Monitoring groundwater from space: Introducing the Global Gravity-based Groundwater Product (G3P)

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Improved Groundwater Management in the Arab Region

Cairo, 31 Octobre 2023

https://www.g3p.eu/

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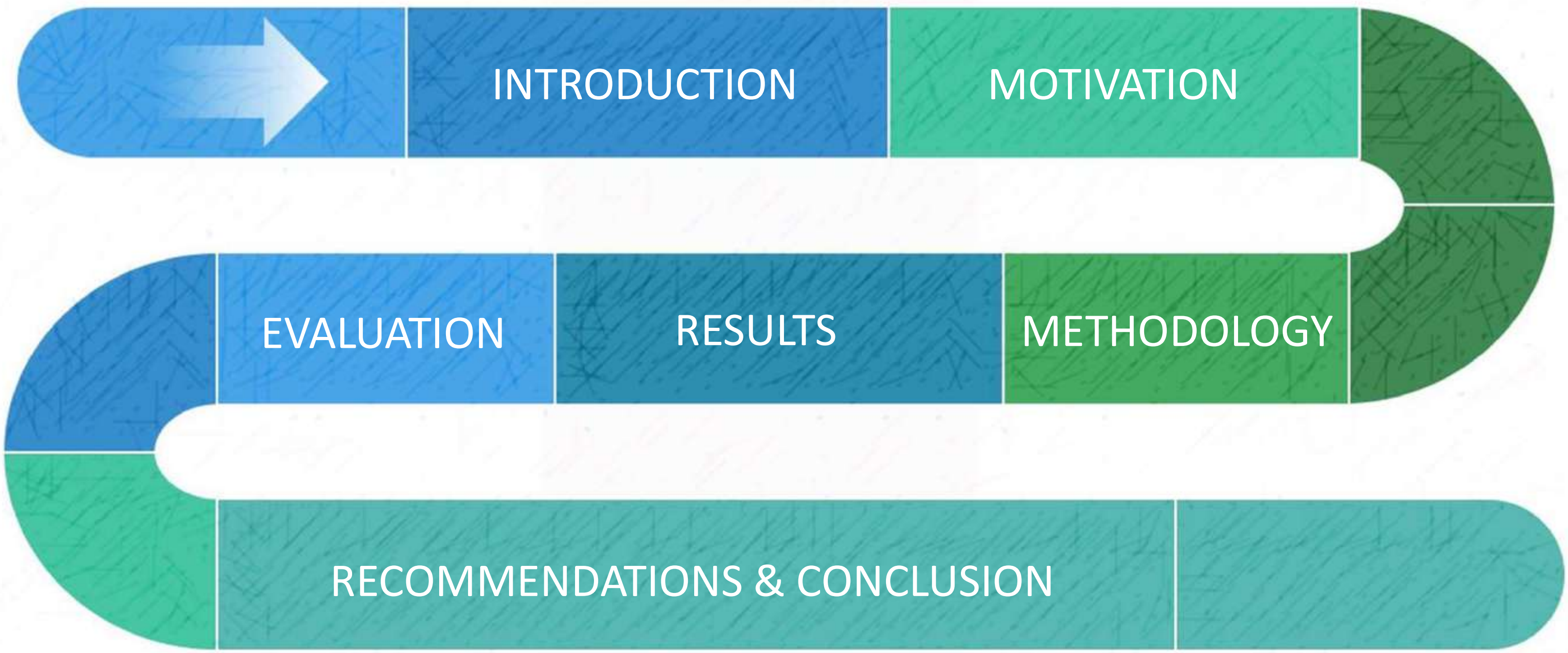

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Groundwater: an introduction

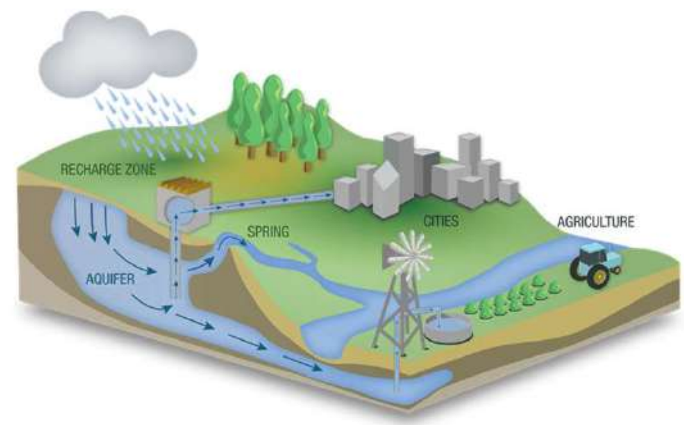
Groundwater accounts for approximately **99%** of all liquid freshwater on Earth

- Groundwater accounts for 33% of the global water withdrawals
- More than two billion people depend on groundwater as primary water resource
- It ensures ecosystem stability, energy and food security.

Main pressures: Overexploitation & climate change

Consequences of groundwater depletion:

- Decrease of agricultural productivity, land subsidence, sea-level rise, seawater intrusion, loss of springs and wetlands, ecosystem degradation, …



Groundwater monitoring and assessment are crucial to achieve informed groundwater management.

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Source: WWDR 2022, https://www.unesco.org/reports/wwdr/2022/en

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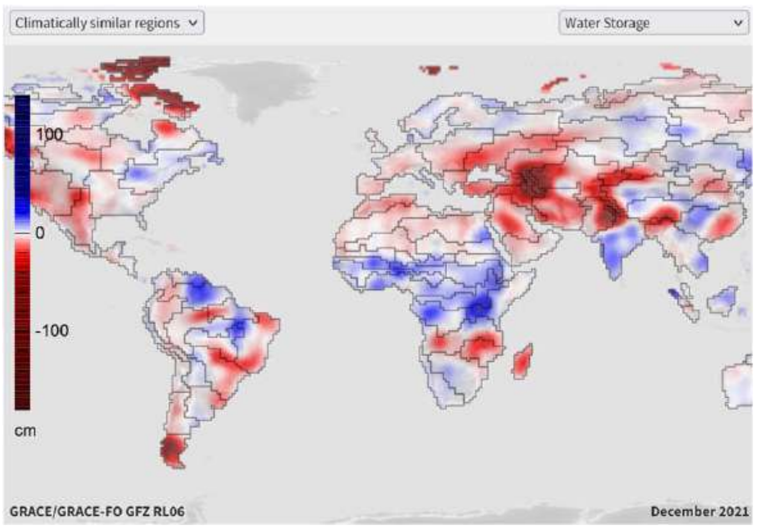
Groundwater monitoring and its limitations

Current state: poor **in-situ monitoring** capabilities in many regions, with **sparse and un-representative** groundwater monitoring networks, largely unknown storage capacities and inaccessibility of data.



