Workshop: 6 - Remote Sensing and Ecology of Small Pelagics
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Application of phytoplankton biomass as an aid in management of marine resources of the southeastern Arabian Sea

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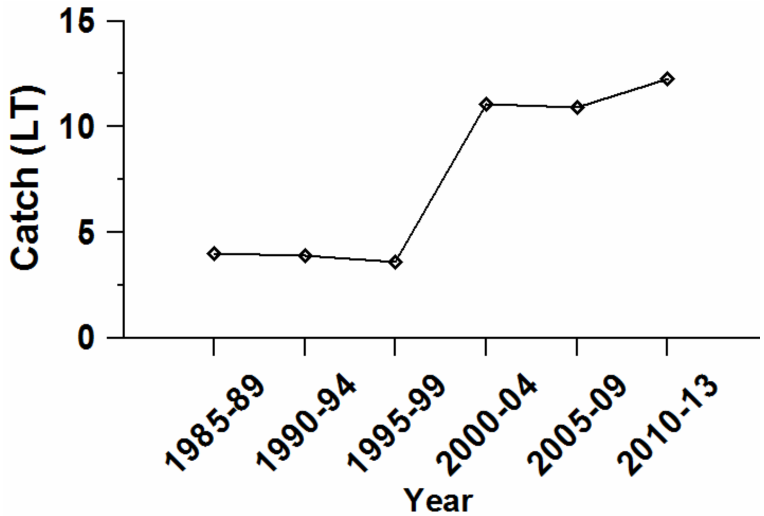
Introduction

- Coastal regions of south eastern Arabain sea, better known as the Malabar upwelling area, contributes to nearly 30-50% of the total marine fish catch from India.

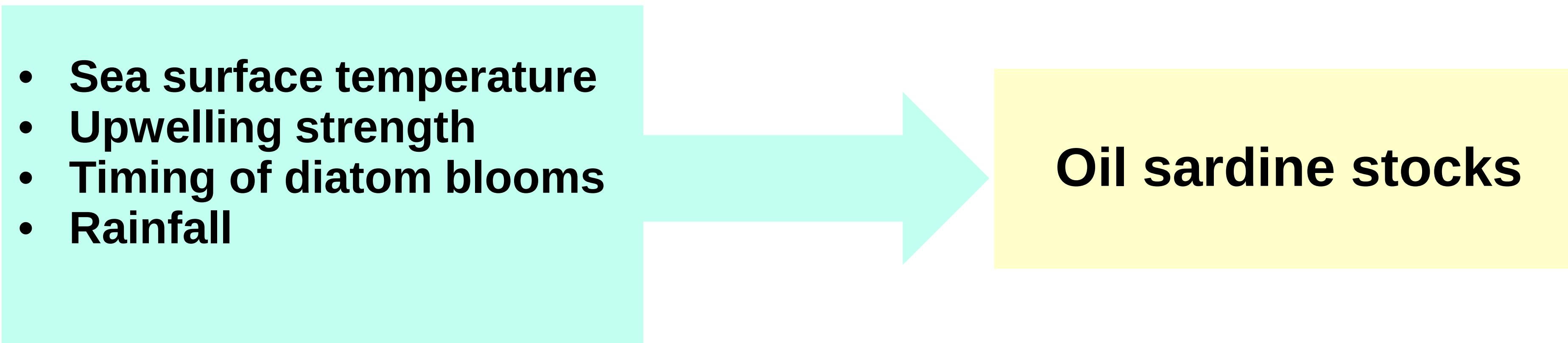
- This area, extending from Ratnagiri in the north to Cape Comorin in the south, is characterised by annual cycle of upwelling associated with the southwest monsoon.

- The ensuing productivity sustains a lucrative fishery of commercially important pelagic finfishes like oil sardine (*Sardinella longiceps)* and Indian mackerel *(Rastrelliger kanagurta),* which contributes to the largest coastal pelagic fishery of South Eastern Arabian Sea.

- The coast of Kerala, which forms an integral part of the Malabar upwelling region, contributes to approximately 10% of India’s total coastline, where inshore fishing is significant.
- Since 1980s small Pelagics catch has increased drastically.
- Among the small pelagic fishes, sardines are mostly consumed by people of Kerala.
- Fluctuations in oil sardine landings over a period of 30 years (Shyam et al., 2015)



- The fluctuations in sardine fishery over the years have a direct bearing on the coastal economy.
- The cause of fluctuation is not due to over exploitation, but due to multitude of environmental factors that affect the various life cycle stages of sardine.


Sea surface temperature
Upwelling strength
Timing of diatom blooms
Rainfall
Oil sardine stocks

