



**GLOBAL CLIMATE
OBSERVING SYSTEM**
KEEPING WATCH OVER OUR CLIMATE



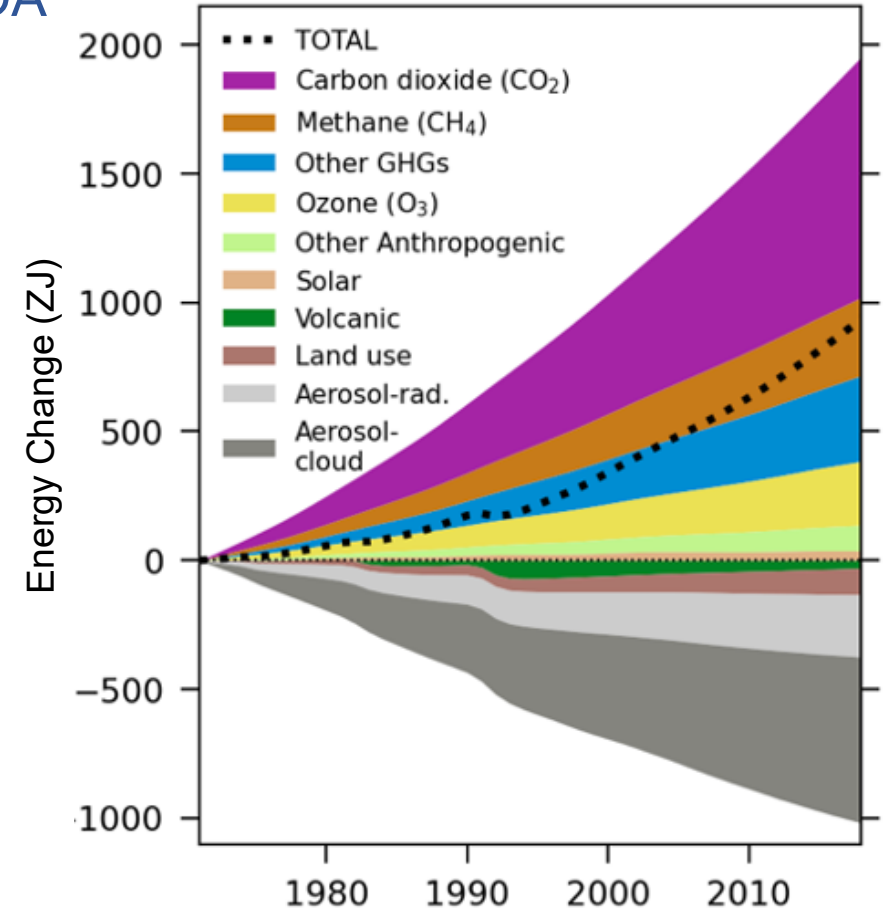
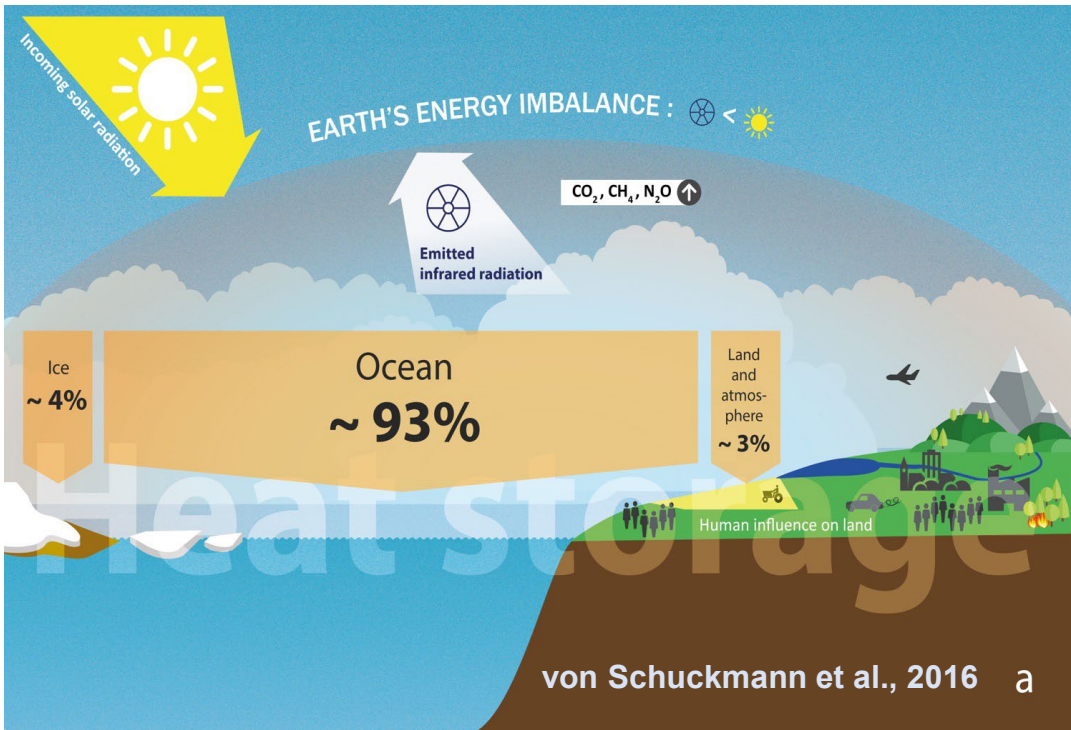
Proposal for the implementation of the Earth Energy Imbalance into the WMO/GCOS Global Climate Indicator framework

