Regression analysis of historical coastal observations off southern California Bight ~~the U. S. West Coast~~

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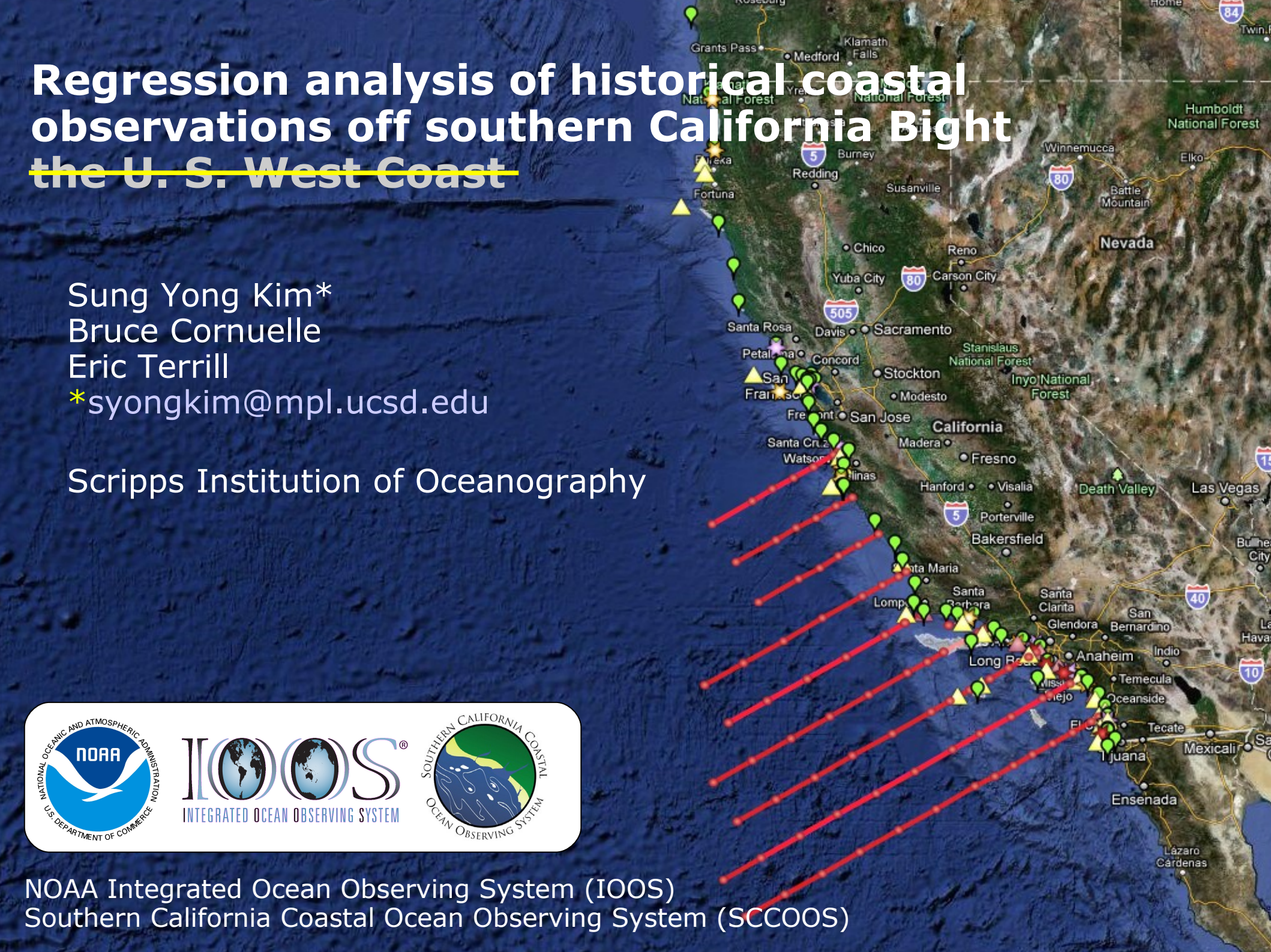


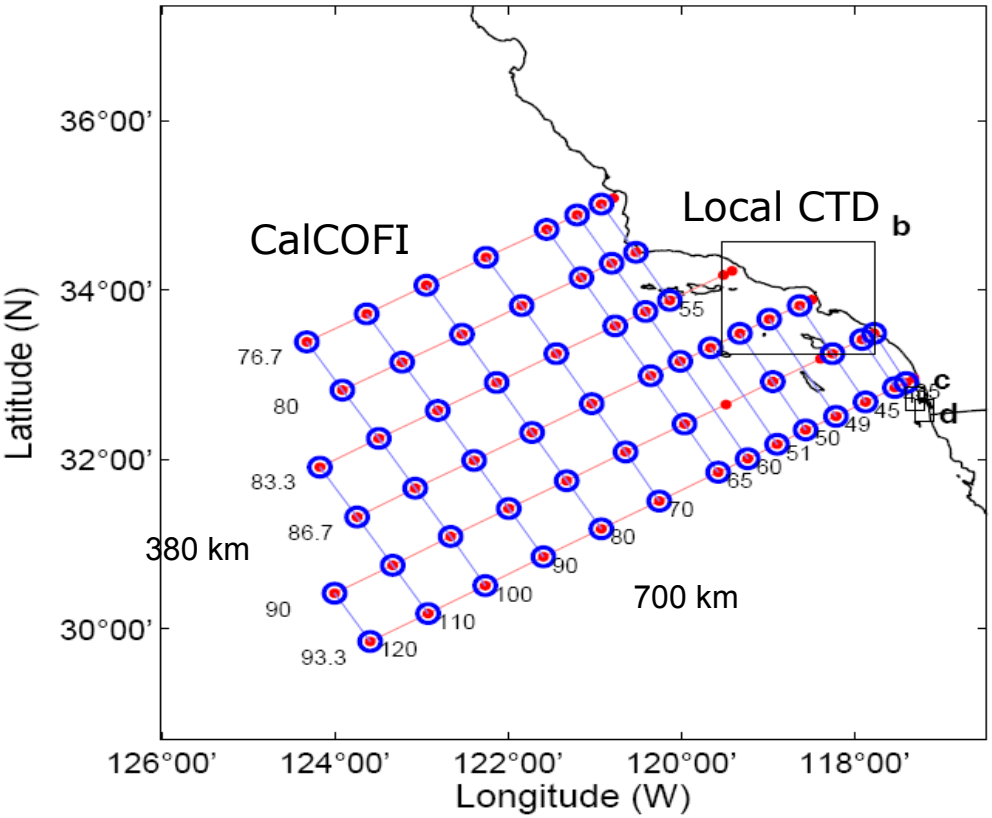
NOAA Integrated Ocean Observing System (IOOS)
Southern California Coastal Ocean Observing System (SCCOOS)

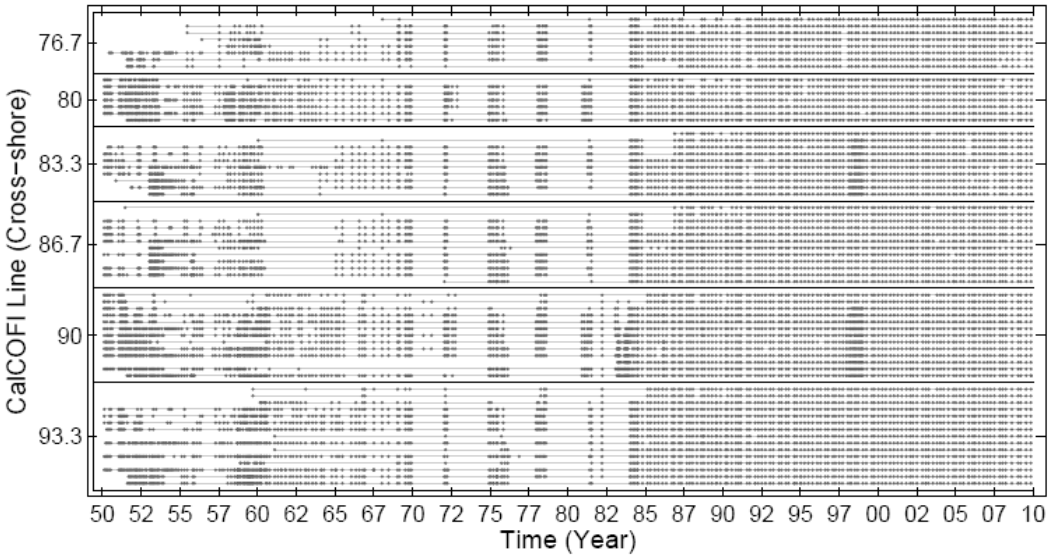
Motivation

- Partitioning of historical data into seasonality, components coherent with climate indices, and linear trend.
- Reporting variance fraction – how much variance is explained by each term?
- Deriving climatology and reconstructing three-dimensional (x,y,z) time series (t).
- Detecting potential climate signals from coastal observations.
- Assisting regional ocean models and observations.

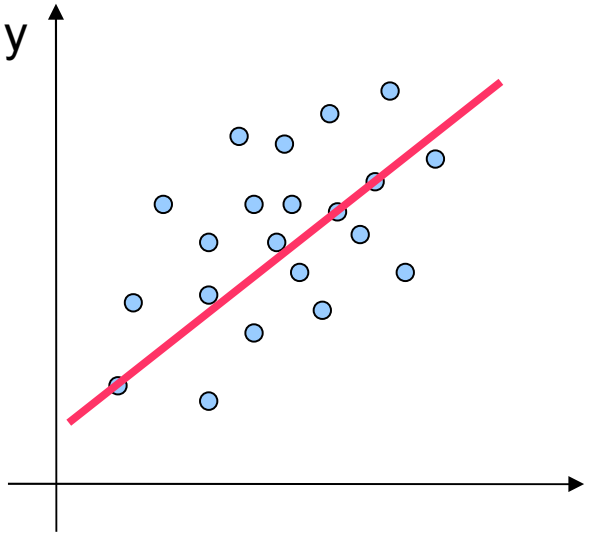
Observations

- Historical data
  - Quarterly California Cooperative Oceanic Fisheries (CalCOFI) CTD data (1950 – 2009).
  - Monthly CTD samplings at local discharge and outfalls off southern California (Bight Water Quality, Point Loma Ocean Outfall, and South Bay Ocean Outfall; 1990 – 2009).
  - Daily sampled surface temperature and salinity at shorestations off the USWC (1920 – 2009).





