ROLE OF COASTAL UPWELLING IN THE GENERATION OF POTENTIAL FISHING ZONES IN THE SOUTH-WESTERN BAY OF BENGAL

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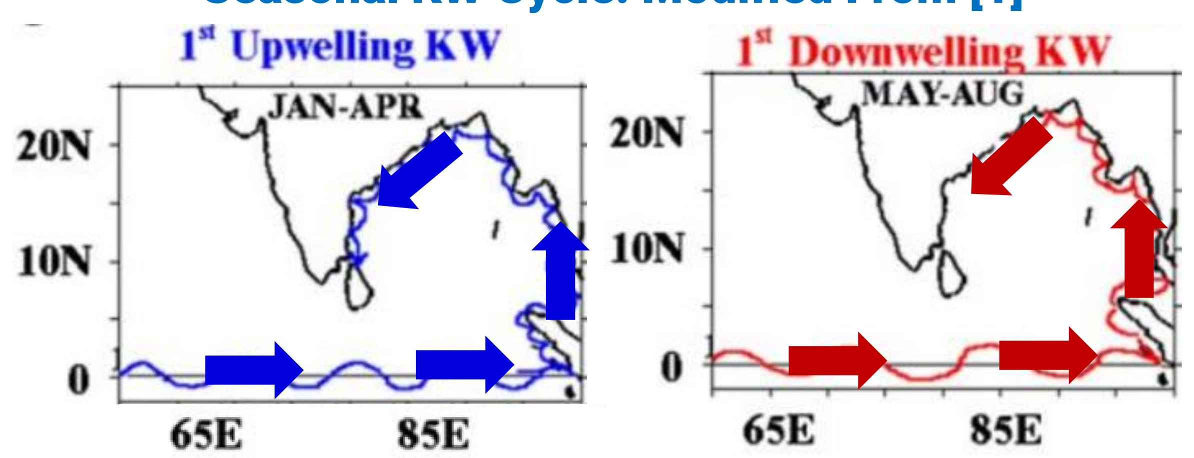
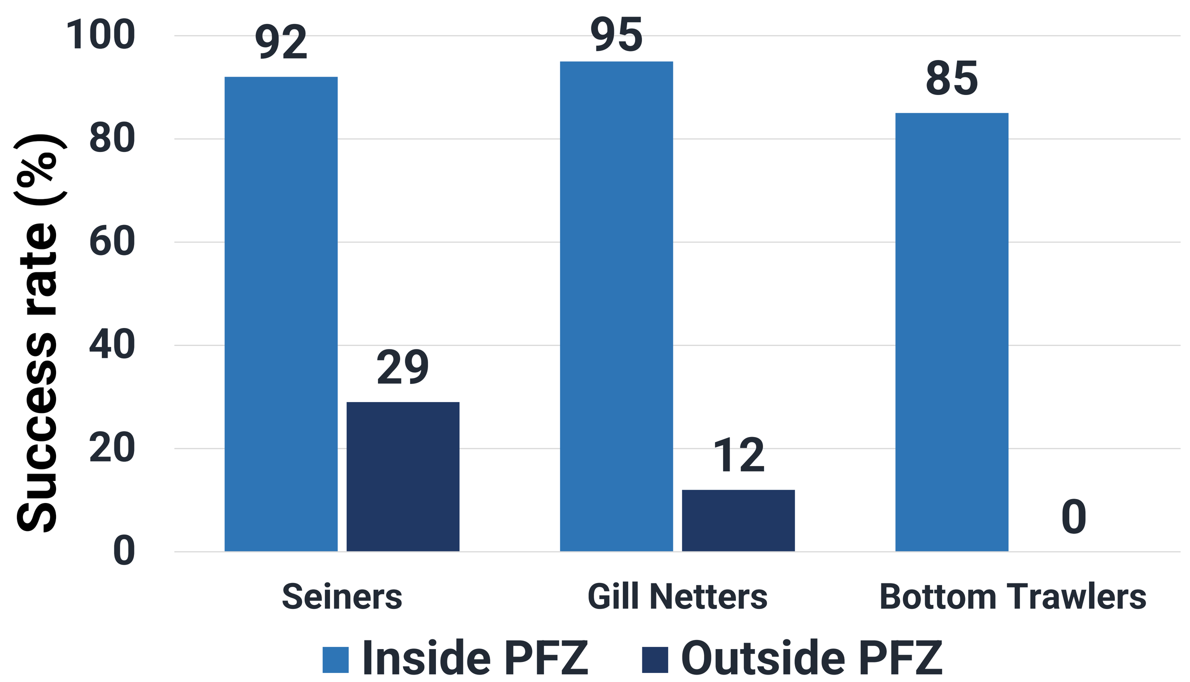
I. INTRODUCTION

- **Coastal Upwelling:** Upward flow resulting from local alongshore wind driven offshore Ekman transport (ET).
- Alternatively, it can also be driven by coastally trapped internal Kelvin waves, in the absence of local winds.
- Coastal upwelling is the most important physical process determining the biological productivity of coastal oceans.

Seasonal KW Cycle: Modified From [1]



- Commercial fishing operations are streamlined through **Potential Fishing Zone (PFZ)** advisories, typically associated with persistent SST fronts[2].
- Average increase in fishing success rate for different methods[3].

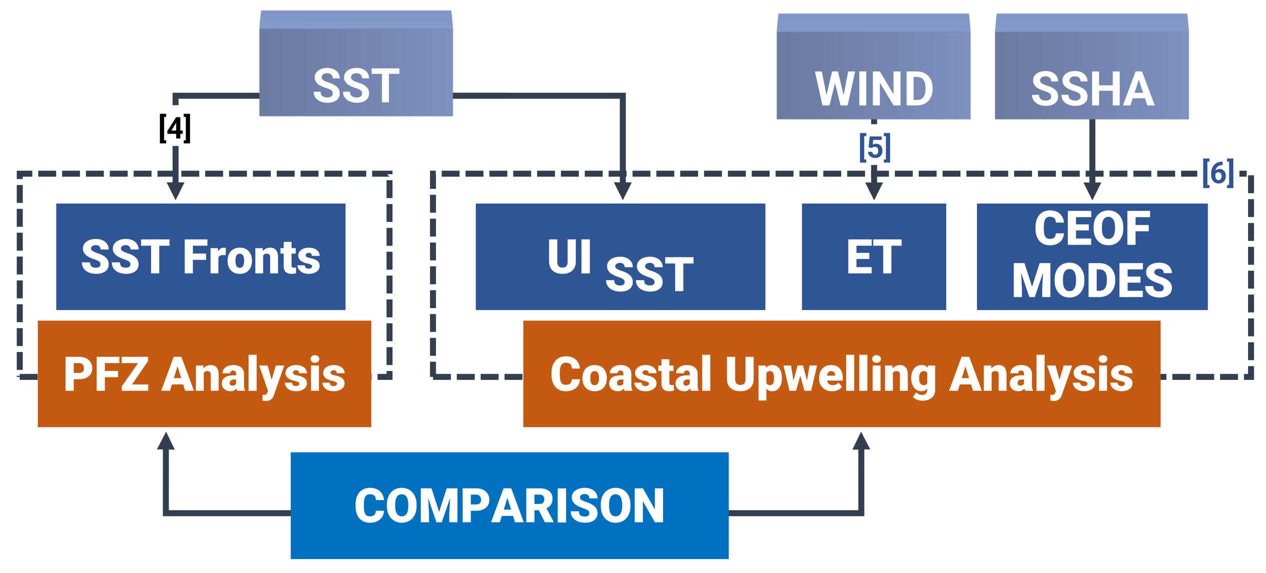


II. OBJECTIVES

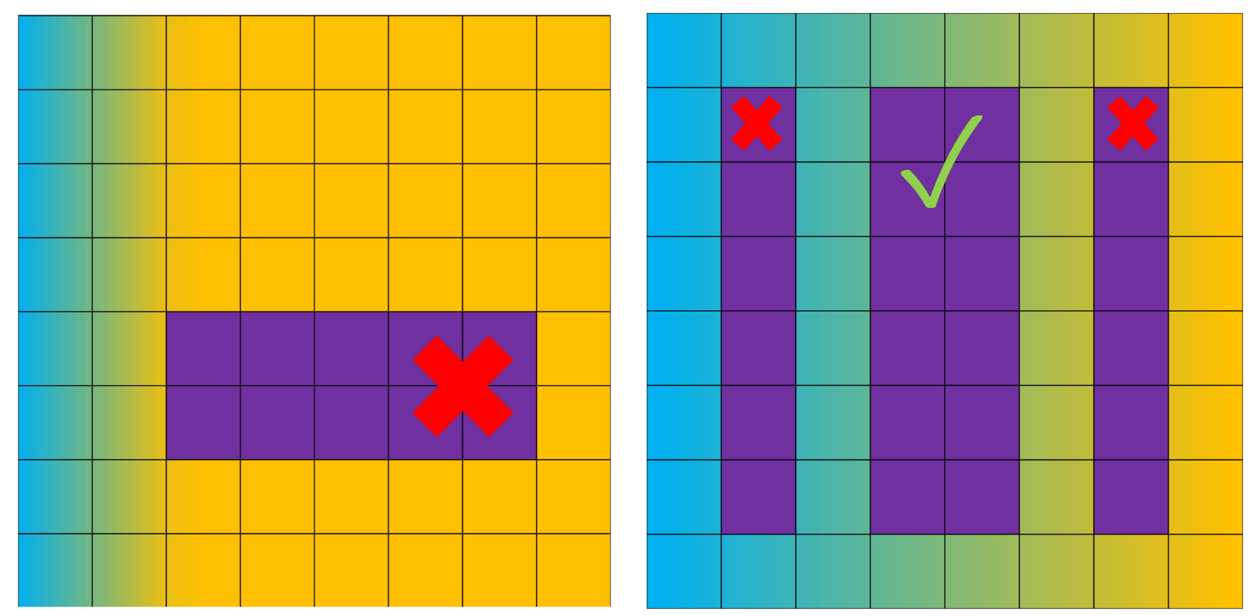
- **Characterize** PFZ occurrence in the SW Bay of Bengal
- Analyse the **connection** of PFZ generation with coastal upwelling.

