DERIVATION OF GLACIAL CATCHMENTS OF THE ANTARCTIC PENINSULA BY MEANS OF INTERFEROMETRIC TECHNIQUES

Stefan Wunderle, Helmut Saurer, Hermann Goßmann

Universität Freiburg, Institut für Physische Geographie, Werderring 4, D-79085 Freiburg

phone ++49 761 203 3550, fax ++49 761 203 3596

email swun ipg.uni-freiburg.de

ABSTRACT

Studies on fluctuations of glaciers on the Antarctic peninsula predict various responses on changes in temperature and precipitation . The explanation of this nonuniform behaviour is difficult due to the poor knowledge about glacial dynamic and glacial catchments in this remote area. To overcome these limitations we used ERS-1/2 SAR data to derive the glacial catchment and the flow dynamics of McClary and Northeast glaciers in Marguerite Bay (68°S). Two SAR datasets of the tandem phase were analyzed by means of interferometric techniques.

1 INTRODUCTION

During the last decades significant changes of ice shelf extension were discovered in the vicinity of the Antarctic peninsula (Vaughan 1996, Doake 1991, Skvarca 1993). Changes of glacier extension and glacier thickness could be also detected on the South Shetland Islands and the Marguerite Bay area (Corbera 1993, Wunderle 1996).

The reason for the disapearence of Wordie Ice Shelf and the northern Larsen Ice Shelf might be a slight increase of air and sea temperature. King (1994) show an increase of 0.02°C/year during the last 40 years. With mean annual air temperatures of -2.2°C on the South Shetland Islands and -5.3°C at Marguerite Bay further warming will considerably increase melt events during the summer season. Therefore it is expected that any further increase of mean annual air temperature will affect the mass balance of small glaciers on the Antarctic peninsula due to strong melt events. To study the behaviour and the response of glacier systems it is necessary to determine the glacial catchments and analyse the flow dynamic.

2 TEST AREA

McClary and Northeast glaciers, both situated in the vicinity of central Marguerite Bay, show distinct responses to the recorded changes in temperature (and possibly in precipitation). Therefore these glaciers are interesting test sites. As changes in the meteorologic conditions are similar for both glaciers, we may presume that the distinct response of the glaciers is due to the differences of the extension of the catchments. In fact, the catchment of Northeast glacier extents to the plateau only, whereas the catchment of McClary glacier is restricted to the coastal zone (cf. fig. 2). Additionally, McClary glacier owns different flow directions. Up to now the catchments have been delimited very roughly. With the aid of two ERS single look complex data sets and a digital elevation model, the velocity fields of the two glaciers could be analyzed. The analysis allows a fixing of catchment boundaries more reliable than earlier estimates.

