Monitoring glacier flow velocity by SAR interferometry and texture tracking method using ALOS PALSAR data around mt. Everest region

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Presentation Outline

- ❑ Background & Introduction
- ❑ Real Case Scenario
- ❑ Objectives
- ❑ Data
- ❑ Methodology
- ❑ Khangshung Glacier Result & discussion
- ❑ Khumbu Glacier Result & discussion
- ❑ Discussions

1. Background & Introduction

- Why to study the Glaciers ?
- Glaciers need to be studied for variety of purposes including
  - ***to track climatic variations***
  - ***effects on hydrology***
  - ***sea level rise***
  - ***hazard assessment***
    - ***Glacier Lake Outburst Flood (GLOF)***

Reference: *WWF Nepal Program March,2005 report*

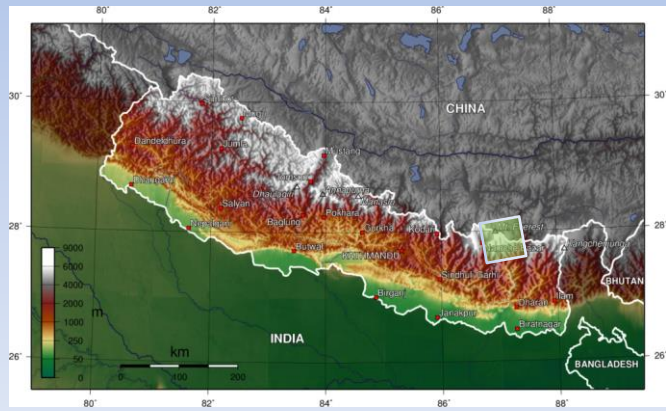
1. Background & Introduction

- The monitoring of temperate glacier that is fast evolving
- As an indicator of the local effects of global climate change
- Regular observations of glacier activity and to provide dense measurements of physical parameters
- Disastrous flood prediction, prevention adaptive measures well before occurrence
- By doing this, it is expected that the extent of the damage of the populated area or infrastructure can be greatly controlled
- Understanding the response of glaciers and glacial lakes with the global rising temperature is an essential aspect of planning water resources as well as managing the potential for GLOF disasters

1. Background & Introduction

Geography of Nepal

- Shaped roughly like a rectangle with China to the north and India on three other sides
- Nepal is situated between latitudes of $26^0 22'$ to $30^0 27'$ north and between longitudes of $80^0 4'$ to $88^0 12'$ east



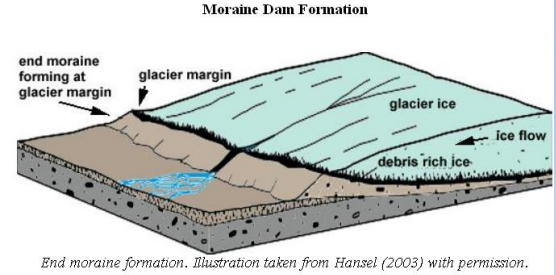
Reference: *WWF Nepal Program March,2005 report*

800 km

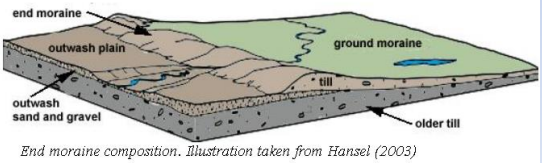
140 km

2. Real Case Scenario

Glacial Lake Outburst Flood (GLOF)



End moraine formation. Illustration taken from Hansel (2003) with permission.



End moraine composition. Illustration taken from Hansel (2003)

- A GLOF is characterized by a sudden release of a huge amount of lake water that rushes along the stream channel downstream in the form of dangerous flood waves.
- Devastating consequences for down hill communities, hydropower stations and other infrastructure.

