Bias correction and Signal Amplification Technique to improve the extended range prediction of extreme weather events

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Introduction

- Extreme weather events such as heavy rainfall events, cyclones, heat/cold waves etc. when interact with vulnerable human and natural systems, can lead to disasters, especially in the absence of a responsive social system.
- Accurate and timely forecast of the extreme events are essential to respond effectively to such events.
- Extended Range Prediction (ERP) at 15-20 days (3-4 pentad) lead time can better serve as a guidance about the impending extreme events, thereby substantially minimizing the loss of lives and damage to property.
- Although the ERP system implemented at IITM can give an outlook on the impending extreme events, spatio-temporal errors w.r.t their location and timing are often noticed .
- The present study proposes a Bias Correction and Signal Amplification (BCSA) technique to reduce the spatio-temporal errors and thus improve the ERP of extreme weather events.

BCSA Technique

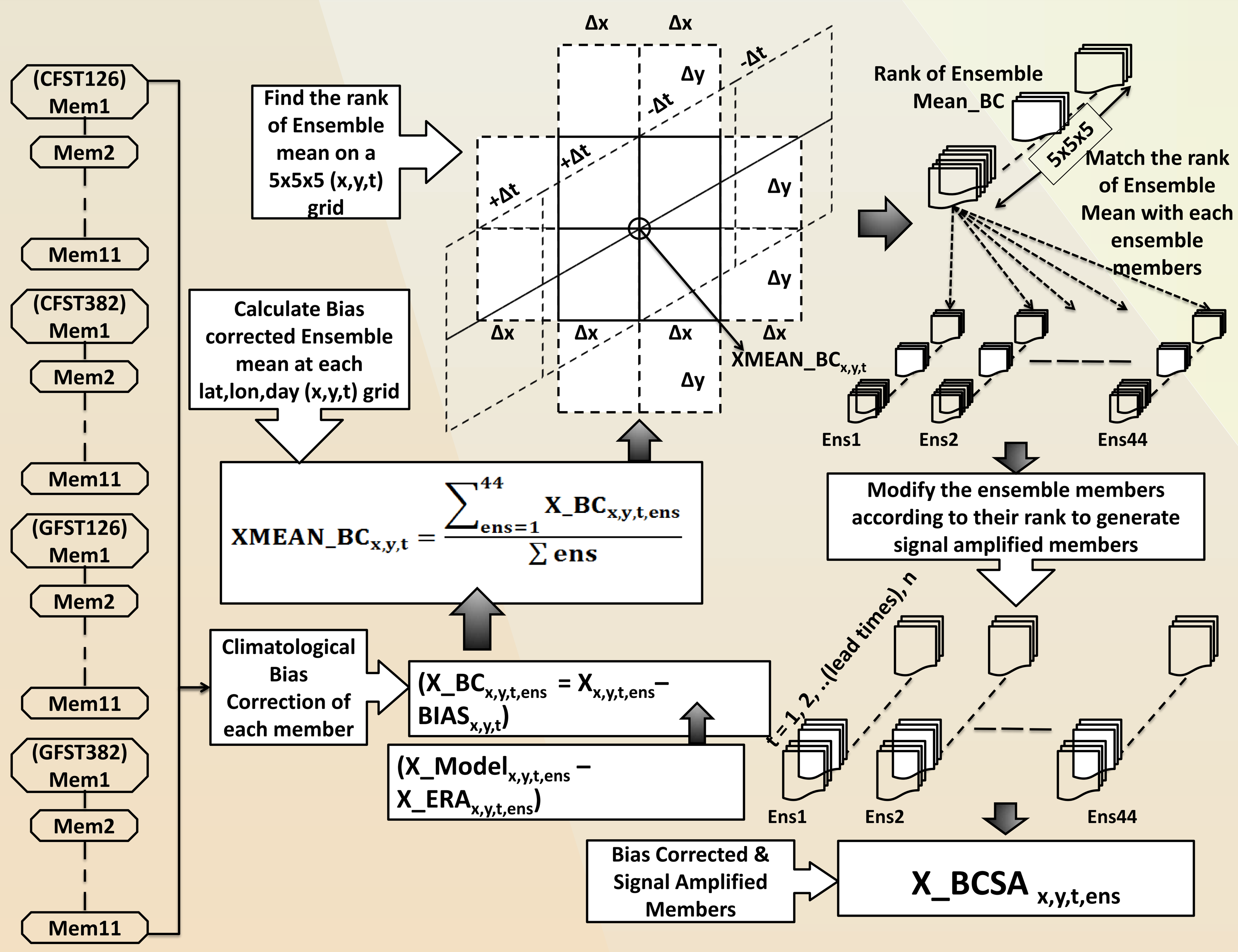


Figure 1: Flowchart of BCSA Technique

To clearly explain the technique, here we give an example of the heavy rainfall event occurred over the north Indian state, Uttarakhand during 16-17 June 2013. The application of the BCSA technique on rainfall forecast from 05 June 2013 initial conditions is discussed.

