에너지인력양성사업

A description of ocean climatology around South Korea with regional and global climate indices

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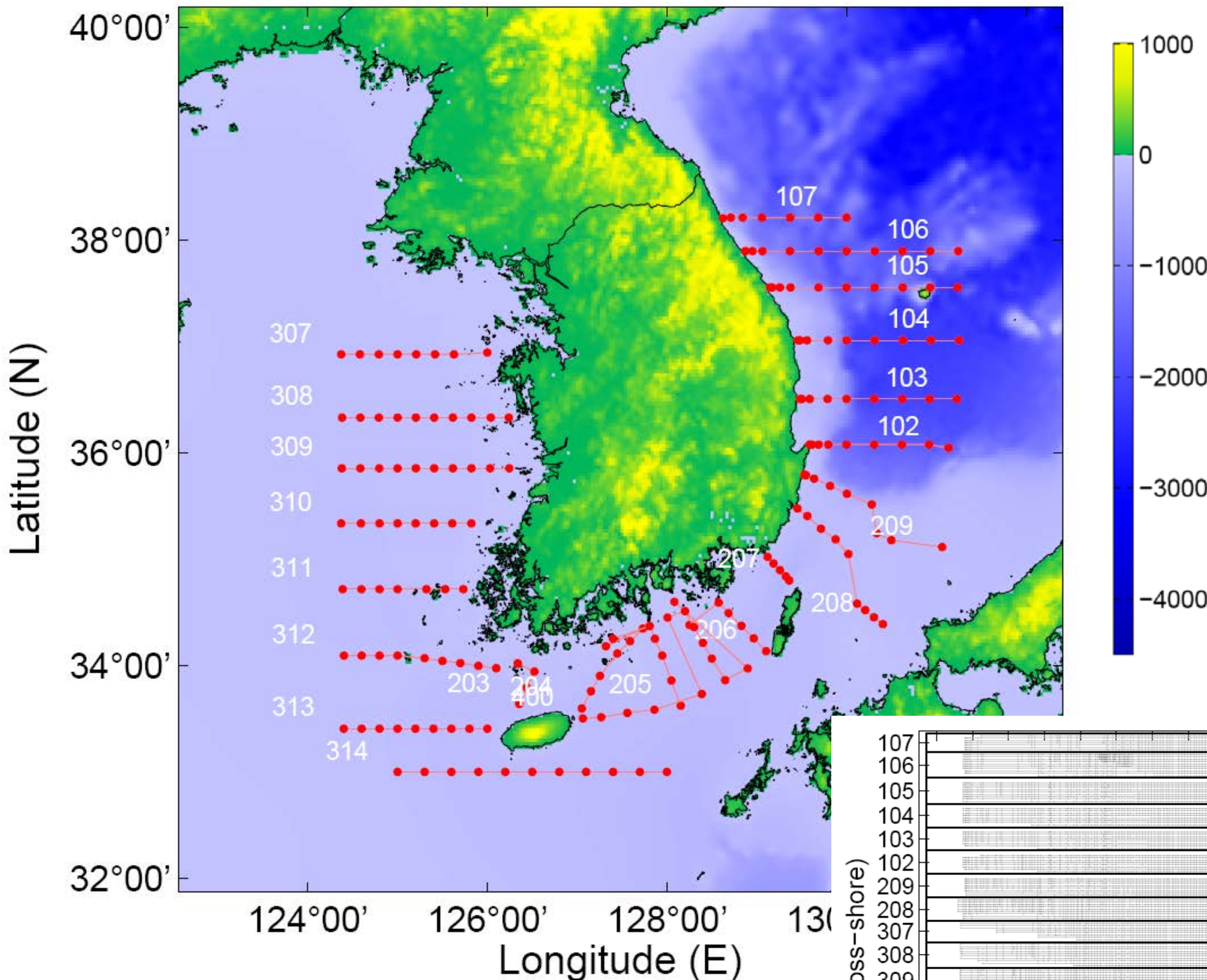
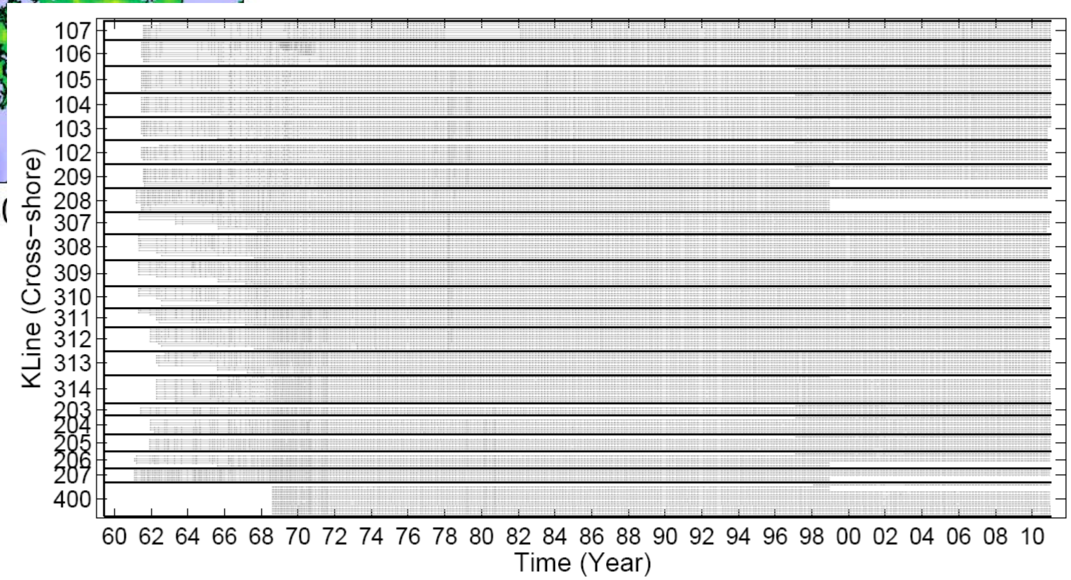
Study domain & motivation



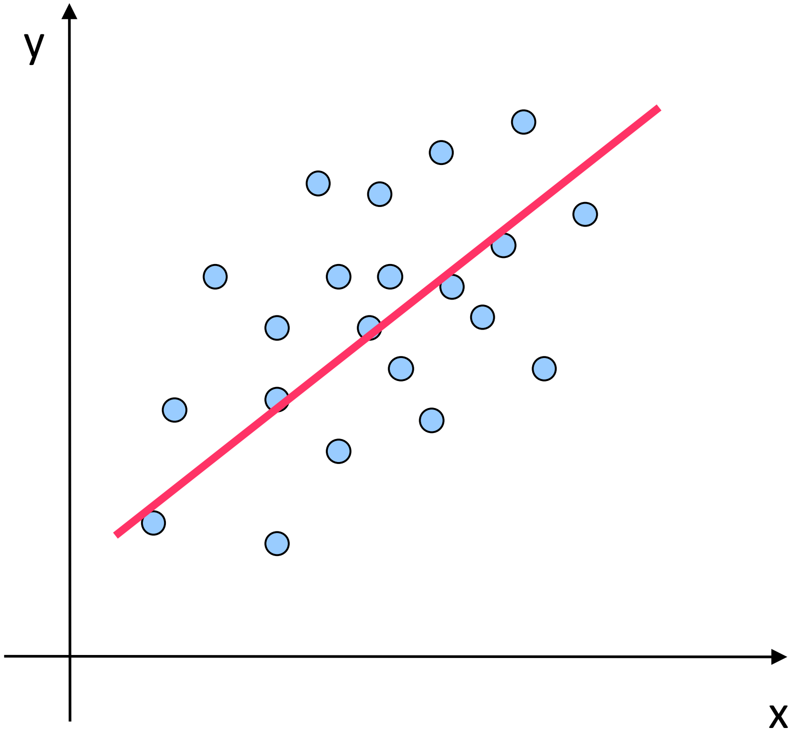
- Derivation of climatology of T and S?
- Variability of T & S
- Coherence between local and global climate indices?



Outline

- Regression analysis using climate indices
  - Regression analysis and basis functions
  - Successive orthogonalization of basis functions
- Cross-shore and along-shore transects of individual amplitudes on temperature (T) and salinity (S)
  - Long-term mean and root-mean-squares
  - Seasonal amplitudes and phases
  - Amplitudes of ENSO, PDO, EKI, and SHI
- Summary

