Using TanDEM-X observations for extracting glacier and sea-ice topographies

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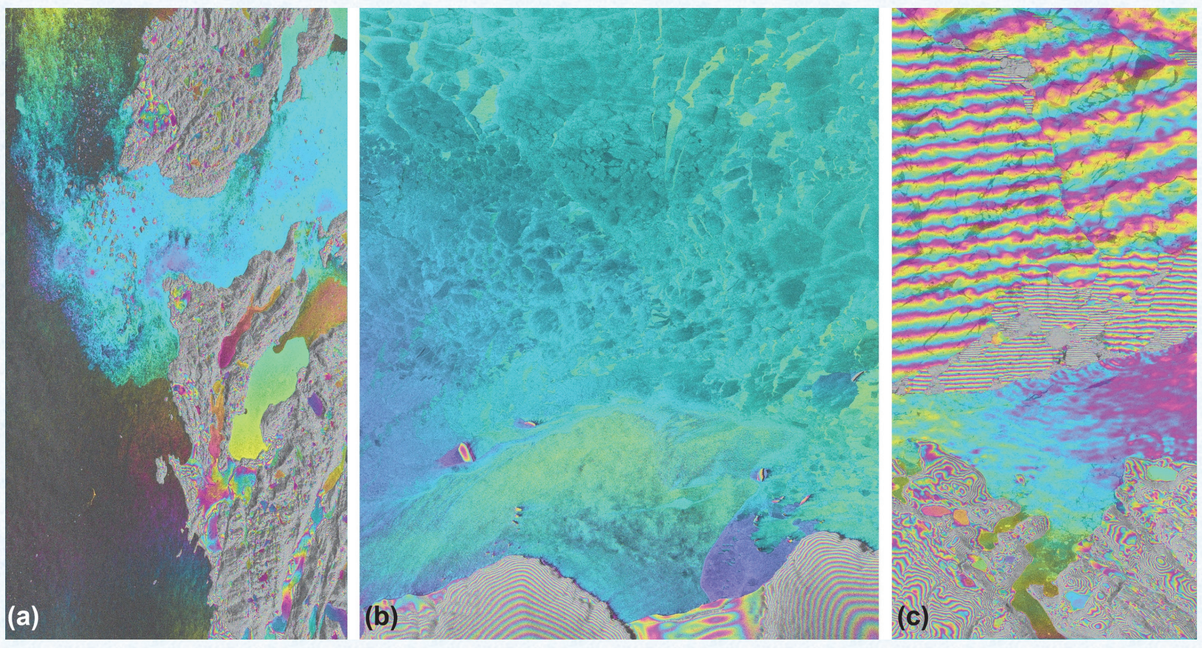
Abstract

Space-based Synthetic Aperture Radar interferometry (InSAR) applications have been widely used to monitor the cryosphere over past decades. Due to temporal decorrelation, interferometric coherence often degrades severely on fast moving glaciers and sea-ice. In addition, higher sensitivity ambiguity by large baseline configurations, which are needed for extracting topographic information over low relief areas such as sea-ice surfaces. TanDEM-X observations, which overcome the temporal decorrelation due to its simultaneous measurements by its two satellite constellation, has used short baseline which are sufficient for generating excellent DEM in most locations around the world. However, it is still difficult to estimate detail topographic characteristics over the low slope sea-ice or glacier surfaces due to relatively less sensitive height ambiguity from small baselines.

In this study, we use the TanDEM-X large baseline formation following scientific phase timeline to generate high spatial and sensitive topographic elevation model for glaciers and sea-ice. We obtained seven TanDEM-X bistatic and pursuit monostatic mode observations of glaciers and sea-ice located in both Greenland and Antarctica. As expected, coherent interferometric phases (0.5 ~ 0.8) are well maintained over sea-ice and glaciers despite their fast movements, thanks to TanDEM-X simultaneous measurements. The height ambiguity of the datasets are ranged from 7.1 ~ 9.7 m, which is very favorable for extracting topographic information in low relief region. Because of high sensitive ambiguity, we can extract detail geomorphological features on sea-ice and glaciers. High resolution interferometric phase including topographic information is also useful for separating iceberg from sea-ice or open water. We will validate the TanDEM-X derived sea-ice topography by comparing it to the SAR/Interferometric Radar Altimeter observations acquired by CryoSat-2. Routine TanDEM-X observations will be very useful for a better understanding of the dynamics of sea-ice and glacier movements.

