

## Review comments 1 (RC1)

The manuscript evaluates the performance of SEAS5 soil-moisture forecasts against the ERA5 product across four soil layers. The topic is relevant to HESS, and the finding that deeper soil layers retain longer memory is physically plausible. However, the manuscript currently overstates the improvement in forecast skill because the evaluation framework is not sufficiently independent, and the EOF reconstruction step appears to enhance agreement largely by construction. Overall, the performance of SEAS5 is not interpreted with sufficient depth.

We sincerely thank the reviewer for being positive about our manuscript and for the detailed comments. Below, we address the concerns point by point

1. The central claim that EOF projection/reconstruction “improves SEAS5 forecast skill” is not convincingly demonstrated. SEAS5 is projected onto the ERA5 EOF basis, and both datasets are then reconstructed within the same reduced space. This procedure will naturally increase correlation by removing unmatched variance and forcing the comparison into a common subspace. While this is a useful diagnostic, it is not equivalent to improving intrinsic forecast skill. The manuscript should therefore reframe this result as improved mode-filtered agreement.

We agree that the current wording may overstate the impact of the EOF projection and reconstruction approach. Our intention was not to suggest that the intrinsic forecast skill of SEAS5 is fundamentally improved through EOF reconstruction. Rather, the purpose of this analysis was to examine how well SEAS5 captures the dominant large-scale variability patterns represented in ERA5. In the revised manuscript, we will therefore avoid using phrases such as “improved forecast skill” and instead describe the results more carefully as “improved agreement within the dominant variability modes”.

2. There is substantial disagreement over Africa and the Middle East, especially at longer lead times in the shallow soil layer and across all lead times in the deeper layers. This

pattern suggests systematic biases in SEAS5. However, the manuscript does not provide sufficient physical interpretation of these regional deficiencies.

We appreciate the reviewer's observation regarding the poor agreement over Africa and the Middle East. Comparing Figure 8 with Figure 1, we can see that the negative correlation over Africa and the Middle East has flipped to a positive correlation in Figure 8. Since Figure 8 removes the first EOF, which is governed by discontinuities associated with the artificial noise produced by the production streams, we infer that the negative correlation is probably a non-physical effect. In the revised version, we will add a short statement about this negative correlation along with the discussion on Figure 8.

3. ERA5 is treated as observational truth, but it is a reanalysis product and is not fully independent of SEAS5. Because both datasets originate from ECMWF systems with related model structures and forcings, part of the reported agreement may reflect shared model characteristics rather than genuine forecast skill. This limitation should be acknowledged much more clearly. If possible, the authors should also validate their results against independent soil-moisture observations or satellite-based products.

Yes, ERA5 cannot be considered a fully independent observational reference. For this reason, we have included the correlation with crop yield, which is an independent dataset for which ERA5 shows usefulness. We think that the link of these three datasets, namely, SEAS5, ERA5, and Lizumi crop data, already contains the information of the potential prediction skill. Also, along with this, we have added the EOF-PCs analyses of ERA5-Land data as an additional dataset (not completely an independent dataset but does provide an extension to the current analysis). Figure S6 represents the EOFs of ERA5 Land data of layer 1 (SWVL1). Most of the EOFs are matching very well with the EOFs of ERA5 and SEAS5 (lead1) anomalies (Figure 2 in the main manuscript), which indicates that these data sets are more similar to each other. In the revised version, we will add to the reviewer's comment to alert the readers, but we will also mention that the demonstrated correlation of ERA5 soil moisture with crop yield serves as an example of the usability of ERA5 and SEAS5, although they come from a similar source. Satellite data are less relevant for this study as we were also interested in analysing the deep soil layers.

4. The treatment of discontinuities in the ERA5/SEAS5 principal components is somewhat ad hoc. Excluding PC1 after identifying non-physical jumps may be acceptable as a sensitivity test, but it should not be presented as a primary result without a more rigorous homogenization strategy and a clearer explanation of when and why these discontinuities occur.

The exclusion of PC1 was intended as a sensitivity experiment after identifying apparent non-physical jumps related to model configuration and assimilation procedures. In the revised manuscript, this point will be further clarified.

