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Block level weather forecast using T-1534 model output and biasfree temperature forecast by decaying weighted mean procedure during summer monsoon season in India

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ABSTRACT

The forecast based upon T-1534 model output and bias corrected technique decaying weighted mean (DWM) for temperature had been prepared and implemented on 1st December 2017 for 655 districts and 6500 blocks. The procedure for getting forecast for the districts and blocks in India including altitude corrections is based upon regular(0.125x0.125) grid output from the T-1534 Model. A verification study is conducted for rainfall forecast at 0.125x0.125 degree grid for Indian Window (0-40°N and 60°E-100°E) and for bias free maximum/minimum temperature for Indian window (7.5°N -37.5°N and 67.5°E-97.5°E) for summer monsoon season (June, July, August and September) 2017. The skill of both these important weather parameters had been found to be very good and usable for all parts of the country except oceanic islands and high terrain regions. From the Indian window, the forecast was down scaled for all the districts and blocks. A detailed verification study for the skill of the forecast at block level for four important weather parameters i.e., rainfall, cloud amount, maximum and minimum temperature is conducted. The skill of the rainfall forecast is obtained for categorical forecast and as well as for yes/no forecast and absolute values of cloud amount and bias free maximum and minimum temperatures. The skill found is very good. The study indicates that forecasts so obtained has the potential to be used for the block level forecast without making much value additions by the forecaster.

Key words: Blocks, Block level weather forecast, T-1534, DWM, Skill Scores, value addition

1. INTRODUCTION

In general the weather forecasts were issued in qualitative terms with the use of conventional methods assisted by satellite data and synoptic information for the location of interest. These forecasts were subjective and could not be used for risk assessment in quantitative terms. Later on the work was initiated to develop an objective medium range local weather forecasting system in India in 1988 at the National Centre for Medium Range Weather Forecasting (NCMRWF). Till then different NWP models were implemented and forecasts were obtained. The NWP models of better physics and dynamics modules and higher resolution was implemented (Kumar, Ph.D Thesis, 2010). Up to monsoon 2016, the T-574 with a higher resolution of 0.25°x0.25° grid was running both at NCMRWF and India Meteorological Department (IMD). In this present study for summer monsoon (JJAS) 2017 the output from T-1534 model with a much higher resolution of 0.125°x0.125° and bias correction procedure had been used for obtaining the temperature forecast.

An objective forecast is a forecast which does not depend on the subjective judgment of the person issuing it. Strictly speaking, an objective forecasting system is one which can produce one and only one forecast from a specific set of data. The objective forecast for the four surface weather parameters i.e., Rainfall, Cloud amount, Maximum and Minimum Temperature is directly obtained from the general circulation model GFS T-1534 operational at IMD for six days. One day is used for running the model and obtaining the weather forecast and then the forecast for five days (Day1 to Day5) from 2nd to 6th day forecast, is obtained every day for the four weather parameters. The forecast for rainfall and cloud amount were the direct model output forecasts from T-1534 model and the forecast for maximum and minimum temperature were obtained as the bias free forecast by using decaying weighted mean (DWM) procedure.

There had been great demand from agriculture scientists and farmers for the weather forecast at sub-district scale that is at block level or even up to village level. In this direction India Meteorological Department had taken a step forward. The work on block level weather forecast was started in April 2012. Till then different NWP models output were tried for obtaining these forecasts and verification studies were conducted (Kumar *et al.,* 2017). In the present study the forecasts are based upon T-1534 model and

DWM procedure for bias free forecast for temperature. The details about the data used in this study is given in section 2, methodology followed in forecast generation and its verification explained in section 3, the results and discussion in section 4 and finally conclusions are explained in section 5.

2. DATA

2.1. Basic data about the blocks in India:

In India there are 6648 blocks and 655 districts. First, the list of all the districts and blocks had been retrieved from Panchayati Raj Ministry's website after discussing with them. The web site is panchayat.gov.in. Now this information is available in the website: lgdirectory.gov.in. Latitude, Longitude and altitude for 655 districts and 6500 blocks out of 6648 blocks in India are recorded from the standard world web sites. This basic data is used for generating the weather forecast for the blocks in India.

2.2. The forecast output from NWP models:

For getting the forecast at all the 6500 blocks, the output from the T-1534 is used. First the outputs are obtained for the Indian window (0-40°N and 60°-100°E) for rainfall and cloud amount and Indian window (7.5°-37.5°N and 67.5°-97.5°E) for bias free forecast for maximum and minimum temperature. Then, the forecast is obtained for these four weather parameters for all the 6500 blocks by downscaling the weather forecast by a procedure explained in the methodology followed.

The Global Forecasting System (GFS) run at India Meteorological Department (IMD) is a primitive equation spectral global model with state of art dynamics and physics (Kanamitsu 1989, Kalnay *et.al.*, 1990, Kanamitsu *et.al.*, 1991, Durai *et.al.*, 2010 Durai and Roybhowmik. 2013). The GFS (*gsm.v12.0.2*), adopted from National Centre for Environmental Prediction (NCEP), at T1534L64 (~ 12 km) in horizontal resolution and in the vertical there are 64 hybrid sigma-pressure (Sela, 2009) layers with the top layer centered around 0.27 hPa (~ 55 km) runs operationally on ADITYA High Performance Computing Systems (HPCS) at Indian Institute of Tropical Meteorology (IITM) Pune twice in a day (00 & 12 UTC) since 01 December 2016 to give deterministic forecast in the short to medium range. The initial conditions for GFS model is generated from the NCEP based global 3-dimensional variation (3D-VAR) Grid Point Statistical Interpolation (*GSI 3.0.0*) scheme till 30 June 2016. Since 01July 2016 the initial conditions are generated from the NCEP based Ensemble Kalman Filter (EnKF) component of hybrid Global Data Assimilation System (GDAS) run on BHASKARA HPCS at National Center for Medium Range Weather Forecasting (NCMRWF).

The current operational dynamical core of the GFS/GSM is based on a two time-level semi-implicit semi-Lagrangian discretization (Sela, 2010) with three dimensional Hermite interpolation (the dynamical core still supports three time-level Eulerian approach). The semi-Lagrangian advection calculations as well as treatment of physics are done on a linear, reduced (for computational economy) Gaussian grid in the horizontal domain. The semi-implicit treatment and implicit eighth order horizontal diffusion are performed in spectral space. This requires the application of Fourier and Legendre transforms to convert between spectral and grid-point spaces. To improve the accuracy of associated Legendre function computation at higher wave numbers, extended-range arithmetic (X-number - Juang, 2014) is used. Also, a correction is applied to the global mean ozone to account for the non-conservation during semi-Lagrangian advection step. For the three time-level Eulerian option for dynamics a positive-definite tracer transport formulation (Yang, 2009) is used in the vertical.

It is important to note that the same physical parameterization package is used across all horizontal and vertical resolutions. Upgrades to the physical parameterizations are ongoing and occur on the average of every other year. The model is based on the usual expressions of conservation of mass, momentum, energy and moisture at T1534 spectral truncation, approximately 13 km physics (Gaussian) grid and 64 levels in a hybrid sigma-pressure vertical coordinate. Output is posted to 0.125 degree equally spaced longitude/latitude grid with 3-h forecast interval to 243-hour. Details about the global forecast model (GFS) are available at http://www.emc.ncep.noaa.gov/GFS/doc.php.

3. METHODOLOGY

3.1. Skill of rainfall forecast over Indian window and homogeneous regions:

The observed and forecasted rainfall values (from GFS T-1534 output) at the regular grid of 0.125x0.125 degree resolution for Indian window 0-40°N and 60°E -100°E, were verified. For this two scores i.e., Ratio score and Hanssen and Kuiper's (HK) score was calculated for yes/no rainfall and two scores i.e., Hit rate (HR) and Hanssen and Kuiper's score quantitative precipitation (HKQ) was calculated for rainfall amounts for summer season 2017 (Fig.2 to Fig.4). A comparative study is conducted for rainfall forecast for the above mentioned Indian window by obtaining the skill scores for all the grids over India as a whole (AI) (7°–37°N,67° –100°E), and over five different regions i.e., North India (NI) (25° –35°N,70° –85°E), West Coast of India(WCI) (10° –20°N ,70° –78°E), North East India (NEI) (22° –30°N, 85° –100° E) , Central India (CI) (22° –28°N,73° –90°E) and Peninsular India (PI) (7° –21°N ,74° –85° E) during summer season 2017. For this Ratio score and Hanssen and Kuiper's (HK) score was calculated for yes/no rainfall and Hit rate (HR) and correct, usable and unusable percentages was calculated for quantitative precipitation (Fig.11).

3.2. Skill of bias free temperature forecast over Indian window and homogeneous regions

The observed and bias corrected temperature (maximum and minimum) forecast from GFS T-1534 output and bias free decaying weighted mean (DWM) procedure at the regular grid of 0.125x0.125 degree resolution for Indian window 7.5ºN-37.5ºN and 67.5ºE-97.5ºE, were verified. For this mean absolute error and usable and unusable percentages of temperatures was calculated for temperature values for summer monsoon season 2017 (Fig.5 to Fig.10). A comparative study is conducted for direct and DWM forecast for the above mentioned Indian window by obtaining the skill scores for all the grids over India as a whole (7.5ºN–37.5ºN, 67.5ºE–97.5ºE), and over five different regions i.e., North India, West Coast of India, North East India, Central India and Peninsular India during summer season 2017. For this mean absolute error and usable and unusable percentages of temperatures was calculated for maximum and minimum temperature values (Fig.12 to Fig.14).

3.3. Decaying weighted mean (DWM) procedure for Bias correction applied for temperatures over Indian window (7.5ºN-37.5ºN and 67.5ºE-97.5ºE)

The DWM bias correction method (Durai and Bhardwaj, 2014) computes bias at each station (k) and at each forecast hour (t) from the previous 14 days daily bias $bk(t)$ starting from the forecast issue day (t = 0) using decreasing weight so that the nearest recent data has the largest weight. The previous forecast errors are weighted averaged together using decreasing weight (Fig.1). The 14-day period is chosen to best account for the seasonal change in model errors and the samples are large enough to eliminate noise.

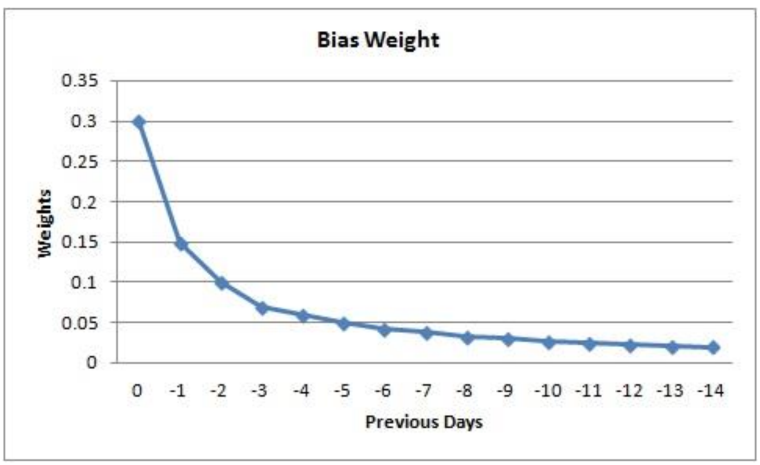

Figure 1 Weights used in the decaying weighted mean bias correction method for computing daily model bias.

The DWM with the weight coefficient $wt_k(t)$ is computed as:

$$wt_k(i) = \frac{wk(i)}{\sum_{t=0}^{14} wk(t)}$$

Where $w_k(i) = \frac{1}{1-i}$; and i = 0,−1, 2,−3, . . ., −14.

The weight $wt_k(t)$ is considered for computing model bias from its past performance starting the forecast issue day (t = 0) and the previous first 14 days are 30.14, 15.07, 10.05, 7.53, 6.03, 5.02,4.31, 3.77, 3.35, 3.01, 2.74, 2.51, 2.32, 2.15, 2%. The weight for the forecast issue day (t = 0) is 30.14 %, followed by the previous first day t =−1 is 15.07%, but the weight became 2% for the last day (t = −14). The systematic bias $B_k(t)$ at each station is computed daily by applying the weight coefficient $wt_k(t)$ at each forecast hour as:

$B_k(t) = Wt_k(t) * b_k(t)$.

