The Seward Eddy *versus* Storm Induced Mixing (?) and the Spring Bloom of 2000 on the Gulf of Alaska Shelf

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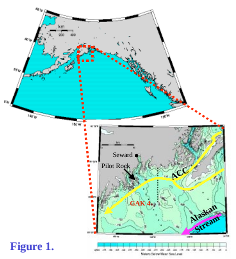


Figure 1.

abstract:

Coastal inhabitants in the northern Gulf of Alaska have a deep respect for the ocean. The sea provides a practically unlimited source of food in the form of salmon, shellfish, seals, and whales. Understanding the ability for this complex ecosystem to maintain its structure when faced with the strain of anthropogenic inputs and exports (oil spills, fishing pressure, etc…) is one of the foremost challenges of oceanography today. In order to make progress in understanding the linkages between phytoplankton, zooplankton and eventually to fish and mammals, insight into the dynamics controlling the physical environment must be attained. At the base of the food chain is primary production, which is entirely controlled by ambient sunlight and availability of nutrients. Physical factors such as coastal currents, eddies and upwelling are sources (or sinks) of nutrient enriched waters which then regulate the amount of primary production taking place on the shelf. The success of the entire ecosystem is strongly influenced by the strength of its lowest level. In fact, one could well think of the *physics as the lowest trophic level*. Biological activity taking place on the coast may be severely disrupted if planktonic organisms were to be transported out of their optimal habitat to regions offshore. The timing of an eddy's impingement on the coast with respect to the reproductive success of fish and zooplankton would be critical.

1. Motivation:

- The upper trophic levels (marine mammals, birds and fish) are intimately tied to the physics of shelf processes through the productivity of the lower trophic levels.
- Cross-shelf transport plays an important part in the coastal dynamics and represents a potential source (sink) of nutrients and planktonic species to the coastal ecosystem.

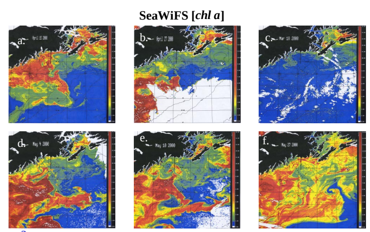
2. Setting:

- Strong freshwater discharges, high winds and steep topographic coastal features influence coastal circulation in the Northern Gulf of Alaska.
- The nearshore (<25 km), low-salinity flow of the Alaska Coastal Current (ACC) is a fairly continuous feature extending from the Columbia River to the Bering Sea (Royer, 1997).
- The shelf southwest of Prince William Sound and seaward of Resurrection Bay is complex, with alternating shallow banks (75-100 m depths) and deep troughs (200-250 m depths) cutting across the shelf.
- The Aleutian Low and the passage of storms from west to the east dominate weather in this region.
- Satellite images show that the region seaward of Resurrection Bay is populated by large numbers of relatively small diameter (20-30 km) eddies.
- **The *major questions*** are:
  - o Do these topographic irregularities, the passage of storms or some combination of both significantly alter the flow of the ACC and cross-shelf transport?
  - o What is the effect of the coastal physical processes on biological productivity of the lower trophic levels?

3. Data:

- SeaWiFS derived chlorophyll a concentrations for the period March 18, 2000 to May 27, 2000.
- Hydrographic data for mid-April and mid-May collected by the GLOBEC LTOP program.
- Winds, air temperature and barometric pressure from the Pilot Rock and Middleton Island meteorological stations.
- Two moorings deployed in March 2000, located at GLOBEC sampling station Gulf of Alaska 4 (GAK4), Figure 1. At 50 km from the mouth of Resurrection Bay, GAK4 is bordered by the ACC to the north and the Alaskan Stream to the south. The moorings contained two ADCPs and a total of five CTD sensors, three of which were equipped with PAR, fluorescence sensors and a nitrate meter.

Temporal Variations in Spring Conditions in the Northern Gulf of Alaska, 4/1/00 – 6/15/00:



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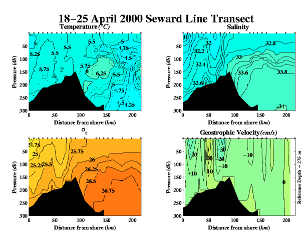

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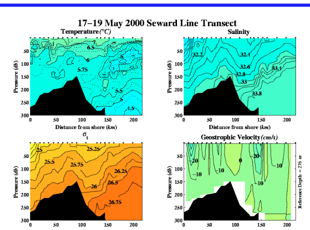

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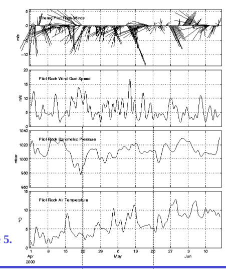

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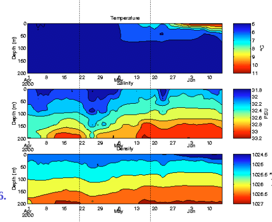

