Response to comments of Anonymous Reviewer #1

I like to thank the Referee for her/his constructive comments that help me to improve the manuscript. Below, detailed responses to all comments are given.

1. In my opinion, there is, however, one very important point missing in the study which should be addressed before the manuscript is finally accepted: The study sets out to identify conditions leading to extreme events. The author finds that specific cyclone and blocking locations favour the development of such extremes. It is suggested that the method can be applied to models of different climates to assess extreme weather events. In order to do so it has to be checked if the relevant cyclone and blocking anomalies are only a necessary or also a sufficient requirement for the development of the extremes. The study forgets to check in how far moderate weather events are linked to the same anomaly patterns and if it is really possible to assess (changes in) extremes by analysing (changes in) the blocking and cyclone patterns. I assume that especially in the case of precipitation the conditional frequency anomaly patterns for extreme and moderate events will be very similar. In my opinion, it is important that this aspect is looked at and discussed. Regardless of the outcome of this check, the paper is interesting and should be published when such a discussion has been added.

This comment brings up two related aspects: the question of necessary or sufficient requirements for the occurrence of extreme events and the anomaly patterns associated with moderate weather events. With respect to the first aspect, it is evident from the frequencies of extreme events and circulation features that the circulation anomalies can only be a necessary requirement, since the circulation features are much more common than the extremes. For instance, the cyclone frequency over the Adriatic Sea is between 20 and 30%, while the frequency of precipitation extremes at the northeastern slope of the Alps (with which those cyclones are often associated, see Figure 4) by definition is only 1%. The following discussion will be added to the conclusion section of the manuscript: 'Note that the circulation features identified here are typically much more frequent than the associated weather extremes, indicating that a cyclone or blocking anomaly usually is a necessary, but not a sufficient requirement for the occurrence of an extreme event. For instance, the depletion of soil moisture can be an additional factor for hot

temperature extremes, as shown in previous studies (see again Fischer et al., 2007; Vautard et al., 2007; Seneviratne et al., 2010; Quesada et al., 2012). A comprehensive characterisation of the sufficient requirements for weather extremes in Europe should be established in future research.'. Note that the evaluation of models with respect to the representation of such necessary, but not sufficient requirements can nevertheless be insightful.

Regarding the second aspect: the circulation anomalies associated with moderate weather events usually have a similar spatial pattern, but a much weaker amplitude compared to extreme events at the same location. As this is common to all types of events discussed in this paper, it will only be shown exemplarily for precipitation extremes at one location in the revised manuscript. The following paragraph and figure will be added to the paper (note that Figure 5 in the new manuscript will be the figure shown below): 'When not only extreme events, but also moderate precipitation events at the same location are considered, a conditional cyclone frequency anomaly is found in a similar region, but with a much weaker amplitude (Fig. 5). This indicates that cyclones south and southeast of the target location can also be associated with less extreme precipitation, and hence there have to be additional factors besides the presence of a cyclone to foster precipitation extremes at the target location. On the other hand, moderate precipitation events often occur in different synoptic settings, leading to the reduction of the amplitude in Fig. 5 compared to Fig. 4b. Spatially coherent feature frequency anomalies with greatly reduced amplitudes like in this case are generally found for moderate events corresponding to all types of weather extremes discussed in the following (not shown).'

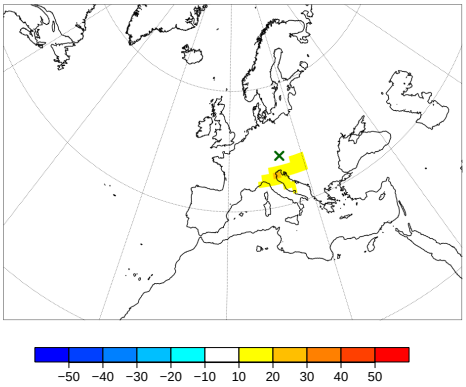

Figure 1: Conditional cyclone frequency anomaly $\tilde{f}_c$ for moderate precipitation events at 14° E, 48° N. The field is only shown where the conditional cyclone frequency differs by more than 10 % from the climatological cyclone frequency of each season. Moderate precipitation events are defined as events with the six-hourly accumulated precipitation above its 80th percentile. Note that, since the percentile is defined based on the complete time series including dry days, the 80th percentile corresponds to a relatively small value of 1.2 mm $(6\text{h})^{-1}$.

2. Section 3.2 In how far do the results depend on the applied cyclone tracking algorithm, which identifies only closed cyclones? It may be that only the steering cyclones are captured. I assume that in a lot of cases there will be an open cyclone closer to the target region. Please look at some individual cases and comment on this.

