ALOS-2による~~アジア高山域山岳~~氷河の解析事例

西クンルン山脈

Observation of mountain glaciers by PALSAR 2 in the West Kunlun Shan, NW Tibet

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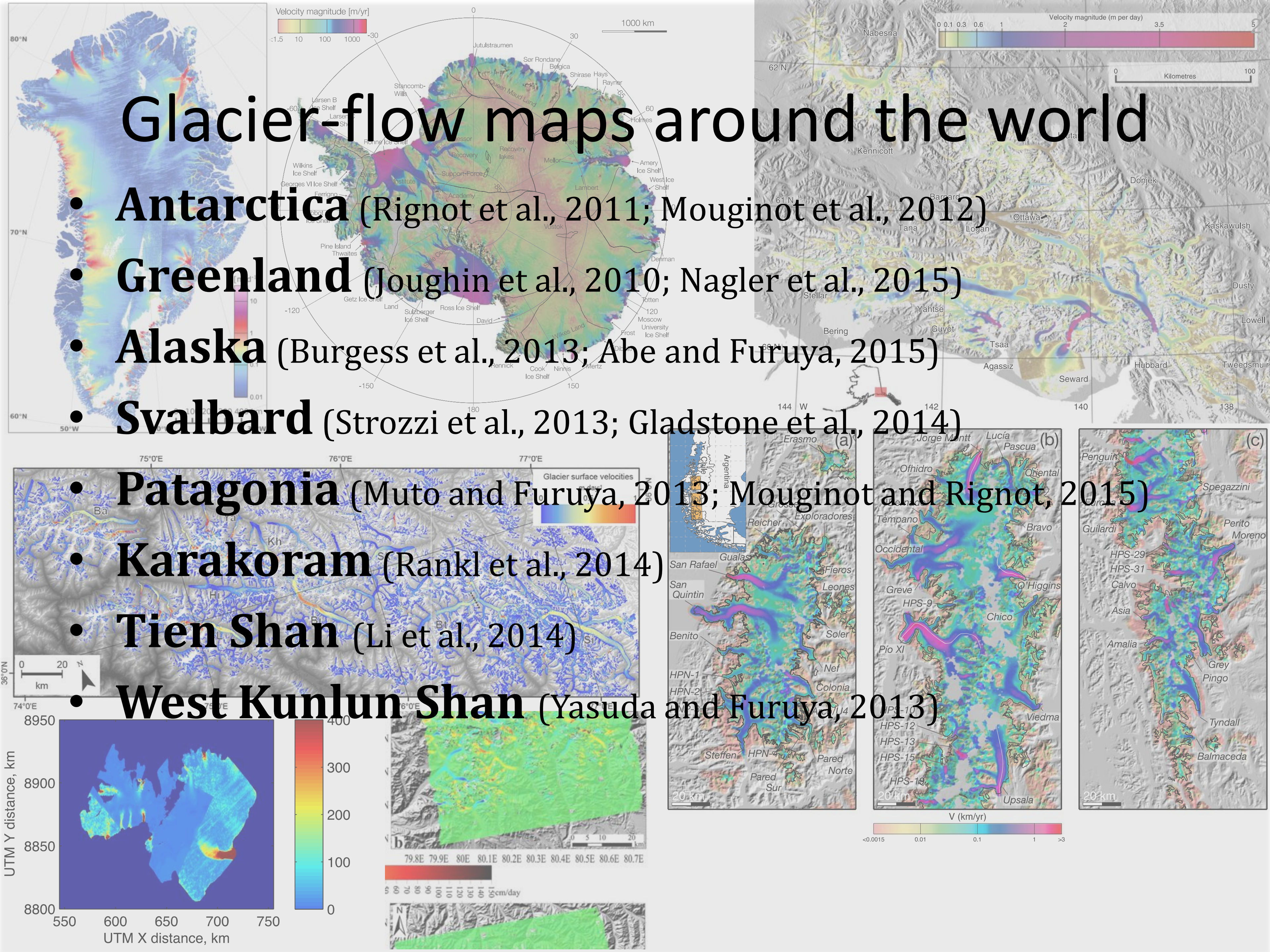
HOKKAIDO UNIVERSITY FOUNDED 1876

Hokkaido University SPACE GEODESY

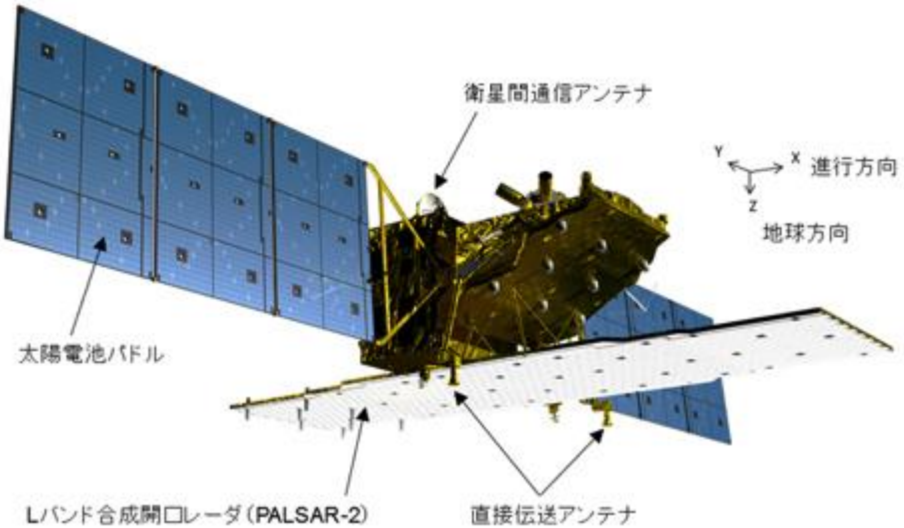


Glacier-flow maps around the world

- **Antarctica** (Rignot et al., 2011; Mouginot et al., 2012)
- **Greenland** (Joughin et al., 2010; Nagler et al., 2015)
- **Alaska** (Burgess et al., 2013; Abe and Furuya, 2015)
- **Svalbard** (Strozzi et al., 2013; Gladstone et al., 2014)
- **Patagonia** (Muto and Furuya, 2013; Mouginot and Rignot, 2015)
- **Karakoram** (Rankl et al., 2014)
- **Tien Shan** (Li et al., 2014)
- **West Kunlun Shan** (Yasuda and Furuya, 2013)

PALSAR2

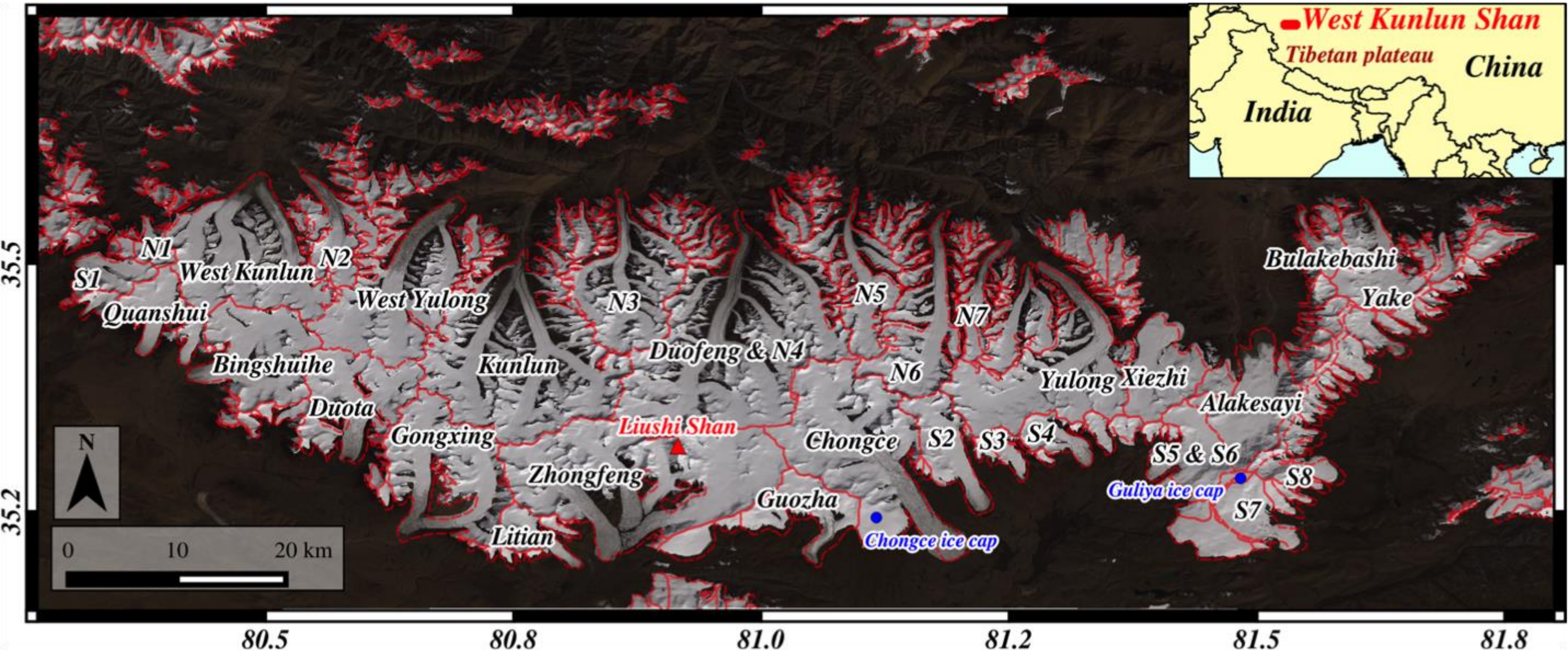
- L-band (1.2 GHz) : deeply penetrating into the ice body
- 14-day revisiting : reduce a temporal decorreration
- Modes : Spotlight, StripMap, ScanSAR
  - Improved spatial resolutions with dual/full polarization



http://www.eorc.jaxa.jp/ALOS-2/about/joverview.htm

West Kunlun Shan

- One of the driest and coldest region around Tibetan plateau (ann. temp. -13.4 ℃, preci.460mm, Zheng et al., 1988)
- Summer accumulation/ablation (mainly May-August) (Zhang and Jiao, 1987)

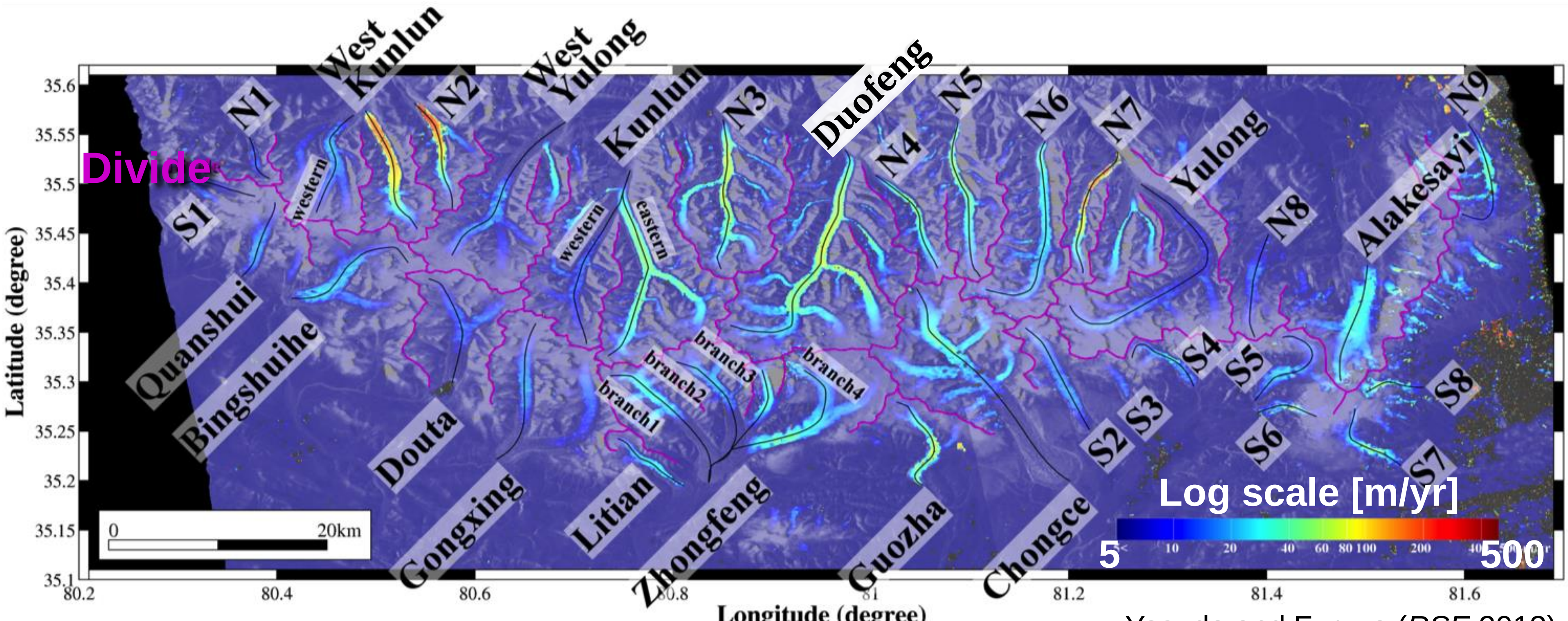


Glacier outline from RGI v3.2

(Yasuda and Furuya, JGR-ES, accepted)

