3D High Resolution Tracking of Ice Flow using Multi-temporal Stereo Satellite Imagery, Franz Josef Glacier, New Zealand

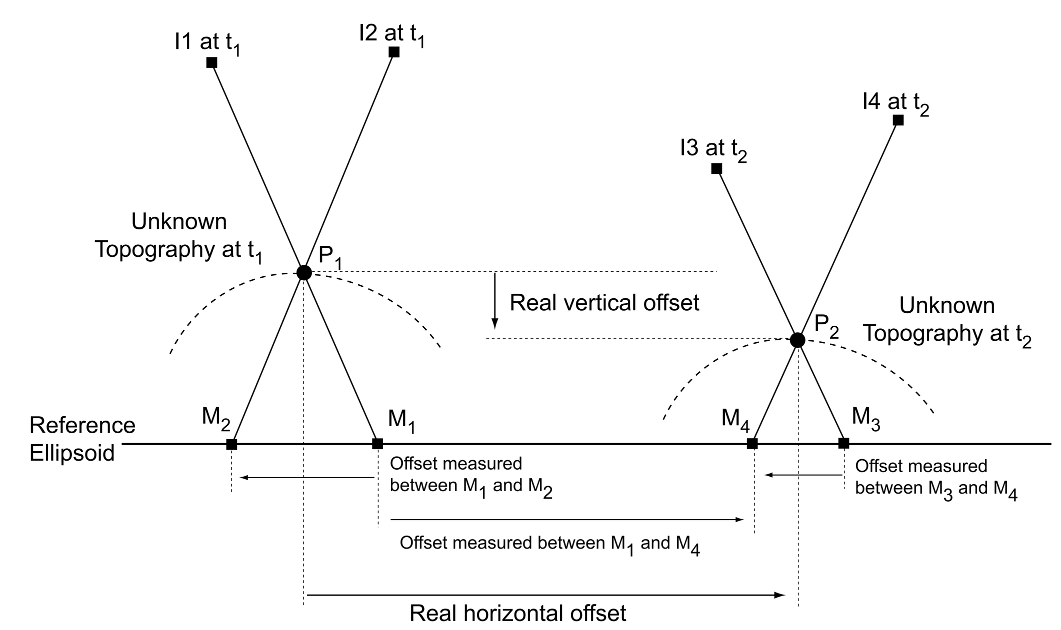
S. Leprince, J. Lin, F. Ayoub, and J.P. Avouac
California Institute of Technology

F. Herman
Universite de Lausanne, Switzerland

Abstract:

We extract 3D glacial velocity over the Franz Josef Glacier, New Zealand, using multi-temporal pairs of Worldview stereo imagery.
We sample two time periods using three stereo pairs at 50 cm ground resolution, acquired during the summer 2013.
Velocity fields extracted cover most of the glacier area, including a good portion of the accumulation zone. Data obtained are in good agreement with the record of continuous GPS near the tongue of the glacier, which show a velocity increase in the first period, corresponding to a sudden increase in precipitations.
This experiment validates the new COSI-Corr 3D extraction technique applied to steep terrain.

Multi-Angle Stereo Processing Principle



Worldview 50 cm Stereo Pairs:

- January 30, 2013
  Along-track angle: 16.4° / -13.5°
  Across-track angle: 25.6° / 24.4°
- February 9, 2013
  Along-track angle: 15.0° / -16.8°
  Across-track angle: 24.8° / 23.4°
- February 28, 2013
  Along-track angle: 13.1° / -14.5°
  Across-track angle: -15.8° / -17.1°

Given two pairs of stereo images (I1, I2) and (I3, I4), respectively acquired at times t1 and t2, the 3D displacement of the topographic surface can be retrieved from the apparent offsets between each image pair measured via sub-pixel correlation [Leprince et al, 2007]. If the topography of the surface is unknown, the point P1 will be seen in images I1 and I2, but respectively projected at M1 and M2 on a reference ellipsoid. After a deformation occurs, P1 will be displaced to P2, which will be projected at M3 and M4 from I3 and I4. Knowing the position of the optical center of the imaging systems, the 3D position of P1 and P2 can be triangulated, from which the 3D displacement vector from P1 to P2 is deduced.

