Extended-range Forecasts of Extreme Rainfall Events over Jammu and Kashmir during September 2014

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ABSTRACT

The monsoon behavior is different from one year to another year as it is influenced by different regional and global features. The unusual features of monsoon 2014 were its sluggish progress northward from southern tip of India after delayed onset on 6th June. The monsoon covered entire India by 17 July and it witnessed very heavy rainfall in September 2014 over many parts of northern India in general and Jammu-Kashmir (J&K) meteorological subdivision in particular, leading to large scale destruction of life and property. The unprecedented flood event occurred over J&K region in active phase of monsoon during September 3-6, 2014. The J& K flood 2014 was most destructive flood over the region till date. Forecasting of such heavy rainfall event with sufficient lead time will enable the disaster managers to take appropriate measures to minimize the loss of life and property In the present study the real-time forecasting of this heavy rainfall event in the extended range time scale is investigated. The performance of the real-time extended range forecasts based on the Climate Forecast System version 2 (CFSv2) coupled model outputs is analyzed. The Global Forecast System (GFS) model analysis has been used to see the observational features of circulation associated with this rain event. The extended range forecast of active phase of monsoon during the heavy rainfall event of Jammu and Kashmir based on CFSv2 model although predicted well, the magnitude was underestimated and the lead time was also very short and the model could capture the features reasonably well only in the first week of forecast.

Keywords*: Active Monsoon, Westerly trough, Heavy rainfall, Short range forecast, Extended range forecast and Coupled model.*

1. Introduction

In the Indian Himalayan region, extreme rainfall events are in general observed during active phase of monsoon. In recent years, extreme rainfall events resulted in several flood events over different parts of the country. The following are some of the examples of extreme rainfall events that occurred in the recent year 2014: Bangladesh heavy rainfall during June 22-24, Madhya Pradesh heavy rainfall during July 21-24,Odisha heavy rainfall during August 4-6, Jammu and Kashmir heavy rainfall during September 3-6, Gujarat heavy rainfall on September 9 (Satyanarayana and Kar, 2016). There are several studies which show that the year 2005, 2009, 2011, 2012 and 2014 received heavy rainfall events during retreat phase of monsoon. However, the year 2003 and 2013 received heaviest rainfall amount during onset phase of monsoon (Kumar et al. 2017). The forecast of heavy rainfall event over Himalayan region is difficult as this region does not have a dense network of rain gauges.

There have been several cases of heavy rainfall event over northern India during recent decade (Kumar 2008; Deb et al. 2008, 2010; Guhathakurta et al. 2011, Ahasan et al. 2013). The number of extreme rainfall event observed over northern India during monsoon 2014 is highest (IMD Met Monograph 2015). Chang et al. (2008) have examined the sub grid scale vertical moisture flux convergence in the 15 Km and 5 Km grid sizes. There are few studies on extended range forecast of heavy rainfall events (Kar et al 2006). Pattanaik et al. (2014) have attempted extended range forecast (weekly period i.e. up to 3 weeks) over India and its four homogenous regions for monsoon 2012. They found that multi model ensemble is superior over Individual model for extended range forecast of monsoon. Several studies have addressed the impact of climate change on

extreme rainfall events (Ray et al. 2014). The advance of southwest monsoon in 2013 had been the fastest during the period 1941-2013 as it took only 15 days to cover the entire country after its normal onset on 1st June. There was very unusual heavy rainfall event over Northwest (NW) India particularly over the meteorological subdivision of Uttarakhand as seen from the sub-division wide monthly rainfall departure during June, 2013 with all the meteorological subdivisions over NW India indicating excess rainfall (a departure ≥ 20%) with the meteorological subdivision of Uttarakhand reported a departure of 191% (Dube et al. 2014; Pattanaik et al. 2015). This type of rapid advance of monsoon with vigorous rainfall activity is associated with movement of a monsoon low from Northwest (NW) Bay of Bengal across central India to NW India during this period (Devi and Yadav, 2014). The extended range forecast of this heavy rainfall event over Uttarakhand during the onset phase of monsoon was reasonably well captured in the model (Pattanaik et al. 2015) Like the Uttarakhand heavy rainfall event of monsoon 2013, the active phase of monsoon 2014 was also associated with heavy rainfall event over Jammu and Kashmir region during the withdrawal phase of monsoon (Lotus S, 2015, IMD Met Monograph).The India Meteorological Department (IMD) report shows that an unusual event of 488.2 mm rainfall in 24 hr (September 4th to September 5th) occurred in Jammu and Kashmir, Himalayan region during the withdrawal phase of monsoon. The occurrence of J & K heavy rainfall events was not rapid but the result of gradual interaction between northwestward moving monsoon current and eastward moving mid-latitude westerly trough. The moisture feeding was mainly from Arabian Sea on September 3-4, 2014, whereas the moisture feeding was observed mainly from the Bay of Bengal on September 5-6, 2014. The MJO state was found to be weak and that occurred during Phase 1 and Phase 2 during the J&K heavy rainfall event. Thus, MJO may have significant role in outbreak of convection and enhancement of rainfall activity over J & K during September 3-6, 2014 as suppressed convection over Indian Seas results in enhancement of convective activity over Indian Subcontinent region.

