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Forecasting the heavy rainfall during Himalayan flooding—June 2013

Anumeha Dube*, Raghavendra Ashrit, Amit Ashish, Kuldeep Sharma, G.R. Iyengar, E.N. Rajagopal, Swati Basu

National Centre for Medium Range Weather Forecasting (NCMRWF), Earth System Science Organisation (ESSO), Ministry of Earth Sciences, A-50, Industrial Area, Phase-II, Sector 62, Noida, Uttar Pradesh 201309, India

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ABSTRACT

On 17th June 2013 the state of Uttarakhand in India (Latitude 28.72°N to 31.45°N and Longitude 77.57°E–81.03°E) received more than 340 mm of rainfall, which is 375% more than the daily normal (65.9 mm) rainfall during monsoon. This caused heavy floods in Uttarakhand as well as unprecedented damage to life and property. In this study we aim at assessing the performance of two deterministic forecast models, Global Forecast System (GFS/T574) and Unified Model (NCUM), run at NCMRWF, in predicting the heavy rainfall observed over Uttarakhand region of India during 17–18th June, 2013.

Verification of the synoptic features in forecasts of the two models suggests that NCUM accurately captures the circulation features as compared to T574. Further verification of this event is carried out based on the contiguous rain area (CRA) technique. CRA verification is used in computing the total mean square error (MSE) which is based on displacement, volume and pattern errors. This verification technique also, confirms the better skill of NCUM over T574 in terms of forecast peak rainfall amounts, volume and average rain rate, lower MSE and root mean square error (RMSE) as well as having higher hit rates and lower misses and false alarm rates for different rainfall thresholds from Day 1 to Day 5 forecasts.

1. Introduction

Over the Indian subcontinent, the amount of rainfall received during the southwest monsoon season (June–September) is very crucial for the agriculture and in turn for the economy. In the past couple of years, there have been several cases of heavy rainfall (3–12 cm/day) events over India. The most recent events (June 2013) are the heavy rainfall observed in Maharashtra (approximately 300% more than the average during 1st to 16th June, 2013 in Mumbai and adjoining areas) and Uttarakhand (approximately 800% more than the average during 13th–19th June, 2013 in Kedarnath and adjoining areas) states of India. These led to a massive destruction of property and loss of life (more than 1000 deaths, several missing persons and more than 61,000 stranded in Uttarakhand, (Disaster Update, 18-June, 2013; Disaster Update, 19-June, 2013; Southwest monsoon-June, 2013; Southwest monsoon-July, 2013). Thus, issuing a reliable short to medium range (3–7 days) forecast is of utmost importance for heavy rainfall events leading to catastrophic floods, loss of life and property over the affected regions. These warnings could help the authorities to take necessary measures to reduce the damage to life and property. Also, accuracy of prediction of high risk events, i.e., the reliability of the forecast, is also a very important part of forecasting weather.

In the last couple of decades, several sophisticated numerical weather prediction (NWP) models have been developed around the world, for example Global Forecast System (GFS) at Environment Modeling Center (National Centers for Environmental Prediction [NCEP]), Unified Model (UM) at UKMet Office, Integrated Forecast system (IFS) at European Centre for Medium Range Weather Forecasting (ECMWF) and The Global Environmental Multiscale Model (GEM) at Environment Canada (Kalnay et al., 1990; Kanamitsu et al., 1991; Brown et al., 2012; IFS, 2012; Côté et al., 1998), which include many complex physical processes and advanced data assimilation schemes. In India, National Centre for Medium Range Weather Forecasting (NCMRWF) provides daily weather predictions based on two NWP models: T574 (Global Forecast System; GFS) and NCMRWF Unified Model (NCUM).

The upper Himalayan territories of Uttarakhand (Latitude 28.72°N to 31.45°N and Longitude 77.57°E to 81.03°E) are mainly covered with forests and mountains. These areas besides being important pilgrimage centers are also famous as tourist attractions especially during the hot summer months of the Indian subcontinent. During 14–17th June, 2013 Uttarakhand received heavy rainfall, and this when combined with the melting snow (due to high temperature during summer season) resulted in an aggravation of

* Corresponding author: Tel.: +91 1202403907; Mobile: +91 9999012055.
E-mail addresses: anumeha.dube@nic.in, anumeha@ncmrwf.gov.in, anumeha.dube@gmail.com (A. Dube).

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floods in this region (Kedarnath [30.73°N, 79.07°E] and adjoining areas). On 17th June alone, the state of Uttarakhand received more than 340 mm of rainfall (37 cm/day in Dehradun [30.32°N, 78.36°E]; as reported in the Climate Diagnostics Bulletin of India, June 2013 (Srivastava and Guhathakurta, 2013), which is 375% more than the daily normal (65.9 mm). The India Meteorological Department (IMD) reported a weekly departure of about 847% in the rainfall volume for the week ending on 19th June 2013 in Uttarakhand.

