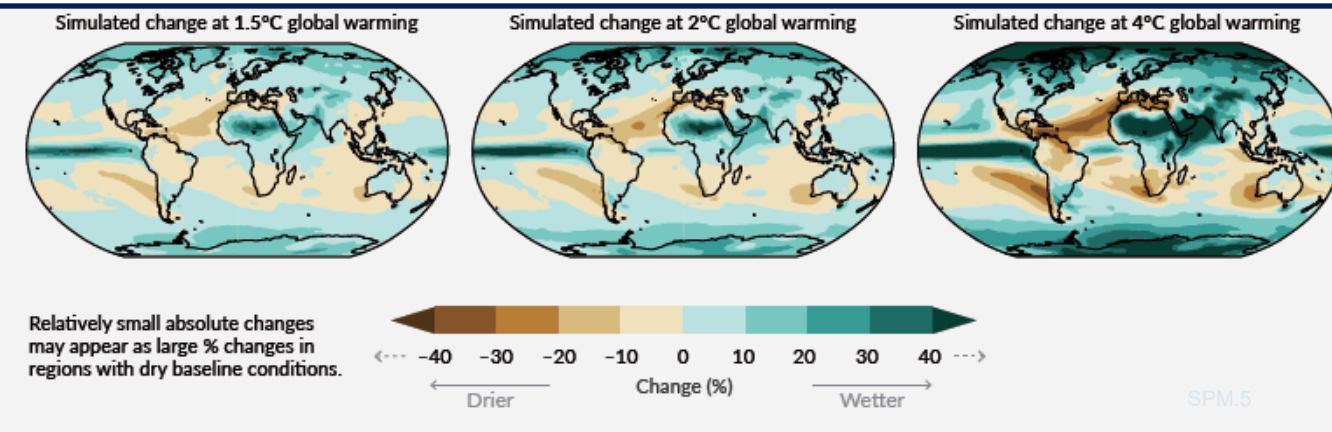


* above pre-industrial (1750) levels



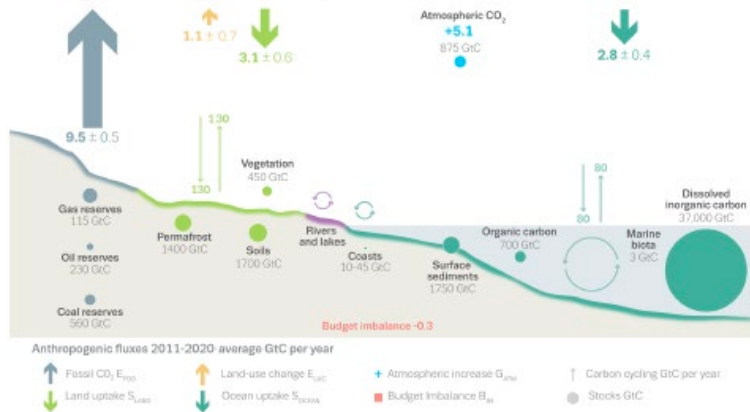
Energy Cycle: Human activity has caused an imbalance of the natural energy flows, leading to an accumulation of surplus heat warming all domains: Ocean, Atmosphere, Land, Cryosphere

Water Cycle: Human activity has caused an intensification of the water cycle & is projected to further intensify, including its variability, global monsoon precipitation and the severity of wet and dry events

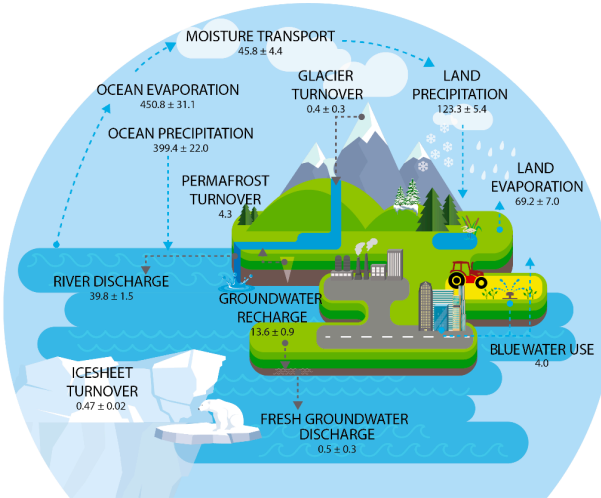


EXAMPLE: Regular knowledge updates of Earth's cycles under GCOS & the global carbon project assessing today's capacities

