Application of Spatial Verification Methods for Ensemble Rainfall Forecasts over India

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Abstract

This study applies contiguous rain areas (CRA), an object based spatial verification method, to ensemble rainfall forecasts from the NCMRWF Ensemble Prediction System (NEPS) over India during the recent heavy rainfall events during 2019. The spatial verification technique aims at representing the spatial uncertainty at the grid-scale. This method allows quantification of uncertainty in different attributes of the spatial rainfall forecasts.

1 Introduction

Verification of rainfall forecasts using traditional verification scores often fail to reflect the improvements due to increased grid resolution. Small errors in the position or timing of convective features result in both false alarms and missed events that dominate the 2x2 contingency table that serves as the foundation of traditional categorical verification scores. The traditional verification scores have limited utility when it comes to diagnosing displacement error or an incorrect mode of convective organization. The spatial verification method Intercomparison Project, or ICP, was organized to explore better ways of evaluating high-resolution numerical model forecasts. The ICP recommended new methods which often do not require one-to-one matches between forecast and observed events at the grid scale in order to give credit to a good forecast. These methods put the grid point forecasts into spatial context. The verification and scoring is based on different attributes of the observed and forecast rainfall object pairs like spatial coverage, peak intensity, shape, orientation, centroid location, and volume of rainfall etc.

In the ensemble based rainfall forecasts, it is often noted that observed rainfall forecast rainfall from individual members display varying degree agreement/mismatch in terms of spatial coverage, peak intensity and other attributes. And quite often probabilistic quantitative precipitation forecasts (PQPF) generated from the quantitative precipitation forecasts (QPF) from ensemble members indicates very good forecast with some spatial displacement compared with observations. This study applies contiguous rain areas (CRA) technique to ensemble rainfall forecasts from the NCMRWF Ensemble Prediction System (NEPS) over India during the recent heavy rainfall events during JJAS 2019. Applying the CRA method to the ensemble rainfall forecasts during the recent heavy rainfall events over India, this study explores uncertainty in different attributes of rainfall forecasts.

2 Data and Methodology

The observed and rainfall data over India used in this study are briefly described in this section.

2.1 Observed Rainfall Data

For rainfall forecast verification, the IMD-NCMRWF daily high resolution (0.25° x 0.25°), satellite and gauge merged rainfall analysis is used. The merged analysis at 0.25° is appropriate for capturing the large scale rain features associated with the monsoon.

2.2 Ensemble Model Forecast Rainfall Data

The NCMRWF Ensemble Prediction System (NEPS) has 12 km horizontal grid resolution with 23 members. The model is integrated to produce forecasts 10 days. NEPS ensemble is initialised to account for uncertainty in the initial conditions as well as in the model physics. Additional details can be found in [1]. The model forecasts are gridded to the 0.25° x 0.25° observed rainfall grids over Indian regions for 122 days from 1st June to 30th September 2019.

2.3 Methodology

CRA is an object-based method that verifies the properties of spatial forecasts of entities. An entity/object is anything that can be defined by a closed contour (Figure 1). Some examples of entities, or blobs, are contiguous rain areas, convective outlook regions, and low pressure minima. For each entity that can be identified in the forecast and the observations, CRA verification uses pattern matching techniques to determine the location error, as well as errors in area, mean and maximum intensity, and spatial pattern. The total error can be decomposed into components due to location, volume, and pattern error. This is a useful property for model developers who need such information to improve the numerical weather prediction models. Detailed description of the CRA method can be found in [2] and its application for model rainfall verification over India in [3].

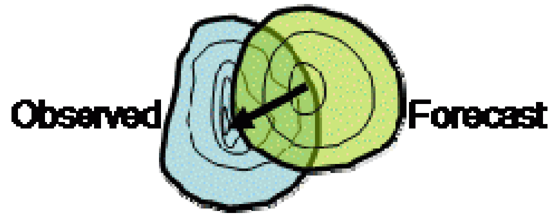

Figure 1. Observed and forecast objects used in CRA Verification.

CRA verification is carried out for each of the ensemble members and the statistics are obtained for various attributes of the forecast rainfall like area, intensity etc. Additionally the contribution (%) to total error due to displacement, volume and patters are also decomposed for each member.

3 Results

The CRA verification is carried out for JJAS 2019. The results are presented for five cases (Table1) of Extremely Heavy Rainfall (EHR) over Mumbai during JJAS 2019:

Table 1. Five cases of Extremely Heavy Rainfall (HER) over Mumbai during JJAS 2019.

