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Using seasonality and particle tracking to trace Intermediate Water in the Strait of Georgia

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How can we track ocean circulation in a dynamic coastal region?

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Area of Study

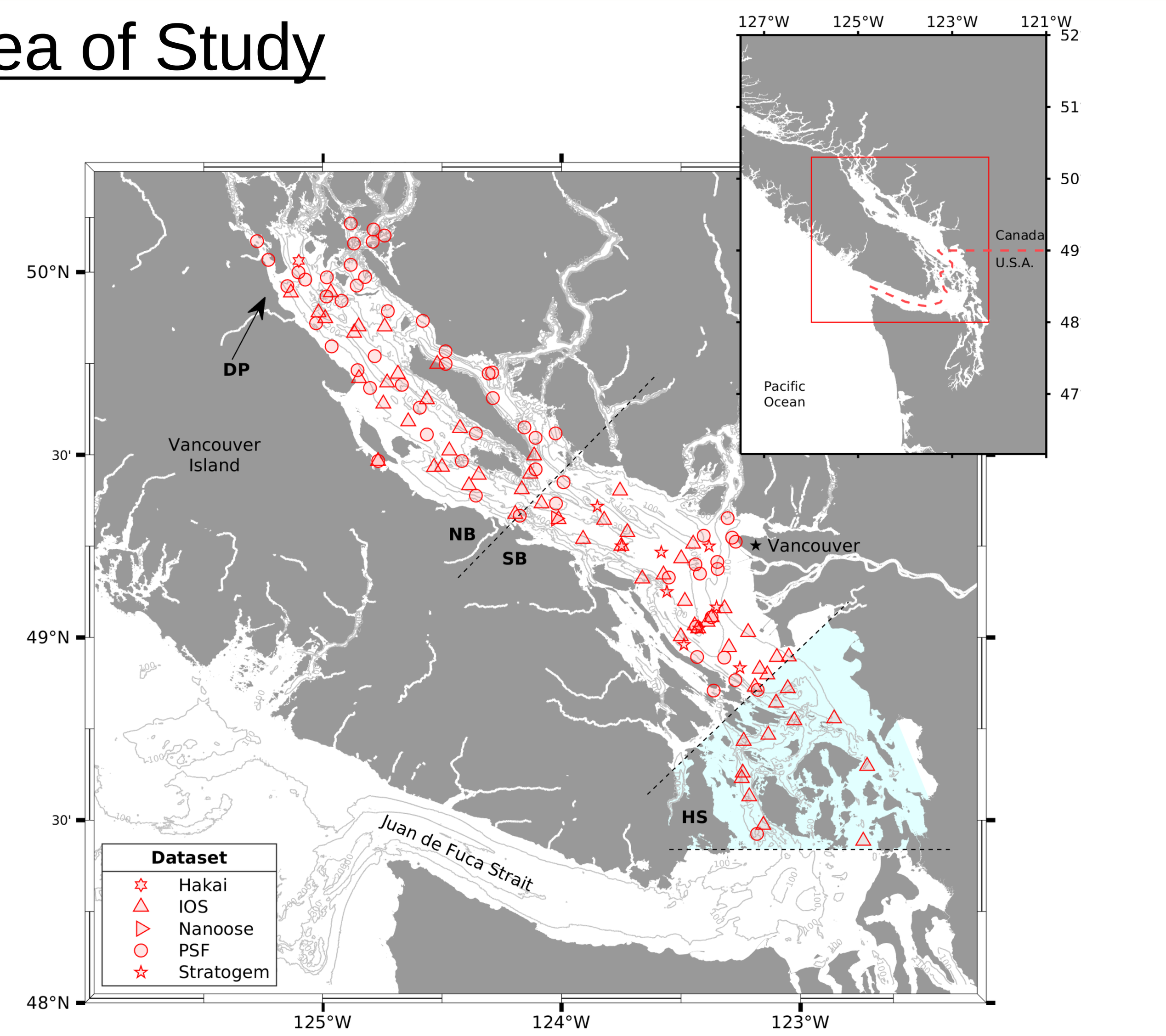

Figure 1: A map of the study region. Hydrographic stations from different datasets are plotted in red. Different areas are: Haro Strait (HS); South Basin (SB); North Basin (NB); and Discovery Passage (DP). Blue region represents IW formation and subduction zone.

