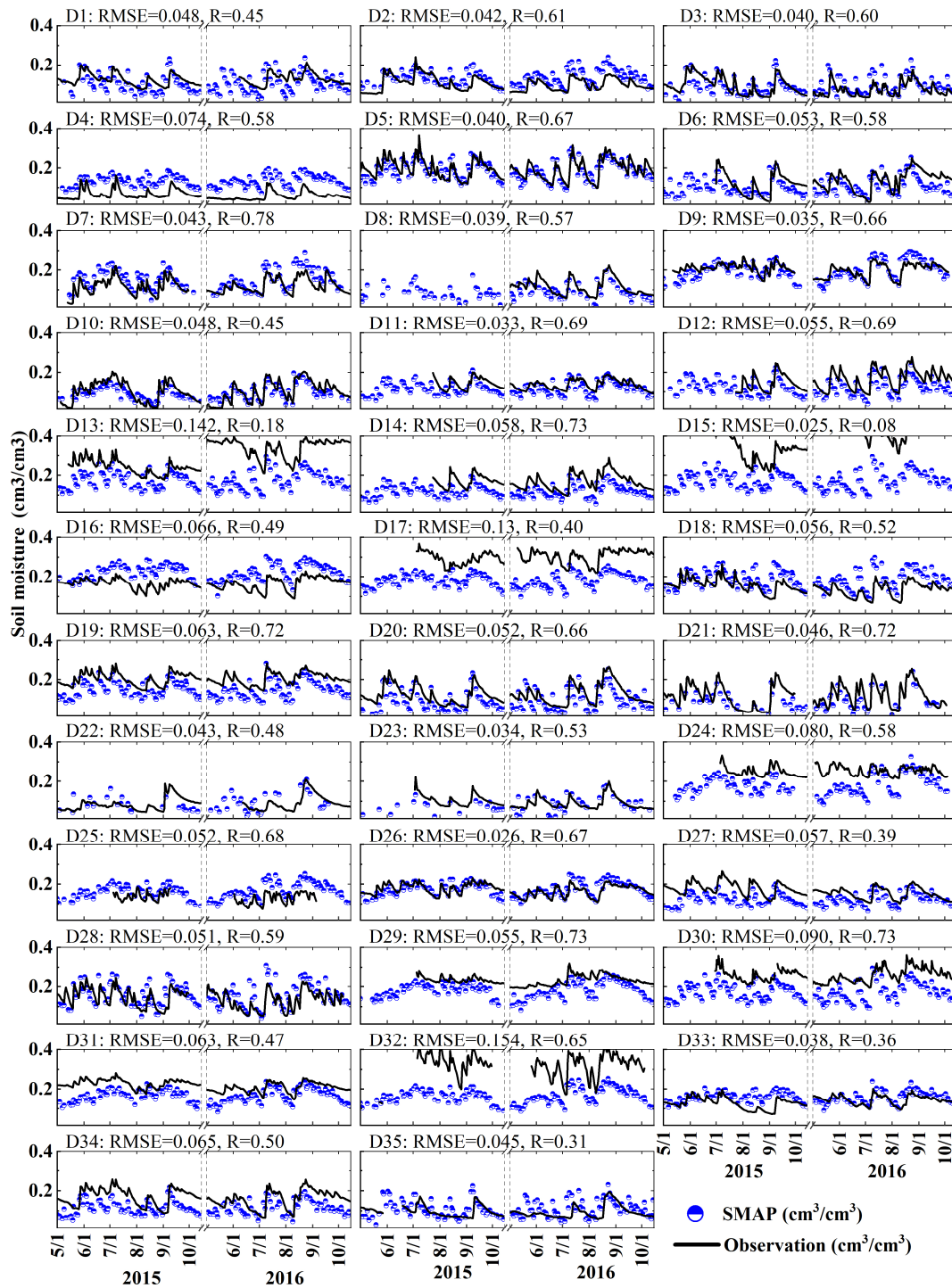


**Fig. S1.** Metrics (NSE, RSR, and Pearson's R) of the different methods for the estimation of subsurface soil moisture from surface soil moisture for each layer of all soil moisture stations. Plot shows the mean value with the error bar of the standard deviation.



5 **Fig. S2.** Comparison of the SMAP and in-situ observations of surface soil moisture ( $\text{cm}^3/\text{cm}^3$ ) data during the growing season of 2015-2016 for the 35 stations. Also with the RMSE and R of the comparisons of the two datasets for each station during the growing season of 2015-2016.



