2015 NISAR Applications Workshop:
Applications Community Suggestions for Developing an Applications Plan

October 13-15, 2015

Workshop Report

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0. Executive Summary

The NASA-ISRO SAR (NISAR) Project conducted its second annual community Applications Workshop on October 13-15, 2015, building on the recommendations and findings of the first workshop held in 2014. NISAR, planned to launch in 2021, will deliver global time-series of polarimetric radar imagery with 12-day sampling and a repeating orbit that will enable repeat-pass interferometry over the life of the mission. The goals of the workshop were to construct a 5-year roadmap for developing the suite of products and software to support the needs of the diverse NISAR applied science end-user community, and to clearly establish guidelines with regard to Project support of applications and data latency to clearly set expectations. Workshop participants were asked to identify key activities (e.g., research/technology development, software or product development, training campaigns) that can be used to guide NASA and the NISAR project, as well as other agencies and private sector investments in the years leading up to NISAR's launch. Following the recommendations of the first workshop for increasing SAR literacy, we held a full day SAR training session on Tuesday, October 13 as a prelude to the two-day workshop October 14-15, 2015.

Invited presentations highlighted applied science areas with the potential to use SAR data, both currently considered mature and those possibly advanced by the mission. Breakout sessions discussed applications community observational needs and data product specifications in greater detail, and how these needs could be met with activities as part of an early engagement plan with the applications community.

There were four broad findings from the workshop that will inform the integration of NISAR into NASA's applications program and NISAR data into the community:

1. A NISAR Applications Plan would serve three categories of users:

- Experienced users: Researchers and other users accustomed to doing their own analysis or procuring end-products for their current needs, and for whom NISAR data will naturally be used as part of data infusion efforts
- Product-ready users: Researchers and potential users of NISAR data who have the technical background to integrate SAR data products into their data assimilation efforts. This community would directly benefit from early involvement with the anticipated developments of products and services that Sentinel-1A (and potentially other systems) will inspire
- Potential Users: Users who could potentially benefit from NISAR-derived products and services, but for whom no path for adoption has been identified

It would be advantageous for an application program from NISAR to address the varying needs of these users. For experienced and product-ready users the applications program could engage with developers in academia, research institutions and companies to foster integration of NISAR data into the products and services that exist or are planned over the coming years, working seamlessly with other SAR data sets. For new users, the Applications Program can engage the experienced users to serve as ambassadors, demonstrating how these data may solve problems for these users, and identify the impediments and solutions for adoption.

2. Workshop participants were in general agreement that the *applications value of NISAR data can be greatly enhanced by producing a set of clearly defined standards and prototype products well before launch* that would support immediate use of NISAR data acquired after launch. Most major NASA projects provide such standards and products before launch, but the request by workshop participants was to add the additional effort that would take NASA science products to application end-user products, or at least provide the necessary means to do so.

3. Workshop participants identified a wide range of applications, products, and services that have not been previously possible. However some of the identified applications could greatly increase the mission resources and volume of data currently planned for the NISAR mission by requiring a change in acquisition plan to include one more more of the following:

- wider bandwidth
- more observations than those planned
- greater polarization diversity than planned
- more ubiquitous dual-wavelength coverage, and
- reduced latency

As the NISAR Mission Level 1 Requirements were defined to meet science objectives, application objectives must be met within this scope. *One of the key objectives for an Application Plan is to balance applications' needs within existing NISAR science objectives and to provide constructive feedback to the mission for consideration in planning and development.*

4. Workshop participants recognized a key need of a NISAR applications plan to facilitate partnerships with a broad range of agencies and organizations. These partner agencies include the end-user communities, and their engagement is critical for a successful applications program. In some cases these partners may need to provide additional resources for the development of application-ready products beyond the scope of the mission. These partners also include groups that can provide expertise in SAR analysis as well as educational resources for increasing SAR literacy.

1. Overview

1.1. Mission Overview

The NASA-ISRO (NISAR) Project is developing a spaceborne satellite with L-band and S-band synthetic aperture radar (SAR) instruments with an expected launch in 2021. The primary science objectives for NISAR include: 1) understanding the response of ice sheets to climate change and the interaction of sea ice and climate, 2) understanding the dynamics of carbon storage and uptake in wooded, agricultural, wetland, and permafrost systems, and 3) determining the likelihood of earthquakes, volcanic eruptions, and landslides. Although the NISAR system design is now largely fixed to meet science requirements, presenting NISAR capabilities to Applications communities can help identify both the utility of the mission and research gaps or needs for using NISAR for applications.

1.1.1 Instrument-Defined Capabilities

The instrument system design includes both L-band and S-band SAR. The L-band instrument design derives from that of Uninhabited Aerial Vehicle SAR (UAVSAR) to incorporate its 80 MHz operation (~10 m ground resolution) and quad-polarization capability. The minimum resolution available in quad-polarization mode is 20 m ground resolution. Figure 1 shows the currently defined instrument capabilities.

NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, north and south

Figure 1 – NISAR radar characteristics, as of Oct. 2015.

1.1.2 Instrument Operational Capabilities

The nominal observation plan, as of October 2015, is designed to meet science requirements (Figure 2). Most of the land mass is to be imaged at 12 m x 8 m resolution, with the exception of some 6 m x 8 m acquisitions in the United States, some globally distributed urban areas, and India. High resolution data (3 m x 8 m) is only planned to be acquired over the Arctic and Antarctic.

1.1.3 Mission Operation Capabilities and Limitations

The mission operation, determined by the orbit, limits the minimum repeat time for acquiring the same swath for interferometry, and the maximum wait time before imaging one particular location on the Earth for disaster response. The repeat image interval for interferometry is 12 days, so if a baseline image has been acquired, in the event of an emergency a repeat acquisition can be made within 12 days.

Product generation and delivery is nominally 30 days after acquisition, but for emergency response, the latency is reduced to 5 hours.

Observation Strategy	L-band		S-band		Culling Approach	
Science Target	Mode+	Resolution	Mode	Resol.	Sampling	Desc Asc
Background Land	DP HH/HV	12 m x 8 m			cull by lat	
Land Ice	SP HH	3 m x 8 m			cull by lat	
Sea Ice Dynamics	SP VV	48 m x 8 m			s = 1 p	
Urban Areas		6 m x 8 m			s = 1 p	
US Agriculture	QP HH/HV VV/VH				s = 1 p	
Himalayas			CP RH/RV		s = 1 p	
India Agriculture					s = 1 p	
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	
Sea Ice Types	DP VV/VH				s = 3 p	

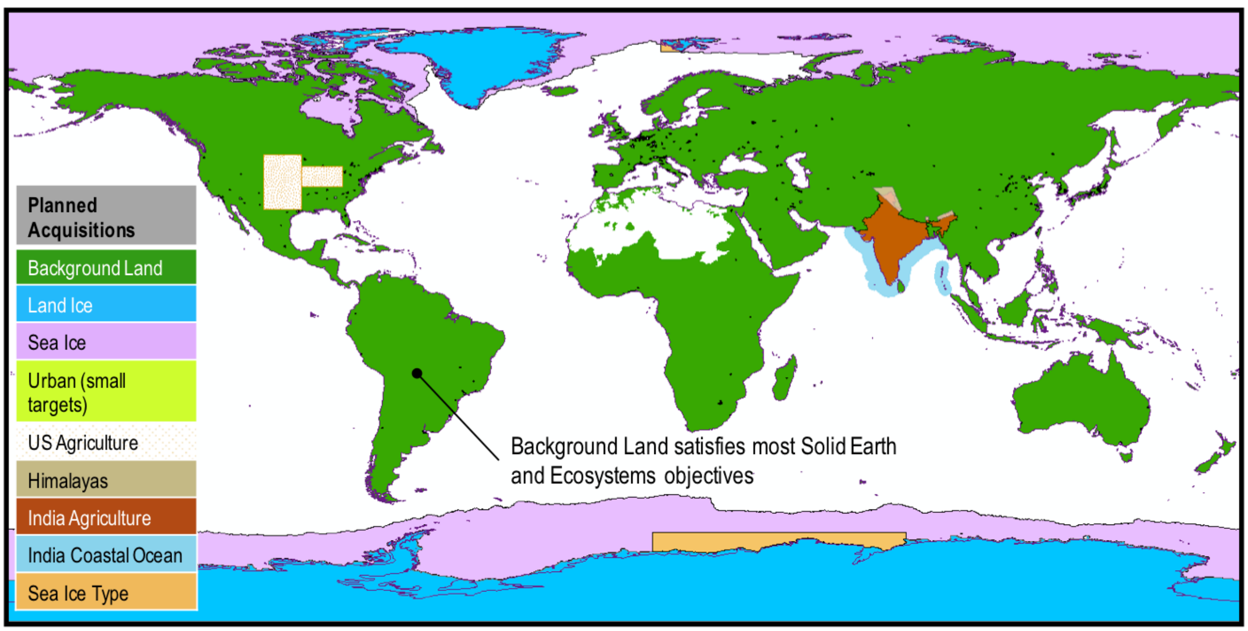

Figure 2. NISAR observation plan, as of Oct. 2015..

1.2. Purpose of Workshop

The NASA-ISRO SAR mission (NISAR), an L- and S-band Synthetic Aperture Radar (SAR) satellite with a global observation plan, is engaging the US and Indian applied science communities in annual workshops, the third of which was held in October 2015 at NASA's Ames Research Center. SAR data can and has been applied to a diverse set of land and water resource management and survey problems; these include post-disaster damage assessment, volcano and landslide hazard assessment, critical infrastructure monitoring, permafrost degradation, wetlands water level change, ocean wind measurements, sea-ice motion and ship detection, sea-level rise, vegetation disturbances and recovery, groundwater induced land deformation, and agricultural land use. The workshops are intended to provide a venue where those in the applications community who can benefit from the rich information provided by NISAR can: (a) get SAR training, and (b) interact and engage with the NISAR project and science team members.

The focus of the 2015 NISAR Applications workshop was 1) constructing a 5-year roadmap for developing a framework to support the use of data products and software that can meet the needs of the diverse NISAR applied science end-user community, and 2) clearly establishing guidelines with regard to project support of applications and data latency. Workshop participants discussed and identified key activities (e.g., research/technology development, software or product development, training campaigns) that could be used to guide NASA and the NISAR project, as well as other agencies and private sector investments in the years leading up to NISAR's launch.

1.3. Workshop Format

The three-day 2015 workshop began with a one-day training session to increase SAR literacy in the applied community, a the recommendation from the 2014 NASA-led workshop, which was followed by the two-day workshop. The workshop included overview presentations on the mission and specific examples of SAR applications, posters on SAR applications, "breakout" discussion sessions, and a private sector panel. Since the bulk of the workshop report represents what was discussed in the breakout sessions, the format of these is described below in more detail. The complete agenda is provided in Appendix (Section 6.1.).

In the workshop, participants were divided into six discussion groups that sought to develop an Applications Roadmap by addressing a series of questions during three breakout sessions. The six discussion groups consisted of four applications and two end-user communities. The four applications included 1) ecosystems, 2) hydrology and subsurface resevoirs, 3) oceans and sea ice and 4) hazards and disaster response. These four applications are not inclusive of all applications for SAR data, but covered the communities present at the workshop. Because there are many levels of experience working with SAR data for each application, two additional discussion groups focused on the different needs of new and experienced users. Each discussion group answered the same set of questions in the three breakout sessions moderated by science definition team, applied science program, and project members with the goals of: 1) identifying key challenges and activities needed, 2) defining multi-mission applications, opportunities, and challenges, and 3) developing a draft applications 'Roadmap.'

2. Overarching Themes/Summary

Four main thematic areas for an application program emerged from the breakouts: 1) engaging with likely and potential users of NISAR data, 2) data products – before and after launch, 3) observation plans/observation tasking process, and 4) leveraging partnerships.

