

# REMOTE SENSING OF CRYOSPHERIC HAZARDS



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*University of Oslo*



Glaciers\_cci  
CCI+ Permafrost  
GlobPermafrost



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# Method matrix

	Landslides	Permafrost subsidence, heave, creep	Snow avalanches	Lake outbursts, floods	Glacier instabilities	Rock/ice avalanches
Image interpretation, change detection (ground-, air-, space-borne)		→ <i>expert assessment</i>				
Automatic classification, change detection (ground-, air-, space-borne)			→ <i>(repeat) mapping</i>			
Stereo techniques (ground-, air-, space-borne)		→ <i>elevation (change)</i>				
Offset tracking (ground-, air-, space-borne)		→ <i>lateral movement</i>				
Radar interferometry (ground-, air-, space-borne)		→ <i>line-of-sight movement</i>				
Altimetry, laserscanning (ground-, air-, space-borne)		→ <i>elevation (change)</i>				

Aletsch Glacier / Swiss Alps



ISS

# Aletsch Glacier / Swiss Alps



ca. 1900

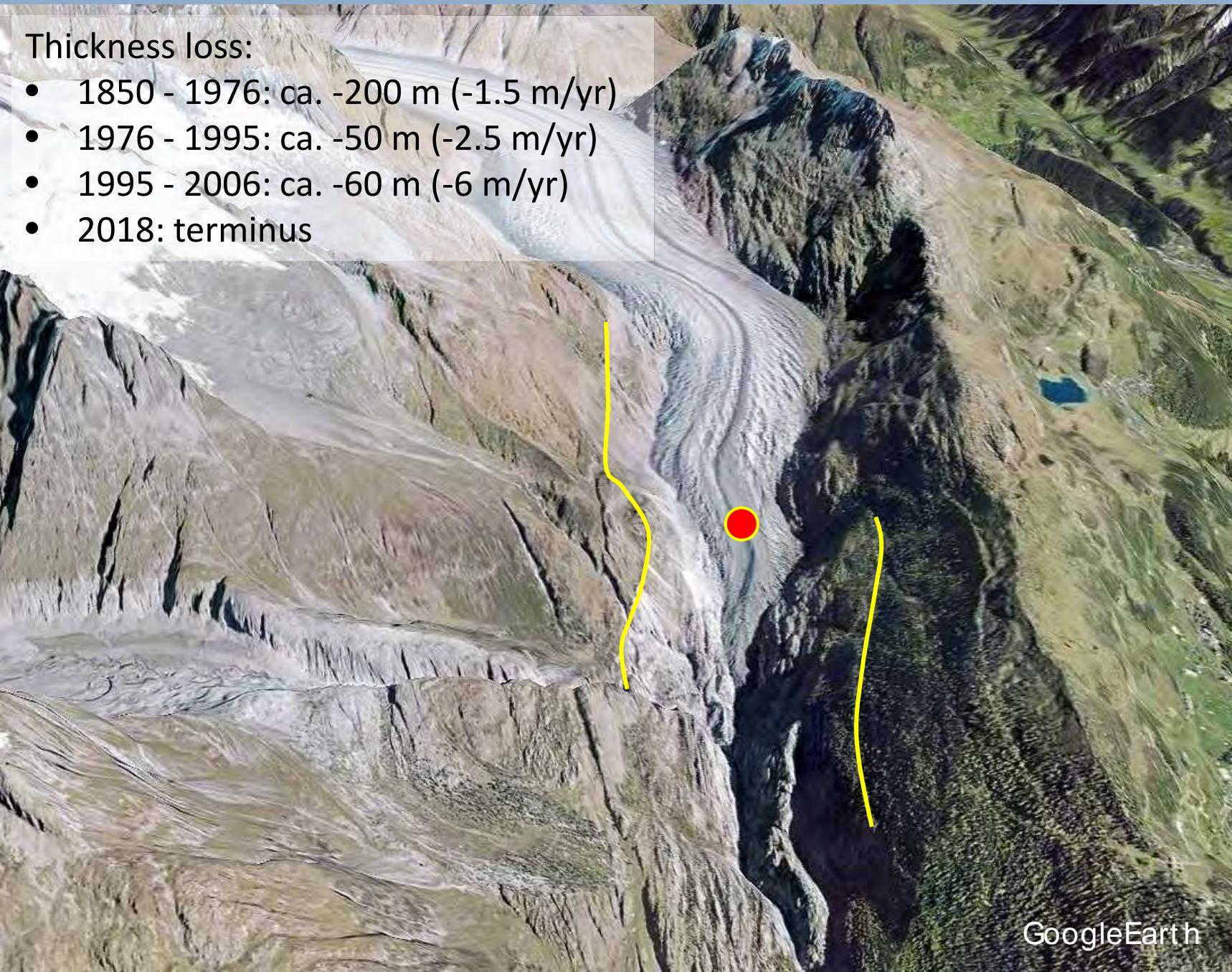


2005

# Aletsch Glacier / Swiss Alps

Thickness loss:

- 1850 - 1976: ca. -200 m (-1.5 m/yr)
- 1976 - 1995: ca. -50 m (-2.5 m/yr)
- 1995 - 2006: ca. -60 m (-6 m/yr)
- 2018: terminus

