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Interactive comment on "Tropical Moisture Exports, Extreme Precipitation and Floods in Northeast US" *by* M. Lu and U. Lall

Anonymous Referee #2

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Review of paper "Tropical Moisture Exports, Extreme Precipitation and Floods in Northeast US" by M. Lu and U. Lall submitted to HESSD

This study investigates the role of tropical moisture exports (TMEs) for extreme precipitation and floods in the northeastern U.S. The authors use an previously published TME climatology by Knippertz and Wernli, and quantify the statistical linkage between TMEs entering the northeastern U.S. and precipitation and floods in the same region. The objective of this study is fine, but the quality of the text and figures is insufficient. Important aspects of the study are not well described, the text is confusing in several places (and contains too many details), and again the figures provide too much information and lack clarity and compelling evidence. Since I think that a complete rewriting of the paper is required, including a redesign of the figures, I recommend very major revisions.

Major comments:

A) The writing should be strongly improved, for instance in the abstract:

- I am not sure how an air mass can be "born", and why "primarily"? The TME approach only considers air masses of tropical origin.

Response: We thank the reviewer for the questions. The birth and death of TME refer to the starting and end points of the tracks

- "contribute to the global climatology precipitation and its extremes" –> "... of precipitation"

Response: We think it is redundant to add "… of precipitation" here.

- I am not sure what is meant by "birth process and steering of TME"

Response: They refer to its formation in the tropics and its movement, respectively.

- what is meant by "TME birth and entrance"? I assume that the authors mean "tropical origin of TMEs and where they reach the NE U.S."

Response: Yes.

- what is meant by an "extreme TME"?

Response: Intensive TME activities.

B) Important meteorological aspects are not well described, in several places because sentence are too long and contain too much information, e.g.:

Response: We appreciate the reviewer's comments here and will take these into consideration for the revision of the manuscript.

- p. 1 line 24 (the first sentence of the introduction): this sentence mixes too many things and become incorrect. The surface baroclinicity mainly drives the extratropical westerlies (jet stream), which then leads to Rossby waves, which can break, and these Rossby wave breaking events are likely involved in events of strong meridional moisture transport. Such meridional moisture transport occurs in extratropical cyclones, but then it typically has no tropical origin; in contrast TMEs (meridional transport with tropical origin) often occurs without extratropical cyclones.

Response: Thanks. We will rewrite this to make it clear

- p. 3 line 9: "Lu et al. (2013) associated TME from the Gulf of Mexico and Tropical North Atlantic Ocean (TNAO) ..." –> no need to introduce an abbreviation if it is not used later! "... east to the Bahamas islands" –> too much detail "... as the major moisture sources for the 1995 January flood in western France" –> end sentence here "... and demonstrated the predictability of the extreme precipitation given only the midlatitude sea level pressure (SLP) fields" –> totally different aspect, why mention predictability here? "...suggesting that steering mechanisms were important" –> isn't this trivial, of course the steering of moist air masses is important(?).

Response: We will revise this given the comment. Yes, predictability is a separate point and we will develop it as such. A purpose of understanding the associated mechanism is to see if it offers an opportunity for prediction beyond the usual time scale of average predictability. Steering of moist air masses is important and in this paper and the cited paper it is shown as a determinant of the extreme precipitation. However, in presentations and in comments to the Lu (2013) paper several hydrologists asserted that local moisture recycling and/or land based sources may be a dominant precipitation mechanism. For the extreme precipitation events, we find that the TMEs may actually play a significant role.

- p. 3 line 20: confusing mixture of "TME tracks" and "trajectories", why tracks? Please

make clear that the TME approach is based on air parcel trajectories.

Response: We'll make it clearer in the revision, and use one term consistently

- p. 3 line 21: "Each trajectory has its moisture source calculated for every 100 km × 100 km box between the equator and 20°N" –> what does this mean? The TME approach by Knippertz and Wernli does not calculate moisture sources! "... such that 90% of all water vapor is integrated" –> I don't understand this.

Response: We will clarify this in the revised version and provide a stepwise procedure used.

- p. 3 line 26: "To ensure that the characteristics of the tropical air parcels are maintained on their way across the subtropics" –> what is meant by this? Which characteristics should be "maintained"?

Response: We will clarify this in the revised version and reproduce the criteria from Knippertz and Wernli (2010).

- p. 4 line 20: "The number of TME that enters the N.E. USA on any given day depends on the associated birth process" –> what is meant by this? Do you simply refer to the region of TME origin? Or do you speak about the processes that make the tropical air mass leave the tropics?

Response: The birth process here refers to where and how many tracks are born, how many were born, and how these vary by season. We will restate this to say exactly that

C) I don't see TMEs studies primarily as studies of moisture sources, TME studies mainly address the question "where when and how does tropical moisture reach the extratropics?" For specific moisture source studies, backward trajectories are more feasible and sophisticated techniques have been developed to obtain detailed moisture source fields for extreme precipitation and flood events, see, e.g., the following studies:

Sodemann, H., C. Schwierz, and H. Wernli, 2008. Inter-annual variability of Greenland winter precipitation sources: 1. Lagrangian moisture diagnostic and North Atlantic Oscillation influence. J. Geophys. Res., 113, D03107, doi:10.1029/2007JD008503.