Regression basis



$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} x_1 & 1 \\ x_2 & 1 \\ \vdots & \vdots \\ x_n & 1 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix}$$

$$\mathbf{d} = \mathbf{G}\,\mathbf{m}$$

$$\begin{aligned} \hat{\mathbf{m}} &= \mathbf{P}\mathbf{G}^{\dagger}\left(\mathbf{G}\mathbf{P}\mathbf{G}^{\dagger} + \mathbf{R}\right)^{-1}\mathbf{d}, \\ &= \left(\mathbf{G}^{\dagger}\mathbf{R}^{-1}\mathbf{G} + \mathbf{P}^{-1}\right)^{-1}\mathbf{G}^{\dagger}\mathbf{R}^{-1}\mathbf{d}, \end{aligned}$$

- SA1 – SA6 (6 harmonics of seasonality)
- ENSO: El-nino Southern Ocean Oscillation (1900-2009)
- PDO (Pacific Decadal Oscillation): 1st mode of North Pacific SST (1900-2009)
- NPGO (North Pacific Gyre Oscillation): 2nd mode of northeastern Pacific SSHAs + SST (1950-2009)
- SIOT: Scripps Pier Temperature (1916-2009)
- Linear trend

Data decomposition

- Decomposition of time series

$$d(t) = d_{\mathrm{S}}(t) + d_{\mathrm{C}}(t) + d_{\mathrm{F}}(t) + d_{\mathrm{R}}(t),$$

  - Seasonality with six harmonics (SA1, SA2, …, and SA6).
  - Climate indices (ENSO, PDO, NPGO, and SIOT).
  - Polynomials (mean and linear trend)

- Successive orthogonalization

  - As climate indicate are coherent each other, there is ambiguity in partition of variance.
  - In a given order of basis functions, a basis function is orthogonalized by basis functions above that in sequentially.
  - Seasonality → ENSO → linear trend → PDO → NPGO → SIOT

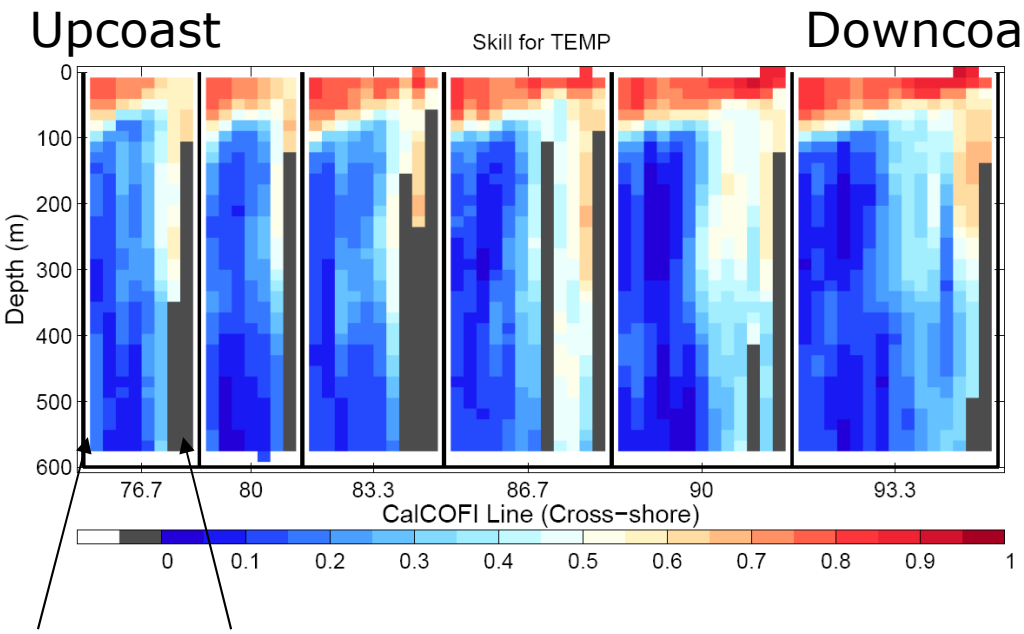
Correlation before orthogonalization

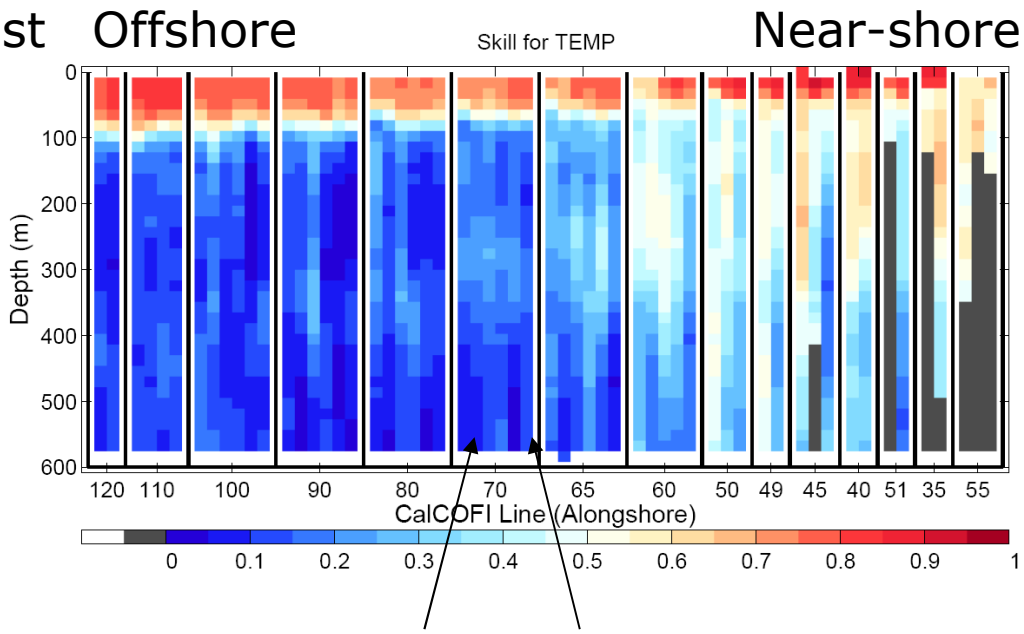
	ENSO	PDO	NPGO	SIOT
ENSO				
PDO	0.58			
NPGO	-0.18	-0.09		
SIOT	0.21	0.20	-0.02	

Correlation after orthogonalization

	ENSO	PDO	NPGO	SIOT
ENSO				
PDO	-0.05			
NPGO	0.07	-0.00		
SIOT	-0.09	0.00	0.00	

Cross-shore and alongshore transects





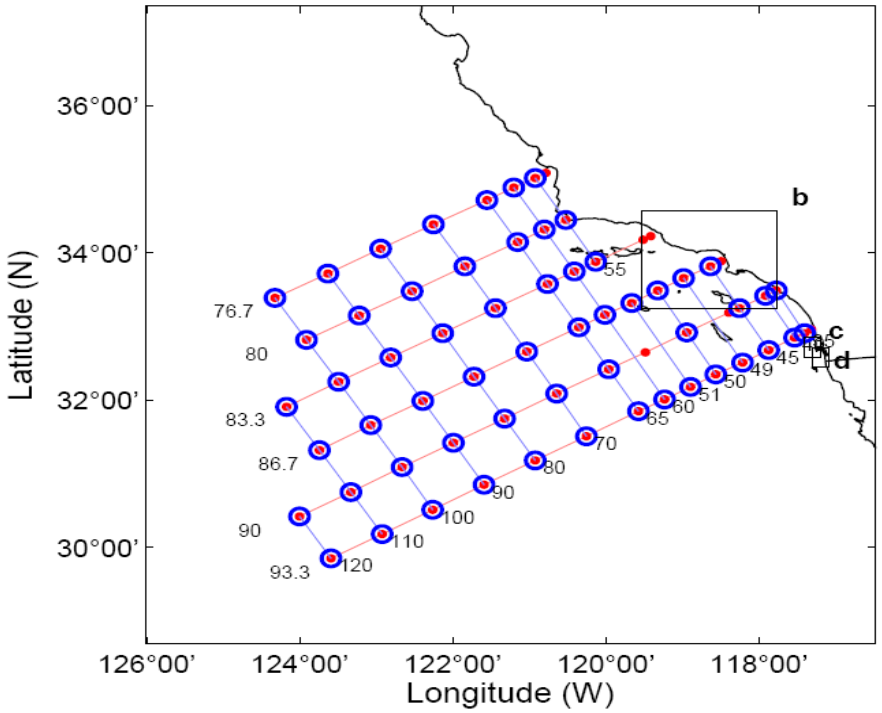
Total skill

$$\kappa^2 = 1 - \frac{\left\langle \left(d - \hat{d}\right)^2 \right\rangle}{\langle d^2 \rangle}$$

Individual skill:

$$\kappa_l^2 = 1 - \frac{\langle (d - d_l)^2 \rangle}{\langle d^2 \rangle}$$

for CalCOFI transects of T/S/sigma-t

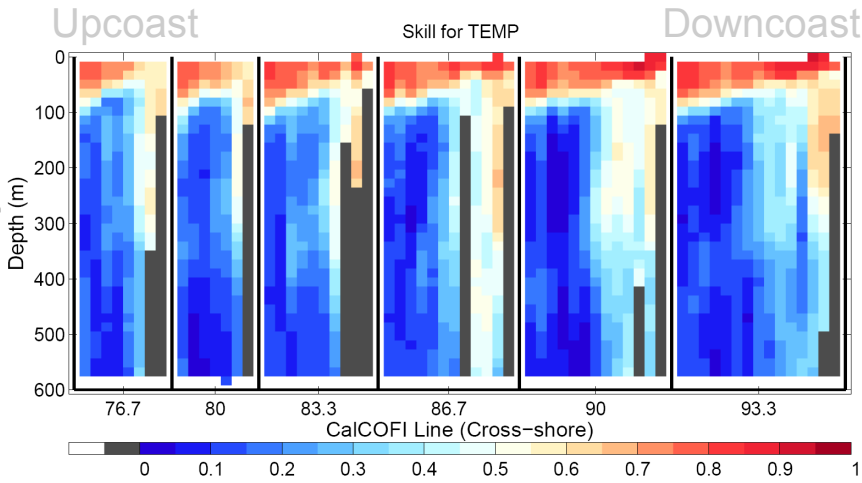


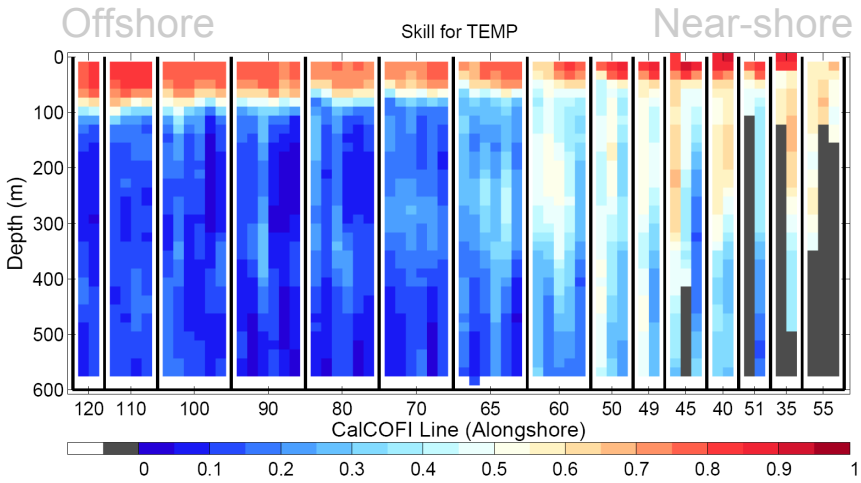
Total skill (CalCOFI)

