Groundwater and Terrestrial Water Storage

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Terrestrial water storage (TWS) comprises all the water on and below the land surface: groundwater, soil moisture, surface water, snow, and ice. In general, snow and ice dominate interannual TWS variability at high latitudes and in alpine regions, surface water dominates in the wet tropics, and groundwater dominates elsewhere (Getirana et al. 2017). Changes in mean annual TWS between 2019 and 2020 as measured by the GRACE (Tapley et al. 2004) and GRACE-FO (Landerer et al. 2020) satellite missions, shown in Figure 1 as equivalent heights of water in centimeters (cm), integrate the effects of multiple hydroclimatic variables. Of note in 2020, heavy rains raised TWS in a large region of south-central and eastern Africa by 12–25 cm equivalent height of water. Exacerbated by increased runoff due to environmental degradation and urbanization (Mafaranga 2020), Lake Victoria consequently gained more than a meter of water, with flooding in the surrounding region.

Groundwater and TWS remained depressed over most of Europe, excluding Scandinavia, following losses in 2019. Much of India experienced large TWS gains, but, directly to the east, drought worsened in the Indochina Peninsula. Above-normal precipitation increased TWS in much of the rest of far eastern Asia as well as north-central Asia. TWS changes in Australia were of mixed sign and generally mild. In North America, the most notable changes were considerable increases in TWS in central Canada and the southeastern United States and drying that stretched from the coast of California to eastern Texas, all of which were driven by precipitation anomalies. Consistent with past years (Tapley et al. 2004), some of the most massive TWS changes occurred in South America, including large increases in eastern Brazil and a north–south swath of large decreases down the center of the continent. Figures 2 and 3 depict time series of zonal mean and global mean monthly TWS anomalies after removing the seasonal cycle. Ice sheet and glacier ablation continued to produce large TWS declines in Antarctica, Greenland, the Gulf Coast of Alaska, and polar islands, hence we excluded these regions from the data used in Figs. 2 and 3, but additional ice mass loss is still apparent at high latitudes in Fig. 2. The large TWS increase in south-central and eastern Africa was apparent near the equator in Fig. 2. TWS decreases near 40°N can be attributed to four factors (Figure 1): droughts in California, the central United States, and the land adjacent to the Aegean Sea and Black Seas; glacier ablation in the Alay Mountains of Tajikistan; persistent water level decline in the Caspian Sea; and groundwater depletion to support irrigated agriculture in the North China Plain. At the global scale (Fig. 3), mean TWS decreased by about 7 mm equivalent height of water from the start of 2020 through June and then quickly gained nearly 12 mm, much of that in central Africa, causing a temporary 4 mm decline in sea level. In situ measurement records of the TWS components are rarely available outside of the United States and parts of Europe and Australia; however, GRACE and GRACE-FO have provided monthly, global maps of TWS anomalies based on precise measurements of Earth's time-varying gravity field. The GRACE and GRACE-FO data were the basis for this analysis. Uncertainty in the derived TWS anomalies varies depending on the latitude (higher near the equator), size of the region of interest (higher at small scales), TWS anomaly averaging period (higher for short periods), and orientation (higher for north–south oriented regions near substantially different gravity change signals). At scales greater than about 500,000 km^2, uncertainty in monthly TWS anomalies is typically around 1–2 cm equivalent height of water (Wiese et al. 2016).

