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TAKING THE PULSE OF OUR PLANET FROM SPACE

Slope instability mapping in glacier forefield environments of the Alps using advanced DInSAR techniques

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Findel Glacier, Switzerland, 1999 - 2019

AlpGlacier Project Context

- Commissioned by ESA
- Part of Alps Regional Initiative (EO4ALPS)
- Consortium of partners in Austria, France and Switzerland, led by University of Zurich
- Enhanced observation capacity and hazard assessment in glacier forefields
- Assessment of glacier flow velocities, lake formation, snow cover and slope instabilities
- Use of Sentinel-1 and Sentinel-2

Methods and Data

- Advanced DInSAR (Sentinel-1)
  - Differential Interferograms
  - Multi Temporal Interferometry (MTI): Stacking and SBAS
  - Persistent Scatterer Interferometry (PSI)

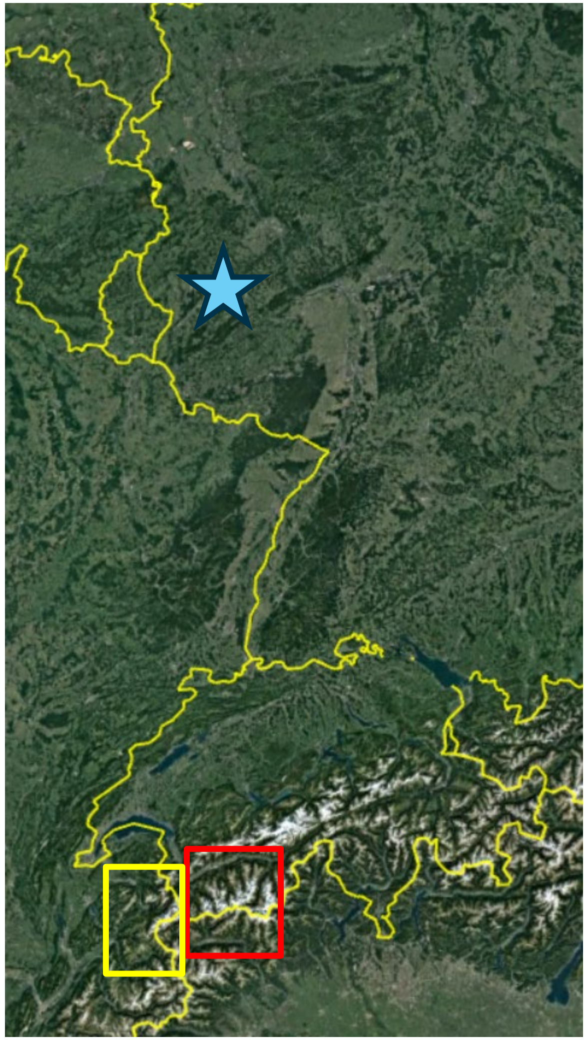
→ Slope instability mapping and classification

