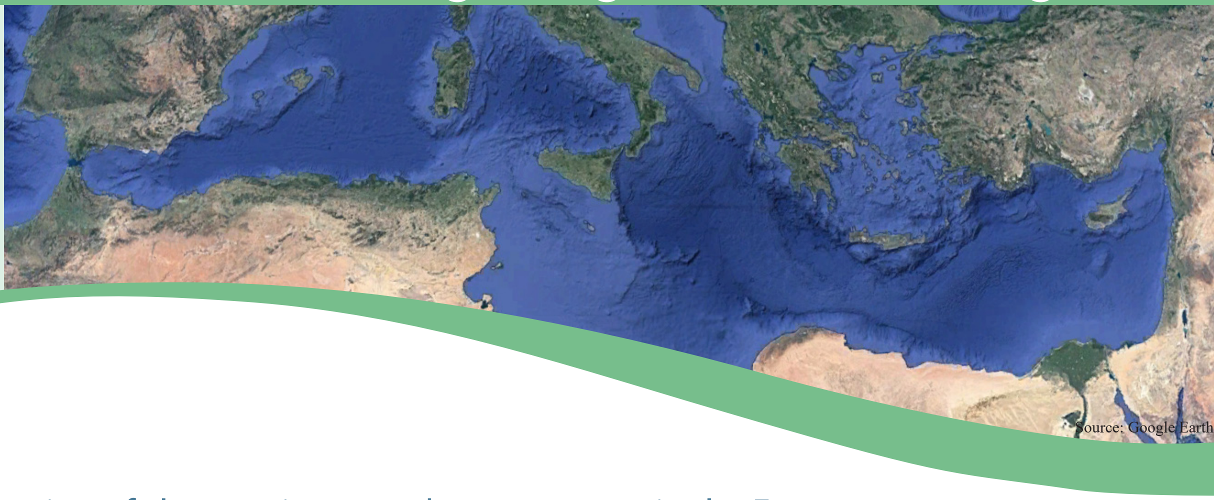
The KARMA Project



Investigation of changes in groundwater storage in the Euro-Mediterranean region using GRACE satellite data

Key findings

Significant trends in GWS can be observed in about 87% of the Euro-Mediterranean region.

With an average negative trend of -2.9 mm/year, the Arabian Peninsula is the most affected region.

Western, Central and Eastern Europe show an average negative trend of -1.5 mm/year, North Africa of -0.9 mm/year and Southern Europe -0.7 mm/year. Northern Europe shows a positive trend of 1 mm/year.

An average negative trend can be observed in 36 of the 47 countries. In 11 countries a positive average trend can be observed.

Groundwater is a major contributor to public and industrial water supplies in most countries of the Mediterranean region. In recent decades, anthropogenic use and climatic impact have led to a sharp decline in groundwater levels in many regions. This indicates an imbalance between natural groundwater recharge and groundwater withdrawals, leading to groundwater stress. Countries in the arid and semi-arid regions of North Africa and the Arabian Peninsula are particularly affected.

In recent years, changes in groundwater storage have been investigated with the help of remote sensing data from the Gravity Recovery and Climate Experiment and its follow-up satellite mission (GRACE/GRACE-FO), where two satellites are used to measure the changes in the gravitational field caused by changes in the Earth's surface total water storage (ΔTWS).

A mass balance approach is used to separate the GWS signal from the TWS signal, while the approach assumes that the change in TWS (ΔTWS) consists mainly of changes in soil moisture (ΔSM), snow water equivalent (ΔSWE), surface water (ΔSWA) and groundwater (ΔGW).

$$\Delta TWS = \Delta SM + \Delta SWE + \Delta SWA + \Delta GW$$

The change in GWS (ΔGW) is calculated by subtracting the soil moisture (ΔSM), snow water water equivalent (ΔSWE), and surface water (ΔSWA) data. These data were taken for the study by Xanke and Liesch (2022) from ERA5-land dataset (Muñoz Sabater 2019), while canopy storage was neglected, because its contribution to water storage in non-tropical climates is small.

Xanke and Liesch (2022) calculated GWS signals to perform a trend analysis using the seasonal Mann-Kendall trend test (Hirsch et al. 1982), which can be used to determine the significance of a monotonic trend based on the null hypothesis. Thresholds for significance were defined as very significant (≤0.01), significant (≤0.05), and not significant (>0.05).

The trend analysis of GWS was carried out for the period 2003 to 2020

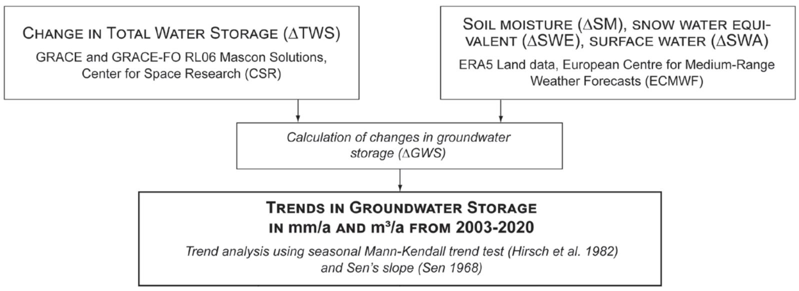


Figure 1 Data, workflow and the relevant calculation steps of the analyses of GWS trends.

