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Simulation of extreme temperature over Odisha during May 2015

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ABSTRACT

An extreme temperature event (heat wave) over the state of Odisha was unique as it lasted for about 2 weeks in the 3rd and 4th weeks of May 2015. There was a similar severe heat wave in western and central Odisha in the month of April 1998. The interesting feature of the recent episodic heat wave is that it prevailed in the late pre-monsoon season with wider spread in the state of Odisha. Around 12–15 cities experienced a daily maximum temperature of over 45 °C during the strong heat wave period, and 25th −27th May was declared as the red box zone. In this study, we first analysed the intense summer temperature of 2015 May using India Meteorological Department observations of daily maximum temperature. The observed heat wave phenomenon was then simulated using the Weather Research and Forecast Model (WRFV3) at 2-km horizontal resolution to assess its ability to forecast such a rare event. The observational analysis clearly indicated that this episodic event was unique both in terms of intensity, geographical spread and duration. An optimized configuration of the WRF model is proposed and implemented for the simulation of the episodic heat wave phenomenon (daily maximum temperature) over the state of Odisha. The time-ensemble simulation of the temperature is shown to be in close agreement with the station-scale observations.

1. Introduction

Recent extreme temperature during May 2015 over coastal Odisha in India caused severe health problems like sunstroke. Several studies indicate that during the last decade (1991–2000) the frequency and persistence of severe heat waves over Odisha (Pai et al., 2004, 2013) is on the rise with huge loss of lives (De and Sinha Ray, 2000). The death due to the 1998 heat wave over Odisha was about 650 (De and Mukhopadhyay, 1998). As there is a direct impact of heat wave on human health, observation and forecast of summer maximum temperature in regions like western central Odisha assumes significance.

Generally extreme temperature results in short-term increase in daily mortality (Braga et al., 2001; Curriero et al., 2002; Huynen et al., 2001; McGeehin and Mirabelli, 2001; Mercer, 2003) because of the heat wave conditions. Heat wave occurrence basically depends upon certain thresholds of maximum temperature over a region. The threshold value of maximum temperature varies from location to location i.e. 28 °C in Denmark, 32 °C in northwestern United States, 40 °C in Australia and 45 °C in India. These variations are mainly due to other atmospheric conditions (humidity) and geographic locations (Das and Smith, 2012).

Extreme temperature events have been of great concern recently, because of their associated public health risk (e.g. De Bono et al., 2004), plant growth and/or ecosystems (e.g. Ciais et al., 2005), the energy supply, and more (IPCC, 2014). The conditions and mechanisms of large-scale extreme temperature events have been extensively studied throughout the world, especially in Europe (e.g. Black et al., 2004; Fink et al., 2004; Schar et al., 2004; Dasari et al., 2014) and North America (e.g. Gershunov et al., 2009; Lau and Nath, 2012). However, in the Indian context very few studies have been carried out (Raghavan, 1966; Mohan and Bhati, 2011).

Also, some studies have illustrated that present-day heat waves over regions like Europe and North America coincide with a specific atmospheric circulation pattern that is intensified by the on-going increases in greenhouse gases, indicating more severe heat waves in those regions in the future (Meehl and Tebaldi, 2004). Another study (Sun et al., 2016) shows the rise in the regional temperature over the Loess Plateau (China) in recent decades, which indicates the regionally-averaged trends in extreme temperature are consistent with global warming.

Some projection studies using multiple climate models and CMIP5 data reveal that heat waves (extreme temperature events) over India are projected to be more intense, of longer durations and will occur at higher frequency (Murari et al., 2015). These projections also indicate many parts of India will experience heat stress conditions in the future. Over the Indian region, few studies have been carried out (Ratnam et al., 2016;

