

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**

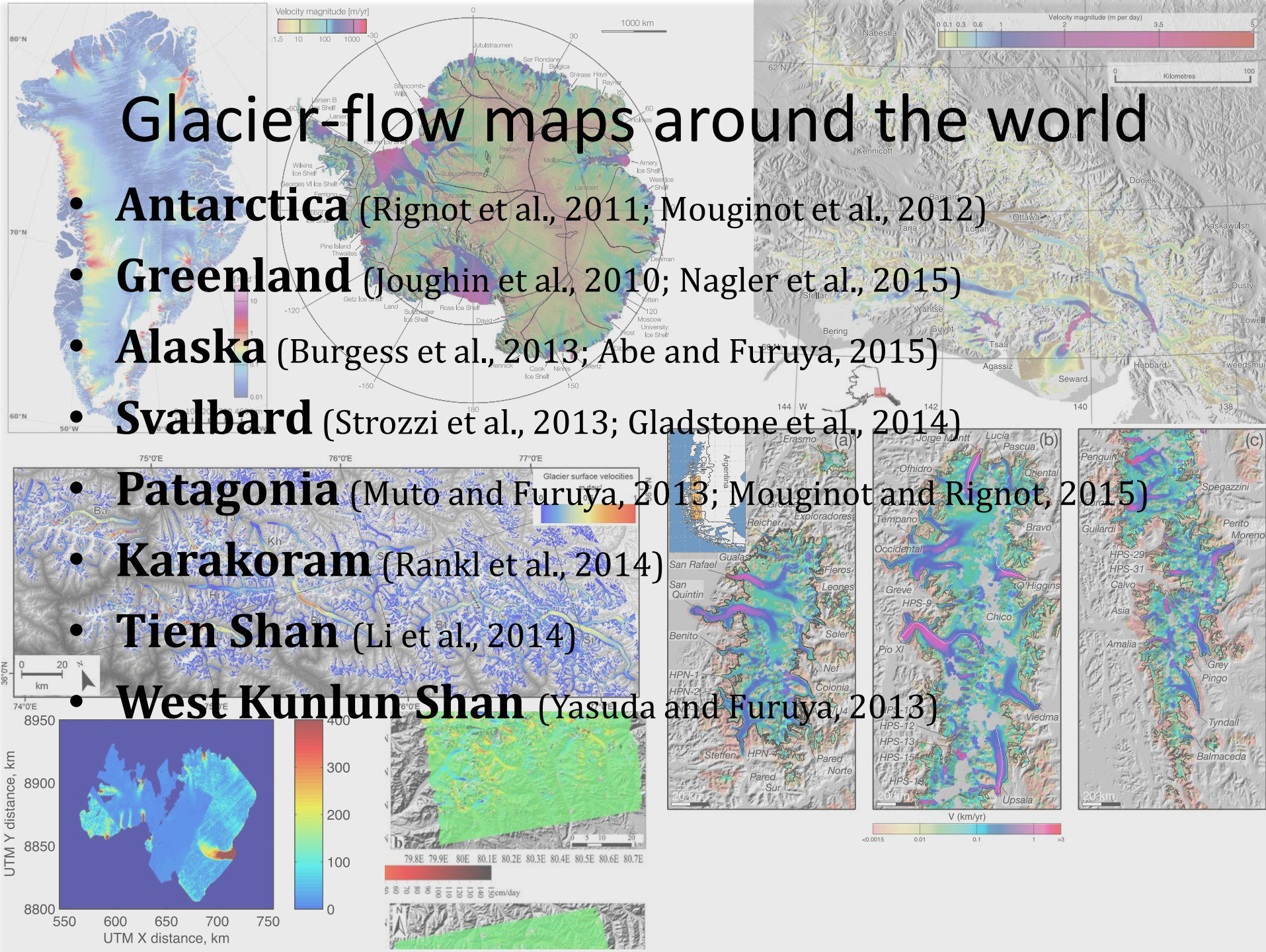
Takatoshi YASUDA and Masato FURUYA

Dept. Earth and Planetary Sciences,
Faculty of Science, Hokkaido University



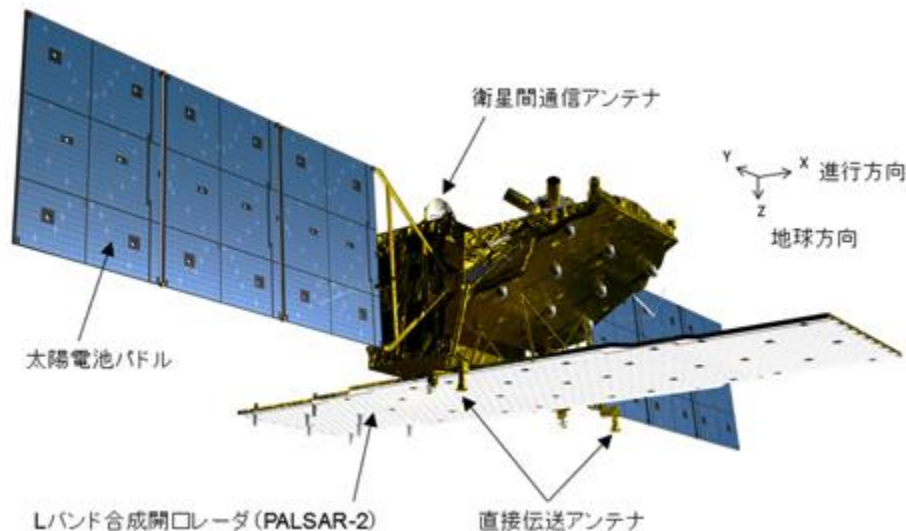
Hokkaido University
SPACE GEODESY





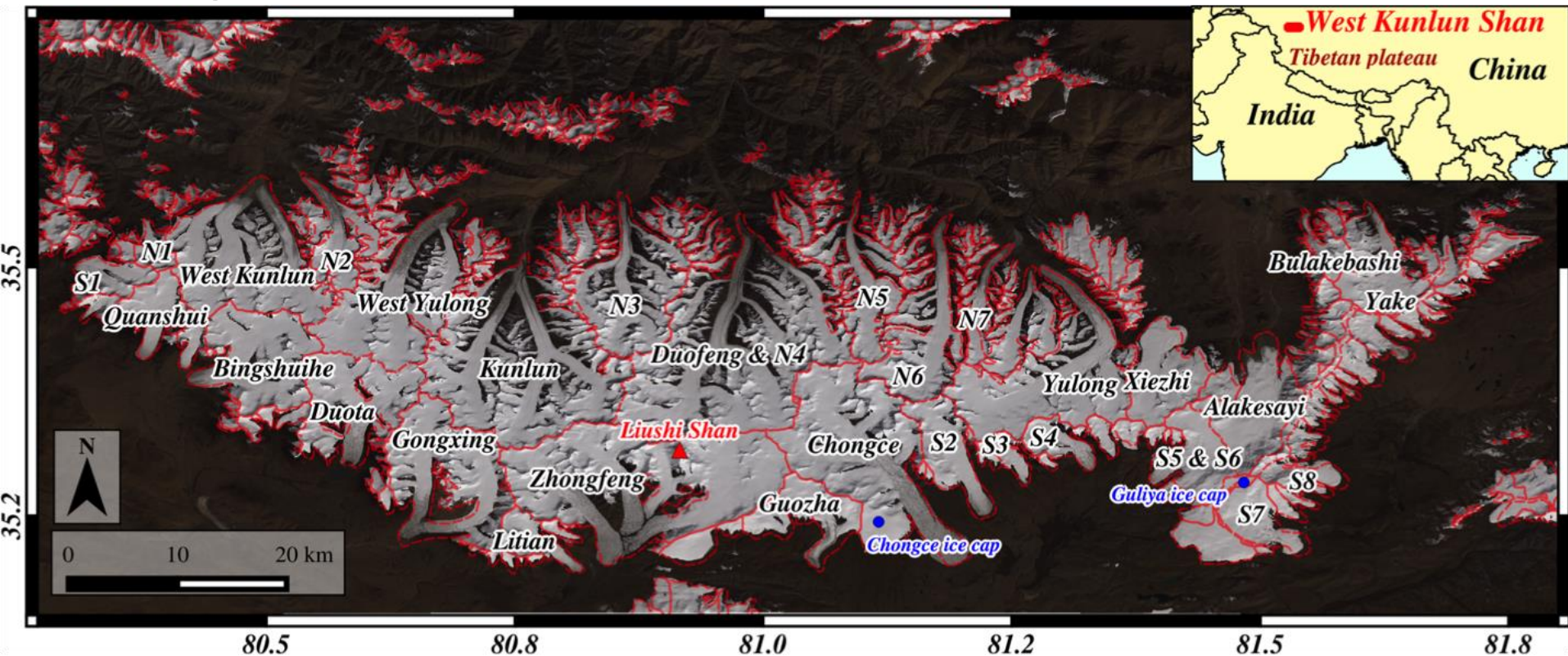
PALSAR2

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



West Kunlun Shan

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

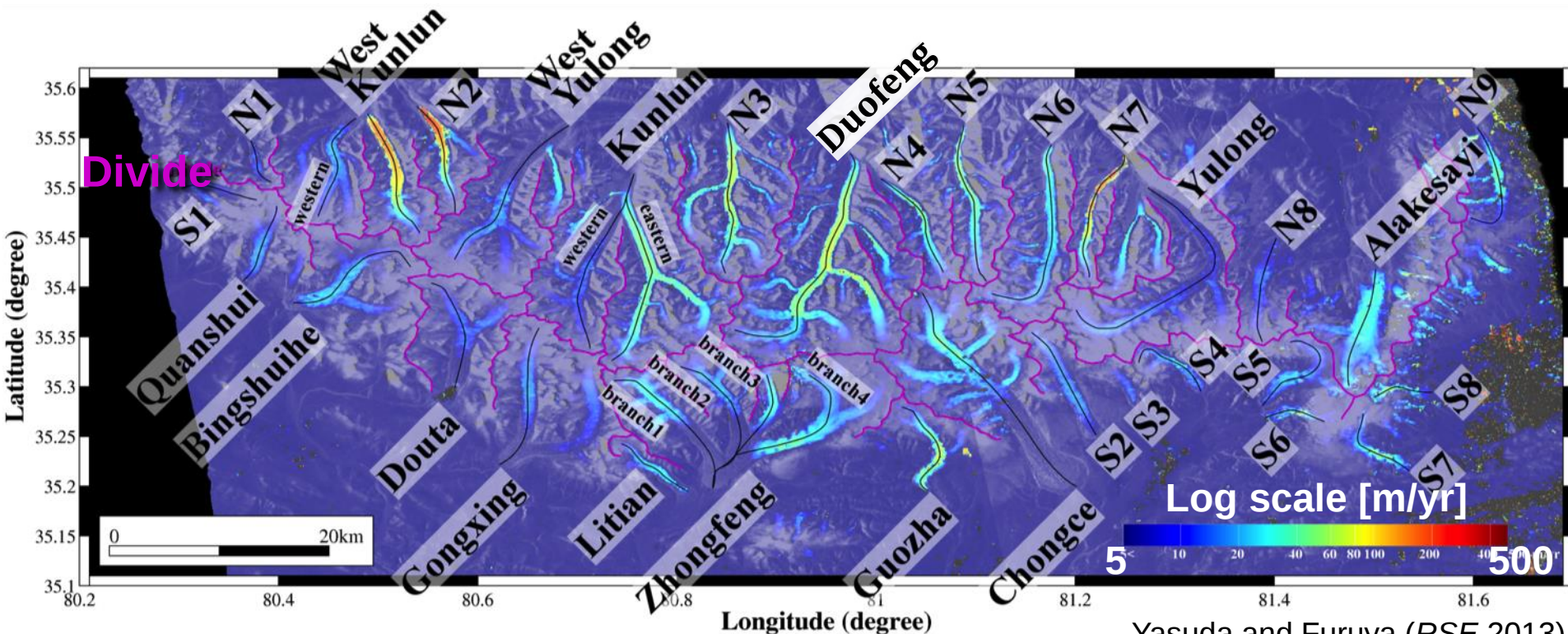


Glacier outline from RGI v3.2

(Yasuda and Furuya, JGR-ES, accepted)

