Global Scale Features Associated with Winter Weather Systems during 2016-17

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ABSTRACT

The global features during the northern winter from December 2016 to February 2017 associated with winter weather systems over the nothern India is discussed in the present article. The Sea Surface Temperature (SST) over the equatorial Pacific & Indian Oceans, Madden Julian Oscillation (MJO), convective activity, maximum & minimum temperature, circulation features, rainfall, northern hemispheric snow cover conditions and its variability during the winter seasons are presented in this article. The SST anomalies over Nino3.4 region indicated borderline ENSO neutral conditions in January 2017 and also continued during February, whereas, the dipole mode index during January and February 2017 also shows neutral Indian ocean dipole conditions caused by the cooling of eastern equatorial Indian Ocean. The winter season of 2016-17 witnessed mainly a warmer maximum and minimum temperature (Tmax and Tmin) over northern India. The above normal rainfall is observed over the northern India only during the month of January, 2017, whereas, rainfall was subdued during December and February. The winter snow cover over Northern Hemisphere (NH) and Eurasian region indicated above normal snow during the winter seasons of 2016-17.

Keywords: *Sea Surface Temperature (SST), Madden Julian Oscillation (MJO), Winter Weather and Northern Hemisphere.*

1. Introduction

India being a vast country situated roughly between 8°N and 37°N latitude, occupies a large area of South Asia and is a land with a unique climatic regime comprising of several characteristic features, including (i) two monsoon seasons (south-west and north-east), (ii) two cyclone seasons (pre- and post-monsoon cyclone seasons), (iii) hot weather season characterized by severe thunderstorms and heat waves, (iv) cold weather season characterized by violent snow storms in the Himalayan regions with heatwave, coldwaves, cyclones, floods, drought, fog, etc are very common during different parts of the year. December to February are the colder months in northern India with normal minimum temperature (Tmin) less than 8°C in many parts of northern India and it is affected by cold waves. During this period after the passage of western disturbances, the cold waves sometimes penetrate almost all the eastern states of India and fog over parts of northern plains. Normally, winters are dry in northern India, although there is rainfall associated with western disturbances. Outgoing long wave radiation (OLR) in the deep tropics is strongly influenced by the presence or absence of deep atmospheric convective activity and tropical Pacific deep atmospheric convective activity spreads eastward during the transition to El Niño state (Chiodi and Harrison, 2008). The regional and global features pertaining to winter weather systems particularly over the northern India during the winter season of 2016-17 is discussed.

2 Data and Methodology

To study the variability of different atmospheric and oceanic variables during December 2016 to February 2017 associated with winter weather systems over the northern India the monthly mean data of Sea Surface Temperature (SST) over the equatorial Pacific & Indian Ocean, Madden Julian Oscillation (MJO), convective activity, maximum & minimum temperature, circulation features, rainfall, northern hemispheric snow cover are collected from different sources. The SST data is obtained from INCOIS Global Ocean Data Assimilation System (GDAS). The wind anomaly is obtained from NCEP reanalysis and the Outgoing Longwave Radiation (OLR) for the study of convective activity is obtained from NOAA. The maximum, temperature, minimum temperature and rainfall data used in the article are obtained from the gridded data available from National Climate Centre, office of Climate Research Services (CRS), IMD Pune. Finally, the MJO data are obtained from Bureau of Meteorology, Australia and the snow cover data is obtained from Rutgers University Climate Lab.

3. Global Features Associated with Winter Weather over Northern India

3.1 El Nino and Indian Ocean Dipole (IOD) conditions during winter 2016-17

Indian Ocean Dipole (IOD) mode has considerable influence on the climates of many regions of the globe (Saji et al., 1999 and Webster et al., 1999). During the month of November, 2016 the sea surface temperature (SST) over the tropical Indian and Pacific Oceans indicated negative anomaly over a narrow band along the central and eastern equatorial Pacific Ocean with weakening of Indian Ocean SST warming in the eastern Indian Ocean.

With the arrival of peak winter season in the month of December, 2016 the border line/weak La Niña conditions prevailed over equatorial Pacific Ocean with negative anomaly over a narrow band along the central and eastern equatorial Pacific Ocean as seen from the monthly mean SST anomalies (Figure 1a). Over the equatorial Indian Ocean warm SST anomalies ($\geq 0.5^0$C) were observed overhead and east Bay of Bengal, East Indian Ocean off the west coast of Australia. Weak cool SST anomalies were seen over the equatorial Indian Ocean and relatively stronger cool anomalies were seen over south Indian Ocean south of about 15^0S along a latitudinal zone with anomalies $\leq$-0.5 °C observed in some areas (Figure 1a).

The monthly mean SST anomalies for January 2017 (Figure 1b) compared to the previous month of December 2016, the cool SST anomalies spread over equatorial Pacific Ocean have reduced. It is observed that, cool SST anomalies persisted along the equatorial eastern and central Pacific Ocean slightly extending west of the date line, while positive SST anomalies were observed over equatorial west Pacific and subtropical Pacific Ocean. On either side of these warm SST anomalies, negative SST anomalies were observed. A westward propagation of the anomalies in the sea surface temperature (SST) along the equator descried extensibly by (Annamalai and Murtugudde, 2004) affected the general circulation and associated weather events. There has been increase of warming tendency over south of equatorial Pacific Ocean in January, 2017 compared to December, 2016 (Figure 1b). Over the Indian Ocean near normal to warm SSTs are observed during the month over most parts of Arabian Sea and Bay of Bengal. Weak cool SST anomalies were seen over the equatorial Indian Ocean and relatively stronger cool anomalies ($\leq$-0.5°C) were seen over south Indian Ocean of about 15^0S-20^0S belt.

