

The authors present a novel approach to provide early warnings for drought events over Europe, based on ECMWF's ERA-Interim reanalysis and ENS forecast system. I really like their basic idea, as it combines a scientifically interesting result with a very practical and applications-oriented framework. Furthermore, the authors have clearly performed an extensive set of analyses in support of their results.

However, I think the manuscript falls short of publication requirements in its current form. In addition to some comments of a more scientific nature, my main concern is the poor form of the submission. The text is often grammatically flawed or very unclear; references to tables are incorrect (and in one case to a table that doesn't exist, at least in the version of the paper I reviewed), and some existing tables are never referenced. Overall the manuscript has a very unrefined feel.

I reiterate that I do find the motivation behind the study and the authors' approach of great interest, so I would encourage them to perform a very thorough review such that their results may be published in NHESS.

We thank the reviewer and we apologise for the typos and wrong numbering of tables. We have revised completely the manuscript correcting all those errors. We have replied to all his/her comments in red.

Major Comments

1. As stated above, I deem the manuscript to be in an advanced draft form rather than at a publication-ready stage. The issues range from simple typos/grammatical errors/incorrectly referenced tables/oversights (some examples here:

I. 25 "While, the"

Corrected

I. 29 "and onset drought events"

Corrected

I. 69 "teleconnections in between"

Corrected

II. 84-85 "observational daily station-based" This is a bit redundant. If something is station based it is very likely to also be observational.

"which provides observational daily station-based precipitation" has been modified by "which provides daily station-based precipitation"

II. 96 Space between "10" and "days" and "32" and "days". Remove multiple spaces between "T1319" and "64".

Modified as suggested

I. 97 "1-degree" no need for hyphen.

Modified as suggested

I. 102 "launched" -> "initialised"

Modified as suggested

I. 111 “done, exclusively”

Corrected

I. 121 There is a lone parenthesis

Modified as suggested

I. 121 “previous studies mentioned earlier” → “aforementioned studies”.

Modified as suggested

I. 130 “identify The closest”

Corrected

I. 146 “Table 1”. Do the authors here mean Table 2? The real Table 1 actually does not seem to be referenced anywhere in the text.

We are sorry for these misunderstandings due to a mistake in the list of tables. They have been all corrected.

I. 156 “datasets from observations” → “observational datasets”

Modified as suggested

II. 157-158 “The choice ... has been verified in Lavaysse et al. (2015) and shown that this assumption”

Modified as suggested

II. 159-160 “some grid points the significant tests are not verified”

Corrected

I. 178 “Table 2” → “Table 3”?

Modified. See previous comment

I. 183 “dump” → “lower”

This has been modified

I.185 “Peirce” → “Pierce”

This has been corrected

I. 198 “leads to coherent picture”

Modified by “leads to depict a coherent picture”

II. 201-202 “they are generally higher teleconnections”

This sentence has been removed.

II. 207-208 “the potential benefits is assessed”

Corrected

I. 213 There is no table 6 in the version of the paper I have reviewed (indeed the tables stop at 4).

The list and the reference of tables have been corrected.

I. 218 “to avoid potential problem”

We have clarified these problems and replaced by “to avoid major changes in the WR classification”

II. 227-228 “also called and presented in the previous section as Reference”

We have clarified this point by clearly mentioning that the forecast based on precipitation is called the Reference.

I. 229 “forecasts” → “forecast”

Corrected as suggested.

I. 247 “anomaly” → “anomalies”

Corrected as suggested.

I. 261 “2.5I. 269 “for all the domain shown in the previous Figures” → “for the whole domain shown in the previous figures”

Modified as suggested.

I. 311 Again a reference to Table 6.

Please see previous comment

I. 316 “e.g.” or “i.e.”?

Modified. We have also checked all the uses of these latin abbreviations to avoid other mistakes.

I. 328 “intensities” → “magnitudes”?

Modified as suggested

I. 344 “showing a more complex observed than forecasted teleconnections”

“complex” has been replaced by “variable”

I. 346 “the relative good representation”

The sentence has been rephrased and the similarities have been quantified.

The new sentence is now:

“Nevertheless over continental regions, there are similarities between the assigned predictors obtained by using ENS and ERAI (impact of WRs b, b-a, a, c-d), with more than 60% of agreement, illustrating the good representation of the impacts of specific WR on precipitation by ENS.”