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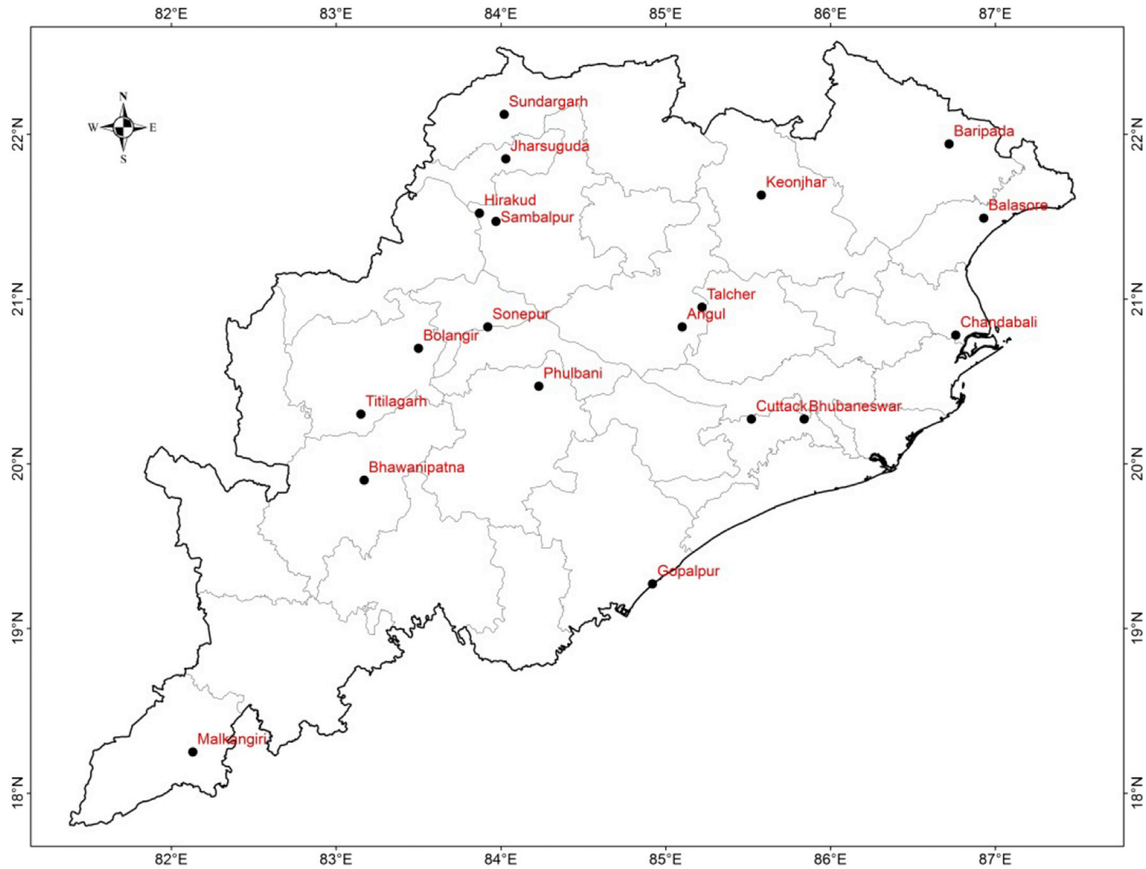

Fig. 1. Location map of the meteorological stations of Odisha state.

Pai et al., 2013).

A relatively large increase in the daily maximum temperature on the west coast is observed (Dash and Mamgain, 2011), as compared with other homogeneous regions over India. They have also emphasized the extreme temperature causing heat wave conditions during 19th May to 10th June 2003 at seven stations on the east coast of India. More importantly, four out of these seven stations received 1 °C more than the 100-yr maximum recorded value of the maximum temperatures. The occurrence of heat waves over India in the 1980–1998 decade are comparatively higher than the previous decade (1979–1988), as presented by another study (De and Mukhopadhyay, 1998). Kothawale et al., 2010 have studied the regional variation in extreme temperature over eastern India, where Odisha state is situated; the hot days are increasing 2.0 days/decade and the daily maximum temperature shows an increasing trend. In view of this, it is pertinent to study the mechanisms and the consequences of heat waves over India and sub-regions like Odisha.

Some earlier studies describe the contributions of climate change and urbanization to increases in surface air temperature, as investigated using observational data (e.g. Hulme et al., 1994; Chung et al., 2004; Li et al., 2004; Ren et al., 2008; Fujibe, 2009). Analysis of long-term temperature (daily maximum) trends can be very useful in understanding the heat wave phenomenon in a given geographical region (Li et al., 2015).

Due to the high risk of vulnerability of large population to heat waves in this region, greater efforts are needed to improve the forecast skill of Numerical Weather Predication (NWP) models and to use these forecasts in disaster management (De et al., 2005). With growing power of high resolution computer simulation using NWP models and the availability of high frequency data, it is now very much possible to predict the extreme temperature at very high resolution with sufficient lead time. Mesoscale models such as WRF are being used by some researchers for the simulation of local weather conditions (heat waves) including extreme temperature over different regions especially over Europe and North America (Bohnenstengel et al., 2011; Salamanca et al., 2012; Giannaros et al., 2013; Giovannini et al., 2013). However, that kind of study is lacking over the Indian Monsoon region. A recent work by Wang et al., 2016 presents the generalized extreme value (GEV) model using the WRF-downscaled extreme maximum temperature through comparison with North American regional reanalysis (NARR) data.

1.1. Study region

The daily maximum temperature analysis for the recent heat wave (19–31 May 2015) is carried out using the India Meteorological Department (IMD) observations at station scales. The locations of the 19 stations considered are shown in Fig. 1. Since the heat wave predominantly prevailed in the western and central Odisha, the coastal region was not considered in the study.

1.2. Data

The daily-average temperature and maximum temperature data over the 19 stations for the period 1969–2015 were obtained from the IMD observed station level (high resolution) data. The gridded (1° × 1°) (Srivastava et al., 2008) as well as the station recorded temperature (high resolution) data are used for the observational analysis. NCEP reanalysis data are used (Kalnay et al., 1996) for wind and solar radiation analysis.

2. Observed long term temperature data analysis

The station-scale daily maximum temperature during the month of May for the period 1969–2015 is analyzed. The trend in the daily maximum temperature obtained over any part of Odisha is computed on a decadal basis, and the trend values are shown in Fig. 2. Trend analysis