***Exxon Valdez* Oil Spill Trustee Council**

Long-Term Research and Monitoring, Mariculture, Education and Outreach

Annual Project Reporting Form

Project Number: 24120114-I

Project Title: Oceanographic station GAK-1 long term monitoring of the Alaska Coastal Current

Principal Investigator(s): Seth L. Danielson

Reporting Period: February 1, 2024 – January 31, 2025

Submission Date (Due March 1 immediately following the reporting period): March 23, 2025

Project Websites:

- https://gulfwatchalaska.org/
- http://research.cfos.uaf.edu/gak1/

Please check all the boxes that apply to the current reporting period.

☒ **Project progress is on schedule.**

☐ **Project progress is delayed**

☐ **Budget reallocation request.**

☐ **Personnel changes.**

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1. Summary of Work Performed:

The GAK-1 project logged numerous successes in FY24 including the May 2024 recovery of the 2023 GAK-1 mooring (Fig. 1) and its redeployment. We recovered data from all mooring sensor deployment depths (nominal depths of 20, 30, 60, 100, 150, 200, and 250 m). A programming error resulted in only a partial dataset being collected by the 250 m conductivity-temperature-depth (CTD) datalogger, but a full data record at that depth was salvaged because the University of Alaska Fairbanks' (UAF's) Ocean Acidification Research Center (OARC) had also deployed an instrument near to that depth level and kindly made the data available to us. We also collected CTD profiles from R/V *Nanuq* and R/V *Sikuliaq*. During this reporting period we also undertook a major revision to our data processing flow and have redistributed some of the workload, allowing us to more quickly update the GAK1 time series for public and agency use.

As part of the Gulf Watch Alaska Long-Term Research and Monitoring (GWA-LTRM) data synthesis efforts, over the 2024-2024 fall and winter we have moved two major data analyses forward. The first is the GWA-LTRM salinity synthesis, undertaken by principal investigator (PI) Danielson and Dr. Tyler Hennon of UAF. The second is a GAK-1 time series reanalysis that assesses thermal and haline variability across the entire length of the 55-year time series. This effort examines trends, seasonality, seasonality of trends, and the relationship between wind forcing and coastal conditions.

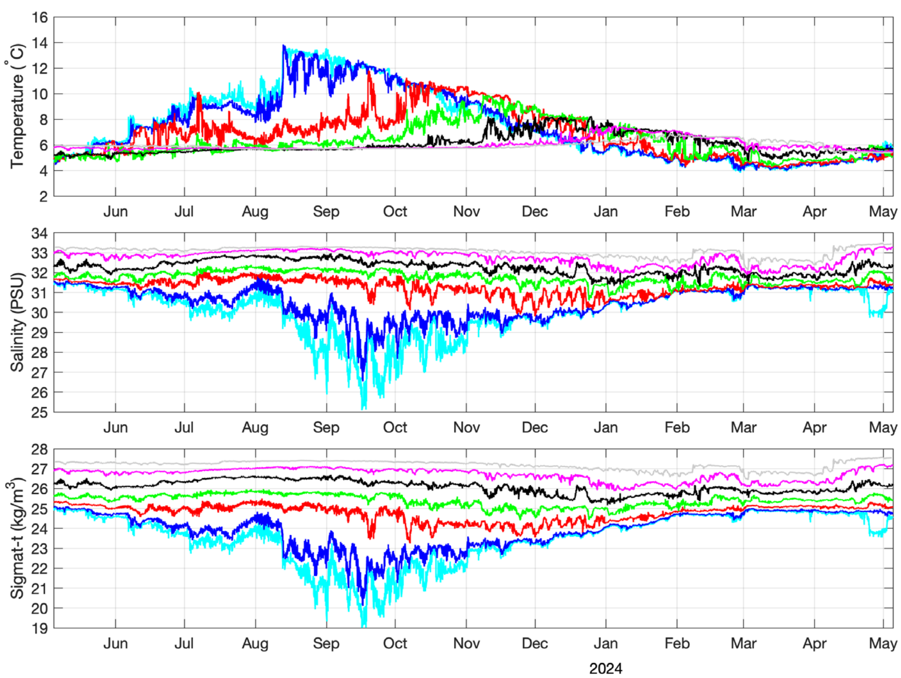

Figure 1. Data records from the 2023-2024 deployment of the GAK-1 mooring, with temperature (top), salinity (middle) and density (bottom). Colors denote different instrument depths, with the 2023 sensors winding up near 19 m (cyan), 32 m (blue), 62 m (red), 102 m (green), 153 m (black), 204 m (magenta) and 254 m (gray).

