Estimation of soil moisture changes based on GRACE terrestrial water storage: Taking the monsoon region in eastern China as an example

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Objectives

Soil moisture (SM) plays a crucial role in the hydrological cycle due to its frequent interaction with surface water and groundwater. Currently, there are two primary methods for monitoring SM: field measurement and remote sensing-based retrieval. However, field SM measurement is limited in large-scale areas with complex terrain as it can not reflect the spatial heterogeneity of SM. On the other hand, remote sensing-based retrieval from optical or radar imagery can acquire SM data at a larger scale, but its obstacle is the limited maximum detection depth of 1-5 cm. SM levels affect various soil and plant dynamics, where surface SM refers to the water in the upper 10 cm of soil, and root zone SM refers to the water available to plants, generally considered to be in the upper 200 cm of soil. Consequently, a new method for obtaining SM should be developed to overcome these issues.

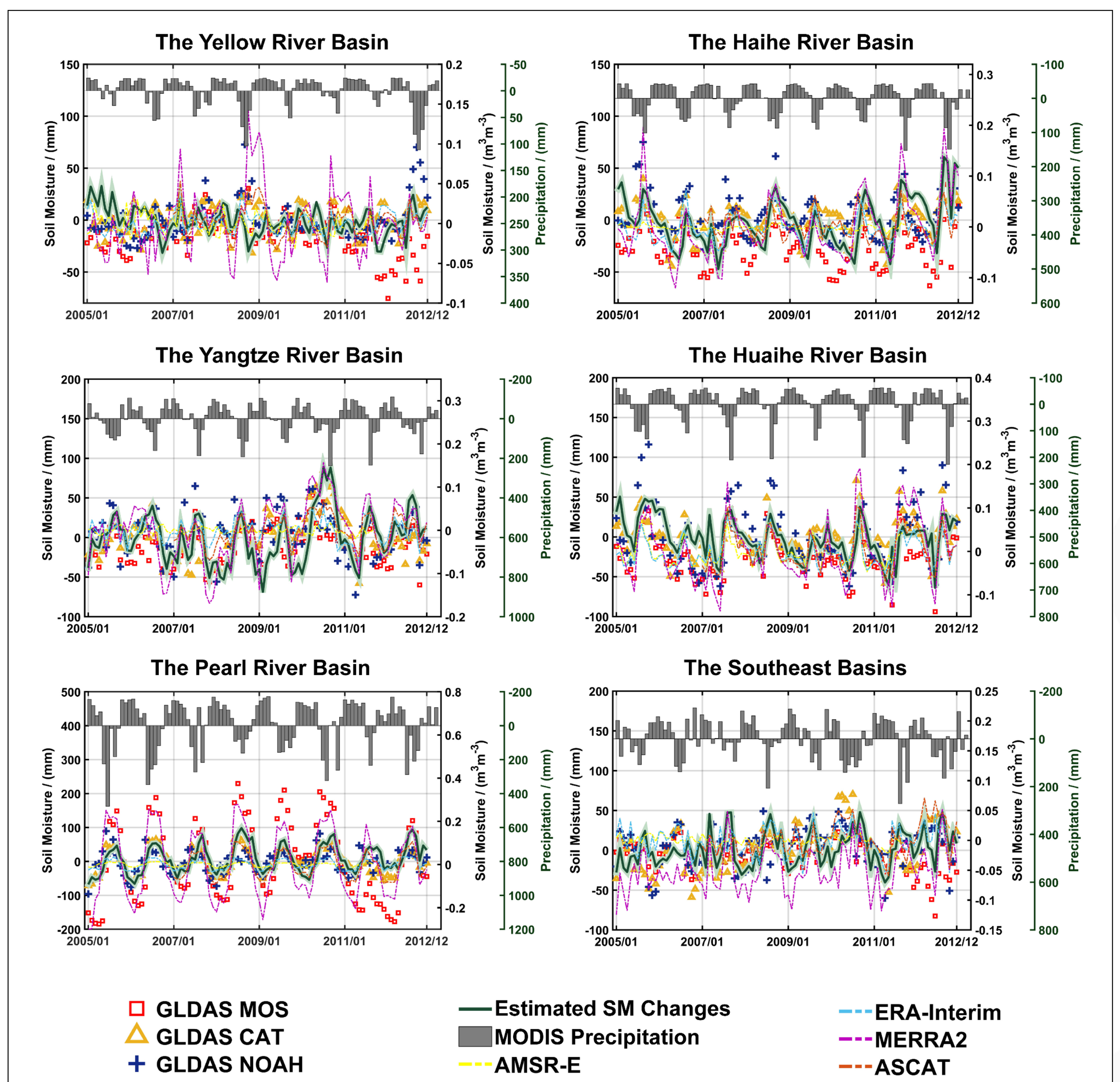

Figure.1 Time series of estimated SM changes, soil moisture changes of various products and MODIS precipitation changes.