Reference:
http://academic.emporia.edu/aberjame/student/dahms4/web1.htm

2. Real Case Scenario

Glacial Lake Outburst Flood (GLOF)

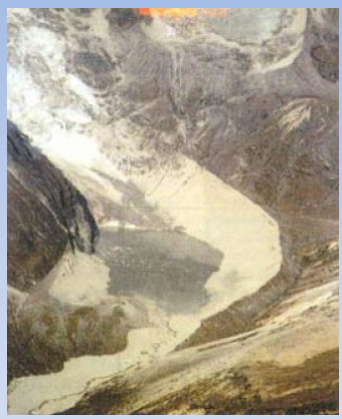
List of GLOF events recorded in Nepal

Date	River Basin	Name of Lake
450 Years ago	Seti Khola	Machhapuchhare
August, 1935	Sun Koshi	Taraco, Tibet
21 September, 1964	Arun	Gelaipco, Tibet
1964	Sun Koshi	Zhangzangbo, Tibet
1964	Trishuli	Longda, Tibet
1968	Arun	Ayaco, Tibet
1969	Arun	Ayaco, Tibet
1970	Arun	Ayaco, Tibet
3rd September, 1977	Dudh Koshi	Nare, Tibet
23rd June, 1980	Tamur	Nagmapokhri, Nepal
11th July, 1981	Sun Koshi	Zhangzagbo, Tibet
27th August, 1982	Arun	Jinco, Tibet
4th August, 1985	Dudh Koshi	Dig Tsho, Nepal
12th July, 1991	Tamo Koshi	Chubung, Nepal
3rd September, 1998	Dudh Koshi	Sabai Tsho, Nepal.

Reference: *WWF Nepal Program March,2005 report*

2. Real Case Scenario

Glacial Lake Outburst Flood (GLOF)



•The Dig Tsho GLOF: The site of Namche Hydropower Project destroyed by the GLOF on 4 August 1985 (left)
•The lake in 2004 (bottom)

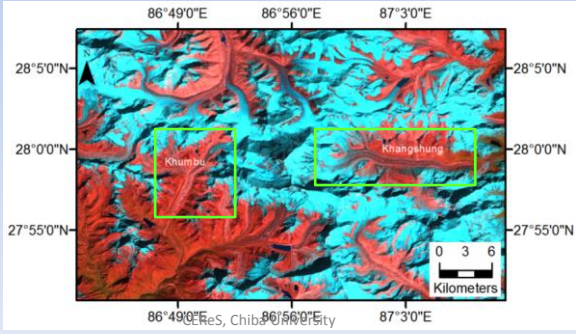
(Source: WWF Nepal Program)

3. Objectives on the Horizon

- Use of ALOS PALSAR Data to
  - Analyze the movement of the Ice surface (moving temperate glaciers made of ice, snow and rocks)
  - Detecting the change in the size of Glacial Lake
- Creating Digital Elevation Model (DEM)
  - Is widely used for flood prediction and estimating the affected area (Disaster mitigation planning)
  - It is possible to detect the temporal changes of glacial lakes, glaciers and moraines by comparing two DEMs produced at two different time intervals

3.1 Current objectives

- Use of ALOS PALSAR Data to
  - Analyze the velocity rate for *Khangshung and Khumbu Glacier* (moving temperate glaciers made of ice, snow and rocks)
    - By using DInSAR technique

