The Seasonal Cycle of Upper Ocean Temperatures of the West Coast: Local Atmospheric Forcing and Rossby Wave Propagation

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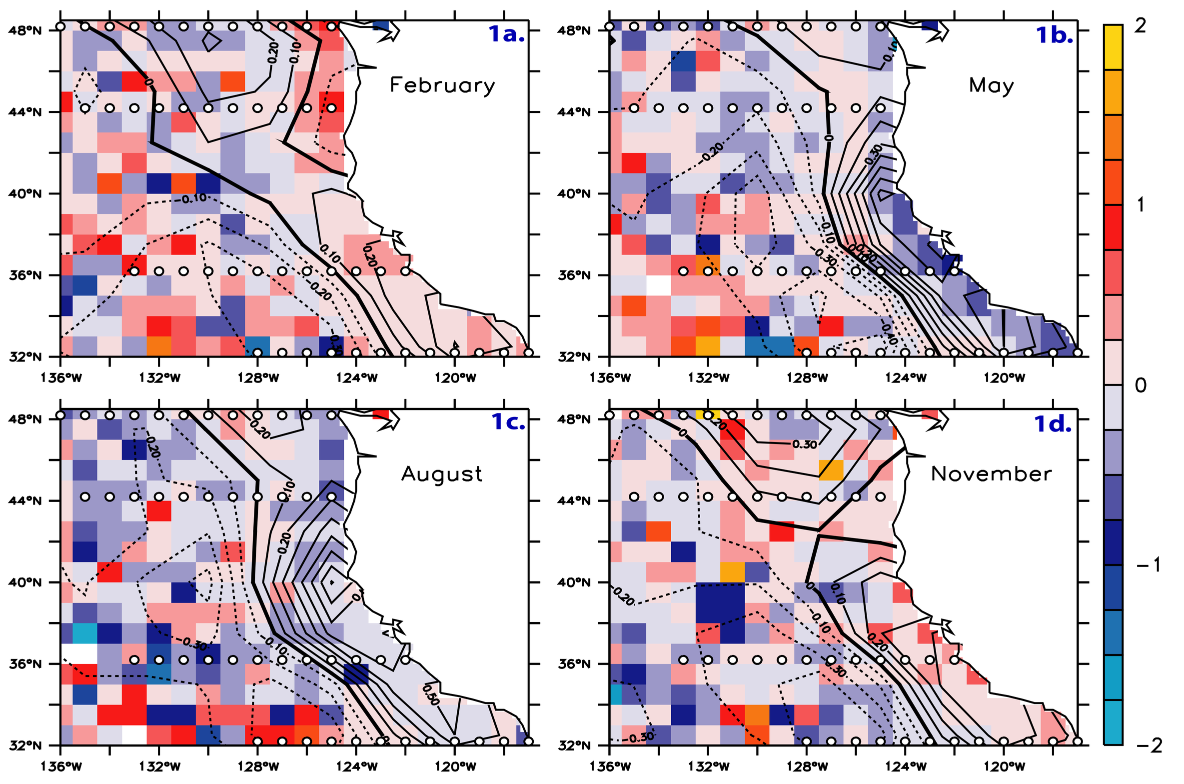


Figure 1. Panels 1a through 1d show wind stress curl (WSC) climatology overlaid on 150m sea temperature (ST) climatology anomalies for February, May, August, and November. Positive (negative) WSC is denoted by solid (dashed) lines and cool (warm) anomalies are represented by blue (red). The position of the WSC zero line is consistent throughout the year and separates onshore and offshore areas. Positive WSC near the coast is greatest in summer. This peak in the WSC moves poleward from late winter to late summer. The minimum in the WSC west of the zero line follows a similar pattern. The coastal temperature is coolest in spring to summer, and the peak follows the positive curl poleward. The signal of the offshore temperature cycle is unclear, having no obvious relationship with overlying WSC .

