A WATER MASS HISTORY OF THE SOUTHERN CALIFORNIA CURRENT SYSTEM

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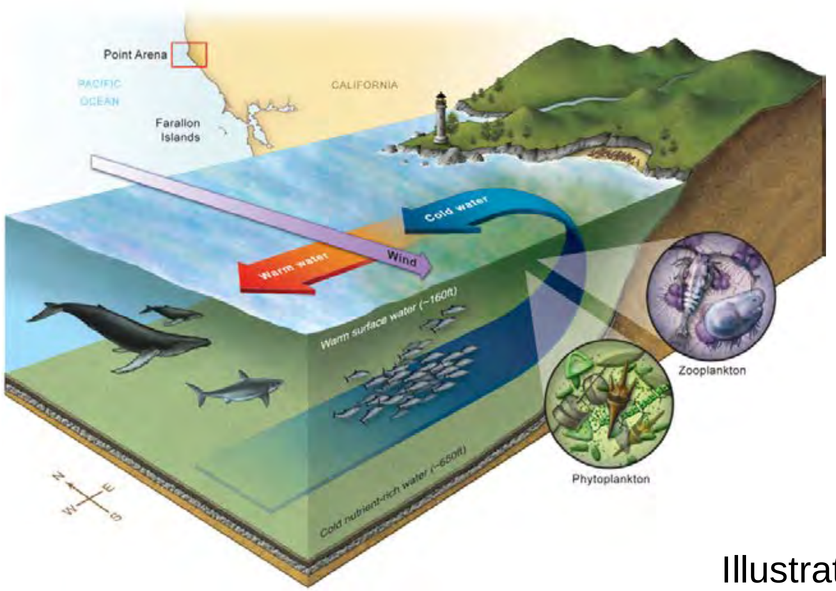
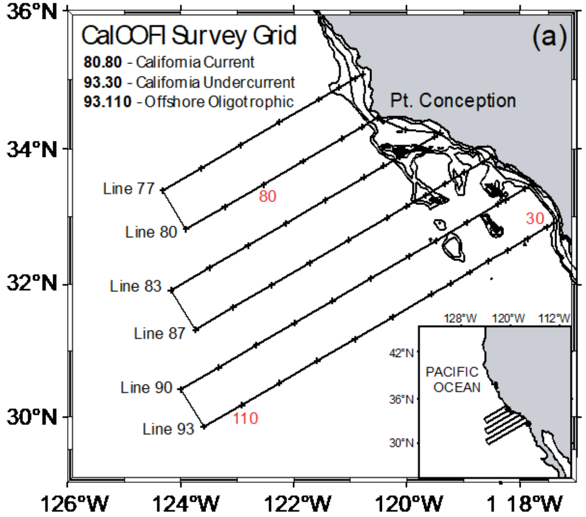
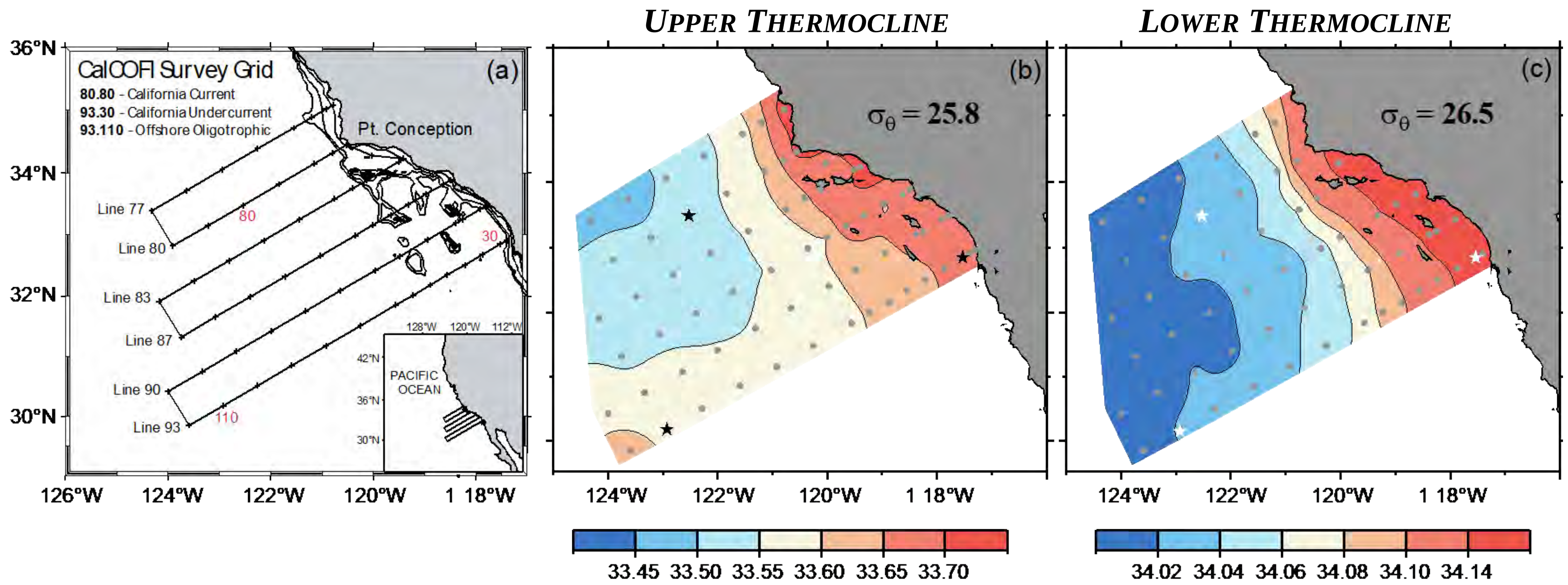


