RADAR ICE MOTION INTERFEROMETRY

Richard Goldstein and Charles Werner
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Dr., Pasadena, CA 91109, USA
phone: 818.354.6999, fax: 818.393.5285

ABSTRACT

We have used tandem pairs of ERS-1/2 radar observations of the Jakobshavn Glacier, in Greenland, for the purpose of estimating the ice motion. Interferograms are made from two such pairs, separated by the 35 day repeat cycle. Motion can be estimated from these without knowledge of the local topography. Although the temporal baseline of the interferograms was only one day, the correlation from the fast moving ice was very low. Because of the resulting phase noise, we have used a scene-dependent filter to help unwrap the interferograms. For the upper part of the glacier, the filter worked well. The filter and the measured ice motion are presented below.

INTRODUCTION

Interferogram phases depend on both the local topography and any motion of the ice which occurs between the observations. If the spatial baseline is short and the scene not too rugged, then the topographic effect is negligible[1]. Jaughin, et al[2], and Cumming, et al[3], have used radar interferograms and local digital topo maps to estimate glacier motion. Here, we use a second interferogram (and assume that the motion is the same between the first tandem pair and the second) to estimate the motion.

The fastest moving glaciers appear to be the most interesting ones. These are also the ones that give the lowest correlation for repeat-track interferometry. The three-day data, when ERS-1 was in the "ice" mode, produced very noisy interferograms of the Jakobshavn Glacier. The one-day repeat data afforded by the ERS-1/2 tandem mission represents a significant improvement. However, much filtering remains to be done.

FILTERING

Decorrelation, which is caused by disturbances in the scene, by baselines approaching the critical length, and by thermal noise, produces interferogram phase noise which is spatially wide-band. The desired signal part of the phase, however, is usually very narrow-band (locally). Globally, the signal is not narrow-band, since most fringe frequencies and directions appear somewhere in the scene.

What is needed is a filter which can accommodate to the changing fringe frequencies and bandwidths. Plate I depicts the need for filtering and presents some results. The top illustration is an unfiltered piece of the Jakobshavn interferogram. Even though fringes can be seen, the noise is too high for the necessary phase unwrapping. Moderate filtering, shown in the second illustration, produces enough improvement to permit successful unwrapping. Heavy filtering, the third illustration, produces remarkable clarity of the fringes.

FILTER PROTOCOL

The filter we have used is simple enough to describe in a few lines. First the interferogram is divided into patches, of size 32 by 32 pixels, with 50% overlap in x, y. Each patch is Fourier transformed, and the following scene-dependent operation is applied to each pixel:

$$\tilde{Z}_{i,j} = \left|Z_{i,j}\right|^{\alpha} Z_{i,j} \qquad (1)$$

where α is the filter parameter.

The patches are then inverse Fourier transformed and reassembled, with a linear taper in x, y. For $\alpha = 0$, no filtering is done; for $\alpha = 1$, there is strong filtering. When $\alpha = 1$, the signal band-area is halved, and the signal-to-noise ratio is squared.

JAKOBSHAVN GLACIER

Figure 1 illustrates the interferogram phases of one line of constant azimuth for two visits of the ERS-1/2 satellites tandem pair.

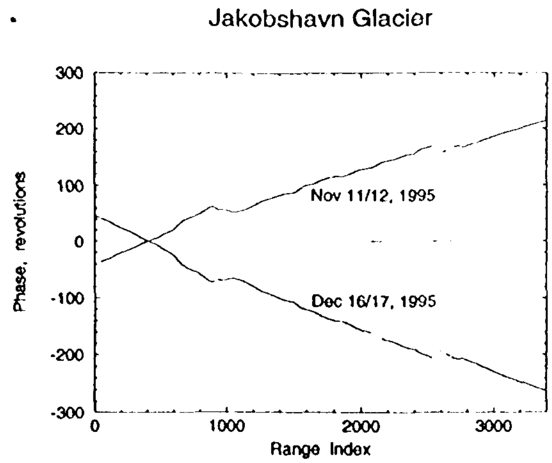


Figure 1: Interferogram phases, showing both motion and topography. The two baselines had nearly the same perpendicular component, but opposite directions. Points that could not be unwrapped show zero phase.

