2.1 # VARIABILITY IN SHELF TRANSPORT IN THE GULF OF ALASKA, PART I: DIAGNOSIS OF AIR-SEA INTERACTIONS

Nicholas A. Bond*[1,3], Richard C. Steed[2], Albert J. Hermann[1,3], and Phyllis J. Stabeno[3]
[1]JISAO, University of Washington, Seattle, WA 98195
[2]Department of Atmospheric Science, University of Washington, Seattle, WA 98195
[3]NOAA, Pacific Marine Environmental Laboratory, Seattle, WA 98115

1. INTRODUCTION

This paper represents an overview of a project focused on how interannual fluctuations in atmospheric forcing result in variations in along-shore and cross-shelf transports in the northern Gulf of Alaska (GOA). These transports appear to be important to the survival of juvenile salmon, through their impacts on advection to favorable nursery grounds, and on availability of suitable prey. The approach has been to carry out a coordinated program of in situ observations and numerical atmosphere and ocean modeling. Previous observational and modeling results indicate the importance of local winds over the shelf to its primary current system, the Alaska Coastal Current (ACC). Direct observations of these winds are insufficient for real-time and retrospective analyses. As illustrated in Part II of this series of papers, a mesoscale numerical weather prediction model, the MM5, has been employed to downscale from the coarse grid provided by the NCEP/NCAR Reanalysis data set. The output from the MM5 has been used to assess various aspects of the atmospheric forcing: the variability in surface heat fluxes versus momentum fluxes, the characteristic patterns of mean wind stress over the shelf, the importance of localized versus distributed freshwater runoff, and the relative roles of the local atmospheric forcing to that over the deep basin of the GOA. Part III in this sequence emphasizes the results from direct observations of the ACC from a moored buoy array. These observations indicate large seasonal and intraseasonal variations in the currents and hydrography and suggest the importance of the local atmospheric forcing over the shelf. These observations are being used to validate numerical ocean model experiments using the Regional Ocean Modeling System (ROMS), as detailed in Part IV of this series of papers. These experiments are being carried out using both the spatially coarse NCEP Reanalysis, and the much finer resolution MM5 output, as boundary forcing in the GOA. Their differences demonstrate the sensitivity of the coastal ocean in the GOA to the local winds.

* *Corresponding author address:* Nicholas A. Bond, NOAA/PMEL/JISAO, 7600 Sand Point Way NE, Seattle, WA 98115, (206)526-6459 (nickolas.a.bond@noaa.gov)

2. OBJECTIVES AND ISSUES

The overall objective of this project is to examine how climate variations are communicated to the ocean over the shelf of the Gulf of Alaska (Fig. 1), with a special emphasis on those properties related to the marine ecosystem. The ultimate goal of this and related work being supported by the Global Ecosystem Dynamics Project (GLOBEC) is to generate the information required to better anticipate changes in marine populations, and hence manage fisheries and other marine activities more effectively.

On the most basic level, our work consists of studying how the physical properties of the ACC are linked to the marine ecosystem. Within this broad subject, a host of specific issues are being addressed, as summarized by the following list of questions. How much of the variability of the ACC is intrinsic (that is, due to internal oceanographic processes) versus due to fluctuations in atmospheric forcing? Of this external atmospheric forcing, what are the relative contributions of the longer-term, gyre-scale component versus the episodic, regional or local-scale component? The local winds are known to be sensitive to the effects of the coastal terrain (e.g., Overland and Bond 1993), but how can these effects be effectively diagnosed? Concerning the local atmospheric forcing, it is known that the winds are important (e.g., Stabeno et al. 1995), but do the surface heat fluxes also play a significant role? The coastal GOA is subject to enormous freshwater run-off (Royer 1982), which definitely causes most of the baroclinity associated with the ACC, but do sub-seasonal fluctuations in this run-off significantly impact the ACC? What is the relative contribution of the baroclinic to the barotropic portion of the flow in terms of determining the net along-shelf transport of the ACC in summer (the critical period for juvenile salmon)? In general, what are the predominant mechanisms for cross-shelf and vertical exchanges over the shelf, and how are they modulated? Finally, how are nutrients supplied to the euphotic zone and hence how well can primary production be linked to the physical properties of the GOA's atmosphere-ocean system?

