Analysis of Outlet Glaciers on the East Coast of the Antarctic Peninsula

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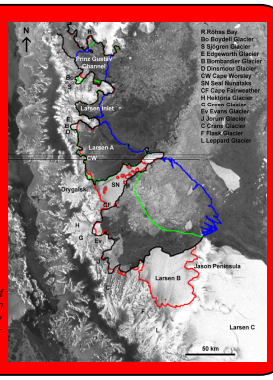
Introduction

Recent changes of Larsen Ice Shelf and outflow glaciers of the Antarctic Peninsula were investigated. The main data sources are Envisat ASAR images, complemented by optical imagery. Of particular interest is the impact of the ice shelf retreat on grounded ice that contributes to sea level rise. Evidence on acceleration of outlet glaciers after ice shelf break up was observed for the glaciers above the previous Larsen A and Prince Gustav Channel ice shelves based on analysis of ERS tandem data from 1995 and 1999 [1]. New data provided by Envisat ASAR enabled us to study also the retreat and acceleration of glaciers after the disintegration of Larsen B in 2002.



Envisat ASAR wide swath image of 1 September 2003, showing the area of the northern Larsen Ice Shelf. Blue/green/black line: ice edge in March 1986/October 2000/June-July 2004. The grounding line (red) is derived by ERS SAR interferometry, for sections that disintegrated before October 1995 from the ice edge.

Estimation of Sea Level Contribution

Glacier/Region	Area [km²] 1995-1999	Area [km²] 1999 -2003	Area [km²] 2003-2004
Röhss Bay	-	+8	-
Sjögren-Boydell Glaciers	+24	+30	-
Dinsmoor-Bombardier-Edgeworth Glaciers	+34	+5	-4
Glaciers north of Cape Worsley	-	+23	-
Drygalski Glacier	+24	+8	-
Hektoria-Green-Evans Glaciers	-	+57	-16
Crane Glacier	-	+3	+19

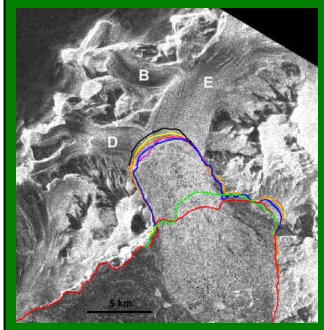
Loss of grounded ice at selected former tributaries of northern Larsen Ice Shelf.

The area of grounded ice lost after January 1995 up to July 2004 at the main tributaries of the northern Larsen Ice Shelf corresponds to 215 km² or 0.014 mm sea level equivalent, with an estimated mean ice thickness of 600 m and 100 m above sea level. The sea level contribution due to export at the front of the main tributary glaciers of Larsen A is estimated at 0.013 mm/a in 1995, 0.021 mm/a in 1999 and 0.012 for 2004; for Larsen B at 0.018 mm/a in 2004. These are estimations based on difference between balance flux and calving flux that will be improved after acquisition of further ice thickness data.

Glacier	SLC [mm/a] 1995	SLC [mm/a] 1999	SLC [mm/a] 2004
Sjögren-Boydell Glaciers	0.0013	0.0026	0.0034
Main Glacier of Larsen Inlet	0.0020	0.0020	0.0015
Dinsmoor-Bombardier-Edgeworth Glaciers	0.0042	0.0085	0.0015
Drygalski Glacier	0.0051	0.0075	0.0058
Hektoria Green Evans Glaciers	(0.0005)	(0.0009)	0.0164
Crane Glacier	(-0.0013)	(-0.0010)	0.0015

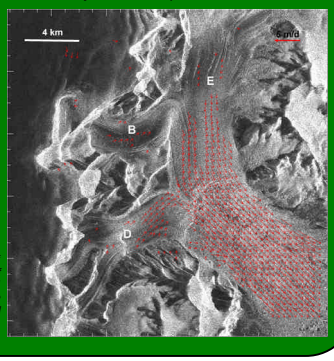
Estimates for sea level contributions (SLC) of several outlet glaciers of the former Larsen Ice Shelf for the years 1995, 1999 and 2004 due to ice export at the front..

Outlet Glaciers above Larsen A



ASAR IMS (image mode single look complex) image, tr152, fr 4941, IS 2 HH, from 2 July 2004 showing ice front positions of Dinsmoor (D), Bombardier (B) and Edgeworth (E) glaciers (red = grounding line estimated from the ice edge in 1995, shortly after the ice shelf collapse, green = 01-11-1996, blue = 31-01-1999, yellow = 24-02-2002, black = 03-11-2002, orange = 04-04-2003, magenta = 13-02 2004 .

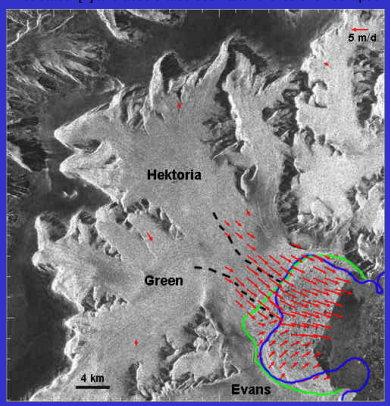
The outlet glaciers of the peninsula accelerated after collapse of Larsen A. The main ice inflow to Larsen A was through Drygalski Glacier and Dinsmoor-Bombardier-Edgeworth (D-B-E) glaciers with a grounded basin of 681 km² in 1995 [1]. Between October 1995 and January 1999 / November 2002 an area of 34 / 38 km² was lost and the distance of the front from the original grounding line was 6.5 / 7.3 km. Between February 2002 and July 2004 the glacier slightly advanced because the proglacial bay was covered by fast ice.
By means of ERS SAR interferometry a velocity of 2.9 m/d was derived in the center of the 6 km wide front of D-B-E glaciers in austral spring 1995. At the central flowline 2 km above the 1999 ice front the velocity accelerated from 1.5 m/d in 1995 to 6 m/d in 1999. For the year 2004 a velocity of 1.8 m/d at the ice front of 2004 was derived by means of amplitude correlation.



