TeleViT: Teleconnection-driven Transformers Improve Subseasonal to Seasonal Wildfire Forecasting

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Motivation

- High variability between fire seasons (largely explained by antecedent conditions)

- Climate change fosters extreme fire conditions

- Crucial to forecast fire season severity early on to improve
  - Procurement of resources
  - Fuel management
  - Evacuation planning

GWIS Annual Statistics for Canada
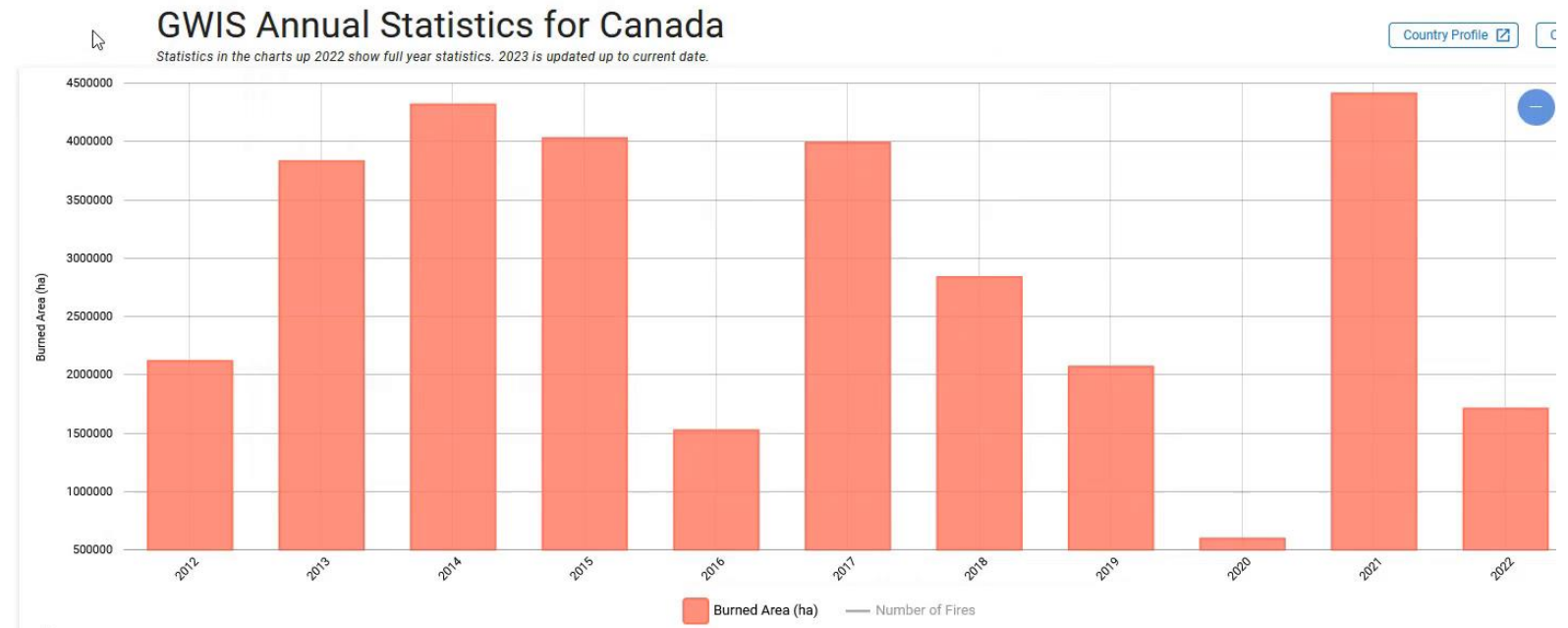
Current state

- Long-term wildfire forecasting as weather anomalies
  - Sub-seasonal forecast

    Temperature, Rain Anomalies 1-6 weeks
  - Seasonal Forecast

    Temperature, Rain Anomalies 1-6 months

- *Gap: For wildfire forecasting, other aspects are also important, e.g. vegetation, sustained drought/moisture, human activity*

