Crustal Deformation in Iceland Measured by Interferometric Analysis of Synthetic Aperture Radar Images (InSAR)

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Over a 400-km-long part of the Mid-Atlantic Ridge is exposed above sea level in Iceland as a series of volcanic and seismic zones. Knowledge about crustal deformation in these areas is important for understanding the geological processes that take place there, such as generation of new crust, plate movements, magmatism, and earthquake activity. In order to put constraints on these processes, crustal deformation in Iceland has been studied for several decades, with variety of geodetic techniques, most recently with InSAR.

Radar satellites such as ERS-1, ERS-2, JERS, and RADARSAT transmit pulses of radar waves that reflect from the surface of the Earth. The signal echo is measured by the satellites, and based on these data synthetic aperture radar (SAR) images are formed. For each image pixel an amplitude and signal phase is assigned. Two SAR images acquired from the same point in space in repeated satellite orbits, but collected at different times, can be compared in a precise way with interferometric analysis to give changes in signal phase for each pixel. In the absence of errors, the resulting interferogram gives a map view of the change in range from ground to satellite, where each full phase cycle corresponds to change of $\lambda/2$, where λ is the radar wavelength, equal to 5.6 cm for the ERS satellites. Reflection characteristics of the ground have to remain the same during the acquisition of the images used, therefore only summertime images free of snow are suitable for study of deformation. Interferograms spanning up to five years have been formed, and these keep good coherence over the abundant Holocene lava flows in Iceland.

A variety of deformation results have been obtained. Interferograms covering the Reykjanes Peninsula in SW-Iceland in the period from 1992-1995 show signs related to plate spreading, as well as about 13 mm/year subsidence due to exploitation of geothermal area in the Reykjanes volcanic system. At the Hengill volcanic area, InSAR has documented uplift of 19 mm/year in the 1992-1998 period, due to magma accumulation. Movements on faults in response to this uplift has been measured, and compared to field studies of surface effects. At the Krafla volcanic system in N-Iceland, variable subsidence of up to several cm/year is observed, due to post-rifting relaxation. Subsidence over recent lava fields due to lava compaction has also been observed at the Krafla volcano, as well as at the Hekla volcano in S-Iceland. At Hekla, pre-eruptive deformation associated with inflation of a deep-seated reservoir is suggested, and co-eruptive deformation associated with the Hekla 2000 eruption has been measured. At the Eyjafjallajökull volcano, InSAR shows uplift of more than 20 cm associated with shallow intrusive activity in 1994 and 1999. Co-seismic deformation from two M6.6 earthquakes in the South Iceland Seismic Zone in 2000 has been captured by InSAR, as well as resulting triggered fault movements on the Reykjanes Peninsula.

At all the study areas, InSAR has provided important new results regarding geological processes. Future studies are, however, uncertain, due to a failure onboard the ERS-2 satellite in early 2001 that has prevented the formation of ERS interferograms covering the summer of 2001 in Iceland. A launch of a new radar satellite, ENVISAT, by the European Space Agency is planned in 2002 and it is hoped that this satellite will provide SAR images of Iceland that can be used for future deformation studies.

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