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RESEARCH ARTICLE

PERFORMANCE OF NUMERICAL WEATHER PREDICTION MODELS (GFS, NCUM, WRF) OVER RIVER BASINS IN GODAVARI AND KRISHNA FOR THE MONSOON SEASON 2020

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ABSTRACT

Rainfall forecast for the river basins is a very important and difficult task also for assessing the flood and inundation in the flood plains. IMD through its Flood Meteorological Offices (FMO) is issuing the Quantitative Precipitation Forecast (QPF) of the various river basins and their sub-catchments during the monsoon season. In the present study we have seen the performance of quantitative Rainfall forecast of various Numerical weather prediction models such as WRF (Mesoscale model), GFS(Global Forecasting System Model), and NCUM(NCMRWF Unified Global Model) over the Godavari and Krishna basin (K7, K10, K11, K12) River basins and its sub-catchments during the Flood Season 2020. It is observed that the model's performance over the river basins is 62% with NCUM 58% with GFS and 55% with the WRF model.

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INTRODUCTION

Changing precipitation patterns and their impact on surface water resources are an important climatic problem, society is facing today. As Associated with global warming, there are strong indications that rainfall changes are already taking place on both the global and regional scale. The accurate prediction of basin/sub-basin rainfall is very difficult due to its vast variability in space and time. In the present century, there has been an enormous development in numerical weather prediction models, both on a global scale as well as a regional scale. The inherent limitation of these NWP models is that they neglect small scale effects and they approximate complicated physical processes and interactions. Despite these limitations, rainfall forecast of NWP model are utilized in various fields such as flood forecasting, water management, planning etc. skills of the NWP models to forecast precipitation has not reached an acceptable level, especially for very short lead times(5 days) lead times and for fine-scale weather systems such as local-regional convective systems (Habets *et al*, 2004). Quantitative Precipitation Forecasting (QPF) is one of the most challenging areas in modern numerical weather prediction (Golding, 2000; Fritsch and Carbone, 2004; Cuo *et al*., 2011), to better prepare for these hazards and reduce their impacts, QPF's and their verifications, especially over heavy-rainfall thresholds from large events, are thus very important. Of course, identifying where the model can make significant improvements in QPF's and also, what approaches are effective to achieve them are crucial (Clark *et al*., 2011). Various Numerical model studies over the Indian subcontinent show the predicted QPF & heavy rainfall with spatial and temporal variations with the various models (Ashwini Ranade *et al*., 2014, V. R. Durai *et al*.,2014, M Dan Singh, M.*et al*. 2014, Sumant Kr. Diwakar *et al*., 2014). India meteorological department is issuing Quantitative Precipitation Forecast (QPF) for the river basins during the monsoon season through its flood meteorological offices (12) situated all over India (IMD 1994, Manual of Hydrometeorology 2017). In the present study we attempted to see the performance of Quantitative Precipitation Forecast of various Numerical weather prediction models such as WRF (mesoscale model), GFS (Global Forecasting System Model), and NCUM (NCMRWF Unified Global Model) over the Godavari and Krishna basins (K7, K10, K11, K12) river basins and its sub-catchments during the Flood Season 2020. The GFS, NCUM, and WRF model for the entire season have been collected from the Flood Met office in Hyderabad for the season 2020.

Godavari River System: The Godavari Basin lies in the Deccan Plateau and is situated between Latitudes 16^0 16' N and

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$22^0$43' N and Longitudes $73^0$26' E and $83^0$07' E and is roughly triangular and the main river itself runs practically along the base of the triangle. The River Godavari, the largest of the Peninsular Rivers, and the third-largest in India, drains about 10% of India's total geographical area. The catchment area of the river is 3,12,812 sq. km and is spread in the states of Maharashtra (48.6%), Telangana (18.5%), Andhra Pradesh(4.9%), Madhya Pradesh (10%), Chhattisgarh (10.9%), Odisha (5.7%) and Karnataka (1.4%). The Godavari basin receives its maximum rainfall during the southwest monsoon. The Western boundary of the Godavari River is about 129 km in length in the high rainfall zone in the Western Ghats. The annual rainfall is around 3,000 mm along this boundary and reduces rapidly to 1000 mm up to a line running approximately from Chitradurga through Sangli and Pune and east of this line it further reduces to less than 600 mm up to a line connecting Rojapally tharda, Raichur, Vijayapura and Ahmednagar.

