# Essential Climate Variables (ECVs) and the contribution of geodetic observations: an overview

**Andreas Güntner[1], Claudia Ruz Vargas[2], Annette Eicker[3]**

[1]German Research Centre for Geosiences (GFZ), Potsdam, Germany
[2]International Groundwater Resources Assessment Centre (IGRAC), Delft, The Netherlands
[3]HafenCity University, Hamburg, Germany

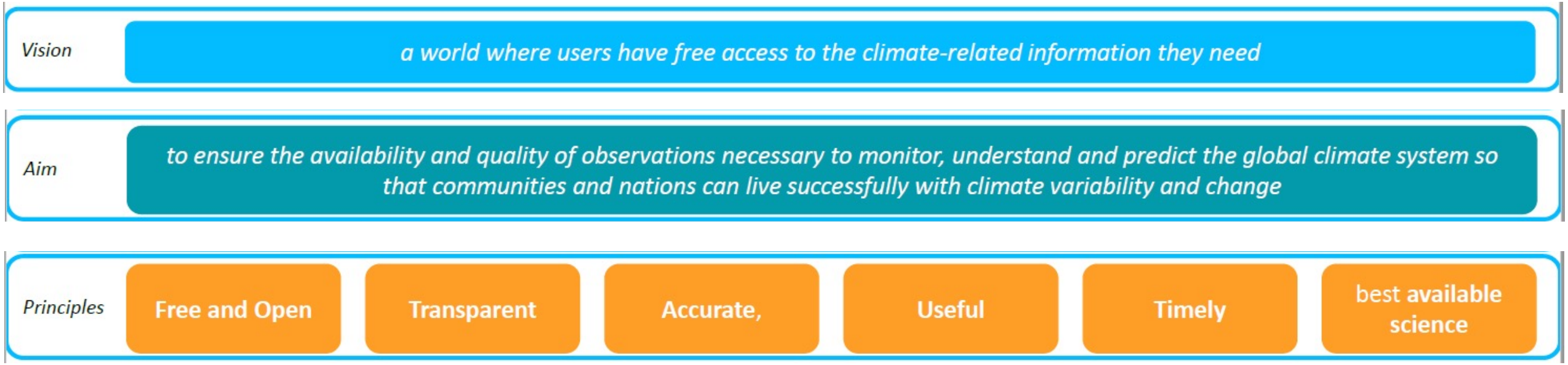
ICCC Workshop, 29.03.2021

# Essential Climate Variables (ECVs)

- are variables that are critical for characterizing the climate system and its changes
- provide the empirical evidence needed
  … to understand and predict the evolution of climate
  … attribute climatic events to underlying causes
  … assess risks
  … guide adaptation measures
  … underpin climate services
- are defined by GCOS (the Global Climate Observing System)

# GCOS – the Global Climate Observing System

## Systematic observations under the UNFCCC (the UN Framework Convention on Climate Change)

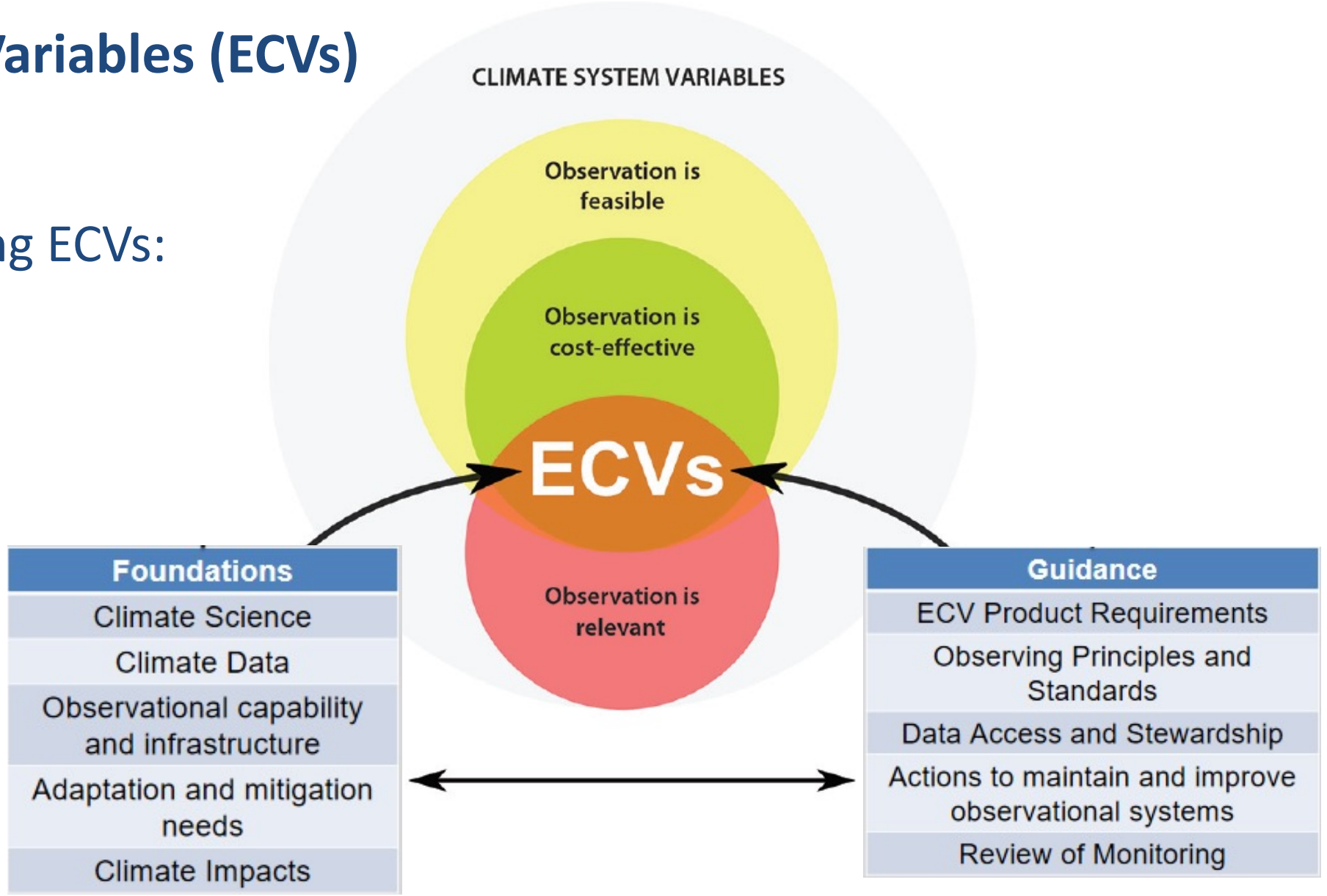



- establish ECVs to distil a complex field of observations/observing systems into a manageable list of priorities, including guidance on requirements and best practices

# Essential Climate Variables (ECVs)

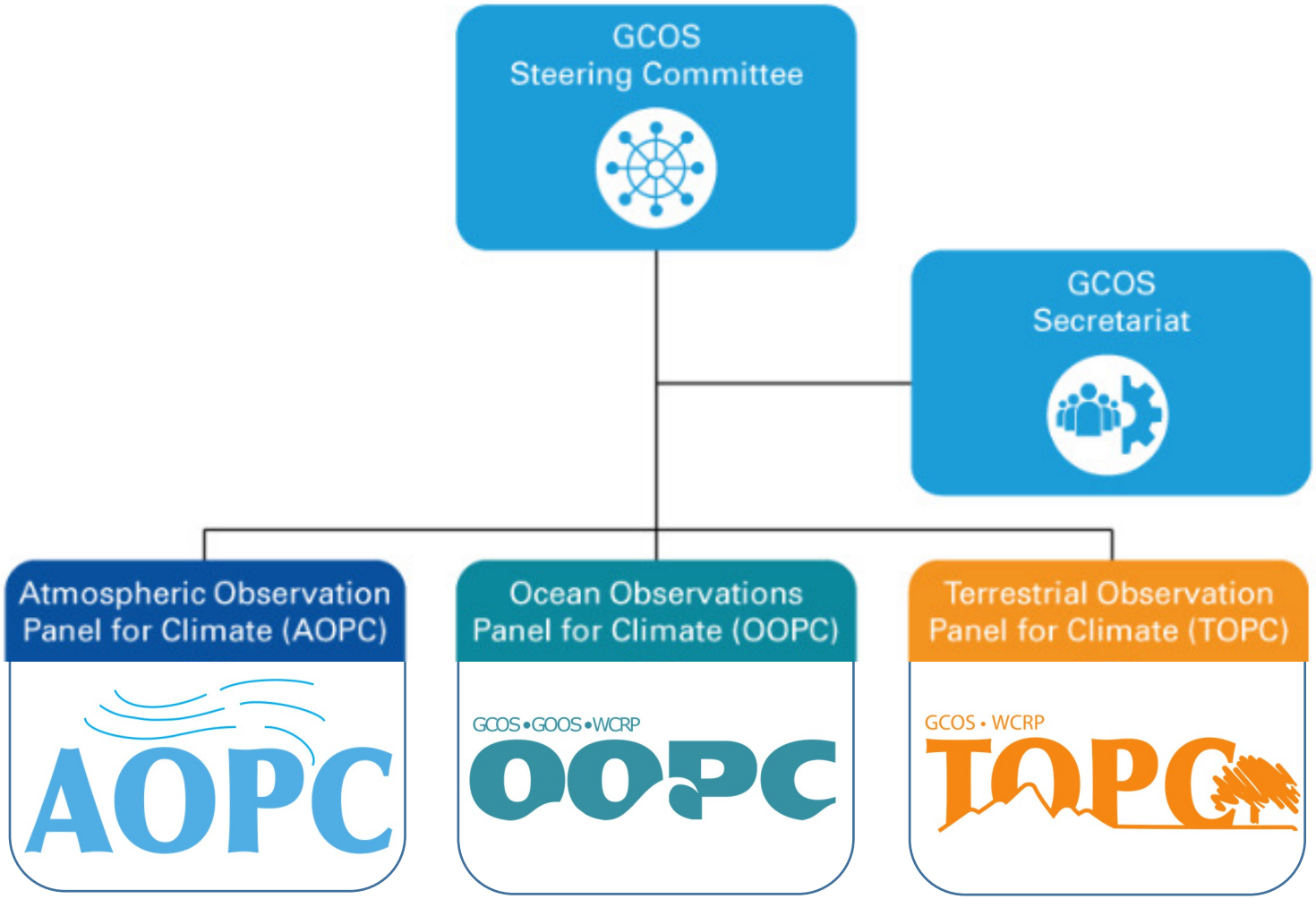
Criteria for identifying ECVs:

