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GEOPHYSICAL Measurements on Outcrops: The Role of Instrument Spatial Weighting Functions

In general, when an instrument-based measurement is made of a physical property, such as electrical resistivity or fluid permeability, the portions of the medium "sensed" by the instrument are not weighted equally [Knight, Water Resour. Res. (WRR), 28(9), 1992; Tidwell et al., WRR, 35(1), 1999; Molz et al., WRR, in review, 2001]. In general, each instrument will have some "averaging volume", but the type of average that results in the reading displayed by the instrument or technique has only recently been studied. The averaging volume question is a difficult one, and it may not have a general answer for all types of heterogeneity. Nevertheless, insight may be gained by first considering an assumed homogeneous, or at least locally homogeneous, system. Current analysis techniques for water content measurements using time domain reflectometry, and permeability measurements using the gas mini-permeameter are based on this type of system. The present paper develops a theoretical basis for calculating spatial weighting functions for both compressible and incompressible flows in a steady, homogeneous, and isotropic domain. A physical interpretation of spatial weighting functions in terms of the ratio of steady-state energy dissipation rate per unit volume of porous medium to total energy dissipation rate over the entire flow domain is formulated. The instrument weighting function is a rather general concept, and applications are presented for gas permeability measurements and electrical resistivity measurements. Possible applications of spatial weighting functions to heterogeneous media are discussed also.