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Conference Abstract

Inference of the evolution of riparian freshwater lenses from multi-vintage airborne electromagnetic data

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Abstract

River-fed freshwater lenses overlying saline groundwater systems in arid and semi-arid regions are an important source of water for riparian vegetation, and monitoring them is critical for long-term floodplain ecosystem health. Electrical resistivity is a good proxy for groundwater salinity, and inversion of airborne electromagnetic surveys is a non-invasive method to infer models of subsurface electrical resistivity. The increasing use of river water for agriculture, manufacturing and community, as well as the effects of more extreme droughts and flood events due to climate change cause these riparian lenses to grow and shrink over time. Spatial delineation of the geometry of a riparian freshwater lens from airborne electromagnetic data commonly means inverting the individual surveys independently. Typically this involves employing a 1D physics approximation, with the interface between the base of the lens and the underlying saline groundwater system modelled as an explicit parameter in the case of a few-layer model, or making interpretations if a smooth model has been inverted from the data. Inversion results are likely to contain artefacts due to noise in the data, the non-uniqueness of the inverse problem and modelling error in the forward problem and, like any other type of noise, it will be significantly amplified in any differencing to detect changes. For repeat surveys simultaneous inversion combining information from the different surveys for model

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parameters that are not anticipated to change is likely to result in fewer artefacts, and for these parameters a time-lapse inversion behaves very much like a joint inversion, and consequently, recovery of the subsurface can be improved for both time states.

For hydrological models on the scale of an aquifer, the boundary between the freshwater and underlying saline water can be approximated by a sharp interface, and this motivates the development of inversion methods that directly estimate the location of the interface and its evolution. A pragmatic conceptual hydrological model for a riparian freshwater lens is a three-layer model, where the freshwater lens overlies a layer of saline groundwater on top of a layer representing regional groundwater. In this work, we introduce a spatio-temporal correlated simultaneous time-lapse inversion for airborne electromagnetic data to track the evolution of spatially coherent interfaces such as the base of a freshwater lens. Trans-dimensional inversion of airborne electromagnetic data for individual sounding locations frequently shows that such few-layer models are sufficient to explain the observed data. The meandering river flow over the floodplain is expected to cause significant temporal variations in resistivity and thickness of the freshwater lens, hence for the recovery of the evolution of the lens we assume that the parameters that are allowed to change in time are the thickness and electrical resistivity of this first layer.

The Murray Darling Basin in Australia is a basin of significant environmental, cultural and economic importance to Australia: 40% of Australia's agricultural produce comes from the basin and it contains 16 ecologically important wetlands of international significance. Among the efforts to characterise and delineate the ecosystem health has been the acquisition and interpretation of numerous airborne electromagnetic surveys for several floodplains along the Murray River since the early 2000s. Simultaneous inversion of airborne electromagnetic surveys for the Bookpurnong, Pike, and Katarapko floodplain along the Murray River in South Australia demonstrate that our time-lapse inversion approach can combine the information from surveys collected at different times to improve recovery of subsurface changes, and specifically the geometry of the riparian freshwater lens. For the Bookpurnong floodplain, our time-lapse results show improved imaging of localised features such as the ingress of freshwater into the floodplain from the Murray River, due to lowering of the groundwater table from pumping. For the more extensive Katarapko floodplain, the method identifies zones where there appears to be an interaction between river height, flow rate, thickness and spatial extent of the riparian freshwater lens (Fig. 1). Recovery of such, along with other changes in the hydrology for floodplains along the Murray River illustrates that the time-lapse inversion methodology introduced here has the potential to invert for the temporal evolution of freshwater-saltwater interfaces and associated uncertainties directly. We believe that our modelling approach and potentially enhanced accuracy of the inversions generated provide a novel pathway for the use of airborne electromagnetic data to monitor floodplains, and ultimately improve its integration into hydrological models to better understand floodplain ecosystem health.

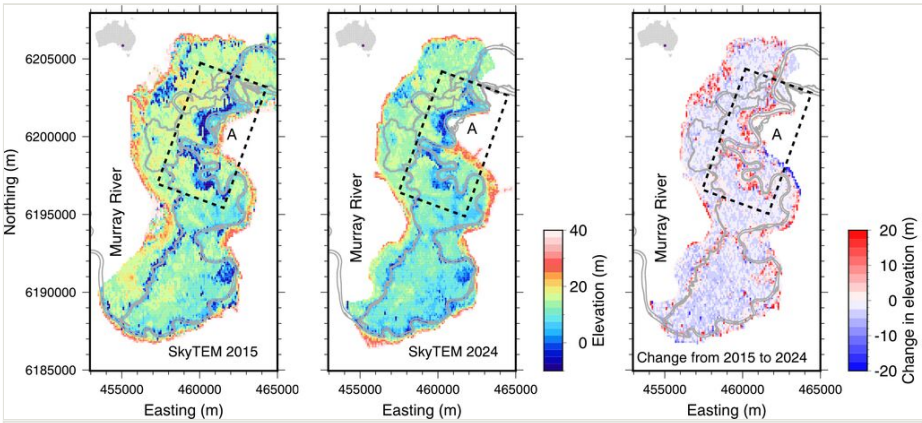

Figure 1. doi

Simultaneous time-lapse inversion of two airborne electromagnetic surveys (SkyTEM) collected in 2015 and 2024 for the evolution of the base of a riparian freshwater lens fed by the Murray River in the Katarapko floodplain in South Australia. The prominent changes of its thickness in area A are likely to be related to the fact that it is controlled by the flow of the Murray River.

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Conflicts of interest

The authors have declared that no competing interests exist.