Illustration by Fiona Morris

Water Mass Influences on the California Current



SALINITY ON ISOPYCNALS

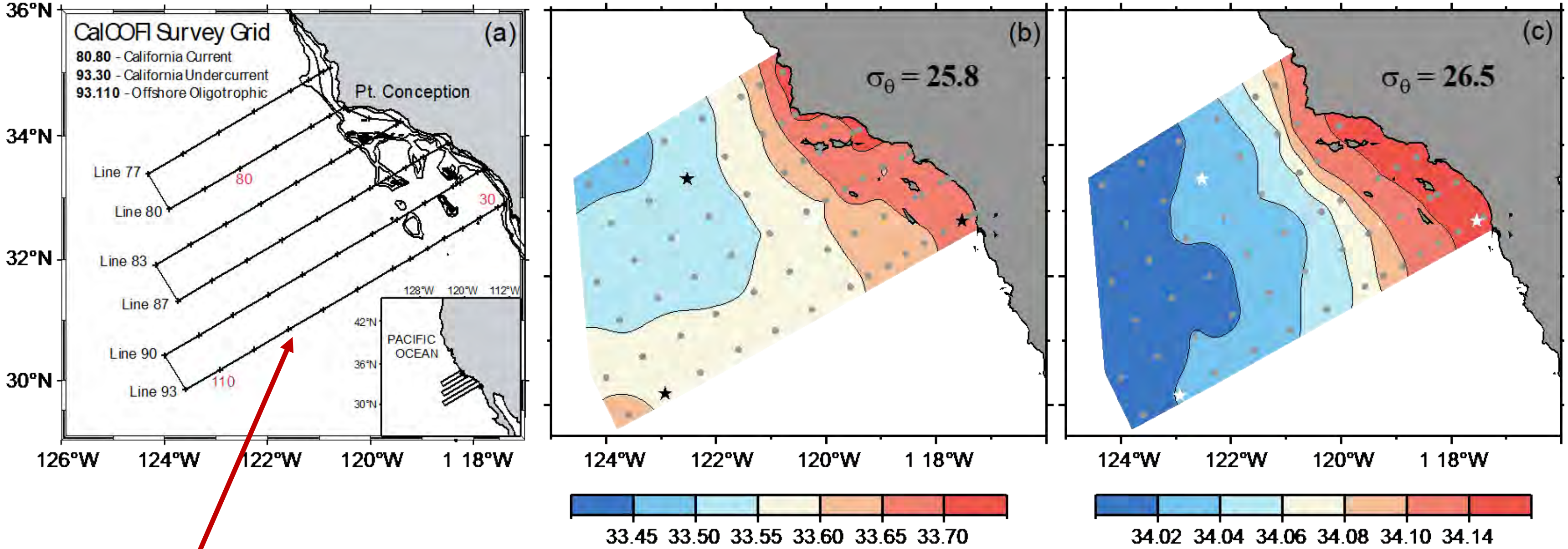


Z ~ 100-150 M

Z ~ 250-300 M

SALINITY ON ISOPYCNALS

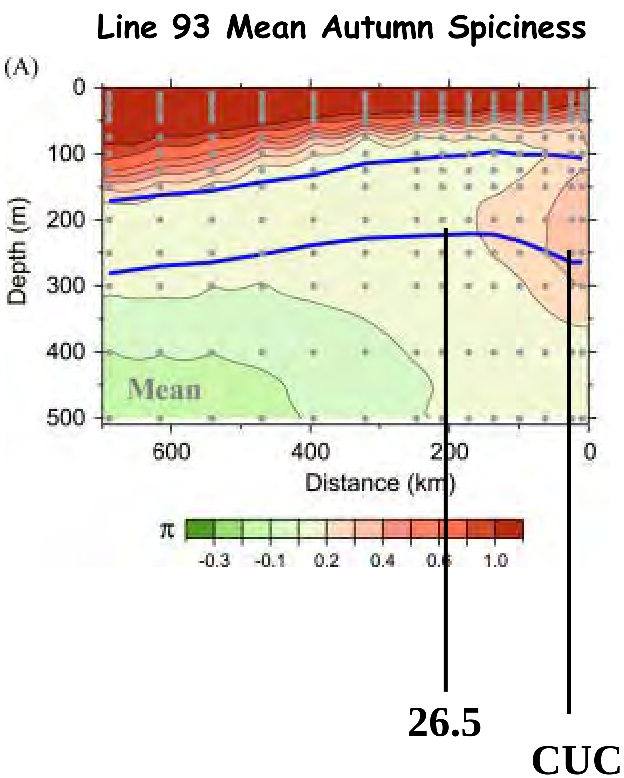
UPPER THERMOCLINE — *LOWER THERMOCLINE*



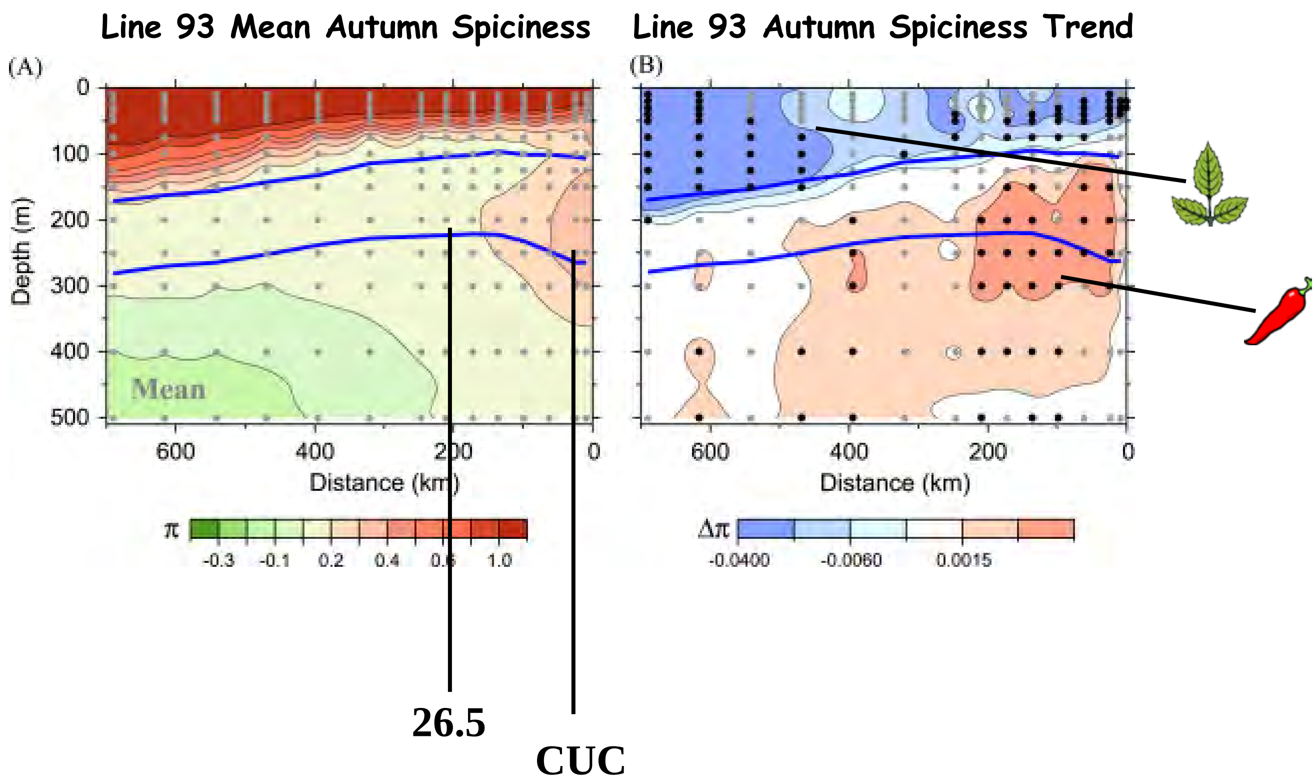
