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Interactive comment

# *Interactive comment on* "Modeling the contributions of global air temperature, synoptic-scale phenomena and soil moisture to near-surface static energy variability using artificial neural networks" *by* Sara C. Pryor et al.

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Response to: Interactive comment on "Modeling the contributions of global air temperature, synoptic-scale phenomena and soil moisture to near-surface static energy variability using artificial neural networks" by Sara C. Pryor et al. Anonymous Referee #3 Received and published: 23 October 2017

Below we list the comments of the reviewer and our responses (in italics below each point). At the end of this document we also provide a tracked changes version of the manuscript showing the changes we have made in full. A pdf of this entire file is provided as a supplement to this response.

. . .<Preamble deleted for brevity> . . . QUOTE START: I think this work will make a valuable contribution to understand the drivers of surface static energy and heat waves, and would recommend publication after some minor revisions.

My comments are listed below: 1) There major drivers (e.g., global temperature, synoptic-scale indices and SM) were used to develop statistical models for $\theta$e. By comparing the statistical models with and without considering the SM (e.g., ANN-HL3-SM vs ANN-HL3), the authors concluded that the SM played a key role in dictating the warming holes. This statement may be misleading. To identify the relative roles of individual drivers, it might be better to develop statistical models by examining different combinations of the drivers (e.g., global temperature and SM, or synoptic-scale indices and SM). It is also possible that the roles of different drivers may vary in different regions. Response: Yes, quite. We do not infer that a key role of SM is generalizable across land areas . . . we have modified our statement in the conclusions to read; 'Our results imply there are large spatial gradients in the importance of the predictors we used herein and also that our framework has greater skill for max-$\theta$e than min-$\theta$e. It is also important to note that in the northeastern portions of our study region inclusion of SM as a predictor has considerably lower impact on model skill for either max-$\theta$e or min-$\theta$e (Figure 4-7). Global T substantially contributes to model skill near the Gulf coast and close to the Great Lakes but is less important over the remainder to the eastern USA, while SM exhibits greatest importance in sub-regions previously noted as exhibiting 'warming holes'. It is possible that inclusion of additional predictors could lead to enhanced model skill particularly for extreme high values of max-$\theta$e or min-$\theta$e that are of greatest importance to human health, and/or derivation of persistence indices (e.g. the occurrence of consecutive nights with high minimum $\theta$e). We can not conclusively discount contributions from other phenomena (e.g. aerosol forcing, cloud cover) to the occurrence of 'warming holes' (areas with declining or no-trends in T) (Meehl et al., 2015), and these features may be a complex response to multiple drivers. However, results presented herein are consistent with past work that has indicated the importance of soil moisture (SM) in determining partitioning of the surface energy budget, and thus the spatiotemporal patterns of $\theta$e over the central and eastern USA (Koster et al., 2011;Koster et al., 2006;Pryor and Schoof, 2016;Pryor et al., 2016;Ford and Schoof, 2016, 2017;McKinnon et al., 2016). Indeed, SM is particularly important in determining the surface energy partitioning and the magnitude of $\theta$e over regions that have previously been identified as exhibiting 'warming holes', and for all grid cells the RMSE for models including SM as a predictor is smaller than the temporal variability of $\theta$e as measured using the standard deviation of the daily $\theta$e values. Specifically, only a model including SM is able to predict the occurrence of extreme (and highly health-relevant) values of $\theta$e over the western portion of Midwestern states such as IA, MO, IL and also in MS and AL. This research thus implies that SM has played and may continue to play a key role in dictating the presence and intensity of 'warming holes' that have been previously noted in analyses of near-surface air temperature data (from both in situ measurements and reanalysis products).' As the reviewer suggests, an alternative approach to the methodology we employed is a stepwise MLR but of course that would mean apriori assumptions regarding the term interactions. But we hope our research will inspire other studies that could employ the approach the reviewer proposes.

