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Analysis of A Permanent Downwelling Zone in the East China Sea Using Hybrid Coordinate Ocean Model (HYCOM)

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[1] NRL Code 7323: Open Ocean Processes and Prediction

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Overview of the East China Sea and Kuroshio Current

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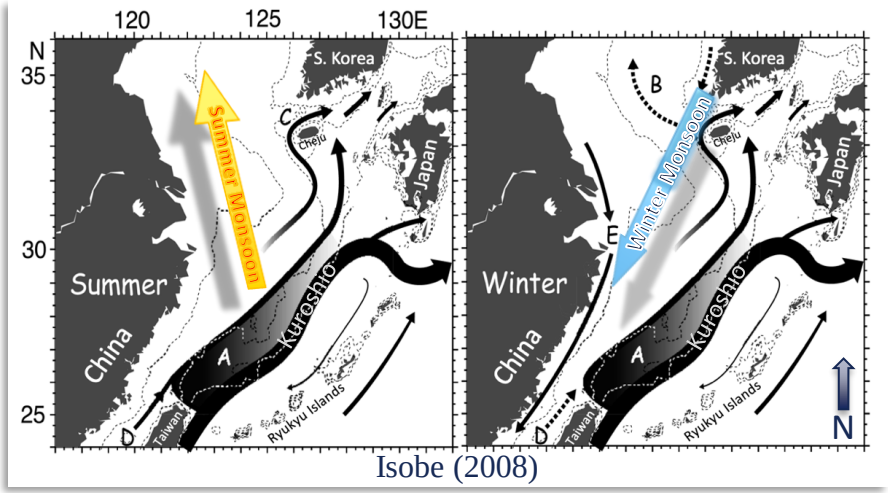
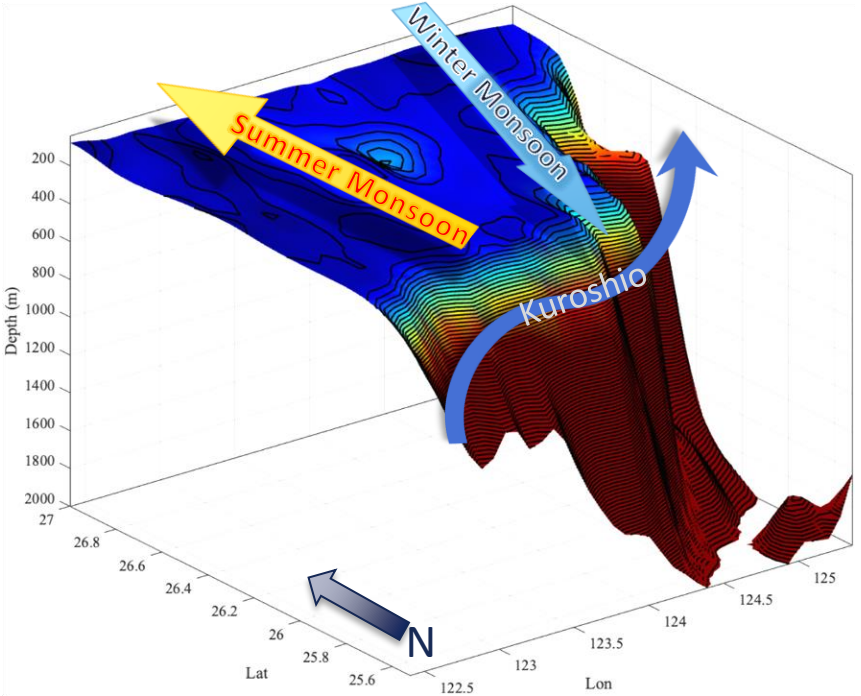
East China Sea

- Summer and Winter Monsoons
- Kuroshio (WBC)
- Topography : Shelf-slope interface



Isobe (2008)



