Glacier change and flow velocity estimation in the West Kunlun mountains based on Landsat images (1977-2013)

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* Nanjing University, China;  # Ludwig-Maximilian-University Munich, Germany
• Introduction
• Study area
• Data set
• Method
• Results
• Conclusion
Introduction

- IPCC AR5 forecasted that temperatures continue to rise, and glacier retreat will continue in the future.

- AR5 pointed out that the sea level rises in 0.76 mm·a⁻¹ due to the glacier melting.
Study area
Study area

- **Location:** 80°E - 82°E, 35°N - 35°42’N, in the West Kunlun Mountains.

- **Geomorphological features:** The majority of glaciers within the basin are found along the mountain range at altitudes above 4500-7150m a.s.l. The south slope is gentler than the north.

- **Glaciers:** There are 445 glaciers, and are extreme continental type. The total glacier area is 3054.62 km² (GLIMS 2003).
Data set

- All of this data is **LIB level**.
- Choose remote sensing data in **summer** to reduce the disturbance by snow.
- Data marked green is also used to evaluate glacier velocity.

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Data set

• GLIMS

• NCEP/NCAR Reanalysis
  • Monthly mean temperature data

• SRTM
Method

• Data preprocessing
  • Calibration
  • FLAASH atmospheric correction

• Extract glaciers
  • NDSI to extract clean glaciers
  • Thermal infrared and optical band to extract debris-covered glaciers

• Glacier Velocity estimation
  • Duofeng glacier
  • CIAS、GIS software
Results — 2013 glacier distribution

- Glacier area is 3000.39 km², including debris-covered glaciers with an area of 1.86 km².
<table>
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<th>Glacier Grade</th>
<th>Glacier ID</th>
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<th>Area (km²)</th>
<th>sum of area (km²)</th>
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<td>Total</td>
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<td>3000.39</td>
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- There are 3 glaciers, and area are **22.6%** of study area.
- **17 glaciers** area are more than 50 km², and sum of their area are **66%** of study area.
- There are **421 glaciers** whose area is less than 20 km². It is just **22%** of all glacier.
Results — 2013 glacier distribution
# Results — glacier change

<table>
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<tr>
<th>Year</th>
<th>Area (km²)</th>
<th>Change (km²)</th>
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<th>Year</th>
<th>Area (km²)</th>
<th>Change (km²)</th>
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<td>1993-2013</td>
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### Results — glacier change

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<th>Area (km²)</th>
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<th>2002</th>
<th>2010</th>
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- Glaciers are in continuous reduction.
- Glacier area decreased **91.12 km²**, and change rate is **2.95%** from 1977-2013.
- Glacier decreased by a rate of **2.55 km²/a** from 1977-2013.
Results — glacier change

- \( V = 0.04 S^{1.35} \)
  by Shiyin Liu;
- \( V = 0.0365 A^{1.375} \)
  by Radić and Hock;

<table>
<thead>
<tr>
<th>Year</th>
<th>area (km(^2))</th>
<th>volume-R (km(^3))</th>
<th>volume-L (km(^3))</th>
<th>water equivalent-R (km(^3))</th>
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- Glacier volume changes **20-21 km\(^3\)** from 1977-2013, and it equals to about **19 km\(^3\)** water equivalent.
1977

Glacier

0 10 20 km
Results — glacier change
Results — glacier change
## Results — glacier change

<table>
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Results — glacier change
Results — glacier change

- a: West Kunlun glacier
- b: West Yulong glacier
- c: Duofeng glacier
- d: Yulong glacier
- e: Chongce glacier
- f: Zhongfeng glacier
- g: Gongxing glacier
## Results — glacier change

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Results — moraine lake area change

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Results — moraine lake area change
Results — moraine lake area change

2010

Debris-covered glacier
Clean glacier
Moraine lake

0 10 20 km
Results — moraine lake area change
Results — glacier velocity

*Spatial variation*— 2013-2014

- Surface velocity decreases with the decrease of altitude below the equilibrium line.
- It decreases from middle axis to sides edge.
- At the end of Duofeng glacier, the surface velocity becomes the lowest.
Results — glacier velocity

**Glacier velocity change**

- Surface velocity was **1.85 m·a⁻¹** in 2001-2002, and **1.71 m·a⁻¹** in 2013-2014.
- At the same position in red border, the average velocity of feature points was **61.92 m·a⁻¹** in 2001-2002, and **54.32 m·a⁻¹** in 2013-2014.
Results — climate change

\[ y_1 = 0.0289x - 61.851 \]

\[ y_2 = 0.0808x - 165.92 \]
Results — climate change

\[ y_1 = 0.012x - 18.233 \]

\[ y_2 = 0.0164x - 28.892 \]

\[ y_3 = 0.1855x - 366.77 \]

\[ y_4 = 0.1443x - 285.87 \]

- 5-9 monthly mean temperature
- 6-8 monthly mean temperature
Conclusion

• The majority of glacier is in a **continuous recession** from 1977 to 2013.

• There are **13 glaciers** terminal altitude rising and **17 glaciers** length becoming shorter of 20 typical glaciers.

• Glacier velocity of Duofeng glacier **decreased** from 2001-2002 to 2013-2014.