Flow map with PALSAR-1

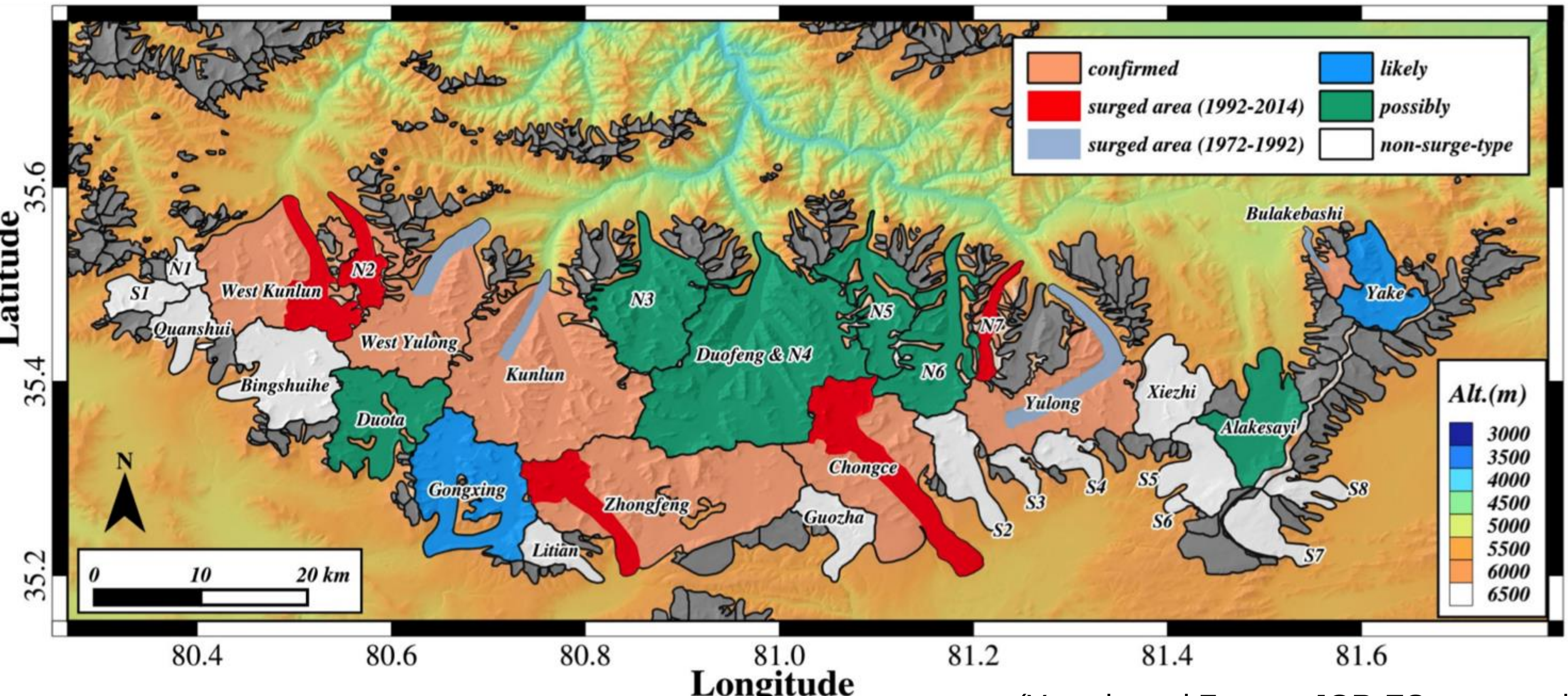
- Non-surge-type : 20-100 m/yr (~0.78-3.8 m/14 days)
- Surging glaciers : >200 m/yr (~7.8 m/14 days)



Yasuda and Furuya (*RSE* 2013)

Clustering of surge-type glaciers

- From Landsat (1972-2013) and satellite SAR (1992-2014)
- Three surging ongoing on the northern slope
- Glacier surging would occur in future.

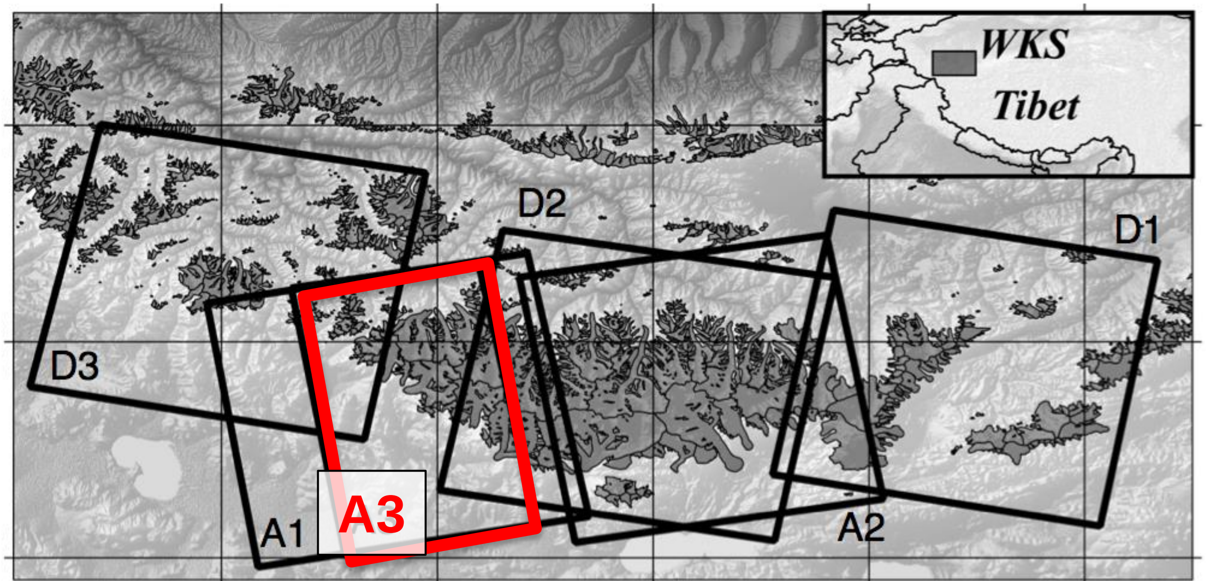


(Yasuda and Furuya, JGR-ES, accepted)

Objectives

- PALSAR2 detects glacier flow in WKS?
  - Yes. (but depend on the time separation)
- New findings?
  - A new surging glacier
- Challenging tasks
  - Phase unwrapping on glaciers
- New applications?
  - Polarimetric SAR (PolSAR)

PALSAR2 data sets



id	pol.	pair	span (days)	Bperp (m)	InSAR	MAI	PO
A1	HH, HV	2014/09/30 – 2015/02/17	140	9	×	×	×
		2015/02/17 – 2015/03/17	28	1009	◎	◎	○
A2	HH, HV	2014/09/02 – 2015/01/20	140	2	×	×	×
A3	full pol.	2015/03/03 – 2015/03/31	28	179	◎	◎	◎
D1	HH, HV	2015/03/14 – 2015/03/28	14	117	◎	◎	×
D2	HH, HV	2015/04/25 – 2015/05/09	14	95	◎	◎	×
D3	HH, HV	2015/03/05 – 2015/03/19	14	705	◎	◎	×

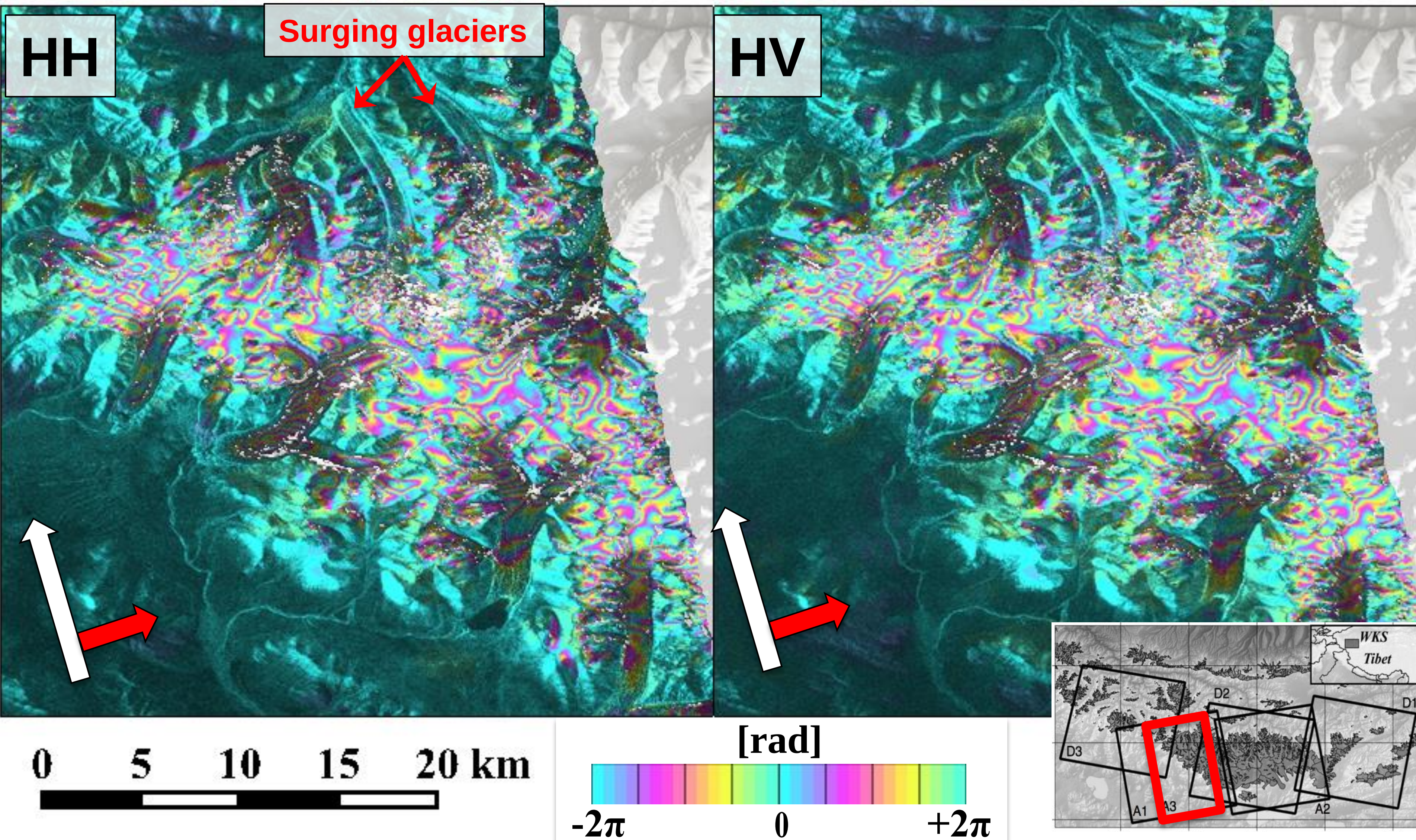
Software :
GAMMA (ver. 2015/07/02)

