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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Sensitivity of US air quality to mid-latitude cyclone frequency and implications of 1980–2006 climate change" *by* E. M. Leibensperger et al.

E. M. Leibensperger et al.

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Response to Comments on "Sensitivity of US air quality to mid-latitude cyclone frequency and implications of 1980-2006 climate change" by Referee 2 September 22, 2008

We would like to thank the reviewer for their insightful comments and suggestions. Our responses to the comments are listed below. The referee's comments are *bold/italicized* and our responses are in normal print.

Major Issues: ***This study of ozone pollution episodes in the northeastern USA and their relationship to changes in emissions and cyclone frequency is intriguing but in its present form fairly unconvincing due to the discrepancy be-***

tween a significant decline in the cyclone frequency between the NCEP/NCAR and NCEP/DOE reanalyses. I read this paper and formulated my own basic response prior to reading the comments of Referee1 and the reply by the authors. All of my major concerns were brought up by Referee1 and the response by the authors has allayed some of those concerns, but not entirely.

Most importantly the paper has to convincingly answer the question of whether or not there is a significant decreasing trend in cyclone frequency above the northeastern USA and southeastern Canada between 1980 and 2006 based on observations and reanalyses. Here is a review of the observational/reanalysis evidence:

1) NCEP/NCAR reanalysis says yes at 99% confidence level, with a trend of -0.15/yr

2) NCEP/DOE says no at 99% confidence interval. When confidence is relaxed to 95% the uncertainty ranges from -0.15/yr to +0.08/yr. So the trend could be as negative as the NCEP reanalysis, but it could also be zero or it could also be positive. What would the interval be at the 99% confidence level? The authors point out in their response to Referee1 that the NCEP/DOE reanalysis only extends back to 1980, perhaps to give some explanation as to why this data set does not show a trend. But I find this point to not have any weight because the time period of interest is 1980-2006, which is fully covered by both reanalyses.

RESPONSE: The 99% confidence interval for the trend in NCEP/DOE Reanalysis 2 is -0.20 to 0.14 a^{-1}. We do not use this statistical analysis in our revised manuscript.

3) Wang et al [2007] analyzed surface pressure across Canada and found that during summer in the region of the Great Lakes (within the regions explored by the present study): "the trend pattern is characterized by significant increases in the number of cyclone deepening events on the east coast with decreases of marginal significance in the Great Lakes area". So this does imply some de-

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crease in cyclones but it8217;s not entirely conclusive because it8217;s only for a portion of the study region, the decrease is of marginal significance, and the time period analyzed is 1953-2002, rather than 1980-2006.

4) The papers by Gulev et al. and McCabe et al. apply to winter so they are not relevant to this summertime analysis. Given that the Wang et al paper seems to support the NCEP/NCAR reanalysis, but that the NCEP/DOE reanalysis (which has better physical parameterizations and error fixes than NCEP/NCAR) shows no significant decreasing trend, I would say that the jury is still out on the existence of a significant decreasing trend.

RESPONSE: We provide the studies of Gulev et al., McCabe et al., Wang et al., etc. as the foundation that trends in cyclones have occurred over the last 50 years and that the identification of a trend is not new and unexpected.

Further information is required to explore the discrepancy between NCEP/NCAR and NCEP/DOE. A good check on the accuracy of the cyclone tracks identified by the two reanalyses is to compare them to the NOAA Daily Weather Maps. These maps are available for 12 UTC above North America every day over many decades and archived at: docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html

These maps are hand drawn by expert NOAA weather forecasters and based on surface observations rather than the reanalyses, so they can be considered to be somewhat independent of the reanalyses.

Most of the discrepancy between the two reanalyses appears to be driven by the years 1981, 1985 1988 and 2003, when the differences between cyclone numbers is greatest, as shown in your Figure 4.

My recommendation is as follows: Take the years of 1981, 1985 1988 and 2003 and print out all of the daily weather maps for June, July, and August (I realize

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this is a lot of paper). Take a clean overhead projector transparency and trace the outline of the 70-90W and 40-50 N box that matches up to the daily weather maps. With this template count all of the cyclones in the box for each day. Then compare this count (and the cyclone positions) with the 12 UTC cyclone positions of the two reanalyses.

Which reanalysis matches the observations best?

Until this ground-truthing of the reanalyses is conducted I don't have any confidence that there is a significant decreasing trend in cyclone frequency above the study region during summer from 1980-2006, and therefore have no confidence in the major conclusions of the paper. Hopefully the NOAA daily weather maps can reveal which reanalysis is the most accurate in terms of cyclone tracks and frequency.

RESPONSE: We appreciate this suggestion by the reviewer. We conducted an analysis of NOAA's daily weather maps and have made that analysis an integral aspect of our paper. We counted the number of marked "Lows" which are within a closed SLP contour. In order to be tallied, the low had to be tracked at least 24 hours (the same lifetime restriction applied by the storm tracking procedure on the 6-hour SLP fields from the reanalysis data) and travel through the region bounded by 70-90°W and 40-50°N.

The resulting time series for 1980-2006 is significantly correlated with Reanalysis 1, Reanalysis 2, and ozone pollution days. As in Reanalysis 1, the NOAA weather maps exhibit a decreasing trend of comparable magnitude (-0.14 a^{-1}). We have added the time series of cyclone derived from the NOAA daily weather maps to our Sect. 5. The result is the same as with Reanalysis 1; ozone pollution days would have an expected value of 0 by 2001.

Analysis of the reanalysis sea-level pressure data indicated that the discrepancy of the cyclone time series resulted from differences in the intensity and position of the sea-level pressure minima for the three different data sets. These differences can result in

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displacement of the cyclone relative to the red box in our Fig. 3 used to identify the southern climatological track, and can occasionally affect cyclone detection. We say so in the revised paper. We cannot conclude from Figure 4 (now including the NOAA weather map statistics) that one of the reanalyses matched the NOAA weather maps better.

Minor Comments: ***Figure 1. The images are too small and the pressure values cannot be seen***

RESPONSE: We have enlarged the image and the text of the pressure contours.

Figure 2. I would also like to see a plot of Reanalysis 1 for 1979-2006

RESPONSE: There are not significant differences between the two periods. We now mention this in the text and further explain our intention of Fig. 2.

"Patterns and magnitudes are in good agreement, showing that the cyclone tracking algorithm applied to the reanalysis data can reproduce the observed large-scale climatological distribution of mid-latitude cyclones. Inspection of 1979-2006 vs. 1950-1977 climatologies in Reanalysis 1 indicates no difference between these two periods in the large-scale cyclone patterns shown in Fig. 2, although there is a significant trend as discussed in Sect. 4."

Figure 3. The boxes only extend from 90W to 75 W instead of to 70 W.

RESPONSE: We have fixed this error in Fig. 3.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 12253, 2008.