Several studies have been carried out on the model simulations of extreme rainfall events in the Himalayan region. Many studies have been performed about the short and medium range forecasting of two recent heavy rainfall events over northern India viz., the Uttarakhand event of 2013 and Jammu-Kashmir heavy rainfall event of 2014. Kar and Tiwari (2014) highlight the uncertainties in regional model forecast of Jammu and Kashmir 2014 heavy rainfall event. Therefore, this study has been undertaken to study the performance of the extended range forecast ofthis unusual feature of monsoon during the retreat phase of monsoon 2014 using coupled model outputs and its multi-model ensembles.

2. Data and Methodology

2.1 Observed data used in the present study

The rainfall observations from large number of stations spread over the entire Indian land mass are used by IMD to prepare the daily time series of area averaged monsoon rainfall over India as a whole and also over the smaller spatial regions. This observed data set of rainfall obtained from IMD over all India, NW India and 36 meteorological sub-divisions over India shown in Figure 1 are used for the verification purpose. For the spatial distribution of rainfall over the surrounding oceanic region outside India, the observed rainfall available from Tropical Rainfall Measuring Mission (TRMM) is also used for the purpose.

2.2 NCEP's Climate Forecast System (Version 2) model output

Outputs from two well known models are used for the extended range forecast of active Jammu and Kashmir phase of monsoon 2014.The National Centre for Environmental Prediction's(NCEP's) Climate Forecast System version 2 (CFSv2) and the JMA's ensemble prediction system (EPS) are used in the present study. The details of these models forecasts and the methodology of multi-model ensembles (MME) are given here.