When the phases from one interferogram are plotted against those from the other, the result should be a small arc of an ellipse[4], with the topographic information suppressed. The line-of-sight motion of the ice is revealed by the departure of the points from the arc. This is illustrated in Figure 2.

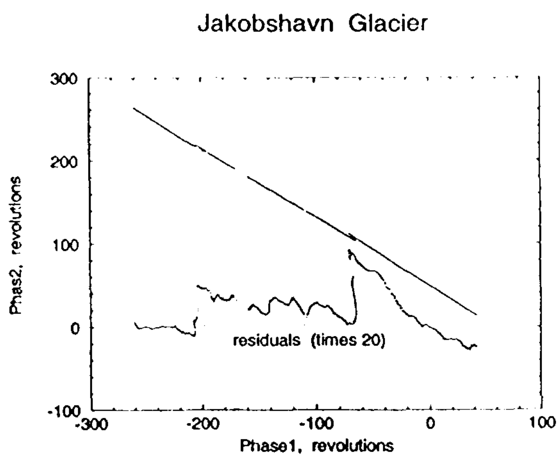


Figure 2: The upper curve is the data from figure 1, replotted. The lower curve gives the residuals from a least-squares ellipse fit, and represents the ice motion.

It was necessary to identify areas in the scene for which there was little or no movement in order to solve for the ellipse. We have also assumed that the motion was the same on the two days between observations.

RESULTS

The results for the upper reaches of the Jakobshavn Glacier are presented in Plate 2, for an area 21 by 17 km. Resolution is about 20 m. The spacecraft flight direction was down, parallel to the right edge of the illustration. No topographic tie-points were used, but estimates of stationary regions were made at the corners, well outside of the illustrated area.

The upper image is of radar brightness; the lower is of line-of-sight displacement, with topography removed. The local maximum at the upper-right bull's-eye was 6.7 cm per day. Each fringe represents an increment of movement of 1.4 cm per day. Areas that could not be unwrapped are replaced with the brightness image. Even the scene-dependent filter could not help in these places.

The research described in this paper was carried out, in part, by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

REFERENCES

1) Goldstein, R. M., H. Engelhardt, B. Kamb and R. M. Frolich, "Satellite Radar Interferometry for Monitoring Ice Sheet Motion: Application to an Antarctic Ice Stream", *Science*, Vol. 262, pp. 1525-1530, 3 Dec., 1993.

2) Joughin, I., R. Kwok and M. Fahnestock, "Estimation of Ice-Sheet Motion Using Satellite Radar Interferometry - Method and Error Analysis with Application to Humboldt Glacier, Greenland", *J. Glaciology*, Vol. 42, No. 142, pp. 564-575, 1996.

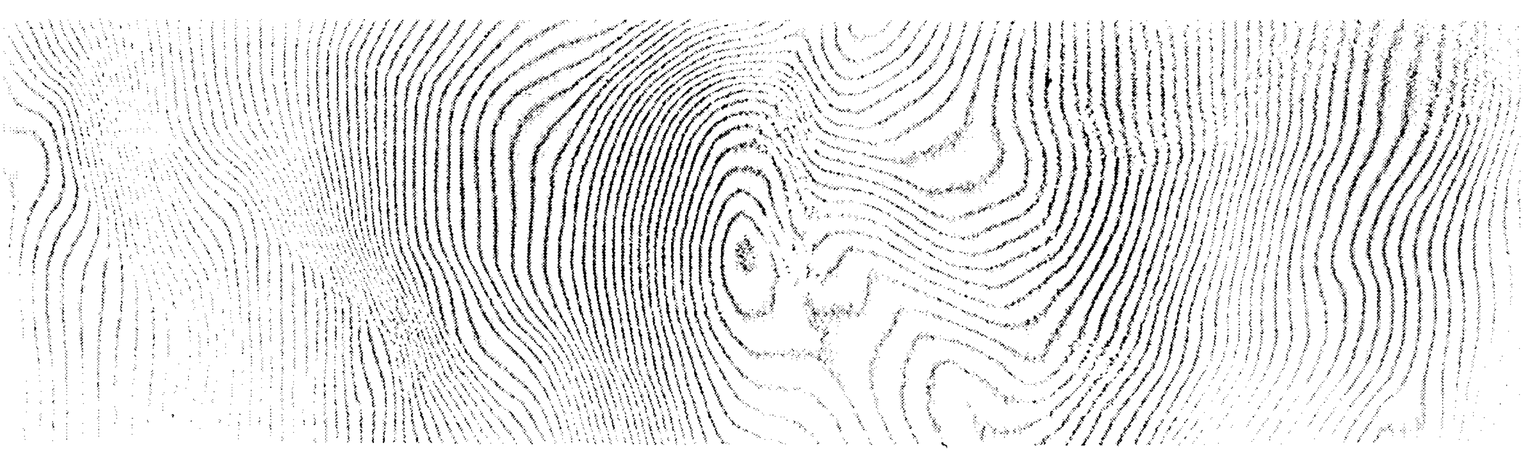
3) Cumming, I. G., J. L. Valero, P. W. Vachon, K. Mattar and M. Brugman, "Measurement of Alpine Glacier Flow Using ERS Tandem Mission SAR Data", *IEEE Trans. Geoscience and Remote Sensing*, in press.

