Hands-on

Marine heat wave and its impact on Marine ecology

Training Course on
“Fundamentals of Remote Sensing & GIS and Oceanographic Applications"
8-12 April, 2024

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Overview of Presentation

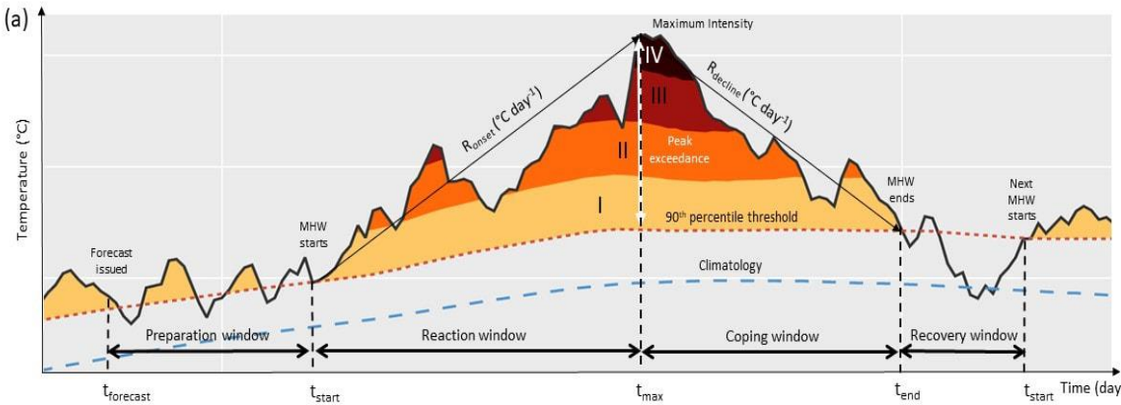
- **Mechanisms of Genesis of MHW.**
- **Spatio-Temporal variability of MHW over Indian Ocean**
- **Persistence of productive surface thermal fronts & heatwave and its impact on fishery**
- **Impact of MHW on Coral Reef.**

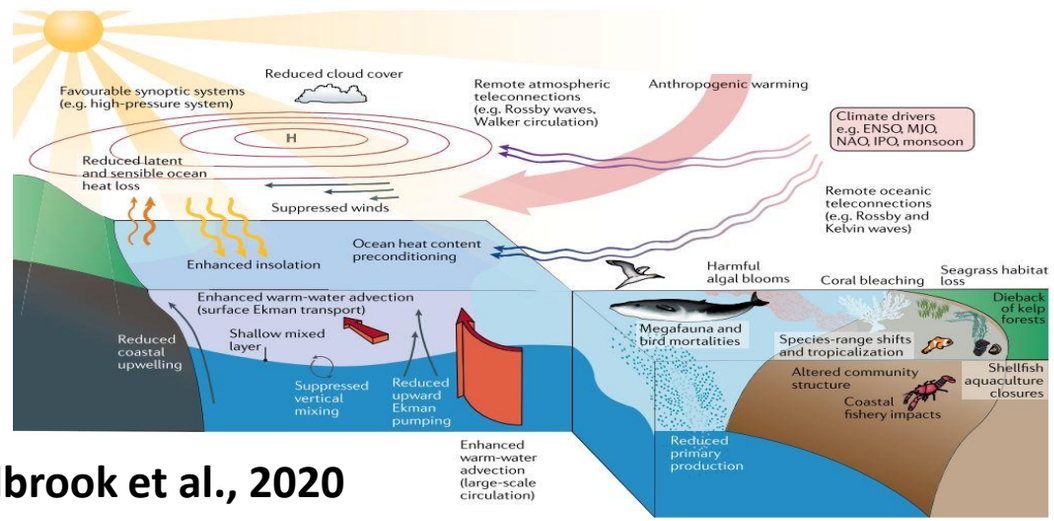
Mechanisms of Genesis of MHW

- Marine Heatwaves (MHWs) **are prolonged extreme oceanic warm** water events.
- **Mechanisms of Genesis of MHW**:

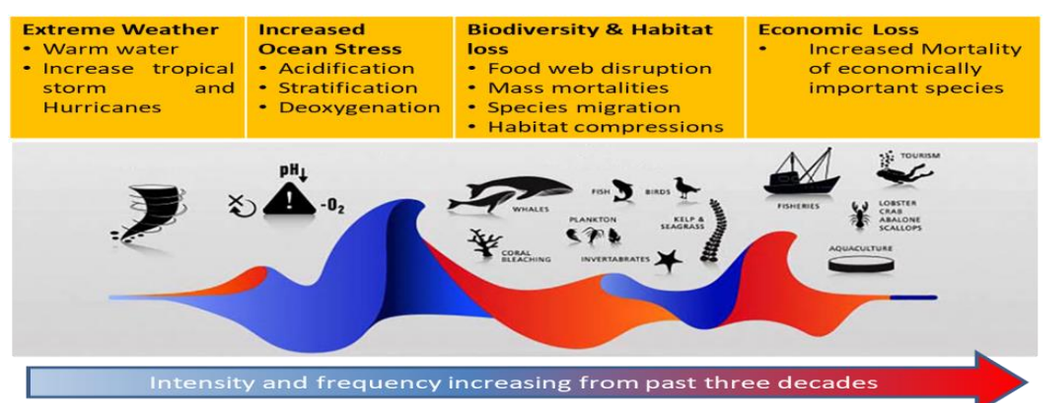
  High pressure zone, reduce the cloud coverage, Solar insulation, suppress the LHF and SHF, increase the advection and reduce the convection, reduce the coastal upwelling, Rossby and Kelvin planetary wave, teleconnection of ENSO, IODM, MJO in different time scale
- **Impact of Marine Heat wave:**

  Marine Habitat: mass coral bleaching, seagrass, kelp forests, fishery, Algae and reduce adaptation of ocean productivity, cyclone, Indian Monsoon etc
- **The skill full MHW advisory** can benefit and guidance to marine ecological conservation, fisheries and aquaculture management stockholder and alert the extreme events



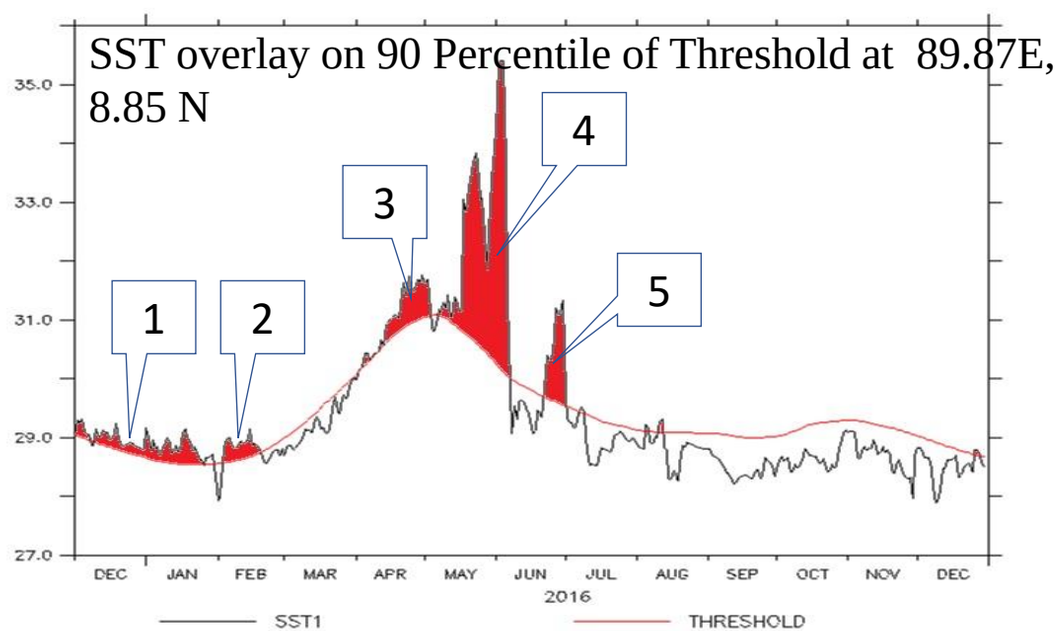


Holbrook et al., 2020



Detection of Marine Heat Wave (MHW)

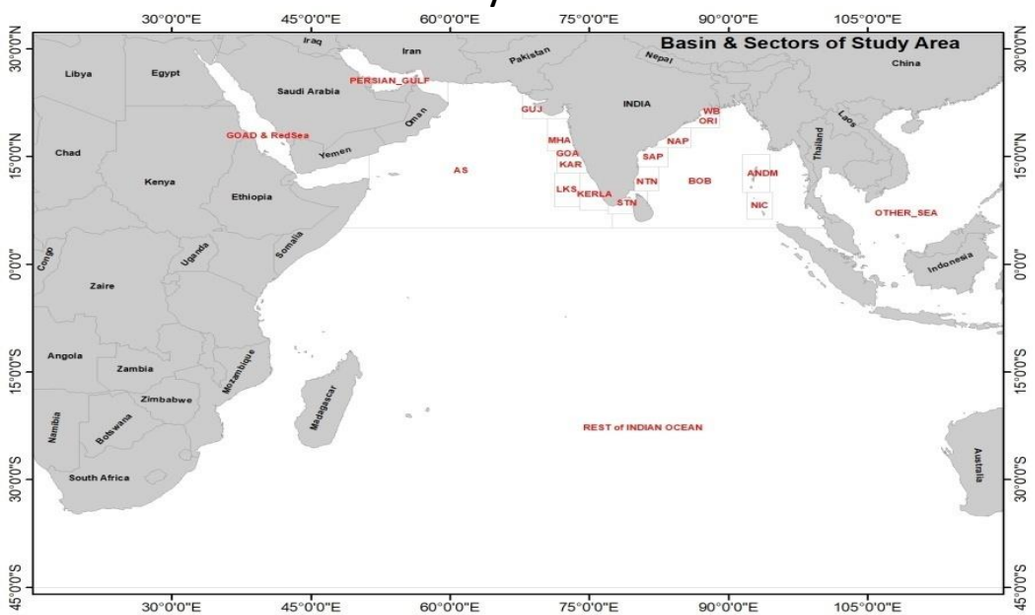
Definition: A Marine Heatwave (MHW) is a **discrete prolonged anomalously warm water event**. The requirements for a warm water event to be described as an MHW are a **duration of five or more days, temperatures greater than the 90th percentile** of minimum 30-year local measurements and **should not be more than or equal 3 days of cooling** occurrence in a specific region (Hobday et al., 2016).