A particular grid point over the Uttarakhand region, 30° N; 79° E has been selected for 17 June 2013 (hereafter termed as $x_0y_0t_0$ and is represented by blue line in Figure 2), and the Signal Amplification technique is applied to the mean bias corrected rainfall data by considering 1-point correction in space and time, for easy illustration.

For 1-point correction, we have considered a point each in longitude (x), latitude (y) and time (t), i.e., x varies from x-Δx to x+Δx, y from y-Δy to y+Δy, and t from t-Δt to t+Δt, where Δx, Δy and Δt are increments in longitude, latitude and time based on resolution of the forecast data (in this case, it is 1°x1° in space and 1 day in time). This technique is applied to each of the ensemble members, and we have total 3 values each in space (both latitude and longitude) and time for the reference grid, $x_0y_0t_0$, totalling to 3x3x3 = 27 values.

Ensemble mean of the rainfall data for all these 27 points are calculated. Then, the rank of ensemble mean of 44 members, corresponding to the target point $x_0y_0t_0$ is found among these 27 values. Here, the rank of ensemble mean of target point is identified as the third value from top. From these 27 values corresponding to each ensemble member, the value whose rank matches with that of the ensemble mean is considered as the value for the corrected ensemble member for $x_0y_0t_0$ (red line in Figure 2). Before correction, the ensemble mean value of rainfall on 17th June was 26.29 mm/day and after correction, it has been enhanced to 40.57 mm/day.

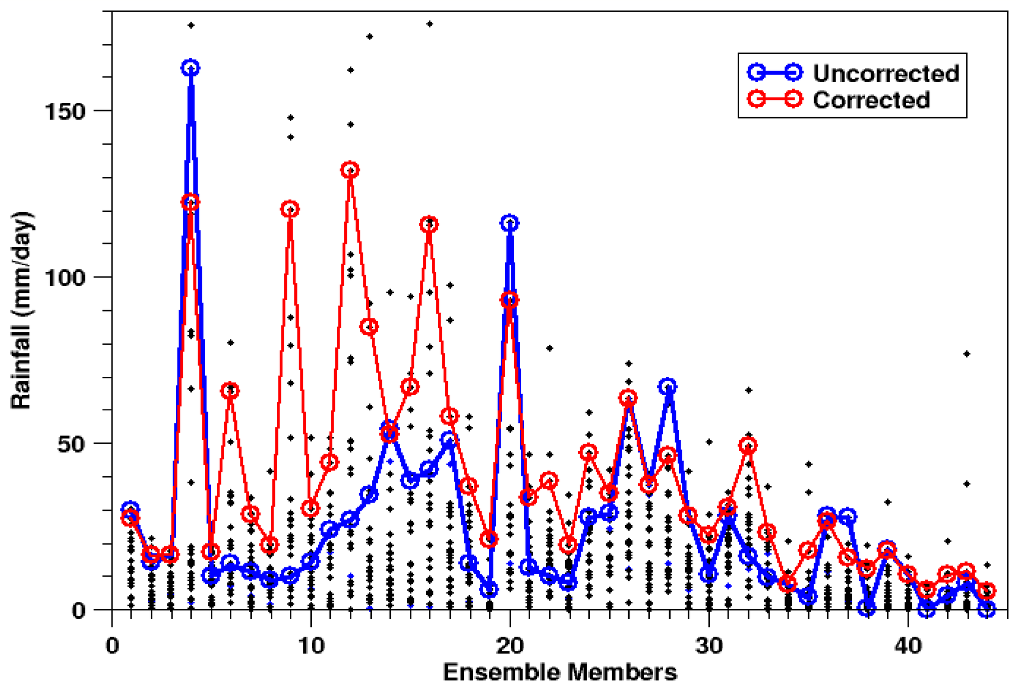


Figure 2: The uncorrected (blue line) and corrected (red line) rainfall data over Uttarakhand region (79°E; 30°N) for each ensemble member