Linear regression



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

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

d: Data (observations)
G: Basis functions
m: Regression coefficients

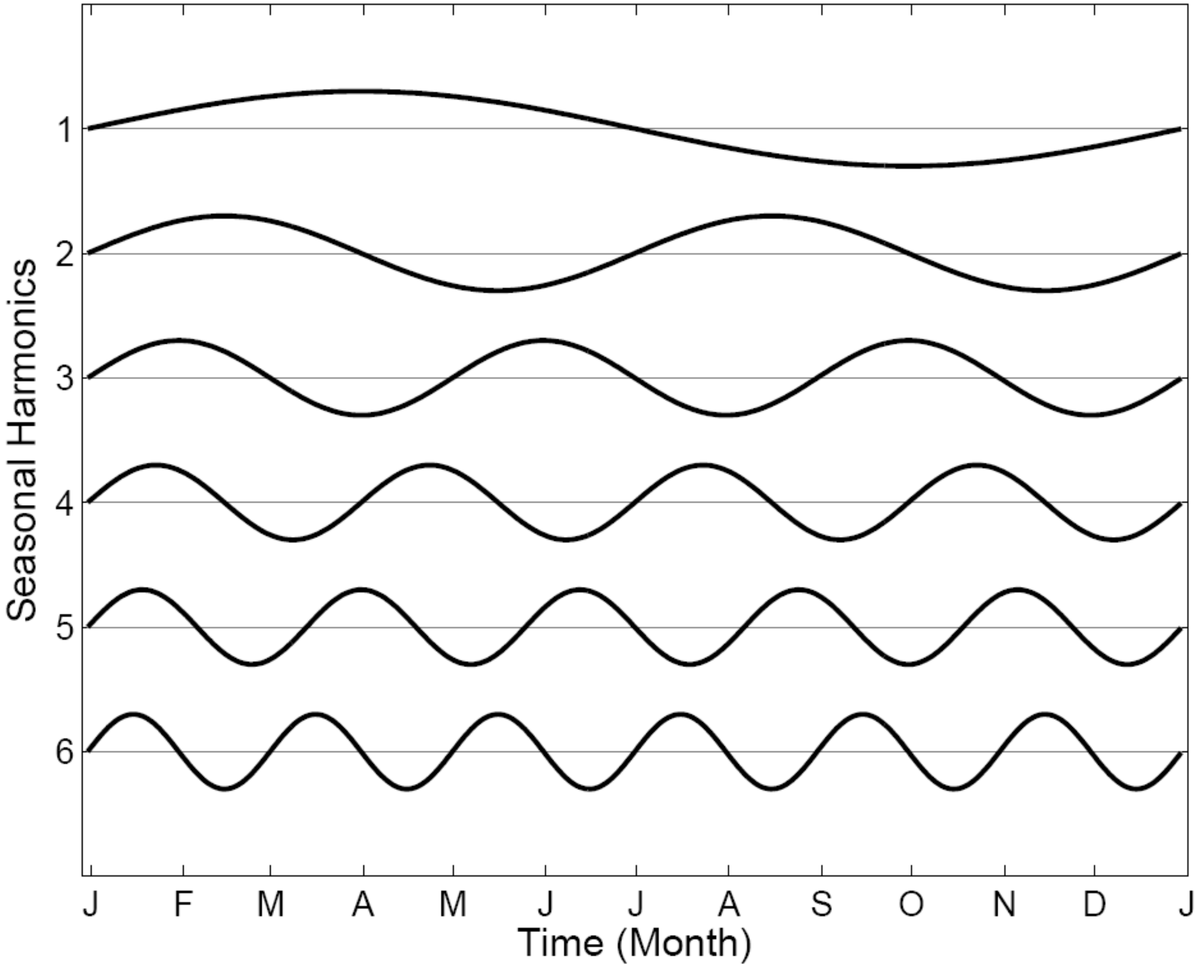
- Least-squares fit (LS fit) for unevenly sampled time series
- Climate indices as basis functions of LS fit

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

P: model covariance
R: error covariance

Regression basis functions

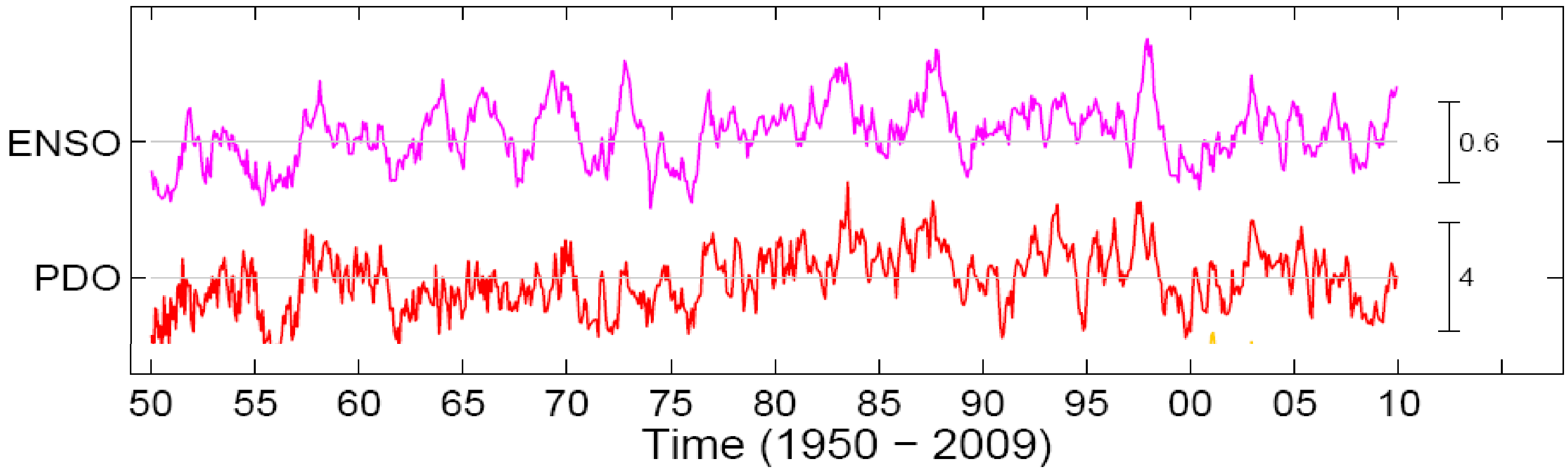
- SA1 – SA6 (6 harmonics of seasonality)



- T = 365.2425 days
- T/2 = 182.6718 days
- T/3 = 121.7812 days
- T/4 = 91.3559 days
- T/5 = 73.0687 days
- T/6 = 60.8906 days

Regression basis functions

- SA1 – SA6 (6 harmonics of seasonality)
- ENSO: El-Nino Southern Ocean Oscillation (1961-2010)
- PDO (Pacific Decadal Oscillation): 1st mode of North Pacific SST (1961-2010)
- EKI (Entry of Kuroshio Index): 1st mode of east China Sea SST (1961-2010)
- SHI (Siberian High Index): 1st mode of NCEP reanalysis atmospheric pressure (1961-2010)
- Linear trend



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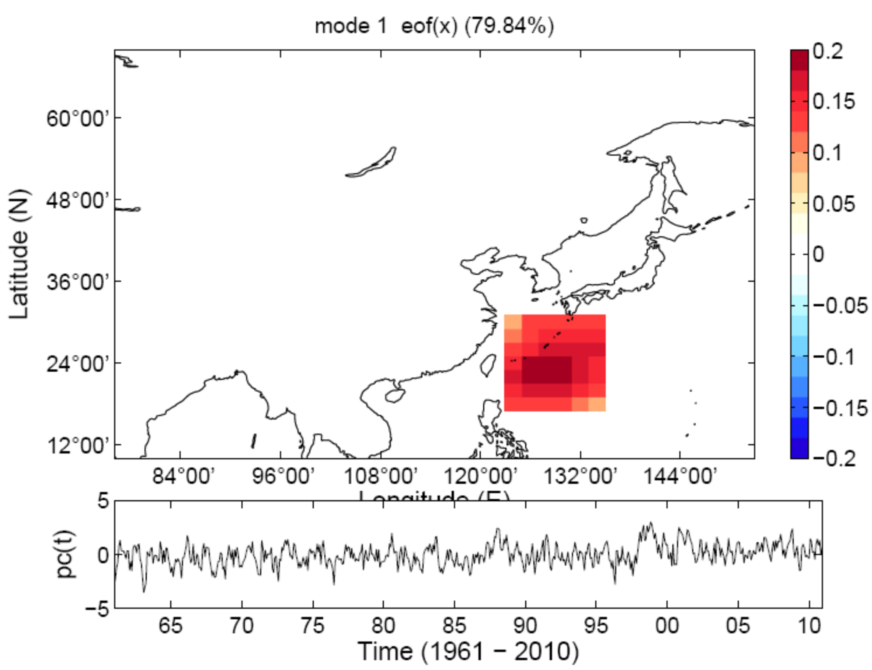
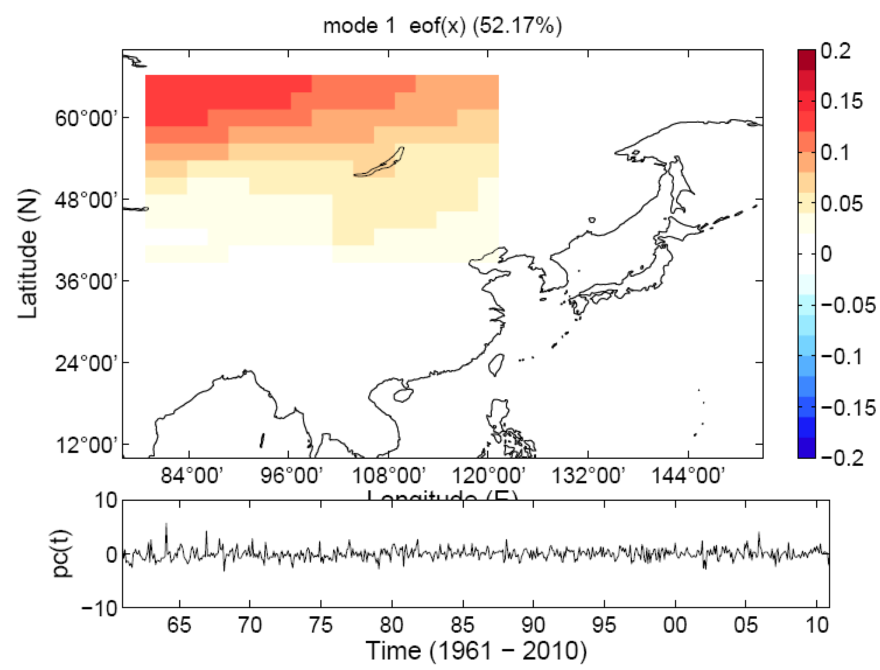




Data decomposition

- Decomposition of time series

$$d(t) = d_S(t) + d_C(t) + d_F(t) + d_R(t),$$

  - Seasonality with six harmonics (SA1, SA2, …, and SA6).
  - Climate indices (ENSO, PDO, EKI, and SHI).
  - Polynomials (mean and linear trend)
- Successive orthogonalization
  - As climate indicate are coherent each other, there is ambiguity in partitioning 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 → EKI → SHI