During February 2017, cool SST anomalies (Figure 1c) persisted along the equatorial central Pacific Ocean slightly extending west of the date line, while positive SST anomalies were observed over equatorial west and extreme equatorial east Pacific Ocean and subtropical Pacific Ocean. On either side of these warm SST anomalies over west Pacific, negative SST anomalies were observed. As compared to January, the cool SST anomaly spread over equatorial Pacific Ocean has reduced. Warming tendency over south of equatorial Pacific Ocean is seen to be decreased as compared to previous month. Over the Indian Ocean near normal to cool SSTs were observed during February (Figure 1c) over Arabian Sea and Bay of Bengal. Weak cool SST anomalies were seen over the equatorial Indian Ocean and relatively stronger cool anomalies were seen over south Indian Ocean along a latitudinal zone of 15^0S-30^0S. Warm anomalies which were observed (in January 2017) over east Bay of Bengal and east Indian Ocean near maritime continents and off the west coast of Australia now (in February) turned near normal to cool SST anomalies. The positive SST anomalies which were observed over the West Indian Ocean along subtropical South Indian Ocean in January 2017 continued with increased areal coverage. In February (Figure 1c), warming of SSTs was observed over most parts of the western and southern equatorial Indian Ocean and south of equatorial Indian Ocean whereas cooling of SSTs was observed over Arabian Sea and Bay of Bengal.

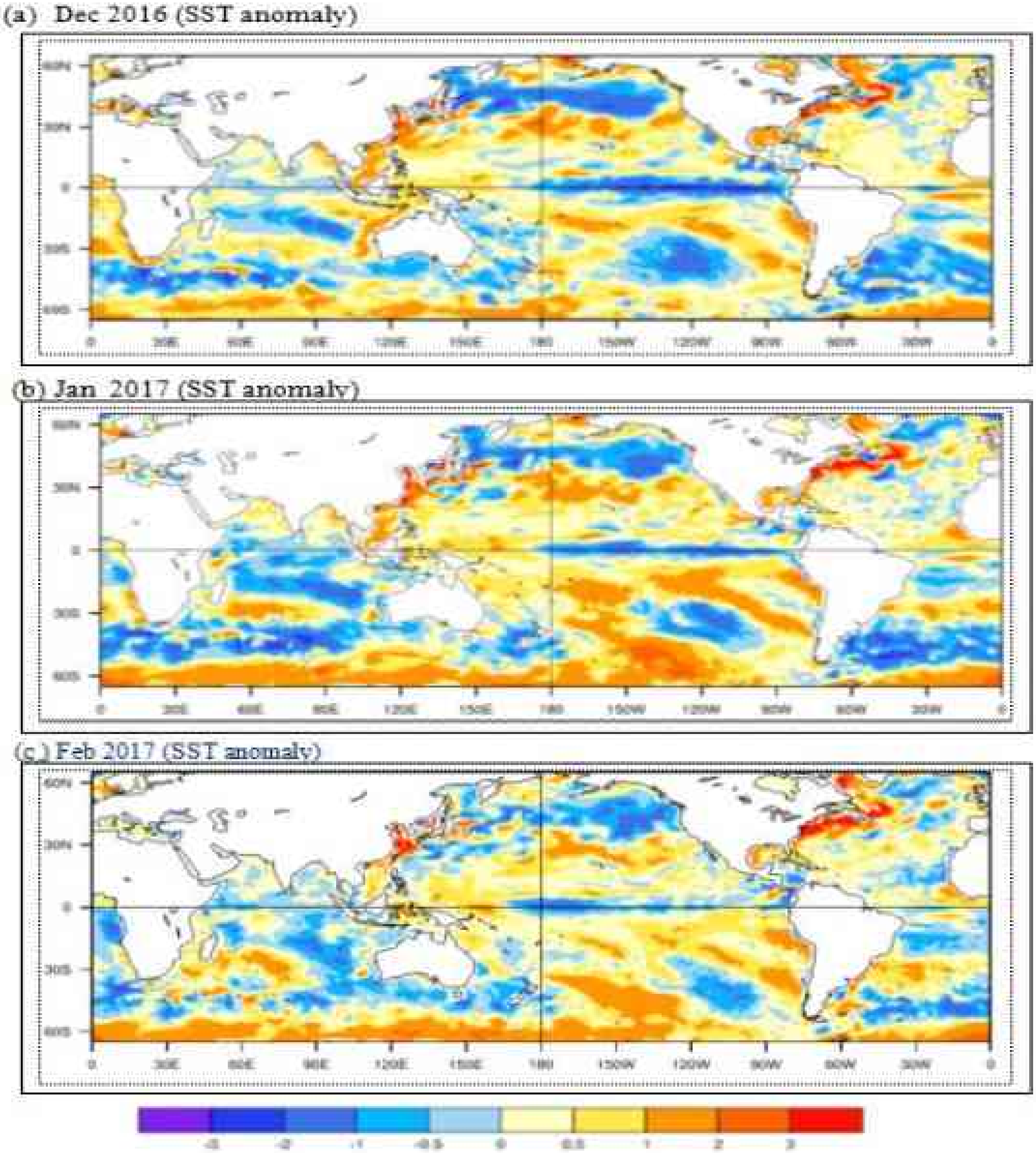


Figure 1: Average SST anomalies (0C) for (a) December 2016, (b) January 2017 and (c) February, 2017. (Data source: INCOIS-GODAS).