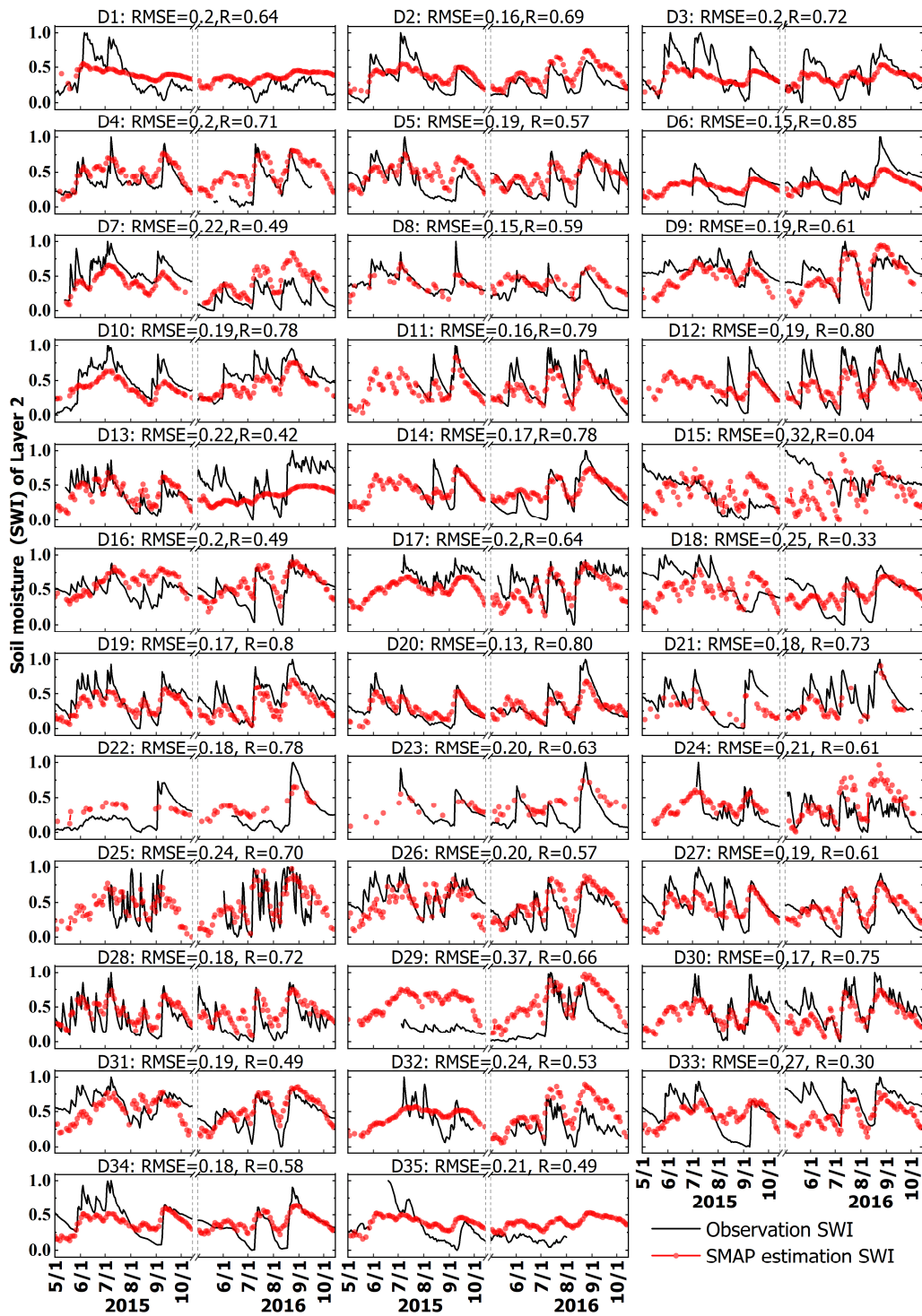
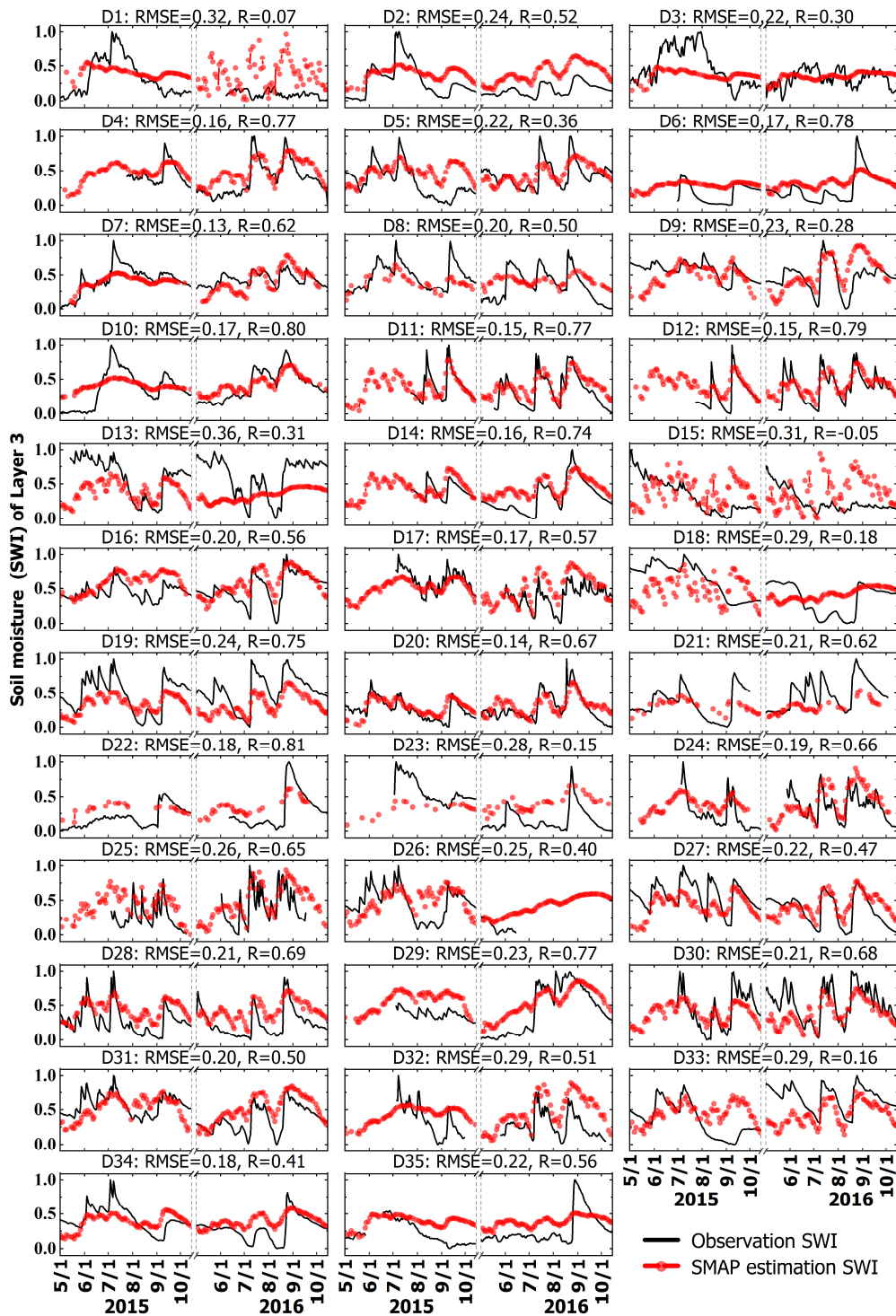


Fig. S3. Comparison of the SMAP estimation and in-situ observation of layer 2 SWI time series during the growing season of 2015-2016 for the 35 stations. Also with the RMSE and R of the comparisons of the two datasets for each station during the growing season of 2015-2016.



