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Lagrangian analysis of seasonal and interannual trends in estuarine flow composition and path between Juan de Fuca Strait and Strait of Georgia and Puget Sound

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WHY? Little is known about the contribution of different Pacific currents to the water entering the Salish Sea through Juan De Fuca Strait (JdF) both annually and interannually, particularly in the winter. This has a significant impact on accuracy of biogeochemical models of the region.
HOW? Apply Lagrangian particle tracking to find the trajectories of water entering the Sea and their physical/chemical characteristics to discern their source.

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REFERENCES

1. Thomson, R. (1981). Oceanography of the British Columbia Coast, volume 56:291. Canada Special Publications, Ottawa, Ontario.
2. R. Pawlowicz, C. Hannah, and A. Rosenberger. Lagrangian observations of estuarine residence times, dispersion, and trapping in the Salish sea. Estuarine, Coastal and Shelf Science, 225, 2019. doi: 10.1016/j.ecss.2019.106246.
3. B. Moore-Maley and S.E. Allen. Wind driven upwelling and surface nutrient delivery ina semi-enclosed coastal sea. Ocean Science Discussions, preprint, 2021. doi: 10.5194/os-2021-21.
4. Thomson, R., Miha'ly, S., and Kulikov, E. (2007). Estuarine versus transient flow regimes in Juan de Fuca strait. Journal of Geophysical Research, 112
5. Debby Ianson, Susan E. Allen, Benjamin L. Moore-Maley, Sophia C. Johannessen, and Robie W. Macdonald. Vulnerability of a semienclosed estuarine sea to ocean acidification in contrast with hypoxia. Geophysical Research Letters, 43(11):5793–5801, 2016.doi: 10.1002/2016GL068996.
6. Elise M. Olson, Susan E. Allen, Vy Do, Michael Dunphy, and Debby Ianson. Assessment of nutrient supply by a tidal jet in the northern Strait of Georgia based on a biogeochemical model. Journal of Geophysical Research: Oceans, 125(8):e2019JC015766, 2020. doi:10.1029/2019JC015766.
7. Erik van Sebille, Stephen M. Griffies, Ryan Abernathey, Thomas P. Adams, PavelBerloff, Arne Biastoch, Bruno Blanke, Eric P. Chassignet, Yu Cheng, Colin J. Cot-ter, Eric Deleersnijder, Kristofer D¨o¨os, Henri F. Drake, Sybren Drijfhout, Stefan F.Gary, Arnold W. Heemink, Joakim Kjellsson, Inga Monika Koszalka, Michael Lange, Camille Lique, Graeme A. MacGilchrist, Robert Marsh, C. Gabriela Mayorga Adame,Ronan McAdam, Francesco Nencioli, Claire B. Paris, Matthew D. Piggott, Jeff A.Polton, Siren R¨uhs, Syed H.A.M. Shah, Matthew D. Thomas, Jinbo Wang, Phillip J.Wolfram, Laure Zanna, and Jan D. Zika. Lagrangian ocean analysis: Fundamentals and practices. Ocean Modelling, 121:49–75, 2018. ISSN 1463-5003. doi: https://doi.org/10.1016/j.ocemod.2017.11.008.
8. Bruno Blanke and Stéphane Raynaud. Kinematics of the pacific equatorial undercurrent: An Eularian and Lagrangian approach from GCM results. Journal of Physical Oceanography, 27(6):1038 – 1053, 1997. doi: 10.1175/1520-0485(1997)027⟨1038:KOTPEU⟩2.0.CO;2

General Plumbing of the Salish Sea

- Water mostly enters through the JdF, ~14% to Puget Sound, ~56% to the SoG, or ~30% entrained back into the outflow (figure 1) [1,2]
- Upwelling in the summer (surface water blown offshore brings deep water to the coast) and downwelling in the winter (surface water blown towards the coast) change coastal conditions significantly [3]
- Source water contributed variably from the California Current, the California Undercurrent, the Davidson Current, the Vancouver Island Coastal Current, the Shelf Break Current and the Columbia River [1]
- Winds also cause variability in regime within the JdF [4]
  - Estuarine = Thin outflow layer over two layers of inflow. 90% of the time in the summer and 55% in winter
  - Transient = Brought on by poleward winds along the WCVI. Inflow along the southern shore, more horizontal variability than vertical