Krishna river system: The River Krishna is the second-largest East flowing interstate river in peninsular India, draining into the Bay of Bengal- The river rises in the Mahadev ranges of the Western Ghats near Mahabaleshwar, about 64 Km from the Arabian Sea at an altitude of 1337 m above mean sea level and flows through the States of Maharashtra, Karnataka and Andhra Pradesh. The basin is situated between East longitudes of $73^0$21'00' to $81^0$09'00' and North latitudes of $13^0$07'00" to $19^0$25'00' in the Deccan plateau. The Krishna basin extends over an area of 259439 km^2 which is nearly 8% of the total geographical area of the country.

Study Area

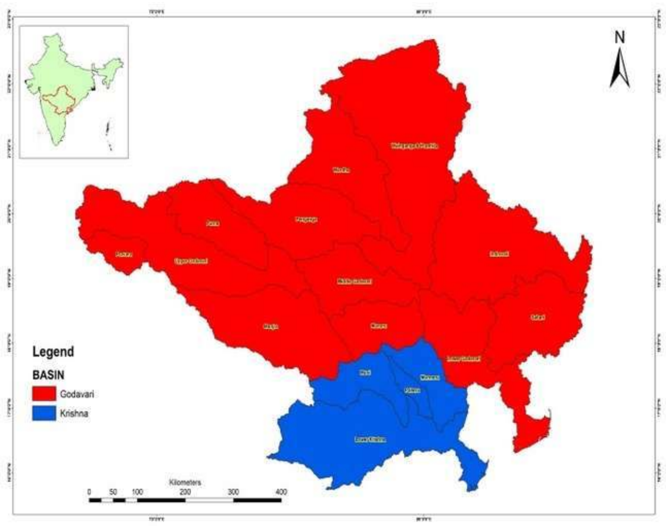

Fig.(1) Study Area Godavari river basin and Krishan river Basin with Sub Basin

METHODOLOGY

Data Used: FMO Hyderabad is started in 1978 to provide of Quantitative Precipitation Forecast (QPF) and Flood Analyzing for the Godavari (08) and Krishna (04) (Upper Krishna, Lower Krishna, Bhīma & Tungabhadra) Sub –basins. Following the formation of FMO Bangalore and FMO Chennai, FMO Hyderabad is issuing the fore forecast for Godavari(12), Krishna(4) Basins in 2016 onwards. These two River Basins mainly lie in the states of Andhra Pradesh, Telangana and Maharashtra. FMO Hyderabad Issues the Quantitative Precipitation Forecast sub-basin wise. Operational QPF is issued sub-basin wise as a QPF forecast by FMO Hyderabad, daily during the flood season from June to October in the following categories.

QPF categories (mms)	0	0.1-10	11-25	26-50	51-100	>100

The sub-basin wise QPF is verified with the observed sub-basin wise Areal Average Rainfall Precipitation (AAP) during the southwest monsoon of 2020. The sub-basin observed aerial rainfall has been computed by averaging the observed rainfall of stations in the area. The rainfall data 649 stations is used to compute sub-basin wise average observed rainfall. The overall QPF issued for Day-1 by FMO Hyderabad during the flood season 2020 is 1952, for Day -2 is 1952 and for Day-3 is 1952. Operationally, the IMD is Preparing the QPF using the three models' output, one is WRF (ARW) 9 x 9 Km, GFS (Globa Forecasting System) 12x1km and Ncum(NCMRWF Unified Model) 12x12km. The rainfall forecast is made available to the Hydromet division by the NWP division at New Delhi and rainfall forecast estimation sub-basin wise for river basins is done by the Hydromet division at New Delhi, using the available data. Then this estimation forecast is uploaded to the IMD website (www.imd.gov.in) operationally during flood season 2014 as an additional tool for issuing QPF for their sub-basins.

Methodology For Verification: This table looks at four possible outcomes:

- An event is a forecast and the event occurs (a)
- An event is a forecast and the event does not occur (b)
- An event is not forecast and the event occurs (c)
- An event is not forecast and the event does not occur (d)

Several measures can be derived from this table of data.

