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Climate of the Past Discussions

Interactive comment on "Extratropical cyclone statistics during the last millennium and the 21st century" *by* Christoph C. Raible et al.

Anonymous Referee #2

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Formal review of manuscript for Climate of the Past

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Title: Extratropical cyclone statistics during the last millennium and the 21st century

Authors: C.C. Raible, M. Messmer, F. Lehner, T.F. Stocker, R. Blender

Recommendation: Minor revision

General Comments: The authors investigate the variability of extra-tropical cyclone characteristics for the North Atlantic / European region based on a long coupled GCM simulation (850-2100). First, the variability pre-1850 is evaluated, rendering the general result that in spite of the identified multi-decadal variability no external forcing imprint

is identified for this period. On the other hand, a general decrease in cyclone numbers (particularly for the Mediterranean) and cyclone related precipitation (e.g. north of 50°N over Europe) is identified for the XXI century. Finally, the authors discuss the possible relevance of thermodynamic vs dynamical processes for the identified trends / variability. The manuscript is well written, the methodologies and statistics are well applied, and the conclusions are largely sound. The consideration of such a long transient run is quite unusual, and the embedded discussion of natural vs anthropogenic forcing is quite interesting. Therefore, I believe the manuscript is a worthy contribution to Climates of the Past. Nevertheless, several minor aspects should be improved / better discussed before the paper is in acceptable form. Therefore, I recommend a minor revision according to the comments given below.

Minor Comments:

#1: lines 47-58: There is quite a lot of additional literature in this topic, so I understand the authors need to do a selection. However, I would recommend to include the two review papers of Ulbrich et al. (2009) and Feser et al. (2015), e.g. on line 48 and 52. If possible, a few more sentences on the different measures of cyclone activity and the regional differences would be excellent.

2: line 60: Please clearly state here that you mean that the low level meridional temperature gradients are reduced on average. On the upper troposphere, it is the opposite, as the strongest warming occurs in the tropical regions. Please find a suggestion below. This should also be stated more clearly other text passages.

"The decrease of the projected low level meridional temperature gradient on average (due to strong high latitude near surface warming associated with polar amplification) implies a decrease of storm activity in the future, (. . .)<"

3: lines 161-163: While I understand the authors′ idea to consider the 90th percentile of central pressure and cyclone depth as a proxy for windiness, I think it would have been easy to assign peak near surface wind speeds close to the cyclone core (e.g.

Zappa et al., 2013) a more adequate measure of windiness associated with the cyclones. What has this not been done? Was the near-surface wind data not stored? Or was there another reason? This potential shortcoming makes a few statements in the manuscript (e.g. line 338-340) less robust and should at least be discussed as a potential shortcoming.

4: lines 185-199: It is a bit unusual that the (lower resolution) GCM has a higher cyclone frequency as the ERA-Interim dataset. While I tend to agree with the authors that this may be partially associated with an enhanced number of weak lows in the GCM, I wonder in how far the (bi-linear!!!) re-gridding of the ERA-Interim played a role here. What do the cyclone statistics with the original ERA-interim grid look like? Are the statistics more comparable if one only considers strong cyclones (e.g. exceeding a certain depth)?

#5: lines 301-310: Given that the main author has co-written a review paper on the NAO variability during the last millennium (Pinto and Raible, 2012), I wonder why so little is discussed about the link well established link between the NAO variability and cyclone variability over the Eastern North Atlantic and Europe (except for this text passage). In my opinion it would be pertinent to strengthen this statement and discuss a bit in how far the NAO variability in the simulation matches (or not) the cyclone variability for various parameters shown in Fig. 4, and in how far this agrees with NAO reconstructions. Even if the authors will surely explore this further in subsequent (and more regional) studies in the future, I suggest expanding the topic a bit here.

6: lines 378-379: I suggest referring to Zappa et al (2013) here, which showed exactly this based on the CMIP5 model ensemble.

7: lines 381-401: The interesting thing here is that the increase in cyclone related precipitation is particularly clear north of 50°N (notably over Europe), while elsewhere reduced precipitation is often found, particularly at lower latitudes. Recent studies (e.g. Santos et al. 2016) have identified that there may be a "circulation independent" in-

crease of precipitation north of $\sim$ 45°N over Western Europe and comparative drying around 35-45°N (cf. their Figure 9). This may imply that for the latter the increase of humidity is overcompensated by temperature (thus lower relative humidity) or hampered by increased subsidence. I think that present statement for the whole region regarding the Clausius-Clapeyron relationship is too general , and a more differentiated regional discussion would be quite interesting.

11: line 424: Please add Ulbrich et al (2009) and Zappa et al. (2013) here.

12: line 429: see discussion in #10, please enhance, maybe adding "at least north of 50°N" or similar.

References (not exhaustive):

Feser F., et al. (2015). Storminess over the North Atlantic and Northwestern Europe: A review. QJRMS, 141, 350-382. doi:10.1002/qj.2364.

Pinto JG, Raible CC (2012) Past and recent changes in the North Atlantic Oscillation. WCC, 3, 79–90. doi:10.1002/wcc.150

Santos JA, (2016) Understanding climate change projections for precipitation over Western Europe with a weather typing approach. JGR-A, 121, 1170–1189. doi:10.1002/2015JD024399

Ulbrich U, et al (2009) Extra-tropical cyclones in the present and future climate: a review. TAAC, 96, 117–131. doi:10.1007/s00704-008-0083-8

Zappa G., et al. (2013) A multimodel assessment of future projections of North Atlantic and European extratropical cyclones in the CMIP5 climate models. JCLIM, 26, 5846–5862. doi:10.1175/JCLI-D-12-00573.1, 2013.

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