Replies to the comments by Ryan Teuling

We thank Ryan Teuling for his interest in our study and for his review of our manuscript. The comments of Ryan Teuling concern the potential effect of variations in wind speed, the strong control of *P* on *E* trends, and the interrelation between trends in vegetation and trends in soil moisture.

Potential effect of changes in wind speed

Concerning the effect of wind: the potential impact should be discussed in more detail. Wind speed is known to have seen significant trends in many regions (Vautard et al., Nature Geosci. 3, 756-761), and this could have impacted ET trends also in this study. According to the offline PM-equation used by the authors, the impact of wind is direct. It should be noted, however, that when coupled to an atmospheric model, the sensitivity of PM ET for wind becomes much smaller (see e.g. Van Heerwaarden et al., Geophys. Res. Lett. 37, L21401). So I consider it unlikely that wind is a strong driver of ET trends locally, but I agree with the other referee that this warrants an in-depth discussion.

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 wind speeds derived from high-resolution downscaled reanalysis data. 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.

Strong control of *P* on *E* trends, interrelation between trends in vegetation and trends in soil moisture

My main concern related to the interpretation of Figure 8c. This figure shows the relation between inferred trends in P and ET. It suggests a very strong control of P on ET trends, which seems somewhat suspicious given the general humid climate conditions in Austria. In my view, two possible explanations exist.

Response: We thank the reviewer for raising this point. We agree that the estimated sensitivity of trends in evapotranspiration to trends in annual *P* as derived from Fig. 8c is relatively high for a generally humid region.

One reason why we expect a relatively high sensitivity of changes in *E* to changes in *P* in our study is the seasonality of the observed changes in *P*. *P* increased not in a uniform way over the entire year but the increases in *P* were concentrated in the summer season (supplementary Figures S4 and S5). Thus, the estimated sensitivity is approximately an estimate of the sensitivity of changes in *E* to changes in summer *P*, which can be expected higher than the sensitivity to changes in annual *P*. While changes in summer *P* are expected to contribute more strongly to changes in *E*, changes in winter *P* more likely result in changes in discharge.

However, we carefully rethought the analysis and became aware that the sensitivity derived from the regression in Fig. 8c might be overestimated since water balanced derived *E* (calculated as *P* - *Q*) and *P* are not independent variables. We have performed Monte Carlo simulations with correlated annual *P* and *Q* series to estimate the magnitude of this effect. This analysis aimed at investigating the strength of the relationship between trends in P and trends in Q resulting from the dependency of the two variables when assuming that trends in E are independent of trends in P. Means and standard deviations of P and Q, the covariance between P and Q, and the spatial variability of the trends in P have been derived from the data. This results in regression relationships with a slope of 0.09 ± 0.05 (i.e. 1 mm y^{-2} increase in P is related to an increase of E by 0.09 ± 0.05 mm y^{-2}) and a correlation coefficient of 0.07 ± 0.04. Based on these results, we estimate that the slope derived from Fig. 8c overestimates the sensitivity of changes in E to changes in P by 0.09 ± 0.05. In the revised paper, we consider this by subtracting the value derived by the Monte Carlo analysis from the regression slope derived from Fig. 8c. This reduces the sensitivity of changes in E to changes in P from 0.30 ± 0.04 to 0.21 ± 0.06. Consequently, we have revised our attribution. The revised estimates suggest that changes in atmospheric conditions, vegetation activity, and precipitation have contributed 43 ± 15 %, 34 ± 14 %, and 23 ± 7 %, respectively, to the average increase in E_{wb} in the study catchments.

It might be that in general, soil moisture constraints on ET have weakened because of increased P. In this case, one would expect inferred actual ET to be significantly lower than potential ET. This relation between actual and potential ET, however, is not explored in the manuscript. I believe such an analysis should be included in a revised version, as it provides important insight into the possible background of the drivers of ET trends.

Response: An analysis of the ratio between E_{wb} to E_0 shows ratios close to or even above one, indicating generally humid conditions. However, estimates of the AET/PET ratio based on the ratio of E_{wb} to E_0 likely overestimate the AET/PET ratio. E_{max} (the maximum possible evapotranspiration under the actual vegetation when soils are saturated) is likely much higher than E_0. The land cover in our study catchments is dominated by forest and grassland, with average fractions over all study catchments of 0.52 and 0.25. Analyses from non-weighable lysimeters indicate that E_{max} for sites with non-deciduous trees (pine forests) was about 20-30% higher than E_0 (ATV-DVWK, 2001). This value is expected to be even higher for spruce, which is the dominant species in non-deciduous forests in our study area. We estimated E_{max} for each catchment as $E_{max} = E_0 \cdot \sum(l_i \cdot f_i)$, where l_i is the fraction of land cover i and f_i is the ratio of E_{max}/E_0 for land cover type i, which was roughly approximated as 1.2 for forests and 1 for all other land cover types. This results in median (upper/lower quantile) values for E_{wb}/E_{max} of 0.84 (0.77/0.91), suggesting that in most catchments the AET/PET ratio is <1, even though the study area is classified as humid.

It should be noted that uncertainties in the estimated E_{wb} contribute to uncertainties in the estimated AET/PET ratio. These uncertainties arise to a large part from uncertainties in P, e.g. due to undercatch errors and the uncertainties in their correction. While the effect of the undercatch correction on the estimated trends in E_{wb} is small, it has a relatively high influence on uncertainties of the absolute E_{wb} estimates (see section 3.1; table 3). The estimates of the E_{wb}/E_{max} ratios have been added to the revised manuscript.

It should be noted that trends in soil moisture and vegetation might possibly be related. This needs to be discussed, along with the implications for the results shown in Figure 9 which assumes soil moisture/P and vegetation effects to be independent.

Response: Regarding the interrelation between trends in vegetation and trends in soil moisture, an analysis of the covariance between trends in P and trends in NDVI showed no significant relation (r = -0.01). This suggests that, in our study area, increases in P were not an important driver for the changes in vegetation activity, and that increases in NDVI are rather driven by increases in air temperature and a longer growing season, increases in atmospheric CO_2 and land cover changes (such as the increase in forest at the expense of grassland). We have added this point to section 3.2.4 and to the discussion section of the revised manuscript.

A second explanation for the relation in Fig. 8c could be that trends in ET are induced by overestimation of trends in P, for instance due to a too strong correction for undercatch. This possibility needs to be explored and discussed.

Response: An overestimation of trends in P by a too strong correction for undercatch has only a small influence on the estimated relationship between trends in P and trends in E_{wb}. As shown in Table 3, the effect of the applied undercatch correction on average trends in P and E_{wb} is small (in contrast to the effect on absolute values). This is also reflected by a small effect on the estimated regression slope between trends in P and trends in E_{wb}.

So in summary, if the correlation is physical/causal, the authors should provide additional evidence for the underlying process, for instance by showing increasing ET/PET ratios. In addition, the dependency of trends in vegetation and soil moisture needs to be explored. Fig 9 is interesting, but these results are currently not sufficiently robust to be published.

Response: We revised our analysis taking into account the dependency between trends in P and trends in E_{wb}, analyzed the relationship between trends in vegetation and trends in P, and provided additional explanation for a high sensitivity of changes in E to changes in P in our study region. In the revised paper, we formulate our attribution more cautious and more clearly mention the uncertainties. Despite the remaining uncertainties, we believe that presenting our results in Fig. 9 is a useful contribution.

Reference:

ATV-DVWK (2001): Verdunstung in Bezug zu Landnutzung, Bewuchs und Boden, GFA-Ges. zur Förderung d. Abwassertechnik e.V.