CISESS ANNUAL REPORT ON RESEARCH FOR THE

JASON PROGRAM

April 1, 2019 to March 31, 2020

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CISESS ALTIMETRY OF THE ARCTIC OCEAN AND SUBPOLAR SEAS: INVESTIGATING CHANGES IN CIRCULATION AND DYNAMIC TOPOGRAPHY

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BACKGROUND

Although sea surface topography is an important parameter in the global ocean climate system, our knowledge is limited in the Arctic Ocean and subpolar seas, due to the constant presence of sea ice. As a result of the permanent ice cover, knowledge of the mean sea surface and bathymetric features of the Arctic Ocean is limited, as is detailed knowledge of geostrophic circulation, and its seasonal and interannual variability. Knowledge of sea surface height (SSH) is critical for deriving sea ice freeboard, and hence ice thickness from satellite altimeter data, where freeboard is defined as the difference between sea ice elevation and the local SSH. Beyond this, measuring SSH in the polar oceans provides a means of conducting a number of geodetic and oceanographic investigations such as monitoring variability in dynamic ocean topography and geostrophic circulation, changes in significant wave height, and the impacts of increasing storms on the marginal ice zone. Satellite altimeters have been profiling the Arctic Ocean and subpolar seas since 1992 via the radar altimeter carried on-board the European Space Agency's (ESA) ERS-1 satellite. Between 1992 and 2012, ERS-1, -2 and Envisat measured polar ocean topography to a latitudinal limit of 81.5^{o}N. Since then, more recent altimeter missions, such as NASA's ICESat and ESA's CryoSat-2, have afforded us the chance to extend coverage pole ward, to 86^{o}N and 88^{o}N, respectfully. Near complete coverage, to 88^{o}N, is maintained by NASA's ICESat-2 mission, which was launched in 2018. Under this task we analyze CryoSat-2, ICESat-2 and Sentinel-3 altimeter data in the Arctic Ocean, as well as Jason-2 and SARAL/AltiKa measurements in the ice-free areas south of the marginal ice zone. We assess satellite-derived sea level anomaly, significant wave height, and dynamic ocean topography estimates, to investigate inter-annual variability and quantify trends over the past two decades. The research supports the NOAA/NASA Ocean Surface Topography Science Team (OSTST).

ACCOMPLISHMENTS

NOAA/NASA OCEAN SURFACE TOPOGRAPHY SCIENCE TEAM

In support of the NOAA/NASA Ocean Surface Topography Science Team (OSTST), we have completed a number of critical studies during Year 3. CISESS scientists provided critical mission support and scientific guidance to two key polar altimeter missions: The NASA ICESat-2 Mission, and the ESA/EU Copernicus Polar Ice and Snow Topography Altimeter (CRISTAL) Mission. Long term, uninterrupted observations of the polar oceans, including sea ice and ice-shelf elevation, are of utmost importance for climate and sea-level related scientific studies, and provide critical support to operational ice services and decision-makers. Continuation of this vital time series is dependent of the successful, and timely, launch of the ESA/EU Copernicus CRISTAL mission, since there is no other proposed, planned or approved altimetric mission to observed beyond 81.5° N/S (Figure 1). CISESS Scientist Dr. Farrell co-chaired the "*Altimetry for Cryosphere and Hydrology*" panel discussion at the 2019 Ocean Surface Topography Science Team (OSTST) Meeting. During this discussion the international earth science community expressed their concerns regarding the expected CRISTAL launch timeframe of 2026/2027. This launch timeframe is not compatible with the current expected lifetimes of the ESA CryoSat-2 and NASA ICESat-2 missions, and could potentially result in a gap in polar altimetric observations (Figure 1), impacting a variety of end users and stakeholders.

