MAUSAM, **68**, 1 (January 2017), 23-40

551.509.313

Block level weather forecast using direct model output from NWP models during monsoon season in India

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(*Received 4 November 2015, Accepted 7 September 2016*)

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सार – भारत के 655 जिलों तथा 6500 प्रखंड़ों के लिए पूर्वानुमान तैयार किया गया और 1 जून, 2014 से इसे लागू कर दिया गया है। भारत में जिलों तथा प्रखण्ड़ों के लिए पूर्वानुमान प्राप्त करने की प्रक्रिया ऊँचाई संशोधन सहित टी-574 मॉड़ल के नियमित (0.25×0.25) ग्रिड और 9 कि.मी डब्ल्यू आर एफ मॉडल के परिणाम पर आधारित है भारतीय परिप्रेक्ष्य (0-40° उ. और 60-100° उ.) में 0.25×0.25 डिग्री ग्रिड़ पर वर्षा पूर्वानुमान के लिए एक सत्यापन अध्ययन भी किया गया है जिससे पता चला है कि महासागरीय द्वीपों तथा उच्च तराई वाले क्षेत्रों को छोड़कर देश के सभी भागों के लिए वर्षा पूर्वानुमान की दक्षता अच्छी रही है और इसे नीचे के किसी स्तर तक प्रखंड के स्तर तक भी देखे तो स्किल स्कोर्स में कोई भिन्नता नहीं होगी। मौसम के सभी आठ प्राचलों जिनका पूर्वानुमान दिया गया है का प्रखंड़ स्तर पर दिए गए पूर्वानुमान की दक्षता के लिए विस्तृत सत्यापन अध्ययन किया गया है। निरपेक्ष पूर्वानुमान तथा हॉ /नहीं पूर्वानुमान के लिए वर्षा पूर्वानुमान की दक्षता प्राप्त की गई है। वर्षा के स्किल स्कोर्स से पता चला है कि हॉनसेन एण्ड कूइपर (HK) स्कोर का उच्चतम मान 0.44 मात्रात्मक वर्षा का हॉनसेन एण्ड कूइपर (HKQ) स्कोर 0.18, हॉ/नहीं पूर्वानुमान का अनुपाती स्कोर 90 प्रतिशत और हिटरेट (HR) 0.83 है। इस शोध पत्र मे 2014 के मानसून में प्रखण्ड़ स्तर पर दिए गए मौसम पूर्वानुमान का व्यापक सत्यापन अध्ययन प्रस्तुत किया गया है और प्राप्त की गई दक्षता अच्छी रही है। इस शोध से यह पता चला है कि इस मॉड़ल पूर्वानुमान में ऐसी क्षमता है जिसमें तात्कालिक मान जोड़ने के बाद प्रखंड स्तर का पूर्वानुमान देने के लिए उपयोग किया जा सकता है जिसके संकेत शोध पत्र के उपसंहार में दिए गए है।

ABSTRACT. The forecast for 655 districts and 6500 blocks had been prepared and implemented on 1st June, 2014. The procedure for getting forecast for the districts and blocks in India including altitude corrections is based upon regular (0.25 × 0.25) grid output from the T-574 Model and output from 9 km WRF model. A verification study for rainfall forecast at 0.25 × 0.25 degree grid for Indian Window (0-40° N and 60-100° N) is also conducted, which had indicated that skill of the rainfall forecast is good for all parts of the country except oceanic islands and high terrain regions and one can down scale to any level, down to the blocks, the skill scores will not differ much. A detailed verification study for the skill of the forecast at block level for all the eight weather parameters for which the forecast was issued is conducted. The skill of the rainfall forecast is obtained for categorical forecast and as well as for yes/no forecast. The skill scores for rainfall had indicated that highest value of Hanssen and Kuiper (HK) score is 0.44, Hanssen and Kuiper score for quantitative rainfall (HKQ) is 0.18, Ratio score for yes/no forecast is 90 percent and Hit rate (HR) is 0.83. The detailed verification study for the block level weather forecast for monsoon 2014 is presented in the paper and the skill found is good. The study indicates that model forecast has the potential to be used for the block level forecast after making the quick value additions for which hints are given in the conclusion part.

Key words – Blocks, Block level weather forecast, T-574, WRF, Skill scores, Quick, Value addition.

1. Introduction

Historically, a weather forecast in India was mainly 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. Hence 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). An R-40 general circulation model with a resolution of 2.8° × 1.8° was installed for this purpose in 1989 and a T-80 general circulation model with a higher resolution of

1.5° × 1.5° was made operational in 1993. In 2002, a T-170 general circulation model with a still higher resolution 0.7° × 0.7° was made experimentally operational. In 2007, a T-254 general circulation model with a much higher resolution 0.5° × 0.5° has been made operational (Ashok Kumar *et. al*., Ph.D Thesis, 2010). Later on T-382 with a higher resolution of 0.3° × 0.3° was implemented and then T-574 with a much higher resolution of 0.2° × 0.2° was implemented both at NCMRWF and India Meteorological Department (IMD). At present T-574, a higher resolution model is being used for the operational forecast at IMD and in the present study output from this model along with the output from WRF, a 9 km horizontal resolution model, is used.

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 eight surface weather parameters, *viz*., Rainfall, Cloud amount, Maximum Temperature, Minimum Temperature, Maximum Relative Humidity, Minimum Relative Humidity, Wind Speed and Wind Direction is directly obtained from the general circulation model T-574 operational at IMD for six days and also from the regional model WRF for first three days. One day is used for running the model and obtaining the weather forecast and then the forecast for five days (2^{nd} to 6^{th} day forecast) is issued every day for all the eight weather parameters, out of which first two days weather forecast is taken from WRF model except for rainfall and cloud amount, which is from T-574 model for all the five days. This hybrid forecast is used for generating the block level weather forecast, as the forecast from WRF model had been found to be better for all the weather parameters except for rainfall and cloud amount.

There had been great demand from agriculture scientists and farmers for the weather forecast at sub-district scale that is 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. The details about the data used, methodology followed in forecast generation and its verification, the results and discussion and conclusion are explained in the following sections.

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-574 and WRF models is used. First the outputs are obtained for the Indian window (0-40° N and 60-100° E) and then the forecast is obtained for the eight weather parameters by downscaling the weather forecast explained in the methodology followed. The basic data about the two models used for generating the weather forecast is given in the following sections.

2.2.1. *T-574 model*

The NCEP GFS run at 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; Moorthi *et al.*, 2001, Durai *et al.*, 2010; Saha *et al.*, 2010). This GFS model is conforming to a dynamical framework known as the Earth System Modeling Framework (ESMF) and its code was restructured to have many options for updated dynamics and physics. Details about the GFS Model are available at http://www.emc.ncep.noaa.gov/GFS/doc.php. The GFS T574L64 (~25 km in horizontal over the tropics), adopted from National Centre for Environmental Prediction (NCEP), was implemented at IMD, New Delhi on IBM based High Power Computing Systems (HPCS; Durai *et al*., 2011). The assimilation system (for GFS T574) is a global 3-dimensional variational technique, based on NCEP Grid Point Statistical Interpolation (GSI *3.0.0*; Kleist *et al.*, 2009) scheme, which is the next generation of Spectral Statistical Interpolation (SSI; David *et al*., 1992). The details about model physics and dynamics are discussed in the recent study by Durai and Roy Bhowmik, (2013). The major changes incorporated in T574 GDAS compared to T382 GDAS are : use of variational quality control, flow dependent re-weighting of background error statistics, use of new version of Community Radiative Transfer Model (CRTM 2.0.2), improved TC relocation algorithm, changes in the land, snow and ice skin temperature and use of some new observations in the assimilation cycle.

In the operational mode, the Global Data Assimilation (GDAS) cycle runs 4 times a day (0000 UTC, 0600 UTC, 1200 UTC and 1800 UTC). The analysis and forecast for seven days are performed using

the HPCS installed in IMD Delhi. One GDAS cycle and seven days forecast (0 -168 hour) at T382L64 (~ 35 km in horizontal over the tropics) takes about 30 minutes on IBM Power 6 (P6) machine using 20 nodes with 7 tasks (7 processors) per node, while the same for GFS T574 (~ 25 km in horizontal over the tropics) is approximately 1 hour 40 minutes. Details of data presently being processed for GFS at IMD are available at http://www.imd.gov.in/section/nhac/dynamic/ data_coverage.pdf .

2.2.2. *WRF model*

ARW (Advanced Research WRF) version of WRF model, developed by National Center for Atmospheric Research (NCAR), USA, is widely used in IMD for day-to-day forecasting over Indian region. The whole mesoscale modeling system in IMD is also consisting of assimilation component WRF Data Assimilation (WRFDA). This is a unified variational data assimilation system built within the software framework of the WRF-ARW model, used for application in both research and operational environments (WRF ARW Version 3.4 Modeling System Users's Guide 2012). The "cold-start" mode of assimilation at each specified time is presently adopted for WRFDA system to yield mesoscale analysis. The processed observational data from different sources are assimilated in mesoscale analysis system WRFDA to improve the first guess attained from the global analysis generated from operational global data assimilation system (GDAS). The WRFDA background error covariance for a month is estimated through the National Meteorological Center (NMC) method, which utilized WRF model forecasts generated during the specified month of previous year. The observational data from GTS and other local data (Automatic Weather Station and Pilot observations) after decoding and quality control has been pre-processed to create PREPBUFR files (in NCEP-BUFR format) which is used as an input to WRFDA system. Observations are accumulated within ±3 hour time-window from a specific hour to generate corresponding PREPBUFR file. In the assimilation system, available observations (except satellite radiances as those are already assimilated in GDAS) over a domain (23° S to 46° N; 40° E to 120° E; covering region of Delhi RSMC - Regional Specialized Meteorological Center) are ingested to create improved mesoscale analysis.

Data assimilation is done only in mother domain with 9 km horizontal resolution and 45 vertical eta levels. Using mesoscale analysis as its initial condition, twice daily at 0000 and 1200 UTC, WRF-ARW model has been integrated for 75 hours. The boundary condition from global forecasts generated by GFS (Global Forecasting System) in IMD has been suitably updated to get a consistency with mesoscale analysis. The model forecasts during the summer monsoon season over the region have been verified rigorously following the recommendation of WWRP/WGNE (World Weather Research Programme/Working Group of Numerical Experimentation; WMO, 2008). The performance verification of the WRF forecasts has been carried out in the annual reports of monsoon published in IMD from the year 2010 to 2014 (Das *et al*., 2011; Pattanaik *et al*., 2012; Roy Bhowmik *et al*., 2013; Rama Rao *et al*., 2015). The verification practice in IMD using continuous and categorical scores within a framework of neighbourhood technique has limitation in evaluating model performance at higher resolution (Hogan *et al*., 2010). Therefore, recently Das *et al*. (2014, 2015) evaluated model forecasts using object oriented verification technique contiguous rain area (CRA) method and found out that the forecast error has large contribution from displacement compared to pattern and volume errors.

