BEST BSIERP Bering Sea Project

Wind and Oceanic Structure and Their Variability over the SE Bering Sea Shelf

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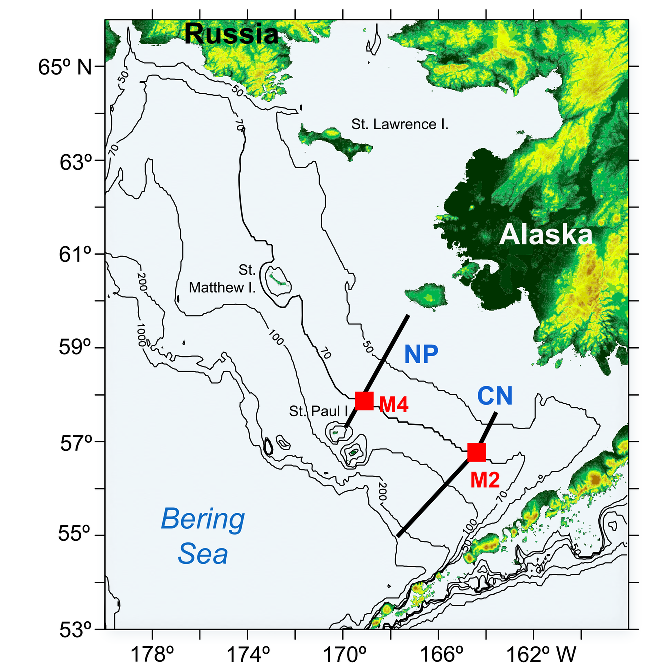
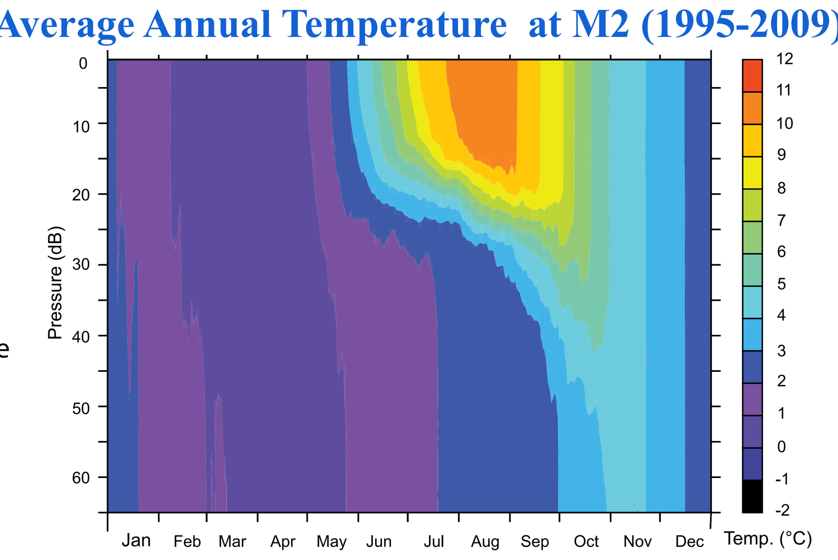


Map of the southeastern Bering Sea showing the location of biophysical moorings (M2 and M4) and the two historical hydrographic lines that were re-occupied during BEST/BSIERP.

The southeastern Bering Sea shelf is a highly productive region subject to marginal sea ice, and highly sensitive to climate variability on many scales. The physical and chemical structure of the water on this shelf is primarily determined by tidal and wind mixing, as well as the extent and durations of the seasonal ice cover. Recently, the BEST/BSIERP Project has been conducting research on many components of the Bering Sea Shelf ecosystem. We compare recent and historic summer hydrographic transects and their associated physical conditions in an attempt to categorize "warm years" (such as the late 1970s and 2001-2005) and "cold years" (1972 - 1976 and 2007-2009), or "windy" and "calm" years. Fifteen years of data from the Eco-FOCI biophysical mooring at M2 are used to define the structure of the mid-shelf and its two-layered water column, its interannual-to-decadal variability, and the physical differences between warm and cold years.