Rationale

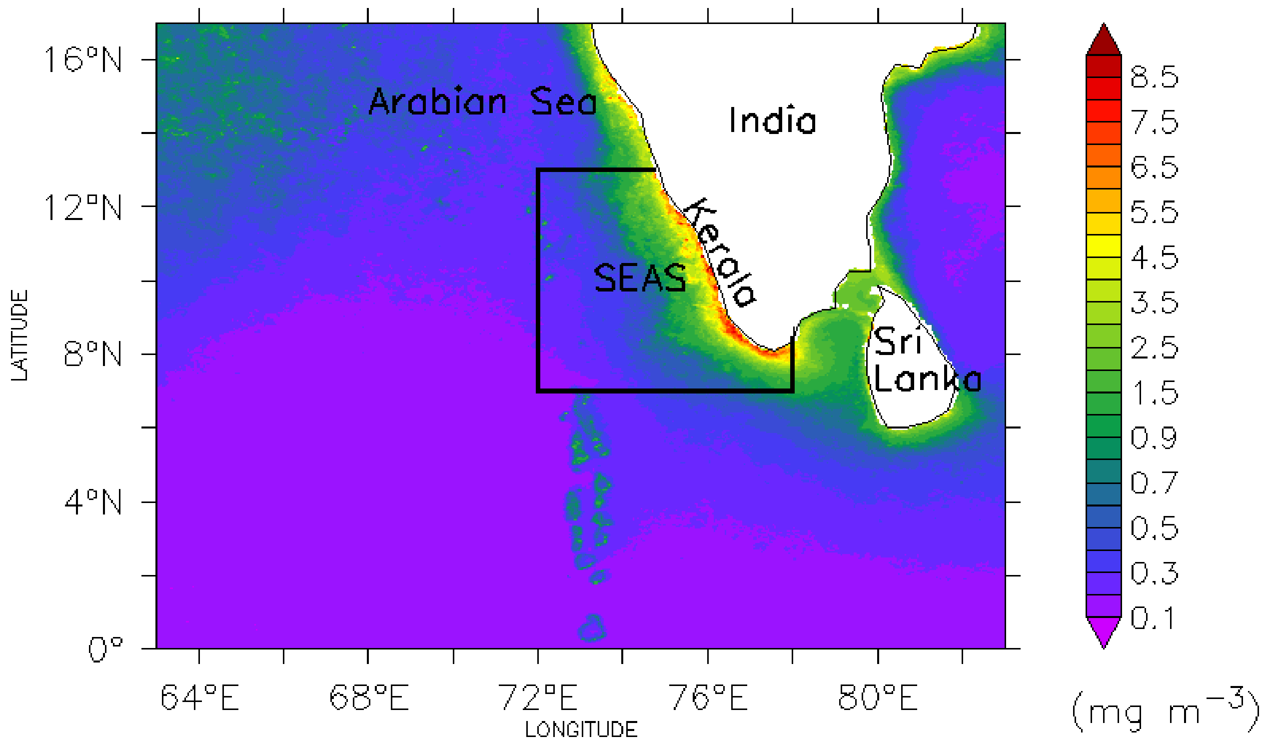
- Studies clearly emphasises that upwelling occurs in SE Arabian sea during the southwest monsoon
- Coastal upwelling elevates the nutrient concentration in the surface waters. Also, heavy river discharge associated with monsoon rains brings nutrients such as silicate required for the algal growth, particularly diatoms in the inshore waters.
- Coastal waters of Eastern Arabian sea are dominated by diatoms during the monsoon season (Martin et al., 2013; Personal unpublished data).
- Minu et al. (2014) have shown that coastal waters of SE Arabian sea are dominated by diatoms but an alteration of dominance between the groups from diatoms to dinoflagellates and cyanobacteria occur in non-monsoon seasons.
- Diatoms, especially the centric diatoms that dominate the phytoplankton community are preferred by sardines.
- The spawning and recruitment period of oil sardine is found to overlap with the major upwelling season of June to September.

Objective

- Sardines are planktivorous, which mainly feeds on diatoms. This enables us to hypothesize a direct relationship between phytoplankton biomass and stocks of *Sardinella longiceps*.

✓ To examine whether the landings of *Sardinella longiceps* in the coastal waters of Kerala is affected by the fluctuations in phytoplankton biomass (Chl-a), which in turn is affected by the upwelling related drivers.

Study area



South Eastern Arabian Sea (SEAS) with the study area (Box) superimposed with OC - CCI Chl-a climatology for SW monsoon season (JJAS)

Data

Sl. No.	Datasets used	resolution	duration	source
1.	Chlorophyll-a	4km	1998-2014	http://www.esa-oceancolour-cci.org
2.	Sea surface temperature		1998-2009	https://www.nodc.noaa.gov/
3.	Sea surface temperature (Night time at 11µm)		2010-2014	https://oceancolor.gsfc.nasa.gov
4.	Sea level anomaly	25km	1998-2014	http://www.aviso.altimetry.fr
5.	ERA-Interim reanalysis wind	25 km	1998-2014	http://www.ecmwf.int
6.	Rainfall data of Kerala		1998-2014	ftp://www.tropmet.res.in
7.	Fish catch data of Kerala		1998-2014	CMFRI, Kochi

Temporal resolution : Monthly mean (for all data)