This is the final bias field which is subtracted from the raw forecasts to produce the bias-corrected forecast.

The new bias-corrected model forecast $F_k(t)$ is generated by applying the bias $B_k(t)$ to current direct forecasts $f_k(t)$ at each station for all day1 to day5 forecasts.

$F_k(t) = f_k(t) - B_k(t)$.

This statistical bias correction is applied to GFS day1 to day5 forecasts at each lead time with respect to observation. This new statistical bias correction method discussed in this study uses the current and previous 14 days bias to calibrate each forecast individually, at each station.

3.4. Downscaling procedure

Rainfall and cloud amount forecast was provided by using 12.5 Km resolution general circulation model i.e., GFS (T-1534 model) for six days that is five forecast days. The maximum and minimum temperature forecast were obtained by using the bias free decaying weighted mean (DWM) procedure and T-1534 model output.

As for obtaining the forecast value of a weather parameter from the regular grid points the four points surrounding the station are considered. As the forecasts are obtained at regular grids and not at a particular location, hence forecast at a specific location is to use the interpolated value from the four grid points surrounding it. But if the location is very near to a grid point, then the forecast at that grid point can also be taken as the forecast for the location. In order to decide as to which forecast among the two should be considered for a location, it is necessary to know the distance of the location from the four grid points surrounding it. If the distance of the location from the nearest grid is less than one fourth of the diagonal distance between any two grid points, then forecast given is for nearest grid forecast values otherwise the interpolated value is considered as explained below (Kumar *et. al.*,2000).

It is hereby mentioned that as the district boundaries are available, hence the average of the forecasts at the grid point falling within the district boundaries are used for obtaining the district level forecast from GFS T-1534 model output. Although the districts falling in the high terrain regions and the block level forecasts are based upon the above mentioned technique.

3.5. Forecast verification procedures

3.5.1. Skill scores used for verification

The standard skill scores are used for rainfall and other weather parameters for verification study (Murphy and Katz, 1985).

3.5.2. Error structure for different variables

PARAMETER	CATEGORY	ERROR STRUCTURE
Rainfall		if observed r/f is out by
	Correct	Diff≤2.5mm for ≤ 10mm
	Usable	2.5mm<Diff ≤ 5mm for ≤ 10mm
	Unusable	Diff > 5mm for ≤ 10mm
Temperature		Maximum and Minimum
	Correct	Diff ≤ ± 1deg C
	Usable	1 deg C < Diff ≤± 2 deg C
	Unusable	Diff > ± 2 deg C
Cloud cover		
	Correct	Diff ≤ ± 2octa
	Usable	2 octa < Diff ≤ ± 3 octa
	Unusable	Diff > ± 3 octa

Here Diff stands for the absolute difference between observed and forecasted.

4. RESULTS AND DISCUSSION

4.1. Skill of rainfall forecast over Indian window and homogeneous Regions

The observed and forecasted rainfall values (from GFS T-1534 output) at the regular grid of 0.125x0.125 degree resolution for Indian window 0-40°N and 60°E -100°E were considered and skill scores are calculated for the above mentioned Indian Window. For this Ratio score and Hanssen and Kuiper's(HK) score was calculated for yes/no rainfall and Hit rate (HR) and Hanssen and Kuiper's score for quantitative precipitation (HKQ) was calculated for rainfall amounts. These scores are plotted as Fig.2 to Fig.4 for Day-1, Day-3 and Day-5. A verification study is conducted for rainfall forecast for the above mentioned Indian window by obtaining the skill scores for all the grids over India as a whole and over five different regions (Fig.11) i.e., North India, West Coast of India, North East India, Central India and Peninsular India during summer monsoon season 2017. The skill of the rainfall forecast was found to be good for all parts of the country except oceanic islands and high terrain regions and hence one can down scale to any level, down to the blocks, the skill of the forecast are good.

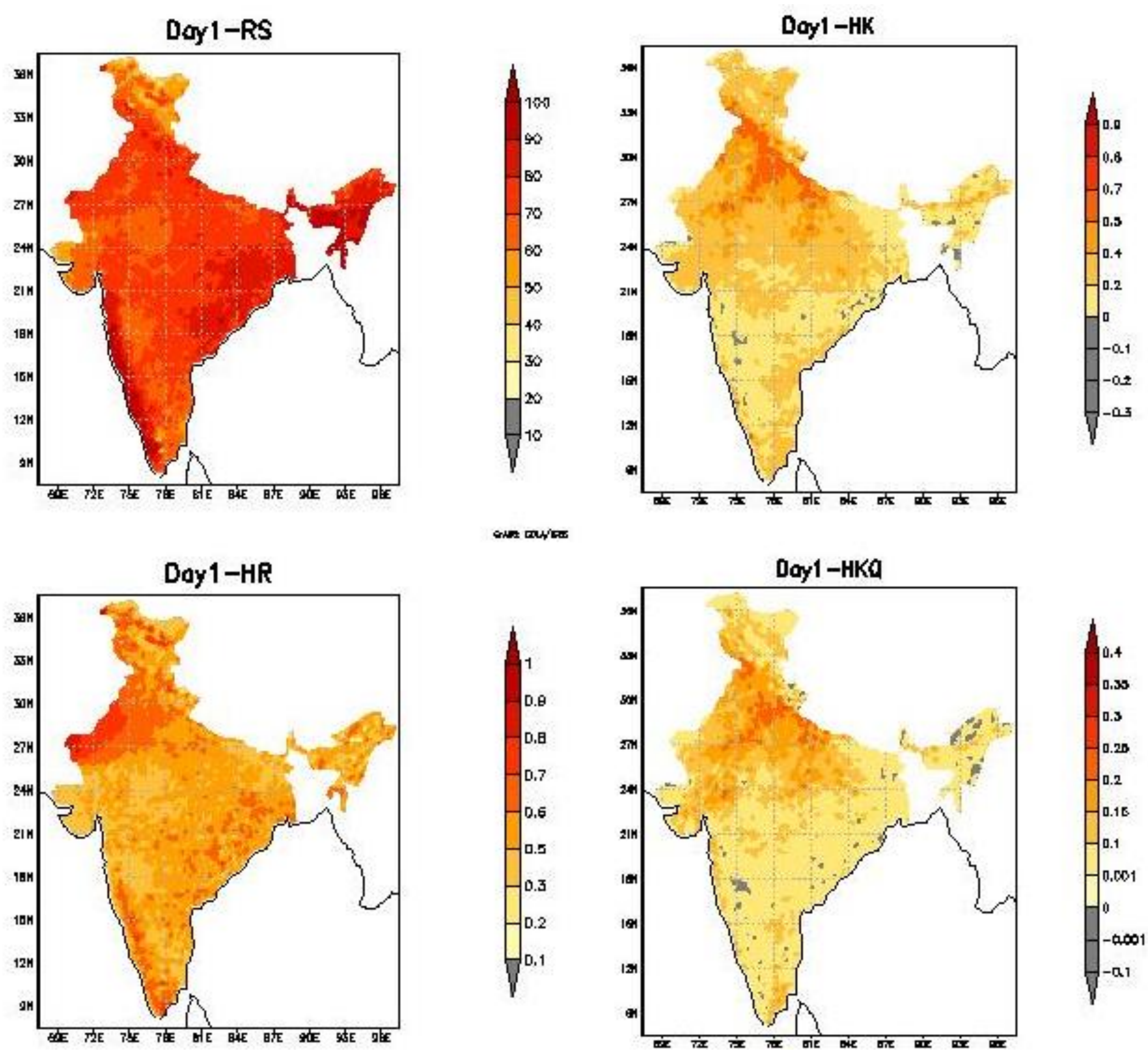

Figure 2 Skill Scores of Categorical (Yes/no) & Quantitative verification of IMD-GFST1534 day1 Rainfall forecast over Indian Window during summer season-2017.

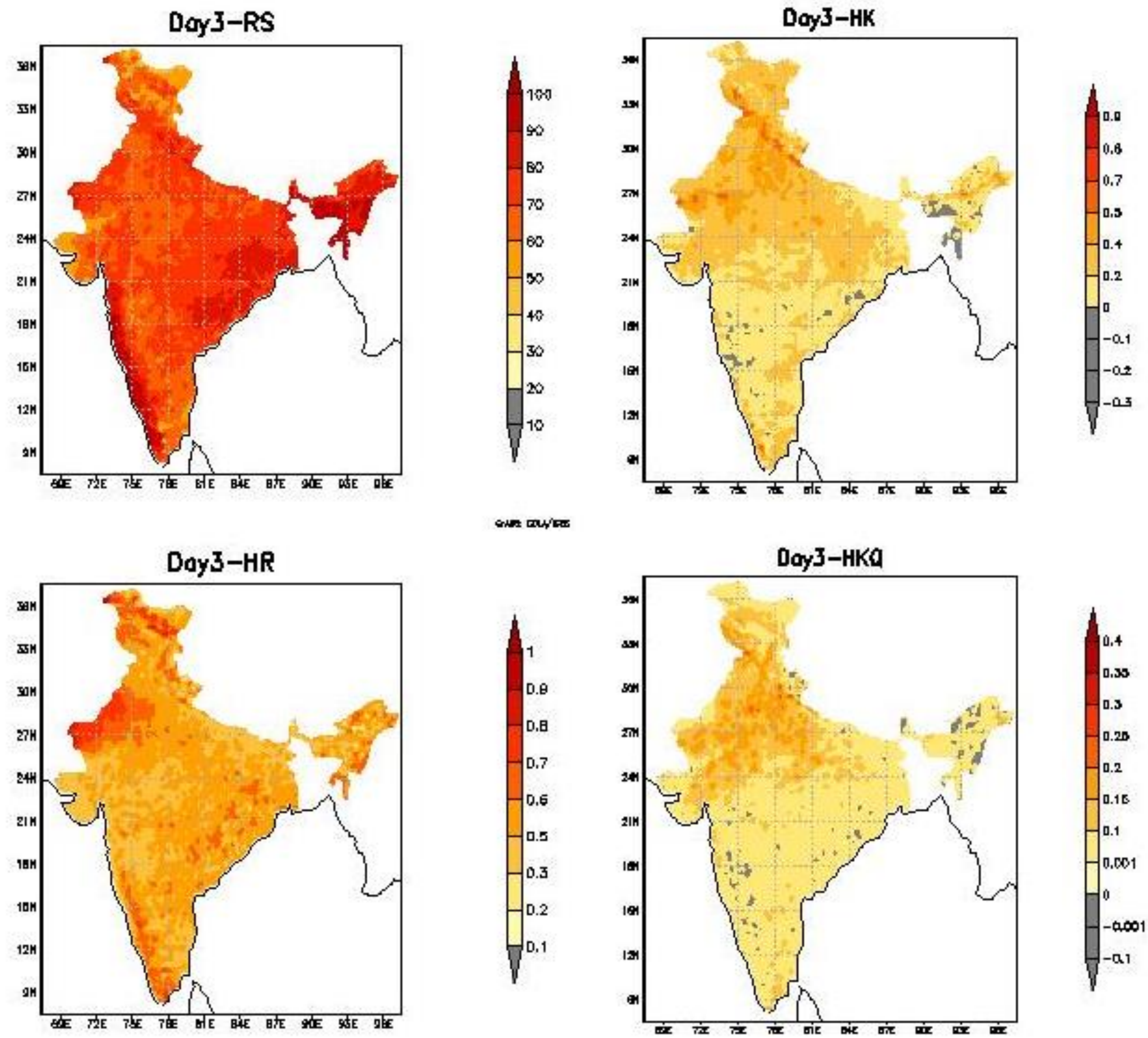

Figure 3 Skill Scores of Categorical (Yes/no) & Quantitative verification of IMD-GFST1534 day3 Rainfall forecast over Indian Window during summer season-2017.

