

Enhanced stratosphere-troposphere and tropics-Arctic couplings in the 2023/24 winter

Corresponding Author: Professor Jian Rao

This file contains all editorial decision letters in order by version, followed by all author rebuttals in order by version.

Version 0:

Decision Letter:

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Dear Professor Rao,

Your manuscript titled "Enhanced stratosphere-troposphere and tropics-Arctic couplings in the 2023/24 winter" has now been seen by 2 reviewers, and we include their comments at the end of this message. They find your work of interest, but some important points are raised. We are interested in the possibility of publishing your study in Communications Earth & Environment, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.
Please also consider the editorial threshold below:

****Explain your methods thoroughly and provide a more thorough discussion of the main results, particularly for sea ice-SSW linkage.**

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We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and the completed checklist:

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We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at Communications Earth & Environment or published elsewhere in the meantime.

Please do not hesitate to contact us if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Kyung-Sook Yun, PhD
Editorial Board Member
Communications Earth & Environment
orcid.org/0000-0001-9990-3581

Alireza Bahadori, PhD
Associate Editor
Communications Earth & Environment

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Please refer to our data policies at <http://www.nature.com/authors/policies/availability.html>.

REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

Comments of the manuscript entitled, 'Enhanced stratosphere-troposphere and tropics-Arctic couplings in the 2023/24 winter' by Lu et al., for plausible publication in Nature-Communications earth and environment. The authors have analyzed the 2023/24 winter stratospheric coupling. The year observed 3 sudden stratospheric warming events. The authors quantify the changes in atmospheric parameters and specifically ozone and water vapor during the period. They present the wave patterns in the Arctic and show the surface temperature anomalies. They have also investigated the background environment in the winter that would have contributed to the anomalous dynamical processes.

The manuscript has a potential for publication, however, needs a moderate revision before I recommend for publication. My specific comments are following :

Specific Comments

I64: Please add the full form of NAM.

I71: tropical portions -> tropical regions

I78: troposphere planetary waves -> tropospheric planetary waves

I82: tropical water vapor -> stratospheric water vapor

I88: Add both poles.

I89-106: Please correct grammatical errors in the paragraph

I111: is -> was

I179: As you have rightly pointed out only planetary waves travel upwards, for which the background wind condition should be suitable for wave propagation. As you have evaluated the flux at 100 hPa and the 60N wind anomalies (Fig. 1c) does not show much variation at 100 hPa, or below 50 hPa for the initial warming events. What could be the reason for the sudden dip in 100 hPa Eddy-heat flux (Fig. 1h)?

I199: It would be beneficial to note the place mentioned in the maps.

I225: I am not able to trace which is the wno 1.

I251: The 12 deg C anomaly seems a little on the higher side. Surface temperature anomalies of +/-2K were shown in Baldwin et al., 2020. [1]. The authors need to justify their claim with sufficient evidence.

I318: mainly due to the concentration of ozone to this region. Can you elaborate on this?

I330: is -> are

I333: The water vapor content in the Arctic was much higher than in the tropics. Please explain how it is inferred from Fig. 6a?

I358: Can you find any reasons why the downwelling is intense a few days before the first SSW onset?

I380: "active in 3-4 phases of MJO". This needs to be elaborate

I404: Please modify the statement: The Barents-Kara (BK) sea ice changes can also induce climate fluctuations.

I406: How have you calculated the composite? Is it the mean of all days in January? Rephrase the paragraph accordingly.

References

Citation:

[1] Baldwin, M. P., Ayarzagüena, B., Birner, T., Butchart, N., Butler, A. H., Charlton-Perez, A. J., et al (2021). Sudden stratospheric warmings. Reviews of Geophysics, 59, e2020RG000708. <https://doi.org/10.1029/2020RG000708>

Reviewer #2 (Remarks to the Author):

