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Separating Height and Mass Signals in Gravity Time Series: the Medicina (Italy) example

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The progress of Earth Sciences and of the relevant societal applications, such as land planning and disaster prevention/mitigation, greatly benefits from the synergetic use of different observing techniques, which allow monitoring and modeling an unprecedented number of geophysical processes. The available observables, however, typically respond to different geophysical phenomena, which can span over various temporal and spatial scales and can involve mass and energy exchanges between the different parts of the Earth System.
A significant example is provided by gravity records which embed the effects of both mass variations and crustal deformations. In this study, we present the results of a 21-year experiment carried out at the Medicina observatory, Italy, in the framework of a collaboration between the Department of Physics and Astronomy (DIFA) of the University of Bologna, Italy, and the Federal Agency for Cartography and Geodesy (BKG), Germany. Since 1996, height and gravity variations have been monitored continuously in Medicina by means of two GPS stations, a VLBI antenna and a superconducting gravimeter. Additionally, absolute gravity observations have been performed twice a year and environmental parameters, such as precipitation, temperature and water table levels, have been regularly acquired. Repeated levelling campaigns have been also carried out to constrain the local ties between the monuments of the different instruments. Geotechnical tests have been performed to characterize the soil response to applied stresses. By combining geodetic and geological observations, we can characterize the different contributions to the gravity data and to quantitatively assess the agreement between the independent observing techniques. The long-term behavior of the gravity time series is mostly controlled by the natural land subsidence, which, in the southern Po plain, can reach 2 mm/year. However, non-linear long-period features, associated to the soil water content and to the anthropogenic contribution to subsidence, are also clearly recognizable. At the annual time scale, a prominent seasonal cycle is observed in the gravity data. This signal is dominated by variations in the hydrological loading, both in terms of mass and vertical displacements, but is also affected by geotechnical effects induced by surficial hydrology (soil consolidation and desiccation). During summer, such effects can cause height variations exceeding 2 cm at the base of the pillar on which the superconducting gravimeter is installed.