It has been consistently seen that NCUM shows better forecasting skills than T574 (Iyengar et al., 2010) (for an entire season) for wind, geopotential height, temperature and humidity at various levels. This is reflected in terms of relatively lower root mean square error (RMSE) and higher anomaly correlation. This is also reflected in forecast rainfall for an entire season as well as extreme cases. It is generally found that the improved skill in NCUM is reflected in the improved spatial organization of synoptic systems and associated rainfall which is missing in T574. This is largely attributed to the 4D-VAR data assimilation currently operational in NCUM as compared to GSI scheme operational in T574 which is based on the 3D-VAR data assimilation (Section 3).

The current study is based on the real time forecast obtained from NCUM and T574 and aims at comparing their performance in predicting the heavy rainfall event, of 17th and 18th June 2013, over Uttarakhand region. While we discuss briefly about the broad scale synoptic features that were observed during this time period, we do not go into the details of the causes and the physical processes leading to the event. Both the NWP models operational at NCMRWF provided a clear indication of 8–16 cm/day rainfall on 17th June, 2013 over Uttarakhand region up to 5 days (3 days) in advance in NCUM (T574). Although the location of the predicted highest rain was different in the two models, the forecasts (Day 1 through Day5 in NCUM and Day 1 through Day 3 in T574)

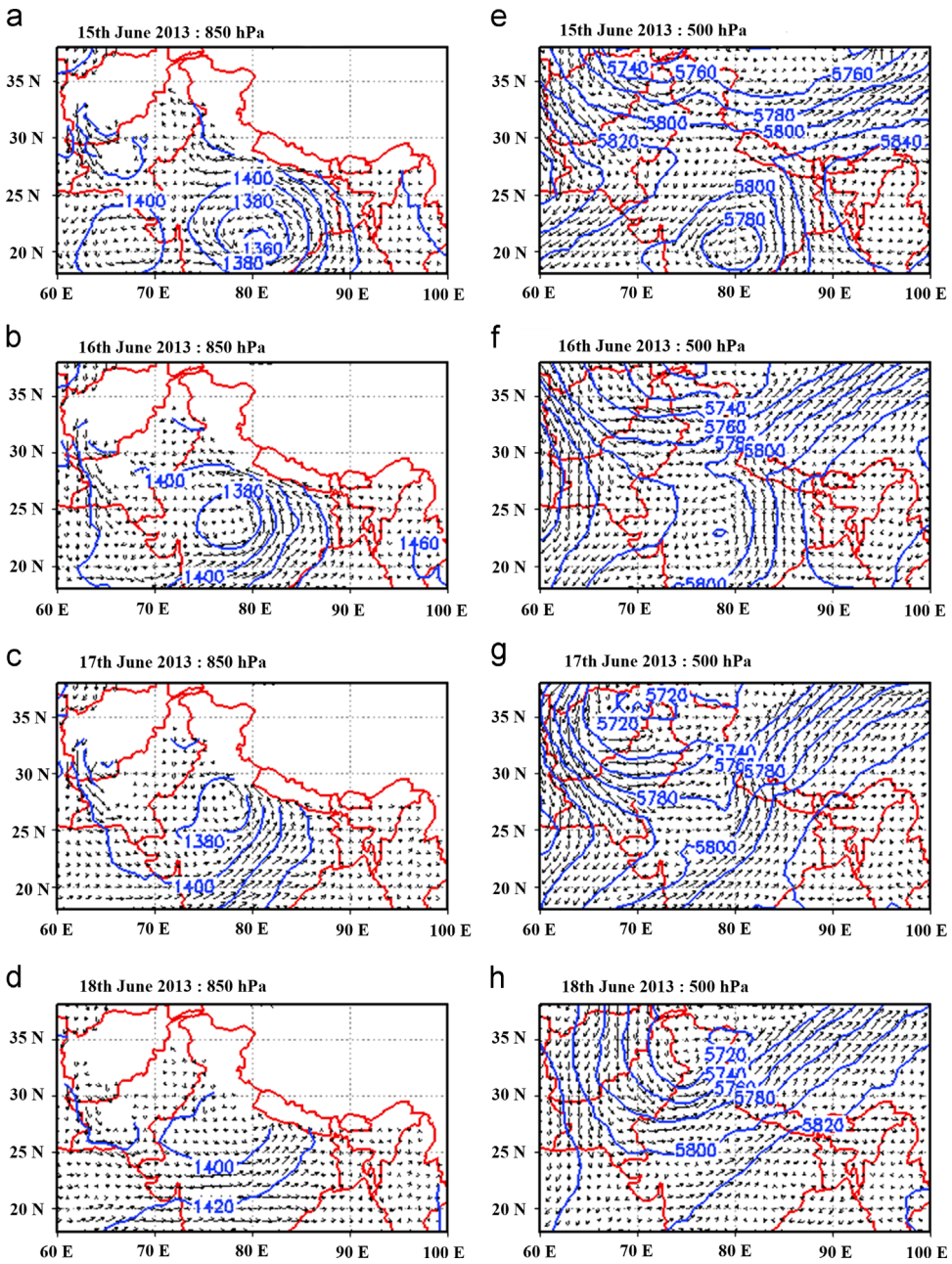

Fig. 1. 850 hPa (a–d) and 500 hPa (e–h) Wind Analysis (m/s) from NCUM for 15–18th June 2013.