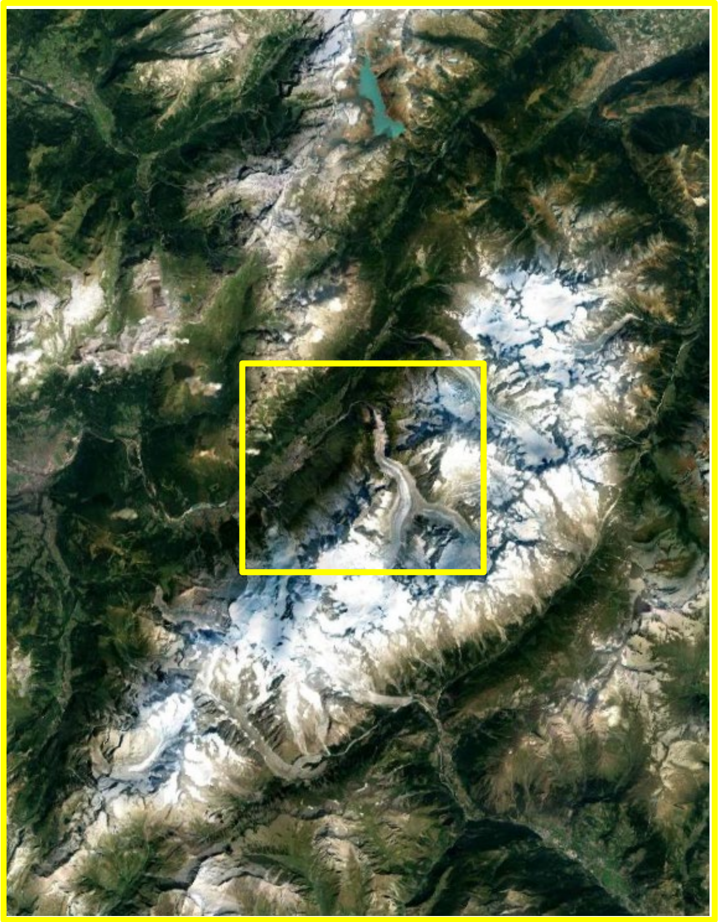
→ Time series of certain movements

Validation/Integration

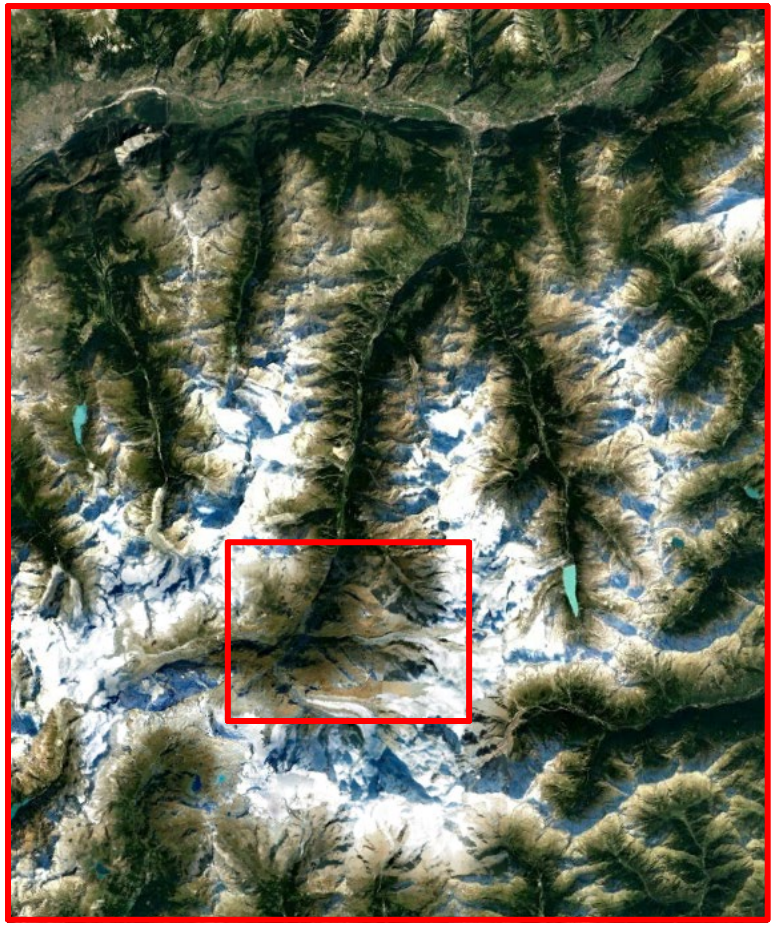
- SAR feature tracking (TerraSAR-X)
- Optical feature tracking (Sentinel-2)
- Geomorphological classification (orthophotos)

Alpine Test Sites





Mer de Glace (France)

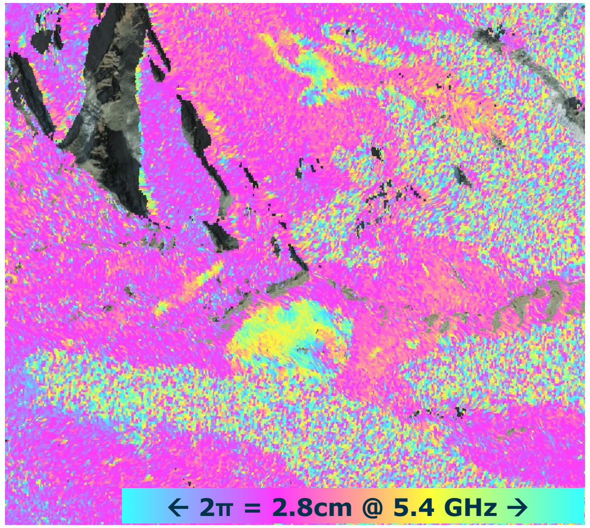


Findel Glacier (Switzerland)

