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CLIMATE & ENVIRONMENTAL MODELLING

The research activities of Climate and Environmental Modeling Programme (CEMP) have been aimed at providing solutions to weather and climate-related problems to minimize their adverse impact on the environment and public. Major research activities of CEMP are: Monsoon, Climate and Weather Informatics, Smart Agriculture, Modelling the impact of climate and weather on epidemiological diseases (Malaria and Chikungunya), and hydro-meteorological disasters. Group activities are also aligned with missions of Government of India such as Samarth Bharat and Swasthya Bharat. The team carries out its research and analysis through open-source codes, state-of-the-art models (LAMs, GCMs, and NWPs), in-house algorithms and visualization tools, field and satellite data sets.

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2.1 Evaluation of WRF simulated multi-level soil moisture, 2m air temperature and relative humidity with in-situ observations over India

The skill of Weather Research and Forecasting (WRF) model in simulating multi-level soil moisture, 2m-air temperature (T_{2m}) and 2m-relative humidity (RH_{2m}) is evaluated over five different locations in India. The WRF model simulations were carried out for 30 cases during different seasons with two different land surface schemes (Noah and RUC). The simulations were compared with in-situ observations which were deployed to routinely measure at 30-minute time interval over the selected five locations. Statistical evaluation showed that though the model could simulate soil moisture reasonably well (majority of the cases fall in <25% relative error (RE) category) at different depths over Delhi and Gulbarga, the model errors were high (most of the cases fall in >50% RE category) over Almora, Hyderabad and Cochin (Figure 2.1). In case of T_{2m}, model errors were high (RE > 15%) over the hilly terrain like Almora, while errors were relatively less (RE < 10%) for plane areas like Hyderabad, Gulbarga, Delhi, and Cochin. In general, the diurnal variation showed that the model underestimated (overestimated) afternoon temperatures during non-rainy (rainy) days. The RH_{2m} were also well simulated by the model over the locations Hyderabad, Gulbarga, and Cochin, though it underestimated RH_{2m} during morning hours over the locations of Almora and Delhi.

