SMAP/ICESat-2 Sea Ice Focus Session

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Focus Session Objectives and Summary

The SMAP/ICESat-2 Sea Ice Focus Session was a follow-up to the SMAP/ICESat-2 Joint Mission Tutorial held in Fairbanks, Alaska on September 18-20, 2012. This follow-on meeting, co-hosted by the United States Naval Research Laboratory (NRL), opened up a unique opportunity to explore, in detail, the benefits for incorporating SMAP (launched 2015) and ICESat-2 (launching 2017) data products into existing sea ice research for operational and commercial applications.

Focus Session Goals

- Examine the challenges and opportunities related to the use of SMAP and ICESat-2 data for developing operational sea ice products. Clarifying how each mission's data products will function within the framework of the operational US Navy. Understand the data and information needs of the maritime community when navigating through the Arctic.
- Assess the potential efficacy of ICESat-2 and SMAP data in operational and decision-making contexts.
- Explore possibilities for combining ICESat-2 and SMAP data products to leverage the functionality of the products for sea ice applications with the NRL. Identifying product synergies between SMAP and ICESat-2 that will enhance existing sea ice products
- Plan how to better utilize mission products for maritime applications and decision support.

Expected Focus Session Outcomes

NRL is the primary development center for operational sea ice data in the Arctic, distributing forecasting information to the National Ice Center and the Maritime Community. Through this workshop we expected the following outcomes:

1. A clear and thorough understanding of functionality of the SMAP and ICESat-2 data products for sea ice;
2. A better understanding of opportunities and limitations in using mission products operationally ; and
3. Linking missions to operational end users to help improve decision-making efforts.

The purpose of this focus session was to address the growing need for improved sea ice forecasts and multi-year sea ice detection requested in the Arctic. The use of future satellite data products from SMAP and ICESat-2 and the current ICESat-2 airborne simulator, Multiple Altimeter Beam Experimental Lidar (MABEL), will provide additional information that can enhance the sea ice thickness, sea ice extent, and sea ice melt/freeze status calculations currently simulated by the NRL forecasting systems using the Arctic Cap Nowcast Forecast System (ACNFS) and the Global Ocean Forecast System (GOFS). This focus session was also geared towards strengthening the existing relationships between these missions, operational users, and the sea ice modeling community by

including feedback from navigators and vessel operators into discussions revolving around developing decision support products for the Arctic. Panel sessions and thematically driven product application discussions were focused on (1) risk awareness, (2) route planning and (3) navigation forecasting and planning. Through panels and discussion we identify data products and information most relevant to the broader maritime user community.

Sea Ice Operations at the US Naval Research Laboratory (NRL)

Ruth Preller, Superintendent of the NRL Oceanography Division, opened the SMAP/ICESat-2 Sea Ice Focus Session with a reminder of just how much ice models have improved. The Polar Ice Prediction System (PIPS), developed by NRL for the US Navy, was the first of its kind—using ocean monthly mean climatology to drive the model and a horizontal grid resolution of 127 km. Further interest by the Navy for a model capable of covering all ice-covered regions in the Northern Hemisphere with a higher resolution, led to the development of a coupled ice and ocean model, PIPS2.0. This model produced 120-hour forecasts daily of ice thickness, ice concentration and ice displacement, with an approximate 27 km horizontal resolution and 15 vertical ocean levels.

One of the most important things to improve forecasting capabilities, according to Ruth, was assimilating satellite ice concentration data from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSMI/I) to provide the model's initial conditions for each day's 5-day forecast. The PIPS2.0 model was the first Navy sea ice forecast system to assimilate satellite sea ice observations using the DMSP SSM/I ice concentration data, which was similar in resolution to the model.

2014 Sea Ice Prediction developed at NRL consists of two operational systems that analyze the changing ice environment: the Arctic Nowcast Forecast System (ACNFS) and the Navy's Global Ocean Forecast System (GOFS). The ACNFS produces forecast for the northern hemisphere, while GOFS3.1 produces forecasts for both the northern and southern hemispheres. Both operational systems are coupled to the Los Alamos CICE model and to the HYCOM ocean model and have a grid resolution of approximately 3.5 km in the Arctic. The models assimilate satellite sea surface temperature, sea surface height and sea ice concentration to produce 168-hour forecasts of ice drift, ice thickness, ice concentration, ocean currents, ocean temperatures, and ocean salinity, among other products.

Table 1 is a summary of the current operational and state-of-art sea ice concentration (SIC) prediction systems at NRL.

