Super-Cyclone Amphan (2020) : Global versus Regional Ensemble Prediction

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The India meteorological department extended range forecast (IMDERF) from 13 May initial condition (IC) evinced 60-80% genesis probability of an approaching storm. However, this forecast lacked in storm intensity and trajectory. Considering the system indication in IMDERF, this ensemble forecast is downscaled using one-way nested Weather Research and Forecasting (WRF) model. The short comparison of the global and regional ensemble predictions from 13 May 2020 IC is presented here.

The advanced scientific and computing resources equipped the forecasters with a range of prediction tools across spatial and temporal scales of weather phenomena. Nevertheless, the rare and unforeseen hazards intermittently put these tools on the test. One such event was the Bay of Bengal (BOB) super cyclone Amphan. Amid the ongoing global pandemic, the first cyclone of 2020 pre-monsoon season in the North Indian Ocean caused havoc in the Eastern Indian states as well as Bangladesh. This cataclysmic storm was one of the strongest occurring in the BOB basin over the past 20 years. The system appeared as low in southwest BOB on 13 May and later organized into cyclonic storm Amphan on 16 May. Amphan rapidly intensified from severe to an extremely severe cyclone on subsequent days, finally amplifying to a super cyclone on 18 May. It slightly weakened under unfavorable shear conditions, still entered West Bengal - Bangladesh coast with high ($45 m.s^{-1}$) wind-gust (IMD, 2020a, 2020b).

Methodology

Global Ensemble System. The operational extended range forecast (IMDERF) is an ensemble of 16 members based on two resolution (T382 and T126) variations of Climate Forecast System and its atmospheric model Global Forecast System(GFS). IMDERF is being generated once every week since 2016.

Regional Ensemble System. The WRF runs are performed with a specified regional domain (25°S-55°N, 30°E-128°E) to downscale all IMDERF ensemble members (M_i) independently. To control systematic error amplification, the global model climatology ($\overline{M}$) is corrected with Climate System Forecasts Reanalysis climatology ($\overline{R}$) beforehand.

$$M_i^{bc} = (M_i - \overline{M}) + \overline{R} \qquad [1]$$

The above correction is applied to all input meteorological variables, the horizontal resolution is targeted at 9km for regional ensemble run. This bias-corrected downscaled ensemble is termed as BC-D-ERF hereafter. Further details can be found in (Kaur et al., 2020) and references therein.

Results

The observed maximum rainfall (Figure 1a) pattern during the cyclonic storm Amphan (during the event) was extended from south-west BOB to head Bay, over the North-Eastern parts of India and Bangladesh. The highest recorded rainfall associated with the event was more than 380 mm.day^{-1}. IMDERF ensemble mean rainfall (Figure 1b) has an eastward positional shift towards Myanmar, and the predicted magnitude is less than 92 mm.day^{-1}. The BC-D-ERF (Figure 1c) also shows location error, but more close to observed distribution than IMDERF. It is evident from the figure that BC-D-ERF predicted rainfall intensity is significantly improved.

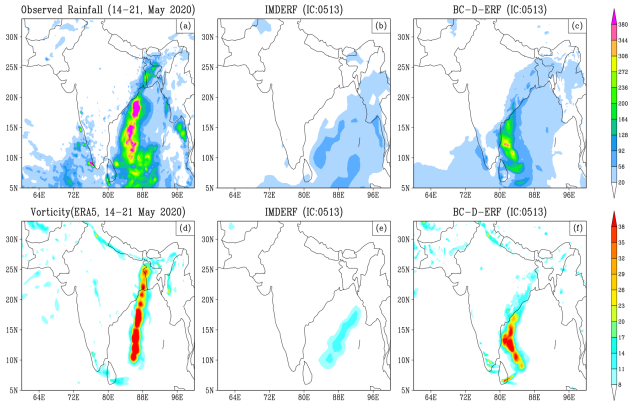

Fig. 1. Evolution of (a-c)maximum Rainfall (mm.day^{-1}) and (d-f) 850hPa vorticity(x10^{-5} S^{-1}) for observation, IMDERF, and BC-D-ERF respectively.

Similar inferences can be made from vorticity plots compared with ERA5 reanalysis (Figure 1d), both IMDERF (Figure 1e) and BC-D-ERF (Figure 1f) failed to capture the storm track. However, BC-D-ERF reproduced the temporal evolution of storm intensity to a good extent.