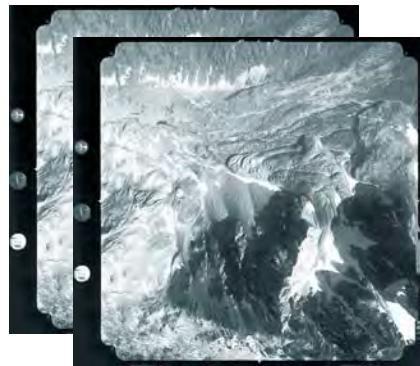


GoogleEarth

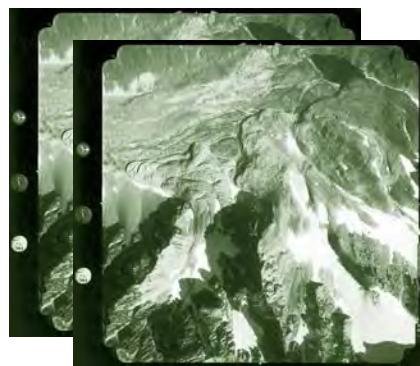
## Rock mass movement / Aletsch Glacier



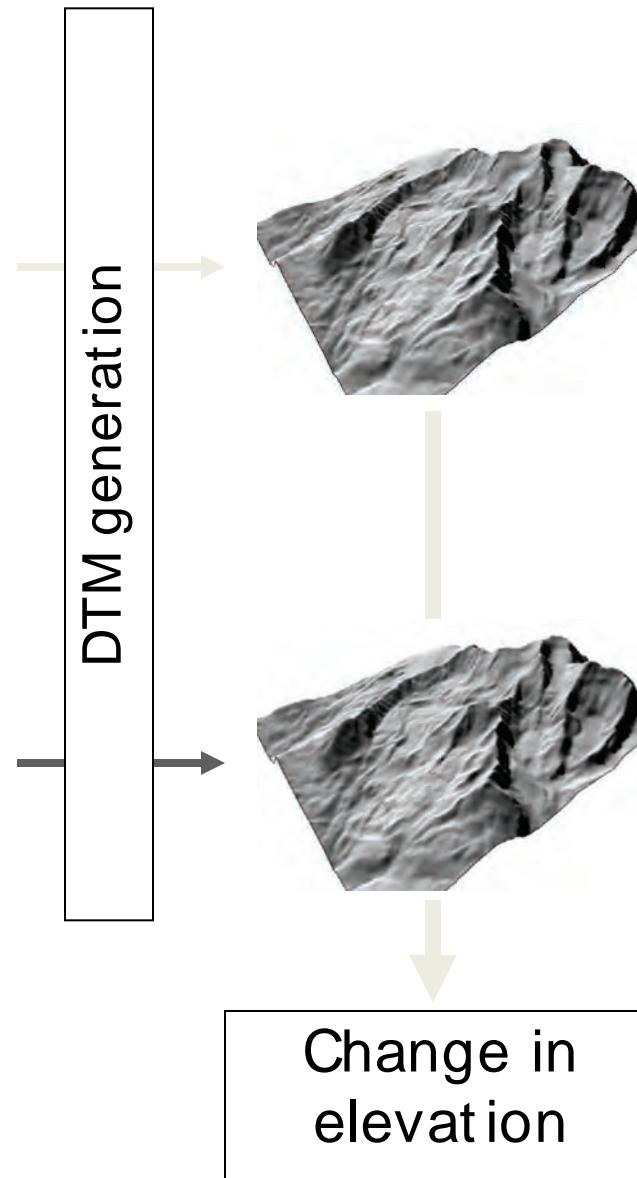
# Multitemporal digital photogrammetry



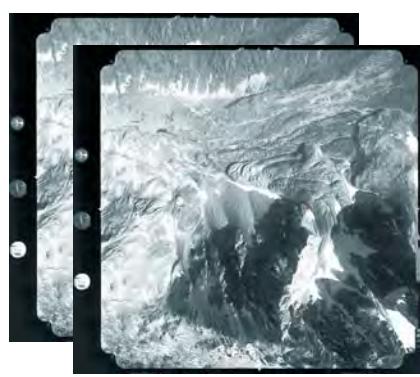
Time 1



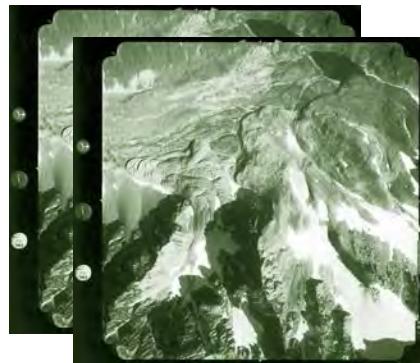
Time 2



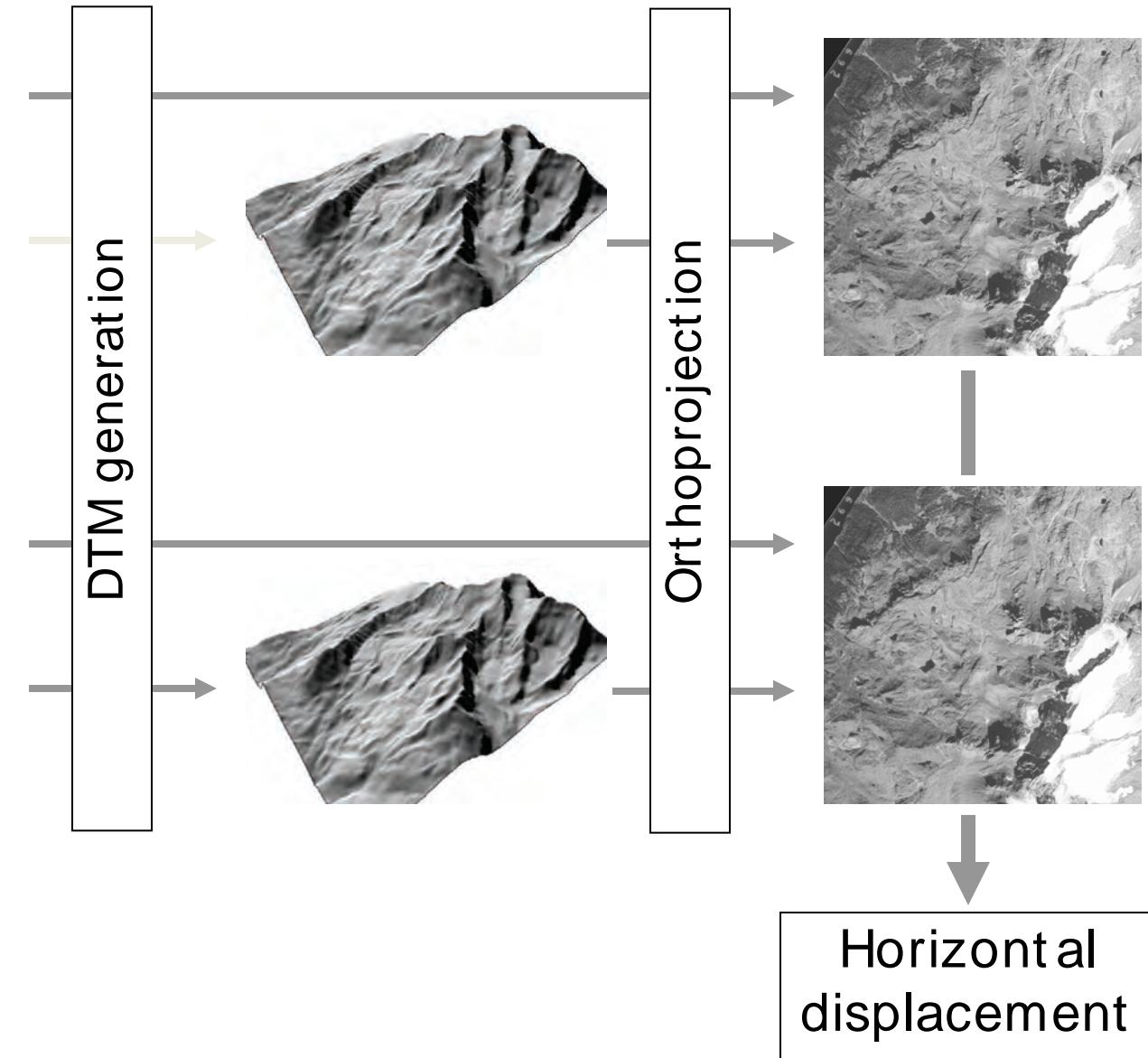
# Multitemporal digital photogrammetry

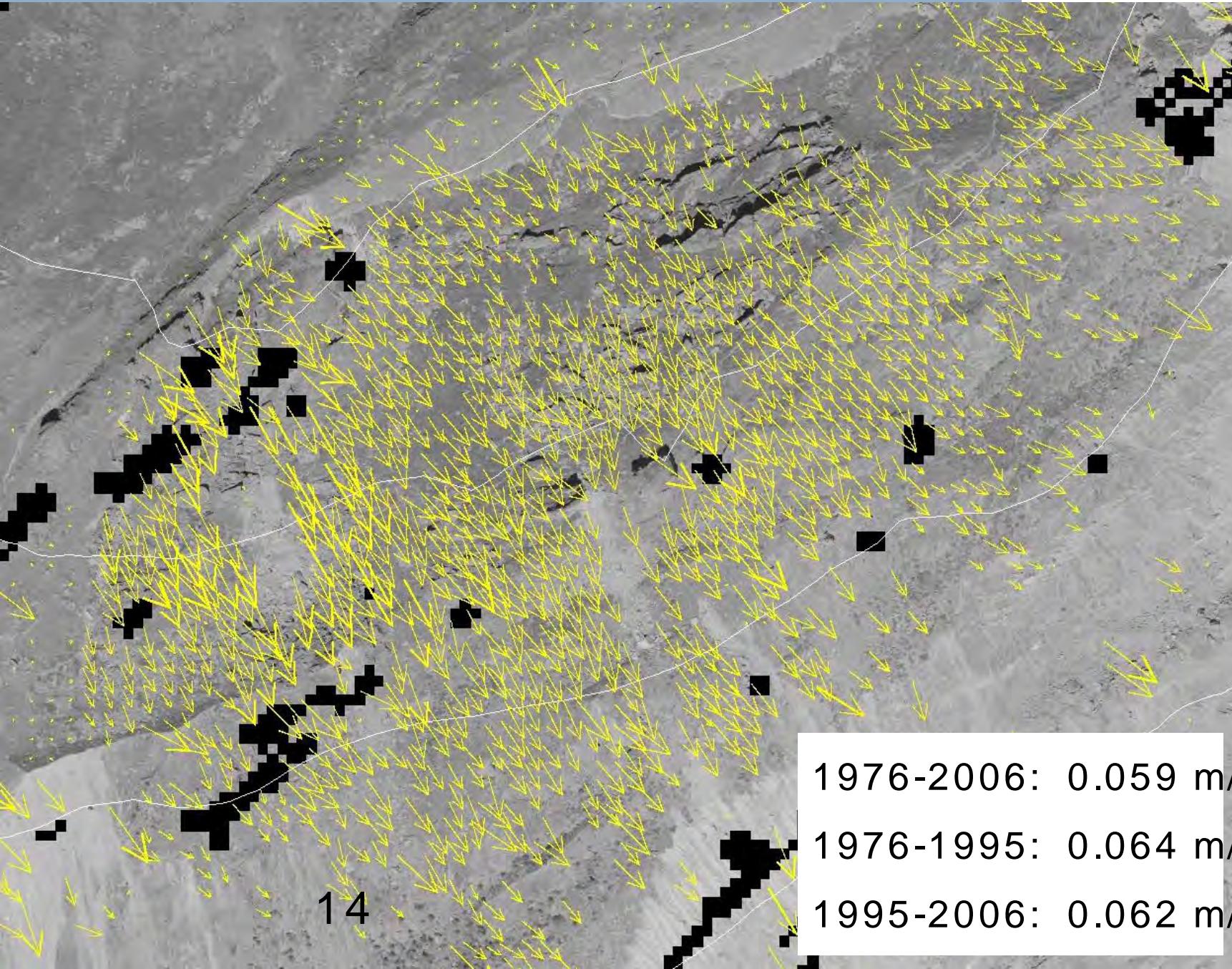


Time 1



Time 2







1976



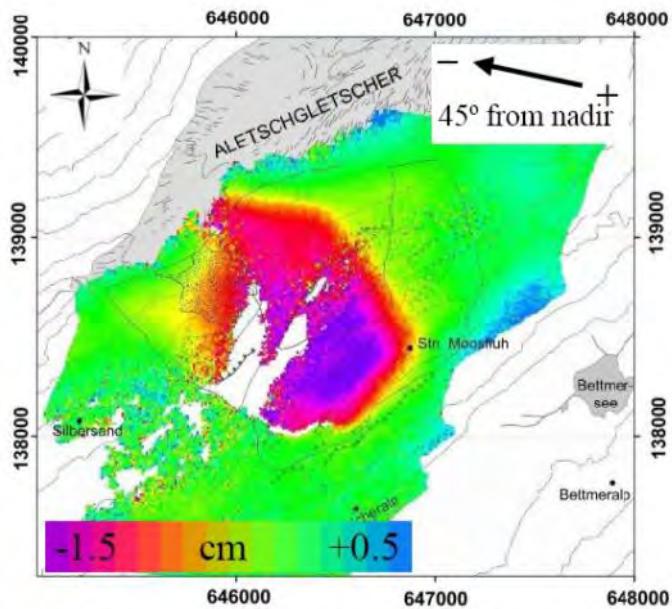
2006

Aletsch Glacier / Swiss Alps

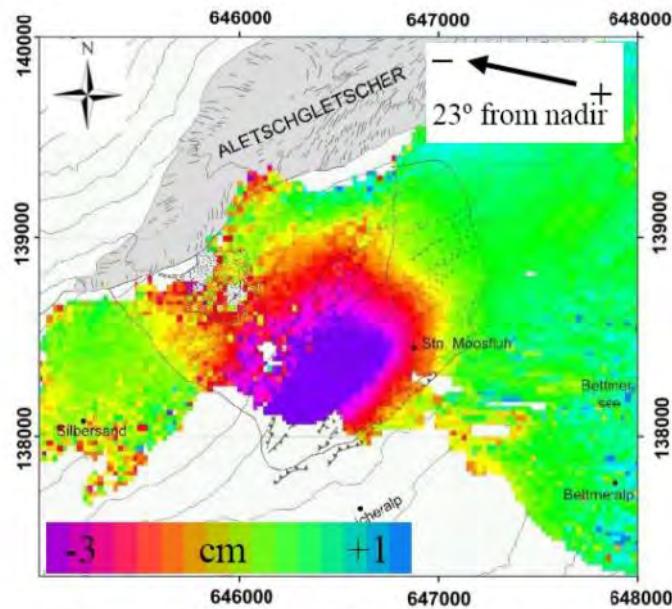


GoogleEarth

# SAR interferometry

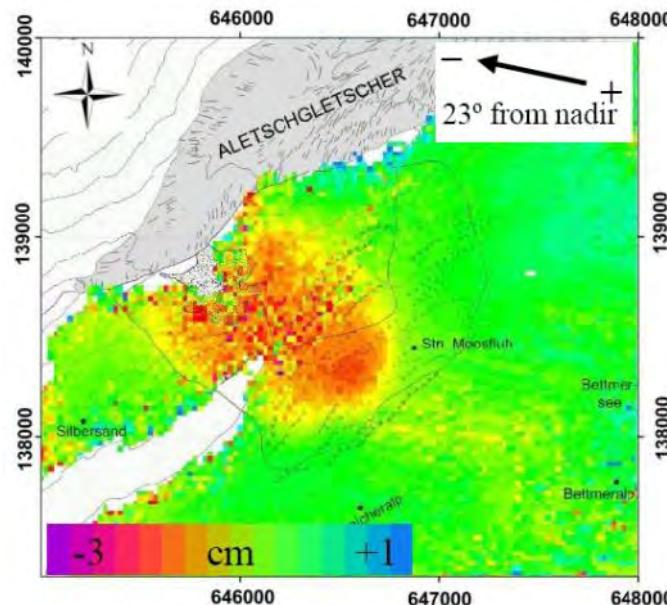


(e) TerraSAR-X 20080822\_20080913

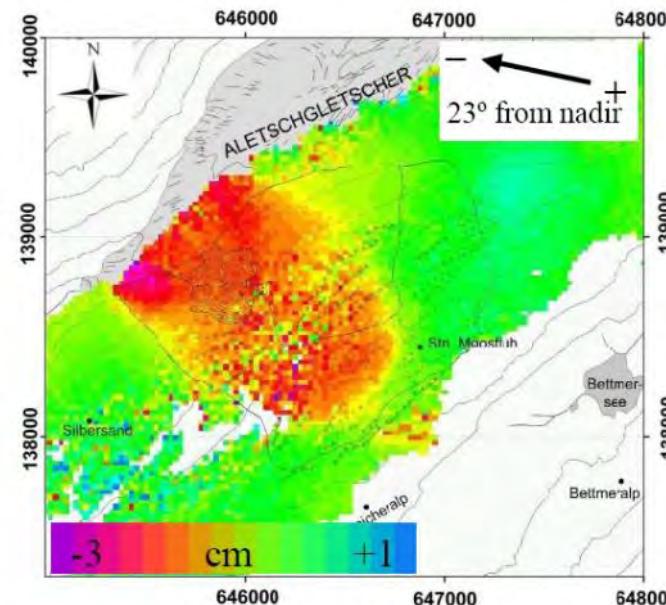


(f) ERS SAR 19950811\_19960726

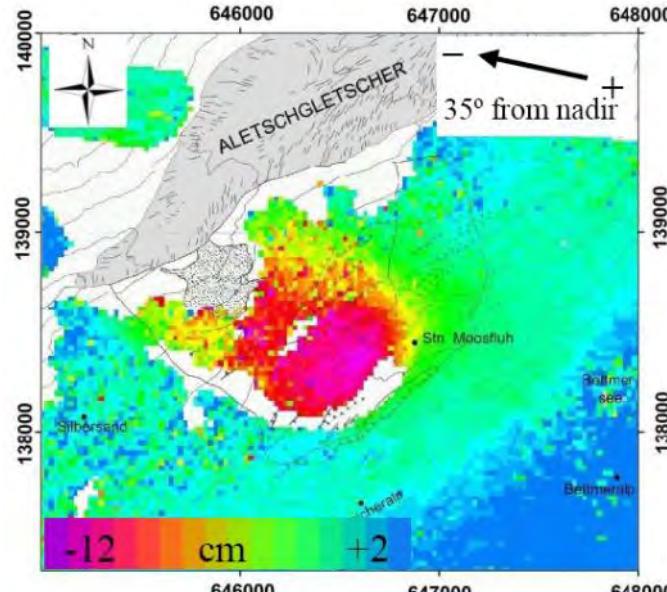
# SAR interferometry



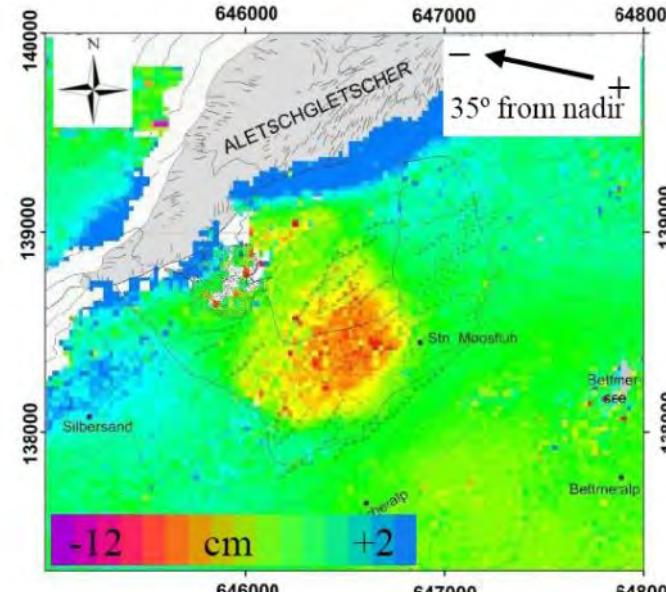
(a) ERS SAR 19921006\_19930921



(b) ENVISAT ASAR 20070629\_20070803



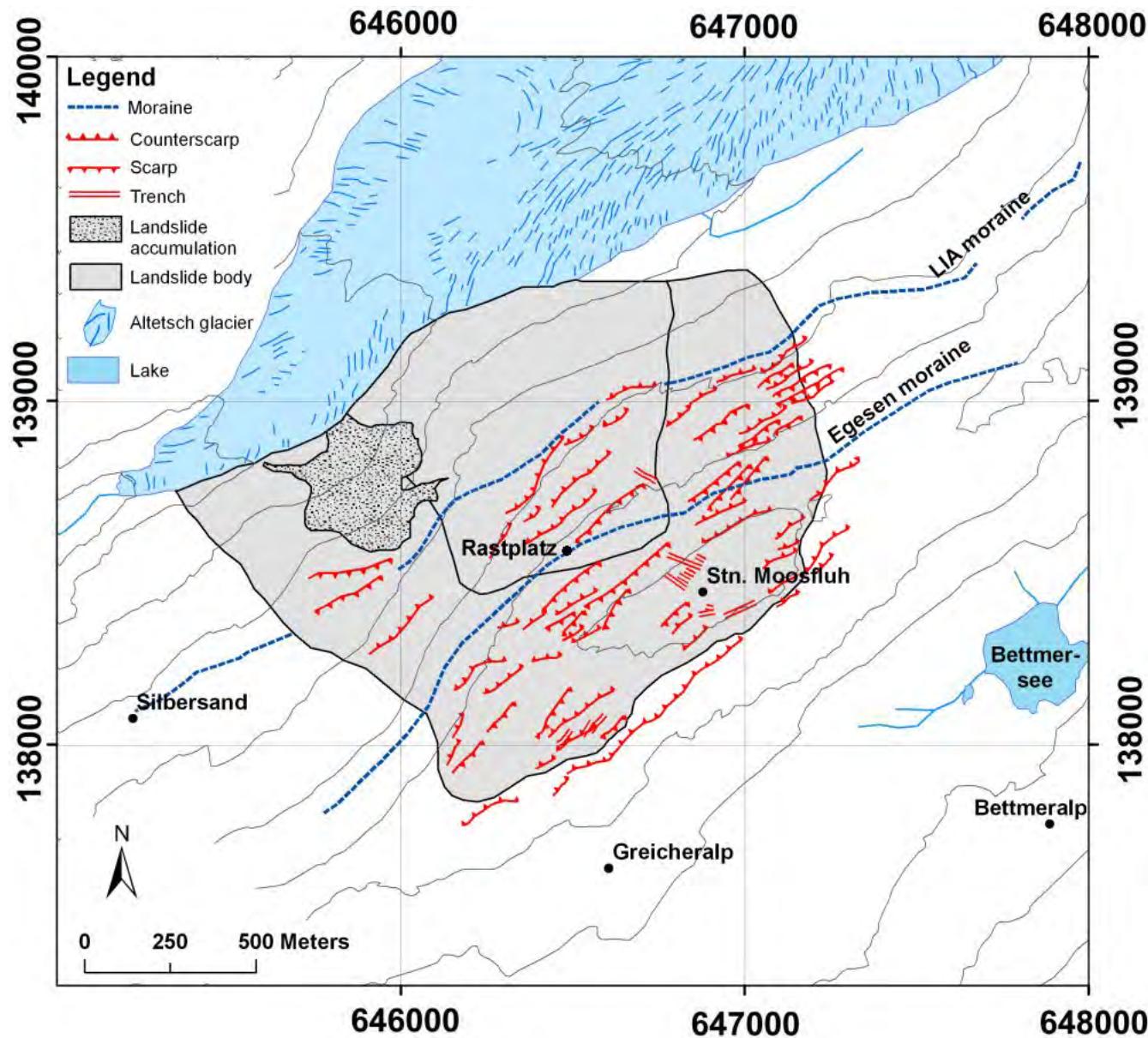
(c) JERS SAR 19930617\_19960804

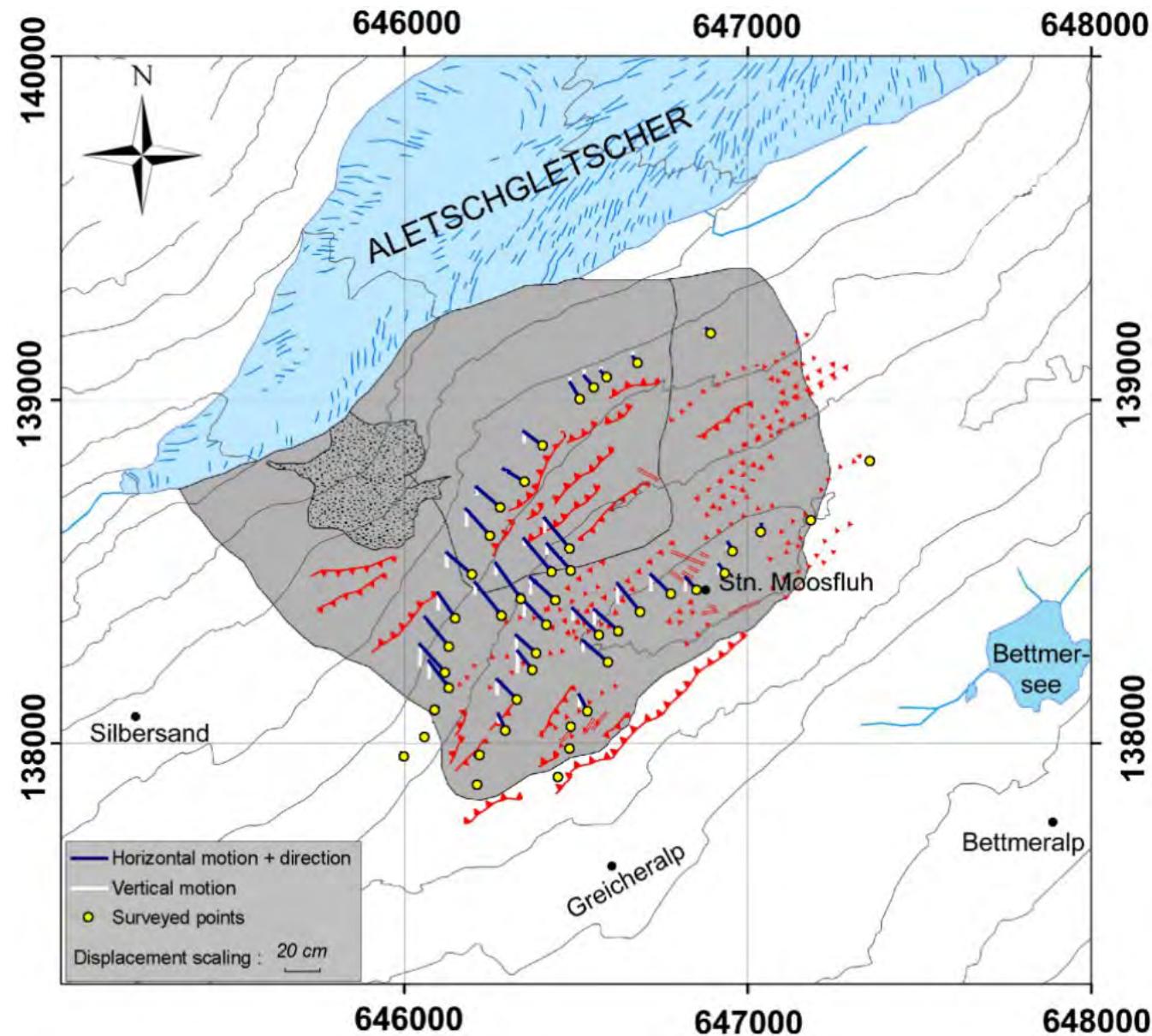


(d) ALOS PALSAR. 20060613\_20061029

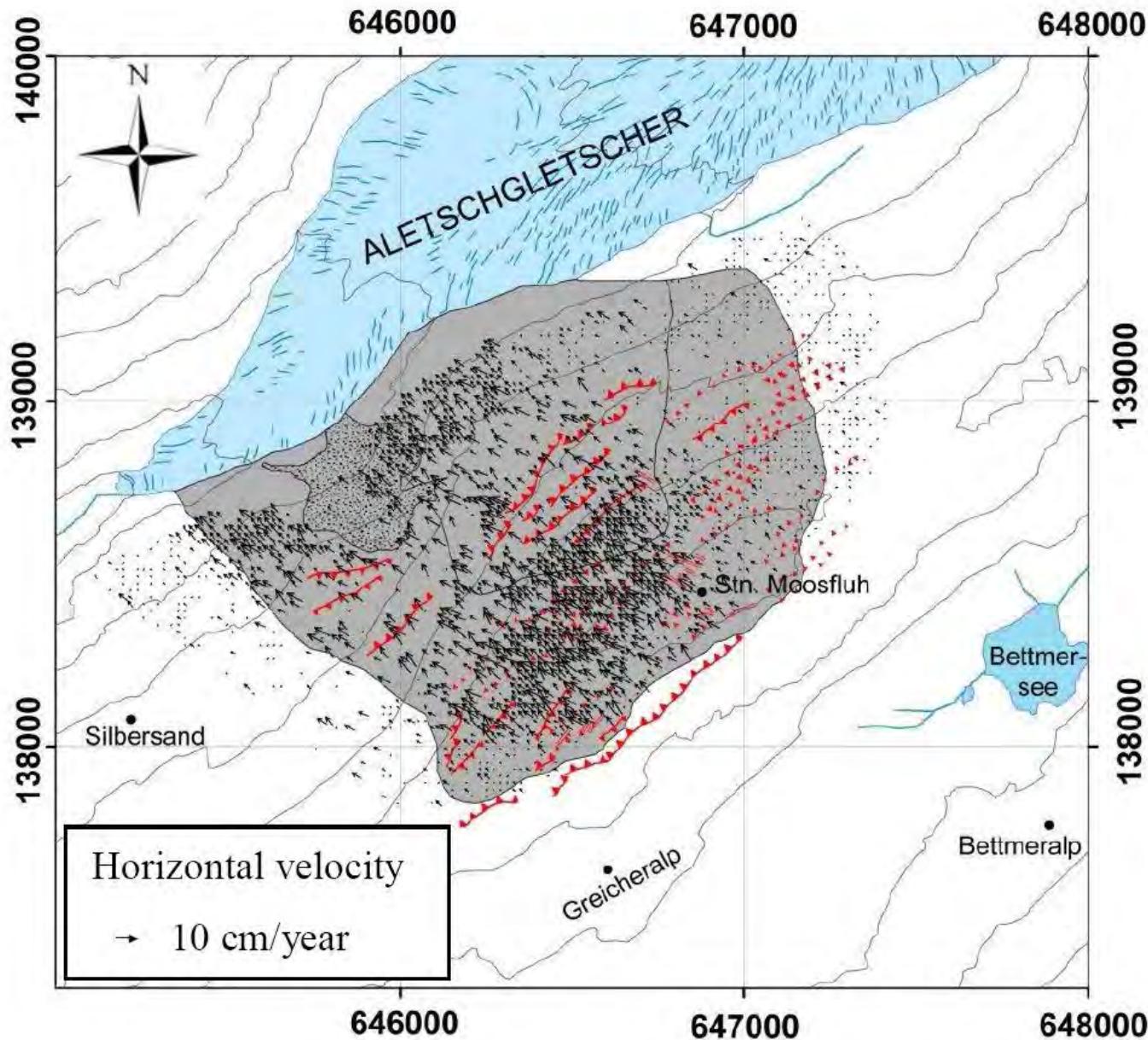
Strozzi et al.

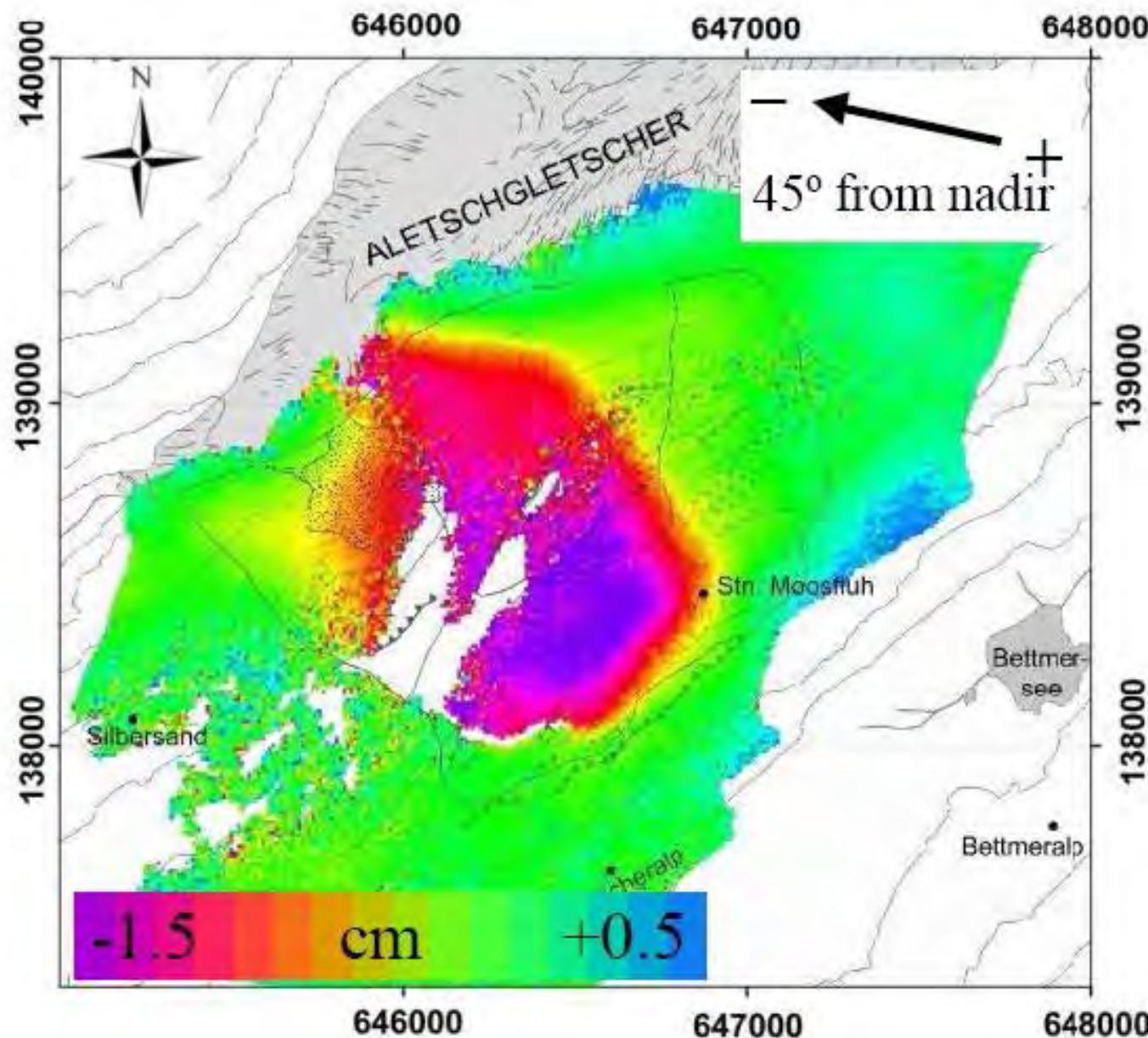
# Mapping





# Multitemporal digital photogrammetry (1976-2006)

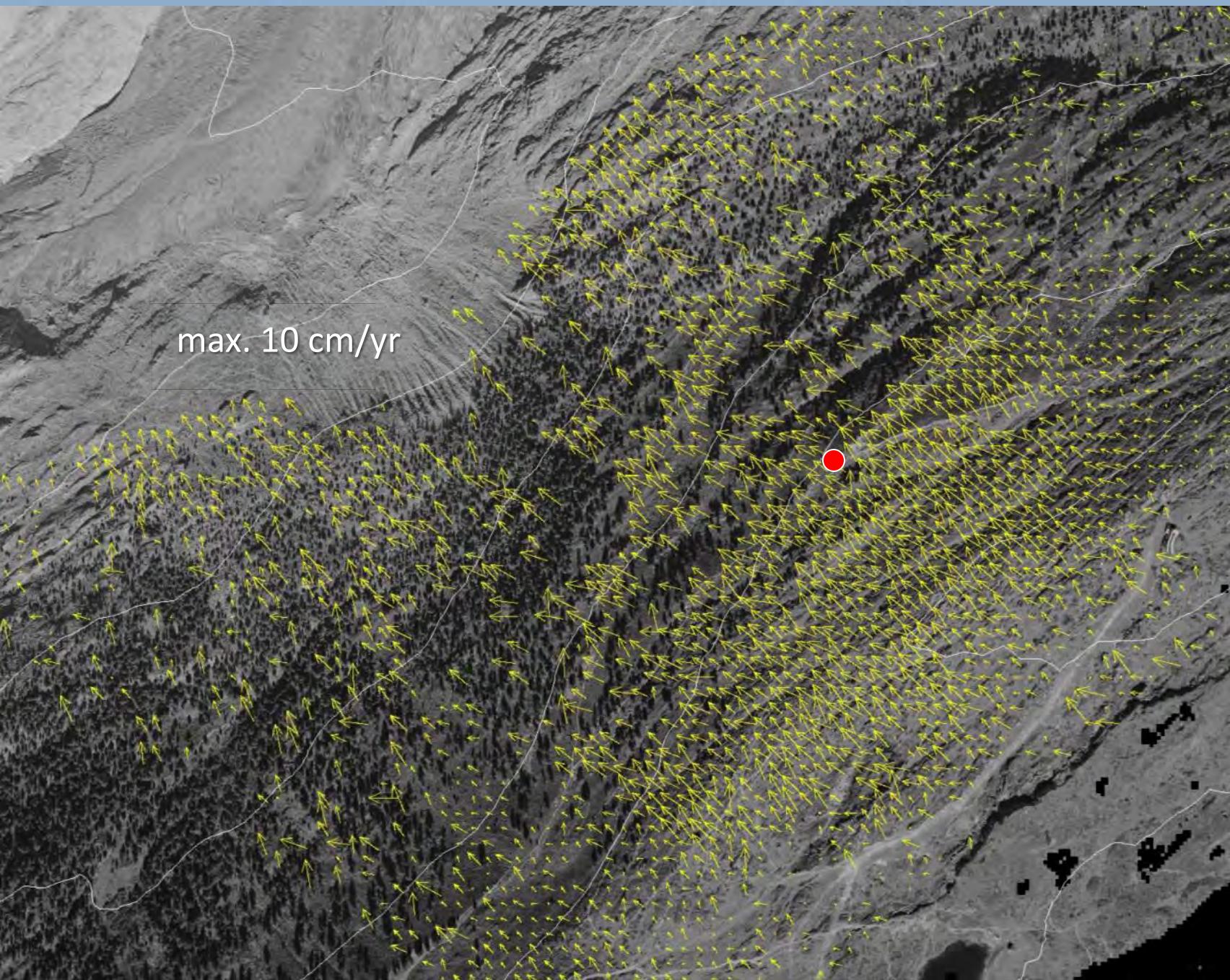




(e) TerraSAR-X 20080822\_20080913

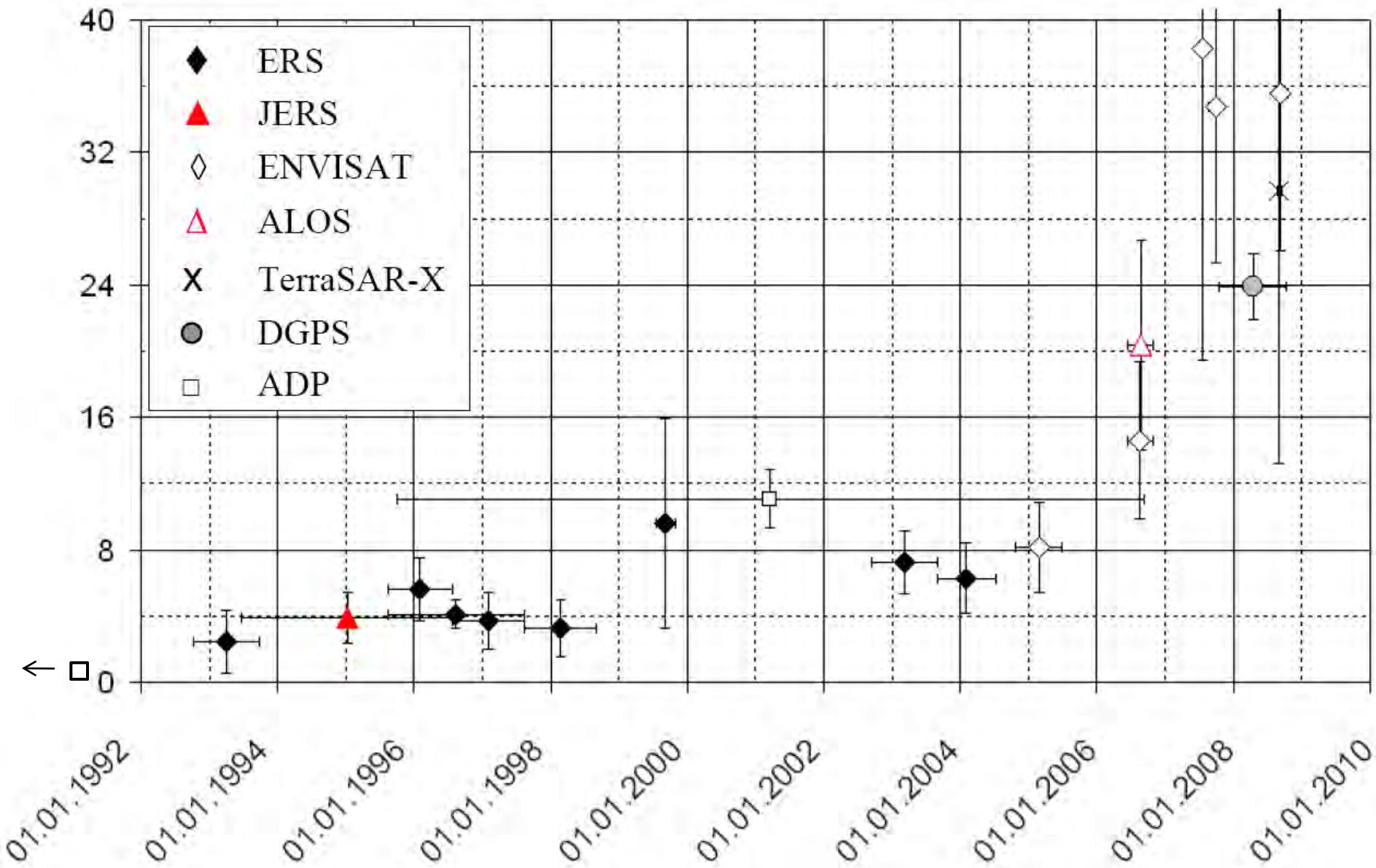
Strozzi et al.

# Multitemporal digital photogrammetry (1976-2006)

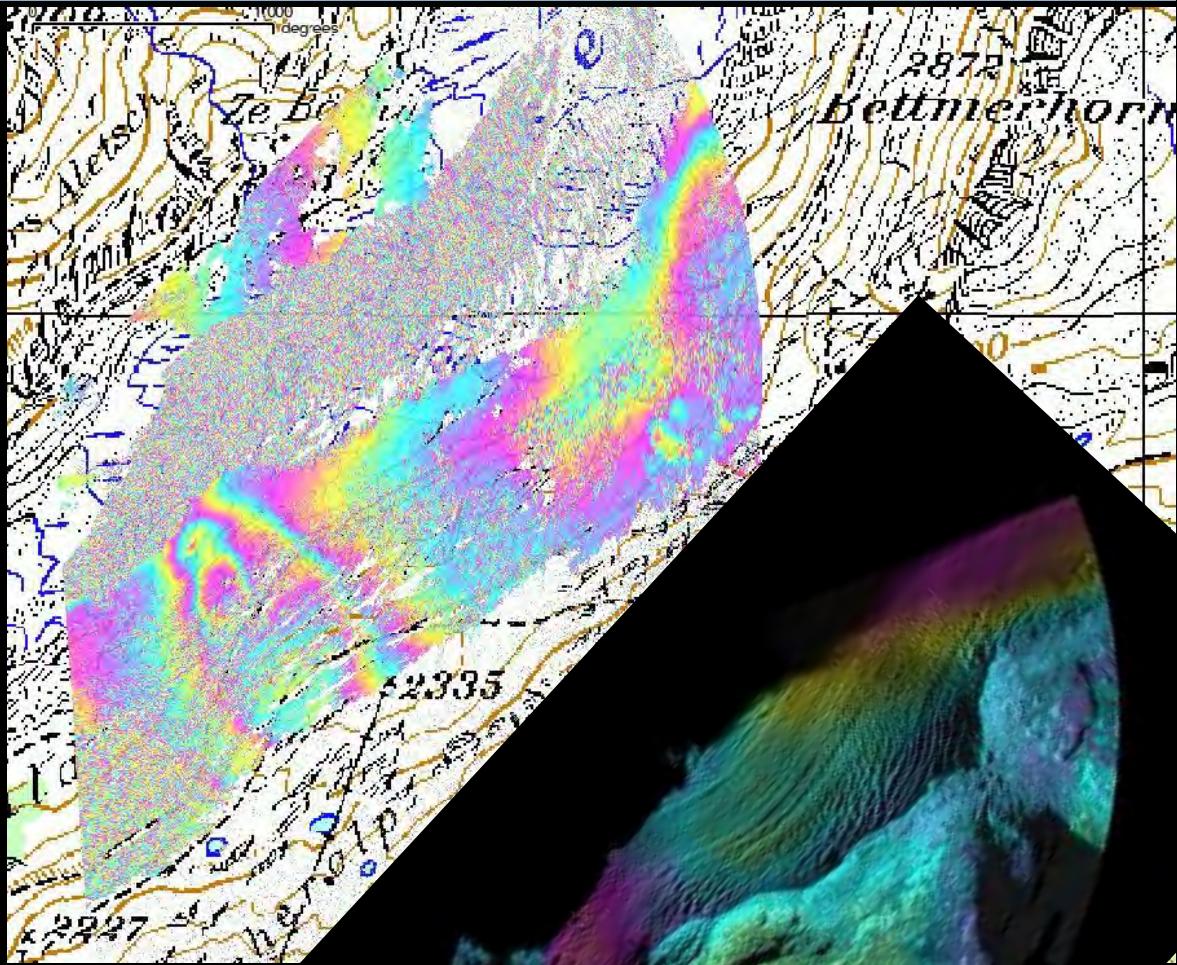


# Combination ("Rastplatz")

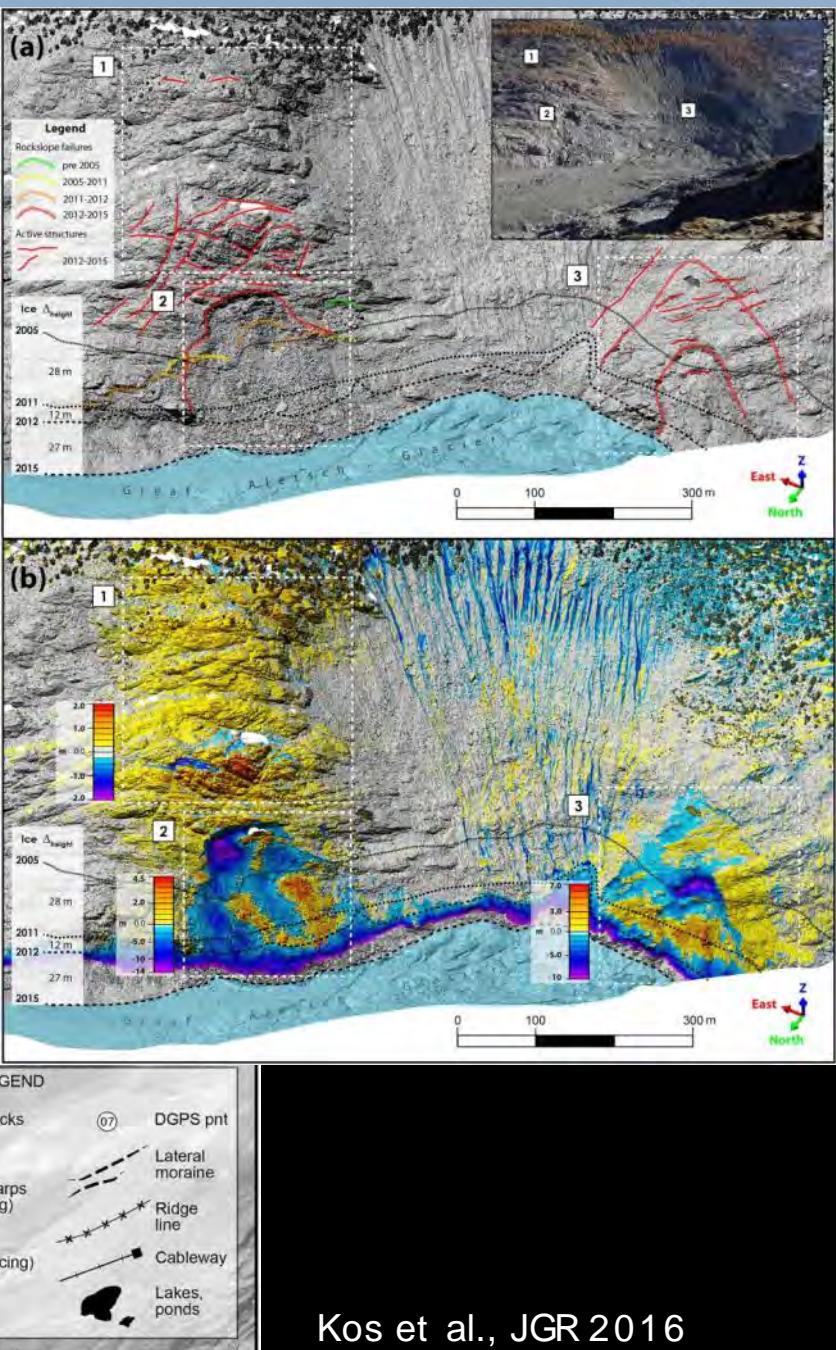
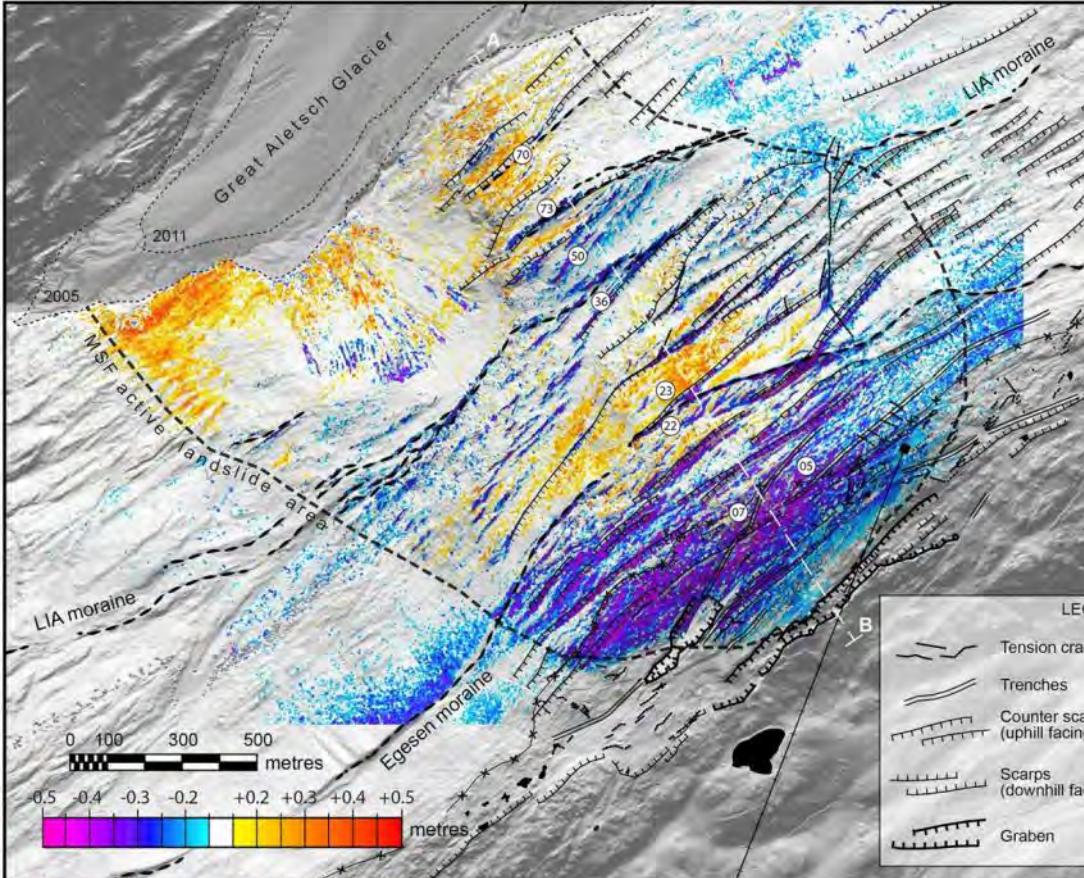
[cm/year]



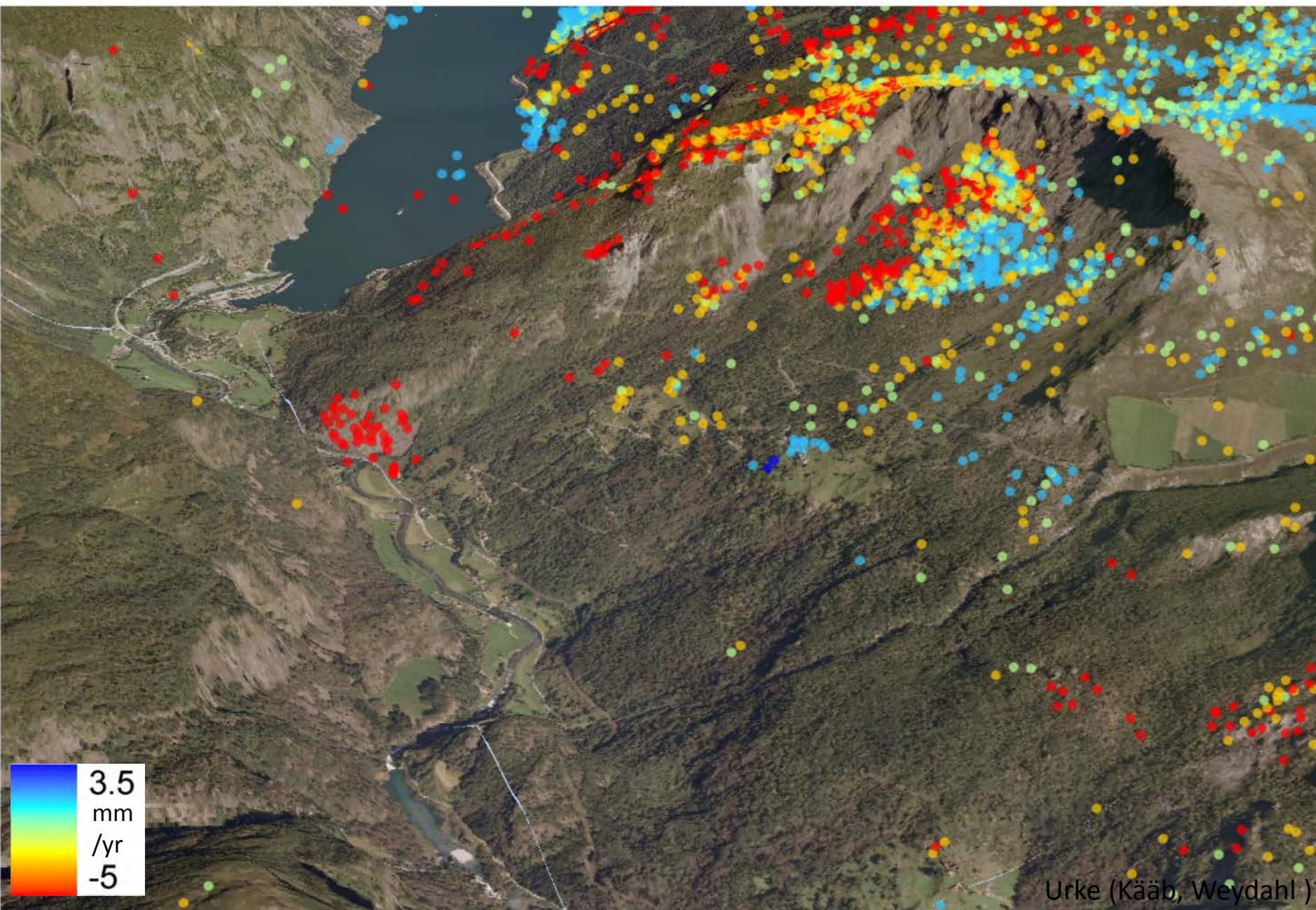
# Rock mass movement / Aletsch Glacier / Ground-based radar

