Appendix G: Implementing Ice Modelling in Our Daily Production

APPENDIX G: SESSION 4 – IMPLEMENTING ICE MODELING IN OUR DAILY PRODUCTION

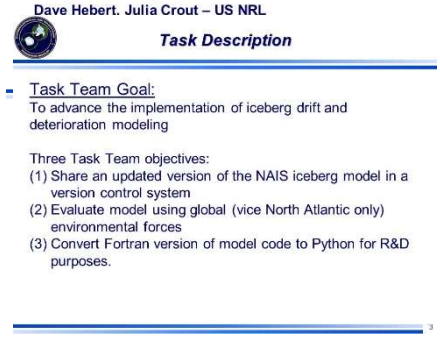
Presentations

Michael Hicks (IIP) - NAIS Iceberg Model Developments in the North Atlantic

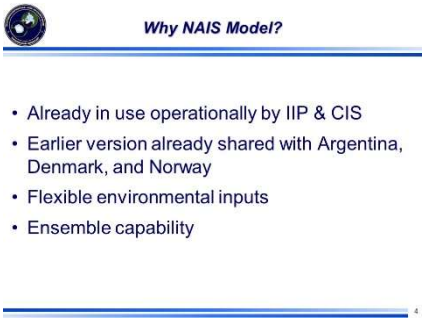
Good morning, good afternoon, and good evening to everybody. I'm going to be presenting a report on the progress for Task Team 2 and it's going to be focused on the North Atlantic, the use of the North American Ice Service iceberg model developments. I'm going to talk a little bit about our goals for the project and the task team and our objectives. Then, in keeping with the theme of the meeting, I'd like to close my presentation with a few examples of how the International Ice Patrol is using iceberg modeling and how we hope to be able to use it in the future.

This is our team. I think we had some excellent cooperation and insight from most of the people on this team and I think that, hopefully, a lot of them will continue to work with us. This is a representation from Europe, from North America, from the Southern Hemisphere and I think it was an excellent team.

Next slide shows our task team goal. The title of it was iceberg model modernization, a fairly broad title. The goal was simply to advance the implementation of drift and deterioration modeling for icebergs. We had three objectives. The first was to share an updated version of the North American Ice Service iceberg model and version control system. Then, to evaluate that model using global environmental data, not just North Atlantic data. And the third objective was to convert the Fortran version, which is used operationally in CIS and IIP, into Python for research and development purposes. I'm happy to report that we've met all three of these objectives. We think this task as it is currently written should conclude. But there's still a great deal of work to be done, particularly in number two to advance iceberg modeling and to keep that same goal.



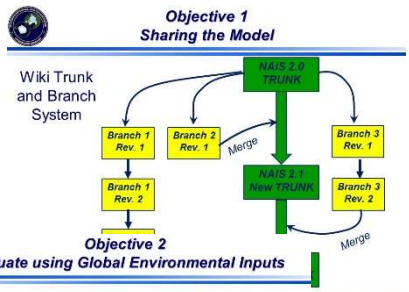
So why the NAIS model? We decided back in Helsinki in 2018 that this would be a good starting point for these reasons. It's being used operationally already. We've had some agreements between Argentina, Denmark, and Norway already. It allows flexible environmental inputs, and it has the ensemble capability. I'll show you an example of that in a moment.



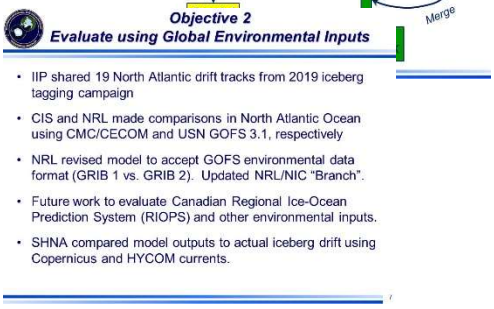
Appendix G: Implementing Ice Modelling in Our Daily Production

So, starting with objective one, sharing the model. Philippe Lamontagne, at the Canadian National Research Council, established a Wiki trunk and branch site and provided username and passwords to all the task team members that were interested in getting the model. The Canadian Ice Service had recently modified the NAIS model code to correct a few errors and uploaded that code to the Wiki site, along with some installation procedures. I thank Hai Tran for his work in doing that and getting it available. The third bullet there, the Ice Patrol realized that we were operating a NAIS model without having a solid documented agreement with NRC. That was really important because, in order for this work to progress, we needed to share the model with the US National Ice Center and, more specifically, the Naval Research Lab working for the National Ice Center, because they were going to be doing most of the work for evaluation. So that was an important step. It took a little bit longer than expected but we got that done and I think was an important administrative step. And finally, we conducted some preliminary evaluations. That's more objective two but Canadian Ice Service, NRL, and Argentina Naval Hydrographic Service conducted evaluations of both hemispheres.

This is just a schematic of the trunk and branch system. I showed this last year but, just as a reminder, the green represents the main code. The yellow branches represent individual organizations' code. The yellow branches remain internal and there is an opportunity, if there are significant revisions made, to merge it back into the main trunk if all agree on it. We never got to that point in this project, but the capability and the infrastructure exists to do that.



So on to objective two. This was again to evaluate the model using global environmental inputs. To do this, at least in the North Atlantic, the Ice Patrol shared 19 drift tracks from our 2019 iceberg tagging campaign. The idea is to compare modeled output to actual iceberg drift. The Canadian Ice Service and NRL made some comparisons in the North Atlantic Ocean. CIS used the Canadian Meteorological Centre winds and waves and Canadian East Coast ocean model (CECOM) ocean currents. The NRL used the US Navy Global Ocean Forecasting System environmental data which includes Naval Global Environmental Model (NAVGEM) winds and HYCOM ocean currents. In order to do this, NRL had to revise the model. They made a revision to accept GOFS data which was provided in GRIB-2 format versus GRIB-1. That required a slight code change. And so, we're able to exercise the whole trunk and branch system because NRL made the update to the code and then reloaded it back into their branch. So, it is available for merging but we haven't gotten to that point yet. One area that I think we need to look at very closely is evaluating different environmental inputs such as the Canadian Regional Ice-Ocean Prediction System (RIOPS) and perhaps other environmental inputs. And as I mentioned, Argentine Naval Hydrographic Service compared model outputs to actual iceberg drifts using Copernicus and HYCOM currents. Gastón is going to talk about that next so I don't want to say anything else about that. He's going to provide a great presentation.



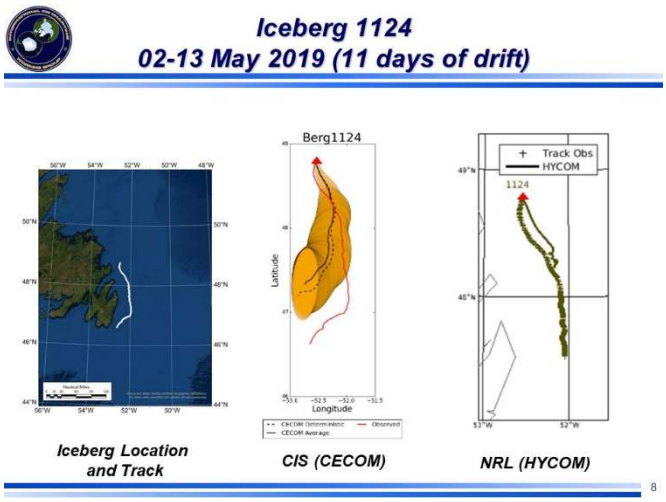
CHAT LINE

A.J. Reiss (USA - NOAA)

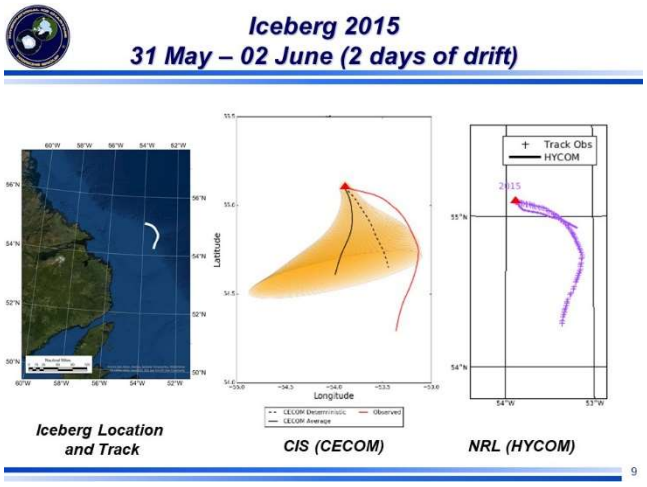
Appendix G: Implementing Ice Modelling in Our Daily Production

I'm interested to learn if ONR's intention is to incorporate NAIS 2.0 into GOFS and run on Navy supercomputers or run as a standalone application. That's for me to look into. The context of my questioning is wondering how important the ocean model boundary conditions are for output accuracy of drift.

Hebert, David A CIV USN NRL DET SSC MS (USA)
We have had that discussion as well. At this point we do not have plans to incorporate it into GOFS to run on NAVY systems. Happy to discuss that possibility for future work though. An immediate is how to initialize (GOFS) with (iceberg) observations in an operational setting.

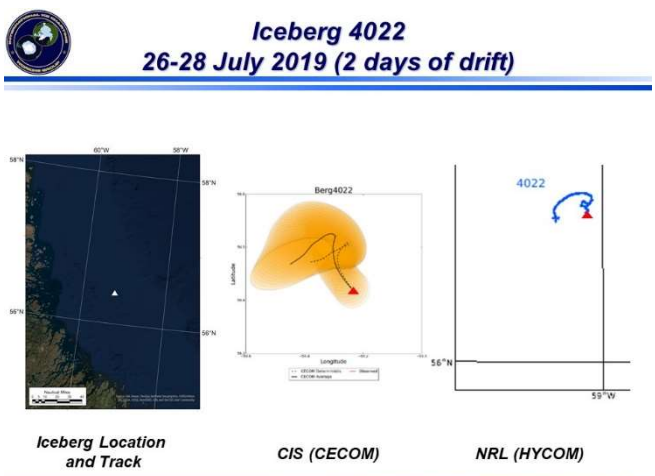


I just want to show a couple of quick examples without getting into too many details. I've got three icebergs I'm going to show from our drift tracks. Each of these slides are formatted the same. On the left side is the iceberg location and track. In the middle is the CIS output in comparison and, on the right, is the NRL output comparison. Focusing on the middle slide for a moment, this is iceberg. 1124 which was the designation for that particular berg. It drifted from 2 to 13 May for 11 days' worth of drift. If you look at this picture in the middle, you see a couple of components. The red solid line represents the actual iceberg drift. You see a number of ellipses which represent the results of the ensemble capability of the NAIS model. Essentially, the CECOM currents were perturbed over a range of different possible currents and the ellipses show the resulting response for the 250 iceberg particles starting at the red triangle at the top. So those are the ensemble results. The solid black line represents the average of the ensemble and the dashed line represents the deterministic results which are without the ensembling applied. So, you can see the CIS example there used the entire track of the iceberg drift. You see a similar setup on the right with the NRL model. The plus signs represent the actual iceberg drift track. Note that it was only looked at the first several days. The solid line on the right represents the HYCOM driven track from the model. Overall, this is actually a pretty good result. We started with 11 days of drift so having the actual iceberg drift so close to the model drift is a pretty good result for that period of time. That's the kind of the approach we took.

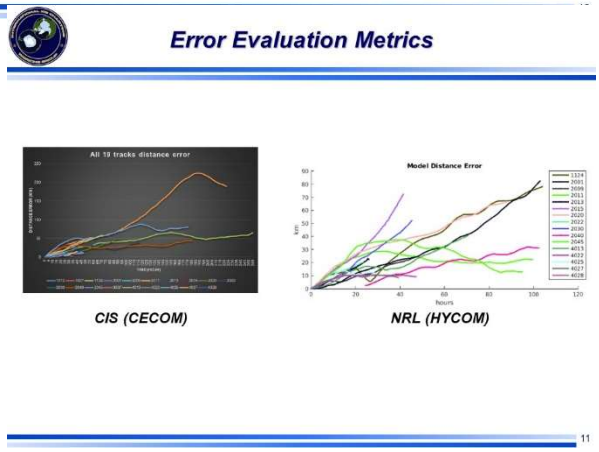


This is just another example using the same symbology. This iceberg was further out on the 1000 meter depth contour off Southern Labrador. The thing I want to point out here is that this was only two days of drift and the iceberg drift track was significantly different than the model tracks over a fairly short

period of time. I think this represents an area that we need to study more carefully - to go back and look at what the iceberg size was when it started, how it deteriorated and the environmental input.



Just a third example. I'm not sure if you can tell or not, but there's no red line in the middle picture. The iceberg didn't drift in this case. This iceberg was aground off the coast of Labrador. But both models had the iceberg moving. That is an issue that we identified. I think we knew this before, but it really came through clearly in this example. That is a result of the way the model looks at land versus bathymetric contour.



In both cases, we calculate some error evaluation. I'm not sure how well you can see these, but both of these graphics represent time on the horizontal axis and error in kilometers on the vertical axis. You can see the different errors for all the different drift tracks that were looked at. This is a pretty standard evaluation metric. It's relatively straightforward to calculate. The question that we have remaining is - what do we do with this? How do we communicate these error results going forward? I think that's an area for future study. This is one evaluation metric, but perhaps there are others that we can look at that can better communicate the problem. So, again, I think this was a good start but I think we have more to work on this.

CHAT LINE

Marc DeVos
Thanks for the response Mike - we can perhaps discuss offline, some interesting skill assessments for trajectory modelling around

Hebert, David A CIV USN NRL DET SSC MS (USA)
Thanks for that suggestion on iceberg skills scores. Is there a reference that has used skill score for iceberg modeling?