LINE 93

Z ~ 100-150 M

Z ~ 250-300 M

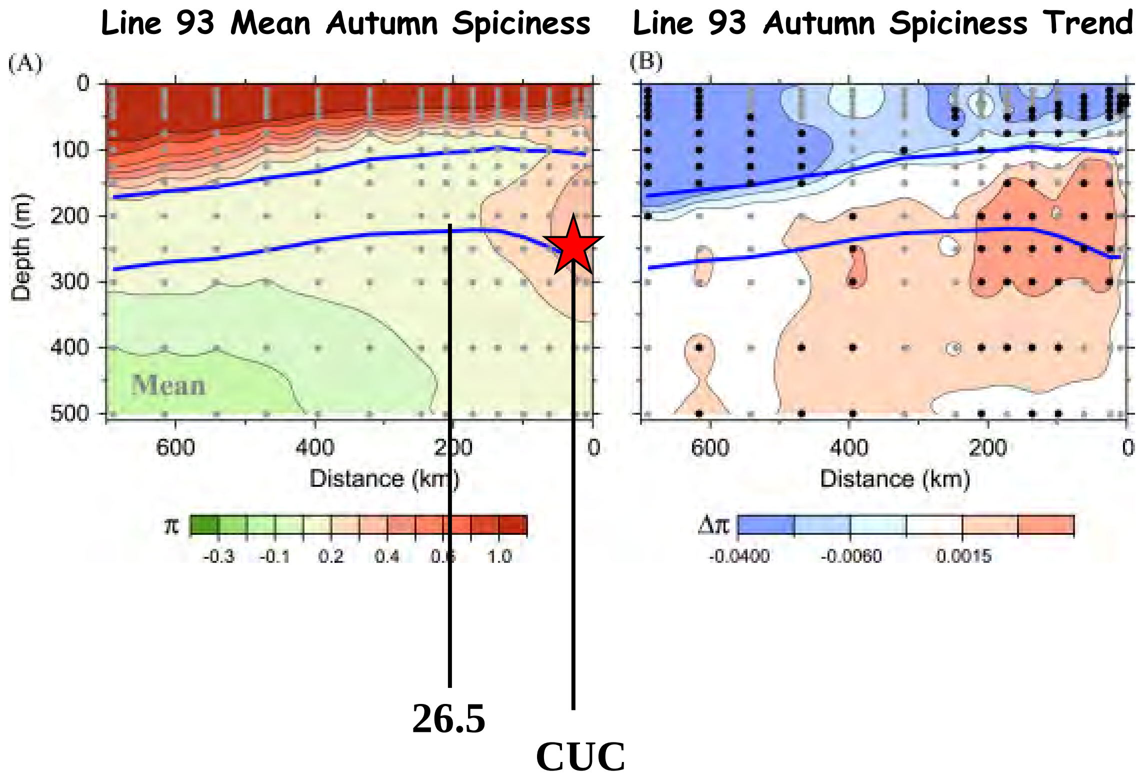


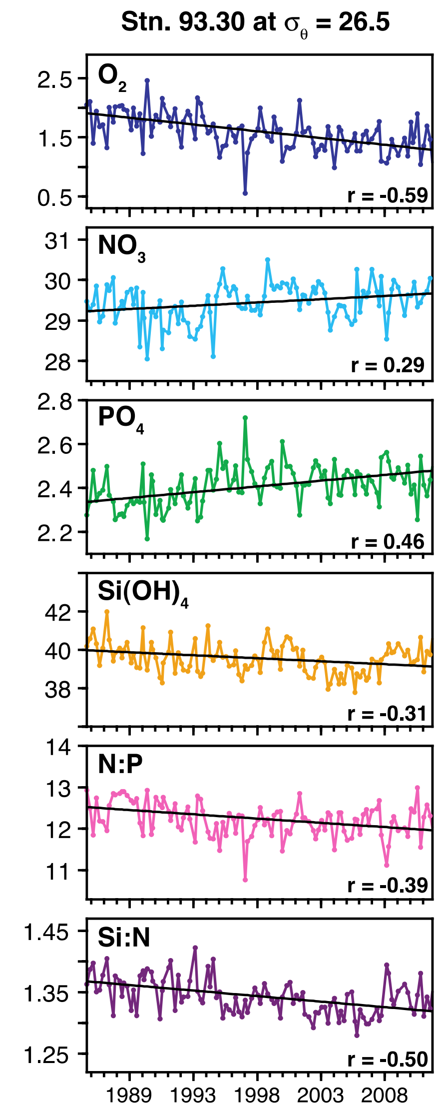
Bograd et al. (2015)



Bograd et al. (2015)

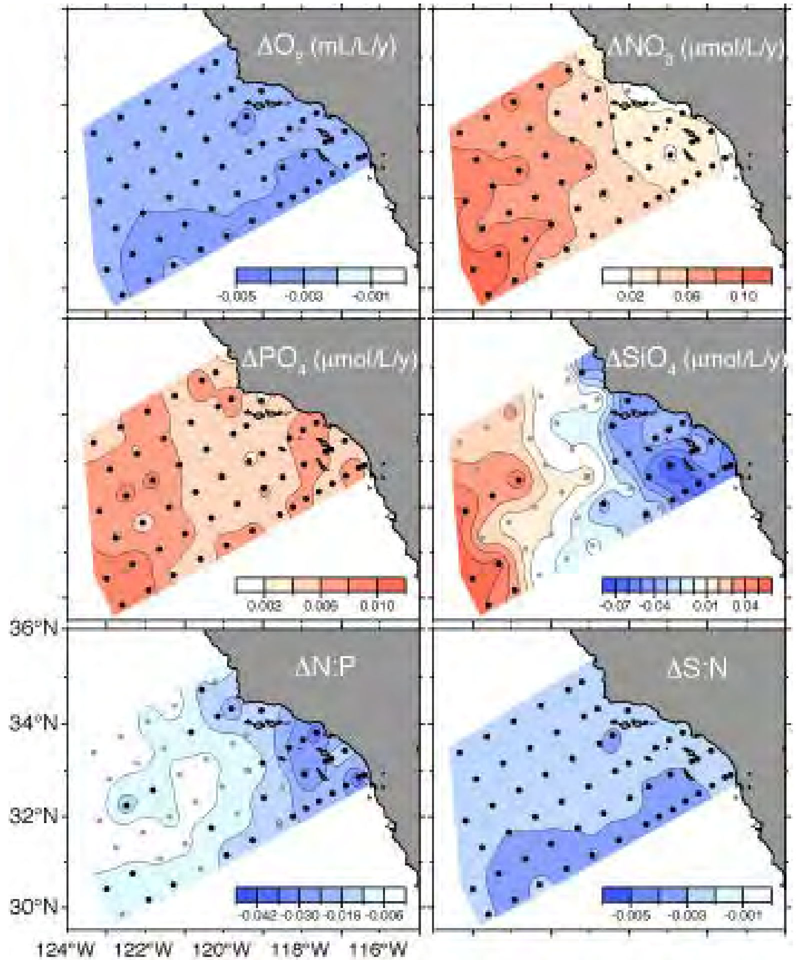
Observed Trends in Physical & Biogeochemical Properties





Bograd et al. (2015)