Percentage of correct (PC): The percentage of correct is the % of correct forecasts. Specifically, PC = (a+d)/n, PC ranges from zero (0) for no correct forecasts to one (1) when all forecasts are correct.

False Alarm Ratio (FAR): The False Alarm Ratio is the fraction of "yes" forecasts that were wrong, i.e., were false alarms. It is calculated as follows: FAR = b/(a+b)It ranges from zero (0) at the good end to one (1) at the poor end.

Threat Score (TS): The Threat Score (TS) or Critical Success Index (CSI) combines Hit Rate and False Alarm Ratio into one score for low-frequency events. It is calculated as follows: TS = CSI = a/(a+b+c)This score ranges from zero (0) at the poor end to one (1) at the good end. It does not consider "not forecast/not occurred" (d) events.

Heideki Skill Score: HSS = 2(AD-BC) / B*B+C*C+2AD+(B+C)(A+D), The range of the HSS is -∞ to 1, Negative values indicate that the chance forecast is better, 0 means no skill, and a perfect forecast obtains an HSS of 1.The Final skill score is the average of this verification over FMO Hyderabad. In addition to the percentage of correct forecasts within the same category. During flood season 2020, the skill scores for operational sub-basin wise QPSs are computed for all FMO Hyderabad for day-1, day-2 and day-3

RESULTS AND DISCUSSION

The Verification of different skill scores for the Model Rainfall forecast is done Categorically for different catchments under FMO Hyderabad Jurisdiction for the season 2020.

