Schwitalla et al. present a study on the coupling strength of moisture and energy fluxes, and atmospheric characteristics over the European continent. The goal is to understand interanual variability of the LA coupling sign and strength in different climatic regions under varying moisture and energy conditions in summer. Focus is placed on the drought conditions. As a reference they chose the climate period 1991 to 2020, while the time series investigated extends to 2022.

We thank you for reviewing our manuscript. Please find our responses to your comments as marked in blue. Following the suggestion of Reviewer #1, our investigation now focusses on the area between 5°W-25°E and 40°N-60°N.

In the quantification of the coupling sign and strength, they use standard indices and correlation coefficients based on linearity assumptions.

We apply the terrestrial and atmospheric coupling indices, which are no standard indices yet to study land-atmosphere coupling. So far, they were not applied on the regional scale in Europe except for one growing season in Germany by Warrach-Sagi et al., 2022. The indices consider, that coupling experiences thresholds, e.g., in case of soil moistures above field capacity, LH is not limited by soil moisture and the no terrestrial coupling due to soil moisture via LH is visible. The study is complemented by correlation of SH and LH, which is applied to gain more information on the energy partitioning role on the coupling (e.g., Knist et al., 2017). In case they are not correlated other processes than LA coupling via soil moisture determines the fluxes and thresholds in moisture or energy limitations may be reached.

A plethora of work has been on published on the sign and strength of LA coupling in the past couple of decades. The study corroborates previous findings; in my opinion there are no surprises, or perhaps I have missed them. In this case, the authors need to revise the manuscript and clearly point out the new findings.

Though multiple studies assessed land-atmosphere feedback during the past two decades, still a huge research gap, particularly for Europe and for the time periods, which are already affected by the climate crises such as the droughts and floodings in the summers since 2015. In the past decades for Europe on the regional scale below 50 km resolution land-atmosphere coupling studies were often based solely surface variables (e.g. Knist et al., 2017). Only recently the regional studies also considered the development and state of the atmospheric boundary layer (e.g. Jach et al., 2020). The existing studies focus on (Central) Europe up to 2015 (e.g., Knist et al., 2017, Jach et al., 2020; Leutwyler et al., 2021) or on a single summer season (e.g., Dirmeyer et al., 2021). Between 2015 and 2022 Europe experienced a strong increase in summer temperature, droughts and heavy precipitation, this is therefore a very interesting period to add in land-atmosphere feedback studies in central Europe. A review of the current state of the art and the studies is included in the introduction from line 33 to line 74.

The analyzed period includes the decades that have been studied previously with respect to land-atmosphere coupling based on regional climate model simulations (e.g. Knist et al., 2017; Jach et al., 2020; Miralles et al.,2019). All other studies were based on the coarse grids of global climate models. It would be questionable if our results would not support previous findings on the same period. Here we extend the study to the current rapid climate change of the past decade. Further the results with ERA5 are closer to observations than regional climate models (Sun et al.,2021, Qi et al.,2023, and Rousi et al.,2023).

Our results show that the extreme drought years 2003, 2018, and 2022 can be identified as changing soil moisture-atmospheric coupling pattern. This in turn leads to a decoupling between SH and LH as shown by the correlation between these two variables. Additionally, the LCL deficit considerably increases during these years further enhancing and amplifying the heat and drought situation. As shown in Benson and Dirmeyer (2021) this can lead to a self-reinforcing mechanism which even further amplifies heat and drought conditions in changing climate.

In the summary and discussion section, the authors touch on the main the goal of the study and many interesting questions. For example, the authors state that “the hydroclimatological conditions during each summer drive considerable interannual variability in LA coupling…”. This would indeed be an interesting finding indeed. However, in my opinion, the analyses does not show this in a rigorous way. The indices of different years are presented, without further analysess.

We have to admit that the wording “hydroclimatology” could be misleading here as we did not investigate the relation between temperature, precipitation, and streamflow. Here we meant that the interannual temperature and soil moisture (and thus precipitation) variability. This sentence has been changed and now reads:

“Our results show that the interannual temperature and soil moisture variability during the different summers considerably drive the interannual variability in LA coupling over Central Europe.”

They also suggest “a growing influence of soil moisture variability on the meteorological conditions…” in the second half of the study period, which was drier than the first half. Again, the presentation of the coupling indices and linear correlations for individual years does not afford this conjecture in my opinion.

Markonis et al. (2021) found a considerable increase of drought events since 2010 due to higher temperature, less precipitation and the resulting soil moisture depletion already occurring in spring. We added this reference to the second last paragraph of our summary.

Two additional points that caught my attention are the categorization of the different years and application of the ERA5 data set (which was also brought up by the other reviewer). In the former, the classification appears to be rather arbitrary.