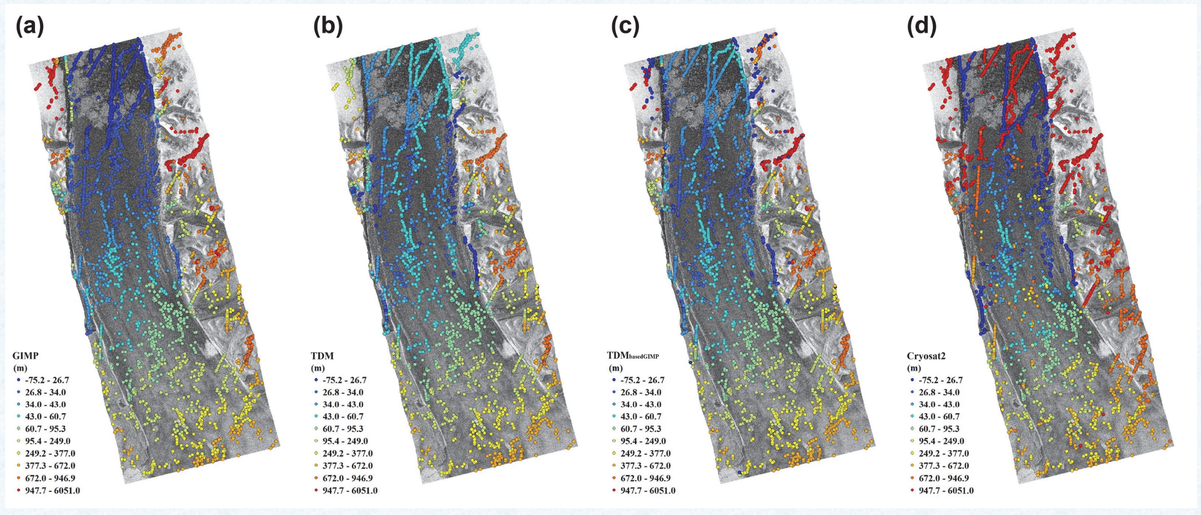
1. Preliminary results of TanDEM-X bistatic and pursuit monostatic observation over sea-ice

(a) Jakobshavn glacier located at the Greenland
: Observation date - 2015. 06. 02. : Temporal baseline – 0 sec : Perpendicular baseline - 406 m : Height of ambiguity - 13.7 m
(b) Sea ice nearby Amundsen sea at the Antarctica
: Observation date - 2015. 09. 09. : Temporal baseline – 0 sec : Perpendicular baseline - 313 m : Height of ambiguity - 22.8 m
(a) Sea ice nearby Ellesmere island at the Canada
: Observation date - 2015. 02. 04. : Temporal baseline – 10 sec : Perpendicular baseline - 391 m : Height of ambiguity - 18.9 m



