A Global Gravity-based Groundwater Product (G3P)

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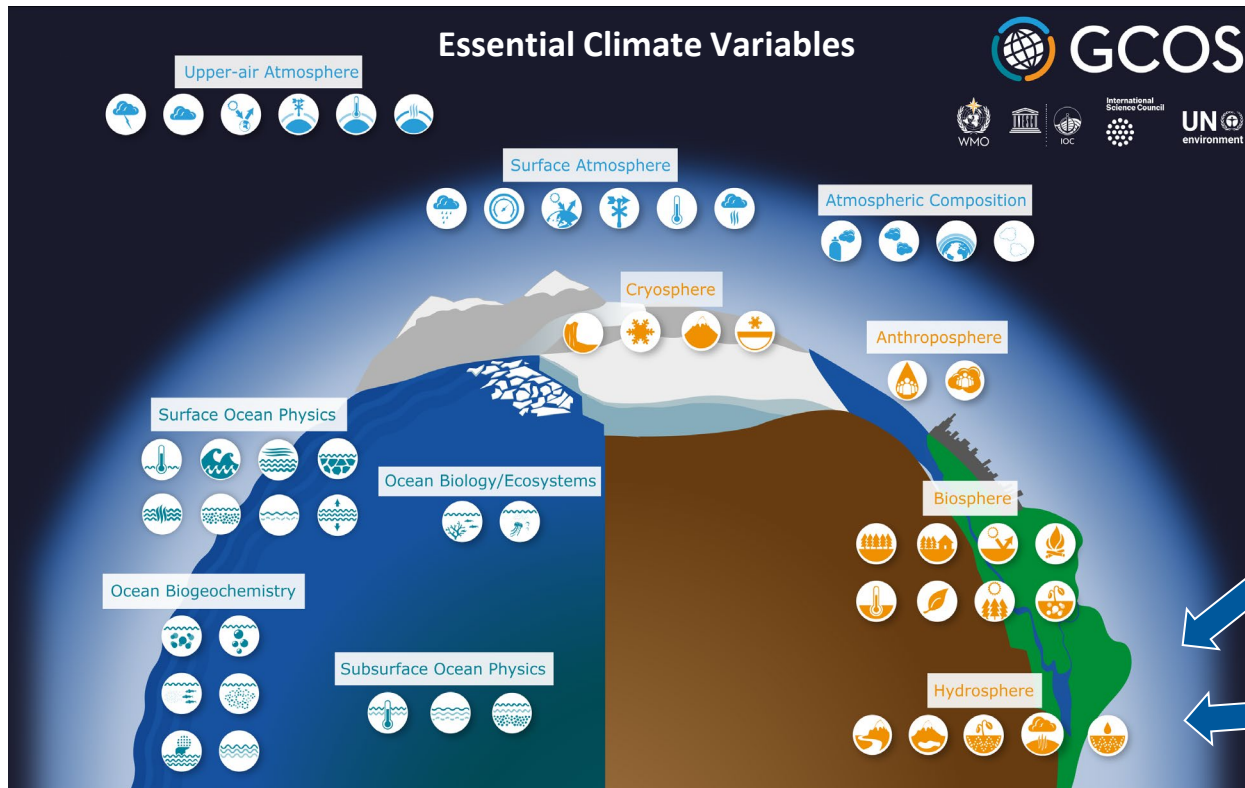[2] University of Bern, Astronomical Institute, Bern, Switzerland
[3] TU Wien, Department of Geodesy and Geoinformation, Vienna, Austria,
[4] IGRAC, Delft, The Netherlands

ESA LP Symposium,
Bonn, May 24, 2022

Essential Climate Variables (defined by GCOS)

New ECV:
Terrestrial Water Storage
(will be included in GCOS implementation plan 2022)
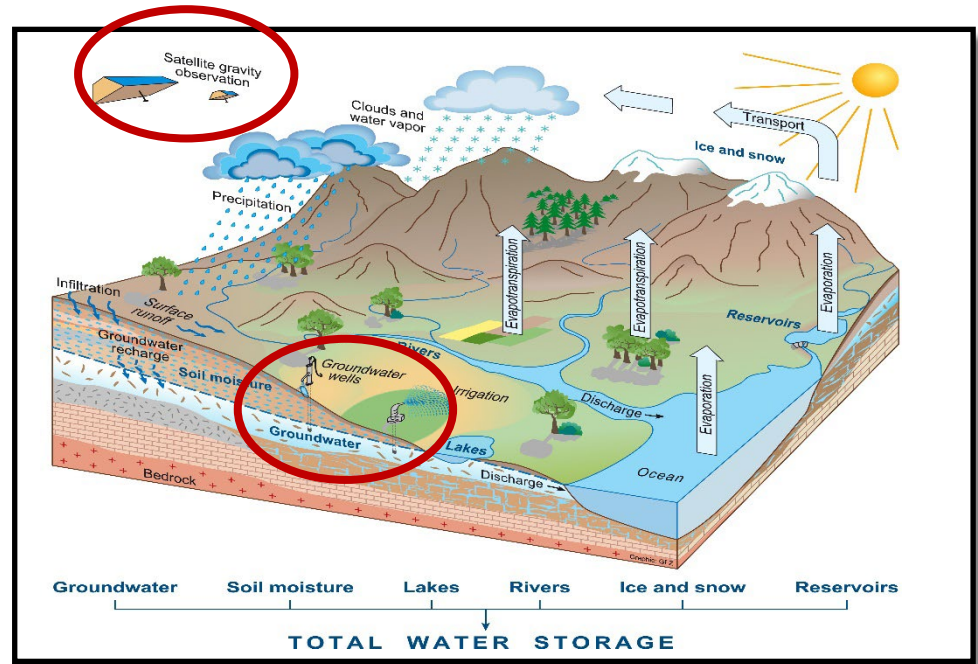
ECV Groundwater

Essential Climate Variables

GCOS defined **Groundwater** and **Terrestrial Water Storage (TWS)** as ECVs

- Copernicus (EU's Earth observation programme) provides services for many ECV products

- **But:**
  no product yet for the ECV Groundwater (nor for TWS)

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

G3P concept (Global Gravity-based Groundwater product)

- Satellite gravimetry observes Total Water Storage (TWS) variations

- Resolving for groundwater storage variations with the following subtraction approach:

Groundwater = TWS - Glaciers - Snow - Soil Moisture - Storage in Surface Water Bodies

G3P objectives

Development of a product of groundwater storage variations

➢ for later operational implementation into the Copernicus Climate Change Service (C3S)

➢ by a cross-cutting combination of GRACE / GRACE-FO satellite gravity data with water storage data based on existing Copernicus services