The global carbon cycle

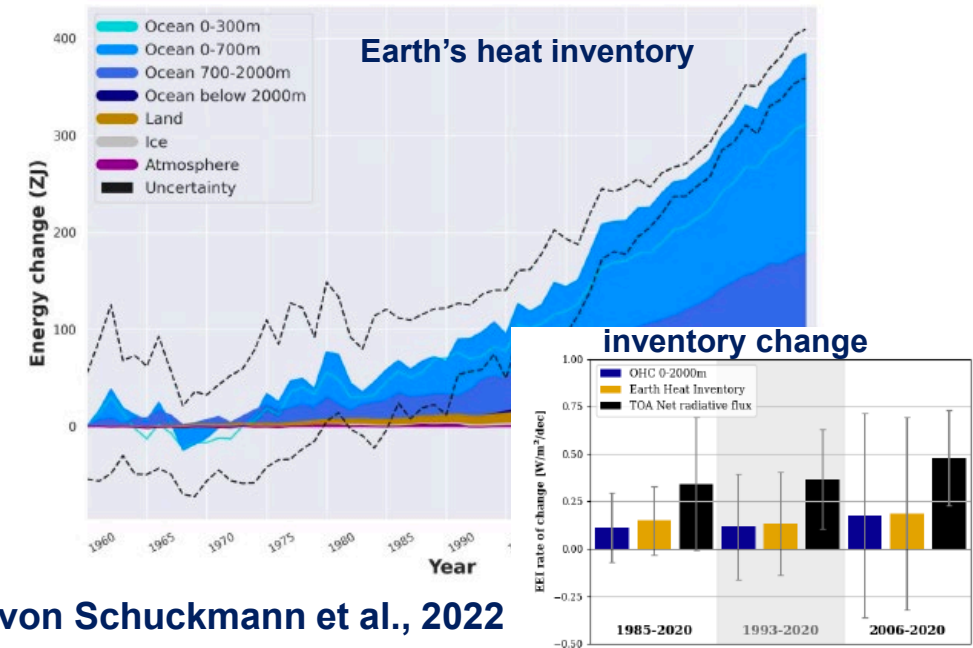


Friedlingstein et al., 2022



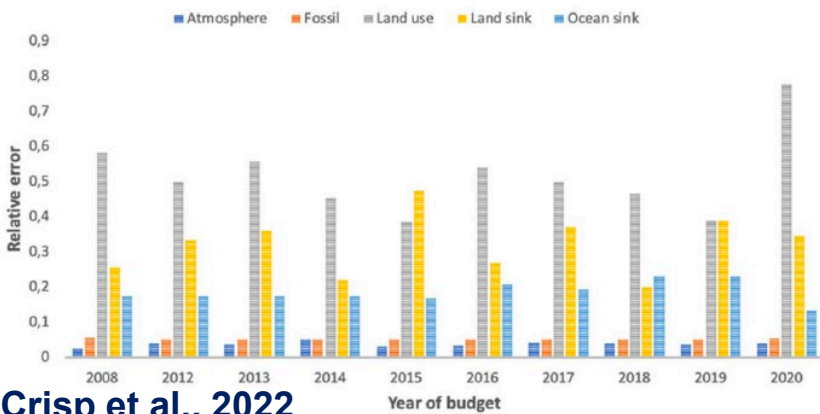
GLOBAL WATER CYCLE FLUXES

Dorigo et al., 2021



von Schuckmann et al., 2022

RELATIVE ERRORS IN THE ANNUAL GCP BUDGETS



Crisp et al., 2022

To monitor, understand, model and predict the Earth system cycles & their feedbacks, **systematic and long-term measurements** are fundamental, and need to be **sustained and enhanced** in the future to support decisions on **climate change action and sustainable development**

A critical element of setting out a robust climate policy regime and credible targets is ensuring the accuracy of the climate trajectory.

- The Earth's system **cycles are the most robust indicators** informing on the state and future evolution of **climate change**.
- **Recognition** that both the **natural cycle** and the **anthropogenic perturbation of the cycles** need to be considered together to accurately monitor, understand and predict **the climate trajectory**.
- Urgent need to **fill observational & knowledge gaps** for a better understanding of the Earth system cycles to achieve any UNFCCC & Paris Agreement **targets for net-zero**.
- Work directly with the **observing, prediction, and research communities (e.g., WCRP)** to maintain focus and regularly evaluate progress on responding to multilateral agreements (UNFCCC, Paris agreement) while **synthesizing and communicating** information about current capacities and gaps **to decision makers**

➔ Towards GCOS endorsement of regular assessment of Earth Cycles from observations

Thank you



**GLOBAL CLIMATE
OBSERVING SYSTEM**

KEEPING WATCH OVER OUR CLIMATE



WMO



IOC

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Science Council



Supported by the European Union