I. 347 “The correlation between the WRs forecasted and the observed precipitation”

Corrected

I. 385 “the dynamic of precipitation”

Replaced by “the atmospheric dynamic associated with the precipitation”

I. 390 “The skill scores is”

Corrected

I. 405 “with regard to” → “for”

Corrected

I. 408 Acknowledgements are missing.

The acknowledgements have been added

Tables 3 and 4 are never referred to in the text.

See previous comment

Fig. 8 caption “GSS*2:w”

Corrected

The figures in the SI aren't prefaced by “S” which makes it hard to figure out whether the authors in the SI refer to the SI figures or those in the main text.

We have now clarified the SI and added S when the text refers to a figure in the SI.

I. 72 in the SI: “?” in place of a reference.)

Corrected

to some very unclear or contradictory passages that I would recommend the authors rephrase (some examples here:

II. 30-32 This is a bit confusing: if the MOAWRs are anomalies of occurrence how can they “depict” a large-scale atmospheric pattern?

We have modified the sentence as follows:

“Finally, in most of the cases, the ENSEMBLE system of the ECMWF successfully represents the observed large scale atmospheric patterns, depicted by the MOAWRs, associated with drought events over Europe.” has been replaced by:

“Finally, the results show that the ENSEMBLE system of the ECMWF successfully represents most of the observed linkages between large scale atmospheric patterns, depicted by the WRs, and drought events over Europe.”

II. 48-52 The authors first discuss precipitation and then switch to wind gusts and temperature extremes without any apparent connection. How are the latter two fields relevant to the study?

This part of the sentence has been removed.

II. 202-203 Why speak of northern and southern Europe and then shift to central and north western Europe?

This sentence has been removed.

II. 212-224 This passage is very important (the authors explain a key aspect of their approach) but also occasionally difficult to understand. For example, what does “uses ENS for the WRs assignment” mean? Do the authors mean that the WRs are defined using the ENS dataset? Similarly, what does “modelled precipitation” refer to? Do the authors mean ENS precipitation (ERA-Interim is a model too)? Linked to the above, the passage describing the forecasting methodologies in the SI (to which the authors point the reader) never explicitly mentions the “idealized” approach, although this is included in Fig. S1. I would suggest the authors simply

include the full description of the methodologies in the main paper (the text in the SI is not that much longer than that already in the main paper), leaving the details of the attribution and MDA analysis in the SI. Again linked to the above, since the authors have given names to the different forecasting approaches, they should use them! For e.g. the caption in Fig. 4 never names the approach it depicts. This is one example, but there are a number of other similar cases throughout the submission.

According to this comment, we have decided to move the text from the SI to the main document. The description of the methodology has been corrected and simplified. Also the names of each experiment are now well defined and explicitly mentioned during the description of the results.

II. 228 Actually, this is never called “Reference” in the previous section.

We have now mentioned what the reference experiment is (derived from the forecast of precipitation) in the previous section.

II. 305-307 The authors first speak about “overestimation of low occurrences in the observations”, which is confusing because observations (or rather reanalysis, if I understood what the paragraph talks about) here are taken as the ground truth and so cannot under or overestimate occurrences. Next they mention the “larger number of forecasted events compared to observed ones with durations shorter than 5 days”. I take this to mean that the forecasts produce a larger number of short events than the reanalysis. However, from Figure 6 it seems that short events are more frequent in ERA-Interim than in the ENS data. I may have misunderstood the whole passage, but in that case other readers may well have the same issue.

We thank the reviewer for this comment. We have clarified through all the manuscript that WRs (and so MOAWRs) derived from ERAI are not observations.

The two figures (Figs. 6 and 7) and the associated paragraphs are different and discuss about two different results. The first part is about the frequencies of each duration, without any information about the concomitant values between ERAI and ENS. The distributions of long and short durations of each WR are checked. In the second part, the temporal evolution of the MOAWR values provided by ENS and ERAI are then compared and the concomitant values analysed. For these reasons, the conclusions can be different. Nevertheless, we agree that these sentences could be misleading. Therefore, we have clarified the text. The sentences: “The WR-distributions as given by the forecasts are characterized by a higher degree of similarity than the ones given by ERAI, with a peak of occurrence at around 5-8 days in winter (blue bars, Fig.6). The same holds for the other seasons (not shown). The lower spread of the forecasted WR occurrences, associated with reduced tails (i.e. reduced occurrences for durations exceeding 20 days), could be explained by the underestimation of the long-term blocking. A further examination of the temporal evolution of these occurrence anomalies suggests that the distribution of forecasted drought occurrences (previously shown) could mainly explain the overestimation of low occurrences using the reanalysis (i.e., larger number of forecasted events compared to those derived from ERAI with durations shorter than 5 days) and the underestimation of longer duration events (i.e., lower events with durations longer than 15 days using ENS than ERAI, red dotted lines in Fig. 7).”