3. SAMPLE RESULTS

The project summarized above is ongoing (it runs through FY05) and so our results are by no means final. Nevertheless, substantial progress has been made, as illustrated in the three examples provided below, and the more detailed results presented in the three other papers of this series.

A modeling system has been developed based on the MM5, using the NCEP/NCAR Reanalysis as initial and boundary conditions. The grid spacing for the inner grid of the MM5 is 15 km, which appears to be suitable for handling the main effects of the coastal terrain, if not the details of its variability on fine scales. The first set of simulations have been carried out for the year of 2001, which represented the first year of comprehensive ocean observations, and a period in which boundary conditions were available for driving ROMS. An example of how the MM5 and Reanalysis compare is shown in Fig. 2. These maps of low-level temperature, sea-level pressure and surface wind show structures typical during situations of a low pressure center in the central Gulf. In general, the MM5 and Reanalysis are similar well offshore, as would be expected, but are significantly different near the coast. The most striking contrast here is the much stronger winds from the MM5 in the immediate vicinity of the coast, because its finer horizontal resolution better accounts for the effects of the Gulf's prominent coastal terrain.

The coastal winds appear to be a key element of the regional forcing of the ACC. For example, current measurements from a mooring located about 15 km south of the Kenai Peninsula during fall 2001 reveal a regular pulsing of the flow in the along-shore direction (Fig. 3). Periods of enhanced flow from the northeast tended to be associated with along-shore winds of a similar sense, and were accompanied by negative salinity anomalies of about 2 psu (not shown). Much more on the character of the flow in the ACC from the mooring observations is provided in Part III of these papers.

A similar character to the observed currents and hydrography has been found in simulations of the ACC by ROMS. A pair of snapshots of surface salinity distributions from ROMS are shown in Fig. 4. This particular simulation was made using climatological (monthly mean) winds from the Reanalysis and an average seasonal cycle for the runoff, and hence illustrates the ACC develops fine-scale variations in its baroclinity associated with largely oceanographic processes. It is interesting that the salinity features from this run had periods on the order of 10 days versus 6 days in the observations. Recent ROMS runs using the often coastally enhanced winds from the MM5 tend to result in a swifter ACC, which should yield a better match in the time scale of the salinity fluctuations.

4. FUTURE DIRECTION

Our work during the remainder of the project will be on a variety of topics. With regards to the air-sea interaction component, we are embarking on much longer MM5 runs to provide additional synthetic data sets for driving ROMS, analyzing more completely the MM5 output to determine the degree to which empirical relationships can account for the effects of coastal terrain, and quantifying the relative contributions of the basin-scale versus coastal zone forcing of variability in the strength and nature of the ACC. In terms of the oceanographic component, we are amassing longer time series of mooring observations for direct study of the ACC and for more comprehensive validation of ROMS. Assuming ROMS is found to be adequate for representing the actual physical oceanography of the GOA, we will rely heavily on its output to diagnose the along-shore transports and cross-shelf exchanges.

5. REFERENCES

Overland, J.E., and N.A. Bond, 1993: The influence of coastal orography: The Yakutat storm. *Mon. Wea. Rev.,* **121**, 1388–1397.

Royer, T.C., 1982: Coastal fresh water discharge in the northeast Pacific. *J. Geophys. Res.*, **87**, 2017–2021.

Stabeno, P.J., R.K. Reed, and J.D. Schumacher, 1995: The Alaska Coastal Current: Continuity of transport and forcing. *J. Geophys. Res.*, **100**, 2477–2485.

