SARによる氷河変動の実態とメカニズムの解明

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- はじめに：「氷河/氷床モニタリング」
- ALOS/PALSARの貢献
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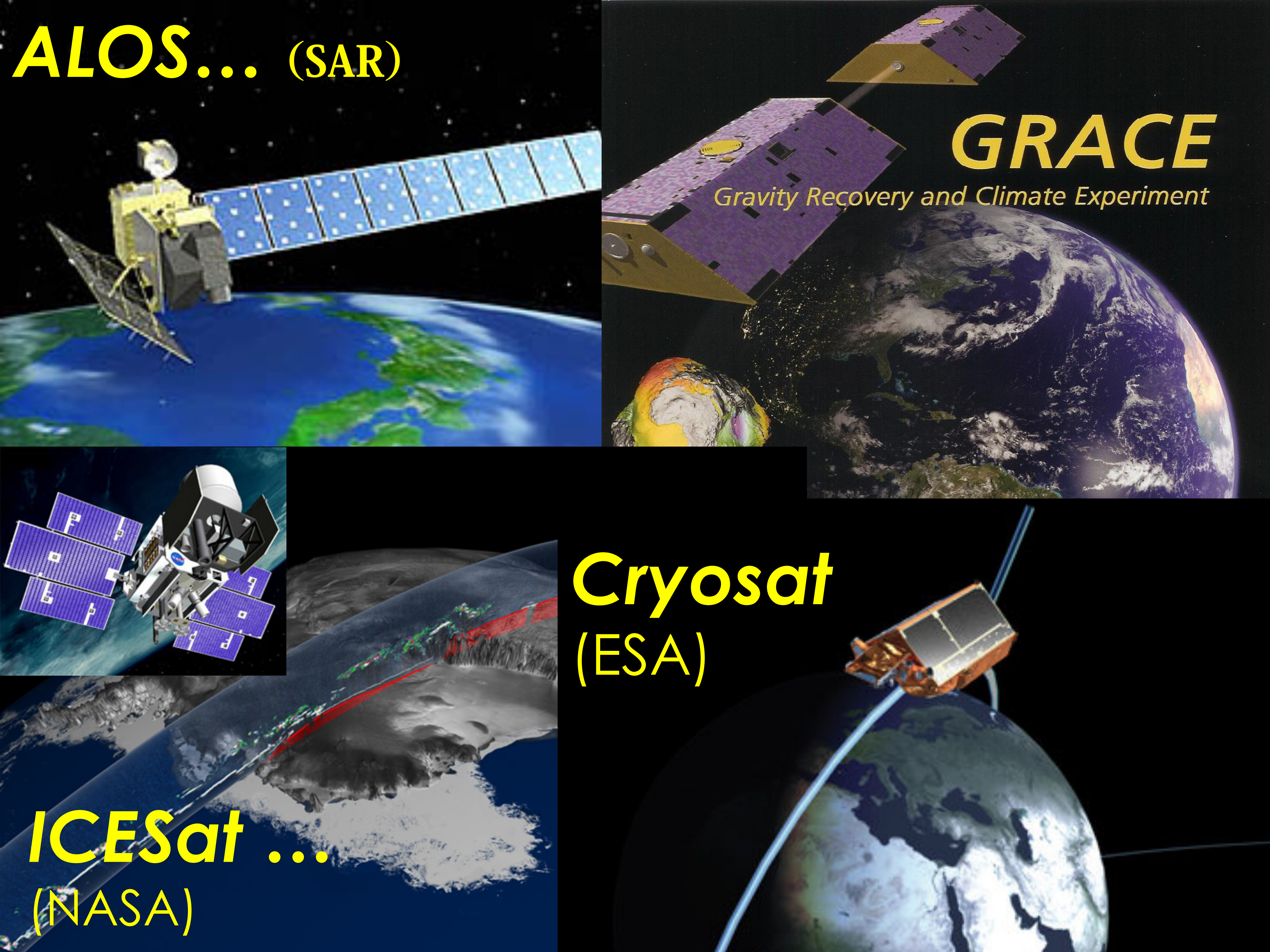
  - -西クンルン山脈での氷河サージ
  - -南パタゴニア氷原
  - -ユーコン地域の冬期加速の発見
- まとめ/課題

氷河/氷床を観測する動機
-Motivations to monitor glaciers-

・温暖化による雪氷域の変動：
海水面上昇，水資源問題
- Global warming and its impact on cryosphere:
  Sea level changes, Water resources
- Quantitative & persistent monitoring

・地上観測データ(GPS,厚さ等)の取得が極めて困難
- Extremely challenging to get ground-based data

「氷河/氷床」の衛星リモートセンシング


ALOS... (SAR)
GRACE
Gravity Recovery and Climate Experiment
Cryosat
(ESA)
ICESat ...
(NASA)

Target (私見)

1. 南極、グリーンランド

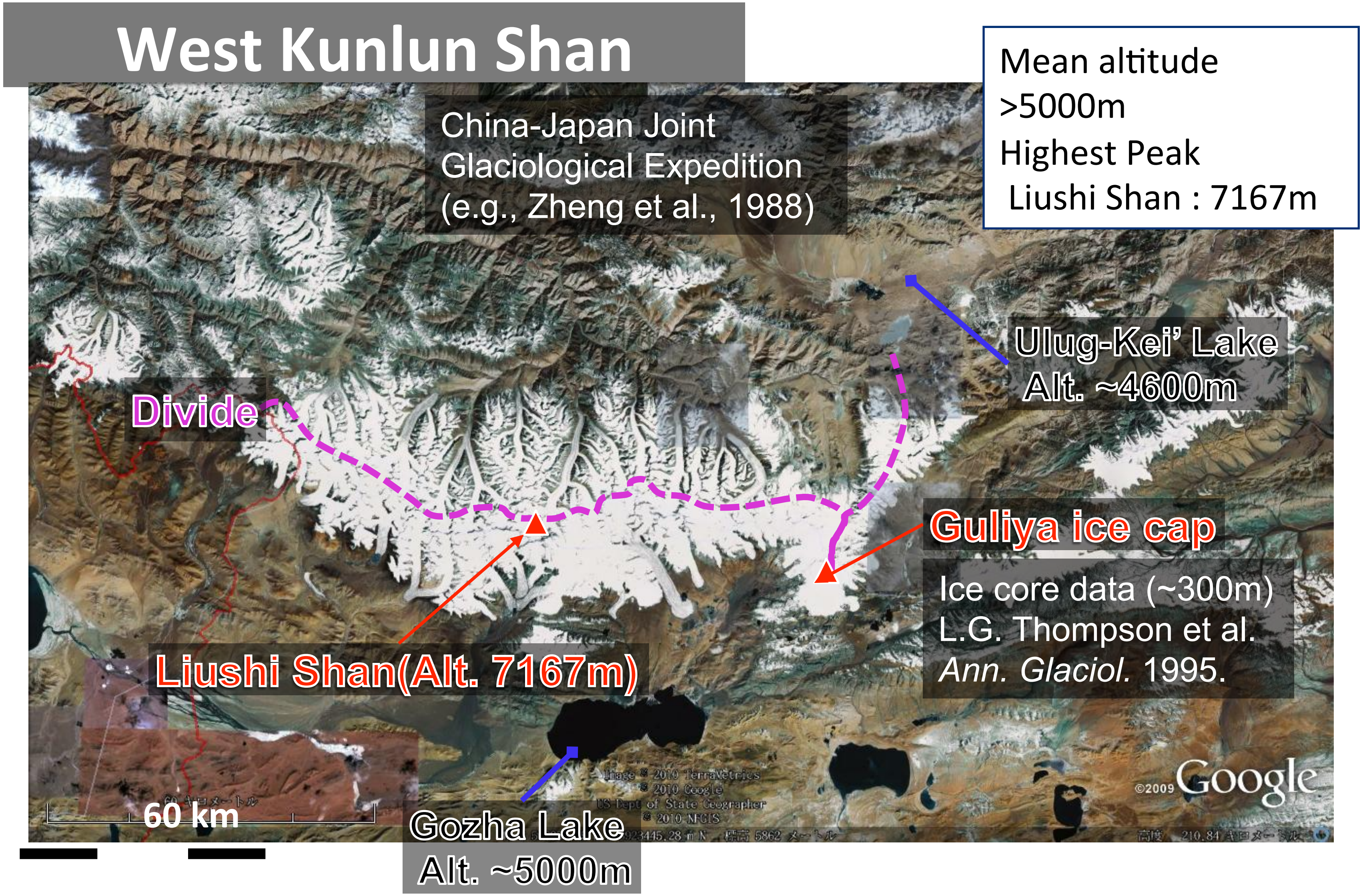
2. 山岳氷河（アジア高山域, パタゴニア, アラスカ/ユーコン):

