

autoRIFT

Autonomous Repeat Image Feature Tracking

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ITS LIVE

a NASA MEaSUREs project



This research was carried out at the **Jet Propulsion Laboratory** and the **California Institute of Technology**
under a contract with the **National Aeronautics and Space Administration**

The big picture

Why: Sea level rise is one of the most consequential outcomes of a warming planet. A lack of knowledge of how glacier flow responds to changes in its stress balance is the largest source of uncertainty in sea level rise projections.

What: Researchers study changes in glacier flow to improve understanding in glacier mechanics.

How: Provide the most complete record of glacier flow by processsing *ALL* large public archives of satellite imagery (optical and radar). Petabytes of data!

Iceberg Calving

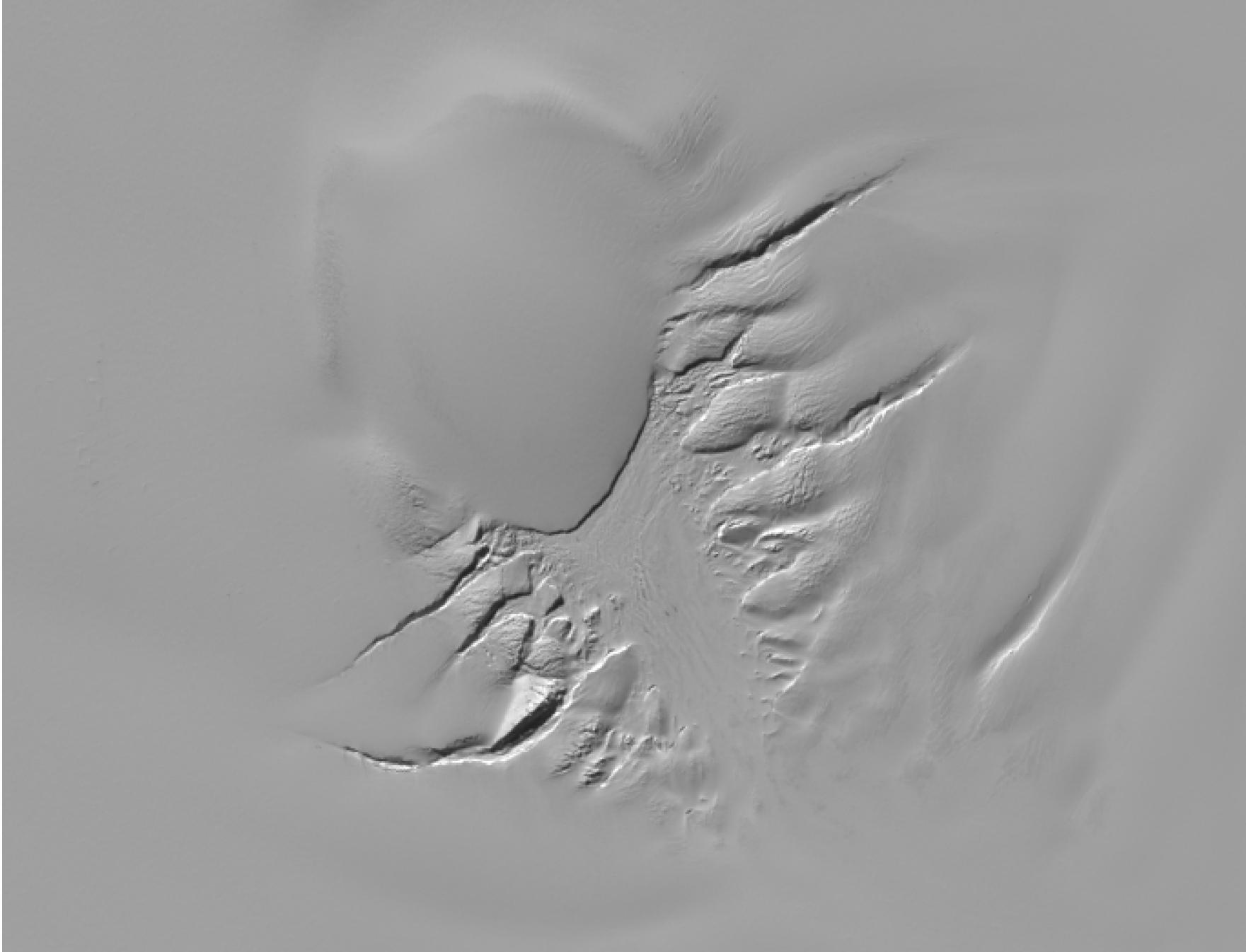


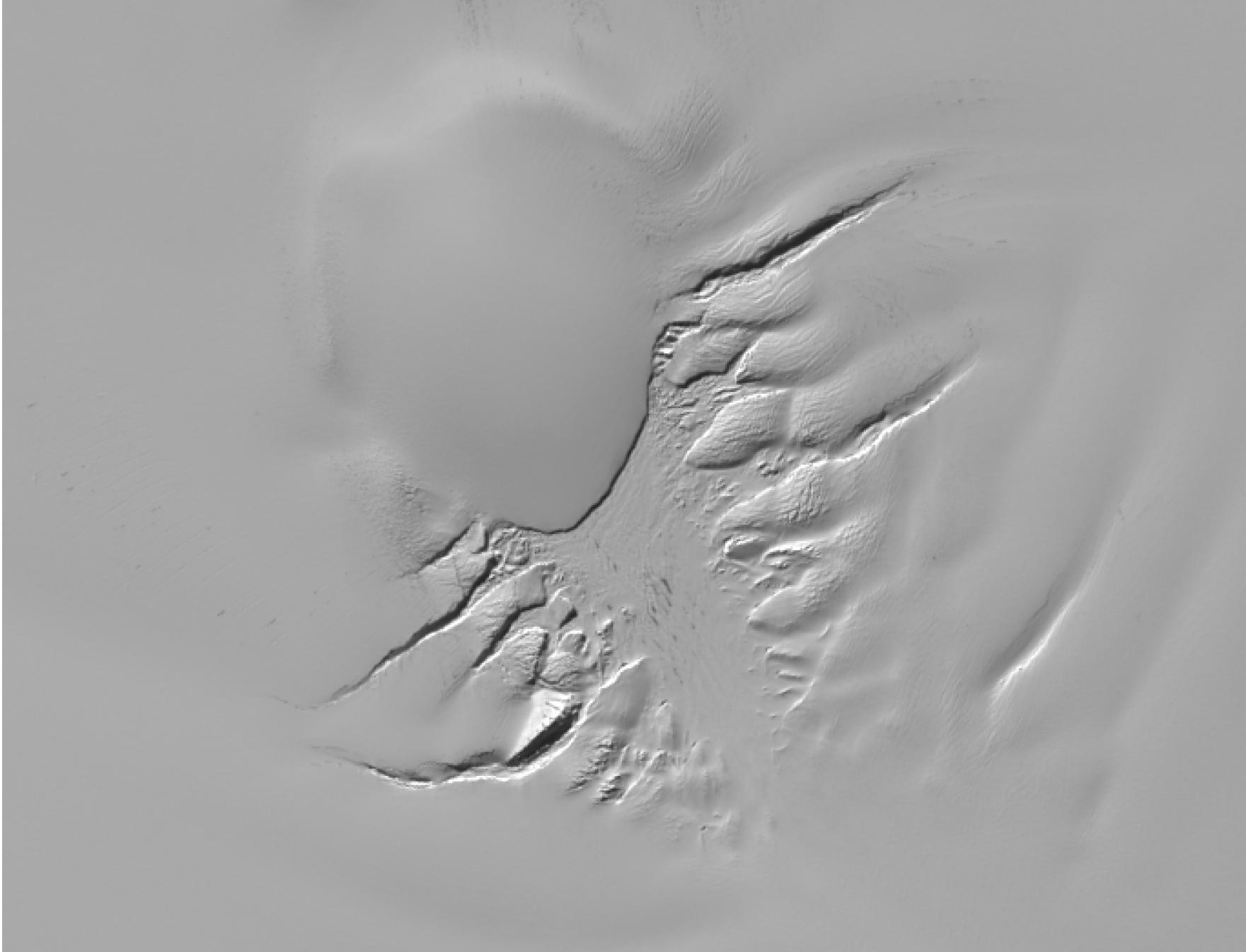
Mark Fahnestock, UAF

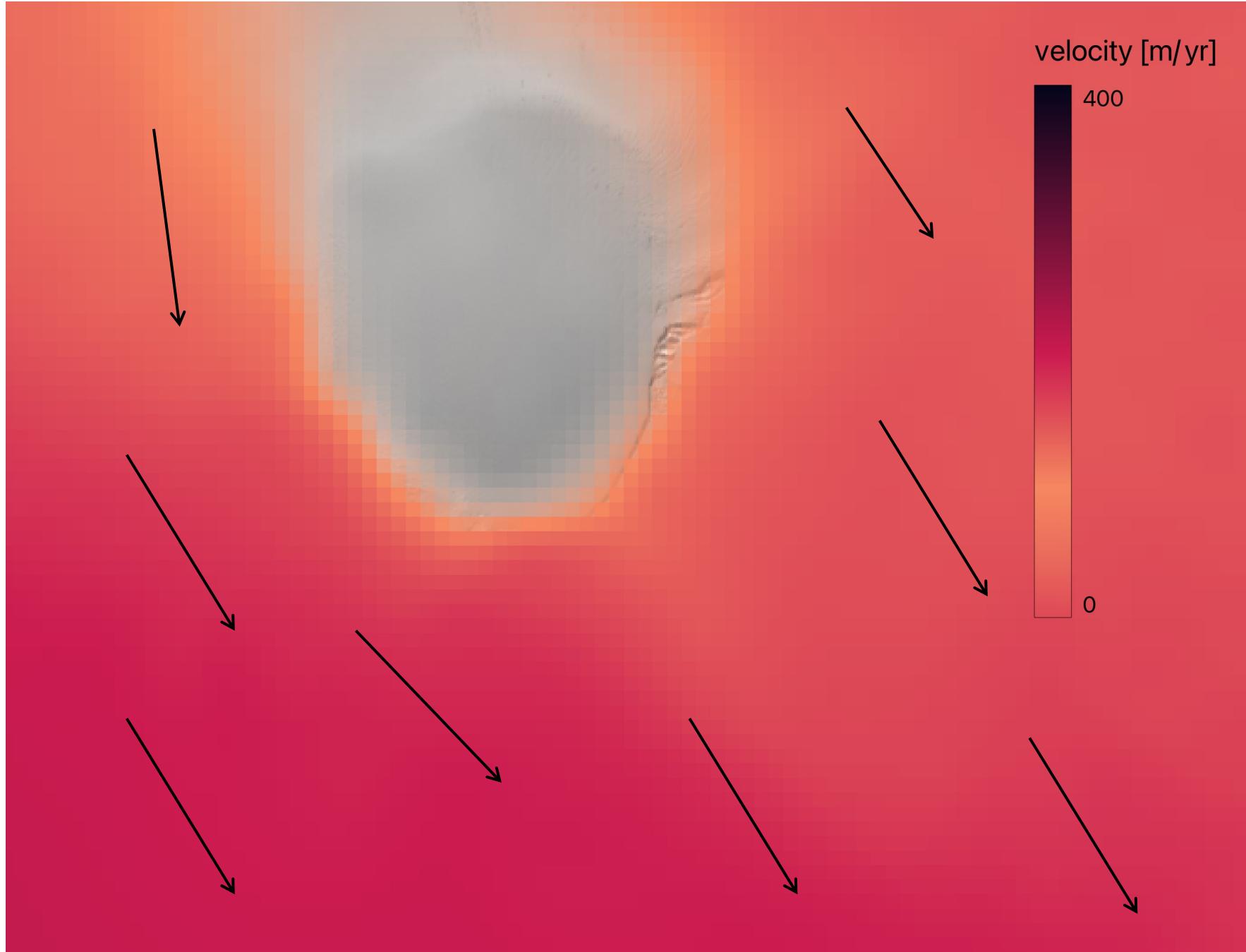


Ice flow from tracking of surface features



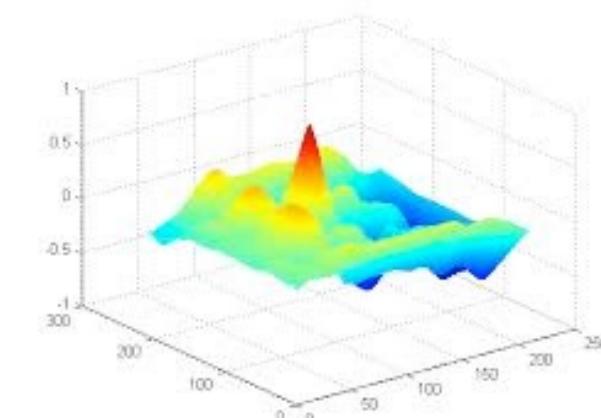
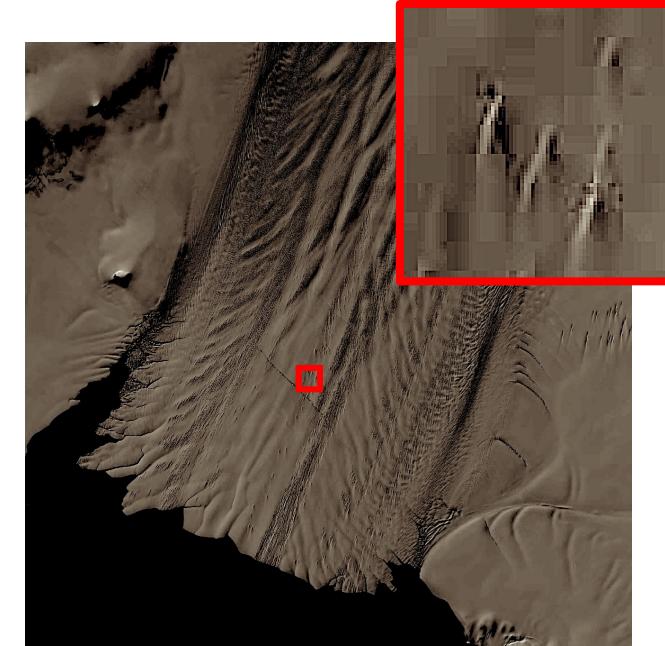