2.1. Engaging with likely and potential users of NISAR data

There are many civilian SAR systems delivering SAR imagery throughout the world. The widespread availability of data for the past decade has spurred the development of a number of software and value-added companies that provide commercial products and services to scientific and operational communities. As a result, there are a very large number of stakeholders that use products derived from existing SAR data. With the recent launch of the Sentinel-1A radar satellite, which is making all data acquired globally free of charge, this user base is going to grow considerably in the years leading up to the NISAR launch. In this sense, there is an established user base that can adopt NISAR data sets for their needs.

The reliability and affordability of SAR data has been an impediment for some potential users. Many scientific and operational SAR users require large quantities of low-latency data, often over large areas, to perform their intended required functions; however, expensive commercial data or sparsely sampled science data do not meet their specific requirements. Thus, these communities remain underserved in terms of available tools and data. The ubiquity and availability of Sentinel-1A SAR data may change that in the coming 5 years, such that the largest pool of potential users are transformed naturally to likely users of NISAR data if useable products are available.

Thus, we can identify three principal categories of users for whom a NISAR Applications plan can serve:

- Experienced user: Researchers and other users accustomed to doing their own analysis or procuring end-products for their current needs, and for whom NISAR data will naturally be used as part of data infusion efforts
- Product-ready users: Researchers and potential users of NISAR data who have the technical background to integrate SAR data products into their data infusion efforts. This community would directly benefit from early involvement with the anticipated developments of products and services that Sentinel-1A (and potentially other systems) will inspire
- Potential users: Users who could potentially benefit from NISAR-derived products and services, but for whom no identified path for adoption has been identified

An application program from NISAR should acknowledge and address the varying needs of these users. For experienced users, product-ready users and those likely to become experienced through on-going developments, the applications program could engage with developers in academia, research institutions and companies to foster integration of NISAR data into the products and services that exist or are planned over the coming years, working seamlessly with other SAR data sets. This engagement could be in the form of working groups and product clearinghouses geared to applications. The Applications Plan could directly engage the potential new users community by seeking the participation of the experienced users to serve as ambassadors, demonstrating how these data may solve problems for these users, and identify the impediments and solutions for adoption. This adoption program could include educational elements (tutorials and workshops), as well as development of specific tailored products that are of high potential value and meet the needs these users.

2.2. Data Products - before and after launch

Workshop participants were in general agreement that the applications value of NISAR data can be greatly enhanced by producing a set of clearly defined standards and prototype products well before launch that would support immediate use of NISAR data acquired after launch. Most major NASA projects provide such standards and science products before launch, but the request by workshop participants was for application-ready products. This could entail:

1. Establishing the use of NISAR data by providing existing SAR data with standard and simple formats (e.g. GIS ready – GeoTiff) to end users before-launch. For some experienced users who develop value added products, this would be with regard to the SAR imagery. Other users will need standards for higher-level data products.
2. Expanding/developing ancillary data bases, e.g. GPS CORS network, that would make it easy for developers or end-users to apply corrections or validate their work that may be outside of the project's science objectives.
3. Ensuring open access to relevant applications data, storage, affiliated data sets
4. Archiving data on a DAAC that houses not just the NISAR science products, but also application-ready products

2.3. Observation plans/observation tasking process

NISAR will offer a unique and enormous observational potential – global coverage, two wavelengths, multiple polarization modes and bandwidths, a large duty cycle for global observing, and a flight system able to offer low-latency data delivery for urgent observations – providing large scale data sets of Earth surface dynamics that are critical to three Earth Science disciplines: 1) Solid Earth, 2) Ecosystems (Vegetation/Carbon Cycle) and 3) Cryosphere and Applications. Given common needs between Science and Applications communities, the same data serves both basic and applied science.

Workshop participants identified a wide range of applications, products, and services that have not been previously possible, however some of the identified applications could greatly increase the volume of data currently planned for the NISAR mission. Specifically, some applications called for:

- wider bandwidth
- more observations than those planned (spatial coverage or resolution, or temporal frequency)
- greater polarization diversity than planned
- more dual-wavelength coverage, and
- reduced processing latency

As the NISAR Mission Level 1 Requirements were defined to meet science objectives, application objectives must be met within this scope. One of the key objectives for an application plan is to balance applications' needs within existing NISAR science objectives and to provide constructive feedback to the mission for consideration in planning and development that advances the usage of NISAR for applications of societal benefit. For example, some applications (e.g., emergency response) require adjustments to mission parameters such as low data product latency, which could be considered in the NISAR mission plan. Because it is difficult for applications users not embedded in the project to understand the true limitations and flexibilities that NISAR offers, a formal NISAR applications plan can provide information to both the project to understand operational scenarios and timelines, and the applications end users to evaluate and quantify the potential of the mission to meet their needs. An application plan should include ongoing discussions of operational scenarios and application-speciic product needs (e.g., timeliness, coverage, resolutions) between the project and the applications community.

2.4. Potential Roles and Leveraging Partnerships

Workshop participants identified the diverse contributions and potential roles both within NASA and with potential partners at external agencies and organizations in order to better integrate SAR data, specifically NISAR data, into operational decision support. The key for an implementable plan is the need for partnerships that can help to:

- provide additional resourcs for research and development
- manage and implement an applications plan
- leverage existing infrastructure that provides educational resources to increase SAR literacy, and
- reach potential and product-ready users at professional meetings and conferences.

Although participants acknowledged the diverse contributions and roles of many programs both within NASA and external to NASA, there was no clear assignment of tangible responsibilities among these groups. Future discussions could more clearly define the roles, needs, and deliverables of partnerships essential for implementing an applications plan.

3. NISAR Applications Represented at the 2015 Workshop

Approximately 130 participants attended the workshop representing Local, State, Federal, foreign governments, private sector and academic institutions (Figure 2). Participants represented the ecosystems (~9% people), subsurface reservoirs and hydrology (~14%), oceans and sea ice (~2%), and hazards and disaster response (~18%) applications communities (Figure 1) with specific interests discussed below. There is a list of workshop participants in Appendix 6.2.

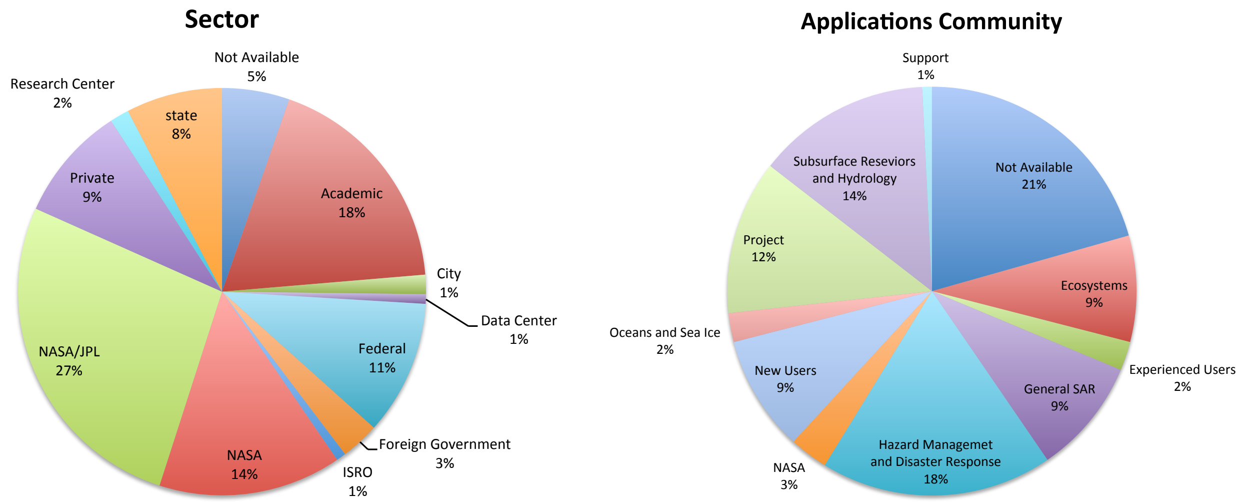

Figure 2. Demographics of the workshop participants by sector and applications community represented.

3.1 Ecosystems

NISAR has the potential to benefit a wide range of ecosystems applications including monitoring silviculture management, carbon monitoring (Figure 3), monitoring forest recovery and succession, assessing crop area and classifying crop types (Figure 4), quantifying agricultural yield, assessing agricultural crop risk to disease or drought, wetland classification (Figure 5), monitoring water level and hydro-period, and soil moisture monitoring (NISAR Application Workshop Report 2014). At the 2015 NISAR Applications Workshop the ecosystems applications community represented a number of sub-communities, including agriculture, forests, and wetlands. These applications were discussed by the 10-15 participants with particular interests for applications relevant to soil moisture, wetlands monitoring for habitat management, agriculture, post-fire vegetation recovery, and forest biomass, structure, disturbance, and recovery monitoring.

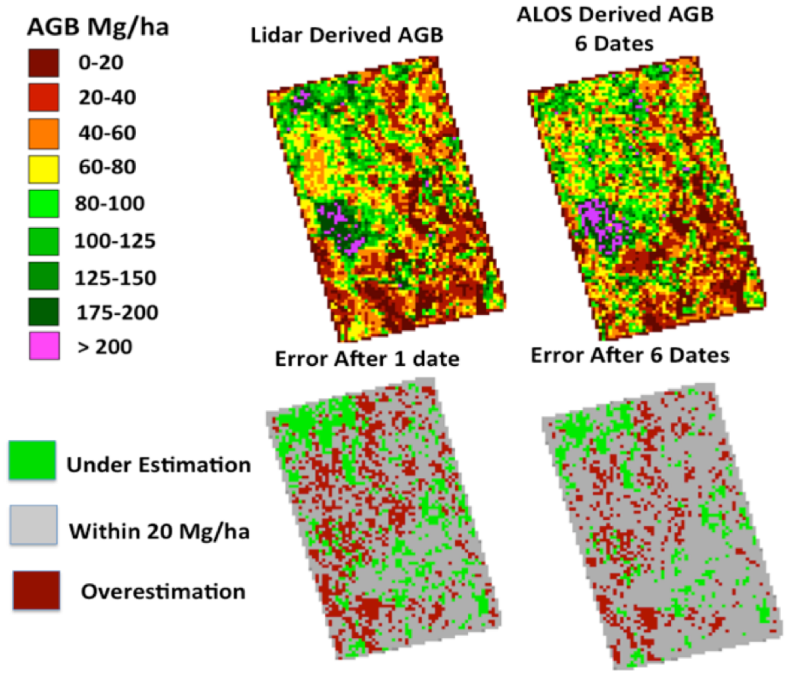

Figure 3. ALOS SAR data can be used to derive aboveground biomass (AGB) with similar accuracy as airborne light detection and ranging (LIDAR) in comparison with what is observed on the ground. Figure courtesy of Sassan Saatchi, Jet Propulsion Laboratory.

Figure 4. Polarimetric decomposition (alpha of H/A/alpha) of a UAVSAR image can classify agricultural crops. Figure courtesy of Tracy Whelen and Paul Siqueira, University of Massachusetts.

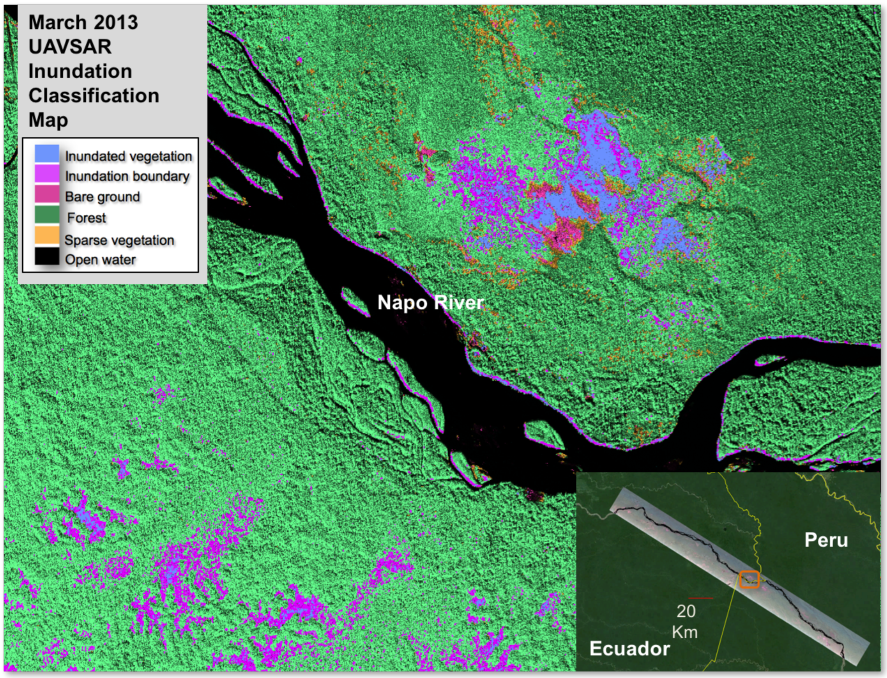

Figure 5. SAR has the ability to penetrate canopy cover to provide inundation classifications both in vegetated areas and boundary areas. Here we show classifications over an L-Band UAVSAR image in March 2013 over the Napo River. Figure courtesy of Bruce Chapman, Jet Propulsion Laboratory, California Institute of Technology.

