Review of manuscript 2022 – 601 submitted to Weather and Climate Dynamics

Bimodality in Ensemble Forecasts of 2-Meter Temperature: Event Aggregation

by C. Bertossa et al.

This study investigates the emergence of bimodality in 2m temperature in subseasonal-to-seasonal forecasts of the ECMWF model. Building on a previous study that introduced a detection method for bimodality, this study introduces a clustering method that helps to identify “bimodal events” and study their characteristics (such as duration, spatial scale, propagation). This method is then applied to study bimodality in three regions: South America, the Southern Ocean, and the western North Atlantic. Case studies indicate that interaction of the large-scale atmospheric flow with boundary conditions (orography, sea ice, SST gradients) are a major cause of bimodality. I find that this approach can lead to interesting insights not only into why bimodality occurs in subseasonal prediction systems, but also into the general workings of the climate system. Accordingly, I find the paper fits well into the scope of WCD.

While I have no concerns about the methodology as such, I think that the exploration of the physical causes of bimodality remains a bit vague and more could be done to pinpoint the actual causes of the bimodality. Some suggestions in that regard are given below.

Overall the paper is well written and figures are readable. However, the language is sometimes unclear and the method could be better explained. Also, there is a lot of jargon, which may be understood by specialists in subseasonal-to-seasonal prediction, but not the general readership of WCD. Since the study is certainly of interest for a broader readership in the climate dynamics community, I suggest the authors reduce the use of specific jargon and try to better explain certain concepts.

General comments:

1. What do you mean by the term “atmospheric events”? This term is used throughout the paper, but it remains unclear what exactly you mean by it. Do you think of synoptic events that might cause some ensemble members to follow a very different trajectory in phase space than most others, hence causing bimodality, or rather slower processes such as the continuous interaction of the atmosphere with the boundary conditions? Reading further ahead, I assume it is the latter. I think it is necessary that the term “atmospheric events” is precisely defined already in the introduction.

2. The geopotential height patterns are reminiscent of Rossby wave breaking events in this region causing cold surges in Brazil, see Sprenger et al. (2013). Hence, I was wondering whether the bimodality is related to the presence and absence of Rossby wave breaking? Considering Rossby wave breaking may give a more direct physical linkage to the causes of the bimodality.

Sprenger, M., Martius, O. and Arnold, J. (2013), Cold surge episodes over southeastern Brazil – a potential vorticity perspective. Int. J. Climatol, 33: 2758-2767. https://doi.org/10.1002/joc.3618

3. The relationship of bimodality in the Southern Ocean region to sea ice is interesting and appears plausible through the different heat capacities of water and ice, resulting in a damping effect on temperature variability in the former case.

   The explanation of why differences in sea ice state occur, however, remains overly vague. Generally, sea ice in this region reacts strongly to persistent wind anomalies, which can push the ice edge far away from its climatological position. Hence, It appears to me that it is not single synoptic events that cause the bimodality, but rather the accumulated effect of anomalous winds (for example through several cyclones passing through the Amundsen and Bellingshausen Seas) over one or two weeks, hence linking these events to longer timescales. Could the authors look into circulation anomalies in the preceding weeks?

4. Could explosive cyclogenesis play a role for the North Atlantic events? This region is well known for the frequent occurrence of bomb cyclones and Fig. 14b suggests the presence of a deep low in mode 2 which is absent in mode 1. Exploring this might give you a more direct physical linkage between the SST gradient associated with the Gulf Stream, which is known to play a crucial role for the rapid intensification of cyclones, and bimodality.

Specific comments:

L5: The phrasing here is a bit awkward. Understanding the origin of bimodality does not affect the skill of the forecasts but it helps understanding why the skill of forecasts sometimes is much worse than otherwise.
L29: Please specify what you mean by “dressing method”.
L37ff: The data used in this study should be explained in the data and methods section, not the introduction.
L53ff: Consider moving this paragraph to the conclusion section. The introduction is meant to expose the open questions guiding the study based on the existing literature.
L71: Please specify what you consider the cold and warm modes of a forecast. I assume that these are the two modes of the bimodal distribution.
L71: And related to the above: how do you decide whether an ensemble member belongs to the cold or warm mode? The two single distributions constituting a bimodal distribution will normally overlap. How then do you attribute one member to a specific mode if it lies between the two?
L92: Please explain what the occupancy is and how the value of 32 follows from the previously said.
L164: What do you mean by erroneous area?
L155ff: If I understand correctly, you only use the ellipse but not the box. In that case there is no need to report on the definition of the box if you don’t use it.
L222: Are you now considering the centroid or the ellipse center? As I understand the centroid

may be different from the center since not all points in the ellipse may exhibit bimodality.
L247: Why do you refer to modes 1 and 2 instead of cold and warm modes? Please be consistent with the nomenclature throughout the paper.
L249: I don't really see this wrapping of the high around the Andes. To me the high seems mostly confined to west of the Andes.
L279: Do you mean **north** of the Antarctic Peninsula?
L288: How is the temperature of a mode defined? Is the temperature taken as the mean over the ellipse of each event or for all individual grid points?
L303: I assume you are referring to the flow in the Bellingshausen and Amundsen Sea west of the Antarctic Peninsula. In the Weddell Sea the flow is northward.
L305: ice sheets is probably not the correct term for sea ice
L363:
L376: I don't understand the sentence "since the Gulf Stream acts as a source of baroclinic instability". How does baroclinic instability allow for the forcing to persist during both seasons? What do you mean by this?

Figures:

- Figure 1 is not well embedded in the text and I am not sure whether it is really needed. If you decide to keep it, it should specifically be used to illustrate the methodology, which is not the case right now.

Technical corrections:

L3: introduces **a** novel methodology
L24: bimodality **is** linked
L25: Consider merging this one-sentence paragraph with the next one.
L31: The sentence from "… noticable improvements…" onward does not seem to be grammaticaclly correct.
L42: guide **the** analysis
L86: Rephrase as "We then define the coherency of a cluster as the number …" or similar.
L90: forecast **lead times** (also elsewhere, "leads" sounds overly sloppy)
L132: is found → is identified
L146: to **grow steadily**
L156f: **northernmost, southernmost etc.**
L158: is found → is identified / is determined
L180: exhibited in → shown in
L186: Please rephrase the sentence "Refer to left panel…"
L206: Question mark missing
L221: Rephrase as "Next it is explored where…"
L235: **is** identified
L237: **from** south to north
L238: **from** west to east
L249: The sentence "The result…" is essentially a repetition of what has just been said. Suggest to remove.

L265: Figure 7 → Fig. 7
L297: flux heat → give away heat
L326: delete as in “to be partly as a result of”
L357: than **in** the South American
L418: introduces **a** novel methodology

Figures: References to individual panels of a figure should be: Fig. Xa not Fig. X(a). Multiple panels should be references as Figs. Xa, b not Fig. Xa and Fig. Xb.

Caption Fig. 2:

- **The** thick black **line** indicates…
- Instead of stating that the red dashed and the solid blue line with white outline are explained in the text, simply say that they are selected members discussed in the text.

Caption Fig. 8 and many others. “As with Fig. X” should be “As Fig. X”