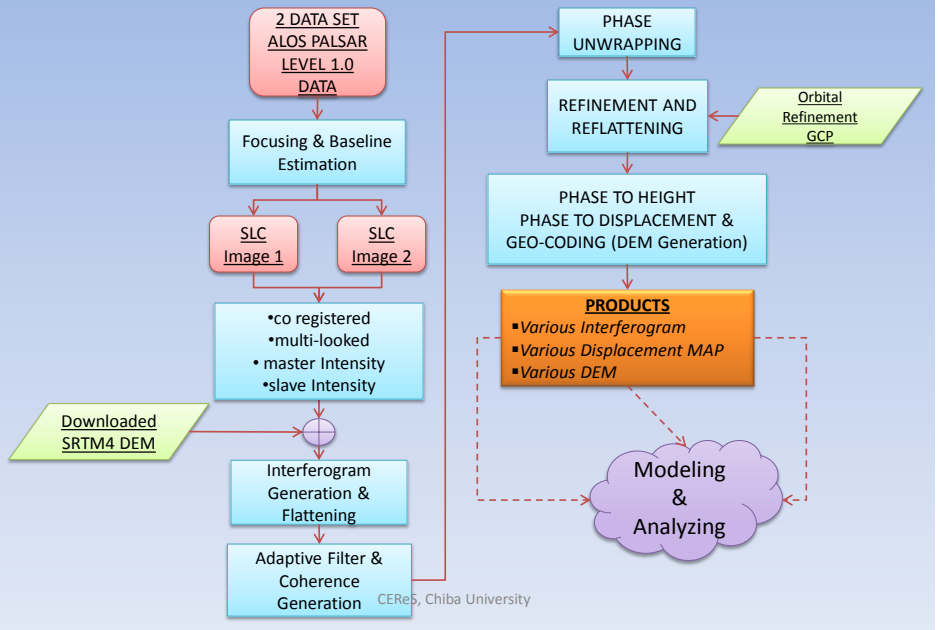


4. Data

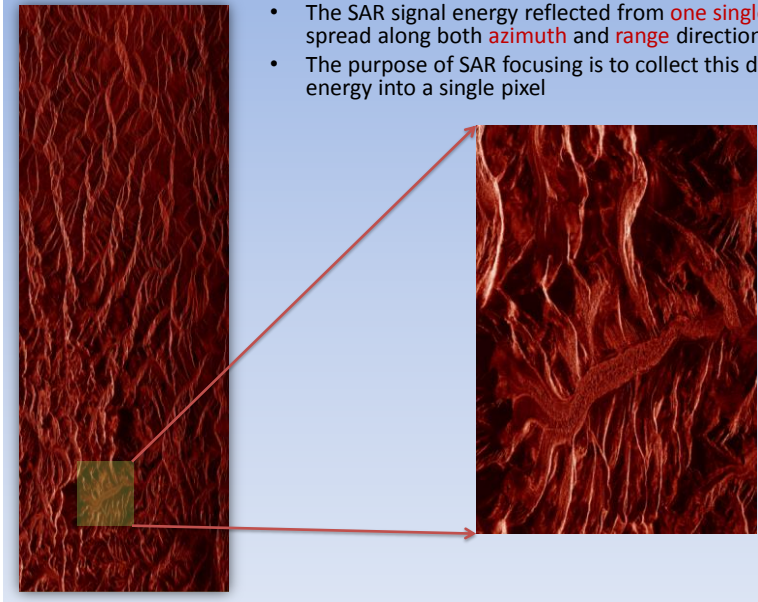
ALOS PALSAR (Synthetic Aperture Radar) Fine Mode

	Satellite	Sensor	Process Level	Off Nadir Angle	Observation Date	Repeat pass period	Perpendicular Baseline (m)	Frame Center Number	Passes
Pair 1	ALOS	PALSAR	1.0	34°	2007/12/13	46 Days	280	540	Ascending
	ALOS	PALSAR	1.0	34°	2008/1/28			540	Ascending
Pair 2	ALOS	PALSAR	1.0	34°	2009/11/2	46 Days	212	540	Ascending
	ALOS	PALSAR	1.0	34°	2009/12/18			540	Ascending

5. InSAR & DInSAR Methodology



Process: Focusing & Baseline Estimation



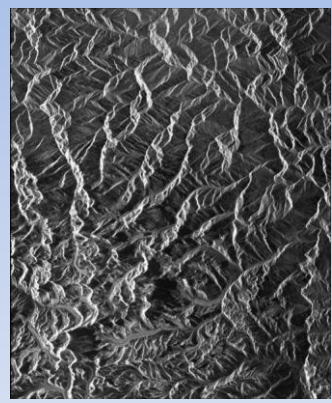
- The SAR signal energy reflected from one single point is spread along both azimuth and range direction
- The purpose of SAR focusing is to collect this dispersed energy into a single pixel

Process:

Co registered + Multi looked

Master Intensity & slave Intensity

2007-12-13



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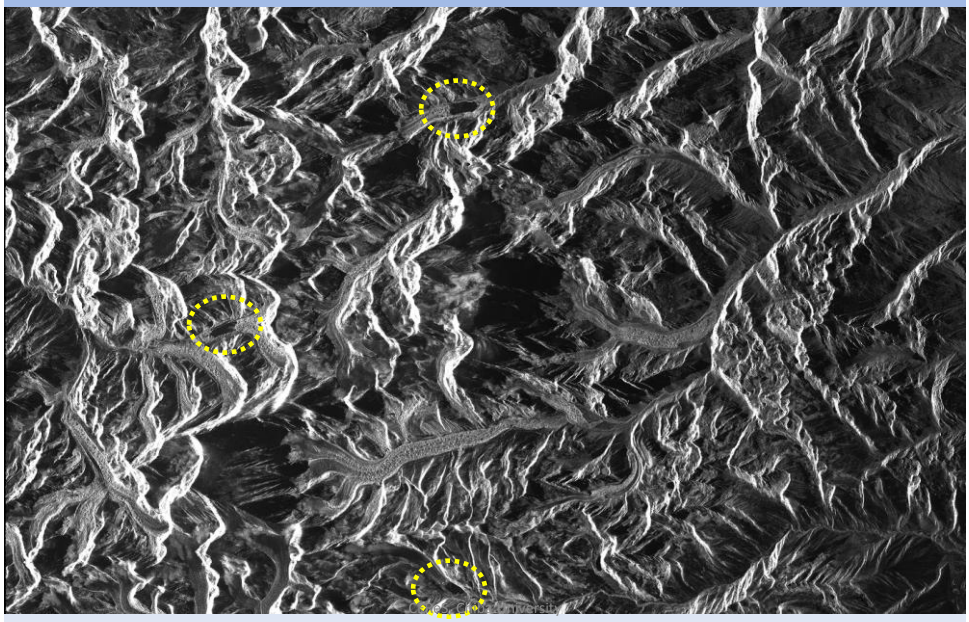
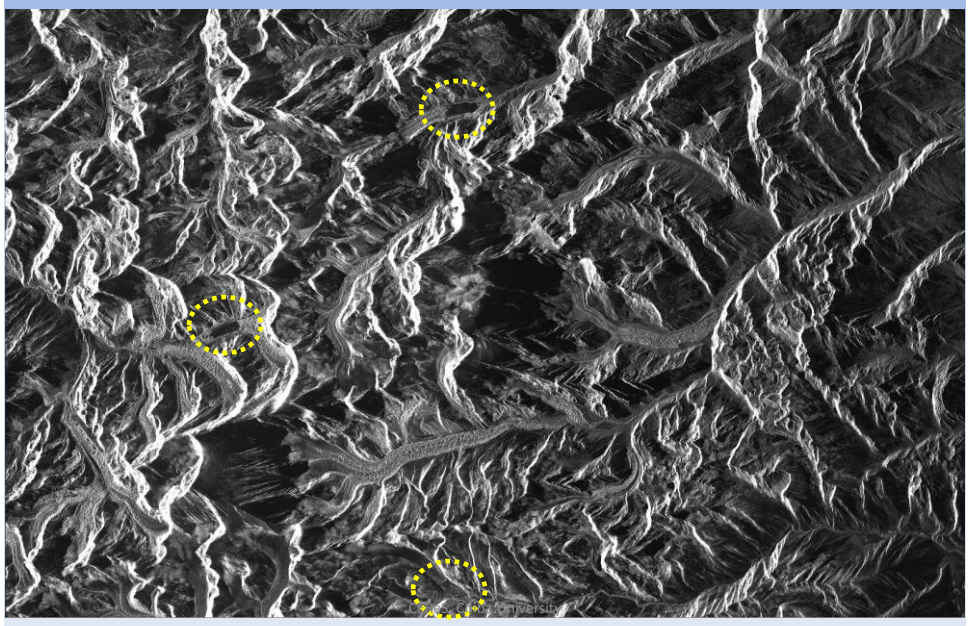
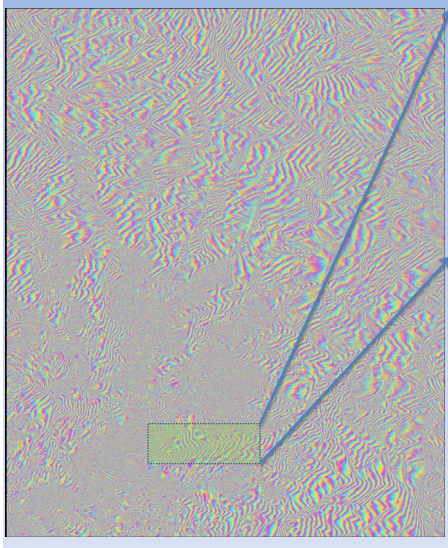
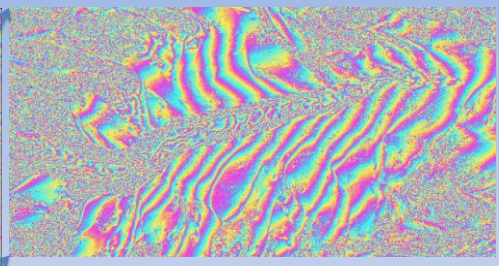




