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Proposing a statistical interpretation for the depth of investigation

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When inversion results from electrical or electromagnetic surveys are interpreted, the depth of investigation (DOI) is a crucial quantity. The DOI is conventionally defined as the smallest depth below which surface data are insensitive to the investigated physical property of the subsurface. Most of the DOI approaches described in literature rely on thresholding the measurement sensitivity with depth. Measurement sensitivity can be derived in different ways, with a perturbation of the estimated inversion parameters in the forward model as the most straightforward approach. For probabilistic inversion, we propose the correlation between prior model parameters and measurement data as a proxy for measurement sensitivity. The DOI is placed where correlation approaches the zero function.
Probabilistic inversion procedures start from sampling a prior probability density function (PDF), desirably drawing a high number of samples to allow an exhaustive search of the model space. If Gaussian prior PDFs are assumed, the PDFs are fully defined by their mean and standard deviation (STD). Computing the forward responses for the samples from the prior PDF, we calculate the covariance between the prior and the forward response. In the Gaussian case, the covariance can be normalized using the STD of the prior PDF to achieve the correlation between the prior PDF of each discrete model layer or cell and the corresponding forward responses. We propose to interpret the derived correlation as a statistical measure for sensitivity. Correlations are restricted to the interval from minus one to one, which has two advantages: (1) correlations from all measurement signals are directly comparable, and (2) the depth at which the correlation curve approaches the zero function gives an intuitive measure for the DOI.
We show how this correlation-based DOI can support the assessment of frequency-domain electromagnetic (FDEM) inversion results and how this DOI relates to measurement sensitivity and commonly used DOI approaches. Furthermore, we show how the results from the correlation-based DOI computation can be readily integrated in a probabilistic inversion of FDEM data, jointly deriving subsurface electrical conductivity and magnetic susceptibility without requiring additional forward model runs than the one performed to estimate correlation.

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