Three largest forcings: Monsoons (Winds), Kuroshio (Current), and topography

Utilizing the Regional HYCOM Model

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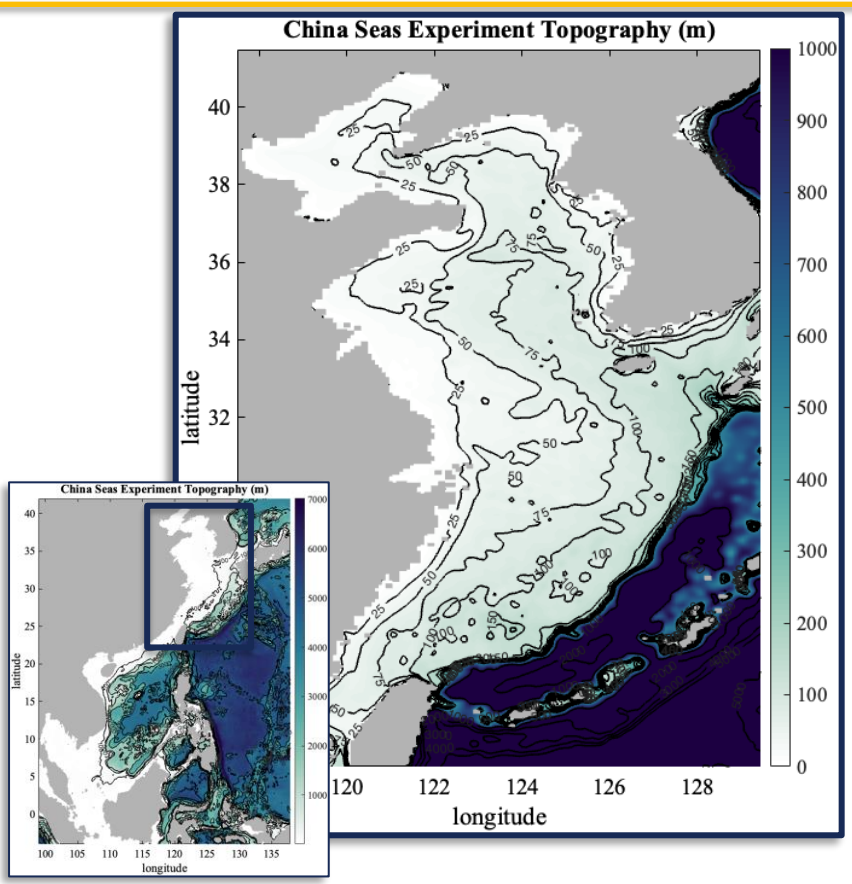

HYbrid Coordinate Ocean Model

- Regional model of western Pacific (1/12°)
  - Boundary conditions from Global HYCOM
  - NCEP CFSR Atmospheric forcing
  - Barotropic tidal forcing (M_2)
  - 5 years (2018 – 2022)
- 41 hybrid layers (*z*, σ, isopycnal)
  - Explore sub-surface vertical motion (*w*) where observations are scarce
  - *w* is determined in post-processing by vertical integration of the continuity equation (Halliwell, 2004)

$$\left(\frac{dw}{dp}\right)_s = -\nabla_s \cdot \mathbf{v}$$

High-resolution models can be used to discern unique subsurface ocean processes.

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Identifying Vertical Motion Areas of Interest

