ARKTALAS HOAVVA PROJECT

DELIVERABLE 140: WEB-STORIES

Customer	ESA
Author	Lasse H. Pettersson
Distribution	Consortium and ESA
ESA Contract Number	4000127401/19/NL/LF
Document Reference	
SoW Deliverable Reference	Deliverable D-140 (WebStories)
Version/Revision	1.0
Date of issue	4. August 2023

Approved by (NERSC)	Johnny A. Johannessen NERSC Project Manager	
Approved by (ESA)	Craig Donlon ESA Technical Officer	Digitally signed by Craig James Donlon Date: 2023.10.22 08:17:37 +02'00'

Revision Change log

Issue	Date	Type	Change description
1.0	4. August 2023		

1 INTRODUCTION

The Arktalas Hoavva project website was established soon after the project Kick-off meeting in July 2019 and has been maintained since then. A screen dump of the front page is included in the Annex.

The web-site have the following content and structure:

- Project News stories; presenting the project results and progress.
- Results - in terms of publications and public data
    - The NERSC Arctic Data Portal – *still limited to project access*
- Project partners
- Calendar of project events and related activities
- Related links (to external activities and missions)
- Documents
    - Publications
    - Project deliverables
    - PPT material
    - Minutes of Meetings

2 THE ARKTALAS HOAVVA WEB-STORIES

The following Arktalas Hoavva news stories have been published and screen-dump of these are included in the Annex:

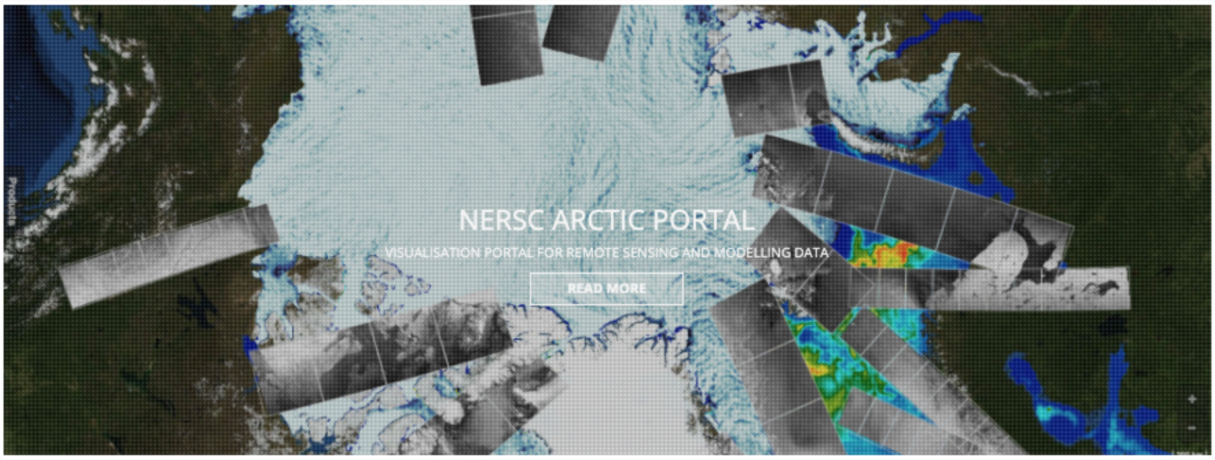
- The ARKTALAS HOAVVA project
- ARKTALAS Hoavva Final Scientific Workshop
- Mechanisms for extreme sea ice break-ups events in the Arctic
- Waves plays an increasing role in shaping the sea ice dynamics in a warmer Arctic Ocean
- Consecutive satellite images detects mesoscale ocean eddies in ice-covered waters
- An emerging apparent Arctic Amplification: A synthesis of paradigms and satellite observations
- Exploration of the linkages between sea ice and ocean tides in the Arctic Ocean
- Response of Total and Eddy Kinetic Energy to the Recent Spinup of the Beaufort Gyre
- Wind-wave attenuation under sea ice in the Arctic Ocean: a review of remote sensing capabilities.
- Observing the changes in the Arctic Ocean: current gaps and impact of the future satellite missions

3 ANNEX

3.1 Arktalas Hoavva front page

Arktalas

Project description | Results | Partners | Calendar | Related links | Documents



Observing the changes in the Arctic Ocean: current gaps and impact of the future satellite missions

Submitted by lasse on Tue, 10/11/2022 - 11:26

Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. In the paper Changes in the Arctic Ocean: Knowledge gaps and Impact of future satellite missions, to be submitted, the past and present satellite observation capacity to address these major scientific challenges (the Arctic Amplification, the impact of more persistent and larger area of open water on sea ice dynamics, the impact of extreme event storms on sea-ice formation pattern and structures, and the Arctic Ocean spin-up) have been analysed.

Read more

Wind-wave attenuation under sea ice in the Arctic Ocean: a review of remote sensing capabilities.

Submitted by lasse on Wed, 05/10/2023 - 14:58

ARKTALAS Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. Waves generated by winds over the ocean propagate into areas covered by sea ice where they can be strongly attenuated and can contribute to break-up of the sea ice and thus pushing the ice more easily around. This paper provides a review of the capabilities of using various types of satellite remote sensing data to assess the wind-wave attenuation under the sea ice is presented.

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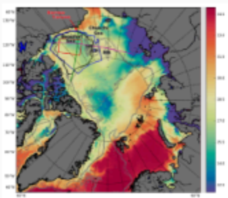
Response of Total and Eddy Kinetic Energy to the Recent Spinup of the Beaufort Gyre

Submitted by lasse on Wed, 05/10/2023 - 14:47



ARKTALAS Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. The Beaufort Gyre in the Arctic Ocean has spun up over the last couple of decades. In this study a high-resolution eddy resolving model has been used to study accumulations of fresh water in the gyre and its role in the ocean circulation in the Arctic Ocean.

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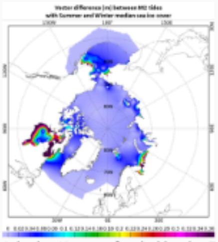
Exploration of the linkages between sea ice and ocean tides in the Arctic Ocean

Submitted by lasse on Tue, 10/11/2022 - 11:09



Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. Related to the Arctic Amplification topic, the study "Impact of sea ice friction on ocean tides in the Arctic Ocean, modelling insights at various time and space scales", to be submitted to Ocean Science, investigated the linkages between sea ice change and ocean tides in the Arctic Ocean, thanks to hydrodynamic simulations, CryoSat-2 satellite altimetry observations and in situ tide gauge measurements.

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An emerging apparent Arctic Amplification: A synthesis of paradigms and satellite observations

Submitted by lasse on Tue, 10/11/2022 - 10:36

ARKTALAS Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. The rapid changes in the Arctic environment and climate, manifested through the Arctic Amplifications have been addressed in a synthesis study exploring the capabilities of satellite observations integrated in reanalysis modelling.

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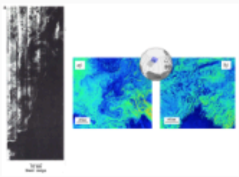
Consecutive satellite images detects mesoscale ocean eddies in ice-covered waters

Submitted by lasse on Mon, 08/29/2022 - 15:47



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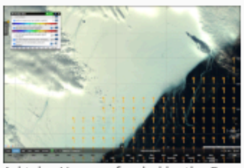
Waves plays an increasing role in shaping the sea ice dynamics in a warmer Arctic Ocean

Submitted by lasse on Mon, 08/29/2022 - 11:34



Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. In the study Modelling the Arctic wave-affected marginal ice zone, comparison with ICESat-2 observations accepted the journal Philosophical Transactions A, the challenges related to characterize the impact of more persistent and larger area of open water on sea ice dynamics in the Arctic Ocean are addressed. The radar altimeter on board the ICESat-2 satellite have been instrumental to quantify the impact on the sea ice of waves propagating into the marginal ice zone.