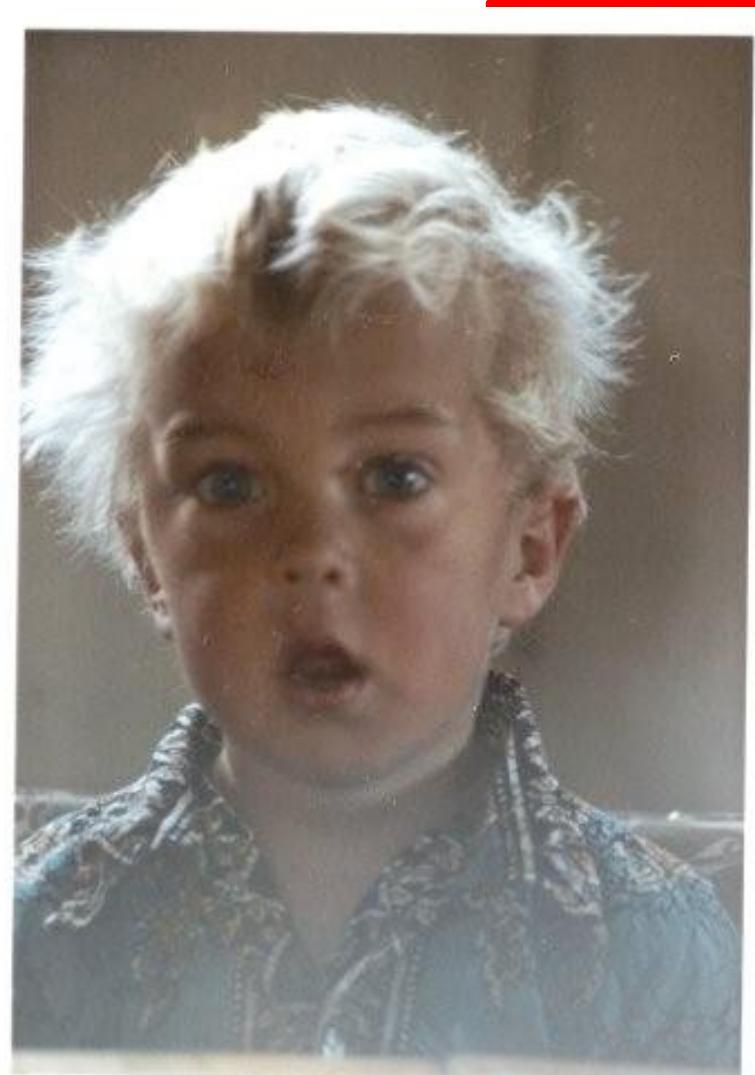
Normalized cross correlation

- Take a template from one image and find the location of the maximum correlation in a reference image... repeat.. a trillion times
- Subpixel displacement = fit a surface to the map of correlation values to refine location of peak
- Nothing new... applied to measure glacier surface velocities in optical and SAR imagery since I was in grade 6



Normalized cross correlation

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But....

Normalized cross correlation is really really computationally expensive

A single Landsat-8 image pair might require 0.5 Billion NCC computations for a single chip size... researchers often compute using 3-4 chip sizes

Typically one of the slowest parts of SAR processing

JPL auto-RIFT

autonomous Repeat Image Feature Tracking

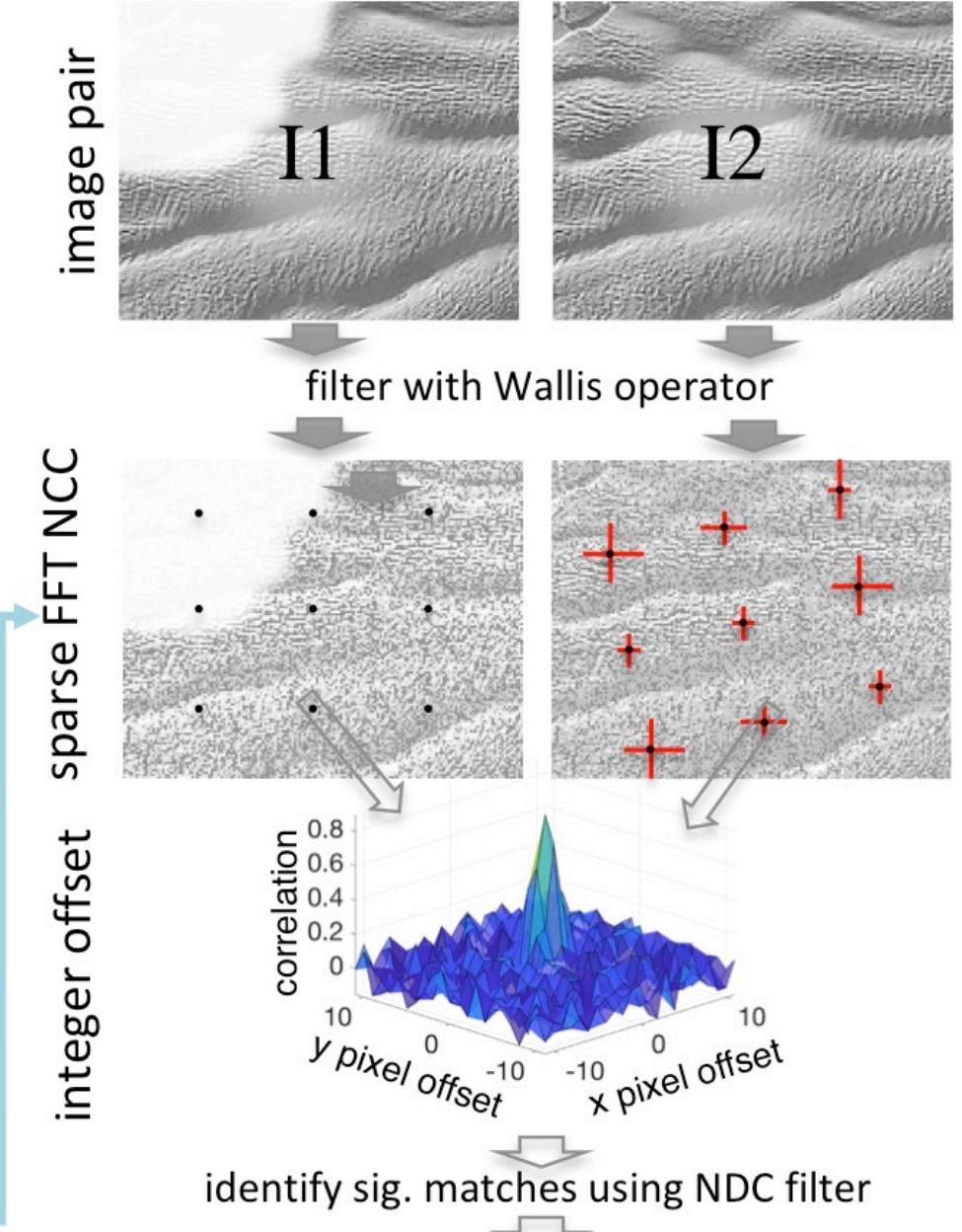
- orders of magnitude faster than conventional NCC implementations
 - Uses a sparse search to inform a dense search
- automatically selects best chip size
- novel outlier rejection that is robust to changes in NCC search parameters (Normalized Displacement Coherence Filter)
- optional sparse /non-uniform search grid
- optional [spatially varying] a priori downstream search
- optional [spatially varying] a priori search range / window
- optional [spatially varying] chip size range
- FFT filtering to remove image banding (Landsat 8)
- novel image no-data gap filling approach (Landsat 7)
- Integrated into JPL ISCE for SAR processing

autoRIFT

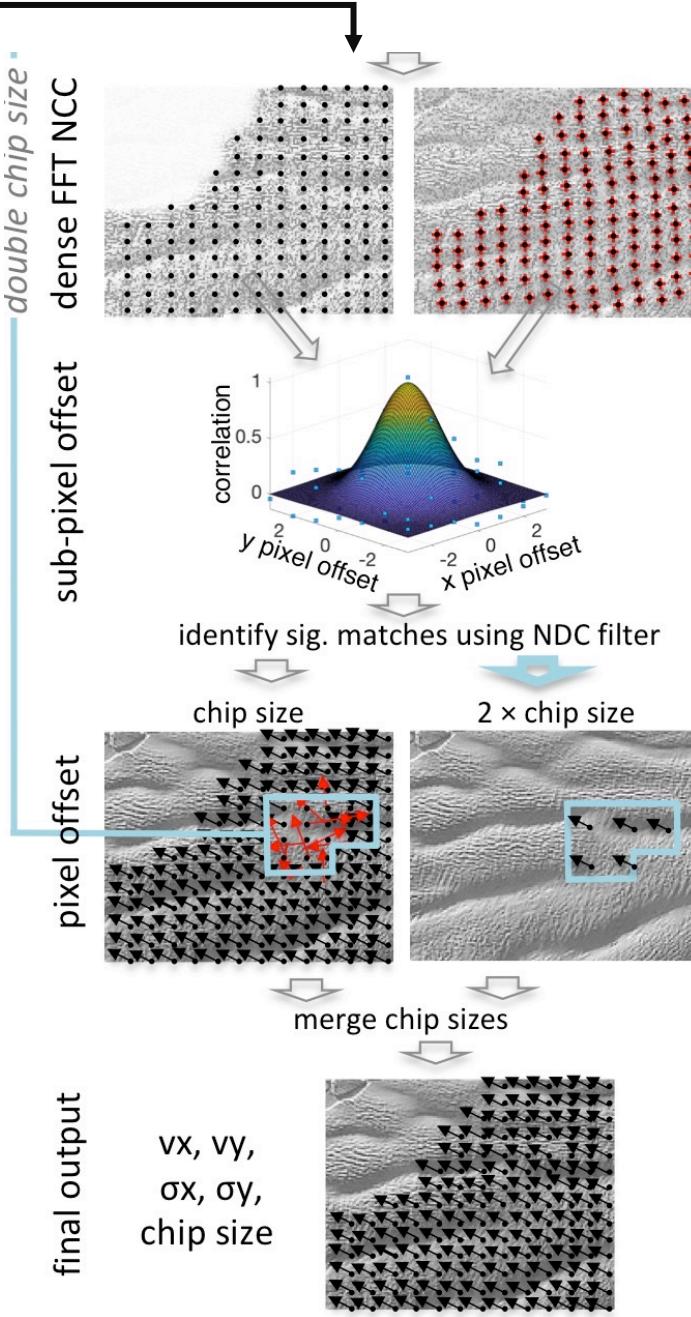
<https://github.com/nasa-jpl/autoRIFT>

The screenshot shows the GitHub repository page for 'nasa-jpl / autoRIFT'. The page has a dark theme. At the top, there's a search bar, navigation links for 'Pull requests', 'Issues', 'Marketplace', and 'Explore', and a user profile icon. Below the header, the repository name 'nasa-jpl / autoRIFT' is displayed with a 'Public' badge. There are buttons for 'Unwatch' (15), 'Fork' (31), and 'Starred' (125). The main navigation tabs are 'Code' (selected), 'Issues' (3), 'Pull requests' (1), 'Actions', 'Projects', 'Wiki', 'Security', and 'Insights'. Below the tabs, it shows 'master' branch, 20 branches, and 13 tags. There are buttons for 'Go to file', 'Add file', and 'Code'. On the right, there's an 'About' section with a description of the project: 'A Python module of a fast and intelligent algorithm for finding the pixel displacement between two images', along with links to 'Readme', 'Apache-2.0 License', and '125 stars'. The main content area lists recent commits:

Author	Commit Message	Date
alex-s-gardner	remove repointing notice	e89e92c 1 hour ago
	Update install.md	7 months ago
	Add files via upload	8 months ago
	Remove dependency on openv highgui component	last month



autoRIFT workflow



Imagery - Things to think about

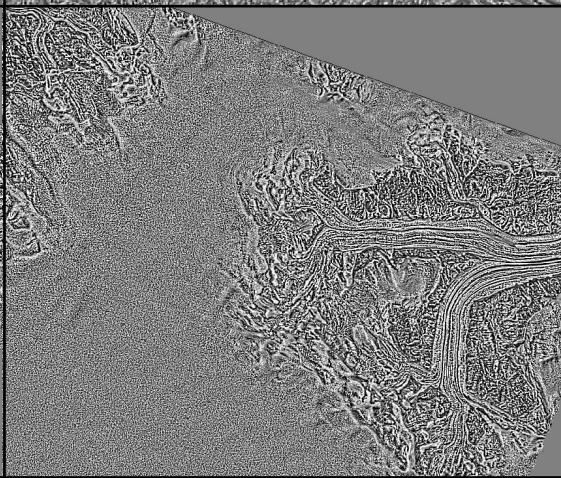
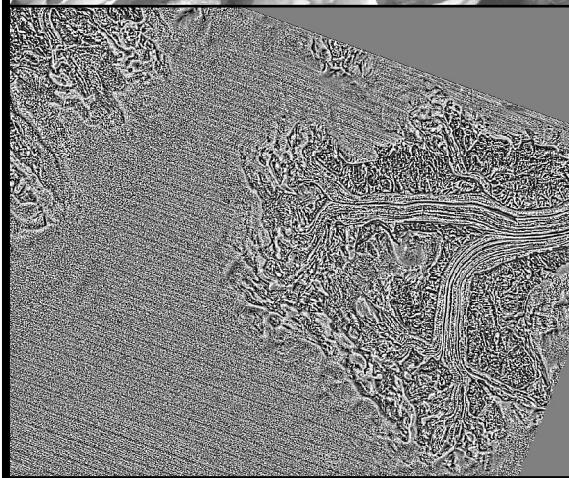
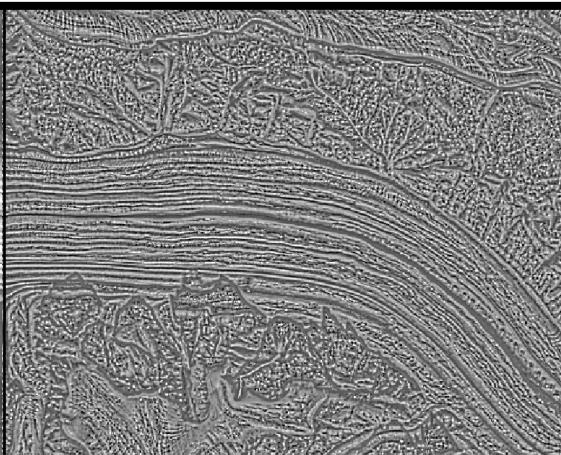
- Viewing geometry
- Changes in illumination
- Cause of illumination
- Surface condition
- Time between repeat images
- Sensor and processing artifacts

Image pre-processing

raw image [L7]



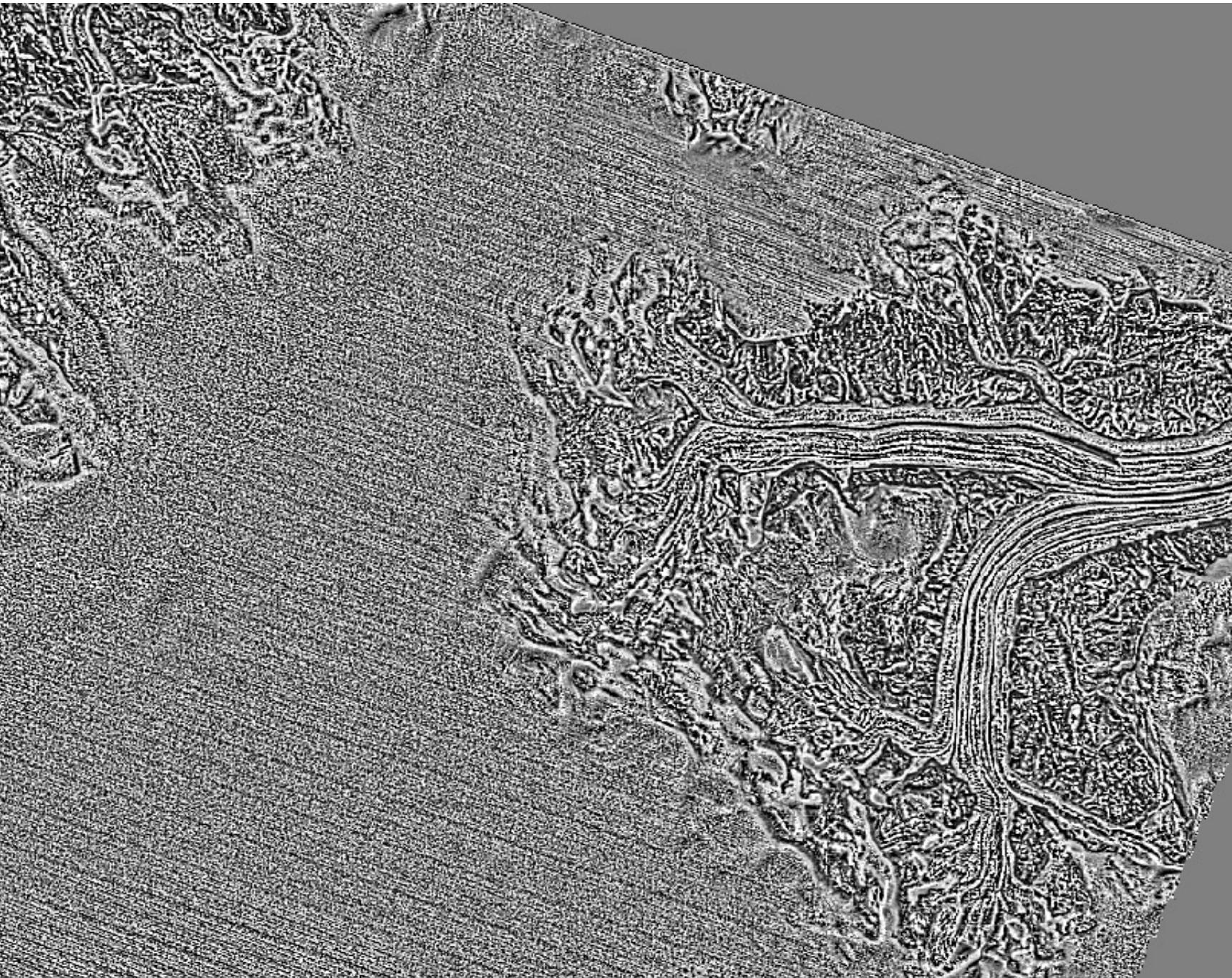
high pass filter [L7/8]



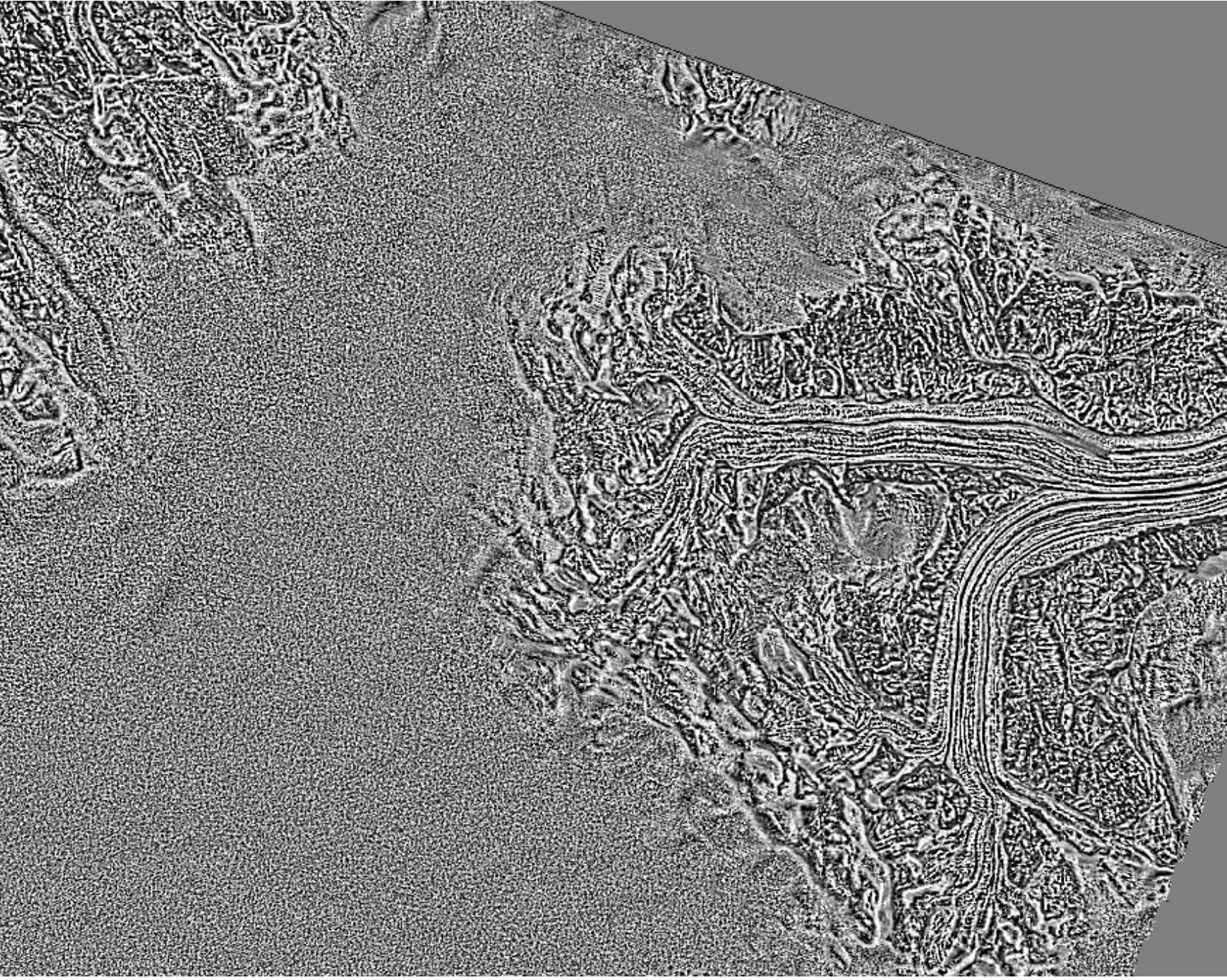
high pass filter + PCA [L4/5]

FFT filtering + PCA [L4/5]

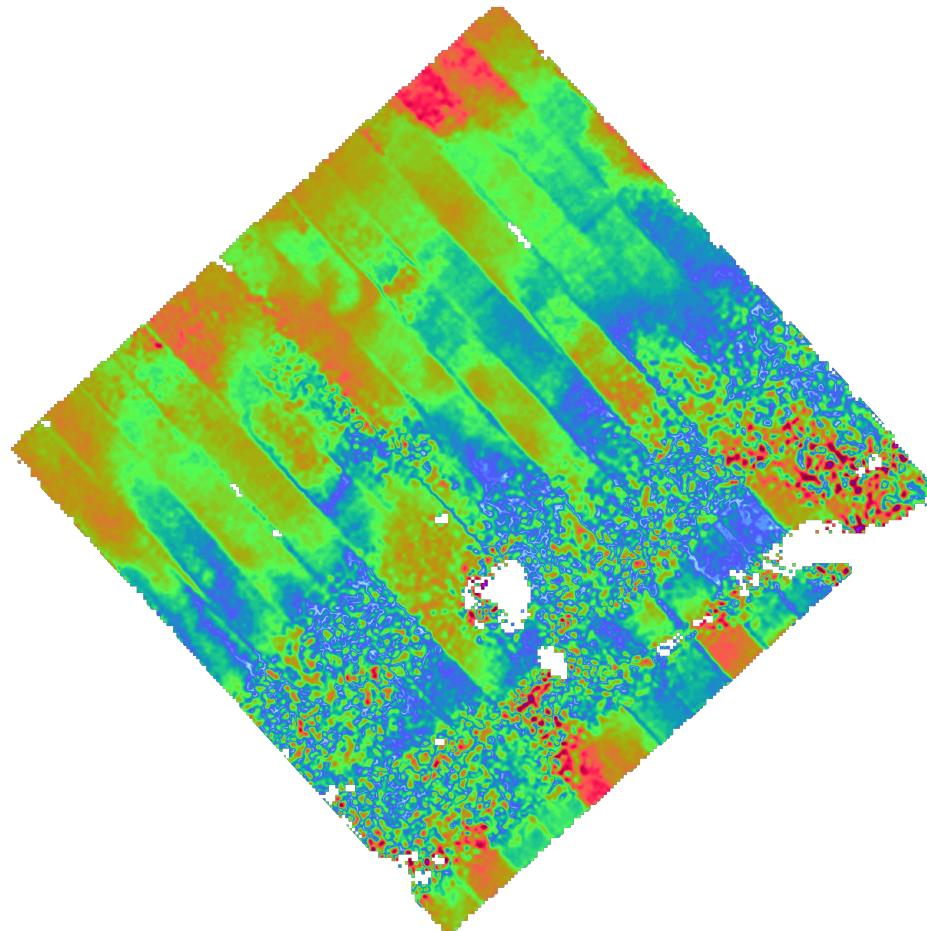
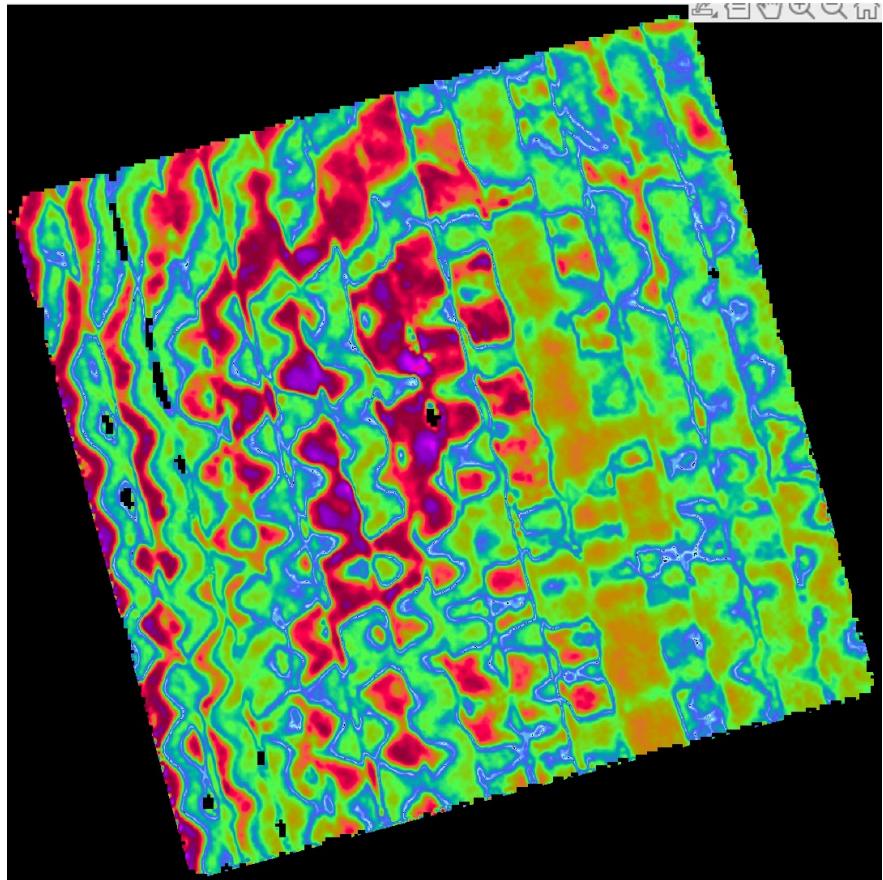
High Pass [Wallis]