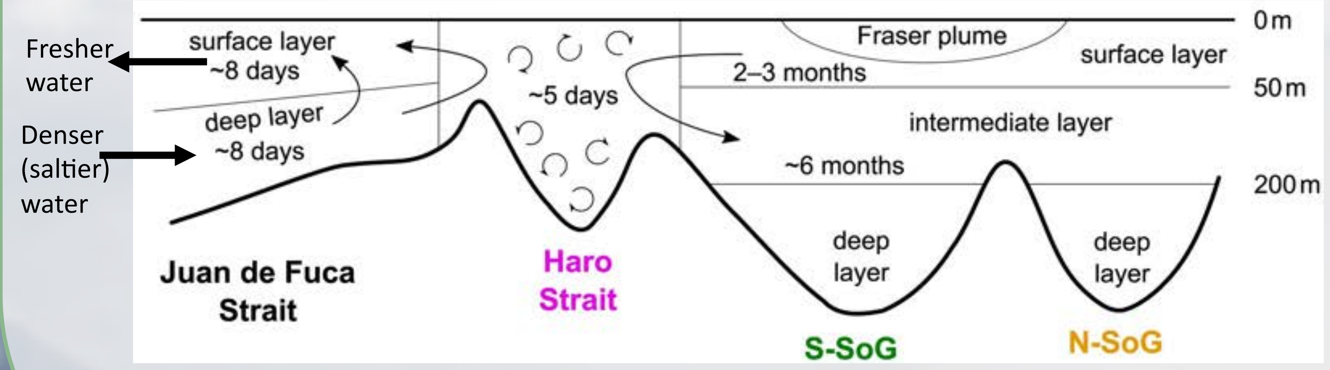

Figure 1: General circulation pattern of the Salish Sea [5] (adapted from R. Pawlowicz). High-salinity water from the Pacific flows into the JDF and a mixture of this water and fresh water flows out at the surface.

Methods

The Model - SalishSeaCast

3D circulation model with coupled biological and carbonate chemistry models, created and maintained by the UBC Mesoscale Ocean and Atmospheric Dynamics (MOAD) Laboratory [6]. The horizontal resolution is 500 m and the vertical resolution is split into 40 cells between 1 m (closer to the surface) and 27 m (at depth).

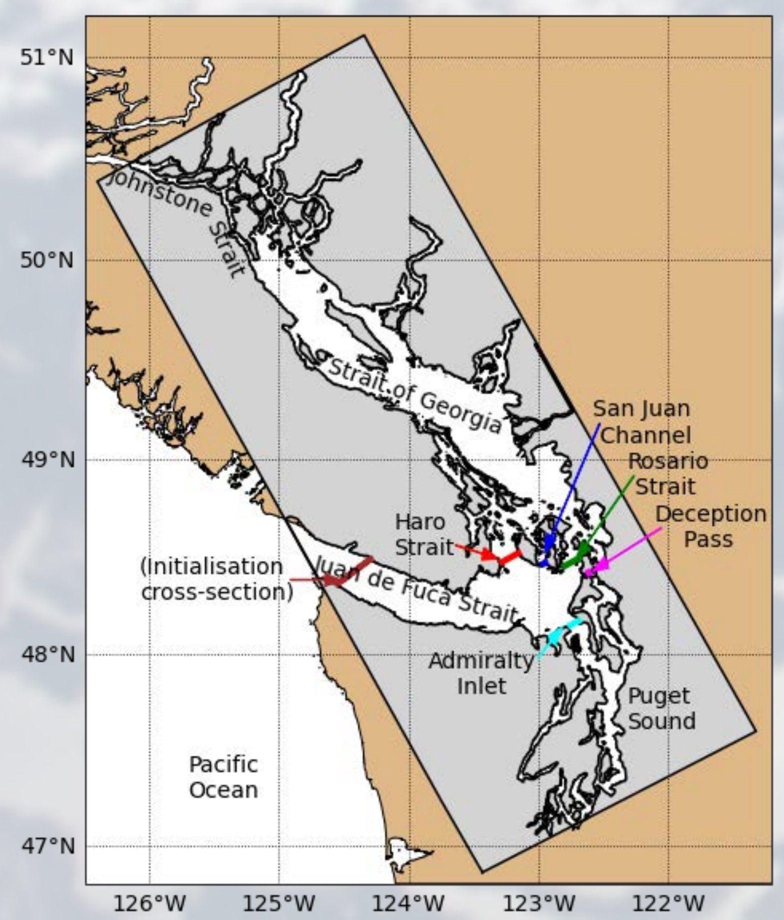

Figure 2: SalishSeaCast model domain, with bathymetry [6]