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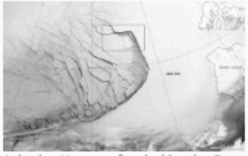
Mechanisms for extreme sea ice break-ups events in the Arctic

Submitted by lasse on Mon, 08/29/2022 - 10:44



Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. In the study Driving mechanisms of an extreme winter sea-ice breakup event in the Beaufort Seapublished in Geophysical Research Letter, the challenges related to understand, characterize and predict the impact of extreme event storms in sea-ice formation, by combined use of satellite sea ice observations and numerical sea ice modelling.

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ARKTALAS Hoavva Final Scientific Workshop

Submitted by lasse on Tue, 05/10/2022 - 17:26

The main goal of the final scientific workshop of the ARKTALAS Hoavva project was to assess the state of the art in use satellite measurements in synergy with in-situ data and modelling tools to characterize and quantify the processes driving changes in the Artic sea ice and Arctic Ocean.

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The ARKTALAS HOAVVA project

The Arktalas project aims to remove knowledge gaps and advance the insight and quantitative understanding of sea ice, ocean and atmosphere, interactive processes and their mutual feedback.

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3.2 The Arktalas Hoavva Web news stories

Arktalas   Project description   Results   Partners   Calendar   Related links   Documents

Home / The ARKTALAS HOAVVA project

The ARKTALAS HOAVVA project

View   Edit   Delete   Revisions

The Arktalas project aims to remove knowledge gaps and advance the insight and quantitative understanding of sea ice, ocean and atmosphere, interactive processes and their mutual feedback.

The project is funded by the **European Space Agency** under the Contract 4000127401/19/NL/LF.

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- The project kicked off on 9 July 2019 and will be executed over 24 months.

72 views

Arktalas   Project description   Results   Partners   Calendar   Related links   Documents

Home / ARKTALAS Hoavva Final Scientific Workshop

ARKTALAS Hoavva Final Scientific Workshop

Submitted by lasse on Tue, 05/10/2022 - 17:26

The main goal of the final scientific workshop of the ARKTALAS Hoavva project was to assess the state of the art in *use satellite measurements in synergy with in-situ data and modelling tools to characterize and quantify the processes driving changes in the Artic sea ice and Arctic Ocean.* This was in particular tailored to the following major interlinked and cross-disciplinary Arctic Scientific Challenges (ASC) addressed in the Arktalas Hoavva project:

- *ASC-1: Characterize Arctic Amplification and its impact*
- *ASC-2: Characterize the impact of more persistent and larger area of open water on sea ice dynamics*
- *ASC-3: Understand, characterize and predict the impact of extreme event storms in sea-ice formation*
- *ASC-4: Understand, characterize and predict the Arctic ocean spin-up.*

In so doing the status of the published and submitted scientific papers to international peer review journals (see list below) under this Arktalas Hoavva project were presented and assessed in respect to achievements and findings relevant to the four ASC. Moreover

Paper 1: Response of Total and Eddy Kinetic Energy to the recent spin up of the Beaufort Gyre *(Relevant ASC-4).*Published in *Journal of Oceanography* in 2019 by H. Regan, C. Lique, C. Talandier and G. Meneghello. https://doi.org/10.1175/JPO-D-19-0234.1

Paper 2: Observational evidences of eddy-sea ice interactions in the pack-ice and in the MIZ *(Relevance to ASC-2).* Published in *Geophysical Research Letter* in 2020 by A. Cassianides, Camille Lique, Anton Korosov. https://doi.org/10.1029/2020GL092066

Paper 3: Wind-wave attenuation under sea ice in the Arctic: a review of remote sensing capabilities (*Relevant to ASC-2).* Published in *Journal of Geophys. Res.-Ocean* by Fabrice Collard, Louis Marie, Frederic Nouguier, Marcel Kleinherenbrink, Frithjof Ehlers, and Fabrice Ardhuin. https://doi.org/10.1029/2022JC018654

Paper 4: Modelling the Arctic wave-affected marginal ice zone, comparison with ICESat-2 observations *(Relevant to ASC-2).* Published in *Philosophical Transactions A* by G. Boutin, T. Williams, C. Horvat and L. Brodeau. https://doi.org/10.1098/rsta.2021.0262

Paper 5: Driving mechanisms of an extreme winter sea-ice breakup event in the Beaufort Sea *(Relevance to ASC-3). Geophys. Res. Letter, 22. June 2022* by Jonathan W. Rheinlænder, Richard Davy, Einar Olason, Pierre Rampal, Clemens Spensberger, Timothy D. Williams, Anton Korosov, Thomas Spengler. https://doi.org/10.1029/2022GL099024

Paper 6: The Arctic amplification and its impact: A synthesis through satellite observations *(Relevance ASC-1) Remote Sens.* **2023**, *15*, 1354. by Esau, I.; Pettersson, L.H.; Cancet, M.; Chapron, B.; Chernokulsky, A.; Donlon, C.; Sizov, O.; Soromotin, A.; Johannesen, J.A. https://doi.org/10.3390/rs15051354

Paper 7: Impact of sea-ice friction on tidal modelling in the Arctic Ocean *(Relevance ASC-1)* To be submitted to tbd by M. Cancet et al., 2022.

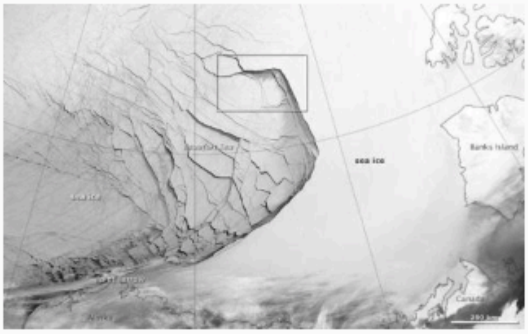
Paper 8: Changes in the Arctic Ocean: Knowledge gaps and Impact of future satellite missions Satellite missions for the Arctic Ocean *(Relevant to all ASCs).* Under review in *Remote Sensing* by S. Lucas, J.A. Johannessen, M. Cancet, L.H. Pettersson, I. Esau, J. Rheinlaender, F. Ardhuin, B. Chapron, A. Korosov, F. Collard, S. Herlédan, E. Olason, C. Donlon.

The ARKTALAS Hoavva final scientific workshop took place at UNIS in Longyearbyen.

The ARKTALAS final scientific workshop report is available here.

Mechanisms for extreme sea ice break-ups events in the Arctic

Submitted by lasse on Mon, 08/29/2022 - 10:44



Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. In the study *Driving mechanisms of an extreme winter sea-ice breakup event in the Beaufort Sea*published in Geophysical Research Letter, the challenges related to *understand, characterize and predict the impact of extreme event storms in sea-ice formation,* by combined use of satellite sea ice observations and numerical sea ice modelling.

The study by Jonathan W. Rheinlænder et al. addresses the loss of thick multi-year sea ice in the Arctic Ocean leads to weaker sea ice that is more easily broken up by strong winds. As a consequence, extreme sea-ice breakup events may become more frequent, even during the middle of winter when the sea ice cover is frozen solid. This can lead to an earlier onset of the melt season and potentially accelerate Arctic sea ice loss. Such extreme breakup events are generally not captured by climate models - potentially limiting our confidence in future projections of Arctic sea ice. The published study has investigated the driving forces behind sea-ice breakup events during winter, exemplified with satellite observations from the merged Cryosat-SMOS data set and the neXtSIM sea ice model predictions for the Beaufort Sea (see movies). The used sea ice model is the first capable to reproduce such breakup events and reveals that the combination of strong winds and thin sea ice are key factors for these breakups. The study team found that winter breakups have a large effect on local heat and moisture transfer and cause enhanced sea ice production, but also increase the overall movement of the sea ice cover, making it more vulnerable. Finally, the study show that if the Arctic sea ice continues to become thinner, these extreme breakup events could become even more frequent under a future Arctic climate. Integrating observations, data processing and assimilation, predictions and presentations of integrated results, the study is a contribution towards the development of a digital twin of the Arctic Ocean.

