Towards a Harmonized Soil Moisture Database for the South Central United States: Evaluating Methods for Depth Standardization and Quality Control

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Research Goal

This project will produce effective soil moisture-based drought indices that decision-makers can use retrospectively or in real-time with data from existing monitoring networks to assess drought severity in the South Central region.

Key challenge = integrating existing soil moisture data collected from diverse networks

(1) Develop a robust QC procedure

(2) Standardize soil moisture measurement depths

(3) Accounting for sensor differences

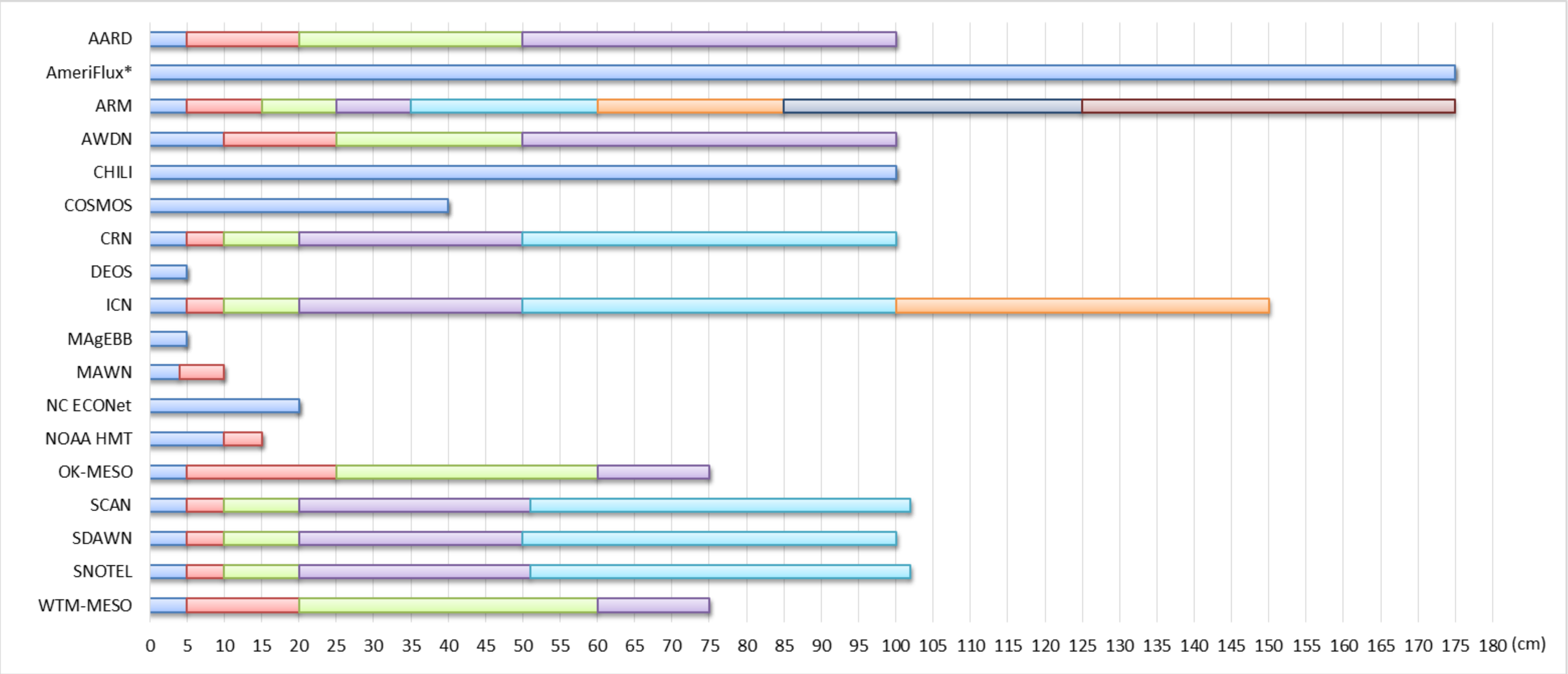


Figure 1. Measurement depths used by 18 of the soil moisture monitoring networks that were archived in the North American Soil Moisture Database (NASMD) from Jan. 1, 2000 to Dec. 31, 2013. The different colors indicated different depth intervals for each network. The depths of soil moisture measurement in the AmeriFlux* network varied from station to station, here we only provided the general range (0-175 cm) of the records.

