Responses to comments from Student Reviewer 4

Key:

SC4 – Comments from Student 4 (short comments)

AC – Author comments

General comments

SC4: The paired watersheds technique cannot differentiate between water loss by transpiration and evaporation from wet surfaces, including canopy surfaces. Even though transpiration is the major component of the total evapotranspiration processes in global water cycle according to Jasechko et al. (2013), other terms of evapotranspiration can exceed transpiration locally. According to Savenije (2004), interception is one of the most underestimated processes in rainfall-runoff analysis. Evaporation from interception is a considerable proportion of the total evaporation, especially in warm climates. The effect of interception is maybe small compared to transpiration, but the effect of interception becomes larger during storm events, which are not rare in this region (Fohrer et al., 2001). Shuttleworth (1993) observed that above forest turbulent diffusion is much more efficient than for other vegetation. Interception in forests exceeds most of time the evaporation from open water. So because this paired watershed is forested with a climate that is specified as humid subtropical (Harder et al., 2007), it is necessary to take interception into account in the discussion and interpretation of the results, as it provides a plausible alternative explanation in addition to transpiration.

AC: The reviewer makes good point here indicating not only transpiration interception should also be taken into account when talking of ET.

As we showed with several examples in responses to three other student reviewers, in this humid coastal plain forests the canopy evaporation of the intercepted water is much lower than the transpirational component. As an additional example, in a recent ET study using eddy flux tower data and all other hydrologic measurements by Domec et al. (2012) on a mid-rotation managed pine forest in coastal North Carolina (just north of this study site), the authors found the transpiration accounted for approximately 70% of total ET by eddy flux method. Canopy interception was estimated to be only 5-10% of annual precipitation and 6-13% of total ET, similar to those values reported by other authors in this coastal region shown in other responses. Annually, soil evaporation represented only approximately 9 and 14% of ETEC at the mid-rotation site and the early-rotation young plantation site, respectively.

Domec, Jean-Christophe; Sun, Ge; Noormets, Asko; Gavazzi, Michael J.; Treasure, Emrys A.; Cohen, Erika; Swenson, Jennifer J.; McNulty, Steve G.; King, John S. 2012. A comparison of three methods to estimate evapotranspiration in two contrasting loblolly pine plantations: age-related changes in water use and drought sensitivity of evapotranspiration components. Forest Science, 58(5):497-512

SC4: The authors concluded that one watershed was able to recover to pre-hurricane levels of canopy transpiration at a quicker rate due to the greater abundance of pine seedlings and sapling in that watershed. The term canopy transpiration is used wrong. Moore et al. (2004) showed that transpiration indeed decreases with forest age but he also showed that canopy interception is proportional to forest age. So before the hurricane, when there were more old trees, interception probably contributed more to the total evapotranspiration than after the hurricane, when there were proportionally more younger trees. The role of transpiration became larger after the hurricane, due to more transpiration of younger trees.

AC: The authors disagree with this because even for older matured well managed trees/forests with higher LAI the maximum canopy interception reported was no more than 32% of the precipitation on a seasonal basis in a coastal North Carolina forest site (Sun et al., 2010). Similar matured managed pine forest in North Carolina yielded an interception loss of only 17.5% of the annual precipitation (Amatya et al., 1996) for a 5-yr study and a recent 21-yr simulation study by Tian et al. (2012) using a validated DRAINMOD-FOREST model showed canopy interception of only 14.3 % of precipitation and 21.4% of total ET at the same site. Our forest with pine mixed with hardwood has a much less LAI in dormant season potentially contributing even less to canopy interception.

SC4: Transpiration is part of evapotranspiration, therefore they can only conclude that one watershed was able to recover to pre-hurricane levels of evapotranspiration instead of transpiration.

AC: Yes, for this part we agree and will restate the conclusion to state ET rather than just T.

SC4: Another comment concerns the work by Harder et al. (2007), who investigated the hydrology and quantified the water budget for the WS80 watershed for the years 2003 and 2004. They concluded that the daily outflows were sensitive to rainfall event size, their frequency distribution and to the antecedent water table positions. Temporal distribution of the rainfall is important for the magnitude of the outflow because if there is large period with less or no rainfall between two major storm events (like 2004) the water tables will decline significant due evapotranspiration. When there is rainfall again, the rainfall is first used to replenish soil water deficits or it will be lost as evapotranspiration before it can take part of the runoff. In the discussion nothing is said about these factors, only transpiration is mentioned. All of these processes shouldn't be neglected, they play an important role for the runoff. Maybe these processes become less important in research which is done over several years, but they should still be mentioned.

AC: The reviewer makes an excellent point in that runoff from WS77 and WS80 as in the case of several recently studied lower coastal plain watersheds is dependent on water table position (REFERENCES). A period of drought could result in depleted groundwater levels that would first need to be replenished before runoff from the landscape takes place. We agree that this aspect does need to be mentioned in the discussion. However, we must also clarify that given similar groundwater positions in both watersheds at the beginning of period of drought, the watershed with higher ET would also be the watershed that would take longer to recover in terms of runoff response. In other words, considering water table position in runoff production is important but would serve to only accentuate ET and runoff differences between two comparable watersheds.

