ISRO Science Plan for NISAR Mission

Manab Chakraborty

Space Applications Centre
### ISRO Supported Applications

1. **Ecosystem Structure:** 1.1 Agriculture Biomass & Crop Monitoring; 1.2 Forest Biomass; 1.3 Biomass Change; 1.4 Mangroves / Wetlands; 1.5 Alpine Vegetation

2. **Land Surface Deformation:** 2.1 Inter-seismic / Co-seismic Deformations; 2.2 Landslides; 2.3 Land Subsidence; 2.4 Volcanic Deformations

3. **Cryosphere:** 3.1 Polar Ice Shelf / Ice sheet; 3.2 Sea Ice Dynamics; 3.3 Mountain Snow/ Glacier 3.4 Glacier Dynamics (Himalayan Region)

4. **Coastal Studies & Oceanography:** 4.1 Coastal erosion / shoreline change; 4.2 High / Low Tide lines; 4.3 Coastal bathymetry; 4.4 Ocean surface wind; 4.5 Ocean wave spectra; 4.6 Ship detection

5. **Disaster Response:** 5.1 Floods; 5.2 Forest Fire; 5.3 Oil Spill; 5.4 Earthquakes / Others

6. **Geological Applications:** 6.1 Structural & Lithological mapping; 6.2 Lineament study; 6.3 Paleo-Channel study; 6.4 Geomorphology
**Agriculture: Indian Agricultural Scenario**

**Geographical Area**: 329 mha

**Net Area Sown**: ~142 mha

**Food production**: >200 mt

**Agri. Share of GDP**: 14%

**CROP PRODUCTIVITY**
- Rice ~ 2.1 t/ha (China 5.8)
- Wheat ~ 2.9 t/ha (UK 6.9)

**Cropping Intensity**: 135.1%

**Net Irrigated Area**: ~57 mha

**Fertiliser Consumption**: ~106 kg/ha

**Area under HYV**: 76 mha

**LAND HOLDING SIZE**
- **Average (India)**: 1.57ha
- Punjab: 4.74 ha
- Uttar Pradesh: 0.83 ha
- Kerala: 0.33 ha

**DEGRADED LAND (% Geo. Area)**
- India: 49.8
- China: 30.0
- Asia-Pacific: 31.3
Forecasting Agricultural output using Space, Agrometeorology and Land-based observations (FASAL)

- Conventional
- Agro Meteorology
- Remote Sensing

- Cropped area
- Crop condition
- Crop acreage
- Crop yield

MULTIPLE IN-SEASON FORECAST:
- Pre-Season
- Early-Season
- Mid-Season State
- Pre-Harvest State
- Pre-Harvest District
Data is acquired based on the region’s crop calendar. Normally three dates are acquired; however, in some critical cases a fourth date is acquired.

FIRST ACQ.  
- Puddling
- Transplanting

SECOND ACQ.  
- Tillering
- Peak Veg.

THIRD ACQ.  
- E. Flowering

FIRST FORECAST  
45 Days after transplanting. Accounts for more than 75% season’s rice

SECOND FORECAST  
30 days before harvesting
Agriculture: Temporal Signatures of Major Crops

Early season crop information, biophysical parameter retrieval, damage assessment due to natural catastrophes.

Crop discrimination with temporal SAR (HH-pol) Data

NI-SAR Science Workshop, SAC Ahmedabad – 17th & 18th Nov. 2014
Agriculture: Crop Acreage and Yield Estimation

Sample Segment Approach

MIDNAPUR Dist. (WB)
Total Segments: 552
Total Crop segments: 533
Sample segments: 72
Crop area per segment: 610.6 ha.
District crop area: 0.325 m ha
CV: 5.38

Acreage:
After classification and accuracy check:
- Crop proportion per segment is calculated
- Proportion is multiplied by N to get the crop area for the district
- Correct for the pseudo district area.
- Aggregate district wise area to get state area.
- Project to National rice area

Yield:
Yield for the season is modeled based on the following information.
- Daily weather data
- Station latitude
- Rain fall, $T_{\max}$, $T_{\min}$ and solar radiation
- GDDs to reach emergence
- GDDs from emergence to flowering
- Historical yield database of the region for the past 15-20 years is considered.
- SAR based rice biomass and grain yield (use HI)
Agriculture: Crop Damage Assessment

Reduction in Rice area in HARYANA State due to drought in 2009

- 2009 Normal Yr
  - FCC: June 10, July 04, July 28

- 2008 Drought Yr
  - FCC: July 09, Aug 02, Aug 26

Damage Assessment due to Cyclone ‘Phailin’, OCT 12, 2013

- Data acquired on Oct 12, 13, 14 and 15 showed the recession of flood waters and data of Oct 25 showed the extent of damage to standing crop. Assessment of damage given to concerned departments by October 20, 2013.

- Crop damage assessed > 0.12 m ha.