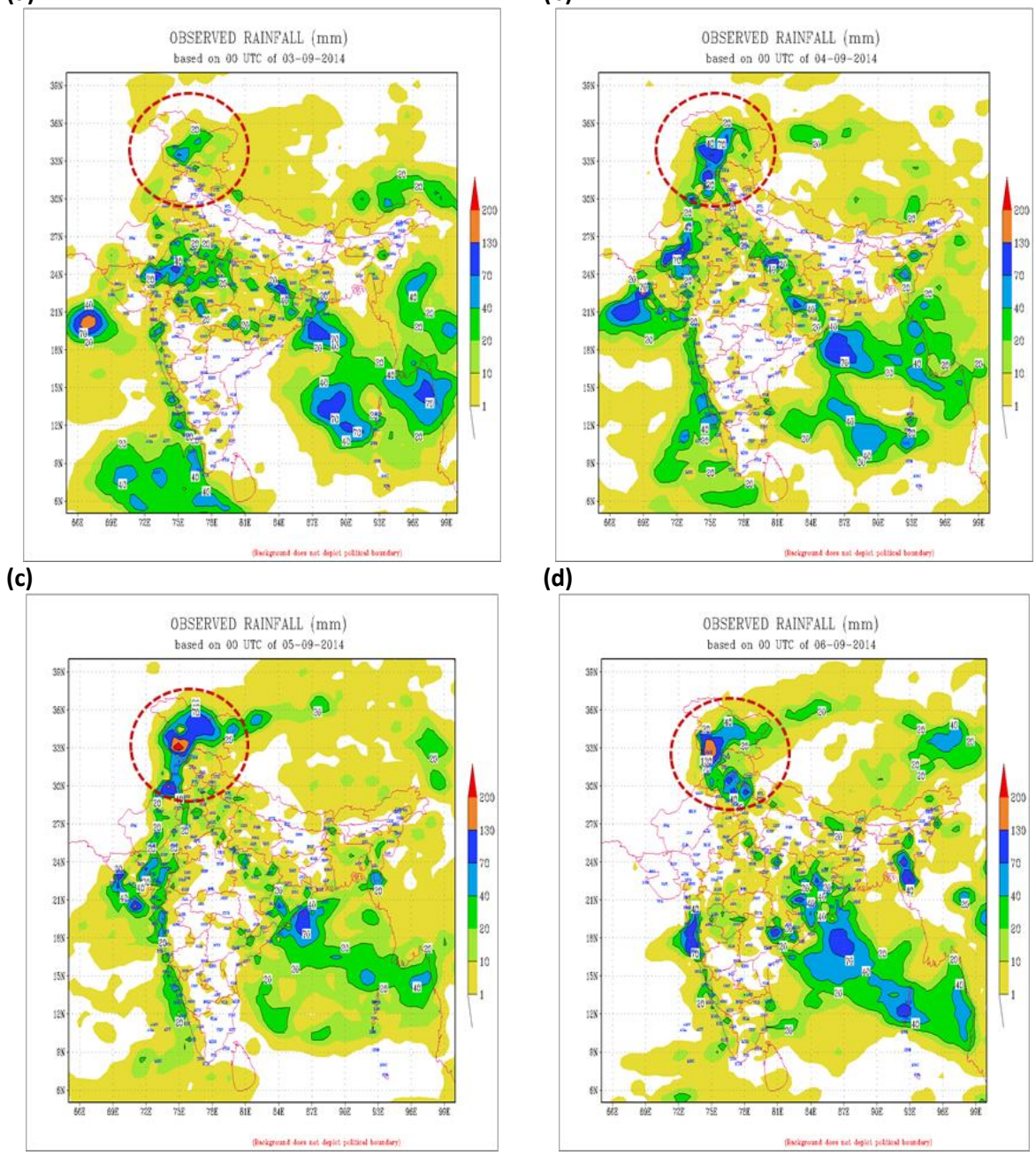


Figure 1: One day rainfall over India with marked over Jammu and Kashmir region during 03, 04, 05 and 06th September, 2014

The Climate Prediction Centre, NCEP was running operationally the coupled model known as the Climate Forecast System version 1 (CFSv1) from 2004 (Saha et al. 2006). The atmospheric component of the operational CFSv1 (T62L64/MOM3) is the NCEP atmospheric GFS model. The oceanic component is the GFDL Modular Ocean Model V.3. The CFSv1 is a fully 'tier-1' forecast system. The second version of the NCEP Climate Forecast System (CFSv2) was made operational at NCEP in March

2011. This version has upgrades to nearly all aspects of the data assimilation and forecast model components of the system. The atmospheric model has a spectral triangular truncation of 126 waves (T126) in the horizontal (equivalent to nearly a 100 Km grid resolution) and a finite differencing in the vertical with 64 sigma-pressure hybrid layers. In operational mode the CFSv2 runs with 16 members daily (Saha et. al., 2014). The CFSv2run based on every Thursday and valid for the forecast periods of days 02-09 (*here after called week-1*), days 10-16 (*here after called week-2*), and days 17-23 (*here after called week-3*), coinciding with Friday-Thursday and for the subsequent Friday-Thursday are considered

3. Results and Discussion

3.1 Diagnostic features and extended range forecast of J & K heavy rainfall episode

Some major synoptic features observed on the 2nd to 7th September 2014 are discussed as follows. The 850 hPa (Fig.2a-f) wind analysis show circulation features during September 1-7, 2014.

The surface wind analysis show the east-west active monsoon trough passing through central India associated with cyclonic circulation over Odisha on 1st September (Fig.2a). The upper wind analysis show Cyclonic circulation over Odisha and adjoining coastal AP. Another cyclonic circulation over Afhganistan region (Fig.2b). The 2ndSeptember wind show east-west active monsoon trough with embeded cyclonic circulation over Chhatisgarh and MP (Fig.2a) and Cyclonic circulation over Afhganistan, Pakistan and adjoining J & K (Fig. 2a).

