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Research Paper

Study of Wind Pattern and its Seasonal Evolution Over Indian Ocean

Physics

KEYWORDS : surface wind; indian ocean; climate change; Monsoon; wind stress curl

Ravindra Jadav Gujarat Arts and Science College, Ahmedabad – 380006,

ABSTRACT

The work presented here is aimed to identify long term wind patterns and its evolution over Indian Ocean. This would be useful in understanding long term evolution of sea surface temperature, ocean currents, local mesoscale system such as monsoons, all such things we describe as 'climate change'. We have used the data of Tokinaga and Xie [2011] and found increasing trend in central areas of Arabian Sea and Bay of Bengal whereas decreasing trend in coastal and equatorial areas of Indian ocean. Further the change (increase or decrease) was maximum during JJA months for all regions. The somali region being relatively deep and the shallow ridge in southern arabian ocean makes a typical structure and behaves differently in terms of change in wind stress curl. The significant net rise in August wind stress curl for Indian Ocean will definitely have some effect on Ocean Circulation which might further be studied.

1 Introduction

The circulation of the upper ocean is driven to a large extent by the transfer of momentum from the atmosphere across the air-sea interface. Climatological fields of the momentum transfer, or equivalently the wind stress forcing, have historically been determined from ship meteorological reports. In such analyses, individual estimates of the momentum transfer are determined from the following formula that relates the windstress $t = r C_D u^2$ where C_D is the drag coefficient, which incorporates the dependence of the transfer on atmospheric stability, and r is the air density.

2 Data Analysis and Results

The data used here were 4 x 4 degree resolution interpolated-regridded ship based measurements' data of global wind speeds from 1950-2009. The interpolation-regriddation was done by Hiroki Tokinaga, we have used same data to understand wind patterns in Indian Ocean. We did analysis of the wind data in terms of wind velocity and wind stress curl. While the wind velocity evolution helps us to understand pattern evolution whereas the wind stress curl helps us in understanding momentum transfer from atmosphere across air-sea interface hence understanding evolution of Ocean Current system. Local mesoscale systems like monsoon depends on such air and sea circulation patterns hence such study helps in understanding long term climate change.

Figure 1 Sea floor topography of Northern Indian Ocean alongwith coloured boxes on certain areas. Red colour indicates increase in wind velocity where as aqua color indicates no long term trend.

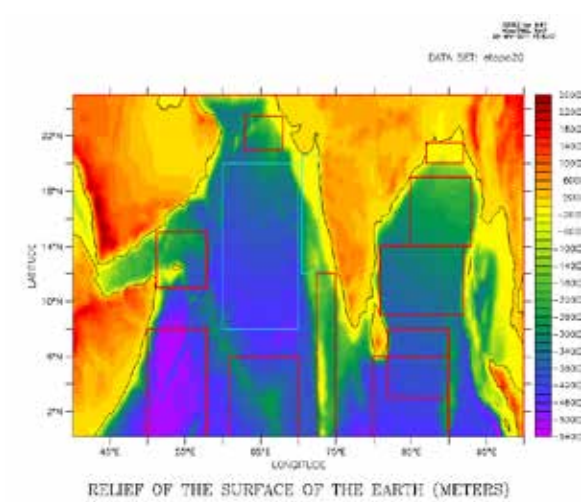

Figure 1 shows Indian Ocean sea floor topography alongwith few boxes in colours. The red boxes are made at a place where the long term wind showed increasing trend. The wind velocity is increasing in all place but central arabian and western coastal areas of India. Figure 2 above shows long term wind velocity trend for identified areas of Indian ocean for different months in a year. It has been observed that in the central and coastal areas of Bay of Bengal the increase in wind velocity in last 50 years is maximum. For example, during Jan-Mar in coastal areas of Bay of Bengal the increase in velocity is upto 4 m/s whereas in central BoB areas the increase is upto 3 m/s. Among other notable things from this image is that in almost all areas the wind velocity in April is increasing substantially and in central areas of Bay of Bengal the velocity increases throughout the year. We have also calculated wind stress curl and its trend for various areas in Indian ocean for 1950 – 2009.