4.2. Skill of bias free temperature forecast over Indian window and homogeneous Regions

The observed and forecasted maximum and minimum temperature values from bias free forecast using DWM and output from GFS T-1534 model at the regular grid of 0.125x0.125 degree resolution for Indian window 7.5ºN-37.5ºN and 67.5ºE-97.5ºE were considered and the skill scores are calculated for bias free and direct forecast for the above mentioned Indian window. For this mean absolute error and usable and unusable percentages of temperatures was calculated for absolute temperature values for summer monsoon season 2017. The skill scores for bias free forecast using DWM are very high as compared to direct forecast for most parts of the country. These scores are plotted as Fig.5 to Fig.10 for Day1, Day3 and Day5. A comparative study is conducted for direct and DWM forecast for the above mentioned Indian window by obtaining the skill scores for all the grids over India as a whole, and over five different regions i.e., North India, West Coast of India, North East India, Central India and Peninsular India during summer season 2017. The bias free forecast using DWM for temperature has highly improved as compared to direct model output forecast (Fig.12 to Fig.14). The skill of bias free maximum and minimum temperature forecast was found to be good for all parts of the country except oceanic islands and high terrain regions and hence one can down scale to any level, down to the blocks, the skill scores found are good.

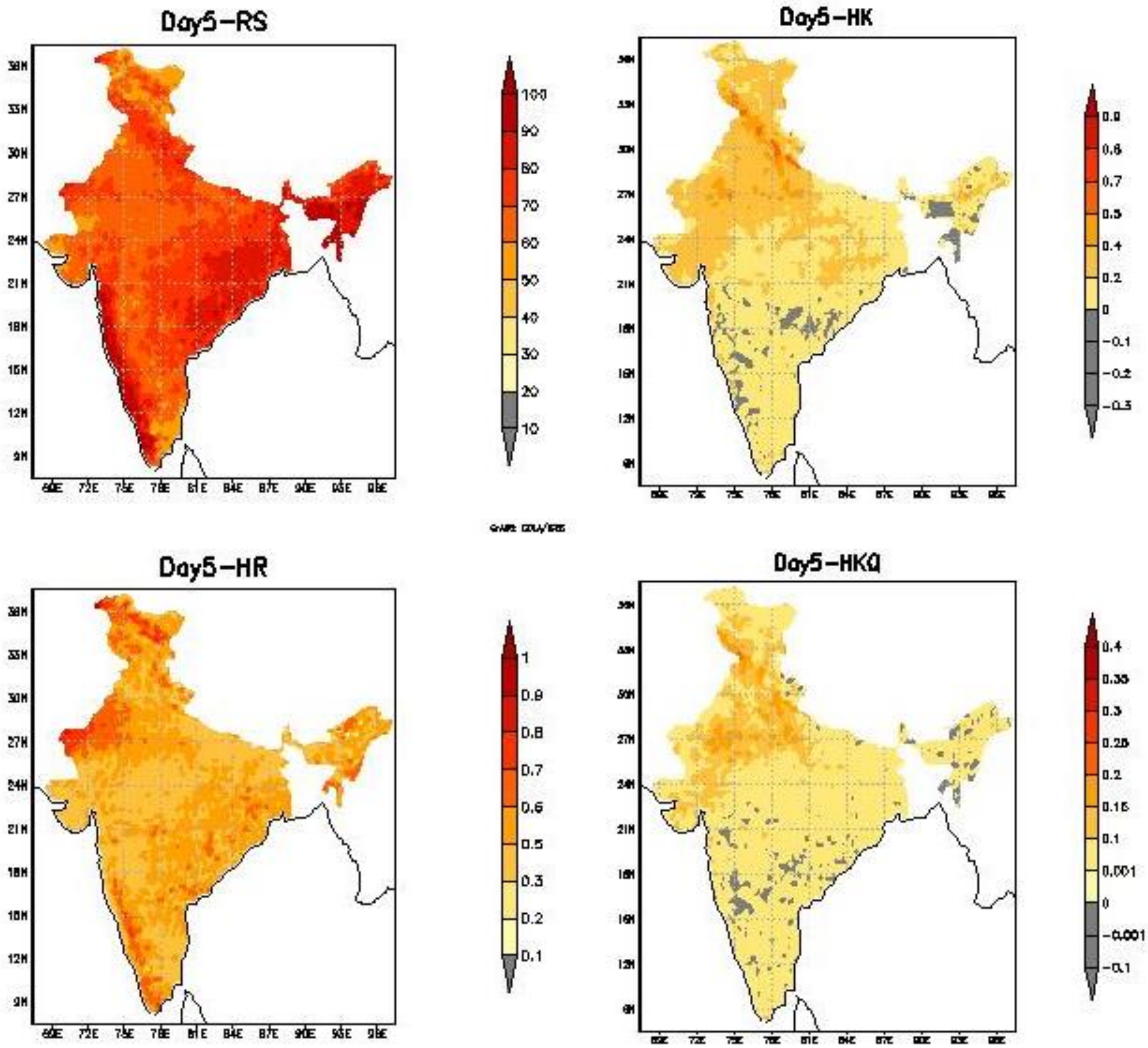

Figure 4 Skill Scores of Categorical (Yes/no) & Quantitative verification of IMD-GFST1534 day5 Rainfall forecast over Indian Window during summer season-2017.

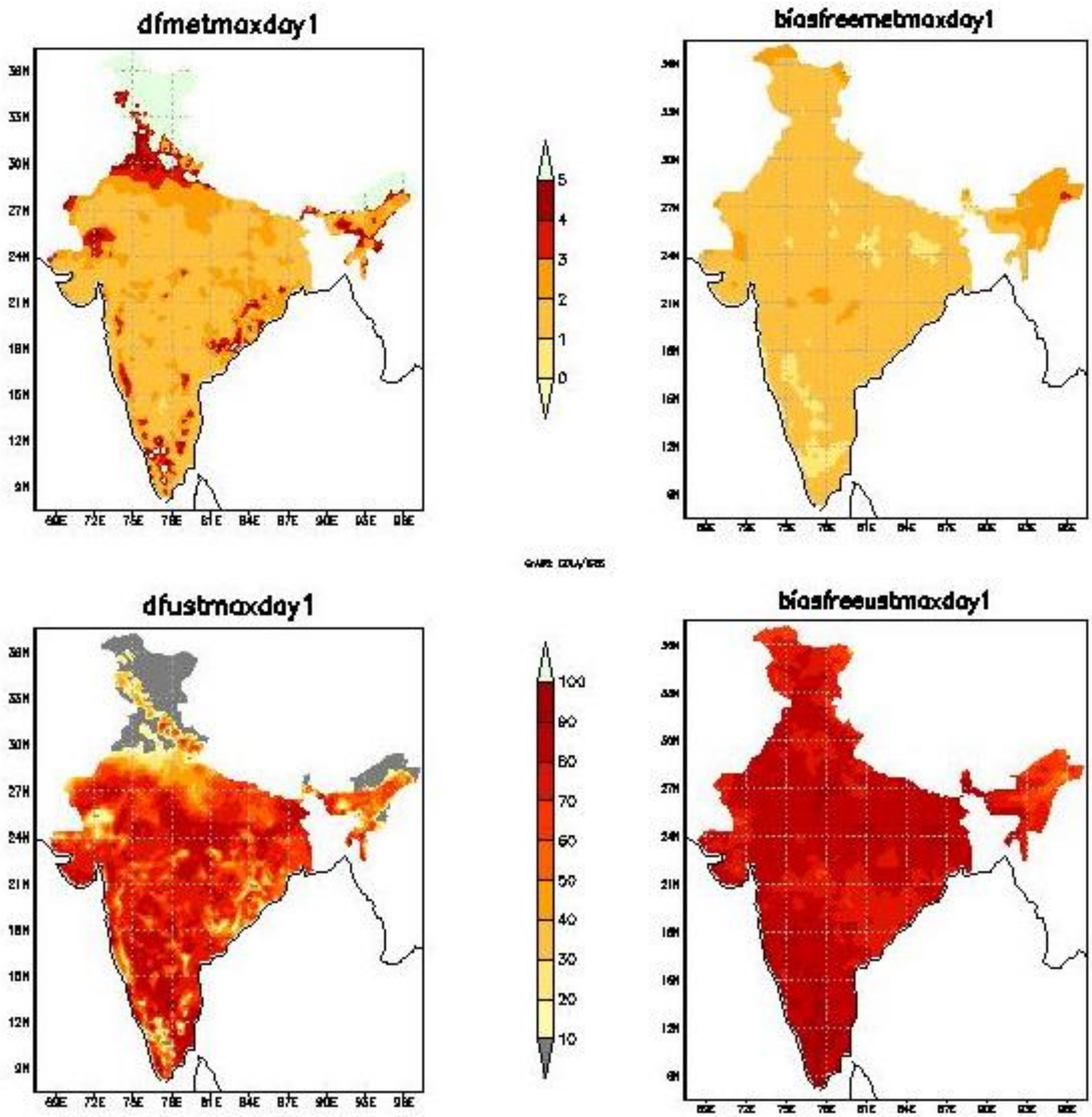

Figure 5 Skill Scores for day1 Maximum Temperature direct forecast & Bias free forecast over Indian Window for the period of summer season-2017.

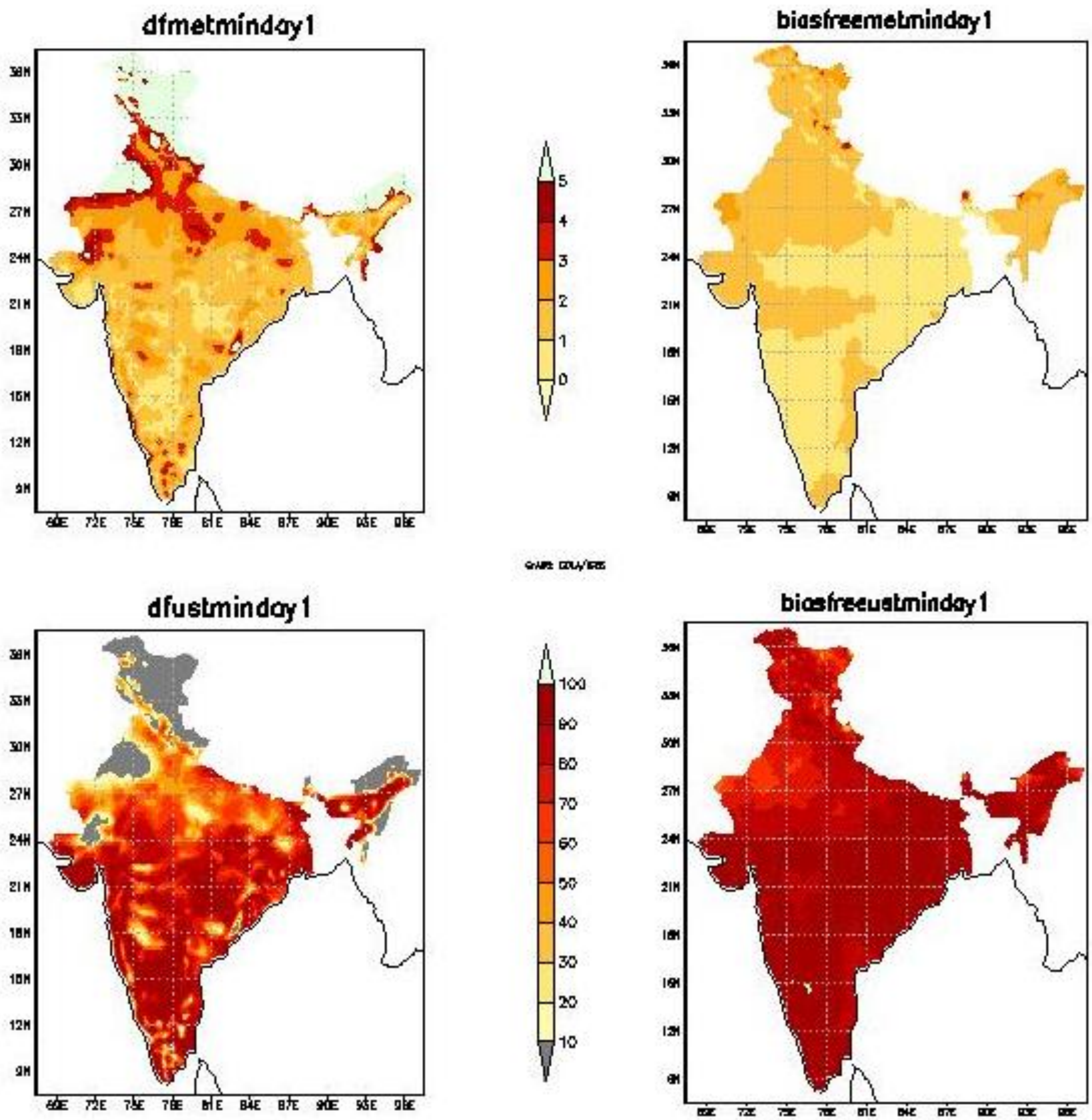

Figure 6 Skill Scores for day3 Maximum Temperature direct forecast & Bias free forecast over Indian Window for the period of summer season-2017.