**Fig. S4.** Comparison of the SMAP estimation and in-situ observation of layer 3 SWI time series during the growing season of 2015-2016 for the 35 stations. Also with the RMSE and R of the comparisons of the two datasets for each station during the growing season of 2015-2016.

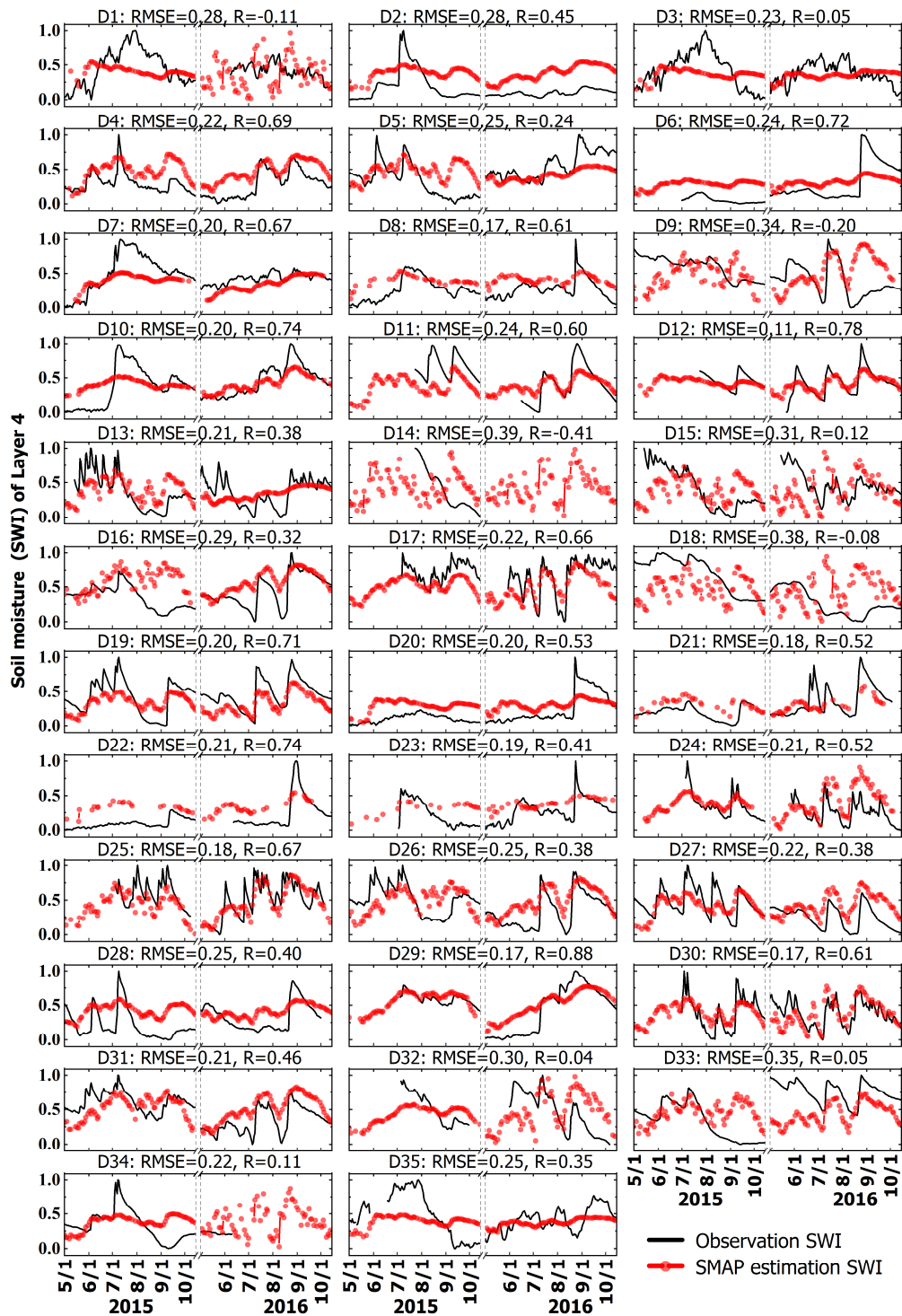
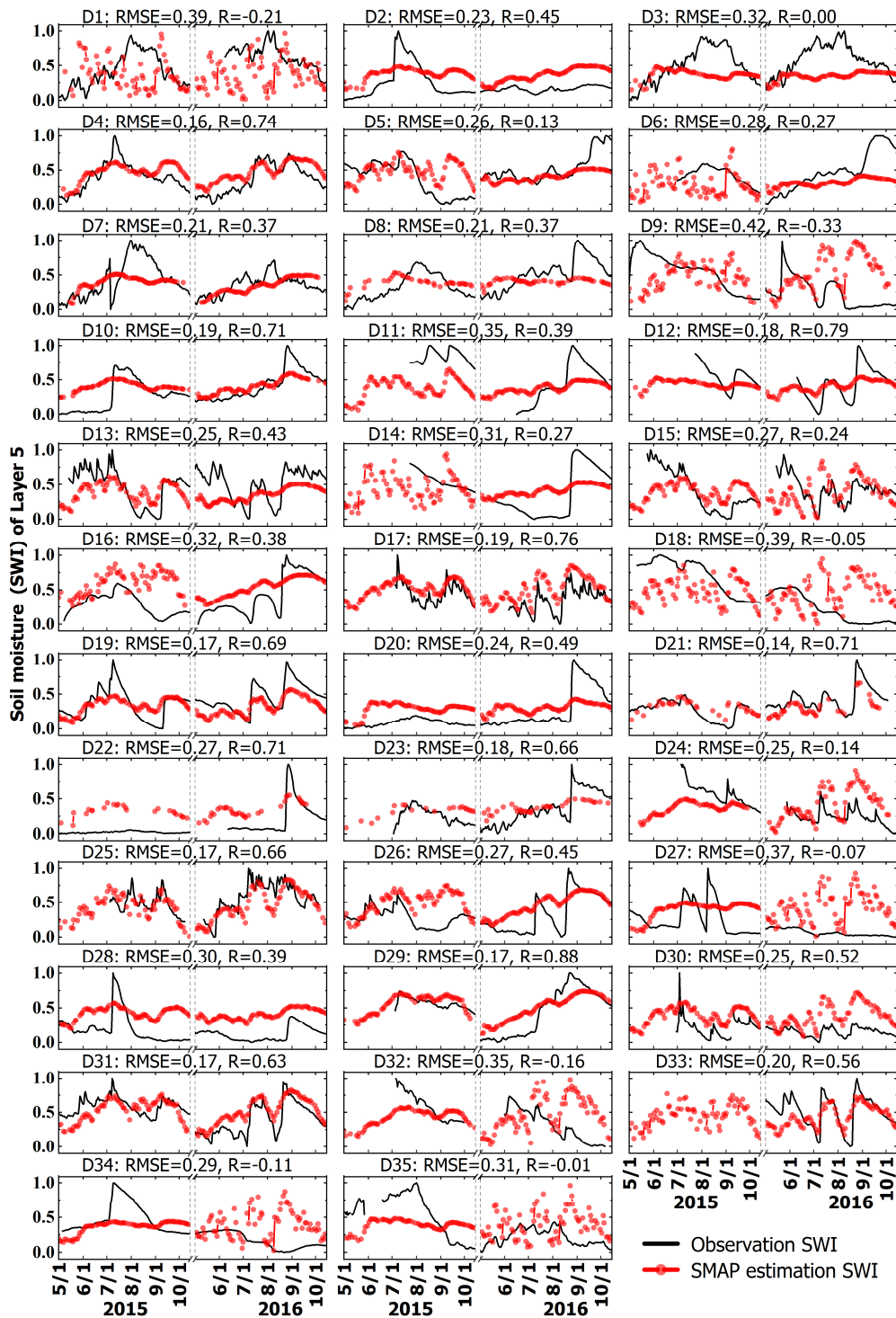


