High Resolution Circulation Features along Indian Coast using HF Radar Derive Surface Currents

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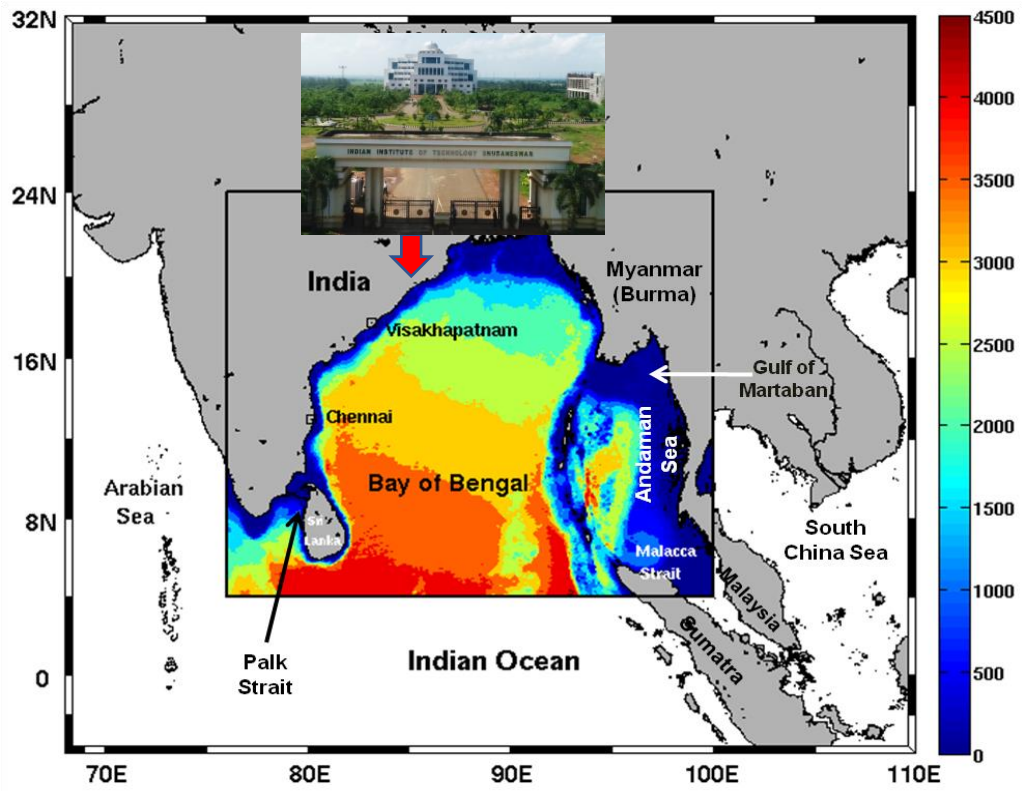
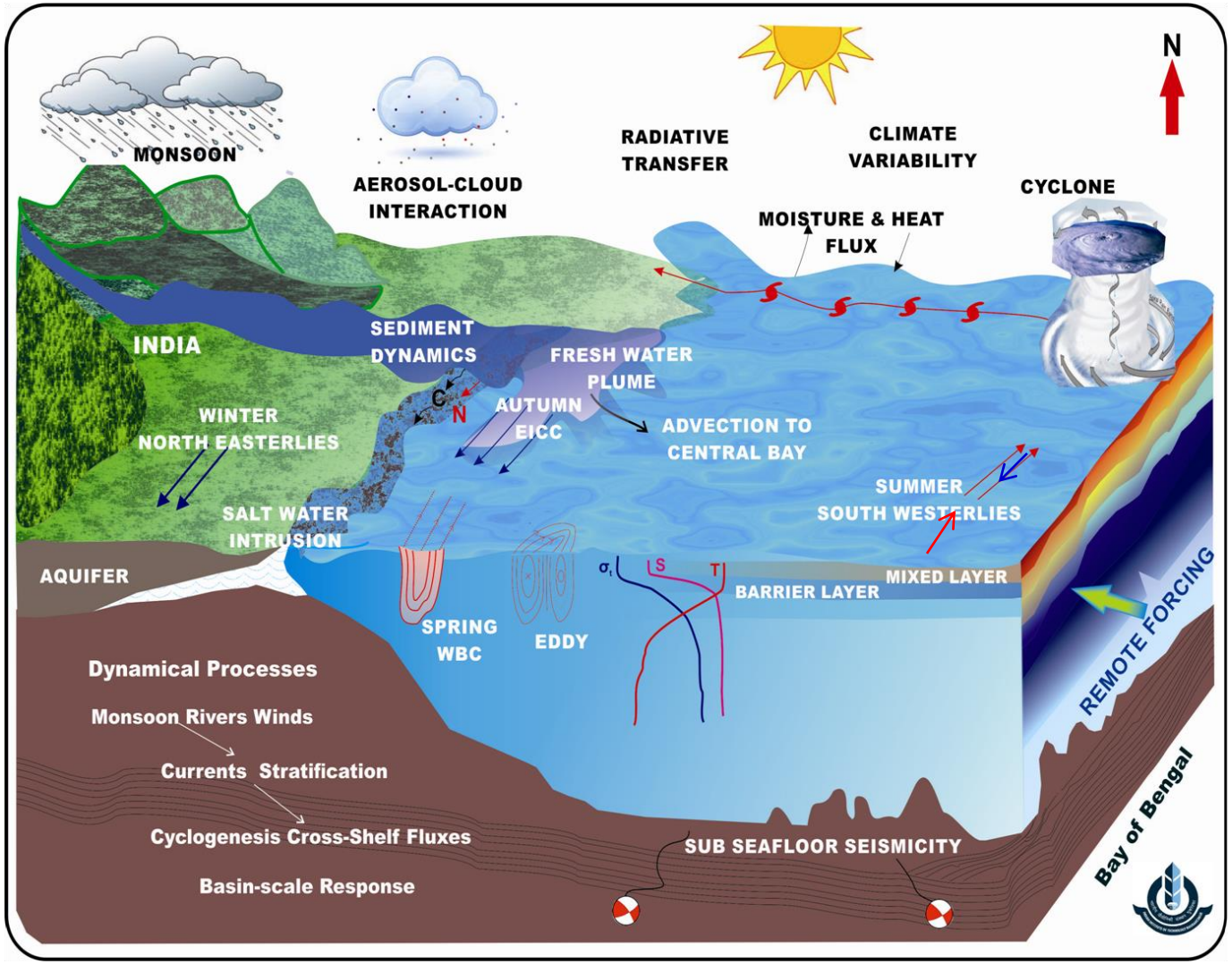
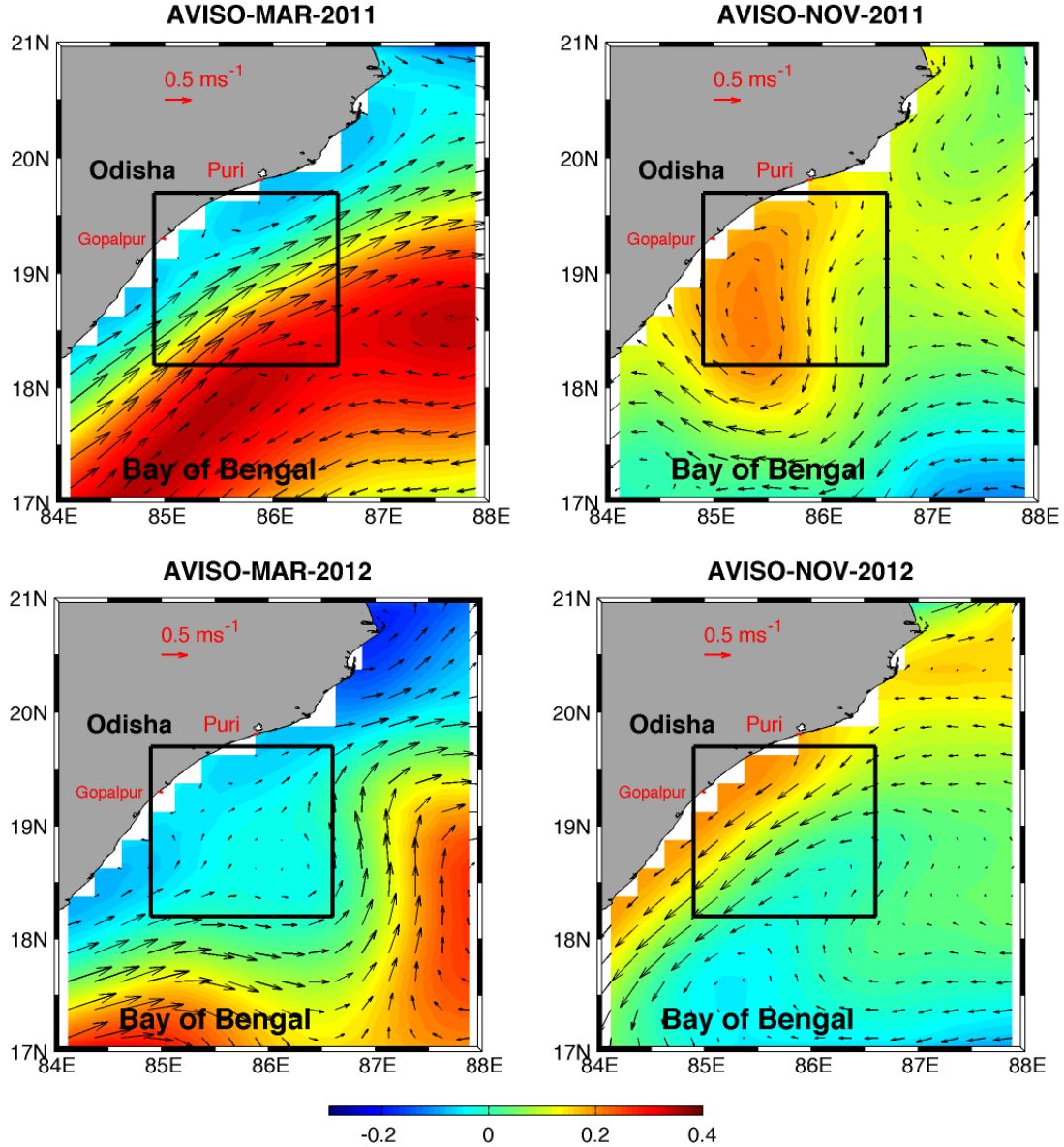
Outline

