Application of SAR Interferometry to Himalayan Glaciers

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Test Sites

- **Gangotri Glacier**
  26 km long with width of 0.8 to 2.4 km.
  Altitude varies from 4200 m - 6000 m
  Major source to north Indian rivers.
  Receding at the rate of 20 meters per year
  Temperature varies from 10°C to –20°C

- **Siachen Glacier**
  78 km long with 2 km width
  Altitude varies from 4200 m - 6500 m
  Temperature varies from 6°C to –40°C
Gangotri Terminus (height of ice is about 80 meters)
The remnants of lateral moraines, rocky debris pushed along by the glacier, can be seen on both sides of the valley up to Gangotri town.
## Data Sets

| Gangotri : (Ascending Pass) | B|| | B_|_ | ERS-1 SAR : Dt. 25 – 3 – 1996 | 31 | 75 | meters |
|-----------------------------|-----|-----|--------------------------------|----|----|--------|
|                             |     |     | ERS-2 SAR : Dt. 26 – 3 – 1996 |    |    |        |

<table>
<thead>
<tr>
<th>Siachen : (Descending Pass)</th>
<th>ERS-1 SAR : Dt. 01- 4- 1996</th>
<th>46</th>
<th>110</th>
<th>meters</th>
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<tbody>
<tr>
<td></td>
<td>ERS-2 SAR : Dt. 02- 4- 1996</td>
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</table>
Gangotri Glacier area, ERS-1 SAR
25 March, 1996
Gangotri Glacier
InSAR Fringes
Gangotri
Coherence
Image
Geocoded Height Image (Gangotri)
Gangotri
Simulated InSAR Fringes from SRTM DEM
Gangotri

Differential Fringes
Plot of velocity in the radar direction for ascending pass over Gangotri glacier.
Plot of velocity in the radar direction for ascending pass over Gangotri glacier.

Velocity Map of Gangotri Glacier (Ascending Pass)
Upper Part of the Full Scene Covering Siachen Glacier Area, April 1, 1996 (Desending pass)
SAR Interferogram, one fringe is (color cycle) $2\pi$ which is equal to 85 m

Siachen Glacier (Descending pass)
Coherence Image - Siachen Glacier (Descending Pass)
Fringes, from Ascending Pass Data
May 2&3, 1996
Siachen glacier
Height map showing contours with interval of 50 m.
Siachen
Simulated InSAR fringes from SRTM DEM
Siachen glacier

Differential Interferograms of Ascending Pass
Siachen glacier

Differential Interferograms of Descending Pass
Differential Interferograms of Descending and Ascending Pass Siachen glacier
Plot of velocity in the radar direction for ascending pass over Siachen Glacier.

Plot of velocity (or displacement along the radar look direction) for the descending pass along the centerline of the Siachen glacier.
Velocity Map of Siachen Glacier (Ascending Pass)

(+): Towards radar direction
(-): Away from radar direction

Legend:
-0.22 -- -0.17 meters/day
-0.17 -- -0.12
-0.12 -- -0.08
-0.08 -- -0.03
-0.03 -- 0.00
0.00 -- 0.06
0.06 -- 0.11
0.11 -- 0.16
0.16 -- 0.21
0.21 -- 0.25
0.25 -- 0.30

\[ + \]
### ENVISAT ASAR Data Sets

#### Gangotri:

<table>
<thead>
<tr>
<th>Date</th>
<th>Pass</th>
<th>Days</th>
<th>Bₚₗₚₜ</th>
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<tbody>
<tr>
<td>09-07-2003</td>
<td>Descending</td>
<td>35</td>
<td>52 meters</td>
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<tr>
<td>13-08-2003</td>
<td>Descending</td>
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<td>26-11-2003</td>
<td>Descending</td>
<td>209</td>
<td>35 meters</td>
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<td>23-06-2004</td>
<td>Descending</td>
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<td></td>
<td></td>
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<tr>
<td>09-07-2003</td>
<td>Descending</td>
<td>349</td>
<td>581 meters</td>
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<tr>
<td>23-06-2004</td>
<td>Descending</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Full scene of ENVISAT ASAR data

09-07-2003 & 13-08-2003

Gangotri Glacier
InSAR Fringes - Gangotri glacier ENVISAT ASAR data pair
09-07-2003 & 13-08-2003, Baseline: 52 mts, Days: 35
InSAR Fringes - Gangotri glacier ENVISAT ASAR data pair
InSAR Fringes - Gangotri glacier ENVISAT ASAR data

Data Pair:
09-07-2003
23-06-2004
Baseline: 581m
Days Gap: 349
April 30, 1993  

Classified wet snow cover map (using Nov. 26, 2003 reference image)

- **Wet Snow**
- **Dry Snow or Snow Free area**
Aug 13 (RED), Nov. 26 (GREEN) and April 30, 2003 (BLUE)
Conclusions

ERS –1&2 Tandem data Pair

• RMS error of 50 m observed in case of Gangotri DEM.

• Due to phase jumps in unwrapping, smaller areas need to be processed for better DEM.

• Differential fringes are seen more in Siachen than Gangotri. Some fringes may be due to poor resolution of SRTM DEM (90m). ASTER DEM may be more useful for generating differential fringes.

  *Ground truth information for movement not available.*
ENVISAT ASAR data pair

- Lot of decorrelation observed over Glacier area using data sets with long time interval.
- Data sets with 35 days gap show better promise.
- Coherence image useful to demarcate terminus and observe glacier retreat.
- More data sets required to achieve better coherence.
- Decorrelation also due to snow melting, vegetation.
- SLC data useful to map glacier facies and snow cover.
Thank-you