Recent Amplification of the Summer Beaufort Sea High and its Impact on Chukchi Sea Ice Extent and Oceanic Circulation

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The Beaufort Sea High (BSH), a closed anti-cyclone over the Beaufort Sea, is an important feature of the sea-level pressure field over the Arctic Ocean. It plays an important role in the export of Arctic sea ice. Years characterized by low Arctic sea ice extent are associated with a reduction in summer cyclones over the Arctic Ocean and the presence of a stronger BSH with the opposite occurring during years with high sea ice extent. This was especially true in 2007, the record minimum sea ice extent, when the BSH was anomalously high throughout the summer. Although there has been a trend towards a loss of Arctic sea ice over the entire spaced-based observational record, i.e. from 1979 onwards, an acceleration occurred in the late 1990s. We show this acceleration coincided with a trend towards a stronger BSH as well as a trend towards a reduction in cyclogenesis over much of the Arctic Ocean including the Beaufort Sea. We argue that these trends are the result of a warming of the Arctic troposphere and the concomitant reduction in baroclincity.

We also show that a consequence of this amplification of the BSH is an increase in the frequency of easterly winds over the Chukchi Sea shelf break that are of sufficient magnitude to result in a upwelling as well as a reversal in the direction of the oceanic shelf break jet. The impact of this increased frequency of upwelling on phytoplankton blooms in the region will be discussed.