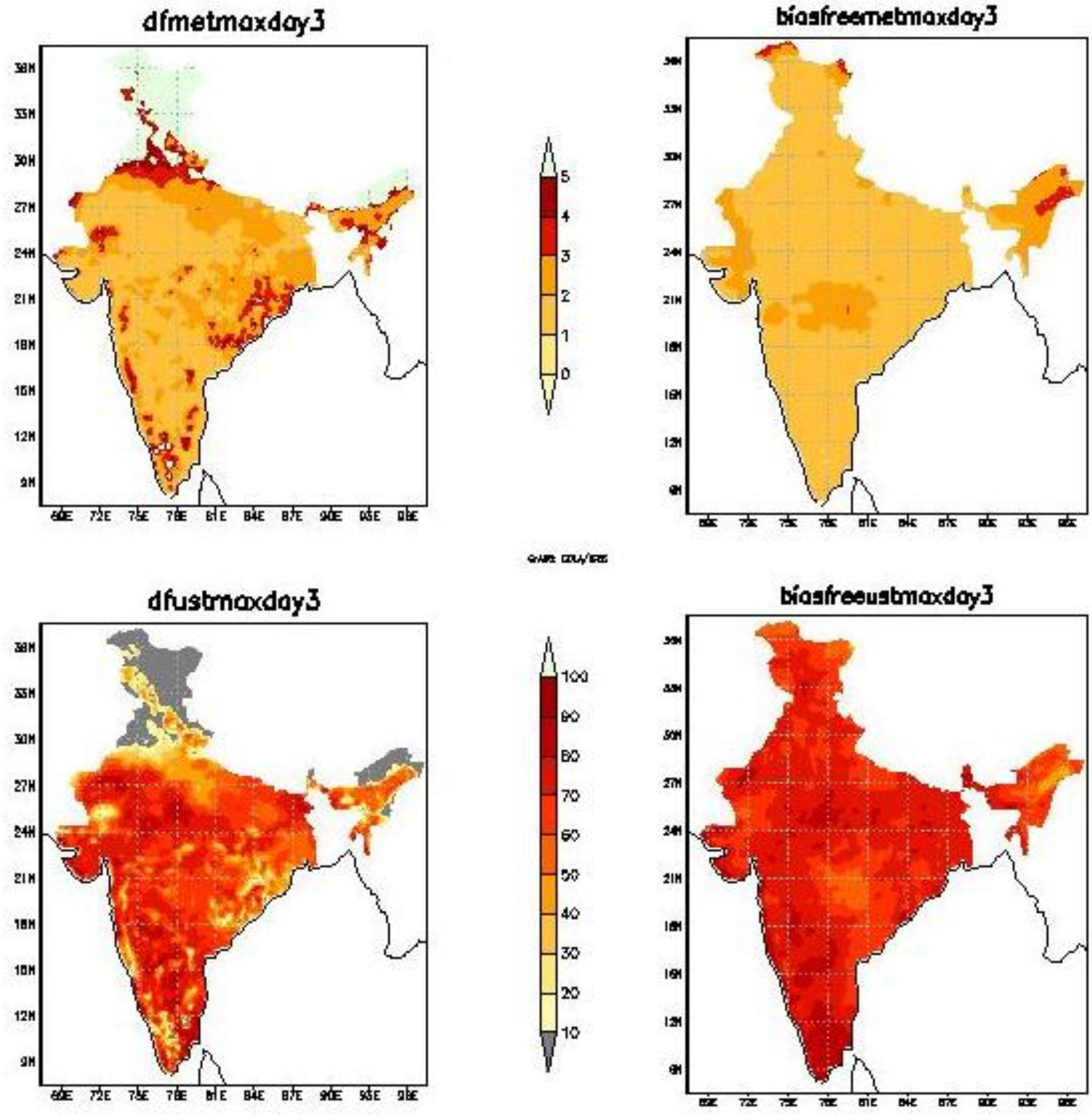

Figure 7 Skill Scores for day5 Maximum Temperature direct forecast & Bias free forecast over Indian Window for the period of summer season-2017.

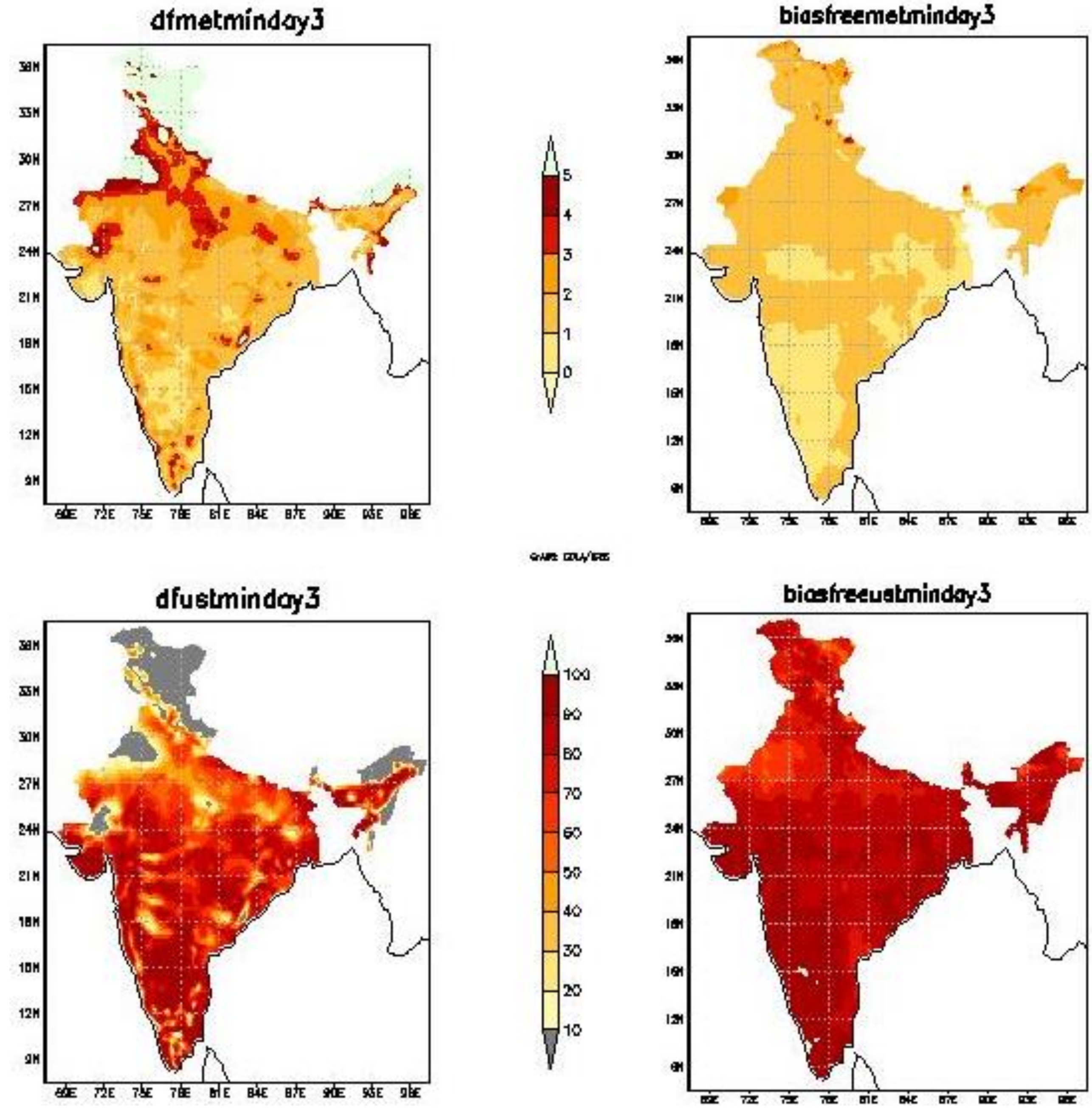

Figure 8 Skill Scores for day1 Minimum Temperature direct forecast & Bias free forecast over Indian Window for the period of summer season-2017.

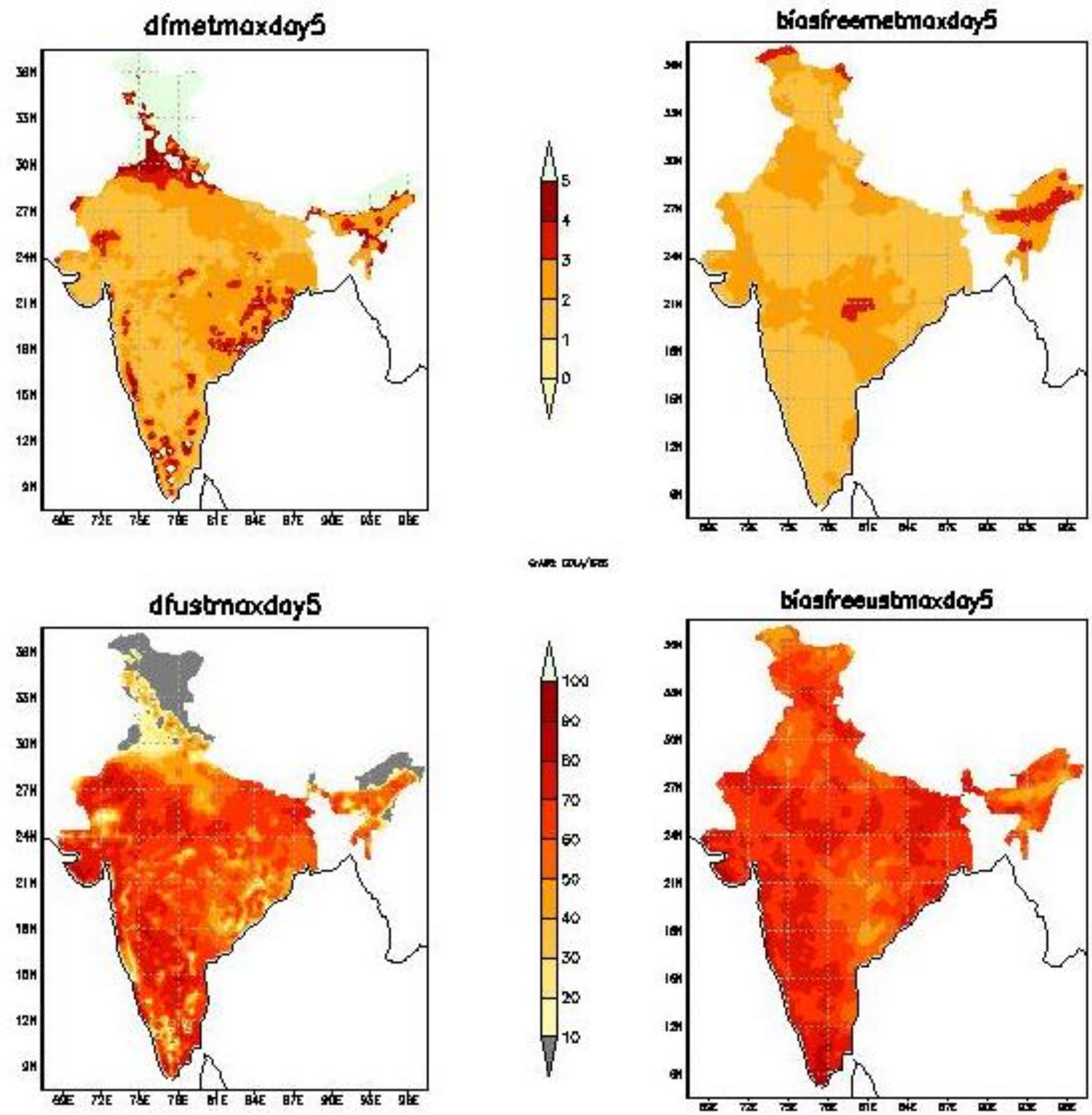

Figure 9 Skill Scores for day3 Minimum Temperature direct forecast & Bias free forecast over Indian Window for the period of summer season-2017.

