Dear Editor,

We would like to thank you and two anonymous referees for the opportunity to revise our manuscript. We found the comments of the two reviewers very useful, which gave us a possibility to address several issues that were initially overlooked. Based on the comments of anonymous referee #1 and #2, our detailed responses to each comment are given below.

Response to Anonymous Referee #1

Comment 1:

As stated by the author, only two components, TSM and SWE, were included in the calculation of TWS. We still have no idea of what the impacts could be if you added the surface and groundwater which will take a large proportion in TWS. There are indeed some difficulties to do this but the GRACE data can help. At least, please add some discussions about the uncertainties caused by the calculation in conclusion part.

Authors' response:

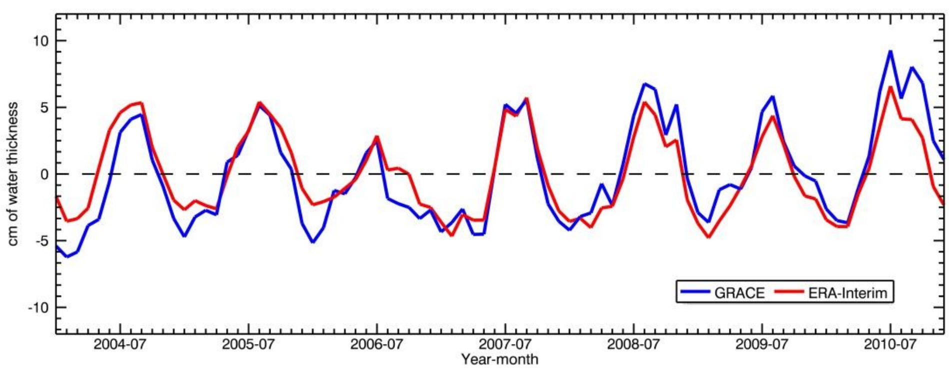

Fig. 9. TWS anomalies [cm] averaged for the Yangtze River Basin for six years period (2004-2010) and obtained from ERA-Interim (red line) and GRACE RL05 (blue line) datasets.

We agree with the reviewer that other components such as surface and groundwater form a large proportion of the TWS. To assess their impact on the matchup, we compare TWS products of ERA-Interim to those derived from GRACE observations (reprocessed Release-05, GRACE RL05) for a seven-year period (2004-2010). Fig. 9 shows that the magnitudes of spatially averaged TWS anomalies from these two datasets (ERA-Interim and GRACE RL05) are similar and exhibit the same variation with determination coefficient as high as 0.79. This means that ERA-Interim product of TWS over a 2 meter soil depth is representative for the GRACE observations that are affected by water storage fluctuations in the entire air-land column including the surface water and groundwater.

Fig. 9 and explanations are in the revised version.

Comment 2:

P9, L15-25, can you explain how you make the comparison in detail? In other words, how did you deal with the point scale and pixel scale? Which station? Yichang? You should point out the name both in the text and the figure caption.

Authors' response:

In the validation section, we used discharge data recoded at the Yichang gauging station. We will point out the name both in the text and the figure caption in the revised version, thank you for your suggestion.

The procedure used to deal with the spatial mismatch between point measurement and model pixel is now better explained in the revised version. This procedure is based on the method of Balsamo et al, (2009) and is implemented in our study as follows:

a) ERA-Interim/GLDAS-Noah

   First, we compute the accumulated monthly runoff from ERA-Interim/GLDAS-Noah at each pixel during the period from 1979 to 2004. Second, we calculate the spatial-mean of the accumulated monthly runoff (mm) of all pixels located in the upper reaches of Yangtze Basin.

b) Discharge of Yichang gauging Station

   First, we compute the accumulated monthly discharge (m^3) from the daily discharge data (m^3/s) of the Yichang station. Second, we divide the accumulated value by the area of the upper Yangtze reaches. The second step is supported by the fact that the Yichang station is the exit of the upper reaches of Yangtze Basin.

Comment 3:

P8, L20-23, I'm confusing about the word 'scale' and the whole sentence. Can you give some other specific contents instead to make it clear?

Authors' response:

The ERA-Interim soil profile includes four layers at 7, 21, 72 and 189 cm depth (289 cm thickness in total), while Noah soil profile includes four layers of 10, 30, 60 and 100cm from (200 cm thickness in total). In order to compare TWS obtained from these data sets we only considered the first 2 meter soil depth of ERA-Interim data, such that both ERA-Interim and GLDAS-Noah has a soil depth of 200cm. We include this explanation to the revised version.

Comment 4:

P10, L13-L15, What's R-square value between GPCC and PREC/L?

Authors' response:

The determination coefficient value between GPCC and PREC/L is 0.86. This value is now in the revised version.

Comment 5:

P14, L26-28, Just give an equation here. It's better than so many words.