規模が小さいため，流動測定には，従来の衛星SARでは必ずしも空間分解能が十分ではなかった…

3. SARの新たな利用(Polarimetryの活用??)

アジア高山域に分布する氷河

Study area

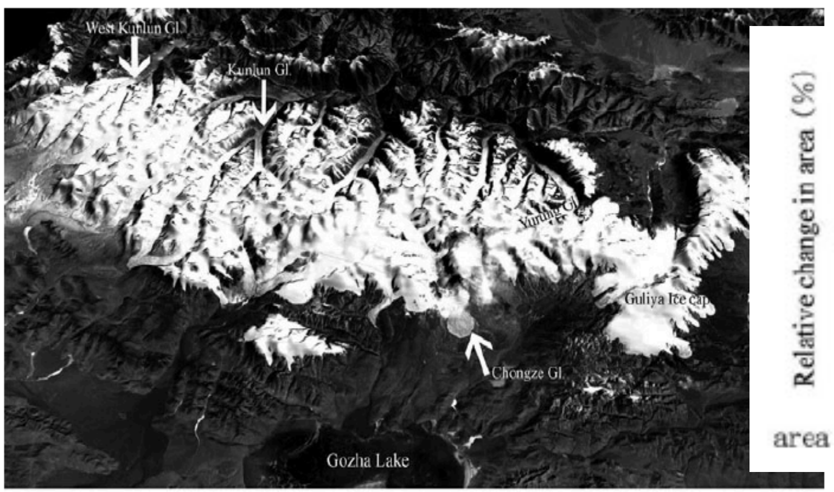

West Kunlun Shan
China-Japan Joint Glaciological Expedition (e.g., Zheng et al., 1988)
Mean altitude >5000m
Highest Peak
Liushi Shan : 7167m
Ulug-Kei' Lake
Alt. ~4600m
Divide
Guliya ice cap
Ice core data (~300m)
L.G. Thompson et al.
Ann. Glaciol. 1995.
Liushi Shan(Alt. 7167m)
60 km
Gozha Lake
Alt. ~5000m
©2009 Google

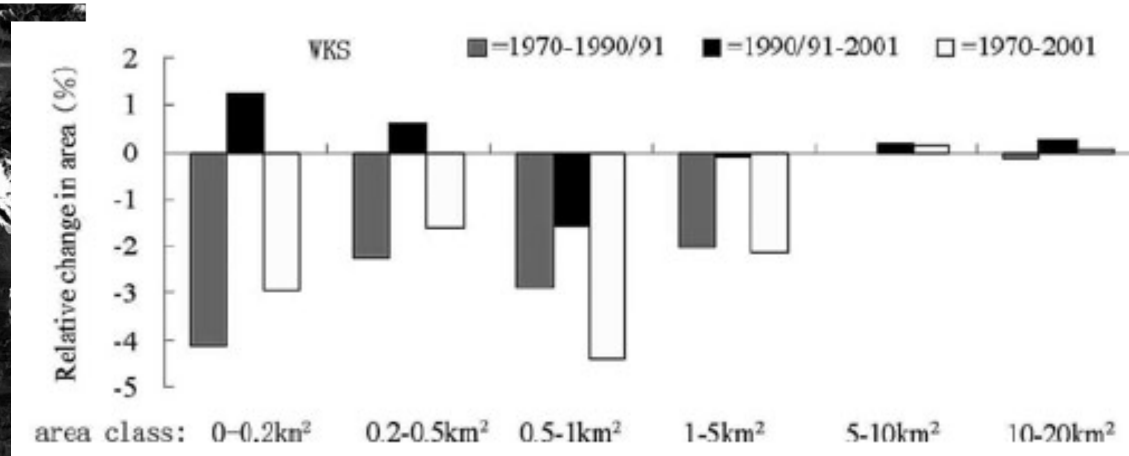
Landsat画像によると…

204 Annals of Glaciology 46 2007

Glacier changes in the west Kunlun Shan from 1970 to 2001 derived from Landsat TM/ETM+ and Chinese glacier inventory data

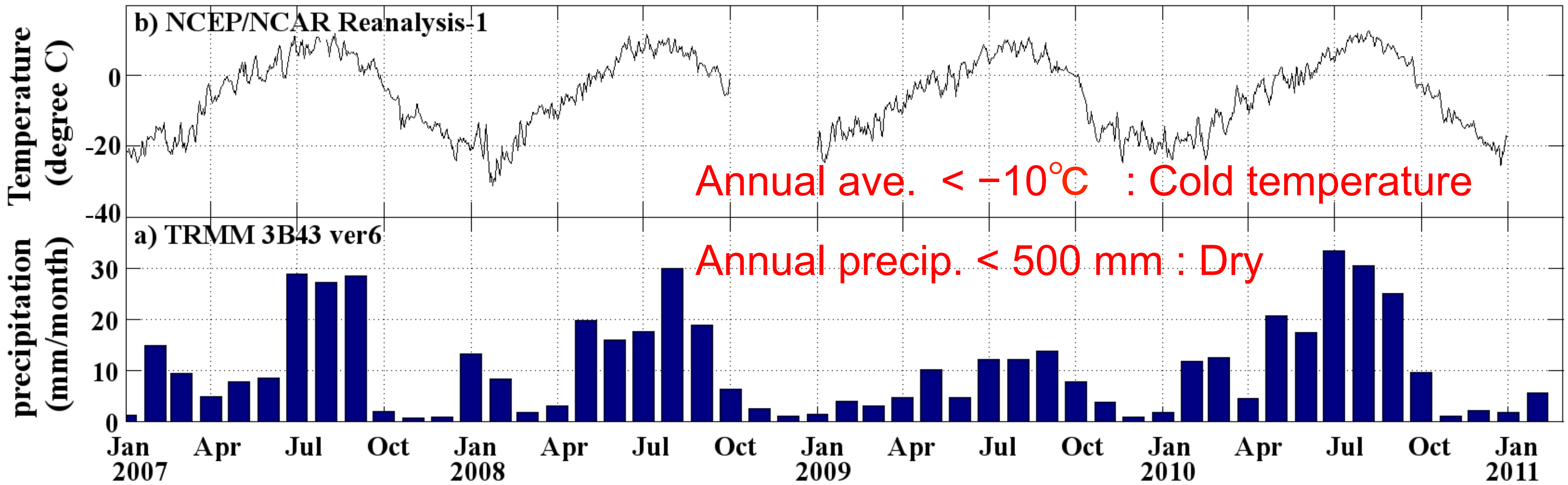
SHANGGUAN Donghui,[1] LIU Shiyin,[1,2] DING Yongjian,[1] LI Jing,[1] ZHANG Yong,[1]
DING Lianfu,[1] WANG Xing,[1] XIE Changwei,[1] LI Gang[1]





➢温暖化に伴う“面積”の減少??

殆ど極域のような気候



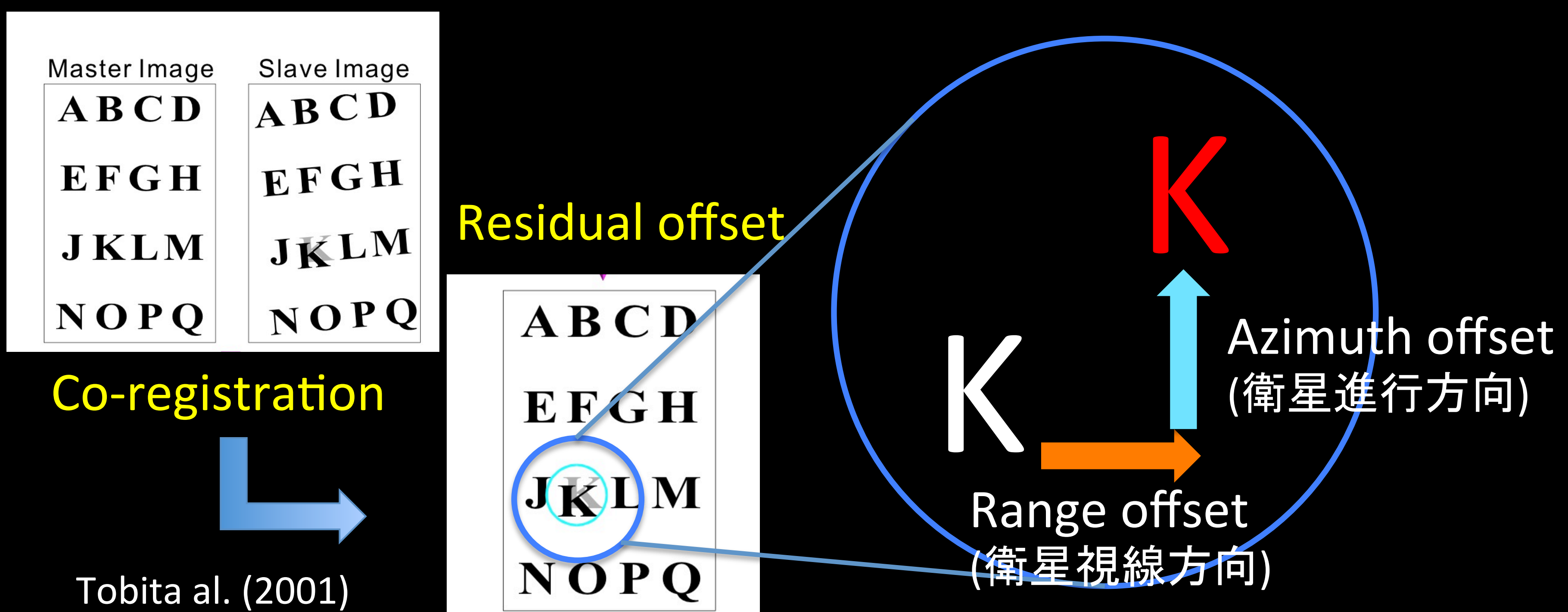
Almost polar climate (similar to Svalbard)

Glaciers have been believed to be cold-based.

底まで氷結と思われていた.