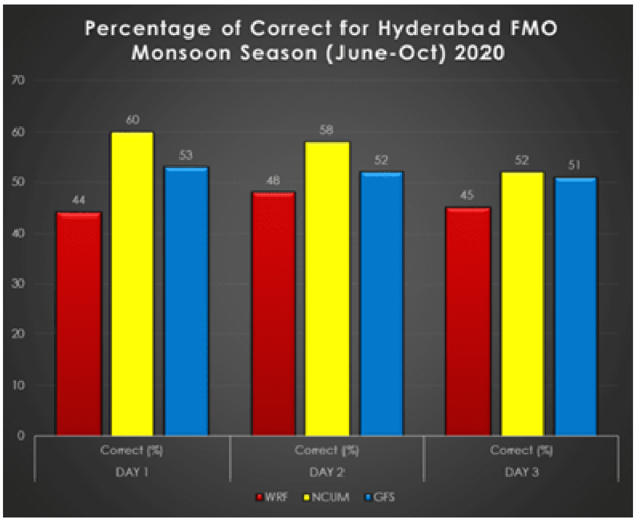

Fig. 2. Percentage of Correct for Hyderabad FMO Monsoon Season (June-Oct) 2020

Figure 2 shows the percentage of correct NWP models for the monsoon season of 2020. The Percentage of correctof the rainfall forecast with the GFS model is 53%, 52% &51% forday1, day2 & day3 respectively, with the NCUM model is 60%, 58%&52% for day1, day2 & day3 with WRF model 44%, 48%& 45% day1 day2 and Day3 Respectively.NCUM is showing the highest percentage of the correct of rainfall Forecast as compared to the GFS and WRF models of day1, day2 and dya3 respectively. Figure 3(a,b,c) shows the Percentage of correct rainfall forecast for the Sub catchment wise of GFS, NCUM and WRF Models. The upper Godavari and Lower Krishna are showing the highest PC of rainfall forecast of more than 68%, 65% and 65% respectively for day1, day2 and day3. The paleru and maneru are showing the lowest performance of the PC of rainfallforecast of 40%.Table 1 shows the Skill scores of CSI (critical Success Index, False alarm Rate, True Skill Score (TSS), and HSS (Heidke Skill Score) with different models of the entire sub-basins. The GFS model shows the CSI value decreases the rainfall forecast for day1, day2and day3 forecast moves towards higher categories. CSI value for day1 is 0.50for 0.1-10 and 0.20 for 50-100. The NCUM model shows the CSI value decreases the rainfall forecast for day1, day2and day3 forecast moves towards higher categories. CSI value is day1 0.50 for 0.1-10 and 0.13for 50-100 respectively. The WRF model shows the CSI value decreases the rainfall forecast for day1, day2and day3 forecast moves towards higher categories. CSI value is0.49 for 0.1-10 and 0.02 50-100 for day1 respectively. The average false alarm rate is maximum is 0.75 with the category 26-50 of all the models and also increases with the day1, day2, and day3 respectively. The False alarm rate is increasing with the category means there is an overestimation of the Models. In The GFS model, TSS and HSS skill scores show non-negative, so the forecast is nil. The HSS score is one means the forecast is correct 0.5 means the forecast of the PC is increasing. The NCUM model TSS and HSS skill scores show non-negative, so the forecast is nil. The HSS score is one means the forecast is correct 0.5 means the forecast of the PC is increasing. The WRF model TSS and HSS skill scores showed negative. The HSS score is one means the forecast is correct -0.2 means the forecast the PC is increasing. On an average of 4-5, low-pressure systems and depressions are forming over the bay Bengal in monsoon season. In the year 2020, there are 11 systems have formed in the Bay of Bengal. Understanding the spatial and temporal distribution of the synoptic systems in the river basin in the models is complex and the Performance of the models in the forecasting of rainfall over small sub-basin. Also, the under prediction of high-intensity rainfall by the models may be due to the lesser spatial extent of such events. To understand the spatial distribution of the models. We have taken the two Heavy rainfall events in the season 2020.

- *Riverine Flood (event:12-08-2020 -22-08-2020)*
- *Urban Flood(event-2:13-10-2020 to 15-10-2020)*

Synoptic situation of event 1: Three spells continuously occurred over the Northwest adjoining West-central Bay of Bengal off Odisha north Andhra Pradesh coasts,it leads the Flood Situation over the Indaravthi Basin.

First Spell (13082020 to 18 082020): Under the influence of the cyclonic circulation over Northwest adjoining West-central Bay of Bengal off Odisha north Andhra Pradesh coasts, a low-pressure area has formed over Northwest Bay of Bengal off north Odisha & West Bengal coasts on 13th August 2020 and its associated cyclonic circulation extends up to 7.6 km above mean sea level tilting south-westwards with height. On 14th August, a Low-pressure system now lies over the north Coastal Odisha & adjoining Gangetic West Bengal. On 15th August, this intensified to a Well-marked Low-pressure System over north coastal Odisha and adjoining areas of the northwest Bay of Bengal and Gangetic West Bengal persists. Associated cyclonic circulation now extends up to 9.5 km above mean sea level tilting south-westwards with height. It is very likely to move west north-westwards. On 16th August, the system moves towards Northeast Madhya Pradesh & adjoining areas of north Chhattisgarh and Southeast Uttar Pradesh and weakens into a cyclonic Circulation system on 17th August.

Second Spell (18.08.2020 to 22.08.2020): A cyclonic circulation between 5.8 km & 7.6 km above means sea level lies over the Northeast Bay of Bengal neighbourhood. Under its influence, a fresh Low-pressure Area is likely to form over the north Bay of Bengal around by tomorrow, 19th August And It becomes well marked Low-Pressure area over north Coastal Odisha & neighbourhood now lies over the north interior Odisha & adjoining Jharkhand on 20th August 2020. It is very likely to move nearly westwards across West Madhya Pradesh and The Well-Marked Low-Pressure Area over East Madhya Pradesh & adjoining north Chhattisgarh lies over central parts of East Madhya Pradesh & neighbourhood from 21st to 22nd August 2020. Along with the Low-pressure system, there is an East-West shear zone between 5.8 km & 7.6 km above mean sea level roughly along Lat. 20 °N-220N across Peninsular India persists from 19th August to 22nd August 2020.

