Derivation of glacier flow velocities and geophysical parameters from high resolution SAR data

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High resolution Synthetic Aperture Radar (SAR) satellite observations offer significant advantages for the remote sensing of glaciers and ice streams. The ability to acquire data independently of solar illumination and cloud coverage, the high sensibility of the radar signal to the properties of ice and snow covered surfaces, and the richness of information contained in the complex SAR signal offer a large potential for various glacier and ice monitoring applications.

Glacier mass balance

The German Aerospace Center (DLR) operates since June 2010 the TanDEM-X mission, which is composed by two twin satellites (TSX-1 and TDX-1) orbiting the earth in close formation and allowing single-pass bistatic SAR interferometry. These data are unaffected by temporal decorrelation and atmospheric fluctuations. The main goal of TanDEM-X is the derivation of a global digital elevation model (DEM) with unprecedented accuracy. A previous DEM was derived with SAR bistatic interferometry by the Shuttle Radar Topography Mission (SRTM) in year 2000, although with lower accuracy and no coverage at high latitudes. The multitemporal TanDEM-X and SRTM elevation dataset has an 11 to 14 year time span and therefore is well suited to measure variations in ice elevation for vast, difficult to access regions.

The DEM differencing applied to TanDEM-X and SRTM was used to derive the mass balance of the Northern and Southern Patagonian Icefields (NPI and SPI), the largest mid-latitude ice masses in the Southern hemisphere. SPI and NPI are drained by outlet glaciers with fronts calving into fresh water lakes or Pacific fjords and have been both affected by significant downwasting in the last decades.
The ice elevation change maps obtained (Fig. 1) display almost exclusively negative trends with a strong variability among different glacier basins, highlighting the necessity of a spatially detailed analysis.

According to the geodetic method, the integration of the elevation change map over the ice area leads to the volume change which allows the calculation of the mass balance of the two icefields. The mass change rate for the 13000 km² SPI was \(-13.1 \text{ Gt a}^{-1}\) while for the 4000 km² NPI it amounted to \(-4.0 \text{ Gt a}^{-1}\) during the investigation period.

**Fig. 1:** Elevation change rate map for the San Quintin, San Rafael and Gualas Glaciers, on the north western margin of NPI obtained from TanDEM-X and SRTM DEM differencing.

**Ice flow velocity**

Complementary to the ice mass changes the ice flow velocity can be derived from TerraSAR-X mission data. The velocity is used for estimating glacier loss through calving.

The TSX-1 and TDX-1 satellites can operate independently in monostatic mode, acquiring images with an 11 day repeat pass cycle. Such data pairs are used to measure the ice displacement between two SAR acquisitions by applying the amplitude correlation technique. This consists in estimating the shift of the peak of the cross-correlation function over a grid of partially overlapping data patches. Velocity fields were obtained for large ice streams of Antarctica and on the outlet glaciers of the Patagonia Icefields. An example of ice velocity map is shown in Fig. 2 for the San Quintin glacier (NPI).

**Fig. 2:** Ice flow velocity for the San Quintin Glacier (NPI) obtained by means of amplitude tracking applied to a pair of TerraSAR-X Stripmap acquisitions from 14 and 25 May 2012.