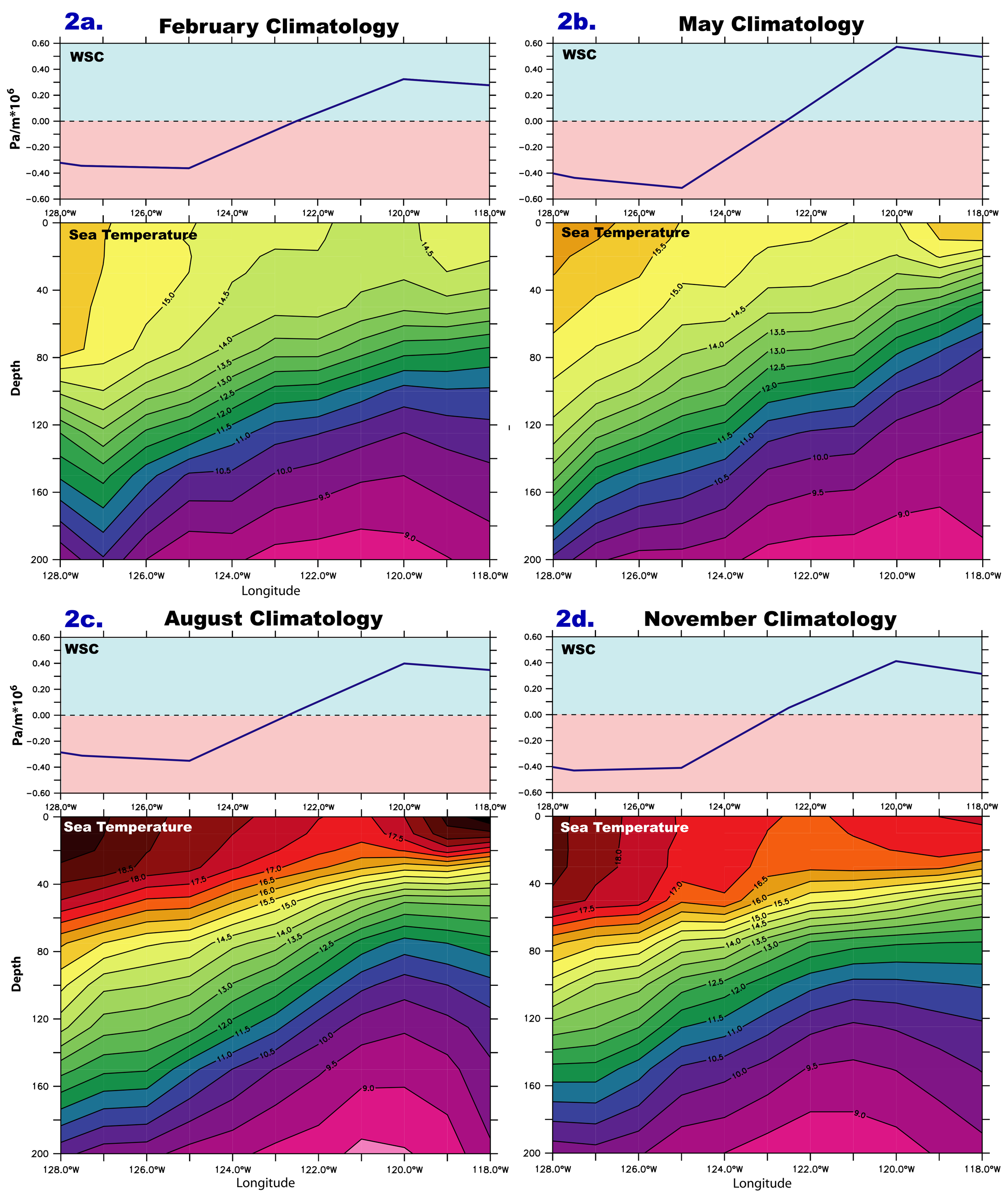


Figure 2. Panels 2a through 2d show the WSC (upper window) and the ST vertical profile (lower window) for an offshore section at 32˚N for February, May, August, and November. The position of WSC zero line is consistent throughout the year. The WSC maximum (minimum) is in May for onshore (offshore) areas. Evolution of isotherm displacement suggests offshore propagation. **See animation!**