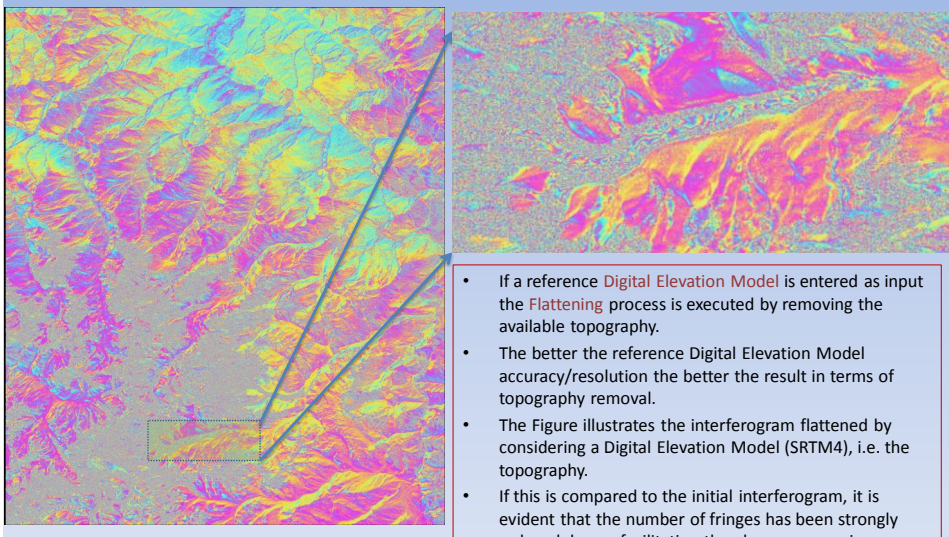
Process: Interferogram Generation





- The distance difference between a point on the Earth and the sensor position on the two acquisitions can be measured by the phase difference (φ) between two complex coregistered SAR images.
- This is performed by multiplying one image by (the complex conjugate of) the other one, where an interferogram is formed.
- The phase of the interferogram contains fringes that trace the topography (or the displacement) like contour lines.

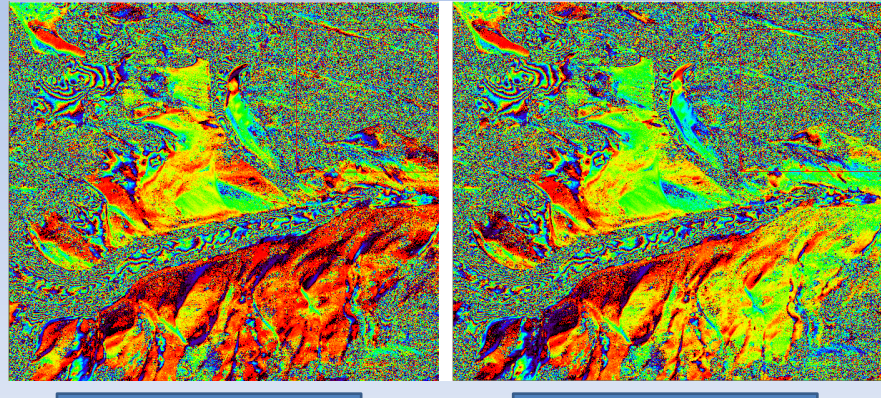
Process: Interferogram Flattening



- If a reference Digital Elevation Model is entered as input the Flattening process is executed by removing the available topography.
- The better the reference Digital Elevation Model accuracy/resolution the better the result in terms of topography removal.
- The Figure illustrates the interferogram flattened by considering a Digital Elevation Model (SRTM4), i.e. the topography.
- If this is compared to the initial interferogram, it is evident that the number of fringes has been strongly reduced, hence facilitating the phase unwrapping process and the generation of the Digital Elevation Model or, in case of differential interferometry, the measurements of ground motions.

Process: REFINEMENT AND REFLATTENING

- This step is crucial for a correct transformation of the unwrapped phase information into height (or displacement) values.
- It allows both to refine the orbits (i.e. correcting possible inaccuracies) and to calculate the phase offset (i.e. getting the absolute phase values), or remove possible phase ramps.
- The execution of this step is mandatory for Digital Elevation Model generation as well as for Displacement Mapping.
- To execute this step a Ground Control Point file must be previously created.