3.2 Hydrology and Subsurface Reservoirs

NISAR has the potential to benefit a wide range of hydrology and subsurface resevoir applications including groundwater monitoring (Figure 6), soil moisture monitoring, mapping snow cover, mapping snow water equivalent, and classifying permafrost (NISAR Application Workshop Report 2014). At the 2015 NISAR Applications Workshop the hydrology and subsurface resevoirs applications community discussed detection of groundwater overdraft in alluvial basins by measurement of subsidence, characterization of oil, gas, and hydrothermal reservoirs through modeling of ground deformation above them, and early detection of potential damage to infrastructure (e.g. roads, canals, railroads) through monitoring of subsidence. Participants who participated these discussions were mainly from state water agencies, the California High-Speed Rail Authority, USGS, and UNAVCO. Unlike the workshop of 2014 that focused more on the use of multiple radar image modes to address applications in surface water, soil moisture, and snow, discussions at this workshop focused on applications of InSAR measurements for monitoring of surface deformation to subsurface reservoirs, which focuses on the inference of the state and dynamics of the fluids in the reservoirs. Models are used extensively to make the connection from observation to understanding. Desired information products would include, for example, height and changes of the water table (hydraulic head), location and depth of oil and gas, shape of hydrothermal reservoirs, etc. In addition, the detection, mapping, and monitoring of surface deformation affecting infrastructure like roads, railroads, canals, electrical transmission lines, pipelines, and flood-control is of key importance for several state and federal agencies.

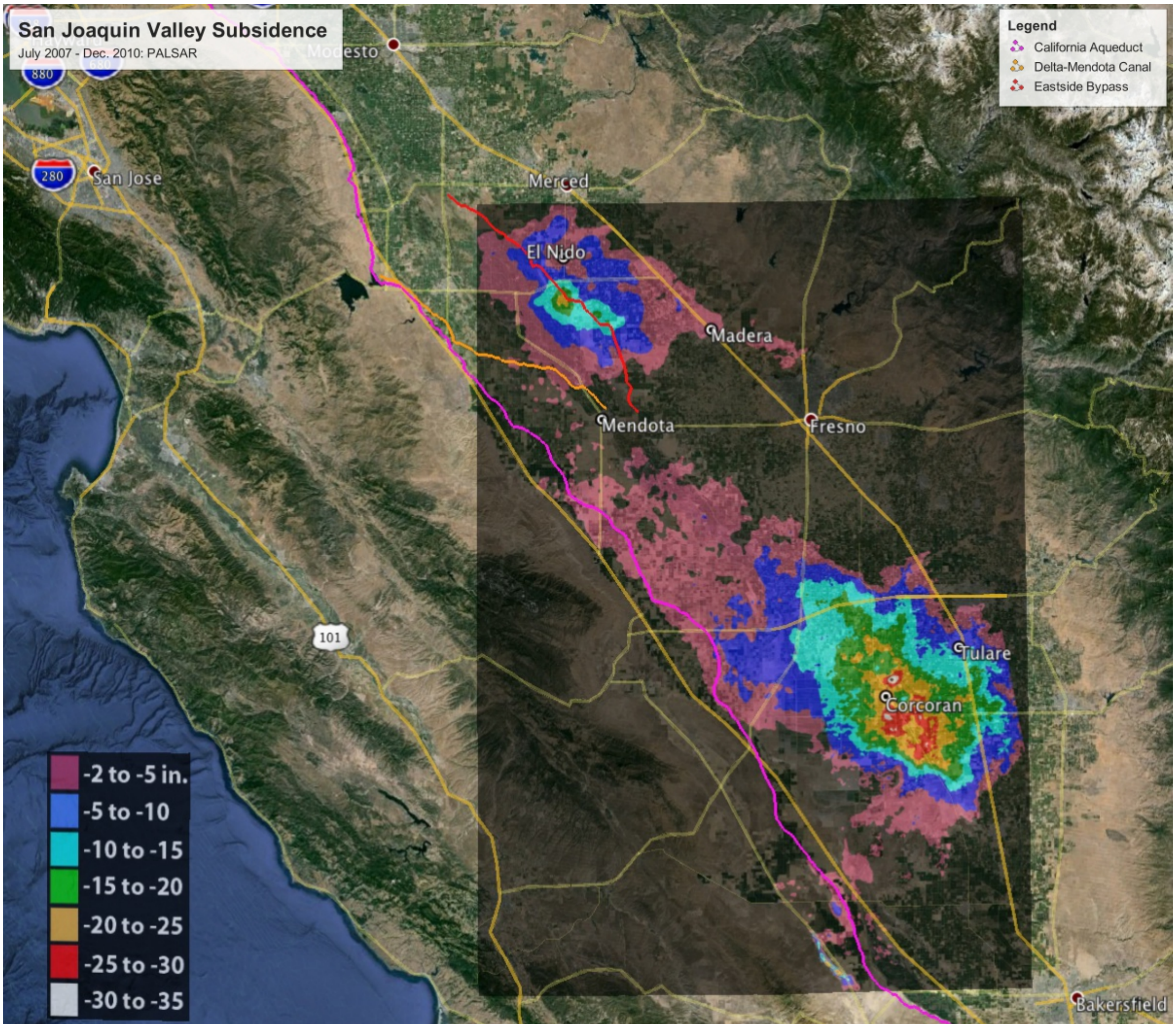

Figure 6. Total subsidence in the San Joaquin Valley, California for the period June 2007 – December 2010 as measured by the Japanese PALSAR. Two large subsidence bowls are evident centered on Corcoran and S of El Nido. Note the narrow banana-shaped subsidence feature at bottom center that corresponds to the Belridge Oil Field, which is subsiding due to oil extraction. An animation of the subsidence in the Tulare basin can be seen at: http://photojournal.jpl.nasa.gov/catalog/PIA16293. Figure Courtesy of Tom Farr, Jet Propulsion Laboratory, California Institute of Technology.

3.3 Oceans and Sea Ice

NISAR has the potential to benefit oceans and sea ice applications including mapping sea ice, monitoring marine wind speed and wave spectra, detecting hard targets, masking oil spills (Figure 7), mapping shorelines, and monitoring severe storms (NISAR Application Workshop Report 2014). At the 2015 NISAR Applications Workshop the oceans and sea ice applications community discussed ocean winds, ocean waves, ocean coastal changes, oil spill monitoring, storm damage assessment, and ship and iceberg direction (2014 NISAR Applications Workshop Report). There were representatives from NOAA, the US National Ice Center, USGS, and various universities. A new application to use SAR for storm surges was identified by Florida participants.

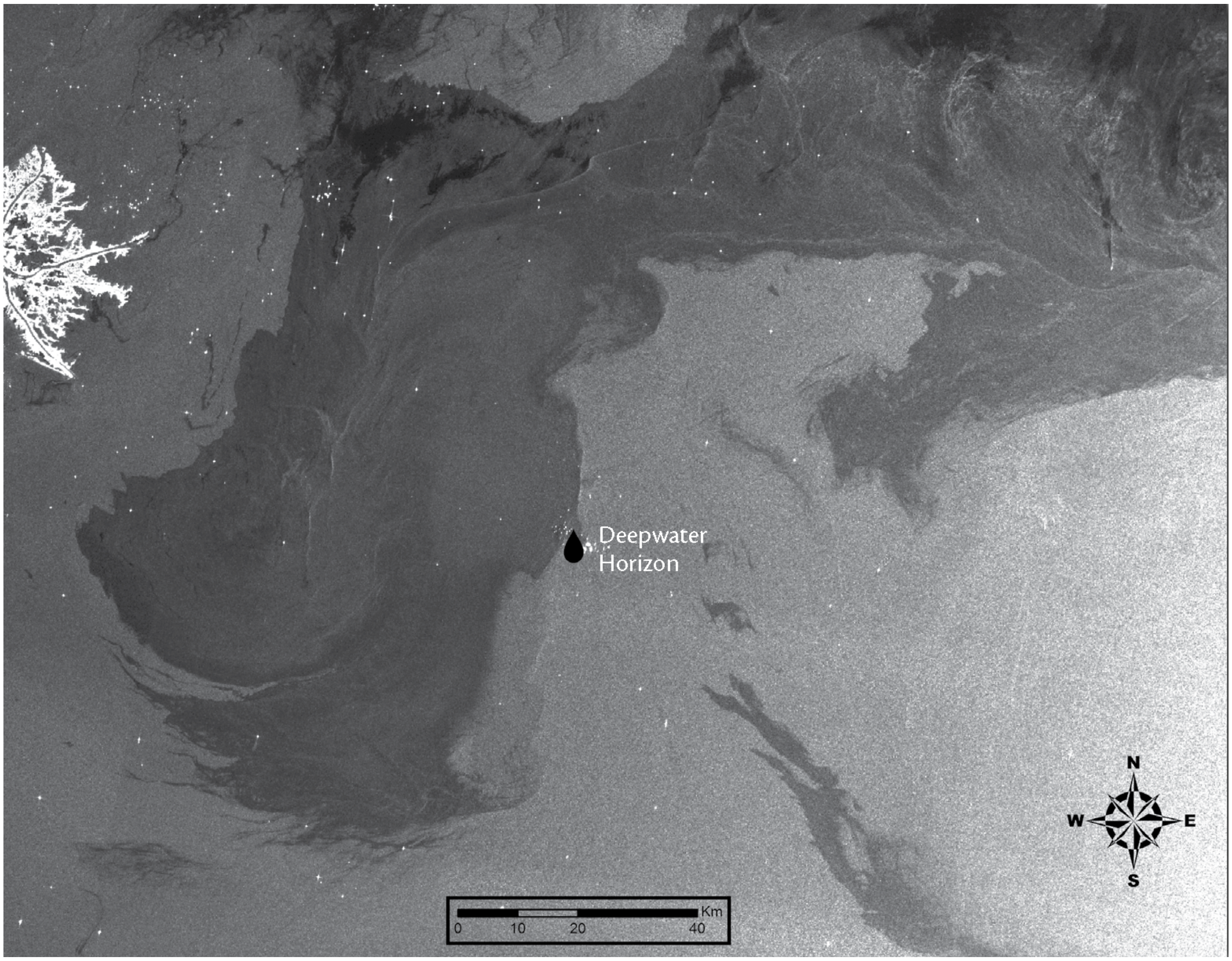

Figure 7. This image, collected from the Advanced Land Observing Satellite (ALOS) L-band SAR, shows dark features near the deepwater horizon oil platform that are surface oil slicks. This figure is reprinted from: Garcia-Pineda, O., I. MacDonald, C. Hu, J. Svejkovsky, M. Hess, D. Dukhovskoy, and S.L. Morey. 2013. Detection of floating oil anomalies from the Deepwater Horizon oil spill with synthetic aperture radar. Oceanography 26(2):124–137, http://dx.doi.org/10.5670/oceanog.2013.38.