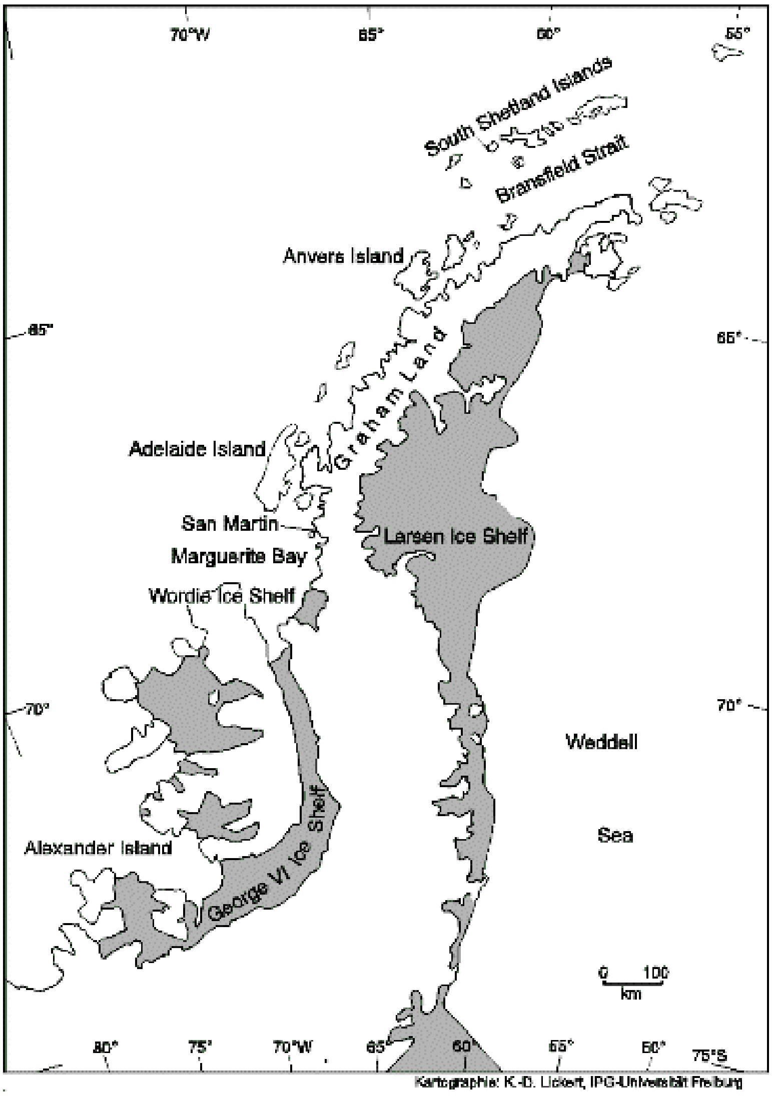

Figure 1. The Antarctic peninsula with the test areas McClary and Northeast glaciers, Marguerite Bay (68°S). The Argentinean base San Martin is located in front of both glaciers. The grey shaded areas show ice shelves.

3 RESULTS

The determination of glacial catchments from SAR images necessitates various processing steps and methods. The interpretation of a single or a multitude of SAR intensity images can only give a very rough determination of catchments and is not sufficient for most purposes (cf. fig. 2). For that reason we used a pair of SAR images aquired on October 15 and 16, 1995. During this time the snow cover was frozen and therefore a strong backscatter is observed which is due to the internal ice layers and lenses. As the meteorologic conditions did not change at the two days mentioned above both datasets can be analysed by interferometric techniques. The stable meteorologic conditions under which no melting occurs, is a prerequisite for interferometry, as a small change in liquid water contents of the snow cover will cause a loss of coherence.

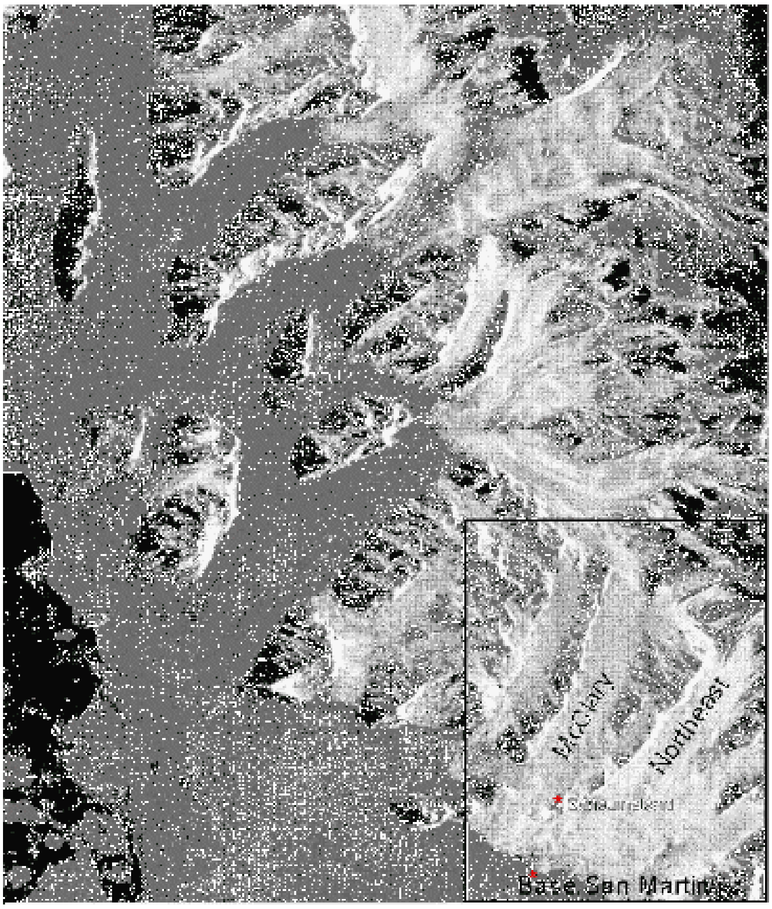

Figure 2. The ERS-1 SAR intensity image covers approximately 50 x 50 km² of the northern Marguerite Bay. At October 15th, 1995, most of the coastal area is still covered by sea ice. The ERS-1 SAR intensity image gives a first overview of the glacial catchments. The subset with McClary and Northeast glacier shown in figure 6 is marked with a box.

As a first analyses, the coherence of the two SAR images was calculated. It is obvious that the resulting image contributes to the determination of glacial catchments, as dark lines within the glaciated area show the limit of different glacier systems (cf. fig. 3). These lines are a consequence of the loss of correlation at the boundary of glaciers with different velocities.