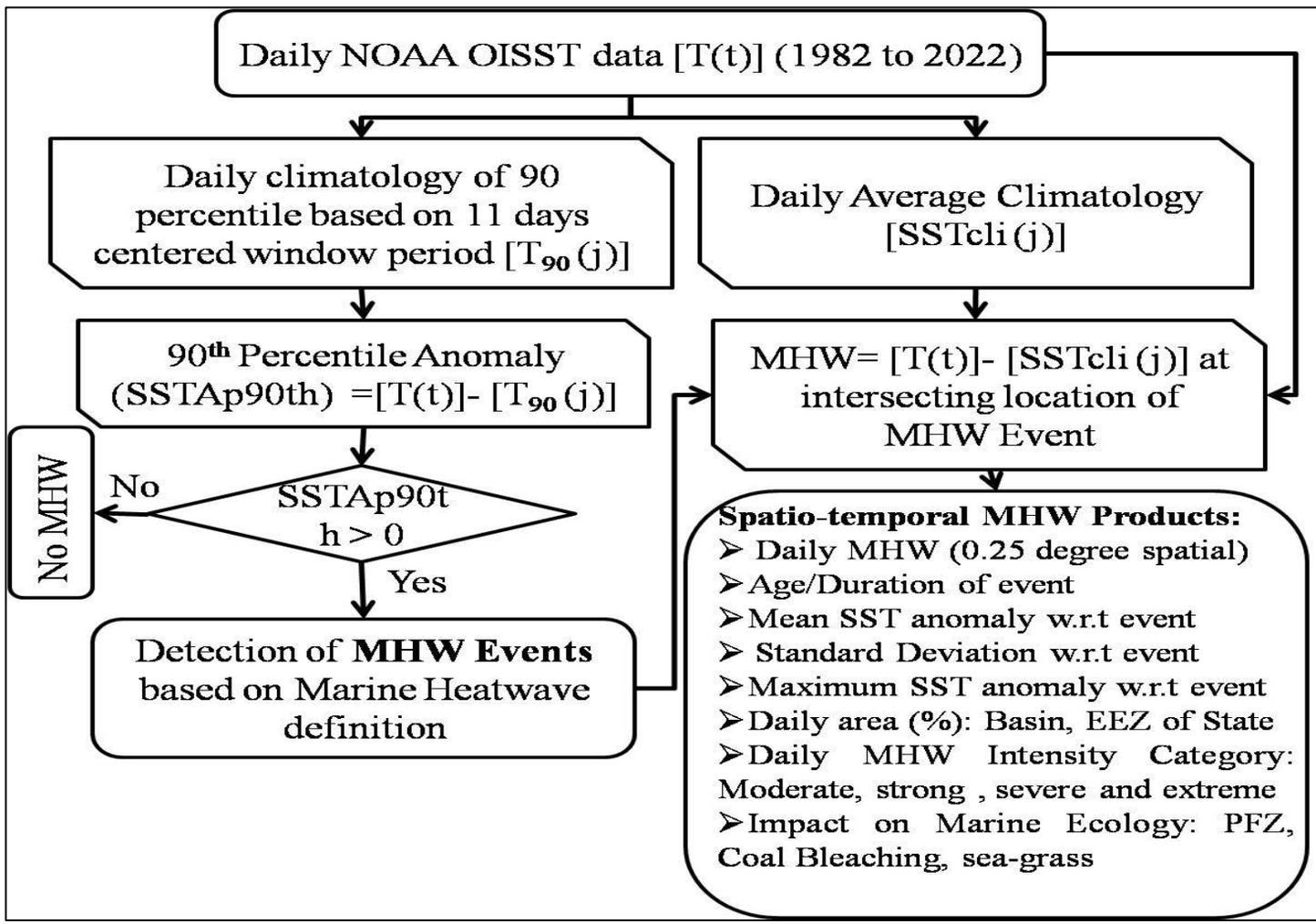
Date	OISST	Daily 90th CLI	Daily avg clim	SSTAp90th= IOSST-90CLI	MHW Event Detection	SSTA= OISST- Daily Avg Clim	MHW
01-JAN-2016	27.04	27.42	26.7	-0.381	....	0.337	....
02-JAN-2016	27.05	27.41	26.69	-0.359	....	0.361	....
03-JAN-2016	27.14	27.4	26.68	-0.257	....	0.464	....
04-JAN-2016	27.29	27.39	26.66	-0.097	....	0.625	....
05-JAN-2016	27.34	27.38	26.65	-0.038	....	0.686	....
06-JAN-2016	27.24	27.37	26.65	-0.13	....	0.595	....
07-JAN-2016	27.41	27.36	26.64	0.048	....	0.774	....
08-JAN-2016	27.65	27.36	26.63	0.295	....	1.021	....
09-JAN-2016	27.48	27.35	26.62	0.132	....	0.856	....
10-JAN-2016	27.44	27.34	26.62	0.099	....	0.82	....
11-JAN-2016	27.45	27.33	26.62	0.116	0.116	0.834	**0.834**
12-JAN-2016	27.48	27.33	26.61	0.153	0.153	0.866	**0.866**
13-JAN-2016	27.47	27.32	26.61	0.149	0.149	0.857	**0.857**
14-JAN-2016	27.52	27.32	26.61	0.205	0.205	0.907	**0.907**
15-JAN-2016	27.53	27.31	26.61	0.219	0.219	0.916	**0.916**
16-JAN-2016	27.45	27.31	26.62	0.143	0.143	0.833	**0.833**
17-JAN-2016	27.48	27.3	26.62	0.175	0.175	0.859	**0.859**
18-JAN-2016	27.5	27.3	26.63	0.198	0.198	0.873	**0.873**
19-JAN-2016	27.76	27.3	26.63	0.46	0.46	1.127	**1.127**
20-JAN-2016	27.63	27.3	26.64	0.331	0.331	0.99	**0.99**
21-JAN-2016	27.76	27.3	26.65	0.46	0.46	1.113	**1.113**
22-JAN-2016	27.75	27.3	26.66	0.446	0.446	1.093	**1.093**
23-JAN-2016	27.76	27.31	26.67	0.45	0.45	1.093	**1.093**
24-JAN-2016	27.71	27.32	26.68	0.391	0.391	1.031	**1.031**
25-JAN-2016	27.59	27.33	26.69	0.259	0.259	0.899	**0.899**
26-JAN-2016	27.55	27.34	26.7	0.206	0.206	0.845	**0.845**
27-JAN-2016	27.48	27.36	26.72	0.123	0.123	0.762	**0.762**
28-JAN-2016	27.45	27.37	26.73	0.078	0.078	0.717	**0.717**
29-JAN-2016	27.42	27.39	26.75	0.033	0.033	0.672	**0.672**
30-JAN-2016	27.32	27.41	26.76	-0.085	....	0.556	....

Material and Methods of detection of MHW

Study Area



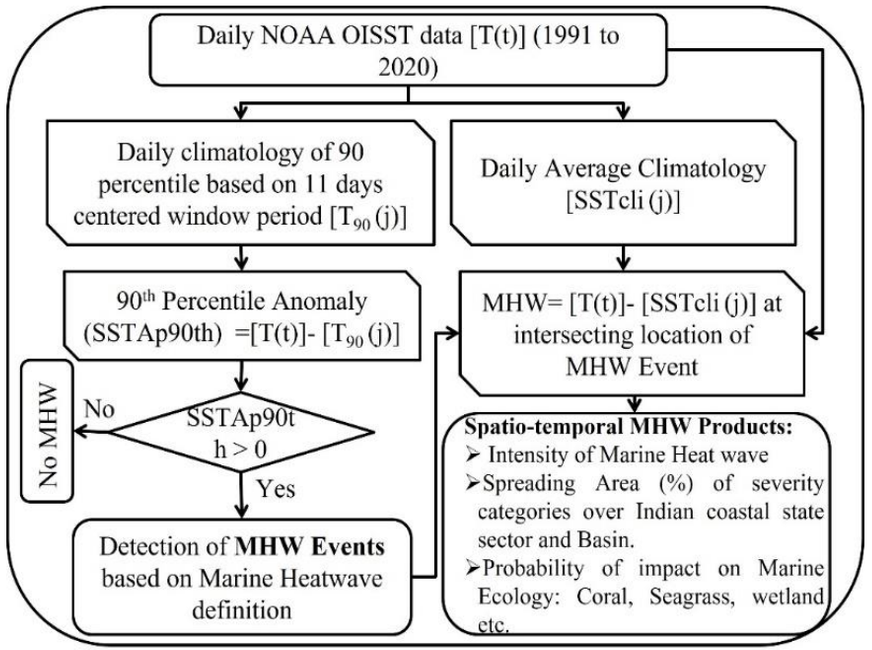
Study area divided into 6 Major Basin:
Arabian Sea (AS), Bay of Bengal (BoB), Rest of Indian Ocean (RestIO), Red Sea, Persian Gulf and Other sea;
14 Number of Indian Coast State sectors



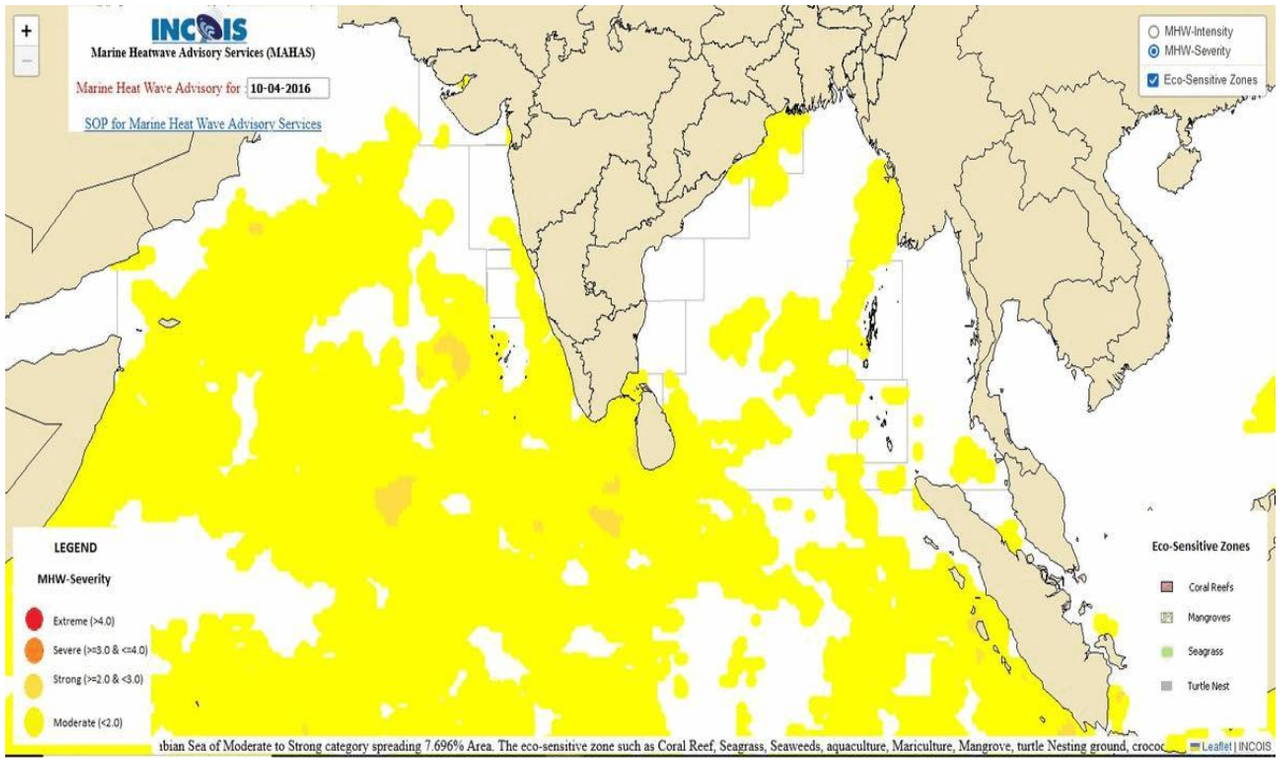
Methodology adapted to generate new services Marine Heat Wave advisory products