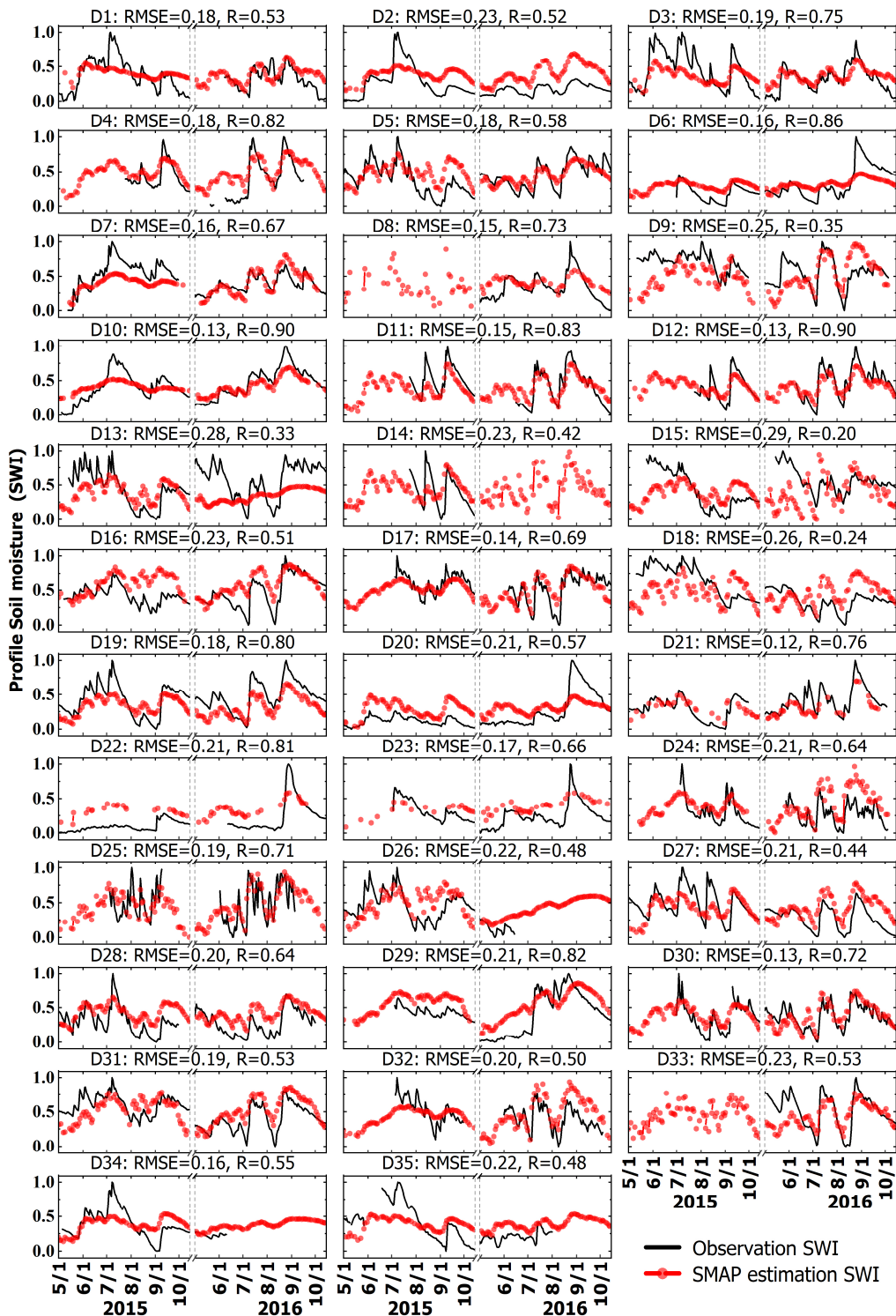
Fig. S5. Comparison of the SMAP estimation and in-situ observation of layer 4 SWI time series during the growing season of 2015-2016 for the 35 stations. Also with the RMSE and R of the comparisons of the two datasets for each station during the growing season of 2015-2016.



