Dear Dr. McMillan,

Thank you for your insightful comments and suggestions. The followings are our responses to each of your comments.

This paper introduces an interesting analysis of flow recessions, where the deviation of (Q,dQ/dt) points from a single-valued, fitted relationship is attributed to ET and used to calculate a daily ET value. By comparing this derived ET value with a remotely-sensed ET value, the proportion of the watershed contributing to the flow (i.e. connected to the outlet) can be inferred. The authors used 9 US watersheds to test their method, with particular focus on the Spoon River watershed in Illinois where additional data such as depth to water table is available. The authors conclude that in their watersheds, significant underestimation of both ET and storage occurs when using standard recession analysis methods.

Thank you for the summary and encouragement.

The paper has the potential to provide a useful analysis method to determine contributing area, which could be used by other hydrologists. However, as it stands, the authors need to go a little further to provide a convincing argument that their various conclusions regarding the ratios of alpha (E/TE) and beta (S/TS) describe real effects and are not artefacts of the data uncertainty or the form of the equations used. I provide more details on these points below.

Thank you for your constructive comments which are helpful to improve the manuscript.

1.P5777 L17. "Eobs is not biased" This was not shown.

Thank you. The detailed uncertainty assessment is provided in *Zhang et. al.*, [2010] and not included in this paper. As discussed in P5777 L19~21, even if the RMSE of 1.2 mm/d of the remote-sensed evaporation from *Zhang et. al.*, [2010] is considered as overestimation, the underestimation of evaporation from recession analysis is still significant. For Spoon River watershed, the estimated multi-year mean annual ET based on remote sensing data (denoted as ET_{RS}) is compared with ET estimated from water balance (denoted as $ET_{Inferred}$), i.e., Figure 8 in Zhang et al. (2010). The percent difference between ET_{RS} and $ET_{Inferred}$ is within $\pm$10%. Zhang et al. (2010) also compared estimated daily latent heat based on remote sensing data with observed tower fluxes, and the correlation coefficient between them is around 0.85 (USBO1 station, which is located in Illinois, shown in Figure 3 of Zhang et al., (2010)). Two other performance indicators (MR and RMSE) are also shown in Figure 5 of Zhang et al. (2010). The accuracy of ET estimation is acceptable in Illinois. Detailed validation of the ET estimation is referred to Zhang et al. (2010).

We also validate by comparing mean annual ET values for the Spoon River watershed. For example, the multi-year (i.e., 1983-2003) averaged ET estimated based on remote sensing data is 642 mm for the Spoon River watershed. Based on soil water balance, Yeh et al. (1998) estimated the average annual ET for the state of Illinois and the value is 659 mm. Assuming negligible mean annual storage change $\overline{\Delta S}$, the multi-year averaged ET can also be estimated by water balance, $\overline{ET} = \bar{P} - \bar{Q}$ where $\overline{ET}$, $\bar{P}$, $\bar{Q}$ are mean annual evaporation, precipitation, and runoff, respectively. Based on MOPEX dataset, the mean annual rainfall $\bar{P}$ is 922 mm and the mean annual runoff $\bar{Q}$ is 272 mm. Then, the estimated $\overline{ET}$ by water balance is 650 mm.

Therefore, the estimated ET by Zhang et al. (2010) is correct in the study watershed if compared with water balance data. This conclusion is consistent with the validation presented by Zhang et al. (2010).

Yeh et al. (1998) estimated the mean monthly evaporation based on atmospheric water balance and soil water balance for the state of Illinois. The mean monthly evaporation during the period of April to October estimated by Zhang et al. (2010) in Spoon River watershed is compared with that estimated by Yeh et al. (1998) as shown in Figure 1. The root mean square error is 15 mm. The mean monthly ET_{RS} is 127 mm and the mean monthly estimated by Yeh et al. (1998) is 118 mm.

