Wind Stress Curl and Ocean Conditions in the Northeast Pacific: A Mechanism for Ocean Climate Change

Phaedra Green (1, 2), Frank Schwing (1), and Tom Murphree (1, 3)

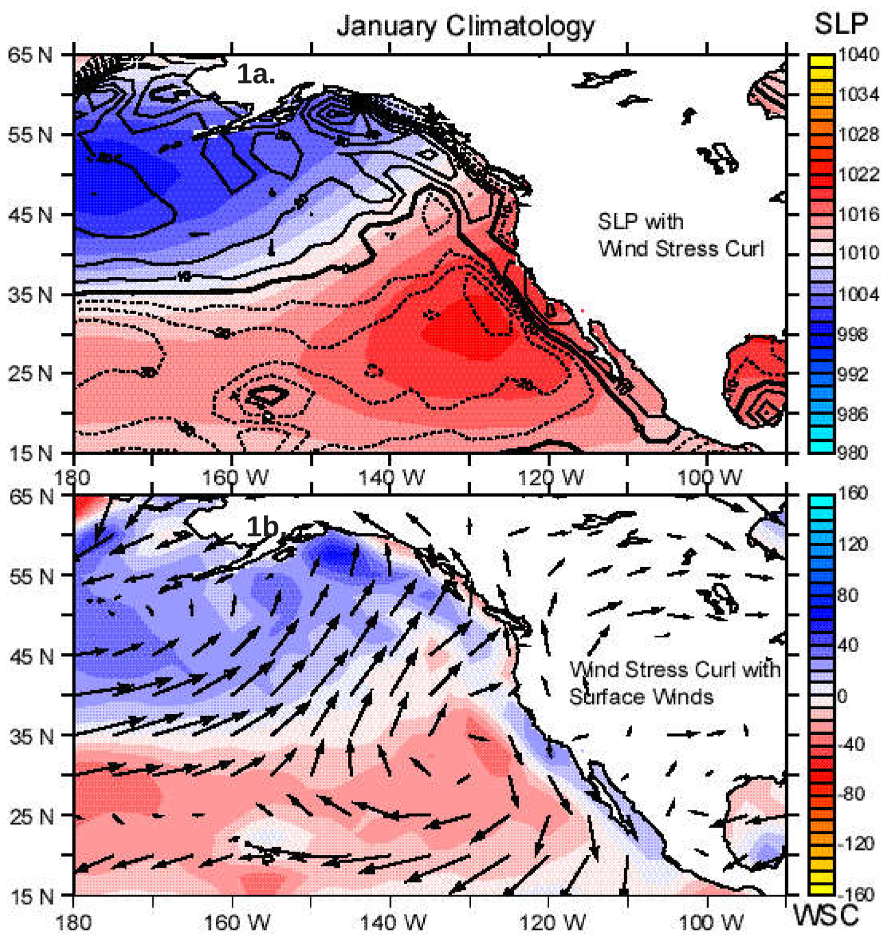
1 PFEL, NOAA, NMFS, Pacific Grove, CA, 2 Joint Institute of Marine and Atmospheric Research, Honolulu, HI, 3 The Naval Postgraduate School, Monterey, CA

