Center for Earth Observation and Digital Earth
Chinese Academy of Sciences

Glacier monitoring by remote sensing techniques in western China

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Outline

1. Introduction
2. Study Area and Results
   - Area study
   - Velocity monitoring
3. Some thoughts

Introduction

- **Qinghai-Tibet Platean, Earth's "Third Pole", with a total glacial area of 100,000 km^2 , act as a water storage tower for South and East Asia, releasing melt water in warm months to the Indus, Ganges, Brahmaputra and other river systems, providing fresh water to more than a billion people**
- **Glacier is important in function of climate change reflection and sea level change**

Introduction

- **Accurate displacement measurements are needed to understand the dynamics of glaciers**
- **The Area change is a indicator of glacier change**
- **Remote Sensing is an effective way to study glaciers, Quality is important**

Tibet Plateau

Source: Microsoft Encarta 2008

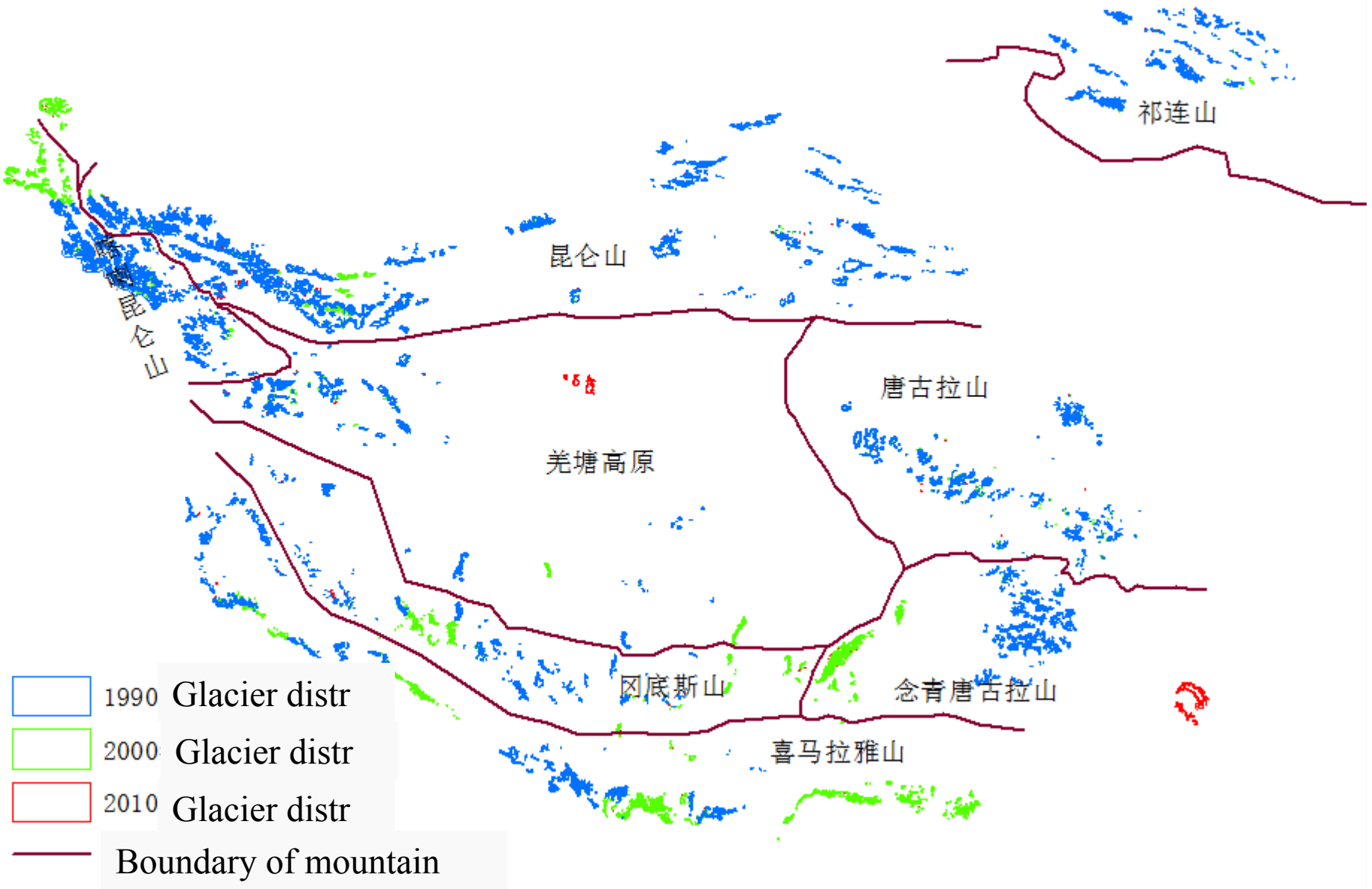
Area change study - update

Datasets

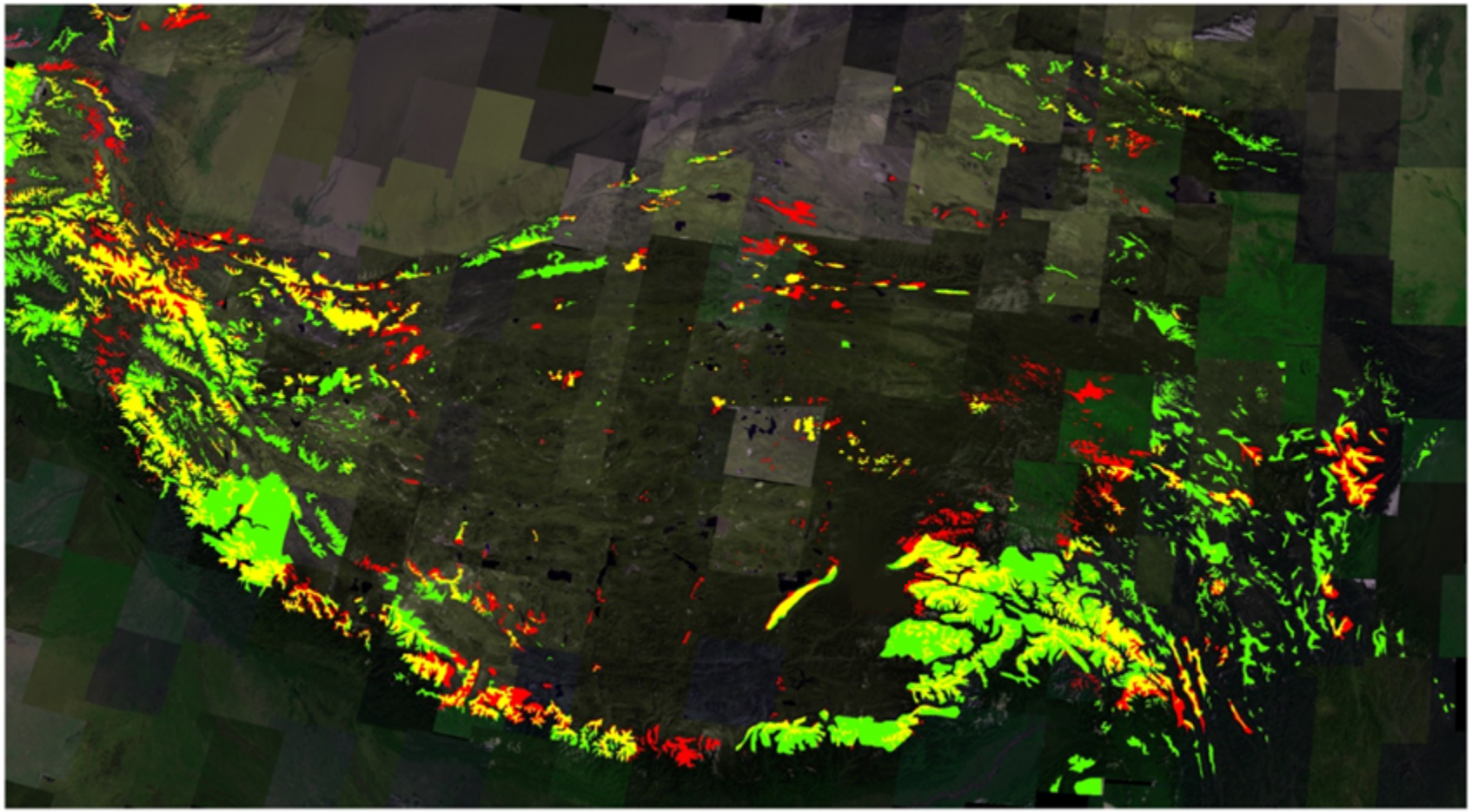
Landsat Satellite Images 5 and 7

Nr.	Path	Row	Acquired date	Acquired date	Acquired date
1	134	33	2010/8/5	2001/7/3	1992/8/27
2	134	40	2009/9/27	2001/10/23	1994/7/8
3	135	33	2008/9/15	1999/9/22	1988/7/28
4	135	38	2011/8/23	1999/7/21	1992/8/10
5	136	33	2010/8/27	2000/7/14	1993/8/27
6	136	37	2011/8/6	2000/7/30	1992/9/2
7	136	38	2011/8/30	2001/9/3	1992/9/2
8	136	38	2011/9/15	2003/7/23	1992/9/2
9	…				

