Problem set 2: Chemistry of Bellingham Bay and the open ocean

The purpose of this problem set is to help you to think more clearly about concepts of salinity, temperature, density, and residence time. We'll examine these concepts using some data from Bellingham Bay and from the open ocean.

**Part 1: What controls seawater density - temperature or salinity?**

Salinity and temperature in Bellingham Bay vary with season and with freshwater inflow from the Nooksack River. But, in summer and fall, surface water salinity in the outer portion of the bay often averages 26 psu whereas deep water salinity is closer to 30 psu. Temperature in surface waters often reaches 11 degrees C, whereas the temperature of deep water is usually around 9 degrees C. For comparison, in the North Pacific Ocean (Station 17C, on the P15 line of the World Ocean Circulation Experiment dataset), salinity in the surface mixed layer averages 33.25 psu compared to water below the pycnocline which averages 34 psu. Surface temperatures average 15 degrees C compared to deeper water temperatures that average around 7 degrees near the base of the pycnocline (200 m).

**Figure.** Temperature and Salinity data from the North Pacific (WOCE data set)
**Problem:** Use the equation of state, which I have entered in the spreadsheet (follow the link in the projects page) to calculate the seawater density based on the temperatures and salinities given above and then answer the following questions.

1: What are the densities (kg/L) of surface and deep waters in Bellingham Bay and at the North Pacific station?

2: Which is more important in determining density in Bellingham Bay - temperature or salinity? Which is more important at the North Pacific station? To answer this question, you'll need to perform a numerical experiment using the equation of state. Use the results of this numerical experiment to support your answer.

**Part 2: Seawater chemistry and residence time.**

**Problem:** The following table lists the average concentrations of several elements in of the open ocean and their average concentrations in rivers. Given a global river runoff rate of $4 \times 10^{17}$ liters/year, and an ocean volume of $1.2 \times 10^{21}$ liters, calculate the residence time of each element in the ocean. Then, compare the two elements with the longest and shortest residence times. What might account for this difference? (Hint: Do some research on the cycling of these elements in the ocean to learn more about what processes remove them from surface seawater, but don't trust anything published before the mid 1980s.)

<table>
<thead>
<tr>
<th>Element</th>
<th>Na</th>
<th>U</th>
<th>Al</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration in ocean water (μmole/liter)</td>
<td>4.68x10$^5$</td>
<td>1.3x10$^4$</td>
<td>2.0x10$^3$</td>
<td>2.3x10$^6$</td>
</tr>
<tr>
<td>Concentration in river water (μmole/liter)</td>
<td>2.3x10$^5$</td>
<td>1.0x10$^4$</td>
<td>1.85x10$^6$</td>
<td>1.3x10$^4$</td>
</tr>
</tbody>
</table>