Fate of the Copper River Plume

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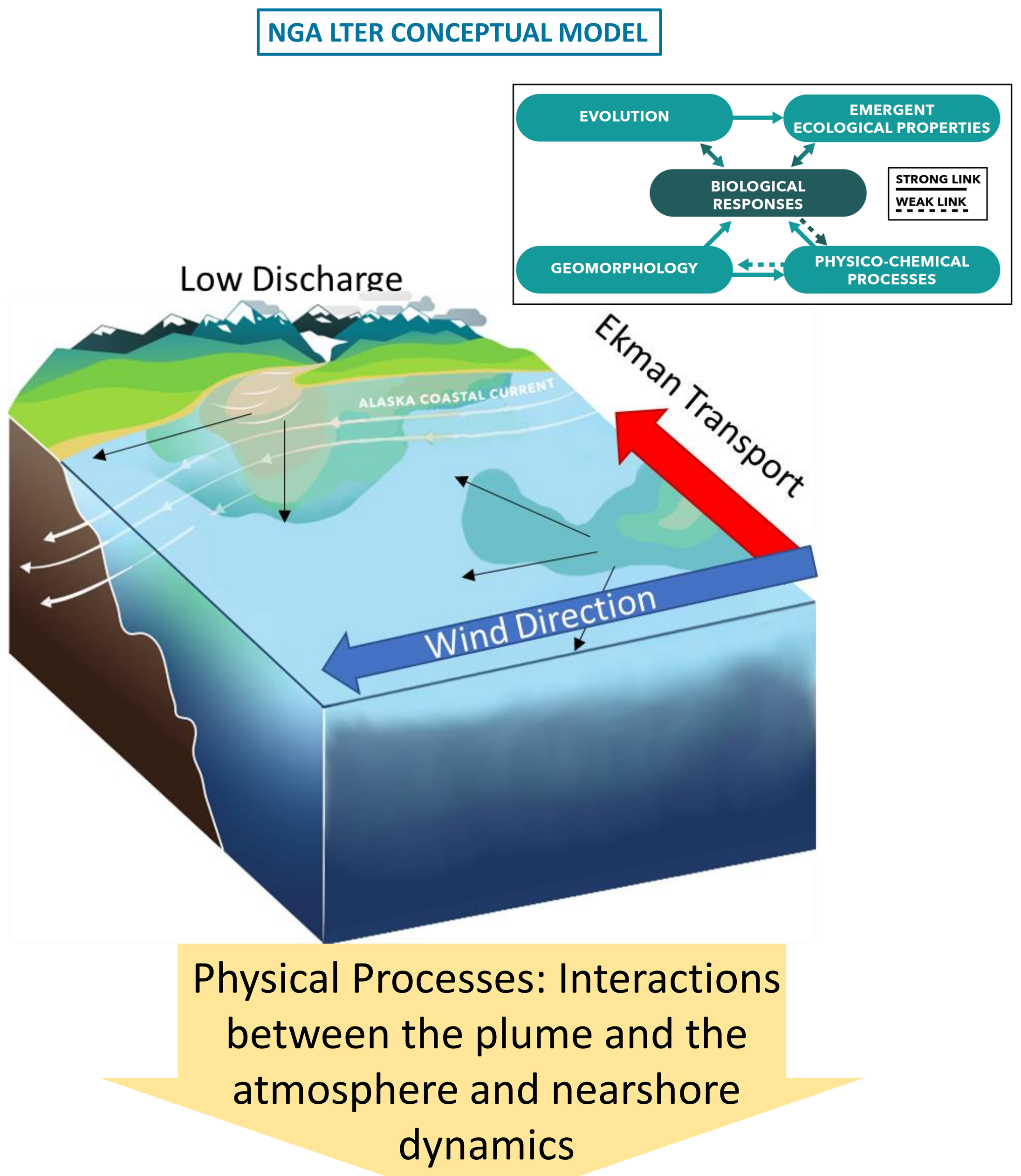
On behalf of the NGA LTER Science Team



- The continental shelf adjacent to the Copper River prodelta decouples the river plume from the bottom.
- The iron-rich outflow then spreads across the NGA shelf. Part of the spreading plume feeds the Alaska Coastal Current and contributes to along-shore advection. Another portion of the plume spreads offshore in a thin surface layer.
- The plume's trajectory is sensitive to wind direction and under suitable wind conditions coastal waters can be swept into the shelf-break flow regime, at times delivering coastal waters beyond the slope to the iron-poor HNLC basin.
- Primary data from 2019 and 2020 NGA process study cruises collected via towed instrumentation. The 2019 process study also included a deployment of satellite-tracked drifters.

