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Natural Hazards and Earth System Sciences
Discussions
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Interactive comment on "Verification of Pre-Monsoon Temperature Forecasts over India during 2016 with focus on Heat Wave Prediction" *by* H. Singh et al.

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We are thankful to the editor and the anonymous reviewer(s) for their helpful suggestions which have helped us to improve the quality of the paper to a great extent. We have tried to incorporate as many of their suggestions as possible.

Replies to the Reviewer #1 comments

1. The verifications are based on extreme heat events for only one year, the authors could consider a few more years to support their results.

Reply:The suggestion by the reviewer is very valid. For the present study the data from the two modes is available only from 2016. Ensemble based forecasts in realtime using

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Discussion paper

the NEPS started in November 2015 at NCMRWF. For a robust and conclusive results it is necessary that the study be based higher number of cases. This will be carried out in future.

2. The authors have used gridded data. This would have definitely suppressed the extreme station temperature values.

Reply:The temperature data from the stations distribution are discussed in the paper which are used to obtain the gridded Tmax and Tmin data. It is indeed likely that some of the station extremes are smoothed out in the gridded data. It should also be noted that the stations data network is sparse 395 and often there are missing values. Gridded data field provides a continuous and gap free data to workwith.

Replies to the Reviewer #2 comments

1. How much of the skill in predicting the heatwaves comes from persisting a heatwave already present in the initial conditions? How does the model perform when the heatwave evolves within the forecast range (e.g. Beyond days 2-3).

Reply: Extreme events like heatwaves are rare in nature and here we provided a general view of the two particular heatwave events (11 April & 21 May). From our experience as well as the forecast for the post heatwave event days, we can state that the skill of predicting an event with the initial conditions of no indication of severity is comparatively lower than when the signature is present in the initial conditions. Even before the event, there is some signature of it as can be seen in the figure. The overall prediction of warm conditions is nicely predicted but at closer lead times, the events are better predicted. Same can be seen in the box and whisker plots for ETS (and rest of the score plots as well). For instance, the skill of NEPS does not fall drastically from Day-2 to Day-7 and thus depicts a reasonable skill. So, overall the NEPS specifically, has a good skill in predicting the extreme event and is relatively robust.

2. Synoptic evolution in heatwave case studies - It would have been good to also

see the prevailing synoptic conditions and larger-scale flow conditions associated with these heatwaves (e.g. MSLP or low level winds) in both observations/analysis and deterministic and EPS (ensemble mean) forecasts. Perhaps also the time series of temperatures (deterministic and EPS members (at day 2, 5, 7), and Observations) over a specific region (e.g. Rajasthan) during one of the heatwave events would also give the reader a more physical feel for the predictability that is difficult to get just from the verification metrics alone. This is achieved to some extent by snapshots in Figs 4-7.

Reply: Thank you for your insightful comment. As per your suggestion, we are adding a figure illustrating synoptic systems (both, MSLP & low-level winds) for the heatwave event considered in the present work (Dated:20160521). We can see that the monsoon heat low shown by low MSLP values over NW Indian and adjoining Pakistan is an important semi-permanent system during the pre-monsoon season. The low MSLP values and high temperatures associated with that create strong land-sea temperature and pressure gradient in the lower troposphere which is crucial for onset and advance of monsoon. As can be seen in the figure below, during this pre-monsoon month, the low pressure is accompanied by the westerly and north-westerly winds and heatwaves over the Indian and the neighboring countries. In the figure, we see it mainly occurring over the central India.

3. Could the authors provide more detail on how the various categorical scores are calculated for the EPS. Are the scores based on the ensemble mean vs. observations or do they use all 44 individual ensemble members to construct a score?

Reply: Computation of the scores is based on the ensemble mean (44 members). An ensemble mean is first computed from each member which is then treated as another model and is further used to obtain the scores. It is known that the ensemble mean has a higher skill than the deterministic forecast especially in the upper air fields (500 hPa) (cite: Ton Hamil et. al) and similar observation is justifiable for the low-level fields as well (fig: score plots).

4. Page 6, lines 11-12 - "Deterministic forecast hardly shows any variation in either of the considered days and illustrates quasi-stationary characteristics of the deterministic forecast from Day-1 through Day-10 forecast". I don't really understand this or know which figure/result it is referencing. Can the authors clarify.