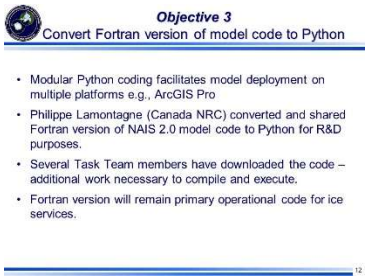
Hicks, Michael R CIV USCG ICE PATROL GROTON (USA)
I know that USCG Search and Rescue community uses a skill assessment for ocean currents using drifting buoys. I think the use of this type of in situ measurement has promise...

Marc DeVos
Hi David - I'm not sure about specific to iceberg modelling, but trajectory modelling in general, an example is perhaps https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010JC006837

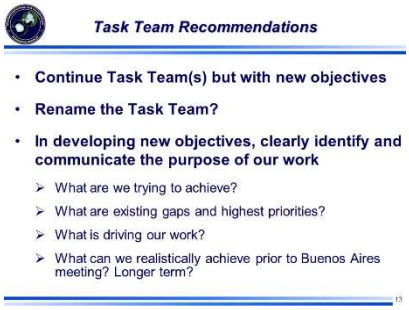
Hebert, David A CIV USN NRL DET SSC MS (USA)

Appendix G: Implementing Ice Modelling in Our Daily Production

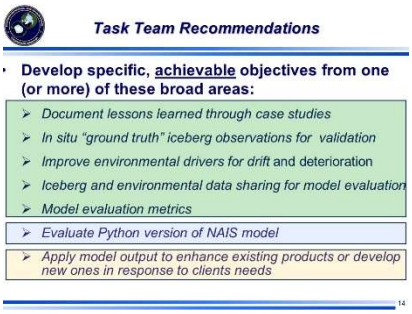
Thank you, Marc, for the link regarding Trajectory modeling!



The third objective was to convert the Fortran version of the code to Python. Python is a modular coding system. It facilitates deployment on a variety of different platforms, for example. In all of the NAIS services, we are using ArcGIS and soon we'll all be using ArcGIS Pro. That is a very Python-friendly environment. So, I think that's a goal to have this available too. Fortran requires compilation and special software. It's very stable for operational use but Python is seen as an excellent opportunity to make some changes without a lot of overhead in terms of coding. As Philippe put it, it can be a little sandbox. Philippe converted and can share the NAIS 2.0 Fortran code for R&D purposes. I thought that was an excellent accomplishment. A number of task team members have downloaded the code and Philippe has agreed to help out with additional work needed to compile and execute the code. Just as a note, the Fortran version will remain the operational code for the ice services until a very rigorous evaluation takes place to consider Python.



So on to our recommendations. As I mentioned, we believe this task team, has achieved our objectives. We think there is a significant amount of modeling work that can still be done, but under new objectives. There was some question about renaming the task team and maybe this is something we can discuss on Friday when we're talking about the task teams. Some of us felt that there's no need to rename the task team. Others think that it's a good idea to rename it so that it is specifically talking about what we want to accomplish. On that note, we had a really great discussion in our team just last week about how to define new objectives and how important it is to define them properly. In doing so, we thought it was very important to understand what we are trying to achieve, what is driving our work, and what are the existing gaps. We need to use those gaps to help us prioritize what work we need to do. Ultimately, what can we achieve realistically, prior to the Buenos Aires meeting next year? How about longer term? I think it's very important to look at this. I'll add one more that there needs to be a champion for any new task team. This isn't just this task team but any one we take on. There needs to be good leadership too to make the task team work.



We came up with several broad topic areas. There's actually seven of them here on which we think we can frame more specific and achievable objectives. I'll just go through those quickly. I think one of the most important is to document our lessons learned through case study. So Gastón is going to show you a couple examples. I showed you a couple of examples where the model worked well and where it didn't. I think we need to dig into that by looking at the various details of the case study. This second bullet is ongoing and that is obtaining ground truth, iceberg observations for validating the model. We'll be talking about this more on the panel. Environmental drivers for drift and deterioration, very important. Garbage in equals garbage out. So, we have to have the right environmental data and the best environmental data we can improve our models. Data sharing from model evaluation: I talked about the trunk and

branch earlier. That was for the code. We think there's a need to have some sort of a mechanism to share data, aside from email, about iceberg information size and shape, environmental data, and model outputs so that we can do comparisons and work better together in a collaborative way. Model evaluation metrics can be developed. Next is evaluating the Python version of the code. We shared it. Now, let's evaluate. And finally, I left this one last for four reasons because it's a good setup for our panel discussion later. How do we apply model output to enhance our existing products or develop new ones? Again, always in response to our client's needs.

CHAT LINE

Richard Hall (RICHH)
Q. to Mike, USCG (and Nick, NMI) how can operators work with national ice agencies to use the iceberg drift model outputs?
Any operator requires the iceberg drift of specific icebergs entering their own surveillance area.
Equally, the operators can report iceberg observations to close the loop and provide feedback on the model results - it is a partnership :-)

A.J. Reiss (USA - NOAA)
@Richard Hall... yes, it's the same partnership with vessels and maritime weather. WMO even runs an observation program called VOS-- Voluntary Observing Ships. So, we also need to integrate this concept... those same vessels need weather and ice, and 'we' need observations of weather and ice. Training an observer for weather observations is somewhat robust... how is training for ice observations? not as robust and perhaps a harder job.

Bourbonnais, Pascale
Plotting icebergs is an important job on a bridge when navigating in polar waters, or even in open/bergy waters, and as such it is recommended to have additional bridge watch resources to maintain a sharp lookout at all times. With good radars, it can be done with a good level of precision. It's just a question of how to effectively share back the info in a timely manner that will not become a burden on the crew.

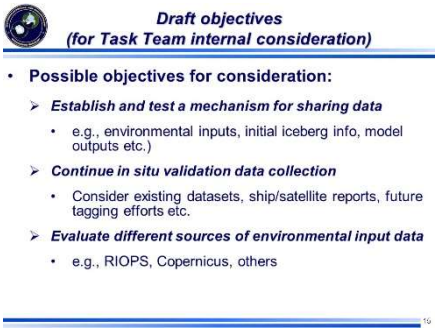
Tuomas Niskanen
I would like to add to Pascale's comment that it is also important to share the observations (not only icebergs but any) in harmonized format. Such harmonization will facilitate faster usage of the observations when analysts does not need to convert calls, email messages, photos etc in the format that GIS and other tools can digest.

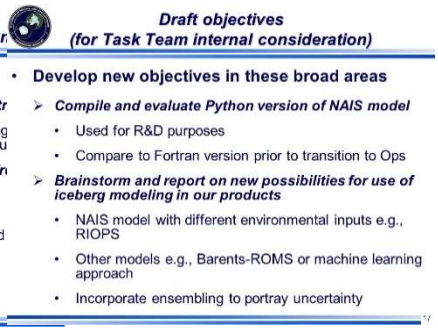
Jan Lieser
Hey AJ: there's some training material available from the ASPeCt project.
http://aspect.antarctica.gov.au/home/conducting-sea-ice-observations

Ole Jakob Hegelund (MET-Norwegian Ice Service)
We also have an archive of visual in situ sea ice observation from ships at https://icewatch.met.no/
Now close to 10k observations

Appendix G: Implementing Ice Modelling in Our Daily Production

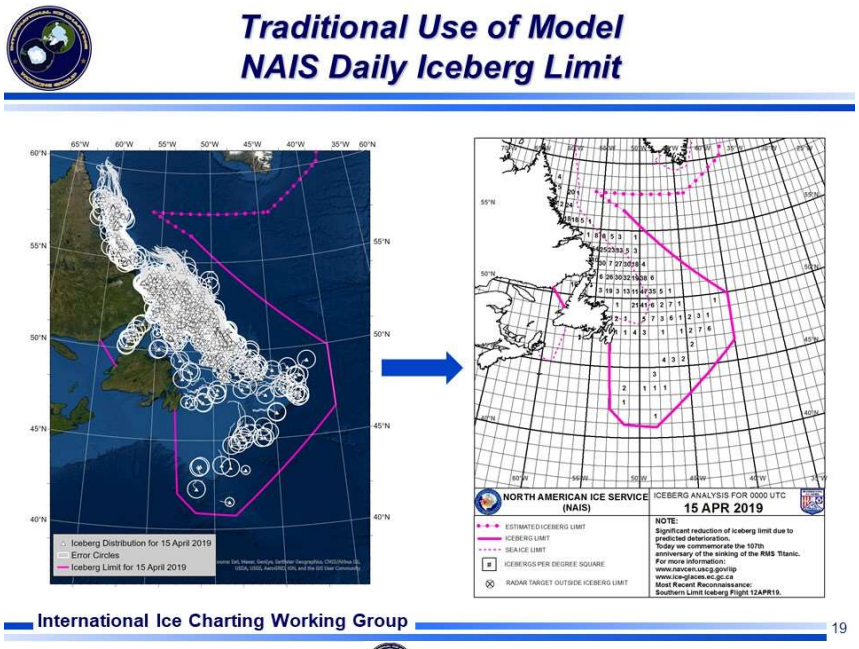
We can look at these as separate tasks or perhaps, next slide, you can see that I put some potential groupings on these. These objectives can be grouped in a way such that, if one of them fails, we

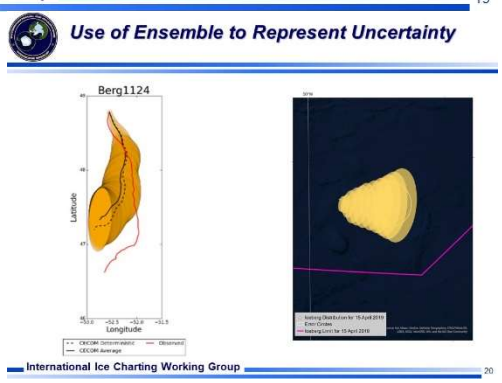




can still make progress in other areas. This was just my interpretation of where that might be. The group plans to meet in early October to hammer out specifics, to prioritize and make the difficult decisions of what we are and aren't going to work on over the next year.

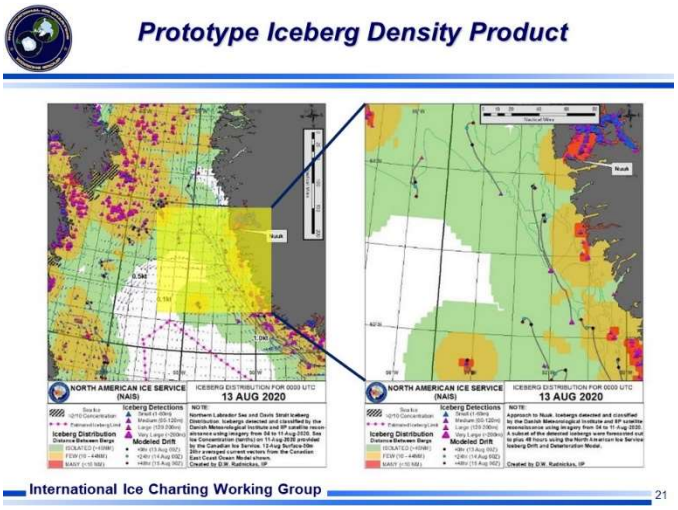
So, just two quick examples to wrap up my talk. This is how the International Ice Patrol and Canadian Ice Service are using iceberg modeling to create their daily product. What you see on the left is, for April 15 of last year, iceberg distribution on the Grand Banks. We use modeling to drift those icebergs and we apply a very rudimentary error circle. You notice, if you look at the ones in the very south, those are fairly small because that iceberg was recently sited. The larger ones go out to 30 nautical miles because the iceberg was sited more than five days ago. From this, we draw our iceberg limit and create our daily product. The picture on the right is what we send out to ships or put on our website for our daily product. By the way, this is a North American Ice Service product. It is the same for the Canadian Ice Service. They are doing the product and creating the exact same picture. So, there's how we are using the model traditionally.





One of the things we'd like to consider is the use of ensemble for representing uncertainty and error.

Appendix G: Implementing Ice Modelling in Our Daily Production



Last slide please. So, this is a prototype iceberg density product that Don Rudnickas came up with that we use to support the Coast Guard cutter Campbell. This talks to several very important topics we've had with ice charting workgroup - the concept of isolated few and many, the concept of scalability. You can see that we provided both of these products, one is an overview, and one is zoomed in. And then we also provided model tracks where the triangle represents the last site position the dot in the middle represents the position at the valid time of the product, and then two other dots for 24 and 48 hours. So, it was a way to communicate to the ship what those specific and most important icebergs were doing. And that concludes my talk. Are there any questions?

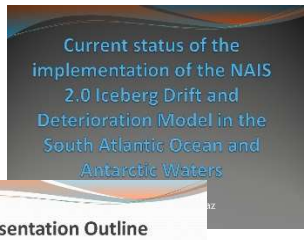
CHAT LINE

Hicks, Michael
Annika, these charts were provided in direct support of a vessel operating off of the Greenland and were prototypes. We are not currently producing these on a daily basis.

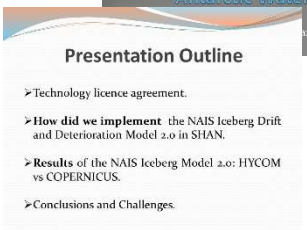
Ogilvie, Annika
Okay, thanks for the reply - will look forward to seeing them produced daily one day

Tuomas Niskanen
Hopefully, the density charts will find their place from your product catalog soon.