Terrestrial Water Storage Anomalies, GravIS:
http://gravis.gfz-potsdam.de/tws

The Global Groundwater Monitoring Network:
https://ggis.un-igrac.org/view/ggmn

Spatially quantification of groundwater storage changes may contribute to fill the monitoring gap, especially at large scales. This can be achieved through satellite technologies

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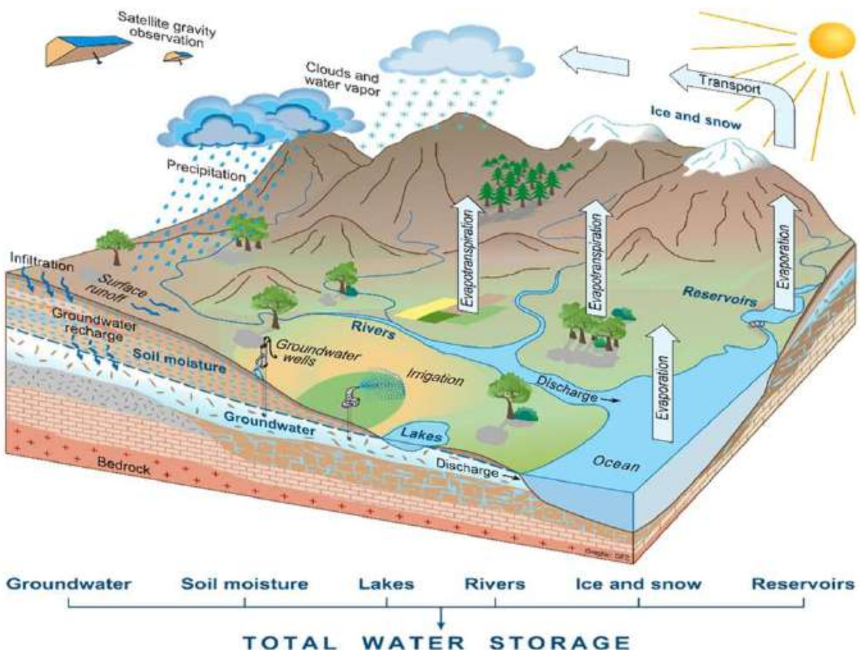
A new product: The Global Gravity-based Groundwater Product (G3P)

Development of a product of groundwater storage variations

- 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 2020
- monthly temporal resolution

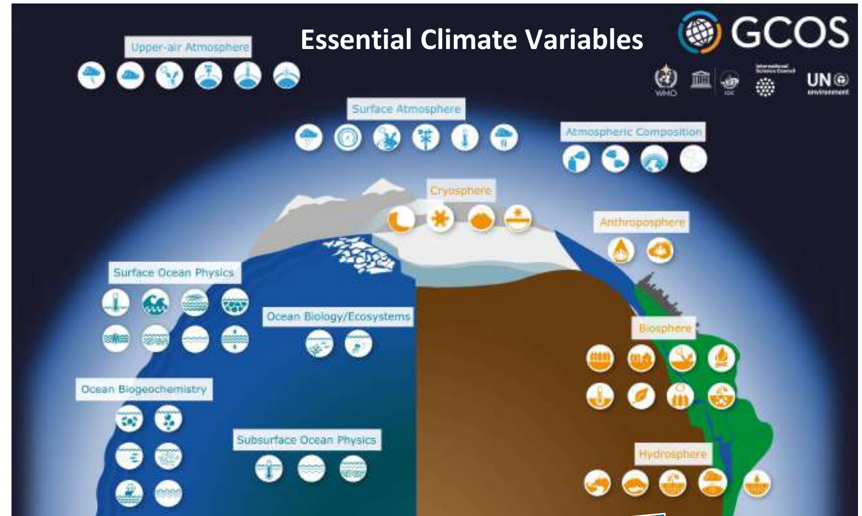


G3P Objectives

- Provide groundwater variations for large aquifers based on satellite gravity based measurements
- Awareness about groundwater depletion around the world
- Compare to global hydrological models
- Detect hotspots of groundwater depletion even in the absence of in-situ data
- To be part of the Copernicus service

ECV Groundwater

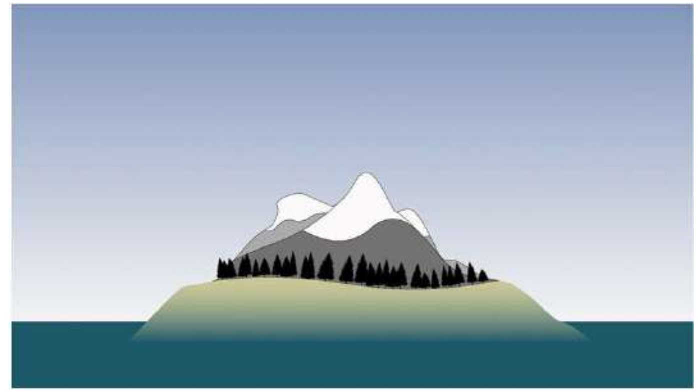
GCOS (the Global Climate Observing System) defined **groundwater** as one of the **Essential Climate Variables** (ECVs)