$\sigma_\theta = 26.5$



⇩ Oxygen

⇧ Phosphate

⇩ N:P

Nitrate ⇧

Silicate ⇧⇩

S:N ⇩

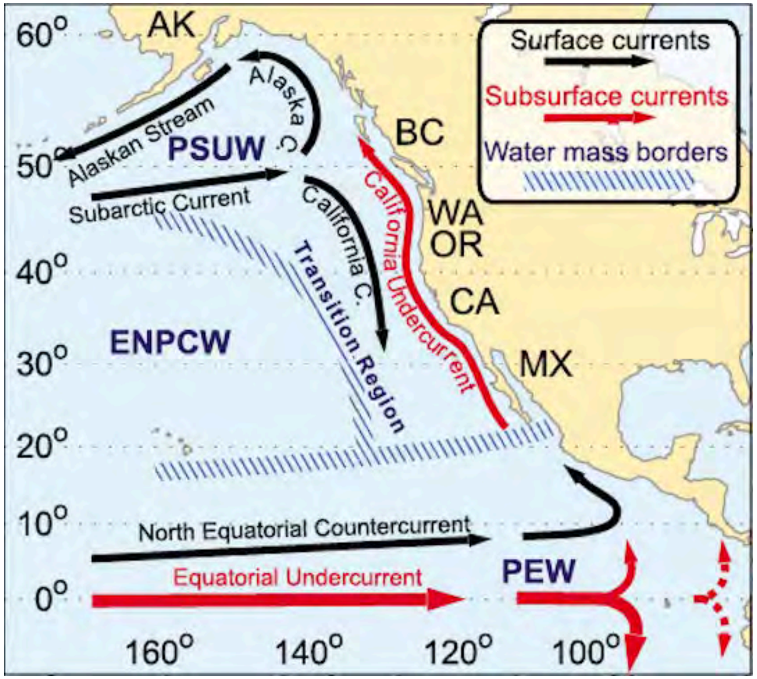
Bograd et al. (2015)

Objectives

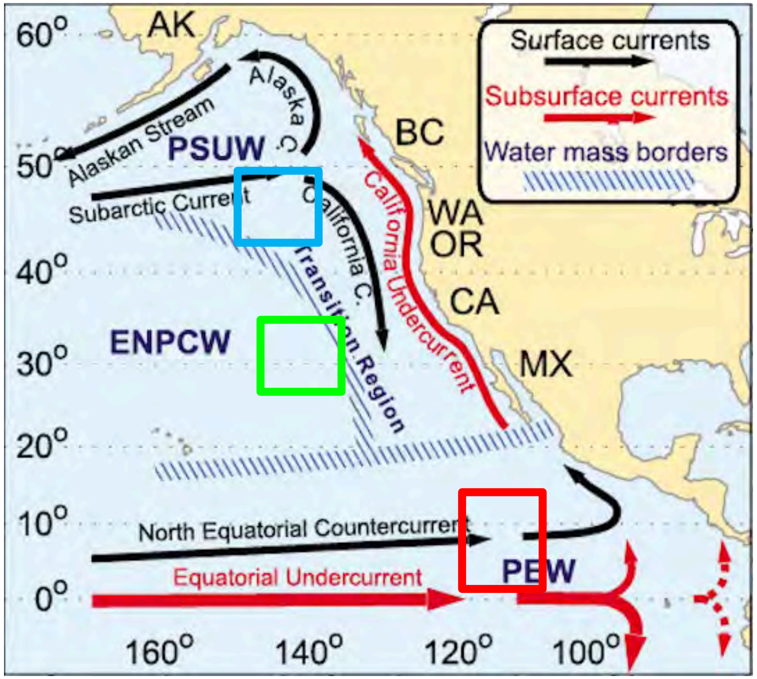
- Quantify water mass contributions to southern California Current
- Investigate spatial and temporal variability
  - Low-frequency variability (trends or change points)
  - Effects of El Niño – La Niña
- Infer mechanisms of biogeochemical trends in CalCOFI data
  - Changes at source? along advective pathway? locally?
- Climate change impacts

PRELIMINARY RESULTS

Water Mass Influences on the California Current

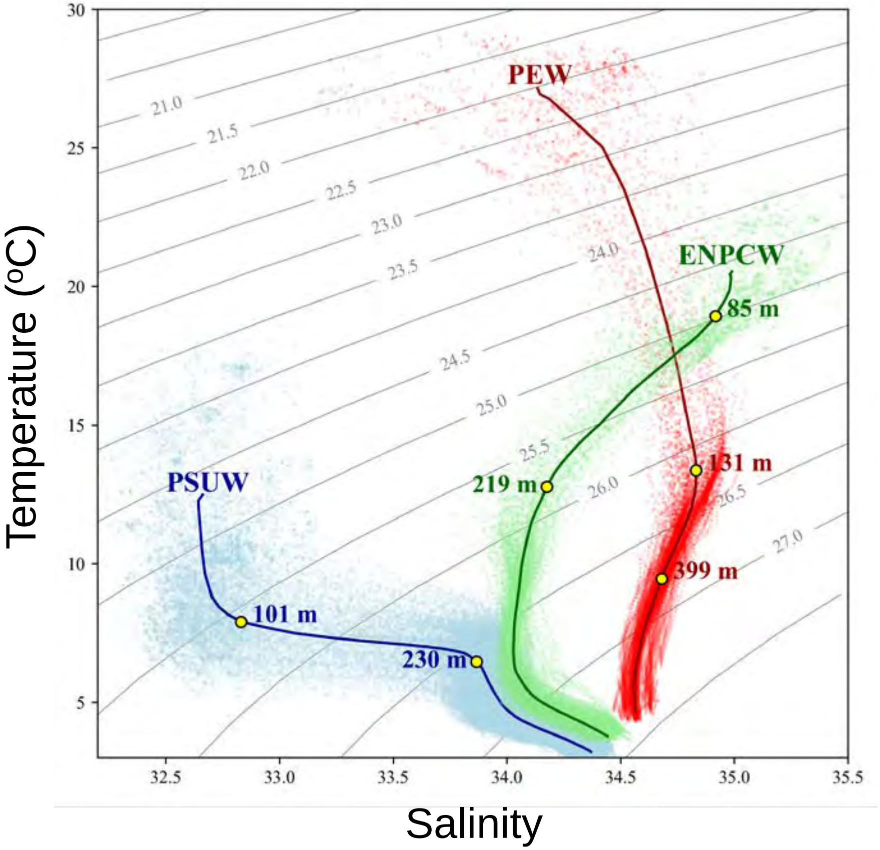


Thomson and Krassovski (2010)



Thomson and Krassovski (2010)

World Ocean Database, 1984-2016



Pacific Subarctic Water (PSUW)

Pacfic Equatorial Water (PEW)

Eastern North Pacific Central Water (ENPCW)