Gaston Lopez (SHNA) - Implementation of the NAIS Iceberg in the Southern Ocean Model



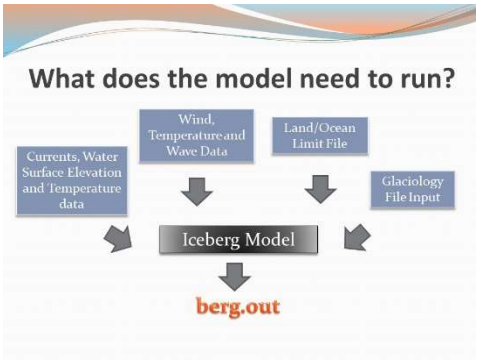
Morning, everyone. I am glad to be here and thank you for this opportunity to share my work with you. I am going to talk about the current status of the implementation of the NAIS 2.0 and the deterioration model in the South Atlantic Ocean and Antarctic waters



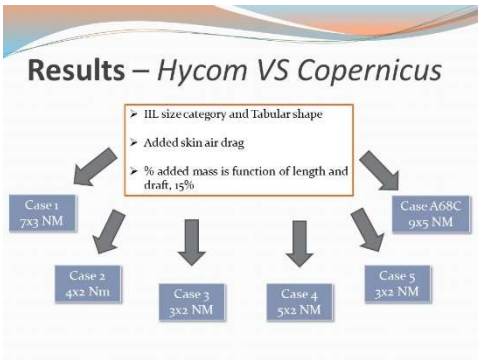
This is the presentation online. First of all, I want to cover the Technology License Agreement. After that, how we implemented the iceberg drift model and deterioration model in the National Hydrographic Service. After that, I will talk about the results of the NAIS model. In particular, I'm going to show a comparison between the HYCOM versus Copernicus model. Finally, I'm will show you the conclusion and challenges.

After the Technology License Agreement was signed between the National Research Council of Canada and the Argentine Hydrographic Service on October 27, 2016, we started the implementation of the model.

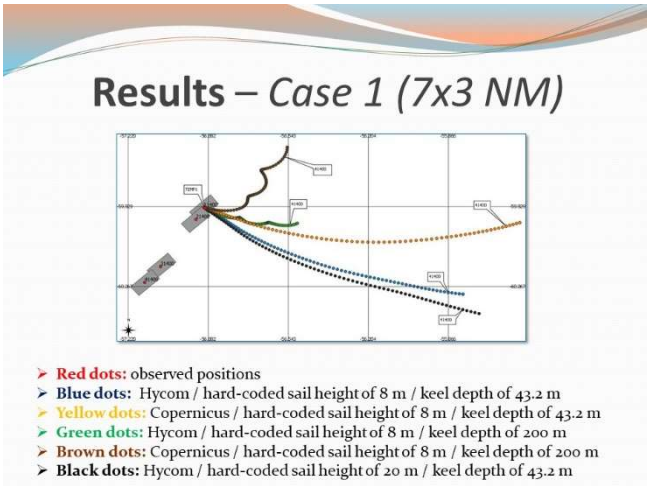
Appendix G: Implementing Ice Modelling in Our Daily Production

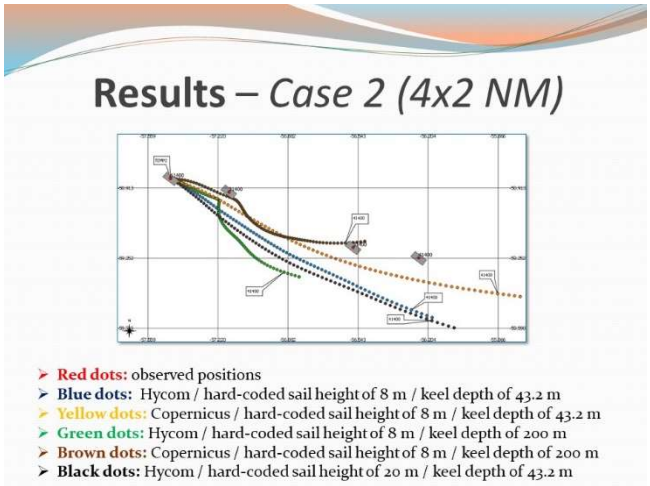


We implemented the model. We need four inputs to run the model. We need first a set of data with current water surface elevation and temperature data. I use a set of data from two different sources. The first one is the Copernicus model and the other one is the HYCOM model. Also, we need a set of data with the wind, temperature, and wave data. This atmospheric data I get from the Global Forecast System. Another input is the land ocean limit file. This file contains the land-water mask used by the model to determine it the iceberg has hit an island. Finally. we need the glaciology file input. This is the berg input. To build this, I need the initial position and length of the iceberg from the glaciology section of the meteorology department. So, we these four inputs, we can run the model. We are going to get the berg.dot output file. This file contains the positions predicted by the model.



For this presentation about the model, you have seen the iceberg size category and tabular the shape. I added the skin air drag and also set up the percent of added mass to 15%. In this case, I choose six different icebergs with different sizes from three by two nautical miles to nine by five nautical miles.

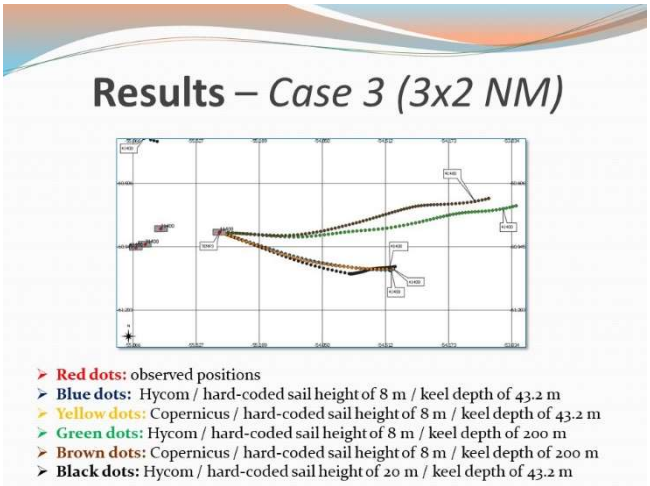


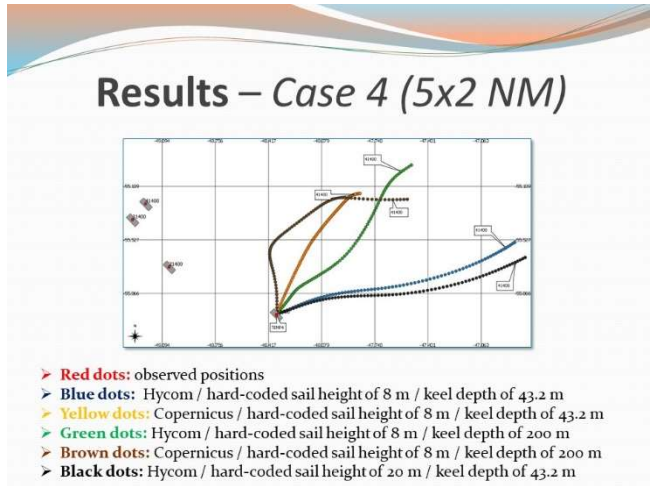


For case one, we have the iceberg with the size of seven by three nautical miles. You can see the observed positions with the red dots. We have an iceberg with a sail height of 8 meters and keel depth of 43.2 meters. The blue dots show the model results with the HYCOM model and the yellow dots show the results with the Copernicus model. So, if we compare this to the results, you can observe that, if I use the Copernicus model, the iceberg is displaces toward the North. Also, we have a result for the green dots and the red dots. Here there is an iceberg with a sail height of 8 meters and a keel depth of 200 meters. If you observe: if I use the Copernicus model, the result has a length of displacement similar to the observed position but the direction of movement for this iceberg is opposite to the observed positions. And finally, we have the black dot results. Here, we have an iceberg with a sail height of 20 meters and a keel depth of 43.2 the two meters. in this case, I use the HYCOM model.

Appendix G: Implementing Ice Modelling in Our Daily Production

In case 2, we have an iceberg with a size of four by two nautical miles. In this case, you can observe, when I use the Copernicus model and increase the keel depth from 43.2meters to 200 meters, I get a result close to the observed positions.

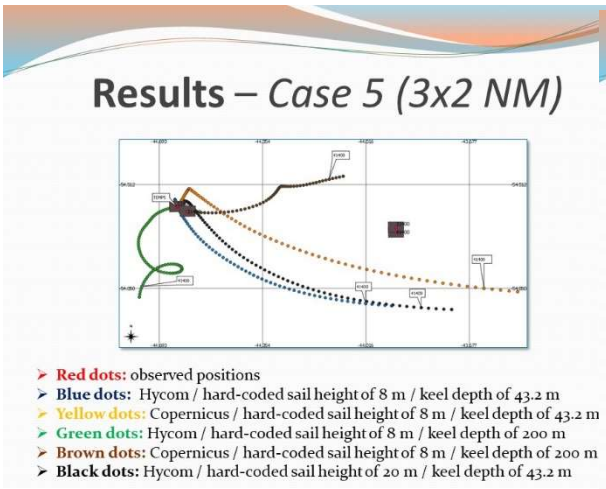


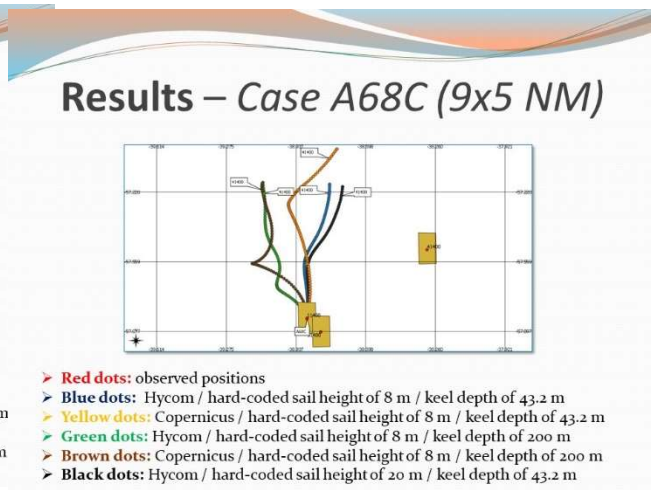


For case 3, the iceberg has a size of three by two nautical miles. And in this case, you can observe that when I increase the keel depth from 43.2meters to 200 meters, the length of the displacement of the results is greater than the observed position. Also, you can observe that all the results of the model have a relation positive to the observed positions.

For case 4, we have an iceberg with the size of five by two nautical miles. In this case, when I use the Copernicus model, I get a direction closer to the observed position. In particular, when I use a keel depth of 200 meters, the length of the displacement for the iceberg is similar to the observed positions.

For Case 5, I have an iceberg with a size 3.2 nautical miles. In this case, again when I use the Copernicus model, I increased the keel depth from 43.2 two meters to 200 meters, I get a result similar to the observed positions.

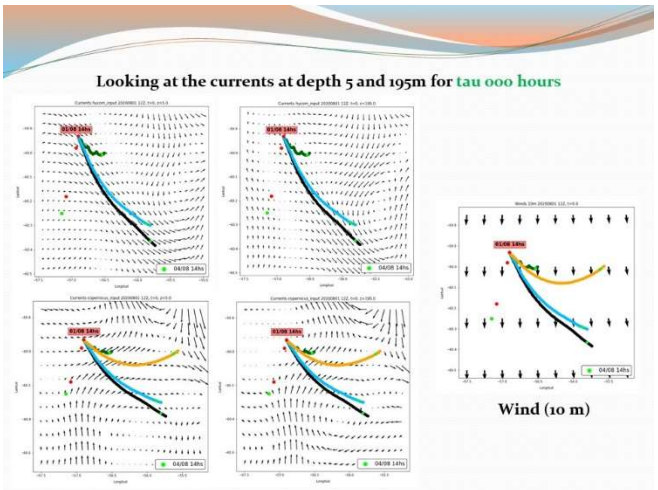


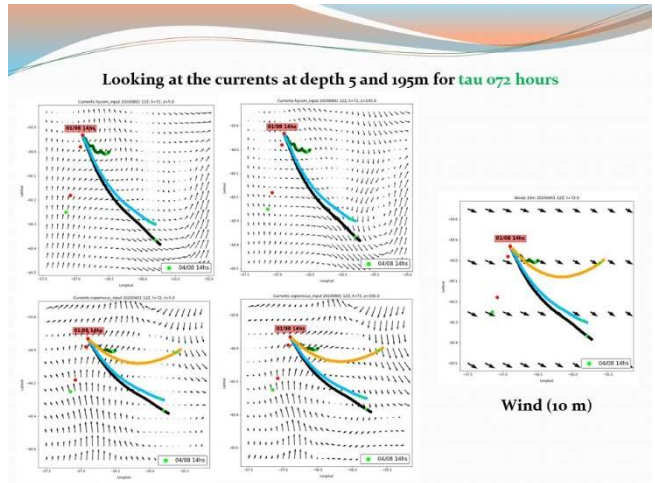


Appendix G: Implementing Ice Modelling in Our Daily Production

So, for the last case of A-68-c, we have an iceberg with a size of 9 by 5 nautical miles. You can observe here that all results have a direction towards the North. In this case, when I use the HYCOM model you can observe with the black dots the direction is close to the observer positions.