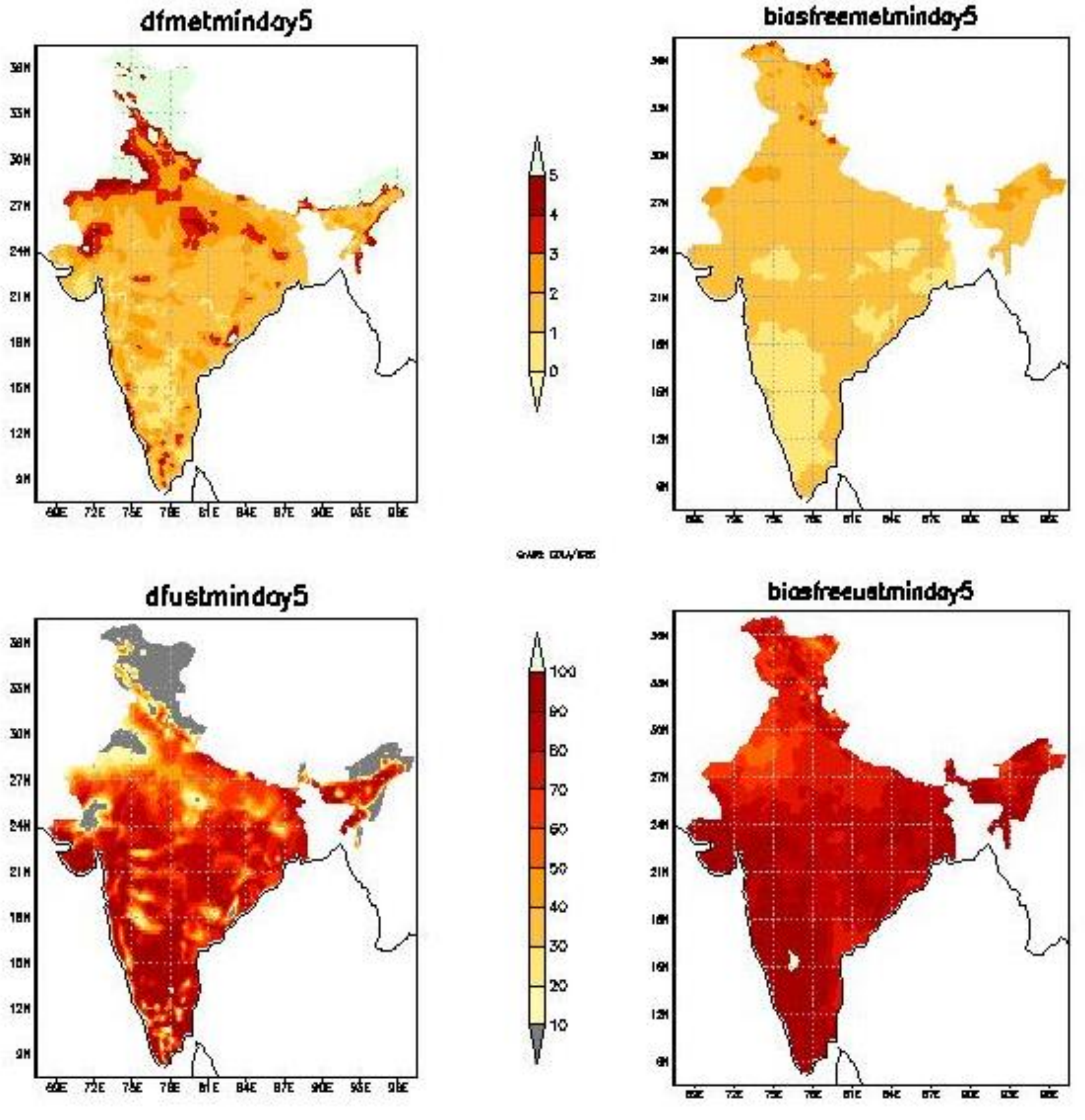

Figure 10 Skill Scores for day5 Minimum Temperature direct forecast & Bias free forecast over Indian Window for the period of summer season-2017.

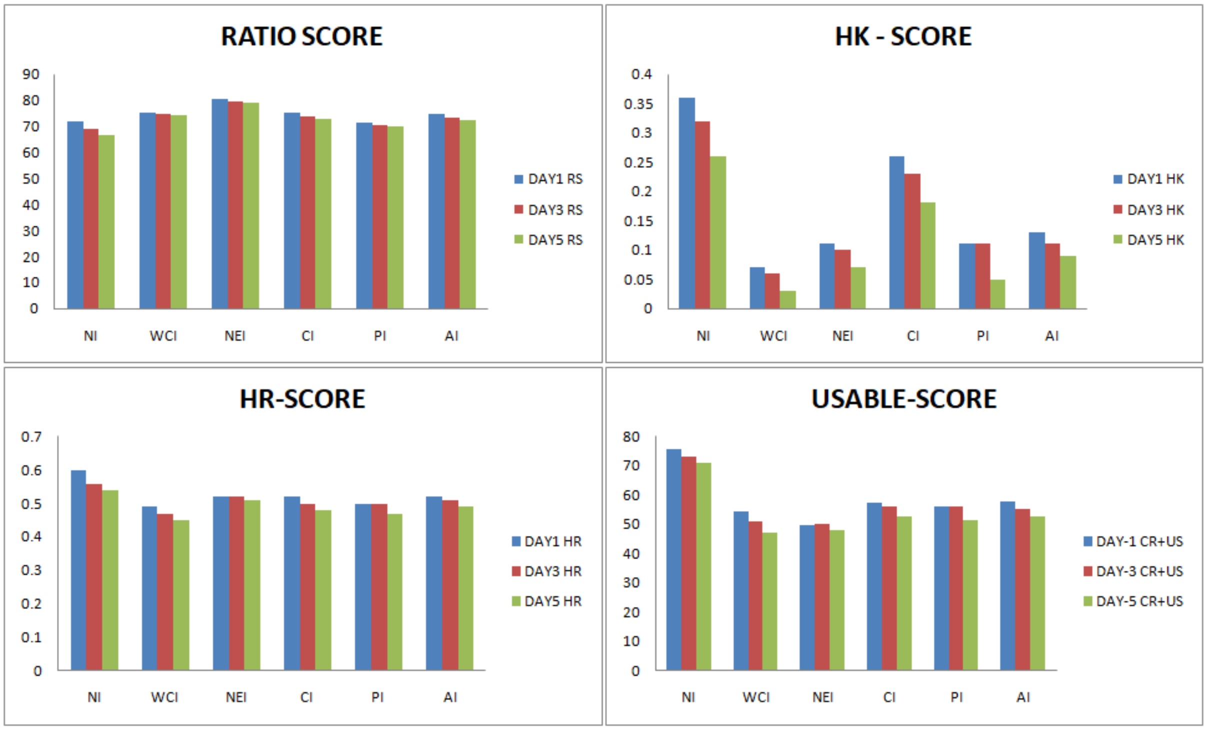

Figure 11 Skill Scores of Rainfall for day1, day3 & day5 over 5 homogeneous regions along with all India for summer monsoon season 2017.

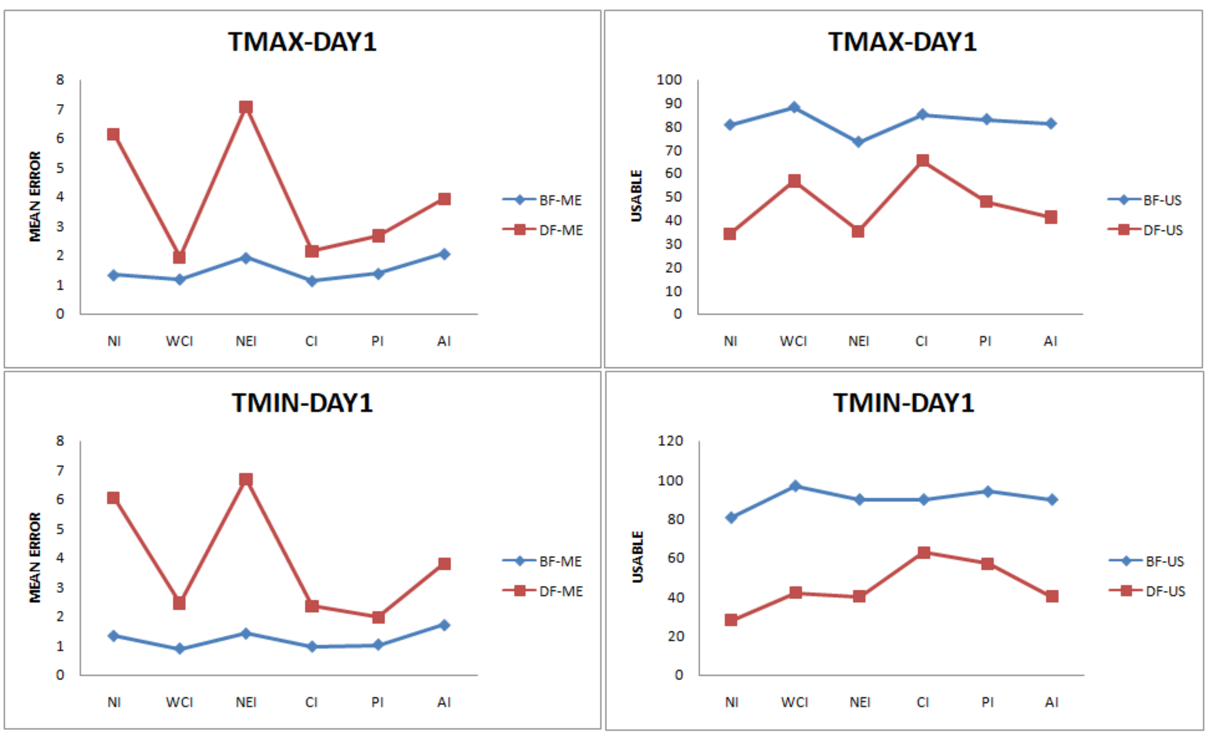

Figure 12 Skill scores (Mean error and Usable) of Direct and bias free for day1 temperature (maximum & minimum) forecast during summer monsoon over 5 homogeneous regions along with all India.