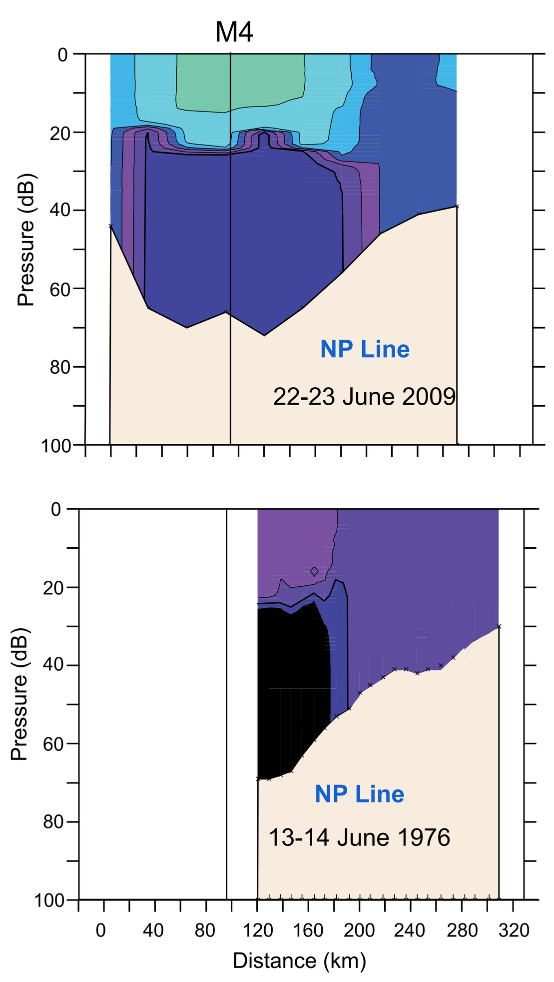
Average Annual Temperature at M2 (1995-2009)

Averaged daily temperature from fifteen years of measurements from M2. Temperature was resolved at 3-m intervals in the upper 30 m and 5 m intervals in the bottom 40 m.
Water properties in winter and early spring are mixed top to bottom. As storms decrease in May, the water column stabilizes into a two layer structure. By late October, surface cooling and increased winds re-mix the water column.



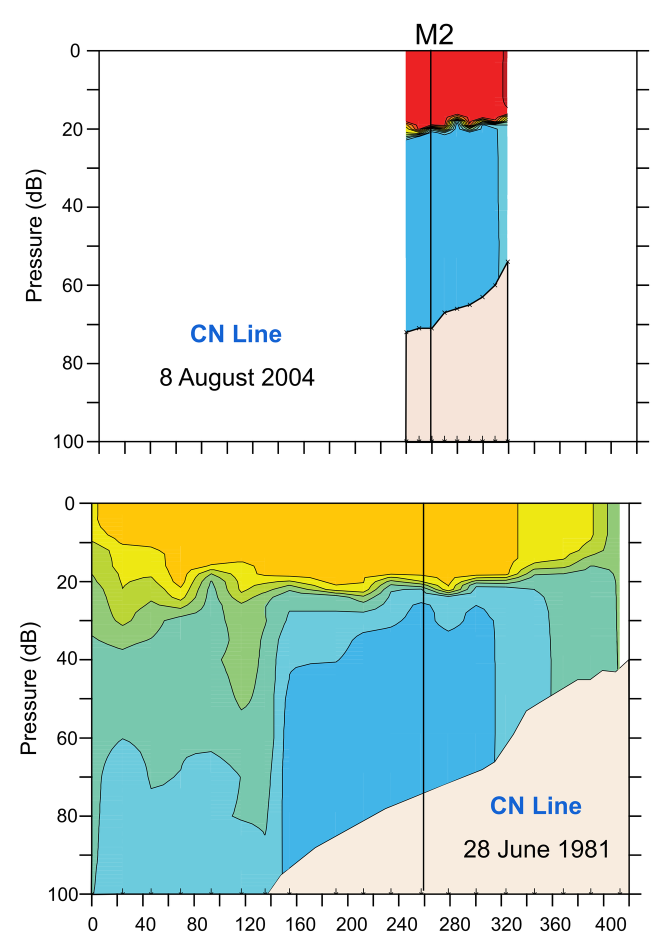
Comparison of Recent and Historic Hydrography