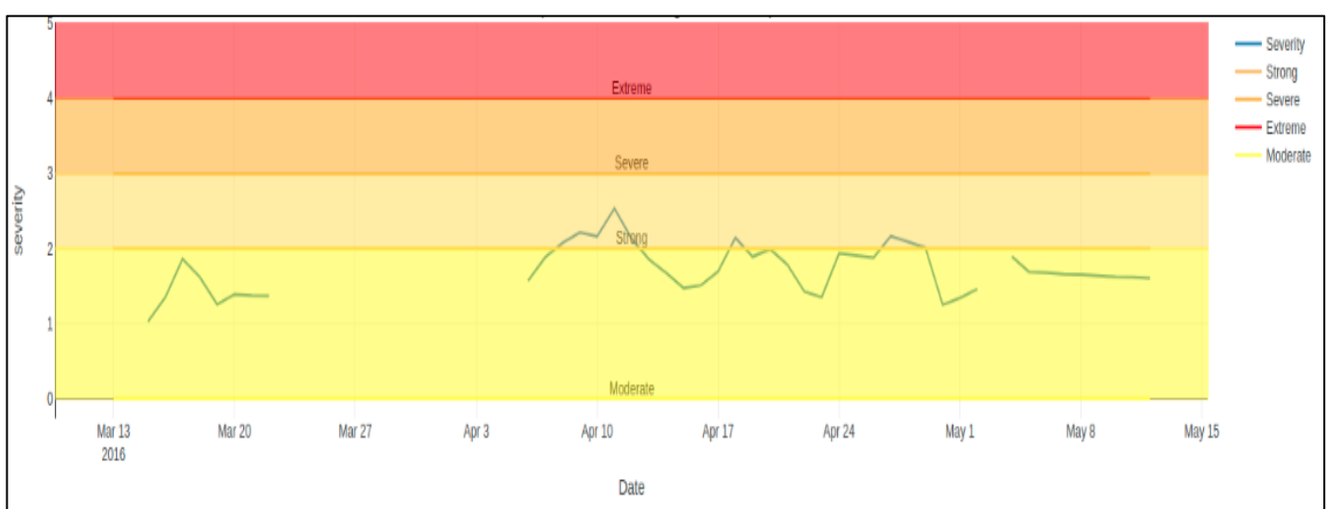
Marine Heat Wave Advisory Service (MAHAS) – A satellite-based service: Methodology

"MHW is a discrete prolonged anomalously warm water event that persists for more than two days above the 90th percentile of climatology"