- Relevance
- Feasibility
- Cost effectiveness



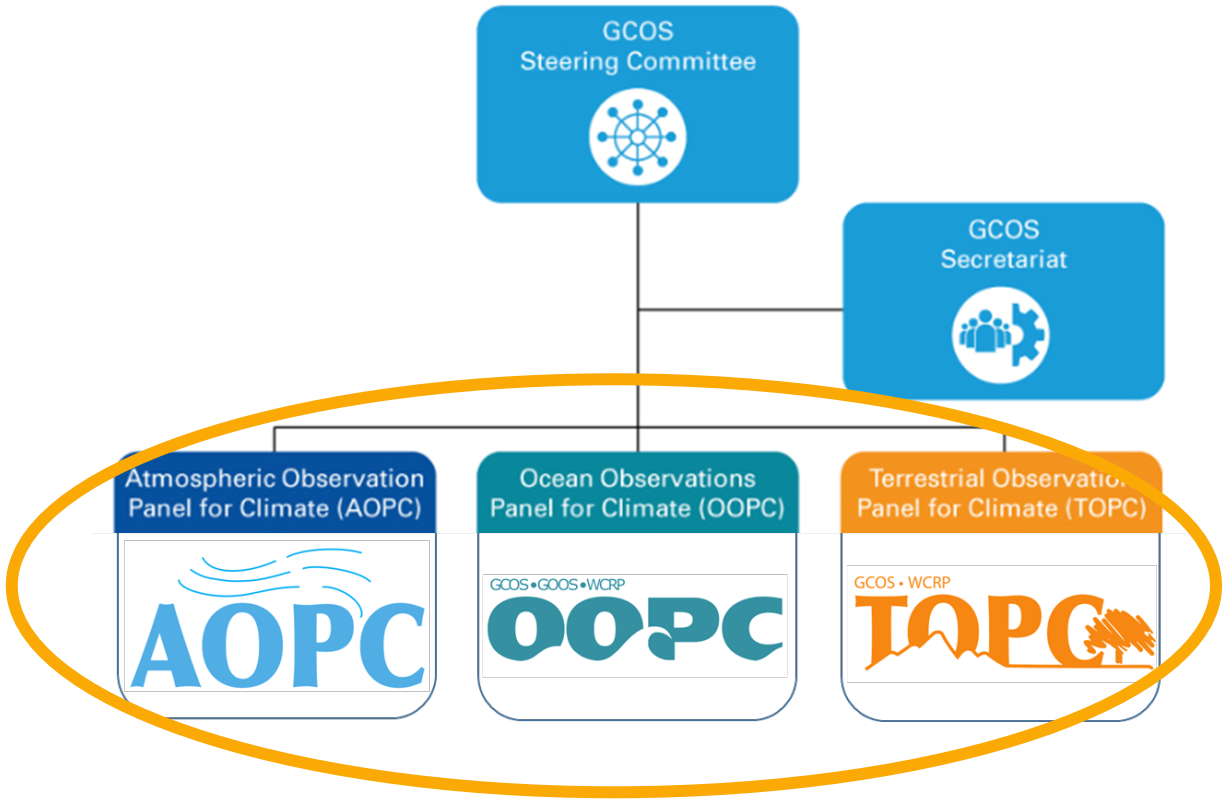

Bojinski et al. (2014): The concept of essential climate variables in support of climate research, applications, and policy. Bulletin of the American Meteorological Society, 95(9)

# GCOS – the Global Climate Observing System




Expert panels

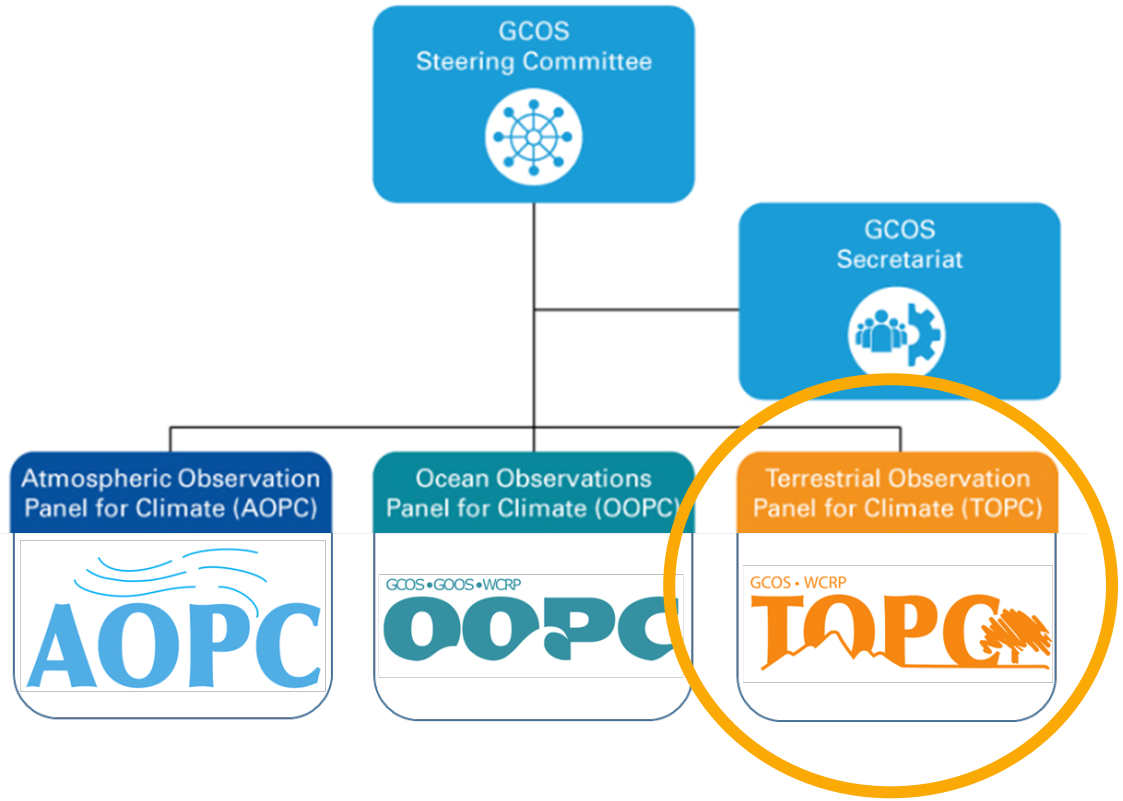
# GCOS – the Global Climate Observing System




## Key activities of the expert panels

- Identify ECVs and climate change indicators
- Define and revise ECV requirements
- Assess the adequacy of current observing networks (in situ, satellite-based)
- Coordinate activities with other global observing systems and panels to ensure the consistency

# GCOS – the Global Climate Observing System




| ECV | Steward(s) | Affiliation |
|---|---|---|
| Above-ground biomass | Dr Sarah CARTER<br>Prof. Martin HEROLD<br>Sassan SAATCHI | GOFC-GOLD, Wageningen University<br>GOFC-GOLD, Wageningen University<br>Jet Propulsion Laboratory California US |
| Albedo | ne GOBRON | European Commission, Joint Researc Environment and Sustainability |
| Anthropogenic GHG fluxes | Dr | European Commission, Joint Researc onment and Sustainability Carbon Observation Syste tructure Consortium |
| Anthropogenic water use | Prof. Nigel TAPPER | re and En onash Unive |
| Evaporation from land | Prof. Diego MIRALLES | Ghent Universi elgium |
| FAPAR | Dr Nadine GOBRON | European Commission, Joint Researc Environment and Sustainability |
| Fire | Prof Emilio CHUVIECO-SALINERO | University of Alcala, Alcalá, Spain |