Flow map with PALSAR-1

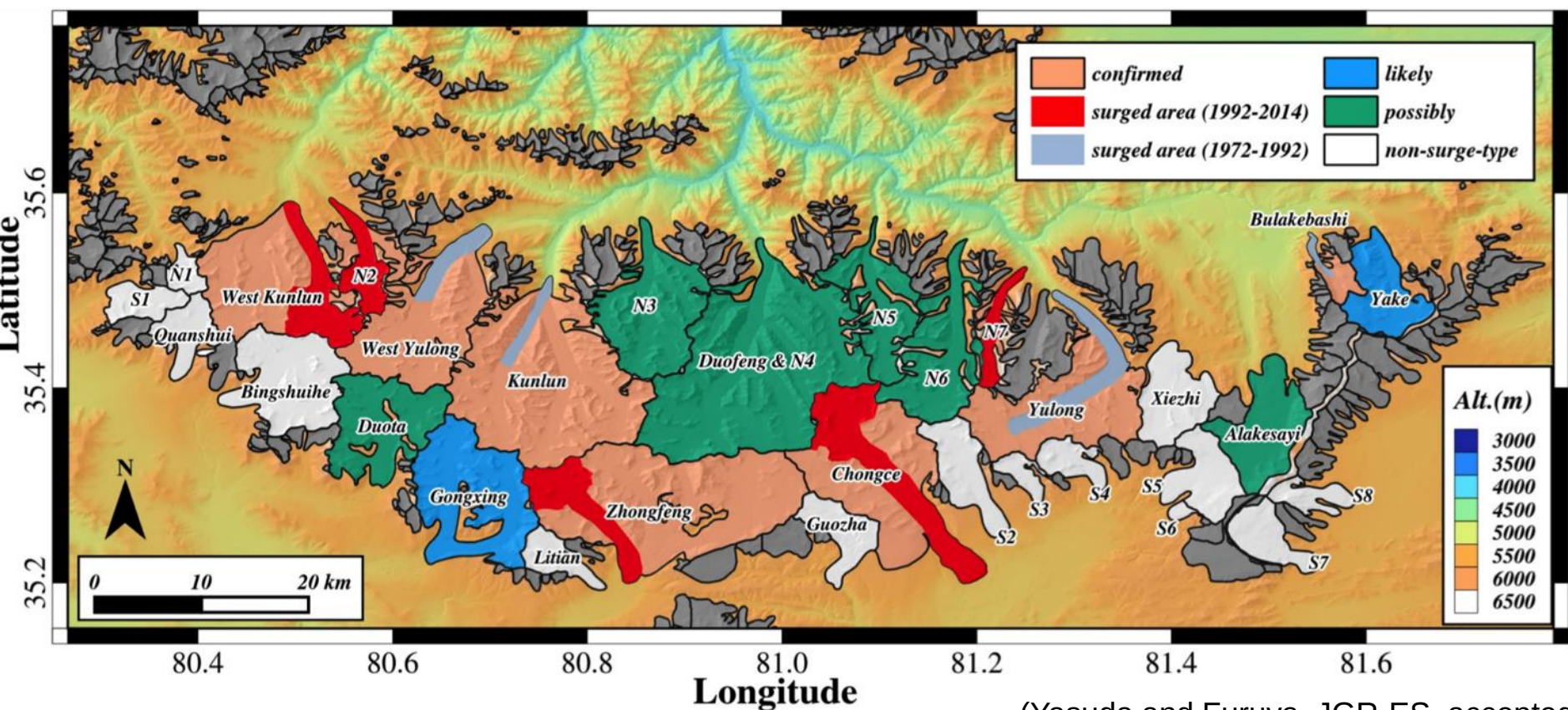
- Non-surge-type : 20-100 m/yr ($\sim 0.78\text{-}3.8$ m/14 days)
- Surging glaciers : >200 m/yr (~ 7.8 m/14 days)



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.

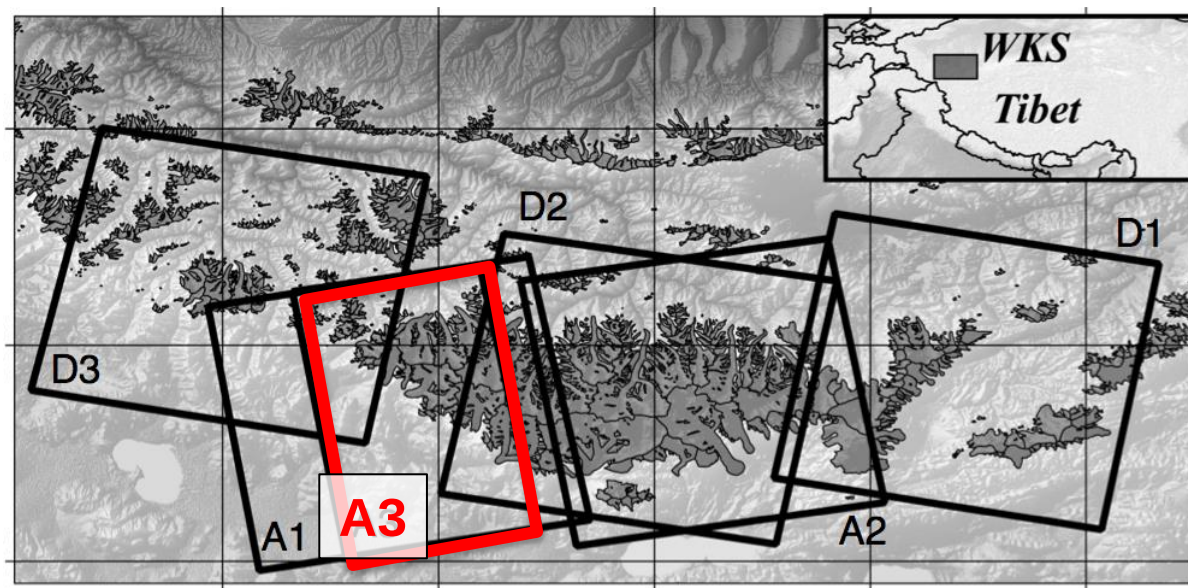


(Yasuda and Furuya, JGR-ES, accepted)

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



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

DEM :
SRTM4

Parameters :
InSAR, MAI

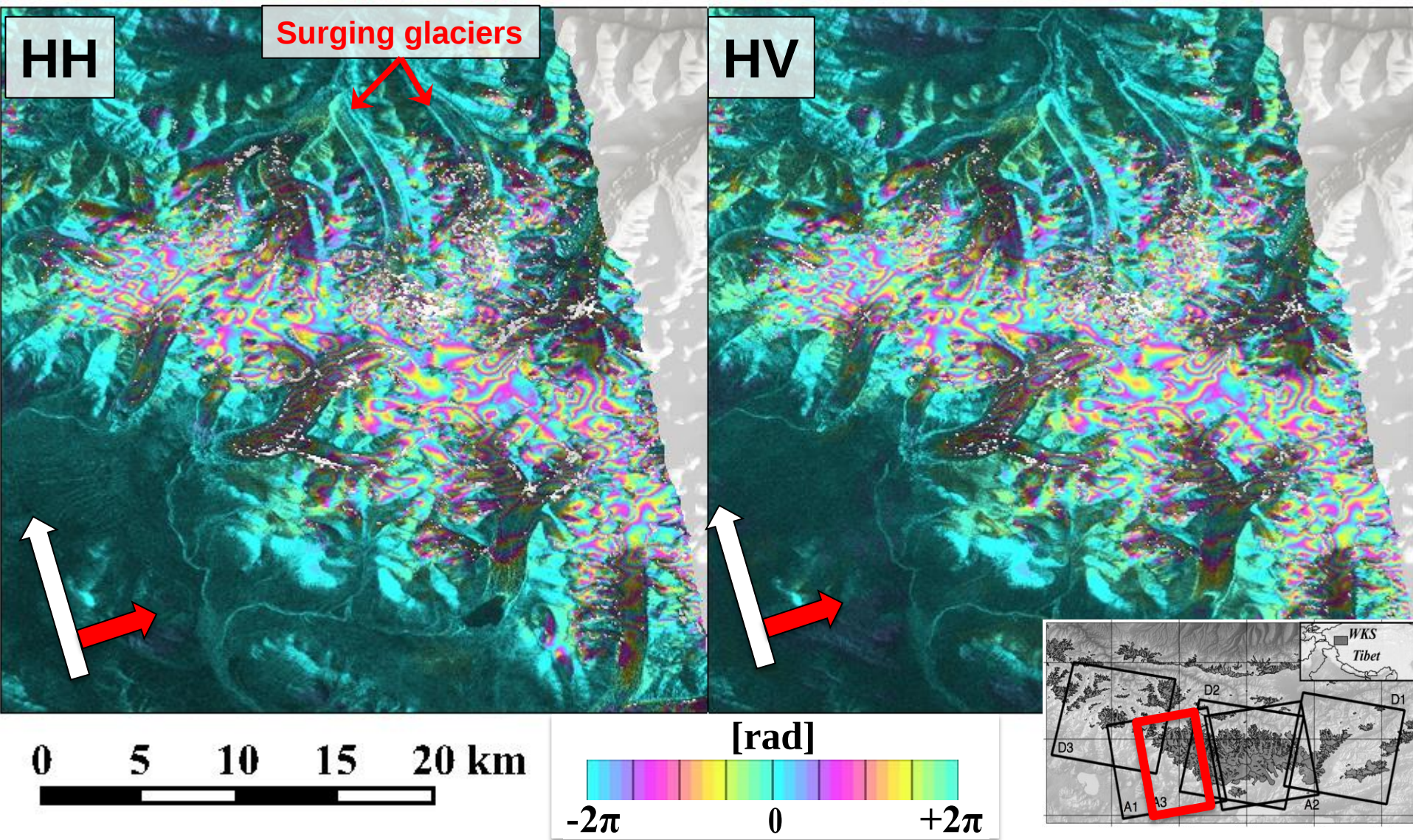
差分干涉 : 3x3 looks
unwrapping : 4x4 looks
(by minimum cost flow)