The **Salish Sea** is a collection of waterways and basins between Vancouver Island and mainland British Columbia. We are interested in the circulation of the **Intermediate Water** (IW) in the Strait of Georgia as the inflowing branch of an estuarine circulation. One reason we are interested is that most of the **wastewater** from Greater Vancouver is discharged directly into it.

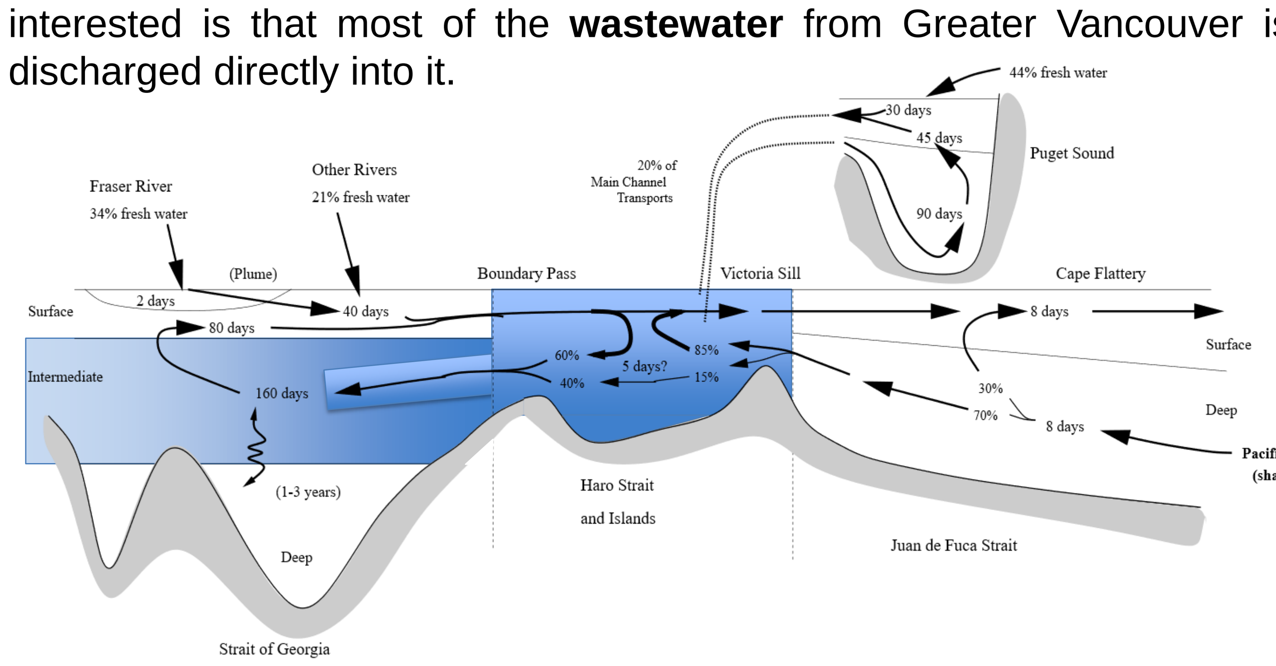

Figure 2: A schematic of the circulation of the Salish Sea, modified from Pawlowicz et al., 2019, Estuarine, Coastal and Shelf Science. Blue region represents IW formation and subduction.

Methods - Where does IW go and how can we track it?

Hydrographic data from over 5000 CTD profiles (primarily from the Pacific Salmon Foundation dataset from 2015-2019) is used to calculate the **phase shift** of temperature seasonal cycles from stations to **age** the IW.

If the **coldest day** of the seasonal cycle occurs on February 10th in Haro Strait (similar to the atmospheric coldest day), and occurs on April 11th at another station, we infer that it has taken 60 days for water to travel between the two stations

We can also study the **amplitude change** of the seasonal cycles to infer **mixing**.

