ENGAGING THE WILDFIRE APPLICATIONS COMMUNITY WITH SAR

NISAR Applications Team: E. Natasha Stavros*, Susan Owen*, Cathleen Jones*

Co-Authors: Marco Lavalle*, Sang-Ho Yun*, Sassan Saatchi*, Josef Kellndorfer (Earth Big Data), Paul Rosen*

* Jet Propulsion Laboratory, California Institute of Technology

Copyright 2017 California Institute of Technology. U.S. Government sponsorship acknowledged. JPL CL#17-1066
OBJECTIVES

• **Increase SAR literacy in the context of wildfire management and the upcoming NISAR mission**

• **Identify the best venue and approach for reaching the wildfire community**
  - **Build partnerships and collaborations to identify and develop needed information products**
  - **Identify gaps in knowledge of highest value to the community with focused and detailed discussions of what the SAR data needs are including:**
    - **Assess the feasibility of NISAR to meet the top priorities for the application area**
    - **Identify high priority Applications for NISAR to focus efforts**
OUTLINE

• Introduction to SAR (15 min)
• Applications for Wildfire Management (15 min)
• NISAR Flight Project and Applications Plan Overview (10 min)
• Table Top Exercise (45 min)
• Concluding Thoughts (5 min)
WHY SAR?

- **Cloud penetration**
  - Key for monitoring tropical forests and Arctic/boreal
  - Key for annual observations
- **Nighttime observations**
  - Monitor poles during winter
- **Sensitivity to forest vertical structure**
- **Sensitivity to flooding and soil moisture**

*Slide Courtesy of: Josef Kellndorfer*

THE BASICS

- **Figures from this slide and fantastic educational resource:** Canada Centre for Mapping and Earth Observation (formerly Canada Centre for Remote Sensing), Natural Resources Canada.

- **Electromagnetic Waves emitted from a source, propagate in horizontal (H) and Vertical (V) with field strength and phase in each direction.**

- **Radar uses microwaves**

- **4 Techniques:**
  1. Simple backscatter
  2. Coherent polarimetry
  3. Polarimetric interferometry (InSAR/PolInSAR)
  4. Tomography

(http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/)
(1) Simple Radar Backscatter

- Radar transmits alternatively H and V polarized waves
- Radar receives simultaneously H and V
- Amplitude of backscattered energy (no phase)

\[
\begin{pmatrix}
E^s_H \\
E^s_V 
\end{pmatrix} = e^{-j\beta r} \frac{r}{S} \begin{pmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{pmatrix} \begin{pmatrix}
E^i_H \\
E^i_V
\end{pmatrix}
\]

scattering matrix \([S]\)

Figure 1-10b from this slide, courtesy of: Canada Centre for Mapping and Earth Observation (formerly Canada Centre for Remote Sensing), Natural Resources Canada

Slide Courtesy of: Marco Lavalle (JPL)
REVIEW THE ROLE OF POLARIZATION

- Polarization – alignment and regularity of EM field components of the wave in a plane perpendicular to the direction of propagation
- Noise – no recognizable frequency and amplitude
- EM Wave with no random component = fully polarized
- “backscatter” is energy (amplitude) that gets reflected back

C = Crown
T = Trunk

Radar Scattering Intensity

Short Wave

Long Wave

SAR Intro  Wildfire Apps.  NISAR  Table Top Exercise  Conclusions

Slide Courtesy of: Josef Kellndorfer
Coherent Radar Polarimetry

- Both amplitude and phase are retained and processed
- "Measurement" is the $3 \times 3$ covariance matrix
- Depolarization and scattering mechanisms to study ecosystems

\[
\begin{pmatrix}
E_v^n \\
E_h^n
\end{pmatrix} = \frac{e^{-j\beta r}}{r}
\begin{pmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{pmatrix}
\begin{pmatrix}
E_h^i \\
E_v^i
\end{pmatrix}
\]

\[
k = \begin{pmatrix}
S_{HH} \\
\sqrt{2}S_{HV} \\
S_{VV}
\end{pmatrix}
\]

\[
[C] = \frac{1}{N} \sum_{i} k_i k_i^H = \begin{pmatrix}
\langle |S_{HH}|^2 \rangle & \sqrt{2}\langle S_{HH}S_{HV} \rangle & \langle S_{HH}S_{VV} \rangle \\
\sqrt{2}\langle S_{HV}S_{HH}^* \rangle & 2\langle |S_{HV}|^2 \rangle & \sqrt{2}\langle S_{HV}S_{VV}^* \rangle \\
\langle S_{VV}S_{HH}^* \rangle & \sqrt{2}\langle S_{VV}S_{HV}^* \rangle & \langle |S_{VV}|^2 \rangle
\end{pmatrix}
\]
(2) Coherent Radar Polarimetry

