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Are earthquakes in south Iceland triggered by seasonal loading variations?

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Seasonal hydrological loading variations have increasingly been related to changes in earthquake rates in different tectonic environments, such as in the Himalayas, Japan, and California. In the south Iceland seismic zone (SISZ), one of the two most active seismic zones in Iceland, a surprisingly large portion of historical earthquakes has occurred in early summer. This pattern of earthquake occurrence incited us to look into the possible causative relationship between seasonal loading and this occurrence pattern.

Seasonal variations in snow, glacier, atmospheric and ocean loading cause significant signals in GPS displacement time series in Iceland, leading to ∼5-10 mm seasonal vertical oscillations of GPS stations in south Iceland. We model the seasonal loading variations using information about the periodic loading histories and the elastic earth structure. We are able to match both the magnitude and phase of the vertical GPS signals, showing that snow loading is the largest contributor of these different loads in the area. The peak loading occurs in April with unloading throughout the summer. Early summer occurrence of historical earthquakes therefore correlates with early unloading rather than with the timing of peak unloading rate or maximum unloading.

The late winter loading leads to increased normal stresses on the seismogenic vertical and north-south striking faults in the SISZ. These periodic normal stress changes dominate Coulomb failure stress (CFS) variations due to the seasonal loading, which are, however, small (∼1 kPa) when compared to the rapid tectonic stressing rate of ∼20 kPa/year. Using rate-and-state friction formulation and information about the seasonal stressing in the SISZ we find that the loading stresses would need to significantly larger to have a notable influence on the earthquake rate and that they predict increased earthquake rate in the fall, not early summer. However, laboratory experiments on periodic loading have shown that when the nucleation time is short compared to the stressing period, earthquake rate correlates with maximum stressing rate rather than peak stress. The maximum stressing rate due to the unloading occurs in the middle of the summer, i.e. somewhat later than the peak in historical earthquake activity. Therefore, the small magnitude of the loading stresses as well as the timing of the stress variations appear to indicate that other seasonal processes, e.g., pore pressure increase due to spring snow melting or upward migration of high-pressured fluids, likely play a significant role in influencing the earthquake activity in south Iceland.