Both monthly anomalies and annual averages of the monthly salinity anomaly recorded at coastal station GAK-1 show opposite trends in the near-surface and near-bottom layers (Figs. 2 and 3). The trends account for only about 10% of the total variance, but both are significant at the 95% confidence level. In the surface layer, waters are freshening ($p \sim 0.01$) at a rate of -0.06 (monthly anomalies) to -0.04 (annual averages) per decade and near the seafloor the rate of salinization is +0.035 to 0.040 per decade. The annual trends exist even with the inclusion of two potential outliers in the salinity data record that potentially suffer from having only two months sampled during the calendar year. These stand out as the largest positive anomaly for near-surface waters in 1981 and the largest negative anomaly in near-bottom water in 1985 (Fig. 2). New analyses show that the record-length trends exhibit seasonality, with near-bottom changes in both temperature and salinity largest in winter and spring, respectively (Fig. 4).

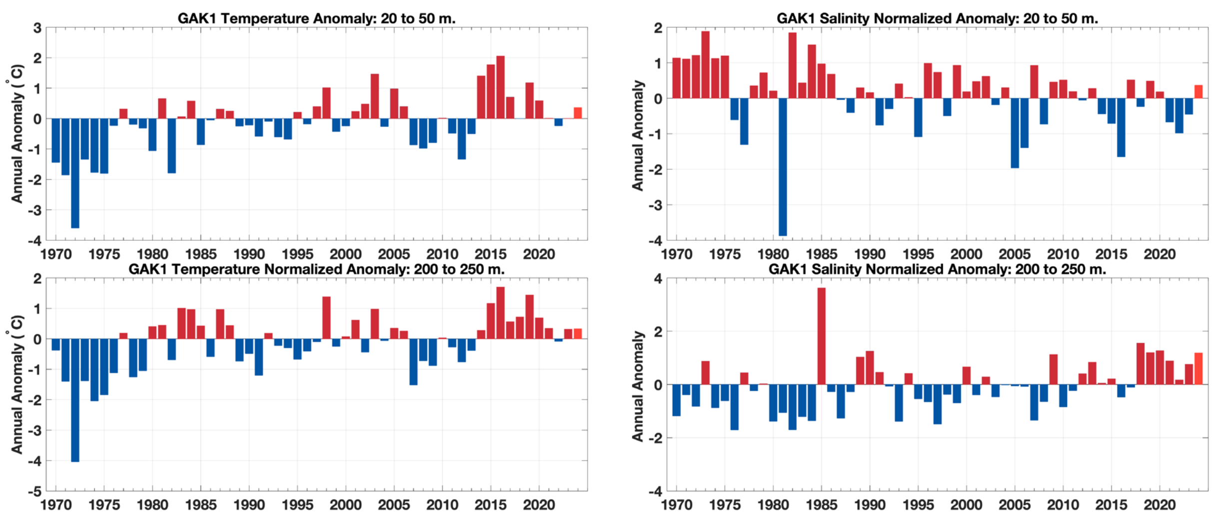

Figure 2. Annual averages over 1970 to 2024 of the GAK-1 monthly temperature (left) and salinity anomaly (right) for near surface (20-50 m, top) and near bottom (200-250 m, bottom) depth layers. Years with fewer than three months sampled are 1981 and 1985.

To diagnose the near-bottom salinization trend observed at the coast, we examined factors that could contribute to such a signal, noting that freshening waters at the surface would increase water column stratification and decrease depth to which wind mixing would penetrate. It is possible that the surface freshening in and of itself is the major driver of increasing bottom salinity.

First, we checked to see whether we could identify the spatial extent of any such increase. Depth-distance analyses of salinity anomaly trends in May and September along the Seward Line do not show large regions of significant trends, but there are weak indications of spatial structure within that suggest distinct realms of both increasing and declining salinities. The strongest significance and largest region of statistically significant increasing salinity is observed at depth over the inner shelf in May, possibly suggesting that the subsurface salinization emanates from the coastal region. Salinization at this time of year is consistent with analyses (Danielson et al. in prep) that suggest near-bottom properties on the inner shelf are set in mid-winter. Freshening waters in the upper 75 m of the water column over the continental slope are found in both May and September agree with Gulf of Alaska basin salinities observed at Ocean Station PAPA (50.1°N, 144.9°W) where the surface magnitude of freshening is in the range of 0.01-0.04 per decade (Freeland and Whitney 2014).