4) Gabriel, A. K. and R. M. Goldstein, "Mapping Small Elevation Changes over Large Areas: Differential Radar Interferometry", *J. of Geophysical Res.*, Vol. 94, No. B7, pp. 9183-9191, 10 July, 1989.

Interferogram Filter

exp=0

exp=0.5



exp=1.0

title → MPF Science ~~Ops~~ Operations Procedures ~~970227~~

Preface all procedure names with above —

Procedure

- ASI/MET Health Check (cruise)
- APXS Health Check (cruise)
- IMP Health Check (cruise)
- ASI/MET Instrument Performance Monitoring
- APXS Instrument Performance Monitoring
- IMP Instrument Performance Monitoring
- IMP Sequence Generation
- APXS Sequence Generation
- ASI/MET Sequence Generation
- Entry Science Quick Look Analysis
- Experiment Scenario and Sequence Generation
- Mission Success Panorama Analysis
- Ramp Pre-deployment Panorama Analysis
- Ramp Post-deployment Panorama Analysis
- IMP Imaging of Rover
- IMP Pointing Verification
- IMP Sun Location Verification
- IMP Radiometric Calibration Verification
- IMP Geometric Calibration Verification
- IMP High-Res Soil Image Targeting
- IMP Monochrome Mosaic Production
- IMP Multispectral Mosaic Production
- IMP Topographic Mapping
- APXS Target Selection
- IMP Data Release
- APXS Data Release
- ASI/MET Data Release
- IMP Data Archiving
- APXS Data Archiving
- ASI/MET Data Archiving
- APX/Rover image RAMP MPE
- IMP Imaging of MPE

Toney, T. 3-0728 230-200 313

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equip (GSE) INTEGRATION AND TEST (I&T) Configuration & Control DETAIL DESIGN REVIEW 06/01/94 Basilio, R. 4-3228, 301-481, Sec341.

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equip (GSE) INTEGRATION AND TEST (I&T) Cabling and Grounding DETAIL DESIGN REVIEW 06/01/94 Basilio, R. 4-3228, 301-481, Sec341

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equip (GSE) INTEGRATION AND TEST (I&T) PPS Simulator DETAIL DESIGN REVIEW 09/14/94 Basilio, R. 4-3228, 301-481, Sec341.

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equip (GSE) INTEGRATION AND TEST (I&T) Propulsion Simulator DETAIL DESIGN REVIEW 06/01/94 Basilio, R. 4-3228, 301-481, Sec341.

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equip (GSE) INTEGRATION AND TEST (I&T) Sun Sensor Controller DETAIL DESIGN REVIEW 06/01/94 Basilio, R. 4-3228, 301-481, Sec341

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equip (GSE) INTEGRATION AND TEST (I&T) SE Star Scanner Hood Controller DETAIL DESIGN REVIEW 09/14/94 Basilio, R. 4-3228, 301-481, Sec341

MPF Guidance & Control Design & Analysis Preliminary Design Review 02/09/94 Lisman,S. 4-4022, 198-326, Sec 345

MPF ATTITUDE AND INFORMATION MANAGEMENT (AIM) Ground Support Equipment (GSE) INTEGRATION AND TEST (I&T) Flt Ops Planning Implementation Plan 02/14/94 Basilio, R. 4-3228, 301-481, Sec341

MPF Ninth Mars Science Working Group Meeting 02/07/94 Golombek, M., 3-7948, 230-235, Sec 323

D#'s please