What drives estuarine circulation?

Jody M. Klymak

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Introduction

Exercise

We will practice some of what we have learnt based on a paper about local waters by Masson and Cummins (2004). As part of your final project you will read about similar processes in Saanich Inlet (Gargett et al., 2003).

Q: Consider figure 1, which shows the salinity observed and modeled in the Strait of Juan de Fuca. Based on these plots, where do you think the mixing is the strongest in the Strait?

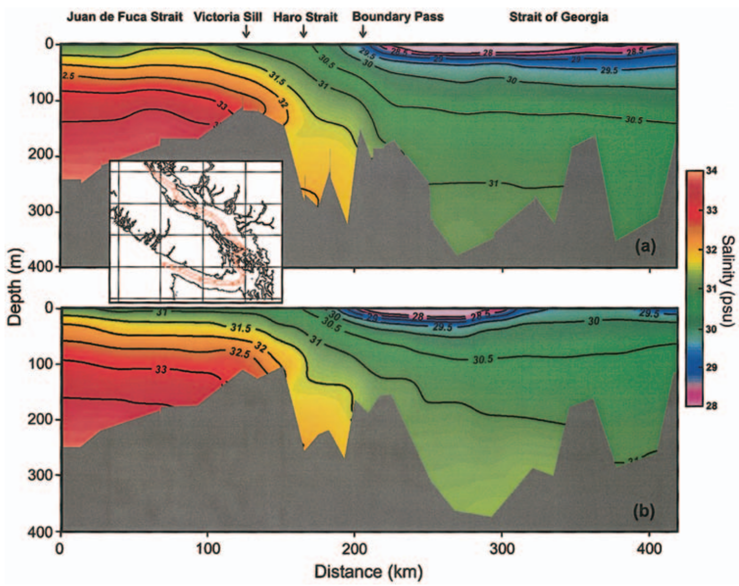

Figure 6. Along-strait section of annual mean salinity from observations (a) and the reference experiment (b).

Figure 1: Observed and modeled salinity in the Straits of Juan de Fuca and Georgia (Masson and Cummins, 2004).

A: Mixing is likely the strongest where the topography is the shallowest and most constrained, i.e. between 100 and 250 km, which represent the region off Victoria to Georgia Strait. Indeed we see that fresh water is mixed away as it enters this region and isohalines are quite vertical.

Q: For the flow in figure 1, sketch where you think the water is flowing. What happens north of the Fraser river?

A: The isohalines generally want to flatten out, which means that the dense water flows up the estuary (to the right) and lighter water flows down the estuary to the ocean (to the left). North of the Fraser (which is at about 250 km), the flow at the surface is probably to the north.

Q: Consider figure 2, which compares two numerical model runs, one with tides and one without. Which do you think is which, and why? Which has the stronger horizontal circulation?

A: The bottom run has more horizontal isohalines, and is likely the model run with less mixing. It also likely has weaker horizontal circulation.

Q: A seasonal time series of the salinity in Haro Strait is given in figure 3. What features of the flow can you identify, particularly in the modeled timeseries (which has more temporal resolution)?

A: In terms of the density of the water, we see the largest contrast in the summer. Here we can see both the Fraser River discharge increasing and denser water entering