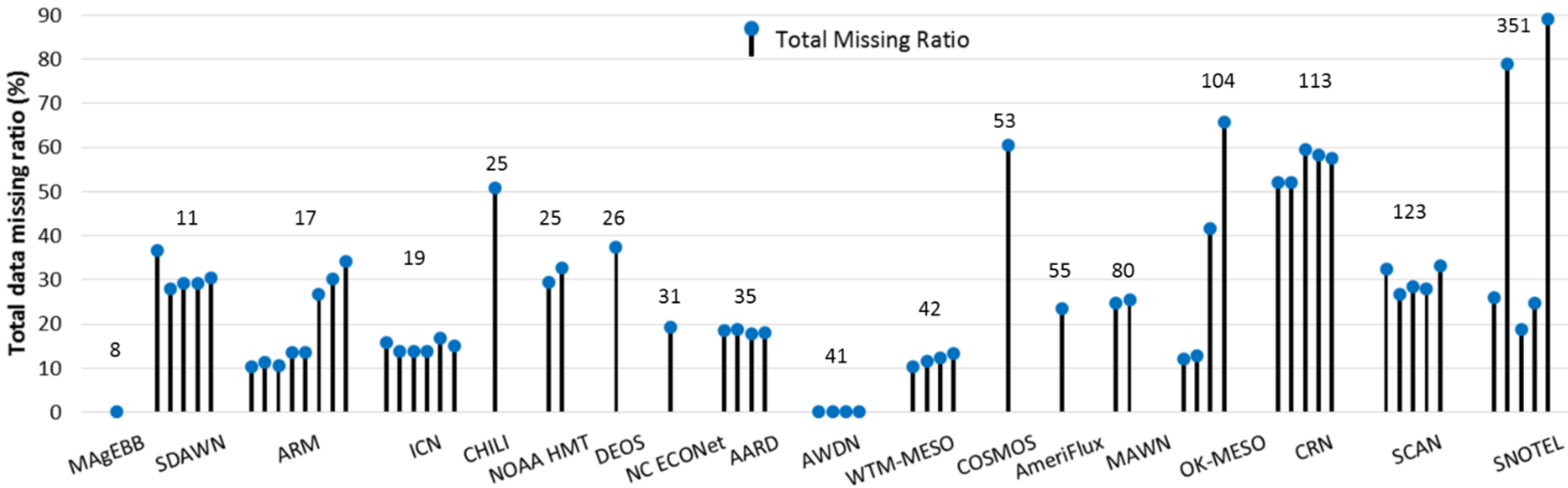


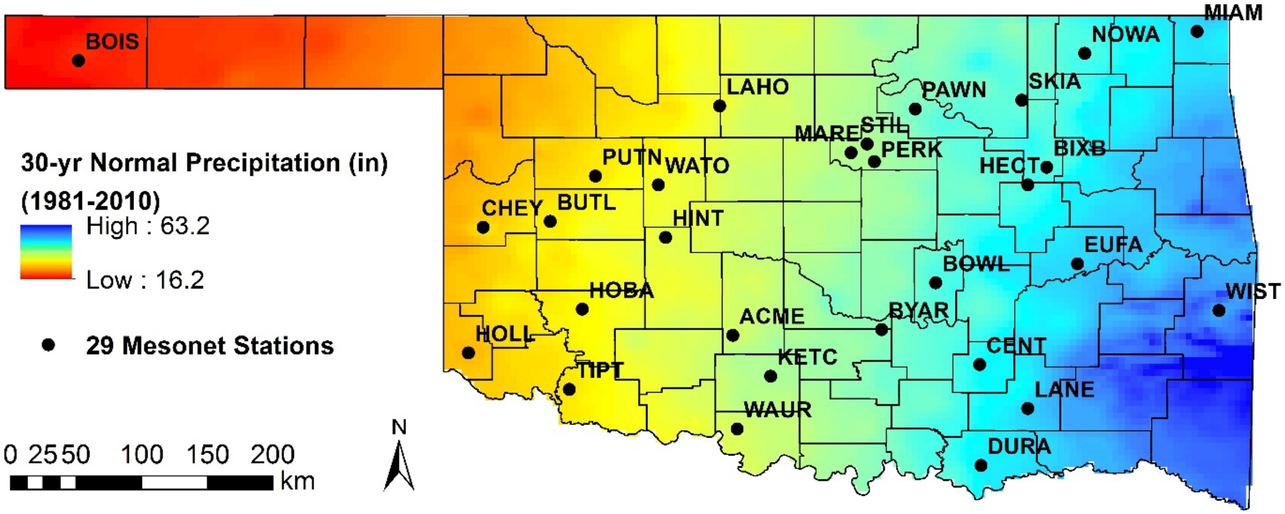
Figure 2. The station total missing data ratio for 18 networks archived in the North American Soil Moisture Database (NASMD) from Jan. 1, 2000 to Dec. 31, 2013. The total missing data ratio is defined as the total number of missing data for that network and depth divided by the total number of data that would have been collected if every station in that network had no missing data for that depth over the specified time period. The numbers in the figure indicate the number of stations extracted from NASMD for each network.

