Leveraging Earth Observations and In Situ Data in Support of Groundwater Sustainability

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Abstract

Water managers face the daunting task of managing freshwater resources in the face of industrialization and population growth. As surface water resources become fully allocated, increased groundwater use can fill the void, particularly during periods of drought. Improper groundwater management can result in reduced water quality, land subsidence, increased pumping costs, and in some cases, the complete exhaustion of an aquifer and the loss of groundwater as a buffer during times of drought. Assessing the long-term impact of various groundwater management decisions can be difficult and costly, and therefore many decisions are made without sufficient analysis. Advancements in the acquisition and dissemination of Earth observations, coupled with advances in cloud computing, web apps, online mapping, and visualization provide a unique opportunity to deliver tools and actionable information to groundwater managers to assist them in addressing global and regional challenges and opportunities. We have developed a web-based tool that ingests in situ groundwater level measurements for specific aquifers and generates time series plots, maps, and raster animations showing groundwater depletion over time and short-term projections into the future. This process involves both temporal and spatial interpolation algorithms. In some aquifers, the observation wells are sparse and/or the historical observations have large gaps, leading to greater uncertainty in the interpolation and the resulting groundwater depletion estimates. To address this, we utilize Earth observations (GRACE, SMAP, etc.) and a co-kriging algorithm to enhance the interpolation process. The utility of the Earth observations in improving the estimates is evaluated using a jackknifing process. We present case studies for application of the system in the states of Utah and Texas.

Leveraging Earth Observations and In Situ Data in Support of Groundwater Sustainability

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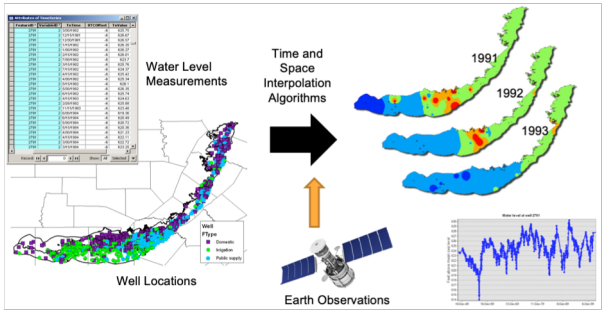
Abstract

Water managers face the daunting task of managing freshwater resources in the face of industrialization and population growth. As surface water resources become fully allocated, increased groundwater use can fill the void, particularly during periods of drought. Improper groundwater management can result in reduced water quality, land subsidence, increased pumping costs, and in some cases, the complete exhaustion of an aquifer and the loss of groundwater as a buffer during times of drought. Assessing the long-term impact of various groundwater management decisions can be difficult and costly, and therefore many decisions are made without sufficient analysis. Advancements in the acquisition and dissemination of Earth observations, coupled with advances in cloud computing, web apps, online mapping, and visualization provide a unique opportunity to deliver tools and actionable information to groundwater managers to assist them in addressing global and regional challenges and opportunities.

We have developed a web-based tool that ingests in situ groundwater level measurements for specific aquifers and generates time series plots, maps, and raster animations showing groundwater depletion over time and short-term projections into the future. This process involves both temporal and spatial interpolation algorithms. In some aquifers, the observation wells are sparse and/or the historical observations have large gaps, leading to greater uncertainty in the interpolation and the resulting groundwater depletion estimates. To address this, we utilize Earth observations and a co-kriging algorithm to enhance the interpolation process. The utility of the Earth observations in improving the estimates is evaluated using a jackknifing process.

Methodology



The inputs to our tool include include well locations, historical water level measurements, and well information such as the wellhead elevation. The tool can directly ingest data from existing databases or for regions where such databases may not exist, data can be uploaded and updated using simple spreadsheets or comma separated value (CSV) text files. The in situ water level measurements are combined with Earth observations to generate rasters and time series illustrating how groundwater resources are changing over time.

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"An AmeriGEOSS Cloud-based Platform for Rapid Deployment of GEOGLOWS Water and Food Security Nexus Decision Support Apps"

