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Discussions

Interactive comment on "Soil Moisture Sensor Network Design for Hydrological Applications" *by* Lu Zhuo et al.

Anonymous Referee #1

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The authors present a useful study on soil moisture network design for use in catchment modelling studies. The approach is fairly novel although the authors fail to cite some key parts of the literature on soil moisture networks and spatial scaling. Much work has been done through various NASA soil moisture campaigns (SMEX, SMAPVEX, etc.) that have provided a wealth of publications. In addition, the approaches of temporal stability analysis and Empirical Orthogonal Functions have been used in the soil moisture community for many years to address key issues on scaling and design. The paper is generally well written but needs greater tie in to the existing soil moisture community literature before publication. Additional grammar editing is also needed, see minor comments for some edits.

Major Comments

1. The authors fail to identify the depth of soil moisture information used in the WRF NoahMP analysis! I assume this is the rootzone integrated product from NoahMP 4 soil layers? Given the large difference between surface and rootzone soil moisture dynamics in space and time I would suggest doing the analysis for both a surface and rootzone layers. I suspect the network design will be different depending on which depth is of interest. Also what are the depths of sensors for the in-situ network?

2. The authors fail to cite key soil moisture techniques for scaling (see Crow 2012 for general review paper, Mohanty 2001 and Famiglietti 2008), mainly the approaches of Temporal Stability Analysis (TSA, Vachaud 1985) and Empirical Orthogonal Functions (EOF, Perry and Niemann 2007). I also suspect the EOF approach and comparison with environmental covariates is very similar to the PCA and CA approach used here (see Wang 2017). Moreover, I am concerned about the influence of temporal variation in the covariance analysis here. While EOF is very similar to PCA, EOF notably splits the variance into time and space components. Wang 2017 find the analysis of the regional NE Mesonet soil sensors that the spatial variability is dominated by the first EOF/PCA and that EOF is highly correlated to clay/sand fraction. I suspect the EOF approach would be enlightening here to show that topographic relief and/or soil texture dominated the 1st EOF from the NoahMP output. Also the map of 1st EOF coefficients will act as a form of spatial clustering analysis. I suspect that the alluvial plains will have similar EOF coefficients, similar to what was found with the clustering analysis here?

Vachaud, G., A. P. Desilans, P. Balabanis, and M. Vauclin (1985), Temporal stability of spatially measured soil-water probability density-function, Soil Sci. Soc. Am. J., 49(4), 822-828.

Perry, M. A., and J. D. Niemann (2007), Analysis and estimation of soil moisture at the catchment scale using EOFs, Journal of Hydrology, 334(3-4), 388-404. doi:10.1016/j.jhydrol.2006.10.014.

Famiglietti, J. S., D. R. Ryu, A. A. Berg, M. Rodell, and T. J. Jackson (2008), Field observations of soil moisture variability across scales, Water Resources Research, 44(1), 16. doi:W01423 10.1029/2006wr005804.

Mohanty, B. P., and T. H. Skaggs (2001), Spatio-temporal evolution and time-stable characteristics of soil moisture within remote sensing footprints with varying soil, slope, and vegetation, Adv. Water Resour., 24(9-10), 1051-1067. doi:10.1016/s0309-1708(01)00034-3.

Crow, W. T., A. A. Berg, M. H. Cosh, A. Loew, B. P. Mohanty, R. Panciera, P. de Rosnay, D. Ryu, and J. P. Walker (2012), Upscaling Sparse Ground-Based Soil Moisture Observations For The Validation Of Coarse-Resolution Satellite Soil Moisture Products, Rev. Geophys., 50. doi:10.1029/2011rg000372.

Wang, T., T. E. Franz, R. Li, J. You, M. D. Shulski, and C. Ray (2017), Evaluating climate and soil effects on regional soil moisture spatial variability using EOFs, Water Resources Research, 53. doi:10.1002/2017WR020642.

3. The scaling of a point sensor to a 5 km grid is not trivial (see Crow 2012). Additional geophysical approaches like GNSS or CRNS can provide integrated soil moisture data at a scale of tens to hundreds of meters as opposed to having a network of point sensors. The CRNS has been implemented with the COSMOS and COSMOSUK networks (Zreda 2012, Evans 2016). COSMOSUK network moving towards integration with operational weather forecasts. CRNS better suited for use in complex terrain and may be a good option to use for a national network as compared to in-situ point sensors. Cost over 10 years probably similar to point sensors with increased maintenance replacement etc. The sensor networks would provide different data for different purposes.

Zreda, M., W. J. Shuttleworth, X. Xeng, C. Zweck, D. Desilets, T. E. Franz, and R. Rosolem (2012), COSMOS: The COsmic-ray Soil Moisture Observing System, Hydrology and Earth System Sciences, 16, 4079-4099. doi:10.5194/hess-16-1-2012.

