Quentin GLAUDE
Ph.D Student

TOPSAR Interferometry on Burst Superposition Areas for Bi-Dimensional Velocity Fields Determination of Antarctic Ice-Shelves

~~TOPSAR Interferometry on Burst Superposition Areas for Bi-Dimensional Velocity Fields Determination of Antarctic Ice-Shelves~~

Or

I measure speed of « glaciers » thanks to radar but in a new and « promising » way

Thesis context

- The thesis is part of a project called **MIMO** (**M**onitoring ice-shelves where **I**ce **M**eets **O**cean)
- Partners are
  - Laboratoire de Glaciologie (ULB) : Myself, Sainan Sun and Frank Pattyn
  - Centre Spatial de Liège (ULiège) : Myself, Dominique Derauw and Christian Barbier
  - Helmholtz-Zentrum für Polar- und Meeresforschung (AWI) : Veit Helm, Olaf Eisen and Sophie Berger
- Global objectives are the monitoring of these ice-shelves, critical for ecological system

Sources : NASA – Landsat Image Mosaic of Antarctica

Thesis context

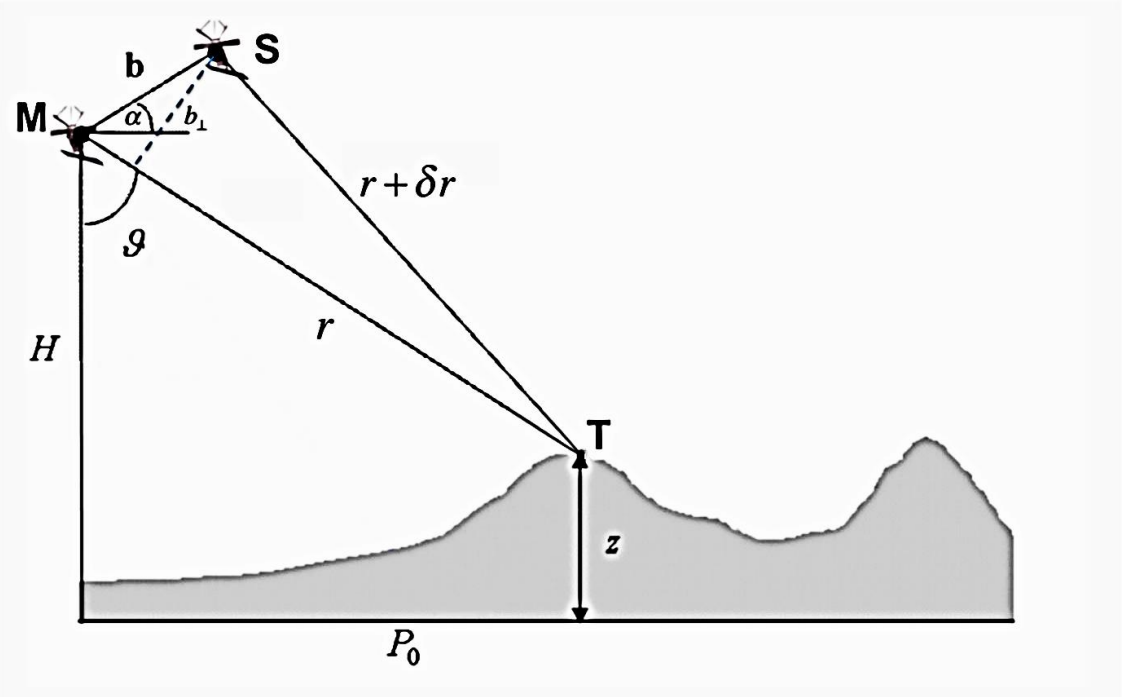
- Global objectives are the monitoring of these ice-shelves, critical for ecological system
- My objectives are the developments of new methods to compute surface velocities fields using SAR remote sensing
- These surface velocities are then integrated into ice models developed by the Laboratoire de Glaciologie (ULB)