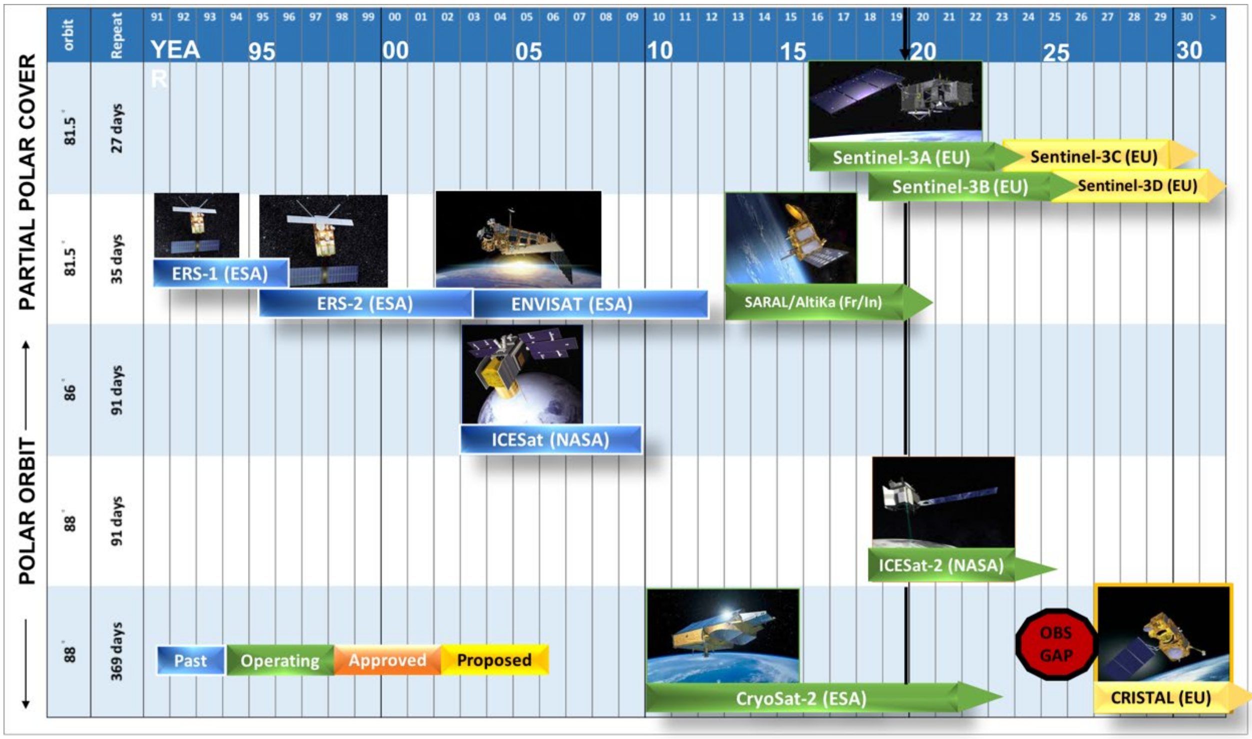

Figure 1. *Polar Altimeter Time Series (1991-present), highlighting a potential gap in high-latitude observations should the launch timeframe for CRISTAL slip beyond ~2025.*

Significance and Importance

Following the OSTST 2019 panel discussion, members of the OSTST (comprising NASA, NOAA, CNES, ESA and EUMETSAT) adopted the following recommendation: *"To minimize likelihood of a gap in polar ocean and ice monitoring, the OSTST encourages Agencies to strive to launch CRISTAL in the early 2020s and to maintain operation of CryoSat-2, ICESat-2, and SARAL/AltiKa as long as possible."*

NOAA POLARWATCH PROGRAM

CISESS scientists continued to support the development and expansion of the NOAA PolarWatch (https://polarwatch.noaa.gov) data catalogue, which is a node of the NOAA CoastWatch/OceanWatch program. PolarWatch enables data discovery, easy access, and broader usage of high-latitude satellite data products, especially those developed by NOAA / NESDIS / STAR/SOCD. It delivers multi-sensor physical and biological ocean remote sensing data in support of broad applications in the Arctic and Southern Oceans. The initial datasets provided through PolarWatch include sea ice concentration, sea surface height, salinity, sea surface temperature, ocean surface winds, and ocean color. An interface has been developed that delivers a suite of satellite data products from a variety of sensors and data providers (Figure 2). The PolarWatch catalog provides data previews in Arctic, Antarctic, and global projections, as well as pages that include both the full dataset details and background information. Data downloads can be customized by area, date, parameter, and file format. In September, Dr. S. L. Farrell, CISESS/UMD, and visiting scientist at the NOAA / NESDIS / STAR / SOCD Laboratory for Satellite Altimetry, College Park, MD, delivered an invited seminar as part of the NOAA Center for Satellite Applications and Research (STAR) Science Seminar Series. Dr. Farrell explored the novel sea ice data products developed at the NOAA Laboratory for Satellite Altimetry which describe changes in the Arctic ice cover during the last two decades. She discussed efforts to advance access to polar ocean remote sensing observations and improve communication with Arctic stakeholders through the NOAA

PolarWatch initiative, which is designed to deliver data products that best address societal needs (polarwatch.noaa.gov). In November, CISESS Scientist K. Duncan presented on Analysis of Arctic sea ice pressure ridges from ICESat-2 during the CISESS Annual Science Meeting.