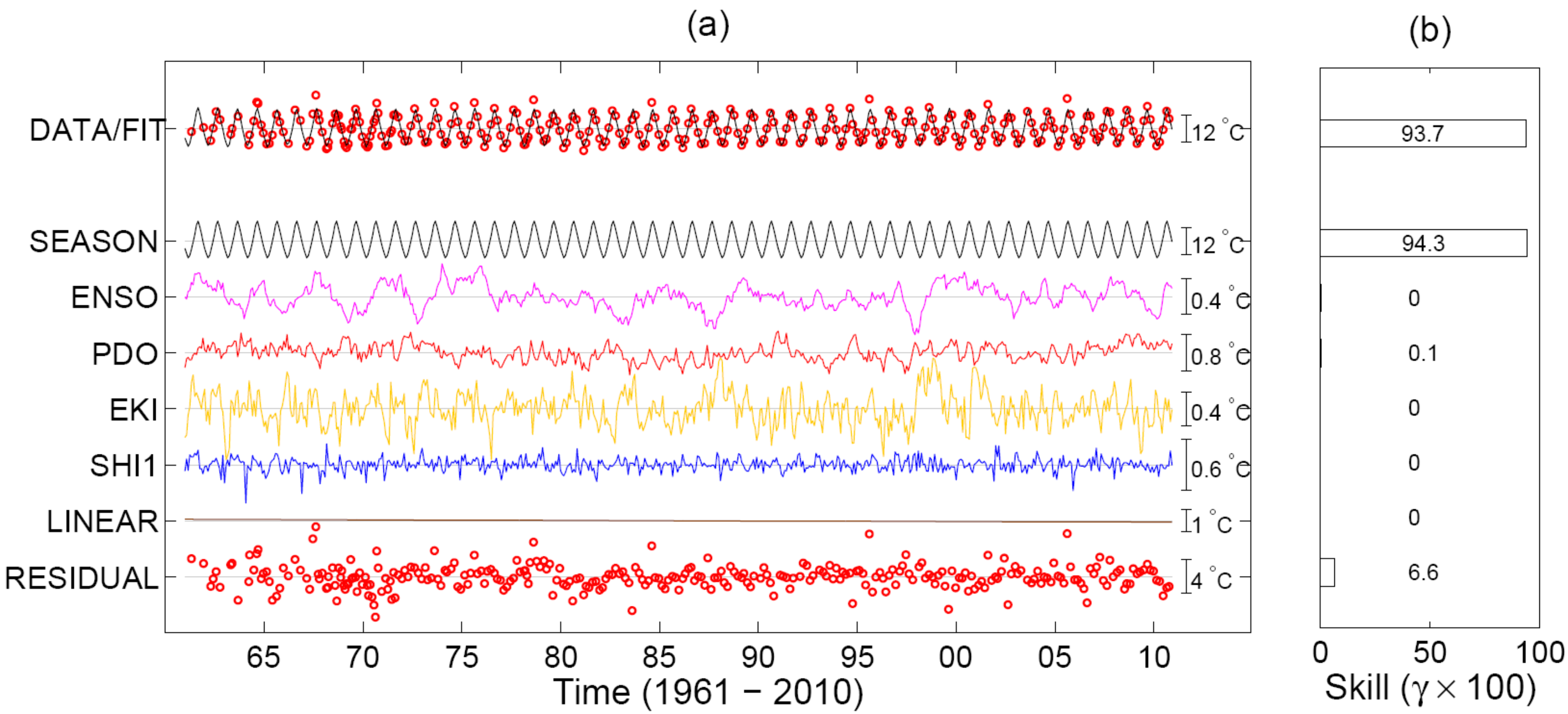
Correlation before orthogonalization

	ENSO	PDO	E1
ENSO			
PDO	0.53		
E1	0.03	-0.09	
H1	0.08	0.17	-0.01

Correlation after orthogonalization

	ENSO	PDO	E1
ENSO			
PDO	-0.01		
E1	-0.02	-0.00	
H1	-0.00	0.00	-0.00

An example of regression for SST in EJS

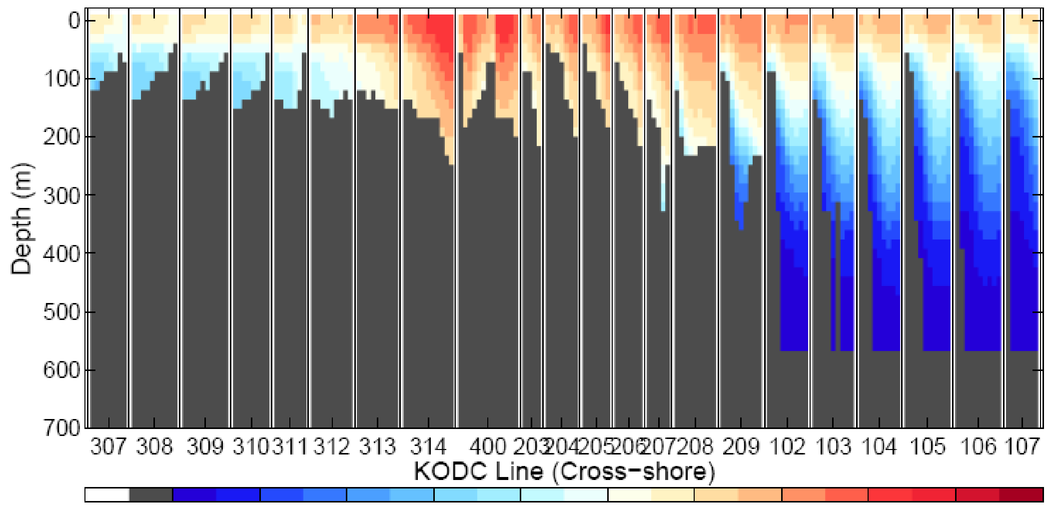


Total skill: $$\kappa^2 = 1 - \frac{\langle (d - \hat{d})^2 \rangle}{\langle d^2 \rangle}$$

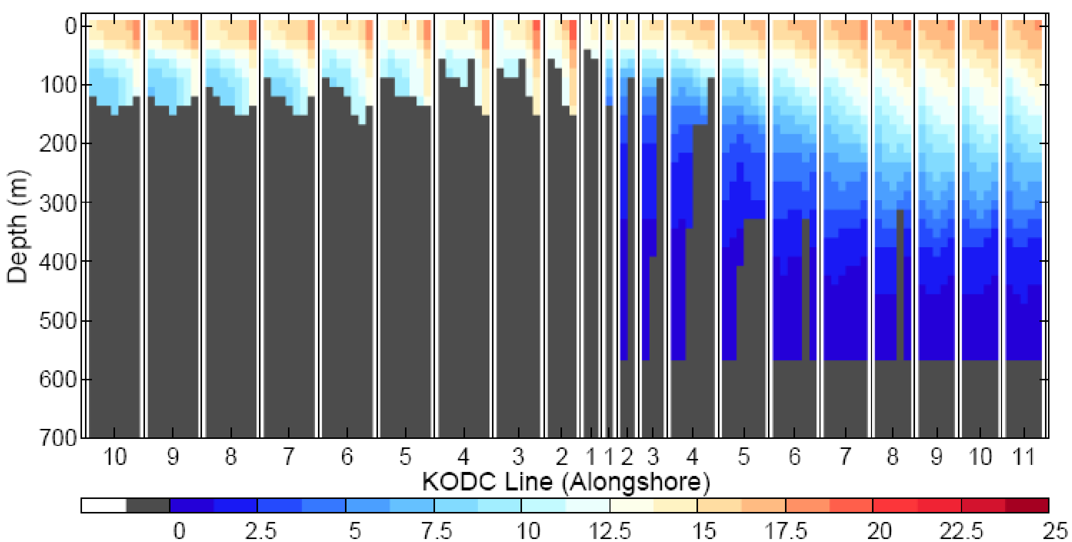
Individual skill: $$\kappa_l^2 = 1 - \frac{\langle (d - d_l)^2 \rangle}{\langle d^2 \rangle}$$