Pixel offset technique
(Feature tracking)

- Co-registration (Matching) of two SAR images based on intensity correlations
- Residual offsets are detected as displacements
- Two components: Range, Azimuth offset



Tobita al. (2001)

Surface velocity field: an example

T. Yasuda, M. Furuya / Remote Sensing of Environment 128 (2013) 87–106 91

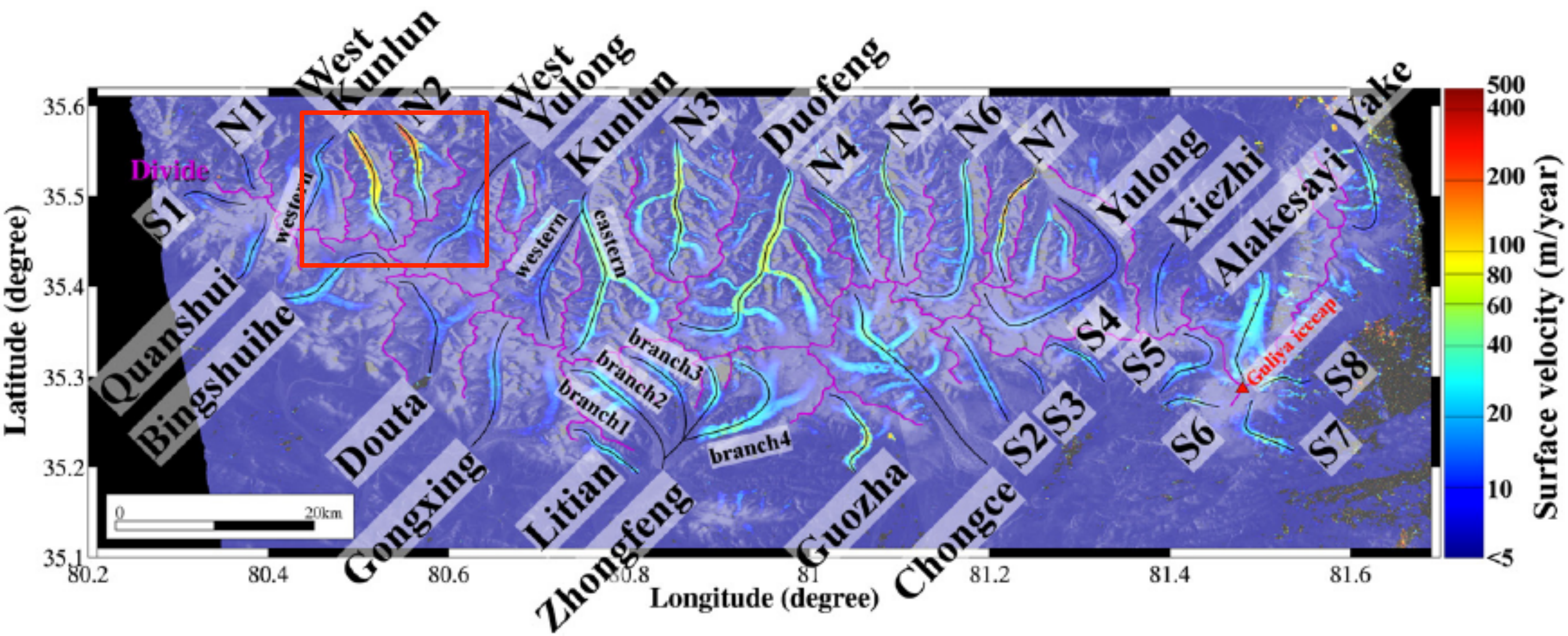
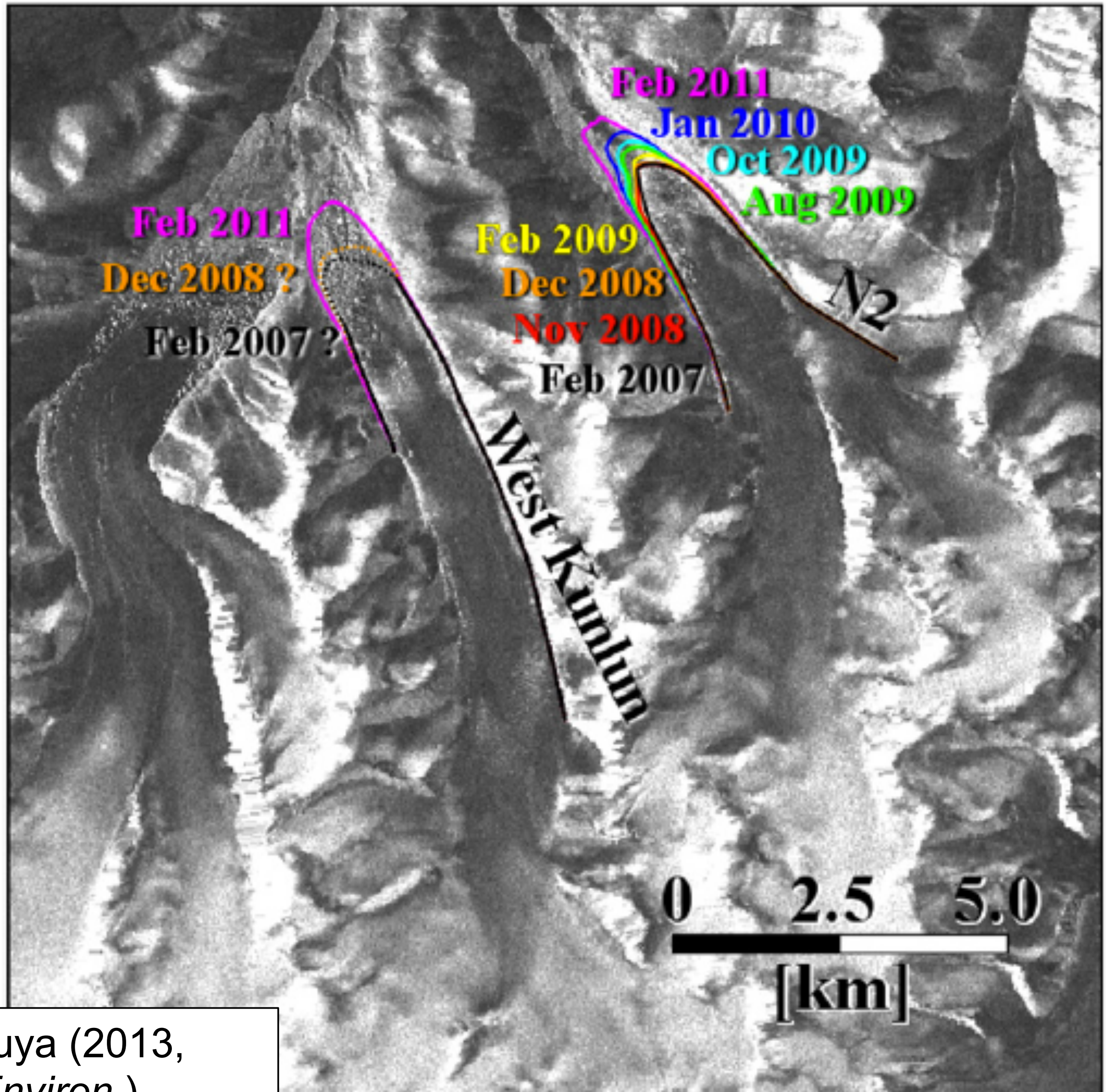


Fig. 3. A sample glacier surface velocity map at West Kunlun Shan overlaid on the PALSAR-based scattering intensity image. Note that the scale is logarithmic. The velocity estimates are derived from November 12, 2008 to December 30, 2008 for the western area (path 516) and from December 12, 2008 to January 28, 2009 for the eastern area (path 515); see Table 1. The examined glacier names and the Guliya icecap are indicated. Thin black lines denote flow lines, and magenta lines are the divides in the middle.

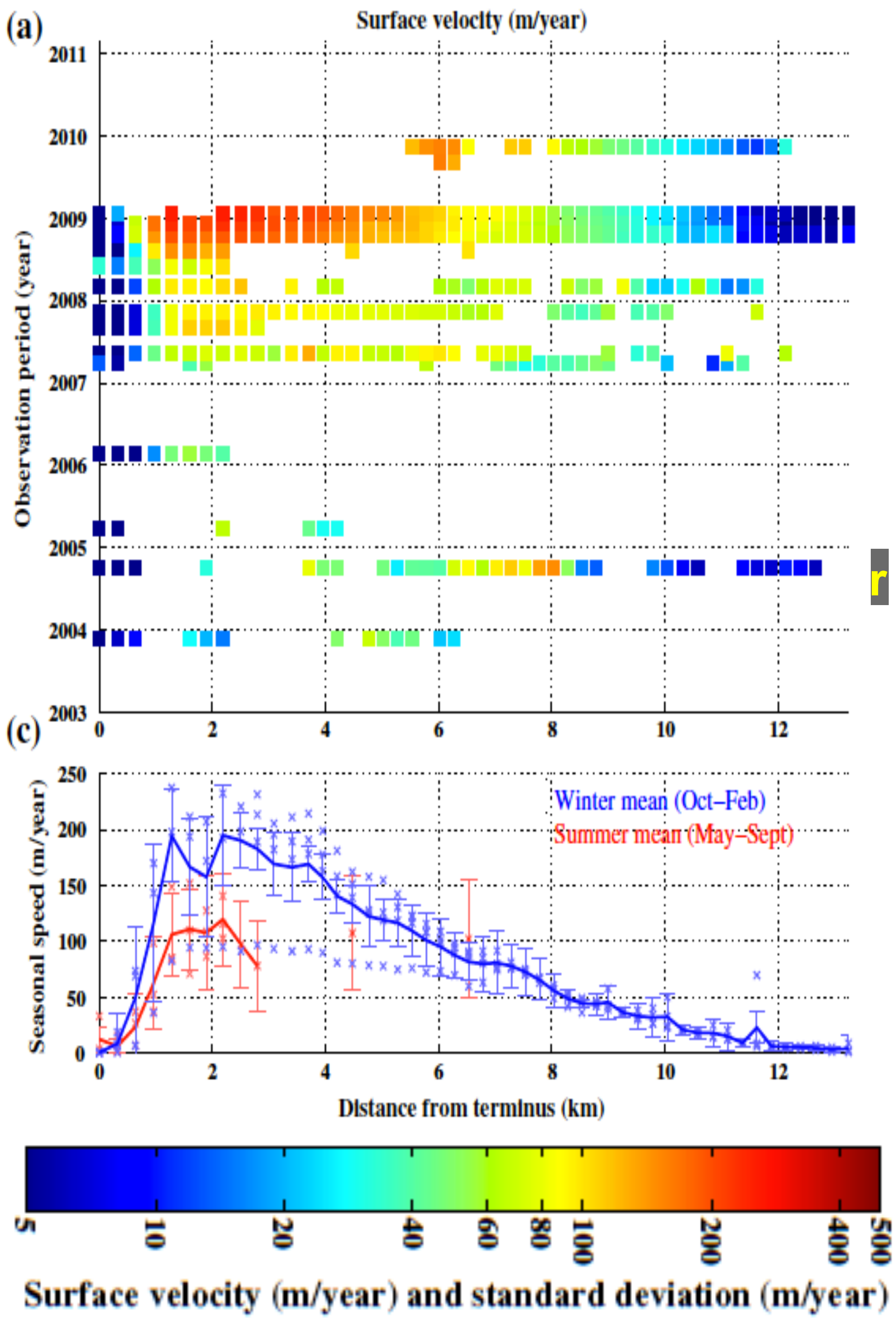
Yasuda, T. and M. Furuya (2013), *Remote Sens. Environ.*

