SAMPLING FREQUENCIES NECESSARY FOR COASTAL OCEAN OBSERVATORIES

Allan Devol, Wendi Ruef
School of Oceanography
University of Washington
Seattle, WA. USA

Jan Newton
Applied Physics Laboratory
University of Washington
Seattle, WA USA

The Northwest Association of Networked Ocean Observing Systems, or NANOOS, is located in the Pacific Northwest of the United States and consists of coastal, inshore and offshore assets. Inshore assets include, among other things, four ORCA (Oceanic Remote Chemical Analyzer) buoys moored in Hood Canal, (Puget Sound, Washington State). Hood Canal is a 100 km long, silled fjord with maximum depth of about 220 m. It is thus prone to hypoxia. The ORCA buoys contain sensors to measure the hydrographic variables temperature, salinity, dissolved oxygen, chlorophyll fluorescence, turbidity, nitrate, PAR and currents as well as the meteorological variables, air temperature, pressure, humidity wind speed and direction. The buoy contains a solar powered winch and computer and is capable of profiling the whole water column up to 12 times daily. All data is telemetered back to a shore-based computer and processed and posted to the internet in real time.

Data from the NANOOS ORCA moorings has proved invaluable in understanding natural phenomenon in the Hood Canal system including, the mechanisms underlying fish kill events due to hypoxia, internal waves and seiches, as well as the coupling of wind induced intrusions of deep water into the euphotic zone and productivity events. The seasonal cycles of variables are clearly resolved, but associated with the general trends there is a large amount of high frequency variability. Because of the high frequency variability single profiles taken at any given time may or may not be representative of the mean condition. Here we show the sampling frequencies required to capture the “true” mean values and trends for several variables. Knowledge of required sampling frequencies is necessary to be able to resolve inter-annual variability and long term trends.

For example, we have used the ORCA data to estimate the sampling frequency required to determine the mean surface and bottom water oxygen chlorophyll and nitrate concentrations during the month of July. First we calculated the average concentrations in the surface bottom layers (upper 6 m and bottom 5 m) using all 368 profiles taken during the month (Fig. 1). This we took as the “true” mean. Next we randomly sub-sampled the data at daily, weekly and monthly frequencies and determined those averages. We repeated this random sampling 12 times to estimate the uncertainty in the daily, weekly, and monthly averages. The results of this exercise are given in Table 1. When all 368 dissolved oxygen profiles were included in the averages the means were 245 μM and 71 μM for the surface and bottom layers, respectively, which we assume is representative of the true value. When one profile was randomly selected from each day the range in the means for the 12 different calculations was 243-248 μM for the surface layer and 68-72 μM for the bottom layer. Daily sampling provided a good approximation of the “true” value. However, if the daily sub-sampling was restricted to the daylight hours then the estimated average oxygen concentration in the euphotic zone was about 15μM higher. The accuracy of the averages then decreased with less frequent weekly and monthly sampling, to the point at which it is doubtful that inner annual variability or long term trends could be confidently detected with these less frequent sampling schedules. Similar results were obtained when nitrate averages were computed. The results for the chlorophyll averages suggest that weekly sampling may be sufficient to capture the dynamics of the chlorophyll distribution

Table 1. Mean values of dissolved oxygen concentration in the euphotic zone (upper 6m) and bottom layer (bottom 5m) as determined by random sub-sampling of the full July 2007 data set. The range shown is for 12 different random samplings of the data. N is the number of profiles in each average.

Sampling interval	N	Euphotic zone O2	Bottom layer O2
Every 2 hr. (all data)	368	245	71
Daily	31	243-248	68-72
Weekly	4	236-254	63-80
Monthly	1	208-276	55-81

A large part of the uncertainty in the estimates based on the low frequency sampling is due to horizontal heterogeneity in the distributions of the variables. This, combined with the approximately 6 km tidal excursion, contributes to the high frequency variability of profiles taken at one location over time. To determine the scales of horizontal variability we use a CTD equipped with oxygen, chlorophyll and nitrate sensors to map the surface distribution around the ORCA mooring site (Fig. 2). Patchiness is observed in all variables with length scales on the order of hundreds of meters to kilometers. Also, all variables display strong fronts with length scales of tens of meters. The main freshwater source to the inlet is the Skokomish river at the southwest end of the Canal, before it turns eastward. The freshwater plume from this river is clearly seen in the salinity distribution as a flow of freshwater heading north along the east side of the canal heading northward. Horizontal surface maps made at different tidal stages show different