WATER MASS INFLUENCES ON THE CALIFORNIA CURRENT

	$PSUW_{deep}$	$PSUW_{shal}$	PEW_{deep}	PEW_{shal}	$ENPCW_{deep}$	$ENPCW_{shal}$
	PSUW 26.6	PSUW 25.6	PEW 26.8	PEW 26.2	ENPCW 25.8	ENPCW 25.0
Temperature	6.41	7.75	9.47	13.41	12.89	18.77
Salinity	33.86	32.80	34.68	34.85	34.18	34.87
Oxygen	3.87	6.24	0.42	1.06	4.94	5.32
Phosphate	2.01	1.16	2.73	2.04	0.66	0.14
Silicate	44.14	14.81	39.72	22.06	9.85	3.87
Nitrate	27.29	10.33	36.41	28.38	7.58	0.25
Mass	1.00	1.00	1.00	1.00	1.00	1.00

Pacfic Equatorial Water (PEW)
Eastern North Pacific Central Water (ENPCW)
Pacific Subarctic Water (PSUW)

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Temperature	6.41	7.75	9.47	13.41	12.89 High	18.77
Salinity	33.86 Low	32.80	34.68 High	34.85	34.18	34.87
Oxygen	3.87 High	6.24	0.42 Low	1.06	4.94	5.32
Phosphate	2.01	1.16	2.73	2.04	0.66	0.14
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Pacfic Equatorial Water (PEW)

Eastern North Pacific Central Water (ENPCW)

Pacific Subarctic Water (PSUW)

Extended Optimum Multiparameter Analysis (OMP)

Six Water Masses: **(PEW, PSUW, ENPCW; Upper and Deep)**

Six Variables: **T, S, O_2, NO_3, PO_4, SiO_4**

Six Equations + Conservation of Mass

Solve for % each Water Mass in **CalCOFI** Domain [1984-2017]

Tomczak and Large (1989)

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Solve for % each Water Mass in **CalCOFI** Domain [1984-2017]

$$X_{PEWu}T_{PEWu} + \ldots + X_{NPCWd}T_{NPCWd} + 0 = T_{OBS} + R_T$$

$$X_{PEWu}S_{PEWu} + \ldots + X_{NPCWd}S_{NPCWd} + 0 = S_{OBS} + R_S$$

$$X_{PEWu}O_{2,PEWu} + \ldots + X_{NPCWd}O_{2,NPCWd} - r_{O/P}\,\Delta P = O_{2,OBS} + R_{O2}$$

$$X_{PEWu}PO_{4,PEWu} + \ldots + X_{NPCWd}PO_{4,NPCWd} + \Delta P = PO_{4,OBS} + R_{PO4}$$

$$X_{PEWu}NO_{3,PEWu} + \ldots + X_{NPCWd}NO_{3,NPCWd} + r_{N/P}\,\Delta P = NO_{3,OBS} + R_{NO3}$$

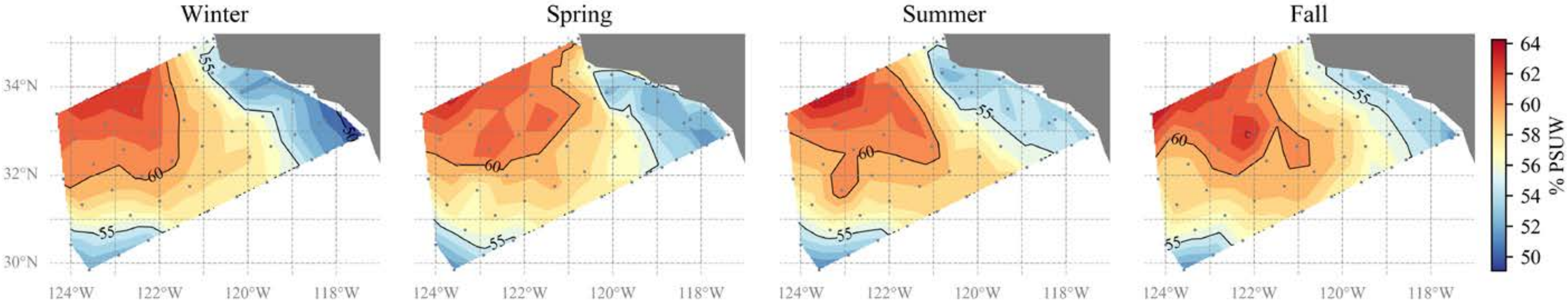
$$X_{PEWu}SiO_{4,PEWu} + \ldots + X_{NPCWd}SiO_{4,NPCWd} + r_{Si/P}\,\Delta P = SiO_{4,OBS} + R_{SiO4}$$

$$X_{PEWu} + X_{PSUWu} + X_{NPCWu} + X_{PEWd} + X_{PSUWd} + X_{NPCWd} = 1 + R_{\Sigma}$$

http://omp.geomar.de/node3.html

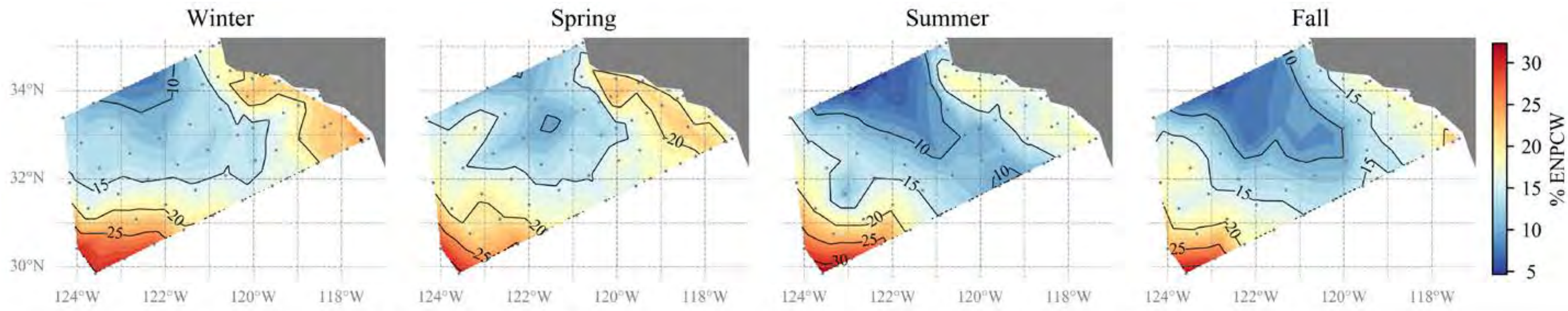
Tomczak and Large (1989)