System	Resolution	Domain	Prediction Lead	SIC Data Source
ACNFS	27 km	Arctic	120 hrs.	SSM/I
GOFS 3.1	3.5 km	Arctic & Antarctic	168 hrs.	SSM/I

The next section discusses the contributions from SMAP and ICESat-2 to the operational needs of the NRL. Data products and mission information are presented in the context of providing information to enhance the NRL mission.

Sea Ice Products from SMAP and ICESat-2

The SMAP Mission

Simon Yueh, Project Scientist for the Soil Moisture Active-Passive (SMAP) mission, Dara Entekhabi, SMAP Mission Science Team Lead, and Kyle McDonald, Associate Director of the CREST Institute, City University of New York, and Part-Time Faculty in the Water and Carbon Cycles Group at the Jet Propulsion Laboratory, California Institute of Technology, all presented on the expected functionality of SMAP data products for sea ice.

The SMAP mission will provide global, continuous high resolution mapping of the earth's surface soil moisture (top 5 cm) and the soil freeze/thaw state. The science objectives for the SMAP mission are to:

1. Link terrestrial water, energy and carbon cycle processes
2. Estimate global water and energy fluxes at the land surface
3. Quantify net carbon flux in boreal landscapes
4. Extend weather and climate forecast skill
5. Develop improved flood and drought prediction capability

While the SMAP mission science is driven primarily by needs for a soil moisture measurement, the data from the SMAP instruments can be applied to develop products specific to sea ice. Exploring the use of SMAP data for sea ice mapping is emphasized through the SMAP mission early adopters and supported by the SMAP Science Team members. The SMAP L-Band active/passive microwave sensor package offers the ability to identify sea ice edge, sea ice quality (first year or multiyear), and sea ice melt/freeze status regardless of solar illumination, weather (clear or cloudy), wind speed, or snow cover. The SMAP Mission Application Program (http://smap.jpl.nasa.gov/applications/) strongly encourages applications not identified by the Mission Science Objectives and welcomes the engagement of users to explore the full potential of mission data through the SMAP Early Adopter Program. This approach has become highly valuable for the project and allows the mission to provide feedback and guidance to communities like the NRL for developing tangible results with instrument data. SMAP data collections over the high Arctic will occur daily, with high resolution radar-based mapping every one to two days depending on the latitude. At high Arctic latitudes there will be significant overlap between observational swaths of the polar-orbiting SMAP observatory, thus reducing the revisit interval, in some cases to sub-daily intervals. The spatial resolution of the radar data ranges from 1-3 km, depending on within-swath observational geometry. The outer 60% to 70% of the swath has 3 km or better resolution. Greater swath overlaps will be achieved for the high Arctic, allowing higher resolution radar data to be realized for the north polar ocean.

Based on the SMAP concept-of-operations, SMAP will collect radar data yielding 1-3 km high-resolution backscatter over all land regions and one swath (1000 km) over coastal

regions during morning (6:00 am) overpasses. Low resolution backscatter and radiometer measurements are made globally using the full aperture (40 km) during both AM and PM passes. Figure 1 shows the coverage. Over the Arctic the high-resolution coverage of the ocean and sea ice regions is nearly complete.
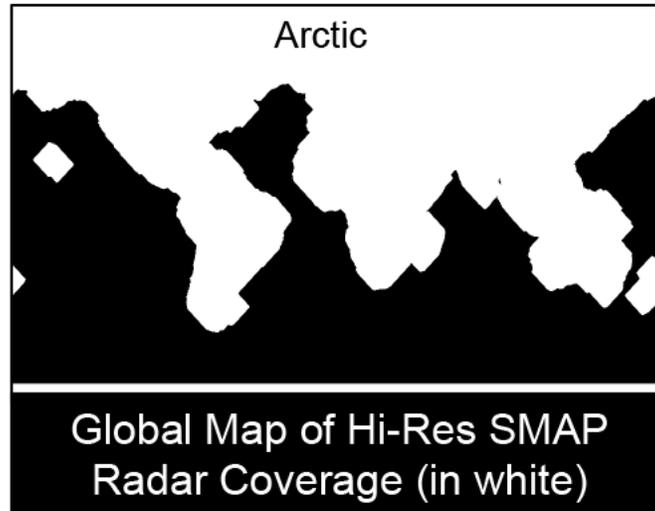

Figure 1: High-resolution radar coverage (AM overpass) in SMAP's L1C_S0_Hi-Res product. The resolution is 1 km over the outer 60% of the swath (3 km over outer 70%). With overlaps of swaths over higher latitudes, high-resolution radar backscatter at 1 to 3 km resolution with 1 to 2 day revisit may be derived from the instrument product files. Antarctica is not covered due to the limitation on downlink data volume.