Sources : NASA – Landsat
Image Mosaic of Antarctica

SAR and surface velocities (InSAR)

- SAR is a radar imaging technique
- SAR images contain a amplitude term (related to back scattering process) and a phase term (related to the path from the satellite to the ground)
- Taking two SAR acquisitions, it is possible to compute an interferogram
- Master image : $M = A_M e^{j\varphi_M}$
- Slave image : $S = A_S e^{j\varphi_S}$
- Interferogram : $M.S^* = A_M A_S e^{j(\varphi_M - \varphi_S)}$

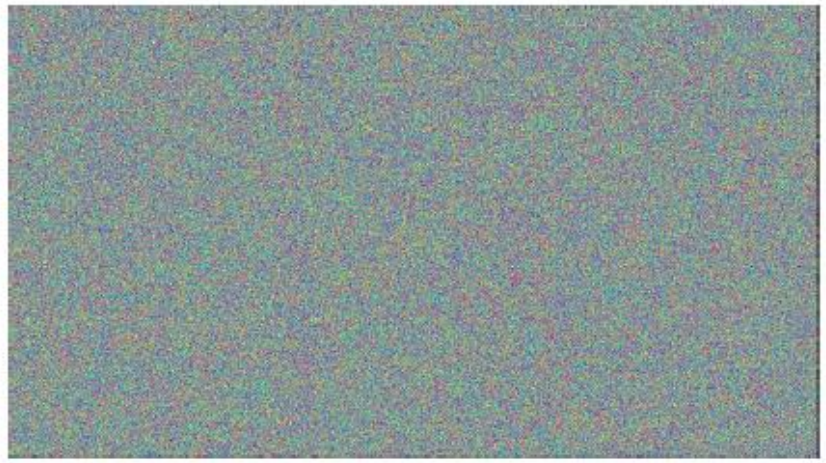
Where we define $\varphi_{intf} = \varphi_M - \varphi_S = \frac{4\pi}{\lambda}\delta r$ as the interferometric phase



Sources : A Review of Interferometric Synthetic Aperture RADAR (InSAR) Multi-Track Approaches for the Retrieval of Earth's Surface Displacements

$$\varphi_{intf} = \varphi_M - \varphi_S$$

Phase Master



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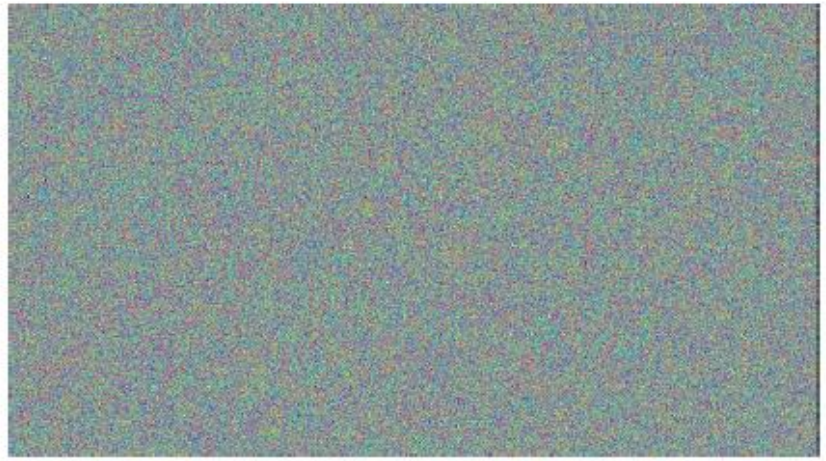
Phase Slave