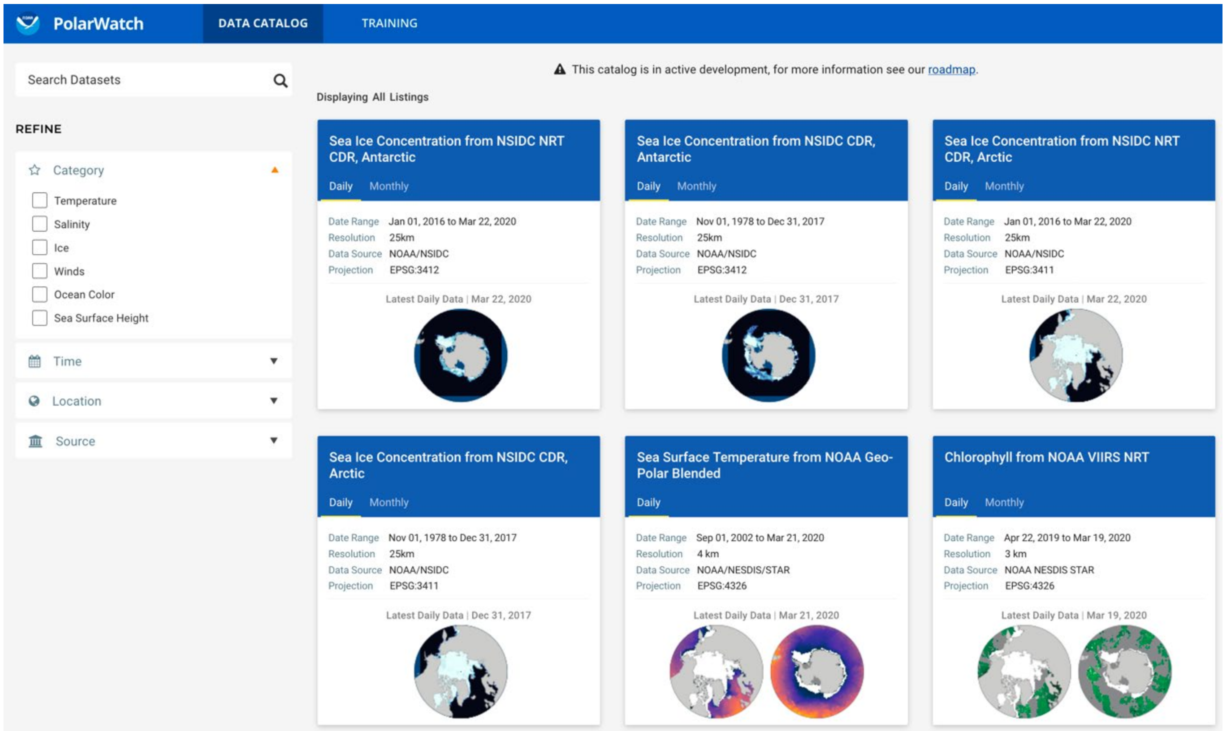

Figure 2. *The NOAA PolarWatch catalogue interface allows users to search and filter satellite datasets, providing data previews in polarstereographic projections. This example displays the current PolarWatch data holdings for sea surface height and sea ice concentration in both the Arctic and Southern Oceans.*

Significance and Importance

Promotes interdisciplinary knowledge of Polar Watch product usage, expanding the Partnerships objective of the NESDIS Strategic Plan. In addition, information-sharing among colleagues improves communication among and within NOAA line offices and identifies new user groups.