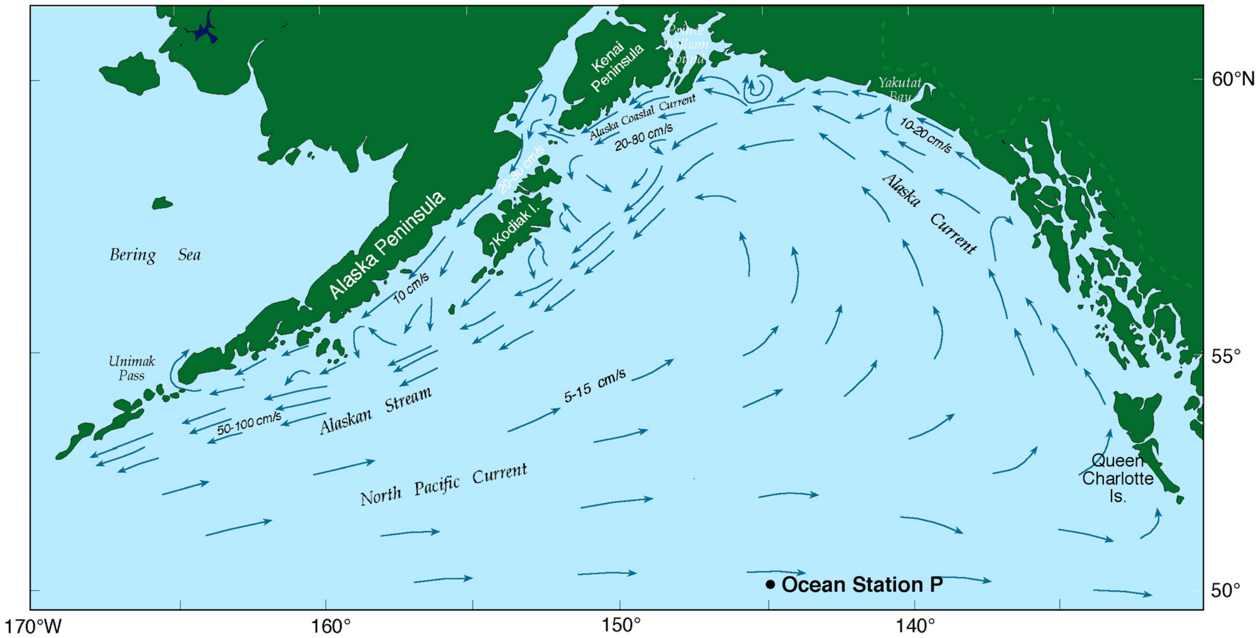

Figure 1. The current system for the Gulf of Alaska.

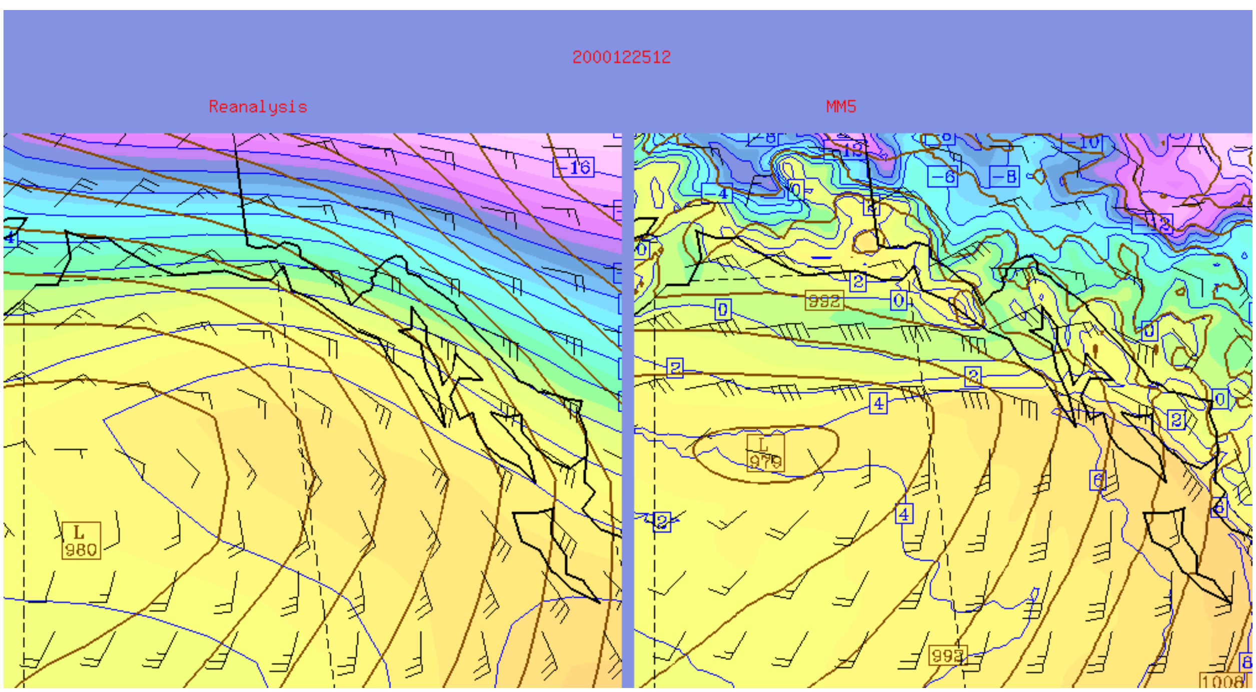

Figure 2. Comparison between the NCEP/NCAR Reanalysis and MM5 output for 25 December 2000. The solid black lines indicate sea level pressure, the colors indicate 925 hPa temperature, and the wind barbs indicate the near-surface winds using the standard meteorological convention.