➢ global coverage

➢ 0.5° spatial resolution

➢ from 2002 until present

➢ monthly temporal resolution
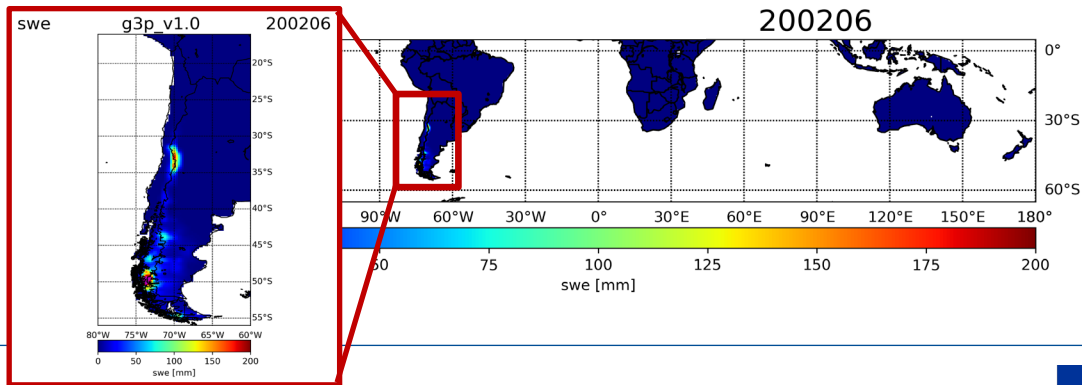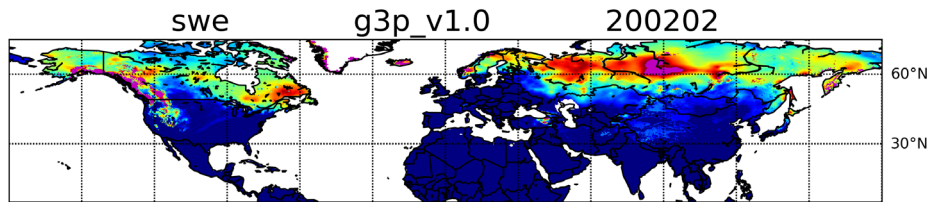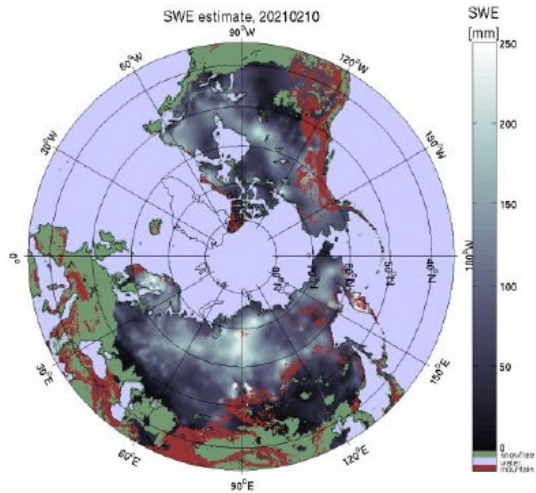
G3P – Cross-cutting Service Combination
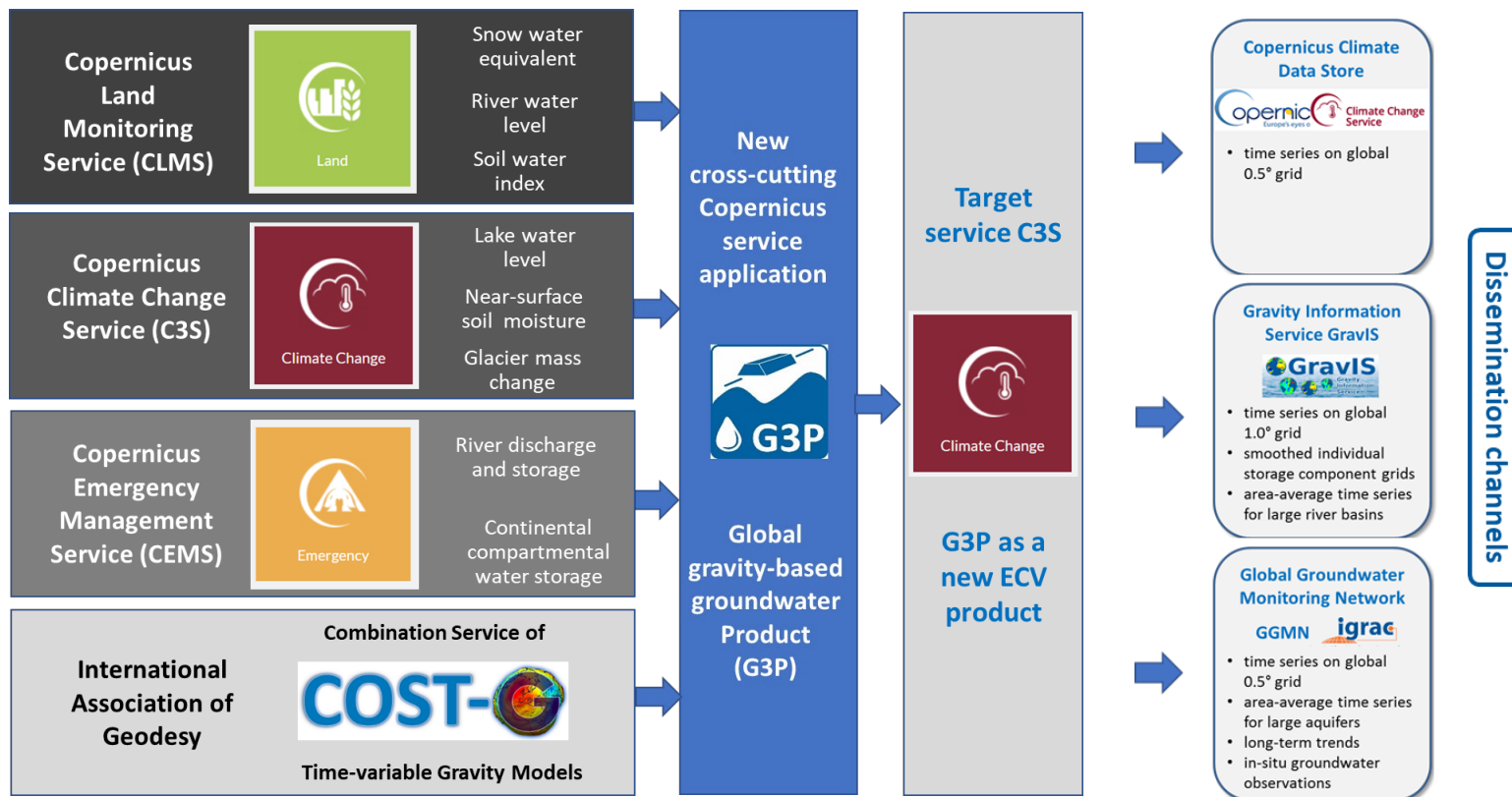
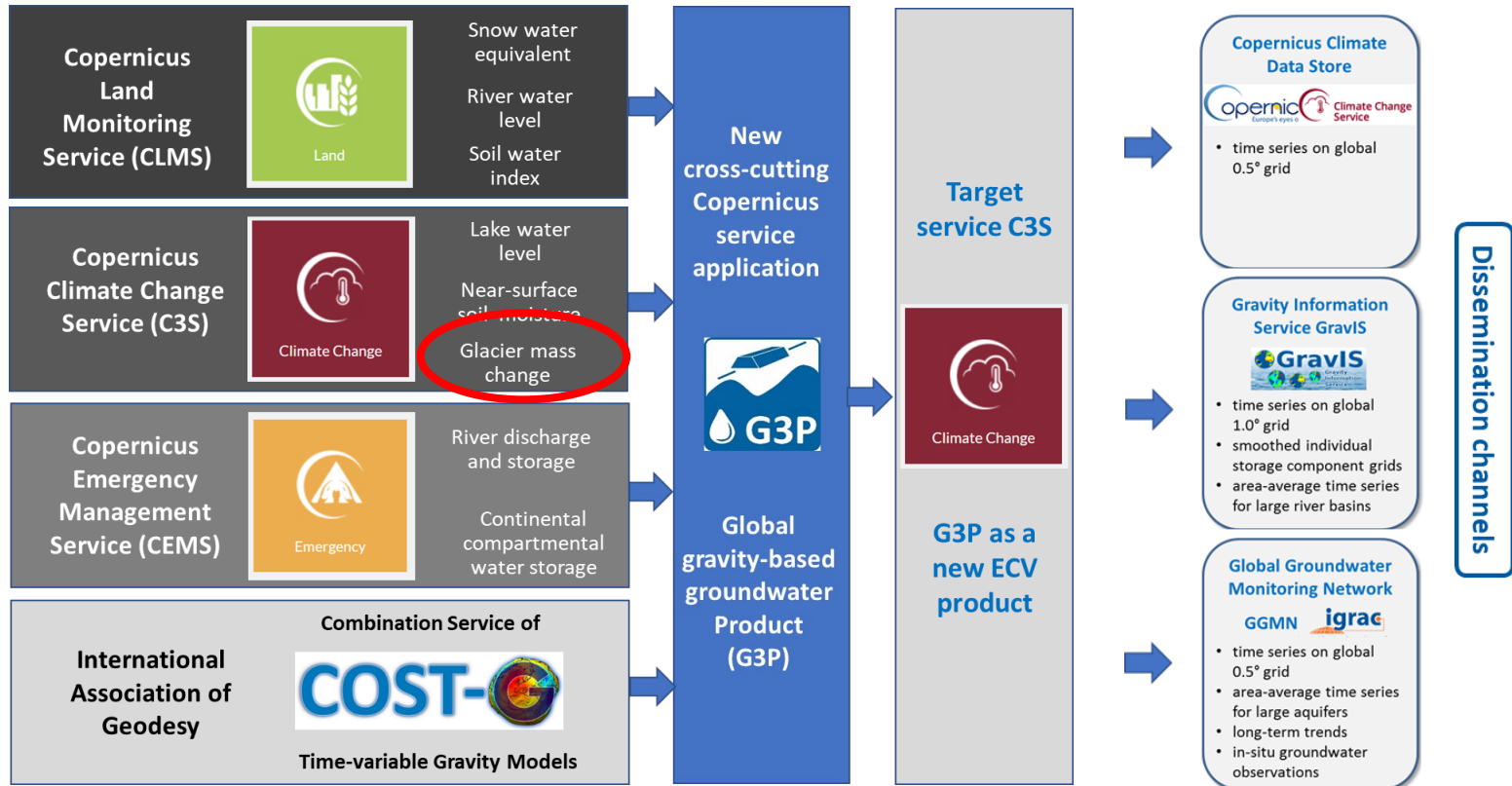# G3P – Cross-cutting Service Combination
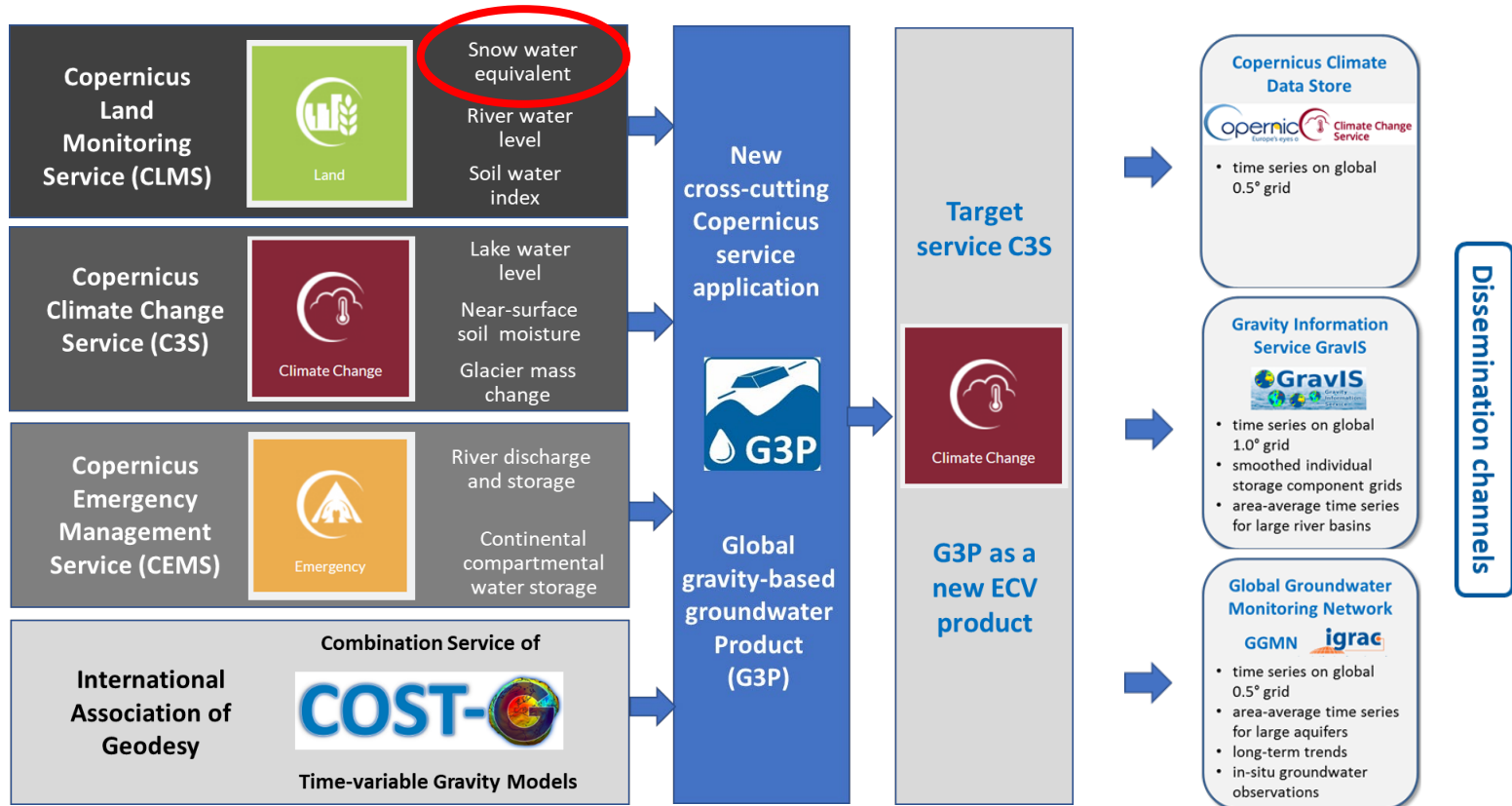
G3P – Observation-based data products: SWE – Snow Water Equivalent