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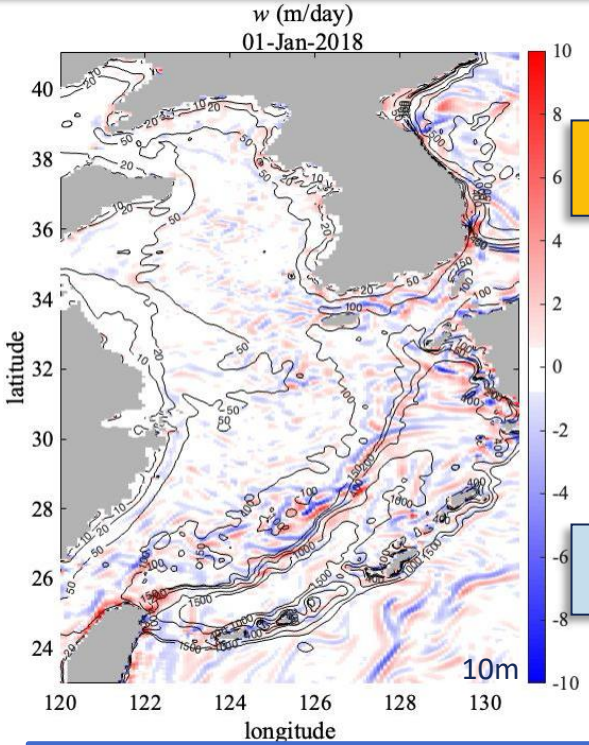
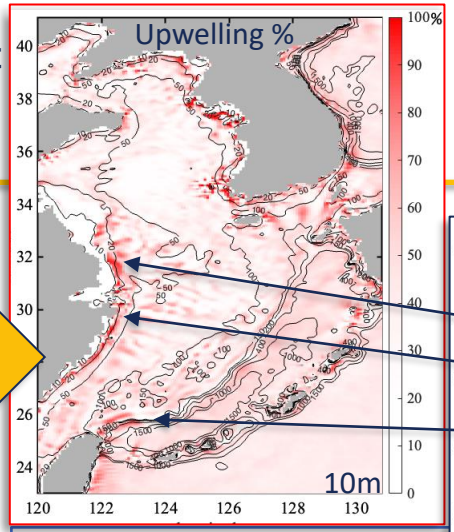
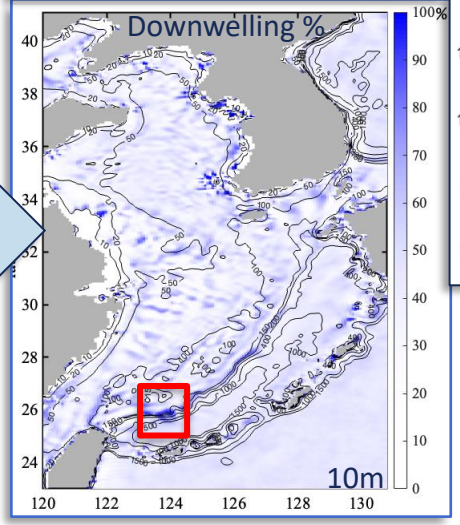
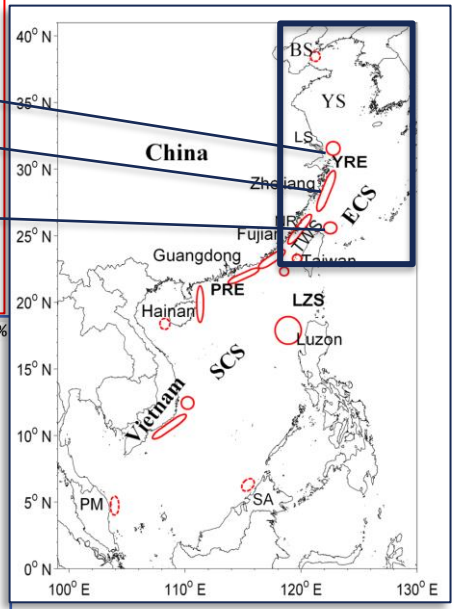


Upwelling ≥ 1 m/day



Downwelling ≥ 1 m/day





Hu and Wang, 2016

Areas of enhanced vertical motion (*w*) identified by HYCOM agree with published observations

Discovering the Permanent Downwelling Zone (PDZ)

