Future plans for the role of climate observations within WCRP – an ESMO perspective

ESMO - WCRP Core Project on **E**arth **S**ystem **M**odelling and **O**bservations

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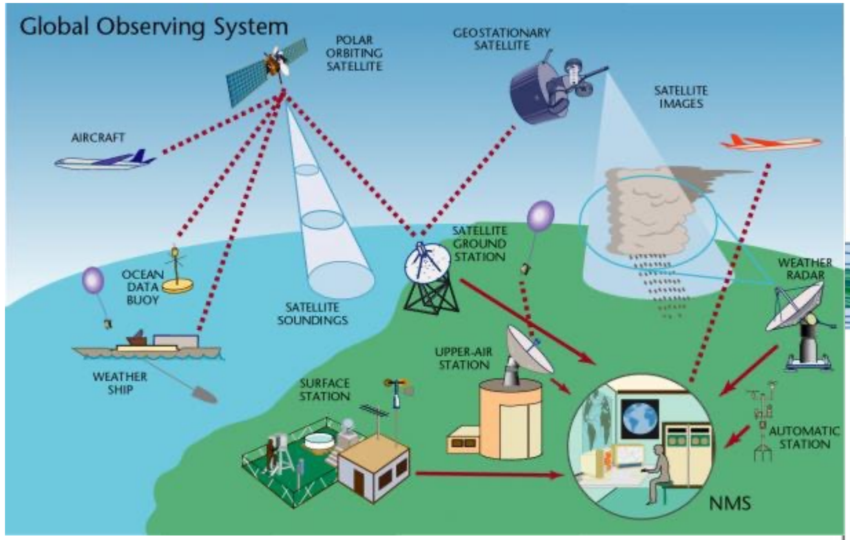
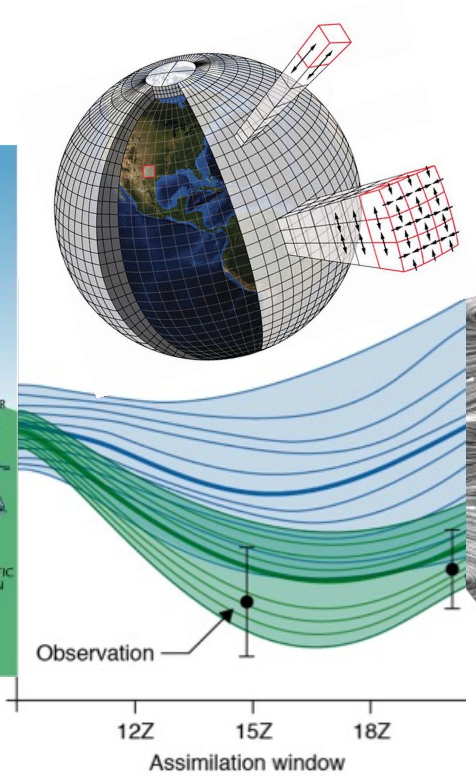
What is ESMO?

Coordinates and advances all

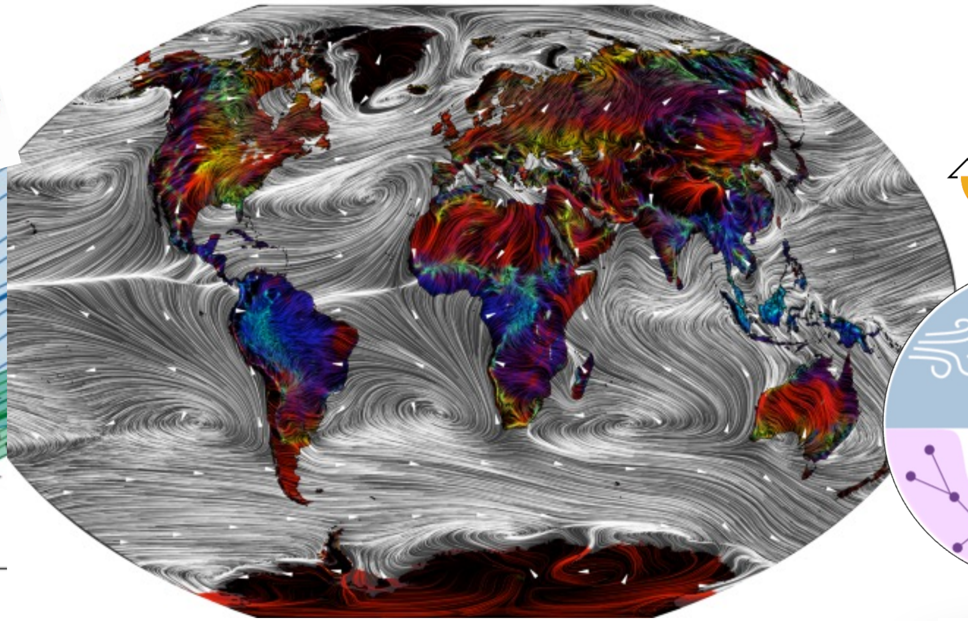
observational, data assimilation and **modelling** activities within WCRP