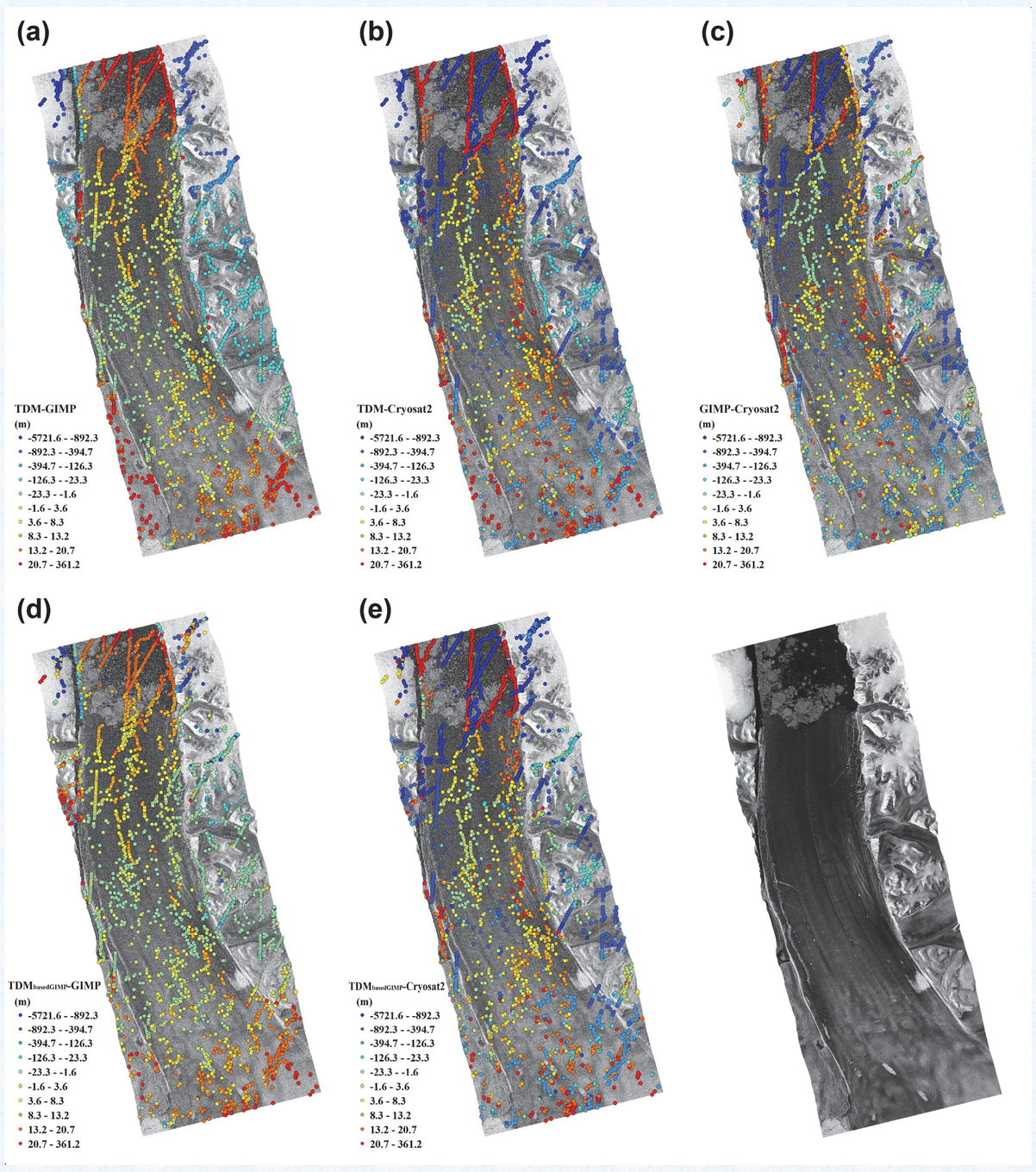
2. Preliminary results of TanDEM-X pursuit monostatic phase over glacier

- Petermann glacier located at the Greenland
: Observation date - 2015. 02. 21. : Temporal baseline - 10 sec : Perpendicular baseline - 527 m : Height of ambiguity - 13.0 m
(a) Plot of Greenland Mapping Project (GIMP) Digital Elevation Model (available from http://nsidc.org/data/nsidc-0645), correspondent to CryoSat-2 altimeter observation (d).
(b) Plot of Digital Elevation Model derived from TanDEM-X pursuit monostatic phase observation, correspondent to CryoSat-2 altimeter observation(d).
(c) Plot of Digital Elevation Model derived from TanDEM-X pursuit monostatic phase observation, which added to GIMP DEM with differential interferometric processing, correspondent to CryoSat-2 altimeter observation (d).
(d) Plot of CryoSat-2 altimeter observation which is collected from 2015. 01. 01 ~ 2015. 03. 31. The L2 data product in SARin operation mode are used in this study. The collected CryoSat-2 observation is height of surface w.r.t. ellipsoid WGS84.