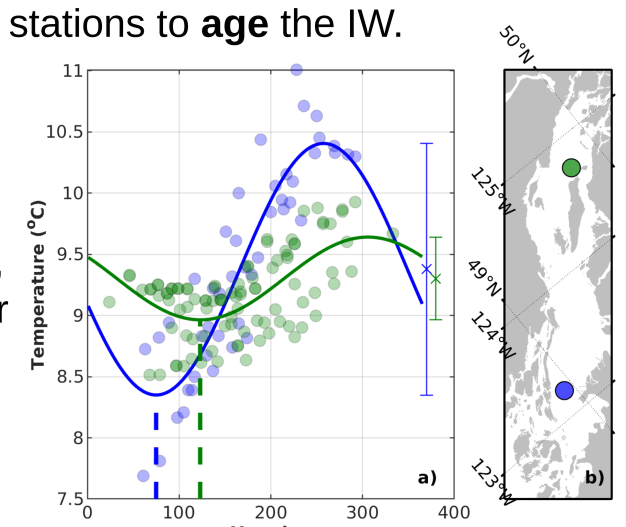

Figure 3: Seasonal cycles of temperature from two representative stations.

Results

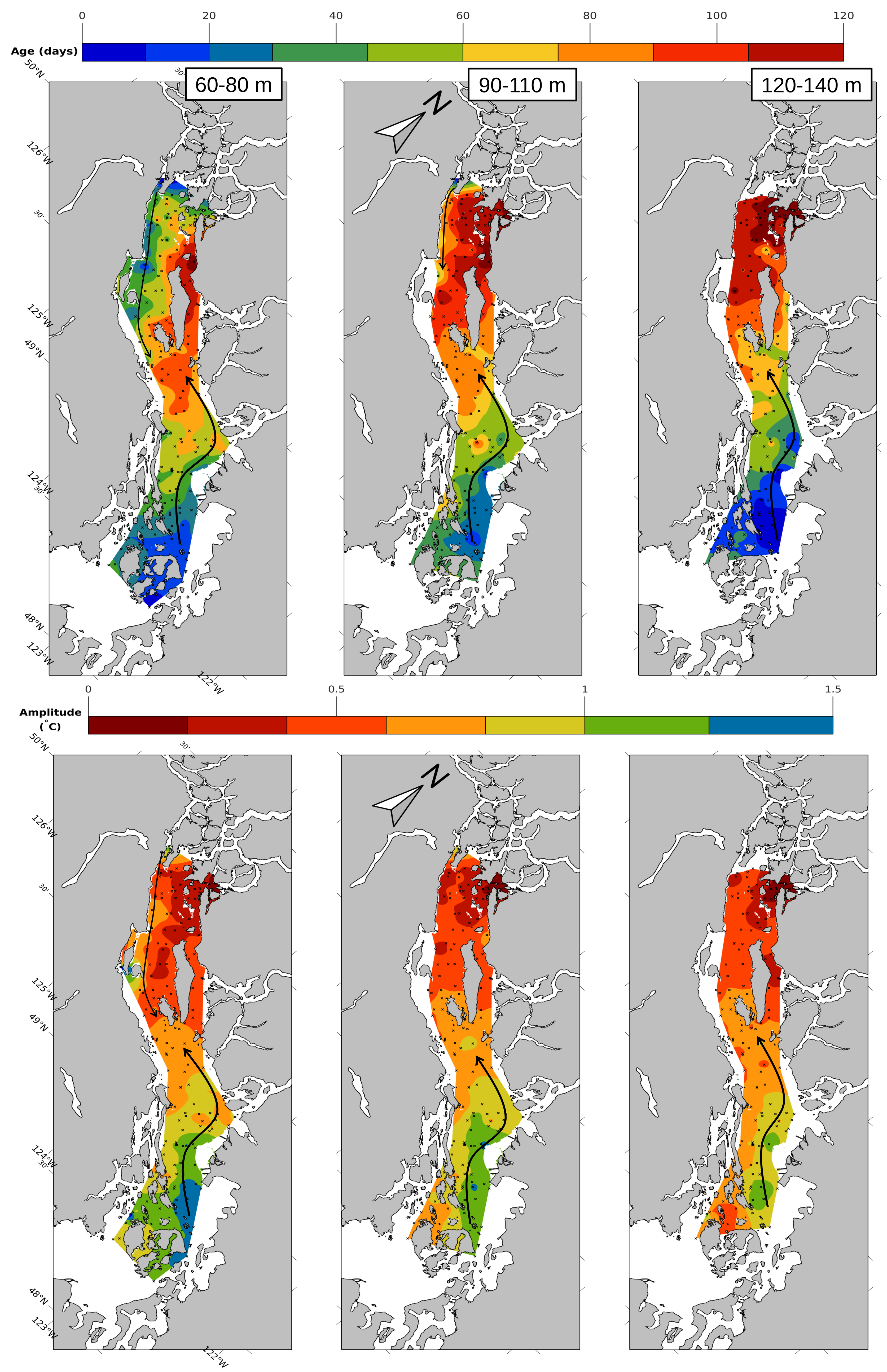

Figure 4: Maps showing the IW age (first row) and temperature seasonal cycle amplitude (second row). Columns are averages for the given depth levels. A kriging interpolation method was used to prior to mapping. Black arrows are a representation of renewal pathways.

We can trace water mass ventilation signals in this region by looking at the spatial variation in seasonal cycles.

Young and/or high amplitude signals represent the origin of an IW renewal e.g. southeast and northwest regions in above figures.

Is the circulation captured by our regional model?

Seasonality analysis of hindcast fields from **SalishSeaCast**, a baroclinic, 3-D, primitive equation model of the Salish Sea forced by real winds (Soontiens & Allen, 2017, Ocean Modelling), depicts a circulation system with similar mean flow structure as seen in our data at left. In addition, **particle tracking** experiments (using ARIANE) in the SalishSeacast hindcasts show the **dispersion of particles** within this mean flow.