Pixel Offset (PO)

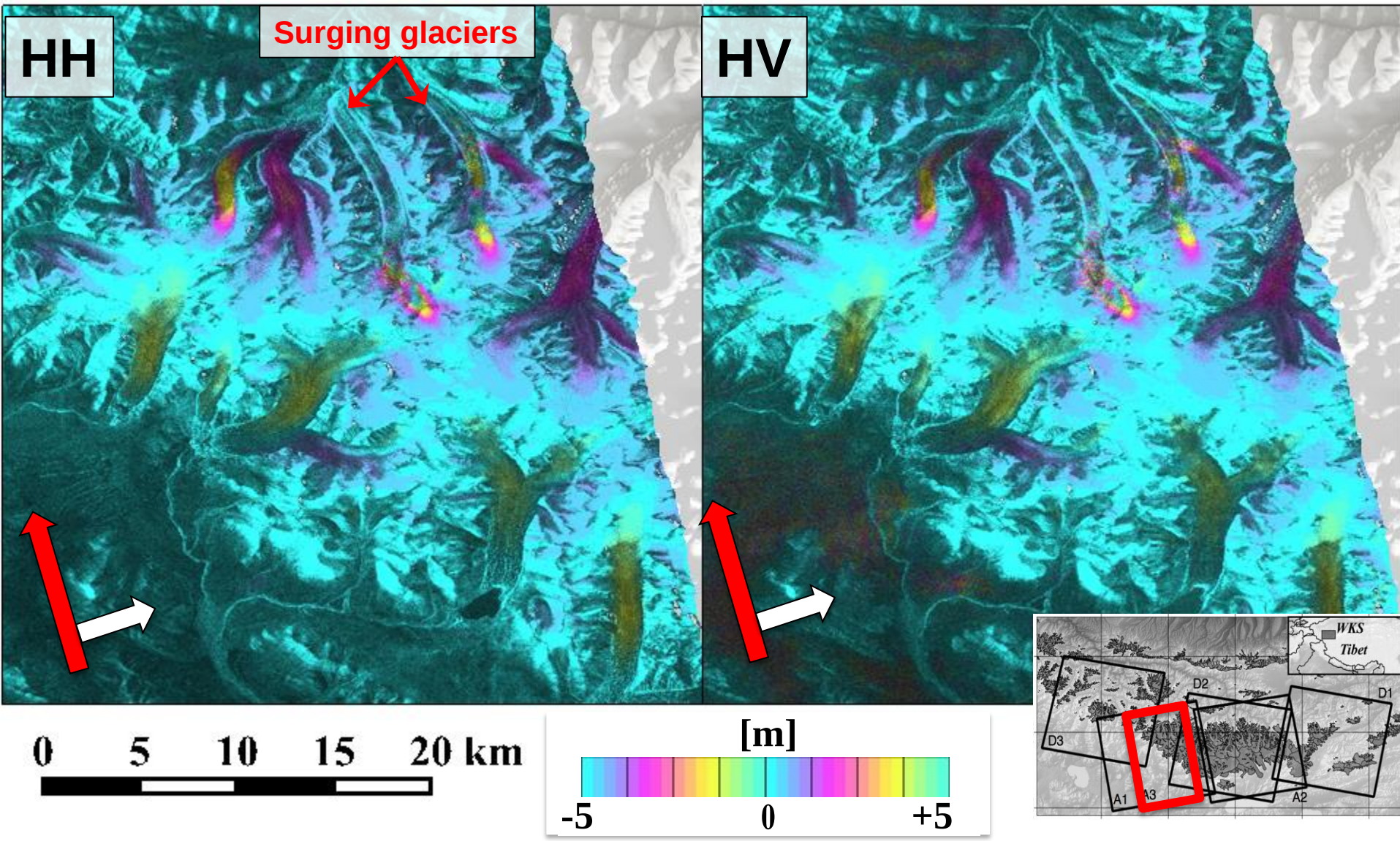
window size : 64x64
step numbers : 9x9
(range x azimuth pixels)

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	⊙	⊙	×

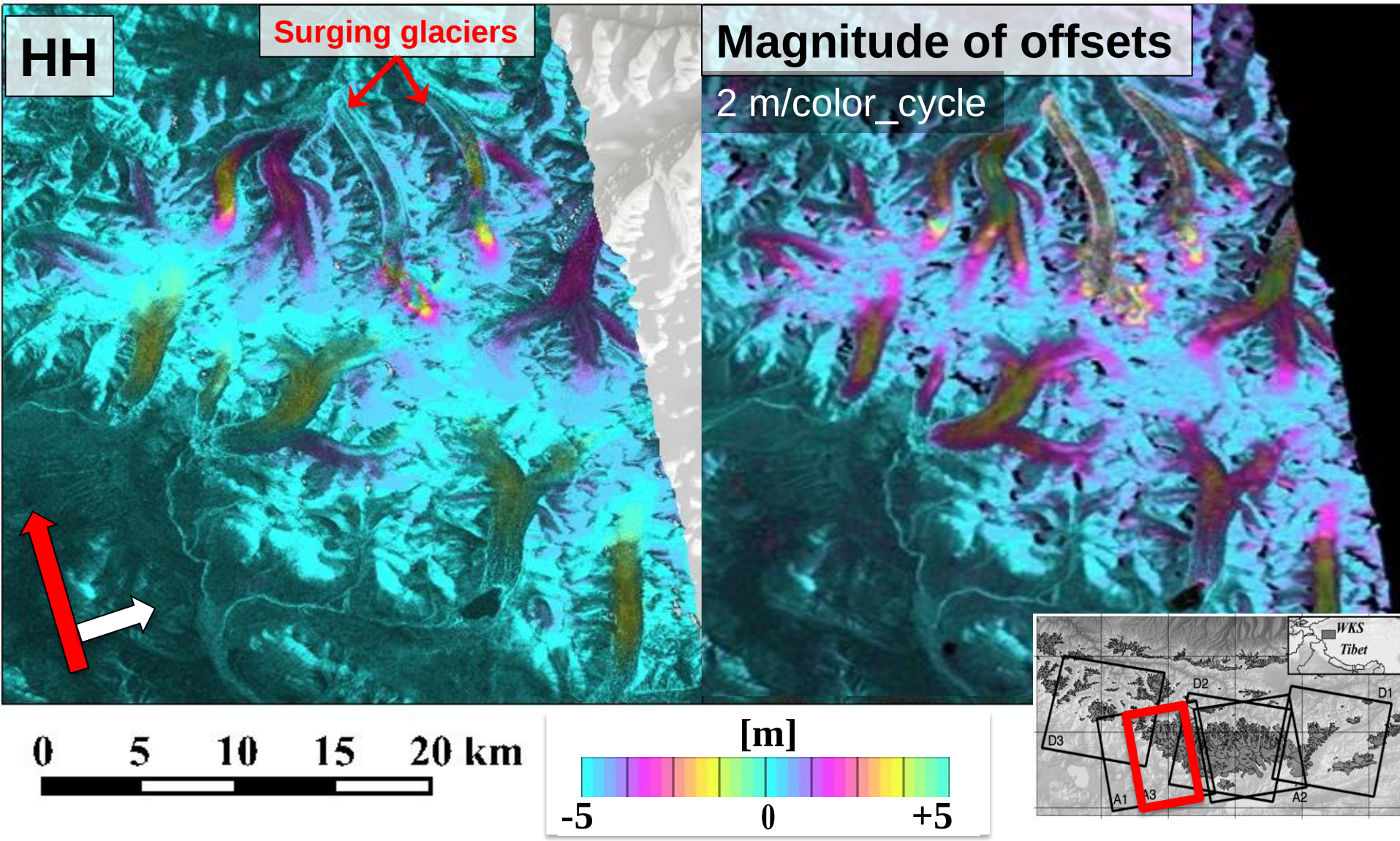
Preliminary results: InSAR (HH, HV) (A3: 2015/03/03 - 2015/03/31)