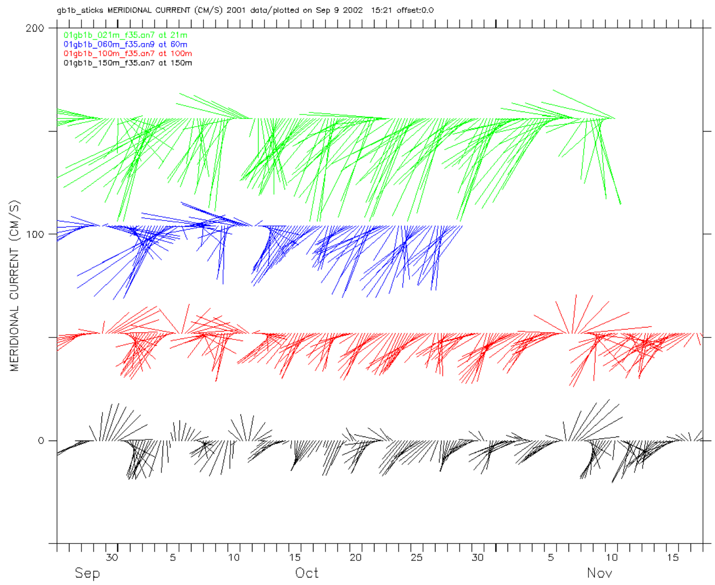

Figure 3. Current from GLOBEC Mooring 1, located about 15 km south of Seward, AK, during early fall 2001. The individual records are from current meters at depths of 21, 60, 100, and 150 m.

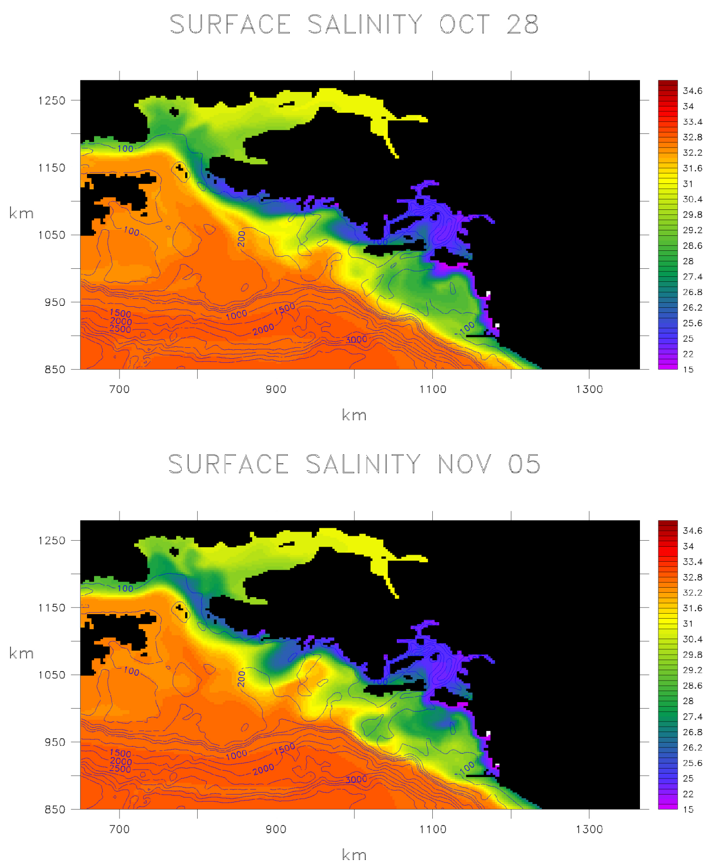

Figure 4. Snapshots of surface salinity distributions from a 10-km grid ROMS simulation using monthly mean winds from the Reanalysis.