Earth Sciences Department

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Historical Reconstruction and Future Projection of Land Surface Boundary Conditions

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Why dynamic LSBC?

Land Surface Boundary Conditions (LSBC): Land Use (LU), Land Cover (LC), and Leaf Area Index (LAI), define land-atmosphere interactions, regulating energy, water, and carbon exchanges, and playing a key role in the carbon cycle.

- **Improved representation of land-atmosphere interactions** ensures more realistic exchanges of water, energy, and carbon between land and atmosphere.
- **Enhanced forecasts and projections** improve near-surface weather and climate predictions for better risk management, adaptation, and mitigation.

Figure is generated by ChatGPT

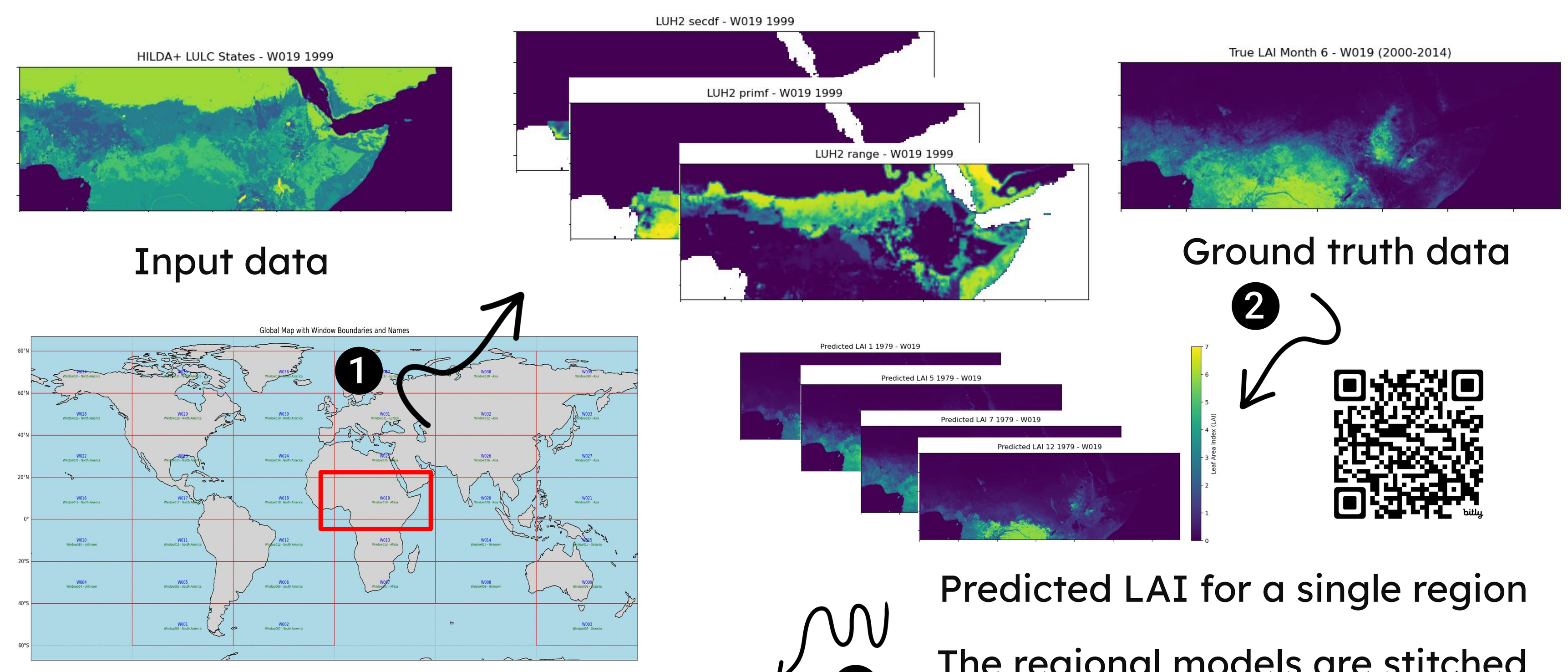
Datasets

- **ESA CCI LC** yearly [1992–2020] maps at 300 m resolution
- **CONFESS LAI** 5-days intervals [1980–2020] maps at 1 km resolution
- **HILDA+ LU** yearly [1899–2020] maps at 1 km resolution
- **LUH2 LU** yearly [950–2100] maps at 0.25° x 0.25° resolution
- **Köppen-Geiger climate classification** [present–future] maps at 1 km resolution
- Soil and Topography from **PNNL Global** at 1 km resolution **LSM for ESM**