5. The agricultural interpretation is currently too broad. Irrigation, management, temperature extremes, radiation, and compound heat-drought effects are discussed qualitatively, but they are not explicitly incorporated into the analysis. As a result, some of the statements regarding soil moisture as a dominant control on yield should be moderated.

We agree that the current discussion is broader than what is directly supported by the analysis. While soil moisture is an important factor influencing agricultural productivity, crop yields are also affected by irrigation (Seibert et al., 2010), management practices, temperature extremes (Rezaei et al., 2023; Zhao et al., 2024), compound impact of radiation and droughts (Lesk et al., 2022). These statements are now better supported by previous works. Furthermore, we have performed correlation analyses of Crop yield anomalies with net radiation and temperature anomalies (Figure S7, S8) along with the irrigation share of wheat and maize (Figure S9, S10) over the Mediterranean region. These figures are included below and will also be added to the revised manuscript to support our statements.

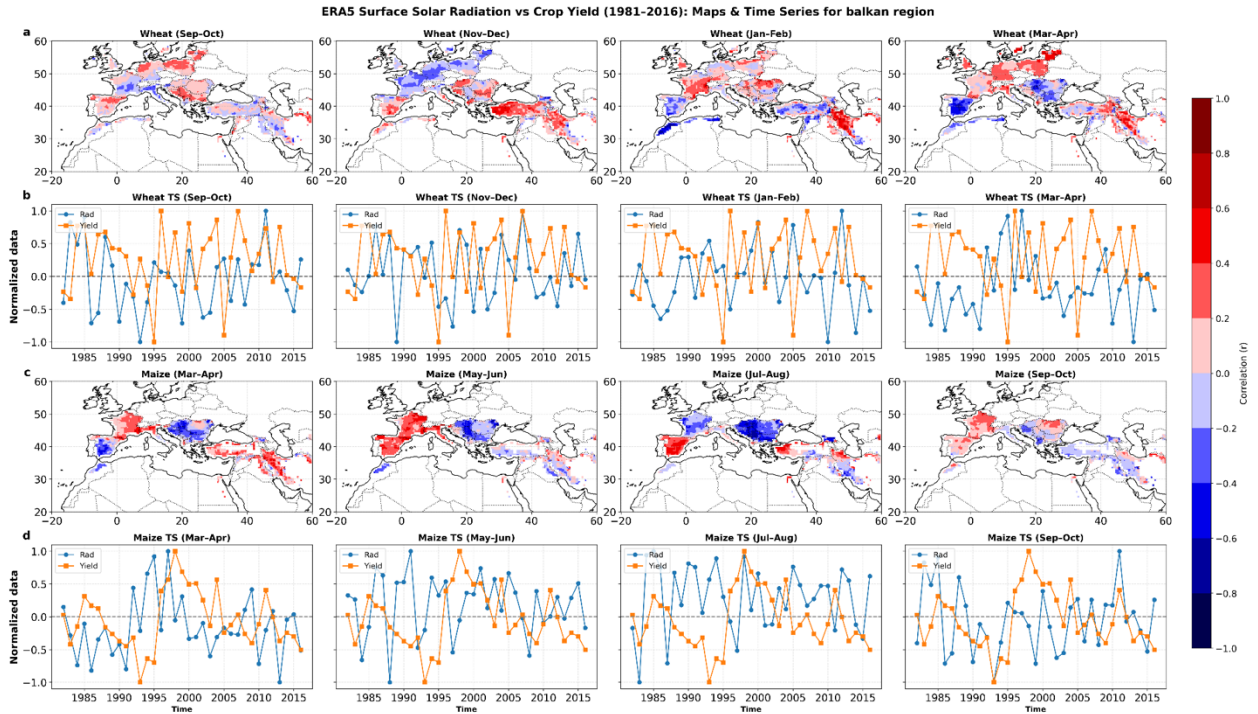


Figure S7: Panels a and c represent the pixel-wise correlation between the shortwave net solar radiation (Rad) and the crop-yield anomalies (Winter wheat and Maize). Panels b and d represent the normalized time-series of crop yield (Winter wheat and Maize) for the Balkan region for the period of 1981 to 2016.