Figure 3. The coherence image calculated from two SLC images shows the degree of correlation between both data sets. Areas with weak correlation appear dark (i.e. lower left side) due to strong changes on the surface. Remarkable are the small black lines

(a, b, c, d) which are the result of different flow velocities. These lines mark the boundary between fast and slow flowing glaciers.

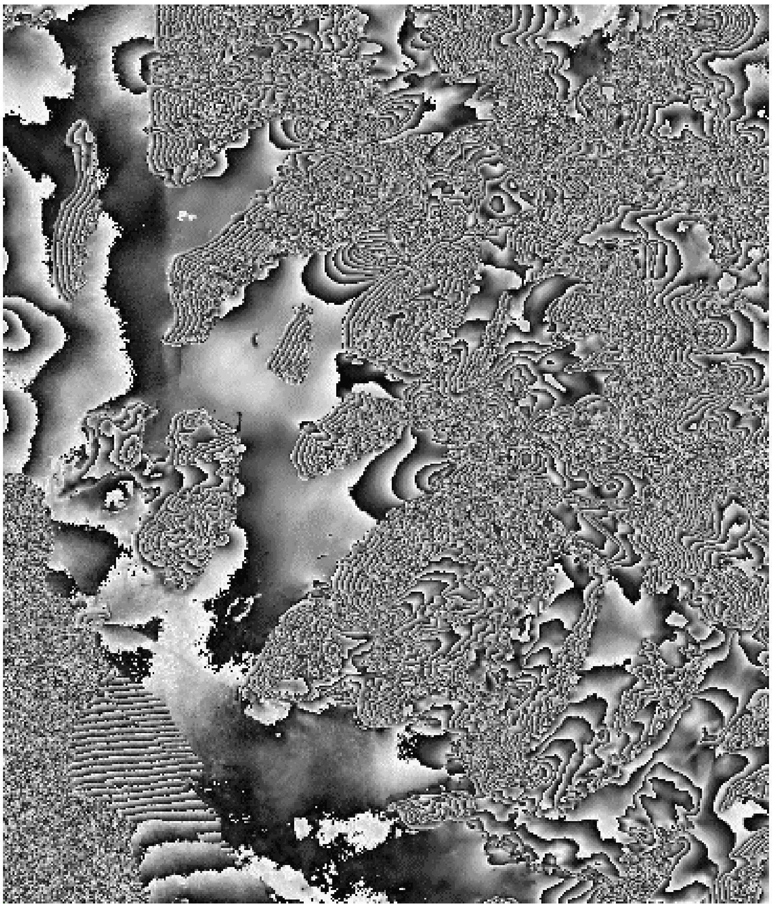

Figure 4. Phase differences from SAR images aquired on Oct. 15 (ERS-1) and Oct. 16 (ERS-2), 1995. The baseline is about 113m.

But this method does not yield to a complete determination of catchments, as the boundary of glaciers with similar velocities can not be recognized.

A first step for better determination of the catchment is to compute the phase difference between both SLC-datasets (cf. fig. 4). The area covered by sea ice appears in 'broad' fringes due to the flatness whereas numerous fringes represent the coastal area. To derive velocity fields the topographic information has to be eleminated from the interferogram because the phase difference contains both, the information on glacial movement and the effect of topography. We used a DTM derived from aerial photos ((c) IFAG-Frankfurt) to eleminate the topographic effect. After a coregistration of DTM and the phase difference we marked ground control points on nunataks where the flow velocity is zero.