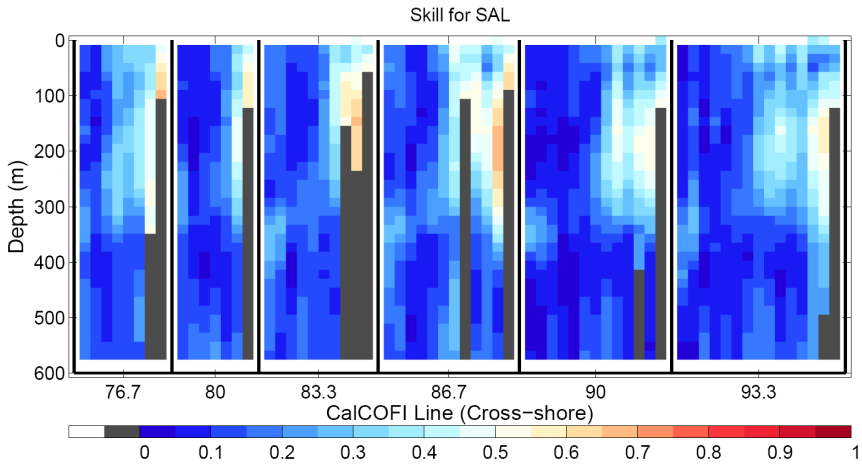
Temperature

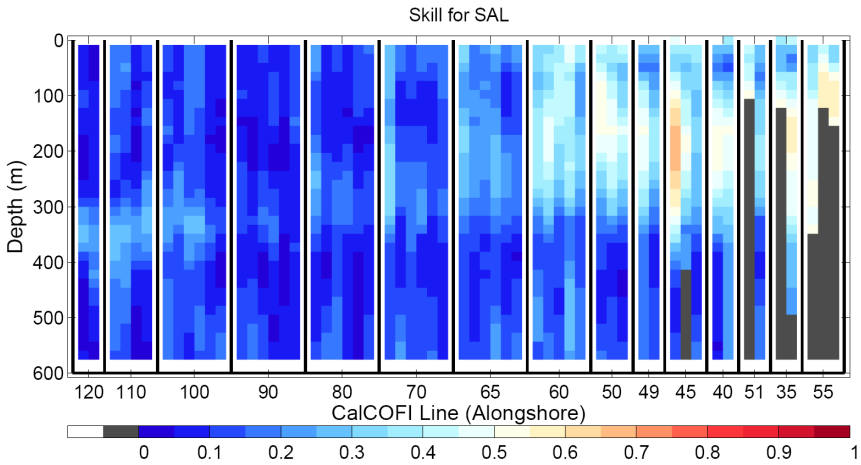
Salinity

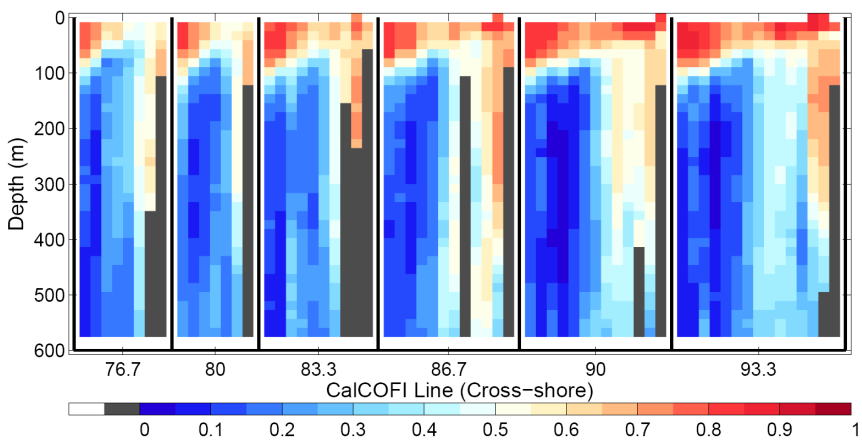
Density

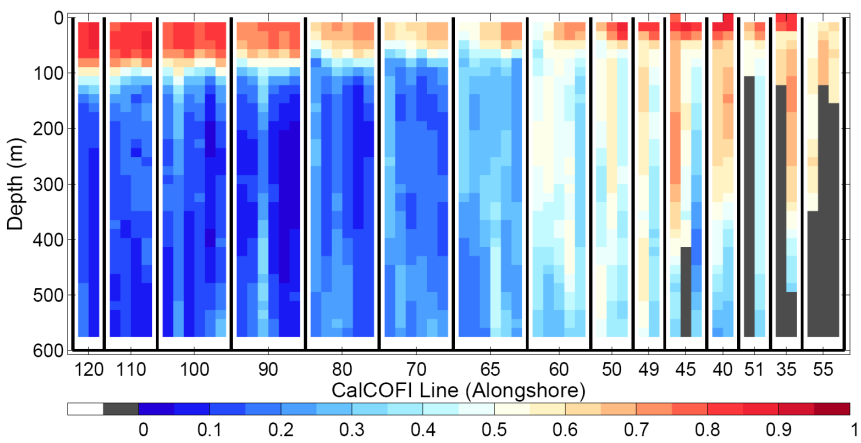










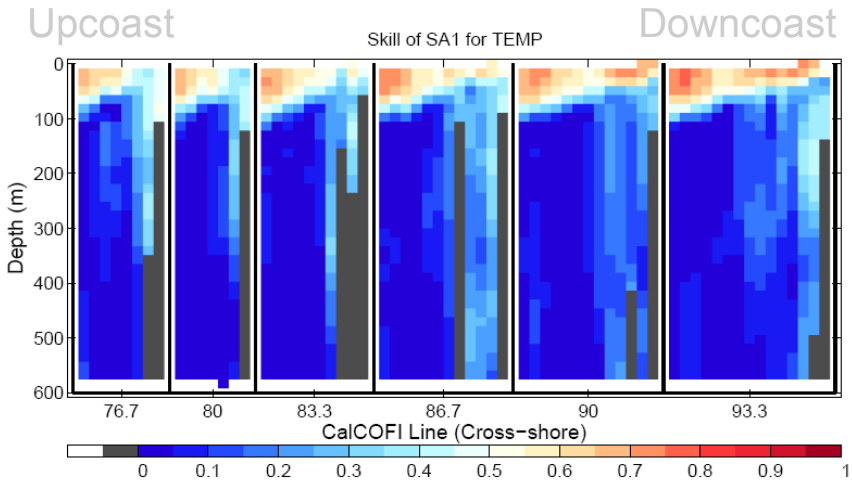


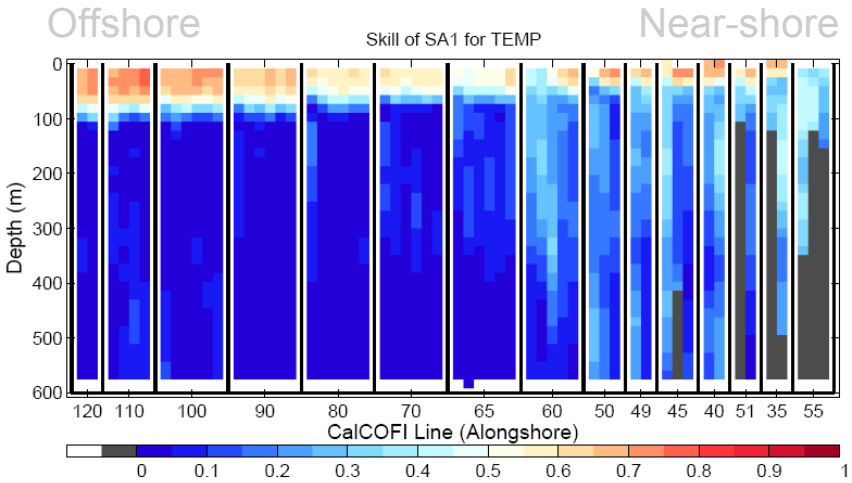
Individual skill for seasonality (SA1; CalCOFI)

