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Ensuring the monitoring of ground heat storage with satellite data

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Global ground heat storage is the second largest term of the Earth heat inventory only after the ocean, representing a 4-5% of the total heat storage within the climate system. Furthermore, determining the heat storage and heat flux in the land subsurface is necessary for closing the surface energy budget and quantifying the total energy exchange between the lower atmosphere and the shallow continental subsurface. Global long-term estimates of ground heat storage have been retrieved from geothermal data, with measurements from Eddy-covariance stations as a complement. Nevertheless, these two databases are biased towards northern extratropical latitudes, and there are not enough records to obtain a global average of ground heat storage after the year 2000. For this reason, ground heat storage for the period 2000-2020 consists in an extrapolation of the trend from the previous 30 years.

We estimate ground heat storage from six remote sensing products provided by the Climate Change Initiative of the European Space Agency (ESA-CCI). The products consist in land surface temperatures derived from three single-sensor (ENVISAT, MODIS-Terra, and MODIS-Aqua) and three multi-sensor datasets (IRCDR, IRMGP, and SSMI-SSMIS), covering all land surface except Greenland and Antarctica. First, ground heat fluxes are derived from the satellite land surface temperatures using two different methods, and are then evaluated against in situ heat flux observations at Eddy-covariance stations from the FLUXNET, the Integrated Carbon Observation System (ICOS), and Ameriflux databases. The heat fluxes are accumulated to derive ground heat storage for each satellite product, and combined with the estimates from geothermal data to cover the period 1960-2020. This new estimate yields a heat storage of 20.9 ± 4.3 ZJ during the period 1960-2018, while previous estimates reached 24.0 ± 5.4 ZJ and 20.47 ± 0.19 ZJ for the same period. During the period without geothermal estimates, from 2000 to 2020, the new multi-satellite average reaches 10.5 ± 6.4 ZJ, a similar value to the one based on a linear extrapolation of geothermal values (10.18 ± 0.22 ZJ). Furthermore, satellite estimates provide spatial patterns of heat flux changes at the global scale with a high spatial (1 km) and temporal (monthly) resolutions, which will allow to perform analyses not possible with other, more coarse, datasets. Overall, these results reinforce the values obtained in previous analyses, while the methodology used here ensures the monitoring of global ground heat storage in the next decades.