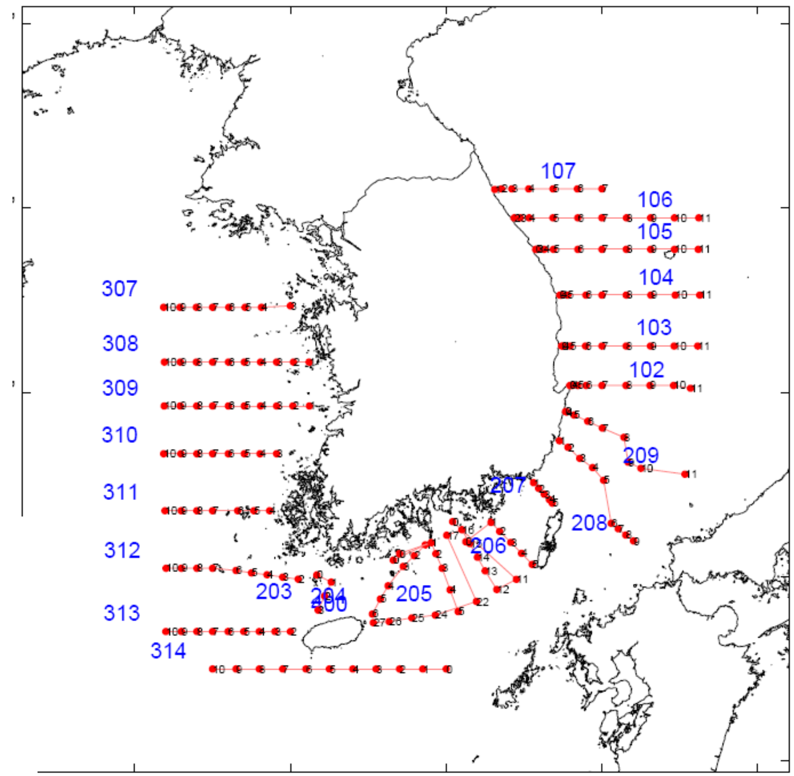
The way to look at figures

West South (Cross-shore) East



West (Along-shore) East





The way to look at figures

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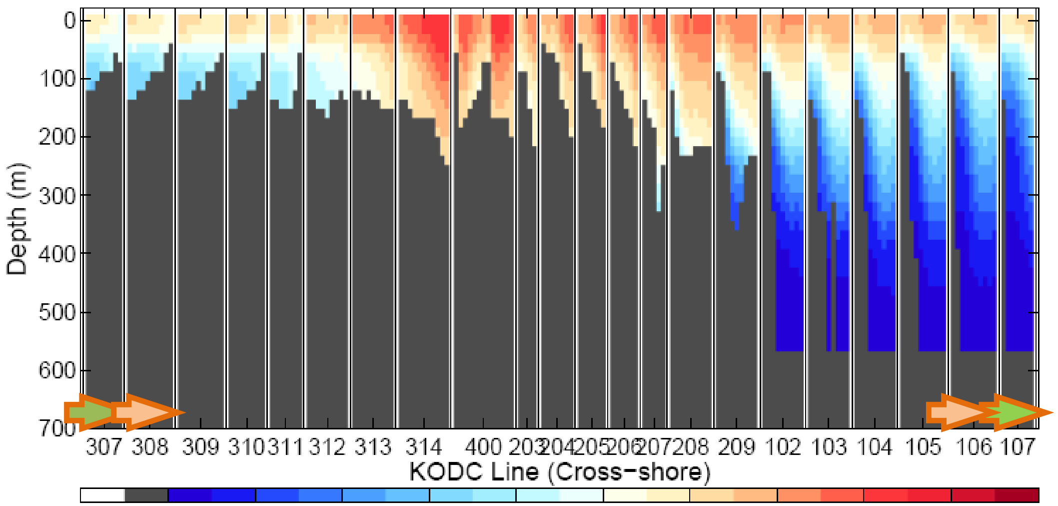
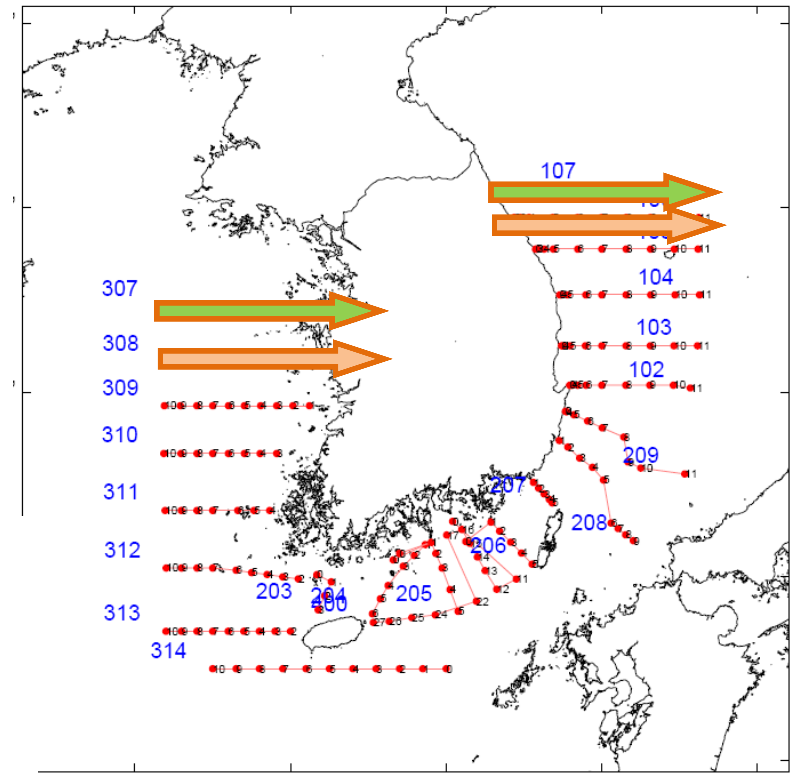
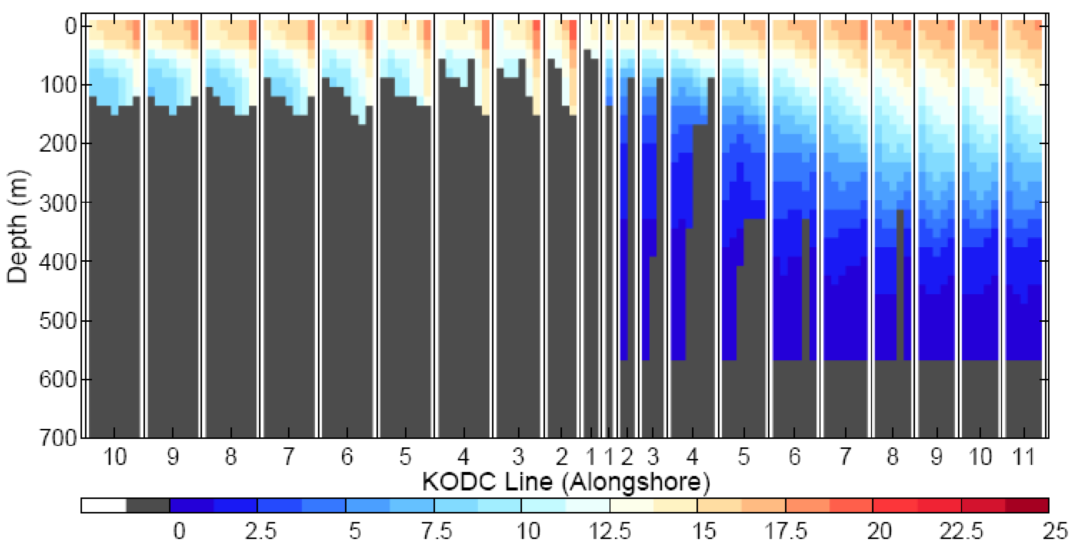


To show W, S, and E



West (Along-shore) East



The way to look at figures

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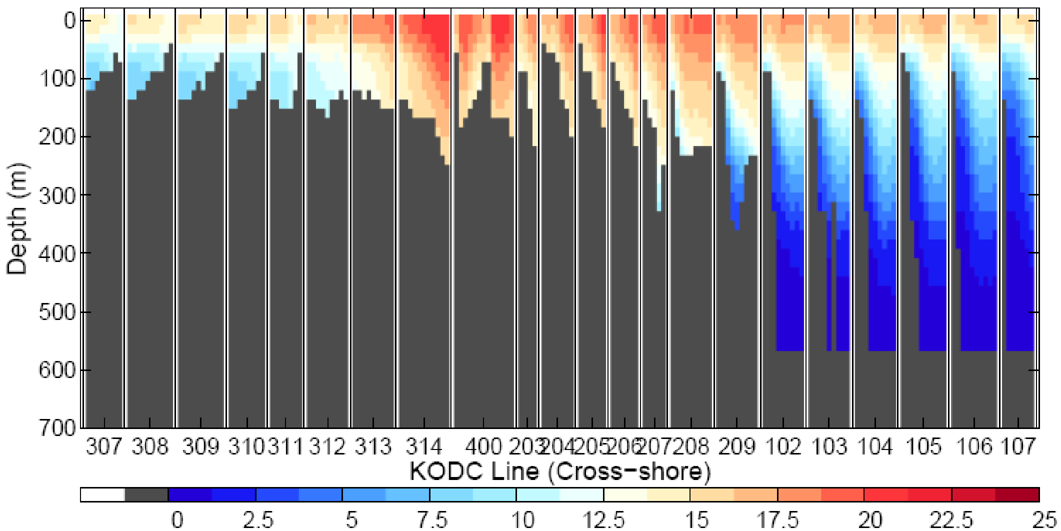
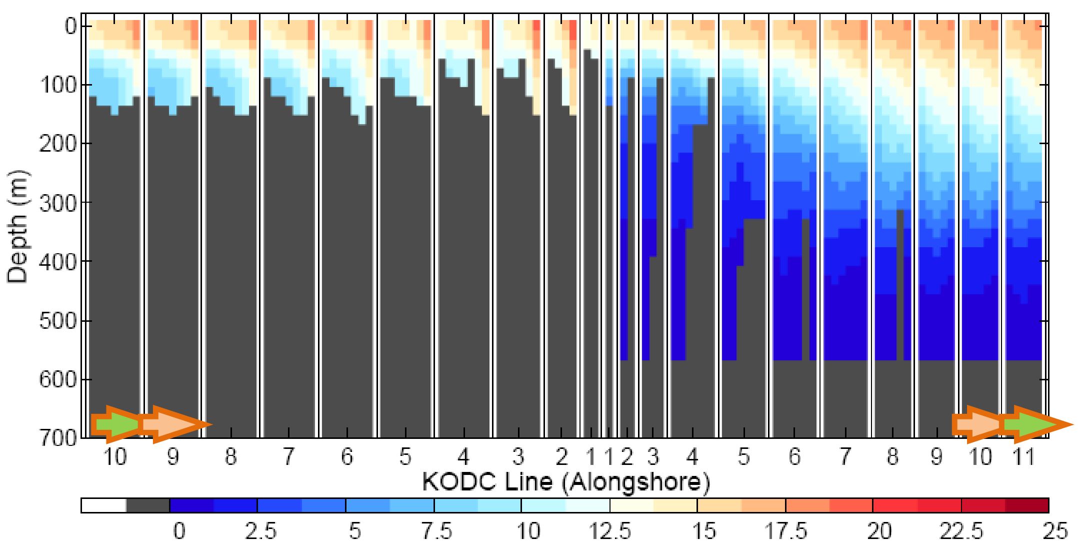
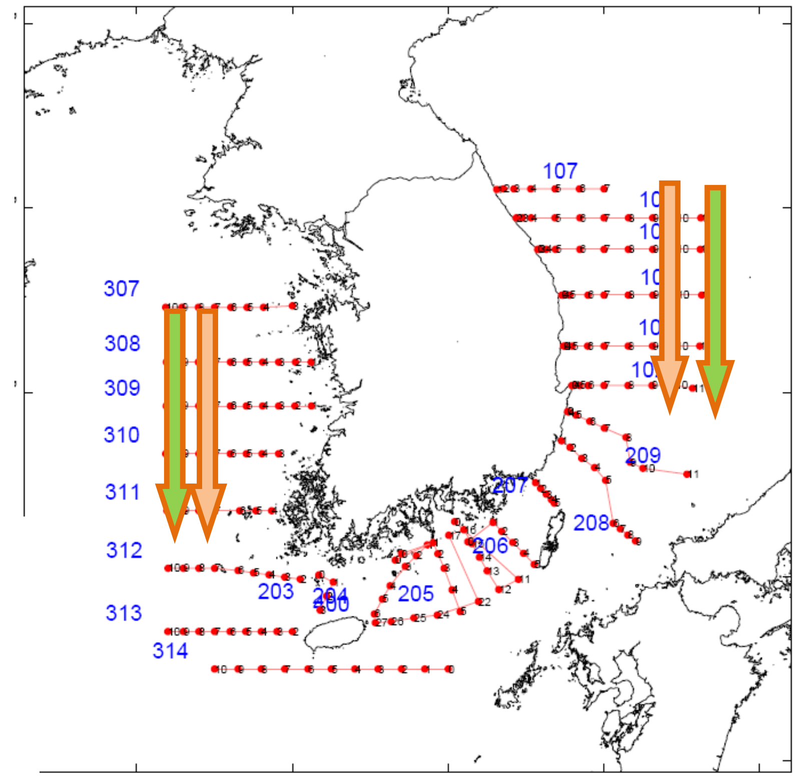


