A review of EGUsphere-2026-1156 (Subseasonal predictability and Rossby wave dynamics of blocking high during transitional seasons: Insights from three successive events in May–June 2023) by Zhixiang Li et al. (2026)

Recommendation: Major revisions

Li et al. (2026) takes a case study approach to examining three consecutive blocking events across the Northern Hemisphere in May and June 2023. Through the calculation of certain blocking diagnostics, the paper helps to establish a dynamic connection between the three successive events. In the second half of the paper, the predictability of these events is examined using the ECMWF subseasonal-range ensemble prediction system.

The paper is interesting and offers a nice foundation for a climatological assessment of similar dynamically linked blocking events. The scope and analysis are of high quality, but I find that there is insufficient context that motivates many of the analysis choices and how the motivation of extreme weather is incorporated into the main paper. I think with additional context, this will be a highly successful paper.

Response: **Thanks for your positive evaluation on our manuscript and very constructive comments.**

General comments

While I am familiar with the metrics and calculations used in this paper (wave activity flux, stationary wavenumber, Tibaldi and Molteni blocking index), there is little context for what these metrics show and what the benefits/limitations of these metrics are. For example, what should the reader take away from the observed zonal wavenumber (k) falling below the stationary wavenumber (K_s)? I think a better description of how these metrics help us to understand the dynamics of these events could improve the paper greatly.

Response: **Thanks for your comments, and we are following your suggestions by adding in the manuscript more description about these metrics and how they help us to understand the dynamics.**

The figures in this paper, especially figures 3 and 4, need to be enlarged for ease of viewing. Much of the results of section 3.1 rely on interpretation of these figures, and the WAF vectors are very difficult to see.

Response: **We fully agree with your comment and enlarged figures have been ready for the revised manuscript.**

Outside of the introduction, there is very little mention of the connection between the three blocking events and the sensible weather extremes of Canadian wildfires, extreme precipitation in Italy and East Asia, and a heatwave over Northwest Europe. There is also very little literature cited that looks at the dynamic connection between blocking and these weather extremes outside of these specific events. Adding this context would help to connect this work to the broader literature on blocking better.

Response: **Your suggestions are very useful, and we plan to add the context you mentioned in the revision. Indeed more relevant literature have been read recently and they shall be properly included in the revised manuscript.**

In section 3.3, the predictability and potential sources of said predictability in the ECMWF ensemble forecasts are discussed. Given that this paper emphasizes the dynamical connection between the three events, could the enhanced predictability of the Ural block in late May be linked to the blocking over Canada in early May? For example, do the best ensemble members for the Ural block successfully capture the block over Canada? This is not a necessary edit, but I wanted to suggest it as a possibility.

Response: **Indeed we've checked the ensembles and found that the best ensemble members for the Ural block are those better capture the later evolution (collapse and then energy dispersion) of the Canadian block, and so in this regard your conjecture is right. But because the prediction experiments do not last long enough for fully covering both blocks, so they are not necessarily the same ensemble members.**

Line-by-line comments

Lines 32–33: The three blocking episodes are not defined before being mentioned here.

Response: **The episodes will be defined explicitly in the revision.**

Line 48: "Northern Hemisphere" should be capitalized.

Response: **Done.**

Lines 169–172: The timing and occurrence of the blocking events have only been alluded to at this point through Figure 1. It might make sense to more explicitly state when and where the blocks occurred, and how they are temporally related to the weather extremes mentioned in lines 53–63.

Response: **We agree with your comments, and we will revise the manuscript accordingly.**

Line 223: What is meant by "scale effects" here?

Response: **The term "scale effects" here follows Hoskins et al. (1985), meaning that for a given amplitude of disturbance, a larger spatial scale leads to a faster westward propagation relative to the eastward zonal mean flow. We use this term to explain the dynamical reason why a smaller wavenumber results in slower or even westward wave propagation. We will clarify this in the revised manuscript by adding a brief explanation and the appropriate citation.**

Hoskins, B. J., M. E. McIntyre, and A. W. Robertson, 1985: On the use and significance of isentropic potential vorticity maps. Quart. J. Roy. Meteor. Soc., 111, 877−946, https://doi.org/10.1002/qj.49711147002.

Line 384: You mentioned that $k<K_s$, but there is not much context for the significance or interpretation of this fact. Tying into my first general comment, more text discussing the implications of your calculations would be helpful.