The basic variables derived from SMAP are expected to contribute to the following ocean science and maritime applications, in addition to addressing the baseline science objectives:

> High-resolution sea-ice concentration mapping regardless of clouds and illumination using high-resolution radar backscatter (using SMAP L1C_S0_HiRes data product)
> Hurricane and tropical storms high wind-speed and direction mapping (using (L1C_S0_LoRes and L1C_TB)
> Coastal and global sea surface salinity (using L1C TB and L1C_S0_LoRes)
> Shallow sea-ice thickness (using L1C_TB)

The SMAP instrument package will have conical scanning capabilities consisting of a 1.26 GHz radar with polarimetry (HH, VV and HV) with an expected resolution of 1 to 3 km over the outer 70% of the 1000 km swath, as well as a 1.4 GHz polarimetric radiometer with a 40 km (3 dB) resolution at a constant 40 degree incidence. SMAP will operate continuously on-orbit providing continuous low-resolution radar data all the time (AM and PM) over land and ocean including over sea ice domains. Launch date for the SMAP mission was announced for January 29, 2015. Expected latency for the SMAP data products was presented by Simon as described in the Appendix A table. NRL and ocean applications of the SMAP data products will be based on the instrument level 1 products. These data will be available for download from the SMAP public archives with no more than 12 hours latency. The latency is small enough to be able to support the current ACNFS

and GOFS 3.1 operations. The resolution and sensitivity of SMAP-derived sea ice information (1 to 3 km) replaces the current SSM/I-based 27 km capability. Assuming the planned January launch date, it is expected that Phase E of the mission will begin on April 8, 2015. Validated data for Level 2, 3, and 4 would be available in April, 2016.

SMAP Sea Ice Application Potential:

Dara Entehkabi emphasized that the SMAP L1 measurements over oceans could potentially yield ocean and coastal surface salinity estimates, ocean surface winds (high winds around hurricanes and tropical storms), high-resolution Arctic mapping and potential shallow sea-ice depth sensing.

Kyle McDonald presented SMAP associated efforts, including the characterization of sea ice extent and melt/freeze status, creating a harmonized freeze/thaw-melt/freeze dataset across the north polar pan-Arctic domain, and merging the SMAP based information with ICESat-2 measurements of ice thickness and extent. He discussed how this merged land-sea ice information could enhance capabilities for climatological and meteorological science needs in the high Arctic.

Kyle encouraged exploring the possibility of a new near real time information system for sea ice monitoring that is modeled after the Carbon in the Arctic Vulnerability Experiment (CARVE) information system that is used for CARVE flight planning. The new system could enhance MABEL, SMAP and ICESat-2 and integrate sea ice components with land and have a processing scheme that would put information out on a timely basis.

The ICESat-2 Mission

Thorsten Markus, Project Scientist for ICESat-2, and Sinead Farrell and Ron Kwok, ICESat-2 Science Definition Team members, presented on the expected functionality of ICESat-2 data products for sea ice.

The design of ICESat-2 is primarily driven by the second objective listed below — the mission's cross-track sampling is critical for resolving elevation changes over outlet glaciers. ICESat-2 will have six beams organized into 3 pairs, with each pair separated by 90 m and consisting of both weak and strong beams. Each beam is expected to illuminate a spot approximately 14 m in diameter. In comparison, the GLAS instrument footprint on the first ICESat satellite was 70 m. ICESat-2 will also have a Pulse Repetition Frequency (PRF) of 10 kHz or 1 measurement every 70 cm. Compared to ICESat, which took a measurement every 167 m, ICESat-2 will provide much more extensive and denser coverage with a 91-day repeat orbit and 92-degree inclination.

ICESat-2's science objectives for ice sheets and sea ice are to:
1. Quantify polar ice-sheet contributions to current and recent sea-level change and the linkages to climate conditions

2. Quantify regional signatures of ice-sheet changes to assess mechanisms driving those changes and improve predictive ice sheet models; this includes quantifying the regional evolution of ice sheet change, such as how changes at outlet glacier termini propagate inward.
3. Estimate sea-ice thickness to examine ice/ocean/atmosphere exchanges of energy, mass and moisture.