I also did an analysis of the currents for case 1. Here, we are looking at the currents at a depth of



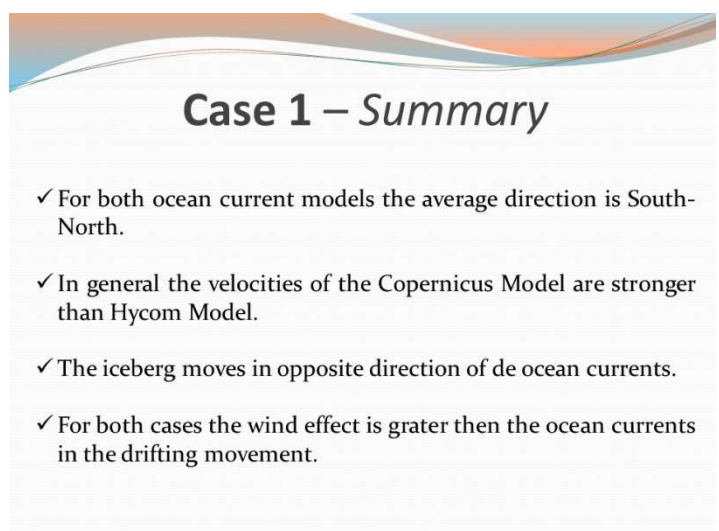


5 and 195 meters for time zero. On the top, you can see the results of the HYCOM model and on the bottom, you can see the results for the Copernicus model. And in both cases, you can observe that the direction of the current is opposite to the observed.

When we observe the wind at 10 meters, you can see that the direction of the wind is agrees with the direction of the movement for the observed positions. So here it is important to note that the effect of the wind is more important than the current.

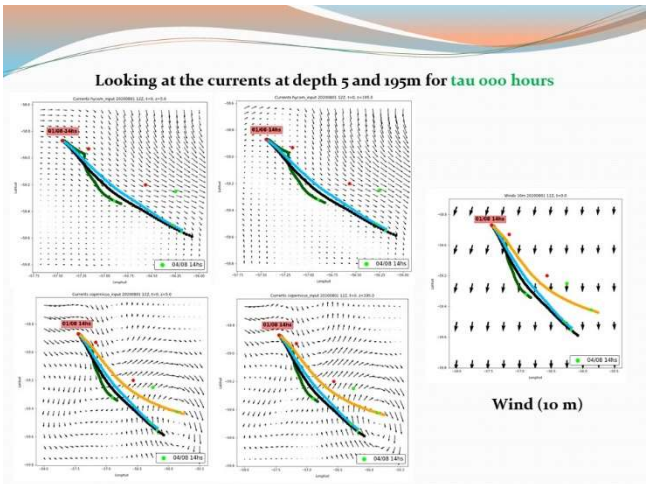
So, now, we are looking at the same depth but 72 hours later. You can observe that the direction of the current for both models is to the north, opposite to the observed positions. In this case, the direction of the wind changed for the exact last position.

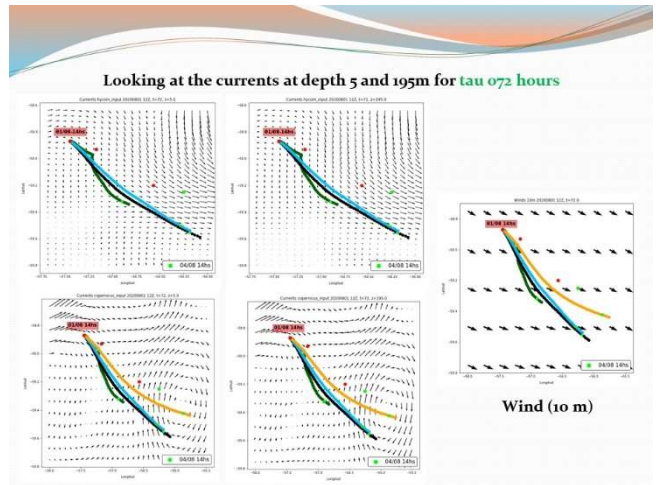
So, in summary for the case one, with both current models, the average direction is solved now. In general, the velocity of the Copernicus model is stronger than the HYCOM model. The iceberg moves in the opposite direction to the ocean currents. For both cases, the wind effect is greater than the ocean currents in the drifting movement.



So, for the case 2, I did the same analysis for the time series. Here, you can see that the observed positions agree with the direction of the currents. In particular, if you observe the image at the

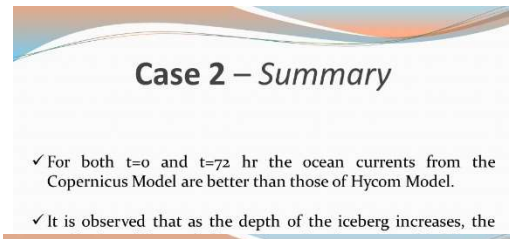
Appendix G: Implementing Ice Modelling in Our Daily Production



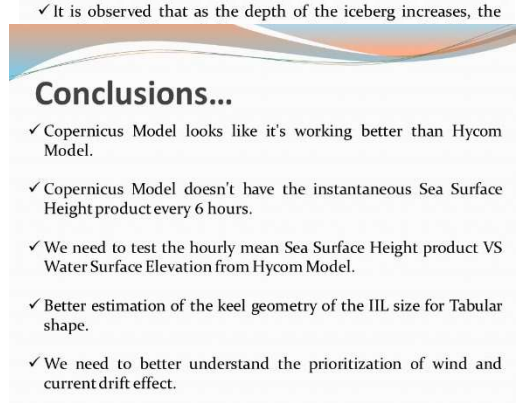


bottom left, you can see that the small change of observed position agrees with the change of the Copernicus current. And if you look at the wind, you can observe that, in this case, the effect of the current is greater than the effect of the wind.

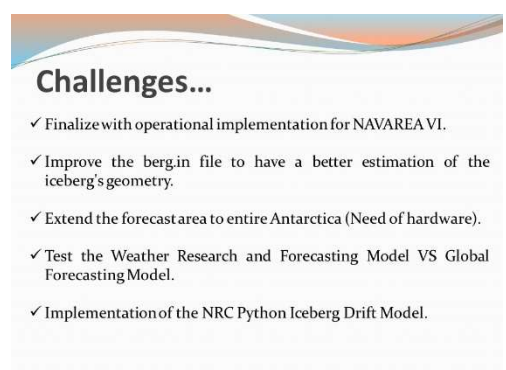
We have the same results for 72 hours later. But in this case, the direction of the wind agrees with the observed positions



So, for both times, the ocean currents from the Copernicus model are better than those of the HYCOM model. It is observed that, as the depth of the iceberg increases, the prediction of the model improves using the Copernicus model.



Finally, we have the conclusions. Copernicus model looks like it's working better than the HYCOM model. The Copernicus model doesn't have the instantaneous Sea Surface Height product every six hours so we need to test the hourly mean Sea Surface Height versus the Water Surface Elevation product from the HYCOM model. Also, we need a better estimation of the keel geometry of the iceberg size or tabular shape. And we need to better understand the prioritization of the wind and current effect.



So, the challenges we find with the operational implementation for NAVAREA-6, improve the berg-in file to have a better estimate of the iceberg geometry. Extend the forecast area to the entire Antarctic area. Test the Weather Research and Forecasting Model versus the Global Forecasting Model. customer. And finally, the implementation of the NRC Python Iceberg Drift Model.

Well, thank you. Any questions?

Appendix G: Implementing Ice Modelling in Our Daily Production

Jørgen Buus-Hinkler (DMI)

I just wondered whether you have observed when the wind is more dominating. Is there a threshold at which the wind speed starts to dominate the ocean currents?

Gaston Lopez

Yes. For the case one in this situation. We have a wind around 10 meters per second against the current average of 0.079 meters per second for the currents.

Marc DeVos (SAWS)

Thanks very much to both presenters It's very interesting. I've had similar considerations dealing with particle-based approaches in the marginal ice zone in the Antarctic in trying to quantify model error and trying to decide between different forcing and boundary conditions. I was wondering, to both guests Gastón and Mike, whether, in the iceberg model, there's any sort of non-dimensional skill score that you assigned to particular configurations. I find this helps to understand when models are performing well versus poorly because, obviously, it's easy to achieve a low distance error and divergence from the observed track when the azimuth doesn't drift very far. So, a two kilometer error is good when the iceberg only drifted a handful of kilometers, but a 10 kilometer error might be impressive if the iceberg traveled 60 kilometers. I was just wondering about that issue, whether you use it.

Mike Hicks

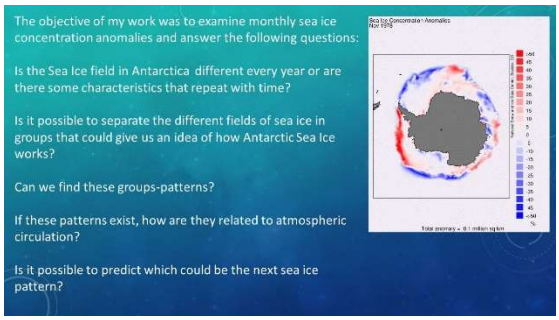
I can address that and say that we do not presently use that. But I think it is an excellent point and observation. We've had some discussions about that and I think one of the discussions that's come out of our task team has been that the metrics, and whether or not a drift model is acceptable, really depends on who's using the product. In our iceberg limit case, it's a transatlantic Mariner who doesn't want to see ice, doesn't expect to see ice at any point. And so we can afford to be a little bit more liberal and perhaps deal with a little more error. If we're looking at making a decision about moving an oil facility, the oil facility needs to have a much more precise model result. So we have to look at those concerns as well. But I think it's a great idea to incorporate some sort of a skill assessment like that.

CHAT LINE

Greg Stuart

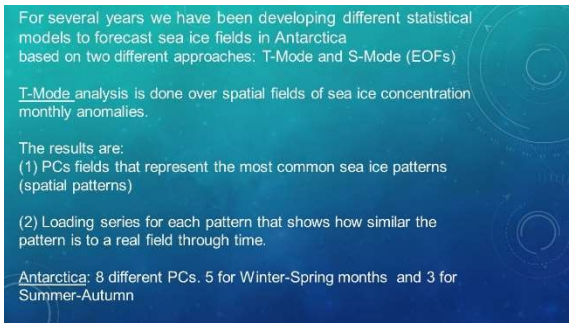
Marc DeVos - I'm keen to share Antarctic experiences between Australia and South Africa

Sandra Barreira (SHNA) - Antarctic Sea Ice Forecast. Development and Validation

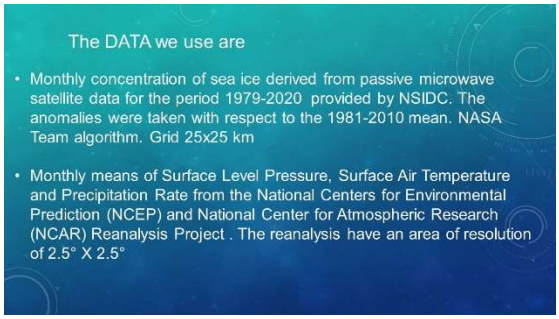


I will introduce our sea ice forecast for Antarctica. In the right side of the slide, you can see a movie of different sea ice anomalies for Antarctica. Blue lines are negative anomalies and red lines are positive anomalies. When I began to work in 2001 with sea ice, I asked myself several questions to answer. I saw these pictures and I asked if there were some characteristics in the Antarctic ice that repeat with time and if it was possible to separate these

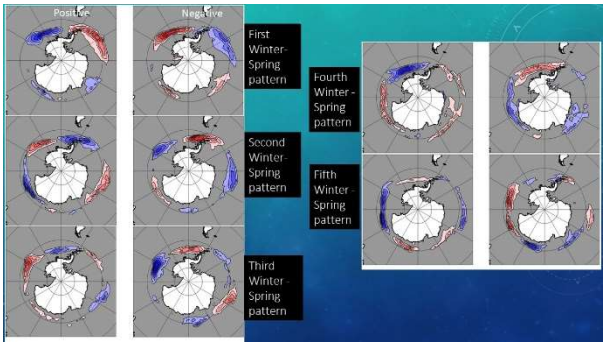
characteristics. If we can separate these characteristics of patterns of growth, it would be possible to forecast these patterns.



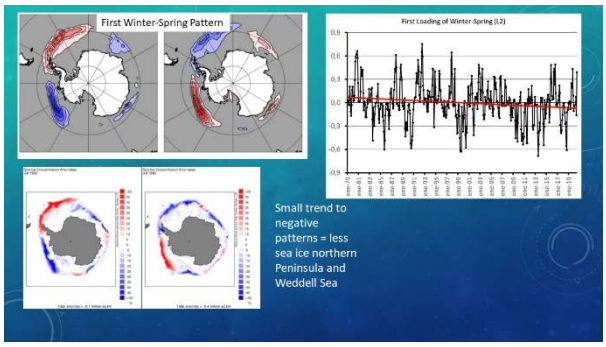
For several years, we have been developing a different statistical model for Antarctica. We use different approaches; the T-mode approach that is done over spatial fields of sea ice concentration, monthly anomalies; and the S mode anomaly that is more similar to the one that people are most used. That approach is done on temporal series but we mostly work on fields of sea ice. Our results have principal components (PCs) that represent the most common sea ice pattern in Antarctica and the loading series when this in principle component happens in Antarctica. For Antarctica, we have eight different PCs that were obtained when the congruent coefficient has a maximum. Five correspond to winter and spring and three for summer and autumn.



The data we use for our model are the monthly sea ice concentration from the National Snow and Ice Data Center of the United States. We have a long archive of data from 1979 to 2020. We are using the mean of 1981-2010 that is the climatology commonly in use now. We use the NASA team algorithm, so the grid is 25 by 25 kilometers. We also use some surface-level pressure and temperature and precipitation rate from NCEP.