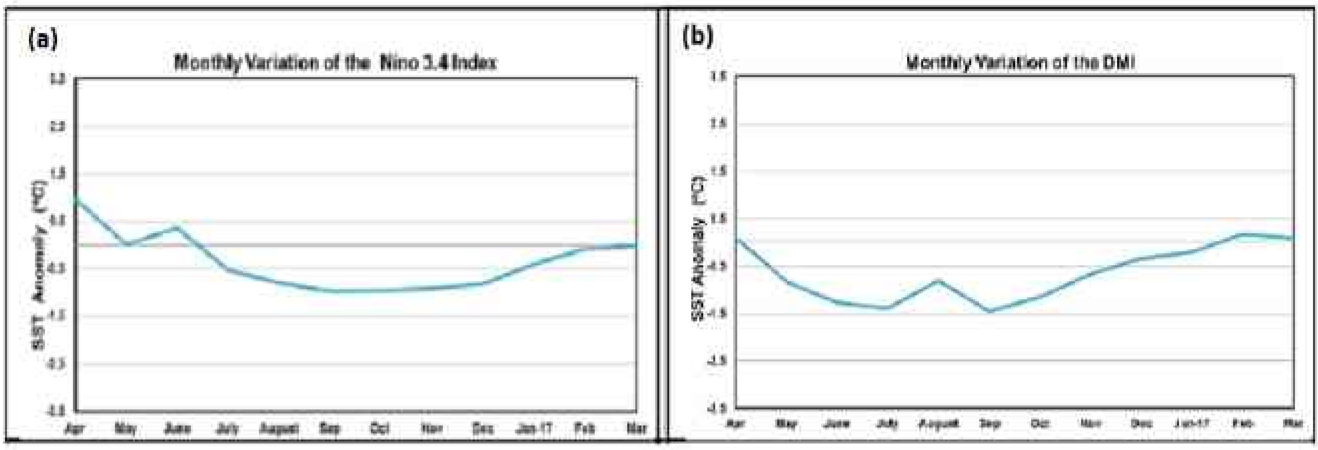


Figure 2: (a) Monthly variation of Niño 3.4 SST index anomaly for the last 12 months and (b) Same as (a) but for Dipole Mode Index (DMI). The anomalies were computed using base period of 1981-2010. Data Source: INCOIS-GODAS.

In order to see the evolution of El Niño and IOD conditions the monthly time series of Niño 3.4 SST anomalies for the last 12 months (Figure 2a) suggest that the borderline/weak La Niña conditions prevailed since July 2016, which turned to cool ENSO neutral conditions in January 2017 and also continued during February and March, 2017. Similarly the Dipole Mode Index (DMI) during December 2016 shows neutral Indian Ocean Dipole (IOD) conditions. The DMI index for the last 12 months suggests that the negative IOD conditions prevailed since May 2016 (Figure 2b) turned to neutral IOD conditions by December 2016. The DMI during January and February 2017 also shows neutral IOD conditions caused by the cooling of eastern equatorial Indian Ocean.

3.2 Low level circulation features during winter 1016-17

The low level monthly mean wind anomaly at 850 hPa during December, January and February, 2017 is shown in Figure 3a-c. As seen from Figure 3a an anomalous cyclonic circulation was observed over the south peninsula and adjoining Seas. Also an anomalous ridge extending from west Rajasthan to central parts of the country was also observed during the month of December. During January, 2017 an anomalous cyclonic circulation was observed over the central Bay of Bengal. This anomalous circulation was also observed at 500 hPa level also (Figure not shown). During February, an anomalous cyclonic circulation was observed over the North Bay of Bengal and adjoining east coast of the country.

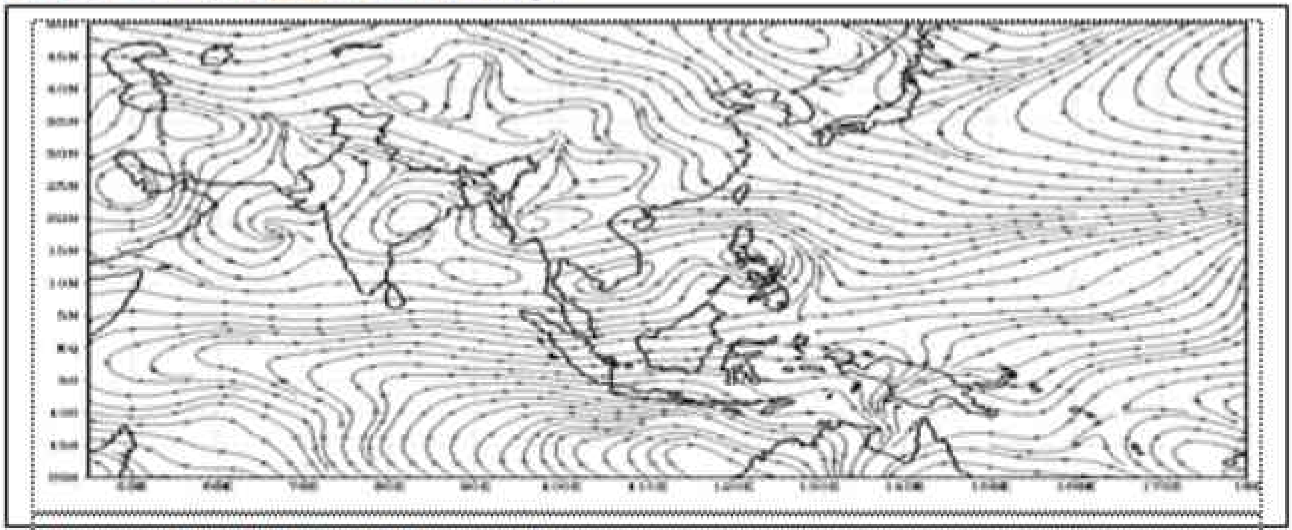
3.3 Convection anomalies

In order to see the magnitude of convective activities during the winter season (2016-17) the OLR anomaly (W/m2) over the Indian region and neighbourhood during December, January and February is shown in Figure 4a-c. December 2016 (Figure 4a) witnessed subdued convective activity over the entire India as represented by positive OLR anomalies (10 W/m2). Over western and central parts of north equatorial Indian Ocean region, positive OLR anomaly exceeding 20 to 30 W/m2 representing the subdued convective activity was also observed. Negative OLR anomaly exceeding 20 W/m2 was observed over the eastern parts of Bay of Bengal. It was only during January, 2017 some parts of Northwest India experienced above normal convective activity. During January, the OLR anomaly over the Indian region and neighbourhood as shown in Figure 4b indicated negative OLR anomaly of about -10 W/m^2 over the northwestern parts of the country associated with above normal convective activities. The eastern parts of Bay of Bengal and the Andaman seas also witnessed above normal convective activity represented by OLR anomalies of -20 to -30 W/m^2. The equatorial Indian Ocean witnessed below normal convective activity with positive OLR anomalies of 30 to 40 W/m2. During the month of February, the OLR anomaly over the Indian region and neighbourhood is shown in Figure 4c with positive OLR anomaly exceeding 10 W/m2 was observed over the eastern/northeastern and extreme southern parts of the country. Over the south Indian Ocean region, positive OLR anomaly exceeding 20-30 W/m2 was observed, while over the eastern equatorial Indian Ocean region, negative OLR anomaly exceeding 20-30 W/m2 was observed. Only a small region over the western parts of India witnessed below normal OLR anomalies represented with above normal convection.