The Ohio State University

Data and Methods

- We compared three methods for vertical extrapolation of soil moisture using data from the Oklahoma Mesonet: artificial neural networks (ANN), linear regression (LR), and exponential filter.

- 29 Oklahoma Mesonet sites used in this study are shown in black dots. Daily air and soil temperature, precipitation and solar radiation observation for the 29 stations were obtained 1998 to 2013 (16 years).



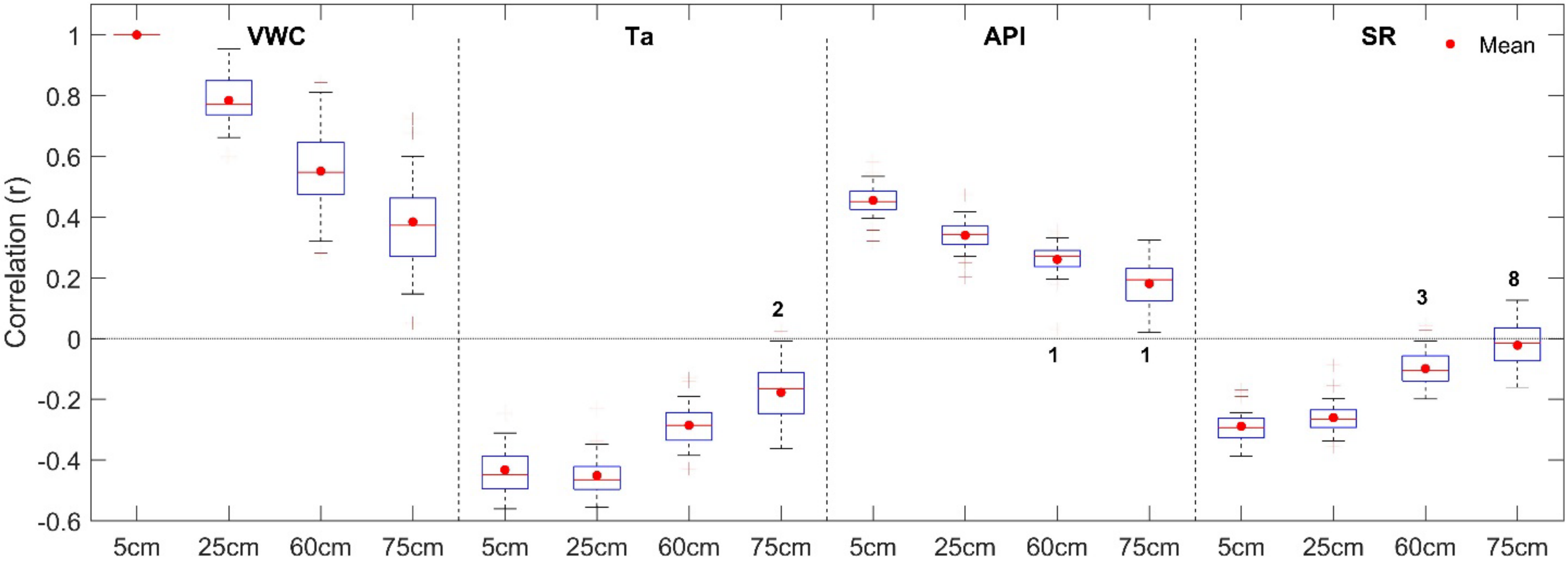


Figure 6. Correlation between surface soil moisture (5 cm) and soil moisture at 5 cm, 25 cm, 60 cm and 75 cm. The second to fourth panels respectively showed the correlations between air temperature (Ta), Antecedent Precipitation Index (API), solar radiation (SR) and soil moisture at four depths. The number stands for the number of stations (out of 29 stations) that presents non-significant correlation ($p>0.05$) with surface soil moisture based on 5,840 daily measurements.