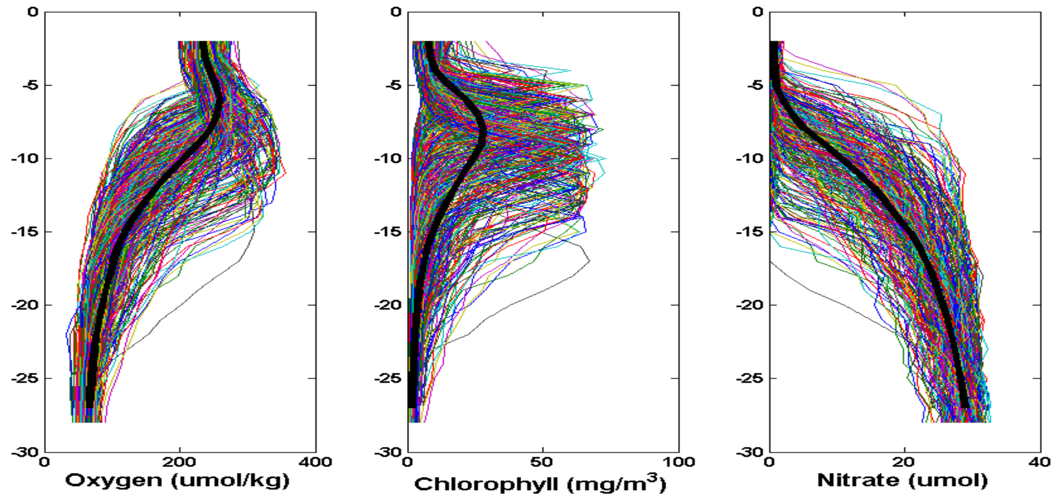

Figure 1. Oxygen (left), chlorophyll (center) and nitrate (right) profiles for the month of July. The average profiles of each are shown by the dark solid line.

distributions, but the same length scales of variability are seen. The net result of this patchiness coupled with tidal advection means that profiles taken at a given location but at slightly different times can be significantly different.

The high frequency variability and the length and time scales of variability

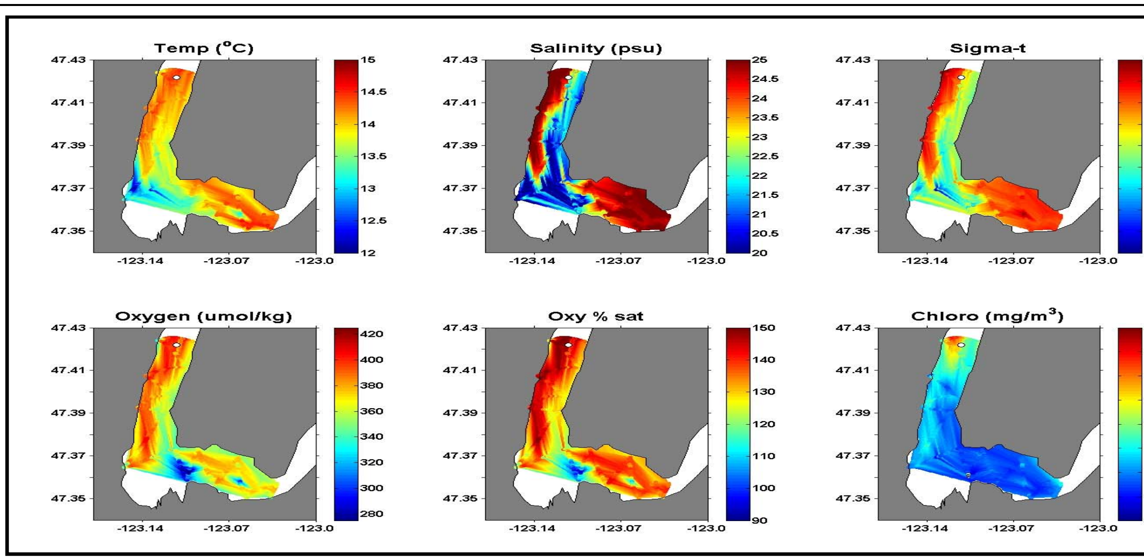

Figure 2. Surface distributions of various properties around the ORCA mooring. Clockwise from top left: temperature, salinity, sigma-t, oxygen, oxygen saturation, and chlorophyll. Axes are latitude and longitude (negative = degrees W).

observed at the ORCA mooring in lower Hood Canal is likely typical of that found in other coastal and inshore waters throughout the temperate latitudes.   Currently, there are numerous coastal observing systems in the US and around the world, with more in planning and construction stages. Some of the main objectives of these systems are to be able to detect inter-annual and long term changes in climate and environment. The results presented here suggest that in order to do this with statistical significance appropriate sampling frequencies must be determined.