

ASSESSMENT OF ICE FLOWS IN GLACIERS OF WESTERN SPITSBERG USING DIFFERENTIAL INTERFEROMETRY

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ABSTRACT

Radar interferometry is a powerful tool which allows the computation of Digital Elevation Models and, as a second order effect, small surface moves of the centimetre range. This technique has been applied to ERS1 data acquired over western Spitsberg during the summer 1991 and the beginning of fall 1991. Most of the scenes acquired in summer cannot be combined into interferometric pairs because the surface of the glaciers is very dark. However, scenes acquired later during the summer/fall transition show a good reflectivity of the icy surfaces, allowing good signal to noise ratio over the glaciers. Among the 12 scenes acquired in this period and processed at CNES, 6 have been especially studied for their good coverage and 3 show the right combination of orbital parameters, leading to good interferometric fringe patterns. The measure of the coherence brings qualitative information about the nature of the moves and may be used as a detection of particularly rapid or particularly tormented flows. A digital elevation model has been used to lock the orbital positions to a geographic reference and to remove the fringes caused by orbital trajectories as well as the ones caused by elevation. The residual fringes allow a monitoring of the ice flow in several glaciers during the time elapsed between data takes. The technique does not require ground information nor specific hardware.

KEY WORDS : SAR, interferometry, ice flows in glacier

1 - INTRODUCTION

1.1. Background

Radar interferometry is a powerful tool which takes advantage of the phases of the SAR image complex pixels. Those phases can be used to measure the variations of the satellite-ground distances in the images. An interferometric combination of two SAR images allows the computation of Digital Elevation Models. If the topography is already given by a Digital Elevation Model, surface moves of the centimetre range can be detected.

CNES initiated in 1985 a research program on small move detection using SAR interferometry and came out in 1993 with the spectacular measure of the displacement field of an earthquake¹.

This technique has also been applied to ERS1 data acquired over western Spitsberg during the summer 1991 and the beginning of fall 1991 (12 scenes in total) to map the displacement field of the icy surfaces of the glaciers.

1.2. ERS-1 scenes used

Most of the scenes acquired in summer can not be combined into interferometric pairs : the glaciers are very dark on the images because of the presence of a water on their surface, which acts like a mirror. Those scenes have no consistent phase information over the glacier but provide nevertheless a useful, more conventional information about the physical state of ice surface.

Some scenes acquired later, during the summer/fall transition, show a good retrodiffusion of the icy surfaces. The good signal to noise ratio over the glaciers allows the use of the phase information.

Among the 12 scenes acquired during this period of time and processed at CNES, 6 have been especially studied for their good coverage and only 3 of them show a right combination of orbital parameters (the satellite tracks are not too far), leading to good interferometric fringe patterns.

Those useful scenes have been acquired the 17 September 1991 with orbit 899 (image 1), the 23 September 1991 with orbit 985 (image 2) and the 2 October 1991 (image 3).

The interferometric pairs used in this paper are 17 September 1991 with 23 September 1991 and 23 September 1991 with 2 October 1991.

¹Massonnet & all. "The displacement field of the Landers earthquake mapped by Radar Interferometry", Nature, 8 July 1993

2 - INTERFEROMETRY RAW PRODUCTS

The two single look complex images of an interferometric pair are firstly co-registered. Then we elaborate three images : an amplitude image, a coherence image and a phase image (or fringe pattern).

We call standard interferometry raw product the set of those three images. Those images share the same geometry.

2.1. Amplitude image

This image is a conventional image of radiometry. It is given to help for locating points of interest on the two other images. Image 10 shows the amplitude image of the 23 September 1991 scene which geometry has been used as reference for the two interferometric pairs.

2.2. Coherence image

The measure of the coherence brings qualitative information about the stability in time of the ground (images 5 and 7).

Thus, the coherence provides qualitative information on ice motion. A good coherence at the ice surface corresponds to the near constant state of the surface and low ice motion. A lack of coherence (dark region of the image) corresponds to a change of the state of the surface and/or to fast glacial flow.

