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Seasonal load variations, cGPS displacements, and crustal rigidity in Iceland

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Annual-cycle displacements can be seen directly on the cGPS network in Iceland. Every year, the country is subject to heavy snowfalls during winter times. The snow accumulates mainly over the five ice-caps and the highland in the central part of the island before melting during spring. This snow is expected to apply an important load on the crust. Other load like atmospheric load and water reservoir load are also subject to annual variations. Previous studies have shown that the crust has an elastic response to these loads.

We analyzed the time-series of 110 cGPS Icelandic stations processed using over 100 worldwide reference stations. We de-trended the data from its secular trends, mainly caused by plate spreading and glacial isostatic adjustments. Signals associated with earthquakes or volcanic activities were also removed. The annual and semi-annual components of the signal were estimated by finding their best fit to a sinusoid using least-square adjustments. In the end, only the stations with a good estimate of these components were kept.

Each of the three coordinates (East, North and Up) of the GPS time-series were analyzed. It appears that the Up coordinate is one with the clearer signal. It is also showing the biggest annual signal amplitude and is thus the more sensitive to annual load changes. By looking at it, we found that almost all cGPS stations show largest subsidence in April. The stations close to ice caps or to the central part of Iceland tends to have their maximum subsidence later than the station further away. It is also clear that the amplitude of the signal gets bigger the closer the station are to ice caps or to the central part of Iceland. These are indications that the snow load is the dominant load in the annual cycle in Iceland.

These data were inverted using the Green function assuming the Preliminary Reference Earth Model (PREM) to get a time-series of the load distribution. As expected, we found that load accumulate on the ice-caps especially on Vatnajokull, the biggest one.

We also had atmospheric pressure data, reservoir water-level data and an estimation of the snow load from a weather model. Using the same model as the inversion but in the direct way, we estimated the contribution of each of the load. We found that the atmosphere has a fairly homogeneous effect in Iceland with the maximum vertical amplitude of 2-3 mm and insignificant horizontal displacements. The reservoir water-level changes are only affecting nearby stations. The snow load data is in agreement with the inversion results: it is the main contributor to annual crust deformation in Iceland.

Having both the load data and the deformation data, we are also expecting to be able to get more information on the Icelandic crust rigidity. We will be able to find out if there is any relevant change in the crustal strength near the plate boundary or the center of the Iceland hot spot.

Keywords: GNSS, GPS, annual crustal deformation, seasonal changes, snow load, crustal rigidity