WMO Global Observing system



Cambridge University Press Climate Model and ECMWF Data Assimilation schematic



Kling and Ackerly, 2020

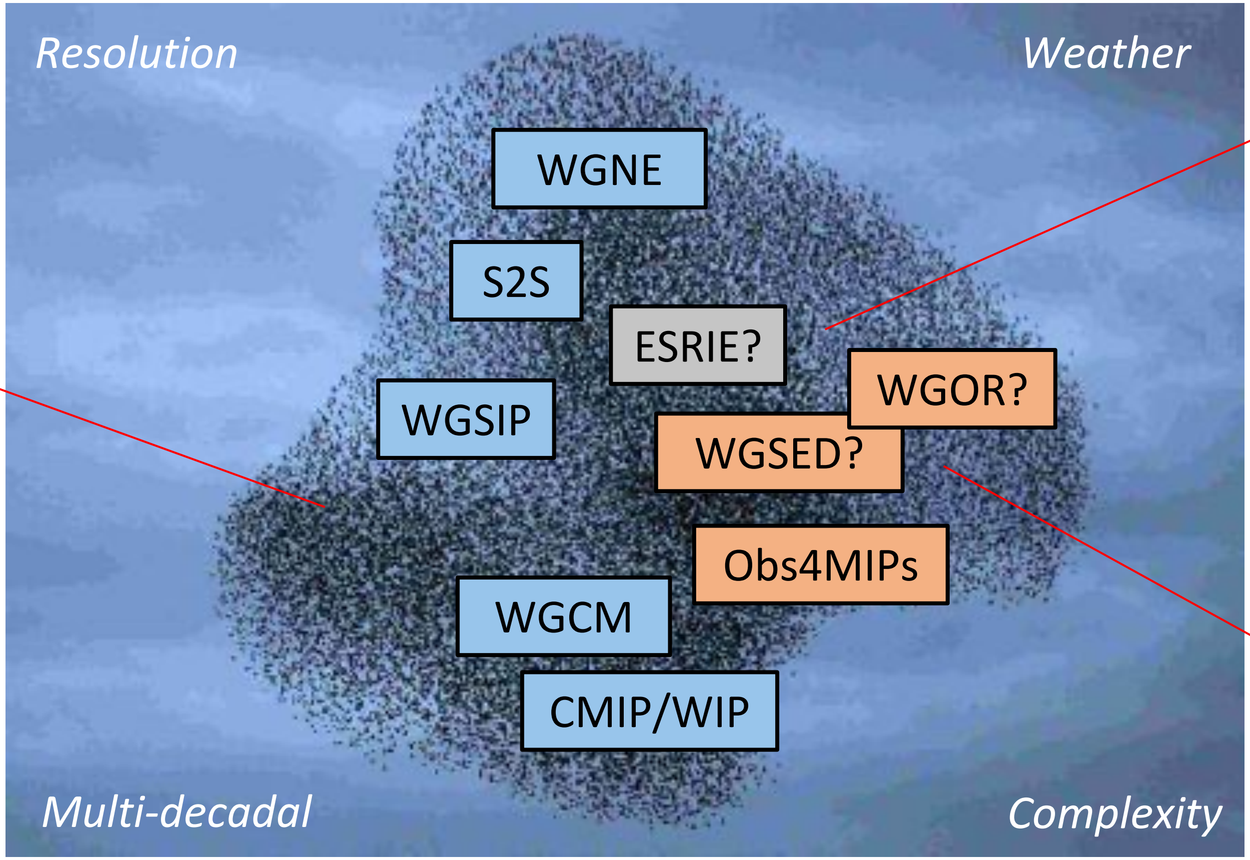
https://machineclimate.de/

Components of ESMO

Earth System Modelling

Cross-cutting Modelling Science

- Seamless ES modelling
- Multi-scale processes
- Process-based diagnostics
- Initialisation
- Global, regional and local change and extremes
- Km-scale modelling
- Urban environments



Picture are self-organizing starlings over Poole,UK

Earth System Assimilation

New Reanalysis Panels?