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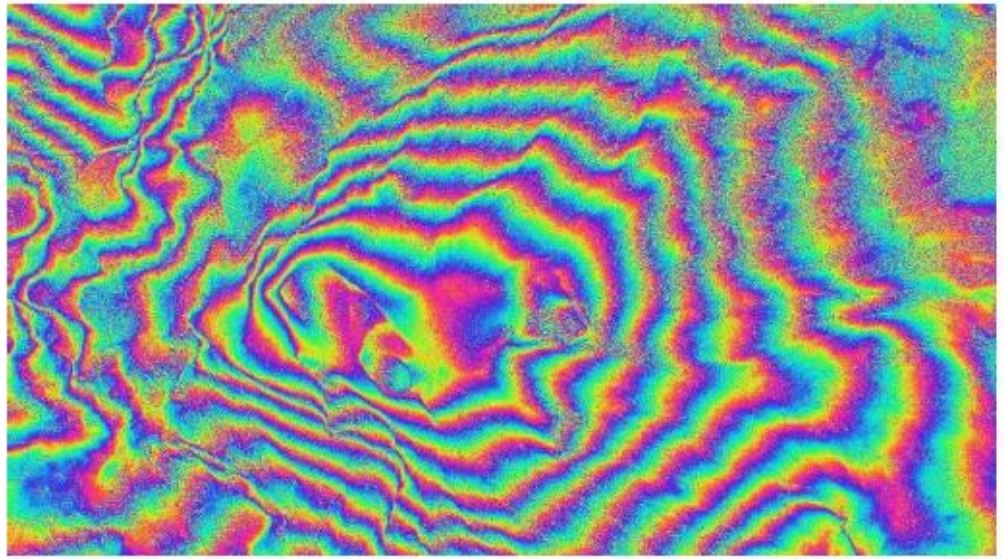
TanDEM-X– Copahue volcano



Sources : Fabspace2.0 , Radar Remote Sensing – Ludivine Libert (2018)

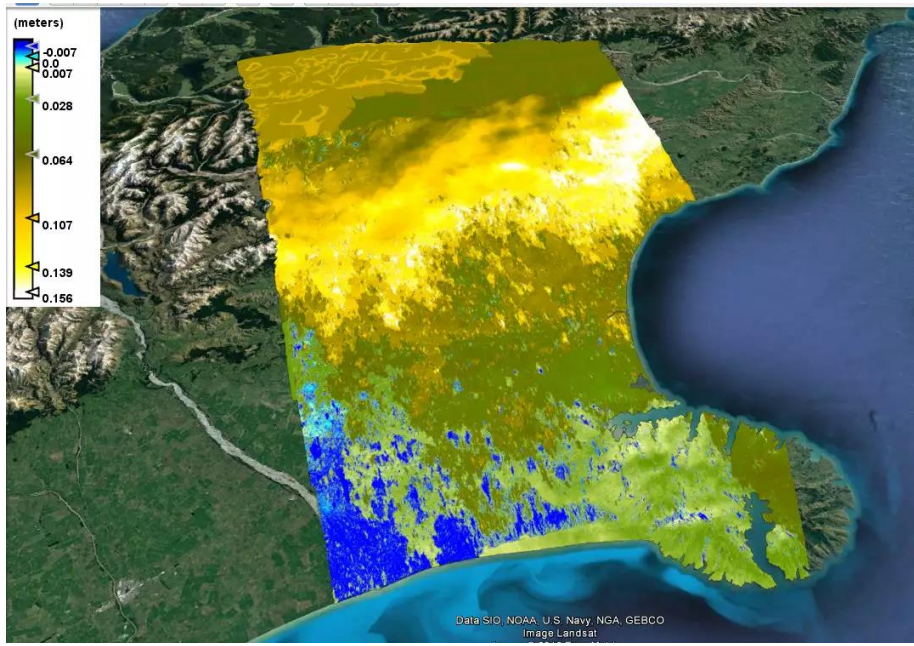
Interferometric Phase Content

- The interferometric phase contains multiple terms

$$\varphi_{intf} = \varphi_{orb} + \varphi_{topo} + \varphi_{mvt} + \varphi_{atm} + (\varphi_{noise})$$

