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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Assessing the large-scale plant-water relations using remote sensing products in the humid subtropical Pearl River Basin in south China" *by* Hailong Wang et al.

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RC1: The manuscript evaluates regional scale plant-water relations in the Pearl River Basin. The authors find a strong inter-annual correspondence between NDVI and GRACE derived TWS, suggesting water limitation in an area where rainfall is generally higher than the potential evapotranspiration. This is an interesting result, but the underlying mechanism remains unclear. The introduction touched on a few important topics such as water limitation and plant water use, but the scientific hypothesis/questions are not clearly defined. "Quantifying the plant-water relations at different temporal scales under different dryness conditions" is a good starting point,

but the specific questions to address need to be defined. The choice of vegetation data needs justification. NDVI is known to saturate in the forest ecosystem. MODIS GPP poorly represents soil moisture limitation on productivity which is directly relevant to the main theme of this study. There are many other vegetation metrics available that are not or less affected by these issues (e.g., SIF and EVI). LAI has also been used in a similar domain (Tong et al., 2018). I suggest the authors adopt these other datasets in the analysis. The strong inter-annual correspondence between NDVI and TWS is interesting, given how humid this area is. It would be of interest to see if this correspondence changes across different biomes (e.g. crops vs. forests) or regions with different levels of aridity, which may be done at mascon resolution. On the other hand, the monthly-scale correlation analysis needs clarification. Is the trend and seasonality removed from the monthly time series? The discussion session lacks a clear focus and sometimes reads like a literature review (e.g. Line 280-294). The discussion should be centered on clearly defined research questions and based directly on the results of this study. AC: We thank you for the recognition of our work and kindly pointing out the weaknesses for us to further improve the manuscript quality. We have stated clearly the specified research questions (reduced to 2 now) and discussed the possible underlying mechanisms (which is still limited based on the analysis) for the relationships from the perspective of energy & water availability in this environment compared to the dry environment. The mechanisms can be obtained with such comparisons but can hardly be verified using the applied data in this study. We have added a few words for the clarification in the Discussion. We were aware that applying different datasets (for both hydroclimate and vegetation) could lead to a possibly different result, therefore, we gave the reasons of our data choice in 4.1 Uncertainties in the datasets and results. Choice of vegetation data was based on literature review, that we found GIMMS NDVI3g is among the most popular datasets for analysis of vegetation phenology and its relationship with hydroclimate change, especially for studies in a relatively large river basin as it covers a moderately long time period (since 1980s) and has a spatial resolution of 1/12 degree. Using

GIMMS NDVI3g may allow the comparison of results in this study with many other studies in the region. Considering most of the forests consist of evergreen trees, and forest cover (∼65%) nearly remains constant from the early 21st century, the NDVI trend is highly likely induced primarily by other land cover types especially croplands (∼18%) and grassland (∼9%). For this reason, we think NDVI is fit for the purpose of this study. Using other vegetation indices like EVI and SIF may result in slightly different values of the trends but the overall changing direction (+/-) may be consistent. As to GPP data, we chose MOD17 products and the reasons are also given in session 4.1 Uncertainties in the datasets and results. This part of discussion has been extended with the assistance of inter-comparison of GPP from MODIS, VPM and PML given in the supplementary figure. Again, we thank you very much for the detailed comments which help improve our manuscript to a large degree. They have been carefully incorporated in the revised version. RC1: Detailed comments: Lines 72-73. This statement needs clarification. Is it to question if water limitation prevails in the humid ecosystems in the long term? AC: This sentence has been rephrased as 'While majority of such studies were carried out in semi-arid regions because of the urgent need to find an equilibrium between ecological restoration and available water resources in these water-limited areas, it is still largely unclear whether the restriction of water resources on vegetation growth also prevails in the humid or semi-humid areas with abundant rainfall.' RC1: Line 105. I think it is better to define the TWS anomaly using the entire analyzed period as a baseline (by removing the mean calculated over the entire period), unless there are specific reasons to believe that the 2004-2009 period better represents a "normal" condition. AC: GRACE satellite data are released by three processing centres as TWS anomaly which is the actual (ungiven) TWS value in each month minus the monthly mean from 2004 to 2009. To be consistent with the TWSA calculation norm, we also use the means of other variables in the same baseline period to obtain their anomalies. There is a good reason to question the representativeness of this period, however, it should be equally effective when analyzing their trends and relationships. RC1: Lines 129-132. The mean annual