The footprint of ICESat-2 is an important consideration in meeting the mission requirement of measuring sea ice freeboard to 3 cm. The freeboard calculation will require distinguishing ice and water (ocean) classification based on 1) signal photon rate, 2) surface roughness, and 3) background photon rate. ICESat-2 will acquire year-round data over ice-covered oceans, different seasons and through seasonal transitions. Measurements during seasonal transitions and summer are an ongoing area of algorithm development.

It is expected that ICESat-2's photon counting approach will provide new possibilities and opportunities in data analysis, including the option to stack histograms, conduct roughness scale analysis, and, as described by Sinead Farrell, the possibility of observing deformation features on sea ice, and an automated approach to measure sea ice freeboard in the marginal ice zone (MIZ). A special feature of ICESat-2, according to Ron Kwok, will be its variable length segments, which will vary along-track and will be different for the weak and strong beams.

ICESat-2's Level 1 baseline science requirement for sea ice:

ICESat-2 shall provide monthly surface elevation products to enable, when sea surface height references (leads) are available and under clear sky conditions, the determination of sea-ice freeboard to an uncertainty of less than or equal to 3 cm along 25 km segments for the Arctic and Southern Oceans, the track spacing should be less than or equal to 35 km at 70 degrees latitude on a monthly basis.

A final sea ice thickness data product is expected to be available roughly 45 days after data collection. The nominal data volume is estimated at 900 GB/day of data, with roughly half the volume (496 GB/day) corresponding to the Level 2A (ATL03) data. Thorsten emphasized the need to preserve all information—every photon will be geolocated and timed in order not to lose any information. An ICESat-2 product Table can be found in Appendix B. The expected ICESat-2 data latency is shown in the diagram below.

ICESat-2 Data Latency (source: Thorsten Markus, presentation)
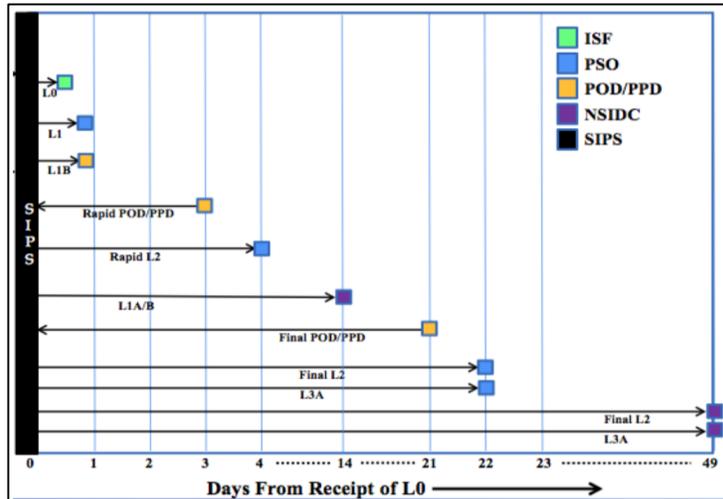
ISF –Instrument Support Facility; **PSO** – Project Science Office; **POD** – Precision Orbit Determination; **PPD** – Precision Pointing Determination; **NSIDC** – National Snow and Ice Data Center; **SIPS** - Science Investigator-led Processing System

Sinead concluded the ICESat-2 Science discussions with an overview of the ongoing research with NRL and with questions for the community. Ongoing research consists of work on data from Operation IceBridge and ACNFS for IceBridge flight planning, and ACNFS sea ice model versus IceBridge 2014 quick look thickness estimates. There are currently 17 planned flights for IceBridge. Operation IceBridge is a NASA airborne mission to observe the changing features of Greenland and Antarctic ice. Data collected during IceBridge will help bridge the gap in polar observations between ICESat and ICESat-2. More information can be found via the following link: http://www.nasa.gov/mission_pages/icebridge/index.html

SMAP and ICESat-2 Mission Action Items

The Missions have taken the following actions in an effort to provide information and data for operational sea ice product development through NRL.

SMAP

➢ Deliver the level 1 (instrument data products) algorithm theoretical basis documents (ATBDs), Products Specification Documents, and sample data products files (simulated data on backscatter and brightness temperature including polarization information, geolocation, radio frequency interference, instrument and processing information and quality flags) to NRL and interested parties so that they become familiar with the type of data that will be forthcoming from SMAP. This information will be shared with NOAA JPSS as an instrument data information source for developing a sea ice product.