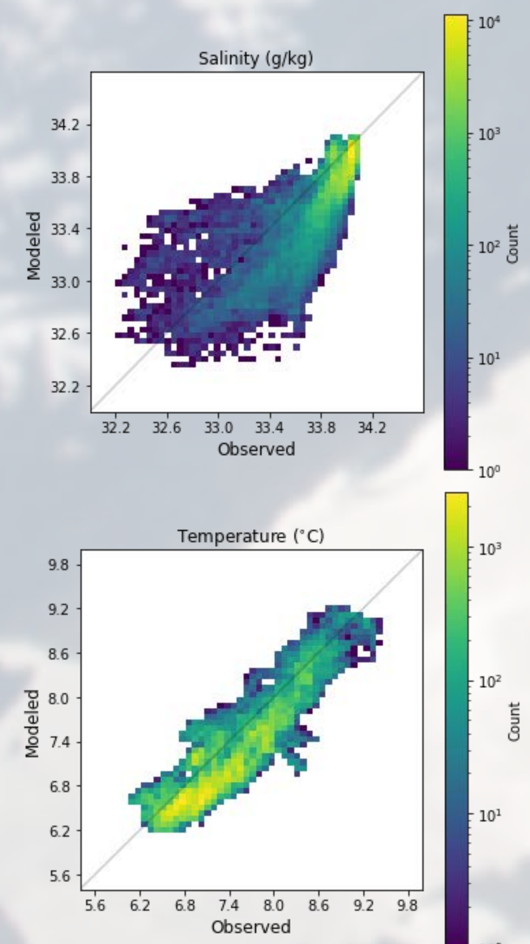

Figure 3: Model (SalishSeaCast) versus observations of Salinity (top) and Temperature (bottom) at a 125 m deep mooring at the mouth of the JDF. The model is largely fresher and slightly colder.

The Analysis – Lagrangian Tracking

Lagrangian ocean analysis tracks the movement of free moving entities to estimate pathways. Virtually, this method tracks simulated particles (or in this analysis, virtual water parcels) to see their path and how their physical characteristics change along this path based on the velocity and tracer fields of an ocean model [7]. This is more involved than other common oceanographic analysis techniques (ex. Eularian) but can result in a much more realistic prediction [7].

Ariane

Based on the volume conservation equation calculates 3D-streamlines to predict water parcel trajectories forward and backwards in time [8].

- Well established (25 years of use)
- Quantitative mode: distribution function and volume transport past cross-sections
- Qualitative mode: detailed particle trajectories

Results

Trajectories

The amount of water entering the Salish Sea through the JdF differs significantly seasonally (figure 4) due to the variability in the strength of the estuarine regime (due to variable shelf salinity and river discharge), but the ordering of 'importance' of the different paths does not change.