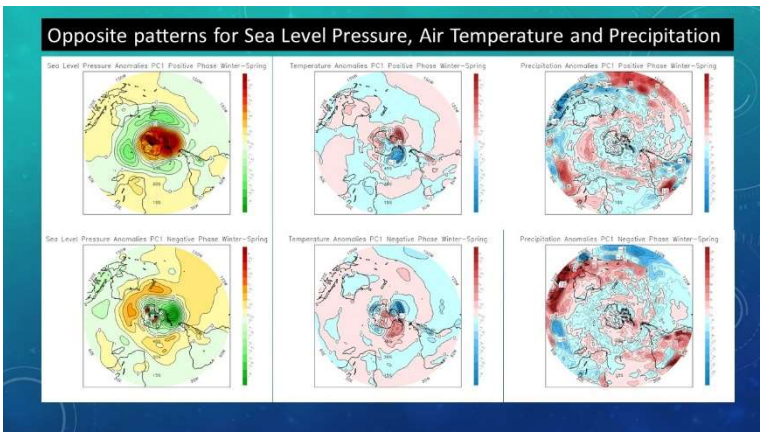
These are the T-mode patterns. You can see the five patterns from winter and spring. A principal component has a positive and a negative phase of each pattern. On the left side of each a pair of figures, you can see the positive phase and in the right side you can see the negative phase of the pattern. All these patterns are quite different from one another.

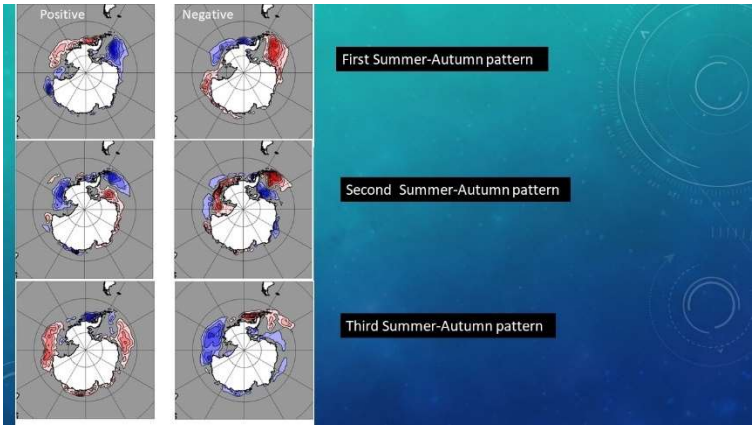


These are these are not principal components. These are patterns of those months with higher values of loading. Here, you have an example for the first pattern. In the upper part of the slide, you have the positive and the negative. I rotated the image so they have the same orientation as the maps from the National Snow and Ice Data Center in the lower portion. You can see that our patterns are quite similar to the real ones. The one on the left corresponds to July 1992 and the one on the right side is from July 1990. And you can see our patterns are quite similar to the real ones. On the right side of the slide is the loading, a series of data. The pattern at the top left is a composite of real fields of sea ice. We compose all the values over 0.3 or below -0.3.

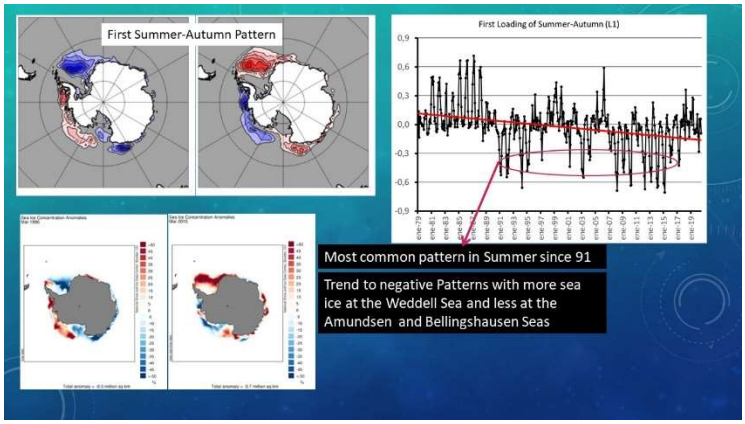
Appendix G: Implementing Ice Modelling in Our Daily Production

This slide shows sea level pressure in the first column, air temperature in the center, and precipitation rate on the right side. The upper figures correspond to the positive phase and the lower figures to the negative phase of the first principal component for winter. As you can see, these are also opposite in both phases. In the center figure, you can see that there is a heating in the equatorial region that corresponds to the structure of an el Nino event. And in the figure of sea level pressure, you can see a wave-three pattern. In the precipitation rate, you can see more precipitation in the equatorial region and in mid latitudes which happens in South America in an el Nino event. In spite of this, there is some correspondence with this and El Nino and SAM. Those indices have been calculated over S-mode and not T-mode like us but the result is quite similar.



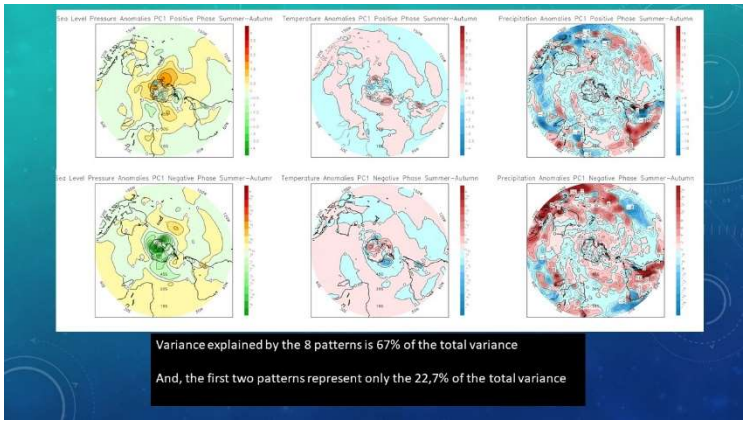


I will introduce you to the three patterns from summer and autumn. As you can see, they are quite the same with a positive and negative for each pattern. These have been built with a composite of the month with higher or lower loading values so they can be compared directly with sea ice anomalies.

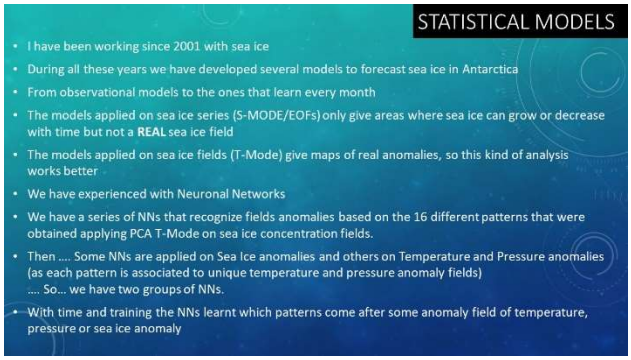


Appendix G: Implementing Ice Modelling in Our Daily Production

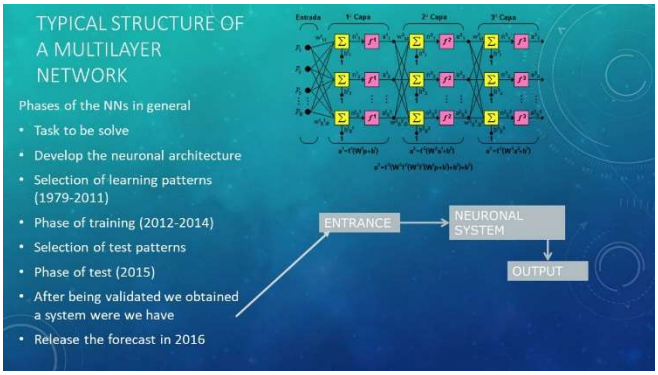
Here, in the lower part of the figure is the real data from the National Snow and Ice Data Center. One corresponds to March 1986 and the other to March 2015. As you can see, our patterns are quite similar to the real ones. And, on the right, you can see the loading and this pattern, in particular, is one of the only ones that has a trend in the occurrence of the pattern. It has been the most common pattern since 1991 to 2017.The last two summers have been quite different patterns. In the Antarctic, we don't have great trends in the patterns like in the Arctic.

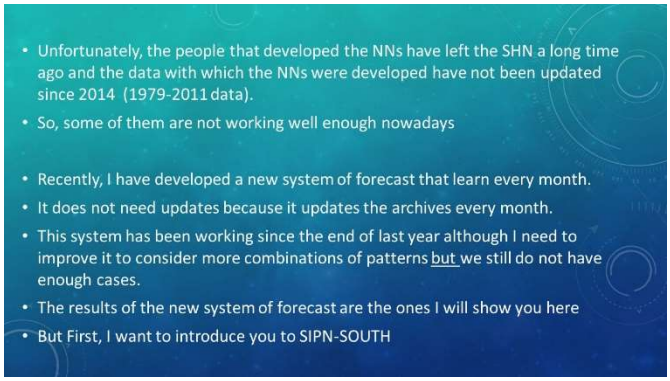


Here you can see again the sea level pressure, temperature, and precipitation rate for this first pattern. In summer, the pattern is less strong in temperature, pressure, sea ice and every variable but, even so, you can see an opposite pattern. There is a negative temperature anomaly in the Amundsen-Bellingshausen and a positive in the Weddell. They have, including the precipitation rate, a quite opposite pattern. What I want to say that is that we use eight patterns or 16 models. We only explain 67% of the total variance. Some people have asked me why we don't use only two patterns. If you use only two, you only explain 22% of the variance. With eight or 16 models, you don't cover all the cases in Antarctic sea ice. We have now more than 500 months and 13% of these months can be classified under any of these patterns.

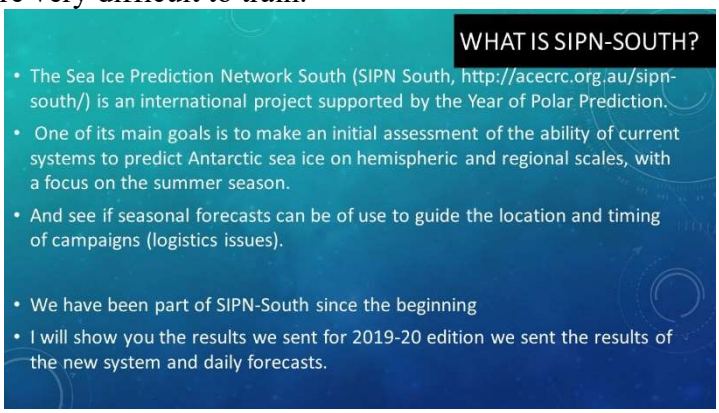


Well, I would just like to show you a bit about our models, and a little about the evolution of our models. We have been developing several models. At the beginning, they were only observational models. And nowadays we have the models that learn every month. So, it was a great evolution over years. And as I told you, we developed both kinds of analysis – S-mode and T- mode. The models applied in S-mode only give us the areas in Antarctica that can grow or decrease. So, which area will have more sea ice or less sea ice? So those kinds of models were not so useful. And so, we were more focused on T-mode analysis because they gave us a



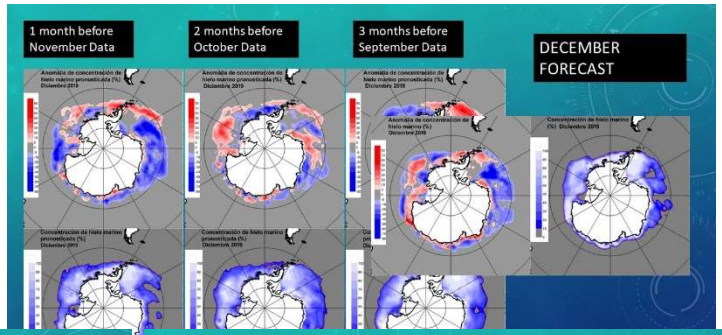


map. There was a good time when we had neural networks working in this. There were two groups of neural networks. Ones that were applied to sea ice and ones that were applied to temperature and pressure. The one applied to sea ice were able to give us 16 patterns. They were not forced to recognize these patterns, but they gave us the 16 patterns automatically. So that gave me some peace with the 16 models that we chose to begin with. The other models, the ones applied to temperature and pressure, were a kind of a neural network similar to facial recognition models. They recognize the centers of pressure and temperature and try to associate those centers in the real data with our models. With these models, we have tons and tons of maps. The problem with this is that a movement of one degree of the center of the pressure or temperature could give you another kind of pattern. These networks are very difficult to train.

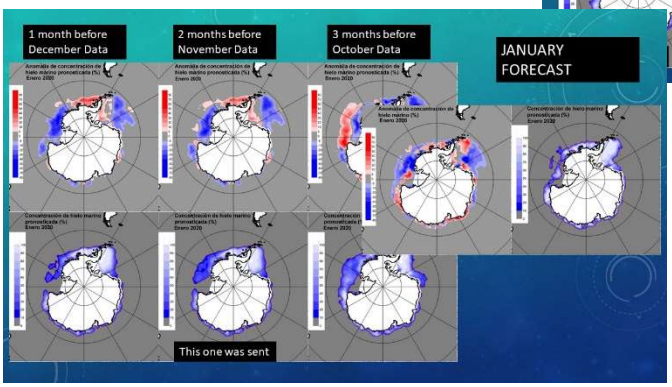


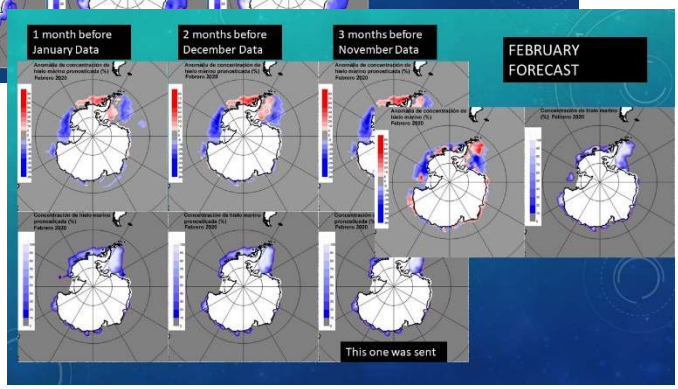
This is a typical structure of a neural network. I did not build it. I gave them the problem and others developed this kind of neural network. We have 20 for sea ice and 14 for surface and temperature. They were working with me for a while but unfortunately are not working anymore. They selected a period for learning in 1979-2011, then they trained in the network during 2012-2014. We selected several patterns to test. The network was tested during 2015 and we released it in 2016. Unfortunately, the people that developed the neural network have left SHNA.