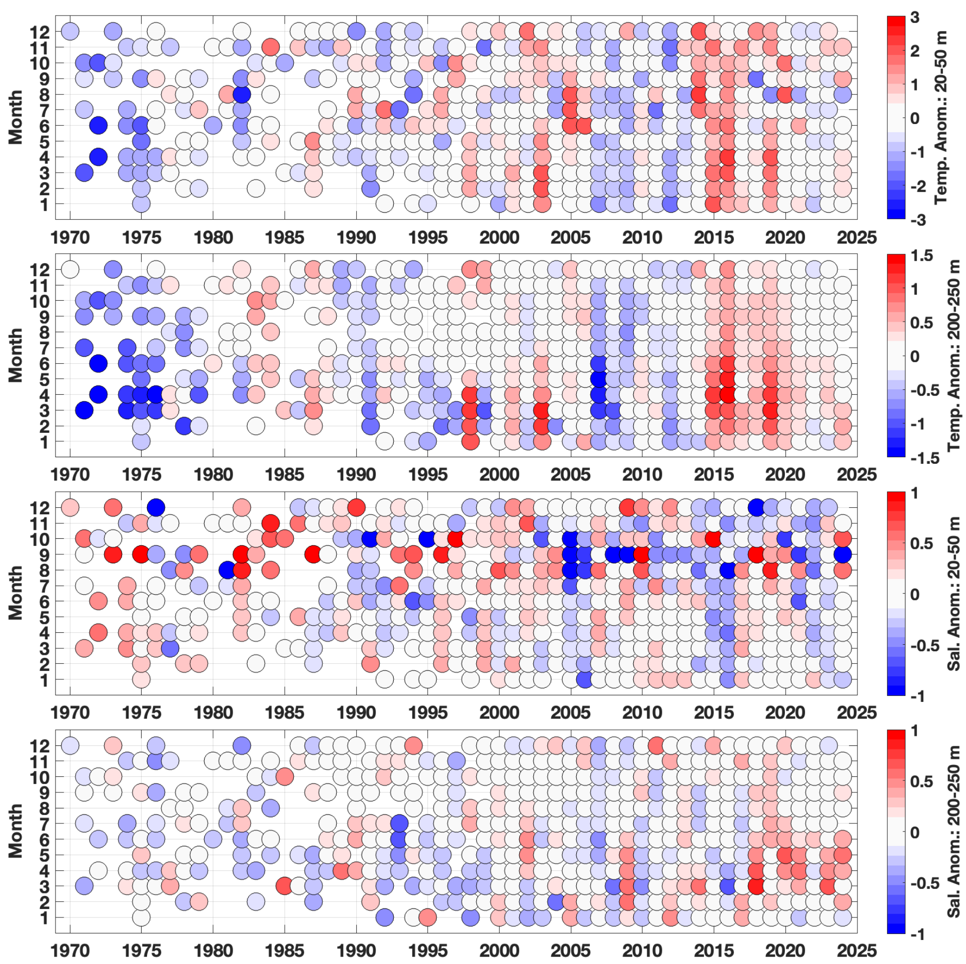

Figure 3. Monthly anomalies of temperature (top two panels) and salinity (bottom two panels) for near surface and near seafloor depth layers over 1970 to 2024, as marked. Note different color scale ranges for the temperature panels.

Finally, we examined the wind field for possible evidence in changes that might explain the salinity trends. Rallu De Malibran et al. (2024) identify an increase of upwelling events and decline of slope/basin mesoscale activity following the 2013 onset of a series of marine heat waves in the Gulf of Alaska. Based on their regime shift timing we differenced the annual mean average wind speed and annual mean average wind speed cube data before and after 2013. Examination of the ERA5 wind field revealed that both the wind speed and the wind speed cubed (the latter is a measure of wind mixing energy) both exhibited a small (up to 0.2 m s^{-1} and 60 m^3 s^{-3}, respectively) but statistically significant decline over the years of the Seward Line sampling. The extent of the significant decline is limited to the coastal zone of the northern Gulf of Alaska (NGA), from land southward to about latitude 59.5ºN between longitudes 150ºW and 141ºW (Fig. 5). The tendency of decreasing winds extends as far south as British Columbia, but the only extended area showing a significant trend is along the coastal NGA near Prince William Sound. This analysis suggests that coastal downwelling over this time period has also modestly decreased, potentially decelerating the Alaska Current and the Alaska Coastal Current. A decline in surface wind mixing could also be partly responsible for the surface freshening trend, but it would not directly account for any change in freshwater inventory.