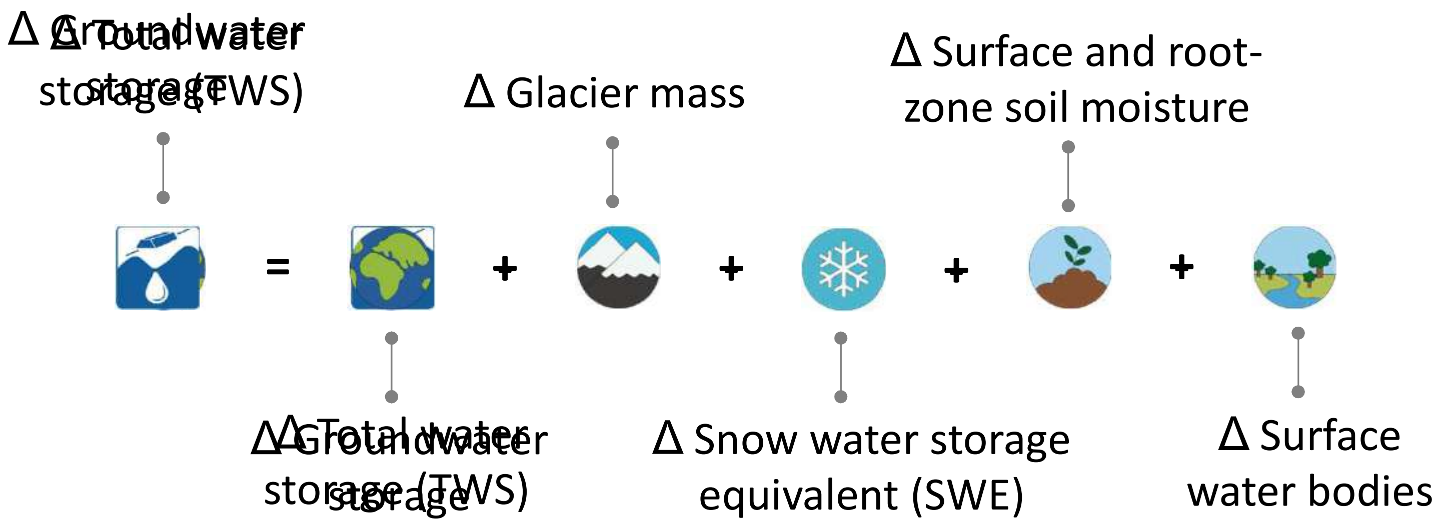
ECV Groundwater

- Copernicus Services provide many ECV data sets
- **But:**
  no product yet for
  the ECV Groundwater

How does G3P work?



The data from the German-American Gravity Recovery and Climate Experiment (**GRACE**) and **GRACE-Follow On (FO)** satellites are used to estimate the variation of total water storage (TWS).



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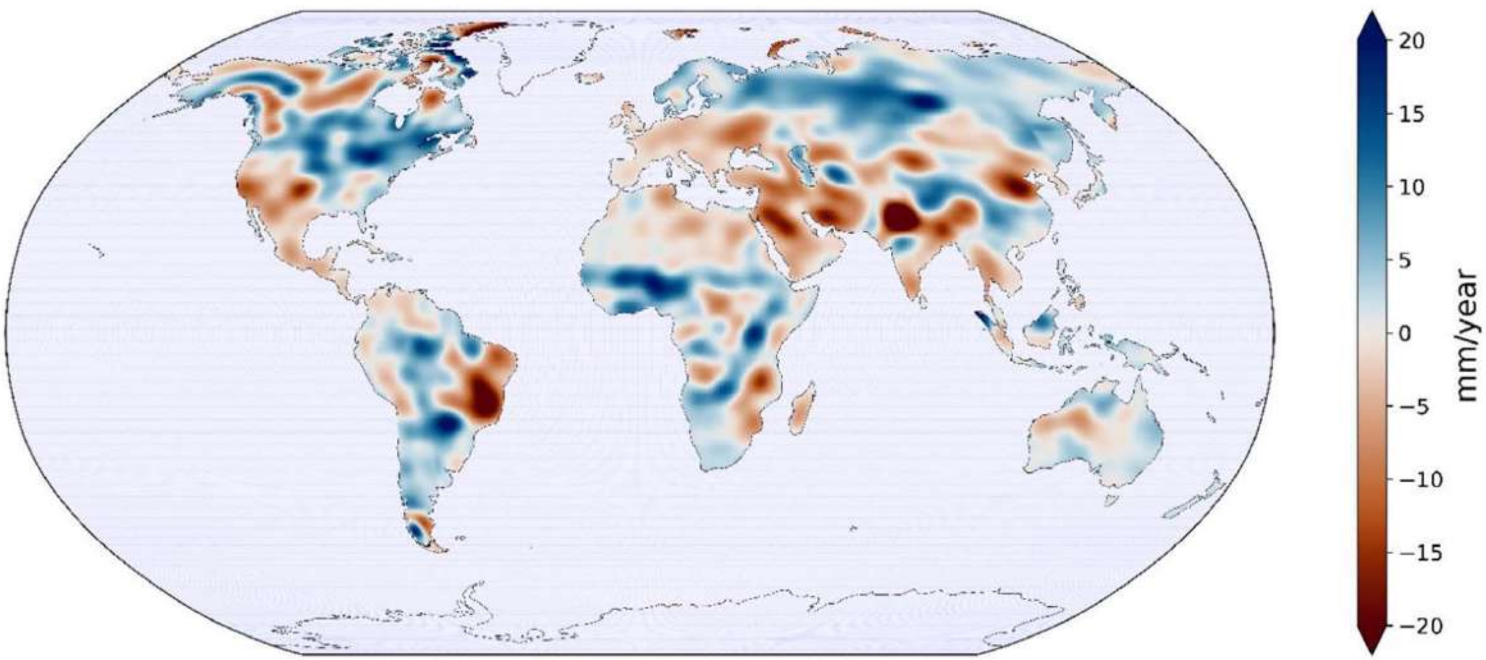
Overview of the gridded water storage compartment datasets

Besides TWS, the other storage compartments are quantified based on in-situ data and, when no available, on models.