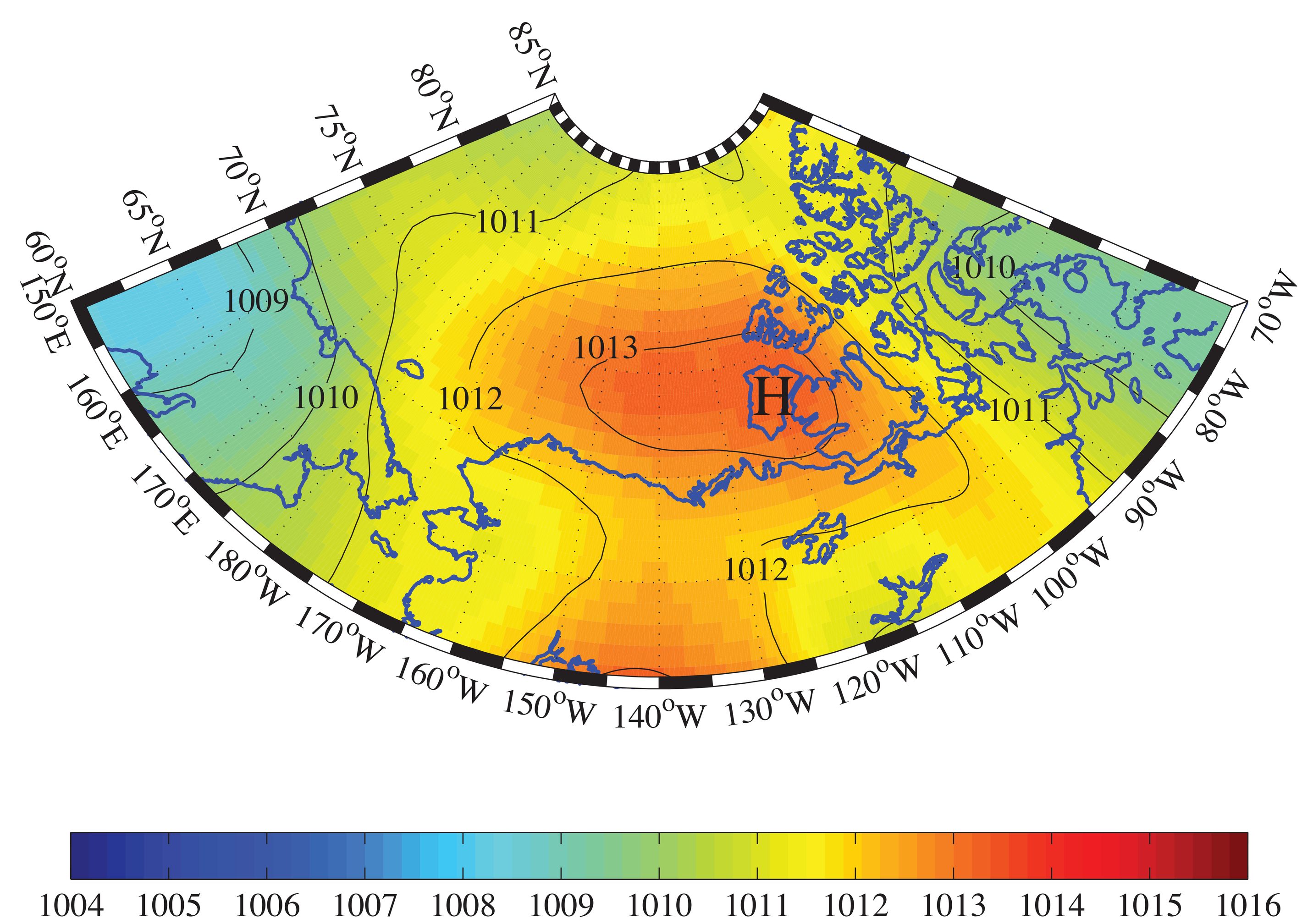


Figure 1) Climatological summer (JJA) sea-level pressure (mb) from the NCEP Reanalysis for the period 1948-2011. The climatological center of the Beaufort Sea High is indicated by the 'H'.