- The first (orbital phase) term can be computed based on satellites' positions and removed
- If a Digital Elevation Model is available, the topographic phase can be removed too
- The atmospheric phase is either neglected or corrected (depending on radar frequency used)
- Then, we can convert the phase to the movement by the relation

$$\varphi_{mvt} = 2\frac{2\pi}{\lambda} displ$$

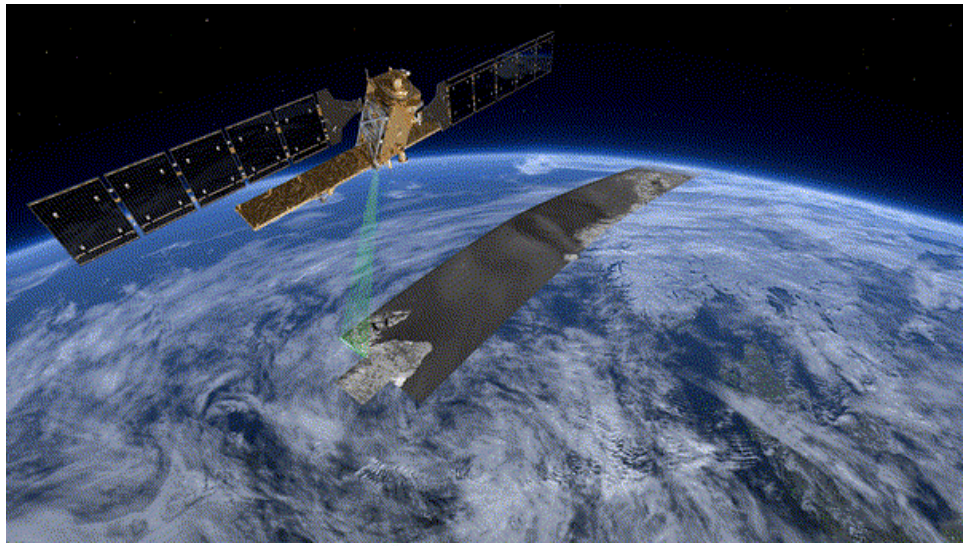


Sources : STEP forum - ESA

Limitations of (D)InSAR

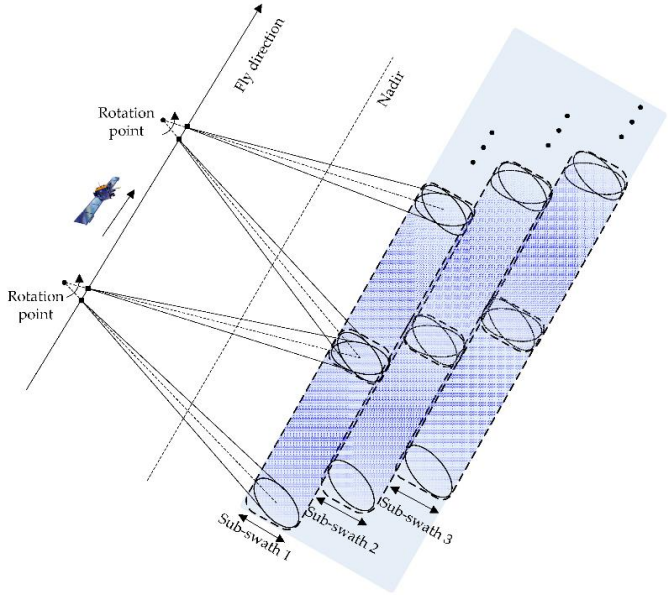
- Displacements are computed in **only** one direction (in the line-of-sight direction of the sensor)
  - However, physical process generally need at least 2D or 3D velocity fields

- We can combine ascending and descending orbits but
  - Not available everywhere (Antarctic coast for exemple)
  - Still West-East like directions (due to polar orbit)



New methods for surface velocities?