Atmosphere

The atmosphere impacts the plume through wind (Figure 1) and runoff which has a peak discharge of 7000 m^3s^{-1}in July and no recordable discharge from January to early March[2].

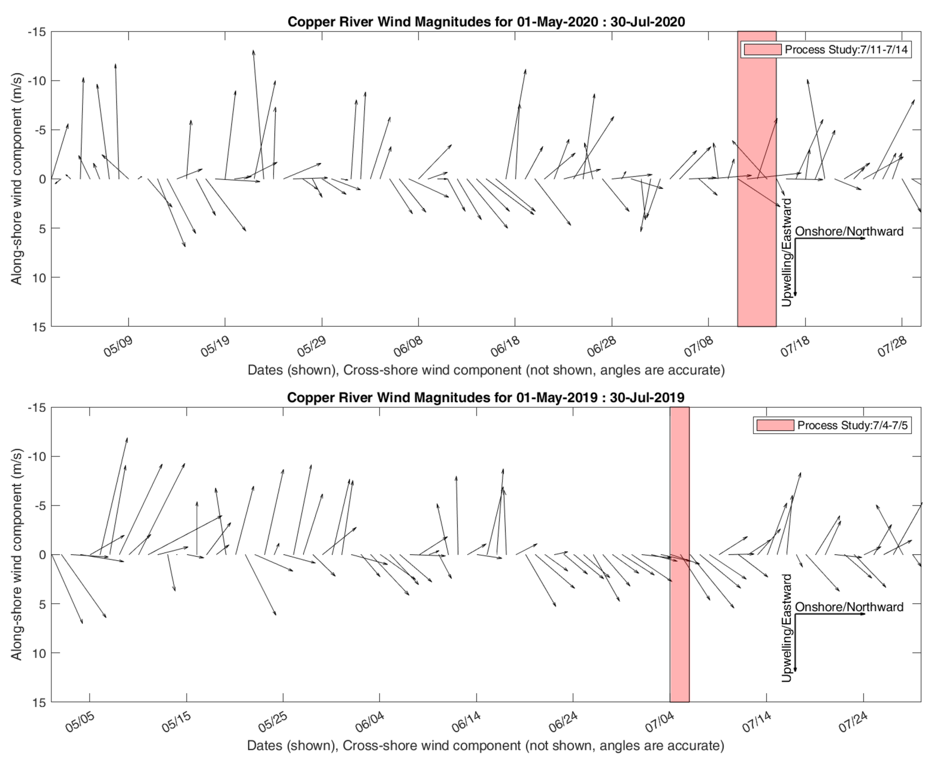


Figure 1: (top) Wind velocities in 2020 just before and during the study were overall downwelling directed, and ≲5 m/s. (bottom) Prior to the 2019 process study, a sustained low velocity wind was present in the upwelling/onshore direction.

Sediment and Salinity

Steep glaciated coastal mountains cause runoff with high amounts of suspended sediment [1]. The Copper River sediment plume can be seen in satellite imagery as aquamarine water (Figure 2 a,b). *In situ* measurements verify that this sediment-laden water has a low salinity due to its fluvial source (Figure 2 c).