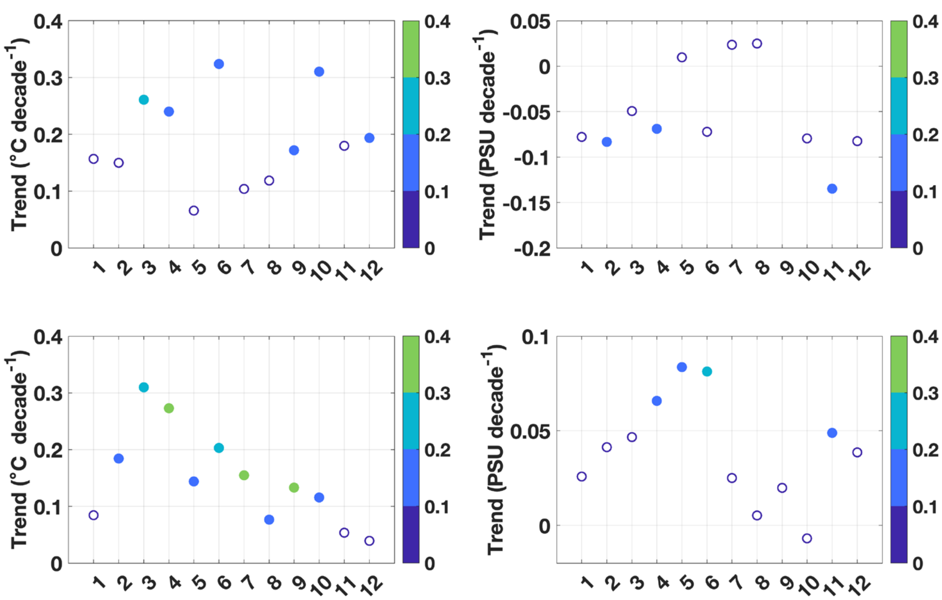

Figure 4. Seasonality of trends in temperature (left) and salinity (right) for the 0-50 m (top) and 200-250 m (bottom) depth layers. Colors denote the r2 value for the linear fit; filled circles denote significant trends ($p < 0.05$). Note different axis scaling amongst the panels.

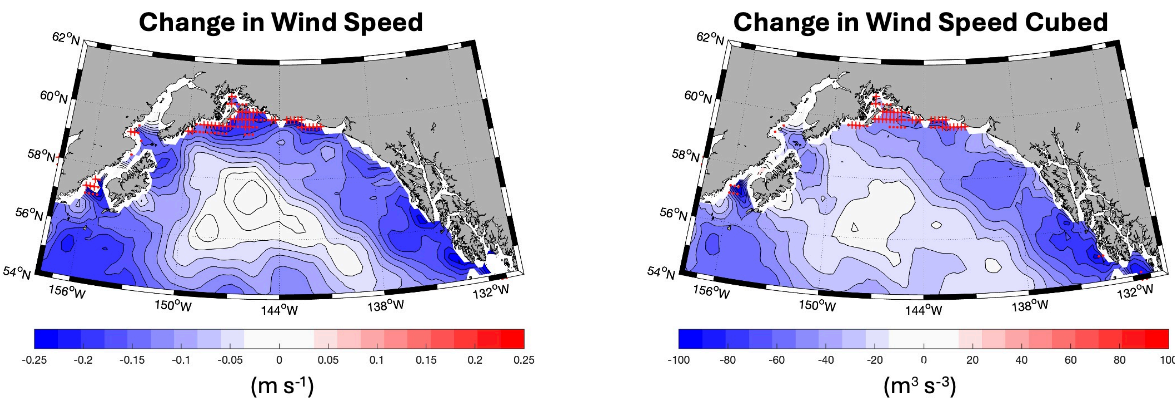

Figure 5. Northern Gulf of Alaska wind field tendency for change over 1997-2023 as resolved by the ERA5 reanalysis. Contours depict differences for mean annual wind speed (left, m s^{-1}) and mean annual wind speed cubed (right, m^3 s^{-3}). For each parameter, averages for 1997 to 2012 are subtracted from the averages of 2013 to 2023; negative values denote a decrease in the latter time interval. Red plus symbols (+) denote linear trends over the whole 24 years that are significant ($p < 0.05$) and red dots (.) depict trends that are weakly significant ($p < 0.10$).