Presenter: Karina von Schuckmann

GCOS SSC meeting, 07.-08.12.2022, remote

THE EARTH ENERGY IMBALANCE (EEI)

EEI given by the difference between incoming solar radiation and outgoing radiation, which determines the net radiative flux at TOA



Forster et al., 2021 (IPCC AR6, Chapter 7)

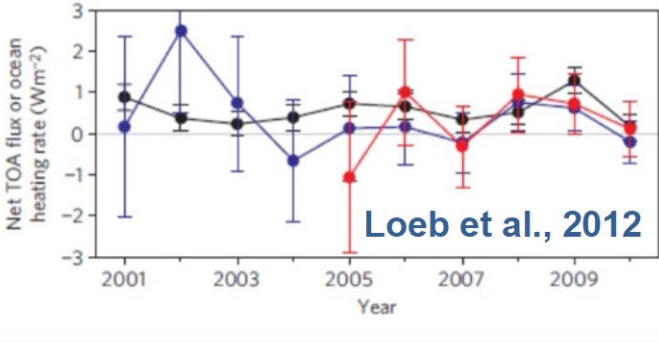
- The Earth climate system is out of energy balance (positive)
- Heat has accumulated continuously over the past decades, warming the ocean, the land, the cryosphere and the atmosphere.
- According to IPCC AR6, this planetary warming is human-driven and results in unprecedented and committed changes to the Earth system, with adverse impacts for ecosystems and human systems.

THE EARTH ENERGY IMBALANCE (EEI)

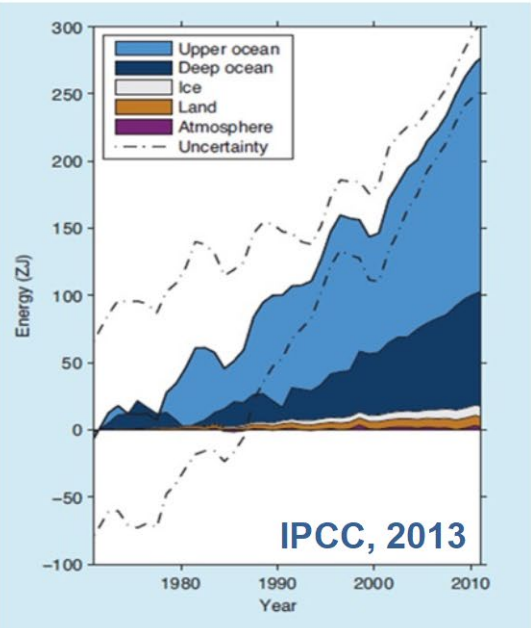
How to obtain an estimate of EEI: different approaches



