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Short communication

Changes in the south Asian monsoon low level jet during recent decades and its role in the monsoon water cycle

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ABSTRACT

June–September mean wind at 850 hPa from ERA-Interim, MERRA and NCEP2 reanalyses shows an increasing trend in the south Asian monsoon Low Level Jet (LLJ) during 1980–2014. In the sub-seasonal scale, the LLJ during July and September exhibits increasing trend, while August shows a decreasing trend. Lesser changes in surface pressure over heat low region and weaker Bay of Bengal convection lead to weakening of LLJ during August while an intense heat low during September results stronger LLJ. The associated moisture transport changes affect the monsoon hydrological cycle with decreasing precipitation during August and increasing precipitation during September.

1. Introduction

The South Asian monsoon during the northern summer months of June–September brings about 80% of the annual precipitation over the Indian subcontinent. The summer monsoon has significant variabilities in seasonal and inter-annual time scales which can affect the livelihood of agrarian people residing over the region (Webster et al., 1998; Gadgil and Gadgil, 2006). Classically the South Asian monsoon circulation is maintained by the land–atmosphere–ocean interaction during the boreal summer months. The differential heating by the Sun over the northern continental landmass and ocean to the south creates temperature and pressure gradients across the equator. This cross equatorial pressure gradient initiates and largely drives the monsoon circulation. The global land and ocean temperature have increased substantially during the last decades and influenced the large scale atmospheric circulations in various time scales (Hoerling et al., 2008). Understanding the long-term changes in the past and future monsoon circulation and precipitation using observations and numerical modelling is well advanced (Turner and Annamalai, 2012). Describing the monsoon as a result of the land–ocean differential heating, the monsoon would have been stronger as the land–ocean temperature contrast increases under the global warming scenario. However, recent studies have shown a decreasing trend in the South Asian monsoon precipitation and weakening of the monsoon circulation (Kitoh et al., 2013; Zuo et al., 2012). Zuo et al. (2012) showed that although the surface temperature of the Asia had increased, the land mass has become a relative “heat sink” because of the larger warming in the other regions of the world, which leads to a weaker monsoon circulation.

However some other studies show intensification of monsoon rainfall (Wang, 2013) and increase in frequency of heavy to very heavy rainfall (Pai et al., 2014). Wang (2013) showed a significant intensification in the northern hemisphere summer monsoon as well as Hadley and walker circulations in the global warming scenario. Another impact of global warming is the shift in the large scale monsoon circulation in the spatial and temporal scales. The strong cross-equatorial Low Level Jet (LLJ) exists over the Indian Ocean and the South Asia is an important component of the South Asian monsoon System (Joseph and Sijikumar, 2004). The monsoon LLJ is maintained by the surface pressure difference between the high pressure area exists over the south Indian Ocean near Mascarene region and the heat low region exists over the Pakistan and the northwest India. The LLJ is the main conduit for transfer of moisture from the ocean to the land mass and any changes in the characteristics of LLJ can substantially affect the monsoon water cycle. Recently, Sandeep and Ajayamohan (2015) reported a poleward shift in the monsoon LLJ under global warming scenario using observations and coupled model simulations. They have shown the northward shift as a result of the strengthened cross-equatorial pressure gradient due to enhanced land–sea temperature contrast. With prominent spatial changes, the LLJ may also have experienced temporal changes under the global warming scenario which can substantially affect the hydrological cycle within the monsoon season. The objective of the present study is to find out temporal changes in the monsoon LLJ during recent decades and how the changes affect the moisture transport and precipitation characteristics during the monsoon season.

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2. Data and methods

The monthly mean wind and sea level pressure data during 1980–2014 are obtained from three reanalyses namely the interim ECMWF Re-Analysis (ERA-Interim) (Dee et al., 2011), the Modern-Era Retrospective Analysis for Research and Application (MERRA) (Rienecker et al., 2011) and the National Centers for Environmental Prediction Reanalysis (NCEP2) (Kanamitsu et al., 2002) which are used to study the monsoon circulation changes. The horizontal resolution of NCEP2 data is 2.5° × 2.5°, MERRA data is 0.5° × 0.33° and that of the ERA-Interim data is 0.75° × 0.75°. The near surface temperature data over land is obtained from Climate Research Unit (CRU) time series version 3.22 (Harris et al., 2014) and the Sea Surface Temperature (SST) data is from NOAA optimum interpolation SST V2 (Reynolds et al., 2002). The grid resolution of CRU surface temperature is 0.5° × 0.5° and NOAA SST is 1° × 1°. The precipitation data used for this study are the monthly mean precipitation data from CMAP (CPC Merged Analysis of Precipitation) (Xie and Arkin, 1997). The linear trends are calculated by least square method. The standard Student's *t* test is used to statistically quantify the significance of trends.

