2017 NISAR Applications Workshop: Sea ice Applications and Science

NOAA Center for Weather & Climate Prediction
College Park, Maryland
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Workshop Report

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1 Executive Summary

The NASA-ISRO Synthetic Aperture Radar (NISAR) is a mission that will map much of the Earth's land and polar areas with a high-resolution, multiple-polarization, L-band SAR built by NASA. The instrument payload will also include an S-band SAR provided by the Indian Space Research Organization (ISRO). One mission science goal is the measurement of the Earth's cryosphere. Given the extent of NISAR coverage of the Arctic and Antarctic, there is the opportunity for both scientific and operational uses of these data. This workshop focused on sea ice measurements.

The modes of operation of NISAR can provide data for operational monitoring of sea ice concentration, sea ice extent and sea ice classification. The extent to which these data will be useful in an operational context depends on the latency with which the data can be provided, particularly in the Arctic with recent increases in marine activity. Most operational products require latencies from 6 to 24 hours, where some weekly products can use data with latencies as great as 24 to 48 hours. There is a preference for dual like-polarization (HH and VV) data for ice type classification, though like-polarization (HH or VV) and dual like- and cross-polarization (HH and HV, or VV and VH) will provide important and useful input to operational cryosphere monitoring. Priorities for rapid processing of NISAR data should be considered in the context of augmenting data from the series of operational Sentinel-1 satellites and the Radarsat Constellation Mission.

From an operational standpoint, a right-looking NISAR configuration which covers more of the Arctic is strongly preferred. If there is a short period of time for left-looking coverage, the seasonal preference is for the Arctic spring, when the Arctic is still largely frozen and there is less ship traffic in the marginal seas.

From a scientific perspective, the sea ice community sees NISAR as providing continuous coverage, with a strong preference in terms of scientific interests for greater Arctic coverage than greater Antarctic coverage. In addition, the L-band imagery is an important complement to the C-band coverage from Sentinel and Radarsat. NISAR has a specific NASA level-1 science requirement to measure both Arctic and Antarctic sea ice velocities on a 5-km grid with an average sampling capability of three days; a velocity accuracy of 100 m/day or better over at least 70% of the sea ice area. This can be met with a largely right-looking mission. This level-1 requirement provides the necessary coverage for both operational and science needs.

In addition to ice motion, the primary scientific measurements of interest for NISAR are sea ice concentration and ice type. Other measurements of interest include deformation of landfast ice, ridge delineation, melt pond coverage, ocean wave height in the marginal ice zone, snow/ice roughness, and floe-size distribution.

The NISAR Sea ice Applications Workshop was held at the NOAA Center for Weather and Climate Prediction (NCWCP) in College Park, Maryland. Copies of the presentations are provided at: https://www.star.nesdis.noaa.gov/sod/mecb/sar/NISAR_Sea_Ice_Workshop/.

2 Overview

2.1 Workshop Objectives

The purpose of the workshop was to advise the NISAR mission on issues of mode of operation, coverage, latency, and other factors that influence the applicability of the NISAR data to sea ice measurements outside the scope of the mission science requirements and operational monitoring programs. Other objectives were to identify the NISAR products most useful to this community, to develop collaborations that increase the utility of the NISAR mission data for sea ice applications, and to consider any additional scientific recommendations in the context of the NISAR cryosphere science requirements.

2.2 Workshop Format

The workshop consisted of presentations by representatives of the NISAR mission, stake holders in operational agencies such as the National Oceanic and Atmospheric Administration, the US Navy, the US National Ice Center, the National Geospatial-Intelligence Agency, and the Environment and Climate Change Canada. Other represented institutions included NASA Headquarters, the NASA Jet Propulsion Laboratory, the Johns Hopkins University Applied Physics Laboratory, the University of Alaska, the University of Calgary, and the Canadian Space Agency.

3 Mission Overview[1]

3.1 Mission Design and Capabilities

NISAR is a joint NASA and Indian Space Research Organization (ISRO) synthetic aperture radar (SAR) mission currently scheduled to launch in 2021. The mission will be equipped with an L-band SAR provided by NASA and an S-band SAR provided by ISRO. ISRO will provide the launch services.

