Investigation of Mixing Processes at Hood Canal Sill

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**Project Summary**

Dense water intrusions occur when dense ocean water is forced over a sill into an estuary of lighter water. Refluxing, also called entrainment, occurs when lighter estuarine water is mixed with incoming ocean water and forced back into the estuarine system. These two processes can occur separately or in tandem. As the intrusion enters the estuary over the sill it will follow along the bathymetry. If the amount of refluxing is high then the size of the intrusion will be small and vice versa. Intrusions bring ocean water into the estuary system which in turn helps force out the river water setting up a circulation pattern. This circulation pattern keeps the estuary from becoming stagnant.

The research will consist of a 6 hour anchor station at the southwestern edge of Hood Canal sill and a single station north of the Hood Canal. During the anchor station CTD casts will be made every 30 minutes to collect density, salinity and temperature profiles of the water column. A single CTD cast will be made at the station north of the sill. Several water samples will be collected during the casts and analyzed in the chemical laboratory so that the salinity sensor can be calibrated. The Acoustic Doppler Current Profiler (ADCP) will be running continuously during the entire cruise. The ADCP gathers data on current velocities in all three planes of the water column. Combined, these two data sets will allow me to see the structure of the water column during the anchor station and to make comparisons to the water column north of the sill. My hypothesis is that an intrusion will occur at depth during the anchor station and that the intrusion properties will be consistent with the water column north of the sill.
Introduction

Landward velocity during a flood tide is strongest along the western side of the Hood Canal sill (MacDonald, 2000). I will study the mixing processes at the sill, specifically the southwestern section. Associated with sills and estuaries are dense water intrusions which bring salty ocean water in at depth underneath out flowing less dense river water (Allen et al, 1998). Intrusions are formed when strong mixing occurs with a density gradient (Mickett et al, 2004; Thein et al, 2004). Intrusions are the primary source of oxygen rich water into Hood Canal. Strong mixing acts to increase entrainment which reduces the effects of strong intrusions and causes renewal time to increase (Liungman et al, 2001). Intrusions can be seen using shear layers and salinity profiles (Brubaker et al, 1999).

The Hood Canal is one of the four main basins in Puget Sound and is characterized by a sill to the north and river input to the south (Figure 1). The Hood Canal is oriented to in the southwest-northeast direction. There are four rivers that account for the freshwater input into the system. They are the Quilcene, Duckabush, Dosewallips and Hamma Hamma. All four rivers enter the Hood Canal south of the time series station so that they can be considered to have a single effect on the water column for the purposes of this project. Dense ocean water enters the Hood Canal from the north coming over the sill. The interface of the two water layers is called the level of no motion. Above this level the fresh water is flowing northward. Below this level the ocean water is flowing southward. The two layers do not interact with each other inside the estuary. At the sill itself the level of no motion breaks down and refluxing can occur.
**Proposed Research**

The field experiment aboard the *R/V Thomas G. Thompson* will consist of a time series station (*Latitude and Longitude*) occurring during a flood tide and an individual station (*Latitude and Longitude*). The individual station will be conducted before entering the Hood Canal and conducting the time series so as to have a record of the water column before the flood tide draws the water southward. Upon arrival at the individual station a single CTD cast will be made for the purposes of gathering temperature, salinity and density measurements of the water column. The ship will then transit inside the sill where it will conduct the time series. Upon arrival at the time series station a new ADCP file will be started and a CTD cast will be made. The ship will then hold position for the duration of the flood tide, roughly 7 hours. During that time the ADCP will continuously gather data and a CTD cast will be made every half hour. Each CTD cast will again consist of temperature, salinity and density measurements. To calibrate the salinity sensor on the CTD water samples will be taken at the individual station and the first and last casts of the time series. Samples will be taken in triplicate from the surface layer and the bottom layer and in duplicate from the isopycnal level as determined by the CTD cast. The samples will be analyzed ashore by the chemical analysis lab at the UW School of Oceanography.

The expected results of the research are a general flow to the south in the ADCP data and the appearance of a dense water intrusion at depth sometime during the flood tide in the CTD data. The bathymetry of the area surrounding the time series station suggests that the flow pattern will be toward the southwest. The flow will start out
slowly, possibly even to the north as residual effects from the ebb tide dissipate, but will increase to maximum before again slowing down. This pattern will bring ocean water like that measured at the individual station south over the sill and into the Hood Canal estuarine system. When this occurs there will be a two layer system. At depth the incoming water will be low in temperature and high in salinity and density. At the surface the water will be high in temperature and low in salinity and density. This two layer system will be dominated by the deep water which will extend to 10-20 meters from the surface. At that depth a level of no motion will occur and will mark the interface between the top, out-flowing, water and the bottom, inflowing, water. The dense water intrusion will occur very close to the bottom. As the time series progresses the incoming ocean water will continue to dominate the velocity profile. At all depths the temperature will decrease and the salinity and density will increase. They will reach their respective maximums or minimums at the very end of the flood tide. As the flood begins to slacken and the tide turns there may occur a slight reversal of the water property trends.

**Project Budget**

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References


Figure 1

Combined image of Puget Sound topography and bathymetry. The subset is a magnification of Time Series Station.
Dense water intrusion flowing into estuary from open water (Thein et al., 2004). Arrows show magnitude and direction of water flow.