3.4 Hazards and Disaster Response

NISAR has the potential to benefit hazards and disaster response including mapping volcanic eruptions, monitoring risk of volcanic eruption and earthquakes, monitoring landslides and land subsidence hazard, detecting sinkholes, characterizing earthquakes, mapping oil spills, detecting infrastructure damange, monitoring infrastructure stability, and mapping floods (NISAR Application Workshop Report 2014). At the 2015 NISAR Applications Workshop the hazards and disaster response applications community focused on developing the capability of risk assessment and hazard identification. In particular, the group discussed mitigation, in recognition of the fact that (a) emergency response can make direct use of products and capabilities developed for assessment, and (b) full social and economic benefit comes from the combination of mitigation (i.e., disaster mitigation) and response. Specific applications discussed included the following. The US Coast Guard expressed the need for iceberg monitoring to provide critical information incorporated into bulletins provided to US and international shipping companies and agencies. Representatives from the U.S. Department of Homeland Security (DHS) and the California Department of Water Resources (CDWR) discussed their interest in using NISAR data for monitoring a wide range of critical infrastructure (e.g., levees, aqueducts, water pipelines, canals, energy production facilities, and transportation infrastructure – bridges and highways), and how this can affect energy production (e.g., monitoring oil production and processing to understand subsidence in the areas of facilities, map distribution networks, and to measure change in facility structures for damage assessment).

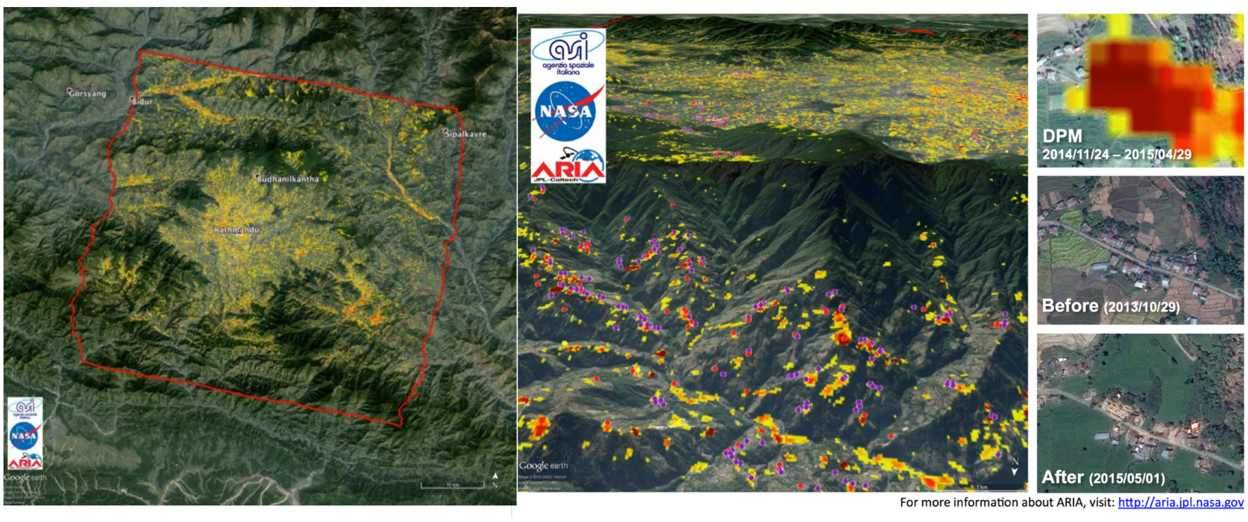

Figure 8. This figure shows a 25-by-31 mile (40-by-50 kilometer) Damage Proxy Map (DPM), which covers the region around Kathmandu, Nepal. Using X-band interferometric synthetic aperture radar data from ASI's COSMO-SkyMed satellite constellation, the Advanced Rapid Imaging and Analysis (ARIA) team at JPL and Caltech can rapidly assess surface changes caused by natural or human-produced damage. The assessment technique is most sensitive to destruction of the built environment by assessing the difference in change between two images prior to the event and change between an image before and after the event. When the radar images areas with little to no destruction, its image pixels are transparent. Increased opacity of the radar image pixels reflects damage, with areas in red reflecting the heaviest damage to cities and towns. The color variations from yellow to red indicate increasingly more significant ground surface change. The time span of the data for the change is Nov. 24, 2014 to April 29, 2015. Each pixel in the damage proxy map is about 100 feet (30 meters) across. The perspective images show the DPM overlaid on the terrain with the locations of damaged buildings identified as red and purple dots by the National Geospatial-Intelligence Agency (NGA) preliminary damage assessment. As an example, the images on the side show how red regions in the DPM correlate with damaged buildings, as shown by the collapsed structures in the "after" image. The base map images were provided by Google. Before and after images were provided by DigitalGlobe. Figure courtesy of: http://photojournal.jpl.nasa.gov/catalog/PIA13911.

4. Findings for Essential Elements of Applications Plan

One of the key goals of this year's NISAR Applications Workshop was to identify key challenges and activities needed for a 5-year applications roadmap for the NISAR applications community. The roadmap is meant to serve as a bridge between SAR scientists and end user communities before launch thus preparing the applications community to fully exploit NISAR data and products. The following section describes the 'Desired Outcomes' and 'Suggested

Approach' for each discussion group as they specifically relate to the development of an NISAR Early Engagement Program.

4.1. NISAR Early Engagement Program: Desired Outcomes and Approaches

The NISAR Early Engagement Program is a proposed applications activity that synthesizes the 'Desired Outcomes' and 'Suggested Approach' from the different discussion groups as outlined below, and would consist of several parts. First, there is a recognized need to engage in capability development through projects involving both SAR scientistis and the end user communities that are executed in the years priort to launch. Secondly, there is an outreach component with the main objective to involve potential end users from communities for which NISAR has high value, but who currently have little experience in working with SAR data. Finally, there was the recommendation that the NISAR program would work with end users in more established applications of SAR data, using a working group structure (Section 4.1.6), towards 1) helping to refine data deliverables specifically related to format, latency, quality, or value added products created by intermediary partners, depending on the application and the resources of the end user, and 2) advocate and publicize the use of SAR data.

4.1.1. Ecosystems

Desired Outcomes

The desired outcomes of an Early Engagement Program from the Ecosystems applications community include 1) involving more end users for all ecosystems sub-communities, 2) capacity building, and 3) conducting research and development of data products.

Suggested Approach

The ecosystems discussion group recommended following an Early Engagement approach similar to Soil Moisture Active Passive (SMAP) project's Early Adopter Program. The SMAP Early Adopter Program included pairing end users with an associated science team member, early access to simulated SMAP data, and a SMAP special issue in a relevant journal highlighting the work of early adopters. Different from SMAP, the Ecosystems applications community suggested providing current SAR data (e.g., UAVSAR and ALOS-1/2) – rather than simulated – to train end user communities. They suggested workshops and focused, hands-on training sessions with targeted end user communities as well as opportunities for end users to participate in a program similar to the SMAP Early Adopter Program. Such a program would host focused workshops for specific sub-communities that could bring together new and experienced SAR users who work on similar applications problems, and who could then provide input on which applications to focus future development. For example, crop classification is well enough developed that Agriculture and Agri-Food Canada (AAFC) already uses Radarsat-2 data operationally with optical data to create their annual crop inventory. However, the US Department of Agriculture (USDA) does not currently use SAR data to generate the equivalent Cropland Data Layer product. A dedicated workshop would bring together SAR scientists from AAFC and participants from the USDA to discuss operational use of SAR data for crop classification.

4.1.2. Hydrology and Subsurface Reservoirs

Desired Outcomes

The hydrology discussion group articulated two desired outcomes from an Early Engagement Program. The first is to have fully processed products relevant to the hydrologic community as specified in Section 4.2.2. The second desired outcome is that past data (e.g., PALSAR, Radarsat) and present (e.g., Sentinel-1) be processed such that a continuous data product exists linking past, present, and future datasets.

Suggested Approach

The hydrology and subsurface reservoirs discussion group recommended several necessary components to integrate into an Early Engagement Program that would facilitate meeting these desired outcomes. First, the Early Engagement Program will need to identify and facilitate processing of products relevant to the hydrologic community that adhere to standardized formats already used by the community for data delivery. In testing methodologies, the group suggests using Sentinel-1a and SAOCOM (international constellation) SAR data as a proxy to develop and refine products for the hydrology community. This complements the need for consistent data products across time. One suggestion was for the NISAR project to consider and comply with existing data formats used by open source software for post-processing, analysis, and modeling to reduce the financial burden on end-users when integrating NISAR data products into existing or new infrastructure. In order to facilitate these outcomes, the hydrologic community would like for the Early Engagement Program to establish and develop partnerships with Alaska Satellite Facility (ASF), Advanced Rapid Imaging and Analysis (ARIA), UNAVCO, USAG, USGS and USAID. The goal these partnerships would be to develop SAR time-series from all of the historic SAR archives dating back to 1992 such that long-term aquifer, surface water, and soil moisture deformation and trends can be assessed with NISAR imagery. Specifically, these partnerships would facilitate providing the data sets mentioned above. For example, ASF/ARIA could facilitate data product production while UNAVCO or USGS could host and display InSAR data in an analogous format as CLICK for LiDAR data. Additionally, partnerships with agencies like USAID can help provide funding for capacity building to ingest and use SAR data. Such partnerships may require support from NASA and an agreement for early access to data sharing to enable participation on data formatting and latency and qualitative and/or quantitative evaluation of value added of the Early Engagement Program. Lastly, the discussion group suggested building awareness with end-user communities of both the NISAR project and SAR applications (e.g., using educational videos) presented at conferences and professional meetings (See Appendix 5.3).

4.1.3. Oceans and Sea Ice

The oceans and sea ice discussion group articulated four desired outcomes from an Early Engagement Program. First, find support for dedicated UAVSAR flights over ground truth sites in the ocean and marginal ice zone for calibration and validation of surface wind model functions. Second, work with the NISAR project to develop techniques for rapid tasking of significant storms (high intensity weather events, e.g. hurricanes, polar lows). Third, establish partnerships that specifically a) develop and deliver sea-ice products from L-band data, and b) facilitate interagency (e.g., NOAA, National Ice Center, DoD, or other agencies providing ground stations) discussions about methods for reducing latency and increasing ocean coverage.

Fourth, enable early access to SMAP, ALOS -1 and -2, SAOCOM, UAVSAR data to facilitate development of software tools for processing and delivering sea-ice products from L-band data.

Suggested Approach

The oceans and sea ice discussion group recommended several necessary components to integrate into an Early Engagement Program that would facilitate meeting these desired outcomes. First, to help the oceans and sea ice find additional support for dedicated UAVSAR flights over ground truth locations in the ocean and marginal ice zone, the discussion group suggested leveraging future experimental programs and coordinating partnerships or supporting rapid response acquisitions proposed through NASA ROSES Rapid Response and Novel Earth Science (RRNES) solicitation. Second, it is necessary for an applications plan to establish methods for the applications community to work with the NISAR project to develop techniques for rapid tasking of significant storms and other disaster events. Rapid tasking includes data acquisition, downlink, and processing. Third, an Early Engagement Program would facilitate partnerships that not only provide access to these data, but also develop and deliver sea-ice products with clear documentation of the software packages used for processing and product specification manuals that articulate how to read the data. If the products do not follow the formats requested (Section 4.3.3.) then software (in a variety of languages) should be distributed for reading the data. Additionally, partnerships, particularly interagency partnerships, may help to resolve latency challenges (Section 4.3.3.) by providing additional resources to reduce latency. Key US Federal agencies identified by the discussion group included NOAA or the DoD. Fourth, to develop and implement applications and their associated ocean/sea-ice information product processing, it is necessary to provide early access to NISAR-like data (i.e., L-band with HH, VV and HV/VH polarizations) to enable pre-launch development. This discussion group recognized that access to data from ALOS-1 and 2, SMAP, SAOCOM, and UAVSAR is necessary for developing and refining algorithms and geophysical model functions of L-band data. These data need to be provided in standard, easy-to-read,ready-to-use file formats (Section 4.3.3. Data Formats).