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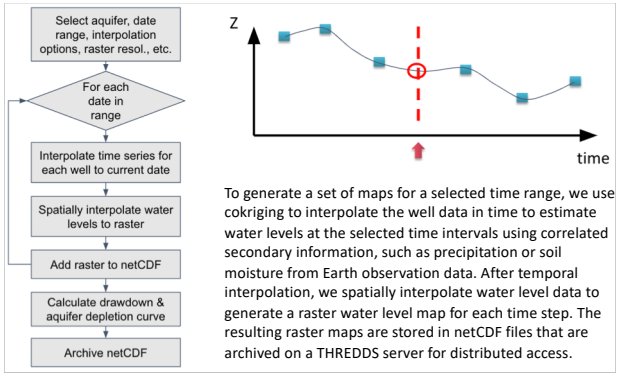
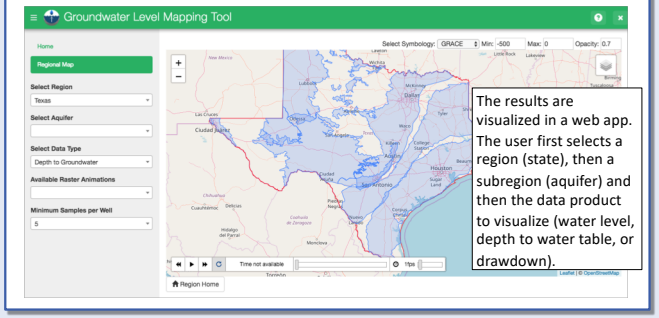
Workflow



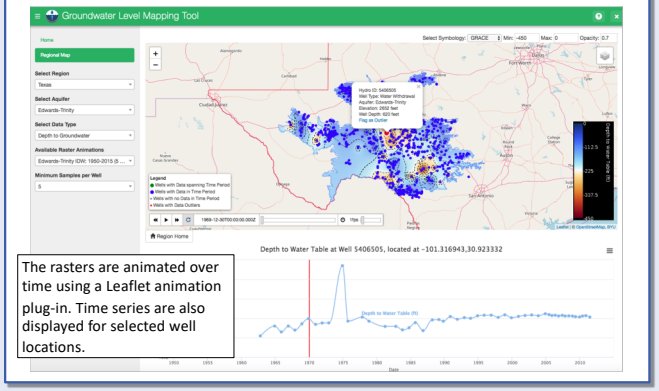
To generate a set of maps for a selected time range, we use cokriging to interpolate the well data in time to estimate water levels at the selected time intervals using correlated secondary information, such as precipitation or soil moisture from Earth observation data. After temporal interpolation, we spatially interpolate water level data to generate a raster water level map for each time step. The resulting raster maps are stored in netCDF files that are archived on a THREDDS server for distributed access.

Web App



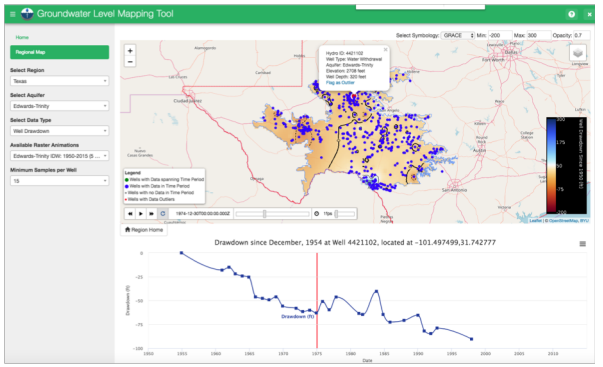
The results are visualized in a web app. The user first selects a region (state), then a subregion (aquifer) and then the data product to visualize (water level, depth to water table, or drawdown).

Data Exploration



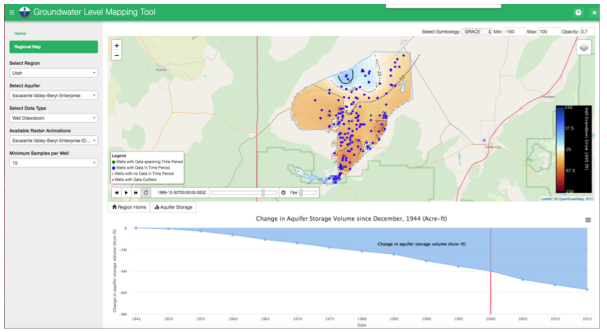
The rasters are animated over time using a Leaflet animation plug-in. Time series are also displayed for selected well locations.

Drawdown



Aquifer drawdown is a primary indicator of unstainable groundwater management. Our app analyzes drawdown by subtracting water level rasters from a baseline condition at the beginning of the selected time domain. Drawdown is visualized using raster animations and time series for selected locations.

Storage Depletion



For a more holistic assessment of storage depletion for a given aquifer, we multiply the drawdown rasters for each time interval by the aquifer area and an average storage coefficient and aggregate the results over time to generate a storage depletion curve. This provides a useful tool for water managers to assess long-term conditions. The results can be incrementally updated as new in situ data is collected and imported to the system.

The groundwater mapping tool was developed using the free and open source Tethys Platform software, created by our BYU team. Tethys Platform is a mature and broadly supported environment for developing web-based geospatial information tools.

http://www.tethysplatform.org/