3. Methodology

3.1. *Skill of rainfall forecast over Indian window (0-40° N and 60-100° E)*

The observed and forecasted rainfall values (from GFS T-574 output) at the regular grid of 0.25 × 0.25 degree resolution for Indian window 0-40° N and 60-100° E, were verified. For this two scores, *viz*., Ratio score and Hanssen and Kuiper's score was calculated for yes/no rainfall and two scores, *viz*., Hit rate (HR) and Hanssen and Kuiper's score quantitative precipitation (HKQ) was calculated for rainfall amounts for monsoon season 2014.

3.2. *Downscaling procedure*

Rainfall and cloud amount forecast was provided by using 25 km resolution general circulation model, GCM (T-574 model) for six days that is five forecast days. Forecast for other weather parameters up to 3-days (two forecast days) was provided by using the 9 km WRF model. Forecast for other weather parameters for day-3, day-4 and day-5 was provided by using 25 km resolution GCM (T-574) model.

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

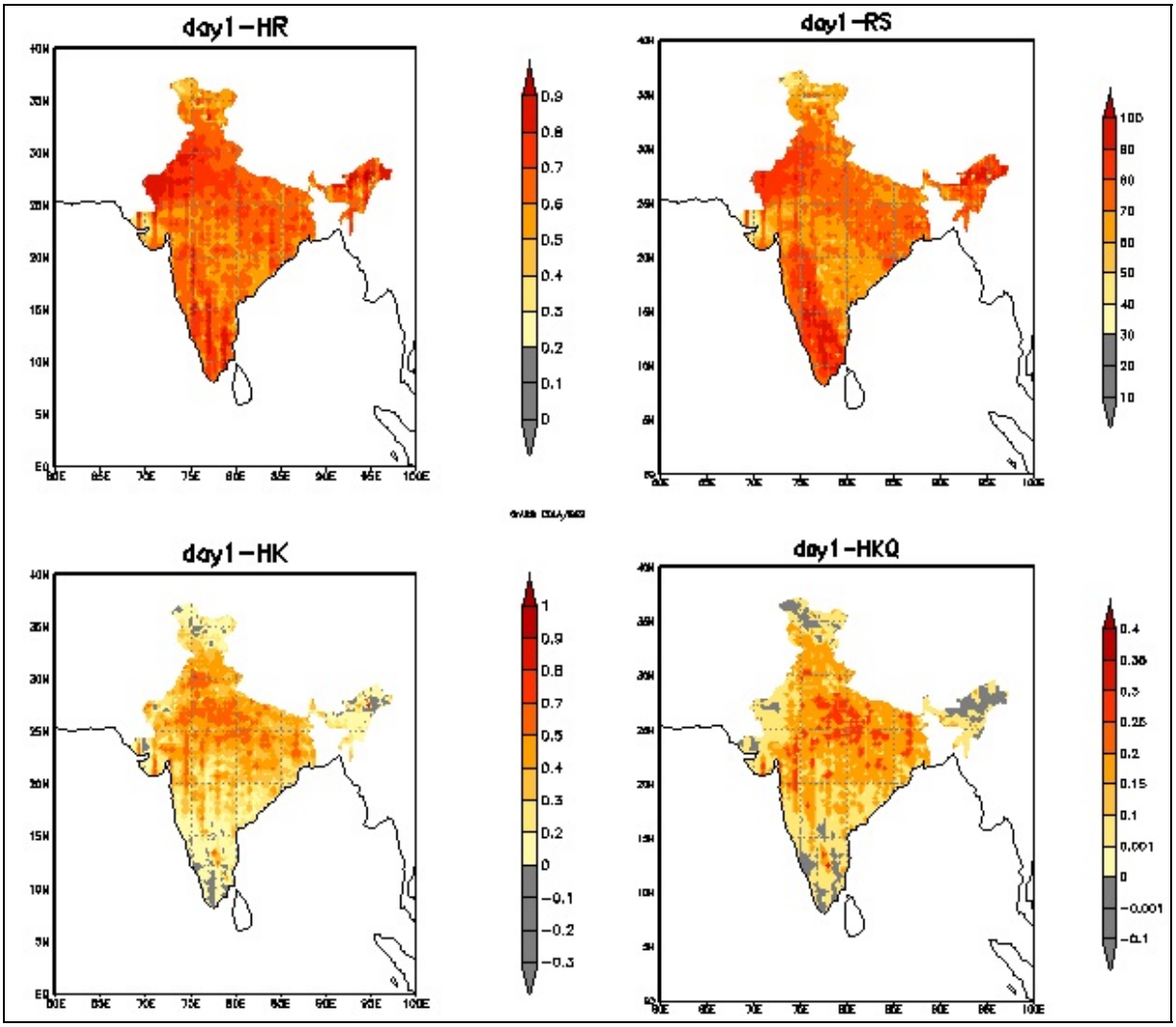

Fig. 1. Skill Scores for fall day1 rain forecast over Indian region during summer monsoon season

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 Fig. 1 (Ashok Kumar *et. al.*, 2000). This procedure is followed for T-574 model forecast and the average for four point surrounding the station is taken for WRF model as this is very high resolution that is 9 km × 9 km.

It is hereby mentioned that as the district boundaries are available, hence the average of the forecasts at the grid point falling with in the district boundaries are used for obtaining the district level forecast from GFS T-574 model output. Although the districts falling in the high terrain regions and all the block level forecasts are based upon the above mentioned technique.

Weather Forecasts are given for the eight weather parameters Rainfall (mm), Maximum Temperature (°C), Minimum Temperature (°C), Total cloud cover (Octa), Maximum and Minimum Relative Humidity (%) and Wind Speed (kmph) and direction.

3.3. *Forecast verification procedures*

3.3.1. *Skill scores used for verification*

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

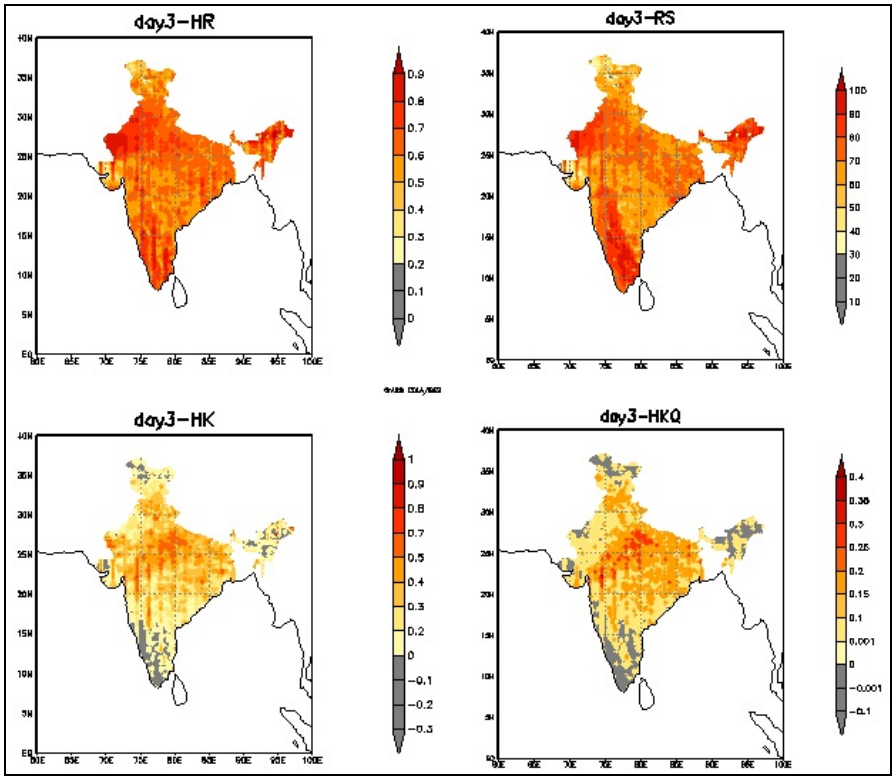

Fig. 2. Skill scores for fall day3 rain forecast over Indian region during summer monsoon season

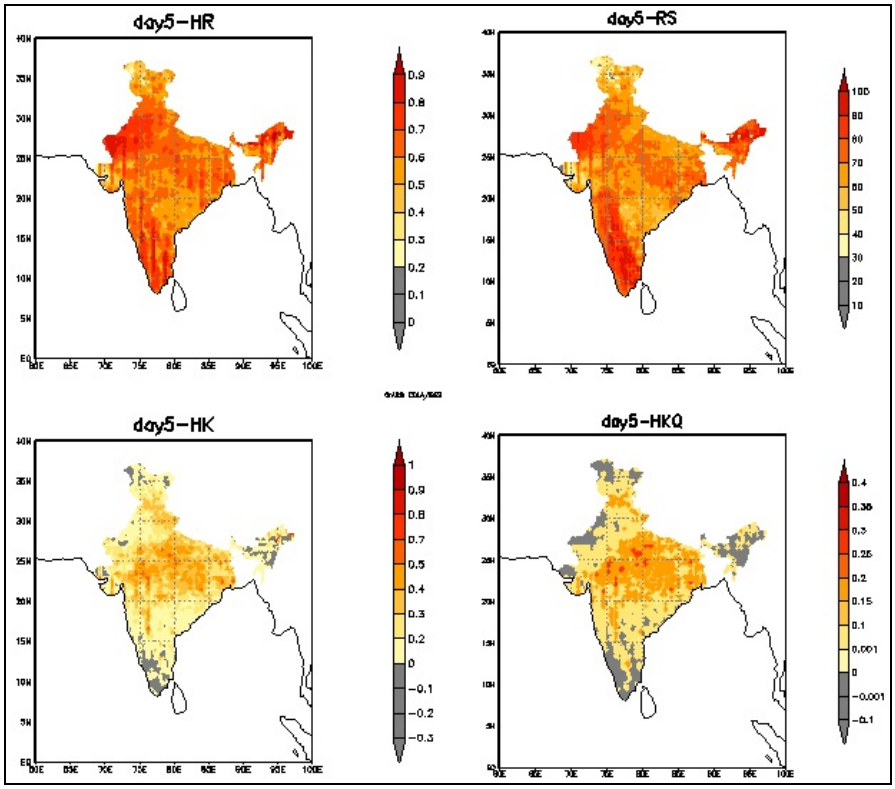

Fig. 3. Skill scores for fall day5 rain forecast over Indian region during summer monsoon season

