Seasonal Ice Zone Reconnaissance Surveys for Aircraft-Based Eulerian and Lagrangian Sampling of a Changing Arctic

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Abstract

Seasonal Ice Zone Reconnaissance Surveys (SIZRS) is a multi-investigator program of repeated ocean, ice, and atmospheric measurements. These measurements make use of U.S. Coast Guard flights across the Beaufort-Chukchi Sea seasonal sea ice zone (SIZ), the region between maximum winter ice extent and minimum summer ice extent. The long-term goal of SIZRS is to track and understand the interplay among the ice, atmosphere, and ocean, contributing to the rapid decline in summer ice extent. The fundamental SIZRS approach is to make monthly flights, June to October, with US Coast Guard Air Station Kodiak C-130s across the Beaufort Sea SIZ along 150°W from 72°N to 76°N or ˜ 1 degree of latitude north of the ice edge, whichever is farther north. We make oceanography stations every degree of latitude by dropping Aircraft eXpendable CTDs (AXCTDs) and Aircraft eXpendable Current Profilers (AXCPs) typically while traveling northbound (PI: J. Morison). On the return leg, we drop atmospheric dropsondes from 3000 meters altitude to measure atmospheric temperature, humidity, and winds (PI: A. Schweiger). We also drop UpTempO drifting buoys that report time series of ocean temperature profiles (PI: M. Steele) and various meteorology and ice-tracking buoys of the International Arctic Buoy Program (IABP, PI: I. Rigor).

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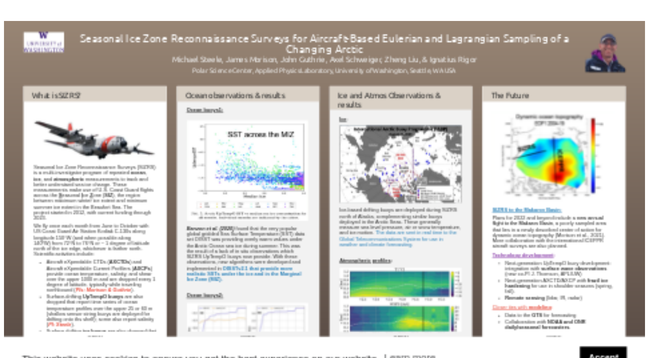

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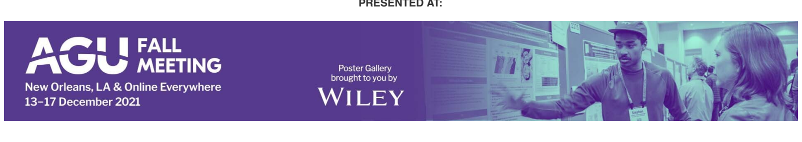


WHAT IS SIZRS?

Seasonal Ice Zone Reconnaissance Surveys (SIZRS) is a multi-investigator program of repeated **ocean**, **ice**, and **atmospheric** measurements to track and better understand sea ice change. These measurements make use of U.S. Coast Guard flights across the **S**easonal **I**ce **Z**one (**SIZ**), the region between maximum winter ice extent and minimum summer ice extent in the Beaufort Sea. The project started in 2012, with current funding through 2023.

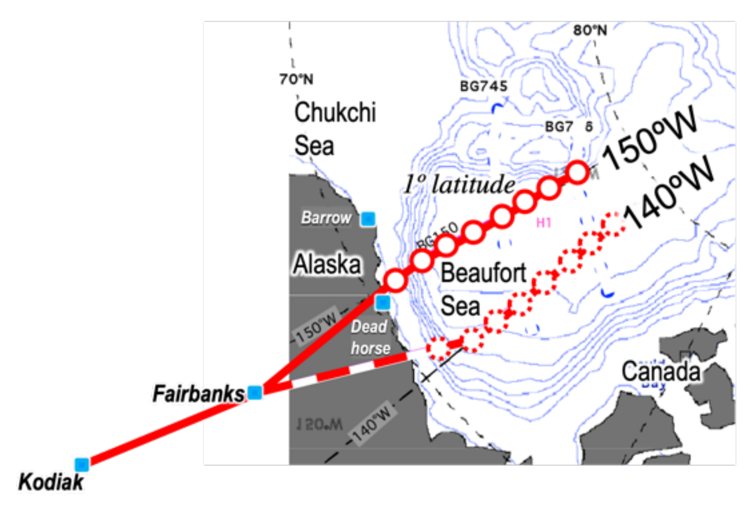
We fly once each month from June to October with US Coast Guard Air Station Kodiak C-130s along longitude 150°W (and when possible along 140°W) from 72°N to 76°N or ~ 1 degree of latitude north of the ice edge, whichever is farther north. Scientific activities include:

- Aircraft eXpendable CTDs (**AXCTDs**) and Aircraft eXpendable Current Profilers (**AXCPs**) provide ocean temperature, salinity, and shear over the upper 1000 m and are dropped every 1 degree of latitude, typically while traveling northbound (***PIs: Morison & Guthrie***).
- Surface-drifting **UpTempO buoys** are also dropped that report time series of ocean temperature profiles over the upper 25 or 60 m (shallow sensor string buoys are deployed for drifting onto ths shelf); some also report salinity (***PI: Steele***).
- Surface-drifting **ice buoys** are also dropped that provide surface meteorological variables and ice motion (***PI: Rigor***).
- On the return leg, we drop **atmospheric dropsondes** from 3000 meters altitude to measure atmospheric temperature, humidity, and winds (***PIs: Schweiger & Liu***).

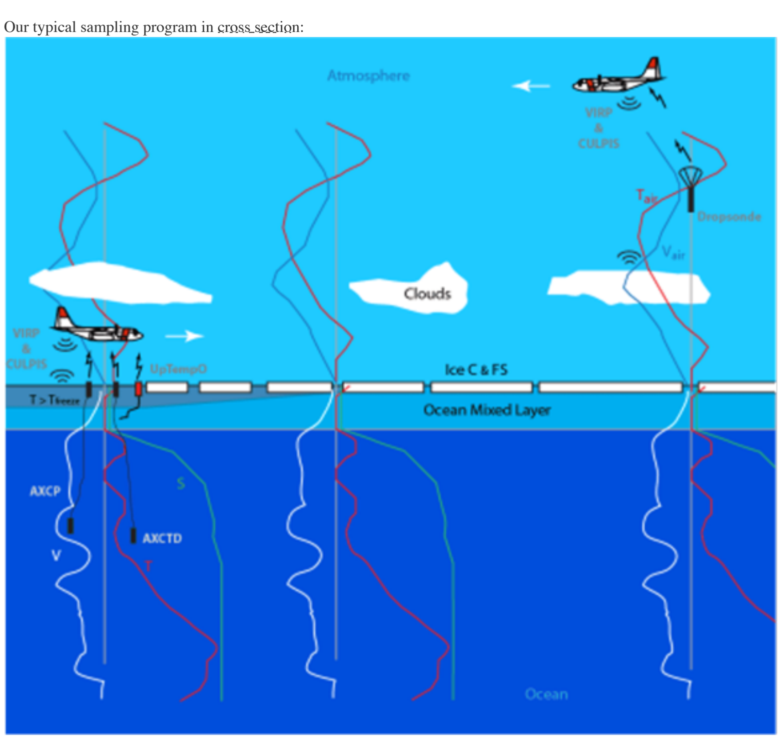
Science support is provided by PSC/APL/UW field engineers **R. Andersen** and **J. Johnson**. We fly in collaboration with other projects, e.g.

- Deployment of expendable ocean profilers via NOAA/PMEL's Arctic Heat project (***PIs: K. Wood & S. Jayne***).
- Atmospheric gas sampling via NOAA/ESRL (***PI: S. Wolter***).