- Proposed WG on Earth System Reanalysis

New Observation Panels?

- Interface with external bodies
- Coordinate requirement across all WCRP

Earth Observations

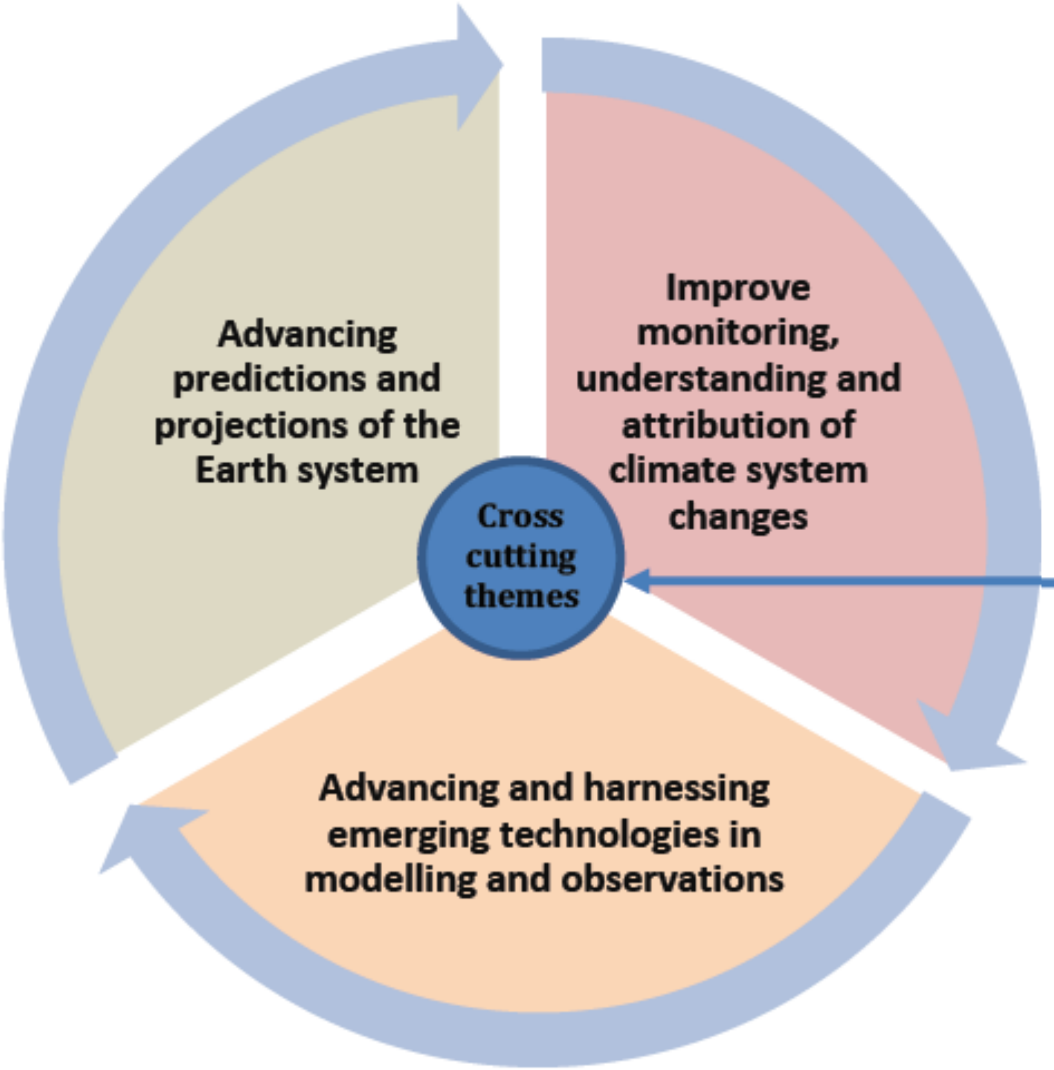
Infrastructure needs:

- Data governance
- Diagnostic tools
- Access & distribution

Tools & methodologies

- Preparing for Exascale
- I/O & data handling
- Urban environments

ESMO objectives



Requires an **integrated, and consistent framework** combining global Earth system observations, data assimilation and modelling.