Slide Courtesy of:
Marco Lavalle (JPL)
(2) Coherent Radar Polarimetry

\[ u_i = \begin{pmatrix} 
\cos \alpha_i \\
\sin \alpha_i \cos \beta_i e^{j \delta_i} \\
\sin \alpha_i \sin \beta_i e^{j \gamma_i}
\end{pmatrix} \]

parameterized eigenvector

\[ p_i = \frac{\lambda_i}{\sum_{q=1}^{3} \lambda_q} \]

eigenvalues

Alpha “scattering mechanism”

\[ \alpha = \sum_{i=1}^{3} p_i \alpha_i \quad 0 \leq \alpha \leq \frac{\pi}{2} \]

Slide Courtesy of:
Marco Lavalle (JPL)
(3) Polarimetric Radar Interferometry

- polarimetry “sees” different forest components
- interferometry retrieves the 3D location of the component
- canopy height, vertical structure

\[ \gamma = |\gamma|e^{j\varphi} = \frac{\langle s_1 s_2^* \rangle}{\sqrt{\langle s_1 s_1^* \rangle \langle s_2 s_2^* \rangle}} \]

PolInSAR coherence (temporal and volumetric)

\[ \gamma(w_1, w_2) = f(p_1, p_2, \ldots, p_n) \]

PolInSAR model

model parameters
- canopy height
- wave extinction
- ground topography
- surface-to-volume ratio

Slide Courtesy of:
Marco Lavalle (JPL)
SAR INTERFEROMETRY: MEASURING HEIGHT

IT'S SIMPLE TRIGONOMETRY

Slide Courtesy of: Josef Kellindorfer

 Courtesy NASA, JPL
(3) Polarimetric Radar Interferometry

Slide Courtesy of: Marco Lavalle (JPL)

(4) Radar Tomography

- Several (3+) repeated acquisitions over the same area
- Physical models and polarimetry are not needed
- Retrieval of 3D structure (layered backscattered coefficient)
APPLICATIONS FOR WILDFIRE MANAGEMENT

1. Change Detection and Mapping
2. Moisture: Soil and Vegetation
3. Biomass
ALOS LHH Time series

April 24th: Before fire
June 6th: 11 days after fire starts
Sept. 9th: Fire scar well identifiable

Acreage of Burn Severity

<table>
<thead>
<tr>
<th>Burn Severity</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unburned to Low</td>
<td>6,035</td>
</tr>
<tr>
<td>Low</td>
<td>2,679</td>
</tr>
<tr>
<td>Moderate</td>
<td>2,787</td>
</tr>
<tr>
<td>High</td>
<td>5,509</td>
</tr>
<tr>
<td>Increased Greenness</td>
<td>45</td>
</tr>
<tr>
<td>Non-Processing Area Mask</td>
<td>3,464</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20,519</strong></td>
</tr>
</tbody>
</table>

MTBS

Latitude: 34° 20' 10.6"
Longitude: -145° 45' 28.8"
Fire Ignition Date: May 26, 2010
Assessment Type: Extended
Pre-Fire Image Date: July 11, 2009 (Landsat 5)
Post-Fire Image Date: July 17, 2011 (Landsat 5)
CHANGE DETECTION USING FREQUENT REPEAT VISITS

UVASAR ID: 26524

- Number of data: 15
  - Before event: 14 & after event: 1
- All data is acquired using Full-Quad polarization
- Baseline: less than ~10 m
- No volumetric decorrelation
- Coherence is mainly determined by temporal decorrelation