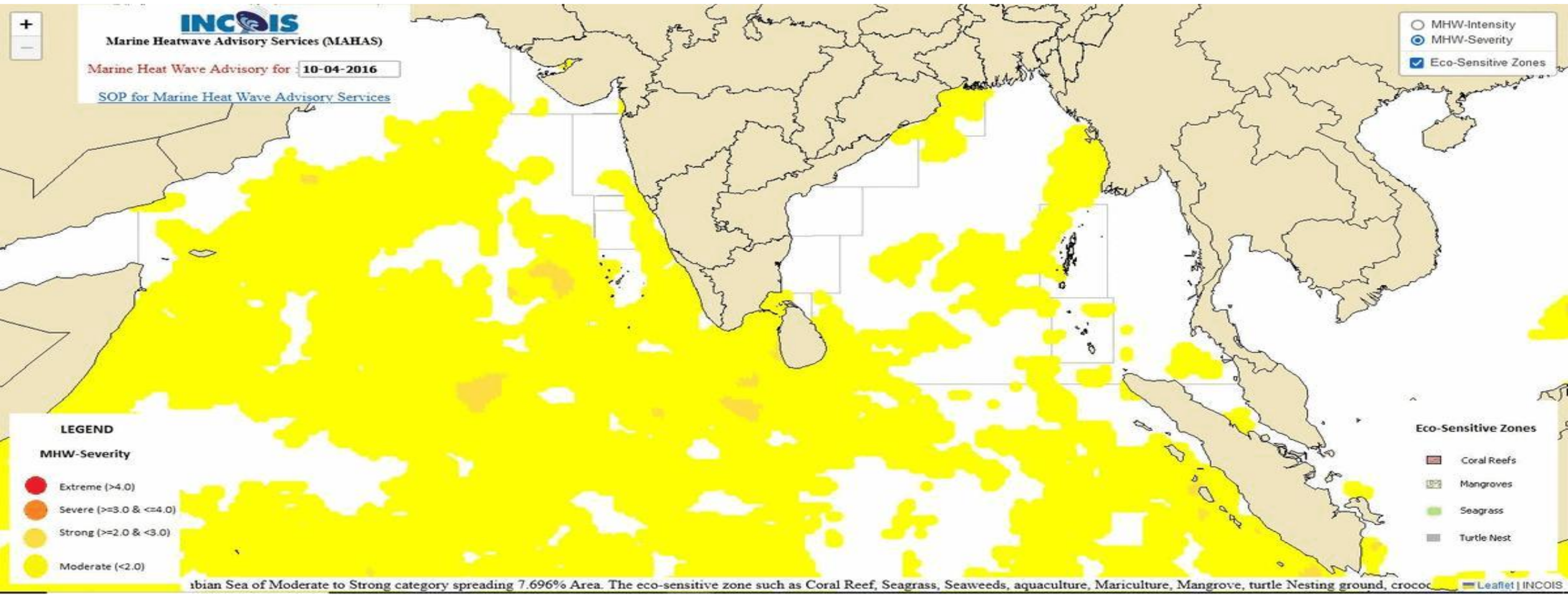


Marine Heat Wave Service on Web

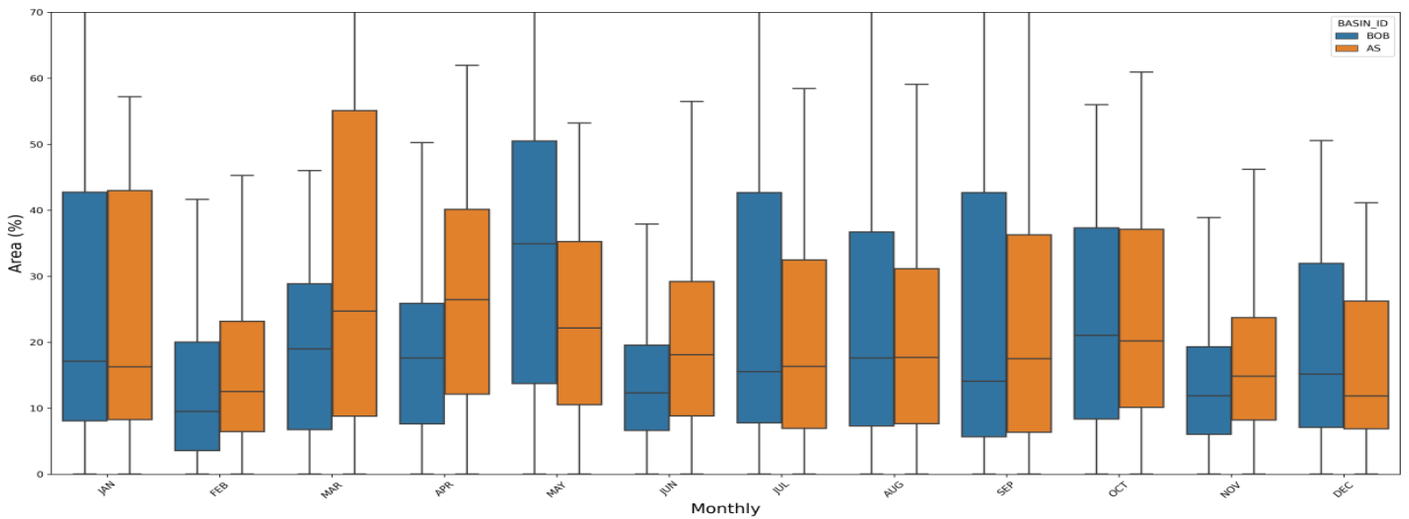


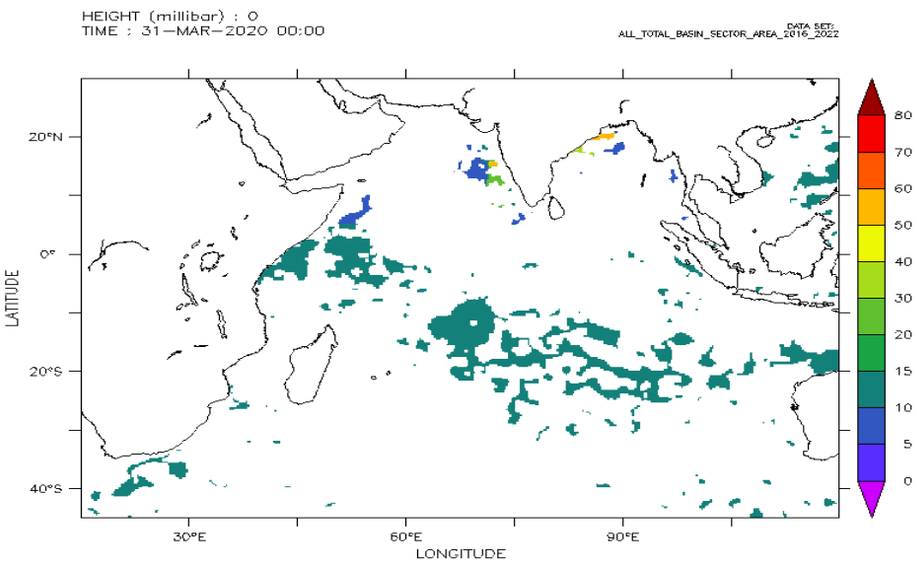


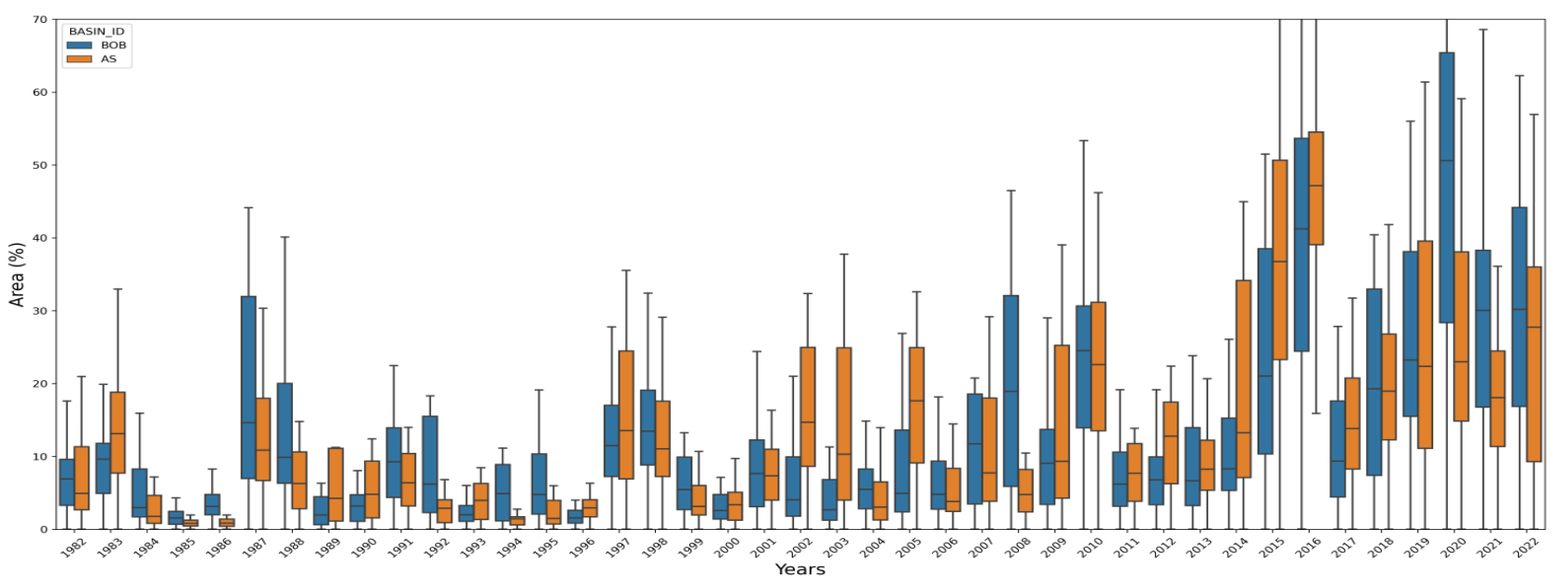
MHW Products for Advisory services: INCOIS MHWA Web Services

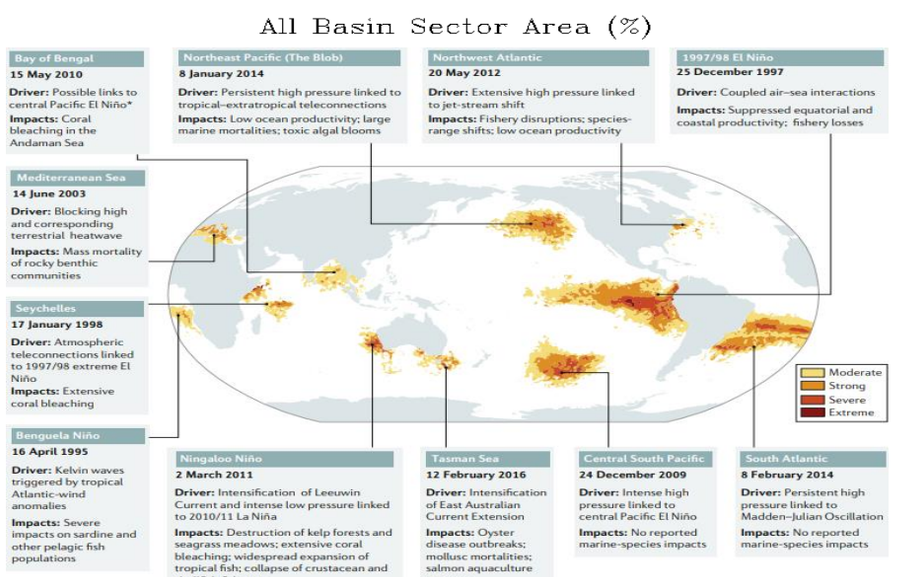


MHW Products for Advisory services: Area of spreading



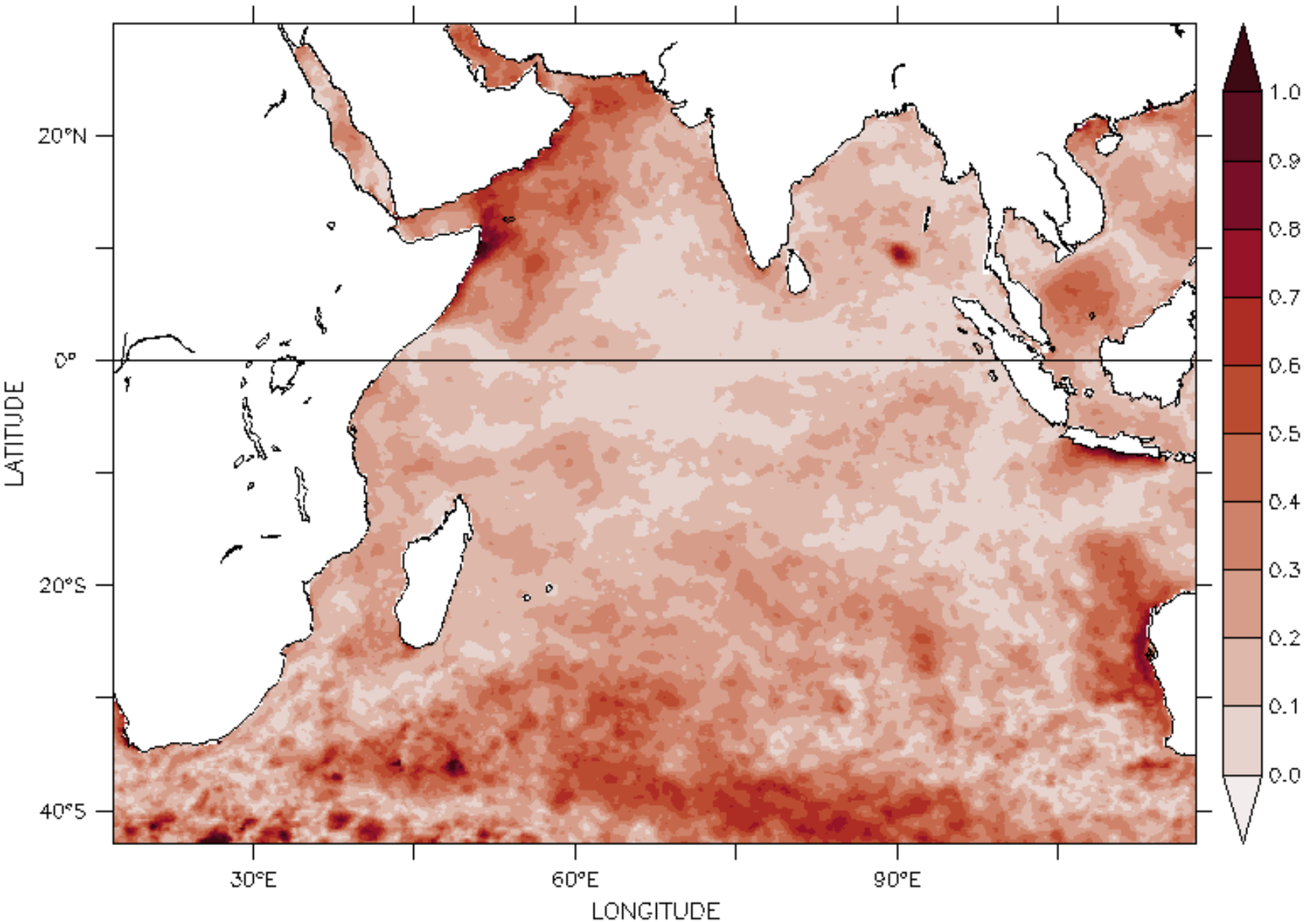






Holbrook et al., 2020

Decadal Annual Amplitude of MH



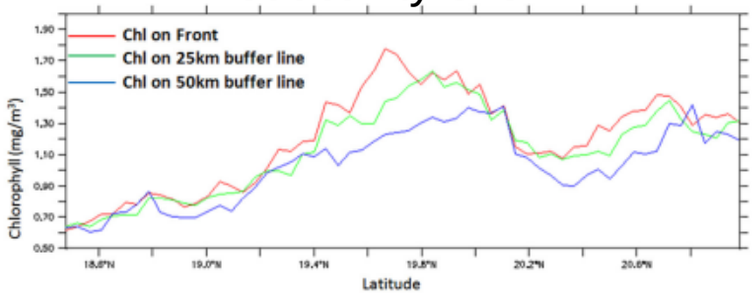
Annual Amplitude during 2011–2020 (~0 C)

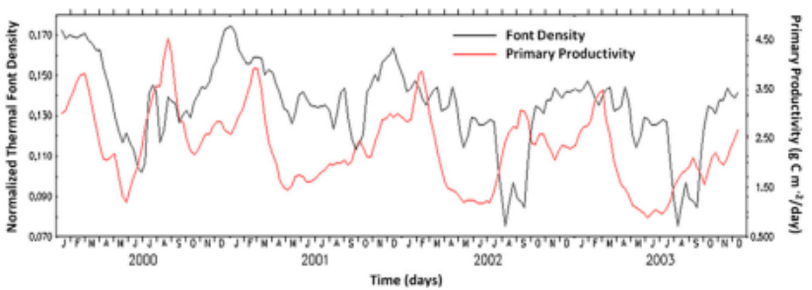
Impact of Thermal stress on Fishery

Persistence of productive surface thermal fronts and its impact on fishery

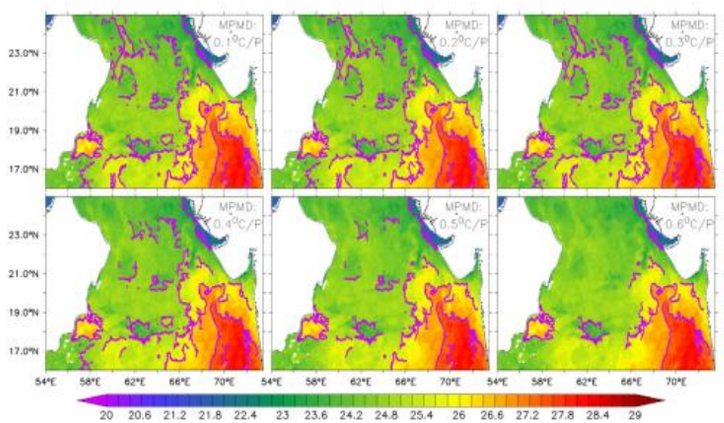
- Frequency of thermal fronts is a persistent high productive zone.
- These productive zones can serve as potential fishing grounds.
- Approach used in this study can substitute satellite data during cloudy days