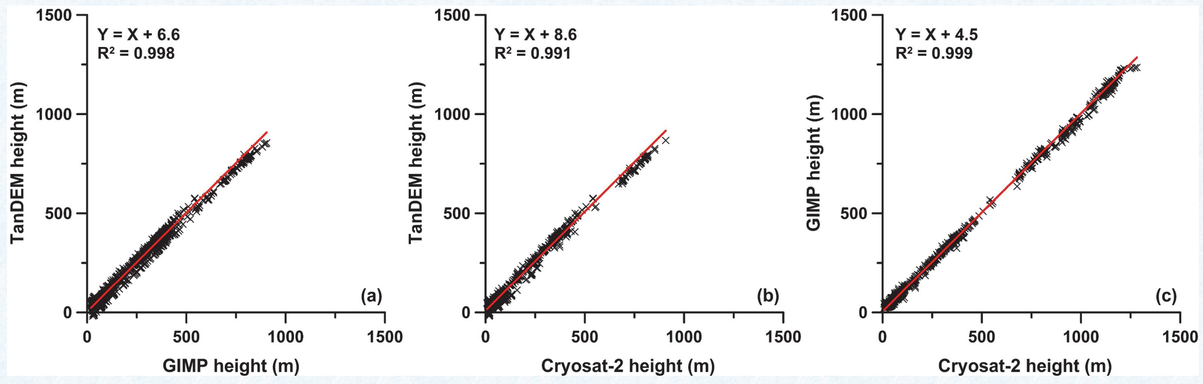
3. Difference of Digital Elevation Model

(a) TanDEM-X – GIMP (b) TanDEM-X – CryoSat-2 (c) GIMP – CryoSat-2
(d) TanDEM-X which added to GIMP DEM with differential interferometric processing – GIMP
(e) TanDEM-X which added to GIMP DEM with differential interferometric processing – CryoSat-2
- Most of large difference in terrain height has been found in the high altitude area and sea-ice region. The small height ambiguity prohibits from phase unwrapping and cause decorrelation in comparison between TanDEM-X and GIMP. Also because there are lots of unexpected artifacts from CryoSat-2 observation, large difference of terrain height are discovered.



4. Comparison of derived Digital Elevation Model

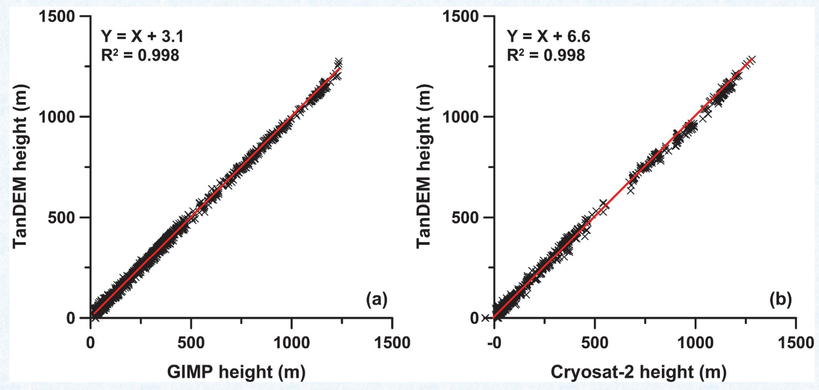
(a) TanDEM-X versus GIMP height (b) TanDEM-X versus CryoSat-2 height (c) GIMP versus CryoSat-2 height
- Overall there is very good agreement among DEMs, even though they have some noises showing at the Section 3.
- We removed the outliers which are located on mostly over high altitude areas, based on the comparison from the result of Section 3, because we are interested on topography over glacier.
- The outliers showing large difference of height have been removed, thus we lose a lot of points above 1000 m in the derived TanDEM-X DEM which has been generated with topographic interferometric application.