- **Quantify changes in the carbon cycle**
- **Monitoring and Predicting Extremes**
- **....**

Will be addressed in collaboration with the WCRP core projects, Light House Activities and Working Groups.

Monitoring, understanding and attribution

Key aspect:

Robust signal detection in observational data sets

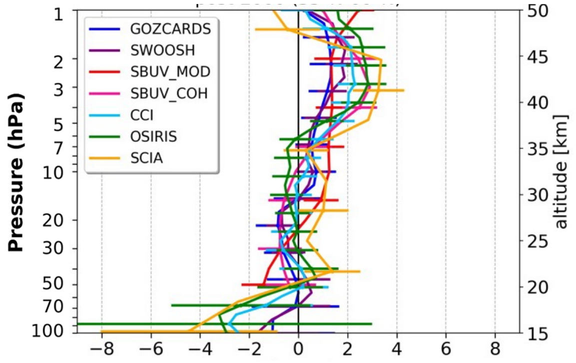
- Physical consistency of measurements
- Consistent uncertainty quantification
  - Taking into account all error sources
  - Consistent methodology for determining uncertainty estimates (e.g., for combined use of observations)

Example – SPARC activity LOTUS (Long-term Ozone Trends and Uncertainties in the Stratosphere)

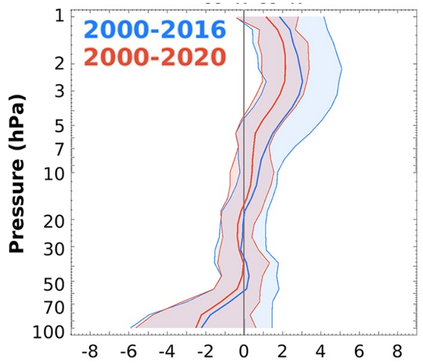
- Combined trends for 35°N – 60°N are only statistically significant above 38 km

Godin-Beekmann et al., 2022

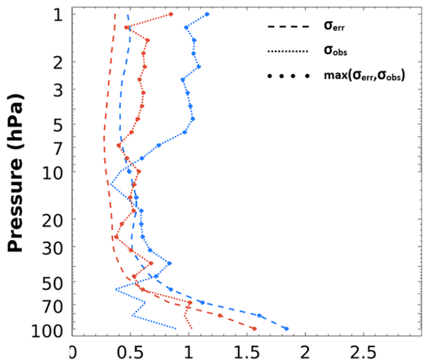
O_3 trends from multiple satellite records (%/dec)



Combined trends (%/dec) and uncertainties (2σ)



Decomposition of error terms for combined trends



Monitoring, understanding and attribution

Future activities, Part I

- ➢ Develop a common understanding of observational and reanalysis uncertainties via promotion of common vocabularies, concepts, and standards for documenting known error effects
- ➢ Implementing metrology concepts to quantify uncertainty in observational data sets at different time and space scales

Example – SPARC activity TUNER (Towards Unified Error Reporting)

- Provide complete and consistent characterization of uncertainty, resolution and a priori information, for space-borne temperature and composition sounders
- Recommendations on how to assess uncertainties and how to report data characterization (von Clarmann et al., 2020)
  - Based on defined framework and consensus terminology
  - Discussion of all sources of errors (e.g., errors due to measurements, models, parameters, a priori information, unknown components, natural variability, drifts, etc.)