References

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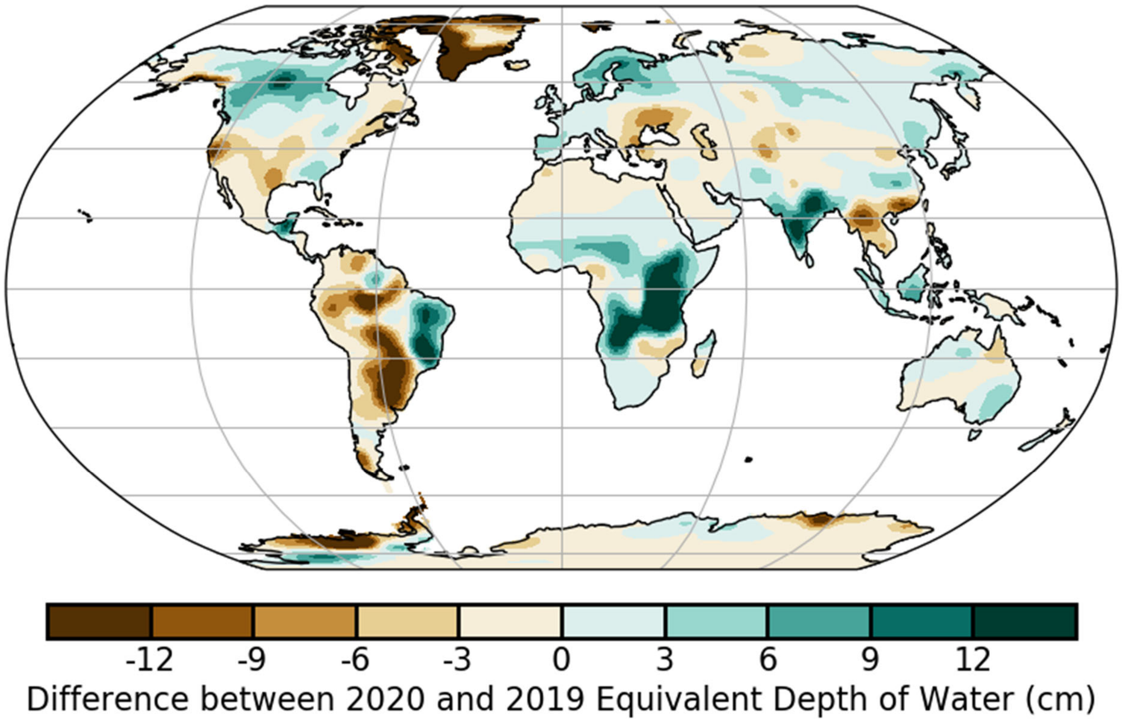

Figure 1. Changes in annual-mean terrestrial water storage (the sum of groundwater, soil water, surface water, snow, and ice, as an equivalent height of water in cm) between 2019 and 2020, based on gravity observations from the GRACE and GRACE-FO satellite missions.