Approach

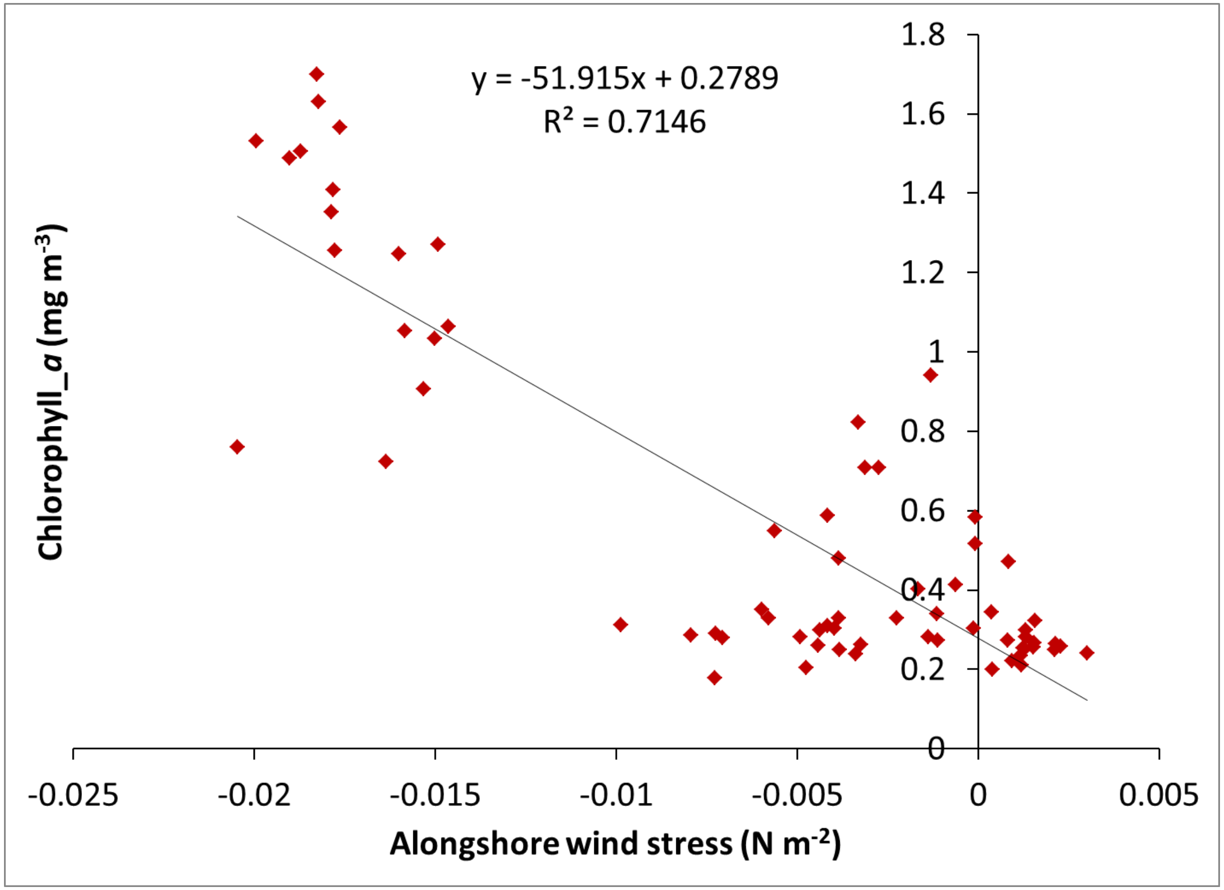
- Each year was divided into 4 seasons based on the monsoons affecting the area:

  1. Northeast monsoon (December, January, February - DJF),
  2. Pre-monsoon (March, April, May - MAM)
  3. Southwest monsoon (June, July, August, September - JJAS) and
  4. Post-monsoon (October, November - ON)

- Seasonal variation of Chl-a and oceanographic forcings were compared.
- Multiple stepwise linear regression analyses were performed to identify significant correlation between oceanographic parameters and Chl-a.
- Cross correlation between seasonal data of Chl-a and sardine landings were done to find the lead-lag correlation.
- Lagged correlation between seasonal Chl-a and seasonal sardine landings were done to find out the influence of phytoplankton biomass on sardine fishery.