Authors' response:

Thank you for your suggestion!

$$A_{ij} = \frac{TWS_{ij} - TWS_{\iota}}{\sigma_i}$$

$$TWS_{\iota} = 1/32 \sum_{j=1979}^{2010} TWS_{ij}$$

$$\sigma_{i=} \sqrt{\frac{1}{32} \sum_{j=1979}^{2010} (TWS_{ij} - TWS_{\iota})^2}$$

Where A_{ij} is the monthly TWS standardized anomaly of the *i*th month and the *j*th year. The subscripts *i* and *j* represent the *i*th month and *j*th year respectively; TWS_{ι} is the TWS of the *i*th month averaged over all the years; σ_i is the standardized deviation of *i*th month TWS over all the years.

These equations are written in the revised version.

Comment 6:

P16, L9-L14, From Fig.8, we can see there are some upward trends for three lines after 2008. Is this a conflict in contrast with the observed drought conditions?

Authors' response:

Indeed, there are some upward trends from three lines after 2008 in Fig.8. Some previous studies also addressed that some regions experienced more severe drought after 2008. Fig.8 shows the spatial averaged TWS of upper reaches, middle and lower reaches and the whole Yangtze River basin, so some regions could have more severe drought while other regions not.

Comment 7:

Fig. 2, what's the interval between every graduation for both X and Y axis? I have no idea about that.

Authors' response:

Sorry for the confusion. We made some mistakes in the interval between every graduation for both X and Y axis. The interval between every graduation for X is 3 months, for Y is 10mm. We also made a mistake in the Y title. We corrected it to 'Accumulated monthly mean of Runoff (mm) '. Please check the updated Fig.2 below.

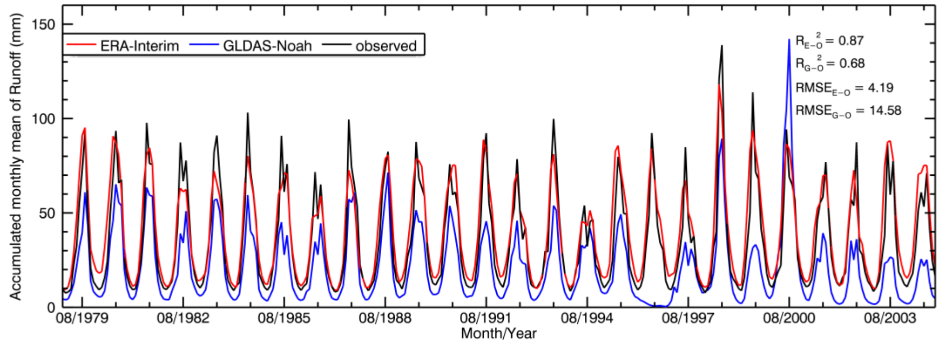

Fig.2

Comment 8:

What's your definition of flood season and dry season?

Authors' response:

'Wet season' is a more accurate word than 'flood season', so 'flood season' is being replaced by 'wet season' in the revised version.

The definition of wet season and dry season is based on the precipitation climatology of the Yangtze River Basin. The Yangtze River Basin experiences a distinct wet season from about May to late September or early October. The corresponding dry season spans from late September or early October to spring. The summer monsoons contribute most of the wet season precipitation (Harvey et al, 2007).

This explanation is now added to the revised version.

Comment 9:

Some confusing contents are listed below. Please make some revisions to make them clear.

(1) P2, L12-13, what's the meaning of 'from both basin and annual perspective'?
(2) P6, L2
(3) P10, L22-24
(4) P11, L13-14

Authors' response:

(1) Yes, it is quite confusing. We actually mean that if we look at the spatial averaged and annual mean of TWS. This confused sentence is deleted in the revised version.

(2) We made mistakes in this sentence of 'what type of vegetation scheme and what type of snow scheme'. This sentence is deleted in the revised version.

(3) Yes, indeed. The sentence of:
'The data qualities of these soil moisture products in the Yangtze River basin can be inferred after comparing the errors of soil moisture estimates in the Yangtze River basin to other locations where have been already validated by in situ measurements.' is changed to:
'It is found that the errors of soil moisture estimates in the Yangtze River Basin are at an intermediate level. '

(4) We put an equation in the revised version, it's better than so many words.

$$B_{ij} = \frac{TWS_{ij} - TWS_J}{\sigma_j}$$

$$TWS_J = 1/12 \sum_{i=1}^{12} TWS_{ij}$$

$$\sigma_j = \sqrt{\frac{1}{12} \sum_{i=1}^{12} (TWS_{ij} - TWS_J)^2}$$

Where B_{ij} is the annual TWS standardized anomaly of the *i*th month and the *j*th year; TWS_{ij} is TWS of the *i*th month and the *j*th year; TWS_J is the mean TWS of the all the months in the *j*th year; σ_j is the standardized deviation of all the months in the *j*th year;

Comment 10:

Technical corrections:

P4, L23, activates→activities
P4, L27, ERA-Interim and ERA-Interim dataset?
P13, L6, soil moisture is very wet →soil is wet
P13, L22, land-surface interaction → land-atmosphere interaction
P18, L16, what's the meaning of TGR?

