Dear Richard Neale, dear Referees, and dear Juan Antonio Añel,

Thank you very much for taking the time to review our manuscript and for providing us with valuable feedback. We greatly appreciate your help in improving our work on the three-dimensional structure of fronts in mid-latitude weather systems.
We have revised the article following your suggestions. Below, we provide point-by-point replies (blue color) to each of your comments (black and in italics).

Andreas Beckert and Marc Rautenhaus, on behalf of the author team

RESPONSE TO CHIEF EDITOR (CEC1):

Unfortunately, after checking your manuscript, it has come to our attention that it does not comply with our "Code and Data Policy".
https://www.*geoscientific-model-development.net/policies/code_and_data_policy.html*
You have archived your code on GitLab. However, GitLab is not an acceptable repository. You must store the code used in your manuscript in other long-term archival alternatives, such as Zenodo, PANGAEA, etc.

Therefore, you must reply to this comment with the relevant information (link and DOI) for the new repositories, as we request that you make it already available before submission and, of course, before the Discussions stage.

Also, please, include in the repository the relevant primary input/output data for your manuscript and the documentation you currently store in another two repositories that are not acceptable either.

Moreover, you must include in a potentially revised version of your manuscript the modified 'Code and Data Availability' section, with the DOI of the code (and another DOI for the dataset if necessary).

Response:

Thank you for this reminder. We have uploaded the code and all datasets with open licenses to Zenodo to comply with GMD's "Code and Data Policy":
Code (Met.3D front detection software): https://doi.org/10.5281/zenodo.7870254
Data (ECMWF datasets): https://doi.org/10.5281/zenodo.7875629
Unfortunately, we are not allowed to publish the COSMO dataset we have used in this study, as it has been obtained from other colleagues at ETH Zurich. However, we ask interested readers to contact us, so we can put them in contact with the creators of the data. Thank you for your understanding.

Action:

Changed the caption of the "Code availability" to "Code and data availability".
Added the Zenodo reference of the Met.3D front detection software into the "Code and data availability" section.
Added the Zenodo reference of ECMWF datasets into the "Code and data availability" section.

Added the following sentence regarding the availability of the COSMO dataset in the "Code and data availability" section: "Please contact the authors for information about the COSMO dataset."

RESPONSE TO Referee

Referee #1 (RC1):

1. *L282-285: Not quite true, because there is no equivalent mapping of theta_e gradients to theta_w gradients. Thus, any filtering threshold applied to a derivative of the thermal parameter will yield (unavoidable) differences in detections between theta_e and theta_w.*

Response:

Thank you for your comment. We clarified the statement by adding a sentence that it might be necessary to adjust the filter thresholds to detect equivalent fronts between theta_e and theta_w.

Action:

Changed the sentence in L284-285 from "In the following, we consider only theta_w, but the arguments should also be valid for theta_e." to "In the following, we consider only *theta_w*; the arguments are similar for *theta_e* (to detect similar structures, however, the filter thresholds need to be adjusted due to the nonlinear relationship between theta_w and theta_e*)*. "

2. *L343-349: I suggest to remove the repetitition. The method description with the same info in more detail is only a page or two above.*

Response:

Again, thank you for your comment.

Action:

Removed the sentences from line 343 – 348: "We use θw as thermal input variable, which includes contributions from both temperature and humidity. It hence might be of interest to 345 distinguish between fronts dominated by humidity or temperature. To do this, additional normal curve filters can be used. Fronts dominated by humidity are expected to have a much smaller temperature gradient across the frontal zone, hence, by adding an additional filter that evaluates the change of dry potential temperature θ allows us to discard features with an only small θ gradient."

Referee #2 (RC2):

1. *I'm slightly unsure of the title, since it suggests there is some model evaluation ("as represented by"). Could this be changed to just "in"?*

Response:

Thank you for this suggestion, we agree.

Action:

Changed the title from "The three-dimensional structure of fronts in mid-latitude weather systems as represented by numerical weather prediction models" to "The three-dimensional structure of fronts in mid-latitude weather systems in numerical weather prediction models".