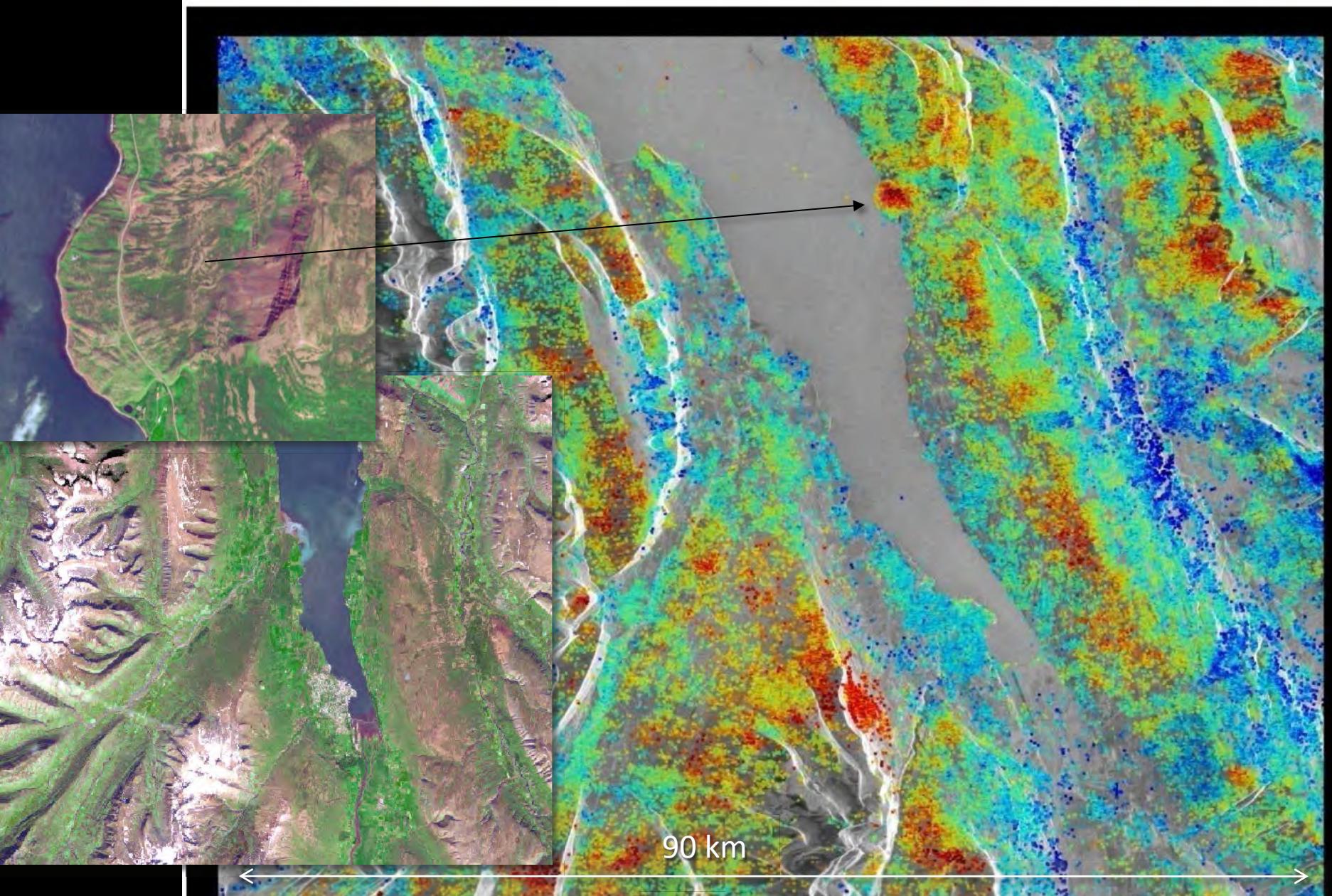


# Rock mass movement / Aletsch Glacier / Airborne + terrestrial laser



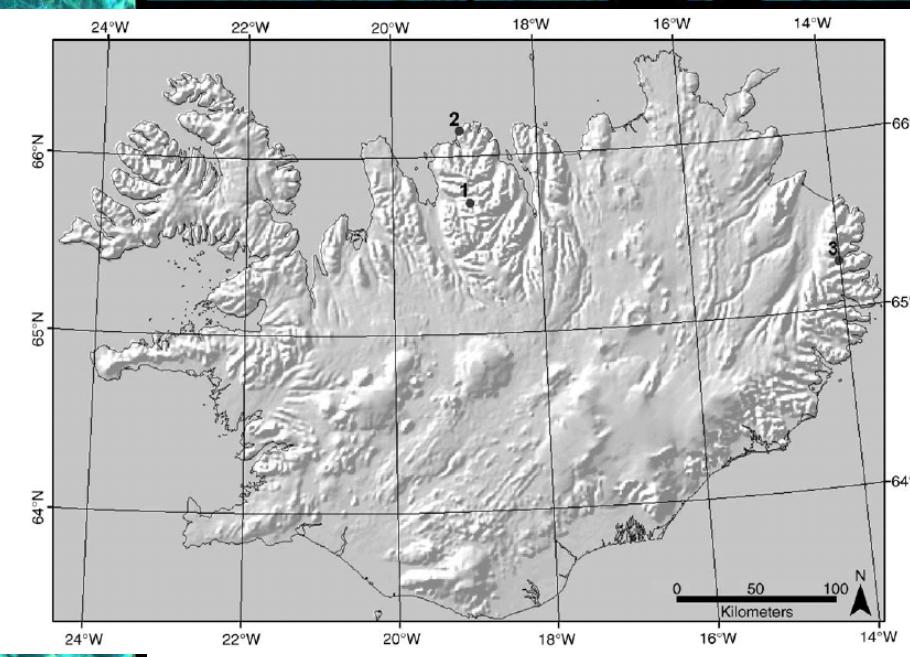
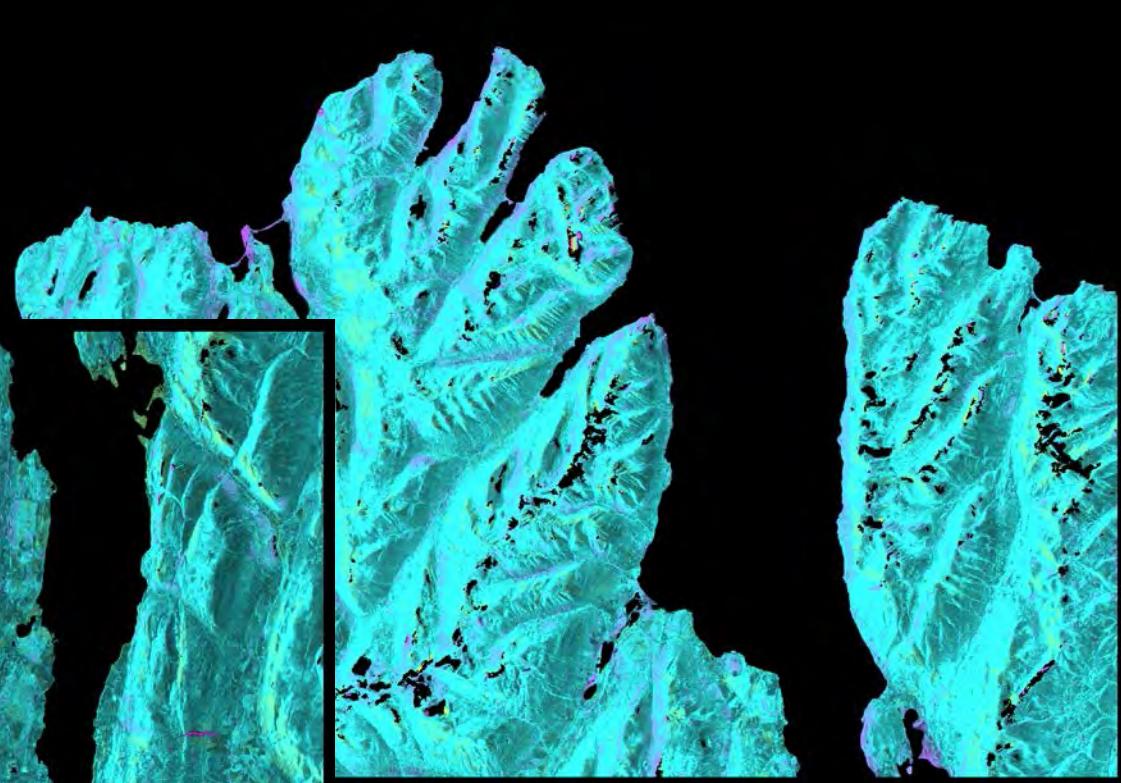
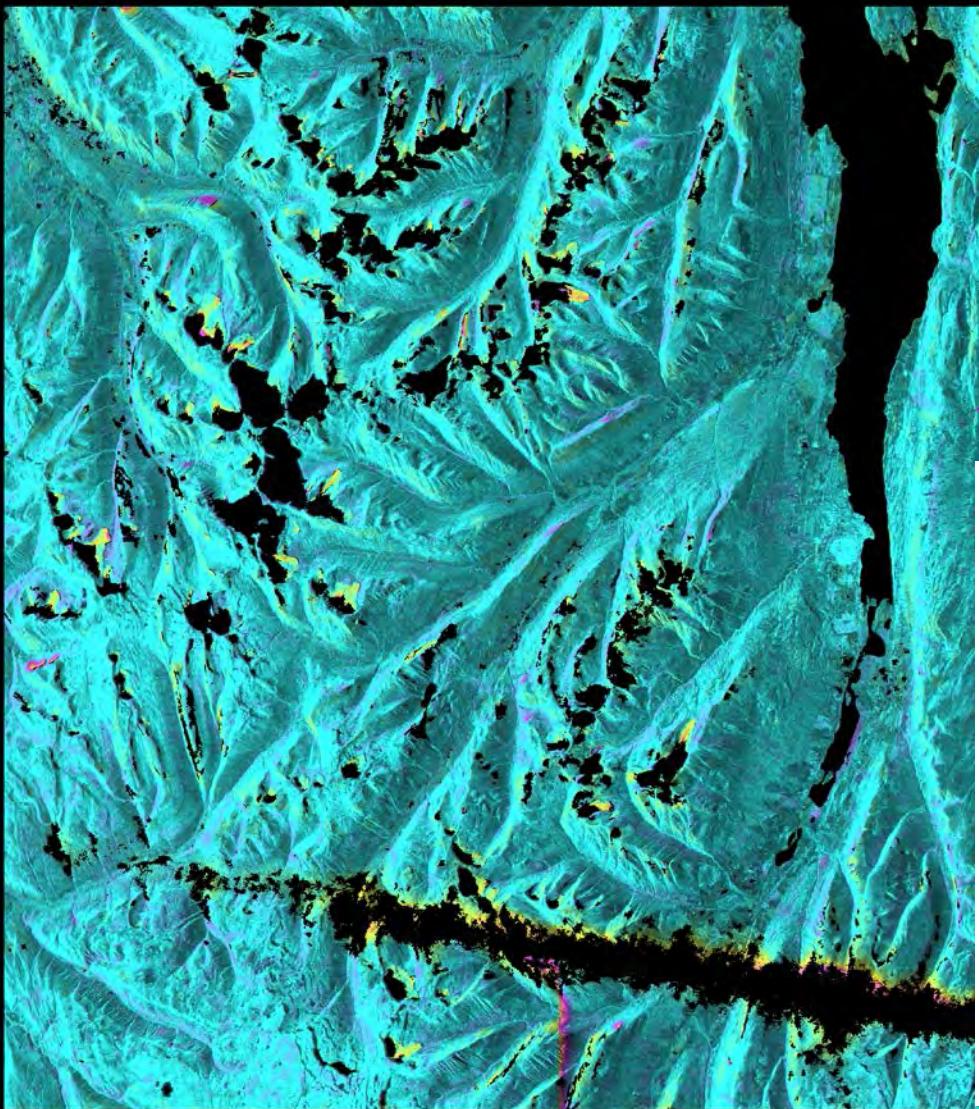
# Persistent scatterer SAR





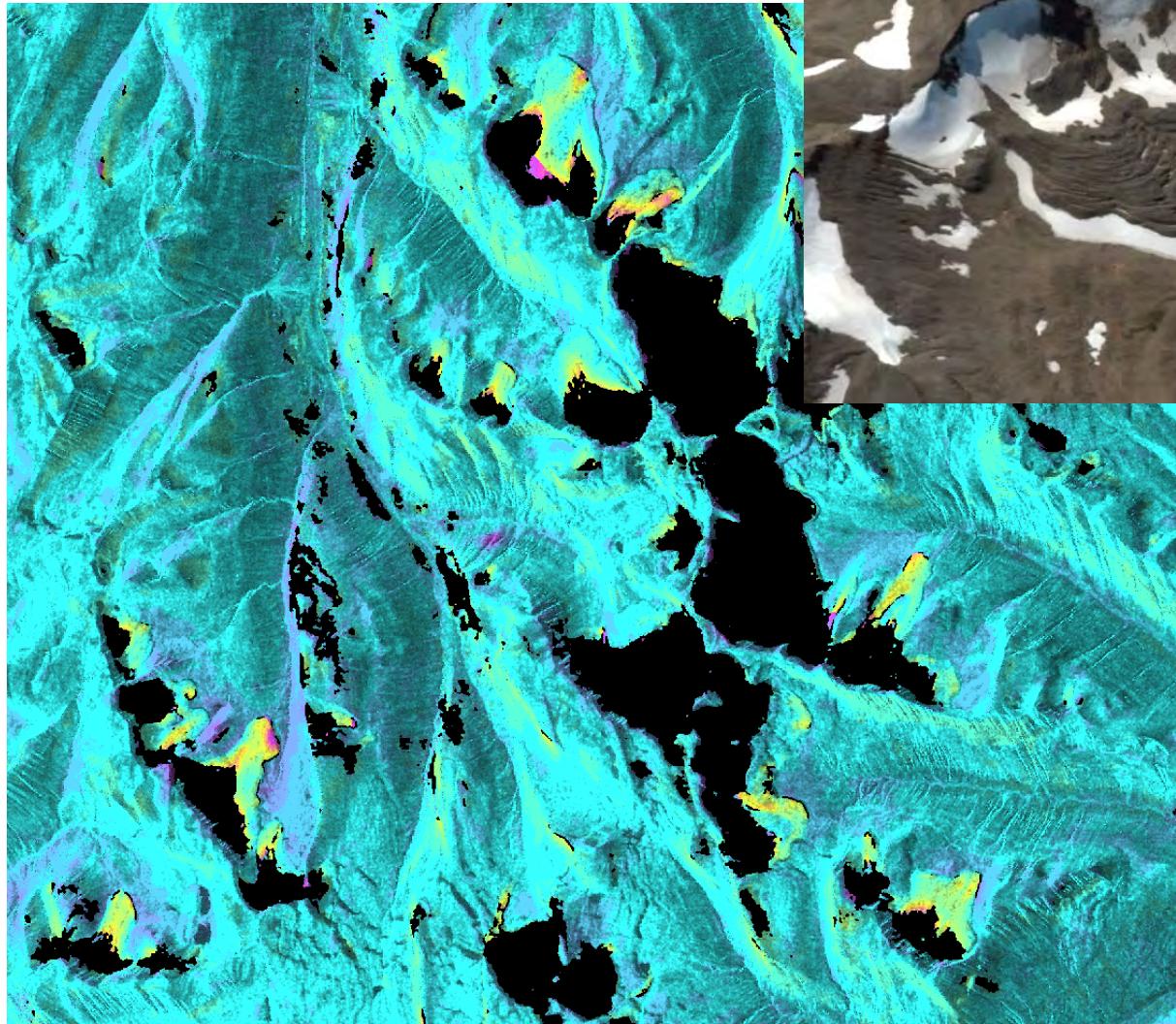
# InSAR, Iceland

PALSAR, 46 d, 2007



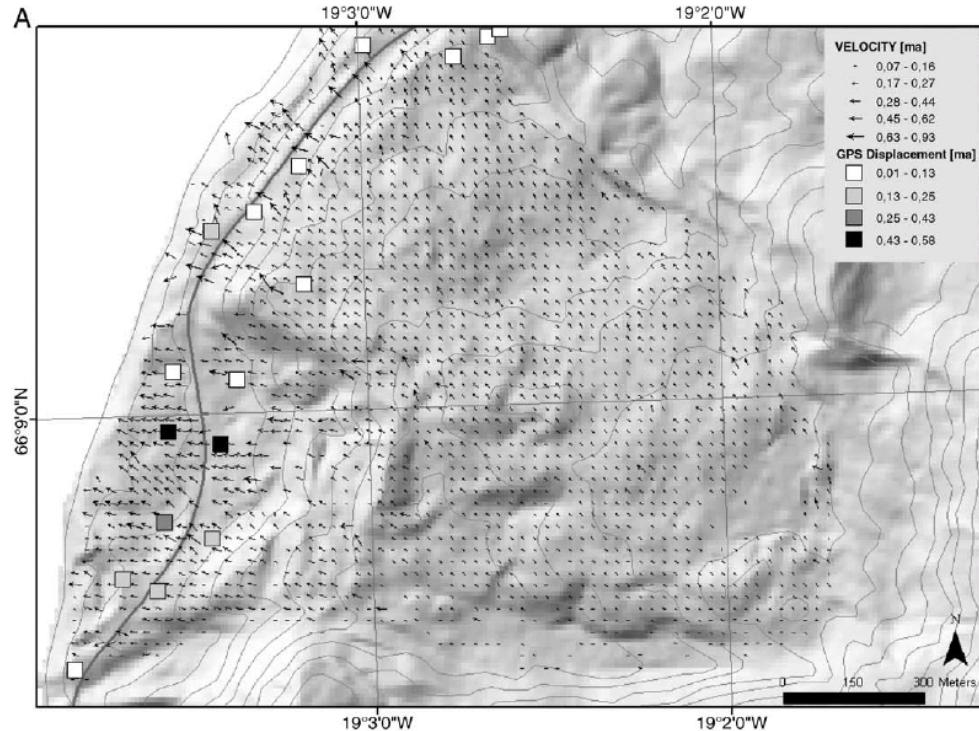
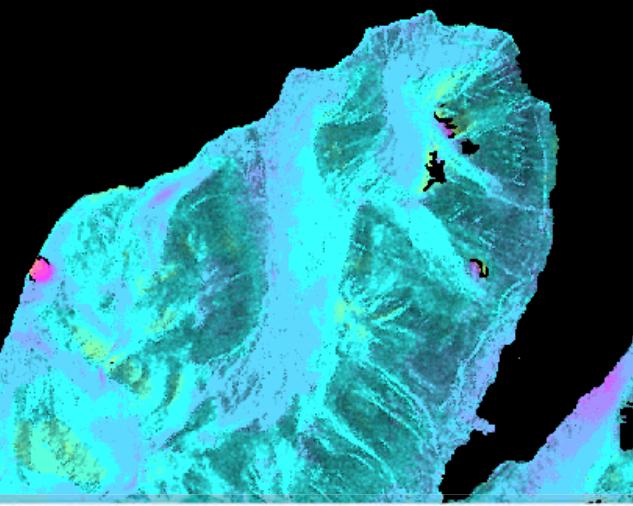
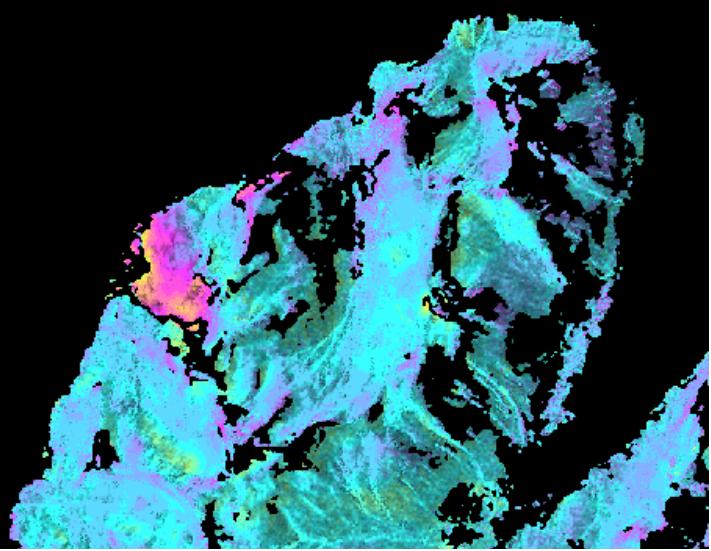
# InSAR, Iceland

PALSAR, 46 d, 2007



2007-2010

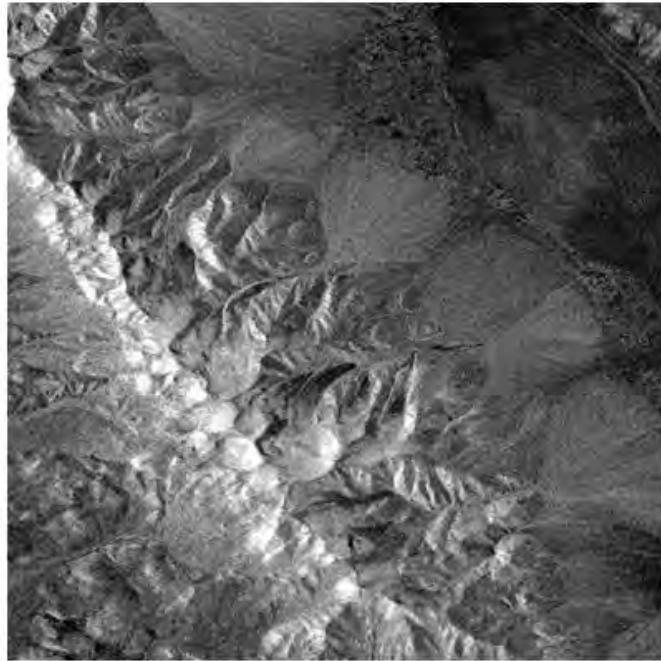
46 d, 2007



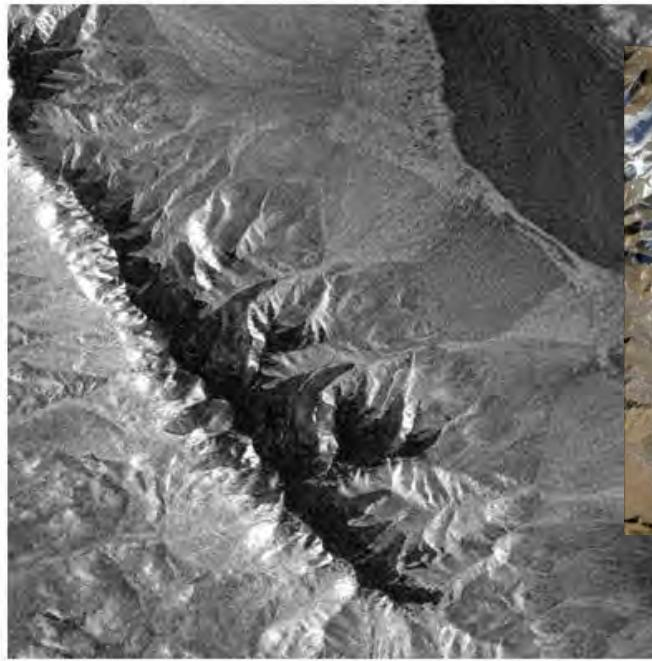
# Method matrix

	Landslides	Permafrost subsidence, heave, creep	Snow avalanches	Lake outbursts, floods	Glacier instabilities	Rock/ice avalanches
Image interpretation, change detection (ground-, air-, space-borne)	✓	✓				
Automatic classification, change detection (ground-, air-, space-borne)						
Stereo techniques (ground-, air-, space-borne)	✓					
Offset tracking (ground-, air-, space-borne)	✓	✓				
Radar interferometry (ground-, air-, space-borne)	✓	✓				
Altimetry, laserscanning (ground-, air-, space-borne)	✓					

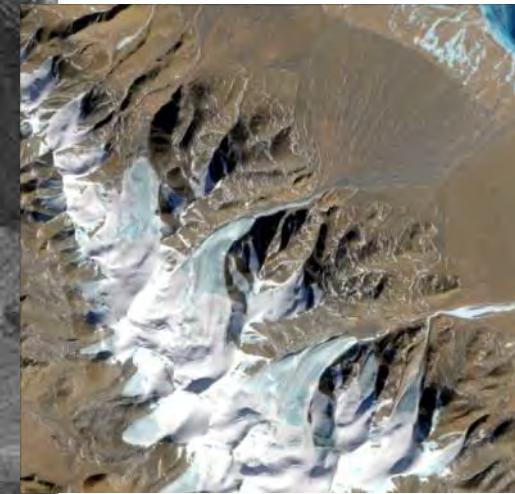
# Snow avalanches



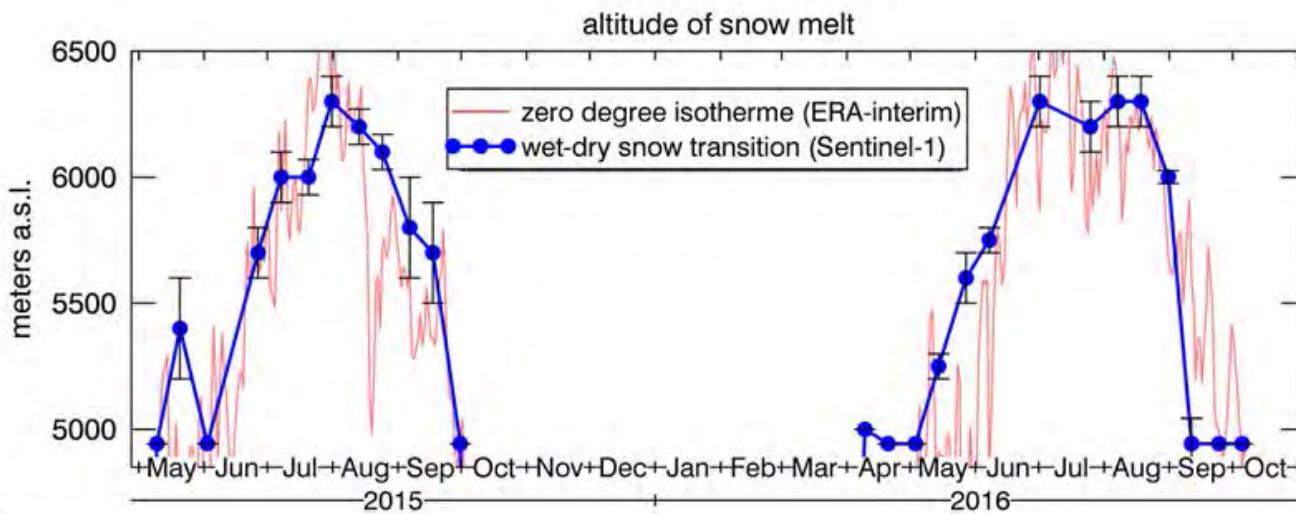
a)



b)



c)



# Snow avalanches

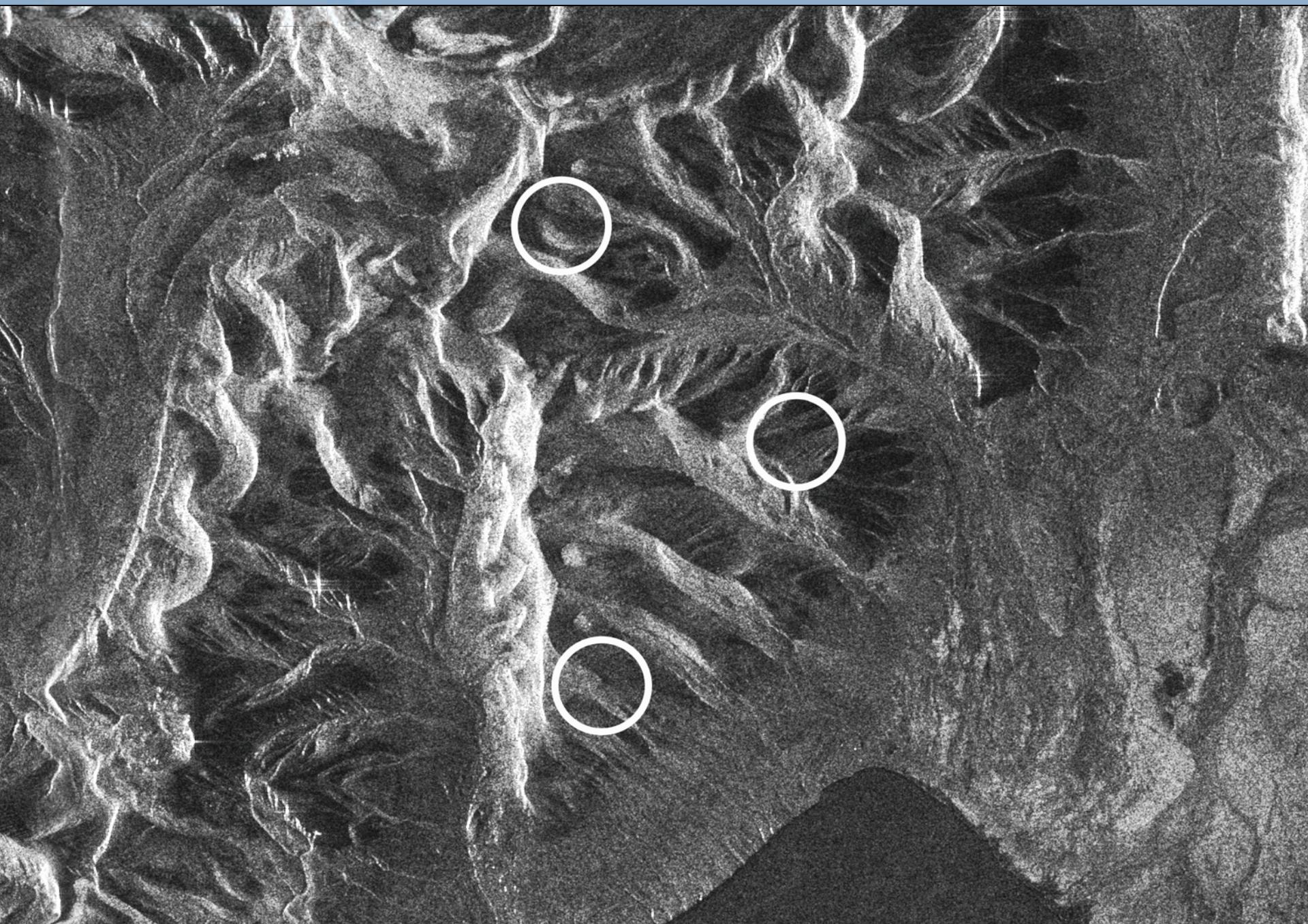
06 Nov 2016



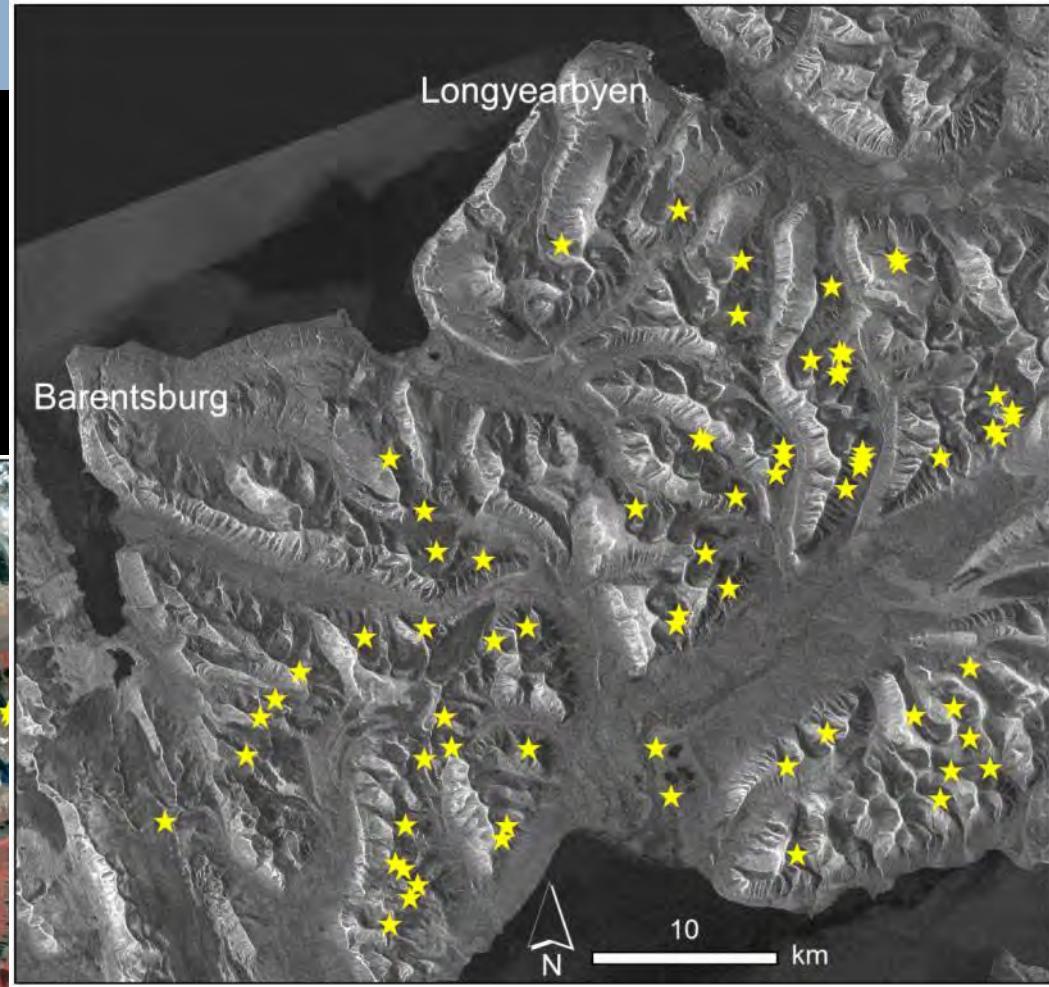
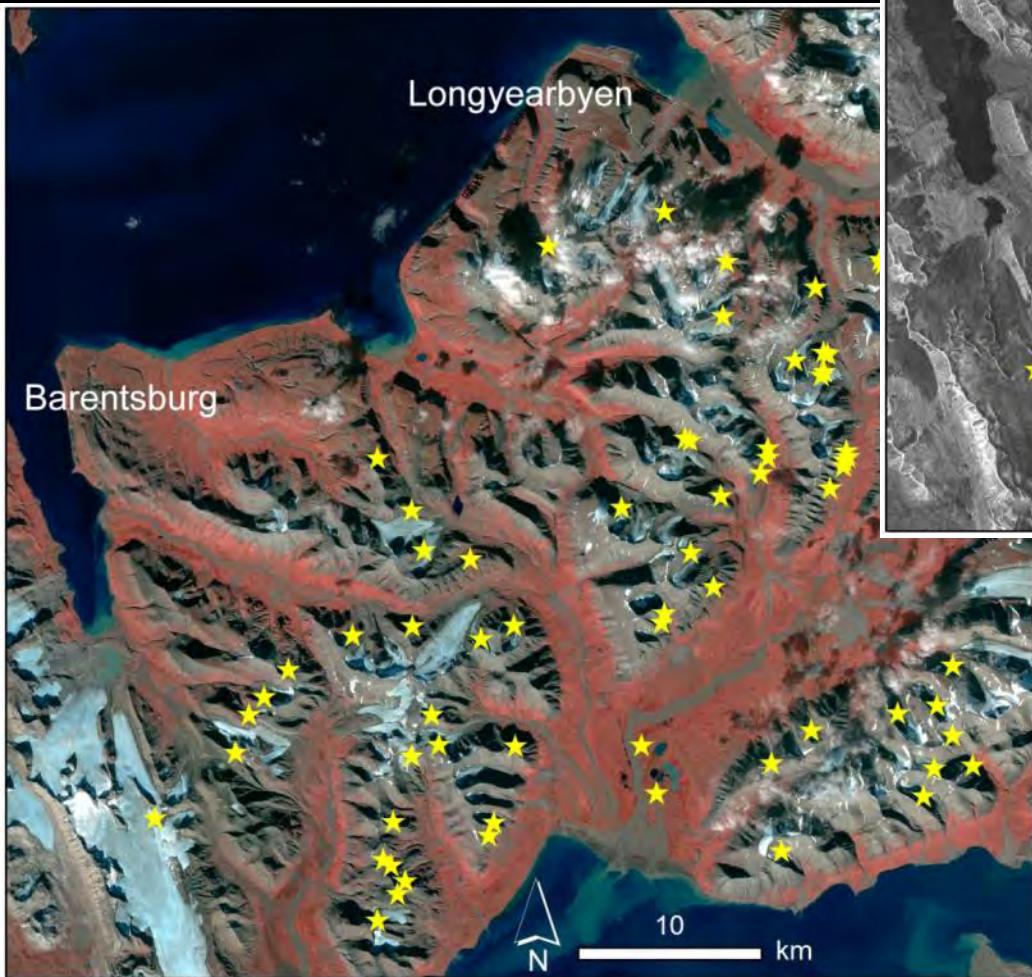
# Snow avalanches