We have participated in SIPN-South for a couple of years. It is the sea ice prediction network for the South that is the same as in the Arctic to test the capability of the models to predict sea ice concentrations in Antarctica. This is not for navigation. It's more for logistical issues. I will show you the results of 2019-2020.



These are the forecasts we have sent to for December. The one I sent was the first column. These are the forecasts from three months before in September, for two months before, and for one month before in November. The first two, September and October, were done with neuron network - the one applying





temperature and pressure. Unfortunately, we don't have the one from sea ice that works better. And the one from November is from the new system that I developed. Compared to the real data from December, our forecast was not so bad. I have to say that December is a very, very hard month to forecast. December and May are the two worst months to forecast. If you have a good forecast for those months, you have a good forecast for the whole winter or summer.

The one we sent for January was the one in the middle and the one in the right side is a from the neural network. We have almost the same forecast one month or two months before and then we are the next. The forecast in the center is not so bad.

All of these were from our new model. Our forecast for February was quite similar to the real data.

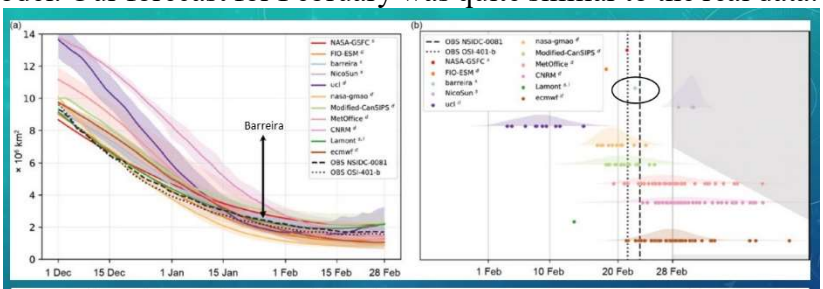


Fig. SB6.4. (a) Total (circumpolar) Antarctic SIA (× 10⁶ km²) of the 11 forecasts for each day of Dec–Feb 2019/20. The superscripts in the legend indicate whether the submission is based on a statistical or a dynamical approach. The black dashed lines are two observational references up to 21 Dec 2019. (b) Timing of the 2020 annual minimum Antarctic SIA from forecasts (colors) and two observational references (Maslanik and Stroeve 1999; Tonboe et al. 2017). To filter out the effects of synoptic variability, the minimum was determined from a quadratic fit of the Feb daily SIA time series. Superscripts in the legend indicate whether the submission is based on a statistical or a dynamical approach and, possibly, if monthly data has been interpolated to daily resolution.

There are several models participating in SIPN-South. There were six global coupled dynamic models. One was the ocean sea ice model and four were statistical models. Ours is the one in light blue. And there were several variables and they were analyzing the total Antarctic sea ice for the whole period. At this time, we sent a daily forecast. It was our first attempt to do that with the new model. So, it was great to see that our forecast was quite good.

The black dots are the observations from Envisat and the National Snow and Ice Data Center. Our model, the light blue looks quite good. The other variable on the right is the time of the minimum. The lines that have a lot of dots correspond to the coupled models because they do a lot of runs. Our model did quite well, which surprised me.

Appendix G: Implementing Ice Modelling in Our Daily Production

This is how our output looks like now. We have a very simple tables where you can see the forecast

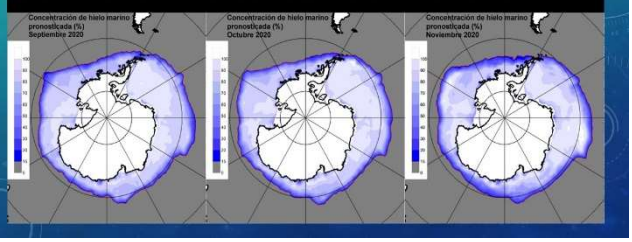
Table SB6.1. Information about contributions to the summer 2019/20 coordinated sea ice forecast experiment. Contributors provided, in order of descending priority: (1) the total Antarctic sea ice area (SIA) for each day of Dec–Feb 2019/20; (2) the SIA per 10° longitudinal band (rSIA) for each day of Dec–Feb 2019/20; and (3) the sea ice concentration (SIC) for each day of Dec–Feb 2019/20.

	Contributor name	Short name	Forecasting method	Number of forecasts	Initialization date	Diagnostics provided
1.	Nico Sun	NicoSun	Statistical model	3	30Nov	SIA + SIC
2.	NASA-GMAO	nasa-gmao	Coupled dynamical model	10	27 Nov	SIA + SIC
3.	FIO-ESM	FIO-ESM	Coupled dynamical model	1	15 Nov	SIA
4.	ECMWF	ecmwf	Coupled dynamical model	51	30 Nov	SIA + rSIA
5.	Lamont Sea Ice Group	Lamont	Statistical model	1	31 Oct	SIA + rSIA + SIC (monthly, interp. daily)
6.	NASA-GSFC	NASA-GSFC	Statistical model	1	30 Nov	SIA
7.	Modified_ CanSIPS	Modified_CanSIPS	Coupled dynamical model	20	30 Nov	SIA + rSIA
8.	Met Office	MetOffice	Coupled dynamical model	42	25 Nov	SIA + rSIA + SIC
9.	CNRM	CNRM	Coupled dynamical model	51	30 Nov	SIA + rSIA + SIC
10.	UCLouvain	ucl	Ocean–Sea Ice dynamical model	10	1 Jul	SIA + rSIA + SIC
11.	Sandra Barreira	barreira	Statistical model	1	30 Nov	SIA + SIC

Sea Ice Prediction Network-South: Coordinating seasonal predictions of sea ice for the Southern Ocean—J. L. LIESER, F. MASSONNET, W. HOBBS, J. FYFE, C. M. BITZ, AND P. REID //Scambos, T. and S. Stammerjohn, Eds., 2020: Antarctica and the Southern Ocean [in "State of the Climate in 2019"]. *Bull. Amer. Meteor. Soc.*, **101** (8), S287–S320, https://doi.org/10.1175/BAMS-D-20-0090.1.

Our forecast gives values like the following and we compose the patterns accordingly to their probability of occurrence.

	L1mas	L1men	L2mas	L2men	L3mas	L3men	L4mas	L4men	L5mas	L5men	L6mas	L6men	L7mas	L7men	L8mas	L8men	NC
sep	0.0	0.0	33.3	0.0	0.0	66.7	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
oct	0.0	0.0	100.0	0.0	0.0	33.3	66.7	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	33.3	0.0
nov	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	66.7	0.0	0.0	0.0	0.0	33.3	33.3



for the next month and the probability of each pattern. These are our forecasts for the next month. I need to still work in this model because there are times when combinations of patterns that conflict. I have to work more in those cases of combination. But I don't have a lot of data to train the model.

The results of the SIPN-South forecast are encouraging but there is still a lot of work to do with the model. We need to consider a lot more combinations of patterns.

Conclusions

We are very satisfied with the results of the new version of the statistical sea ice model both the monthly and daily forecast. Even the 3-month monthly.

Anyway, we still need to work on the programs to include more cases with combination of patterns.

Russ White

Okay, thank you very much, Sandra. That was a fascinating presentation. We are going to have to move along now. We've had three presentations about some model development. We're now moving into the panel discussion about the application of model outputs to operations, and really, the transfer into products and services that can lead to a reduction in risk for those working in the marine environment.

Panel Discussion

Introduction

This panel discussion focused on the use and application of sea ice and iceberg models and model outputs in operations to enhance products and services in support of maritime safety.

Moderator:

- Dean Flett

Panelists:

- Mike Hicks (IIP)
- Sandra Barreira (SHNA)
- Marc DeVos (SAWS)
- Phil Reid (BOM)
- Nick Hughes (MetNorway)
- Kevin Berberich (NIC)

Appendix G: Implementing Ice Modelling in Our Daily Production

Key Messages

- Some ice services (e.g. USNIC) use sea ice models to support daily production. Other services (e.g. Norway) use a variety of models to support various operations. Still others (e.g. South Africa and Australia) are just beginning to look at how models can be used operationally.
- Environmental input to models is crucial to accuracy but often highly suspect. Some necessary model parameters are practically unobtainable (e.g. iceberg underwater shape). Ice model output is still useful but must be considered in light of these deficiencies.
- Ice services generally have a very small number of scientific staff able to develop models. Partnerships among ice services and with other scientific institutions are critical to success.
- Ice modelling community in the Antarctic is not as well connected as that in the North. Representatives from all of the Southern Hemisphere ice services indicated a desire to work more closely and collaboratively. Connecting with the IICWG Data Assimilation and Sea Ice Modelling group might be a way forward.
- Validation and verification of model output and ice information products is essential but difficult. Close ties between ice services and their clients to obtain both in situ observations and feedback on products is invaluable.
- Ultimately, the purpose of ice models is to produce forecasts of future ice conditions that can be used for decision making. At present, model output is, at best, only suited to use by expert ice analysts. Considerable work is needed to transform model output into risk assessment or hazard warning tools directly applicable to mariners.

Session Transcript

Dean Flett (CIS)

The title of our panel session is the use and application of sea ice and iceberg models and model outputs in operations to enhance products and services and maritime safety. A long title but that was partially intentional to try to focus the discussions for this portion of the session today. You can refer to the background paper and the bios for the individuals in our illustrious panel for information. But I would like to highlight that basically, rather than getting into discussion about models themselves and any details, and we've had some description of that through Sandra's presentation for Argentina, it's more on the application and use of models and model outputs in operational centers.

So, the approach that I've taken here is that we're going to give the panelists two open rounds to make some comments. The first is to essentially give us a brief statement describing the status of applications of models and modeling outputs in their organizations. Again, not focused on the models too much, but on how do they use the models and model information. That will be followed by a second round where there is a number of questions, which you can refer to in the background paper, that have been posed to the panelists to try to stimulate their thoughts after the description of some of the challenges, barriers, and issues in terms of the use of models and model output. So, we'll do a second round of that and, time permitting, we'll accept questions.

Appendix G: Implementing Ice Modelling in Our Daily Production

Mike Hicks (IIP)

Hello again, everybody. The last few slides in my presentation lead into this discussion, as mentioned. So how is the International Ice Patrol using modeling for our daily operational products? I just like to say that the Ice Patrol and the Canadian Ice Service are both using the same two models. One is the NAIS model that you heard about from Gastón's presentation earlier. We also use what we call the IIP model. The IIP model has been around for many years - since the 1980s, actually. Both of those models are physics-based, dynamic models, where we start with an iceberg position, apply air-drag, water-drag, and Coriolis force along with, for the NAIS model, wave forcing, and project where the iceberg is going to drift in response to those environmental forces. We run both models several times a day, both to predict where the iceberg is going and also to estimate the deterioration of an iceberg. Operationally speaking, if an iceberg is "melted" greater than 150% by the model, we have the authority to remove it from the database. In certain cases, we'll talk to the Ice Patrol commander to make a decision to perhaps leave it on if we have a flight going up in a day or so. Maybe we'll leave it on to be conservative. We take that approach for icebergs that are very close to the to the iceberg limit. But as I mentioned, the model is run several times a day. Our iceberg analysts, our staff, draw the iceberg limit based on the model results and that becomes our product. I showed that example here today. The IIP model, as I mentioned, is old. The NAIS model has several advantages, which is why we're moving towards that. I think this season coming up we are going to rely more on the NAIS model versus the IPP model. The IIP model does have its advantages, for example, in the Flemish Pass, where we have a lot of good information on ocean currents, it does quite well. And also, when we have the opportunity to ingest in situ observations from buoy drift, the IIP model does pretty well. And so that's all I want to say about that work. But I will add we're looking at different ways. As I mentioned in the last slide, I showed that actually provides iceberg locations per the model for tailored support. And so that's all I wanted to say for my opening statement, so thank you.

Sandra Barreira (SHNA)

Well, they are for research use only because this has been the first time we are working with a daily focus. And so, we will see how it works. Because daily is very hard to forecast in the digital model. But we'll see what happens. It's not easy because you ask for comments about the forecast and they say, "what am I to do with this?" I have been working for 20 years with sea ice and this last year has been the best with Alvaro in charge of the ice service. I have served in the military with bosses that didn't like to see the model output. Alvaro has been a really good for the people that do the models.

Marc DeVos (SAWS)

I guess I'll start off by saying that South Africa doesn't run any dynamical sea ice models and we're also not an operational ice service. We're kind of in a pre-operational R&D phase waiting for some institutional issues to be sorted out before we make that step. As far as modeling goes, we are in the testing phase of a particle-based sea ice edge model, which basically will satisfy the basic requirements of a SOLAS sea ice edge information product and go slightly beyond that. There are various reasons related to the actual science and the accuracy of products and available information for our METAREA-7 which made us start with that. But there's a practical reason as well. For an institution which has very little institutional knowledge of sea ice, this kind of automatic and modeled approach provides a good first guess field for less experienced analysts or forecasters going forward. And so, we envisage that if we can get that spun up within a region, with an

enhanced level of accuracy, that we can spin up analysts on the desk faster. As far as dynamical sea ice modeling goes, we are involved in a community effort, but only from the perspective of trying to improve the representation of sea ice in dynamical models. So we go down to the Antarctic, we kept to pancake flows, we analyze in sea ice, mechanics, thermodynamics, and all kinds of things like that, both to improve the rheological representation of sea ice in the models, but also to try and improve or close the gap on remote sensing artifacts which we see frequently in our area of responsibility.