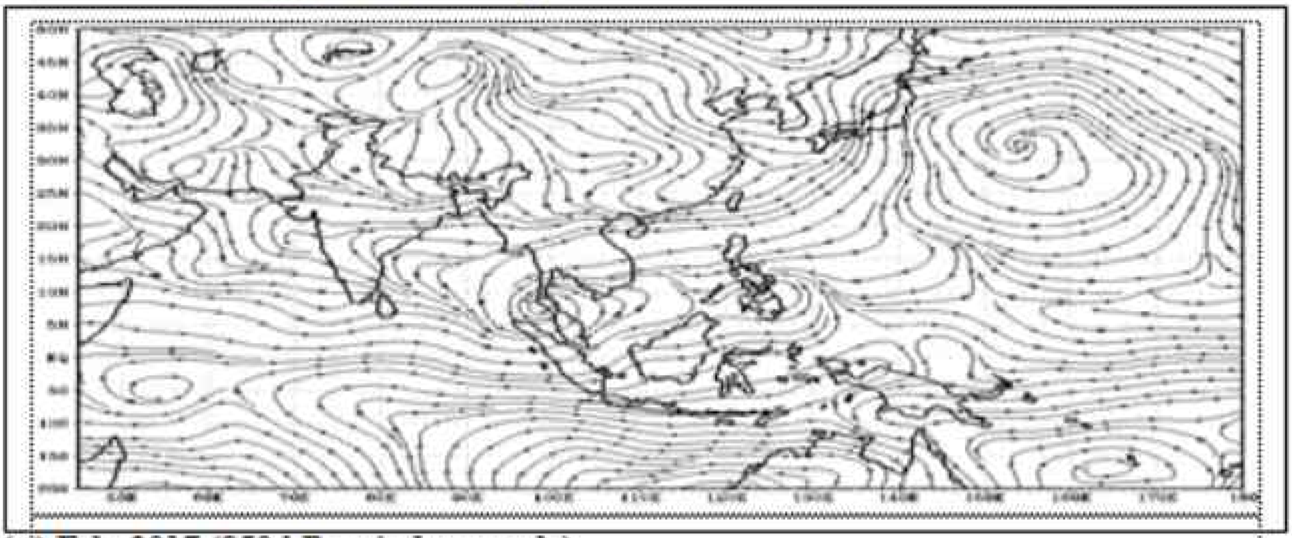
3.4 Rainfall during winter months

Associated with the convection anomalies shown in Figure 4a-c, the rainfall patterns also reflect the same. The monthly mean rainfall and its anomaly associated during December 2016 to February 2017 is shown in Figure 5a-c and the corresponding anomaly of rainfall is shown in Figure 5d-f. The month of December was the driest month rainfall for the country as a whole was 50% of its LPA value with Northwest India receiving only 9% of its Long Period Average (LPA) during the month. The spatial pattern of rainfall during the month of December, 2017 (Figure 5a) indicated that it is mainly confined to the south peninsula, the Islands and extreme northern and northeastern parts of the country with large negative anomaly in rainfall observed over northern India (Figure 5d. The month of January was very active with rainfall for the country as a whole was 140% of its LPA and as the second highest since 2001 (2005, 28.1mm). It

(a) Dec 2016 (850 hPa wind anomaly)



(b) Jan 2017 (850 hPa wind anomaly)



(c) Feb 2017 (850 hPa wind anomaly)

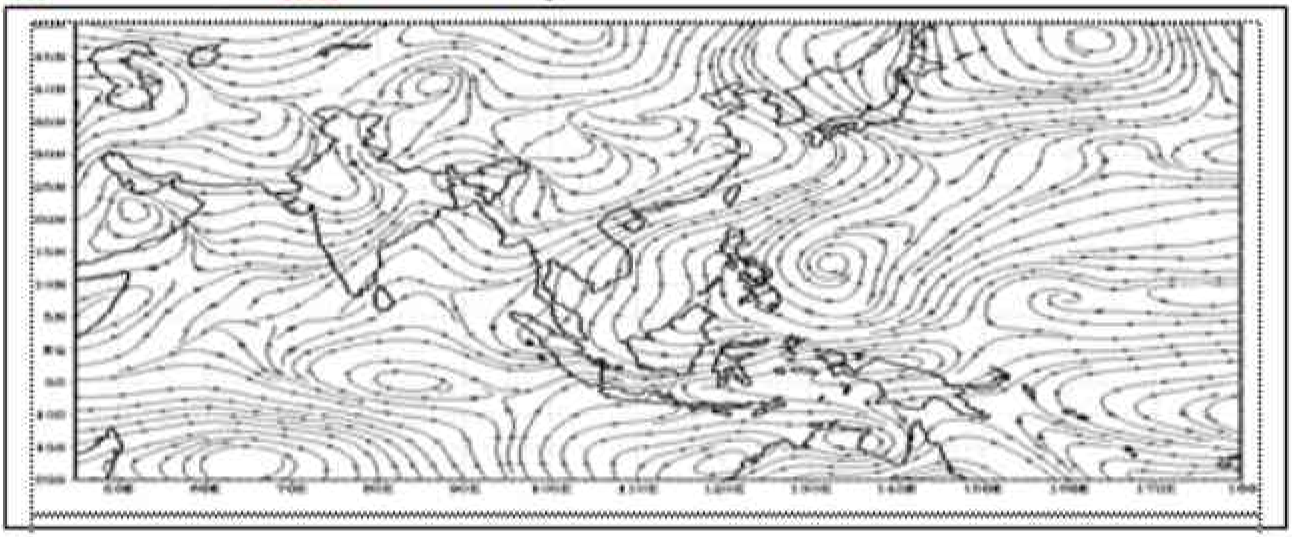


Figure 3: 850 hPa monthly mean ciculation anmalies (a) December 2016 , (b) January 2016 & (c) February, 2017.