Post-cyclone flood is shown in orange, additional area of persistent flood on 25th Oct. is shown in Magenta.
Agriculture: Rice Biomass Estimation

Rice Transplantation Monitoring using C-band SAR data

04 September 2011

Progress in Rice transplantation and biomass in Gangetic West Bengal as monitored using SAR Data

Legend
- Deep water rice
- Intermediate water rice
- Shallow water rice
- Permanent vegetation
- Urban
- Water

Colour Codes

<table>
<thead>
<tr>
<th>TP Dates</th>
<th>Biomass kg/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 1F</td>
<td>0 – 1</td>
</tr>
<tr>
<td>Jun 2F</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Jul 1F</td>
<td>2 – 3</td>
</tr>
<tr>
<td>Jul 2F</td>
<td>3 – 4</td>
</tr>
<tr>
<td>Aug 1F</td>
<td>4 – 5</td>
</tr>
<tr>
<td>Aug 2F+</td>
<td>5 - 6</td>
</tr>
</tbody>
</table>
Evaluation of the Impact of Bringing Green Revolution in Eastern India (BGREI) program using RISAT-1 Data

<table>
<thead>
<tr>
<th>Physiographic zones</th>
<th>Gross percentage change in peak biomass of BGREI over non-BGREI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012-13</td>
</tr>
<tr>
<td>Coastal Odisha</td>
<td>12%</td>
</tr>
<tr>
<td>Central Odisha Plateau</td>
<td>16%</td>
</tr>
<tr>
<td>North-western irrigated belt</td>
<td>7%</td>
</tr>
<tr>
<td>Southern highlands</td>
<td>21%</td>
</tr>
</tbody>
</table>
### Science Questions and Applications Focus

- How are the carbon cycle and ecosystems (in Indian perspective) changing and what are the consequences for ecosystem sustainability and services?
- How do changes in climate and land use affect the carbon cycle, agricultural systems and biodiversity?
- Investigate management opportunities for minimizing disruption in the carbon cycle.

### SAR Mission Science and Applications Objective

- Determine the changes in carbon resulting from disturbance and subsequent re-growth of woody vegetation system
- Determine the area and yield of major crops in agricultural systems and their changes.
- Determine the extent of wetlands and the dynamics of flooded areas.
- Understand the impacts of ecosystem structure and its dynamics on biodiversity and habitat.

### Measurement Objectives

- Quantify woody biomass disturbance and recovery in India at hectare scales, annually.
- Characterize the seasonal dynamics of rapidly changing wetlands and agricultural systems in India.
- Characterize changes in Indian Himalayan alpine vegetation that serves as an indicator for climate change.

### Measurement Requirement

- Produce estimates of aboveground woody biomass of Indian forests within an error of 25% (or 25 t/ha) at 1 ha resolution for areas of low biomass (< 100 t/ha) annually.
- Map areas of vegetation disturbance at 1 ha resolution half-yearly for areas losing at least 50% canopy cover in India with a classification error < 25%.
- Map major crop area and yield (biomass < 60 t/ha) at 1 ha resolution every 12-24 days, over selected states in India. Crop area error shall be < 15% and biomass error < 25%.
- Map areas of wetlands including mangroves in India at 30m resolution and measure inundation dynamics (timing and area) every 15 days at 30m resolution within 25% error.
- Map areas and estimate aboveground biomass of alpine vegetation in Indian Himalayan region at 1 ha resolution half-yearly. Vegetation area error shall be <15% and biomass error < 25%.

**To be Updated ...**
Ecosystem Objectives

- Monitoring Changes in Ecosystem Structure and Biomass in Indian Region
  - Agriculture biomass
  - Forest Biomass and Biomass Change
- Mangrove Characterization
- Alpine Vegetation Characterization
- Wetlands Mapping and Inundation Monitoring

- The differential penetration of L- and S-band can be useful to characterize tree trunk biomass and vegetation undergrowth which is an important component for forest carbon stock estimation.
- L- and S-band in combination, can produce better above-ground biomass estimation and temporal change in biomass, compared to single frequency alone.

C-band HH backscatters from rice fields and measured fresh biomass. Saturation to biomass response can be seen from 5 kg/m² (50 t/ha). The retrieval accuracy is good up to 4 kg/m². It is expected that S- / L-band retrieval would be good from 4 to 10 kg/m², thereby, allowing monitoring of high-yielding crops.
Biomass of open forest, Mangroves, Scrub lands constituting more than 10% of the total geographical area of India and almost all agriculture crops can be mapped using L/S band SAR.

**Forest Cover of India (FSI, 2005)**

<table>
<thead>
<tr>
<th>Class</th>
<th>Area (Km²)</th>
<th>% of Geog. Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Dense Forest ( &gt; 70% crown cover)</td>
<td>54,569</td>
<td>1.66</td>
</tr>
<tr>
<td>Moderately Dense Forest (40% - 70% crown cover)</td>
<td>332,647</td>
<td>10.12</td>
</tr>
<tr>
<td>Open Forest (10% - 40% crown cover)</td>
<td>289,872 (≈43% of total FC)</td>
<td>8.82</td>
</tr>
<tr>
<td><strong>Total Forest Cover</strong></td>
<td>677,088</td>
<td><strong>20.60</strong></td>
</tr>
<tr>
<td>Scrub Land</td>
<td>38,475</td>
<td>1.17</td>
</tr>
<tr>
<td>Mangroves</td>
<td>4,639</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Open forests & Mangroves are subjected to most of the disturbances and account for major contributors of biomass change.
Forests: Estimation of Carbon Stock in Indian Forests by FSI

Attributes attached with each sample plot

<table>
<thead>
<tr>
<th>S. No</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OID</td>
</tr>
<tr>
<td>2</td>
<td>Longitude</td>
</tr>
<tr>
<td>3</td>
<td>Latitude</td>
</tr>
<tr>
<td>4</td>
<td>State</td>
</tr>
<tr>
<td>5</td>
<td>District</td>
</tr>
<tr>
<td>6</td>
<td>Land Use</td>
</tr>
<tr>
<td>7</td>
<td>Crop Composition</td>
</tr>
<tr>
<td>8</td>
<td>Plot Volume of Trees 10 cm &amp; above (cu.m.)</td>
</tr>
<tr>
<td>9</td>
<td>Plot Leaf BM of Trees 10 cm &amp; above (kgs)</td>
</tr>
<tr>
<td>10</td>
<td>Plot Wood BM of Trees 10 cm &amp; above dia (kgs)</td>
</tr>
<tr>
<td>11</td>
<td>Plot Woody BM of Trees &lt;10 cm dia (kgs)</td>
</tr>
<tr>
<td>12</td>
<td>Plot Leaf BM of Trees &lt;10 cm dia (kgs)</td>
</tr>
<tr>
<td>13</td>
<td>Plot Forest floor BM (kgs)</td>
</tr>
<tr>
<td>14</td>
<td>Per Ha. Forest floor OCC (kgs)</td>
</tr>
<tr>
<td>15</td>
<td>Plot soil OCC (kgs)</td>
</tr>
<tr>
<td>16</td>
<td>Strata</td>
</tr>
</tbody>
</table>

