Oceanic drivers of seasonal and interannual winter subsurface temperatures in the Northern California Current System

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Introduction : Management decisions for fisheries, protected species, and ecosystem health services require reliable short-term forecasts 6-9 months off US West coast. A variety of marine species are known to be sensitive to sub-surface ocean conditions of the region such as, lower-trophic species -krill, higher trophic level species - Pacific hake, and bottom feeders - Dungennes crab. Monthly variation in temperature at depth (TD) in the Northern California Current System (N-CCS) are related to a linear combination of factors, including North Pacific spice anomalies, and the PDO and ENSO climate indices (*Ray et al., 2020*). However, the mechanisms for seasonal predictability of the N-CCS temperatures at depth are relatively less known. The temperatures during summer upwelling season is connected to the winter prior, however the strength of the connection depends on whether its an ENSO winter or not. In this study we investigate the physical processes driving the seasonal and interannual variations in subsurface temperatures of the N-CCS through a subsurface heat budget approach.

Data and method

NOAA's Climate Forecast System Reanalysis (CFSR) – monthly fields for the period 1979-2017; daily fields for 1979

Horizontal Resolution: 25-50 km

Temperature at depth (TD) = temperature along 26.4σ (roughly the depth of pycnocline in North Pacific) averaged in N-CCS

Winter prior correlations

- ENSO-neutral years show relatively higher correlations compared to ENSO years

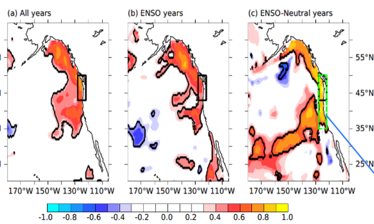


Fig 1. Lag correlation in MJJ averaged TD in N-CCS (black box) to prior OND averaged temperature. 90% significant correlations in bold black contours.

- Deep winter mixing leaves its footprint on TD close to the coast

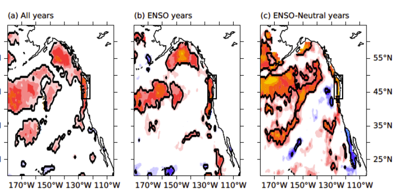


Fig 2. Lag correlation in MJJ averaged TD in N-CCS (black box) to prior OND SST. 90% significant correlations in bold black contours.

- At the most 25% of the summer TD variation is explained by SST variations from winter prior.

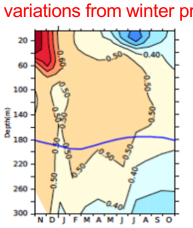
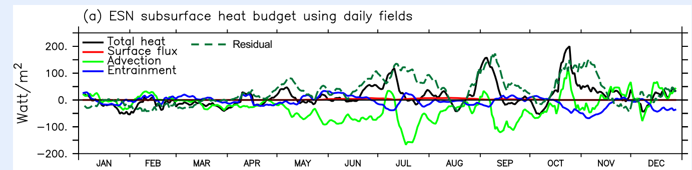


Fig 3. Lag correlation of N-CCS averaged SST anomaly in November to temperatures at depths averaged in the same domain. The depth of 26.4σ isopycnal layer in the N-CCS domain is shown in blue line.

- **Role of oceanic advection** ⭐
- **Role of coastally trapped waves**

Subsurface heat budget

An intermediate layer heat budget is estimated in a domain averaged within the green box (ESN) in Fig 1c, using the equation below. The budget is calculated for two layers (i) $h = h_{26.4\sigma}$ (depth of 26.4σ), and (ii) $h = h_{ML}$ (depth of ML). The intermediate layer heat budget is then calculated as the difference between the individual terms from the two layers.



$$\frac{\partial T}{\partial t} = \left|\frac{1}{\rho C_p} Q\right| + \left|\frac{\partial}{\partial z}\left(\kappa \frac{\partial T}{\partial z}\right)\right| - \{u_{\perp}(T - T_r)\}_{\Lambda} + \left|\frac{1}{h}\Delta T \frac{\partial h}{\partial t}\right| - \{w(T - T_r)\}$$