- Coastal Circulation of Indian Coast
- Indian Coastal Ocean Radar Network (ICORN)
- Application of HF radar current for multi-scale circulation
- Challenges in HF Radar for Assimilation – Gap Filling
- Summary

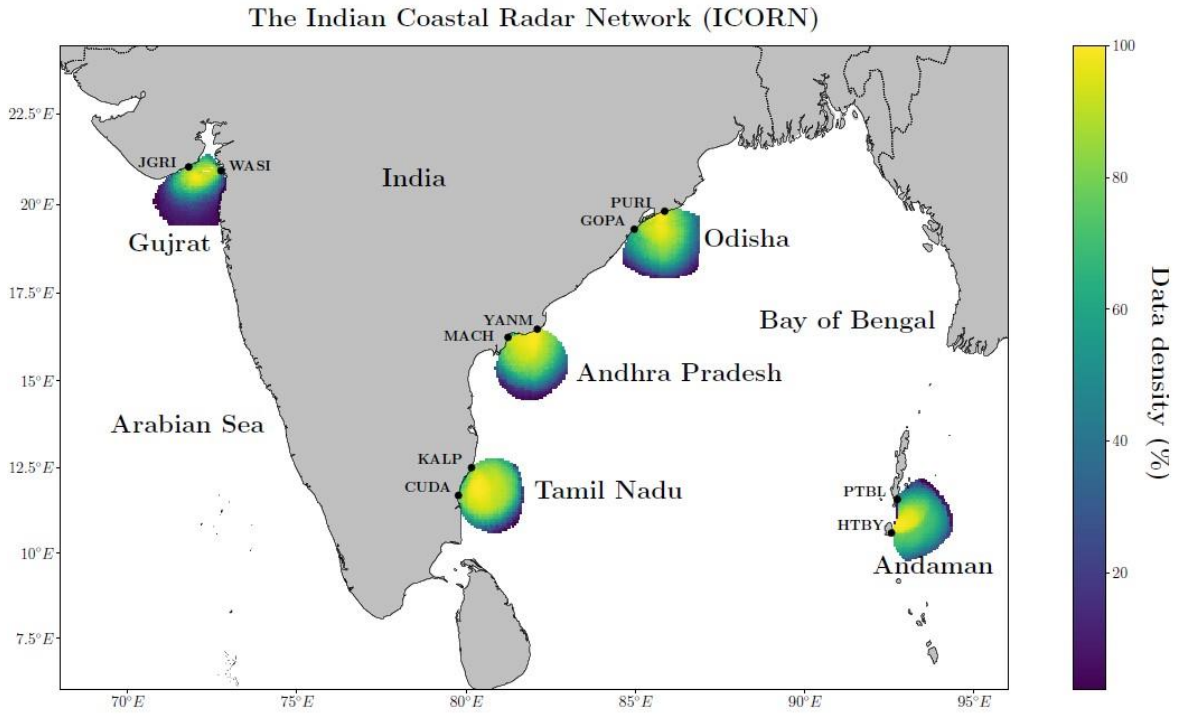


Air-Sea Processes and Coastal Currents in Bay of Bengal (BoB)





Indian Coastal Radar Network (ICORN)



Operating Parameter	Values
Operating Frequency	4.4 MHz
Band Width	25 KHz
Radar Wavelength (λ)	68 m
Maximum Range	200 km
Range Resolution	6 km
Temporal Resolution	1 hour
Spatial Coverage	200 km
Data availability	Since 2009

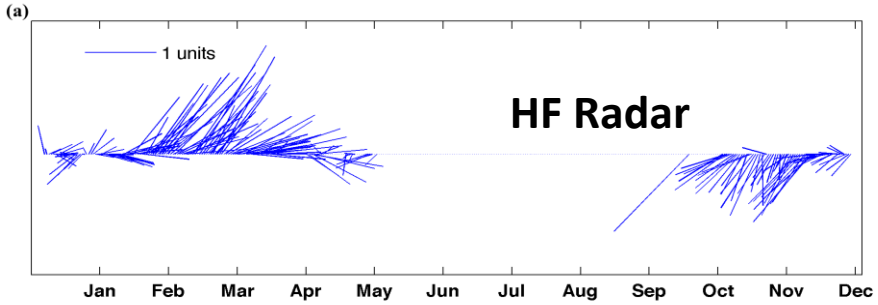
(source: Jena et al., 2019)

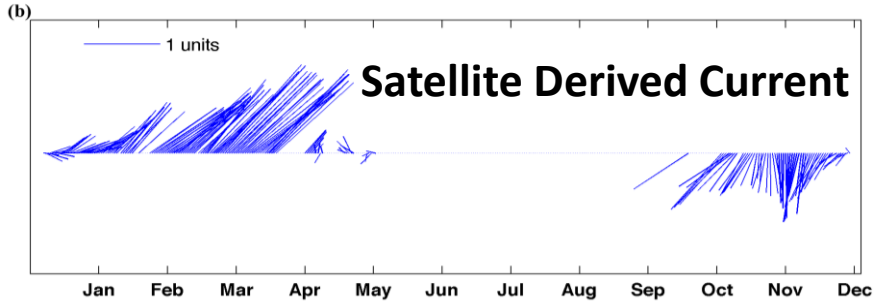
Ministry of Earth Sciences (MoES), Govt. of India