This paper analyzes stratosphere-troposphere and the tropics-Arctic couplings during the unusual 2023/24 winter. Zonal wind, temperature, and geopotential height from ERA5 data are used to investigate the primary characteristics of three stratospheric disturbances. The SSW disturbances in the stratosphere were closely associated with ozone and water vapor variations. The QBO and strengthened BD circulation together directly affected ozone and water vapor in tropical regions, displaying the tropic and Arctic couplings. Meanwhile, frequent stratospheric disturbances in the 2023/24 winter are possibly due to different driving forcings, including the Barents-Kara Sea ice increase, the warm tropical Pacific SST, the easterly QBO, and the active MJO. In general, the paper brings new aspects to our understanding of the effects of these stratospheric disturbances; as SSWs are known to affect the whole atmosphere from the troposphere to the mesosphere even higher altitudes, understanding its drivers and impacts is of course very important. However, I found the paper in parts difficult to follow. In particular how BK sea ice loss and increase explain the circulation anomalies. As previous studies have found that BK sea ice loss plays a unique role in driving the weakening of stratospheric polar vortex, an increase in BK sea ice in the 2023/24 winter partially explained the tropospheric circulation anomalies. This should be clarified. In addition, in the results section, the tense keeps changing between present and past tense, and the most appropriate one should be determined. I also have a rather long list of minor comments mostly regarding unclear wording listed below.

Minor points:

Line 52-53: ... and westerly wind at 10hPa/60°N changes to easterly wind, it is recognized as a major SSW.

Line 55: remove 'about'?

Line 58: remove 'being'?

Line 64: define NAM

Line 81: 'low temperature' could be written 'low-temperature'?

Line 90: '...quasi-biennial oscillation (QBO)', which seems to be used QBO abbreviation in the abstract?
 Line 102: define ENSO
 Line 135-136: 'in recent 30 years' change to 'in the last 30 years'
 Line 138: remove 'in'?
 Line 152: 'were' should be 'was'?
 Line 166-167: '... downward propagation to the near surface especially during the first and third disturbance period' should change '... downward propagation to the near surface, especially during the first and third disturbance periods'.
 Line 176: 'weaken' to 'weakened'
 Line 240: '50-hPa' or '500-hPa'?
 Line 236-237: '... presenting a wavenumber 1 pattern, accompanied with weakening of tropospheric planetary wave activities.' Could be better 'accompanied by a weakening of tropospheric planetary wave activities'?
 Line 288: 'were' should be 'was'?
 Line 317-318: '...mainly due to the concentration of ozone to this region.' Clarify what is meant here.
 Line 347-350: Suggest that 'which is one of the key reasons for meridional advection of ozone from ozone - richer regions' because the vertical eddy effects play a crucial role in the increasing ozone as well, more details in de la Cámara et al. (2018), Hong and Reichler (2021), Bahramvash Shams et al. (2022) publications. In addition, there is an enhancement of the BDC after the second SSW (positive vertical advection anomaly in Fig. 6g), why doesn't ozone anomaly appear in the upper stratosphere in Fig. 6e? What is the reason?
 Line 350-351: Suggest change 'The ozone anomalies ...' to 'The high concentration of ozone ...'.
 Line 384: remove 'both'?

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Version 1:

Decision Letter:

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Dear Professor Rao,

Your manuscript titled "Enhanced stratosphere-troposphere and tropics-Arctic couplings in the 2023/24 winter" has now been seen by our reviewers, whose comments appear below. In light of their advice we are delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment.

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

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We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Alireza Bahadori, PhD
Associate Editor
Communications Earth & Environment

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

I have carefully read the author's responses to my remarks and recommendations. All my queries/comments are well addressed and the suggestions are implemented in the revised manuscript. The author's response satisfies me. Thus, I recommend the manuscript for publication.

Reviewer #2 (Remarks to the Author):

The authors have satisfactorily addressed both the major and minor comments in their responses.

I have only one minor suggestion: Lines 419-421: The authors should provide references corresponding to the previous studies mentioned.

In conclusion, I recommend a minor revision before the paper is considered for publication in Communications Earth & Environment.

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Responses to the Reviewer # 1

Reviewer#1:

Comments of the manuscript entitled, 'Enhanced stratosphere-troposphere and tropics-Arctic couplings in the 2023/24 winter' by Lu et al., for plausible publication in Nature-Communications earth and environment.