High Pass Filter [Wallis] + FFT Filter

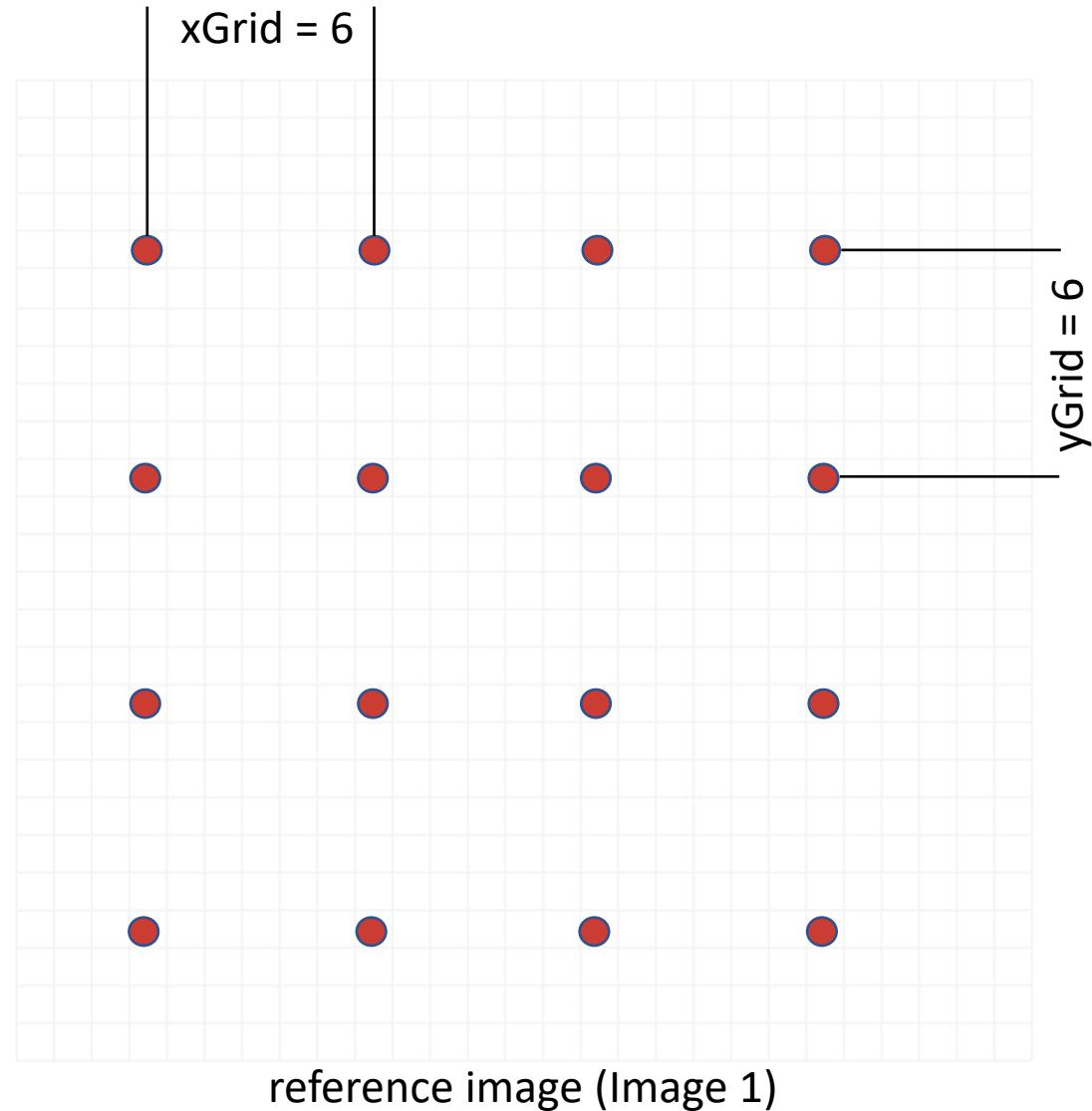


Landsat 9: example of sensor artifacts

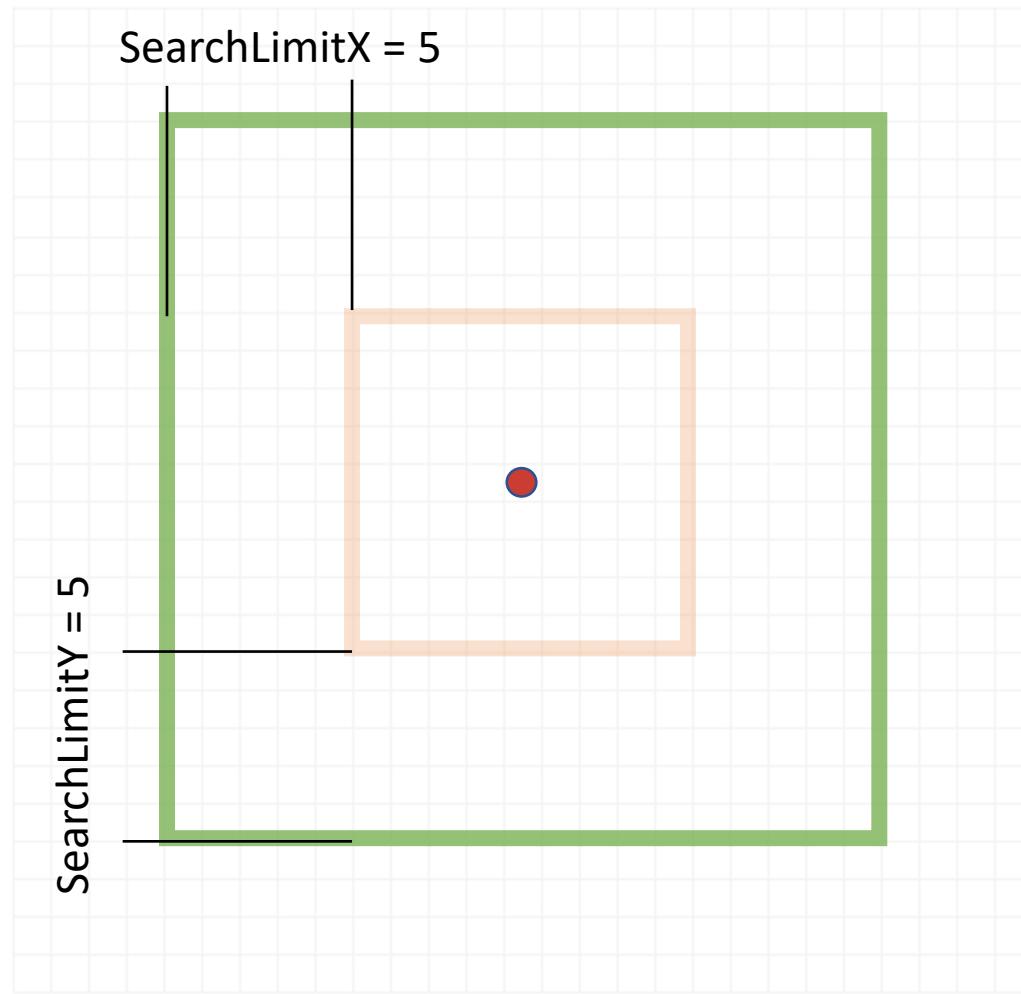


autoRIFT basic inputs

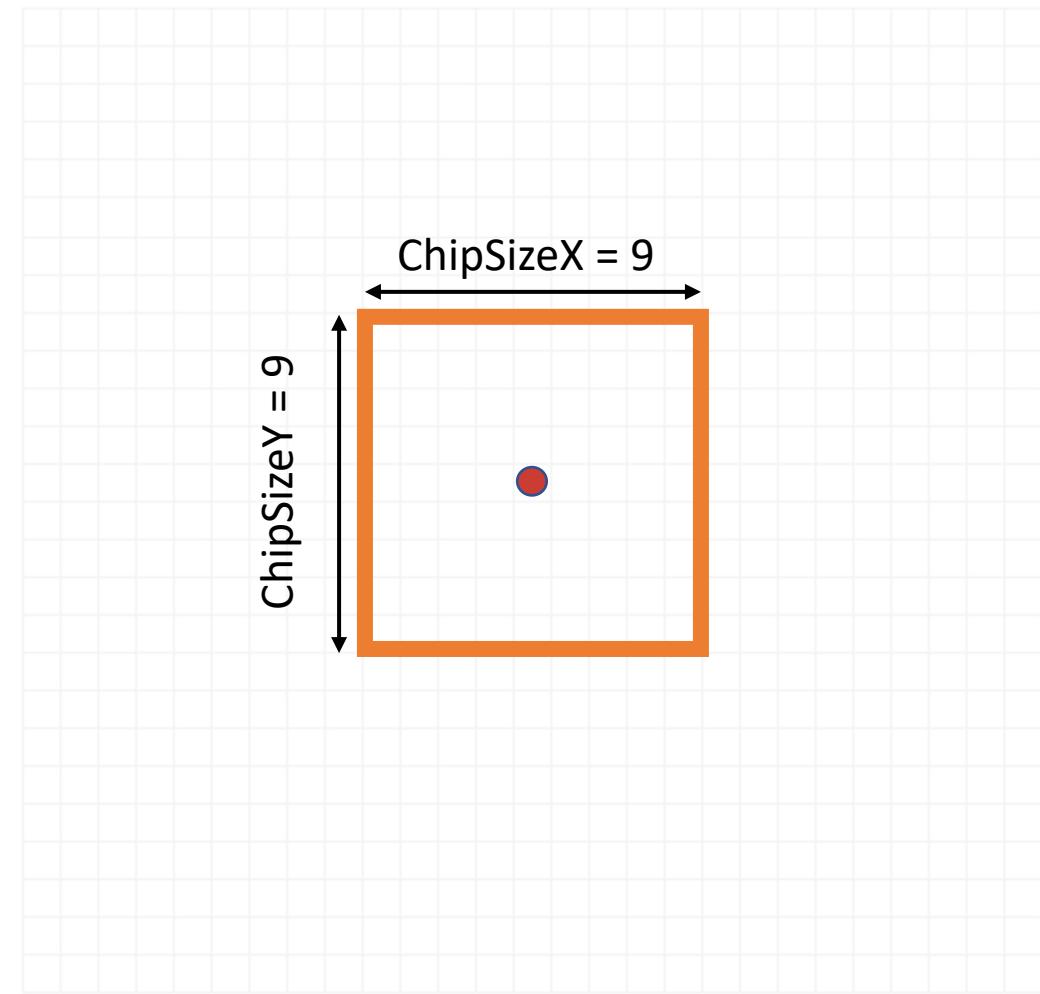
● search centers



- search centers
- search window
- template or image chip

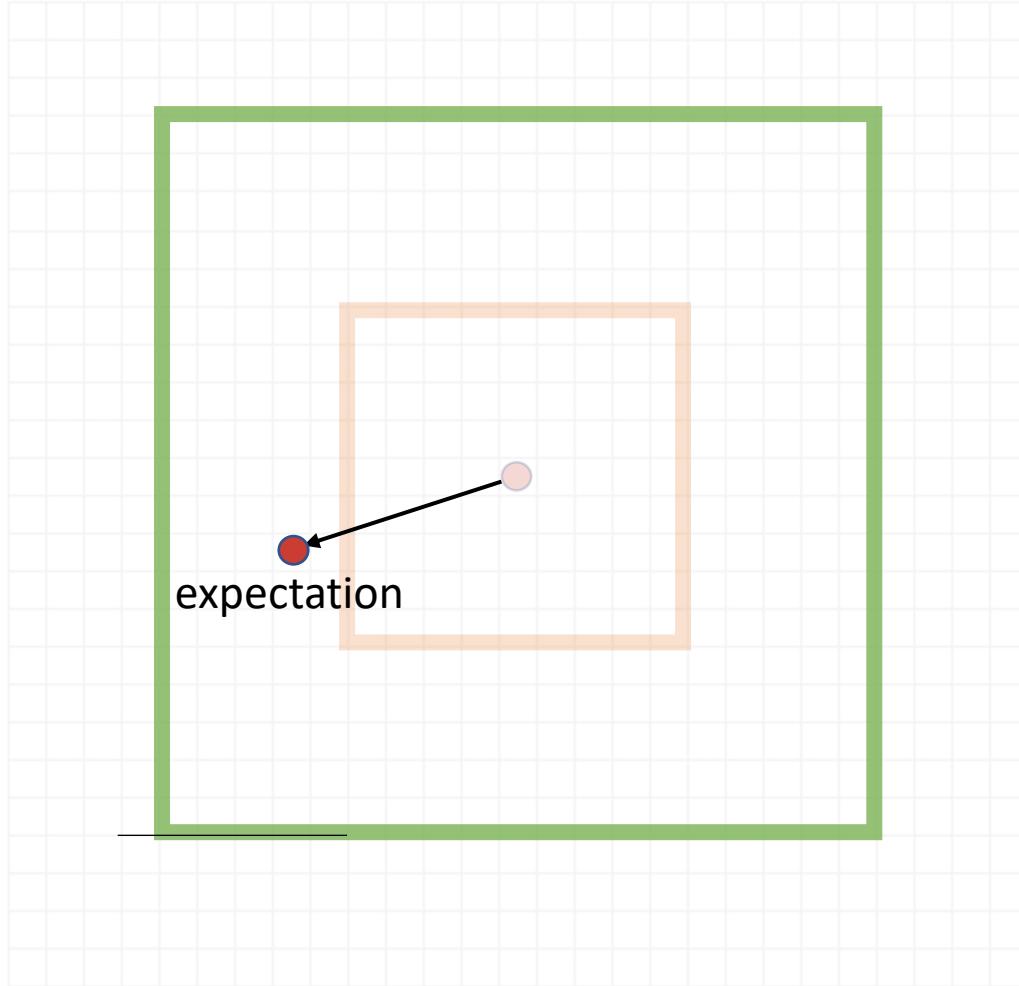


