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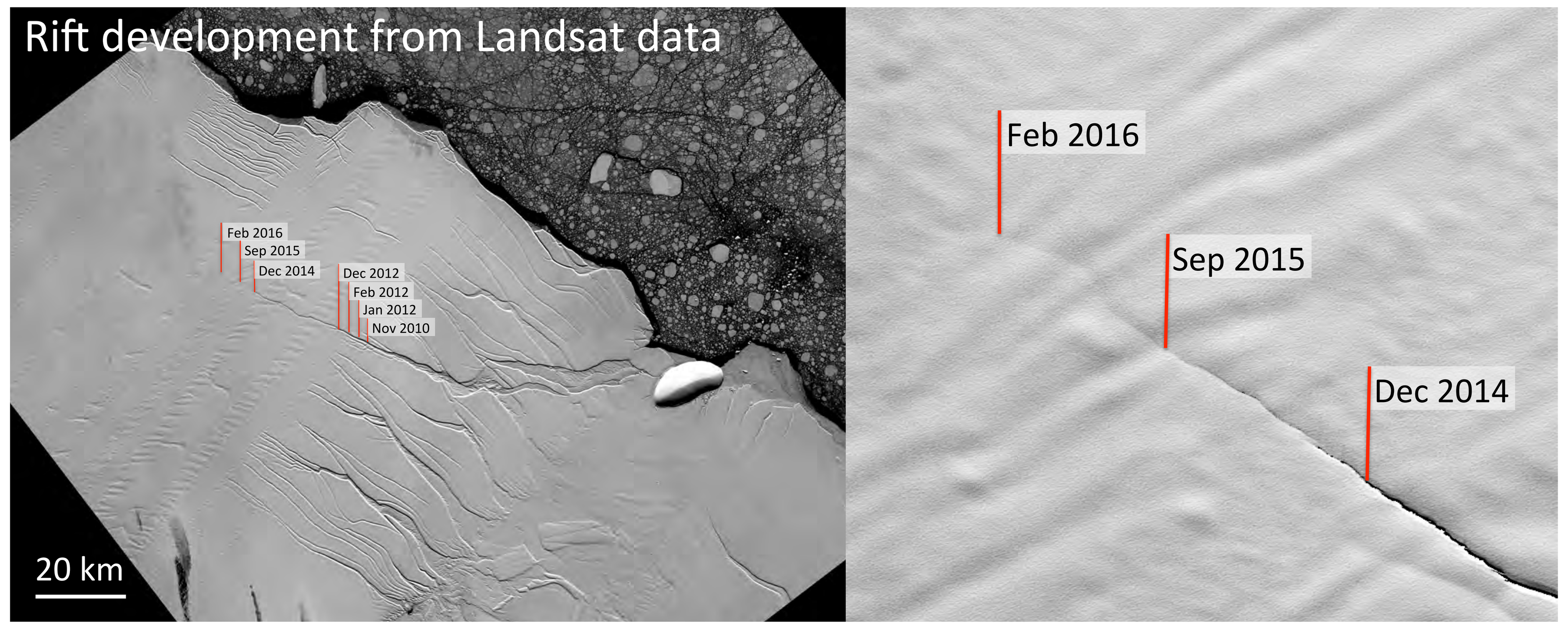
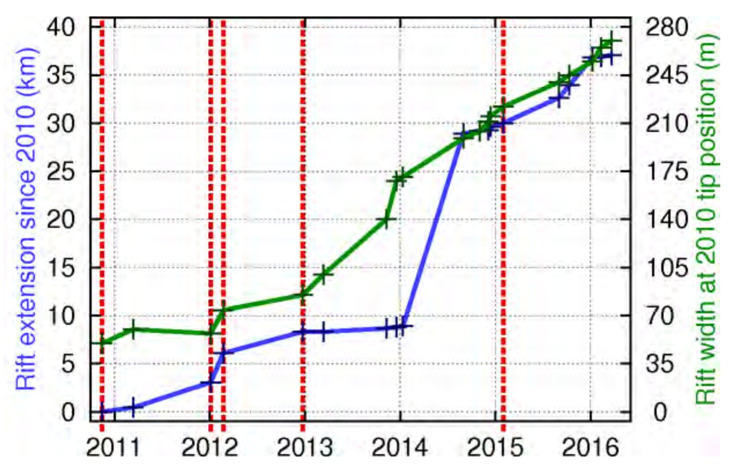
Observed rift propagation in the Larsen C Ice Shelf from Sentinel 1-A radar data

