

## ***Interactive comment on* “Temporal variation of soil moisture over the Wuding River Basin assessed with an eco-hydrological model, in-situ observations and remote sensing” by S. Liu et al.**

**S. Liu et al.**

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Response to Anonymous Referee #1

Q1: The authors used a vegetation interface processes model and observed long-term climate data to investigate temporal variation especially trend of the soil moisture over Wuding River basin. Understanding long-term change of soil moisture in this basin, a strategically selected basin in a transition zone from farmland and grassland to desert in the China Loess Plateau, is very important, as it may provide early warning on land desertification. The paper would be of interest to the HESSD readership and is suitable for publication in the journal. I have some comments below, but most of them

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are related to presentation.

There might be a room to improve readability as the manuscript does not flow very well. The abstract and the introduction read a bit bumpy.

A: Thanks. I have revised the abstract and introduction and tried our best to improve the English.

Q2: I am concerned about how the trend analysis is conducted. You indicated that there was strong low frequency variability (persistence) in the data. This is an indication of auto-correlation that needs to be addressed in the trend analysis. The trend detection mention you used requires the data being i.i.d. While this method is widely accepted in both hydrology and climate community, if it is applied on auto-correlated data, the trend detection results are not very reliable (e.g. you would detect more trend than the nominal level if there is no trend in the series). This is because an auto-correlation in the series would make the effective independent sample size much smaller than the actual sample size, leading to a too small critical value. There are different ways to deal with this issue but pre-whitening the time series is perhaps the easiest to do.

A: Many thanks for the referee to bring this very important point to this manuscript. Yes, as the referee pointed out, generally, the multi-year variability of SM over the 48 years (1956-2004) is the least comparing with other climate-eco-hydrological (CEH) variables as shown in Table 1. This reminds that we should consider auto-correlation before we use Mann-Kendall method to do the trend analysis.

Based on the suggestions of the reviewer, I have dealt with this issue via pre-whitening. There have been at least three ways to consider prewhitening in this field, such as von Storch method, Yue method and Zhang method. Further discussion about these techniques is out of the topic of this manuscript. What I did is to compare the trend analysis results based on these three techniques. In order for making a comparison and showing the effects of prewhitening, the analysis on linear trend and its significance

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is also done. In order to compare the trends among different variables with different units, dataset normalization is used before making the trend analysis.

Q3: I am not a hydrologist and am not sure how the VIP model works. I was under an impression that the VIP model uses physical based parameters and thus does NOT need to use runoff data for parameter estimation. However, you indicated that hydrological data were used to validate model (section 3.2.2) but did not clearly show how well the model output compare with runoff later. This needs to be clarified.

A: Yes, as VIP model is a physically process-based model, we do not need to use runoff data for parameter estimation (calibration). However we do use the stream discharge data to validate the model in that the difference between the observed annual precipitation and observed annual discharge, which is treated as observed evapotranspiration (ET), is compared with the estimate of evapotranspiration output from the VIP model. A figure of the comparison between simulated ET and that estimated ET from the water balance is added in the revision, as shown in new Fig. 5. The Pearson correlation coefficient is 0.90.

Q4. Section 5.2 Man-made or nature-made north drying. For climatologist, man made change includes a) local changes such as land use, b) large-scale changes that caused by anthropogenic forcing such as global warming. There are also two types of nature made changes that include a) natural internal variation of the climate system and b) natural forcing external to earth climate system such as changes in solar output. The man-made change you discussed seems to mean regional-local land use change etc. if I understood correctly. We do not know what are the exact causes of the precipitation decrease and temperature increase in the region under study, though there are convincing evidences that temperature increase in China can be attributed to greenhouse gases related warming. It would be useful to spell out what do you mean by man-made and nature-made changes.

A: Many thanks. Yes, human activities, such as land use change and water conser-

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vancy measures are the main causes of environmental change in the basin. What we mean man-made in the manuscript is thus such activities as turning grassland into crop-land and overgrazing. Water delivered to crop-land and domestic and industrial usages are also considered to alter the water cycle. I have added a paragraph in the discussion section, according to the suggestions of the reviewer, to make it clear.

Q5: There is another point you need to be careful. You argued that the soil moisture change you obtained from running model does NOT include changes in land use etc. This in itself is a good thing that you know soil moisture change as simulated by your model is due to changes in climate. Land use change (which is not reflected in the simulation) would have had an important contribution to soil moisture change in the real world, but this contribution is very hard to access as the observation or remotely sensed data are both too short for trend analysis. So it is not clear how representative is the simulated soil moisture change to that in the real world. I am not sure how to address this question. It would be useful to point this out and offer some discussion.

A: (1) From our previous study and documented studies, yes, man-made change is a main, at least half of the contributor to the change of the runoff, which was showing the decreasing tendency. (Mo et al., 2006; Li et al., 2007). However, for soil moisture, as it has the least coefficient of variation (CV) relative to other meteo-hydrological variables, it has been used as a more effective hydrological indicator of climate change (Robock et al. 2000). (2) As the VIP model is a distributed model, it can be used to detect the soil moisture under different land uses, which has been a world-widely interesting topic. From the documented publications, it was found that there are discernible SM differences between land use or crop types planted (Cai and Wang, 2006; Yang and Rong, 2007; Yang, et al, 2008). This is one of the important reasons to use the VIP to simulate SM for the Wuding River. (3) From the observed records, it shows that the crop types have not changed much during the last twenty years in the Wuding river basin. The land use change over the time is less than 5%. This is the reason that although we did not consider very much the temporal variation of vegetation type for

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SM simulation, the SM simulation still matches the observed in an acceptable way.

Based on the above analysis, owing to the slow temporal variation of SM and yet obvious spatial variation over the basin under the different Land use/covers, the simulated SM data from the VIP, which reflect the temporal changes more attributed to climate and yet also reflect the spatial variation over the basin, can be assumed to represent the realistic condition of SM. The agreements between the simulated SM and observed SM at the stations and the regional remotely sensed SM support this assumption. As the observed or remotely sensed data are both too short for trend analysis, long-term SM from VIP simulation takes advantages over the observation for trend analysis.

This is added in the newly added subsection of the discussion.

Q6: In the discussion session (and else where earlier on) you mentioned lower variability in soil moisture, do you have any explanation on this?

A: Thanks for the great comment. Lower variability in soil moisture can be explained in the following three courses. Firstly, the Wuding River basin is located in a semi-arid climate zone where annual precipitation is about 400 mm/yr and most of it falls in summer. The low precipitation leads to low surface soil moisture, which is close to wilting point. Secondly, scientists found that owing to its larger inertia and longer memory to atmospheric driving force, than other hydrological components, soil moisture, along with snow cover, is the most important component of meteorological memory for the climate system over the land (Delworth and Manabe 1988, 1993; Robock et al., 2000). Thirdly, the CV of SM in daily, monthly and yearly scale are all smaller than those of other CEH variables, as shown in originally Fig.11, now Fig. 12 in the revised version. This supports our first impression to the low variability in SM of the Wuding River.

One thing is worthy to be mentioned, although the absolute value of SM are small, the normalized trend of SM is large (Fig. 18). This indicates that Northern Drying is an important signal worthy to do further study and need to be paid attention to in making decisions.

The above is added into the discussion right after the New Fig. 12.

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