Hydrogeophysical modeling for improved understanding of permafrost distributions in the Yukon Flats, Alaska

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Airborne electromagnetic (AEM) data have been used to characterize the distribution of permafrost surrounding surface water features in the Yukon Flats, Alaska. One goal of this survey was to identify potential surface – groundwater connections that develop beneath lakes where an underlying talik (unfrozen zone) has fully thawed through the permafrost. Inversion of the geophysical data have yielded valuable insights into the distribution of permafrost, but a lack of ground truth information makes it difficult to validate our interpretations. Therefore, we are using an integrated hydrogeophysical modeling approach to better understand the features that we can expect to resolve from the AEM survey.

A coupled thermal-hydrologic modeling algorithm (SUTRA Ice) is used to simulate the progressive thawing of permafrost beneath a lake, based on the geometry and properties of lakes in the AEM survey area. At each time step in the simulation, we calculate a bulk electrical resistivity model based on the spatial distribution of temperature and ice saturation. Our initial efforts use Archie's Law, where the water resistivity is defined as a function of temperature, and ice saturation reduces the effective porosity. From the electrical resistivity models, we simulate the AEM forward response, which can then be inverted with realistic noise assumptions in order to assess the ability to resolve different features, both spatially and over time. We also investigate the potential influence of 3D artifacts due to large lateral resistivity variations on 1D inversions by simulating the geophysical data with a 3D algorithm, but inverting the data under a 1D assumption.

By incorporating physics-based simulations of hydrogeophysical properties, we hope to gain a better understanding of the accuracy and limitations of features imaged by our AEM survey. In addition, we use the simulations to explore alternate physical property relationships that relate hydrologic and geophysical properties, and how uncertainty in these relationships translates to uncertainty in our geophysical interpretations.