➢ Although Sea Ice applications are beyond the scope of the SMAP Project, there are obvious applications for SMAP in Ocean science. The Science Team will circulate a published report titled: 2012 Ocean Science and Maritime Application using the NASA SMAP Instrument Data Products.

Questions from the Mission to the Community

Is characterizing seasonal transitions relevant for sea ice or not?

ICESat-2
- ➤ Develop a plan to use the 2014 MABEL Alaska campaign (July 9 to August 1) and other MABEL data.
- ➤ Work with SMAP and other missions to support maritime community.
- ➤ Provide up to date information on MABEL campaigns and available data in the Arctic.

Questions from the Mission to the Community
1. What MABEL product readers are needed (e.g. Python)? Currently, HDF5 product readers can be downloaded for Fortran, IDL, and Matlab.
2. For once-per-year (or seasonal) initialization of Arctic Cap Nowcast Forecast System (ACNFS) and Global Ocean Forecast System (GOFS 3.1) models with ICESat-2 sea ice thickness field – what observation month/season is most suitable? March (winter maximum)?
3. Could a preliminary and automatic lead detection system (with signal-finder) be used for a MIZ "quick-look" freeboard product (with large error bars!)? (Higher lead freq. in MIZ).

Distributed Active Archive Centers (DAACs)

The Distributed Active Archive Centers (DAACs) are an integral part of the missions. DAACs provide the mission data products after launch and develop user services that allow data to be accessed and manipulated easily and expeditiously. The DAAC distributes data both via its Restricted Data Portal, which provides restricted data and related documentation until the data is made fully public, and via the Public Data Portal. The Public Data Portal will provide information about SMAP and ICESat-2 and provide public access to some of the validation campaign data. Its important to include the DAACs in early mission applications discussions and provide them the feedback from the user community so the public data portals and user services are reflective of mission and users needs.

Amanda Leon, the SMAP DAAC representative for the National Snow and Ice Data Center (NSIDC) and Doug Fowler, the ICESat-2 DAAC representative for the NSIDC, provided an overview of DAAC services for the missions and discussed the structure for mission data product distribution. The NSIDC DAAC provides a Reverb Search and Order (http://reverb.echo.nasa.gov/) tool, which allows multi-faceted search of NASA's Earth Science data holdings and on-demand services for NSIDC DAAC data. The recently developed Worldview/ Global Imagery Browse Services (GIBS) system (https://earthdata.nasa.gov/labs/worldview/), also provides interactive browse and download of full-resolution imagery and access to the source data (SMAP imagery will be available by launch). Doug Fowler underlined the need for subsetting ICESat-2 data. With an estimated 880 gigabytes per day average size for all ICESat-2 data products and an expected 2-3 Petabytes archived at the end of the mission, there is a need for tools to reduce data size and perform on-demand analysis. As the ICESat-2 mission continues

to develop, user services and tools will evolve. Communication from the Applications community is strongly encouraged to make user services a well integrated process.

The Operational User Community Action Items

The way data are used and the decision data that products support give the mission perspective as to the impact mission products can have within the operational maritime community. Users and Decision makers from this community were asked to present how they use information when navigating through the Arctic. They also highlighted the data gaps and challenges they face with the existing information and provided suggestions for the use of SMAP and ICESat-2 data products in Arctic operations. Carven Scott, Chief of the Environmental and Scientific Services Division of the NOAA National Weather Service (NWS) Alaska Region Headquarters, opened the discussion with a presentation on Alaska Sea Ice Operations.

NWS Alaska Region

The National Weather Service Alaska Region, has historically focused on two sea ice services: sea ice analysis and situational awareness on Alaska waters. The major partner for NWS Alaska Region is the U.S. Coast Guard (USCG) and its stakeholders range from subsistence hunters to icebreakers, fishing fleet and large vessel traffic. The NWS Alaska Region currently provides the following services:

- Forecasts and warning services for the Arctic, North Pacific, Bering Sea, and Gulf of Alaska waters
- Coastal storm surge forecast and warnings
- Spot support for HAZMAT and Search and Rescue missions
- Direct contact with mariners for delivery of critical information and collection of volunteer observations

Moving forward, the NWS needs to be more proactive in such areas as cruise and ocean tourism, and in support of determining how and with what infrastructure oil companies can extract gas and oil in the Arctic safely.

The goal of the NWS Alaska Region, is to:
1) Expand out to address user requirements with very highly spatially and temporally granular forecasts out to day 5.
2) Move to a more robust forecast operation which would include NRL's Arctic Cap Nowcast Forecast System (ACNFS) or the Global Ocean Forecast System (GOFS 3.1).