Evans, J. G., H. C. Ward, J. R. Blake, E. J. Hewitt, R. Morrison, M. Fry, L. A. Ball, L. C. Doughty, J. W. Libre, O. E. Hitt, D. Rylett, R. J. Ellis, A. C. Warwick, M. Brooks, M. A. Parkes, G. M. H. Wright, A. C. Singer, D. B. Boorman, and A. Jenkins (2016), Soil water content in southern England derived from a cosmic-ray soil moisture observing system - COSMOS-UK, Hydrological Processes, 30(26), 4987-4999. doi:10.1002/hyp.10929.

4. Much work has been done on soil moisture network design and implementation. See the NSMN for USA and ISMN databases for globe. These networks and efforts should be better acknowledged.

http://nationalsoilmoisture.com/ and papers by S. Quiring.

Dorigo, W. A., A. Xaver, M. Vreugdenhil, A. Gruber, A. Hegyiova, A. D. Sanchis-Dufau, D. Zamojski, C. Cordes, W. Wagner, and M. Drusch (2013), Global Automated Quality Control of In Situ Soil Moisture Data from the International Soil Moisture Network, Vadose Zone Journal, 12(3), 21. doi:10.2136/vzj2012.0097.

5. What do the CA clusters look like, that is are they nonconvex? How did you chose the optimal number of clusters (see Amiri 2019)? Please add more information on the CA approach used here.

Amiri, S., B. S. Clarke, J. L. Clarke, and H. Koepke (2019), A General Hybrid Clustering Technique, Journal of Computational and Graphical Statistics, 28(3), 540-551. doi:10.1080/10618600.2018.1546593. Minor comments

L 14. “variable in hydrological”

L 53. “for hydrological research”

L54. Large space? Sentence needs editing.

L62. NSMN and ISMN address are key sources of soil moisture information. In USA state Mesonets are designed to fill such gaps. See http://nationalsoilmoisture.com/ and OK Mesonet, NE Mesonet, SCAN, CRN for some networks available etc.

71. “of soil moisture”

72. Would disagree. TSA and EOF approaches have been used for such purposes.

Vachaud, G., A. P. Desilans, P. Balabanis, and M. Vauclin (1985), Temporal stability of spatially measured soil-water probability density-function, Soil Sci. Soc. Am. J., 49(4), 822-828.

Perry, M. A., and J. D. Niemann (2007), Analysis and estimation of soil moisture at the catchment scale using EOFs, Journal of Hydrology, 334(3-4), 388-404. doi:10.1016/j.jhydrol.2006.10.014.

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Crow, W. T., A. A. Berg, M. H. Cosh, A. Loew, B. P. Mohanty, R. Panciera, P. de Rosnay, D. Ryu, and J. P. Walker (2012), Upscaling Sparse Ground-Based Soil Moisture Observations For The Validation Of Coarse-Resolution Satellite Soil Moisture Products, Rev. Geophys., 50. doi:10.1029/2011rg000372.

L108. Sentence is awkward, please revise.

L114. What are soil depths for model? Surface or rootzone?

L 180. section 3.2.1. How do you deal with temporal component of variation in PCA? EOF splits temporal and spatial components to identify dominant spatial structures.

Perry, M. A., and J. D. Niemann (2007), Analysis and estimation of soil moisture at the catchment scale using EOFs, Journal of Hydrology, 334(3-4), 388-404. doi:10.1016/j.jhydrol.2006.10.014.

L 217. How do you deal with nonconvex clusters and selection of number of clusters (Amiri 2019)? PCA + CA seems similar to EOF approach used by others.

Amiri, S., B. S. Clarke, J. L. Clarke, and H. Koepke (2019), A General Hybrid Clustering Technique, Journal of Computational and Graphical Statistics, 28(3), 540-551. doi:10.1080/10618600.2018.1546593.

L257. KGE criteria has been shown to be superior to NSE (Gupta 2009). KGE uses correlation, bias in mean and standard deviation. Here you use both NSE and correlation, why not switch to KGE for simplicity?

Gupta, H. V., H. Kling, K. K. Yilmaz, and G. F. Martinez (2009), Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling, Journal of Hydrology, 377(1-2), 80-91. doi:10.1016/j.jhydrol.2009.08.003.

L411-413. I would disagree. See comments above about work on soil moisture scaling and implications to network design, like NSMN or USA state Mesonets.

L458. CRNS good option for long-term deployment in complex terrain.

Zreda, M., W. J. Shuttleworth, X. Xeng, C. Zweck, D. Desilets, T. E. Franz, and R. Rosolem (2012), COSMOS: The COsmic-ray Soil Moisture Observing System, Hydrology and Earth System Sciences, 16, 4079-4099. doi:10.5194/hess-16-1-2012.

Evans, J. G., H. C. Ward, J. R. Blake, E. J. Hewitt, R. Morrison, M. Fry, L. A. Ball, L. C. Doughty, J. W. Libre, O. E. Hitt, D. Rylett, R. J. Ellis, A. C. Warwick, M. Brooks, M. A. Parkes, G. M. H. Wright, A. C. Singer, D. B. Boorman, and A. Jenkins (2016), Soil water content in southern England derived from a cosmic-ray soil moisture observing system - COSMOS-UK, Hydrological Processes, 30(26), 4987-4999. doi:10.1002/hyp.10929.

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