Based on ALOS/PALSAR © JAXA/METI (ALOS 3rd PI: 538 + PIXEL)

強度画像(path516, Feb. 2007 – Feb. 2011, 13 scene)



Yasuda and Furuya (2013, *Remote Sens. Environ.*)



Surface velocity (m/yr)

←Surface Velocity: 2003-2011 (Envisat + ALOS)

- The Unnamed glacier was slower in 2004.
- The Envisat C-band data is noisier.

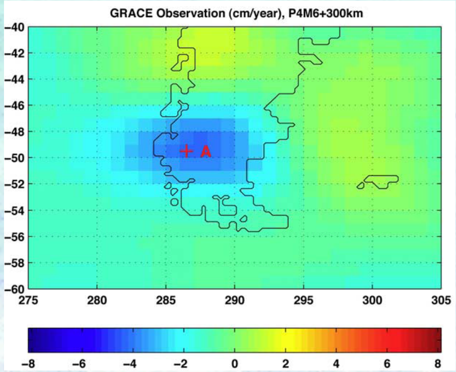
・氷河サージ

→ 氷河末端の前進

(面積増!)

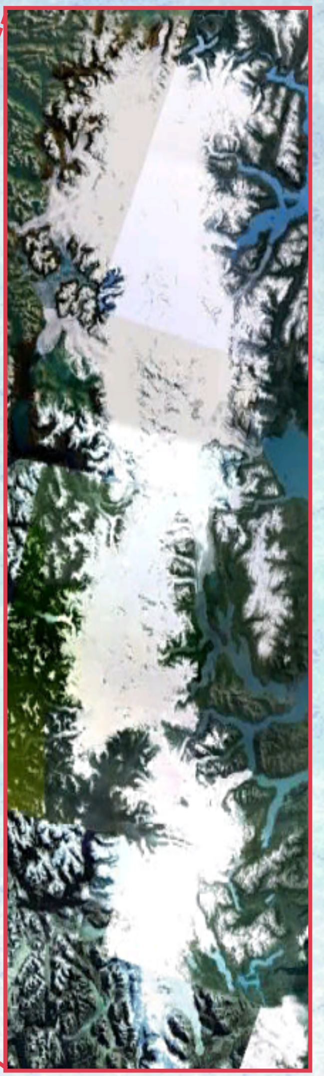
Southern Patagonia Icefield

- 南半球最大の温暖氷河群
- 総面積 : 約 13000 km^2
- 標高 : 平均 1355 m
- 多くの氷河は近年後退しており、海水準の上昇にも影響（Rignot et al., 2003）
- GRACEの観測
  2002-2006年の質量損失
  -27.9±11 km^3/year
  （chen et al., 2007）



Chen et al., 2007

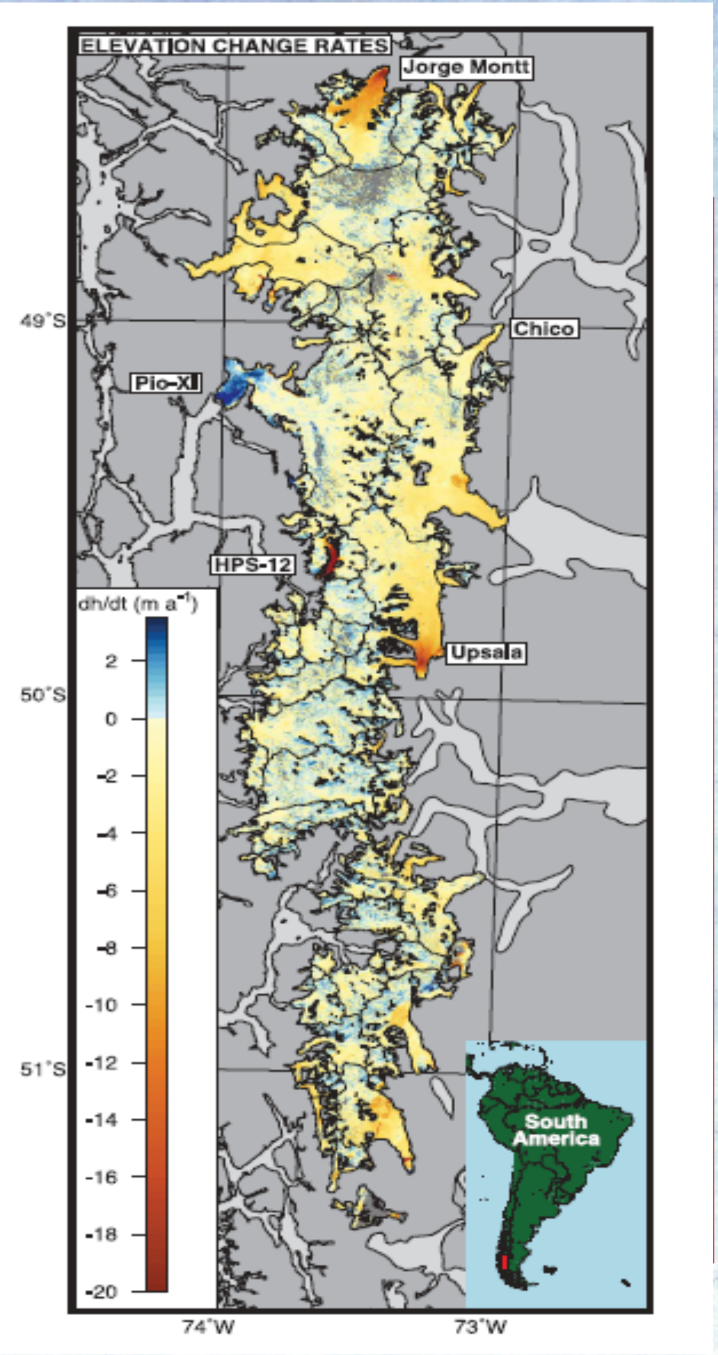
Southern Patagonia Icefield



Background

- アクセス困難な環境・厳しい気候
- 多くの氷河について流動速度がわかっていない
- DEMデータ(ASTER等)に基づく氷厚変化のデータ(Willis et al. 2012)