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**Fig. S6.** Comparison of the SMAP estimation and in-situ observation of layer 5 SWI time series during the growing season of 2015-2016 for the 35 stations. Also with the RMSE and R of the comparisons of the two datasets for each station during the growing season of 2015-2016.

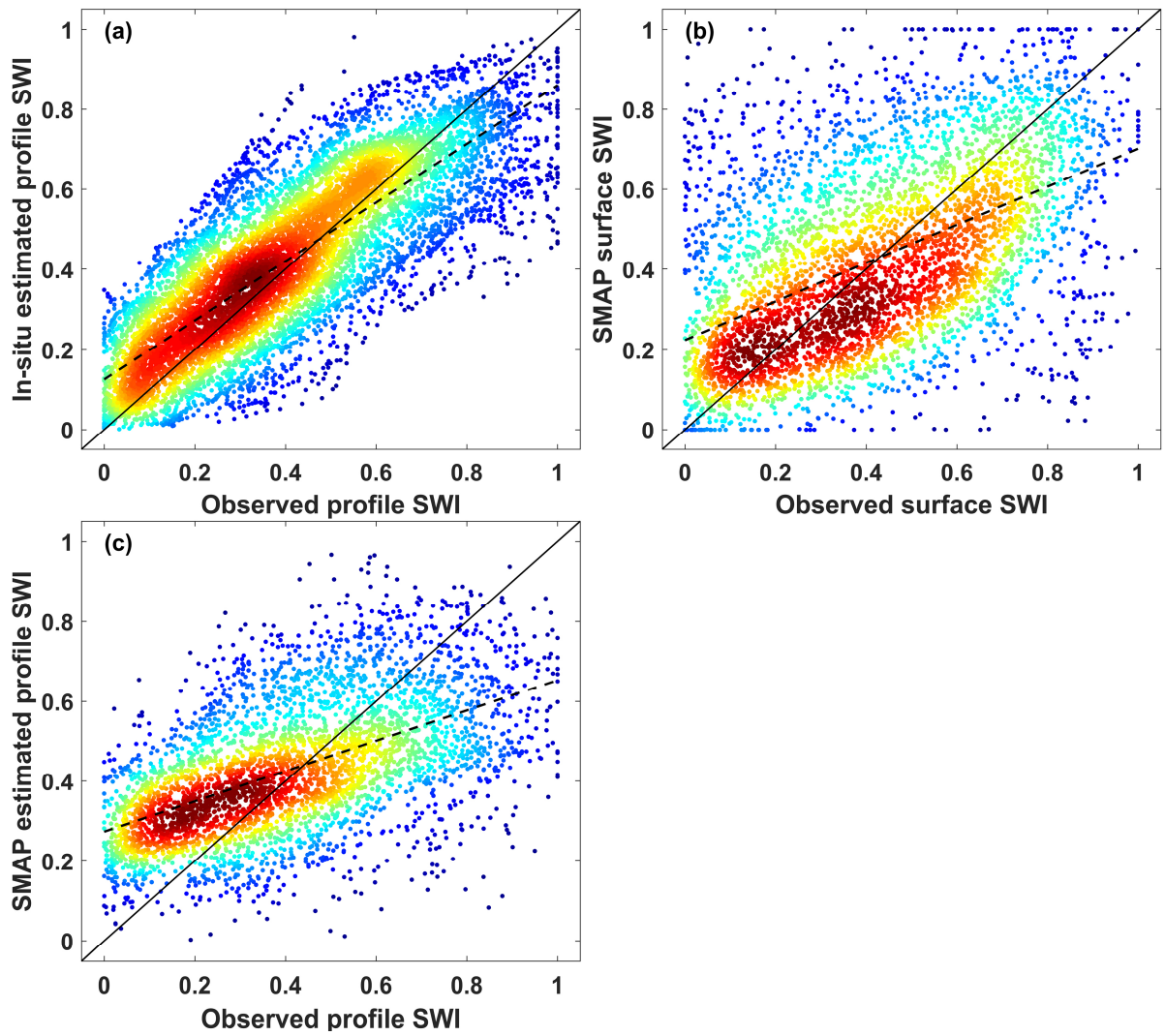




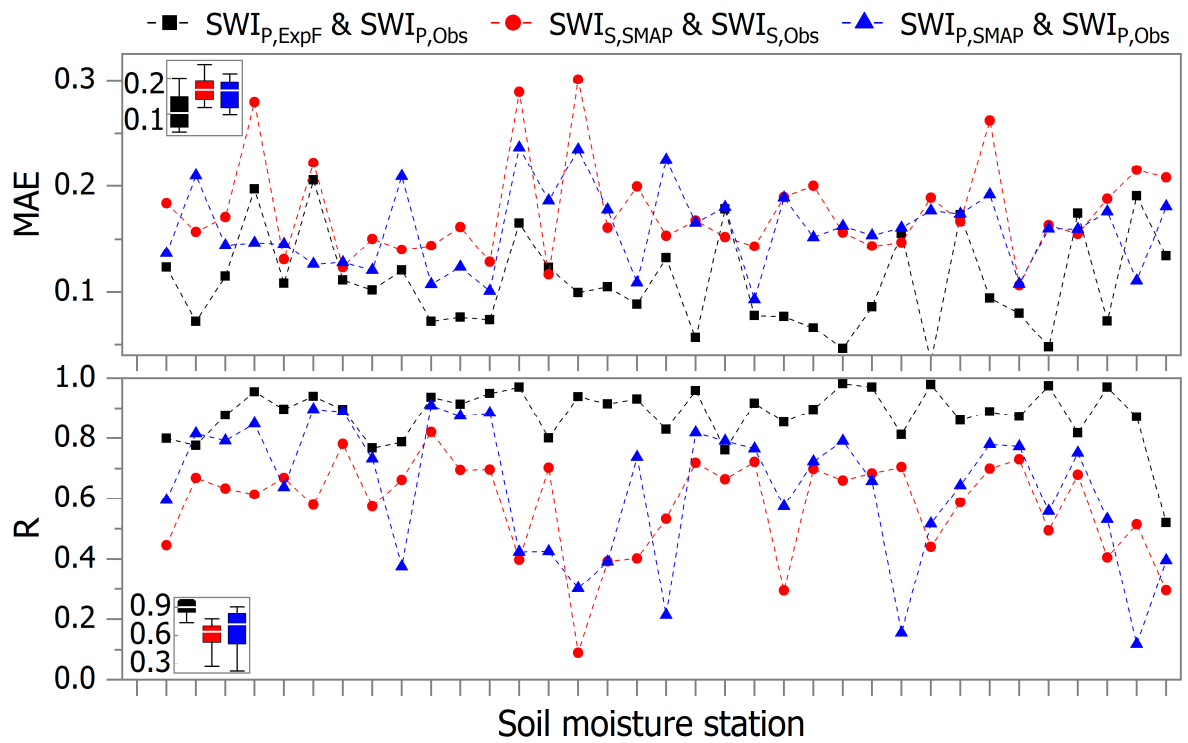
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**Fig. S7.** Comparison of the SMAP estimation and in-situ observation of profile SWI time series during the growing season of 2015-2016 for the 35 stations. Also with the RMSE and R of the comparisons of the two datasets for each station during the growing season of 2015-2016.