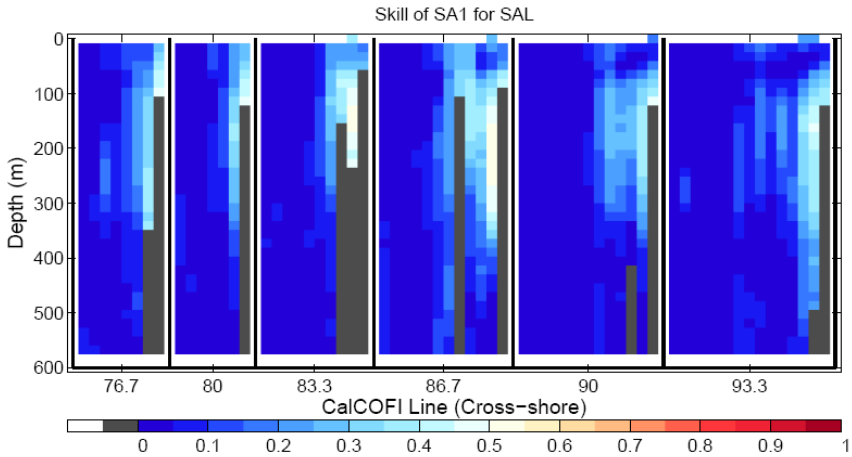
Temperature

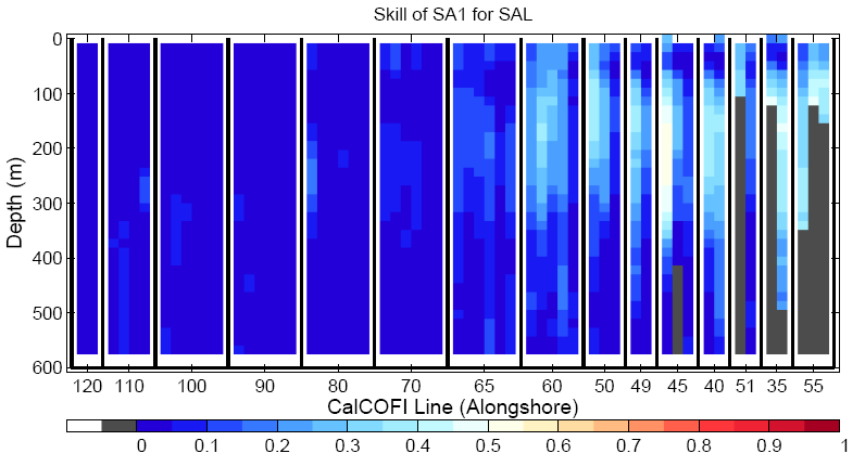
Salinity

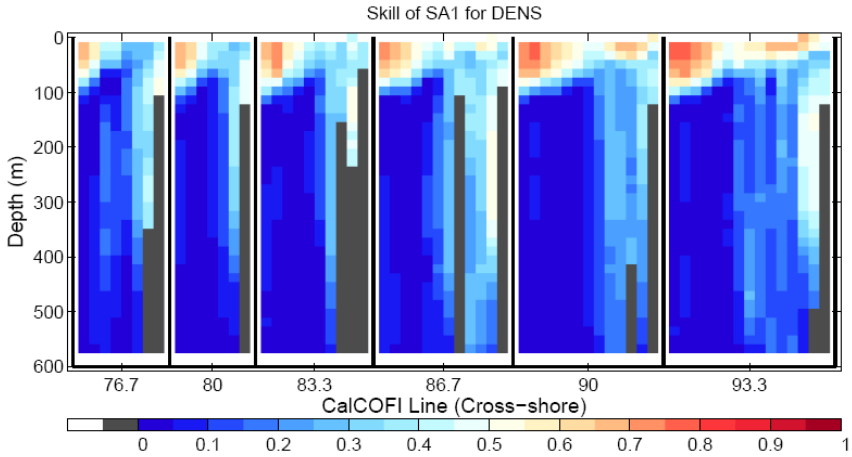
Density

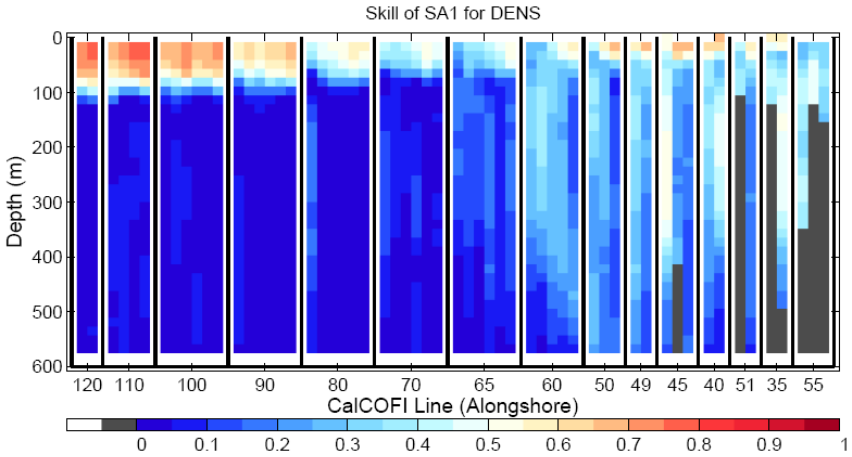








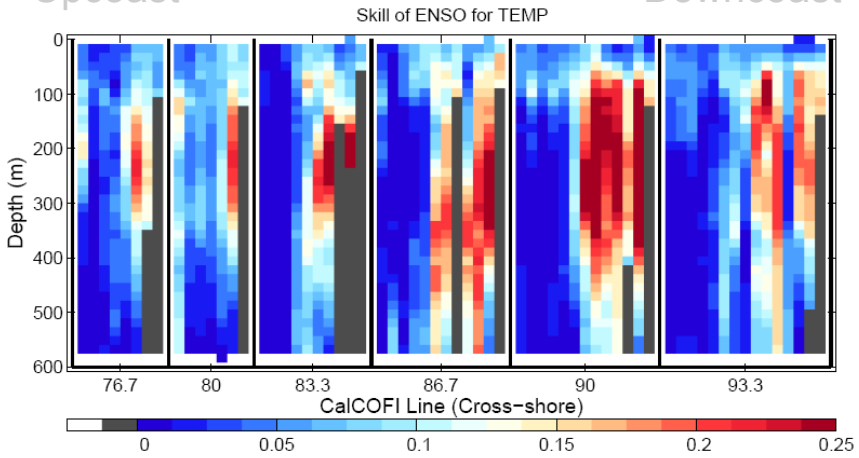


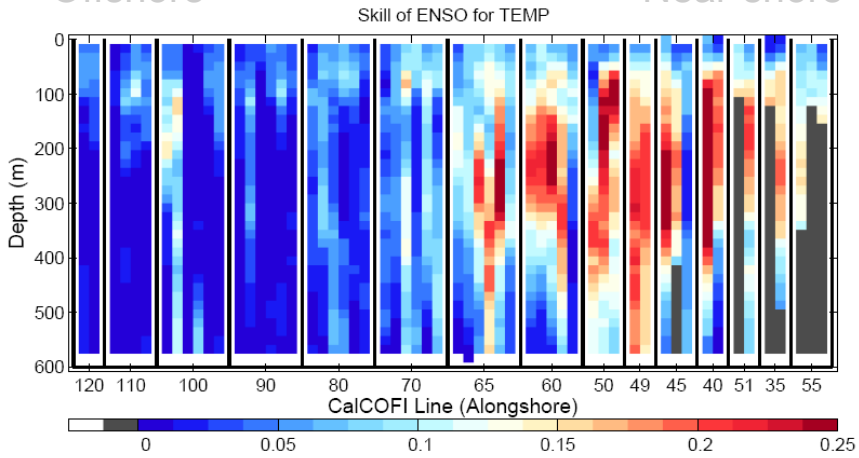


Individual skill for ENSO (CalCOFI)

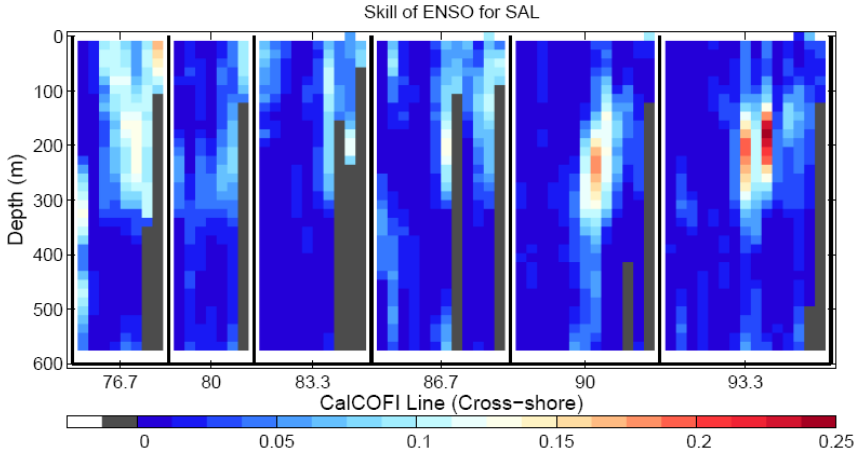
Upcoast Downcoast Offshore Near-shore

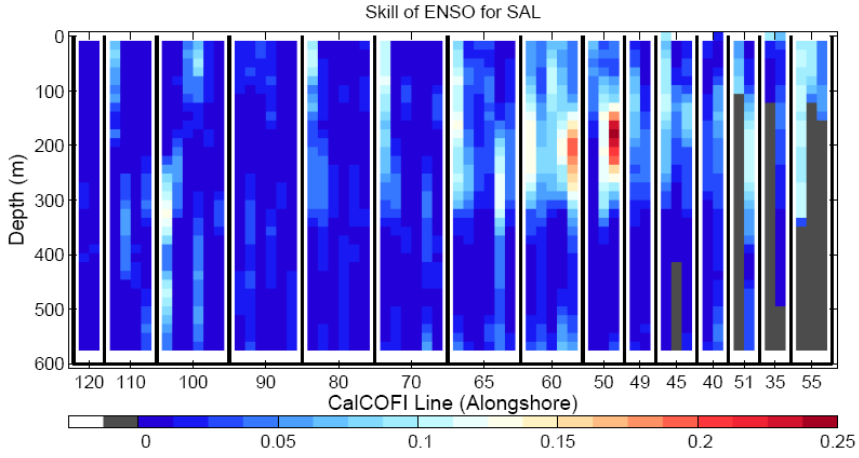
Temperature



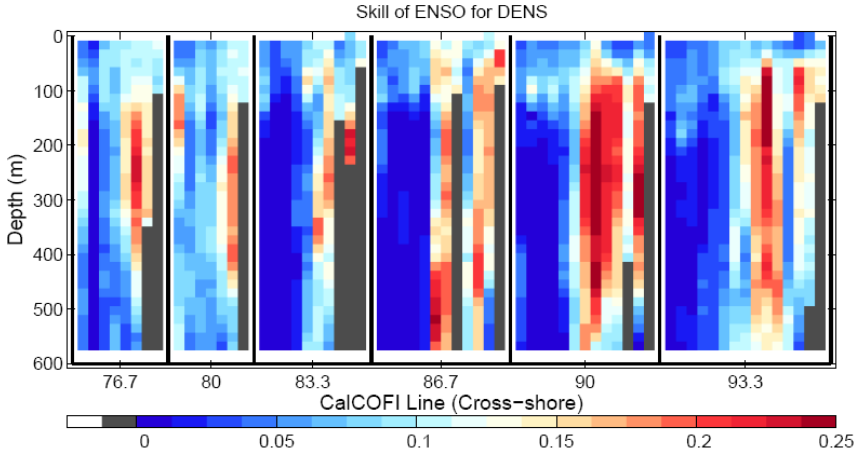


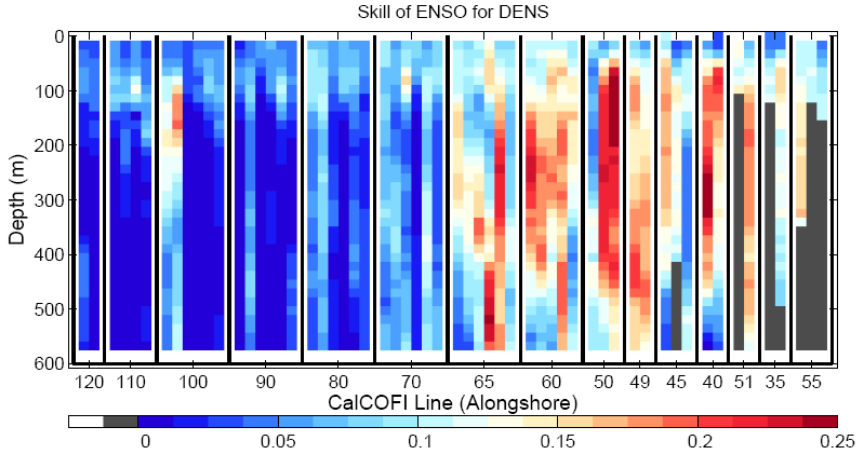
Salinity





Density

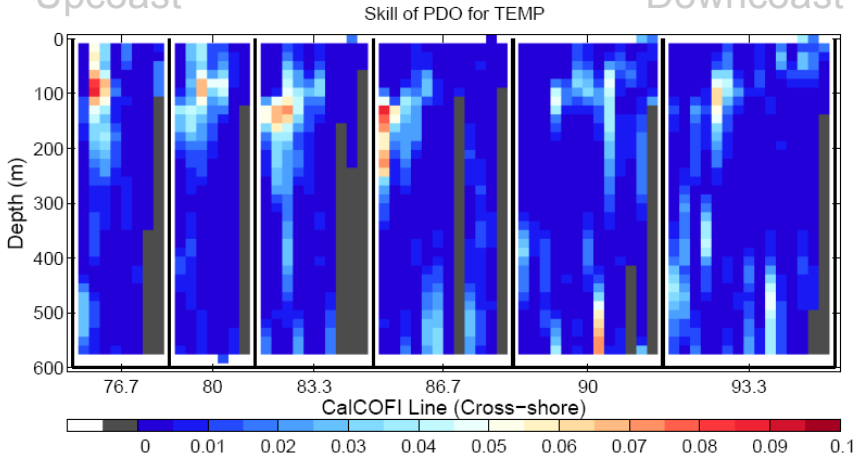


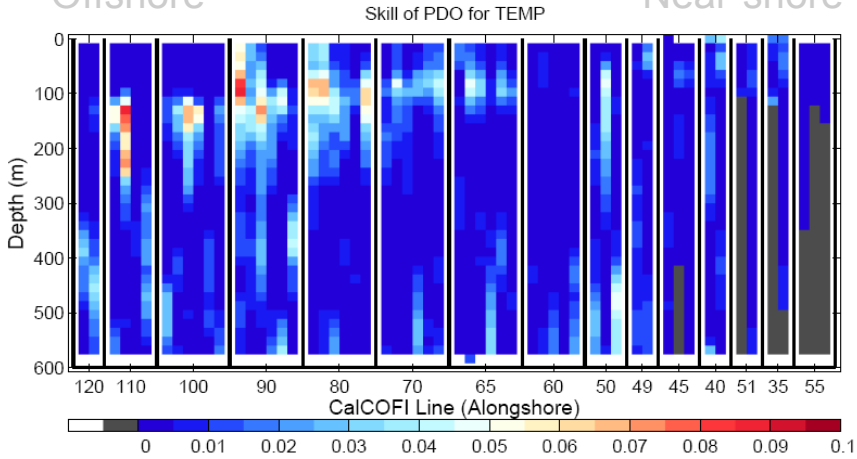


Individual skill for PDO (CalCOFI)