3.3.2. *Error structure for different variables*

Parameter	*error structure*
Rainfall	if observed r/f is out by Correct:- Diff ≤ 2.5 mm for ≤ 10 mm Diff ≤ 25% of observed for > 10 mm Usable:- 2.5 mm < Diff ≤ 5 mm for ≤ 10 mm 25% of observed < Diff ≤ 50% of observed for > 10 mm Unusable:- Diff > 5 mm for ≤ 10 mm Diff > 50% of observed for > 10 mm
Temperature	for observed maximum or minimum temperature + 1 °C correct + 2 °C usable >± 2 °C incorrect
Relative humidity	± 10% correct +-20% usable >± 20% incorrect
Wind direction	± 30 degree correct + 40 degree usable >± 40 degree incorrect
Wind speed	± 2 m/s correct +-4 m/s usable >± 4 m/s incorrect
Cloud cover	± 2 octa correct + 3 octa usable >± 3 octa incorrect

4. Results and discussion

4.1. *Skill of rainfall forecast over Indian window (0-40° N and 60-100° E)*

The observed and forecasted rainfall values(from GFS T-574 output) at the regular grid of 0.25 × 0.25 degree resolution for Indian window 0-40° N and 60-100° E were considered and skill scores are calculated for the above mentioned Indian Window. For this Ratio score and Hanssen and Kuiper's score was calculated for yes/no rainfall and Hit rate (HR) and Hanssen and Kuiper's score quantitative precipitation (HKQ) was calculated for rainfall amounts for monsoon season 2014. These scores are plotted as Fig. 1 to Fig. 3 for Day-1, Day-3 and Day-5. The scores are good the highest value of Hanssen and Kuiper (HK) score is 0.44, Hanssen and Kuiper score for quantitative rainfall (HKQ) is 0.18, Ratio score for yes/no forecast is 90 percent and Hit rate (HR) is 0.83.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 scores found are good.

4.2. *Verification for block level weather forecast*

The verification study is conducted for all the blocks for which data was readily available from the 30 states and from the remaining five states no data at block level could be obtained. The skill for rainfall (Yes/No) rainfall forecast, cloud amount, Maximum relative humidity and wind speed are good for almost all the states and almost no human intervention is required for the improving the forecast. But for the remaining weather parameters the human intervention that is the quick value addition for improving the skill of the forecast is required for improving the skill for some of the states. The detail about the quick value addition and scope for improvement is given in conclusion part of the paper.

The detail about the skill scores (Table 1 to 10) found are given in the following paragraphs;

Rainfall

Day 1 : RS : The forecast for yes/no rainfall is having high skill score (60 – 90.5%) over all the states. HK : HK is also good (0.07-0.44) over all the states except 2 states. POD : All the states are having very high (0.60-1) POD. FAR : Except 7 states the remaining states have very less (0.06-0.42) False alarm rate.

Day 3 : RS : The forecast for yes/no rainfall is having high skill score (58 – 91.1%) over all the states. HK: HK is also good (0.07-0.44) over all the states except 2 states. POD : All the states are having very high (0.60-1) POD except Delhi (0.44). FAR : Except 7 states, the remaining states have very less (0.06-0.42) False alarm rate.

Day 5 : RS : The forecast for yes/no rainfall is having high skill score (60 – 91.1%) over all the states, but on 5 states RS is less (RS<58). HK : HK is also less on 5 states, the remaining states HK is good (0.04-0.40). POD: All the states are having very high (0.50-1) POD except 3 states. FAR : Here 8 states having high FAR, the remaining states have very less (0.06-0.42) False alarm rate.

TABLE 1

Skill score for rainfall

S. No.	States	DAY-1				DAY-3				DAY-5			
		RS	HK	POD	FAR	RS	HK	POD	FAR	RS	HK	POD	FAR
1.	And. and Nico. Islands	70.33	0.06	0.97	0.29	70.33	0.06	0.97	0.29	70.33	0.06	0.96	0.3
2.	Andhra Pradesh	63.16	0.28	0.67	0.49	59.56	0.17	0.54	0.52	55.98	0.13	0.57	0.53
3.	Arunachal Pradesh	75.44	0.13	0.96	0.24	76.32	0.11	0.98	0.23	75.44	0.08	0.98	0.24
4.	Assam	66.46	0.21	0.84	0.27	63.21	0.14	0.82	0.30	61.46	0.07	0.83	0.32
5.	Bihar	65.80	0.32	0.79	0.39	61.89	0.24	0.80	0.42	56.18	0.10	0.81	0.47
6.	Chhattisgarh	71.11	0.33	0.81	0.27	63.53	0.19	0.69	0.32	67.58	0.26	0.76	0.29
7.	Delhi	65.59	0.28	0.61	0.61	65.16	0.16	0.44	0.64	63.31	0.12	0.41	0.67
8.	Goa	90.58	0.41	0.96	0.06	88.64	0.44	0.94	0.07	87.94	0.30	0.96	0.09
9.	Gujarat	69.13	0.44	0.87	0.47	66.86	0.41	0.86	0.49	66.53	0.40	0.85	0.47
10.	Haryana	72.35	0.37	0.63	0.61	76.32	0.37	0.57	0.56	70.70	0.13	0.36	0.69
11.	Himachal Pradesh	65.9	0.32	0.64	0.34	66.80	0.36	0.72	0.35	65.26	0.23	0.73	0.4
12.	Jammu and Kashmir	63.67	0.30	0.72	0.51	64.78	0.26	0.58	0.49	57.38	0.14	0.58	0.56
13.	Jharkhand	66.21	0.31	0.81	0.36	58.92	0.17	0.74	0.41	56.06	0.12	0.74	0.43
14.	Karnataka	72.53	0.26	0.83	0.29	71.6	0.21	0.80	0.3	70.83	0.20	0.79	0.31
15.	Kerala	81.48	0.26	0.91	0.14	76.37	0.13	0.86	0.17	78.02	0.21	0.86	0.15
16.	Lakshadweep	67.99	0.07	0.94	0.30	70.46	0.14	0.96	0.29	65.15	0.04	0.91	0.32
17.	Madhya Pradesh	69.8	0.41	0.77	0.39	68.06	0.36	0.71	0.40	66.31	0.32	0.68	0.42
18.	Maharashtra	71.56	0.34	0.83	0.32	68.84	0.29	0.79	0.35	69.1	0.27	0.76	0.34
19.	Meghalaya	77.63	0.07	0.89	0.14	75.87	0.16	0.85	0.12	77.63	0.04	0.9	0.14
20.	Mizoram	78.95	0	1	0.21	74.56	-.06	0.94	0.22	79.82	0.02	0.98	0.19
21.	Nagaland	67.53	0	1	0.32	70.13	0.04	1	0.3	67.95	0.02	0.98	0.32
22.	Odisha	67.18	0.20	0.92	0.33	66.45	0.19	0.91	0.33	64.80	0.14	0.93	0.35
23.	Punjab	72.78	0.39	0.62	0.56	70.48	0.37	0.64	0.57	67.54	0.25	0.53	0.63
24.	Rajasthan	76.8	0.44	0.67	0.51	76.44	0.40	0.62	0.52	74.87	0.26	0.44	0.54
25.	Sikkim	88.39		0.88	0	91.07		0.91	0	94.69		0.95	0
26.	Tamil Nadu	69.04	0.3	0.60	0.63	64.03	0.16	0.52	0.70	61.76	0.18	0.59	0.69
27.	Tripura	68.86	0.11	0.83	0.22	67.54	0.12	0.8	0.23	63.15	0.04	0.76	0.25
28.	Uttarakhand	65.45	0.36	0.74	0.33	65.44	0.33	0.83	0.37	65.0	0.31	0.81	0.37
29.	Uttar Pradesh	61.83	0.37	0.88	0.54	60.48	0.34	0.86	0.55	56.77	0.288	0.86	0.58
30.	West Bengal	69.66	0.22	0.93	0.30	66.62	0.14	0.91	0.32	65.03	0.08	0.94	0.34

Note : RS : Ratio Score ; HK: Hanssen and Kuiper score

Quantitative rainfall verification

Day 1 : HR : Hit rate is less over Meghalaya (0.45) the remaining states having very high (0.5-0.83) HR. HKQ : Here HKQ is less over 4 states, the remaining states HKQ is high (0.02-0.17). Usable & Unusable: Here 9 states are unusable (*i.e.*, unusable > 50) and the remaining 21 states are usable (*i.e.*, unusable < 50).

