APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

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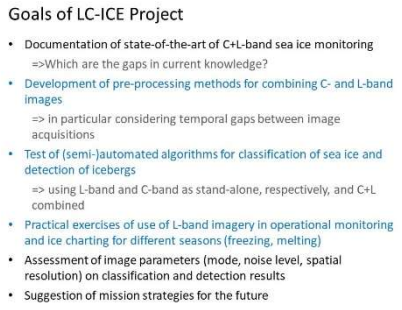
Presentations

Use of L- and C-band SAR Satellites for Sea Ice Monitoring - Wolfgang Dierking (AWI/UiT)

A little bit about our Task 1 "ROSE-L". Our task investigates the potential benefit we may get in sea ice and iceberg monitoring if you complement C-band SAR by L-band SAR images. We do this in principle in two branches. The first branch is the LC-ICE project which is funded by the European Space Agency. It involves the partners listed here: the University in Tromsø which is the leader of this project; Chalmers University; the Alfred Wegener Institute; and, from the International Ice Charting Working Group, the Norwegian Ice service, the Danish Meteorological Institute, the International Ice Patrol, and the Canadian Ice Service. The goals of the LC-ICE project are as follows. First, we have to start with a literature study to describe the state-of-the-art knowledge and, in particular, to find the gaps of knowledge. Printed in blue here are the major work packages of the project. First, Chalmers and the Alfred Wegener Institute have to find a way to combine C- and L-band images if they are acquired with a certain time gap between them. This can be tricky since sea ice may evolve significantly within hours in dynamic regions. It's in particular tricky to do this for drifting icebergs and sea ice floes in the marginal ice zone. Further steps that we will carry out, mainly at the University in Tromsø, is to use semi-automatic or fully automatic classification algorithms on stand-alone L- or C-band images and on the combination of those two to assess the strength of each band and of the combination. The participating ice services are analyzing L-band SAR images in comparison to C-band, as stand-alone and in combination to judge the gain of adding L-band in operational ice charting. This is done for freezing and melting conditions. And finally, we also assess the influence of sensor parameters and will suggest strategies for extending the Copernicus SAR missions.



The second branch is our task team of the International Ice Charting Working Group. We have very similar goals as defined for the ESA project and, in fact, the work on the task team is meant to support ESA's advisory group that deals with defining the requirements for an L-band SAR mission. This mission got the name ROSE-L, which is the Radar Observing System for Europe at L-band. Within the task group more ice services are contributing than in the ESA project. The ESA project is focused on the Arctic because of political reasons, which means that the ice services mainly working on the northern hemisphere, which are here indicated in blue, can actively contribute.

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

We are now in the process of extending our task team activities to the Southern Hemisphere led by the Naval Hydrographic Service of Argentina. SAOCOM L-band images are analyzed and compared to X- and C-band images. So, it is only natural to have Alvaro as a second task leader, and we can focus both on the Arctic and Antarctic waters.

Recent extension: ROSE-L (Arctic) and SAOCOM (Antarctic) Task Team of the International Ice Charting Working Group

Task Objective:

Investigate the advantages of using combinations of C- and L-band images for operational ice charting in Artic and Antarctic waters

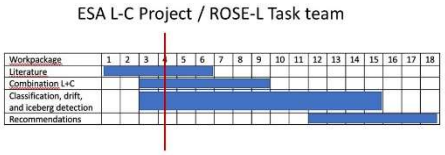
Task Team Leaders: Alvaro Scardilli, SERVICIO DE HIDROGRAFÍA NAVAL
Wolfgang Dierking, CIRFA/UiT & AWI

Task Team Members:

- Canadian Ice Service
- Norwegian Meteorological Institute
- Danish Meteorological Institute
- International Ice Patrol
- NOAA/NESDIS Center for Satellite Applications and Research
- Swedish Meteorological and Hydrological Institute
- Finnish Meteorological Institute
- Antarctic Meteorological Service
- Antarctic Climate & Ecosystems Cooperative Research
- Argentine Naval Hydrographic Service
- South African Weather Service

Regarding the question whether the task team shall continue working, the answer is definitely yes. You can see the timetable for the ESA LC-ICE project which started in June this year and will be finished at the end of November 2021. The red line on the table shows at which point in time we are now. Alvaro and ice service partners from the Southern Hemisphere and I will set up the research scenario quite soon.

ESA L-C Project / ROSE-L Task team



Task team SAOCOM / SH: ongoing planning meetings

=> Continuation of ROSE-L task until end of 2021

The first results for the Southern Hemisphere on the use of L-band SAOCOM in comparison to the X- and C-band will be shown in the next presentation by Constanza. Here we have a short summary of the strategy of our research to have combined analyses of Sentinel-1 and ALOS-2/PALSAR-2 images of the Northern Hemisphere and SAOCOM, Sentinel-1. Cosmo SkyMED in the southern hemisphere. Images are acquired with shortest possible temporal gaps complemented by optical satellite sensors whenever possible. For the Northern Hemisphere, we may also have the chance to get Terra SAR-X and Cosmo SkyMED images over a shorter period. Images are acquired over the whole project length so it's quite a lot of images. The work is supported by JAXA, CONAE and ESA. ALOS-2/PALSAR images are provided by JAXA through a mutual cooperation project between ESA and JAXA on using synthetic aperture radar data in earth science applications. We have SAOCOM and Cosmo SkyMED data provided by the Argentine space agency - also due to a mutual cooperation project. Sentinel-1 and Sentinel-2 images can be downloaded for free from the Copernicus open access hub.

Strategy of research:

Combined analyses of
Sentinel-1 and ALOS-2/PALSAR-2 (NH)
SAOCOM, Sentinel-1, COSMO SkyMed (SH)
images acquired with shortest possible temporal gap, complemented by optical satellite sensors whenever possible *(+possibly TerraSAR-X and COSMO SkyMED over the Arctic, during a shorter period)*

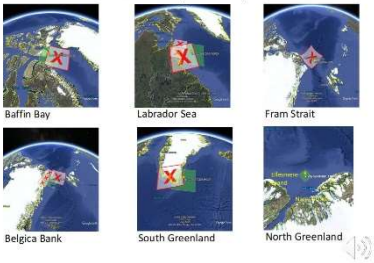
The work is supported by JAXA, CONAE, ESA:

ALOS-2/PALSAR-2 data are provided by JAXA through the 2019 to 2022 mutual cooperation project between ESA and JAXA on *Using Synthetic Aperture Radar Satellites In Earth Science and Applications.*

SAOCOM and COSMO SkyMed are provided by CONAE (Argentine Space Agency) due to mutual cooperation through license agreement.

Sentinel-1 and Sentinel-2 are downloaded from COPERNICUS Open Access Hub.

Test Sites (all Arctic)

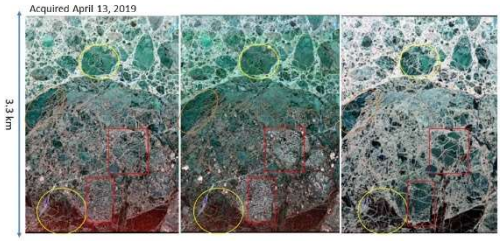


Here we have a summary of the test sites. We have six test sites that were selected on the advice of the ice services. There is Baffin Bay, Labrador Sea, Fram Strait, Belgica Bank, South Greenland and North Greenland.

In addition, we have also data from the airborne F-SAR of the German aerospace center. The data consist of one back and forth profile from Davis Strait acquired on April 30 last year. The interesting thing is, it's not only L- and C-band, but also X-band images. They were acquired simultaneously. All have very high spatial resolution on metre scales so that you see a lot of details.

Additional: F-SAR images over sea ice in Davis Strait

Acquired April 13, 2019



Ongoing activities: Comparison with aerial photography and RS-2 images

F-SAR data and photographs: DLR / ESA
RS-2 images: CIS / MDA (through agreement with Government of Canada)

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

We also got Radarsat-2 images acquired with a short time difference to this airborne data set. So, we can also investigate the effect of coarser spatial resolution.

The preceding viewgraphs focused on the organizational part. My presentation will now end with a short flavor of the literature study. I will not talk about details of the more than 50 articles. Instead of reading through this list, I think we should jump into short examples.