4.1.4. Hazards and disaster response

Desired Outcomes

The hazards and disaster response applications community has several desired outcomes from of a NISAR Early Engagement Program. There is a need for active engagement between SAR scientists and the end user communities through projects that develop and implement SAR-based products within decsision support systems. This requires 1) availability and access to pre-processed data products, discussed in detail in section 4.2.3, with proven reliability and utility that would be ready to ingest into end-user decisions support systems, and 2) transparent and reproducible processing of higher-level data products that can be incorporated into incident response operational decision support.

Suggested Approach

The hazards and disaster response discussion group identified three areas that Early Engagement Program should consider: 1) processing and providing final data products delivered, 2) inter-agency, university, and private sector partnerships, and 3) educating new and potential users of SAR-derived information products. It was suggested that the best method for integrating these approaches is by means of a team structure. The team consists of users (incident commanders or decision makers), data providers, data processing/analysis/product developers, and a NISAR program representative to ensure that the acquisition, analysis, and product development and delivery process is constructed within the defined mission capability suite for NISAR.

Specifically, addressing the first consideration about data product development the discussion group concluded that the full utility of data products in hazard and disaster applications is in both higher level data that is ready for integration into decision support tools and also confidence by end users communities in the utility of products. It was recognized that products generated for monitoring, assessment, and mitigation and vetted by the end users are generally of use for emergency response, provided they are delivered during the response or recovery period.

While radar measurements are necessary, applications end users need pre-processed data products for real-time decision support; data processing is discussed in more detail in Section 4.3.3. Processing from acquisition to final products, formatting and integrating into operational decision support tools must be transparent in order for end users to have complete confidence in SAR products. Providing early access to NISAR proxy data and data products pre-launch would enable research and development to give end-users confidence in SAR-derived products before NISAR data are used in real-time operational decision-making. Quantitatively, users would like confidence values that can be used to eliminate false positive signals and accuracy estimates. As the processing needed to deliver such data products is beyond the NISAR project requirements, an Early Engagement Program could facilitate partnerships that enable processing of NISAR data to deliver higher-level information products specifically relevant to the hazard/disaster communities.

The discussion group advocated for a funding solicitation (e.g., ROSES) for new development of higher-level SAR products in advance of launch because the NISAR project is currenly not budgeted to provide higher-level products. As such, product development and distribution would rely on partnerships to develop such higher-level products and these end users may need incentives to incorporate SAR data for a mission that has not yet been launched. Such a solicitation would include an agreement between the NISAR project and the partners that NISAR would provide data pre-launch and pre-beta release. Providing NISAR proxy data from existing SAR data in the same data product formats and latency would not only build end user confidence, but also enable application of any developed tools to include all SAR, thus lengthening applications beyond the life of NISAR as an added benefit for end users. In return for providing such a dataset, partners can better identify and communicate to the NISAR project and the NASA Applied Sciences Program: 1) how the data is useful, 2) what geographic areas are of highest concern with respect to the usefulness of the data, and 3) what level of scientific research and development is needed to apply measurements from SAR data in near-real time disaster and hazard response. The discussion group also acknowledged that establishing such a partnership will take time and that perhaps more than one solicitation would be most beneficial for encouraging end users to participate. Lastly, the discussion group suggested an outreach program in which some partners would advocate the use of SAR data.

4.1.5. New Users

Desired Outcomes

Desired outcomes for new users from an Early Engagement Program include broad outreach to new user communities, education/training for new users, and access to data and tools.

Suggested Approach

The new users discussion group detailed a training program and considerations for finalizing data products. The group suggested a two-phase training program: Phase 1- Ambassador Program and Phase 2- SAR training and development

Phase 1: Ambassador Program

The primary objective of the Ambassador Program is to raise awareness of existing applications amongst all potential end user communities through outreach at specialized conferences outside of the SAR community (See section 5.3. for specific conference suggestions) and working with NASA's existing capacity building programs (e.g., SERVIR or NASA ARSET). The outreach at specialized conferences would be conducted by ambassadors and would provide a means for not only communicating about SAR applications (e.g., using two-page "elevator speech" informational specific to different applications), but also listening to end user communities to understand how SAR data can be used to address their needs. Importantly, this program would not only focus on NISAR, but all SAR data. NISAR Ambassadors would improve the applications communities' readiness for the NISAR mission by interacting directly with the end-user. As a NISAR Ambassador, partners commit to working with NASA, JPL and other Ambassadors to strengthen the connection of the data community with end-users. Thus, Ambassadors for each discipline should be featured on the NISAR webpage using an approach similar to the "Distinguished Lecturer" program of the IEEE Geoscience and Remote Sensing Society. Through the distinguished lecturer program, Ambassadors can be "booked" to provide application-specific trainings. Ideally, the distinguished lecturer program would have some NASA support, so that it could be structured such that applications communities will incur little or no cost in making use of this program.

Phase 2: SAR training and development

Expanding the SAR end user community requires a commitment to SAR training and development, where a key approach to facilitate this training would be through a SAR applications webpage. There is the general impression within the applications communities that utilizing SAR in their work is difficult and that SAR focused trainings and course curricula are scarce and difficult to find. Hence, a SAR applications webpage should provide:

1. Organized information on already existing training resources (e.g., the online resources of SAREdu (https://saredu.dlr.de/)
2. Newly-developed application-specific SAR training material with a shift in focus away from broad trainings to more modular application-specific sessions and clearly defined objectives (e.g., basic research, applications development, and end user)
3. Links to relevant software packages such as ISCE
4. Links to a set of application-specific pre-packaged virtual "SAR Lab" environments that include:

- Relevant open-source, software packages or access to processing tools (e.g., ENVI) on the cloud for optimal access by end-users
- Example data sets (and correct answers) that are "sensor agnostic," demonstrating continuity across time and space (i.e., georeferencing aligns) with associated error bars to enable untrained end users to understand which signals they can trust. Data file sizes (e.g. tiling) should accommodate low download and processing capability.
- Processing "cookbooks"/manuals

5. Information on upcoming SAR trainings and workshops including their application focus and geographic location.

A first conceptualization of the ***NISAR education webpage***, based on the suggestions from the discussion group, is shown in **Figure 9**.

The ***virtual SAR labs*** should be designed as online lab environments, that are easily accessible through a selected cloud provider. The labs should provide all of the state-of-the-art (NASA-focused) SAR software pre-installed and ready for use. They should also provide standardized, pre-packaged, applications-specific data sets including all "cookbooks" and instructional material needed for successfully processing these data sets. Also included could be information on basic software packages for viewing and displaying original SAR data as well as processing results.

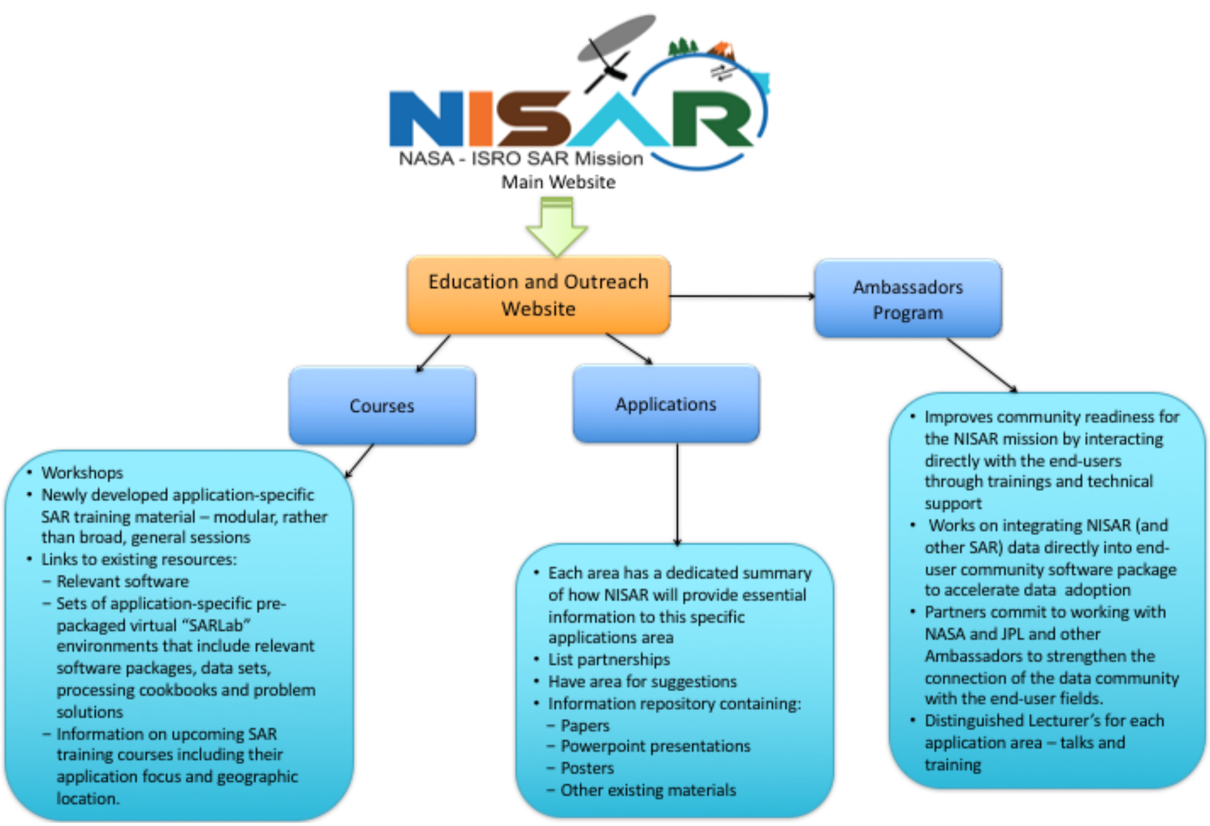

Figure 9. First concept of a NISAR education webpage developed during the NISAR Applications Workshop at NASA Ames in October 2015.

4.1.6. Experienced Users

Desired Outcomes

The experienced users discussion group articulated three desired outcomes from an Early Engagement Program including 1) expanding SAR data user community, 2) providing sample NISAR-formatted data using existing SAR datasets, and 3) facilitating experienced user involvement with processing decisions, as there are a number of issues relevant to applications users that may or may not be addressed by the project, and if addressed may not be with the applications user in mind.

Suggested Approach

First, to expand the SAR data user community, the discussion group suggested engaging the broader GIS community by presenting NISAR talks at relevant venues (See section 5.3 for specific suggestions). The group specifically identified that an additional benefit of working with the GIS user community is that this community could provide ground truth data for validation. Additionally, they suggested outreach to university remote sensing powerhouses (e.g., University of Texas and Arizona State University).

Second, to provide NISAR proxy data developed using exisiting SAR datasets, the discussion group suggested that proxy data be available for specific target application communities represented in the Early Engagement Program. Providing actual SAR data in the NISAR format would enable end-users to start building workflows. To do this, there should be a plan between space agencies for access to all archive data so that a standardized format with similar architectures and quality flags (e.g., HDF5 vs. geotiff) can be developed. Currently it is difficult to compare SAR data from different sensors as access to the data and corresponding metadata (e.g., auxillary and calibration data) is limited. An Early Engagement Program could facilitate cohesive data across platforms engaging various data providers (e.g., Radarsat and ALOS) to expose their datasets (with metadata) via a search protocol or application program interface (e.g.. UNAVCO SSARA or Google Earth). Also discussed was the need for an Early Engagement Program to assess data product latency and how latency affects different applications. Specifically, they considered two types of data product latency: (1) immediate access and downlink of data, and (2) access to archived data. The discussion group advised NISAR to consider the least restrictive model.

Third, to facilitate experienced user involvement with processing decisions, the discussion group suggested organizing thematic working groups to steer a smooth course toward useful data and metadata designed to bring together project staff, scientific community, and applications users early in the project to. Three working groups were identified: Data Access and Visibility (DAVWG), Processing Working Group (PWG), and an Atmospheric and Ionospheric Correction (AICWG). Each are described in terms of purpose and tangible objectives or products of the activity.