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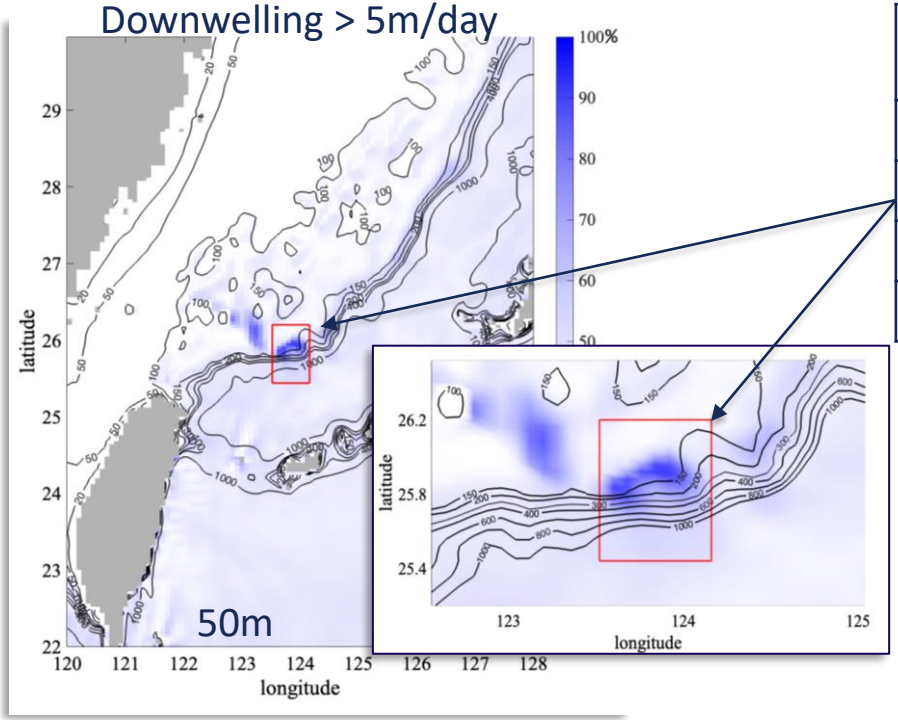
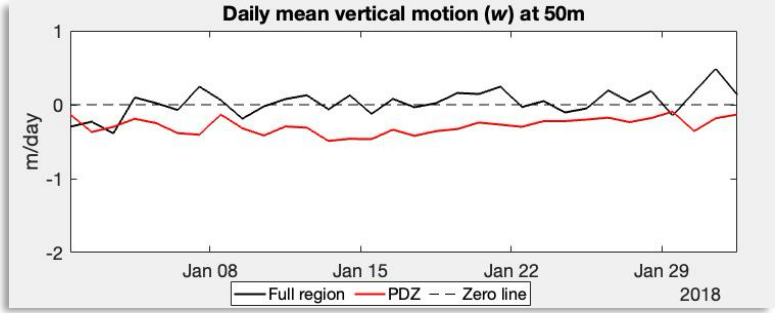


Depth (m)	Threshold (m/day)	Downwelling (%) in PDZ	Equivalent Days per year
50	1	87%	318
50	5	81%	296
100	1	95%	347
100	5	91%	339



In hourly snapshots of 100m in PDZ, Downwelling >1 m per day occurs, the equivalent of 347 days per year!