Day 3 : HR : Except 4 states the remaining 26 states having very high (0.5-0.83) HR. HKQ : Here HKQ is less on 3 states, the remaining 27 states have high (0.02-0.17)

TABLE 2

Skill score for rainfall

S. No.	States	DAY-1		DAY-3		DAY-5	
		HR	HKQ	HR	HKQ	HR	HKQ
1.	And. and Nico. Islands	0.55	0.02	0.56	0.02	0.54	0.01
2.	Andhra Pradesh	0.58	0.10	0.57	0.07	0.53	0.05
3.	Arunachal Pradesh	0.5	0.11	0.45	0.08	0.42	0.06
4.	Assam	0.56	0.09	0.51	0.05	0.48	0.03
5.	Bihar	0.59	0.14	0.55	0.10	0.49	0.05
6.	Chhattisgarh	0.60	0.14	0.54	0.07	0.56	0.11
7.	Delhi	0.62	0.09	0.62	0.04	0.63	0.05
8.	Goa	0.49	0.14	0.42	0.08	0.41	0.03
9.	Gujarat	0.63	0.18	0.59	0.14	0.61	0.15
10.	Haryana	0.7	0.10	0.74	0.10	0.69	0.04
11.	Himachal Pradesh	0.58	0.13	0.58	0.14	0.58	0.08
12.	Jammu and Kashmir	0.59	0.11	0.59	0.09	0.53	0.06
13.	Jharkhand	0.59	0.13	0.54	0.08	0.52	0.07
14.	Karnataka	0.57	0.10	0.55	0.09	0.55	0.07
15.	Kerala	0.56	0.11	0.48	0.05	0.52	0.07
16.	Lakshadweep	0.60	0.03	0.63	0.06	0.57	0.01
17.	Madhya Pradesh	0.62	0.17	0.62	0.15	0.60	0.13
18.	Maharashtra	0.57	0.14	0.54	0.11	0.56	0.11
19.	Meghalaya	0.45	-0.01	0.46	0.00	0.46	0.01
20.	Mizoram	0.66	0	0.6	-0.03	0.65	-.01
21.	Nagaland	0.58	0.01	0.62	0.02	0.64	0.04
22.	Odisha	0.55	0.08	0.55	0.08	0.53	0.06
23.	Punjab	0.70	0.12	0.67	0.11	0.66	0.09
24.	Rajasthan	0.73	0.15	0.73	0.13	0.72	0.09
25.	Sikkim	0.83	0	0.83	0	0.88	0
26.	Tamil Nadu	0.67	0.08	0.62	0.04	0.60	0.04
27.	Tripura	0.59	0.06	0.57	0.04	0.52	0.01
28.	Uttarakhand	0.59	0.16	0.57	0.13	0.54	0.11
29.	Uttar Pradesh	0.57	0.14	0.56	0.13	0.52	0.10
30.	West Bengal	0.5	0.09	0.55	0.05	0.53	0.03

Note : HR : Hit rate for quantity of rainfall (0-0.1, 0.1-35, 35-125, >125 mm); HKQ : Hanssen and Kuiper's score for quatity of rainfall

HKQ. Usable & Unusable : 10 states are unusable the remaining 20 states are usable.

Day 5 : HR : Hit rate is less on 4 states, the remaining 26 states having very high (0.5-0.88) HR. HKQ : All the states have good (0.02-0.13) HKQ, except 5 states. Usable & Unusable : Except 13 states, remaining 17 states are usable.

Maximum temperature

Day 1 : Correlation : we can find positive correlation over all the states, but 8 states having less correlation, *i.e.*, corr < 0.5 the remaining states are having high (corr > 0.5) correlation. RMSE : 23 states are having less RMSE ≤ 3 and 7 states having high RMSE > 3. Usable & Unusable: we got 11 states unusable

TABLE 3

Skill score for rainfall

S. No.	States	DAY-1			DAY-3			DAY-5		
		CR	US	UN	CR	US	UN	CR	US	UN
1.	And. and Nico. Islands	19.77	21	59.22	19.25	15.35	65.40	17.11	18.18	64.70
2.	Andhra Pradesh	60.24	13.48	26.26	61.86	13.71	24.42	58.57	13.82	27.60
3.	Arunachal Pradesh	16.67	19.3	64.04	14.91	8.77	76.32	12.28	11.4	76.32
4.	Assam	31.46	16.06	52.47	27.31	17.34	55.34	26.88	14.16	58.95
5.	Bihar	45.35	11.92	42.72	38.39	13.60	47.99	32.84	14.63	52.51
6.	Chhattisgarh	40.26	11.79	47.93	40.00	16.21	43.77	35.52	13.33	51.14
7.	Delhi	67.46	11.27	21.26	66.55	9.015	24.44	67.44	9.025	23.53
8.	Goa	27.19	15.75	57.06	24.26	11.74	63.99	21.13	12.64	66.22
9.	Gujarat	67.07	9.56	23.35	65.37	8.696	25.92	70.86	7.67	21.45
10.	Haryana	72.95	8.10	18.94	73.33	7.80	18.86	73.39	6.57	20.03
11.	Himachal Pradesh	53.23	13.25	33.51	49.57	12.29	38.13	44.45	13.38	42.16
12.	Jammu and Kashmir	67.53	12.22	20.23	68.21	10.64	21.13	63.94	11.85	24.2
13.	Jharkhand	45.89	15.53	38.57	44.03	16.25	39.71	35.94	15.66	48.39
14.	Karnataka	44.60	17.06	38.32	46.00	16.31	37.68	45.88	17.12	36.99
15.	Kerala	28.95	15.96	55.08	23.59	15.83	60.56	25.36	14.55	60.08
16.	Lakshadweep	31.34	26.06	42.59	28.29	24.77	46.92	27.46	23.29	49.24
17.	Madhya Pradesh	56.31	12.70	30.97	56.87	11.90	31.21	57.14	11.47	31.37
18.	Maharashtra	43.87	15.71	40.41	44.7	13.56	41.73	43.36	14.04	42.59
19.	Meghalaya	14.03	13.15	72.80	14.47	14.03	71.49	14.47	12.28	73.24
20.	Mizoram	19.3	22.81	57.89	15.79	32.46	51.75	21.05	22.81	56.14
21.	Nagaland	15.58	15.58	68.83	16.88	20.78	62.34	19.23	20.51	60.26
22.	Odisha	36.93	14.69	48.37	34.79	13.09	52.10	31.11	15.69	53.18
23.	Punjab	74.86	8.62	16.51	73.41	8.68	17.90	71.67	8.09	20.23
24.	Rajasthan	70.89	7.74	21.366	72.87	8.05	19.07	75.93	6.48	17.58
25.	Sikkim	0.89	5.36	93.75	2.68	6.25	91.07	9.73	11.5	78.76
26.	Tamil Nadu	72.15	11.21	16.63	68.99	12.55	18.44	68.01	12.55	19.43
27.	Tripura	30.7	19.73	49.56	36.40	13.59	50	32.02	14.91	53.07
28.	Uttarakhand	52.2	13.78	34.01	45.56	14.62	39.82	35.42	15.92	48.65
29.	Uttar Pradesh	62.71	10.29	26.98	61.55	9.96	28.48	55.69	11.31	32.99
30.	West Bengal	37.87	15.82	46.29	37.52	15.15	47.32	35.14	14.49	50.36

Note : CR: Correct; US : Usable; UN : Unusable

(*i.e.*, unusable > 50%) and 19 states are usable (*i.e.*, unusable < 50%).

Day 3 : Correlation : we can find positive correlation over all the states, but 10 states have less correlation, *i.e.*, corr < 0.5, the remaining states are having high (corr > 0.5) correlation. RMSE : 14 states are having less RMSE ≤ 3 and 16 states having high RMSE > 3. Usable & Unusable: we got 19 states unusable, *i.e.*, > 50% and 11 states are usable (*i.e.*, unusable < 50%).

Day 5 : Correlation : we can find positive correlation over all the states. 12 states have corr < 0.5 the remaining18 states are having high (corr > 0.5) correlation. RMSE: 11 states are having less RMSE ≤ 3 and 19 states having high RMSE > 3. Usable and

TABLE 4

Skill scores for cloud amount

S. No.	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	0.14	1.63	89.1	7.71	3.11	0.05	1.62	88.07	8.802	3.12	0.11	1.63	88.34	8.56	3.09
2.	Andhra Pradesh	0.21	1.81	84.21	8.75	7.03	0.15	2.09	77.20	13.06	9.72	0.21	1.98	80.65	9.99	9.35
3.	Arunachal Pradesh	0.43	2.04	75.44	14.91	9.65	0.36	2.15	72.81	16.67	10.53	0.39	2.21	71.93	14.91	13.16
4.	Assam	0.20	2.39	71.30	12.73	15.96	0.18	2.36	71.72	12.77	15.49	0.17	2.45	69.65	13.14	17.19
5.	Bihar	0.42	1.92	81.17	11.16	7.66	0.41	1.88	83.57	9.43	6.99	0.43	1.9	82.82	8.78	8.39
6.	Chhattisgarh	0.21	2.04	100	0	0	0.23	2.24	100	0	0	0.24	2.26	100	0	0
7.	Delhi	0.40	2.78	62.03	15.74	22.22	0.46	2.92	65.74	12.5	21.76	0.44	2.94	66.97	11.01	22.02
8.	Goa	0.21	1.5	93.64	2.73	3.64	0.14	1.78	89.91	4.59	5.5	0.28	1.73	86.24	11.93	1.83
9.	Gujarat	0.44	2.20	73.26	15.32	11.41	0.44	2.26	71.94	16.05	11.99	0.49	2.29	70.37	15.21	14.4
10.	Haryana	0.35	2.72	60.67	19.11	20.21	0.39	2.77	63.9	14.31	21.71	0.32	2.87	62.86	14.42	22.71
11.	Himachal Pradesh	0.35	3.15	59.20	14.38	26.4	0.34	3.15	59.80	12.67	27.53	0.27	3.13	60.87	14.99	24.1
12.	Jammu and Kashmir	0.16	2.46	64.86	18.51	16.62	0.16	2.44	67.86	14.68	17.45	0.19	2.48	66.76	16.09	17.14
13.	Jharkhand	0.34	1.92	83.66	8.63	7.7	0.39	1.96	83.24	9.505	7.255	0.38	2.00	80.19	11.25	8.55
14.	Karnataka	0.15	2.13	79.25	8.04	12.69	0.10	2.14	79.55	8.57	11.87	0.11	2.19	78.26	8.79	12.94
15.	Kerala	0.18	1.57	88.10	9.123	2.76	0.07	1.70	87.39	8.211`	4.39	0.06	1.79	84.70	9.61	5.68
16.	Lakshadweep	0.31	1.64	87.12	9.2	3.68	0.24	1.78	83.45	12.41	4.13	0.28	1.81	85.41	8.21	6.38
17.	Madhya Pradesh	0.37	2.37	71.82	13.7	14.47	0.37	2.48	69.98	14.84	15.17	0.43	2.45	70.01	15.05	14.9
18.	Maharashtra	0.26	2.36	73.50	10.31	16.17	0.28	2.37	73.27	11.10	15.61	0.31	2.40	72.59	11.02	16.38
19.	Meghalaya	0.24	1.57	88.18	10.44	1.37	0.12	1.79	86.95	7.38	5.66	0.10	1.74	84.79	10.51	4.70
20.	Mizoram	0.34	1.35	92.86	6.25	0.89	0.2	1.38	95.54	2.68	1.79	0.26	1.27	92.86	6.25	0.89
21.	Nagaland	0.07	2.38	70.83	8.33	20.83	0.18	2.37	64.21	17.89	43.3	0	2.47	64.58	13.54	21.88
22.	Odisha	0.29	2.30	73.60	14.28	12.11	0.28	2.27	73.93	14.73	11.32	0.31	2.24	31.11	15.69	53.18
23.	Punjab	0.40	2.75	61.61	17.04	21.35	0.47	2.66	65.40	12.34	22.25	0.37	2.89	60.13	16.55	23.31
24.	Rajasthan	0.49	2.50	68.46	15.42	16.10	0.48	2.63	65.31	14.89	19.79	0.49	2.67	65.14	15.09	19.75
25.	Sikkim	-0.08	3.29	54.17	13.54	32.29	-0.14	3.28	58.33	19.79	21.88	0.06	2.94	66.67	11.43	21.88
26.	Tamil Nadu	0.11	2.10	77.16	12.78	10.04	0.09	2.12	76.59	13.16	10.24	0.01	2.19	74.55	14.18	11.26
27.	Tripura	0.35	1.46	92.10	5.26	2.63	0.25	1.59	89.03	8.33	2.63	0.30	1.45	89.91	8.77	1.31
28.	Uttarakhand	0.40	3.28	55.76	17.35	26.88	0.42	2.94	64.42	13.70	21.87	0.42	2.92	67.00	12.21	20.79
29.	Uttar Pradesh	0.35	2.65	54.63	29.22	16.13	0.32	2.76	55.10	27	17.89	0.39	2.78	55.69	11.31	32.99
30.	West Bengal	0.25	2.09	76.38	14.60	9.00	0.25	2.11	75.14	15.67	9.17	0.29	2.03	77.45	14.32	8.22