Response: We agree with that the significance of k<Ks deserves more discussion. In the revised manuscript, we will expand this section to explain that when the local zonal wavenumber is much smaller than the stationary wavenumber, Rossby waves can propagate westward. In addition, a larger spatial scale also corresponds to a broader area of influence for extreme weather events (e.g., the extent of Canadian wildfires). We will link this to the phase speed diagnostics (the observed westward propagation), and the spatial extent of extreme weather impacts (with appropriate citations) during the blocking episodes.

Line 401: How is "meaningful" benchmarked in terms of predictability? Probabilities of blocking also fell in subsequent forecasts, so is the enhanced predictability just random change?

Response: This is a valuable comment. We use "meaningful" subseasonal predictability to refer to cases where more than 40% of ensemble members correctly predict the positive Z500 anomaly, with very few members indicating a negative anomaly, at lead times of 15–19 days.

We acknowledge that predictability varies with initialization date, and we will add a discussion noting that this may reflect potential windows of predictability rather than random chance. In fact, we find that this >2-week predictability originates from the accurate prediction of upstream wave precursors, as shown in the Hovmöller diagram in Figure 8. To further illustrate this, we will add a new figure comparing the horizontal propagation of wave energy between good and bad ensemble members, where the importance of accurately predicting Rossby wave energy propagation is clearly evident.

Line 402: Change "ensembles" to "ensemble members"

Response: **Done.**

Lines 425–435: If SSTs are considered a possible driver of planetary-scale wave structures, why were they not examined in the ECMWF ensemble?

Lines 429–431: I am not sure how your results "highlight the importance of midlatitude SST anomalies for the evolution of circulation patterns" when the analysis is only mentioned at the very end of the summary and discussion section.

Response: **The discussion about SST will be removed in the revision. Logically only interactive SST will play a role in predictability, but here the SST are prescribed in the experiments.**

Reviewer #2

Recommendation: Major Revisions

General Comments:

This study analyzes three consecutive blocking events that occurred in May-June 2023. Li et al. (2026) present a novel analysis of each event through the diagnosis of Rossby wave parameters, as calculated using a Hilbert transformation. Through this, the authors successfully demonstrate the interconnected nature of these three events. Additional work is shown to examine the predictability of the three blocking events using the ECMWF S2S model. They show maxima in predictability for each event at 15-19 day lead times and shortly before the initiation of each blocking event.

The analysis presented, especially those of Rossby wave parameters, are excellent and do well to establish a useful perspective on the temporal and spatial evolution of blocking events. My primary concern for improving this manuscript is the need for additional contextualization of the methodology utilized. Additionally, there is a real need to reevaluate several figures, both in their visual presentation and the utilization of the analysis within the text. Further, the motivation for this study could use bolstering. Upon revision, I believe this study would prove an excellent addition to literature of atmospheric blocking.

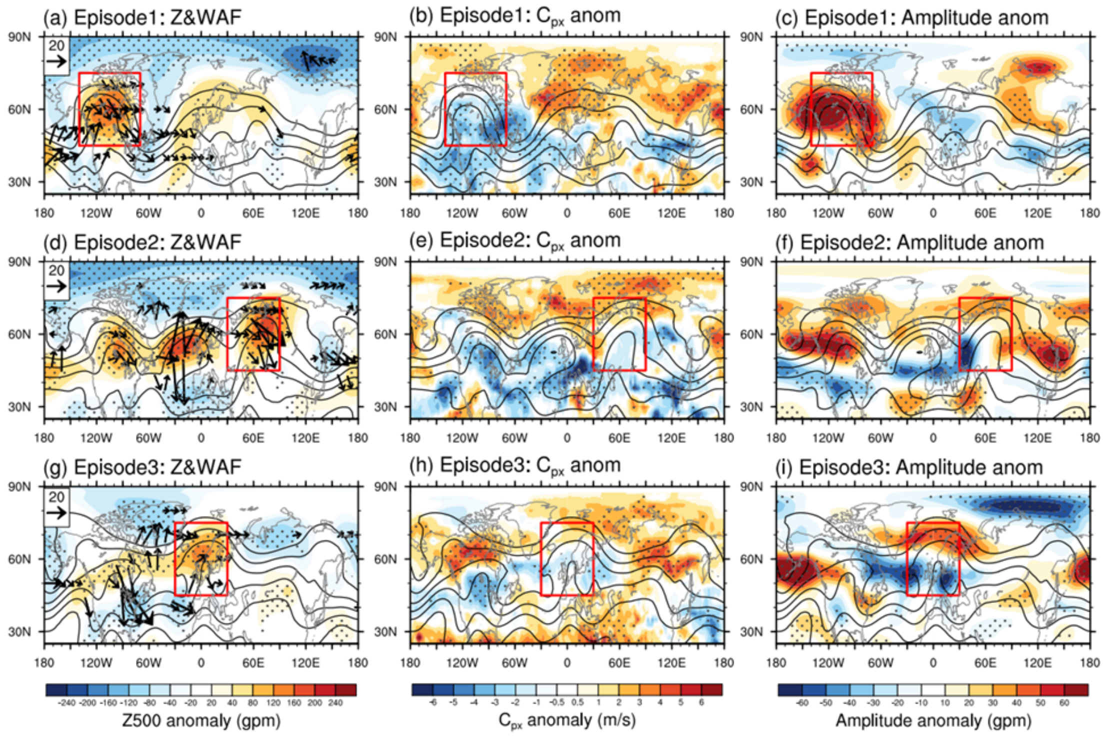
Response: We appreciate very much your encouraging evaluation and useful comments on our manuscript.