Glacier area change of Tibet Plateau - update



Glacier area change of Tibet Plateau

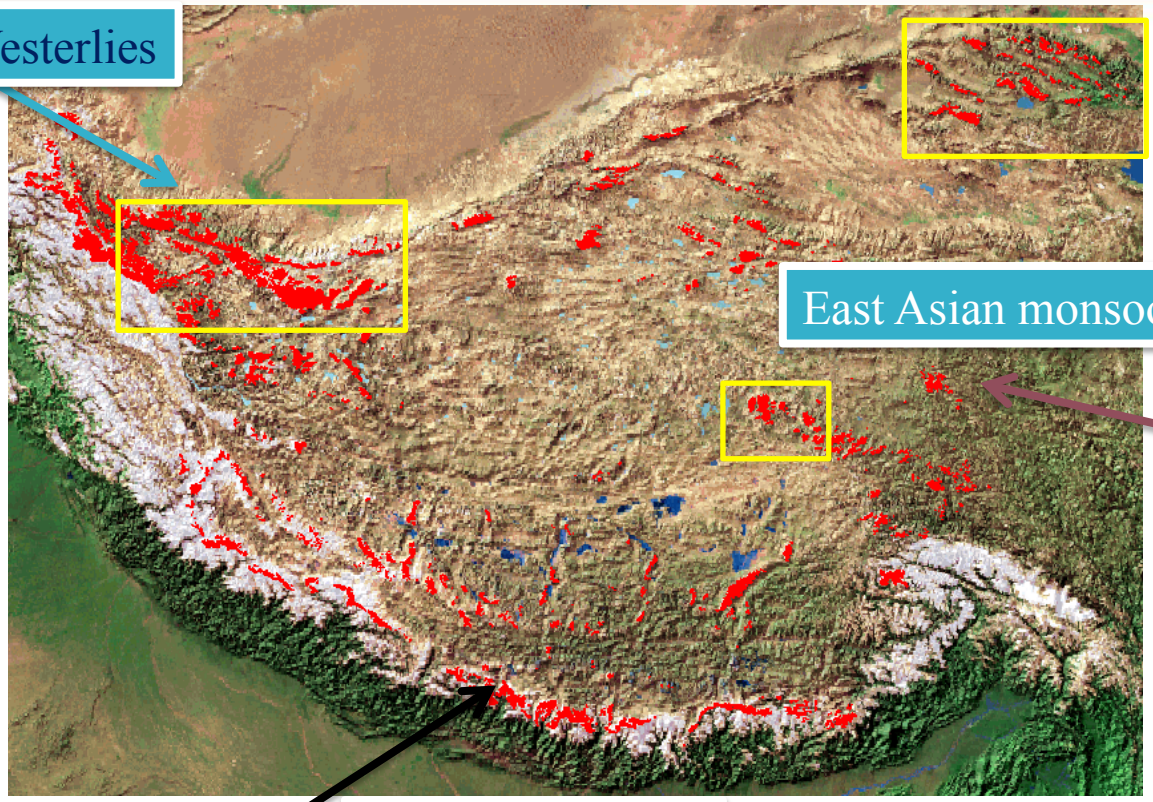


Decrease

No change

Increase

Glacier inventory on Qinghai-Tibetan Plateau -update

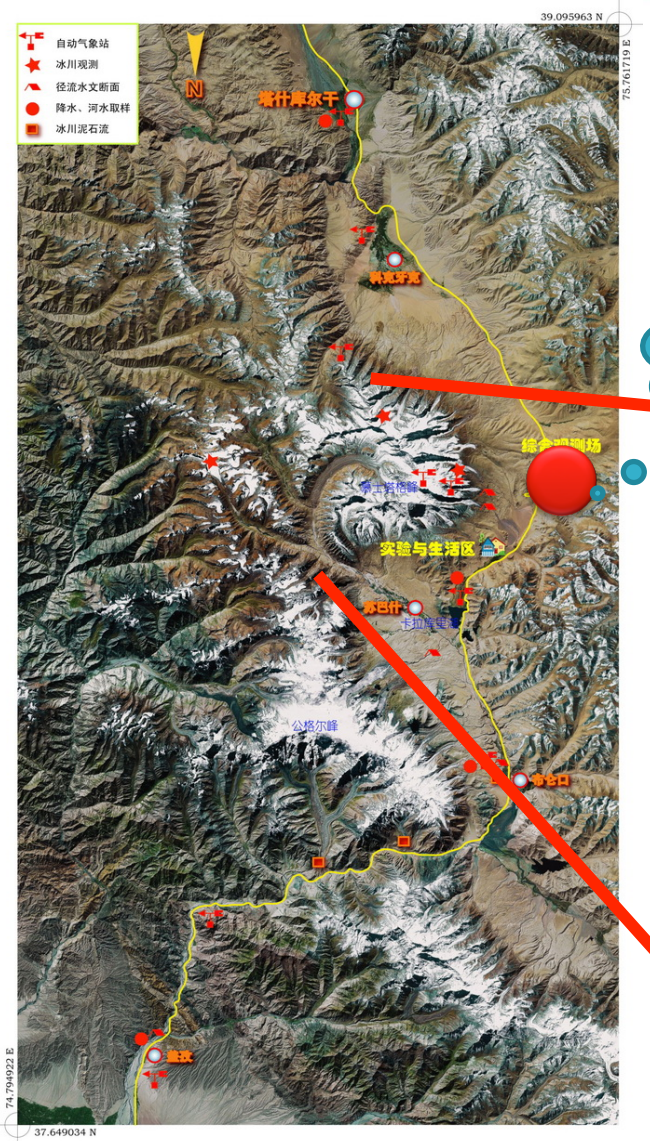


- Based on Landsat TM/ ETM+ images in 1990, 2000 and 2010 (more than 200 scenes)
  Glacier inventory covering major glacier distribution on Qinghai-Tibetan Plateau
- Preliminary statistics
  - West Kunlun Mountain
  - Qilian Mountain
  - West section of Tangula Mountain

	Glacier area coverage (km2)			Change rate		
	1990	2000	2010	1990-2000	2000-2010	1990-2010
West Kunlun Mountain	10309.48	9530.031	9356.009	7.56%	1.83%	9.25%
Qilian Mountain	1799.599	1720.95	1572.428	4.37%	8.63%	12.62%
West Tanggula Mountain	1236.666	1158.474	1122.322	6.32%	3.12%	9.25%