Interestingly, it seems that freshwater is not accumulating in the nearshore zone, despite documented freshening in the North Pacific and net glacial ablation. Instead, it appears that the Alaska Coastal Current represents a leaky boundary and that coastal freshwater anomalies quickly disperse offshore to the mid and outer shelf region, and perhaps beyond to the deep basin.

Our analysis suggests that a combination of factors is responsible for the near-seafloor salinization at station GAK-1. Glacial meltwaters contribute to salinity stratification by adding ever more freshwater to the NGA system. Surface freshening increases stratification, increasing the amount of energy required to mix surface waters downward. In addition, downwelling-favorable wind stress has modestly decreased in the NGA coastal zone. It is clear that the observed changes in environmental forcings are altering the marine environment within which the NGA biological pump operates.

To further diagnose the relationship between wind forcing and hydrographic responses, we compute zero-lag correlations between the along-shore wind component and monthly anomalies of the thermohaline structure at GAK-1 (Fig. 6). This analysis clearly shows how downwelling winds regulate coastal conditions. A negative correlation in temperature shows that strongly downwelling wind (blowing to the west) in fall and winter drive warmer water temperatures, while a positive correlation in salinity shows that more downwelling tends to freshen the entire water column (Fig. 6). The wind-salinity relation tends to break down in summer months, with a slight (but not significant) tendency for inverse correlation near the surface at this time of year. Positive anomalies in temperature at depth in the summer may be related to cross-shelf flows at depth.

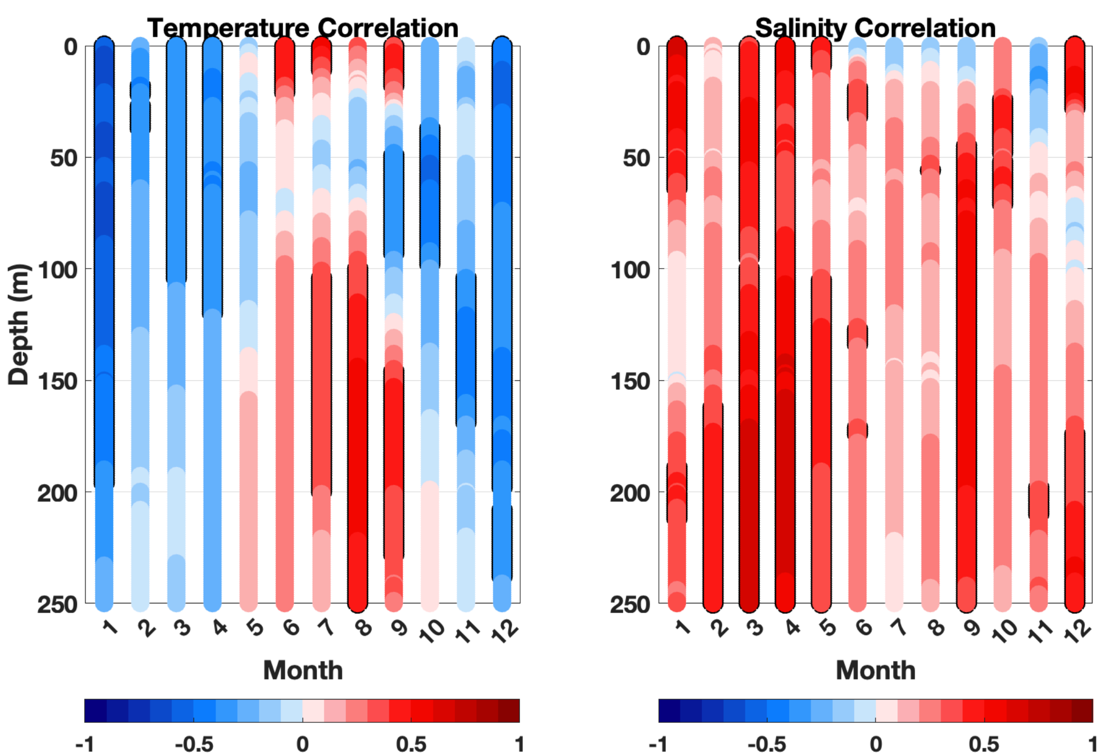

Figure 6. Zonal winds (U10; averaged over the month of the conductivity-temperature-depth observations and the month prior) projected on the monthly profiles of temperature (left) and salinity (right). Colors denote the magnitude of the correlation coefficient at zero lag.