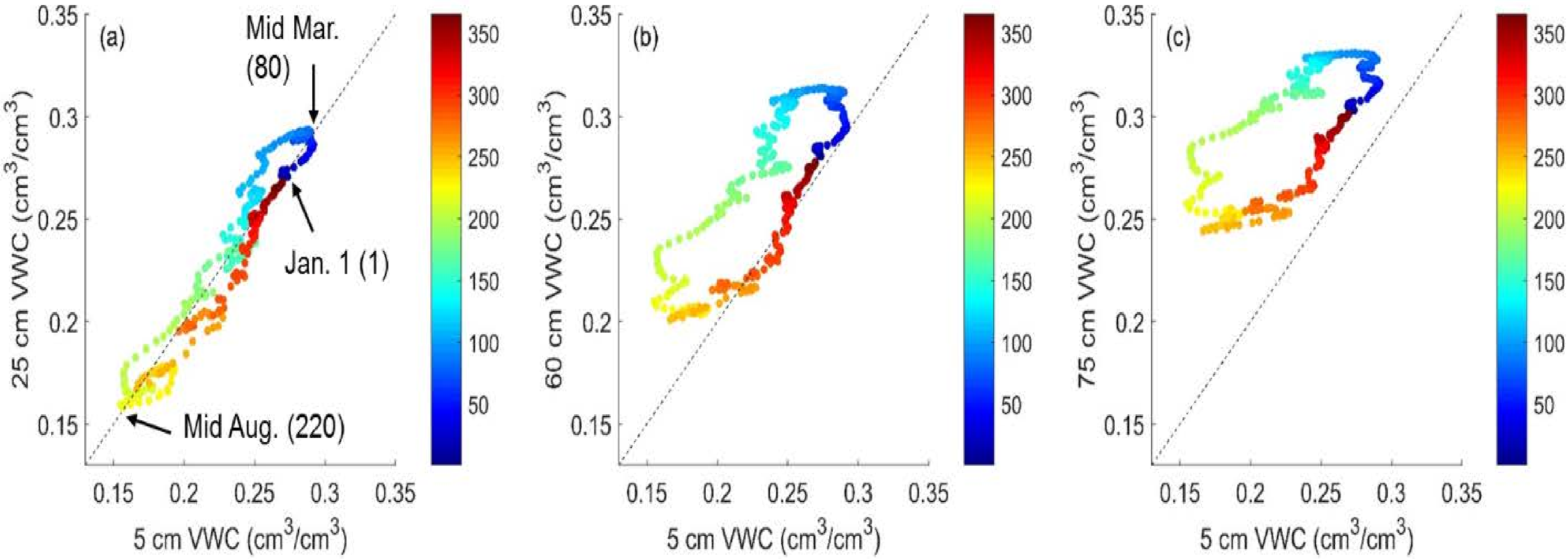


Figure 4. Scatter plot of spatial and temporal averaged soil moisture between three depth pairs: (a) 5 cm vs 25 cm, (b) 5 cm vs 60 cm, and (c) 5 cm vs 75 cm. Each dot represented a daily soil moisture measurement averaged over 29 Mesonet stations from 1998 to 2013 (a total of 16 years). The color for each dot represented the day of the year (DOY) from 1 to 365.