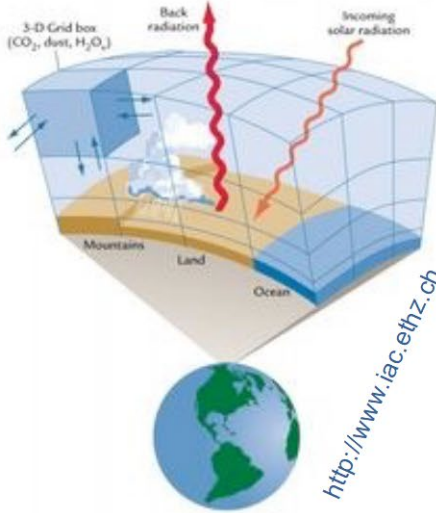
Radiation at TOA



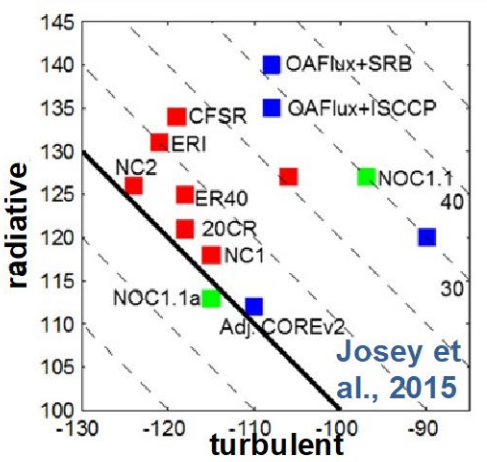
Earth Heat Inventory

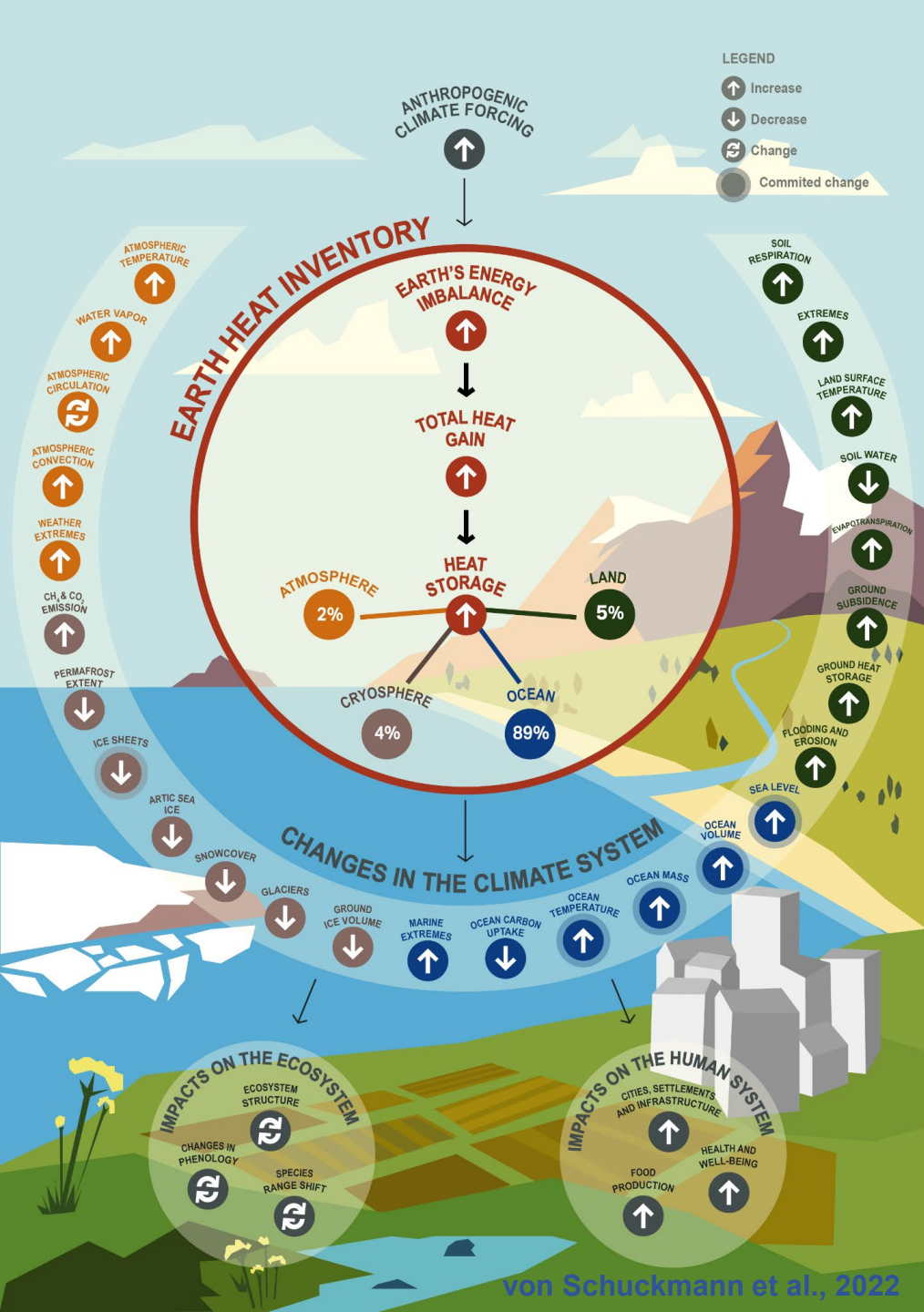


Climate models



Surface flux





THE EARTH HEAT INVENTORY

- how much and where surplus anthropogenic heat is available for melting the cryosphere & warming the ocean, land and atmosphere
- allows evaluation of associated changes in the climate system
- improve climate predictions & projections → improved planning for and adaptation to climate change

→ International & multidisciplinary collaboration across all domains (Ocean, Cryosphere, Atmosphere, Land), and increasing collaboration across different international initiatives