2. *Section 2.1 - is there an ideal vertical resolution to use? Or a minimum vertical resolution?*

Response:

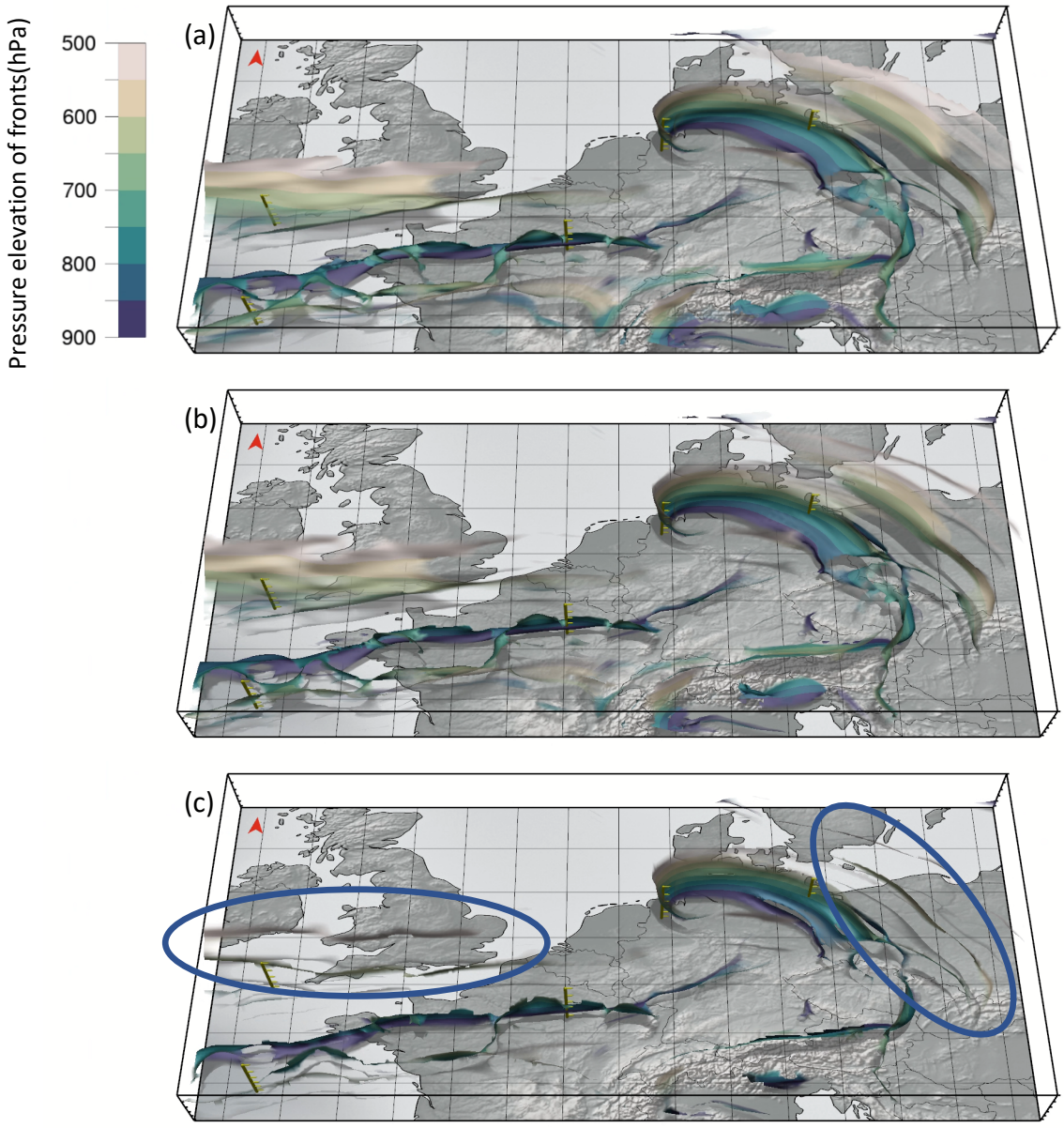

Figure 1: Impact of the vertical resolution on detected fronts. (a) original vertical resolution of ECMWF with 137 vertical level. (b) vertical level retained to 68 level. (c) vertical levels retained to 28 levels.