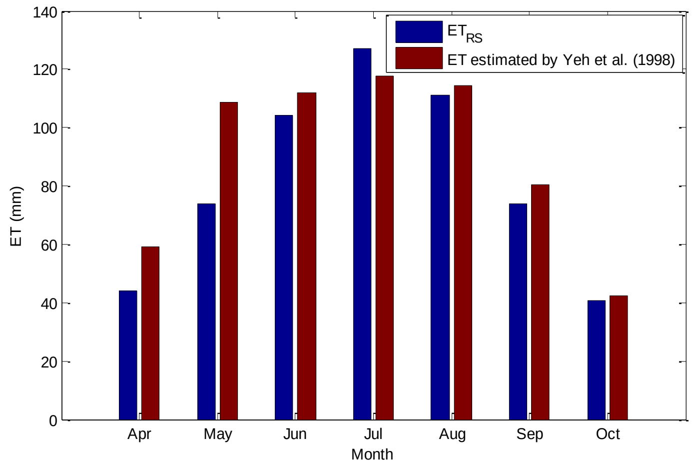


Figure R1: Mean monthly evapotranspiration estimated from remote sensing data (Zhang et al., 2010) and soil water balance (Yeh et al., 1998)

Yeh, P. J.-F. and J. S. Famiglietti (1998), Regional Groundwater Evapotranspiration in Illinois, *Journal of Hydrometeorology*, 10, 464-478. DOI: 10.1175/2008JHM1018.1

Zhang, K., Kimball, J. S., Nemani, R. R., and Running, S. W.: A continuous satellite-derived global record of land surface evaporation from 1983–2006, *Water Resour. Res.*, 46, W09522, doi:10.1029/2009WR008800, 2010.

2.P5778 L15-19. Alpha declines during recession events. Since Eobs is approximately constant, this translates as 'E declines during recession events', i.e. measured (Q, dQ/dT) points are closer to the fitted relationship. Given that the fitted relationship is a simplification of true catchment behaviour (i.e. power law relation between storage and discharge), please could the authors comment on whether their conclusion is robust to errors caused by the simplification.

Thank you for the comment. We agree that the decrease of alpha during a recession event can be interpreted as the decrease of vertical distance between the data point and the lower envelope, given that the E_{obs} is relatively constant and the lower envelop is fixed. In other words, the slope of single recession events is not the same as the slope of the lower envelope. Figure R2 and Table R1 show three recession events in Spoon River watershed. As the data shows, when the slope of individual event is larger than the slope of lower envelope (slope=1.20) as shown in Event 1 (slope=3.33) and Event 2 (slope=3.54), which is the most common case, the value of α

will decrease during the recession. When the slope of the individual event is equal or smaller than the lower envelope as shown in Event 3 (slope=1.13), the value of alpha will stay relatively constant or even increase a little bit due to uncertainty of evaporation data. However, for all the three events, α is smaller than 1, so the underestimation of evaporation is shown in all the events while the changing trend of alpha may be variable.