Short term	Name	Data source	Temporal resolution
TWS	Terrestrial Water Storage	S	monthly
RZSM	Root Zone Soil Moisture	S-R	daily
SWE	Snow Water Equivalent	S-R	daily
Glacier	Glacier mass change	G	monthly
SWS	Surface water storage	M	daily

in-situ observation (G); satellite (S); reanalysis (R); hydrological models (M)

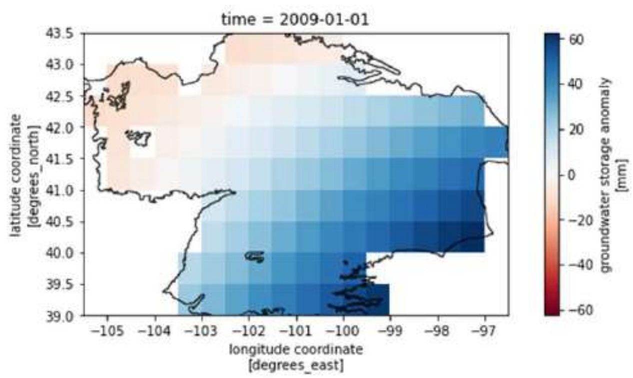
Final Product

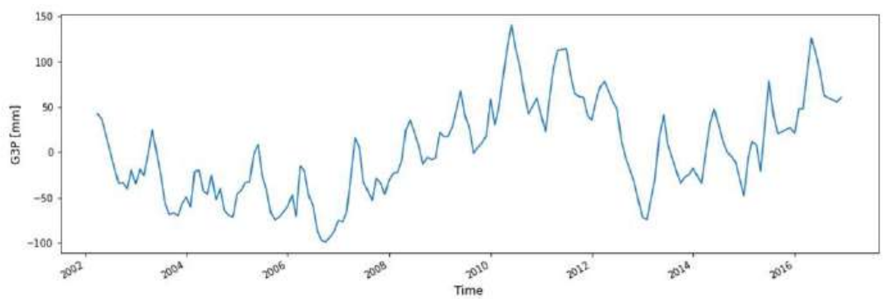


Global groundwater storage trend April 2002 to December 2020

Evaluation: Comparing G3P with GWSA using in-situ values

- From the **G3P product** → Extracted the area average time series of GWSA from 2002 to 2016





- From the **in-situ measurements** → Calculate the Groundwater Storage Anomaly using groundwater heads and specific yield.
- In the absence of geological data, the signal of the groundwater level anomalies (GWLA) was used instead.

Conceptualization:

1. $GWSA = \sum(h_{anomaly} * area * SY/ Total\ Area)[mm]$

$h_{anomaly}$ = Head values relative to mean head value on each site
area = Thiessen polygon area per available borehole
SY = Specific yield corresponding to the thiessen polygon area

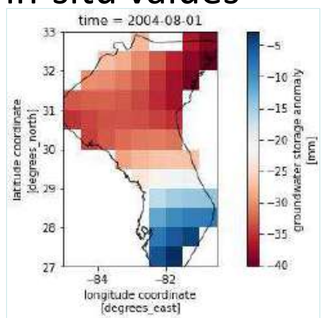
2. $GWLA = average(h_{anomaly})[mm]$

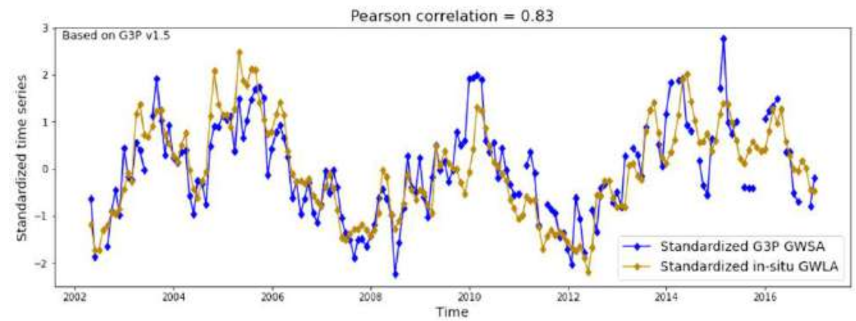
Global research and assessment

Comparing G3P with GWSA using in-situ values

Floridan aquifer

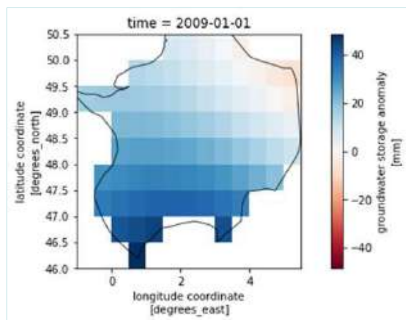
(60 stations)

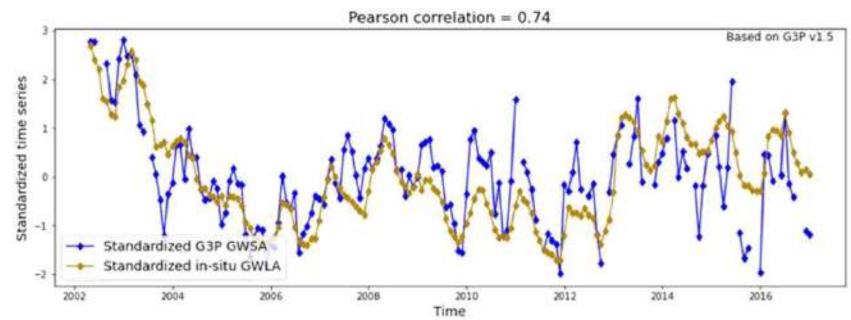




Paris basin aquifer

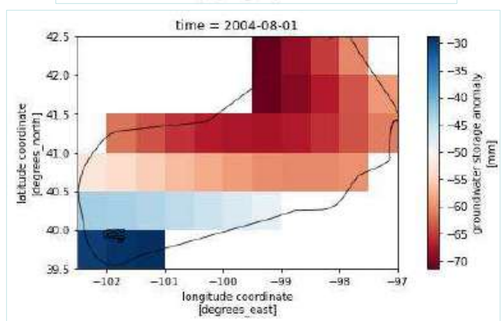
(310 stations)