Motion field of Hektoria-Green-Evans glaciers, derived from the ASAR IMS image pair, IS2 HH, of 12 May 2004 and 16 June 2004 by means of amplitude correlation (blue: grounding line derived by ERS SAR interferometry, green: recent ice front, black: central flowlines of Hektoria and Green glaciers) .

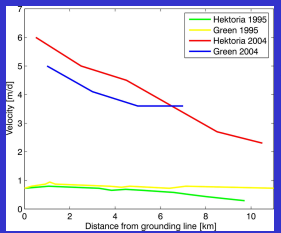
Outlet Glaciers above Larsen B

As observed for Larsen A the outlet glaciers above former Larsen B retreated [2] and accelerated soon after the ice shelf collapse in 2002.



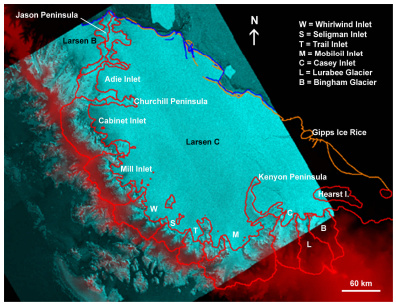
Motion field of Hektoria-Green-Evans glaciers, derived from the ASAR IMS image pair, IS2 HH, of 12 May 2004 and 16 June 2004 by means of amplitude correlation (blue: grounding line derived by ERS SAR interferometry, green: recent ice front, black: central flowlines of Hektoria and Green glaciers) .

The motion field of Hektoria-Green-Evans (H-G-E) glaciers with a grounded area of 1583 km² before the ice shelf collapse, one of the largest tributary glaciers of Larsen B, was mapped by means of amplitude correlation with 2004 ASAR data. The H-G-E glaciers showed major retreat behind the grounding line in summer 2003 and have been advancing slightly since April 2004.



Magnitude of the velocity vector along the central flowlines on Hektoria and Green Glaciers derived from ERS interferometric pair of 31 October-1 November 1995 and ASAR amplitude correlation pair of 12 May-16 June 2004.

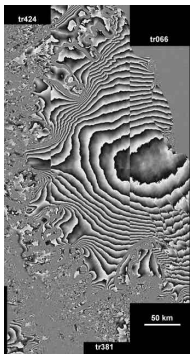
A comparison of the velocities of Hektoria and Green glaciers in 1995, derived by ERS SAR interferometry, and the velocities in 2004 shows significant acceleration of flow.



ASAR WSM image from 6 May 2004 plotted on a digital elevation model (DEM) (blue = ice front 6 May 2004, orange = ice front 22 March 2000 derived from a MODIS image) showing the Larsen Ice Shelf C and its catchment basins (red line). The grounding lines are derived by means of ERS SAR interferometry.

Larsen C

In contrast to the northern Larsen Ice Shelf no major changes of the ice front position of Larsen C were observed in the last 15 years. The last big calving events took place between 1975 and 1986-89 when two large icebergs calved off [3].
The catchment basins were determined using a digital elevation model and various optical and SAR images. The grounded area amounts to about 27000 km² and the floating area between Jason Peninsula and Hearst Island covers about 55000 km².
The interferogram of Larsen C shows velocities up to 500 m/a in the middle of the ice front. Discontinuities between the tracks are due to orbit errors and different tidal motions. Analysis in progress.



ERS Tandem Interferogram of Larsen C

Conclusions:

- As observed for Larsen A the outlet glaciers above former Larsen B retreated and accelerated soon after ice shelf collapse (up to the 8-fold velocity within 2 years). This confirms that ice shelf backpressure has an important impact on the stability of grounded ice.
- The outlet glaciers above former Larsen A and the ice shelf in Larsen Inlet are slowly approaching a new equilibrium after rapid retreat during the first years after collapse.
- The area of grounded ice lost after January 1995 up to July 2004 at the main tributaries amounted to 215 km² corresponding to 0.014 mm sea level equivalent for the nine year interval.
- The sea level contribution due to export at the front of glaciers north of Jason Peninsula in 2004 is estimated at 0.03 mm/a. This amounts to approximately 1 % of the global sea level rise.
- The catchment basins of Larsen C are under investigation. No major changes of the ice front position of Larsen C were observed in the last 15 years. Further observations and detailed analysis of the flow field are planned to obtain a baseline for possible future changes.

References:

[1] Rott H., et al. Northern Larsen Ice Shelf, Antarctica: further retreat after collapse, Ann. Glaciol., Vol. 34, 277 – 282, 2002.
[2] Rack W. and Rott H., Pattern of retreat and disintegration of Larsen B Ice Shelf, Antarctic Peninsula, Ann. Glaciol., Vol. 39, in press.
[3] Skvarca P., Changes and surface features of the Larsen Ice Shelf, Antarctica, derived from Landsat and Kosmos mosaics, Ann. Glaciol., Vol. 20, 6 – 12, 1994.

Acknowledgements:

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