Our ongoing reanalysis shows that the GAK-1 time series now has the statistical power to reveal associations between forcings and responses that have been previously hypothesized but never demonstrated with such clarity and statistical rigor. Modern reanalysis models help the effort by providing relatively high-resolution hindcast data that are necessary for these efforts.

Literature cited:

Danielson, S. L, T. D. Hennon, A. Aguilar Islas, I. Reister, and R. A. Potter. In prep. Salinity structure, drivers, and time variability in the Northern Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Synthesis Report. *Exxon Valdez* Oil Spill Trustee Council Program 24120114. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Freeland, H., and F. Whitney. 2014. Unusual warming in the Gulf of Alaska. PICES Press 22:51-52.

Rallu De Malibran, M. C., C. M. Kaplan, and E. Di Lorenzo. 2024. Marine heatwaves suppress ocean circulation and large vortices in the Gulf of Alaska. Communications Earth and Environment 5:622. https://doi.org/10.1038/s43247-024-01785-x.

2. Products:

<u>*Peer-reviewed publications:*</u>

Almeida, L. Z., B. J. Laurel, H. L. Thalmann, and J. A. Miller. 2024. Warmer, earlier, faster: Cumulative effects of Gulf of Alaska heatwaves on the early life history of Pacific cod. Elementa: Science of the Anthropocene 12:00050.

Miller, J. A., L. Z. Almeida, L. A. Rogers, H. L. Thalmann, R. M. Forney, and B. J. Laurel. 2024. Age, not growth, explains larger body size of Pacific cod larvae during recent marine heatwaves. Scientific Reports 14:19313.

St. John, C.A., L. E. Timm, K. M. Gruenthal, and W. A. Larson. 2025. Whole genome sequencing reveals substantial genetic structure and evidence of local adaptation in Alaskan red king crab. Evolutionary Applications 18:e70049.

Reports:

Danielson, S. L. 2024. Oceanography at the nearshore GAK1 Mooring. Pages 72-73 *in* B. E. Ferriss, editor. Ecosystem Status Report 2024: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, Alaska. https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2024/GOAecosys.pdf.

Danielson, S. L, T. D. Hennon, A. Aguilar Islas, I. Reister, and R. A. Potter. In prep. Salinity structure, drivers, and time variability in the Northern Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Synthesis Report. *Exxon Valdez* Oil Spill Trustee Council Program 24120114. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Danielson, S. L., T. D. Hennon, H. Statscewich, and R. Hopcroft. 2024. Seward Line spring oceanography. Pages 74-76 *in* B. E. Ferriss, editor. Ecosystem Status Report 2024: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, Alaska. https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2024/GOAecosys.pdf.

Hennon, T. D., and S. L. Danielson. 2024. Predicted ocean temperatures in Northern Gulf of Alaska. Pages 40-42 *in* B. E. Ferriss, editor. Ecosystem Status Report 2024: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, Alaska. https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2024/GOAecosys.pdf.

Popular articles:

No new contributions for this reporting period.

Conferences and workshops:

Danielson, S. 2025. Northern Gulf of Alaska Long Term Ecological Research Lightning Talk. Oral presentation, Northern Gulf of Alaska Long Term Ecological Research All-Hands Meeting, Fairbanks, Alaska, March.

Danielson, S. 2025. Northern Gulf of Alaska Long Term Ecological Research Data Nuggets Presentation. Online presentation to Northern Gulf of Alaska Long Term Ecological Research team and collaborators, February.

Danielson, S. 2024. GAK1 project updates. Online presentation, *Exxon Valdez* Oil Spill Trustee Council Public Advisory Committee Meeting, October.

Danielson, S. L. 2024. Seward Line and oceanographic station GAK1 updates. Online presentation, National Oceanic and Atmospheric Administration Preview of Ecosystem and Economic Conditions, May.