III. METHODOLOGY

DATA: CMEMS Multi-satellite Reanalysis



Cayula and Cornillon Fronts

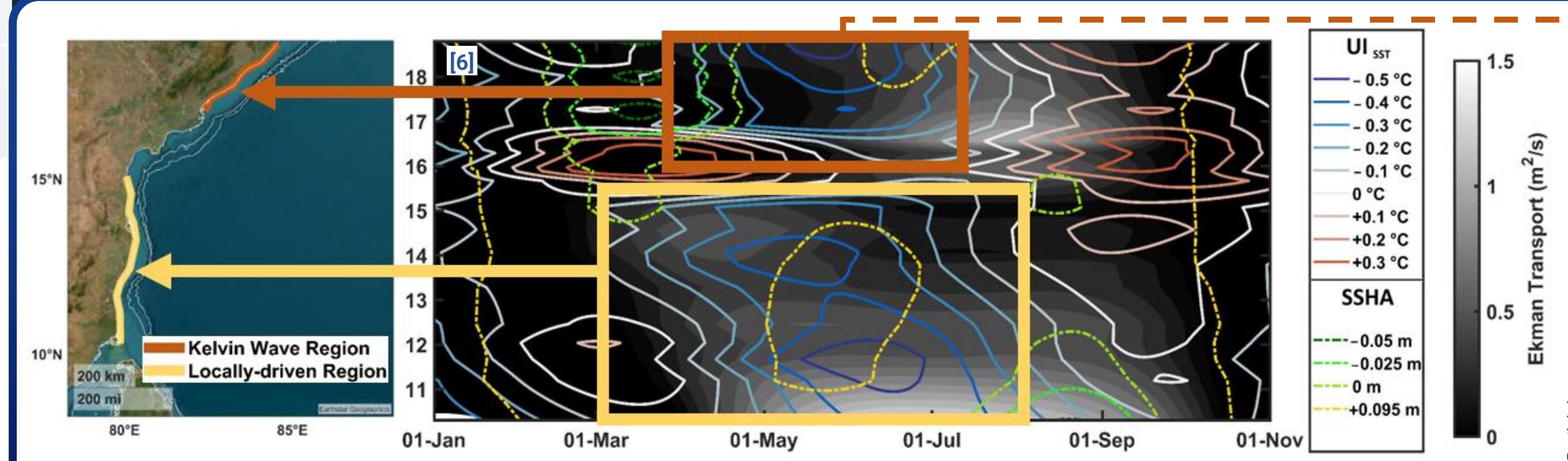


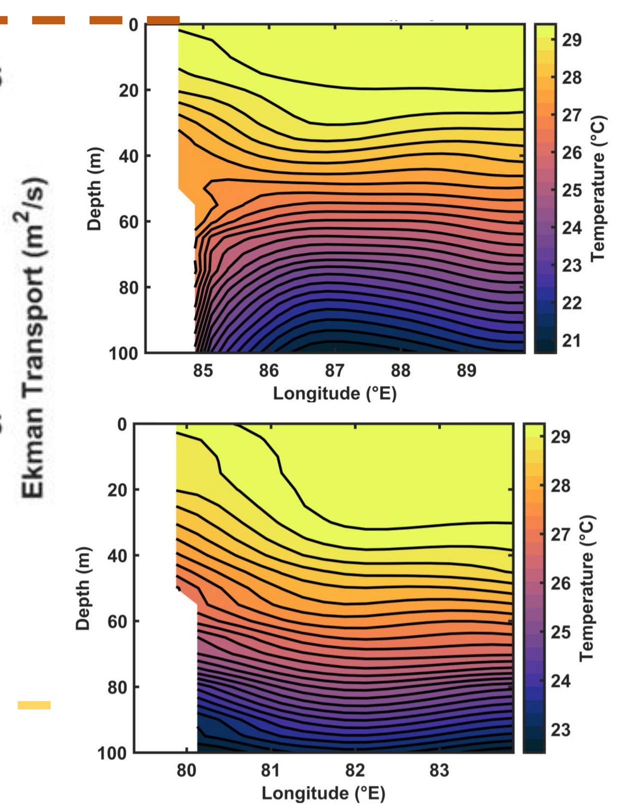
Front Detection (Cayula and Cornillon algorithm[4])

Histogram Analysis

Front Characterization: FPI and F1[7]

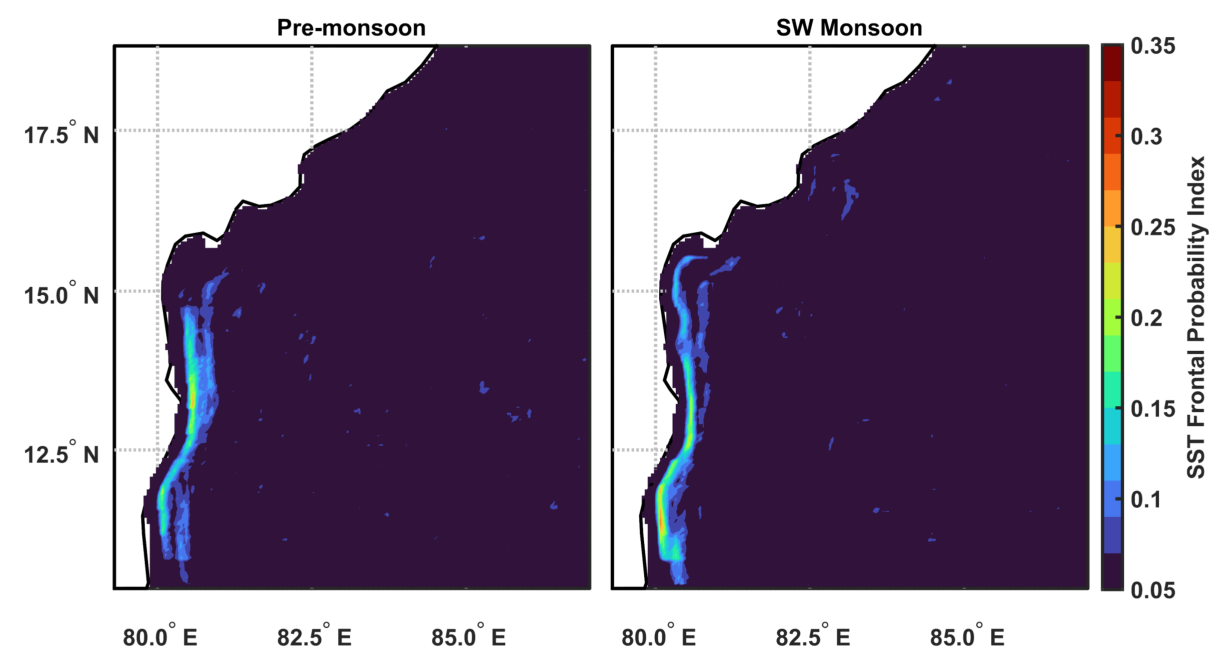
IV. THE BAY OF BENGAL COASTAL UPWELLING SYSTEM

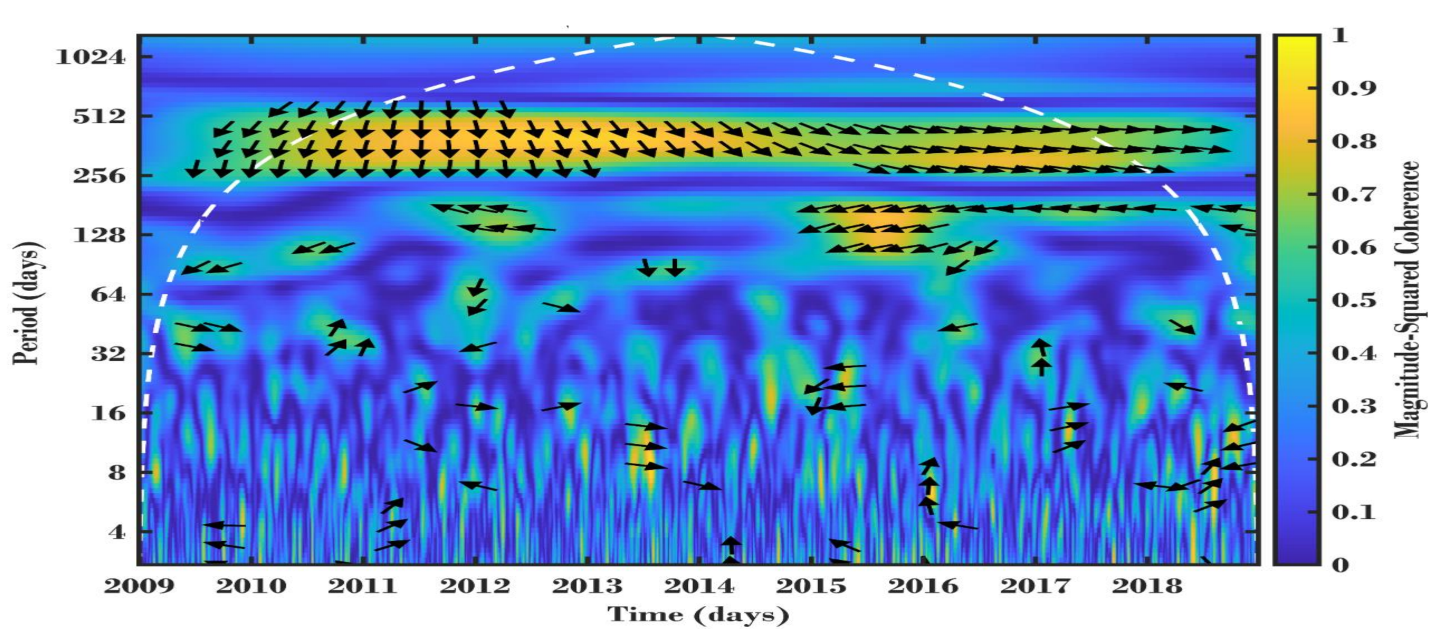




- **North:** Local wind driven upwelling
- **South:** Remote coastal Kelvin wave driven upwelling