The role of the Beaufort Sea High in transporting sea ice out of the western Arctic is evident.

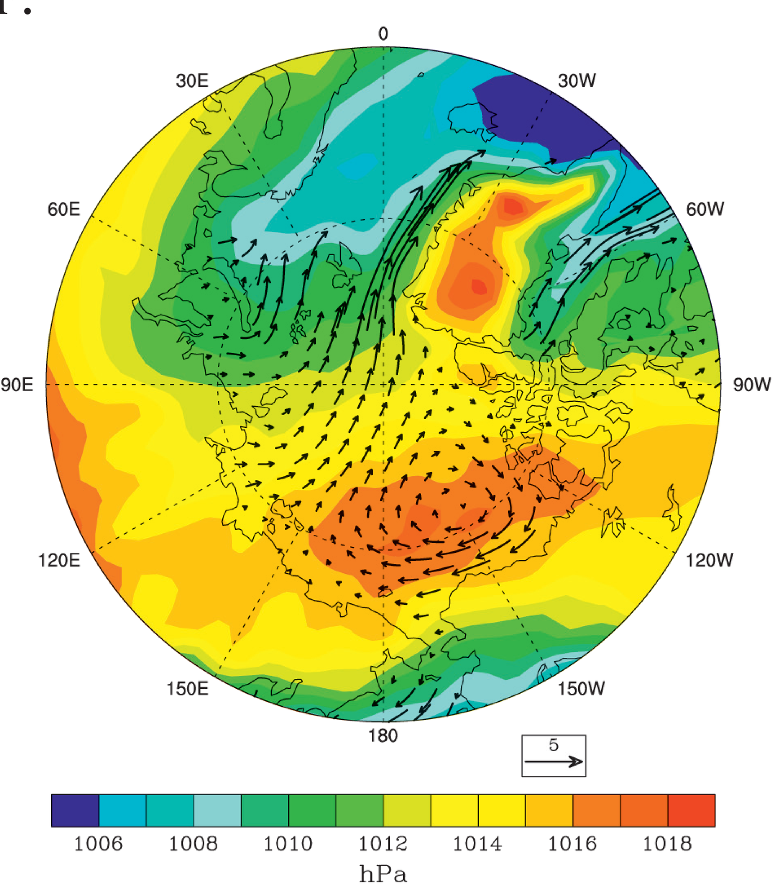
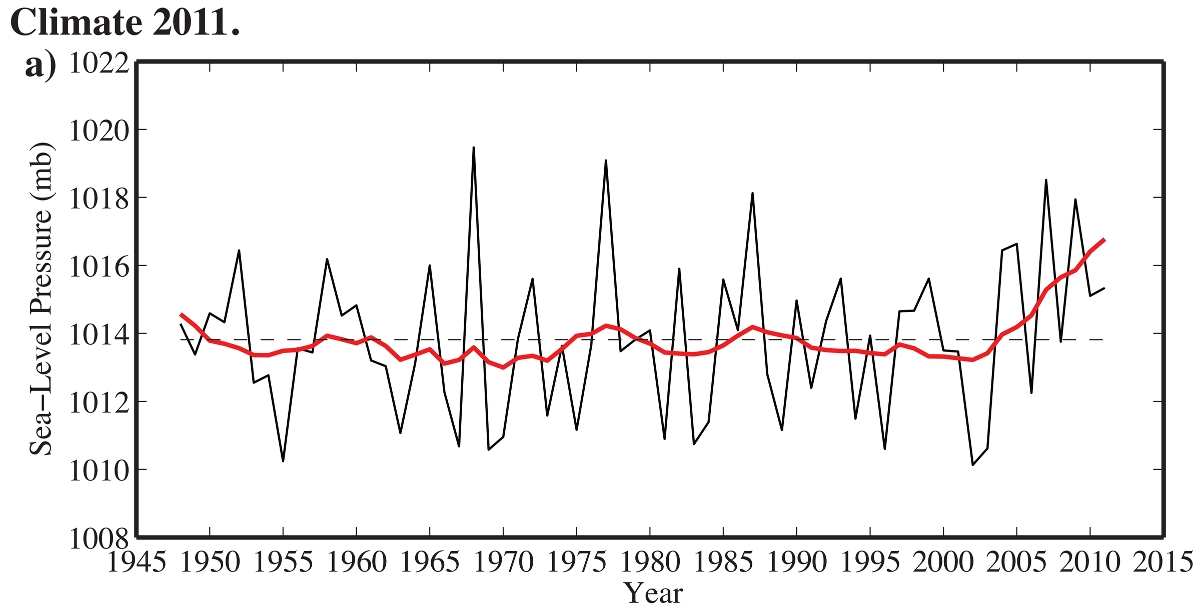