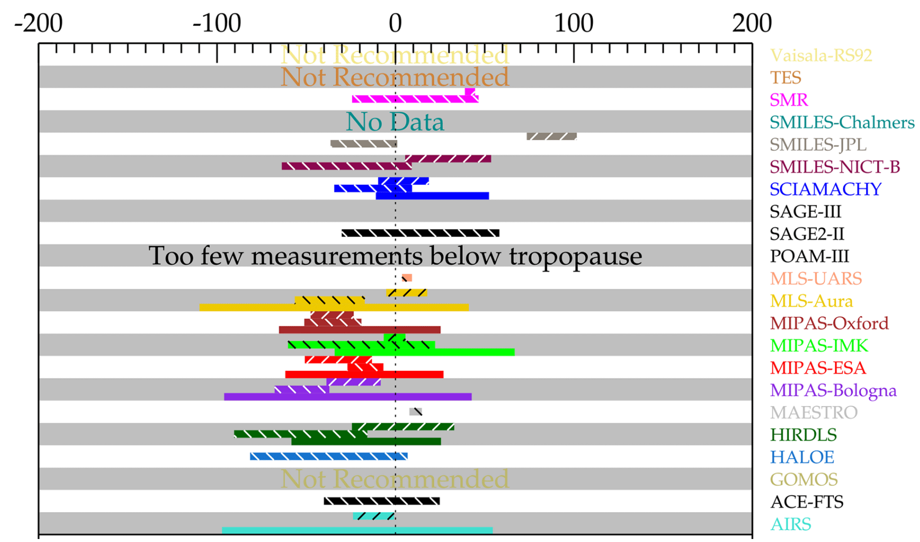
Monitoring, understanding and attribution

Future activities, Part II

- Develop methodologies and tools for handling observational uncertainties, e.g., for binning uncertainties that are correlated across space and time
- Organisation of observation inter-comparison projects to identify and correct systematic errors, e.g., uncertainty quantification activity in ocean datasets

Examples – Inter-comparisons of observations carried out in core projects, e.g.,

- GDAP Data Set Quality Assessments (GEWEX)
- SPARC assessment reports on stratospheric composition
  Upper tropospheric humidity biases (%) for satellites and Vaisala RS92 relative to balloon frost-point hygrometers (Read et al., 2022).



Which approaches and methodologies were used?

What can be learned from past assessments?

-> Guidelines for WCRP wide observation inter-comparisons

Advancing predictions and projections

Use of observations for model and reanalysis evaluation and input data

- Consistency of observations (e.g., across components of the Earth system)
- Uncertainties and error sources
- Temporal consistency via homogenization efforts

Currently:

obs4MIPs
Observations for Model Intercomparisons Project

Collection of satellite datasets

- CMIP formatted and organized
- 218 datasets currently available via the ESGF

Next steps

- Define observational requirements for model evaluation in consistent manner
- Quantifying uncertainties in observational changes and error sources
- Unifying simulated observation techniques for model-data comparisons (at radiance level)

Climate observation networks

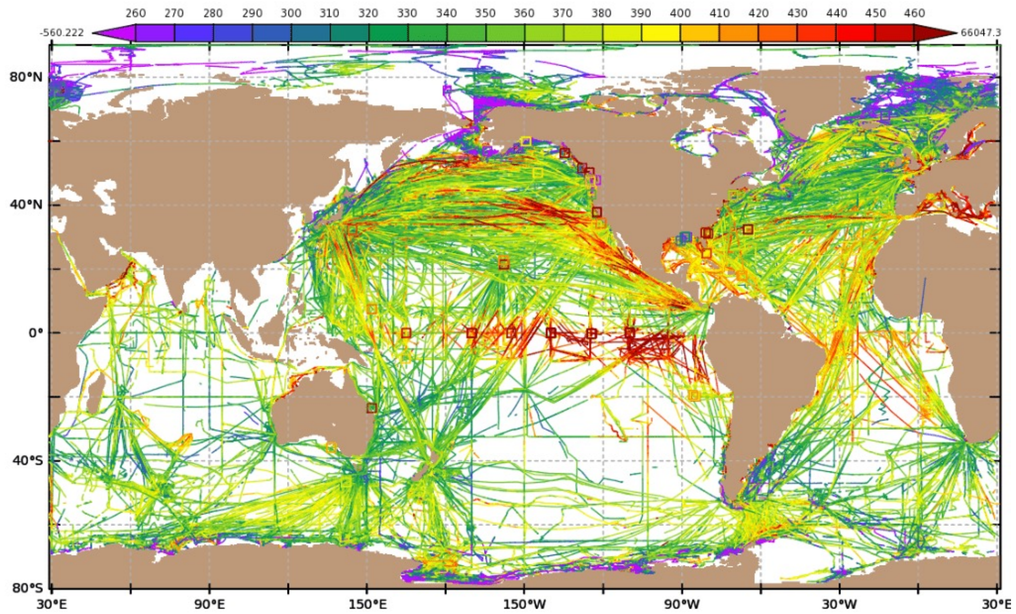
In collaboration with the core projects and WCRP partners:

Identify gaps in-situ reference observations needed for model evaluation, earth observation validation and physical process understanding

- e.g., sparsely observed areas such as the deep ocean, coasts, biogeochemistry

Example:

Surface ocean carbon data from ships and fixed, drifting and autonomous platforms.