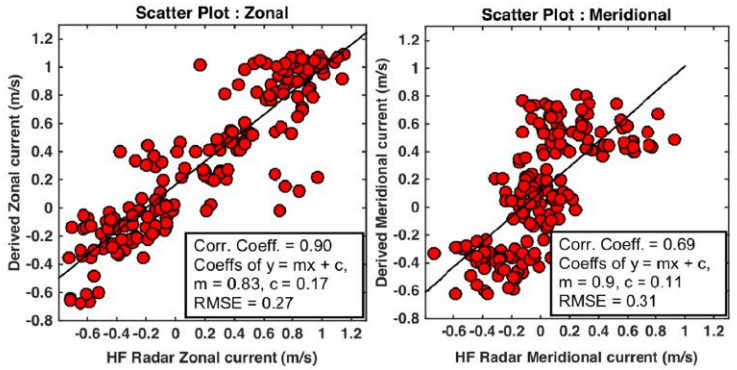
- Stations are maintained by National Institute of Ocean Technology (NIOT), Chennai, India
- Data is provided by Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, India

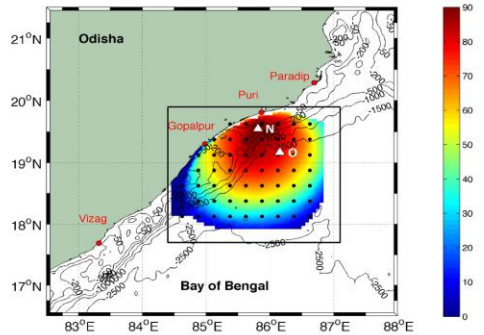
Validation of HR Radar Current

Current in 2010 at the Location O

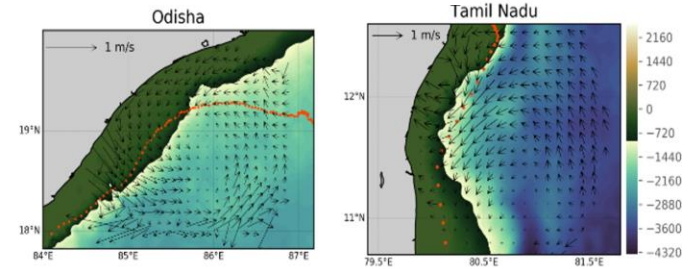


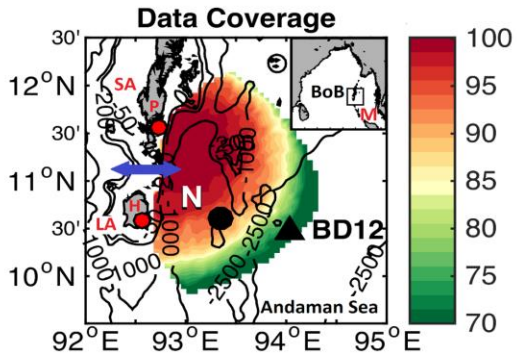


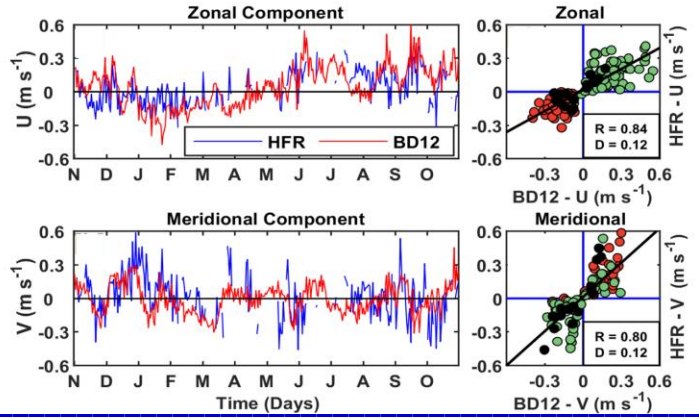




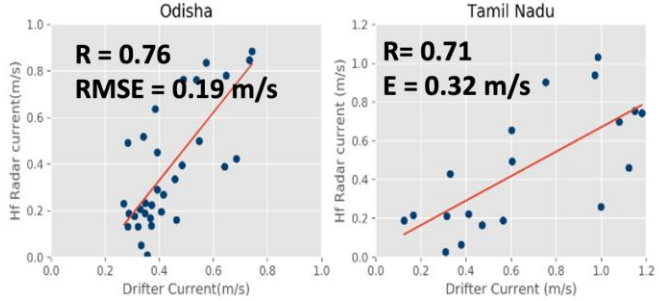
HFR vs Satellite