Figure 2) Annual mean sea-level pressure over the period 1979–2008 from the NCEP reanalysis with overlay of mean sea ice velocity vectors for 1979–2006 based on a combination of satellite and buoy data. Ice motion is cm s^{-1}. Figure from Serreze and Barrett J. Climate 2011.

The central pressure of the BSH began to increase in the late 1990s.



The central pressure of the BSH exhibits variability on the decadal time scale

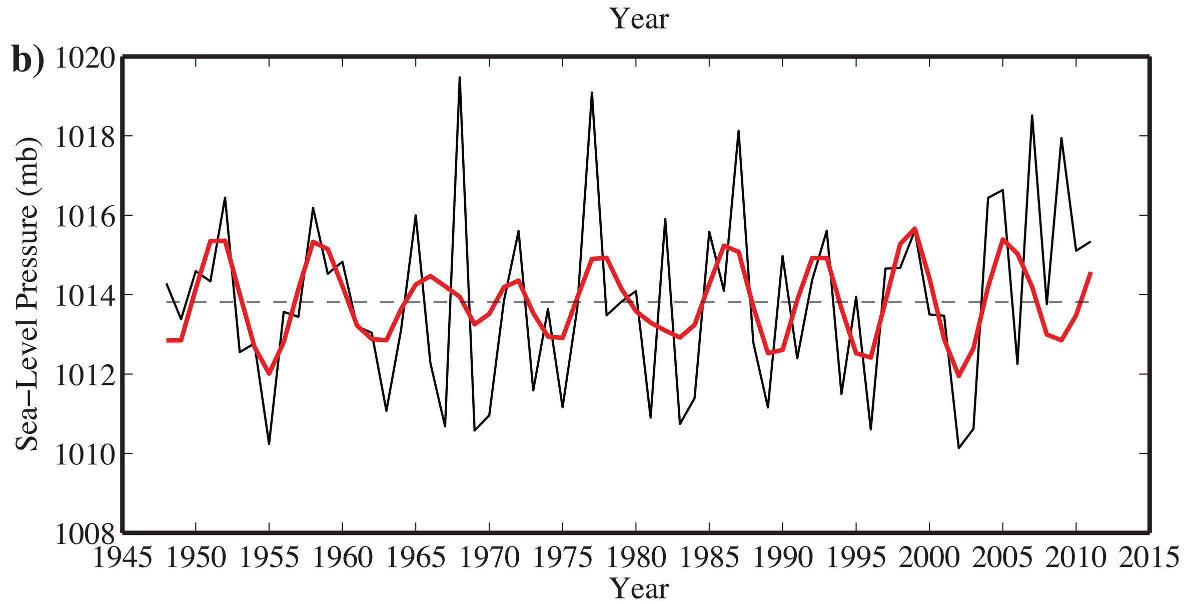


Figure 3) Time series of the summer (JJA) sea-level pressure (mb) in the center of the Beaufort Sea High from the NCEP Reanalysis during the period 1948-2011. The mean over this period is indicated by the thin dashed line. In (a), the low-frequency reconstruction of the time series is indicated by the thick red line. In (b), the reconstruction that captures variability in the time series on the decadal time scale is indicated. Both were computed using the Singular Spectrum Analysis (SSA) technique.

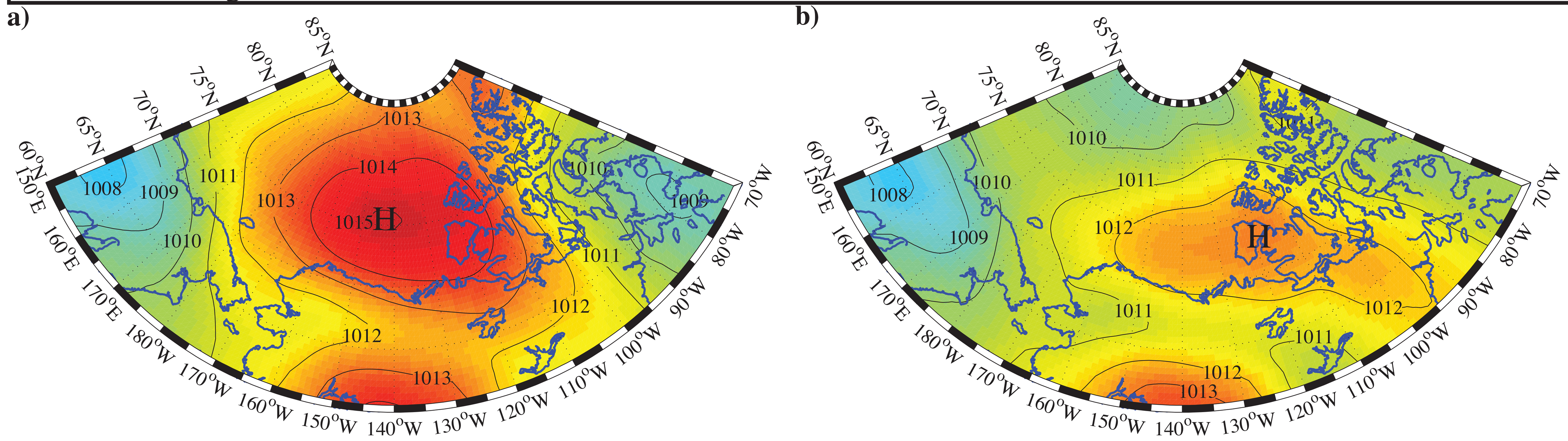


Figure 4) Composite of the sea-level pressure (mb) during high (a) and low (b) index summers, based on the Singular Spectrum Analysis reconstruction of the variability on the decadal time-scale (Figure 3b). ***The BSH alternates between a deeper anti-cyclone centered near 75°N, 145°W and a weaker trough-like circulation centered near 70°N, 120°W.***

Sea-level pressures over the western Arctic have been increasing at a statistically significant rate since the late 1990s.