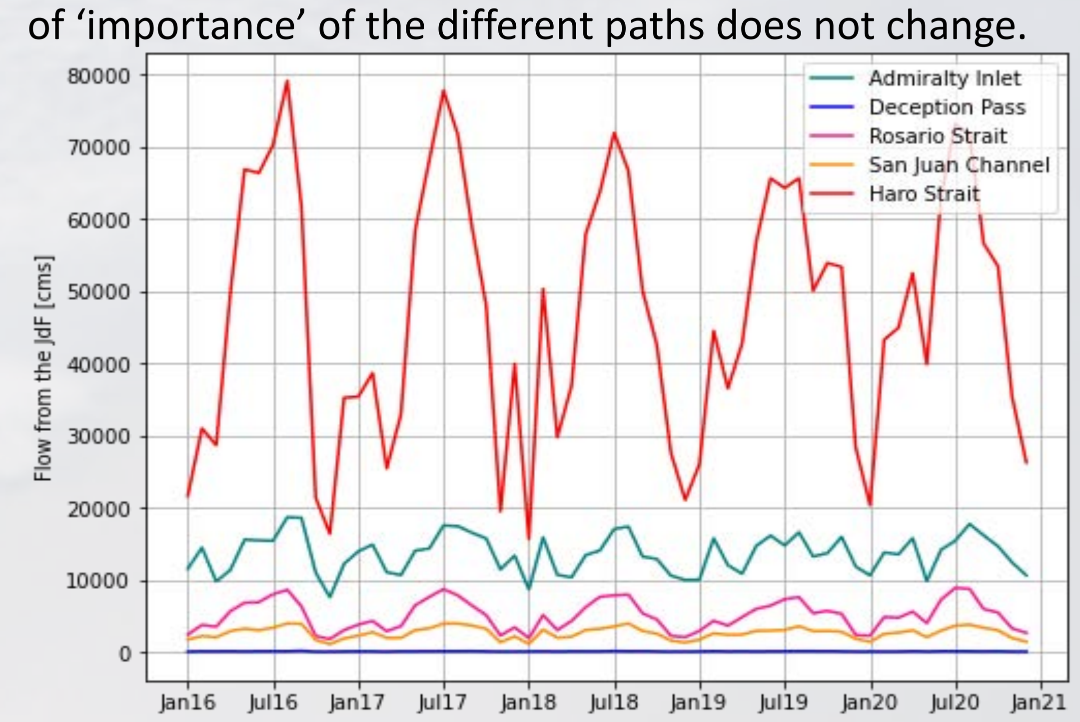

Figure 4: Model (SalishSeaCast) versus observations of Salinity (top) and Temperature (bottom) at a

The path of the water entering the sea changes as well due to the dominance of the estuarine or transient flow regime in winter (left) versus the summer (right)

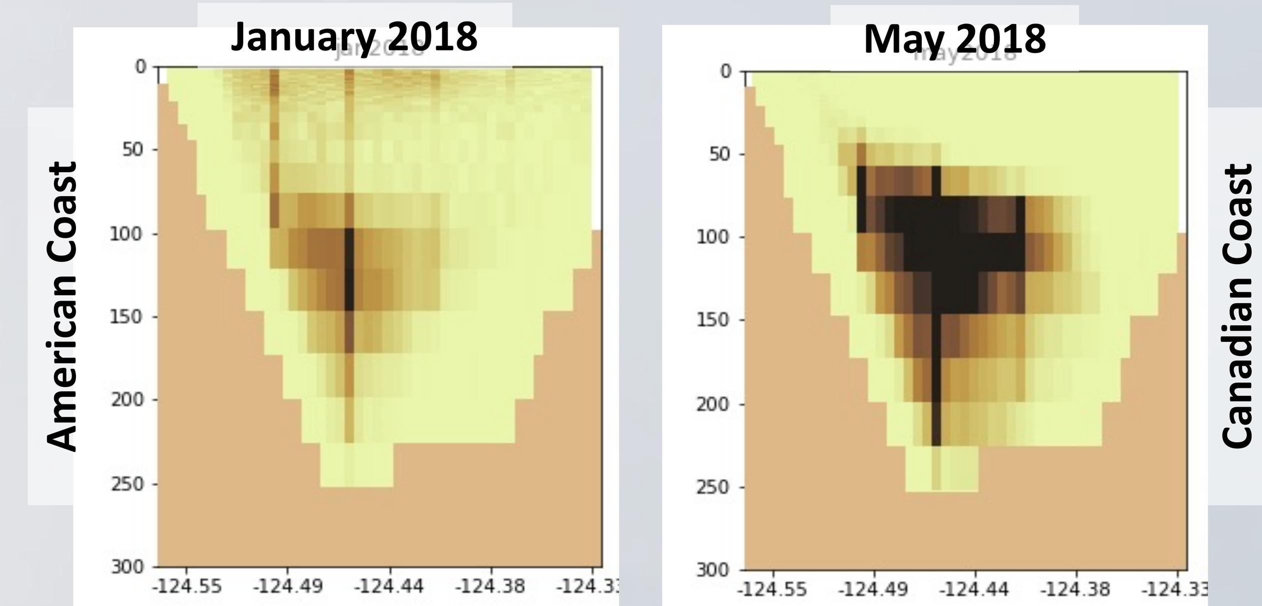

Figure 5: JdF cross-section of the flux of parcels that reach the SoG or Puget Sound in a typical winter month (left) and a typical summer month (right)

