Replies to the comments by Referee #3

We would like to thank Referee #3 for his/her interest and the comments on our manuscript. These relate to the relationship between the driving variables and the effect on the attribution estimates, the possible effect of variations in storage, the calculation of the trends, and the effect of variations in wind speed.

Relationship between the driving variables and the effect on the attribution estimates

[1] The authors clearly acknowledge that drivers of ETwb are tightly interlinked in the discussion. Does the attribution methodology adequately take this into account though? Have you explored the covariance among attributing variables? For example, if increases in P lead to increases in NDVI, are increases in P being overstated in the current attribution?

Response: We agree that the effect of increases in P would be overestimated if trends in P and trends in NDVI were correlated and thus Fig. 8c included indirect effects of P on vegetation activity. However, we checked partial correlation coefficients when trends in NDVI and E_0 were accounted for, and this did practically not affect the correlation between P and E_{wb}. Increases in P are not related to increases in NDVI (r = -0.12) or increases in E_0 (r = -0.01) in our study area (Fig. 1). Covariances between P and E_0 or NDVI therefore do not influence our attribution analysis. However, Monte Carlo simulations with synthetic P and Q series suggest that the effect of increases in P was overestimated in the current attribution (see the reply to the comments of Ryan Teuling). We take account of this in the revised manuscript.

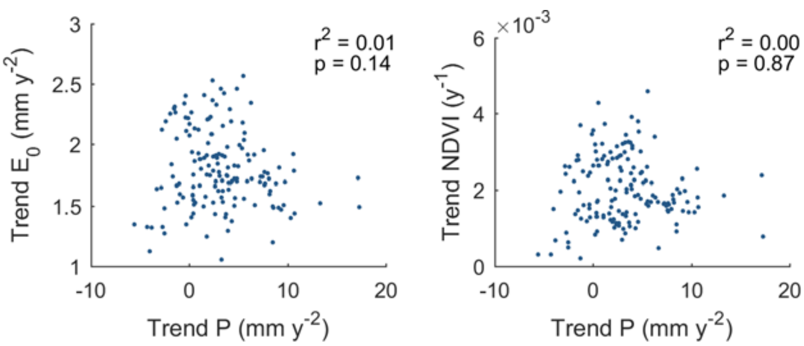

Fig. 1: Scatter plots of the relationships between trends in E_0 and NDVI against the trend in P.

Possible effect of variations in storage

[2] Section 2.1.3. I am a little confused about the time scale of ETwb data being smoothed and plotted in Fig. 2. Are you estimating <annual ETwb> = <annual P> - <annual Q> and smoothing these annual estimates with the Gaussian filter? If so, could increases in precipitation add to storage and not necessarily ET?

Response: Yes, Fig. 2a and d show variations in anomalies of E_{wb} estimated as <annual E_{wb} > = <annual P> - <annual Q>. Values for individual years cannot be interpreted as variation in E_{wb} since variations in P may have added to storage. The data were therefore smoothed by a Gaussian filter. Changes in surface water, soil, and snow storage can be assumed small over periods of several years. Studies on groundwater level changes in Austria do not show large-scale groundwater changes over the study period (Blaschke et al., 2011; Neunteufel et al., 2017). We therefore assume that changes in groundwater storage (and changes in any groundwater fluxes) are small. Since changes in glaciers can result in significant storage changes, catchments including glaciers were excluded. This suggests that changes in storage are likely small and that the trend in *P*-*Q* can be interpreted as trend in *E*.

Calculation of trends

Also, are the trends in ETwb consistent with changes in ETwb inferred by actually dividing the time series into larger time intervals where changes in storage can assumed to be much smaller (e.g. <ETwb> estimated from average data 1977 to 1995, and <ETwb> estimated from average data 1996 to 2014)?

Response: Trends calculated from the annual series are consistent with changes in E_{wb} derived from dividing the series into two parts from 1977 to 1995 and from 1996 to 2014, as in this equation:

$$t = \frac{\overline{E_{wb96-14}} - \overline{E_{wb77-95}}}{\overline{y_{96-14}} - \overline{y_{77-95}} + 1} * 10$$

Where t is the trend (mm y^{-1} decade^{-1}), $\overline{E_{wb96-14}}$ ($\overline{E_{wb77-95}}$) is the average E_{wb} over 1996-2014 (over 1977-1995), and $\overline{y_{96-14}}$ ($\overline{y_{77-95}}$) is the average year of the second (first) half of the study period (i.e. 2005 and 1986). Calculating the trend in E_{wb} this way results on average over all catchments in a trend of 30.4 mm y^{-1} decade^{-1}, compared to an average trend of 29.3 mm y^{-1} decade^{-1} when calculated from the annual series.