%PSUW IN CALCOFI DOMAIN AT $\sigma_\theta = 25.8$



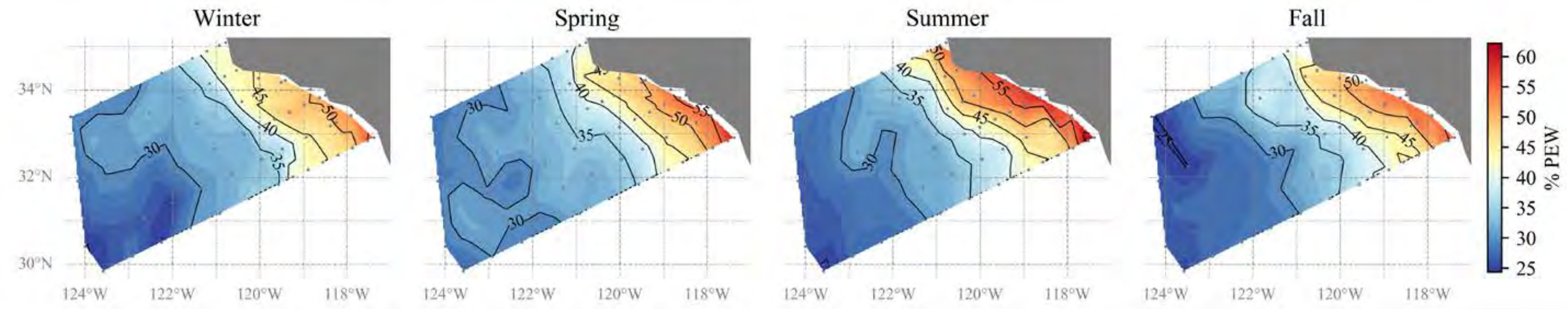
- SEASONAL MEAN PSUW CONTRIBUTIONS IN UPPER THERMOCLINE
- WATERS AT THIS LEVEL ARE 55-60% PSUW THROUGHOUT
- HIGH PSUW OFFSHORE - INFLUX OF CALIFORNIA CURRENT; LOW INSHORE
- MINIMUM INSHORE PSUW CONTRIBUTION IN WINTER

%ENPCW IN CALCOFI DOMAIN AT $\sigma_\theta = 25.8$



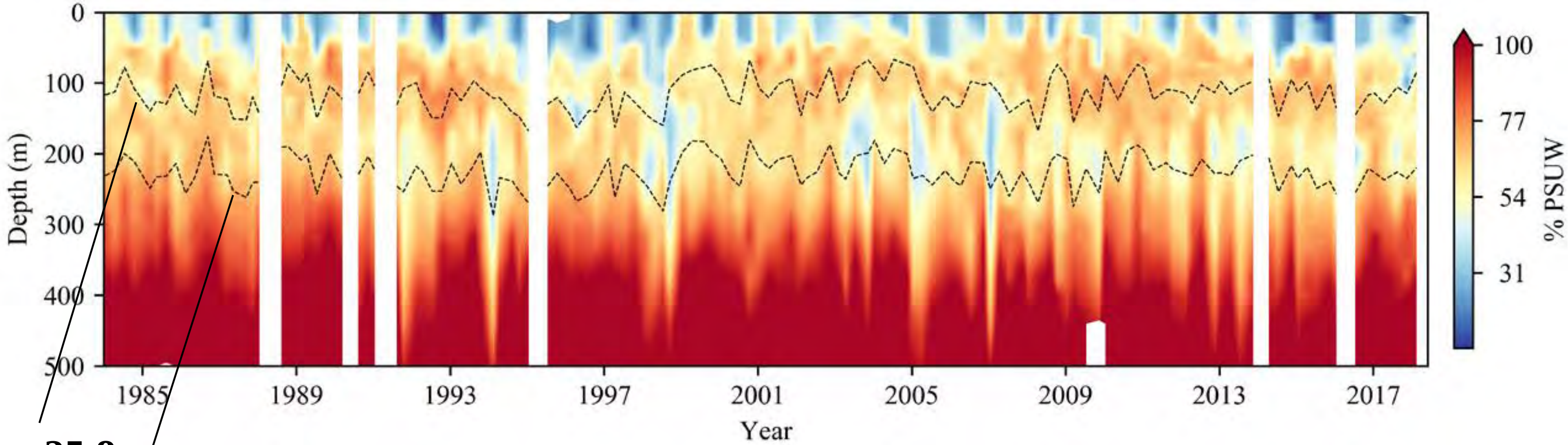
- SEASONAL MEAN ENPCW CONTRIBUTIONS IN UPPER THERMOCLINE
- WATERS AT THIS LEVEL ARE ONLY 5-15% EPNCW
- HIGHEST EPNCW IN SOUTHWEST CORNER AND INSHORE

%PEW IN CALCOFI DOMAIN AT $\sigma_\theta = 26.5$



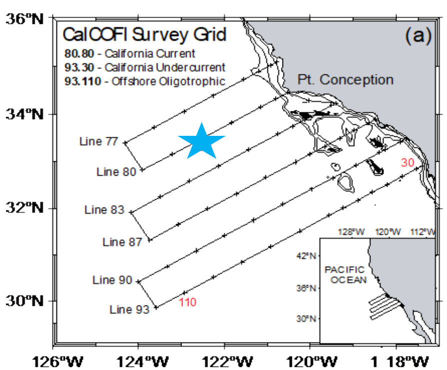
- SEASONAL MEAN PEW CONTRIBUTIONS IN LOWER THERMOCLINE
- STRONG CROSS-SHORE GRADIENT IN DISTRIBUTION OF PEW
- 50-60% PEW CONTRIBUTION IN NEARSHORE REGION
- STRONG SEASONALITY – MORE PEW IN SUMMER-FALL (STRONG CUC)

CALCOFI STATION 80.80 (CALIFORNIA CURRENT)