SAR and Optical monitoring glacier velocity- update

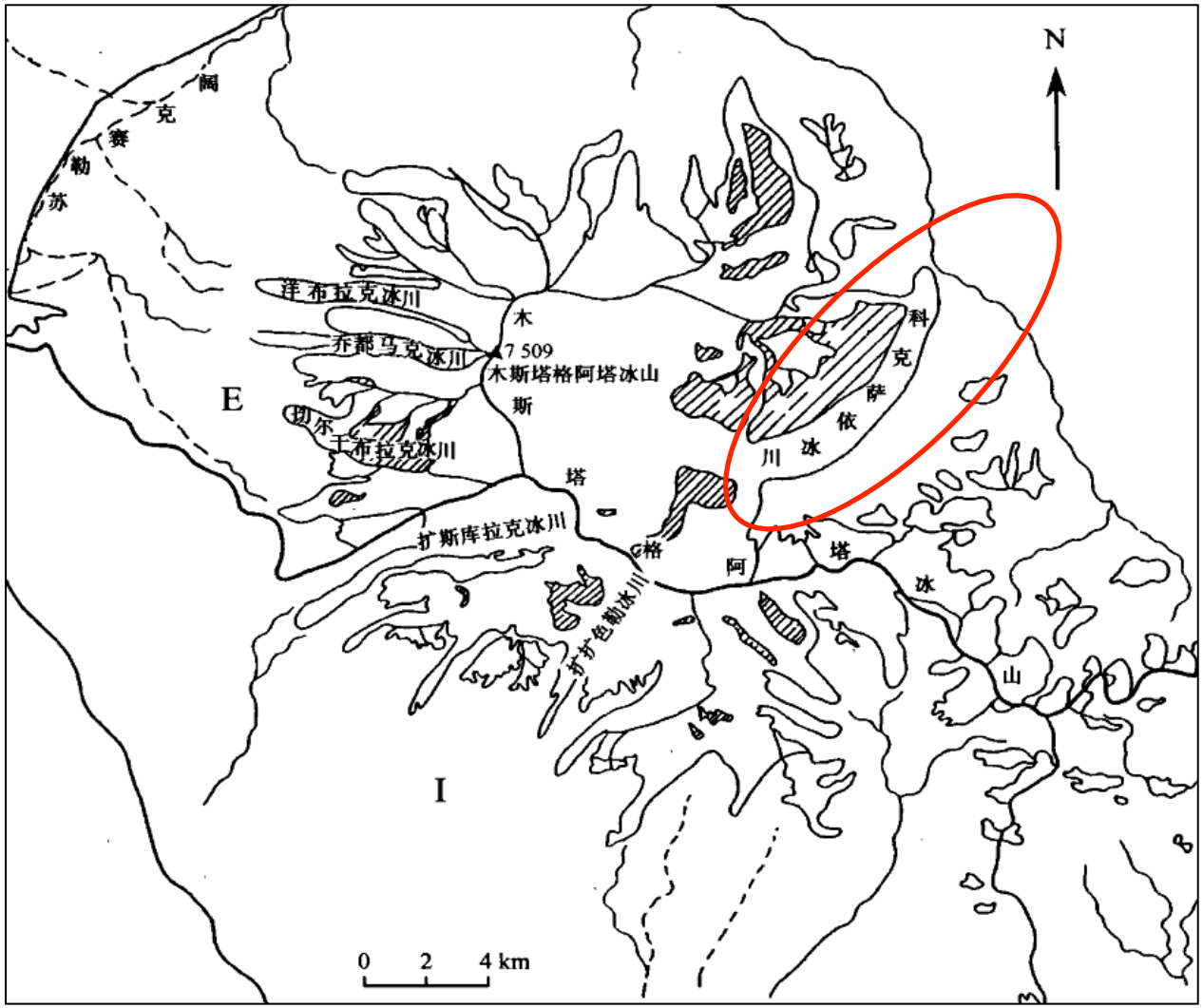
Study Area and Datasets



Muztagh Ata
7546 m

Station

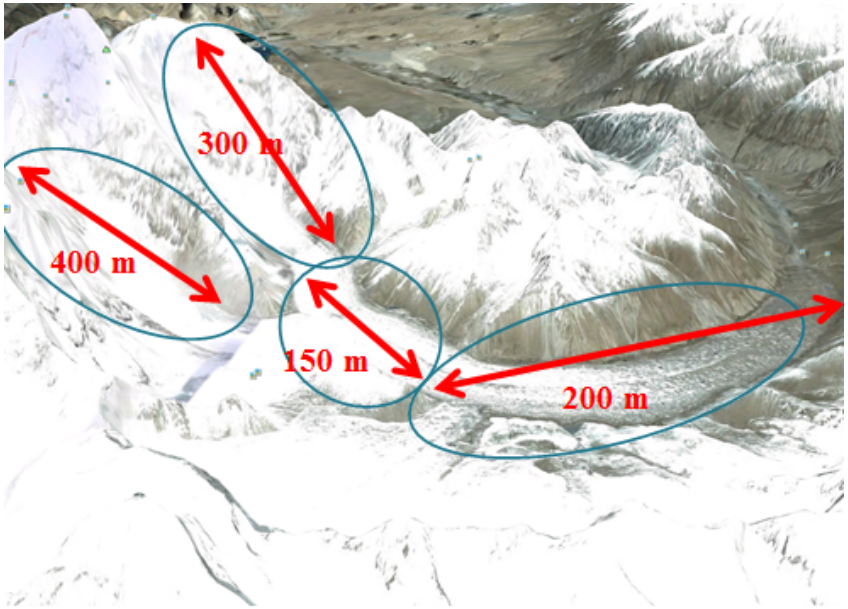
Glacier distribution

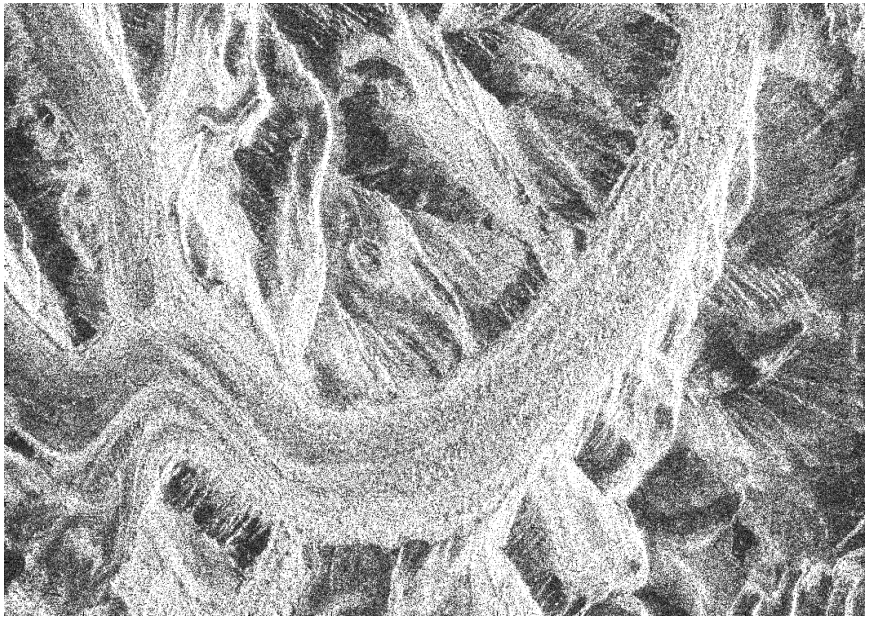


Since its high altitude and cold weather, there are snow perennially. More than 100 modern glacier around this area, the whole area is more that 345 km^2

An Observation on Surface Ablation on the Yangbark Glacier in the M uztag Ata， China, PU jian chen, etc

Kuksai Glacier



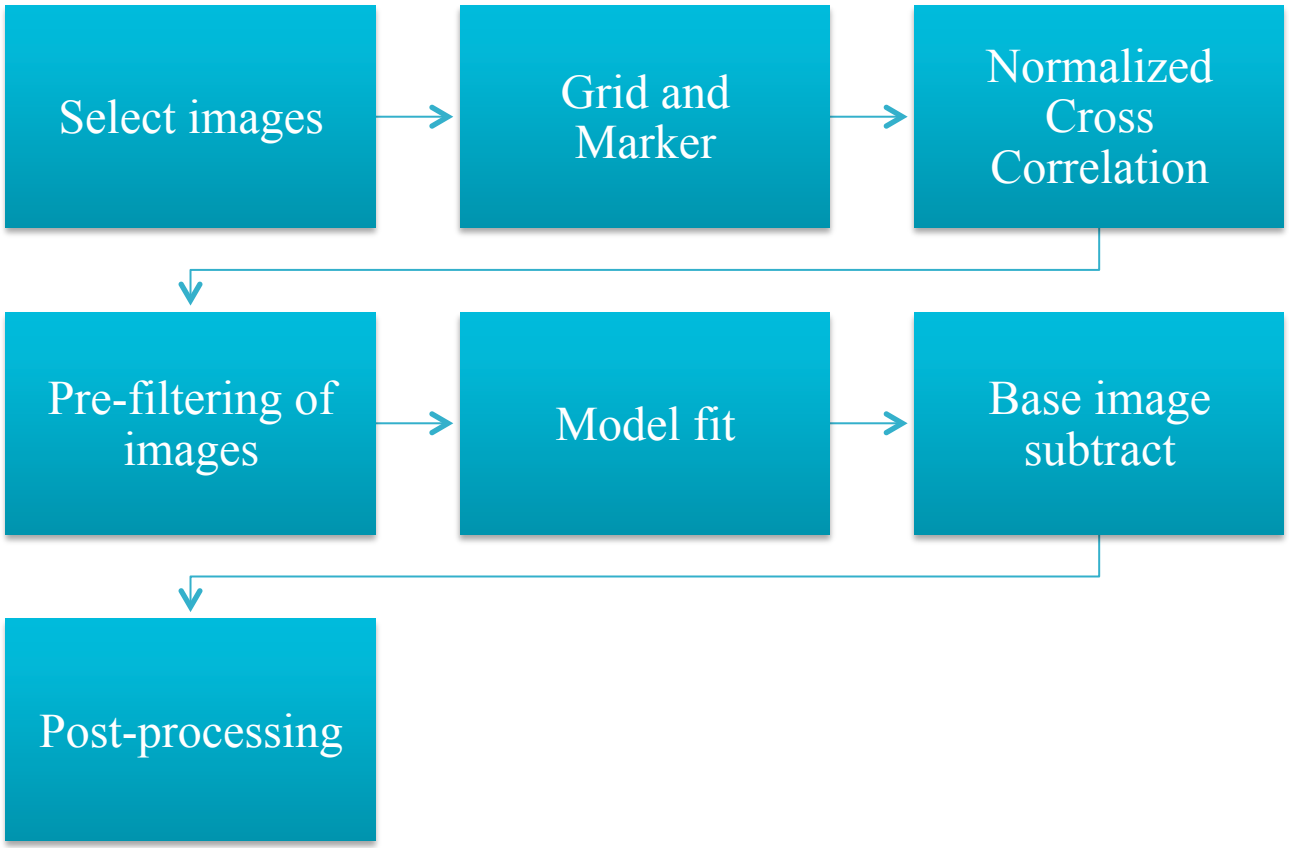


Kuksai Glacier, with area of 86.5 km^2, is the largest one around the Mt. Muztagh Ata. It is about 18 km long and with the maximum width 1.5 km. Its altitude varies slowly from 3,900 m up to about 4,900 m with moderate terrain. most of its surface is covered by debris.

Methodology

Glacier Movement Estimation

Pixel Track Method



Datasets

ALOS/PALSAR SAR Images

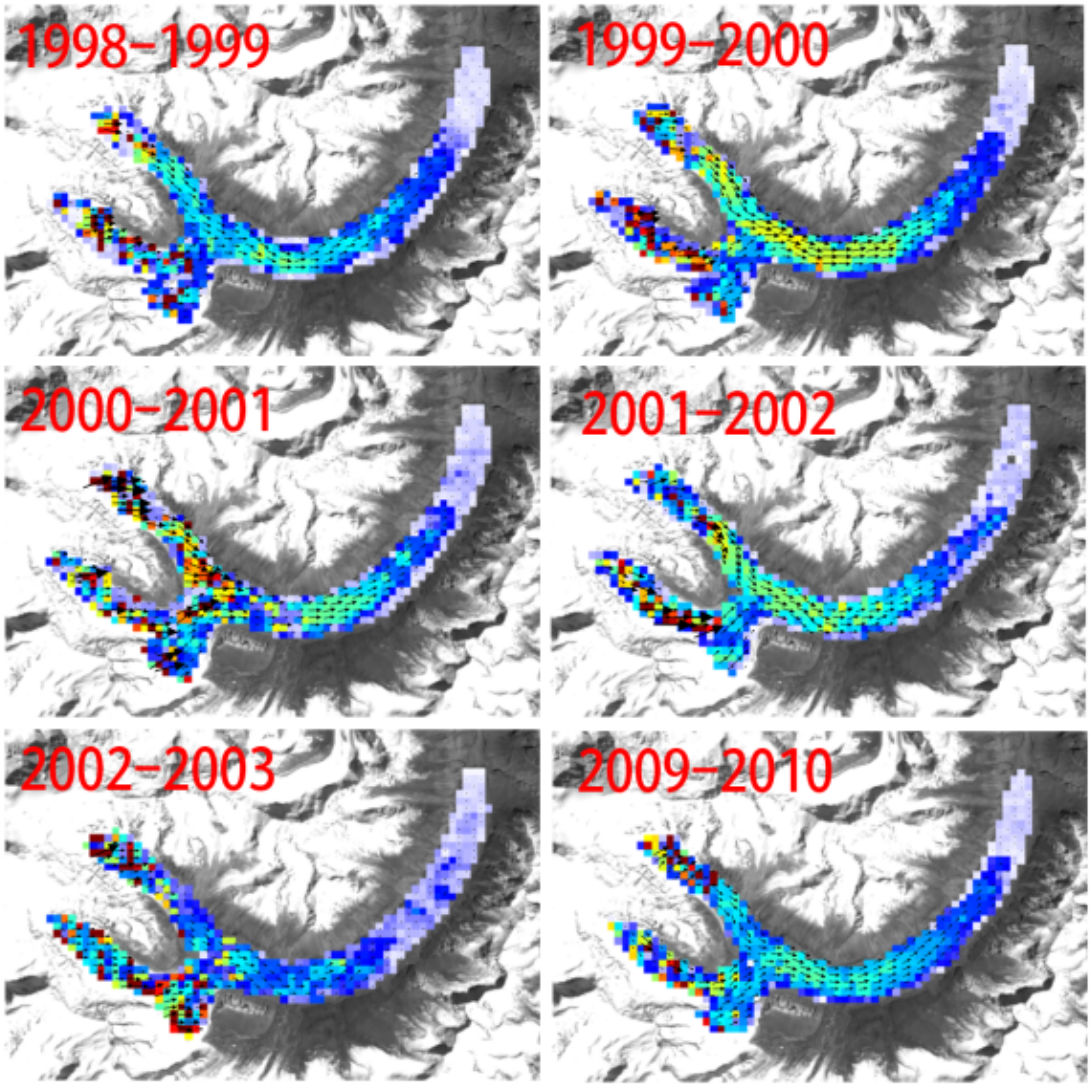
Date	Bpara(m)	Bperp(m)	Path	Frame	Temporal baseline(day)
01/14/2009	189	249	525	750	44
03/01/2009					
09/01/2009	140.92	-213.16	525	750	44
10/17/2009					