The authors have analyzed the 2023/24 winter stratospheric coupling. The year observed 3 sudden stratospheric warming events. The authors quantify the changes in atmospheric parameters and specifically ozone and water vapor during the period. They present the wave patterns in the Arctic and show the surface temperature anomalies. They have also investigated the background environment in the winter that would have contributed to the anomalous dynamical processes.

The manuscript has a potential for publication, however, needs a moderate revision before I recommend for publication. My specific comments are following:

Response: Thanks very much for the reviewer's suggestions and comments. We have studied the comments carefully and made corrections. All those changes have improved the overall quality of this paper.

Specific Comments

L64: Please add the full form of NAM.

Response: Added "Northern Annular Mode (NAM)". (L64-65)

L71: tropical portions -> tropical regions.

Response: Changed. (L71)

L78: troposphere planetary waves -> tropospheric planetary waves.

Response: Changed. (L78)

L82: tropical water vapor -> stratospheric water vapor.

Response: Changed. (L82)

L88: Add both poles.

Response: Added. (L88)

L89-106: Please correct grammatical errors in the paragraph.

Response: Changed to use the present tense. (L89-106)

L111: is -> was.

Response: Changed. (L111)

L179: As you have rightly pointed out only planetary waves travel upwards, for which the background wind condition should be suitable for wave propagation. As you have evaluated the flux at 100 hPa and the 60N wind anomalies (Fig. 1c) does not show much variation at 100 hPa, or below 50 hPa for the initial warming events. What could be the reason for the sudden dip in 100 hPa Eddy-heat flux (Fig. 1h)?

Response: To well address your concerns, we show Fig. R1 for your reference. The zonal winds at 30 hPa, 50 hPa, 100 hPa and their anomalies were calculated respectively. Since the easterly anomaly was maximized around 70°N, we replaced the diagram in the manuscript with zonal winds at 70°N. (Fig. 1c and L145-151)

The planetary waves usually propagate upward under the background of westerly winds. Namely, the upward propagation of planetary waves is inhibited under the background of easterly winds. Such a sudden dip in 100 hPa eddy-heat flux can be seen soon after the onset of SSW when the easterly winds form (see Fig. R1a, c, e vs Fig. 1h). We added a sentence to well address your concern:

“... followed by the sudden dip in the eddy heat flux due to the development of background easterly winds.” (L180-181)

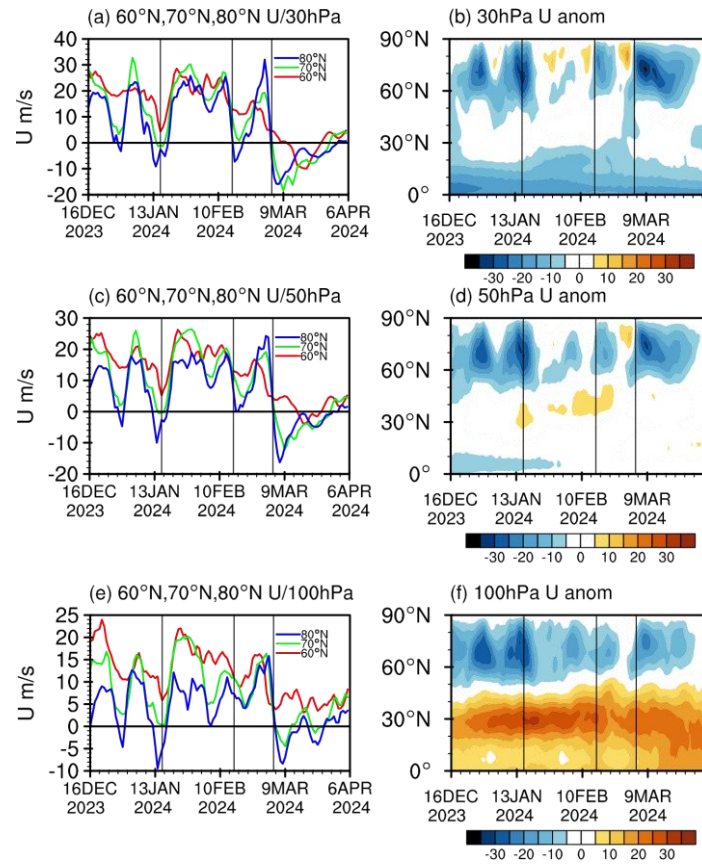


Fig. R1 U wind and its anomalies at 30 hPa, 50 hPa, and 100 hPa.