Findel Glacier Region – DInSAR

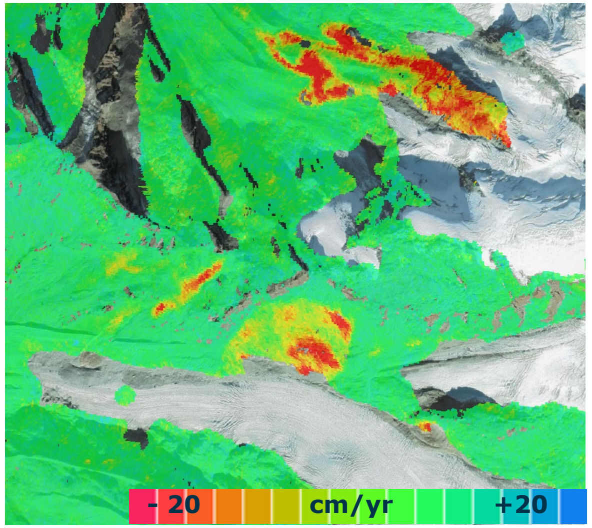
Differential interferogram (6d)

T066D 20190821 – 20190827



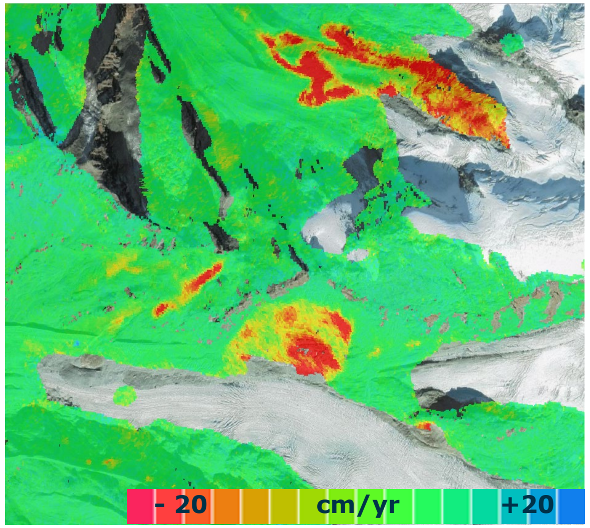
Stacking

T066D Summer 2015 – 2021



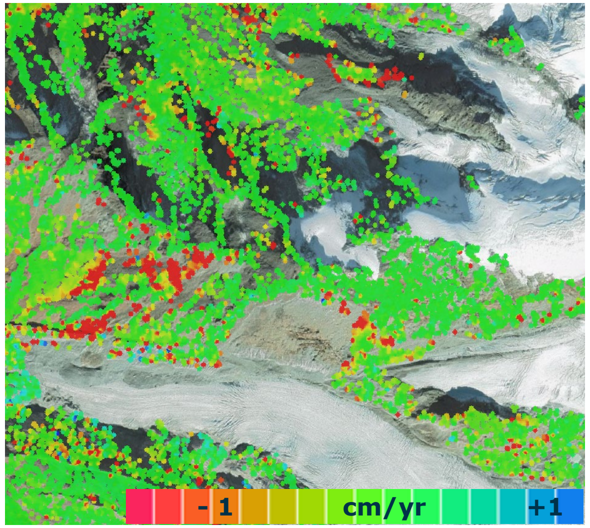
SBAS

T066D Summer 2015 – 2021



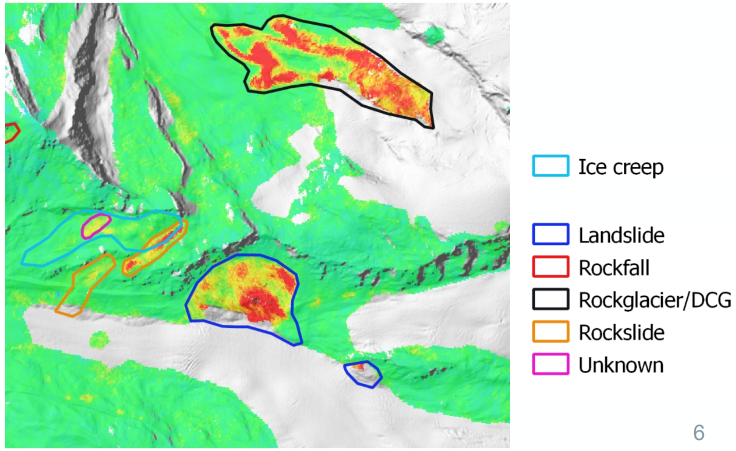
PSI

