EGU25-4905, updated on 12 Apr 2026
https://doi.org/10.5194/egusphere-egu25-4905
EGU General Assembly 2025

Deep learning-based ENSO modeling and its prediction and predictability study

Lu Zhou[1] and Rong-hua Zhang[1,2]
[1]School of Marine Sciences, Nanjing University of Information Science and Technology, Nanjing, China
[2]Laoshan Laboratory, Qingdao, China

A novel deep learning (DL) transformer model, named the 3D-Geoformer, has been developed for ENSO-related modeling studies in the tropical Pacific. Multivariate input predictors and output predictands are selected to adequately represent ocean-atmosphere interactions; so, this purely data-driven model is configured in such a way that key fields for the coupled ocean-atmosphere system are collectively and simultaneously utilized, including three-dimensional (3D) upper-ocean temperature and surface wind stress fields, which represents the coupled ocean-atmosphere interactions known as the Bjerknes feedback in the region. The 3D-Geoformer achieves high correlation skills for ENSO prediction at lead times of up to one and a half years. The reasons for the successful prediction with interpretability are explored comprehensively by performing perturbation experiments to predictors and quantifying input‐output relationships in predictions using the 3D-Geoformer. This is achieved by investigating how the thermal precursors contribute to ENSO prediction skills, with the dependence of the precursor representations on preconditioning multi-month input predictors elucidated. Results reveal the existence of ENSO‐related upper‐ocean temperature anomaly pathways and consistent phase propagations of thermal precursors around the tropical Pacific in the DL framework. The research demonstrates that 3D thermal fields and their basinwide evolution during multi-month time intervals act to enhance long‐lead prediction skills of ENSO. It is demonstrated that the 3D-Geoformer can not only have its ability to effectively improve prediction skills of sea surface temperature variability in the eastern equatorial Pacific, but also explain how and why it is so, thus enhancing model explainability.