The years 2021 may server as an example, which is categorized as a warm and dry year in the table, but exhibits a wet anomaly and is referred to as warm and wet in the text, if I am not mistaken. This type of confusion does not lend confidence in the results.

Indeed, the definition of 2021 in Table 1 was wrong. 2021 shows a precipitation dry bias connected to a warm bias. We will carefully check all summer seasons again to ensure a correct classification.

Following the suggestion of Reviewer #1, we decided to focus our analysis to a smaller region between 5°W-25°E and 40°N-60°N. In addition, we only consider only warm summer seasons where the median 2-m temperature anomaly exceeds +0.5 K.

In the latter, the issue of data assimilation in ERA5 in the diagnosis of LA coupling has to be discussed further. Also in my opinion, reanalyses are of limited value in feedback studies, which leads to the challenge of identifying feedbacks in simulations while reproducing real world weather conditions.

Reanalyses data provide the three-dimensional consistent land and atmosphere gridded multidecadal timeseries of diurnal cycles closest to observations and therefore allow to study on the regional climate scale LA coupling beyond studying surface variables. It is not the goal of this study to evaluate reanalysis data or a model simulation. It is the goal to study the land-atmosphere interaction based on the best available 3-dimensional long-term gridded data set for Europe which is also applied in very recent studies of Rousi et al., 2022 and Rousi et al., 2023 to investigate feedback effects between the atmosphere and the land surface.

Apart from the 12-hourly atmospheric data assimilation (Hersbach et al., 2020), a sophisticated Kalman Filter based soil moisture assimilation is applied hourly (de Rosnay et al., 2013) in ERA5 which connects the atmosphere with the soil during the subsequent forecasts. Martens et al. (2020) clearly showed that ERA5 outperforms its predecessor ERA-I with respect to surface fluxes which was confirmed by a study of Muñoz-Sabater et al. (2021).

As shown in Muñoz-Sabater et al. (2021), the representation of the surface fluxes, soil moisture and net radiation in ERA5 is very reasonable compared to in-situ measurements over Europe as well as in comparison with data from GLEAM project (Miralles et al., 2011). Dirmeyer et al. (2021) successfully applied ERA5 for the investigation of LA feedback processes during the severe summer drought over Europe in 2018. The ERA5 variables used in this study (soil moisture, 2-m temperatures, surface sensible and latent heat flux) were successfully applied in LA feedback studies of Sun et al. (2021), Qi et al. (2023), and Rousi et al. (2023).

To summarize, ERA5 data deliver the required 3D data to apply LA feedback metrics that combine the variables of our study. We added the discussion accordingly to the manuscript.

Perhaps one has to make a choice and accept that in case of feedback studies in order to identify mechanisms, internal model consistency is more important than reproducing past weather. It would be interesting to understand the perspective of the authors in a more in depth discussion.

We disagree with this statement. An improvement of the representation of metrics must directly propagate in improved forecasts and vice versa. As explained above, it is not the goal of this study to evaluate reanalysis data or a model simulation. It is the goal to study the land-atmosphere interaction based on the best available 3-dimensional long-term gridded data set with diurnal cycles for Europe. We study the feedback based on the variables, not in the process chain calculated in parameterizations of the surface and boundary layer and within the land surface model. That would require model simulations, high resolution vertical and horizontal observations and would answer different research questions (e.g., Milovac et al., 2016 and Bauer et al., 2023).

Further, global and regional climate model simulations suffer from biases in the representation of surface fluxes, e.g., due to an inaccurate simulation of precipitation and thus an improper simulation of (root zone) soil moisture (Diez-Sierra et al., 2022). Although the general climate change signal can still be present in the simulations (Ban et al., 2022), even a bias correction of precipitation would not be sufficient in this case as this does not impact other prognostic variables.

A short paragraph has been added to section 2.1 why we used ERA5 and no other reanalysis data sets.

In my opinion, the study requires much more work beyond major revisions in order to contribute new and interesting results addressing the important issue of interannual variability of LA coupling in summer.

As stated above, between 2015 and 2022 Europe experienced a strong increase in summer temperature, droughts and heavy precipitation. This is therefore an interesting period to add in land-atmosphere feedback studies over Central Europe. Studies on LA feedback that also use data in the atmospheric boundary layer are either based on reanalyses data or model simulations and limited for Europe. Europe in the past has not been a hot spot, however this may now change as our study shows for the last decade. The problems of the purely model simulation-based studies are outlined above. The reanalyses data is suitable for the metrics. The results of the metrics can be used to study the capability of regional and global models “to identify mechanisms, internal model consistency.”

We are confident that we sufficiently addressed all your concerns mentioned above so that the manuscript can now be published.

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