TOPC members act as ECV stewards

# ECVs as a community effort

Public consultations on the ECV requirements (2020, 2017)

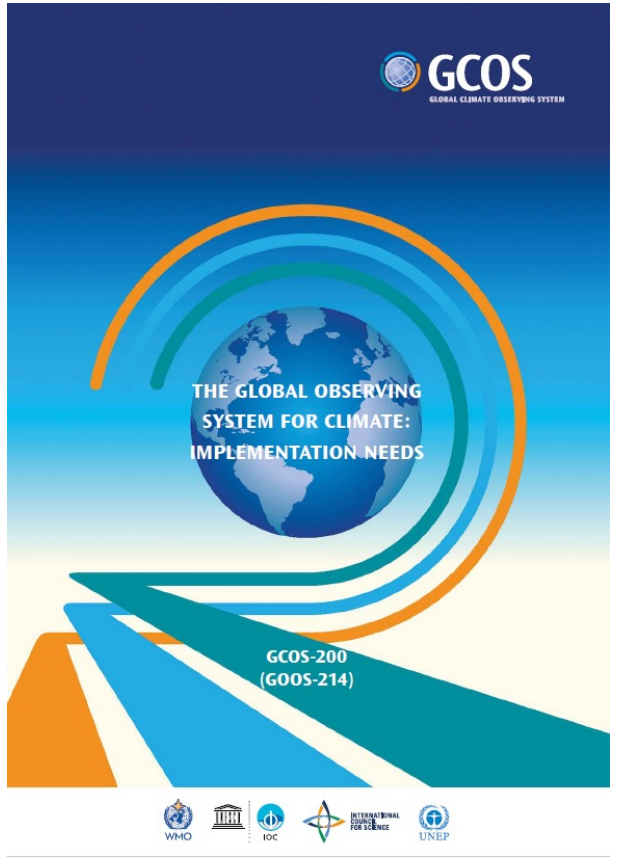
GCOS status report (**2021**)

GCOS implementation plan (**2022**, 2016)

# ECVs as a community effort

## GCOS implementation plan (2022, 2016)

- proposes **how to implement the global observing system** for climate, building on its current status and actions
- sets out the way forward for **scientific and technological innovations for the Earth observation programs** of space agencies and for the national implementation of climate observing systems and networks



# ECVs as a community effort

## GCOS implementation plan (2016)

| Action G31: | Improve gravimetric measurements from space |
|---|---|
| Action | Prepare for satellite missions to provide continuity and consider improved performance to meet the observational requirements in Table 2 |
| Benefit | Improved monitoring of water transport and distribution. |
| Who | Space agencies. |
| Time frame | For 2023 |
| Performance indicator | Published plans and agreed missions |
| Annual cost | US$100 000–1 million |

# ECVs as a community effort

## GCOS implementation plan (2016)

| Action T14: | Operational groundwater monitoring from gravity measurements |
|---|---|
| Action | Develop an operational groundwater product, based on satellite observations |
| Benefit | Global, consistent and verified datasets available to users |
| Time frame | 2019 |
| Who | Satellite agencies, CEOS, CGMS |
| Performance indicator | Reports to UNESCO IHP and WMO CHy on the completeness of the GTN-GW record held in GGMS, including the number of records in, and nations submitting data to, GGMS; web-based delivery of products to the community. |
| Annual Cost | US$ 1–10 million |

# ECVs as a community effort

## GCOS implementation plan (2016)

| Action A22: | Develop a repository of water vapour climate data records |
|---|---|
| Action | Develop and populate a globally recognized repository of GNSS zenith total delay and total column water data and metadata |
| Benefit | Reanalyses, water vapour CDRs |
| Who | AOPC to identify the appropriate responsible body |
| Time frame | By 2018 |
| Performance indicator | Number of sites providing historical data to the repository |
| Annual cost | US$ 100 000–1 million |

# ECV fact sheets

Public consu
ECV rec
(202


## Groundwater
ESSENTIAL CLIMATE VARIABLE (ECV)
FACTSHEET

GLOBAL CLIMATE OBSERVING SYSTEM
KEEPING WATCH OVER OUR CLIMATE

ECV IN BRIEF

| | |
|---|---|
| Domain: | Terrestrial |
| Subdomain: | Hydrology |
| Scientific Area: | Hydrosphere |
| ECV Stewards: | Claudia Ruz Vargas, Andreas Guntner, |
| Products: | Groundwater storage change<br>Groundwater level |

## Groundwater

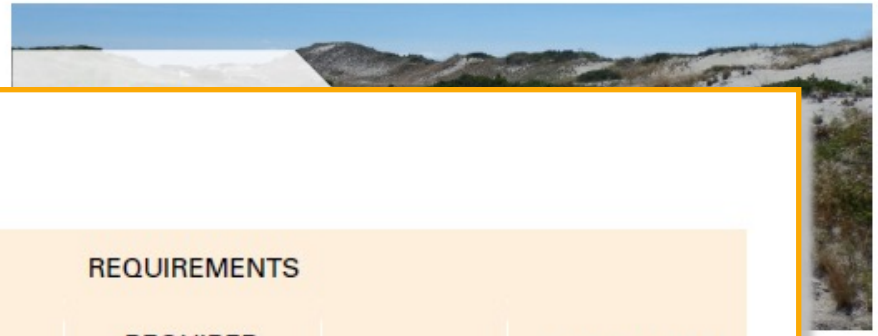
It is estimated that groundwater accounts for about 30% of the world's total freshwater resources, and it is by far the largest available reservoir of liquid freshwater. Groundwater counts in average for one third of the freshwater consumed by humans, but at some parts of the world, this percentage can reach up to 100%. Climate change affects groundwater recharge rates through changes in precipitation and

[1] Current Products and Requirements as in the Implementation Plan 2016 (GCOS-200). GCOS is reviewing and will update the requirements as part of their contribution to the UNFCCC Global Stocktake. More information on: climatedata.wmo.int.

www.gcos.wmo.int gcos@wmo.int @gcos_un In collaboration with WCRP

# ECV fact sheets

Public co
ECV
(2



## ECV Product[1]

| PRODUCT | DEFINITION | REQUIREMENTS | | | | |
|---|---|---|---|---|---|---|
| | | FREQUENCY | RESOLUTION | REQUIRED MEASUREMENT UNCERTAINTY | STABILITY | STANDARDS/ REFERENCES |
| **Groundwater storage change** | **The volumetric loss or gain of groundwater between two time periods** | Monthly | 100 km | 10 cm | TBD | ISO/TC 147 |
| **Groundwater level** | **The level of water table, the upper surface of the saturated portion of the soil or bedrock** | Weekly | Per well | 1 cm | | ISO 5667-18:2001 part 18 |

[1] Current Products and Requirements as in the Implementation Plan 2016 (GCOS-200). GCOS is reviewing and will update the requirements as part of their contribution to the UNFCCC Global Stocktake. More information on: climatedata.wmo.int.

www.gcos.wmo.int gcos@wmo.int @gcos_un

in collaboration with WCRP World Climate Research Programme

# ECVs as a community effort

Public
EC

## GCOS status report (2021)

- provides an overview of the adequacy of the observing system as a whole and assesses the status of each ECV
- expert review of the draft report is ongoing until April 2nd 2021, registration until March 26

# ECVs as a community effort

Expert review of report until April 2nd 2021

## GCOS status report (2021) – draft of action item progress

### Gravimetry

| | | |
|---|---|---|
| G31 | Improve Gravimetric Measurements from Space | (2) Underway |
| T14 | Operational groundwater monitoring from gravity measurements | (3) The Global Gravity-based Groundwater Product (G3P) will show groundwater storage variations with global coverage and monthly resolution from 2002 until present. |

### GNSS

| | | |
|---|---|---|
| A22 | Develop a repository of water vapour climate data records | (2) The potential for ECMWF as the entrusted entity to the Copernicus Climate Change Service to host the centre has been identified and an initial selection of global stations is in the process of being archived via the C3S Data Store. |

# ECVs as a community effort

Public consultations on the ECV requirements (2020, 2017)