Literature Study for ESA LC-ICE

> 50 articles dealing with use of L-band SAR

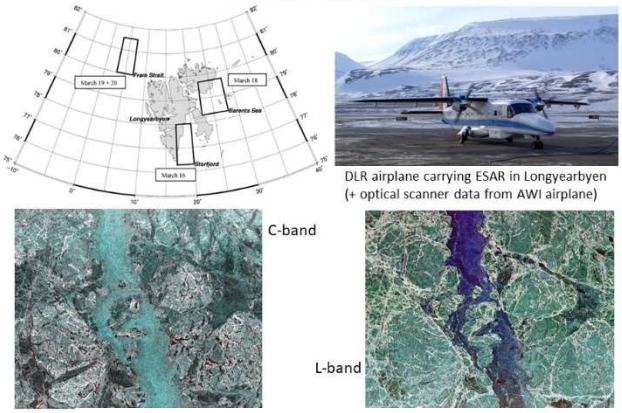
Reported applications:

- (polarimetric) radar signature analysis using airborne & ground-based data
- incidence angle sensitivity at L-band
- multi-frequency (+ multi-polarization) sea ice classification
- ice parameter retrieval using L-band or C+L
  - thickness, roughness/topography
  - landfast ice extent, deformation, and trafficability
- sea ice mapping during the melt season
- sea ice drift (comparing L- and C-band performance)

The first application is the signal analysis in general: what's the difference between L-band and C-band signatures? Analysis is usually carried out by measuring radar signatures on the ground or from the airplane and, at the same time, collecting data on sea ice properties. This example is from the ICESAR campaign of 2007, at which measurements were also taken by the airborne E-SAR of the German Aerospace Center. Measurements were taken at three different test sites at C- and L-band, but not simultaneously - first at L-band and then, on the way back, at C-band. The images had a spatial resolution of three meters so you can see a lot of detail, and additional optical data and notes on sea ice conditions were taken from an airplane owned by AVI.

Example: Signature Analysis (1)

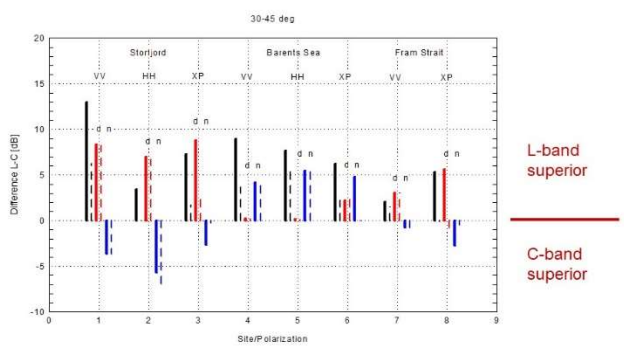
ICESAR 2007 campaign



DLR airplane carrying ESAR in Longyearbyen
(+ optical scanner data from AWI airplane)

This graph tells us that L-band reveals a larger dynamic range than C-band, shown as the black bars. The solid bars are airplane data, and the dashed bars are from satellite. Satellites have higher noise levels, or the dynamic range is not as large. What we can see as well, with the red bars, is that deformed and level ice can be better distinguished at L-band at all test sites. We have these three test sites – Storfjord, Barents Sea and Fram Strait. Separation of new and first year ice, which is indicated by the blue bars, works mostly better at C-band, but not all the time. In some cases, also L-band may be superior in this case. So that really depends on the ice conditions.

Example: Signature Analysis (2)



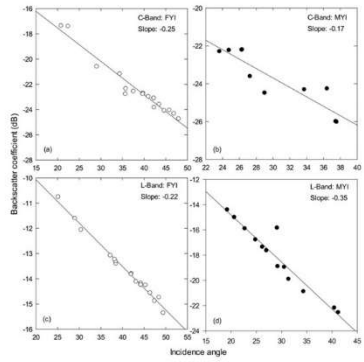
Solid: airborne, dashed: satellite
black: dynamic range L-C,
red: deformed-level, blue: level-new

W. Dierking, "Mapping of different sea ice regimes using images from Sentinel-1 and ALOS synthetic aperture radar", *IEEE Trans. Geosci. Remote Sens.*, vol. 48, no. 3, pp. 1045 – 1058, 2010, doi:10.1109/TGRS.2009.2031806

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

This example concerns the incidence angle sensitivity of the backscatter coefficient, which has to be considered when we use Scan-SAR or Wide-beam images. The result of this particular investigation is that C-band and L-band differ in sensitivity over multi-year ice and here the l-band reveals larger sensitivity.

Example: Incidence Angle Sensitivity



Results of single ROIs

TABLE II
SUMMARY OF BACKSCATTER INCIDENCE ANGLE DEPENDENCE (SLOPE) FOR 10 FYI AND 30 MYI ROIS FROM BOTH L- AND C-BAND FROM 2018. UNITS ARE IN DB/1°

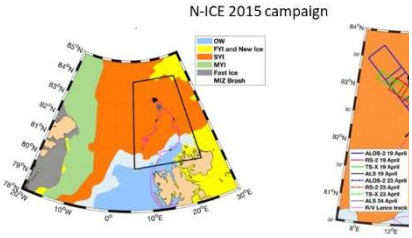
Frequency	L-band		C-band	
Statistics	FYI	MYI	FYI	MYI
Min	-0.16	-0.23	-0.17	-0.14
Max	-0.29	-0.39	-0.29	-0.19
Mean	-0.21	-0.30	-0.22	-0.16
Standard deviation	0.04	0.04	0.03	0.01
Mean r^2	0.77	0.91	0.91	0.90

M. S. Mahmud, T. Geldsetzer, S. E. L. Howell, J. J. Yackel, V. Nandan, R. K. Scharien, "Determination of the incidence angle dependence of C- and L-band backscattering intensities", IEEE Transactions of Geoscience and Remote Sensing, vol. 56, no. 11, 2018, doi: 10.1109/TGRS.2018.2841343

Sea ice classification is one of the most popular topics and there are many articles about it. These studies focus on various combinations of frequency bands and polarizations. We have an example where L-, C- and X-band polarimetry data were combined and different polarimetric parameters were used for classification via a neural network. Ship-based observations and airborne measurements of ice statistics were used for the assessment of the classification results.

Example: Classification (1)

N-ICE 2015 campaign



Available: L-, C-, and X-band SAR images acquired with temporal gap
ship-based observations (R/V Lance), airborne laser scanner measure
Classification: polarimetric feature extraction + trained neural networ

S. Singha, M. Johansson, N. Hughes, S.M. Hvidgaard, H. Skonrup, "Arctic sea ice char spaceborne fully polarimetric L-, C-, and X-band SAR with validation by airborne mea Transaction on Geoscience and Remote Sensing, Vol. 56, No. 7, 2018, doi:10.1109/TGI

Example: Classification (2)

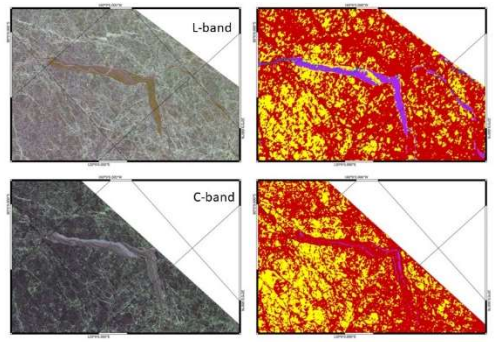
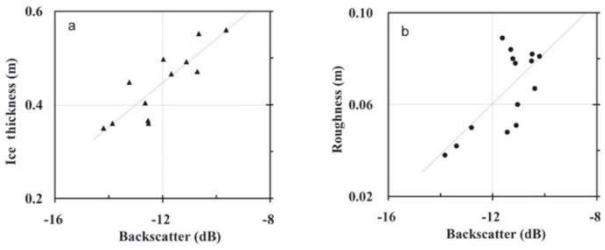


Fig. 12. (Left) Geocoded Pauli RGB composite (red: HH-VV, green: HV + VH, and blue: HH + VV) of the ALOS-2 and RS-2 acquisition on April 23, 2015. (Right) YI representation on ALOS-2 and RS-2 acquisition on April 23, 2015. Blue: open waterinlas (OW). Purple: YI. Yellow: SFYI. Red: RFYMYI.

This neural network automatic classifier performed better at L-band when it came to separating young ice in the lead from the adjacent ice, which is shown here. Otherwise, in this particular study, there were not many detailed examples of separately analysing L-band and C-band. It was mostly combining both and also X-band and then trying the different radar attributes in the classification process.

Some studies focused on retrieval of ice thickness or ice roughness from L-band and C-band SAR images. Sometimes it worked to a certain degree, as in this example, which is from the Sea of Okhotsk from 2008. In this case, the authors used ALOS/PALSAR ScanSAR mode images. But overall, when you compare different articles, the results are quite variable regarding the use of either C- or L-band and also regarding the quality of those retrievals. I haven't seen a really robust algorithm so far.