Complete Processing Steps

1 • Select tie-points between all image pairs, outlier filtering with reverse matching,

2 • Remove tie points from moving glaciers (intensity mask on glaciers + visual check),

3 • Optimize all satellite attitude angles (roll, pitch, yaw) using second order polynomials,

4 • Create map projected images using seed topography,

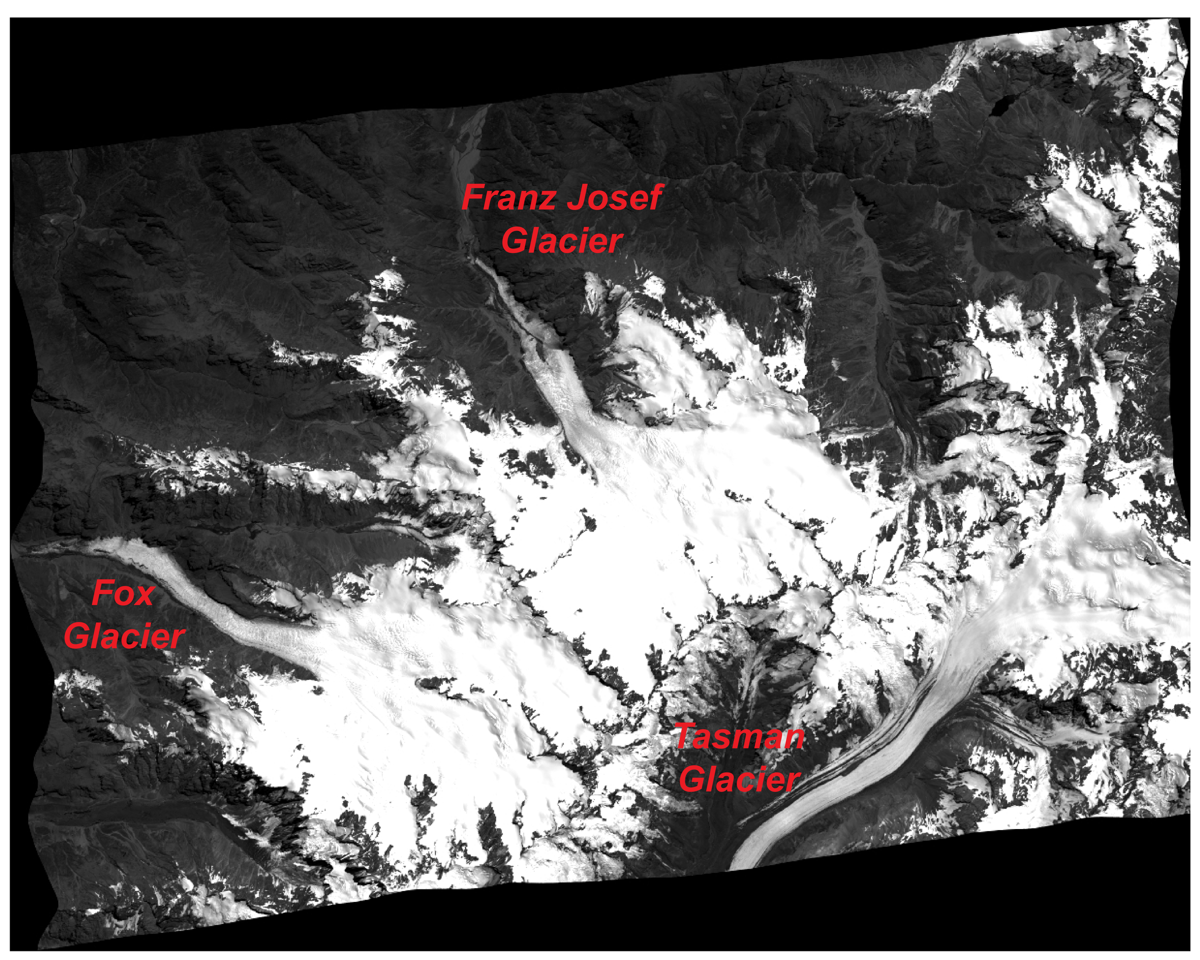
5 • Correlate all image pairs using multi-scale, regularized correlation,

6 • Triangulate image pairs (see figure on the left) to create cloud of vector displacements,

7 • Grid cloud of vector displacements using nearest neigbhor interpolation.