Carbon Stock in Indian Forests (FSI, 2007)

<table>
<thead>
<tr>
<th></th>
<th>Biomass (million tons)</th>
<th>Carbon stock (million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above ground biomass</td>
<td>4760</td>
<td>2162</td>
</tr>
<tr>
<td>Below ground biomass</td>
<td>1501</td>
<td>682</td>
</tr>
<tr>
<td>Dead wood</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>Litter</td>
<td>383</td>
<td>161</td>
</tr>
<tr>
<td>Soil</td>
<td>-</td>
<td>4270</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6674</td>
<td>7290</td>
</tr>
</tbody>
</table>
Estimation of Forest Biomass

Dehradun Region (Natural Forest)

Figure:
(a) C-band (Radarsat-2) and (d) L-band (ALOS-PALSAR) polarimetric images and corresponding maps of aboveground biomass (ton/ha) derived from filtered (b) C-HV, (c) C-RVI, (e) L-HV and (f) L-RVI data, using empirical inversion methods.

Kaithal Region, Haryana (Plantation)

Figure:
Left: RGB Image showing combination of X-, C- and L-band SAR data
Right: corresponding biomass map using multi-frequency based model

C- and L-band SAR backscatter (HV-pol) were found to saturate for Biomass of 80Mg/ha and 100-120Mg/ha, respectively (depending on vegetation type and structure). Dual-frequency SAR in L and S-bands will help in better estimation of biomass.
Biomass Accuracy Assessment

RMSE $\sigma^0 \approx 1.0$ dB (MAE = 0.7 dB)
Biomass : 80 t/ha

Mean Error: 09 t/ha (11%)
Biomass range: < 80 t/ha

\[ \sigma_{hv}^0 (b) = A \left( 1 - e^{-B*b} \right) + C \]

\( b \): Aboveground Biomass (ton/ha)
‘A’, ‘B’ and ‘C’ are calibration coefficients
Forests: Retrieval of Forest Biomass (above ground) using SAR data

**Multi-Linear Regression (MLR) Based Model**

**Study Area:** Saraswati Plantation Area, Kaithal, Haryana

**Veg. Type:** Plantation (*Eucalyptus, Acacia, Prosopis Juliflora*)

**Data Used:** FRS-1 HH+HV and RH+RV

---

**Multi-Linear Regression Model:**

\[
\text{Biomass} = a + b \times \sigma_{HH} + c \times \sigma_{HV}
\]

---

**Biomass Estimation using RISAT-1 FRS Dual-pol Data (Jun 2013)**
### Type-wise estimates of wetlands in India

<table>
<thead>
<tr>
<th>Wetland Type code</th>
<th>Wetland category</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1101</td>
<td>Lake/Pond</td>
<td>729532</td>
</tr>
<tr>
<td>1102</td>
<td>Ox-bow lake/Cut-off meander</td>
<td>104124</td>
</tr>
<tr>
<td>1103</td>
<td>High altitude wetland</td>
<td>124253</td>
</tr>
<tr>
<td>1104</td>
<td>Riverine wetland</td>
<td>91682</td>
</tr>
<tr>
<td>1105</td>
<td>Waterlogged (Natural)</td>
<td>315091</td>
</tr>
<tr>
<td>1106</td>
<td>River/Stream</td>
<td>5258385</td>
</tr>
<tr>
<td>1201</td>
<td>Reservoir/Barrage</td>
<td>2481987</td>
</tr>
<tr>
<td>1202</td>
<td>Tank/Pond</td>
<td>1310443</td>
</tr>
<tr>
<td>1203</td>
<td>Waterlogged (Man-made)</td>
<td>135704</td>
</tr>
<tr>
<td>1204</td>
<td>Salt pan (Inland)</td>
<td>13698</td>
</tr>
<tr>
<td>2101</td>
<td>Lagoon</td>
<td>246044</td>
</tr>
<tr>
<td>2102</td>
<td>Creek</td>
<td>206698</td>
</tr>
<tr>
<td>2103</td>
<td>Sand/Beach</td>
<td>63033</td>
</tr>
<tr>
<td>2104</td>
<td>Intertidal mud flat</td>
<td>2413642</td>
</tr>
<tr>
<td>2105</td>
<td>Salt Marsh</td>
<td>161144</td>
</tr>
<tr>
<td>2106</td>
<td>Mangrove</td>
<td>471407</td>
</tr>
<tr>
<td>2107</td>
<td>Coral Reef</td>
<td>142003</td>
</tr>
<tr>
<td>2201</td>
<td>Salt pan (Coastal)</td>
<td>148913</td>
</tr>
<tr>
<td>2202</td>
<td>Aquaculture pond</td>
<td>287232</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>14705015</strong></td>
</tr>
</tbody>
</table>