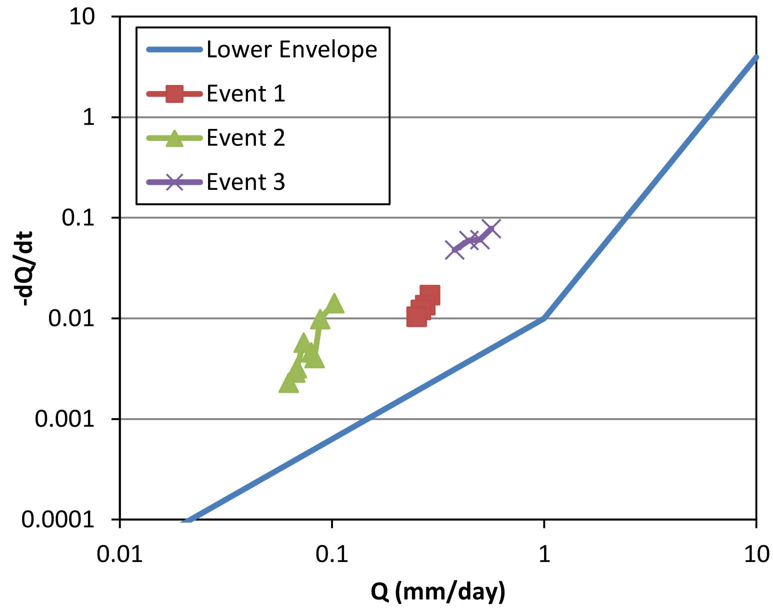


Figure R2. Three recession events in Spoon River watershed

Table R1. Data for the 4 recession events in Spoon River Watershed

	Date	Q (mm/day)	-dQ/dt (mm/day^2)	E_{obs} (mm/day)	E_{est} (mm/day)	α
Event 1	5/3/1988	0.2889	0.0171	2.39	1.90	0.793
	5/4/1988	0.2745	0.0136	2.31	1.48	0.641
	5/5/1988	0.2618	0.0122	2.54	1.33	0.523
	5/6/1988	0.2502	0.0104	2.79	1.12	0.402
Event 2	6/13/1988	0.1023	0.0142	3.97	2.14	0.539
	6/14/1988	0.0878	0.0099	3.74	1.51	0.405
	6/15/1988	0.0826	0.0041	3.69	0.58	0.158
	6/16/1988	0.0797	0.0046	3.83	0.68	0.178
	6/17/1988	0.0734	0.0058	3.33	0.90	0.269
	6/18/1988	0.0682	0.0032	3.17	0.48	0.151
	6/19/1988	0.0670	0.0029	3.27	0.43	0.132
	6/20/1988	0.0624	0.0023	3.33	0.34	0.102
Event 3	7/19/1986	0.5623	0.0780	5.73	3.88	0.678
	7/20/1986	0.4970	0.0607	5.54	3.52	0.635
	7/21/1986	0.4409	0.0596	4.58	4.10	0.897
	7/22/1986	0.3779	0.0480	5.36	4.03	0.751

3. P5779 L15-19. DS/DTS is correlated to E/Eobs. Is this a real effect or does it follow from the form of the equations for DS, DTS and E?

Thank you for the comment. The relation between ΔS/ΔTS and E/E_{obs} can be expressed by the following equation:

$$\frac{\Delta S}{\Delta TS} = \frac{S_{t-1} - S_t}{Q_t + E_t^{obs}} \quad \text{(R1)}$$

Assuming the late stage recession and substituting equation 5(b) into equation R1, one obtains:

$$\frac{\Delta S}{\Delta TS} = \frac{1}{a_2(2-b_2)} \frac{Q_{t-1}^{2-b_2} - Q_t^{2-b_2}}{Q_t + E_t^{obs}} \quad \text{(R2)}$$

Since $Q_t \ll E_t^{obs}$,

$$\frac{\Delta S}{\Delta TS} \approx \frac{1}{a_2(2-b_2)} \frac{Q_{t-1}^{2-b_2} - Q_t^{2-b_2}}{E_t^{obs}} = \frac{1}{a_2(2-b_2)} \frac{Q_{t-1}^{2-b_2} - Q_t^{2-b_2}}{E_t} \alpha \quad \text{(R3)}$$

Substituting equation (4) into equation R2,

$$\frac{\Delta S}{\Delta TS} \approx \frac{1}{a_2(2-b_2)} \frac{Q_{t-1}^{2-b_2} - Q_t^{2-b_2}}{\frac{-dQ_t/dt}{a_2} Q_t^{1-b_2} - Q_t} \alpha \quad \text{(R4)}$$

When the variability of $\frac{Q_{t-1}^{2-b_2} - Q_t^{2-b_2}}{\frac{-dQ_t/dt}{a_2} Q_t^{1-b_2} - Q_t}$ is not significant, the correlation between ΔS/ΔTS and E/E^{obs} is strong.

4. P5779 L25. Beta value of 0.38 is incorrect

Thank you for the correction. The correct β value for the event in Spoon River watershed is around 0.43 in Table 2a.

5. P5779 L22-27. Stable value of beta. The values for beta in Table 2a are calculated from an iterative formula based on Eq 11. It is possible to express the value of beta(ti) as a function of Q0, a, b, mean(alpha), initial Q, and the values {Q} and {TE}. Using the values given for these by the authors, I could show that in this case, beta (ti) was dominated by the term mean(alpha), largely because the initial storage was large compared with the derived changes in storage. So beta is stable in large part because mean(alpha) is constant. Therefore I am not yet convinced that the stable beta is a real effect rather than an artefact of the particular Q0,a,b values for this watershed. To convince the reader, I think the authors could give the general form for beta(ti) and discuss which terms dominates and to what extent are calculated beta value provides more information than the mean(alpha) term.