• **Climate warming** is the main reason of glacier retreat and ablation.
Thank you!
An update on the second Chinese glacier inventory in the southeastern Tibetan Plateau using ASAR images

ID. 10612

Chang-Qing Ke*; Jun Chen*; Ralf Ludwig#

*Nanjing University, China; # Ludwig-Maximilian-University Munich, Germany
• Introduction
• Data set
• Method
• Results
• Discussion
• Conclusion
Overall, there is very high confidence that globally, the mass loss from glaciers has increased since the 1960s, and this is evident in regional-scale estimates (IPCC AR5, 2013)
The most intensive shrinkage in the Himalayas (excluding the Karakorum)

The greatest reduction in glacial length and area and the most negative mass balance.

The shrinkage generally decreases from the Himalayas to the continental interior.

The eastern Pamir, characterized by the least glacial retreat, area reduction and positive mass balance.

Yao et al., 2012, *Nature climate change*
Global Glacier Inventory

GLIMS geospatial glacier database

- Data source: Landsat, ASTER, SPOT, etc.
- http://www.glims.org

The Randolph Glacier Inventory

- in order to meet the needs of IPCC AR5
- Data source: Landsat 5 TM, Landsat 7 ETM+, ASTER, IKONOS, and SPOT 5 high-resolution stereo (HRS).
Regional Glacier Inventory

- The inventory of glaciers and ice caps on Greenland (Rastner et al., 2012)
- A glacier inventory for the European Alps (Paul et al., 2011)
- A glacier inventory for Norway (Andreassen et al., 2008; Paul et al., 2011)
- A glacier inventory for western Alaska (LE Bris et al., 2011)
- Canada Glacier Inventory (Ommaney, 2009; Svoboda and Paul, 2009; Bolch et al., 2010)
- … … … …
Chinese Glacier Inventory

The first Chinese glacier inventory (CGI-1)
- Data source: aerial photographs and topographical maps from 1960s-1980s.
- Compilation period: 1978-2002

The Second Chinese glacier inventory (CGI-2)
- Compilation period: 2007-2013
- 6201 glaciers with an area of 8753 km² from the first Chinese glacier inventory, mainly distributed in the southeastern Tibetan Plateau, where no cloudy-free Landsat TM/TM+ images for glacier outline delineation can be found during 2006–2010. Guo et al., 2015, J. Glaciology
• Introduction
• Data set
• Method
• Results
• Discussion
• Conclusions
**ENVISAT ASAR images:**

Format: IM SLC, VV, descending

16 images

June-September, 2010

To delineate glacier outlines
Glaciers on the original ASAR images in Yigong Zangbo Basin
Data set

Landsat 8 (OLI/TIRS):
18 images

June-October, 2013

To validate glacier outlines

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Digital elevation models

- The Shuttle Radar Topography Mission (SRTM) DEM version 4 (http://srtm.csi.cgiar.org)

- where voids were filled using different auxiliary DEMs

- to derive glacier topographic attributes
• Introduction
• Data set
• **Method**
• Results
• Discussion
• Conclusion
Flow chart of delineating glacier outlines

- Topographic correction
- Geocoding and Speckling removing
  - Visual interpretation
  - Vector polygon
  - Manual correction
  - Glacier outlines
- Landsat images
- The second Chinese glacier inventory
- DEM
  - Hydrology
    - River basin
  - Topography
    - slope
    - Terrain ridge line
- Accuracy evaluation
- Glacier delineation
- Single glacier
Deriving glacier outline based on ASAR images

Interpreted glacier from geocoded ASAR images, then to modify the glacier outline on the basis of Landsat images
Accuracy of glacier delineation

Based on 27 points, estimated Error: ±30 m
• Introduction
• Data set
• Method
• Results
• Discussion
• Conclusion
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This study: Disappeared 831, 13% 5.59 0.01 248.22 3%
Retreat 1101, 18% 43.45 0.000374 534.27 6%
Advance 663, 11% 6.63 0.000859 118.50 1%
No change 3606, 58%
Total 5370, 87% 663.99 8%(shrink) 8089.28

CGI-1 CGI-2 Total 6201, 100%
• Introduction
• Data set
• Method
• Results
• **Discussion**
• Conclusion
- ASAR image speckle

- Incidence angle in relation to complicated terrain with very steep slope, resulting in foreshortening, shadow, layover effects

- Snow and glacier distinguishing

- Accuracy is not as high as optical image, e.g., Landsat images
• Introduction
• Data set
• Method
• Results
• Discussion
• Conclusion
The second Chinese glacier inventory in the southeastern Tibetan Plateau was updated using 16 ASAR images in summer 2010.

Glacier outlines were corrected on the basis of Landsat images, and the accuracy was also evaluated.

In the updated inventory, 831 glaciers disappeared, their area is 248.22 km², accounting for 3% of total area.
1101 glaciers retreated, retreated area is 534.27 km², accounting for 6% of total area.

663 glaciers advanced in their terminus, advanced area is 118.50 km², only accounting for 1% of total area.

Compared to CGI-2, the updated inventory has a glacier area of 8089.28 km², and 663.99 km² shrink, accounting for 8% of CGI-2’s glacier area.
Thank you!