Further, it is seen that Cyclonic circulation over Rajasthan and north Gujarat embeded with north-south tropugh (Fig. 2b) and Cyclonic circulation over Gujarat region on 3rdSeptember (Fig.2b). The 4th September wind show Cyclonic circulation over North Rajasthan with N-S trough passing from this to north Arabian Sea (Fig. 2c) and feeble N-S trough over Rajasthan and adjoining Pakistan (Fig.1c). However, the Cyclonic circulation over Punjab adjoining J & K and Pakistan (Fig. 2d) and N-S trough over J&K and adjoining Punjab (Fig. 2dj) on 5th September. The 6th September analysis show Cyclonic circulation over J & Kand adjining Pakistan (Fig. 2e) and N-S trough over J & K (Fig. 2e). The 7th September 850 hPa (Fig.2f) wind show no significant system over J&K. The analysis shows that the 40-70 mm/day rainfall occurred over Shrinagar during 03 to 06 September, 2014 (Fig. 1a-d). The 5th September analysis show very heavy rainfall event (70-200 mm/day) over Jammu-Kashmir (Fig.1c), which is decreased slightly on 06th September, 2014.

Based on the coupled models outputs the extended range forecast is prepared for 2 weeks. The weekly mean and anomaly wind based on the initial condition of 27th August, 2014 is shown in Figure 3a-d. Based on the initial condition of 27th August the two weeks forecasts indicate active monsoon condition with prominent monsoon trough and cyclonic circulation over central India during the period from 29 Aug-4Sep and 5-11 Sept (Fig. 3a-b), which is also seen in the wind anomaly forecast (Figs 3c-d). The associated forecast mean and anomaly rainfall indicates positive rainfall anomaly over J & K region during the period from 29 Aug-04 Sep and 5-11 September (Fig. 4b & 4d) respectively. Thus, the week 1 forecast based on 27th August, 2014 indicates just the positive anomaly of rainfall over J & K region during the period from 29 Aug-04 Sep, 2014.