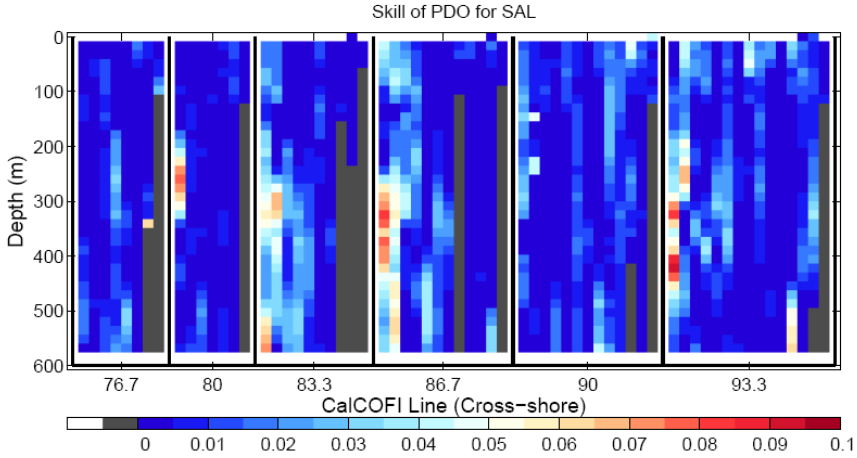
Upcoast Downcoast Offshore Near-shore

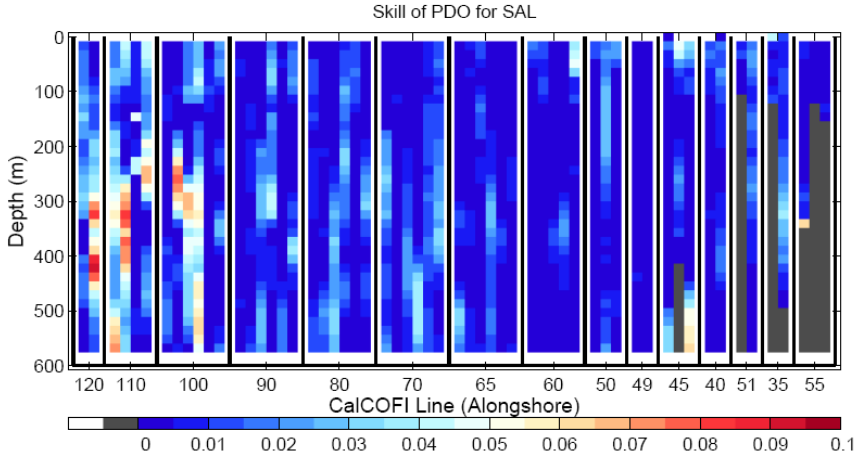
Temperature



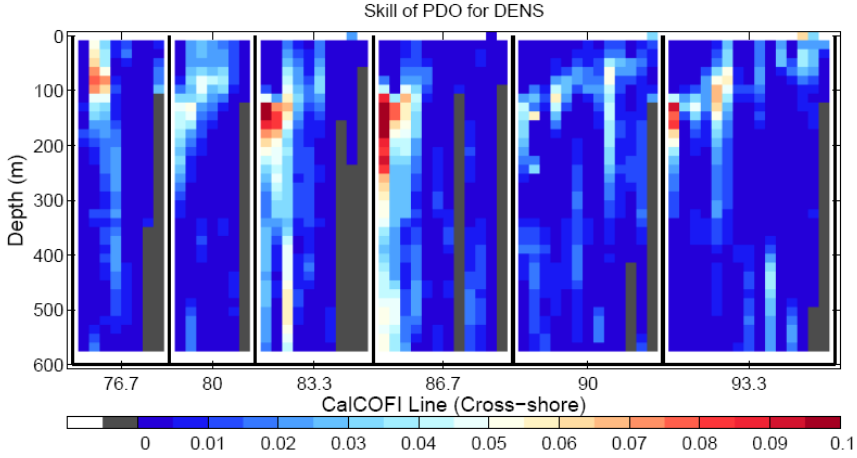


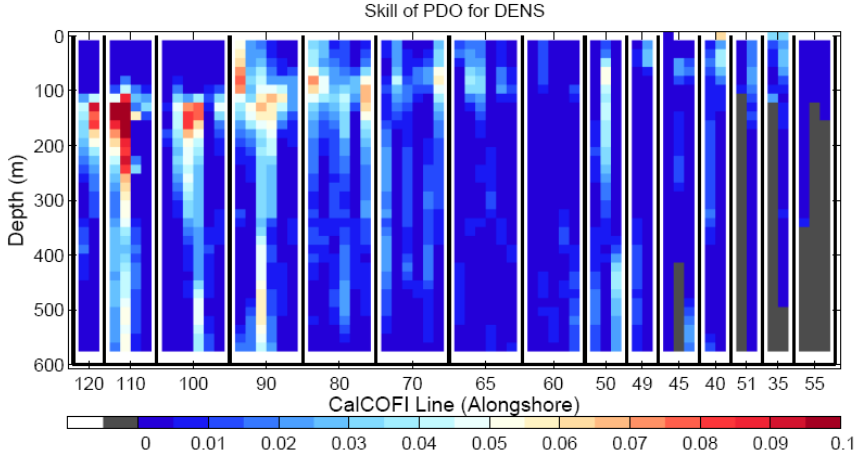
Salinity





Density

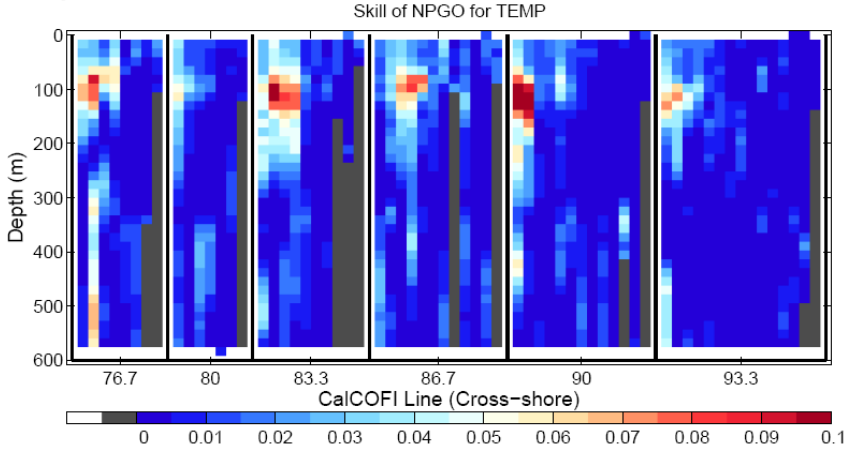


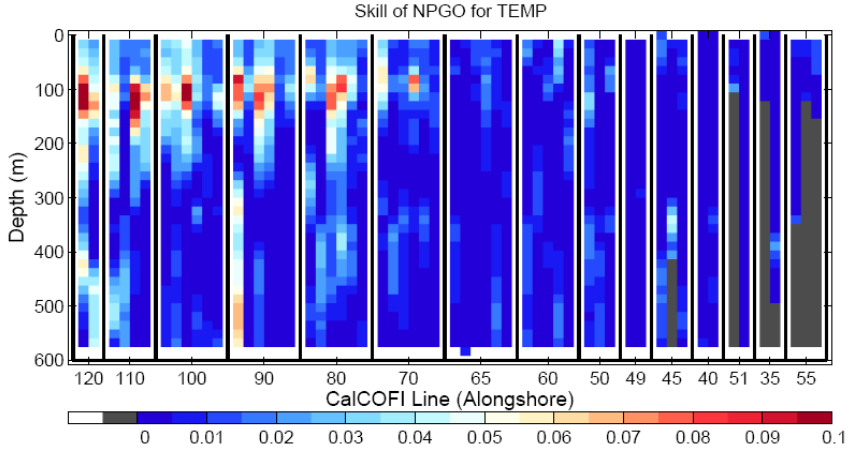


Individual skill for NPGO (CalCOFI)