Productivity over TE

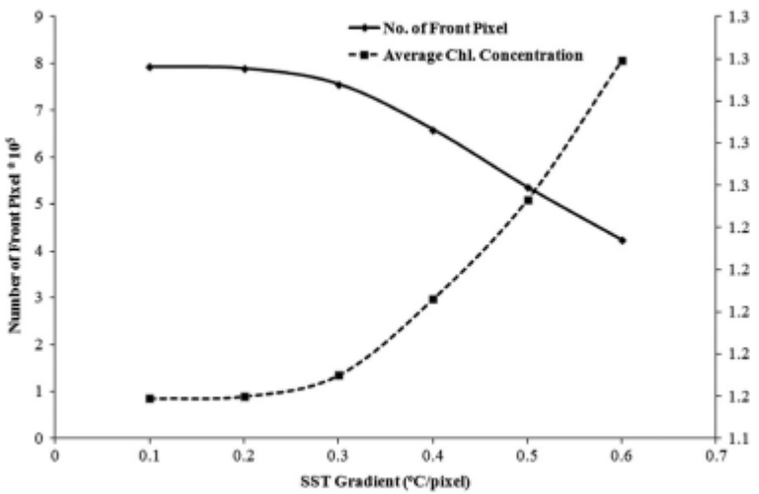




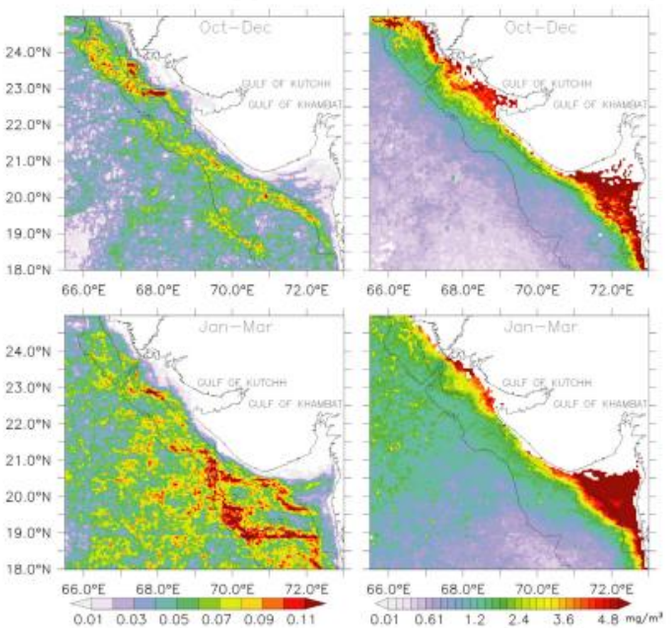
Thermal Front (TE)



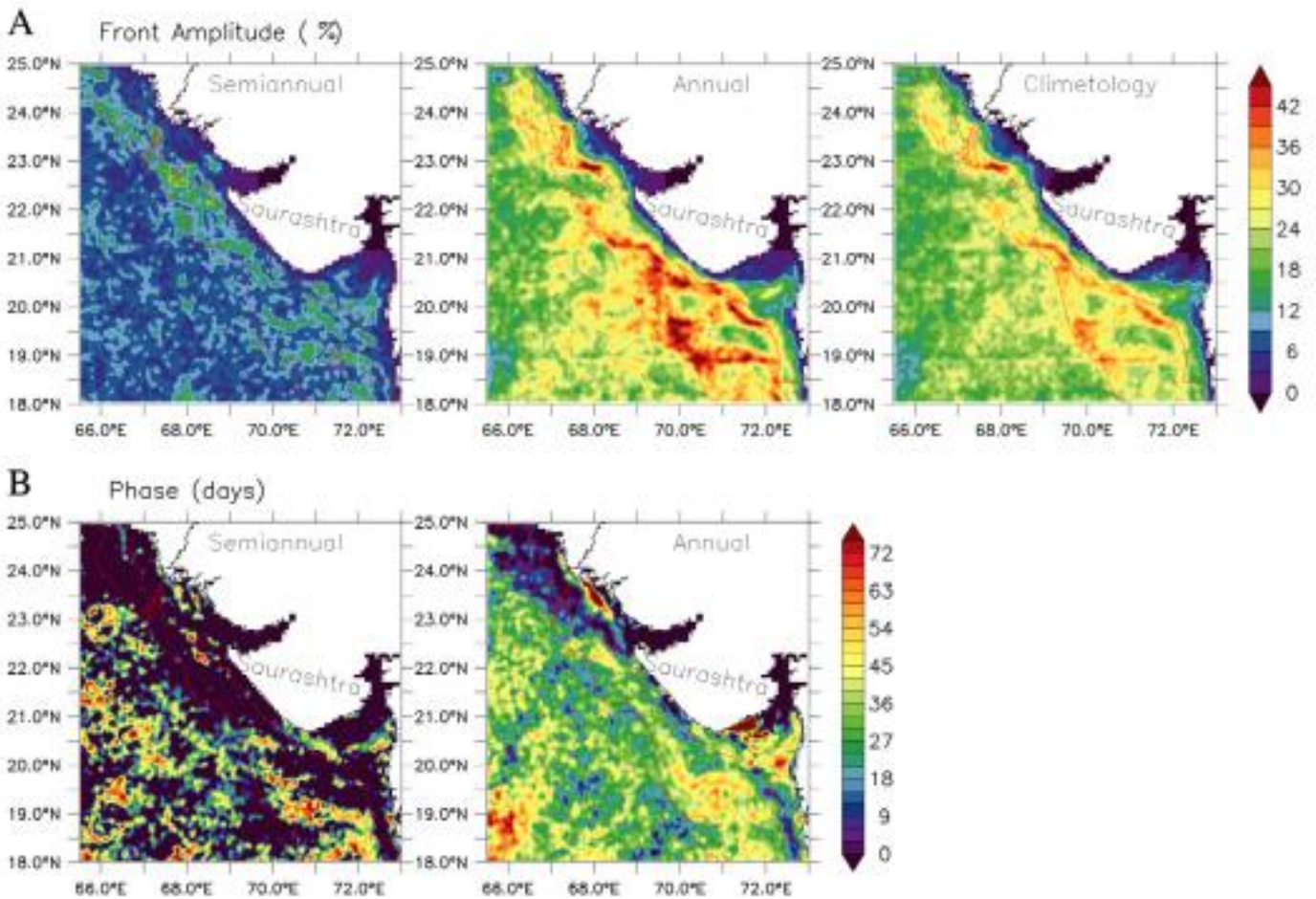
Chlorophyll Vs density of TE



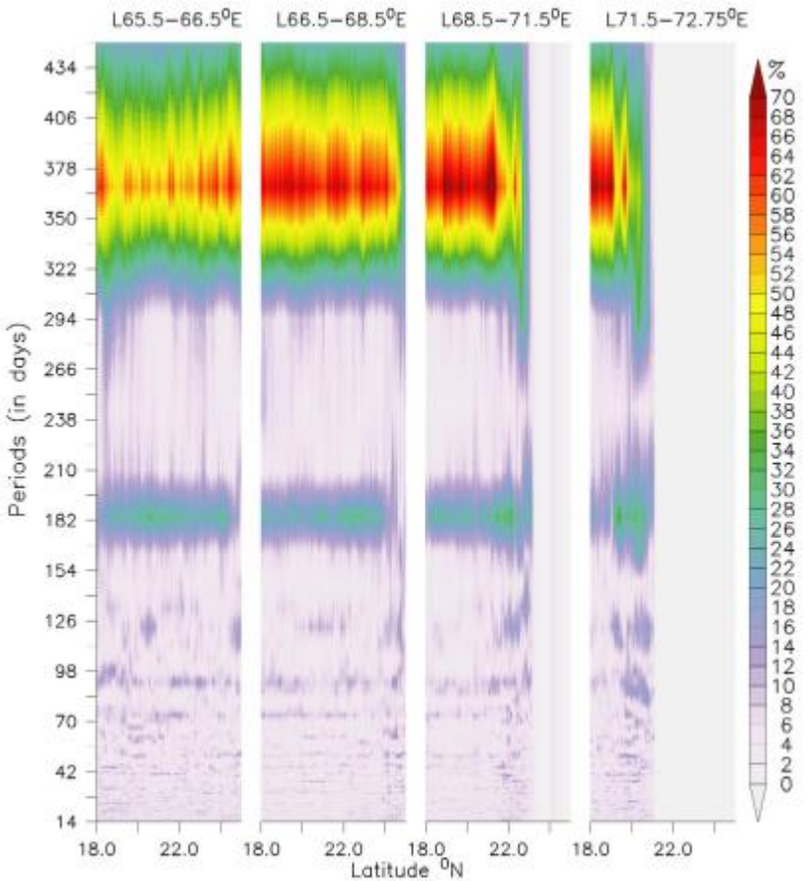
Climatology of TC and Chlorophyll



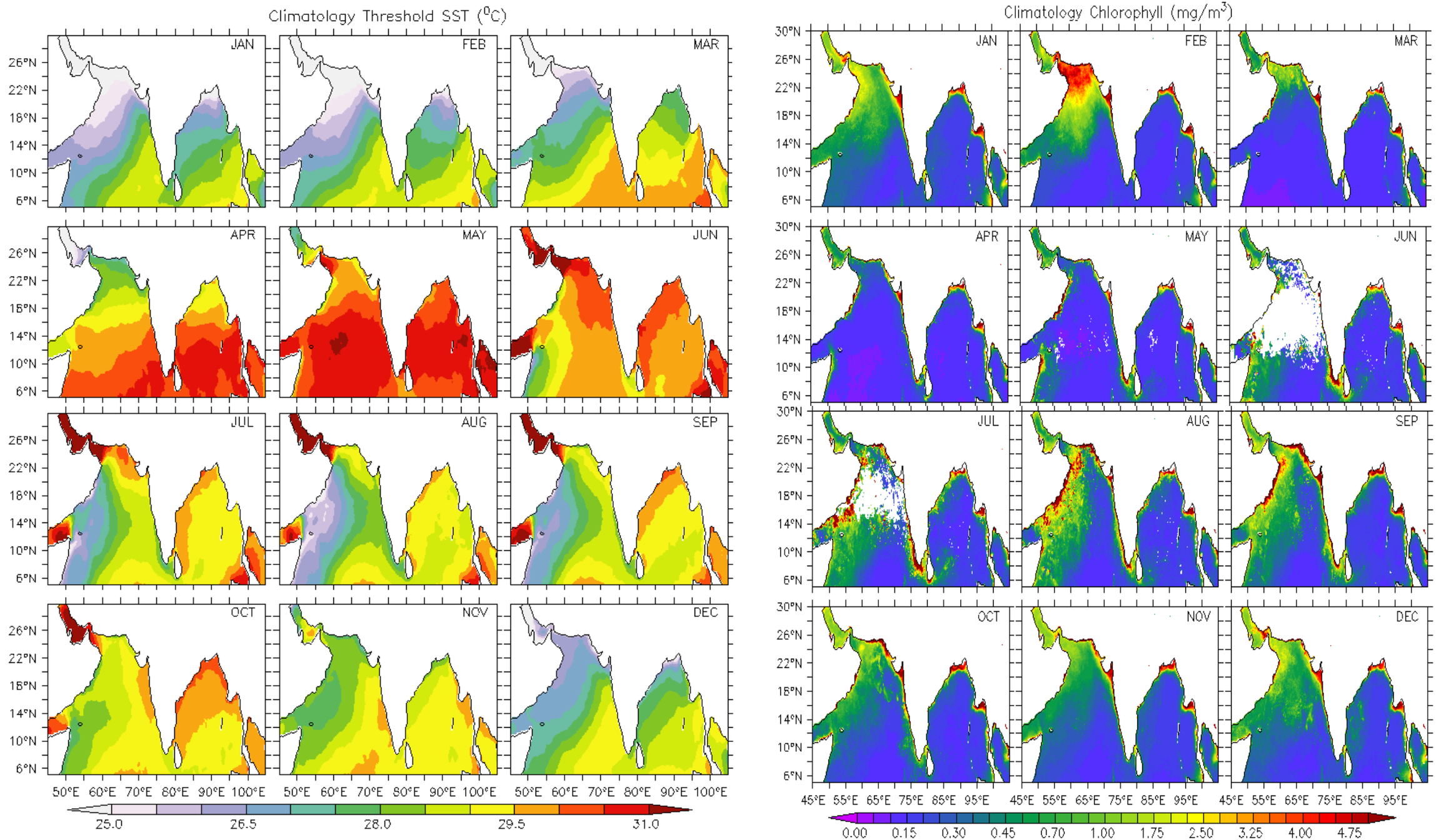
Amplitude and phase of Persistence of productive surface thermal fronts