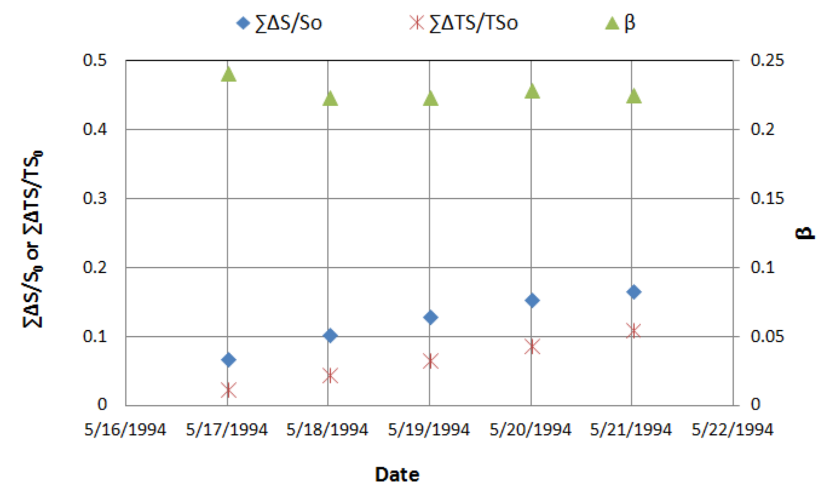
Thank you for the insightful comments. The general form of β_t can be written as:

$$\beta_t = \frac{S_t}{\frac{S_0}{\bar{\alpha}} - \sum_{i=1}^{t} Q_i - \sum_{i=1}^{t} TE_i} \quad \text{(R5)}$$

where S_0 is the initial storage, and S_t is storage at time *t*; $\bar{\alpha}$ is the initial value of β. Since $\Delta TS_i = -(\Delta Q_i + \Delta TE_i)$, equation (R5) can be written as:

$$\beta_t = \frac{S_0 + \sum_{i=1}^{t} \Delta S_i}{\frac{S_0}{\bar{\alpha}} + \sum_{i=1}^{t} \Delta TS_i} \quad \text{(R6)}$$

Based on this equation, if $S_0 \gg \sum_{i=1}^{t} \Delta S_i$ and $\frac{S_0}{\bar{\alpha}} \gg \sum_{i=1}^{t} \Delta TS_i$, then β_t will be close to $\bar{\alpha}$ as you pointed out. Figure R3-1 shows $\frac{\sum_{i=1}^{t} \Delta S_i}{S_0}$, $\frac{\sum_{i=1}^{t} \Delta TS_i}{\Delta TS_0}$, and β_t for the event shown in Table 2a for Spoon River watershed. The values of $\frac{\sum_{i=1}^{t} \Delta S_i}{S_0}$ and $\frac{\sum_{i=1}^{t} \Delta TS_i}{\Delta TS_0}$ are indeed small (around 0.1), and the value of β_t is stable (the range of variability is within 0.05). However, the initial storage varies seasonally and by events. Figure R3-2 shows $\frac{\sum_{i=1}^{t} \Delta S_i}{S_0}$, $\frac{\sum_{i=1}^{t} \Delta TS_i}{\Delta TS_0}$, and β_t for an event during October 1988 for Spoon River watershed. The values of $\frac{\sum_{i=1}^{t} \Delta S_i}{S_0}$ and $\frac{\sum_{i=1}^{t} \Delta TS_i}{\Delta TS_0}$ are up to 0.4, but the range of variability of β_t is also within 0.05.