have been replaced by :

“The WR-distributions as given by the forecasts are characterized by a higher degree of similarity between the WRs than the ones given by ERAI, with a peak of occurrence at around

5-8 days in winter for the four distributions (blue bars, Fig. 6a-d). The same holds for the other seasons (not shown). The lower spread of the forecasted WR occurrences, associated with reduced tails (i.e. reduced occurrences for durations exceeding 20 days), could be explained by the underestimation of the longer blocking episodes. A further comparison of the MOAWRs from ERAI and ENS (scatter plots in Fig. 7) suggests that : i) the distribution of forecasted drought occurrences could be explained by the overestimation of low occurrences using ENS than the reanalysis (i.e., larger number of forecasted events compared to those derived from ERAI with durations shorter than 5 days) and, ii) the underestimation of longer duration events (i.e., lower events with durations longer than 15 days using ENS than ERAI, red dotted lines in Fig. 7). ”

II. 346-351 From this sentence I understand that the correlation values are low where the teleconnection with precipitation is the strongest, while Figure 9 (and logic) suggests the opposite.

We agree that these sentences were not clear. We have modified them.

“The correlation values, which can be compared to the correlation shown in Fig. 9a, are quite low as a result of the relatively low predictability of the WRs previously discussed and where the teleconnection between WRs and precipitation is the highest (e.g. in southern Norway and the northern part of the U.K.).”

has been modified as follows:

“The correlation values, which can be compared to the correlation shown in Fig. 9a, are quite low as a result of the relatively low predictability of the WRs previously discussed. The values are also sensitive to the strength of the teleconnection between WRs and precipitation (i.e. highest scores in southern Norway and the northern part of the U.K, lowest scores in Central Europe.).”

II. 361-363 Do the authors mean that the results clearly point to the ability in forecasting the large-scale atmospheric circulation as a factor limiting the skill of this approach?

This conclusion needs to be clarified. We point out that due to the good representation of the relationship between MOAWRs and precipitation in ENS, the use of this predictor is rather limited. Indeed, the purpose of this method is based on the use of more predictable predictor (i.e. WRs) than the predictant (i.e. the precipitation). If the connection between the two is well represented, the two variables have relatively close scores in term of predictability. This could limit the benefit of this approach.

We have modified the text as follows:

“This highlights the overall good representation of the processes linking large scale circulation and precipitation deficits by ENS. So the ENS model succeeds in capturing the impacts of the WR occurrence on the precipitation anomalies as shown in the observations over a large part of Europe. These results could suggest limitations in using such predictors as the lack of skill score could result from a failure in forecasting the large-scale atmospheric circulation (rather than from a misrepresentation of the physical processes).”

modified by:

“Despite some differences observed in southern France and Italy where 'Process' overestimates the large-scale forcing on precipitation (i.e. with stronger correlation with WRs than observed), the patterns obtained when comparing the correlation values between SPI-1 (observed or forecasted) and MOAWRs (from ERAI or ENS) in Figs. S3, S5 and S10 are very similar. This highlights the overall good representation by ENS of the processes linking large scale circulation and local precipitation deficits. So the ENS model succeeds in capturing the

impacts of the WR occurrences on the precipitation anomalies as shown with observations and ERAI over a large part of Europe. These results could suggest limitations in using such predictors as the lack of skill score could result from a failure in forecasting the large-scale atmospheric circulation rather than from a misrepresentation of the physical processes from the large scale forcing to local weather.”

II. 391-393 I think that I understand what this means, but the phrasing is very awkward.

The sentence has been modified as follows.

“Due to the location of the geopotential anomalies and the induced wind fields, or connected with the local effects that reduce the influence of the large scale forcing, the impacts of these MOAWRs on precipitation could be low, as observed in winter over central Europe.”

has been modified by:

“Due to the distance of the geopotential anomalies to some target regions, or because of some local effects that could be predominant to the large scale forcing, the impacts of these MOAWRs on precipitation could be low, as observed in winter over central Europe.”