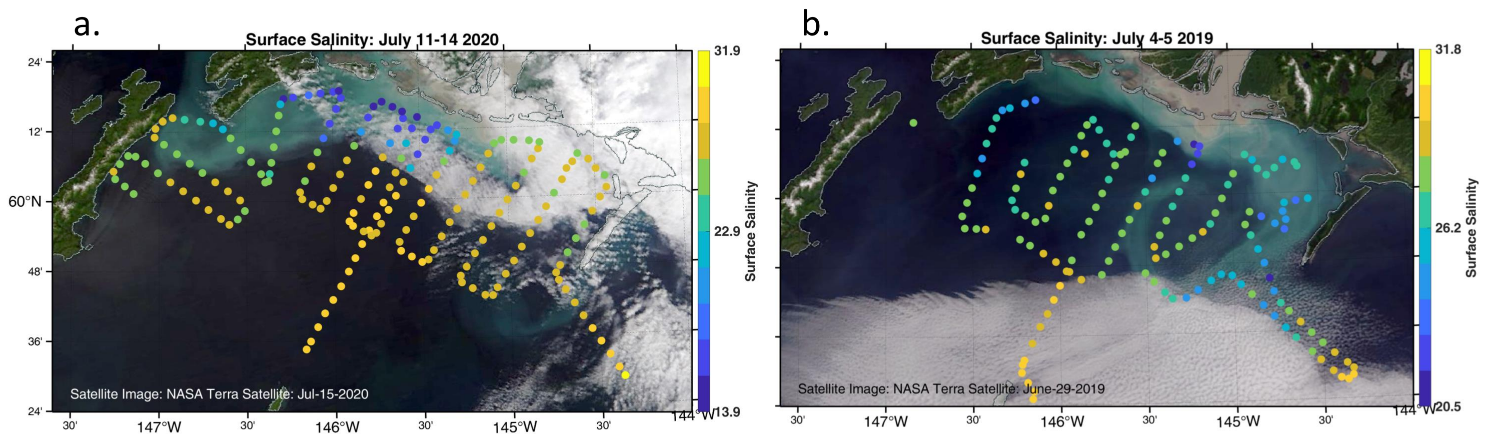
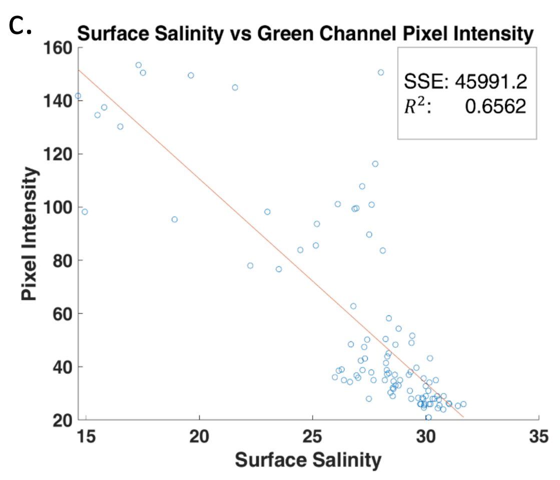


Figure 2: (a,b) *In situ* surface salinity overlaying near simultaneous satellite imagery. (c) Regression plot of pixel intensity versus surface salinity. A negative relationship means high salinities (low) associate with lower (higher) pixel intensity.



Temporal Variability

We used Self Organized Mapping (SOM), a machine learning analysis technique, to produce anomaly patterns based on 294 satellite images, representing plume distribution states having the highest frequency of occurrence (FO) (Figure 3). One-way ANOVA tests were performed to compare the effect of pattern type on alongshore wind velocity and river discharge. Box plots and multiple comparisons tests provide key findings(Figure 4).