Note : Corr. : Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

Unusable : we got unusable on 19 states (unusable, *i.e.*, > 50%) and usable (*i.e.*, unusable < 50%) on 11 states.

Minimum temperature

Day 1 : Correlation: 14 states have less correlation *i.e.*, corr < 0.5 the remaining 16 states are having high (corr > 0.5) correlation. RMSE : 23 states are having less RMSE ≤ 3 and 7 states having high RMSE > 3. Usable & Unusable : we got 8 states unusable (*i.e.*, unusable > 50%) and the remaining 22 states are usable (*i.e.*, unusable < 50%).

Day 3 : Correlation: 14 states have less correlation *i.e.*, corr < 0.5 the remaining 16 states are having high (corr > 0.5) correlation. RMSE: 20 states are having less

TABLE 5

Skill scores for *T*-max

S. No.	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	0.18	2.35	26.18	21.76	52.04	0.20	2.47	24.61	23.27	52.11	0.14	2.52	24.07	22.10	53.81
2.	Andhra Pradesh	0.74	2.63	31.28	25.32	43.39	0.70	2.81	31.25	25.72	43.05	0.59	3.08	29.67	23.51	46.81
3.	Arunachal Pradesh	0.65	3.99	15.79	13.16	71.05	0.6	3.52	27.19	18.42	54.39	0.5	4.34	21.05	20.18	58.77
4.	Assam	0.46	2.53	33.50	23.98	42.50	0.46	3.73	19.40	19.04	61.54	0.35	3.96	21.63	17.95	60.40
5.	Bihar	0.55	3.27	23.75	26.55	49.69	0.54	4.68	21.20	15.47	63.32	0.51	4.34	18.21	22.95	58.83
6.	Chhattisgarh	0.80	3.54	27.94	21.18	50.87	0.70	2.96	20.16	14.83	65.00	0.65	4.51	19.65	17.31	63.02
7.	Delhi	0.91	2.04	43.21	29.09	27.68	0.87	2.55	31.11	30.94	37.94	0.83	2.63	33.35	24.14	42.49
8.	Goa	0.62	2.5	22.81	16.67	60.53	0.68	2.4	20.18	14.91	64.91	0.55	2.43	19.3	16.67	64.04
9.	Gujarat	0.77	2.40	33.50	27.07	39.42	0.71	2.77	26.81	24.62	48.55	0.65	2.88	24.98	21.77	53.23
10.	Haryana	0.88	2.73	28.4	27.84	43.75	0.81	3.42	29.9	18.01	52.08	0.80	3.35	25.51	17.58	56.9
11.	Himachal Pradesh	0.68	3.52	19.00	19.01	61.98	0.72	4.35	17.17	11.46	71.35	0.67	4.56	16.29	10.80	72.89
12.	Jammu and Kashmir	0.67	4.72	6.37	11.58	82.04	0.47	6.85	8.065	7.577	84.35	0.44	7.15	7.67	8.64	83.68
13.	Jharkhand	0.81	2.13	53.39	15.79	30.80	0.76	3.77	13.96	11.83	74.19	0.68	4.05	12.97	11.78	75.23
14.	Karnataka	0.64	2.52	29.31	24.46	46.20	0.67	2.63	26.64	24.85	48.50	0.56	2.70	26.25	24.37	49.36
15.	Kerala	0.34	2.85	19.33	23.52	57.14	0.48	3.01	15.32	16.02	68.65	0.40	3.11	14.44	14.94	70.61
16.	Lakshadweep	0.28	2.99	7.31	18.71	73.97	0.28	2.99	6.43	19.88	73.68	0.25	3	6.72	19.59	73.68
17.	Madhya Pradesh	0.89	2.49	40.27	24.93	34.78	0.84	2.96	33.56	26.26	40.17	0.80	3.07	31.58	24.78	43.62
18.	Maharashtra	0.74	3.04	27.62	22.69	49.67	0.72	3.23	23.92	20.39	55.67	0.77	3.34	24.46	20.48	55.04
19.	Meghalaya	0.33	2.83	14.47	15.35	70.17	0.40	2.25	35.08	30.26	34.64	0.30	2.69	32.45	26.31	41.23
20.	Mizoram	0.41	3.19	13.16	13.16	73.68	0.27	3.37	14.91	17.54	67.54	0.3	3.41	14.04	16.67	69.3
21.	Nagaland	0.49	1.89	35.71	34.82	29.46	0.66	1.6	52.68	25	22.32	0.43	2.25	48.67	23.01	28.32
22.	Odisha	0.62	3.41	26.91	21.41	51.66	0.55	4.63	30.49	25.90	43.59	0.55	4.57	18.68	17.46	63.84
23.	Punjab	0.88	2.89	33.33	16.66	50	0.79	4.57	15.49	18.13	66.37	0.76	4.81	14.32	17.25	68.42
24.	Rajasthan	0.89	2.21	43.30	27.23	29.45	0.85	2.64	34.07	25.55	40.36	0.79	2.95	32.25	25.76	41.97
25.	Sikkim	0.33	7.26	0	0	100	0.3	11.9	0	0	100	0.14	11.6	0	0	100
26.	Tamil Nadu	0.54	2.84	28.50	22.46	49.03	0.45	2.39	31.91	26.89	41.18	0.34	2.58	32.06	25.97	41.96
27.	Tripura	0.37	1.93	39.47	34.21	26.31	0.42	2.16	41.66	26.75	31.58	0.28	2.37	41.23	22.37	36.405
28.	Uttarakhand	0.81	2.75	21.05	32.455	46.49	0.80	4.97	7.45	13.6	78.35	0.79	4.90	10.09	15.79	74.12
29.	Uttar Pradesh	0.87	2.62	36.49	25.11	38.39	0.83	3.67	23.82	22.21	53.95	0.81	3.58	24.10	22.24	53.64
30.	West Bengal	0.59	2.68	34.58	25.74	39.66	0.49	3.83	25.05	22.35	52.58	0.44	3.88	25.36	19.02	55.60

Note : Corr. : Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

RMSE ≤ 3 and 10 states having high RMSE > 3. Usable & Unusable : we got 11 states unusable (*i.e.*, unusable > 50%) and 19 states are usable *i.e.*, unusable < 50%.

Day 5 : Correlation: 14 states have less correlation *i.e.*, corr < 0.5 the remaining 16 states are having high (corr > 0.5) correlation. RMSE : 17 states are having less RMSE ≤ 3 and 13 states, having high RMSE > 3.

Usable & Unusable : we got 11 states unusable (*i.e.*, unusable > 50%) and 19 states are usable (*i.e.*, unusable < 50%).

Cloud amount

Day 1 : Correlation : we can find positive correlation but less correlation (corr 0.1 to 0.5) over all the states and Sikkim have negative correlation. RMSE : All the states