**Delineation of Maximum Water-spread using SAR Data**

- **West Bengal, India**
  - 07 July
  - 31 July
  - 24 Aug
  - 3-date

**Wetlands of India**

**Wetland Types**
- Inland
  - Lake/Pond
  - Ox-bow Lake
  - High Altitude wetland
  - Riverine Wetland
  - Waterlogged(natural)
  - River/Stream
  - Reservoir/Barrage
  - Tank/Pond
  - Waterlogged(man-made)
  - Salt Pan
- Coastal
  - Lagoon
  - Creek
  - Sand/Beach
  - Intertidal Mud-flat
  - Salt Marsh
  - Mangrove
  - Coral Reef
  - Salt Pan
  - Aquaculture Pond
  - State Boundary

**Distances**

- 0 kilometers
- 250 kilometers
- 500 kilometers
- 750 kilometers
- 1000 kilometers
<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Swath (Km)</th>
<th>Ground Range Resolution</th>
<th>Incidence Angle (Deg.)</th>
<th>Polarization</th>
<th>InSAR/PolinSAR</th>
<th>NEσ° (S-band)</th>
<th>Frequency of Coverage</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture Biomass</td>
<td>&gt; 200</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV (T) FP(B)</td>
<td>N/R</td>
<td>-20 dB</td>
<td>2 weeks for 4 months</td>
<td>Regional</td>
</tr>
<tr>
<td>Forest Biomass</td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV OR VV+VH (T) FP (B)</td>
<td>InSAR (B)</td>
<td>-20 dB</td>
<td>4 months</td>
<td>Regional/Global</td>
</tr>
<tr>
<td>Mangrove / Wetlands Characterization</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH+HV (T) FP(B)</td>
<td>InSAR (B)</td>
<td>-20 dB</td>
<td>4 months 2 weeks (B)</td>
<td>Regional</td>
</tr>
<tr>
<td>Alpine Vegetation Characterization</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH+HV (T) FP (B)</td>
<td>InSAR (T)</td>
<td>-20 dB</td>
<td>4 months</td>
<td>Regional</td>
</tr>
<tr>
<td>Biomass Change</td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV OR VV+VH (T) FP (B)</td>
<td>InSAR (B)</td>
<td>-20 dB</td>
<td>4 months</td>
<td>Regional/Global</td>
</tr>
</tbody>
</table>

Note: σ° sensitivity of 1dB is expected.

N/R: Not Required
T: Threshold; B: Baseline Requirements
### Science Traceability Matrix for L and S-band SAR

#### Deformation Objectives: Inter-Seismic Deformation, Landslide, Land Subsidence

<table>
<thead>
<tr>
<th>Science Questions and Applications Focus</th>
<th>Measurement Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>• How does the likelihood of damaging earthquakes change with location over time?</td>
<td><strong>Determine the changes in the near surface stress field and geometry of active fault systems over major seismically active regions in India</strong></td>
</tr>
<tr>
<td>• What behaviour of landslides and land subsidence can be used to forecast the onset of the activities / predict the magnitude in future?</td>
<td><strong>Determine land subsidence rates of major reported land subsidence areas (due to mining and/or groundwater induced) in India</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Map major landslide prone areas in the hilly regions of India</strong></td>
</tr>
<tr>
<td><strong>SAR Mission Science and Applications Objective</strong></td>
<td><strong>Measure displacement over known seismically active regions in India with an accuracy of 20mm with 12 days sampling capability at hectare scale</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Measure surface displacement over known land subsidence regions in India with an accuracy of 20mm with 12 days sampling capability at hectare scale</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Measure surface displacement over hill slopes in landslide prone areas with an accuracy of 50mm with 6 days sampling capability at hectare scale</strong></td>
</tr>
<tr>
<td><strong>Measurement Requirement</strong></td>
<td><strong>Map 3D surface displacement over some of the seismically active regions in India every fortnight to the greater of 20mm/yr at hectare scale</strong></td>
</tr>
<tr>
<td><strong>Instrument Requirement</strong></td>
<td><strong>Map 3D surface displacement/deformation over some of the land subsidence regions in India every fortnight to the greater of 20mm/yr at hectare scale</strong></td>
</tr>
<tr>
<td><strong>Spacecraft Requirement</strong></td>
<td><strong>Measure surface displacement over hill slopes in some of the landslide prone areas in India every week with accuracy greater than 50mm/cycle at hectare scale</strong></td>
</tr>
<tr>
<td><strong>Mission Requirement</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Data Returned and Data Products</strong></td>
<td></td>
</tr>
</tbody>
</table>

To be Updated ...
- Landslides
- Land Subsidence
- Deformation due to Seismic Activity
  - Co-Seismic
  - Inter-Seismic

Landslide movement observed on ERS 1 & 2 Differential Interferogram (a) with in red polygon and landslide scare observed on corresponding ETM PAN image in red square box (b).

The average rate of land subsidence in Kolkata city obtained from differential interferogram is 6.55 mm/year (Image Courtesy: R.S. Chatterjee et al, 2006).
Postseismic stress changes (in bars) after 6 years of 2001 Bhuj earthquake. The star represents the epicenter of 2001 Bhuj earthquake. A good correlation is observed between the positive stress region (max 1 bar) and the migration of seismicity towards east along the SWF and towards NW in the Banni area.

Post Seismic deformation in Kachchh region, Gujarat mapped using ENVISAT ASAR data for 2008-2009. The LOS displacement is negative (~ -20 mm) to the south indicating upliftment and positive (~20 mm) to the north indicating subsidence. (Image Courtesy: K.M. Sreejith, SAC)
Deformation : Seismicity

Seismicity in India

Cartoon showing schematically the flexure of India caused by its collision with the southern edge of the Tibetan Plateau. (from Bilham et al.)

