AI-powered ecosystem demography model to tackle the computational bottleneck

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Science Questions

- Can deep learning models approximate the complex ecological processes in the ecosystem demography (ED) model? What's the impact of error accumulation?
- Can deep learning approximations reduce the computational cost of ED?

Analysis

- Datasets: meteorology from NASA Dayment and MERRA2, soil properties from the POLARIS dataset, and CO2 concentration from NOAA Carbon Tracker.
- Existing models for time-series forecasting, e.g., long-short-term-memory (LSTM) models and variants, long- and short-term time-series network (LSTNet), sequence2sequence (Seq2seq) models.
- Proposed a new deep learning model, Deep-ED, to address challenges of long-term error accumulation through targeted designs, including a multi-granularity multi-branch network architecture, a specialized de-sequencing loss, self-guided learning, and active learning.

Results/Significance

- Direct applications of standard deep learning models (e.g., LSTM, LSTNet models) suffer from error accumulations over long-term, leading to low estimation performance.
- Our model, Deep-ED, showed high approximation quality through new designs to handle compounding errors for vegetation height, above-ground biomass, soil temperature, etc.
- Computationally, ED uses CPU whereas Deep-ED uses GPU. While not an apple-to-apple comparison, it took ED ~192 CPU hours to generate forecasts for 1000 sites with 8 initial conditions for 40 years, and Deep-ED ~72 seconds (~0.02 hours) for the same task.

Acknowledgements

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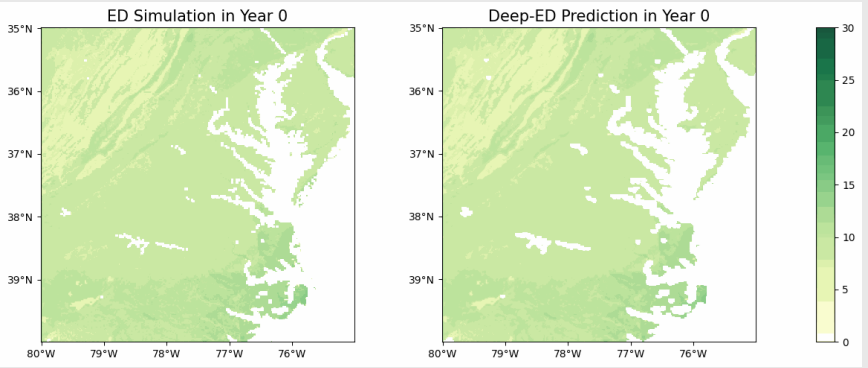

Figure 1: Comparison of the results on vegetation height (unit: meter) between ED and Deep-ED in the Northeastern US (35°N~40°N, 75°W~80°W) during 1980 to 2020. The results show that Deep-ED can achieve high-quality approximation over long-term.

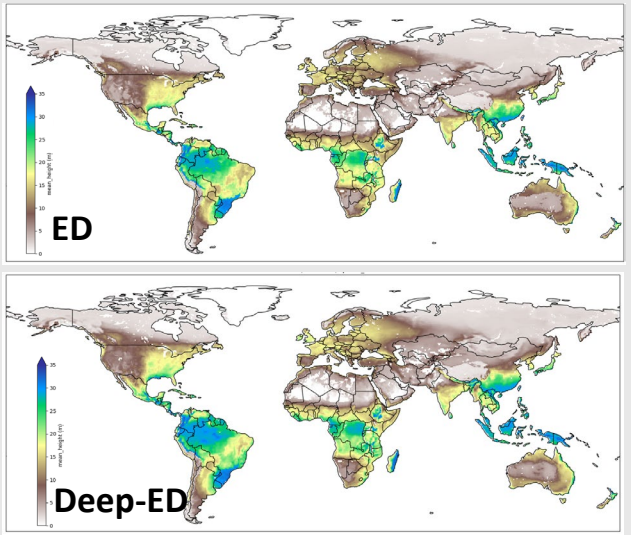

Figure 2: Deep-ED for estimating global vegetation height over 40 years at 0.5-degree resolution.