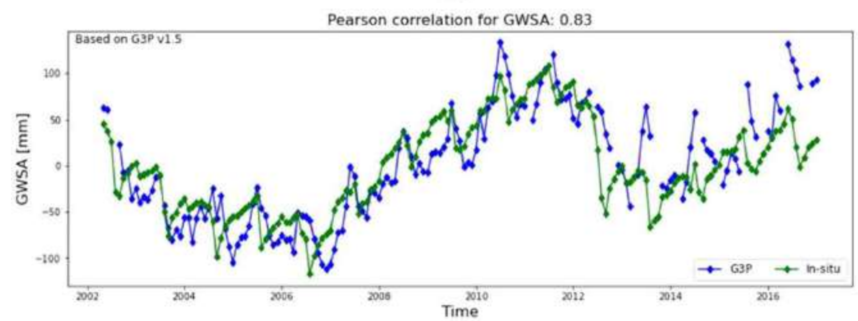




High Plains (Ogallala) aquifer

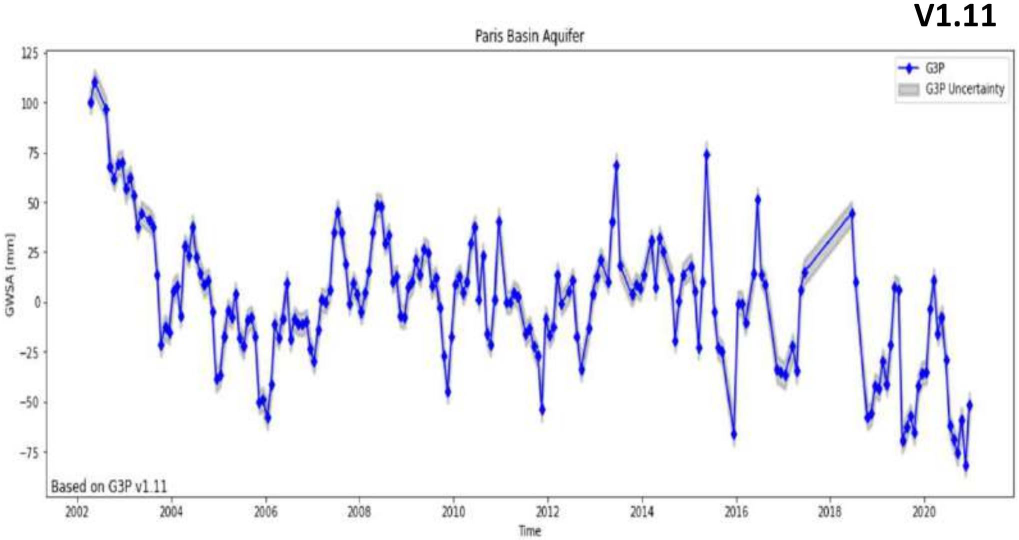
(30 stations)





