POLARIZATION EFFECT ON GLACIER MOVEMENT ESTIMATION USING DIFFERENTIAL SAR INTERFEROMETRY

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01/02/2019
Glacier and it’s dynamics

- Glacier is one of the important component in the cryosphere and it is an indicator of climate change
- An understanding of the response of glaciers to climate change must include basic concepts of ice dynamics

  - **Glacier velocity**
  - Glacier Thickness
  - Glacier mass balance
Glacier velocity

- Glacier Velocity: The movement rate of a glacier per period of time
- The glacier moves because of its gravity, slope and pressure from the weight
- Field based techniques like DGPS give very accurate results but difficult to collect ground truth points and also spatially limited
- Remote sensing techniques are very helpful to measure glacier movement

Ablation zone of Hamta Glacier, Himachal Pradesh (source: P. Kaushik 2013)
Remote sensing techniques

Differential SAR Interferometry (DInSAR)

It is a millimetre accuracy technique to estimate the glacier movement using phase information.

Offset Tracking

The accuracy and resolution of this technique are poorer than differential SAR interferometry and it uses amplitude/intensity information to estimate the glacier movement.

Differential SAR Interferometry (DInSAR) for glacier movement

\[ \Delta R = -\frac{\lambda}{4\pi} \Delta \varphi \]
DInSAR problems for glacier movement

Decorrelation effects due to

- **Fast** moving of glaciers
  - Solution: Using small **temporal baseline** data
- Decorrelation due to **Snow** cover
  - Solution: Using **longer wavelength** data
- **Debris and moraines** covered in glacier
  - Solution: Using multiple **polarization channels**
Himalayan glaciers

- Mountain glaciers are irregular in structure and shape and moreover, they are covered with snow, sediments, and moraines.
- DInSAR technique can give better information when combined with polarimetry because it contains the backscattered information of the target sensitive to geometrical structure, shape, and orientation.
- In this work, multi-polarized (HH, HV, VH, and VV) data is used to check the effect on estimated glacier movement due to moraine and debris cover.
Study Area: Bara Shigri glacier

- Bara Shigri is the **longest** glacier in Chandra basin, Himachal Pradesh.
- Length nearly 28 km and area 126.5 km$^2$
- Covered with snow, moraines, debris and sediments
- Suitable glacier to check sensitivity to multi-polarimetric DInSAR
### Data used

- **ALOS-2/PALSAR-2 L-band Repeat-pass Quad polarization data used**

<table>
<thead>
<tr>
<th>Season</th>
<th>Dates</th>
<th>Look angle</th>
<th>Perpendicular Baseline (m)</th>
<th>Pass</th>
<th>Temporal Baseline (Days)</th>
<th>Polarization</th>
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<tbody>
<tr>
<td><strong>Accumulation</strong></td>
<td>25th Mar 2016</td>
<td>36.5</td>
<td>176</td>
<td>ASC</td>
<td>14</td>
<td>Quad Pol</td>
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<tr>
<td></td>
<td>08th Apr 2016</td>
<td>36.5</td>
<td></td>
<td>ASC</td>
<td></td>
<td>Quad Pol</td>
</tr>
<tr>
<td><strong>Ablation</strong></td>
<td>06th Oct 2017</td>
<td>32.5</td>
<td>10.3</td>
<td>ASC</td>
<td>14</td>
<td>Dual Pol (HH+HV)</td>
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<tr>
<td></td>
<td>20th Oct 2017</td>
<td>32.5</td>
<td></td>
<td>ASC</td>
<td></td>
<td>Dual Pol (HH+HV)</td>
</tr>
</tbody>
</table>
Coherence map with different polarizations

HH
Mean Coherence: 0.47

VV
Mean Coherence: 0.47

HV
Mean Coherence: 0.4

25th March 2016 & 08th April 2016

Accumulation region (Covered with snow)

Ablation region (covered with debris)
Interferograms with different polarizations

25th March 2016 & 08th April 2016
Interferograms in different seasons

March (accumulation)

October (ablation)

25th March 2016 & 08th April 2016
06th October 2017 & 20th October 2017
Velocity map

Mar 2016 HH

Mar 2016 HV

Oct 2017 HH

Velocity (cm/day)

- <1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- >12

0 3.25 6.5 13 km

77°36'0"E 77°44'0"E

77°36'0"E 77°44'0"E

77°36'0"E 77°44'0"E
Velocity profile along the glacier flow line

Velocity Profile in 2016 Mar with HH Polarization

Comparison between accumulation and ablation season

Velocity Profile in 2017 Oct with HH Polarization

Accumulation

Ablation

Profile points

Oct Vel

Mar Vel
Analysis

- Co-polarized (HH and VV) giving the same and high coherence for the snow-covered area

- Cross-polarized (HV and VH) giving the same and high coherence for the debris-covered area

- But the fringes over the volume scattering regions are not good for all the polarization channels in the accumulation season (March)

- But October month is giving good fringe pattern over the ablation region due to the reason of snow free
Analysis

- The maximum line of sight (LOS) velocity of a Bara Shigri glacier observed is \(~8 \text{ cm/day}\) for both the seasons - March (accumulation) and October (ablation).

- Velocity gradually decreases from accumulation to ablation region.

- We have also observed higher glacier movement rate in the ablation season (compared with accumulation season) for the debris covered region (Ablation region).
Summary

- Time series analysis of glacier movement will give more information about glacier health and can also predict the climatic conditions.

- Glacier movement is different in different seasons (Accumulation and ablation).

- Therefore, combining the velocity map for two different seasons is not accurate.

- We are working to combine these two maps with some calibration (Future work).
THANK YOU