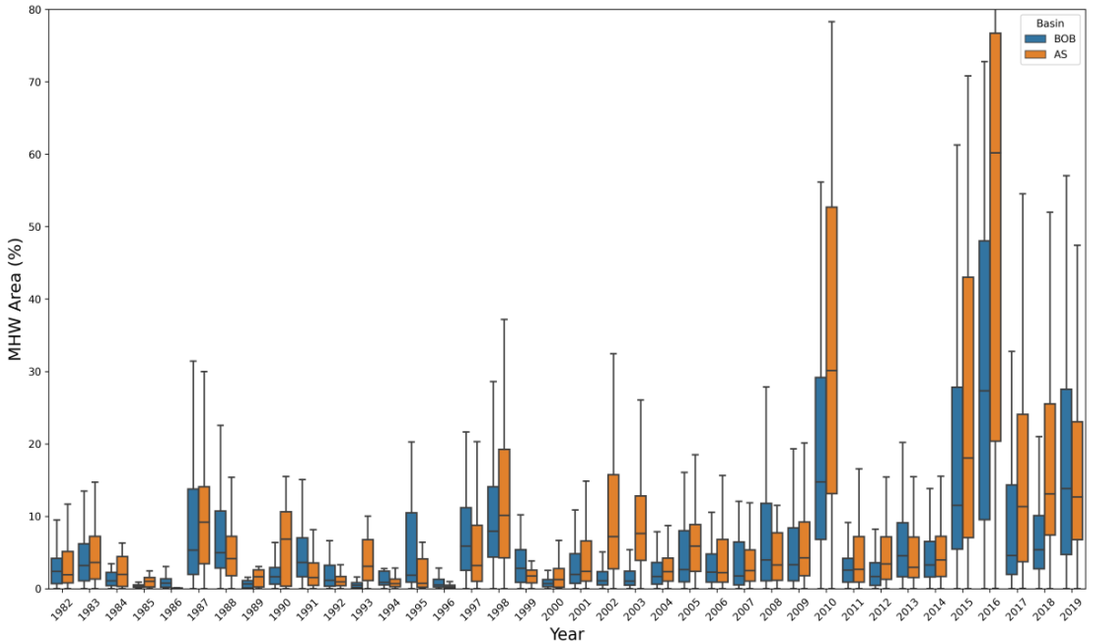
Maps of amplitude and phase associated with annual and semi-annual harmonics of the thermal front density. Bathymetry contours (red) of 50 m and 200 m are overplayed.

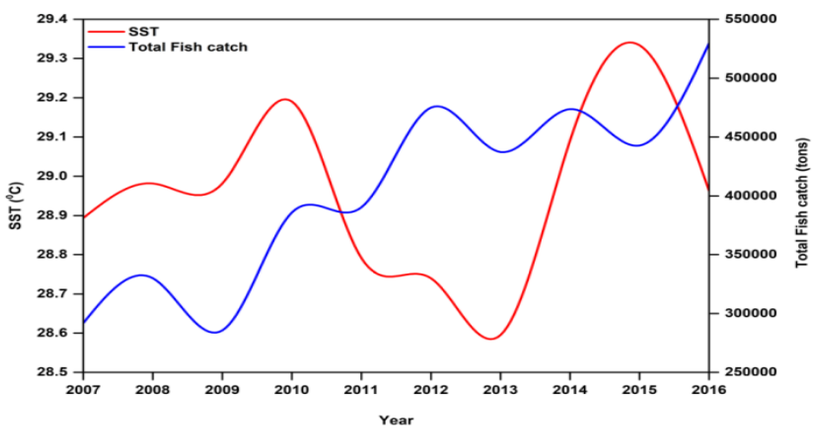


Amplitude distribution of thermal front density for four longitudinal segments as the function of latitude and time period


Climatology Threshold SST (°C)
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
26°N
22°N
18°N
14°N
10°N
6°N
50°E 60°E 70°E 80°E 90°E 100°E
25.0 26.5 28.0 29.5 31.0
Climatology Chlorophyll (mg/m³)
30°N
26°N
22°N
18°N
14°N
10°N
6°N
45°E 55°E 65°E 75°E 85°E 95°E
0.00 0.15 0.30 0.45 0.70 1.00 1.75 2.50 3.25 4.00 4.75

Impacts of MHW on Fisheries

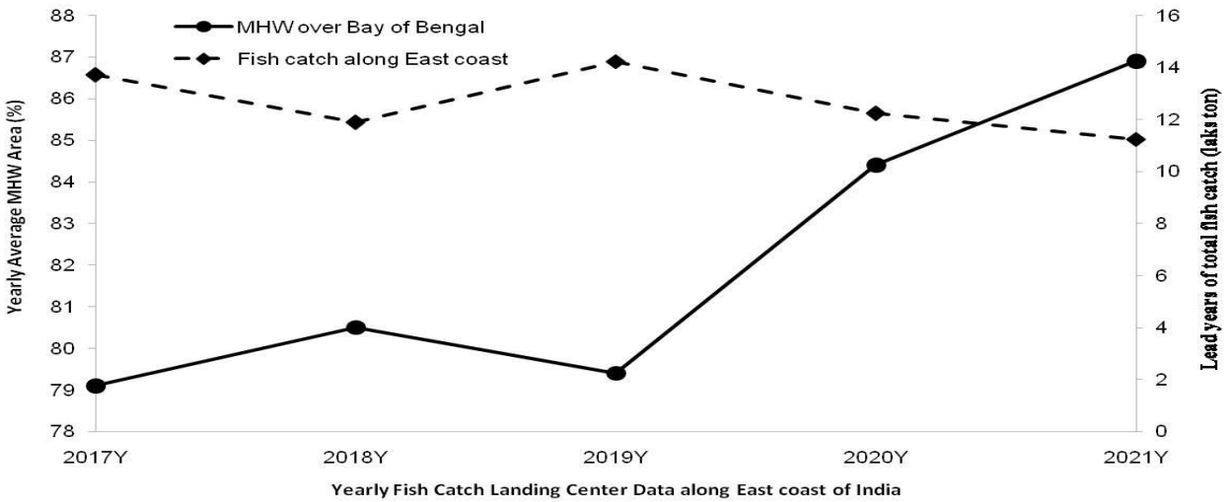




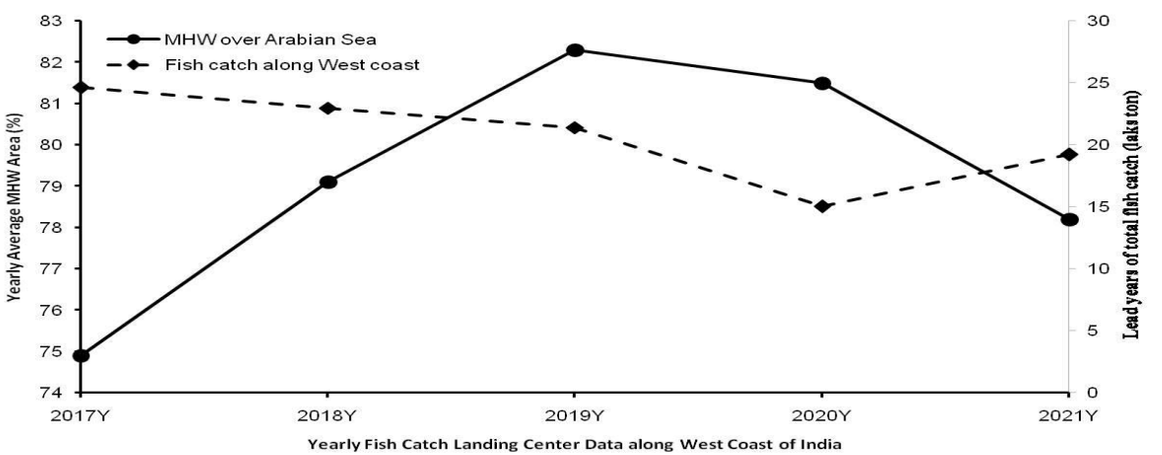
Inter-annual variations in SST and total fish catch from 2007 to 2016

Kumari et al. (2021). Journal of Indian Society of Remote sensing

Relation between MHW and Fish Catch along East coat of India

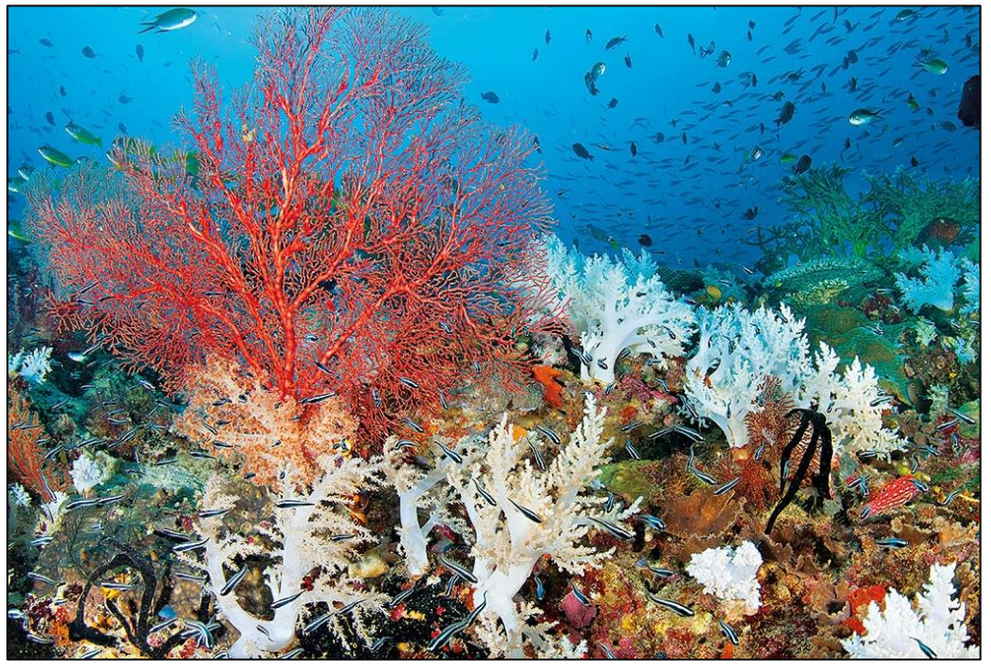


Relation between MHW and Fish Catch along west coast



Fish catch data from CMFRI

Impact on Coral Reef



What is a Coral Reef (Plant, Animal?)