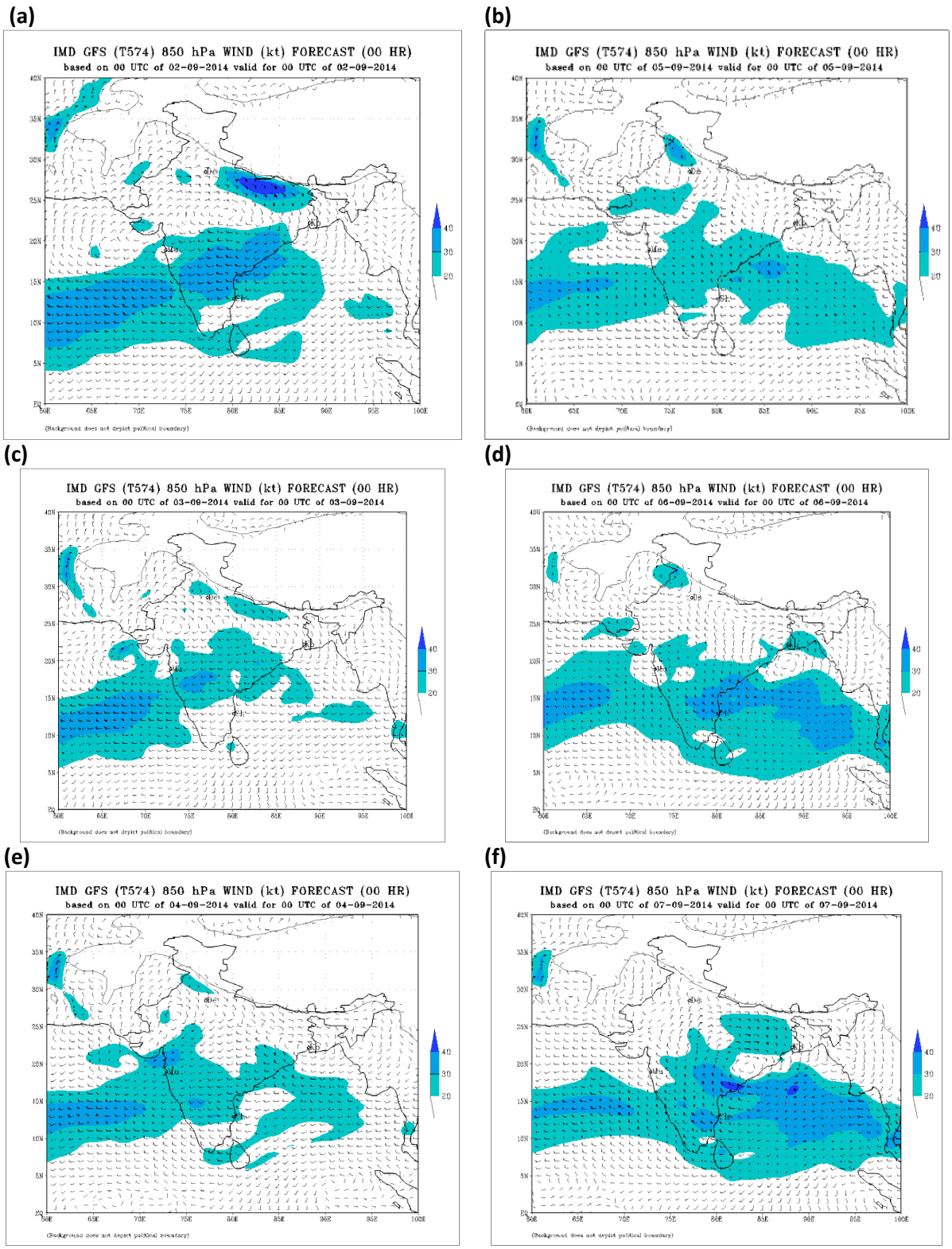


Figure 2. 850 hPaanalysed wind (a-f) from 02 September, 2014 to 07 September, 2014.