Authors' response:

Thanks for your technical corrections :)
TGR means Three Gorges Reservoir.

Response to Anonymous Referee #2

Comment 1:

English should be corrected by a native English speaker. In the uploaded addendum I corrected already many awkward expressions and flaws. Also suggestions for improvement have been added.

Authors' response:

Thanks for your suggestions. They are now in the revised version.

Comment 2:

Fig.4 and Fig.5 have identical legends. What is the difference between both?

Authors' response:

Sorry, we made a mistake in the Fig.5 legend, 'TWS' should be replaced by 'TWSC'. TWSC means terrestrial water storage change.

Comment 3:

The statistical methods should be explained in more detail for the reader. E.g. the MK test, the MKS test, the concept of stationary and the principles of forward and backward sequencing with reference to inflections.

Authors' response:

More detail about MK test is added to the revised version as follows:

The MK test statistic is given by

$$Z = \begin{cases} \frac{(S-1)}{\sigma} & S > 0 \\ 0 \quad if & S = 0 \\ \frac{(S+1)}{\sigma} & S < 0 \end{cases}$$

Where

$$S = \sum_{i=1}^{n-1} \sum_{j=i-1}^{n} Sgn(X_j - X_i)$$

$$Sgn(x) = \begin{cases} +1 & x > 0 \\ 0 \quad if & x = 0 \\ -1 & x < 0 \end{cases}$$

$$\sigma = \sqrt{\frac{n(n-1)(n-5) - \sum_t t(t-1)(2t+5)}{18}}$$

Where X_j and X_i are the sequential data values, n is the data length, t is the extent of any given tie (the number of annual maxima in a given tie), and Σ is the summation over all ties. Positive and negative values of *Z* indicate increasing and decreasing trends, respectively. The statistic Z follows a normal distribution N (0, 1) (Burn and Elnur, 2002).

More detail about MKS test is added to the revised version as follows:

Let $x_1, \ldots, x_n$ be the data points. For each element x_i, the numbers n_i of elements x_j preceding it (j < i) such that $x_j < x_i$ are computed. Under the null hypothesis (no trend), the test statistic

$$t_k = \sum_{i=1}^{i=k} n_i$$

is normally distributed with mean and variance given by

$$t_k = E\ t_k = \frac{k(k-1)}{4}$$

$$\sigma t_k^2 = var\ t_k = \frac{k(k-1)(2k+5)}{72}$$

Let

$$UF_k = \frac{t_k - t_k}{(\sigma t_k^2)^{1\ 2}}$$

be the normalized variable, which is the forward sequence. This principle can be usefully extended to the backward sequence UB_k which is calculated using the same equation but with a reversed series of data.

Comment 4:

In Fig.1 many gauging stations are indicated. Nevertheless only the data of one gauging station are used for validation purposes. This is hardly representative for the catchment of the Yangtze and its upper middle and lower reaches, which have completely different mass flow regimes. I did not find the validation section where the gauging station data are used, unless in Fig.1 runoff is related to the gauging data form singular station. This is however not explicitly mentioned.

Authors' response:

Yes, indeed, only the data recoded at the Yichang Gauging station are used for validation purpose. Since Yichang gauging station is the exit of upper reaches of Yangtze River Basin, it can somehow be representative for the upper reaches. We also think using the data of one gauging station is not enough. However, no discharge data of other gauging station are available, so we also use precipitation data from GPCC and PERC/L to support the validation. In addition, we checked the error structures of ERA-Interim or GLDAS-Noah soil moisture data estimated using the triple collocation technique. The Interim reanalysis top layer soil moisture is characterized by a relatively low error in the Yangtze River basin.

We explained how to deal with the scale mismatch between point and pixel scales in detail, please revise our answer to Referee #1, comment 2.

Reference:

Balsamo, G., Beljaars, A., Scipal, K., Viterbo, P., van den Hurk, B., Hirschi, M., and Betts, A. K.: A Revised Hydrology for the ECMWF Model: Verification from Field Site to Terrestrial Water Storage and Impact in the Integrated Forecast System, Journal of Hydrometeorology, 10, 623-643, 10.1175/2008jhm1068.1, 2009.

Burn, D. H. and Elnur, M.A.H.: Detection of hydrologic trends and variability, J. Hydrol., 255, 107-122, doi: 10. 1016/S0022-1694(01) 00514-5, 2002.

Harvey, J., Tang, L.: Analysis of the Global Precipitation Climatology Project Data for Four Global River Basins, GPCPReport, GPCP, University of Maryland, 2007.