Anomalously cold conditions on the northern Gulf of Alaska shelf in spring 2007

Markus Janout[1], Seth Danielson[1], Tom Weingartner[1], and Tom Royer[2]

[1]Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, Alaska 99775 (Contact: janout@sfos.uaf.edu)

[2]Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, Virginia 23529

1) Introduction

The 37-year temperature and salinity time series from the coastal hydrographic station GAK 1 on the northern Gulf of Alaska (GOA) shelf and NCEP meteorological data are used to describe the anomalous cooling of the winter 2006-07. That cooling interrupted a ~1ºC/30 yr increase in deep (>150 m) temperatures on the shelf and resulted in spring 2007 temperatures being >1ºC lower than normal throughout the water column. The deep temperatures were the lowest observed since 1973. Spring salinities were also anomalous, being fresher at depth and saltier at the surface, and consistent with abnormally strong winter mixing and decreased coastal freshwater discharge. While anomalies in winter heat fluxes, wind mixing, and downwelling in the winter 2006-07 contributed to the cooling, it also appears that low winter runoff reduced shelf stratification and enhanced deep mixing. Our results underscore the sensitive dependence of temperature distributions on salinity for this shelf. Anomalously low temperatures persisted through fall and finally increased in December 2007.

Figure 1: Map of northern coastal GOA including dominant currents, hydrographic stations, and weather buoy 46082. GAK1 is highlighted in red.

2a) Cold GAK1 waters in May 2007

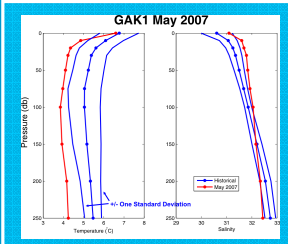


Figure 2: May 2007 GAK1 temperature (left) and salinity (right) profile (red) in comparison with the historic average during May (blue).

-While May profiles in recent years were warmer than the historical mean, May 2007 was…

- anomalously cold throughout the water column (below 10 m) (Fig.2)

- saltier than normal above 150 m

- fresher than normal below 150 m

- less stratified than normal

GAK1 temperature record 1970 - present

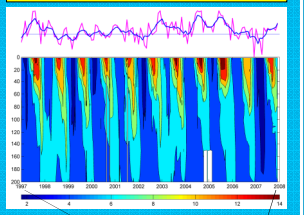
-2007 coldest since the early 1970s (Fig. 3)

-2007 cooling counteracts the GAK1 warming trend of ~0.8ºC/30y (Royer and Grosch, 2006)

-Variability upper layer > lower layer

-1991 and 1999 La Ninas were cold

Figure 3: Colors show GAK1 temperature profiles from 1997-present in relation to normalized NCEP GAK1 air temperature anomalies (top, horizontal line marks zero). Pink line shows monthly averages, blue line shows the running mean.



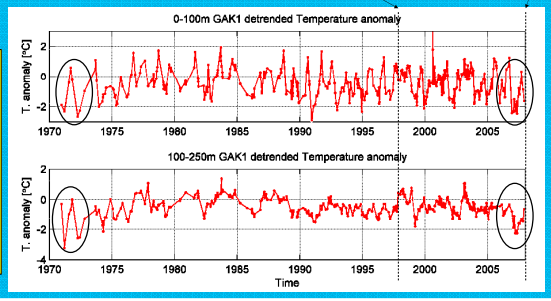


Figure 4: Averaged upper layer (0-100 m) (top) and lower layer (100-250 m) (bottom) temperature anomalies at GAK1 from 1970-present. The anomalies were detrended as described in Royer and Grosch (2005). Horizontal lines mark two standard deviations.

2b) November 2006: The start of the cooling!

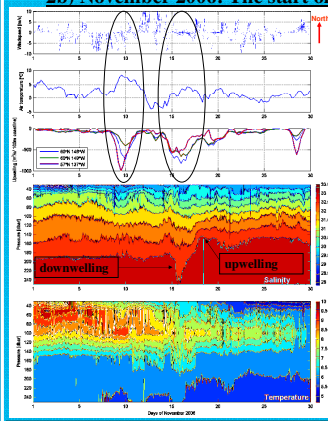


Figure 5: November recordings of 1) wind speed and direction (meteorologic convention, north winds come from the north), 2) air temperatures from weather buoy 46082, 3) PFEL upwelling index, 4) GAK1 mooring salinity and 5) temperature from sensors at 30, 50, 100, 150, 200, 250 m.