SWE retrieval combines satellite-based Passive Microwave with ground-based snow depth data

- Daily operational SWE production in Copernicus CLMS (operated by FMI)
- **In G3P:** Filling data gaps in mountainous areas + Southern Hemisphere by merging with Land Surface Model SWE fields (combination of GLDAS and MERRA2)
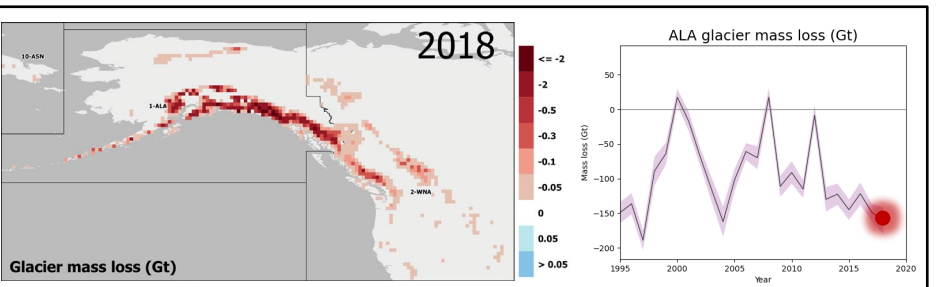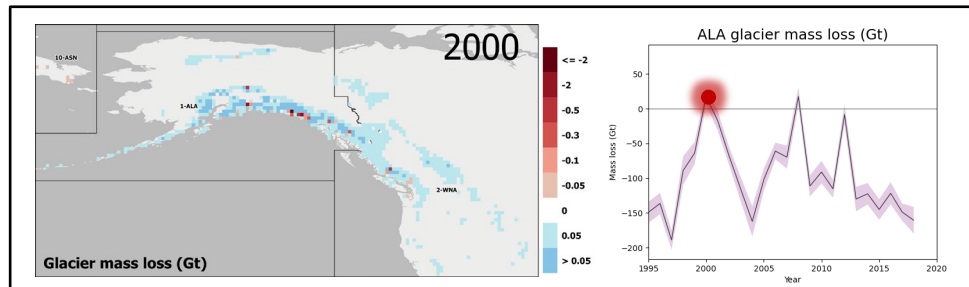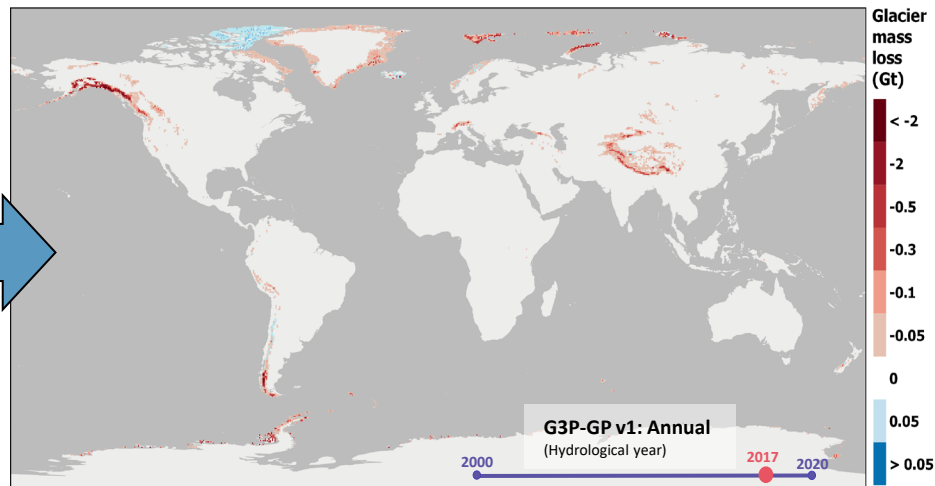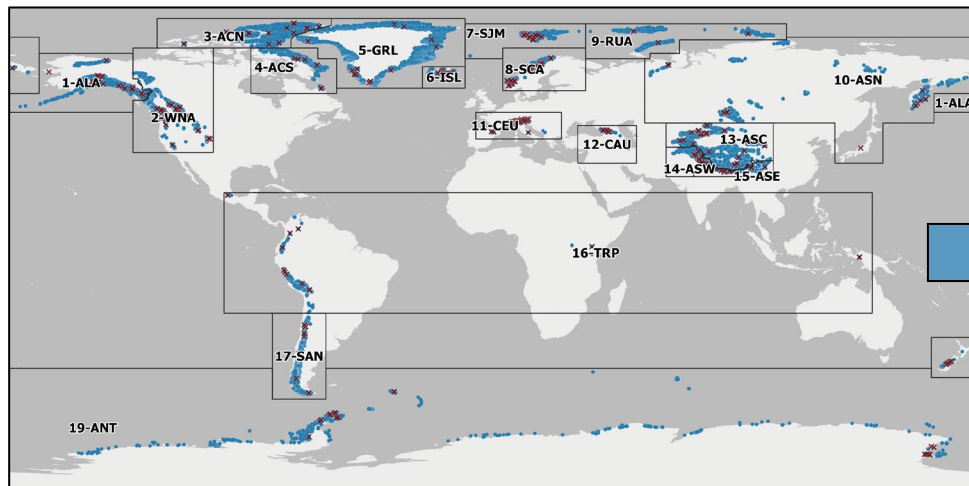
G3P – Cross-cutting Service Combination
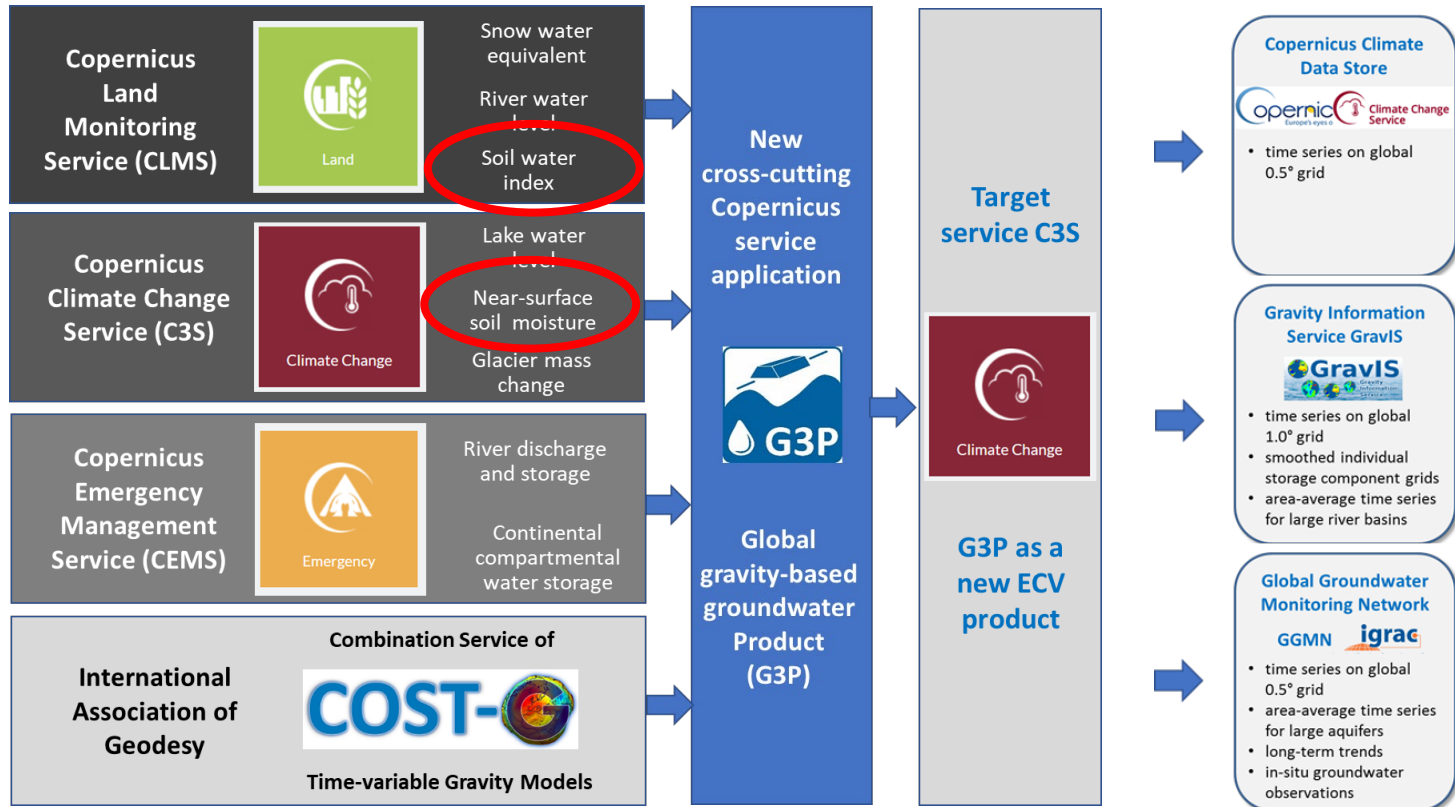
G3P – Observation-based data products: Glacier mass change