Specific Comments:

- Many figures are difficult to decipher due to their size within the manuscript, specifically Figs. 1, 3, and 4. Figure 3 is far too small, especially given how critical this figure proves to be for the analysis presented in sections 3.1 and 3.2. It is very difficult to distinguish the WAF vectors from the stippling in the left column. One other potential improvement to Figure 3 could be the contouring of WAF convergence, given that this quantity proves important to the interpretation of the figure. If this makes the figure too busy and less legible, it would be understandable to leave out.

Response: We agree that Figures 1, 3, and 4 should be presented more clearly. In the revised manuscript, we have enlarged all figures and the WAF vectors. Regarding WAF convergence, however, as the reviewer anticipated, this would make the figure excessively busy, especially given the dense information already present (Z500 anomalies, Z500 contours, WAF vectors, stippling). Therefore, we have chosen to keep the current format.

The new Figure 3, shown below as an example, illustrates this improvement.



New Figure 3.

- 1 is seemingly the motivation for the study, as it shows the extreme impacts of the three blocking events; however, these results are utilized throughout the study. There is little reference to either Fig. 1 or to literature to specifically tie the blocking events to the weather extremes. How is the blocking event in Canada explicitly connected to the wildfires? What connects the blocking event in the Ural Mountains to the anomalous precipitation in East Asia? What dynamics force the European heatwave? I do not mean to suggest more analysis needed; rather, the text needs to explicitly address these questions through references to Fig. 1 and literature.

Response: We thank the reviewer for this suggestion. In the revision, we will add a paragraph in the introduction explaining how these three blocking events caused the respective extreme events, with appropriate citations, such as shown below:

"*Specifically, the Canadian blocking is suggested to enhanced surface temperature and vapor pressure deficit while suppressing precipitation and soil moisture, thereby promoting severe wildfires (Barnes et al., 2025; Luo et al., 2025). The Ural ridge and associated East Asian trough are widely considered to lead southward cold-air advection, thereby favoring anomalous precipitation in East Asia (Tao, 1980; Diao et al., 2023). The European blocking contributed to the Northwest Europe heatwave via sustained subsidence and clear skies, further amplified by marine heatwave feedbacks (Berthou et al., 2024).* "

New citations:

Barnes, C., Jain, P., Keeping, T., Gillett, N., Boucher, J., Gachon, P., Heinrich, D., Kirchmeier-Young, M., and Boulanger, Y.: Disentangling the roles of natural variability and climate change in Canada's 2023 fire season, Environ. Res.: Climate, 4, 035013, https://doi.org/10.1088/2752-5295/adec0f, 2025.

Luo, B., Xiao, C., Luo, D. et al. Atmospheric and oceanic drivers behind the 2023 Canadian wildfires. Commun. Earth. Environ., 6, 446, https://doi.org/10.1038/s43247-025-02387-x, 2025.