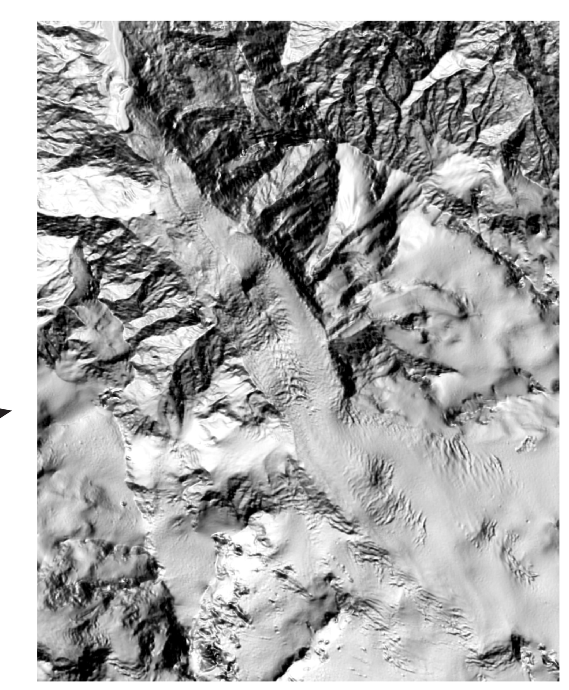
Implementation using GPS Fram cluster

Multi-Angle Stereo Processing Results

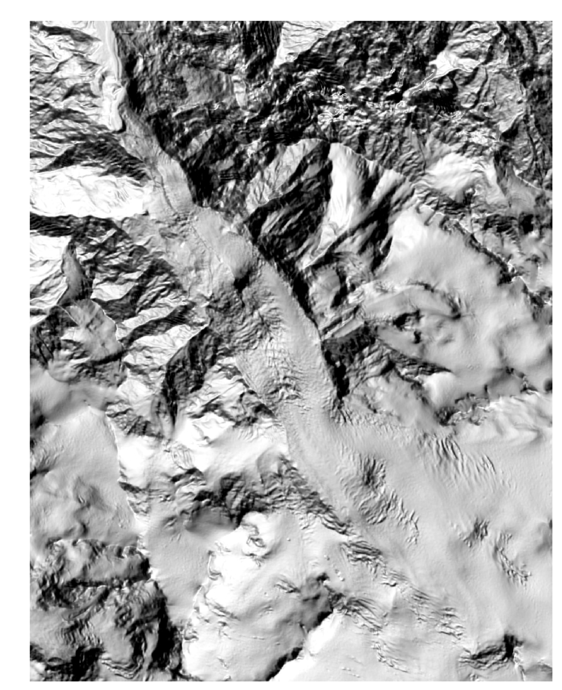


Multiple stereo-pairs

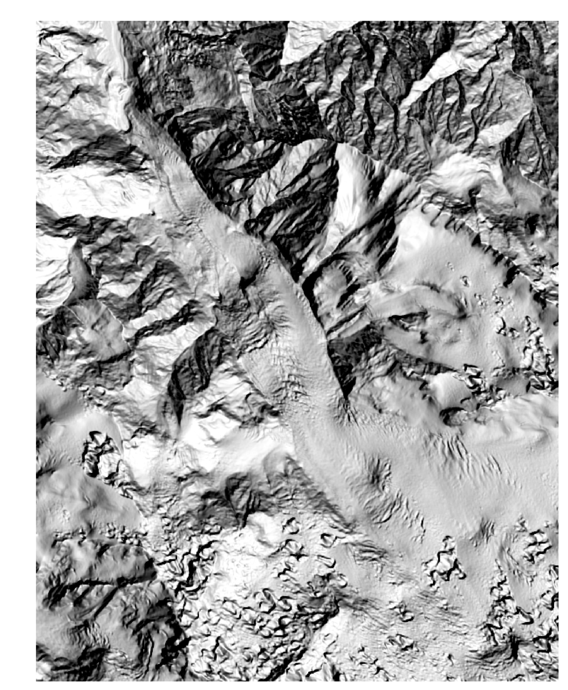
By-product: elevation models at each date