reference image (Image 1)

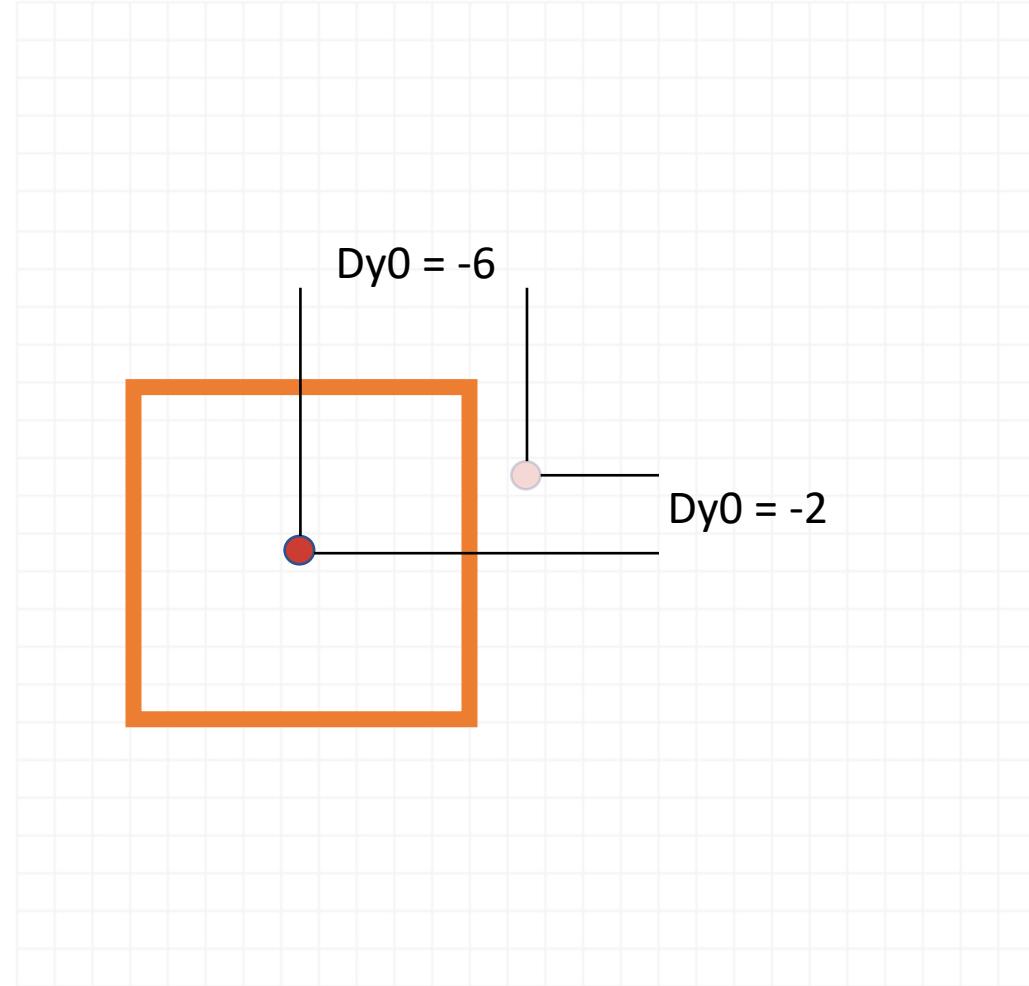


template or image chip (Image 2)

- search centers
- search window
- template or image chip

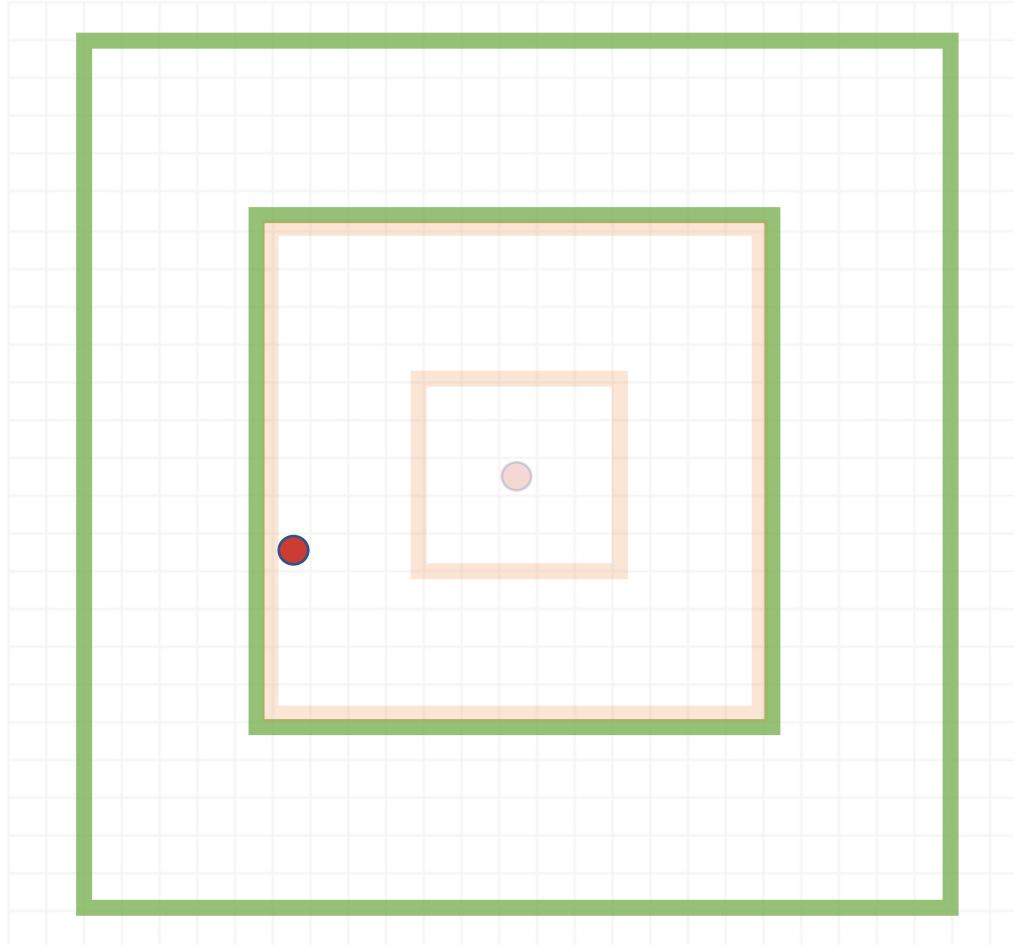


reference image (Image 1)

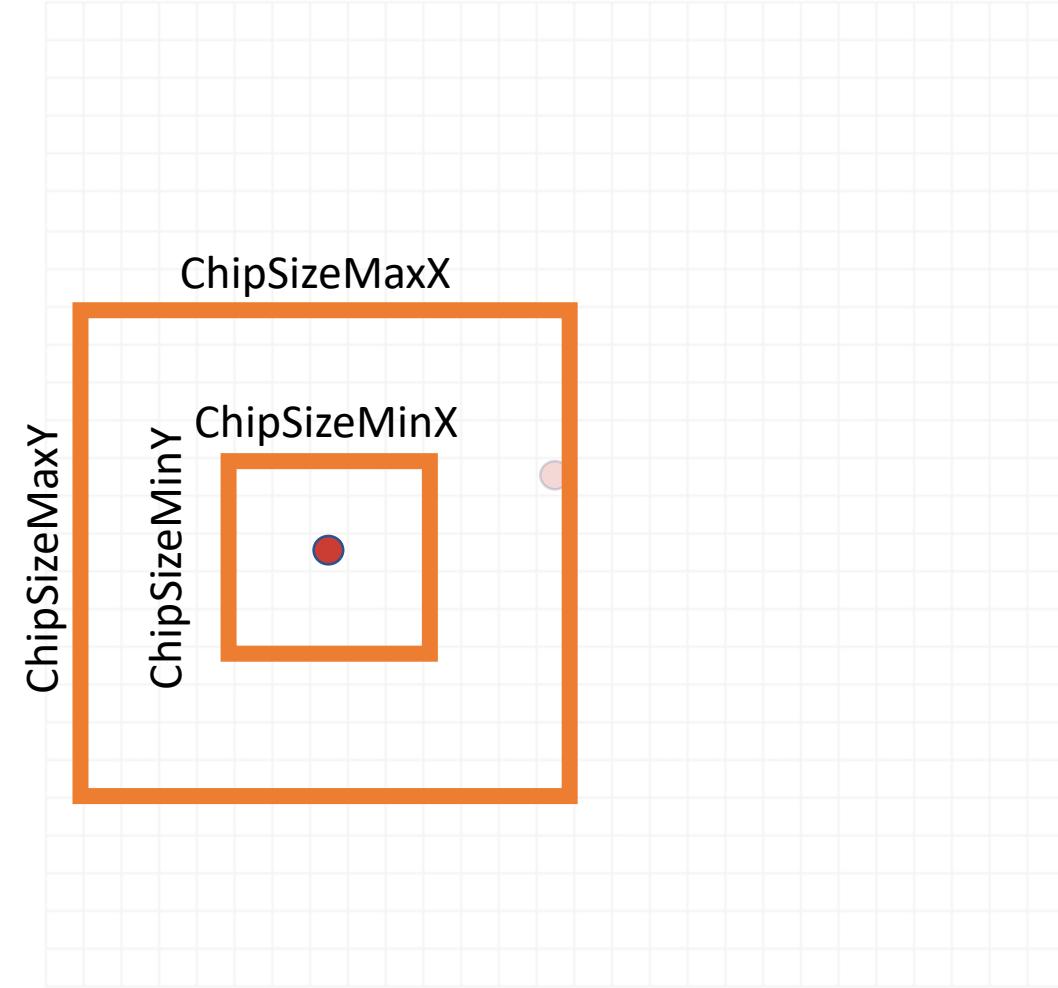


template or image chip (Image 2)