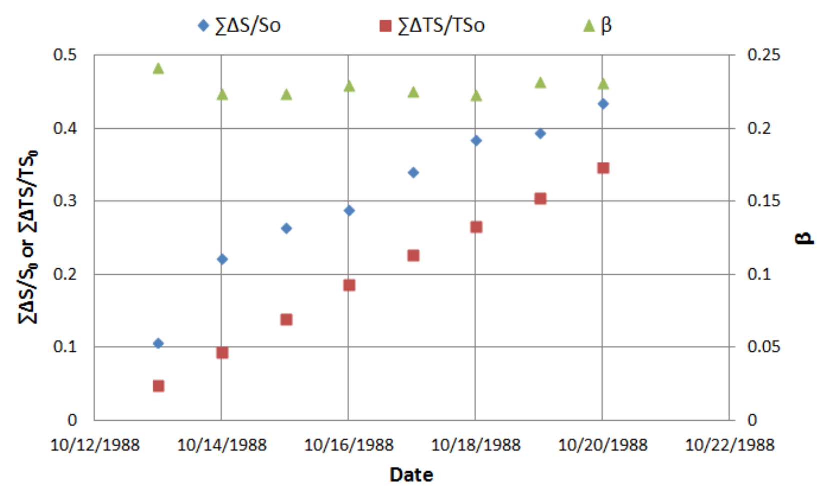
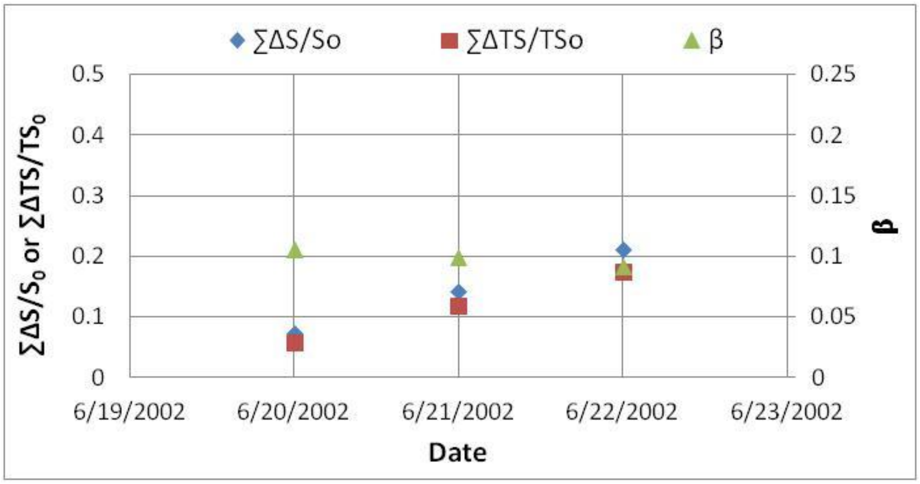


Figure R3: Spoon River watershed

In the 9 study watersheds, the Big Nemaha River Watershed (Gage ID 06815000) has the lowest water storage in general. Figure R4 shows two recession events in the Big Nemaha River watershed. The range of variability of β_t is within 0.05 when the values of $\frac{\sum_{i=1}^{t} \Delta S_i}{S_0}$ and $\frac{\sum_{i=1}^{t} \Delta TS_i}{\Delta TS_0}$

are very small (<0.2) or up to 0.5. As a result, we agree that the large difference between ΔS and S can contribute to the stability of β value, but it is not the only case.



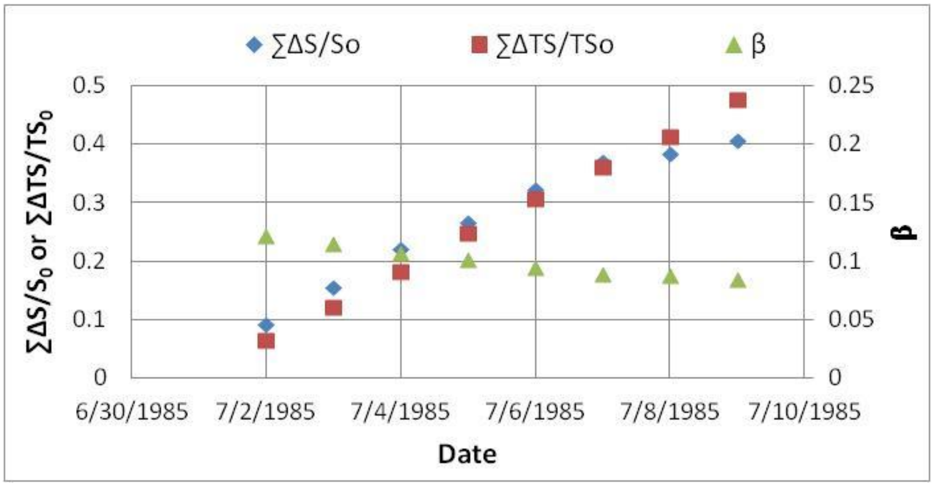


Figure R4: Big Nemaha River watershed

6. P5780 L7-10. Beta decreases with increasing depth to water table. As described above, beta is approximated by mean(alpha) = mean(E/TE). E is the vertical distance between the (Q,dQ/dt) points on Fig 2, and the fitted line. As can be seen (the graph is on log axes) this distance decreases with decreasing Q, i.e. increasing depth to water table. Hence I am unclear whether this is a real effect, or just due to the larger spread of dQ/dt at high Q values.