Example for Parameter Retrieval: Ice Thickness And Roughness

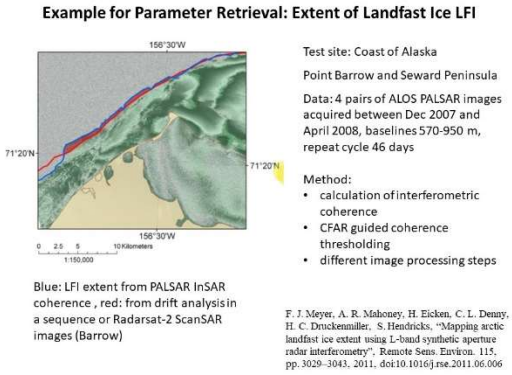


Test site: Sea of Okhotsk, time: February 2008
Satellite image: ALOS PALSAR ScanSAR mode, IA sensitivity considered
Ice thickness data from ship-based video system along 35 km profile
Snow-on-ice surface roughness data from ship-based laser profiler

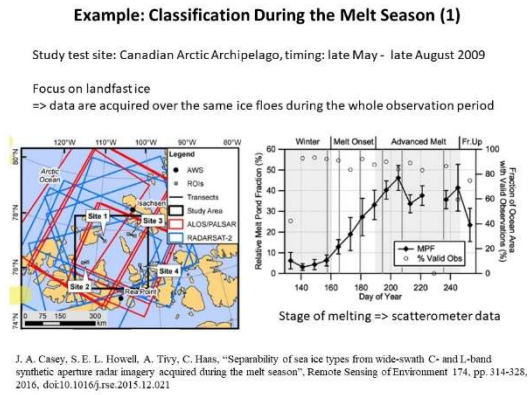
T. Toyota, S. Ono, K. Cho, K. I. Ohshima, "Retrieval of sea-ice thickness distribution in the Sea of Okhotsk from ALOS/PALSAR backscatter data", Annals of glaciology (52)57, 2011, doi:10.3189/172756411795931732

Another interesting application is to determine the extent of land fast sea ice. In this case, interferometric data was acquired at L-band with a time gap of 46 days, the revisit time of ALOS-1. For this purpose, interferometric coherence was employed, which is very low for drifting ice, but considerably higher for land fast

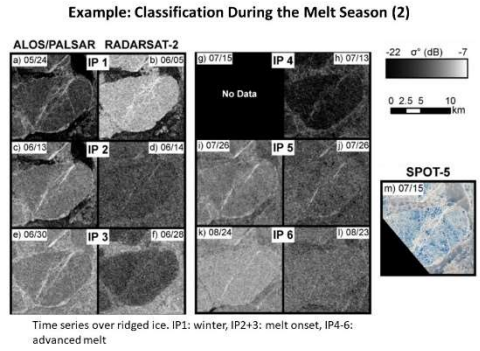
ice, and that's how to distinguish them. So, you can see a lot of structure in the land fast ice, which is in green, and you see a lot of noise above that which is from the drifting ice. In that way, the extent of land fast ice is estimated. The two lines indicate the reference and the line made from the interferometric data. There are some deviations, of course, but the reference data is also not 100% correct.



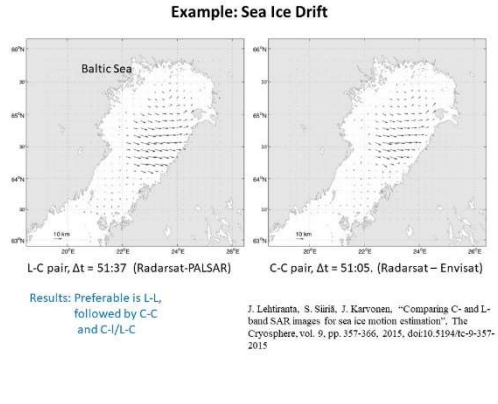
This here is a very popular application of L-band because it's regarded as particularly useful during the melt season since it has a large penetration depth. This was investigated during one whole melt season over land fast ice in the Canadian Arctic Archipelago. This was done on land fast ice to be able to look at the same spot during the entire melt season.



I find these images rather instructive. They show a particular ice floe, which you also see in an optical image on the right side. On this ice floe there are ridges. The sequence of images is during the melt season but starting (a) is the winter. You see how the signatures change, particularly at C-band on the right side. It's sometimes very difficult to identify ridges in the C-band images but you see them quite well in the L-band images almost all the time.

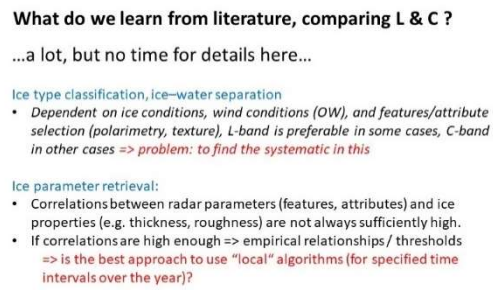


This is the final example - ice drift. It was found that ice drift can often be retrieved better from L-L-band pairs than from C-C-band pairs. But this really depends on the ice conditions. If you have a lot of texture, then L-band does a better job but, in other cases, C-band might be better. Combinations of L- and C-band images are also of interest, in particular, for our project. Here, this works. But the problem is that the rate of signature variations differs because of the different penetration depths at L- and C-band, which makes it more difficult to find matching structures in the C-L image pair.



So, what do we learn from literature comparing L- and C-band? A lot, but I will not go into details here. There are two things. One is the ice type classification or ice-water separation. That depends on the ice conditions (and wind conditions if you have open water), and on the radar feature attributes selection. L-band is preferable in some cases, but C-band maybe be preferable in other cases. So, the problem here is to find the systematic in this and to describe it. Regarding the ice parameter retrieval, correlations between radar parameters, features, attributes and ice properties, for

instance thickness or roughness, are not always sufficiently high. So that's the first point. Do we have a robust algorithm? And then the correlation, is it high enough? We have an empirical relationship of thresholds but usually they are not valid in general, for any situation. So, is it then the best approach to stick to those local algorithms for specified time intervals over the year? These are the questions we have to deal with in our work in the task team and for the sub project. This concludes my talk.

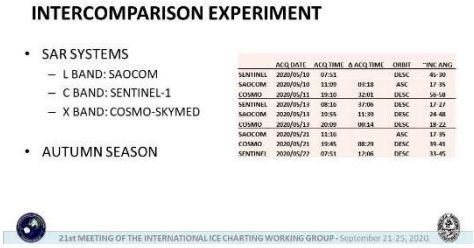


Comparison of L-band, C-band, and X-band SAR Imagery - Constanza Salvo (SHNA)

My name is Constanza and I work in the Argentine Naval Hydrographic Service. Before I start, I want to say thanks for this opportunity. I have not been working with remote sensing of sea ice for very long, so for me, it's an honor to share this presentation among the experienced participants in this meeting. I'm going to show examples that are results of an intercomparison experiment carried out in our institution for the study of floating ice using multi frequency SAR systems. The frequencies used are L-band from SAOCOM, C-band from Sentinel-1, and X-band from Cosmos SkyMED. In all these analyses, the focus was on the operational environment. Our main objective is to combine the SAR systems in the operational activities.

Why combine SAR systems? The most obvious thing is that, when we are including more bands, we are definitely including more information. Firstly, we have an additional time acquisition to analyze our dynamic ocean for study of the sea ice and icebergs. Also, multi-frequency images can provide valuable information regarding the interaction between the signal and the object observed. There are four different sensitivities that can contribute to improvements in sea ice classification and iceberg detection.

However, we need to consider the different SAR parameters that are involved in the backscatter signal. For example, the spatial resolution of the images that are closely related to the SAR operational modes, the polarization, the incidence angle and so on. Moreover, when combining the SAR systems for the study of sea ice and dynamic objects, we need to consider the time of acquisition in particular for the gap between the images. Also, we have to bear in mind the operational context when using different SAR systems. We have to consider the time needs for information, the direct use of the images, the large variety in the SAR parameters of the images used, and the visual interpretation of them.

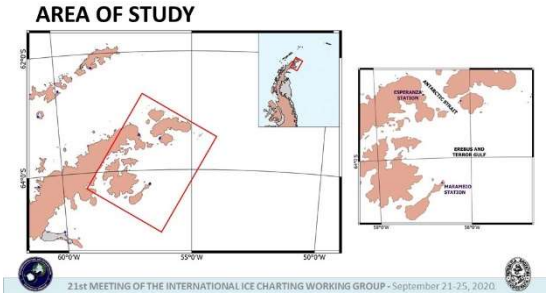


	ACQ DATE	ACQ TIME	Δ ACQ TIME	ORBIT	~INC ANG
SENTINEL	2020/05/10	07:51		DESC	45-30
SAOCOM	2020/05/10	11:09	03:18	ASC	17-35
COSMO	2020/05/11	19:10	32:01	DESC	56-58
SENTINEL	2020/05/13	08:16	37:06	DESC	17-27
SAOCOM	2020/05/13	10:55	11:39	DESC	24-48
COSMO	2020/05/13	20:09	09:14	DESC	18-22
SAOCOM	2020/05/21	11:16		ASC	17-35
COSMO	2020/05/21	19:45	08:29	DESC	39-41
SENTINEL	2020/05/22	07:51	12:06	DESC	33-45