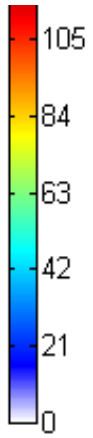
Landsat Satellite Images

Nr.	Path/Row	Acquired date of Landsat5	Acquired date of Landsat7
1	149/33	29/08/1998	
2	149/33	16/08/1999	
3	149/33		11/09/2000
4	149/33		30/09/2001
5	149/34		30/09/2001
6	149/34		03/10/2002
7	149/34		31/05/2003
8	150/33	21/10/2009	
9	150/33	08/10/2010	

Glacier monitoring with TM Images

Glacier surface displacement





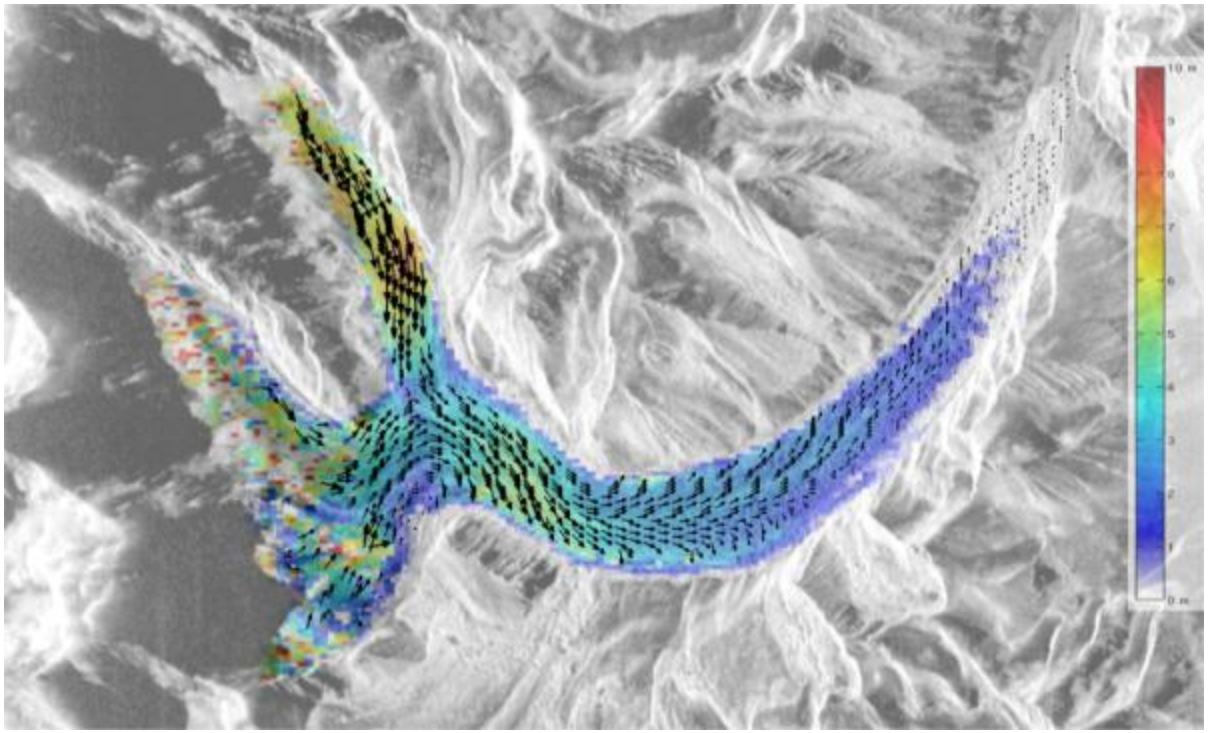
The surface debris-cover of the glacier makes automated glacier outline mapping difficult, but provides useful features to monitor glacier movement

This study demonstrates that glacial movements can be routinely monitored using Landsat images, providing an opportunity and an input to detailedly study the glacier dynamics.

Fluctuations and movements of the Kuksai Glacier, western China, derived from Landsat image sequences, In Review

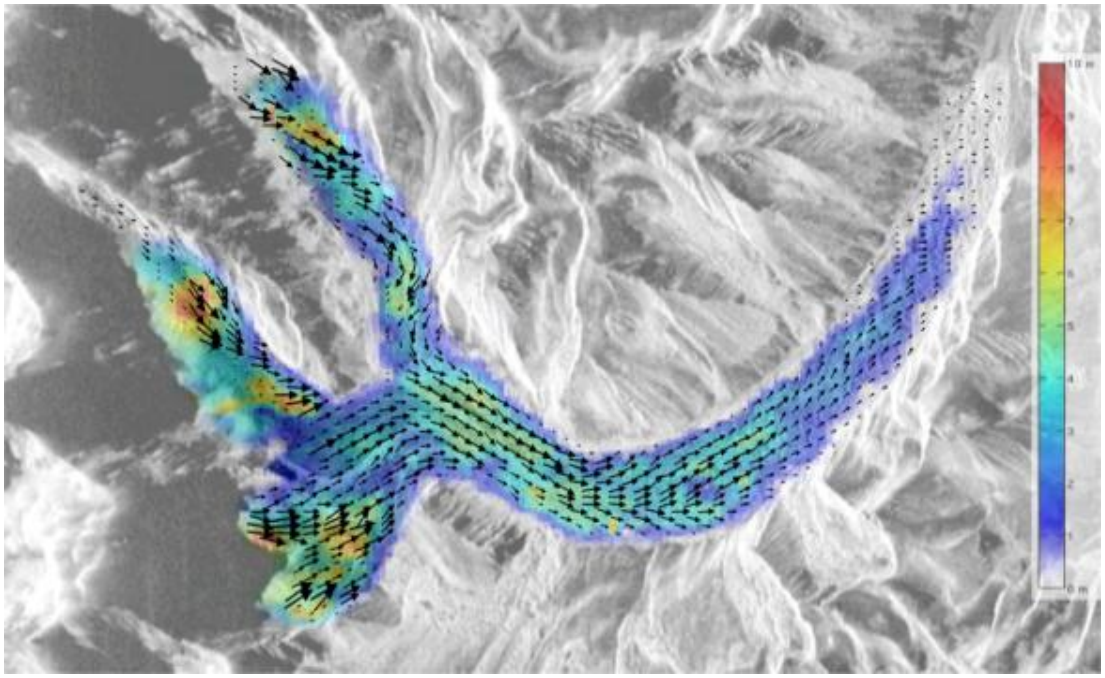
Velocity Field on Glacier Surface

- **Kuksai Glacier**
- **Temporal Baseline: 44days Jan-Mar,2009**
- **Total Average Velocity: 2.6m/44days**