With precision orbit determination, NISAR will provide interferometric measurements that can

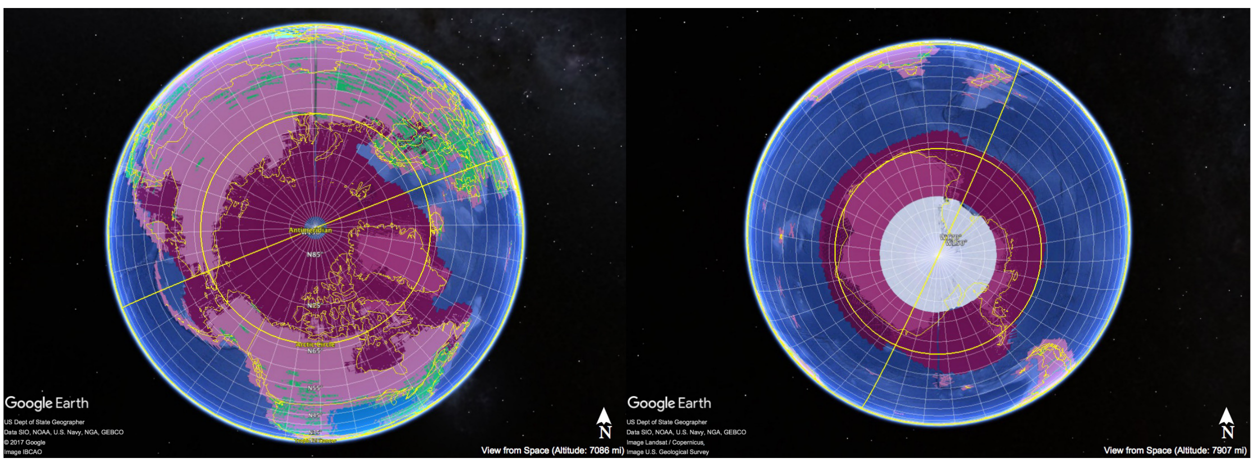

Figure 1 NISAR coverage of the Arctic (left) and Antarctic (right) for the nominal right-looking configuration The yellow circles are the Arctic and Antarctic circles, respectively. The white area in Antarctica is the region not sampled by NISAR in the right looking mode.

measure surface deformations and motions as well as provide calibrated normalized radar cross section (NRCS) measurements. The four primary science missions cover: Earth Surface and Interior, Cryosphere, Ecosystems, and Ground Water Changes. In addition, the NISAR mission has recognized the need to provide support to other possible SAR applications to the extent that they can be reasonably accommodated within the scientific mission goals.

Because of the relatively complete coverage of the Arctic and Antarctic, NISAR data will allow monitoring of sea ice, including sea ice motion and deformation, and changes in sea ice concentration, sea ice extent, and sea ice type.

3.2 Current Mission Observation Plan

NISAR will be in a 12-day repeat orbit. Figure 1 shows the current NISAR observation plan (right-looking SAR-pointing) in the polar regions.

[1] Based on presentations by Paul Rosen and Maher Hanna-JPL.

This plan provides extensive repeat coverage of the Arctic regions in the right-looking configuration up to 87.5°N, with coverage in the Southern Hemisphere to 77.5°S. The Antarctic land-ocean border is largely further north than 77.5°S, so that virtually all of the Antarctic sea ice will be imaged even in a right-looking configuration. In a left-looking SAR-pointing configuration, the extent of maximum latitude coverage is reversed. The dominant polar coverage mode shown as dark purple in Figure 1 is at VV-polarization with a resolution of 48 m × 8 m.

NISAR has a specific NASA level-1 science requirement to measure both Arctic and Antarctic sea ice velocities on a 5-km grid with an average sampling capability of three days; a velocity accuracy of 100 m/day or better over at least 70% of the sea ice area. The current mission observation plan described above meets this requirement.