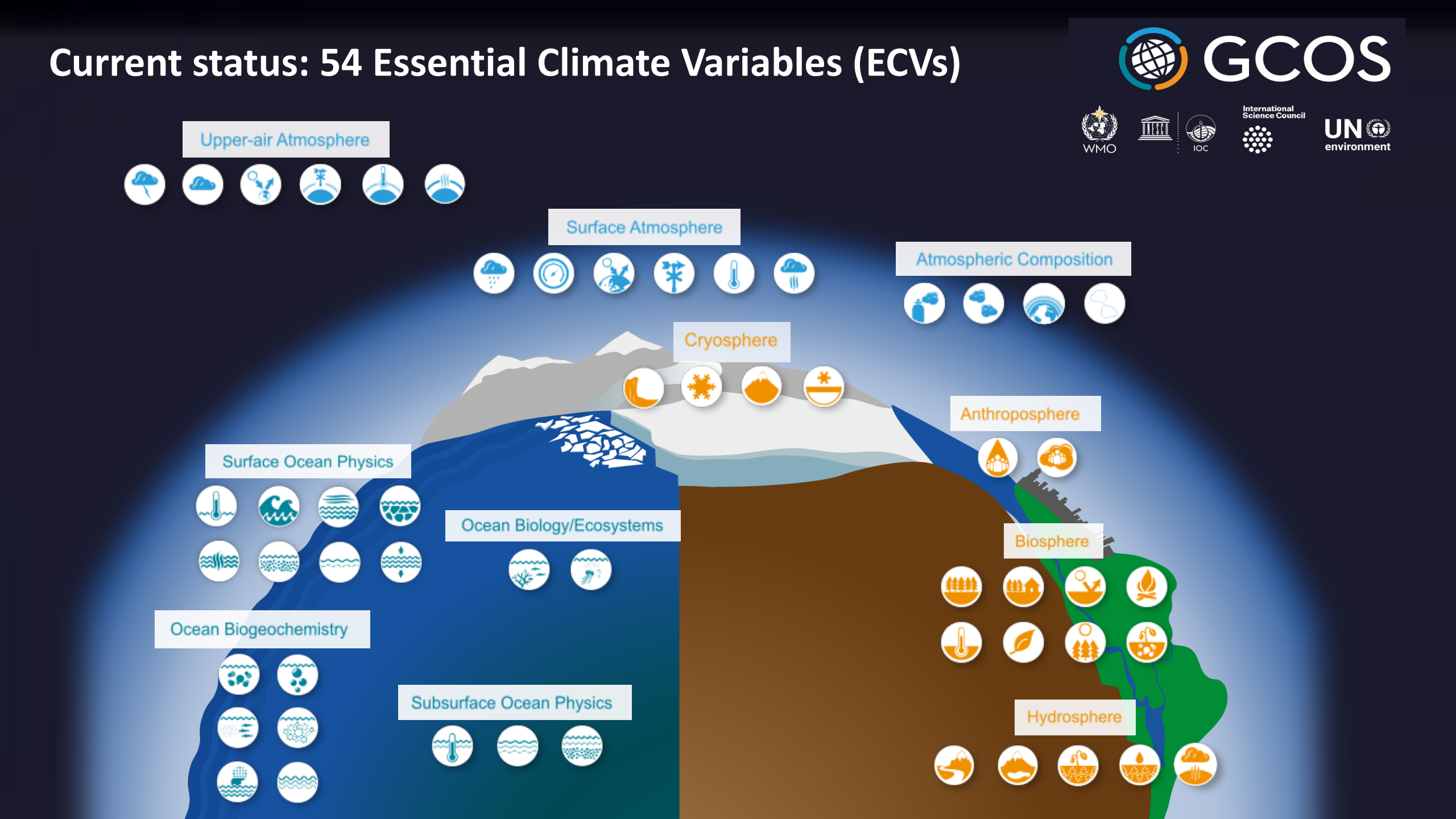
Expert review of report until April 2nd 2021

GCOS status report (**2021**)

Public review, 1st half of 2022

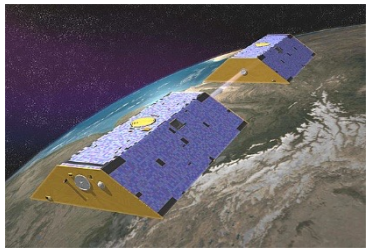
GCOS implementation plan (**2022**, 2016)