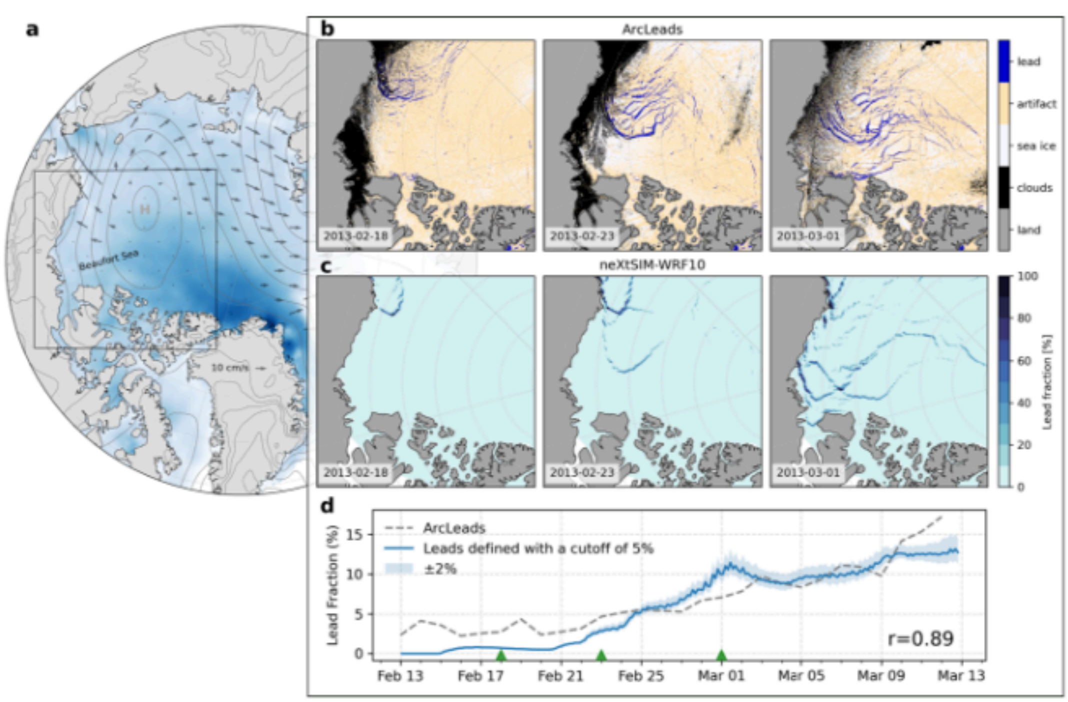
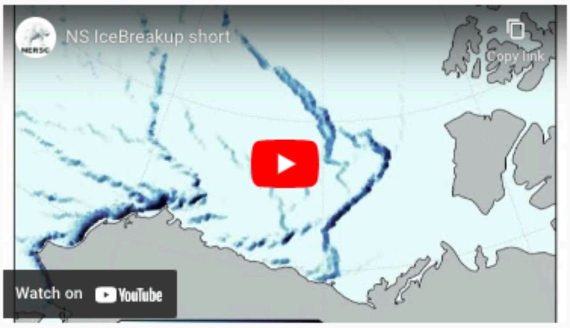


Figure 1. *(a) Schematic map of the Beaufort Sea with the observed winter sea-ice thickness from CS2/SMOS (shading), ice flow from neXtSIM (arrows), and mean sea-level pressure from ERA5 (solid, grey lines) all shown on 23 February 2013. (b) Daily categorical lead map following Willmes and Heinemann (2015) based on MODIS imagery. (c) Simulated lead fraction using WRF10 as the atmospheric forcing. (d) Time series of lead area fraction in the Beaufort Sea for the model (blue) and Arcleads (grey dashed line). Leads are defined as areas where the lead fraction exceeds 5%. The shading shows the sensitivity to using a threshold value of 3% and 7% respectively. The r-value is the correlation coefficient between observed and modelled lead fraction. Both b and c for 18, 23 February, and 1 March 2013 marked by green triangles in d.*

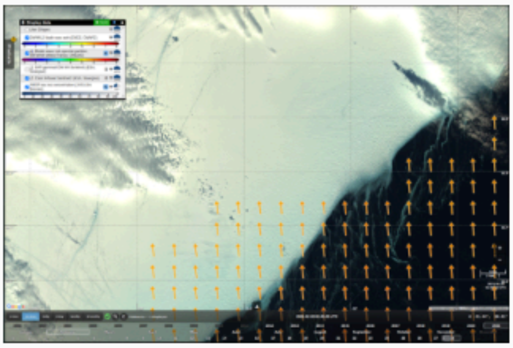


***Movies**: The sea ice break up in the Beaufort Gyre in in February 2013, as resolved in the MODIS times series of satellite images (upper) and reproduced by the neXtSIM s ea ice model (lower).*

The Arktalas Hoavva publication: Driving mechanisms of an extreme winter sea-ice breakup event in the Beaufort Sea. *Geophys. Res. Letter. June 2022.* by Jonathan W. Rheinlænder, Richard Davy, Einar Olason, Pierre Rampal, Clemens Spensberger, Timothy D. Williams, Anton Korosov, Thomas Spengler. https://doi.org/10.1029/2022GL099024

Waves plays an increasing role in shaping the sea ice dynamics in a warmer Arctic Ocean

Submitted by lasse on Mon, 08/29/2022 - 11:34



Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. In the study *Modelling the Arctic wave-affected marginal ice zone, comparison with ICESat-2 observations published in* the journal Philosophical Transactions A, the challenges related to *characterize the impact of more persistent and larger area of open water on sea ice dynamics in the Arctic Ocean* are addressed. The radar altimeter on board the ICESat-2 satellite have been instrumental to quantify the impact on the sea ice of waves propagating into the marginal ice zone (MIZ).

The sea ice covering the Arctic Ocean significantly attenuates the waves as they propagate from the open ocean into the pack ice. Consequently, waves are primarily penetrating into the vicinity of the ice edge - the so called marginal ice zone (MIZ). Waves play an important role in the MIZ as they can fragment the ice cover into floes of sizes ranging from a few metres to a few hundred metres. This fragmentation has a strong effect on atmosphere-ice-ocean interactions in the MIZ and can also affect the ice motion close to the ice edge, which is crucial to sea ice forecasting. It is therefore important that numerical models are able to predict where and when waves will be present in sea ice. Progress has been made in recent years thanks to knowledge acquired during various in-situ campaigns, but the evaluation of wave-in-ice models at the scale of the Arctic Ocean and over periods longer than a few days remains challenging. Very recent work has managed to estimate the ice-covered area of the Arctic that is affected by waves, which the authors call the wave-affected fraction (WAF), using an altimeter onboard ICESat-2, a satellite that was launched in 2018.

The study by Guillaume Boutin and colleagues has addressed this question of "Can we predict how far waves propagate in the sea ice". This study makes use of the WAF dataset to assess the ability of a coupled wave—sea ice model (described in Figure 1) to capture the extent to which the waves propagate in ice. This comparison is not straightforward as model and observations data are very different. Observations from ICESat-2, in particular, are sparse and only detect waves above a certain height. The study suggests some approaches that address these difficulties and allow us to evaluate the model over the whole Arctic from January 2019 to April 2020. We find that the estimated wave propagation in ice in the model agrees well with observations, especially in winter (Figure 2). In autumn, however, the model underestimates the area affected by waves in the western part of the Arctic Basin. The study highlights the need for wave-in-ice models to have strong wave attenuation in thick, compact ice, but weaker attenuation in summer or during sea ice formation periods, in order to increase the quality of the predictions of sea ice breakup and formation. This increased understanding of wave-ice interactions modelling will enable a better assessment of the impact of more persistent and larger area of open water on sea ice dynamics in the Arctic Ocean in future studies.