TABLE 6

Skill scores for *T*-min

S. No.	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	0.14	3.56	11.87	19.02	69.11	0.26	3.79	5.79	16.52	77.68	0.23	3.82	5.96	15.81	78.21
2.	Andhra Pradesh	0.59	2.04	43.75	27.03	29.19	0.60	2.36	39.80	25.77	34.23	0.58	2.43	39.97	24.50	37.53
3.	Arunachal Pradesh	0.57	2.35	16.67	34.21	49.12	0.47	1.6	51.75	26.3	21.19	0.47	1.77	44.74	29.82	25.44
4.	Assam	0.48	1.39	57.84	29.79	12.36	0.51	1.46	57.18	26.87	15.94	0.46	1.54	51.05	30.26	18.67
5.	Bihar	0.35	10.81	31.89	24.37	43.73	0.42	3.69	20.86	19.73	59.4	0.41	3.56	20.65	18.36	60.98
6.	Chhattisgarh	0.64	2.45	39.19	20.76	40.03	0.70	2.96	31.86	22.63	45.5	0.61	3.03	32.14	21.82	46.03
7.	Delhi	0.68	2.06	45.4	28.18	26.42	0.68	3.93	14.99	21.57	63.43	0.69	3.78	18.5	21.17	60.33
8.	Goa	-.07	2.93	27.82	23.79	48.38	0.20	2.96	20.61	24.15	55.24	0.14	3.04	23.37	17.08	59.54
9.	Gujarat	0.66	1.55	47.68	32.38	19.93	0.74	1.59	49.92	31.80	18.27	0.73	1.62	49.08	30.62	20.29
10.	Haryana	0.61	3.20	18.51	23.56	57.91	0.63	4.89	2.393	15.23	82.37	0.59	4.73	12.28	11.67	76.0
11.	Himachal Pradesh	0.65	3.41	22.71	17.46	59.82	0.62	4.94	12.59	9.50	77.89	0.66	5.64	10.60	11.28	78.11
12.	Jammu and Kashmir	0.72	3.72	13.33	18.18	68.48	0.71	4	13.69	16.18	70.11	0.67	4.19	17.08	11.49	71.42
13.	Jharkhand	0.65	2	30.66	36.85	32.48	0.71	2.56	30.20	28.56	41.23	0.71	2.62	28.68	28.80	42.51
14.	Karnataka	0.41	1.74	48.06	25.17	26.75	0.47	2.03	35.36	29.51	35.11	0.43	1.93	33.34	32.91	33.74
15.	Kerala	0.10	1.92	33.85	29.64	36.49	0.28	2.29	18.17	32.51	49.31	0.23	2.23	19.75	31.83	48.41
16.	Lakshadweep	0.12	2.54	29.43	20.05	50.51	0.26	2.34	29.96	22.65	47.38	0.25	2.34	31.72	22.05	46.22
17.	Madhya Pradesh	0.63	2.39	41.61	28.15	30.22	0.66	3.18	33.67	24.36	41.95	0.63	3.08	34.64	24.47	40.88
18.	Maharashtra	0.61	2.06	47.29	25.03	27.67	0.65	2.74	29.45	26.81	43.73	0.63	2.66	28.73	26.36	44.89
19.	Meghalaya	0.53	3.08	0.87	10.09	89.03	0.5	1.42	47.81	33.77	18.42	0.58	1.39	48.68	35.52	15.79
20.	Mizoram	0.46	0.99	71.05	26.32	2.63	0.45	2.71	2.63	28.07	69.3	0.54	2.64	6.14	28.95	64.91
21.	Nagaland	0.43	3.15	3.54	7.08	89.38	0.45	1.31	48.67	38.05	13.27	0.45	1.35	51.33	37.17	11.5
22.	Odisha	0.38	2.46	29.69	27.43	42.87	0.43	2.73	30.49	25.90	43.59	0.47	2.58	28.44	28.78	42.77
23.	Punjab	0.63	2.54	32.74	24.72	42.53	0.61	4.17	22.03	21.05	56.90	0.61	4.34	22.93	20.19	56.87
24.	Rajasthan	0.68	2.36	37.34	28.51	34.14	0.71	2.74	37.82	21.3	40.87	0.63	3.10	38.22	22.73	39.04
25.	Sikkim	-0.04	14.5	1.89	2.83	95.28	0.04	15.66	3.77	4.72	91.51	0.05	15.7	4.72	3.77	91.51
26.	Tamil Nadu	0.41	2.20	35.84	32.33	31.82	0.39	1.76	46.32	30.51	23.14	0.34	1.76	45.29	30.72	23.97
27.	Tripura	0.18	1.16	65.98	27.63	6.58	0.2	1.19	61.84	31.14	7.01	0.16	1.22	65.35	25.87	8.77
28.	Uttarakhand	0.64	2.78	24.14	24.67	51.17	0.69	2.72	24.73	25.61	49.65	0.71	2.67	30.91	20.78	48.3
29.	Uttar Pradesh	0.60	2.69	28.04	27.16	44.79	0.63	4.23	18.77	18.95	62.27	0.61	4.06	20.56	19.76	59.67
30.	West Bengal	0.32	1.64	55.89	25.99	18.10	0.27	2.16	47.74	26.58	25.66	0.29	2.19	43.53	28.67	27.78

Note : Corr.: Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

are having very less RMSE ≤ 3 but 3 states having RMSE > 3. Usable & Unusable: We got All the states usable (*i.e*., unusable < 50%).

Day 3 : Correlation: we can find positive correlation but less (corr 0.1 to 0.5) correlation over all the states, and Sikkim have negative correlation. RMSE : All the states are having very less RMSE ≤ 3 but 2 states having RMSE > 3. Usable & Unusable: We got usable (*i.e*., unusable < 50%) over all the states.

Day 5 : Correlation : we can find positive correlation but less (corr 0.1 to 0.5) correlation over all the states, except Nagaland. RMSE : All the states are having very

TABLE 7

Skill scores for RH-max

S. No.	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	0.02	8.04	80.67	17.92	1.40	-0.01	9.06	71.85	27.09	1.05	-0.01	9.02	72.02	27.09	0.88
2.	Andhra Pradesh	0.34	15.63	42.29	36.76	20.94	0.32	12.15	62.41	26.35	11.18	0.35	12.91	59.83	28.11	11.94
3.	Arunachal Pradesh	0.58	10.32	66.67	28.07	5.26	0.47	15.04	53.51	26.32	20.18	0.26	15.09	55.26	24.56	20.18
4.	Assam	0.17	10.77	66.06	27.32	6.60	0.20	9.36	74.35	21.48	4.15	0.15	9.77	71.36	24.03	4.60
5.	Bihar	0.25	12.51	53.26	37.47	9.25	0.21	11.37	68.51	23.0	8.48	0.26	10.69	73.0	20.36	6.64
6.	Chhattisgarh	0.44	12.20	62.47	29.96	7.56	0.43	12.64	65.53	24.08	10.38	0.41	14.04	66.3	20.54	13.15
7.	Delhi	0.51	13.62	64.60	24.33	11.06	0.5	19.08	37.17	33.18	29.64	0.46	18.45	41.59	33.18	25.22
8.	Goa	-0.03	7.54	84.07	15.04	0.88	0.04	9.08	66.37	33.63	0	0.03	9.47	64.6	35.4	0
9.	Gujarat	0.37	13.24	40.83	50.91	8.24	0.6	7.40	84.39	14.85	0.75	0.55	7.57	85.28	13.59	1.12
10.	Haryana	0.60	11.39	67.67	25.71	6.61	0.55	2.77	36.83	36.65	26.50	0.52	17.90	42.09	33.56	24.34
11.	Himachal Pradesh	0.30	16.38	58.31	19.75	21.93	0.28	18.72	51.24	22.95	25.80	0.26	18.17	54.17	24.23	21.59
12.	Jammu and Kashmir	0.28	13.69	35.14	55.76	31.16	0.27	17.41	44.1	29.52	26.37	0.28	18.18	44.79	26.86	28.34
13.	Jharkhand	0.56	13.27	54.19	40.09	5.72	0.51	15.61	56.81	29.5	13.68	0.45	15.84	60.33	25.10	14.56
14.	Karnataka	0.08	10.75	64.78	24.63	24.63	0.14	11.07	57.15	35.54	7.29	0.10	11.49	55.72	36.6	7.66
15.	Kerala	0.01	7.39	82.51	17.18	0.29	-0.04	9.42	67.72	31.78	0.48	-0.0	9.52	65.88	33.33	0.78
16.	Lakshadweep	0.03	7.8	76.82	23.17	0	0.08	7.02	85.89	14.10	0	0.02	7.15	84.58	15.42	0
17.	Madhya Pradesh	0.61	13.26	56.56	31.09	12.33	0.58	11.80	66.37	24.22	9.39	0.55	12.67	65.49	23.56	10.93
18.	Maharashtra	0.29	12.58	59.44	29.90	10.65	0.33	11.31	65.80	27.11	7.07	0.30	11.69	63.96	27.64	8.38
19.	Meghalaya	0.16	10.65	67.10	22.80	10.09	0.03	10.62	67.98	21.49	10.52	-0.02	10.98	65.35	24.12	10.52
20.	Mizoram	0.02	17.42	31.58	37.72	30.7	-0.02	18.48	26.55	38.05	35.4	0.02	18.26	25.66	39.82	34.51
21.	Nagaland	0.11	13.88	31.96	62.89	5.15	0.1	12.8	43.3	52.58	4.12	-0.05	13.37	39.8	55.1	5.1
22.	Odisha	0.18	11.97	59.75	30.71	9.52	0.25	11.02	68.12	25.31	6.56	0.24	10.42	70.61	24.57	4.81
23.	Punjab	0.41	14.23	57.23	31.11	11.65	0.60	19.77	42.38	27.67	29.94	0.54	19.35	40.23	32.47	27.29
24.	Rajasthan	0.45	15.93	45.94	33.52	20.53	0.43	12.97	61.17	24.95	13.86	0.34	14.56	59.43	26.67	13.88
25.	Sikkim	0.24	4.36	99.12	0.88	0	0.32	11.97	47.37	49.12	3.51	0.27	11.98	52.63	44.74	2.63
26.	Tamil Nadu	0.17	17.20	32.85	39.03	28.11	0.18	12.68	56.14	32.84	11.01	0.19	12.72	55.13	34.23	10.63
27.	Tripura	0.07	17.22	21.49	53.94	24.56	-0.03	15.65	30.26	49.12	20.61	-0.08	15.51	32.01	50	17.98
28.	Uttarakhand	0.48	15.54	66.37	19.44	14.18	0.45	20.70	58.86	20.78	20.78	0.42	19.53	64.64	18.12	17.24
29.	Uttar Pradesh	0.37	13.44	55.57	33.31	11.11	0.28	18.04	50.76	25.15	24.08	0.24	17.46	52.15	25.77	22.06
30.	West Bengal	0.24	13.85	49.84	37.34	12.81	0.21	11.30	69.98	20.95	10.05	0.19	11.43	67.45	22.80	9.73

Note : Corr.: Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

less RMSE ≤ 3 but Himachal-Pradesh having RMSE > 3. Usable & Unusable : All the states are usable (*i.e.*, unusable < 50%) except Odisha.

Maximum relative humidity

Day 1 : Correlation: We got high (corr > 0.5) correlationn on 5 states. The remaining states have less correlation *i.e.*, corr < 0.5 and negative correlation on Goa. RMSE : All the states are having high RMSE > 7. Usable & Unusable: we got All states usable (*i.e.*, unusable < 50%).