Permanent Downwelling Zone (PDZ) region Analysis

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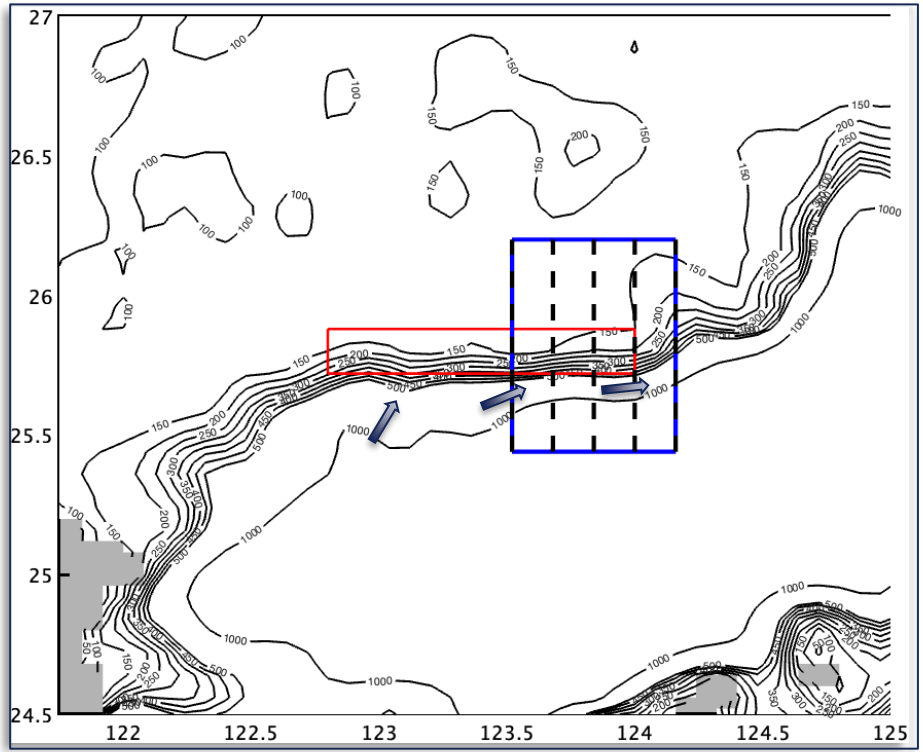

Cross-slope transects

- Visual of motion at the shelf break
- Kuroshio (V) and vertical motion (*w*)

Along zonal shelf-slope interface

- West of PDZ versus PDZ
- Impact of Horizontal flow

PDZ

- *w* at depth over time
- Seasonal differences

Cross-section analysis and seasonal variation

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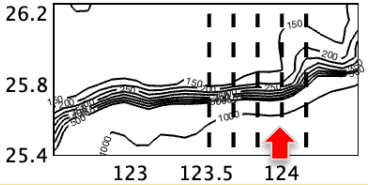
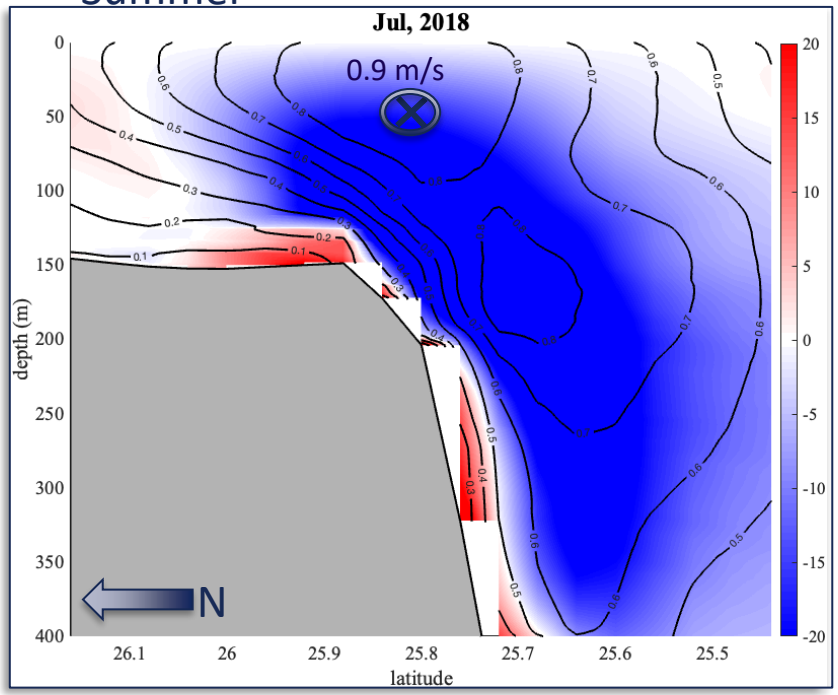
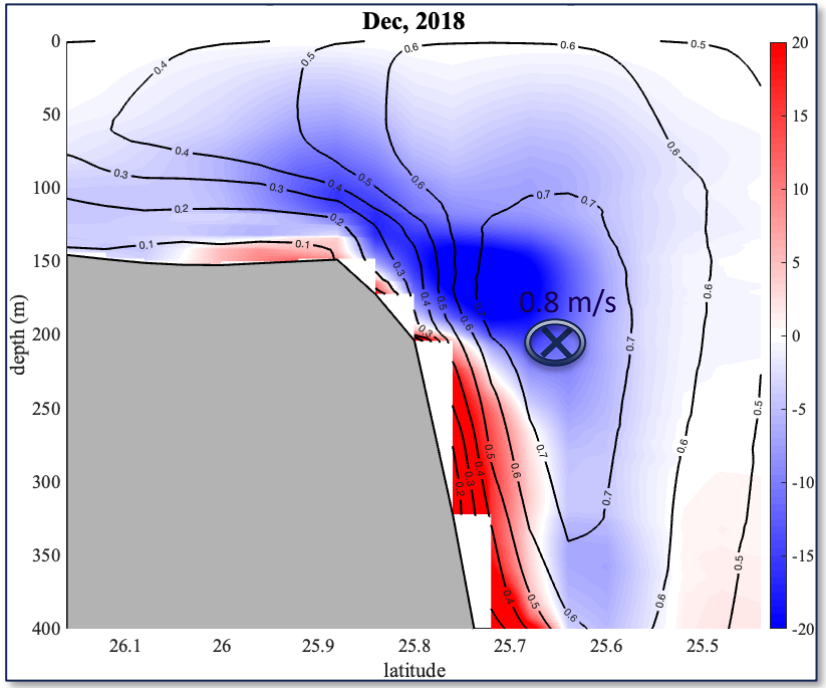