T066D Summer 2015 – 2021



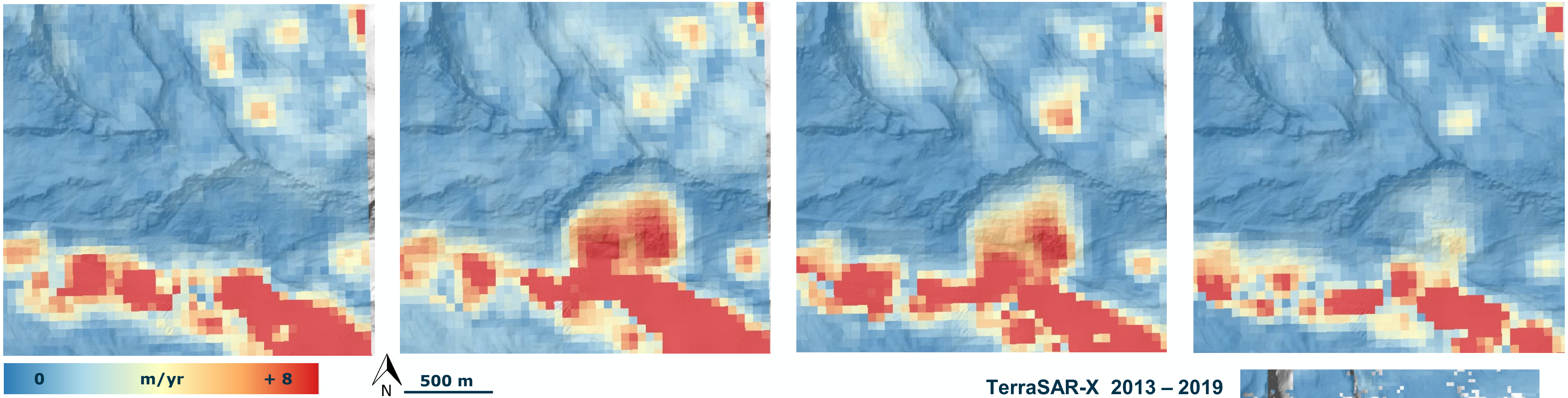
N 1 km

- Coherence relatively high in summer
- Findel Glacier slide strong signal in interferograms, stacking and SBAS
- Longer temporal baselines lead to strong decorrelation
- Identification of slides, rockfalls, rock glaciers and slower slope deformations (PSI)