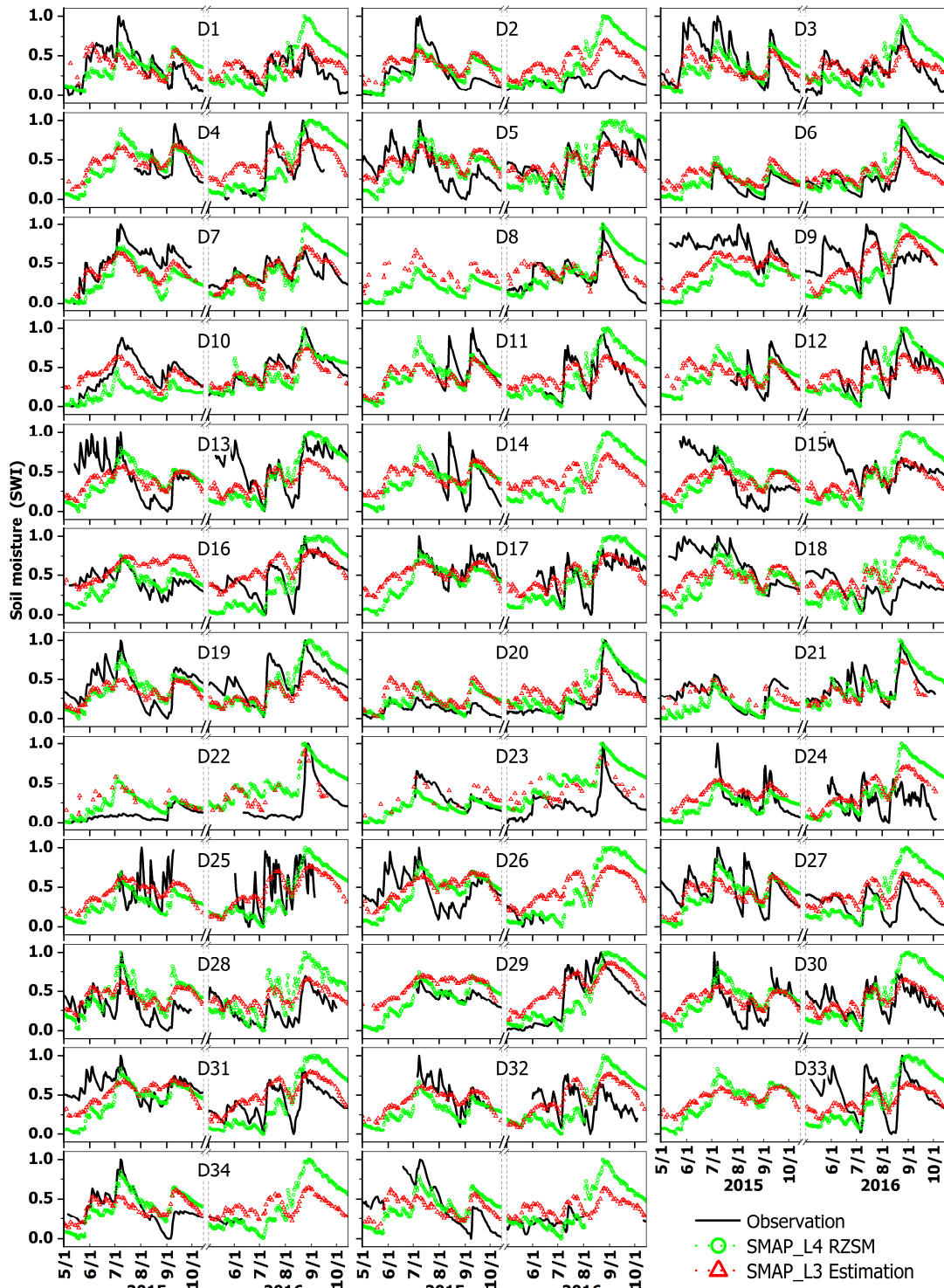


**Fig. S8.** Scatterplot of the comparisons of (a) estimated-observed profile SWI, (b) SMAP-observed surface SWI, and (c) SMAP-observed profile SWI for the 35 stations during the growing seasons of 2015-2016.