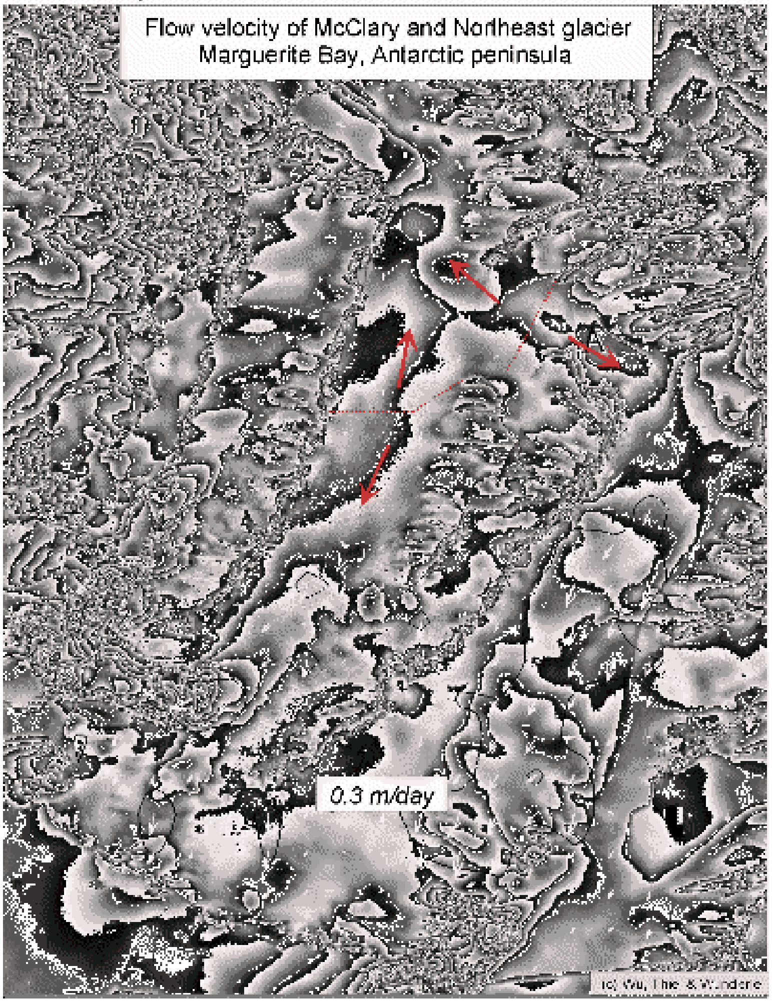

Figure 5. Flow vectors on McClary and Northeast glacier derived from ERS-1/2 SLC images aquired Oct. 15./16., 1995. The mean flow velocity estimated from the modified interferogram is about 0.3 m/day in the central areas of Northeast glacier. This value corresponds well with ground measurements. A maximum velocity of about 0.4 m/day (=145 m/year) is found on Northeast glacier. Observations of flow directions allows the determination of ice divides.. The local ice divide of McClary for example is marked schematically with a dashed line. Additionally other flow directions are shown with black arrows.

An additionally input were GPS measurements of flow velocity and flow direction near the confluence zone of McClary and Northeast glaciers. These datasets offer the possibility to determine the flow vectors of the whole test area using only one tandem pair of SLC-data. Regarding the phase differences of the two images in conjunction with a DTM and GPS-points a much more precise determination can be done as flow vectors can be calculated (cf. fig. 5). The areas with very low velocities and different flow directions are ice divides. Therefore, the determination of catchments can done by means of remote sensing only.

4 REFERENCES

Corbera, J. & J. Calvet 1993, Use of SPOT panchromatic imagery to evaluate glacier fluctuation in Livingstone Island, SELPER, Vol.9, pp. 31 - 35

Doake, C. S. M. & D. G. Vaughan 1991, Rapid disintegration of the Wordie Ice Shelf in response to atmospheric warming, Nature, Vol. 350, pp.328 - 330.

King, J. C. 1994, Recent climate variability in the vicinity of the Antarctic peninsula, International Journal of Climatology, Vol. 14, pp. 357 - 369

Skvarca, P 1993, Fast recession of the northern Larsen Ice Shelf monitored by space images, Annals of Glaciology, Vol. 17, pp. 317-321

Vaughan D G & C S M Doake 1996, Recent atmospheric warming and retreat of ice shelves on the Antarctic Peninsula, Nature, Vol. 379, pp 328 - 330.

Wu X, K-H Thiel & S Wunderle 1996, The use of tandem data in the Antarctic area, ERS SAR Interferometry Workshop, University of Zurich, 30 Sept. - 23 Oct. 1996, 8 p., http://www.geo.unizh.ch/rsl/fringe96/papers/thiel-wu-1/

Wunderle S 1996, Die Schneedeckendynamik der Antarktischen Halbinsel und ihre Erfassung mit aktiven und passiven Fernerkundungsverfahren, Freiburger Geographische Hefte Nr. 48, University of Freiburg, 172 p.

Wunderle S & H Saurer 1995, Snow properties of the Antarctic Peninsula derived from ERS-1 SAR images, Proceedings of the 21st Annual Conference of the Remote Sensing Society 11th - 14th of September 1995, University of Southampton, pp 1231-1237.

ACKNOWLEDGMENT

The work was supported by the German Secretary of Science and Research (BMBF) within the programme ‘Dynamic Processes in Antarctic Geosystems’ (DYPAG)(Contract# 03PL016A) and by ESA project ‘Monitoring of Dynamic Processes in Antarctic Geosystems’ (MODPAG)(Contract# AO2.D149). The authors would like to thank the Instituto Antartico Argentino (IAA), the

German Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI) and the British Antarctic Survey (BAS) for their support in respect to logistics and field equipment.