### Parameter

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>L-Band 1217.5 to 1297.5 MHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>80 MHz</td>
</tr>
<tr>
<td>Resolution</td>
<td>1.67 m Range, 0.8 m Azimuth</td>
</tr>
<tr>
<td>Polarization</td>
<td>Full Quad-Polarization</td>
</tr>
<tr>
<td>ADC Bits</td>
<td>2, 4, 6, 8, 10 &amp; 12 bit selectable BFPQ, 180Mhz</td>
</tr>
<tr>
<td>Waveform</td>
<td>Nominal Chirp/Arbitrary Waveform</td>
</tr>
<tr>
<td>Antenna Aperture</td>
<td>0.5 m range /1.5 azimuth (electrical)</td>
</tr>
<tr>
<td>Azimuth Steering</td>
<td>Greater than ±20° (±45° goal)</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>&gt; 3.1 kW</td>
</tr>
<tr>
<td>Polarization Isolation</td>
<td>&lt; -25 dB (&lt; -30 dB goal)</td>
</tr>
<tr>
<td>Swath Width</td>
<td>&gt; 23 km</td>
</tr>
</tbody>
</table>

### Index & Acquisition Date

<table>
<thead>
<tr>
<th>Index</th>
<th>Acquisition Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2009.04.23</td>
</tr>
<tr>
<td>2</td>
<td>2009.09.18</td>
</tr>
<tr>
<td>3</td>
<td>2010.03.03</td>
</tr>
<tr>
<td>4</td>
<td>2010.04.15</td>
</tr>
<tr>
<td>5</td>
<td>2010.10.14</td>
</tr>
<tr>
<td>6</td>
<td>2010.12.07</td>
</tr>
<tr>
<td>7</td>
<td>2011.07.08</td>
</tr>
<tr>
<td>8</td>
<td>2011.10.28</td>
</tr>
<tr>
<td>9</td>
<td>2012.04.27</td>
</tr>
<tr>
<td>10</td>
<td>2013.05.31</td>
</tr>
<tr>
<td>11</td>
<td>2014.01.17</td>
</tr>
<tr>
<td>12</td>
<td>2014.10.23</td>
</tr>
<tr>
<td>13</td>
<td>2015.01.08</td>
</tr>
<tr>
<td>14</td>
<td>2015.05.11</td>
</tr>
<tr>
<td>15</td>
<td>2015.06.29</td>
</tr>
</tbody>
</table>

- Lake Fire
INCOHERENT CHANGE DETECTION (AMPLITUDE)

COHERENT CHANGE DETECTION (AMPLITUDE AND PHASE)

Slide Courtesy of: Sang-Ho Yun (JPL)

SAR Intro  Wildfire Apps.  NISAR  Table Top Exercise  Conclusions
PERFORMANCE EVALUATIONS

<table>
<thead>
<tr>
<th>Product</th>
<th>PFA @ PD=0.85</th>
<th>PD @ PFA=0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coherence opt1</td>
<td>0.25</td>
<td>0.68</td>
</tr>
<tr>
<td>Coherence opt3</td>
<td>0.29</td>
<td>0.68</td>
</tr>
<tr>
<td>Individual Prob. of ground</td>
<td>0.14</td>
<td>0.77</td>
</tr>
<tr>
<td>Individual Prob. of volume</td>
<td>0.16</td>
<td>0.75</td>
</tr>
<tr>
<td>Averaged Prob. of ground</td>
<td>0.07</td>
<td>0.87</td>
</tr>
<tr>
<td>Averaged Prob. of volume</td>
<td>0.08</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Slide Courtesy of: Sang-Ho Yun (JPL)
MOISTURE: SOIL AND VEGETATION

Slides Courtesy of:

SAR Intro  Wildfire Apps.  NISAR  Table Top Exercise  Conclusions
Soil moisture estimation: ALOS-2 example

- Polarimetric ALOS-2 SLCs
- Multilook and coherency matrix generation
- Separation of scattering mechanisms
- Soil [T] matrix elements
- Model-based inversion
- Dielectric constant to soil moisture
- Soil moisture map