Our typical sampling program in plan view:



Our typical sampling program in cross section:



OCEAN OBSERVATIONS & RESULTS

Ocean buoys1:

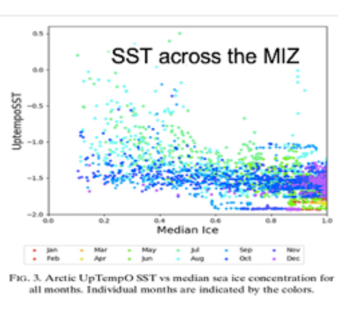
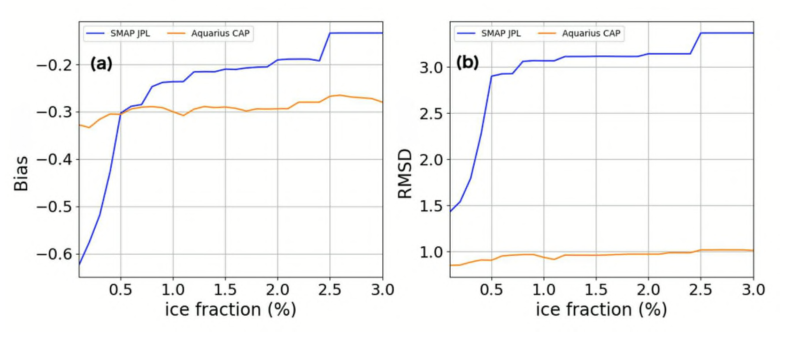


FIG. 3. Arctic UpTempO SST vs median sea ice concentration for all months. Individual months are indicated by the colors.

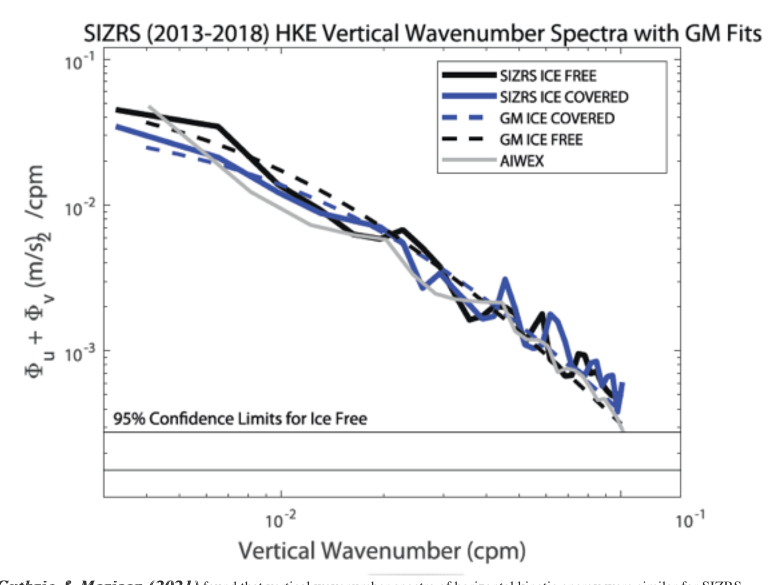
Banzon et al. (2020) found that the very popular global gridded Sea Surface Temperature (SST) data set OISST was providing overly warm values under the Arctic Ocean sea ice during summer. This was the result of a lack of in situ observations which SIZRS UpTempO buoys now provide. With these observations, new algorithms were developed and implemented in **OISSTv2.1 that provide more realistic SSTs under the ice and in the Marginal Ice Zone (MIZ).**

Ocean buoys2:



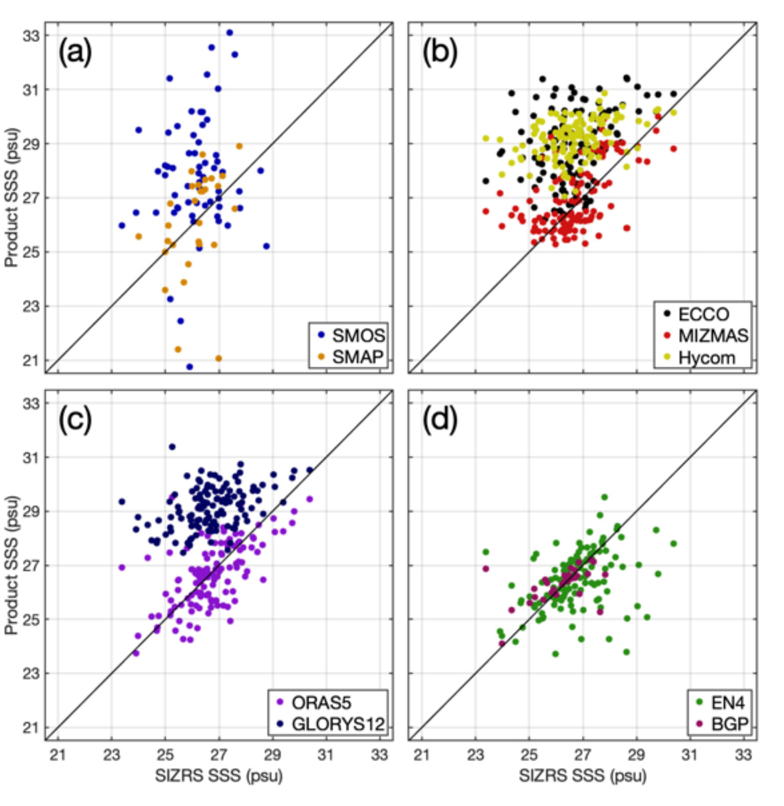
Fournier et al. (2019) found that satellite-derived sea surface salinity (SSS) bias and error relative to in situ observations (including SIZRS UpTempO buoys) increased at even very small sea ice concentrations (< 3%). However, ***Tang et al. (2021)*** have **developed a new algorithm that holds promise for increasing the accuracy of satellite SSS closer to the ice edge**.

Ocean profiling1:



Guthrie & Morison (2021) found that vertical wavenumber spectra of horizontal kinetic energy were similar for SIZRS (2012-present) and AIWEX (1985) data, indicating that subsurface internal wave energy has not declined in recent years. They found that the main reason for low internal wave energy was NOT declining sea ice, but rather the thin surface mixed layer and the low value of planetary beta (the meridional gradient of the Coriolis parameter). Further, surface stratification is expected to increase in the future owing to an enhanced global hydrologic cycle, while beta is fixed. Thus, **internal wave energy in the Arctic Ocean is expected to remain low in the future, even as the sea ice cover declines**.

Ocean profiling2:



Hall et al. (2021) compared sea surface salinity from satellite, model, ocean reanalysis, and observed gridded hydrographic data sets with SIZRS AXCTD 5 m salinity. While some correlations were very good, **more work is clearly needed to validate these data sets**.

References:

Banzon, V., T.M. Smith, M. Steele, B. Huang, and H. Zhang, Improved Estimation of Proxy Sea Surface Temperature in the Arctic. J. Atmos. Oceanic Technol., 37, 341–349, https://doi.org/10.1175/JTECH-D-19-0177.1, 2020.

Fournier, S.; Lee, T.; Tang, W.; Steele, M.; Olmedo, E. Evaluation and Intercomparison of SMOS, Aquarius, and SMAP Sea Surface Salinity Products in the Arctic Ocean. Remote Sens., 11, 3043. https://doi.org/10.3390/rs11243043, 2019.