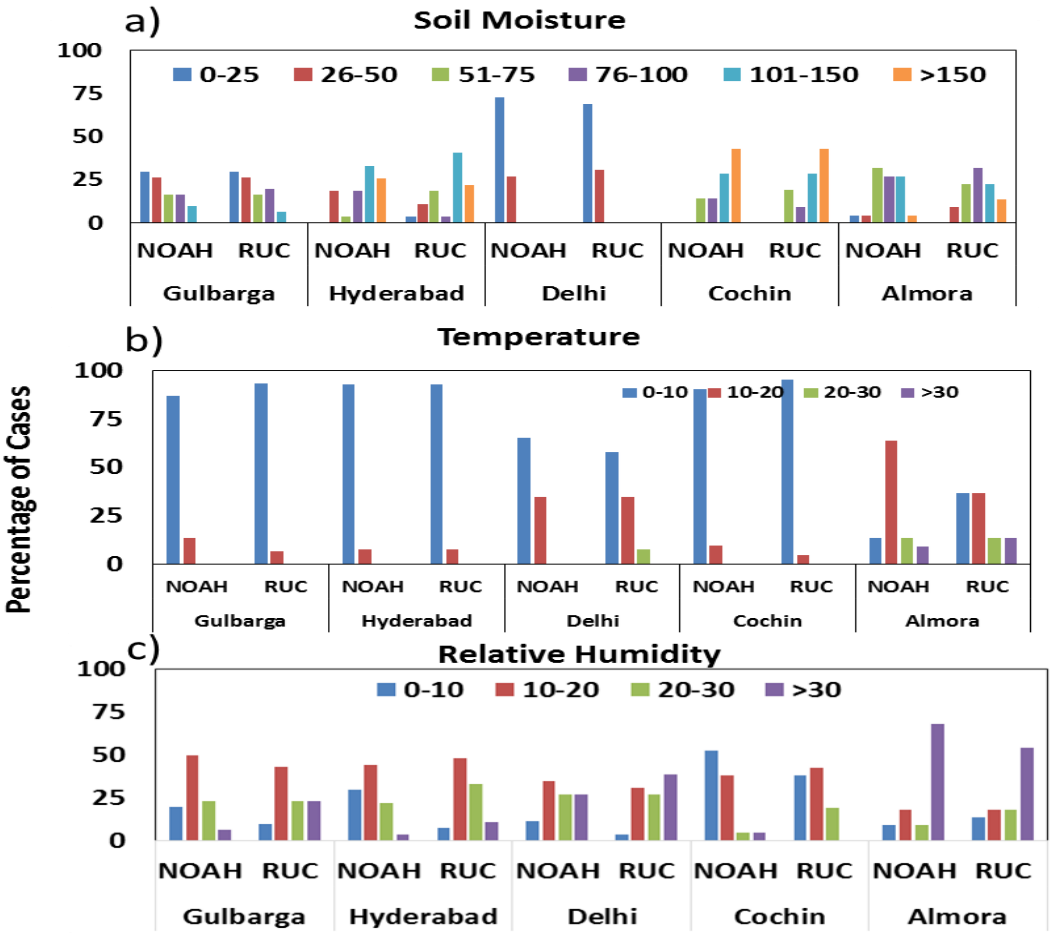

Figure 2.1 Percentage of cases in different error bins for the parameter surface soil (a) moisture, (b) temperature, and (c) relative humidity

2.2 Sensitivity of WRF model simulated urban thermodynamic features to microphysical parameterizations

In this study, the sensitivity of the WRF model simulated thermodynamic features associated with extreme rainfall events to mycrophysical parameterizations in the model are examined over the Bengaluru city. The thermodynamic indices like CAPE (Convective Available Potential Energy) and K-Index are calculated from the model at 0600 UTC (11:30) IST and 1200 UTC (17:30 IST) for each case over Bengaluru city from domain 4 (1 km resolution) and are verified against observations from the FNL data. For the evaluation of forecasted thermodynamic indices, a number of standard evaluation parameters such as bias and relative error of forecasts with respect to FNL observations were computed. Analyses showed that while the model could reproduce the observed distribution of stability indices and thereby the rainfall for non-localized EREs, it differed from observation for many localized ERE cases. We have also examined the sensitivity of model results to different microphysical parameterization schemes in WRF model and results showed that in the case of CAPE, among the schemes tested, the MP16 and MP7 schemes showed lower bias and relative error. For CAPE, all the schemes, particularly MP10 and MP7, showed lower percentage errors in case of local EREs (06 Hr) (Figure 2.2), while the MP7 and MP10 schemes produced better results (12Hr) for local EREs.