Reply: Suitably modified and referred to a figure. "The deterministic forecast shows lesser variation as compared to the ensemble forecast on either of the considered days and possibly show a quasi-stationary characteristic of the deterministic forecast from Day-1 through Day-10 forecast (Fig. 2, Fig. 3)"

5. Figure 1 suggests that the deterministic forecasts (and to a lesser extent the EPS) underpredicts the frequency of heatwaves compared to observations over Indian land points. This appears to be inconsistent with later discussions around figures 2 and 3 which suggest that the deterministic and EPS over predict the number of heatwave days (>40) compared to the Observations? Can the authors explain this inconsistency?

Reply: The figure was prepared to choose ranges of the verification metrics and does not serve a purpose to indicate any sort of over or under prediction. This is because the figure represents the "fraction" of the total number of days and the grid points (i.e. counts/92X2686 (days X grids)). The denominator includes all the grid points with or without the Tmax > 40C.

6. In Fig 6. the NCUM and to lesser extent the NEPS forecasts show a growing warm bias over NW India with FC range. Do the authors have any physical explanation for this bias (e.g. soil moisture initialization, model systematic errors in circulation?)

Reply: In 21 May case, warming is increasing drastically for both, NEPS and NCUM. This is not based on one initial condition and include several different initial conditions. We have error growth and warm bias In the present study the impact of soil moisture feedback is not attempted. The land surface scheme involves soil moisture data assimilation using extended Kalman Filter technique. The soil moisture analysis prepared based on screen level humidity and temperature observations and ASCAT

surface soil wetness observations from MetOP-A satellite (C- band, Level2 product). Systematic errors in circulation have been widely and extensively studied and documented for monsoon (JJAS) season. Typically for the pre-monsoon conditions such detailed analysis would be useful and will be taken up as a follow up of this study.

7. Predictability of heatwaves - In the summary the authors state "Unless the atmosphere is in a highly predictable state, we should not expect an ensemble to forecast extreme events with a high probability". It would be good to see some discussion of whether these heatwave events are highly predictable (e.g. links to large scale flow anomalies), given they seemed to be predictable several days ahead? Was the ensemble spread of Tmax smaller or larger than normal in these heatwaves?

Reply: As stated earlier in response to the second point, the extreme events are rare which offeres a small sample size, thereby making their predictability and verification difficult as such. However, signature of the events are noticeable in the synoptic systems, a few days ahead of the event (ex. Wind patterns and MSLP, fig).

8. Are there plans to use these EPS predictions of heatwaves to give warnings to the public? Perhaps some discussion in summary?

Reply: This preliminary study indicates potential skill in forecasting heatwave conditions. With the use of suitable calibration/downscaling and bias correction methods, these forecasts of heatwaves could be useful for the forecasters at operational agency Indian Meteorological Department.

Apart from these specific comments we have incorporated all the technical errors/comments in the manuscripts.

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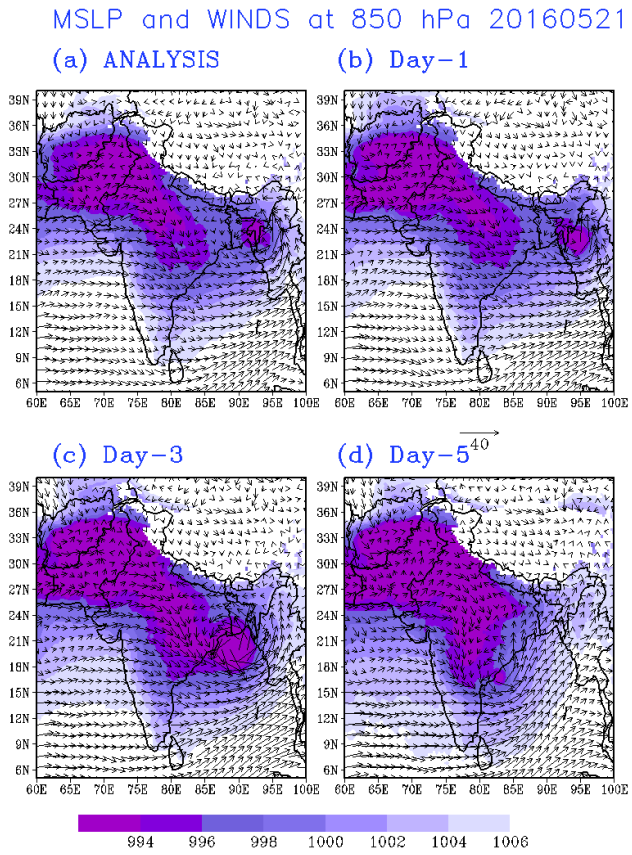
MSLP and WINDS at 850 hPa 20160521
(a) ANALYSIS
(b) Day-1
(c) Day-3
(d) Day-5
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Fig. 1.