In general, working groups would include a representative from the NISAR Science Definition Team (SDT), nominally the Applications lead or delegate, a NISAR Applied Science Deputy Application Lead (DPA), a representative from the project science element and the Science Definition System (SDS) team, and a range of applications community members. Additional members might include partner agency representatives or Data Active Archive Center (DAAC) representatives in the case of the DAVWG and the PWG, or disciplinary atmospheric and ionospheric scientists (e.g. from UCAR) in the case of the AICWG. Working groups would likely be chaired by the DPA or someone with the responsibility for the outcomes of each working group, though the group could choose the lead. The chair would be responsible for the tasks and deliverables of the WG within the constraints of available funding. A suggested 5-yr roadmap of tasks and responsibilities of each working group are provided in Appendix 6.3.

Data Access and Visibility Working Group (DAVWG)

Purpose

The DAVWG would keep the user community engaged in project decisions about data and metadata format, development of simulated or demonstration data products, delivery mechanisms, latency options. This group would be responsible for coordinating (across space agency data archives) and developing NISAR formatted data from existing SAR missions that would provide a pre-launch prototype from which end users can acquaint themselves with NISAR data products. The group could potentially identify activities and coordinate outside the project scope. For example, if there is an end-user product that is not part of the project science data validation effort (e.g. ocean winds), the DAVWG could work to define the products, develop sample products, and make them available to the community.

Objectives and Work Products

The primary objective would be coordination of products for seamless integration into user communities' tools. The project would be responsible for delivering data, simulated data, and documentation of those data. This would require an applications user interface specification or data format document. The DAVWG would be also responsible for informing the project of applications community needs with respect to data format, latency, and access. For applications-unique products that are beyond the scope of the project, the DAVWG would need to develop a mechanism to create and maintain the sample products. This might be done in partnership with the project, through NASA Applied Sciences Program solicitations, or through other co-funded activities with partner agencies.

Processing Working Group (PWG)

Purpose

The PWG would work with the project to ensure the processing approaches adopted by the project are compatible with applications needs, specifically focusing on algorithms or techniques that could affect data quality for applications (e.g., persistent scatter algorithms). The project does not have requirements at the moment to develop such algorithms, but the applications community may rely on them for a significant portion of their products. The project algorithms should keep these capabilities in mind even if not needed, and any additional costs needed to implement them would need to be factored into either the project or financially supported by the application requesting it.

Objectives and Work Products

The objectives of PWG would be to coordinate algorithms for use in user communities' tools. The products would be specific code or pseudo-code that could be implemented into applications-specific products.

Atmospheric and Ionospheric Corrections Working Group (AICWG)

Purpose

The responsibility of the AICWG would be to ensure that the best possible atmospheric and ionospheric models are available (in a convenient format). The models would be used to generate multiple product types, including a rapid and precise correction product (similar to rapid, preliminary orbits and precise GPS orbit products that are released later). The rapid correction products would be extracted from weather forecast models. The precise correction products would be generated from reanalysis runs with temporal and spatial grid spacing adjusted to the NISAR data acquisition plan.

Objectives and Work Products

The objectives of AICWG would be to make atmospheric and ionospheric models available online via Application Program Interfaces (APIs) so that that they can be readily downloaded and used during data processing (similar to JPL's Online Services for Correcting Atmosphere in Radar -OSCAR).

4.2. Research Needs for NISAR Applications Development

Each application discussion group identified algorithm development and research needs that may require additional funding in order to integrate NISAR data into operational processing streams. For example, research and development is needed for applications that are considered low maturity or applications that require new methods to combine data from an international constellation of SAR satellites that can be used to generate cohesive SAR dataset for applications requiring long time series of observations. For all applications, there is a need for NASA's direct engagement with other federal and state agencies to facilitate partnerships and joint or externally funded opportunities.

4.2.1 Ecosystems

For Ecosystems applications, research is needed to connect relevant SAR retrievals and higher-level data products to end-user agencies. Currently, research products are available that have application value but the link to end users needs to be developed. End user agencies dealing with ecosystem products are less familiar with SAR processing techniques than other applications, thus research and development is needed in the applied sciences that enables development of algorithms and end-product processing streams that merge L-band NISAR data with previous SAR datasets to provide end users with a continuous record of SAR ecosystem observations relevant for decision making. Early release of NISAR data formats, using existing SAR, prior to launch is necessary for SAR data integration into operational decision-making post-launch.

4.2.2. Hydrology and Subsurface Reservoirs

While the production of interferograms and time series of deformation is a relatively mature technology, the conversion of the data into operational information products is not. The main research focus for this community uses models of surface deformation observations along with other ancillary data to produce an understanding of subsurface fluid state and dynamics. As understanding develops, the capability to predict state and dynamic response to various forcings (e.g. climate change) becomes possible. Thus, the one of the primary research needs for this community is the development of algorithms that stich together a long-term time series of existing SAR data that can be processed into information products (e.g., ground water level) relevant for the hydrology community.

The goal of research and algorithm development for this application community is to have a uniformly processed archive of NISAR data products using historic (e.g., ALOS) and current (e.g., Sentinel) SAR data. Such an archive should use systematic processing to produce data products in a similar format to what NISAR will produce, in order to facilitate integration into the science workflow and provide operational decision support. Algorithm development would employ different models that account for variable look, observation strategies, and format sources from different SAR platforms. Research is needed to investigate the trade in applying basin-by-basin models that prioritize key target basins versus applying a global model. Lastly, such an archive would need to adopt a SAR data product standard that could be defined by a workshop involving an international SAR community spanning the full spectrum of stakeholders. The workshop could investigate and recommend a data standard, prescribing the format (e.g., data file type, metadata, processing approaches, etc.) and suggesting optimal data products for application integration.

This application community also advised that data management plans, as proposed to funding agencies, should specify data formats, archives, and supporting end user agencies of the proposed format. It was also advised that funding agencies clarify, in their solicitations, data sharing requirements and access permissions.

4.2.3. Oceans and Sea Ice

The oceans and sea ice sub-group of the hydrology and subsurface reseviours group identified three research needs by developing model functions and algorithms that fully exploit L-band data. Applications are mature using C- and X-band data, but synergy between existing approaches and future NISAR L-band is needed. Existing L-band data (e.g., SMAP, ALOS-1 and -2, SAOCOM, and UAVSAR) can be used to refine ocean/ice application algorithms. It may even be advantageous to support dedicated UAVSAR flights over the ocean marginal ice zone and "ground"-truth for calibration and validation of surface wind models using L-band.

4.2.4. Hazards and Disaster Response

Hazards and disaster response applications need research to transition from basic research to operational applications specifically for:

- developing processing streams to provide end users with high-level operational products that are openly shared and stored. This will require sample NISAR data derived from existing SAR platforms. Verification and validation processes are needed that both demonstrate the integrity of the of SAR products and qualify their utility in response decision support. Thus, research must extend beyond the use of basic research that has been accomplished to develop products for any single pilot project, and assess the impact of that product for decisions support by testing data products in models used for decision support. Such research would need to establish partnerships with end user agencies to identify fundamental information gaps and define what is needed to improve hazard monitoring and speed disaster response.
- leveraging science to improve understanding of hazards and how these relate to a database of historical SAR data (e.g., deformation vectors) to provide guidance about potential anomalies and how they relate to disasters.

To meet these research needs the discussion group emphasized the need for funding opportunities for research using SAR in hazard mitigation or in response to disasters (e.g., rapid response) that explicitly calls for inter-disciplinary collaboration spanning not only different subject disciplines (e.g., solid Earth and urban planning), but also observation strategies (e.g., *in situ* vs. remote sensing). The discussion group also suggested inter-agency, and even international collaborations (e.g., International Charter), to fund and accomplish the research and development needed. The group emphasized that support during emergency response is only a small part of the communittees needs, which spans all stages of hazard from monitoring to identify potential problems, observation of progression, post-failure (response), recovery from disaster, to minimizing impact.

4.3. Observation needs for Applications

Many observation needs for different applications communities were discussed. Observations needs not already discussed in detail in the 2014 NISAR Applications Workshop Report are detailed in the following subsections.

4.3.1. Ecosystems

Modes of Operation

The current NISAR baseline plan is adequate for only some ecosystems applications needs, while increases in the modes of data collected and spatial and temporal extents and resolutions as well as decreased latency could vastly increase operational use. Specifically, dual-pol L-band coverage meets the minimum requirements for most ecosystems applications, while increased quad-pol coverage would improve land cover classification accuracies and enable new applications such as soil moisture estimation. Another example includes the NISAR acquisition plan that has nominal zero spatial baseline, which is excellent for interferometric SAR, but which prevents estimation of forest vertical structure and tree height, as well as limiting biomass estimation up to 100 Mg/Ha. To enable new ecosystem applications, utilizing a collection of SAR-derived forest structure and biomass with long temporal baselines is necessary. In addition, multi-frequency data would benefit monitoring a broader range of vegetation types, which could include either increased coverage by the S-band system, and/or data product compatibility with outside systems (e.g., Sentinel-1A or BIOMASS). The spatial resolution of the planned NISAR mission is expected to be adequate for all ecosystems needs. The temporal resolution of NISAR is adequate for almost all ecosystem monitoring applications, although some soil moisture events may be missed with the current resolution.

Latency

Agricultural applications have higher need for low latency than forest applications, whose latency needs are already met by the current NISAR plan. Because the US Department of Agriculture (USDA) has monthly reporting deadlines for in-season crop monitoring, operational application of SAR for crop forecasting, which would include soil moisture measurements, require data within less than a week.

Data Format

Ground-projected geocoded images are required to enable easy integration of NISAR data into existing operational applications for many end users who could potentially benefit from the NISAR mission, but who may have minimal SAR experience. Since NISAR will be likely used in conjunction with other data products (e.g., hyperspectral, lidar, precipitation data), standard formatting is important. End users would benefit from knowing the exact data formats prior to launch. The availability of higher-level products such as maps of biomass and forest change would also be beneficial, and would help with operational application in organizations that have minimal internal SAR processing capabilities.

Challenges

Although low data latency and increased quad-pol and/or S-band coverage would both happen in an ideal world, reducing data latency for applications is viewed as a challenge that is more likely to be resolved than the request to modify operational modes. Thus, data latency is the primary challenge for operational applications of ecosystems, particularly in the context of agriculture and soil moisture estimation, which cover large spatial extents. To reduce latency, one option could be to increase download bandwidth, which would support more observation downlink with reduced latency, or could accomodate more dual-pol L-band observations, increased quad-pol, or S-band coverage.

4.3.2. Hydrology and Subsurface Reservoirs

Modes of Operation

The subsurface reservoir group focused on the application of the InSAR mode and its time series of deformation. Most applications are satisfied by the current acquisition plan.

Latency

For monitoring purposes, latency is not an issue; weekly to monthly product delivery is adequate. As identified at the 2014 workshop, response to hydrologic disasters such as floods requires much more rapid turnaround. Not discussed in 2014 was the possibility of disasters related to leaking reservoirs such as oil-well leaks and natural gas blowouts such as the recent Porter Ranch leak. Monitoring surface deformation on a rapid basis may help respond to such disasters. Latency for such disaster responses is discussed in section 4.3.4.

Data Format

The primary data product discussed was a time series of deformation delivered in a standard format that can be read by ArcGIS (e.g., GeoTiff). From the time series the hydrologic community would be able to produce maps and animations of surface deformation, pixel histories for specific locations, and subsidence profiles along linear structures such as roads and canals.

Challenges

The main challenge identified by the hydrology and subsurface reservoir discussion group was that understanding and potential prediction of groundwater state and dynamics requires long time series, which challenges users with merging time series from multiple missions. In addition, this community requires spatial and temporal coverage over large areas including alluvial basins and oil and gas fields and these basins need to be monitored on a regular basis, preferably weekly. The current NISAR observation plan meets the spatial coverage needs and the planned 12 day repeat is considered adequate but not optimal.