PLANNED WORK

- Continue mission support for the ICESat-2, CRISTAL, Sentinel-3, and OSTST Science Teams.
- Continue assessments of CryoSat-2, Sentinel-3 and ICESat-2, to investigate ice and ocean surface topography measurements in the Arctic Ocean and surrounding seas.
- Continue to support the development and expansion of the NOAA PolarWatch web-portal.
- Monitor sea surface topography in the Arctic Ocean and subpolar seas using suite of available radar and laser altimeter data, to quantify mean dynamic topography and geostrophic circulation, on monthly and inter-annual time-scales.
- Calibrate and validate the ICESat-2 ocean height and significant wave height measurements through detailed comparisons with the suite of radar altimeter data available through RADS.
- Continue to develop Arctic Ocean data products and distribute them through the NOAA Laboratory for Satellite Altimetry website at: www.star.nesdis.noaa.gov/sod/lsa/SeaIce/DataProducts/.

PUBLICATIONS

1. Kern, M., R. Cullen, B. Berruti, J. Bouffard, T. Casal, M. R. Drinkwater, A. Gabriele, A. Lecuyot, M. Ludwig, R. Midthassel, I. Navas Traver, T. Parrinello, G. Ressler, E. Andersson, C. Martin Puig, O. Andersen, A. Bartsch, **S. L. Farrell**, S. Fleury, S. Gascoin, A. Guillot, A. Humbert, E. Rinne, A. Shepherd, M. R. van den Broeke, J. Yackel, (2020), The Copernicus Polar Ice and Snow Topography Altimeter (CRISTAL): Expected Mission Contributions, *The Cryosphere Discuss*., https://doi.org/10.5194/tc-2020-3.
2. **Duncan, K., S. L. Farrell**, J. Hutchings, J. Richter-Menge (2020), Late Winter Observations of Sea Ice Pressure Ridge Sail Height, *IEEE Geoscience & Remote Sensing Lett*., under review.
3. **Buckley, E. M., S. L. Farrell, K. Duncan**, L. N. Connor, J. M. Kuhn, R. T. Dominguez (2020). Classification of Sea Ice Summer Melt Features in High-resolution IceBridge Imagery, *J. Geophys. Res*., under review.
4. Perovich, D., W. Meier, M. Tschudi, **S. Farrell**, S. Hendricks, S. Gerland, L. Kaleschke, R. Ricker, X. Tian-Kunze, M. Webster and K. Wood (2019b), *Sea ice, Arctic Report Card 2019*, peer-reviewed, https://arctic.noaa.gov/Report-Card/Report-Card-2019
5. Magruder, L., T. Neumann, H. Fricker, **S. L. Farrell**, K. Brunt, A. Gardner, D. Hancock, K. Harbeck, M. Jasinski, R. Kwok, N. Kurtz, J. Lee, T. Markus, J. Morison, A. Neuenschwander, S. Palm, S. Popescu, B. Smith and Y. Yang (2019), New Earth orbiter provides a sharper look at a changing planet, *EOS,* 100, https://doi.org/10.1029/2019EO133233
6. Kwok, R., Markus, T., Kurtz, N. T., Petty, A. A., Neumann, T. A., **Farrell, S. L**., Cunningham, G. F., Hancock, D. W., Ivanoff, A., Wimert, J. (2019), Surface height and sea ice freeboard of the Arctic Ocean from ICESat-2: Characteristics and early results, *J. Geophys. Res.,* 124. https://doi.org/10.1029/2019JC015486
7. Perovich, D., W. Meier, M. Tschudi, **S. Farrell**, S. Hendricks, S. Gerland, C. Haas, T. Krumpen, C. Polashenski, R. Ricker and M. Webster (2019a), Sea ice cover [in “State of the Climate in 2018”], Bull. Amer. Meteor. Soc., 100(9), S146–150, https://doi.org/10.1175/2019BAMSStateoftheClimate.1
8. Sallila, H., **S.L. Farrell,** J. McCurry, and E. Rinne (2019). Assessment of Contemporary Satellite Sea Ice Thickness Products for Arctic Sea Ice. *The Cryosphere*, 13, 1187-1213, 2019 https://doi.org/10.5194/tc-13-1187-2019