Temperatures in Cold Years



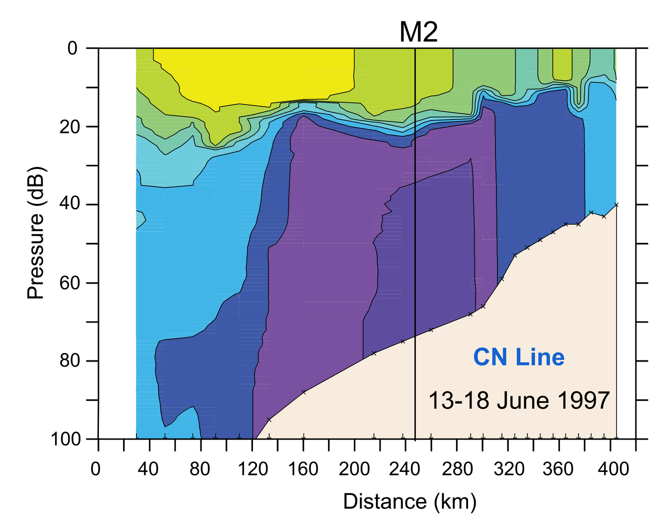
Although 2009 had among the most extensive ice cover since 1976, neither the ice cover nor its duration was as great as in 1976. In 2009, by mid May the last sea-ice had melted, so the water column began warming sooner than it did in 1976, when sea-ice retreated several weeks later. Both years had extensive bottom "cold pools", defined by temperatures < 2°C.

Temperatures in Warm Years



The water column in each year from 2000-2005 was very warm, a characteristic of years with limited ice cover. The 2004 transect is 5.5 weeks later than the 1981 transect; so surface temperatures reflect the increasing warming that happens as the summer progresses. In both 2004 and 1981, a bottom "cool pool" (bottom temperature of ~3.5°C) was present. The entire summer of 2004 had normal or calmer than normal wind stress. The effect of such extended calm conditions is the sharp thermocline.

1997- Warm or Cold Year?-



Biological Implications

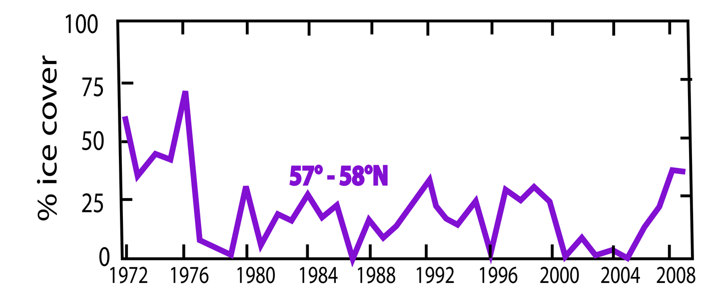
The water column structure in summer of 1997 does not fit the standard definition for a warm or cold year. The bottom had a cold pool, but the shallow upper layer was very warm. A sequence of weather events had a major impact on the ecosystem. A very calm April led to an early spring bloom. Then a storm in late May mixed the water column to 55m, introducing nutrients that fueled a second bloom. Subsequent calm winds (June – July) established a shallow thermocline permitting a subsurface phytoplankton that stripped the nutrients from the cold pool. Sustained summer production at the inner front shut down, leading to massive bird die-off, and the establishment of a huge coccolithophorid bloom.

Defining Warm or Cold Years

Warm and cold years on the southeastern Bering Sea shelf have been traditionally been defined by the presence of a "cold" (T < 2°C) or "cool" (2° < T< 4°C) pool in the bottom water. This table uses all the hydrography data for the period before 1995 and the M2 data since then.

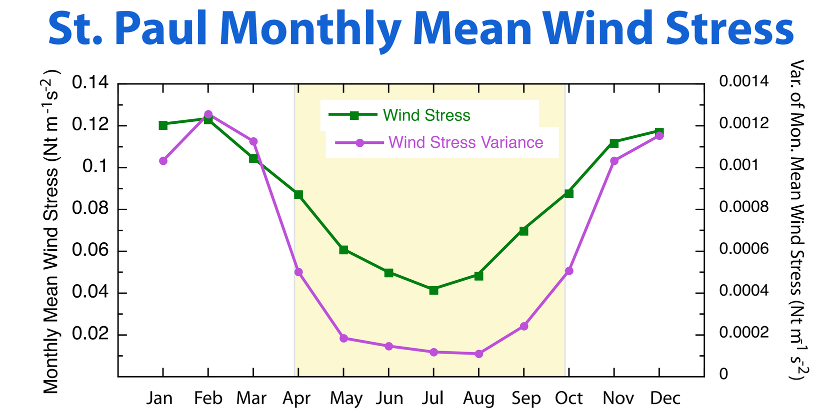
Year	Warm or Cold
2009	cold
2008	cold
2007	cold
2006	cold
2005	warm
2004	warm
2003	warm
2002	warm
2001	warm
2000	warm
1999	cold
1998	warm
1997	cold
1996	cold
1995	cold
1994	
1993	
1992	
1991	
1990	
1989	cold
1988	
1987	
1986	
1985	
1984	
1983	
1982	cold
1981	warm
1980	warm
1979	warm
1978	warm
1977	warm
1976	warm
1975	cold
1974	cold
1973	
1972	