In situ surface ocean fCO_2 values (µatm) with an accuracy of < 5 µatm in version 2021. Data source: www.socat.info. GOOS Ocean Observing System Report Card 2022.

Climate observation networks

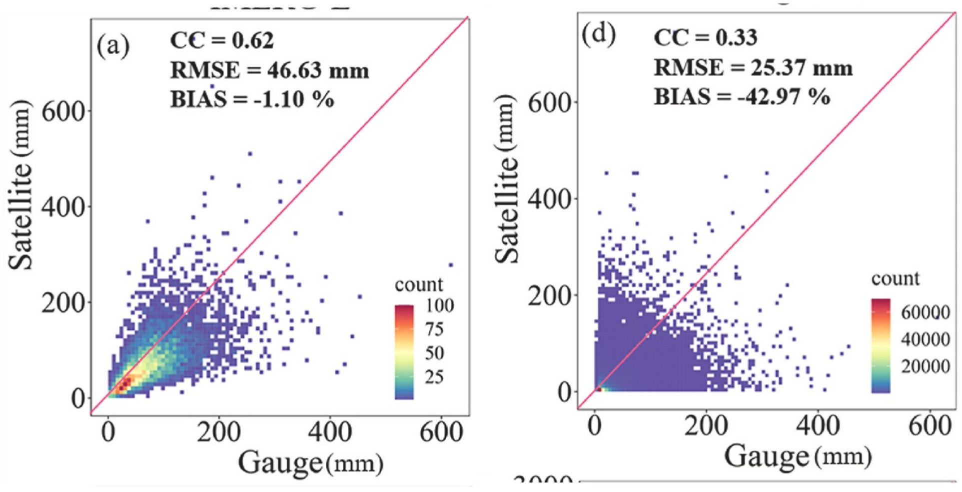
In collaboration with Global Extremes Platform in RIfS:

Observations of extreme events

- Needed for validation of satellite products, high-resolution regional reanalyses, evaluations of km-scale modelling of extreme events and urban climate
- Extended in-situ reference networks and increased temporal frequency
- Focus on some key variables and processes?
- **Requirements need to be defined**

Example:

Validation of satellite products in detecting extreme precipitation and drought



Scatter plots of extreme precipitation from in-situ gauge observations versus satellite estimates (Yu et al., 2022)

Building and sustaining climate data records

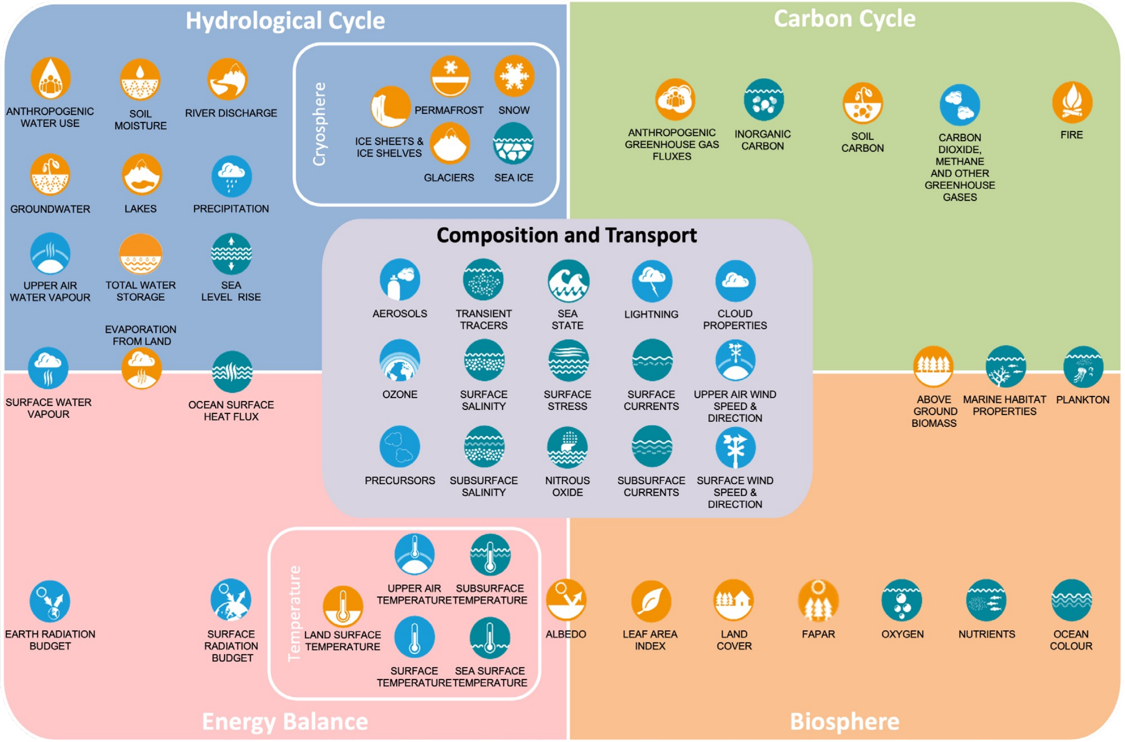
Input to GCOS for consolidation in the observing system requirements and advocacy