4.3.3. Ocean and Sea Ice

Modes of Operation

The NISAR instrument has the capability of making important ocean and sea-ice measurements relevant for many applications. The preferred mode of operation may vary as significant information can be gleaned from a variety of modes. Data collection modes for ocean applications preferably operate with polarizations VV or HH with VV. Generally, wide swaths are preferred with resolutions of 50 m or better. Data for US operational agencies like NOAA are of most interest within 500 km of the US coasts. Data collection modes for ice typically operate at HH polarization in polar areas where sea-ice is an issue. HH-polarization imagery generally offers the highest contrast in normalized radar cross section between the ocean and ice covered areas. However, those trying to track sea-ice dynamics by examining scene-to-scene motion prefer VV and for ice classification, dual polarization VV and HH is preferred.

Latency

Not only do data collection modes vary by application, but also latency requirements; however, for general operational use, a latency of 3-24 hours is necessary. For ocean winds and waves, 3 hours is preferred, but 6 hours is still useful. For sea-ice monitoring, 6 hours is preferred and a 12 to 24 hour latency is still useful. For the science of monitoring the climatology of wind and waves or sea-ice, latency is not an issue.

Data Format

For algorithm development, clear instructions and examples (including software in a variety of languages) for reading the data and for calibration are required. For end users, products should be made available in standardized, easy-to-read, ready-to-use file formats (e.g. GeoTIFF, XML, KMZ, NetCDF).

Challenges

For ocean and ice applications, timeliness and spatial coverage are essential, yet challenging as net download bandwidth depend on the number and location of ground stations. The greatest limiting factor on the amount of data collected by NISAR is the ability to download. If download bandwidth can be increased, downloads can happen more frequently thereby reducing latency. An increase in download bandwidth would also make possible an increase in coverage possible. NASA could work with NOAA, the National Ice Center, the Department of Defense or other operational agencies that might require more coverage and low latency about how to make the necessary upgrades to download networks.

4.3.4. Hazards and disaster response

Modes of Operation

The continuum for acquisition modalities and spatial and temporal resolutions vary greatly with hazards and disaster response applications. For iceberg detection and mapping, SAR polarizations HH and VV are needed to detect icebergs of at least 15 m in size. A 5 to 15 day observation revisit is required during late spring and late summer along the Grand Banks of Newfoundland. For oil spill detection, multi-polarization using HH and VV modes is needed to analyze spill characteristics at a spatial resolution <30 meters and map spills at >30 meters and <100 meters within 200 km of the US coast. For critical infrastructure monitoring and emergency response, some applications need polarimetry. In general, a high fidelity InSAR baseline is necessary for coherent change detection and interferometry, which must be renewed at regular intervals. Observations are needed over areas with high-value critical infrastructure throughout the US including urban and rural areas. These observations will require the highest spatial resolution possible by NISAR when monitoring levees and structures of similar dimensions, while spatial resolution requirements can be relaxed for larger scale structures. For flood extent mapping, soil moisture monitoring will require 12 day revisit observations, which may completely miss a precipitation event, but could capture longer time period trends relevant for water levels in a wetland or downstream flooding related soil moisture.

Latency

Different hazards and disaster response applications have different latency requirements. For example, "No-Notice" disaster events of short duration such as single tornado and localized earthquakes require rapid product delivery and high spatial resolution, while large earthquakes, hurricanes, and floods have a longer response time and thus lower, albeit still timely, latency. Data latency not only constrains how and where to respond ot disasters, but in some cases *if* a community can respond. For example, smaller communities affected by mid-level disasters depend on federal disaster assistance in order to respond, the more quickly the disaster is characterized and understood, more quickly they can receive assistance. Specific to applications discussed, iceberg mapping requires final product delivery within 7 days from observation, oil spill response requires data product deliverly within 8 hours of observation, critical infrastructure monitoring requires a latency of no more than 30 days, and emergency response requires no more than 3-day latency. Some monitoring functions have much less stringent latency requirements and are in the main expected to be met by the standard NISAR product latency.

Data Format

In general, many data products are required for hazards and disaster response, however, universally, end users need finished products delivered in Geographic Information System (GIS) compatible formats with no additional processing needed for integration into their decisions support systems. It is essential that disaster response end users get precise NISAR data formats prior to launch, in order to facilitate integration of products into decision support tools for real time operational use. This is particularly true for experienced early engagers who develop "value-added" products from NISAR Level 1 data.

This community advises adopting data standards that maintain data as "agnostic" and not tied to any specific platforms or technologies. Key standards recommended by the community are:

- the Open Geospatial Consortium (OGC; http://www.opengeospatial.org/), and "international industry consortium of over 534 companies, government ageinces and universities participating in a consensus process to develop publicly available interface standards. OGC® Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services and mainstream IT. The standards empower technology developers to make complex spatial information and services accessible an duseful with all kinds of applications," and

- the National Information Exchange Model (NIEM, http://www.niem.gov/), Emergency Data Exchange Language (EDXL). "EDXL was designed to enable information about life-saving resources to be shared across local, state, tribal, national and non-governmental organizations. Implementation of EDXL standards aims to improve the speed and quality of coordinated response activities by allowing the exchange of information in real time."

While implementing OGC and NIEM EDXL standards is recommended, the community advises not using them at all is better than only partial implementation of standards, which can create even worse problems.

Challenges

The primary challenges in meeting hazards and disaster response applications are generally defined by data product latency for emergency response, some additional ocean coverage, and higher spatial resolution over sites where there would be high socioeconomic benefit from NISAR data. A key challenge for hazards and disaster response applications is prioritizing acquisition requests in the event of disasters such as a mechanism for submitting an "urgent request" for data collection during and shortly after disasters. Urgent requests should be defined in coordination with stakeholders who will use this feature during periods of emergency response. It is possible that such a protocol could be used to address spatial resolution needs in high priority urban areas for critical infrastructure monitoring. Whether these challenges could be met within the existing downlink capability of the instrument needs to be explored, for example by considering more agile tasking and examining the acquisition strategy in more detail.

4.4. Using Available Data to Implement the NISAR Applications Plan

Throughout the workshop participants articulated the need for an applications plan to use exisiting SAR datasets to produce NISAR-like data prior to launch. Also, some particiapants mentioned the use of other missions that produce similar geophysical variables as those that can be produced from SAR for training and validating products needed for applications.

4.4.1. Missions that can provide sample NISAR data formats

- Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) – airborne L-band radar
- SAOCOM (expected launch 2016)– Argentina's L-band full polarimetric Synthetic Aperture Radar (SAR) and a thermal infrared camera satellite.
- Radarsat-2 (2007-present) – part of Canada's Space Agency C-band multi-polarization satellite constellation
- Sentinel-1a/b (2014- present) part of the European Space Agency (ESA) C-band multi-polarization satellite constellation that provides open-source data
- Advanced Land Observing Satellite (ALOS) PALSAR (2006-2011) and ALOS-2 (2014 – present) – the Japanese Aerospace Exploration Agency (JAXA) L-band multi-polarization satellite

4.4.2. Missions with complementary data for product training and validation

- Ice, Cloud, and land Elevation Satellite (ICESat) ICESat-2 (expected launch 2017) – NASA's laser altimetry mission that can provide ice sheet elevation change, sea ice thickness, topography and tree height information
- Global Ecosystem Dynamics Investigation (GEDI) LiDAR (expected launch in 2018) – NASA's spaceborne LiDAR for deployment on the International Space Station will provide biomass and disturbance and recovery information.
- BIOMASS (expected launch 2020) – ESA's P-band radar measurements are expected to help monitor the ionosphere, glaciers and ice sheets, and for map subsurface geology in deserts and surface topography below dense vegetation

5. NASA, Partnerships, Existing SAR Education and Outreach Opportunities

The fourth finding of the workshop was the need for an applications plan to develop and facilitate partnerships within NASA and external to NASA. Such partnershps can leverage existing infrastructure for capacity building or provide additional resources for the development of application-ready products beyond the scope of the mission.

5.1. Stakeholder: NASA

The programs and projects listed below were discussed by participants as programs within NASA that could be leveraged to meet the goals of a NISAR applications plan. Developing the applications plan will require contributions from all of the following, but further discussions are needed in order to clearly articulate and define the roles of each in meeting applications needs as part of the NISAR applications plan.

5.1.1. Research and Analysis Program

Research Opportunities in Space and Earth Sciences (ROSES) is the annual call for proposal of research and analysis by NASA. Several times throughout the workshop, participants suggested solicitations pre- and/or post-launch to provide incentives for applications stakeholders to develop and integrate NISAR data products in their applications streams. Such funding could help new users in terms of capability development, experienced users in working groups developing tools that facilitate meeting both mission and applications requirements.

5.1.2. Applied Sciences

NISAR Program Deputy Application Leads (DPA)

The NISAR Program DPAs are responsible for acting as liaisons between end users and the NISAR mission. As part of this responsibility, DPAs will work with end users to identify application stakeholders and needs (e.g., data product formats, latency, training, etc.). DPAs will also be knowledgeable of mission development and requirements in order to inform end users of how NISAR data can be used. As part of this engagement DPAs will help design the applications plan and run education tutorials and workshops producing summary reports to facilitate a dialogue between end users and the mission. Information learned from engaging directly with end users will be reported to the NISAR mission for consideration in planning and development. The DPAs are responsible for developing an Applications Plan, whose objectives, success criteria, approach, and evaluation methods will be outlined in a report before the end of Fiscal Year 2016.

SERVIR

SERVIR is a joint venture between NASA and the US Agency for International Development (USAID) that "provides state-of-the-art, satellite-based Earth monitoring, imaging and mapping data, geospatial information, predictive models and science applications to help improve environmental decision-making among developing nations in eastern and southern Africa, the Hindu-Kush region of the Himalayas and the lower Mekong River Basin in Southeast Asia." While SERVIR "relies on other agencies for expertise in scientific research and international development," it may prove a useful partner in capacity building for NISAR applications.

Applied Remote SEnsing Training (ARSET)

ARSET is a NASA program with a mission to "increase the utility of NASA earth science and model data for policy makers, regulatory agencies, and other applied science professionals in the areas of health and air quality, water resources, forecasting, and disaster management" through webinars and in-person workshops. A partnership with ARSET could help in the DAVWG and capacity building for NISAR applications.

5.1.3. NISAR Project

The NISAR project is responsible for ensuring the scientific and engineering success of the mission in meeting the mission requirements as specified during project selection and during standard NASA reviews (e.g., PDR, CDR, etc.) that occur throughout mission development.

5.1.4 NISAR Science Definition Team

The NISAR Science Definition Team is not directly funded by the NISAR project, but does work directly with the project to ensure the mission meets its science objectives and requirements. The Science Definition Team includes an Applications Co-Lead, selected from a ROSES solicition and who is charged with representing the applications community within the Science Definition Team discussions.

5.1.5 NASA Data Active Archive Centers (DAACs)

Two DAACs have been identified by participants that may serve for implementing a NISAR applications plan:

1. The Alaska Satellite Facility (ASF) is a DAAC that downlinks, processes, archives, and distributes remote-sensing data to scientific users around the world while promoting, facilitating, and participating in the advancement of remote sensing in order to support national and international Earth science research, field operations, and commercial remote-sensing applications that benefit society. As the committed data archiving center, ASF may prove to be a valuable partner in the DAVWG and PWG.
2. National Snow and Ice Data Center (NSIDC) DAAC "manages and distributes scientific data, creates tools for data access, supports data users, performs scientific research, and educates the public about the cryosphere." NSIDC may be a valuable partner in the DAVWG and PWG.

5.2. Partnerships

Participants at the workshop identified several potential partners across Federal agencies, academia, and the private sector. These partnerships can range in character from those that receive NISAR data and have no substantial additional requirements on data to those that require additional mission resources, and therefore more coordination and potentially financial support. Below we list partner objectives/missions and potential roles that were explicitly identified by participants. We recognize that the following list is not complete and that other partners may also may be interested in participating in a NISAR applications plan (e.g., other potential partners include the Department of Energy or the American Association of State Geologists).

5.2.1. U.S. Federal Agencies and Organizations

The following include a list of US agencies and organziations, identified by participants, that may prove to be useful partners or potential end users to benefit from a NISAR applications plan.