2.3. Raw fringe pattern

The fringe patterns (images 4 and 6) contain information on orbital satellite position, ground topography and motion of the glaciers. Clear fringes correspond to stable surface state and are associated to high coherence.

The effect due to orbital satellite position and ground topography can be removed using a DEM to highlight the motion of the glacier towards the satellite. This is done by differential interferometry.

3 - DIFFERENTIAL INTERFEROMETRY

3.1. Use of a Digital Elevation Model

A conventional Digital Elevation Model was not available on the Spitsberg but only elevation contour lines extracted from a map (image 8). We therefore had to derive the elevation map from the elevation contour lines (image 9).

This elevation model has been used with the orbital data of the tracks to simulate a SAR image (image 11). By correlation with the actual SAR image of 23 September 1991 (image 10), the orbital positions could be locked to a geographic reference.

The elevation model has then been used again, but with the locked orbital positions, to compute the fringe pattern caused by orbital trajectories as well as elevation (image 12) in the interferometric pair of 17 September 1991 with 23 September 1991.

3.2. Differential fringe pattern

The fringe pattern caused by orbital trajectories and elevation (image 12) has been removed from the raw fringe pattern (image 7), to produce the differential fringe pattern (image 13). Image 14 is the same image, but the regions of low coherence have been masked.

The differential fringe pattern is caused by glacier moves (and errors in the elevation model used) and measures only the component of the displacement of the icy surface toward the satellite. The precision of the results will depend highly on the direction of the flows.

4 - CONCLUSION

This work on the ice flows in glaciers of western Spitsberg is not finished. For instance, the elevation model used is too unprecise and its derivation from the elevation contour lines has to be improved.

However, those preliminary results show that differential interferometry did to allow a monitoring of the ice flow in several glaciers during the time elapsed between data takes.



Image 1 :
September
@ESA/ER

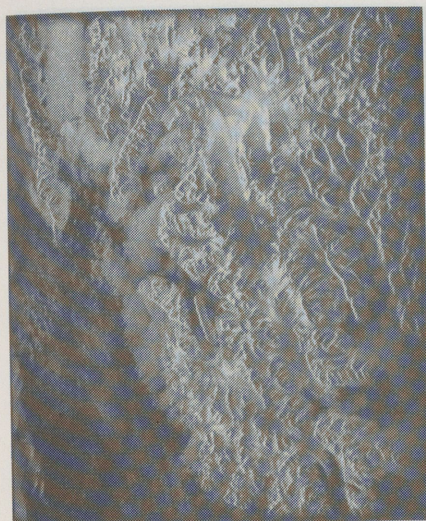


Image 1: (A) ERS-1 SAR scene acquired the 17 September 1991 (orbit 899, frame 1611)
@ESA/ERS-1 data, CNES processing

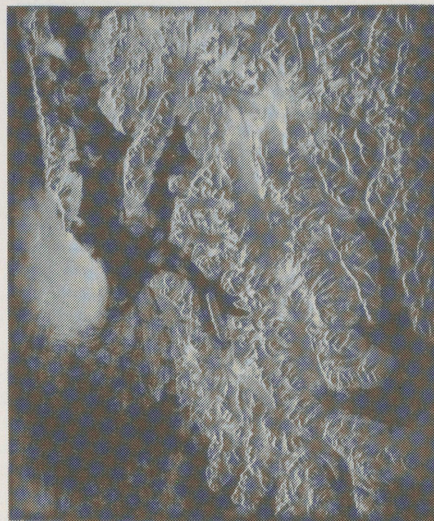


Image 2: (B) ERS-1 SAR scene acquired the 23 September 1991 (orbit 985, frame 1611)
@ESA/ERS-1 data, CNES processing