# Current status: 54 Essential Climate Variables (ECVs)

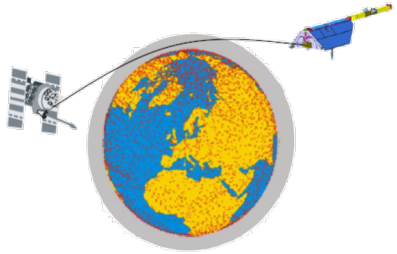


# ECVs – the (potential) contribution of geodesy

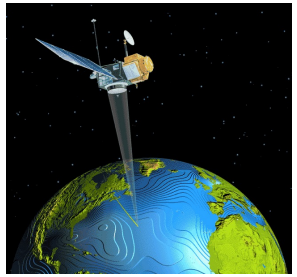
Satellite gravimetry



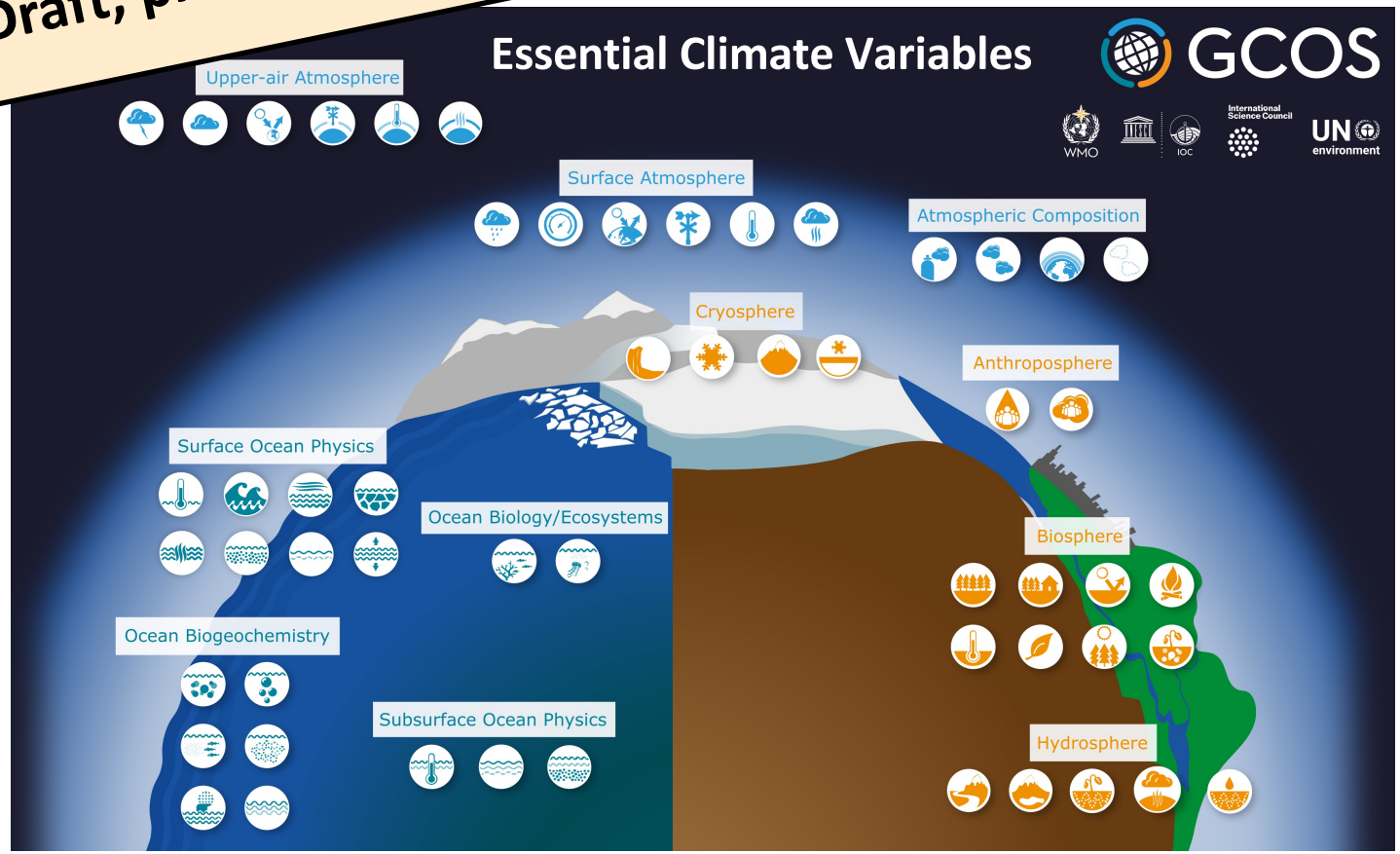
Radio occultation



Satellite altimetry



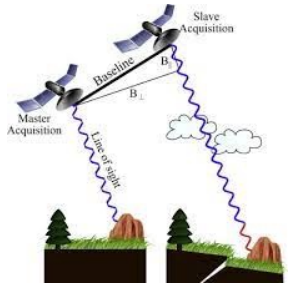
**Draft, please contribute!**



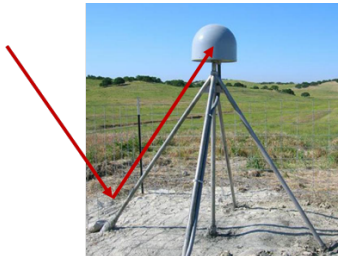

GNSS/VLBI

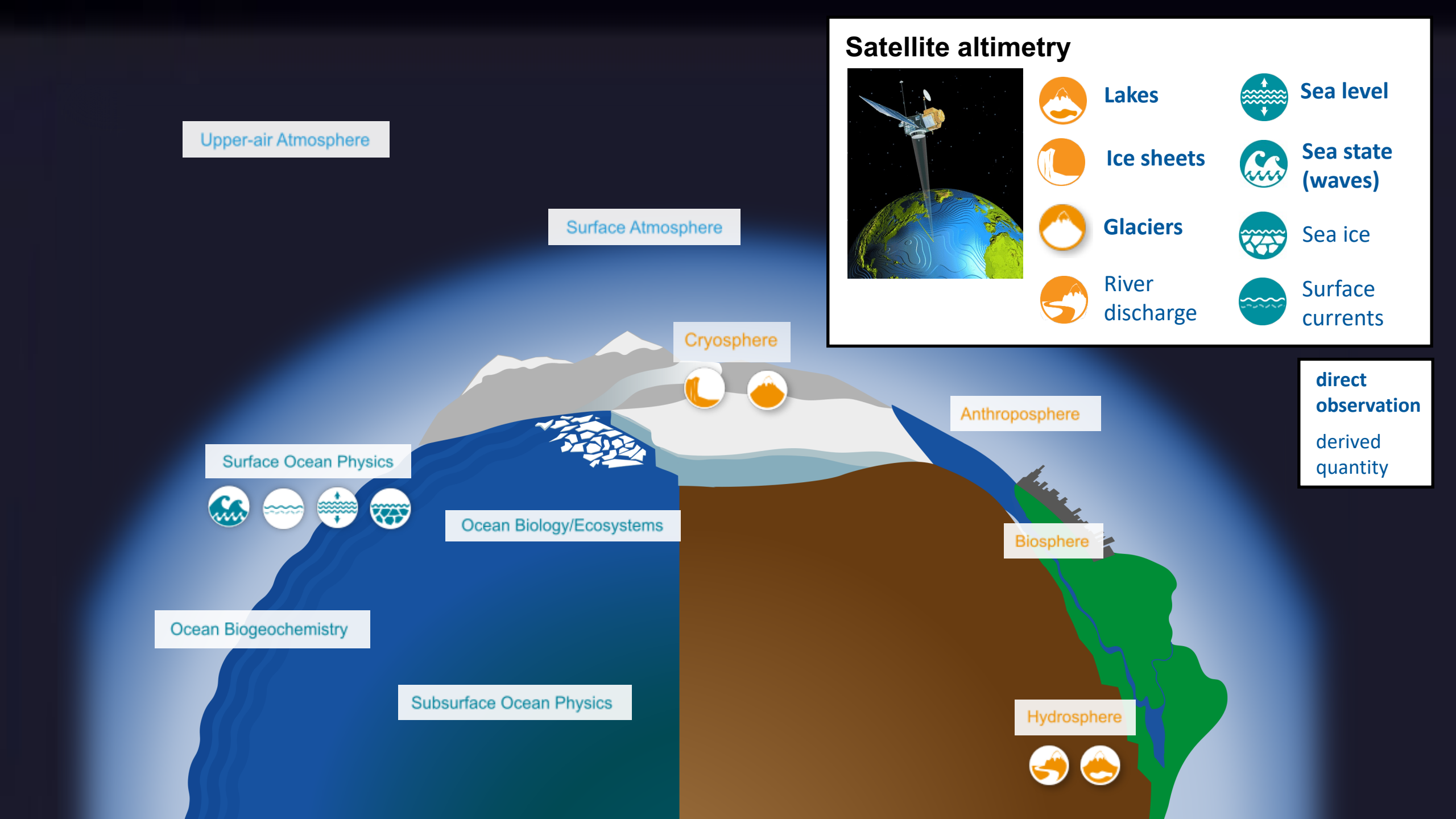
Terrestrial gravimetry

InSAR




GNSS reflectometry




Satellite altimetry
Lakes
Sea level
Ice sheets
Sea state (waves)
Glaciers
Sea ice
River discharge
Surface currents
direct observation
derived quantity
Upper-air Atmosphere
Surface Atmosphere
Cryosphere
Anthroposphere
Surface Ocean Physics
Ocean Biology/Ecosystems
Biosphere
Ocean Biogeochemistry
Subsurface Ocean Physics
Hydrosphere