Slide Courtesy of: Marco Lavalle (JPL)
Soil moisture estimation: ALOS-2 example

**ALOS-2**
- Acquisition date is 2015/03/07
- Posting is 3.3 km to match SMAP posting
- Quad-polarimetric SAR data
- Model-based soil moisture retrieval

**SMAP**
- Acquisition date is 2015/04/25
- Posting is 3 km after multilooking
- 1 dot = 1 pixel enlarged for display
- Gaps are retrieval failures

---

Slide Courtesy of: Marco Lavalle (JPL)
SAR can help measure carbon emissions and removals from deforestation, degradation, and regeneration by measuring vegetation biomass and monitoring changes.

\[
\Delta C = \sum \Delta A \cdot B \cdot E_{def} + \sum A \cdot \Delta B \cdot E_{deg} + \sum A \cdot \Delta B \cdot R_{reg}
\]

where \( A \) is the area of forest type, with biomass \( B \), emission efficiency factor \( E \), and removal efficiency \( R \).
MAPPING GLOBAL FOREST BIOMASS

Conifer Forests

Deciduous Forests

L-band HH and HV (ALOS PALSAR)

Biomass Derived from L-band SAR & National Inventory

Slide Courtesy of: Sassan Saatchi (JPL)
NASA-ISRO SYNTHETIC APERTURE RADAR (NISAR) OVERVIEW AND APPLICATIONS PLAN OVERVIEW

Slides Courtesy of: Paul Rosen and Natasha Stavros
NISAR MISSION OBJECTIVES

**Relevant Scientific Objectives:**
- Understand the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems

**Relevant Applications Objectives:**
- Provide agricultural monitoring capability in support of food security objectives
- Apply NISAR’s unique data set to explore the potentials for urgent response and hazard mitigation

To be accomplished in partnership with the Indian Space Research Organisation (ISRO) through the joint development and operation of a space-borne, dual-frequency, polarimetric, synthetic aperture radar (SAR) satellite mission with repeat-pass interferometry capability.

Slide Courtesy of: Paul Rosen (JPL)
NISAR MISSION CONCEPT OVERVIEW

- Major partnership between US National Aeronautics and Space Administration (NASA) and Indian Space Research Organisation (ISRO)
- Baseline launch date: No earlier than 2021
- Dual frequency L- and S-band Synthetic Aperture Radar (SAR)
  - L-band SAR from NASA and S-band SAR from ISRO
- NASA 3.5 Gbps Ka-band telecom system to polar ground stations (> 24 Tbits/day downlink capability)
- Spacecraft: ISRO I3K with 1 Gbps telecom system
- Launch vehicle: ISRO Geosynchronous Satellite Launch Vehicle (GSLV) Mark-II (4-m fairing)
- 3 years science operations (5+ years consumables)
- All science data (L- and S-band) will be made available free and open, consistent with the long-standing NASA Earth Science open data policy
**NISAR CONCEPT SCIENCE OBSERVATION OVERVIEW**

<table>
<thead>
<tr>
<th>NISAR Characteristic</th>
<th>Would Enable:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-band (24 cm wavelength)</td>
<td>Low temporal decorrelation and foliage penetration</td>
</tr>
<tr>
<td>S-band (12 cm wavelength)</td>
<td>Sensitivity to light vegetation</td>
</tr>
<tr>
<td>SweepSAR technique with Imaging Swath &gt;240 km</td>
<td>Global data collection</td>
</tr>
<tr>
<td>Polarimetry (Single/Dual/Quad)</td>
<td>Surface characterization and biomass estimation</td>
</tr>
<tr>
<td>12-day exact repeat</td>
<td>Rapid Sampling</td>
</tr>
<tr>
<td>3-10 meters mode-dependent SAR resolution</td>
<td>Small-scale observations</td>
</tr>
<tr>
<td>3 years since operations (5 years consumables)</td>
<td>Time-series analysis</td>
</tr>
<tr>
<td>Pointing control &lt; 273 arcseconds</td>
<td>Deformation interferometry</td>
</tr>
<tr>
<td>Orbit control &lt; 500 meters</td>
<td>Deformation interferometry</td>
</tr>
<tr>
<td>&gt;30% observation duty cycle</td>
<td>Complete land/ice coverage</td>
</tr>
<tr>
<td>Left/Right pointing capability</td>
<td>Polar coverage, North and South</td>
</tr>
<tr>
<td>Noise Equivalent Sigma Zero ≤ -23 db</td>
<td>Surface characterization of smooth surfaces</td>
</tr>
</tbody>
</table>