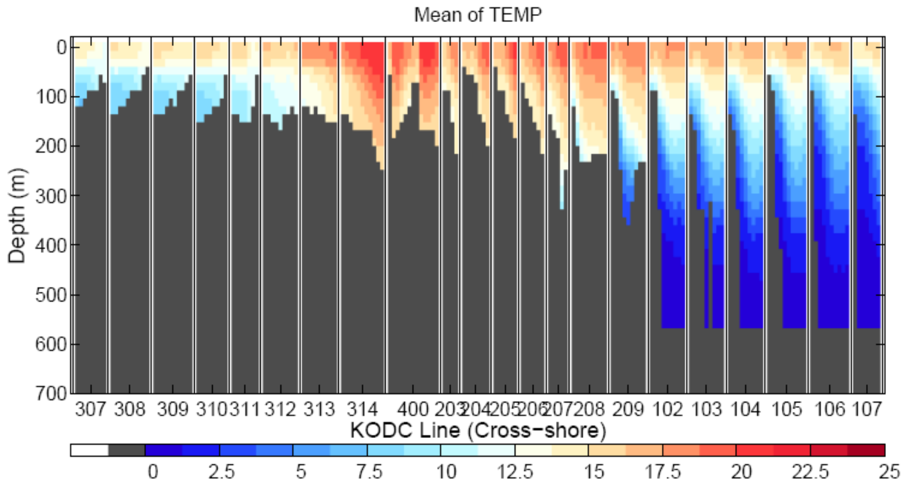
West (Along-shore) East

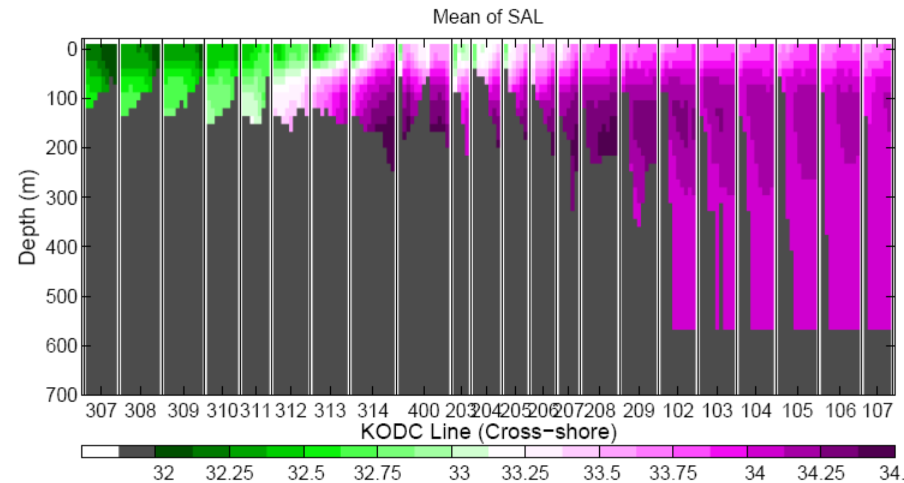


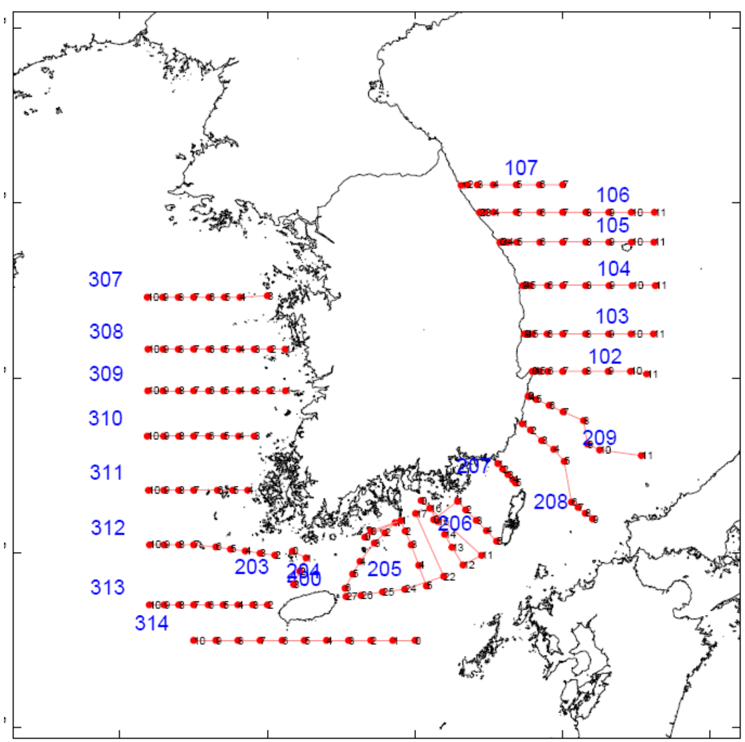


To show cross-shore structure in W & E

Long-term mean of T and S

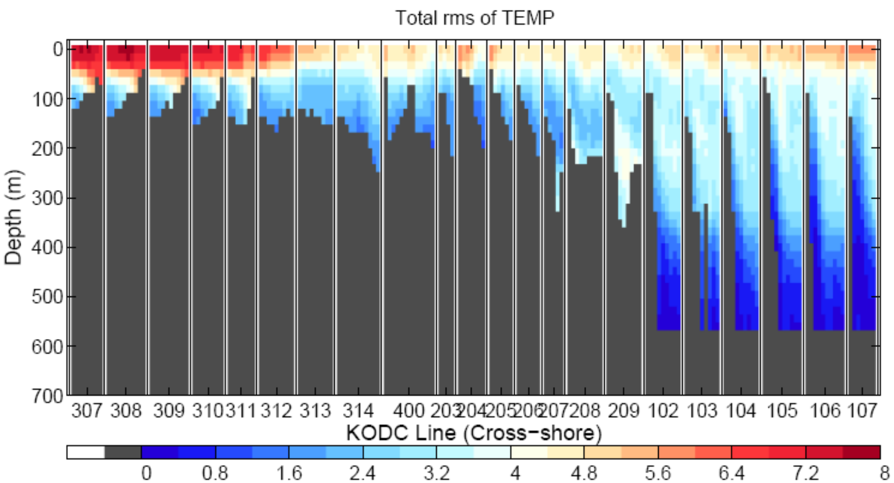


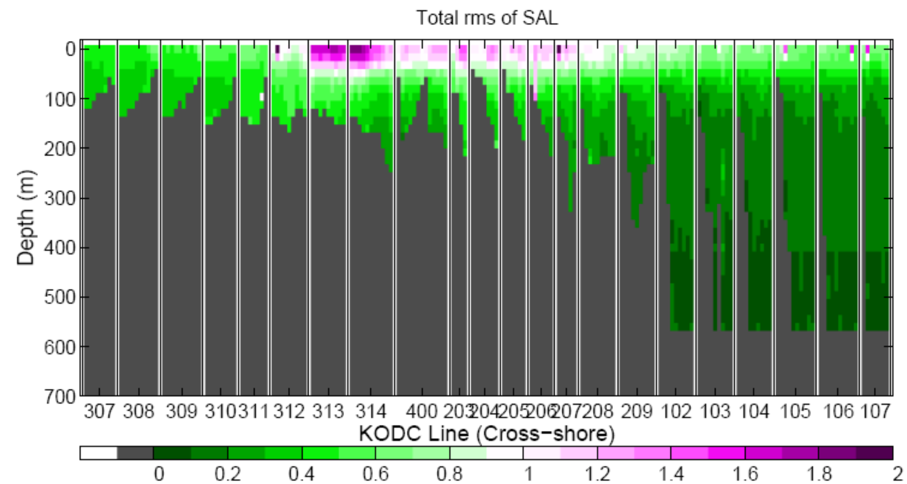


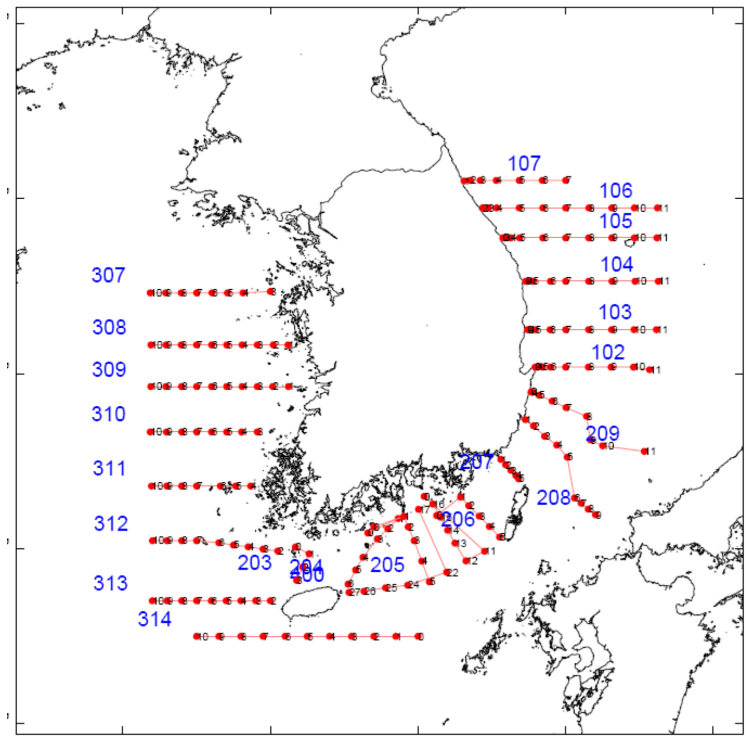


- Upward sloping of thermoclines toward to the coast (E): northward geostrophic currents.
- Slightly downward (or flat) slope below 400 m: southward undercurrents (possibly)
- Southward tilt of thermocline (E & W): eastward geostrophic currents.
- Salinity maximum depth: 100 to 250 m, tilt along with thermoclines.