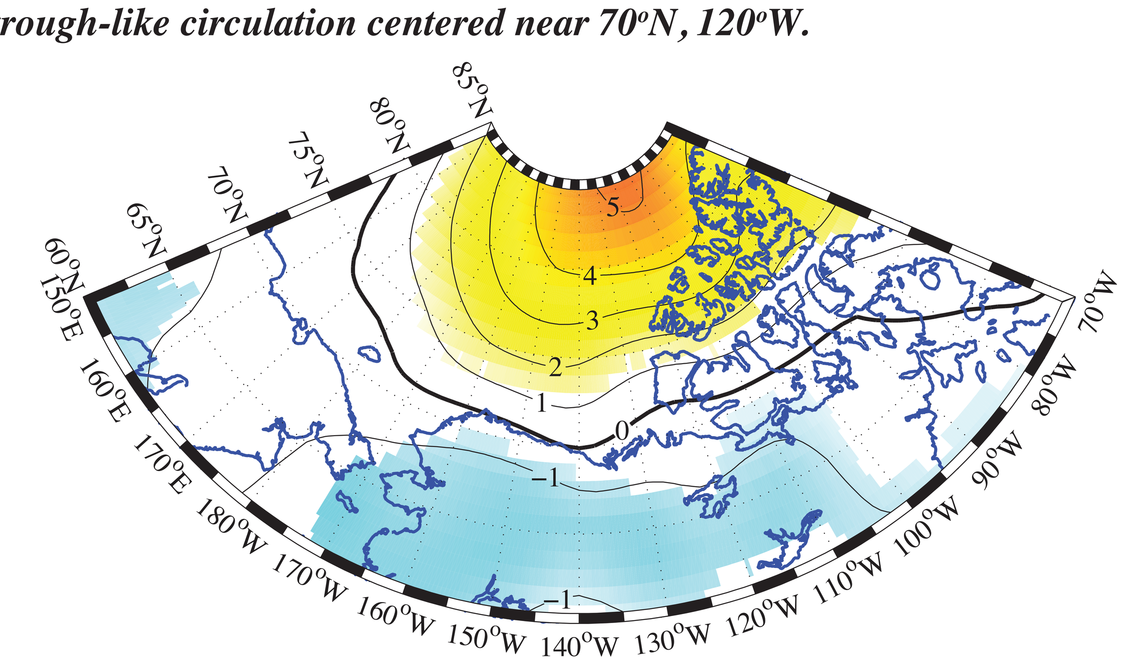


Figure 5)The trend in the summer (JJA) sea-level pressure (mb/decade) from the NCEP Reanalysis for the period 1996-2011. The trend is statistically significant at the 95% level in the shaded regions using a test that uses the red-noise characteristics of the sea-level pressure field.

