On the Inter-decadal variation of Intensity of Tropical Cyclones in the Arabian Sea: role of ocean heat content

K. Niranjan Kumar[1], M. Rajeevan[2], J. Srinivasan[1], C. Gnanaseelan[3], and M. M. Ali[4]

[1] Divecha Centre for Climate Change, Indian Institute of Science, Bangalore, 5601012, India
[2] Ministry of Earth Sciences (MoES), Mausam Bhavan Campus, New Delhi, 110 003, India
[3] Indian Institute of Tropical Meteorology, Pune, 411008, India
[4] National Remote Sensing Centre, Indian Space Research Organisation, Hyderabad, 500625, India

email : **nirukin2003@gmail.com**

Objective

To discuss the role of natural variability of vertical wind shear and increasing trend of upper ocean heat content on the observed trend in the intensity of TCs over the Arabian Sea.

Database

✓Cyclone tracks and intensity details from India Meteorological Department (IMD).

✓The vertical wind shear estimated from the NCEP/NCAR reanalysis data.

✓ Tropical Cyclone Heat Potential (TCHP) from National Oceanic and Atmosphere Administration (NOAA) derived using satellite altimeter data during 1993-2011. (http://www.aomal.noaa.gov/phod/ cyclone/data/)

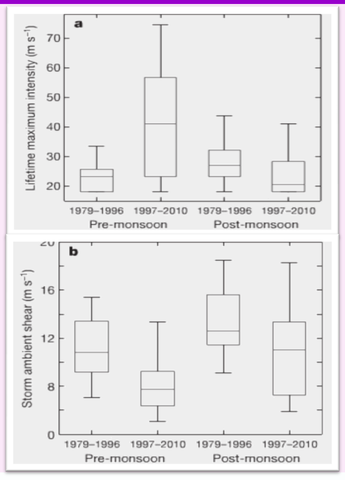
✓TCHP derived from the inter-annual three monthly mean temperature profiles of the World Ocean Atlas (WOA) during 1955-2011. (http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/anomaly_data.html)

Introduction

✓ During the recent years, an increase in the intensity of pre-monsoon (May to June) tropical cyclones (TC) has been observed over the Arabian sea (e.g. Evan et al., [2011], *Nature*).

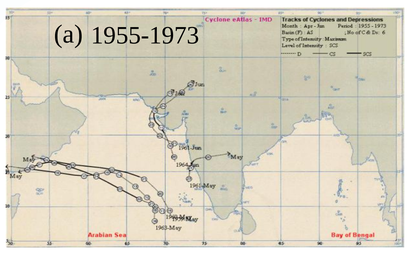
✓The change in intensity is suggested due to basin wide decreasing trends in vertical wind shear caused by the simultaneous upward trend in anthropogenic black carbon and sulphate emissions

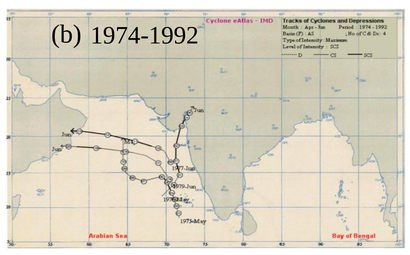
✓One of the decisive factors influencing the tropical cyclone (TC) intensity and its intensification is ocean thermal energy in the upper ocean.

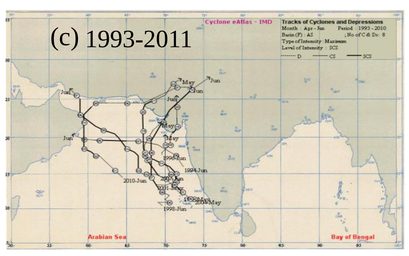


Results

Epochal variations of Arabian Sea TCs







Tracks of intense Tropical Cyclones formed over the Arabian Sea during the pre-monsoon season (May-June) of a) 1955-1973, b) 1974-1992 and c) 1993-2011 epochs.