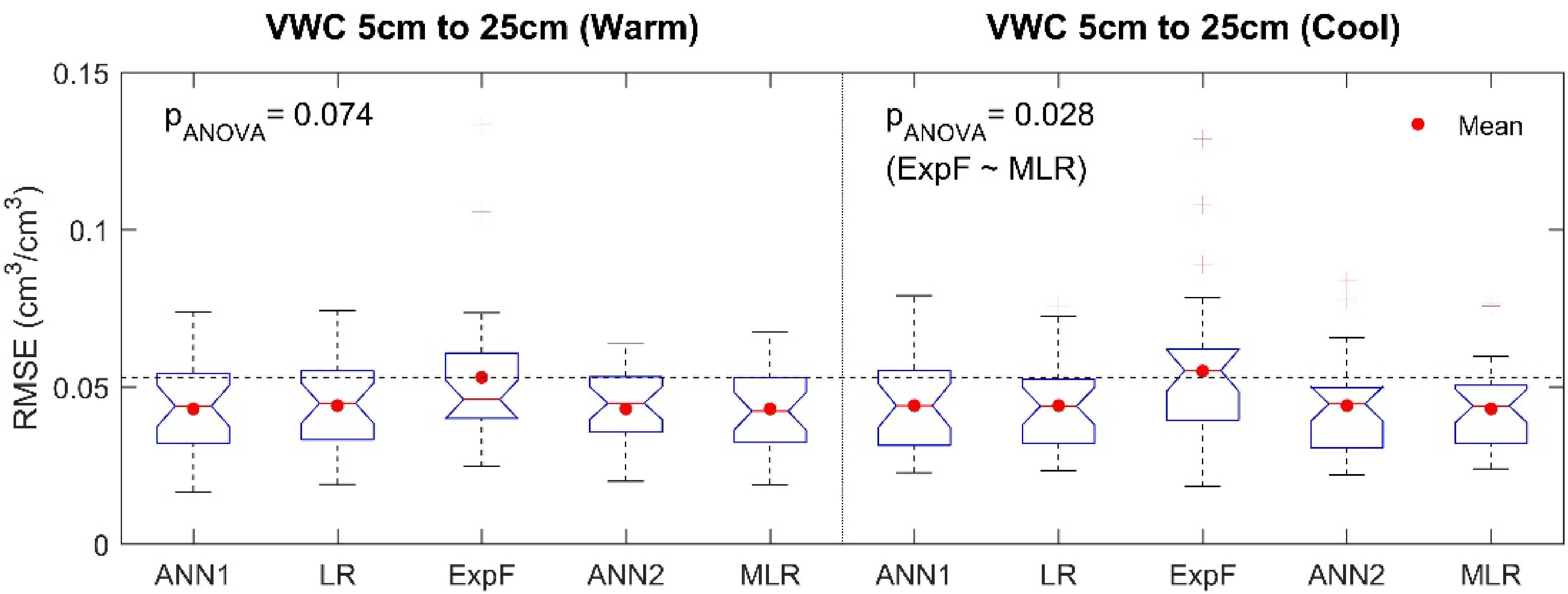
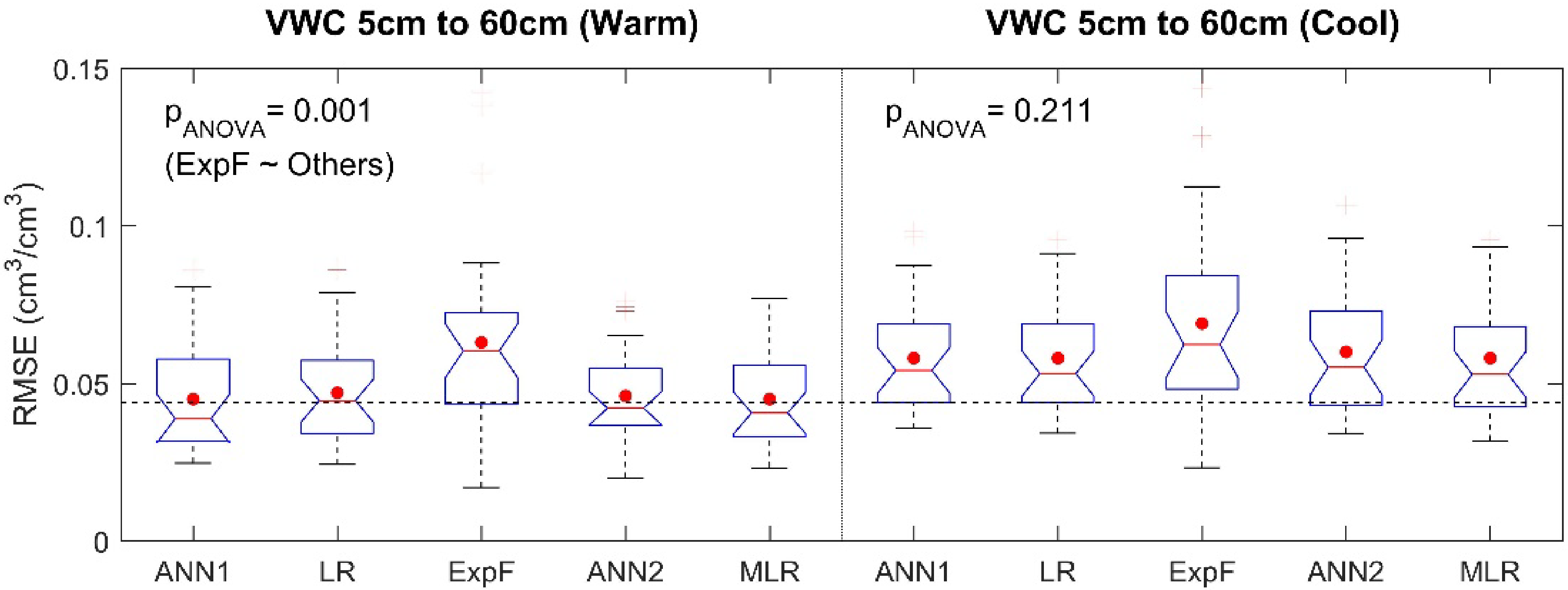