Potential InSAR Application Areas

A. Interseismic / Post Seismic Deformation
   1. The Indo-Eurassian collision zone (velocity @ 10-25mm / year across Regional Thrusts)
   2. Intra-plate seismic zones
      a. Kutch (Gujarat)
      b. Jabalpur (Madhya Pradesh)
      c. Latur (Maharashtra)

B. Co-seismic deformation monitoring in these areas
Land Subsidence: Potential NISAR Applications

1. Mining / Coal fire related Land subsidence in Jharaia coal field (Jharkhand)
2. Ground water related land subsidence in Indo-Gangetic Plains
3. Oil /Ground water exploitation related subsidence in Delta regions (Krishna-Godavari Delta)

Landslides: Potential NISAR Applications

1. Measurement of Creep as indications of future slope failures
2. Interferometric Coverage of major landslide events (coherence loss) during rainy season (where optical data coverage is not feasible)

- About 0.41 million km² i.e. 12.6% of land area of India is vulnerable to landslides
- Triggered mainly during monsoon (June-Sept.) or by cloudbursts / earthquakes
### Science / Observational Requirement for Deformation Objectives

<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Swath (Km)</th>
<th>Ground Range Resolution</th>
<th>Incidence Angle (Deg.)</th>
<th>Polarization</th>
<th>InSAR/PolInSAR</th>
<th>NEσ° (S-band)</th>
<th>Frequency of Coverage</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inter-Seismic Strain</strong></td>
<td>&gt; 200</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH (T)</td>
<td>InSAR (T)</td>
<td>-15 dB</td>
<td>2 weeks</td>
<td>Global (&gt;1mm/yr)</td>
</tr>
<tr>
<td><strong>Co-Seismic Deformation</strong></td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH (T)</td>
<td>InSAR (T)</td>
<td>-15 dB</td>
<td>2 weeks</td>
<td>Regional (&gt;1mm/yr)</td>
</tr>
<tr>
<td><strong>Land Subsidence</strong></td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH (T)</td>
<td>InSAR (T)</td>
<td>-15 dB</td>
<td>Monthly 2 weeks (B)</td>
<td>Local (&gt;5mm/yr)</td>
</tr>
<tr>
<td><strong>Landslide</strong></td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH (T)</td>
<td>InSAR (T)</td>
<td>-15 dB</td>
<td>Weekly (during rainy season)</td>
<td>Local (&gt;5mm/yr)</td>
</tr>
<tr>
<td><strong>Volcanic Deformation</strong></td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH (T)</td>
<td>InSAR (T)</td>
<td>-15 dB</td>
<td>2 weeks (selective)</td>
<td>Local (&gt;1mm/yr)</td>
</tr>
</tbody>
</table>

Note: Temporal Baseline of 2 weeks and Spatial Baseline of 300m is required as threshold

T: Threshold;  B: Baseline Requirements
### Science Questions and Applications Focus

- What is the response of ice sheets to climate change? What will the future contribution of ice sheets to sea level be?
- What is the interaction between sea ice and climate? What are the inter-annual changes in sea ice, surface melting and permafrost?
- What is the state of Himalayan Glaciers and how do Himalayan glaciers respond to regional hydrological cycle and climate change?

### Measurement Objectives

<table>
<thead>
<tr>
<th>SAR Mission Science and Applications Objective</th>
<th>Measurement Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine ice sheet and sea ice deformation to characterize and understand the controlling processes and their sensitivity to climate change</td>
<td>Map 3D surface displacement of ice sheet/shelf each winter to the greater of 1m/yr at 100m resolution at weekly sampling intervals.</td>
</tr>
<tr>
<td>Understand the dynamics of polar ice and its possible impact on climate change at regional scale.</td>
<td>Map inter-annual variability of ice sheet/shelf horizontal velocity in areas of rapid seasonal change to the greater of 5m/yr at 500m resolution, at weekly sampling intervals.</td>
</tr>
<tr>
<td>Determine spatio-temporal changes of Himalayan Glaciers to understand their response to regional climate change</td>
<td>Measure sea ice velocity at 100m/day accuracy on a 5km grid every 3 days.</td>
</tr>
</tbody>
</table>

###Measurement Requirement

- Characterize sea ice by thickness, age, types and measure sea ice velocity at 100m/day accuracy on a 5Km grid every 3 days.
- Acquire data sets to characterize Himalayan snow/glaciers at 30m resolution every 12 days. Map glacier zones, Snowline and ELA. Measure glacier movement with an accuracy of 1m/day and glacier displacement of 5cm/yr at 100m scale every 6 days.

### Map glacier zones and estimate transient ELA every 12 days for representative glaciers from each climatic zone of HKH region. Measure glacier velocity within an error of 1m/day and glacier displacement within an error of 1m/yr at 100m scale, every week over Himalayan region.

### To be Updated...
Dynamics of polar ice sheet – Glacier - Ice shelf - Ocean system

Sea ice Dynamics in Polar Oceans
- Sea-ice Thickness
- Sea-ice Motion
- Sea-ice Types

Mountain Snow and Glacier
- Snow Cover Area
- Dry / Wet Snow Characterization
- Snow Physical Parameter Retrieval

Mountain Glacier Dynamics

Fig: (Top) Surface melting observed over the Antarctic Ice-shelves using scatterometer data (Here Melting Index MI represents the accumulated temporal reduction in Sigma-0 during summer from its average (preceding) winter value). [Antarctic Ice Shelves (1) Amery, (2) West and (3) Shackleton; QuikSCAT Data: 1999-2009; OSCAT Data: 2009-10].