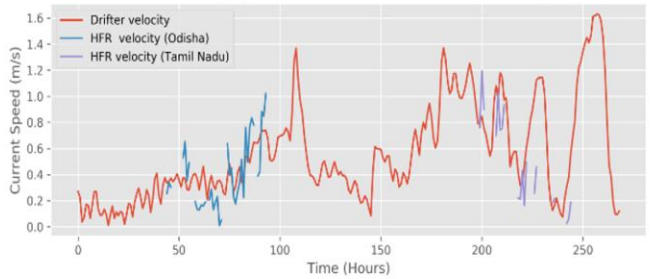






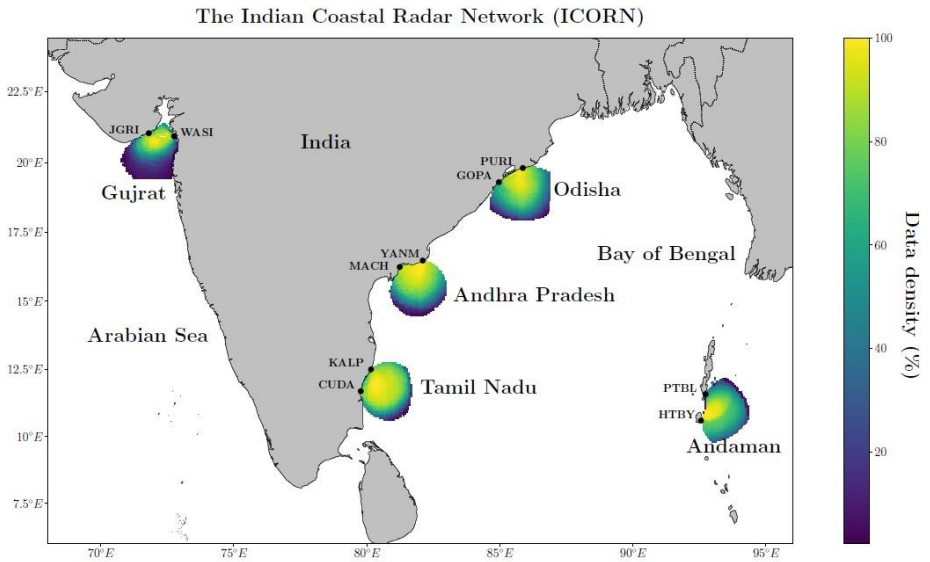
HFR vs Drifters





HFR vs Buoy

Multiscale Applications of HF radar current



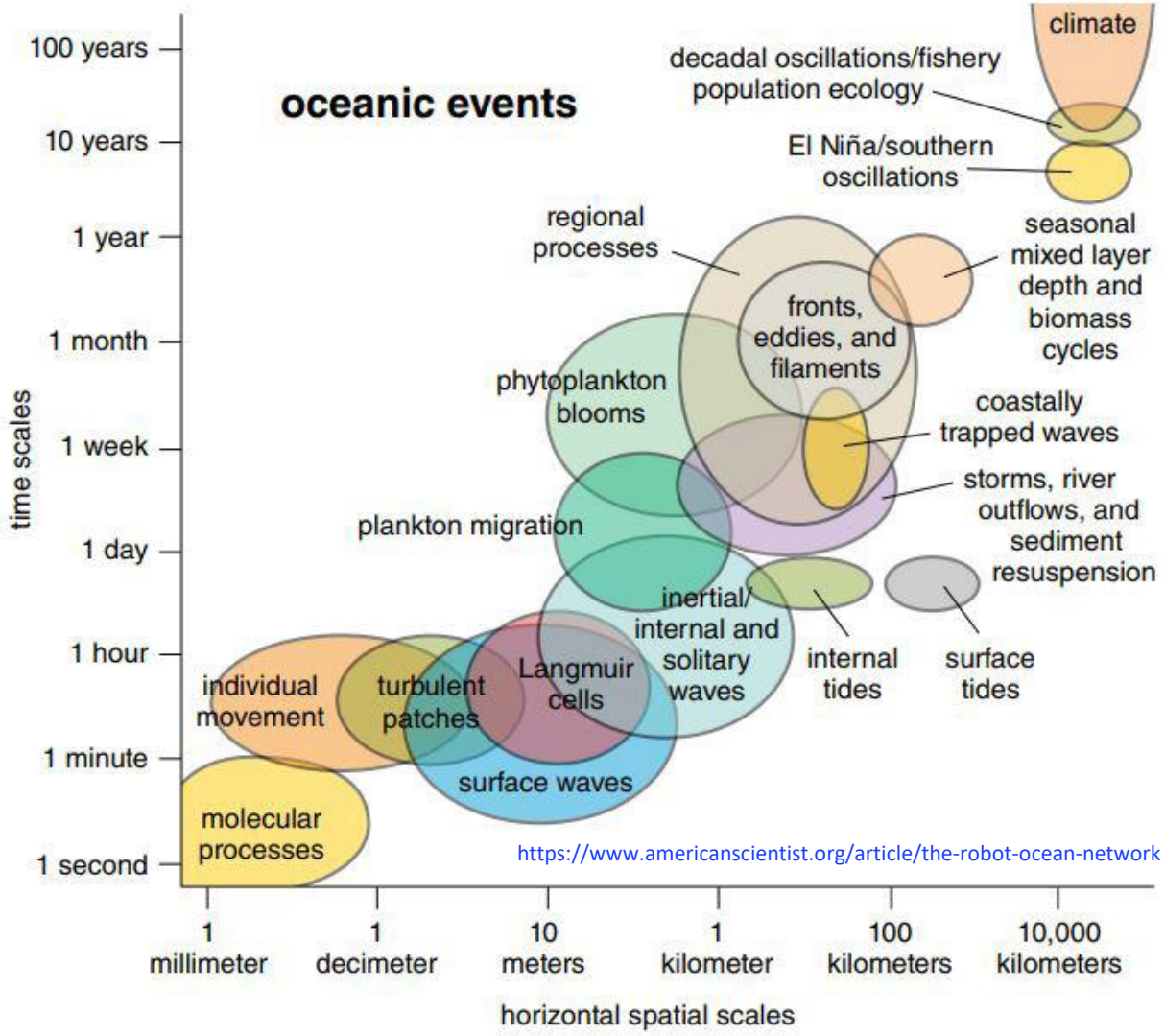
Applications of HF radar current

a. Extracting Tidal Currents along Indian Coast

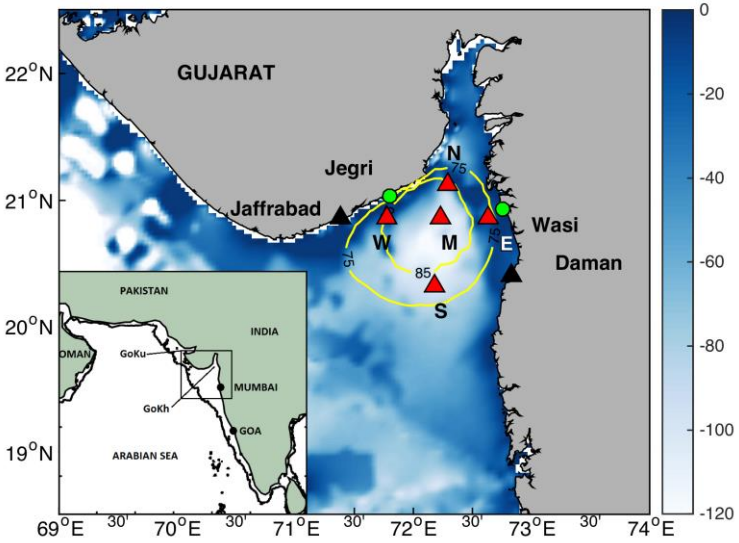
b. Finding the nature of tidal asymmetry at the Indian coast.

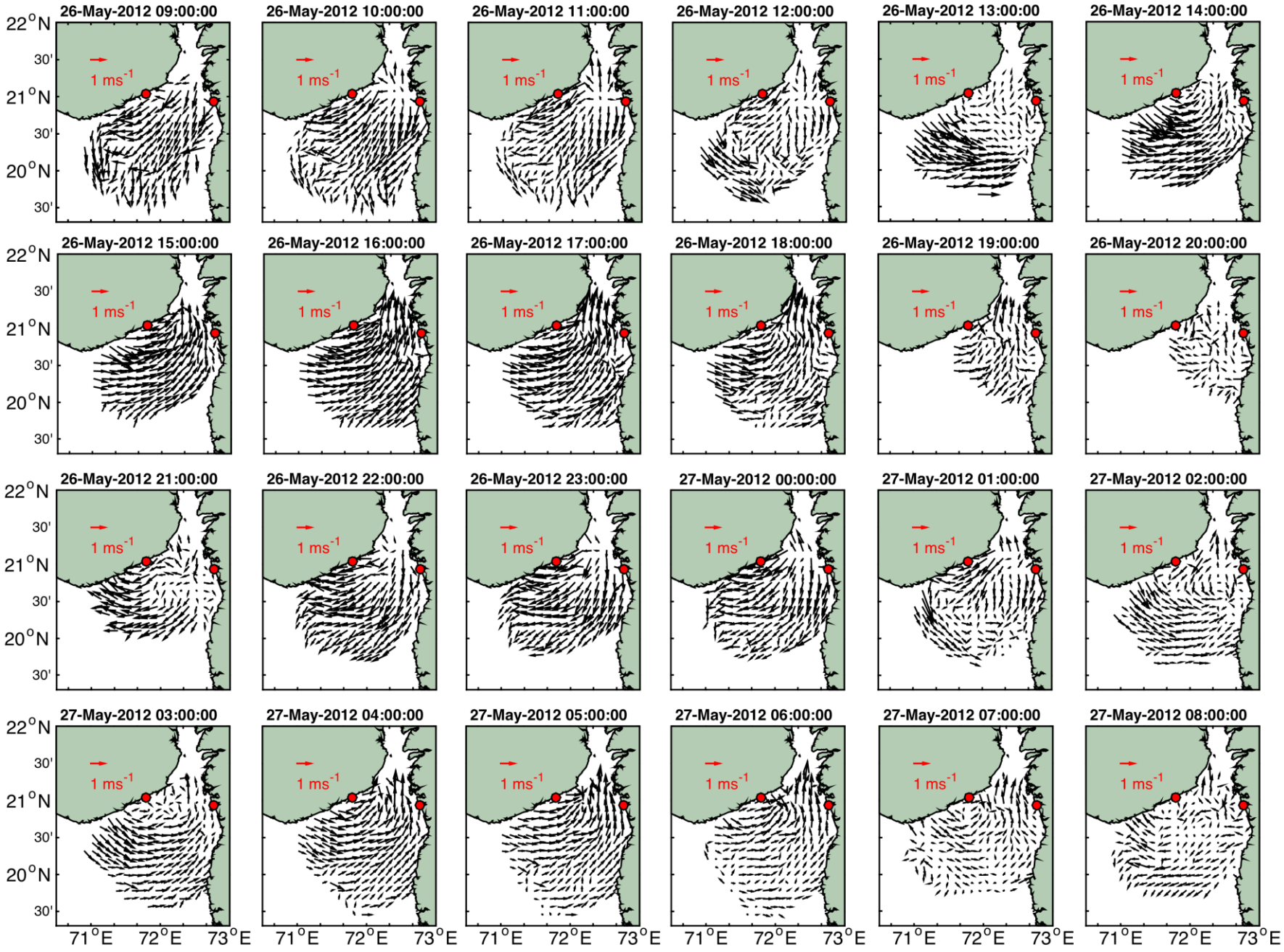
c. Quantification on of Eddy-Tide-Current Interactions

d. Monitoring mechanism of the mesoscale coastal processes.