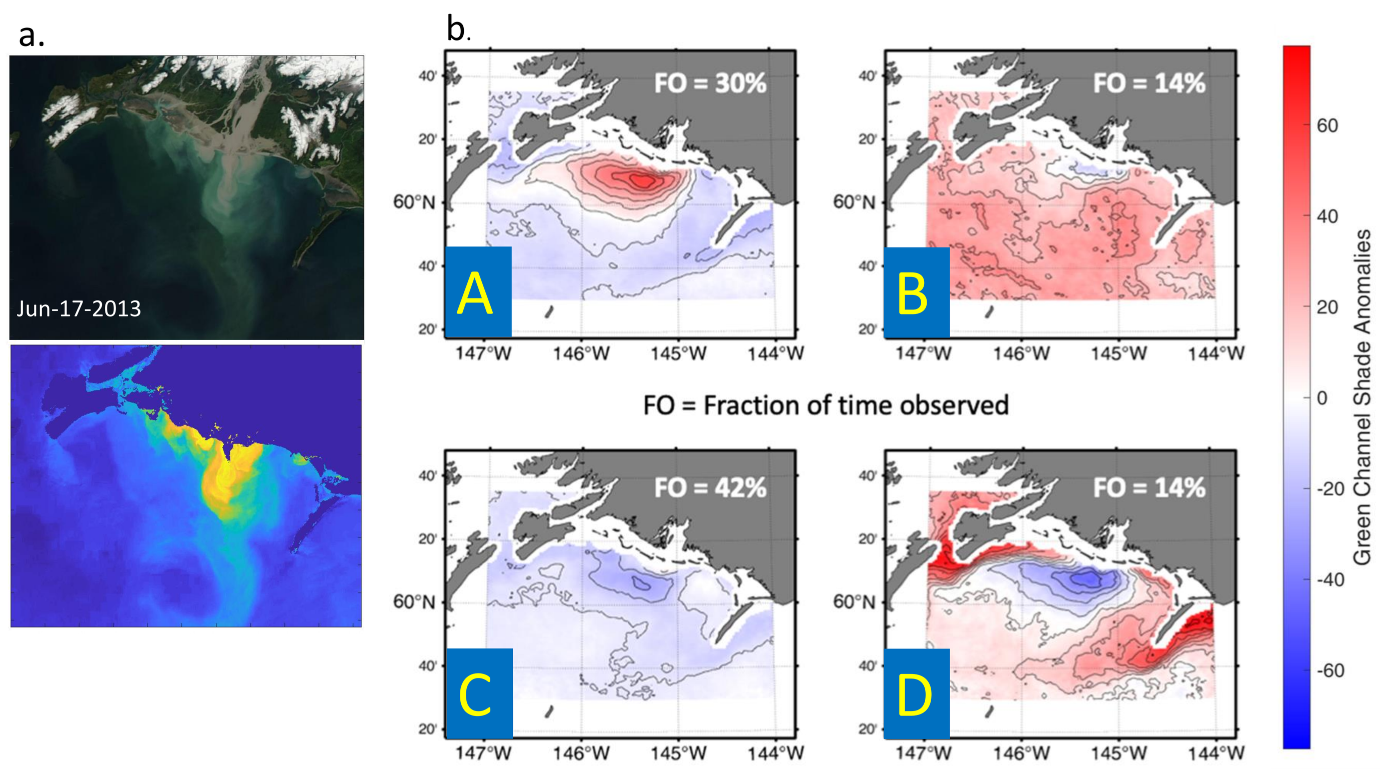


Figure 3: a.) Example of true color satellite image with green channel filter below. **b.)** Anomaly maps generated by subtracting the mean from the 4 patterns. A) Plume extended away from the coast. B) Sediment laden waters extend across the study area. C) Clearer waters across the study area. D) High sediment south of Kayak and Hinchinbrook Islands.

