Freshwater in the Northern Gulf of Alaska Marine Environment

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Introduction

Freshwater plays a critical role in stratification of the Northern Gulf of Alaska (NGA) water column and is biologically important to phytoplankton blooms through its control of the light and chemical environments. Much of the ongoing work of the NGA Long Term Ecological Research (LTER) program (2018-present) is built on the pre-existing Global Ocean Ecosystem Dynamics (GLOBEC, 1997-2004), and Gulf Watch Alaska (2012-present) programs, which focused efforts toward sampling the Seward Line transect and Prince William Sound stations. The NGA LTER expands the cross-shelf sampling with the Middleton Line and Kodiak Line transects, while continuing the sampling of the Seward transect to 24 years (Figure 1). The cruises, which sample all transects, are completed every May, July, and September. During sampling, Conductivity-Temperature-Depth (CTD) profiles are obtained for each station, from which freshwater height can be derived using the relation:

$$\mathrm{FWH} = ((S_r * \rho_r * d)/S_s * \rho_s) - d$$

Where S is salinity, ρ is density, subscripts r and s designate reference and station respectively, and d is integration depth. Using the long time-span of the Seward transect and the spatial extent of all three transects, we investigate hydrographic spatial structure and temporal variability of the Northern Gulf of Alaska.

Freshwater Height Anomalies

In the Northern Gulf of Alaska, the main source for freshwater is coastal runoff, estimated by Royer (1982) to be approximately 820 km^3 yr^{-1} and peaks in fall. Our analysis of Seward Line transect data clearly shows this peak, as well as possible oceanic contributions (Figure 2).

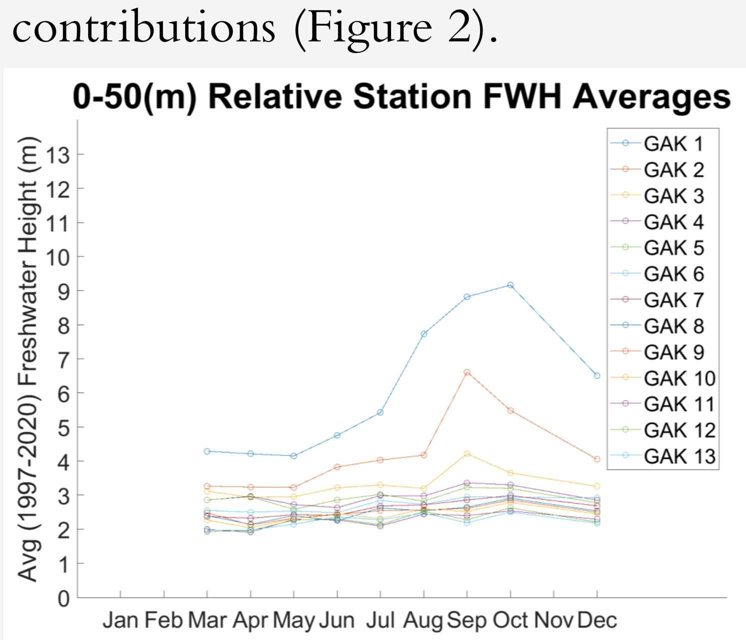

Figure 2. Monthly freshwater height averages for each station along the Seward Line based on 24 years of hydrographic data. A peak in freshwater height occurs in October for GAK1, which is the station closest to coast. The decline in freshwater height for farther off-shore stations may reflect contributions of waters of oceanic origin.

We use the CTD data from the 24 years of Seward Line transect data to identify recurring low-salinity anomalies that may reflect the existence of important freshwater pathways. Freshwater height decreases the farther from the coast (Figure 2) as the coastal discharge mixes into the water column or is routed along-shore by the Alaska Coastal Current (ACC) flow. Anomalies (Figure 3) represent isolated pockets of freshwater. We find that GAK9 and GAK5 register anomalies about 15 % of the time.