V. POTENTIAL FISHING ZONE GENERATION





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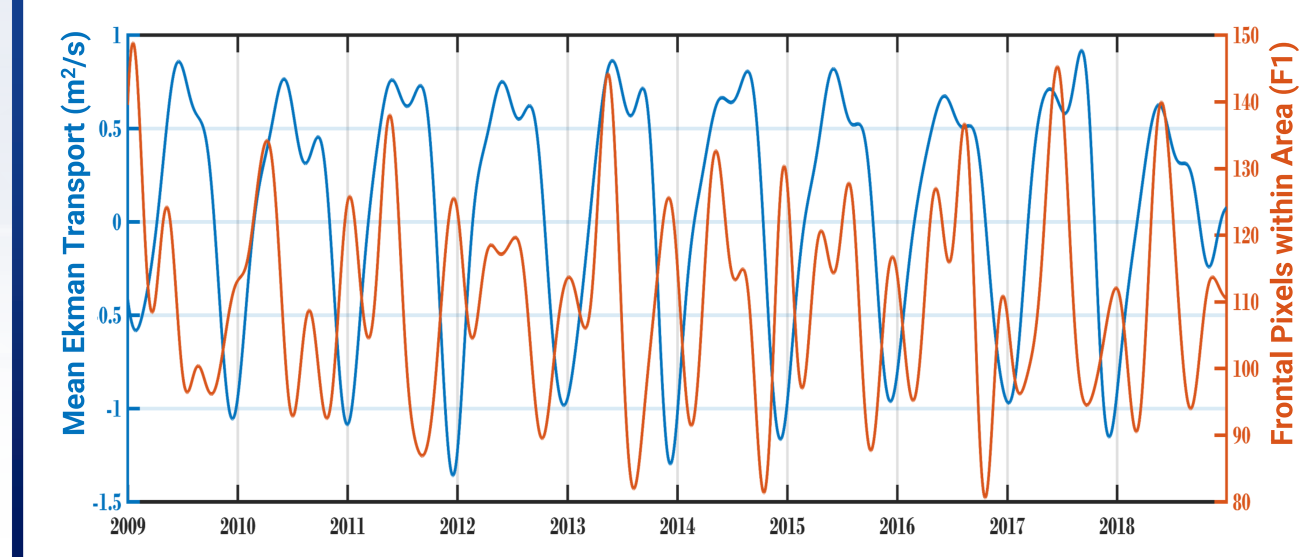

VI. CONCLUSIONS

- PFZ Generation is **only observed for the stronger locally driven system (south)**, not for the remotely driven one (north).
- Frontal activity is strongly **coherent** with local upwelling wind forcing at seasonal time periods in the south.
- **Peak PFZ** activity is observed during the season of **maximum upwelling-favouring Ekman transport** in the south.

References:

[1] Rao RR, Kumar MG, Ravichandran M, Rao AR, Gopalakrishna VV, Thadathil P. Interannual variability of Kelvin wave propagation in the wave guides of the equatorial Indian Ocean, the coastal Bay of Bengal and the southeastern Arabian Sea during 1993–2006. Deep Sea Research Part I: Oceanographic Research Papers. 2010 Jan 1;57(1):1-3. | **[2]** Chakraborty K, Maity S, Lotliker AA, Samanta A, Ghosh J, Masuluri NK, Swetha N, Bright RP. Modelling of marine ecosystem in regional scale for short term prediction of satellite-aided operational fishery advisories. Journal of Operational Oceanography. 2019 Nov 20;12(sup2):S157-75. | **[3]** Tummala SK, Masuluri NK, Nayak S. Benefits derived by the fisherman using Potential Fishing Zone (PFZ) advisories. InRemote sensing of inland, coastal, and oceanic waters 2008 Dec 19 (Vol. 7150, pp. 127-138). SPIE. | **[4]** Cayula JF, Cornillon P. Edge detection algorithm for SST images. Journal of atmospheric and oceanic technology. 1992 Feb;9(1):67-80. | **[5] Ray, S., & Swain, D. (2023). A Systematic Method of Estimation of Alongshore Windstress and Ekman Transport Associated with Coastal Upwelling. *MethodsX*, 102186**

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Role of Coastal Upwelling in the Generation of Potential Fishing Zones in the South-Western Bay of Bengal

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Abstract

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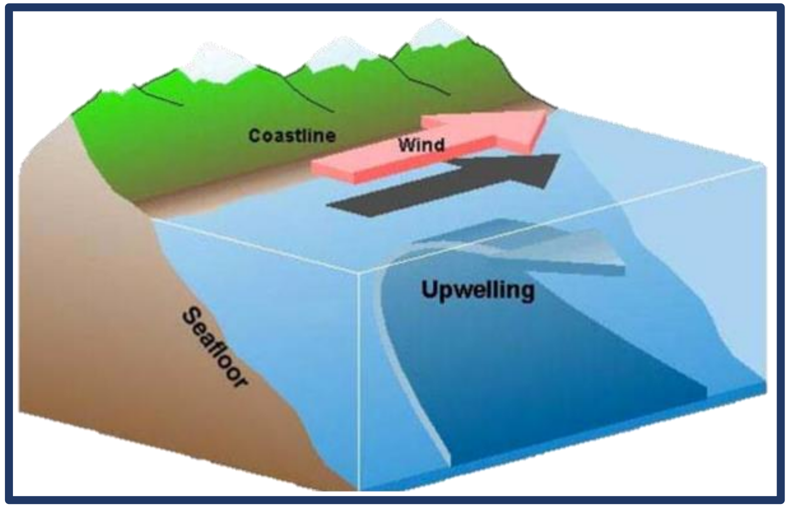
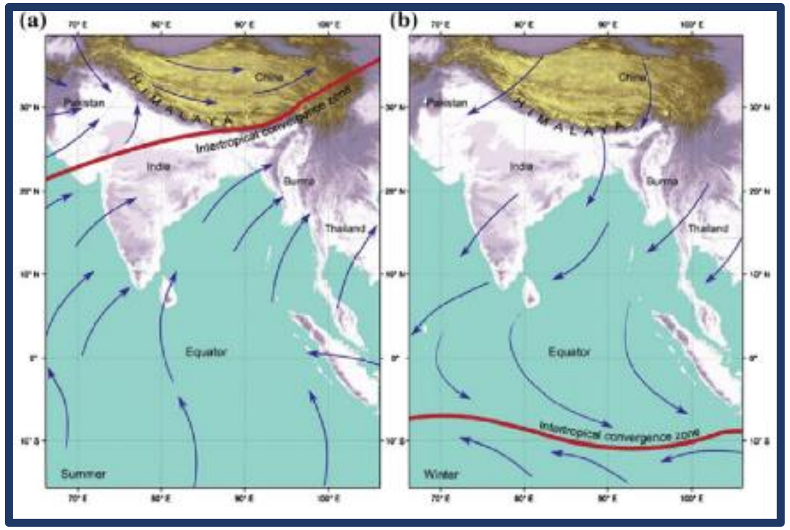
I. Introduction

Locally Forced Coastal Upwelling

https://oceanexplorer.noaa.gov/facts/upwelling.html



Bibi & Métais, 2016

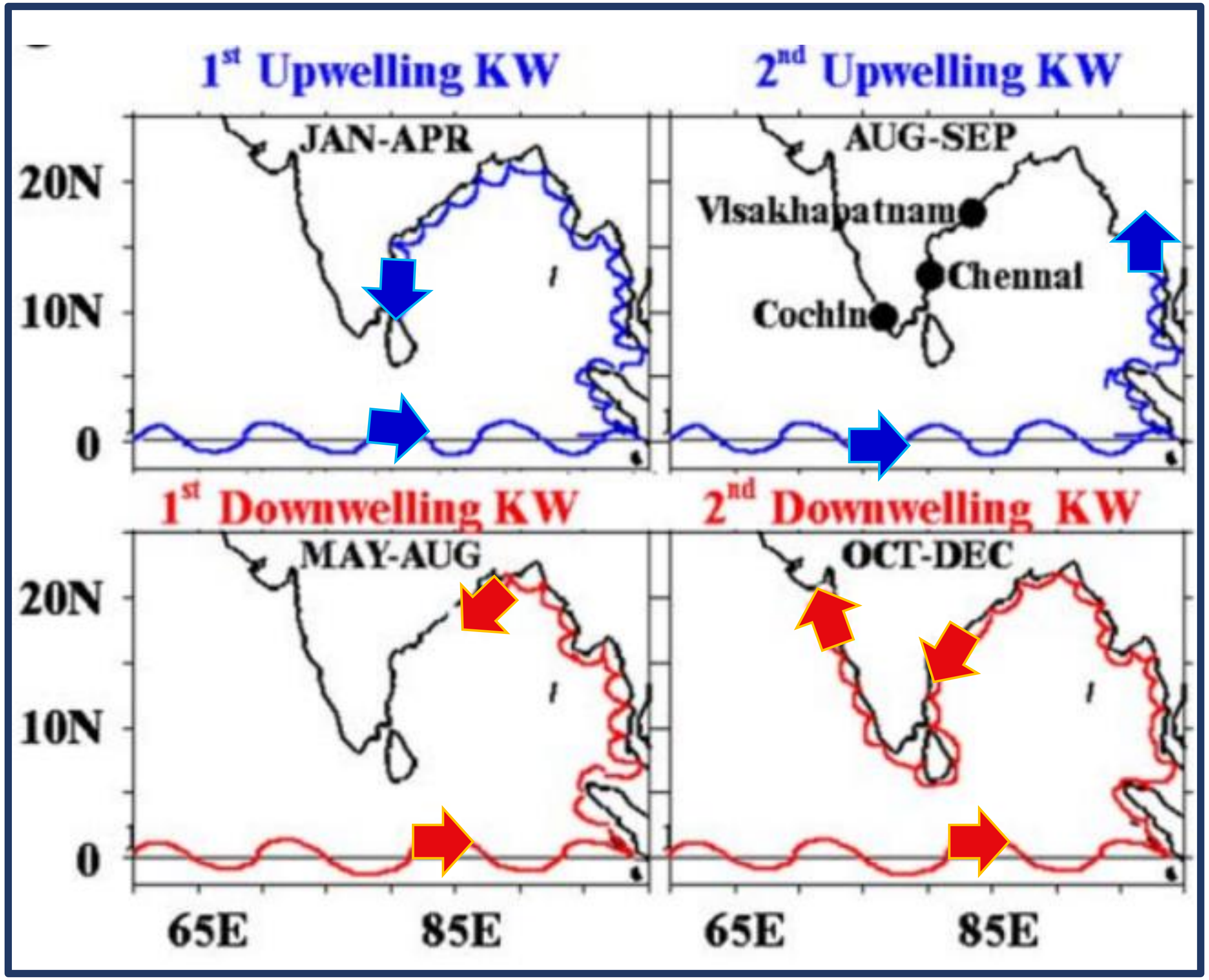


- **Coastal upwelling – upward movement of nutrient rich waters along coast.**
- The most important physical process driving **ocean productivity**.
- Nutrient enrichment by upward vertical velocities driven by positive alongshore windstress **(AWS) and** resulting in offshore **Ekman Transport (ET).**
- In the **South West Bay of Bengal** peak AWS occurs in pre-monsoon and Southwest Monsoon.