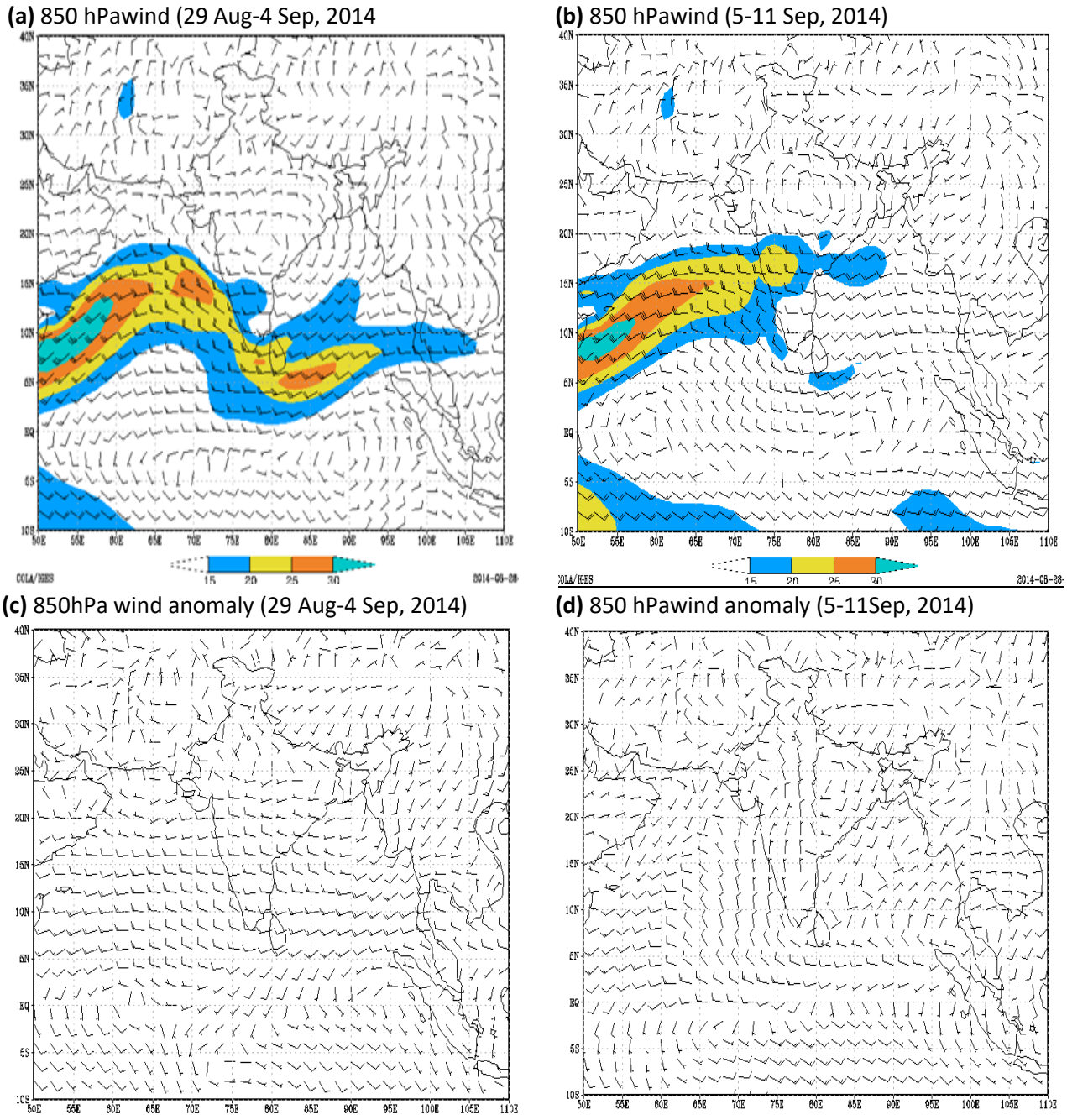


Figure 3: 850 hPa weekly forecast wind based on initial condition of 27th August, 2014. (a) and (b) weekly mean wind valid for 29 Aug-04 Sep and 05-11 Sep respectively. (c) and (d) same as 'a' and 'b' but for forecast wind anomaly