How SMAP and ICESat-2 can help better inform the US Coast Guard and Alaska maritime community:

SMAP
- 12 hours latency within window for operations
- Resolution is sufficient
- Return time over Alaska
- Very helpful in building total picture across the Arctic…especially snow cover
- Help build database for improving sea ice models

ICESat-2
- Hindcasts for improving sea ice modeling; not a lot of use for it in operations
- Help build database for improving sea ice models; and verification of forecasts

NOAA National Ice Center

Behnjamin Zib and LTJG David Keith of the NOAA National Ice Center (NIC) were both in attendance at the sea ice focus session. Behnjamin presented on plans for operational use of SMAP data at NIC. The NIC is the primary user of NRL model data. They distribute the NRL and NIC sea ice products to the military and commercial Arctic maritime community

The NOAA National Ice Center is a multi-agency operational center consisting of the Navy, NOAA, and U.S. Coast Guard, that provides direct operational support to COMSUBFOR (submarine communities), U.S. Navy (USN), USCG, Fleet Weather Centers (FWCs), NOAA, and National Science Foundation (NSF) Ships. The NIC provides global sea ice analysis and forecasting, has national and international sea ice and meteorological partnerships, and also provides unclassified and classified support to various entities ranging from COMSUFOR to the National Maritime Intelligence Center. NIC's primary customers are NOAA NWS National Centers for Environmental Prediction (NCEP) Environmental Modeling Center (EMC) and the Climate Prediction Center (CPC). NIC also has various secondary customers including private companies and the general public. Additionally, the NIC has various special support customers in the Southern Hemisphere that would benefit from any coverage over the Antarctic waters. NIC is the official agency that tracks, monitors and names all icebergs greater than 10 nautical miles over the Southern Hemispheres—NIC does daily ice mapping over this region.

The desired latency to maximize operational use at NIC is 6 hours for the L1C Data Product (L1C_S0_HiRes, L1C_TB). "We see a real opportunity for SMAP to aid in sea ice operations." NIC hopes to do the following with the use of SMAP data:

1. Slightly increase 1000 km offshore acquisition threshold in Arctic waters to maximize cover of the high Arctic, Transpolar Current, and the Fram Strait

2. SMAP HiRes RADAR data (will add to the capabilities of operational sea ice analysis)

Maersk Line Limited

Captain Robert Lee, Ice Pilot to Maersk Peary, presented on behalf of the Maersk Line Limited (international shipping company) on navigation of oil/chemical tankers through sea ice. Capt. Robert Lee has commercial and military experience for navigating through multi year sea ice (MYI) and provided operational insight on the impact multi sensor data and easily accessible data products have on sea ice navigation.

"The simple goals of an ice pilot: avoid ice; if unavoidable, minimize contact; stay clear of multiyear ice; and stay clear of icebergs. Cargo ships are not icebreakers—the level of protection on a cargo ship can vary quite a bit—hundreds of miles are traveled to avoid ice."

Capt. Robert Lee emphasized that there is a significant benefit from any coverage over Antarctic waters/ice shelf. A very important American endeavor is completed in this area dealing with multi-million dollar ships and the oil industry. He encouraged coordination between NIC and NSF to lessen the demands for a high resolution product, which is really only needed in a small window of time. High-resolution images are essential if a cargo ship gets stuck; they allow the ice pilot to pick the best lead in order to minimize contact and provide landmarks for navigation. MYI is considered the deadliest to a ship; especially, ridged MYI. It is not possible to distinguish between first year ice and ice berg via a navigational radar. Fog is considered one of the worst complicating factors due to its potential thickness, which limits the ice pilot to using only navigational radar. Snow storms—another complicating factor—also reduce visibility and blocks all radars.

Ideal data products for the Pack Ice Navigation Community:

1) *Identification of Multi Year Ice*
2) *Good cloud penetration*
3) *Frequency – daily or better (48 hours is doable)*
4) *Resolution – 500 meters or less (1Km is also acceptable)*
5) *Ability to decipher ice thickness*
6) *Need real time server such as MODIS Rapid Fire*

Marine Trade & Energy Group

Michael Kingston, partner at DWF LLP, in the Marine Trade & Energy Group, presented on the insurance industry contributions to operationalizing the Polar Code in the Arctic.