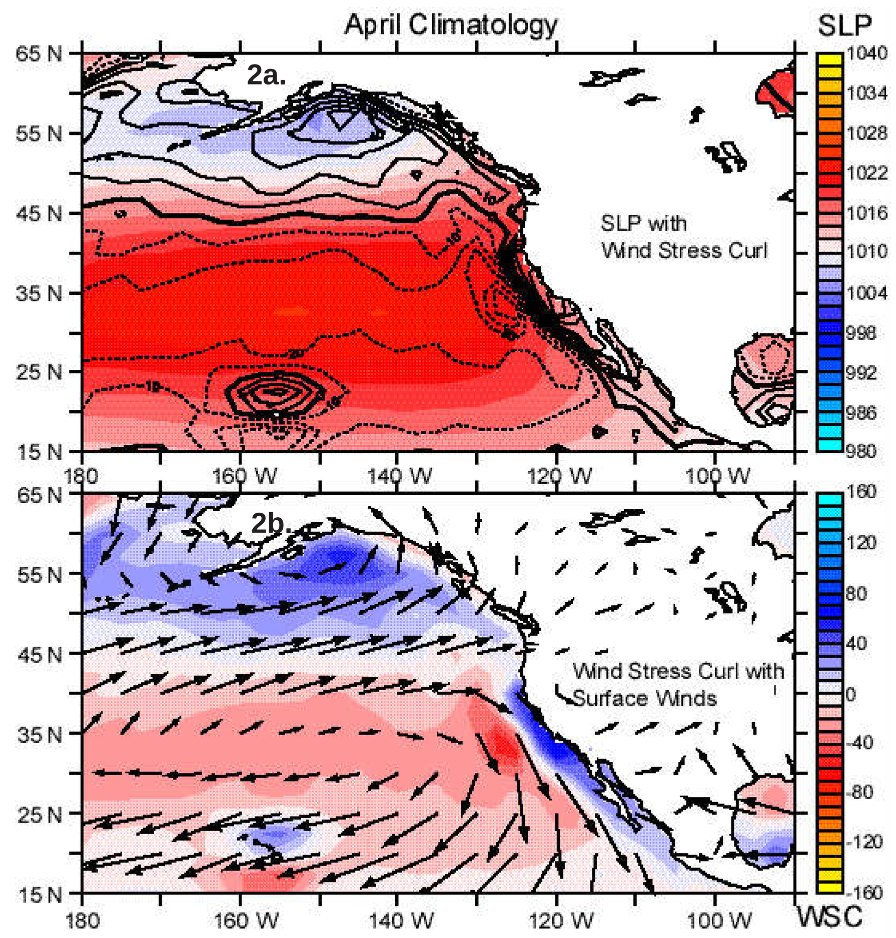
pgreen@pfeg.noaa.gov, fschwing@pfeg.noaa.gov, murphree@nps.navy.mil

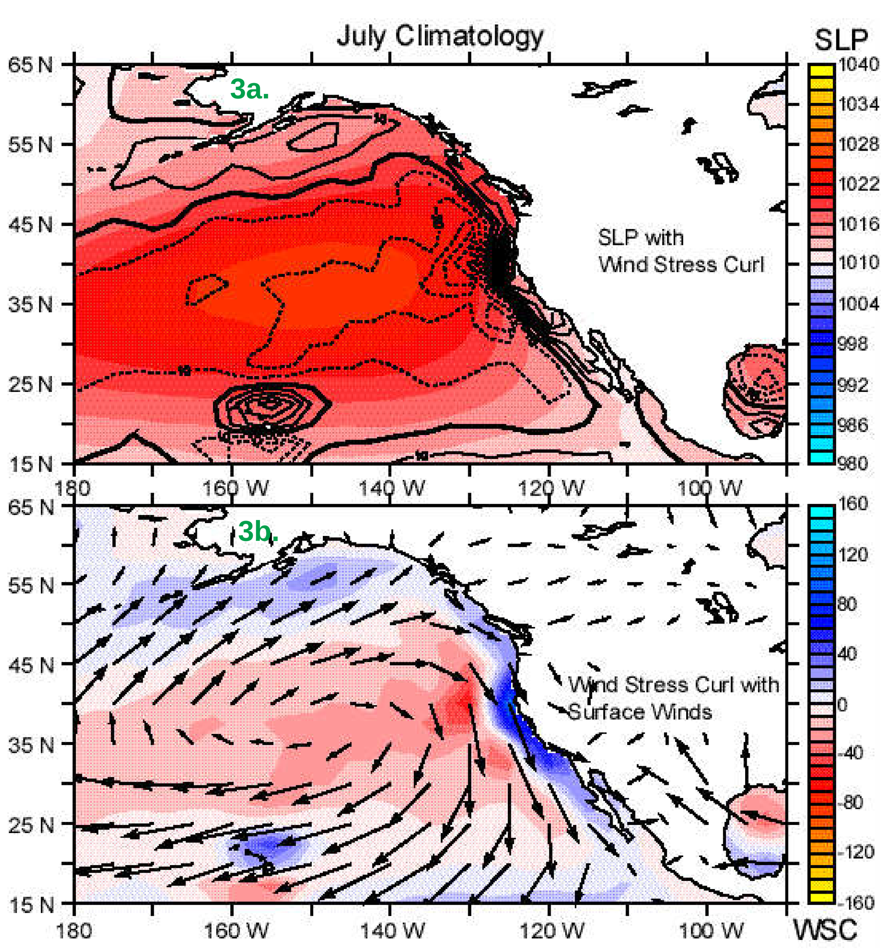
Abstract:

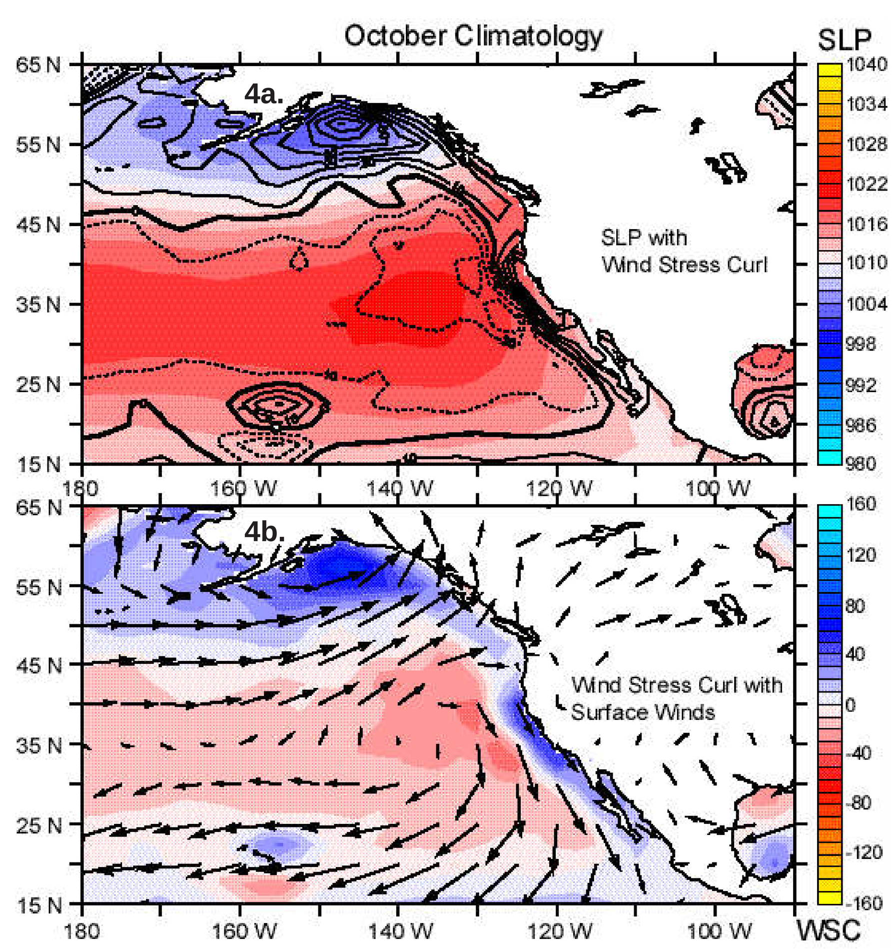
Wind stress and wind stress curl strongly shape upper ocean conditions in the North Pacific on a full range of time scales. The NCEP reanalysis surface daily winds have been processed to define climatologies and monthly values and anomalies of wind stress curl over the Pacific Basin. Prior work by Bakun and Nelson have shown that cyclonic wind stress in coastal regions coupled with alongshore equatorward flow can affect upwelling and therefore coastal temperatures, stratification, and productivity. By comparing the evolution of wind stress and curl to SST and subsurface temperature we are able to investigate the impact of ekman processes on the seasonal progression of ocean conditions.

Climatologies show zonal bands of positive curl from the equator to 20N in winter and from 20N to 35N in summer. From climatologies, the time of maximum annual wind curl occurs later in the season with distance from the equator along the West Coast of North America spring and fall. Isotherms shoal seasonally in response to the annual wind stress curl cycles. Because the ocean response to atmospheric forcing is "dynamically similar" on annual and longer periods, the seasonal evolution of the wind field and the ocean's response will provide insight on the development of ocean anomalies during extreme events such as El Niño and decadal oscillations.









Figures 1 through 4 show panels of atmospheric and oceanic climatologies for the months of January, April, July, and October. Panel a. shows SLP as colored shading with wind stress curl (WSC) in black contours. Warmer (colder) shades denote higher (lower) pressure. Dashed (solid) lines denote negative (positive) wind stress curl (WSC). Panel b. shows wind stress curl in colored shading with black arrows denoting surface winds. Cooler (warmer) shades denote positive (negative) WSC. Units for WSC are kg per meter squared per second squared, pressure is in millibars, and wind is in meters per second. A WSC dipole region at 35N, 130W-120W persists throughout the year. A southward wind maximum separates the two WSC regions. The zero line of WSC changes very little along the coasts of California to British Columbia, but changes dramatically to the south of central Alaska with the growth and decline of the Aleutian low.