## GNSS/VLBI tomography

**Upper air water vapor**

Surface water vapor

Precipitation

**direct observation**

derived quantity

Upper-air Atmosphere

Surface Atmosphere

Cryosphere

Anthroposphere

Surface Ocean Physics

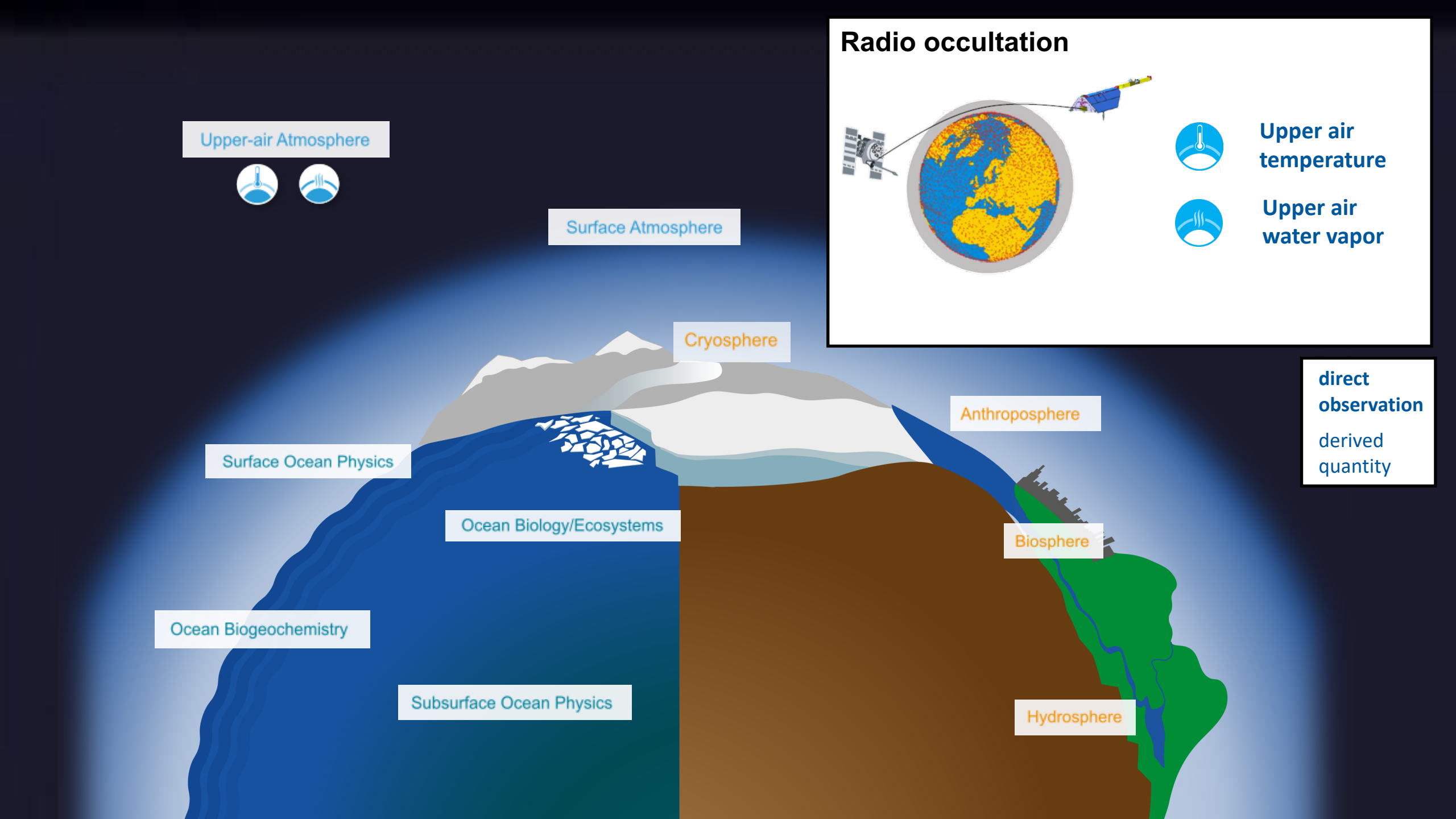
Ocean Biology/Ecosystems

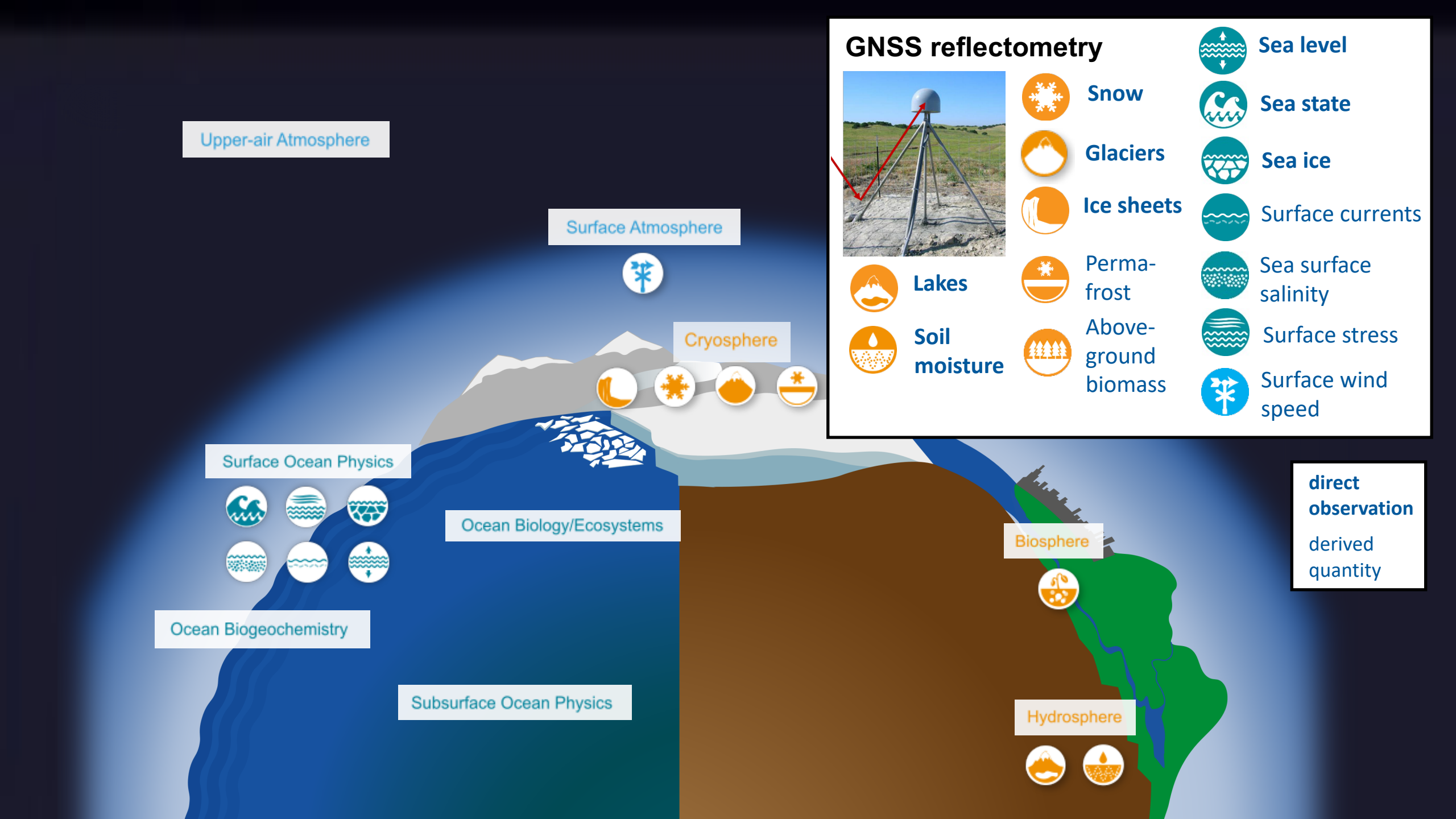
Biosphere

Ocean Biogeochemistry

Subsurface Ocean Physics

Hydrosphere


Radio occultation
Upper air temperature
Upper air water vapor
direct observation
derived quantity
Upper-air Atmosphere
Surface Atmosphere
Cryosphere
Anthroposphere
Surface Ocean Physics
Ocean Biology/Ecosystems
Biosphere
Ocean Biogeochemistry
Subsurface Ocean Physics
Hydrosphere


Upper-air Atmosphere
Surface Atmosphere
Cryosphere
Surface Ocean Physics
Ocean Biology/Ecosystems
Ocean Biogeochemistry
Subsurface Ocean Physics
Biosphere
Hydrosphere
GNSS reflectometry
Snow
Glaciers
Ice sheets
Lakes
Soil moisture
Perma-frost
Above-ground biomass
Sea level
Sea state
Sea ice
Surface currents
Sea surface salinity
Surface stress
Surface wind speed
direct observation
derived quantity

Upper-air Atmosphere

Surface Atmosphere

Cryosphere

Surface Ocean Physics

Ocean Biology/Ecosystems

Ocean Biogeochemistry

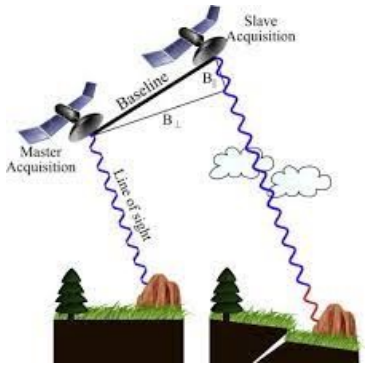
Subsurface Ocean Physics

Anthroposphere

Biosphere

Hydrosphere

## InSAR




Glaciers

Groundwater

Water use

**direct observation**

derived quantity

# Essential Climate Variables (ECVs)

Upper-air Atmosphere

Surface Atmosphere

Cryosphere

Surface Ocean Physics

Ocean Biology/Ecosystems

Ocean Biogeochemistry

Subsurface Ocean Physics

Anthroposphere

Biosphere

Hydrosphere

## Terrestrial gravimetry

- **Lakes**
- Precipitation
- **Soil moisture**
- Evaporation from land
- **Ground-water**
- Permafrost
- **Glaciers**
- Water use
- **Snow**
- **Total terrestrial water storage**