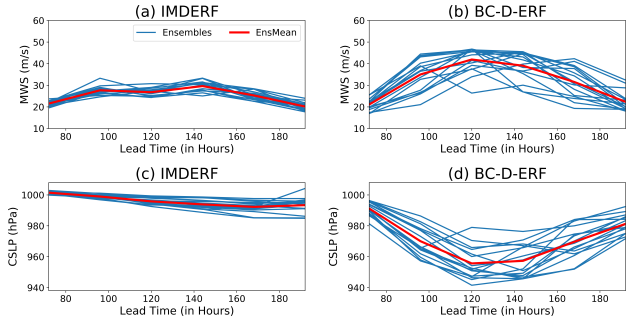

Fig. 2. 10m wind speed (MWS) and sea level pressure(CSLP) predicted by IMDERF(a & c) and BC-D-ERF (b & d)

It is worth mentioning here that IMD reported wind-gust of 155-165 kmph (43-45 m.s^{-1}) during the landfall of the cyclone Amphan. For further insights into the predicted

surface winds, the system accompanying maximum 10m wind speed and minimum sea-level pressure predicted by IMDERF and BC-D-ERF are compared in Figure 2. IMDERF ensemble substantially underestimates the wind-speed (Figure 2a) as well as CSLP (Figure 2c), whereas the BC-D-ERF ensemble enacts MWS(Figure 2b) and CSLP(Figure 2d) reasonably well. It has predicted intensification of the system on 18 May (at lead 120hours), followed by a drop in the storm strength similar to the one documented by IMD. The BC-D-ERF ensemble has a larger spread promising better probabilistic skill than IMDERF.

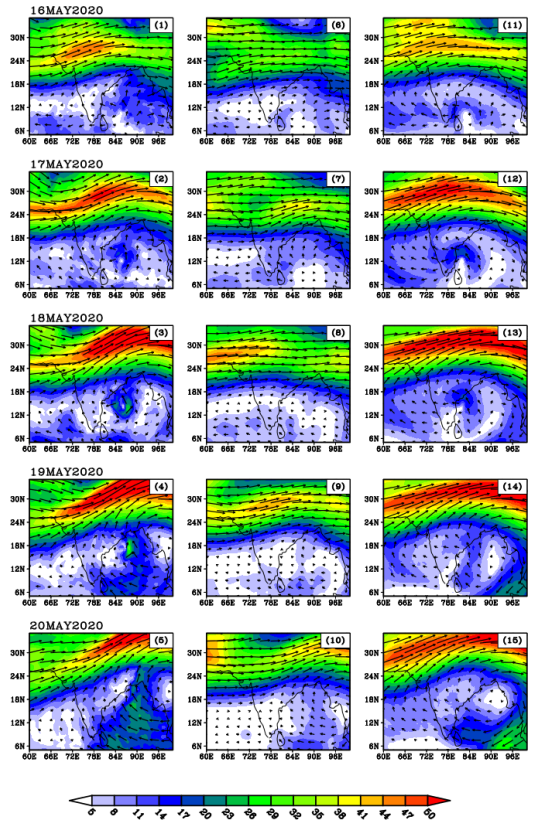

Fig. 3. 200hPa wind(m.s^{-1}) for ERA5(1-5), IMDERF(6-10) and BC-D-ERF(11-15) from 16-20 May

As inferred from Figure 1, the cyclonic system predicted by BC-D-ERF moved in the proximity of the east coast of India, and it weakened at lower latitudes than the observation. For better understanding, 200hPa wind from ERA5, IMDERF and BC-D-ERF are analyzed in Figure 3. ERA5 (Figure 3(1-5)) shows the cyclonic circulation associated with the system in BOB (17-19 May), and its outward flow interaction with strong anti-cyclonic circulation in the subtropical jet stream. The 200hPa wind in IMDERF(Figure 3(6-10)) is comparatively weaker with the dominant westerly component. On the other hand, BC-D-ERF (Figure 3(11-15)) simulated upper-level winds are stronger and have broader and upward shifted circulation maxima. Consequently, the system interaction with large scale flow, and hence trajectory is impacted. Since the large scale boundary conditions are crucial for downscaling, the upper-level circulation bias in BC-D-ERF could have probable origination from driving IMDERF fields. The other possible cause could be the regional model physics. An additional investigation is planned shortly.

Conclusions

Despite the strong genesis signal, the intensity and track forecast of the super cyclonic storm Amphan is mostly underestimated by the global ensemble prediction system IMDERF. The regional ensemble prediction (BC-D-ERF) generated by downscaling IMDERF rectified the storm forecast. BC-D-ERF imitated the temporal evolution of observed super cyclonic storm exceptionally well. The bias in upper-level wind led to a slightly imprecise system trajectory by BC-D-ERF, which can be refined with further understanding. In short, the regional ensemble has the potential for spatial-temporal improvement over the global ensemble in a 7day advance forecast.

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