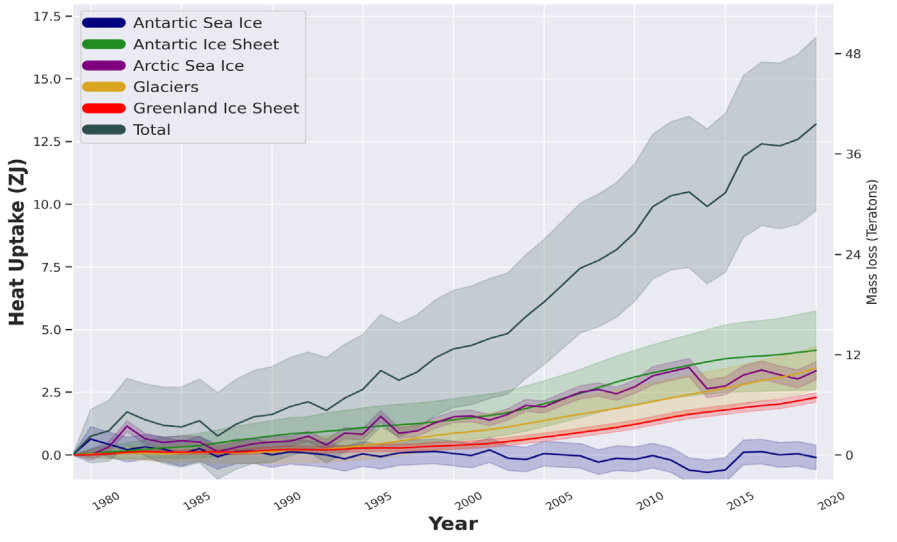
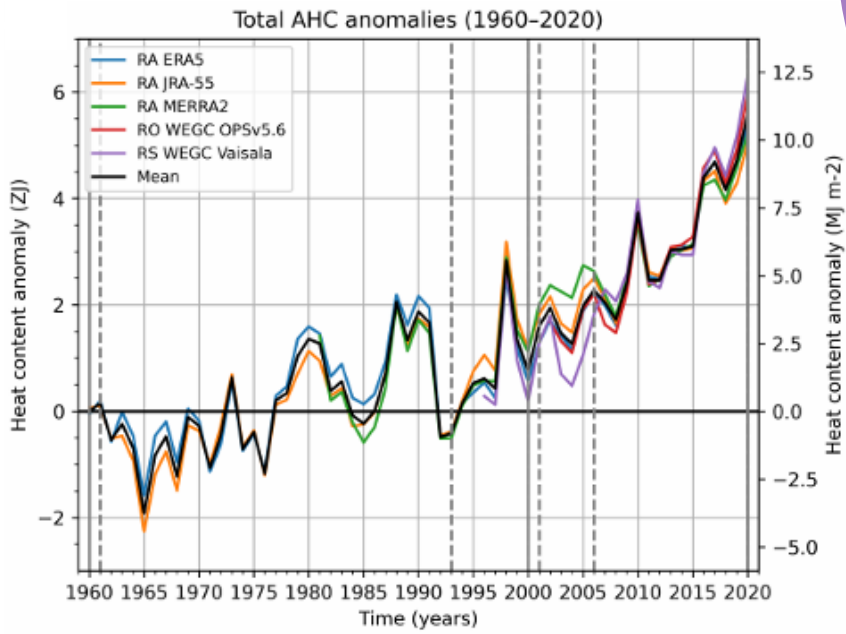
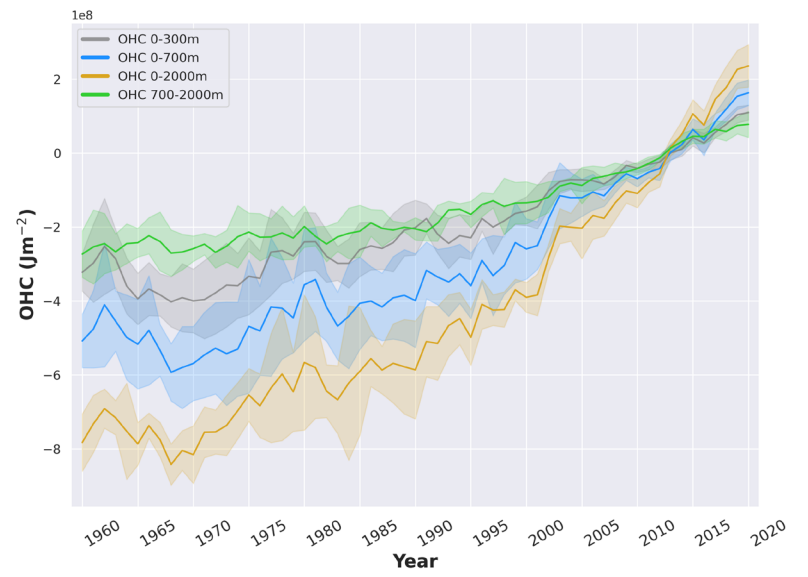
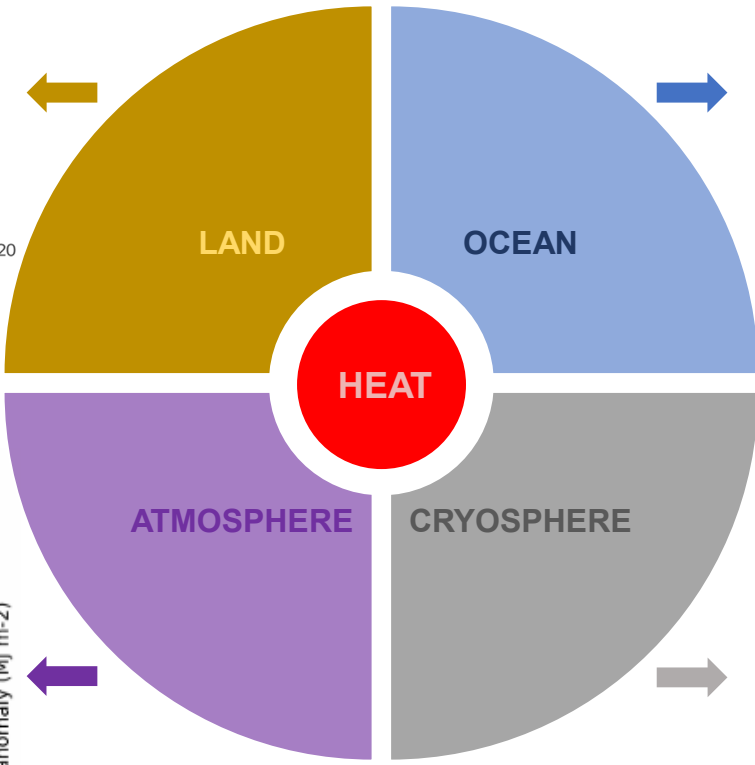
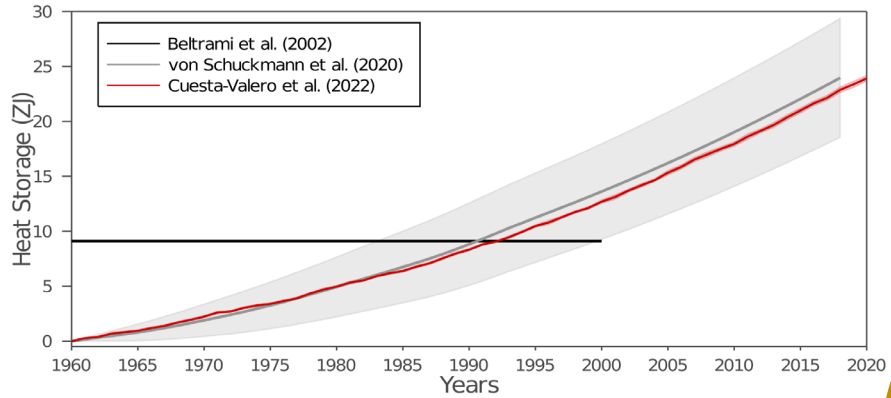
An international and multidisciplinary effort on the Earth heat inventory