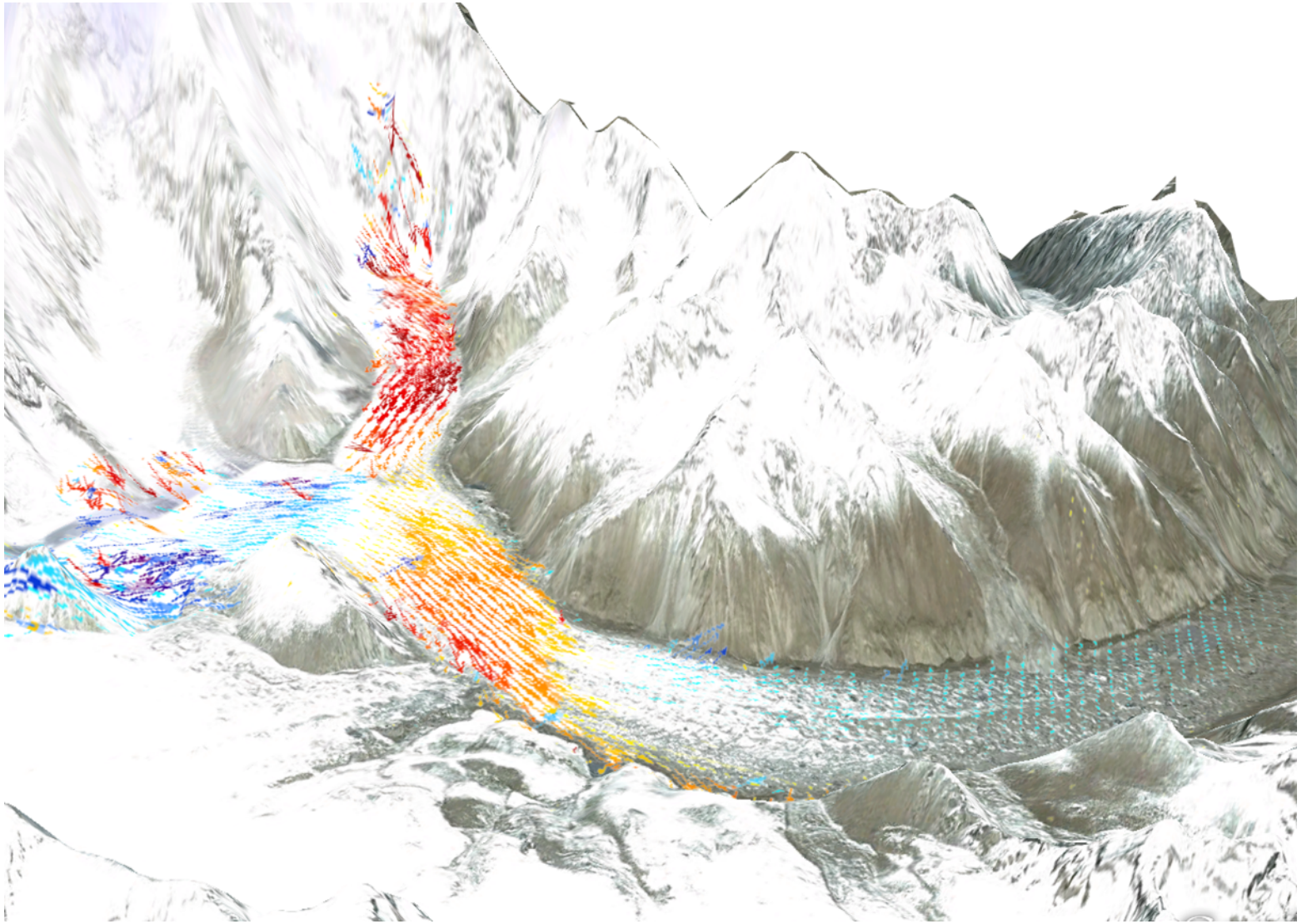
Velocity Field on Glacier Surface

- **Kuksai Glacier**
- **Temporal Baseline: 44days Sept-Oct, 2009**
- **Total Average Velocity: 3.0m/44days**

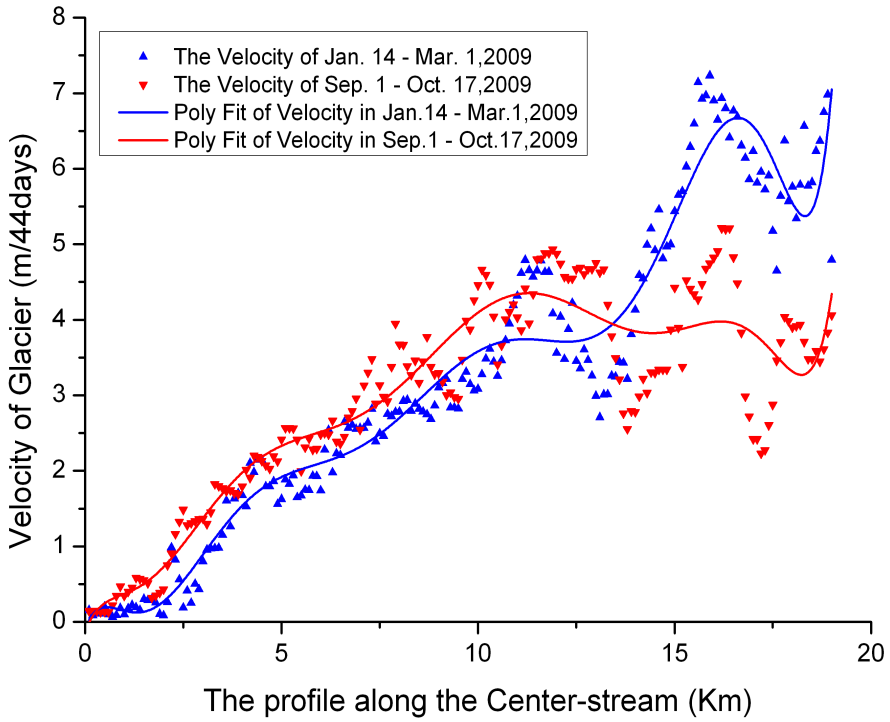


Monitoring Muztagh Kuksai Glacier Surface Velocity with L-band SAR Data in Southwestern Xinjiang, China, In Review

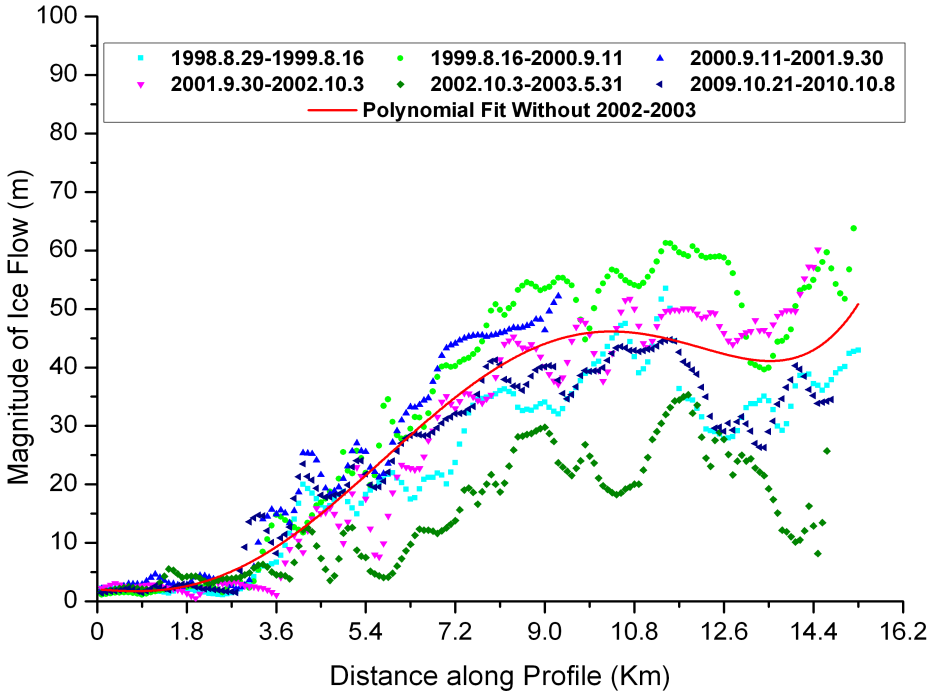
3D version



Velocity Profiles-Kuksai Glacier



Velocity profiles along glacier from SAR images



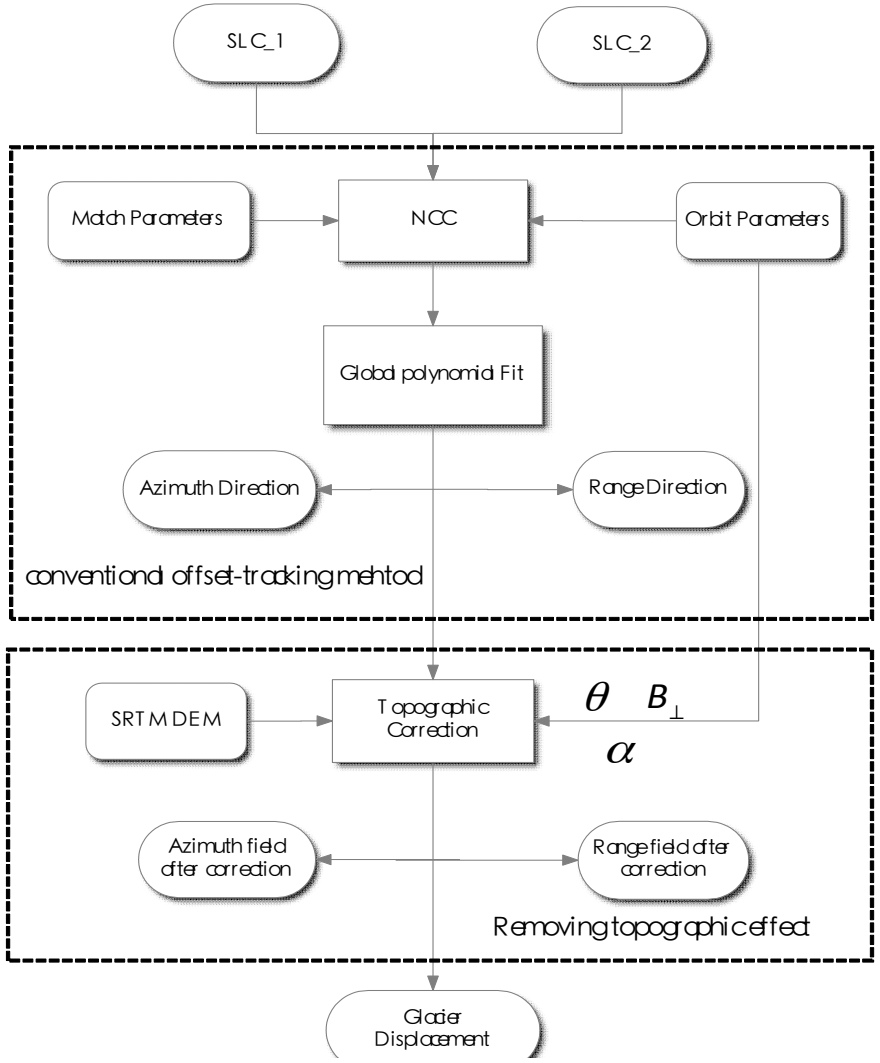
Velocity profiles along glacier from TM images

Results show the variability of the glacier movements in the middle and upper portions, especially in the 9-16km upstream from the glacier terminal, is much larger than that of the downstream part among different years.