C3S Climate Data Store - GLACIER DATASETS Copernicus *Europe's eyes on Earth* - from **glaciers** in C3S to a global **gridded data set** in G3P

G3P – Cross-cutting Service Combination

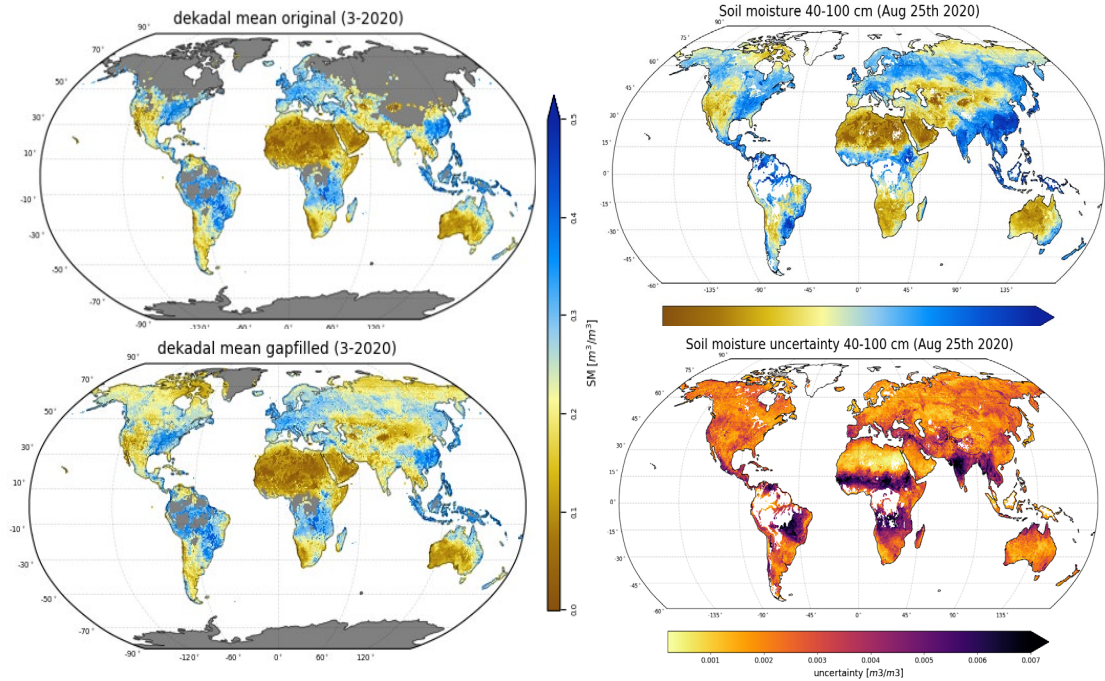A. Güntner et al. | The Global Gravity-based Groundwater Product

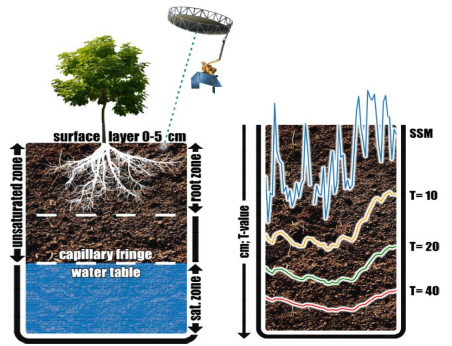# G3P – Observation-based data products: Soil moisture
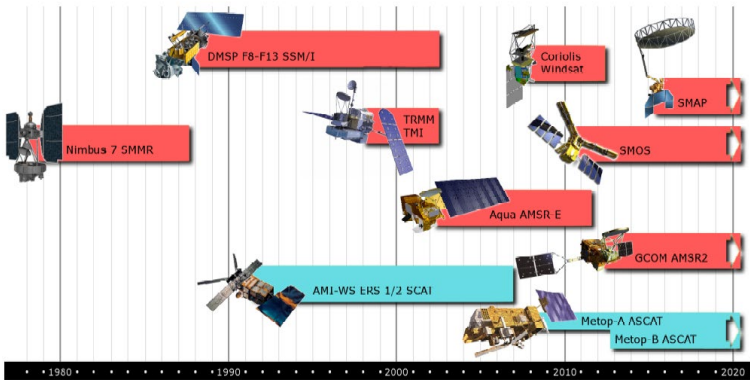
In G3P:

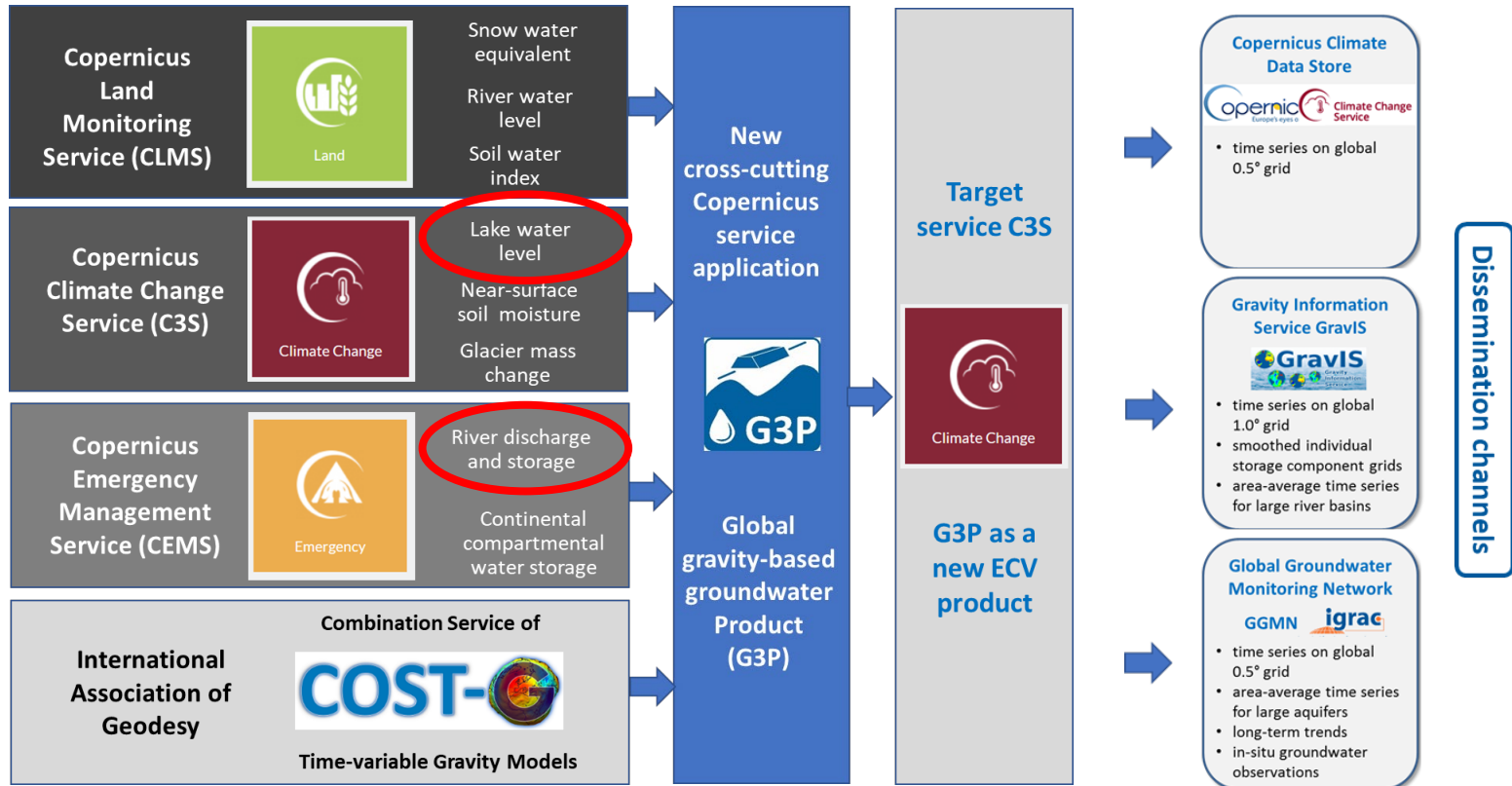**Gap-filled and error-characterized C3S soil moisture product**
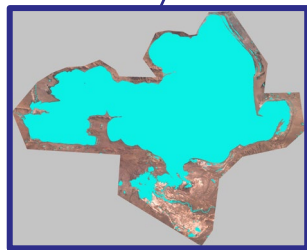Latest version (v202012) based on the ESA CCI v5 algorithm

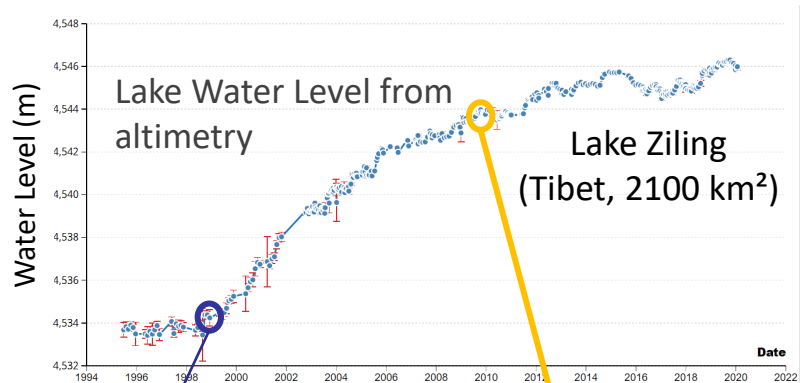**From surface to unsaturated zone soil moisture products**

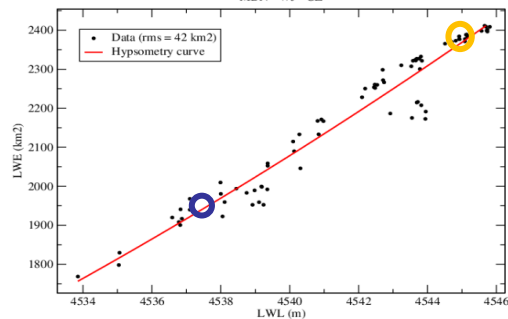A. Güntner et al. | The Global Gravity-based Groundwater Product

G3P – Cross-cutting Service Combination

G3P – Observation-based data products: Surface Water - Lakes

Lake Water Level from altimetry

Lake Ziling (Tibet, 2100 km²)

Hypsometry relationship (extent w.r.t level)

Lake extent from optical or SAR images

In G3P:
Target 200 greatest lakes

G3P – Observation-based data products: Surface Water - Rivers
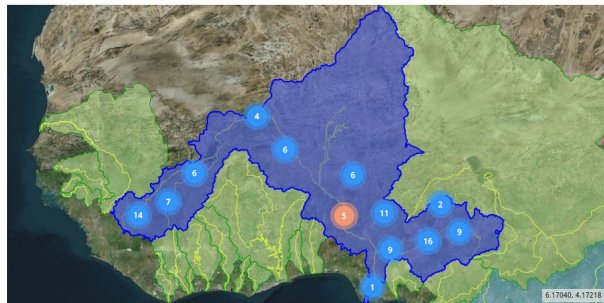
Assimilate observations into MGB model
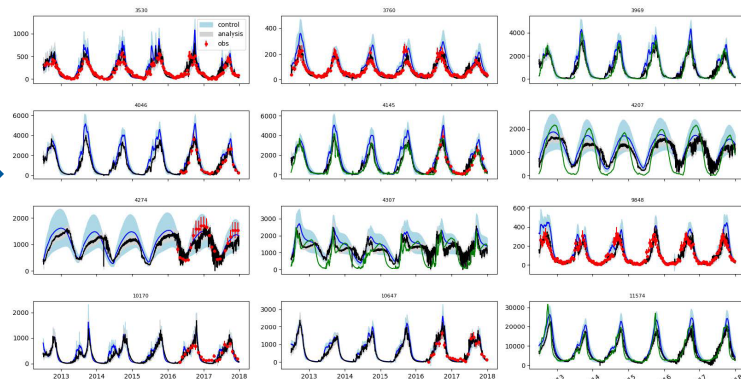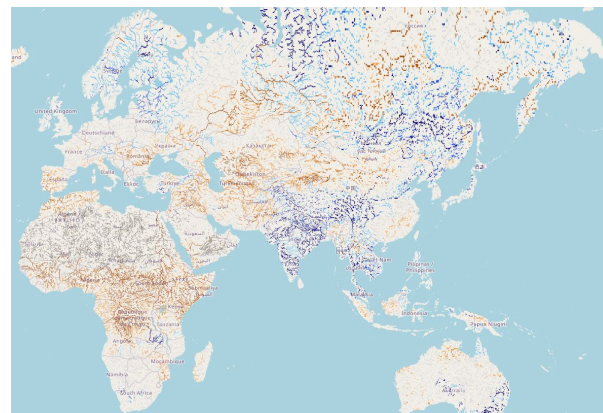(Collischonn et al. 2007, Paiva et al. 2013)
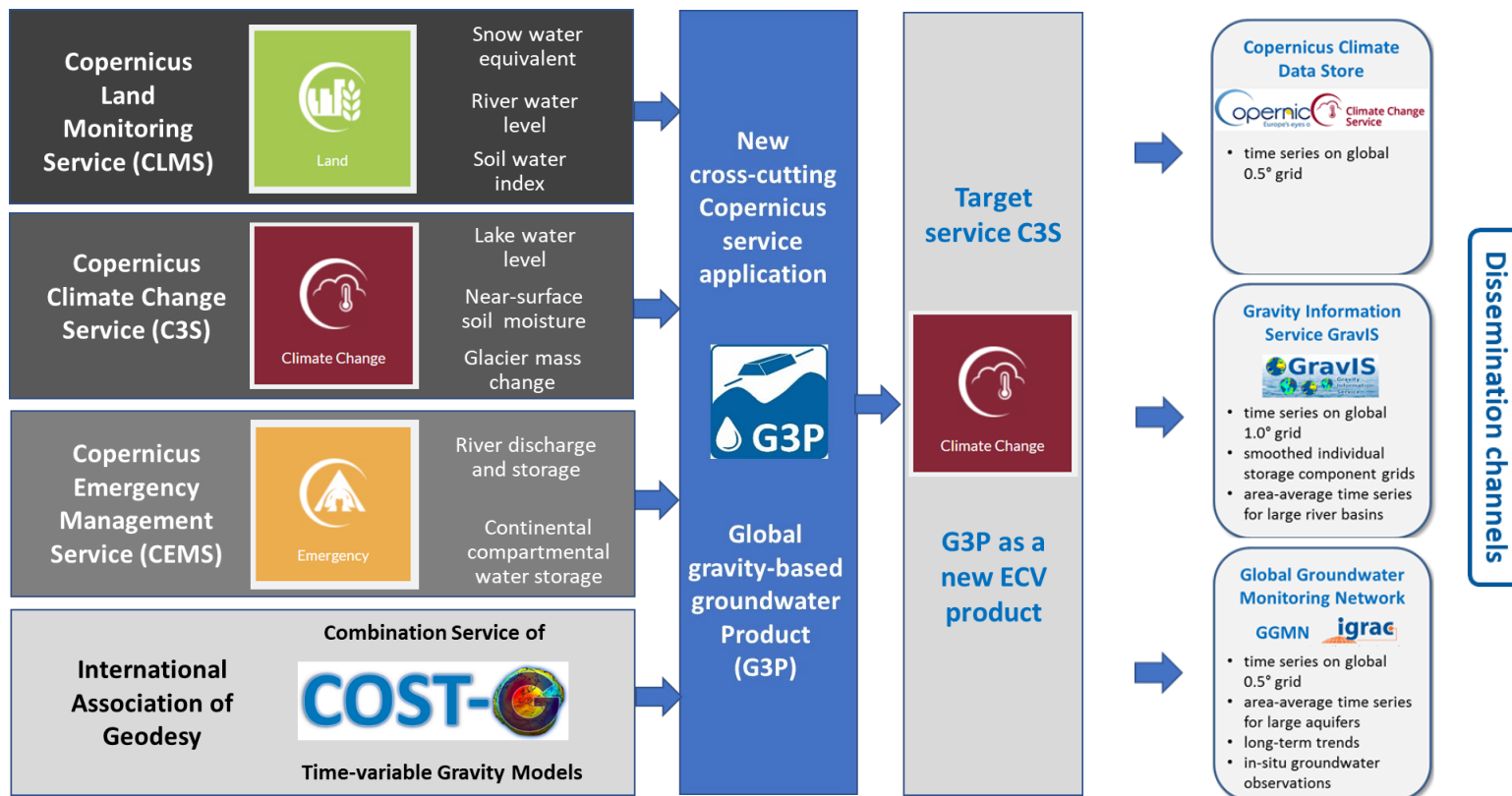
Potential:
Assimilate river altimetry data