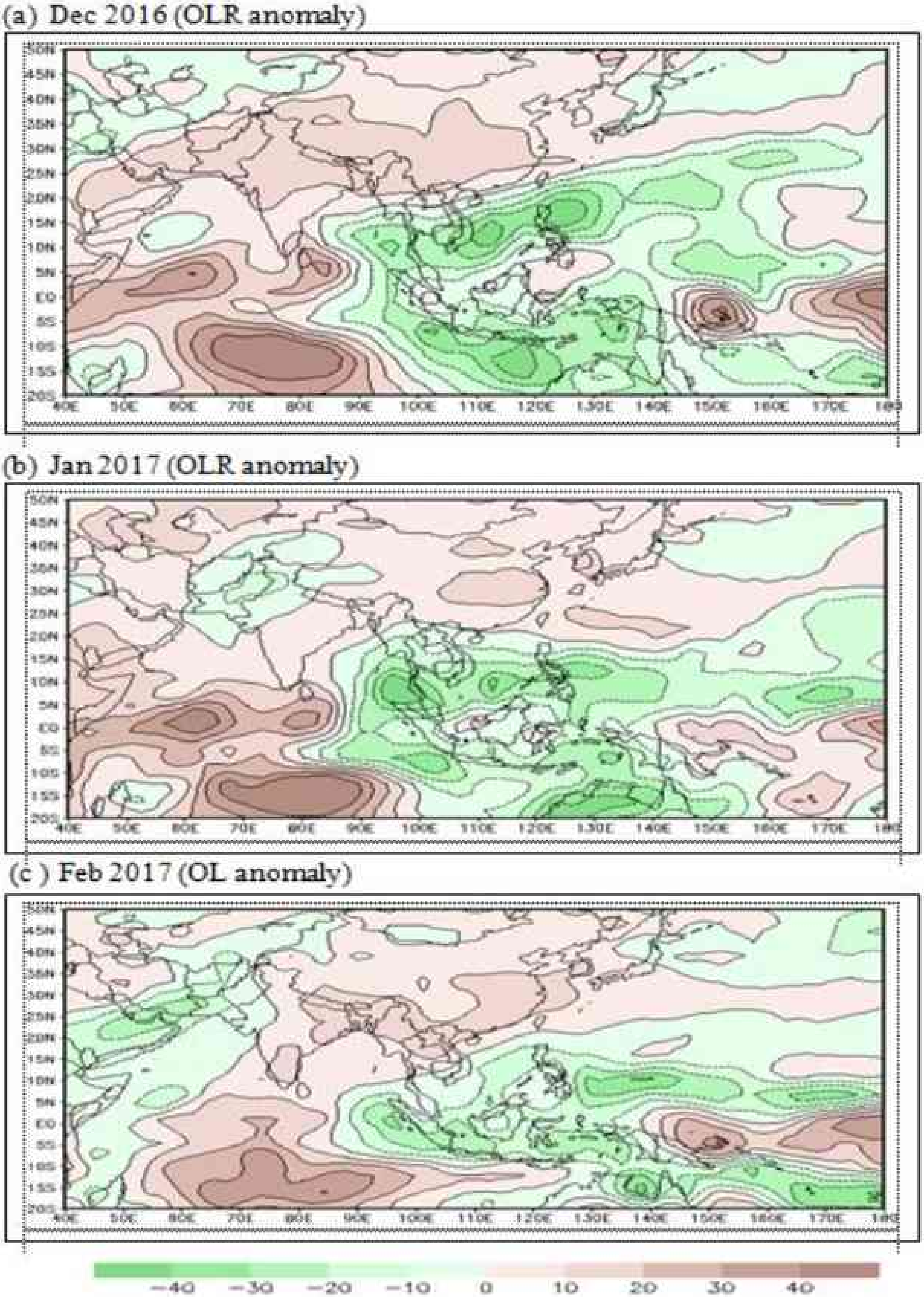


Figure 4: OLR anomalies during (a) December 2016 , (b) January 2016 and (c) February, 2017.
(Source : NOAA CDC).