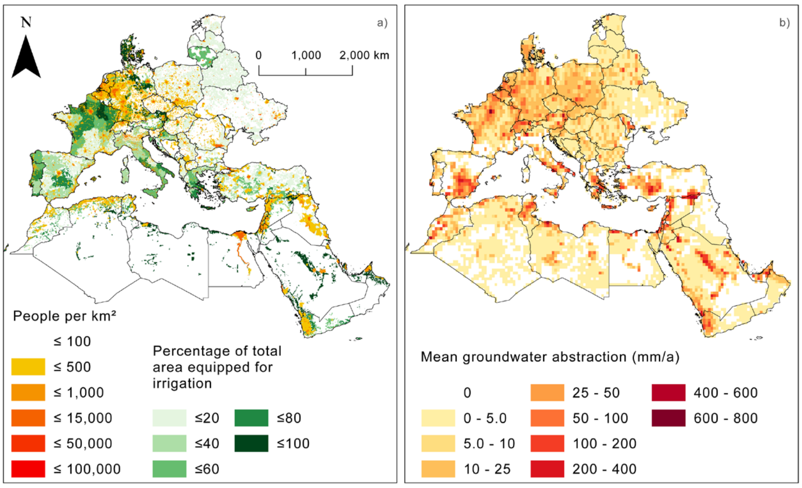


Figure 2 a) areas equipped for irrigation (FAO 2021) and population density (CIESIN 2018) and b) mean annual net groundwater abstraction (WaterGAP; Müller Schmied et al. 2021).

and given as an annual mean value. The trend shows whether there is an increase or decrease in GWS in a given area over the period considered. A negative trend is equivalent to a decrease in groundwater resources and a positive trend indicates an increase. It should be noted that GRACE-derived data always refer to the entire vertical aquifer column and thus the sum of GWS changes in multilayer aquifer systems and observed groundwater level records of individual aquifers may therefore differ.

About 82% of the study area reveal highly significant trends in GWS ($p \leq 0.01$), while 5% are still significant ($p \leq 0.05$). About 13% have no significant trend ($p > 0.05$). Of the significant trends, about 80% are negative and 20% have positive values. Negative trends on average are found in 36 of the 47 countries, while 11 countries have a positive mean trend. The overall mean value of trends in the Euro-Mediterranean region is -2.1 mm/year. Weak to moderately negative mean trends are observed in Western, Central, and Eastern Europe, as well as in North African countries. The Arabian Peninsula, on the other hand, is the most affected region with strong negative trends, e.g., in Iraq (-8.8 mm/year) and Syria (-6.0 mm/year; Figure 3).

Although the negative trends cannot be attributed to any specific cause, it is obvious that groundwater resources are declining across the entire region, especially in highly urbanized and agricultural areas (Figure 2a and 2b; Xanke and Liesch 2022).

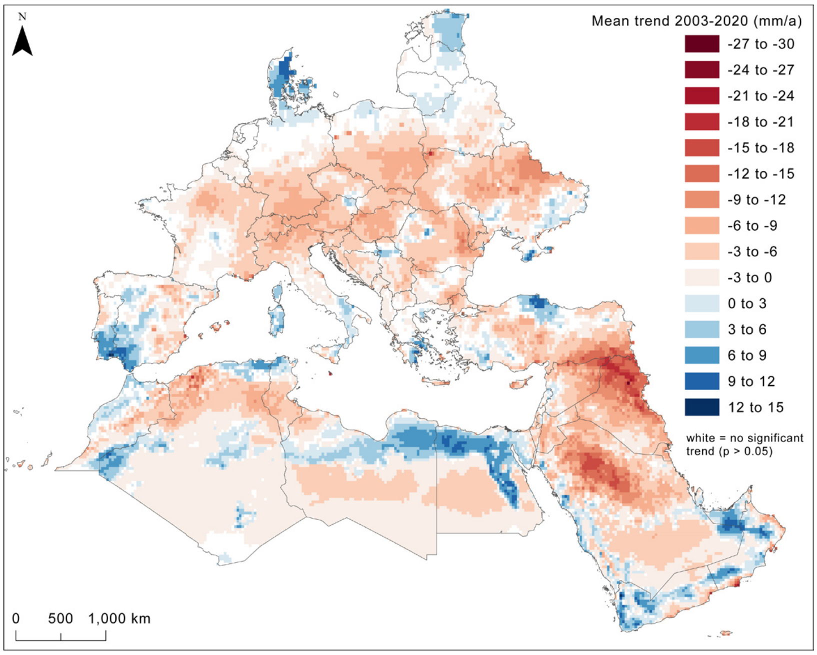


Figure 3 Mean annual trend of GRACE-derived GWS for the period 2003-2020.

References and further Reading

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- Müller Schmied H, Cáceres D, Eisner S, Flörke M, Herbert C, Niemann C, Peiris TA, Popat E, Portmann FT, Reinecke R, Schumacher M, Shadkam S, Telteu CE, Trautmann T, Döll P (2021) The global water resources and use model WaterGAP v2. 2d: model description and evaluation. Geosci Model Dev 14(2):1037–1079
- Xanke J, Liesch T (2022) Quantification and possible causes of declining groundwater resources in the Euro-Mediterranean region from 2003 to 2020. Hydrogeology Journal, 1-22.

KARMA policy briefs present relevant scientific results of projects concerning a better karst groundwater management across the scale of the Mediterranean area, single catchments and selected springs.

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