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The Impact of Geophysical Measurement Support in Quantifying the Correlation Structure of Anisotropic Systems

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One of the challenges in developing catchment-scale models of hydrologic processes is accurately representing the spatial variation of subsurface properties. There is growing interest in the application of surface-based or borehole geophysical methods to obtain information about the correlation structure of hydrogeologic systems. It is well known, for all forms of measurement, that the support of the measurement impacts the derived estimates of correlation structure. Of interest in our work is the effect of the support of geophysical measurements on estimated correlation lengths. We define the support of a geophysical measurement as the presumed-homogeneous volume of the subsurface to which we can assign, given the methods of data acquisition and inversion, a single property. Accounting for the effect of the support becomes particularly important when integrating geophysical measurements of properties with other hydrologic measurements. The merged data sets are derived from measurements on scales that are rarely coincident with each other or the scale at which the properties are applied in hydrologic models. A number of previous studies have examined the impact of measurement scale on the estimated apparent correlation length for isotropic property fields. Most hydrologic property fields, however, are anisotropic at the catchment-scale. A further complicating factor is that geophysical measurements commonly have directionally-varying support dimensions.

In this study we numerically generate both isotropic and anisotropic property fields and allow the orthogonal dimensions defining the measurement support to vary independently. When creating the anisotropic fields we define maximum and minimum correlation lengths, referred to as the underlying correlation lengths; these lengths are the same in the isotropic case. We initially estimate the apparent correlation length when the measurement support is equal to the grid size on which the field is defined. The increase in apparent correlation length relative to this initial estimate, or the error in apparent correlation length, is presented as a function of increasing measurement support, termed the error response curve. Our results show that the errors vary with both measurement support and the anisotropy of the measured property.

In systems where the measurement support is equidimensional and the property field is anisotropic, the slope of the error response curve is consistently greater when calculated in the direction of minimum underlying correlation length. For isotropic property fields and non-equidimensional measurement support, the error response curve has a steeper slope when the direction of increased measurement support dimension is coincident with the direction in which we estimate the apparent correlation length. When the property field is anisotropic and the measurement support is non-equidimensional, three factors affect the behavior of the error response curve: the anisotropy of the property field, the direction of increasing measurement support, and the direction in which the apparent correlation length is estimated. The error response curve has a shallower slope when measurement support dimension increases in the perpendicular direction to that in which we estimate the apparent correlation length. This behavior is independent of the degree of anisotropy in the property field. However, as the anisotropy in the property field increases, the slope of the error response curve becomes even shallower. At large measurement supports, the error response curve flattens when increasing measurement support is perpendicular to the direction of estimation of the apparent correlation. The opposite is true when the measurement support increases in the same direction as we estimate the apparent correlation; the slope of the error response curve increases at large measurement supports. In both cases, the behavior of the error response curve is more sensitive to changes in measurement support when the underlying correlation length is smaller in the direction of estimated apparent

correlation length. The dependence of the estimated correlation length on the measurement support and anisotropy of the underlying property field highlights the need to better represent the geophysical measurement process, and resulting support, when integrating geophysical data into hydrologic models at the catchment-scale.