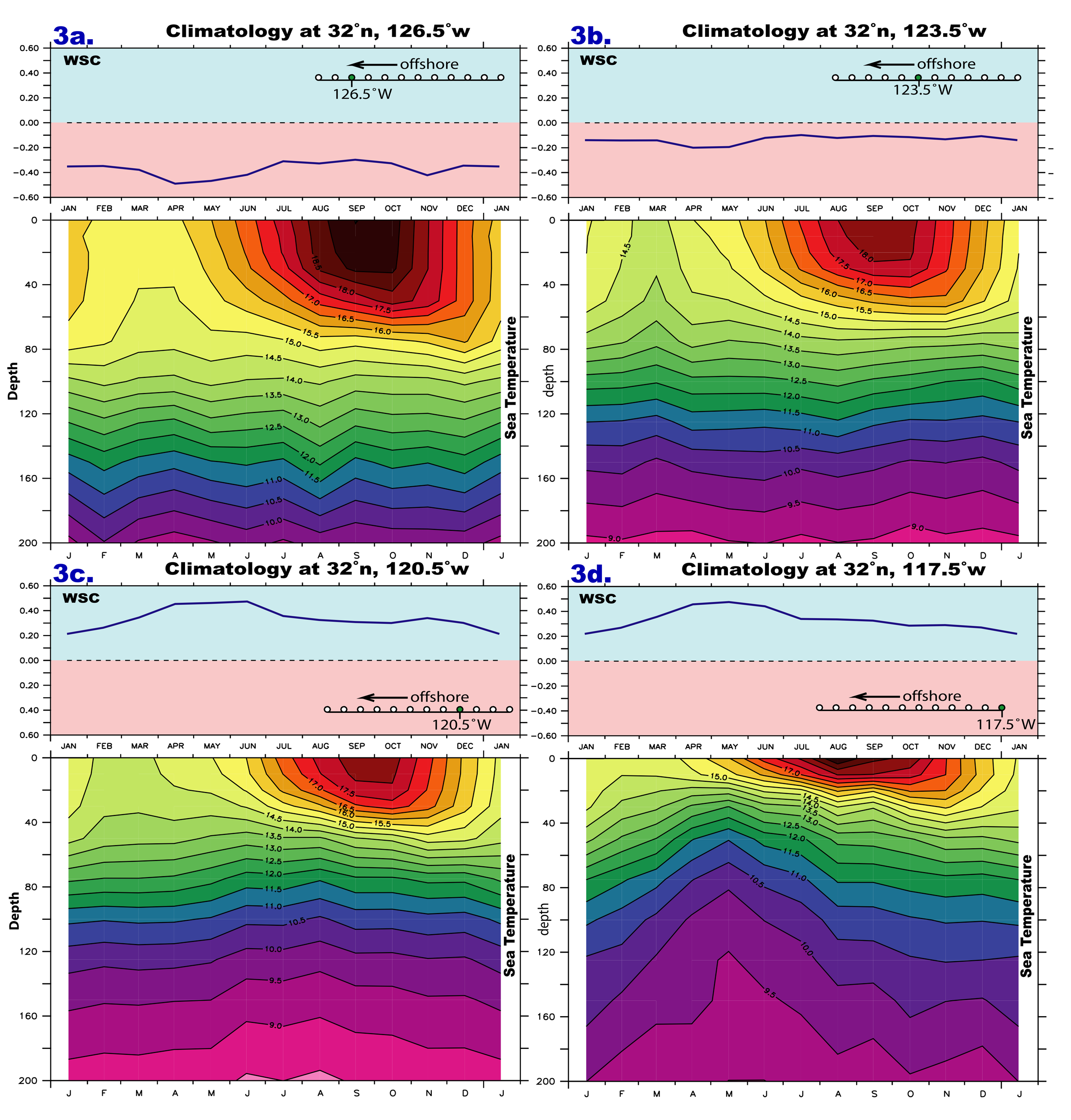


Figure 3. Panels 3a through 3d show the climatologies of WSC (upper window) and ST (lower window) for 32˚N at 126.5˚W, 123.5˚W, 120.5˚W and 117.5˚W. The doming upwelling signal in the thermocline shows a maximum displacement in May at the coast (figure 3d). The maximum displacement three degrees offshore appears in August (figure 3c). The thermocline has little annual cycle in the negative WSC region (figures 3a, 3b). **See animation!**