DEM :
SRTM4

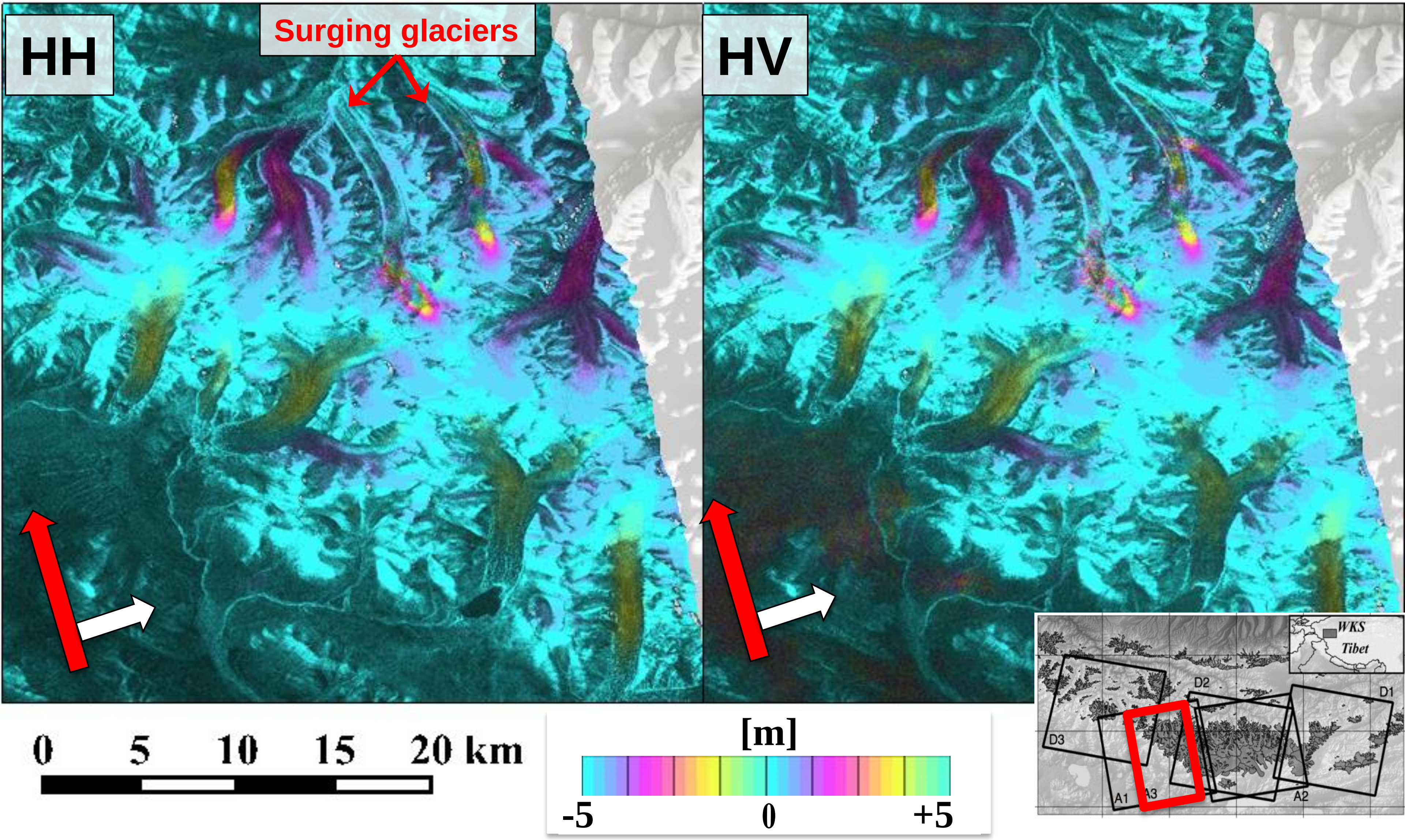
Parameters :
InSAR, MAI
差分干渉　：3x3 looks
unwrapping：4x4 looks
(by minimum cost flow)

Pixel Offset (PO)
window size　：64x64
step numbers： 9x9
(range x azimuth pixels)

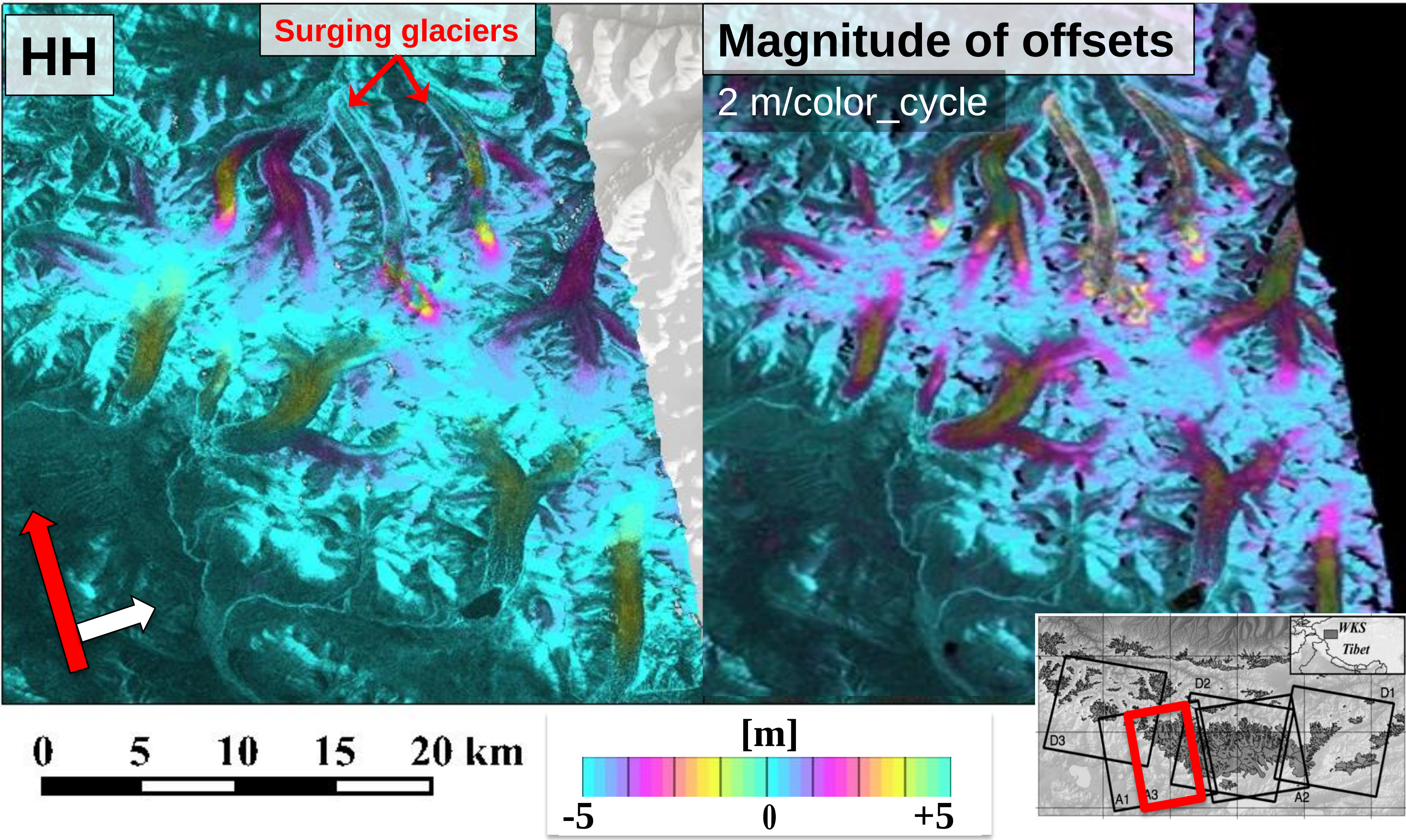
Preliminary results: InSAR (HH, HV)
(A3: 2015/03/03 - 2015/03/31)



Preliminary results: MAI (HH, HV)
(A3: 2015/03/03 – 2015/03/31)



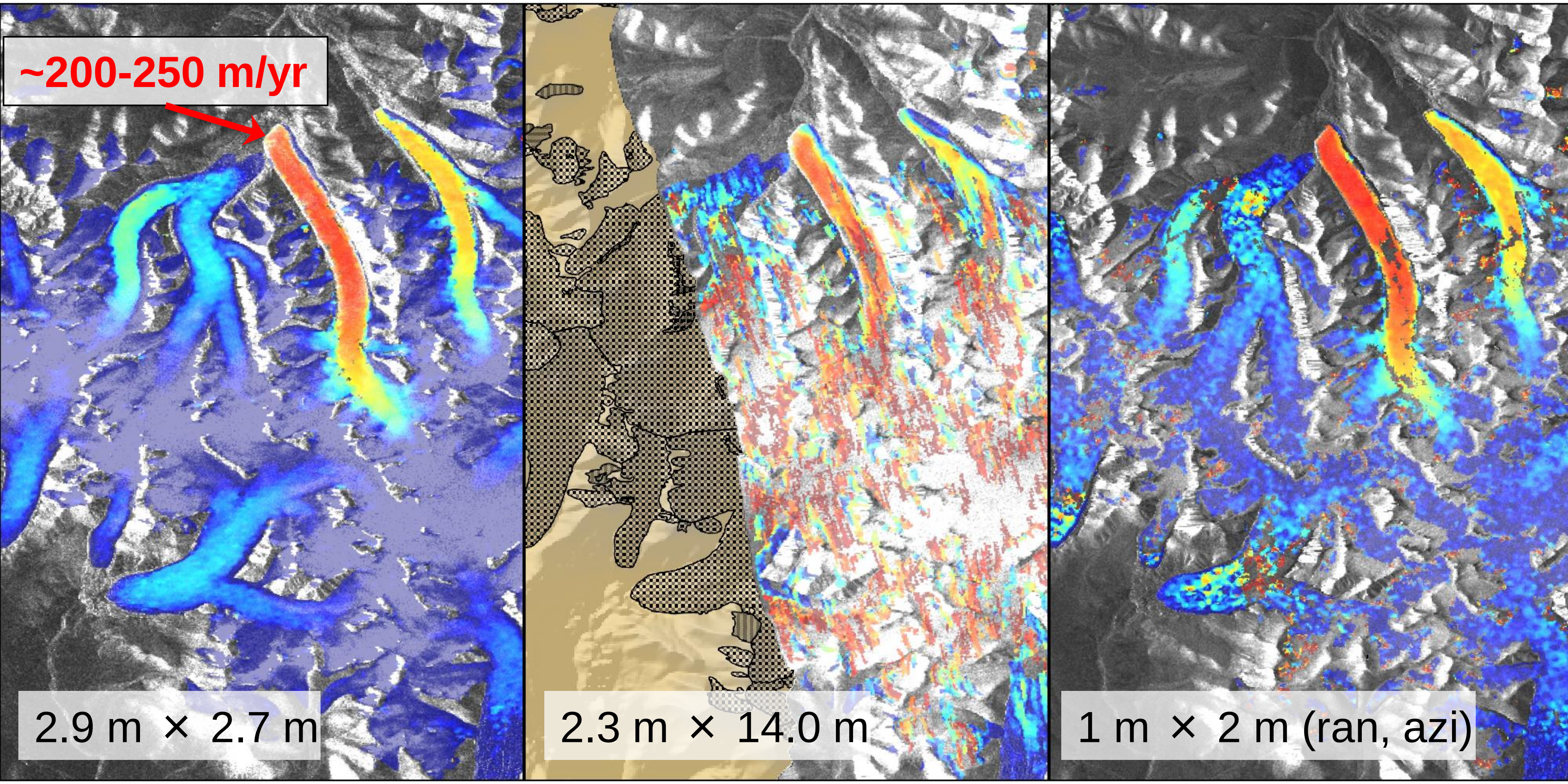
Preliminary results: MAI and Pixel offset (A3: 2015/03/03 – 2015/03/31)

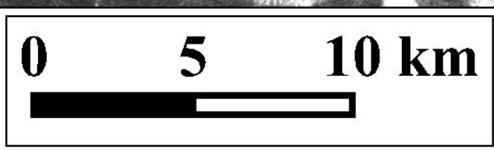


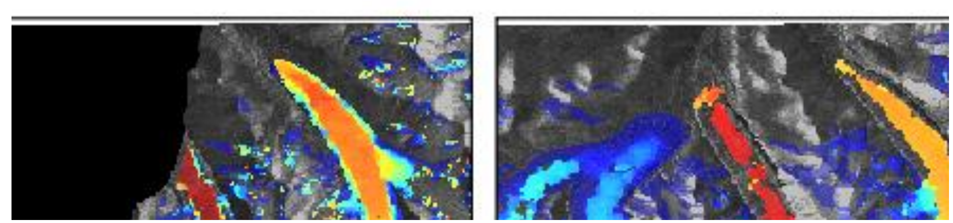
PALSAR2 (L-band)
2015/03/03 – 2015/03/31
StripMap (HH), 28 days