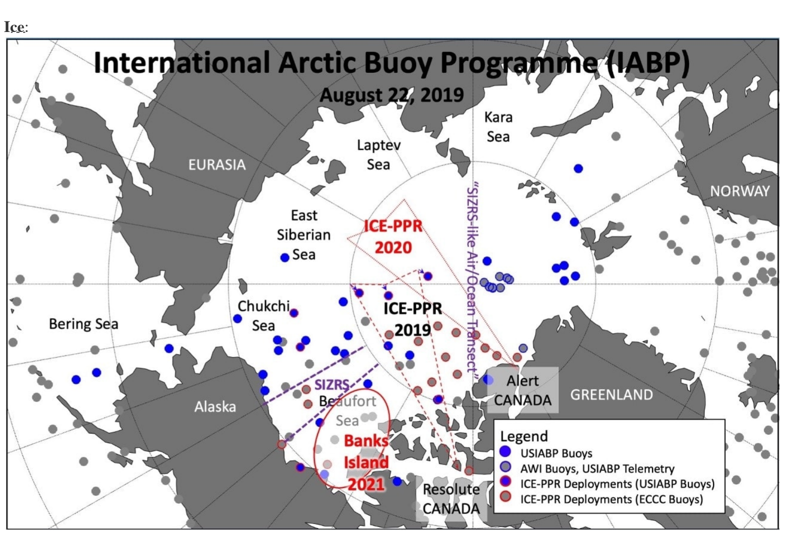
Guthrie, J. D., & Morison, J. H. Not just sea ice: Other factors important to near-inertial wave generation in the Arctic Ocean. Geophysical Research Letters, 48, e2020GL090508. https://doi.org/10.1029/2020GL090508, 2021.

Hall, S.B.; Subrahmanyam, B.; Morison, J. H. Intercomparison of Salinity Products in the Beaufort Gyre. Remote Sens (in review), 2021.

Tang, W., S. H. Yueh, A. G. Fore, A. Hayashi and M. Steele, "An Empirical Algorithm for Mitigating the Sea Ice Effect in SMAP Radiometer for Sea Surface Salinity Retrieval in the Arctic Seas," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 11986-11997, doi: 10.1109/JSTARS.2021.3127470, 2021.

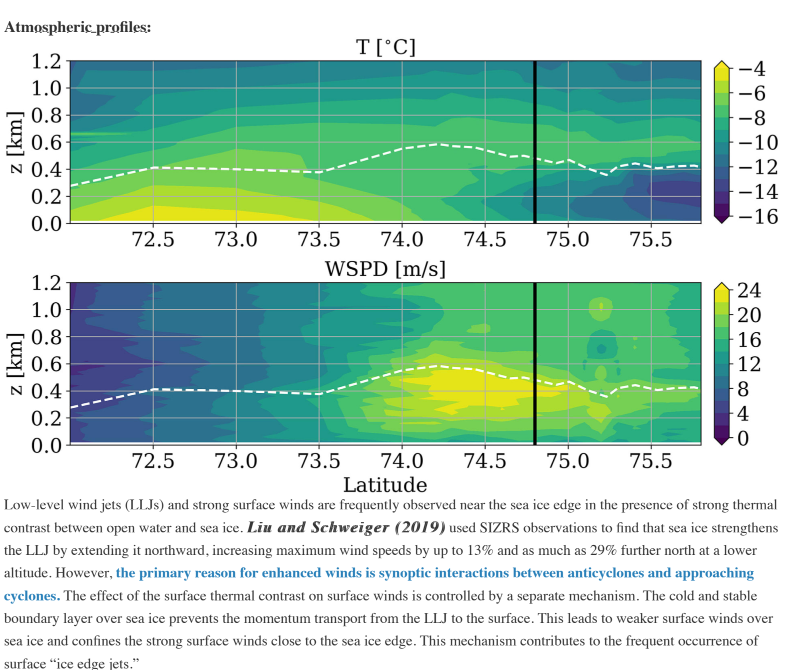
ICE AND ATMOS OBSERVATIONS & RESULTS

Ice:



Ice-based drifting buoys are deployed during SIZRS north of Alaska, complementing similar buoys deployed in the Arctic Seas. These generally measure sea level pressure, air or snow temperature, and ice motion. The data are sent in real time to the Global Telecommunications System for use in weather and climate forecasting.