# Snow avalanches

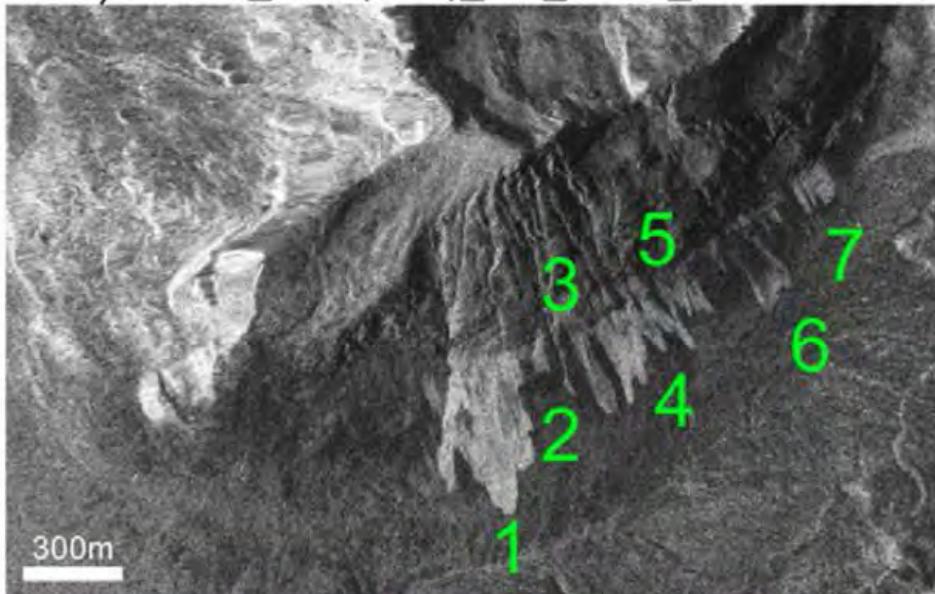


# Snow avalanches

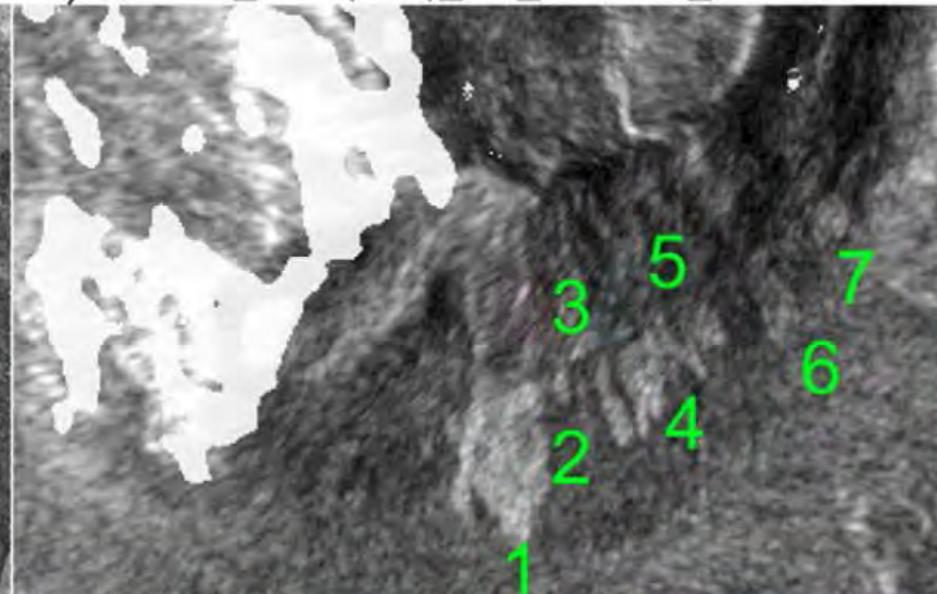


# Snow avalanches

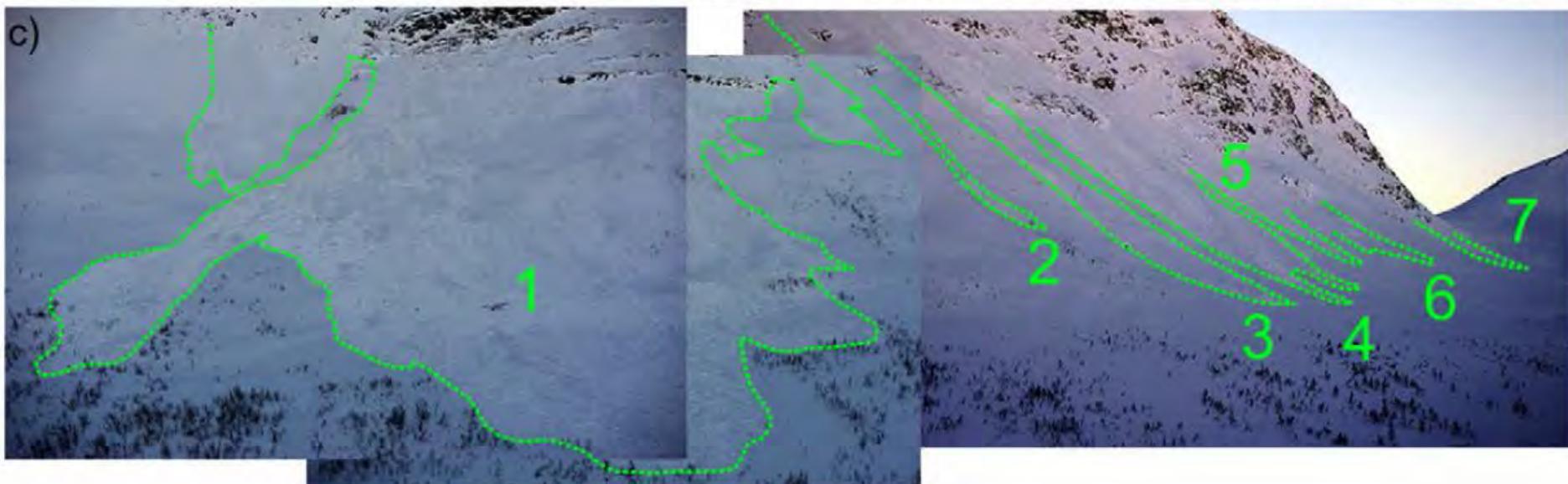
a) RS-2U\_ASC(U24)\_HH\_3x3m\_20150103



b) S1A-IW\_ASC(131)\_VV\_10x10m\_20150106



c)

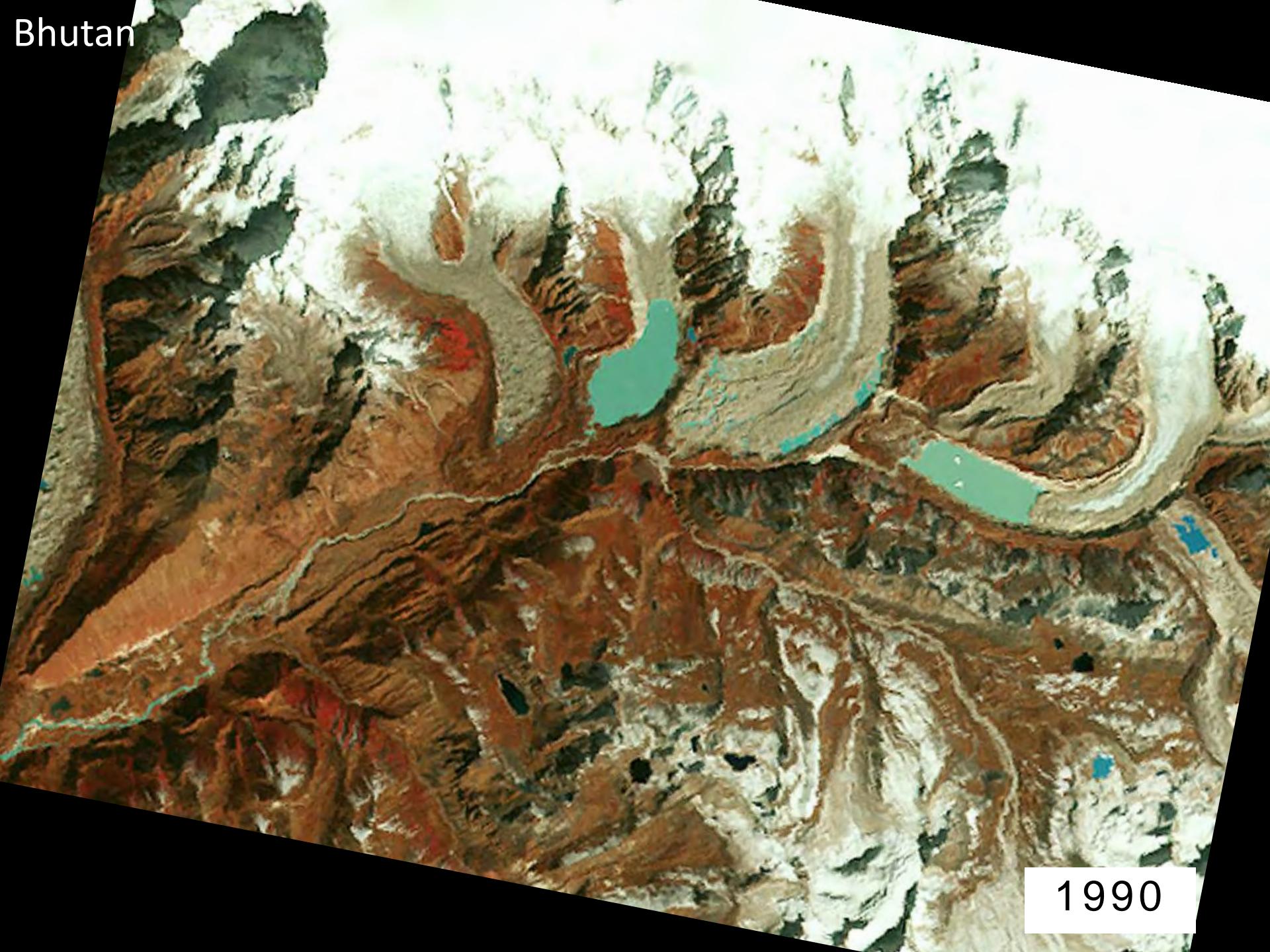




Lugge Tsho (Bhutan): 7 Oct 1994, 28mio m<sup>3</sup>, >20t

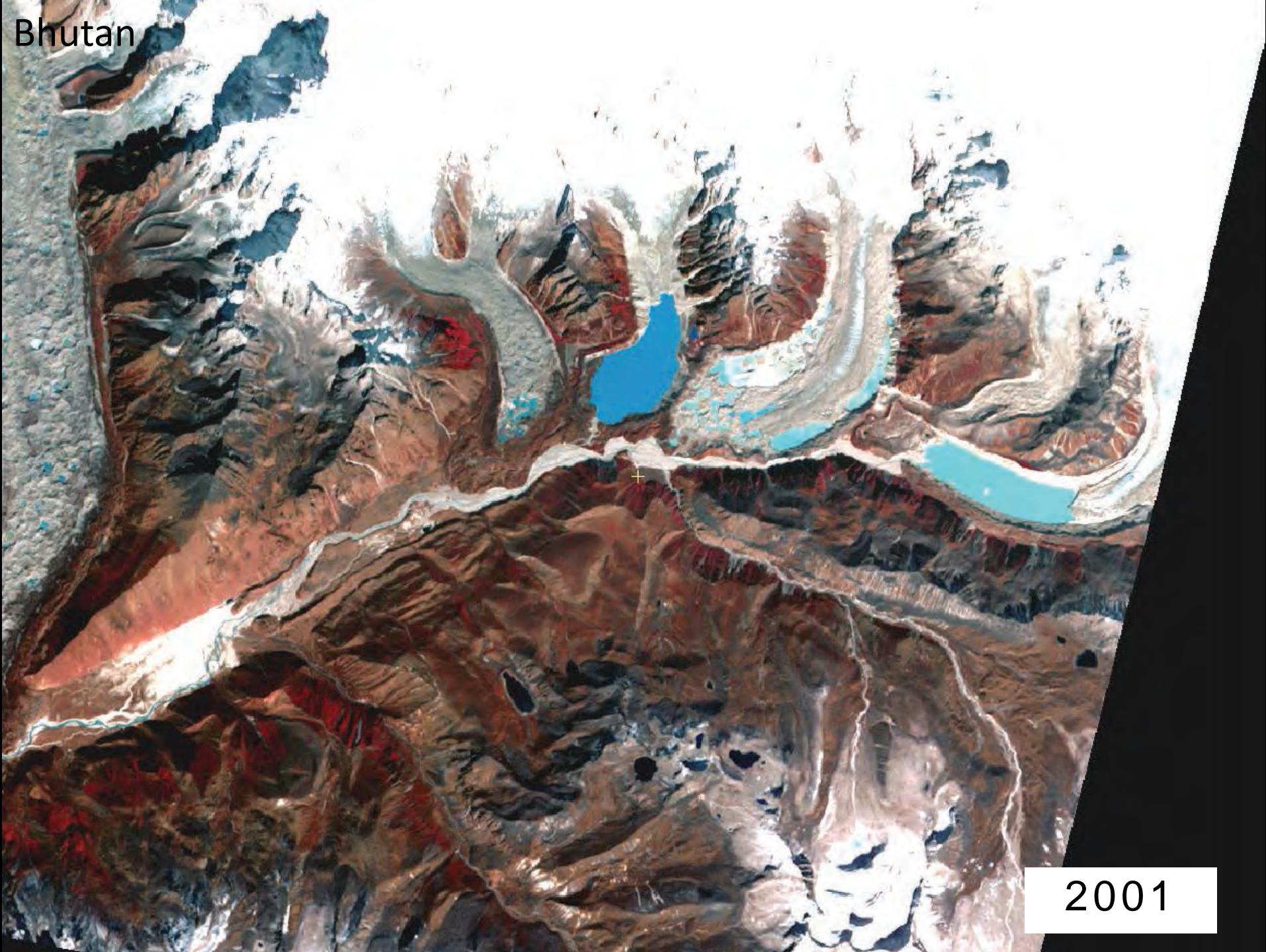


Bhutan



1990

Bhutan



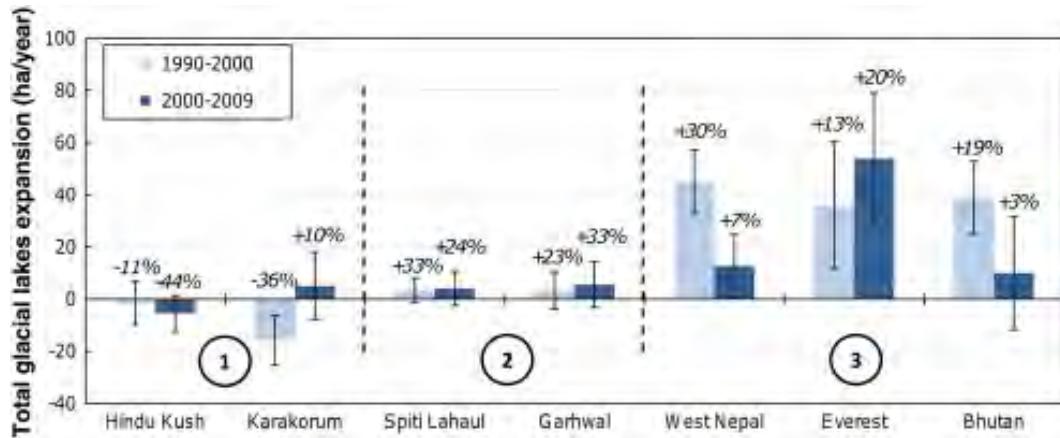
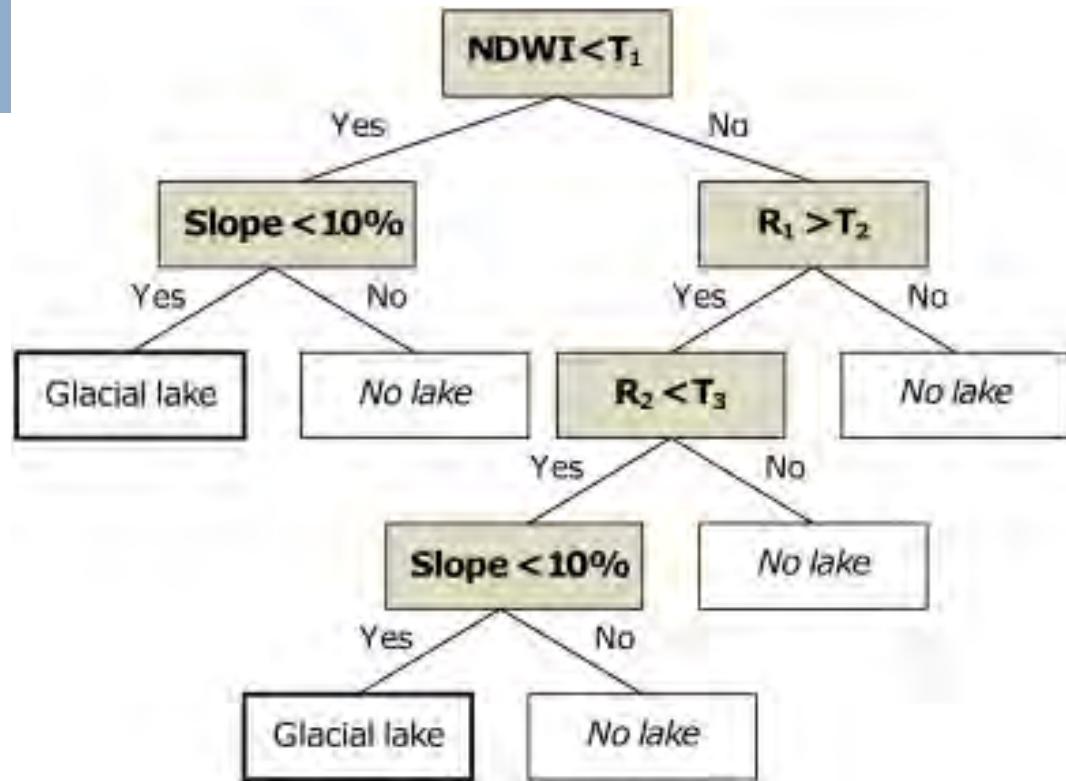
2001

Bhutan



2018

# Automatic detection of glacier lakes



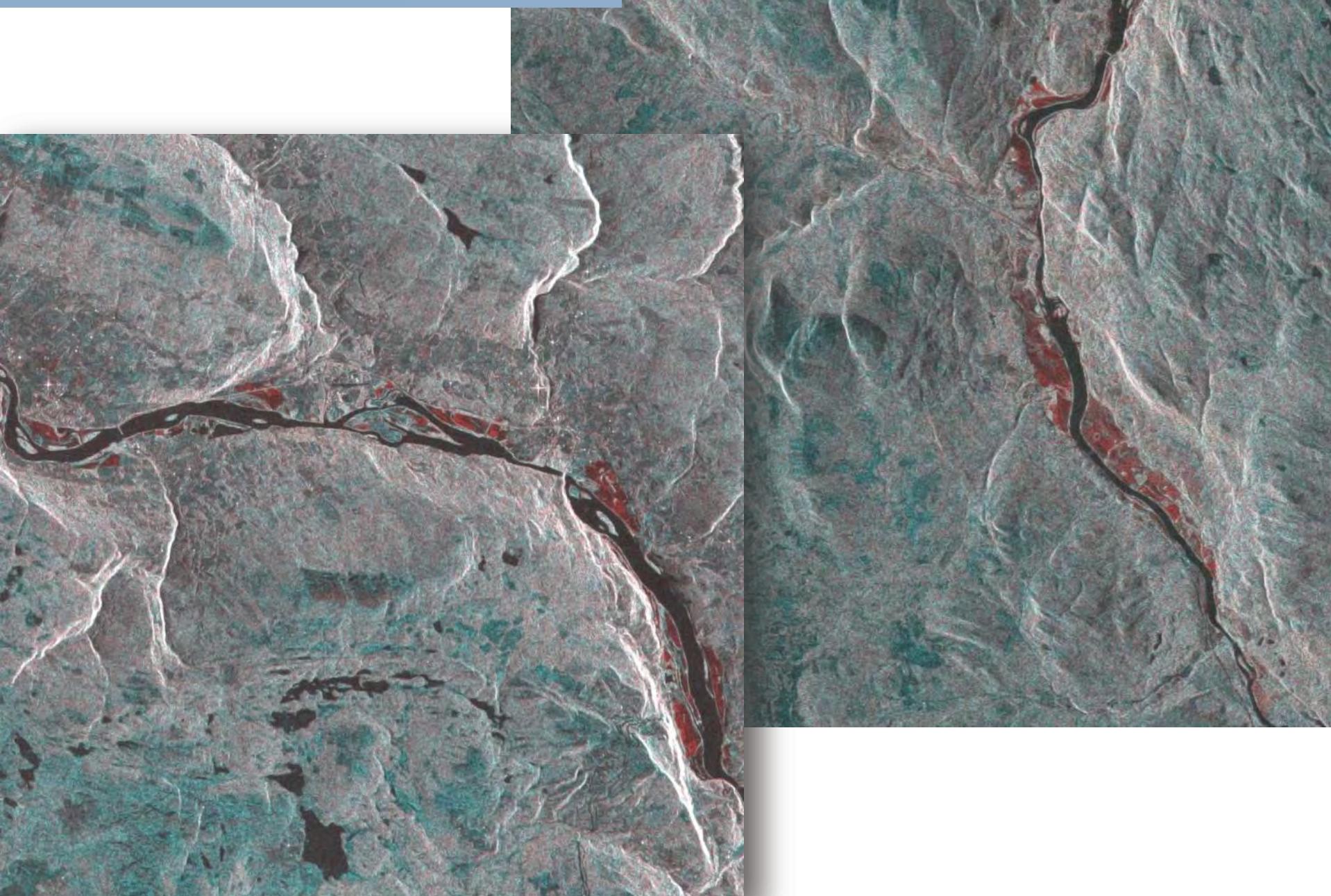
$$NDWI = \frac{B_{NIR} - B_{Blue}}{B_{NIR} + B_{Blue}}$$