Un-Refined Interferogram (Before)

Refined Interferogram (After)

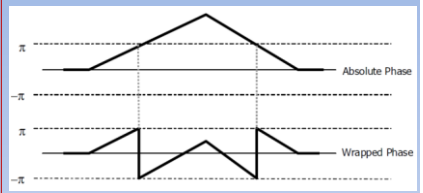
Process: Adaptive Filter & Coherence Generation

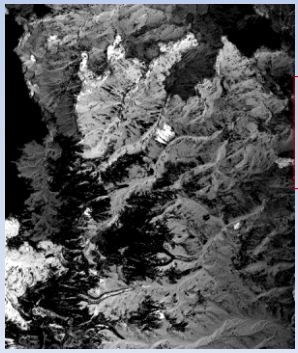
- Given two co-registered complex SAR images (S1 and S2), one calculates the interferometric coherence (g) as a ratio between coherent and incoherent summations
- The observed coherence - which ranges **between 0 and 1** - is, in primis, a function of systemic spatial decorrelation, the additive noise, and the scene decorrelation that takes place between the two acquisitions.
- In essence coherence has, in primis, a twofold purpose:
  - To determine the quality of the measurement (i.e. interferometric phase). Usually, phases having coherence values lower than 0.2 should not be considered for the further processing.
  - To extract thematic information about the object on the ground in combination with the backscattering coefficient (σ^0).

- The Figure illustrates the estimated coherence
- Bright values correspond to values approaching to 1, while dark values (black = 0) are those areas where changes (or no radar return, radar facing slope, etc.) occurred during the time interval, 48 days in this case.

Process: Phase Unwrapping

- The phase of the interferogram can only be modulo 2π
- Hence anytime the phase change becomes larger than 2π the phase starts again and the cycle repeats itself.
- Phase Unwrapping is the process that resolves this 2π ambiguity.
- Several algorithms (such as the branch-cuts, region growing, minimum cost flow, minimum least squares, multi-baseline, etc.) have been developed; in essence, none of these is perfect and different or combined approaches should be applied on a case by case basis to get optimal results.

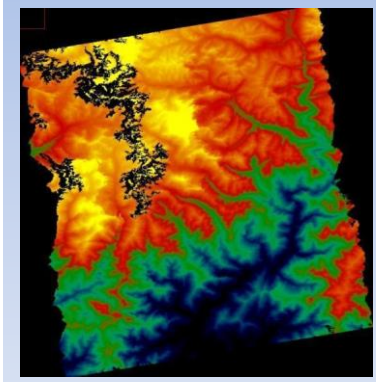


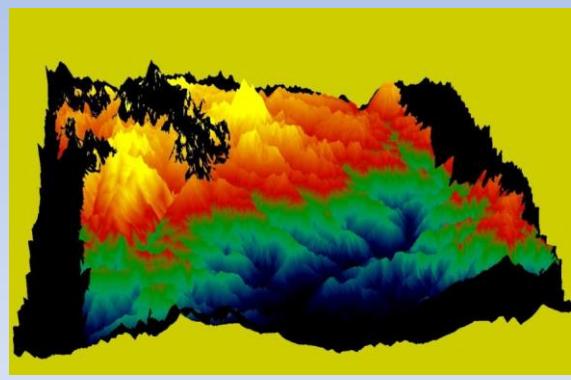


- The Figure illustrates the unwrapped phase.
- At this stage the grey levels representing the phase information are relative and must be absolutely calibrated in order to convert it to terrain height

Process: PHASE TO HEIGHT & GEO-CODING (DEM Generation)

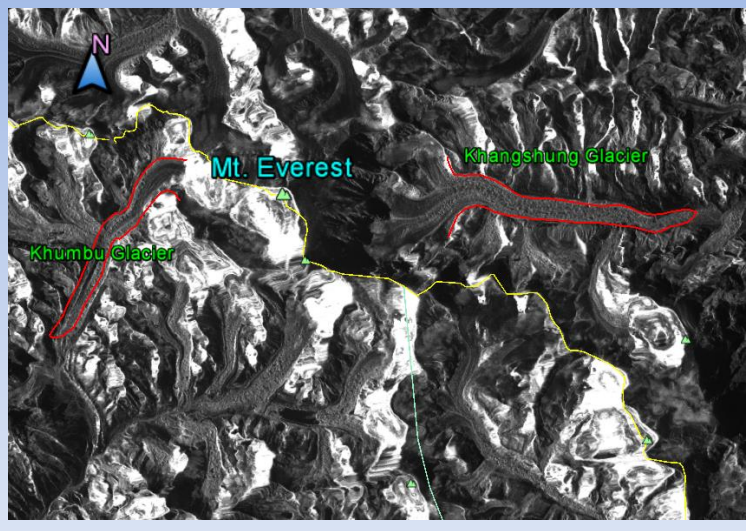
- The unwrapped phase is recombined with the synthetic phase and is converted to elevation and geocoded into a specified map projection.
- This step is performed in a similar way as in the geocoding procedure, by considering the Range-oppler approach and the related geodetic and cartographic transforms.



