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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Summertime cyclones over the Great Lakes Storm Track from 1860–2100: variability, trends, and association with ozone pollution" *by* A. J. Turner et al.

Anonymous Referee #2

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This paper examines summer Great Lakes storm track (GLST) cyclone frequency trends across different reanalyses datasets, and simulated present-day and future changes in GLST frequency and their relationship to ozone exceedence events in the GFDL CM3 coupled chemistry-climate model. They report some interesting findings: a) previously reported present-day trends in cyclone frequency are strongly sensitive to the period chosen; b) a reduction in winter and summer cyclone frequency between present-day (2006-2025) and future (2081-2100) as well as slightly reduced variability in summer cyclone frequency in the future; c) a declining trend in summer cyclone frequency from 2006-2100 and d) a weak anti-correlation between simulated de-trended cyclone frequency and de-trended "high" ozone events over the period 2006-2100. The

analysis between GLST cyclone frequency and high ozone events for different definitions of "high" ozone events is particularly informative. There are nice summary tables of simulations and datasets. Overall these are interesting results that could be tightened and made clearer in a number of places. Hence a good deal of my comments relate to text changes.

Major comments:

1) The distinctions between this work and Leibensperger et al. (1008) should be clearly laid out in the Introduction and methods, since a number of figures are similar to those in Leibensperger et al.

2) Table 2 presents results from a comparison of the reanalyses datasets over the full time period that the reanalyses is available for. This time period differs considerably amongst the datasets listed in Table 2. The comparison of the NCEP/NCAR reanalyses over the shorter period equivalent to that used in Liebensperger et al. is rather more insightful. Some further comparison of trends for all the reanalyses datasets for as similar periods as possible would be a useful addition to Table 2, as well as some discussion of differences in trends on decadal vs. centennial timescales.

3) The study makes use of a control simulation to quantify internal model variability in cyclone frequency but doesn't make use of the 5 ensembles for the historical period to quantify 20th century variability in cyclone frequency (ranges based on min and max ensemble members are depicted in Fig. 3 only the ensemble mean is discussed hereafter). Analysing the trends in cyclone frequency over the historical period would relate more directly to the findings of Liebensperger et al. who find a role of climate change between 1980-2006 on cyclone frequency. Hence, the analysis performed in Fig 4 performed for the 5 historical ensemble members (trends and their significance) may yield useful insights. If space is tight I think the analysis of the historical runs may be more useful that the analysis of the control run.

4) These ensemble member would also be useful for assessing the importance of the

changes in summer storm track frequency between 2006-2025 and 2081-2100. i.e. are the differences in cyclones /summer between 2081-2100 and 2006-2025 (Fig 6 , 3rd column) greater than the differences in cyclones/summer between the 5 ensemble members for present-day.

5) 21685: line 14 “any storm tracking through the region”-How much of the storm track (number of points along its track) needs to fall in the bounded region for the “storm” to be included and how sensitive are the trend results to such assumptions?

General comments:

6) In a number of places numerical values in the text should be accompanied by the relevant period e.g. “a reduction of 5.7 cyclones in summer between 2006 and 2100”.

7) In places numerical values are given in the text that are hard to see based on the figures scales as is. This applies in particular to Figs. 1 and 2. Make sure the figures scales and companion body text are compatible.

8) The abstract contains a lot of technical details that could be trimmed especially as these are given in the methods e.g. the details of the RCP 4.5* scenario. Some p values could be trimmed.

9) The authors state that their findings do not refute Yin (2005) yet the results in Fig. 5 do seem to differ from Yin (2005) in that there is no obvious dipole of change in behaviour. The argument given could be rejected or confirmed by considering percentage or normalised changes.

10) The authors also state that their findings are more consistent with Tai et al. (2012) who performed analysis for the period 1999-2010, yet the authors state above this text that on decadal rather than centennial periods that they find some periods in which cyclone frequency and high ozone events are strongly anti-correlated (r=-0.79).

11) Storm track methodology description- (21684: line 21): It is unclear how this methodology (Bauer et al. 2102) differs from that used in Liebensperger et al. (2008)

or from the other studies cited- how is it more comprehensive?

12) Can the authors check the p-values throughout the text and tables. In fig 4. panels (d-g) seem to show clearer trends than panel (i) yet the p-values vary widely.

13) The use of normalised cyclone frequencies is advocated to account for offsets or biases in Fig 2a. Hence, a comparison of Fig 6 and Fig 2a would be useful to see if there are any biases when using the starting years of the RCP scenario. An extra column in Fig 6, showing the normalized cyclones/summer for the base 2006-2025 period would achieve this.

