

Review of egusphere-2026-3137

‘Isolating flow-dependent uncertainty in ensemble reanalysis data and its relation to Euro-Atlantic weather regimes and warm conveyor belts’

by Henry Schoeller and Stephan Pfahl

Manuscript in review for *Weather and Climate Dynamics*

Summary

The manuscript presents an analysis of the uncertainty in ERA5 500-hPa geopotential height (Z500) and relates the underlying uncertainty patterns to European weather regimes and the occurrence of warm conveyor belts (WCBs). Specifically, the authors separate uncertainty variability across different timescales and remove the influence of long-timescale variability, which is largely associated with changes in the observing system and data assimilation settings. A statistical GLS regression analysis is conducted to quantify how data assimilation uncertainty varies under different synoptic conditions and to relate weather regimes and WCB occurrence to characteristic patterns of assimilation uncertainty. The authors find that each weather regime is associated with a specific uncertainty pattern which relates to the underlying Z500 pattern. The authors further conclude that moisture contributes to enhanced uncertainty (through observation uncertainty) while model uncertainty plays a smaller role. The study is based on the ERA5 archive, which is widely used in the atmospheric science community, and generally extends recent research on flow-dependent uncertainty associated with WCBs and weather regimes over the North Atlantic. The topic fits well within the scope of Weather and Climate Dynamics, and to the best of my knowledge, the use of ERA5 Z500 ensemble spread in this context is a novel approach which I find quite inspiring.

The manuscripts overall reads quite well but is also very long (maybe too long for the presented key results and conclusions). The analysis is conducted thoroughly, and the results are clearly summarized in the conclusions. I support publication of the manuscript in Weather and Climate Dynamics, but I have several major concerns that should be addressed before publication. These concerns primarily relate to the length of the manuscript, the clarity of the overall storyline, and the interpretation of results.

1 General comments

1 Storyline

The abstract and conclusions are very well written and provide a clear and concise summary. However, this concise storyline is less apparent throughout the main text. In particular, the statistical methodology is described in too much detail (see also general comment 2), and the presentation of the results is not always sufficiently focused on the key scientific conclu-

sions. I encourage the authors to streamline the manuscript by concentrating on the methods and results that are essential for understanding the main findings. At times, some additional interesting aspects of the data are mentioned, but not explored further, which interrupts the overall narrative. A separation between the presentation / interpretation of results and a discussion of methodological limitations (currently included with the description of results), might further improve the structure and readability. Overall, I think that the manuscript would benefit from a more concise focus on the key results, with highly methodological details moved to the appendix where appropriate.

2 Statistical concept

The authors apply timeseries analysis to isolate the short-timescale uncertainty required to focus on synoptic-scale uncertainty pattern and perform a thorough statistical analysis to explain uncertainty pattern. Non-standard statistical methods to isolate uncertainty in Z500 are applied, and the authors provide detailed explanations of these methods. Generally, I appreciate a detailed description of the methods, however, the extensive, at times overly detailed, description of the statistical approach comes at the expense of the overall narrative and makes it difficult for the reader to focus on the key aspects. The current level of detail disrupts the reading flow, and I found it challenging not to get lost in technical aspects rather than retaining the broader scientific picture. Specifically, I found it challenging to understand a-priori the purpose of the timeseries analysis (Section 4.1), which was clarified only later in Section 5.1. Overall, the reader could benefit from a brief overview (and possibly schematic) of the applied methods presented in the beginning which outlines the overall approach. I therefore encourage the authors to streamline the presentation of methods, concentrating on the details that are necessary to follow the main line of argument.

3 Research questions

The manuscript addresses several important and relevant research questions, including the characterization of ERA5 uncertainty, the separation of long- and short-timescale variability, and in particular the dependence of uncertainty on weather regimes and specific flow conditions. However, the respective research questions could be stated more explicitly in the introduction section to provide the reader with a clearer roadmap and facilitate navigation through the manuscript.

4 Interpretation of results

The manuscript strongly emphasizes the statistical methods, which occasionally obscures the meteorological interpretation of the results. I encourage the authors to place greater emphasis on describing and discussing the findings in the meteorological context as well as highlighting their physical interpretation more clearly. I do not question the overall conclusions drawn from the presented analysis, but recommend a clearer description and discussion in the main text.

5 Writing Style

Overall, the manuscript is well written, in particular abstract and conclu-

sions. However, some sections are unnecessarily verbose, and a few colloquial expressions (e.g. "in the spirit of Occam's razor...", "taken with a grain of salt", "de novo") may not be ideally suited. Given the overall length of the paper, a more concise writing style focusing on the key information required to support the main storyline would further improve readability.

2 Specific comments

- l 1. "assimilation uncertainty": It might be helpful to add how "assimilation uncertainty" is defined in this study
- l. 50 What do you specifically mean by "forecasts initialized with assimilation uncertainty"?
- Data (Section 2): The authors could consider to add 3 subsections for each ERA5 Z500 spread, weather regimes, and WCBs.
- l. 93 - 121 This paragraph already describes the performed data analysis; I suggest to rephrase it with weaker emphasis on the data analysis framework (e.g., omit "we obtain a data set", "we then investigate", "we employ", "We do so by", etc.)
- Section 3.1 This section provides a detailed description of the different components contributing to ensemble spread in the ERA5 data assimilation system. While the authors state that "readers familiar with data assimilation may skim through" this section, I still suggest to shorten it and clearly name the key components in the beginning. The authors provide a considerable level of detail in this section, which I appreciate. However, at times it becomes challenging to keep the overall storyline in mind. I agree that understanding the different sources of uncertainty is essential, and finding the appropriate level of detail is undoubtedly a challenge.
- Reference to equations in the text: it may be helpful to add "eq." to the text and not just the number (e.g., "model 24", "model 21", "Compared to 21", "model with added covariates 24"); I sometimes found it challenging to jump back to the respective equation, maybe a meaningful model name or short description would help.
- l. 380-381 Are these details needed here?
- l. 566 ff I find this discussion distracts from the main storyline; maybe it could be omitted?
- l. 777 - 814 I suggest to streamline the text about the gradient and Laplacian more strongly, it interrupts the reading flow.
- l 553: "is of due"
- l. 673 - 697: I suggest to focus more strongly on the description of Fig. 7 and its relation to the weather regime pattern. This is not described in detail and not everyone might be familiar with the regime pattern.

- Section 5.3.1 Several dynamical (gradient/Laplacian, jet stream, and eady growth rate) and physics (humidity and clouds) variables were selected as possible predictors for assimilation uncertainty. Did the authors think of (or even test) any additional potentially relevant predictors that could influence the uncertainty, possibly als independent of the weather regimes?
- l. 1060 The authors may want to refer to Fig. 14 in the text.
- Please consistently use fig. or figure.
- l. 1121 ff: This paragraph rather belongs in the 'data availability' section.