PRODUCTS

1. **NOAA PolarWatch**: PolarWatch (https://polarwatch.noaa.gov/) increases access to physical and biological ocean remote sensing data to diverse end-users across disciplines within NOAA, in support of broad applications in Arctic and Southern Ocean science. The primary goals of the program are to enable data discovery, easy access, and broader use of high-latitude satellite remote sensing data products, such as surface winds, sea ice properties, ocean color, waves, temperature, salinity, and sea surface height, through a fit-for-purpose, web-based data catalogue.
2. **Arctic sea ice data products** produced by the NOAA / NESDIS / STAR Laboratory for Satellite Altimetry (LSA) Polar Ocean Data System (PODS): Daily, near-real-time and science-quality remote sensing products characterizing Arctic sea ice.
   https://www.star.nesdis.noaa.gov/sod/lsa/SeaIce/DataProducts/products_SeaIce.php
   ftp://ftp.star.nesdis.noaa.gov/pub/socd/lsa/SeaIceProducts/Airborne/

PRESENTATIONS

1. **Farrell, S. L., K. Duncan, E. M. Buckley**, C. Jackson and the ICESat-2 Science Team (2019), Exploring the Potential for ICESat-2 Observations to Advance Prediction of Arctic Sea Ice, 2019 *Fall Meeting, AGU*, San Francisco, CA. [**Invited**]
2. **Farrell, S. L., K. Duncan,** C. Jackson, L. N. Connor, J. Richter-Menge, S. Hendricks, R. Ricker, and the ICE-Sat-2 Science Team (2019), From ICESat to ICESat-2 via IceBridge: New Insights into a Changing Sea Ice Cover, 2019 *Fall Meeting, AGU*, San Francisco, CA. [**Invited**]
3. **Duncan, K. and S. L. Farrell** (2019), Analysis of Arctic Sea Ice Pressure Ridges from ICESat-2, CISESS Annual Science Meeting, University of Maryland, College Park, MD, November 2019.
4. Kern, M., **Farrell, S. L**., et al. (2019), Overview and Status of the Copernicus Polar Ice and Snow Topography Altimeter (CRISTAL) Mission, *Ocean Surface Topography Science Team Meeting* 2019, Chicago, IL, 21-25 October 2019
5. **Farrell, S. L**. (2019), Assessment of ICESat-2 Performance over the Arctic Ocean During its First Year in Orbit*, Ocean Surface Topography Science Team* 2019, Chicago, IL, 21-25 October 2019
6. **Farrell, S. L**. (2019), ICESat-2 Sea Ice Update*, Copernicus Polar Ice and Snow Topographic Mission Advisory Group Meeting*, ESA/ESTEC, The Netherlands, 8-9 October 2019
7. **Farrell, S. L.** (2019), Advances in Satellite and Airborne Altimetry over Arctic Sea Ice – Towards Improved Prediction, NOAA Center for Satellite Applications and Research (*STAR) Science Seminar Series,* NOAA Center for Weather and Climate Prediction, College Park, MD, USA, 11 September 2019. [**Invited**]
8. **Farrell, S. L., E. Buckley, K. Duncan**, N. Kurtz, R. Kwok, S. Hendricks, H. Skourup, T. G. D. Casal (2019), Early Assessment of ICESat-2 Capabilities for Arctic Sea Ice, *IGS Sea Ice Symposium*, Winnipeg, Mani-toba, Canada, 18-23 August 2019
9. **Farrell, S. L.** (2019), ICESat-2 Status Update - Incorporating Photon Counting Altimetry in your Sea Ice Research, presentation to the US Interagency Arctic Research Policy Committee (IARPC) *Sea Ice Collaboration Team*, 24 June 2019
10. **Farrell, S. L.** (2019), ICESat-2 Update, *Copernicus Polar Ice and Snow Topographic Mission Advisory Group Meeting*, ESA/ESTEC, The Netherlands, 17-18 June 2019
11. **Farrell, S. L., K. Duncan, E. Buckley**, C. Jackson, and L. Connor (2019), Sea Ice Geophysical Processes - New Insights from Airborne and Satellite Remote Sensing, *ESA Living Planet Symposium* 2019, Milan, Italy, 13-17 May 2019
12. **Farrell, S. L**. (2019), NASA ICESat-2 Mission Update, *Copernicus Polar Ice and Snow Topographic Mission Advisory Group Meeting*, ESA/ESTEC, The Netherlands, 2-3 April 2019.