As shown in the examples in Fig. 2 below, there are indeed cases when, in addition to a larger cyclone further to the north, a small system with a more open, trough-like SLP structure is found closer to the target grid point (a short note on this will be added to the manuscript). This is most prominent for the case of "Lothar" in December 1999. Nevertheless, also for this case the algorithm finds a closed contour and thus captures the signal of the secondary system. There may be cases of just developing frontal waves in which this is not the case, but these are most probably very rare and thus do not substantially affect the statistical results.

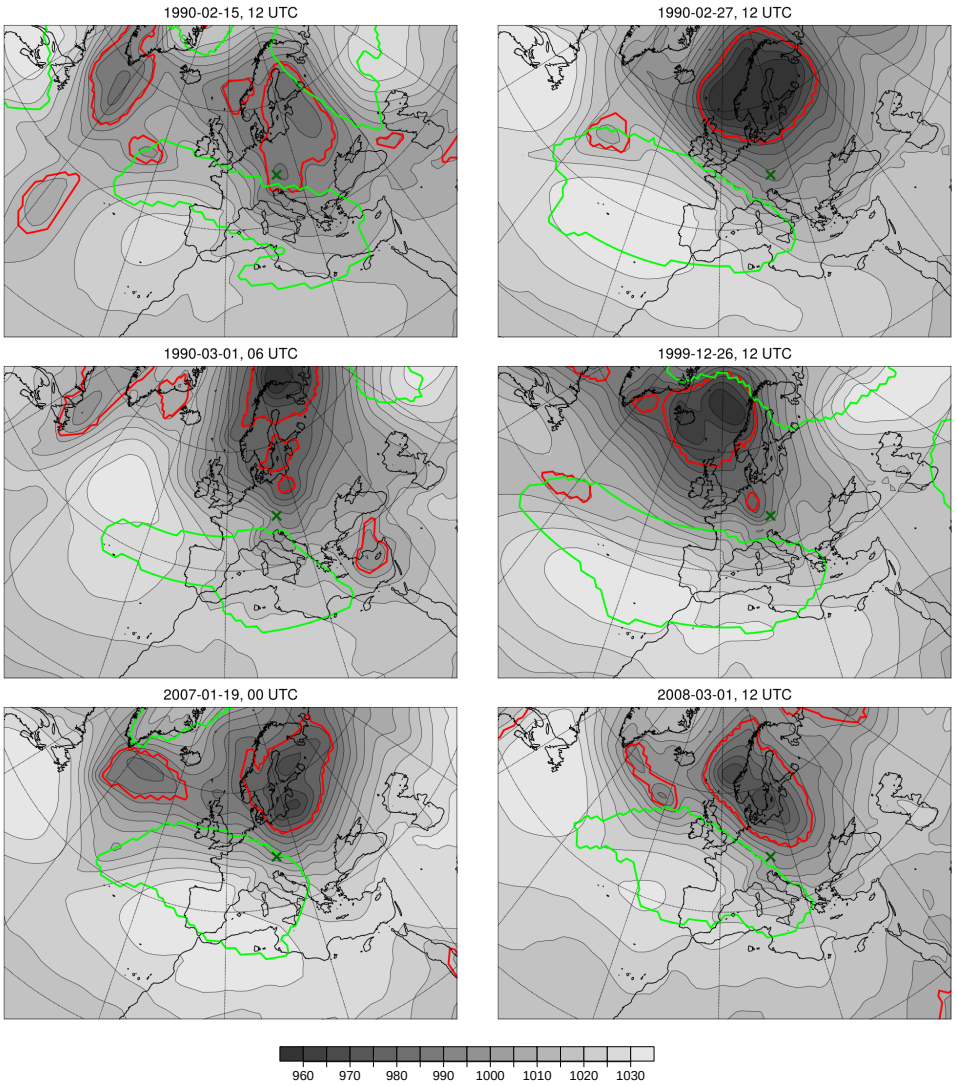

Figure 2: Sea level pressure (gray contours, in hPa), cyclone (red contours) and blocking (green contours) areas during most intense wind gust events at 14° E, 48° N. Note that all these events correspond to well-known historic storms.

3. P1881-1882 Is blocking on its own sufficient to cause a windstorm or is the presence of a cyclone also required?

For the example shown in Fig. 7a of the discussion paper, the absolute conditional cyclone frequency over the Baltic states is on the order of 80%. As cyclones do not always occur at the same location (and spatial shifts induce some smoothing in the composite anomaly pattern), this indicates that a cyclone is present somewhere to the north or northeast of the target grid point during virtually all extreme events. This is in agreement with all individual cases I have looked at (including those shown in Fig. 2 above), also for other grid points. Wind storms typically result from the combination of both circulation anomalies. The wording in section 3.2 will be slightly adapted to make this clearer.

4. Figures: It is difficult to distinguish the yellow and turquoise shades in the conditional cyclone frequency anomaly plots.

The colour scheme will be slightly adapted to make the colours more distinguishable (as in Fig. 1 of this document).