On the nature of tidal asymmetry in the Gulf of Khambhat





Mandal, Sil et al., 2020a, ECSS

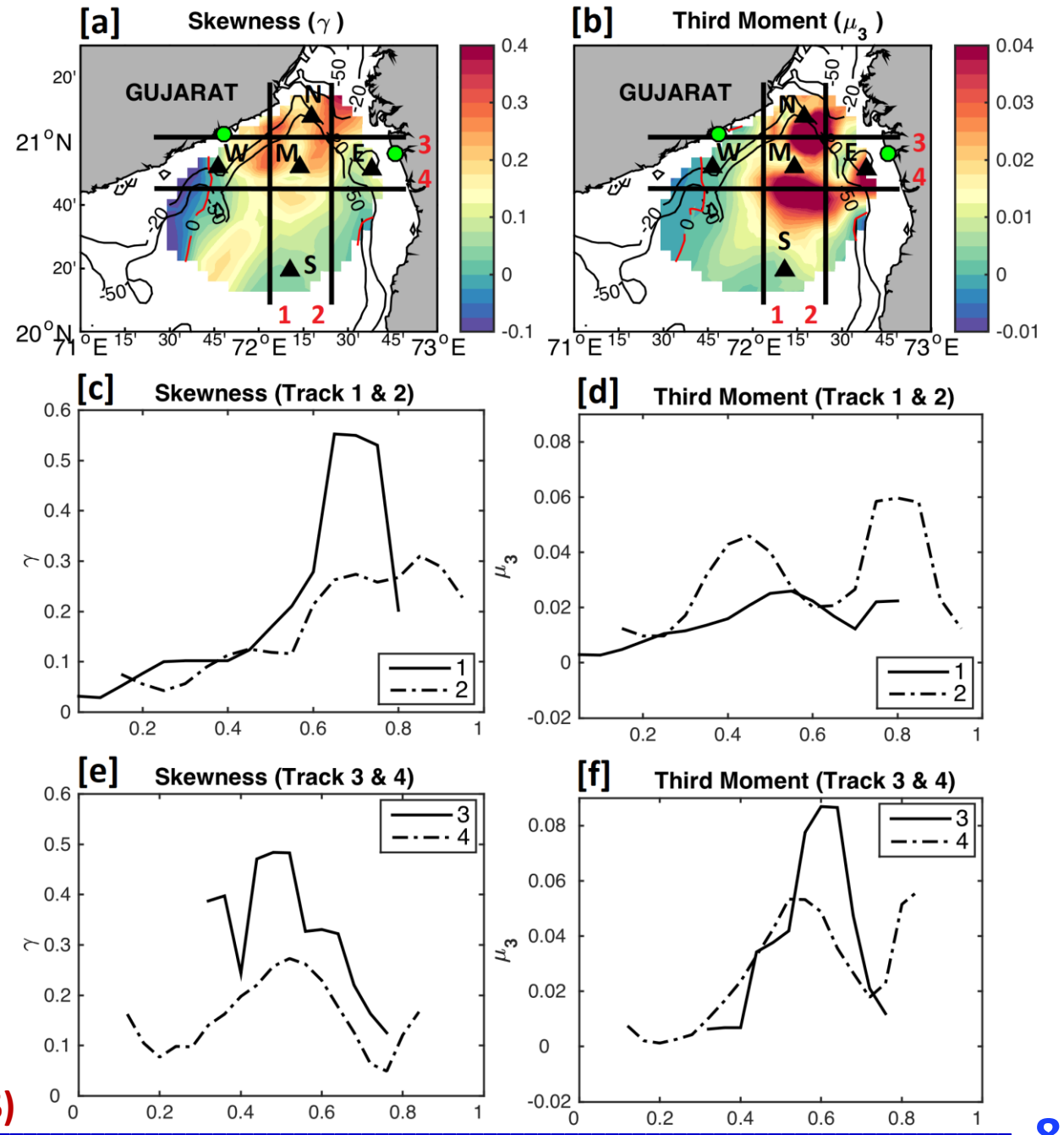
On the nature of tidal asymmetry in the Gulf of Khambhat

Typically, the skewness (γ) is a quantitative measure of asymmetry as defined by (Nidzieko, 2010; Song et al., 2011; Gong et al., 2016):

$$\gamma = \frac{\mu_3}{{\mu_2}^{3/2}} \quad where \mu_m = \frac{1}{N-1}\sum_{i=1}^{N}(x_i)^m$$

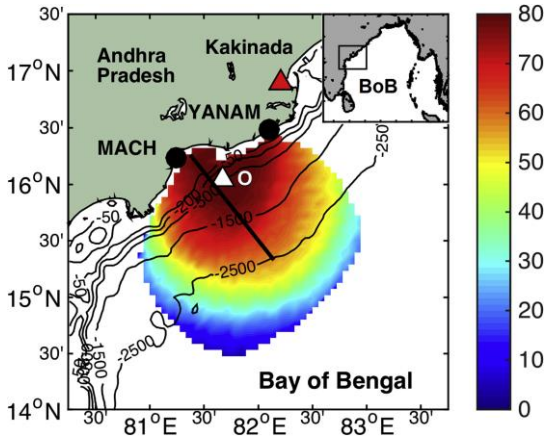
Current velocity is denoted by '*x*'. The Gulf would be flood asymmetric, if $\gamma > 0$, and would be ebb-dominant, if $\gamma < 0$.

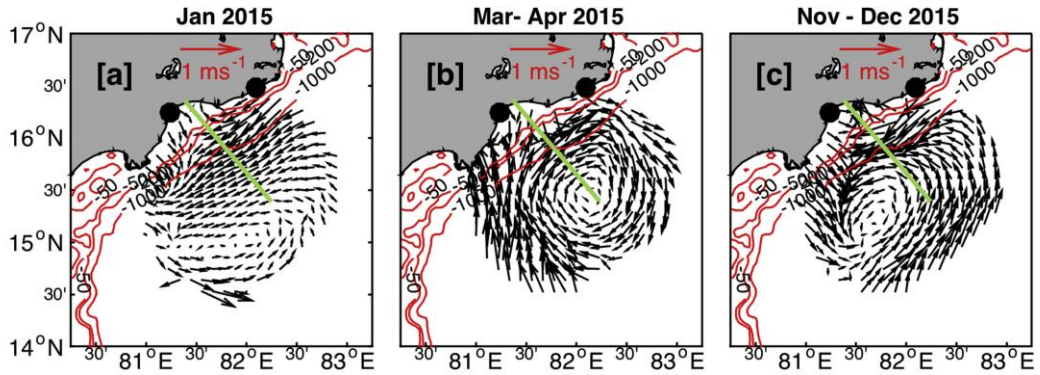
Positive asymmetry factor and skewness characterize the Gulf as flood asymmetric. The (M2/S2/MS4) combination follows the (M2/M4) in contributing towards asymmetry.

