REVIEW OF LU AND LALL

GENERAL COMMENTS

This paper discusses the role of tropical moisture exports in extreme precipitation and flooding events in the Northeastern United States. The authors seem to have done a thorough investigation, but I found it difficult to assess the value of their results. My main points are:

Lack of comprehensiveness. I found it difficult to pick up the main messages from the paper, because it is lengthy with many figures and many abbreviations. Moreover, the text is often literally saying what is already seen in the figures, but not saying what we learn from these figures. The tables are often full of data, but could often be moved to a Supplement. The methods and definitions should be given more clearly. The conclusions are not 1-to-1 related to the research questions. I'd advice the authors to seriously condense their manuscript.

Response: We appreciate the reviewer's comments and suggestion on improving the writing and organization of the results. We will address these points in our revised manuscript by (1) providing a more comprehensive discussion of the results with improved consistency with listed research questions and (2) reorganize the content substantially and shorten the manuscript.

Context. What is the reason the Norteastern United States were picked as a study region? Is this part of a bigger project or something else? Why is ENSO given so much attention as previous studies showed little influence of ENSO in this region? These main point will also come back in the specific comments below.

Response: The northeastern United States were chosen because we are located in this area and have experienced more and intense storms during the recent years. However, this area has not been widely studied in the context of tropical moisture transports associated with extreme storms. This area was also chosen since in a previous study for Western France, we saw moisture tracks for some extreme storms in France originating in the Gulf of Mexico and passing through N.E. US, with precipitation in the N.E. US enroute to France. A nearly planetary scale organization in atmospheric circulation marked the French flood event, that delivered far field moisture to France.

SPECIFIC COMMENTS

1 and 1.1. The section 1.1 appears to be a mixture of literature review, objectives and method description. Please follow a more common outline. Part of it should go to the introduction and another part should be in Methods and merged with 2 Data, which is a misleading name as well, because it also discusses the modelling framework.

Response: Thanks for the suggestion regarding the layout. We will improve on this in the revised manuscript. The equations provided in data section were for clarifying how we processed with the TME dataset, provided by Dr. Knippertz, and how we calculate the calendar day climatology. These are directly linked to the dataset we use, and it is not a modelling procedure.

Why is not the latest version of the LAGRANTO model used (Sprenger and Wernli, 2015)?

Response: The TME dataset was provided by Dr. Knippertz, who had previously run LAGRANTO and save the trajectories as a a comprehensive data base. Consequently, we did not run it again for our study.

Is backward tracking from the NE- US applied or forward tracking and then integrated?

Response: All tracks in the Knippertz database, that passed through the N.E. USA at any point were retained. The data base considers forward tracking and retains only those tracks that cross 15 deg N, and have a minimum duration, as described in the manuscript

Is the LAGRANTO model run at all by the authors or did they post- process a dataset from previous work? This is all not clear to me.

Response: Please see the response above, and the citation *Knippertz et al.* (2013) in the Section 1.1 Tropical Moisture Export Characterization.

P2:L10-L11: There are many more regions in the world besides the NE-US that not have been studied much in this context. Is there any specific reason why the NE-US has been chosen as a region of study?

Response: In addition to the consideration that this area has not yet been studied in

this context, N.E. US is an interesting area that we observed seasonally changing spatial patterns of the TME tracks in our previous study (*Lu et al*., 2013). **The trajectories have clear spatial patterns that are regulated by seasonal atmospheric circulations. And we have experienced more and intensive extreme events in the past several years, an improved understanding of the hydrometeorological factors associated with them has potential for contribution is needed.**

P2:L14-24: Some suggested definitions are discussed for ARs, "moist conveyor belt" and TME, but what is the exact definition that is used in this paper?

Response: The focus of this study is the tropical moisture exports, which is a broader concept to study the movement of moist air and its linkage with precipitation and associated atmospheric drivers. The definitions provided in the manuscript are the commonly adapted definitions of ARs. They are given in the manuscript to serve as literature review and to show that the concepts of ARs limit a general study; on the other hand, the identification procedure of Tropical Moisture Exports (Knippertz and Wernli, 2010) consists three steps: (1) identify the tropical moisture sources between 0 and 20°N, between 1000 and 490 hPa; (2) retain tracks that reach 35°N within 6 days, this relatively short time span is also to ensure that the selected air parcels are likely to maintain their characteristics of tropical air when they cross the subtropics; (3) further select the tracks by only retaining those reach a water vapor flux of at least 100 k kg^{-1} m s^{-1} somewhere north of 35°N. More details about the definition can be found in Knippertz and Wernli (2010).