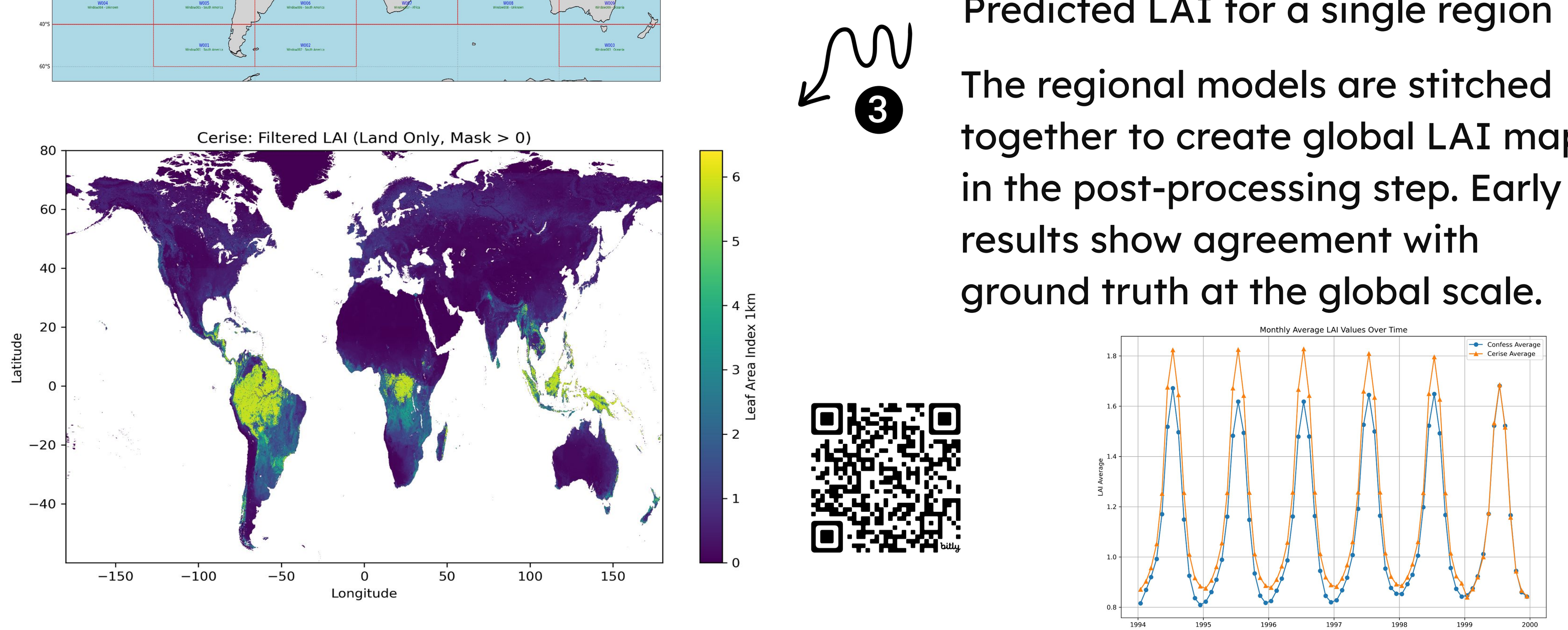
LAI

Historical reconstruction of LAI

We developed a multi-scale approach for monthly LAI reconstruction at 1 km resolution using LUH2 and HILDA+ LU data. The global domain was partitioned into 39 independent regional tiles of 20°× 60°, with each model trained using Extreme Gradient Boosting on 14 years of data. The pipeline included re-gridding to target resolution, regional model training on GPU, and post-processing to generate seamless global outputs. Models achieved approximately 90% average misfit reduction.