The cross validation is match.

Topographic effect correction

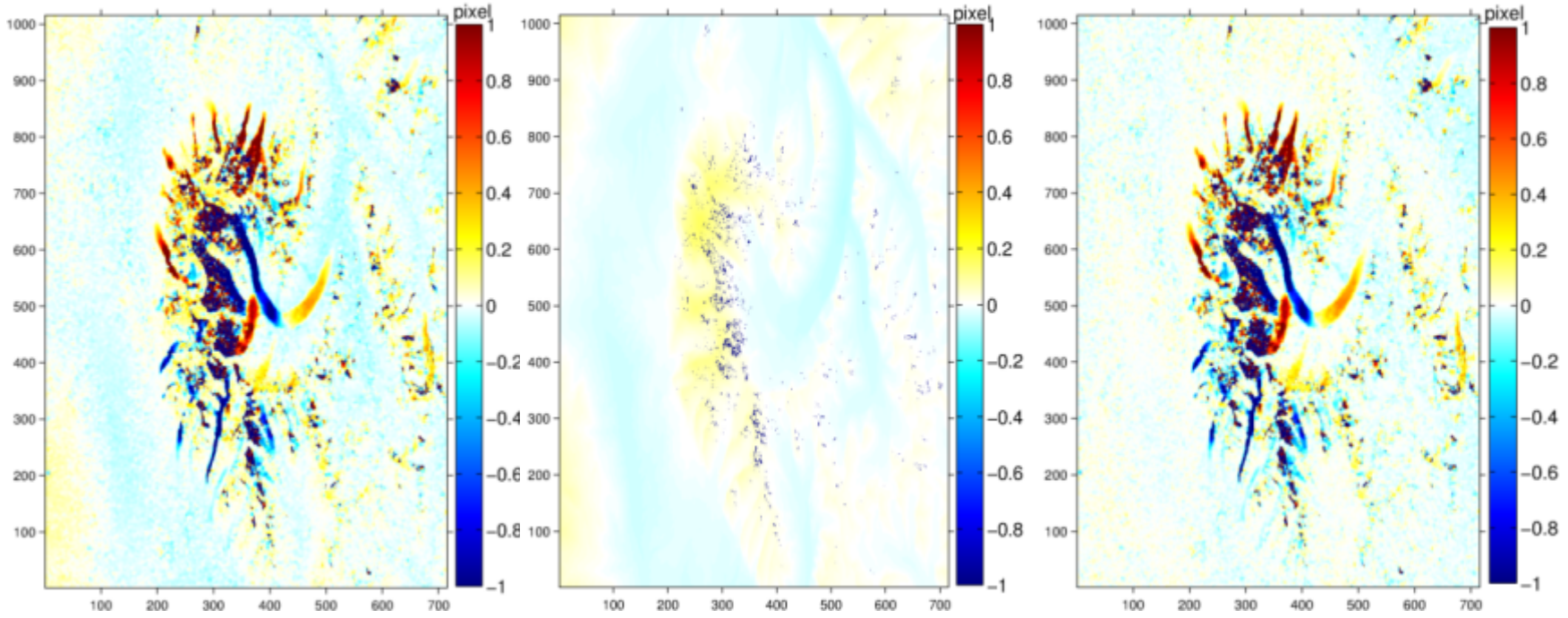
Data processing flowchart of DEM-assisted offset-tracking



In mountain area, the topography will effect the accuracy of the velocity estimation, especially in our study area of mountain glaciers

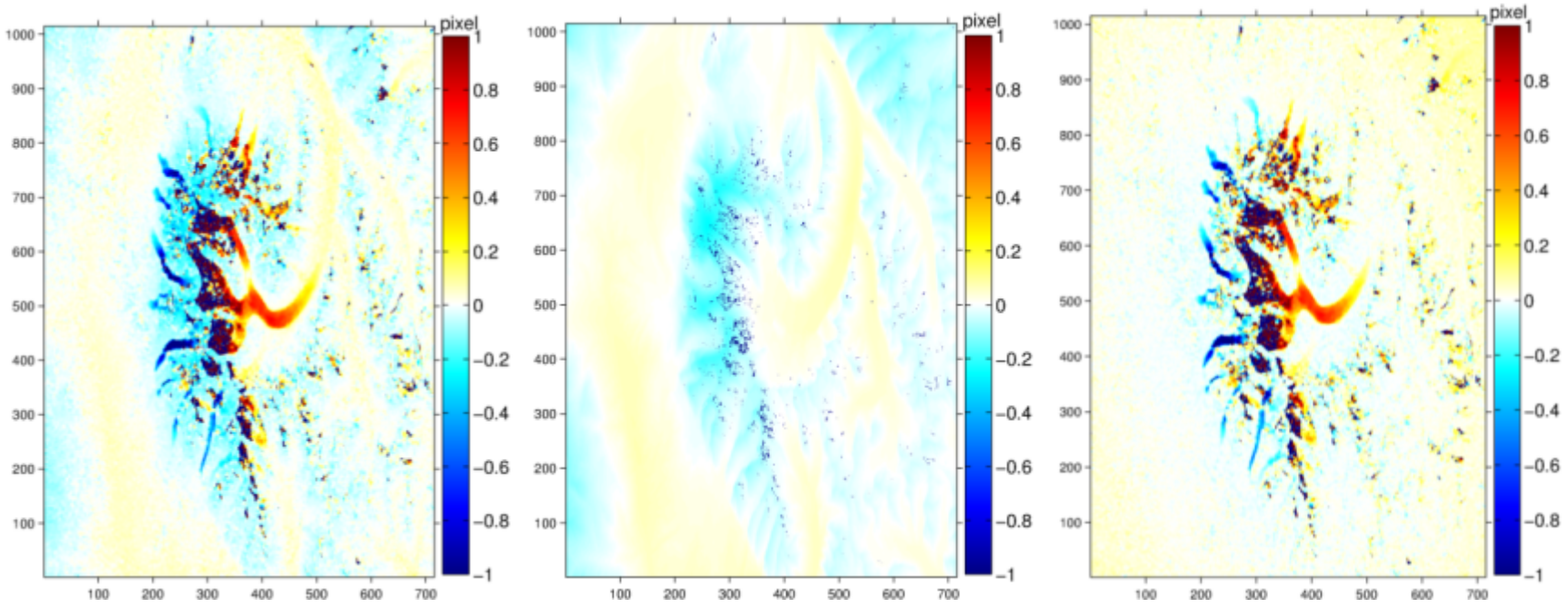
ALOS/PALSAR SAR Image Pair

Date	B_para(m)	B_perp(m)	Path	Frame	B_temp(day)
2009-1-14 2009-3-1	189.3	248.9	525	750	44



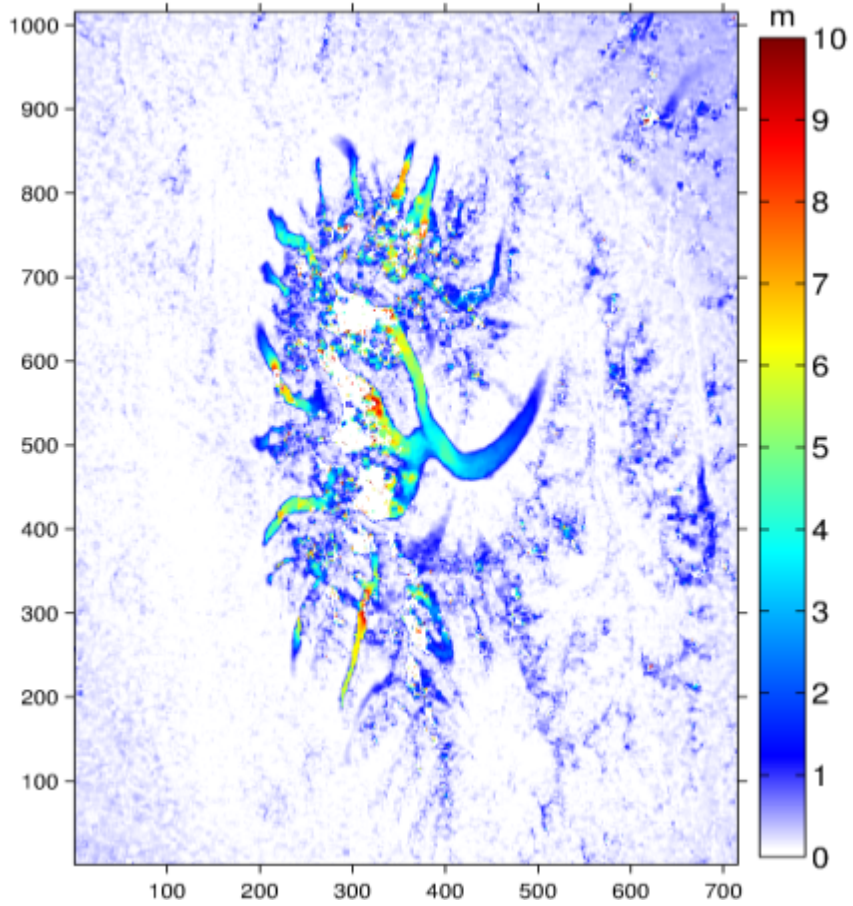
(a) Before terrain Correction (b) Terrain effect (c) After terrain Correction