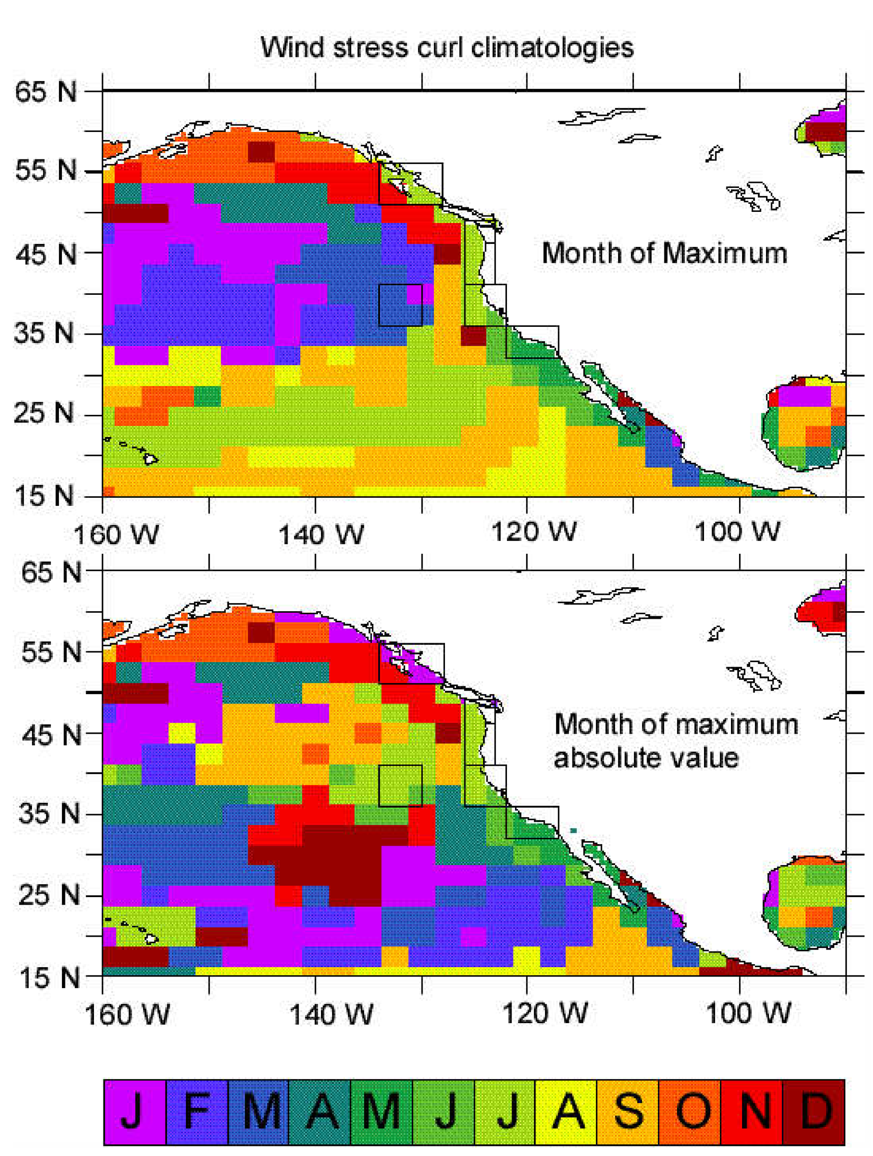


Figure 5a shows month of where the maximum WSC occurs in colored blocks; this could either show the month of the strongest positive WSC or the weakest negative WSC in regions that experience negative WSC throughout the year. Figure 5b shows the month of the maximum absolute value in colored blocks. In spring and summer, the maximum annual WSC progresses along the coast of North America from south to north. The absolute value of the WSC show the dipole set as having their peak amplitudes in July.