Third Spell (23.08.2020 to 25.08.2020): In continuation of August 22nd, 2020 low pressure over Northwest Madhya Pradesh & neighbourhood is becoming a Well-Marked Low-

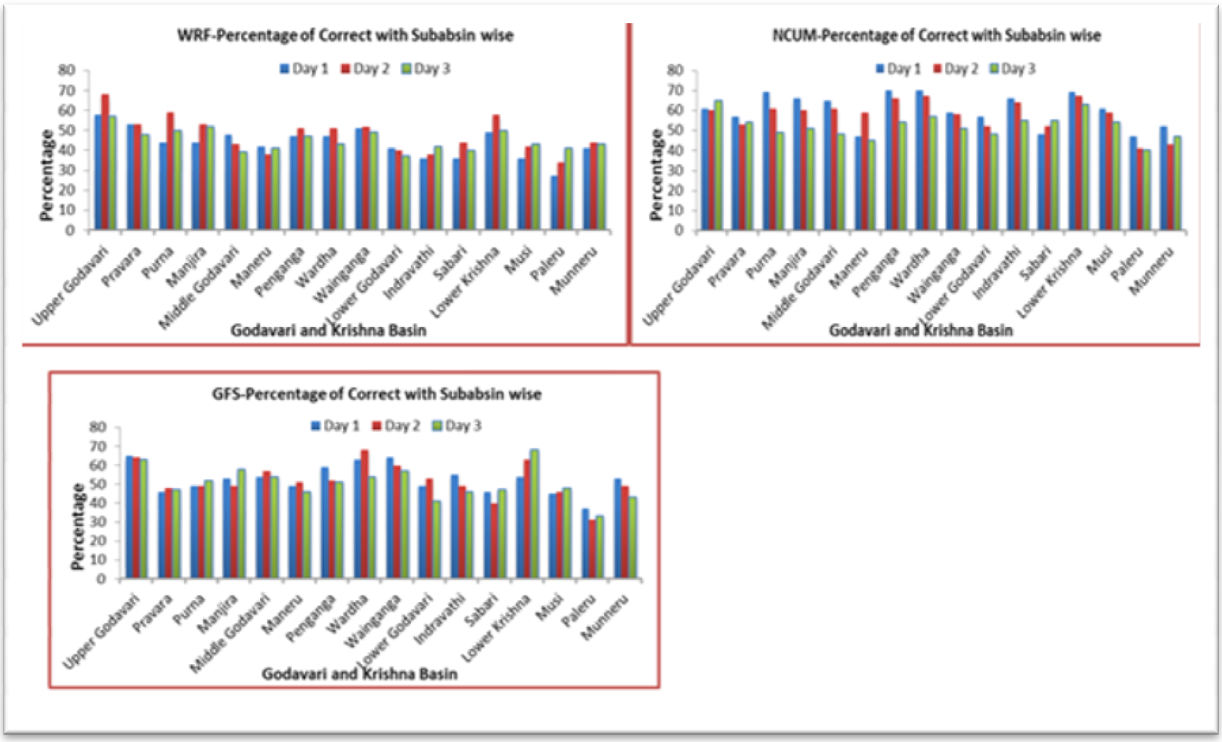

Figure 3. (a,b,c) shows the Percentage of correct rainfall forecast for the Sub catchment wise of WRF, NCUM and GFS Models

Table 1. Skill Scores of WRF, GFS and NCUM with Two River Basins and all Sub Basins

