Surface velocities of Wilkins Ice Shelf between 2006 and 2009

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Content

Surface velocities of the central part of the Wilkins Ice Shelf for 2006, 2007, 2008 and 2009 as presented in:

> Rankl et al. (2017) Dynamic changes on Wilkins Ice Shelf during the 2006-2009 retreat derived from satellite observations, The Cryosphere, 11 (1-12), doi:10.5194/tc-11-1-2017.

Products are inferred from ALOS PALSAR intensity-offset tracking (image details in Table 3). Displacement components are given for both horizontal direction. Chosen units are meters per day. The data is presented on 50m x 50m resolution.

dx_2006-06-14--2006-07-30.tif	(EPSG:32719, WGS 84 / UTM zone 19S)
dx_2007-09-26--2007-11-11.tif	(EPSG:32719, WGS 84 / UTM zone 19S)
dx_2008-09-28--2008-11-13.tif	(EPSG:32718, WGS 84 / UTM zone 18S)
dx_2009-09-09--2009-10-01.tif	(EPSG:32719, WGS 84 / UTM zone 19S)
dy_2006-06-14--2006-07-30.tif	(EPSG:32719, WGS 84 / UTM zone 19S)
dy_2007-09-26--2007-11-11.tif	(EPSG:32719, WGS 84 / UTM zone 19S)
dy_2008-09-28--2008-11-13.tif	(EPSG:32718, WGS 84 / UTM zone 18S)
dy_2009-09-09--2009-10-01.tif	(EPSG:32719, WGS 84 / UTM zone 19S)

Data description

Surface velocities of Wilkins Ice Shelf and its tributary glaciers were derived from SAR (Synthetic Aperture Radar) intensity-offset tracking (Strozzi et al., 2002) using repeat ALOS PALSAR (46 day time interval) Single Look Complex (SLC) image pairs (Table 3). This technique cross-correlates the backscatter intensity pattern of a pair of SAR images of different acquisitions dates. For this purpose, small image patches are shifted over the entire image (Table 1) and for each patch, the maximum of the 2-D cross-correlation function yields the image offsets in range and azimuth directions. If coherence between both image patches is retained, the speckle pattern is additionally correlated. Offsets of minor confidence were rejected based on a signal-to-noise-ratio (SNR ≤ 4). The processing was performed using Gamma Remote Sensing software (Werner et al., 2000). Geocoding of the final range and azimuth offsets from SAR to map geometry was based on the WGS84 ellipsoid. The spatial gridding was set to 50x50 m.

The method relies on surface patterns, which are identifiable in both images. However, co-registration and intensity-offset tracking performed on single scenes of the nearly structure-less ice shelf was rarely successful. Therefore, single scenes were concatenated along-track. Additionally, we used a binary mask of very slow/non-moving (e.g., ice rises, bedrock) and moving areas (ice shelf, tributary glaciers, sea) to perform co-registration on stable areas only. In a post-processing step, the flow magnitude and direction were filtered using the approach described in Burgess et al. (2012). By using a 5 x 5 pixel moving window approach, displacement vectors were discarded iteratively when deviating more than 30% from the median length of the window's centre vector or when deviating from a predefined orientation of the centre vector (thresholds 20°, 18° and 12°).

For each year, several displacement fields were mosaicked. The mosaicked surface flow shows slight deviations in the flow magnitude along the boundaries of each satellite flight path. These offsets might be due to short-term variations of ice flow between image acquisitions, processing artefacts or due to varying co-registration accuracies related to the restricted availability of non-moving areas in each scene. The magnitude of these offsets is non-linear and ranges between ~3 and 18 m yr^{-1} on the main ice-shelf area. The offsets are larger close to the ice front, where the displacement fields capture the short-term motion of the ice mélange. The derived flow fields were not corrected for these non-linear offsets, however, the estimated co-registration accuracy in Table 2 accounts for these deviations (see below).

Table 1: Parameter settings used for SAR intensity-offset tracking.