Fig: (Left) Decadal changes observed in surface melting over the Antarctic Ice-shelves using scatterometer data. (a) & (b) Maximum MI observed over the Antarctic continent and (c)&(d) Average MI observed for the Antarctic continent. The area showing higher MI in (a) and (c).
**Cryosphere Objectives**

**Snow wetness Mapping and Mountain Glacier Dynamics**

*Fig*: Glacier motion studies in the Himalayan region using SAR and Optical data based on feature tracking techniques; (a) Interferogram and (b) Coherence Image of Gangotri Glacier prepared from ERS-1/2 images of 25-26 March 2006; (c) corresponding Glacier displacement image (Thakur et al., 2012)

*Fig*: Snow wetness mapping in Manali watershed area (Beas River, Himachal Pradesh, India) using ENVISAT ASAR data (Thakur et al., 2008).
Snow/Glacier and Sea-Ice / Polar-Ice Applications

- L- and S-band SAR due to their different scattering properties associated with buried rocks and ice can be used together to identify buried moraines in glaciers.

- Radar index based on L- and S-band backscatter can be used to study subsurface features / materials in Polar Ice.

- Sea-ice classification and estimation of sea-ice thickness have been found to improve when dual-frequency SAR data is used.

Simulated SAR backscatter in L- and S-band as varies with Inc. angle corresponding to ice and buried rocks.

Radar Index based on L-band and S-band backscatter that separates a layer consisting of rock debris from a layer consisting of ice.
Potential of NISAR Application

Himalayan Snow / Glaciers
1. Mass balance studies
2. Glacial velocity
3. Glacial Lake Dynamics
4. Snow cover mapping

Snow Wetness

Snow wetness (w%) vs. Backscattering Coefficient (σ0) in dB

\[ \sigma_0 = -0.3155w^3 + 4.3491w^2 - 19.235w + 9.8077 \]
\[ r = 0.96 \]
\[ SE = 1.5571 \]
at 95 % CI
Cryosphere: Himalayan Snow/Glacier

Comparison of SAR derived result with Optical remote sensing analysis

LEGEND
- DCIZ
- BIZ
- SIZ
- WSZ
- WSZ not fully wet
- Seasonal FPZ

Snowline Altitude of Gangotri Glacier

Snowline Altitude of Chhota Shigri Glacier

RISAT-1 MRS dual-pol FCC 24/07/2013
Landsat 8 natural color composite 23/07/2013
Decadal average and maximum Melting Index (MI)

Impact of surface melting on rift propagation

Data: (i) For Melting Index (MI): QuikSCAT (1999-2009) and OSCAT (2009-10); (ii) For Rift length: RAMP data (2000); RADARSAT-2 (2013) and MODIS (500m from NSIDC)

- Melting Index found to be significantly correlated with the propagation of rifts with narrow width (like T1)
- Episodic intense melting events accelerates rift propagation

Melt pattern over West and Shackleton are similar to that observed for Larsen

Increase during 2000-2013 (km)

<table>
<thead>
<tr>
<th>Rift</th>
<th>Length</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>18.0</td>
<td>2.0</td>
</tr>
<tr>
<td>T2</td>
<td>11.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Monitoring of ice shelf advancement (Amery Ice Shelf)

Data: 1997 and 2000 RAMP RADARSAT data; 2013: RISAT-1 data

Disp=17.6 km
Disp=15.9 km
Disp=10.8 km
Disp=10.1 km

1997 position
2000 position
2013 position

1997
2000
2013

Data: 1997 and 2000 RAMP RADARSAT data; 2013: RISAT-1 data
<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Swath (Km)</th>
<th>Ground Range Resolution</th>
<th>Incidence Angle (Deg.)</th>
<th>Polarization</th>
<th>InSAR/PolInSAR</th>
<th>NE&lt;sup&gt;σ°&lt;/sup&gt; (S-band)</th>
<th>Frequency of Coverage</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice Sheet / Shelf Dynamics</td>
<td>&gt; 200</td>
<td>100 m</td>
<td>30 - 45</td>
<td>VV (T) VV+VH (B)</td>
<td>InSAR (T)</td>
<td>-25 dB</td>
<td>2 weeks over winter months</td>
<td>Antarctica</td>
</tr>
<tr>
<td>Sea ice Dynamics</td>
<td>- do -</td>
<td>100 m</td>
<td>30 - 45</td>
<td>VV (T) VV+VH (B)</td>
<td>InSAR (T)</td>
<td>-25 dB</td>
<td>2 weeks</td>
<td>Polar</td>
</tr>
<tr>
<td>Sea ice Types/ Thickness</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>VV+VH (T) FP (B)</td>
<td>N/R</td>
<td>-25 dB</td>
<td>2 weeks</td>
<td>Polar</td>
</tr>
<tr>
<td>Mountain Snow/Glacier</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH+HV (T) FP (B)</td>
<td>N/R</td>
<td>-25 dB (T) -28 dB (B)</td>
<td>2 weeks</td>
<td>Himalayan region</td>
</tr>
<tr>
<td>Mountain Glacier Dynamics</td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV OR VV+VH (T) FP (B)</td>
<td>InSAR (T)</td>
<td>-25 dB (B) -28 dB (B)</td>
<td>2 weeks</td>
<td>Himalayan region</td>
</tr>
</tbody>
</table>

Note: σ° sensitivity of 1dB is expected.
### Science Questions and Applications Focus

- What is the temporal behavior of ocean physical parameters such as wave spectra, coastal wind speed?
- How do environmental factors influence the coastal processes such as erosion/deposition and coastal LU/LC change?
- Retrieval of coastal bathymetry and high tide line in Indian coasts. Use SAR data for ship detection and oil-slick detection.