Michael works closely with the Lloyd's of London in relation to the assessment of risk for navigation in the Arctic. With the U.S.' upcoming leadership in the Arctic Council, it is important that NASA provide the most recent satellite data products that can suggest Best Practices for sea ice navigation within the Polar Code. This code will be an international document providing guidance for a range of planned and possible situations via a Polar Waters Operations Manual (PWOM) and also provide a Polar Ship Certificate. The use of satellite data will help inform the ice descriptions used to distinguish each of the polar class rules, as presented in the diagram below. The polar class rules provide guidance as to where and when a vessel can operate.

IACS Polar Class Rules - Interpretation

	Polar Class	Ice Description (based on WMO Sea Ice Nomenclature)
How can these be applied to a real operation?	PC 1	Year-round operation in all Polar waters
	PC 2	Year-round operation in moderate multi year ice conditions
Where can a vessel operate?	PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions
	PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
When can it operate?	PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
	PC 6	Summer/autumn operation in medium first year ice which may include old ice inclusions
	PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

Some of the key motivations for the current effort to operationalize polar codes in the Arctic are significant knowledge gaps and the potential for environmental consequences of disasters being worse in the Arctic compared to any other region. The insurer's attitude to insuring above 70 degrees north is to turn risk away—impacting operators who are operating with best practices. It is not possible to determine what requirements are necessary if current ice conditions in the Arctic are not established. Thus the reinsurance industry would like to divide the Arctic into distinct geographical areas based on ice conditions. Michael concluded with the following questions that need to be addressed for sustainable Arctic development.

Questions from Reinsurance Industry:
1.   How can the Polar Code, which is currently being drafted, help address some of these issues?
2.   What factors need to be taken into account for reducing risk?
3.   How can we make it work?
4.   How can the NASA and NRL teams help?

Workshop Outcomes

The outcomes of the meeting are the following:

1. A follow-on meeting between NOAA, NASA, and NRL is being planned for early 2015 to discuss the integration of satellite products for developing improved products to inform the Arctic Maritime industry and the Arctic Council.
2. An improved understanding of user needs and workshop participants also acquired an awareness of how mission products will help support operations.
3. The reinsurance sector expressed interest in collaborating with NASA to help guide policy for the Arctic Polar Code and best practices:
     News release from Lloyds: http://www.lloyds.com/news-and-insight/news-and-features/emerging-risk/emerging-risk-2014/cooperation-needed-to-allay-arctic-risks

The early mission engagement with the Maritime community, data product developers, operators and decision makers provided valuable insight to the SMAP and ICESat-2 missions. Through the focus session discussions and panels the Missions learned that access to data is more valuable than resolution of the products. Decisions in the Arctic require information at varying scales and time domains. Thus including all data, regardless of latency, into Arctic maritime discussions will help assess risk and provide awareness to decision makers.

Using SMAP and ICESat-2 for developing new user driven products (e.g. a joint product, Mission multi-year ice thickness product) is of interest and could be done with the guidance of the Missions and the existing efforts of the mission community and Early Adopters.

Follow-up to this focus session will result in working sessions where the SMAP mission will provide Level 1 product documents, product specs and sample data files. The SMAP and ICESat-2 mission and Early Adopters studying sea ice will continue engagement with the NRL and Early Adopters in order to support real and measurable application outcomes. With launch approaching on January 29, 2015, the SMAP mission encourages end users, such as the NRL, to produce sample derived geophysical variables that are unique to their system or application (decision support).

Appendix A
SMAP Mission Product Table

Product	Description	Gridding (Resolution)	Latency**	
L1A_Radiometer	Radiometer Data in Time-Order	-	12 hrs	Instrument Data
L1A_Radar	Radar Data in Time-Order	-	12 hrs	
L1B_TB	Radiometer T_B in Time-Order	(36x47 km)	12 hrs	
L1B_S0_LoRes	Low Resolution Radar σ_o in Time-Order	(5x30 km)	12 hrs	
L1C_S0_HiRes	High Resolution Radar σ_o in Half-Orbits	1 km (1-3 km)	12 hrs	
L1C_TB	Radiometer T_B in Half-Orbits	36 km	12 hrs	
L2_SM_A	Soil Moisture (Radar)	3 km	24 hrs	Science Data (Half-Orbit)
L2_SM_P	Soil Moisture (Radiometer)	36 km	24 hrs	
L2_SM_AP	Soil Moisture (Radar + Radiometer)	9 km	24 hrs	
L3_FT_A	Freeze/Thaw State (Radar)	3 km	50 hrs	Science Data (Daily Composite)
L3_SM_A	Soil Moisture (Radar)	3 km	50 hrs	
L3_SM_P	Soil Moisture (Radiometer)	36 km	50 hrs	
L3_SM_AP	Soil Moisture (Radar + Radiometer)	9 km	50 hrs	
L4_SM	Soil Moisture (Surface and Root Zone)	9 km	7 days	Science Value-Added
L4_C	Carbon Net Ecosystem Exchange (NEE)	9 km	14 days	