Introduction

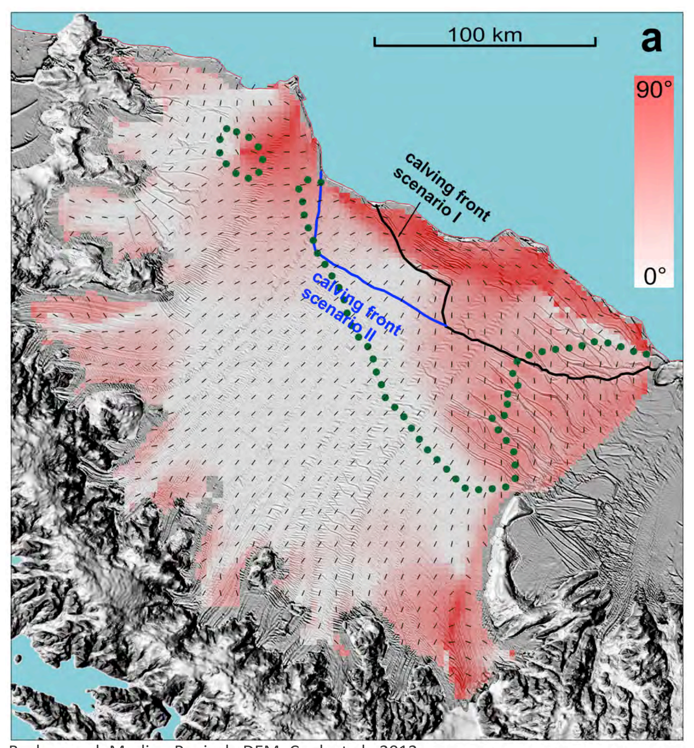
The Larsen C Ice Shelf is the most northerly of the remaining major Antarctic Peninsula ice shelves and is vulnerable to changes in both to ocean and atmospheric forcing. There have been observations of widespread thinning, melt ponding in the northern inlets, and a speed-up in ice flow, all processes which have been linked to former ice shelf collapses.
The tips of large rifts in the vicinity of the Gipps Ice Rise have been observed to align at a suture zone between two flow units within the shelf. Several studies suggest that marine ice inhibits the propagation of rifts.
In a change from the usual pattern, a northwards-propagating rift from Gipps Ice Rise has recently penetrated through the suture zone. We followed the rift propagation on Landsat imagery and with Sentinel 1-A radar data.



Rift development



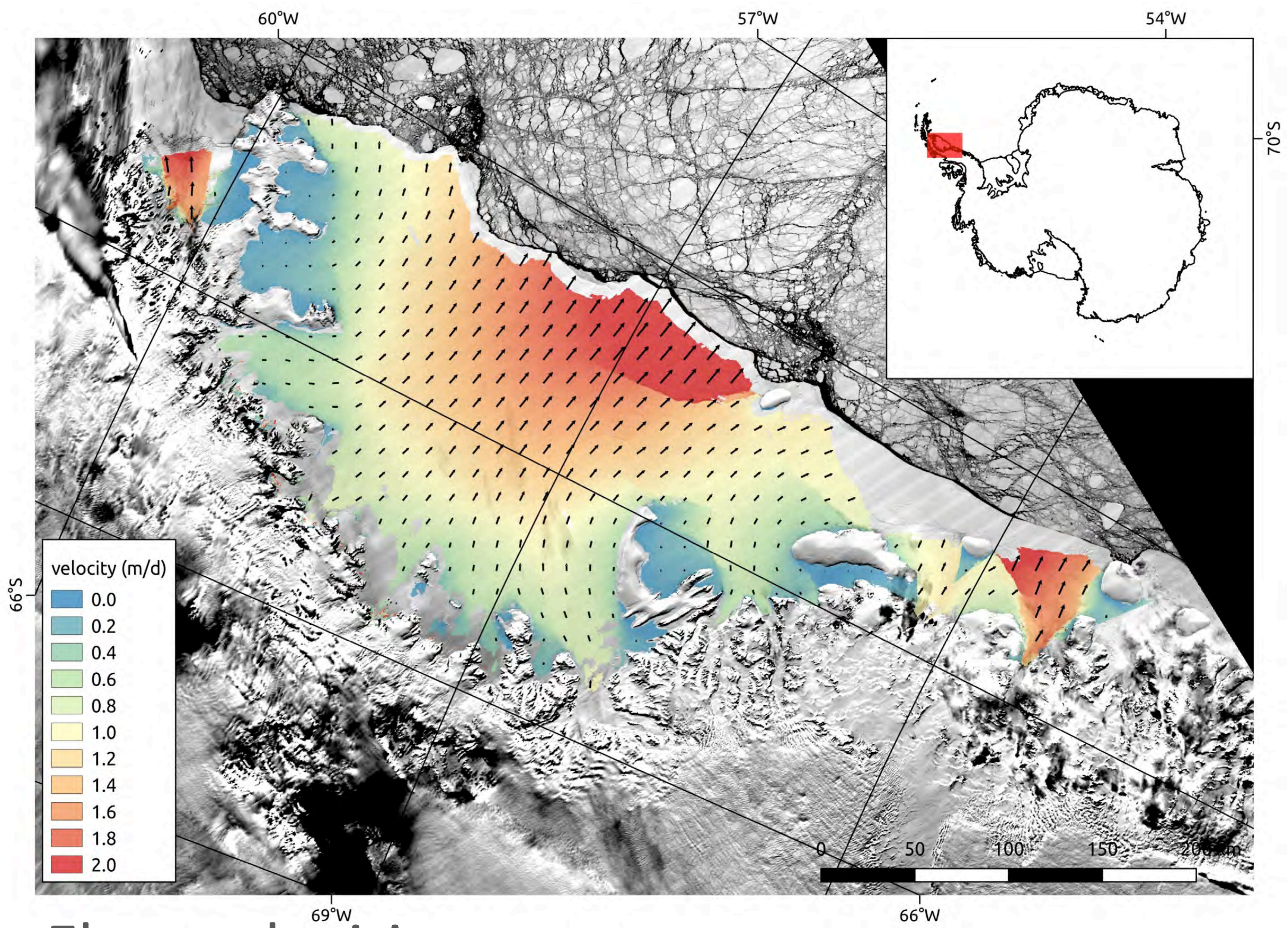
The rift first propagated into the suture zone in 2012 and progressed during 2013 into a region which previously resisted fracturing. Between January and August 2014, the rift crossed the entire Trail Inlet flow unit (~ 20 km) in just 8 months. The width of the rift is also increasing at a rate of ~40 m/year. Since the large increase of rift extension in 2014 the rift appears to grow steadily in width and extension.
To investigate the impact of future calving events we evaluated the difference between modelled directions of ice flow and of first principal stress (shaded in red). Low stress-flow angles are likely to be more affected by small-scale calving, regions with a stress-flow angle approaching 90° are likely to be stable (Kulessa et al., 2014, Jansen et al., 2015).