### SAR Mission Science and Applications Objective

- Determine temporal behaviour of ocean wave spectra and coastal wind speed/direction.
- Determine coastal bathymetry in selected Indian coasts.
- Monitor coastal erosion and deposition at half-yearly time scale and Demarcate high tide line for selected Indian coasts.
- Detect and monitor ships and oil-slick in selected coastal waters of India.

### Measurement Objectives

- Retrieve wave spectra and coastal wind speed on weekly basis at 1 sq km scale.
- Retrieve coastal bathymetry at 100m resolution and map coastal erosional/depositional features at 30m resolution, half yearly.
- Detect and Monitor of ships and oil-slicks in the coastal water on daily to weekly basis.

### Measurement Requirement

- Produce estimation of coastal wind speed weekly within the error of 2m/sec at 1km resolution.
- Produce estimation of coastal bathymetry half yearly within the error of 20cm at 100m resolution.
- Produce maps of coastal erosional/depositional features at 30m resolution, half yearly.
- Produce maps of coastal high tide line and low tide line within the error of 5m at 30m resolution, monthly basis.
- Detect and Monitor ships and oil-slicks in the coastal water on daily to weekly basis (depending on the need).

To be Updated …
Coastal & Ocean Science Objectives

- Mapping Coastal Erosion and Shore-line Change
- Demarcation of HTL and LTL for CRZ mapping
- Ocean Parameter Retrieval
  - Ocean Surface Wind Speed
  - Determination of wave spectra and identification of Upwelling zones
  - Coastal Bathymetry
  - Current Fronts, Eddies & Internal Wave
- Ship Detection

Synthetic aperture radar images of the ocean surface very often reveal a range of signatures inscribed on the uppermost layers of the sea.

These telltale variations in surface roughness can be interpreted in terms of geophysical processes occurring on the surface of the sea.

L-band is much more sensitive to the ocean roughness rather than C-band SAR, enabling better sensitivity to capillary waves to study oceanic internal waves, current fronts.
Coastal & Ocean Science Objectives

**Fig:** Retrieval of Coastal bathymetry from Envisat ASAR data

**Fig:** Ship detection using SAR data

**Fig:** Retrieval of ocean surface winds from Envisat ASAR data
Ocean and Coasts: Retrieval of Physical Parameters

Retrieval of high resolution (~1Km) Ocean Surface Winds

Retrieved Winds (13-Sep-2012)

Retrieval of ocean surface wave spectra from Envisat ASAR data

Ships Detection Using RISAT-1 Data

Validation with DG Shipping Data

<table>
<thead>
<tr>
<th>SAR Lat (Deg. N)</th>
<th>SAR Lon (Deg. E)</th>
<th>DG Ship Lat (Deg. N)</th>
<th>DG Ship Lon (Deg. E)</th>
<th>Distance (Deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.98</td>
<td>82.28</td>
<td>16.98</td>
<td>82.28</td>
<td>0.0039</td>
</tr>
<tr>
<td>17.00</td>
<td>82.31</td>
<td>17.00</td>
<td>82.32</td>
<td>0.0056</td>
</tr>
<tr>
<td>16.98</td>
<td>82.32</td>
<td>16.97</td>
<td>82.32</td>
<td>0.0110</td>
</tr>
<tr>
<td>16.98</td>
<td>82.32</td>
<td>16.97</td>
<td>82.32</td>
<td>0.0154</td>
</tr>
</tbody>
</table>

Violating dimension criteria
| Science Objectives               | Swath (Km) | Ground Range Resolution | Incidence Angle (Deg.) | Polarization | InSAR/PolinSAR | NEσ° (S-band) | Frequency of Coverage | Coverage       |
|---------------------------------|------------|--------------------------|------------------------|--------------|----------------|--------------|----------------------|----------------|----------------------|
| Coastal Erosion / Shoreline Change | > 200      | 30 m                     | 30 - 45                | HH+HV (T) FP / CP (B) | InSAR (B)    | -25 dB        | Half Yearly          | Local (selective) |
| High Tide / Low Tide Line       | - do -     | 30 m                     | 30 - 45                | HH+HV (T) FP / CP (B) | N/R           | -25 dB        | Half Yearly          | Local           |
| Coastal Bathymetry              | - do -     | 100 m                    | 30 - 45                | VV (T)       | N/R           | -20 dB        | Half Yearly          | Local (selective) |
| Ocean Wave Spectra              | - do -     | 100 m                    | 30 - 45                | VV (T)       | N/R           | -20 dB        | Bi-weekly           | Local           |
| Coastal Wind Speed              | - do -     | 100 m                    | 30 - 45                | HH+HV (T)    | N/R           | -20 dB        | Bi-weekly           | Local           |
| Ship Detection                  | - do -     | 30m                      | 30 - 45                | HH+HV (T)    | N/R           | -20 dB        | Weekly               | Local           |

Note: σ° sensitivity of 1dB is expected.

N/R: Not Required
T: Threshold;  B: Baseline Requirements
**Science Questions and Applications Focus**

- How can NISAR mission data best be used for disaster response?
- How can NISAR mission data be used for monitoring disaster prone areas to help adopt suitable management strategies?

**SAR Mission Science and Applications Objective**

- Respond to and mitigate the effect of disasters such as floods, earthquakes, forest fire and oil spill
- Monitoring of areas prone to natural or anthropogenic disasters such as floods, forest fire and oil spill

**Measurement Objectives**

- In the event of any natural or anthropogenic disaster anywhere in India, data shall be made available for rapid response.
- Monitor areas known to be prone to natural / anthropogenic disasters for any precursor of the event.