An important concern for operational use is data latency since many operational centers support customers that require as close to near real time data as possible. The older the data, the less representative it is for real time applications. NISAR is a science mission, so there are no formal requirements for low latency. Data latency is the sum of component latencies. The first latency limit is the time between data acquisition at the satellite and download at a ground station. It is expected that data will be downloaded a maximum of 9 hours and typically less than two hours past acquisition. The second latency is the time from download to delivery for processing. The maximum time for this is expected to be about two hours. Processing of data to L0a/b levels could take up to 12 hours, depending on the delivery of precision orbits. Without the use of precision orbit solutions, the processing would take less time. The maximum data latency is not the sum of the maximum latency of each component. It is expected that L0a/b data will be available within 14 hours, and this time may be substantially smaller. At present, there is no estimate of the mean or median data latency. As the mission design matures before launch, we anticipate a better estimate of these quantities.

4 Sea ice in an Operational Context[2]

Two primary operational users of SAR sea ice imagery are the US National Ice Center (NIC) and the Canadian Ice Service (CIS), although other Arctic countries have ice services as well. The NIC is a joint operation of the US Navy, NOAA, and the US Coast Guard. The CIS and NIC cooperate in monitoring the Arctic sea ice as part of the North American Ice Service (NAIS).

4.1 Coverage

The primary mission of these operational services is to provide information important for safety and navigation for operations in ice covered waters, including the Arctic, Antarctic, and the Great Lakes. There is far more marine traffic in the Arctic regions than in the Antarctic. In terms of tradeoffs between Arctic and Antarctic coverage, Arctic coverage has a higher priority for operational users. The extent of sea ice, sea ice concentration, and ice type are monitored by a variety of remote sensing and in situ measurements. Because of their high (<40 m resolution), all weather, day-night capabilities, Radarsat-2 and Sentinel-1A/B SAR imagery are the primary sensors currently used. Radarsat-2 data are purchased from MacDonald, Dettwiler and Associates by the NIC for critical areas near the ice edge or to support particular operations. Because of cost limitations, usually a dozen images a day or fewer are obtained from Radarsat-2. By

[2] Based on presentations from LDCR Colin Thornton, Christopher Jackson, Sean Helfrich, and Yves Crevier.

contrast, Sentinel-1A and Sentinel-1B are freely available via ESA. Several hundred images over both polar regions are available daily.

Figure 2 shows the Arctic coverage for Sentinel-1A and Sentinel-1B. The Eastern Arctic is heavily sampled by both satellites with significantly less coverage over the Western Arctic. Sentinel-1A coverage extends to about 81°N, limited not by the orbit, but by the acquisition schedule. Sentinel-1B coverage extends to about 87.5°N, though it, like Sentinel-1A, is in a right-looking configuration with a similar orbit.

In 2018, the Canadian Space Agency (CSA) plans to launch the Radarsat Constellation Mission (RCM).