Standard deviation (std) of T and S

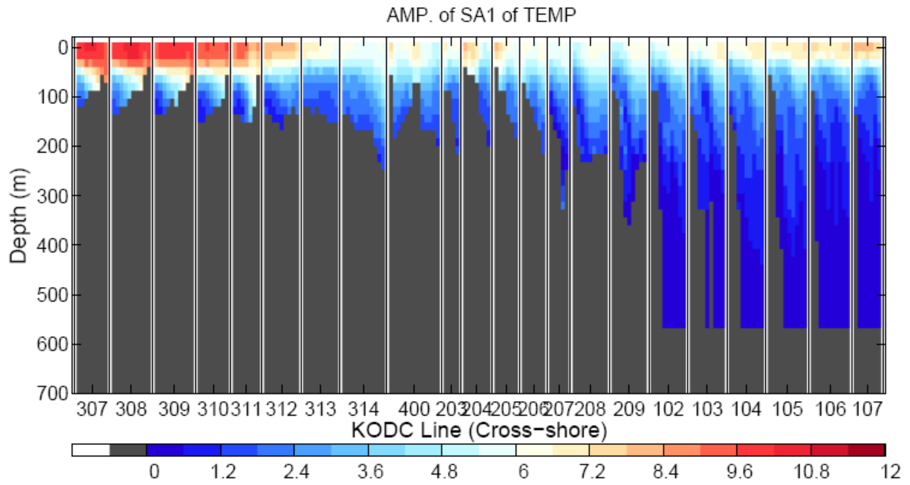


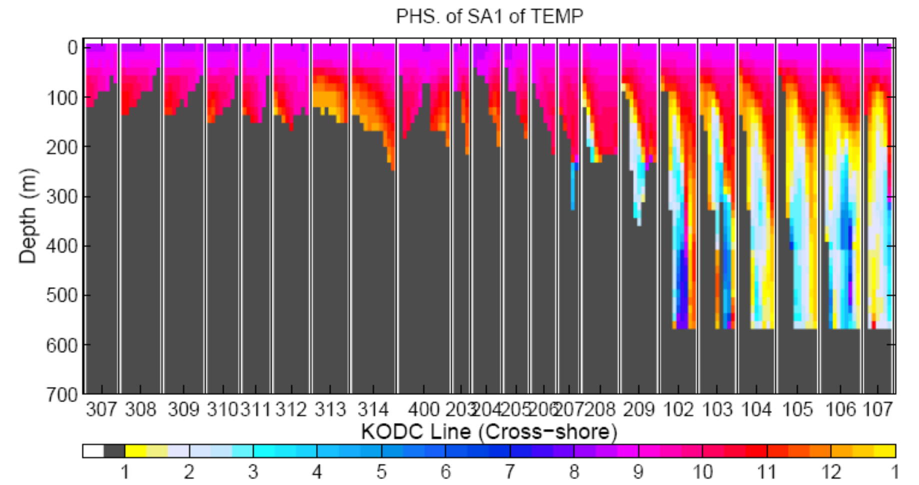


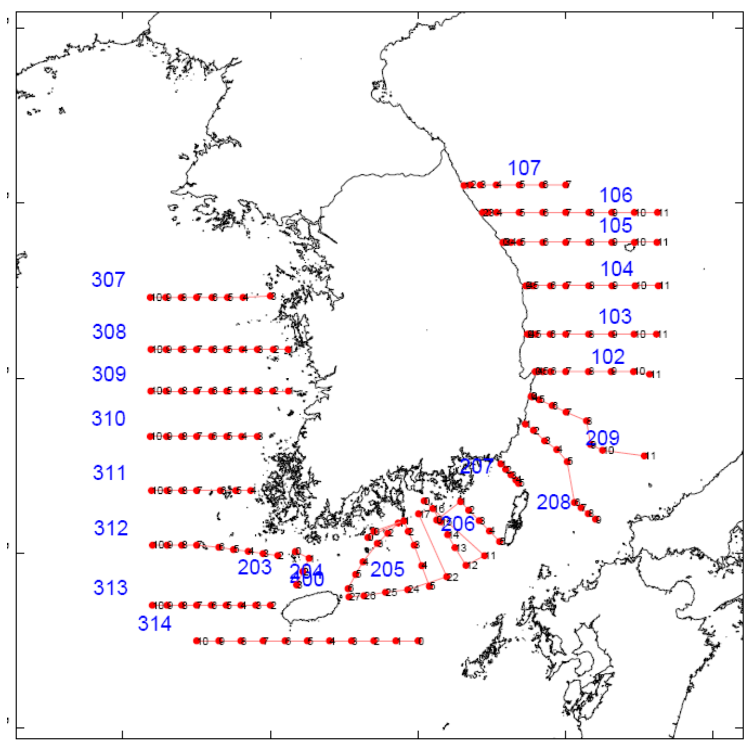


- T has the highest rms in West and S in South.
- Penetration depth of T and S (E)

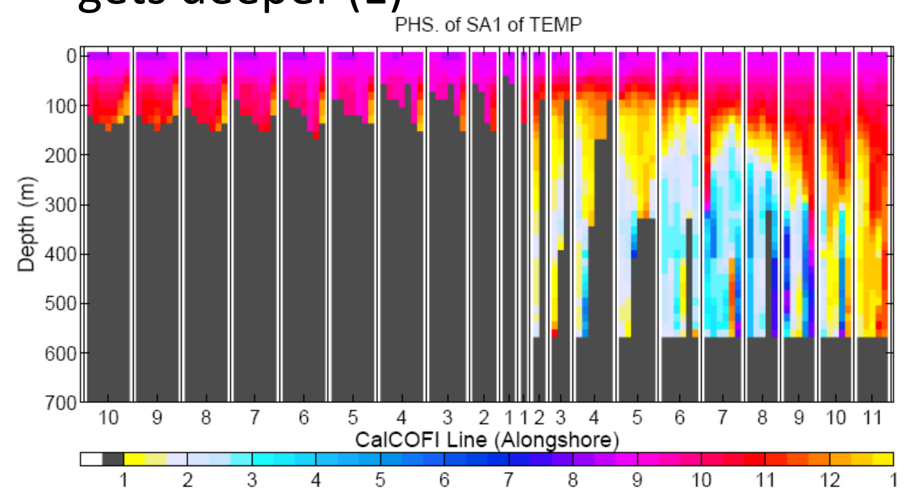
Seasonal amplitudes of T





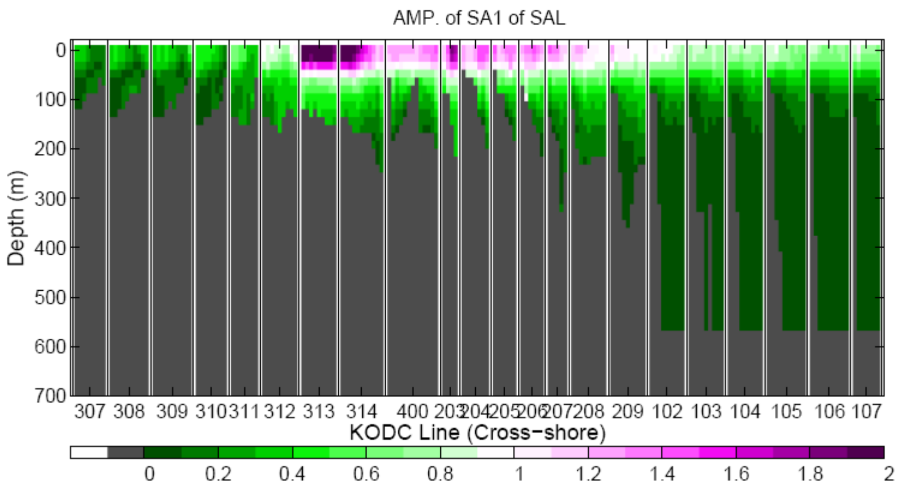


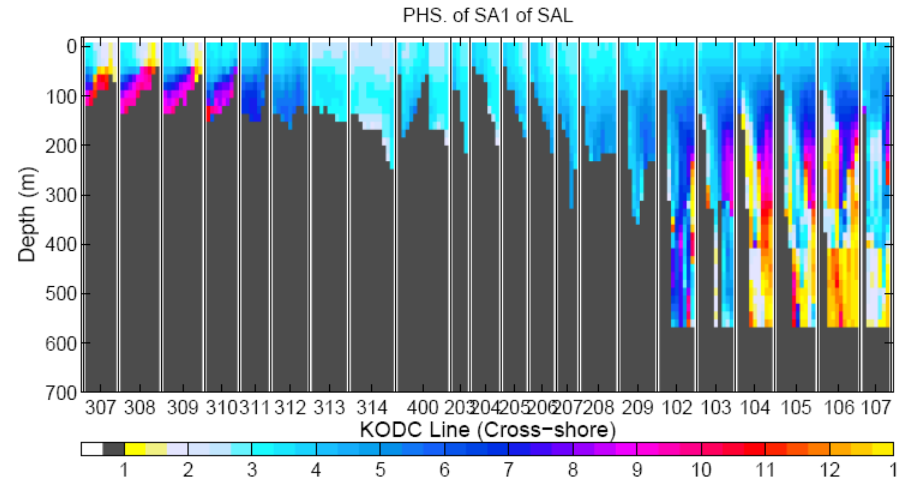
- Seasonal mixing or penetration depth gets deeper (E)

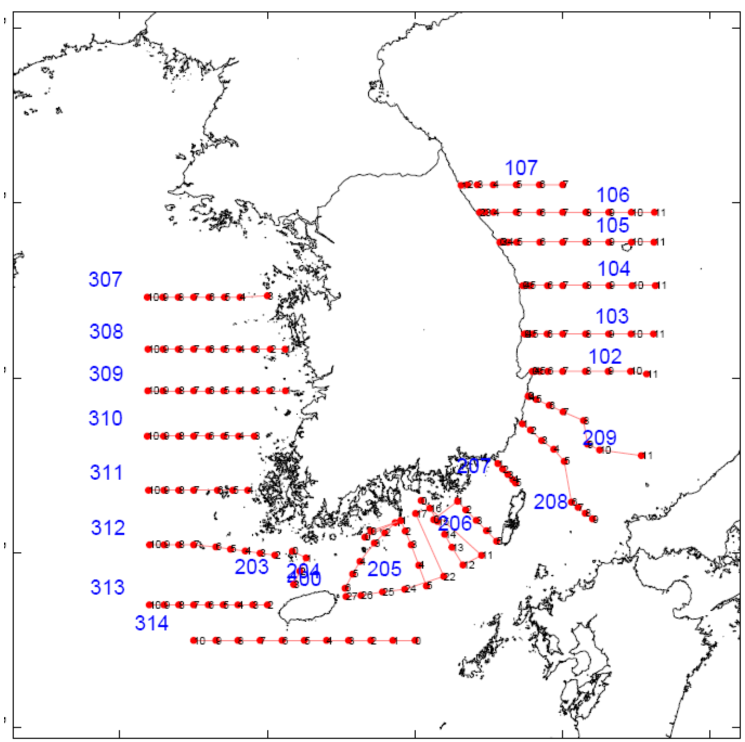


- Increasing phase toward the coast (E) westward signals? Rossby wave?