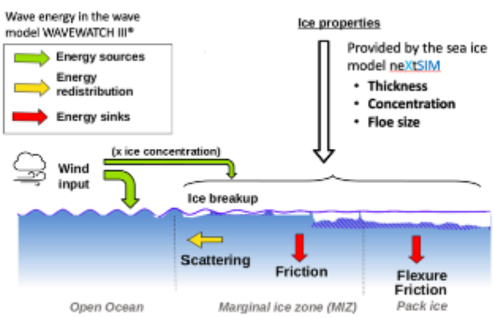


Figure 1: Summary of the wave-in-ice model. For full explanation see the publication.

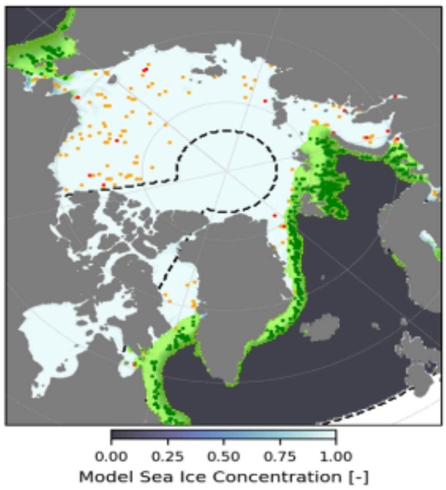
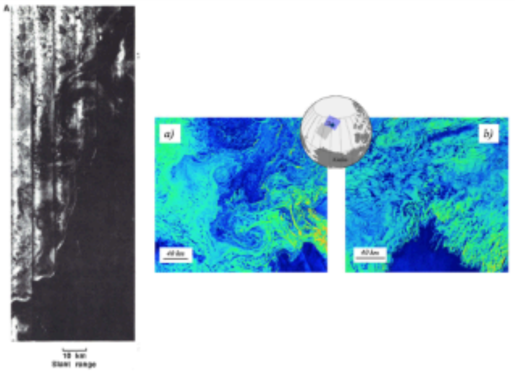


Figure 2: *Comparison of the wave affected area between the model and ICESat-2, for February 2019. The green shaded area corresponds to the modelled wave affected area using the criterion defined in the study and validated for the dark green points. Red and orange points show wave observations that are not encompassed within the modelled wave-affected area.*

The Arktalas Hoavva publication: Modelling the Arctic wave-affected marginal ice zone, comparison with ICESat-2 observations *(Relevant to ASC-2).* Published in *Philosophical Transactions A* by G. Boutin, T. Williams, C. Horvat and L. Brodeau. A380: 20210262. https://doi.org/10.1098/rsta.2021.0262

Consecutive satellite images detects mesoscale ocean eddies in ice-covered waters

Submitted by lasse on Mon, 08/29/2022 - 15:47



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Mesoscale eddies are routinely observed by satellites in the world oceans. Yet, in the ice-covered Arctic Basin, the presence of sea ice makes it challenging to characterize the eddy field. The study lead by Angelina Cassiandes, present a detection method of surface ocean eddies based on their signature in the displacement of sea ice, using high spatial resolution satellite images. A dipole composed of a cyclonic and an anticyclonic eddy is identified over a week in mid-October 2017 with a horizontal scale of 80–100 km. Its presence is confirmed by direct in-water measurements of strong orbital motion in the surface layer during the same period. This work demonstrates that detailed processing is required for identifying the signature of eddies in sea ice covered waters, which is not always obvious at first sight.

Aerial surveys or high-resolution satellite observations of the Arctic MIZ have frequently reveals swirling movements of sea ice that are the signature of mesoscale ocean eddies. This was illustrated with the L-band airborne SAR image from the Fram Strait in July 1984 (Source: Johannessen et al., 1987) at a high resolution of 3 meters. Other examples of such satellite SAR observations mesoscale eddies in the marginal ice zone are here shown for the Canadian Basin in October 2017 and 2018, respectively (Figure 1). Many studies of eddies in sea ice are detected primarily based on visual interpretation of the images (e.g. Kozlov et al, 2019), which increases the risk of not detecting all eddies present.

By combining upper ocean currents under the sea ice from the Beaufort Gyre Exploration Project, the signature of ocean surface eddies in sea ice vorticity have been detected based on the analysis of high-resolution images from synthetic-aperture radar (SAR).

Through processing of pairs SAR images for the locations of eddies identified in the current measurements have been done. The sea ice drift is estimated combining feature tracking and pattern matching techniquesand projecting the images on a regular orthogonal grid. Combining two or more images the sea ice vorticity can be calculated over several time periods of observations, to evaluate the persistence of the signal. This is exemplified with the vorticity pattern obtained from any single pair of SAR images, although the intensity tends to be more pronounced when averaging over a week (compare panels b and c of Figure 4). On average, two strong anomalies are visible close to the mooring data used: a cyclonic signal West of the mooring and an anticyclonic one East of it, both with a horizontal scale of 80–100 km. Considering that our ocean dipole would be advected by the background flow with velocity of ‒0.05 m/s , it would have roughly travel northward by only 30 km over the week considered, consistent with the persistence of the sea ice vorticity pattern.

The combination of the sea ice vorticity anomaly and the presence of eddies captured by the mooring, the lack of a significant wind forcing over that period, and the scaling arguments presented before, allows to attribute the signal to the signature of the ocean mesoscale eddies. The presence of two vorticity anomalies with opposite signs indicates that the signal is indeed a dipole, composed of a cyclone and an anticyclone.

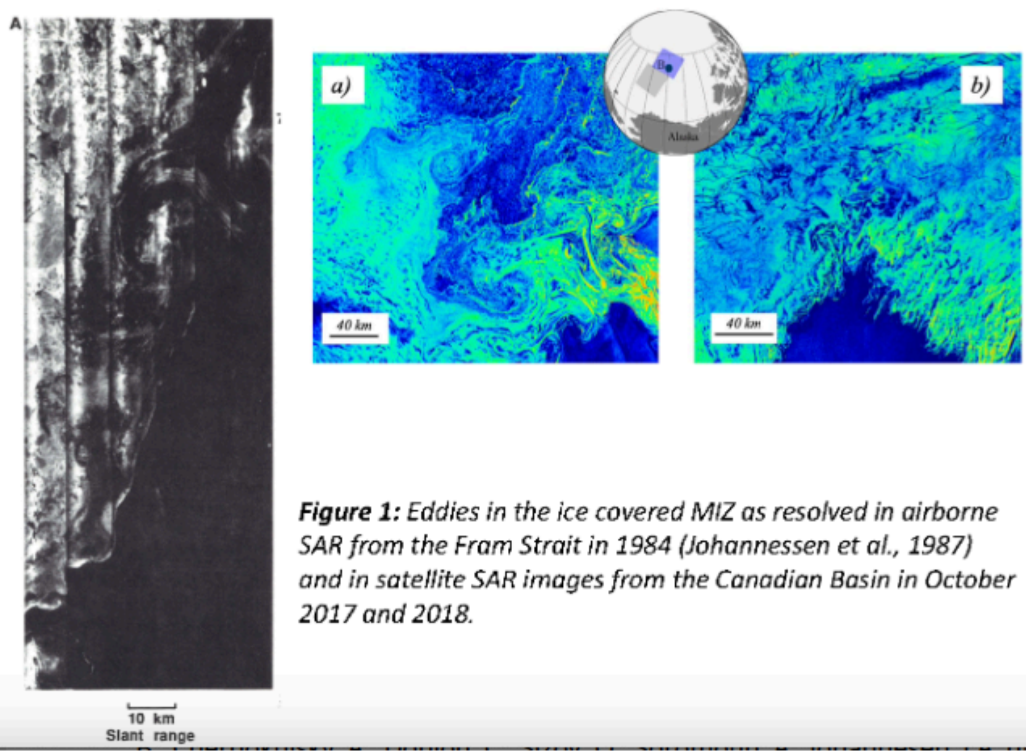

Figure 1: *Eddies in the ice covered MIZ as resolved in airborne SAR from the Fram Strait in 1984 (Johannessen et al., 1987) and in satellite SAR images from the Canadian Basin in October 2017 and 2018.*