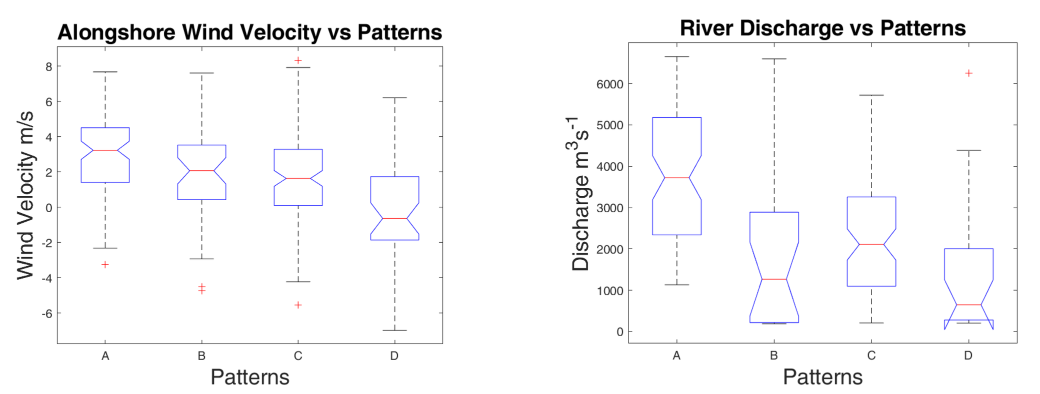


Figure 4: A one-way ANOVA test shows a statistically significant difference in wind velocity between at least two patterns (F (3, 290) = 16.92, p = <.01) and likewise for river discharge (F(3,191)=23.66, p=<.01). Via multiple comparisons tests and box plots, Pattern D is associated with downwelling winds and Pattern A is associated with a high discharge (p=<.01 against all other patterns for both cases)

Hydrography

We used GPS data from the drifters to find out how surface currents respond to wind (Figure 5). Towed data enables mass transport estimates (Figure 6) and hydrographic cross-sections (Figure 7) that reveal how the Copper River marine environment moves beneath the waves.

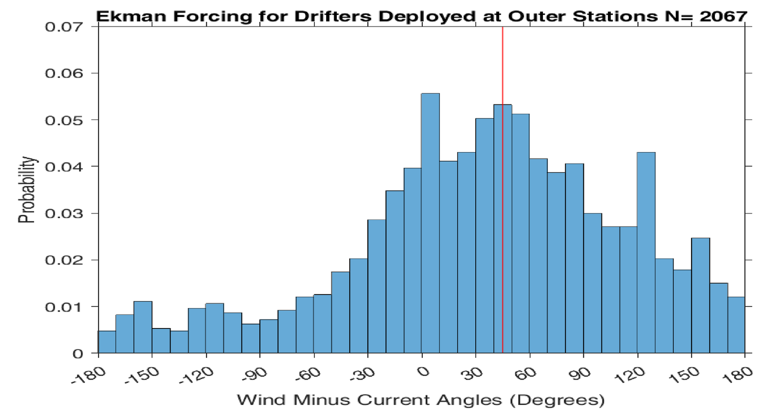


Figure 5: A histogram of the difference between (smoothed) wind and drifter directions shows a peak at 45°, indicating that Ekman dynamics have some influence on the surface current

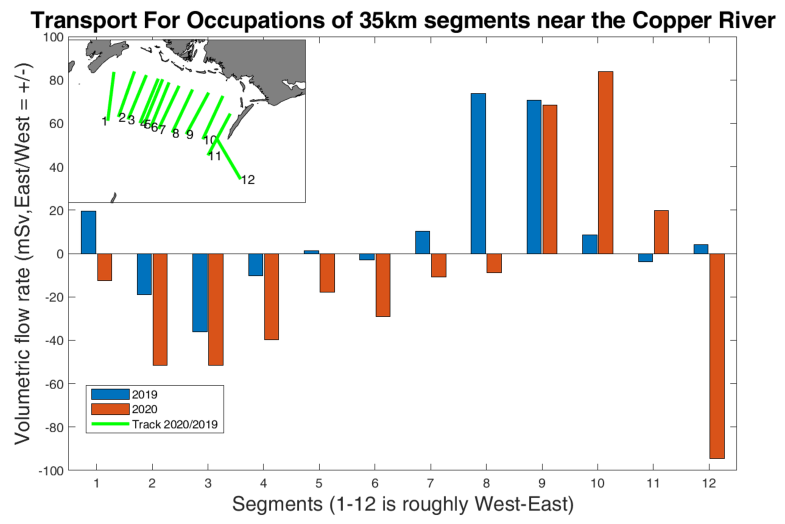


Figure 6: Mass transport calculations for 2019 and 2020 process studies for an array of transects. 1-6 show westward transport. 8-11 primarily show eastward transport.