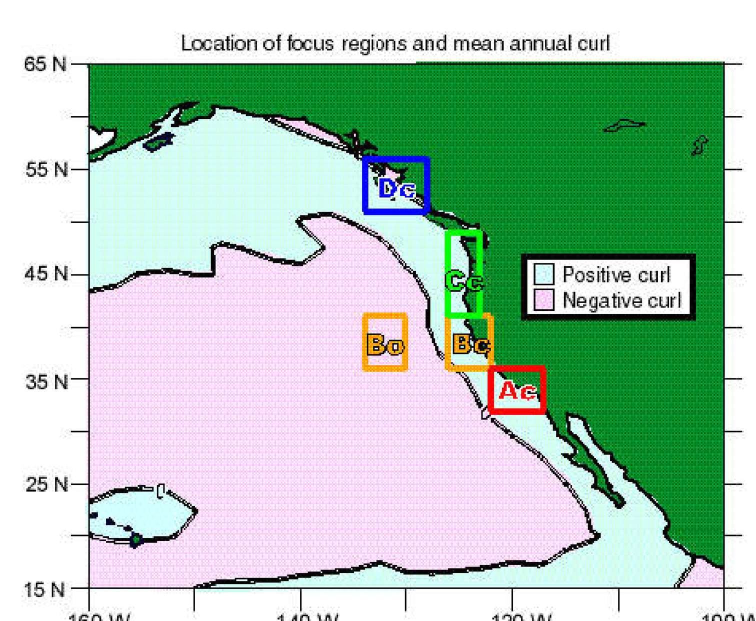


Figure 6 shows the selected regions, four coastal and one offshore. The zero contour line is shown for the WSC, pink (blue) regions denote negative (positive) WSC.

Methodology:

Wind curl climatologies were formed from NCEP daily winds; stress was calculated from these and the curl was taken of the wind stress, the base period is 1968-1997. Monthlies were calculated from the daily wind stress curl (WSC) climatology. The subsurface climatologies were extracted from the WODB. The surface pressure and surface winds are from the NCEP climatologies.

The authors would like to thank Lynn Dewitt, Chris Moore, and Steve Cummings of PFEL. Additional thanks to Julie McClean and Paul Jessen of NPS.