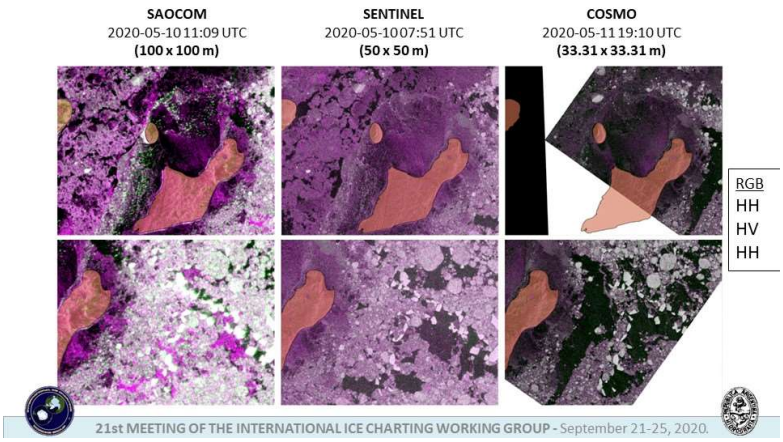
Our intercomparison experiment, involved the L-, C-, and X-band from SAOCOM, Sentinel-1, and Cosmos SkyMED. We have worked with nine images, where the gap between acquisitions ranges from a few minutes to about 37 hours in the worst case. The images were acquired

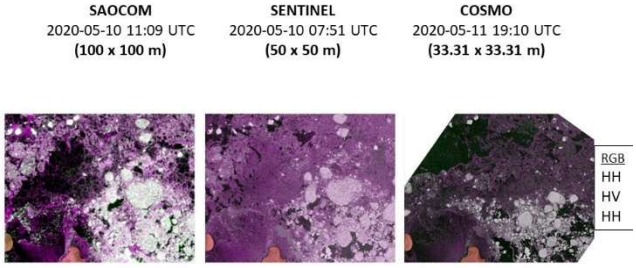
in an autumn season, in the month of May. Our area of study was the Northern Peninsula of Antarctica.

In particular, we worked in the Erebus and Terror Gulf and in the Antarctic Strait. This area was selected because of the wide diversity of ice types present in the zone. We also used in situ meteorological data from Marambio and Esperanza Station to corroborate the environmental conditions near the time of acquisition.



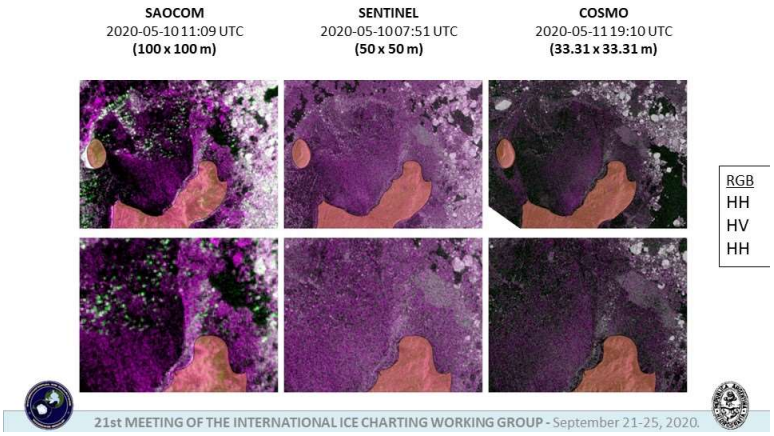
From now on, the images will be shown from left to right by increasing frequency of the SAR systems starting with SAOCOM, then Sentinel, and lastly Cosmos SkyMED. All the images are in H-H, H-V, and H-H polarization for the RGB composite. We can see that the L-band shows a high H-V response for icebergs. We can appreciate these on the upper left image where the icebergs appeared in a bright green color. We notice that the responses for these small icebergs are similar in C- and X-band, but L-band detects them better, even in coarse resolution. Also, we can observe that large icebergs, like the tabular ones in the lower images, also have a saturated response in L-band, compared to the lower contrast in C- and X-band.





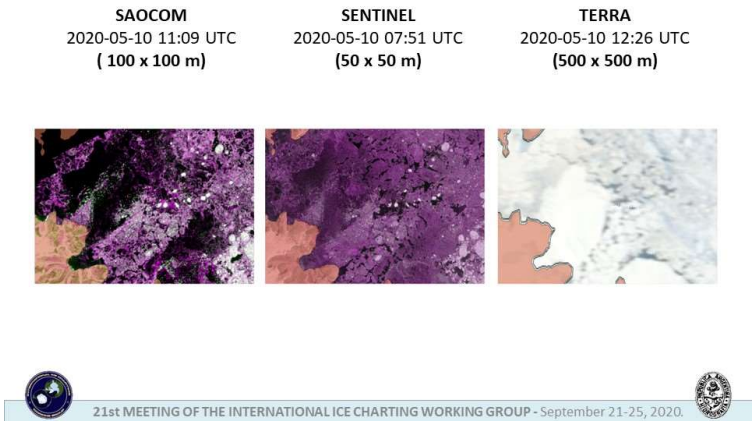
Regarding the response in C- and X-band, in the middle upper of the images there is mainly young and first year ice and, at the bottom, we find old ice. Both categories can be clearly separated even in a quick visual interpretation. If we look at L-band, the young stages of sea ice definitely present more complexity in the response providing more information about the observed feature.

In the next figure, I show fast ice around Marambio Island and again we can see a similarity in the backscatter in C- and X-band. Additional information for this type of ice is presented by L-band. For example, in the images at the

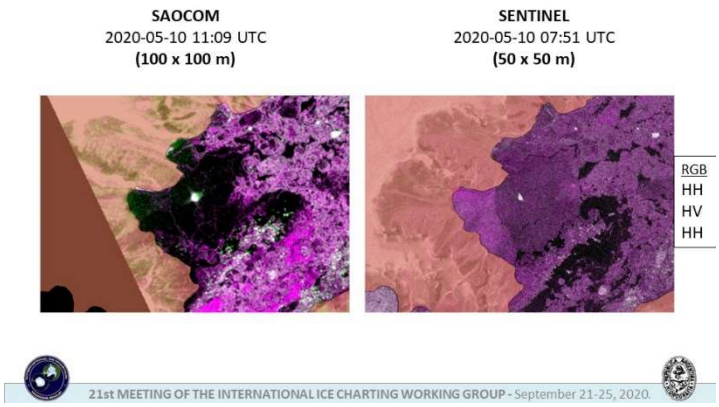


bottom, we can see a bright zone north of Marambio Island in C- and X-band. Meanwhile, in L-band, same area appears dark representing the lower backscatter in the area. It is known that the greater penetration of L-band allows these differences but the mechanisms for this response aren't clear, as we can see in the next slide.

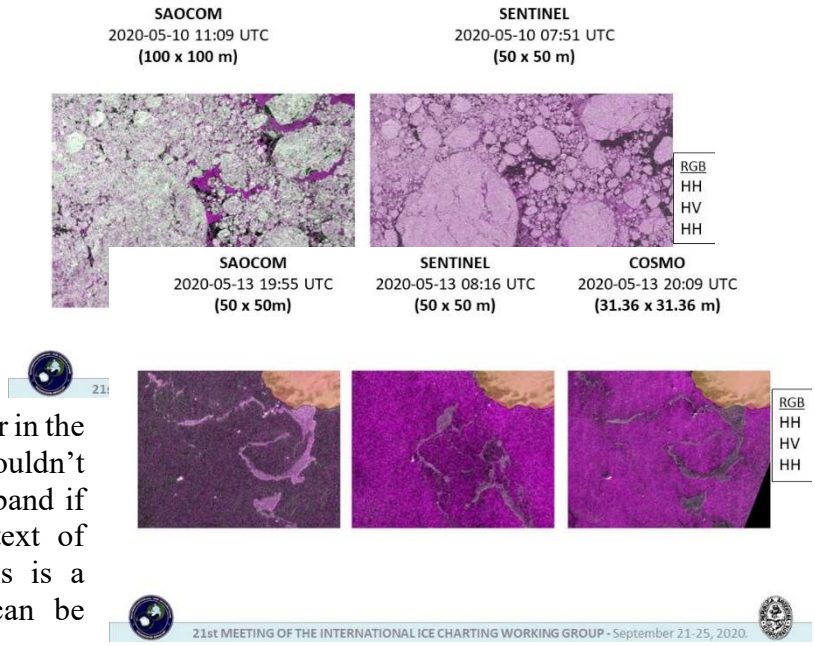
Here we are looking at the fast ice in Ross Island. When comparing the L- and C-band from optical imagery, the mechanisms in the backscatter are not so clear, neither to attribute it to an ice type nor to establish a criterion for the recognition of them. We can see that some patterns can be very similar in both bands without corresponding to the type of ice that can be recognized in the optical image. But this similarity fades gong north of the fast ice not allowing an easy explanation for the response.



In this slide, we can see another example of this complexity in the fast ice of Ross Island in the darkest zone of L-band. In this area, the L-band detects bright lines which can easily be attributed to deformation processes. But when comparing with C-band, we can see that not all of these bright lines are representing that and some of them represent small openings in the fast ice. So the response for the roughness of the surface cannot directly be explained.