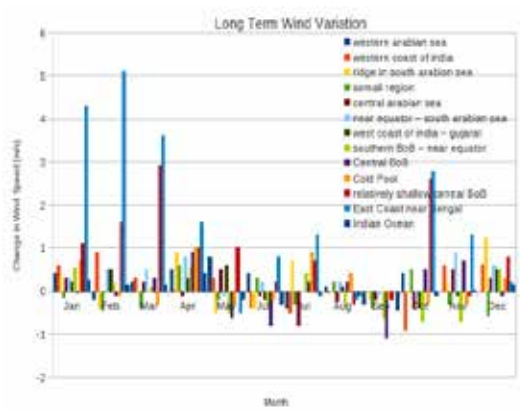

Figure 2: The plot shows increase in Wind speed for various areas in Indian Ocean for different months of an year.

Monthwise climatological changes for various areas is plotted in Figure 3 and 4. Figure 3 is showing results for parts of Arabian sea whereas figure 4 is for parts in Bay of Bengal as well as average picture for Northern Indian Ocean. As we can see from Upper Left and Upper Right image in figure 3 that in western part of Arabian sea near gulf of Oman the trend is negative with maximum decline in JJA months whereas in coastal areas near Gujarat the wind stress curl is decreasing through the year except May and October. The middle left and middle right for central Arabian sea and western coast of India along Maharashtra and Karnakata, negative trend is maximum during JJA months. In Somali region (lower left), the reverse trend is observed where during JJA months wind stress curl increases but decrease mainly in other seasons. On ridge area there is positive change in all months except June and September. Thus, in all of the Arabian sea there is mix trend with general tendency of rise in wind stress curl in central areas and decrease in coastal areas in JJA months.

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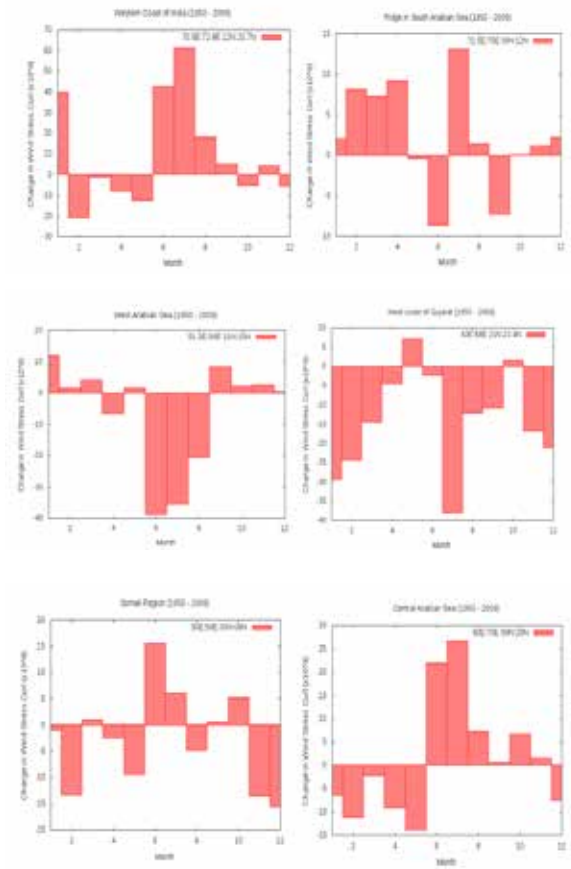
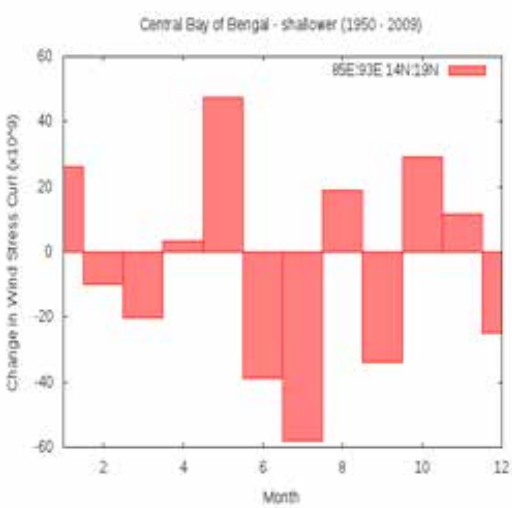


Figure 3: Month wise Climatological Change in wind stress curl in various areas in Arabian sea. General name of the area is indicated on the top of the figure whereas the latitude – longitude of that place is written on top right corner of plot.