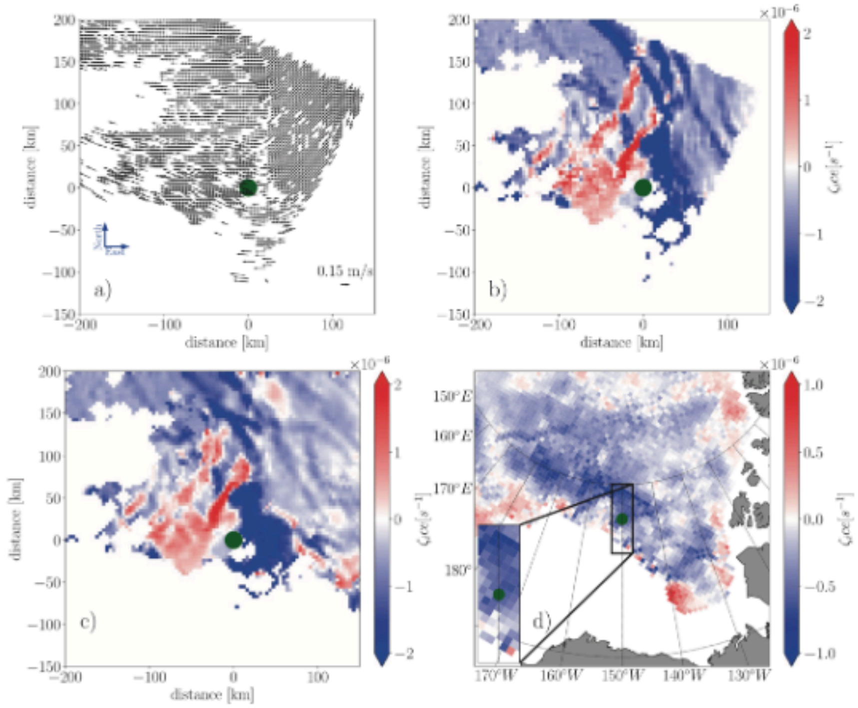

***Figure 2:** (a) Sea ice drift field and (b) sea ice vorticity from one pair of SAR images for October 12–13; (c) average of sea ice vorticity from five pairs of SAR images for October 7–13 and (d) from the National Snow and Ice Center (NSIDC) for October 7–13. The green dot indicates the position of mooring B, and the black box indicates the window of (a, b, and c).*

The Arktalas Hoavva publication: Observational evidences of eddy-sea ice interactions in the pack-ice and in the MIZ *(Relevance to ASC-2).* Published in *Geophysical Research Letter* in 2020 by A. Cassianides, Camille Lique, Anton Korosov.https://doi.org/10.1029/2020GL092066

Arktalas

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Home / An emerging apparent Arctic Amplification: A synthesis of paradigms and satellite observations

An emerging apparent Arctic Amplification: A synthesis of paradigms and satellite observations

Submitted by lasse on Tue, 10/11/2022 - 10:36

ARKTALAS Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. The rapid changes in the Arctic environment and climate, manifested through the Arctic Amplifications have been addressed in a synthesis study exploring the capabilities of satellite observations integrated in reanalysis modelling.

The Arctic changes rapidly. Global warming in this remote and cold region of the Earth is amplified and accelerated. Satellites witness temperature raise, sea ice loss and retreat, shortening of snow seasons, and massive changes in the Arctic biosphere, which include enhancement of phytoplankton and vegetation productivity as well as gradual northward advance of terrestrial tree-line and marine fisheries migration. The most pronounced changes are observed in the northern and eastern European parts of the Arctic i.e. Barents Sea [1], including the Svalbard area [2]. Here, mean wintertime temperatures have raised by 5-10 degrees C - three to seven times of the global average - over the last 100 years. Undoubtedly, this area become a culprit of the Arctic Amplification of the global warming.

The Arctic Amplification of surface temperature comes in pulses [3], see Figure 1. Long periods of high internal climate variability and slow climate trends are followed by intense decades of rapid and considerable changes. The most recent such periods have been captured by multitude of satellite observations. Rapid Arctic environmental transitions were spotted by satellites since mid-1990s, followed along 2000s, and further monitored until present. Figure 2 presents emergence of this apparent Arctic Amplification over several last decades, including the maximum index in 2000s coinciding with the period of the rapid multiyear sea ice retreat and drop of sea ice volume. As the transitions were unfolding in the marginal sea ice zone - the areas inaccessible to ground-born observations, - satellites have been indispensable in documenting those significant apparent climate shifts in the Arctic [4].

Satellite observations come in forms of assimilated retrospective weather analysis data (reanalysis) and gridded and native resolution satellite data products. Reanalysis is an important source for Arctic climate studies, for discovery of interacting physical processes and interlinked changes. Climate modeling further extends applications of the satellite observations, capitalizing on climate feedback studies as well as on projection of the Arctic Amplification to the future [5]. Yet, it was the satellite data products of poorly modeled essential climate variables (sea ice characteristics, vegetation indices, cloudiness) which have been essential to the recent fundamental change of the Arctic Amplification paradigm [6].

The traditional paradigm put the weight on local climate processes and feedbacks, such as, e.g., the ice-albedo feedback. The new paradigm attributes the Amplification drivers to the global energy sink and source redistribution, and therefore to dynamic effects in the atmospheric and oceanic meridional circulation. The local feedbacks are following in this paradigm making the Amplification apparent in the surface changes as soon as the surface transitions allow. The manifest of emerging apparent Amplification is the recent rapid temperature raise at the Barents Sea northern margins. Here, multiyear sea ice kept both the surface air temperature and the sea surface temperature at melting point during summertime, thus, holding on heat accumulation and related surface-layer feedbacks. In 2000s, multiyear ice has largely retreated [7], see Figure 3. Solar heating got access to the upper ocean storage reservoir setting back winter ice formation and triggering further warming. As land cover is more responsive to heat inflow in the atmosphere, Arctic vegetation productivity began to increase earlier with dominant effect of tundra shrubification and afforestation [8], see Figure 4.

The ARKTALAS study of the apparent Arctic Amplification synthesizes the new paradigm of this influential climate phenomenon and fragmented satellite observation studies which reveals one or another aspect of the Arctic environmental transitions. Our analysis builds upon diverse aggregated, processed, and published satellite data sets so that we can divert our attention from technical details of data acquisition and modeling favoring coherent discussion of physical hypothesis and broader assessment of evidence.

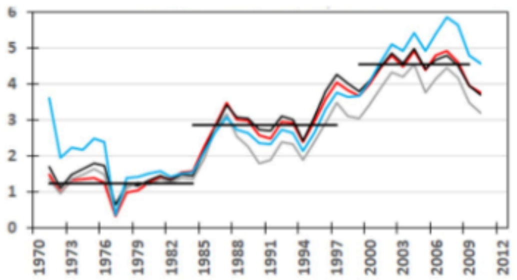

Figure 1 (from [3]). The pulses in the apparent Arctic Amplification from ground-based datasets of surface temperature. The values of Arctic amplification index obtained from HadCRUT5.0 (red), GISS (black), NOAA NCEI (grey), and HadCRUT/CW (blue) are shown. The step-like approximation of pulses is shown as horizontal black lines.

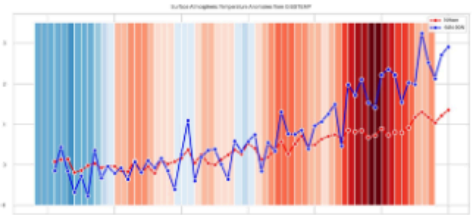

Figure 2. Emergence of the apparent Arctic Amplification in the surface atmospheric temperature anomalies. Data source: GISSTEMP (includes satellite data product AIRS). The curves show regionally averaged annually mean temperature anomalies relative to 1960-1990 for the Northern Hemisphere (red) and the Arctic (blue). The color shading shows an Arctic Amplification Index (ration of the two curves filtered with 7-years centered running mean).