$$R_1 = \frac{B_{Green}}{B_{NIR}}$$

$$R_2 = \frac{B_{NIR}}{B_{MIR}}$$

Spring floods, Norway, 2018

Repeat Sentinel-2





• Oslo



# • Oslo





● Red River of the North

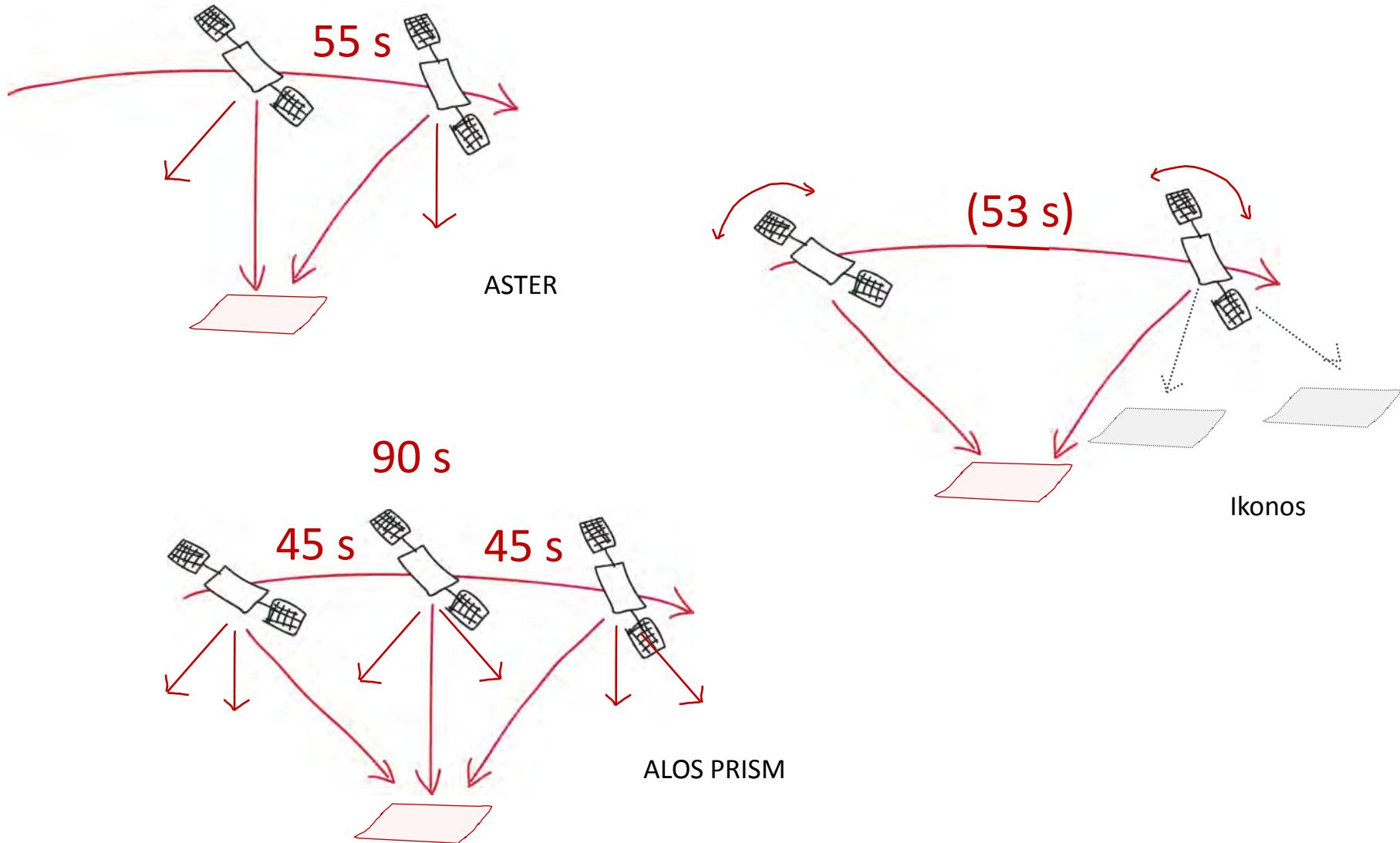


27 km

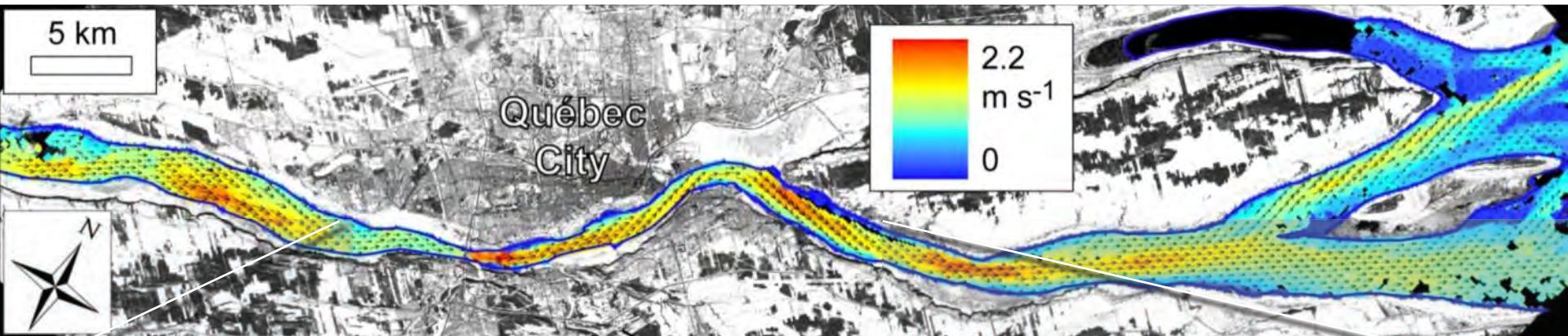


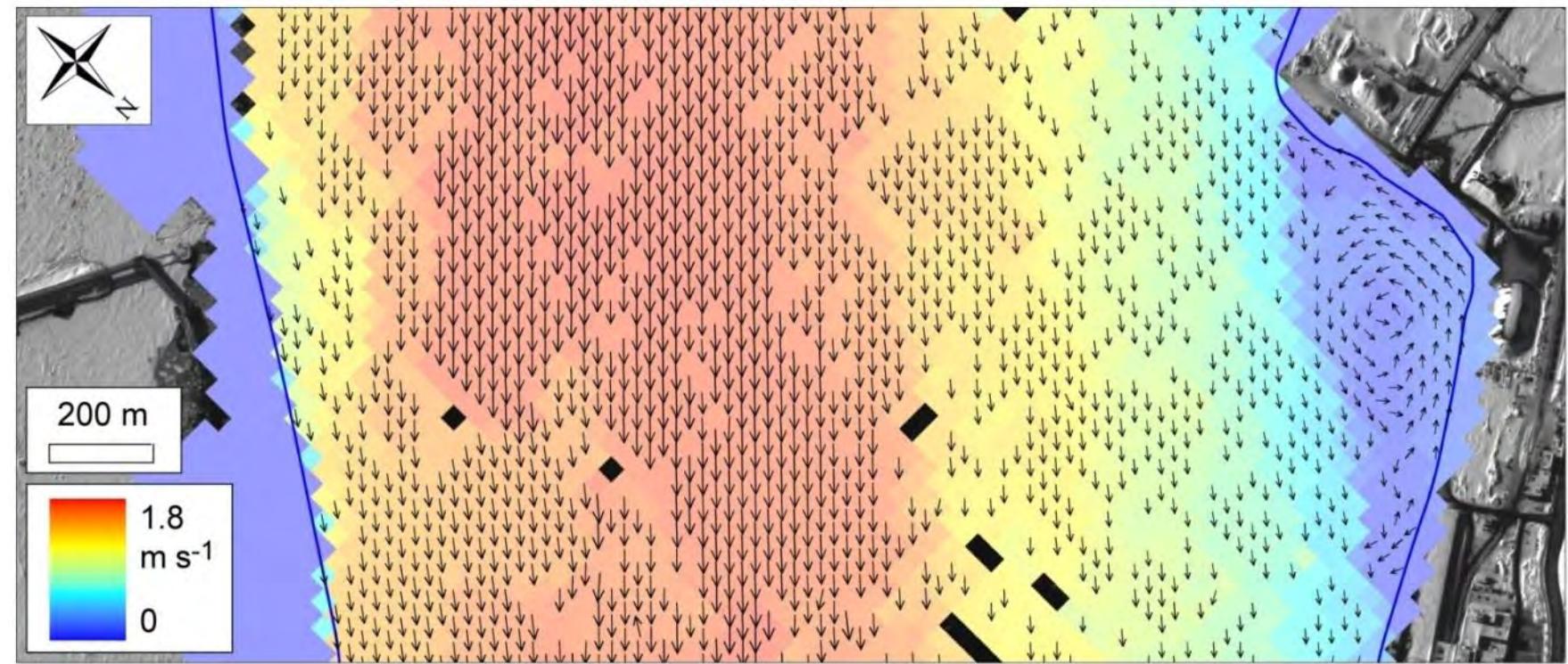


## • Alongtrack stereo



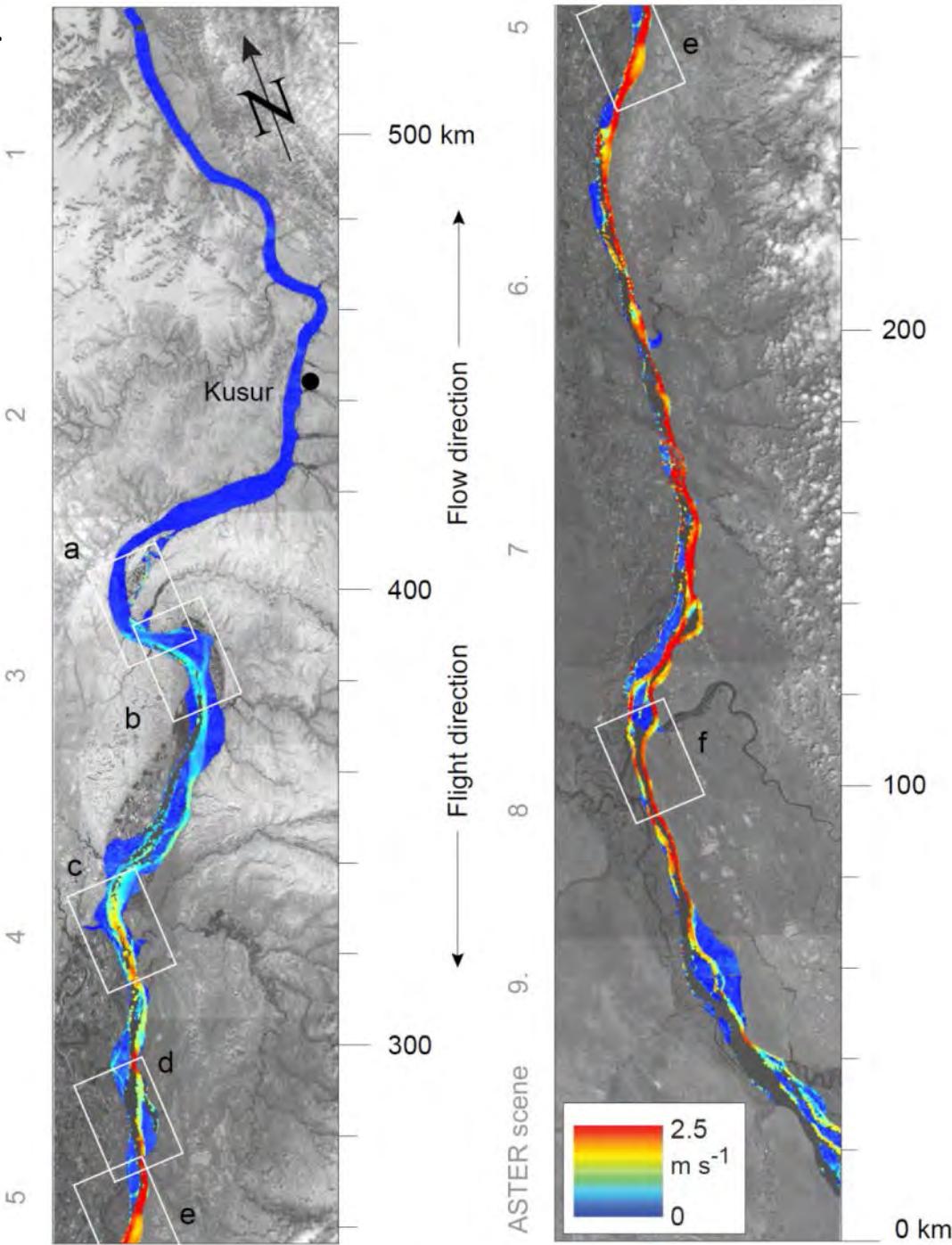
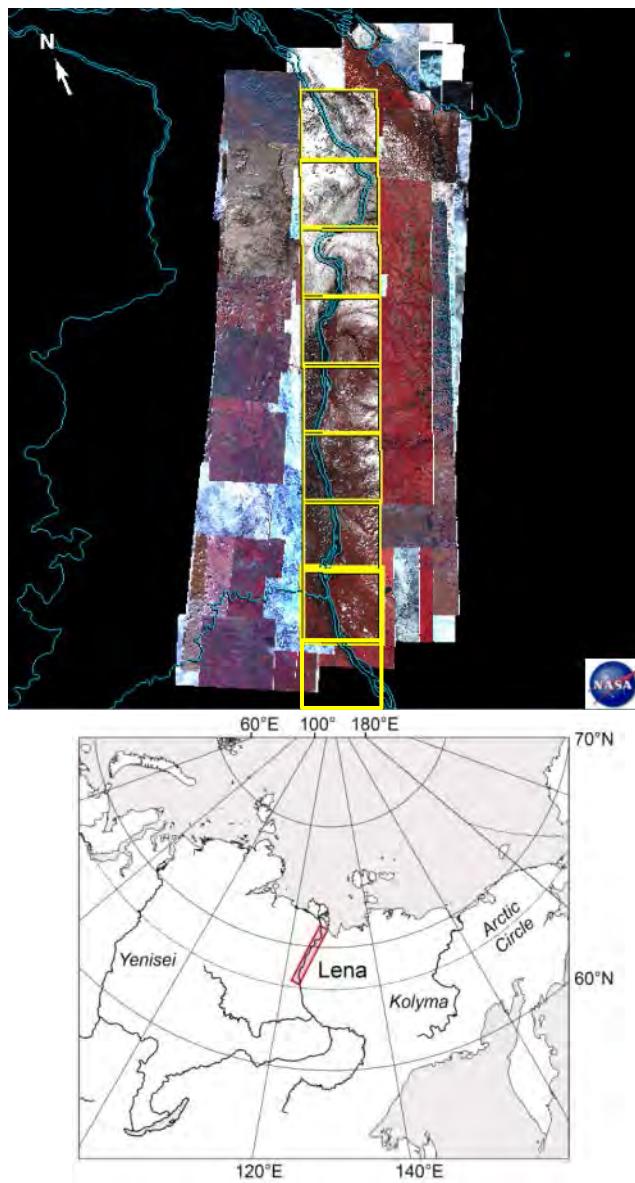
# • St. Lawrence River, Quebec City

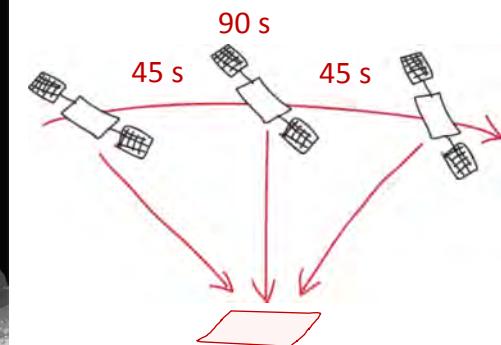
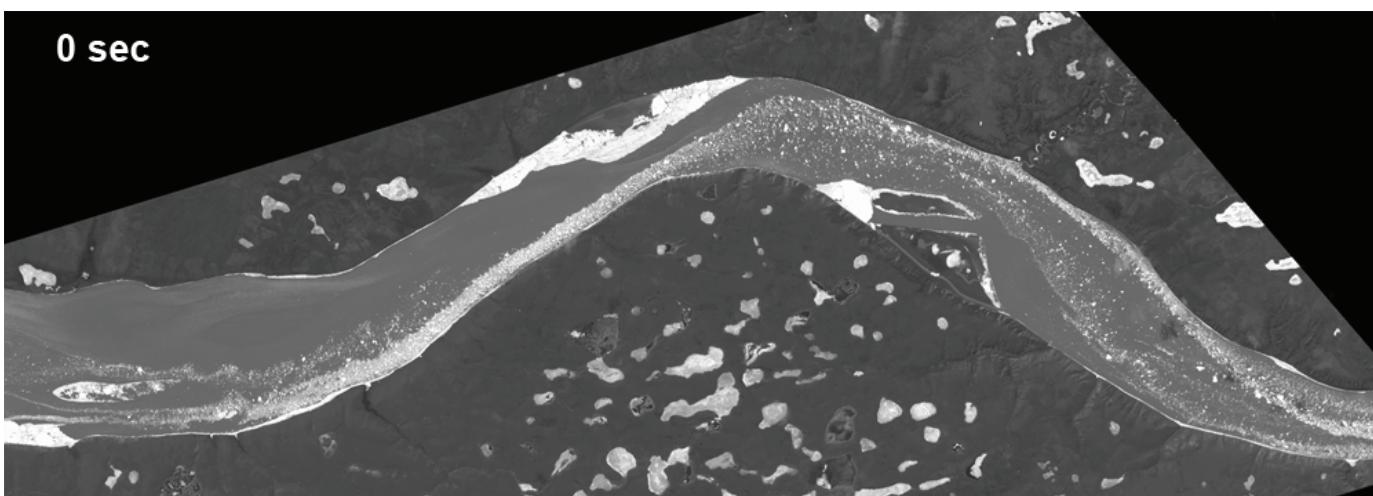
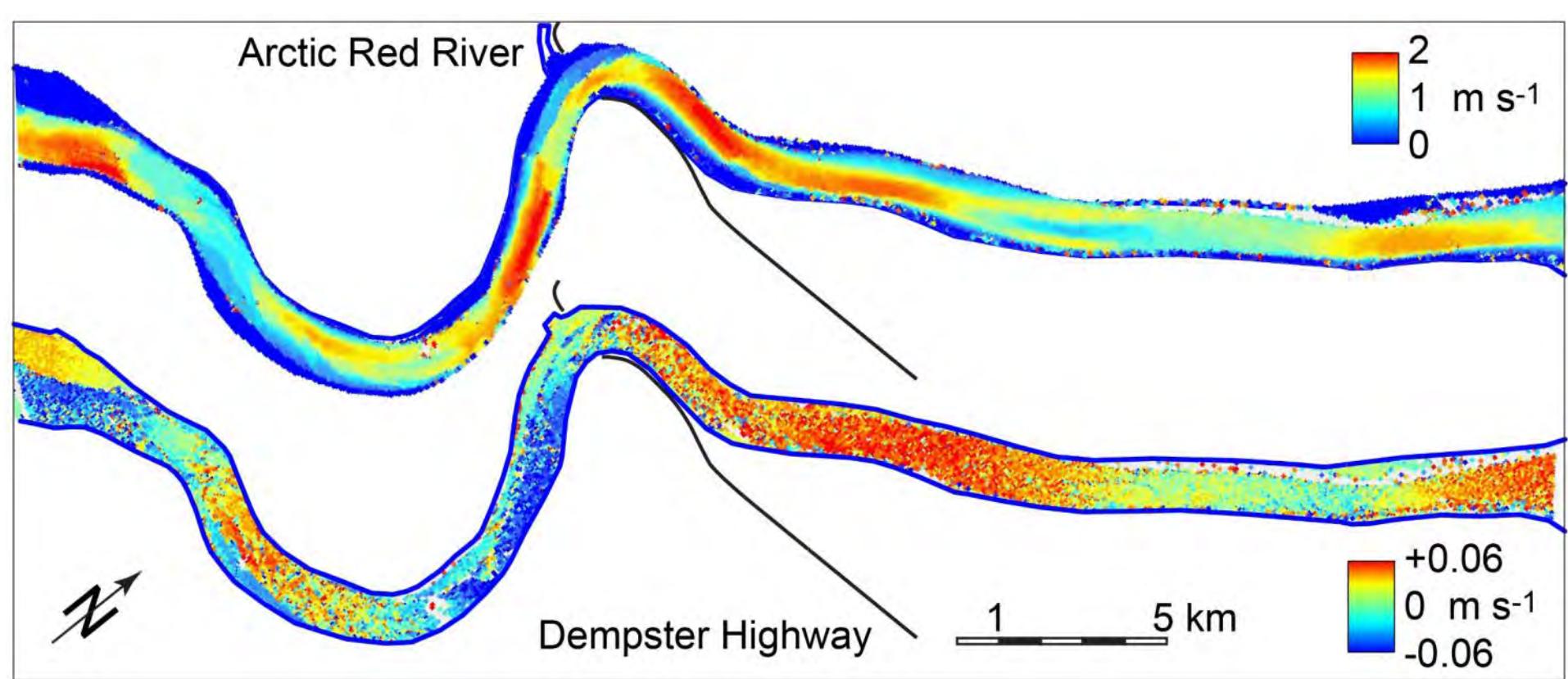




● Lena river  
27 May 2011  
Ice speeds

Kääb et al.



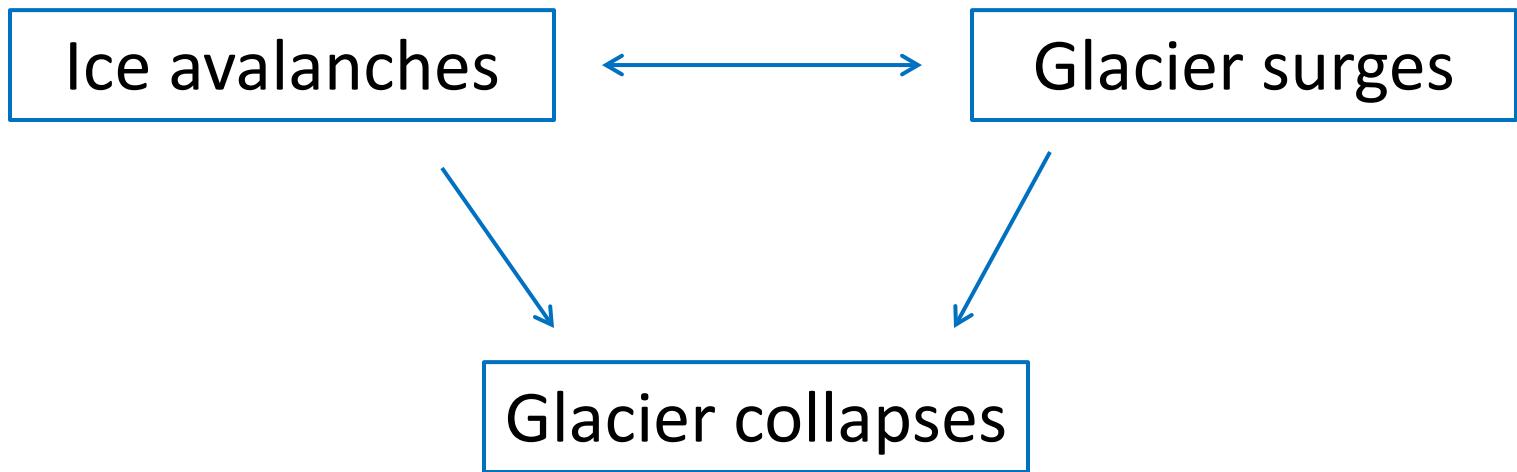


Prism

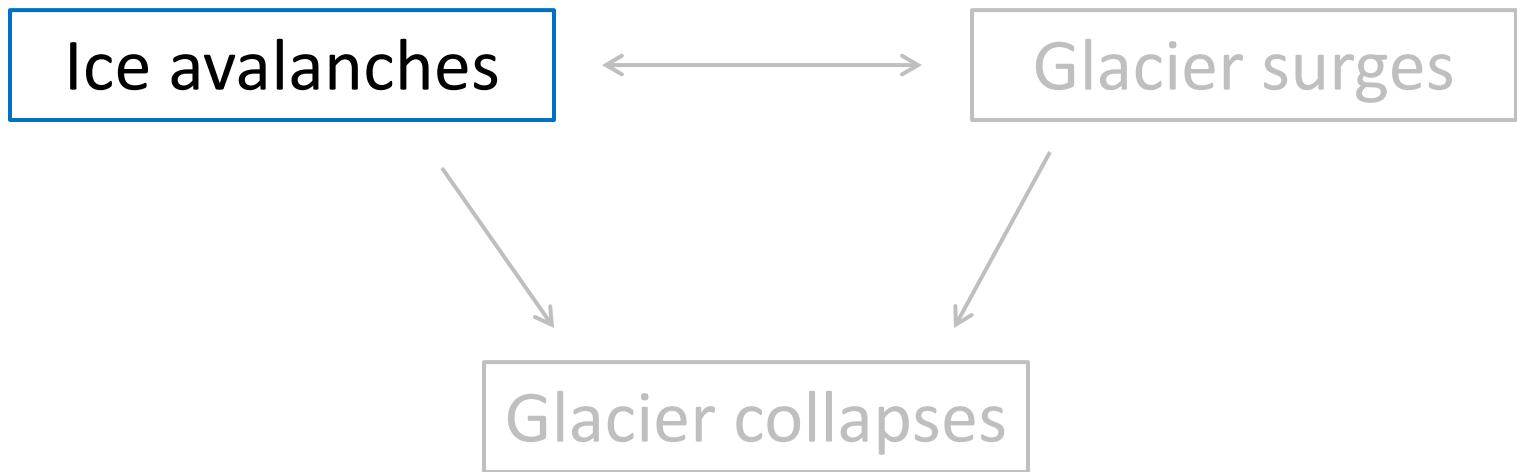
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Image interpretation, change detection (ground-, air-, space-borne)	✓	✓	✓	✓		
Automatic classification, change detection (ground-, air-, space-borne)			✓	✓		
Stereo techniques (ground-, air-, space-borne)	✓				✓	
Offset tracking (ground-, air-, space-borne)	✓	✓		✓		
Radar (interferometry) (ground-, air-, space-borne)	✓	✓	✓	✓		
Altimetry, laserscanning (ground-, air-, space-borne)	✓					