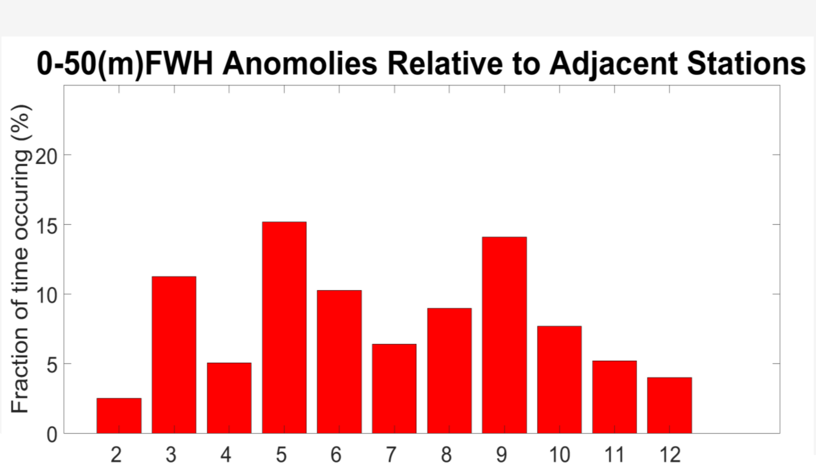

Figure 3. Summary plot of FWH anomalies for stations GAK2 through GAK12 for 24 years of data along the Seward Line transect. Anomalies are defined by a station registering a higher freshwater height than both of its adjacent stations.