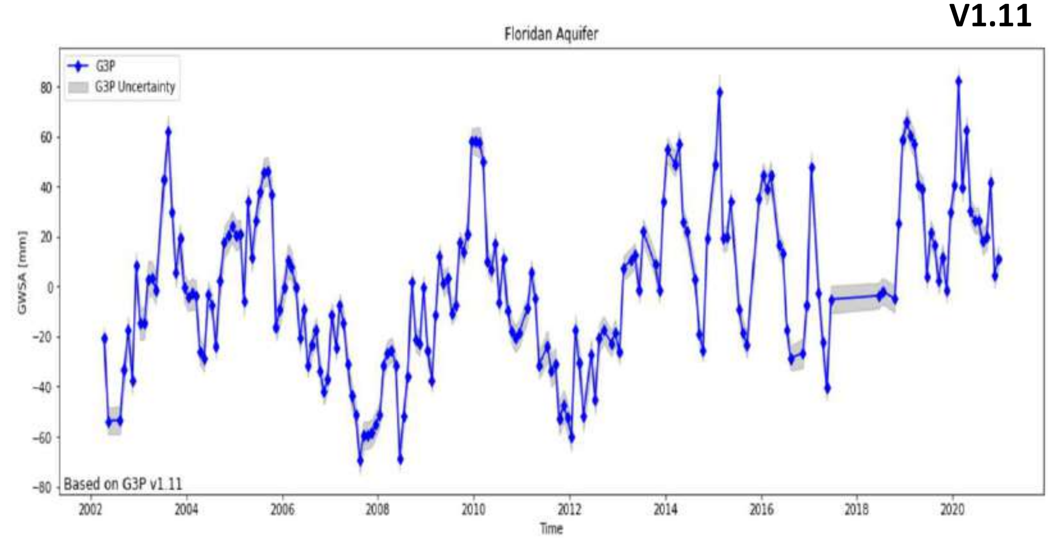
Paris basin aquifer

V1.11

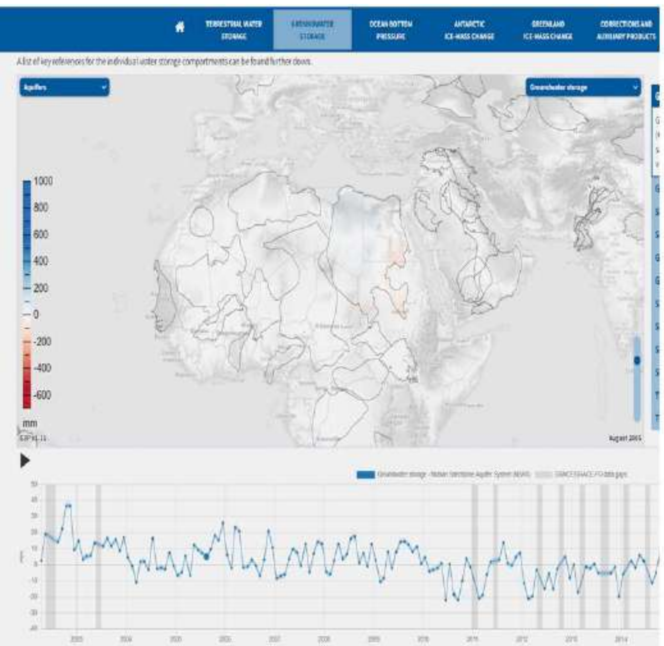


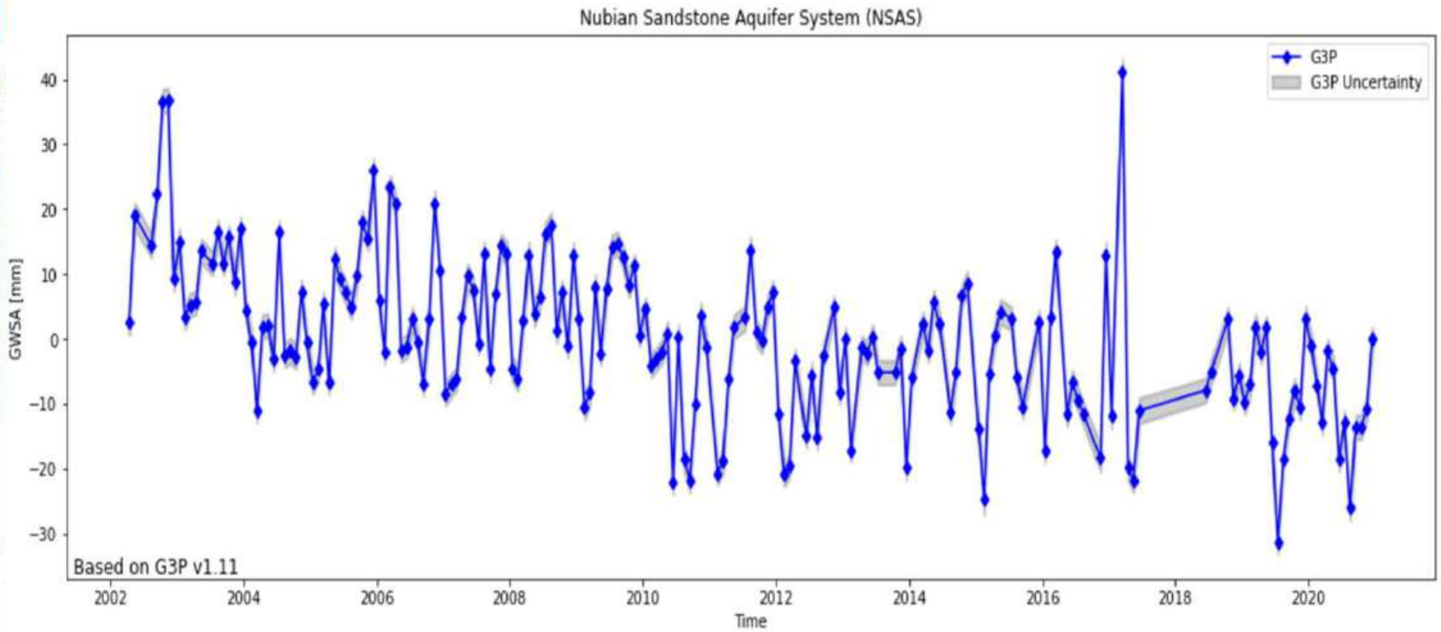
Floridan Aquifer

V1.11



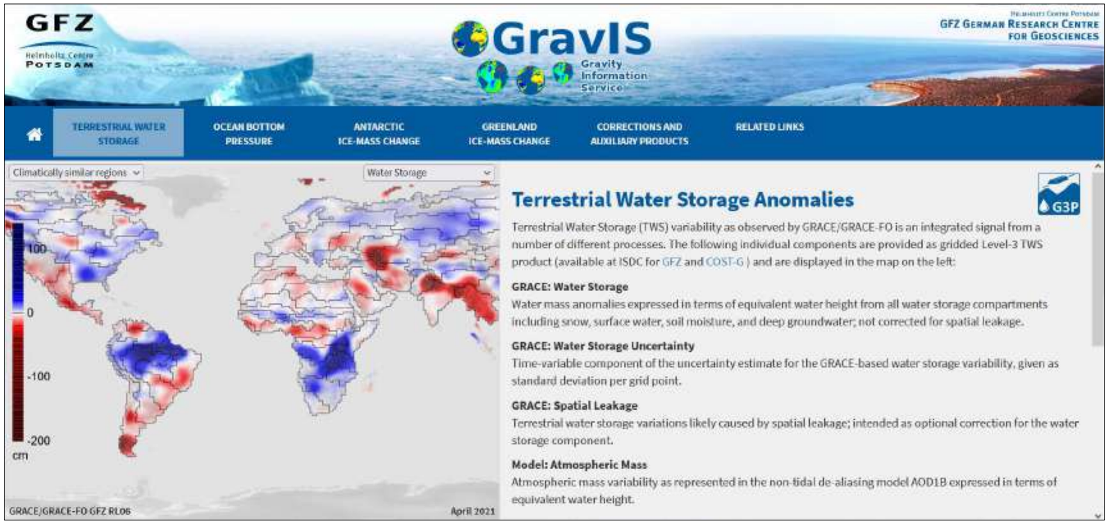
Nubian Sandstone Aquifer System (NSAS)