January 30, 2013

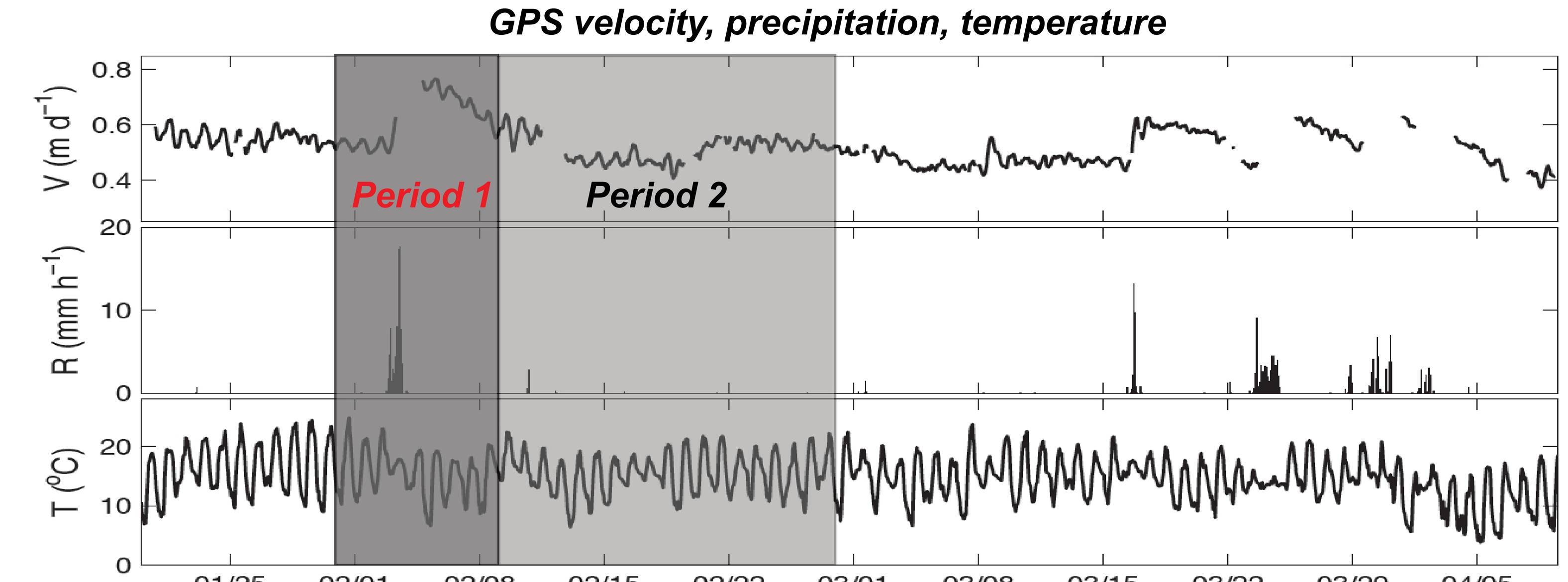


February 9, 2013

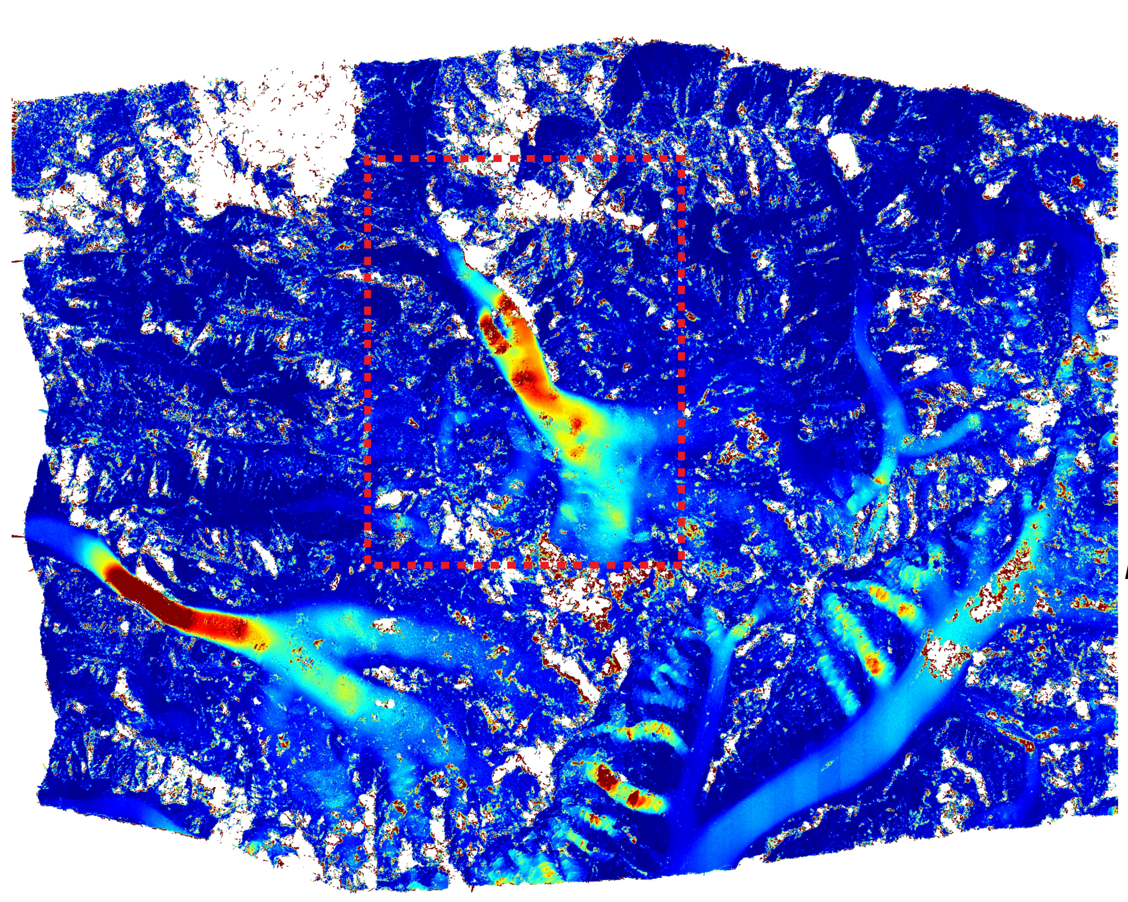


February 28, 2013

GPS velocity, precipitation, temperature

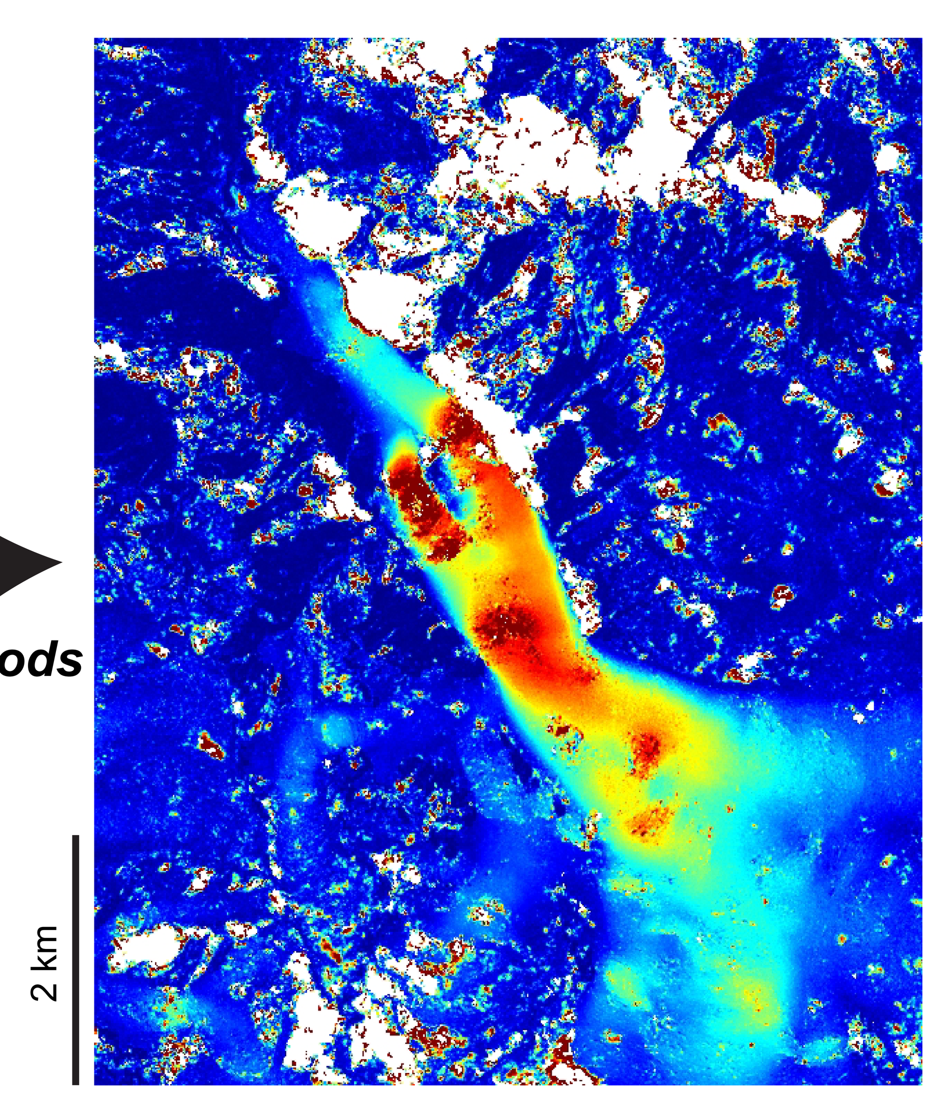


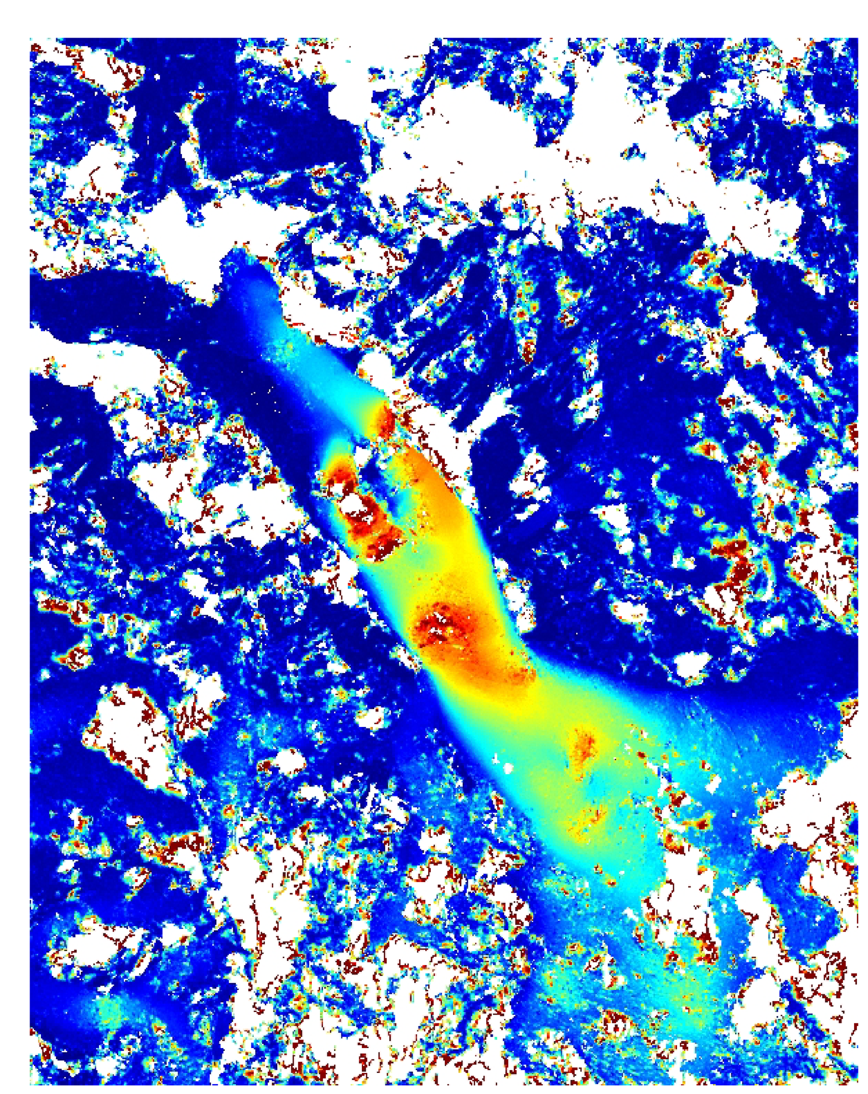
3D Vector Field



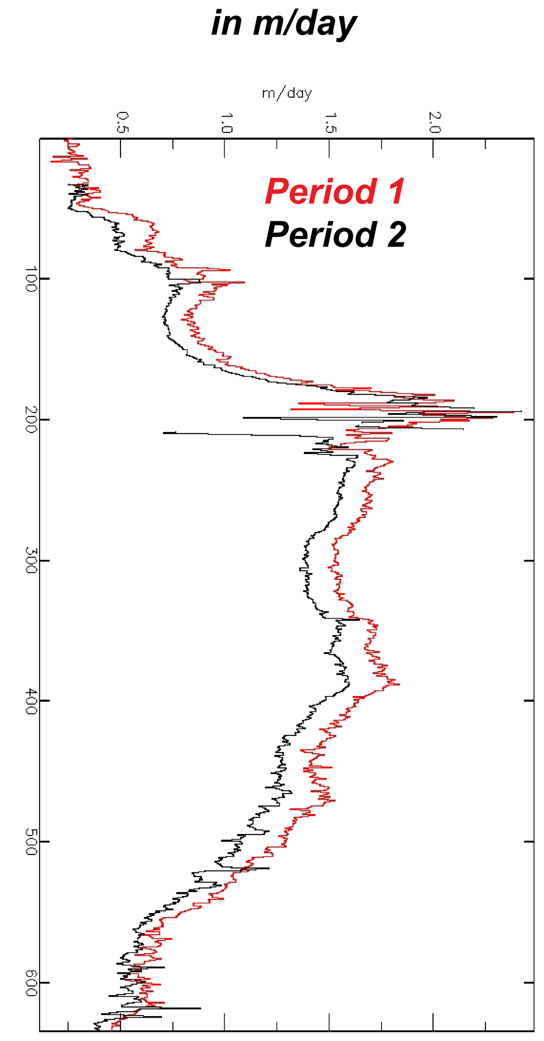
Norm of 3D displacement

Multi-periods





Norm of 3D velocity in m/day



Conclusions:

- We validated the implementation of the new COSI-Corr 3D processing chain.