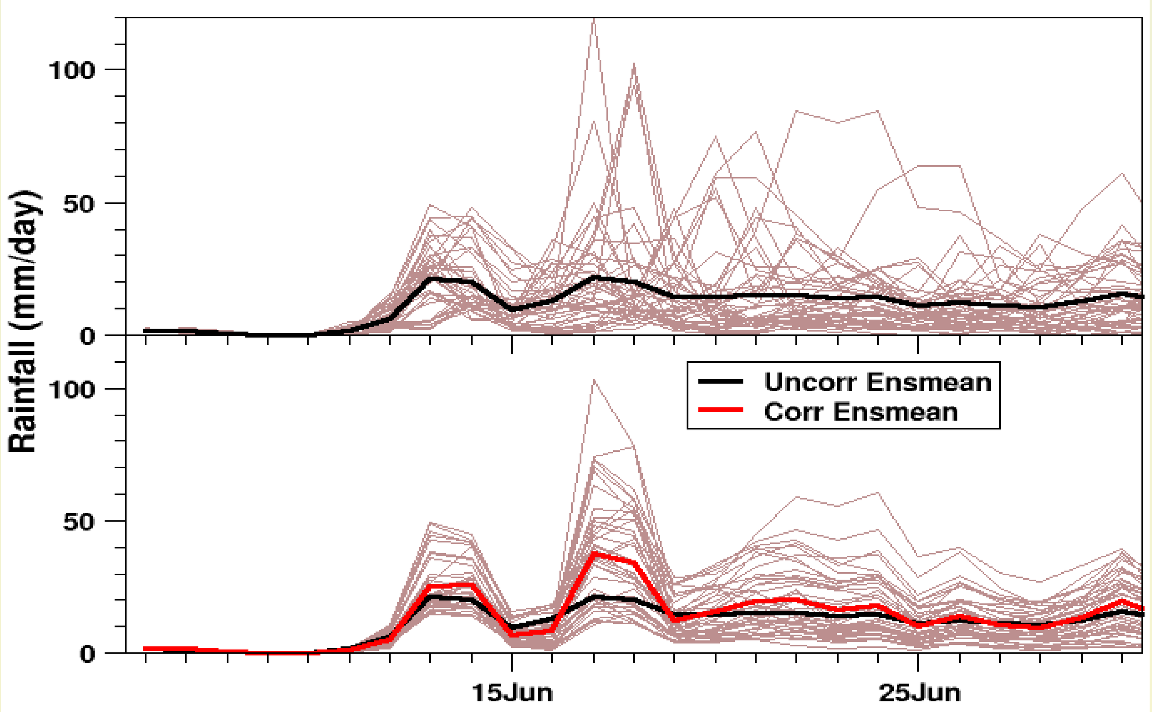
Results

The methodology includes, in actual, a 2-point correction in space and time. Therefore, the technique is applied to the rainfall forecast for next 40 days starting from 06 June, based on 05 June initial conditions, for all grid points.

The rainfall forecast before and after doing the BCSA correction over the Uttarakhand region 78°-80°E; 29°-31°N is shown in Figure A3. The top (bottom) panel shows the uncorrected (uncorrected) forecast. The brown lines represent the rainfall forecast from individual ensemble members and the black and red lines represent the uncorrected and corrected ensemble mean values respectively.

It is clear from the figure that the ensemble mean has improved (inflated/deflated following the signal which is ensemble mean in this case) after applying BCSA technique.

Figure 3: The corrected and uncorrected rainfall forecast from 05 June 2013 initial conditions, over Uttarakhand region.



The application of BCSA technique to improve the track prediction of cyclonic storms (CS) over north Indian Ocean is shown next.

Three cyclones that formed over BoB basin (0° - 30° N and 60° – 110° E) in the year 2013 are selected: CS Viyaru (May 11-16), Extremely Severe CS (ESCS) Phailin (October 8-24) and Very Severe CS (VSCS) Lehar (November 23-28).

It is clear from the figure that track variations for BCSA-mean predictions were reduced relative to MME-mean predictions for all CS cases. Tracks are smoother and more refined in MME-BCSA-mean forecasts which closely match observations for most IC.

