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Transfer learning models for predicting spatiotemporal dynamics of groundwater levels

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Abstract: Accurate assessment of groundwater resources, particularly through the evaluation of groundwater levels, not only aids in understanding the impacts of natural and human activities but also enables effective management policies to address unsustainable groundwater usage, especially in drought-prone areas. Additionally, the quantification of dynamic groundwater levels plays a crucial role in the design of water banking schemes in aquifers aquifer (aquifer recharge to bank available water resources for recovery during dry or drought periods), offering a cost-effective solution to meet dry-season water demand and minimize evaporative losses during storage. Predicting temporal dynamics of groundwater levels across aquifers (i.e. spatial variation between observations) represents a step forward for predicting water tables or piezometric head surfaces that are typically modelled using interpolation techniques at a point in time.

This study evaluated the benefits of transfer learning for better generalization performance of spatiotemporal prediction of groundwater levels in seven key alluvial systems in the Murray-Darling Basin (MDB). We first built deep learning models with convolutional structures for capturing the spatiotemporal relationships between groundwater levels (represented as depths to water tables in this study) and the driving factors that account for the spatiotemporal variations in groundwater levels in each alluvial system. For each deep learning model, we optimized the weights during training and fine-tuned the hyperparameters during validation. Then the pretrained models with optimized parameters and fine-tuned hyperparameters were used to predict the groundwater levels in each alluvial system and compared with observations during the test period.

The results demonstrated the effective predictive skill of predicting groundwater levels when knowledge transferring and static descriptors are used to improve model generalization in alluvial systems in the MDB. The applicability of transfer learning is also explored in this case study. By utilizing transfer learning, the accurate assessment and prediction of groundwater levels become feasible, offering substantial benefits for combating drought and supporting agricultural planning. The models also enable prediction of level responses (hindcast and forecast) given ancillary datasets (e.g., climate projections), to inform future groundwater and agricultural management. Reliable predictions of groundwater levels during drought periods are crucial for agricultural planning. Farmers can optimize irrigation strategies, adjust cropping patterns, and allocate water resources effectively, thus mitigating the impacts of water scarcity on agricultural productivity.

Keywords: *Transfer learning, deep learning, spatiotemporal modelling, groundwater levels, Murray–Darling Basin*