US Department of Homeland Security (DHS)

- National Protection and Programs Directorate/Office of Infrastructure Protection (OIP): Part of its mission is to promote a secure and resilient critical infrastructure across the Nation through the provision of tools, techniques, and training to both government and private sector infrastructure managers.
- Federal Emergency Management Agency (FEMA) supports US citizens and first responders to build, sustain and improve capability to prepare for, protect against, respond to, and recover from all hazards. The 2014-2018 Strategic Plan has an objective (4.1.) to play a role in developing, coordinating, and disseminating quality risk assessment data and tools. As such FEMA may prove to be a partner in the DAVWG and capacity building.
- US Coast Guard (USCG) Marine Safety Enhancement Plan (MSEP) is a “multi-layered, several-year comprehensive program to enhance Marine Safety systems, knowledge, and processes in order to be more effective and efficient in promoting safe, secure, and environmentally sound maritime commerce” and may be actively interested in NISAR mission planning (e.g., observational strategy) for iceberg detection and oil spill mapping.

US Department of Agriculture (USDA)

- Agricultural Research Service (ARS): likely end users of data as planned (i.e., not imparting any additional observational needs)
- Forest Service (USFS): has ground truth sites called Forest Inventory Analysis (FIA) and conducts surveys to monitor and report that state of forest service lands. A key program within USFS is the Remote Sensing Activities Center (RSAC), which has a group dedicated to Rapid Disturbance Assessment Services (RDAS). RDAS has developed a new radar processing tool that simplifies the development of a flood map. It currently works with Radarsat, TerraSAR, and other assets. It would be valuable to deliver the necessary information concerning NISAR so that this tool would read NISAR data.
- National Agriculture Statistics Service (NASS) is committed to providing timely, accurate, and useful statistics regarding US Agriculture. Part of this work involves production of a Cropland Data Layer.

US Department of Commerce: National Ocean and Atmospheric Administration (NOAA)

NOAA aims to "understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resource." NOAA accomplishes this through research, development and capacity building for implementing cutting-edge research and high-tech instrumentation in order to provide citizens, planners, emergency managers and other decision makers with timely, reliable information on weather, climate, oceans and coasts, fisheries, satellites, research, marine and aviation, charting, and marine sanctuaries. NOAA may prove as beneficial partner in DAVWG, PWG, and capacity building. NOAA is also involved in operational monitoring of U.S. waters for oil and other toxin releases.

US Department of Interior: US Geological Survey (USGS)

USGS "serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life." As USGS has several advanced users of SAR data, particularly using SAR for deformation studies related to groundwater, earthquakes hazard and volcano monitoring, the USGS may partner with NISAR serving in the DAVWG and PWG, and may prove beneficial in pilot studies for applications in hazard management and disaster.

Federal Agencies

- United States Agency for International Development (USAID) has two missions to end "extreme poverty and promot[e] the development of resilient, democratic societies that are able to realize their potential." Additionally USAID has partnered with NASA to develop the SERVIR program that can be used for capacity building to integrate NISAR data.
- Environmental Protection Agency (EPA) has the mission to protect human health and the environment through developing and enforcing laws achieved by funding research to identify and solve environmental problems. The EPA may play an important role for research and development for using NISAR data.

5.2.2. Other Organizations

Other partners and key end users identified by the applications community as potential, new and experienced end users include:

- Louisiana Parish Offices of Homeland Security and Emergency Management was created because Louisiana is a "high-risk State for emergency events and disasters." Thus, it is "responsible for coordinating the State's efforts throughout the emergency management cycle to prepare for, prevent where possible, respond to, recover from and mitigate against to lessen the effects of man-made or natural disasters that threaten our State."
- California Geological Survey has a mission to provide scientific products and services about the state's geology, seismology and mineral resources that affect the health, safety, and business interests of the people of California. The CGS produces state regulatory Zones of Required Investigation for hazards including earthquake fault rupture, soil liquefaction, earthquake-induced landslides, and tsunami. In addition, the CGS Geologic

Hazards program conducts highway corridor mapping, forest and watershed landslide mapping, and provides maps, geologic information, advice, and monitors activity on minerals related to environmental and public health issues such as asbestos, mercury and radon. Following major earthquakes in California, the CGS activates the Calfiornia Earthquake Clearinghouse to provide intelligence about the geologic effects of large earthquakes and tsunamis, to state and federal disaster managers, local communities, and others. Timely acquisition of SAR data can maximize use of observations to science, and response, by improving accuracy of pre-disaster mitigation products, and helping to focus field teams, who then report to CGS personnel embedded with the State Operations Center during disaster response, respectively.

- California Department of Water Resources protects, restores, and enhances California water resources by preventing and responding to floods, droughts, and catastrophic events, thus making the California Department of Water Resources a potential end user of NISAR data.
- California Office of Emergency Services has the mission to "serv[e] the public through effective collaboration in preparing for, protecting against, responding to, recovering from, and mitigating the impacts of all hazards and threats" with departments in Technological Hazards and Systems and Technology Operations. Either of the departments may provide beneficial partnerships for verifying NISAR applications in hazards and disaster response.
- World Bank has two missions to end extreme poverty and promote shared prosperity. World Bank offers financing to developing countries and "offers support… through policy advice, research and analysis, and technical assistance… support[ing] capacity development… and host[ing], or participat[ing] in many conferences and forums on issues of development, often in collaboration with partners."
- Canada Agriculture and Agri-Food Canada (AAFC) "provides leadership in the growth and development of a competitive, innovative and sustainable Canadian agriculture and agri-food sector." Perhaps the most relevant department for NISAR is the Science and Technology Branch Sector with strategic initiatives to provide research to augment knowledge acquisition, develop applications for that knowledge and transfer the knowledge and technologies to stakeholders including varying levels of government, academia, the private sector and other organizations across Canada. As such, this may be a partnerships involved in capacity building, DAVWG and PWG working groups.

5.3. Existing Infrastructure for Outreach and Engagement

Participants recognized that education and outreach would be necessary for a NISAR applications plan in order to inform new users and engage potential end users. Several existing SAR educational organizations were identfieid and lists of professional meetings and conferences provided.

5.3.1. Organizations

Participants explicitly identified two existing orgranizations/programs with the objective to provide SAR educational resources and increase SAR literacy. A NISAR applications plan could work with these organizations for capacity building.

1. UNAVCO is a non-profit, university-governed consortium, facilitating geoscience research and education for using geodesy. UNAVCO offers SAR tutorials and workshops and may be a valuable partner is NISAR outreach and education.
2. SAREdu is a joint coordination between Friedrich-Schiller University Jena and the German Aerospaice Center to provide "knowledge about the basics, methods and applications of Radar Remote Sensing to users and scientists." SAREdu hosts many useful tools and that can linked from the NISAR applications outreach and education pages.

5.3.2. Suggested Conferences

Participants identified several key workshops and professional meetings of which may valuable for reaching end user communities including:

- ACWA - Association of California Water Agencies
- AEG
- AGU
- AGU Ocean Sciences Meeting
- Air-Sea, Boundary Layer Meetings
- AMS Hurricane
- Annual National Hurricane Center (NHC) Meeting
- ASAR WS
- ASG - Association of State Geologist
- ASPRS
- Association of State Geographics System Information (GIS)
- AZ hydro society
- DOE – Geothermal
- ESRI
- FEMA Capstone Exercise
- ForestSAT
- Fringe
- GEOINT
- Geothermal Research Council
- Groundwater resources Association of California
- IGARSS
- International Association of Landscape Ecology
- Living Planet
- NGA-preferred venue
- NGWA - National Ground Water Association
- Polar Science Meeting.
- SPIE Defense and Commercial Sensing
- SPIE Remote Sensing
- Stanford Geothermal workshop
- Western Governors Association
- Western States Water Council

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6. Appendices

6.1. Agenda

13 October Tuesday		
8:30 AM	*Check-in*	
9:00 AM	Paul Rosen	SAR Overview
10:30 AM	*Break*	
10:45 AM	Scott Hensley, Naiara Pinto, Maggi Glasscoe, Andrea Donnellan	UAVSAR Tutorial
12:00 PM	*Lunch*	
1:00 PM	First tutorial Session	
	Sassan Saatchi, Paul Siqueira	Ecosystems & Agriculture
	Brad Hager, Brian Conway, Tom Farr, Gerald Bawden	Surface Deformation for Subsurface Reservoirs
2:55 PM	*Break*	
3:05 PM	Second Tutorial Session	
	Frank Monaldo	Ocean Applications
	Mark Simons, Franz Meyer	Change Detection for Disaster Response & Surface Deformation for Natural Hazards
5:00 PM	*Adjourn*	
14 October Wednesday		
8:00 AM	*Check-in*	
8:30 AM	Craig Dobson, David Green, NASA HQ	Welcome to Workshop
8:45 AM	Paul Rosen, JPL, NISAR Project Scientist	Overview of Mission/Update since last workshop
9:30 AM	Franz Meyer, University of Alaska, NISAR Science Definition team	Mission Data Products
10:00 AM	*Break*	
10:15 AM	Susan Owen, JPL, NISAR Deputy Applications Lead	Recommendations from last workshop, charge for this workshop

10:35 AM	Brian Conway, AZ DWR	"Using InSAR Data for Groundwater Management in Arizona"
11:00 AM	Poster Session #1	
12:00 PM	*Lunch*	
1:30 PM	Paul Spielman, Ormat Technologies	"Applying InSAR to Managing Geothermal Reservoirs: Case Study at Brady's Hot Spring, Nevada, USA. "
1:50 PM	Susan Owen, JPL	Charge for Breakout #1
2:00 PM	Breakout #1: Identify key challenges/activities needed for using NISAR	
3:45 PM	*Break*	
4:00 PM	Frank Monaldo, NOAA	Presentation on addressing continuity challenge
4:20 PM	Breakout subgroup leaders	Reports from Breakout #1
5:00 PM	*Adjourn*	
15 October Thursday		
8:00 AM	*Check-in*	
8:30 AM	Sassan Saatchi, JPL	Presentation on multi-mission/data fusion application
8:50 AM	Susan Owen, JPL	Charge for Breakout #2
9:00 AM	Breakout #2 - Multi-mission applications, opportunities and challenges	
10:15 AM	*Break*	
10:30 AM	Breakout subgroup leaders	Reports from Breakout #2
11:00 AM	Poster Session #2	
12:00 PM	*Lunch*	
1:00 PM	Private Sector Panel: Alessandro Ferretti, TRE; Richard Carande, Neva Ridge; Todd Jamison, Observera; John Peter Merryman Boncori, Sarmap; Tyler Erickson, Google. Moderator: Andrea Donnellan, JPL	
2:00 PM	Susan Owen, JPL	Charge for Breakout #3

2:10 PM	Breakout #3 - Discuss and Draft Applications 'Roadmap'	
3:45 PM	*Break*	
4:00 PM	Breakout subgroup leaders	Reports from Breakout #3
4:30 PM	Paul Rosen, NISAR Project Scientist	Summary
5:00 PM	*Adjourn*	

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6.3. Experienced Users Suggested Working Group Tasks

	DAVWG	PWG	AICWG
FY16			○ Identify willing atmospheric and ionospheric scientists outside the InSAR community
FY17			○ Hold well-planned meetings in both an atmospheric science and/or an ionospheric science institution to develop a plan ○ Engage the atmospheric community a day before or after an SDT meeting
FY18	○ Provide feedback to the project regarding definition of data products defined in FY17 ○ Develop data products not within the scope of the project ○ Develop partnerships for handling the sample data and the mission products	○ Provide feedback to the project regarding data products defined in FY17 ○ Develop algorithms for applications that are not in scope for the project ○ Work with the project or DAVWG to integrate these algorithms into applications-specific products	○ Release first prototype products (based on forecast models) for testing and quality assessment using Sentinel-1 and ALOS-2 data
FY19	Establish funded mechanisms for dealing with		

	applications-specific products	
FY20	Test the processes established by the DAVWG for applications data products as the project conducts its readiness tests	Work with the DAVWG on testing as the project conducts its readiness tests
FY21	Dissolve, or migrate to a funded operational applications program element for product generation and dissemination	Dissolve, or merge with a funded operational applications program element for product generation and dissemination