Predicted LAI for a single region

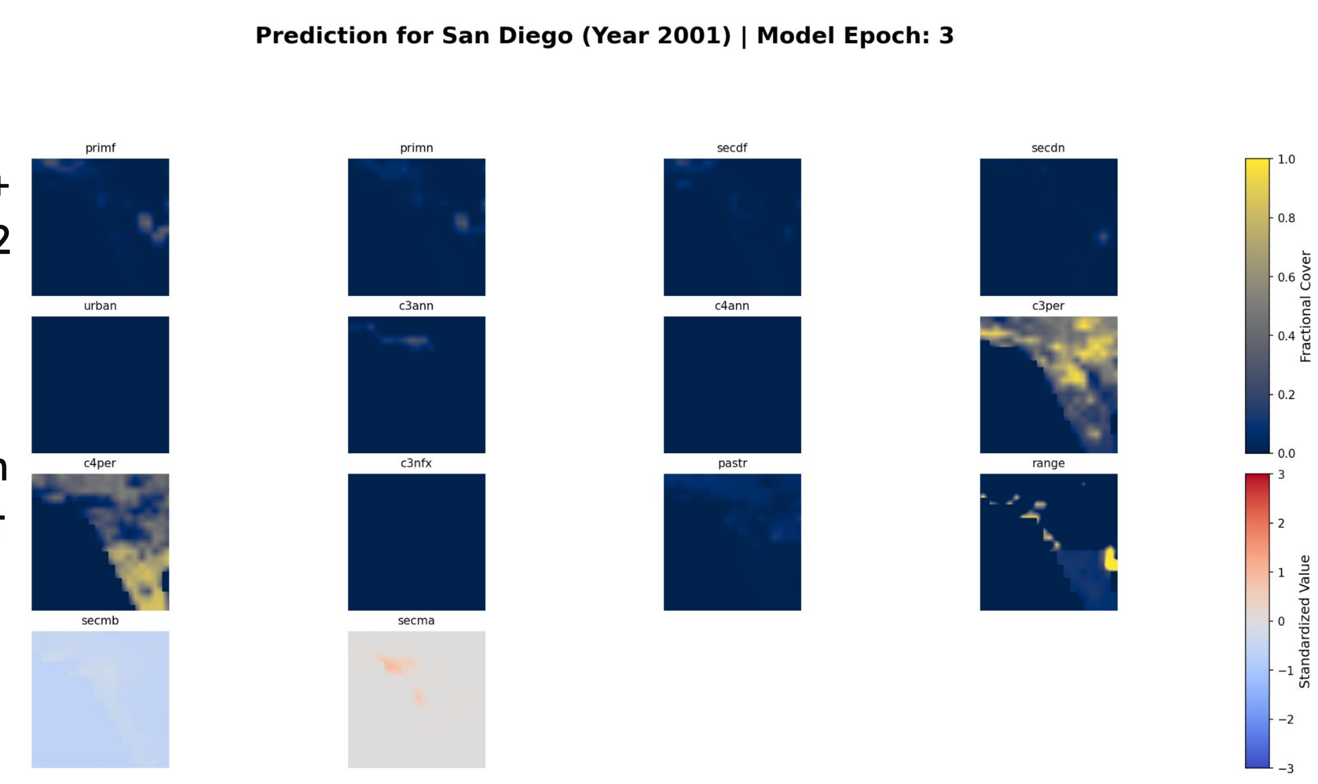


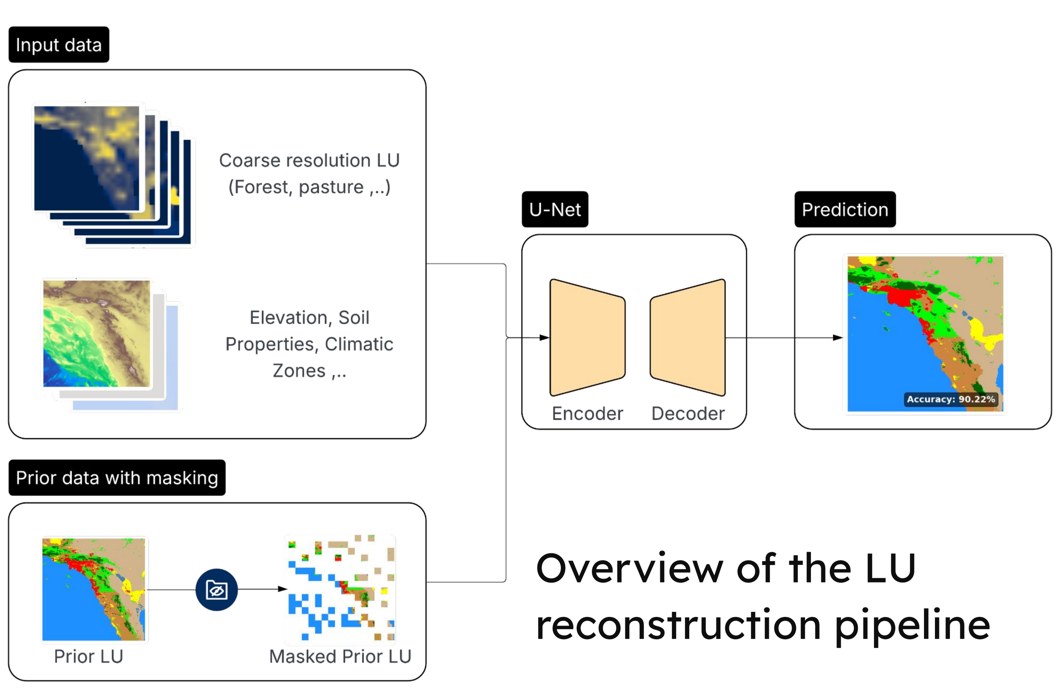
The regional models are stitched together to create global LAI maps in the post-processing step. Early results show agreement with ground truth at the global scale.