Sentinel-1A (C-band)
2015/04/02 – 2015/04/26
TOPS IW (VV), 24 days

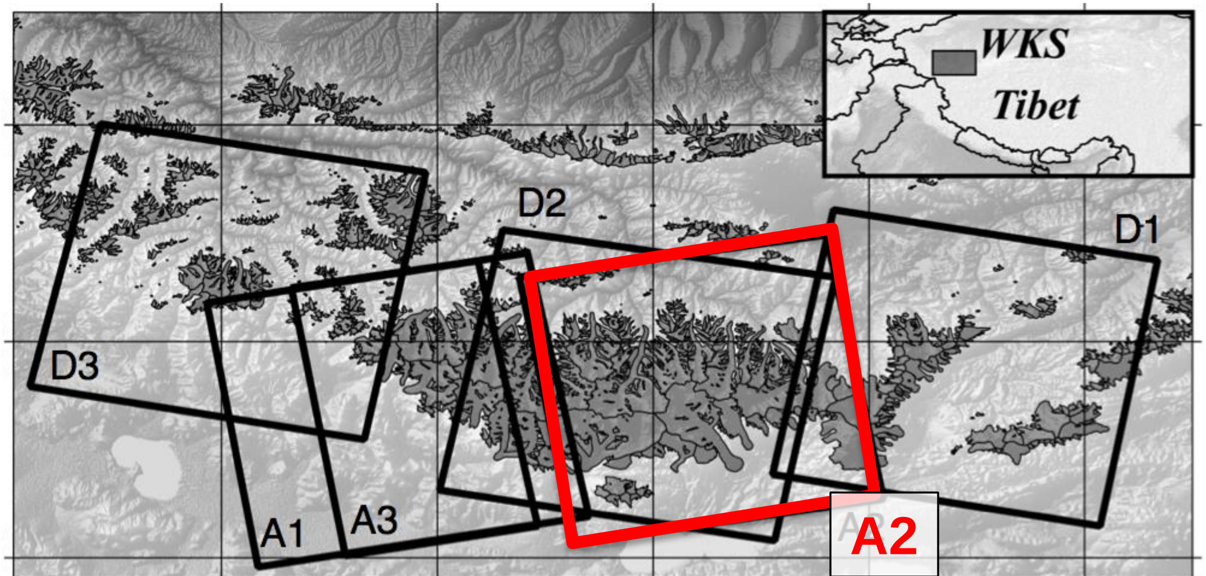
TerraSAR-X (X-band)
2015/05/04 – 2015/05/15
StripMap (HH), 11 days







PALSAR2 data sets



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Pixel Offset (PO)
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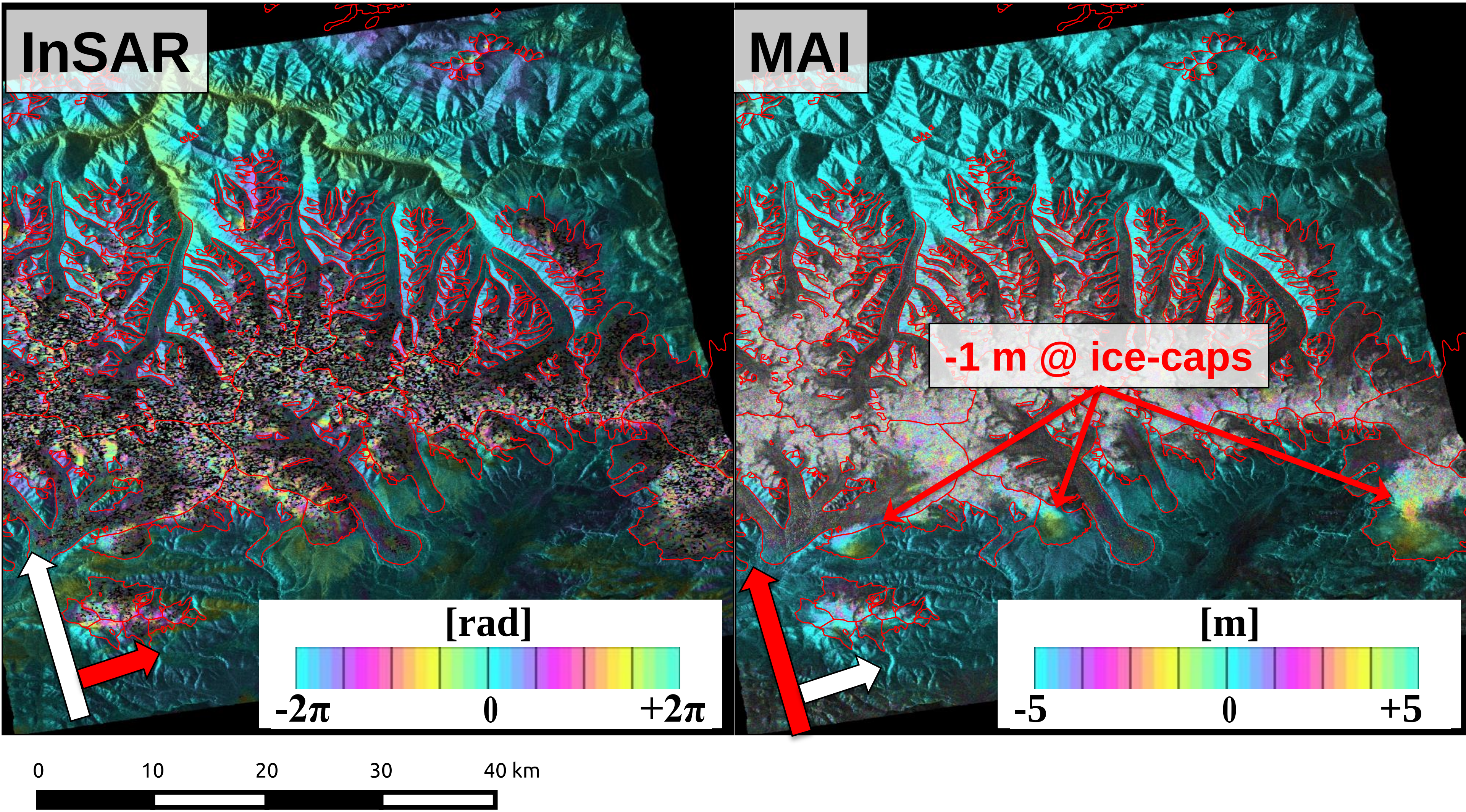
step numbers :　9x9
(range x azimuth pixels)

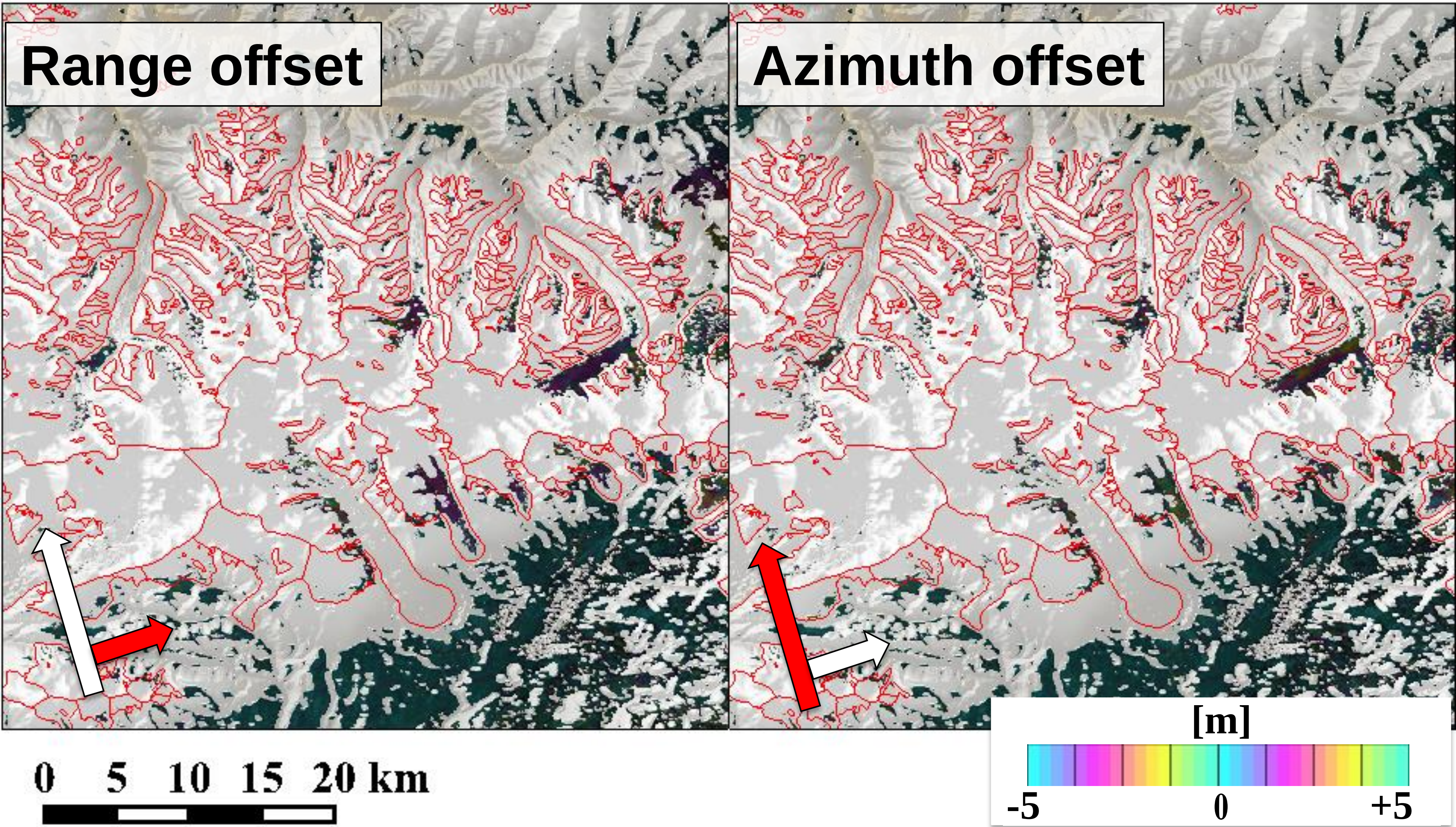
Preliminary results: InSAR, MAI (HH)

- A2: 2014/09/02 - 2015/01/20 (140 days)

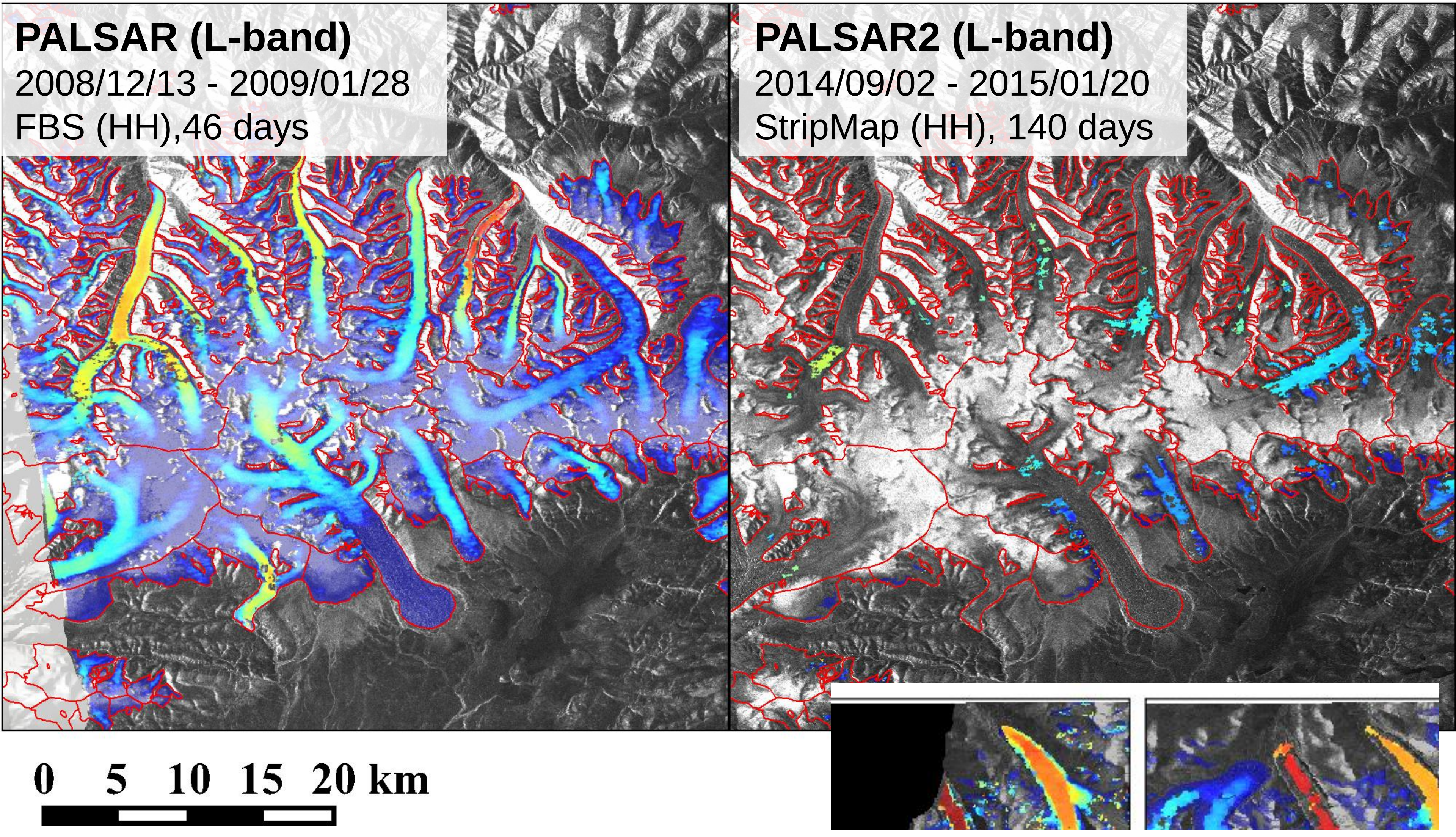


Preliminary results: Pixel Offset (HH)