L199: It would be beneficial to note the place mentioned in the maps.

Response: In Fig.2, H is marked in the high center of the potential height, and L is marked in the low center. It helps identify the location. “The letters H and L denote the high and low centers, respectively.” (Fig. 2)

L225: I am not able to trace which is the wno 1.

Response: Changed to “...a wavenumber 2 pattern.” (L229-230)

L251: The 12 deg C anomaly seems a little on the higher side. Surface temperature anomalies of ± 2 K were shown in Baldwin et al., 2020. [1]. The authors need to justify their claim with sufficient evidence.

Response: We have recalculated the maximum center value to well address the reviewer's concerns and have not found errors. On a 10-day average time scale during this winter, the cold anomaly center reached 12 °C.

Figure R2 shows the composite surface temperature anomalies in the literature (Baldwin et. al., 2021; Butler et al.,2017). It is worth noting that it was composite of the 60 days after the historical SSWs. Namely, the maximum temperature anomalies are actually smoothed.

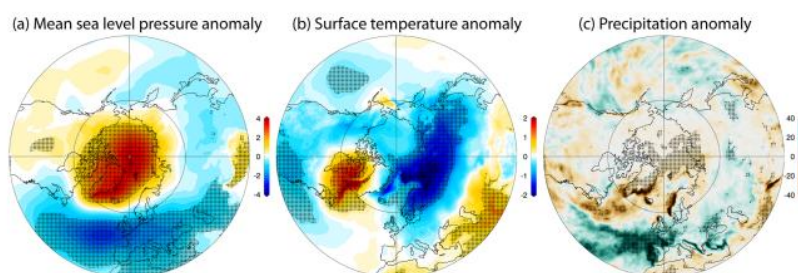


Figure 4. Composites of the 60 days after historical SSWs in the JRA-55 reanalysis for (a) mean sea level pressure anomalies (hPa), (b) surface temperature anomalies (K), and (c) precipitation anomalies (mm). The stippling indicates regions that are significantly different from the climatology at the 95 % level.

Fig. R2 Surface temperature anomalies in (Baldwin et. al., 2021) and (Butler et al., 2017)

We further calculate the surface 2-m temperature anomaly 60 days after the first SSW, which is shown in Fig. R3. It can be found that the cold anomaly center in northern Eurasia is also 2°C. This calculation is not reasonable, because this winter has three SSWs, which is a rare case. The distribution of temperature anomalies for this special case also differs from the composite map. After careful consideration, we still show the interval-time mean every 10 days based on the evolution of the SSWs.

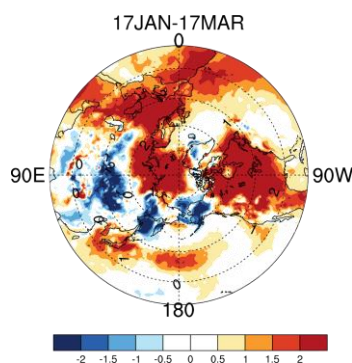


Fig. R3. Surface temperature anomalies for 60 days after the first SSW.

L318: mainly due to the concentration of ozone to this region. Can you elaborate on this?

Response: Changed to "...mainly due to the transport of lower stratospheric ozone to this region (Fig. 5i)." (L321-322)

L330: is -> are

Response: Changed. (L334)

L333: The water vapor content in the Arctic was much higher than in the tropics. Please explain how it is inferred from Fig. 6a?

Response: Thanks for your suggestion. This is obtained by comparing Fig.6a with Fig. 5e. Changed to "The water vapor content in the Arctic was much higher than in the tropics (Fig. 6a vs Fig.5e)." (L337-338)

L358: Can you find any reasons why the downwelling is intense a few days before the first SSW onset?

Response: Added "A few days before the first SSW, enhanced wave forcing denoted by a strong eddy heat flux pulse (Fig.1h) drove the strengthening of the BD circulation." (L371-373)

L380: "active in 3-4 phases of MJO". This needs to be elaborate.