Hennon, T. D., and S. L. Danielson. 2025. Spatiotemporal modes of temperature and salinity variability in the northern Gulf of Alaska. Poster presentation, Alaska Marine Science Symposium, January, Anchorage, Alaska.

Reister, I., S. L. Danielson, T. D. Hennon, H. Statscewich, and K. Ballantine. 2025. Controls of the northern Gulf of Alaska spring bloom over coastal and mid shelf waters. Poster presentation, Alaska Marine Science Symposium, January, Anchorage, Alaska.

Statscewich, H., S. L. Danielson, J. K. Horne, T. B. Kelly, M. Yamane, E. Farley, D. G. Kimmel, and C. W. Mordy. 2025. Extending autonomous underwater glider-based ecosystem monitoring across multiple trophic levels. Oral presentation, Alaska Marine Science Symposium, January, Anchorage, Alaska.

Public presentations:

No new contributions for this reporting period.

Data and/or information products developed during the reporting period:

In association with the GAK-1 and Gulf Watch Alaska salinity synthesis manuscripts, we have generated a new "best combined" monthly CTD and mooring dataset that aggregates all available data into a single monthly gridded dataset. This new data product should make utilization of the GAK-1 dataset even easier for public and scientific applications. It will be published in association with the new (in prep) GAK-1 55-year reanalysis.

Data sets and associated metadata:

Danielson, S. Environmental Drivers: Gulf of Alaska Mooring (GAK1). Gulf of Alaska Datap Portal: https://gulf-of-alaska.portal.aoos.org/#metadata/3c4ecb88-6436-4312-8281-ed584e020b0e/project.

Additional Products not listed above:

Updates to the UAF GAK1 project are also provided publicly at a project website homepage: http://research.cfos.uaf.edu/gak1/.

Hennon, T. D. S. L. Danielson, A. Aguilar Islas, I. Reister, and R. A. Potter. Salinity structure, drivers, and time variability in the Northern Gulf of Alaska, *Peer-review manuscript in preparation.*

Danielson, S. L, T. D. Hennon, T. Klenz, K. McMonigal, T. J. Weingartner. Wind and climate-mediated variability in a 50-year coastal hydrographic time series. *Peer-review manuscript in preparation.*

3. Coordination and Collaboration:

The Alaska SeaLife Center or Prince William Sound Science Center

PI Danielson engaged in scientific discussions with Alaska SeaLife Center researcher Dr. Tuula Hollmen. These were in support of graduate student Brendan Higgen's M.S. Thesis (Danielson is a graduate committee member; Hollmen is advisor) and in support of potential future joint analyses that describe oceanographic conditions inside of Resurrection Bay relative to Dr. Hollman's surveys of coastal seabirds. Prince William Sound Science Center (PWSSC) provides administrative and program coordination support to the GAK-1 project and GAK-1 is funded through the National Oceanic and Atmospheric Administration grant that is administered by PWSSC.

EVOSTC Long-Term Research and Monitoring Projects

The GAK-1 project benefits from the Seward Line project because CTD casts taken by the Seward Line project can be directly incorporated into the GAK-1 CTD time series. In turn, the monthly GAK-1 cruises on R/V *Nanuq* for CTD sampling also collect plankton net tows and water for nutrient and chlorophyll a collections that are supported by the Seward Line project. The Seward Line consortium supports the GAK-1 mooring turnarounds by providing vessel support for the mooring recovery and deployments during their May cruises.

EVOSTC Mariculture Projects

No new contributions for this reporting period.

EVOSTC Education and Outreach Projects

Ms. Nicole Webster is a PhD student in PI Danielson's UAF oceanography lab and since 2023 has been working closely with Katie Gavenus of the Homer-based Center for Alaskan Coastal Studies, joining Community Organized Restoration and Learning (CORaL) Network (project 24220400) visits to Prince William Sound communities and leading science exploration especially in the realm of underwater soundscapes. Through the CORaL network, Danielson's lab also joined the February 2025 Collective Alaska Native Perspective (CANP) workshop in Cordova, AK. Although Danielson missed the workshop due to illness, senior lab member Rachel Potter did attend.

Individual EVOSTC Projects

The GAK-1 project works with the Data Management program to ensure data collected are properly reviewed, have current metadata, and are posted to the Gulf of Alaska data portal within required timeframes.