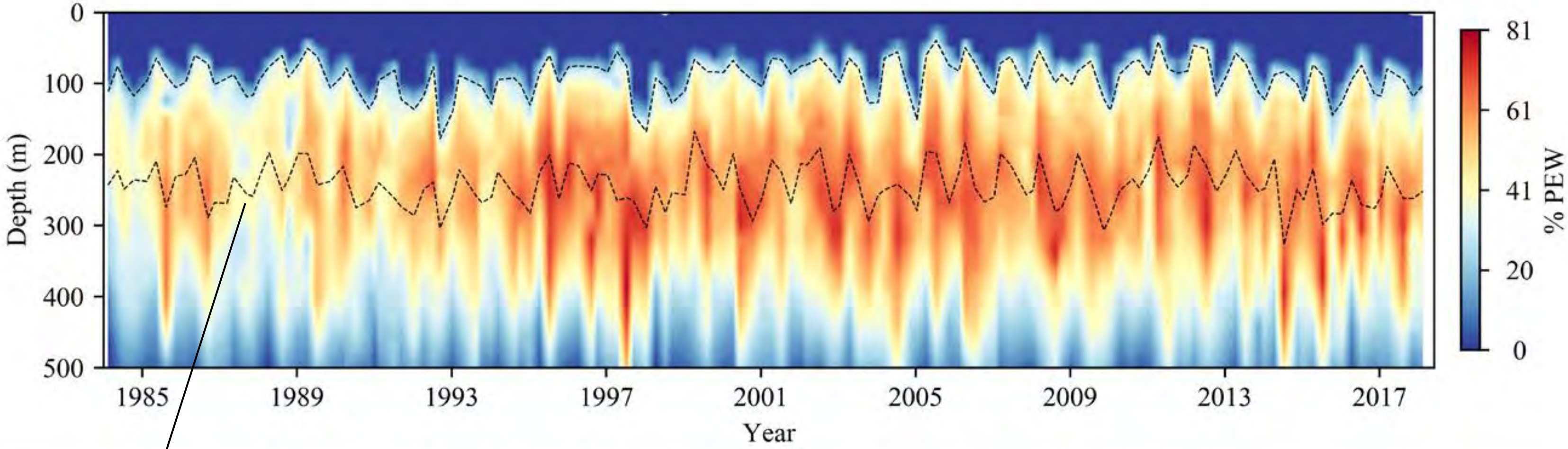
$\sigma_\theta = 25.8$

$\sigma_\theta = 26.5$

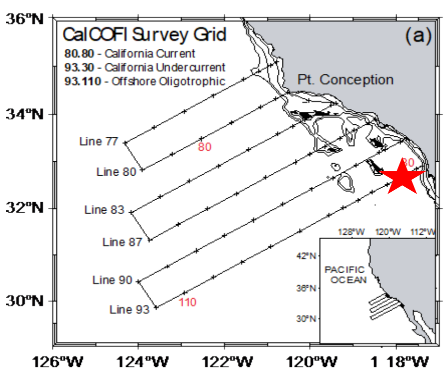


- TIME-DEPTH PLOT OF PSUW AT STATION 80.80
- SEASONAL VARIABILITY IN SURFACE LAYER
- HIGH PSUW CONTRIBUTION WITHIN CALIFORNIA CURRENT
- STRONG INTERANNUAL VARIABILITY IN UPPER 200 M IN QUANTITY OF PSUW & DEPTH STRUCTURE

CALCOFI STATION 93.30 (CALIFORNIA UNDERCURRENT)



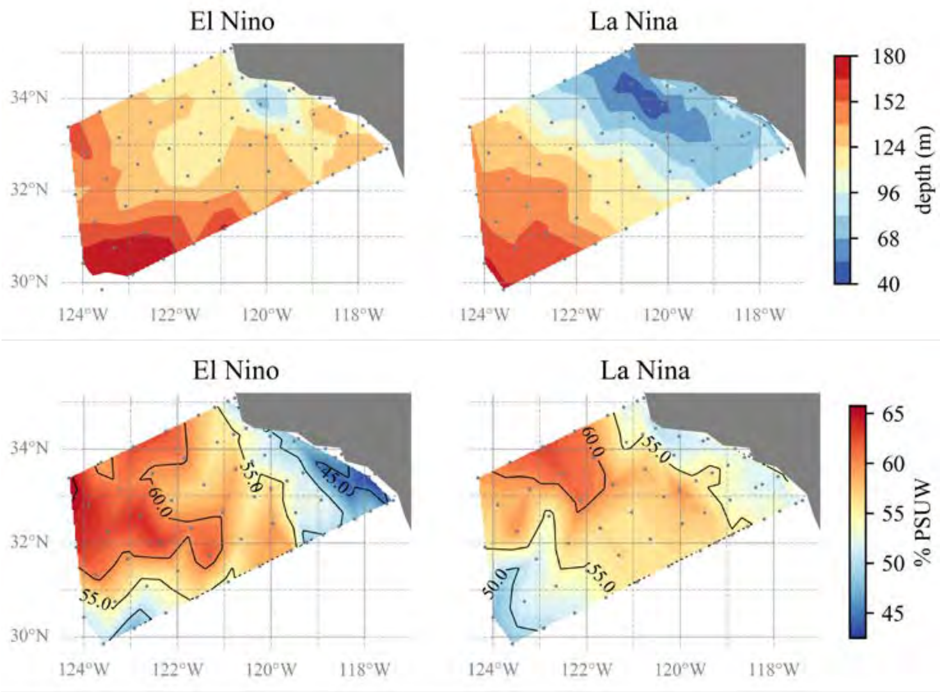
$\sigma_\theta = 26.5$



- TIME-DEPTH PLOT OF PEW AT STATION 93.30
- HIGHEST PEW CONTRIBUTION AROUND $\sigma_\theta = 26.5$ (CUC)
- STRONG INTERANNUAL VARIABILITY: TREND TO HIGHER PEW
- HIGHER PEW CONTRIBUTION IN EL NIÑO YEARS (STRONGER CUC)

Water Mass Changes associated with ENSO Events

Winter Z and %PSUW in CalCOFI domain at $\sigma_\theta = 25.8$

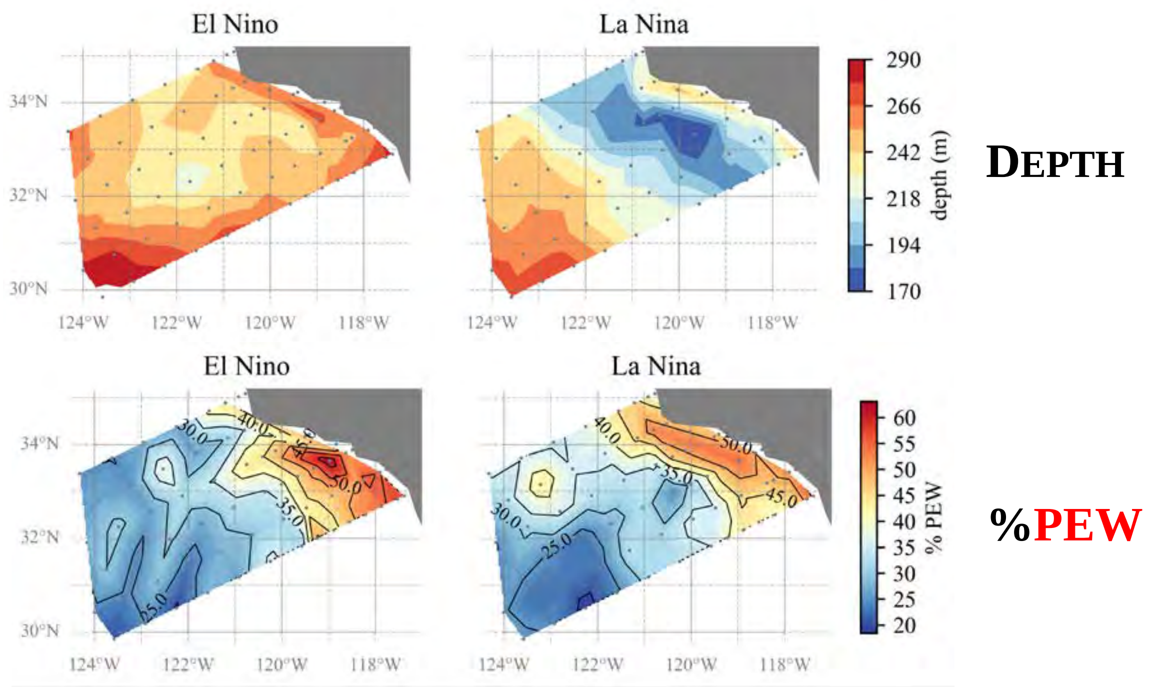


Depth

%PSUW

- Mean upper thermocline depth, PSUW contribution during El Niño, La Niña
- Higher PSUW contribution offshore, lower inshore during El Niño
- High PSUW content within California Current core during La Niña