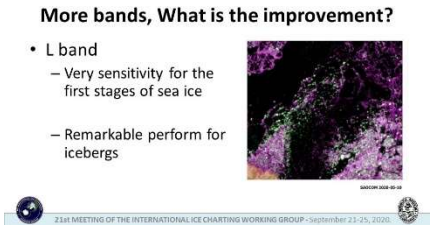
This figure shows an old ice field with large floes and young ice present in the leads among the floes. Again, the response of young ice is darker in L-band with black colors and higher backscatter in C-band. I like this image very much because under these environmental conditions in both images, the young ice can be recognized even in visual interpretation. But, if we consider windy conditions where the water in the leads gains more surface roughness, we couldn't recognize this young ice so easily in C-band if we consider a typical operational context of having only the H-H polarization. This is a perfect example of information that can be



collected when using multi-frequency data and also an example of using the L- band for young ice stages during windy conditions.

L-band has a different response for the roughness of the water than the higher frequencies but, for now, the reasons are not understood by us. More SAR parameters need to be considered to establish a solid conclusion about these different responses.

So, to conclude in the next slide, I sum up some ideas on the promise of having more bands. As I said before, it is obvious that we have additional information and that is always good news for operational activities. Also, we need to start thinking about the contribution of multi-frequencies for different environmental conditions, different objects of study, and the multiple combinations of these situations. For sure, with more bands we have more information about different ice types. However, we need to weigh the pros and cons of having this information for different operational activities considering the time constraints and, in the worst case, the file size capacity of the reception for each operational activity.



With L-band, we saw there is a great sensitivity for the first stages of sea ice. This was already known but the causes of the response are still unclear. Without a doubt, L-band has remarkable performance for the detection of icebergs and they can be seen clearly even at lower spatial resolution – a point that is very important for operational use. Although more research for the application of L-band for iceberg detection is needed, such as the precision of the detection or possible ghost reflections, on so forth, L-band gives a clear idea of the density of icebergs in a zone. Further studies also need to be considered for the iceberg detection inside thicker ice, because all our samples are in young and thin first year ice.

So, more investigation is needed to understand the mechanisms involving the signal backscatter. And what is more relevant in ice services activities, is the necessity to gather criteria for the recognition patterns, the initial interpretation when seeing multi-frequency bands. It is also important to start defining which band could be better considering different conditions. This will help in selecting the correct band, or the combination of bands, that suits the different tasks carried out with SAR images in the ice services.

I thank you all for your attention and I hope you enjoyed the presentation.

Panel Discussion

The objective of this panel discussion was to provide an overview of the experience of ice services with multi-frequency data (specifically including L-band), to judge the benefits versus efforts to implement a multi-frequency analysis into the daily routine work, and to emphasize special requirements of operational ice services with regard to ROSE-L (e. g. technical issues such as available polarizations, spatial resolution etc).

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

Moderator: Wolfgang Dierking (AWI/UiT)
Panelists:

- Dean Flett (CIS)
- Constanza Salvó (SHNA)
- Mike Hicks (IIP)
- Keld Qvistgaard (DMI)
- Nick Hughes (MetNorway)

Key Messages

- L-band is shown to be very effective at identifying icebergs in sea ice.
- L-band images at 100 metre resolution detects icebergs as well as C-band at 50 metres.
- Combination of L-band provides different information about the ice surface from C-band but the causes are not well-explained. L-band should provide another instrument in the box of SAR image analysis tools but more research is needed to understand what is being sensed.
- The choice between wide swath and high resolution depends on the operational context. Wide swath is preferred for large scale monitoring over wide areas. Finer resolution swaths are needed when detailed observations are required – such as community hazard mapping.
- Small icebergs present the greatest hazard to shipping because of the difficulty in detecting them, whether on ship, or by satellite. There is a question about whose responsibility it is to map the smallest icebergs. Where does the responsibility of the national ice services end and the maritime operator's responsibility begin?

Session Transcript

Wolfgang Dierking (AWI/UiT)

We have about six minutes for each question. We have four questions. We agreed beforehand that each ice service will provide a more complete answer to one of the questions and, if there's time, I will ask the other ice services about their view on that particular topic. For icebergs, we will have a special discussion with Mike and all those who have experience with iceberg detection.

So, the first question. Does your ice service already have some experience using L-band images for sea ice monitoring and iceberg detection? For instance, through systematic comparisons between C- and L-band data. If yes, what are your conclusions?

Dean Flett (CIS)

Thanks, Wolfgang. Yes, we have a number of case studies thanks to you and the Rose-L ESA project. As you and some of the others know, we've collected a variety of images. We've only really started the analysis. I must acknowledge Melanie Lacelle, the physical scientist in our science unit at the Canadian Ice Service. The comparative analysis is ongoing. We have not used it in an operational setting yet but Melanie's done some work to look at doing that comparison. The first thing that we noticed is the structural information that is apparent in L-band which is very complementary to C-band. We've also observed some increased separability between ice types but

the jury's still out on that in terms of whether it's really stage of development or just more of the structural aspects. These are the kinds of things that we hope to learn a lot more about as we go through the image comparative datasets. I'd also note that about 2008-2009 we acquired several L-band images through JAXA and also noted the sensitivity to ice roughness and structure. At that time, we were focused on ice island detection and tracking because at that time the Peterman Glacier had discharged some large ice islands and we were interested in tracking those. We found that the contrast in L-band with the background ice pack was highly enhanced and they popped right out. We found it was very good for ice island tracking.

Nick Hughes (MetNorway)

I can say we had some experience using L-band data since the late 2000s. We started doing some comparisons with the old Envisat ASAR C-band and ALOS-1 PALSAR. That was only single polarization but even with that you could see instances where the icebergs, particularly around the Greenland coast, were popping right out of the sea ice cover. It was very easy to spot them. More recently, you showed an example in your presentation Wolfgang in which Suman Singha has C-, L-, and X-band comparison using the data north of Svalbard. Again, yes, I showed that the L-band was providing different information to the C- and X-bands. So it should be very complementary for use in automatic classification algorithms.

Wolfgang Dierking

Constanza showed very nice examples of the icebergs popping out in the L-band images. Mike, could you please comment on your experience with L-band and C-band iceberg detection?

Mike Hicks (IIP)

My first experience with L-band was from the ALOS collections last year. I looked at a C-band Sentinel-1 extra wide swath image right next to an ALOS L-band in sea ice. Like the others have mentioned, I was really surprised to see icebergs popping out in L-band compared to C-band. Our experience is very limited but it is very hopeful. And, especially after seeing Costanza's presentation this morning, I think it's going to be a very important tool in our box to help us detect and identify icebergs.

Keld Qvistgaard (DMI)

The experience that we have is very limited but we have been very encouraged by what I've seen so far with the ALOS/PALSAR data received over the past year and a half. As Mike points out, there are some promising elements in what we can see and, especially, the detection of icebergs in sea ice looks promising. We need to dig deeper into that, of course but there's lots to learn. I'd also like to congratulate Constanza with a very nice presentation, because you really hit the targets where we need to do more work for the comparisons where we're focusing on the seasons, the modes, the resolution, and also to draw in the operational context. Typically, we start out with working with offline data and things may look nice, but you have to think further and bring it into an operational context. So, the second step of this is how do we, in an operational context, actually understand the L-band features where we have manual inspection and analysis to put into an ice chart, but also towards the long term implementation of smart algorithms.

CHAT LINE

Sean Helfrich

The USNIC had some experience using ALOS-1 over Alaskan waters. It is not clear if the analysts had enough training to properly apply the differences between C- and L-band imagery when they were not co-located.

Patrick Eriksson
Question to the panel: Are there L-C image pairs that reliably can demonstrate a multi-frequency analysis, even if it would be done by artificial reduction of the acquisition time gap and bitmap synchronization?

Richard Hall (RICHH)
@patrick - there are old examples with Envisat and ALOS-1 as they were in the similar orbits.
(1 liked)

Neal Young
Can panel comment on relative value of L/C/X in identifying structures such as ridging / shear zones. Regarding icebergs, do comments still hold when using only single polarisation? An important adjunct to these investigations is a clear view of when it works and when it does and when it does not work!!! re false positive / false negative.

Wolfgang Dierking

Going on to the second question, is L-band a useful extension? How does it improve ice type separation or iceberg detection? What is the additional information gained when using L-band? Constanza, would you summarize your thoughts with a few words from the operational perspective?

Constanza Salvo (SHNA)

Definitely regarding the sea ice and the thinner stages of sea ice, like young ice or thin first year ice, we have a really good appreciation of differences in the surface. It's not so easy to attribute the causes because there is a lot of sensitivity in L-band from the surface roughness. It's really complicated but due to the complexity of the situation, but it is really interesting because we are definitely seeing more things with the L-band. Regarding the icebergs, I think that the L-band has a real advantage even with lower spatial resolution. I did not show many examples in my presentation, but I have seen some images where we can see the same icebergs in SAOCOM L-band in a 100 metre spatial resolution imagery as are visible in C-band with 50 metre resolution. For me, that is awesome, considering our operational context. Our service produces an iceberg chart that covers a lot of area in the Antarctic, Weddell and Bellingshausen Seas. Imagery that can cover a wide extensive area is definitely more important for us to than to have a finer spatial resolution. So, this result for us is awesome.