Figure 7. Comparison of RMSE (cm^3/cm^3) of the vertical extrapolation of VWC using different methods across the 29 sites. ANN1: ANN model with single input of surface moisture; LR: Linear regression; EXPf: Exponential filter; ANN2: ANN models with ancillary input (T_a and API); MLR: Multiple linear regression with ancillary variables (T_a and API). The horizontal dashed line indicates the measurement uncertainty (RMSE) of Mesonet soil moisture at each depth (0.053 cm^3/cm^3 at 25 cm) according to Scott et al. (2013).



The p_{ANOVA} indicates the p value from one-way analysis of variance (ANOVA) test for the five models. The null hypothesis of ANOVA is all model means are equal, and the alternative hypothesis is at least one model is different from the others at 0.05 significance level. The post-hoc analysis are conduct on the significant case ($p<0.05$) to determine which method is significantly different from others and the results are listed in parenthesis (eg. ExpF~MLR denotes the RMSE of ExpF is significantly different from that of MLR method).

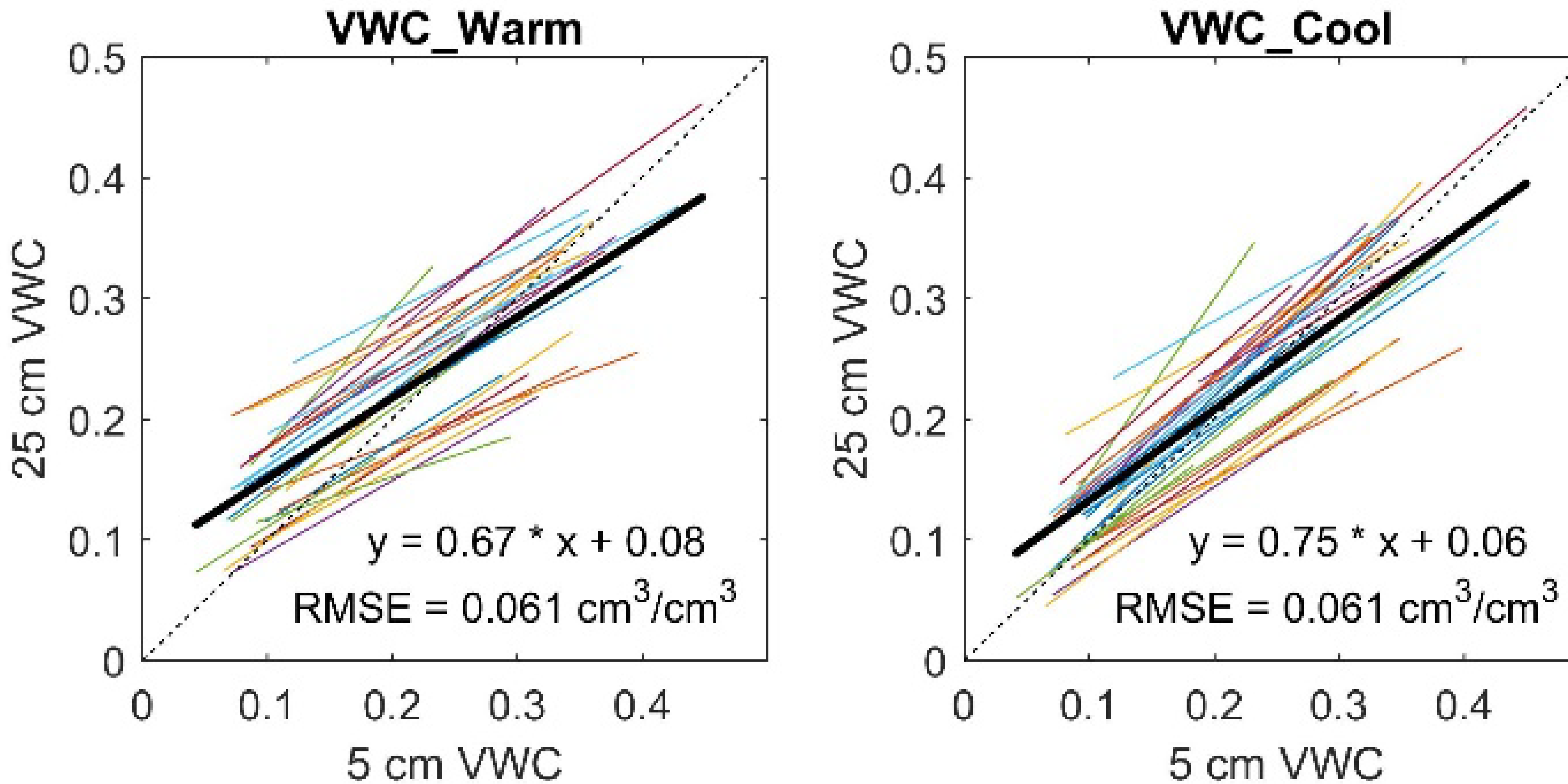


Figure 9. Comparison of site-specific linear regression and general regression for VWC and SWI over 29 sites among different depth pairs. The colored thin lines indicated the linear regression for each site; the thick black line indicated the general linear regression over 29 sites with regression equations shown at the bottom of each panel. The RMSE is for the general regression and it is calculated based on out-of-sample data.

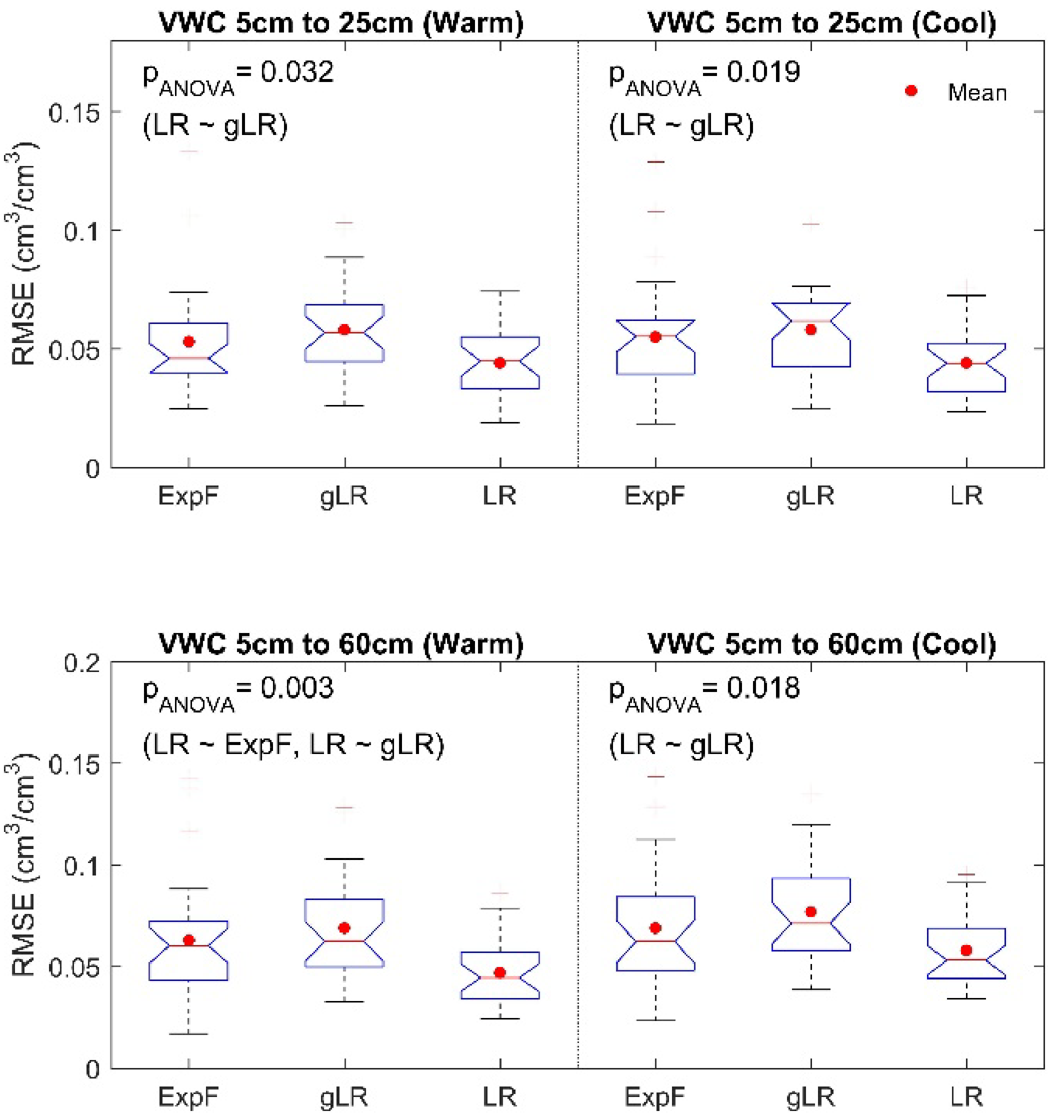


Figure 10. Comparison of RMSE between Exponential filter, site-specific linear regression (LR) and general linear regression (gLR) using VWC (a) and SWI (b). The post-hoc analysis are conduct on the significant case ($p<0.05$) to determine which method is significantly different from others and the results are listed in parenthesis (eg. LR~gLR denotes the RMSE of LR is significantly different from that of gLR method).