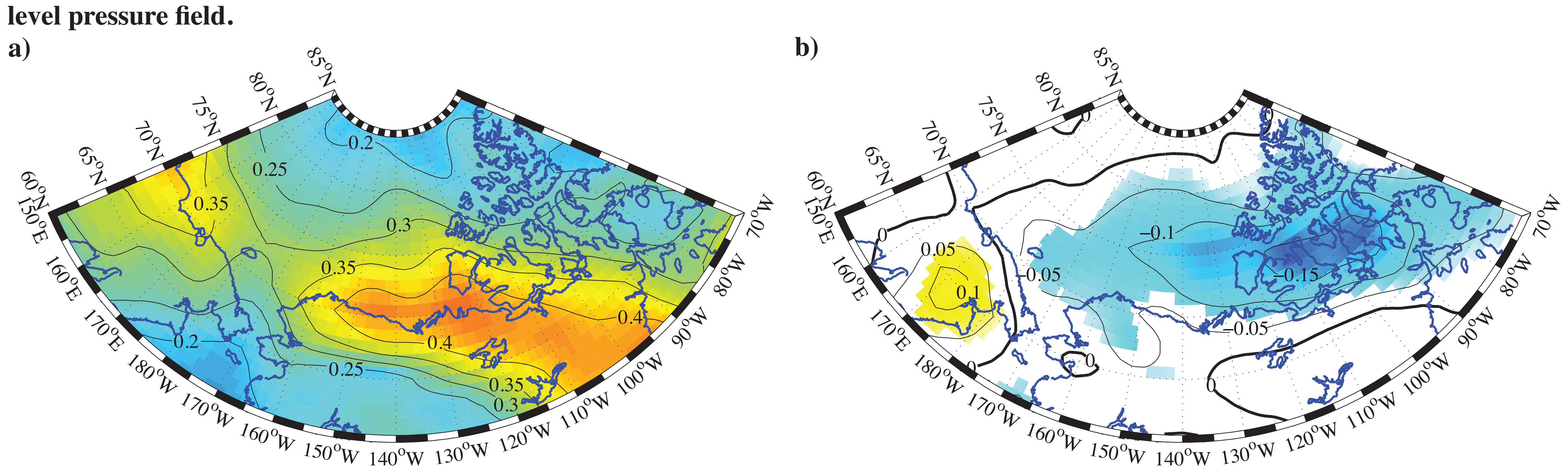
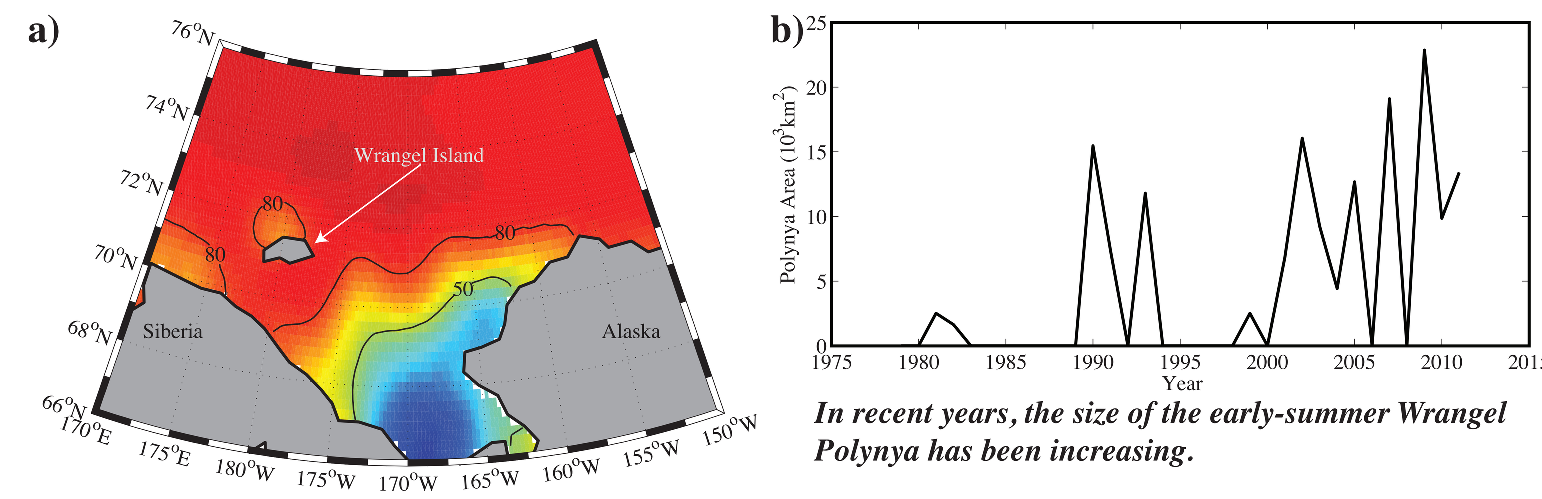


Figure 6) (a) The summer (JJA) Eady Growth Rate (days^{-1}) from the NCEP Reanalysis during the period 1948-2011. (b) The trend in the summer (JJA) Eady Growth Rate (days^{-1}/decade) during the period 1996-2011. In (b), the trend is statistically significant at the 95% level in the shaded regions. ***In (a) the region of large Eady Growth Rate that extends southeastwards from the Beaufort Sea represents the storm track associated with the Arctic Front. In (b), there is a statistically significant trend towards lower Eady Growth Rates that is consistent with the trend towards higher sea-level pressures in the region (Figure 5) and a more intense BSH (Figure 3a). The trend towards lower Eady Growth Rates is the result of a reduction in the meridional temperature gradient resulting from a differential warming of the western Arctic's troposphere.***



In recent years, the size of the early-summer Wrangel Polynya has been increasing.

Figure 7) (a) The monthly mean sea ice concentration (%) over the Chukchi Sea during June 1979 to 2011. (b) The polynya size (10^3 km^2) in the region north of Wrangel Island for June 1979 to 2011. The polynya size was determined as the area for which the sea ice concentration was less than 80%.

