Review result of "The movement of atmospheric blocking systems: can we still assume quasi-stationarity? Mourik et al."

Overall recommendation: Major revision or rejection.

The topic of this manuscript is interesting. However, there are many ambiguous issues in this manuscript. In this manuscript, the authors emphasized the difference of the impact between eastward- and westward-moving ones. In fact, these differences are obvious and natural. In this study, the authors repeated previous studies and results. Thus, no enough new results are found in this manuscript. The authors should further discuss the relationship among the size, movement speed and strength of blocking because they are not independent each other in a blocking system. The authors also ignored many previous similar studies in the introduction and text in this manuscript so that the authors said "**To our knowledge, no studies have considered the effect that the propagation velocity of atmospheric blockings has on our weather**" in the introduction. Such a description is completely misleading. Moreover, I do not think that the author's 2D Cell-tracking Algorithm on the zonal propagation velocity of atmospheric blocking is correct. Thus, I recommend a major revision or even rejection.

Major comments:

(1) Misunderstanding of the quasi-stationarity of blocking.

In fact, the quasi-stationarity of atmospheric blocking as planetary-scale waves is said relative to the movement of synoptic-scale weather systems. The quasi-stationarity does not mean that blocking is not moving. Atmospheric blocking is often classified into three types: stationary or quasi-stationary, westward- and eastward-moving.

(2) **Lines 45-46**: The description on "**To our knowledge, no studies have considered the effect that the propagation velocity of atmospheric blockings has on our weather**" is not correct. The impact of the propagation velocity of atmospheric blockings on local weathers or short-term variability of Arctic sea-ice has been widely investigated in previous studies. For example, Chen and Luo (2017, GRL) and Yao et al. (2017, JC) examined different impacts of westward-moving and

stationary (sometimes, referred to as quasi-stationary) blocking events over Greenland and Ural region on continental cold anomalies or weathers. Then, Chen et al. (2018, JC) further classified Ural blocking into quasi-stationary, westward- and eastward-moving Ural blocking and examined the impact of the three types of Ural blocking on the short-time variability of Arctic sea-ice and continental cold anomalies. Zhang and Luo (2020) also examined how the Arctic sea-ice decline over the west of Greenland influences the zonal propagation velocity of Greenland blocking (GB) and how the zonal movement of GB influences cold anomalies over North America and Europe. In the introduction, the authors completely ignored the previous studies so that the authors incorrectly said "**To our knowledge, no studies have considered the effect that the propagation velocity of atmospheric blockings has on our weather**". Please the authors read these previous papers.

(3) **Lines 55-56:** "Our study has two objectives: to start with, we will assess the characteristics of the zonal propagation velocity of atmospheric blocks and how it relates to blocking size, intensity, duration". In previous theoretical studies, the zonal propagation velocity of atmospheric blocking linked to the blocking size, intensity and duration has been established in Luo et al. (2019) and Zhang and Luo (2020). They found that a small meridional potential vorticity gradient favors the persistence of atmospheric blocking. When atmospheric blocking is stronger, it shows less eastward movement, larger zonal scale or blocking size and slower decay (Zhang and Luo 2020). What is the difference between the author's results and previous results? Please read the previous papers.

(4) In the Data and Method section (lines 130-144), the authors tried to use the two-dimensional (2D) Cell-tracking Algorithm to calculate the zonal propagation velocity of atmospheric blocks. However, I think that such a 2D Cell-tracking Algorithm fails to identify the zonal propagation velocity of atmospheric blocking because this 2D Cell-tracking algorithm cannot differentiate the group velocity and phase speed or zonal propagation velocity of the blocking anomaly in the form of

$\psi_B = B\sqrt{\frac{2}{L_y}}\exp[i(kx-\omega t)]\sin(my)+cc$ (Luo et al. 2019), where cc denotes the complex conjugate of its preceding term, L_y is the width of beta channel and B(x,t) is the complex blocking envelope amplitude and the time-longitude variation of absolute B(x,t) or $|B|$ denotes the group velocity of the blocking anomaly ψ_B with zonal wavenumber k, $C_p=\omega/k$ is the zonal propagation velocity of the blocking anomaly in a linear theory framework. In a nonlinear theory framework, the zonal propagation velocity of the blocking anomaly is $C_{NP} = U - \frac{\mathrm{PV_y}}{k^2+m^2+F} - \frac{\delta_N M_0^2}{2k\mathrm{PV_y}}$ (Luo et al. 2019, JAS), where U is the basic zonal wind, PV_y is the meridional gradient of background potential vorticity and M_0 is the blocking amplitude or intensity. If the authors calculate the zonal movement speed of ψ_B by tracking the maximum or minimum intensity of ψ_B, this movement speed cannot represent the zonal propagation velocity of atmospheric blocking. Thus, I do not think that the results based on the 2D Cell-tracking algorithm are correct. Please see Zimin et al. (2003, 2006) about how to calculate the group velocity and zonal propagation velocity of atmospheric blocking.

(5) The unit about the zonal propagation velocity of atmospheric blocking. The zonal velocity of Rossby waves is expressed in the unit of "m/s". Thus, I suggest that in Tables 1-2 and Figs. 4, 9, the unit "km/day" should be changed into the unit:"m/s".

(6) There are different zonal movement speeds of atmospheric blockings in different region. The authors should calculate the zonal propagation velocity of atmospheric blocking by dividing the Northern Hemisphere into three (five) regions in winter (summer) according to Fig.2. Unfortunately, the authors did not discuss this issue.

(7) **Line 183**: The authors should clearly describe what do the 10th, 50th, and 90th percentiles mean.

(8) Please explain why the large blocking size tends to be westward-moving and why long-lived or large amplitude blocking tends to be eastward-moving in Fig. 4.

(9) I do not think that the results in Fig. 6 are correct. I do not understand why summer eastward-moving atmospheric blocking events are more frequent in high-latitudes.

In contrast, winter eastward-moving atmospheric blocking events are more frequent in the relatively low latitudes.

(10) In the conclusion section, the authors should also strengthen some comparisons with the previous similar studies.

References:

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Yao Y., et al., 2017: Increased quasi-stationarity and persistence of Ural blocking and Eurasian extreme cold events in response to Arctic warming. Part I: Insight from Observational Analyses. J. Climate, 30, 3549-3568.

Luo, D., et al., 2019: A nonlinear theory of atmospheric blocking: A potential vorticity gradient view. J. Atmos. Sci., 76, 2399-2427.

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Zimin, A. V., I. Szunyogh, D. J. Patil, B. R. Hunt, and E. Ott, 2003: Extracting envelopes of Rossby wave packets. Mon. Wea. Rev., 131, 1011–1017.

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