Naval Postgraduate School

NOAA Pacific Fisheries Environmental Lab

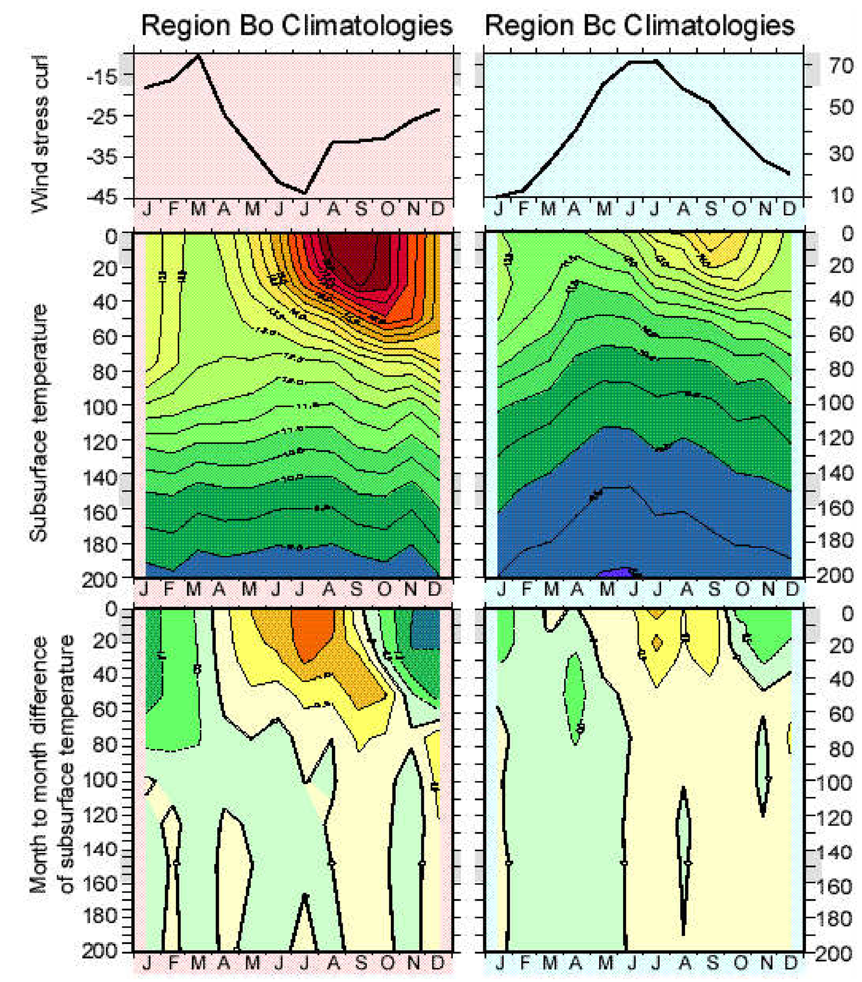


Figure 7: Climatologies of wind stress curl (top panels), subsurface temperature in vertical profile (middle panels), and subsurface temperature month to month differences in vertical profile (lower panels) averaged over the regions of Bo (left panels) and Bc (right panels). Units for temperature are in Celsius and units for WSC are in 10e8 kilogram per meter squared per second squared.

Negative anticyclonic WSC occurs offshore off the coast of California (region Bo). The coastal nearshore region (Bc) exhibits positive curl throughout the year. Region Bc is cooler than region Bo, due to the persistent positive WSC and ekman pumping. The MLD is shown deeper in region Bo, than in region Bc. Warming and cooling at depth lags the surface by 2-3 for region Bo and 1-2 months for region Bc. Ekman pumping may reduce the entrainment of heat into the thermocline in region Bc.