5. Comparison of derived Digital Elevation Model based on GIMP

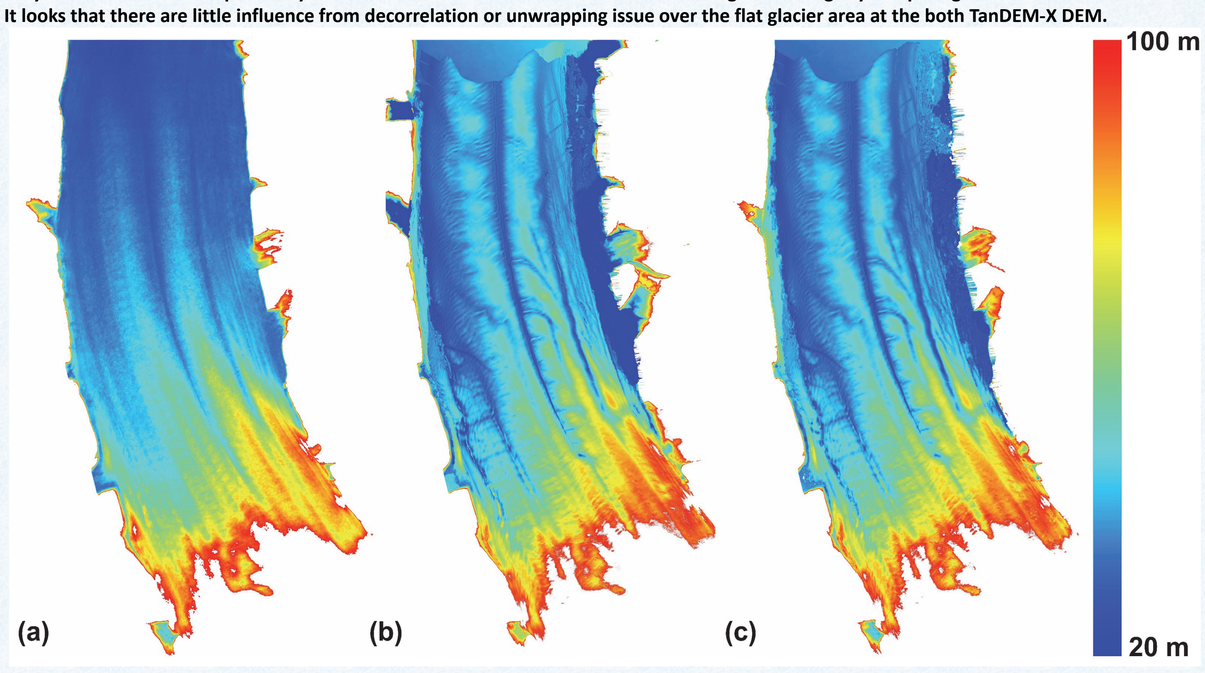
(a) TanDEM-X versus GIMP height
(b) TanDEM-X versus CryoSat-2 height

- Now lots of high altitude points above 1000 m has been retrieved by differential interferometric application based on GIMP DEM
- It suggests that differential InSAR processing should be required with TanDEM-X cases with large perpendicular baseline for high altitude region.



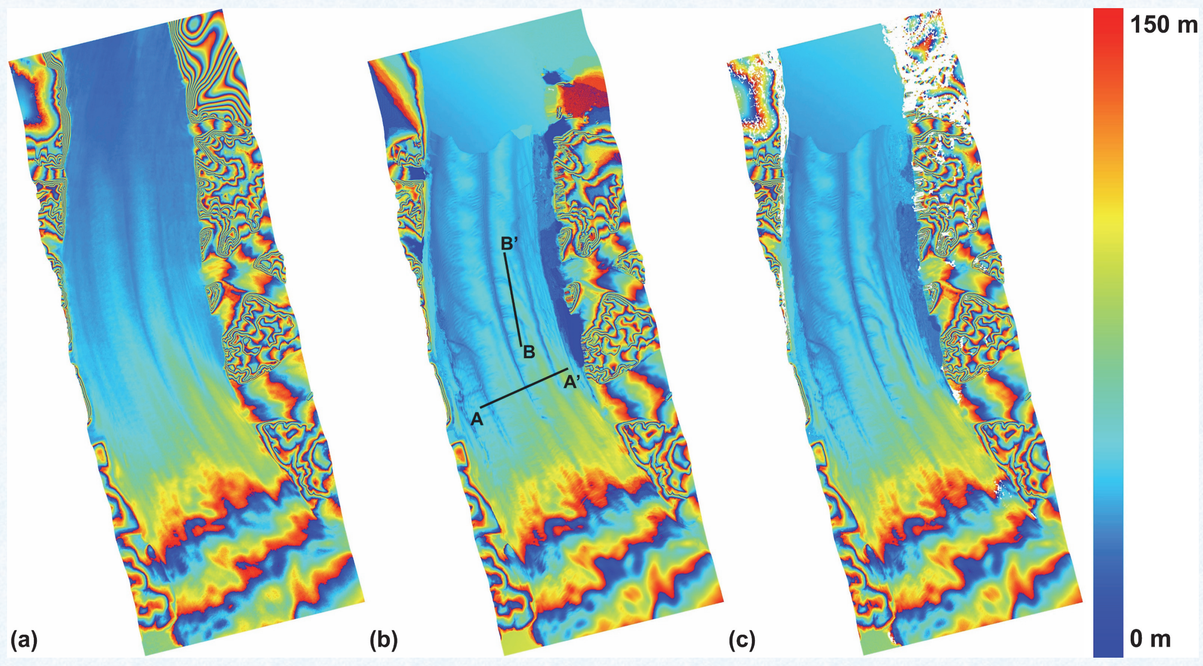
6. The usefulness of small height of ambiguity