				DAY 1						DAY2						Day 3					
Basin	Sub basin	Model	Skill Score	0	0.1-10	11-25	26-50	51-100	>100	0	0.1-10	11-25	26-50	51-100	>100	0	0.1-10	11-25	26-50	51-100	>100
All	All	GFS	CSI	0.08	0.5	0.26	0.1	0.2	0	0.12	0.5	0.24	0.08	0.13	0	0.07	0.49	0.22	0.11	0.02	0
All	All	GFS	FAR	0.71	0.26	0.68	0.79	0.68	1	0.71	0.29	0.68	0.83	0.73	1	0.88	0.31	0.68	0.78	0.93	1
All	All	GFS	TSS	0.08	0.26	0.23	0.13	0.33	0	0.14	0.23	0.17	0.09	0.19		0.07	0.18	0.14	0.13	0.02	
All	All	GFS	HSS	0.11	0.25	0.18	0.14	0.32	0	0.17	0.28	0.15	0.1	0.22	0	0.07	0.17	0.13	0.14	0.03	0
All	All	NCUM	CSI	0.16	0.61	0.23	0.15	0.05	0	0.22	0.58	0.19	0.1	0.02		0.17	0.53	0.15	0.08	0.04	
All	All	NCUM	FAR	0.45	0.28	0.62	0.72	0.88	1	0.51	0.3	0.67	0.8	0.93		0.76	0.32	0.7	0.82	0.92	
All	All	NCUM	TSS	0.18	0.32	0.2	0.2	0.06	0	0.27	0.26	0.14	0.12	0.02		0.27	0.18	0.08	0.09	0.05	
All	All	NCUM	HSS	0.25	0.33	0.2	0.21	0.07	0	0.33	0.26	0.14	0.12	0.03		0.22	0.18	0.09	0.1	0.06	
All	All	WRF	CSI	0.02	0.39	0.22	0.1	0.03	0	0.14	0.46	0.17	0.02	0		0.11	0.45	0.14	0.02	0	
All	All	WRF	FAR	0.95	0.32	0.74	0.7	0.8	1	0.79	0.36	0.73	0.92	1		0.86	0.36	0.74	0.87	1	
All	All	WRF	TSS	-0.02	0.1	0.15	0.11	0.03		0.2	0.05	0.07	0	0		0.22	0.06	0.03	0.01	0	
All	All	WRF	HSS	-0.03	0.09	0.1	0.14	0.05	0	0.17	0.05	0.06	0.01	-0.01		0.11	0.06	0.04	0.02	0	

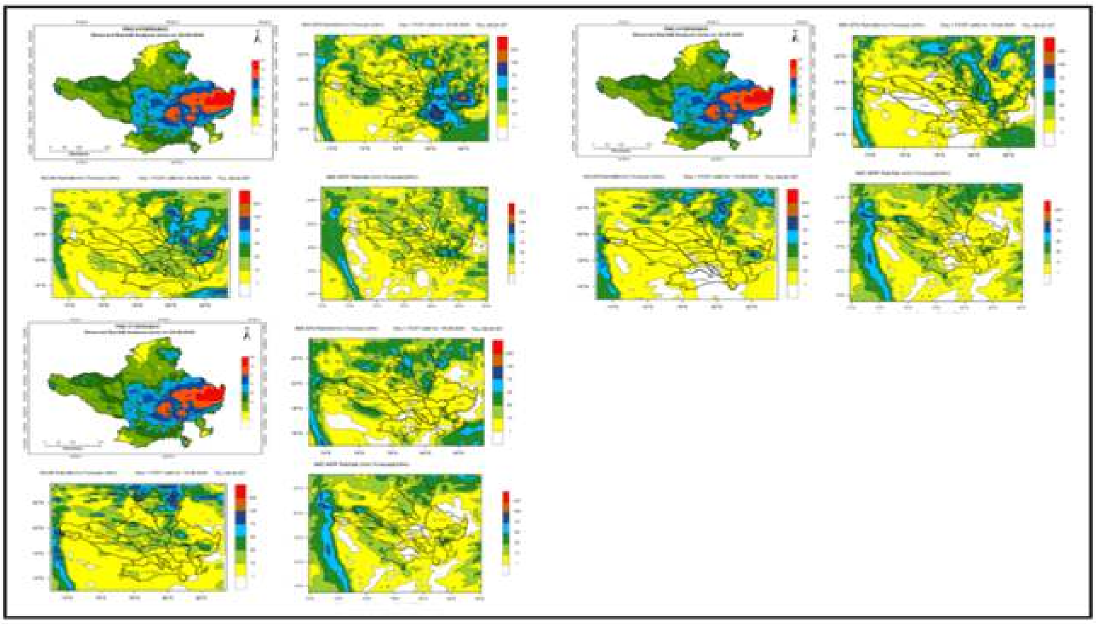

Fig. 4. Shows the comparison of the model's Event 1. From 20-Aug-2020 to 21-Aug-2020 with GFS, WRF and NCUM Models (DAY 1)