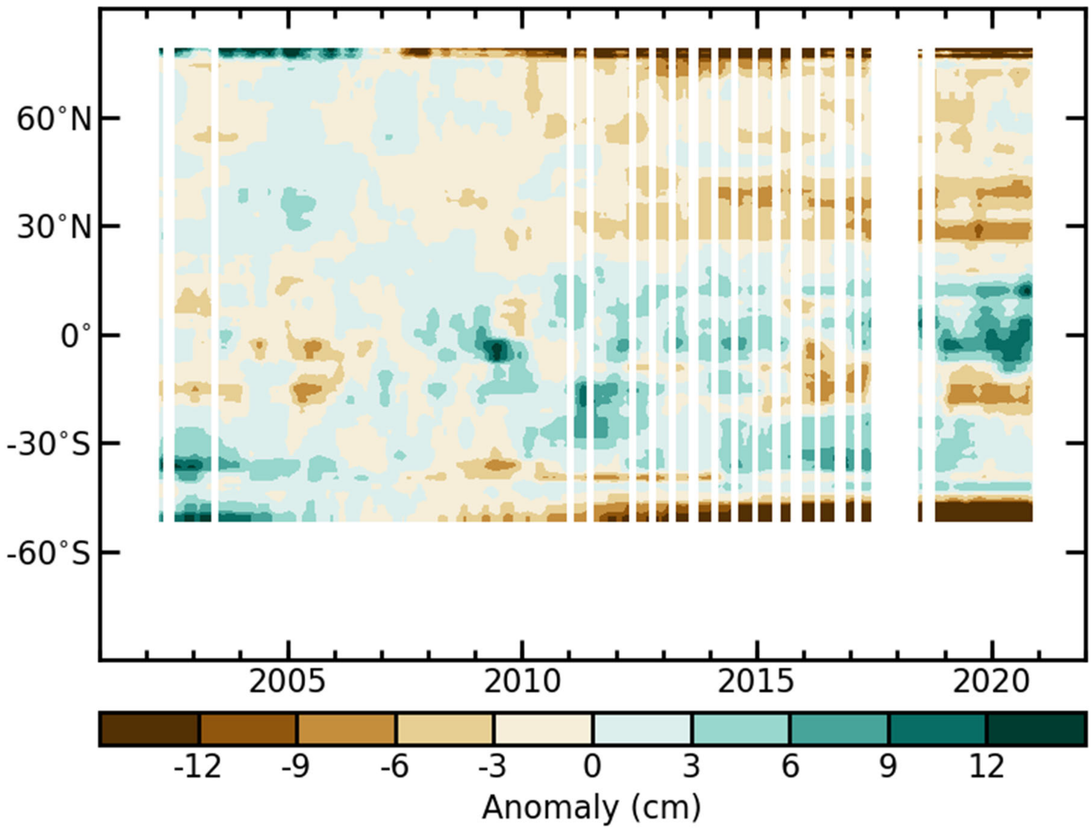

Figure 2. Zonal means of terrestrial water storage anomalies, excluding those in Antarctica, Greenland, the gulf coast of Alaska, and polar islands, in cm equivalent height of water, based on gravity observations from GRACE and GRACE-FO. The anomalies are relative to a base period of 2004-09.

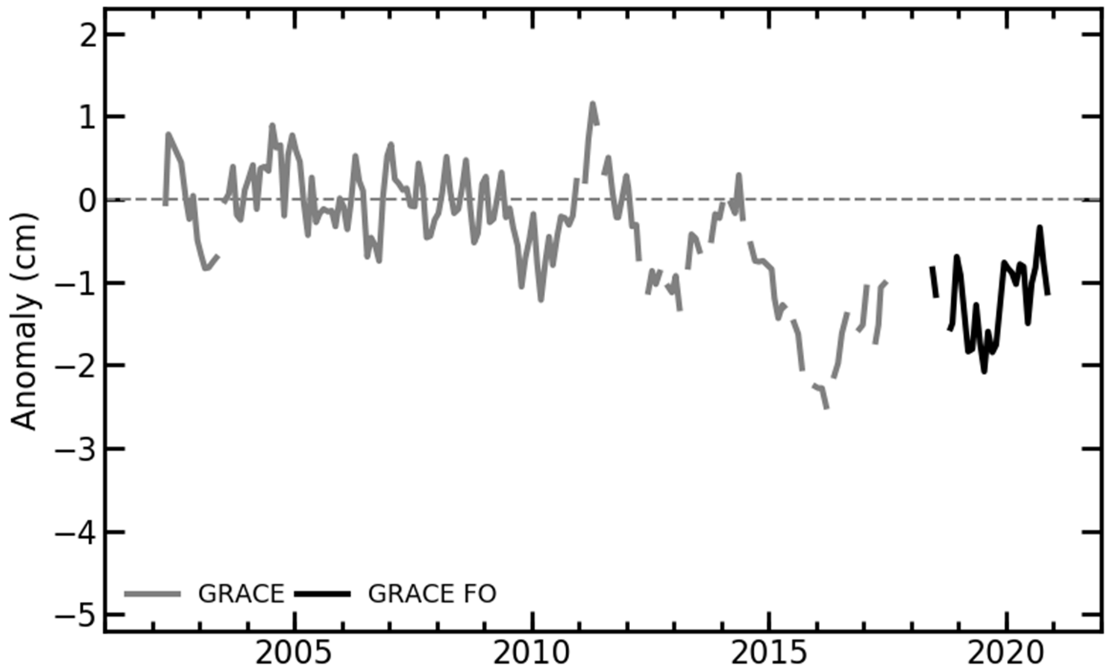

Figure 3. Global average terrestrial water storage anomalies from GRACE (gray) and GRACE-FO (black), in cm equivalent height of water, relative to a 2004-09 mean baseline.

Datasets used and their URLs

JPL GRACE Mascon Ocean, Ice, and Hydrology Equivalent Water Height RL06 CRI Filtered Version 02.

Acknowledgements

N/A

Summary bullet points

- Large terrestrial water storage gains in east-central Africa, eastern Brazil, and India.
- Large terrestrial water storage losses in central South America.
- Global terrestrial water storage anomaly close to unchanged for the year.