Project Number: **040340**

Project Title: **Long-term oceanographic monitoring of the Gulf of Alaska Ecosystem**

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Project website address (if applicable): **http://www.ims.uaf.edu/gak1/**

Summary of Work

Weingartner et al. (2002), *Royer* (2005), *Sarkar et al.*, (2005), *Weingartner et al*., (2005), *Royer and Grosch* (2006) give a more complete description and a recent analysis of the data collected thus far. A summary of important findings derived from GAK 1 data collected under EVOS-TC support include:

1. The anomalous summer 1997 warming (~1-2^{o}C above normal) was due to anomalously low summer cloud cover and wind speeds and was confined to the upper 40 m of the ocean.
2. The El Niño-induced warming (~2^{o}C above normal) in winter 1998 occurred over the entire 250 m depth of the shelf, and was accompanied by unusually fresh shelf waters and above normal ACC transport. Stratification occurred early and might have induced an earlier than normal spring bloom. These anomalies provide a glimpse of what may be the norm if future climate change entails warmer and wetter winters in the Gulf of Alaska. Earlier stratification might induce an earlier spring bloom in the sound and the ACC thereby resulting in a timing mismatch between the bloom and zooplankton feeding.
3. Several factors were responsible for these anomalies: 1) coastal Alaska discharge [computed following *Royer* (1982)] was above average in fall 1997 and winter 1998, 2) Pacific Northwest river discharges were above average during summer and fall 1997, and 3) coastal downwelling around the Northeast Pacific was stronger than normal from summer through winter. In aggregate these factors decreased nearshore salinities and strengthened ACC alongshore transport. The simultaneous occurrence of all of these anomalies is unusual; 1997-98 was the only year since 1970 (the start of the GAK 1 record) in which all of these anomalies coincided.
4. Most of the discharge appears to be transported within the upper 75 m of the water column and within ~40 km of the coast (*Weingartner et al.*, 2005).
5. There are statistically significant relationships between monthly anomalies of GAK 1 salinity and/or dynamic height and anomalies of ACC mass and freshwater transport (*Weingartner et al.*, 2005). These results could be applied to resource management issues, for evaluating numerical model performance and/or for retrospective ecosystem studies. For example, *Coyle* (2005) suggests that variations in ACC alongshore transport in late winter/spring affects zooplankton dispersal and recruitment processes.
6. Coastal discharge can hindcast ACC transports using the precipitation record assembled by *Royer* (1982) that begins in 1930 for the Gulf of Alaska. *Weingartner et al.* (2005) extended Royer's runoff time series from 1930 to 1900 based upon correlations between anomalies of

runoff and atmospheric sea level pressure difference between Seward and Ketchikan (ΔSLP_{KS}). We find that winter ΔSLP_{KS} anomalies are significantly correlated ($r = 0.055$) with the winter Pacific Decadal Oscillation (PDO; *Mantua et al*., 1997) anomalies, although that index explains only ~25% of the variance in the runoff. Minimum discharge occurred from 1900-1910 and maximum discharge in the 1930s. Coastal discharge and coastal salinities suggest a decrease in freshwater discharge in the Gulf of Alaska from the late 1950s through the mid-1970s followed by increased discharge from the mid-70s through the early-80s, coincident with the regime shift of the 1970s and with the PDO (*Mantua et al.,* 1997; *Overland et al*., 1999). These findings add to suggestions of a freshening across the North Pacific Ocean basin since the 1970s (*Wong et al.,* 1999).

7. The mooring has provided a platform for other scientists, for example in 2001-02 we placed prototype halibut tags, developed by USGS-BRD scientists, onto the GAK 1 mooring for testing. These tags are now being routinely applied to halibut migration studies (*Seitz et al*., 2003). Recently we have informed the Pacific Ocean Shelf Tracking (POST) Project that the GAK 1 mooring could easily incorporate the acoustic sensors that POST uses to track salmon. In principle the results could be combined to analyze salmon migration as a function of environmental variables.

8. The GAK1 monthly time series has underscored the large interannual and interdecadal variability of the northern Gulf of Alaska. With the inception of the moored time series, shorter period variations, reflecting important dynamical transitions, are being detected and quantified. The in-month variance of the moored data is generally less than the monthly variance computed from the historical monthly CTD sampling and the integral time scales are longer than 1 month. Both results suggesting that temporal aliasing associated with the monthly CTD sampling has not been a significant problem.

9. *Royer* (2005) documented a 30 year warming and freshening trend in the upper 100 m of the Gulf of Alaska shelf that implies an increase in ACC transport (Weingartner et al., 2005) and an increase in upper layer stratification (*Royer et al*., submitted), which could influence biological production.

10. The general warming and freshening in the northern Gulf of Alaska might have led to the outbreak of *Vibrio parahaemolyticus* reported in Prince William Sound (*Royer et al.,* submitted). The freshening surface layer appears to retain summer heat thereby allowing these organisms (which causes gastroenteritis in humans) to flourish. More frequent similar occurrences are predicted if the present trends in upper ocean salinity and temperature continue.