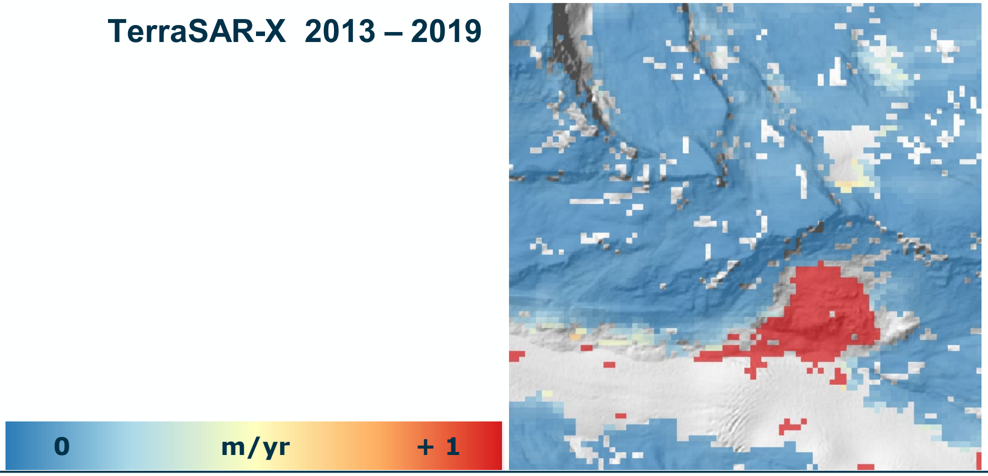


Findel Glacier Region – Feature Tracking

Sentinel-2 20160701 – 20170631 | 20170701 – 20180631 | 20180701 – 20190631 | 20190701 – 20200631