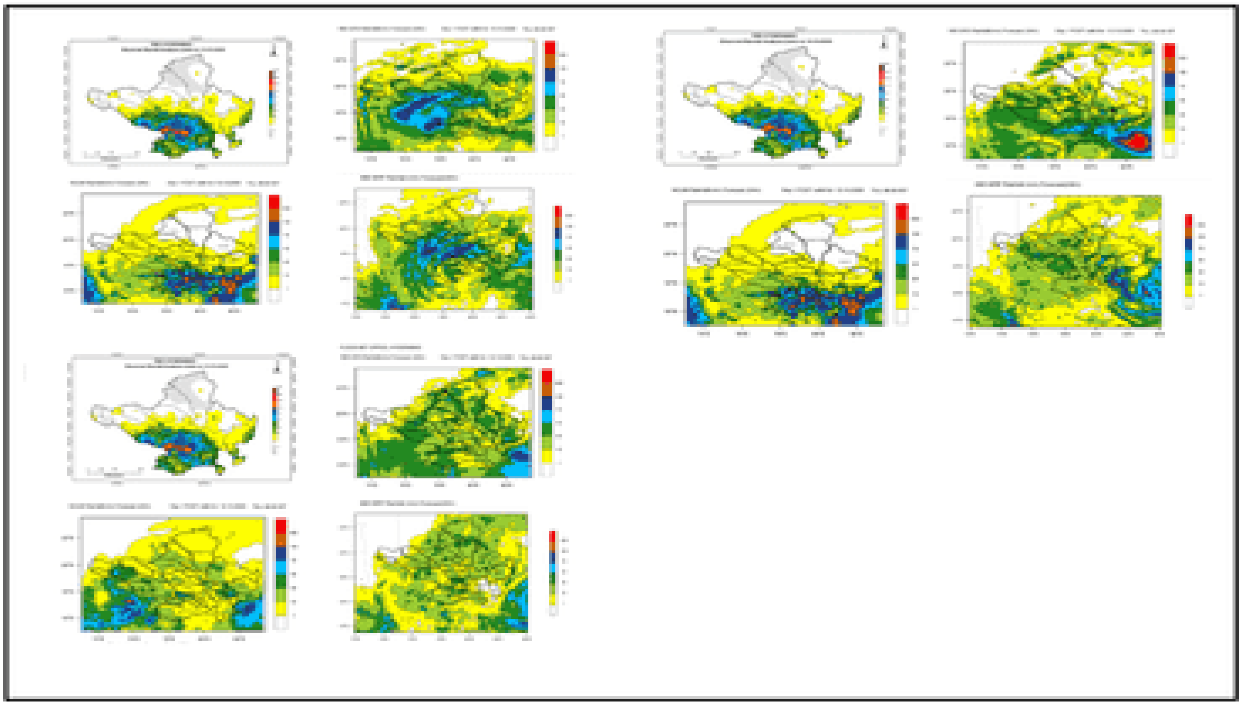

Fig 5. Shows the rainfall Comparison between GFS, WRF and NCUM Models (DAY 1) with the observations

Pressure Area on 23rd August over central parts of East Rajasthan & neighbourhood with the associated cyclonic circulation extending up to 7.6 km above mean sea level tilting southwestwards with height. It is very likely to move nearly westwards and weakens into low-pressure on the same day. Fig 4 shows the Comparison of the models' Event 1. From 20-Aug-2020 to 21-Aug-2020 with GFS, WRF and NCUM Models, were used from 20 Aug 2020 to 21 Aug 2020 (DAY 1). Three day forecast. The observed rainfall over 20th august 2020 is showing the maximum extremely heavy rainfall in the Indrāvati and Sabari sub-basins. In the day1 forecast the GFS and NCUM models are showing very heavy rainfall in Sabari and indaravthi basins,The WRF model is under predicting. Comparison of Event 1.

