Referee #1

Thank you for all the comments and questions. Below, you will find our responses to your comments:

Referee comments	**Answers**
'-The irrigation prescription is idealized. The irrigation timing varies by region and crop. For example, the authors acknowledge that night irrigation is common in the Ebro basin, while their irrigation occurs at 05 UTC. This is not a minor uncertainty: the timing of irrigation controls the partitioning between evaporation, sensible heat, boundary-layer development, and potentially convection. At 3-km resolution, timing becomes particularly important because irrigation can influence the diurnal boundary layer. I would quantify the uncertainty in the magnitude of irrigation and uncertainty in the timing and diurnal distribution of irrigation, which can alter the atmospheric response even if the annual irrigation volume is correct.	We agree that the timing of irrigation is a significant source of uncertainty, especially for the diurnal land-atmosphere response. Therefore, we have added some in the revised manuscript, which states that previous model sensitivity experiments provide evidence that realistic changes in irrigation timing mainly influence the diurnal cycle, with negligible effects on average soil moisture, sensible heat, or upward moisture fluxes (Valmassoi et al., 2020). Also, we state in the conclusions section that our irrigation scheduling is a source of uncertainty.
'-The paper uses maize as the representative crop while their irrigation map contains irrigated croplands generally, not maize-specific irrigated areas. So, there is a conceptual mismatch? Different European crops have varying rooting depths and seasonal water requirements, which can strongly influence the calculated RAW and, in turn, the irrigation volume.	We agree that crop type is an important source of uncertainty in the estimation of irrigation water requirements. Different crops have different rooting depths, growing seasons, and water requirements. This, of course, affects the calculation of readily available water (RAW). We selected maize as a representative irrigated crop and applied its rooting depth since crop types cannot be distinguished in TERRA. We already acknowledge the uncertainty associated with prescribing a constant rooting depth and the absence of crop-specific representation in the manuscript (Lines 430–440). Now, we have added in the revised manuscript that our prescribed irrigation amount should be interpreted as a reference irrigation amount based specifically on soil available water, rather than a real estimate of crop-specific irrigation requirements, since we use a constant root depth and soil hydrologic parameters (Field capacity and permanent

	wilting point).
'-What is the actual irrigation water applied? Can the authors show the annual irrigation amount by region and compare with independent irrigation water use estimates? Otherwise, it is difficult to know whether the climate response is physically realistic.	Thank you for this observation. We already presented the irrigation amounts for the Alps, Mediterranean, and Mid-Europe in Figure A1. However, a comparison with an independent irrigation dataset is still missing. Therefore, we have now compared our May - August accumulated irrigation water with independent estimates of irrigation water use from the Global Crop Water Model (GCWM; Siebert and Döll, 2010) for the Alps, Mediterranean, Iberian Peninsula and Mid-Europe. The comparison shows that our prescribed irrigation water is higher than the values estimated by GCWM. However, the two irrigation datasets are not exactly equivalent. As stated in the methodology, the irrigation amount in our simulation is a prescribed amount based on available water of a specific soil type. In contrast, the GCWM calculates evapotranspiration of blue crop water. In our case, not all irrigation amount is used for evapotranspiration since part of it may be stored in the soil profile or contribute to surface and ground runoff. We find it valuable to compare our irrigation amount with the GCWM estimates, although this should not be considered as a direct validation. Moreover, since we found large differences between the irrigation datasets, we have now emphasized in the manuscript that our prescribed irrigation is an important source of uncertainty when interpreting the simulated climate response. Siebert, S. and Doll, P. (2010). Quantifying blue and green virtual water contents in global crop production as well as potential production losses without irrigation. Journal of Hydrology, 384(3):198–217. Green-Blue Water Initiative (GBI). https://doi.org/10.1016/j.jhydrol.2009.07.031
'-The irrigation water is sourced externally and is not subtracted from other water reserves. This means the experiment is adding water to	We already acknowledge this simplification in the manuscript, stating that we considered an external water source. However, we agree that