In G3P:

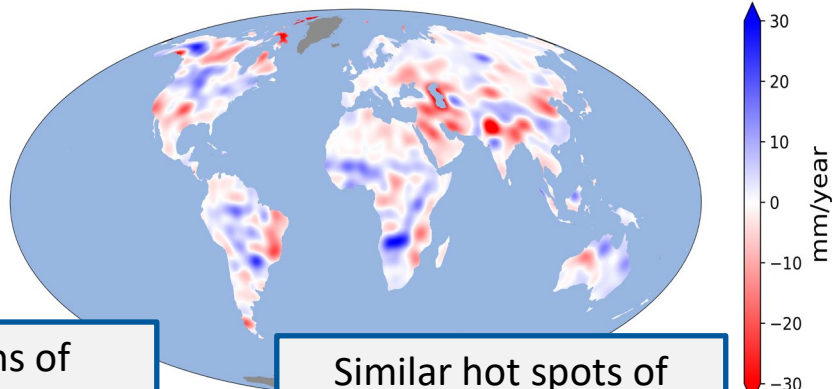Merge lake and river products with **GloFAS/Lisflood**-based surface water product

G3P – Cross-cutting Service Combination

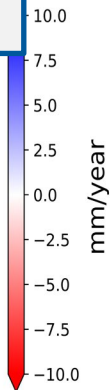# G3P – Preliminary results - Groundwater storage trend 2002 - 2016

G3P (observation-based)

Lisflood global hydrological model

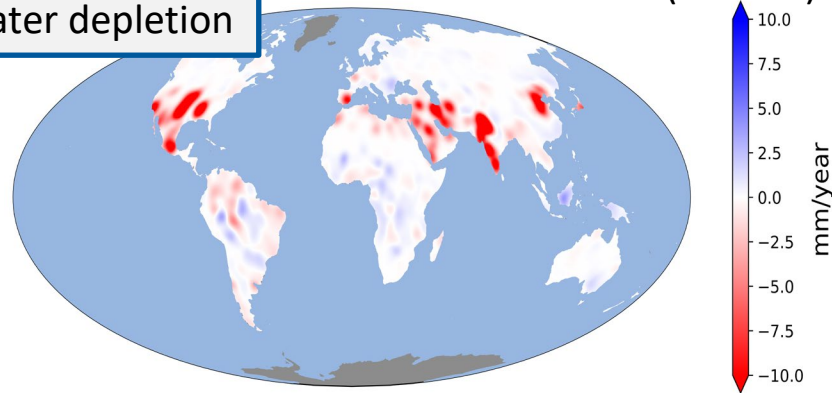WaterGAP Global Hydrological Model (WGHM)

Similar patterns of long-term natural GW change

Similar hot spots of anthropogenic groundwater depletion

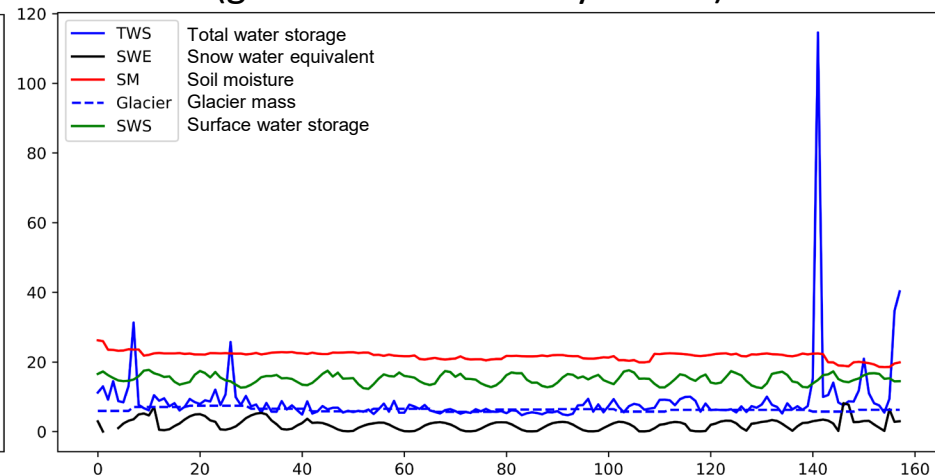# G3P – Groundwater storage – uncertainty analysis

Global mean groundwater storage
with uncertainties
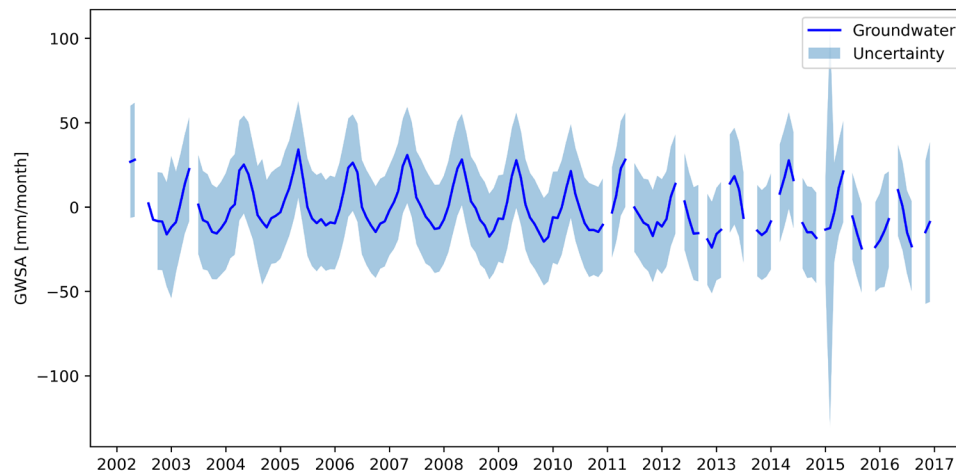
Uncertainties of water storage compartments
(global mean monthly values)

Propagated uncertainties from 0.5 degree grid scale
to a global mean uncertainty

G3P – Product evaluation

Global large trans-boundary aquifers

GGMN – Global Groundwater Monitoring Network at IGRAC
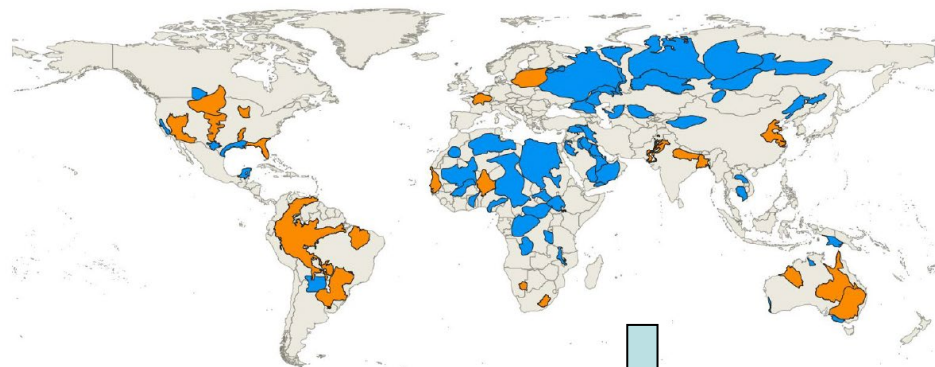
Groundwater monitoring well
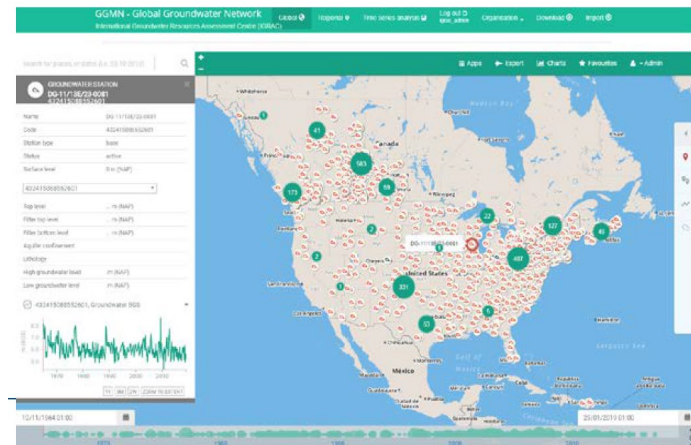
$$\Delta GWS_{in-situ} = \Delta h \cdot S \cdot Area$$