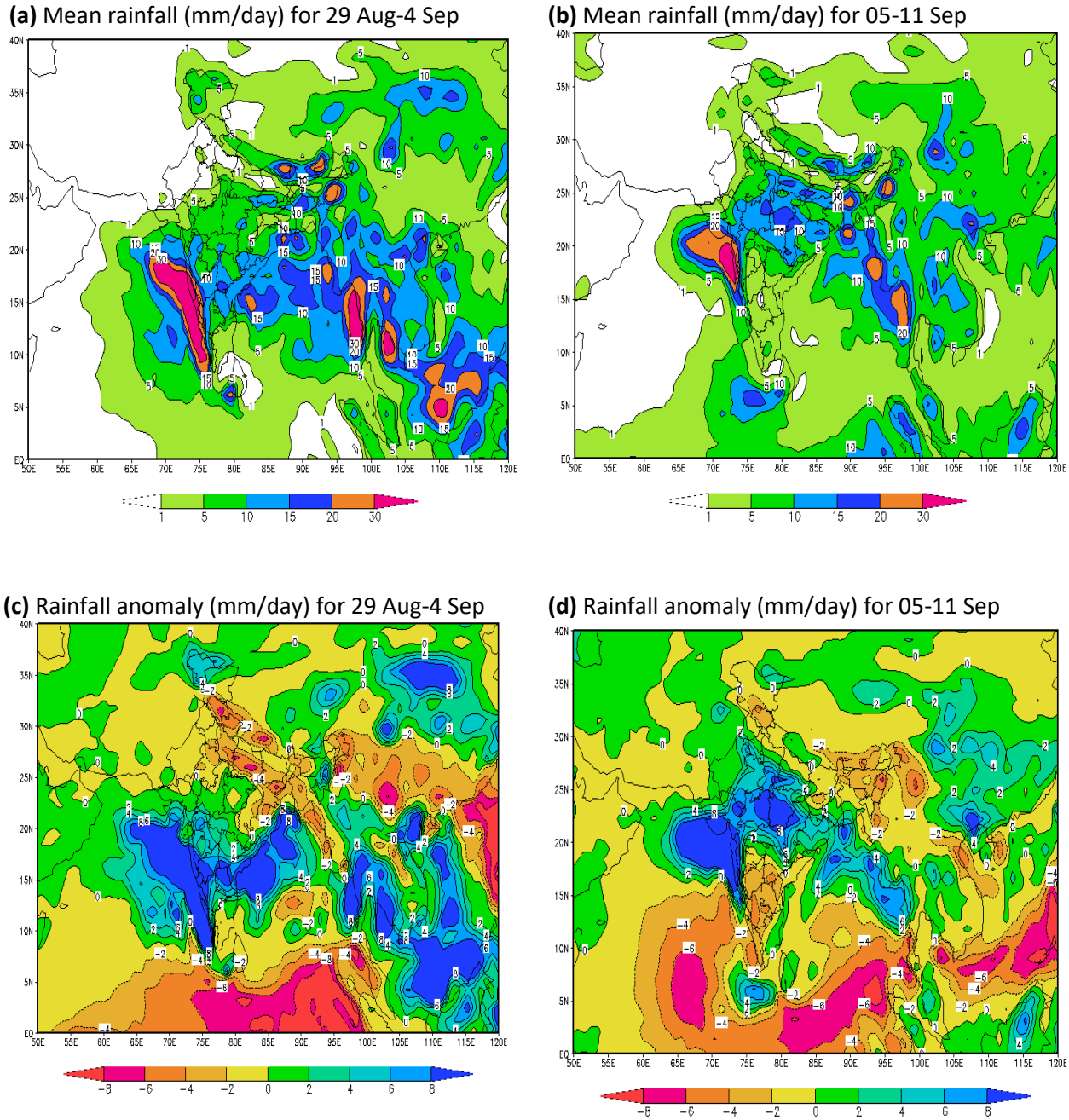
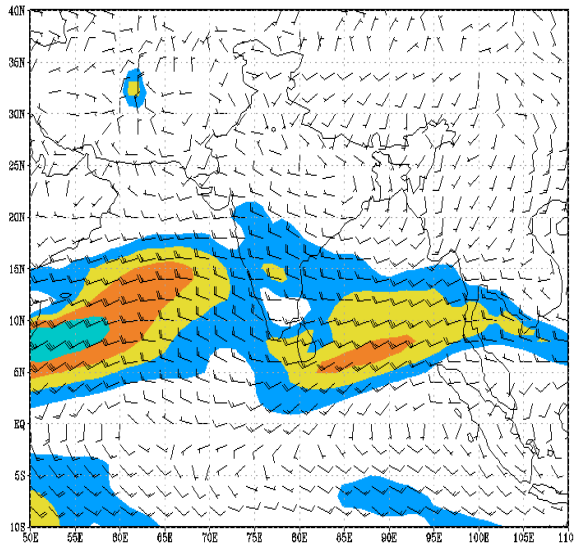
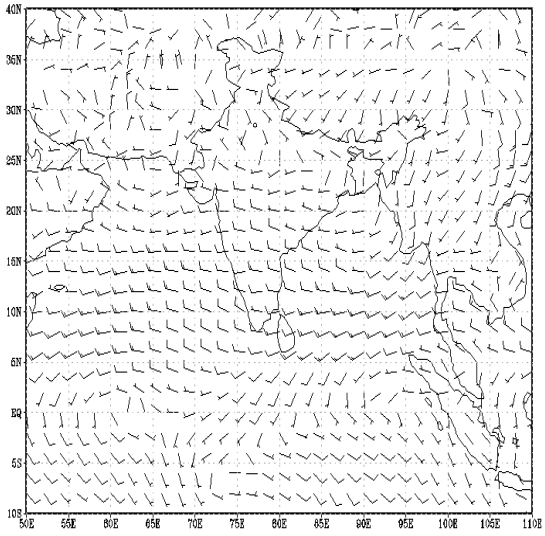


Figure 4: Forecast mean rainfall in mm/day based on initial condition of 27th August, 2014. (a) and (b) weekly mean rainfall valid for 29 Aug-04 Sep and 05-11 Sep respectively. (c) and (d) same as 'a' and 'b' but for forecast rainfall anomaly