Response: Changed to "During 2-15 January, a dozen days before the first SSW except for a few days, MJO was active in 3-4 phases with amplitudes exceeding one σ ." (L394-395)

L404: Please modify the statement: The Barents-Kara (BK) sea ice changes can also induce climate fluctuations.

Response: Changed to “Previous studies have reported Arctic sea ice loss especially in the Barents-Kara Sea can enhance the upward propagation of planetary waves and subsequently affect the intensity of the stratospheric polar vortex.” (L419-421)

L406: How have you calculated the composite? Is it the mean of all days in January?
Rephrase the paragraph accordingly.

Response: Sea ice loss is reported to enhance the extratropical wave activities and weaken the stratospheric polar vortex. However, the sea ice shows some growth in the 2023/24 winter. A statistical table is shown in the paper, and the composite for sea ice is removed.

References

Citation:

[1] Baldwin, M. P., Ayarzagüena, B., Birner, T., Butchart, N., Butler, A. H., Charlton-Perez, A. J., et al (2021). Sudden stratospheric warmings. *Reviews of Geophysics*, 59, e2020RG000708. <https://doi.org/10.1029/2020RG000708>

Responses to the Reviewer # 2

Reviewer #2:

This paper analyzes stratosphere-troposphere and the tropics-Arctic couplings during the unusual 2023/24 winter. Zonal wind, temperature, and geopotential height from ERA5 data are used to investigate the primary characteristics of three stratospheric disturbances. The SSW disturbances in the stratosphere were closely associated with ozone and water vapor variations. The QBO and strengthened BD circulation together directly affected ozone and water vapor in tropical regions, displaying the tropic and Arctic couplings. Meanwhile, frequent stratospheric disturbances in the 2023/24 winter are possibly due to different driving forcings, including the Barents-Kara Sea ice increase, the warm tropical Pacific SST, the easterly QBO, and the active MJO. In general, the paper brings new aspects to our understanding of the effects of these stratospheric disturbances; as SSWs are known to affect the whole atmosphere from the troposphere to the mesosphere even higher altitudes, understanding its drivers and impacts is of course very important.

[Response: Thanks very much for your positive comments.](#)

However, I found the paper in parts difficult to follow. In particular how BK sea ice loss and increase explain the circulation anomalies. As previous studies have found that BK sea ice loss plays a unique role in driving the weakening of stratospheric polar vortex, an increase in BK sea ice in the 2023/24 winter partially explained the tropospheric circulation anomalies. This should be clarified. In addition, in the results section, the tense keeps changing between present and past tense, and the most appropriate one should be determined. I also have a rather long list of minor comments mostly regarding unclear wording listed below.

[Response: Thanks very much for your suggestions. All of your concerns in our revisions.](#)

- [1\) As some studies have found the possible relationship between the Arctic sea ice loss and the weakening of the stratospheric polar vortex, the sea ice growth in the](#)

2023/24 winter did not explain the variability of the stratospheric polar vortex. The possible relation between the Arctic sea ice and stratospheric polar vortex is still very controversial and uncertain, we finally removed the composite of height anomalies.

- 2) The possible relationship between the sea ice and stratospheric circulation is discussed based on more references. (L419-429)
- 3) We provided a new table showing the statistics for sea ice variability and major SSWs.

Table 1 Relationship between detrend normalized BK sea ice index and major SSW in winter from 1979/80 to 2023/24.

BK ice-SSW relationship			
BK ice phase	Winter no.	SSW no.	SSW frequency
BK ice more ($\geq 0.5\sigma$)	15	8	0.53
BK ice loss ($\leq 0.5\sigma$)	18	10	0.56
Neutral ($ \text{BKI} < 0.5\sigma$)	12	9	0.75
Total	45	28	0.62

- 4) Considering that this study focuses on a historical case, the past tense is the most suitable choice. The grammar was modified and the tense was changed to the past tense.

Minor points:

Line 52-53: ... and westerly wind at 10hPa/60°N changes to easterly wind, it is recognized as a major SSW.

Response: Changed. (L52-53)

Line 55: remove 'about'?