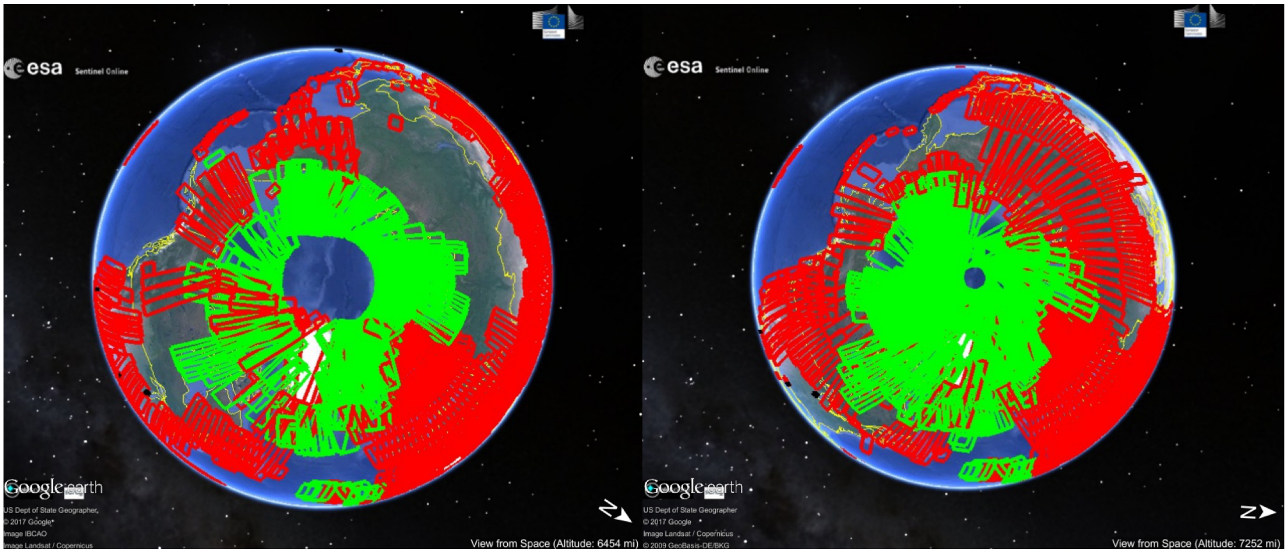

Figure 2 Sentinel-1A (left) coverage and Sentinel-1B (right) coverage over 12-day repeat. Red is the Interferometric Wide mode (240 km width) and the green is Extended Wide mode (400 km width).

We anticipate that the majority of these data will be free and open, with coverage focused over Canada and the Canadian Arctic including the Beaufort Sea (see Figure 3).

It is important to recognize that despite the operational availability of non-US SAR data sources, NISAR offers important complementary information. NISAR operates at L-band rather than C-band, with important additional capablities in sea ice type discimination and derived ice motion. Although there are other sources of L-band data, particlarly ALOS-2 data, these other sources of L-band imagery will not likely be available in sufficient quantity for effective use in an operational context.

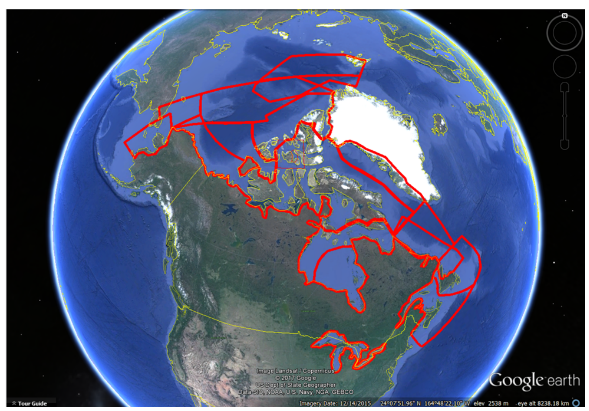

Figure 3 Radarsat Constellation Mission coverage areas.

In addition, the sea ice motion measurements from NISAR aid in sea ice modeling and forecasting.

4.2 Latency

The necessary latency for effective use of SAR imagery depends on the product being produced. Daily products, for example, require lower latency than weekly products. Table 1[3] lists products produced by the US National Ice Center that involve sea ice information. The right-hand column is the time to expiration. No older data should be included in the product. Because the product involves some automatic and human processing, in actuality data should be available significantly before the expiration times to be usefully incorporated into the final product.

The most challenging products for NISAR's contribution are tactical ship support and iceberg monitoring. To support either of these, rapid processing would be needed for data collected over the ocean without use of the precision orbit, or the operational agencies would need to process L0 NISAR data themselves.

US National Ice Center Sea ice Products	Expiration
Daily ice edge and Marginal Ice Zone	24 hours
48HR ice edge forecast	24 hours
Sea ice routing	24 hours
Fractures Lead and Polynyas	24 hours
Tactical Ship Support	12 hours
NASA Icebridge Support	24 hours
Weekly ice chart	5 days
Alaska Imagery Support	18 hours
Blended IMS Snow and Ice Cover	36 hours
Blended Ice Concentrations	18 hours
Great Lakes Ice Analysis	48 hours
Iceberg monitoring	12 hours

Table 1 US National Ice Center products and expiration times.

5 Sea ice: New Applications and Science

5.1 Automated Sea ice Discrimination

The US NIC and the Canadian CIS have relied for decades on teams of analysts to interpret satellite imagery in the generation of their products. As satellite data have grown in volume, it is becoming more difficult for people to visually interpret each element of data. In addition, if sea ice products are to be incorporated into prediction models, the variability of the products from analyst-to-analyst needs to be reduced. Efforts to at least partially automate the generation of these products are beginning to take place.