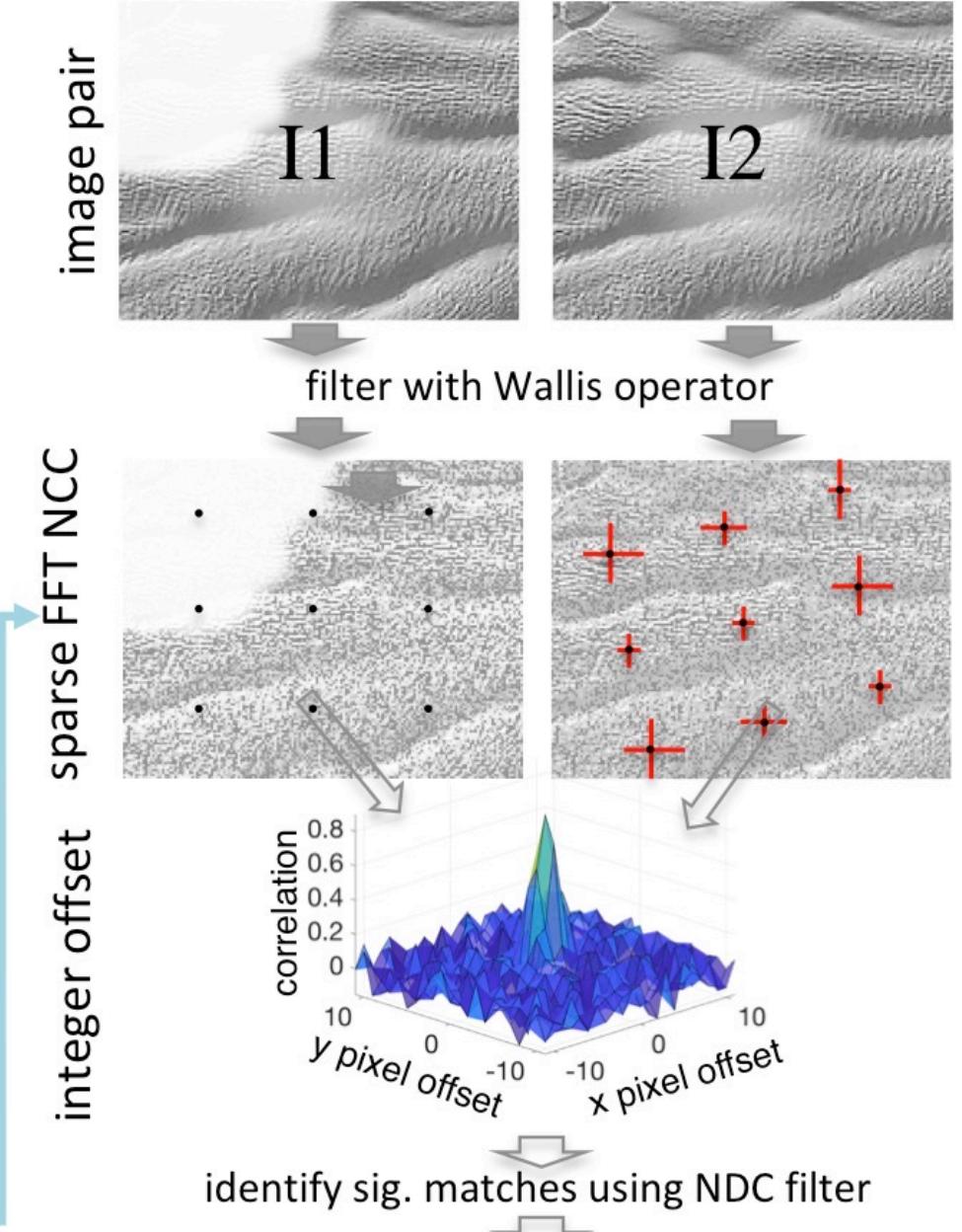
- search centers
- search window
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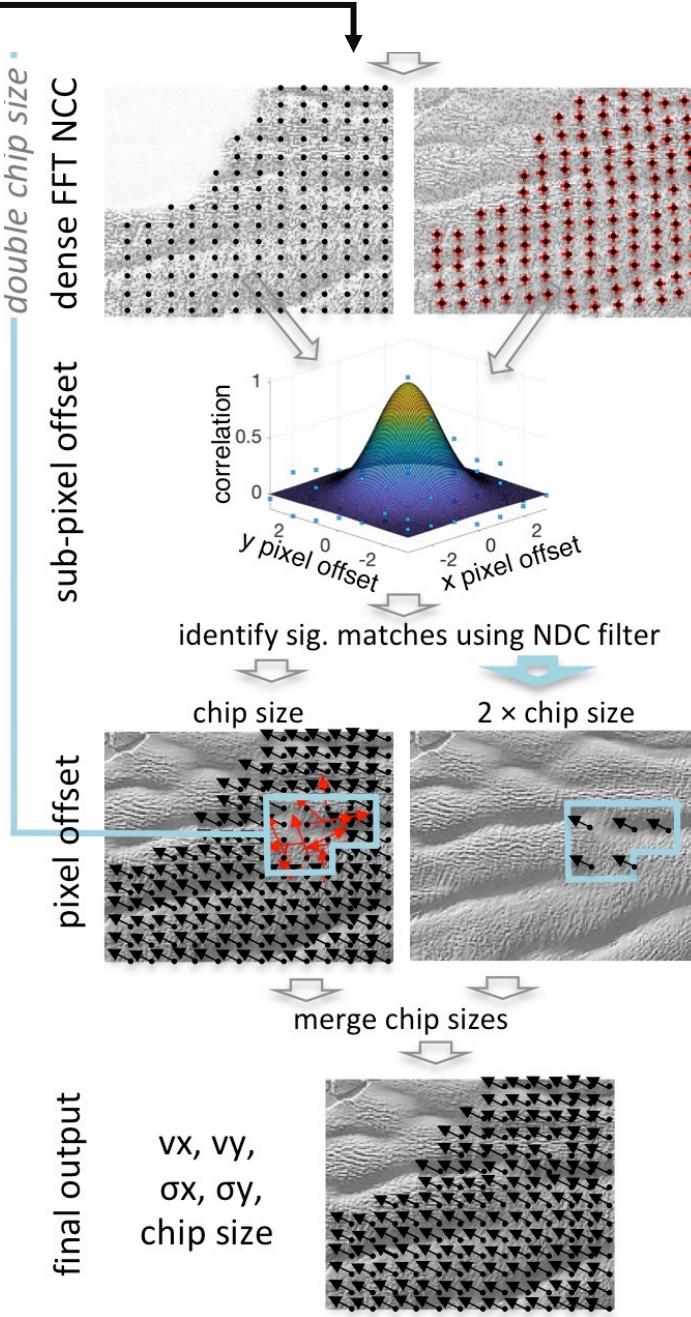
reference image (Image 1)



template or image chip (Image 2)



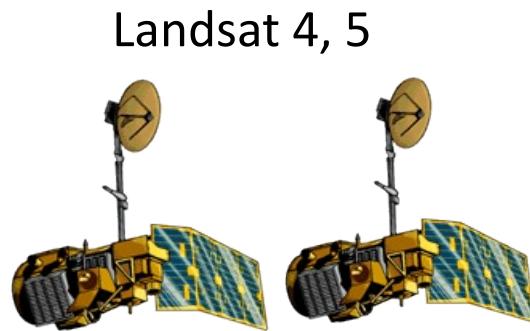
autoRIFT workflow



autoRIFT and ITS_LIVE

Glaciers and ice sheet surface velocity

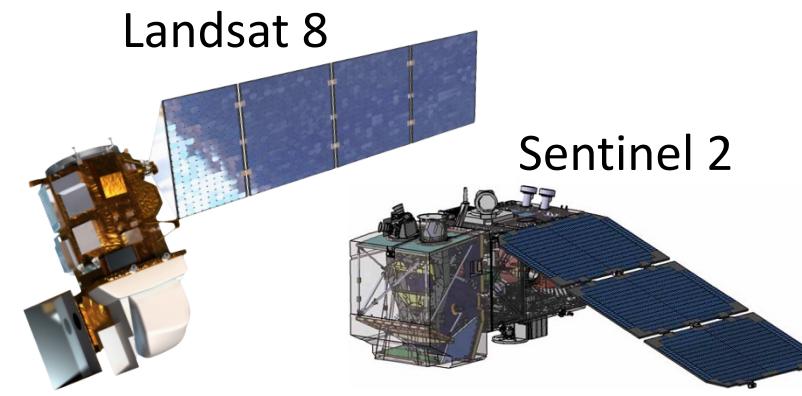
Optical



Landsat 4, 5



Landsat 7

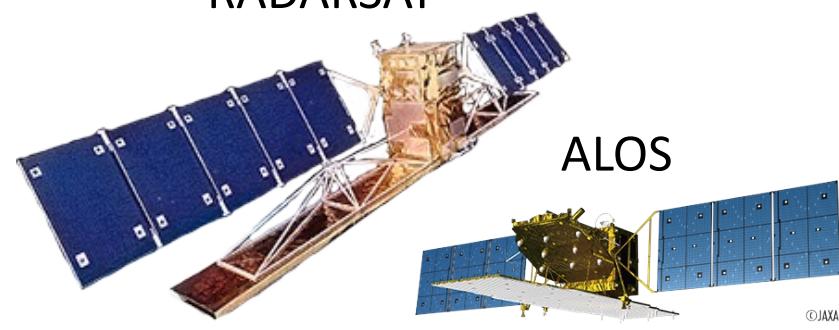


Landsat 8

Sentinel 2



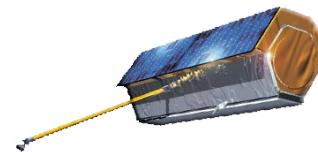
Radar



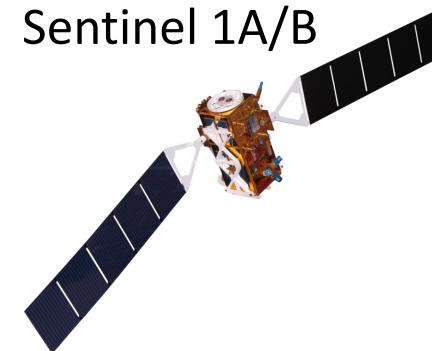
RADARSAT

ALOS

TerraSAR-X

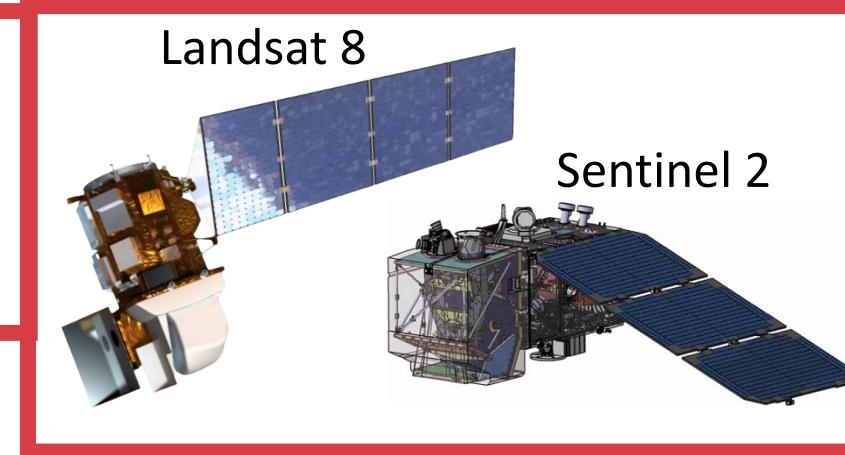
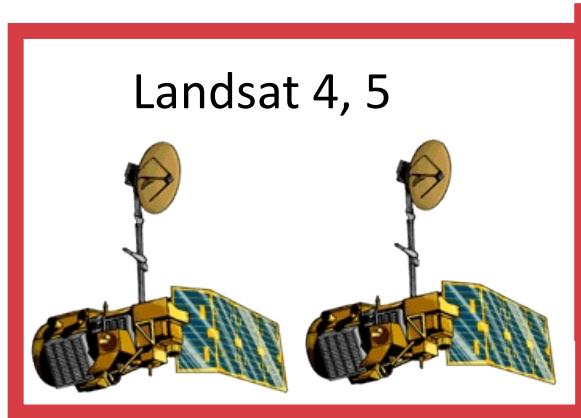


Sentinel 1A/B

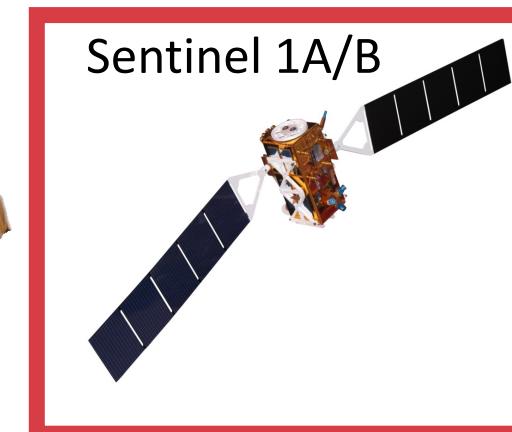


Glaciers and ice sheet surface velocity

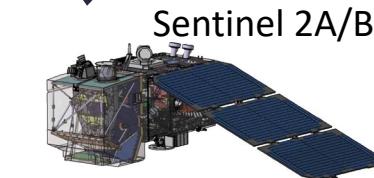
Optical



Radar



An accelerated paradigm for supporting science



Imager: Radar (sees through clouds)
Date: 2014/2015-present
Resolution: 3x12 m
Repeat: 6 & 12 day

Imager: Optical
Date: 2015/2017-present
Resolution: 10 m
Repeat: 5 & 10 day

Imager: Optical
Date: 2013/2021-present
Resolution: 15 m
Repeat: 8 & 16 day

Imager: Optical
Date: 1999-present*
Resolution: 15 m
Repeat: 16 day
*SCL failure in 2003

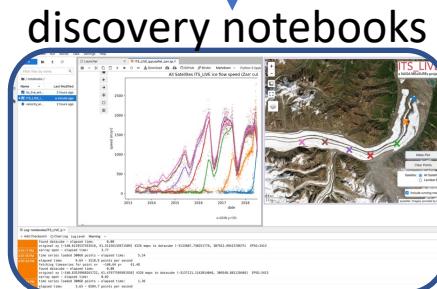
Imager: Optical
Date: 1982-1993, 1984-2011
Resolution: 30 m
Repeat: 16 day

Data all in
AWS
Simple
Storage
Service
(S3) cloud

In: image-pairs

Processed in AWS
cloud using
JPL autoRIFT
job management
using
ASF HYP3
output back to S3