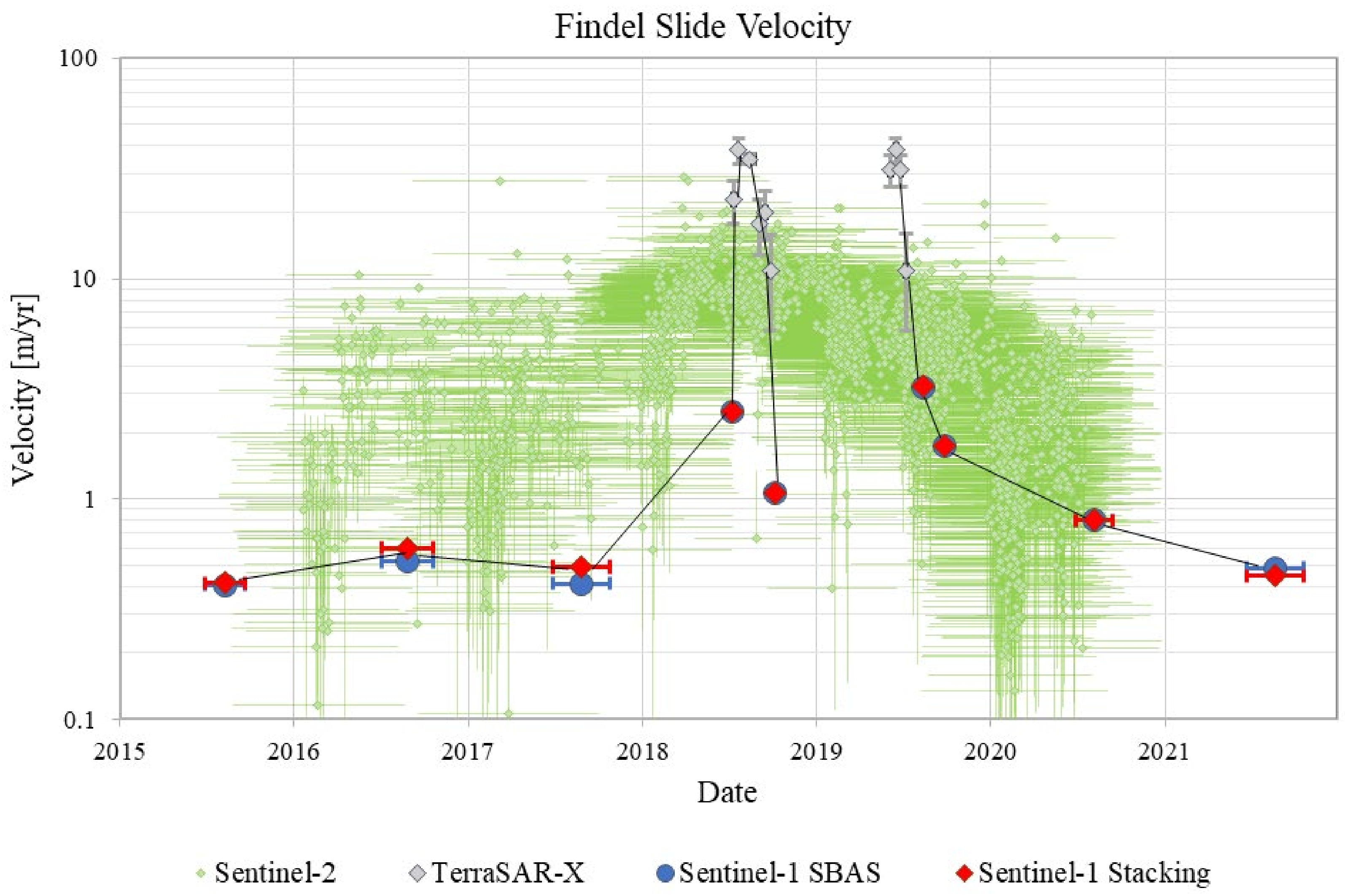


TerraSAR-X 2013 – 2019



- Findel Glacier slide strong signal in SAR and optical tracking
- Sentinel-2 clearly shows acceleration in 2018 and 2019
- TerraSAR-X strong signal likely biased by acceleration
- Thanks to IGE, Grenoble

Findel Glacier Slide Time Series

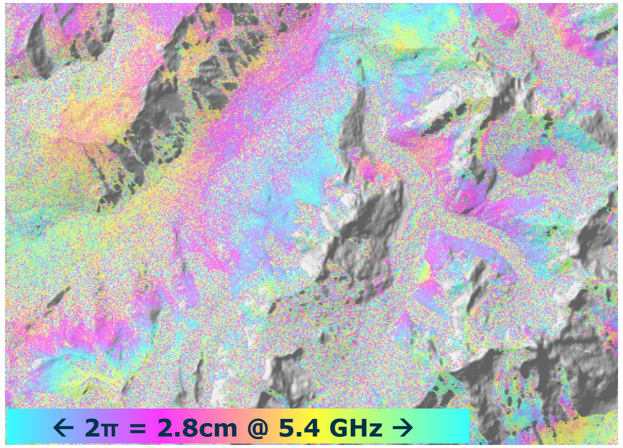


Mer de Glace Region – DInSAR

AlpGlacier esa

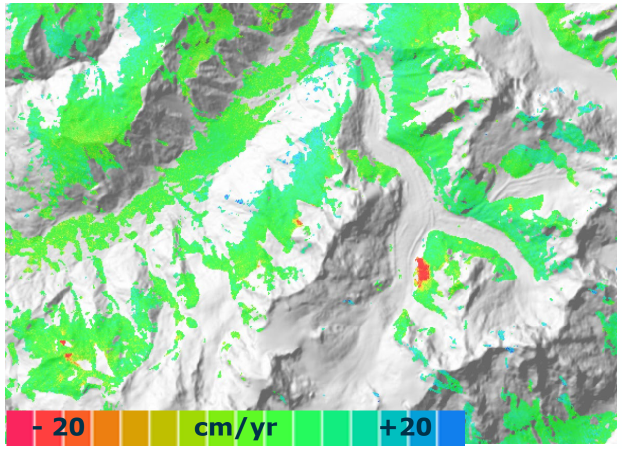
Differential interferogram (6d)