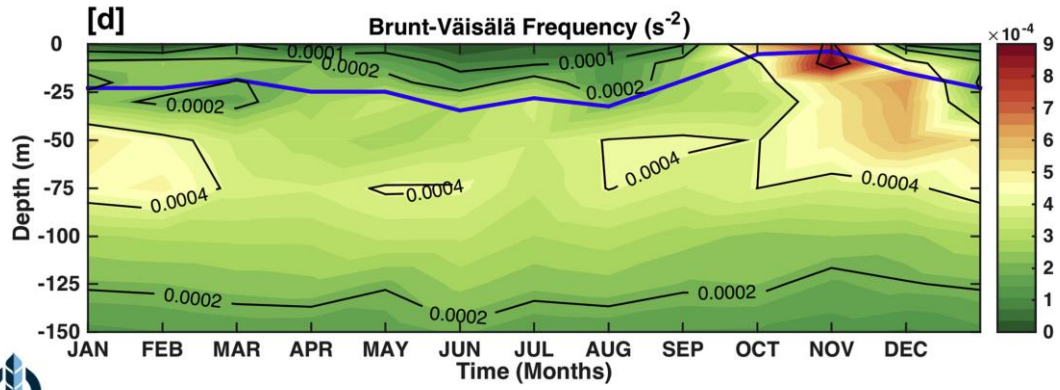


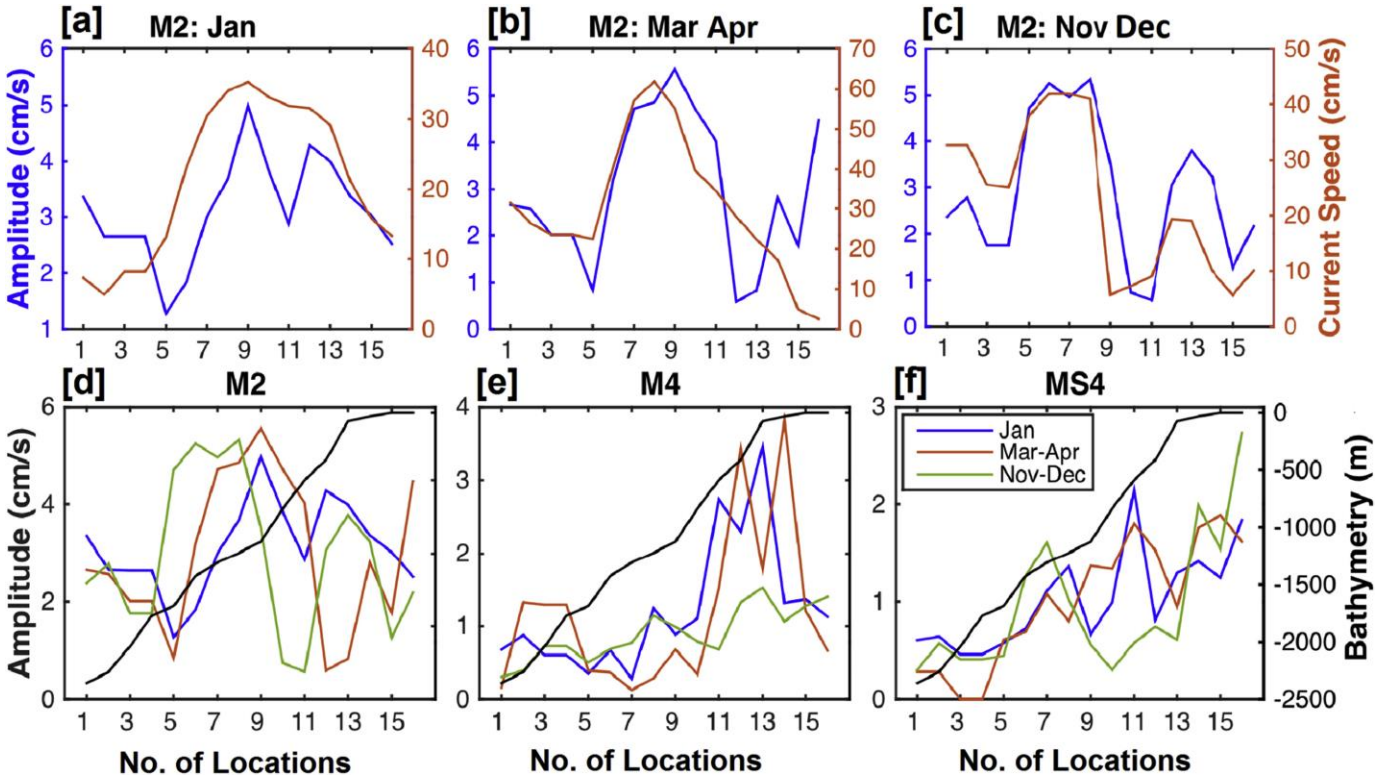
(Mandal, Sil et al., 2020a, ECSS)

Seasonal variation of tidal currents



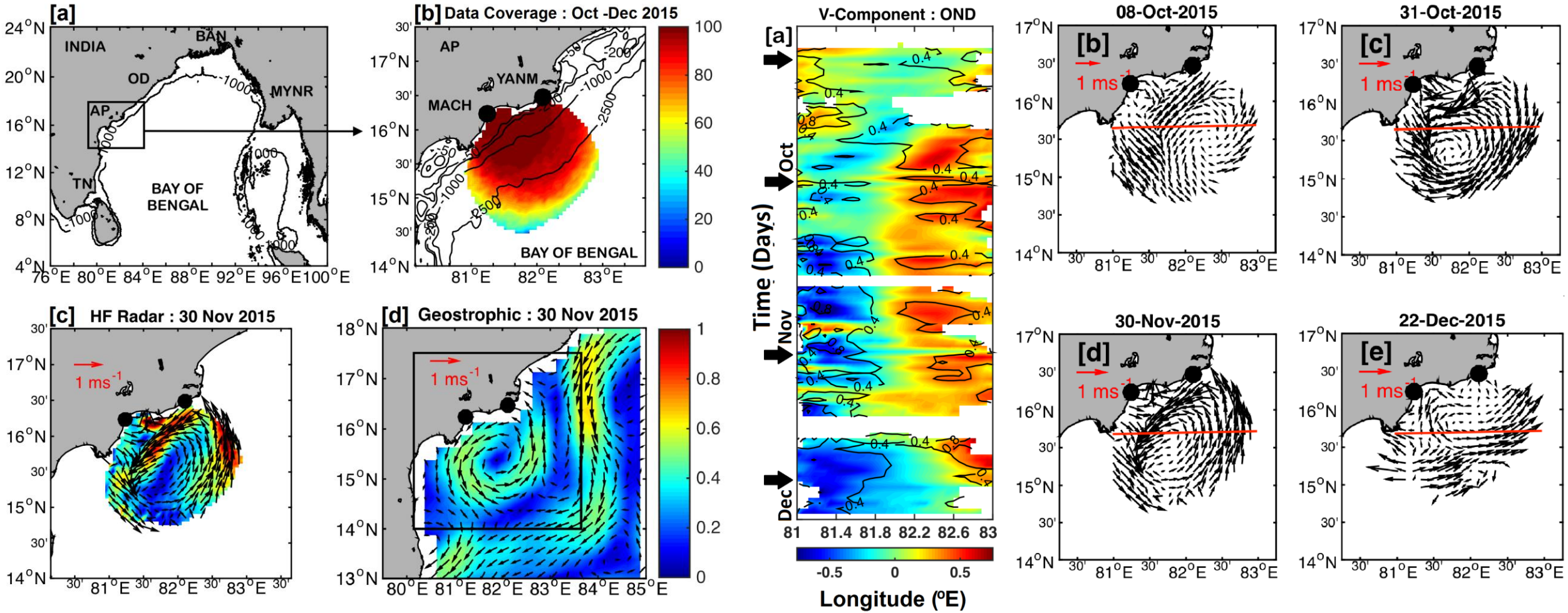






- Tidal variance is about 40–70% of the total current variability.
- M2 tidal currents get amplified by the seasonal mean flow in the offshore regions.
- M4 and MS4 constituents amplify with non-linear interactions with bathymetry.
- M2 tides attain maximum amplitudes during November–December due to stratification. **(Mandal, Sil et al., 2020b, ECSS)**

