26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

A machine learning framework to enhance long-term drought forecast with spectrally transformed climate predictors

Liangjing Zhang [a], Ze Jiang [a], Bede Johnson [b], and Ashish Sharma [a]

[a] *School of Civil and Environmental Engineering, University of New South Wales, Sydney, 2052, Australia,*
[b] *WaterNSW, Parramatta, New South Wales, 2150, Australia*
Email: ze.jiang@unsw.edu.au

Abstract: Robust decadal hydrological forecasts are indispensable for water-resources planning, disaster-risk reduction, and climate adaptation. Large-scale climate teleconnections such as El Niño–Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), El Niño Modoki (EMI) are widely used as predictors for long term drought forecasts. However, the complex interactions among these systems, together with limited data availability, constrain forecast skill at long lead times. This raises the question of whether machine learning methods can improve prediction skills. The aim of this research is to develop a spatiotemporal machine learning framework combined with spectrally transformed climate predictors by Wavelet System Prediction (WASP) to improve decadal drought forecast.

We first propose a spatially and temporally independent machine learning framework integrating empirical and dynamical predictions. The empirical forecasts use historical sea surface temperature anomalies as predictors, while the dynamical forecasts adopt concurrent climate indices simulations from different CMIP6 Decadal Climate Prediction Project (DCPP) models (Boer, Smith, Cassou et al., 2016). Spectral transformation using WASP significantly enhances the predictive capacities of climate teleconnections (Jiang & Sharma, 2025). Then machine learning method simplifies climate predictors selections and automatically combine variables in a complex and nonlinear pattern, producing predictions of standardized precipitation index (SPI) across Australia. Results show that prediction skill of SPI can extend up to lead 2-3 year with the spatially and temporally independent machine learning framework.

To address limitations of data availability due to the relatively short hindcast record of CMIP6 DCPP (from 1961 onward), a spatiotemporal machine learning framework is further developed to give reliable forecasts. Rather than considering simulations of responses as independent locations, spatial model captures effects of predictors of adjacent grids, while models with temporal pattern involve simulations of different lead in one general model with larger number of effective datasets as inputs. Spatiotemporal machine learning model efficiently improves model stability for predictions up to 5 years by virtue of increasing datasets and avoid overfitting occurred in independent simulations of each grid.

The spatiotemporal machine learning framework is promising for long-term hydrological prediction. Combing the method with the derived drought indices (Jiang, Johnson, & Sharma, 2023), the framework can better predict future dry and wet anomalies in the decadal time scales. This research contributes to Australian industries like WaterNSW actionable guidance for reservoir operation optimization, roadmaps of water management, and climate-adaptation strategies.

REFERENCES

Boer, G. J., Smith, D. M., Cassou, C., Doblas-Reyes, F., Danabasoglu, G., Kirtman, B., . . . Eade, R. (2016). The Decadal Climate Prediction Project (DCPP) contribution to CMIP6. *Geosci. Model Dev., 9*(10), 3751-3777.

Jiang, Z., Johnson, F., & Sharma, A. (2023). Do Derived Drought Indices Better Characterize Future Drought Change? *Earth's Future, 11*(7), e2022EF003350. doi:10.1029/2022EF003350

Jiang, Z., & Sharma, A. (2025). Decadal drought prediction via spectral transformation of projected Sea Surface Temperatures. *Journal of Hydrology X, 27*, 100203.

Keywords: *Decadal prediction, Hydrologic forecasting, Spectral transformation, Machine learning*

Acknowledgements: The authors are especially grateful to the support and encouragement provided by the late Mr Golam Kibria of WaterNSW, from acquisition of funding, to refinement of the proposal, to presentation of the research.