NISAR Will Uniquely Capture the Earth in Motion

Additional content:

- SAR Intro
- Wildfire Apps.
- NISAR
- Table Top Exercise
- Conclusions
LEVEL 3 ECOSYSTEM PRODUCTS CURRENTLY BEING DEVELOPED FOR GLOBAL PRODUCTION AND RELEASED ANNUALLY

- **BIOMASS ESTIMATION**
  
  aboveground woody vegetation biomass annually at the hectare scale (1 ha) to an RMS accuracy of 20 Mg/ha for 80% of areas of biomass less than 100 Mg/ha.

- **DISTURBANCE DETECTION**
  
  global areas of vegetation disturbance at 1 hectare resolution annually for areas losing at least 50% canopy cover with a classification accuracy of 80%.

- **Agriculture Classification**
  
  crop area at 1 hectare resolution every 3 months with a classification accuracy of 80%.

- **Wetland Classification**
  
  inundation extent within inland and coastal wetlands areas at a resolution of 1 hectare every 12 days with a classification accuracy of 80%.
Slide Courtesy of: Paul Rosen (JPL)

NISAR APPLICATIONS PLAN

Legend
- NASA ESD Research & Analysis
- NASA ESD Project Division
- NASA ESD Applied Science
- NASA ESD Earth Science Technology Office (ESTO)

Roles
- Process/Method
- Deliverable

Activities
- FY 17-18
- FY 19-21

Funding
- NASA ESD
- Non-NASA Funding
- ROSES Solicitations
- NISAR Flight Project
- Distributed Active Archive Centers

Develop exemplar data products, partnerships for L3+ data production and distribution, and case study demonstration

Hands-on, table-top exercise Workshops

Online Webinars

NISAR Applications Working Groups

Application Area-Specific Workshops

Envoy Program

Online Virtual SAR Literacy Labs

Science Definition Team with Applications Co-Lead

Deputy Program Applications Leads

NISAR Flight Project

Applied Science Program Manager

NISAR Mission Program Manager

NASA HQ ESD

NISAR Flight Project

Alaska Satellite Facility Data Active Archive Center

Online Virtual SAR Literacy Labs

Non-NASA Funding

ARSET

ROSES Solicitations

Distributed Active Archive Centers

SAR Intro

Wildfire Apps.

NISAR

Table Top Exercise

Conclusions
QUESTIONS?
7 TABLES:
- 2 TABLES: BIOMASS/FOREST HEIGHT
- 2 TABLES: VEG/SOIL MOISTURE
- 2 TABLES: DETECTION AND MAPPING
- 1 TABLE: OTHER (CONSERVATION, ETC.)

BREAK INTO 3 GROUPS TO DISCUSS (20 MIN) & REPORT OUT (20 MIN):
1. WHAT AGENCIES/ORGANIZATIONS ARE THE KEY PLAYERS (I.E., WHO IS THE TRUSTED SOURCE OF INFORMATION USED IN THIS ARENA? IS THERE A “CHAMPION” WE SHOULD BE WORKING WITH?)
2. WHAT ARE THE CURRENT DECISION SUPPORT SYSTEMS EMPLOYED?
3. WHAT ARE THE INFORMATION GAPS IN THE CURRENT DECISION SUPPORT SYSTEMS?
4. CAN YOU SEE SAR HELPING TO FILL ANY OF THESE INFORMATION GAPS? IF SO, WHAT INFORMATION PRODUCTS WOULD NEED TO BE DEVELOPED (INCLUDING SPECIFICATIONS OF FREQUENCY, LATENCY, ETC.)?
5. WHAT ARE THE BEST WAYS TO ENGAGE WITH THE COMMUNITY WHO WOULD MOST WANT THIS DATA (E.G., HOW DO WE GARNER TRUST AND A COLLABORATIVE RELATIONSHIP)?
• **NISAR Ecosystems Deputy Application Lead:** [Natasha.Stavros@jpl.nasa.gov](mailto:Natasha.Stavros@jpl.nasa.gov)
  • NISAR Applications Mailing List: Workshops, NISAR Status updates, etc.
  • SAR Expert Connections
  • DEEPOL -- 10 week feasibility studies to see how SAR can work for you
  • 2 page informational on table
  • Tutorials/Educational Resources
    • SAREdu
    • UNAVCO
    • Natural Resources Canada
    • ARSET
THINGS TO THINK ABOUT
FROM DAVID GREEN’S ASP DISASTERS PROGRAM