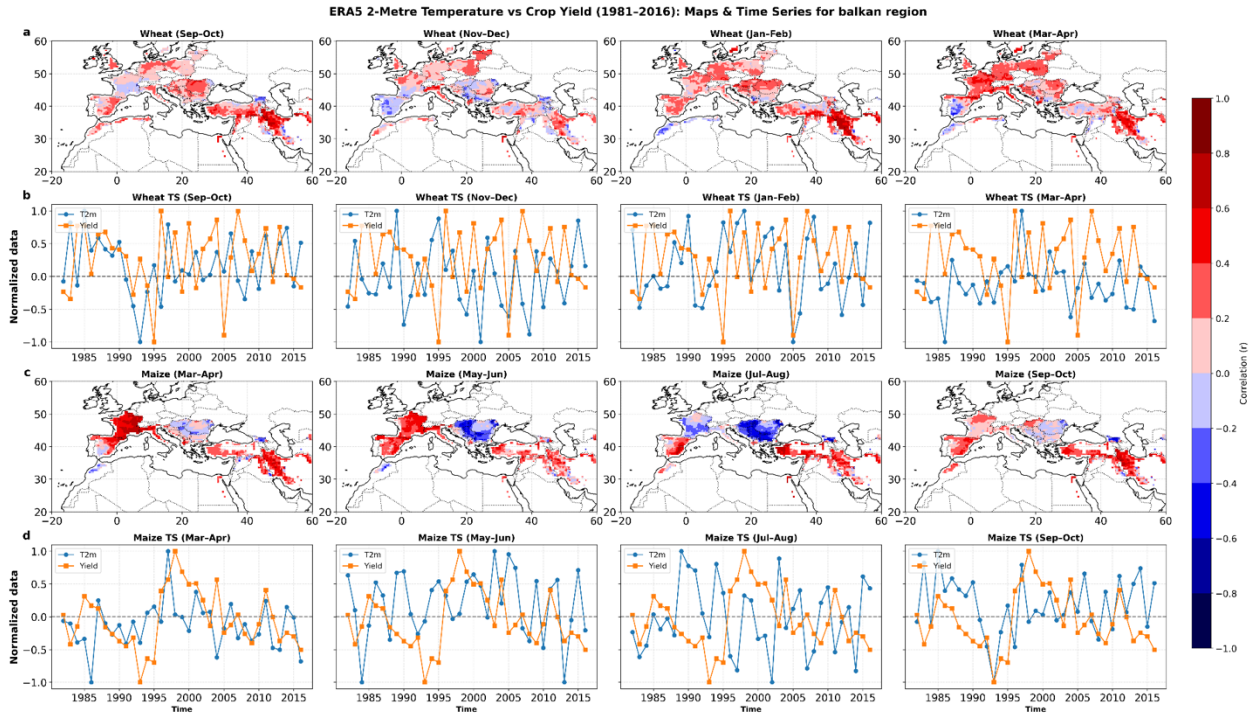


Figure S8: Panels a and c represent the pixel-wise correlation between the 2m temperature and the crop-yield anomalies (Winter wheat and Maize). Panels b and d represent the normalized time series of crop yield (Winter wheat and Maize) for the Balkan region for the period of 1981 to 2016.