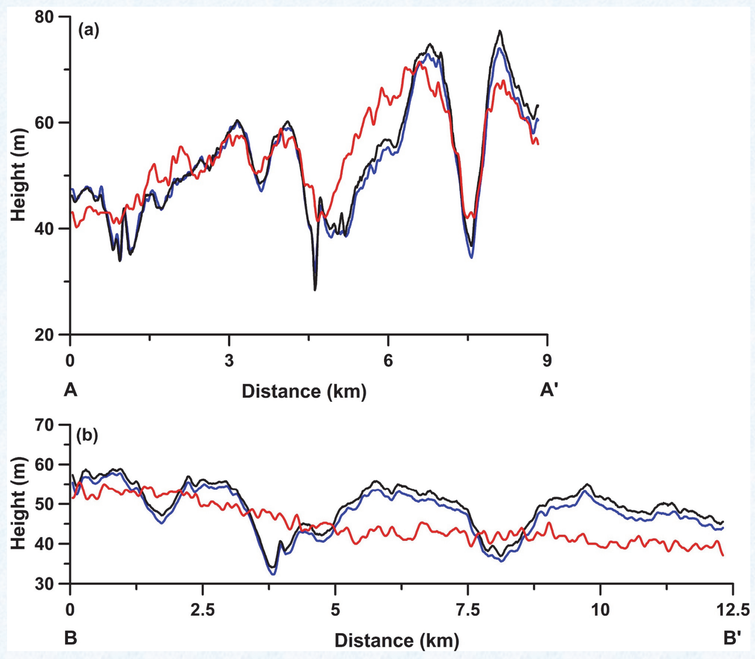
(a) GIMP (b) TanDEM-X with topographic InSAR (c) TanDEM-X with differential InSAR
- Very detail features are captured by the both TanDEM-X DEMs thanks to the small height of ambiguity comparing with GIMP DEM.
- It looks that there are little influence from decorrelation or unwrapping issue over the flat glacier area at the both TanDEM-X DEM.



7. Phase unwrapping issue from small height ambiguity

(a) GIMP height (b) TanDEM-X with topographic InSAR (c) TanDEM-X with differential InSAR
- Partial terrain height information has been retrieved at the some areas.
- In order to derive topography over the sea-Ice, much larger perpendicular baseline and more coherence with higher resolution may be required.





8. Profiles over glacier

- Two profiles are plotted along the A-A' and B-B' traverse line.
- The red line is from the GIMP DEM, the black line is from the TanDEM-X DEM with topographic InSAR processing and the blue line is extracted from the TanDEM-X DEM with differential InSAR processing.
- It is certain that the TanDEM-X DEM with small height ambiguity is showing very detail topographic variation.
- A time-series of TanDEM-X DEM with small height of ambiguity can be utilized for monitoring ice volume over the glacier.

9. Acknowledgement

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