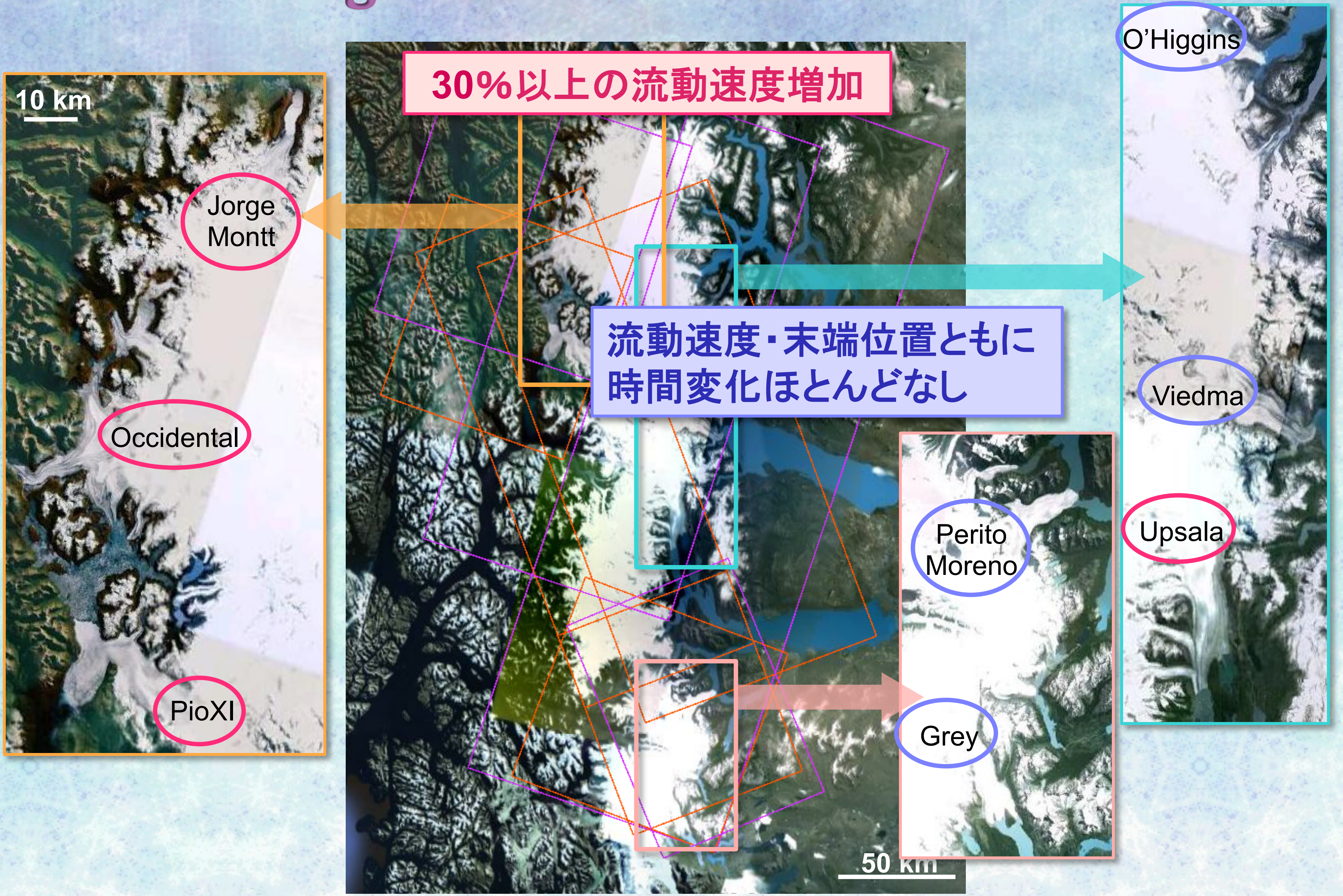
•加速・後退は起こっているのか？
•どの氷河で？いつ？？



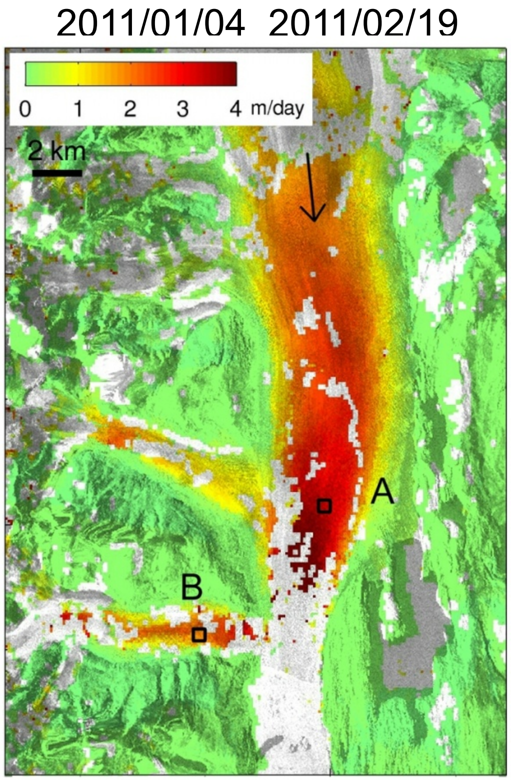
Willis et al., 2012

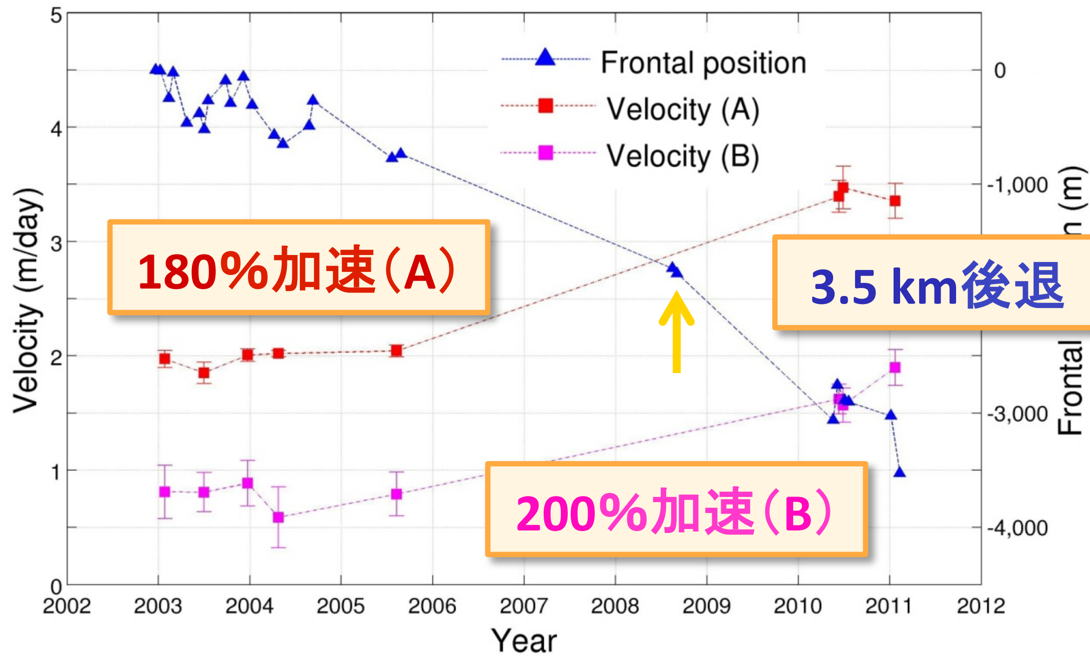
Muto & Furuya (2013, RSE, in press)