Properties

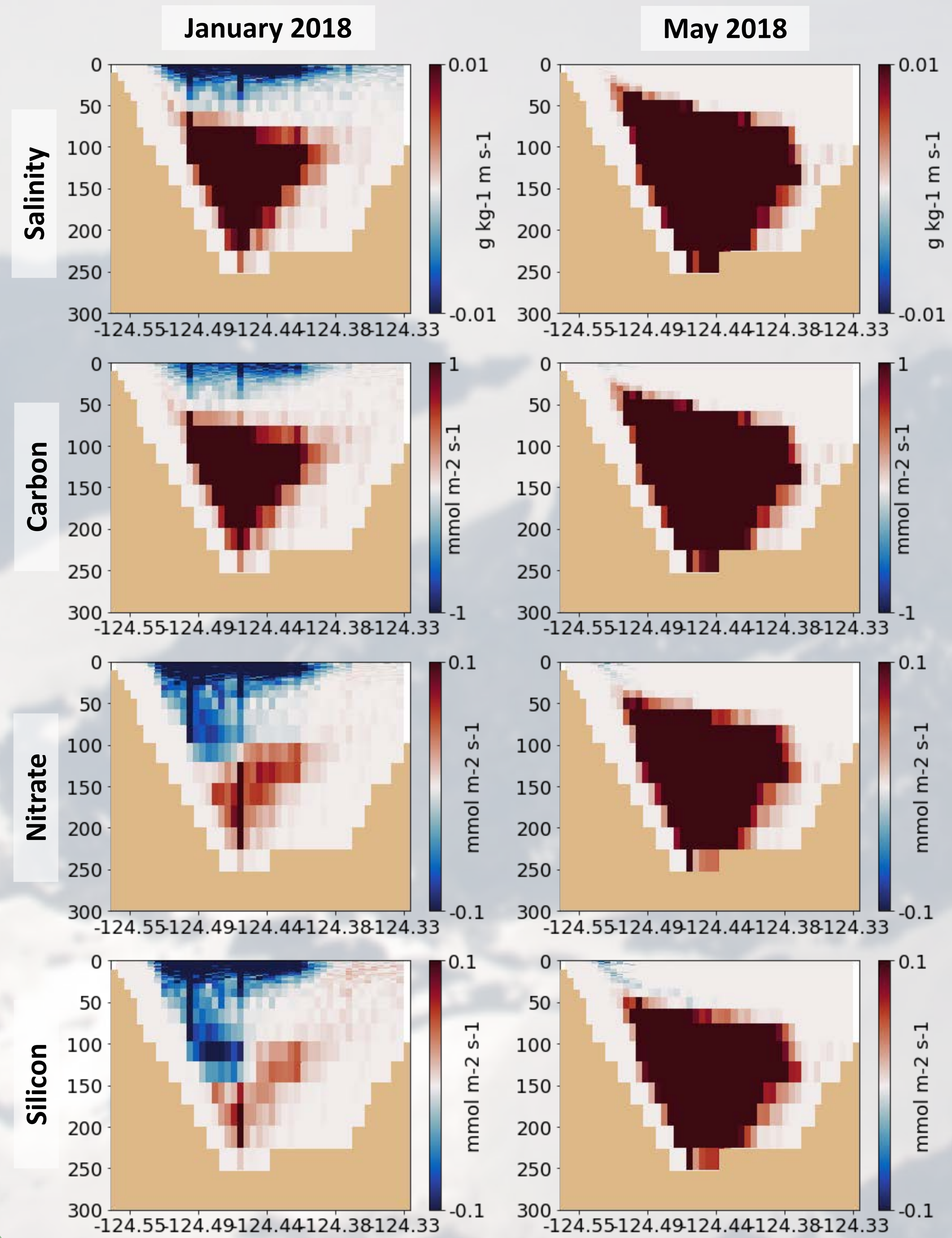

Figure 6: Fluxes from figure 5 coloured by the difference between the flux of tracers (salinity, dissolved inorganic carbon, nitrate, dissolved silica) in each cell and the ambient tracer concentration in the region (red meaning the influx is a higher concentration than the climatology and blue meaning a lower concentration).