8 Nov: Changing wind direction from southerly to easterly causes strong downwelling along Alaska's south coast

11 Nov: Winds veer to northerly and increase speed, air temperatures drop and water begins cooling rapidly

14 Nov: strong downwelling, cooling and mixing with isohalines deepening throughout the water column.

18 Nov: isohalines rebound, upwelling of cold, saline water from shelf break, shelf cools at surface *and* bottom!!

2c) Atmospheric conditions at GAK1 in winter/spring 2006/07

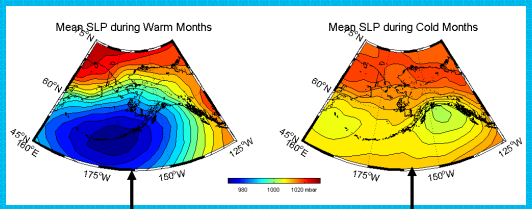


Figure 6: Average sea level pressure distribution during anomalously warm (left) and cold (right) winter months in the northern Gulf of Alaska.

Above normal air temperatures occur with strong Aleutian Lows (centered over the Aleutians) that transport warm and moist oceanic air from southern latitudes to the northern GOA

Below normal air temperatures occur with a less pronounced low pressure system at the head of the Gulf, that causes advection of cold and dry continental air over the northern GOA

NCEP GAK1 parameters show that Winter 06/07 and, in particular March 2007:

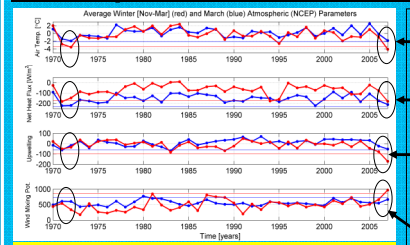


Figure 7: NCEP mean March (red) and mean winter (Nov-March, blue) values from 1970 – 2007 of: a) air temperatures, b) net heat flux, c) upwelling index (PFEL), d) wind mixing potential at 60ºN, 147.5ºW. Horizontal line show two standard deviations below the mean of March (red) and winter (blue) values.

- was the coldest winter since 1972
- was the coldest March since 1970
- had one of the largest winter heat losses
- had one of the largest downwelling winters and the strongest March downwelling since 1970
- had the largest wind mixing potential since 1970

Winter 06/07 was a very cold winter, but perhaps more importantly, March 2007 was one of the harshest on record!

3) Summary and Conclusion:

Spring 2007 conditions on the northern GOA shelf included: 1) anomalously weak stratification, 2) the coldest temperatures in ~35 years, 3) anomalously high salinities in the upper 100 meters and 4) anomalously low salinities at depths >150 m.

Responsible mechanisms include:

- A weakening of shelf stratification (by downwelling and wind mixing) early in winter, e.g., November 2006;
- Low air temperatures and strong winds that induced vigorous cooling and imply reduced coastal runoff;
- Mean monthly runoff between November 2006 and March 2007 was 12000 m^3-s^{-1}; only 60% of the normal winter runoff;
- Low runoff increased upper ocean salinities, weakened along-shelf flow and thus northward heat transport by the Alaska Coastal Current (Weingartner et al. 2005), and reduced stratification over the inner shelf;
- anomalously strong March downwelling-favorable winds that enhanced mixing and cooling at depth

Potential ecosystem consequences are:

- Nutrients were likely more abundant in the spring euphotic zone due to weak stratification; metabolic rates affected by low temperatures

The Cold Temperature Anomaly may strengthen this winter

- La Niña is expected to continue into spring 2008 and the Arctic Oscillation has been trending toward negative values. Both indices tend to result in cooler and saltier conditions on the GOA shelf,
- Anomalously low temperatures were observed through fall 2007 at depths below 100 m depth on the shelf. Thus we are entering the cooling season with temperatures below normal.

Acknowledgements: This work was supported under Project 070340 from the Exxon Valdez Oil Spill Trustees Council and projects 520, 603 & 708 from the North pacific Research Board. We also thank NSF and NOAA for the data collection support from 1997 through 2004 in the northern Gulf of Alaska. Support for this presentation was provided by the Center for Global Change and IARC. We downloaded weather station data from the Alaska Ocean Observation System (www.AK.AOOS.org) and greatly appreciate their help and service.

References: Royer, T. C. and C. E. Grosch, 2006, **Ocean warming and freshening in the northern Gulf of Alaska,** Geophysical Research Letters, 33 (16).
Weingartner, T., S. Danielson, and T. Royer, 2005: **Freshwater variability and predictability in the Alaska Coastal Current**. Deep-Sea Research II (52), 169-191.