Tao, S. Heavy Rainfalls in China (in Chinese), Science Press, Beijing, China. 225 pp., ISBN 130311305, 1980.

Diao, Y., Guo, J., Zhang, Y. et al. Trend turning of North China summer extreme precipitations around early 2000s and its possible reason. Clim Dyn 61, 5367–5386, https://doi.org/10.1007/s00382-023-06860-1, 2023.

- In the current form of the manuscript, references to SST add minimal to the analysis produced. If the authors intend to use SST as a source of predictability, the current analysis should be expanded. This should likely be included in the results section, following the discussion of predictability in the S2S model, rather than at the end of the summary and discussion.

Response: We thank the reviewer for this constructive suggestion. As already discussed in response to the first reviewer (last two minor comments), we think the discussion on the role of SST in predictability of blocking irrelevant, so will remove this part in the revision.

However, to better illustrate the essential role of waves' energy propagation in predictability, we will add a new figure comparing the horizontal propagation of wave energy (using WAF) between the good and bad ensemble members. This figure will show that only those ensemble members capable of accurately capturing the (planetary-scale) Rossby wave energy propagation can successfully predict the blocking events at a 2-week lead time. In contrast, the bad members tend to predict the wave energy propagating primarily as synoptic-scale waves along the subtropical jet.

In this way, through both observations and S2S prediction, our results highlight the critical importance of group velocity for both the formation and the subseasonal predictability of atmospheric blocking.

- The mentions of WAF and Ks could use additional physical contextualization. While these methods are often encountered in other studies, the present work would be improved with a brief discussion in the methods section or results of how these two measures are used to bolster the compelling evidence presented from the Rossby wave dynamics analysis.

Response: We thank the reviewer for the valuable suggestion. In the revised manuscript, we will clarify in the methods:

1. The vectors of WAF correspond to the direction of group velocity of quasi-stationary waves, thus highlights the horizontal propagation of quasi-stationary Rossby wave energy, thereby revealing the dynamical linkages among the three successive blocking events.

2. The Ks provides a theoretical reference for the zonal scale at which Rossby waves tend to become quasi-stationary under a given background flow. Therefore, comparing the local zonal wavenumber k (diagnosed based on Hilbert transform) with Ks helps explain the propagating behavior of blocking circulation. For example, waves tend to remain quasi-stationary when $k \approx Ks$ or slightly smaller, retrograde when $k \ll Ks$, and propagate eastward when $k \gg Ks$.

We will also clarify the linkage between the WAF/Ks diagnostics and the Rossby wave parameter results (phase speed, and wavenumber) in the 'Results' .

- 2b-c are only referenced once within the text, despite showing an interesting result. Based on this figure, there is a key difference in episode 2, relative to the other two periods, as the primary blocking signal seems to be dominated by higher wavenumber variations, whereas episodes 1 and 3 are more attributable to planetary scale waves.

Response: Thank you for pointing this out. Indeed, as shown in Figs. 2b–c, in the later stage of Episode 2 (28 May–5 June 2023), the Ural blocking exhibited a signal close to zonal wavenumber 4, whereas in the earlier stage of Episode 2 (20–27 May 2023), it was still dominated by a distinct zonal wavenumber 2. This is also consistent with our Hilbert-transform-based calculation, which shows a time-mean local zonal wavenumber of approximately 2–3 over Episode 2 (Fig. 4c), while the temporal evolution of zonal wavenumber (Fig. 5k) exhibits a transition from wavenumber 2 to wavenumber 4. However, the Hovmöller diagram has the disadvantage of losing spatial (meridional) locality and cannot directly yield quantitative wavenumber magnitudes.

In the revised manuscript, we will add several references to Figures 2b–c, for example to highlight the differences in zonal wavenumber characteristics among the different episodes, as well as to compare and validate our Hilbert-transform-based calculations.

- Why was 2.5-degree resolution used for ERA5 data? It's my understanding that native resolution is .25-degree. This is a minor concern, but I am just curious if this was a data choice or if the data were regridded and, if so, why.