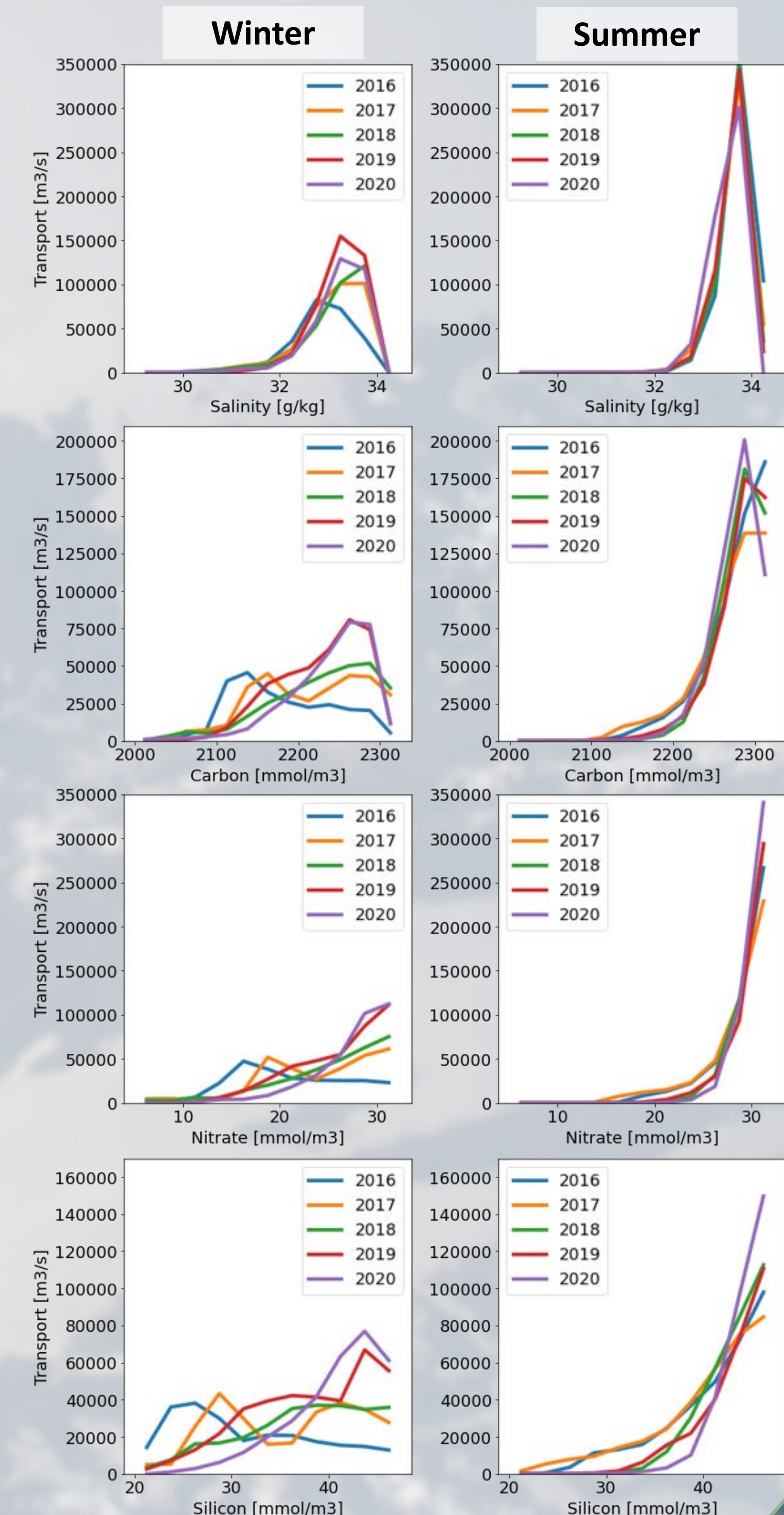

Figure 7: Composition hydrographs of parcels that make it to the SoG or Puget Sound from JdF in the winter (Oct-Mar) and summer (Apr-Sep).

Conclusions

- Significant seasonal variability in flow rates, path, and composition
- Summer conditions are similar interannually while winter conditions vary noticeably year-to-year
- Water reaching the SoG and Puget sound from JdF varies between tracer rich in the summer to tracer poor in the winter

Next Steps

Similar analysis with another 3D circulation model (CIOPS BC12) that covers the Salish Sea (at a lower resolution) but goes offshore. These results alongside the SalishSeaCast results will allow us to produce an estimate of the contribution of different Pacific water masses by following this process:

1. CIOPS BC12 qualitative run for open ocean boundary selection
2. CIOPS BC12 within Salish Sea quantitative run and comparison to SalishSeaCast
3. CIOPS BC12 yearlong (2017) shelf quantitative runs
4. Origin of flow into JdF based on the location of the centers of flow, and the salinity and temperature from step (3)