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Discussions

Interactive comment on "Climate change increases the probability of heavy rains like those of storm Desmond in the UK – an event attribution study in near-real time" *by* van Oldenborgh et al.

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Reply to Interactive comment #4.

General comments

This paper examines the attribution of the "Desmond-like" heavy-rain event in the UK in the context of climate change. The authors provide a probability attribution analysis for the extreme rain event using three independent methods: historical observed trends, coupled climate model simulations and a large ensemble of regional model simulations.

All three methods agree that the effect of climate change makes the extreme event more likely.

The manuscript could be an important contribution to diagnosing attribution of extreme weather events in the context of climate change. However, the paper is not well-written and is hard for readers to follow. In addition, the role of internal climate variability such as NAO is not well discussed, given the fact that the NAO is in the positive phase this winter. Therefore, I expect the paper will be suitable for publication after a major revision with consideration of my major points listed below.

We agree that the paper was not well-written due to self-imposed time constraints. For the next study (http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-308/) we took more time. prompted by all reviewers we also made this article much more readable.

We address the NAO point below.

Major points

P13200L2 *"Low-frequency variability also plays a minor role here." I am not convinced with this statement, given the fact that NAO is in the positive phase this winter. There is a robust relationship between NAO and precipitation in UK. I would suggest to compute the conditional probability of the extreme rain event modulated by NAO. If the NAO matters, it would be interesting to see if the conditional probability of the extreme event to NAO is more likely due to the climate change.*

The NAO of course matters greatly for precipitation in this area. However, this is only at short time scales. The probability of extreme precipitation in NW England in December is higher if the NAO is higher in December, but it is not significantly higher if the NAO is high over the whole season studied, October–February, simply because the main decorrelation time scale of the NAO is well below one month.

In this study we attempt to separate the probability of extremes occurring in two components: trend and chance. The randomly varying weather component of the NAO falls squarely in the chance category, and is therefore implicitly included in the calculations as such.

There are two possible complications to this simplified picture. One is that the NAO may have a trend component due to global warming. As the reviewer is well aware, a lot of research has gone into this since the high NAO values of the 1990s, with as outcome that the trend is small, both in models and in observations up to now ($r = -0.05$ for the correlation between the October–February Gibraltar-Iceland NAO from CRU and smoothed global mean temperature 1880–2014). Anyway, this component would have been included as a dynamical contribution to the trend in this study, and hence affected the risk ratio in the attribution statement.

The second, more worrying, complication could be that the NAO (or another relevant mode of climate variability) has a low-frequency component. This would mean that our error estimates are too small, as these assume all years are independent. The sentence quoted above addresses this possibility. Concerning the NAO, the October–February averaged NAO index has lag-1 yr autocorrelation zero, and the spectrum does not show significant low-frequency variability beyond the integrated effect of the high-frequency variability. There is month-to-month autocorrelation but that does not affect our seasonal maximum analysis.

Other low-frequency modes that could have caused dependences between different years are the AMO and PDO. However, we show that high precipitation in the area of interest has very low correlations with these two modes, so they do not affect the results.

Added text: 'precipitation extremes are not significantly correlated to the Atlantic Multidecadal Oscillation (AMO) or Pacific Decadal Oscillation (PDO) at $p<0.1$ over 80 years of observations.' The connections with ENSO are also not signifi-

cantly different from zero. We are not aware of any other low-frequency variability that could influence extreme precipitation in this region.'

Minor points

1. **P13201L15** *"The results are shown in Fig.2 for the two regions." The figure here should be Fig. 3.*

   Thanks, this has been fixed.

2. **P13201L16** *"The horizontal line denotes the preliminary indication for precipitation in these areas." What does preliminary mean here?*

   It means that the precipitation has been estimated from the ECMWF analysis, which cannot be compared directly to the ERA-interim reanalysis as it is at a much higher resolution. Since we wrote the manuscript the updated Northwest England and South Scotland series have been made available by the UK Met Office. These give return times below 7 years for the event on these two area averages (the rain was spread over two 9-9 days; locally and with other start times the return times are larger.)

   The ERA-interim 0-24 value for the larger box is 25.1 mm/dy, indeed lower than the analysis. In the EC-Earth ensemble this gives a return time of about 20 years, even lower than we estimated when writing the article. The risk ratio is assumed not to depend on the return time when using the GEV fit in the observations and EC-Earth data. The Weather@Home analysis does not make this assumption but also shows little dependence on the return time between 20 and 100 years, the 95% CI changes from 1.05. . . 1.4 to 1.01. . . 1.35. We added these numbers to the text, clearly labeled as added in the revision.

3. **P13206L21** *"After a an impactful climate . . . " There is an extra "a" here.*

   This sentence has been rephrased.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 13197, 2015.