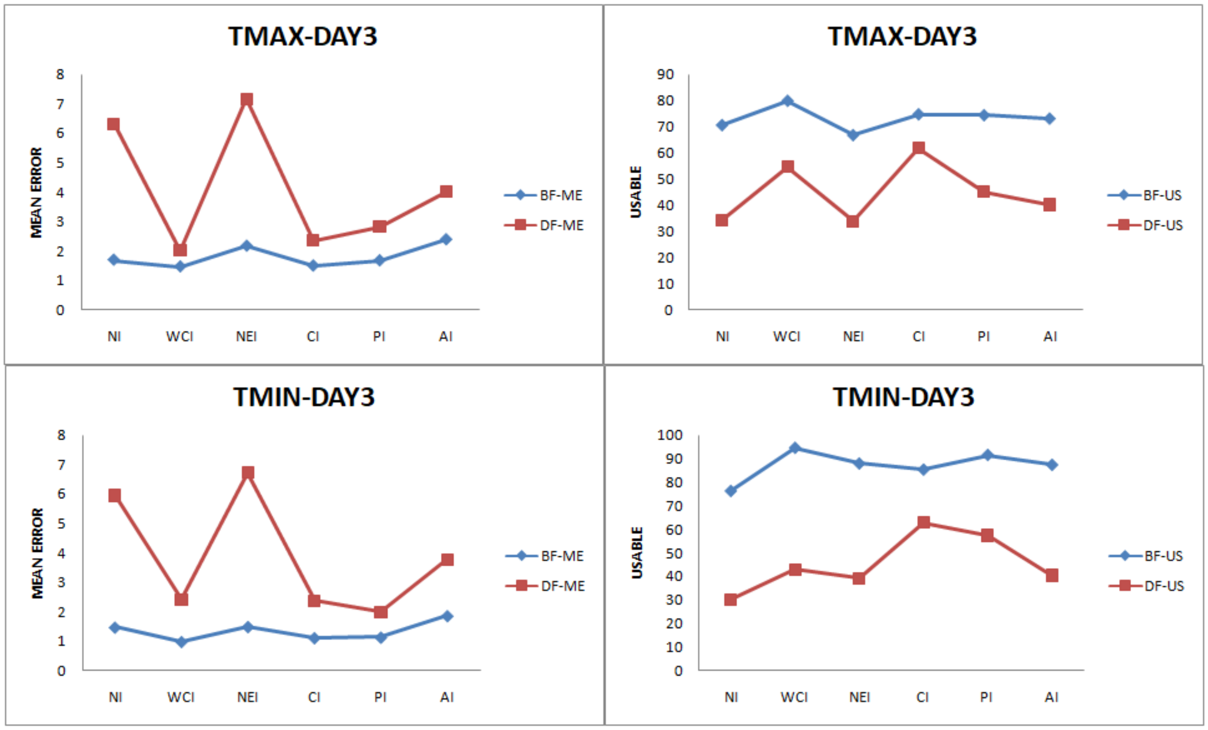

Figure 13 Skill scores (Mean error and Usable) of Direct and bias free for day3 temperature (maximum & minimum) forecast during summer monsoon over 5 homogeneous regions along with all India.

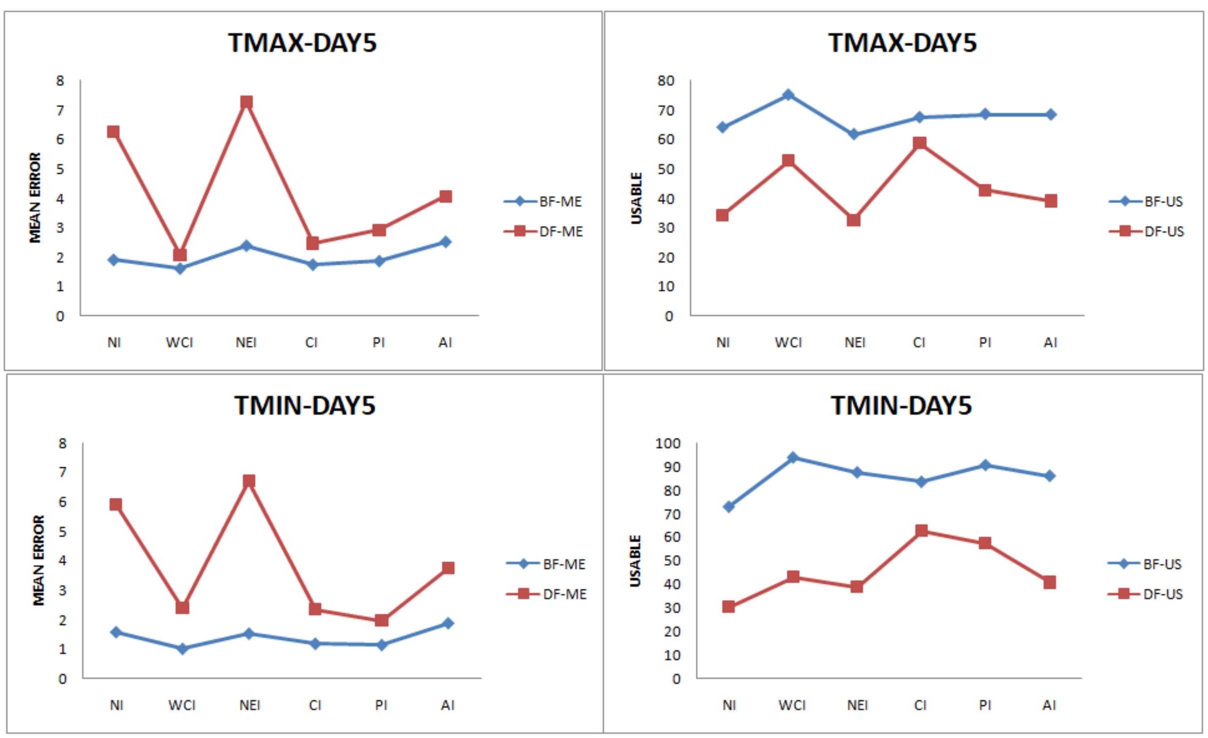

Figure 14 Skill scores (Mean error and Usable) of Direct and bias free for day5 temperature (maximum & minimum) forecast during summer monsoon over 5 homogeneous regions along with all India.

4.3. Block level weather forecast verification Results

The verification study is conducted for few blocks for which observational data was readily available for the 34 states and for the remaining two states no data at block level could be obtained. The skill for four weather parameters i.e., rainfall, cloud amount and maximum and minimum temperature are found to be good for almost all the states and almost no human intervention is required for improving the forecast.

The results from the skill scores (Table 1 to 5) are given in the following paragraphs;

Table1 skill scores for Yes/no Rainfall forecast.

	STATE	DAY-1				DAY-3				DAY-5			
		RS	HK	POD	FAR	RS	HK	POD	FAR	RS	HK	POD	FAR
1	And. and Nico. Islands	62.63	0.06	1.0	0.39	62.03	0.03	1.0	0.39	63.39	0.06	0.98	0.38
2	Andhra Pradesh	55.94	0.15	0.79	0.47	51.19	0.05	0.79	0.50	49.27	0.01	0.84	0.51
3	Arunachal Pradesh	72.0	0.24	0.88	0.23	68.43	0.21	0.82	0.24	66.41	0.09	0.85	0.28
4	Assam	64.64	0.13	0.93	0.34	61.55	0.11	0.90	0.36	62.06	0.11	0.92	0.36
5	Bihar	55.89	0.17	0.96	0.49	50.73	0.07	0.96	0.51	47.68	0.02	0.95	0.530
6	Chhattisgarh	70.20	0.23	0.96	0.31	67.78	0.15	0.95	0.33	66.12	0.08	0.98	0.34
7	Diu	60.91	0.23	0.89	0.44	66.36	0.34	0.98	0.4	60.91	0.23	0.91	0.44
8	Delhi	63.13	0.35	0.90	0.48	65.44	0.36	0.80	0.45	64.96	0.36	0.84	0.46
9	Goa	89.14	0.17	0.99	0.11	88.23	0.19	0.98	0.11	86.74	0.03	0.98	0.12
10	Gujarat	61.06	0.31	0.96	0.49	56.77	0.23	0.93	0.51	55.56	0.21	0.93	0.52
11	Haryana	61.41	0.36	0.85	0.56	61.44	0.35	0.83	0.56	58.38	0.29	0.80	0.59
12	Himachal Pradesh	71.56	0.38	0.86	0.28	70.21	0.35	0.85	0.29	69.66	0.30	0.88	0.31
13	Jammu and Kashmir	64.68	0.31	0.87	0.39	63.6	0.26	0.82	0.4	61.08	0.19	0.79	0.42
14	Jharkhand	68.41	0.25	0.93	0.34	65.04	0.16	0.94	0.36	63.81	0.10	0.96	0.37
15	Karnataka	64.79	0.15	0.96	0.37	62.91	0.08	0.96	0.38	62.69	0.04	0.97	0.38
16	Kerala	74.33	0.17	0.86	0.19	73.07	0.17	0.83	0.19	69.33	0.05	0.81	0.22
17	Lakshadweep	72.47	0.04	0.98	0.27	72.78	0.07	0.97	0.27	73.09	0.08	0.99	0.27
18	Madhya Pradesh	58.56	0.20	0.94	0.47	55.40	0.14	0.91	0.49	52.12	0.09	0.93	0.51
19	Maharashtra	65.42	0.12	0.95	0.36	63.25	0.09	0.93	0.38	62.34	0.07	0.95	0.38
20	Manipur	72.97	0.09	0.96	0.26	72.07	0.05	0.99	0.28	73.64	0.05	0.99	0.26
21	Meghalaya	83.20	0.04	0.96	0.15	83.91	0.01	0.99	0.15	83.18	-.01	0.98	0.16
22	Mizoram	88.11	0	1	0.12	87.45	0	1	0.13	88.2	0.0	1.0	0.12
23	Nagaland	73.96	0	1	0.26	72.16	0	1	0.28	73.2	0	1	0.27
24	Odisha	61.16	0.11	0.90	0.39	59.61	0.07	0.91	0.40	57.63	0.03	0.92	0.41
25	Pondicherry	51.74	0.12	0.68	0.62	53.97	0.21	0.82	0.58	47.67	0.09	0.80	0.61
26	Punjab	57.31	0.27	0.81	0.58	53.98	0.22	0.83	0.60	54.57	0.26	0.87	0.59
27	Rajasthan	65.70	0.36	0.79	0.56	62.13	0.27	0.72	0.59	61.04	0.25	0.70	0.60
28	Sikkim	69.73	0.22	0.72	0.06	64.21	-.11	0.69	0.10	73.05	0.09	0.76	0.06
29	Tamil Nadu	61.78	0.22	0.74	0.55	57.3	0.15	0.74	0.58	55.82	0.10	0.72	0.60
30	Telangana	56.01	0.12	0.88	0.47	55.54	0.11	0.90	0.47	53.36	0.06	0.92	0.48
31	Tripura	83.63	0.05	1.0	0.16	80.98	0.03	0.98	0.18	80.98	0.04	0.99	0.18
32	Uttarakhand	69.22	0.22	0.94	0.31	69.02	0.19	0.95	0.31	68.07	0.17	0.96	0.32
33	Uttar Pradesh	59.74	0.33	0.94	0.51	54.11	0.22	0.92	0.55	49.45	0.14	0.91	0.57
34	West Bengal	61.37	0.12	0.94	0.40	59.54	0.09	0.94	0.41	57.38	0.03	0.95	0.42

RS: Ratio Score; HK: Hansen Kuiper's score; POD: Probability of detection; FAR: False Alarm Rate.

Table 2 Skill scores of quantitative Rainfall forecast

SN	STATE	DAY-1		DAY-3		DAY-5	
		HR	HKQ	HR	HKQ	HR	HKQ
1	And. and Nico. Islands	0.52	0.03	0.50	0.02	0.52	0.04
2	Andhra Pradesh	0.52	0.07	0.47	0.02	0.45	0

3	Arunachal Pradesh	0.48	0.10	0.49	0.10	0.45	0.05
4	Assam	0.52	0.06	0.47	0.04	0.48	0.04
5	Bihar	0.47	0.07	0.42	0.03	0.40	0.01
6	Chhattisgarh	0.62	0.09	0.59	0.06	0.55	0.03
7	Diu	0.52	0.12	0.55	0.16	0.46	0.08
8	Delhi	0.59	0.15	0.62	0.17	0.61	0.16
9	Goa	0.38	-0.03	0.35	-0.03	0.30	-0.11
10	Gujarat	0.53	0.14	0.49	0.10	0.49	0.10
11	Haryana	0.57	0.14	0.57	0.13	0.54	0.11
12	Himachal Pradesh	0.60	0.15	0.59	0.14	0.58	0.13
13	Jammu and Kashmir	0.6	0.14	0.59	0.12	0.56	0.09
14	Jharkhand	0.58	0.11	0.53	0.06	0.54	0.06
15	Karnataka	0.51	0.06	0.49	0.04	0.48	0.02
16	Kerala	0.61	0.09	0.61	0.07	0.56	0.02
17	Lakshadweep	0.66	0.03	0.66	0.03	0.66	0.03
18	Madhya Pradesh	0.52	0.08	0.49	0.05	0.46	0.03
19	Maharashtra	0.51	0.06	0.48	0.04	0.46	0.03
20	Manipur	0.59	0.03	0.61	0.02	0.6	0.01
21	Meghalaya	0.57	0.04	0.57	0.01	0.52	-0.01
22	Mizoram	0.78	0.02	0.77	0.03	0.74	-0.01
23	Nagaland	0.16	0	0.14	-0.02	0.13	-0.03
24	Odisha	0.54	0.05	0.51	0.03	0.48	0.0
25	Pondicherry	0.50	0.04	0.52	0.09	0.45	0.03
26	Punjab	0.54	0.11	0.50	0.10	0.50	0.10
27	Rajasthan	0.62	0.14	0.59	0.10	0.58	0.10
28	Sikkim	0.59	0.05	0.53	-0.02	0.59	0.03
29	Tamil Nadu	0.55	0.07	0.50	0.04	0.49	0.03
30	Telangana	0.50	0.05	0.50	0.05	0.48	0.03
31	Tripura	0.69	0.04	0.68	0.02	0.66	0
32	Uttarakhand	0.51	0.08	0.49	0.06	0.51	0.08
33	Uttar Pradesh	0.54	0.15	0.47	0.09	0.43	0.06
34	West Bengal	0.51	0.06	0.48	0.04	0.47	0.02