Figs. 4 and 8 I would suggest briefly mentioning that GSS is multiplied by 2 so that the same scale as for the other metrics can be used.)

Modified as suggested.

to some figures that need to be refined before they may be published

(Fig. 3 The authors should mention somewhere the different intervals used and the fact that the FAR colourmap is inverted

The caption of Fig. 3 has been modified as suggested.

Fig. 9 Why is there no land mask in panel d)?

The land mask has been applied.

Fig. 9 If the correlation in panels b) and d) is to be compared to that shown in the previous figures (e.g. Fig. 2) as suggested in the main text, then the colour maps should be the same.

Figure 9 has been modified as suggested.

Fig. 9 Why is the colourbar labelled differently wrt Fig. 1? It would be better if the two were consistent (either numbers or text is fine).

Changed as suggested

Fig. S3 Depending on how you chose to change the correlation colour maps in Figs 2 and 9, please ensure that this is consistent too).

Figure S3 is a bit different since it shows the correlation values (positive or negative) whereas Figs. 2 and 9 provide absolute values of correlation to highlight the strength of the connection and to select the best predictor. For these reasons, we prefer to keep different colour scales.

2. The results presented in the study are very application-oriented. Why not enhance this aspect by providing the equivalent of Fig. 4 for the operational and optimised forecasts?

The same figure for the ‘Optimized’ forecast has been added in SI.

Fig. 4 shows already results provided by the ‘Operational’ forecast. It highlights the benefits of this forecast in relation to the forecast of precipitation (‘Reference’). According to this

misunderstanding and the previous comment on the use of the experiment names, we have clarified the caption.

3. The reader finds out about the leave-one-out approach only on l. 245. This needs to be discussed before and in more detail, as it is a crucial aspect of the methodology. Related to this, have the authors re-calculated the WRs every time without the “left out” year to ensure no information leakage between training and test data?

We do not really see the link between the leave-one-out used for the skill scores and the identification of the WRs. Leaving one year out and re-running the WR identification do not modify the already identified WRs as the procedure is stable and avoid the trap of local minima since k-means has been nested with a genetic algorithm.

4. Fig. 1: Why is this only shown for winter if all four seasons are then discussed?

The automatic attributions for the others seasons have been added in the same figure.

5. ll. 281-287 This is one of the most interesting passages of the paper. Since the authors have clearly performed a comprehensive set of analyses, I would encourage them to expand the discussion of the physical drivers that may be behind these results.

Thank you for this comment. Behind the role played by the physical drivers, it is worth to highlight these results are relative to the ‘Reference’ experiment. Thus, they are also related to the behavior of the atmospheric model and how it represents extreme events. An exhaustive physical interpretation would require a complete and independent analysis that is out of the scope of this study. Nevertheless, we have now mentioned this point in the perspective as follows:

“Finally, the physical drivers should be analysed in detail to better understand why the predictors are more useful when predicting the most extreme events.”

Other Comments

1. l. 36 When they say “models” are the authors referring to climate models, NWP models in general, deterministic forecasts, ensembles or what here?

Clarified as suggested.

2. l. 53 This repeats what just said above: “WRs are highly teleconnected to ... precipitation” and “They are well known to ... either favour or inhibit precipitation in Europe”.

This sentence has been modified.

3. It might be helpful to mention the four canonical weather regimes over the North Atlantic.

Mentioned as suggested

4. l. 59 “The WRs also have an impact on extreme events” is a repetition of what said on l. 49 and l. 52.

This sentence has been removed.

5. l. 65 As not all readers may be familiar with WRs, the authors should mention that they are often (although not exclusively) diagnosed using 500 hPa geopotential height and maybe provide a reference.

Added as suggested.

6. I. 91 This is a very odd choice. The authors state that they upscale E-OBS and ENS to 1 degree but then use ERA-Interim at 1.125 degrees (which is certainly not its native resolution). Why not use it at the same resolution as E-OBS (or alternatively at the highest recommended resolution of 0.75 degrees, if it will be at a different resolution from the other data anyways)?

The ERAI datasets are here used to define WRs and high horizontal resolution is not really needed in this exercise. Many studies dealing with WRs are using even coarser datasets, such as NCEP/NCAR with 2.5 degrees resolution.