- Profit from specificities of Sentinel-1 new acquisition mode
- The satellite scans the region by electronically steering the angle backward to forward, leaving it enough time to scan the region further
- The image is then composed of multiple bursts and swaths, with overlapping regions
- In these areas, pixels are being scanned according to different look angles, introducing new phase terms related to azimuthal displacement
- The objective of this thesis consists in exploiting this new information in order to derive 2D displacements



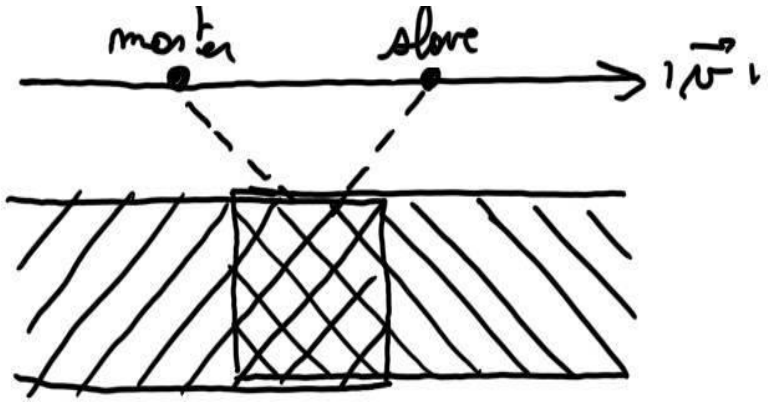
Sources : TOPSAR – Terrain Observation by Progressive Scans

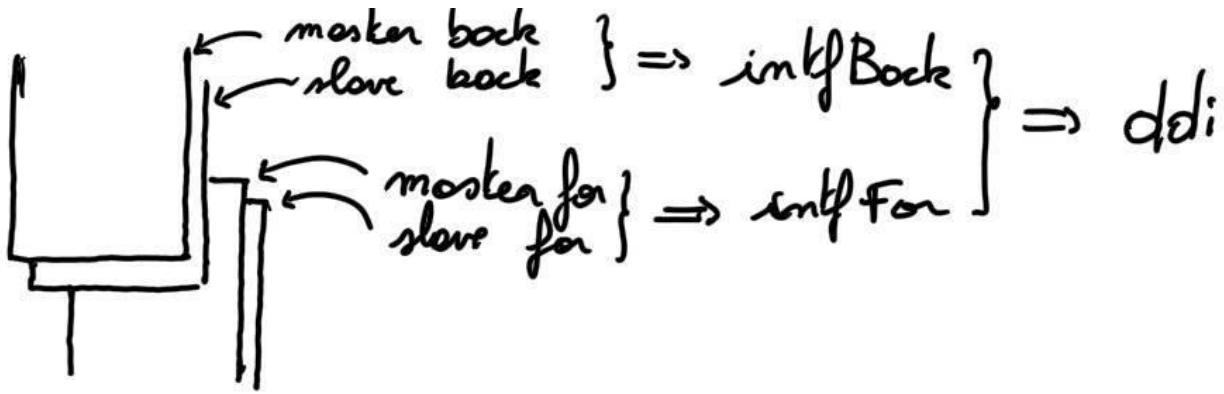
New methods for surface velocities?

When computing an interferogram between a forward master image and a backward slave image, lots of terms are to be compensated :

- Orbital phase
- Topographic phase
- Slant-range displacement phase
- Atmospheric phase
- Phase ramp (TOPS acquisition)

Double difference Interferogram (ddi) is a way to get rid off most of unwanted phase terms excepted the azimutal component.