Late Summer FWH Distributions

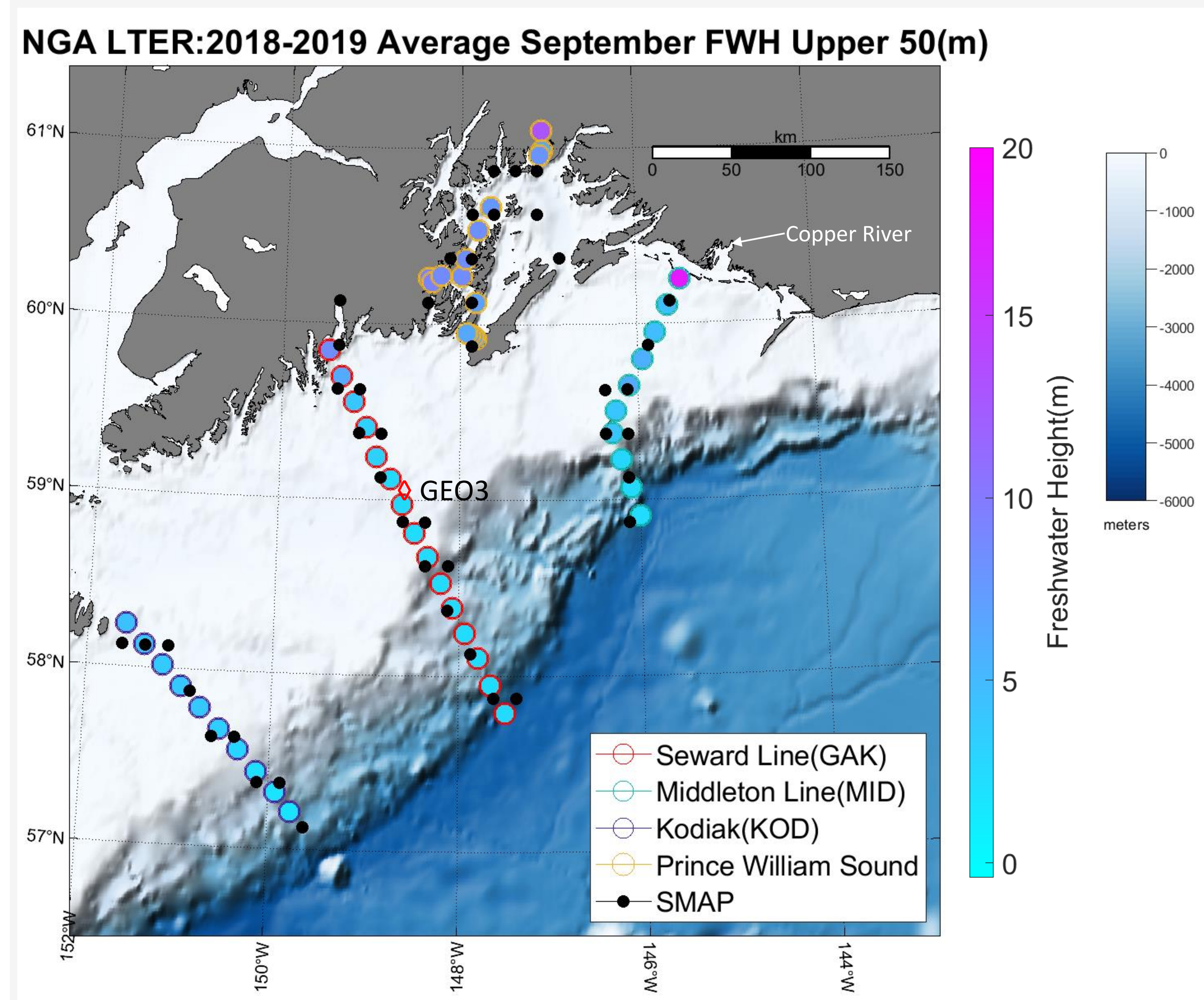

Figure 1. Gulf Watch Alaska and Northern Gulf of Alaska Long Term Ecological Research (NGA LTER) sampling stations, designated by colored marker outlines. Locations of Conductivity-Temperature-Depth (CTD) profile stations shown along each line by marker. Averages of the 2018-2019 September freshwater height, calculated from a 50-meter integration at each station, is shown by the colored marker fill. Year-round mooring location for GEO3 (deployed in July of 2019) is denoted by the red diamond. Salinity data retrieved from the Soil Moisture Active Passive (SMAP) L3 satellite are shown by the smaller black circles. Bathymetry from 0-6000 meters highlights the shelf break.

Freshwater distributions (Figure 1) show higher values of freshwater height near the coast and in Prince William Sound, with the greatest freshwater height located at the near-shore station of the Middleton Line, near the mouth of the Copper River. Freshwater anomalies of 4.36 m extend much farther offshore along the Middleton Island Line than along the Seward Line.

Relative to FWH on the offshore side of the Seward and Kodiak transects, we find elevated FWH values at the oceanic side of the Middleton Island transect. For flow streamlines that follow the continental slope bathymetric contours along the shelf, this observation suggests that the accumulation of freshwater at the eastern-most line is mixed vertically into the water column as the flow and its water masses progress from east to west.

Synoptic Scale Variability

Near-surface measurements of atmospheric conditions (Figure 4) and surface salinity depict freshwater increases during September, due to a) local precipitation; b) cross-shelf advection; or c) along-shelf advection. Barometric pressure at sea level (SLP) declines from August to late October as the Aleutian Low pressure system sends storms into the NGA. Daily averages show instances of FWH and SLP that vary inversely, such as in the first week of October 2020, and other instances where they are in phase, such as the first week of September 2019. SLP minima are often indicative of wind (i.e., mixing and Ekman flow) and precipitation events (new freshwater input). The response shown indicates that synoptic-scale atmospheric forces exert some control over near-surface layer freshwater height variations over the time scale of days.

