Leaf Area Index Prediction Using ConvLSTM: Application to South-Central US with Insights into Atmosphere-Vegetation Interactions

Zhixing Ruan[1], Lixin Lu[1], Yu Zhang[2]
1. CIRA, Colorado State University, Fort Collins, CO;
2. The University of Texas at Arlington, Arlington, TX

Evaluating the two-way interactions between the atmosphere and land surface processes is crucial to our understanding of regional and global climate, vegetation dynamics, and watershed hydrology. Weather and climate have deterministic effects on vegetation growth and decay. At the same time, the land surface plays a key role in partitioning radiative energy received at the Earth's surface. Vegetation, through its transpiration and evaporation, modifies the atmospheric and land surface hydrological processes.

Modeling vegetation phenology using common community physics packages can be challenging due to their inability to capture interannual variations, complex spatial heterogeneity, and limited predictive skills. To address this deficiency, we developed a machine learning model, ML-LAI, based on convolutional Long Short-Term Memory (LSTM) techniques to study regional-scale interactions between the atmosphere and Leaf Area Index (LAI). Our model utilizes surface air temperature and precipitation data from meteorological stations, trained with data at 4-day intervals and 1 km spatial resolution, to predict LAI over Southwestern and south-central parts of the United States. We used data from 2003 to 2021 for training, and tested the model's performance for the years 2022 and 2023.

We evaluated the model by comparing its predictions with the Moderate Resolution Imaging Spectroradiometer (MODIS) LAI product MCD15A3H, a 4-day composite dataset with a 500-meter pixel size. This product algorithm

selects the best pixel available from both MODIS sensors on NASA's Terra and Aqua satellites. The average predicted LAI values across the domain area differed by less than 0.03 from the actual LAI values, and effectively captured both seasonal and interannual variations. Additionally, we analyzed regional LAI values based on different land cover types. The model demonstrated robustness in predicting LAI for shrublands, croplands, evergreen needle leaf forest, grasslands, savannas and woody savannas. This shows its potential as a valuable tool for studying the complex interactions between the atmosphere, biosphere, and hydrosphere.