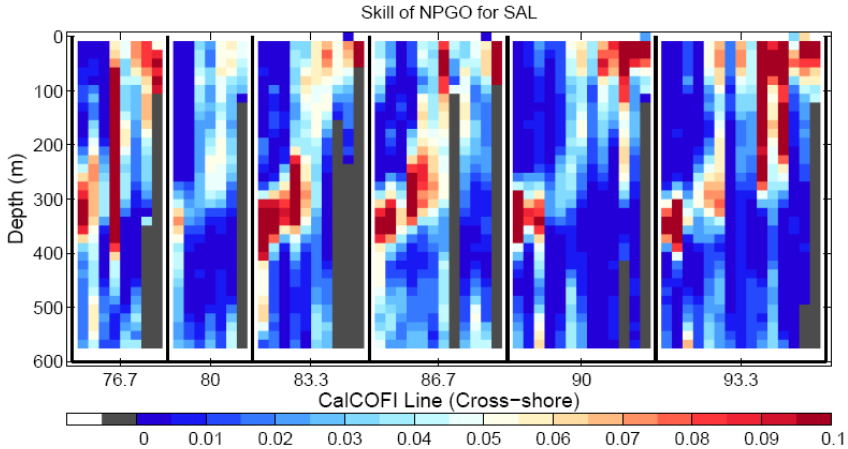
Upcoast Downcoast Offshore Near-shore

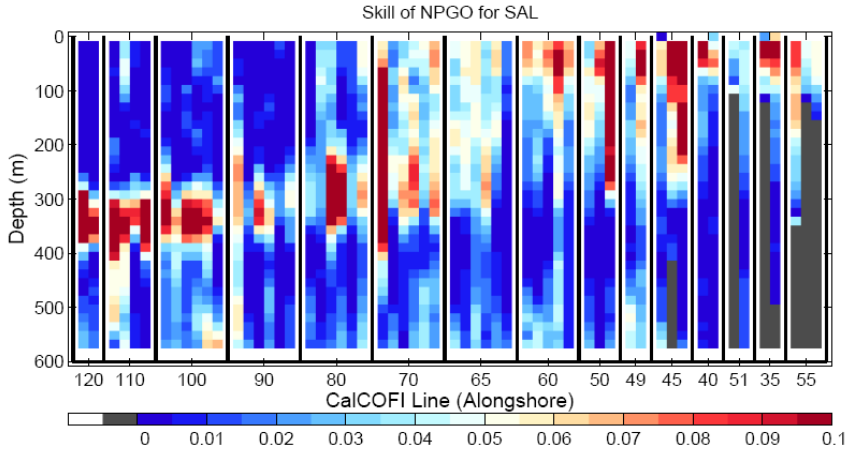
Temperature



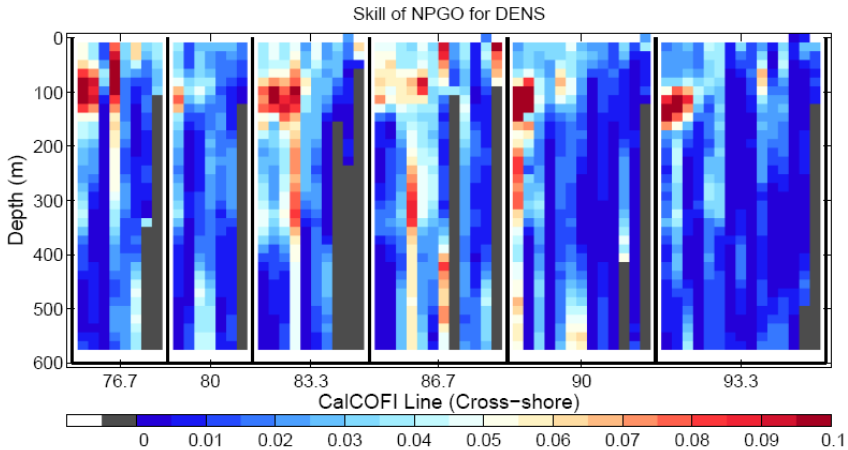


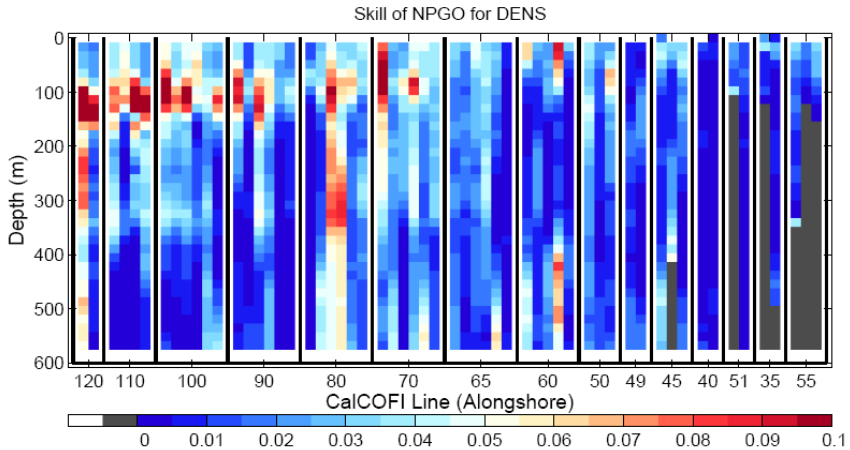
Salinity





Density

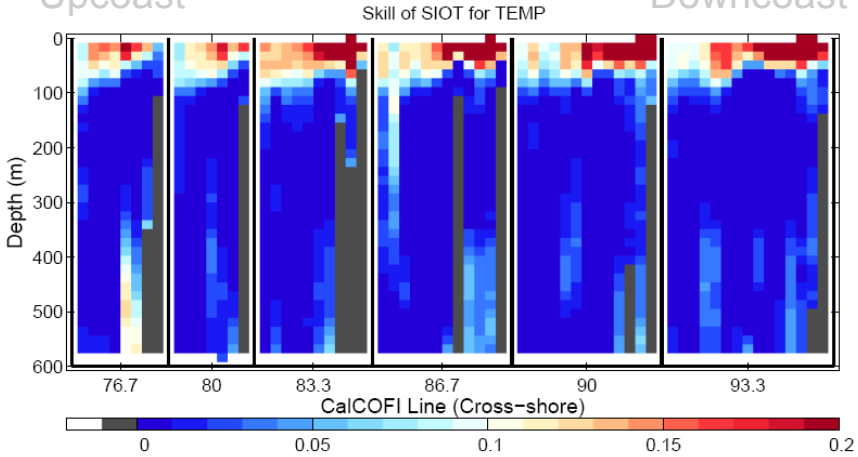


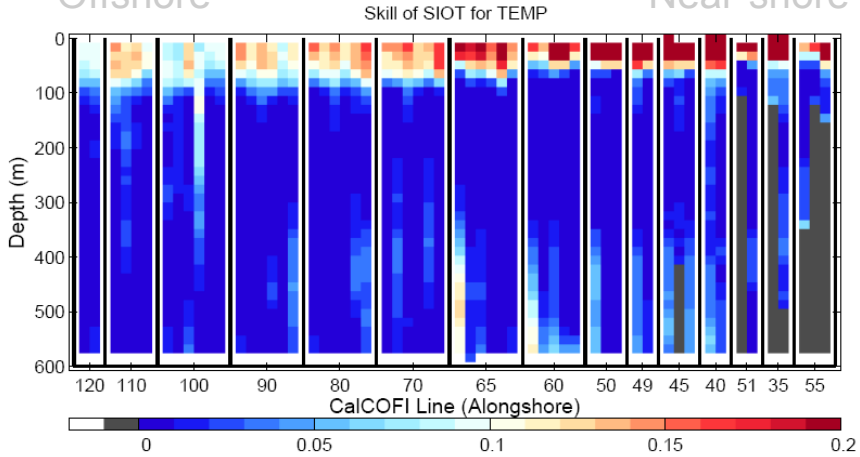


Individual skill for SIOT (CalCOFI)

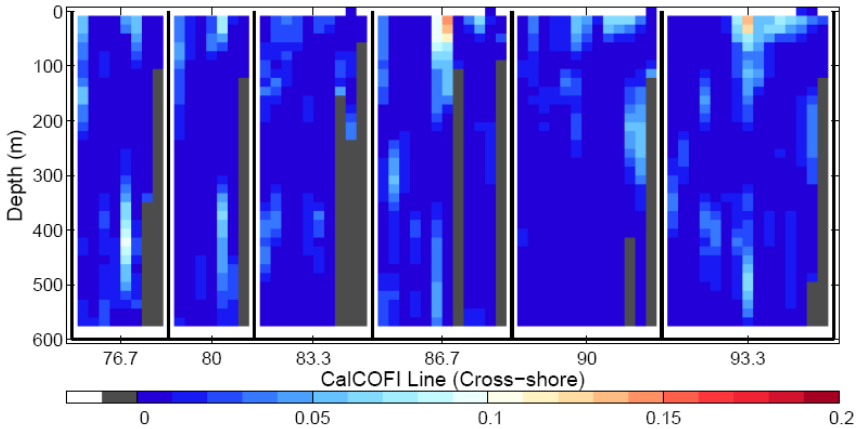
Upcoast Downcoast Offshore Near-shore

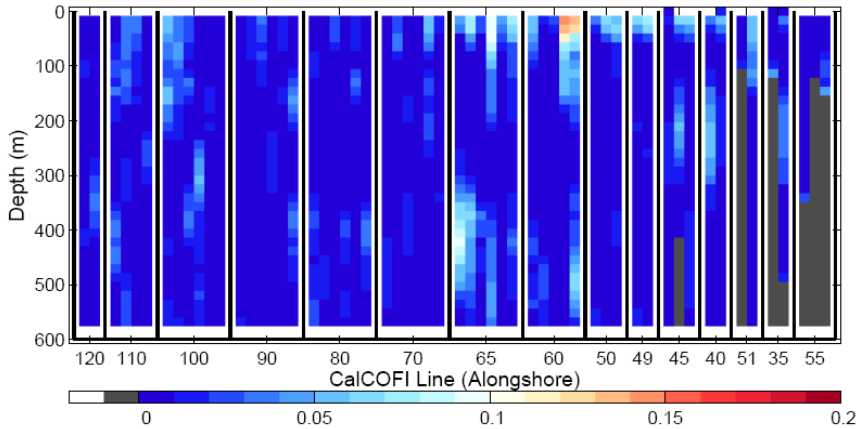
Temperature





Salinity





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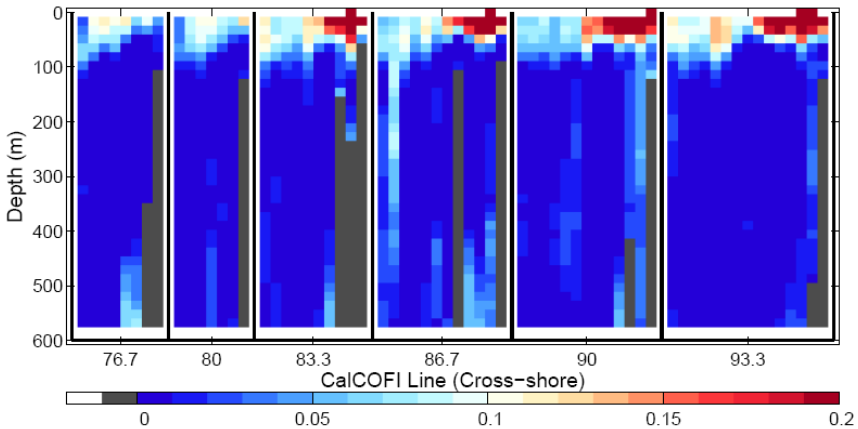
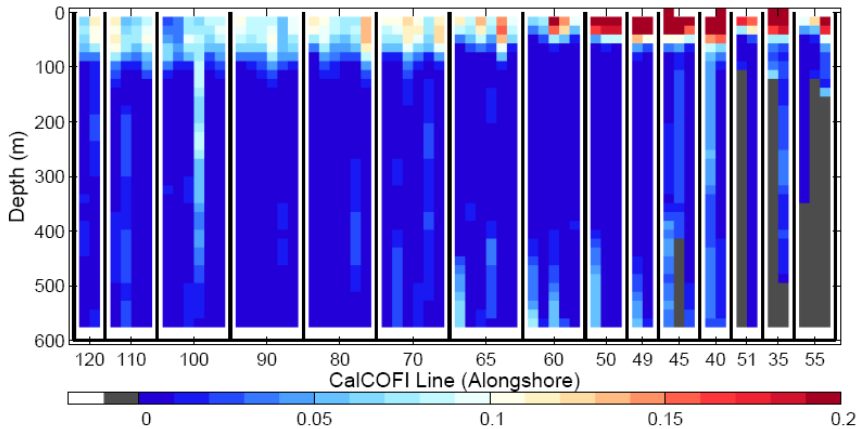
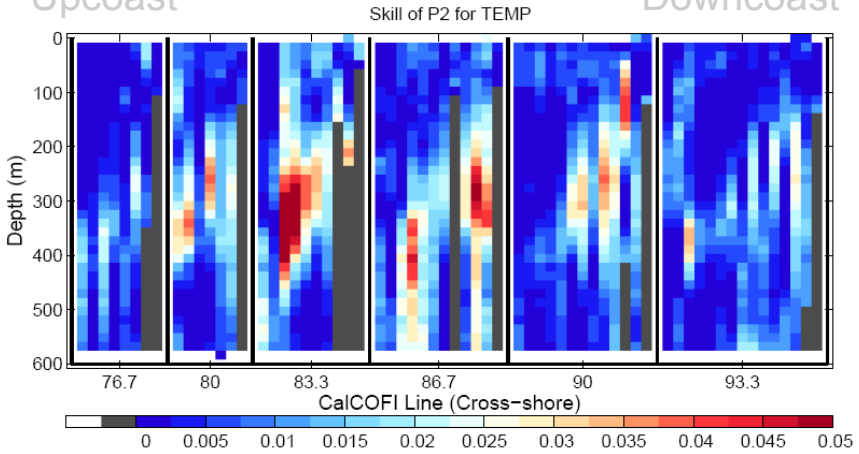


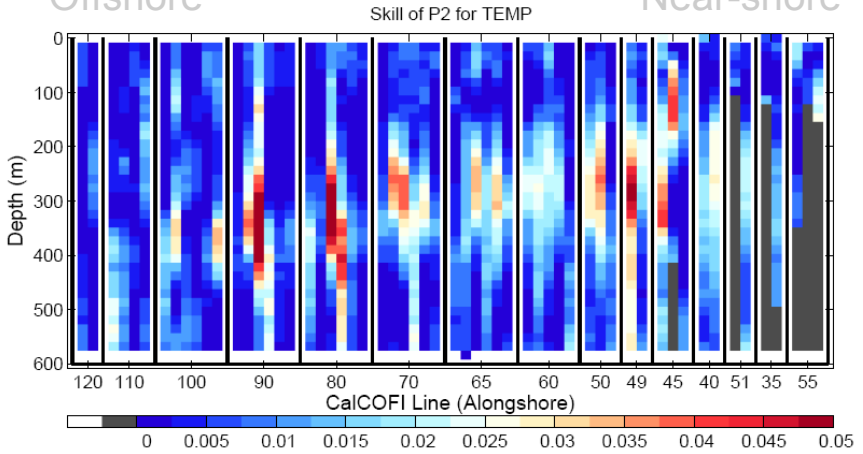


Individual skill of linear trend (CalCOFI)