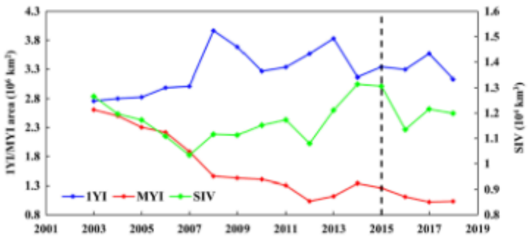

Figure 3 (from [7]). The transitions in the Arctic Ocean sea ice volume (SIV) and the first-year ice (1YI) area and the multiyear ice (MYI, i.e., 2YI to 5YI) area from 2003 to 2018. The SIVs calculated by the Envi-PIO and CS-2 SITs are used in the map. The extent used to calculate the sea ice age areas is masked by the extent of the Arctic Ocean.

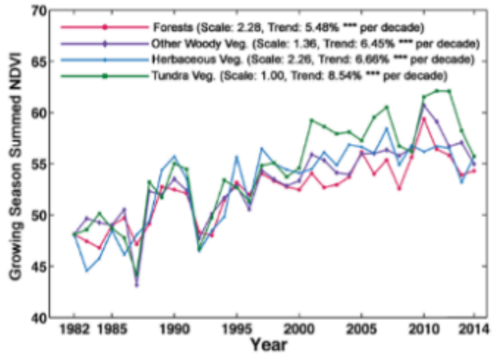

Figure 4 (from [8]). The transition in the terrestrial vegetation production (NDVI) during the onset of the recent warming pulse (1994 - 2002). Data from the GSSNDVI product.

The study is published in Remote Sensing:

Esau, I.; Pettersson, L.H.; Cancet, M.; Chapron, B.; Chernokulsky, A.; Donlon, C.; Sizov, O.; Soromotin, A.; Johannesen, J.A. **The Arctic Amplification and Its Impact: A Synthesis through Satellite Observations**. *Remote Sens.* **2023**, *15*, 1354. https://doi.org/10.3390/rs15051354

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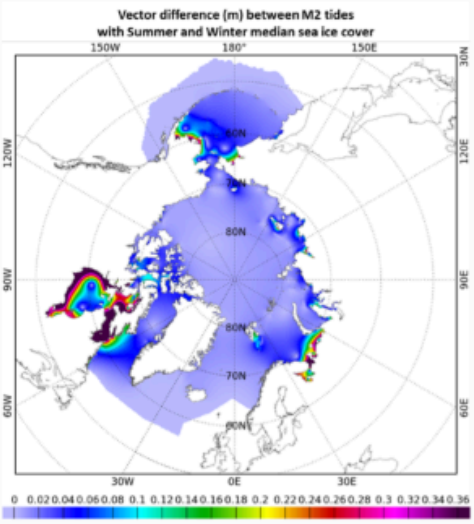
Exploration of the linkages between sea ice and ocean tides in the Arctic Ocean

Submitted by lasse on Tue, 10/11/2022 - 11:09



The Arktalas Hoavva project, funded by the European Space Agency, addresses four major scientific challenges for the Arctic, notably the Arctic Amplification and its impact, the impact of more persistent and larger area of open water on sea ice dynamic, the impact of extreme event storms in sea-ice formation and the impact of the Arctic ocean spin-up. Related to these challenges the specific study on "Impact of sea ice friction on ocean tides in the Arctic Ocean: Modelling insights at various time and space scales" investigated the linkages between sea ice change and ocean tides in the Arctic Ocean. In so doing, it linked hydrodynamic model simulations together with CryoSat-2 satellite altimetry observations and in situ tide gauge measurements.

Although ocean tides are one of the major contributors to the energy dissipation in the Arctic Ocean, they remain relatively poorly known. In particular, their interactions with the sea-ice, grounded-ice and fast-ice cover are often simply ignored in tidal models or considered through relatively simple combinations with the bottom friction.

In order to obtain more realistic simulations of the tides in the Arctic Ocean at seasonal to decadal time scales several approaches have been explored to improve the prescription of the friction under sea ice in the hydrodynamic model. Validation of the tidal model simulations in the Arctic Ocean is challenging as very few long time series of high-frequency (time stepping of less than 1 hour) tide gauge observations are available. As such colocations for comparisons with the model simulations were limited to less than ten points. On the other hand, the CryoSat-2 mission brings an invaluable picture of tidal estimates representative of the most recent period (2010-2020), with almost complete coverage of the region, including sea surface height estimates in the leads.

Results show that the seasonal variations of the tides due to the presence of sea ice reach several tens of centimetres in some regions of the Arctic Ocean (Figure 1). Over the long term (40 years), we also observed that the variability of the main tidal components (M2 and K1) locally reaches a few centimetres not only in the Arctic Ocean but also in areas at long distances, such as the English Channel, clearly demonstrating the strong connection with the Arctic in terms of ocean tide dynamics.

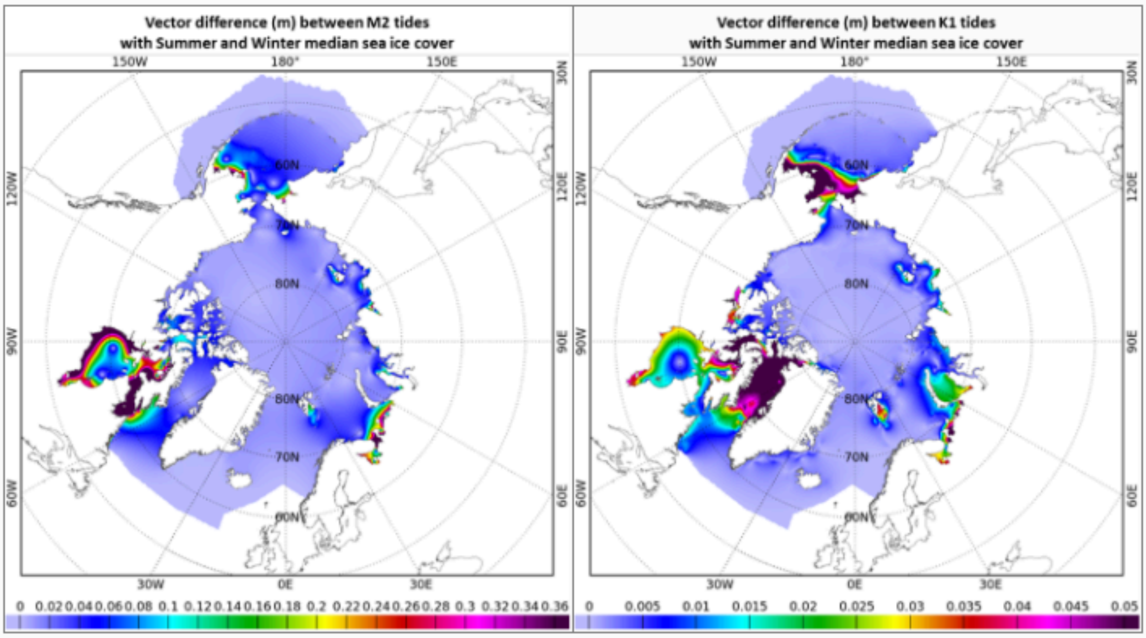
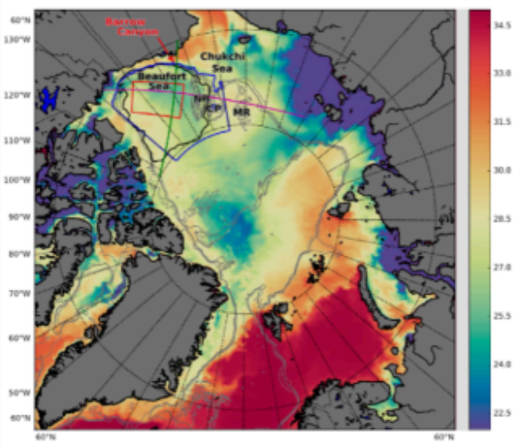


Figure 1 Vector differences (in meters) between tidal simulations based on Summer and Winter median sea ice configurations, for the M2 (left) and K1 (right) main tidal components.