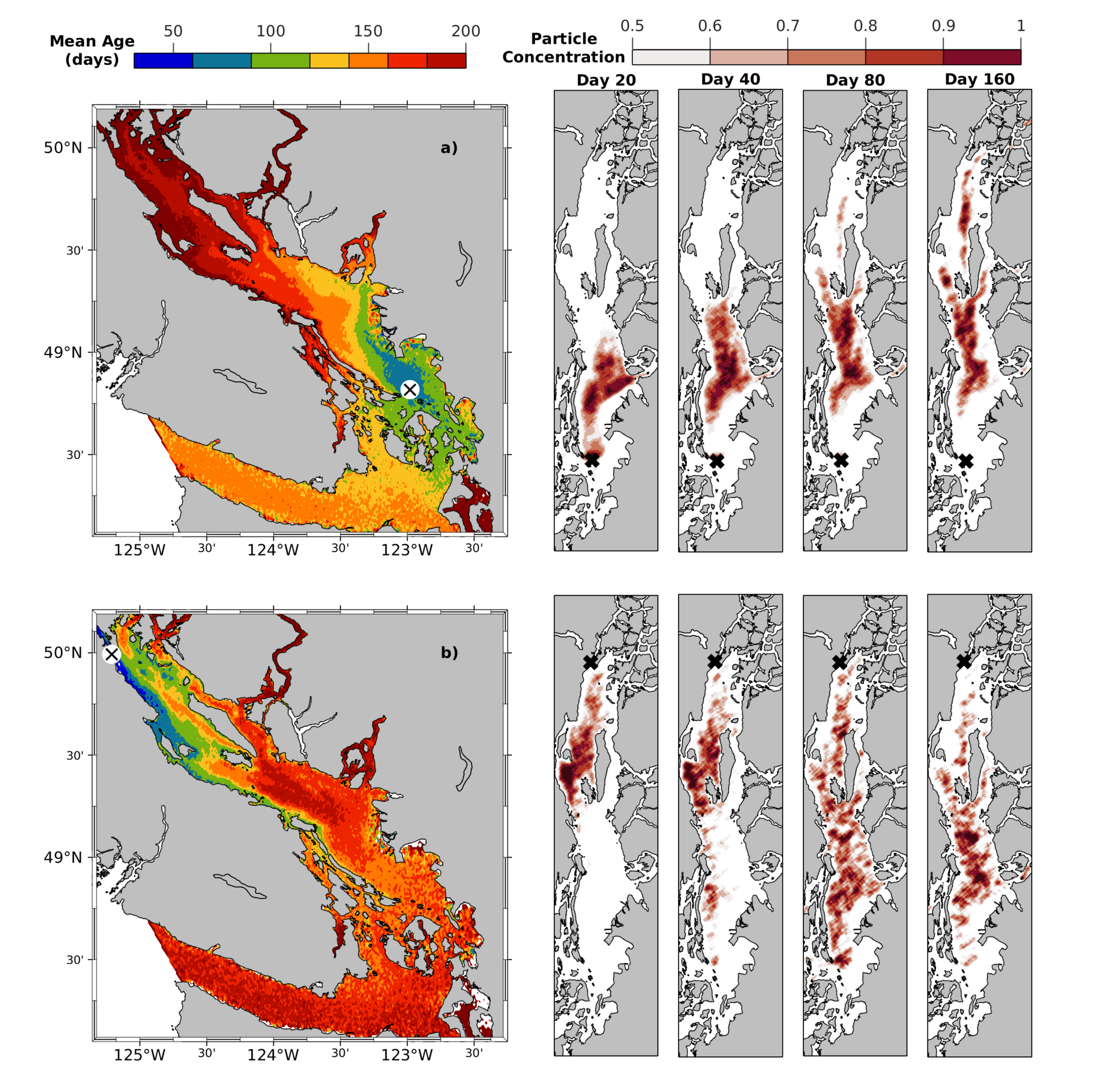

Figure 5: Results of particle tracking experiments showing mean age of IW particles released from Haro Strait and Discovery Passage (black x's). Normalised particle distributions at certain time steps are also mapped.

Statistical inference

We can compare the age of the water to its displacement to calculate along-strait (i.e. northwest) **advection velocities** of 1.5-3.0 cm s^{-1}. We can also use the particle displacement distributions for insight into the advection-diffusion characteristics of the system.

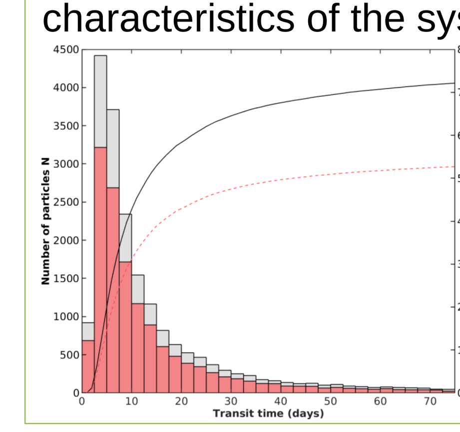

Figure 6: Age distribution of particles passing into the southern basin (black) and through the southwestern renewal current (red).