**direct observation**

derived quantity

# Essential Climate Variables (ECVs)

Upper-air Atmosphere

Surface Atmosphere

Cryosphere

Surface Ocean Physics

Ocean Biology/Ecosystems

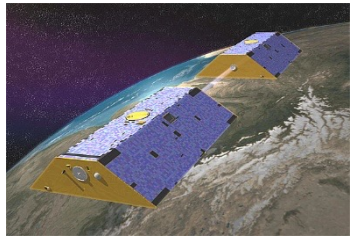
Ocean Biogeochemistry

Subsurface Ocean Physics

Biosphere

Hydrosphere

## Satellite gravimetry



**Ice sheets**

**Glaciers**

**Snow**

**Lakes**

**Soil moisture**

**Ground-water**

Water use

River discharge

**Sea level**

Surface currents

Subsurface currents

Precipitation

Evaporation from land

**Total terrestrial water storage**

**direct observation**

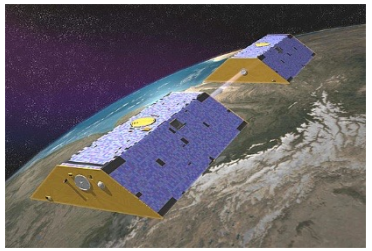
derived quantity

# ECVs – the (potential) contribution of geodesy

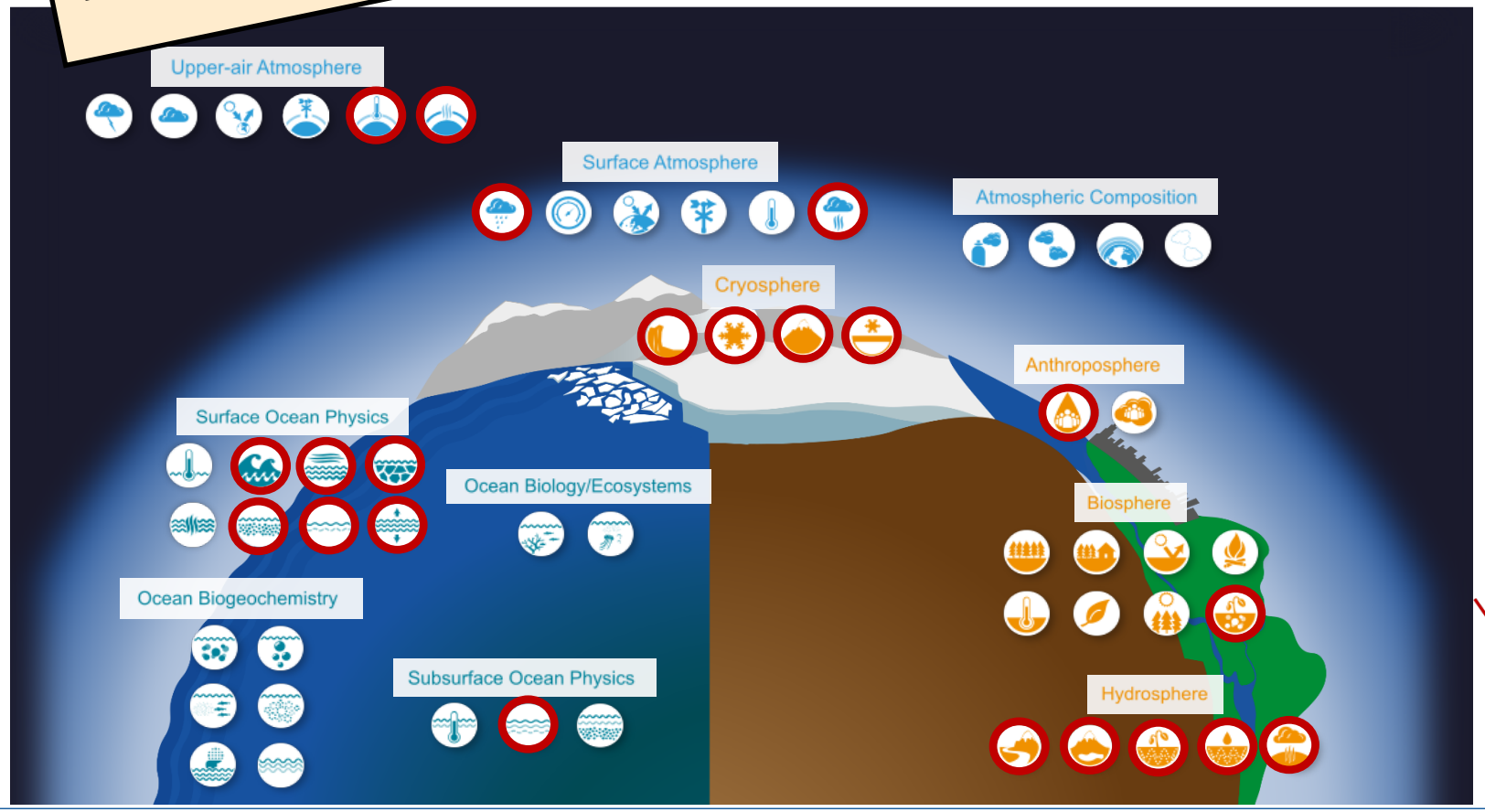
GNSS/VLBI

Terrestrial gravimetry

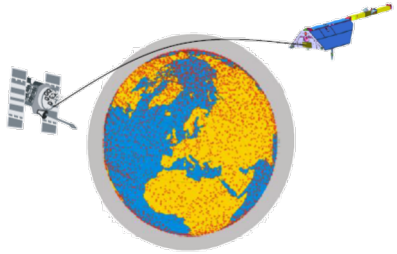
Satellite gravimetry



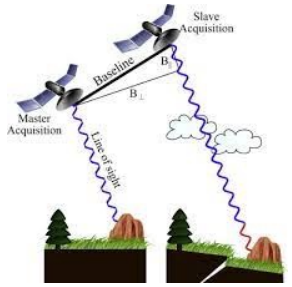
Draft, please contribute!



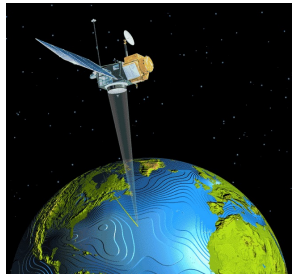

Radio occultation



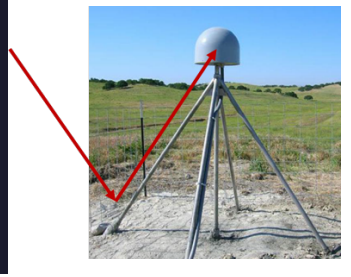
InSAR




Satellite altimetry



GNSS reflectometry

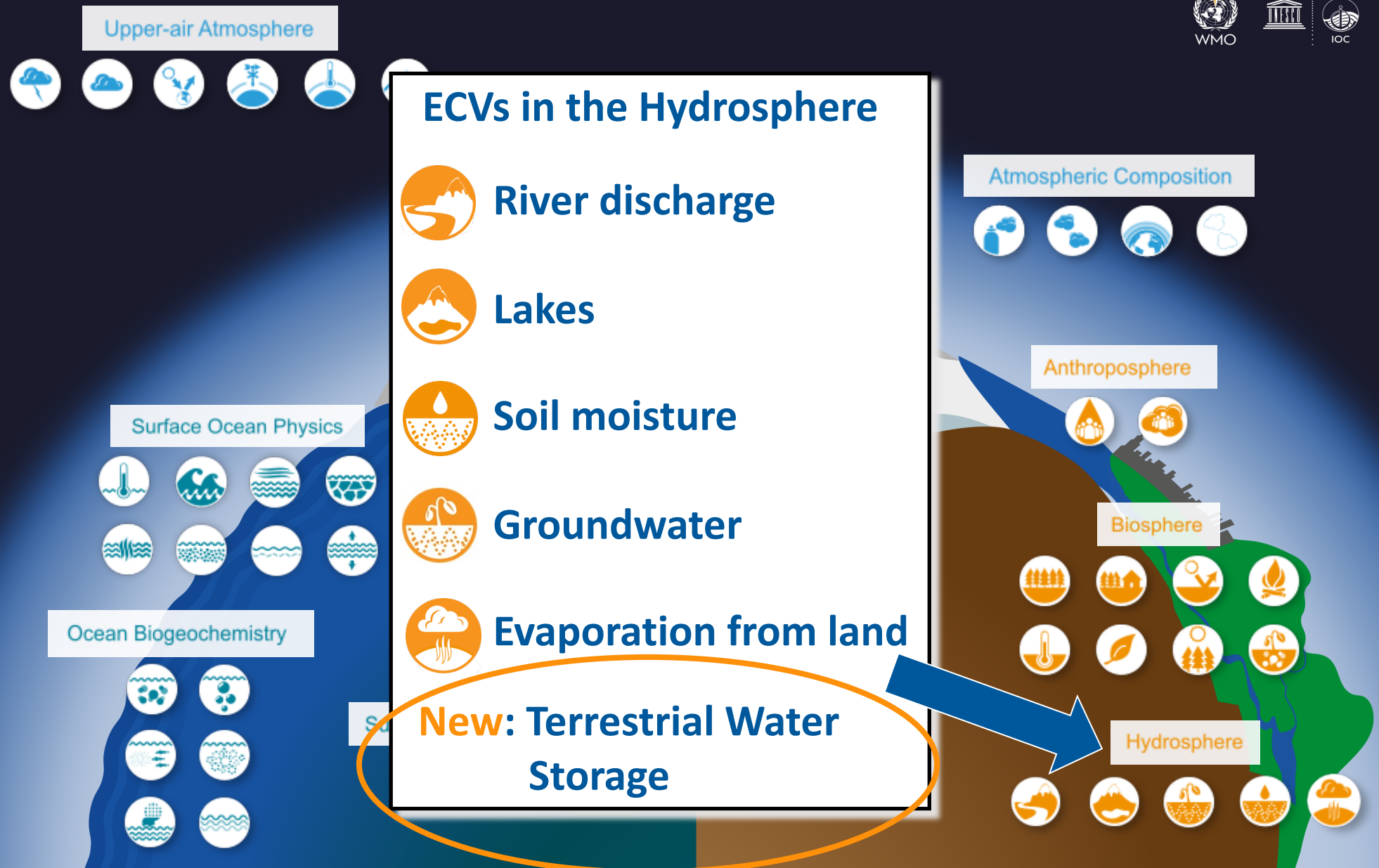


Thanks to Denis Dettmering, Kyriakos Balidakis, Henryk Dobslaw and Jens Wickert for their inputs to these slides

# Essential Climate Variables (ECVs)

GCOS

WMO IOC International Science Council UN environment




## ECVs in the Hydrosphere

- River discharge
- Lakes
- Soil moisture
- Groundwater
- Evaporation from land
- **New**: Terrestrial Water Storage

