CReSIS Student Organization Mentoring Award

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Do strain rates determine the spatial density of crevasses on the Greenland ice sheet?

Crevasses form in areas of high strain rates on glaciers or on the flanks of continental ice sheets, where the ice fractures because stresses reach its tensile strength [1, p. 446]. The tensile strength varies spatially, however – largely in response to ice temperature – so that crevasse formation is not easily predicted by strain rates alone [2]. Even from place to place on an isothermal glacier, crevasses may or may not form under similar strain rate conditions, so ice temperature alone cannot account for all the variability [3]. There is yet no explanation for this surprisingvariability in crevasse formation as a function of strain rates, except for one study that suggests that crevasse patterns may reflect highly localized variations the strain rate field [4]. Previous studies [2][3][4] have been limited to the areas of individual mountain glaciers, though, and may not have had enough spatial coverage to expose fine patterns over large spatial scales.

The margin of the Greenland ice sheet provides an ideal area over which to conduct a larger-scale study of crevasse formation in response to strain rates. Here, complex basal topography and relatively fast flow give rise to large zones of compression or extension; there are also large areas densely populated by crevasses and areas with almost a complete absence of crevasses. I propose to take an inventory of the crevasses on the western flank of the Greenland ice sheet and correlate them with the local strain rates. We have calculated the strain rate field from velocity measurements (described in [5]) with nearly complete spatial coverage at relatively fine resolution. High-resolution satellite photos capture the crevasses with up to 0.4 meter resolution. For this project, the student will design an algorithm to count the spatial density and areal coverage of crevasses from these images[1]. The density will vary over square-kilometer-scale areas of the ice sheet; the student will need to develop an interpolation process to create a map of the crevasse density smoothed over area. Finally, the student will compare this density map with the strain rate map and identify the degree of correlation between them. The student will determine the tensile strength of ice – how much extension is necessary to open a crevasse? – and its variability across the study field. This would be the first published calculation for this quantity on the Greenland ice sheet.

If the student is interested in the science beyond the image analysis, or if the correlation between crevasse density and strain rates is complex, we can examine data in this area of the Greenland ice sheet on a number of glaciological quantities that influence crevasse formation:

- **Ice temperature at depth** [6] determines the viscosity of the ice, which directly links the formation of crevasses in response to driving stresses and strain.

[1]The crevasse-counting algorithm may be as simple as drawing a box and counting the number of lines that meet some defined criteria of crevasses and summing the total area they cover, or it may be as involved as running a Fouier transform on the dark-light crevasse-ice pattern to determine the typical width of and spacing between crevasses.

- **Mean annual air temperature** influences the amount of summer melt and refreezing of that melt in winter; a crevasse filled with refrozen ice may be a weak spot that is susceptible to open again under lower strain rates.
- **Meteorological data** [7] may show rapid cooling events that can potentially fracture the ice through thermal contraction [1, p. 451].
- **Slope of the ice sheet and ice thickness** [8] control the driving stress that acts on the ice to strain and fracture it.
- **Bedrock topography** [9] exerts perhaps the largest influence on the strain rate of the ice; areas of high strain rates are expected above and just downstream of significant bedrock highs due to vertical compression then extension as the ice flows over and past the bump [1, p. 397-8].

These quantities influence the motion of the ice through their effects on stress and viscosity. There is much potential for the student to explore the physics behind ice dynamics in light of explaining their findings on the correlation between the size and spatial density of crevasses and the strain rates responsible for creating them.

References

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