Wolfgang Dierking

Thank you very much and I may also add my own comments. What I saw in your presentation, and correct me if I'm wrong, you had split these different polarizations into red, green, and blue. We saw green parts on the icebergs, which would mean that the cross polarization H-V is relatively strong. We saw this at L-band but not at C-band, which would, of course, be explainable because of the larger penetration depth. The interesting thing is that we developed a detector which includes this H-V component. If it's very strong then the detector would work much better than it did in our experience. So, Dean, did you have similar experience when you looked at icebergs?

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

Dean Flett

I wanted to pick up on a couple of points that Keld already brought up and Costanza illustrated in her presentation and that is about trying to understand the use of the multi-frequency from an operational perspective. One of the things that Melanie did for our work with the ROSE-L is doing essentially a chart analysis type of approach. We're taking the C-band and doing an image analysis chart. Taking the L-band and doing an image analysis chart. Then looking at the combination of the two and seeing where the complementarities lie. We're gonna have to learn a lot as we have access to more data. We're so jealous of Costanza's L-. C- and X- data set.

Mike Hicks

I just wanted to add a comment about the value of detecting icebergs and sea ice. Obviously, for a ship operating in sea ice, it's important to know that there's a hazard there. But I would like to mention that in mid-March of every year, the sea ice reaches its southern-most extent along the Newfoundland coast and in the Grand Banks and then it starts receding, but the icebergs continue south. That's really when it gets exciting for the International Ice Patrol, having icebergs and open water and fishing vessels. So I hope and expect that L-band will be able to help us understand the population of icebergs that are in sea ice, so that we can better plan our operations. So, just a note on the value from my perspective on being able to get a better understanding of the iceberg population in sea ice in February and March so that we can better plan our operations.

Keld Qvistgaard

I can actually add to this. We see a similar pattern in Greenland because we have icebergs coming down with multi-year ice along the east coast of Greenland. In the beginning of the season, most icebergs are just packed into sea ice. But later in the season, around late March and into April, we begin seeing more and more icebergs, and it would be very nice to have a better feeling for how many icebergs are actually stored in the ice pack so we can see how the season is actually going to progress. As an example, last year in 2019, we had quite a severe season for icebergs in the May-June timeframe. But this year, in 2020, it was pretty light. We would have an opportunity to predict those types of seasons if we could see and detect those bergs in sea ice.

Wolfgang Dierking

I agree with you. But what I see from a scientific point of view, when doing signature analyses, the problem is that for sea ice, in particular, if it's deformed or older sea ice, I also have relatively strong cross polarization. Whereas when the icebergs are out in open water, the H-V component of the cross polarization is very small for open water but strong for the iceberg. So, we should see the icebergs much better in open water than we do in the deformed sea ice.

Wolfgang Dierking

I will go on with question three, which is regarding L-band acquisitions. It's a three part question and Nick volunteered to go first. Would you prefer to combine high resolution limited swath L-band images with Sentinel-1 interferometric wide swath or extra wide swath images so that one of the image pair is at high resolution but has a smaller coverage whereas the other one, usually C-band has a very wide coverage but coarse resolution? Would this be something interesting for the ice services?

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

Nick Hughes

Yes, this kind of relates to the question Patrick raised about reduction of the acquisition time gap. What we see, particularly as the service moves towards the use of more automated products, is that trying to combine high resolution products from different sources is quite complex. We saw this with the Suman Singha paper and the three different satellites we used there. It was very tricky to get them all to match up to provide a combined multi-frequency dataset. So, Norway's preference for operational use is the wide swath for medium resolution and the interferometric wide swath for high resolution with the acquisitions synchronized between Sentinel-1 and ROSE-L. Having a very short time gap between the two means you can very easily combine the two data sets. That makes it a lot easier to implement an automatic classification algorithm without having to take into account the sea ice drift or the satellites being in different orbits. You're looking at the same target from different angles. The second part of the question was whether full polarimetric capability is necessary or if dual-pole polarization, that is H-H, H-V that we have in Sentinel-1, is sufficient? Or would the co-polarization V-V plus H-H be useful? I think what we've seen in a lot of studies is that dual polarization is often not sufficient. We're interested to see what the capabilities of, maybe not full polarimetric, but compact or hybrid polarimetric, are. I'd like to hear from Dean about how they're getting on with the Radarsat Constellation Mission in Canada. The final part of the question was: do you think that C- and L-band information can be combined, even if a time gap between image acquisition is as large as to make a direct stacking of images impossible? My response to that is yes, but it makes it a lot more difficult. With the L-band-C-band comparison study we're doing now for ESA, we are working with the Belgica Bank area because that's an area of land fast ice. Even though we have very long time differences between the images, we know that the ice is not moving, and we're looking at the same ice and icebergs between images. Having movement of the ice between acquisitions, just means you have a whole lot more center target geometry configurations that you need to start considering. It makes classification a more difficult task.

Dean Flett

While we are collecting background compact polarimetry data, we haven't had the opportunity to do analysis yet. The majority of the data collections for RCM for Government of Canada requirements, which are pretty packed, are using operational settings. Maybe my EO and RCM technical lead, Benjamin, can comment in the chat about our plans. But at present, we haven't started any analysis. All of our analysis results and preparation has been done using the simulated data in the past few years with Radarsat-2. We're looking forward to doing that but we're trying to just get on with sorting out the operational issues right now. Compact polarimetry is not the default polarization choice right now. We're using the dual pol at present. So more to come on that in the future.

Regarding question three, I agree, generally, with what Nick said. Do we think the full polarimetric capability is required? I don't think so. That's just my personal opinion. I think, as Constanza's presentation showed, if you can get multifrequency in a pretty close temporal timeframe, you can get a lot of information with the dual pol. Compact pol would be interesting, and we'll see what happens in the future with that. Do we want high resolution or wide swath? It depends. We'd want wide swath operationally. However, we're doing a lot of community-focused monitoring now where complementary high resolution might be useful. Particularly in the case where we're trying

to detect structural information because it's about navigation or travelling on the sea ice as opposed to ships going through the sea ice.

CHAT LINE

Deschamps,Benjamin (ECCC)
One of the challenges with CP (or even FP) is the "typical" representations (decompositions) require more in-depth understanding of the physical scattering mechanisms in the image. Because of correlation between CH and CV, in our experience there was less information in the CH,CV intensities alone than in our regular dual-pol co/cross acquisitions. Based on our experience with simulated RCM data, to get the benefit from CP we need to process SLC imagery to obtain decompositions, etc. (CPSeaIce, m-chi).
CIS is presently conducting a sea ice SAR signature field validation campaign with our Ice Services Specialists gathering photographs and other field observations from Coast Guard vessels, aimed to be near-coincident with CP and DP RCM acquisitions.

Constanza Salvo

The high resolution imagery definitely helps to understand the composition of the ice field better but it always depends on the operational context that we are involved in. If we are looking for details, we are absolutely going to use a better spatial resolution imagery. But if we need to cover large areas, then the wide swath images are the ones that are better suited to that task. So, it depends on the context which is better.

Wolfgang Dierking

We have to find rules in principle to define what is better in which situation so we could order appropriately. I want to ask Keld to comment on these questions but also, in particular, regarding icebergs. On one hand, we are forced to have a wide coverage to monitor icebergs but, on the other hand, it is difficult to see the small icebergs in coarse resolution. We have an example in the area of Svalbard where we have people out in the field looking at very small icebergs and we can't find them in the Sentinel wide swath images, for instance. What is your opinion?

Keld Qvistgaard

I more or less fully agree with what's been said already. Concerning this ESA project where we're working with a number of test sites, we have actually picked the ocean area around the southern tip of Greenland because it's a very severe area. We're dealing with multi-year ice here. We're dealing with icebergs. We're dealing with severe weather. It's actually a very dangerous area for shipping. We are actually dealing with the two different modes, a ScanSAR mode and a very fine beam mode. Currently, we have pretty good experience with the interferometric mode from Sentinel-1 and that's 10-metre pixels. There is lots of sea ice and icebergs we can actually see but also I want to bring your attention to what we're not seeing, and that's the small scale ice. We should always bear in mind that that's the most difficult for shipping. We always need to balance this. We focus on what we can see but we also need to focus on what is it that we don't see? So, we have kind of the uncertainty. What is the uncertainty in this message we're providing internally, but also to the marine community? So that's important.