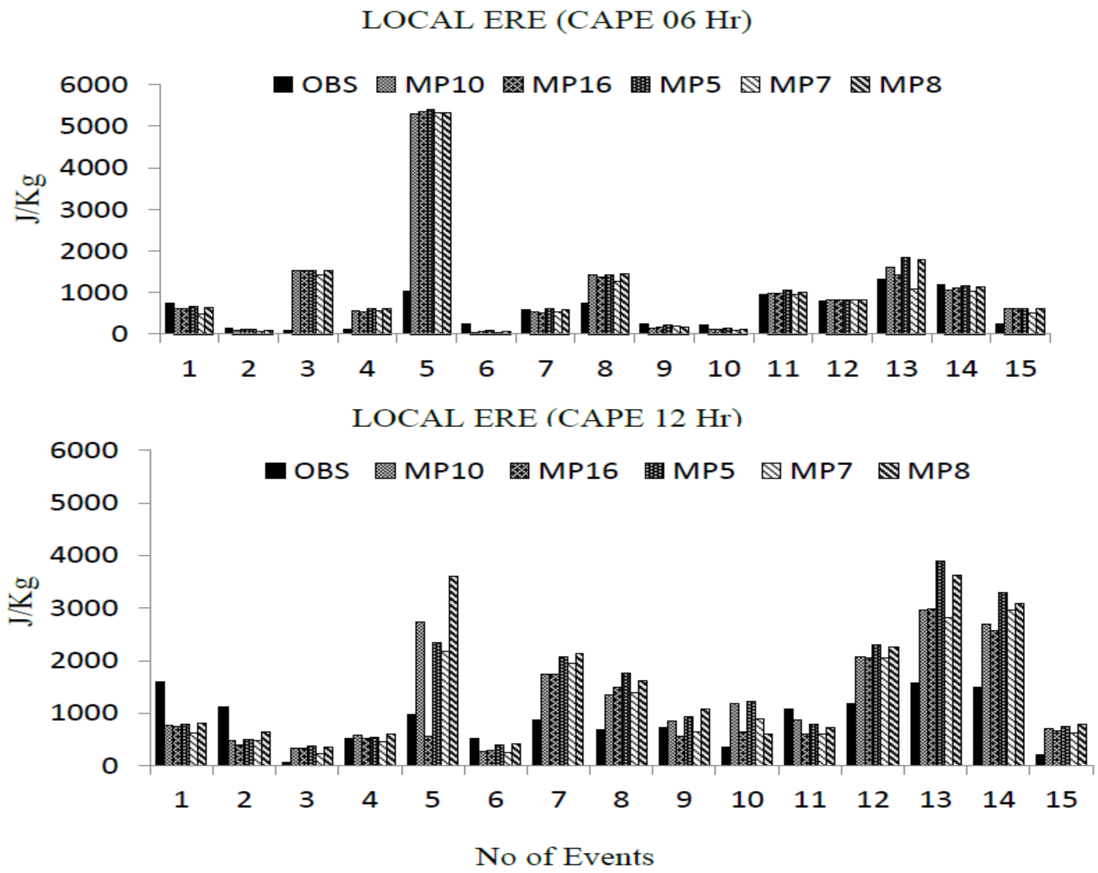

Figure 2.2: Observed and model simulated Convective Availability of Potential Energy (CAPE in J/Kg) for 06 hour (top) and 12 hour (bottom) averaged over Bengaluru city with different micro-physics scheme.

2.3 Temperature dependent model to predict Chikungunya epidemic in India.

The risk of Chikungunya transmission in recent years of climate is gradually increasing in India. This work has been carried out in collaboration with CSIR-IICT, Hyderabad to develop a mathematical model to predict the Chikungunya epidemic in India. During 2016, Delhi experienced an epidemic caused by Chikungunya virus with more than 12,000 cases. Similarly, other parts of India also reported a large number of Chikungunya cases, the highest incidence rate was observed during 2016 in comparison with the last 10 years of epidemiological data (Figure 2.3). The model developed in the present study using empirical estimates the effects of the temperature range for optimal transmission of Chikungunya by predicting pathogen traits and entomological factors. This temperature-driven model provides regions risk for Chikungunya transmission and regions predicted for likely occurrence of disease outbreaks in India. The model described here helps in public health preparedness and vector management operations in predicted risk zones of Chikungunya well in advance.

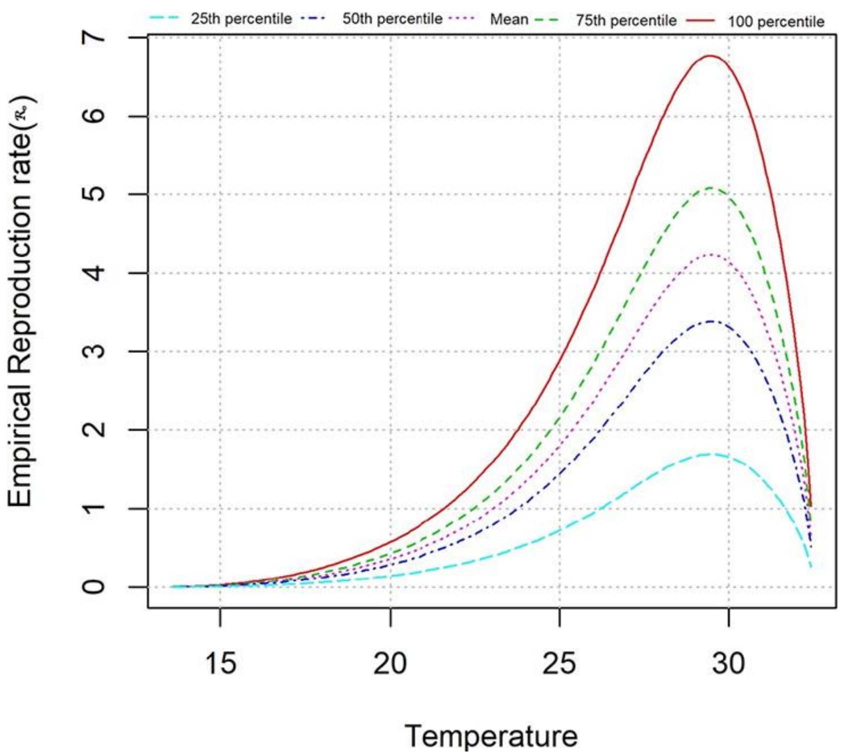

Figure 2.3 Variation of Empirical reproduction rate with temperature for Chikungunya