Day 3 : Correlation: Here 8 states are having very high (corr > 0.5) correlation, remaining states have positive but less correlation (*i.e.*, corr < 0.5) and we got

TABLE 8

Skill scores for RH-min

S. No.	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	0.04	8.72	76.26	19.69	4.03	-.01	13.41	47.09	39.28	13.61	-0.02	13.40	48.22	36.45	15.32
2.	Andhra Pradesh	0.26	20.22	37.3	30.79	31.9	0.26	22.83	31.31	25.64	42.88	0.24	24.03	29.26	27.12	43.61
3.	Arunachal Pradesh	0.57	21.67	14.91	42.98	42.11	0.53	19.08	49.12	19.3	31.58	0.41	19.42	46.49	24.56	28.95
4.	Assam	0.21	18.22	28.37	42.26	29.35	0.22	25.79	16.27	25.28	58.43	0.17	24.90	22.24	25.39	52.35
5.	Bihar	0.15	25.47	19.12	30.78	50.09	0.16	31.59	6.69	22.15	71.14	0.11	29.79	8.01	23.53	68.46
6.	Chhattisgarh	0.37	25.96	18.23	30.34	51.42	0.32	29.97	15.10	24.45	60.44	0.26	29.76	17	20.99	62.00
7.	Delhi	0.31	26.51	17.12	39.85	43.02	0.26	29.11	12.49	37.51	49.99	0.2	29.09	11.00	37.17	51.83
8.	Goa	0.16	10.99	63.72	28.32	7.96	0.04	11.87	59.29	30.97	9.73	0.2	12.82	55.86	31.53	12.61
9.	Gujarat	0.32	15.24	59.6	23.87	16.52	0.26	16.82	48.79	30.14	21.06	0.19	17.36	47.53	30.06	22.35
10.	Haryana	0.4	26.02	13.37	36.51	50.11	0.34	28.54	11.36	26.75	61.88	0.27	28.64	9.51	29.43	61.04
11.	Himachal Pradesh	0.20	27.34	17.38	24.38	58.22	0.15	32.26	8.41	21.17	70.41	0.09	31.5	10.54	25.45	64.0
12.	Jammu and Kashmir	0.07	23.75	29.81	24.39	45.79	0.06	34.84	7.53	19.91	72.54	0.04	34.89	9.18	18.78	72.02
13.	Jharkhand	0.38	25.34	25.31	26.26	48.43	0.33	29.64	19.79	19.40	60.8	0.24	30.48	17.49	25.16	57.34
14.	Karnataka	0.20	16.11	50.5	27.69	21.80	0.14	16.89	47.24	30.23	22.52	0.11	16.83	49.34	27.84	22.8
15.	Kerala	0.10	10.52	67.77	26.76	5.46	0.11	13.01	56.21	31.71	12.06	-0.02	13.36	55.89	29.19	14.91
16.	Lakshadweep	-.01	7.14	86.16	13.83	0	0.04	7.47	84.32	14.76	0.92	-0.03	7.54	84.46	14.16	1.37
17.	Madhya Pradesh	0.19	20.07	42.17	28.80	29.02	0.16	22.34	34.45	31.2	34.33	0.15	22.78	32.88	35.9	7.85
18.	Maharashtra	0.28	16.71	49.53	28.48	21.97	0.22	17.90	46.77	27.89	25.32	0.18	18.14	46.37	27.55	26.07
19.	Meghalaya	0.29	12.18	58.33	32.89	8.77	0.30	21.21	22.37	29.82	47.80	0.27	21.03	26.31	29.38	44.29
20.	Mizoram	0.03	18.88	33.04	33.93	33.04	0.09	28.31	11.61	22.32	66.07	-0.17	28.37	12.5	21.43	66.07
21.	Nagaland	0.17	13.12	57.84	28.43	13.73	0.1	24.95	12.75	25.49	61.76	0.07	25.62	14.56	23.3	62.14
22.	Odisha	0.19	25.92	19.93	27.0	53.05	0.20	32.54	7.94	17.10	74.94	0.19	31.78	9.07	18.13	72.79
23.	Punjab	0.41	26.44	18.65	26.07	55.26	0.38	29.49	8.07	24.74	67.18	0.3	29.73	8.0	29.52	62.46
24.	Rajasthan	0.33	18.35	52.55	27.18	20.26	0.25	18.31	57.52	20.30	22.17	0.21	20.0	54.60	21.57	23.82
25.	Sikkim	0.15	21.18	8.11	50.45	41.44	0.16	31.89	0	5.41	94.59	0.03	31.04	2.68	8.93	88.39
26.	Tamil Nadu	0.24	19.86	37.12	27.01	35.86	0.14	23.86	30.95	20.93	48.11	0.08	23.71	31.90	20.38	47.70
27.	Tripura	0.11	16.37	43.42	33.33	23.23	0.1	15.12	45.17	36.4	18.42	0.09	14.74	48.68	32.01	19.3
28.	Uttarakhand	0.28	27.79	18.7	26.5	54.8	0.25	38	1.82	10.04	88.14	0.17	36.78	3.625	14.93	81.45
29.	Uttar Pradesh	0.22	25.2	20.82	30.02	49.15	0.20	29.29	9.82	24.74	65.43	0.17	28.90	9.833	24.87	65.29
30.	West Bengal	0.22	21.67	29.86	32.43	37.7	0.20	27.50	15.99	25.56	58.43	0.16	27.09	17.71	24.97	57.30

Note : Corr.: Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

negative correlation on 4 states. RMSE: All the states are having high RMSE > 7. Usable & Unusable : we got Usable on All the states (*i.e.*, unusable < 50%).

Day 5 : Correlation: We got negative correlation on 5 states, and 8 states are having very high (corr > 0.5) correlation. The remaining states have positive but very less correlation, *i.e.*, corr < 0.5. RMSE : All the states are having high RMSE > 6. Usable & Unusable : we got All the states are usable (*i.e.*, unusable < 50%).

Minimum relative humidity

Day 1 : Correlation : We got negative correlation on Lakshadweep, and the remaining states have positive but less correlation *i.e.*, corr < 0.5. RMSE : All the states are having high RMSE > 7. Usable & Unusable: we got

TABLE 9

Skill scores for wind speed

S. No.	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	0.15	23.88	4.39	12.28	83.33	0.16	26.96	5.26	8.77	85.96	0.25	27.36	7.02	7.89	85.09
2.	Andhra Pradesh	-0.04	18.34	24.01	32.59	43.39	-0.03	12.98	43.05	43.00	13.94	-0.03	13.09	44.63	39.65	17.65
3.	Arunachal Pradesh	0.01	11.19	13.16	78.07	8.77	0.02	4.04	100	0	0	-0.13	4.09	100	0	0
4.	Assam	0.09	9.44	56.69	35.02	8.28	0.04	4.56	84.3	14.91	0.78	0.07	4.60	83.69	15.62	0.68
5.	Bihar	0.14	10.61	42.08	41.09	16.82	0.20	9.56	41.29	47.49	11.21	0.2	9.60	42.54	46.27	11.18
6.	Chhattisgarh	0.08	10.70	35.92	38.49	25.58	0.06	7.32	54.49	43.73	1.76	0.04	7.42	53.04	44.26	2.69
7.	Delhi	0.02	7.94	64.47	28.95	6.58	0.14	8.26	60.08	32.02	7.89	0.19	7.92	63.6	28.94	7.45
8.	Goa	0.27	11.34	73.68	20.18	6.14	0.23	12.99	53.51	28.95	17.54	0.2	12.49	56.14	34.21	9.65
9.	Gujarat															
10.	Haryana	0.03	7.90	55.26	32.46	12.28	0.14	8.57	38.15	35.08	26.75	0.15	8.56	39.47	32.89	27.63
11.	Himachal Pradesh	0	19.59	3.51	25.44	71.05	0	8.16	57.89	42.11	0	0	8.15	56.14	42.11	1.75
12.	Jammu and Kashmir	-0.09	8.35	61.01	28.45	10.52	-0.04	6.22	75.68	23.17	1.14	-0.01	6.18	75.66	23.18	1.15
13.	Jharkhand	0.02	8.15	60.08	34.21	5.7	0.16	5.67	76.75	22.81	0.44	0.10	6.13	76.75	21.93	1.31
14.	Karnataka	0.19	13.92	26.05	32.71	41.22	0.22	12.97	34.15	33.12	32.71	0.18	12.158	38.18	31.57	30.23
15.	Kerala	0.10	10.62	49.12	30.99	19.88	0.16	12.55	35.47	31.77	32.74	0.09	12.077	38.40	31.09	30.50
16.	Lakshadweep	0.55	10.04	64.91	23.68	11.4	0.38	9.91	65.79	23.68	10.53	0.32	10.15	68.42	23.68	7.89
17.	Madhya Pradesh	-0.14	12.88	27.13	37.01	35.85	-0.18	10.65	22.70	54.11	23.18	-0.19	11.69	21.14	51.37	27.47
18.	Maharashtra	0.07	13.37	36.50	31.23	32.25	0.08	11.81	42.18	34.24	23.56	0.13	11.61	41.85	35.73	22.40
19.	Meghalaya	0.14	14.35	28.51	35.96	35.52	0.12	7.79	42.10	55.26	2.63	-0.01	7.87	43.42	53.07	3.50
20.	Mizoram	0.24	13.9	25.44	39.47	35.09	0.09	5.15	55.26	19.3	25.44	-0.01	5.28	51.75	21.05	27.19
21.	Nagaland	-0.02	11.21	64.04	26.32	9.65	0	2.65	23.68	52.63	23.68	0.03	2.62	27.19	48.25	24.56
22.	Odisha	0.14	13.83	33.72	32.20	34.06	0.16	7.48	59.62	35.34	5.03	0.15	7.44	61.44	33.12	5.43
23.	Punjab	0.03	8.53	45.03	40.93	14.03	0.09	7.26	56.14	35.67	8.18	0.10	6.98	57.30	34.21	8.48
24.	Rajasthan	0.25	13.42	35.08	28.07	36.84	0.30	16.07	29.63	28.26	42.10	0.28	18.02	24.66	27.68	47.66
25.	Sikkim	0.1	7.69	58.82	41.18	0	0.18	6.69	82.35	17.65	0	-0.02	6.62	79.41	20.59	0
26.	Tamil Nadu	0.07	12.70	42.54	30.06	27.38	0.16	10.03	49.81	30.99	19.19	0.16	9.98	49.21	32.74	18.03
27.	Tripura	0.34	10.36	32.45	48.68	18.86	0.23	8.98	42.10	42.54	15.35	0.20	9.34	44.73	37.28	17.98
28.	Uttarakhand	0.16	11.56	42.10	31.58	26.32	0.14	7.33	70.61	25.87	3.50	0.14	7.36	69.74	26.31	3.94
29.	Uttar Pradesh	0.02	9.82	46.38	36.71	16.89	-0.04	9.97	28.07	57.73	14.18	-0.11	10.32	24.77	57.24	17.97
30.	West Bengal	0.10	11.29	37.71	40.22	22.06	0.14	7.59	57.25	34.95	7.79	0.02	7.59	58.85	33.42	7.72

Note : Corr.: Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

unusable (*i.e.*, unusable > 50%) over 5 states and all the remaining states are usable (*i.e.*, unusable < 50%).