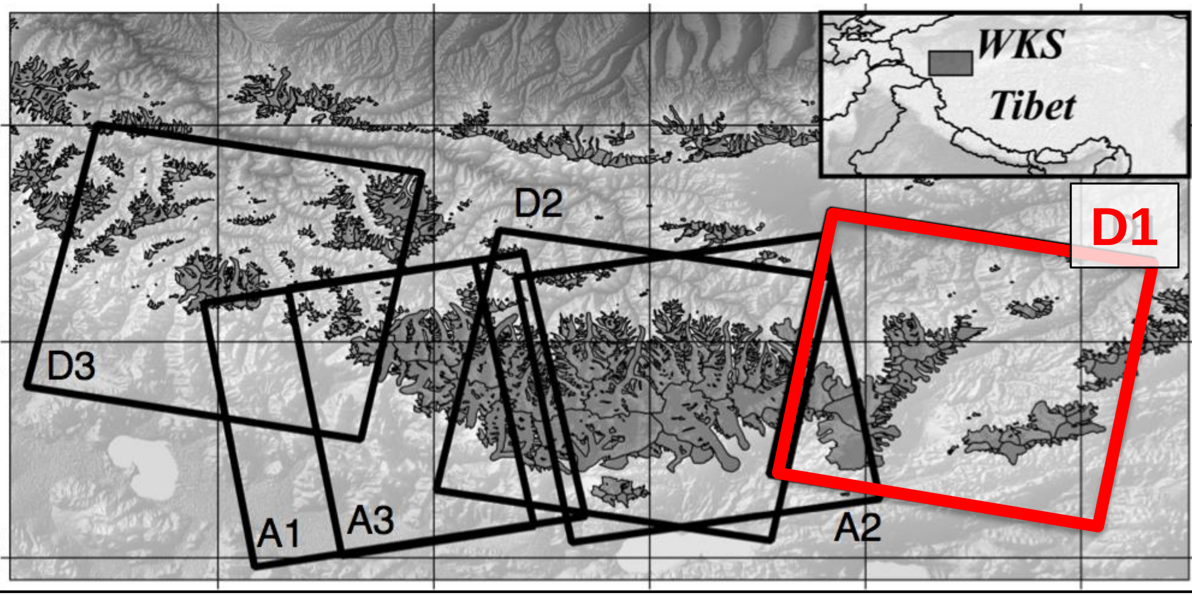
- A2: 2014/09/02 - 2015/01/20 (140 days)



Velocity maps



PALSAR2 data sets



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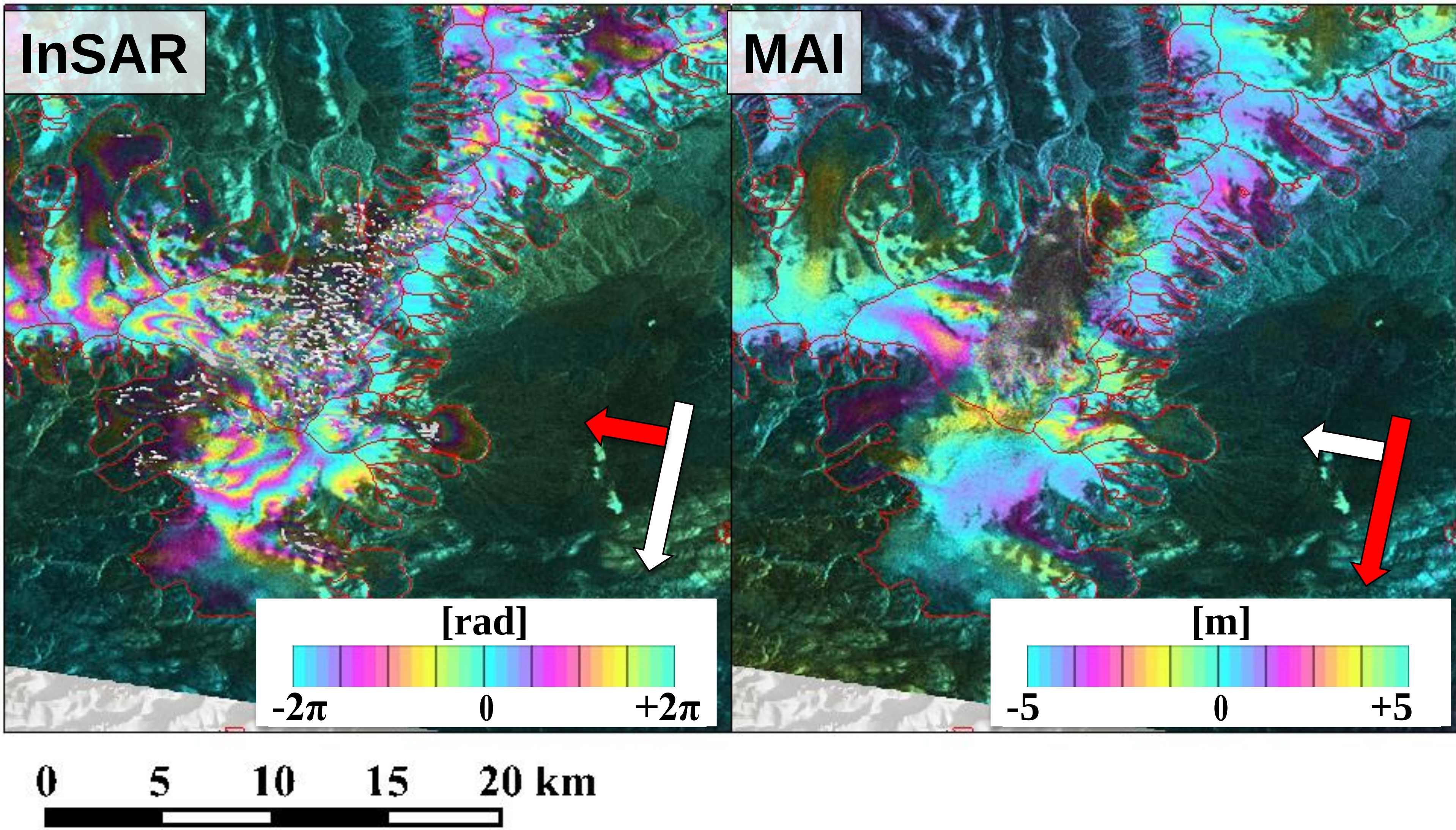
step numbers :　9x9
(range x azimuth pixels)

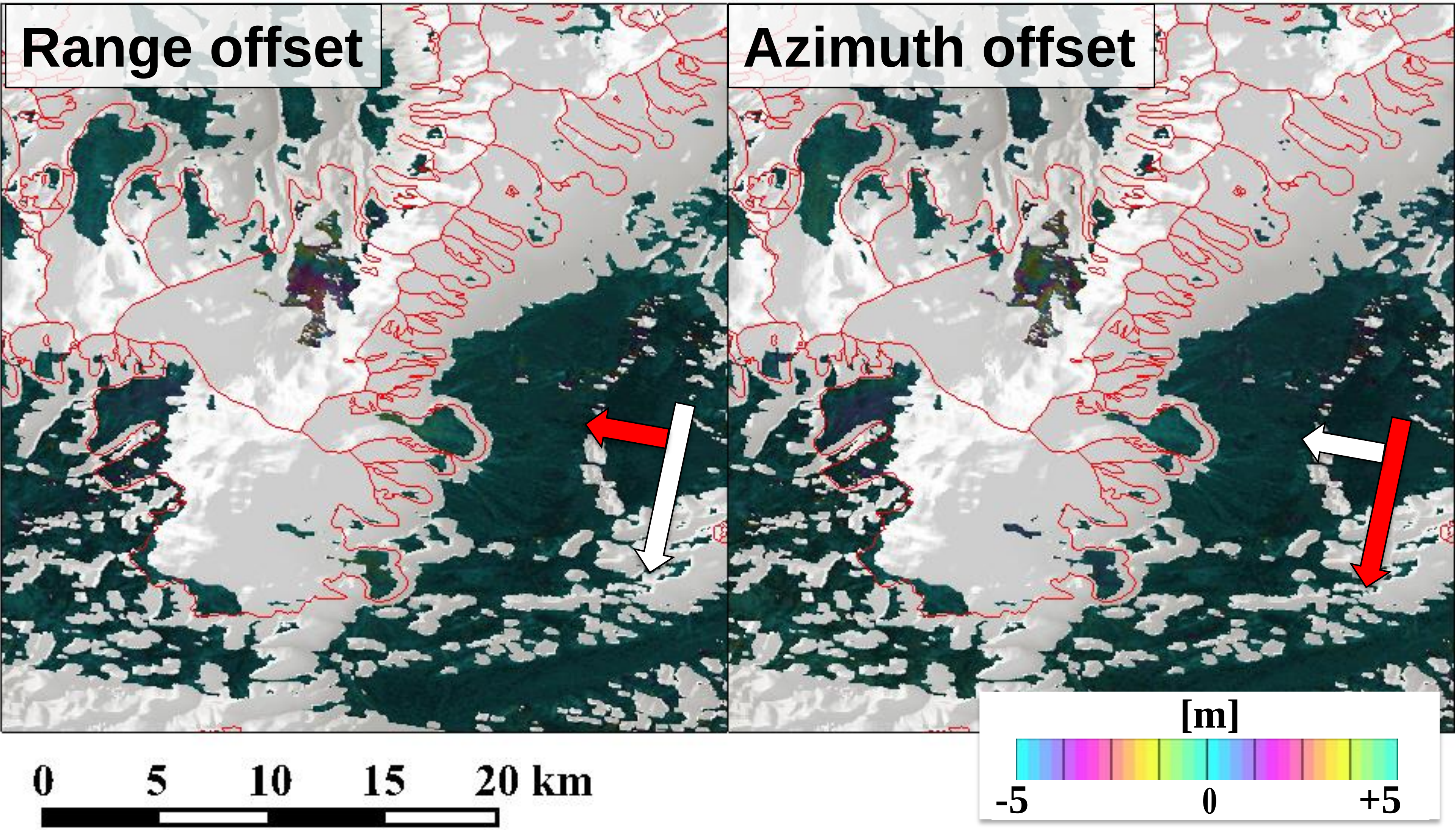
Preliminary results: InSAR, MAI (HH)

- D1: 2015/03/14 - 2015/03/28 (14 days)

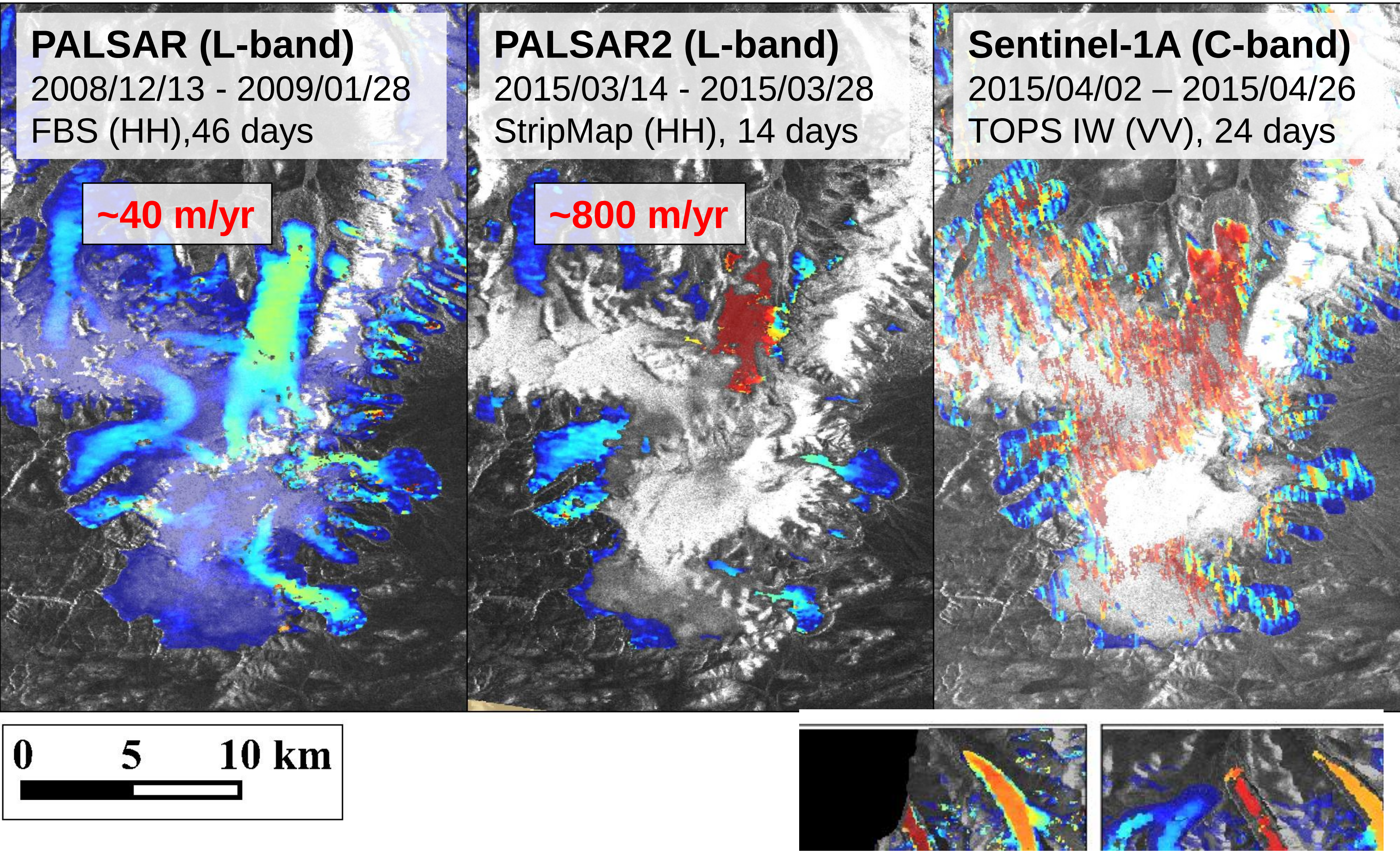


Preliminary results: Pixel Offset (HH)