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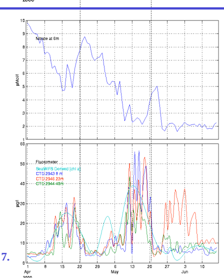

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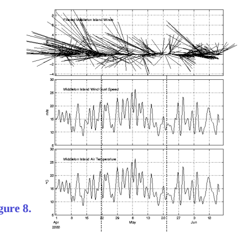

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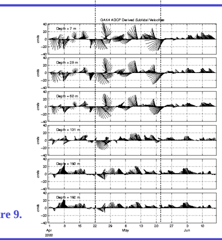

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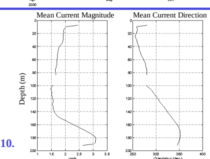

Figure 10.

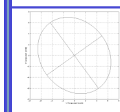

Figure 11.

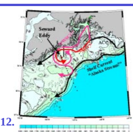

Figure 12.

4. Results:

- **Figure 2a**, SeaWiFS derived chlorophyll a concentrations from March 18, 2000, reveals that the Gulf shows very little productivity except for the regions within and east of the Prince William Sound (PWS) and a narrow band along the coast that is deflected offshore at Resurrection Bay. In contrast to this, **Figure 2b**, collected April 15, 2000, reveals that the spring bloom has begun on the shelf west of Resurrection Bay.
- Satellite images and *in situ* hydrography indicate (See schematic, **Figure 12**):
  - o ACC waters form a "ring" of high chlorophyll around the rim of the cyclonic **Seward Eddy** (diameter = 50-100 km); satellite images indicate that the **Seward Eddy** is present most of the year.
  - o The **Seward Eddy** is a result of topographic steering by the Chiswell Ridge of the barotropic flow associated with the ACC.
  - o Offshore of the **Seward Eddy,** is a counter-rotating eddy (diameter = 50 km), with high chlorophyll around its rim.
  - o A cyclonic slope current meander (eddy?, diameter = 100 km) is upstream of and interacts with the anticyclonic eddy. These eddies resemble observations elsewhere on the Alaskan coast (Ahlnas, et al. 1987, Lagerloef, 1983, Thompson and Gower, 1998).
- **Figures 2c-2f** show the evolution of the eddies and the chlorophyll field.
- **Figures 3** and **4** show hydrographic snapshots of the series of events described above. In mid-April the bottom front associated with the shelf-break is located 80 km from the coast, and further inshore there are two distinct regions defined by the structure of the halocline. The structure closest to the shore is the baroclinic buoyant plume associated with the ACC. Moving offshore, the doming of the halocline and reversal of geostrophic velocities suggests that the ACC has reversed direction, assuming a fully 3-dimensional current structure. Relative vorticity is > f, thus ageostrophic dynamics are important. In mid-May the bottom front has moved further inshore. The halocline shows that the recirculation in the **Seward Eddy** has moved offshore and the associated geostrophic flow is dispersed over a much greater region than in April.
- The winds and barometric pressure collected at Pilot Rock reveal three major storm systems passed the Gulf during the spring, **Figure 5**.
- The Middleton Island meteorological station located 150 km to the east of Pilot Rock, **Figure 8**, reveals that the storm events occur almost simultaneously at these two locations.
- Subtidal currents derived from the GAK4 ADCPs reveal that surface currents rotate cyclonically with the passage of each storm event and reach a peak magnitude of 40 cm/s, **Figure 9**.
- The mean current magnitudes are between 1-3 cm/s over the spring time period with a heading of near west near the surface and rotating clockwise to due north with depth, **Figure 10**.
- **Figure 11** reveals the principal axis of the fluctuating currents is oriented along the axis of the trough at GAK4.
- The storms of April 20 and May 23 shown by dashed lines on **Figures 5-7** caused depressions of the halocline by 50 m at the GAK4 mooring. The passage of this storm raised the ambient levels of NO3 and salinity at the surface and lowered the level of primary production at this site to pre-bloom conditions.
- *The decrease in fluorescence, increase of nitrate and decrease in salinity are not consistent with the paradigm that storm events disrupt the bloom by destroying the stratification. If this were the case, high salinity from below would be apparent in the upper water column.*
- *The satellite images, as well as the ADCP velocities indicate that the outside rim of ACC water derived from PWS (PWSCC) is now further offshore and the inner water in the **Seward Eddy**, which is derived from water on the outside of Montague Island, is over the mooring.*

5. Open Questions and Future Work:

- What is the variability associated with the fluctuations in cross-shore eddy displacements?
- What is the trigger for the spring bloom: is it a localized event advected downstream by the ACC or does it occur over broader areas simultaneously?
- Are bottom boundary processes involved in the cross-shore fluctuations of the boundary current?
- Does the steering of the flow field constitute an example of the Taylor-Proudman effect or is it more directly connected to baroclinic instabilities?

References:

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