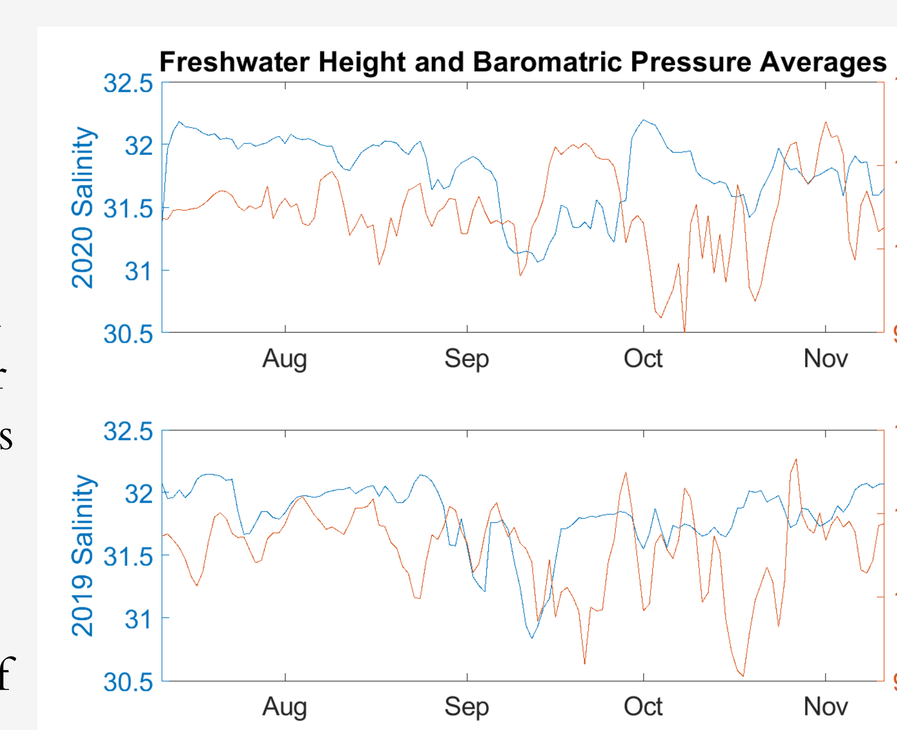

Figure 4. 2020 (top) and 2019 (bottom) daily averages of salinity (1 meter depth) and barometric pressure (sea level), collected by GEO3 mooring. Time span is from July 11 to November 18 for each year.

Satellite vs. *In situ* Comparison

Comparisons of *in situ* data to remotely sensed surface salinity data collected by the NASA SMAP satellites show that the satellites achieve only limited fidelity (Figure 5) in reproducing the shipboard observations and that their accuracy and precision depend both on season and location. Data comparisons between SMAP and Seward Line hydrography show no statistically significant relation.

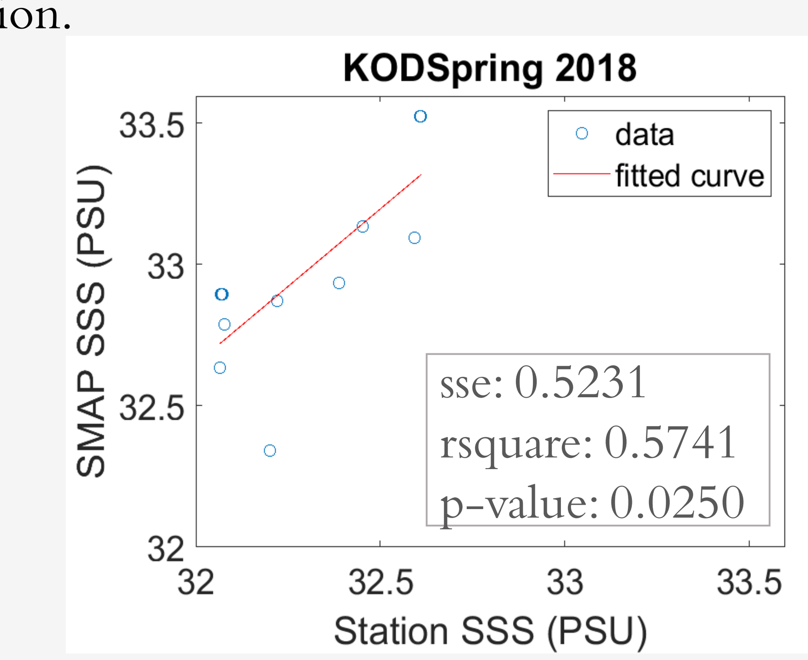

Figure 5. Comparison of the Soil-Moisture Active Passive Satellite surface salinity with the in-situ data from the Kodiak transect in May of 2018. The r^2 value indicates that the satellite captures 57% of the in-situ variability. This does not represent the majority of SMAP vs in-situ comparisons, most of which show much higher variability, particularly near shore. For example, the r^2 value for the Seward Line transect for May of 2018 is 0.3441.

Conclusions

- FWH declines from east to west at the slope, revealing a loss of freshwater from the upper 50 m of the water column.
- Maxima in FWH at GAK5 and GAK9 suggest potentially important freshwater pathway locations.
- Comparisons of in situ data to remotely sensed surface salinity data collected by the NASA SMAP satellites show that the satellites are not useful for assessing salinity changes across the NGA.

References

Royer, T.C., 1982. Coastal fresh water discharge in the northeast Pacific. *Journal of Geophysical Research: Oceans*, *87*(C3), pp.2017-2021.

Acknowledgements

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