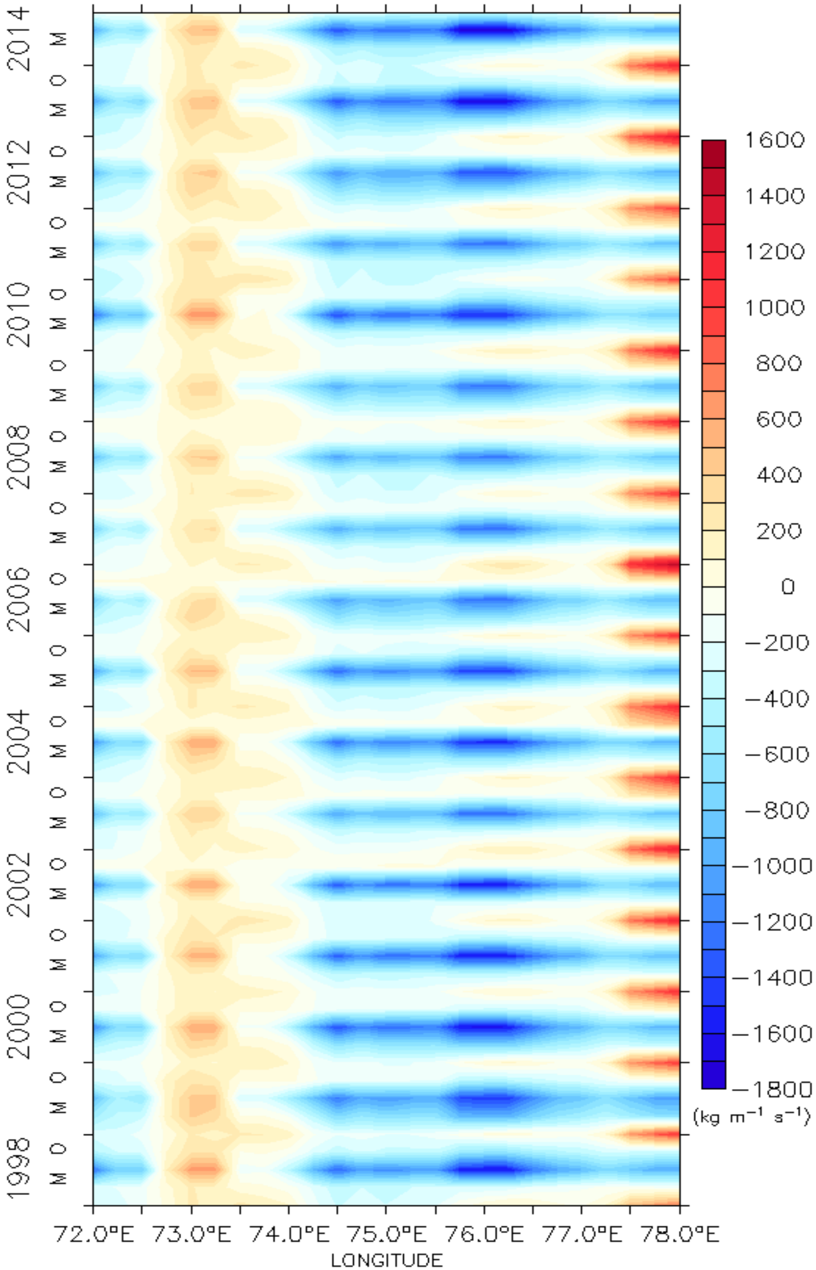
Results

Chl-a and alongshore wind stress



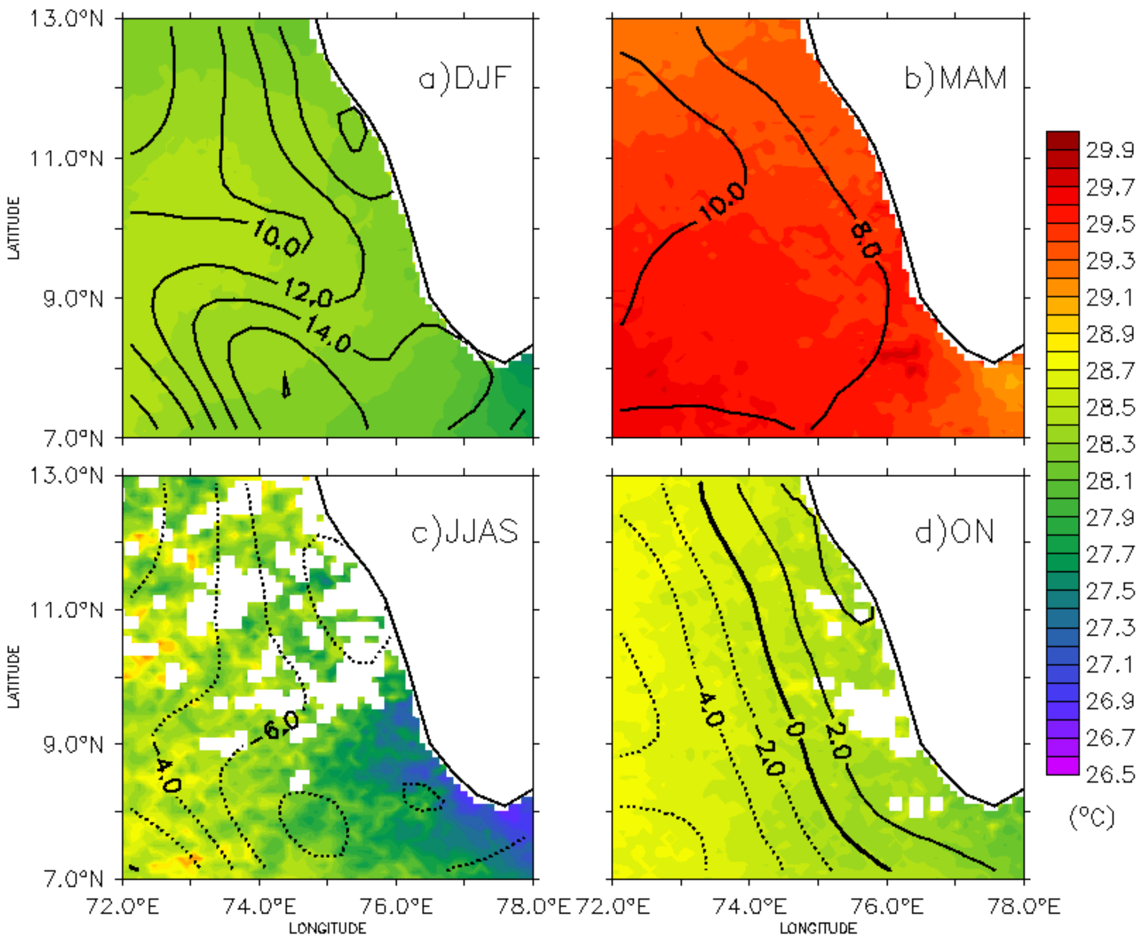
- Strong negative correlation between along-shore wind and Chl-a is observed.