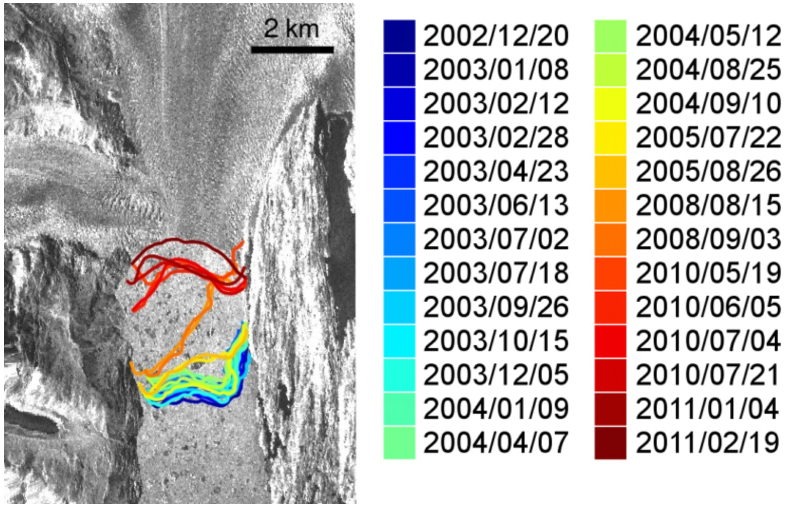
Examined glaciers



Upsala氷河

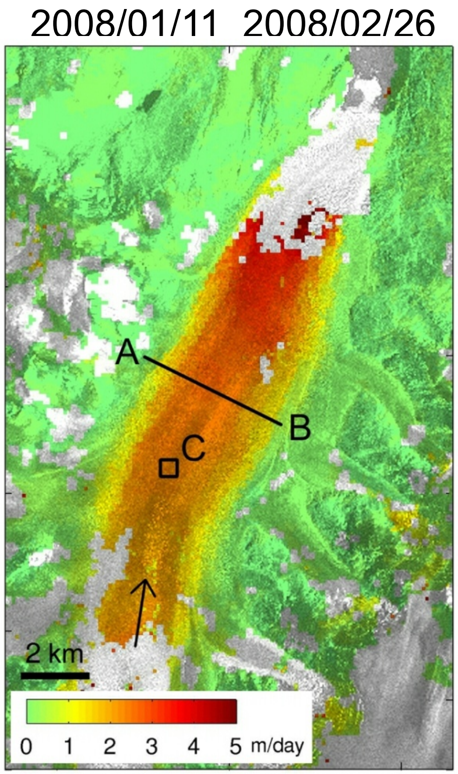


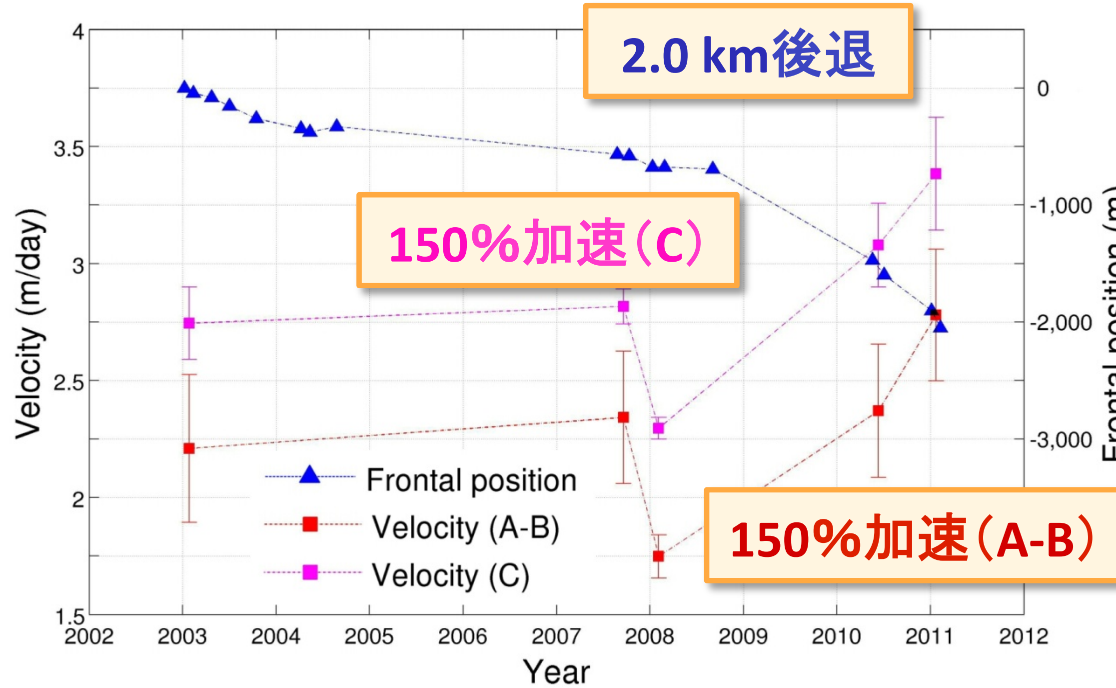


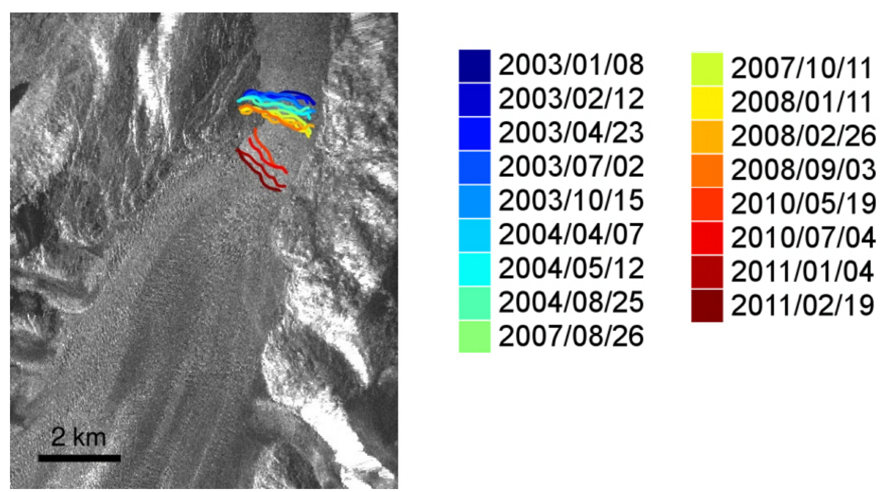


Muto & Furuya (2013, RSE, in press)

Jorge Montt氷河







Muto & Furuya (2013, RSE, in press)

Results

- 3つの氷河（Upsala氷河，Jorge Montt氷河，Occidental氷河）で急激な加速と後退

- Pio XI氷河は流動速度が複雑に変化
末端は後退なし

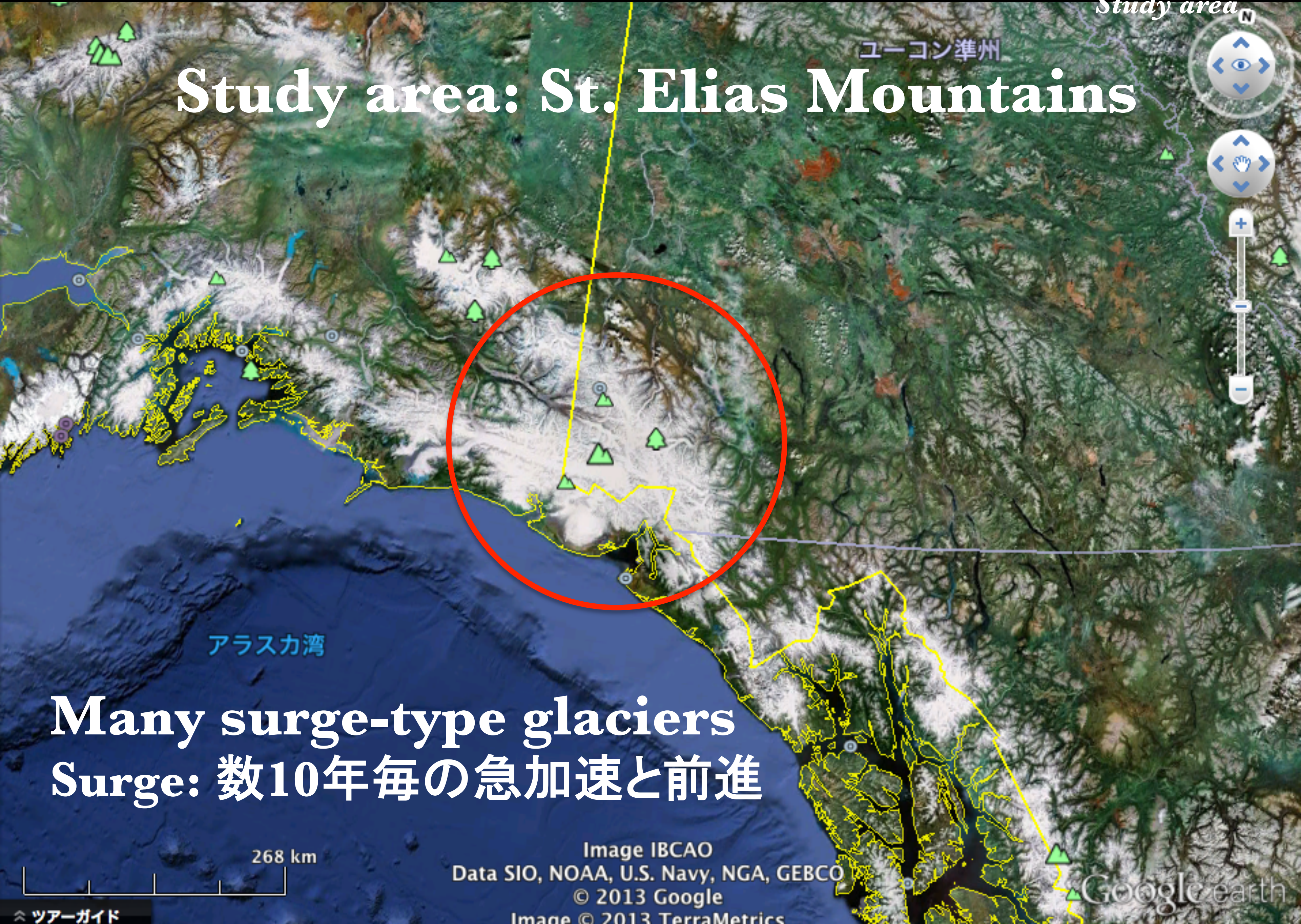
- 加速・後退の原因は？

→ グリーンランドの場合：暖かい海水による底面融解
（Holland et al., 2008）

別の原因

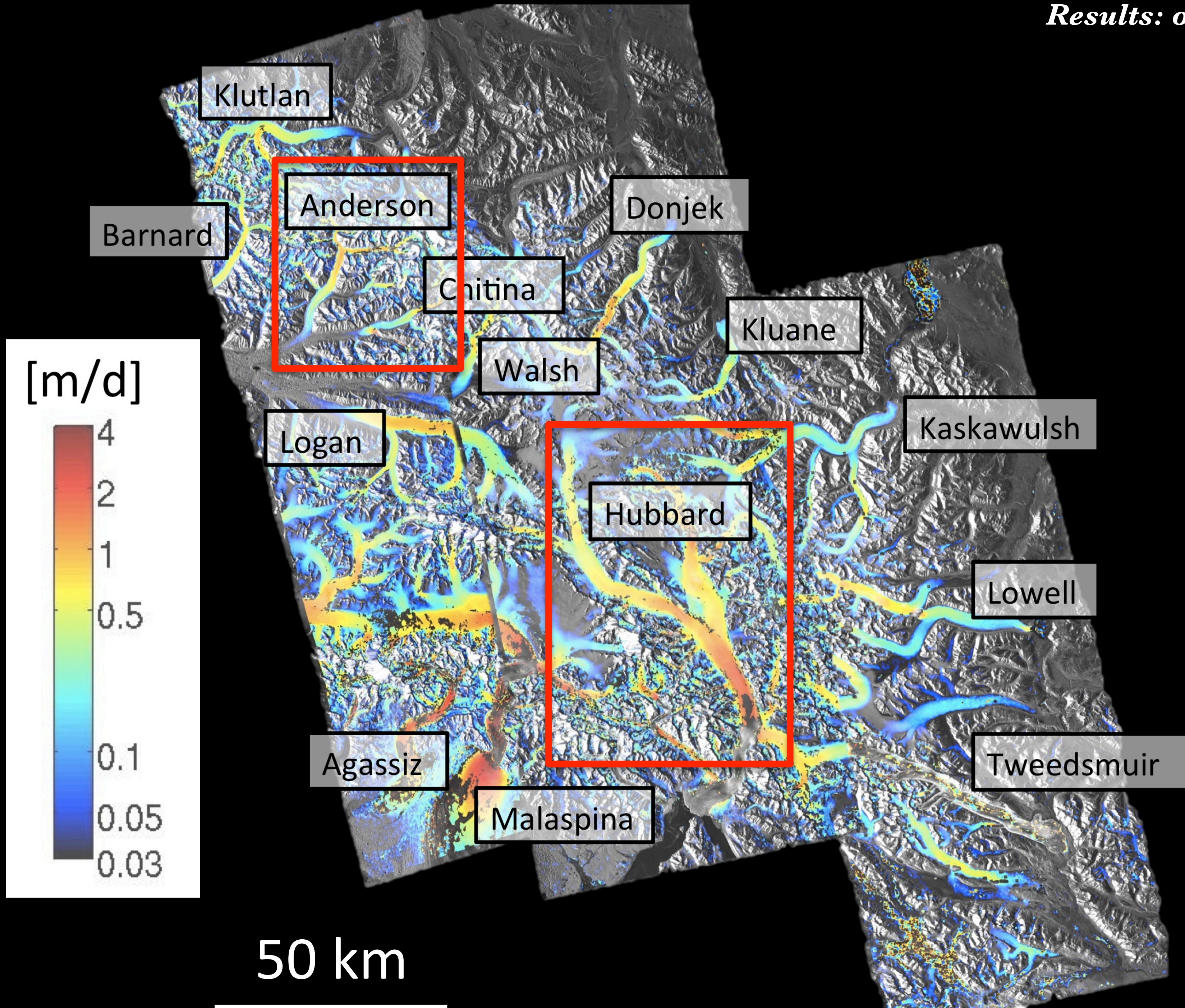
Muto & Furuya (2013, RSE, in press)

