Multi-scale Monitoring Framework for Risk Assessment

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Motivation

Freshwater resources are limited, and the majority of these limited resources (~68%) are locked in glaciers and icecaps, making them inaccessible to humankind. Groundwater accounts for 30% of freshwater resources; more than 2 billion people globally and 155 million people in the United States (50% the population) rely on groundwater for their primary source of drinking water (Alley et al., 2002). The demand for water is increasing, yet the water supply is decreasing because of the growing population and its consumption practices. For example, the Ogallala Aquifer – the largest aquifer, spanning eight states in the United States – is rapidly depleting and the recharge is slow. In fact, the part of the Ogallala Aquifer located in Kansas has already been used up by 30%, and another 40% will be consumed in next few decades with the current rate of pumping. Moreover, water resources are under extreme duress due to climate change and emerging contaminants. Therefore, protecting the world's freshwater resources requires identifying threats across the scales, from global to local.

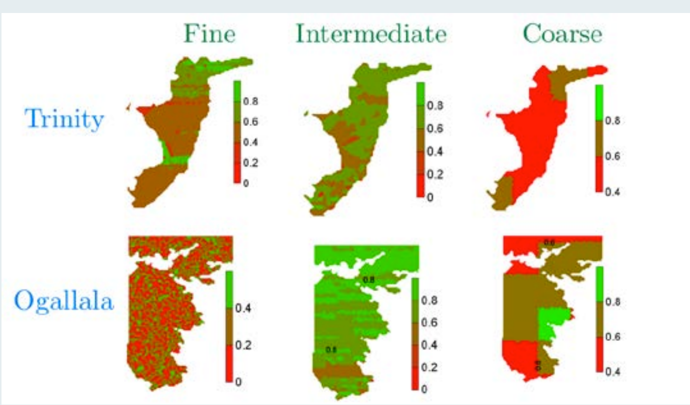

Figure 1: The Trinity and Ogallala Aquifers are major groundwater resources in Texas. Several studies have reported high levels of nitrate in these aquifers. The Hurst exponent of nitrate in both aquifers at fine, intermediate, and coarse scales highlights different physical controls of nitrate contamination (Dwivedi and Mohanty, 2016). The Hurst exponent ranges from 0 to 1. H close to 0, 0.50, and 1 shows anti-persistence, random behavior, and persistence, respectively.

Technological Challenges

The first step toward developing sustainable solutions for protecting freshwater resources entails the monitoring of groundwater resources. Currently, sites are monitored using Geographical Information System (GIS) to locate and calculate proximity to identified sources. However, contaminants demonstrate significant spatio-temporal variability; in addition, contaminants' plumes change over time because of natural processes and climatic perturbations. These limitations lead to sparse and uncertain datasets for the risk assessment. Even so, it is not possible to monitor every location because sampling is expensive. Therefore, we aim to develop a new multi-scale monitoring framework using smart data analytics.

Research

Recent studies have indicated that California is a hub for various contaminants, such as nitrate, chromium, and certain types of carcinogens. To advance the current monitoring approach to include a multi-scale treatment of available datasets and evaluate the impact of new information using data science and machine learning, we propose the following steps:

- Develop a database for different contaminants by leveraging the efforts of various agencies in California;
- Develop an adaptive learning framework combining point sources of information with hydrology and climate datasets (e.g., gridded reconstruction, process understanding, information [entropy] theory);
- Identify important factors using machine learning tools leading to contamination; and
- Find time-varying hot spots of contamination to design targeted monitoring locations.

Ultimately, we expect to reduce the cost of sampling without losing any significant information.

References

Alley et al., Flow and storage in groundwater systems. Science 2002, 296, 1985–1990.

Dwivedi and Mohanty, Hot spots and persistence of nitrate in aquifers across scales, Entropy, 18 (2016), p. 25, 10.3390/e18010025.