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



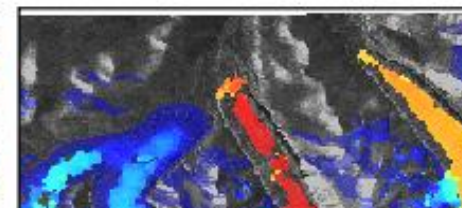
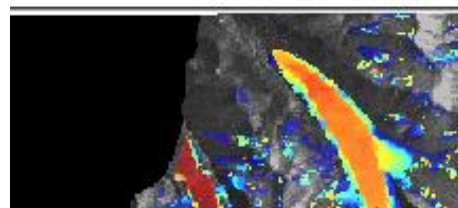
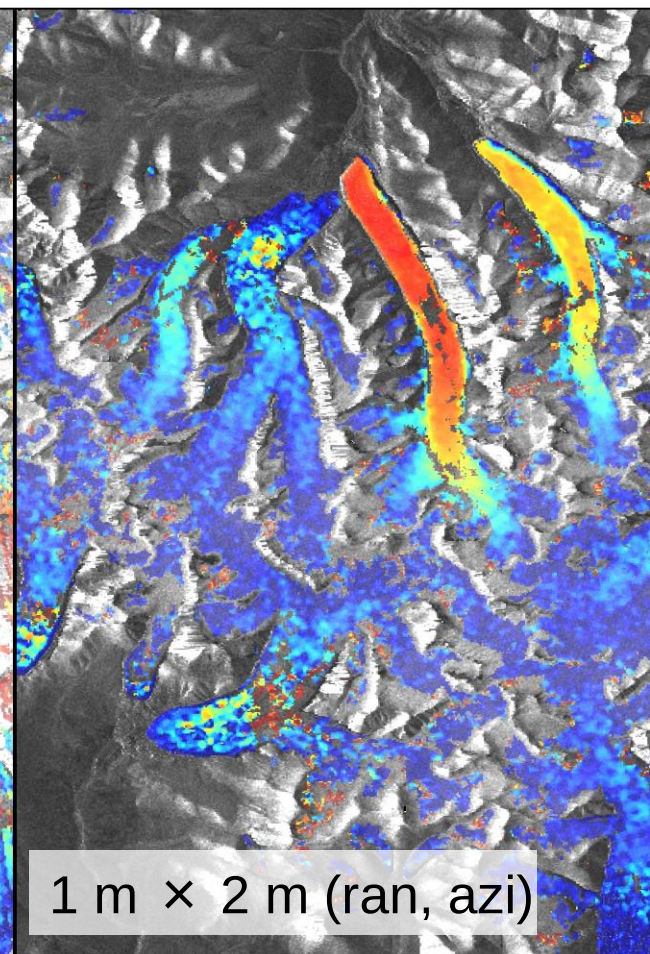
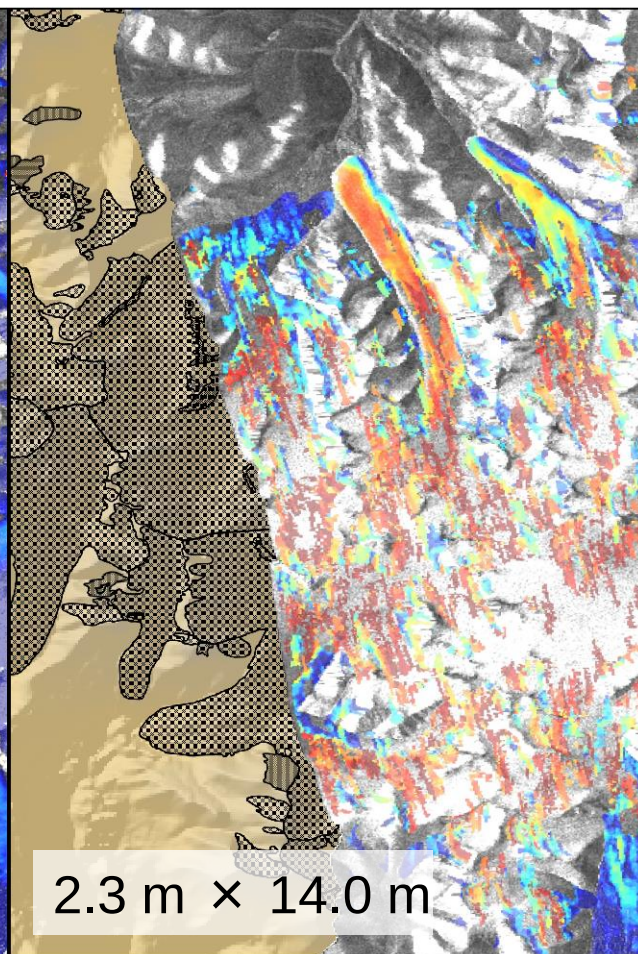
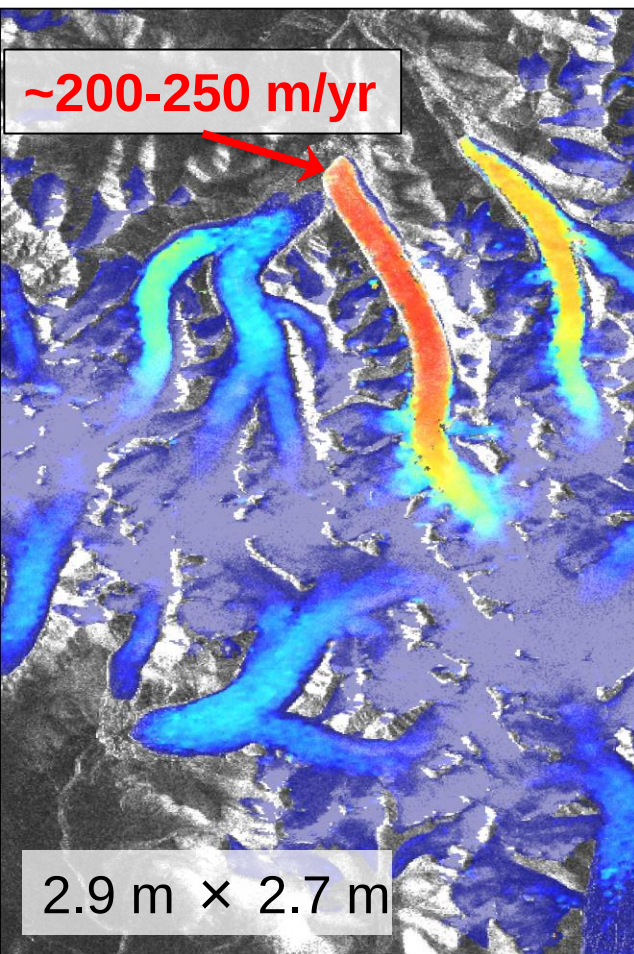
Preliminary results: MAI and Pixel offset (A3: 2015/03/03 – 2015/03/31)



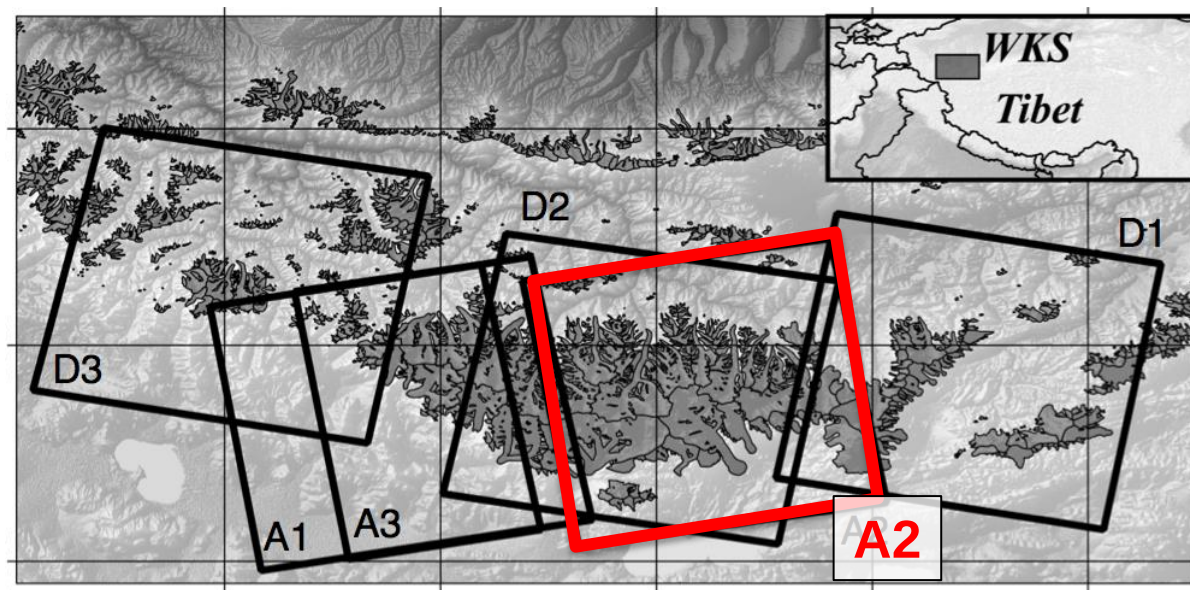
PALSAR2 (L-band)
2015/03/03 – 2015/03/31
StripMap (HH), 28 days

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



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

DEM :
SRTM4

Parameters :
InSAR, MAI

差分干涉 : 3x3 looks
unwrapping : 4x4 looks
(by Minimum Cost Flow)

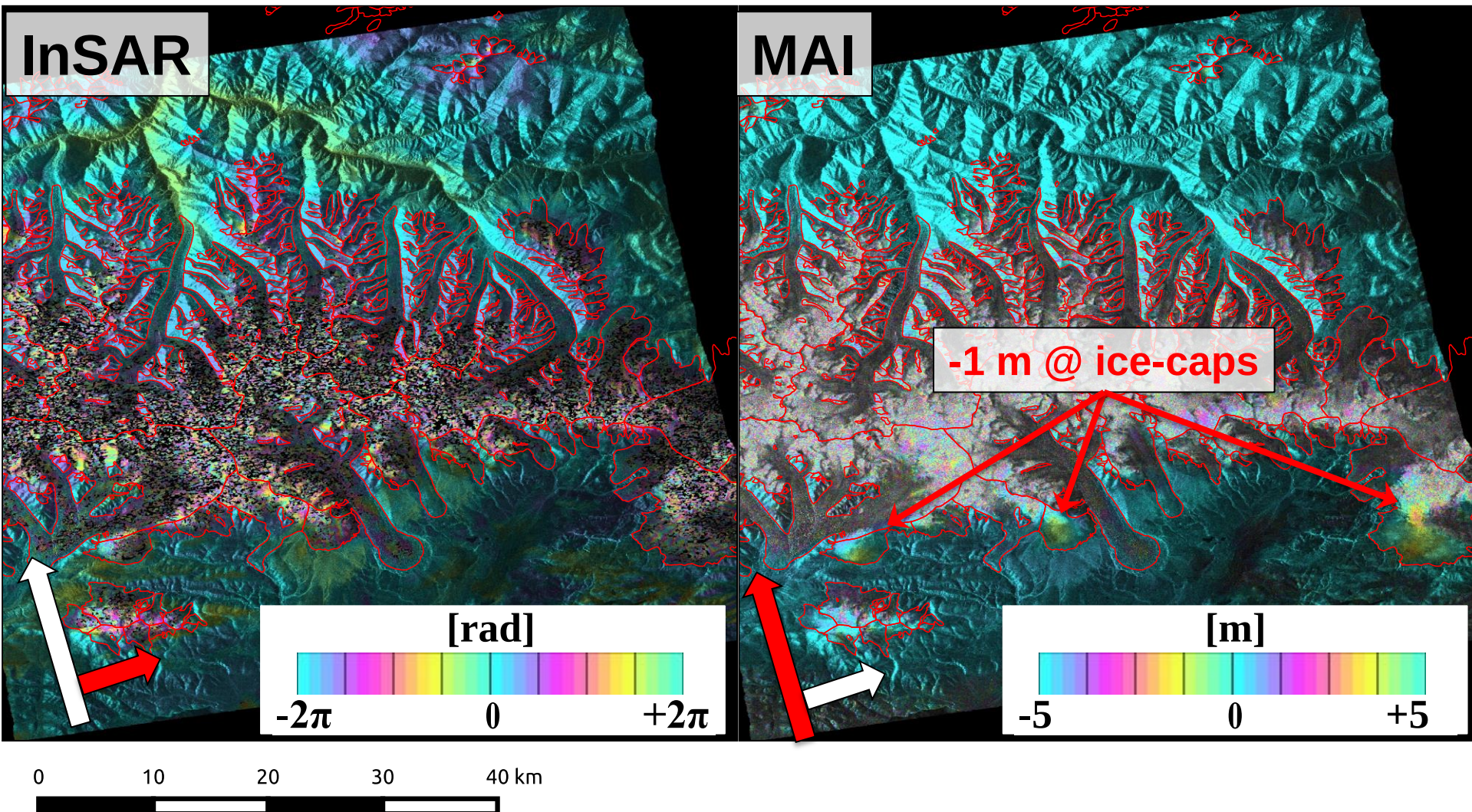
Pixel Offset (PO)