Effect of variations in wind speed

[3] Lastly, I agree with the three previous comments that the attribution would benefit from a more thorough discussion of the impacts of wind speed and water availability. I think these suggestions were well elaborated in the previous comments. With regards to wind speed though, it could be useful to perform a sensitivity analysis of ETo to possible wind speed trends (e.g. based on the magnitude of the trend inferred from ERA Interim data) rather than using uniform monthly wind speed.

Response: We have now analyzed the effect of changes in wind speed. In order to estimate the potential effect of changes in wind speed we derived spatially smoothed patterns of average monthly trends in wind speed from station observations. These were applied to spatial patterns of absolute wind speeds derived from high-resolution downscaled reanalysis data. This approach was chosen since suggested drivers for the trends in wind speed are changes in the atmospheric circulation and an increase in surface roughness, which however are not captured by reanalysis data (Vautard et al., 2010). Initial results show that wind speeds have indeed decreased in Austria (by about 2% per decade) but the effect on trends in reference evapotranspiration is small. When allowing for decreasing wind speed the average trend in reference evapotranspiration is 2.9% per decade, as compared to 3.1% when assuming no trends in wind speed. We have added the analyses to the supplement and we refer to it in the main text.

Minor comments:

[1] Page 2 (L26): In addition to CO2, stomata also respond to changes in atmospheric demand, temperature, and soil moisture.

Response: We have reformulated this sentence. Since the focus in this sentence is on the changes in atmospheric CO_2 as a further driver of changes in *E*, other factors that influence stomata closure are not mentioned here.

[2] Page 3 (L27): PET, "Potential evapotranspiration".

Response: Has been changed to reference evapotranspiration.

[3] Page 5 (L14): It may be helpful to explain this in more detail: "wind data were regarded as not representative with respect to evaporation trends", i.e. "not representative" is vague.

Response: Has been changed: "Trends in wind data were not included in the analysis since station observations of wind speeds are known to be prone to inhomogeneities (Böhm, 2008), annual anomalies of wind speed data from 85 stations in Austria appear unrelated to each other (Supplementary Figure S1a), and temporal trends over 1977–2014 do not show any spatial pattern (Supplementary Figure S2a) (see Supplement S1)."

[4] Since the phrase "vegetation activity" is used frequently, it might be useful to add a sentence in the 2.3.2 explaining the potential physical mechanisms driving "vegetation activity" (as represented to NDVI), e.g. vegetation fraction, vegetation type, LAI, phenology, etc.

Response: Good idea, we have added the following sentence: "Changes in vegetation activity as observed by the NDVI represent an integrated signal of changes in the phenology, the leaf area index, the vegetation fraction, the vegetation type and the land cover."

[5] Page 12 (L20): with higher values during the early 1990s, right?

Response: Yes, thank you.

[5] Clarify titles in Figures S7-S8.

Response: Has been changed to "…for biweekly averages over the course of the year (the plot titles indicate the starting day of the two-week period)."

References:

Blaschke, A., Merz, R., Parajka, J., Salinas, J., and Blöschl, G.: Auswirkungen des Klimawandels auf das Wasserdargebot von Grund- und Oberflächenwasser, Österreichische Wasser-und Abfallwirtschaft, 63, 31-41, 2011.

Böhm, R.: Heisse Luft: Reizwort Klimawandel: Fakten, Ängste, Geschäfte, Ed. Va Bene, 2008.

Neunteufel, R., Schmidt, B.-J., and Perfler, R.: Ressourcenverfügbarkeit und Bedarfsplanung auf Basis geänderter Rahmenbedingungen, Österreichische Wasser- und Abfallwirtschaft, 69, 214-224, 2017.

Vautard, R., Cattiaux, J., Yiou, P., Thepaut, J. N., and Ciais, P.: Northern Hemisphere atmospheric stilling partly attributed to an increase in surface roughness, Nature Geoscience, 3, 756-761, 10.1038/ngeo979, 2010.