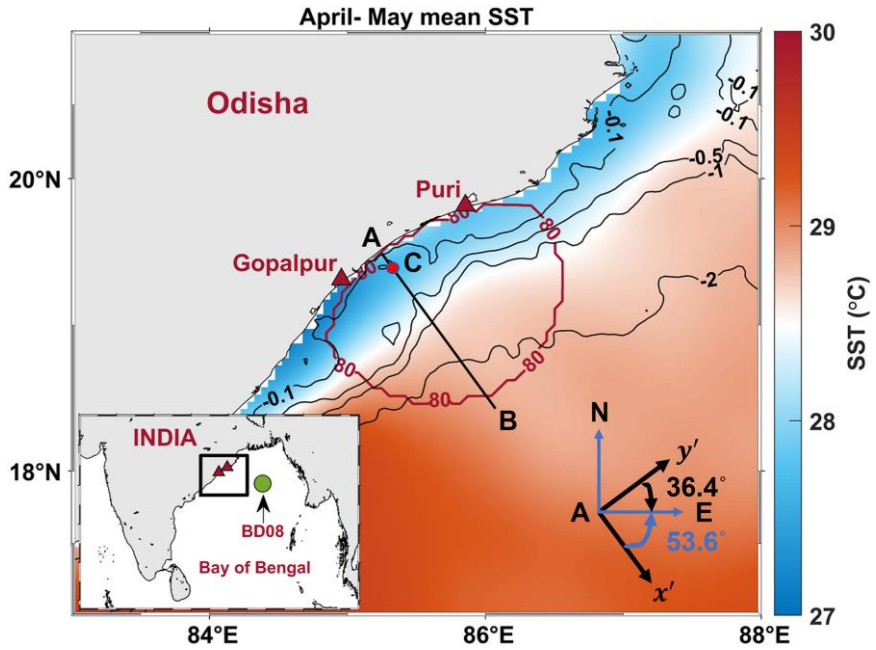
Characteristics of a Coastal Mesoscale Eddy



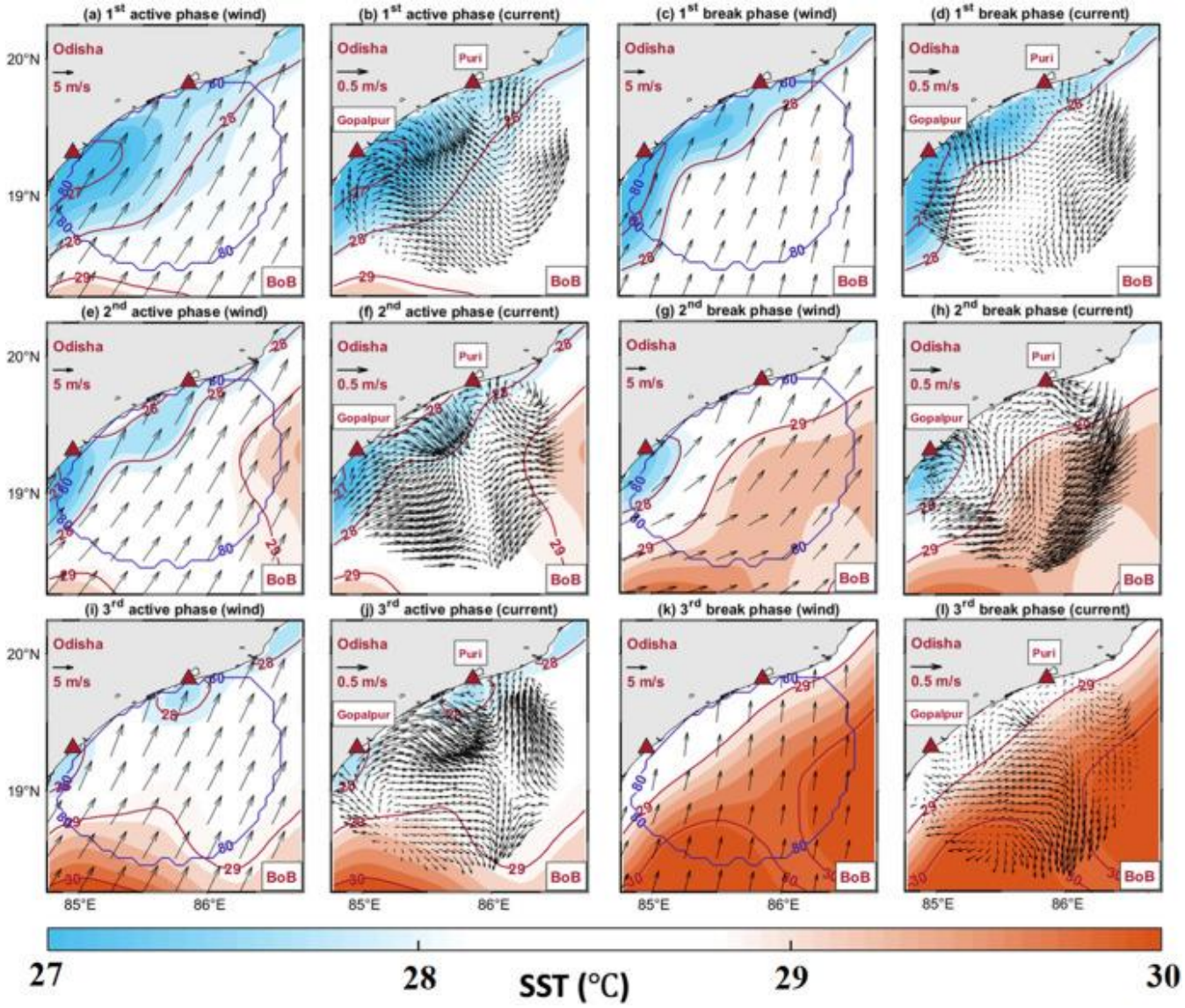
- HFR captured the westward propagation of a coastal mesoscale cyclonic eddy (R_0 = 0.6–1.2) in the western Bay of Bengal.

(Mandal, Sil et al., 2019 DAO)

Spatio-Temporal Variability of Coastal Upwelling



- Upwelling is characterized by three active (~10 days) and break phases (~5 days).
- Upwelling signature is seen maximum up to 40–135 km from the coast.
- Feedback between wind and SST are responsible for of active and break phases.



(Dey and Sil 2023, ECSS)

Publications: Application of HF radar total Currents

Multiscale Coastal Circulation along Indian Coast

Estuarine, Coastal and Shelf Science 232 (2020) 106481

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: http://www.elsevier.com/locate/ecss

On the nature of tidal asymmetry in the Gulf of Khambhat, Arabian Sea using HF radar surface currents

Samiran Mandal [a], Sourav Sil [a,*], Avijit Gangopadhyay [b,a,c], Basanta Kumar Jena [d], Ramasamy Venkatesan [e]

JOURNAL OF OPERATIONAL OCEANOGRAPHY
2018, VOL. 11, NO. 2, 65–81
https://doi.org/10.1080/1755876X.2018.1479571

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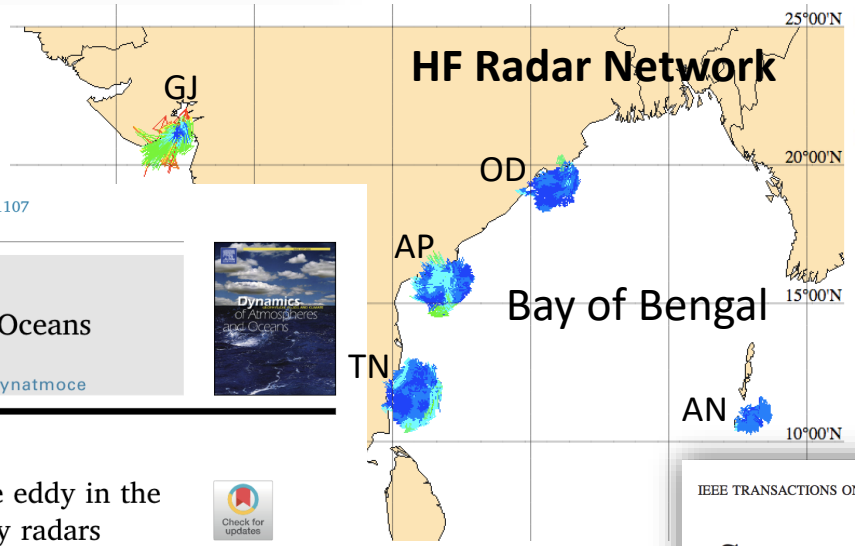
On extracting high-frequency tidal variability from HF radar data in the northwestern Bay of Bengal