11. Since 1970 ocean temperatures have increased by ~0.8^{o}C over the entire 250 m water column. Upper layer (100 m) salinities have decreased while lower layer salinities have increased simultaneously indicating that the vertical density stratification has also increased (*Royer and Grosch*, 2006). These changes in temperature and upper layer salinity are consistent with those occurring elsewhere in the Gulf of Alaska (*Freeland et al*., 1997). Moreover, a decrease in upper layer salinity implies an increase in ACC along-shore transport (*Weingartner et al*., 2005).

12. We have determined that the ACC is a principal source of freshwater for the Bering Sea shelf and thereby influences biological processes on both this shelf and the Chukchi Sea through

Bering Strait (*Weingartner et al*., 2005; *Aagaard et al*., in press). These results imply that the GAK 1 monitoring effort has implications for other important Alaskan marine ecosystems.

13. *Weingartner et al*. (2005) outlined a simple, cost-effective, statistically-sound ACC monitoring system. They suggested establishing 3 stations (with sampling similar to that being conducted at GAK 1) between Southeast Alaska and Unimak Pass that would represent a circum-Gulf network for monitoring the shelf.
14. There was also a major gap in the moored time series. This occurred in the 2003 and 2004 time frame because the mooring was apparently dragged off site (we believe by a barge under tow) in April 2002 and not found until September 2003. (It had been displaced some 20 km from its deployment site.) We then requested a supplement to our budget to incorporate an ARGOS transmitting pressure-activated beacon on the GAK 1 mooring. The beacon will alert us if the mooring inadvertently surfaces in the future. EVOSTC granted us the request and the mooring, with the new beacon, was then re-deployed in June 2004.
15. Under EVOS support we incorporated a fluorometer on the mooring in 2004. Under Alaska Ocean Observing System (AOOS) support we incorporated two nitrate sensors onto the GAK 1 mooring in 2006.

Summary of Future Work
The GAK 1 mooring was deployed in May 2006 and will be recovered in spring 2007.

Coordination/Collaboration: We have worked with other investigators during this reporting period to provide data for publications and graduate theses (this includes the work by Royer and Grosch and Royer's graduate student Sarkar. Weingartner is a member of her graduate research committee.)

Community
Involvement/TEK and Resource Management Applications. Not applicable.

Information Transfer

The data, figures, and a history of the GAK 1 project are available at the project website: http://www.ims.uaf.edu/gak1/. Recent papers published and talks given using GAK 1 data or insights obtained from this data set:

Aagaard, K., T. J. Weingartner, T. J. Danielson, S. L., Woodgate, R. A., Johnson, G. C., Whitledge, T. E. What controls flow and salinity in Bering Strait? (in press, *Geophys. Res. Lett*.)

Weingartner, T.J., S.L. Danielson and T.C. Royer. 2005. Freshwater Variability and Predictability in the Alaska Coastal Current, Deep Sea Res. II, 52:169-191.

Royer, T.C., 2005. Hydrographic Responses at a Coastal Site in the Northern Gulf of Alaska to Seasonal and Interannual Forcing, Deep Sea Res. II, 52, 267-288.

Sarkar, N, T. C. Royer, C. E. Grosch. 2005. Hydrographic and mixed layer depth variability on the shelf in the northern Gulf of Alaska, 1974-1998. Cont. Shelf. Res. 25: 2147 – 2162.

Presentations made using GAK 1 data

Royer, T. C., C E. Grosch, T. J. Weingartner, and S. Danielson. 2006. Hydrographic changes in the coastal northern Gulf of Alaska during Northeast Pacific GLOBEC (1997-2004), presented at the AGU-ASLO Ocean Sciences Meeting, Honolulu, HI, February, 2006.

Sarkar, N., T.C. Royer, C.E. Grosch. Modeling Seasonal Mixed Layer Depths in the Northern Gulf of Alaska (#OS32C-01) Presented at the Ocean Sciences Meeting, Portland, Oregon, January 2004. [poster]

Schroeder, I. D., C. E. Grosch, and T.C. Royer. EOF analysis of hydrographic data along the Seward Line. Presented at the Ocean Sciences Meeting, Portland, Oregon, January 2004. [poster]

Royer, T.C., C.E. Grosch, T.J. Weingartner and S. Danielson. 2004. A fresher, warmer northern Gulf of Alaska? Presented at the 13th Annual PICES meeting, Honolulu, HI, 20 October.

Royer, T.C. 2005. Alaskan Oceanography: Past, Present and Future – A Personal Perspective, Keynote Presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2005 (Invited Paper).

Royer, T.C. and C.E. Grosch. 2005. Sea Level Changes Associated with the Warming and Freshening of the Coastal Northern North Pacific. Presented at the PICES/GLOBEC Workshop on Climate Variability and Sub-Arctic Marine Ecosystems. Victoria, BC 18 May.

Royer, T.C. 2005. A Maritime Window of Opportunity for Human Migration during the Last Glacial Maximum. Presented at the Paths Across the Pacific IV Conference in Sitka, Alaska 21 July.

Budget – No changes