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

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	⊙	⊙	×

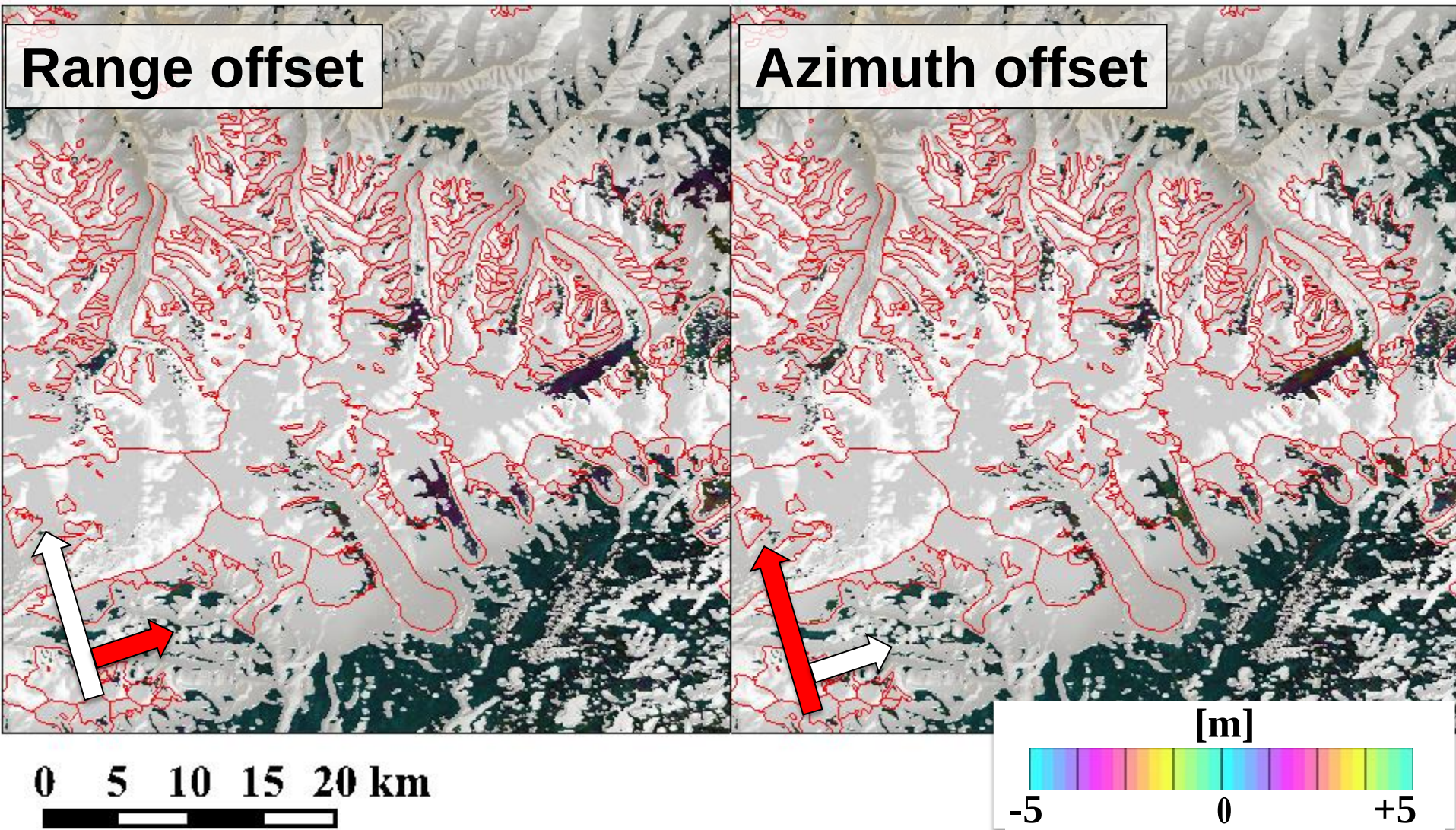
Preliminary results: InSAR, MAI (HH)

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

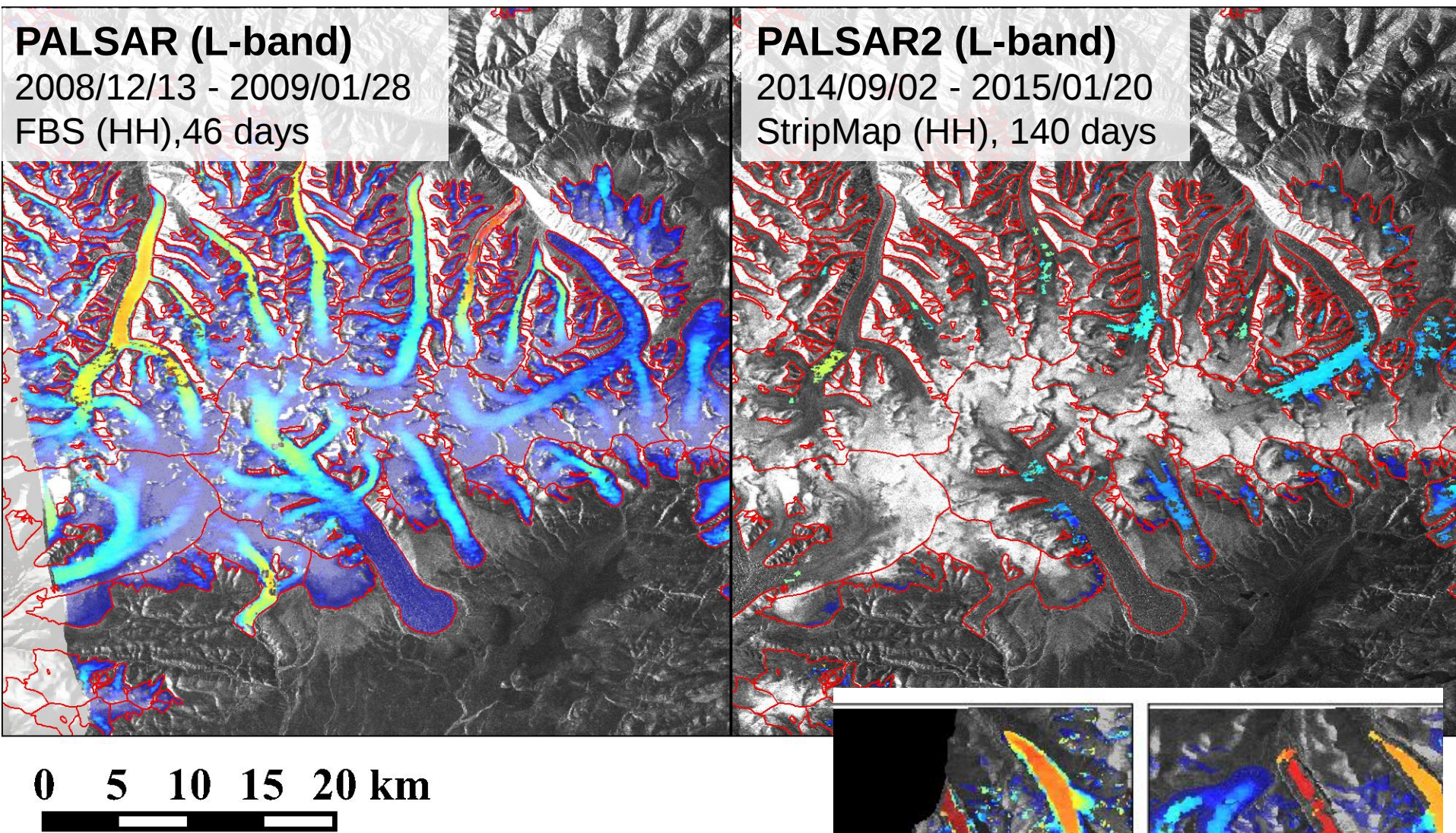


Preliminary results: Pixel Offset (HH)

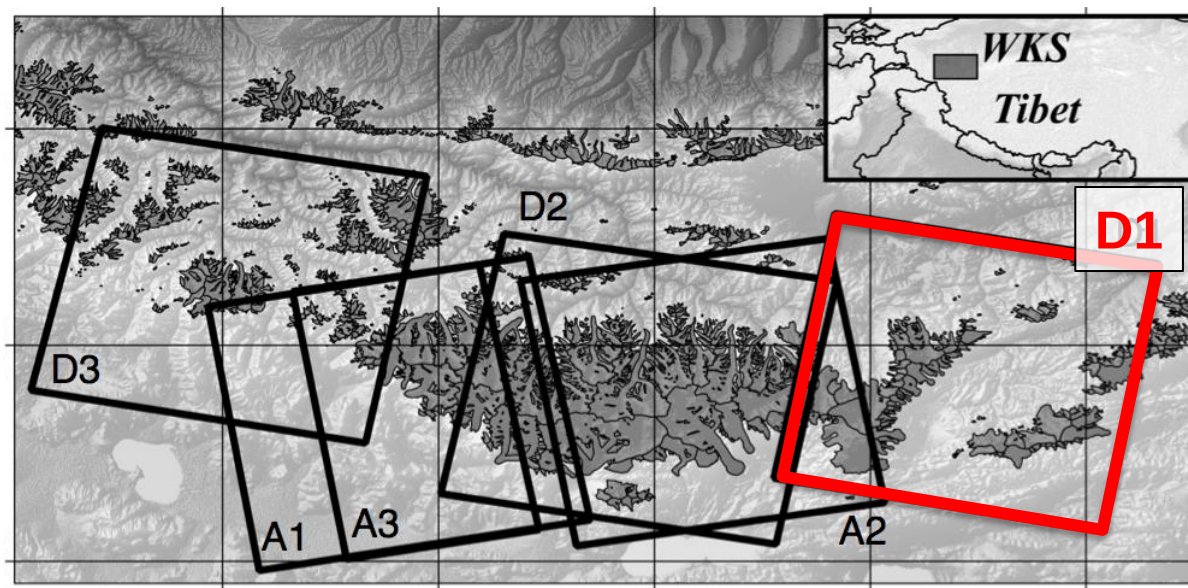
- A2: 2014/09/02 - 2015/01/20 (140 days)



Velocity maps



PALSAR2 data sets



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

DEM :
SRTM4

Parameters :
InSAR, MAI

差分干涉 : 3x3 looks
unwrapping : 4x4 looks
(by minimum cost flow)