OTHER

SCIENCE TEAMS

1. *NOAA/NESDIS/STAR/SOCD Ocean Remote Sensing Sea Ice And Polar Dynamics Team*: CICS-MD/CISESS Scientists Dr. **Sinéad L. Farrell** and **Kyle Duncan** are members of the NOAA/NESDIS/STAR/SOCD Ocean Remote Sensing Sea Ice and Polar Dynamics Team (SIPD)

2. *Ocean Surface Topography Science Team***:** CICS-MD/CISESS Scientist Dr. **Sinéad L. Farrell** serves as a member of the NOAA/NASA Ocean Surface Topography Science Team (2017-present)

3. *ICESAT-2 Science Team* **:** CICS-MD/CISESS Scientist Dr. **Sinéad L. Farrell** serves as a member of the NASA ICESat-2 Science Team (2012-present)

4. *Copernicus Polar Ice And Snow Topography Altimeter (CRISTAL) Mission Advisory Group***:** CICS-MD/CISESS Scientist Dr. **Sinéad L. Farrell** serves as a member of the Mission Advisory Group (MAG) for the ESA CRISTAL mission (2018-present).

COMMUNITY OUTREACH

CICS-MD/CISESS Scientist Dr. **S. L. Farrell** served as a scientific session co-chair at the American Geophysical Union Fall Meeting 2019, the Ocean Surface Topography Science Team Meeting 2019, and the European Space Agency Living Planet Symposium 2019.

MENTORING, ADVISING, TEACHING

CICS-MD/CISESS Scientist Dr. **Sinéad L. Farrell** mentored graduate student Ms. **Ellen Buckley** at the Dept. Atmospheric & Oceanic Science, University of Maryland, in collaboration with CICS-MD/CISESS

CISESS UNH MULTI-SENSOR AIR-SEA INTERACTION STUDIES USING THE SATELLITE ALTIMETER CONSTELLATION WITH ADDITIONAL WORK TO HELP DEVELOP FULLY-FOCUSED SAR ALTIMETRY FOR OCEANOGRAPHIC APPLICATIONS

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BACKGROUND

As part of extensive past research in wind, wave, and sea state bias (SSB) correction measurements using satellite altimetry, our group at UNH brings significant data tools to bear for this study sea state, surface radar backscatter and SSB models for the delay Doppler altimeters of Cryo-Sat and Sentinel 3. We have previously helped to develop and formalize non-parametric methods for operational empirical sea state bias solutions and their validation for pulse-limited altimetry (Tran et al., 2010; Feng et al, 2010). This includes three-input SSB correction models that include use of ancillary global ocean wave model data shown to clearly improve performance and that can only be produced using sea level anomaly averaging approaches rather than crossovers or collinear methods employed so far for standard 2D-input models.

This project has several goals tied to improved and expanded use of the delay Doppler (SAR) altimeters in collaboration with CICS PI A. Egido. We intend to 1) investigate how ocean swell directionality with respect to a SAR altimeter ground track impacts the form or the application of the sea state range bias corrections, and the implications of this in the consistency between Low Resolution Mode (LRM) and SAR altimetry for the Jason-CS mission. Another goal is to 2) help identify new higher-resolution altimeter capabilities on the ocean such as the ability to better resolve narrow coastal currents and fronts using SAR altimetry. This work will be focused on use of high-resolution FF-SAR processed data provided by CICS PI A. Egido to better characterize the wave field and assist in the re-tracking and SSB correction. Separate from this FF-SAR work, but also part of our overall project under this funding, we are working to 3) apply these new data along with past altimeter datasets to improve on the capability of altimeters to resolve slicks on the ocean surface, prevalent in low wind situations, and indicative of biological and/or anthropogenic (e.g. microplastics, oil spills) influences. Finally, a fourth focus area is to 4) explore methods that combine radar and radiometers flown on conventional and SAR altimeters with the objective to better detect wave breaking via surface foam measurements.

