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Reply on RC3

Lisa-Ann Kautz et al.

Author comment on "Atmospheric blocking and weather extremes over the Euro-Atlantic sector – a review" by Lisa-Ann Kautz et al., Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2021-56-AC3, 2021

Reply on RC3

Recommendation: suggested revision

Comments: This paper surveys current and recent literature describing the weather and climate implications of atmospheric blocking over the Euro-Atlantic sector. Temperature, hydrological, winds and compound anomalies are discussed, together with predictability and future climate projections.

It is widely recognized that blocking patterns drive surface weather anomalies but there are few papers that catalog many specific events that demonstrate their associations and this review paper is unique in that regard. On the other hand, the discussion of hazard types and case studies is sprawled over many disparate events and pertinent publications yet it is hard to grasp key points other than that each event is different (it was a laborious read). Certainly section 8 nicely summarizes the current state of the field and main challenges (I agree with all the points raised in that section), but instead of just laying them out in the conclusion, the authors can proactively structure the text to address some of these challenges.

Reply: We thank Noboru Nakamura for his positive and insightful review. We have tried to outline the difficulties and challenges of this area of research in the main text. In section 8, we summarize these challenges, but also address specific points that should be investigated in future research. Following the reviewers' suggestions, these will be implemented during the revision. In addition, we will better motivate the individual sections and add some explanations and concluding statements.

For example:

- I think it is important to stress the importance of case studies at the beginning because (i) the sporadic nature of events hinders statistical analysis of data and (ii) there is a wide variety of weather extremes associated with the types and position of blocks

Reply: Thank you very much for this pertinent suggestion! We agree that the importance of case studies has not yet been sufficiently emphasized in the manuscript. Thus, we will take the reviewer's suggestion and point it out already in the introduction.

- How one generally determines whether a surface event is related to blocking is probably worth discussion before diving into the list of case studies, even though this may reveal the main challenge of the field (metric dependence, etc).

Reply: We agree with this point and that this could be better captured in the text. We will therefore add a paragraph on how studies conclude that a blocking has had an impact on the development/formation of a surface weather extreme event.

- It would be useful to have a table (possibly in the supplementary material) that lists the notable events mentioned in this paper, with the dates, affected regions, the types of hazards, the association with the block according to the region specified in Figs.1 and 2, the phase of NAO, and the estimated damage/fatalities. (It is not easy to find an authoritative estimate of economic losses even remotely associated with blocking. The list will be an easy reference for scientists who search for past relevant events.)

Reply: That is a great idea. We will add such a table in the revised manuscript as an overview.

- If we have a list of events in the table mentioned above, perhaps Sections 3-5 may be shortened, highlighting only quintessential examples.

Reply: After the table has been compiled, we will carefully re-evaluated sections 3-5 and check where we can shorten the text.

Other points:

LL17-20 (also Section 3.1): I'm not sure about Europe, but in the US, heat waves on average kill more people annually than any other form of natural hazards: https://www.nrdc.org/sites/default/files/tracking-silent-killer-heat-health-fs.pdf (and many are demonstrably related to blocking). Since heat affects the population in otherwise cool climate the most, its potential danger may be stressed more.

Reply: Thanks for the comment. Also in Europe, heat waves are among the deadliest natural hazards, while storms and floods are among the costliest. We will add further information to the introduction and re-phrase the text to enhance clarity and details.

LL122-124: This reads like low PV air generated near the surface is advected upward. Is it what it implies? — I suspect latent heating can occur over a column of the troposphere; in that case it is the upward diabatic mass flux that 'dilutes' PV in the upper troposphere that leads to a negative PV anomaly (what gets advected from the boundary is mass, not PV)? (Hayne s and McIntyre 1987, JAS p.828 Fig.2)

Reply: Exactly, we do not want to imply that low PV air is just passively advected upward from the surface. We will reformulate the sentence accordingly. Methven (2013) investigated PV in WCB outflow in general and could show that the PV distribution within a WCB depends primarily on the net diabatic transport of mass.

LL128-133: Meridional displacement of PV is generally related to Rossby wave transience, but it can operate in different ways — feeding of transient Rossby waves from upstream is an important ingredient but the modulation of quasi-stationary Rossby waves by the remote (sub)tropical sources can be also important.

Reply: Thanks for this suggestion! We will add this statement to the text.

LL235-240: Does orography play any role at all (e.g. adiabatic heating associated with a foehn wind)?

Reply: Some studies have provided evidence that warming associated with foehn winds can play a role during heat waves (e.g. Ma et al. 2014). However, since our aim was not to describe the dynamic processes of heat waves in general, but rather to focus on the impact of blocking, we have excluded the information of the orographic effects in the manuscript.

LL254-259: Does the balance between radiative cooling and adiabatic warming (subsidence) play more prominent role in summer (in association with heat waves) when advection is weaker?

Reply: Yes, these mechanisms are more important during summer than in winter. In summer, heat waves can develop well underneath (blocking) anticyclones, as the short-wave radiation reaches the ground in an unhindered manner during daytime. In addition, there is adiabatic heating due to subsidence. The radiation-induced cooling then plays a role, especially at night, counteracting the warming through subsidence. As a result, there is a temperature drop during nighttime. However, this temperature drop can be very small - for example during tropical nights when the temperature nevertheless remains above 20 degrees.

LL349-359: I think droughts here largely refer to meteorological droughts, but there are other types of droughts (hydrological, agricultural, socioeconomic, and ecological) that could spawn from persistent blocking events and making that distinction may be useful.

Reply: Thank you for pointing this out. We will address the definition of droughts in the revision.

L482: One of the most exceptional drought —> One of the most exceptional droughts

Reply: We will correct this.

LL534-535: Record-breaking snowfall happened the northern part of the Alps —> Record-breaking snowfall happened in the northern part of the Alps

Reply: We will correct this.

L584: Costal storm surges —> Coastal storm surges

Reply: We will correct this.

L600: the presence of and a blocking system —> the the presence of a blocking system

Reply: We will correct this.

L624: power plants —> power outages (?)

Reply: We will replace "power plants" by "losses in power plant operation" as suggested.

LL630-637: The discussion in Section 6 focuses on short-term predictability. But climate models tend to underestimate blocking occurrences in the Euro-Atlantic sector. Does that mean that climate models also underpredict the frequency of extreme weather?

Reply: The representation of blocking systems in climate models was discussed in detail in the review by Woollings et al. (2018) and is therefore not dealt with in section 6. However, we do consider this topic in section 7, where we point out that it is not possible to transfer the possible trends in blocking frequency to the occurrence of weather extremes. This is partly because weather extremes can also develop without the influence

of blocking. In addition, there are complex interactions on different space and time scales, which make it difficult to make statements about causal relationships under future climate conditions. Thus, one can expect that a change in the frequency of blockings will also have some impact on the occurrence of weather extremes – but there is not enough evidence now to quantify this effect.