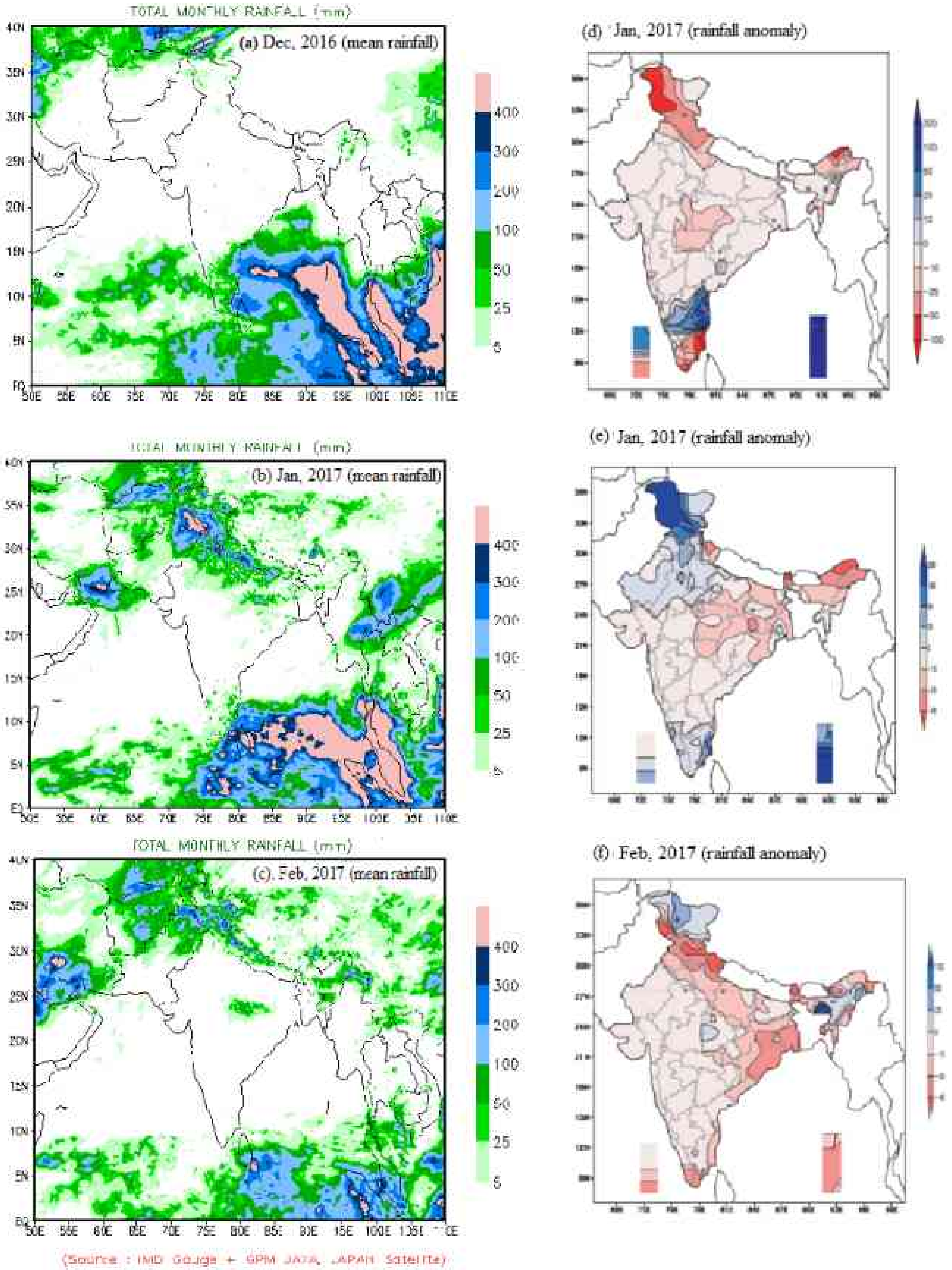


Figure 5 : Mean rainfall (mm) during (a) December 2016, (b) January and (c) February 2017. (d) to (f) Same as 'a' to 'c' but fo rainfall anomaly (mm).

was basically due to the active rainfall over the Northwest India (205.5% of its LPA, highest since 2001) associated with large positive anomaly over north, northwest and southern peninsular India (Figure 5b & d). During the month of February, only a portion of northern India received the rainfall (Figure 5e) as a result the anomaly was negative over most parts of the country except for some parts of northern and northeastern region (Figure 5f). For February 2017, rainfall for the country as a whole was 56% of its LPA value. The rainfall for the month was below normal over the Northwest India and East & Northeast India (66% and 65% of LPA respectively) as indicated by negative anomaly over most of the regions (Figure 5f).

3.5 Maximum and minimum temperatures

The winter season of 2016-17 witnessed mainly a warmer maximum and minimum temperatures (Tmax and Tmin) over northern India. As shown in Figure 6a-b the month of December, 2016 indicated warmer than normal maximum and minimum temperatures over the Northern, northwestern and northeastern parts of the country. As shown in Figure 6a except for Indo-Gangetic plains most parts of northern, northwestern and extreme northeastern region of the country witnessed above normal Tmax of about 2 to 3 ^{0}C with parts of Jammu & Kashmir, Himachal Pradesh and West Rajasthan, was above normal by more than 4 ^{0}C.

Similarly, the Tmin during the month was below normal over central and peninsular regions of the country with Tmin of below normal by about 1 ^{0}C over some parts of central region viz. Odisha, Chattisgarh, southern parts of Madhya Pradesh, Vidarbha and Marathwada (Figure 6b). The Tmin was above normal over rest of the country. About 53 people lost their life due to cold wave in Bihar & Uttar Pradesh particularly during the period from 9-12 December, 2016.

During January, 2017 the Tmax was above normal over most parts of the country except for some parts of northern/northwestern region and some isolated places. The homogeneous region of East & Northeast India was abnormally warmer in respect of maximum temperature during the month (second warmest since 1971) with most parts of northeast India, it was above normal by about 2 to 3 ^{0}C (Figure 6c). Tmin was also above normal over most parts of the country except for some parts of central and northeastern region. Over most parts of northwestern/northern region and some parts of northeastern region and south peninsula, it was above normal by 1 to 2 ^{0}C (Figure 6d). The cold wave events were relatively less during the month. Severe cold wave conditions prevailed only for a shorter duration over parts of northwest and adjoining central India from 10th-15th of the month. A few stations over the plains even reported sub-zero temperatures during this period. Cold wave claimed 12 lives during the month from northern/northwestern parts of the country. Also, shallow to moderate or dense to very dense fog prevailed at isolated, few or many places over the plains of north India and also over the hills of north and northeast India almost throughout the month. During 25-27 January, 26 people, including 20 soldiers died in a series of avalanches in Baramulla, Srinagar and Budgam districts of Jammu & Kashmir.

During the month of February, 2017, the mean temperature for the month this year was above normal by about 1.3 ^{0}C thus making it the fourth warmest February month since 1901. Tmax was above normal almost throughout the country. It was above normal by more than 2 ^{0}C over most parts of northern northwestern, central and extreme northeastern region (Figure 6e). Unusual heat wave conditions occurred along the west coast during last week of the month. Tmin was below normal over some parts of south peninsula and central and adjoining eastern region and above normal over rest of the country (Figure 6f).