The Earth's Energy Imbalance: Where does the energy go ?

Karina von Schuckmann, Audrey Minère, Flora Gues, Francisco José Cuesta Valero, Gottfried Kirchengast, Susheel Adusumilli, Fiamma Straneo, Richard P. Allan, Paul M. Barker, Hugo Beltrami, Tim Boyer, Lijing Cheng, John A. Church, Damien Desbruyeres, Han Dolman, Catia M. Domingues, Almudena García-García, Donata Giglio, John E. Gilson, Maximilian Gorfer, Leopold Haimberger, Stefan Hendricks, Shigeki Hosoda, Gregory C. Johnson, Rachel Killick, Brian King, Nicolas Kolodziejczyk, Anton Korosov, Gerhard Krinner, Mikael Kuusela, Moritz Langer, Thomas Lavergne, Isobel Lawrence, Yuehua Li, John Lyman, Ben Marzeion, Michael Mayer, Andrew H. MacDougall, Trevor McDougall, Didier Paolo Monselesan, Jan Nitzbon, Inès Otosaka, Jian Peng, Sarah Purkey, Dean Roemmich, Kanako Sato, Katsunari Sato, Abhishek Savita, Axel Schweiger, Andrew Shepherd, Sonia I. Seneviratne, Leon Simons, Donald A. Slater, Thomas Slater, Noah Smith, Andrea Steiner, Toshio Suga, Tanguy Szekely, Wim Thiery, Mary-Louise Timmermans, Inne Vanderkelen, Susan E. Wjiffels, Tonghua Wu, Michael Zemp