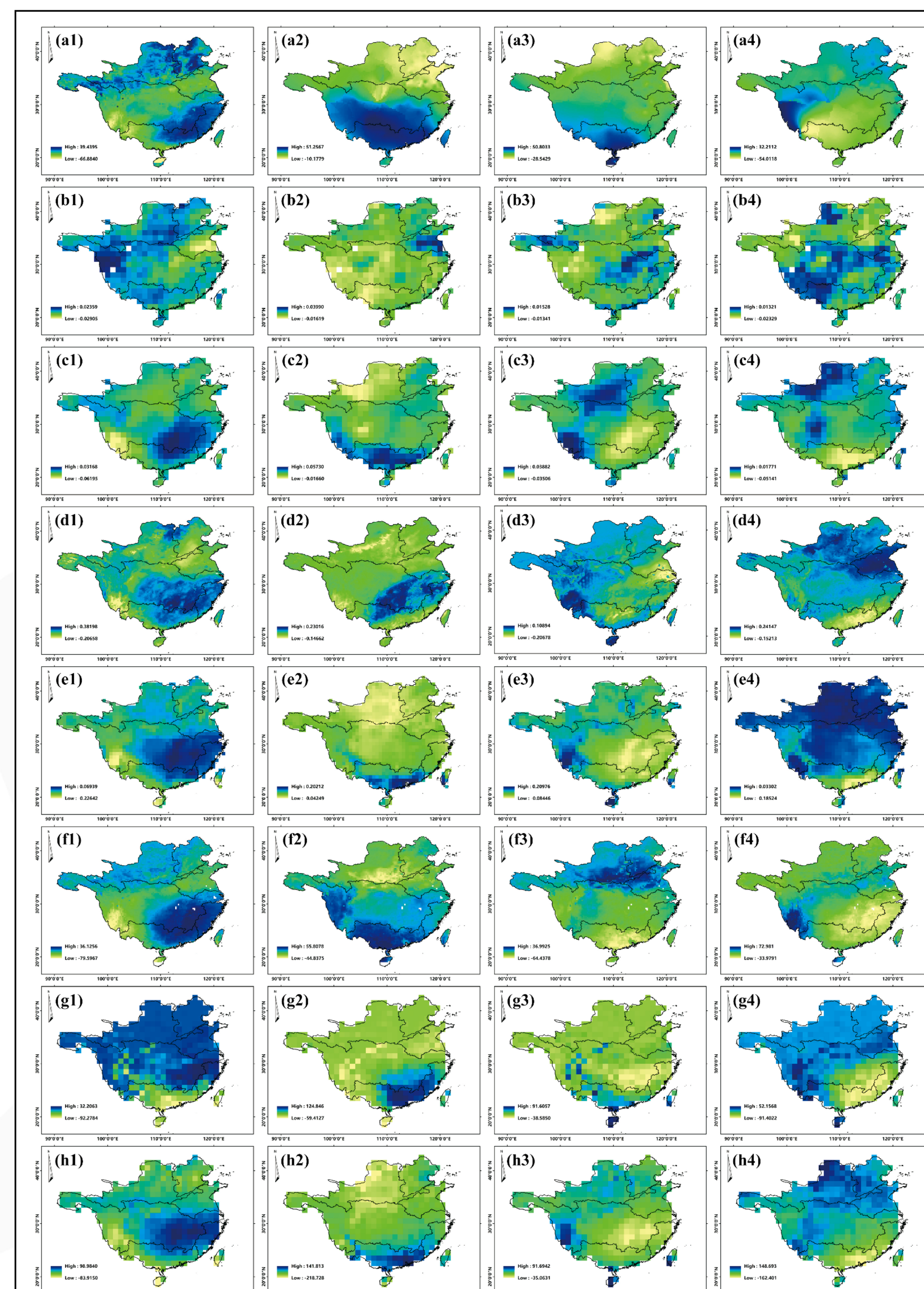

Figure.2 The spatial distribution of the annual average change in soil moisture of each season. Among them, (a1-a4) are the estimated SM, (b1-b4) are AMSR-E, (c1-c4) are ERA-Interim, (d1-d4) are ASCAT, (e1-e4) are MERRA2, (f1-f4) are GLDAS-NOAH, (g1-g4) are GLDAS-Mosaic, (h1-h4) are GLDAS-Catchment. The first column is spring, the second column is summer, the third column is autumn, the fourth column is winter.

Methods

Based on the principle of water balance, changes in terrestrial water storage (TWS) involve three primary components: changes in surface water storage, SM, and groundwater storage. Specifically, changes in surface water storage are dominated by changes in snow depth and surface runoff. TWS changes were obtained from downscaled GRACE data, changes in surface runoff and snow depth were from GLDAS NOAH data, and changes in groundwater from measured groundwater level. These data were used to construct the water balance equation to calculate changes in SM. The estimated SM changes were then compared with other seven SM products using five statistical indicators.