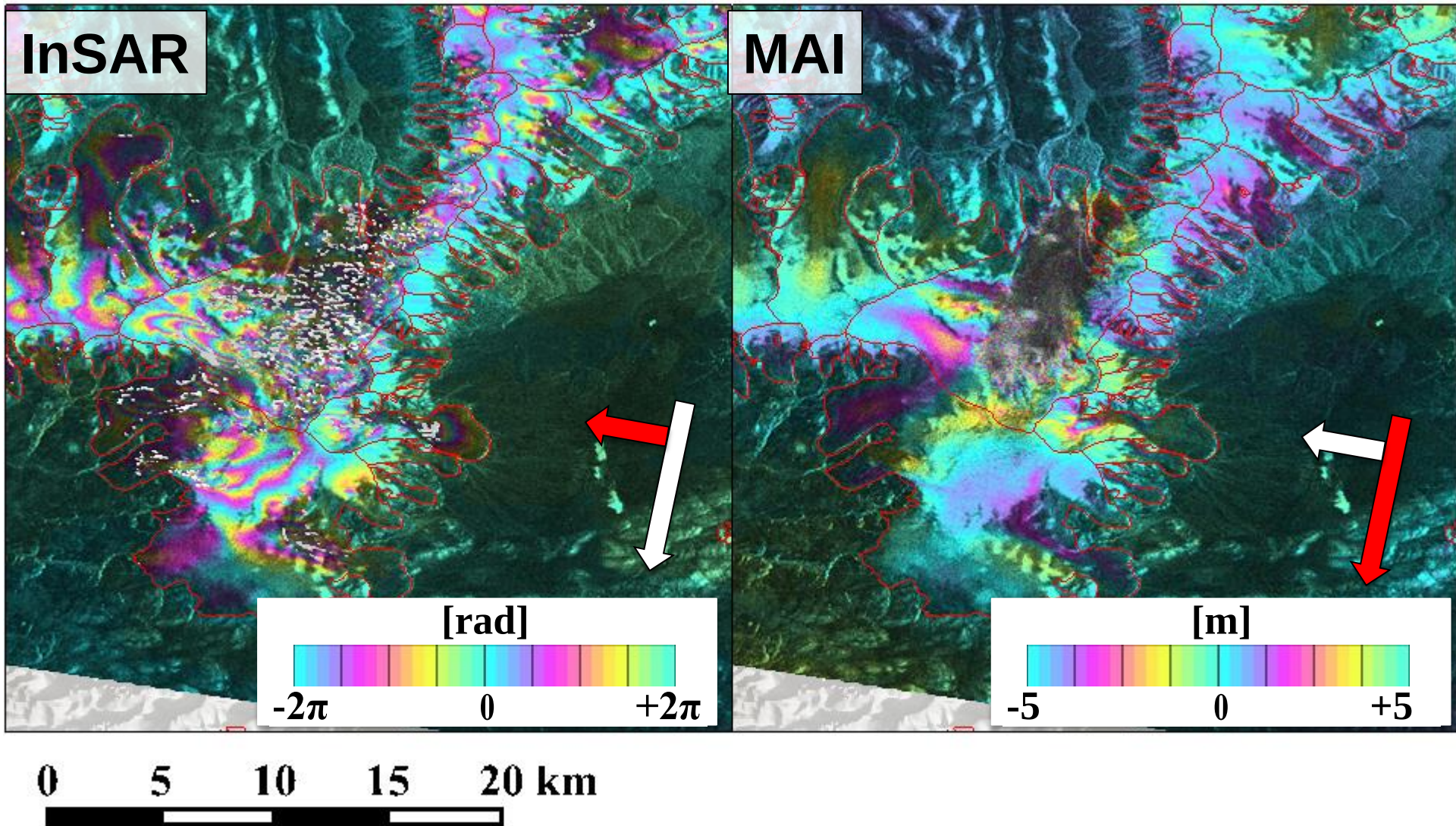
Pixel Offset (PO)

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

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	×	×	×
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D1	HH, HV	2015/03/14 – 2015/03/28	14	117	⊙	⊙	×
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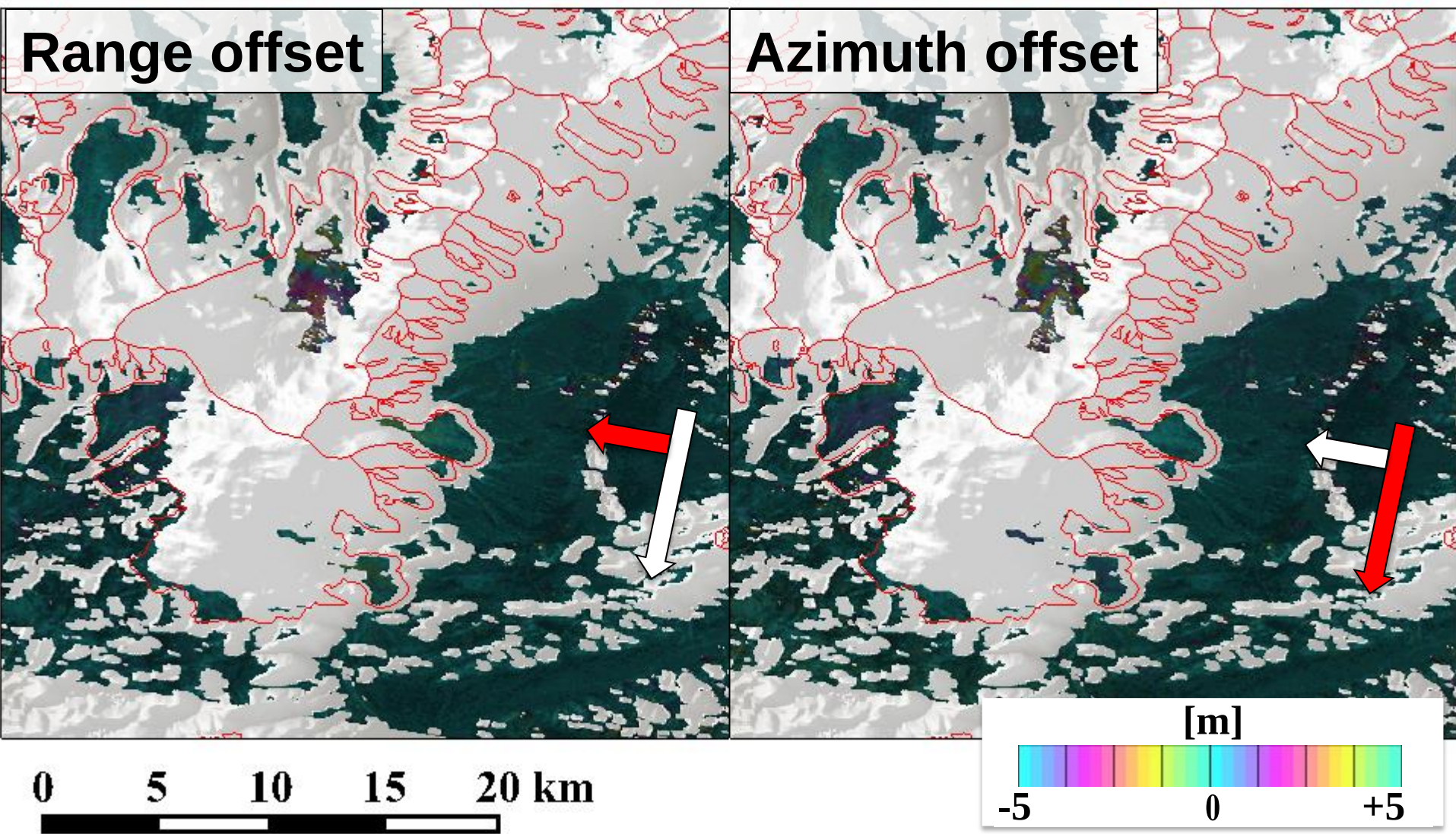
Preliminary results: InSAR, MAI (HH)

- 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)

PALSAR (L-band)

2008/12/13 - 2009/01/28

FBS (HH), 46 days

~40 m/yr

PALSAR2 (L-band)

2015/03/14 - 2015/03/28

StripMap (HH), 14 days

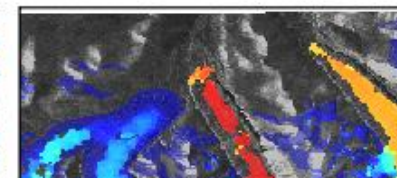
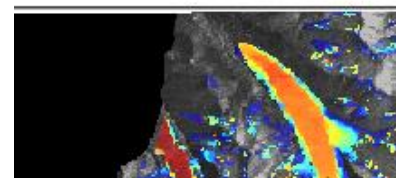
~800 m/yr

Sentinel-1A (C-band)

2015/04/02 – 2015/04/26

TOPS IW (VV), 24 days

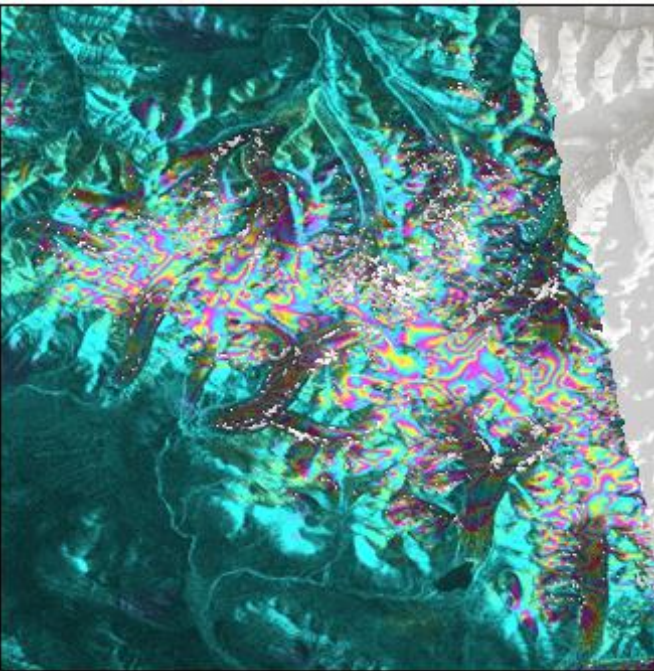
0 5 10 km



Phase unwrapping on glaciers

CHALLENGING TASKS

Phase unwrapping on glaciers



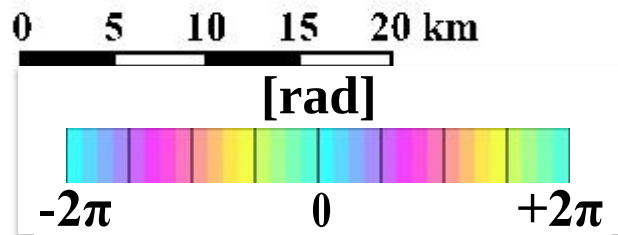
Problem: large displacement of ice flow

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

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

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

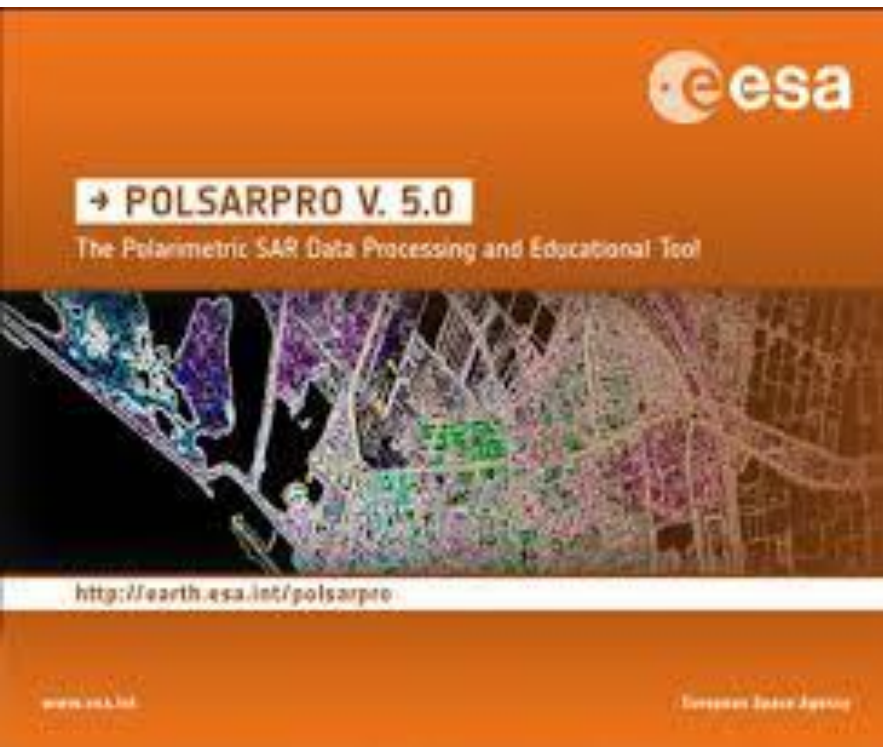
→unwrapping only the residual part: ϕ_{res}