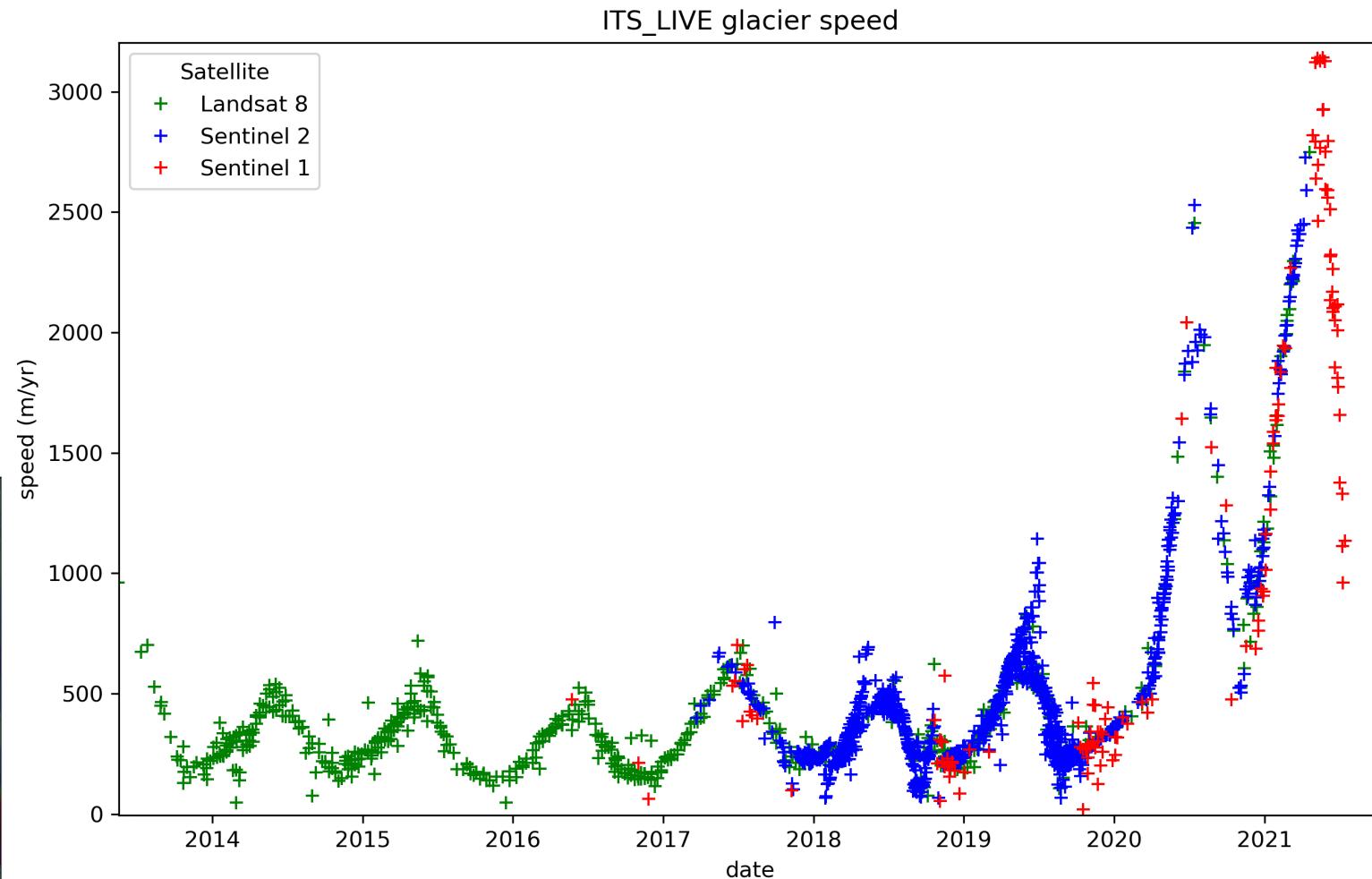
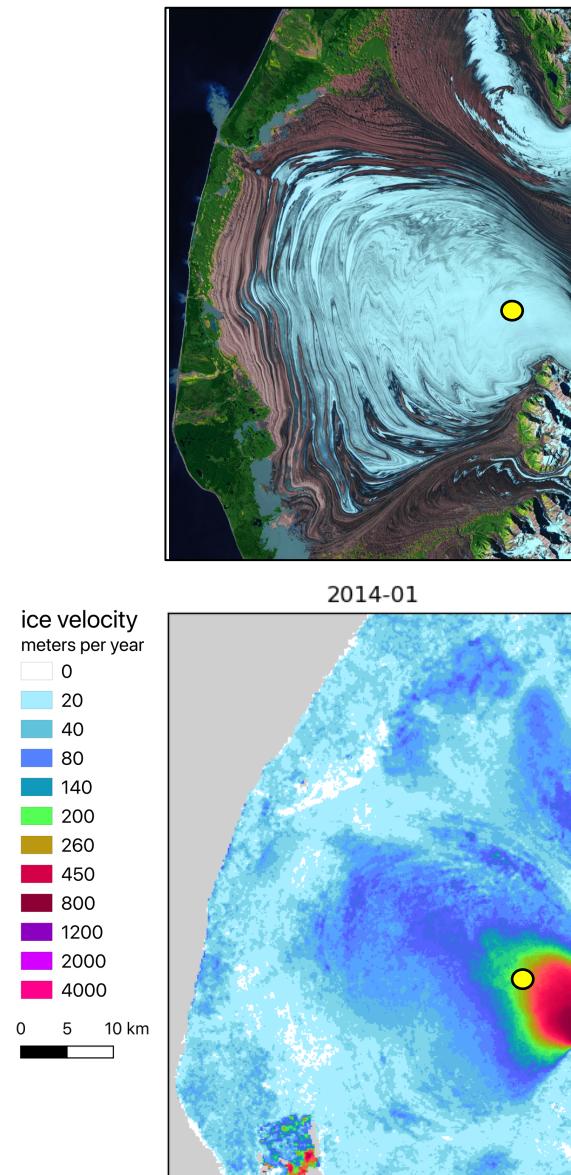
Out: surface velocity