ACCOMPLISHMENTS

We developed and published a new study (Tran et al., in press) assessing altimeter-derived sea state bias correction error associated with short-wavelength noise due to altimeter retracking issues. The work specifically addressed the fact that noise in sea state (significant wave height) measurements is known to be correlated altimeter range noise, and a strategy must be devised to account for this. Jason-2 and Jason-3 data low-resolution model (LRM) were used to define the problem and propose a correction that significantly improves altimeter range measurement quality at length scales inside of 200 km. We also evaluated this same range noise issue for Sentinel -3 fully focused SAR altimeter data with Co-I A. Egido and found that the S-3 FFSAR product already attenuates this SWH noise contribution and thus such a need for sea state bias adjustments is much less for S-3 data (Feng et al., 2019, Vandemark et al., 2019).

A new evaluation of FF-SAR data application question was detailed in Feng et al. (2019) and Vandemark et al. (2020) using new Sentinel-3 FF-SAR data for the Nova Scotia rand Gulf of Maine region, data

provided by CICEES Co-I A. Egido. The results are quite promising and indicate that the FF-SAR approach is able to both lower range noise and provide more data for the 10 km closest to the US and Maritime Canada coastlines. These improved data then allow us to resolve coastal currents and their time variability that have previously not been possible without SAR altimetry. The specific focus is on the Scotian Shelf and Gulf of Maine coastal currents. A manuscript is in preparation.
We are finalizing new SSB models for J3, Sentinel 3 (SAR mode and Pseudo Low Resolution Mode) , and ALtiKa in advance of SSB work with the FF-SAR datasets.

UNH scientists Vandemark and Feng continued work with Co-I J. Tournadre from IFREMER on a 20 year global assessment of ocean slicks/calm water events based on long-term satellite altimeter data records with latest results presented at the fall 2020 OSTST meeting (Tournadre et al., 2020). This work is, in part, performed in anticipation of new higher-resolution mapping capabilities of these events using fully-focused SAR altimeter data being produced by CICS PI Alejandro Egido. As shown at the 2020 OSTST, we are now working to investigate the possibility that surface biogenic films can be detected using a combination of C and Ku-band backscatter data.

A project team meeting with UMd colleague A. Egido was held in Oct. 2019 during OSTST-Chicago to review progress on S3A altimeter waveform retracking by Egido and the set the agenda for the next year's work.

PLANNED WORK

In year four we will continue to work with CICS PI A. Egido (UMd) to implement the necessary tools to process large volumes of data from SAR altimeters in an efficient way. Specific FY20-21 tasks are:

- Complete a new manuscript using finalized coastal fully-focused S-3A SAR altimeter datasets from A. Egido with a focus on the NW Atlantic shelf where results are being used to derive geostrophic currents for comparison against unfocused SAR and PLRM altimeter datasets as well as gridded GlobCurrent products;
- Receive and evaluate a first global 6 month fully-focused SAR altimeter datasets for S3A from A. Egido to permit sea state bias model training dataset generation that includes merging the new altimeter results with global wave model data for first multi-month trail evaluation subset;
- Complete a new manuscript describing sea state bias differences between Ku- and Ka-band altimeters following on from Vandemark et al. (2019);
- Ongoing work between Vandemark , Feng, and Tournadre at IFREMER on the topic of ocean slick detection using C and Ku-band altimeter backscatter data;
- Preparation of year 4 science studies for the OSTST science team meeting in Oct. 2020;
- Make preparations for support of Sentinel-6 calibration and validation activities (S6VT) on the specific topic of sea state bias.

PUBLICATIONS

PEER REVIEWED:

1. Tran, N., **D. Vandemark**, E. Zaron, P. Thibaut, and N. Picot , Assessing the effects of sea-state related errors on the precision of high-rate Jason-3 altimeter sea level data, *Advances in Space Research*, in press.
2. Gommenginger C, Chapron B, Hogg A, Buckingham C, Fox-Kemper B, Eriksson L, Soulat F, Ubelmann C, Ocampo-Torres F, Buongiorno Nardelli B, Griffin D, Lopez-Dekker P, Knudsen P,