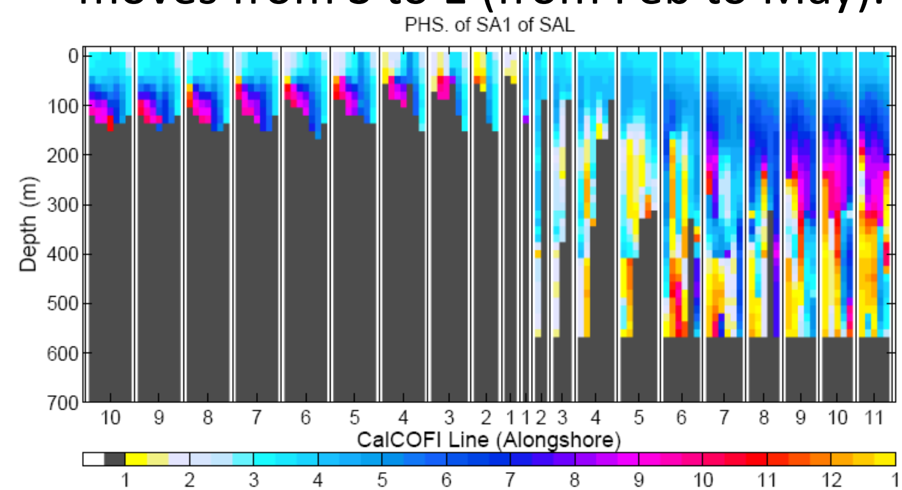
Seasonal amplitudes of S





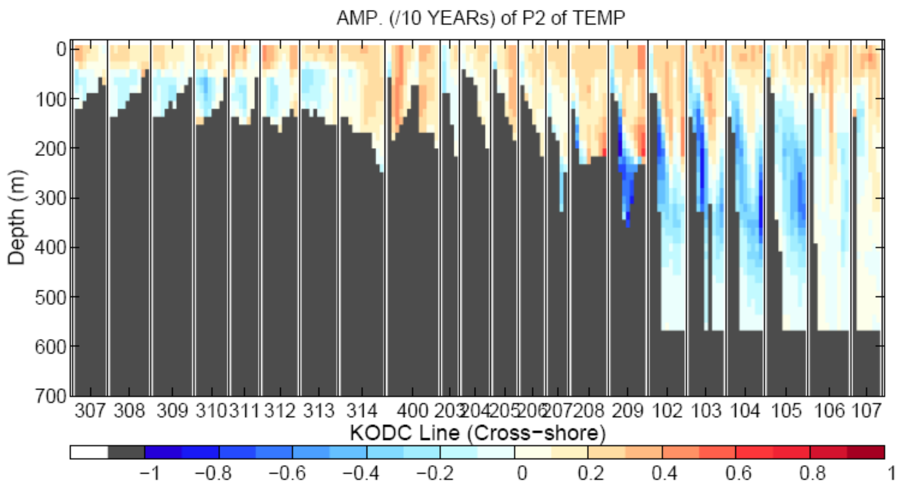


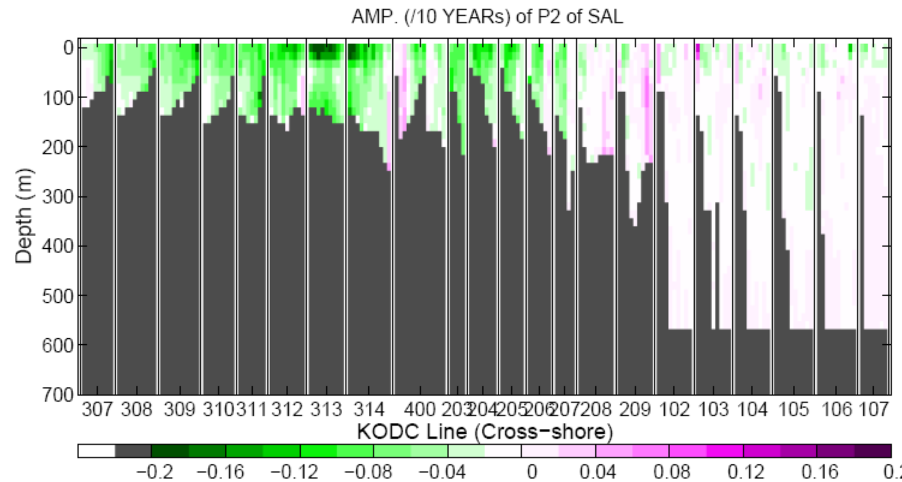
- Salinity maximum in upper 100m moves from S to E (from Feb to May).

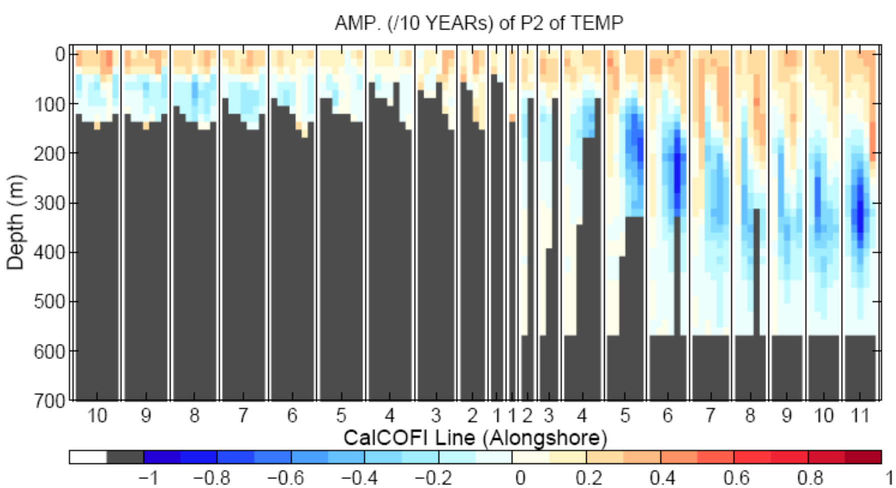


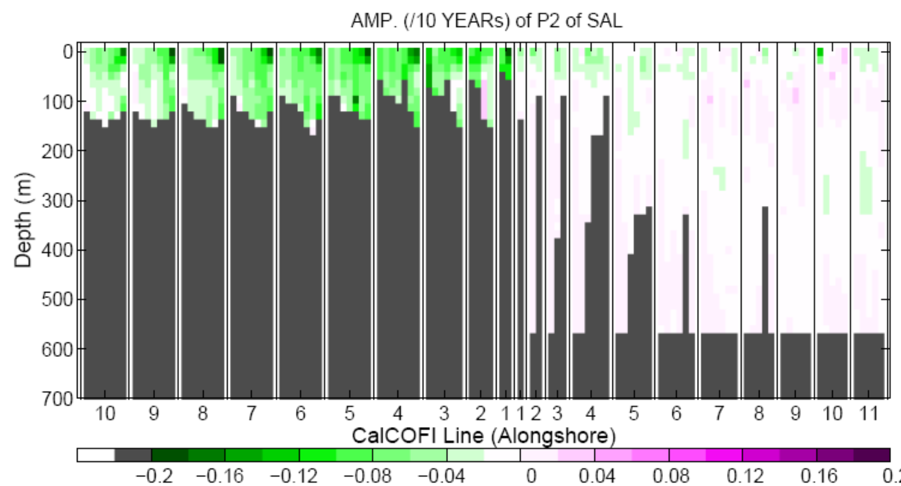
- Seasonal intrusion of saline water (S)