TWSA depends on the choice of the reference period. The trend analysis is a better way to illustrate wetting/drying information. Are all the trends significant in Fig 2d? AC: Indeed the mean annual TWSA and the annual trend would vary with the reference period. Here we show the values over 04/2002-03/2015 totaling 13 hydrologic years. Areas with p>0.05 in Figure 3d are distributed in the west edge where the annual trends are fairly small. Because it takes a small proportion of the entire basin, we did not take these pixels out. RC1: Fig 2e. Please clarify how the basin average and the associated errors (measurement and leakage) are calculated. This should be included in the Method session. AC: Thanks for the suggestion. We have added information in the 1st paragraph of subsession 2.2. Data sources and pre-processing as suggested. Please refer to Line 119-122. RC1: Line 145. What is the trend in space? Note that here the trend in time does not have an error bar. AC: We have rephrased this sentence as '... with an overall positive trend spatially (0.004 ± 0.012) and temporally (0.007 ± 0.028), ...'. Spatially, we calculated the linear trend for each valid pixel, and then the average of all with the standard deviation. RC1: Figs 3-5. Please change the color scheme to improve the readability of the figures. For example, a sequential colormap is ideal for the aridity index. For the anomaly and trends, it is better to use a diverging colormap with a symmetric scale. AC: Thank you for the suggestion. We have changed the color scheme accordingly to improve the figure readability. Please refer to the updated figures. RC1: Line 153. Please label the significant trends in the map. AC: The NDVI trend map has been reproduced as below with pixels of p<0.05 marked with crosses. RC1: Lines 159-161. This reads like discussion, not actual results. AC: We have carefully checked the results and moved the discussion-like contents to Discussion. RC1: Lines 169-170. Needs other proxies for plant productivity to confirm this. MODIS GPP directly accounts for the limitation from VPD but not from soil moisture supply. AC: Thank you for the suggestion. Indeed, MODIS GPP does not account for moisture constraint but rather atmospheric controls. In our study area, rainfall and water storage is high in the growing seasons and slightly lower in the nongrowing seasons. In this case, the moisture restriction on GPP might be small.

In addition, we compare GPP from three sources (MODIS, VPM and PML) in the supplementary figures, and with that support, we still use MODIS GPP in the analysis. Session 2.2 regarding data sources and session 4.1 regarding data uncertainty are extended to incorporate this content (Line 130-139 and 261-275). RC1: Fig 7. Please either label the areas with significant correlations or mask the insignificant ones. Trends can inflate the correlation results. Have you de-trended the time series? AC: Linear trends are removed from the correlation analysis. This has been added in the Method session (Line 148-149). Thanks. RC1: Line 182. It is unclear how the monthly scale regression is calculated. Note that to quantify water limitation, the seasonality should be removed from the monthly time series. AC: Information has been added in the Method session (Line 148-149). Data were detrended before calculating the correlation coefficients. RC1: Lines 189-190. It is unclear what this means. How are the water restriction and water consumption quantified and compared? In fact, quantifying the amount and timing of plant water consumption (e.g. ET in wet and dry years) might be helpful to understand why there is an apparent water restriction in such a humid area. AC: This sentense has been rephrased (Line 221-223). We meant to show that the influence of water availability on vegetation development may be stronger than the impact of vegetation growth on water resources (mostly water storage), because decline of TWSA occurred prior to reduction of NDVI. RC1: Line 196. How is the span of the growing season defined in this area? AC: Growing season months have been given in Method session (Line 138). Because it can vary from year to year for each type of vegetation cover, we use the conventional definition in this study, i.e. from April to October. Precise quantification of growing season length can be done with NDVI/LAI time series but won't be necessary for this study. RC1: Lines 212-220. This should go to the Data and Method session. AC: We have moved this part to Data and Methods right after introduction of GLDAS precipitation. RC1: Line 230. The uncertainty of the trend needs to be evaluated. AC: Uncertainty has been added. RC1: Lines 232-241. This should go to the Data and Method session. The authors present examples where MODIS GPP shows consistency with other vegetation

data, but in thisstudy, the analysis based on the two datasets (MODIS GPP and NDVI) shows different plant-water relations. It is unclear if the difference is physical (e.g. due to the different responses of vegetation state and vegetation productivity) or caused by data accuracy issues. In this case, other vegetation metrics are needed to justify the results. AC: We have added a few sentences in Data and Method about GPP data, and also extended a bit in this part of Discussion (Line 130-139 and 261-275). RC1: Line 257. Note that this is an active area for ecological restoration, including the Grain to Green project (Tong et al., 2018). Reference: Tong, X., Brandt, M., Yue, Y., Horion, S., Wang, K., Keersmaecker, W. De, : : : Fensholt, R. (2018). 1. Nature Sustainability, 1(1), 44–50. https://doi.org/10.1038/s41893-017-0004-x AC: Noted and incorporated into disucssoin (Line 289-292). In their Fig. 3, Tong et al. mapped the convervation efforts in their study area most of which show low-moderate levels. They also show increasing trends of LAI in the region where croplands dominate (lower right part of their study area, with low-moderate conversation level). This indirectly supports our finding that the vegetation growth in this cultivated area has been enhanced. RC1: Lines 272-275. This point seems important but is not fully developed. Are there results in this study showing enhanced or perhaps near-normal productivity under drier than normal condition? AC: We have rephrased this part (Line 311-316).The comparisons of NDVI, GPP in dry and wet years in Fig. 10b-c and the relationships between them and P/TWS in Fig. 11 support this speculation. NDVI in dry and wet years was largely different, while GPP in dry years was only slightly lower than that in wet years, showing a less sensitive response of GPP to drying than that of NDVI.

Please also note the supplement to this comment:
https://hess.copernicus.org/preprints/hess-2020-242/hess-2020-242-AC2-supplement.pdf

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