$\Delta GWS_{in-situ}$ Groundwater storage change based on in-situ data

Δh Water level change in observation well

S Storativity / specific yield

$Area$ Aquifer area

Horizon2020

G3P – Preliminary results – product evaluation example

Seine basin (France) (~73500 km²)

Regional groundwater storage data set based on in-situ observations
← Hsu, Eicker, Güntner, Longuevergne (DFG German Research Unit GlobalCDA)

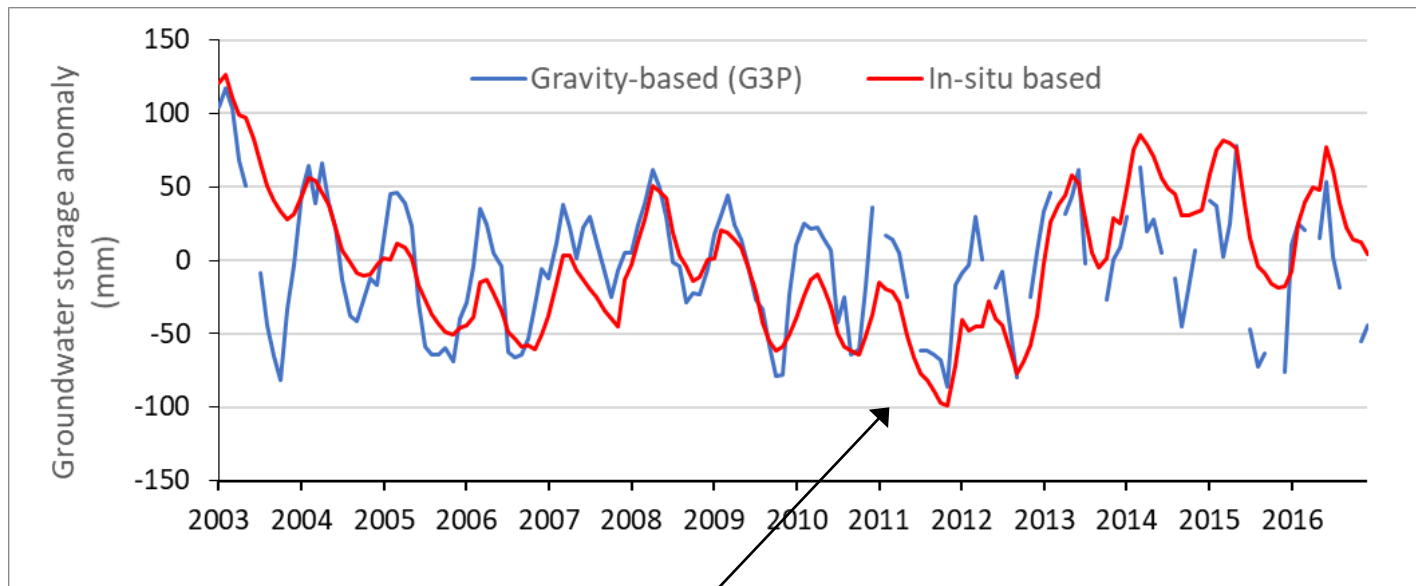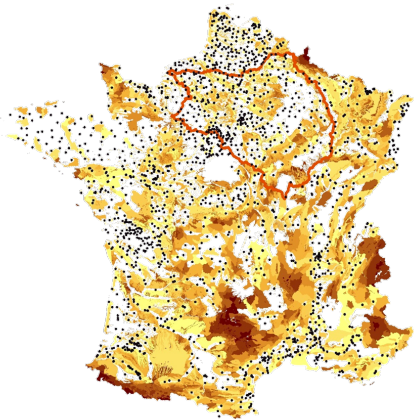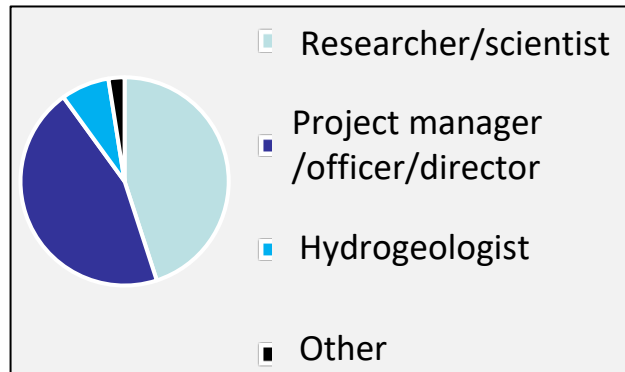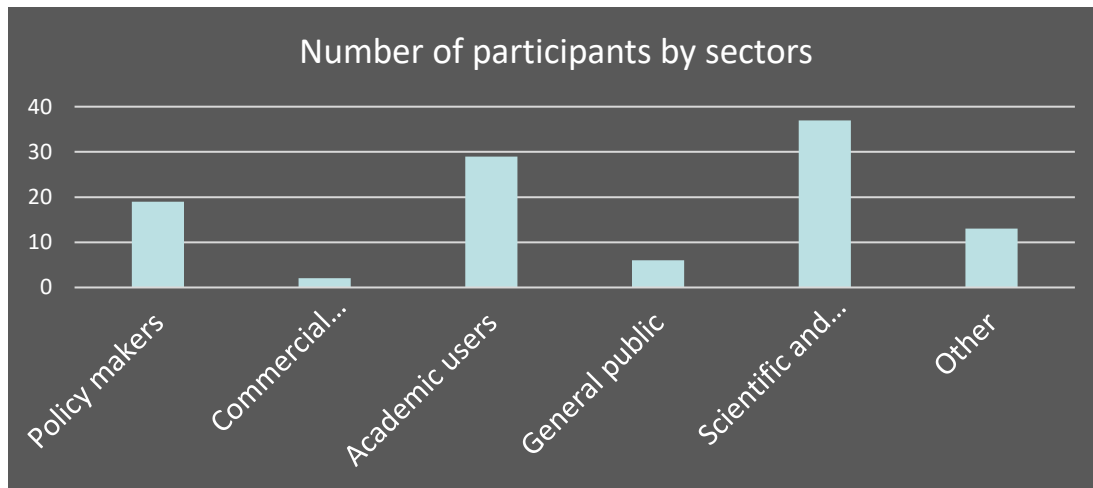# G3P – User requirements survey

Pie chart legend:
- Researcher/scientist
- Project manager /officer/director
- Hydrogeologist
- Other

Number of participants by sectors

Categories: Policy makers, Commercial..., Academic users, General public, Scientific and..., Other

80 participants in total (examples):

- Geological surveys from: Spain, Denmark, Sweden, Slovenia, Austria, Croatia, Romania, Cyprus, UK…
- Universities/research institutes: Lesotho, Tehran, Aberdeen, Stellenbosch, Potsdam, Texas A&M, IHE Delft, Twente, Saskatchewan, Latvia, Mersin, Florida…
- International / Intergovernmental organisations: Mekong River Commission, Pacific Community
- UN: UNESCO, IUCN NL, IWMI, FAO, IIASA…
- Governmental organisations from several countries: Water administration/authority, Ministry of Agriculture…
- Charities: Water Witness International, World Vision, Woord en Daad…
- EU: European Commission (JRC, EDO/GDO), ESA

G3P – User requirements survey

Is a **monthly resolution** of the groundwater product appropriate for your applications?
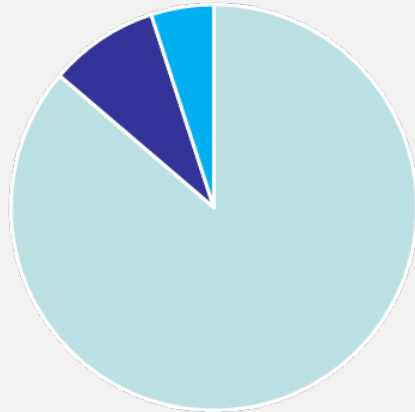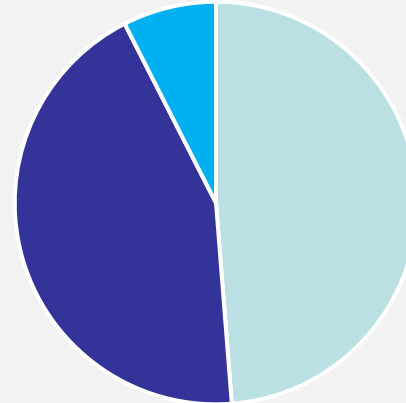
Other:
- Weekly (3)
- Daily
- 15-day
- 10-day