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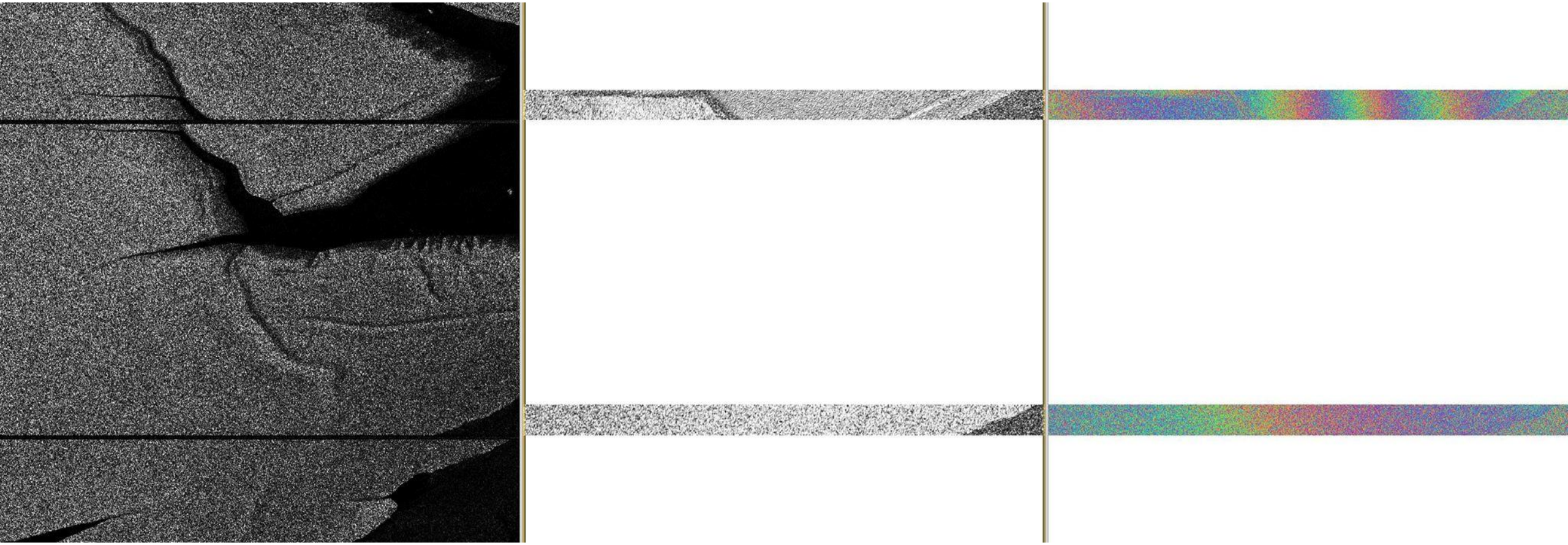
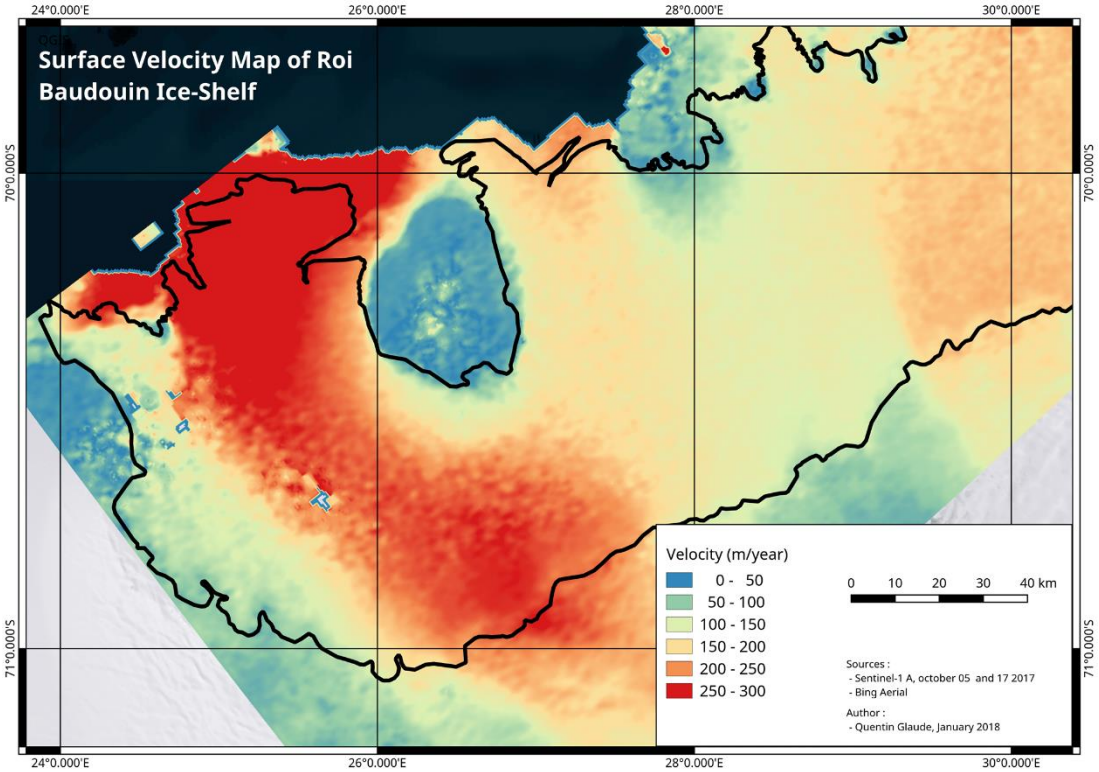
New methods for surface velocities?