T139D 20180825 – 20180831



Stacking

T139D Summer 2015 – 2021

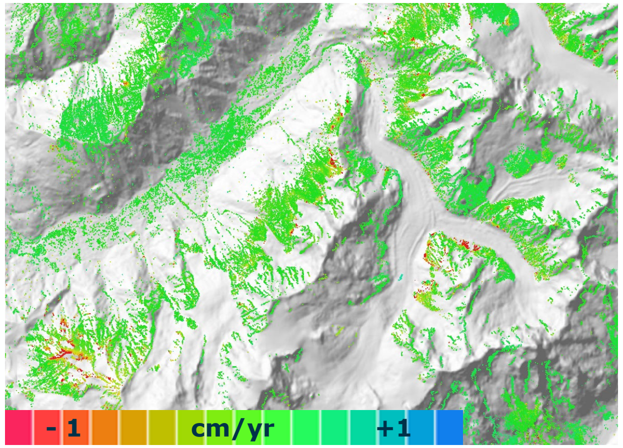


PSI

N

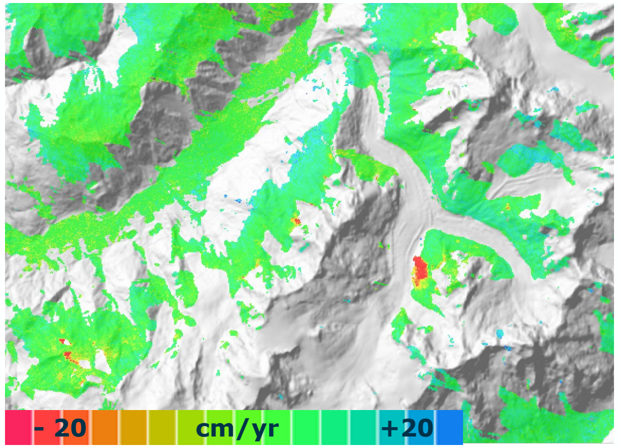
2 km

T139D Summer 2015 – 2021

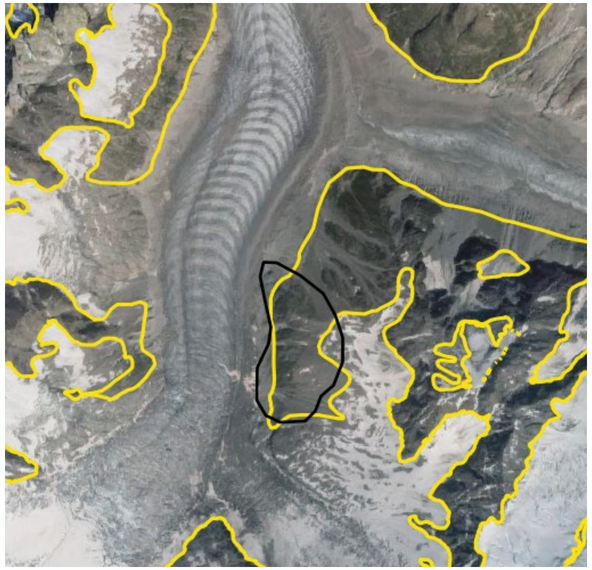


SBAS

T139D Summer 2015 – 2021

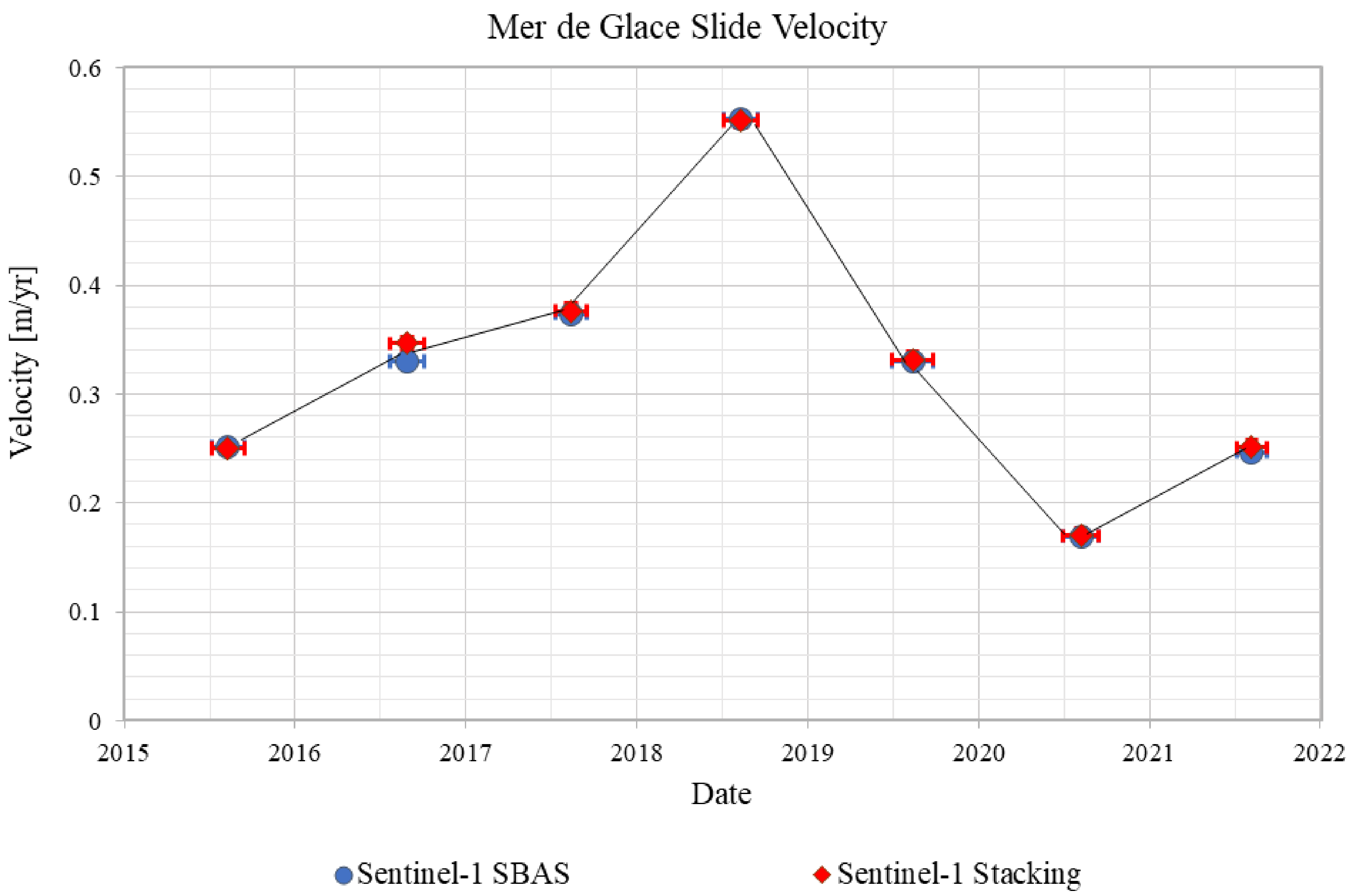


- Overall low coherence due to extensive snow cover
- Mer de Glace slide strong signal in stacking and SBAS
- Longer temporal baselines lead to strong decorrelation
- Identification of slides, rock glaciers



500 m

Mer de Glace Slide Time Series



Uncertainty and Considerations

- Highly dependent on sensor characteristics (wavelength, baselines, resolution, etc.)
- Accuracy of approx. 1-2 cm/yr for stacking and SBAS
- Accuracy of approx. 1-2 mm/yr for PSI

- Geometric distortions (layover and shadowing) and no data areas

- Low coherence due to snow, ice and vegetation
- Data gaps in winter due to extensive snow cover

- Limited detectable velocities and movement directions (1D LOS displacement)
- Approx. 30-80 cm/yr for differential interferograms, stacking and SBAS