Response: Removed. (L55)

Line 58: remove ‘being’?

Response: Removed. (L58)

Line 64: define NAM

Response: Added “Northern Annular Mode (NAM)”. (L64-65)

Line 81: ‘low temperature’ could be written ‘low-temperature’?

Response: Changed. (L81)

Line 90: ‘...quasi-biennial oscillation (QBO)’, which seems to be used QBO abbreviation in the abstract?

Response: Yes. The abstract and the main body of the paper should define their abbreviations, separately. (L89-90)

Line 102: define ENSO

Response: Added “El Niño-Southern Oscillation (ENSO)...” (L101-102)

Line 135-136: ‘in recent 30 years’ change to ‘in the last 30 years’

Response: Changed. (L135-136)

Line 138: remove ‘in’?

Response: Removed. (L138)

Line 152: ‘were’ should be ‘was’?

Response: Changed. (L152)

Line 166-167: ‘... downward propagation to the near surface especially during the first and third disturbance period’ should change ‘... downward propagation to the near surface, especially during the first and third disturbance periods’.

Response: Changed. (L166-L167)

Line 176: 'weaken' to 'weakened'

Response: Changed. (L176)

Line 240: '50-hPa' or '500-hPa'?

Response: Changed. (L244)

Line 236-237: '... presenting a wavenumber 1 pattern, accompanied with weakening of tropospheric planetary wave activities.' Could be better 'accompanied by a weakening of tropospheric planetary wave activities'?

Response: Changed. (L241-242)

Line 288: 'were' should be 'was'?

Response: Changed. (L292)

Line 317-318 '...mainly due to the concentration of ozone to this region.' Clarify what is meant here.

Response: Changed to "...mainly due to the transport of lower stratospheric ozone to this region (Fig.5i)." (L321-322)

Line 347-350: Suggest that 'which is one of the key reasons for meridional advection of ozone from ozone - richer regions' because the vertical eddy effects play a crucial role in the increasing ozone as well, more details in de la Cámara et al. (2018), Hong and Reichler (2021), Bahramvash Shams et al. (2022) publications. In addition, there is an enhancement of the BDC after the second SSW (positive vertical advection anomaly in Fig. 6g), why doesn't ozone anomaly appear in the upper stratosphere in Fig. 6e? What is the reason?

Response: Thanks for your suggestion. We carefully studied and cited this literature. Changed to "...which was mainly attributed to the enhanced meridional advection of ozone from ozone - richer regions^{38,55,56} (Fig. 6e)" (L352-354)

"Due to the short interval between the second and the third SSW, the BD circulation was almost continuously enhanced during the two SSWs (Fig. 6g, h). From the spatial distribution of BD circulation (Fig. 6i), it was also obviously seen that there was a strong downdraft in the Arctic, and ozone was transported to the middle and lower stratosphere without staying in the upper stratosphere. After the first and third SSWs, the strengthening of BD circulation was followed by a weakening period, when the ozone transported to the Arctic was able to stay in the upper stratosphere." (L354-361)

Line 350-351: Suggest change 'The ozone anomalies ...' to 'The high concentration of ozone ...'.

Response: Changed. (L361)

Line 384: remove 'both'?

Response: Removed. (L399)

List of Responses

Dear Editor:

Thank you for your letter and for the reviewers' comments concerning our manuscript. Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our research. We have studied the comments carefully and made corrections which we hope meet with approval. The main corrections in the paper and the responses to the reviewer's comments are as follows:

Responses to the Reviewer # 1

Reviewer #1:

I have carefully read the author's responses to my remarks and recommendations. All my queries/comments are well addressed and the suggestions are implemented in the revised manuscript. The author's response satisfies me. Thus, I recommend the manuscript for publication.

Response: Thanks very much for your positive comments.

Responses to the Reviewer # 2

Reviewer #2:

The authors have satisfactorily addressed both the major and minor comments in their responses. I have only one minor suggestion: Lines 419-421: The authors should provide references corresponding to the previous studies mentioned. In conclusion, I recommend a minor revision before the paper is considered for publication in Communications Earth & Environment.

Response: Thanks very much for your positive comments. We cited references in L421.