# Total Water Storage (TWS) as a new ECV

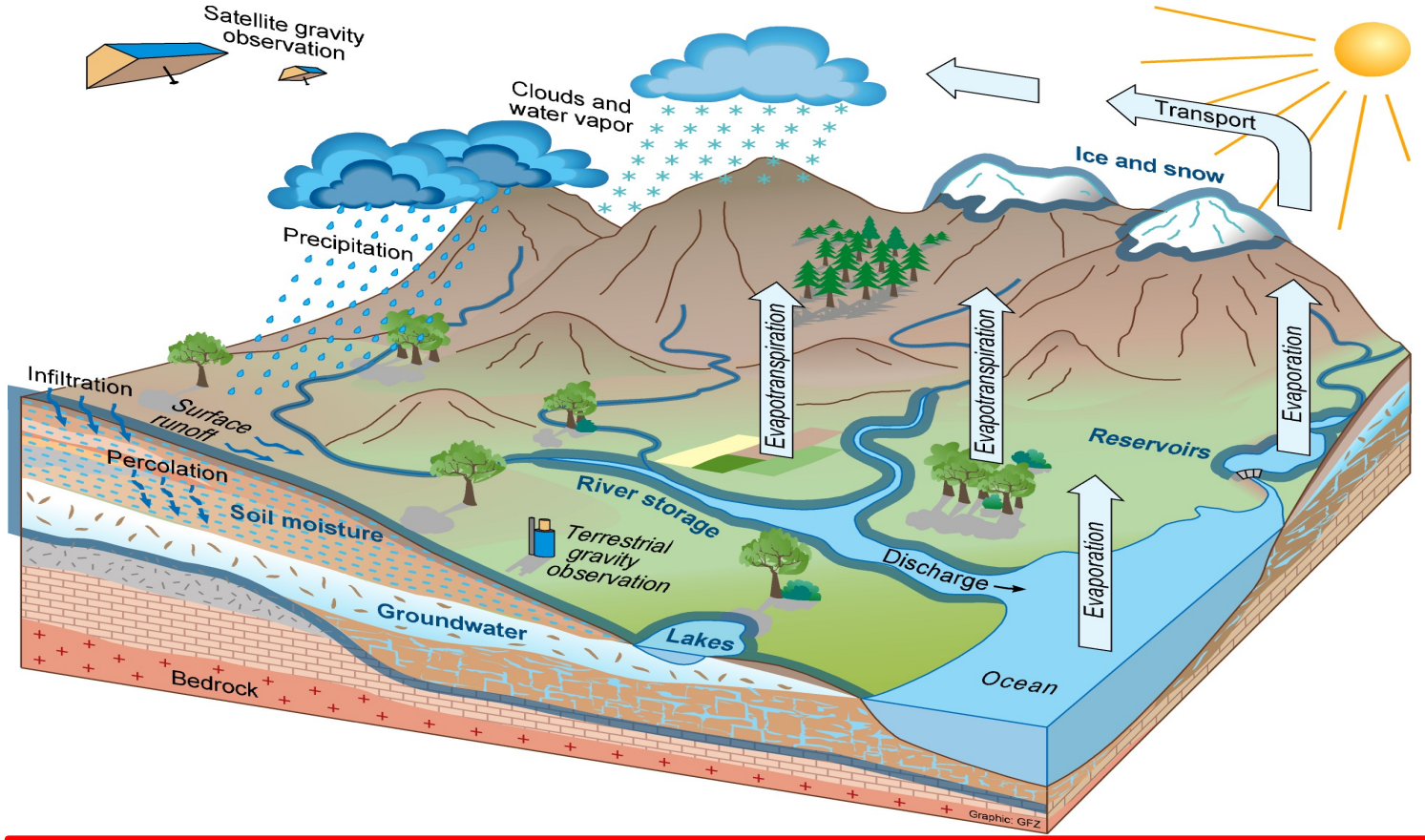
## Relevance

- Hydrological change on the continents
- Closing the terrestrial water balance

### Continental water balance

$$P = ET + Q + \Delta TWS$$

P: Precipitation
ET: Evapotranspiration
Q: Runoff
ΔTWS: Storage change



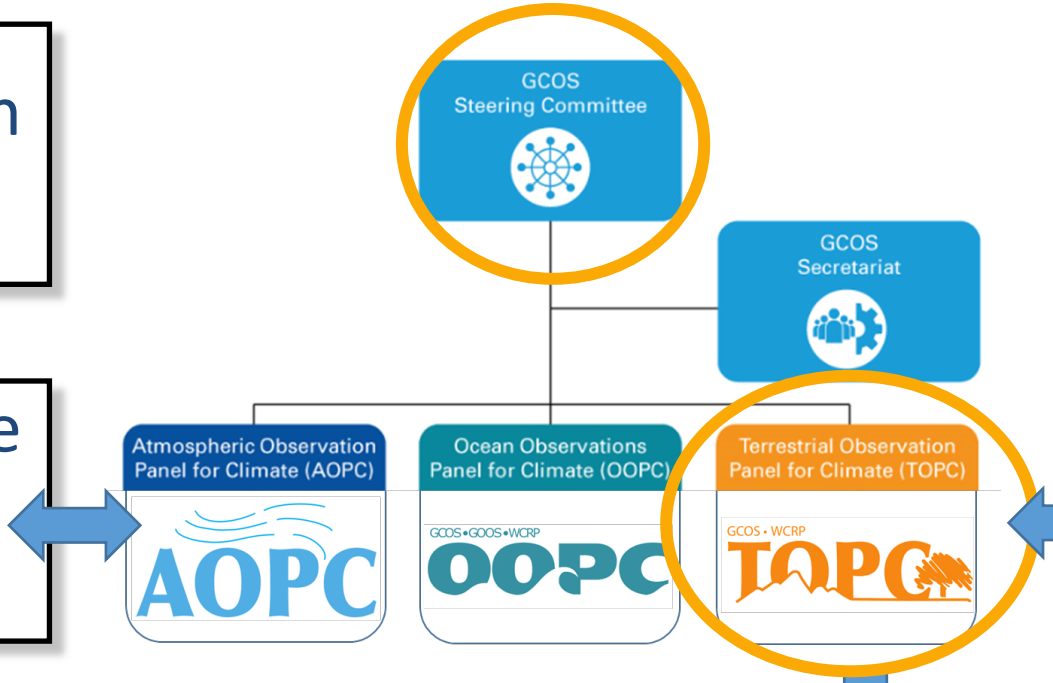

Groundwater | Soil moisture | Lakes | River storage | Ice and snow | Reservoirs

TOTAL WATER STORAGE

# Total Water Storage (TWS) as a new ECV

GCOS implementation plan (2016)

Public consultations on the ECV requirements (2017)




Public review 1st half of 2022

GCOS implementation plan (**2022**)

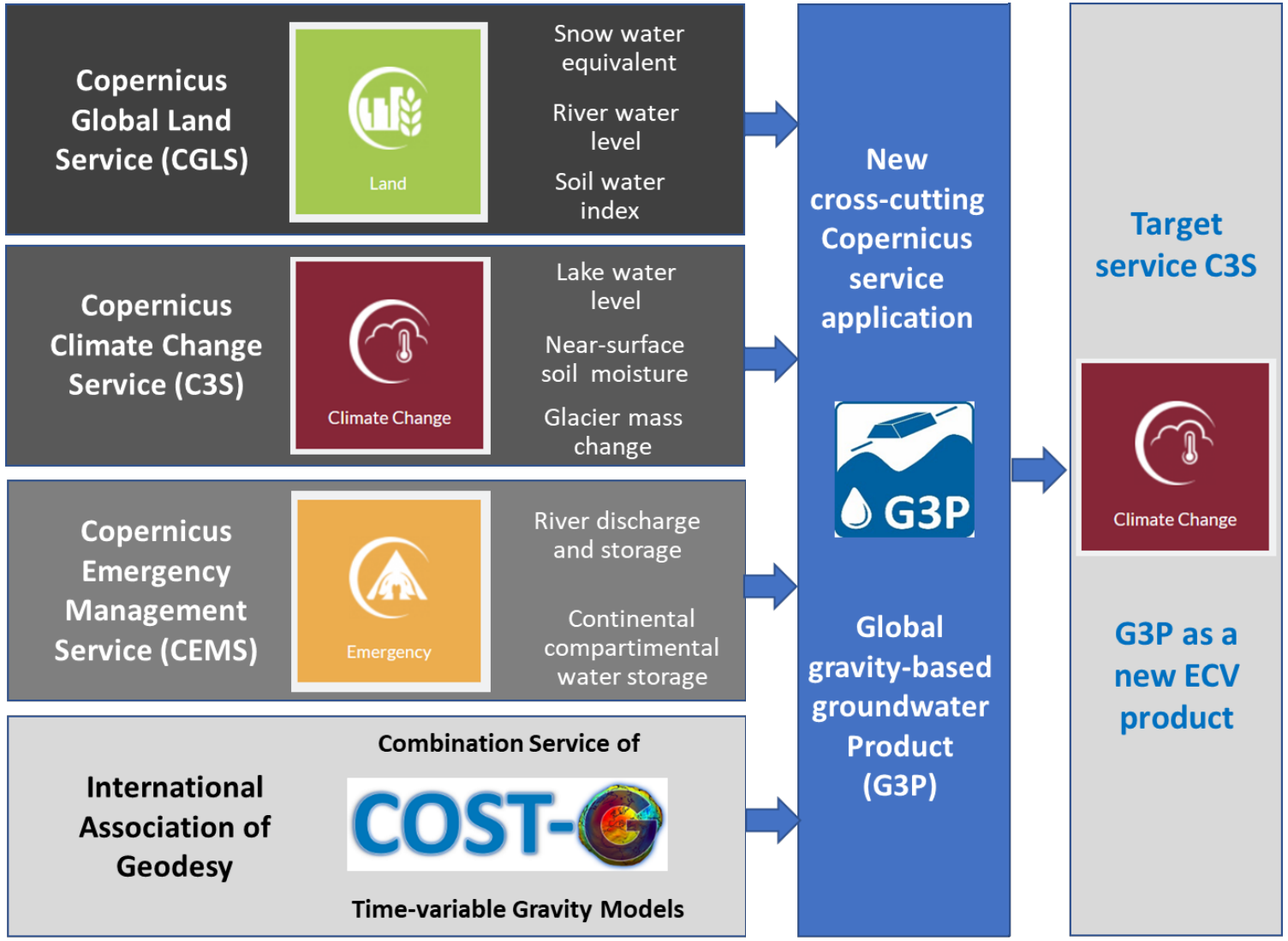
# ECV data products via Copernicus services


EU's Earth observation programme Copernicus provides data sets for a larger number of ECVs.

**But:**
there is no product yet for the ECV Groundwater.

This gap will be filled by **G3P**, the Global Gravity-based Groundwater Product

# ECV data products via Copernicus services




EU's Earth observation programme Copernicus provides data sets for a larger number of ECVs.

**But:**
there is no product yet for the ECV Groundwater.

This gap will be filled by **G3P**, the Global Gravity-based Groundwater Product

G3P receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 870353.