

## Review of 'Past Evolution and Recent Changes in Western Europe Large-scale Circulation'

In this paper the authors study the non-stationarity of large scale weather patterns (LSCs) over Western Europe, using a set of patterns developed specifically for explaining the differing dynamical origins of French precipitation patterns in Garavaglia (2010). They introduce several metrics which they use to quantify the amplitude, uniqueness and persistence of the large scale circulation patterns in different seasons, and evaluate both the long term representation of these metrics in multiple reanalyses, and more recent trends in ERA5.

Both halves of this work are of interest. The reanalysis intercomparison provides an interesting perspective that clearly highlights some issues with circulation patterns in reanalyses in data-sparse time periods, which perhaps would not be so apparent using more conventional metrics. The analysis of recent trends in circulation presents an interesting approach to exploring non-stationarity in atmospheric dynamics, and shows some interesting shifts in the behaviour of the different LSCs over the last 70 years.

However, in my mind there is a final step which I think would enhance the work quite significantly. As the LSCs used in this paper were developed specifically to explain precip variability, and possible impacts of the LSC changes on precip make up an important part of the conclusions of the paper, it seems a shame that changes in the actual precipitation from 1950-2019 – are not considered. For example, in the conclusion the authors write:

*Mediterranean circulations featuring a marked flow and stationary flow directions that are closely reproduced in the climatology are more frequent over the last 30 years in autumn, which could impact autumn extreme precipitation over the Southwestern Alps.*

I believe showing whether such changes can actually be observed would really strengthen the work, and improve its impact.

Apart from this issue, I believe the manuscript itself needs some slight reworking. Lines 27-54 in the introduction provide a very comprehensive review of the various LSC impacts on Western European weather and extremes. It's actually a very useful collation of these results, but it is incredibly dense and hard to read. Additionally, as there are few links or comparisons made in the paper between the 4 weather types used and these other LSC classifications, a lot of this paragraph is not directly relevant to this work, other than to repeatedly emphasise that LSC has important impacts on surface weather. I would suggest either synthesising these lines down into a more readable form, or else only including in the main text those studies that are most directly relevant to the work done here, and putting the rest in a helpful reference table (i.e. of weather types against geographical region, with the documented impacts listed in each appropriate cell). I also think better motivation is needed for the various metrics used, due to the fundamentally applied motivation of the work – for example, what does a low singularity mean of an LSC for surface weather? Finally, a bit more work needs to be done in the conclusions to emphasise the implications of the results. For example, at the end of the paper I still don't know what I'm supposed to think about figure 10, or the low significance of the bimodal kdes in figure 9 when compared to the significant unimodal changes of figures 5, 7, and 8.

I highlight specific technical issues below, which while quite numerous shouldn't take very long to correct. In summary, I believe this paper represents a valuable piece of work, well suited for inclusion in *Weather and Climate Dynamics*. I am pleased to see work on circulation pattern non-stationarity, as I consider it to be an understudied but very important area of research. However I am recommending major revisions, so that the authors can include an analysis of the impact of LSC changes on precipitation directly, and to make the more minor revisions to the manuscript I have

suggested. If they would rather not include a direct consideration of precipitation, then I think they need to do a better job of arguing why the changes in these quite regional circulation patterns are interesting enough in their own right.

### Specific issues

- I find the use of ‘analogy’ throughout the paper a bit confusing. It is a matter of personal taste, but I suggest the authors consider using ‘analogues’ or ‘analogue methods’ to be clearer.
- Table 2 is not incredibly easy to read and takes up a lot of space. Consider putting it into supplementary material and instead include a table summarising just the significant/interesting differences.
- [line no. 99] ERA20C is in fact a 10 member ensemble. You should verify whether you are using the ens mean or first member, and correct the text.
- [line no. 113] I think more detail is needed here on the weather pattern classification, especially as the approach used is rather atypical. As these patterns are central to this paper, I shouldn’t really have to read through all of Garavaglia 2010 to understand what you’ve done. A few lines explaining that its a hierarchical approach that identifies geopotential patterns associated with rainfall clusters would suffice.
- [line no. 255] If the underlying assimilating model tends to produce calmer, less stormy weather – as most low resolution models do – then the less-constrained reanalysis in the 19<sup>th</sup> century might be expected to produce calmer weather. This would be consistent with the celerity and singularity trends you find.
- [Line 394] ‘Implications for summer heatwaves’ - what are the implications? It would be best to state these explicitly.

### Technical/editing issues

- [line no. 21] ‘Over the large scale’ is redundant
- [line no. 41] Something is missing: ‘..low amplitude through over the UK...’
- line no. 55] ‘Over the long run’: quite colloquial, better to be more specific – what timescale?
- line no. 55] As this is not a paleo paper is it necessary to refer to the Holocene? At least you should indicate this is the last 10,000 years.
- line no. 73] ‘weather pattern’
- line no. 95] identify/determine rather than ‘derive’
- line no. 109] ‘Studying changes in LSC is carried out’: This is not a valid construction. Perhaps ‘Changes in LSC are studied using...’?
- [line no. 120] Trends can’t really be ‘rather poor’. Perhaps say ‘small’, ‘negligible’, or ‘statistically insignificant’ as the case may be
- [line no. 127] A bit more motivation for this score is needed as it is not so common. A brief comment explaining its somewhat similar to using a pattern correlation would help clarify I think.
- [line no. 130] I believe I have worked out this equation now – it is a normalised sum of differences in meridional and zonal gradients at all gridpoints between 2 Z500 maps? Perhaps you could make this a bit clearer. Also ‘horizontal and vertical directions’ is

misleading, and implies different pressure levels are being considered. 'meridional and zonal directions' would be more precise.

- [Figure 1b] You should make it clear that the black lines are showing trajectories in phase space.
- [line no. 134] 'celerity that is understood as the celerity of deformation...' This is tautological. I suggest 'the speed of deformation' or 'rate of deformation'.
- [line no. 155] 'Even more resembling than usually' is incorrect. I suggest 'Even more similar than usual'. Same for similar errors on lines 308 and 390.
- [line no. 176] 'got' is wrong, I suggest 'obtained'.
- [line no. 240] 'Reduced quantity' rather than 'lower number'?
- [line no. 274] 'found in ERA5' rather than 'thanks to ERA5'?
- [Figure 5] 'sup-periods'