Observational requirements currently not covered by existing ECVs.

For example:

- Carbon cycle monitoring across all relevant processes (e.g., ecosystems and interfaces).
- Land surface data products (e.g., vegetation and other physiographic fields).
- ECVs for urban modelling (e.g., evaporation, land surface temperature and soil water content).

Essential Climate Variables and the climate cycles



The 2022 GCOS Implementation Plan

Accessing, archiving, and processing climate data

Promote and help with:

- Fair and open access to data
  - Challenges for global south and data sparse areas to access high quality data
  - Cloud computing with associated analysis platforms -> global access to to observational and model data for wider range of scientists
  - What about access to data for citizens?
  - How to interact with organizations that develop information for climate solutions?
- Common vocabulary between producers and users of data (standards and format, searchability and discoverability of the data).
- Traceability of data processing throughout the data chain; from raw to product, using consistent and standardized recording methods within the metadata.

Summary

Observational uncertainties and errors

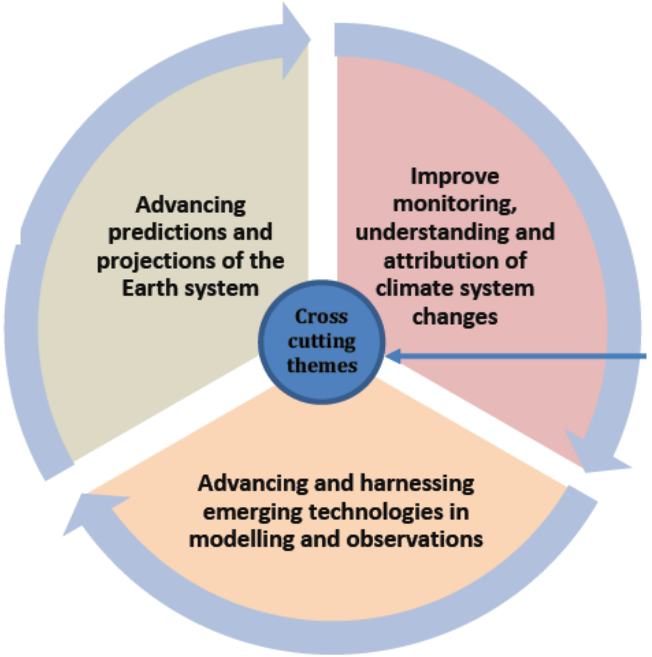
- Develop a common understanding
- Implement metrology concepts
- Methodologies and tools (e.g., binning)
- Observation inter-comparison projects

Observations for models & reanalysis

- Define observational requirements
- Homogenization efforts
- Unifying simulated observation techniques

Climate data records

- Input on observational requirements currently not covered by ECVs



Accessing, archiving, and processing

- Common vocabulary, traceability
- Fair and open access, cloud computing

Climate observations networks

- Identify gaps in-situ reference observations
- Extended and focused observations of extreme events

Effort on coordinating OSEs/OSSEs

- Goal: to inform the design of observing systems