Mike Hicks

A point from the Ice Patrol's perspective. We frequently set our iceberg limit on a single iceberg, or maybe a handful of icebergs in their very last stages. And so, it's very important for us to simply ask the question: Is this an iceberg? Or is this a vessel?" If that can be done with a coarser resolution over a wider area, I think that's a very important advantage to using L-band. I also want to mention

the need to have a reliable and confident way to distinguish ships, either through AIS or VMS on the Grand Banks for fishing vessels. I think those are two important pieces. I hope we're going to learn from that as we look at icebergs and open water with L-band. Depending on how small the iceberg is, I think that's going to be a very important piece as well. One of the other tools is using both Radarsat-2 and hopefully the Radarsat Constellation Mission to decrease the amount of time between images. That will help us piece together icebergs detected from one image to another. So I think really, the combination of coarse resolution over a large area, hopefully with L-band, we'll be able to detect small icebergs and combining that with other sources such as Radarsat-2 will be very helpful as well. We did note in recent tests last year, we were unable to detect a 57 meter iceberg with Sentinel-1 IWS. It's those icebergs, as Keld says, that are really problems for a maritime community and being able to distinguish that. I will mention we're going to talk more about this on Wednesday but the ability to have reliable and accurate models is also going to be key in this discussion.

CHAT LINE

Richard Hall (RICHH)
small icebergs always come from big icebergs

Neal Young (Australia)

All the discussion here has been pretty much Arctic apart from Constanza. And I'm really delighted to see what is coming out of dual pol L-band in the Antarctic in detecting icebergs. One of the biggest issues we have is the low level of frequency of acquisitions in the Antarctic. Now, I wasn't privy to the inner workings of the committees that made the recommendations for Sentinel-1 operation plans, but one of the specifications was to get coverage every six days. To do that, the operational services running Sentinel-1(a) and (b), alternately in various places, almost always use extended wide swath mode which is not really good for trying to detect things and usually only with single polarization. Even with dual pol, it's often hard to detect icebergs. So, in looking down the track in making suggestions and recommendations for operations and what sort of satellites and how frequently and so on, we need to look at the two hemispheres in different ways.

Alvaro Scardilli (SHNA)

I would like to add to Keld's comments about the detection of icebergs for mariners. That is one of our main objectives as an ice service. We have to look for them in very big area. In our case, we have not only Polar Waters, but we also have the southwestern South Atlantic Ocean. We have a lot of icebergs drifting North due to the Malvinas Current. It's a deviation of the Antarctic Circumpolar Current. Every year, we have a lot of icebergs going north where they are not expected to be. We have icebergs in very low latitudes. If we consider the impact of climate change and the increase of temperatures, we will have more and more of these situations. Also, the increase of the westerly winds in the 40-50 degrees latitude increases the deviation to the north. In our case in the southern hemisphere, Coriolis moves to the left so increasing the westerlies will produce more and more drifting to the north. That's something to be noticed. We need to cover huge areas so maybe the very best resolution will not be a solution for us. Another thing that we also need to consider in these cases, that's been improving every year, is that we need to share more and more SAR imagery between ice services. That's very important for us, for everyone, I guess, especially in the southern hemisphere. Now we have SAOCOM and Sentinel but we need to share as much information as we can.

CHAT LINE

Richard Hall (RICHH)
Richard Hall, CIRFA & Equinor
Comment: The roles and responsibilities of the different actors may need a revisit.
Whose responsibility is it to detect the smallest iceberg? Is it the national ice agency or is it the operator (captain/navigator of the ship)?
The national ice agencies have the responsibility of providing an overview of ice conditions in the area of responsibility. However, a vessel has a responsibility to navigate safely, which includes carrying out observations for icebergs.

Bjørn Kay
Richard is right this needs to defined by IMO!

Alvaro Scardilli (SHN Argentina)
Responsibility in safe navigation is always for the vessel. National agencies can provide support but it is impossible to have a perfect knowledge of the position of each iceberg drifting. Specially with bergy bits and growlers, or even small icebergs not detectable by SAR

Folomeev Oleg (AARI)
It may be useful to use for operation the term "small iceberg big risk" based on forecast data about large icebergs

Jennifer Lewis (NOAA)

Richard Hall has a question and comment in the chat concerning the responsibilities of the different actors. Whose responsibility is it to detect the smallest icebergs? Is it the national ice agency? Or is it the operator/Captain/navigator of the ship? But national ice agencies have the responsibility of providing the overview.

Keld Qvistgaard

It's a balance. We should also bear in mind that, except for the International Ice Patrol, this is pretty new. From DMI's perspective, we are in our second season of providing iceberg information. We have a success story but we still need help if we'd like to bring this further. We cannot monitor every single growler in the North Atlantic Ocean. That's impossible. We need to watch something that's updated frequently, that makes sense, and has the necessary content. We always want the mariner or the captain to have the right tools to make a decision so he knows about the risk, when and where to go or maybe to navigate into an area he should wait another several weeks? There are many different aspects of that. But that's the type of thinking and discussions we should always have in the ice services. How can we go? How far can we go and take that up with the marine community?

Wolfgang Dierking

We're running out of time so I want Mike to show the experiment they have planned for the icebergs. Then if there's still a few minutes, I wanted to talk to Sean Helfrich about the analyzes they did in their Ice Center.

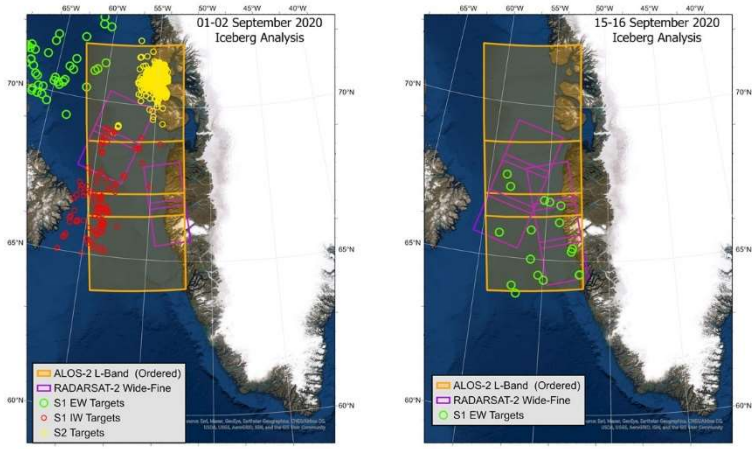
APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

Mike Hicks

As many of you know, the International Ice Patrol has been working for decades on getting away from aerial reconnaissance towards satellite reconnaissance. We've made tremendous strides. In 2017, we had the availability of Sentinel-1 data publicly and the procurement of a license to operate C-CORE's iceberg detection software in our operational center. And lastly, some really motivated and enthusiastic people who have the same core purpose as everybody on this call and that is to promote maritime safety. What I'm going to say actually addresses a bit of Richard's question as well. So, we have been focused primarily on C-band in our work thus far. In 2020, we started operationally including multispectral imagery through Sentinel-2. I must acknowledge Lieutenant Don Rudnickas for his work in developing a Python script that looks at Sentinel-2 imagery and helps guide the analyst as to what is and what isn't a potential iceberg that can be looked at further. Don has done tremendous work with this and continues to do so. But I wanted to point out some of the challenges. We've talked about icebergs and sea ice. Detecting icebergs in high sea state and in high wind conditions using SAR has always been a challenge. Of course, multispectral with cloud cover is a tremendous challenge. So is detecting and identifying an iceberg on the Grand Banks in open water when there are also many fishing vessels around that can look like an iceberg in SAR imagery. As I mentioned, we started using Sentinel-2 in an operational sense to help us identify icebergs. We hope that L-band is going to be one more tool in our in our box to help us in our goal to move away from aerial reconnaissance towards remote sensing.

Iceberg L-Band, C-Band Data Collection Effort

01/02 and 15/16 September 2020



Since early August, we've been supporting a US Coast Guard Cutter off of the west coast of Greenland involved in search and rescue exercises with Danish vessels, Canadian vessels, French naval vessels and US naval vessels. We have been sending them iceberg density products since early August. Because the ship was going to be operating in the area, we requested that the Baffin Bay region that Wolfgang showed earlier be extended for a limited time. Shown on the left of the slide are the results of that request. The large orange box is a ScanSAR ALOS image footprint. We have not received the imagery yet but it's been ordered and it should be coming hopefully soon. The picture on the left is for the 1st and 2nd of September. The ALOS image is around 0300 UCT on the 2nd of September. The purple boxes represent the Radarsat-2 wide fine imagery we received. That is the operational mode that we've been focused on within the International Ice Patrol. These were late in the evening on the 1st of September and early morning on the 2nd of September so there's about a six hour gap between the evening passes and the morning passes the next day, compared to the ALOS-2. That's about the same for Sentinel. In the slides on the left, we had many targets, many possible icebergs. On the right, you see fewer icebergs. The

reason is that a very significant storm system passed through Southern Greenland on the 15th and 16th of September. We were unable to detect as many icebergs, though we knew they were there. So our hope, when we get the L-band imagery, is that we have something else, in addition to just looking through sea ice, to be able to detect and identify icebergs in a high sea state in difficult weather conditions. That's our plan.