Annual Percent Ice Cover 57-58°N



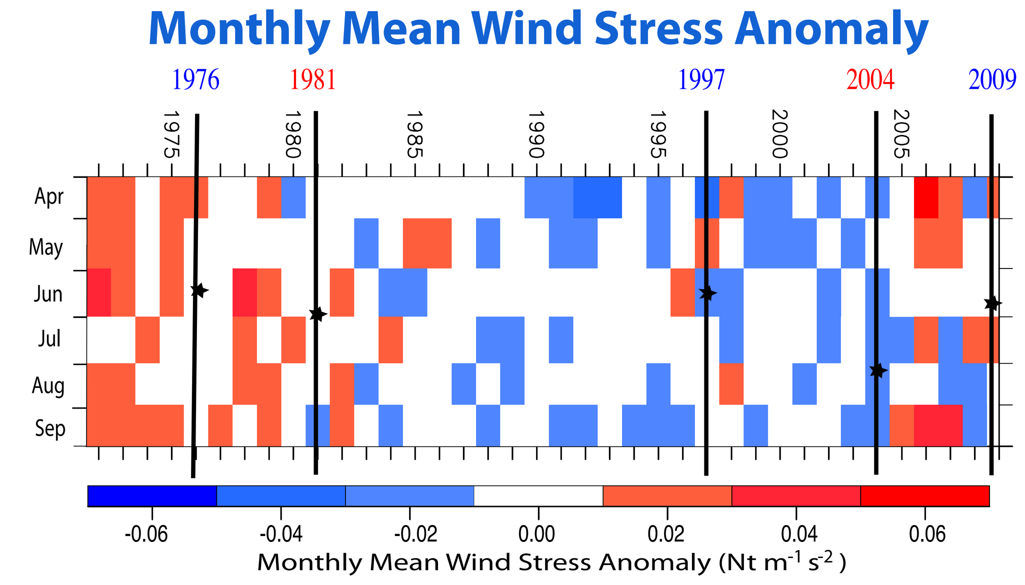
Percentage of ice cover across the Bering Sea shelf in the band between 57°- 58°N east of 171°W longitude.

St. Paul Monthly Mean Wind Stress



Monthly mean wind stress and its variance calculated at St. Paul Island (1948-2009).