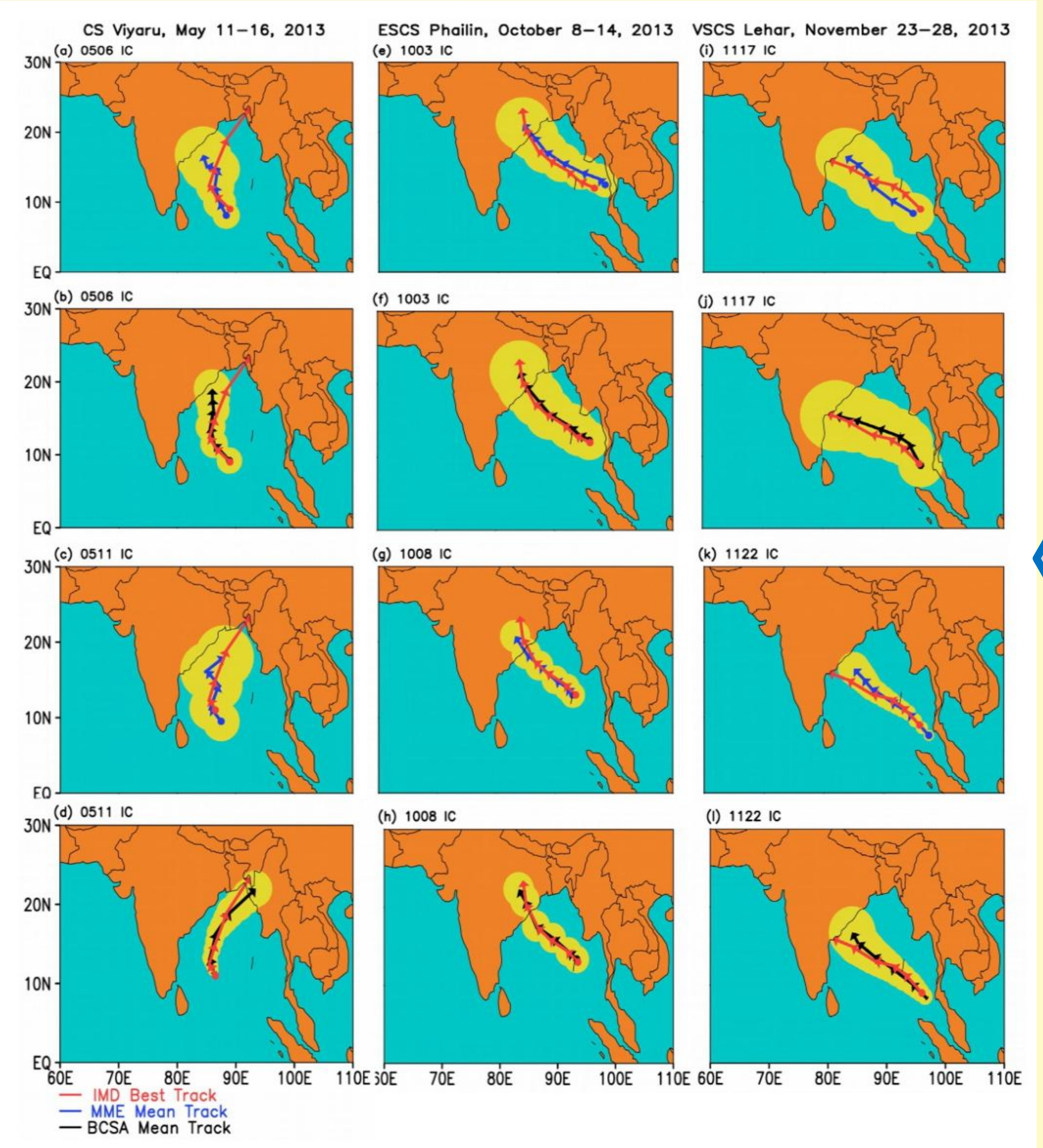


Figure 4: Track Forecasts for all storm cases; left column for Viyaru (a-d), center column for Phailin (e-h) and right column for Lehar (i-l). Plot (a) shows MME mean track vs IMD Best-Track observations (b) BCSA mean Track vs IMD Best-track observations, for 0506 IC, (c) and (d), same as (a) and (b), but for 0511 IC, (e) and (f) for 1003 IC, (g) and (h) for 1008 IC, (i) and (j) for 1117 IC, (k) and (l) for 1122 IC (c) respectively

Conclusions

The BCSA technique is a unique post processing tool and computationally less expensive as it can be used on any number of already available MME outputs.

It is shown that the technique is functional in reducing the spatio-temporal errors in the extended range prediction of heavy rainfall event over Uttarakhand.

The technique is also useful in improving the track prediction of CS over north Indian Ocean , even at longer leads. It is found that the tracks are much smoother and refined after subjecting to BCSA technique.

The weakness of this method is that it considers the ensemble mean as the signal which is being amplified/deflated. Therefore, BCSA can be less useful if the ensemble mean does not contain the proper signal.

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