New methods for surface velocities?

- Between those superposition areas, 2D-surface velocities can still be computed by pixel offset techniques using image correlation (coarser sensitivity)

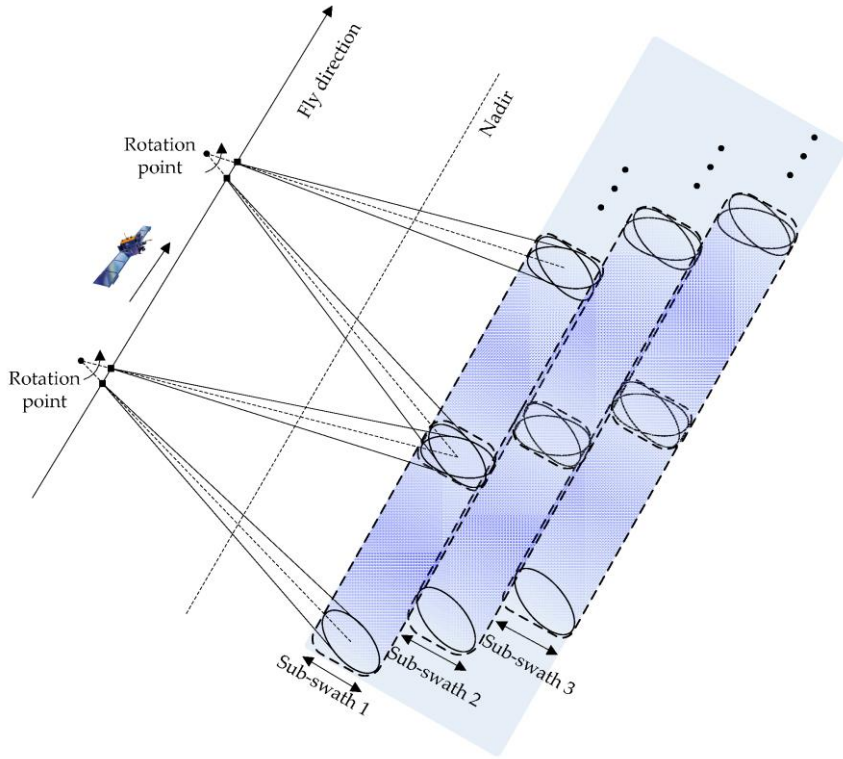
- In SAR images, according to the input images used, we called that *speckle tracking* (amplitude image) or *coherence tracking* (complex image)



Summary

- Use of the specificities of Sentinel-1 acquisition mode to derive 2D displacement maps in burst superposition areas
  - ➢ Fine method

- Use the coherence/speckle tracking to infer 2D displacements between overlapping areas (method to be adapted to S1 data)
  - ➢ Coarse method



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