Coral reefs are diverse underwater ecosystems held together by calcium carbonate structures (Coral polyp) secreted by corals. Coral reefs are beautiful, colorful and the cornerstone of a healthy ocean ecosystem.

- Corals are animals, even though they may exhibit some of the characteristics of plants and are often mistaken for rocks.
- Often called "rainforests of the Ocean/sea," shallow coral reefs form some of the most diverse ecosystems on Earth. Coral reefs provide complex, three-dimensional habitat for a huge variety of plants and animals (large and small!), and protect many young fish species as they grow
- Coral reefs only occupy 0.1% of the area of the ocean but they support 25% of all marine species on the planet.

How does it form ?

- Polyp are tiny animal the thrive, grow and then die and leave their limestone skeletons behind which layer by layer form reef. Polyps make their own limestone cup to hide in during the day . At night, polyps come out to catch plankton floating by.
- zooxanthallae is microscopic algae.
- Coral reef = Coral polyp + Zooxanthellae
- Symbiotic relationship between Coral Polyp and Zooxanthellae.
- Zooxanthallae assist coral in nutrient production through its photosynthesis activities which provide coral fixed carbon compound for energy and enhance calcification.
- Host coral polyp provide its zooxanthellae with protected environment to live within and steady supply of carbon dioxide for its photosynthesis process.
- Reefs grow best in warm, marine, shallow, clear, sunny and agitated waters

Satellite based Coral Bleaching Mapping:

Inputs:

SST monthly climatology data

NOAA AVHRR SST data

HotSpot (°C) = SST – (MMM SST Climatology)

DHWs (°C-week) = 0.5 * ∑ preceding 24 bi-weekly HotSpots

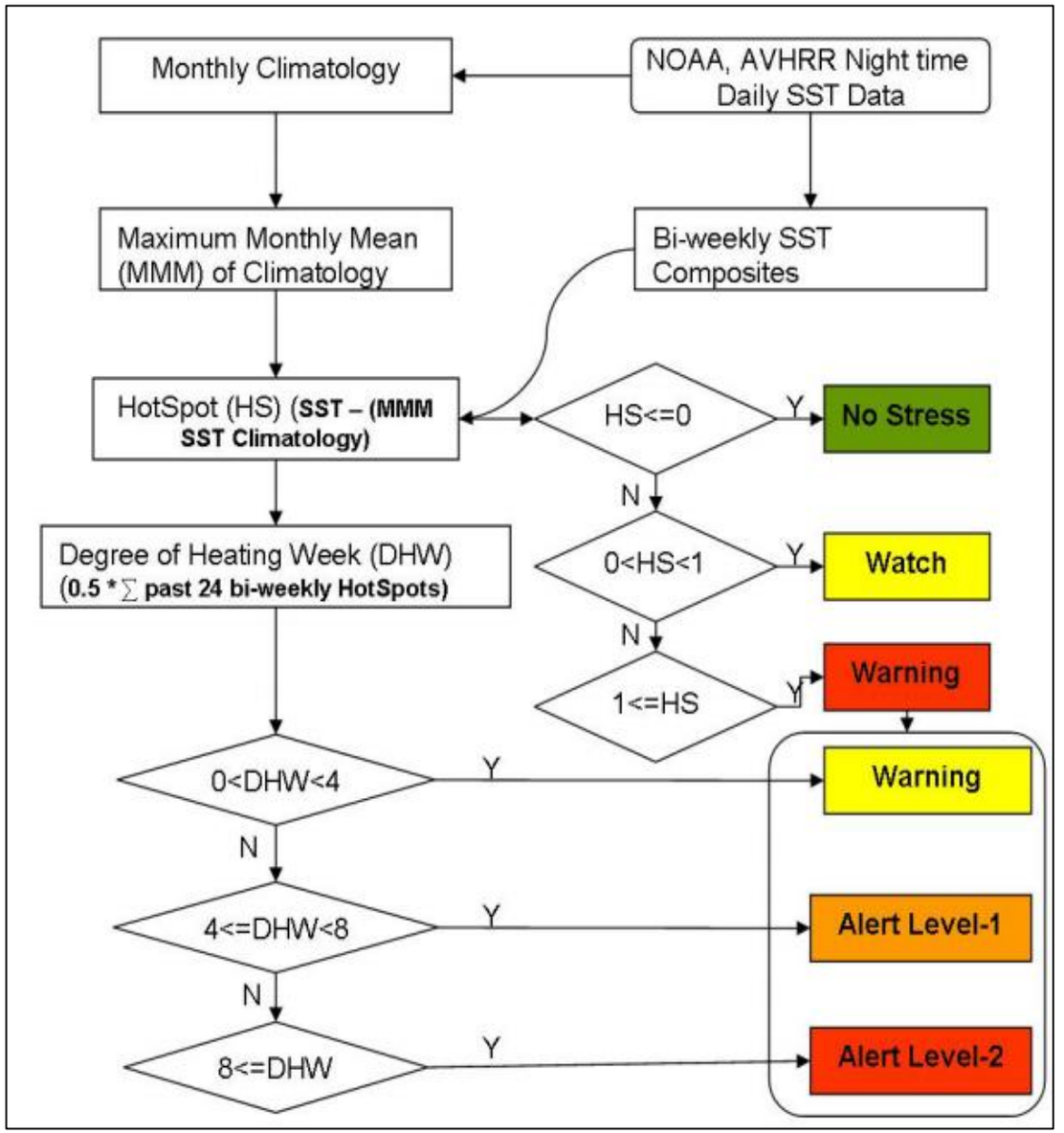
No stress: No thermal stress on the corals

Watch: Low thermal stress on the corals

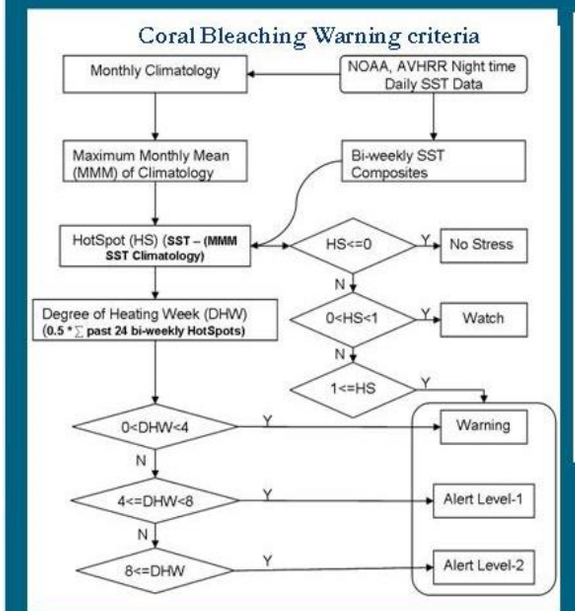
Warning: Thermal stress accumulated on corals

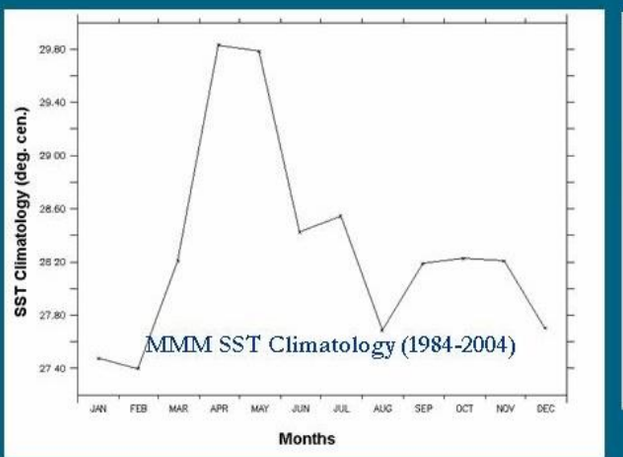
Alert Level1: Strong thermal stress on the corals, which may result in the partial bleaching

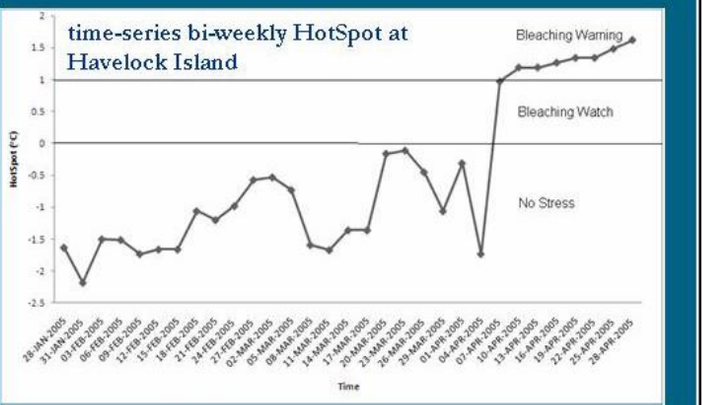
Alert Level2: Severe thermal stress on corals, which may result in widespread bleaching with likely coral mortality