Summer

Cross-slope *u* (contours) and *w* (colorplot) for

Winter





Kuroshio and downwelling within the PDZ are both stronger in summer

⊗ *u* velocity is into page

Correlation Between Kuroshio Core and Downwelling at Slope

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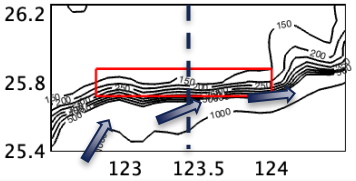

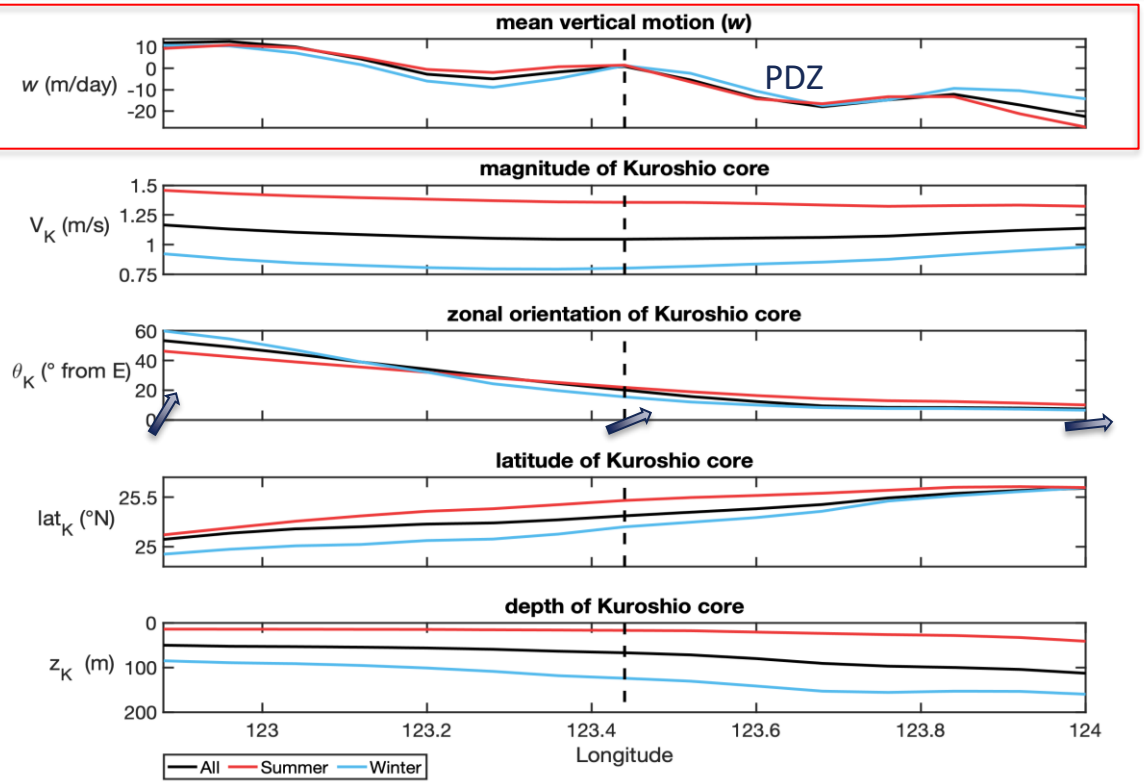

5 year mean along slope (m/day)

Season	West	PDZ
Summer	4.00	-13.5
Winter	0.81	-9.96
Total	2.85	-12.2

Kuroshio Core

- 0.5 m/s faster avg in Summer