The early-summer Wrangel Island Polynya is associated with a more intense BSH and enhanced easterly flow across the Beaufort and Chukchi Seas. The trend towards a more intense BSH would also lead to enhanced easterly flow in this region.

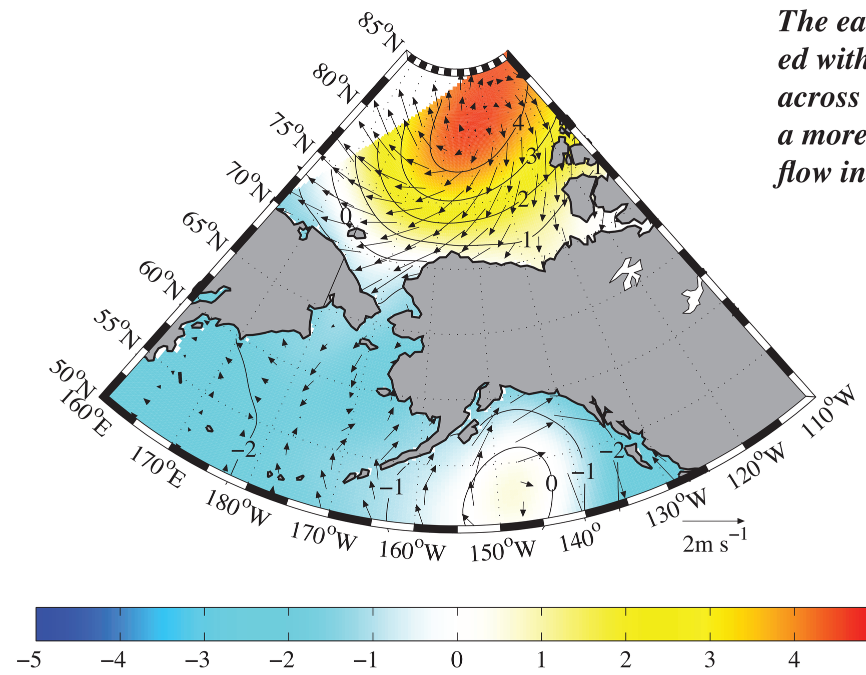
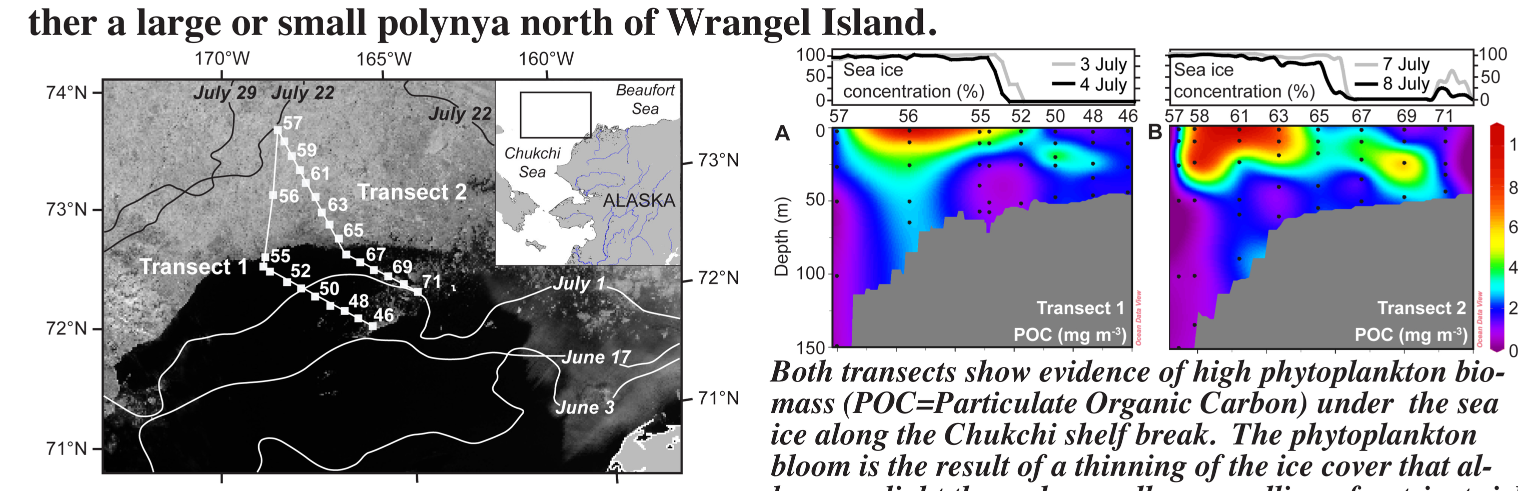
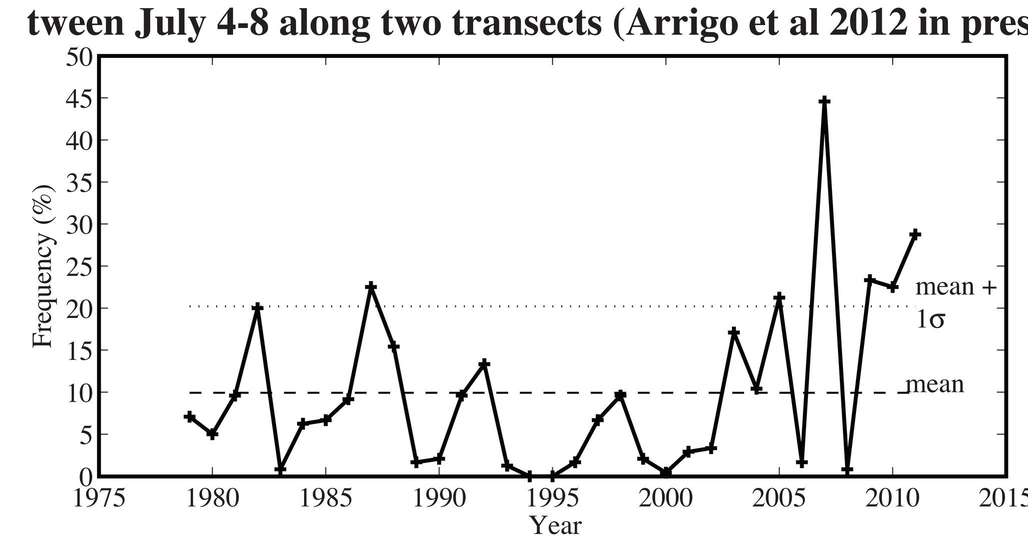