The seasonal and inter-annual variability of Ekman mass transport



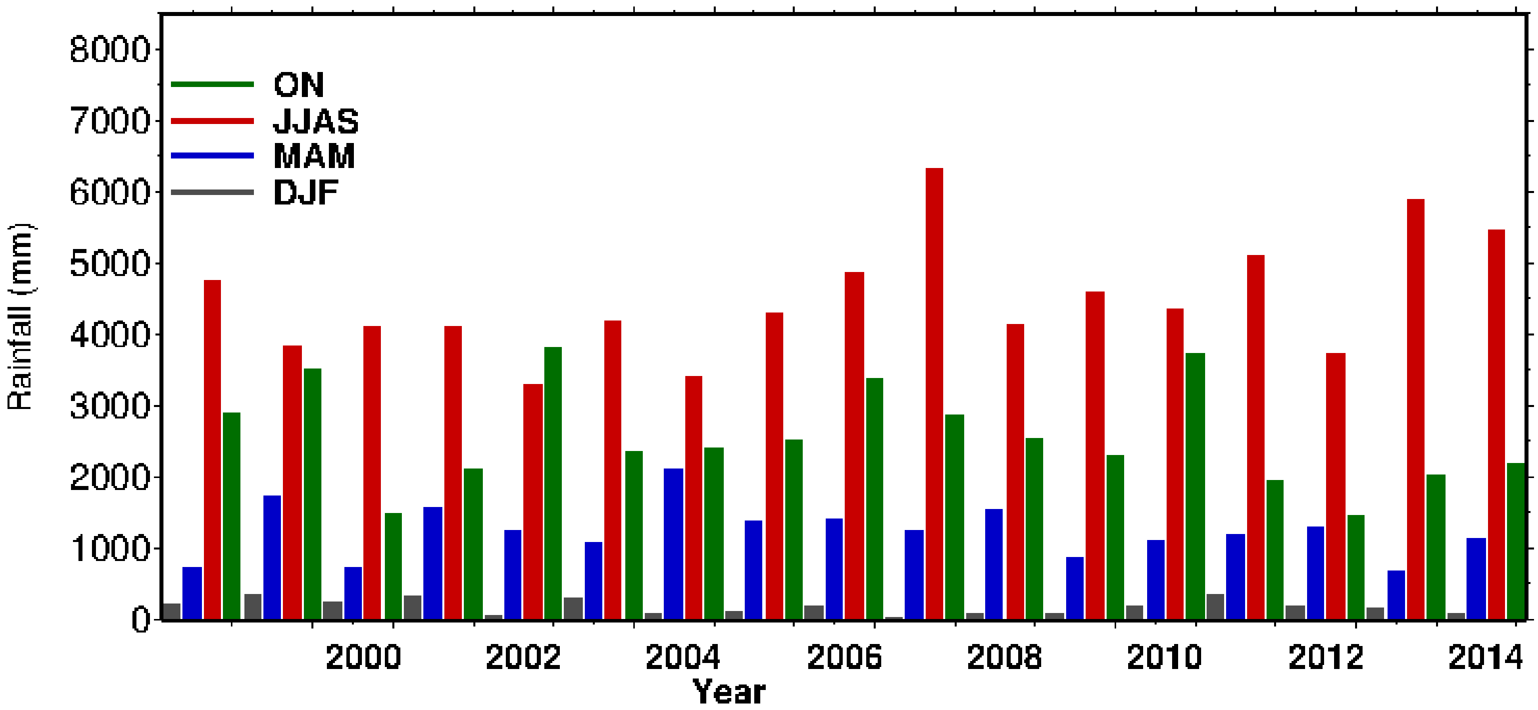
- Alongshore component wind was found to be negative (northerly) during SW monsoon season of all years.
- High negative values of Ekman mass transport that reach upto -1800 kg m^{-1} s^{-1} responsible for coastal upwelling in this region was seen during SW monsoon season with inter-annual variability in intensity.
- Offshore transport of a lesser intensity was observed during NE monsoon season.

Seasonal climatology of SST plots overlaid with SLA for the period 1998 to 2014



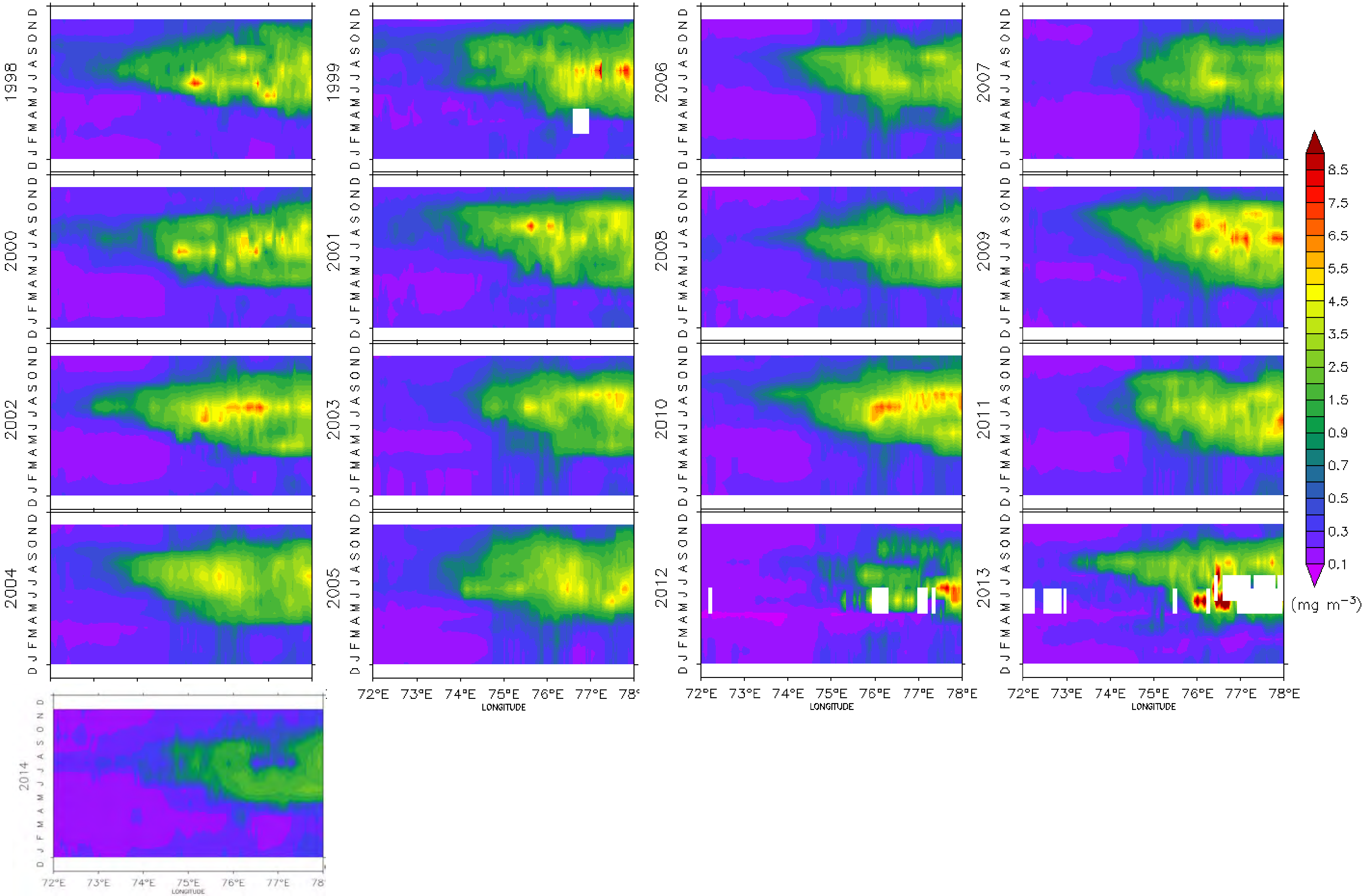
- As SST is suggested to be the most reliable indicator of coastal upwelling in the Arabian Sea, the cooler surface temperatures observed were checked for signatures of upwelling.
- In agreement with the findings of Shetye et al. (1991), the development of Lakshadweep low (drop in sea level forming a circular low to the east of Lakshadweep islands) during SW monsoon leading to strong negative SLA was evident during the monsoon season in the present study.