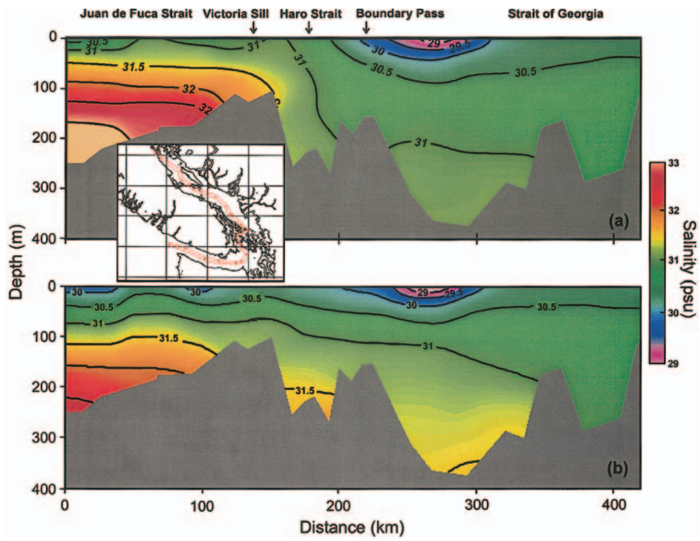

Figure 2: Salinity for two model runs, one with and the other without tides (Masson and Cummins, 2004).

Haro Strait, likely from summer upwelling offshore. On a smaller timescale we can see clear evidence of a twice a month time scale in the modelled data. We would expect the densest water to make it through during neap tides at this location, because the sills to the south are wide and very turbulent, and able to mix away density.

Q: Use the Knudsen relation on the two data plots in figure 2 to *estimate* the exchange flow if the river input is $10^4\ \mathrm{m^3\,s^{-1}}$. Which case has a stronger exchange, a) or b)?

A: The Knudsen relation is

$$Q_i = \frac{RS_o}{S_i - S_o} \tag{1}$$

so, if we know R, we need only estimate the outflowing salinity S_o and the inflowing salinity S_i. For a) we might say $S_i \approx 32$, $S_o \approx 31$, so $Q_i = 31R$! For b) the salinity difference is larger: $S_i \approx 32$, $S_o \approx 30.5$, so $Q_i = 30.5R/1.5 \approx 21R$. This accords with our guess from above.

References

Gargett, A., D. Stucchi, and F. Whitney, 2003: Physical processes associated with high primary productivity in Saanich Inlet, British Columbia. *Est. Coast. and Shelf Sci*, **56**, 1141–1156.

Masson, D., and P. F. Cummins, 2004: Observations and modeling of seasonal variability in the Straits of Georgia and Juan de Fuca. *J. Mar. Res.*, **62**, 491–516.

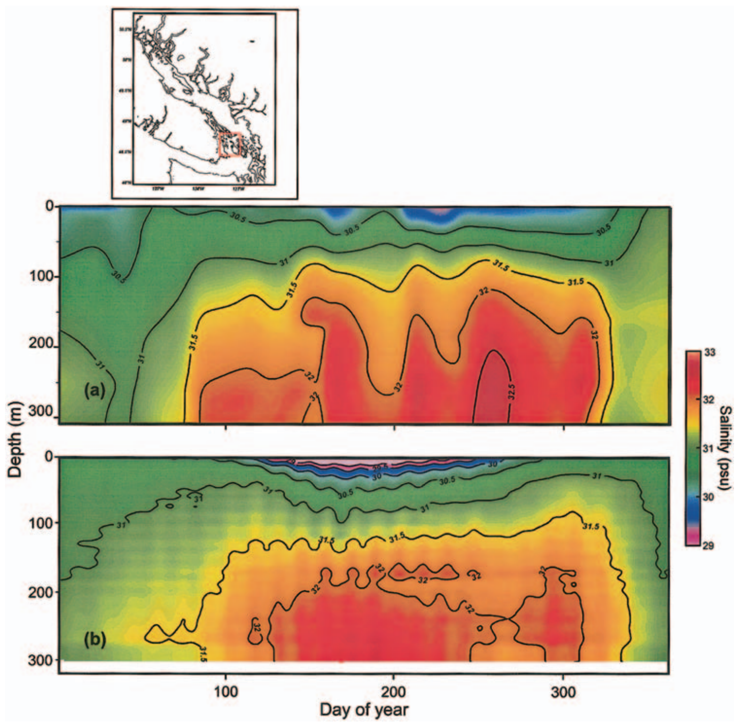

Figure 3: Time evolution of observed and modeled salinity in Haro Strait (Masson and Cummins, 2004).