Sean Helfrich (NOAA)

I just wanted to make a comment about NISAR, which is going to be an L-band satellite that NASA and ISRO will be launching. It was originally expected to launch in early 2020 but, due to COVID, there's been some delays. They're currently looking at a launch time period of either October 11, 2022 or January 29, 2023. They basically had to evacuate the entire JPL area where they were building the satellite as well as the instrument for several months. Also, some delays in the S-band delivery from ISRO. They're back on track with actually building the instrument. They've actually completed functional testing on the instrument. We're looking at being able to have imagery from NISAR within six hours. It will be available at the ASF facility through their cloud processing. As well as you could actually link through the Amazon clouds to actually provide algorithms to do processing. That'll be somewhat exciting and is a new way of doing processing for SAR products. They will have an ice motion product as well as the imagery. It's going to be primarily based on the L-band but keep in mind that there was going to be some S-band available over the Antarctic stations for the Indians. There had been a request through myself and some other people to make S-band available in the Chukchi and Beaufort Sea area. They did an analysis of how much that would add to the power needs and determined there are no power restrictions that they would face by doing S- and L-band over the Chukchi and Beaufort Sea area.

Wolfgang Dierking

Unfortunately, we are at the end now. I just want to thank all the panelists for their contributions and a lively discussion which we could have extended for another half an hour. Thank you again.

CHAT LINE

Keld Qvistgaard
Question 4: NRT and Stable data provision is essential. Technical implementation a couple of months, but we need test things, train analysts, investigate one full year (at least) regionally. check seasonality, regional differences, sea state impact, melting stage. also consider purpose of L-band supplement C-X band information and coverage. implement smart extraction of ice parameters to supplement C-X

Jørgen Buus-Hinkler
...and identify the limitations of L-band regarding physical target-size (seems that L-band performs surprisingly good at sub-pixel level when it comes to detect "object type"). C and X-band I assume still might be superior in determining object shape/size. Combining the two is thus most considerable...

Appendix D1: Session 1 Background Paper

Background

In several previous studies, airborne and satellite L- and C-band SAR images acquired over sea ice have been jointly analysed. Compared to C- and X-band, large-scale sea ice deformation structures such as ridges, cracks, and rubble fields are easier to recognize in L-band images. The L-band signals penetrate deeper into the ice and interact with disturbances in the deeper ice volume that are caused by the deformation processes. The use of L-band imagery improves sea ice

classification when employed in combination with C- or X-band data, particularly during certain phases of the summer melting season. It also reveals some sensitivity to ice thickness. For iceberg monitoring, however, the usefulness of L-band radar and the combination of L- and C-band has not been studied systematically to date. Because of the limited availability of L-band SAR images, their use for supporting ship navigation and offshore operations in sea ice covered waters or in ocean regions with occurrences of icebergs has been confined to single case studies. In Session 1 of the IICWG-XXI meeting, we introduce a project supported by ESA and JAXA. The project was started to deliver information for the design and implementation of a concept for ROSE-L (Radar Observing System for Europe at L-band) from the perspective of sea ice monitoring. The objective is to define the advantages of a combined use of C- and L-band SAR images specifically in an operational environment for sea ice charting and iceberg detection.

Panel Discussion

The objective of the discussion is to provide an overview of the experience of ice services with multi-frequency data (specifically including L-band), to judge the benefits versus efforts to implement a multi-frequency analysis into the daily routine work, and to emphasize special requirements of operational ice services with regard to ROSE-L (e. g. technical issues such as available polarizations, spatial resolution etc).

Moderator: Wolfgang Dierking (AWI / UiT)

Panelists:

- Dean Flett (CIS)
- Constanza Salvó (SHNA)
- Mike Hicks (IIP)
- Keld Qvistgaard (DMI)
- Nick Hughes (MetNorway)

Prepared Questions

Because of time limitation, panelists will be asked to indicate their "favorite" question to which they will give input.

1) Analysts who have some experience in using L-band images for sea ice monitoring / iceberg detection (e.g. through systematic comparisons between C- and L-band data) summarize their findings.
2) Is L-band a useful extension? How does it improve ice type separation / iceberg detection (I.e. what is the additional information gained when using L-band)?
3) What are the demands regarding the L-band acquisitions?
    a) would you prefer to combine high-resolution limited-coverage L-band images with Sentinel-1 IWS/EWS images? Or vice versa? Or both at wide-swath modes / narrow swath high-resolution over key regions?
    b) Do you think that full-polarimetric capability is necessary, or is dual pol (like/cross, e.g. HH/HV) sufficient? Would the VV/HH ratio be useful?
    c) Do you think that C- and L-band information can be combined even if the time gap between image acquisitions is as large as to make a direct stacking of images impossible (e.g. because of heavy ice deformation or differences in the paths of drifting icebergs)?

4) Which areas would you regard as key regions for iceberg detection?
5) Provided that L-band image acquisitions meet the needs of the operational centers: how can their use be implemented in the routine map production? What would be the time horizon for a service to operationally use C- and L-band in combination after the requirements of data acquisitions and distribution are fulfilled for operational use?

Wolfgang Dierking

September 2, 2020

Appendix D2: Session 1 Bios

Wolfgang Dierking

Wolfgang is with the Alfred Wegener Institute Helmholtz Center for Polar and Marine Research in Germany, where he works as senior scientist with satellite monitoring of the Arctic and Antarctic environment. He is lecturer for ocean remote sensing at the University of Applied Sciences in Bremerhaven, Germany, and adjunct professor with the Center for Integrated Remote Sensing and Forecasting for Arctic Operations at the University in Tromsø, Norway, leading a group which is focussing on the development of techniques for sea ice mapping and iceberg detection based on the use of satellite data. At present, Wolfgang is coordinating a project between ESA and the IICWG on a study of an L-band SAR mission which is one of six high priority candidates to expand the current capabilities of the Copernicus space component.

Constanza Sofía Salvó

Constanza works at the Argentine Naval Hydrographic Service (SHN) and has a Degree in Environmental Science. She is an ice analyst who leads the ice charting production. Her work is focused on the routine elaboration of ice charts for Antarctica and the Southwestern Atlantic Ocean and on the development of new and accurate products for mariners in ice infested waters. She has operational experience onboard an Argentine Navy Icebreaker during the last two Summer Antarctic Campaigns. Constanza also participates in research projects related to remote sensing and floating ice, such as the current intercomparison of different Synthetic Aperture Radar (SAR) systems for studying sea ice.

APPENDIX D: SESSION 1 – MULTI-SPECTRAL SAR

Dean Flett

Dean is Senior Manager, Applied Science and Development with the Prediction Services-Atlantic & Ice division of the Meteorological Service of Canada, within which the Canadian Ice Service resides. Dean has been a participating member of the IICWG since its inception in 1999 and has attended 10 of the 19 meetings to date. Dean was the first Co-Chair of the Science Standing Committee for several years, and the last co-chair prior to the establishment of the Task Team structure. Dean's interest, expertise, and focus during his career has been on the operational exploitation and use of Earth Observation data in marine monitoring applications, particularly for sea ice using Synthetic Aperture Radar (SAR) data. When Dean is NOT thinking about that, he is usually thinking about when and where his next golf game will be.

Michael Hicks

Mike completed 21 years of active duty service with the United States Coast Guard that culminated in a tour as Commander of the International Ice Patrol (IIP). His active duty work included two years as a bridge watch officer on a USCG cutter and four years supervising a Rescue Coordination Center in San Francisco Bay, California. He returned to the IIP as a civilian in 2012 to serve as Chief Scientist/Oceanographer with a focus on iceberg detection and the operational application of iceberg drift and deterioration modeling. Mike has participated in many IICWG meetings serving as Iceberg Committee Chair and leader of the Iceberg Model Modernization Task Team.

Nick Hughes

Nick is leader of the Norwegian Ice Service based in Tromsø. He is responsible for the daily operation of the Ice Service and for project management including the development of new data processing algorithms and information services. Nick has 21 years' experience in Arctic and Antarctic research including 15 field campaigns. Currently he is Coordinator for the EC Horizon 2020 research project Key Environmental monitoring for Polar Latitudes and European Readiness (KEPLER), and Work Package Leader for the Polar Use Case in From Copernicus Big Data to Extreme Earth Analytics (ExtremeEarth). Nick is the creator of the new QGIS-based ice charting system Bifrost.

Keld Qvistgaard

Keld is a senior ice specialist at the DMI Greenland Ice Service. He has been with the Ice Service since 1992. Along with his expertise in Greenland/Arctic/Antarctic sea ice & icebergs, he is skilled in using high resolution satellite images, both SAR and non-SAR, for support of navigation in ice-covered waters and is the coordinator of satellite data for the Ice Service. Keld manages commercial programs for high resolution customized services to ships in Greenland waters, mariner training, and international relations with ice services around the Globe, Polar shipping, marine training centers, satellite data providers and the WMO.