Response: The 2.5°×2.5° resolution was a deliberate choice (regridded) for the following reasons. **(1)** Our study focuses on the evolution of large-scale circulation and the Rossby wave parameters. Excessively high resolution would introduce small-scale waves (e.g., gravity waves) that are not of interest to this study. Moreover, the diagnosis of Rossby wave parameters requires filtering out the influence of these small-scale waves; otherwise, physically unreasonable results may occur (although we would set these points to missing values), as demonstrated in our previous study (Li et al., 2025). Therefore, a 2.5° resolution is both sufficient and reasonable for our analysis. **(2)** We use the convolution calculation to complete the Hilbert transform-based local wave parameter diagnostic method (Section 2.2), and the convolution operation becomes computationally very expensive at 0.25° resolutions. **(3)** The wave activity flux calculations (Section 2.4) need large-scale background flow, for which 2.5° resolution is better than 0.25°.

We will state the reasons for using the 2.5° resolution in the revised manuscript.

Li, Z., Lu, J., and Liu, Y.: The Period and Phase Speed of Upper-tropospheric Planetary- and Synoptic-scale Waves during the Solstice Seasons: Climatology and Trends during 1979–2023, Adv. Atmos. Sci., 42, 2223–2234, https://doi.org/10.1007/s00376-024-4236-1, 2025.

- The paragraph at the end of section 3.3 is structured in a confusing manner to me. I think it would make more sense to discuss the predictability of the 3 episodes in the order in which they occurred, rather than beginning with episode 2.

Response: Thank you for this valuable comment. In the revised manuscript, we will reorganize the discussion of predictability for the three episodes at the end of Section 3.3, presenting them in the order in which they occurred.

Technical Corrections:

- The grey lines in Figs. 5 and 6 are very difficult to make out for me. Perhaps these could be darkened slightly.

Response: Thank you for pointing this out. Following the suggestion, we have darkened the grey lines in both Figures 5 and 6 in the revised manuscript to improve their clarity.

- The previous studies mentioned in L57-58 should be cited.

Response: We have now cited appropriate citations, see the Major Comments No. 2.

- It would be worthwhile to cite literature on the interactions between planetary- and synoptic-scale waves at L228.

Response: Thank you for the suggestion. We will add some appropriate citations at the indicated location. Here is a revised version:

"*suggesting the 'block' of the eastward progression of synoptic waves and possible interactions between planetary-scale blocking and surrounding synoptic-scale waves, as documented in Shutts (1983), Yamazaki and Itoh (2013), and Luo et al. (2014, 2023).*"

Luo, D., Cha, J., Zhong, L., and Dai, A.: A nonlinear multiscale interaction model for atmospheric blocking: The eddy-blocking matching mechanism, Q. J. R. Meteorol. Soc., 140, 1785–1808, https://doi.org/10.1002/qj.2337, 2014.

Luo, D. H., Luo, B. H., and Zhang, W. Q.: A perspective on the evolution of atmospheric blocking theories: From eddy-mean flow Interaction to nonlinear multiscale interaction. Adv. Atmos. Sci., 40(4), 553−569, https://doi.org/10.1007/s00376-022-2194-z, 2023.

Shutts, G. J.: The propagation of eddies in diffluent jetstreams: Eddy vorticity forcing of 'blocking' flow fields. Q. J. R. Meteorol. Soc., 109, 737–761, https://doi.org/10.1002/qj.49710946204, 1983.

Yamazaki, A., and Itoh, H.: Vortex‐vortex interactions for the maintenance of blocking. Part I: The selective absorption mechanism and a case study. J. Atmos. Sci., 70 , 725–742, https://doi.org/10.1175/JAS-D-11-0295.1, 2013.

- The vertical levels of ERA5 data utilized should be mentioned at L107.

Response: Only data at 500 hPa are used, we will clarify it in our revised manuscript.

- A number of minor word choice suggestions or grammatical corrections are listed below:
  - Insert 'the' at the end of L48

- Use ‘is’ instead of ‘are’ in L61
- Insert ‘the’ at beginning of L78
- The phrase ‘scale itself’ at the end of L82 is slightly awkward
- Use ‘has’ instead of ‘have’ in L94
- Use ‘shifts’ instead of ‘shifted’ at L237
- Use ‘approaches’ instead of approaching at L241
- Use ‘occurring’ instead of occurred at L245
- Use ‘predict’ instead of predicting at L310
- Use ‘research’ or ‘literature’ or similar instead of ‘researches’ at line 416
- Insert a comma after ‘amplitude’ on L417

Response: We sincerely thank the reviewer for carefully identifying these errors. All corrections have been made in the manuscript.