# Glacier flow instabilities



# Glacier flow instabilities



## Ice avalanches



# Permafrost - ice - geology interactions



## Rock/ice avalanches (e.g. Huascarán, 1970)

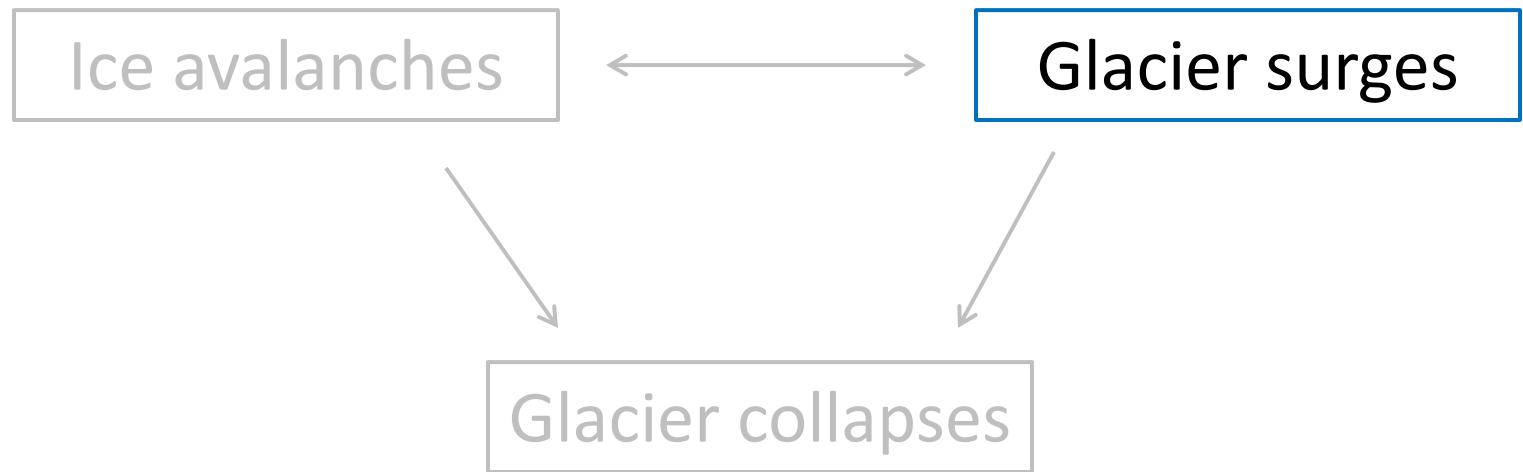


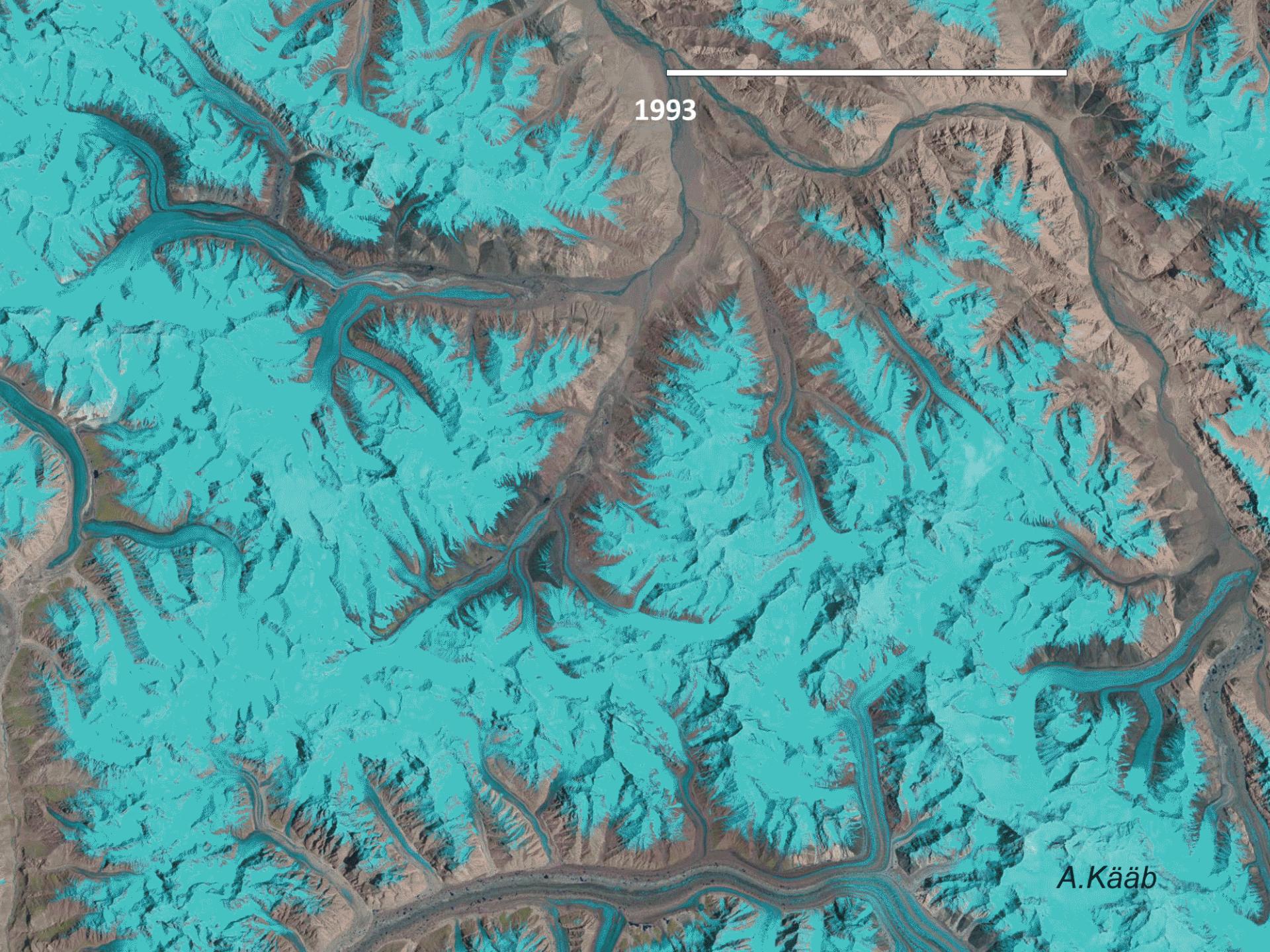
T. Hatakeyama



G. Plafker

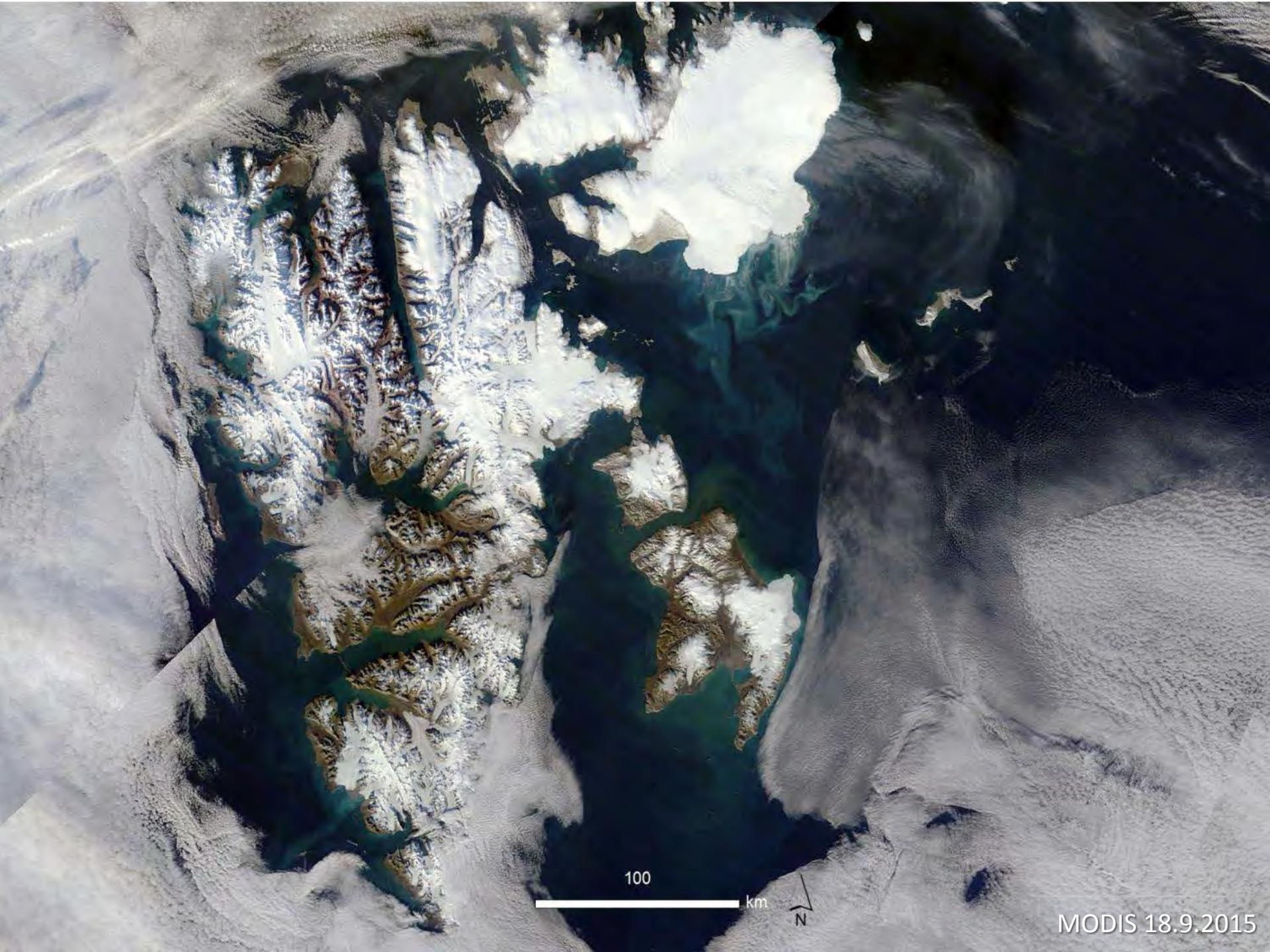
# Glacier flow instabilities





1993

A.Kääb



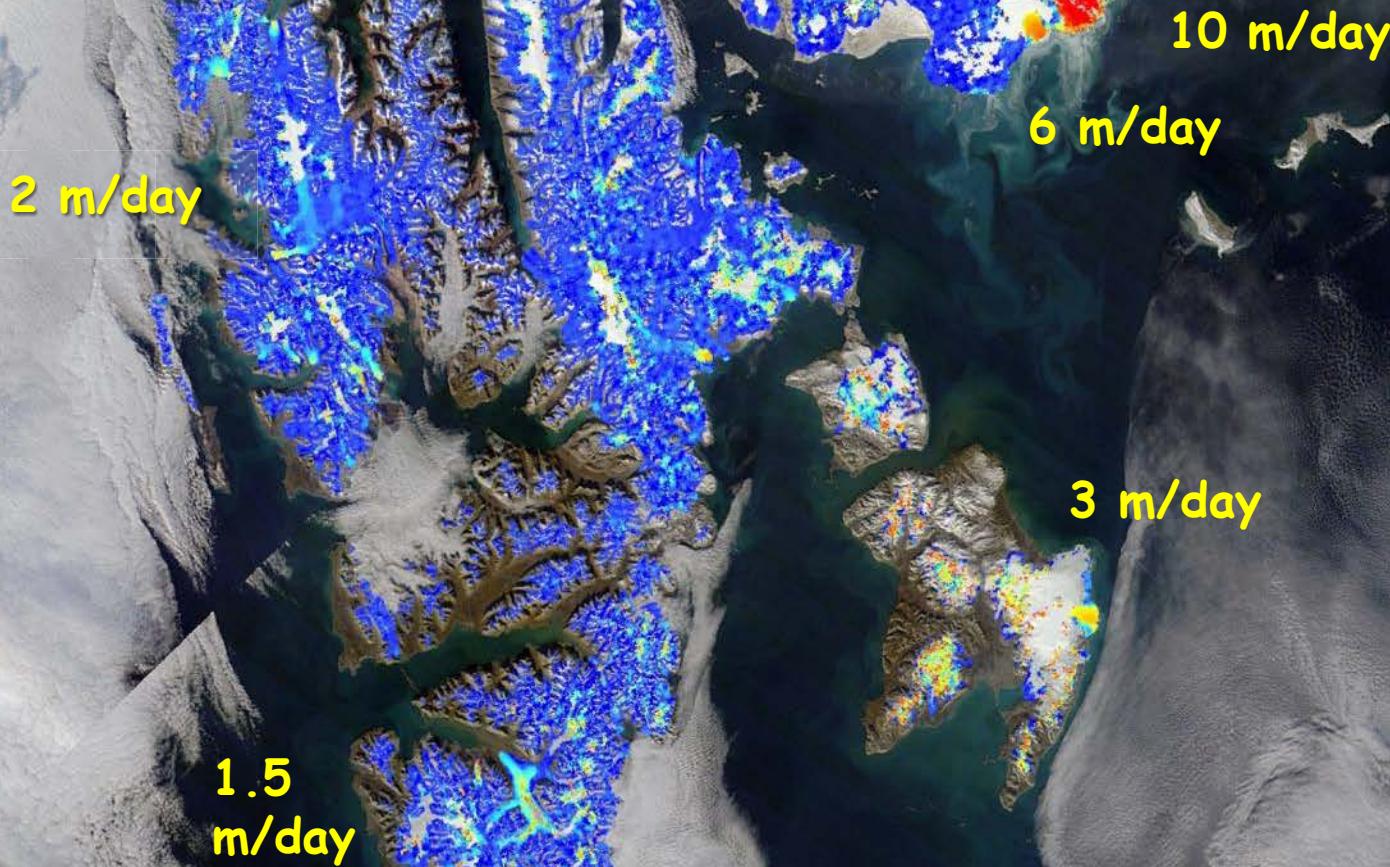
100

km

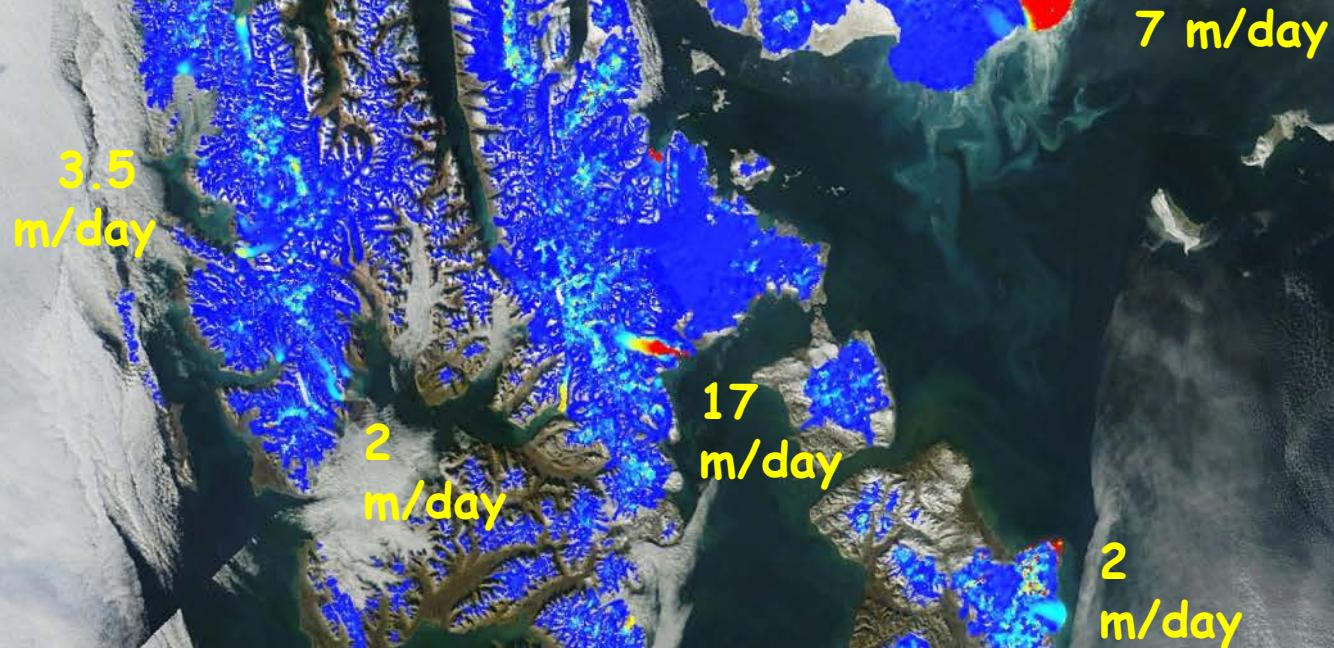
N

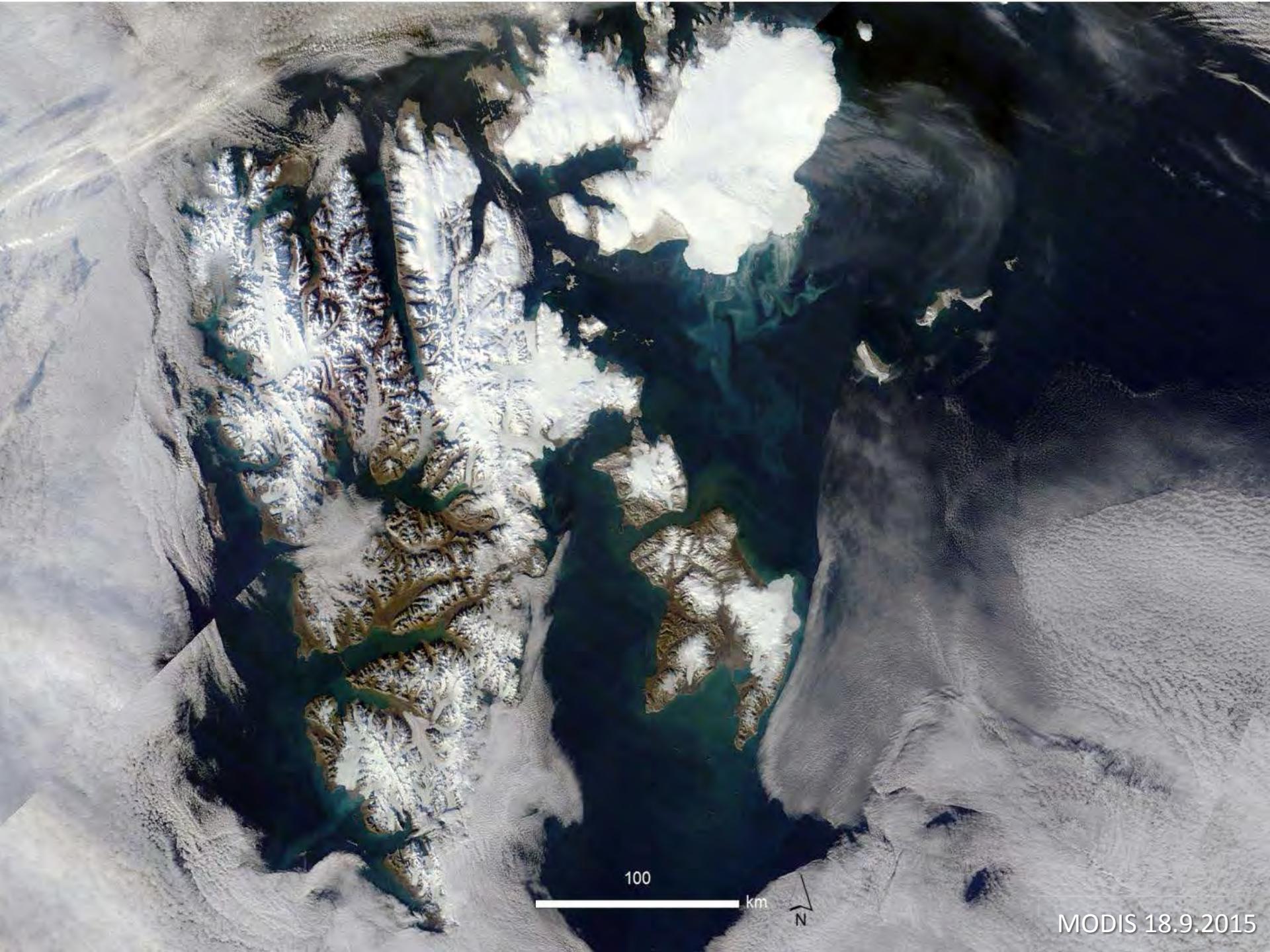
MODIS 18.9.2015

Glacier speed  
January 2016



Glacier speed  
January 2018



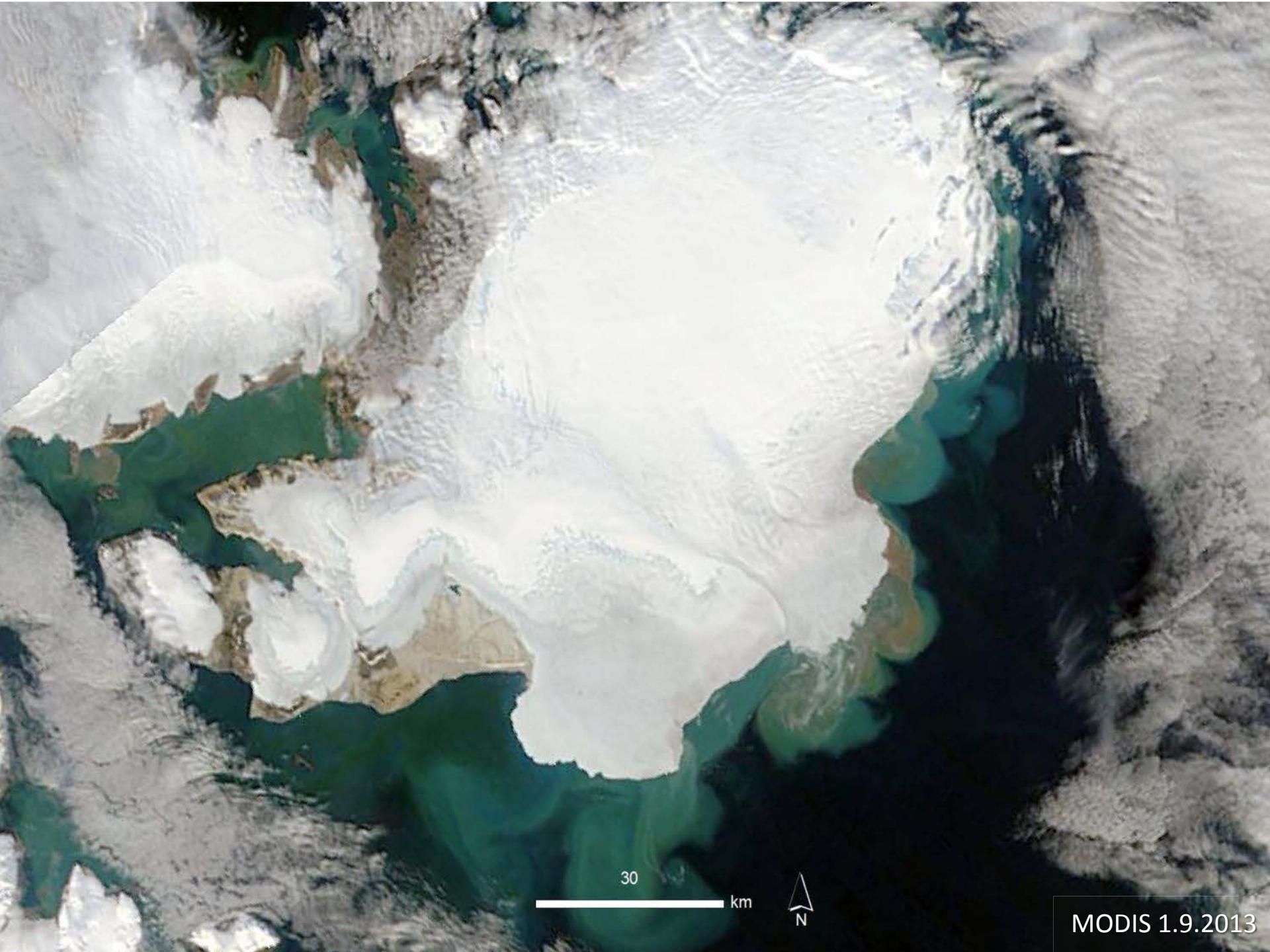


100

km

N

MODIS 18.9.2015

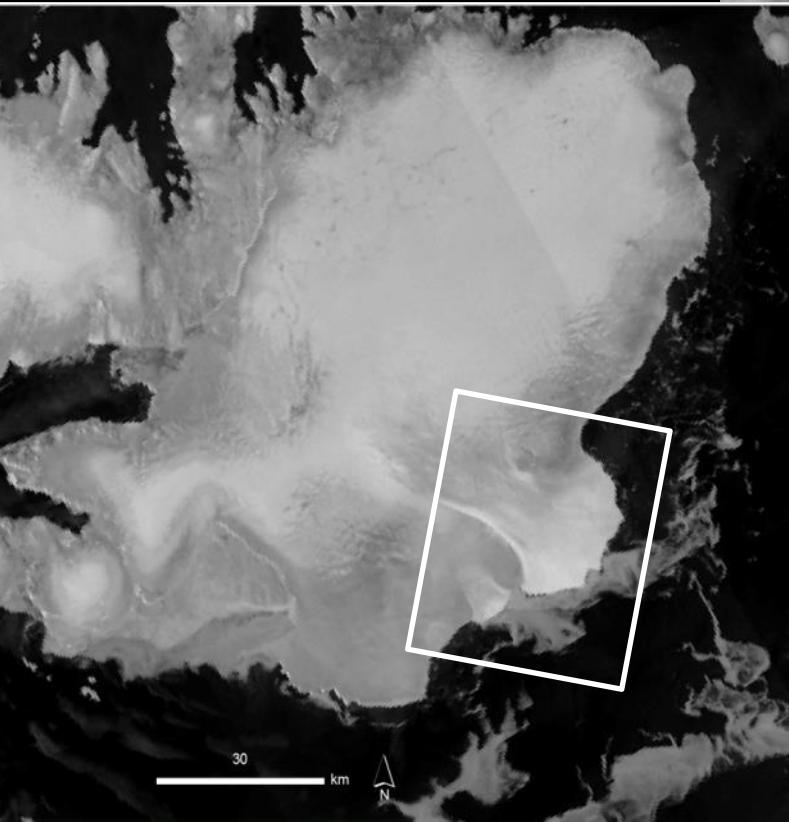


30

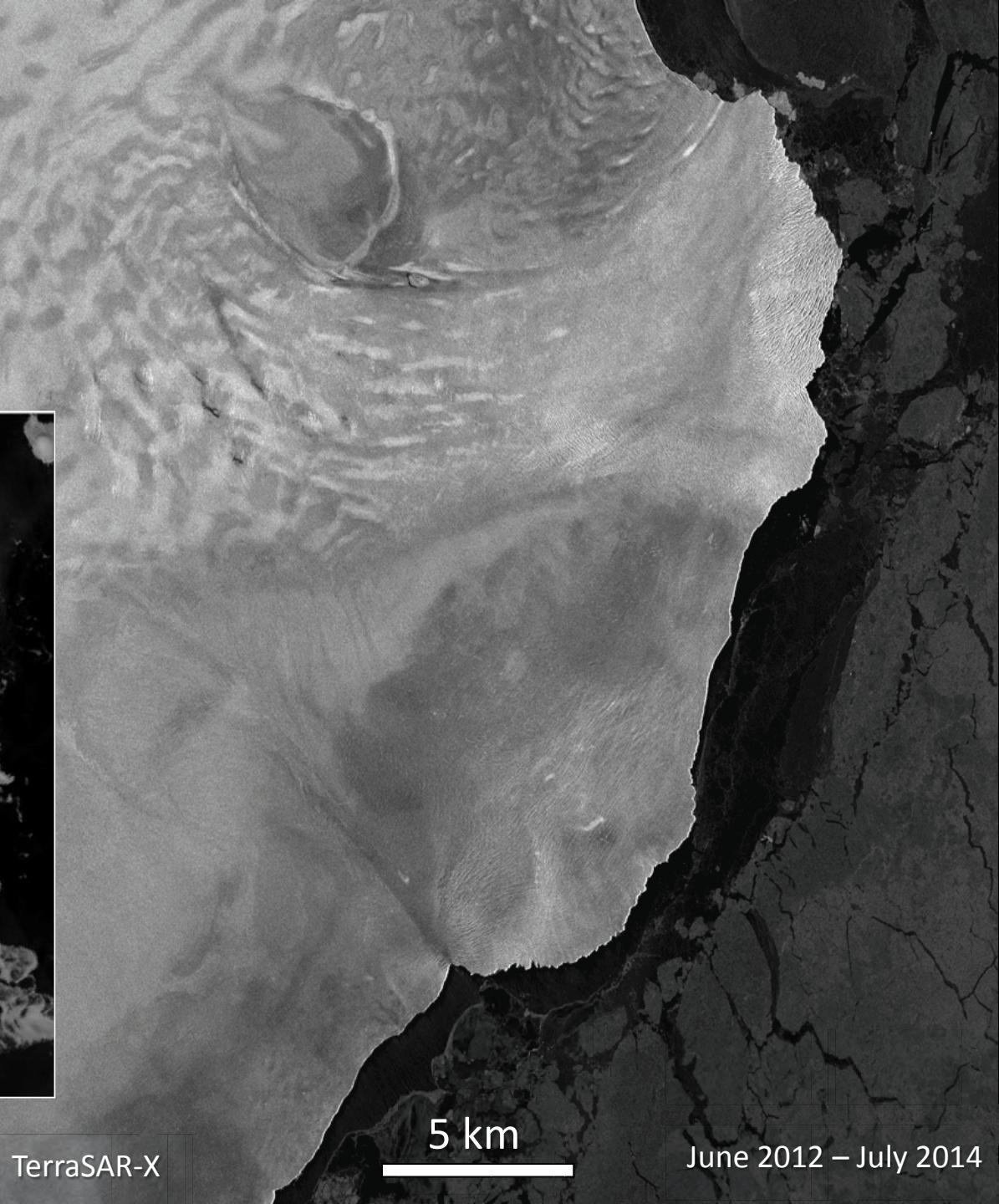
km



MODIS 1.9.2013



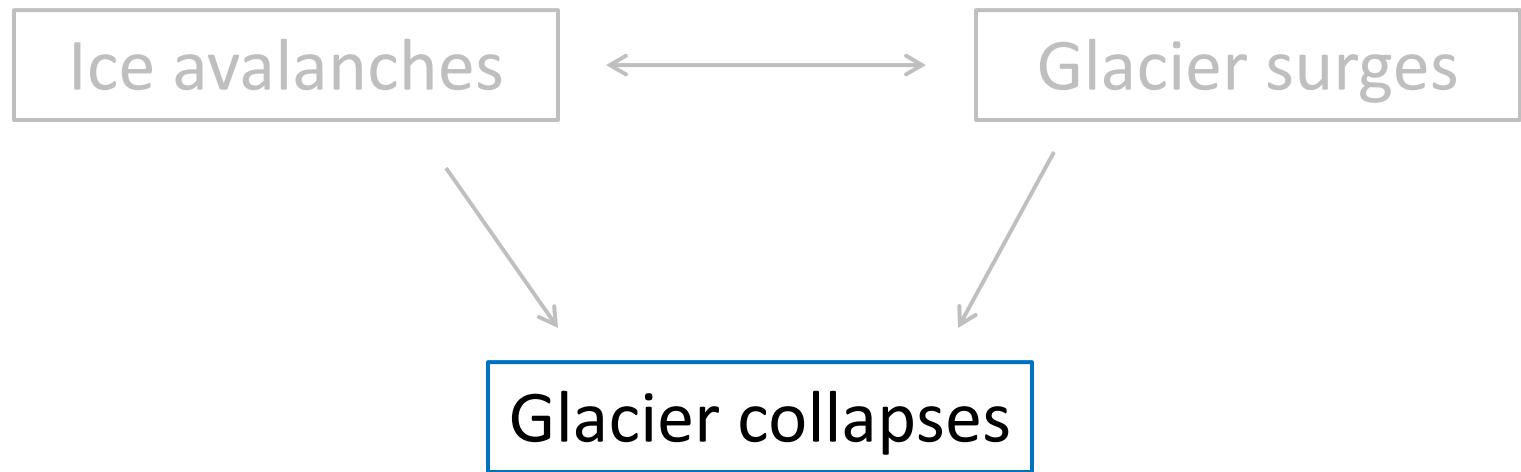
Sentinel-1, January 2016

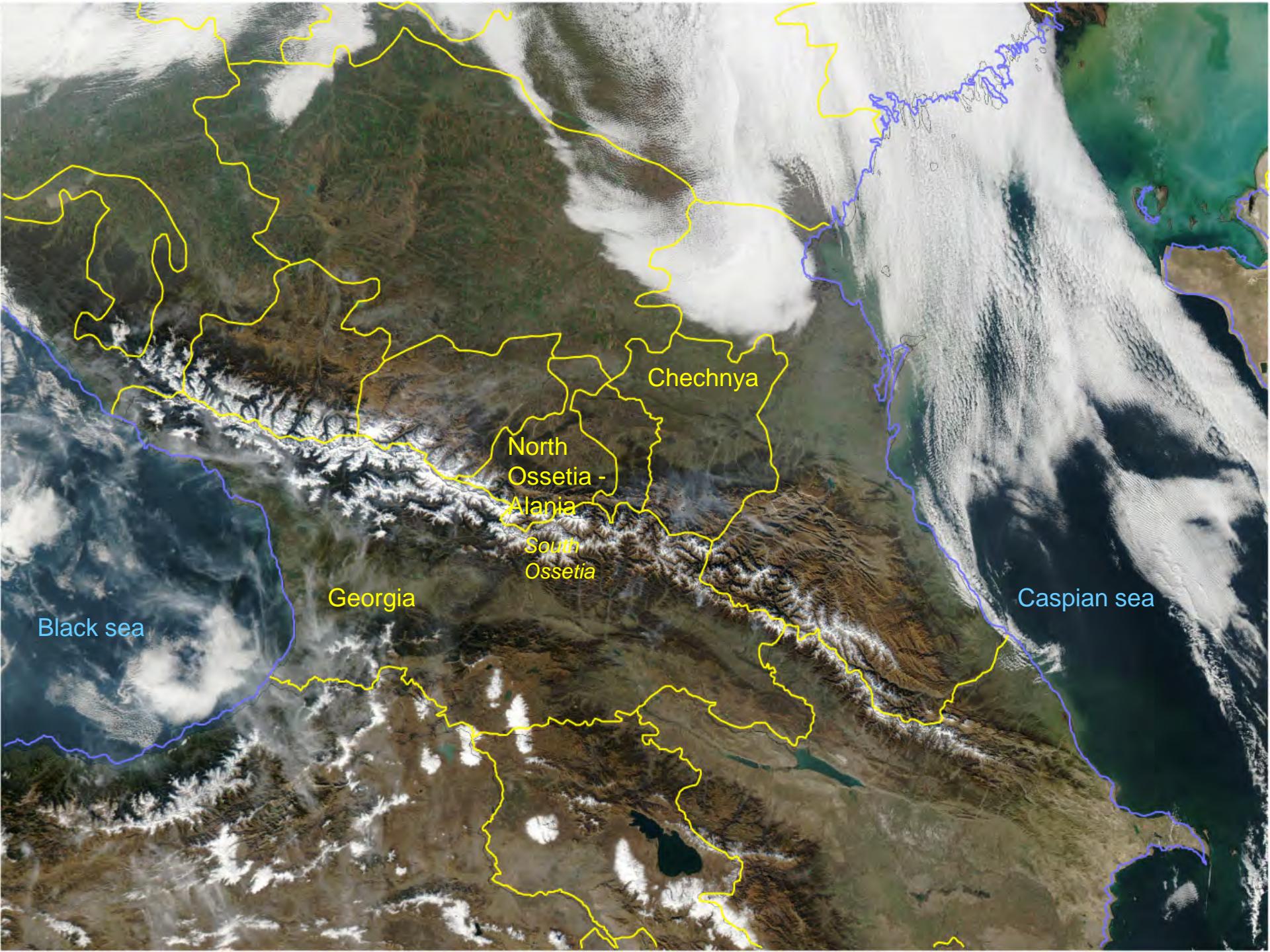


TerraSAR-X

June 2012 – July 2014

# Glacier flow instabilities





Black sea

Georgia

North  
Ossetia -  
Alania  
South  
Ossetia

Chechnya

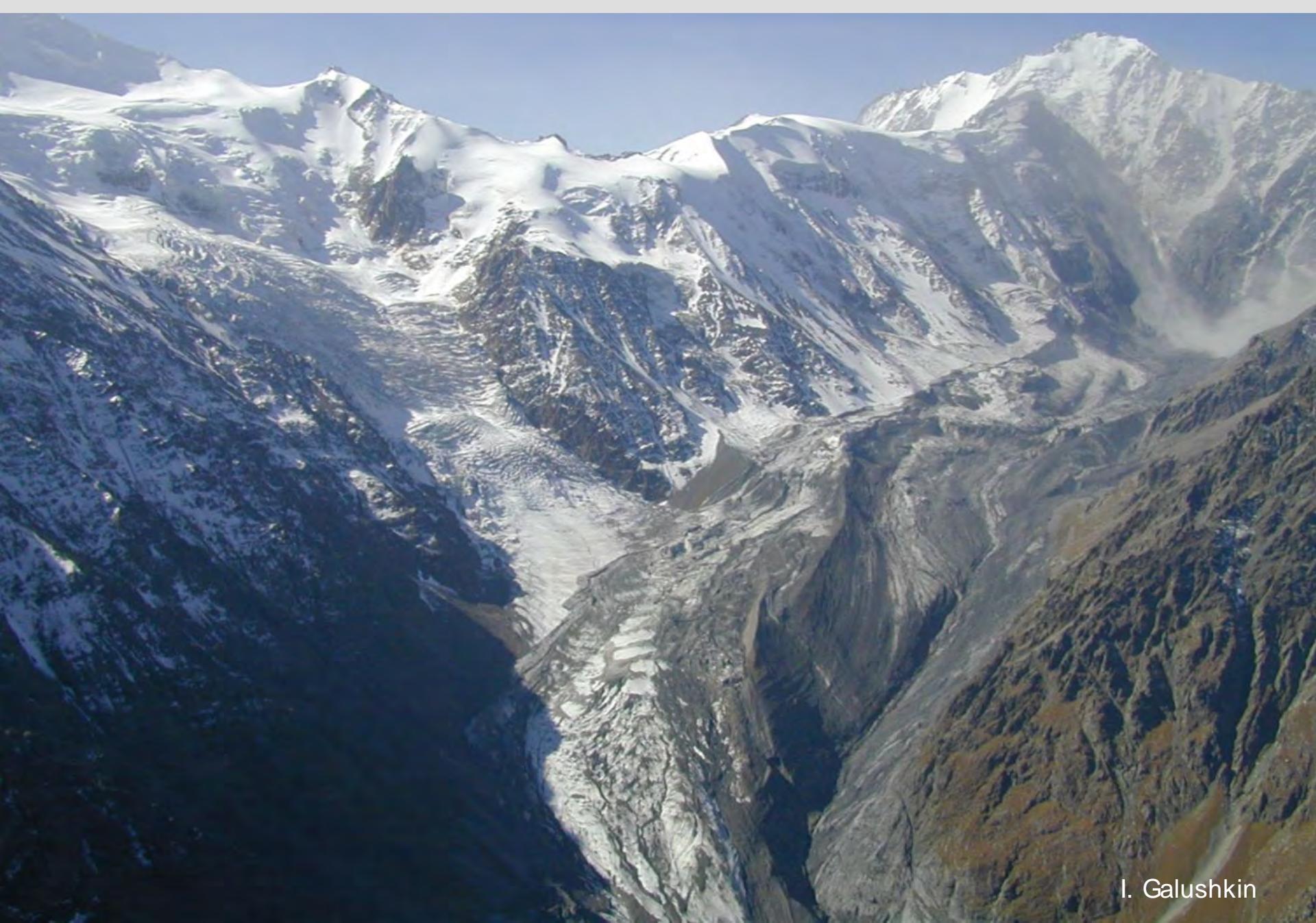
Caspian sea

Caucasus/ Kazbek, 20 September 2002



International Space Station / Uragan

Caucasus/ Kazbek, 20 September 2002



I. Galushkin

Up to 300 km/h fast



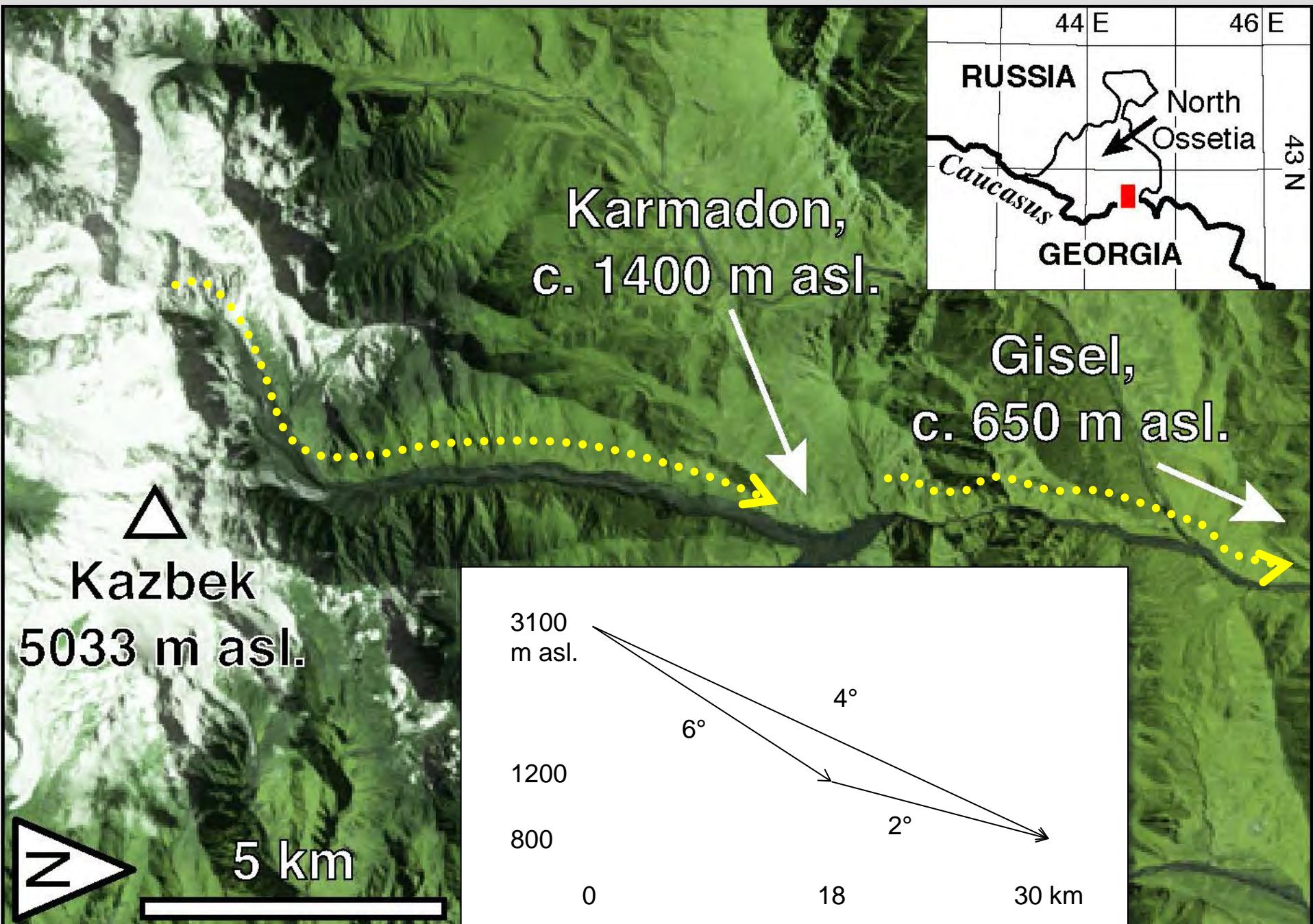
Karmadon, 18 km and 5 minutes later, 120 Mio m<sup>3</sup>