WINTER Z AND %PEW IN CALCOFI DOMAIN AT $\sigma_\theta = 26.5$



- MEAN LOWER THERMOCLINE DEPTH, PEW CONTRIBUTION DURING EL NIÑO, LA NIÑA
- HIGHER PEW CONTRIBUTION INSHORE DURING EL NIÑOS (STRONGER CUC), LESS DURING LA NIÑA

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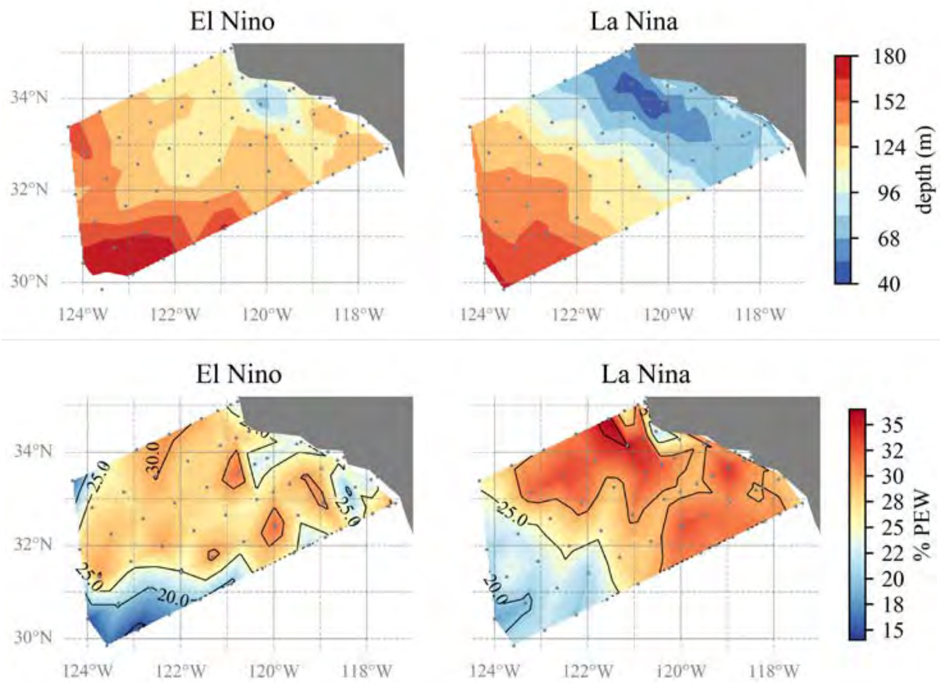

Depth

%PEW

- Mean upper thermocline depth, PEW contribution during El Niño, La Niña
- Higher PEW contribution during La Niña, but isopycnal much shallower
- Although weaker PEW contribution during La Niña, stronger upwelling may tap this nutrient-rich water more effectively

- OPTIMUM MULTIPARAMETER ANALYSIS (OMP) IS A USEFUL TOOL FOR CHARACTERIZING WATER MASSES

Summary

- Optimum Multiparameter Analysis (OMP) is a useful tool for characterizing water masses
- Low frequency variability in water mass contributions in southern California Current
  - Trend towards a stronger Undercurrent/PEW influence
  - Stronger Undercurrent/PEW influence during El Niño events
  - Stronger upwelling during La Niña may tap nutrient-rich PEW more effectively
  - Water mass transformation along advective pathway (not shown)

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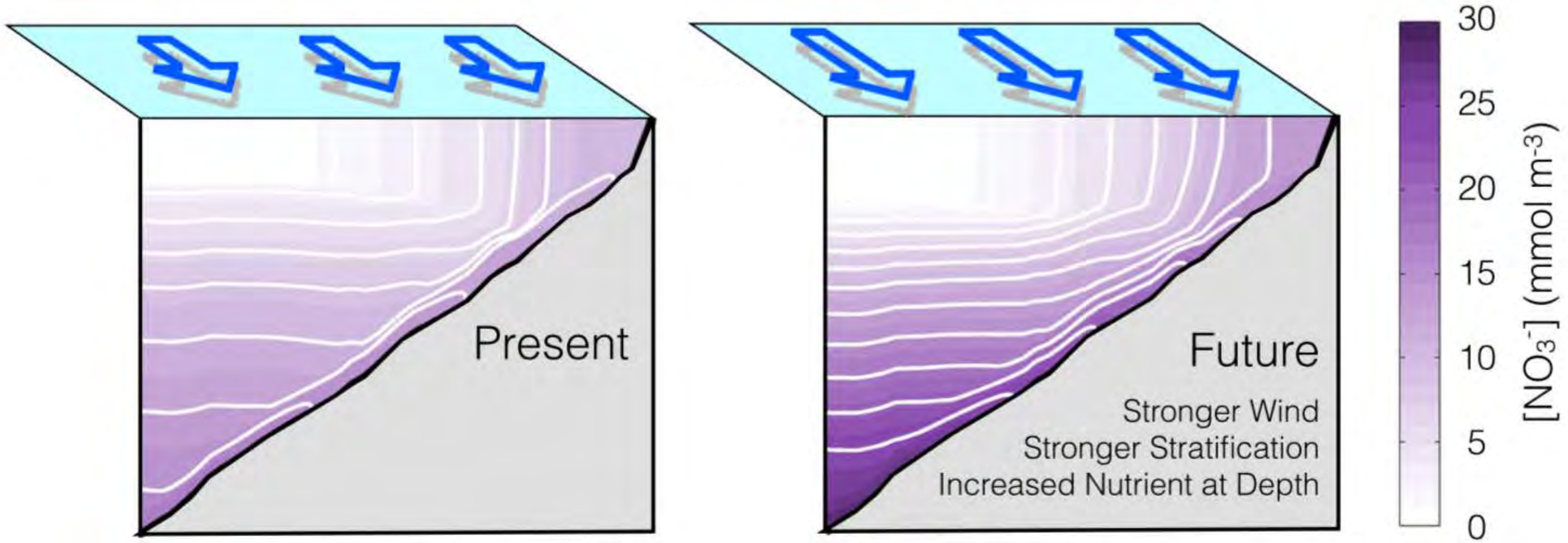
  - Water mass transformation along advective pathway (not shown)
- Future work:
  - Upwelling source depth vs. Undercurrent location & strength
  - Biological implications of different water mass distributions



Jacox et al. (2015)

- o Changes in nutrient content of source waters …?
- o Changes in stratification …?
- o Increased hypoxia and ocean acidification …?
- o Plasticity of species dependent on coastal upwelling …?

QUESTIONS?