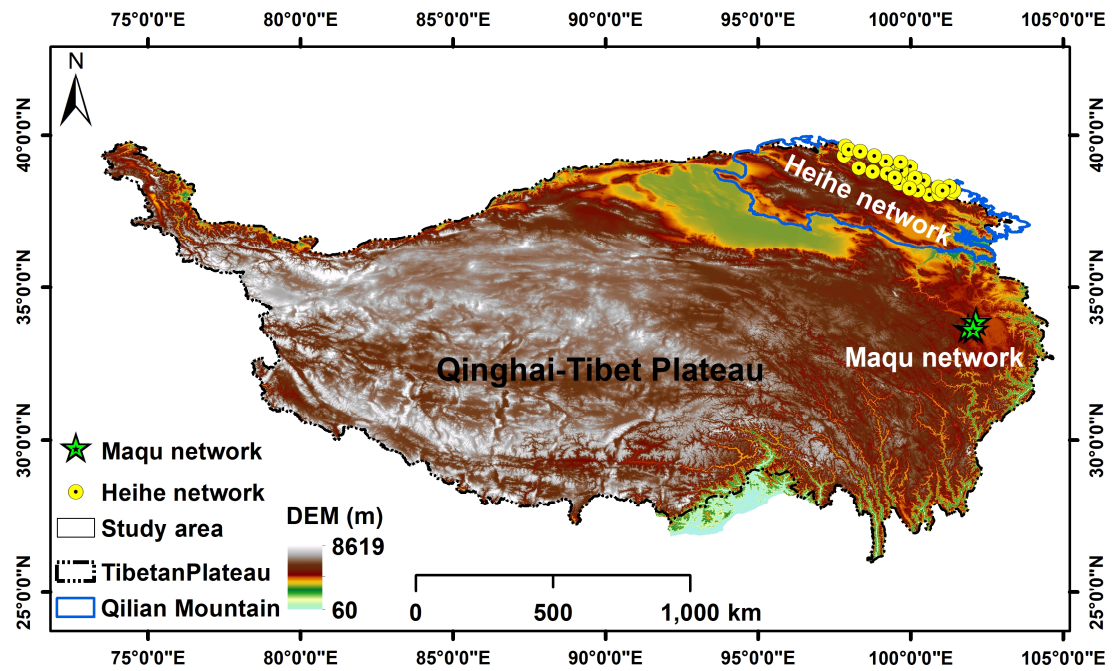
30

**Fig. S9.** The plot shows R and MAE of the comparisons of estimated-observed profile SWI datasets, SMAP-observed surface SWI datasets, and SMAP-observed profile SWI datasets for the 35 stations during the growing season of 2015-2016. Boxplot in each plot shows the distribution of the metrics for different comparisons represented by different colors.

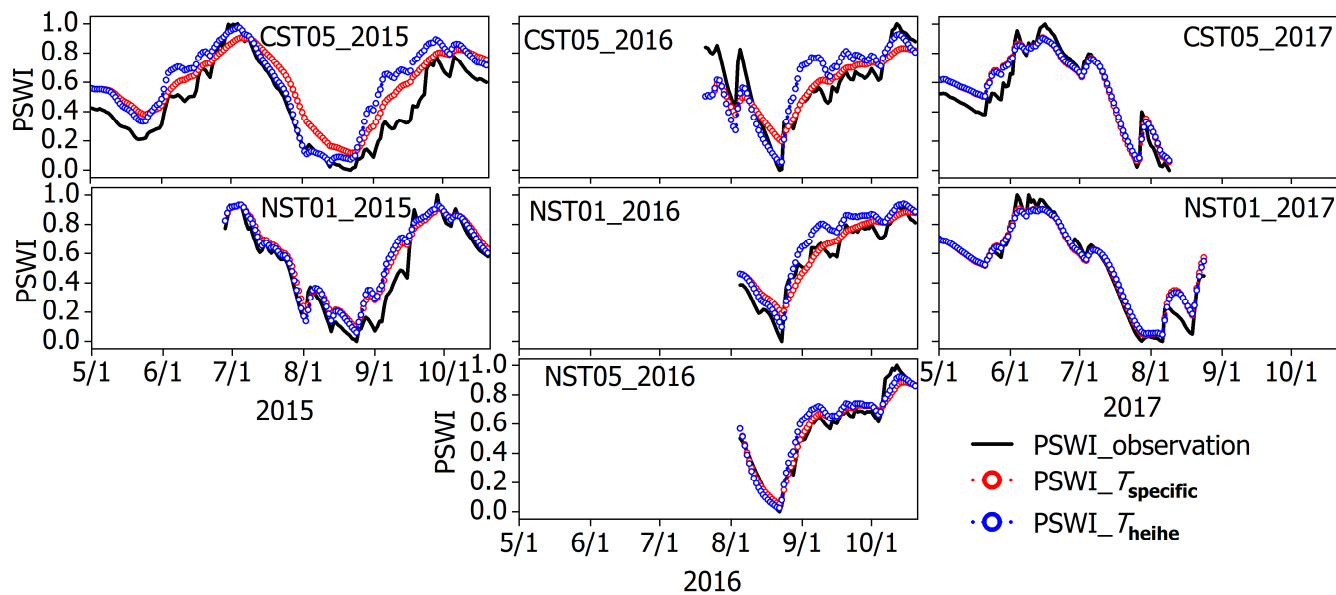


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**Fig. S10.** Comparison of the SMAP\_L3 estimated PSWI, SMAP\_L4 PSWI and in-situ observation of PSWI time series during the growing season of 2015-2016 for the 35 stations.