  - 27% seasonal difference in *w*
  - 36% seasonal difference in K_{vel}
- Flow direction changes from NNE to Eastward in PDZ
- ~30km further North in summer.
  - Summer Max V_K @ 20m
  - Winter Max V_K @ 120
- Deeper in PDZ region

Correlation between Directional and Seasonal Variations of Kuroshio core and –*w* in PDZ

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Seasonality of the Downwelling Zone

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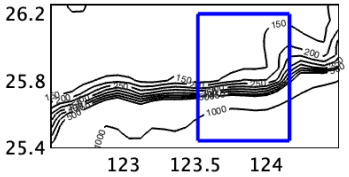
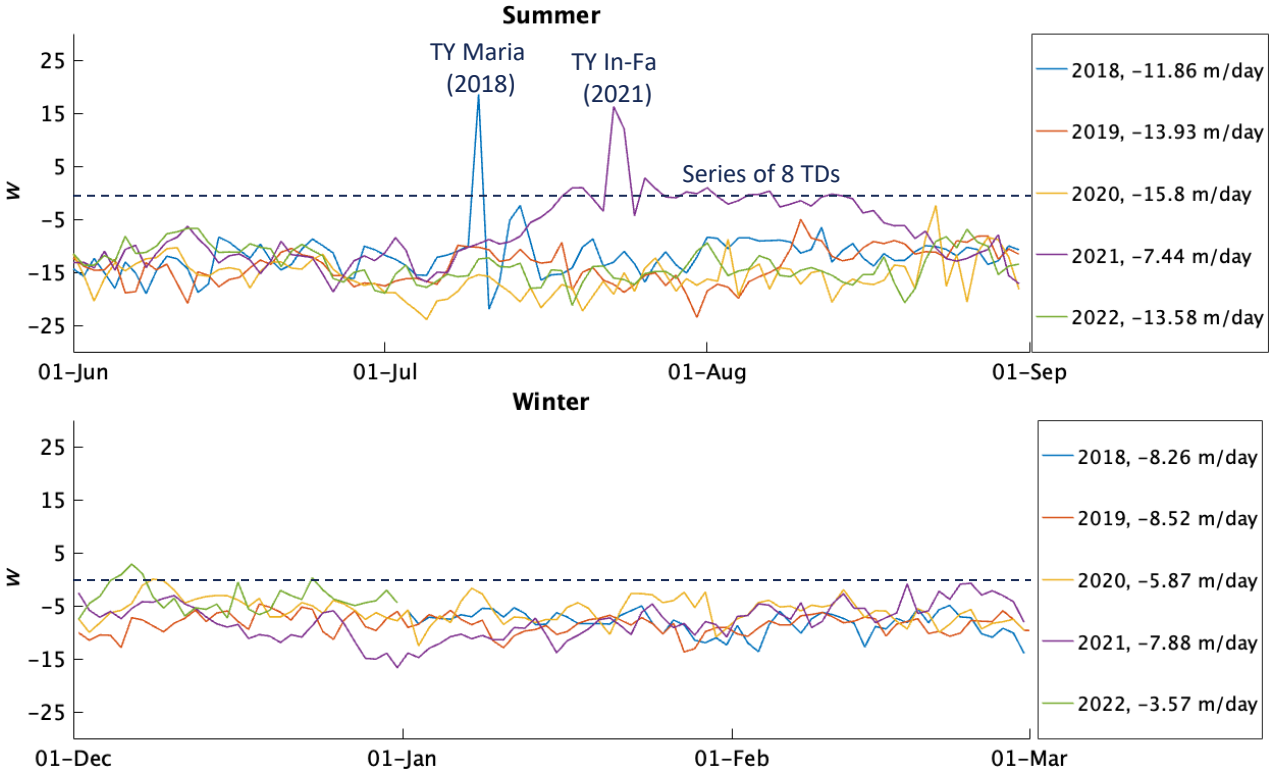