***Publication*: Impact of sea-ice friction on tidal modelling in the Arctic Ocean.** (Mathilde Cancet,Florent H. Lyard, Ergane Fouchet). To be submitted to Ocean Modelling 2023.

Response of Total and Eddy Kinetic Energy to the Recent Spinup of the Beaufort Gyre

Submitted by lasse on Wed, 05/10/2023 - 14:47



ARKTALAS Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. The Beaufort Gyre in the Arctic Ocean has spun up over the last couple of decades. In this study a high-resolution eddy resolving model has been used to study accumulations of fresh water in the gyre and its role in the ocean circulation in the Arctic Ocean.

The Beaufort Gyre in the Arctic Ocean is an anticyclonic upper-ocean circulation feature that is the largest reservoir of fresh- water in the Arctic. The gyre has spun up over the past two decades in response to changes of the wind forcing and sea ice conditions, accumulating a significant amount of freshwater. This will have an impact on the circulation in the Arctic Ocean as well as the variability of freshwater export from the Arctic, which again has the potential to influence the North Atlantic circulation and climate affecting the deep-water formation and global conveyor belt circulation. In this study a simulation performed with a high-resolution, eddy-resolving model is analyzed to provide a detailed description of the total and eddy kinetic energy and their response to this gyre spinup. The results of the model simulation (see Figure) describe the spatiotemporal evolutions of the total and eddy kinetic energy in the Canada Basin. In contrast to previous results, we find that the gyre is able to spin up and sustain a higher level of mean kinetic energy that is generally not accompanied by higher levels of eddy kinetic energy. On average, and in contrast to the typical open ocean conditions, the levels of mean and eddy kinetic energy are of the same order of magnitude, and the eddy kinetic energy is only intensified along the boundary and in the subsurface. In response to the strong anomalous atmospheric conditions in 2007, the gyre spins up and the mean kinetic energy almost doubles, while the eddy kinetic energy does not increase significantly for a long time period. This is because the isopycnals are able to flatten and the gyre expands outwards, reducing the potential for baroclinic instability.

In agreement with previous studies the study indicates that the Arctic Ocean freshwater content holds a memory of the previous decade of atmospheric forcing. However, our results suggest that different features of the gyre can respond differently to long term trends and strong anomalous events in the atmospheric forcing, but also show that the gyre can retain a strong memory of extreme atmospheric events. The projected increase in Arctic storminess may thus have an impact on the large scale circulation in the Arctic.

These results have implications for understanding the mechanisms at play for equilibrating the Beaufort Gyre and the variability and future changes of the Arctic Ocean freshwater system and its export to the global oceans through the Fram and Bering straits.

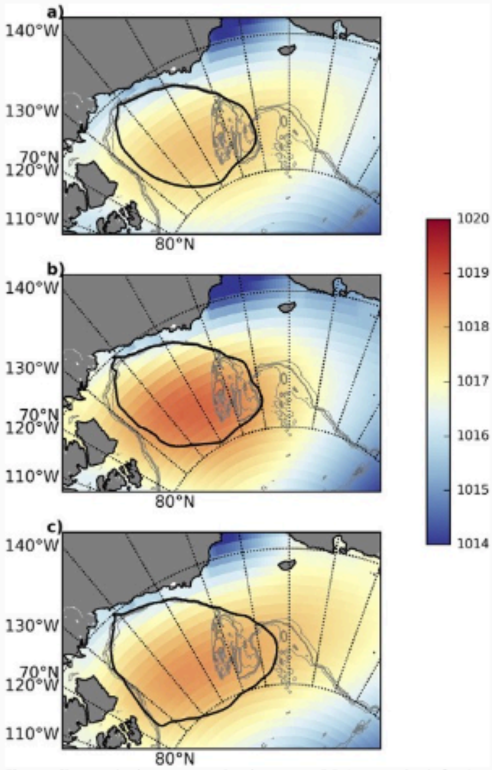
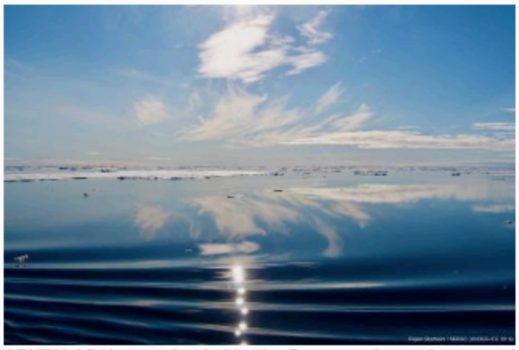


Figure: Changes in the mean sea level pressure (hPa) atmospheric forcing dataset for the pre-spin up (a; 1990–2014), the spin up (b;2003–07), and post-sin up periods (c; 2008–14). The average gyre contour over the respective years is shown in black. Bathymetry contours are shown at 500, 1000, and 1500 m in gray.

Publication: **Response of Total and Eddy Kinetic Energy to the recent spin up of the Beaufort Gyre** (H. Regan, C. Lique, et al.) Published in JPO, March 2020, https://doi.org/10.1175/JPO-D-19-0234.1

Wind-wave attenuation under sea ice in the Arctic Ocean: a review of remote sensing capabilities.

Submitted by lasse on Wed, 05/10/2023 - 14:58



ARKTALAS Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. Waves generated by winds over the ocean propagate into areas covered by sea ice where they can be strongly attenuated and can contribute to break-up of the sea ice and thus pushing the ice more easily around. This paper provides a review of the capabilities of using various types of satellite remote sensing data to assess the wind-wave attenuation under the sea ice ispresented.

Wave patterns in Arctic sea ice have been found in all radar and optical measurements in the Marginal Ice Zone (MIZ) and near the ice edge. These observations can provide useful observation for understanding the interactions of waves and sea ice. Such patterns are resolved in data from several sensors such as the ICESat-2 laser altimeter, Sentinel-1 imaging radar, the Sentinel-2 optical imager, Sentinel-3 radar altimeter, and CFOSAT wave-measuring instrument SWIM. In the study *Wind-wave attenuation under sea ice in the Arctic: a review of remote sensing capabilities* published in JRG-Ocean, the Arktalas Hoavaa project team presents several examples of such wave patterns in sea ice. A consistent quantitative interpretation of ICESat-2 and Sentinel-2 data is made on waves generated by storms in the Barents Sea (see example in figure 1) that are observed to travel hundreds of kilometers across the marginal ice zone and into the pack ice. For Sentinel-3 and SWIM, a quantification of wave heights still have to be validated, possibly based on data from the other two satellite instruments. Such use of multi senor data will strongly expand the quantity of available wave information for scientific investigations and operational applications in the polar oceans.

Wind-generated waves strongly interact with sea ice and impact air-sea exchanges, operations at sea, and marine life. Unfortunately, the dissipation of wave energy is not well quantified and its possible effect on upper ocean mixing and ice drift are still mysterious. As the Arctic is thawing and opening up the wave energy increases and penetrates into new parts of the Arctic Ocean. The lack of high quality in-situ observations is a clear limitation to thescientific understanding of this change. Both radar and optical remote sensing has revealed the frequent presence of waves in the ice, and could be used more systematically to investigate wave-ice interactions. In this study the Arktalas Hoavaa team show that, in cloud-free conditions, Sentinel-2 images exhibit brightness modulations in ice-covered water, consistent with the presence of waves measured a few hours later by the ICESat-2 laser altimeter. They also demonstrate that a fully-focus SAR processing of Sentinel-3 radar altimeter data reveals the presence of waves and their wavelengths in the ice, within minutes of Sentinel-2 imagery. The SWIM instrument on CFOSAT is another source of quantitative evidence for the direction and wavelengths of waves in the ice, when ice conditions are spatially homogeneous. In the presence of sea ice, a quantitative wave height measurement method is not yet available for all-weather near-nadir radar instruments such as altimeters and SWIM. However, their systematic co-location with optical instruments on Sentinel-2 and ICESat-2, which are less frequently able to observe waves in sea ice, may provide the empirical transfer functions needed to interpret and calibrate the radar data, greatly expanding the available data on wave-ice interactions.