It was above normal by about 2 to 3 ^{0}C over parts of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, West Uttar Pradesh, West Rajasthan, Gujarat state and at some isolated places and was below normal by more than 1^{0}C over parts Odisha & adjoining Chattisgarh and Telangana and also over parts of Rayalaseema, South Interior Karnataka and coastal Tamil Nadu. Cold wave conditions prevailed only at isolated places for a day or two over central parts of the country during last week of the month. Shallow to moderate or dense to very dense foggy conditions

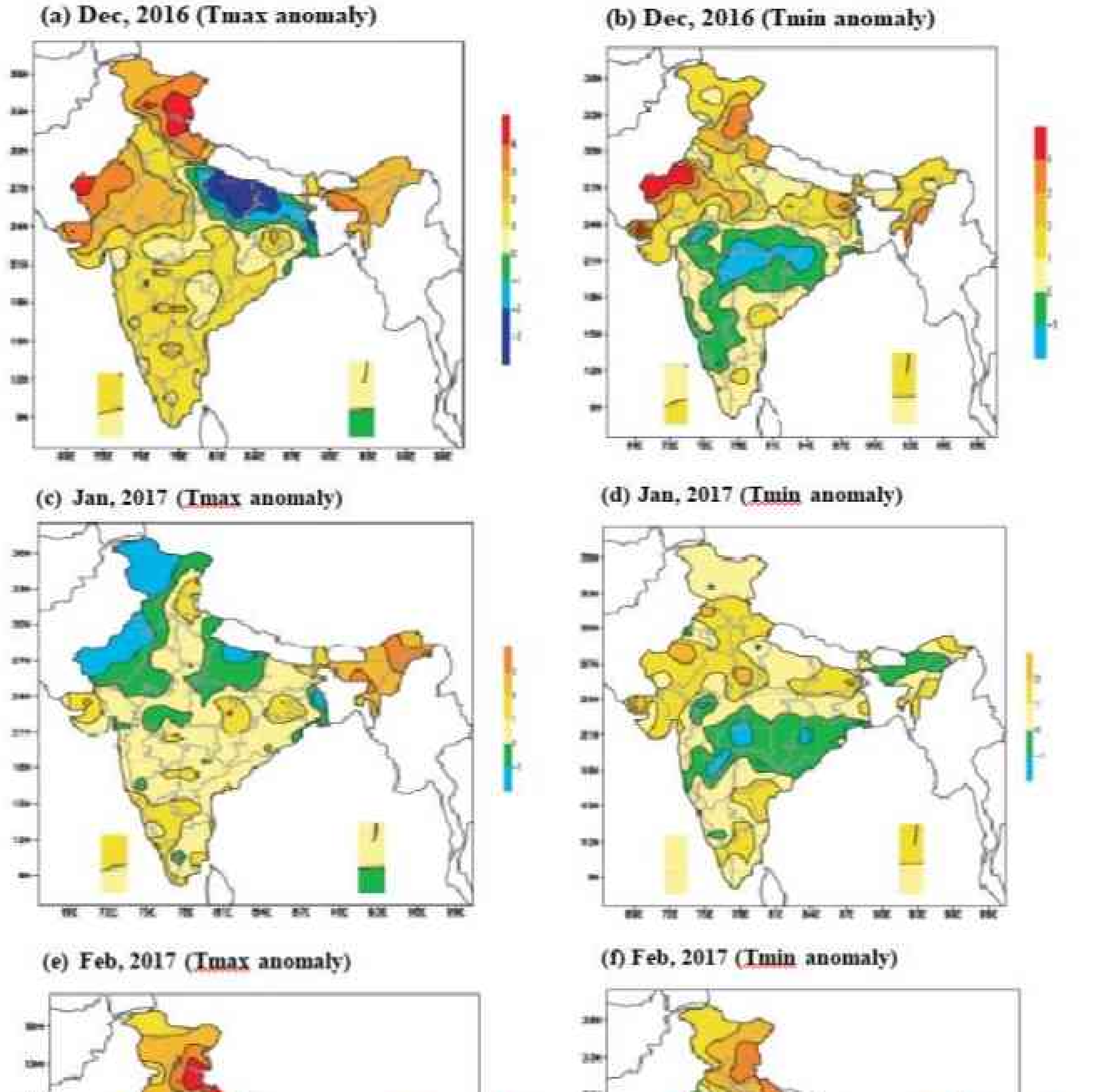


Figure 6: Mean maximum temperature (Tmax) anomaly in ^{0}C (a) December 2016, (b) January and (c) February 2017. (d) to (f) Same as 'a' to 'c' but fo minimum temperature anomaly (^{0}C). (Normal used is fom 1971 to 2000; Source : CDBI, IMD Pune).