Trustee or Management Agencies

The GAK-1 project along with the National Park Service contributed to the support of a UAF-based summer oceanography field course, an intensive 11-day 3-credit course that introduces students to modern oceanographic field techniques. The students get to sample at GAK-1, contributing to the 50-year time series. The GAK-1 project supports one day of vessel charter time for the course, and benefits by having the August CTD profile conducted by the students. The 2025 offering will be the third year in a row that the course is run, although our funding support model is necessarily changing.

Native and Local Communities

Ms. Nicole Webster is a PhD student in PI Danielson's UAF oceanography lab. In February 2023 Ms. Webster traveled to the PWS community of Tatitlek to provide outreach learning opportunities for K-12 students in this community. Ms. Webster's academic focus is on underwater sound, and her activities included listening to an underwater hydrophone and discussing underwater soundscapes. Ms. Webster continues to strengthen relationships made at the meeting and in collaboration with Katie Gavenus of the Center for Alaskan Coastal Studies.

4. Response to EVOSTC Review, Recommendations and Comments:

September 2024 EVOSTC Science Panel Comment:

The PIs have completed the work proposed, which involves continuing long-term monitoring of the GAK-1 time series of physical oceanographic data. They report successful recovery and re-deployment of the mooring in May 2022 with a full dataset and only a modest number of data removed due to quality concerns. These data continue to be useful both in leveraged publications and in direct publications involving these data. We are pleased to see the re-analysis of the entire GAK-1 dataset, including the planned error analysis.

The Science Panel does not have any concerns about this project.

PI Response:

Thank you for continued support of the GAK-1 project. Demonstrating the scientific value of this dataset is important to our program, and examples abound from the ever-expanding citation database of studies utilizing the record. Beyond applications outside of this project, the ongoing half-century re-analysis of the GAK-1 dataset continues to feed new and better understandings of the mechanisms that drive Gulf of Alaska environmental variability.

2024 EVOSTC Executive Director and Public Advisory Committee Comments:

None.

5. Budget:

Two unavoidable expenses have increased since proposal submission. The cost of the vessel charter has gone up a bit, and the cost of CTD calibrations has gone up significantly. Due to the delay in the FY24 NOAA grant until January 2025, the project delayed equipment purchases and some salary (to the degree possible) to buffer for the uncertainties. Also, by holding off on equipment purchases, the project may get better quality discounts. The underspending will level out in the coming year.

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PROJECT BUDGET PROPOSAL AND REPORTING FORM

Budget Category:		Proposed FY 22	Proposed FY 23	Proposed FY 24	Proposed FY 25	Proposed FY 26	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel		$43,544	$44,921	$46,045	$85,132	$87,420	$307,062	$77,273
Travel		$6,528	$6,562	$6,599	$6,635	$6,673	$32,997	$8,782
Contractual		$7,200	$7,385	$7,573	$7,769	$7,968	$37,895	$49,265
Commodities		$3,150	$3,229	$3,310	$3,392	$3,478	$16,559	$4,659
Equipment & F&A Exempt		$49,552	$63,680	$60,473	$59,081	$61,202	$293,988	$49,611
Indirect Costs Rate = (non-equipment)	25%	$15,106	$15,524	$15,882	$25,732	$26,385	$98,628	$17,640
SUBTOTAL		$125,080	$141,301	$139,882	$187,741	$193,126	$787,129	$207,230
General Administration (9% of subtotal)		$11,257	$12,717	$12,589	$16,897	$17,381	$70,842	N/A
PROJECT TOTAL		$136,337	$154,018	$152,471	$204,638	$210,507	$857,971	
Other Resources (In-Kind Funds)							$0	

COMMENTS:
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Indirect Costs: Facilities and Administrative (F&A) Costs are calculated at 25.0% of the Modified Total Direct Costs (MTDC), as per the proposal guidelines. MTDC includes Total Direct Costs minus tuition, scholarships, participant support costs, rental/lease costs, subaward amounts over $25,000, and equipment. A copy of the agreement is available at: http://www.alaska.edu/cost-analysis/negotiation-agreements/.

FY22-26

Project Number: 24120114-I
Project Title: GAK-1 Mooring
Primary Investigator: Danielson (UAF)

NON-TRUSTEE AGENCY SUMMARY PAGE