Results

By analyzing the validation indicators, the estimated SM variation performed best agreement with other products in the Pearl River basin, witch Pearson correlation coefficients are 0.70, 0.79, 0.86, 0.85, 0.81, 0.50,and 0.51 with AMSR-E, ASCAT, ERA-Interim, MERRA2, GLDAS NOAH, GLDAS Mosaic, and GLDAS Catchment. And the univariate Moran′s I was similar with MERRA2,ASCAT,and GLDAS Catchment (0.67,0.80,and 0.74), the bivariate Moran′s I was also similar with ERA-Interim,MERRA2,and ASCAT (0.70,0.70,and 0.77).

The estimated SM changes showed poor consistency in the Yellow River basin, with Pearson correlation coefficients are all below 0.41,and the M-K tests all show a near opposite trend to the other products, which may be the combined effect of retrieval errors in GRACE data due to the mountainous terrain and the difficulty of land surface model data to accurately describe SM transport in loess soils.

Conclusions

(1) the estimated SM changes generally showed good temporal agreement with each SM product in the research area, except for the Yellow River basin and the Haihe River basin. This could be due to significant differences in the soil discrepancy characteristics during the permafrost and non-permafrost periods in these basins, which affected the SM changes detected using microwaves.

(2) the estimated SM changes showed high spatial and temporal correlation with all other products in the Pearl River basin, indicating that the estimation method is highly applicable in this basin.

(3) while the proposed method can estimate SM of all soil layers above groundwater level, it does not consider the changes of biological water and the influence of human activities, which may introduce some uncertainty.

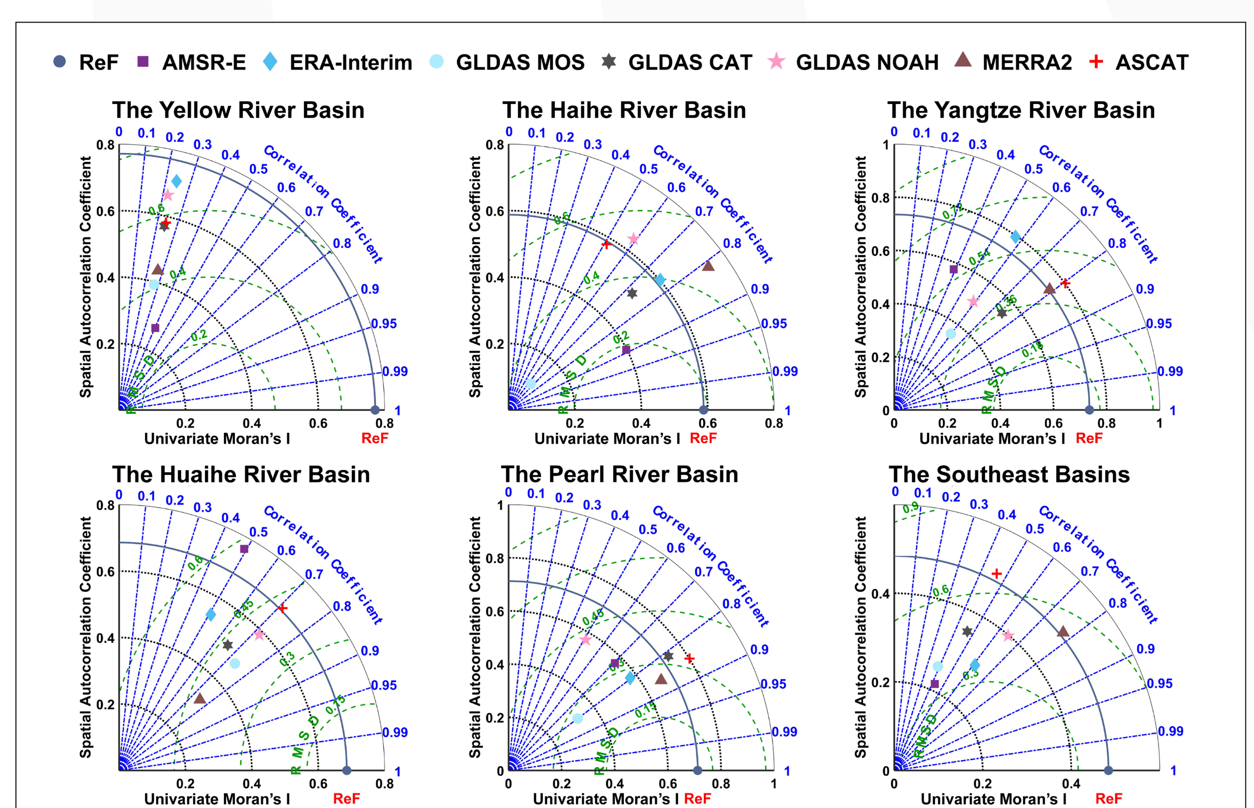

Figure.3 Comparison of Pearson Correlation Coefficient, Univariate/Bivariate Moran's I and Root Mean Square Error.