Phil Reid (BOM)

As with Mark, the Bureau is quite a fledgling service. We are not a dedicated ice service agency. So, for me and for us, this is very much a learning process. We provide forecast model guidance, but not sea ice, mostly in support of our national Antarctic operations. We provide real time shipping guidance of expert ice analysis. That's Jan Lieser's work. There is no NWP timescale sea ice product as yet. We run a coupled seasonal model but it's not really fit for purpose or for producing realistic contingency planning for sea ice. We have an automated daily sea ice edge analysis for METAREA-10, but it provides general guidance only for sea ice concentration that's less than 15%. Our future aim is to provide an integrated weather and sea ice service from our fully coupled, high resolution model based on the unified model partnership. That's basically it from Australia.

CHAT LINE

Jan Lieser
For those interested in SIPN-South: there's a brief paper available in the Antarctica and the Southern Ocean chapter of BAMS State of the Climate in 2019 report (pages S313-S315)...https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/
State of the Climate
An international, peer-reviewed publication released each summer, the State of the Climate is the authoritative annual summary of the global climate published as a supplement to the Bulletin of the American Met society www.ametsoc.org.

Nick Hughes (MetNorway)

The Norwegian Ice Service regularly makes use of the forecast model results. But we've yet to settle on a specific model for use in our daily operations. For example, we had a salvage operation for a wrecked crawler in Svalbard, trawler North Guider, this summer which used an experimental 2.5 kilometer resolution model called Barents-ROMS (https://thredds.met.no/thredds/fou-hi/barents25.html) to produce the ocean and ice forecast, coupled with open drift and open iceberg particle drift forecast. Both of these were developed in house at MetNorway. In conjunction with that operation, we also looked at some seasonal forecasting from the European Center for Medium Range Weather Forecasting during the planning stage. We've explored a variety of other models to support other users in our geographical area and had a mix of good and bad results. Regarding the iceberg modeling and forecasting, particularly Task Team 2, we look forward to investigating further the NAIS iceberg model and comparing that against the OpenDrift+OpenBerg (https://opendrift.github.io/autoapi/opendrift/models/openberg/index.html) forecasts.

Kevin Berberich (U.S. NIC)

Yes, I'm Kevin Berberich, Deputy Director at the US National Ice Center. To kick things off for my intro, I just want to mention supply and demand. We're all here for the mariners and they are

looking for where the ice is going, more predictive information, more forecasts, more integrated information. So, at the US National Center, we're talking about modeling, per se. We really want to home in on what value will the information bring to the Center. How will it be applied and for what purpose? So that construct is evaluated through an internal Transition and Initiatives program that we have at the Center. We pretty much flush out all that information and the relevant answers. We take a deep dive into the timeliness of the information and how we're going to apply it. Ultimately, we flush out the value of the information that we're going to bring in. I bring that up because retirement is big. We look at what we have and what we're going to have and what we can retire within the U.S. National Center. So, how does the U.S. make use of models today? We use it daily for producing our operational products. We do that in two ways. The first way is direct use - applying information directly onto our products. We cite or give credit to where the information came from. The second way is through indirect use. When I say that, it's really about bringing in that information, whether it's operational or experimental, and using it as a tool for guidance for an analyst to produce operational products.

Someone mentioned the future, the vision, is to provide integrated services. Yes, that's exactly it. That's the vision here as well, to flush out and integrate new information - packaged information out to the mariner. We're migrating toward that and, as you heard from Joe Sienkiewicz yesterday, we're working with him on the ocean side to help that integration piece and the weather piece.

Dean Flett

That was excellent. Kevin. I think you highlighted the crux of what we are dealing with. There's so much information and data out there. We came across that in the discussion yesterday in terms of, how do you deal with all these inputs and all the information and data that's available at your fingertips? And then where do you go to make that actually useful and applicable to your operational mandate.

We'll go to what I'll call the second round with the panelists. I asked them to take a take a look at the guiding questions or discussion topics. For those that have the session background paper, they are listed there. The first two questions are: what kind of barriers and challenges do the organizations have in the use of models? And how do you deal with those? The third question is about performing verification and/or validation and what approaches you might look at there? The fourth question is also related to the validation or verification. What are the issues there? Mike has already brought up, in the iceberg example in the earlier discussion, that it's hard to get good data on icebergs. What about on the sea ice side? And then a fifth question is a bigger one in terms of more and more models, alluding to the point that Kevin raised - they're getting better and they're getting higher resolution, accuracy, etc. And they can produce essentially their own products that may or may not be applicable directly by mariners. That's something I want to get into a discussion about at some point. I asked the folks on the panel to generally consider that and then maybe make some comments about any or all of those elements that they'd like to make some key points. I'll circle back around to Mike and ask him for his input.

Mike Hicks

First off, I have three challenges that I wanted to bring up. I mentioned these in my brief and I think it applies to all cases. That is the accuracy and the reliability of the input into the models. That includes for icebergs, for example, the size and shape of the iceberg, both above and below the waterline. Being able to model that is, I think, really important. And of course, environmental input winds, waves, and ocean currents - making those as accurate as possible is very important.

Appendix G: Implementing Ice Modelling in Our Daily Production

One of the ways that we've been able to overcome that with ocean currents is by incorporating in situ observations, for example, a drifting buoy. We've done that and we do it daily when we have drifting buoys available with our Ice Patrol model. We're able to do that because it's a very simplistic representation of the top 50 meters of the ocean. If we use the Canadian East Coast Ocean Model, there are actually 20 different layers down to 200 meters in depth. So, it's much more difficult to apply drifting buoys to all of those layers - not impossible - but it's more complex. So being able to incorporate in situ environmental data into the model, I think, is very important and a challenging area for further work. The second challenge that I'd like to bring up is iceberg deterioration. The task team that I've reported on really focused on iceberg drift, but we really need to consider and develop deterioration models. There's a whole bunch of other factors that go into an iceberg deterioration model. Being able to predict that, I think is important because deterioration determines whether an iceberg is present or not. But it also affects its drift as we move from a very large iceberg down to a growler. They drift very differently and being able to model that is important. The third challenge I want to bring up is that the International Ice Patrol has a very small staff, there are only 16 of us and we're not modelers. We rely on this partnership and the partnership within the North American Ice Service to do that hard modeling work. People like Hai Tran and Lynn Pogson at CIS and Dave Hubert and Julie Crout at the Naval Research Lab. Without having that partnership available to us through these meetings, we would have a very difficult time making any progress in changing our models. So, I want to just bring out those three kinds of barriers and challenges and what we're doing to overcome them. We can do more of the overcoming bit through continued collaboration.

Sandra Barreira

I want to say that, when we had the neuron network running, it took seven days to get a monthly forecast. The new model takes only three days to get the monthly forecast so we have really reduced the time required to get the monthly issue of the model. To obtain the daily forecast for 3 months out, takes 10 days of run time. We don't have powerful computers, so to have our daily forecast sooner, we must buy better computers. We have been doing the validation of the model for several years but only a couple of times and not in a continuous period of our daily forecast. We have a forecast now in October so we will begin with a better validation now after October.

Marc DeVos

I'm going to stay in my lane and stick to what I experienced personally and anecdotes from those that I've worked quite closely with. Case in point, Neil Young from Australia has been quite helpful in guiding our research expeditions. One of the biggest challenges we found in the use of models is reliability and accuracy, specifically because of a lack of regional tailoring. I'm a coastal oceanographer so when I was tasked with this kind of work, I went on to CMEMS and, fantastic, there was a seven-day sea ice forecast available. That's where we started. We learned very quickly that it is virtually unusable for any kind of operational decision making, not due to anything other than a lack of region specific tailoring as I was to learn from the sea ice scientists themselves, in terms of the way the sea ice is actually represented. So, I'd say that's quite a big challenge. It results in significant overestimation, underestimation, misplacement of features, and so on. If you're talking ice edge, even the case of ice avoidance for people that don't want to see any ice at all, because of the severity of the weather in the Southern Ocean and, if you have a transient storm system passing through, your estimate can be out by the order of 100 to 200 kilometers between model runs. That, I would say, is a big challenge in their use at tactical to three-day lead times. I think another thing that we're aware of is that data assimilation is key. But, because you're

essentially assimilating derived products versus the geophysics itself, data assimilation is limited by the accuracy of the, for example, passive microwave algorithms that are deriving sea ice concentration, which themselves are subject to a whole range of inaccuracies in our area. One of them being that the passive microwave algorithms really struggle to detect ice types other than well-defined pancake ice floes. Frazil and brash are poorly represented but they are there and present a hazard, nonetheless. And so, we really don't give the models a chance to assimilate good information in that sense. To what extent can we overcome the challenges? Well, we certainly haven't overcome them yet. There are two aspects we're working on specifically to try and improve the concentration algorithms looking at passive micro. And we really rely so heavily on passive micro just because of its spatial availability in our area of interest. We don't have the luxury of on-demand SAR. We have very little SAR at all. The other aspect is, as I said, that in-situ science is going on with an interdisciplinary working group of people looking at the actual thermodynamics and ice mechanics of the floes in the Southern Ocean, with the hope that we could collaborate with the people that run these far more sophisticated models to try and improve parameterizations for our region. Do we perform validation and verification? We do. But there are two issues with this. When we get the chance, we do. But we don't get the chance very often. So, at the moment, we do a lot of intensive work every other year when we get down to the sea ice specifically to do science work and when we have time to do things other than logistics. But that only happens every other year. And then, generally, for the time in between, we work up the data. But that's still quite infrequent if you're talking about evaluating operational ice models for daily use. The other issue is that I sense that, and I don't have nearly as much experience as most of the people in this forum, the Antarctic user community is more fragmented than the Arctic one. It's difficult to get regular and robust feedback and evaluation from users - quantitative and qualitative feedback in terms of what people are using and how the products are performing.

Phil Reid

Thanks again, Dean and thanks Marc. That was excellent. The fragmentation of some Antarctic work is noted. Yeah, it would be nice to work a little bit more collaboratively with other Antarctic partners. So, thanks for these topics they're excellent. Doing model development is certainly a barrier. Model physics in Antarctica is quite different relative to global model physics, mid-latitude model physics. Antarctic polar regions are the worst forecast in WP time scale globally. That's probably due to two reasons: some polar specific physics are not included in the model such as getting atmospheric boundary layers correct; and lack of data and data assimilation. We need to get the model physics correct. We need to get sea ice processes correct, particularly for operation-relevant components such as fast ice convection. We intend to go for a polar, fully coupled model, which is a bit of a misnomer really, because we talk about ocean, atmosphere, sea ice, and waves. But we don't necessarily talk about the other cryospheric components such as freshwater runoff which can influence, on NWP timescales, sea ice formation. Data assimilation and observations have already been mentioned. That's obviously a barrier. Resources: ice comes under the banner of competing priorities. Antarctica is probably about 1500 nautical miles away from us so it's not seen nationally as a huge priority, particularly when you have a lot of other competing areas of national interest. Expertise is a big challenge. We have now decided we're working through a plan to go down the route of fully coupled model development. But you look around and you can't get expertise off a tree. We need to grow locally some expertise through PhD development and strong collaboration. So how do we overcome some of these barriers? Some collaborative efforts?

CHAT LINE

Andrew Fleming - UKRI BAS

Re fragmentation of Antarctic work - given that SCAR have a remit to coordinate Antarctic science - are these modelling considerations on their agenda?

Richard Hall (RICHH)
Listening to the model computing demands, particularly in the southern hemisphere, should SCAR be looking into an ECMWF solution for Antarctica?

Petra Heil
ASPeCt (SCAR Expert group) encapsulates sea-ice modelling, but not necessarily carrying emphasis on short-term runs nor forecast simulations. It is one of major objectives of ASPeCt supported topics.

Andrew Fleming - UKRI BAS
Thanks Petra Heil - useful reminder. Just occurred to me that Antarctic is often pointed to as one of the best areas for cooperation - not perfect, but there are structures.

If you want me to touch on verification and validation on a broad regional scale. We will be building model verification against its own analysis on an ongoing timescale. There will be another ongoing component, but just as Marc said earlier, research vessels are few and far between. So, we'll use those to look at finer scale processes, such as snow on top of sea ice, which can be a particular problem in the Antarctic. And convergence and divergence and sea ice thickness. etcetera. So again, validation becomes an ad hoc component of the model process.

CHAT LINE

Greg Stuart
Do we have a clear understanding of which type of observations would provide the biggest increase in forecast skill of the ice models?
Phillip Reid
This is a big one and the topic of current discussion with the DA team and R2O. Can discuss later if you like

Marc DeVos
Wr.t. the most important variables to improve: one for us is ice type. In our AOI, there are large fields of brash, frazil and grease ice which go completely unnoticed by common algorithms (and models will suffer where this goes unassimilated). We are keeping our eye on the Uni Bremen ice type algorithm and one of our partners is trying to evaluate in-situ

Nick Hughes (MET Norway)
We have some people here at University of Tromsø and at Norwegian Computing Centre looking at algorithms for thin ice, both from SAR and optical.

Sean Helfrich
Thank you, Marc. Your need for better characterization of the thinner ice types is great to know.

