

Reviewer #1:

In this manuscript, the authors provide an overview of recent atmospheric circulation changes. They discuss some examples in-depth, possible mechanisms, and known disagreements between models and observations. Providing such a summary is valuable since many in the climate science community could benefit from it. However, my main comments are first that the manuscript is currently written so that many phenomena are not discussed in depth. Second, the manuscript focuses too much on the mechanisms underlying the phenomena (although also here, the discussion remains flat in some cases), which leaves the reader not with the broad perspective such work could provide. Third, the mixing of "detected signals" vs long-term trends provides a false impression that should be fixed.

**Thank you for the valuable comments which significantly improved the manuscript. Our responses to your comments are presented in bold. The line numbers referenced in our response correspond to those in the revised manuscript.**

Major comments:

1. The authors re-define the term detection here as a long-term trend, which is not the canonical definition used in the literature (IPCC and the many papers on the subject). Detection is when a given signal (e.g., long-term trend) exceeds the noise. There are different ways to conduct detection analysis, and this is heavily discussed in the IPCC report. First, this would only confuse the general reader that you are suggesting that signals are detected, and such an error impression could propagate to wrong citations of this manuscript in the future. Second, given that you are not covering only signals that have been detected (in a formal manner), i.e., that they emerged from the background noise, in the long list of phenomena summarised in Table 1 and mentioned in the text, there could be phenomena that are simply due to internal variability and are not part of the forced response (i.e., they are not projected to continue in the coming decades). Because of these two reasons above, I suggest not to redefine detection and, indeed, discuss in more depth detected signals (that have emerged) or signals that show similar responses to what we predict.

**Thank you for your feedback. Following the reviewers suggestion we revised the text and now define signals as statistically significant long-term trends over the satellite era or longer. We then highlight signals that have been detected and attributed to human activities based on definitions from the IPCC (see Table 1 caption). In particular, we added text to Section 2 about the role of human activities (see lines 85-121) and added new columns to Table 1 to indicate the circulation signals that have been detected and attributed to human activities according to IPCC definitions (see Table 1 caption).**

2. Throughout the manuscript, the authors choose to focus only on a few examples of circulation changes, although this should be a perspective paper. The authors choose to put more weight on the mechanism part but do not go in-depth into describing all detected signals and their mechanisms. Specific examples are given below.

2a. In section 2 of detected signals, the authors go in-depth into the impact of ozone forcing on the flow but do not mention the other circulation changes in recent decades. Again, given that this is a perspective, the reader would like to know of all robust detected changes, not only the ones in Southern Hemisphere summer due to ozone. For example, changes in the Hadley cell strength in the Northern Hemisphere, storm tracks and jet stream during summer in the Northern Hemisphere, changes in storm tracks during winter in the Southern Hemisphere, etc. These should not just be mentioned but discussed in some depth.

**Thank you for the suggestion. We removed Box 1 and revised section 2 to include a discussion of the signals that have been attributed to human activities (see lines 85-121). We also revised the mechanism section 3 to focus on mechanisms related to the signals in Table 1 (lines 123-211). We added as much discussion as possible given the length restrictions. In order to add this text we trimmed sections 3 and 4.**

2b. Related to the above, the discussion in Section 2 is cumbersome. You start by talking about the impact of ozone, then move to briefly mention Table 1, and then go back to the ozone story. I would again provide detailed information on each metric that has been detected (signal-to-noise ratio-wise).

**Thank you for the suggestion. We revised section 2 to include a discussion of signals that have been attributed to human activities (see lines 85-121). In order to add this text we trimmed sections 3 and 4.**

2c. In section 3.1.1 on the upper tropospheric warming in the tropics, the authors too heavily refer to papers by the first author of this manuscript, while other studies should be discussed in more detail, including the impact of the upper warming on the Hadley cell width (Lu 2007 paper and the Held 2000 two-layer mechanism), Hadley cell strength (Chemke and Polvani 2019, 2021 papers on the impact of static stability vs latent heating), winter North Atlantic storm tracks, etc.

**Thank you for the suggestion. We completely revised the mechanism section to focus on signals in Table 1 (see lines 123-211). We added citations to Lu et al. (2007), Chemke & Polvani (2019, 2021). Section 3 was trimmed significantly and focuses on the signals in Table 1. We could not further expand the text on mechanisms because of length restrictions.**

2d. In section 3.1.3 on Arctic warming, the impact of high latitude warming on storm tracks during summer should be mentioned. Coumou et al. 2015 is a good starting point, as well as Chang et al., 2016, and the recently detected/attributed signal found in Chemke and Coumou 2024.