Winschall, A., S. Pfahl, H. Sodemann, and H. Wernli, 2014. Comparison of Eulerian and Lagrangian moisture source diagnostics – the flood event in eastern Europe in May 2010. Atmos. Chem. Phys., 14, 6605-6619.

Piaget, N., P. Froidevaux, P. Giannakaki, F. Gierth, O. Martius, M. Riemer, G. Wolf, and C. M. Grams, 2015. Dynamics of a local Alpine flooding event in October 2011: moisture source and large-scale circulation. Quart. J. Roy. Meteorol. Soc., 141, 1922- 1937.

Response: You are right as to the point of TME studies. Definitely, as indicated in the references cited, a backwards trajectory approach for each event will identify the associated moisture sources. Since the data base available from Knippertz is based on a forward trajectory analysis, we censored those data to retain only the tracks that pass through our area of interest. As a result, we are not able to identify all moisture sources associated with the events, and are only identifying the TME contribution to the precipitation associated with the event. We have used HYSPLIT in other work for backwards trajectory identification, and indeed at the event scale that is the way to identify the fraction from each potential source. Here, we were trying to take advantage of the pre-processed data from Knippertz, and identify just how the tropical sources varied by space and season in their influence on extreme precipitation events in our region, using this data set.

D) p. 4/5: very nice that the authors have specific research questions; they sound good, but they are unclear to the reader. What is an "entrance mechanism"? What are "identifiable atmospheric circulation patterns"? Why identifiable?

Response: We'll revise the language here to be clearer.

E) To me, the tables are much too detailed. Consider only showing seasonal mean values (not monthly) and maybe reduce the number of tables.

Response: We'll reorganize the tables and figures in a way that total number of tables and figures will be reduced and some will be moved to supplementary document.

F) Figures: - to me, Fig. 1 is not insightful, "month" and "ENSO" should not be similar categories

Response: We were considering these as factors influencing TME occurrence – namely seasonality and ENSO – can separate.

- Fig. 2: far too many panels, please reduce the information such that it becomes attractive for the reader

Response: Will simplify and separate to supplement

- Fig. 3: is this for all TMEs, or only for TMEs entering the northeastern U.S.?

Response: All TMEs born in the four regions respectively.

- Fig. 3-5: my impression is that some information in these figures is redundant. Would Fig. 5 not summarize the key information and Figs. 3 and 4 could be omitted?

Response: We'll reorganize the tables and figures in a way that total number of tables and figures will be reduced and some will be moved to supplementary document.

- Figs. 7 and 8: I think here the reader is completely lost, this information is not yet well "digested" by the authors. These monthly fields look so strikingly different such that I don't know what I can learn from these fields. Why showing the entire Northern Hemisphere? The key processes of TMEs entering the northeastern U.S. should be much more local. Also I have no idea what the unit is in these panels (500 Pa? = 5 hPa?). Why are the signals not much stonger near the U.S.? - Fig. 10: caption is unclear. Minor comments: 1) Title, should read "... in the northeastern U.S."

Response: Figure 7 and 8 link the large scale atmospheric circulation with TME entrance. They compare the composite anomalies between active and inactive TME entrance days. For the TME to enter the study area, the associated atmospheric circulation pattern has to be in favour of such convergence of moist air, and we think the large-scale organization contributes to the local organization as shown in our previous study Lu et al., (2013) in Western France, and it also relates to the wave interaction hypothesis advanced in Screen and Simmonds 2014. The unit is added in the revision and the title is modified accordingly.

Screen, J. A., & Simmonds, I. (2014). Amplified mid-latitude planetary waves favour particular regional weather extremes. *Nature Climate Change*, *4*(8), 704-709.

2) p. 2 line 17: instead of Wernli (1997), it was Knippertz and Martin (2007, Weather and Forecasting), who introduced the term "moisture conveyor belt". This sentence is not fully clear to me, I think the main difference between ARs and TMEs is the Eulerian vs. Lagrangian defintion - this should be better emphasized.

Response: We appreciate the reviewer's comment on this. It is very helpful, we will incorporate this in the literature review part.

3) p. 3 line 6: "note" –> "noted"

Response: Typo is corrected.

4) p. 3 line 7: "tropical born moist air masses" –> again, "born" does not make sense; air masses cannot be born or die, what changes is their moisture content, and therefore we

can speak about moisture sources and sinks

Response: The birth and death corresponds to the fact that the data only records up to 7 days. We want to avoid misleading to the commonly adapted definition of sources and sinks.

5) p. 5 line 14: unit should be "kg" not "Kg"

Response: Typo is corrected.

6) p. 5 line 14: "The position of the air parcel was updated every 6 hours, thus each track has 29 (4 updates up to 7 days including birth place, 4×7+1) positions (latitudes & longitudes) recorded on its trajectory." This is terribly complicated and not understandable, why not just "For all TME trajectories, position information (lon, lat) is available every 6 hours". On line 21 you say the same thing again.

Response: We will rewrite as suggested.

7) p. 5 line 22: "death location" is very awkward, this is just the end of the TME trajectory calculation!

Response: Yes.