E-OBS provides local precipitation datasets, so there is no needs to have common resolutions. There is still a potential and limited impact when comparing the WRs distributions provided by ENS and ERAI. But the other resolution available for ERAI is 0.75 degrees that is still different to the ENS ones.

7. II. 100-103 Would be more logical to have these earlier in the paragraph, before discussing the regriding.

Displaced as suggested.

8. I. 129 Are there other studies that recover 3 WRs? If so, cite them. If not, provide a more detailed explanation of why you find a different number. With regards to the possible sources of discrepancy, one may argue that, assuming a more-or-less stationary system, if the number of WRs depends on the period chosen, then the length of the period is simply too short to define WRs in the first place.

Choosing the optimal number of clusters is still an open statistical issue, therefore, it is a difficult task in any classifying exercise. Most of the studies have focused only on winter and as stated by the reviewer have identified four weather regimes. It is important to highlight that three of them are associated with preferred latitudinal position of the jet stream, while the last one is related to blocking. Now, our analysis confirms the four regimes in winter while it points to 3 regimes in summer and autumn. This difference clearly shows the seasonal dependence of the regimes, since the system cannot be considered stationary (there is a time dependence) and the period can be considered long enough to detect regimes (as also confirmed by the four ones identified in winter).

9. It would be nice to see the equivalent of Fig. S3 for ENS (even though it is not mentioned in the caption I guess Fig. S3 uses ERA-Interim and E-OBS only?)

The caption has been clarified. Yes, in Fig. S3 ERAI and E-OBS are used.

We have now added the equivalent of Fig. S3 for 'Optimized' and 'Process' forecasts in SI (new Fig. S5 and S10). The similarities with S3 are remarkable and discussed in the main document.

10. II. 166-168 Do the authors have some evidence or reference to support this? Do any of the national civil protection services or other public services in Europe routinely make use of this type of information?

We have added references.

11. I. 170 vs I. 108 I am a bit confused as to what is computed up to 2014 and what up to 2013. This is a detail, but if some of the figures/results are indeed computed using 2014 too, then a time interval column could be added to Table 1.

All the data are computed up to 2013. 2014 is the end of the forecast period, but we used only the hindcasts of these forecasts to get significant results without big changes of the model

versions (as mentioned in the datasets section). So all the dataset in Table are going up to 2013.

12. I. 233 An improvement with respect to what?

'... an improvement ...' has been modified by '... high scores ...'

13. I. 279 Is a forecast with such a score useful in an operational context? More generally, can the authors make an assessment of where (geographically speaking) and to what extent their method would actually provide "operationally useful" information?

I want to clarify that I am not suggesting the paper would be less valuable if no such operational information can be obtained from the results presented in it. However, I think that an honest discussion of this aspect would make the paper more useful to both the research and public service communities.

We agree with adding discussion about that. Nevertheless, we cannot evaluate the usefulness of this operational forecast without taking into account the costs of the damages in each case of the contingency table (hits, misses, false alarms). Moreover it is quite difficult to find a common and general cost function for all the users. These costs may strongly vary depending on their applications (i.e. civil protection, water management services, farmers ...).

The only statement we can provide is that, according to the probabilistic scores, there is a significant improvement in using forecasts w.r.t. the climatology (based on the GSS). We have also shown that the forecasts using predictors generate, in some regions and in some seasons, significant improvements.

Most of the weather services provide now forecasts up to several months. It seems very important to honestly evaluate the added values of these forecasts. That is the main objective of this study.

This paragraph has been added in the conclusion:

"Most of the weather services provide now forecasts up to several months. For users, it appears essential to scientifically and statistically evaluate the added values of these forecasts for specific extreme events such as meteorological droughts. This is the main objective of this study.

Nevertheless, evaluating the practical usefulness of this operational forecast is difficult without taking into account the costs for each case of the contingency table (hits, misses, false alarms) that strongly vary depending on their applications (i.e. civil protection, water management services, farmers' decision supporting systems, etc.). The statement provided in this study is based on statistical scores independent of these costs. According to the GSS, there is a significant improvement of using forecasts in relation to the climatology. Moreover, the forecasts using predictors generate, in some regions and some seasons, significant improvements of these forecasts by using the same score. To evaluate these improvement for specific users, the costs should be taken into account that is a major perspective of this study."