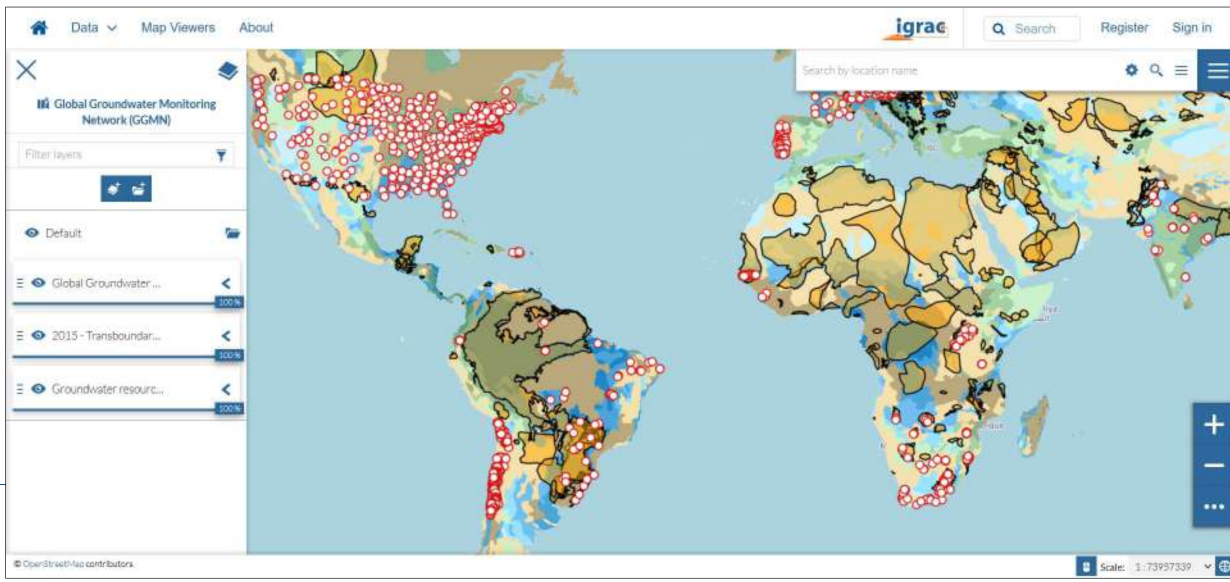


Groundwater Storage Anomalies in GravIS: http://gravis.gfz-potsdam.de/gws

Average Time series with uncertainties G3P v1.11



Terrestrial Water Storage Anomalies and other water compartments are available in GravIS: http://gravis.gfz-potsdam.de/gws



Groundwater Storage Anomalies are available on IGRAC platform GGIS: https://ggis.un-igrac.org/view/G3P/

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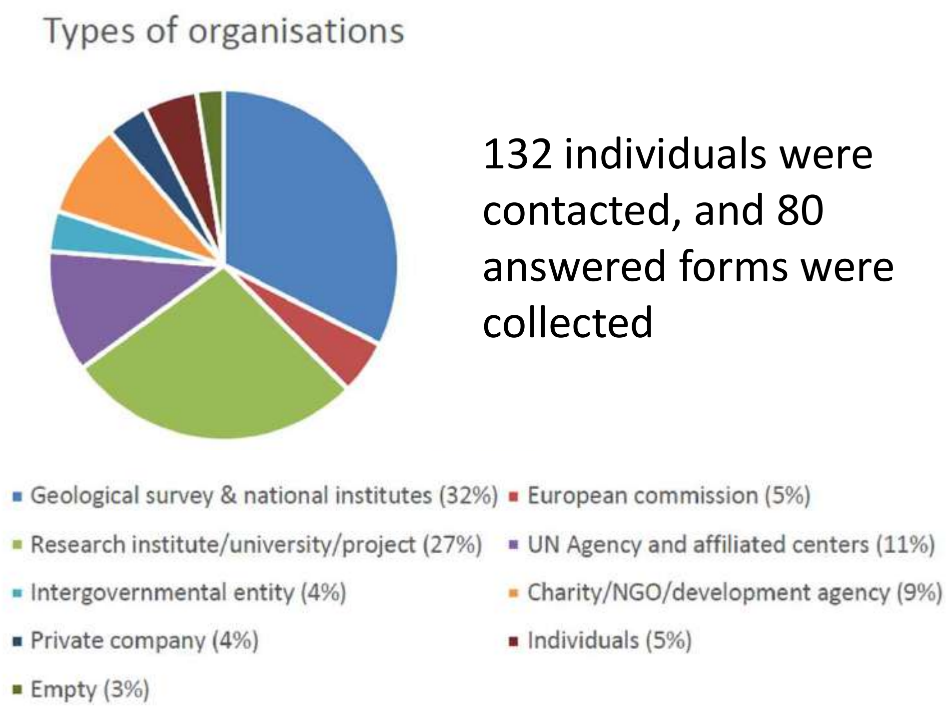
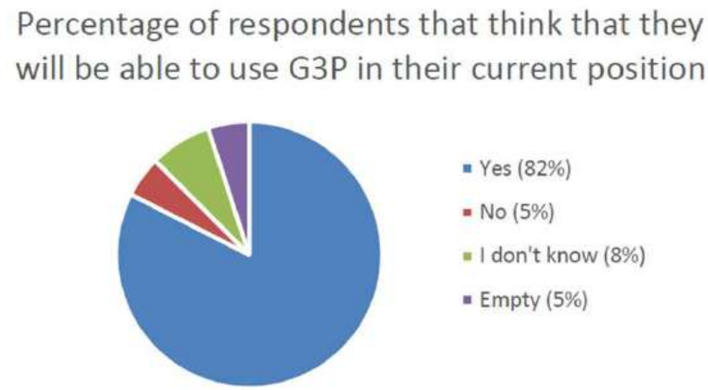
G3P – User survey



132 individuals were contacted, and 80 answered forms were collected

16 questions in total, including questions about preferred:

- Spatial and temporal resolution
- Ways of presenting uncertainty
- Alternative ways of sharing data



- For advocacy/awareness raising; science-policy interface; management (17 a.)
- In combination with models (13 a.)
- For monitoring/forecasting (10 a.)
- Groundwater assessment (6 a.)
- General answer (e.g. "I will use it for research") (6 a.)
- To compare with/complete other datasets (5 a.)
- In Managed Aquifer Recharge (MAR) projects (2 a.)
- Not applicable/other (4 a.)

https://www.g3p.eu/fileadmin/user_upload/G3P_survey_report.pdf

Conclusions and recommendations

- G3P is a tool that contributes to a better understanding of groundwater storage changes on a regional and global scale
- G3P supports water resources management activities, as well as raising awareness on the pressures that the resource is increasingly facing
- G3P is a satellite tool that can be used when no in-situ data is available
- G3P should complement rather than replace in-situ groundwater monitoring

The **G**lobal **G**ravity-based **G**roundwater **P**roduct (G3P)

G3P is funded in response to the Earth observation call

LC-SPACE-04-EO-2019-2020
“**Copernicus evolution – Research activities in support of cross-cutting applications between Copernicus services**”

As part of the H2020-SPACE-2018-2020 activity
“**Leadership in Industrial Technologies - Space Part**”

https://www.g3p.eu/

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Thank you for your attention!