# Mudflow, another 15 km far



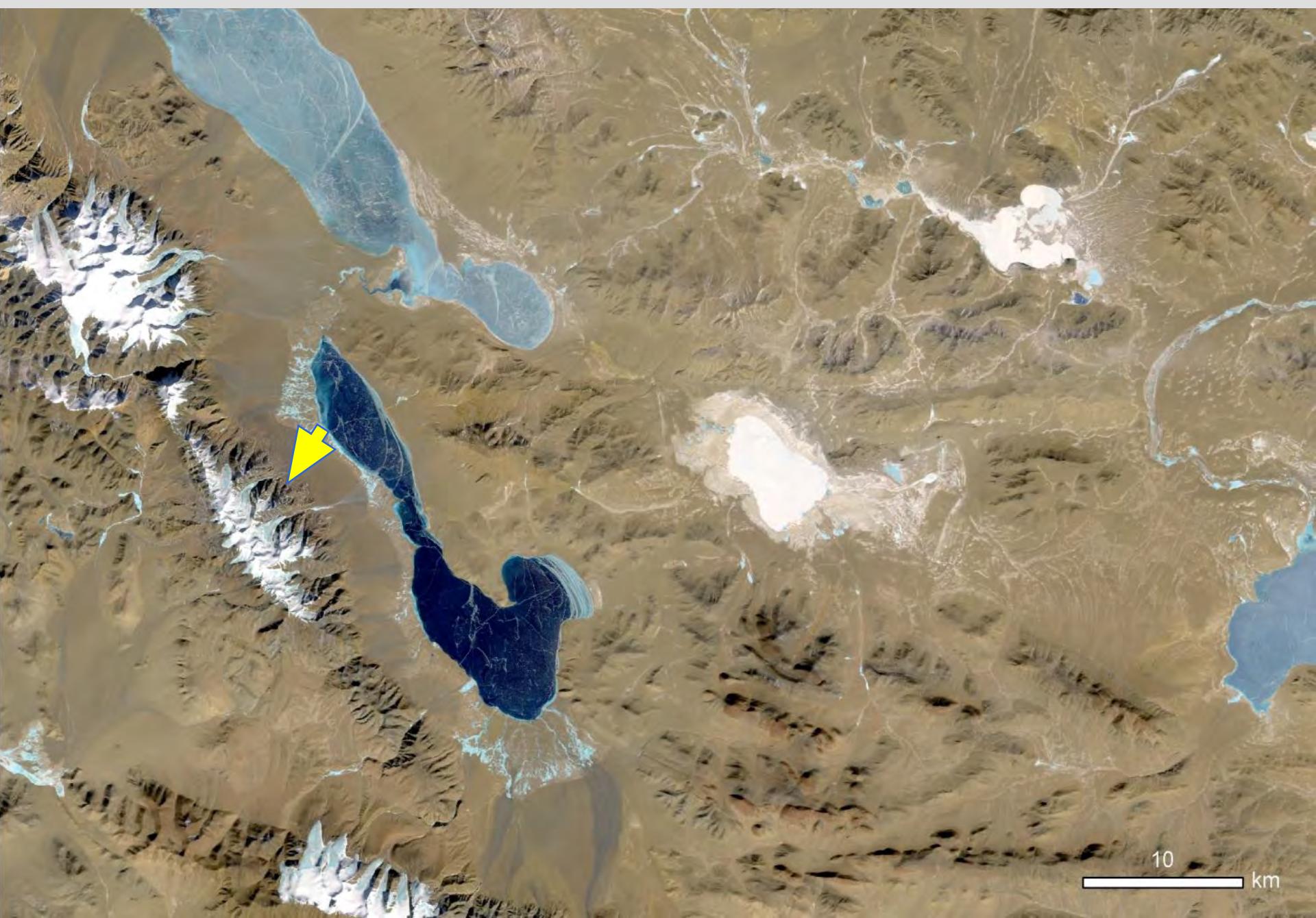
# Rock-ice avalanche at Kolka/ Karmadon



# Tibet



# Aru, Tibet

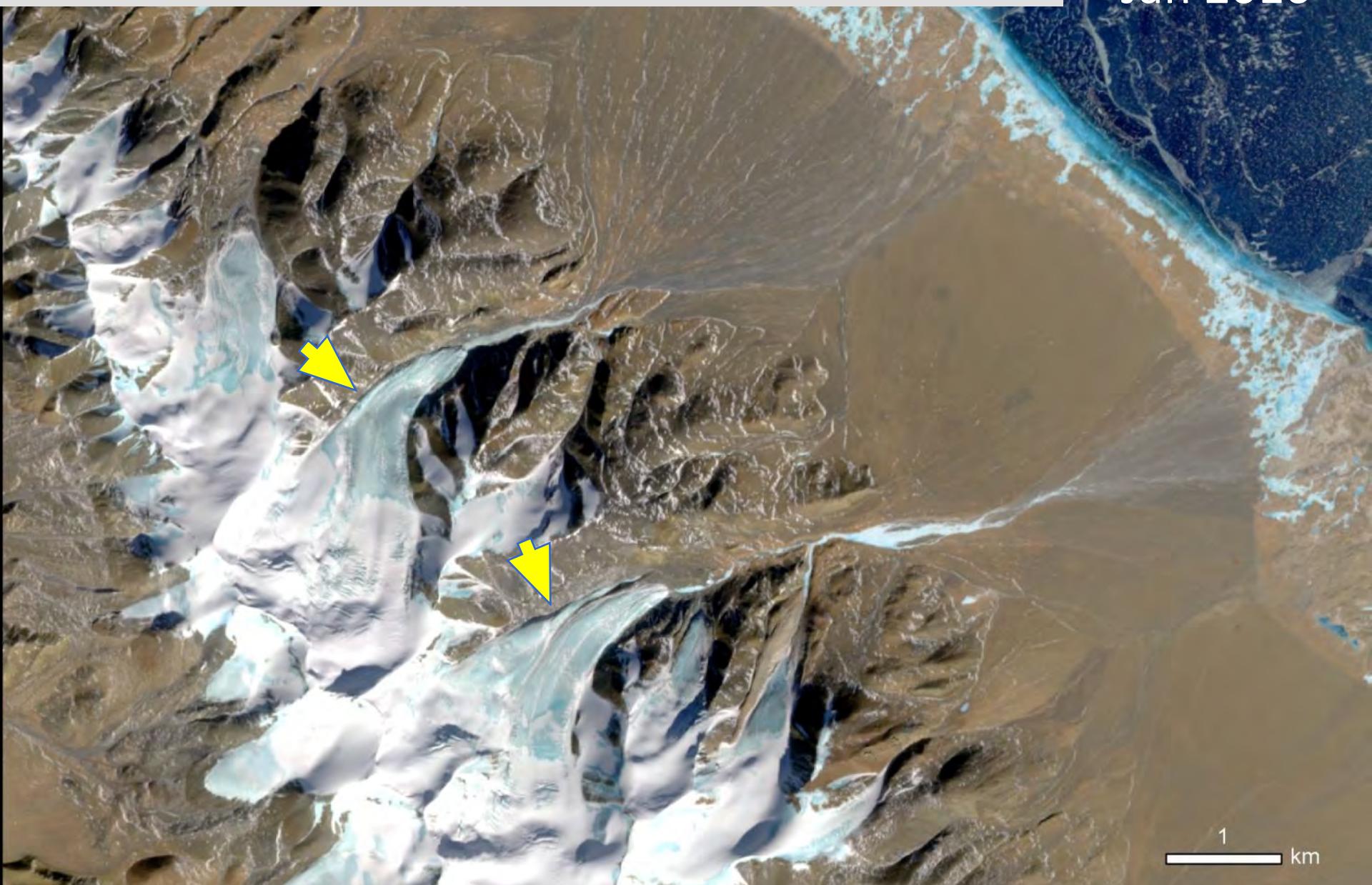


10

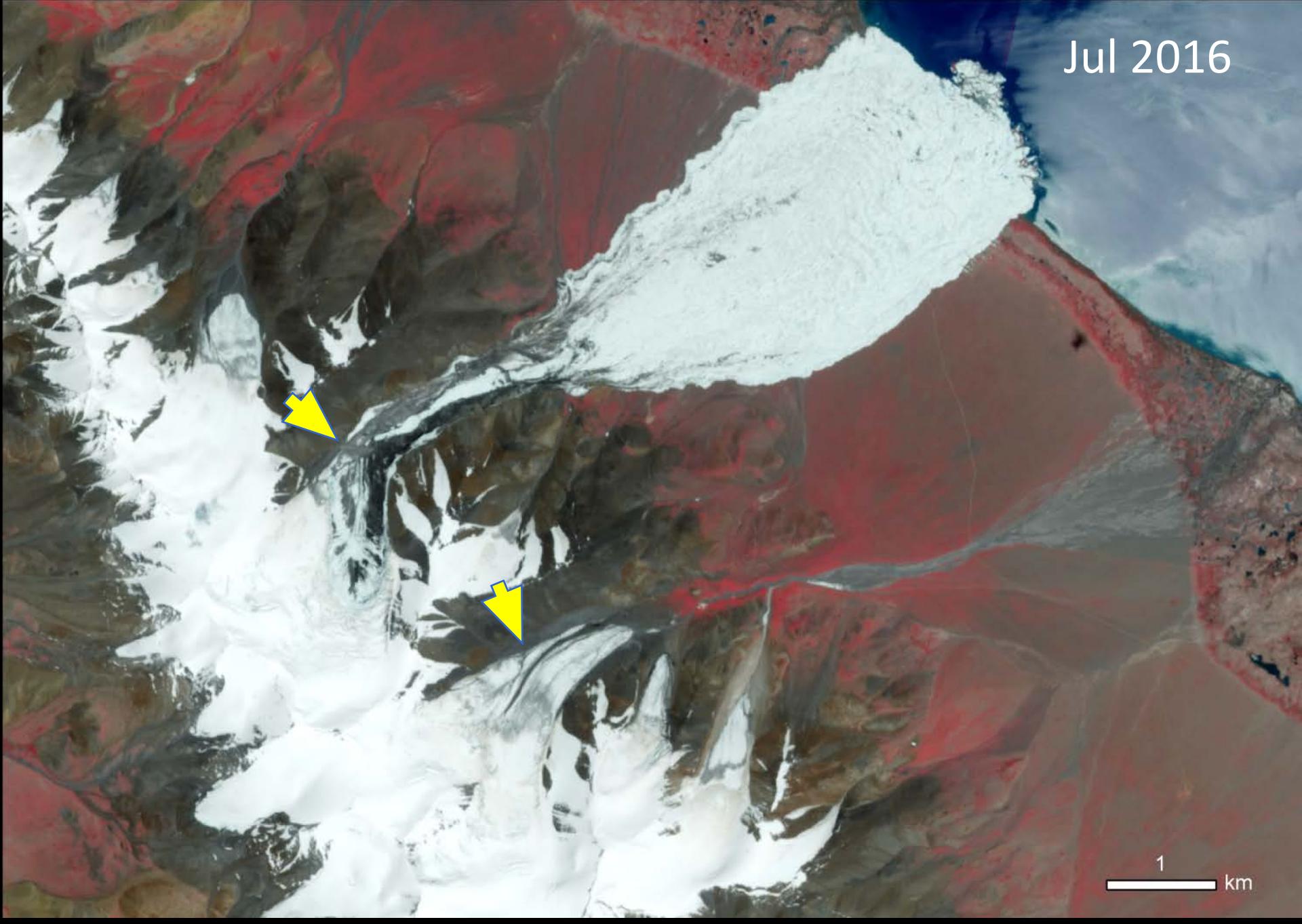
km

Aru, Tibet

Jan 2016



Jul 2016



Sep 2016



1  
km

Aru, Tibet

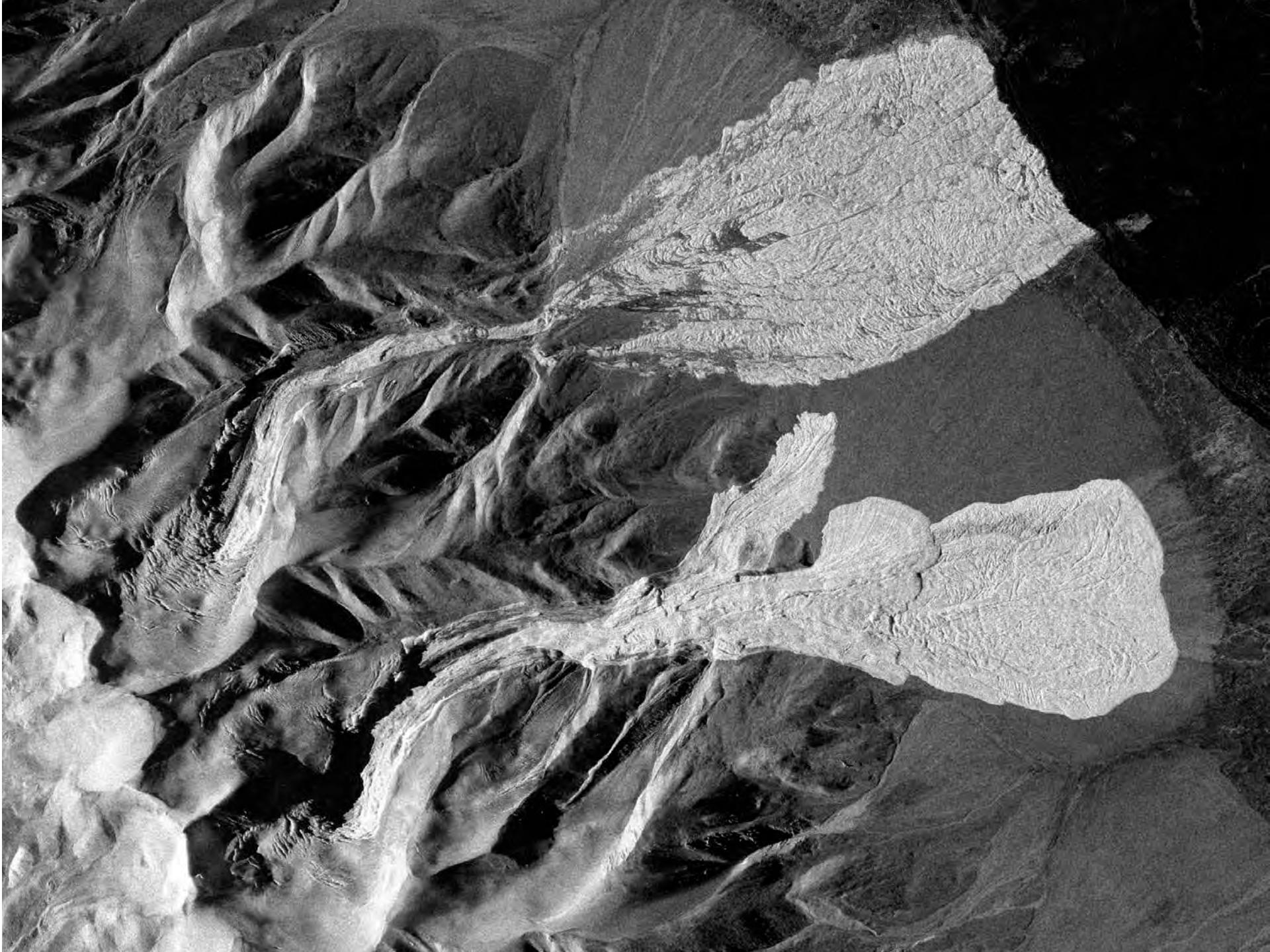


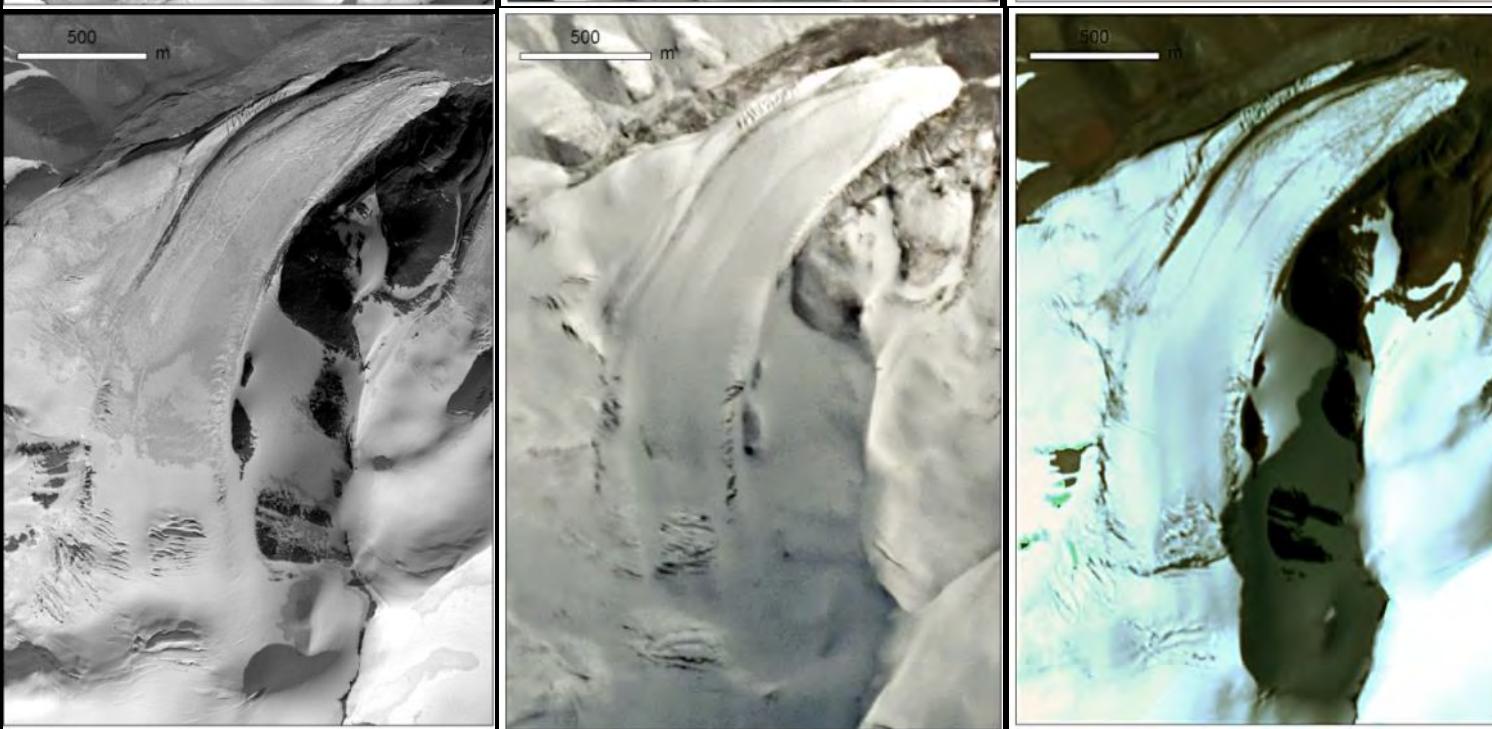
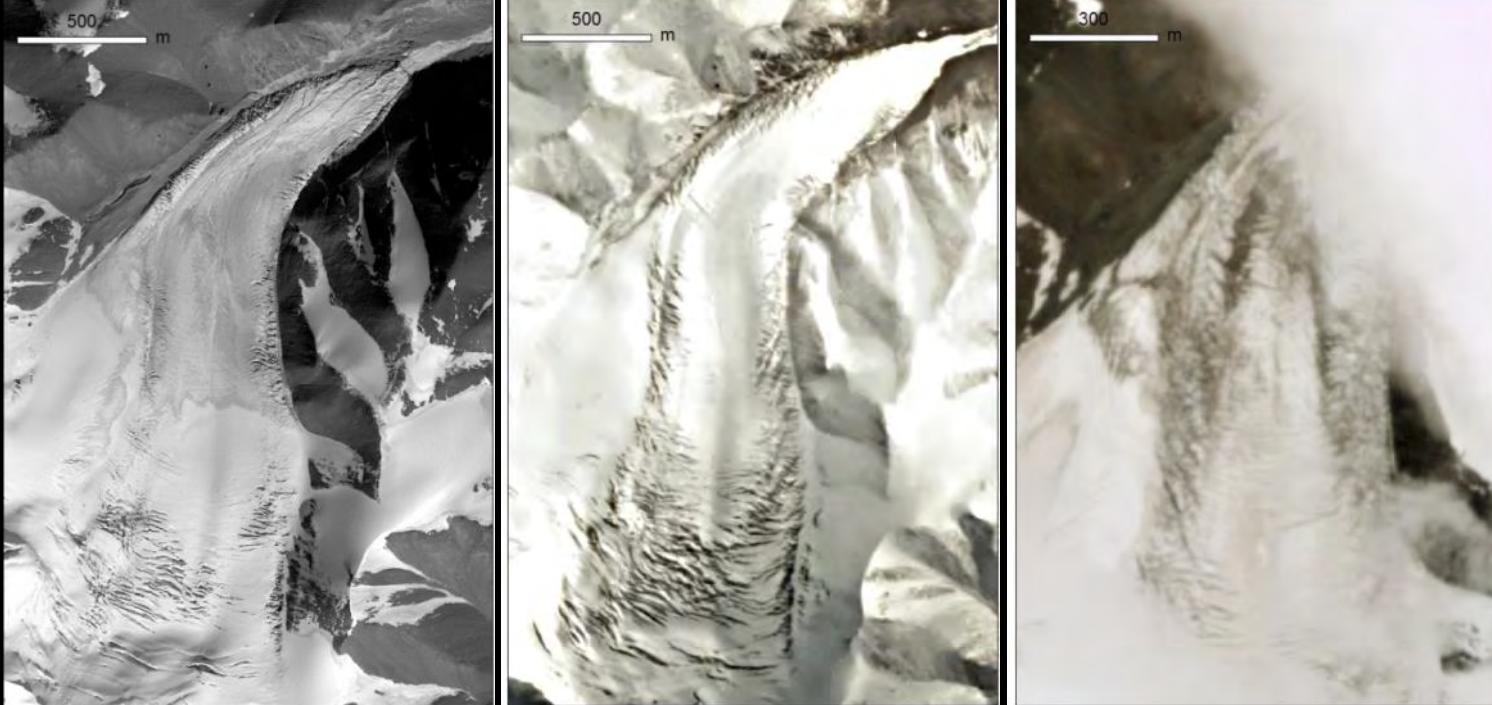
Aru, Tibet



Aru, Tibet

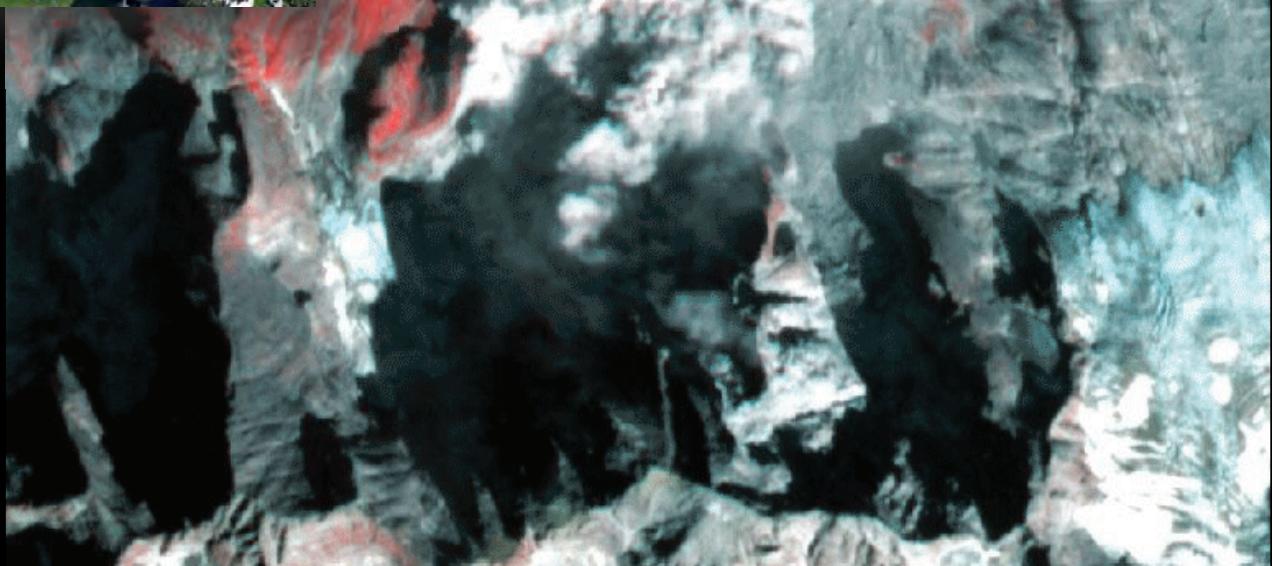
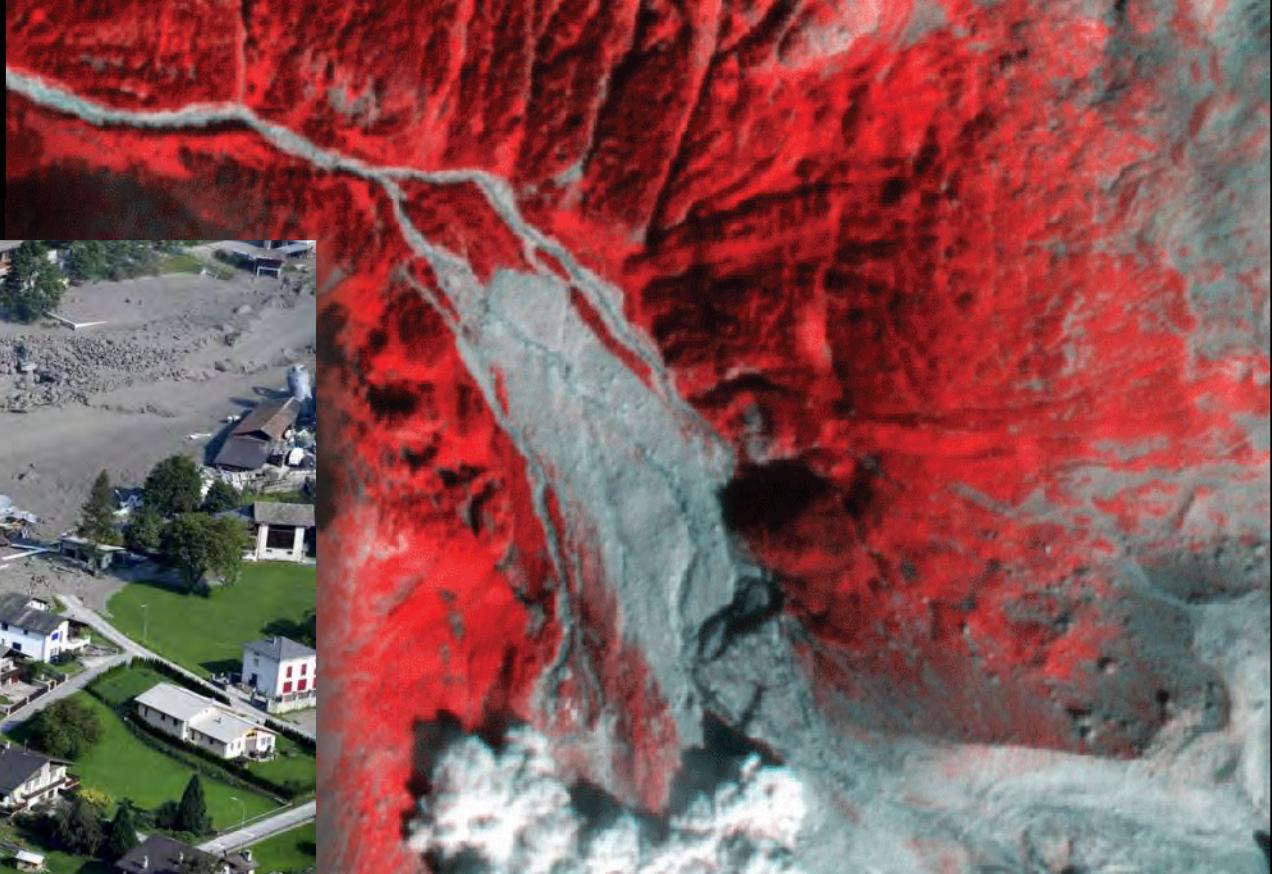
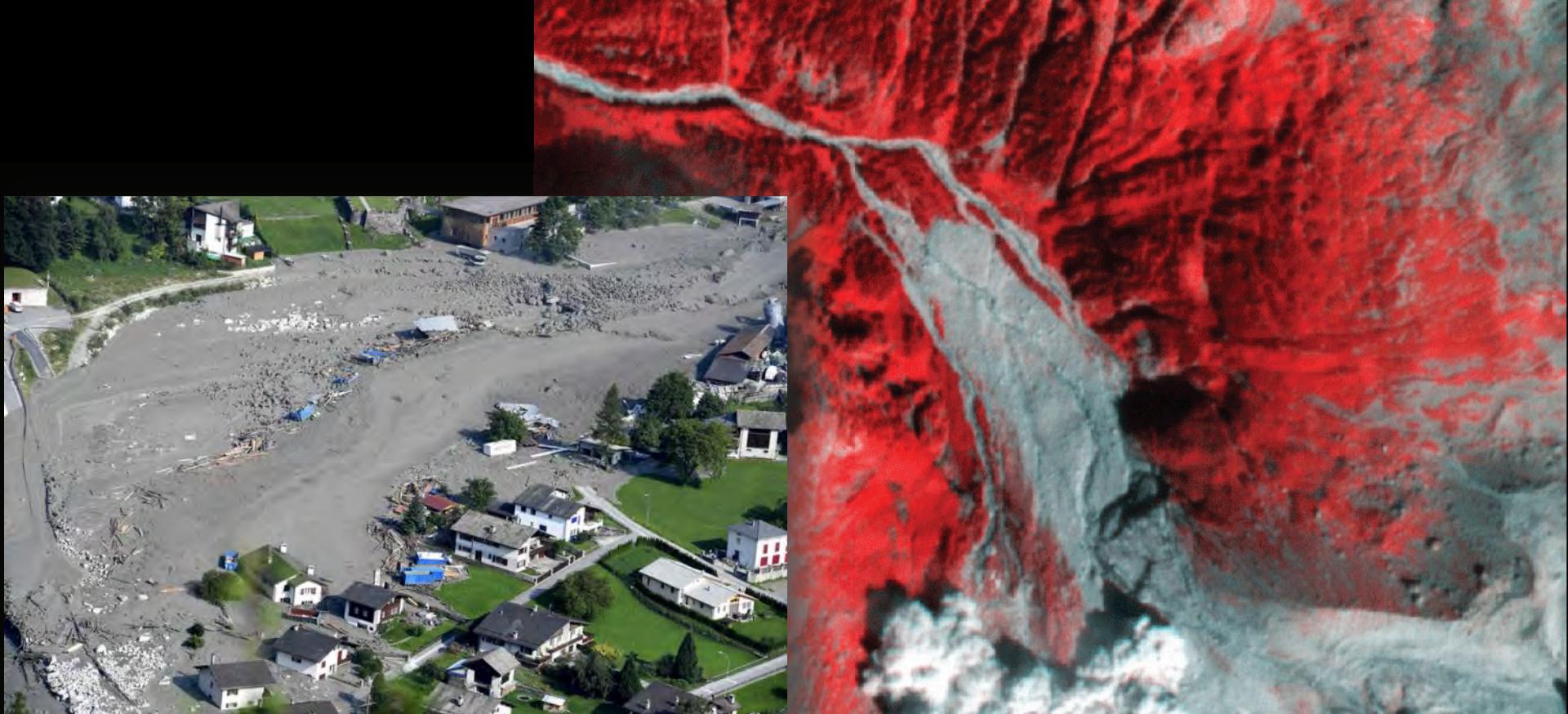