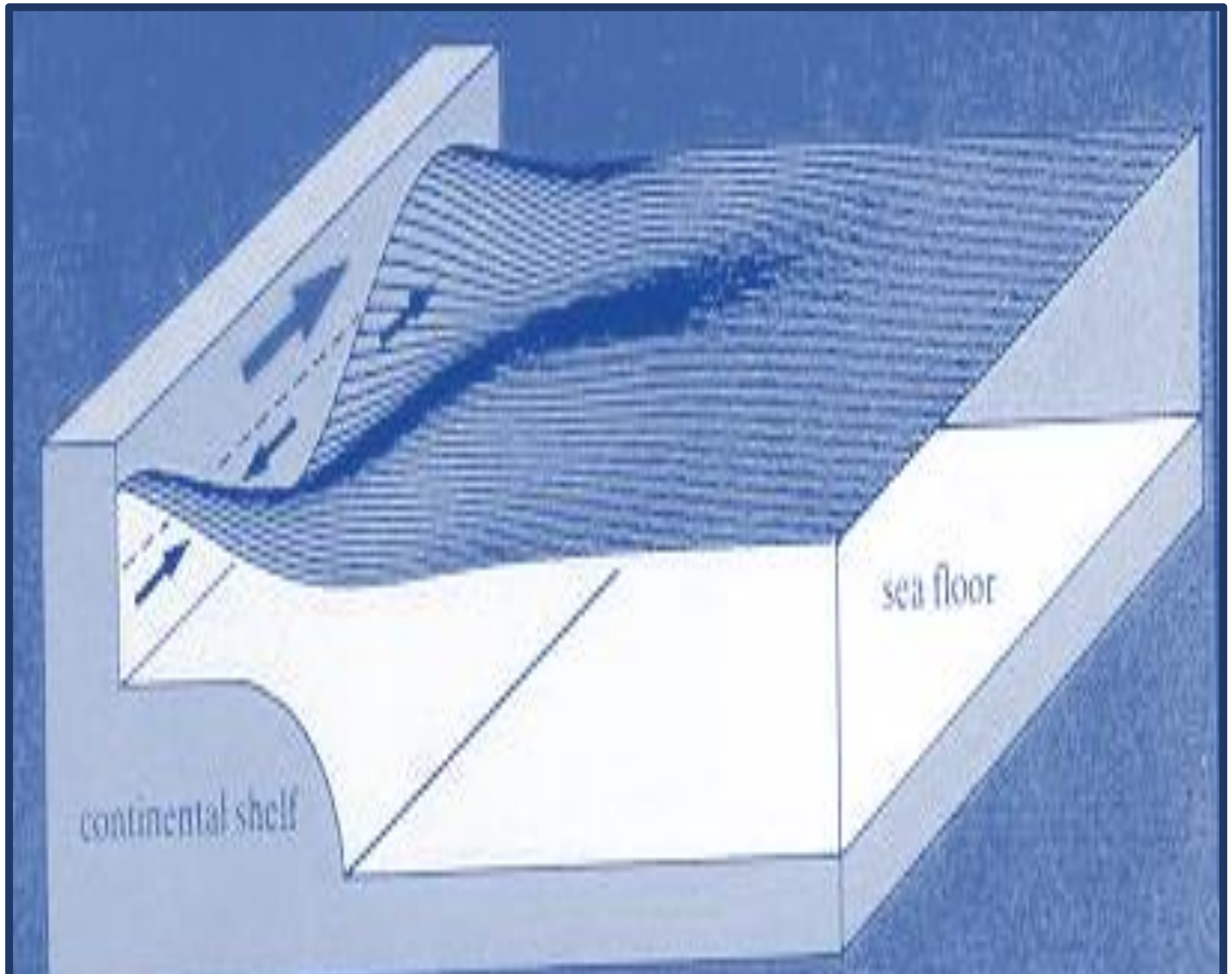
Remotely Forced Coastal Upwelling

- Coastal Upwelling can also be driven by coastally trapped **Kelvin waves**.
- These are sea surface **height variations along topographic boundaries** in the ocean that propagate along these boundaries.
- They **modulate the nutracline depth**, sometimes bringing nutrients into the surface euphotic layer, leading to phytoplankton blooms.

Seasonal Cycle of Kelvin waves

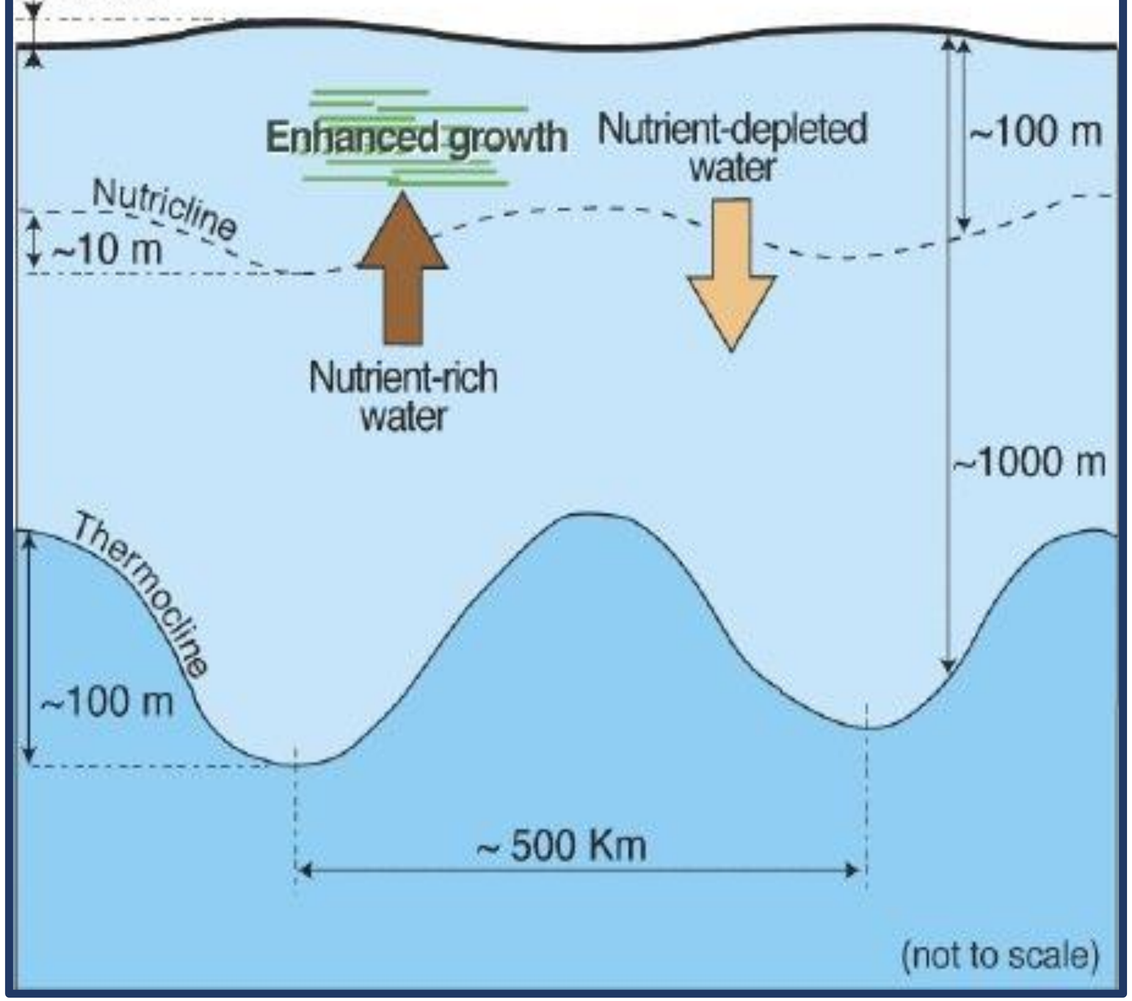


Modified from Rao et al., 2010



http://www.physocean.icm.csic.es/ShelfCoast/chapter08-en.html

Coastally trapped Kelvin wave propagation

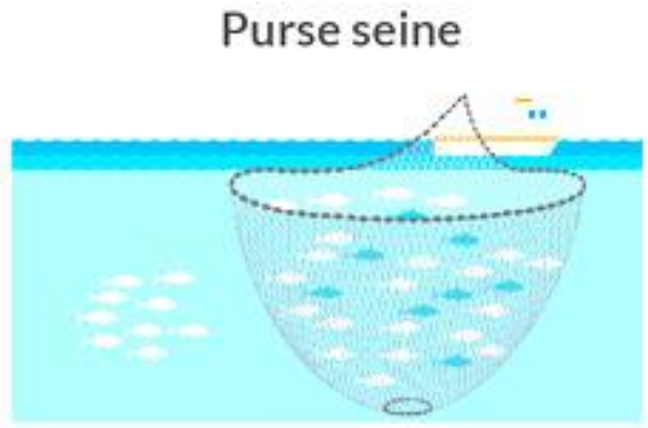


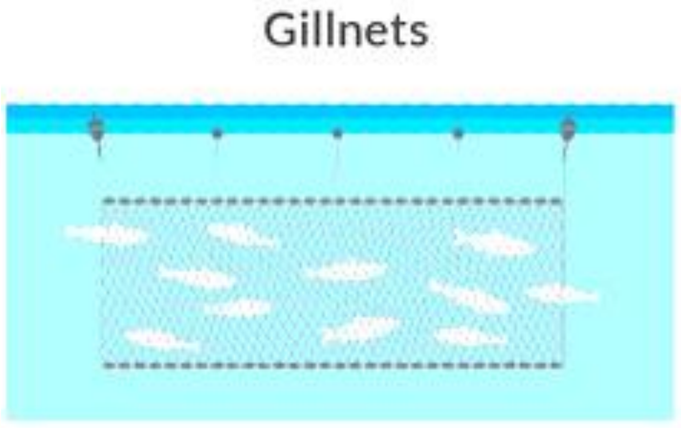
Modified from Cipollini, 2006

Kelvin wave coastal upwelling

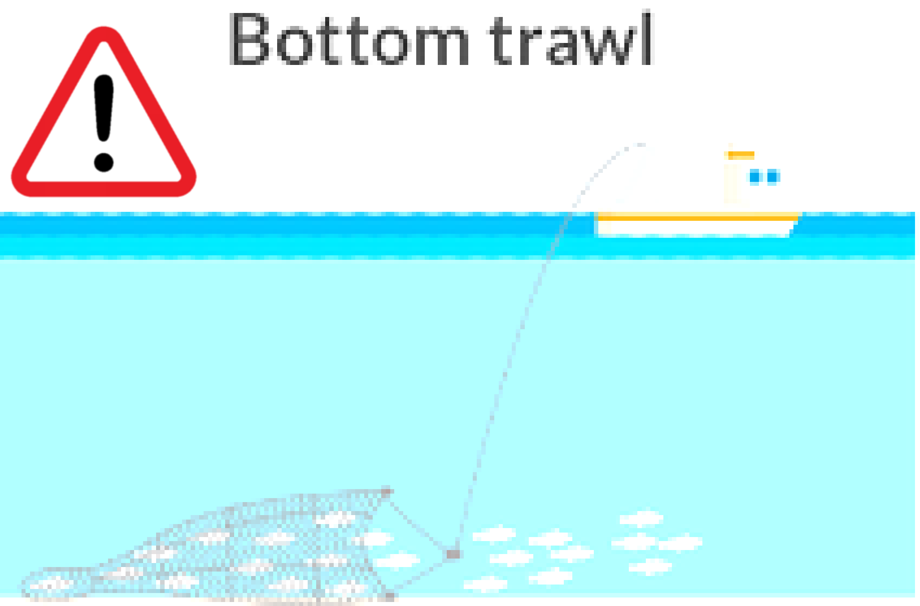
Commercial Marine Fishing & Potential Fishing Zones