In turn, it opens up for a great potential for a synergistic use of these five remotely sensed data sources, some of which allow exact co-location in space with time differences of only a few minutes, to reach a more quantitative understanding of the radar measurements, leading to novel insight of wave-ice interactions as well as practical applications to marine safety and Earth System modelling.

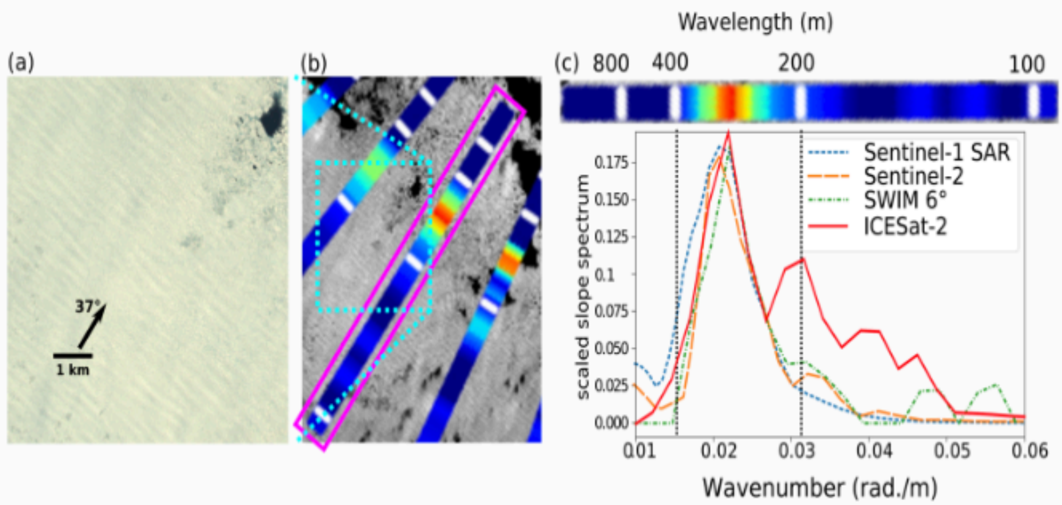


Figure: An example of wave patterns observed in collocated remotely sensed data from the CFOSAT-SWIM, Sentinel-1 SAR and Sentinel-2 optical images. For details figure 10 in Collard et al., 2022.

Publication: **Wind-wave attenuation under sea ice in the Arctic: a review of remote sensing capabilities.** By Fabrice Collard, Louis Marie, Frederic Nouguier, Marcel Kleinherenbrink, Frithjof Ehlers, and Fabrice Ardhuin**.** Published in Journal of Geophys. Res.-Ocean. https://doi.org/10.1029/2022JC018654

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Observing the changes in the Arctic Ocean: current gaps and impact of the future satellite missions

Submitted by lasse on Tue, 10/11/2022 - 11:26

Arktalas Hoavva, funded by the European Space Agency, addresses four major scientific challenges for the Arctic. In the published paper Knowledge Gaps and Impact of Future Satellite Missions to Facilitate Monitoring of Changes in the Arctic Ocean, , the past and present satellite observation capacities to address these major scientific challenges, i.e. the Arctic Amplification, the impact of more persistent and larger area of open water on sea ice dynamics, the impact of extreme event storms on sea-ice formation pattern and structures, and the Arctic Ocean spin-up have been analysed.

To further understand our planet and in particular the Arctic Ocean requires reliable, consistent and regular information from satellites for a wide range of ocean and sea ice geophysical variables. Some observational gaps were identified in terms of spatial and temporal coverage and resolution, and also regarding some geophysical variables that are today estimated as the result of combinations between different sources of observations (e.g., the total ocean surface currents, or the snow depth over the sea ice).

The satellite-based continuity and new approved missions (see Sankey Diagrams) are expected to advance the monitoring of the above-mentioned challenges and secure long time series. To ensure accurate satellite observations over the long term, there is also a crucial need for Fiducial Reference Measurement (FRM) data for calibration and validation activities, especially in such challenging regions as the high-latitude seas and the Arctic Ocean. Finally, because of the difficulty to observe the Arctic Ocean with the spatiotemporal resolution that would be needed, either from satellites or in situ instruments, most studies rely today on the synergy between satellite observations, in situ measurements and modelling. Complemented with advances in development of a Digital Arctic Twin and multi-modal physical constrained analyses it is likely to deliver more reliable estimates of sea ice damage, break-up, leads formation, new ice formation, sea ice freeboard height, sea ice volume and mean sea level. The new observations, often at higher resolution, brought by the future satellite missions will also contribute to improve the validation of higher-resolution models and the understanding of the complex processes in the Arctic Ocean, allowing reanalyses and reconstruction of more reliable long time series.

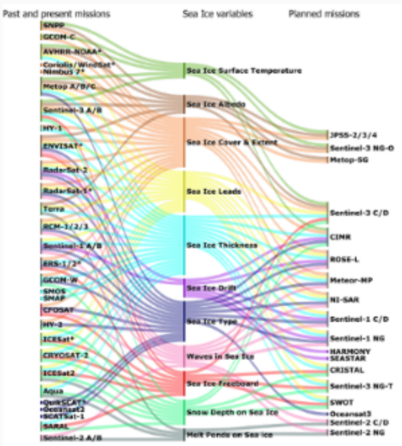

*Figure 1: Sankey diagram linking past, present and future satellite missions and their ocean measurement capabilities. (left) Past (identified with *) and present missions; (center) retrieved ocean variables; (right) future approved missions. RCM stands for RadarSat Constellation Mission.*

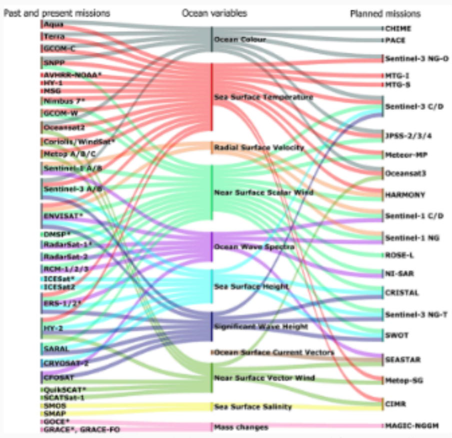

*Figure 2: Sankey diagram linking past, present and future satellite missions and their sea ice measurement capabilities. (left) Past (identified with *) and present missions; (center) retrieved sea ice variables; (right) future approved missions. RCM stands for RadarSat Constellation Mission.*

The study *Knowledge Gaps and Impact of Future Satellite Missions to Facilitate Monitoring of Changes in the Arctic Ocean* is published in Remote Sensing:

Lucas, S.; Johannessen, J.A.; Cancet, M.; Pettersson, L.H.; Esau, I.; Rheinlænder, J.W.; Ardhuin, F.; Chapron, B.; Korosov, A.; Collard, F.; Herlédan, S.; Olason, E.; Ferrari, R.; Fouchet, E.; Donlon, C. **Knowledge Gaps and Impact of Future Satellite Missions to Facilitate Monitoring of Changes in the Arctic Ocean.** *Remote Sens.* **2023**, *15*, 2852. https://doi.org/10.3390/rs15112852