- D1: 2015/03/14 - 2015/03/28 (14 days)



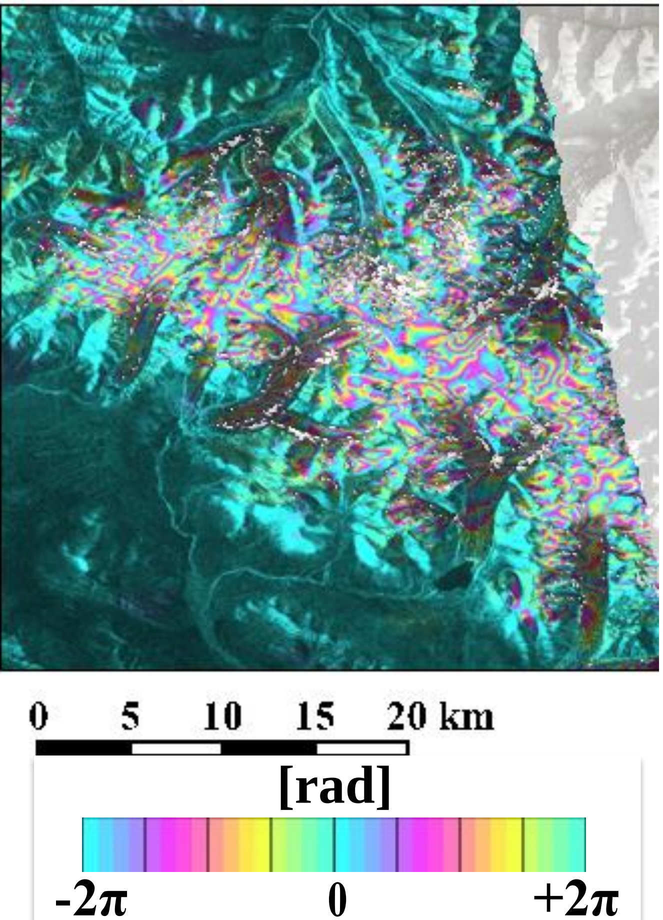
A new surging glacier (D1: 2015/03/14 – 2015/03/28)



Phase unwrapping on glaciers

CHALLENGING TASKS

Phase unwrapping on glaciers



Problem: large displacement of ice flow

$$\Delta\phi_{wrap} = \phi_{disp} + \phi_{error} \quad (-\pi < \Delta\phi_{wrap} \leq \pi)$$

Simulating ‘flow fringe’ from range offsets and/or a flow map.

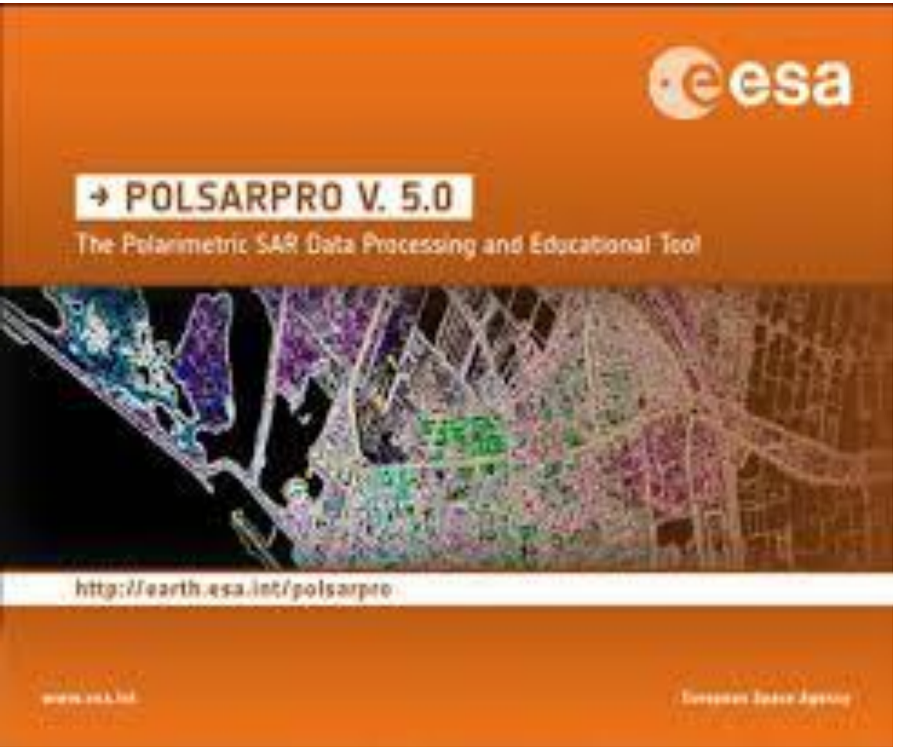
$$\phi_{disp} = \phi_{flow} + \phi_{res}$$

→unwrapping only the residual part: ϕ_{res}

POLARIMETRIC SAR

PolSARpro

- The toolbox for dual-pol and full-pol SAR (https://earth.esa.int/web/polsarpro/home)

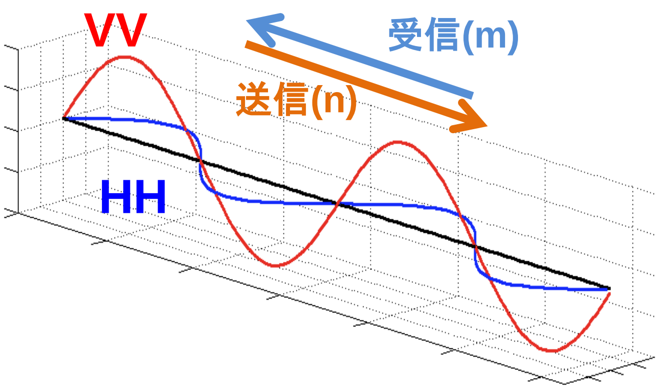


- ✓ **Free and open source**
- ✓ **GUI and CUI**
- ✓ **Read ENVI format (*.hdr, *.bin)**
- ✓ **Sentinel-1A toolbox**

(https://sentinel.esa.int/web/sentinel/toolboxes)

Polarimetric SAR (POLSAR)

Vertical/horizontal polarization

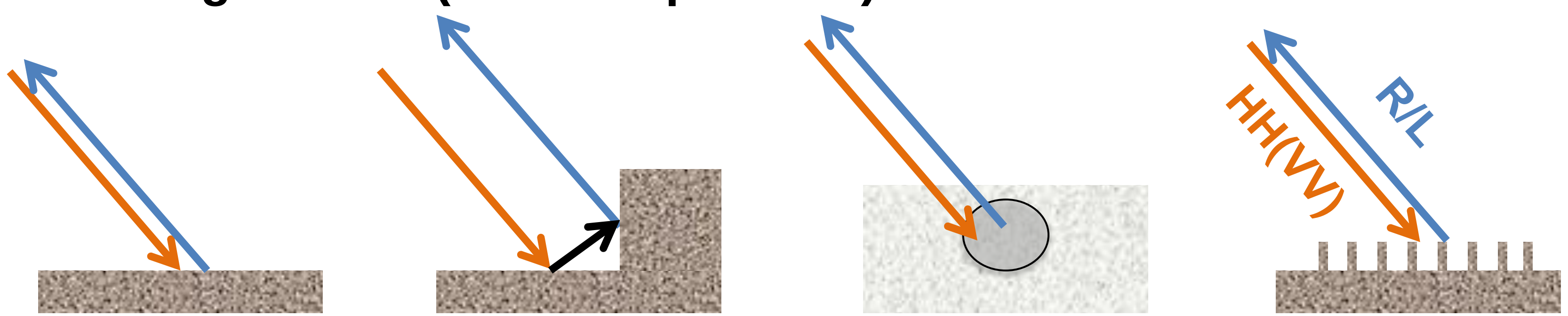


Scattering matrix

$$S_{mn} = \begin{bmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{bmatrix}$$

※送信・受信の順番に注意
m：受信, n:送信
PALSAR1/2の場合（IMG-XY）
X:送信, Y:受信

Scattering models (four components)