From GFS, WRF and NCUM Models were used from 20 Aug 2020 to 21 Aug 2020 (DAY 2). Three day forecast. It is also showing the system has crossed near the south Orissa coast it has given heavy to very heavy rainfall in the Indrāvati, Sabari and maneru sub-basins but on the Day 1, the forecast GFS model is showing the extremely heavy rainfall in the manjira and maneru sub-basin while the NCUM is showing the Waingangā and Indrāvati basins. There will be a difference in the spatial distribution of rainfall in both the models, as the WRF could not capture the heavy rainfall event. The synoptic situation of event 2(13-10-2020 to 14-10-2020): Low pressure has been formed over the east-central Bay of Bengal on October 9th and moved towards the central Bay of Bengal on 10th October and moved west-northwestwards and the system crossed north Andhra Pradesh coast close to Kakinada(near Lat. 17.0°N and long. 82.4°E) between 0630 & 0730 hours IST of today, the 13th October 2020, as a Deep Depression with maximum sustained wind speed of 55-65kmph gusting to 75kmph and moved towards the Telangana Region as depression and sustained as 12hours as depression in Telangana region. The Depression over Telangana moved farther west northwestwards with a speed of 32kmph during the past 06 hours and lay centred at 0830 hours IST on 14th October 2020, over North Interior Karnataka & adjoining areas of Maharashtra and Telangana, near latitude 17.7°N and longitude 77.5°E, about 80 km northwest of Gulbarga (North Interior Karnataka) and about 160 km east of Sholapur (Madhya Maharashtra). Fig 5 shows the rainfall Comparison between GFS, WRF and NCUM Models (DAY 1) with the observations. Compared to the observations of the three models NCUMmodel captured well the intensity of the rainfall. The model shows the maximum rainfall over the western part of Telangana but actually, the observed rainfall is in central and southern Telangana.

CONCLUSION

Overall NCUM model showed a consistent performance as compared to the other model GFS and WRF. The average percentage of correct is 62% with NCUM 58% with GFS and 55% with WRF model. In the higher category of rainfall forecast, the False alarm rate is more compared to the 0.1-10 & 11-25 categories. For the heavy rainfall incidents, it is observed that all the models failed to capture the day3 forecast. The WRF model is under-predicted as compared to the GFS and NCUM models. Due to the series of low-pressure system models didn't well capture the intensity and distribution of the storm .on the second urban convective event the model well capture the movement of the storm and intensity also but the spatial errors are much as compared to the observations. There may be a positional difference in the synoptic system captured by the model from its actual position which may change the spatial distribution of rainfall and result in a decrease in the performance of the model in the forecasting of rainfall over small areas.

REFERENCES

Ashwini Ranade, A. K. Mitra, Nityan and Singh, Swati Basu. 2014. A verification of Spatio-temporal monsoon rainfall variability across the Indian region using NWP model output. Meteorology and Atmospheric Physics 125:1-2, 43-61.

Clark, M.P. and Hay, L.E. 2004. Use of medium-range numerical weather prediction model output to produce forecasts of stream flow, Journal of Hydrometeorology, 5 (1), 15-32.

Fritsch, J. M., and Carbone, R. E. 2004. Improving quantitative precipitation forecasts in the warm season-A USWRP 558 research and development strategy, Bull. Am. Meteorol. Soc., 85, 955–965, https://doi.org/ 10.1175/ BAMS-85-7-955.

Golding, B. W. 2000. Quantitative precipitation forecasting in the UK. J. Hydrol., 239, 286–305.——, 2009: Long lead time flood warnings: Reality or fantasy? Meteor. Appl., 16, 3–12.

Cuo, L., Pagano, T. C., and Wang, Q. J. A review of quantitative precipitation forecasts and their use in short- to 538 medium-range stream flow forecasting, J. Hydormeteorol., 12, 713–728,

Habets, F., Le Moigne, P., and Noilhan, J. 2004. On the utility of operational precipitation forecasts to serve as input for streamflow forecasting, Journal of Hydrology, 293 (1–4), 270-88.

Harihara Ayyar, P.S. and Tripathi, N. 1973. Indian J. of Met. Geophysics, Vol. 24, 3, pp.279-282.

Manual of Hydrometeorology (Revised), 2017. India Meteorological Deptt

Sumant Kr. Diwakar, Surinder Kaur, Ashok Kumar Das., Anuradha Agarwala., Performance of WRF (ARW) over River Basins in Odisha, India During Flood Season 2014 (IJIRST/ Volume 2 / Issue 06/ 015)

Durai, V. R. S. K. Roy Bhowmik. 2014. Prediction of Indian summer monsoon in short to medium range time scale with high-resolution global forecast system (GFS) T574 and T382. Climate Dynamics 42, 1527-1551

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