POLARIMETRIC SAR

PolSARpro

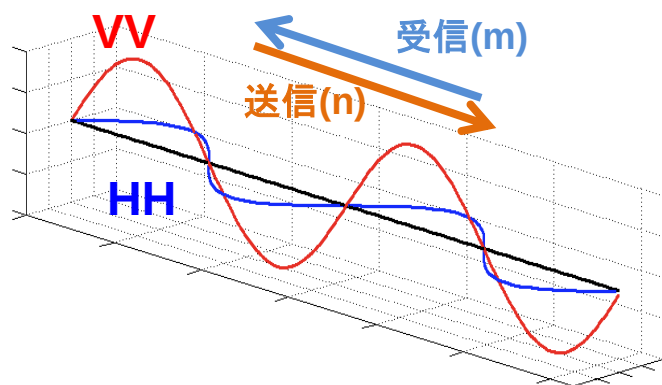
- The toolbox for dual-pol and full-pol SAR
(<https://earth.esa.int/web/polsarpro/home>)



- ✓ **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

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

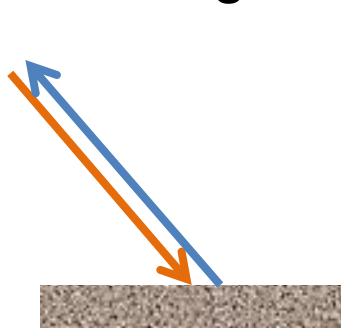
※送信・受信の順番に注意

m : 受信, n: 送信

PALSAR1/2の場合 (IMG-XY)

X: 送信, Y: 受信

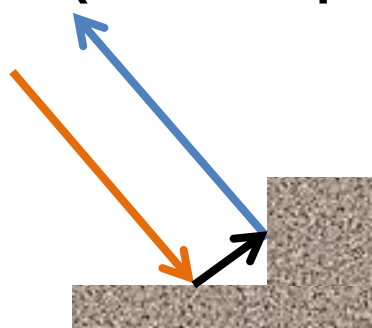
Scattering models (four components)



Single bounce

Sea
Low vegetation

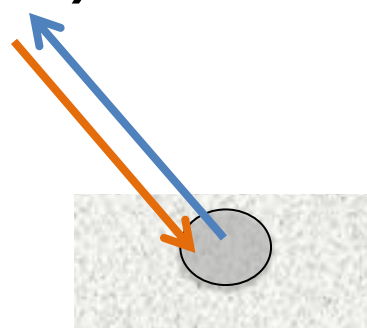
$$|S_{HH} + S_{VV}|$$



Double bounce

Tree trunk
Building

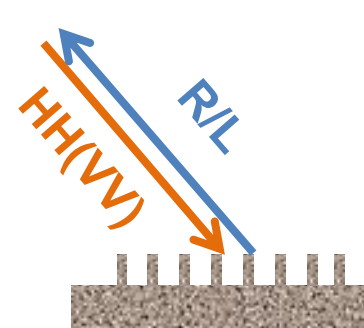
$$|S_{HH} - S_{VV}|$$



Volume scattering

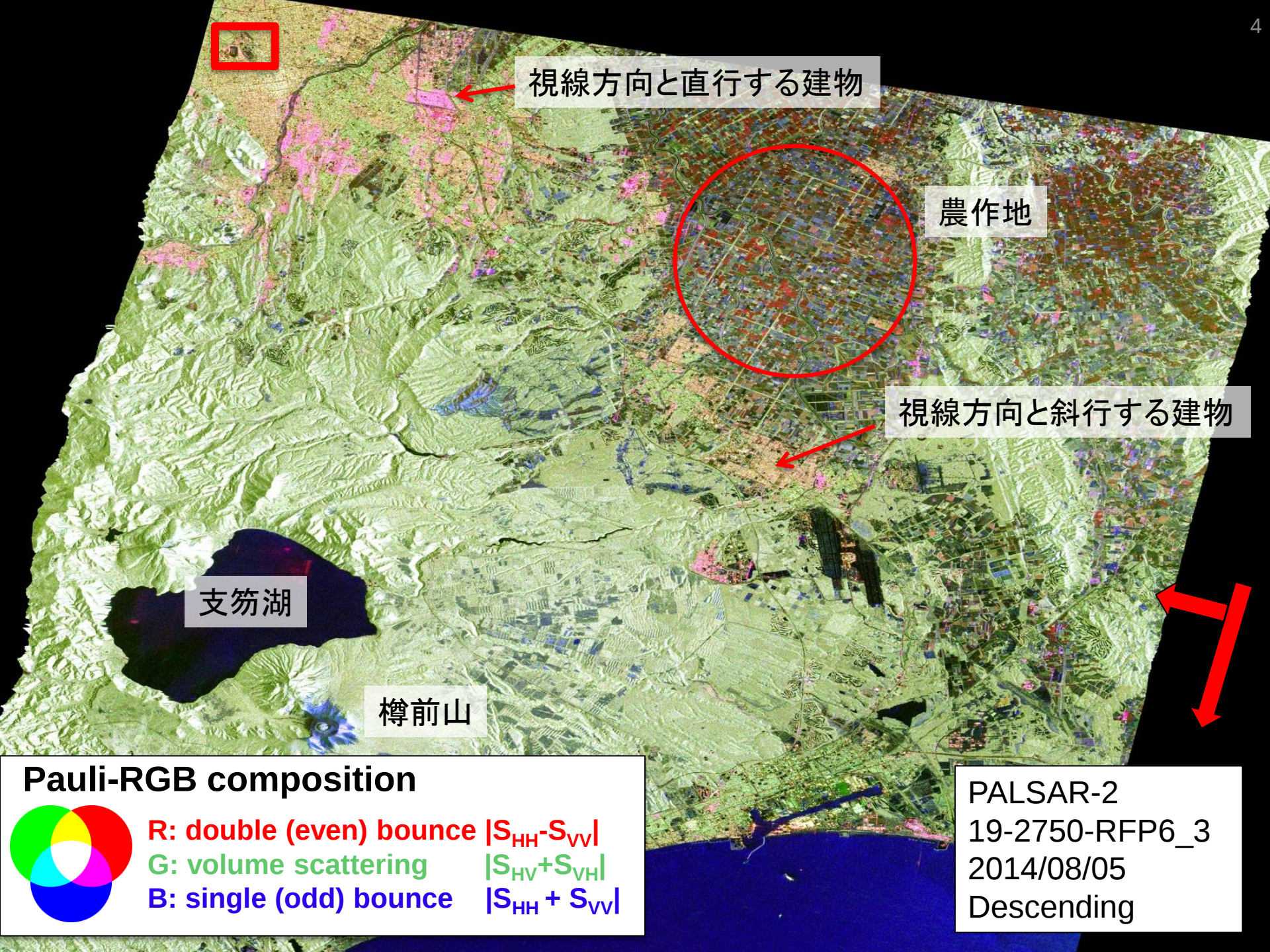
Forest
Dry ice

$$|S_{HV} + S_{VH}|$$



Helix scattering

交差ワイヤや
1/4 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 $|S_{HH} + S_{VV}|$

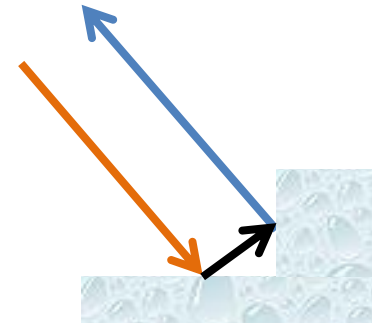
PALSAR-2
 19-2750-RFP6_3
 2014/08/05
 Descending

Pauli-RGB composition on glaciers

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

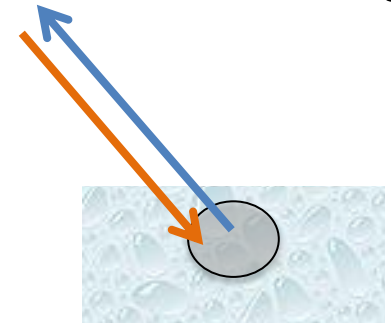


Crevassed surface ~ slant buildings



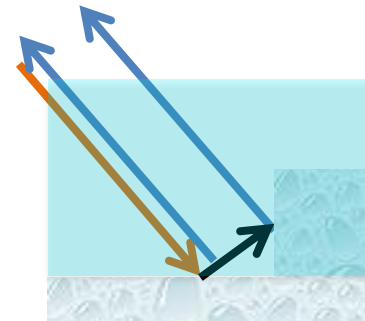
Double bounce

Crevassed wall + slant to line-of-sight

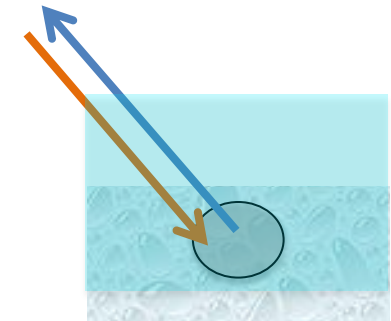


Volume scattering

Ice structure in glaciers?