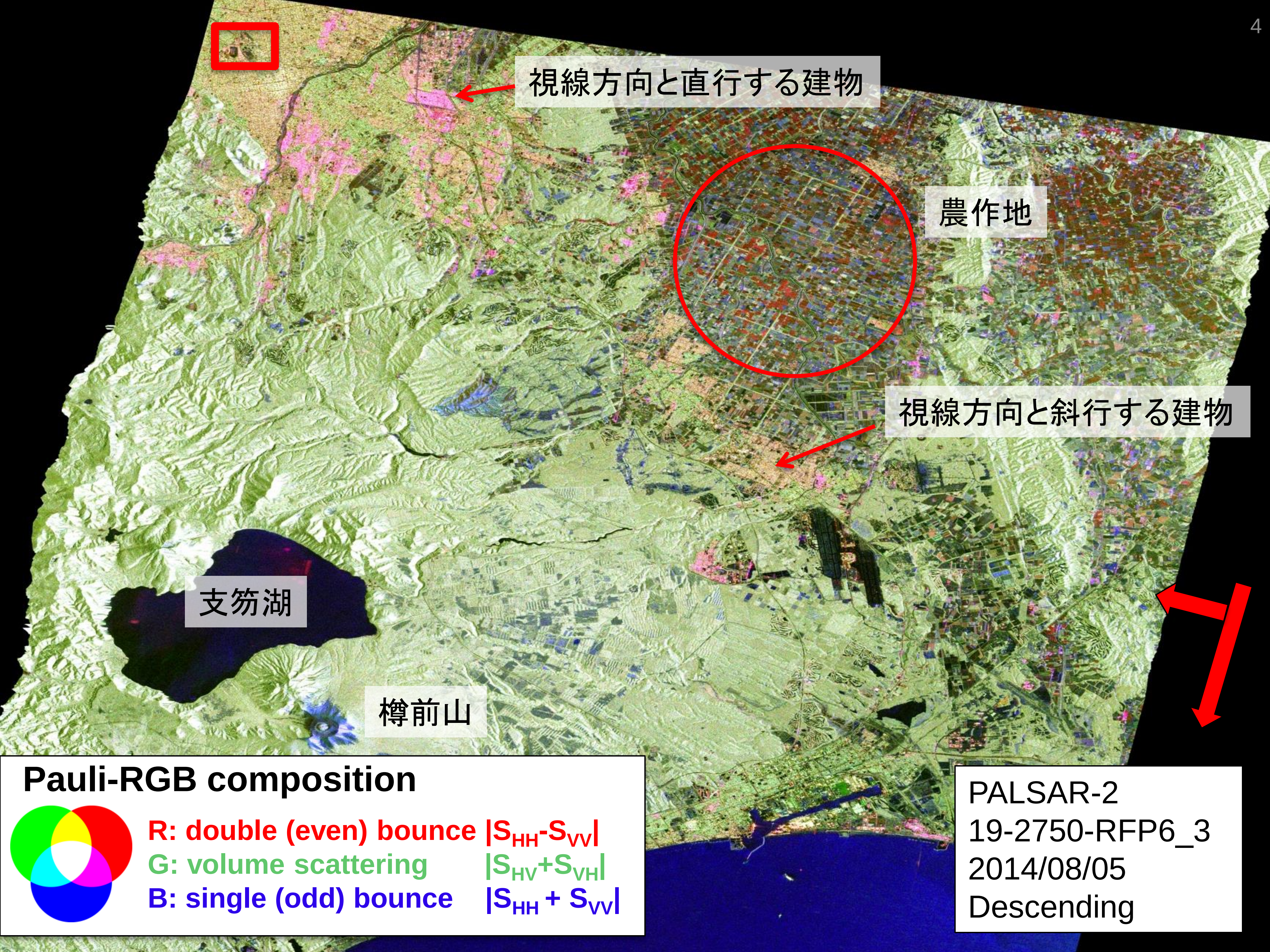


Single bounce
Sea
Low vegetation
$|S_{HH} + S_{VV}|$

Double bounce
Tree trunk
Building
$|S_{HH} - S_{VV}|$

Volume scattering
Forest
Dry ice
$|S_{HV} + S_{VH}|$

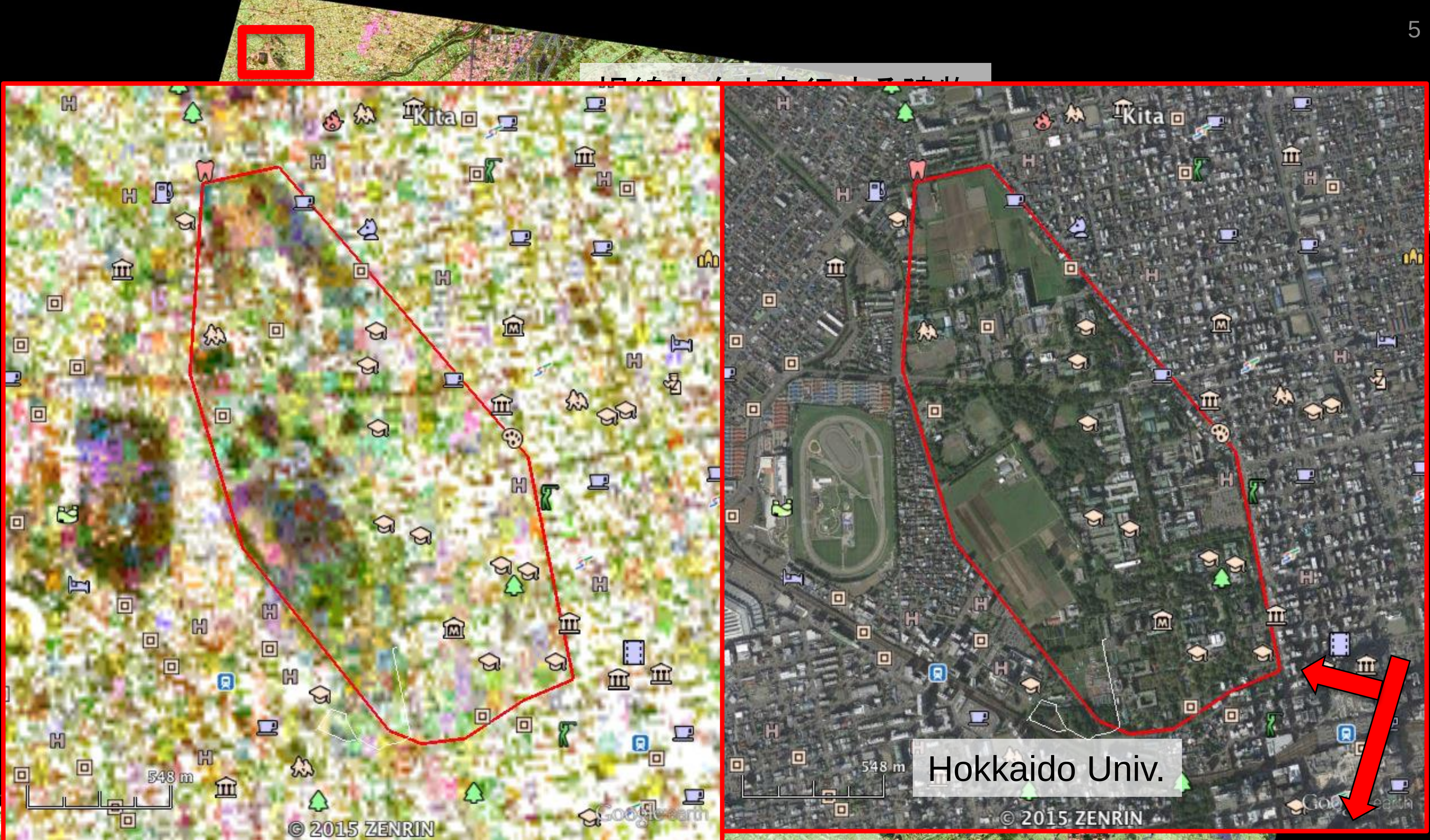
Helix scattering
交差ワイヤや
¼ 波長離れた
2面構造物



Pauli-RGB composition

R: double (even) bounce $|S_{HH}-S_{VV}|$
G: volume scattering $|S_{HV}+S_{VH}|$
B: single (odd) bounce $|S_{HH}+S_{VV}|$

PALSAR-2
19-2750-RFP6_3
2014/08/05
Descending



Pauli-RGB composition

R: double (even) bounce $|S_{HH}-S_{VV}|$

G: volume scattering $|S_{HV}+S_{VH}|$

B: single (odd) bounce $|S_{HH}+S_{VV}|$

PALSAR-2
19-2750-RFP6_3
2014/08/05
Descending

Pauli-RGB composition on glaciers

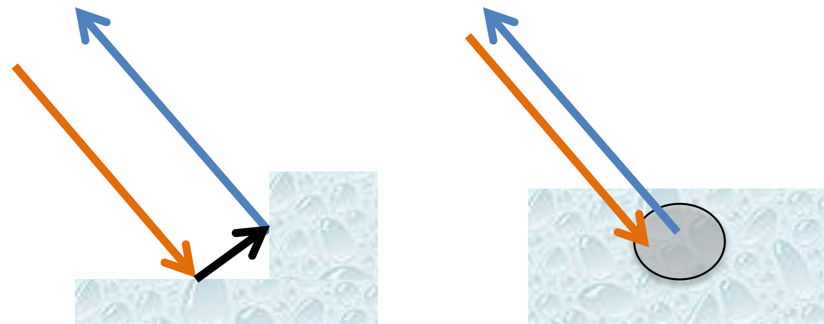
(A3) 2015/03/03 : Pauli RGB composition

R: double (even) bounce $|S_{HH}-S_{VV}|$

G: volume scattering $|S_{HV}+S_{VH}|$

B: single (odd) bounce $|S_{HH}+S_{VV}|$

Crevassed surface ~ slant buildings

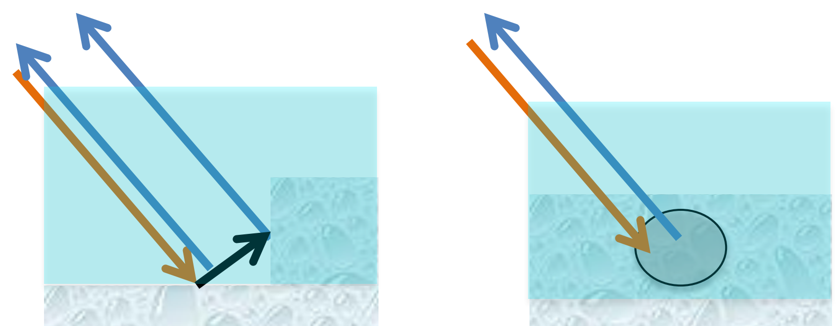


Double bounce

Volume scattering

Crevassed wall + slant to line-of-sight

Ice structure in glaciers?

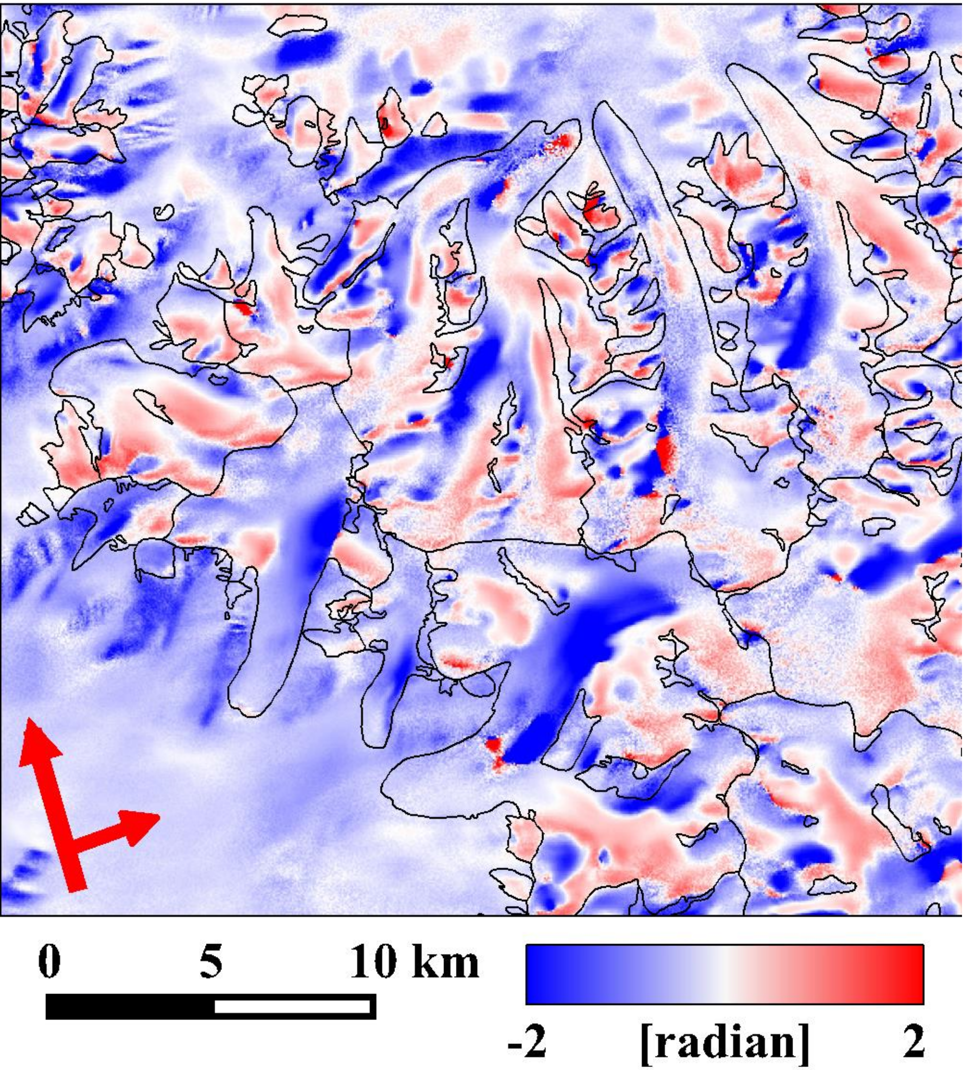


Single/double bounce

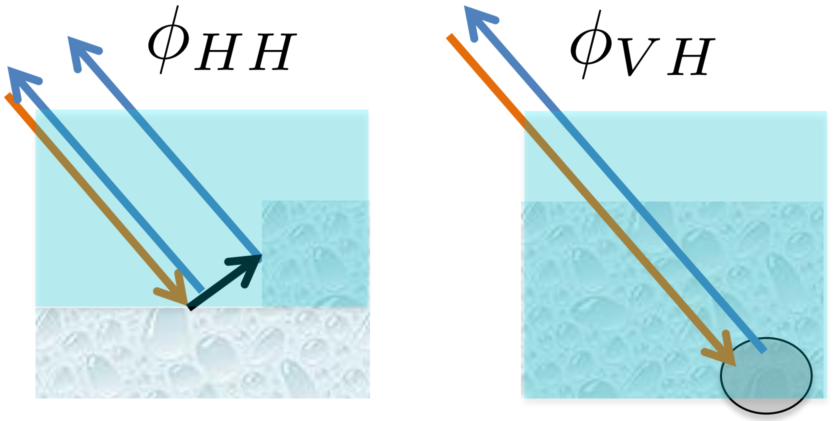
Volume scattering

Unwrapped phase : $\phi_{HH} - \phi_{VH}$

2015/03/03 : $\phi_{HH} - \phi_{VH}$ (unwrapped)



Differences of the center of scattering?