Andersen O, Stenseng L, Stapleton N, Perrie W, Violante-Carvalho N, Schulz-Stellenfleth J, Woolf D, Isern-Fontanet J, Ardhuin F, Klein P, Mouche A, Pascual A, Capet X, Hauser D, Stoffelen A, Morrow R, Aouf L, Breivik Ø, Fu L-L, Johannessen JA, Aksenov Y, Bricheno L, Hirschi J, Martin ACH, Martin AP, Nurser G, Polton J, Wolf J, Johnsen H, Soloviev A, Jacobs GA, Collard F, Groom S, Kudryavtsev V, Wilkin J, Navarro V, Babanin A, Martin M, Siddorn J, Saulter A, Rippeth T, Emery B, Maximenko N, Romeiser R, Graber H, Alvera Azcarate A, Hughes CW, **Vandemark D**, da Silva J, Van Leeuwen PJ, Naveira-Garabato A, Gemmrich J, Mahadevan A, Marquez J, Munro Y, Doody S and Burbidge G (2019) SEASTAR: A Mission to Study Ocean Submesoscale Dynamics and Small-Scale Atmosphere-Ocean Processes in Coastal, Shelf and Polar Seas. *Front. Mar. Sci.* 6:457. doi: 10.3389/fmars.2019.00457

3. Cronin MF, Gentemann CL, Edson J, Ueki I, Bourassa M, Brown S, Clayson CA, Fairall CW, Farrar JT, Gille ST, Gulev S, Josey SA, Kato S, Katsumata M, Kent E, Krug M, Minnett PJ, Parfitt R, Pinker RT, Stackhouse PW Jr, Swart S, Tomita H, **Vandemark D**, Weller RA, Yoneyama K, Yu L and Zhang D (2019) Air-Sea Fluxes With a Focus on Heat and Momentum. *Front. Mar. Sci.* 6:430. doi: 10.3389/fmars.2019.00430

NON-PEER REVIEWED:

4. **Vandemark, D**., Feng, H., A. Egido, and J. Wilkin, Assessment and application of Sentinel-3 fully-focused SAR altimeter data: enhanced detection of coastal currents along the Northwest Atlantic shelf, 12th Intl. *Coastal Altimetry Workshop*, Frascati, Feb. 2020.
5. Tran, N., P. Thibaut, G. Dibarboure, F. Boy, N. Picot, **D. Vandemark**, Reducing the high frequency noise in Jason-3 and Sentinel-3 significant wave height data*, NASA Ocean Surface Topography Science Team Meeting*, Chicago, Oct. 2019.
6. **Vandemark, D**., H. Feng, N. Tran, and B. Chapron, Evaluation of Ku- and Ka-band sea state bias variability using Jason-3 and ALtiKa data, *NASA Ocean Surface Topography Science Team Meeting*, Chicago, Oct. 2019.
7. Feng, H., **D. Vandemark**, N. Tran, and S. Desai, Sea state bias for TOPEX side B retracked altimeter data, *NASA Ocean Surface Topography Science Team Meeting*, Chicago, Oct. 2019.
8. Feng, H., A. Egido, and **D. Vandemark**, Exploring the potential of Sentinel-3 fully-focused SAR altimeter range data for enhanced detection of coastal currents on the Northwestern Atlantic shelf, *NASA Ocean Surface Topography Science Team Meeting*, Chicago, Oct. 2019.
9. Tournadre, J. and **D. Vandemark**, Surface films: is it possible to detect then using Ku/C band sigma0 relationships, *NASA Ocean Surface Topography Science Team Meeting*, Chicago, Oct. 2019.

PRODUCTS

1. A TOPEX side B altimeter seas state bias model was produced as two and three input look up tables and provided to team collaborators at NASA JPL (see Feng et al., 2019). This product is available from the PI upon request.

PRESENTATIONS

1. Tournadre, J. and **D. Vandemark**, Surface films: is it possible to detect then using Ku/C band sigma0 relationships, Invited Talk, NASA Ocean Surface Topography Science Team Meeting, Chicago, Oct. 2019.
2. **Vandemark, D**., Feng, H., A. Egido, and J. Wilkin, Assessment and application of Sentinel-3 fully-focused SAR altimeter data: enhanced detection of coastal currents along the Northwest Atlantic shelf, 12th Intl. Coastal Altimetry Workshop, Frascati, Feb. 2020.

APPENDIX: CISESS PROJECT SLIDES

This report includes two single slide summaries of the accomplishments of:

- Sinéad L. Farrell and
- Douglas Vandemark, UNH

You can download these slides in PowerPoint from the CISESS DropBox:
https://www.dropbox.com/sh/p5u5jw22tq6h36q/AAByBJ2XiGHMCIYJ7I8yfaz2a?dl=0