The NRCS from a particular location in a single SAR image acquired with a single polarization is related to sea ice concentration and ice type, but these quantities cannot be uniquely determined from the single measurement. In addition to the NRCS, analysts use image texture and knowledge of previous sea ice states to generate maps of current sea ice parameters.

As more satellite SAR imagery become available at different polarizations and frequencies, automated product generation becomes easier. While a single NRCS measurement may be limited, an area imaged at

[3]Helfrich, S. Operations at the NIC, NISAR Sea Ice Applications Workshop, College Park, MD, 2017.

different polarizations and frequencies will constrain whether that area is open ocean or ice-covered, and possibly indicate ice type. Komarov and Buehner[4] used Radarsat-2 data at C-band HH- and HV-polarizations plus SAR image texture to discriminate between ice and water. The results were compared with sea/water estimates by the Interactive Multisensor Snow and Ice Mapping System (IMS) and CIS ice charts constructed from analysts' interpretations. The most recent version of the approach was able to obtain an ice or no-ice retrieval 66% of the time, and these retrievals had a 99.7% accuracy. The lower frequency L-band of NISAR has greater penetration into ice than C-band and may help resolve the 34% for which no retrieval was obtained.

SAR data can also be used in conjunction with other measurements. Keller[5] demonstrated examples where higher-ordered statistics from SAR could be combined with passive microwave polarization ratios to aid in automated sea ice extent discrimination.

5.2 Sea ice Uses of InSAR

Interferometric SAR (InSAR) is the use of two SAR images separated in space or time to measure surface topography or surface motion, an analysis methodology for which the NISAR mission is largely designed for multiple investigations. The sea ice pack has rapid time scales of motion and deformation that are not suitable for using InSAR, particularly at the 12-day NISAR orbit repeat interval. However, sea ice may form along the coast and remain in place (landfast ice), with only vertical fluctuations observed due to tidal changes. In such conditions, INSAR has been shown to be useful for assessing stability and small-scale displacement, of importance for indigenous activities and as a means to monitor the safety of ice roads.[6,6]

5.3 Particular Advantages of L-band

Although there are a number of SAR systems in orbit, the systems that will produce imagery on a free and open basis and in sufficient quantities to be operationally useful are Sentinel-1A/B and soon the RCM, which

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[4] Komarov, A. S. and M. Buehner, Automated detection of ice and open water from dual-polarization RADARSAT-2 images for data assimilation, *IEEE Transactions on Geoscience and Remote Sensing*, vol. 55, no. 10, pp. 5755–5769, Oct. 2017.

[5] Keller, M., Active/Passive Dual Polarization Sea Ice Detection, NISAR Sea Ice Applications Workshop, College Park, MD, 2017.

[6] Damman, D. O., H. Eicken, F. J. Meyer, and A. R. Mahoney, Assessing small-scale deformation and stability of landfast sea ice on seasonal timescales through L-band SAR interferometry and inverse modeling, *Remote Sens. Environ., 187*, 492–504, 2016.

[6] Meyer, F. J., A. R. Mahoney, H. Eicken, C. L. Denny, H. C. Druckenmiller, and S. Hendricks, Mapping arctic landfast ice extent using L-band synthetic aperture radar interferometry, *Remote Sens. Environ.*, vol. 115, no. 12, 3029–3043, 2011.

both operate at C-band. Although the ALOS L-band SAR data have been very valuable, NISAR imagery will allow larger scale uses of L-band imagery over sea ice: [7,8,9,10,11]

- Has shown an ability better than C-band for observing deformed sea ice, due to increased penetration and volume scattering. This leads to improved feature detection and identification of individual floes;
- Has greater penetration and together with multiple polarization allows for better discrimination between first-year and multi-year ice;
- Because of improved feature detection, initial results indicate improved ice motion detection particularly during summer melt periods.