Background: Modis Penisula DEM: Cook et al., 2012

Sentinel

Sentinel-1A (ESA) was launched on 3 April 2014 (12 days repeat pass). The instrument is a C-band Synthetic Aperture Radar (SAR) with a centre frequency of 5.405 GHz.
Sentinel-1B is scheduled for 2016 (6 days repeat pass with both satellites in orbit) --> the shorter temporal baseline will increase the coherence between two satellite passes which is essential for SAR interferometry.
Here we use Level-1 Single Look Complex (SLC) products acquired in Interferometric Wide swath (IW) mode, covering a 250 km swath on the ground.

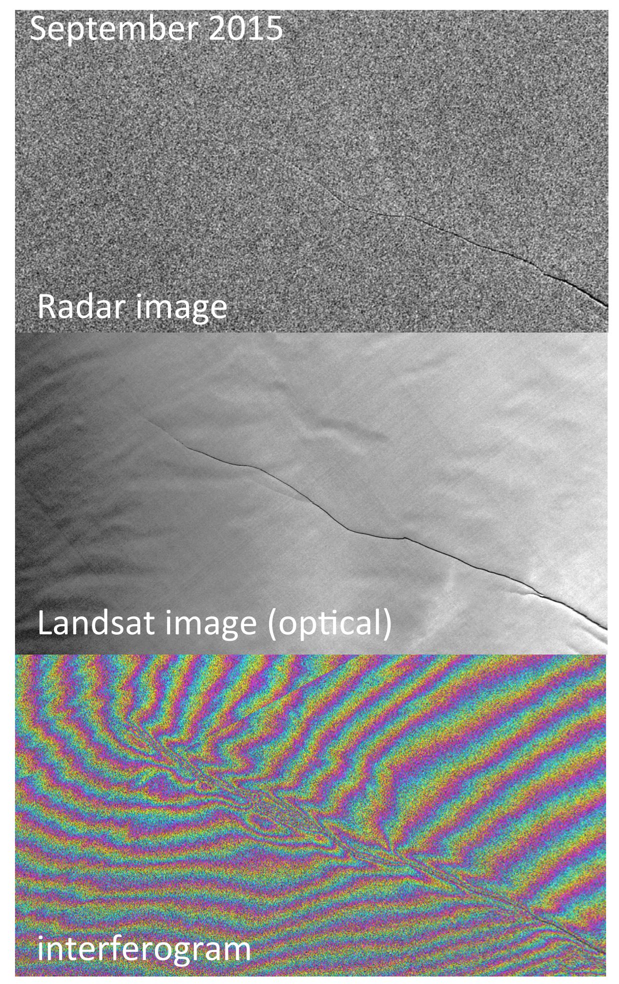


Flow velocities

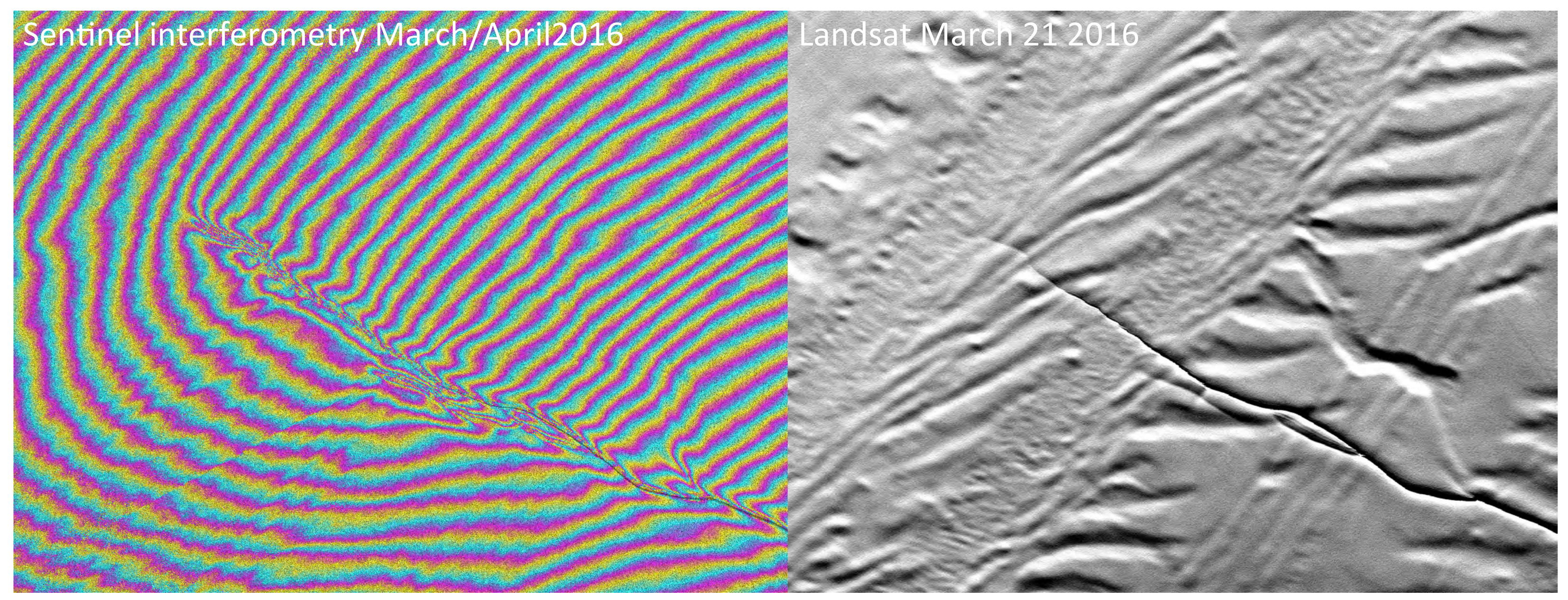
Surface velocities were derived by offset intensity tracking for every 12-day repeat pass acquisition starting in November 2014. The tracking was done on the original SLC data, employing a search window size of approximately 1 km at 250 m steps. Range and azimuth offsets were translated into surface displacements and projected into a metric coordinate system. Due to the very precise orbit information available for Sentinel-1A no global fit to in-situ displacement measurements is needed.
Overall the magnitudes of the calculated velocities agree well with previous observations. The rift stands out as a sharp velocity jump, with its magnitude decreasing towards the tip. The jump in velocity magnitude does not represent the opening rate of the rift, which is smaller by a factor of three. It is much more likely that the apparent high velocities are due to the different vertical movements caused by the ocean tides. This process probably also contributes to the steady growth of the rift.

Using interferometry for monitoring rift propagation

In order to monitor the rift propagation, interferograms were derived for every 12-day repeat pass acquisition starting in November 2014. Here a very precise co-registration of the SLC pairs is mandatory. The topography induced phase information was removed with the help of a recent Cryosat-2 DEM (Helm et al. 2014).



A big advantage of radar remote sensing data is that is is also available during the polar night (Mid-April to Mid-August) and that it is independent from cloud cover. Radar imagery alone is not suitable to monitor the rift tip, as it is masked by the speckle. The inconsistencies in the fringes however clearly highlight the extension of the rift. The figure on the left shows (a) the Sentinel radar image (b) the Landsat image and (c) the interferogram (September 2015).
Thus, interferometry can be used in a qualitative way for monitoring the rift. Problems occur when the coherence is lost due to surface melting or accumulation event. Therefore we did not get a continuous record.



Conclusions

- The rift in the Larsen C Ice Shelf is continuing to grow in extension and width
- Sentinel 1-A interferometry is a convenient way to track the development of the rift during the coming polar night and in cloudy conditions
- Results hopefully will improve with the launch of Sentinel 1-B due to the shorter repeat cycle

References:

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