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Direct integration of gravity measurements in pumping test analyses

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Pumping tests often suffer from a limited number of observation locations. Installation of monitoring wells is commonly too expensive to allow for addition of monitoring points for pumping tests. In contrast, gravity stations can be installed inexpensively, allowing for addition of multiple monitoring locations specifically for use during a pumping test. However, given the difference between the point scale support volume of monitoring wells and the distributed sensitivity of a gravimeter, it was not clear that gravimeters could provide useful data for constraining a pumping test. As part of an effort to improve interpretation of geophysical methods for hydrologic applications, we examine the optimal use of gravity measurements for estimating aquifer properties from a pumping test. We demonstrate that measurements made with gravimeters during a pumping test are as capable as monitoring wells for constraining the inversion of aquifer properties. They are only limited by the method measurement uncertainty. However, for maximum effectiveness, gravimeter responses must be interpreted in a coupled hydrologic-gravimeter model. That is, the water table elevation distribution should not be interpreted independently based on gravimeter responses. Rather, each iteration of the hydrologic model, during inversion, should be used to predict the gravimeter responses through time for the gravimeter stations used. These predicted gravimeter responses are compared with the measurements and the hydraulic properties are adjusted to improve this fit. We show that this approach automatically accounts for the effects of spatially variable water levels within the sample volume of each gravimeter measurement, which leads to errors in independent gravity inversions. This coupled analysis translates to improved accuracy of the interpretation of aquifer tests.