- Total Fish Production (India): 12.60 million metric tonnes
- Annual potential yield from the EEZ: 3.93 million tonnes
- Potential fishing zones (PFZs) are areas of fish aggregation in the ocean.
- PFZs are detected from SST (and surface Chlorophyll-a when available).



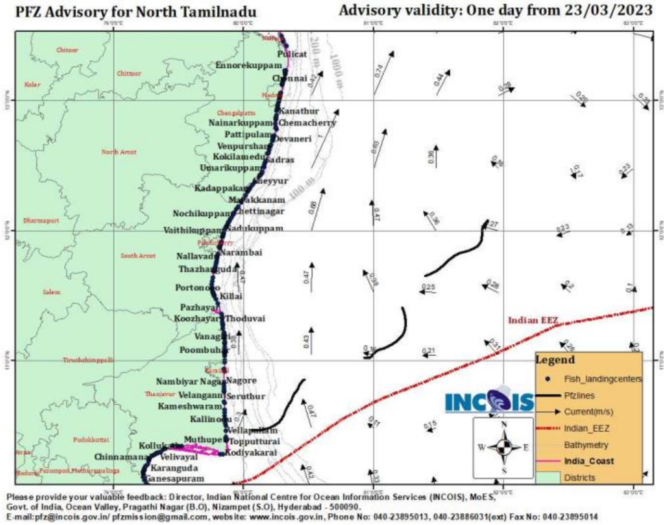


Tummala et al., 2008 18 controlled experiments	**Inside PFZ**	**Outside PFZ**
Average Catch Per Unit Effort	**3464 Kgs**	**793 Kgs**
Average net profit per vessels	**Rs.68,683**	**Rs.14,260**
Seiners: Average success rate	92 %	29 %
Gill netters: Average success rate	95 %	12 %
Bottom Trawlers: Average success rate	**85 %**	**0 %**



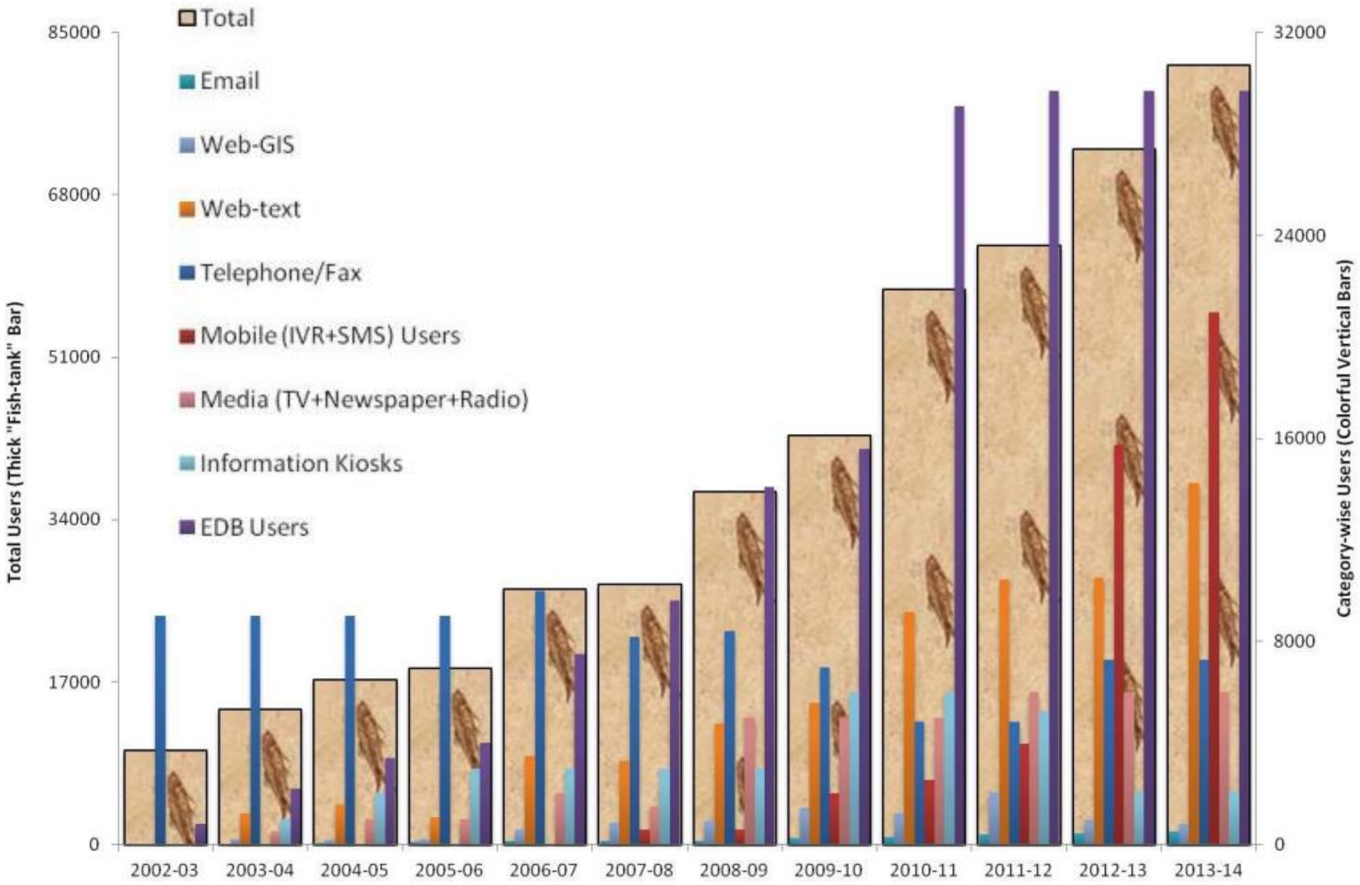
https://ourworldindata.org/fish-and-overfishing#methods-of-fishing

INCOIS PFZ Advisory



Electronic Display Board (EDB)

https://nfdb.gov.in/



https://incois.gov.in/documents/ITCOocean/PFZ_forTrainer&Operators_OSF_web.pdf

- Indian Marine Fishery Advisory System was set up to provide PFZ advisory through INCOIS.
- PFZ advisory distributed through Phone, SMS, EDBs, etc.
- Serves 3.17 lakhs of users directly or through partner organizations.

II. OBJECTIVES

1. Characterize PFZ occurrence in the SW Bay of Bengal

2. Analyse the connection of PFZ generation with coastal upwelling.

III. Methodology

DATA

Multi-satellite

reanalysis

Zonal & Meridional Windstress
Sea Surface Temperature
Sea Surface Height Anomaly

Upwelling Indices

$$\mathrm{AWS} = -\frac{\mathrm{abs(lat)}}{\mathrm{lat}}\left(\tau_x \cos\left(\theta - \frac{\pi}{2}\right) + \tau_y \sin\left(\theta - \frac{\pi}{2}\right)\right)$$

$$\mathrm{ET} = \frac{AWS}{\rho f}$$

Ray & Swain., 2023

$$UI_{SST} = SST_{coast} - SST_{offshore}$$

Kelvin wave identification

Complex EOF Analysis of SSHA

- Hilbert Transform of data
- SVD of autocovariance matrix of complex data
- PC modes consists of **lagged excitations**

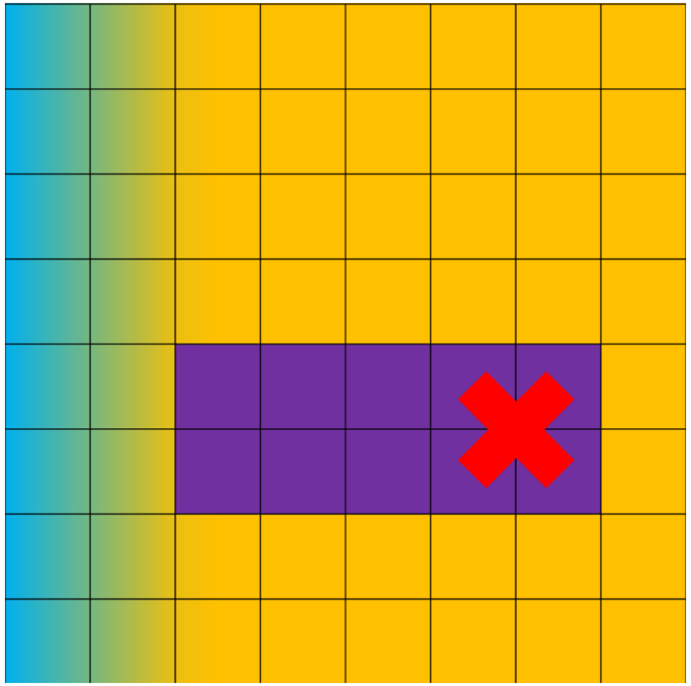
Frontal Analysis Methodology

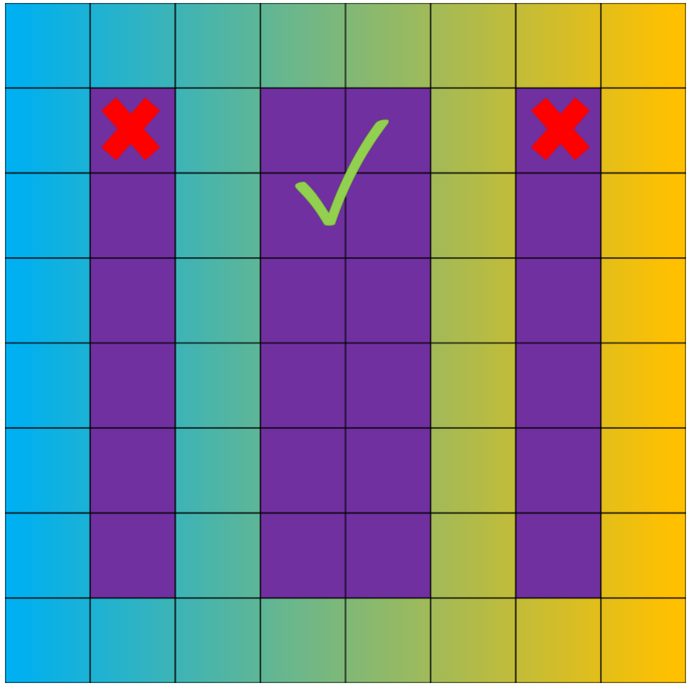
SST Front Detection

Cayula Cornillon SIED

(Cayula and Cornillon, 1992)