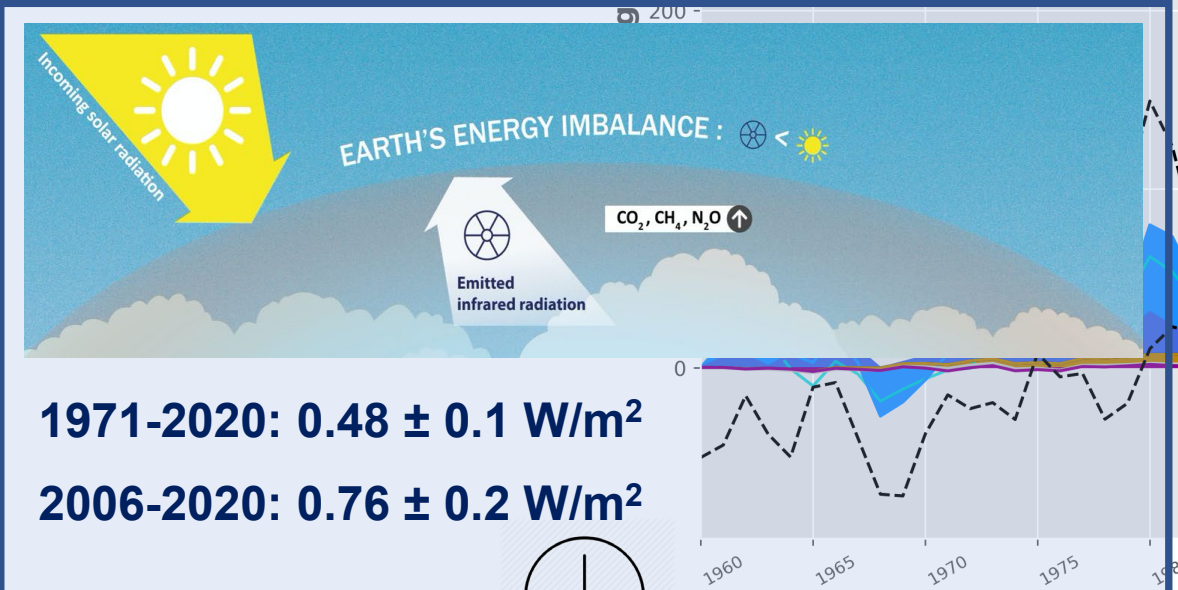
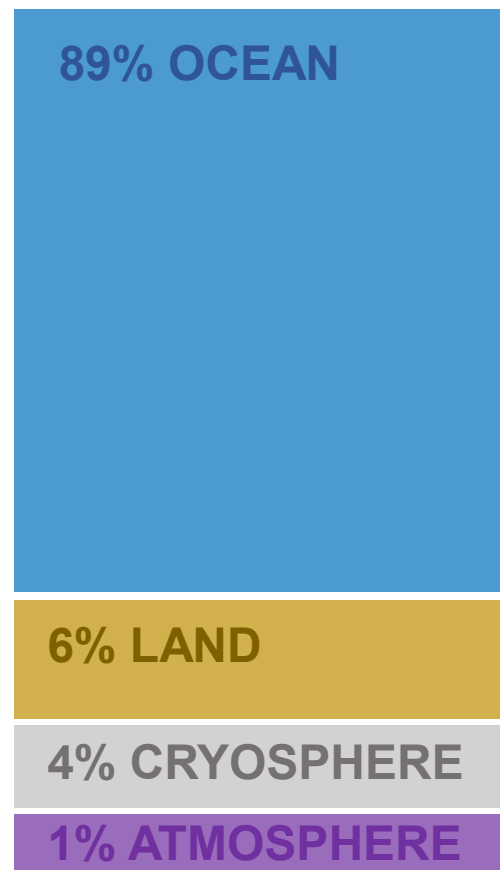
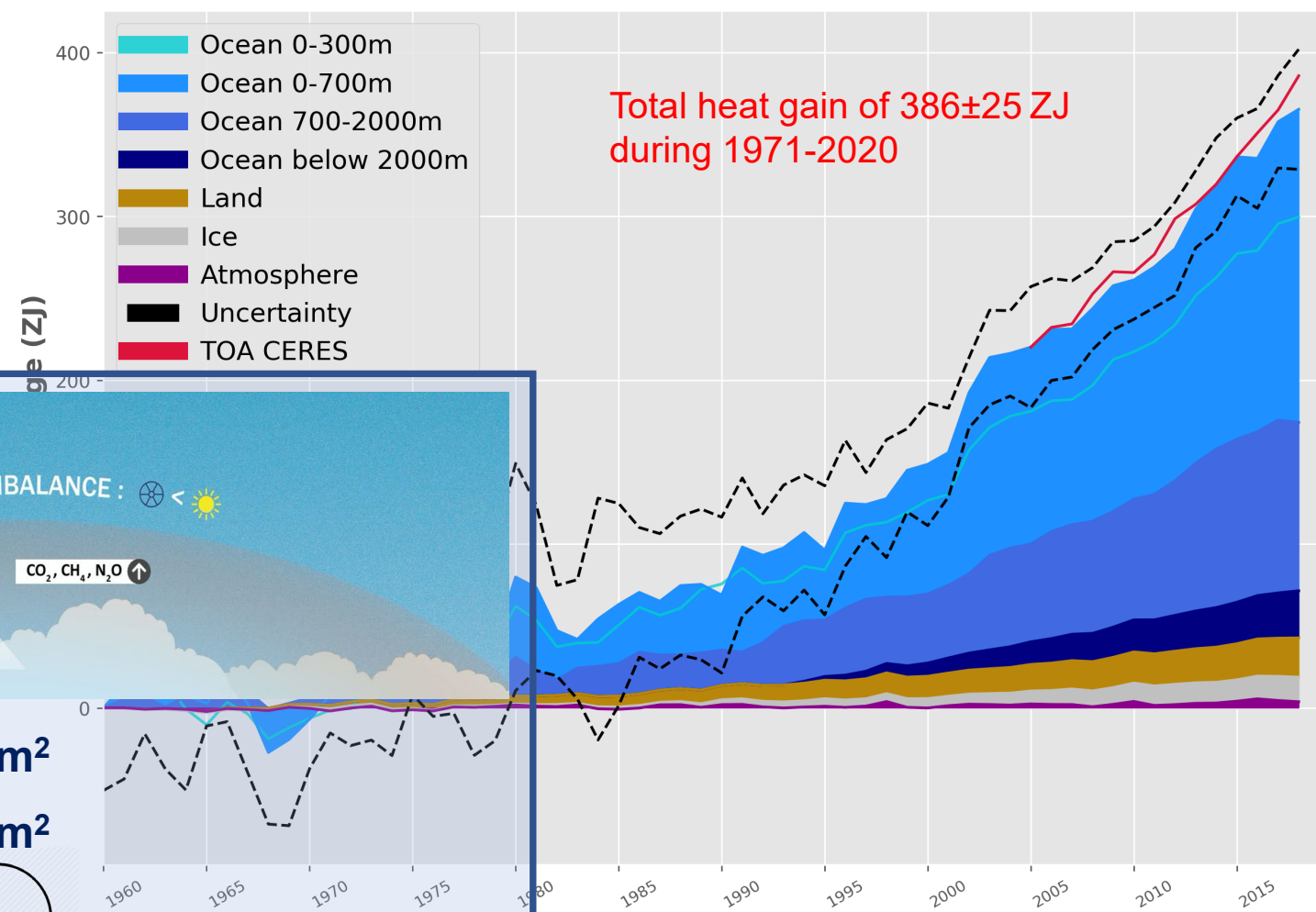
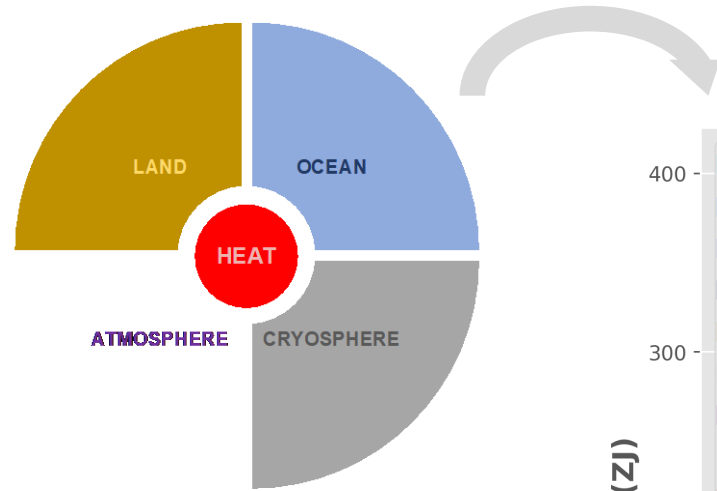
WHERE DOES THE ENERGY GO?