Single/double bounce

Volume scattering

Summary

- PALSAR2 detects glacier flow in West Kunlun Shan.
  - InSAR, MAI ≤ 28 days pairs
  - Pixel Offset ≥ 28 days pairs (Gaps with 14 days pairs)
- Velocity maps were consist with Sentinel and TerraSAR-X
  - A new surging glacier (40m/yr → 800 m/yr by 2015)
- Challenging tasks:
  - Phase Unwrapping on glaciers
- Future plans:
  - Polarimetric SAR

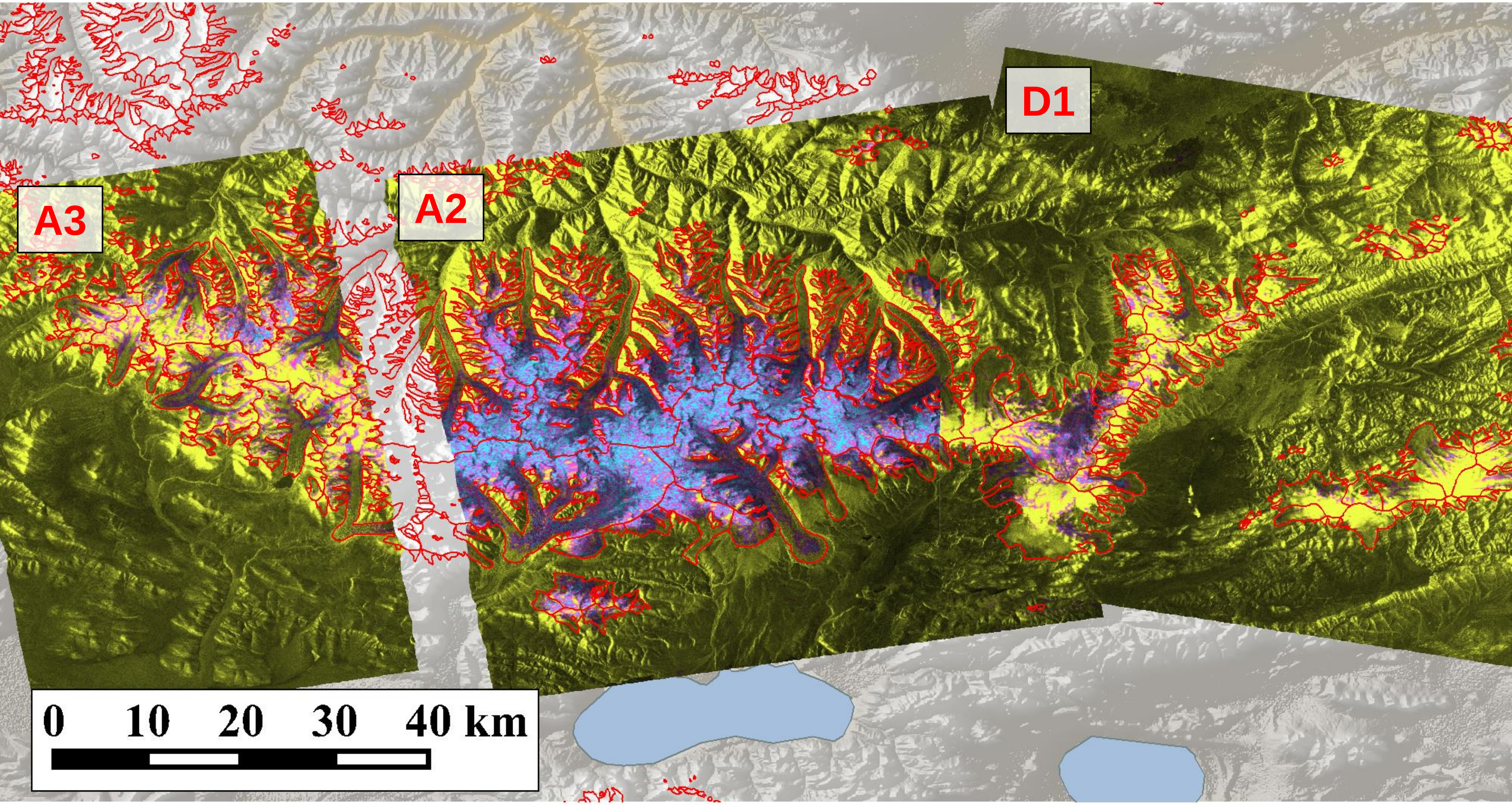
Thank you for listening

Acknowledgements

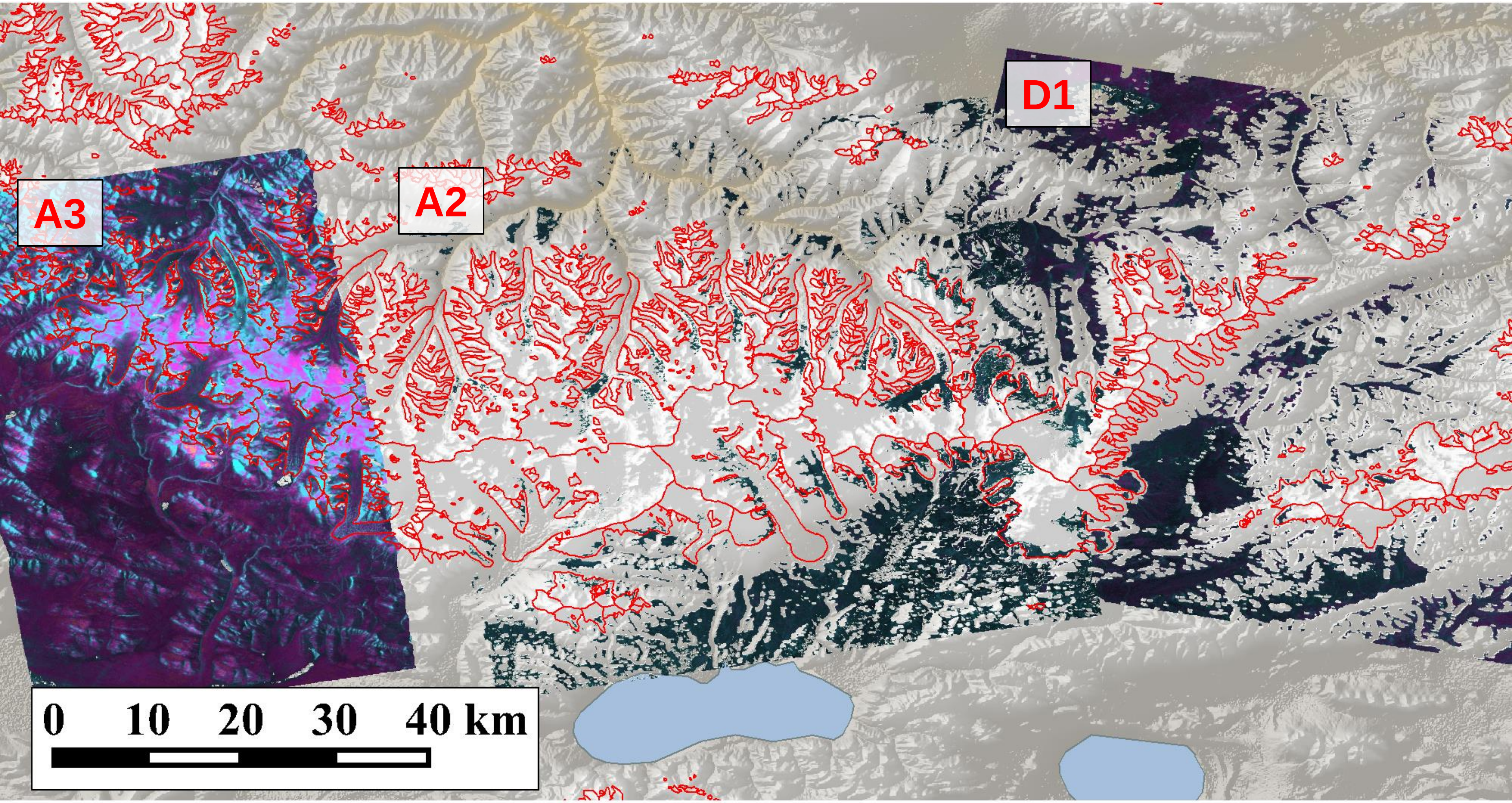
- PALSAR level 1.0 data were provided partly from the PIXEL (PALSAR Interferometry Consortium to Study our Evolving Land surface) and partly from ALOS 3rd PI (#538) under a cooperative research contract with JAXA.
- PALSAR 2 data were provided from ALOS RA4 (#1179) under a cooperative research contact with JAXA.
- PALSAR and PALSAR 2 data belong to METI and JAXA, Sentinel-1 data are copyrighted by ESA, TerraSAR-X /Tandem-X data are copyrighted by DLR, respectively.
- This work was partially supported by JSPS DC-2 fellowship to T. Yasuda and by KAKENHI (#24651001).

SUPPLEMENTAL SLIDES

Coherences (InSAR, HH)



SNR (Pixel Offset, HH)

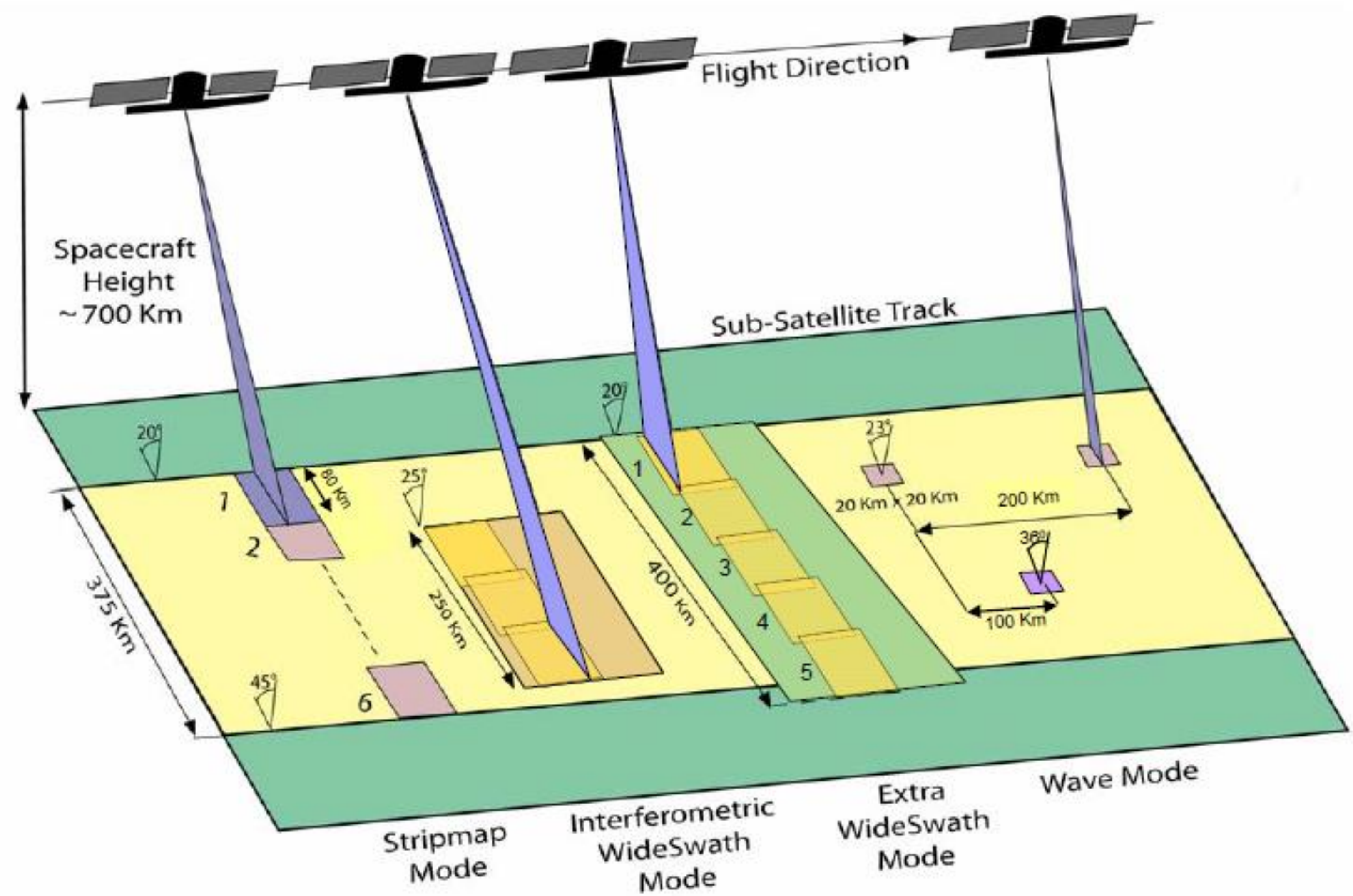


Sentinel 1A

- C-band (5.405 GHz), revisit : 12 days
- Launched : Apr. 2014 (1B scheduled for 2016)
- Main mode: TOPS (Terrain Observation with Progressive Scan)
- Data access : https://scihub.esa.int

http://www.esa.int/spaceinimages/Images/2014/02/Sentinel-1

Sentinel 1A



https://sentinel.esa.int/web/sentinel/sentinel-1-sar-wiki/-/wiki/Sentinel%20One/Acquisition+Modes