1. **Histogram Analysis**
2. Cohesion Test
3. Edge Detection
4. Edge Verification





Characterization of Fronts

Belkin et al., 2009

FPI = N/C

F1: sum of number of frontal pixels in an area

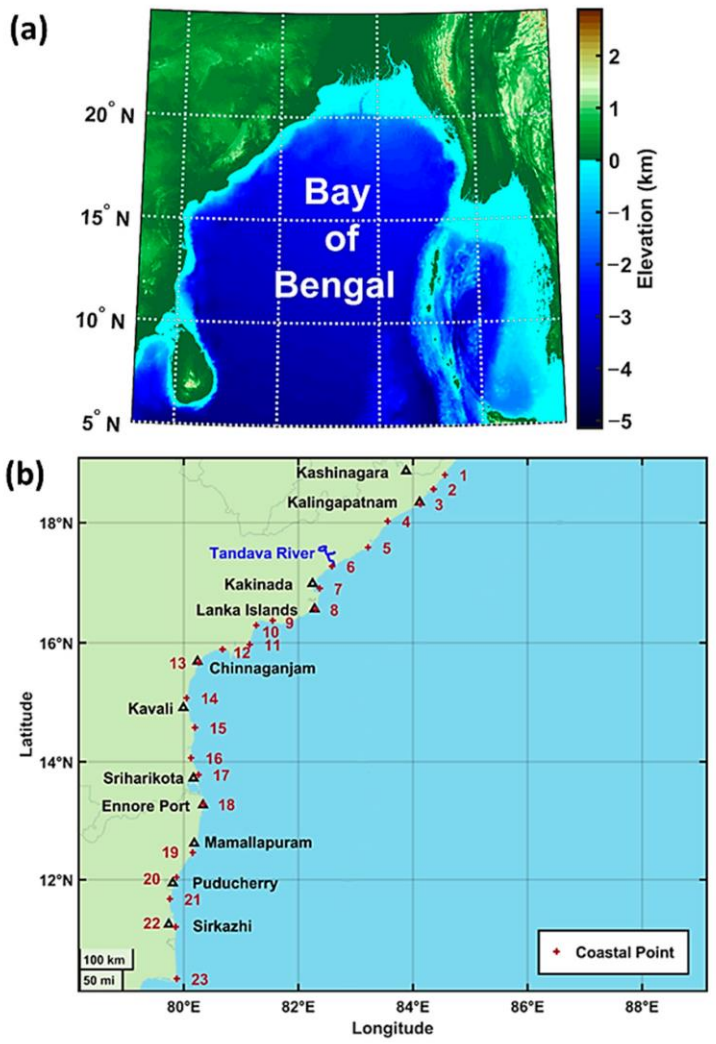
Front Characterization following Belkin et al., 2009

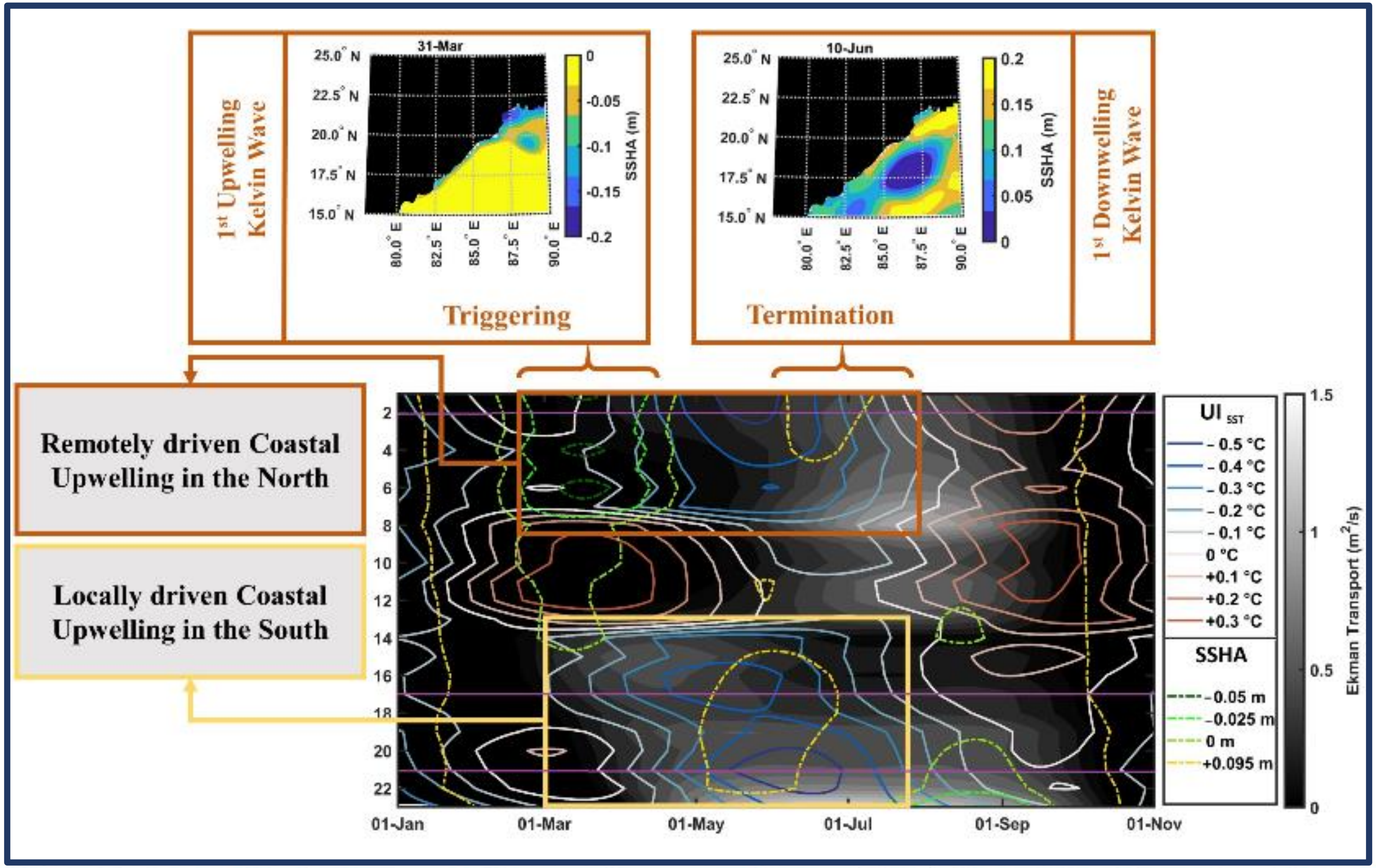
1. Long term mean frontal frequency maps
2. Weekly Composite Frontal Maps