Daily mean *w* at 100m averaged over PDZ



Also, downwelling is twice as strong at 100m than at 50m

Annually, downwelling in summer is 2-times stronger and more erratic than in winter

Conclusions and Future Research

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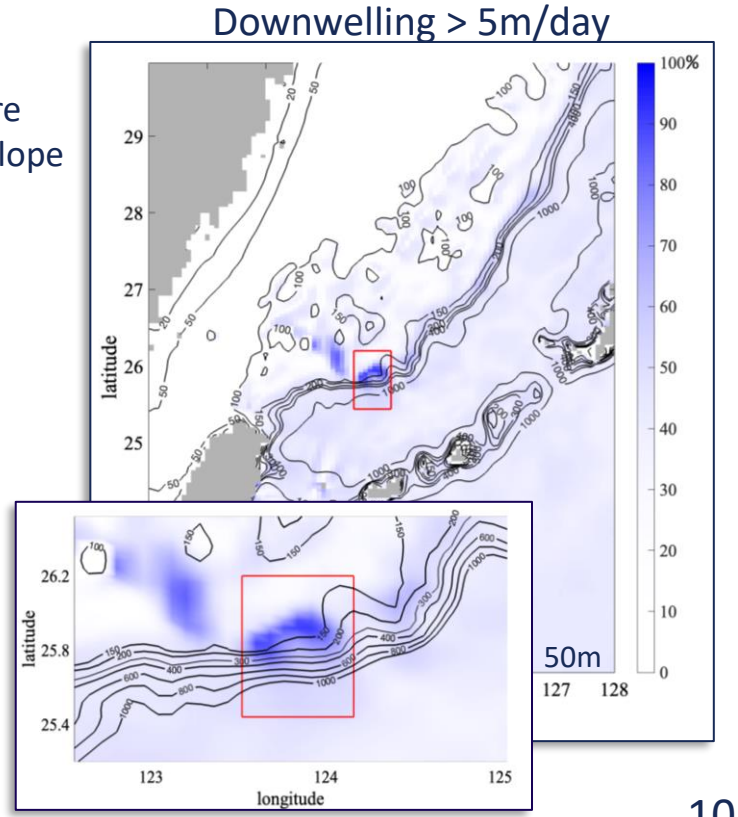
Regional HYCOM experiments were conducted to identify regions of strong vertical motion in East China and Yellow seas (ECSYS).

- HYCOM output shows a Permanent Downwelling Zone (PDZ) where the Kuroshio converges with and runs parallel to the continental slope
- Relationship exists between Kuroshio core and PDZ
  - Angle of incidence
  - Magnitude of flow
  - Proximity to shelf
  - Depth
- Seasonal variation exists in PDZ but it doesn't go away (not wind-driven)

The future of this study will examine:

- Physical causality of the PDZ
  - Upwelling beneath PDZ
- Increase model resolution in the vertical
  - Investigate other AOIs in the ECSYS
- Study effect of remote barotropic tides applied at BCs



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Merci beaucoup!

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