2) The climate variations in the eastern USA are influenced by different climate modes (e.g., ENSO, NAO, IPO). The aerosol may also play some roles on the warming holes. It is not clear why these modes were not used in this study. Response: Yes, the reviewer is quite correct – as we state in the introduction; 'Global scale forcing due to enhanced greenhouse gas concentrations and internal climate variability (e.g. ENSO (Mann et al., 1998)). As T increases the atmospheric water vapor content responds in proportion to the saturation vapor pressure (Willett et al., 2007;Allen and Ingram, 2002). Thus, both components (T and q) of static energy ($\theta$e) are enhanced in years and seasons with high global mean air temperatures. Previous research has indicated that variability in equivalent temperature (Te, i.e. the temperature computed from (1) but

excluding the correction for bringing the air parcel adiabatically to a reference pressure of 1000 hPa) in the North Atlantic is strongly linked to NAO (Ribera et al., 2004), and the probability of ‘heat waves’ across the US is linked to hemispheric waves (Teng et al., 2013) and thus the PNA (Trenberth, 1990).’ We did not explicitly include the teleconnection indices because they will influence the synoptic PC scores. And yes, we quite concur, aerosol radiative forcing may indeed play a key role in warming holes... we have modified our statement in the conclusions to read; ‘We can not conclusively discount contributions from other phenomena (e.g. aerosol forcing, cloud cover) to the occurrence of ‘warming holes’ (areas with declining or no-trends in T) (Meehl et al., 2015), and these features may be a complex response to multiple drivers.’

3) For SM index. The 90-day running mean estimate of antecedent SM in 3x3 grid cells were used. Why it is necessary use the 90-day running mean and 3x3 grid cells average? It was found that the SM would influence the climate downstream. Do you think it is possible to improve the model results by averaging the SM over a large region (e.g., 5x5 or 10x10 grid cells)? Response: Yes, this is an interesting point. We have elaborated on ‘next steps’ by adding; ‘Thus, there would be value in applying this framework to additional observationally constrained data sets to evaluate: (1) The degree to which the findings of a key role of SM to determining the model skill for daily maximum $\theta$e in specific sub-regions are generalizable and spatially consistent between reanalyses, and further if the predictability of $\theta$e exhibits sensitivity to the spatiotemporal averaging used in deriving the SM predictors. (2) If use of a reanalysis product (or forecast model) that does not employ bias-correction of precipitation amounts would substantially alter the ANN model structure. (3) If the partial truncation of the upper percentiles of daily maximum $\theta$e in the model predictions is also a generalizable finding when our model framework is applied to different data sets.’

4) Page 4, line 15. How were the daily maximum and minimum $\theta$ e calculated? Did you firstly compute the $\theta$e using the hourly T, q, and P, and then derive the maximum and minimum values? Response: Yes. We have clarified by writing; ‘An estimate of (i) daily

maximum $\theta$e and (ii) daily minimum $\theta$e in each grid cell (see Figure 1c and d). The daily minimum and maximum values are used as the predictands in the downscaling and are derived using Eq(1) applied to hourly T at 2-m, q at 2-m and surface pressure (P).'

5) Page 5, last sentence. The global T and 15 synoptic-scale PC scores are common to models built for all grid cells, whereas the SM is grid-cell specific. Therefore, it is not a surprise that the SM plays a more important role in the model performance. Response: I am not sure why this would be the case since the models are built grid cell by grid cell and thus the ANN (and MLR) weights can vary in space – thus I am not sure an a priori case could be made that SM must per se exhibit a stronger influence.

6) Table 1. The # of grid cells with r>0.8 & RMSE < 5K were shown. However, it might be better to show the percentage because the number of grid cells depends on the spatial resolution of the dataset used. Response: Yes, I have given the total number of grid cells in the caption to help contextualize the numbers.

7) Figure 2. Would it possible to add the state or continental boundary to the figures? Response: I tried a number of different iterations attempting to add additional lines but sadly it rendered the frames less and less legible.

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Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2017-367/acp-2017-367-AC2-supplement.pdf

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