Day 3: Correlation: All the states have positive but less correlation *i.e.*, corr < 0.5, except Andaman. RMSE : All the states are having high RMSE > 6. Usable & Unusable : we got 15 states unusable (*i.e.*, unusable > 50%), the remaining 15 states are usable (*i.e.*, unusable < 50%).

Day 5 : Correlation : We got negative correlation on 4 states, remaining states have positive but less correlation *i.e.*, corr < 0.5. RMSE : All the states are having high RMSE > 7. Usable & Unusable : we got 16 states

TABLE 10

Skill scores for wind-direction

S. No.	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	86.34	28.83	7.15	64.0	0.09	74.70	44.18	2.05	53.76	0.04	75.29	43.15	3.36	53.48
2.	Andhra Pradesh	0.02	72.45	34.20	7.0	58.78	0.04	70.37	37.37	6.61	56.0	0.05	70.17	33.09	7.12	58.32
3.	Arunachal Pradesh	-0.1	48.93	50	5.26	44.74	-0.12	98.64	23.68	0.88	75.44	0.23	99.18	29.82	4.39	65.79
4.	Assam	-0.01	100.2	17.36	5.98	76.65	-0.04	112.3	15.10	3.39	81.5	0.03	110.6	14.24	3.56	82.18
5.	Bihar	0.05	91.25	20.59	4.14	75.26	0.09	102.6	18.44	3.69	77.86	0.01	102.2	18.09	3.71	78.19
6.	Chhattisgarh	0.02	93.64	24.50	6.82	68.67	0.09	84.30	33.89	4.43	61.67	0.09	83.77	32.66	4.82	62.51
7.	Delhi	0.30	79.95	28.11	6.91	64.97	0.09	76.83	38.69	10.6	50.7	0.15	86.07	37.90	8.21	53.88
8.	Goa	-0.02	68.79	41.82	10	48.18	0.04	48.06	65.14	7.34	27.52	0.08	48.88	56.88	10.09	33.03
9.	Gujarat	-0.05	54.19	51.60	10.66	37.72	0	51.97	63.06	4.45	32.47	0.04	53.97	58.9	5.61	35.48
10.	Haryana	0.13	104.19	13.22	2.52	84.26	0.06	90.10	26.44	2.44	71.10	0.12	93.48	24.68	2.72	72.58
11.	Himachal Pradesh	0.01	74.35	6.19	9.15	84.65	-0.07	90.74	6.79	1.94	91.26	-0.07	91.56	9.57	0.74	89.68
12.	Jammu and Kashmir	0.03	105.54	9.08	3.23	87.68	0	94.88	17.31	1.60	81.07	0.03	93.60	18.47	0.68	80.83
13.	Jharkhand	0.19	93.83	26.94	7.57	65.49	0.06	91.51	27.07	4.96	70.72	0.04	94.58	29.61	4.46	65.92
14.	Karnataka	-0.05	58.28	46.24	9.33	44.41	-0.03	53.25	58.37	4.31	37.31	-0.02	54.78	57.71	3.86	38.42
15.	Kerala	-0.07	79.51	32.64	7.36	59.98	-0.03	57.22	45.89	10.63	43.47	0.01	57.83	45.81	9.89	44.28
16.	Lakshadweep	-0.05	35.31	65.52	11.97	22.51	-.01	26.08	87.1	2.76	10.13	-0.05	28.22	84.03	5.93	10.03
17.	Madhya Pradesh	0.09	84.01	29.03	6.86	64.10	0.55	75.0	36.29	5.45	58.25	0.08	78.27	34.67	4.81	60.50
18.	Maharashtra	-0.05	72.07	37.74	9.03	53.22	-.01	67.06	42.55	5.72	51.71	0.04	66.66	41.90	5.58	52.51
19.	Meghalaya	0.06	120.06	7.01	3.07	89.91	-0.11	148.7	2.19	0.44	97.36	0	145.6	4.38	0.44	95.61
20.	Mizoram	0.02	129.9	19.64	3.57	76.79	0.11	131.6	25	0	75	0.06	131.0	24.11	2.68	73.21
21.	Nagaland	0.04	129.2	8.82	3.92	87.25	-0.14	120.76	11.88	2.97	88.12	0.02	125.07	13.73	0.98	85.29
22.	Odisha	0.02	93.98	25.47	6.59	67.93	0.07	94.64	23.06	5.25	71.67	0.07	95.73	22.39	5.38	72.22
23.	Punjab	0	106.6	15.79	4.59	79.26	0.08	89.93	31.46	3.70	64.82	-0.05	96.39	26.39	4.90	68.69
24.	Rajasthan	0.11	78.01	39.89	5.43	54.66	0.09	79.76	46.28	2.88	50.83	0.09	83.80	46.09	1.93	51.96
25.	Sikkim	0.04	49.61	59.46	19.82	20.72	0.04	154.33	0.9	0	99.1	-0.11	151.12	1.79	0.89	97.32
26.	Tamil Nadu	-0.03	63.69	34.06	9.49	56.44	0.05	66.03	39.96	3.65	56.37	0.06	68.37	38.97	4.13	56.83
27.	Tripura	-0.05	107.5	32.01	3.95	64.03	-0.15	110.75	42.10	2.63	55.26	-0.04	110.7	41.23	1.75	57.02
28.	Uttarakhand	-0.01	111.48	9.11	3.19	87.69	-0.15	104.6	26.06	1.36	72.57	-0.01	99.84	27.20	1.8	70.99
29.	Uttar Pradesh	0.05	93.75	20.0	7.06	72.93	0.04	90.01	30.90	7.34	61.75	0.01	94.75	28.24	6.41	65.33
30.	West Bengal	0.02	84.90	30.55	7.88	61.55	-.04	90.37	36.40	4.45	59.13	0.02	90.16	33.17	5.76	61.06

Note : Corr. : Correlation ; rmse : Root Mean Square Error ; CR : Correct ; US : Usable ; UN : Unusable

unusable (*i.e.*, unusable > 50%) and all the remaining states are usable (*i.e.*, unusable < 50%).

Wind-speed

Day 1 : Correlation : We got positive but less correlation *i.e.*, corr < 0.5 on all the states and negative correlation on 4 states. RMSE : All the states are having high RMSE > 7. Usable & Unusable : we got All the states are usable (*i.e.*, unusable < 50%) but 2 states unusable (*i.e.*, unusable > 50%).

Day 3 : Correlation : We got negative correlation on 4 states, and the remaining states have positive but less correlation *i.e.*, corr < 0.5. RMSE : All the states are having high RMSE > 4. Usable & Unusable : All the

states are usable (*i.e*., unusable < 50%), except Andaman & Nicobar unusable (*i.e*., unusable > 50%).

Day 5 : Correlation : We got negative correlation on 8 states and the remaining states have positive but less correlation *i.e*., corr < 0.5. RMSE: All the states are having high RMSE > 4. Usable & Unusable : Here All the states are usable (*i.e*., unusable < 50%), except Andaman & Nicobar unusable (*i.e*., unusable > 50%).

Wind-direction

Day1 : Correlation : We got negative correlation on 11 states and the remaining 19 states have positive but very less correlation *i.e*., corr < 0.3. RMSE : All the states are having high RMSE > 35. Usable & Unusable: we got 6 states usable (*i.e*., unusable < 50%). All the remaining states are unusable (*i.e*., unusable > 50%).

Day 3 : Correlation : We got negative correlation on 12 states, and the remaining states have very less correlation *i.e*., corr < 0.17. RMSE : All the states are having high RMSE > 26. Usable & Unusable : we got 5 states usable (*i.e*., unusable < 50%). All the remaining states are unusable (*i.e*., unusable > 50%).

Day 5 : Correlation : We got negative correlation on 7 states, and the remaining states have positive but very less correlation *i.e*., corr < 0.17. RMSE : All the states are having high RMSE > 25. Usable & Unusable : we got 5 states usable (*i.e*., unusable < 50%). All the remaining states are unusable (*i.e*., unusable > 50%).

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

5. Conclusions

The forecast for yes/no rainfall (Table 1) and cloud amounts (Table 4) are having high skill for almost all the states and Day-1 to Day-5 forecasts, as is clear from the tables. Hence these forecasts can be issued without any further value addition.

The forecast for rainfall amounts (Tables 2 & 3) is also having the positive skills, but for oceanic islands and some of the high terrain regions and regions having orographic rainfall the rainfall amounts fall under the unusable category (that is more than 50% unusable), for such situations the value added rainfall amounts needs to be given after considering the effects of orographic rains. Although many states are having the rainfall amounts under the usable (less than 50% unusable), for such situations value addition is not required.

First two days (Day-1 & Day-2) forecast for maximum and minimum temperature (Tables 5 & 6) was taken from WRF model and next three days (Day-3 to Day-5) was taken from GFS T-574 model). As earlier also the WRF model forecast was found marginally better and more over the forecast for most of the states is found usable(less than 50% unusable) for first two days except for the oceanic islands and high terrain regions. Hence quick value addition is required for maximum and minimum temperature both, after making the order of temperature values as for first two days keeping the trends same is given for Day-3 to Day-5 forecasts.

The forecast for maximum relative humidity had (Table 7) been found to be having high skill that is forecasts fall under usable category for almost all the states and Day-1 to Day-5 forecasts, as is clear from the table. Hence this forecast can be issued without any further value addition. The forecast for most of the states for minimum relative humidity (Table 8) is found usable (less than 50% unusable) for first two days(as this was also from WRF model) except for oceanic islands and high terrain regions. Hence quick value addition is required for minimum relative humidity after making the order of values as for first two days keeping the trends same as is given for Day-3 to Day-5 forecasts.

The forecast for wind speed (Table 9) had been found to be usable for most of the states for all the days of the forecast. This can be given as obtained from the model. But for certain states RMSE values are on somewhat higher side, for such states it had been found that model forecasts are showing the values on higher side, hence a seasonal factor can be obtained for a particular state so as to reduce the model forecasted value by the factor obtained before issuing the final forecast for wind speed.

The forecast for wind direction (Table 10) had to be found to be unusable for most of the states. This is the only weather parameter which needs the values addition at most of the places. Hence for wind direction it is suggested to issue the final forecast mostly based upon the seasonal climatological value for a particular location.

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 the down scaling the forecast up to any level (*viz*., 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 that is 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 way could be trying the

- Neural Network Technique for MME forecast for rainfall.
- Kalman filter for Maximum/minimum temperatures.
- Model Output Statistics (MOS) guidance for different weather parameters.

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