THE EARTH HEAT INVENTORY

HOW MUCH?

WHERE?



Observing system recommendations

OCEAN:

- Technical developments & fostering ongoing activities to extend the GOOS into undersampled areas
- Continued efforts to further advance bias correction methodologies, uncertainty evaluations, data recovery, and processing of the historical datasets.

LAND:

- Increase sampling of subsurface temperature profiles
- Implementation of international data acquisition and curating efforts

PERMAFROST:

- improve sampling for soil temperature
- establish monitoring for ground ice and water contents
- improve simulations allowing for the inclusion of other relevant process (e.g., ground subsidence).

Inland water:

- Data use from the upcoming SWOT mission (planned for upcoming ISIMIP3).
- Estimate of river water storage should be improved, together with an explicit representation of water temperature in global hydrological models.

Cryosphere:

- Sustained remote-sensing with polar-focused orbits & multi-frequency altimeters (e.g., albedo, sea ice area & thickness); earlier launch of Sentinel-1c for monitoring ice-speed change at higher frequency.
- reliable gravimetric, geodetic, and ice velocity measurements; need for ice thickness & extent, snow/firn thickness & density

Atmosphere:

- Sustain and enhance a coherent operational long-term monitoring system for the provision of climate data records of relevant ECVs, and associated reference data (e.g., upper air network GRUAN, radio occultation)
- urgent need for satellite missions in high inclination orbits to provide full global and local time coverage in order to ensure global climate monitoring.
- Also, archiving of measurement data, metadata and processing information needs to be ensured.
- open data access & coordinated international efforts needed for monitoring of ice loss & related energy uptake.

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- Technical developments & fostering ongoing activities to extend the GOOS into undersampled areas
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- Increase sampling of subsurface temperature profiles
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PERMAFROST:

- improve sampling for soil temperature
- establish monitoring for ground ice and water contents
- improve simulations allowing for permafrost parameterizations (e.g., Ground Surface Temperature)

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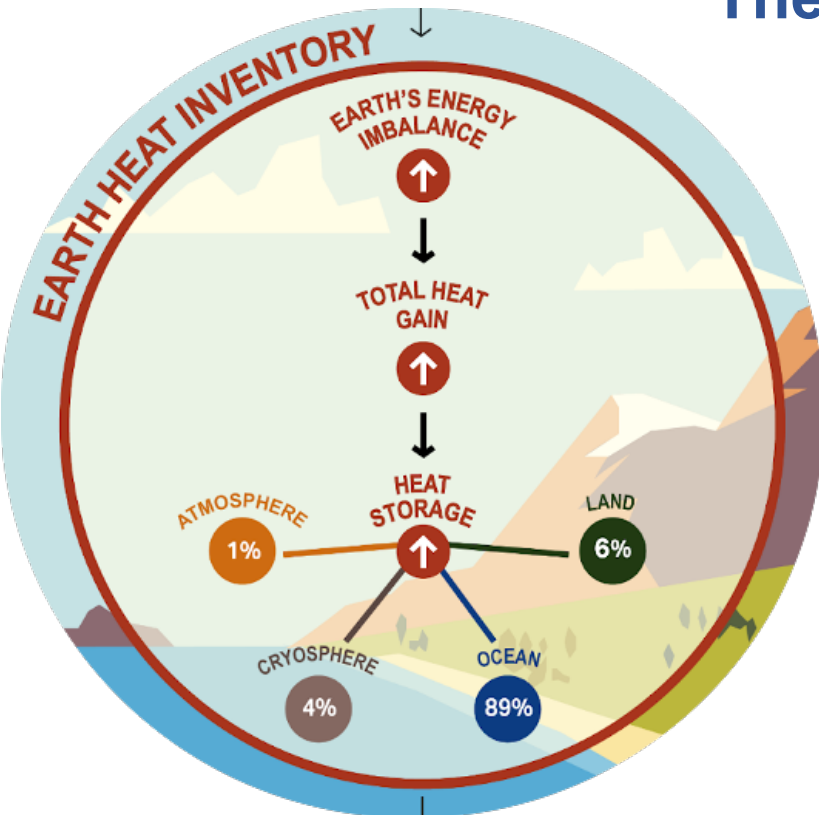
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- Also, archiving of measurement data, metadata and processing information needs to be ensured.
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This concerted international effort recommends archiving, rescuing, continuity and calibration efforts for the GCOS to enable sustained and improved global monitoring of the Earth heat inventory.