**Thank you for the suggestion. We referred to Coumou et al. (2015) and Chang et al. (2016) in the submitted manuscript (see lines 229-232 of the submitted manuscript). We added a reference to Chemke & Coumou (2024) (see line 114).**

2e. In section 3.1.4, ocean processes were also found to affect the Hadley cell (e.g., Wang et al., 2018, Chemke 2021), and Southern Hemisphere storm tracks (e.g., Grise and Polavni 2014, Chemke 2022)

**We completely revised the mechanism section and removed the subsection on ocean processes. The mechanism section was trimmed to focus on the signals in Table 1 (see lines 123-211).**

2f. Another impact of aerosol forcing is on the summer storms in the Northern Hemisphere found in Chemke and Coumou 2024.

**We added the suggested citation (see line 114).**

2g. In section 4.1, more discussion is needed on each metric instead of just naming the discrepancies. These are interesting stories, and we could learn a lot from them. These are more relevant in such a perspective paper than the underlying mechanisms, in my opinion. Another example that is missing here is the Hadley cell strength. Also, in line 317, the first paper that identified the discrepancy between modeled and reanalysis trend in summer storms in Cuomou 2015, which was recently resolved in Chemke and Coumou 2024 (should also be added to Table 1). Lastly, it is crucial to discuss our limitation in observed flow changes, as we heavily rely on reanalyses that, similar to models, could also be biased.

**We added a reference to the Hadley cell strength discrepancy (see lines 237-239). We added Chemke & Coumou (2024) to Table 1. We added a discussion of the fact that atmospheric circulation signals rely heavily on observational products (reanalyses), which can exhibit large spread, such as in the case of Southern Hemisphere signals, and sometimes biases as in the case of diabatic heating trends (see lines 251-259).**

3. I could not understand why aerosol forcing is an important chapter in this perspective. In a similar way, you could have done a chapter for each forcing agent separately. The aerosol forcing, while interesting, is actually the one that would likely have a smaller effect in the future. My suggestion is to remove this part.

**We think it is important to highlight anthropogenic aerosol forcing since attribution studies show it drives approximately half of the summertime circulation weakening (see lines 106-121, 199-211). Aerosol forcing is regional and short lived and its future effects over the next few decades will depend on emissions, which are highly uncertain (Persad et al. 2022). Indeed the record breaking global average temperature in 2023 has been suggested to partly be a result of aerosol forcing. Given these factors we think it is important to discuss aerosol forcing.**

4. The figures in the manuscript are referred to without any explanation. Please explain every symbol in each figure for the reader to understand the figure and your reference.

**We revised the figure captions and their reference in the text.**

5. In addition to the above, there are several missing references. First, in the discussion on ozone's impact on the circulation in the Southern Hemisphere, the paper by Polvani et al., 2010 should be cited. Second, line 120 is missing a reference. Third, the discussion around line 121 should include the discussion in Barnes et al., 2014 on the delayed GHG response. Fourth, in several cases, when discussing mechanisms underlying flow changes, the authors refer to Shaw 2019. Another broader related paper that provides an overview of the mechanisms underlying large-scale flow changes in the tropics and extratropics is Vallis et al., 2015 (QJRMS).

**Thank you for the suggestions. We now refer to Thompson et al. (2011) when discussing the ozone hole impact since it's a broad review paper and Lee & Feldstein (2013) who documented the poleward shift due to ozone in reanalysis data (see lines 97-105). We removed the discussion of ozone hole recovery and de-emergence of the ozone hole signal. We added a reference to Vallis et al. (2015) and Hoskins & Woollings (2015) when discussing mechanisms (see lines 125-126).**

Table 1. The Hadley cell intensification is most entirely in the Northern Hemisphere, not in both hemispheres.

**We revised Table 1 to separate Northern and Southern Hadley cell signals (see Table 1).**

Minor comments:

1. line 98. Thus -> Thus,

**The text was removed as part of the revision.**

2. line 350: The general reader would benefit from it if you would refer to this in its canonical way: attribution analysis

**The text was removed as part of the revision. We now define attribution following IPCC terminology (see caption of Table 1).**