Thank you. Figure R5-1 shows the updated figure for β versus groundwater table depth. Figure R5-2 shows Q versus groundwater table depth. As you pointed out, Q declines with increasing water table depth. However, estimated E does not necessarily declines with decreasing Q as shown in Figure R5-3. Please also refer to the data in Event 1 and Event 2 in Table R1.

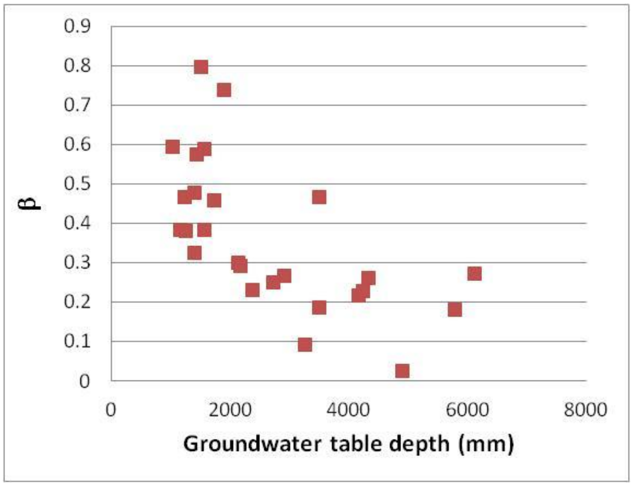


Figure R5-1: β versus groundwater table depth (the labels in the horizontal axis in Figure 8 of the HESSD are corrected)

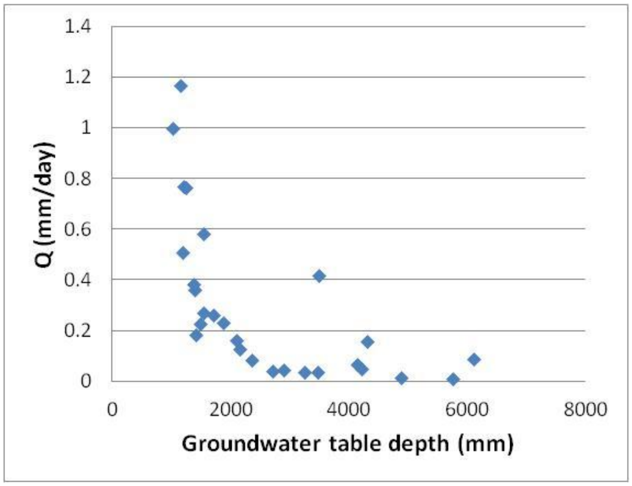


Figure R5-2: Q versus groundwater table depth

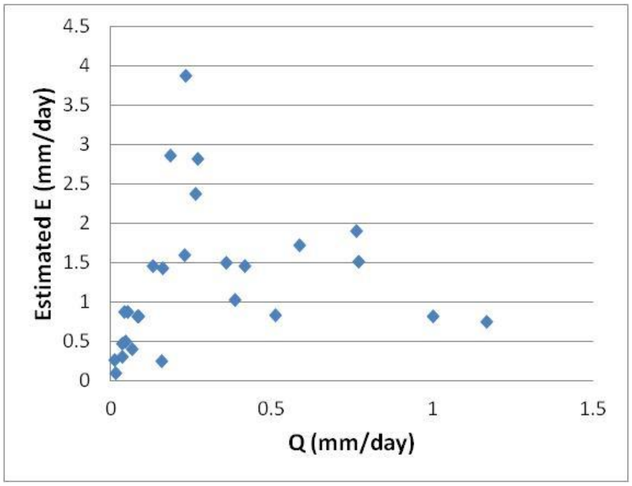


Figure R5-3: Estimated *E* versus *Q*