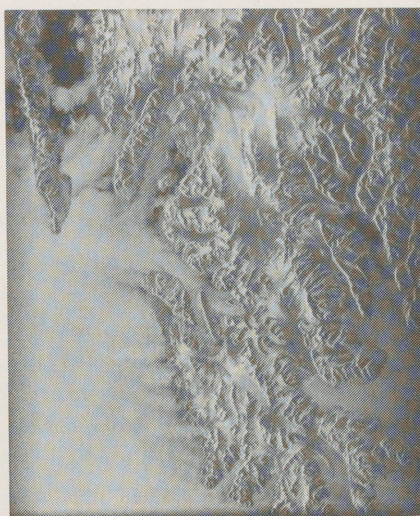
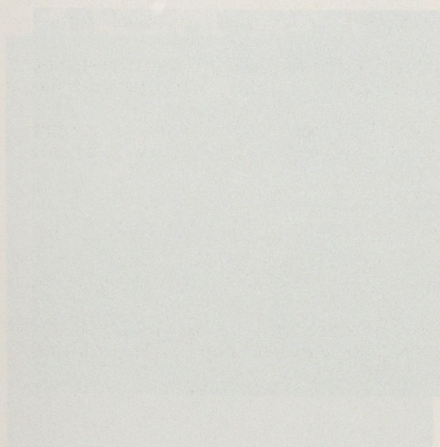


Image 3: (C) ERS-1 SAR scene acquired the 2 October 1991 (orbit 1114, frame 1611)
@ESA/ERS-1 data, CNES processing

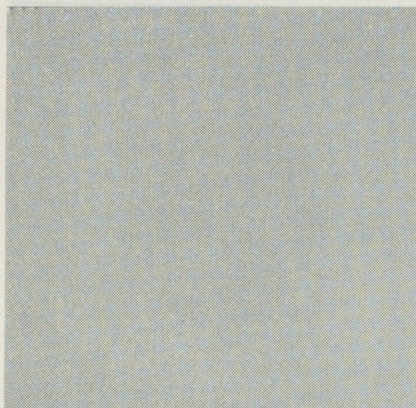


Image 4: Raw fringe pattern from the combination of the ERS-1 data A (17 September 1991) and B (23 September 1991)
@ESA/ERS-1 data, CNES processing



Image 5: Image of coherence from the combination of the ERS-1 data A (17 September 1991) and B (23 September 1991)
@ESA/ERS-1 data, CNES processing

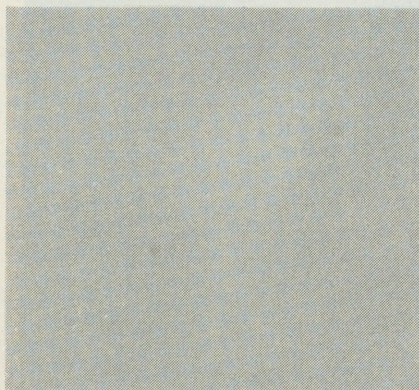


Image 6: Raw fringe pattern from the combination of the ERS-1 data B (23 September 1991) and C (2 October 1991)
@ESA/ERS-1 data, CNES processing



Image 7: Image of coherence from the combination of the ERS-1 data B (23 September 1991) and C (2 October 1991)
@ESA/ERS-1 data, CNES processing



Image 8: Elevation contour lines extracted from a map

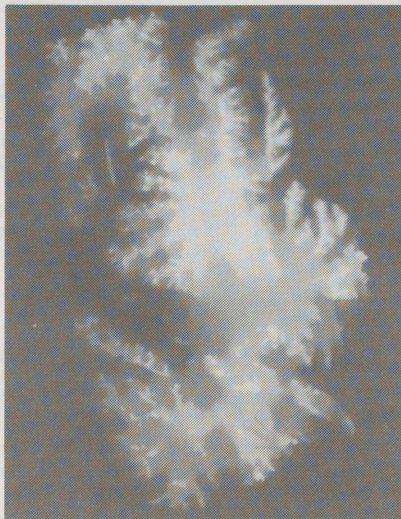


Image 9: Digital Elevation Model (DEM) computed from the elevation contour lines @CNES processing