Frontal activity – Upwelling Index Covariation

IV. The Bay of Bengal Coastal Upwelling System

Ray et al., 2022

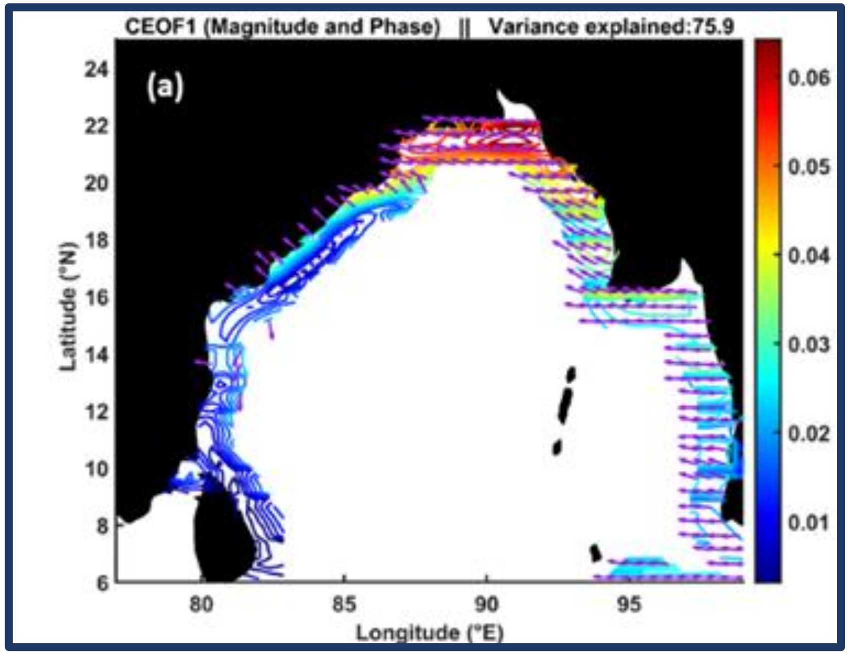


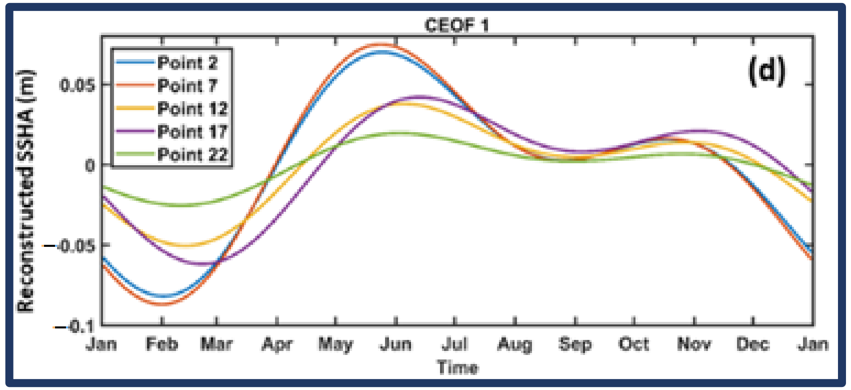


Kelvin wave propagation & sub-surface variations

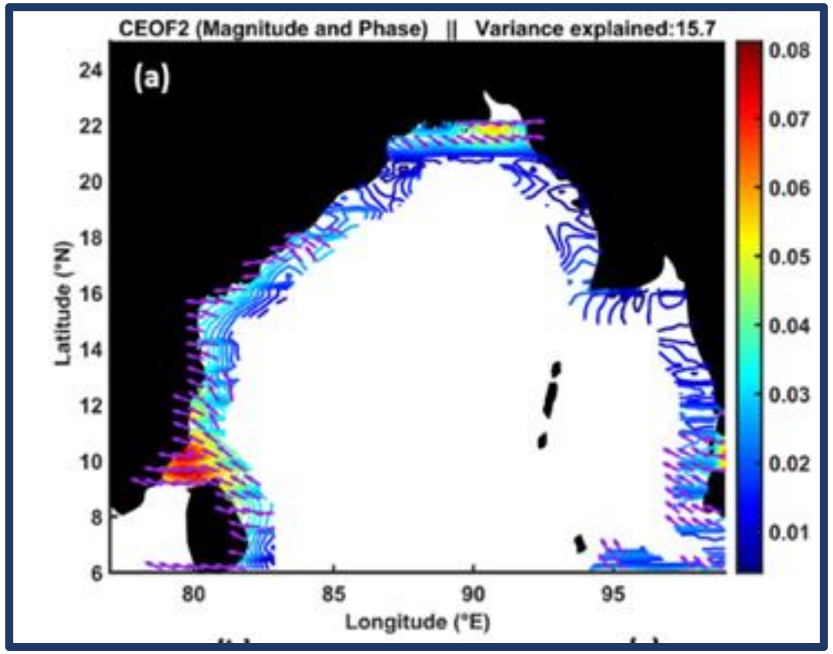
Ray et al., 2022

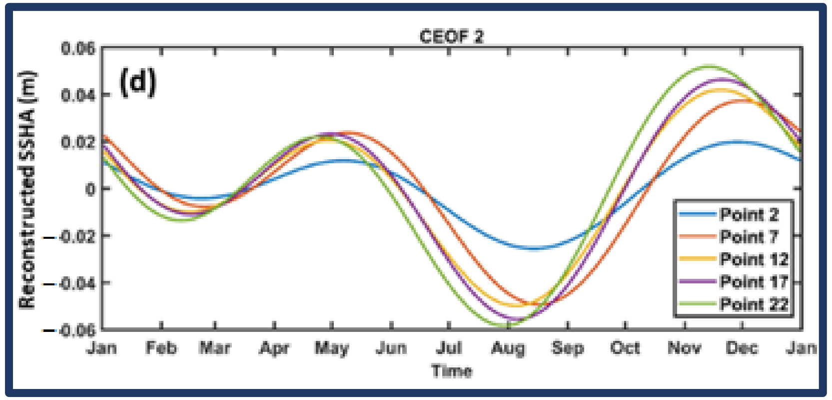
Remotely Driven Mode

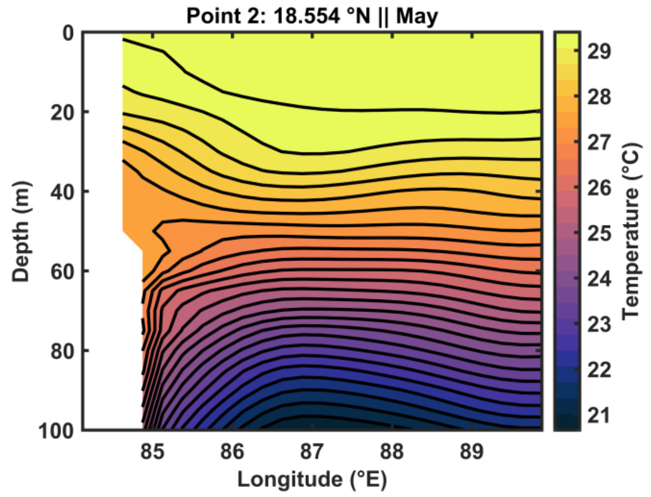


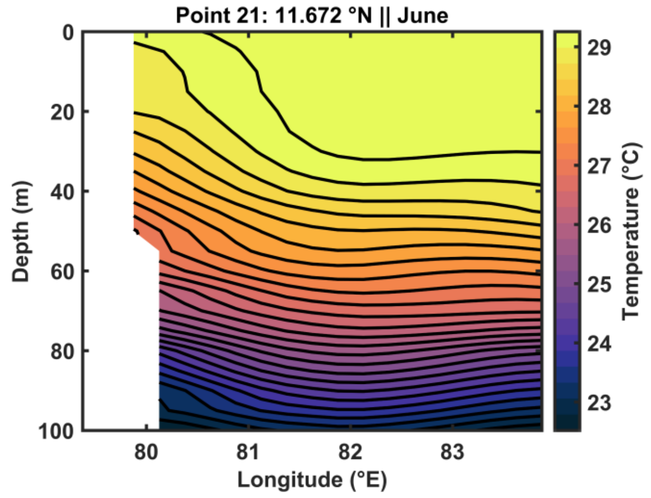


Locally Driven Mode



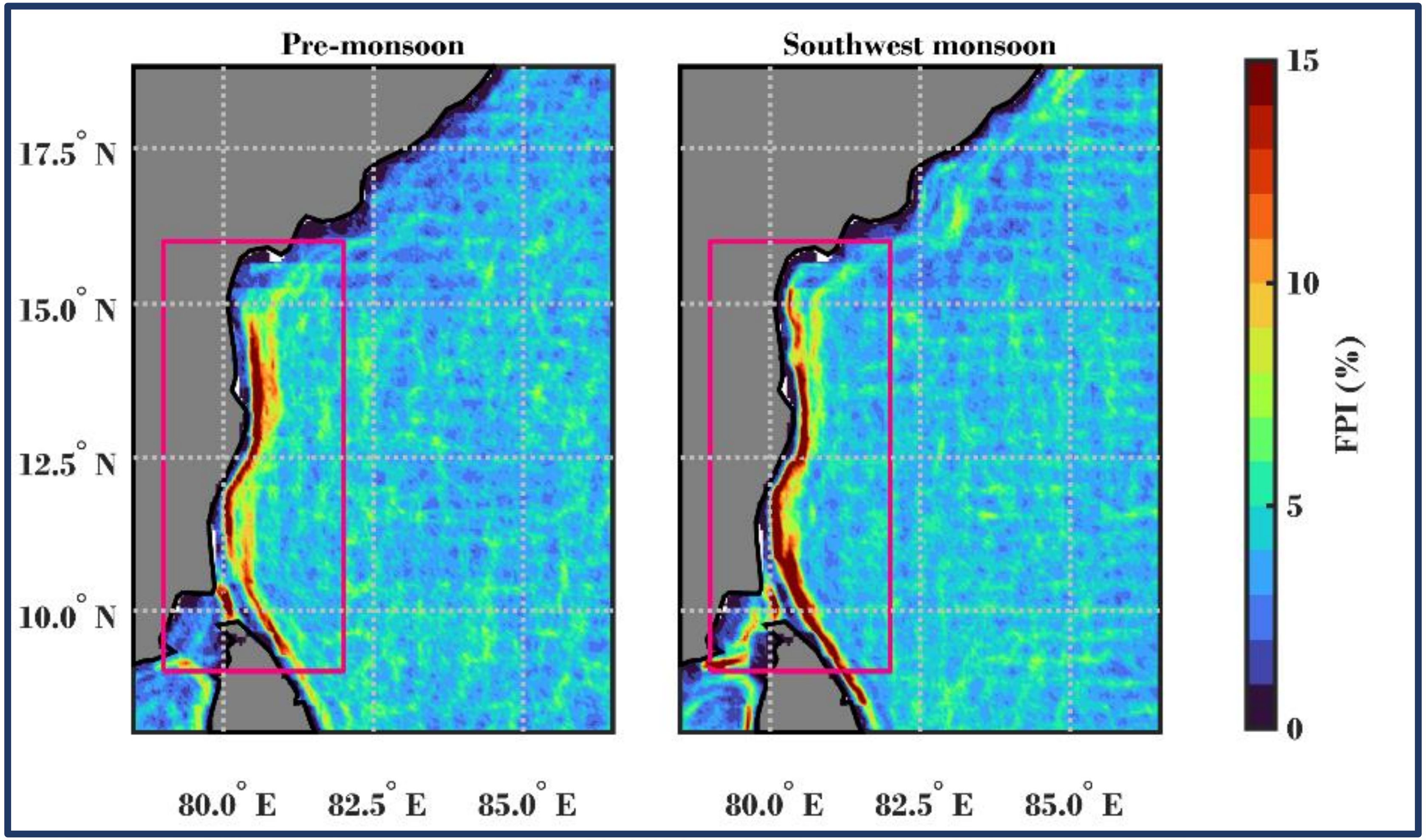




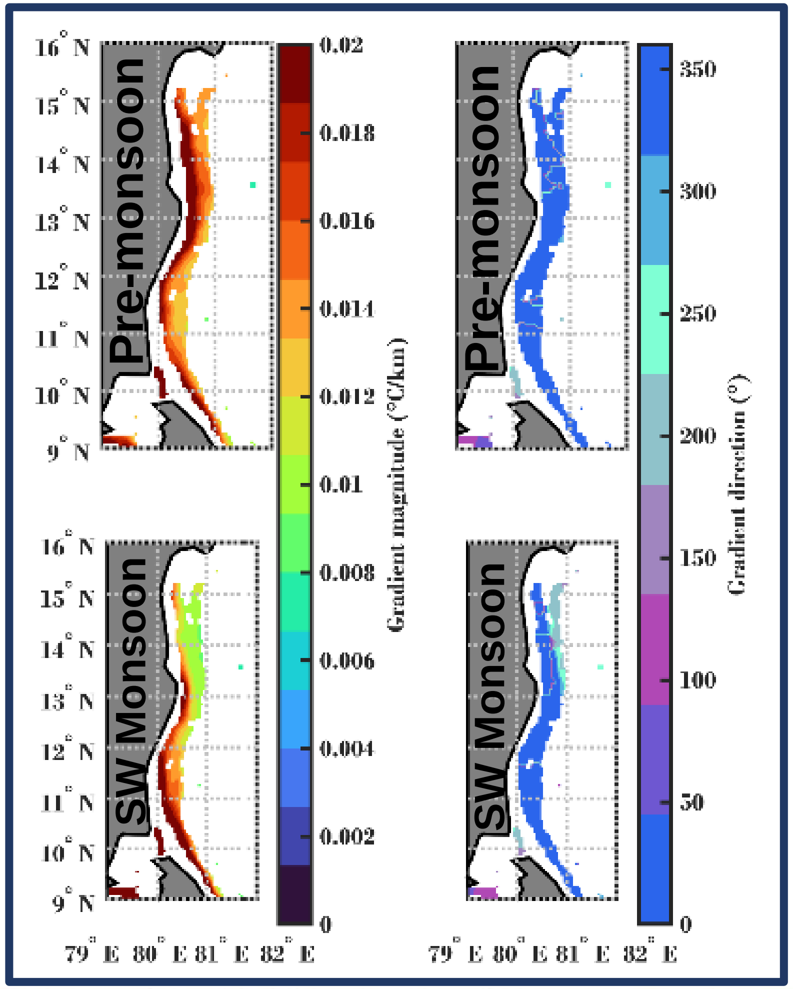


V. Potential Fishing Zones

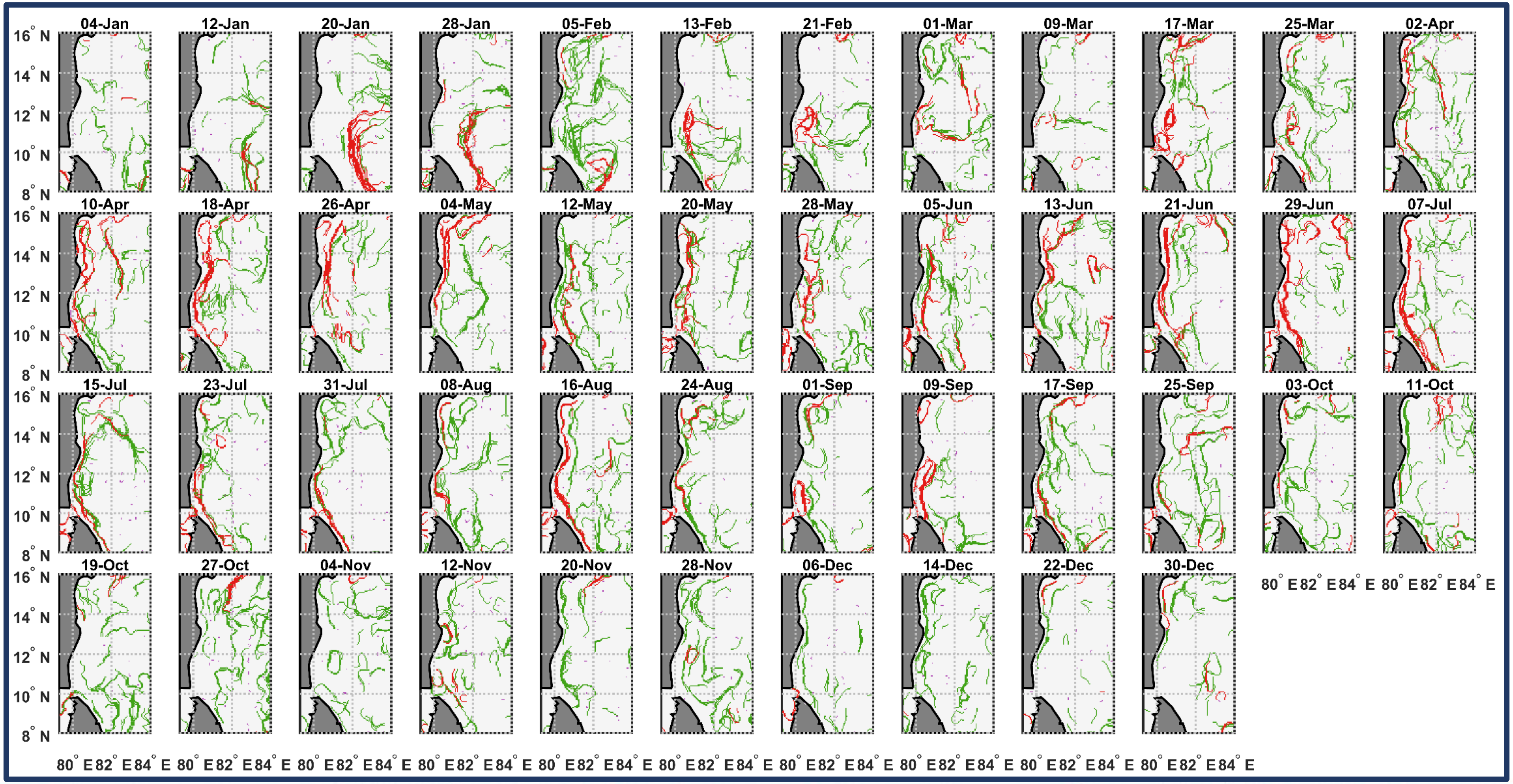
Long term mean frontal frequency maps



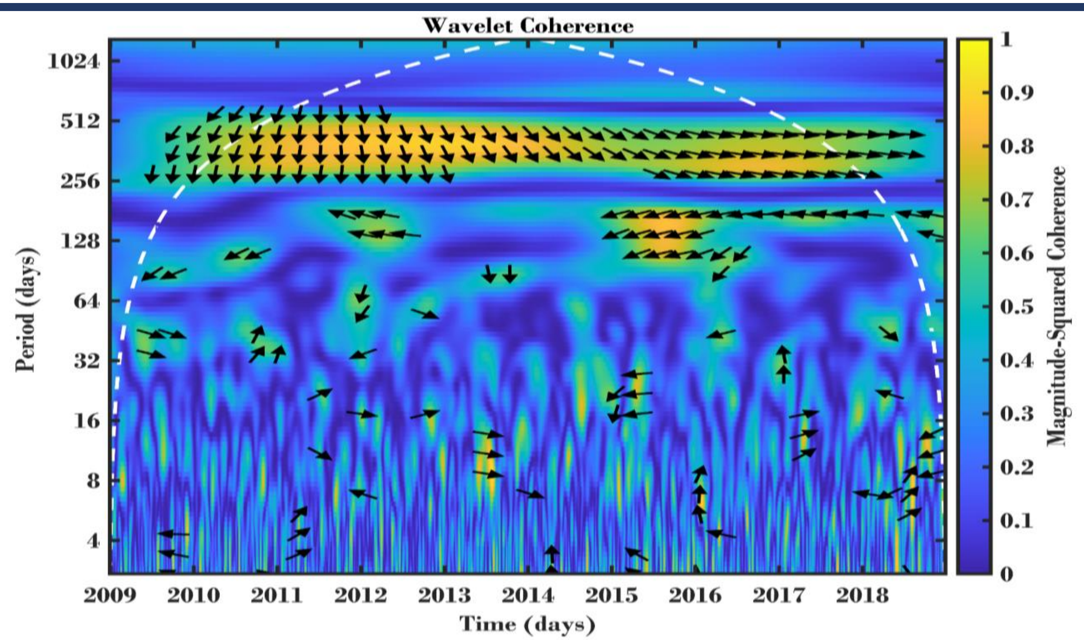
Long term mean frontal gradient



Weekly Composite Frontal Maps: Increase in nearshore fronts in SW Monsoon

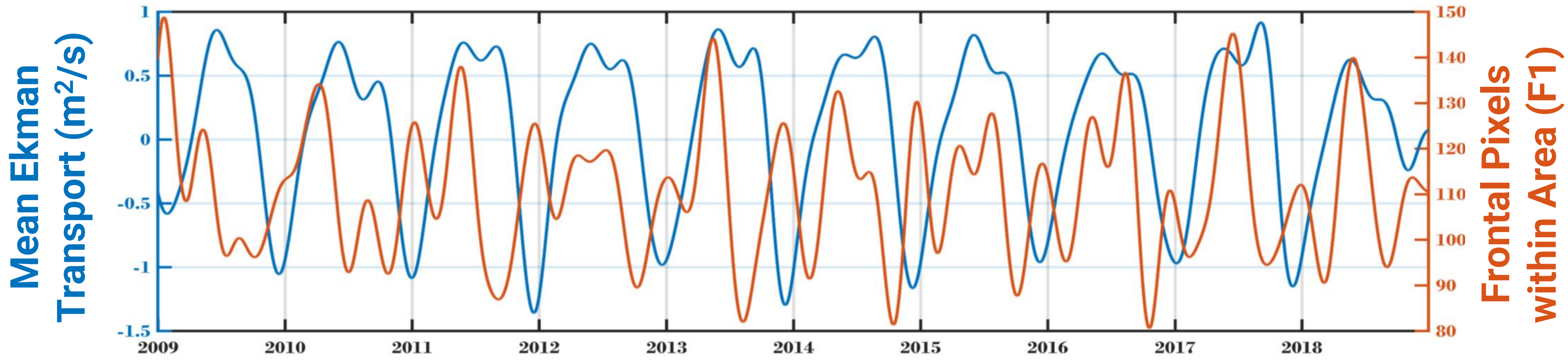


UI – PFZ coherence



Upwelling Index – Potential Fishing Zone Cooccurrence

1. Wavelet Cross-coherence: **Strong Seasonal Coherence**
2. Peak area-averaged frontal probability occurs during season of positive alongshore windstress.



VI. Conclusions

<u>Summary</u>

- A qualitative difference is observed between the surface thermal response of coastal upwelling to the North and South of Krishna Godavari Delta (KGD).
  - Both systems illustrate cold water accumulation at the coast.
  - However, persistent thermal fronts are only associated with the southern system.
- Area averaged frontal probability (F1) and the Wind-based upwelling index (Ekman Transport: ET) are strongly coherent over seasonal scales.
- The maximum F1 occurs during the period of peak positive ET, during the pre-monsoon and southwest monsoon period.

<u>Implications</u>

- This association between windstress and frontal activity can potentially allow us to estimate frontal activity based on windstress data, which can help **overcome the existing data scarcity**.
- Help predict potential **long term shifts** in the efficiency and feasibility of commercial fishing, based on climatological changes in coastal upwelling.

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