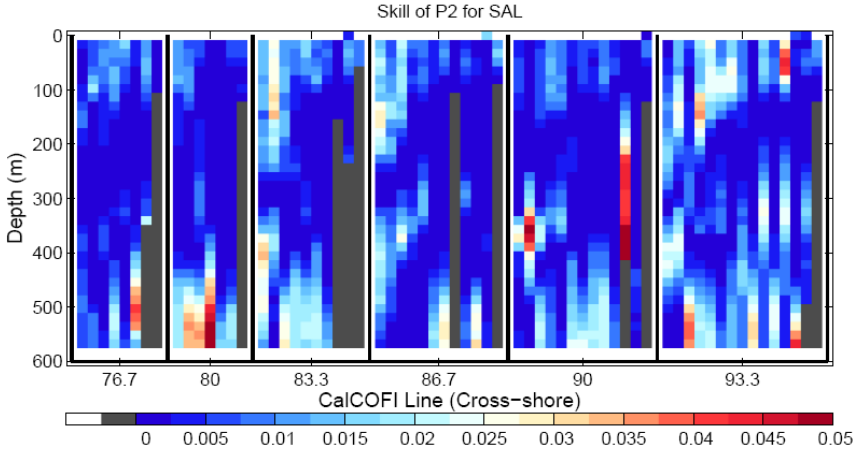
Upcoast Downcoast Offshore Near-shore

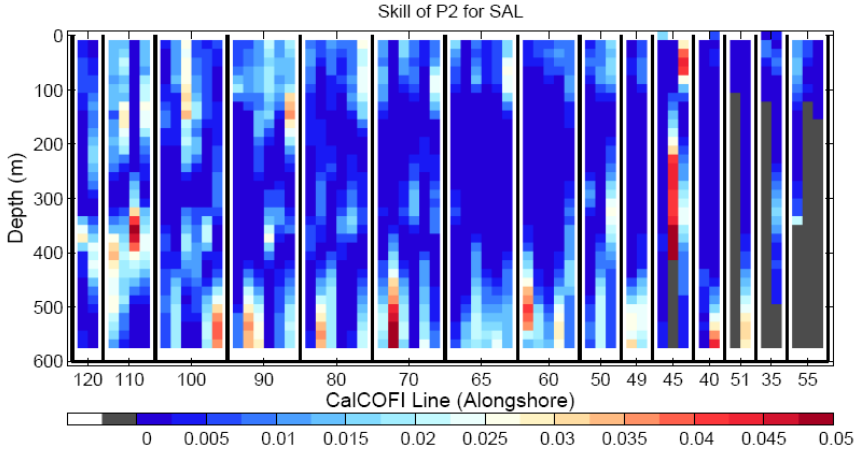
Temperature





Salinity





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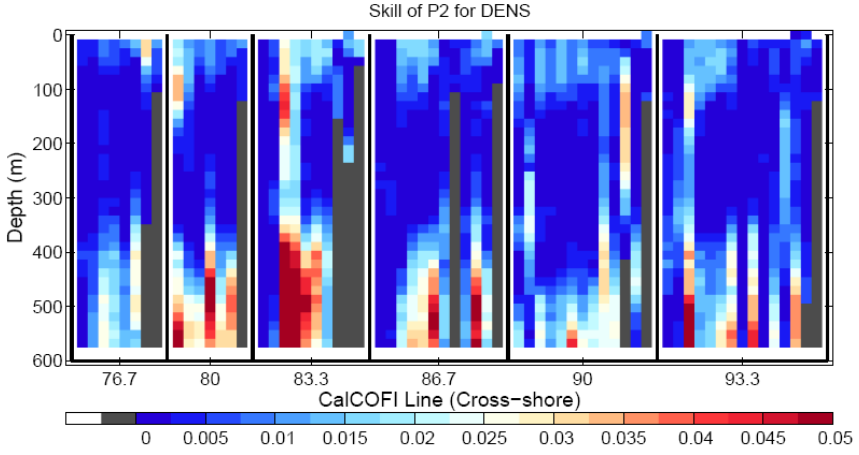
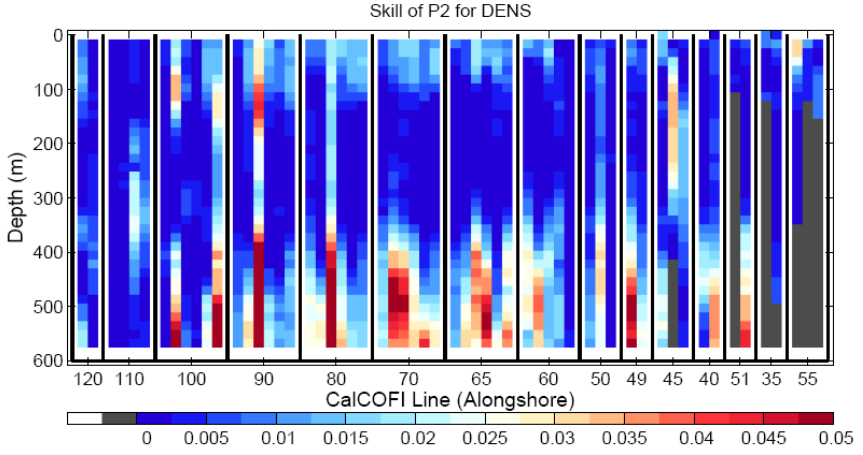


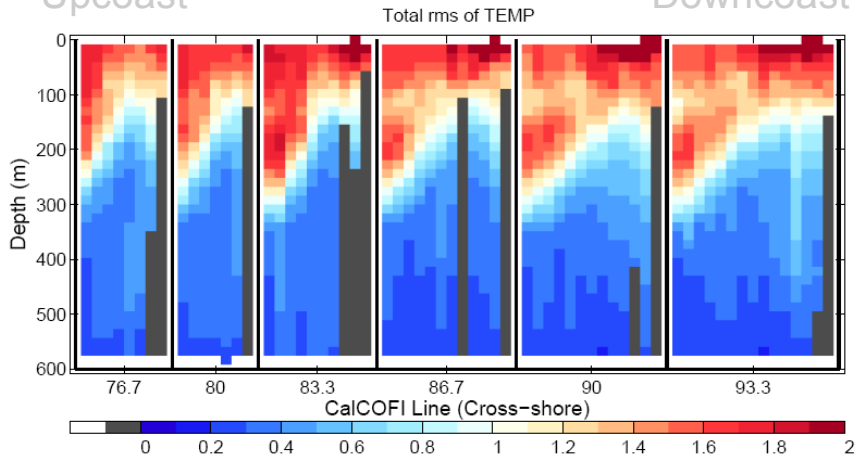


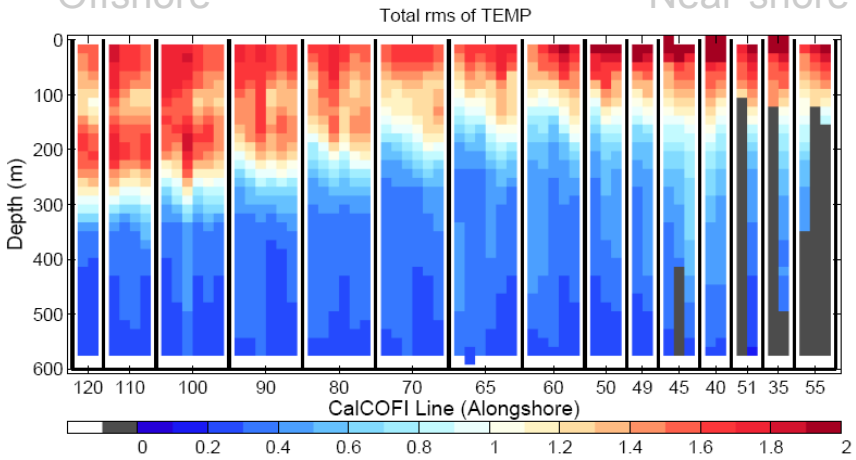
Total RMS (CalCOFI)

$$\sqrt{\langle d^2 \rangle}$$

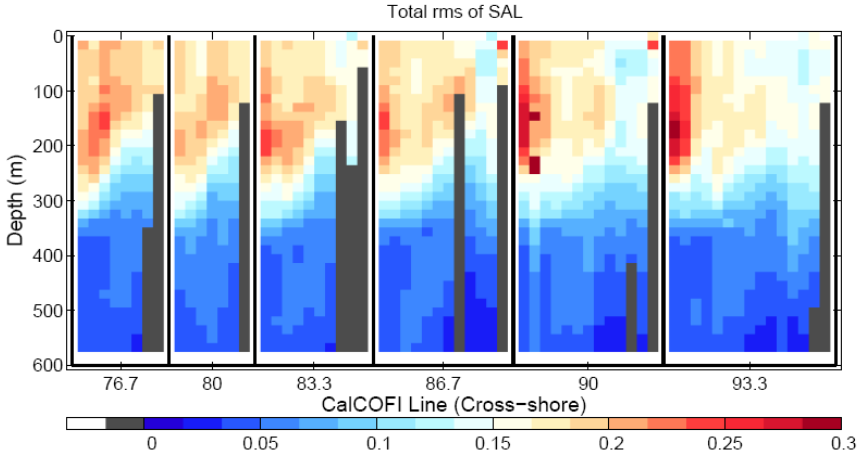
Upcoast Downcoast Offshore Near-shore

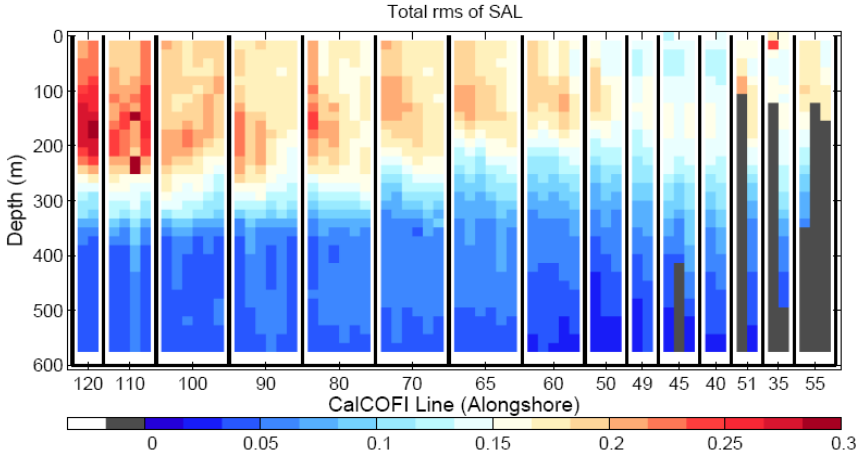
Temperature



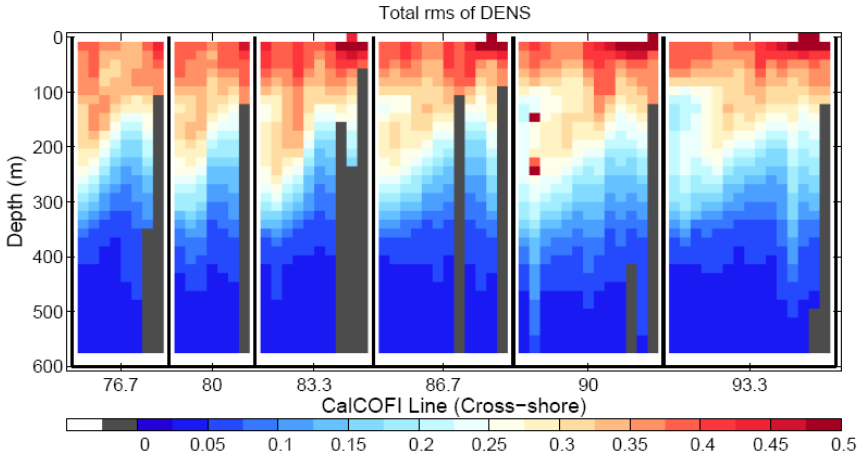


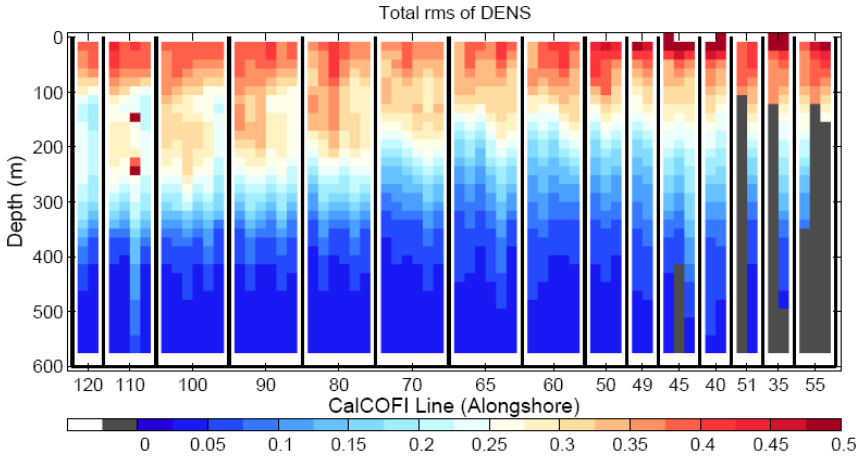
Salinity





Density





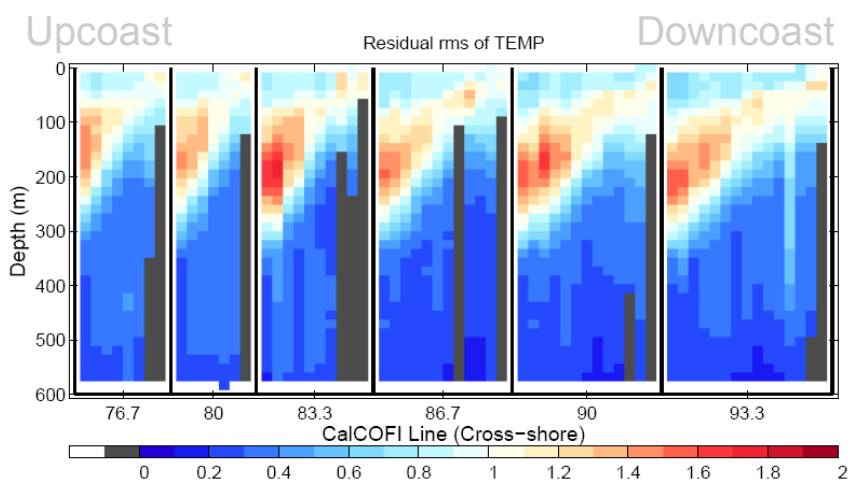
Residual RMS (CalCOFI)