Conclusions

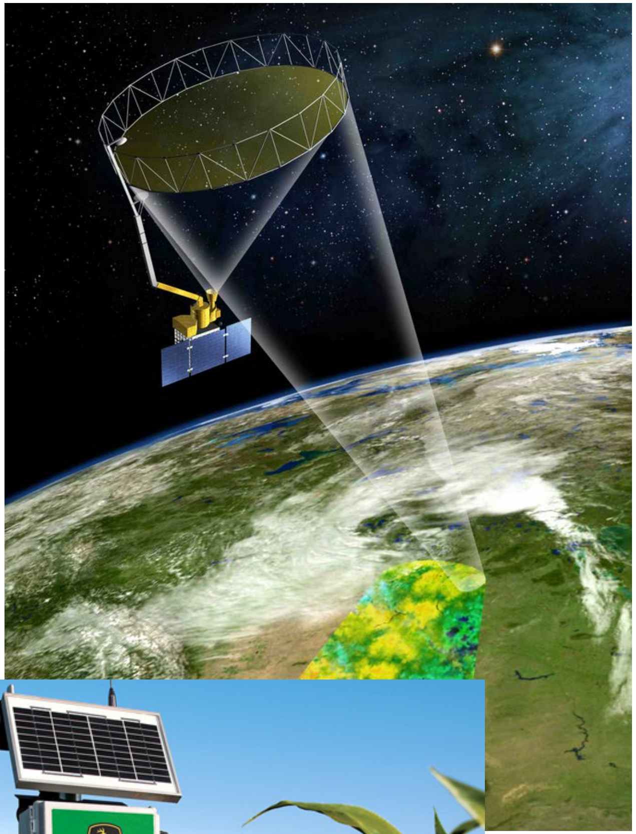
- All three methods performed better in the warm season than in the cool season
- Accuracy decreased with depth. None of the methods performed well estimating soil moisture below the 60 cm depth
- ANN had similar performance to LR; however, LR is preferable due to its stability and simplicity.
- Using air temperature and antecedent precipitation did not significantly improve the accuracy
- A general LR can be used for vertical extrapolation, which provides a potential solution for soil moisture estimation at sites where training data are not available.

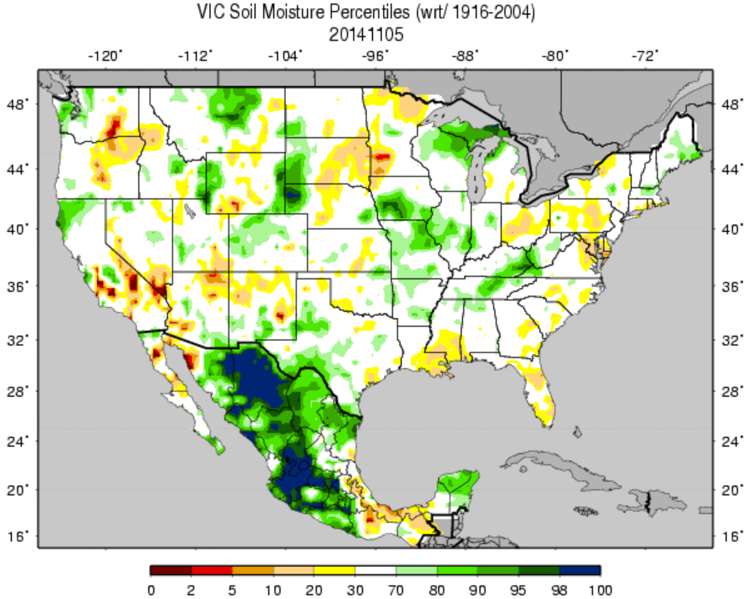
Applications

1) Soil-moisture based drought monitoring and assessment of agricultural impacts

2) Developing standardized and homogenized soil moisture datasets from multiple networks

3) Satellite-derived rootzone soil moisture





Future Work

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Acknowledgements

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