SC4: According to the paper of Harder et al. (2007) 2003 was an extremely wet year (300 mm above average rainfall) and nearly half of annual rainfall was lost from the watershed through stream flow. Also the amount of average rainfall in 2003 was the second highest recorded amount of average rainfall in the last 15 years in this region. However 2004 was an extremely dry year (400 mm below average), where the total outflow was only 8% of the annual rainfall and most of the watershed losses where through evapotranspiration. In the transition of the extremely wet year to the extremely dry year the flip era has started. Now is my question **if the large difference in rainfall amount between these years**

has any influence on the break dates in this period? Do the two watersheds react different on severe drought and extreme wetness after the hurricane? Have the other structural change points also a large difference between the amounts of rainfall between the years? My suggestion is to add a few lines in the discussion which can answers these questions or a small part which can tell if this should be taken into account or not.

AC: We thank the reviewer for a very insightful observation on the correspondence of the onset of the Flop era to a very wet year (2003) followed by a very dry year (2004). Based on the three methods of analysis (LOESS, MOSUM on watershed specific rainfall-runoff relationship, and MOSUM on between watershed relationships), the onset of the Flop era ranged from April 2003 to December 2004. As mentioned in the previous response, a dry year would result in groundwater depletion caused by ET – if ET rates between watersheds are variable then it would be expected that the extent of groundwater depletion would also differ between watersheds, in turn causing differences in the timing of runoff production due to variable times of groundwater recovery with the onset of normal rainfall. This more nuanced commentary on runoff production and impacts of drought years will be added to the discussion section as a possible catalyst for the end of the Flop era.

SC4: MOSUM is a method that not every scientist is using on a daily basis, so more explanation of this method is preferred. In fact, the authors explain more about CUSUM, the method that was not used for analysis, than the method that is used. Also the graphs obtained from MOSUM (Figure 4 and 5) are confusing.

AC: Section 3.5 is re-written to provide more background on MOSUM. Refer to responses to Student Reviewers #1 and #2.

SC4: At the moment it is unclear why the structural breaks are not consistent with when the line is crossing the 95% confidence interval, as mentioned as the criterion for a structural break beneath Figure 4. Especially the third structural break in Figure 4 is very unclear where it comes from. A more clearer description is necessary. Furthermore the x-axis of Figure 4 and 5 is linear, instead of non-linear. The amount of years which the x-axis represents is not linear. It is a good idea to indicate where the missing data are in Figure 4 and 5, so it is easy to see where the data is 'glued' together.

AC: Please refer to responses to Student Reviewers #1 and #2.

SC4: The method used for estimating the structural change point in the monthly streamflow (breakpoint or break date) assumes a predefined number of breakpoints (see section 3.5). The authors assume that there is only a single breakpoint, because Hurricane Hugo was the major climatic event that might have caused a shift in post event response of monthly flows on either WS77 or WS80. But in the results (section 4.1) there are suddenly more structural changes. How is this possible if there must be a number of predefined breakpoint? Is this a typo or is this adjusted further one in the research, or are break dates and breakpoints not the same as structural change points as suggested in line 11 on page 11527? At the moment it is unclear and more explanation is necessary.

AC: It was a typo and the typo is corrected in the revised manuscript. Thank you for this observation.

Specific Comments from SC4

Page 11522, line 8: 'most of the temperate knowledge a 1938 hurricane that struck Harvard Forest (foster, 1988a, b)'. Improvement: 'most of the temperate knowledge came from a 1938 hurricane that struck Harvard Forest (foster, 1988a, b)'. (AC: Thank you)

Page 11530, lines 27–28: 'During the flip era (mid-1992 to end-2004) however, mean monthly flows from WS80 exceeded WS77by 15.7 +/− 3.2 mm month−1.' According to Table 1, 2004 is already the flop era and the average monthly flow difference is according to Table 1 in the flip era 17.1 +/− 3.4 mm. Page 11531, line 3: '...60% greater than in 1989–1992 and...'. According to Table 1, this period is from 1989 to 1991 instead of 1992. The time periods in the text are different than in Table 1, this results in confusion. (AC: Thank you – you and several other reviewers identified inconsistences between Table 1 and the narrative. While numbers in Table 1 are correct, the narrative is not and will be fixed to remove all inconsistencies.)

Page 11533, line 12. The reference is to Table 9, this must be Table 2. (AC: Thank you)

Page 11533, line 15. In one sentence there are two different methods used for writing the units. (AC: Thank you)

Page 11546, Table 1. The years of the flip and flop era are wrong. (AC: Thank you)

Page 11554, Figure 6. In column 4, for the period 1992–2003, no treatment is listed (AC: Thank you)