HR: Hit Rate; HKQ: Hansen and Kuiper's score for Quantitative precipitation

Table 3 Skill scores of Cloud Amount

SN	STATES	DAY-1					DAY-3					DAY-5				
		Corr.	rmse	CR	US	UN	Corr.	rmse	CR	US	UN	Corr.	rmse	CR	US	UN
1.	And. and Nico. Islands	0.07	1.72	86.18	9.05	4.77	0.06	1.74	84.19	10.90	4.91	0.07	1.75	84.52	11.19	4.30
2.	Andhra Pradesh	0.31	2.02	79.48	11.64	8.88	0.32	2.02	79.94	11.53	8.53	0.04	2.27	74.73	12.08	13.19
3.	Arunachal Pradesh	0.48	2.13	79.59	8.70	11.72	0.53	2.17	78.27	7.07	14.66	0.30	2.16	77.0	11.75	11.26
4.	Assam	0.36	2.04	79.08	11.71	9.21	0.33	2.10	78.27	10.0	11.73	0.23	2.16	77.29	10.29	12.42
5.	Bihar	0.37	2.44	71.44	14.45	14.11	0.30	2.65	69.21	13.01	17.78	0.25	2.84	65.41	13.95	20.64
6.	Chhattisgarh	0.44	1.95	80.93	11.92	7.15	0.44	2.05	79.28	12.64	8.07	0.27	2.35	72.35	14.66	13.02
7.	Diu	0.37	2.25	73.64	12.73	13.64	0.38	2.22	69.09	19.09	11.82	0.26	2.39	70	15.45	14.55
8.	Delhi	0.45	2.40	68.18	15.46	16.37	0.40	2.67	68.64	13.64	17.73	0.43	2.61	73.19	11.82	15.0
9.	Goa	0.14	1.46	93.59	5.51	0.91	0.17	1.61	93.38	3.18	3.44	-0.02	1.59	89.11	7.45	3.44
10.	Gujarat	0.41	2.34	70.87	15.17	13.96	0.38	2.37	70.22	15.64	14.14	0.31	2.48	67.14	16.61	16.26
11.	Haryana	0.31	2.67	67.84	14.48	17.68	0.27	2.80	64.8	14.9	20.29	0.30	2.76	64.11	16.12	19.77
12.	Himachal Pradesh	0.38	2.74	65.57	16.25	18.18	0.34	2.88	61.36	18.05	20.59	0.35	2.80	60.84	20.63	18.52

13.	Jammu and Kashmir	0.22	3.06	57.8	18.96	23.24	0.15	3.36	55.62	17.95	26.44	0.14	3.23	56.83	18.49	24.68
14.	Jharkhand	0.50	2.05	81.82	7.99	10.19	0.37	2.28	75.67	12.0	12.33	0.24	2.53	71.93	12.66	15.41
15.	Karnataka	0.14	2.10	77.84	10.21	11.95	0.09	2.12	77.83	10.71	11.46	0.11	2.12	77.13	10.7	12.17
16.	Kerala	0.25	1.76	86.02	8.79	5.20	0.23	1.75	87.69	7.78	4.52	-.02	1.95	81.83	10.47	7.71
17.	Lakshadweep	0.28	1.626	88.46	9.42	2.13	0.28	1.64	87.85	10.01	2.13	0.07	1.80	82.69	12.76	4.55
18.	Madhya Pradesh	0.41	2.41	70.02	15.35	14.63	0.33	2.55	68.22	14.37	17.41	0.3	2.69	65.84	14.71	19.45
19.	Maharashtra	0.20	2.43	71.49	12.52	15.99	0.18	2.48	69.77	13.48	16.75	0.17	2.54	68.88	13.24	17.88
20.	Manipur	0.34	1.78	85.96	8.77	5.26	0.27	1.71	84.21	12.28	3.51	0.26	1.67	86.84	12.28	0.88
21.	Meghalaya	0.34	1.67	87.68	8.54	3.78	0.27	1.67	84.90	10.44	4.66	0.14	1.77	84.71	9.34	5.95
22.	Mizoram	0.06	1.61	90.28	6.30	3.42	0.01	1.57	91.85	4.85	3.30	-.08	1.48	91.09	6.46	2.46
23.	Nagaland	0.05	2.92	47.92	27.08	25	0.21	2.93	46.39	26.8	26.8	0.22	2.99	49.48	25.77	24.74
24.	Odisha	0.31	2.46	70.25	12.79	16.96	0.26	2.54	68.24	13.38	18.39	0.15	2.71	65.29	13.41	21.30
25.	Pondicherry	0.13	2.21	70.87	15.62	13.51	0.16	2.15	74.38	12.57	13.06	0.01	2.26	71.76	14.31	13.93
26.	Punjab	0.38	2.8	57.45	24.02	18.53	0.33	2.97	56.85	21.59	21.57	0.35	3.0	53.49	24.33	22.19
27.	Rajasthan	0.38	2.65	65.61	16.61	17.78	0.32	2.77	62.09	16.78	21.13	0.34	2.78	61.96	17.52	20.52
28.	Sikkim	0.28	2.39	73.67	11.34	15.0	0.23	2.52	70.30	12.17	17.54	0.28	2.28	71.95	12.14	15.91
29.	Tamil Nadu	0.11	2.48	65.45	17.37	17.18	0.11	2.47	64.87	17.52	17.61	-.01	2.62	62.47	17.48	20.06
30.	Telangana	0.30	2.40	73.36	11.0	15.64	0.23	2.43	73.63	10.34	16.04	0.09	2.57	72.92	8.19	18.89
31.	Tripura	0.30	1.51	92.11	5.27	2.63	0.19	1.56	90.79	5.71	3.51	0.06	1.61	89.92	7.02	3.07
32.	Uttarakhand	0.58	2.22	75.14	13.37	11.49	0.50	2.38	73.50	13.30	13.20	0.50	2.39	73.49	13.61	12.90
33.	Uttar Pradesh	0.42	2.41	70.14	15.43	14.42	0.41	2.56	66.79	15.54	17.67	0.34	2.72	64.79	14.75	20.46
34.	West Bengal	0.26	2.41	72.21	11.49	15.79	0.19	2.53	68.95	13.08	17.96	0.17	2.58	68.41	12.48	19.11

Corr: Correlation; Rmse: Root mean square error; CR: correct; US: Usable; UN: Unusable score.

Table 4 Skill scores of Maximum Temperature.

SN	STATES	DAY-1					DAY-3					DAY-5				
		Corr.	rmse	CR	US	UN	Corr.	rmse	CR	US	UN	Corr.	rmse	CR	US	UN
1.	And. and Nico. Islands	0.20	1.78	45.16	31.10	23.73	0.18	1.83	44.36	30.15	25.48	0.10	1.95	43.58	29.57	26.85
2.	Andhra Pradesh	0.61	2.59	34.54	27.00	38.46	0.40	3.0	29.68	27.86	42.46	0.28	3.11	28.62	22.30	49.08
3.	Arunachal Pradesh	0.49	3.18	25.43	23.26	51.31	0.48	3.40	26.79	25.0	48.21	0.44	3.68	24.03	18.64	57.34
4.	Assam	0.48	3.09	27.42	24.90	47.68	0.46	3.63	25.43	21.55	53.03	0.39	4.07	22.44	19.23	58.33
5.	Bihar	0.55	2.52	35.58	25.39	39.03	0.56	2.58	36.11	25.60	38.29	0.44	2.68	33.80	24.69	41.52
6.	Chhattisgarh	0.74	2.56	33.61	25.46	40.94	0.69	2.75	32.38	26.55	41.07	0.56	3.08	29.50	24.41	46.09
7.	Diu	0.59	1.93	55.05	22.02	22.94	0.6	1.77	55.96	21.1	22.94	0.5	1.93	49.54	22.02	28.44
8.	Delhi	0.73	2.54	35.26	25.24	39.51	0.69	2.55	32.97	28.92	38.12	0.57	2.88	38.96	21.11	39.93
9.	Goa	0.27	1.55	53.62	29.27	17.12	0.12	1.75	52.99	25.88	21.14	-0.19	1.91	51.81	25.15	23.05
10.	Gujarat	0.70	2.31	39.22	25.62	35.16	0.66	2.35	36.39	27.36	36.26	0.61	2.42	36.27	25.77	37.96
11.	Haryana	0.60	2.68	35.18	25.58	39.23	0.50	2.97	31.26	25.20	43.54	0.38	3.37	32.55	20.33	47.13
12.	Himachal Pradesh	0.45	4.57	11.33	13.33	75.34	0.43	4.6	12.49	12.65	74.86	0.22	4.84	14.30	11.01	74.70
13.	Jammu and Kashmir	0.54	3.17	29.93	20.90	49.17	0.55	3.11	26.06	21.95	51.98	0.29	3.55	24.28	18.41	57.32
14.	Jharkhand	0.73	2.45	36.48	25.77	37.74	0.67	2.55	34.65	26.99	38.36	0.54	2.90	32.52	23.61	43.87
15.	Karnataka	0.49	2.51	32.73	24.60	42.66	0.31	2.75	27.98	25.25	46.76	0.19	2.80	27.21	23.61	49.18
16.	Kerala	0.28	2.55	36.64	22.76	40.60	0.20	2.66	35.56	22.26	42.17	0.07	2.77	35.90	20.84	43.25
17.	Lakshadweep	-0.17	1.53	46.79	36.70	16.51	-0.09	1.51	48.93	32.41	18.65	0.05	1.46	47.40	36.39	16.21
18.	Madhya Pradesh	0.83	2.32	40.08	26.68	33.24	0.76	2.74	33.71	24.33	41.96	0.65	2.91	33.34	22.68	43.98
19.	Maharashtra	0.58	2.70	31.22	26.40	42.38	0.48	2.84	28.56	25.59	45.85	0.34	3.03	27.58	23.94	48.48
20.	Manipur	0.38	3.74	17.7	23.01	59.29	0.23	4.15	22.12	12.39	65.49	0.19	4.14	15.93	15.93	68.14
21.	Meghalaya	0.53	3.72	15.04	18.87	66.09	0.29	4.13	18.43	9.21	72.36	0.21	4.30	14.62	14.85	70.53
22.	Mizoram	0.58	2.42	37.93	32.76	29.31	0.42	3.11	30.36	25.0	44.64	0.15	3.74	25.93	24.07	50.0
23.	Nagaland	0.26	6.01	0.98	5.88	93.14	0.3	5.97	2.94	1.96	95.1	0.31	6.05	0	3.92	96.08
24.	Odisha	0.53	2.77	31.66	24.88	43.47	0.49	2.72	31.64	25.33	43.03	0.40	3.13	29.06	23.42	47.52
25.	Pondicherry	0.68	1.56	53.07	29.96	16.97	0.61	1.83	45.49	30.89	23.63	0.50	2.36	35.29	35.71	29.0

26.	Punjab	0.70	2.46	35.15	31.21	33.64	0.55	3.15	30.61	22.12	47.27	0.40	3.33	29.70	22.12	48.18
27.	Rajasthan	0.80	2.62	32.57	26.68	40.75	0.76	2.71	30.72	24.77	44.51	0.67	2.98	27.67	24.98	47.35
28.	Sikkim	0.58	3.61	9.0	13.45	77.55	0.38	3.81	12.74	16.52	70.75	0.26	3.88	12.46	11.58	75.96
29.	Tamil Nadu	0.60	2.78	35.18	25.20	39.61	0.45	3.09	30.86	24.63	44.50	0.37	3.29	28.79	23.13	48.08
30.	Telangana	0.70	2.46	39.94	25.30	34.76	0.48	2.89	30.15	26.84	43.01	0.37	2.91	31.46	24.22	44.32
31.	Tripura	0.53	3.11	15.46	24.26	60.29	0.43	3.27	16.32	14.55	69.13	0.27	3.50	15.43	18.96	65.61
32.	Uttarakhand	0.62	5.94	3.41	4.32	92.27	0.57	5.97	3.64	6.36	90.0	0.41	6.08	4.55	7.50	87.96
33.	Uttar Pradesh	0.77	2.49	34.65	26.26	39.09	0.72	2.59	31.24	30.11	38.66	0.58	2.92	26.61	28.20	45.19
34.	West Bengal	0.55	2.35	37.86	26.93	35.20	0.41	2.80	35.29	24.92	39.79	0.26	2.95	30.23	25.87	43.89

Corr: Correlation; Rmse: Root mean square error; CR: correct; US: Usable; UN: Unusable score.