**Measurement Requirement**

- Map flood inundation area at 1 ha resolution every 3-5 days in the event of flood with an error of estimation < 15%
- Map forest fire / oil spill area at 1 ha resolution every 3 days or less in the event of an accident with an error of estimation < 15%
- Monitor identified flood prone areas in India during Monsoon season on weekly basis for possible water spread
- Monitor oil-slicks in the coastal water at selected locations on a weekly basis (depending on the need)
- Monitor selected forest fire prone areas on a fortnightly basis during pre-monsoon season for incidents of forest fire

**To be Updated …**
Floods
Forest Fire
Oil Spill

Floods in Bihar - 2010

The Saran embankment along Gandak River breached in Gopalganj district, North Bihar on 16th Sep, 2010. A new ring bund which was constructed parallel to the Saran Main Embankment to stop the gushing river water also caved in on 19th Sep, 2010 and flood waters entered several villages of Barauli block of Gopalganj district.

DSC, NRSC monitored the event and the flood inundation information was disseminated to Govt. of Bihar.

Fig: Mapping of Floods in Bihar – 2010 using SAR data (Source: NRSC)
**Fig:** Monitoring of Mumbai oil spill in August 2011 (Source: NRSC)
Oil Spill identified with areas of 0.72 sqkm (L Band) and 0.50 sqkm (C Band) for the 90L oil Spill

Experimental oil spill studies off Diu coast, Gujarat with DLR ESAR Data

Disaster Response: Oil Spill
Potential NISAR Application for Flood Hazard

- Monitoring and mapping of wide area floods in India as NISAR increases the frequency of monitoring
- Detailed flood mapping for specific areas

Near Real Time Flood Mapping and Monitoring

Monitoring of cyclone "Phailin" in Oct, 2013

Flood progression within 12 hrs as captured by RISAT & RADARSAT
<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Swath (Km)</th>
<th>Ground Range Resolution</th>
<th>Incidence Angle (Deg.)</th>
<th>Polarization</th>
<th>InSAR/PolinSAR</th>
<th>NE$\sigma^o$ (S-band)</th>
<th>Frequency of Coverage</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>&gt; 200</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV (T)</td>
<td>N/R</td>
<td>-25 dB</td>
<td>Weekly (event based)</td>
<td>Local</td>
</tr>
<tr>
<td>Forest Fire</td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV (T)</td>
<td>N/R</td>
<td>-20 dB</td>
<td>Weekly (event based)</td>
<td>Local</td>
</tr>
<tr>
<td>Oil Spill</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH+HV (T)</td>
<td>N/R</td>
<td>-20 dB</td>
<td>Weekly (event based)</td>
<td>Local</td>
</tr>
<tr>
<td>Others / Earthquake</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH+HV (T)</td>
<td>N/R</td>
<td>-20 dB</td>
<td>Weekly (event based)</td>
<td>Local</td>
</tr>
</tbody>
</table>

Note: $\sigma^o$ sensitivity of 1 dB is expected.

N/R: Not Required

T: Threshold; B: Baseline Requirements
Geological Applications

- Detection of Paleo-channels and other sub-surface Features
- Geo-morphological and Structural Mapping
- Lineament Mapping
- Lithological Mapping

**Fig:** Applications of SAR Data in Identification of Lineaments and Paleo-channels

**Fig:** RISAT SAR and LandSat ETM Merged (Bundi Area)

**Science Requirement:** Dual pol (HH+HV) data, Inc. angle: 30-45 deg, Ground range resolution 100m (except for lineament/paleo-channel where 30m data is required), Coverage 1 month – half year, Very high resolution (10m) data for morphological mapping.
Potential NISAR Application

- **SAR Data** can highlight Geological Structures (faults/fractures) in Pediment / Weathered or Shallow Buried Pediment Areas / Alluvial or Aeolian Plains
  - Feeble signature in optical data
  - Clearly discernable in SAR data of appropriate look direction and polarization and incidence angle
- **Mapping of Palaeochannels** in Arid environment
- **Can** highlight low-relief morphological features

Comparison of structure in optical and C band SAR data Rajpura-Dariba Area, Rajasthan, India

- East looking , Risat-1 MRS, HH Data
- Optical Data

Lineaments nearly co-trending the Look Direction are highlighted in the HH polarization Data

Identified Uranium Prospects (red dots) along intersection of faults/fractures
<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Swath (Km)</th>
<th>Ground Range Resolution</th>
<th>Incidence Angle (Deg.)</th>
<th>Polarization</th>
<th>InSAR/PolinSAR</th>
<th>NEσ° (S-band)</th>
<th>Frequency of Coverage</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural &amp; Lithological Mapping</td>
<td>&gt; 200</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV (T) FP / CP (B)</td>
<td>InSAR (B)</td>
<td>-20 dB</td>
<td>Half Yearly</td>
<td>Regional</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>- do -</td>
<td>30 m</td>
<td>30 - 45</td>
<td>HH+HV (T) FP / CP (B)</td>
<td>InSAR (B)</td>
<td>-20 dB</td>
<td>Half Yearly</td>
<td>Local / Regional</td>
</tr>
<tr>
<td>Lineaments / Paleo-channel</td>
<td>- do -</td>
<td>30m</td>
<td>30 - 45</td>
<td>HH+HV (T)</td>
<td>N/R</td>
<td>-20 dB</td>
<td>Half Yearly</td>
<td>Local / Regional</td>
</tr>
</tbody>
</table>

N/R: Not Required
T: Threshold;   B: Baseline Requirements
THANK YOU