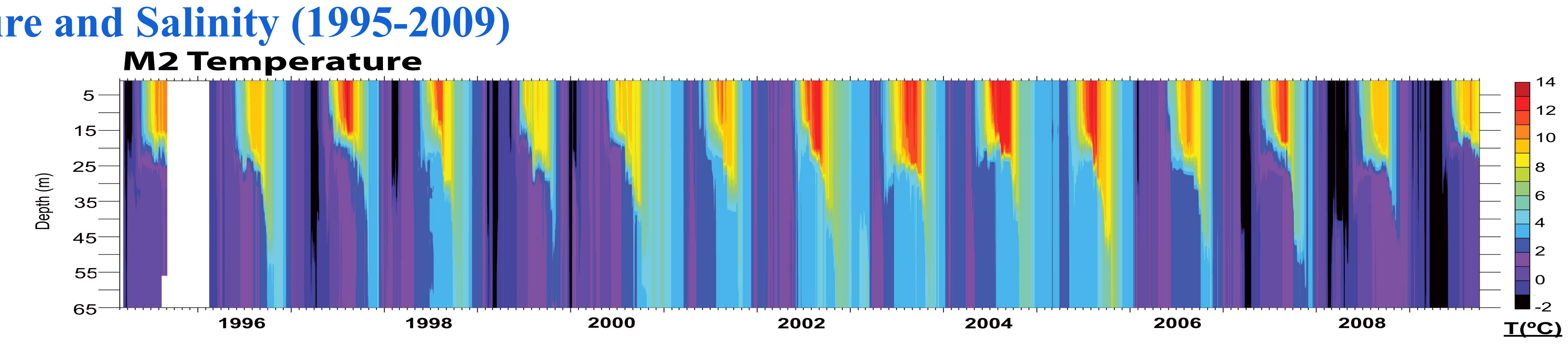
Monthly Mean Wind Stress Anomaly



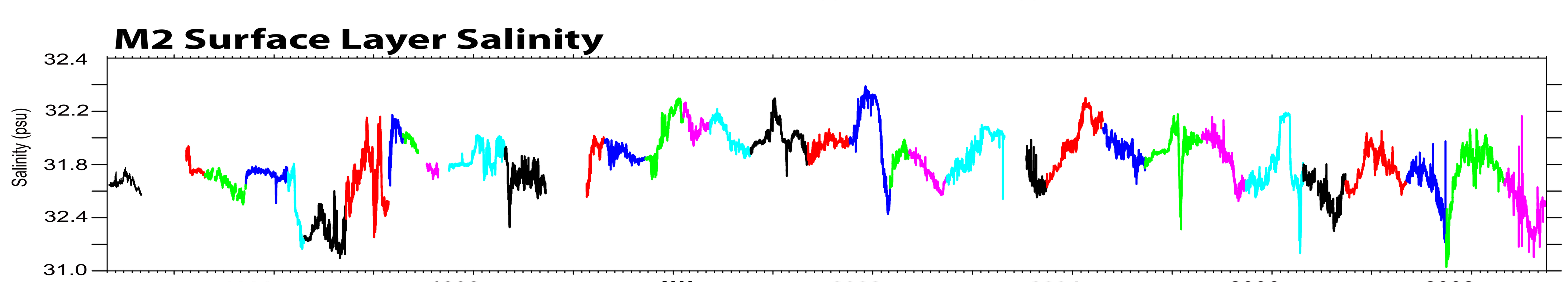
The monthly wind stress anomaly for the summer months. The years and dates of the hydrographic transects are indicated. No year is consistently above or below the mean. Correlations of ecosystem components with wind stress or mixing need to take monthly (or shorter) differences into consideration, if species have critical times when wind conditions may be important.

M2 Mooring: Temperature and Salinity (1995-2009)

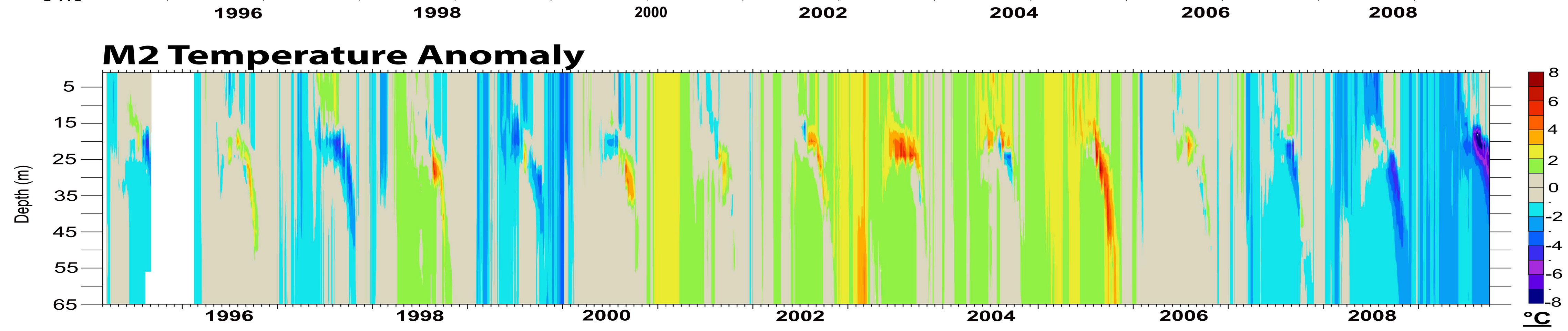
Bands of black indicate that ice covered the site and cooled the water column to −1.7°C.



The surface salinity measured at M2, with successive mooring deployments shown in different colors. The warm years (2000-2005) have higher salinity waters in both summer and winter than cold years (2007-2009). Surprisingly, the lowest salinity waters of the cold years are present in late summer, likely as a result of advection to M2 from inshore areas (Bristol Bay).



Daily temperature anomalies were calculated by subtracting the 15-year annual daily average temperature (top right figure) from the time series of daily temperature (above). In most years (1997 is exception), the top and bottom layers have the same sign (warm or cold). Years that are ~ average (e.g. 2000 and 2006) separate series of warm or cold years. In warm years, late summer storms mix anomalous heat downward (yellow to red bands), while in the cold years like 2007-2009, the region below the thermocline is colder that normal (blue to purple). Either storm related wind mixing is reduced in late summer, or extra density stratification associated with the introduction of lower salinity water slows the breakdown of stratification in cold years.



Conclusions

Most years can be defined as "warm" or "cold" using the temperature of the bottom water on the mid-shelf. This definition applies to the entire water column.
However, there are exceptions, like 1997.

Years cannot be classified as being "windy" or "calm" from April to October. All years showed mixes of normal, above, or below average wind stress. Therefore, studies of ecosystem components need to consider the wind stress conditions on shorter time-scales, during those periods critical for development or survival.

Acknowledgements

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