- *Goal: Use Machine Learning → learn to associate burned areas to weather and EO data*
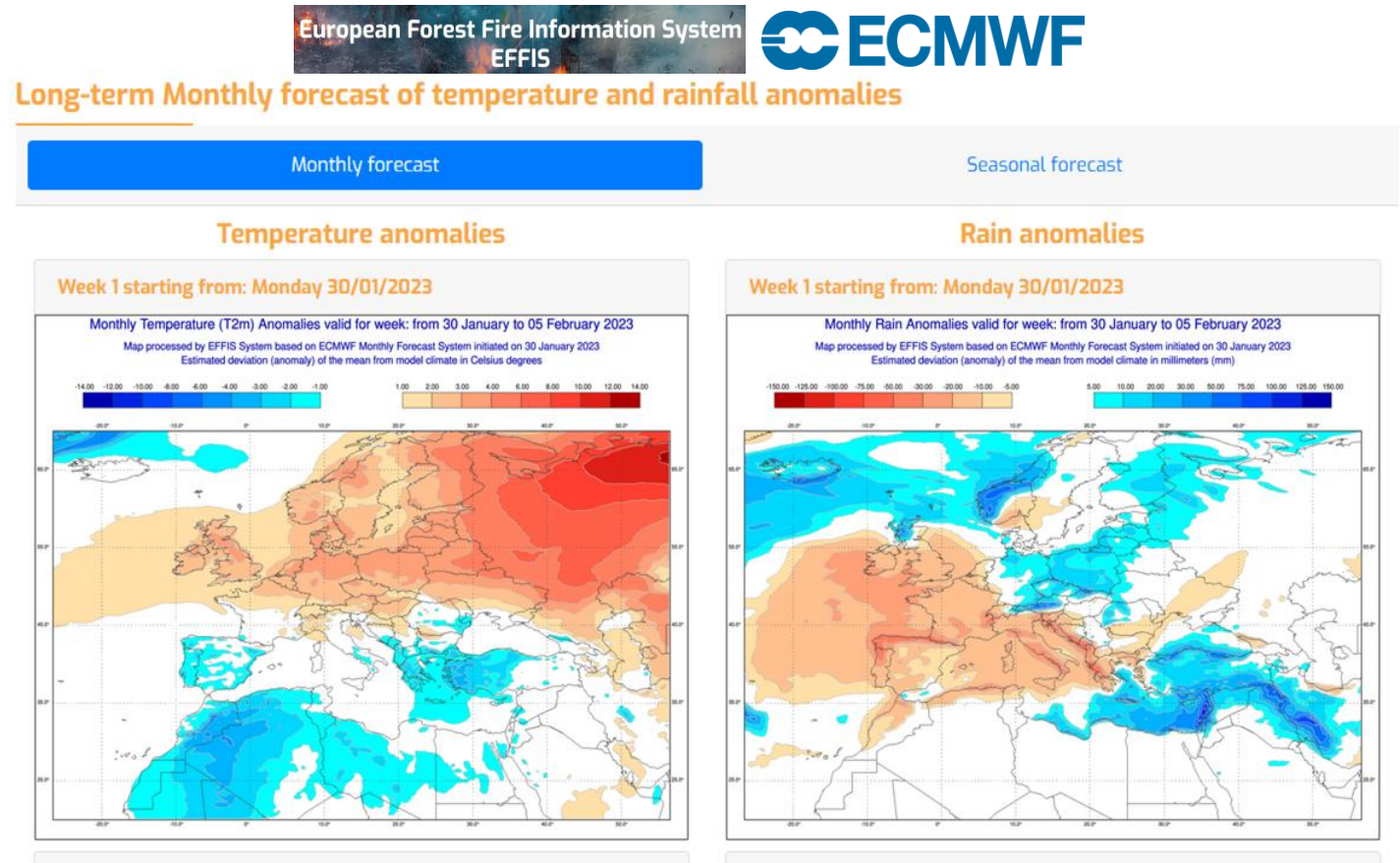
EFFIS long-term forecasts
https://effis.jrc.ec.europa.eu/apps/effis.longterm.forecasts/