International Groundwater Resources Assessment Centre

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How to estimate each water compartment?

Overview on compartmental water storage data used and processed in G3P

	Source: Earth observation data (EO) or model (M)	Existing Copernicus service product	Development in G3P	Spatial coverage, resolution	Temporal resolution
Snow	EO	Snow water Equivalent in Global Land	Extension to global coverage	Northern hemisphere, 5 km	Daily
Glacier mass changes	EO	C3S glacier extents, elevation changes and mass changes.	Combination of C3S glacier services.	Global, 1 degree.	Annual, seasonal
Soil Moisture	EO + M	Surface soil moisture in C3S	Soil Water Index for the unsaturated zone	Global, 0.25 degree	Daily, 10-daily and monthly aggregates
Lake and reservoir storage	EO	Lake levels in Global land monitoring Service	Combination of lake surface and water level	Global coverage for large lakes	Daily to monthly
River network storage	EO + M	None	Assimilation of altimetry into model	Danube, Niger, Condo	Daily
River network storage	M	GloFAS	None	Global	Daily
Snow soil moisture Lake/reservoir storage	M	GloFAS	None	Mostly 0.5 degree, global	Daily or higher

Procedure

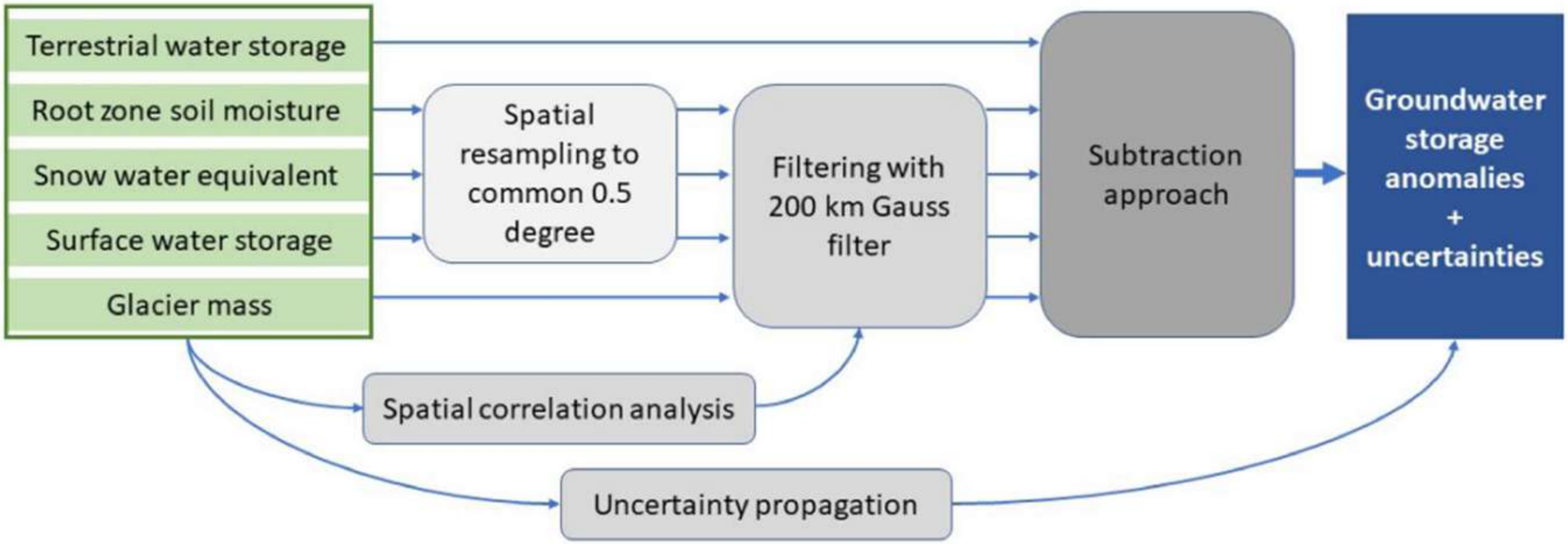

Figure 2: Flowchart of G3P procedure to produce the groundwater storage data set.

Resolution

Short term	Name	Data source	Spatial Resolution	Temporal resolution
TWS	Terrestrial Water Storage	S	0.5°	monthly
RZSM	Root Zone Soil Moisture	S-R	0.25°	daily
SWE	Snow Water Equivalent	S-R	0.05°	daily
Glacier	Glacier mass change	G	0.5°	monthly
SWS	Surface water storage	M	0.1°	daily

User Survey Questions

- Is the groundwater product (data of groundwater storage variations with global coverage and monthly resolution from 2002 until present) something that might be useful for your organisation?
- G3P will be provided as global grids with 0.5 degree and 1.0 degree resolution, and as area-average time series for large aquifer systems. Is this spatial resolution appropriate for your requirements? If not, please indicate what you prefer in the field "Other" (multiple choice, best answer).
- G3P data will be provided monthly. Is this temporal resolution appropriate for your requirements? If not, please indicate what you prefer in the field "Other" (multiple choice, best answer).
- What way of showing uncertainties would be useful for you? (multiple choice, multiple answer). o Min-max – 37 answers o Percentiles – 29 answers o Confidence interval – 44 answers o Other – 3 answers
- The groundwater product (G3P) on long-term monthly groundwater storage variations will be made available for visualization, analysis and download through two service portals: Global Groundwater Monitoring Network (GGMN, https://ggmn.un-igrac.org) and the Gravity Information Service (GravIS, http://gravis.gfz-potsdam.de/home). Is there another way of accessing to the data that we should consider? (multiple choice, multiple answer). (Answers: FTP, Cloud catalogues)
- Do you think that you would be able to use the groundwater product in your current position? (multiple choice, best answer).