Temperature tendency = TD; Net surface heat flux = $Q_{sfc} - Q_{pen}$; Vertical diffusion (part of residual); Horizontal advection; Entrainment; Vertical advection

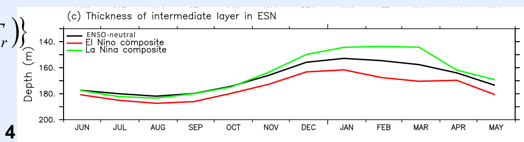


Fig 4

- Reduced heating in relatively thinner intermediate layer in winter
- Residual heating accounts for the missing heating from vertical diffusion
- Adjusted temperature tendency due to innovations – part of residual

ENSO-neutral years

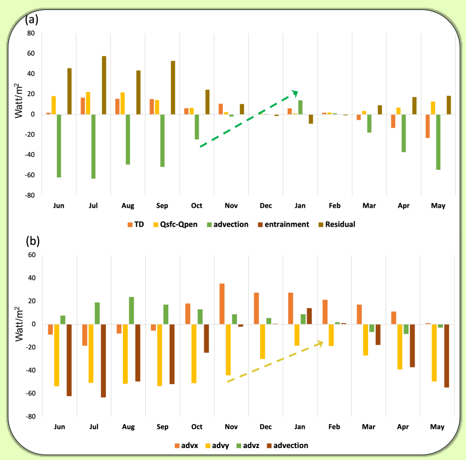


Fig 5. ESN intermediate layer heat budget for ENSO-neutral years

- Advection drives the heating in winter
- Meridional advective cooling decreases in winter - seasonal appearance of poleward California Undercurrent

Composite of El Niño years

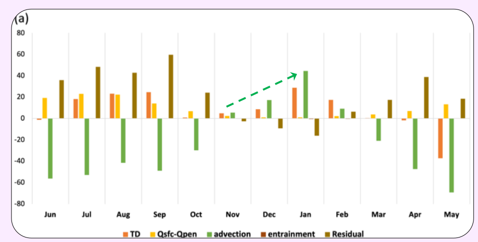
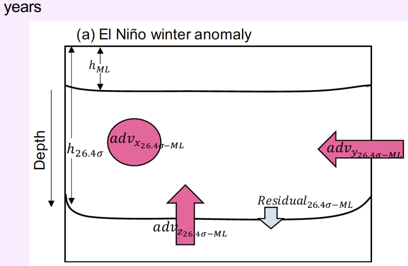


Fig 6. ESN intermediate layer heat budget for composite of El Niño years



- Downwelling driven convergence of advective fluxes associated with CTW propagation
- Strengthened CUC – meridional flux convergence

Summary

- **N-CCS summer TD are more strongly correlated with winter prior temperatures during ENSO-neutral years**
- **Deep winter mixing explains at the most 25% of the summer TD in N-CCS**
- **CUC plays a leading role in pre-conditioning the winter subsurface for the following summer, during ENSO-neutral years**
- **Downwelling of 26.4σ layer associated with CTW propagation includes deeper waters, during El Niño years**
- **Strengthened CUC brings warmer water from south during El Niño years**

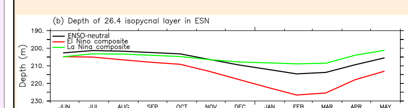


Fig 7. Depth of bottom boundary of the intermediate layer, averaged in ESN for ENSO-neutral and composite of El Niño years

References

Ray, S., N. Bond, S. Siedlecki, and A. Herman : Influence of winter subsurface on the following summer variability in Northern California Current System, (*in review*)

Ray, S., S. Siedlecki, M. Alexander, N. Bond and A. Herman (2020) : Drivers of subsurface temperature variability in the northern California current, JGR-Oceans, 125(8), e2020JC016227