

Interactive comment on “The Nonequilibrium Thermodynamics of Atmospheric Blocking” by Andrew Jensen

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I would like to thank the reviewer for the helpful review and the excellent suggestions for improvement. I will take them into account in a future version of the manuscript which will be much improved by your review.

Major Points:

1) It's unclear what additional insight the study provides, beyond an indication of the importance of sensible heating to the maintenance of the blocking events. What does "added value" does the thermodynamic interpretation bring, for example over the use of the Bowen ratio?

Reply: One of the principal reasons for using entropy is that it can be used to exam-

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ine the vertical structure of blocking events. This is a complementary approach since blocking is very often examined on a single surface, such as a constant pressure surface. As mentioned in the manuscript, entropy also combines many variables into one (not just the sensible and latent heat fluxes), which also is an advantage.

2) The framework here closely follows that of Li and Chylek (2012). However, lateral fluxes are neglected here. As noted by Li and Chylek, these are zero when integrated globally, but lateral fluxes are likely to be important in a regional application like this. How do you rationalize neglecting them?

Reply: The framework also follows Li and Chylek 2014. However, not including the lateral fluxes is a weakness in the current version of the manuscript. In a future version of the manuscript I will add calculations and spatial plots of entropy advection (lateral fluxes). The addition of the lateral fluxes should add value to the analysis by showing more comprehensively what is occurring in the blocking region.

3) It would have been more convincing had the author examined more than just the two cases considered here. Since the results for these two events aren't fully consistent, we don't know to what extent they carry over to similar episodes. Are there really only two episodes of this type of blocking available?

Reply: One of the points of the manuscript was to compare the two events, to highlight similarities and differences. The events had different mechanisms sustaining them, which the entropy variables highlight. I looked for other events that occurred at the same time and place (January-February) with approximately the same duration. I didn't find any that included the Blob in the same way. However, the analysis could be performed for other events.

4) The author notes in several places that entropy production increases disorder in the system. Yet a quasi-stationary blocking situation seems to be a more ordered state than one dominated by storms. You state that "blocking tends to dissipate the orderly structure in a region" when it seems to do the opposite. There is also the claim that

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the "blocking state was in part maintained by adding large amounts of entropy...when entropy production was decreasing, the exact opposite of the negative entropy flows in highly organized phenomena...". Again, a stationary high seems like an organized phenomenon.

Reply: I apparently didn't make the my argument and perspective on entropy entirely clear. In a future version of the manuscript I will remedy this. I offer here a summary that I hope alleviates any concerns.

The use of the order/disorder description of entropy isn't necessarily the best way to describe blocking. There are only a few sentences mentioning this in the manuscript and I will modify them in a future version. I will also add a discussion highlighting the differences between equilibrium vs. non-equilibrium thermodynamics in blocking.

For example, in the past blocking has often been viewed as an equilibrium state (Charney, DeVore 1979, etc.) or even a quasi-barotropic state. It can be argued that these approaches aren't necessarily realistic. For example, that blocking is not always necessarily best characterized in this way is evidenced by the strong entropy production in the calculations in the manuscript. The calculations here suggest that blocking is closer to a non-equilibrium steady-state, strongly entropy producing with significant boundary fluxes.

Also, I didn't mean to imply that blocking wasn't coherent. It is. The main ideas in the manuscript have been influenced and motivated by an analogy with the characterization of long-lived coherent vortices as maximum entropy structures, such as occur in two-dimensional turbulence (see Turkington et al. 2001, Bouchett and Sommeria 2002, Sommeria 2005). Under certain conditions, including maximum entropy, these vortices can be anticyclonic. Blocking is long-lived with a characteristic lifetime of ~ 10 days with many events more than twice that length so it is long-lived 'coherent vortex'. I chose two such events here. Hence the coherent vortex maximum entropy structure idea. This is an equilibrium concept, while the calculations here suggest that the anal-

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ogy isn't perfect; but again, it motivated the present study. Again, blocking is closer to a non-equilibrium steady-state, strongly entropy producing coherent vortex with significant boundary fluxes. In a future version of the manuscript I will compare and contrast the two approaches.

5) Does using a fixed geographical region matter? In episode 2, the Blob migrates southward, and I wonder to what extent this affects the results.

Reply: It matters, but for comparing both events I wanted the analysis regions to be the same. Including lateral fluxes (entropy advection) should provide a more detailed picture of what occurred in the blocking regions.

Minor Points:

The writing needs some work. You state in many places that the results are "derived below" or "as will be shown below", sometimes in subsequent sentences. The line "However, less so for the 2015 event..." on page 7 isn't a sentence.

Reply: Thank you for pointing this out. I will check the language.

Page 4, and again on Page 5 – You claim the blocking episode formed out of a strong drought-associated ridge. But certainly the ridge was associated with the block, ie. they occurred simultaneously?

Reply: Blocking events form out of preexisting ridges. The blocking event is itself a large-amplitude ridge also.

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