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Remote sensing observations of active volcanic and tectonic processes in Iceland

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Measuring deformation of the Earths crust is an important tool in trying to obtain insight into the geological processes working at depth. Iceland is an excellent target for remote sensing of crustal deformation processes, especially for the use of interferometric combination of synthetic aperture radar images (InSAR). The Icelandic crust deform continuously, due to a variety of volcanic and tectonic processes, and the relatively barren ground furthermore makes an ideal reflector for radar beams emitted from the SAR satellite. The focus of this talk will be on three examples of InSAR observations of recent crustal deformation in Iceland, and the inferences such measurements facilitate related to active plate spreading processes, tectonic faulting and subsurface magma movements.

1. The Northern Volcanic Zone (NVZ) in Iceland is an extensional rift segment, forming a sub-aerial exposure of a part of the mid-Atlantic ridge. The NVZ is bounded to the south by the Icelandic mantle plume, and to the north by the Tjörnes transform zone. The NVZ has typically been divided into five partly overlapping en-echelon fissure swarms, each with a central main volcanic production area. A series of InSAR images reveal a complex interplay of a number of tectonic and magmatic processes in the NVZ. Two subsiding shallow sources coinciding with the known crustal magma chambers, plate spreading related subsidence within narrow fissure swarms (15-20 km), horizontal plate spreading distributed over a much wider zone (∼80-100 km), and finally a wide area of uplift which may reflect on processes near the crust mantle boundary. Construction of finite element models, have facilitated exploration of the role spatial variation of rheological properties play, in modifying the style of surface deformation at this extensional plate boundary. Our models indicate that the observed inter-rifting plate spreading deformation field is controlled by local rheological variations within the arrangement of fissure segments, and that a regional central ridge axes model does not apply. The best fitting crustal structure within the most active fissure swarms consists of a wedge of weak elastic material on top of a local visco-elastic ridge.

2. The South Iceland Seismic Zone (SISZ) is a transform zone connecting the western and eastern volcanic zones in Iceland. The SISZ consists of many parallel right-lateral N-S striking faults, which accommodate an overall left-lateral E-W shearing associated with plate spreading, a phenomenon also known as" bookshelf tectonics". Two MW = 6.5 earthquakes in June 2000 happened on two parallel N-S striking faults and the resulting deformation were recorded in a series of InSAR images. Inverse modeling results indicate that a maxima of 2.9 meters of pure right-lateral strike-slip, occurred. The distribution of slip with depth may be correlated to crustal layering, with more than 80% of the total geometric moment release occurring in the uppermost 6 km. The total moment released by the two events equals only a fraction of the moment accumulated in the area since the last major earthquake in 1912.

3. The typical pattern of surface deformation observed prior to, spanning and following eruptions of Iceland's frequently active volcanoes, relates to melt accumulation, drainage and renewed replenishment from crustal magma chambers. However, such a simple model cannot explain the complex behavior observed at the moderately active Eyjafjallajökull volcano, where an eruption in the spring of 2010 caused an exceptional disruption to European air traffic. Ground deformation measurements through 18 years of intermittent unrest have facilitated a coarse mapping of the volcano's complicated plumbing system. A network of sill intrusions forming at about 5 km depth explains the distinct behavior of the Eyjafjallajökull volcano.