Figure 8) The difference in the monthly mean sea-level pressure (contours and shading - mb) and 10m wind field (vectors - m/s) for June between those years in which there is either a large or small polynya north of Wrangel Island.



Both transects show evidence of high phytoplankton biomass (POC=Particulate Organic Carbon) under the sea ice along the Chukchi shelf break. The phytoplankton bloom is the result of a thinning of the ice cover that allows sunlight through as well as upwelling of nutrient rich bottom water.

Figure 9) During ICESCAPE 2011, an under ice phytoplankton bloom was observed between July 4-8 along two transects (Arrigo et al 2012 in press Science).



Recent increase in upwelling favourable winds that coincided with recent trend towards a more intense BSH. Correlation coefficient between the two is 0.59.

Figure 10) Frequency of upwelling favourable, i.e. easterly, winds along the Chukchi shelf break during early July 1979-2011.

Conclusions:

- **The summer BSH exhibits variability on the decadal time scale as well as a trend towards higher central pressures that began in the late 1990s.**
- **The decadal scale variability is manifested by a meridional shift in the center of the BSH.**
- **Since the late 1990s, there has been a statistically significant increase in sea-level pressure across the western Arctic.**
- **This trend is coincident with a reduction in Eady Growth Rate in the region that is the result of a reduction in baroclinicity associated with differential warming of the western Arctic's troposphere.**
- **The increase in the central pressure of the BSH has resulted in enhanced easterly flow across the Beaufort and Chukchi Seas.**
- **This has lead to an increased frequency of occurrence of the summer Wrangel Island Polynya.**
- **The enhanced easterly flow has also resulted in an increase in upwelling along the Chukchi self break.**
- **This has increased the nutrient levels near the surface that contributed to the existence of an under ice phytoplankton bloom that was observed in early July 2011.**