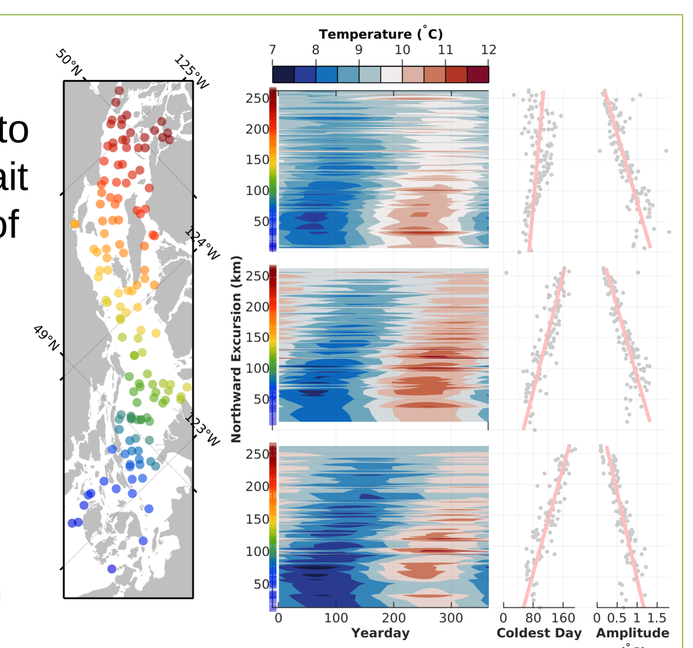

Figure 7: Seasonal temperature cycles and their characteristics from all stations, plotted as a function of northward excursion. Station colours correspond to coloured bar on contour plots.

What have we learnt?

- We can use **varying seasonality** in the interior of a coastal ocean to map a complex circulation system.
- Two **ventilation "jets"** renew IW in the Strait of Georgia- one in the north and one in the south.
- 78-85% of the seasonal cycle amplitude is attenuated by the time the southern inflow reaches the northern basin due to **mixing** between adjacent water masses.
- We can replicate, and expand upon, these results in a 3-D regional model.