Study area: St. Elias Mountains



Many surge-type glaciers

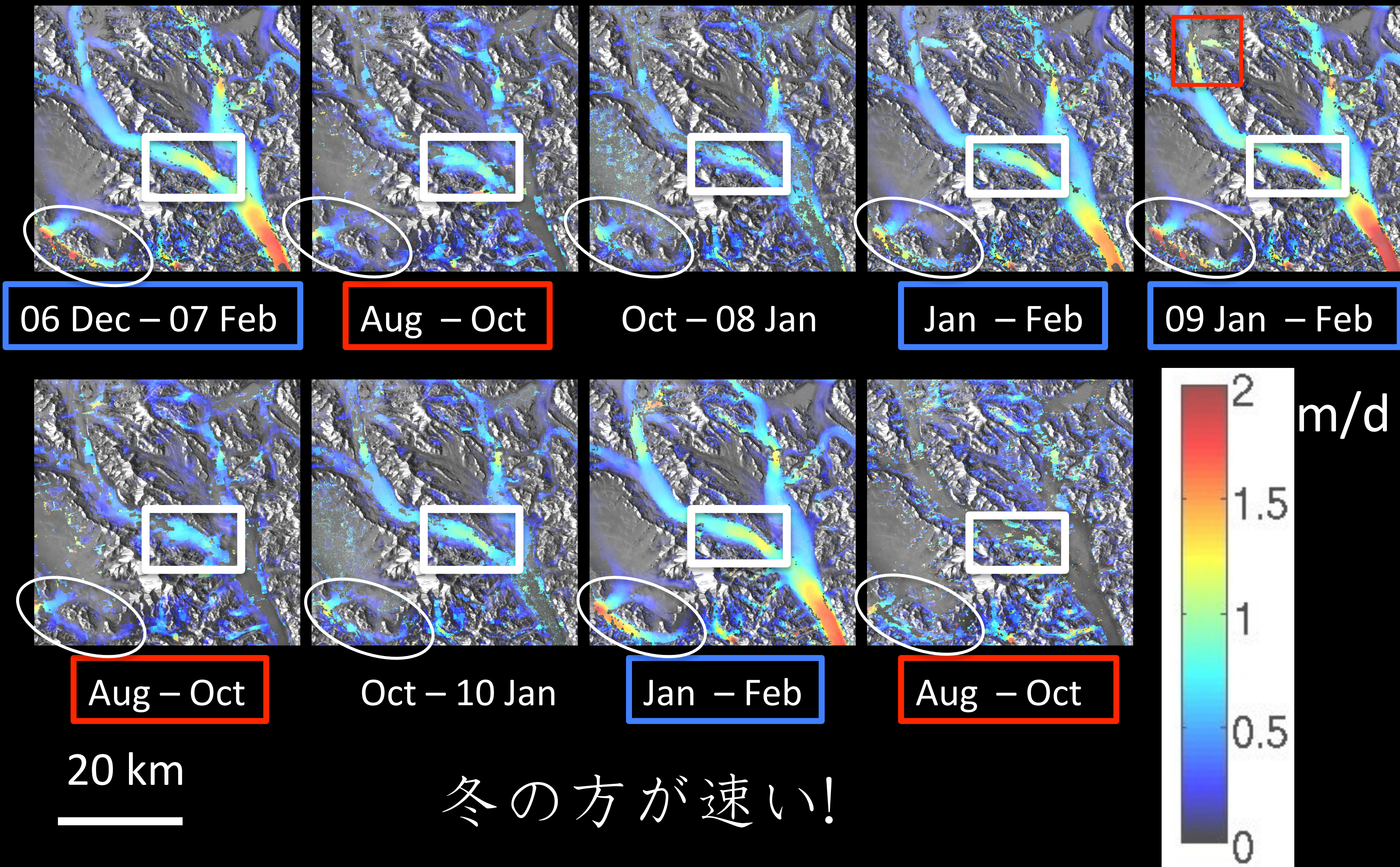
Surge: 数10年毎の急加速と前進

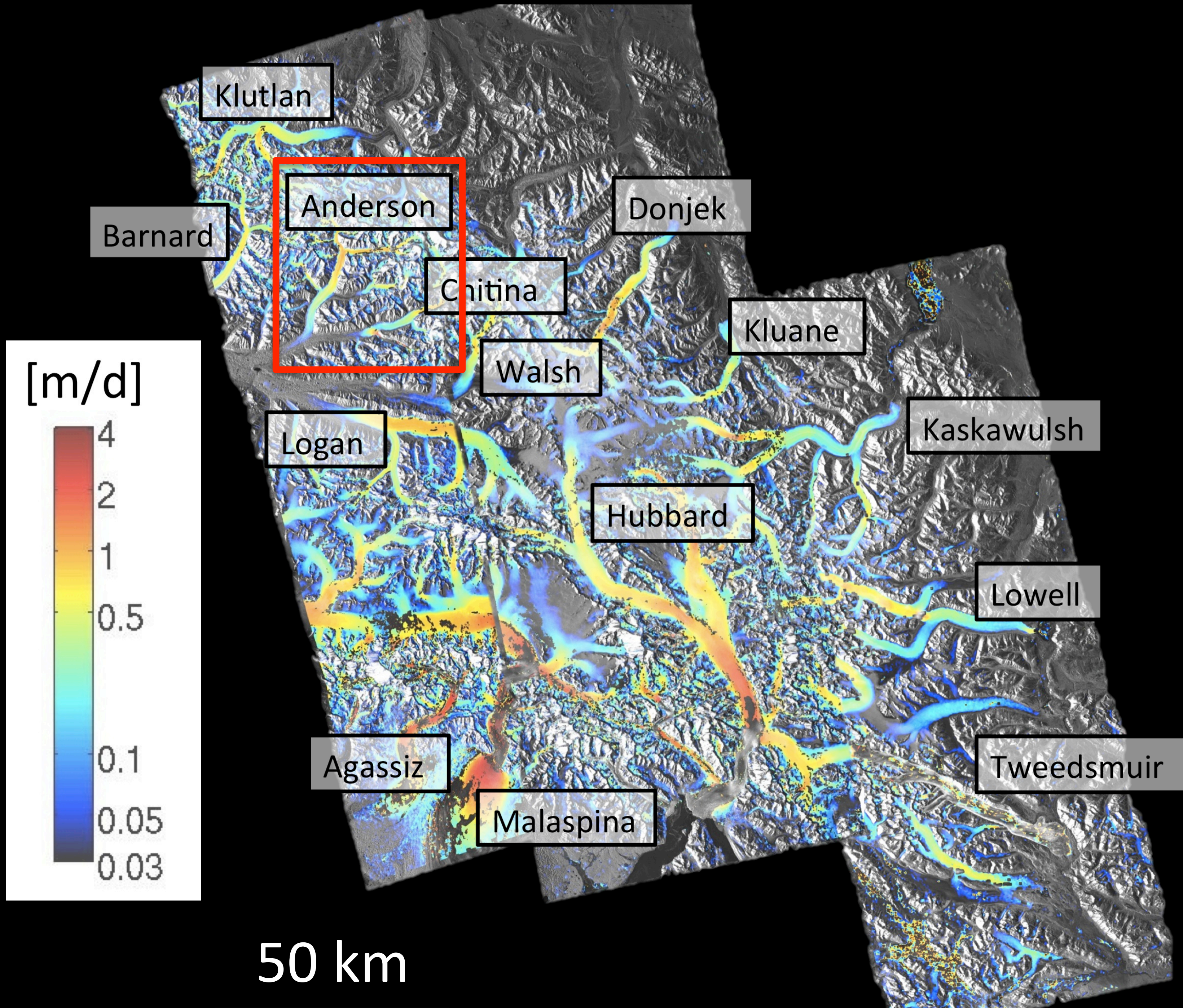

Klutlan
Anderson
Barnard
Donjek
Chitina
Kluane
Walsh
[m/d]
4
2
1
0.5
0.1
0.05
0.03
Logan
Kaskawulsh
Hubbard
Lowell
Agassiz
Tweedsmuir
Malaspina
50 km