5.4 Sea ice Modeling

Passive microwave or scatterometer observations of sea ice are currently the main source of information assimilated in operational short-range numerical sea ice prediction systems.[11] However, the low spatial resolution (~20–50 km) of these types of data makes them difficult to apply in the vicinity of a shoreline and within narrow channels. Furthermore, current algorithms using passive microwave have been demonstrated to underestimate the ice conditions along the edge, in the marginal ice zone, and when melt ponds are present. Assimilation of high-resolution SAR observations in numerical sea ice prediction models is an emerging application which will potentially improve the short-term forecast. Only SAR-derived retrievals with very high level of confidence could be assimilated in numerical prediction systems in order to avoid translating and magnifying errors in the resulting ice forecasts. Ice and water detection with very high accuracy of 99.7% are performed from C-band dual-polarization (HH-HV) Radarsat-2 images.[4]

However, currently, on average only 66% of Radarsat-2 data are confidently classified as ice or water. It was shown that L-band SAR provides more ice motion vectors (i.e., more similar features detected in two successive images) with higher confidence compared to C-band due to the increased penetration depth of L-band signal.[10] Therefore, it is anticipated that richer texture of L-band dual-polarization NISAR images could provide improved ice/water detection and ice concentration retrievals compared to C-band SAR.

Ice/water state and ice concentration along with other important characteristics of sea ice such as melt pond coverage derived from SAR could be used for data assimilation in sea ice forecast models.

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[7] Casey, J. A. et al., Separability of sea ice types from wide swath C- and L-band synthetic aperture radar imagery acquired during the melt season, *Remote Sensing of the Environment,* vol. 174, pp. 314–328, https://doi.org/10.1016/j.rse.2015.12.021, 2016.

[8] Dierking W. and T. Busche, Sea ice monitoring by L-band SAR: an assessment based on literature and comparisons of JERS-1 and ERS-1 imagery, in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 44, no. 4, pp. 957–970, April 2006.

[9] Dierking, W., Sea ice monitoring by synthetic aperture radar, *Oceanography,* vol. 26, no. 2, pp. 100–111, http://dx.doi.org/10.5670/oceanog, 2013.

[10] Howell, S. A., A. S. Komarov, M. Daboor, B. Montpetit, M. Brady, R. K. Scharien, M. S. Mahmud, V. Nandan, T. Geldsetzer, and J. A. Yackel, Comparing L- and C-band synthetic aperture radar estimates of sea ice motion over different ice regimes, *Remote Sensing of Environment*, vol. 204, pp. 380-391, http://dx.doi.org/10.1016/j.rse.2017.10.017, 2018.

[11] Buehner, M., A. Caya, T. Carrieres, and L. Pogson, Assimilation of SSMIS and ASCAT data and the replacement of highly uncertain estimates in the Environment Canada Regional Ice Prediction System, *Q. J. R. Meteorol. Soc.*, vol. 142, pp. 562–573, Jan. 2016.

Furthermore, the high-resolution NISAR products such ice motion, ice/water state, and ice concentration will represent an important source of data for verification of sea ice forecast systems.

6 Summary and Recommendations from the Workshop

6.1 Operational Use

With the advent of operational SAR imagery delivered in near real time from the Sentinel-1 satellite series and the Radarsat Constellation Mission, we are entering a new age in sea ice monitoring and classification using SAR imagery. We can expect coverage sufficiently dense to monitor and track sea ice in the Arctic and Antarctic. Although it is understood that NISAR is not an operational mission, its current configuration offers the important prospect of significant additional regularly-acquired imagery. Since both Sentinel-1 and RCM operate at C-band, NISAR offers frequency diversity that can aid in automated sea ice detection and concentration estimates as well as sea ice classification.

We have the following recommendations for operational parameters and acquisition mode configuration of NISAR that will be best for sea ice science and applications.

6.1.1 Polarization:

In order of preference, we recommend:

- Dual, like-polarization (HH/VV),
- Dual, cross-polarization (HH and HV or VV and VH, no preference),
- Single, like-polarization (VV or HH, no preference).

6.1.2 Coverage:

The current coverage of NISAR in its right-looking mode meets operational needs and is strongly preferred. There is sufficient coverage of the high-Arctic (up to 87.5°N) and the coverage extends to the land-sea Antarctic boundary. In a left-looking configuration and in the summer months even the ice edge would be challenged to cover, particularly in the Eastern Arctic. If there is a short period of time for left-looking coverage, the seasonal preference is for the Arctic spring, when the Arctic is still largely frozen and there is less ship traffic in the marginal seas. However, the measurement of high-Arctic surface motion, that can help drive sea ice coverage models, in a left-looking configuration is limited by the maximum northern coverage level of 77.5°N.