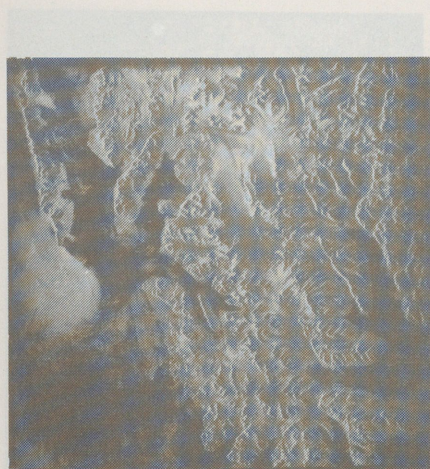


Image 10: image of amplitude of the ERS-1 data B (23 September 1991) @ESA/ERS-1 data, CNES processing

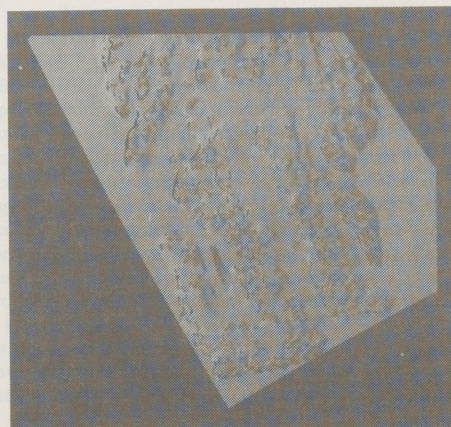


Image 11: simulated image of amplitude computed from the DEM @CNES processing

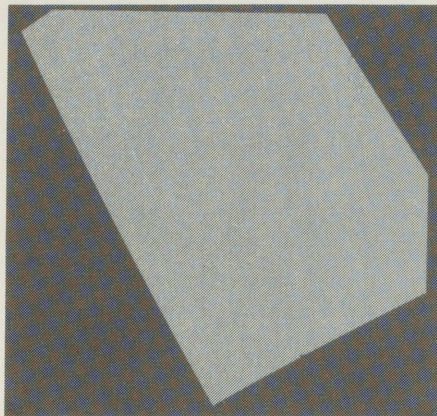


Image 12 : Simulated fringe pattern computed from the DEM and the orbital positions of data A (17 September 1991) and B (23 September 1991) @CNES processing

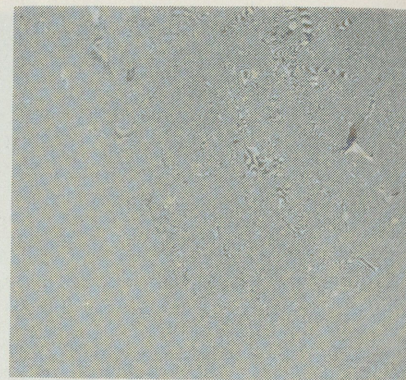


Image 13 : Differential fringe pattern of data A (17 September 1991) and B (23 September 1991). A grey cycle corresponds to a relative move of the icy surface of 28 millimetres toward the satellite @ESA/ERS-1 data, CNES processing

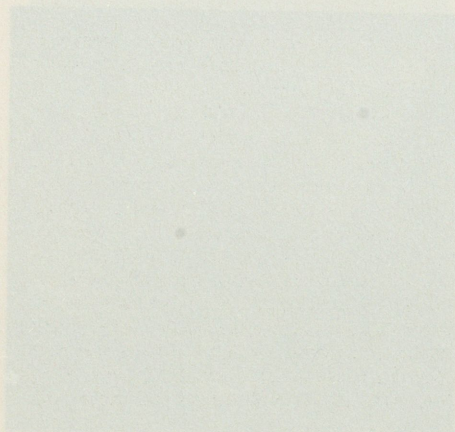


Image 14 : Most coherent pixels from the differential fringe pattern of data A and B. A grey cycle corresponds to a relative move of the icy surface of 28 millimetres toward the satellite @ESA/ERS-1 data, CNES processing

ABSTRACT

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KEY WORDS

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