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Retrospective stress-forecasting of earthquakes

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Observations of changes in azimuthally varying shear-wave splitting (SWS) above swarms of small earthquakes monitor stress-induced changes to the stress-aligned vertical microcracks pervading the upper crust, lower crust, and uppermost ∼400km of the mantle. (The microcracks are intergranular films of hydrolysed melt in the mantle.) Earthquakes release stress, and an appropriate amount of stress for the relevant magnitude must accumulate before each event. Iceland is on an extension of the Mid-Atlantic Ridge, where two transform zones, uniquely run onshore. These onshore transform zones provide semi-continuous swarms of small earthquakes, which are the only place worldwide where SWS can be routinely monitored. Elsewhere SWS must be monitored above temporally-active occasional swarms of small earthquakes, or in infrequent SKS and other teleseismic reflections from the mantle.

Observations of changes in SWS time-delays are attributed to stress-induced changes in crack aspect-ratios allowing stress-accumulation and stress-relaxation to be identified. Monitoring SWS in SW Iceland in 1988, stress-accumulation before an impending earthquake was recognised and emails were exchanged between the University of Edinburgh (EU) and the Iceland Meteorological Office (IMO). On 10th November 1988, EU emailed IMO that a M5 earthquake could occur soon on a seismically-active fault plane where seismicity was still continuing following a M5.1 earthquake six-months earlier. Three-days later, IMO emailed EU that a M5 earthquake had just occurred on the specified fault-plane. We suggest this is a successful earthquake stress-forecast, where we refer to the procedure as stress-forecasting earthquakes as opposed to predicting or forecasting to emphasise the different formalism.

Lack of funds has prevented us monitoring SWS on Iceland seismograms, however, we have identified similar characteristic behaviour of SWS time-delays above swarms of small earthquakes which have enabled us to retrospectively stress-forecasting ∼17 earthquakes ranging in magnitude from a M1.7 swarm event in N Iceland, to the 1999 M7.7 Chi-Chi Earthquake in Taiwan, and the 2004 Mw9.2 Sumatra-Andaman Earthquake (SAE). Before SAE, the changes in SWS were observed at seismic stations in Iceland at a distance of ∼10,500km the width of the Eurasian Plate, from Indonesia demonstrating the 'butterfly wings' sensitivity of the New Geophysics of a critically microcracked Earth. At that time, the sensitivity of the phenomena had not been recognised, and the SAE was not stress-forecast.

These results have been published at various times in various formats in various journals. This presentation displays all the results in a normalised format that allows the similarities to be recognised, confirming that observations of SWS time-delays can stress-forecast the times, magnitudes, and in some circumstances fault-breaks, of impending earthquakes.

Papers referring to these developments can be found in geos.ed.ac.uk/home/scrampin/opinion.
Also see abstracts in EGU2015 Sessions: Crampin & Gao (SM1.1), Liu & Crampin (NH2.5), and Crampin & Gao (GD.1).