Geophysical Research Abstracts
Vol. 15, EGU2013-2428, 2013
EGU General Assembly 2013

Deformation in the Rutford ice stream, West Antarctica: measuring shear-wave anisotropy from icequakes

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Ice streams provide major drainage pathways for the Antarctic ice sheet. The stress distribution and style of flow in such ice streams produces elastic and rheological anisotropy, which informs ice flow modelling as to how ice masses respond to external changes such as global warming. Here we analyse elastic anisotropy in the Rutford ice stream, West Antarctica, using observations of shear wave splitting from three-component icequake seismograms to characterise ice deformation via crystal preferred orientation. Over 110 high quality measurements are made on 41 events recorded at five stations temporarily deployed near the ice stream grounding line. To the best of our knowledge this is the first well-documented observation of shear wave splitting from Antarctic icequakes. The magnitude of the splitting ranges from 2ms to 80ms and suggest a maximum of 6% shear wave splitting. The fast shear wave polarisation direction is roughly perpendicular to ice flow direction. We consider three mechanisms for ice anisotropy: a cluster model (VTI model); a girdle model (and HTI model); and crack-induced anisotropy (an HTI model). Based on the data we can rule out a VTI mechanism as the sole cause of anisotropy – an HTI component is needed, which may be due to ice crystal a-axis alignment in the direction of flow or the alignment of cracks or ice-films in the plane perpendicular to the flow direction. The results may suggest a combination of mechanisms are at play, which represent vertical variations in the symmetry of ice-crystal anisotropy in an ice stream, as predicted by ice fabric models.