LU

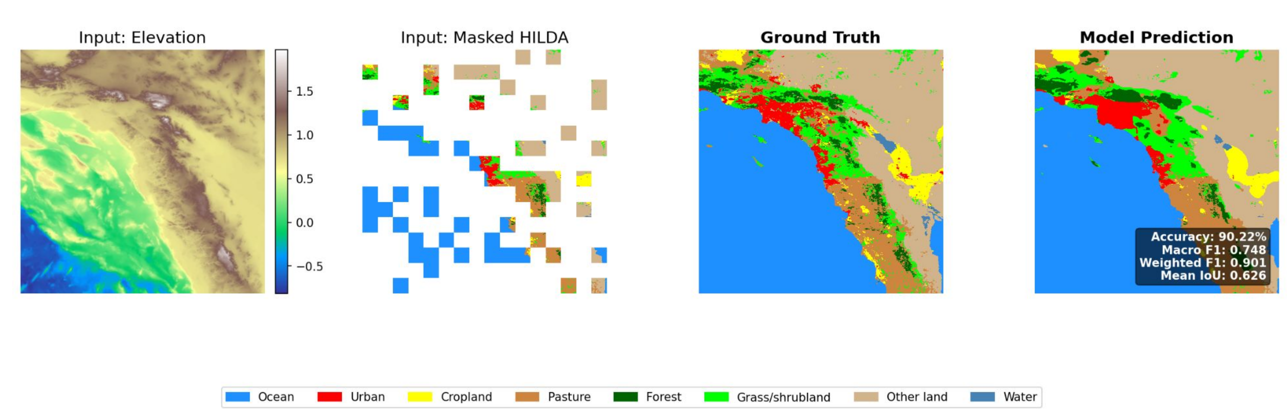
Historical reconstruction & future projection of LU

We developed a U-Net architecture for LU reconstruction with a preprocessing pipeline aligning datasets to HILDA+ at 1 km resolution. Inputs included coarse-resolution LUH2 fractional LU variables, topographical data, and a partially masked prior LU map. The encoder-decoder U-Net with skip connections was trained on 30,000 samples, achieving 90% accuracy under 75% masking with mean Intersection over Union of 0.626. This reflects robust performance on dominant classes but confusion between similar vegetation types and difficulty detecting small features. Average mIoU of ~0.42 across test regions highlighted challenges with underrepresented LU types.





Overview of the LU reconstruction pipeline



Reconstruction of the LU map for the city of San Diego for the year 2001, using LUH2 fractional LU with 0.25° x 0.25° resolution, an elevation map, and a prior LU map randomly 75 percent masked with 32 by 32 pixel patches.

What is next?

- **Expand LU reconstruction:** Incorporating climatic zone and soil information as additional input channels to improve model accuracy.
- **Develop LC prediction:** Expanding to high-resolution LC reconstruction using ESA CCI dataset with climate variables from ERA5 data.
- **Implement LAI modeling:** Extending framework to predict monthly LAI maps, exploring sequential models and joint multi-task approaches.
- **Adopt models as emulators:** Integrating developed LU, LC, and LAI models as emulators within IFS and ICON weather-climate modeling frameworks.

CONCERTO TerraDT CERISE

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