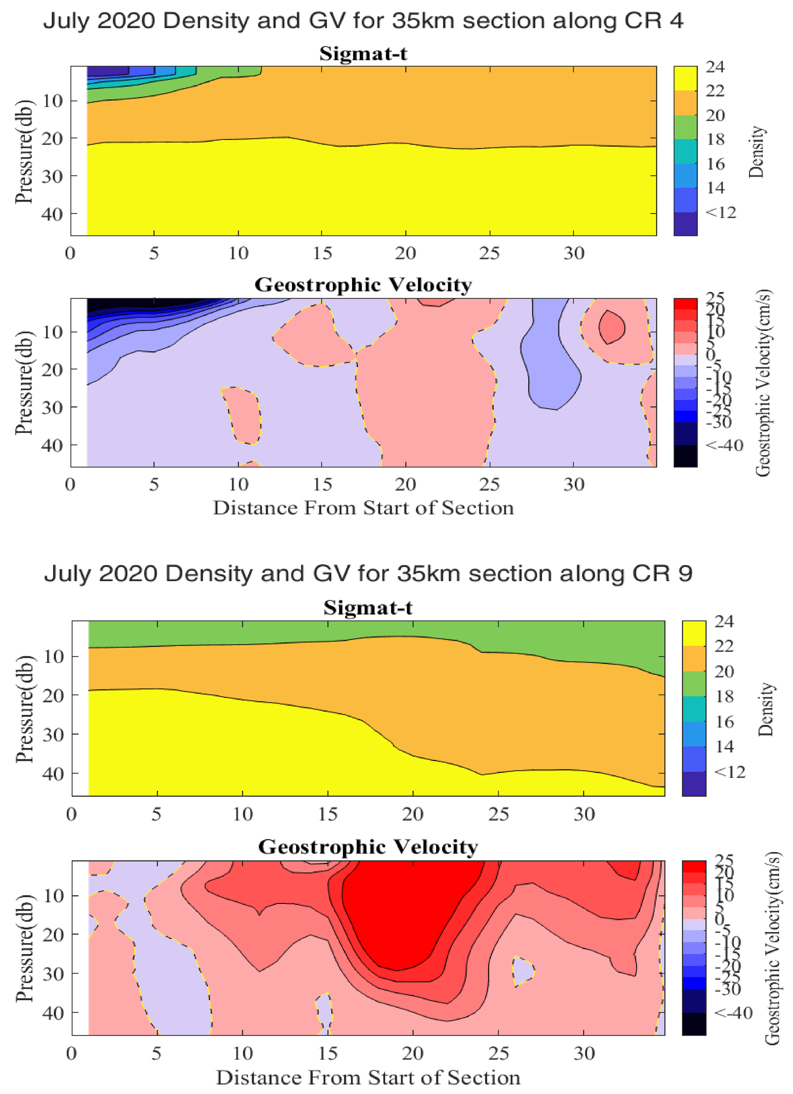


Figure 7: 2020 density anomaly and baroclinic currents for track 4 (top). A 10 m thick surface plume drives a strong westward flow. 2020 track 9 (bottom) shows isopycnals deepening away from shore, meaning slightly fresher water located offshore. A large eddy, possibly induced by Kayak Island, drives eastward flow.

Main Takeaway

- **Satellite imagery provides means to identify freshwater in the Copper River plume.**
- **SOM analysis of satellite imagery suggests that wind direction and river discharge are both important for the seasonal variation in plume spatial patterns.**
- **Baroclinic currents were strongest where CTD tows intersected the Copper River plume, driving westward flow. A large eddy on the eastern edge of the study region drives eastward flow.**

References:
1 Jeager 1998 et al. Sediment accumulation along a glacially impacted mountainous coastline: north-east Gulf of Alaska
2 Million Dollar bridge flowmeter (15214000 COPPER R) maintained by USGS (1989-present time series)

Acknowledgements:
NSF's Northern Gulf of Alaska Long Term Ecological Research Program, the Exxon Valdez Oil Spill Trustee Council via the Gulf Watch Alaska program, the North Pacific Research Board, the M.J. Murdock Charitable Trust, and the Alaska Ocean Observing System. Satellite data provided by the Jet Propulsion Laboratory NASA. Discharge data from USGS. Wind data from ERA5