	Date	Rainfall
1	29th June 2019	23 cm/day
2	02nd July 2019	37 cm/day
3	27th July 2019	22 cm/day
4	04th Aug 2019	20 cm/day
5	05th Sep 2019	24 cm/day

3.1 Cases of Extremely Heavy Rainfall (EHR)

The five cases of EHR are tabulated in Table 1which are the 24h accumulated rainfall in Santacruz. The rainfall activity in each of these events is associated with well defines synoptic condition involving the mid-tropospheric cyclonic systems (MTC). The observations and forecasts (not shown) clearly show well defined MTC. The model accurately captures the development and westward movement of the MTC over the central India.

3.2 Observed and Forecast EHR

The rainfall activity during the abovementioned dates was also noted to be widespread as indicated in Figure 2. The top panels show the observed rainfall exceeding 8cm/day (shaded blue) extending over coastal Maharashtra to the north and south of Mumbai. The 8cm/day contour in the top panels is from the NEPS deterministci control run. In two of the three cases the observed and forecasts 8cm/day objects show good overlap. However, in the first case, the determinsitc control has completely missed predicting the event showing no sign of any overlap. The bottom panels show the 8cm/day object from each of the 22 ensemble members.

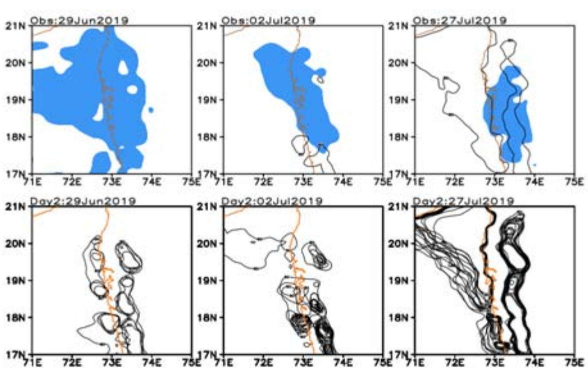

Figure 2. Observed rainfall (>8cm/day; *blue object in top panels*) and the members forecasts in day-2 (bottom panels).

3.3 Ensemble CRA

Basing on the observed and forecast object pairs involving the NEPS ensemble members, CRA verification are carried out for all the five EHR events during JJAS 2019. The verification analysis is carried out for rainfall exceeding 1, 2, 4 and 8cm/day thresholds for each of the cases and for all forecast lead times from day-1 to day-5. The displacement errors for the case of 2nd Jul 2019 are shown in Figure 3 for 2, 4 and 8 cm/day objects. The southward bias in the rainfall is prominently seen.

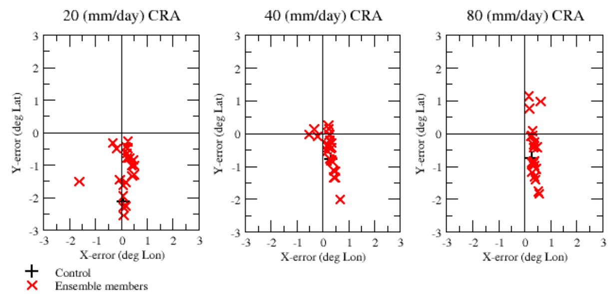

Figure 3. Displacement error in the NEPS Control and Ensemble members for 20, 40 and 80 (mm/day) CRA in the Day-2 forecast valid on 2nd Jul 2019 for the case of Extremely Heavy Rainfall (EHR) over Mumbai

4 Summary

.Spatial verification of ensemble rainfall forecasts using CRA method is carried out in this study for five cases of Extremely Heavy Rainfall (>20cm/day) over Mumbai. The high resolution deterministic control forms an impressive overlap with the observed rainfall >8cm/day. The use of ensemble members further clearly suggest enhanced forecast skill in terms of predicting spatial coverage. However, the forecasts have southward displacement errors. While the use of ensemble mean for EHR forecast is very limited, since ensemble mean overestimate the rain area and volume and underestimate mean rain intensity. As cab be expected, averaging of several rain forecasts has the effect of increasing the rain area and reducing the mean rain intensity.

References

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[3] Sharma, K., Ashrit, R., Ebert, E. et al. Assessment of Met Office Unified Model (UM) quantitative precipitation forecasts during the Indian summer monsoon: Contiguous Rain Area (CRA) approach. J Earth Syst Sci 128, 4 (2019). https://doi.org/10.1007/s12040-018-1023-3