Table 5 Skill scores of Minimum Temperature

SN	STATES	DAY-1					DAY-3					DAY-5				
		Corr.	rmse	CR	US	UN	Corr.	rmse	CR	US	UN	Corr.	rmse	CR	US	UN
1.	And. and Nico. Islands	0.13	1.62	49.20	31.31	19.49	0.07	1.67	48.22	30.49	21.30	0.0	1.70	45.38	32.32	22.30
2.	Andhra Pradesh	0.29	1.85	43.07	31.78	25.15	0.17	1.96	41.30	30.45	28.25	0.13	1.91	40.87	31.09	28.04
3.	Arunachal Pradesh	0.22	1.94	38.97	34.57	26.47	0.10	2.06	43.10	28.90	28.0	-0.02	2.15	38.79	33.04	28.17
4.	Assam	0.49	2.45	33.83	33.33	32.84	0.39	2.65	34.21	26.99	38.80	0.27	2.82	31.18	28.66	40.16
5.	Bihar	0.38	1.73	43.74	31.58	24.68	0.39	2.0	40.25	29.02	30.73	0.30	1.89	41.92	30.91	27.17
6.	Chhattisgarh	0.66	1.43	53.60	31.67	14.73	0.57	1.55	50.69	30.91	18.40	0.38	1.66	51.31	29.70	18.99
7.	Diu	0.79	0.95	73.39	22.94	3.67	0.81	0.91	75.23	23.85	0.92	0.79	0.93	74.31	22.94	2.75
8.	Delhi	0.56	1.91	38.26	33.62	28.12	0.48	2.04	46.55	23.92	29.54	0.27	2.32	34.08	33.63	32.29
9.	Goa	0.07	1.33	57.50	29.05	13.46	-0.14	1.48	48.23	35.63	16.15	-0.18	1.37	55.47	29.40	15.14
10.	Gujarat	0.68	1.46	58.02	26.51	15.47	0.68	1.44	56.57	28.20	15.22	0.64	1.49	55.08	28.65	16.27
11.	Haryana	0.42	2.55	37.79	32.66	29.55	0.44	2.62	34.48	30.52	35	0.39	2.72	32.62	27.61	39.76
12.	Himachal Pradesh	0.48	3.31	17.21	17.60	65.19	0.48	3.32	17.19	16.96	65.85	0.44	3.36	17.53	16.21	66.26
13.	Jammu and Kashmir	0.72	2.43	33.13	25.64	41.23	0.68	2.54	30.96	27.05	41.99	0.63	2.63	31.26	24.12	44.62
14.	Jharkhand	0.49	1.75	42.95	28.03	29.02	0.41	1.89	40.82	29.26	29.93	0.32	1.88	39.90	31.41	28.70
15.	Karnataka	0.27	1.76	43.88	26.85	29.27	0.15	1.76	44.17	27.67	28.16	0.06	1.77	43.87	26.889	29.24
16.	Kerala	0.24	2.12	45.11	18.78	36.11	0.19	2.14	46.12	18.45	35.43	0.08	2.22	43.25	20.48	36.27
17.	Lakshadweep	-0.07	1.61	47.84	26.24	25.93	0.09	1.58	47.84	30.25	21.91	0.08	1.60	45.06	30.56	24.38
18.	Madhya Pradesh	0.61	2.12	45.43	28.0	26.58	0.49	2.32	44.39	26.66	28.94	0.28	2.44	41.60	26.71	31.69
19.	Maharashtra	0.48	1.71	47.70	29.27	23.03	0.33	1.78	44.15	29.70	26.14	0.19	1.79	45.72	28.89	25.39
20.	Manipur	0.15	2.55	16.07	27.68	56.25	0.3	2.3	16.07	330.04	50.89	0.18	2.3	15.18	36.61	48.21
21.	Meghalaya	0.34	2.81	23.06	17.95	58.98	0.44	2.79	24.09	17.49	58.42	0.10	2.94	19.21	18.22	62.57
22.	Mizoram	0.09	7.42	6.04	21.55	72.42	0.15	7.44	6.25	16.07	77.68	-0.11	7.39	5.56	19.45	75.0
23.	Nagaland	0.08	6.27	0	0.96	99.04	0.01	6.21	0	0	100	-0.06	6.23	0.0	0.95	99.05
24.	Odisha	0.27	1.95	43.21	27.84	28.95	0.23	1.98	42.64	28.03	29.34	0.18	2.03	40.11	28.85	31.04
25.	Pondicherry	0.26	1.59	56.72	28.55	14.73	0.24	1.62	52.73	28.14	19.13	0.25	1.61	55.41	28.11	16.49
26.	Punjab	0.52	2.52	36.29	30.48	33.23	0.50	2.42	38.71	27.16	34.13	0.45	2.42	36.60	28.35	35.05
27.	Rajasthan	0.49	2.31	37.97	26.86	35.17	0.48	2.28	37.02	28.58	34.40	0.33	2.54	35.48	25.20	39.32
28.	Sikkim	0.36	1.46	46.12	39.07	14.82	0.12	1.63	45.21	34.32	20.48	0.12	1.63	45.72	30.06	24.23
29.	Tamil Nadu	0.35	2.29	40.08	26.21	33.71	0.30	2.30	41.01	24.50	34.49	0.25	2.33	41.14	24.67	34.19
30.	Telangana	0.40	1.91	38.97	30.72	30.32	0.20	1.99	38.33	29.0	32.67	0.06	2.02	38.65	29.95	31.40
31.	Tripura	0.40	2.71	5.76	21.74	72.51	0.37	2.75	5.31	22.65	72.05	0.30	2.75	5.75	22.18	72.07
32.	Uttarakhand	0.44	4.82	5.07	8.99	85.94	0.34	4.96	5.53	10.14	84.33	0.27	4.92	6.22	8.99	84.80
33.	Uttar Pradesh	0.47	2.35	39.57	25.86	34.58	0.43	2.79	38.06	27.36	34.58	0.26	2.92	37.40	25.46	37.15
34.	West Bengal	0.31	1.56	53.79	29.14	17.07	0.24	1.67	51.63	28.85	19.51	0.21	1.63	51.32	29.12	19.56

Corr: Correlation; Rmse: Root mean square error; CR: correct; US: Usable; UN: Unusable score.

4.4. Categorical and Quantitative Rainfall Verification

The skill of categorical verification for yes/no rainfall from day1 to day5 (Table.1) shows The Ratio Score for day1 to day5 forecast verification shows very high skill score i.e., 50 to 90% over all the states. HK score also good i.e., in day1 0.05-0.36 over all the states, in day3 it varies from 0.03-0.36, except Mizoram, Nagaland and Sikkim. In day5 also HK is good (0.07-0.82) except Mizoram, Nagaland and Meghalaya. POD is also very high from day1 to day5 i.e., 0.7 to 1.0. FAR is also very less i.e., less than 0.6 from day1 to day5.

The Quantitative rainfall verification from day1 to day5 (Table.2) shows HR score is very high i.e., 0.4 to 0.78 over all the states except Goa and Nagaland. HKQ score also shows positive skill over all the states but Andhra-Pradesh, Goa, Meghalaya, Mizoram, Odessa, Tripura and Nagaland show less skill.

4.5. Cloud amount

The results of cloud amount verification from day1 to day5 (Table.3) are as follows, there is positive correlation (corr: 0.1 to 0.5) over all the states, except Andaman-Nicobar, Goa, Kerala, Tamilnadu, Mizoram and Nagaland (corr<0.1). RMSE is also less for all the days over all the states (RMSE<= 3 octa) but Jammu and Kashmir and Punjab state shows RMSE>3 octa. From day1 to day5 all the states are under usable (i.e., unusable < 50%) category.

4.6. Maximum and Minimum Temperature

Maximum Temperature verification results from day1 to day5 (Table.4) shows positive correlation over all the states except Lakshadweep and Goa. In day1 verification 24 states shows less RMSE (<3ºC) and 10 states (Arunachal Pradesh, Assam, Himachal-Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Nagaland, Tripura, Uttarakhand, and Sikkim) show high RMSE (>3ºC). In day3 verification 13 states (Arunachal-Pradesh, Bihar, Himachal-Pradesh, Jammu & Kashmir, Manipur, Nagaland, Meghalaya, Sikkim, Uttarakhand) show high RMSE (>3ºC) and 21 states having less RMSE (<3ºC). Similarly in day5 verification 18 states (particularly Nagaland and Uttarakhand shows large bias i.e., RMSE>5ºC) show high RMSE (>3ºC) and 16 states having less RMSE (<3ºC). In case of Usable & Unusable, in day1 verification 8 states unusable (i.e., unusable > 50%) and 26 states are under usable (i.e., unusable < 50%) category. In day3 verification 13 states show high RMSE (>3ºC) and 21 states having less RMSE (<3ºC). Similarly in day5 verification 10 states are unusable (unusable i.e., > 50%) and 24 states are usable (i.e., unusable < 50%) category.

The Minimum Temperature verification results from day1 to day5 (Table.5) shows day5 all the states are showing positive correlation, except Lakshadweep, Goa. RMSE also less over 30 states (<3ºC) and 4 states (Himachal-Pradesh, Jammu & Kashmir, Mizoram, Nagaland, Uttarakhand) shows high RMSE (>3ºC). In case of Usable & Unusable, 7 states unusable (i.e., unusable > 50%) and 27 states are under usable (i.e., unusable < 50%) category.

5. CONCLUSIONS

The comparative study by using the observed and forecasted (bias free using DWM and direct) maximum and minimum temperature data for Indian window and different Indian regions has shown that the bias free technique DWM has highly improved the temperature forecast.

The forecast for yes/no rainfall and quantitative rainfall, cloud amounts, bias free maximum and minimum temperature are having high skill for almost all the states and Day1 to Day5 forecasts, as is clear from the tables, except for the oceanic islands and high terrains. Hence the forecasts for these four weather parameters can be issued almost without any further value addition for all the blocks.

Although forecasts are generated for maximum/minimum relative humidity and wind speed and wind direction also and put on ftp server and web site, but for this quite a lot value addition is required especially for minimum relative humidity and wind direction, hence this may only be attempted for the certain experimental blocks and not for all.

These forecasts are put on the ftp server and website of India Meteorological Department that is www.imd.gov.in .

In the era of high resolution models for down scaling the forecast up to any level (i.e., district, blocks and village level) is going to give the forecast of almost of the same skill. More over the forecasts have become skillful up to day five to seven, of course with a slight decrease in skill. Hence forecasts can easily be issued up to day-5.

The difficult orography regions i.e., high terrain areas and oceanic islands have shown the problems in the skill of the forecast. This is a typical problem for which the NWP models needs to be improved based upon the results obtained from the special projects like Himalayan Meteorology and Coupled Ocean Atmospheric model. The alternative procedure for obtaining the bias free forecast i.e. decaying weighted mean (DWM) had been applied in this paper, which had solved the problem up to a large extent. But for the improvement in the rainfall forecast Model Output Statistics (MOS) guidance using neural network technique would be applied in future.

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