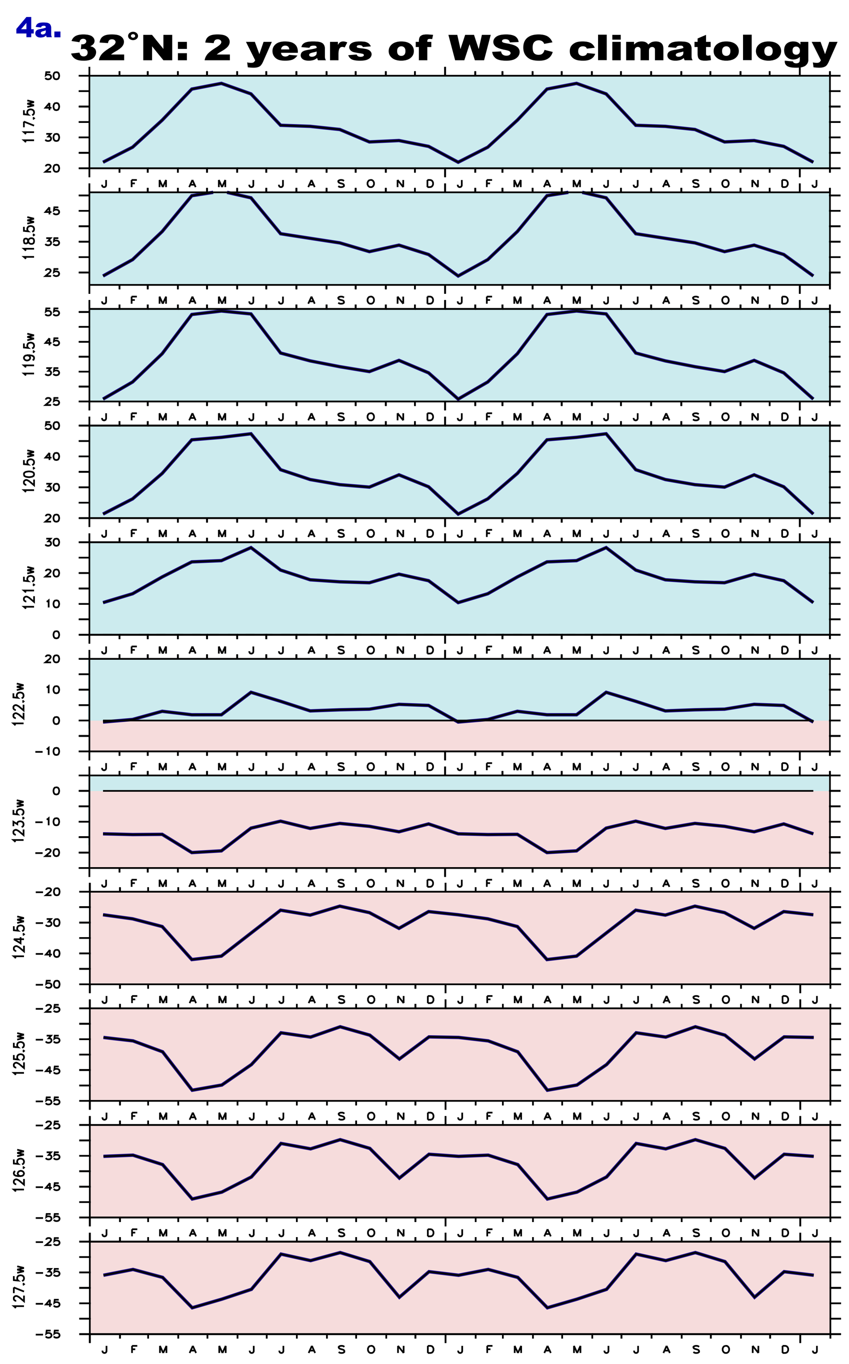
Introduction

Wind stress and wind stress curl strongly shape upper ocean conditions in the North Pacific on a full range of time scales. Prior work by Bakun and Nelson has shown that wind stress curl in coastal regions coupled with alongshore winds can affect local upwelling and therefore coastal temperatures, stratification, and productivity. This relationship may be complicated by westward propagating Rossby waves, which may be generated by local wind forcing and/or remotely forced Kelvin waves. By comparing the evolution of wind stress curl to ocean temperature we are able to investigate the impact of local Ekman processes and Rossby waves on the seasonal cycle of ocean conditions. The NCEP reanalysis daily surface winds and upper ocean temperatures at standard depths from WODB98 are analyzed to define climatologies, monthly values, and anomalies of wind stress curl (WSC, 1968-96) and sea temperature (ST,1946-96) over the Pacific Basin, and their spatial and temporal relationships.

We test two null hypotheses:

Hypothesis A: Local WSC (Ekman pumping) does not have a strong impact on the seasonal cycle of subsurface temperature.

Hypothesis B: There is no evidence from the subsurface temperature climatology of offshore Rossby wave propagation.