Appendix B
ICESat-2 Mission Product Table

ICESat-2 Science Data Products

Product Number	Name	Short Description	Latency*
ATL00	Telemetry Data	Raw ATLAS telemetry in packet format.	Downlinked 8 times per day
ATL01	Reformatted Telemetry	Parsed, partially reformatted into HDF5, generated daily, segmented into several minute granules.	2 days
ATL02	Science Unit Converted Telemetry	Photon time of flight, corrected for instrument effects. Includes all photons, pointing data, spacecraft position, housekeeping data, engineering data, and raw atmospheric profiles, segmented into several minute granules.	2 days
ATL03	Global Geolocated Photon Data	Precise latitude, longitude and elevation for every received photon, arranged by beam in the along-track direction. Photons classified by signal vs. background, as well as by surface type (land ice, sea ice, land, ocean), including all geophysical corrections (e.g. Earth tides, atmospheric delay, etc…). Segmented into several minute granules.	21 days
ATL04	Calibrated Backscatter Profiles	Along-track atmospheric backscatter data, 25 times per second. Includes calibration coefficients for polar regions. Segmented into several minute granules.	21 days
ATL06	Land Ice Height	Surface height for each beam with along- and across-track slopes calculated for each beam pair. Posted at 40m along-track; segmented into several minute granules.	45 days
ATL07	Arctic/Antarctic Sea Ice Elevation	Height of sea ice and open water leads at varying length scale based on returned photon rate for each beam presented along-track.	45 days
ATL08	Land Water Vegetation Elevation	Height of ground including canopy surface posted at fixed length scale, for each beam presented along-track. Where data permits include canopy height, canopy cover percentage, surface slope and roughness, and apparent reflectance.	45 days
ATL09	ATLAS Atmosphere Cloud Layer Characteristics	Along-track cloud and other significant atmosphere layer heights, blowing snow, integrated backscatter, and optical depth.	45 days
ATL10	Arctic/Antarctic Sea Ice Freeboard	Estimate of sea ice freeboard over specific spatial scales using all available sea surface height measurements. Contains statistics of sea surface and sea ice heights.	45 days
ATL11	Land Ice H(t) Series	Time series of height at points on the ice sheet, calculated based on repeat tracks and/or cross-overs.	45 days from receipt of last data in product
ATL12	Ocean Elevation	Surface height at specific length scale. Where data permits include estimates of height distribution, roughness, surface slope, and apparent reflectance.	45 days from receipt of last data in product
ATL13	Inland Water Elevation	Along-track inland water elevation based on specific inland water mask. Where data permits, include roughness, slope and aspect.	45 days from receipt of last data in product
ATL14	Land Ice Gridded Height	Height maps of each ice sheet for each year based on all available elevation data.	45 days from receipt of last data in product
ATL15	Antarctica / Greenland Ice Sheet dh/dt Gridded	Height change maps for each ice sheet, for each mission year, and for the whole mission.	45 days from receipt of last data in product
ALT16	ATLAS Atmosphere Weekly	Polar cloud fraction, blowing snow frequency, ground detection frequency.	45 days from receipt of last data in product
ATL17	ATLAS Atmosphere Monthly	Polar cloud fraction, blowing snow frequency, ground detection frequency.	45 days from receipt of last data in product
ATL18	Land/Canopy Gridded	Gridded ground surface height, canopy height, and canopy cover estimates.	45 days from receipt of last data in product
ATL19	Mean Sea Surface (MSS)	Gridded ocean height product.	45 days from receipt of last data in product
ATL20	Arctic / Antarctic Gridded Sea Ice Freeboard	Gridded sea ice freeboard.	45 days from receipt of last data in product
ATL21	Arctic/Antarctic Gridded Sea Surface Height w/in Sea Ice	Gridded monthly sea surface height inside the sea ice cover.	45 days from receipt of last data in product

* Latency is defined as the approximate time it takes from the data acquisition on a satellite until it reaches an individual in a usable format.