Rainfall in Kerala



- Similar to Chl-a, rainfall peak is also observed for the southwest monsoon season.

The seasonal and inter-annual variability (1998-2014) of Chl-a



Multiple Linear Regression Analysis (MLRA) to assess the influence of environmental forcings on phytoplankton biomass (seasonal values)

Independent variable	Standardized Reg. coefficient	Standard error	t-value	Prob>|t|, P	R^2	Adj. R^2
SST	-0.079	0.035	-2.23	0.029	0.87	0.86
Kerala rain	-3.7E-5	3.0E-5	-1.23	0.222*		
Wind stress	-392.509	121.545	-3.23	0.002		
Ekman transport	0.008	0.003	2.95	0.004		
SLA	-3.347	0.536	-6.23	4.4E-8		

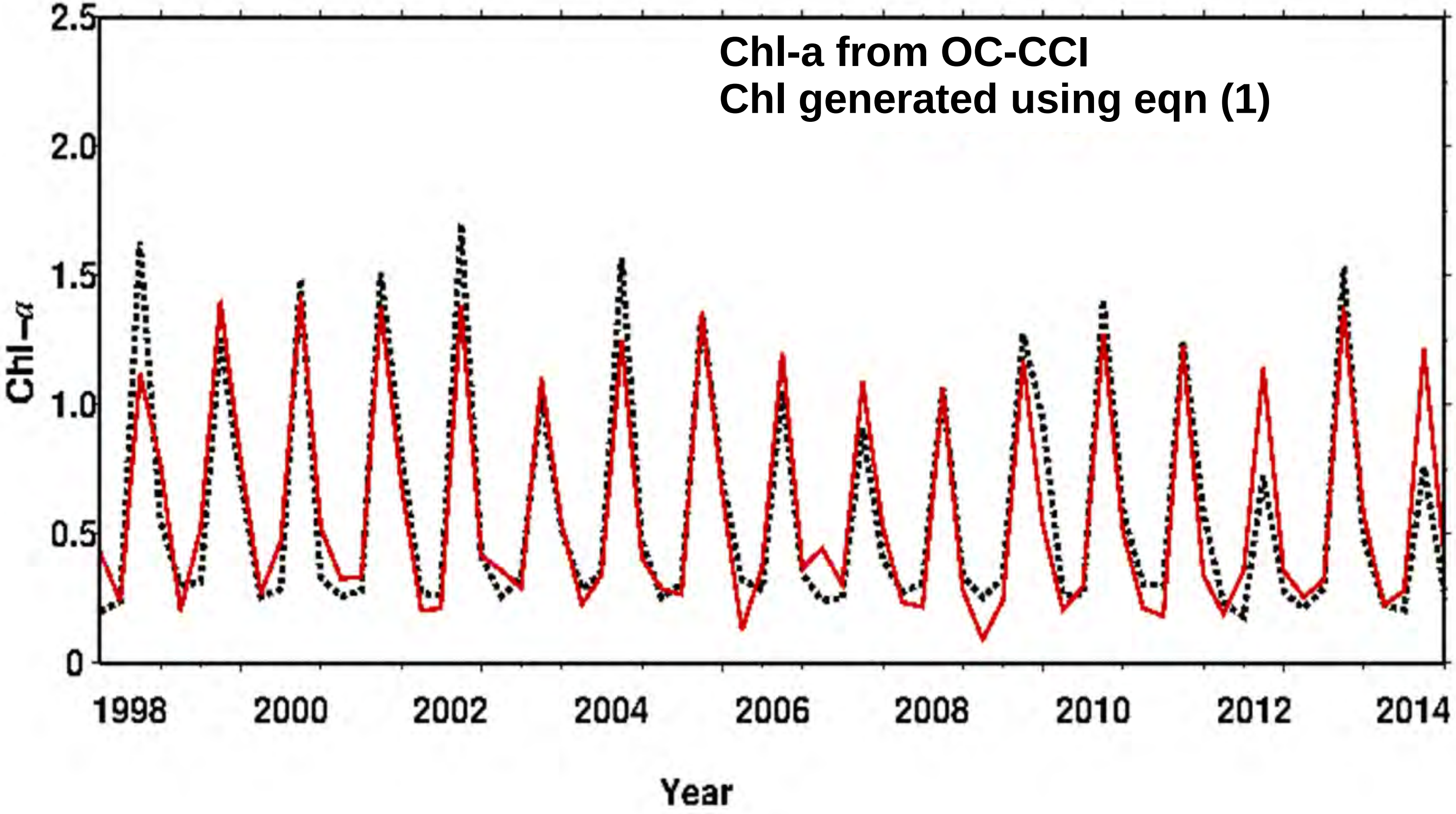
***P>0.05: statistically not significant**