Linear trend of T and S

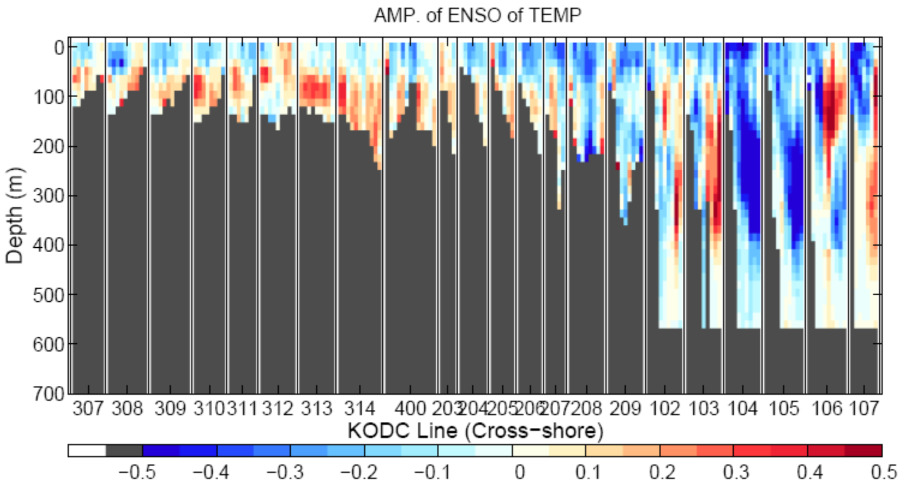


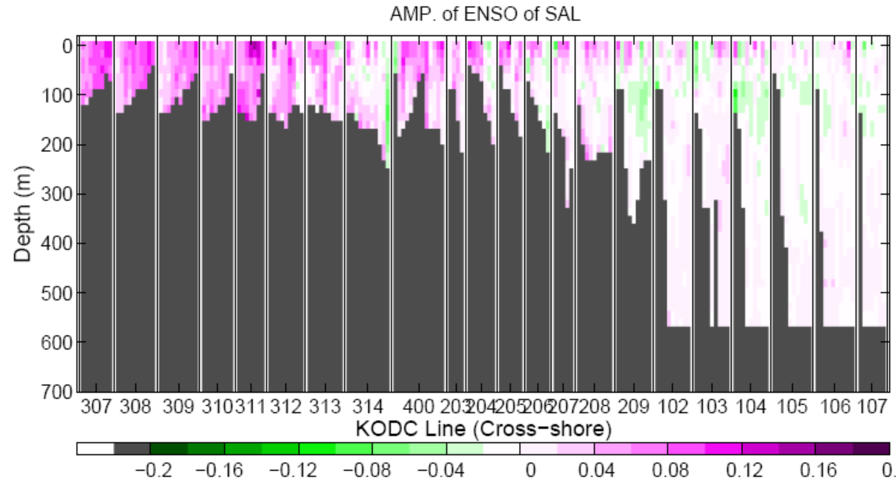


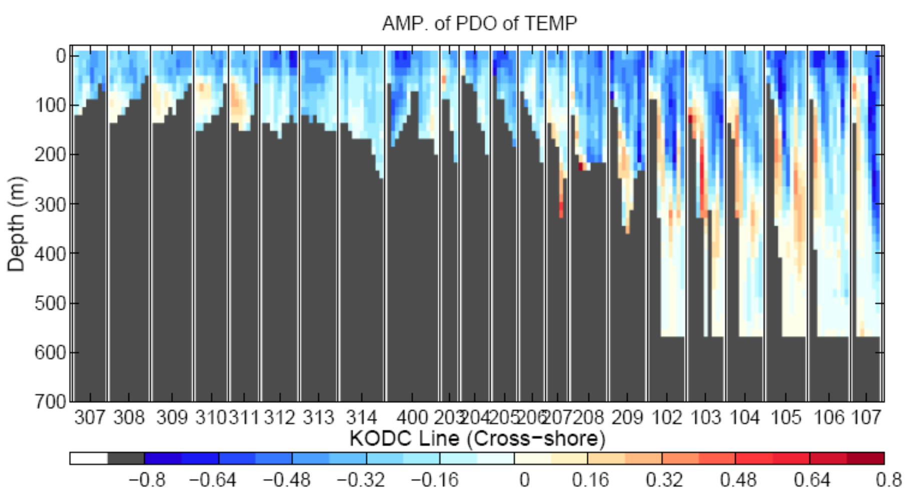


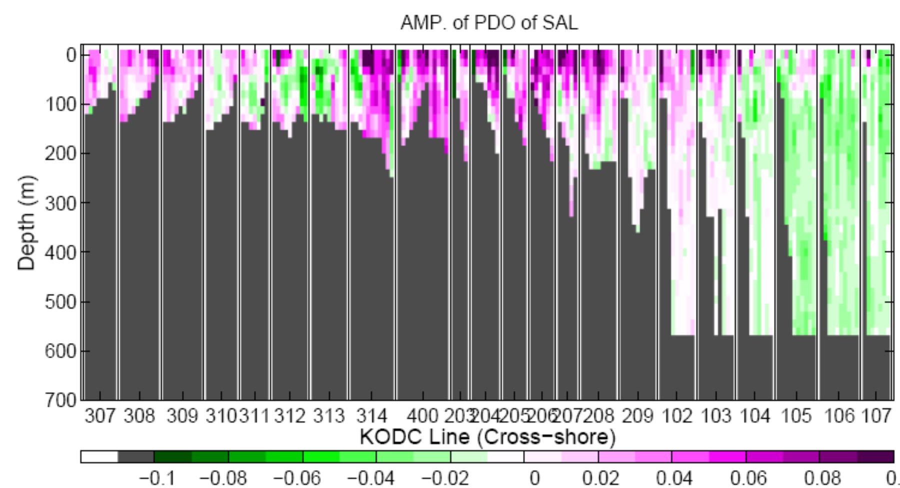


ENSO and PDO on T and S

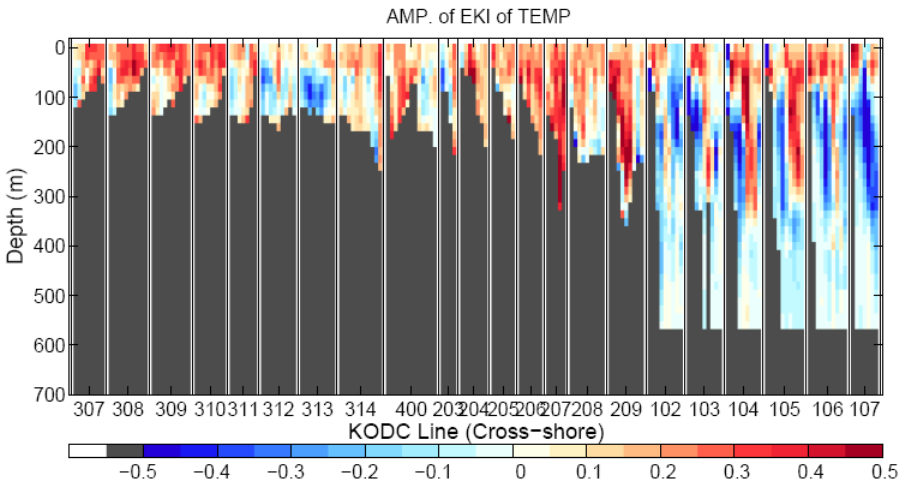


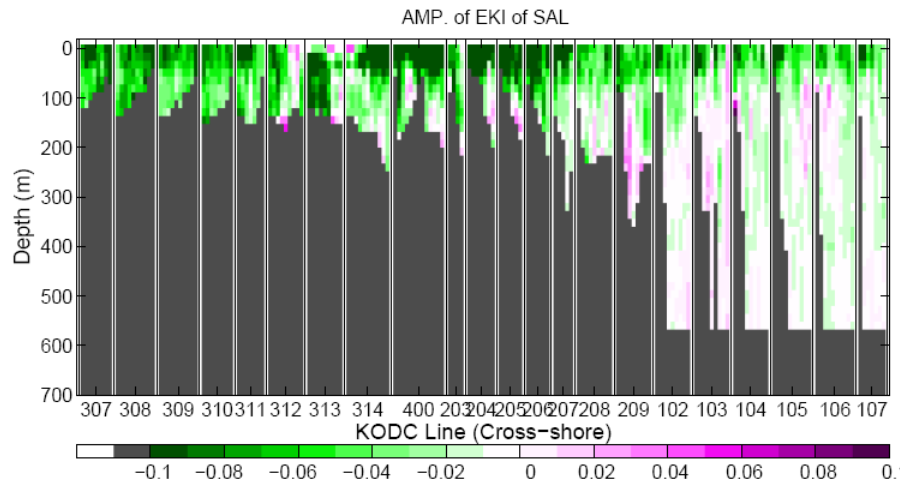


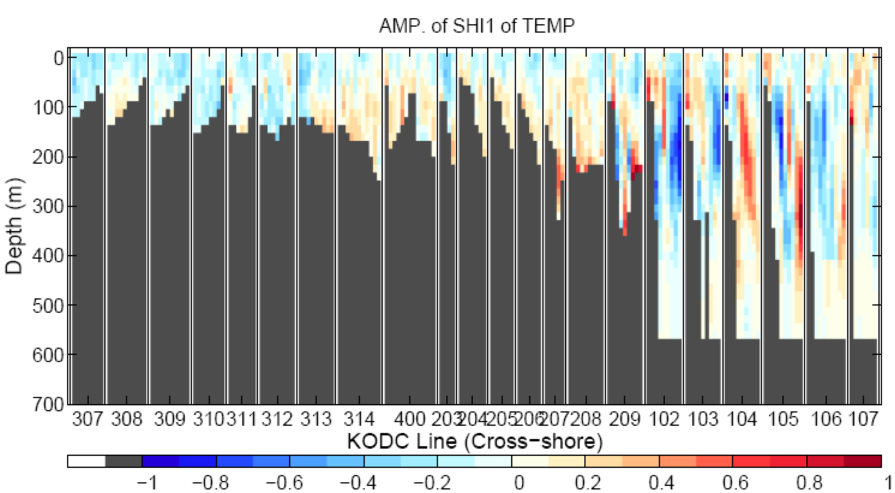


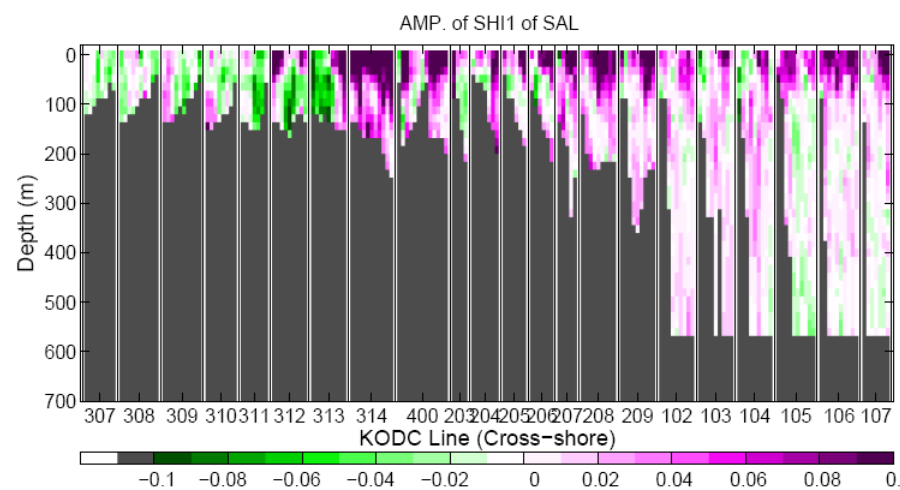


EKI and SHI on T and S









Summary

- Regression with seasonality, local climate indices (EKI and SHI), global climate indices (ENSO and PDO), and linear trend.
- Successive orthogonalization reduces the ambiguity in partitioning of variance.
- In the East Sea, northeastward geostrophic currents, deepening of seasonal mixing (from the vertical penetration of phase). In the Yellow Sea, the temperature has maximum seasonal amplitudes. In the South Sea, the seasonal variability of saline water is highest.
- More things to do to find the role of climate indices associated with circulation around Korea
- Applicable to density, spiciness, oxygen, nitrate, and etc