- 2017 ROSES Disaster Call (out in May)
  - Strings:
    - Cost-sharing (multi-year take more burden each year)
    - ARL 4-9 exceptions can be made
    - Must have letter of support/Co-I/active member of team by stakeholder
  - Rolling 1 pg proposals that use ARIA ($40-50k to raise low ARL to ARL4 for proposing to the Disasters call + highly desired for many people across NASA centers/agencies)

- ESRI integration of NASA data into ArcGIS Online ——
  - Highest priority stakeholder community needs
  - What are decisional and science products
  - Highest priority is high ARL products
BACK-UP
NISAR IMAGING AND ORBIT GEOMETRY

- **Wide swath in all modes for global coverage at 12 day repeat (2-5 passes over a site depending upon latitude)**
- **Data acquired ascending and descending**
- **Left/Right Pointing Capability (Right nominal)**

*Observation Geometry*

12 m diameter Reflector

6 AM / 6 PM Orbit
98.5° inclination
Arctic Polar Hole: 87.5°R/77.5°L
Antarctic Polar Hole: 77.5°R/87.5°L
NISAR 12-day global forest observation allows estimation of forest biomass at 1-ha with the low uncertainty for biomass < 100 Mg/ha.
The global distribution of regions dominated by woody biomass < 100 Mg/ha

Slide Courtesy of: Sassan Saatchi (JPL)
LATENCY

SLIDES COURTESY OF: PAUL ROSEN
<table>
<thead>
<tr>
<th>Product</th>
<th>To DAAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>L0</td>
<td></td>
</tr>
<tr>
<td>L0A (catalog incoming raw data)</td>
<td>3.25</td>
</tr>
<tr>
<td>L0B Radar Signal Data</td>
<td>3.25</td>
</tr>
<tr>
<td>L1</td>
<td></td>
</tr>
<tr>
<td>Range-Doppler (i.e., Radar-Coordinate) Single-Look Complex (SLC)</td>
<td>30.33</td>
</tr>
<tr>
<td>Multi-Look Detected Browse (MLD)</td>
<td>0.54</td>
</tr>
<tr>
<td>L2 (all modes)</td>
<td></td>
</tr>
<tr>
<td>Geocoded Single-Look Complex</td>
<td>30.33</td>
</tr>
<tr>
<td>Interferogram (nearest-time pair)</td>
<td>8.67</td>
</tr>
<tr>
<td>Amplitude Image (most recent image in InSAR pair)</td>
<td>4.33</td>
</tr>
<tr>
<td>Unwrapped Interferogram</td>
<td>4.33</td>
</tr>
<tr>
<td>Geocoded Amplitude Image (most recent image in InSAR pair)</td>
<td>4.33</td>
</tr>
<tr>
<td>Geocoded Unwrapped Interferogram</td>
<td>4.33</td>
</tr>
<tr>
<td>L2 Ecosystem (Quad)</td>
<td></td>
</tr>
<tr>
<td>Polarimetric Image Channels</td>
<td>0.43</td>
</tr>
<tr>
<td>Polarimetric Coherence</td>
<td>0.43</td>
</tr>
<tr>
<td>Geocoded Polarimetric Image Channels</td>
<td>0.43</td>
</tr>
<tr>
<td>Geocoded Polarimetric Coherence</td>
<td>0.43</td>
</tr>
</tbody>
</table>

| Summary * |         |
| Prod Level | # of Prod Types | Volume (TB/day) |
| Level 0 | 2 | 6.5 |
| Level 1 | 2 | 30.9 |
| Level 2 | 10 | 58.1 |
| Total | 14 | 95.4 |