SeasFire Datacube
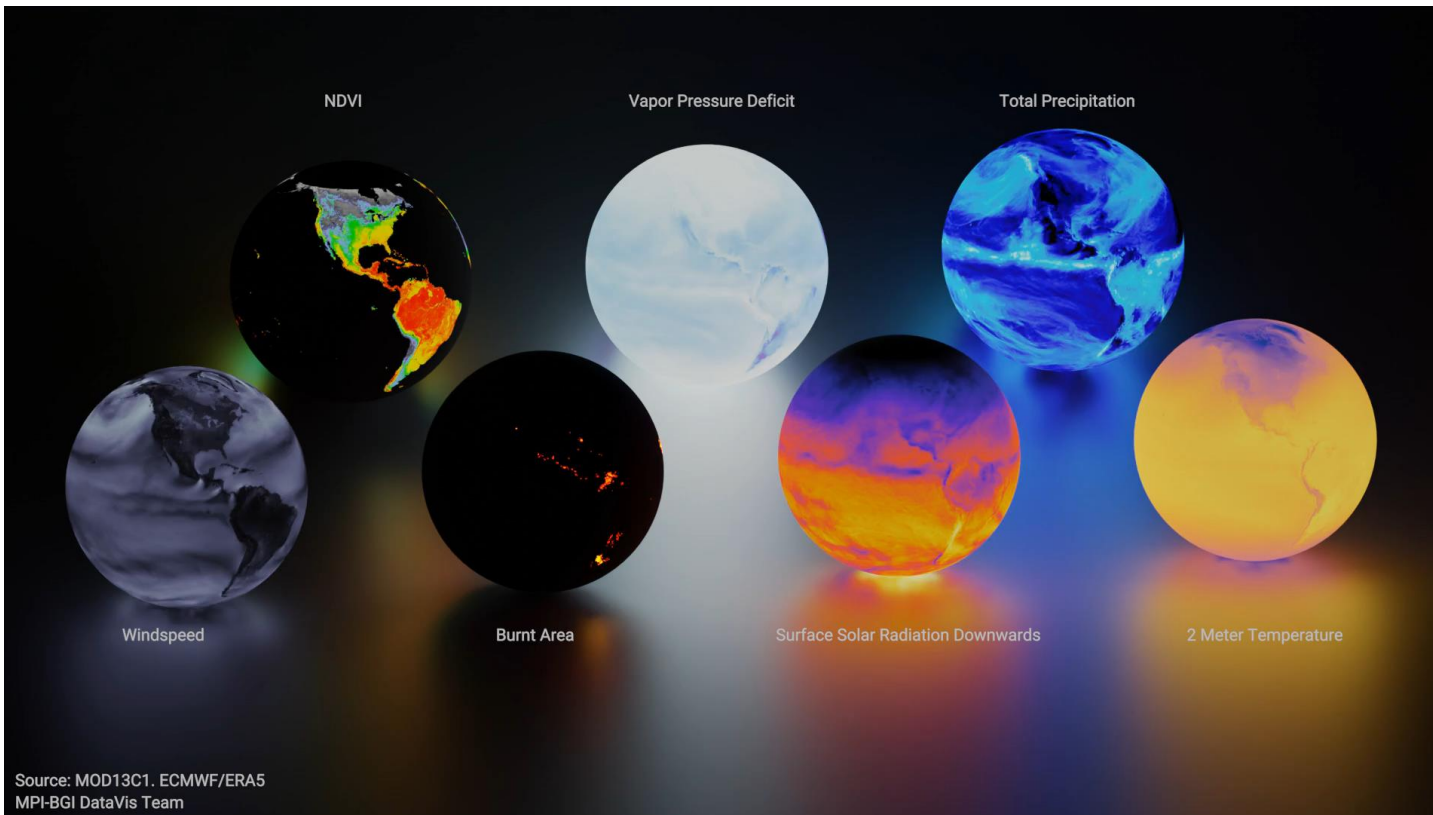
SeasFire Cube: A Global Dataset for Seasonal Fire Modeling in the Earth System [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7108392