2.4 Land-use changes in megacities and their impact on the dynamics of heavy rainfall

This is one of the case studies of the impact of land-use changes and urbanization on the processes and mechanisms of a heavy rainfall event that occurred over Bengaluru. The analysis is based on high resolution (2 km), time-ensemble simulation of one of the heaviest rainfall events that occurred on 27th May 2017. The simulations are carried out using Weather Research and Forecasting (WRF4) model that is coupled with a single-layer urban canopy model (UCM). The high resolution (30s) land use data derived from Indian Space Research Organization (ISRO) with the reference date of 2017 is shown to be realistic in representing the current land-use scenario with a three-fold increase in urbanization when compared to USGS land-use data which has the reference date of 1992 as shown in Figure 2.4. Simulation and analysis of large-scale circulation pattern revealed that the event was triggered and sustained by the low-pressure system and cyclonic circulation over the Bay of Bengal. Simulated rainfall was found to be remarkably sensitive to land-use changes as shown by control (USGS) and test (ISRO) simulations. The simulated rainfall intensity and spatial distribution are close to observation in test simulations with relatively less error in 24-hr averaged rainfall (9%) when compared to control simulations (32%), indicating the importance of realistic representation of land-use in the model and its impact on rainfall processes. The surface energy fluxes and thermodynamic indices as shown by test simulations are consistent with the current land-use scenario with increased urbanization and found to be favorable for heavy rainfall events. This study has clearly demonstrated and quantified the impact of urbanization on land surface processes (latent heat flux, sensible heat flux, surface temperature, diurnal temperature), on circulation (horizontal & vertical draft), and rainfall. Urbanization is found to significantly contribute to the intensification of rainfall, urban heat island effect, and increase in diurnal temperature change. It is also shown that a realistic representation of the current land-use pattern is crucial in improving model skill and forecast reliability of heavy rainfall events over megacities.

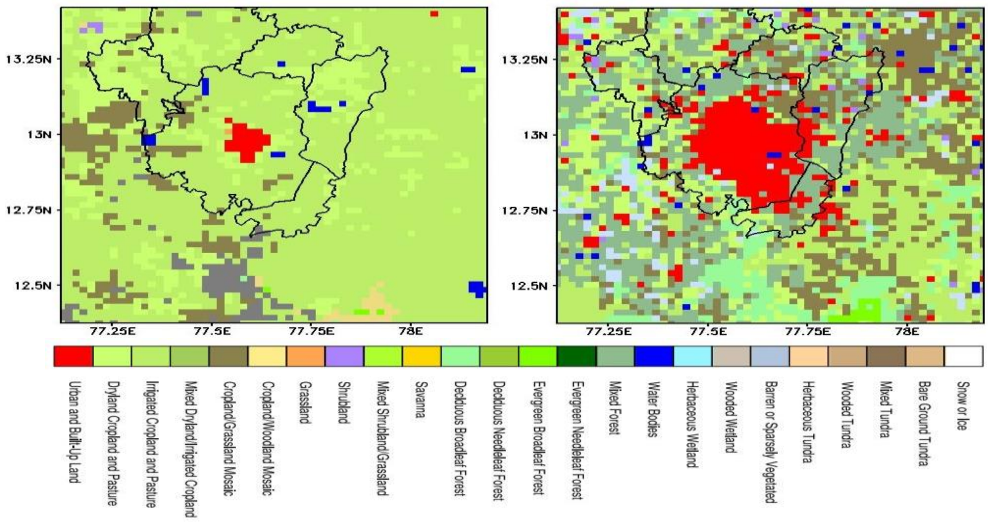

Figure 2.4 High resolution land-use pattern over Bengaluru; USGS (left) and ISRO (right) used in WRF-UCM for rainfall simulation. A three-fold increase in urbanization over the central region of Bengaluru between 1992 and 2017 is evident in the right panel

2.5 High resolution long-range dynamical forecasting of Indian monsoon 2018

The date of onset of monsoon (DOM) with the first sustained and significant rainfall over Kerala signifies the arrival of the main agricultural season in India. Thus, accurate and advance prediction of DOM can help agricultural planning like preparation of land and sowing schedule. However, advance dynamical prediction had been traditionally considered unfeasible as DOM involves highly chaotic rainfall variability. For 2018, the CSIR-4PI forecast of the date of Onset of Monsoon matched exactly with the date announcement by IMD i.e. 29th May 2018.

Following its standard procedure, CSIR-4PI issued its experimental forecasts of monsoon 2018 in early April, 2018. There is very good agreement between distribution of monthly and seasonal rainfall from forecast and observation; there are only a few regions of errors. Out of the 24 cases (six sectors, three months and one season for each), the categories (Excess/Normal/Deficit) forecasts match observations for almost 15 cases as presented in Table 2.1.

Table 2.1: Comparison of the forecast and observation of 2018 monsoon rainfall both at monthly and seasonal scale for the different regions over India

Region	Extent	June		July		August		Jun-Aug	
		Model	Obs	Model	Obs	Model	Obs	Model	Obs
All India	Continental land	N	N	N	N	D	N	N	N
North India	(72-84°E, 24-30°N)	N	N	N	N	D	D	D	N
South India	(75-78°E, 8-12°N)	N	N	D	N	N	N	N	N
Central India	(72-84°E, 20-28°N)	D	N	N	N	D	D	N	N
North-East India	(92-96°E, 24-30°N)	D	D	E	D	D	D	D	D
North-West India	(68-75°E, 24-30°N)	D	N	E	N	N	D	N	D