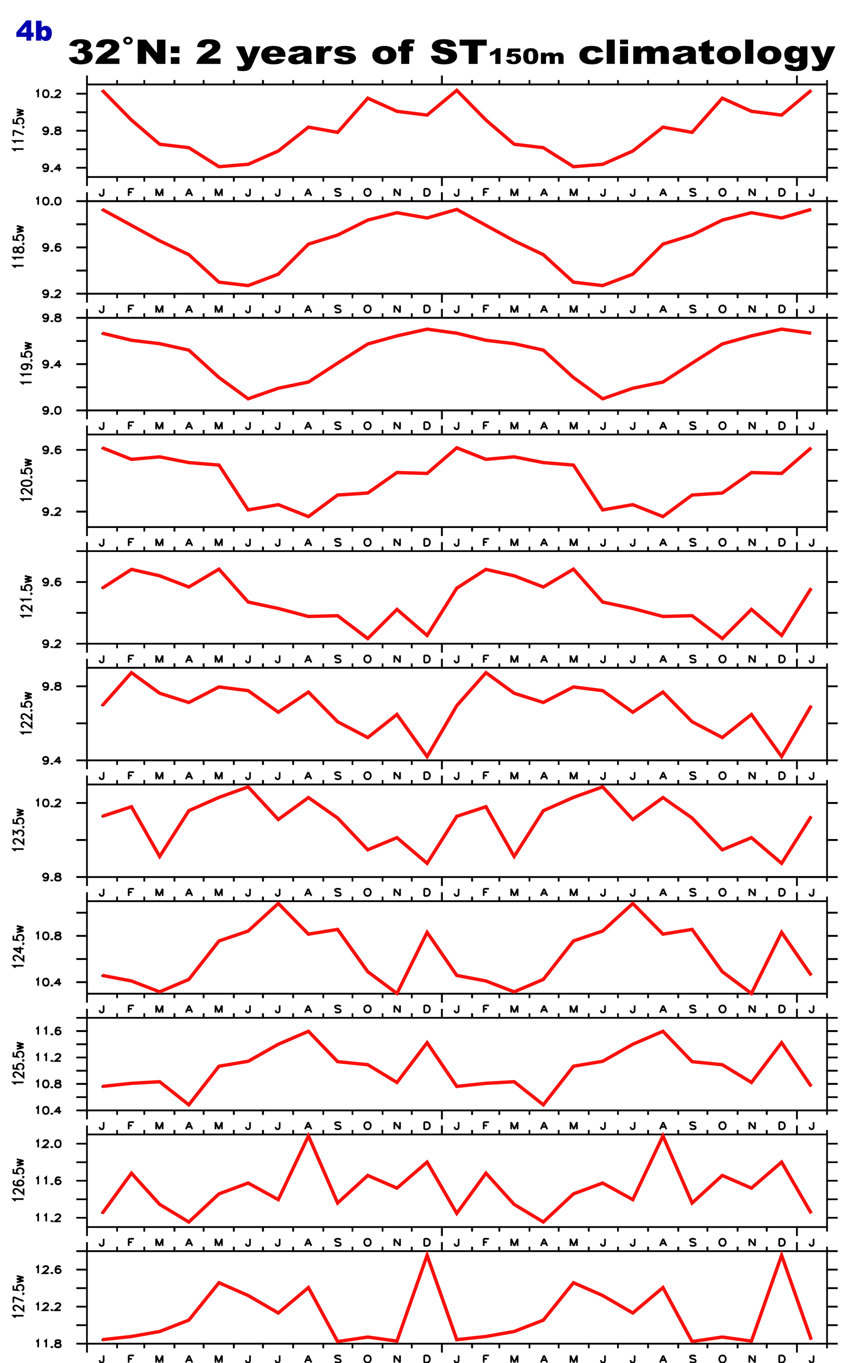


Figure 4. Stackplots show 2 cycles of the climatologies of the WSC and ST(150m) at 32˚N from 117.5˚W to 127.5˚W. Positive WSC occurs year-round from the coast to 122.5˚W (figure 4a). Negative WSC occurs year-round offshore of 122.5˚W. The maximum (minimum) for WSC onshore (offshore) is in spring. The maxima and minima develop in phase. Coastal temperatures are coolest in late spring and warmest in winter (figure 4b). The temperature annual cycle lags the coastal temperature by about 1˚ longitude per month.