P3:L23-25: "Each trajectory represents 3 * 10^{12} kg of atmospheric mass" I do not understand the (relevance of) this statement. How many parcels are released from the vertical? Why is the unit not kg m^{-2}?

Response:. We clarify this in the revised manuscript as "One-day forward trajectories are calculated from every 100 km X 100 km X 30 hPa box between 0 and 20N, between 1000 hPa and 490 hPa. Specific humidity can be converted into water mass as each trajectory represents the same atmospheric mass of ~ 3 X 10^{12} kg (Knippertz and Wernli, 2010).

P4:L14: I suppose that little HESS readers will be familiar with the mei-yu-baiu front. Some explanation is required for readability. The four regions should also be outlined in a Figure. Why isn't sea level pressure data used from the same source as the input to LAGRANTO (ERA-Interim)? Sea level pressure and

Oceanic Niño Index is being used how and why exactly? Four paragraphs are used to discuss Fig. 2. Could this not be summarized in one table?

Response: Since mei-yu-baiu front is not very relevant to the focus of this study, we didn't extend the discussion about this. We will consider the suggestion of providing a figure or a reference for the for TME hotspots regions. We have used NCEP/NCAR Reanalysis dataset before and the quality of the data is assessed and the data resolution and characteristics fit the objective and plan of this study.

P9:L25-26: Is this conclusion drawn from Fig. 2? Or from somewhere else?

Response: It is drawn from the entire study. The sentence here also provides a reason why we further analyse other factors in Fig.1 to complete the framework.

P10: I'd expect a general conclusion from Fig. 3, besides the discussion of the individual panels only. The influence of ENSO seems rather small in general, and definitely not statistically significant, as the neutral years or often not in between El Niño and La Niña, am I right?

Response: The influence of ENSO is seasonal, and we have provided a detailed explanation for each TME source region on which season, the separation between El Niño and La Niña is statistically significant. And the neutral ENSO state line is not necessarily to be always between El Niño and La Niña lines, because the lines show the average number of tracks both in the region. We are interested in the influence of abnormal ENSO years, i.e., El Niño or La Niña.

7 Summary and Discussion: There appear to be 5 key findings, but it would help the reader if the 4 research questions from Page 4 are exactly answered. Moreover, this section could be named Conclusions and significantly condensed.

Response: Thanks for the excellent suggestion. We will modify this section accordingly.

Figure 1: What is the meaning of the different colors of the arrows? What does EP mean? None of it is explained in the caption.

Response: EP, extreme precipitation, is introduced in P4 Line 23. Starting from P4 line 19, we introduced and explained Figure 1, the colors correspond to different levels of our analysis of the dependence. We will further clarify this in the manuscript by adding the explanation on the colors, added text in bold: The conceptual framework of the analysis presented in this paper is indicated in Figure 1. The causal

structure illustrated considers the potential dependence of the TME Birth process as a function of the source location, the season and ENSO state **(red arrows in Figure 1)**. The number of TME that enters the N.E. USA on any given day depends on the associated birth process, the season, the source, the ENSO state, and the atmospheric circulation **(blue arrows in Figure 1)**. The total water released (ΔQ) by the TME in the N.E. USA on a given day is taken to depend on the number of TME entering; the extreme precipitation amount, EP, is considered to depend on the ΔQ **(black arrows in Figure 1)**.

Figure 2: The panels are really tiny and difficult to read. I'd advice to split this into at least two figures or maintain only the most important panels. Please also provide this as a movie, pdf or ppt in the Supplement with each individual panel in one view.

Response: We will take the reviewer's suggestion to provide a supplementary document containing each figure in a separate page.

Figure 2: What is the exact definition of a storm track being born?

Response: In the data section, we've stated that "…daily tracks born in the tropics that meet the following criteria: (1) they reach 35°N within the next 6 days after crossing 20°N, and (2) water vapor flux of any track is not less than 100 g kg^{-1} m s^{-1}."

Figure 2: I suppose the dots are connected to become actual tracks? This is not distinguishable from the tiny panels. Does all tracks "end" in the NE-US? If so, what is the exact definition of the "end" of a storm track?

Response: A supplementary document will be provided. As stated in the manuscript data section that "… each track has 29 (4 updates up to 7 days including birth place, 4×7+1) positions (latitudes & longitudes) recorded on its trajectory." The end of a track is the position on the 7th day after it was born in the tropics. TME tracks can end anywhere, but when we analyze the TME entrance in section 5, we focus on tracks that <u>entered</u> the area, those tracks could enter the study region and exit.

Figure 3: I suppose that the number of tracks is not really a physical quantity, but dependent on the resolution used in LAGRANTO or am I wrong? This should be explained.