Atmospheric profiles:

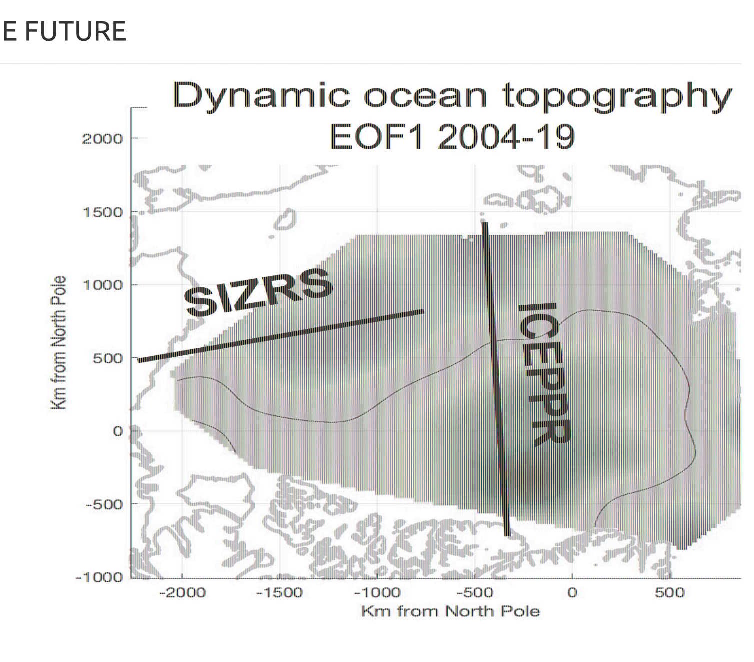


Low-level wind jets (LLJs) and strong surface winds are frequently observed near the sea ice edge in the presence of strong thermal contrast between open water and sea ice. ***Liu and Schweiger (2019)*** used SIZRS observations to find that sea ice strengthens the LLJ by extending it northward, increasing maximum wind speeds by up to 13% and as much as 29% further north at a lower altitude. However, **the primary reason for enhanced winds is synoptic interactions between anticyclones and approaching cyclones.** The effect of the surface thermal contrast on surface winds is controlled by a separate mechanism. The cold and stable boundary layer over sea ice prevents the momentum transport from the LLJ to the surface. This leads to weaker surface winds over sea ice and confines the strong surface winds close to the sea ice edge. This mechanism contributes to the frequent occurrence of surface "ice edge jets."

References:

Liu, Z., & Schweiger, A. (2019). Low-level and surface wind jets near sea ice edge in the Beaufort Sea in late autumn. Journal of Geophysical Research: Atmospheres, 124, 6873– 6891. https://doi.org/10.1029/2018JD029770

THE FUTURE



SIZRS to the Makarov Basin:

Plans for 2022 and beyond include a new annual flight to the Makarov Basin, a poorly sampled area that lies in a newly described center of action for dynamic ocean topography (Morison et al., 2021). More collaboration with the international ICEPPR aircraft surveys are also planned.

Technology development:

- Next-generation UpTempO buoy development: integration with **surface wave observations** (new co-PI J. Thomson, APL/UW)
- Next-generation AXCTD/AXCP with **frazil ice hardening** for use in shoulder seasons (spring, fall).
- **Remote sensing** (lidar, IR, radar)

Closer ties with **modeling**:

- Data to the **GTS** for forecasting
- Collaboration with **NOAA and ONR daily/seasonal forecasters**.

Closer ties with **satellite and UAV remote sensing**:

- **ICESat-2** underflights
- **Oliktok Point** overflights

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Questions? Mike Steele: mas@apl.washington.edu

phone 1 (206) 302-8129

References:

Morison, J., Kwok, R., Dickinson, S., Andersen, R., Peralta-Ferriz, C., Morison, D., Rigor, I., Dewey, S., & Guthrie, J. (2021). The Cyclonic Mode of Arctic Ocean Circulation, Journal of Physical Oceanography, 51(4), 1053-1075. Retrieved Dec 15, 2021, from https://journals.ametsoc.org/view/journals/phoc/51/4/JPO-D-20-0190.1.xml

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