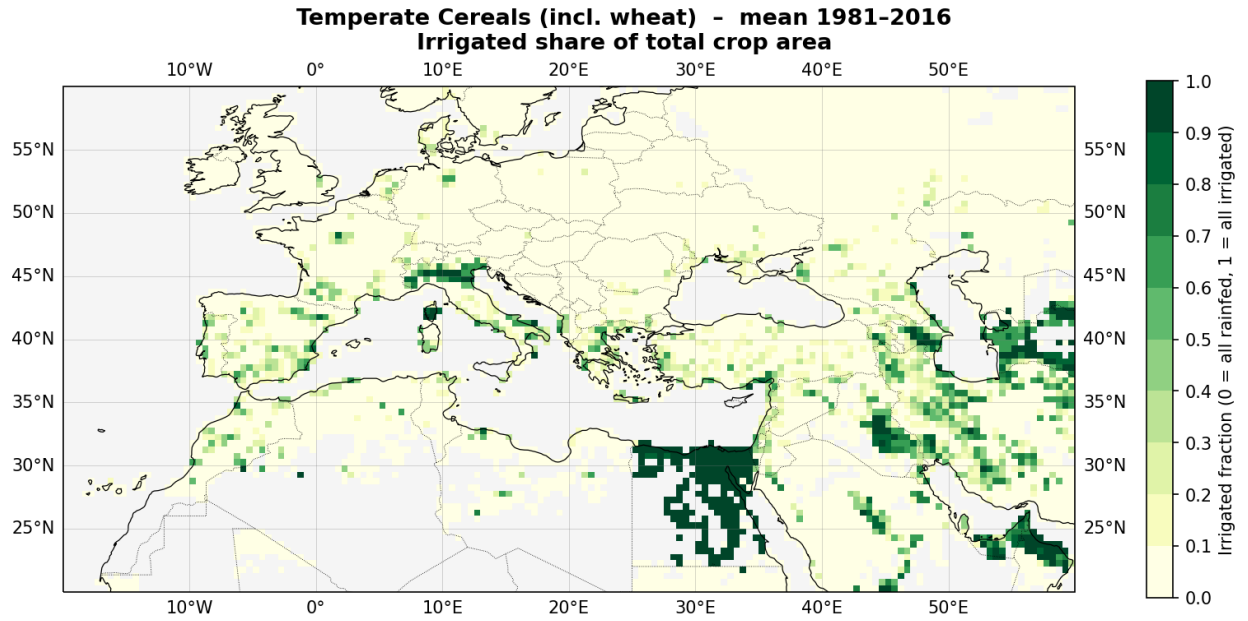


Figure S9: Irrigated share of the wheat crop area over Europe and the Mediterranean region for the mean of 1980 to 2016.

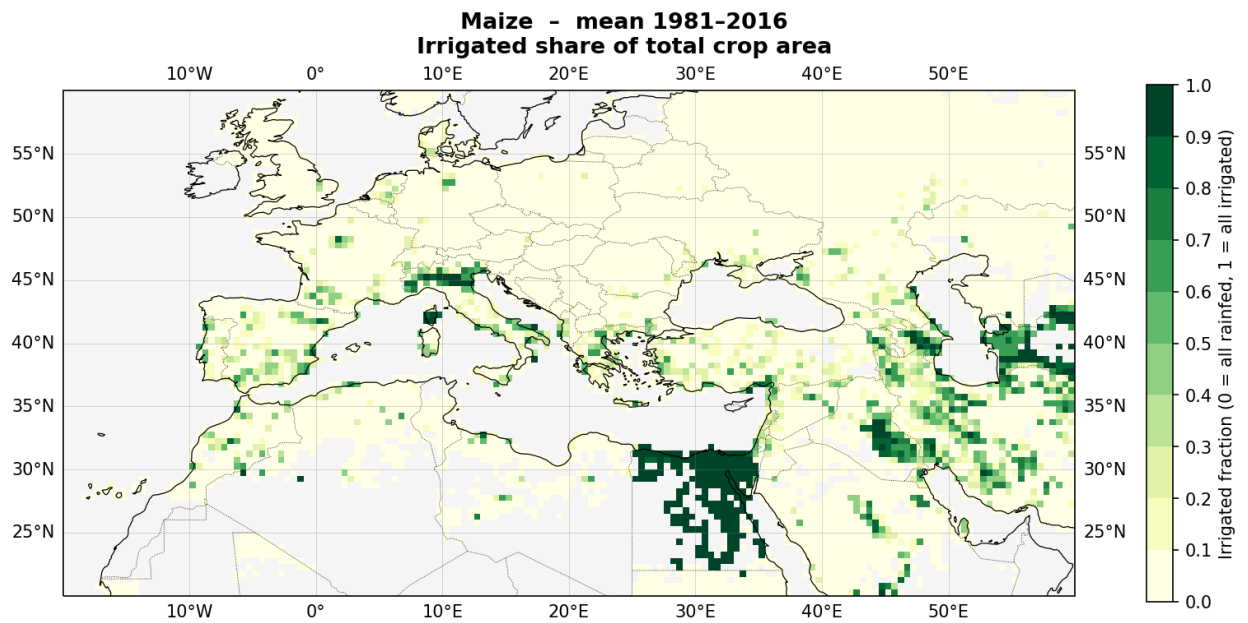


Figure S10: Irrigated share of the Maize crop area over Europe and the Mediterranean region for the mean of 1980 to 2016.

## References

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