THE EARTH ENERGY IMBALANCE (EEI)

The EEI is a fundamental global climate indicator...

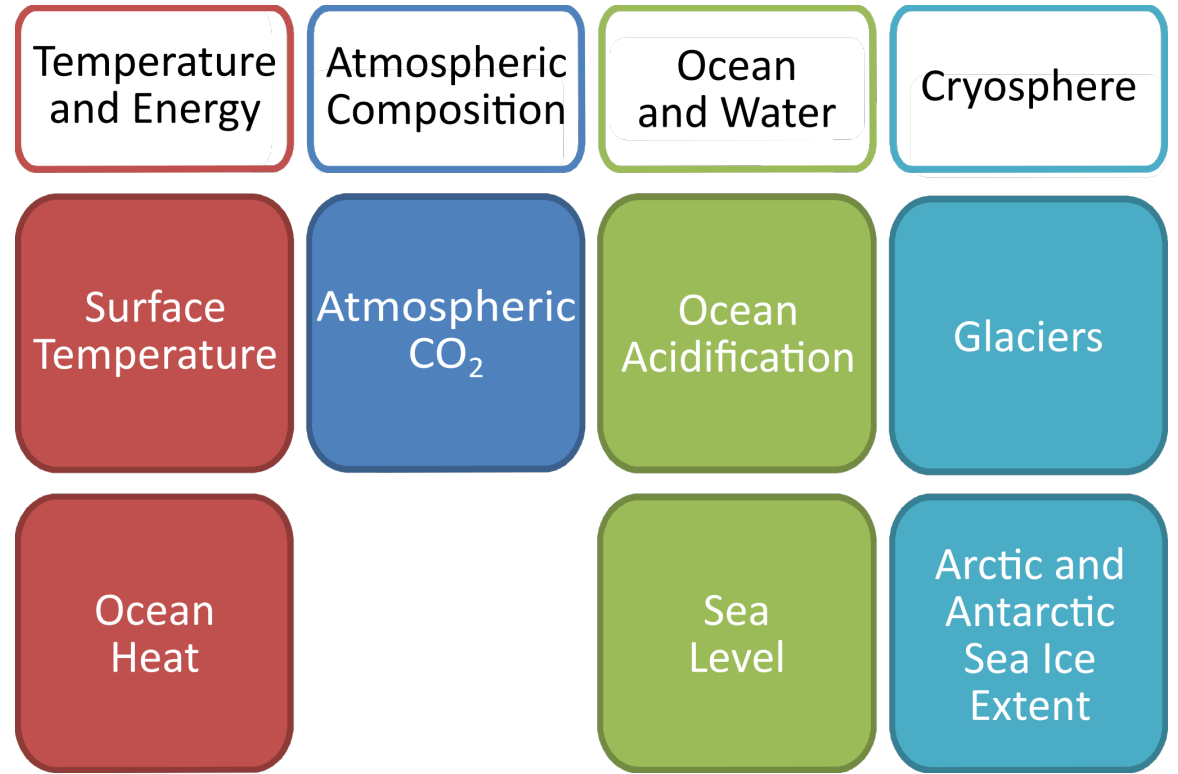
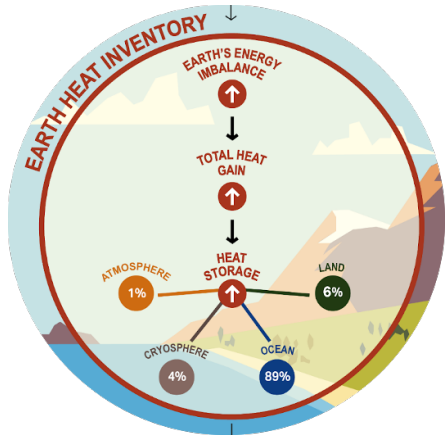


von Schuckmann et al., 2022

- informs on the equilibrium state of the Earth energy budget
- integrated view of effective radiative climate forcing, Earth's surface temperature response & climate sensitivity
- informs about the status of global warming: how much heat is 'in the pipeline'? → committed change
- how much and where surplus anthropogenic heat is available for melting the cryosphere & warming the ocean, land and atmosphere, and associated change
- assessing the status of the GCOS
- enables concerted international multidisciplinary collaboration & advancements in climate science

The EEI is the most fundamental global climate indicator that the scientific community and the public can use as the measure of how well the world is doing in the task of bringing anthropogenic climate change under control, and to assess adaptation options.

THE EARTH ENERGY IMBALANCE (EEI)



The EEI replies to all criteria:

- **Relevance:** Clear indicator for global climate change with high relevance due to its integrated nature
- **Representativeness:** Highly representative of changes to the Earth system related to climate change.
- **Traceability:** Internationally & multidisciplinary regular assessments, published.
- **Timeliness:** Process started (2nd paper in review)
- **Data adequacy:** Robust estimates available, and regular quantifications provides robust observing system recommendations

→ **Proposal for the implementation of the Earth Energy Imbalance into the WMO/GCOS Global Climate Indicator framework**

Any question?

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