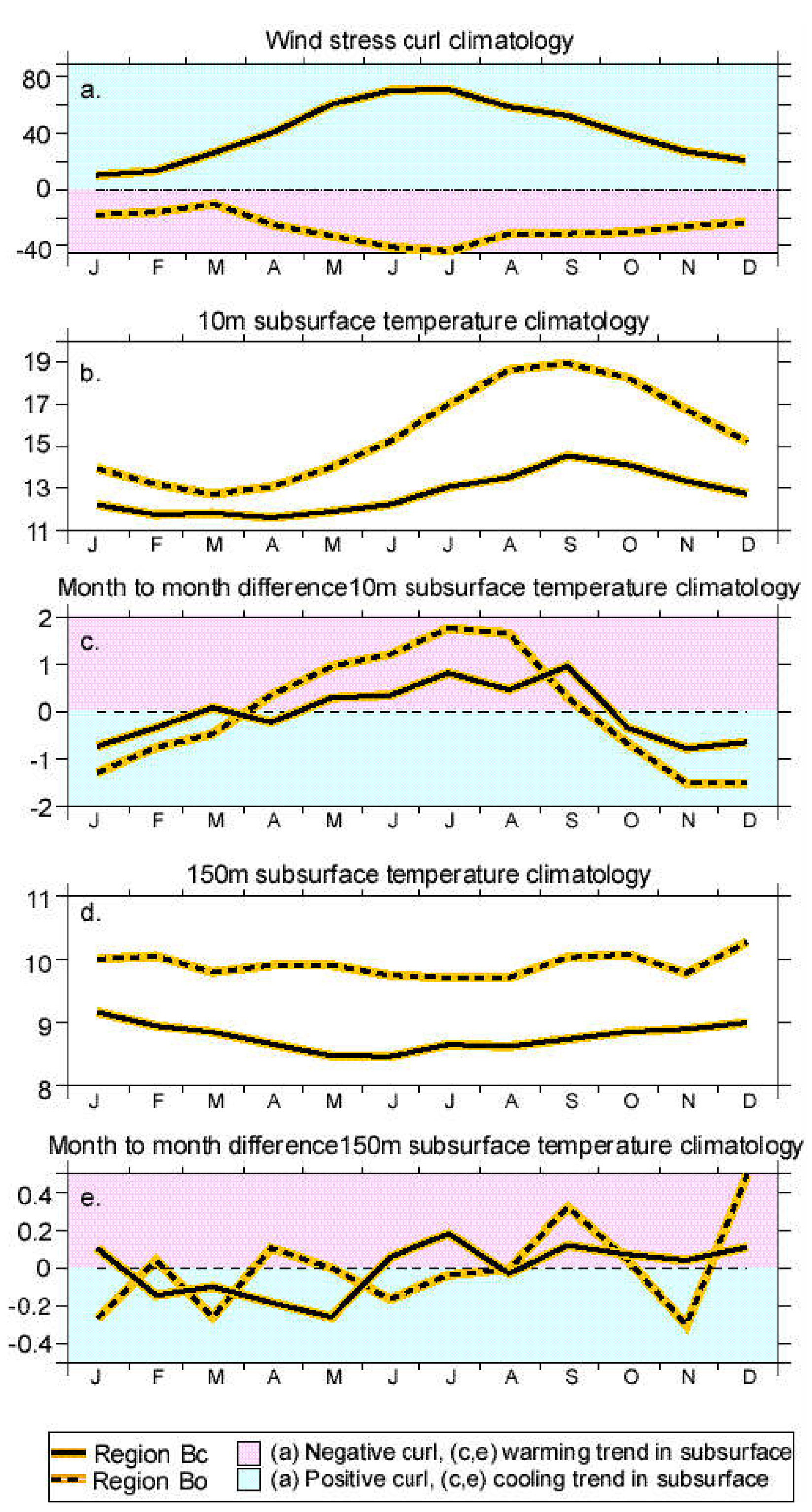


Figure 11 panels compares climatology time series of regions Bc (solid black and yellow line) and Bo (dashed black and yellow line). Panel a shows wind stress curl, panel b (panel d) shows 10m (150m) subsurface temperature and panel c (panel e) shows the monthly difference of the 10m (150m) subsurface temperature. Units for temperature are in Celsius and for WSC are in 10e-8 kilogram per meter squared per second squared. The WSC of Bo and Bc show an analogous relationship (Figure 11a). At the same latitude, seasonal warming of the mixed layer temperature near the coast is damped due to the positive WSC. A strong cooling trend in the coastal thermocline accompanies positive WSC.

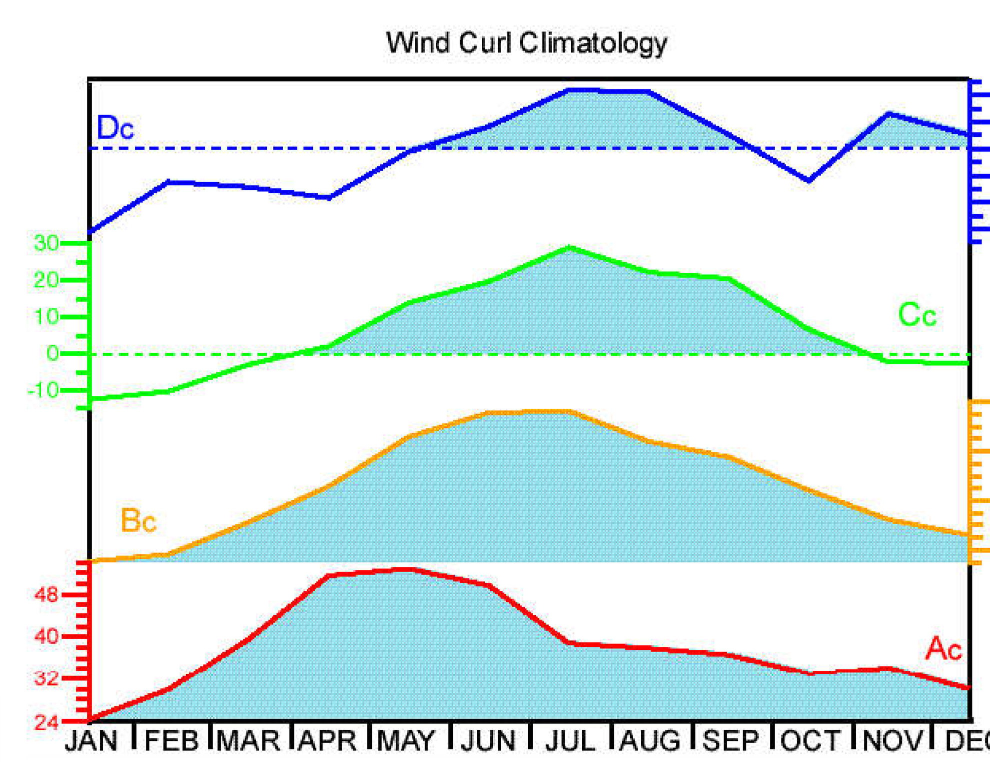


Figure 8 shows time series of wind stress curl climatology averaged over the regions Ac, Bc, Cc, and Dc. Blue regions denote where curl is positive. Units for wind stress curl are 10-8 kilogram per meter squared per second squared. The maximum WSC peaks at Ac in the spring, at Bc in the summer, and at Cc in the late summer. Locations Cc and Dc are in an area of negative WSC in winter and spring.