Response: It is not a physical quantity. More details regarding the dataset can be found in (Knippertz and Wernli, 2010), but we have emphasized in the manuscript in

section 1.1 that "To ensure that the characteristics of the tropical air parcels are maintained on their way across the subtropics, only trajectories that reach 35°N within the next 5 to 6 days after crossing 20°N were retained; … The water vapor fluxes of the retained tracks in the dataset must reach 100 g Kg-1 m s-1, a threshold chosen to represent 'fast' events and yet get meaningful statistics (Knippertz and Wernli, 2010)."

Figure 3: Do all these TMEs also go to the NE-US? If not, what is the value of this figure?

Response: The figure corresponds to the diagnosis of the seasonality and interannual variability of the moist tracks born in the tropics. It is based on all tracks born in these four regions. It is an important step to complete the framework in Fig.1.

Figure 4: Is a birthplace (source region) the same as an evaporative source (e.g. Keys et al., 2012) or something else?

Response: Yes, the birthplace of a track corresponds to where the convection occurred.

Figure 5b: This is very much scale-dependent and that should be mentioned.

Response: Thanks – we will clarify this

Figure 6: P stands for what? Precipitation, probability? I suppose probability, but it is not defined. As the ENSO signal does not do much, could this whole figure not be merged with Fig. 5b to show the variability?

Response: It has been stated in the manuscript that the formulas, P(X|Y) correspond to conditional probability. We will include a reference on the how we calculate the conditional probability in this study. It actually follows the classical calculation. Figure 5(b) focuses on comparison among all sources; while Figure 6 focuses on separation under different ENSO states. We will consider the reviewer's suggestion to find a better way, also condensed, to present the results.

Results could be compared to http://cola.gmu.edu/wcr/ (Dirmeyer et al., 2009) and then looking at the St. Lawrence river basin.

Response: We thank the reviewer's suggestion on reference, and we will incorporate into revised manuscript.

I am missing the entire point of Figures 7 and 8. What do they explain?

Response: Figure 7 and 8 link the atmospheric circulation with TME entrance. It compares 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.

Figure 9 and Page 14 (and other places as well): Precipitation is a flux is should be defined per unit of time. The time integrator of ΔQ is not given. See http://www.hydrology-and-earth-system-sciences.net/for_authors/manuscript_preparation.html

Response: In Eqn. (2), the change of total specific humidity integrated over all the tracks is calculated for a given date. Our analysis refers to this enter date and focuses on the total precipitation due to TME. We will clarify this in the revised manuscript

Regarding floods and ENSO reference should be given to Ward et al. (2010) and their findings should be mentioned. They find little influence of ENSO in the NE-US.

Response: We thank the reviewer's suggestion on reference, and we will incorporate into revised manuscript. It might be worth mentioning here again that our results suggest a nonlinear relationship between ENSO and TME in N.E. US. This is quite different than the analysis in Ward et al. (2010) for ENSO correlations with computed seasonal discharge.

The number of tables is exaggerated and could for a large part be moved to a Supplement.

Response: Thanks. We will reorganize the tables and move to supplementary document.

Page 16, 2nd bullet: This is a weak and scale-dependent conclusion. I could equally pick any number between 1 and infinite, assign that number of regions and calculate the percentage they contribute.

Response: We will clarity this point further in the revised manuscript.

Page 16, 3rd bullet (and other bullets as well): Please direct the reader to the figures from which the conclusions are drawn. I cannot follow the reasoning around ENSO here.

Response: We will clarity this point further in the revised manuscript.

TECHNICAL CORRECTIONS

It is kg and not Kg is often used in the paper.

Response: Typo is corrected.

The enormous amount of abbreviations makes the paper difficult to read. Please use abbreviations sparsely. The four source regions do not have to be abbreviated in my opinion. IWV is used only once, TNAO only twice, DFO only twice, thus it makes no sense to abbreviate. Please check for more of these examples. TME needs to be redefined in the summary section to be able for the cross-reader to read this sections stand-alone. Should it not be TMEs by the way? "N.E. USA" is supposed to be the abbreviation of Northeast United States as read in the abstract. As there is no "A" (see title) and the placement of the dots is a bit random I would suggest to write is as NE-US and it to be the abbreviation of the Northeastern United States.

Response: We really appreciate the reviewer's suggestion on this writing details. We will incorporate all these in the revised manuscript.

Response: All the following typos are corrected.

P2:L18: "Tropical Moisture Exports (TME) was" "were"

P4:L20: "enters" "enter"

P5:L1: "mechanism" mechanisms. There are simply too many plural/singular mistakes that I will not list any more.

P5:L1: "Atmospheric" atmospheric

P5:L15: & and

P11:L5: place a comma after First

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