the terrestrial system without accounting for river withdrawal, groundwater depletion, reservoir storage, etc. For an atmospheric irrigation-impact experiment, this can be acceptable if the purpose is specifically to isolate the atmospheric response to irrigation. Still, the paper sometimes discusses the results as if they represent realistic irrigation. The distinction needs to be much clearer.	this distinction was not stated from the beginning. Therefore, we have revised the manuscript and added this explicitly in the methods section. Moreover, we have revised other statements that might communicate that we introduce irrigation realistically.
'-The paper uses Siebert et al. (2013). Does this mean that the experiment doesn't capture the expansion of irrigation during the recent period? What about changes in crop type and irrigation technology?	Yes, we agree that the use of the Siebert et al. (2013) dataset results in a static representation of irrigated areas throughout our simulations. Similarly, we did not account for transient crop type and irrigation practices information. Our manuscript already discussed as future work the need for different crop types and the use of high-resolution irrigation datasets. However, we agree that we did not explicitly mention the importance of applying transient crop, irrigation area, and irrigation practices maps. Since this is relevant in long-term simulations, we have revised the manuscript and mentioned this limitation.
'-Does an irrigated grid cell become entirely "irrigated cropland"? At 3 km, many grid cells may contain cropland, forest, grassland, water, and non-irrigated agriculture. Replacing the land-cover class could introduce a land-use perturbation that is not irrigation alone.	Thank you for the observation. TERRA represents surface heterogeneity within a grid cell using the tile approach, and we irrigate only the irrigated cropland tile within a grid cell. Moreover, other tiles or surface types do not receive irrigation water. We agree that this information was not clear in the original manuscript. Therefore, we have added some text in the methods section to specify that irrigation is applied only to the irrigated cropland tiles.
'-The paper validates the simulations against 3-hourly quality-controlled observations from ICON DREAM reanalysis. But ICON-DREAM is a reanalysis, not an observational dataset. More details are required on which observation network, stations, number of stations, spatial distribution, and whether the station observations are independent of the reanalysis.	We use the WMO-WIS observations, the same as ERA5 (Hersbach H., et al. 2020). The density and temporal distribution are already described in ERA5 (and commented on the WMO documentation/historical records). The quality control done refers to well-accepted procedures already applied in observations reprocessing work (e.g. Copernicus Climate Change Service, Climate Data Store, 2025 and EUMETSAT, 2021), where the reanalysis provides the background information for the assessment

	of the observation itself. This is commonly done to avoid verifying against faulty/unrepresentative observations, even if this process does not always ensure a correct removal of such observations, e.g. ECMWF, 2026 with the ERA5T issue in snow depth. We have revised the manuscript and added this information and some spatial observation plots per region. Regarding the validation, we are aware that the observations might not be considered independent from the reanalysis, as they are assimilated with a cycled frequency; see the discussion in the ERA5 paper about its validation. Furthermore, in our approach we used an observational dataset; the only difference is how the quality control, but not bias-correction, on the observations themselves is done, and here it is done by ICON-DREAM. Therefore, the observations are only checked for consistency, but their observed quantity is not altered. As note, the aforementioned radiosonde dataset, which is both validated and bias-corrected with ERA5, will be assimilated in ERA6. Our approach offers a distinct level of independence compared to many validation procedures that validate ERA5-forced downscalings against ERA5 itself. In our approach, the observations are only checked for orography mismatches and physical consistency. While 2-meter temperature and relative humidity are quality controlled and assimilated, they do not directly influence the analysis increments fed to the reanalysis system given the fact that those are diagnostic variables (not prognostic ones). Now, we also acknowledge in the revised manuscript that the observations are not fully independent of the reanalysis. - Hersbach H, Bell B, Berrisford P, et al. The ERA5 global reanalysis. Q J R Meteorol Soc. 2020; 146: 1999–2049. https://doi.org/10.1002/qj.3803 - Copernicus Climate Change Service, Climate Data Store, (2025): Comprehensive upper-air observation network from 1901 to present. Copernicus Climate Change Service (C3S)

	Climate Data Store (CDS). DOI: 10.24381/ba504f7a (Accessed on 24-08-2026) - EUMETSAT (2021): Atmospheric Motion Vectors Climate Data Record Release 2 - MFG and MSG - 0 degree. V. 2. EUMETSAT. (dataset). https://doi.org/10.15770/EUM_SEC_CLM_0020 - European Centre for Medium-Range Weather Forecasts (2021). ERA5T issue in snow depth. https://confluence.ecmwf.int/spaces/CKB/pages/242084340/ERA5T+issue+in+snow+depth. Accessed: 2026-08-24