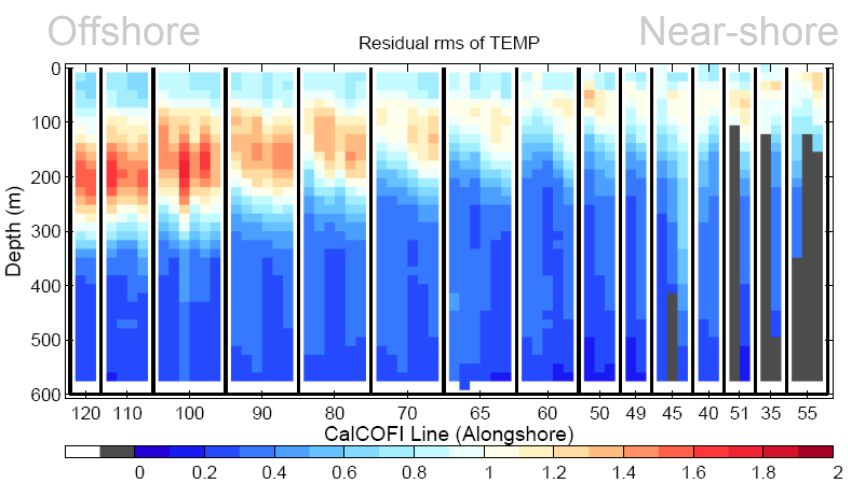
$$\sqrt{\left\langle \left(d - \hat{d} \right)^2 \right\rangle}$$

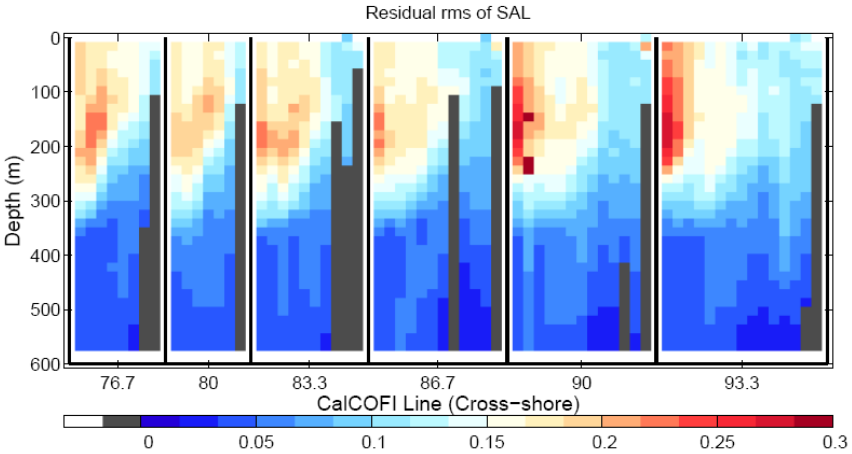
Temperature

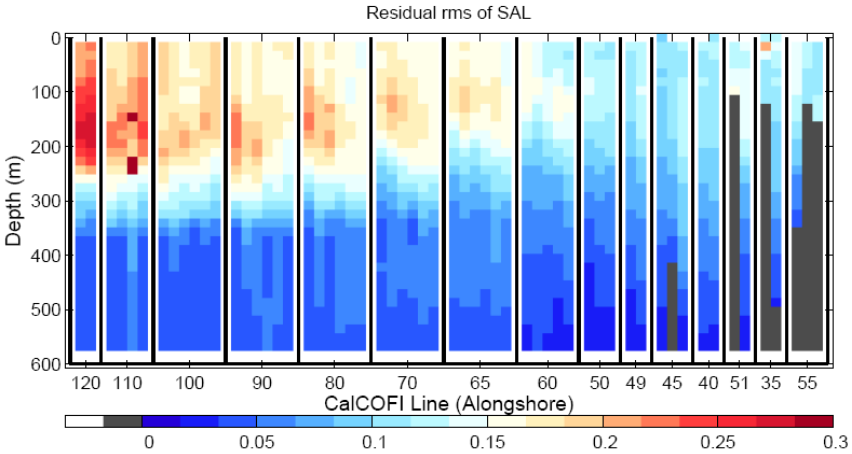
Salinity

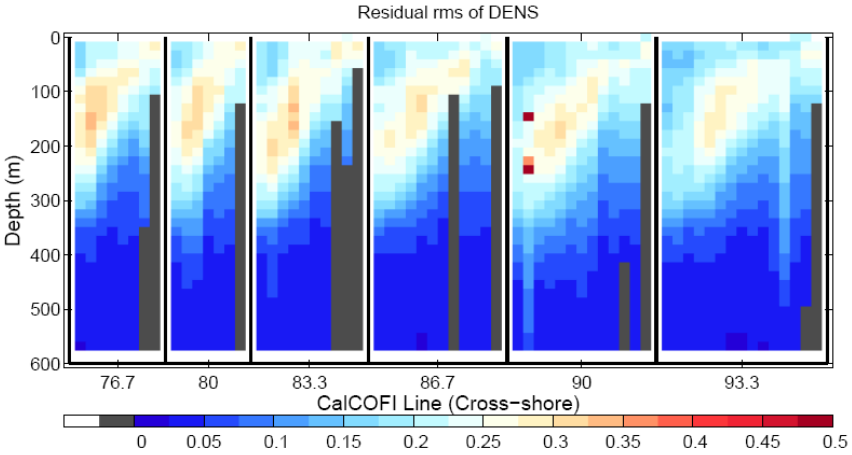
Density

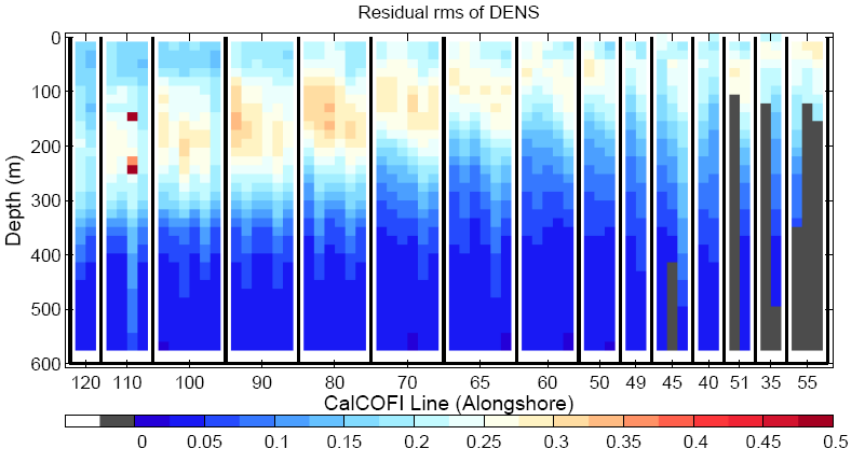




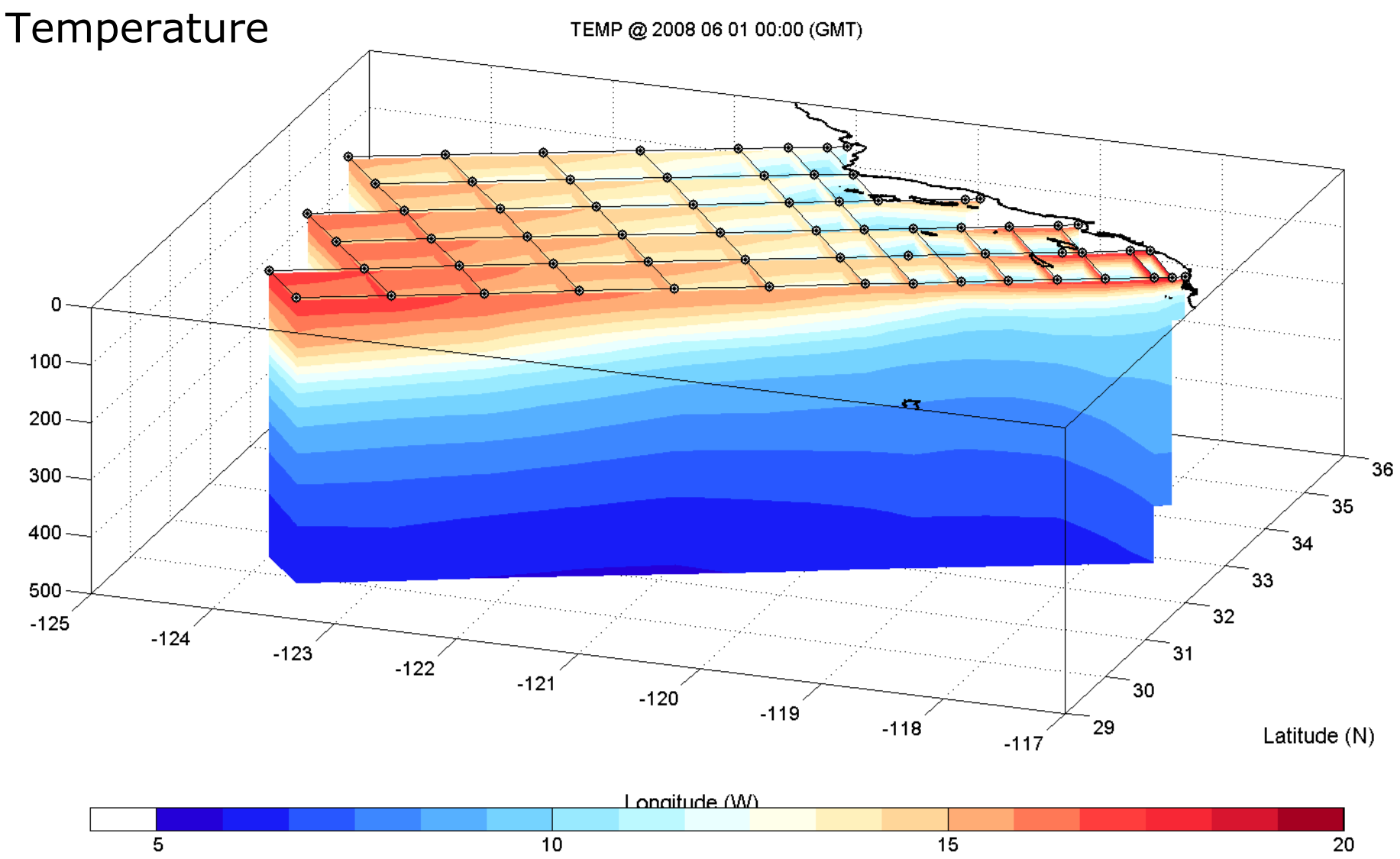








Reconstructed data



Summary and future work

- Partitioning of historical coastal observations into seasonality, climate indices-coherent components, and linear trend.
- Successive orthogonalization was implemented for coherent basis functions.
- CalCOFI T/S/sigma-t are fitted with SA1, SA2, ENSO, linear trend, PDO, NPGO, and SIOT.
- Climate signal detections with other data sets.