Single/double
bounce



Volume scattering



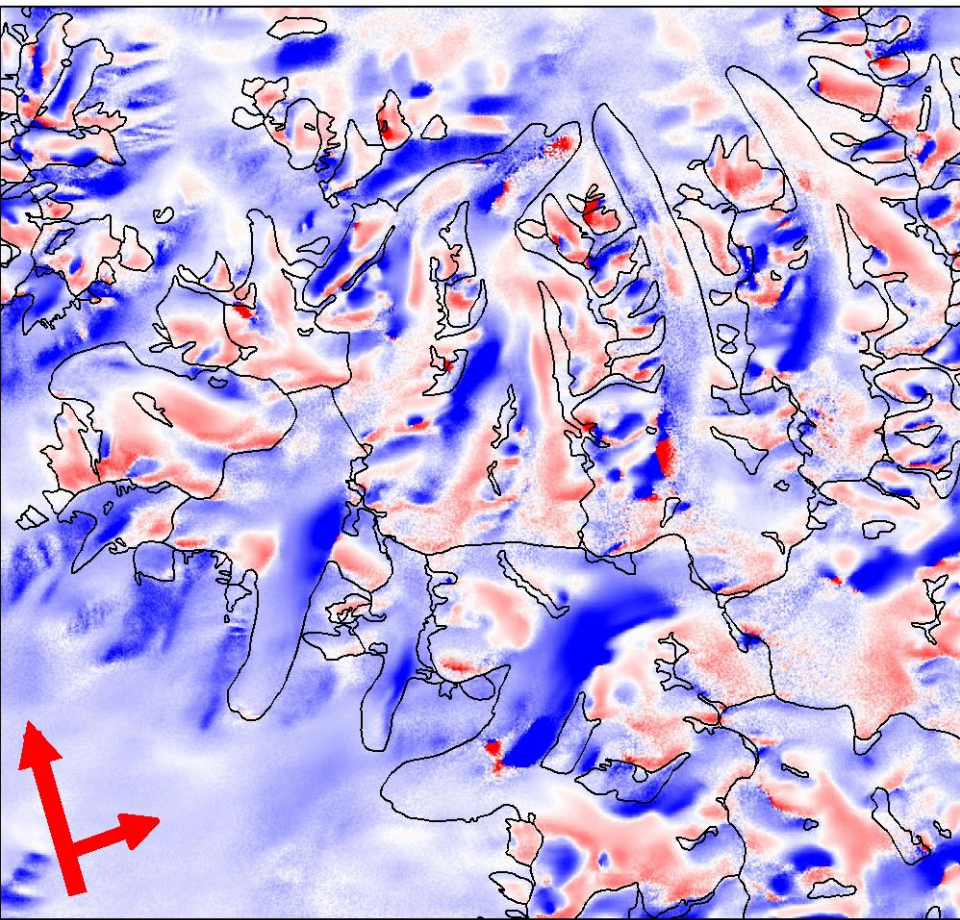
R: double (even) bounce $|S_{HH} - S_{VV}|$

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

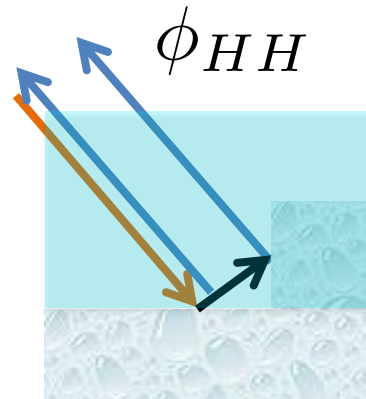
B: single (odd) bounce $|S_{HH} + S_{VV}|$

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

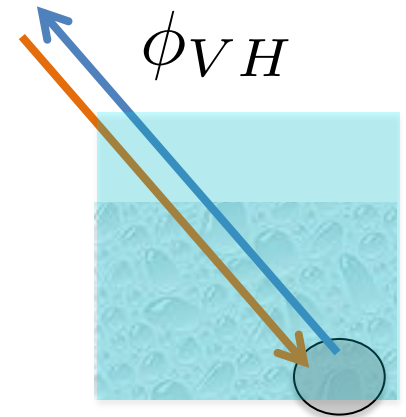
2015/03/03 : $\phi_{HH} - \phi_{VH}$ (unwrapped)



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 $\rightarrow$ 800 m/yr by 2015)
- Challenging tasks:
 - Phase Unwrapping on glaciers
- Future plans:
 - Polarimetric SAR

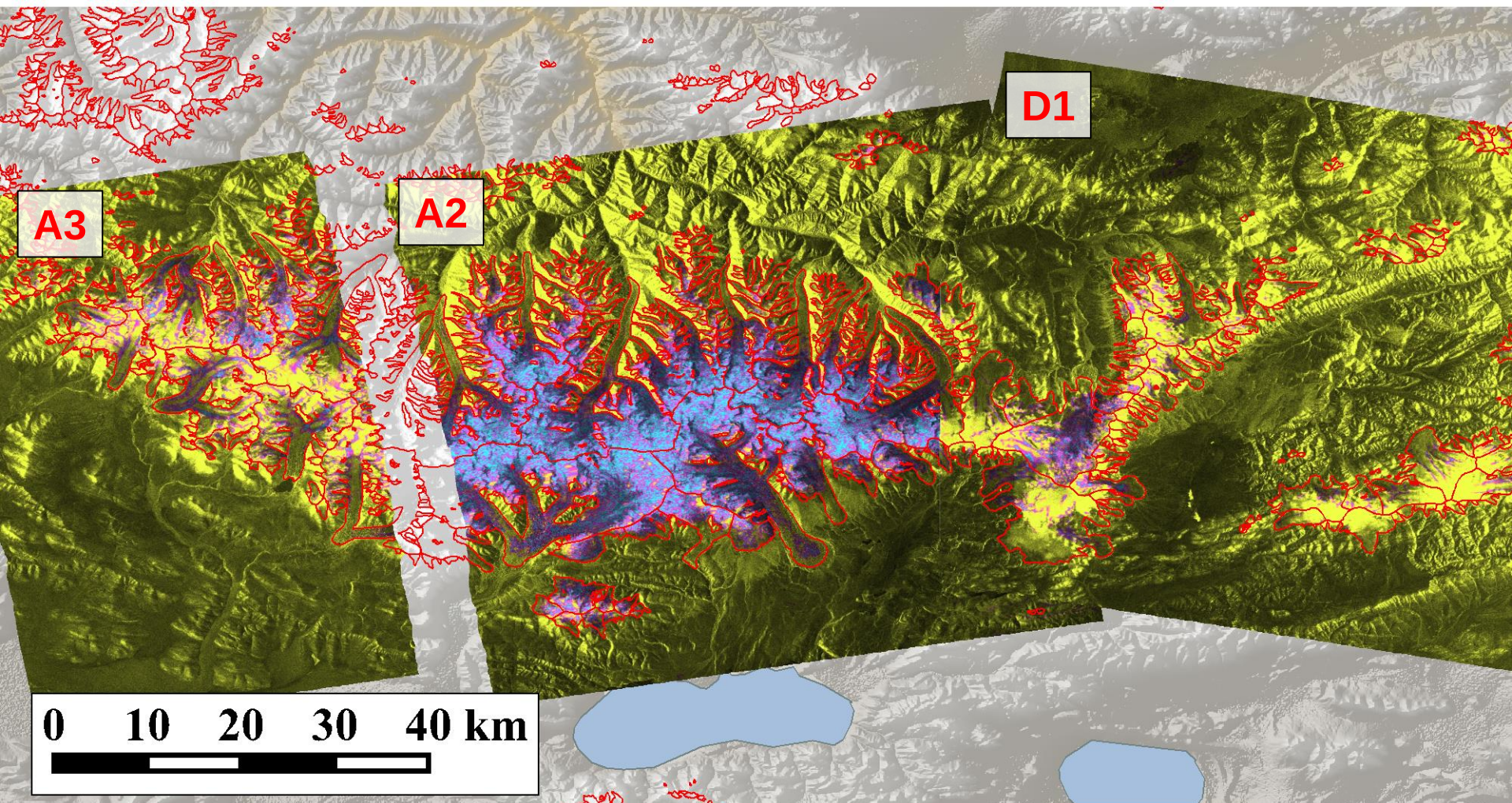
Thank you for listening

Acknowledgements

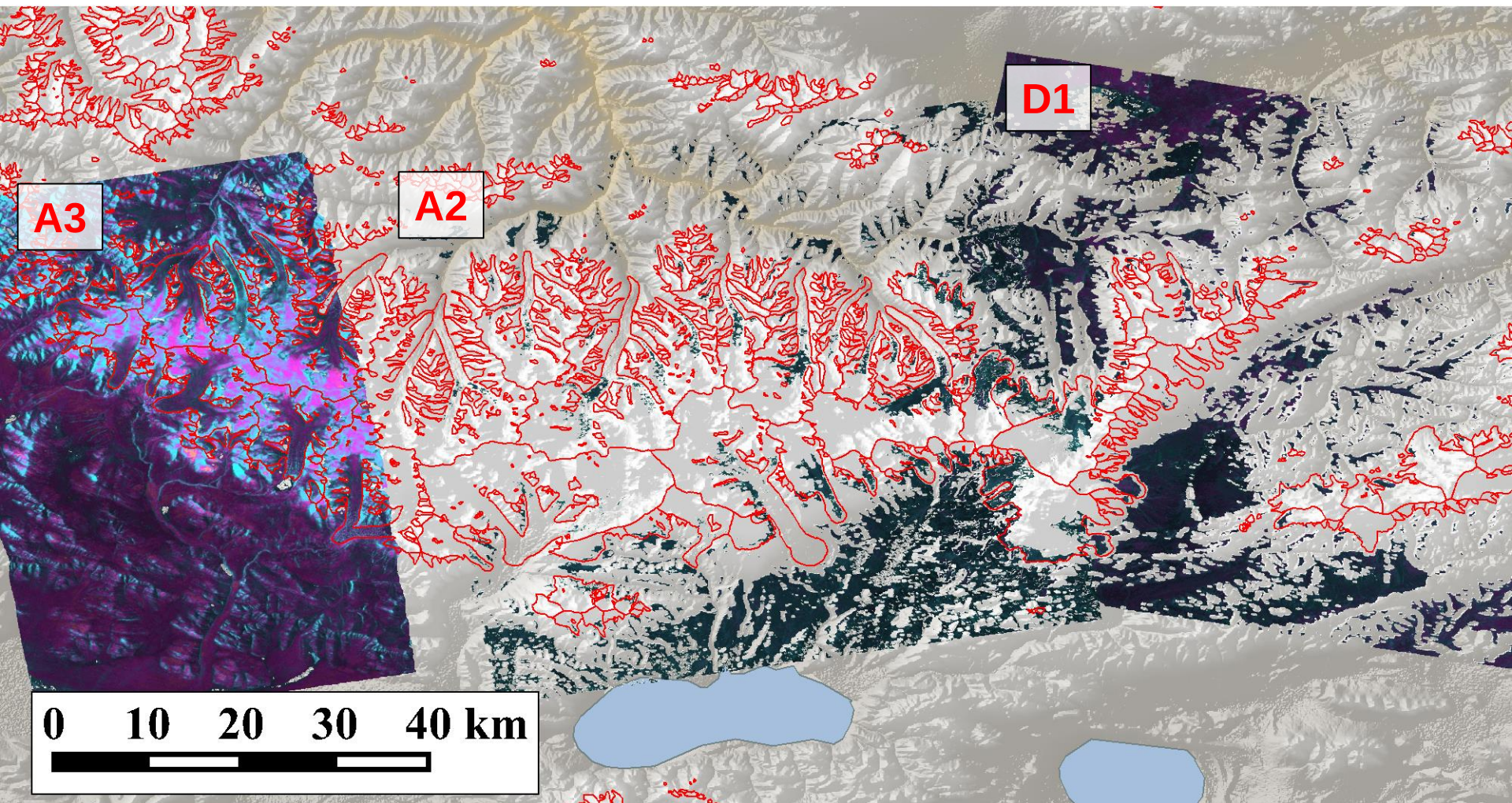
- PALSAR level 1.0 data were provided partly from the PIXEL (PALSAR Interferometry Consortium to Study our Evolving Land surface) and partly from ALOS 3rd PI (#538) under a cooperative research contract with JAXA.
- PALSAR 2 data were provided from ALOS RA4 (#1179) under a cooperative research contact 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>



Sentinel 1A