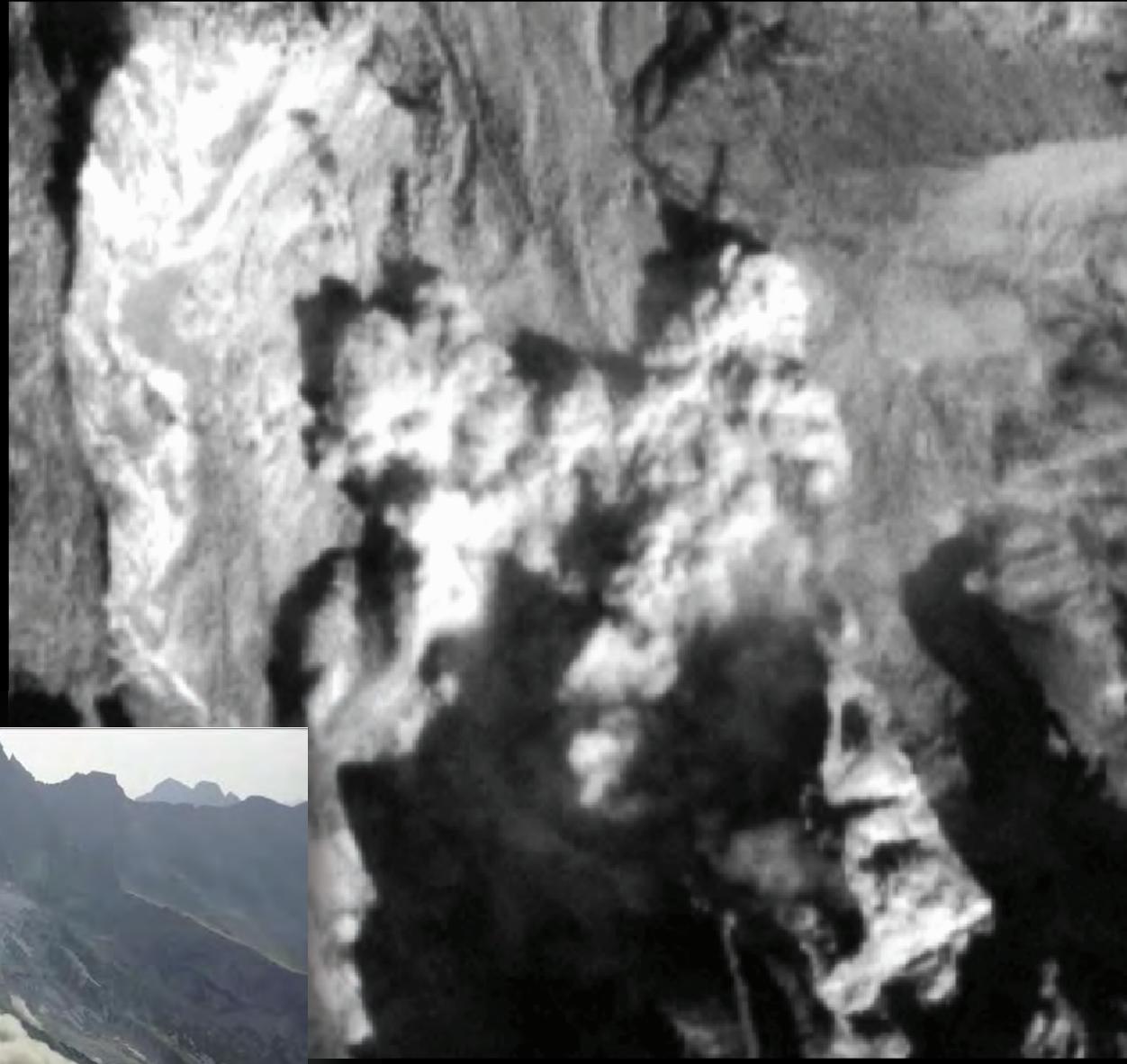


# Method matrix

	Landslides	Permafrost subsidence, heave, creep	Snow avalanches	Lake outbursts, floods	Glacier instabilities	Rock/ice avalanches
Image interpretation, change detection (ground-, air-, space-borne)	✓	✓	✓	✓	✓	
Automatic classification, change detection (ground-, air-, space-borne)			✓	✓		
Stereo techniques (ground-, air-, space-borne)	✓			✓		
Offset tracking (ground-, air-, space-borne)	✓	✓		✓		✓
Radar (interferometry) (ground-, air-, space-borne)	✓	✓	✓	✓	✓	
Altimetry, laserscanning (ground-, air-, space-borne)	✓					



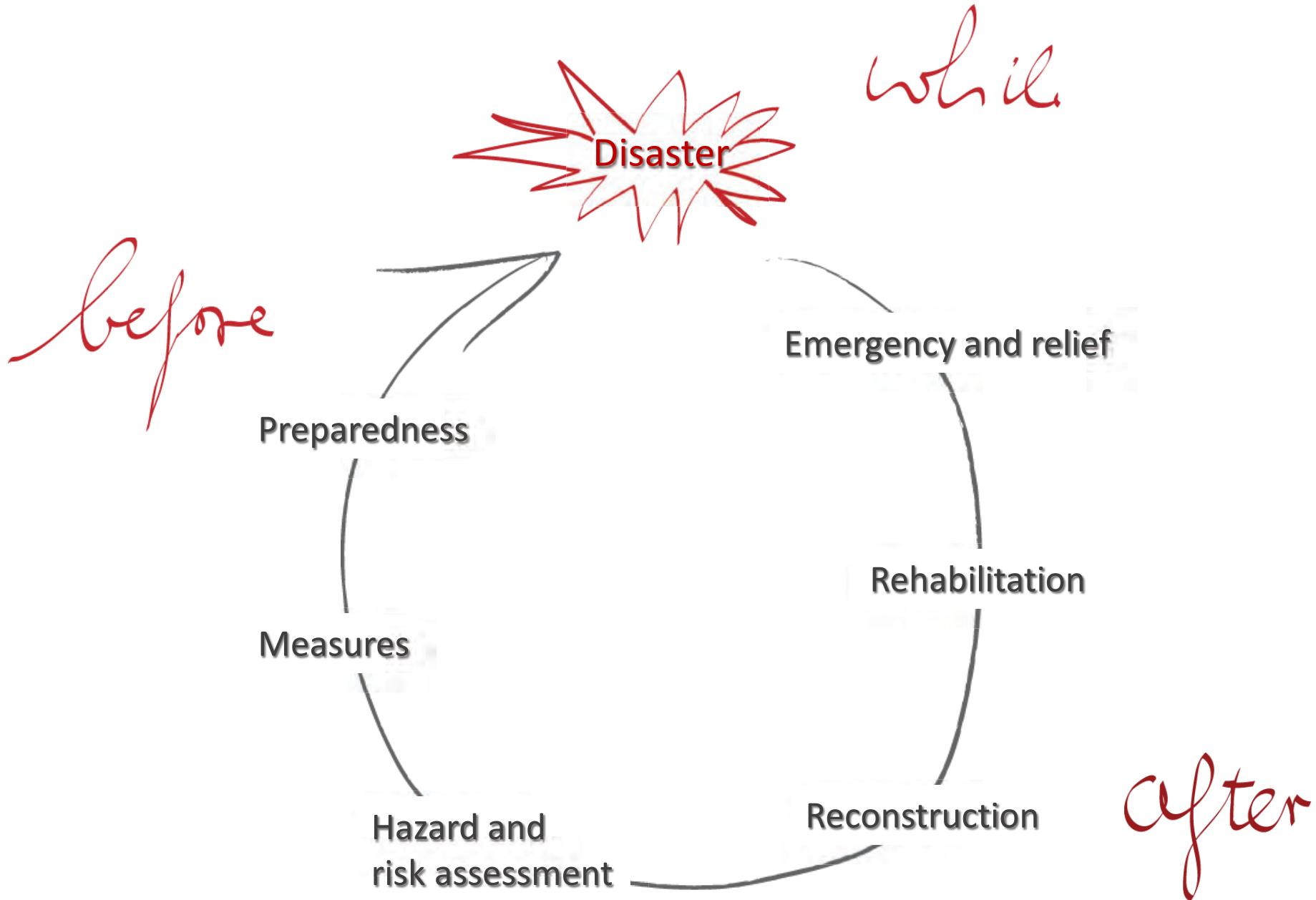
Planet



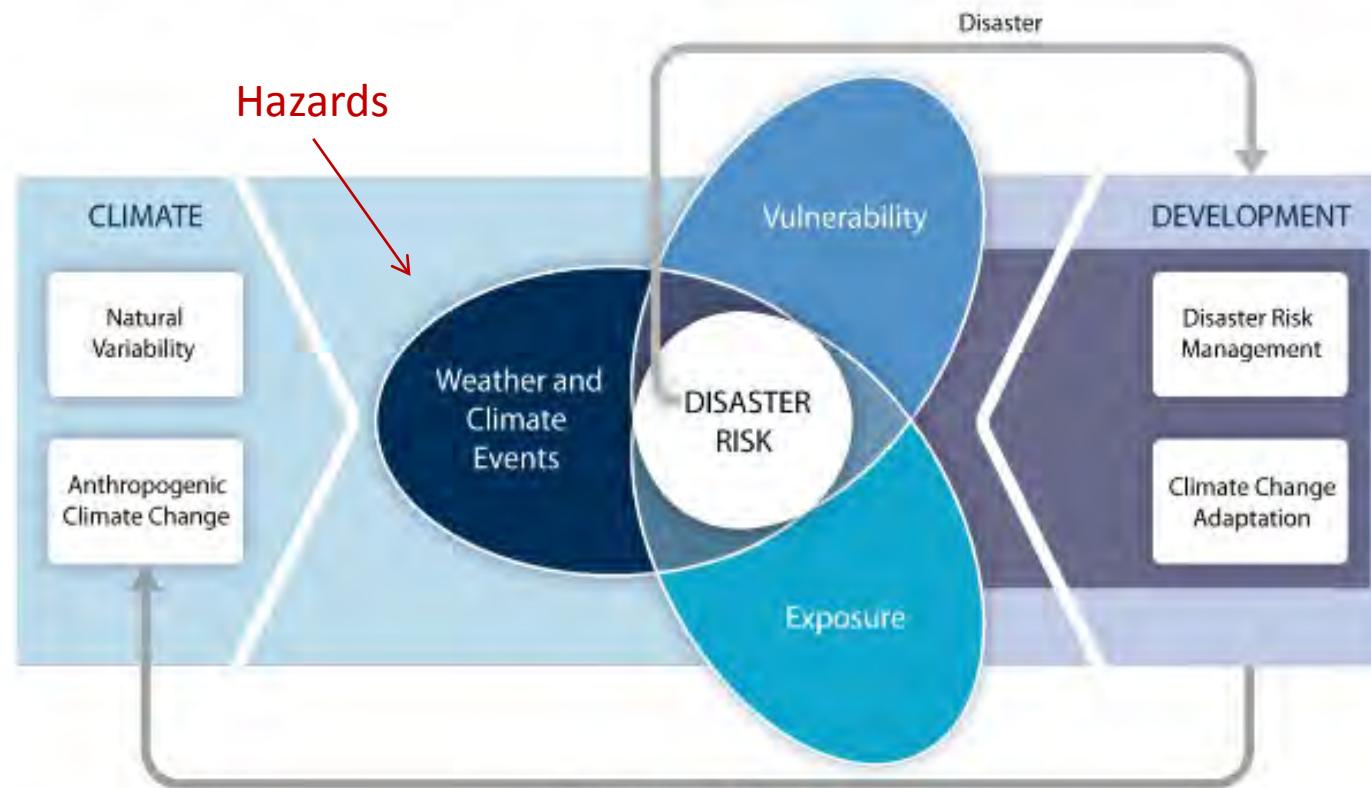
Planet

## *Concluding remarks*

# Risk Cycle



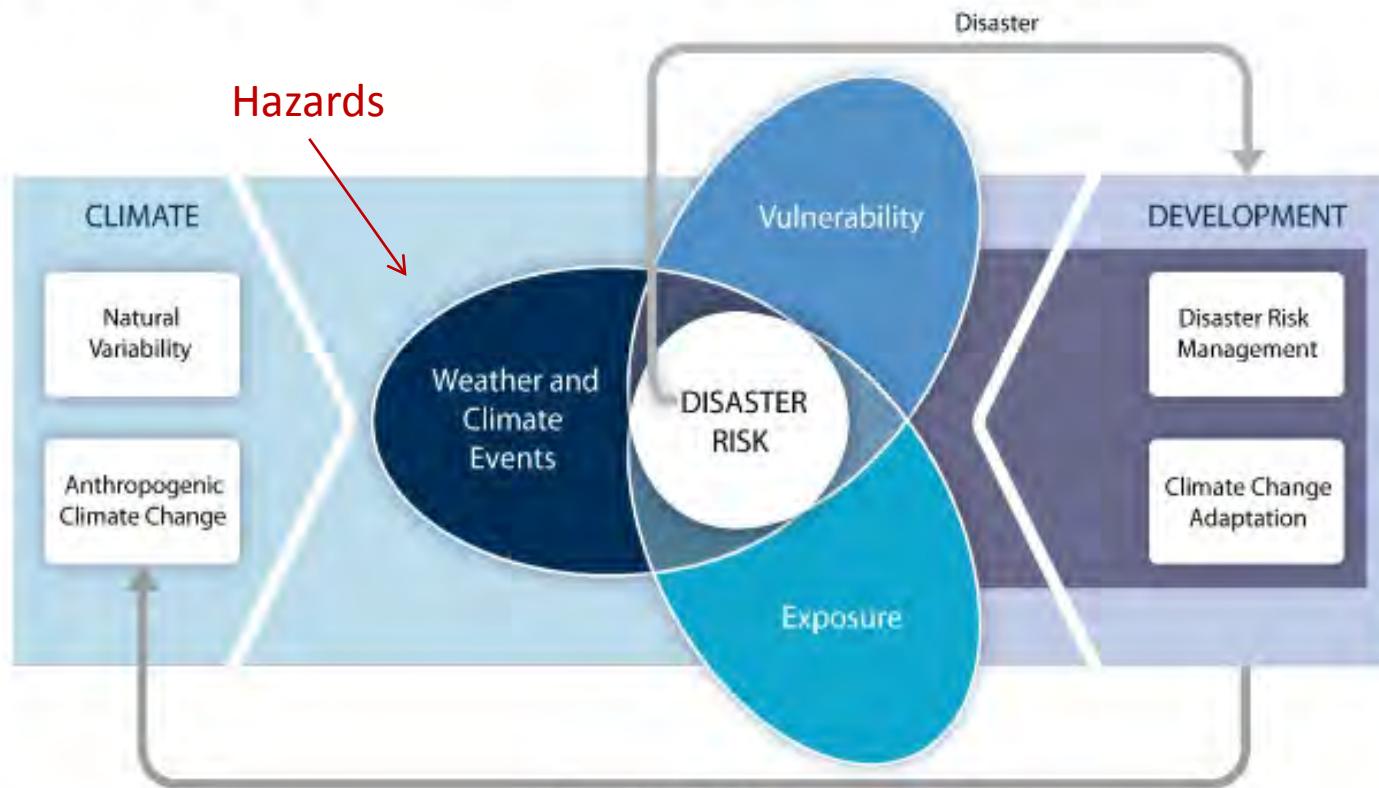
Increasing vulnerability, exposure, or severity and frequency of climate events increases **disaster risk**



*Disaster risk management and climate change adaptation can influence the degree to which **extreme events translate into impacts** and **disasters***

# Risk propeller / Disaster risk

Increasing vulnerability, exposure, or severity and frequency of climate events increases **disaster risk**



**Disaster risk**  
The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery

**Exposure**  
The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected

**Vulnerability**  
The propensity or predisposition to be adversely affected.

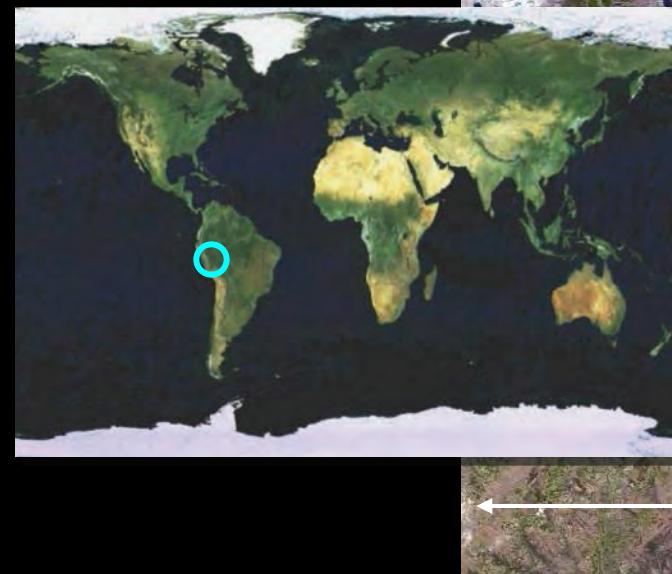
*Disaster risk management and climate change adaptation can influence the degree to which **extreme events translate into impacts** and **disasters***

# *Responsible Conduct*

# *Responsible Conduct*

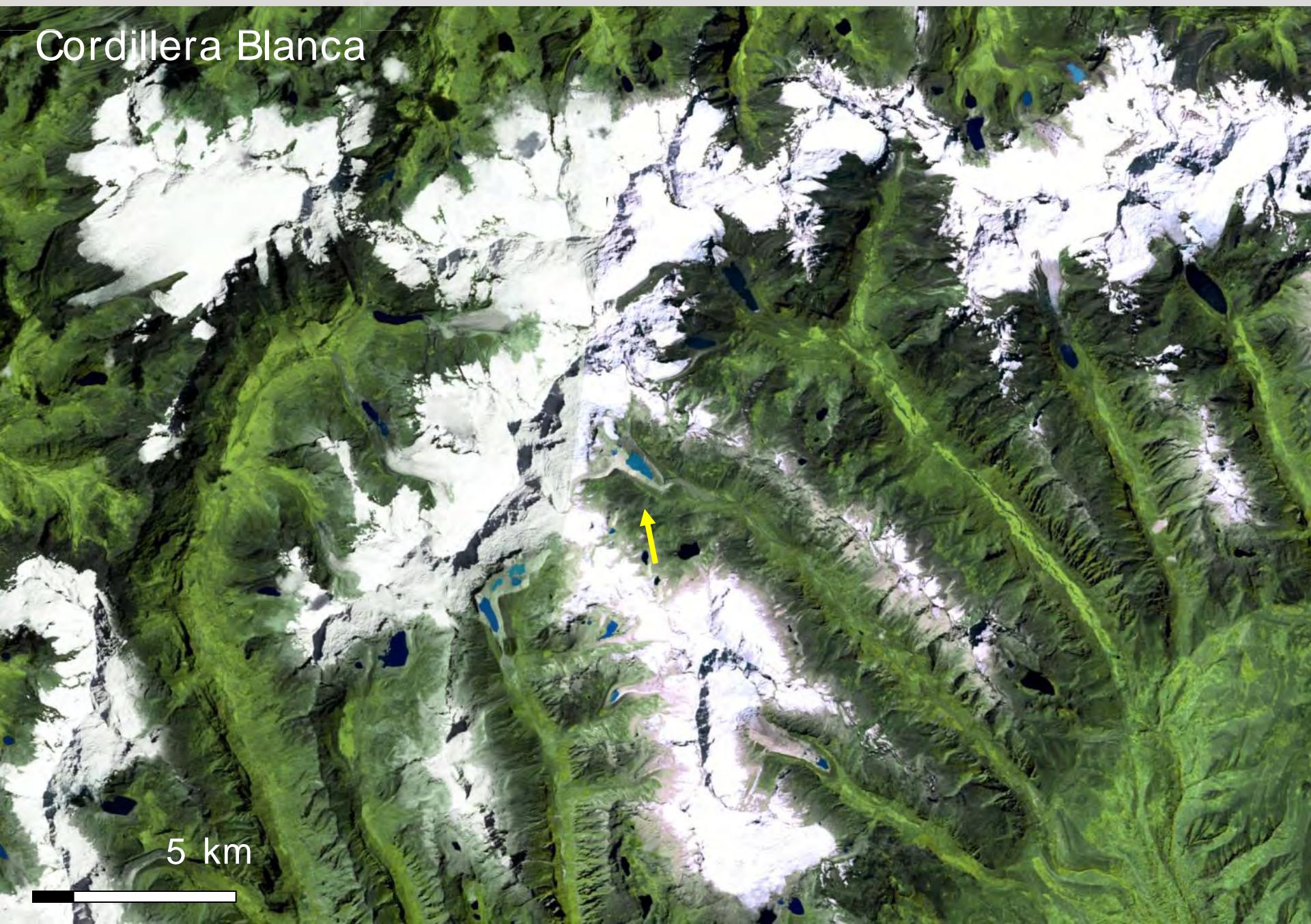
Cordillera  
Blanca

Laguna Palcacocha (Peru): 13 Dec 1941, 4mio m<sup>3</sup>, ca. 6000+

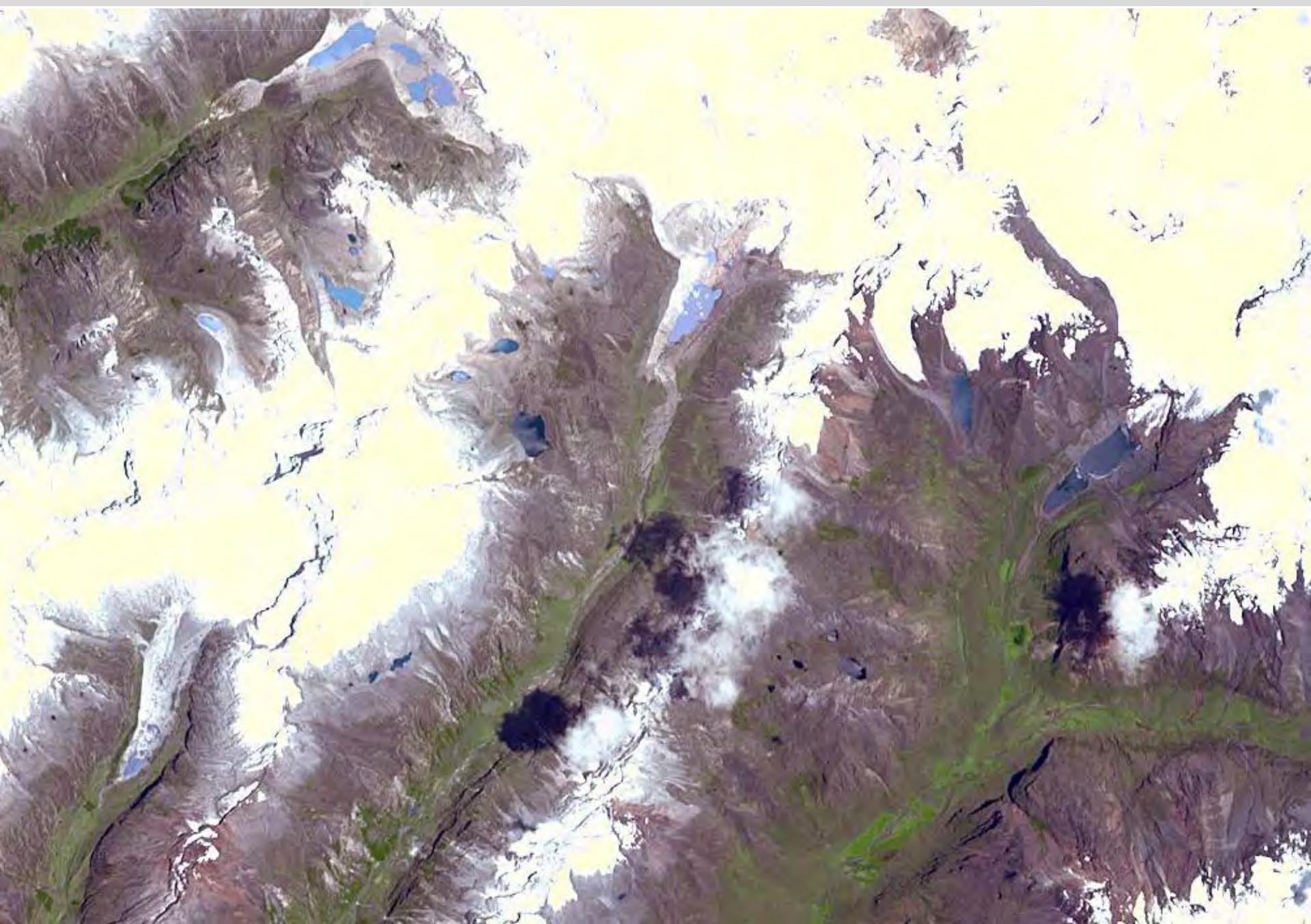


# *Responsible Conduct*

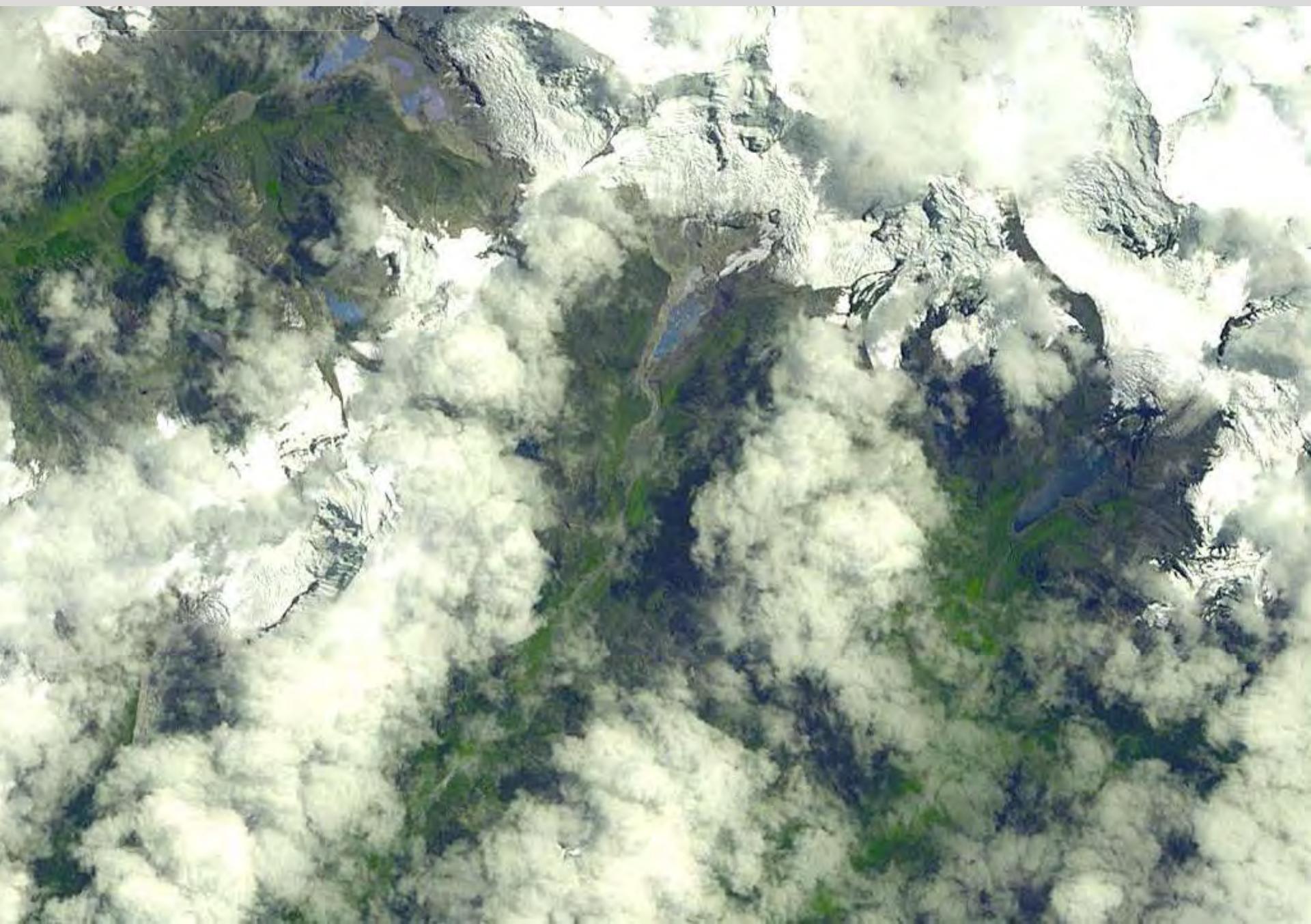
## Cordillera Blanca



# *Responsible Conduct*



# *Responsible Conduct*



# *Responsible Conduct*



I. Machguth

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<http://folk.uio.no/kaeaeb/publications/>

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ESA links:

- [https://www.esa.int/spaceinvideos/Videos/2017/06/Sentinel\\_Stories\\_Interviewing\\_a\\_remote\\_sensing\\_expert](https://www.esa.int/spaceinvideos/Videos/2017/06/Sentinel_Stories_Interviewing_a_remote_sensing_expert)
- [https://sentinel.esa.int/web/sentinel/home/-/journal\\_content/56/247904/2745132](https://sentinel.esa.int/web/sentinel/home/-/journal_content/56/247904/2745132)
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Thank you !