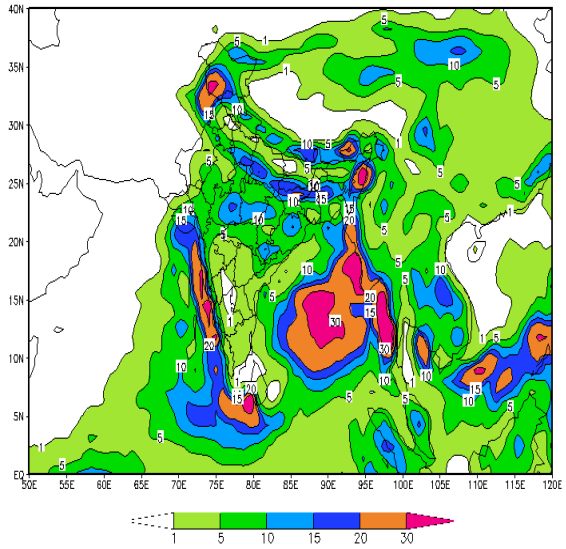
(a)850 hPa mean wind (5-11 Sep, 2014)



(b)850 hPawindanomaly (5-11 Sep, 2014)



(c) Mean rainfall in mm/day (5-11 Sep, 2014)



(d) Rainfall anomaly in mm/day (5-11 Sep, 2014)

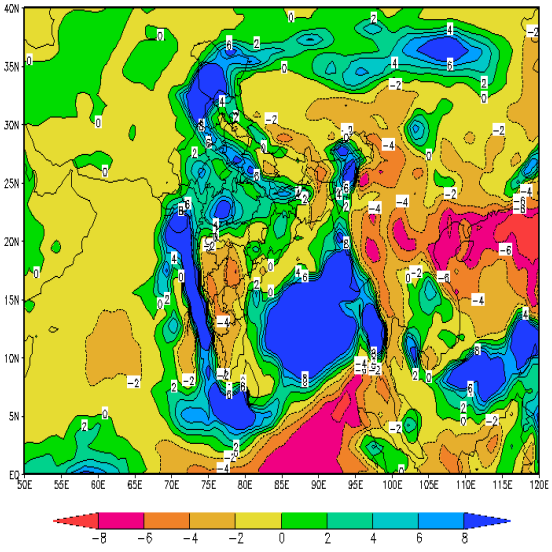


Figure 5: Forecast mean and anomaly wind based on initial condition of 3rd September, 2014. (a) and (b) weekly mean and anomaly wind for 5-11 September, 2014. (c) and (d) Same as 'a' and 'b' but for the mean and anomaly rainfall for 5-11 September, 2014

The weekly forecast wind and rainfall based on the initial condition of 3rd September and valid for 5-11 September, captured the event very well as shown in Figure 5 with active monsoon trough and northward shifting of the western end of the monsoon trough (Fig. 5 b). Associated with this the weekly forecast rainfall also gives magnitude of rainfall exceeding 20 to 30 mm/day over parts of J & K (Fig. 5c) along with its anomaly of exceeding about 8 mm/day during the week for 5-11 Sep,2014 (Fig. 5d). Thus, although the extended range forecast reasonably captured the rainfall event, its magnitude was slightly better captured with shorter lead time.
Thus, the two weeks forecasts for August 29th to September 4th and September 5th to September 11th are made based on the initial conditions of August 27th. Further, the second stage (September 5th to September 11th) prediction is made based on the initial conditions of September 3rd. The wind and rainfall mean and anomaly values show the incidences of heavy rainfall during three days (September 4th to September 6th) of first week of September, 2014.

4. Conclusions

The severe flood over J & K during the first week of September, 2014 occurred due to heavy rain fall associated with active monsoon condition and some interaction with middle troposphere westerly system. Interaction between tropics and mid latitude led to intensification of western disturbances, outbreak of convection and enhancement of rainfall activity over Jammu and Kashmir during September 3-6, 2014. The J& K flood 2014 was most disastrous flood over northwest India till date. The probable cause of severe flood during monsoon 2014 was continuous rainfall during September 1-6, 2014 with most stations reporting heavy rainfall during 3 days during September 4-6, 2014. There are other theories which have proposed the occurrence of cloud burst at various places particularly higher reaches of valley. This coupled with snow melt water resulted into surge in water level of the main Kashmir river. The extended range forecast of heavy rainfall event of Jammu and Kashmir although predicted well, its lead time was very short. The extended range forecast of such a severe flood event is more useful for mitigation purposes.

Acknowledgements

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