Yes ■ Other ■ N/A

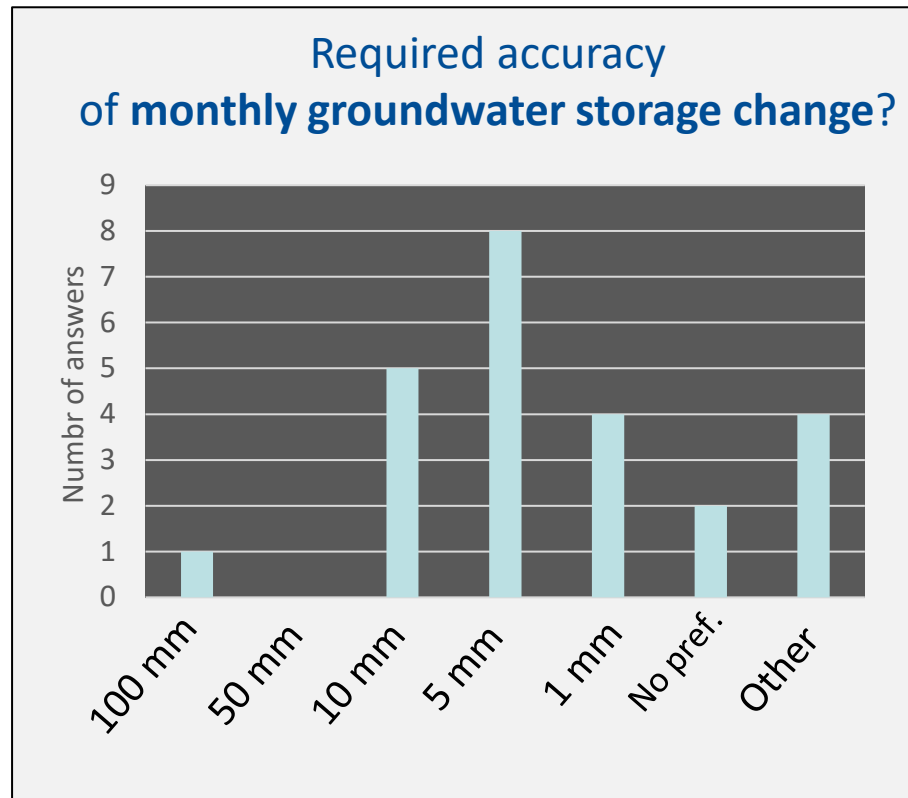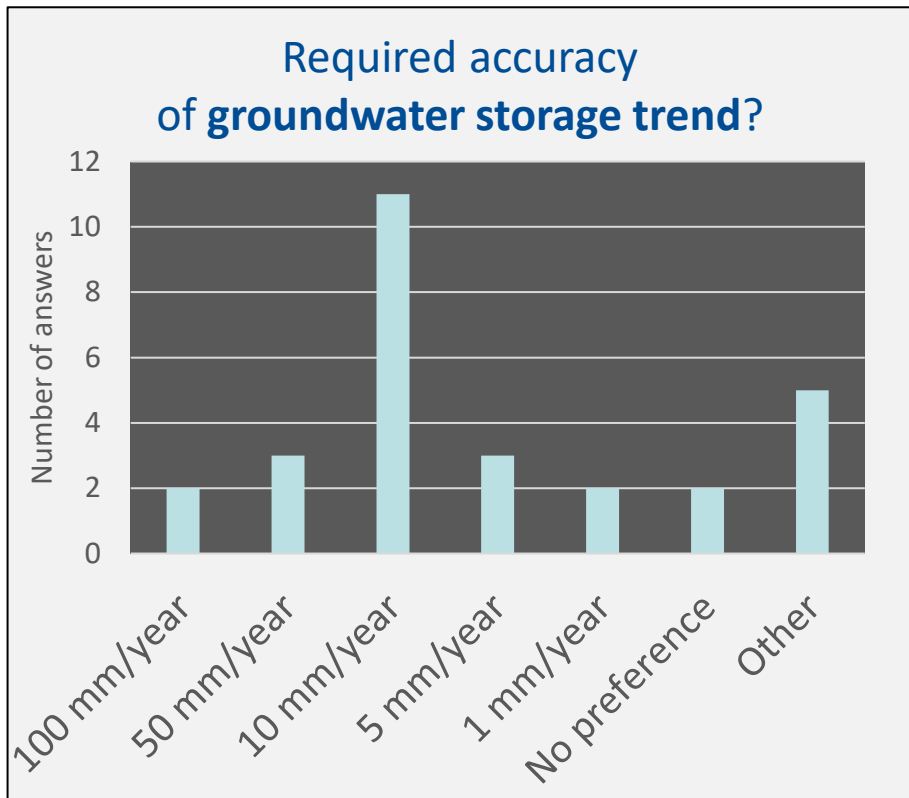Is a **0.5/1.0 degree spatial resolution** of the groundwater product appropriate for your applications?

Other:
- Higher resolution
- 0.1 - 0.3 degree
- 0.05 degree
- 10x10 km
- 1 km resolution
- 90x90 m
- Flexibility preferred

Yes ■ Other ■ N/A

Clear priority of higher spatial resolution over higher temporal resolution

G3P – User requirements survey

Required accuracy
of **groundwater storage trend**?

Required accuracy
of **monthly groundwater storage change**?

23 answers in total.   Units in mm water equivalent.

www.g3p.eu

> **G3P will provide a consistent global-scale GW data set based on satellite gravimetry that is complementary to in-situ and model-based data**
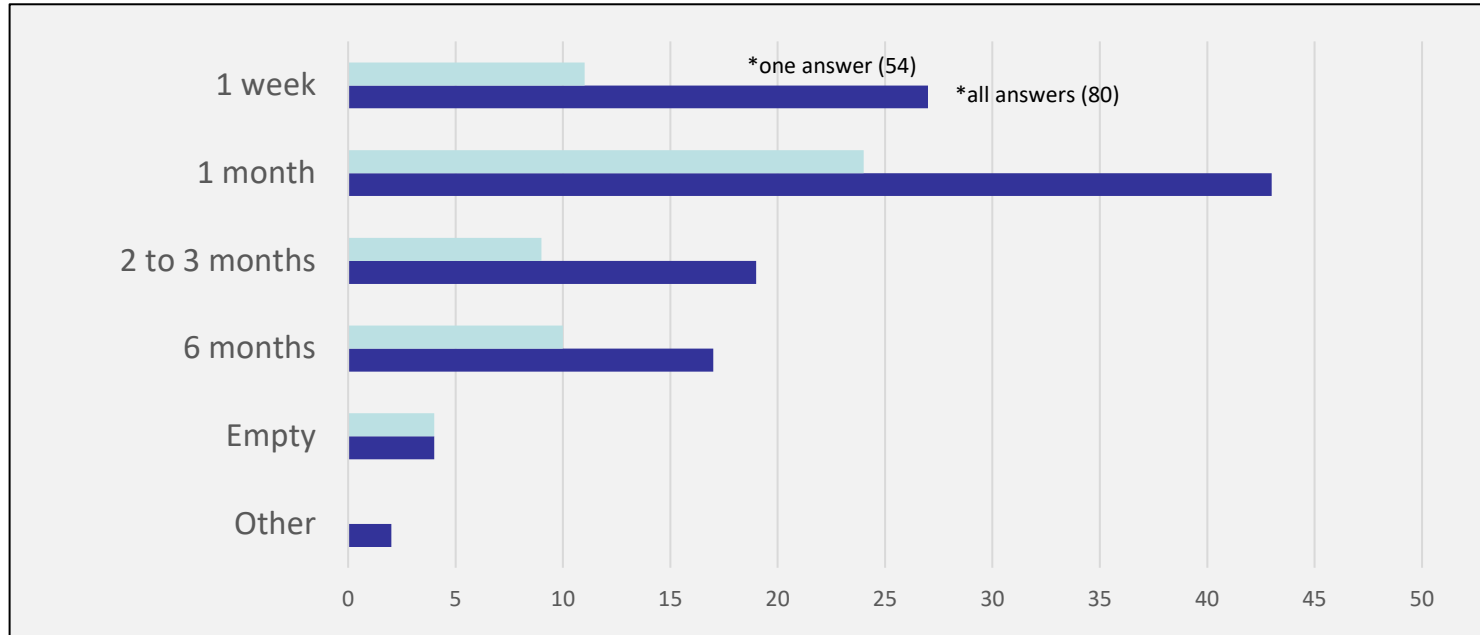
GLOBAL GRAVITY-BASED
GROUNDWATER PRODUCT

> **Continuation of satellite gravity missions needed to secure the long-term data record for supporting ECVs**

A. Güntner et al. | The Global Gravity-based Groundwater Product

G3P – User requirements – Global user survey

Which latency is useful for you? (Time between observation taken and data provided to user)

80 participants in total