Sensor	Sensor wavelength	Tracking window size (range * azimuth)	Step (range/azimuth)
ALOS PALSAR	23.5 cm L-band	128*384	12/36

Velocity error estimate

The estimation of errors in the derived velocity fields was done as described in McNabb et al. (2012) and in Seehaus et al. (2015). For each velocity field a value based on the accuracy of the co-registration ($\sigma_v{}^C$) was calculated and a second value ($\sigma_v{}^T$) described uncertainties involved in the intensity-offset tracking algorithm

(Table 1). Further error contribution related to the orbital information of the image acquisitions or the atmospheric influence are still difficult to quantify. The magnitude of the term σ_v^C was derived from the median of the velocities over non-moving areas (based on up to 25,000 samples per image pair), e.g., ice rises or bedrock, where zero ice motion is assumed. The error estimation over non-moving ground is a standard procedures when using intensity-offset tracking for ice velocity determination (e.g., Burgess et al., 2012; McNabb et al., 2012; Quincey et al., 2009, 2011; Seehaus et al., 2015). Since no additional calibration of the derived offset fields over stable ground has been undertaken, the term σ_v^C captures all errors related to the co-registration procedure. The second term σ_v^T describes uncertainties related to the intensity-tracking algorithm, the spatial resolution and the time interval between image acquisitions. It is calculated using

$$\sigma_v^T = \frac{C\Delta x}{z\Delta t} \qquad \text{(Seehaus et al., 2015).} \qquad (1)$$

C describes the uncertainty of the tracking algorithm (C=0.4), Δx the image resolution in ground range, z the oversampling factor used in the tracking process and Δt the time period between image acquisitions. The final error estimate σ_v is derived from the sum of both terms σ_v^C and σ_v^T (Table 2).

Table 2: Error estimation of derived velocity fields.

Date **yyyy-mm-dd--yyyy-mm-dd**	**Sensor**	σ_v^C **[m/d]**	σ_v^T **[m/d]**	σ_v **[m/d]**
2006-06-14--2006-07-30	ALOS PALSAR	0,267962	0,03	0,297962
2007-09-26--2007-11-11	ALOS PALSAR	0,25396	0,03	0,28396
2008-09-28--2008-11-13	ALOS PALSAR	0,113365	0,03	0,143365
2009-10-01--2009-11-16	ALOS PALSAR	0,1476365	0,03	0,1776365

When calculating first spatial derivatives of the surface velocities, a wavelike pattern emerges in 2006, 2008 and 2009, which dominates in areas where flow speeds are small. This pattern was detected in comparable studies calculating surface velocities from intensity-offset tracking (Joughin, 2002; Nagler et al., 2015). It was attributed to fluctuations in the polar ionospheric electron density and may affect the phase measurement of a SAR sensor, but also the correct mapping of the azimuth pixels' position (Gray et al., 2000). This effect is found to be larger for L-band than for C-band acquisitions. The wavelength of this pattern in L-band frequencies was scaled to 5-10 km (Gray et al., 2000), which is comparable to the pattern visible in Figures 3 and 4. A smoothing of this pattern by averaging several flow fields over multiple acquisitions as proposed in Nagler et al. (2015) is impossible on WIS due to lack of further, suitable image pairs. Another study found variations in the tropospheric water content influencing the measured path delay with InSAR (Drews et al., 2009). However, this effect was restricted to C-band InSAR (Williams et al., 1998) and no influence on the image intensity is known. Hence, ionospheric disturbances remain a likely explanation for the detected wavelike pattern in this study. However, as the pattern has some link to the structure of the ice shelf and is persistent over years, we cannot rule out completely that it is a real feature of the displacement field.

SAR Data

Table 3: Satellites and sensors used

Sensor	Date	Rel. orbit/strip	Frame
ALOS PALSAR	14/06/2006	190	5650-5680
ALOS PALSAR	30/07/2006	190	5650-5680
ALOS PALSAR	26/09/2007	175	5670-5720
ALOS PALSAR	11/11/2007	175	5670-5720
ALOS PALSAR	28/09/2008	175	5680-5720
ALOS PALSAR	13/11/2008	175	5680-5720
ALOS PALSAR	01/10/2009	175	5680-5710
ALOS PALSAR	16/11/2009	175	5680-5710

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