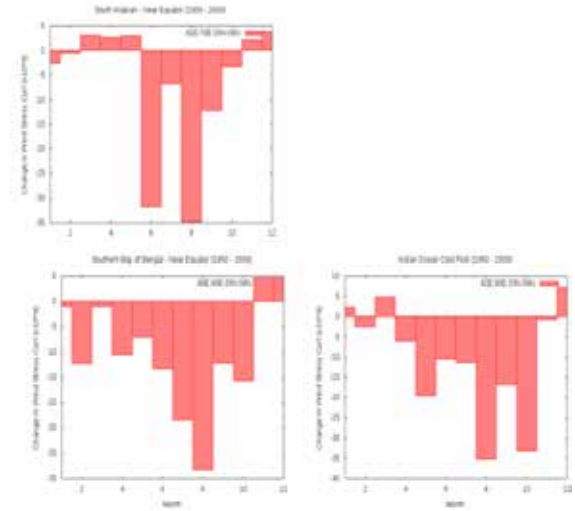


Figure 4: Month wise Climatological Change in wind stress curl in various areas in Bay of Bengal as well as for whole Indian Ocean and equatorial parts. General name of the area is indicated on the top of the figure whereas the latitude – longitude of that place is written inside the box.

Figure 4 contains change in wind stress curl plots mostly for Bay of Bengal regions. One of the plot at lower left is for equatorial Arabian sea whereas lower right plate is for the whole Northern Hemispheric Indian Ocean. For central Bay of Bengal the wind stress curl shows increasing trend for all months with a maximum in JJA (Upper Left) whereas northern part of it shows mixed trend with increase in April and decrease in July. As shown in Middle left and middle right plots of near equatorial parts of southern Bay of Bengal and a place called Indian Ocean Cold Pool, there is substantial decreasing trend throughout the year but December with maximum negative trend in August in both areas. Near equatorial parts on Arabian sea side (lower left) also showed similar trend having maximum negative trend during August followed by June. Finally the plot for average values for whole Indian Ocean indicates neither increase or decrease except that in August it shows very high positive trend where the change in wind stress curl is of 2 orders of magnitude over 60 years period.

3 Discussion

Surface winds are a driving force for ocean current and thermocline fluctuation, and are closely linked with atmospheric convection and circulation. As the circulation of the upper ocean is driven to a large extent by the transfer of momentum from the atmosphere across the air–sea interface [e.g., Gill 1982], Climatological study of the momentum transfer by wind stress curl would help in understanding long term evolution of ocean circulation. Ward and Hoskins [1996] have reported earlier long term rise in wind velocity observed using Anemometer based data as spurious. Tokinaga and Xie [2011] used corrected Wave- and Anemometer based sea surface wind data and compared it with Special Sensor Microwave Imager (SSM/I) data. They found good agreement in trend pattern between the two. We have used the same data used by Tokinaga and Xie [2011] and found increasing trend in central areas of Arabian Sea and Bay of Bengal whereas decreasing trend in coastal and equatorial areas of Indian ocean. Further the change (increase or decrease) was maximum during JJA months for all regions. The Somali region being relatively deep and the shallow ridge in southern Arabian ocean making a typical structure and behaves differently in terms of change in wind stress curl. The significant net rise in August

wind stress curl for Indian Ocean will definitely have some effect on Ocean Circulation especially which might further be studied.

Young et al., [2011] studied global trends in wind speed and wave height and concluded that over the past two decades there has been a consistent trend towards increasing wind speeds. Such a result indicates that the intensity of extreme events is increasing at a faster rate than that of the mean conditions. Our results are similar to Young et al., [2011] if we look at whole Indian Ocean however if we look at various parts of, the trends are mixed.

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