

Assessing Earth's crustal deformation through GNSS network analysis: insights from Iran and the Luxembourg permanent GNSS network

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Abstract:

Global Navigation Satellite Systems (GNSS), including the GPS, GLONASS, Galileo, and BeiDou, provide precise positioning, navigation, and timing (PNT), and critically, geodetic monitoring of crustal deformation. Using Precise Point Positioning (PPP), GNSS time series can resolve station positions and provide valuable information about the Earth's deformation and associated processes. Given the importance of GNSS networks for monitoring ongoing crustal deformation, we analyze two networks: (i) a 14-station GNSS network in southwestern Iran, and (ii) Luxembourg's permanent network (SPSLux), consisting of 6 stations distributed across the country. GNSS observations from the Iranian network are processed with PRIDE-PPPAR, while SPSLux data are processed with GROOPS. For SPSLux, we estimate positions and velocities in the local north, east, and up (NEU) components over 1 August 2006-31 December 2020. SPSLux stations exhibit consistent horizontal motion with mean velocities of ~ 18 mm/year east and 15 mm/year north, implying a northeastward motion consistent with the rigid motion of the Eurasian plate relative to North America. Long-term vertical rates are small (0.5 mm/year uplift), superimposed on pronounced seasonal signals: monthly-smoothed time series show minima of ~ -10 mm near the start of each year and maxima of $\sim +10$ mm in spring, consistent with hydrological loading. At Walferdange, a cumulative upward displacement exceeding 40 mm by early 2020 is observed, suggesting local processes in addition to seasonal loading. For southwestern Iran, station positions and velocities were first estimated for the period from 9 December 2015-24 May 2016. The stations exhibit northeastward motions, with mean velocities of ~ 32.23 mm/yr east and 28.97 mm/yr north. We then inverted the GNSS velocities for two-dimensional strain and rotation using the Spakman and Nyst approach, discretizing the region with 51 triangles and 32 model nodes. This method yields spatially variable deformation rates that are independent of prior geological or geophysical constraints, providing new insights into present-day surface kinematics. These results demonstrate the value of PPP-based GNSS time series for quantifying plate motion, seasonal mass loading, and regional strain, thereby improving our understanding of the coupled tectonic-hydrological behavior of the Earth system.