3. Results

Climatologically, the cross-equatorial monsoon LLJ has core at an altitude about 1.5 km over the Indian subcontinent and adjoining oceanic region (Joseph and Sijikumar, 2004). Fig. 1a–c

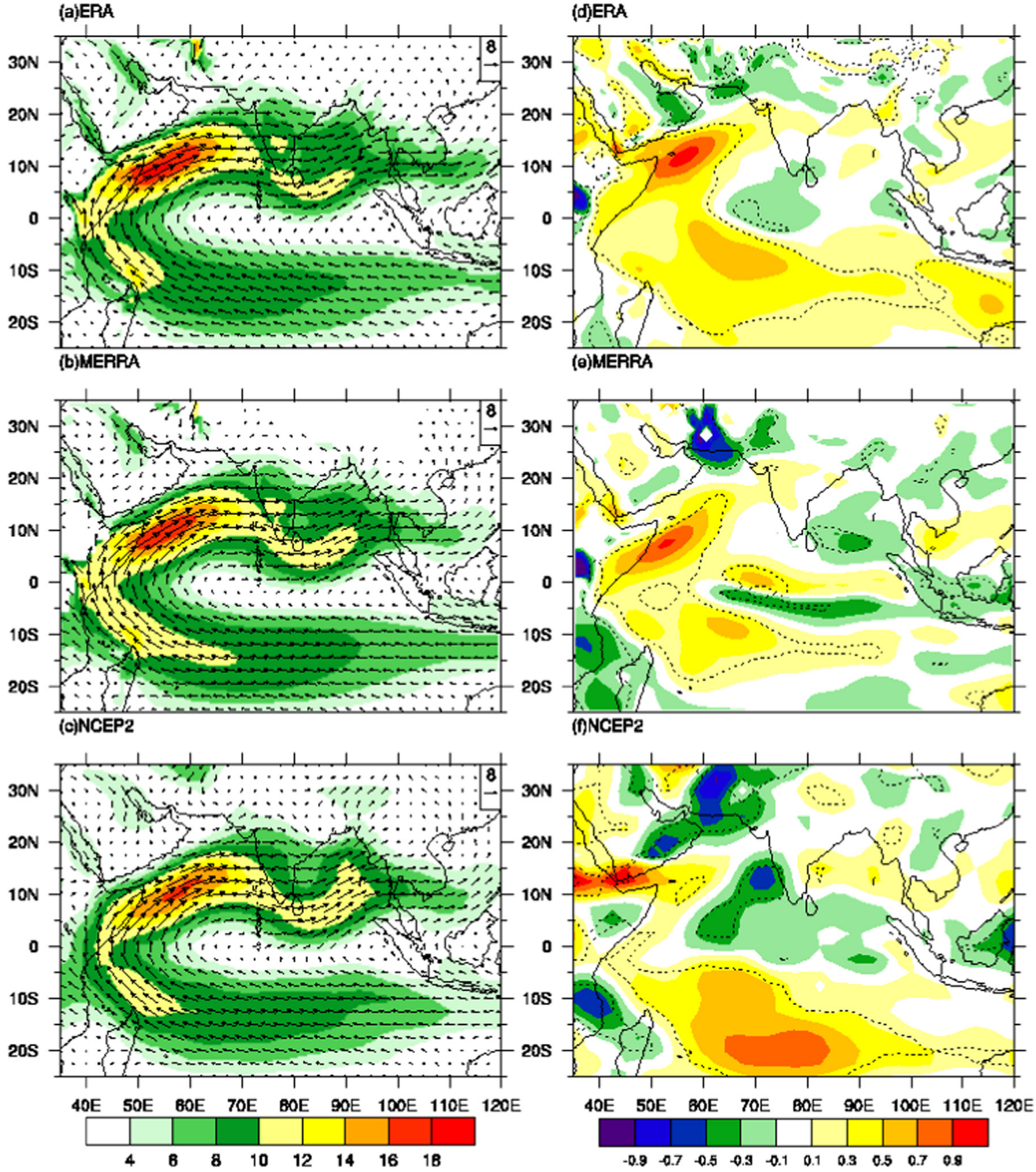

Fig. 1. The 850 hPa June–September (JJAS) mean wind climatology during 1980–2014 from (a) ERA, (b) MERRA and (c) NCEP2 reanalyses. The shaded contours represent wind magnitude and arrows represent both direction and magnitude. Units of wind speed is in m s^{-1}. Linear trend in JJAS mean wind at 850 hPa from (d) ERA, (e) MERRA and (f) NCEP2 reanalyses during 1980–2014. Shading represents the linear trend and significance 95% or above are marked in dotted contour. Unit is in m s^{-1} decade^{-1}.