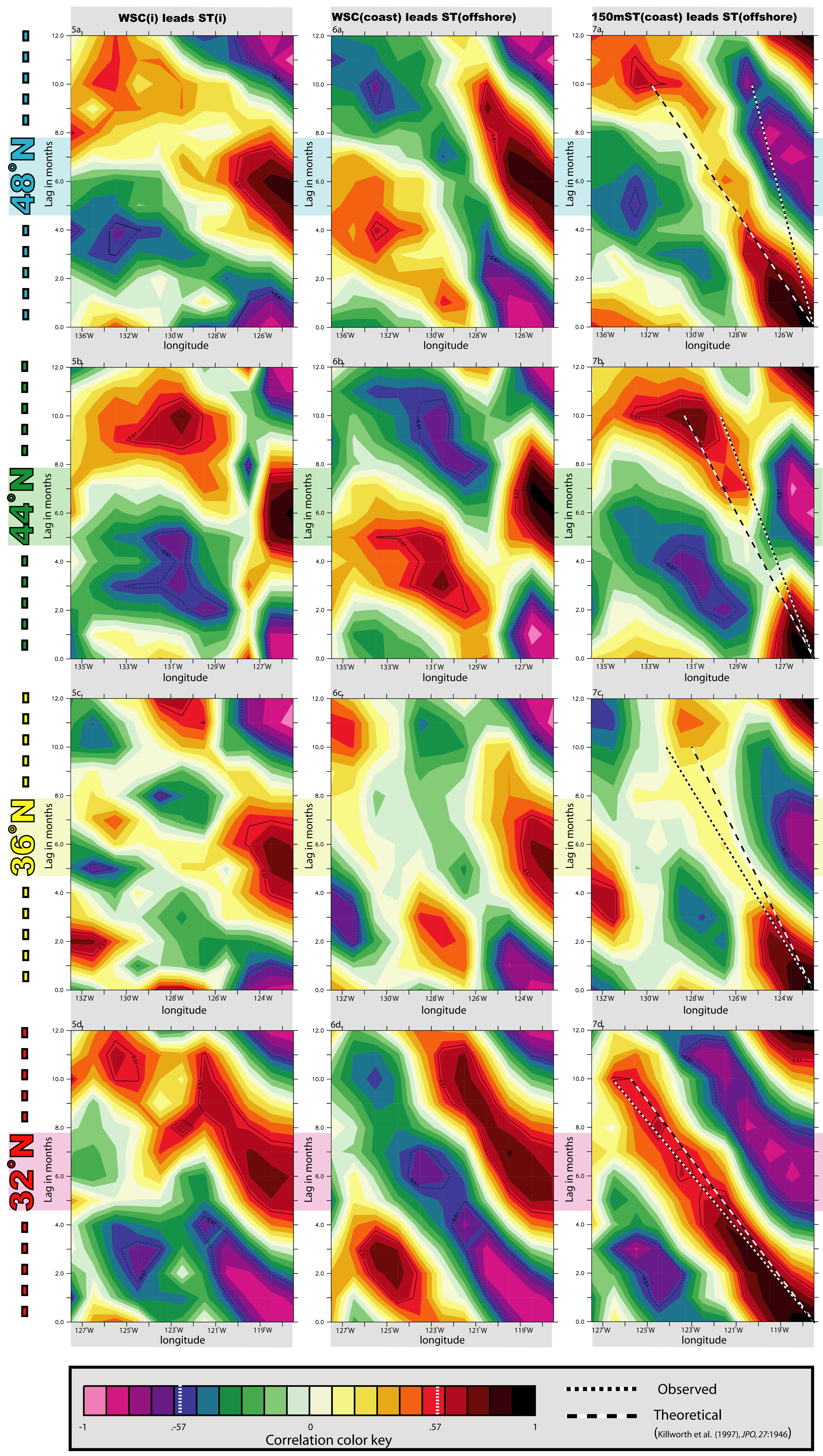


Figure 5-7. Lagged-correlations of ST150(i) at 48˚N, 44˚N, 36˚N and 32˚N with WSC(i) (figure 5), WSC(1) (figure 6), and ST(1) (figure 7). i = 1:11 represent 1˚ longitude boxes offshore, i=1 is at the coast. X-axis is longitude (offshore towards left), and Y-axis is lag in months. Significant (0.05 level) negative (positive) correlation is represented by purple (brown and red).

Figure 5.

o Direct forcing of ST by Ekman pumping indicated by significant negative correlation and minimal lag between WSC(i) and ST(i).

o This relationship holds only at the coast (WSC(1) vs ST(1)).

o WSC (Ekman pumping) does not appear to be a dominant factor in direct forcing of the offshore ST seasonal cycle.

Figure 6.

o Significant negative correlation between offshore ST(i) and WSC(1), with increasing lag with distance offshore, implies seasonal cycle of offshore ST may be due to Ekman pumping at coast.

o Highest negative correlations are at 32˚N.

Table 1:
Rossby Wave Phase Speed
(in cm/s)

Lat.	Theor.	Obs.	$R_{obs.}$
48˚N	0.8	2.1	0.72
44˚N	1.3	1.8	0.85
36˚N	2.3	1.9	0.88
32˚N	3.3	3.0	0.99

Figure 7.

o Dashed (dotted) lines show the observed annual ST (internal Rossby wave) phase speed at each latitude.

o Coastal subsurface temperature is well correlated with subsurface temperature offshore with lags consistent with Rossby wave propagation.

o The signal is clearest at 32˚N, possibly due to a relatively weaker influence of Rossby waves at higher latitudes or aliasing of signal at higher latitudes .

o Measured propagation speed is very close to theoretical at 32˚N, and reasonably close at higher latitudes (Table 1).

Conclusions:

o We can support hypothesis A. The seasonal cycle of offshore subsurface temperature (ST) does not appear to be greatly affected by local wind stress curl (WSC). There seems to be a relationship between coastal WSC patterns and offshore ST with increasing lag.

o We cannot rule out hypothesis B. There is intriguing evidence of coastal isotherm displacement propagating offshore at speeds consistent with internal Rossby wave theory.

o Future work: More complete theoretical wave modeling, comparison with GCM output, analysis of observed ST time series.

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