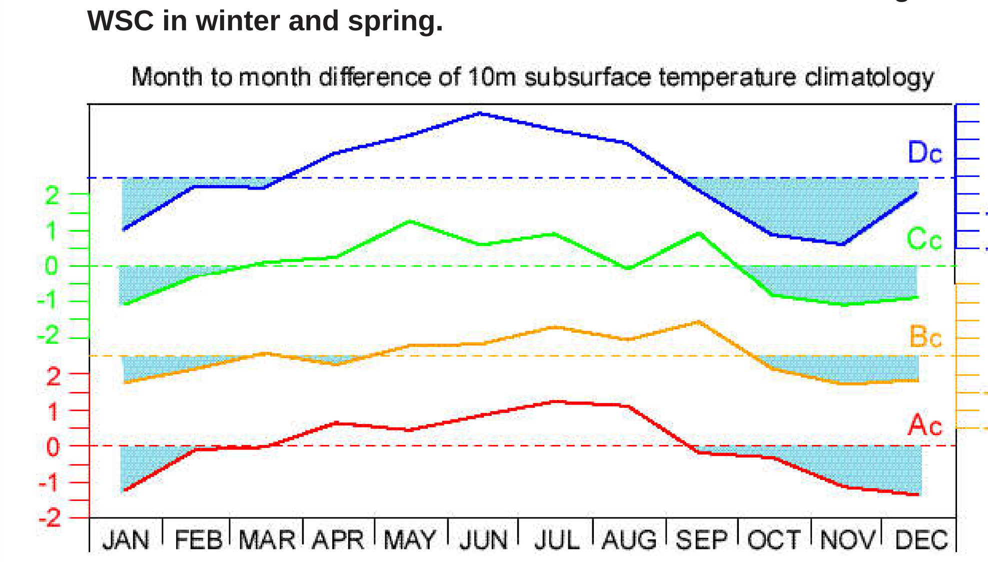


Figure 9 shows time series of 10m subsurface temperature climatology averaged over the regions Ac, Bc, Cc, and Dc. Blue regions denote where temperature is cooling. Units for temperatures are in Celsius. The 1Om mixed layer temperatures show the strong seasonal cycle., however during times of strong positive WSC, the signal is supressed. Region Dc suggests that there is something else controlling its pattern in spring and winter. A lag in the warming and cooling (blue shading) roughly follows the curl from south to north.

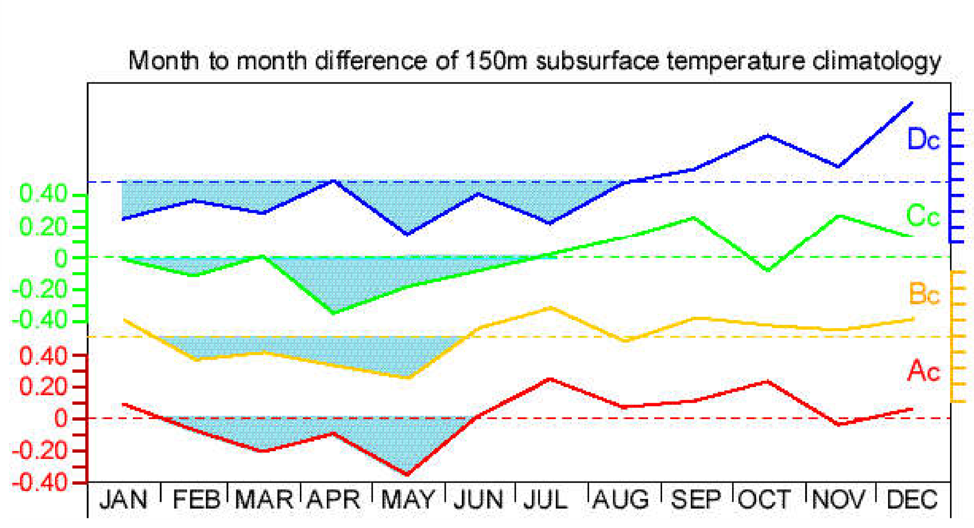


Figure 10 shows time series of 150m subsurface temperature climatology averaged over the regions Ac, Bc, Cc, and Dc. Blue regions denote where temperature is cooling. Units for temperatures are in Celsius. There is thermocline cooling when WSC is increasing. Region Dc suggests that there is something else controlling its pattern in spring and winter. A lag in the warming and cooling (blue shading) roughly follows the curl from south to north.