6.1.3 Latency:

At the time of the workshop, the maximum expected time from acquisition of the data at the satellite to download and processing into L0a/b imagery is 14 hours. It is not yet clear what the median time for image delivery will be. For some applications, particularly weekly sea ice status reports, this latency is adequate. To expand NISAR's utility, we strongly recommend efforts to generate detected imagery in 6-12 hours after acquisition. It should be noted that for sea ice applications precision orbits are not required.

6.1.4 Calibration

The current NISAR calibration requirements of radiometry will be sufficient for sea ice applications.

6.1.5 Geolocation

Geolocation accuracy should be better than 100 m, preferably comparable to the image resolution. This is met by NISAR's current configuration.

6.2 New Applications and Science

6.2.1 Scientific Use

NISAR will provide an important opportunity to understand the dynamics of sea ice and its impact on climate. The participants in the workshop concluded that the necessary scientific measurements could be characterized by thee levels of priority.

6.2.1.1 Priority 1

The measurements of highest priority are sea ice concentration and ice motion. Since sea ice concentration can vary from 0-100%, sea ice concentration is derivable from high-resolution sea ice extent. Not only does sea ice extent control the temperature fluxes between the ocean and atmosphere, so does sea ice thickness. In addition, the measure of ice motion, including drift as well as convergence and divergence, is an important dynamic measurement.

6.2.1.2 Priority 2

The next highest priority measurements are sea ice type, the deformation of landfast ice, ridge delineation, and surface roughness. Although sea ice thickness is strongly correlated with sea ice type, they are not the same. Multi-year ice has a different crystalline structure and reduced salinity than even thick first-year ice. Landfast ice protects shores from ocean storm waves, so the structure and stability of land-fast ice is an important parameter that needs better understanding. These measurements for landfast ice area can be optimally done using InSAR processing, which requires data acquisitions to be obtained in the same mode for all acquisitions over an area. In addition, sea ice structure can be better understood with measurement of ridge delineation.

6.2.1.3 Priority 3

The third level of measurement priorities are melt pond coverage, particularly in the summer; wave height in the marginal ice zone; and floe size distribution. L-band can be used to measure melt-pond coverage, but even with its greater penetration depth, it could still be difficult to discriminate between ponds and leads. S-band imagery from NISAR and C-band imagery from Sentinel-1 could alleviate this issue. Combined L-band and S-band imagery could help measure snow depth over the ice. NISAR ocean wave height measurements in the marginal ice zone will help determine wave stress that can contribute to sea ice breakup. High-resolution NISAR imagery will also help map floe size distribution.

6.2.2 Challenges

Although NISAR will provide comprehensive L-band imagery over the Arctic, there remain challenges to the use of these data:

•There is a need for additional development of techniques for the assimilation of sea ice data into both atmospheric and ice-prediction models.

•The signals from melting ponds and thinner ice types can be very low, so the instrument noise floor may be an issue. An evaluation of the spatial resolution vs. noise floor is needed to determine the best observation mode for this application.

•Sea ice science would significantly benefit from continuous coverage of the Arctic in a right-looking configuration. This may conflict with other science requirements.

6.2.3 Polarization

The instrument polarization requirements are identical to those requirement for operation sea ice monitoring. In order of preference, we recommend:

- Dual, like-polarization (HH/VV),

- Dual, cross-polarization (HH and HV or VV and VH, no preference),
- Single, like-polarization (VV or HH, no preference).

6.2.4 Coverage
Similar to requirements for science, operational measurements are best made in a right-looking configuration to capture as much of the Arctic sea ice as possible.