Displacement in Azimuth Direction



(a) Before terrain Correction (b) Terrain effect (c) After terrain Correction

Displacement in Range Direction



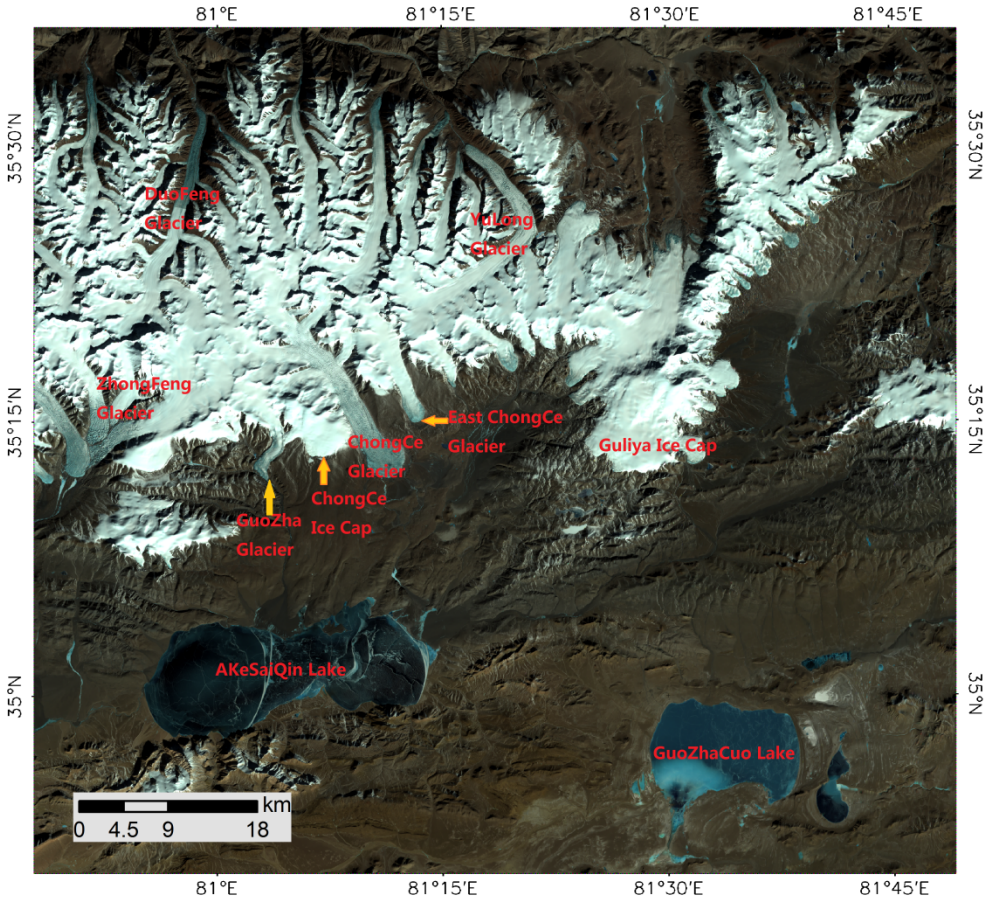
Glacier surface displacement with terrain correction in Mt. Muztagh Ata Jan-Mar, 2009

Topographic effects are reduced and the accuracy (0.98 m) is increased

InSAR and Offset Track combination

Study site

- **The eastern section of West Kunlun Mountain**
  - **Facing the Qinghai-Tibetan Plateau on the south, and bordering the Taklimakan Desert on the north**
  - **One of the most dense glacier distributions in China, and there are 3165 glaciers in this area.**
  - **There are 4 glaciers larger than 100km^2, and Duofeng glacier is largest with length of 26.8km and area of 251.7km2**



Detecting Mountain Glacier Motion using ALOS/PALSAR data by combination of Radar Interferometry and Offset Teacking methods, In review

Monitoring glacial dynamics

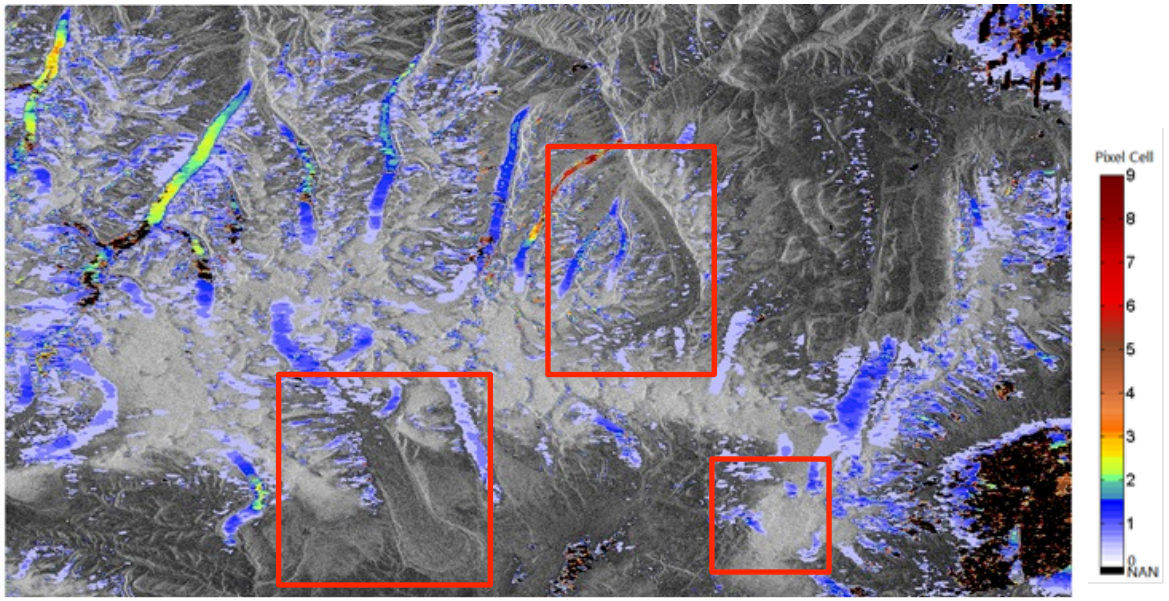
- **Problem**
  - **Glacier velocity changes a lot even of one glacier**
- **Techniques**
  - **Offset tracking**
  - **InSAR**
-

TABLE. 1.
PROCESSING DATA IN THE STUDY AREA

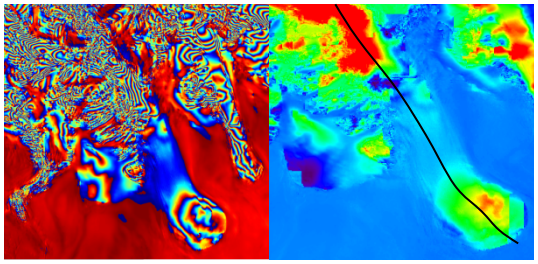
Acquisition time	Time Span (day)	Track/ Frame	Perpendicular baseline (m)	Resolution in slant-range/ azimuth (m)
2007.12.11 -2008.01.26	46	515/ 690	411.05	4.68 / 3.51
2008.12.13 -2009.01.28	46	515/ 690	286.66	4.68 / 3.51
2009.12.16 -2010.01.31	46	515/ 690	613.49	4.68 / 3.51

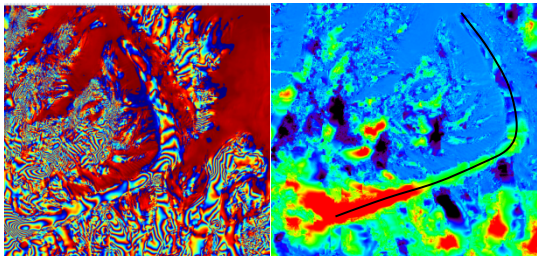
Offset Maps Update

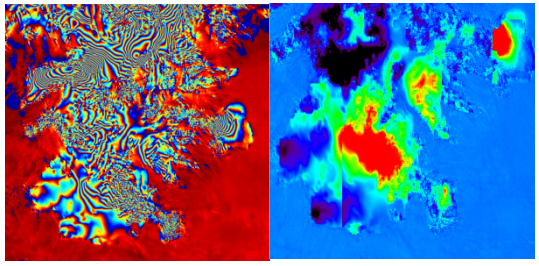
Offset acquired using offset tracking



Using InSAR complementary to offset tracking results



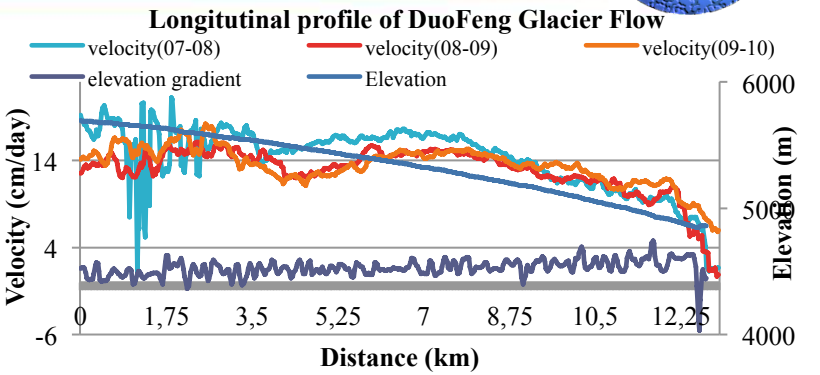


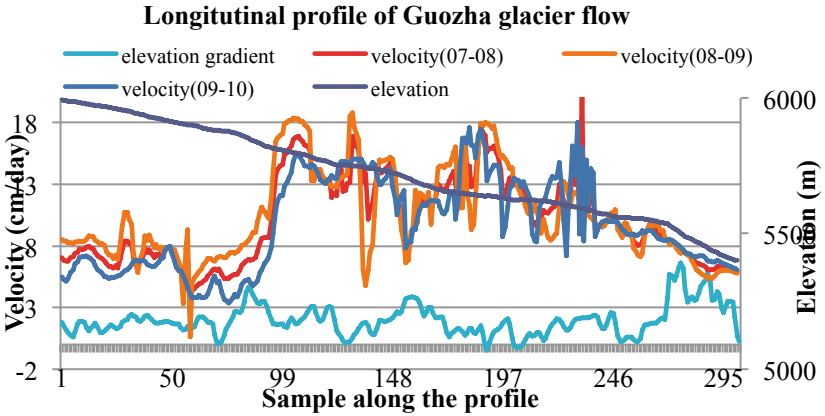


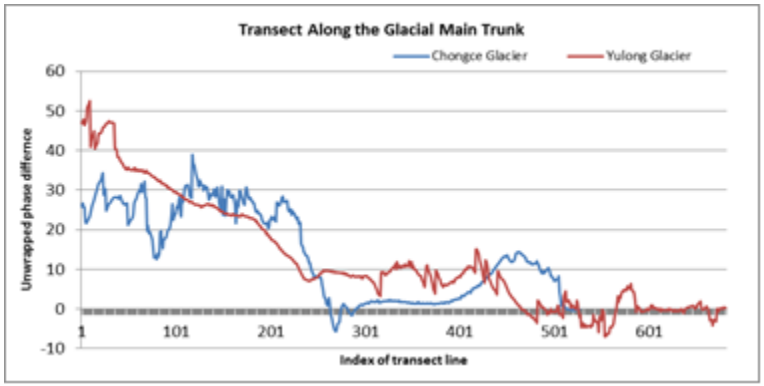
Glacier movement

Statistics of winter glacier motion field during 3 years. (The value larger than 95% of the velocity field is taken as the maximum, and less than 5% as the minimum.)