Nick Hughes

I'd like to echo Marc and Phil. One of the biggest barriers for us in using models is a lack of resources to do the sort of data visualizations and data extractions that can produce products that mariners in our areas can understand and in the kind of format that they have said they require. We typically get a lot of model data in NetCDF format and it takes time either for the model

developer, who may not be familiar with the types of output the ice service requires, or for the ice service itself to convert those files into meaningful maps or graphics. I would also like to repeat what Marc said. Challenges include having to assess the suitability of the model results for our purposes, both in terms of things like the realism of the model parameterizations used in replicating physical phenomena, and for the input data sets which are assimilated into these models and used to drive them. We understand there's different uses like long range, seasonal and climate forecasts versus the tactical sorts of short-term ones. And they will provide some benefits, but it depends on which user is the target here, whether it's the mariner or someone else. We know from a modeling perspective, that there's challenges with initializing the short-term models using high resolution data. Yet for things like long term seasonal forecasts, the low-resolution data is not so much of an issue. We also need to make sure that we understand the errors and uncertainties in these models before we can properly use them in an operational way. How have we been able to overcome some of these challenges? We have a lot of good collaborations with the model developers in addressing things like model parameterizations and assessing the types of input data that are being assimilated. We still have a long way, I think, to go towards developing the types of model that ice services need for supporting our end users. Where we see there's a lot more work to do is with the automatic products which are used to drive these models. This severely affects inaccuracies and those severely affect the usability of many forecasts produced. So, although the model is producing realistic drift patterns, it starts off from a wrong place and doesn't get any better. The errors just continue multiplying. We do try to work towards doing some more validation and verification. We're strapped for resources which makes it difficult. However, we know lots of model developers, particularly at MetNorway, that are well aware of the need for these good validation routines, and they routinely compare their results against observations either from the in-situ or from derived products. They are also working on developing metrics. I think things like the integrated ice edge error, and variations on that, which can be used to assess the model results. At the moment, our assessments tend to be a bit more qualitative such as comparing the forecast maps against the ice charts. However, we are trying to go to more quantitative work. Looking into things like the Ice Watch shipboard observation program and trying to maximize the number of eyes on the ground as it were in the places in the areas that we're trying to support - like the Arctic.

Kevin Berberich

I will try not to duplicate other answers and stay centric to the challenges at the US National Ice Center. Staffing. The USNIC is staffed for operations. We don't have a very large science department. In fact, over the past year, it was one or two bodies. We lack the R&D arm as well - the science department, science and innovation, and new technology that comes up in operations. Lacking that bottom piece of the pyramid really makes it a challenge for bringing in new models and understanding what the models will do for us and the value that they bring. Another thing is model accuracy and utility. Understanding the biases and the uncertainties in the data. We struggle to understand how we're going to apply the information accurately. We don't want to put out information that isn't accurate. How do we overcome these challenges? It's been said – partnerships and collaborations are really core and central to the success of the US National Center, and, I'm guessing, all the centers online today. I mean, we really leverage the partnerships and the work that they do. Partnerships are more than just with operational ice communities. It's the R&D arms within our agencies, our international partners. Really just working to have those partnerships, those arrangements, those agreements in place, so we can leverage the information globally to do what we do. Also, within the USNIC, we recently made internal arrangements to have one analyst rotate into our science department for a three-month period. That provides the analyst experience

with the snow and ice sector of science, but the focus for that individual is also to help science - understanding science, new initiatives, R&D. We're on our second individual and it's been highly advantageous so we're going to keep up that effort. We continue to have very good feedback from that. You asked, do you perform any verification and validation work? The answer is yes. Nick mentioned comparison of products to forecasts. We do two things: informal and internal daily verification of the Navy GOFS model, the global ocean forecast system; and we compare the USNIC ice edge to the GOFS forecast at 48-hour 1% ice fraction line. That shows the model accuracy and provides understanding of the model bias. The second thing that we do is informal and internal verification of the USNIC 48-hour ice edge forecast line with the current ice edge line that we put out. That rotation position that I mentioned, the analyst going into the science department, actually does some of the verification work which has been very helpful.

CHAT LINE

Sean Helfrich
Can you discuss which output variables in your models that provide the most utility within your ice centers? Which output variables would provide the most use if it was improved?

Jürgen Holfort
Assessing model forecast - after finishing a polygon we try to go into the model output and output the statistics of the ice in the model. That's one possibility to more easily make the model output accessible to the analysts.

Russ White (co-chair)

Could we ask the panel to include in their responses the perspective of the role for the national ice services in translating model output into risk reduction products. There were some comments yesterday from Joe Sienkiewicz's presentation in terms of the amount of model output and how we make that step from model output to something that can actually drive decision making in ice infected waters? I think the NAIS product for icebergs is quite interesting because they actually provide a limit, which incorporates all the uncertainty within the modeling of the iceberg tracking. But what we give to the mariners is: Here's your limit. So, if we can have the panel sort of include that perspective in their response, I think that will reflect some of the discussion we're having in the chat.

CHAT LINE

Richard Hall (RICHH)
Good question about risk assessment, Russ – thanks

Mike Hicks

We've been doing the iceberg limit since 1913. We are basically taking the model information, our confidence in the observations and trying to convey that in a very simple way. I think our approach towards the isolated-few-many contours is directly a result of the International Ice Charting Working Group, but I think it's also a very simple way to communicate iceberg density. And that all links back to who the customer is. As I've mentioned before, the transatlantic mariner doesn't want to see ice at all, they want to get across the Atlantic Ocean as fast as possible and deliver their cargo and go back. If there's a ship operating in ice infested waters, even without sea ice, but a lot of icebergs, they want to know what the density is for icebergs. How likely is it going to be that they're going to site icebergs? Do they need to post an extra lookout on the bridge, for example? So being able to communicate that very simply, I think is very important. We did get some feedback during our recent experience last month with response to the isolated-few-many

depiction, and that was that they actually wanted more levels of iceberg density. They wanted six levels instead of three. And so there's that sort of approach of keeping it as simple as possible. And as I showed very briefly in my presentation on the application of model results, we picked off a few select icebergs knowing what the ship is doing. Knowing where the ship is going is very important to that selection. I noticed one of Richard's comments earlier in the chat about how we get information back and forth between the vessels. I think that is absolutely key to have a partnership between your client and the operational ice service to make this valuable. The client provides input and observations as to the accuracy of the model and the ice service can communicate what their level of uncertainty is with the model drift and actual model projections. I would like to make one other point that Marc hit on a bit in his intro and that is the use of models for satellite analysis. One of our biggest challenges is positively detecting and identifying an iceberg over a small vessel. If we have more accurate and reliable models, I think we can incorporate the actual model drift into our satellite iceberg identification process. The mariner would never see that but we would be much more confident in calling one object an iceberg versus a vessel.

CHAT LINE

Joe Sienkiewicz
Regarding some of the discussion, within NOAA at the working level we are trying to emphasize ice as a critical parameter at the modeling level.

Zagon, Tom (ECCC)
I've seen some mariners use iceberg density to navigate through bergy waters, though not sure if that was one of the intended uses.

Patrick Eriksson
Good points there from Mike! In a similar manner, a simplified and clear ice drift vector field from the FMI ice model is visualized on the icebreakers' awareness tool on top of satellite imagery. Only essential information is shown.

Nick Hughes

I guess assessing the level of risk really depends on the type of input data you've got driving those models. If those models are being initialized and then driven with data you wouldn't use for making a tactical navigation decision, then the forecast level of risk you're going to get is going to be very misleading - and probably quite dangerous. We've seen this particularly with some of the seasonal models and even with the short-term models.

Marc DeVos

I think it’s probably quite dangerous because people are going to have a different perspective at a fledgling service because the tendency is probably going to be an over-reliance on models, as opposed to mature services which have a healthy kind of skepticism. Tom Carrieres’ book actually has a chapter on this which some of the panelists contributed to and is some really nice work. I think they sketch some flow diagrams and some concepts about how this might be integrated into workflow. I think the best place at the moment, given what we know about model uncertainty, is in the hands of the expert analyst who can use it but modulate what ends up in the hands of the decision maker before it's released out into the wild. So, it's probably an intermediate step there. Less dangerous in the hands of somebody who knows how to trust it.

Appendix G: Implementing Ice Modelling in Our Daily Production

Kevin Berberich

Model uncertainty and the maturity of the information coming out is really where myself and other USNIC leadership struggle with right now. I almost say we're hesitant to apply the information to the products. A lot of the model information we do receive, whether it's operationally blessed or whether it's experimental, we use as a guidance tool on the operations floor. So, we continue to operate that way. We are starting to apply, not only ice drift vectors, but also weather information directly onto our tailored support products, like wind vectors or whatnot. So that provides the mariner information related to the winds, information related to the ice movement, and that provides them a little bit more information for decision support. We're going to continue doing that. But a very good conversation about risk reduction, though.

Dean Flett

I think we only have a couple of minutes left so if I can make a couple of comments. I imagine the Southern Ocean, ice interested bodies are already collaborating but it sounds like there's an opportunity for even more collaboration, particularly on model development and model verification and that sort of thing. Another thing, in terms of the collaboration between the modelers and the ice services, kind of points me to Task Team-10 on this concept of getting back more with the data simulation and modeling group. As many of you know, we had an intent to try to participate more in that, which was going to take place in October. It's been postponed until next year. They hope to meet in person in the first half of 2021. That may be a little ambitious. Nevertheless, my point is that I think we need to continue to try to connect with them more and make our issues known to them. And with that, I'm going to close it up.

Russ White

Okay. Thanks very much, Dean. And again, thanks to the panelists. I think that was an excellent discussion that really followed on well from the presentations.

CHAT LINE

Cathy Geiger
Dovetailing yesterday's conversation on e-learning with today's talks and, given that icebergs are a high priority maritime safety issue, would e-learning modules on the geophysics of icebergs be a good place to start some e-learning modules - especially in relation to the modeled physics. Just an idea possibly to discuss on Friday.

A.J. Reiss (USA - NOAA)
There is another aspect to our discussion... and that goes back to the economic value of what Joe called authoritative sources of data. We all have direct customers and must meet their needs, but there are also many other uses of our authoritative data that we'll never have the capacity to tailor and meet. Instead, weather, ice, and shipping industry support companies can figure out how to package and deliver... in other words, focusing on getting our high quality authoritative data into a server for industry to access is perhaps as or more important than figuring out exactly how to package our final products.

Appendix G1: Session 4 Background Paper

Appendix G: Implementing Ice Modelling in Our Daily Production

The session will open with three 20-minute presentations to:

- highlight the accomplishments of Task Team 2 (Iceberg Model Developments);
- demonstrate how the North American Ice Service (NAIS) iceberg model is being adapted for use in the Southern Ocean; and,
- introduce Argentina's progress in sea ice modelling.

Following the presentations, we have set aside 60 minutes for a panel discussion on "the use and application of sea ice and iceberg models and model outputs in operations to enhance products and services in support of maritime safety". Rather than getting into the details of various models, each of the panelists will give a brief statement describing the status of applications of modeling and model outputs in their respective organizations. This will be followed by a moderated discussion that, at a minimum, will delve into the processes and challenges of getting model data and information from the research and modeling centers to the operations desk and into products and services

Panel Discussion

Moderator: Dean Flett

Panelists

- Mike Hicks (IIP)
- Sandra Barreira (SHNA)
- Marc de Vos (SAWS)
- Phil Reid (BOM)
- Nick Hughes (MetNorway)
- Kevin Berberich (NIC)

Guiding Questions/Discussion Topics:

1. What are the barriers and challenges to your organization's use and application of models/model outputs?
2. To what extent have you been able to overcome these challenges? If so, how?
3. Do you perform any verification and/or validation of model outputs, either informal/ad-hoc or formal?
4. What are your challenges in performing Validation and Verification?
5. As models increase in resolution, accuracy, and precision, and become more readily available to users (i.e. web portals, "raw" data/product servers, etc.), how do you see that impacting the products and services that operational ice services provide?

Appendix G2: Session 4 Bios

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.

Gastón López Díaz

Gastón works at the Argentine Naval Hydrographic Service (SHN) and has a Degree in Physical Oceanography. His work is focused on the implementation and development of numerical models for Antarctica and Southwestern Atlantic Ocean. He is working on the operational implementation of the CIS Iceberg Drift and Deterioration Model, the WaveWatch III, and the Storm Wave Model.

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.

Phil Reid

Phil has worked for the Bureau of Meteorology for the last 20 years, and most specifically on various sea ice projects over the last 10. The Bureau has plans to develop and implement a regional fully-coupled (ocean, atmosphere and sea ice) NWP model over the next five years, and Phil is responsible for this project. Phil also contributes to the sea ice program of the Australian Antarctic Program Partnership (AAPP). He is based in Hobart, Tasmania.

Marc de Vos

Marc is a researcher in the Marine Unit of the South African Weather Service (SAWS). A physical oceanographer by training, Marc is involved with technical research and development of met-ocean tools and services related to coastal and maritime safety. His research areas include numerical ocean prediction and marine-weather risk analysis. Since 2017, he has been involved in scoping a sea ice information capability at the SAWS. Marc maintains an operational role within the National Sea Rescue Institute, the principal maritime SAR organisation in South Africa.

Appendix G: Implementing Ice Modelling in Our Daily Production

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.

Kevin Berberich

A meteorologist by training, Kevin is the Deputy Director of the U.S. National Ice Center and also serves as the Ice Service Branch Chief at the National Weather Service Ocean Prediction Center. He supported the transition of the Interactive Multisensor Snow and Ice Mapping System from NOAA's Satellite Analysis Branch to operations at the USNIC. Kevin has also worked on satellite product development at NOAA's Office of Systems Development including the transition into operations of systems to link satellite data with end users.

Sandra Barriera

Sandra has a PhD in atmospheric and oceanic sciences from the University of Buenos Aires. From 1982 to 2001 she worked on Numerical Modelling [Parametrization of physical processes - radiative transfers (ultra-violet, infrared, etc.), cloud formation schemes, microphysical processes within clouds that lead to the formation of precipitation, the deep convection responsible for tropical thunderstorms, land-surface schemes describing atmospheric-soil-vegetation interactions, photochemical processes, etc.] and Wave modelling first at the University of Buenos Aires and since 1988 at the Naval Hydrographic Service. Since 2001 she has been working on Sea Ice and Climate in the Arctic Ocean and Southern Oceans. She developed several statistical systems to forecast Sea ice concentration in Antarctica.