6.2.5 Latency
The current planned latency of 14 hours is sufficient for scientific uses of NISAR data for sea ice.

6.2.6 Calibration
The current NISAR calibration requirement will be sufficient for sea ice science.

6.2.7 Geolocation
Geolocation accuracy should be comparable to the image resolution, of order 10 meters.

7 Appendices

7.1 Agenda

8:00 AM – 8:30 AM	Arrival & Sign-In
8:30 AM – 9:30 AM	Overview of NISAR Mission
	NISAR Mission, *Paul Rosen, JPL*
	NISAR Coverage, *Paul Rosen, JPL*
	NISAR Products and Latency, Maher Hanna, *JPL*
9:30 AM – 9:45 AM	U.S. National Ice Center Mission, *LCDR Colin Thornton*
9:45 AM – 10:00 AM	*Break*
10:00 AM – 10:45 AM	National Ice Center Operations & Users of SAR *Chris Jackson: Sentinel processing, possible products* *Sean Helfrich: Operations at the NIC*
10:45 AM – 11:30 PM	Radarsat 2+ and Sentinel-1 coverage *Yves Crevier: (Discussion of Radarsat-2 and RCM)* *Frank Monaldo: Sentinel-1 coverage*
11:30 PM - 12:30 PM	Lunch Break & *Sabrina Delgado Arias: ICESAT-2 Early adopter experience*
12:30 PM – 2:45 PM	Science talks *Andy Mahoney: Sea ice applications of InSAR and altimetry* *John Yackel: L-Band SAR for Arctic Sea Ice Monitoring* *Alexander Komarov: Automated detection of ice and open water from RADARSAT-2* *Mary Keller: Active/Passive Dual Polarization Sea Ice Detection* *Jia Wang: Modeling Great Lakes and Arctic ice cover using FVCOM+ice model*
3:00 PM – 4:00 PM	Breakout Session 1: Operations Priorities – *Frank Monaldo*
3:00 PM - 4:00 PM	Breakout Session 2: Science Priorities - *Susan Owen and Cathleen Jones.*
4:00 PM - 5:00 PM	Joint Session to outline feedback to the NISAR mission (*coverage, latency, products, modes*)
5:00 PM	*Adjourn*

7.2 Participants

First Name	Last Name	Affiliation
Jordan	Bell	NASA
Kevin	Berberich	NOAA
Jennifer	Clapp	NOAA
Larry	Connor	NOAA
Yves	Crevier	Canadian Space Agency (presentation via Webex)
Sabrina	Delgado Arias	NASA
Craig	Dobson	NASA
Vanessa	Escobar	NASA
Sinead	Farrell	NOAA
Kyle	Foster	NGA
Maher	Hanna	NASA JPL
Sean	Helfrich	NOAA
Benjamin	Holt	NASA JPL
Christopher	Jackson	NOAA
Cathleen	Jones	NASA JPL
Mary	Keller	Johns Hopkins APL
Alexander	Komarov	Environment & Climate Change Canada
Li	Li	US Navy - NRL
Xiaofeng	Li	NOAA
Andy	Mahoney	University of Alaska, Fairbanks
Dave	McAdoo	NOAA
David	McCormick	NOAA
Mark	Middlebusher	US Navy
Frank	Monaldo	NOAA/Johns Hopkins APL
Sofia	Montalvo	NOAA
Susan	Owen	NASA JPL
William	Preissneer	NGA
Paul	Rosen	NASA JPL
Colin	Thornton	NOAA
Jia	Wang	NOAA Great Lakes
John	Yackel	University of Calgary (presentation only)

7.3 Acronyms

ALOS	Advanced Land Observing Satellite
APL	Applied Physics Laboratory
CIS	Canadian Ice Service
CSA	Canadian Space Agency
ESA	European Space Agency
HH	Horizontal Transmit/Horizontal Receive
HV	Horizontal Transmit/Vertical Receive
InSAR	Interferometric Synthetic Aperture Radar
ISRO	Indian Space Research Organization
JPL	Jet Propulsion Laboratory
NAIS	North American Ice Service
NASA	National Aeronautics and Space Administration
NESZ	Noise Equivalent Sigma Nought
NGA	National Geospatial-Intelligence Agency
NIC	National Ice Center (US)
NISAR	NISAR-ISRO Synthetic Aperture Radar
NOAA	National Ocean and Atmospheric Administration
NRCS	Normalized Radar Cross Section
NRL	Naval Research Laboratory
RCM	Radarsat Constellation Mission
SAR	Synthetic Aperture Radar
VH	Vertical Transmit/Horizontal Receive
VV	Vertical Transmit/Vertical Receive