Equation obtained from MLRA:

Chl = -0.079SST -3.8E-5 rain -92.510 wind stress + 0.008 Ekman transport – 3.347 SLA + 2.817

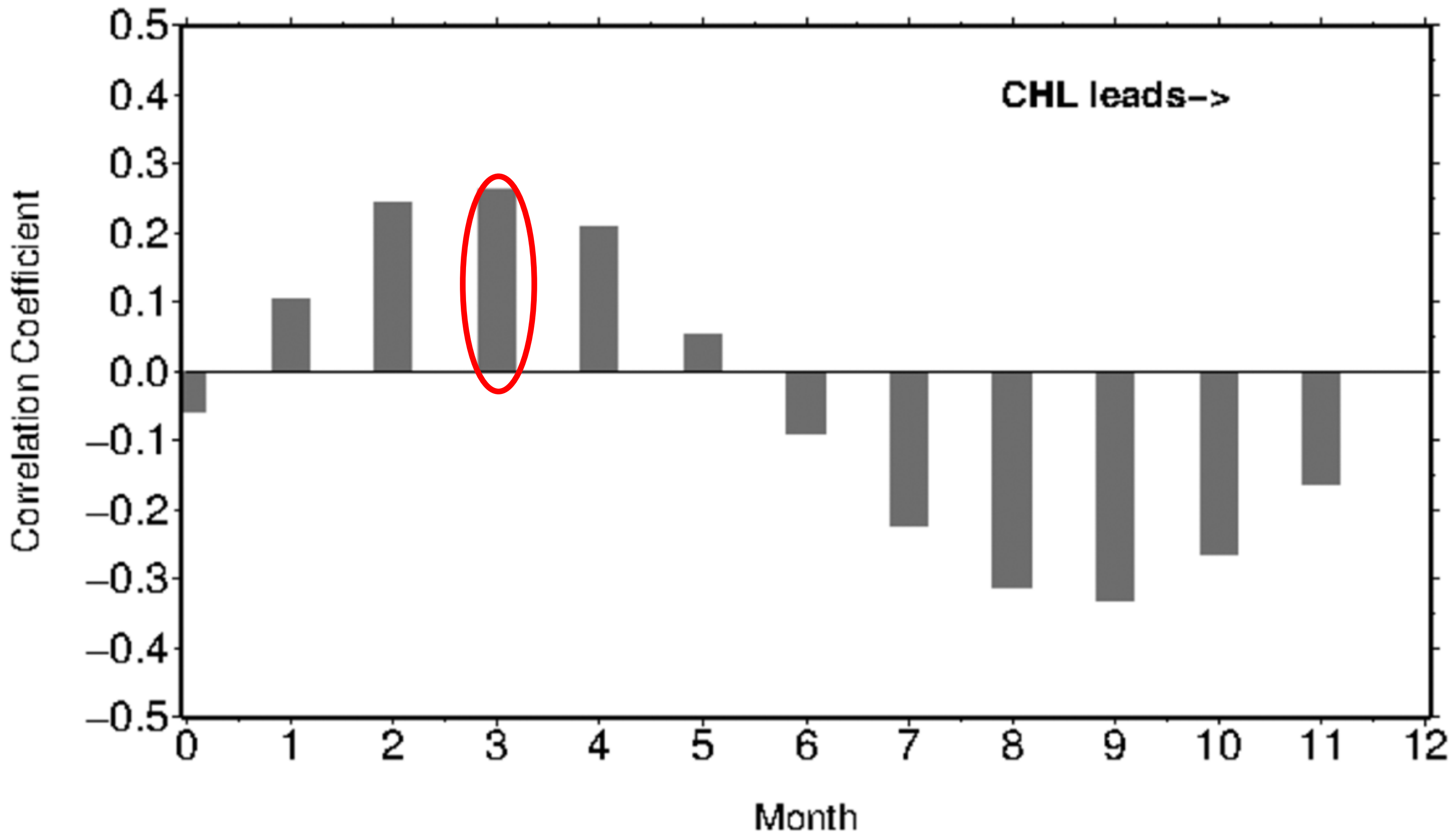
Eqn (1)