Samiran Mandal [a], Sourav Sil [a], Avijit Gangopadhyay [a,b], Tad Murty [c] and Debadatta Swain [a]

[a]School of Earth, Ocean and Climate Sciences, Ind
Technology, University of Massachusetts, Dartmc



Estuarine, Coastal and Shelf Science 282 (2023) 108228

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Estuarine, Coastal and Shelf Science

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Spatio-temporal variability of coastal upwelling using high resolution remote sensing observations in the Bay of Bengal

Shouvik Dey, Sourav Sil *

School of Earth, Ocean and Climate Sciences, Indian Institute of Technology Bhubaneswar, India

Dynamics of Atmospheres and Oceans 88 (2019) 101107

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Tide-current-eddy interaction: A seasonal study using high frequency radar observations along the western Bay of Bengal near 16°N

Characteristics and evolution of a coastal mesoscale eddy in the Western Bay of Bengal monitored by high-frequency radars

Samiran Mandal[a,*], Sourav Sil[a], Saikat Pr
Basanta Kumar Jena[c]

Journal of Coastal Research | SI | 89 | 132-138 | Coconut Creek, Florida | 2020

Sub-Mesoscale Circulation Features along the Andhra Pradesh Coast, Bay of Bengal: Observations from HF Radars

Samiran Mandal†*, Saikat Pramanik†, Sourav Sil†, Kondetharayil Soman Arunraj††, and Basanta Kumar Jena††

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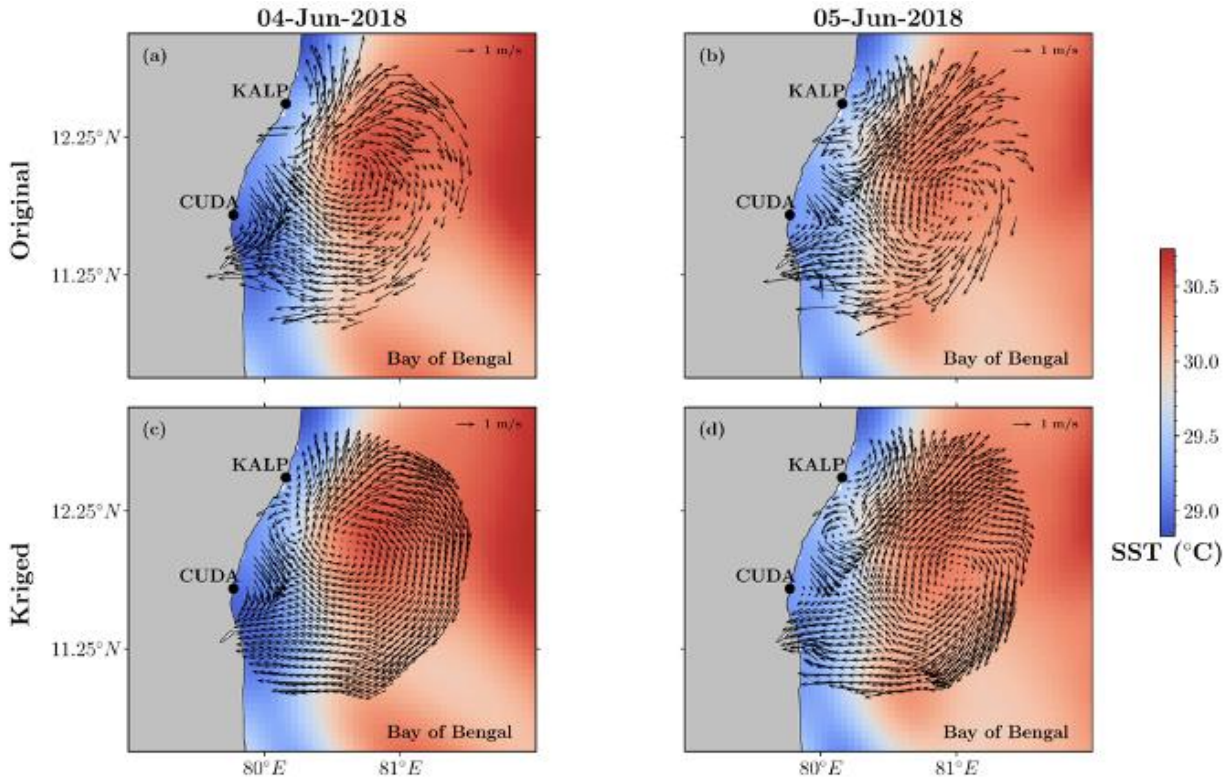
Seasonal and Tidal Variability of Surface Currents in the Western Andaman Sea Using HF Radars and Buoy Observations During 2016–2017

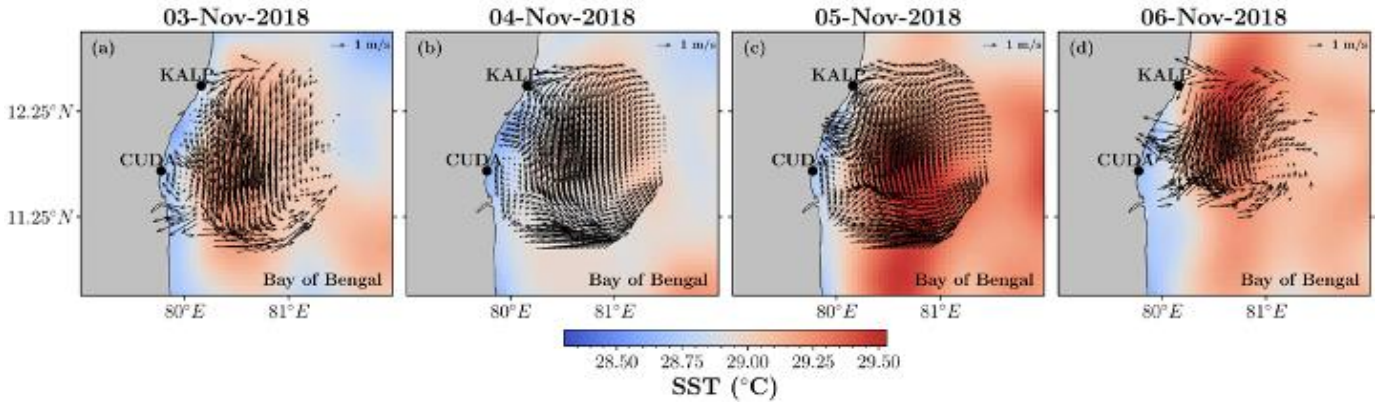
Samiran Mandal, Sourav Sil, *Member, IEEE*, Avijit Gangopadhyay, Basanta Kumar Jena, Ramasamy Venkatesan, *Senior Member, IEEE*, and Glen Gawarkiewicz

Gap Filling with Spatio-Temporal Kriging for Data Assimilation

TABLE III: Summary of the LOOCV statistics performed on 10% of the data from a 7-day period of each of the three months.

Month	Component	Total points	LOOCV points	% of points	RMSE (m/s)	Correlation	p-value
February	Zonal	1944	204	10.49	0.048	0.99	$< 10^{-4}$
	Meridional				0.047	0.98	$< 10^{-4}$
June	Zonal	1941	237	12.21	0.092	0.96	$< 10^{-4}$
	Meridional				0.091	0.95	$< 10^{-4}$
November	Zonal	1889	241	12.76	0.080	0.97	$< 10^{-4}$
	Meridional				0.094	0.96	$< 10^{-4}$





- **The product-sum with exponential marginal models for both space and time found to the best**
- **The error is less than 10 cm/s**

(Deogharia and Sil 2023, IEEE-JOE)

Summary

- The HF Radar plays a vital role on monitoring the coastal circulations, which are important in social benefits
- Challenge: Model are not efficient at the coastal region as comparative to open ocean due to complexity in shallow bathymetry and availability of air-sea fluxes.
- Data assimilation is a good option, subject to the performance coastal models.

Thank You

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