Thank you for raising this question! We have not tested our method for a "minimum" required vertical resolution in detail and have decided not to add any information to the manuscript. However, here we would like to provide an example of how the number of vertical levels affects the detected fronts. Figure 1 above reproduces Figure 5h from the manuscript to show the impact of reducing vertical resolution in ECMWF forecast data with originally 137 vertical levels. As can be expected, the more the vertical resolution is decreased, the less detail is visible. Also, frontal surfaces that appear connected when using 137 levels (Figure 1a) break up when reducing the vertical resolution. Examples of this are the fronts highlighted by the blue circles in Figure 1c: While the impact of halving the vertical resolution (from 137 to 68) is small, further reducing the vertical resolution to 28 levels (Figure 1c) leads to

structures breaking up. Note that (similar to the other figures in the paper) we are only showing fronts in the lower troposphere between 900 to 500 hPa. This corresponds to about 24 vertical levels of the original 137 levels. Halving the vertical resolution leaves about 12 vertical levels between 900 hPa and 500 hPa. In the lowest vertical resolution shown in Figure 1c only 5 vertical levels remain for front detection.

Action:

No action.

3. *Line 158: "at both THE cold and warm SIDES…"*

Response:

Yes, thank you.

Action:

Changed "at both cold and warm side" to "at both the cold and the warm sides".

4. *Line 168: Could this be made clearer with "The filter based on the average frontal strength along the normal curve…"?*

Response:

Thank you, we agree and rephrased this sentence, albeit a little different to avoid repetition.

Action:

Rephrased line 168 from "The normal curve is applied to the remaining warm air side frontal candidates." to "Filters based on normal curves are evaluated for the remaining warm air side frontal candidates."

5. *Line 341: I wonder if this additional feature is important - is there any surface weather associated with the feature?*

Response:

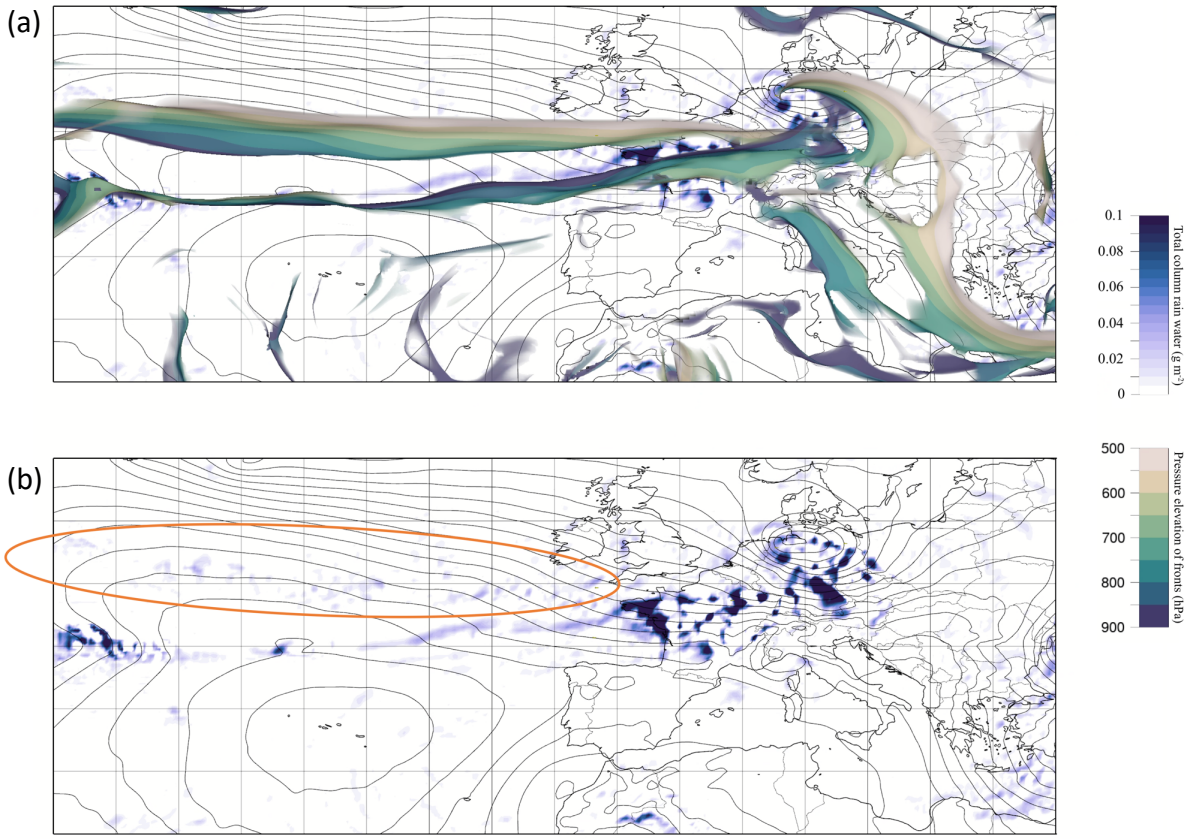

Figure 2: Total column rain water and 3-D fronts of ECMWF HRES simulation on 18 January 2018, 12:00 UTC, initialized on 18 January 2018, 00:00 UTC. (a) 3-D fronts and total column rain water. (b) Total column rain water. The orange circle highlights the position of the secondary cold front shown in (a).

This is an interesting question, thank you. Based on ECMWF HRES forecast data, there is indeed a noticeable signature of the total column rain water content in the vicinity of the secondary cold front (see the above Figure 2). Additionally, we checked a UK radar image (not shown here due to copyright), which shows a fragmented band of convective rain in the area of the secondary cold front over the UK. There hence is some surface weather that can be observer, however, we have no proof to confirm a direct link between this band of convective rain and the secondary cold front. Further investigation is required to confirm a possible link between the two. We have hence not added any information about this issue to the manuscript.

Action:

No action.

6. *Line 403: "purpose", I think should maybe be "propose".*

Response:

Yes, thank you.

Action:

Replaced "purpose" with "propose".

7. *Line 449: "choose" should be replaced with "have" since they are not aware.*

Response:

Yes, thank you.

Action:

Replaced “choose” with “have”.

8. *Line 527: “idealized” – do you mean “conceptual” model?*

Response:

Yes, thank you.

Action:

Replaced, “idealized” with “conceptual”.

9. *Line 541: I think the Figure 4 reference should be for Figure 11.*

Response:

Yes, thank you, it should be Figure 11.

Action:

Replaced reference from “Figure 4” to “Figure 11”.

10. *Line 583: “the secondary front detected….” Would be clearer if “…in theta w” was added.*

Response:

Yes, thank you.

Action:

Added “detected in theta_w” to the sentence.

11. *Line 608: “atmosphere” -> “atmospheric”.*

Response:

Yes, thank you.

Action:

Replaced “atmosphere” with “atmospheric".

RESPONSE TO MS RECORD NOTIFICATION ABOUT COLOUR SCHEMES:

Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) and revise the colour schemes accordingly.

Response:

Thank you for pointing out that our maps and charts may need to be revised to make them interpretable to readers with colour vision deficiencies. We have checked our figures in a colour vision deficiency simulator and have optimized the colors of those figures for which problems occurred to ensure they are also interpretable for readers with color vision deficiencies.

Action:

- Revised Figure 1: changed green line to yellow.
- Revised Figure 2e: changed red-green diverging colour map to red-blue diverging colour map.
  Revised Figure 8: changed colour map of trajectories.