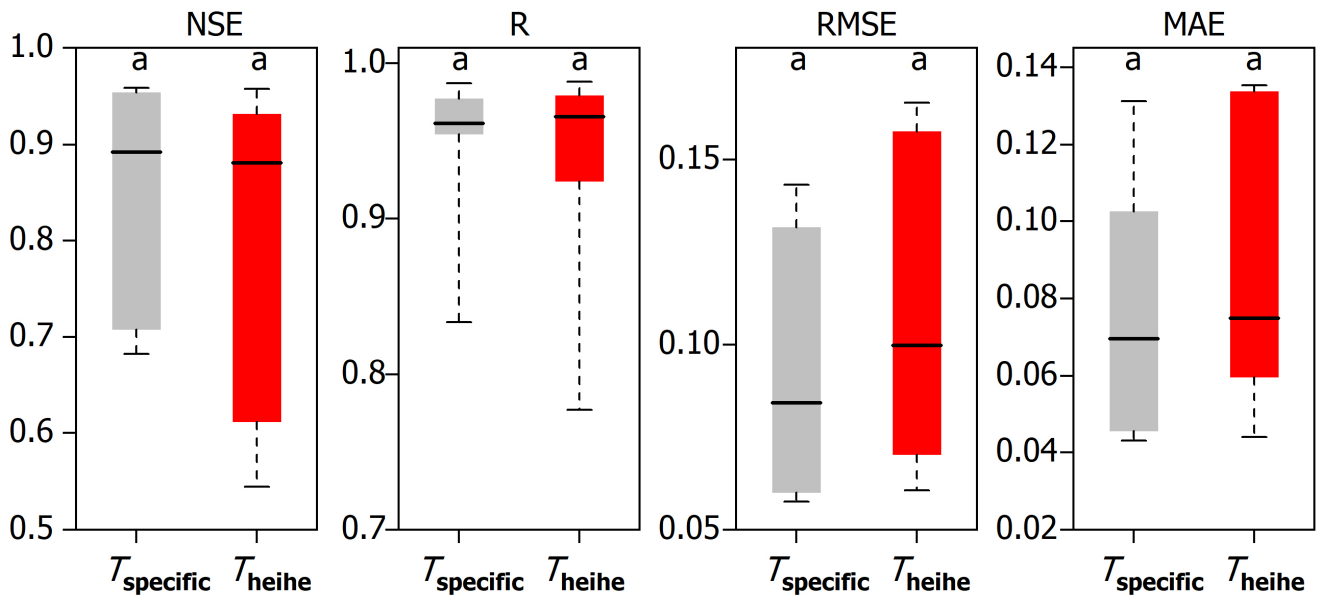
**Fig. S11.** The location of the Maqu soil moisture monitoring network, the Heihe soil moisture monitoring network, the study area (upper stream of the Heihe river Basin), Qilian mountainous area, and Qinghai-Tibet plateau.



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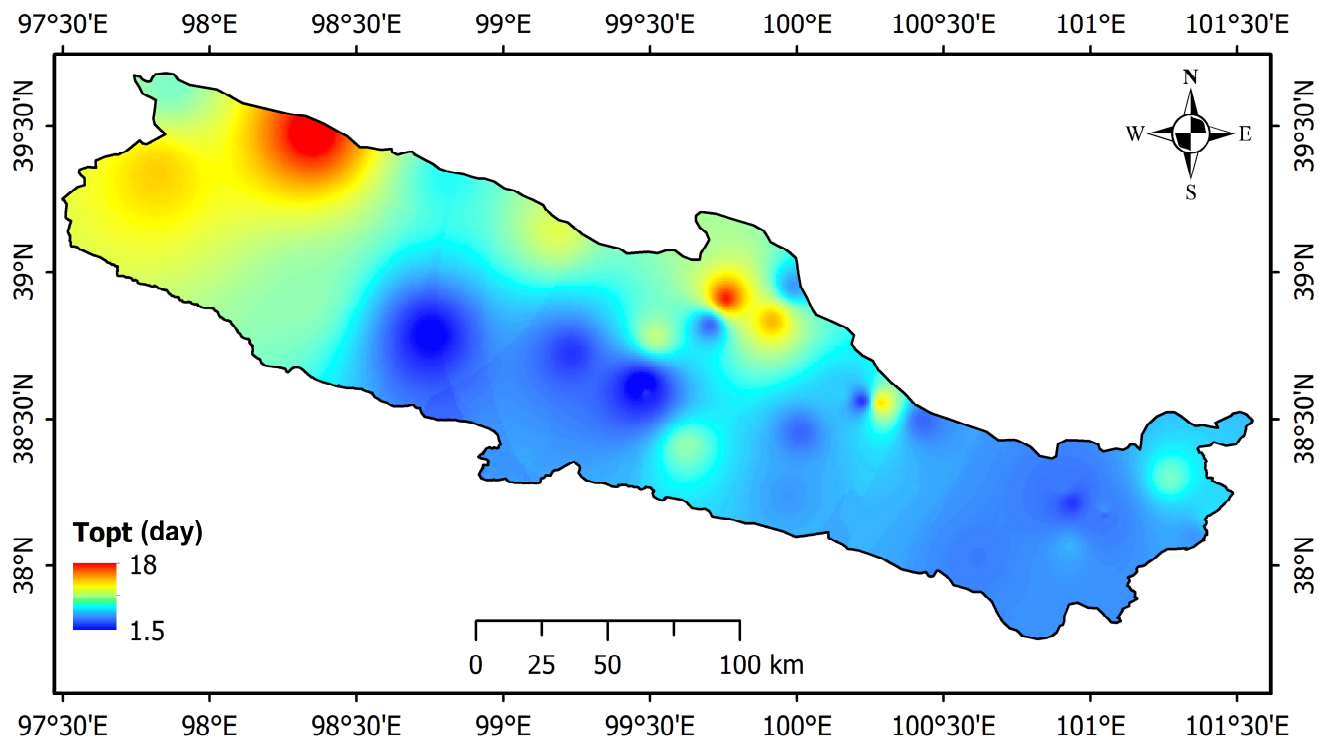
**Fig. S12.** Comparisons of the estimations (with  $T_{\text{specific}}$  and  $T_{\text{heihe}}$ ) and in-situ observations of profile SWI time series of the growing season of 2015, 2016 and 2017 for the Maqu soil moisture stations.





**Fig. S13.** The boxplot of metrics (NSE, Pearson's R, RMSE and MAE) of the estimations with  $T_{\text{specific}}$  and  $T_{\text{heihe}}$ . The same letter above box indicate the difference of different  $T$  is nonsignificant.

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**Fig. S14.** The spatial distribution of  $T_{opt}$  for the estimation of profile soil moisture from the SMAP surface soil moisture.

**Table S1.** The statistics of the performance of different T ( $T_{\text{specific}}$  and  $T_{\text{heihe}}$ ) for estimating profile soil moisture from surface soil moisture in the Maqu network

$T$	Statistics	RMSE	R	NSE	MAE
$T_{\text{specific}}$	Mean± Standard Deviation	0.09±0.03	0.95±0.05	0.86±0.1	0.08±0.03
	Median	0.08	0.96	0.89	0.07
$T_{\text{heihe}}$	Mean± Standard Deviation	0.11±0.04	0.94±0.07	0.81±0.15	0.09±0.03
	Median	0.10	0.97	0.88	0.08