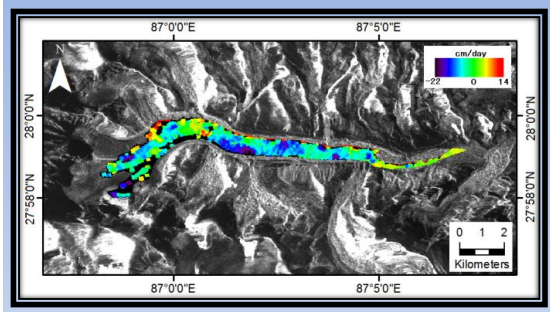


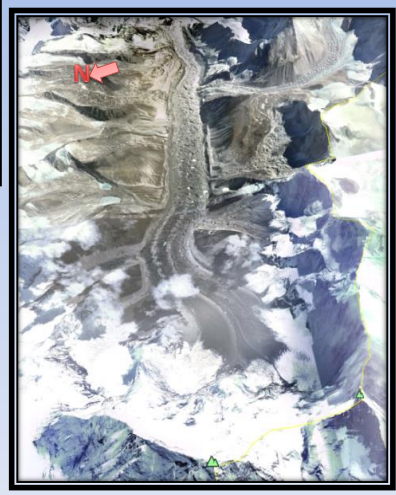
Generated DEM

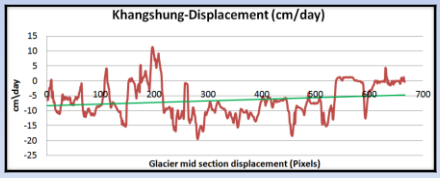
7. Study Site in SAR Intensity (Amplitude) Image

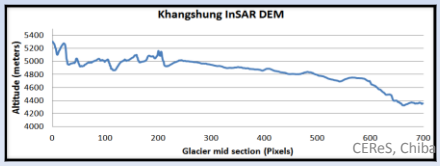


Khangshung Result & Discussion









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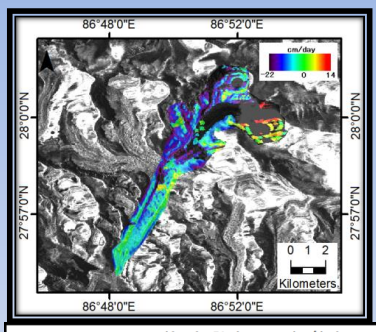
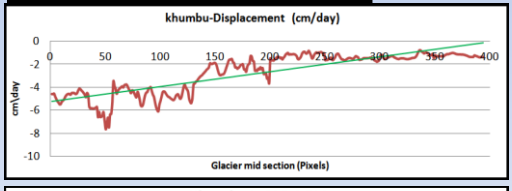
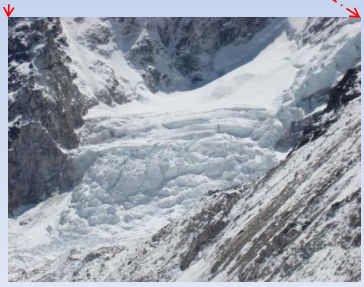
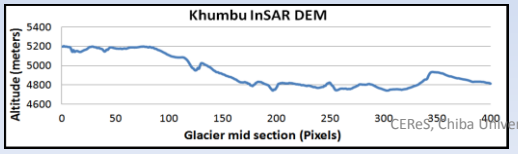
Khumbu Result & Discussion









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8. Discussion

- InSAR is considered for giving high level of accuracy if perfect image (good baseline, high coherrence, lower period of repeat pass) is selected for the process
- Other Satellite data are most welcome
- Both Ascending and Descending satellite data to bring out more accurate measurement specially in case of North-South flow
- It is somehow difficult to obtain good coherence in stiff slopes and terrain area so Amplitude tracking could also be recommended
- More to do in Future…

THANK YOU
FOR YOUR
KIND ATTENTION