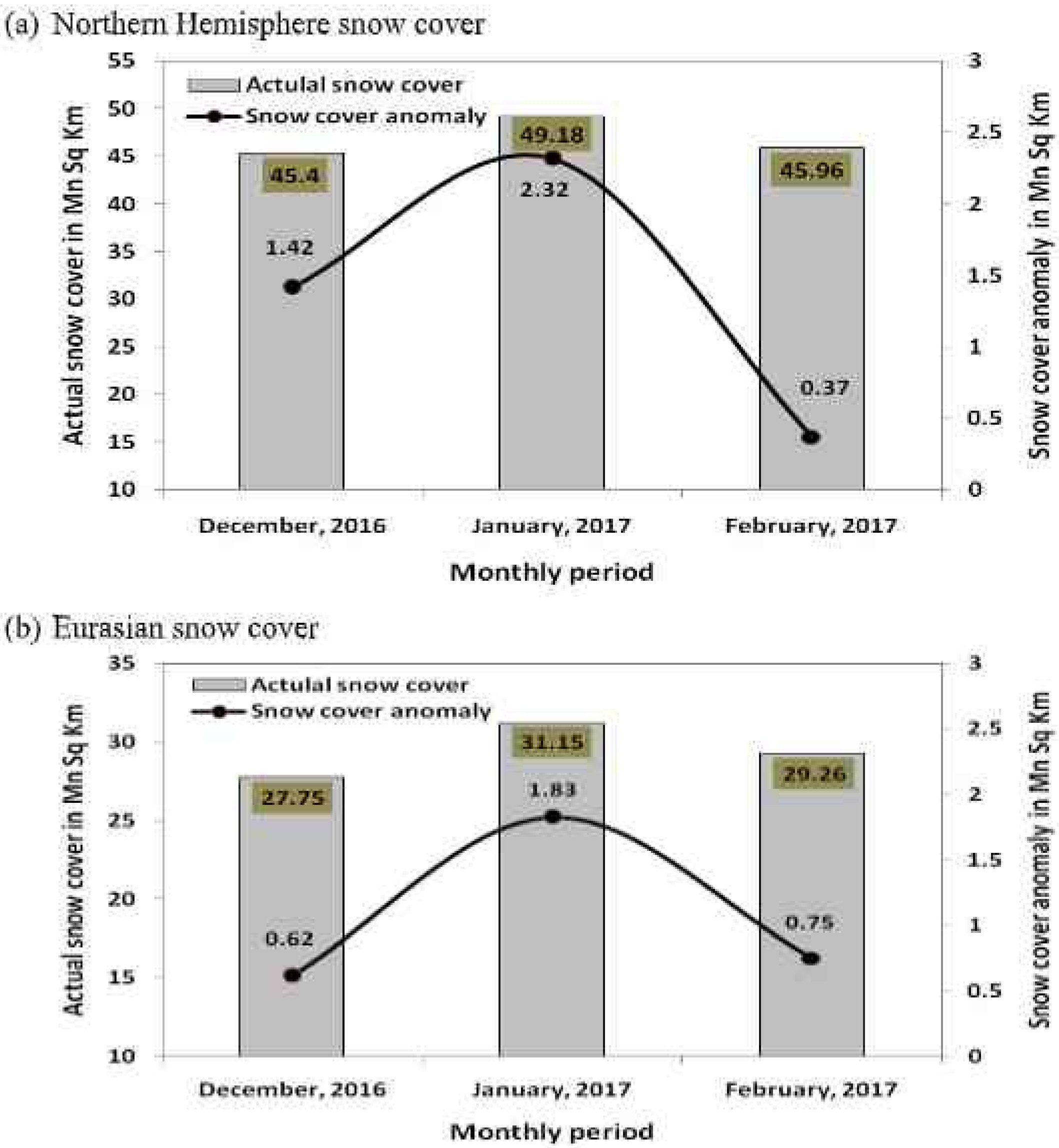


Figure 7: Monthly snow cover and its anomaly (Million Square Km) over Northern Hemisphere and Eurasian regions during Dec 2016 to February, 2017. The mean used is for the period 1981 to 2010 fo the calculation of anomaly (Data Source: Rutgers University Climate Lab).

prevailed at few places over the plains of north India and eastern parts of the country during first three weeks of the month.

3.6 Madden Julian Oscillation (MJO)

The typical length of the MJO cycle usually lasts between 30-60 days, and the degree of MJO activity is often quite variable (Madden & Julian, 1972). During first week of December 2016, MJO was active over West Hemisphere and Africa in phase 8 and phase 1 and later propagated to Indian Ocean in phase 2 with weak amplitude. It further moved eastwards to phase 3 and then over to Maritime Continent in phase 4 and 5. In the mid of December, MJO propagated to western Pacific in phase 6 and remained there till the end of December with weak amplitude. During first week of January 2017, MJO was active over Maritime continent in phase 5 and later propagated to Western Pacific in phase 6 and 7 with weak amplitude. In the mid of January, MJO propagated to West Hemisphere and Africa in phase 8 and 1 with increased amplitude. It further moved westwards to Indian Ocean in phase 2 and 3 and entered Maritime Continent by the end of January with weak amplitude. During February MJO was very strong with first 6 days it was over the maritime continents in phase 4 & 5, which entered to western Pacific in to the phases 6 & 7 till 12 February. The MJO entered to western Hemisphere and Africa in phase 8 and 1 during 3rd week of February and subsequently was over the western equatorial Indian Ocean during last week of February, 2017. (Data Source: http://www.bom.gov.au/climate/ mjo/).

3.7 Northern Hemisphere snow cover

The snow cover over and its anomaly over the Northern Hemisphere (NH) as a whole and the Eurasian region during the winter months from December 2016 to February, 2017 is shown in Figure 7a-b, which indicate more than normal snow cover during all the three months. As shown from Figure 7a during January, 2017 the NH the snow cover area (49.18 million sq. Km) was more than the 1981-2010 normal by 2.3 Million Sq. km.

Similarly, the monthly snow cover in December, 2016 and February 2017 was also above normal by 1.42 and 0.37 Mn. Sq. Km. over the Northern Hemisphere. Like in the NH the Eurasian region also witnessed above normal snow cover in winter (Figure 7b) with January, 2017 indicating the snow cover area (31.15 million sq. Km) was more than the 1981-2010 normal by 1.83 Million Sq. km. Similarly, the monthly snow cover in December, 2016 and February 2017 was also above normal by 0.62 and 0.75 Mn. Sq. Km. over the Eurasian region.

4. Summary

The global features during the winter season of 2016-17 (Dec 2016 to Feb 2017) indicated borderline cool ENSO neutral conditions prevailed during the period associated with neutral Indian ocean dipole conditions caused by the cooling of eastern equatorial Indian Ocean. The winter season of 2016-17 witnessed mainly a warmer maximum and minimum temperature (Tmax and Tmin) over northern India. However, the cold wave condition prevailed over Bihar & Uttar Pradesh particularly during the period from 9-12 December, 2016, which was responsible for the death of more than 50 people. During the peak winter month of January, 2017 Tmin was also above normal over most parts of the country except for some parts of central and northeastern region. The above normal rainfall is observed over the northern India only during the month of January, 2017, whereas, rainfall was subdued during December and February. The winter snow cover over Northern Hemisphere (NH) and Eurasian region indicated above normal snow during the winter seasons of 2016-17.

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