- Rigorous 3D processing is necessary to use the potential of high resolution imagery, which is often acquired with large incidence angles.
- Strong correlation between glacial velocity and precipitation validates that glacial dynamics are strongly affected by hydrology.
- The processing chain comprises bundle adjustment with automatic tie-points selection, multi-scale and regularized correlation, and gridding of the resulting point clouds.
- Results deliver offset field in 3D, with, as by-product, a digital surface model for each stereo pair.
- The processing chain uses parallel processing and has been successfully implemented on the Fram Caltech GPS cluster.
- We found that occlusions on steep topography are the main limitation to the technique.
- Generic implementation, valid for all pushbroom sensors and other surface processes.
- Further work will focus on automating the processing chain, in particular on improving the transition between the different stages of the process.

References:

F. Herman, B. Anderson, and S. Leprince, "Mountain glacier velocity variation during a retreat advance cycle quantified using sub pixel analysis of ASTER images," Journal of Glaciology, Volume 57, Issue 202, Pages 197-207, 2011

S. Leprince, S. Barbot, F. Ayoub and J. P. Avouac, "Automatic and Precise Orthorectification, Coregistration, and Subpixel Correlation of Satellite Images, Application to Ground Deformation Measurements," IEEE Transactions on Geoscience and Remote Sensing, Vol.45, No.6, June 2007.