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Temporal Earth's gravity variations derived from GPS, GLONASS, and SLR satellites

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The time-variable gravity field provides the information about the mass redistribution in the system Earth, i.e. the relationship of mass transport between atmosphere, oceans, and land hydrology.
We recover the low-degree parameters of the temporal gravity field variations using microwave observations from GPS and GLONASS satellites and from SLR data to five geodetic satellites, namely LAGEOS-1+2, Starlette, Stella, and AJISAI.
GPS satellites are particularly sensitive to specific coefficients of the Earth's gravity field, because of the deep 2:1 orbital resonance with Earth rotation (two revolutions of the GPS satellites per sidereal day). The resonant coefficients cause, among other, a "secular" drift of the semi-major axes of up to 5.3 m/day (actually periodic variations of very long periods) of GPS satellites.
We processed 10 years of GPS and GLONASS data using the standard orbit models from the Center of Orbit Determination in Europe (CODE) with a simultaneous estimation of the Earth gravity field coefficients and other parameters, e.g., satellite orbit parameters, station coordinates, Earth rotation parameters, troposphere delays, etc. The weekly GNSS gravity solutions up to degree and order 4 are compared to the weekly SLR and the monthly GRACE gravity field solutions. Finally, the time-variable gravity field parameters are derived from a combined GNSS+SLR solution including: (1) microwave and SLR observations from GPS+GLONASS and (2) SLR observations of spherical geodetic satellites.