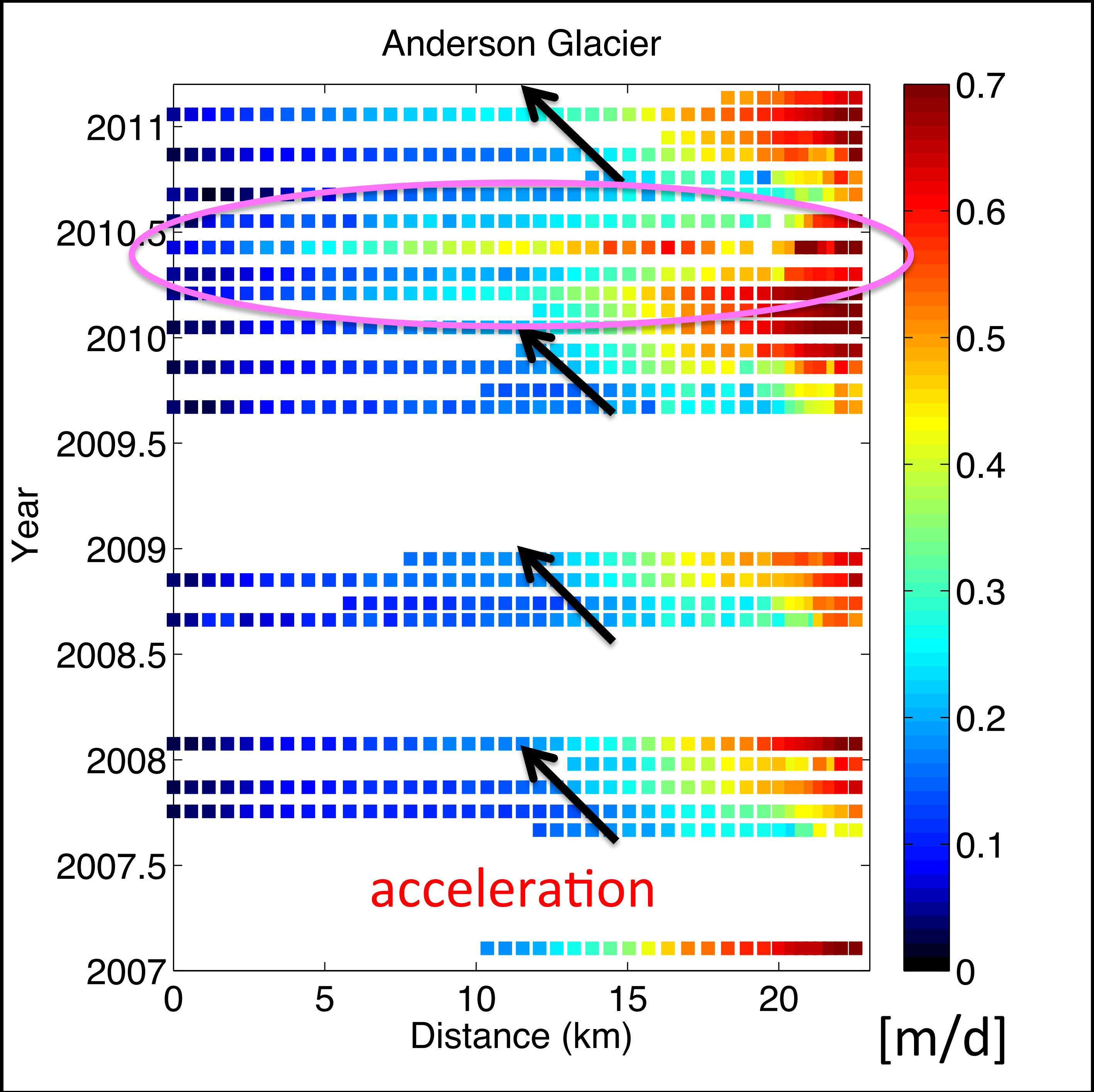
Red: Summer (Aug - Oct)

Blue: Winter (Jan - Feb)

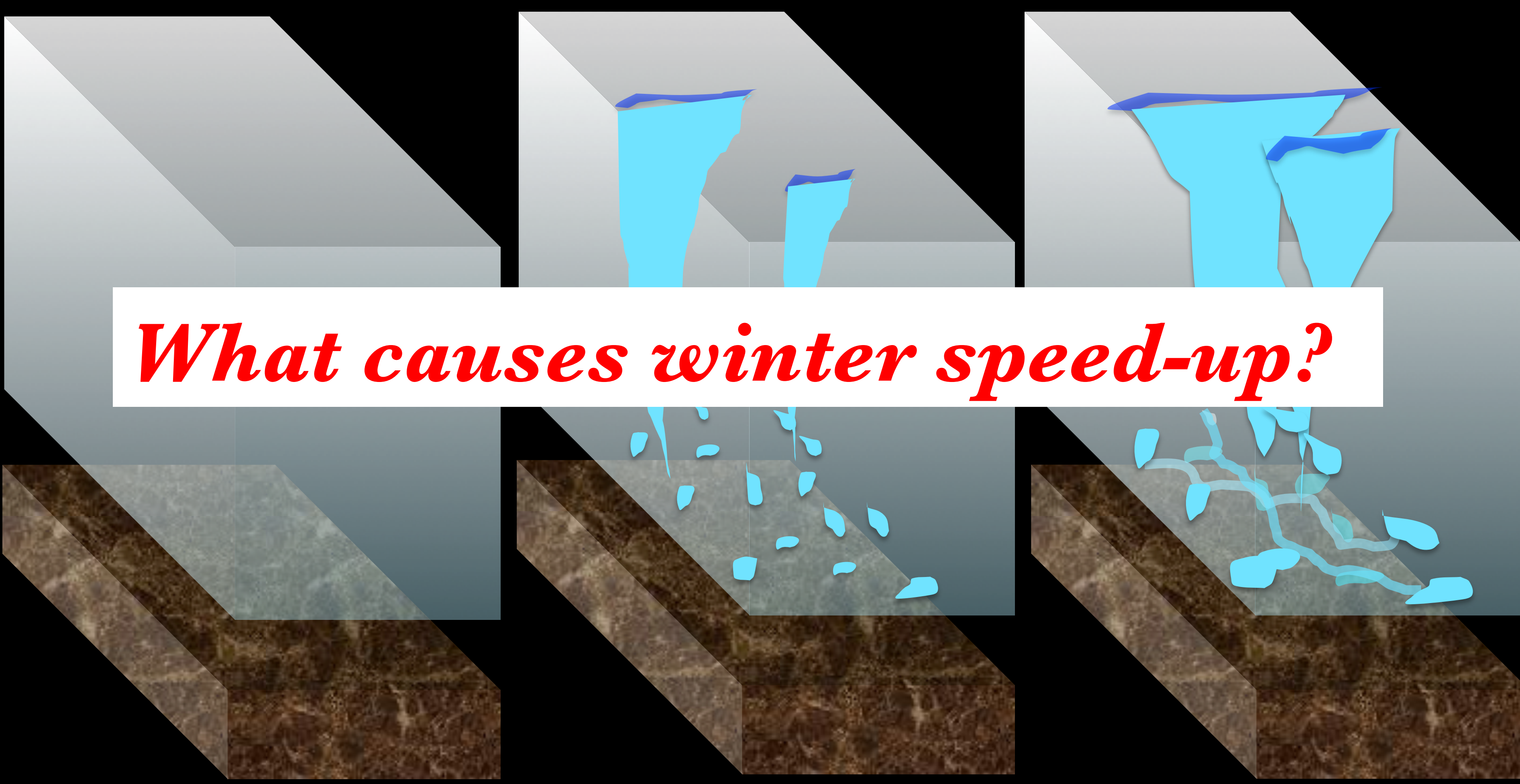
Hubbard Glacier +




Klutlan
Anderson
Barnard
Donjek
Chitina
Kluane
Walsh
Logan
Kaskawulsh
Hubbard
Lowell
Agassiz
Tweedsmuir
Malaspina
[m/d]
4
2
1
0.5
0.1
0.05
0.03
50 km


Anderson Glacier
2011
2010.5
2010
2009.5
2009
2008.5
2008
2007.5
2007
Year
0
5
10
15
20
Distance (km)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
[m/d]
acceleration

普通はSpring/Summer Speed-Up



- No water input
- Conduit closure by ice creep

- Inefficient drainage system
- Higher p_w and lower N

- Efficient drainage system
- Lower p_w and higher N

まとめ：今後の課題

1. 南極、グリーンランドの流動速度の変化

2. 山岳氷河（アジア高山域, パタゴニア, アラスカ/ユーコン)
 規模が小さく, 流動測定には, 従来の衛星SARでは
 必ずしも空間分解能が十分ではなかった…

3. SARの新たな利用(Polarimetryの活用?)
 多偏波によるInSAR, Pixel-offset…
 流動速度以外の物理量(e.g., 厚さ変化??, 降雪量?)

4. 雪氷研究者へのSARユーザの拡大

Acknowledgement

- PALSAR level 1.0 data in this study were provided from the PIXEL and the ALOS 3rd PI project. The ownership of PALSAR data belongs to JAXA and the METI/Japan. Envisat data are copyright ESA and were provided under Cat-1 project 7344. We acknowledge the ESPEC Foundation for Global Environment Research and Technology and JSPS (KAKENHI) for supporting this study.