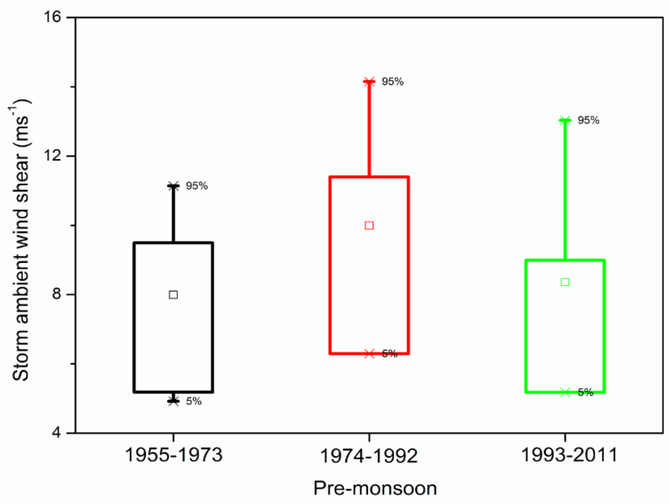
Low pressure systems with max wind exceeding 48 knots (Severe Cyclonic Storm category) only were considered.

Frequency of intense TCs and total number of intense TC days observed over the Arabian sea during different epochs

	1955-1973	1974-1992	1993-2011
Frequency of intense TCs (severe cyclonic storm and above)	6	4	7
Days of intense TCs	17	6	20

Vertical Wind Shear

The storm-ambient wind shear is defined as the vertical wind shear (vector wind difference between 850 and 200 hPa for every cyclone fix 48 h before the arrival of the storm to decrease the contamination of the reanlaysis fields by storms themselves) at the location of the storm averaged over the period during which the TC's intensity increases from 17 ms^{-1} to its Lifetime Maximum Intensity (LMI).



Storm ambient vertical shear calculated during the pre-monsoon season (April-June) during the periods 1955-1973, 1974-1992 and 1993-2011. The box plots show the mean (square) and interquartile range (25th-75th percentile) along with 5th and 95th percentiles respectively (whiskers).

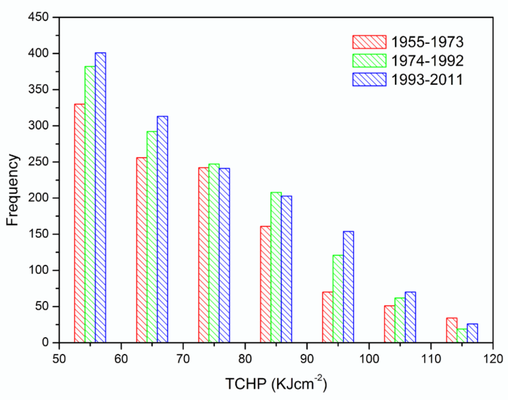
The recent decrease in the reduction of the storm-ambient wind shear could be just a part of the natural variability of wind shear observed over the Arabian Sea basin during the pre-monsoon season.

Ocean heat Content

The ocean thermal energy is defined as TCHP and is calculated by assuming the heat content in a column where the sea temperature is above 26°C

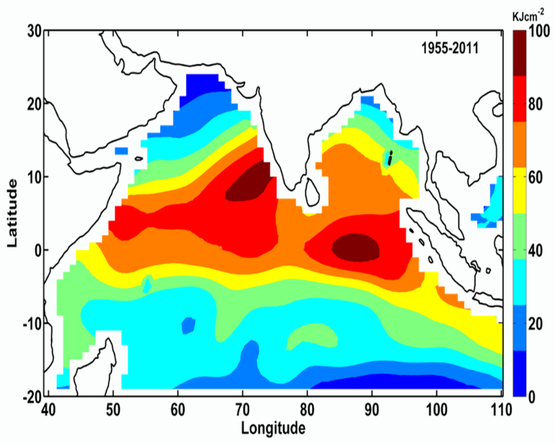
$$Q_{TCHP} = \sum_{h=0}^{H} \rho C_p (T - 26) \Delta Z$$

where ρ is the density of the sea water at each layer, Cp is the specific heat at constant pressure, T is the sea temperature, and ΔZ is the thickness at each layer. When T is below 26 C, it is reset to 26 C.



Histogram of frequency distribution over the box 10N-25N, 55-75E for these 3 different periods

Mean spatial distribution of TCHP from WOA averaged at each grid point during 1955-2011



TCHP exceeding 90 $KJcm^{-2}$ is considered to be conducive for TC intensification.