Total (TB) 95.44
# Standard Data Product Generation

## Timeline

- **Start = Day 0**
- **Day 1**
- **Days 10–21**
- **Finish = Days 11–30**

## Data Processing Flow

<table>
<thead>
<tr>
<th>Stage</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>Get TLM</td>
</tr>
<tr>
<td></td>
<td>Get Aux., Anc. Data</td>
</tr>
<tr>
<td></td>
<td>Process L0B Data</td>
</tr>
<tr>
<td></td>
<td>Get POE</td>
</tr>
<tr>
<td></td>
<td>Generate L1 Data</td>
</tr>
<tr>
<td></td>
<td>Generate L2 Data</td>
</tr>
<tr>
<td></td>
<td>Generate Science Report</td>
</tr>
</tbody>
</table>

## Data Sources

- **TLM**: Telemetry data
- **Aux., Anc. Data**: Auxiliary and ancillary data
- **L0A/B Data**: Level 0A/B data
- **Precision Orbit Data**: Precision orbit data
- **L1 Data**: Level 1 data
- **L2 Data**: Level 2 data
- **Science Report**: Science accountability and assessment report
- **Proc Parameters**: Processing parameters
- **DEM CalVal Data**: Digital elevation model calibration data
- **Aux. Data (NWP, etc)**: Auxiliary data (National Weather Service, etc.)
- **Observation Plans**: Planning data
- **Instrument Cal data**: Instrument calibration data
- **TLM**: Telemetry data
- **Observation Plans Ancillary data**: Observation planning ancillary data
- **L0A/B Data**: Level 0A/B data
- **DEM CalVal Data**: Digital elevation model calibration data
- **Observation Plans Aux., Anc. Data**: Planning and auxiliary/ancillary data
- **L0A/B Data**: Level 0A/B data
- **Precision Orbit Data**: Precision orbit data
- **Offline Analysis QA Data Problem Handling**: Offline analysis quality assurance and problem handling

## Analyst

- **Analysis**
- **Data Providers**

## External Data Providers

- **ASF DMRC**
- **JPL MDOOT (DDOIT)**
- **JPL FDT**
- **JPL MDOOT (DDOIT)**
- **JPL GPS**
- **ISRO**
**Notional* Urgent Observations**

*Urgent Response Plan is currently under development*

---

**Initial Response Planning**
- **3 hours**

**Plan Generation & ISRO Notification**
- **Updated Observation Plan**

**Generate L-band Updates**
- **Updated Uplink Products**

**Receive and Prepare Products for Uplink**
- **Wait for Uplink Pass and Uplink**

**Wait for Over-flight**
- **Observe & Downlink**

**Data Transfer to JPL**
- **Process to L1 (tbc)**

---

**Period**
- **Time from Request to Scheduled Observation(s)**: 24 (TBR) hours
- **Wait for overflight**

**Requirement**
- **5 – 11 hours**
- **3 to 5.5 hours**
- **0 – 8 days**

**Estimate**
- **Wait for overflight**

---

**Notes**
1. Only changes in observation priorities from “normal” to “urgent” are required. Only L-SAR changes are required.
2. Assumes 2 hour ISTRAC processing time.
3. Assume only one pass required for uplink.
4. Based on Monte-Carlo analysis showing >97% probability of over-flight at an arbitrary latitude within 8 days.
5. Assumes an DTE coverage gap no longer than 3 hours.
6. Assumes urgent response data is no more than 10% of daily volume.

---

**Responsibility Key**
- ISRO
- NASA/JPL
- **NISE/Indian**
Issues and Challenges of Near Real-Time Data Acquisition and Management

For missions:
• Mode requirements
• Mission operations
• Downlink costs
• Developing an urgent response play book to mark “urgent response” protocols
• Trade studies for understanding costs of meeting low latency
• Network costs

For applications communities:
• There is needed infrastructure for higher level processing for information products (that aren’t usually in L1 & L2 requirements)
• Such infrastructure requires investment for development
• Longer time-series of information products that utilize the international synthetic aperture radar (SAR) constellation can help justify the investment for such development
• High priority NRT data products for SAR:
  • change detection
  • soil moisture
  • sea ice