Glacier	Velocity direction	Glacier flow velocity (cm/day)					
		2007.12.11 -2008.01.26		2008.12.13 -2009.01.28		2009.12.16 -2010.01.31	
		Mean	Max/ Min	Mean	Max/ Min	Mean	Max/ Min
1.Duofeng	South -north	9.82	19.57/ 1.50	10.36	15.79/ 1.57	10.71	16.14/ 1.57
2.North slope	South -north	6.35	20.14/ 0.79	5.28	12.57/ 0.79	4.96	15.71/ 0.86
3.Yulong	South -north	1.46	4.29/ 0.01	1.00	6.07/ 0.00	1.19	2.79/ 0.29
4.Guozha	North -south	5.19	15.50/ 1.21	5.79	16.64/ 1.29	5.79	14.36/ 1.14
5.Chongce	North -south	4.18	10.21/ 1.64	3.76	7.50/ 0.86	3.97	6.64/ 1.50
6.East Chongce	North -south	2.66	3.93/ 1.29	3.07	4.36/ 1.29	2.91	5.07/ 1.14
7.Guliya ice cap	-	2.44	16.00/ 0.36	1.91	6.79/ 0.29	1.31	5.79/ 0.36
8.Chongce ice cap	-	1.93	14.50/ 0.43	1.57	1.93/ 0.07	1.23	2.79/ 0.29
Average glacier velocity on north slope (direction: south to north)		5.88	-	5.54	-	5.62	-
Average glacier velocity on south slope (direction: north to south)		4.01	-	4.21	-	4.22	-







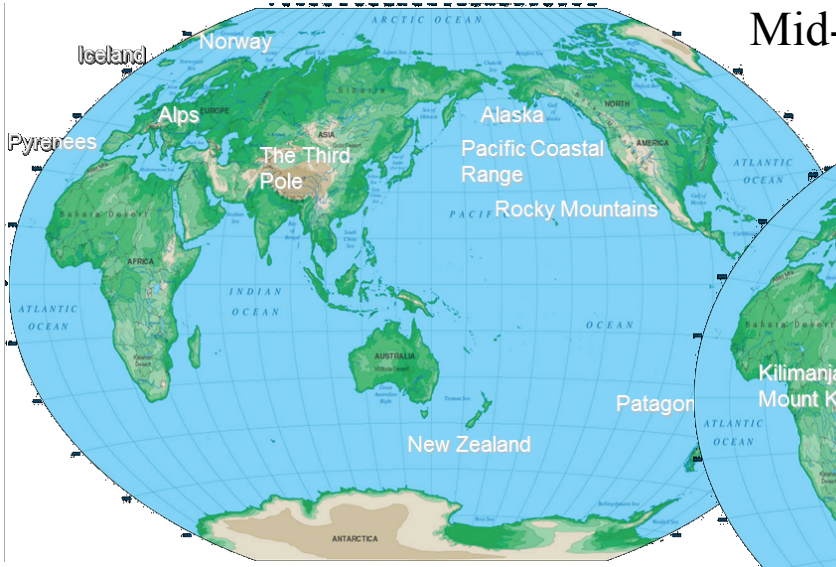
Yulong glacier：the upper section about 1.34-2.67cm/day; a long smooth motion on the middle part around 0.67 cm/day.

Chongce glacier：upper section has the strongest motion about 1.34-2.00cm/day; the majority velocity on glacier tongue around 0.29 cm/day.

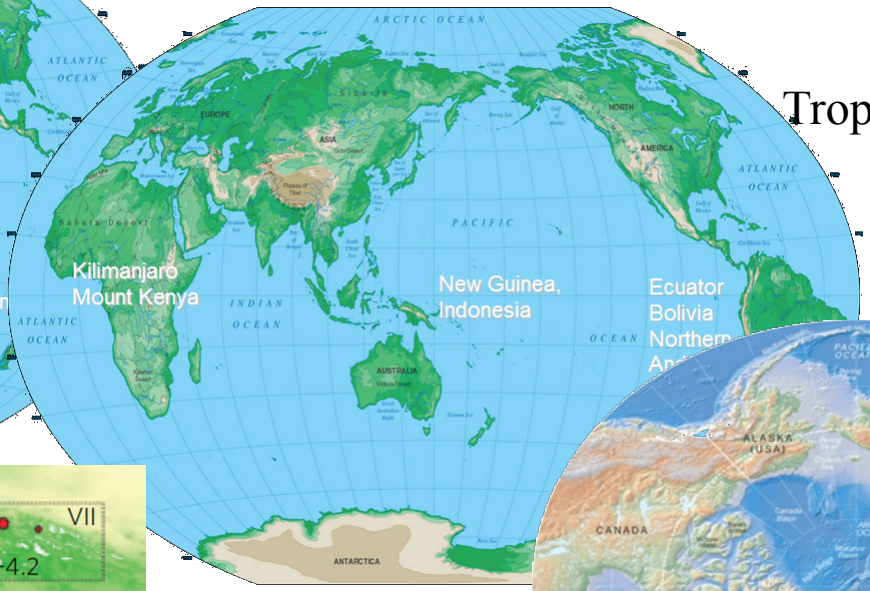
Some thoughts

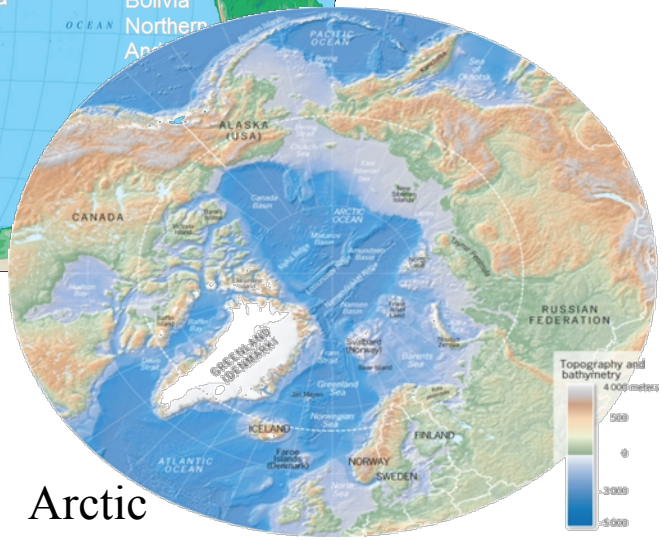
Mid-latitude glaciers

Ref: Helgi Björnsson

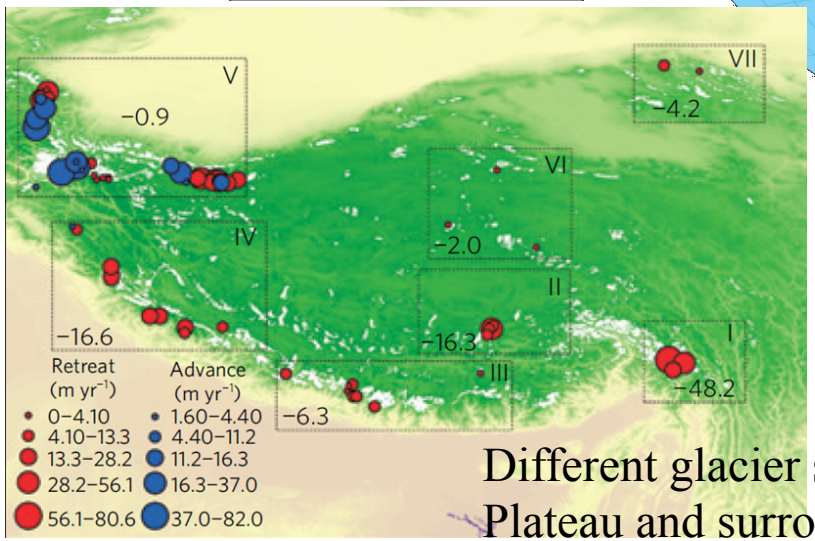


Tropical glaciers





Arctic



Different glacier status with atmospheric circulations in Tibetan Plateau and surroundings

Nature Climate Change，2012

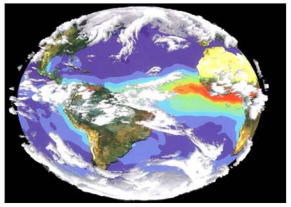
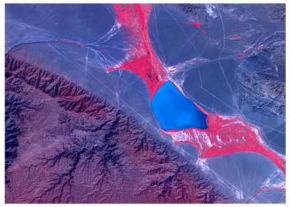
Some thoughts

Different glacier status with same laws?

- **atmospheric circulations**
- **Types**
- **Different altitude**
- **Coverage**
- **Sizes**
- **Continents**
- **Mass balance**

Thanks



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