Ocean Heat Content

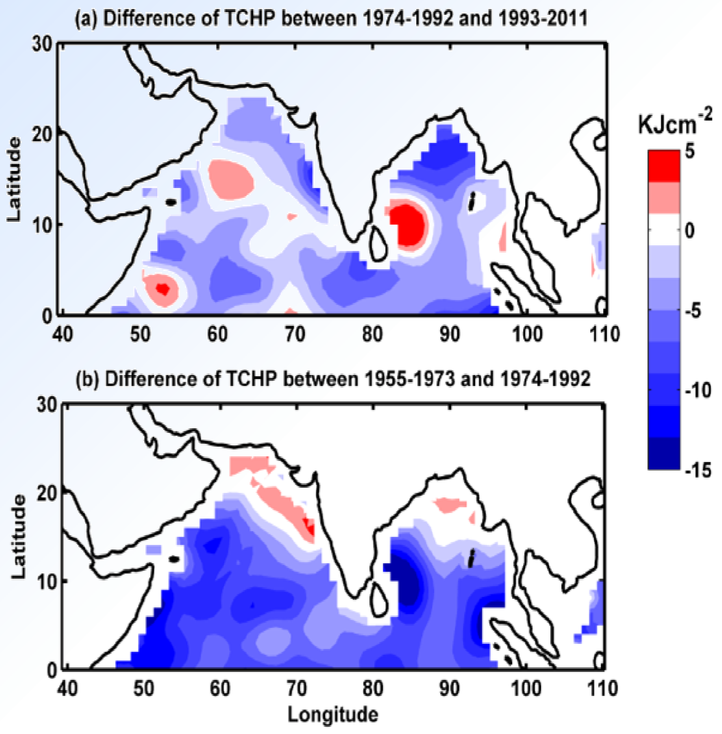
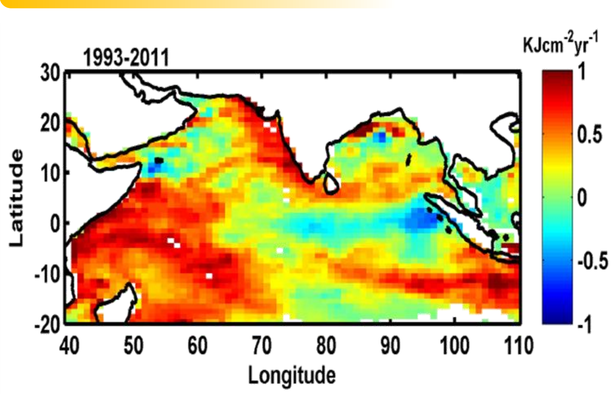


Figure shows the difference of TCHP between three epochs in pre-monsoon months (1955-1973, 1974-1992, 1993-2011) using WOA

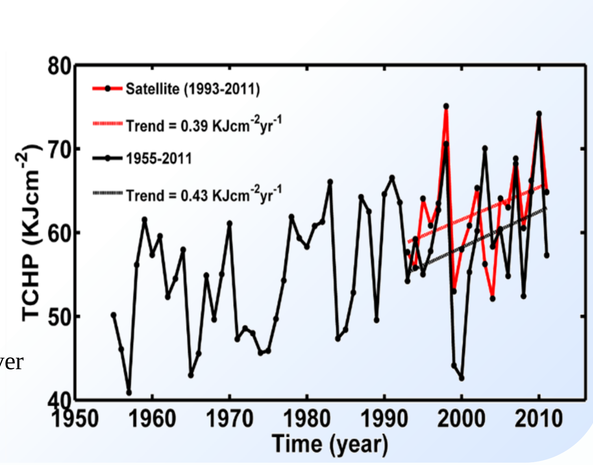
The Figure reveals a significant increase in the TCHP over the Arabian sea during Pre-monsoon season in recent years

The increase in TCHP implies a warmer upper ocean, which helps TCs to sustain or increase its intensity by uninterrupted supply of sensible and latent heat fluxes from the ocean surface to the atmosphere.

Ocean heat Content



Linear trends of pre-monsoon (April- June) TCHP (KJ cm^{-2} yr^{-1}) during the period 1993-2011 derived from Satellite data



Time series of area averaged (10-25 N, 55-75E) TCHP over the Arabian Sea from satellite and WOA data sets

Summary

During the recent years, an increase in the intensity of pre-monsoon (May to June) tropical cyclones (TC) has been observed over the Arabian sea.

While assuming the important role of vertical wind shear, we have demonstrated that the recent increase in intensity of TCs may be attributed to the epochal variability of vertical wind shear observed over the Arabian Sea.

Another important factor which may explain the recent increase in storm intensity is the role of upper ocean heat content. The analysis using satellite and WOA data sets revealed a significant increase in the TCHP over the Arabian Sea during the pre-monsoon season in recent years. This increase in TCHP during the recent years could also be responsible for the observed increase in intensity of pre-monsoon TCs over the Arabian Sea.

Acknowledgements: We are thankful to NOAA for kindly supplying us the satellite derived TCHP data set for our analysis.