14) The smaller variability in the future period in Fig. 7 is an interesting result. Has this been reported elsewhere? It may show up more clearly in the standard deviation than in the RSD (which only shows differences of $\sim$2%).

15) Fig 1: (21686: line 15): the reductions of 30 and 40 ppb are hard to ascertain from Fig 1. First, the units on the scale (increments of “14”) could be modified to make for an easier comparison with the text. It might be useful to highlight the points on the track that are observed for each day (e.g. July 26 and 27 show identical northern storm tracks). As a minor point - give the year of July storm event in Fig 1 caption and body text.

Specific comments:

21680: Line 6: expand “yr” to “years” in all places.

21681: line 21: “Mid-latitude cyclones ..synoptic and climatic scales .. regional scale.” This sentence could be written more clearly.

21683: very briefly outline how H1 to H5 differ- e.g. initial conditions

21683: line 25: The temperature values given depends on the GCM. Make sure this is noted e.g. ”corresponds to an .. warming of 4.5K in the GFDL CM3 GCM” .

21684: line 16: mention some of the well-known storm tracks

algorithms (often used operationally): e.g.: Serreze et al. http://www.esrl.noaa.gov/psd/map/docs/stormtracks.maproom.html Hodges et al. A Comparison of Extratropical Cyclones in Recent Reanalyses ERA-Interim, NASA MERRA, NCEP CFSR, and JRA-25 , 2011, K. I. Hodges, R. W. Lee and L. Bengtsson, J. Clim. , 24, 4888-4906

21685: line 10: Why is the "maximum travel distance" needed if you impose a maximum speed criteria? The use of the parabolic fit is similar to that used by Murray and Simmonds (1991) and related schemes. Murray, R. J., and I. Simmonds, 1991: A numerical scheme for tracking cyclone centres from digital data. Part I: Development and operation of the scheme. Aust. Meteorol. Mag., 39, 155-166.

21685: line 15: explain why the southern storm track is “southern”.

21685: line 18 rephrase “as major storm track”.

21685: line 22 defining GLST here is rather repetitive (c.f. line 24 on page 21682).

21687: line 6: – the “relative standard deviation” is commonly referred to as the coefficient of variation.

21687: line 10: Explain what “following Liebensperger et al.” means in this context.

21687: line 17: clarify what “the GFDL CM3 model cyclone frequency is within 10% throughout ” means, make sure the scale in Fig 2c is somewhat compatible in its labelling.

21687: line 25: explain the trend fitting procedure -“p-value of a trend”.

21688: line 2: re-word “interannual correlation coefficient” (ditto Fig 8. caption)

21688: line 24: Control or unforced simulations are commonly performed to quantify internal model variability within a model hence the reference to ENSO in unnecessary.

21688: line 27: The results from the control simulations may differ depending on period

chosen. Some comment on the sensitivity of the resulting trends to the period of trend fitting should be given.

21689: line 17: “For comparison . . .” this sentence needs re-written.

21689: line 21: it would be helpful to add values for the reduction in cyclone frequency.

21690: line 7: Fig 6c not Fig 6f?

21690: line 18: “-0.03 a-1 corresponding to a decrease of 2.85 cyclones per summer. . .” for this statement to make sense the period e.g. “between 2100 and 2006” needs to be added.

21691: line 28: explain how fig 8b represents the Northeastern US as single times series of high ozone events. Is this an average or a sum?

21692: line 6: Re=phrase the sentence “While the sensitivity found ..the sensitivity is not robust.” for clarity.

21693: line 5: clarify both “climate-driven shifts” and “recent decades”.

21693: line 17: “significant trends in other reanalyses products” clarify if this statement only refers to the whole period of the data given in Table 2 or also applies to the 1980 -2006/2010 periods.

21693: line 28: “Lang and Waugh. . .” This sentence is not an explanation of the result in the previous sentence.

21694: line 4: “weakly anti-correlated” does this refer to the original data (fig 8b) for which no r-value was given or for the de-trended data in fig 8c.

21694: line 16: “This work demonstrates. . . insights . . .applied..quantifying feedbacks to the chemistry-climate system”. This sentence is rather complex and the connection with quantifying feedbacks (if that is climate affecting chemistry affecting climate) is not obvious. A simpler sentence would be more useful.

Table 2: Add trend fit values to p-values for clarity. RSD column fits better after sigma values.

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