Chl-a obtained from OC-CCI and multiple linear regression model



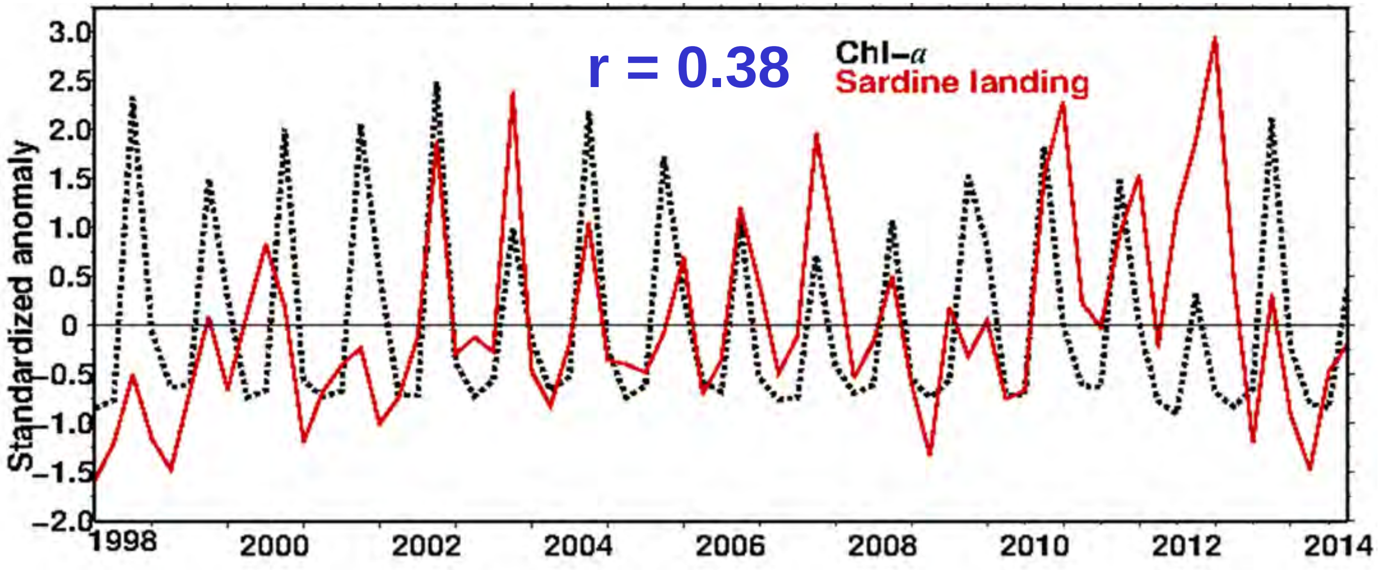
- Chl-a generated using MLRA equation could bring out the seasonal as well as inter-annual variability and is comparable with Chl-a OC-CCI data

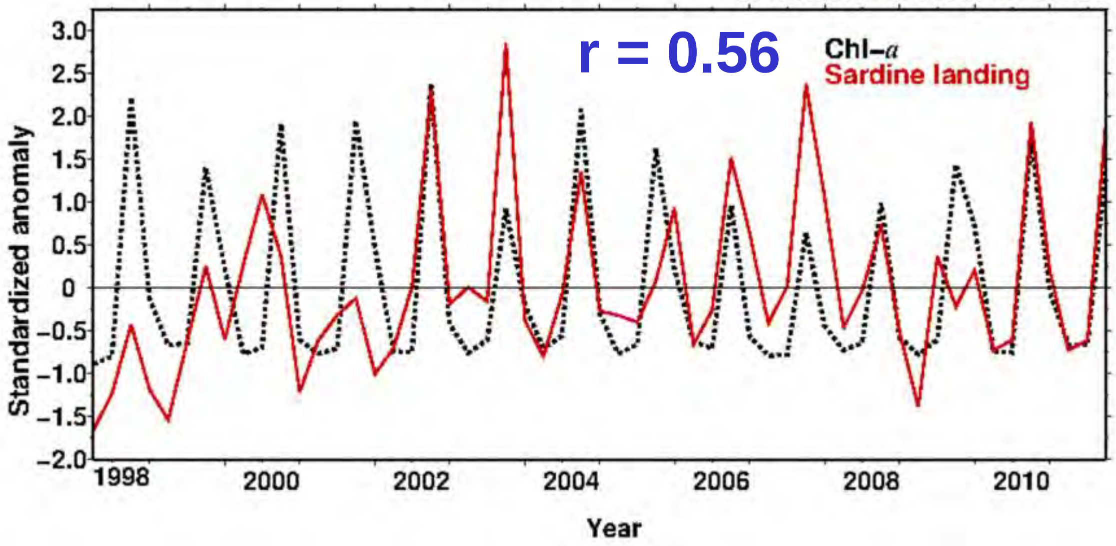
Lead lag correlation analysis between Chl-a and sardine landing (with Chl-a leading) for the period Jan 1998 - Dec 2014.



- **Maximum positive correlation is at 3 month lag (+0.26, statistically significant at the 99% confidence level).**

Time series of standardized anomalies of Chl-a and sardine landing with a lag of one season for the period (1) 1998-2014 and (2) 1998-2011





- **The result is in agreement with the findings of Longhurst et al. (1990) that a decadal (or 11 year to be precise) variation in the stock size is observed in oil sardine.**

Conclusions

- The present study shows strong signals of coastal upwelling in the SEAS as evident from alongshore wind, Ekman mass transport, SST, SLA and Chl-a
- The fact that rain also have its peak value during the southwest monsoon suggest that rain may have an influence on production. However, multiple linear regression analysis (MLRA) showed rain rate has less significant relationship with Chl-a.
- Importance of individual parameters were checked by assigning ranks based on the magnitude of the standardized regression coefficients obtained from MLRA, rank of the variables obtained are as follows: (1) alongshore wind, (2) Ekman transport, (3) SLA, (4) Kerala rain and (5) SST
- Chl-a reconstructed using this MLRA model equation shows good similarity with that obtained from OC-CCI.

THANK YOU

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