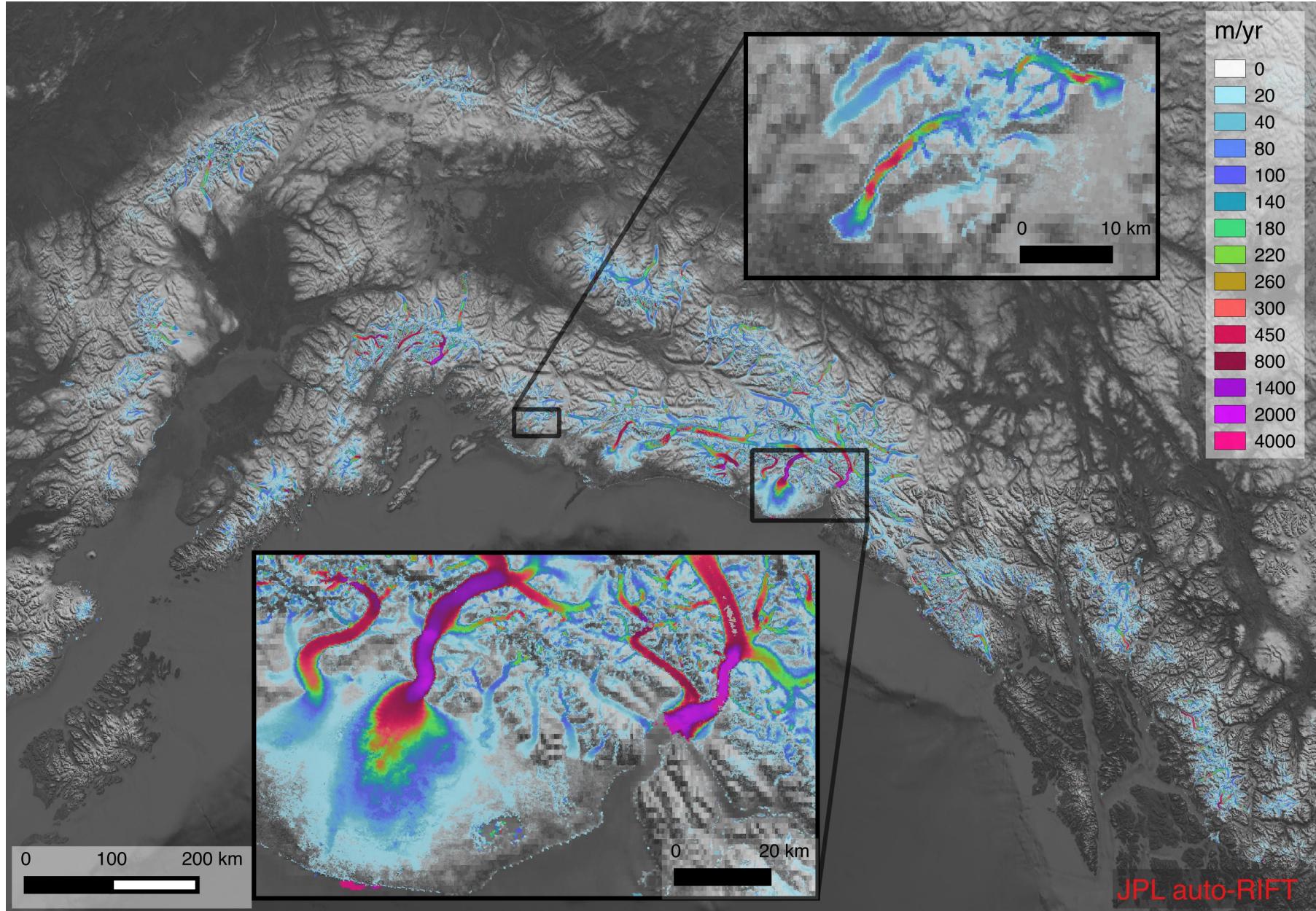
<https://nsidc.org/apps/itslive>

https://github.com/nasa-jpl/its_live

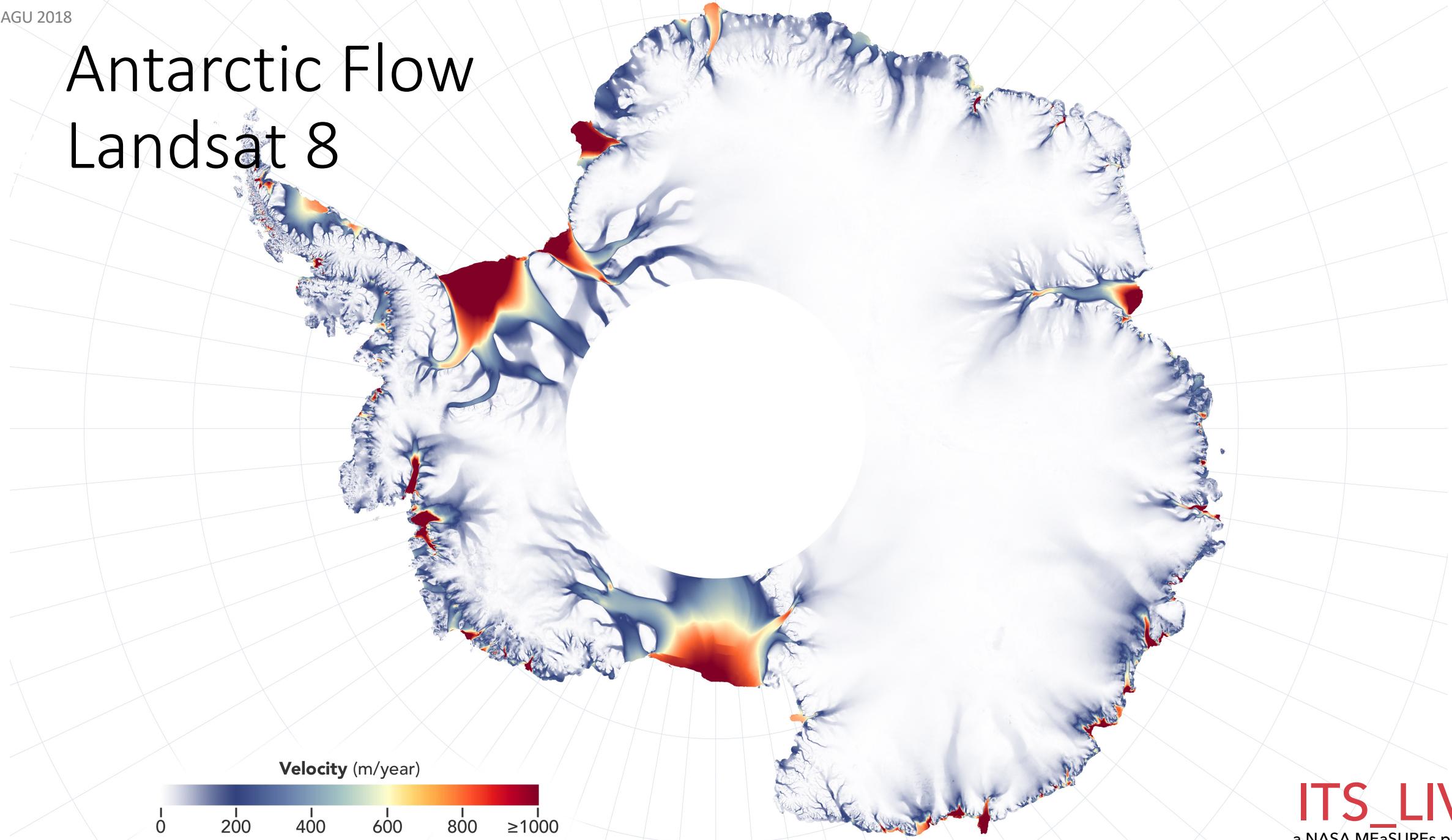
ITS_LIVE at work: Malaspina Glacier



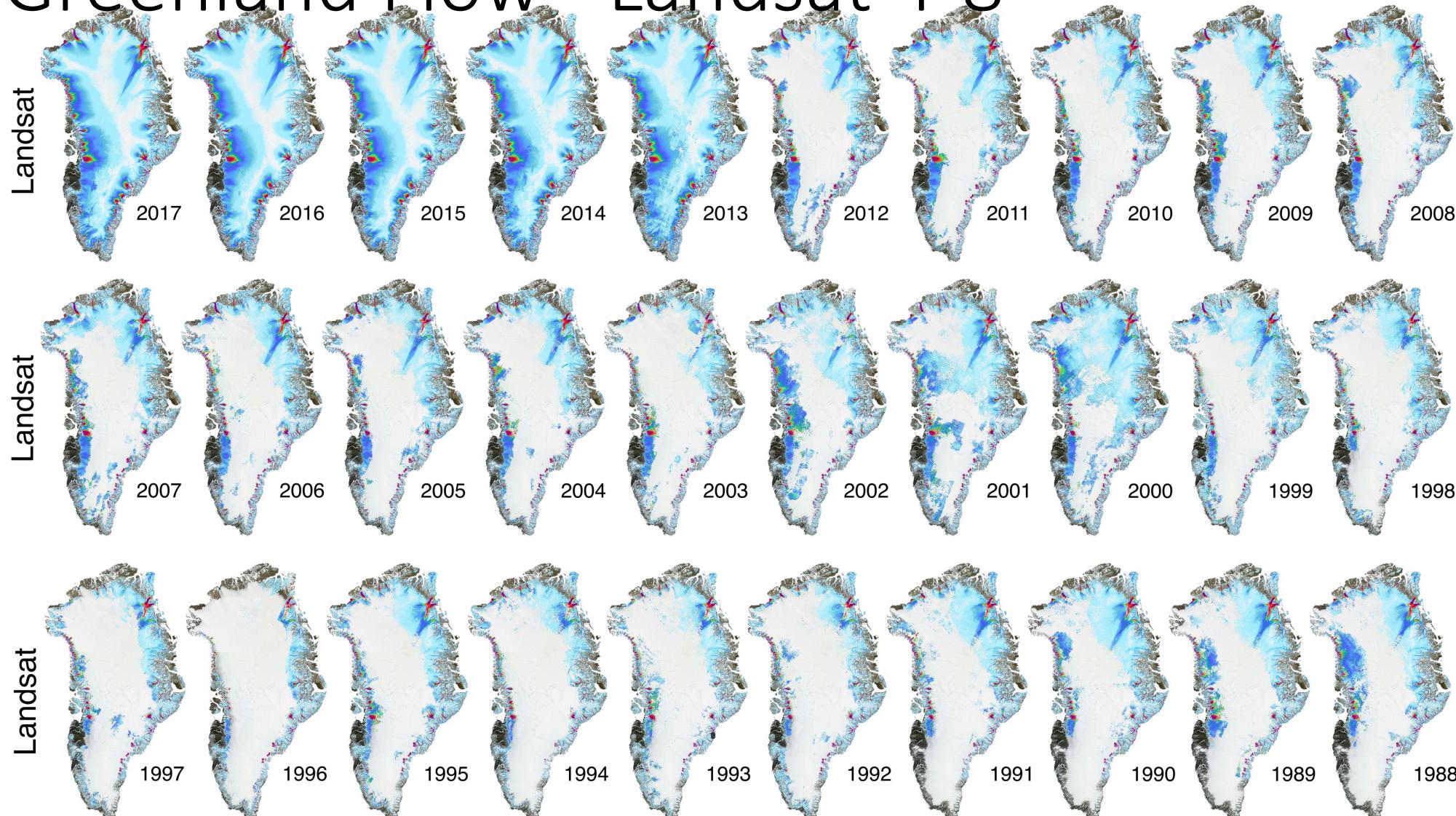
Alaska



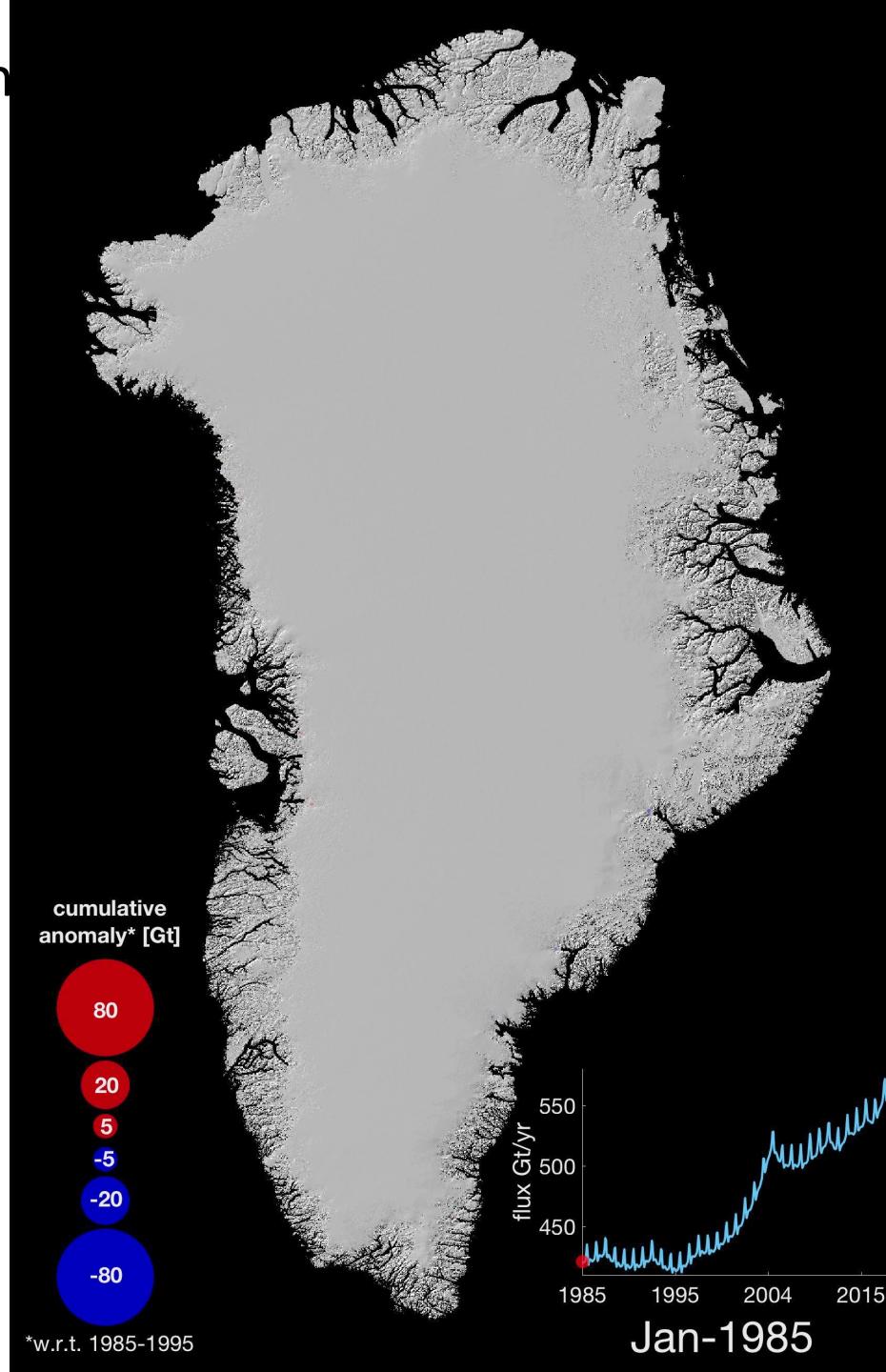
Antarctic Flow Landsat 8



Greenland Flow - Landsat 4-8

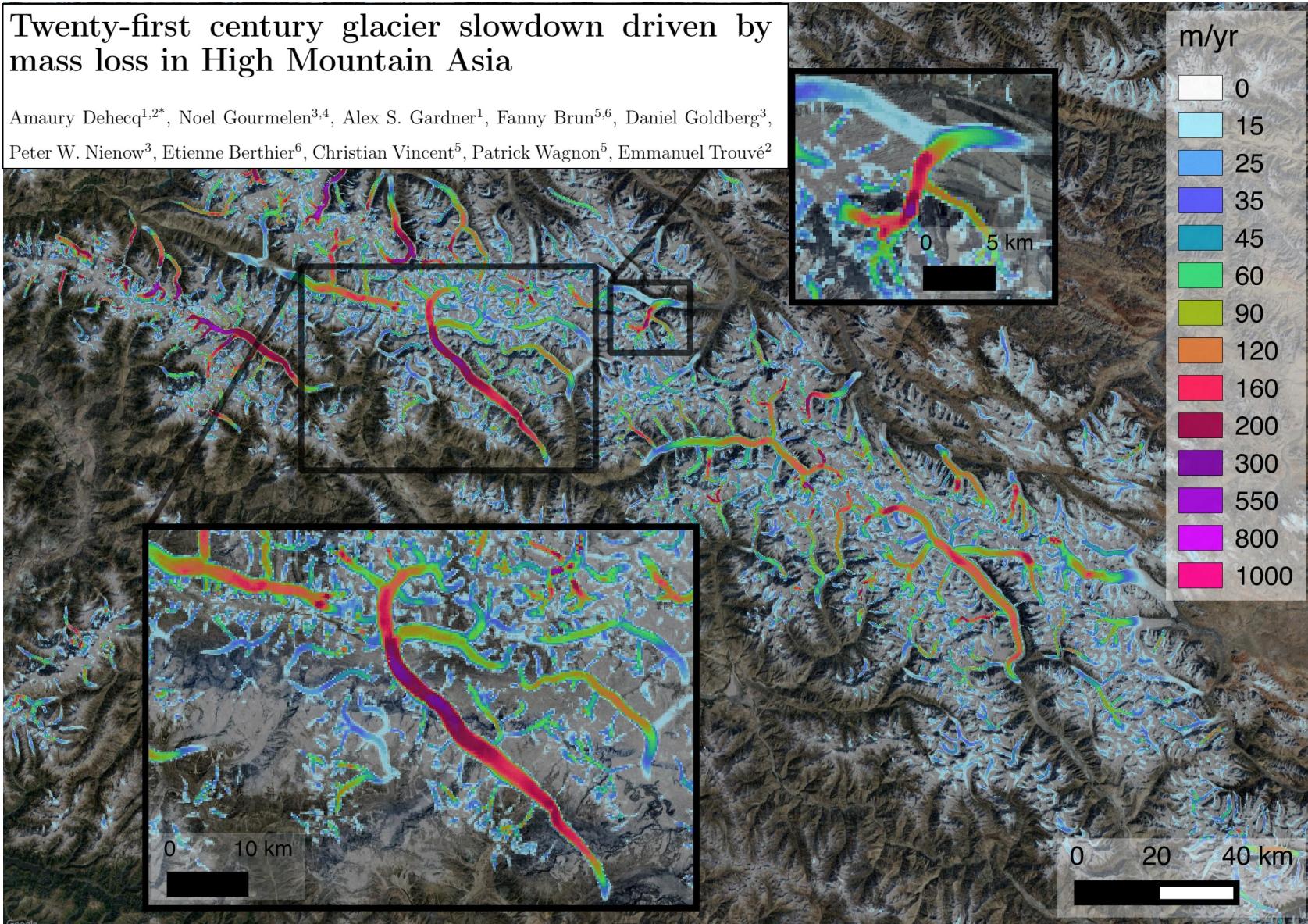


33 year record of Greenland ice discharge



Twenty-first century glacier slowdown driven by mass loss in High Mountain Asia

Amaury Dehecq^{1,2*}, Noel Gourmelen^{3,4}, Alex S. Gardner¹, Fanny Brun^{5,6}, Daniel Goldberg³, Peter W. Nienow³, Etienne Berthier⁶, Christian Vincent⁵, Patrick Wagnon⁵, Emmanuel Trouvé²



Resources

- <https://github.com/nasa-jpl/autoRIFT>
- https://gitter.im/its_live/community
- https://github.com/nasa-jpl/its_live
- <https://github.com/alex-s-gardner/ItsLive.jl>

Publications

- Gardner, A. S., Moholdt, G., Scambos, T., Fahnstock, M., Ligtenberg, S., van den Broeke, M., & Nilsson, J. (2018). Increased West Antarctic and unchanged East Antarctic ice discharge over the last 7 years. *The Cryosphere*, 12(2), 521–547. <https://doi.org/10.5194/tc-12-521-2018>
- Lei, Y., Gardner, A., & Agram, P. (2021). Autonomous Repeat Image Feature Tracking (autoRIFT) and Its Application for Tracking Ice Displacement. In *Remote Sensing* (Vol. 13, Issue 4). <https://doi.org/10.3390/rs13040749>
- Lei, Y., Gardner, A. S., & Agram, P. (2021). Processing methodology for the ITS LIVE Sentinel-1 ice velocity product. *Earth Syst. Sci. Data Discuss.*, 2021, 1–27. <https://doi.org/10.5194/essd-2021-393>
- Greene, Chad A., Alex S. Gardner, and Lauren C. Andrews. "Detecting seasonal ice dynamics in satellite images." *The Cryosphere* 14.12 (2020): 4365-4378.