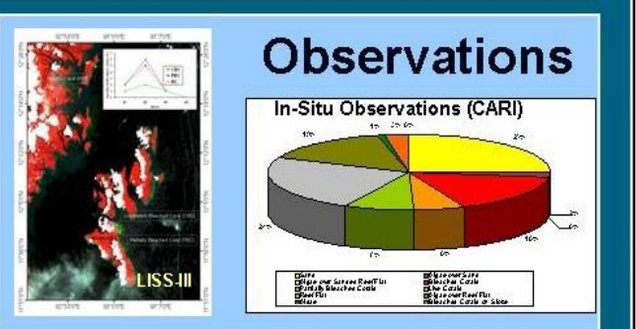


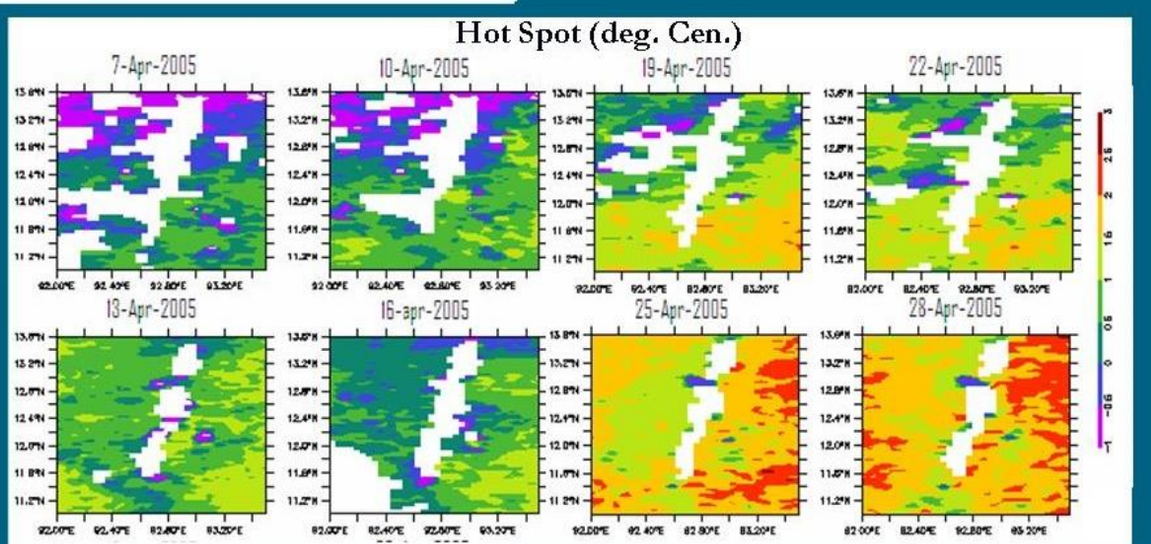
Bleaching Case Studies: April-May 2005 at Andaman

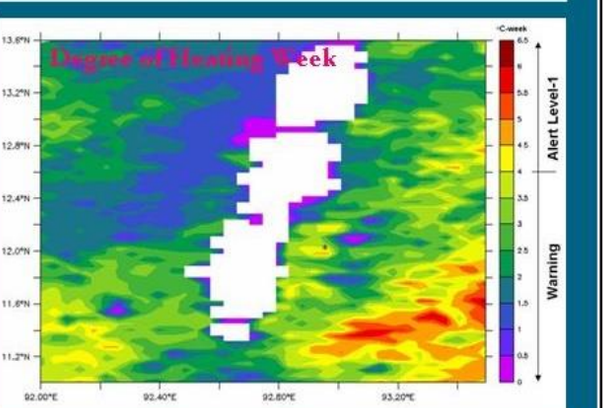












- The SST assessment depicted the coral bleaching with status “Alert Level1” was detected.
- The similar studies were planned for the other bleaching events in the Indian coral environs

Impacts of MHW on Coral Bleaching

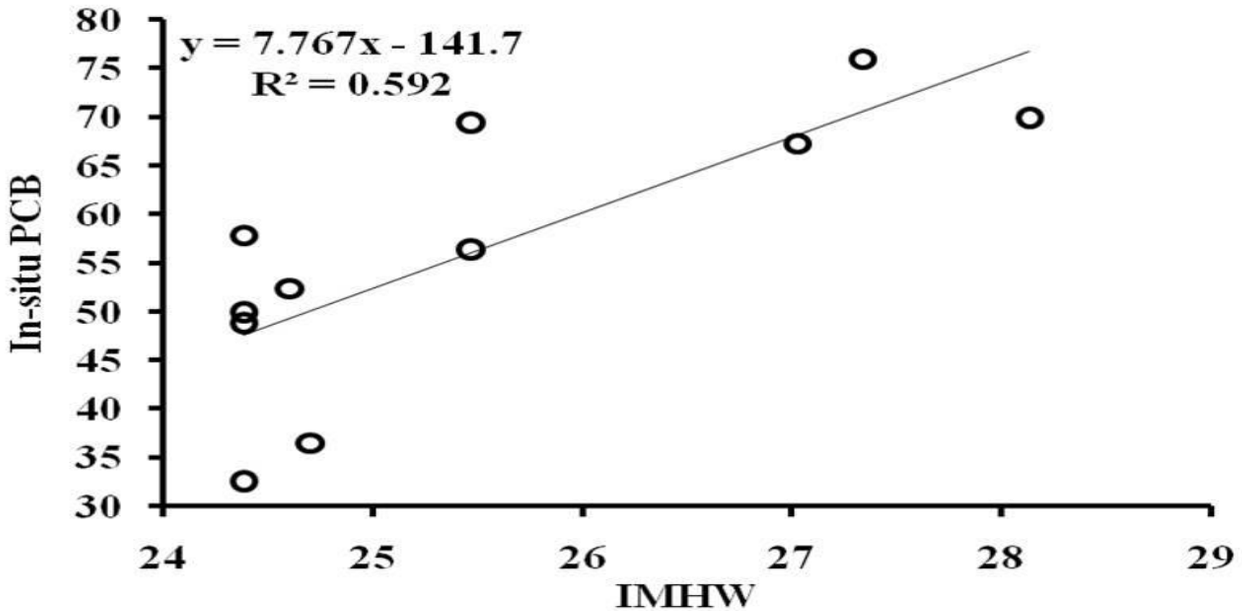
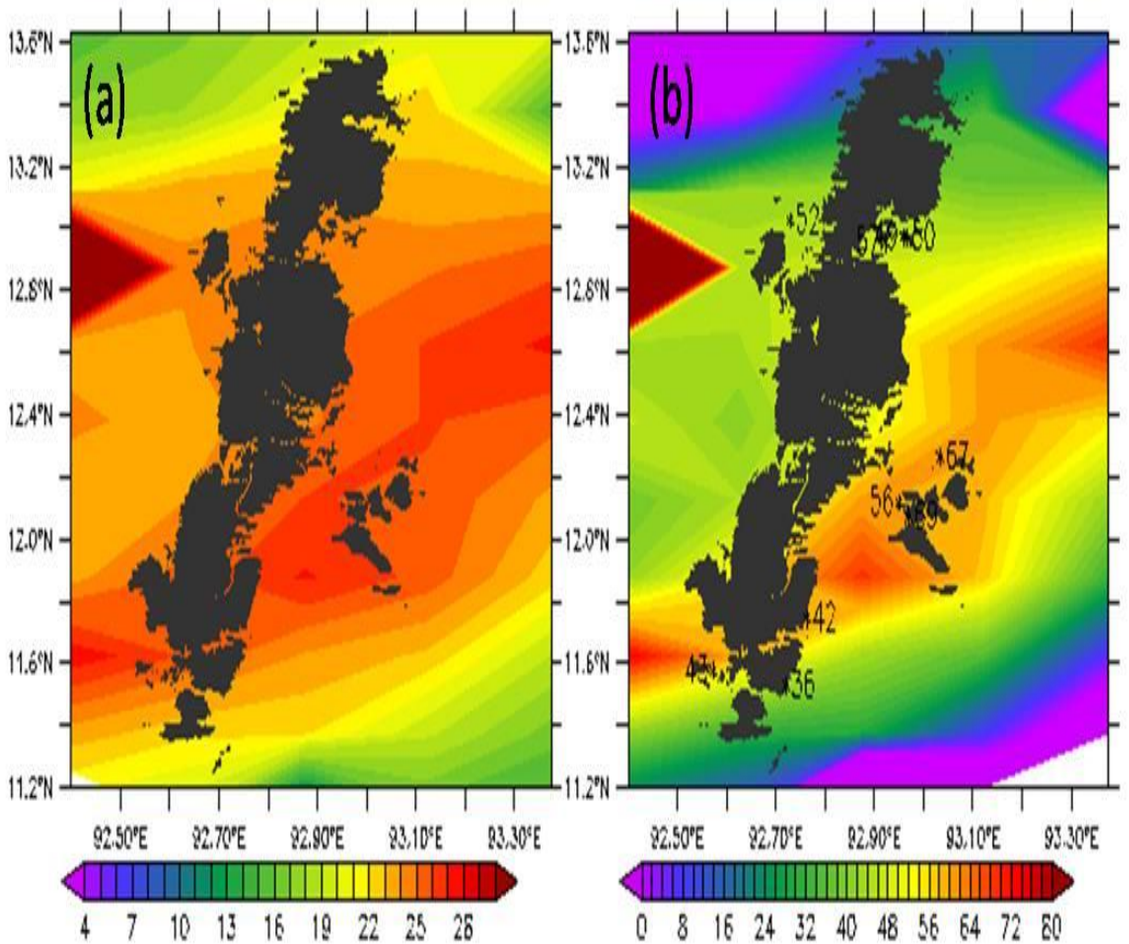


Figure : Scatter plot showing the Intensity of Marine Heat Wave (IMHW) plotted against observed percentage of Coral Bleaching (PCB).

$$PCB(\%) = 7.767 * (IMHW) - 141.7$$

Note: This empirical relationship has been setup based on some sporadic data available on open sources/published-literature/survey. However it need to be continuous time series of PCB and spectral characteristic using radiometer data required during bleaching event time to improve this algorithm.

Mohanty et. al., 2021 in *Environmental monitoring and assessment*



(a) Spatial patterns of Intensity of Marine Heat Wave (IMHW) during month of May, 2010 and (b) PCB computed empirically based on the equation2 along with In-situ observation bleaching percentage value at selected points (marked in value points).

Relevant Publications

- **Mohanty P.C.,** Kushabaha A., Mahendra R S., Nayak R. K., Sahu B. K., Pattabhi Rama Rao E., Sinivasa Kumar T. (**2021**). Persistence of marine heat waves for coral bleaching and their spectral characteristics around Andaman coral reef. ***Journal of Environ Monitoring and Assessment***. 193:491

- Vinaya K. P., Thomas S., **Mohanty P. C**., Jayappa K. S., Mahendra R S and Gupta A. (2021) Potential Consequences of Changing Sea Surface Temperature on Productivity and Fisheries along Karnataka, West Coast of India. ***Journal of the Indian Society of Remote Sensing***. 49(12):3027–3041

- **Mohanty P.C**. ,Mahendra R.S., Nayak R.K., Nimit Kumar, Srinivasa Kumar T. ,Dwivedi R.M (2017). Persistence of productive surface thermal fronts in the northeast Arabian Sea. ***Regional Studies in Marine Science*.** vol:16, pp:216–22; Year:2017

- **Mohanty P. C**., Mahendra R. S., Bisoyi H., Srinivasa Kumar T., Grinson George, Nayak S. and Sahu B.K. (2013). Assessment of the coral bleaching during 2005 to decipher the thermal stress in the coral environs of the Andaman Islands using Remote Sensing. ***European Journal of Remote Sensing***:46, 417-430, DOI: 10.5721/EuJRS20134624