- Approx. 5 cm/yr for PSI

Conclusions and Outlook

- DInSAR techniques are well suited to detect slope instabilities in glacier forefield environments
- Good foundation for mapping and classification
- Limitations can be partly overcome through use of validation methods/other sensors

- Completion of classification into activity class and hazard
- Apply to third test site: Oetztal in Austria

Thank you

References

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Uncertainty

Method	Atmospheric Error	Noise Error	Estimated Error / Accuracy	Standard Deviation	Maximum detectable velocity	Majority of detectable velocity
Standard DInSAR (6-days temporal baseline)	7 mm	1-2 mm	c. 40 cm/y	N/A	λ/4 = 84 cm/year	N/A
Standard DInSAR (24-days temporal baseline)	7 mm	1-2 mm	c. 10 cm/y	N/A	λ/4 = 21 cm/y	N/A
Stacking	p/2 / 5-6 mm	1-2 mm	c. 1-2 cm/y	c. 2.7 cm/y	35-70 cm/y	±10 cm/y
SBAS	p/2 / 5-6 mm	1-2 mm	c. 1-2 cm/y	c. 4 cm/y	20-50 cm/y	±10 cm/y
PSI	p/2 / 5-6 mm	1-2 mm	1-1.8 mm/y	0.6-0.7 mm/y	5 cm/y	±3 mm/y

Strozzi et al., 2018 ; Crosetto et al., 2016

Findel Glacier Slide Historic Time Series