SeasFire Datacube

- Resolution: 8days x 0.25° x 0.25°
- Extent: Global, 2001 - 2021

Wildfire drivers

- Meteorology (ERA5)
- Satellite Observations (MODIS)
- Vegetation, Surface Temperature
- Oceanic Indices (NOAA)
- Population Density (NASA SEDAC)
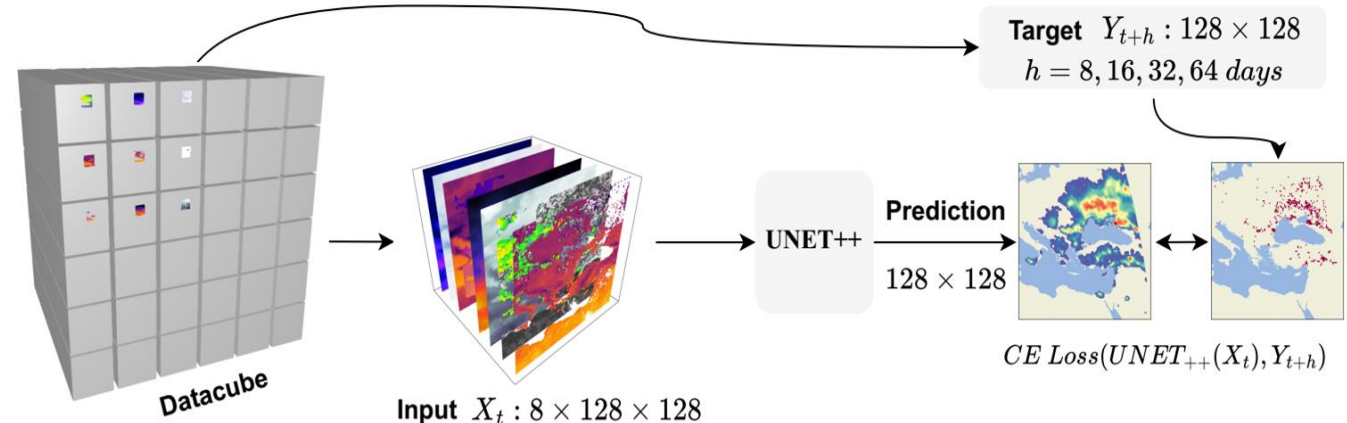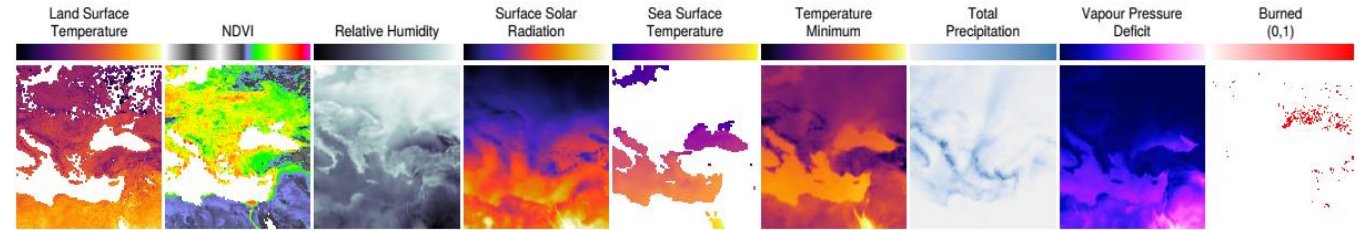- Land Cover (ESA CCI)

Wildfire variables

- Burned Areas (GFED, FireCCI, GWIS)
- Fire Emissions (GFAS)

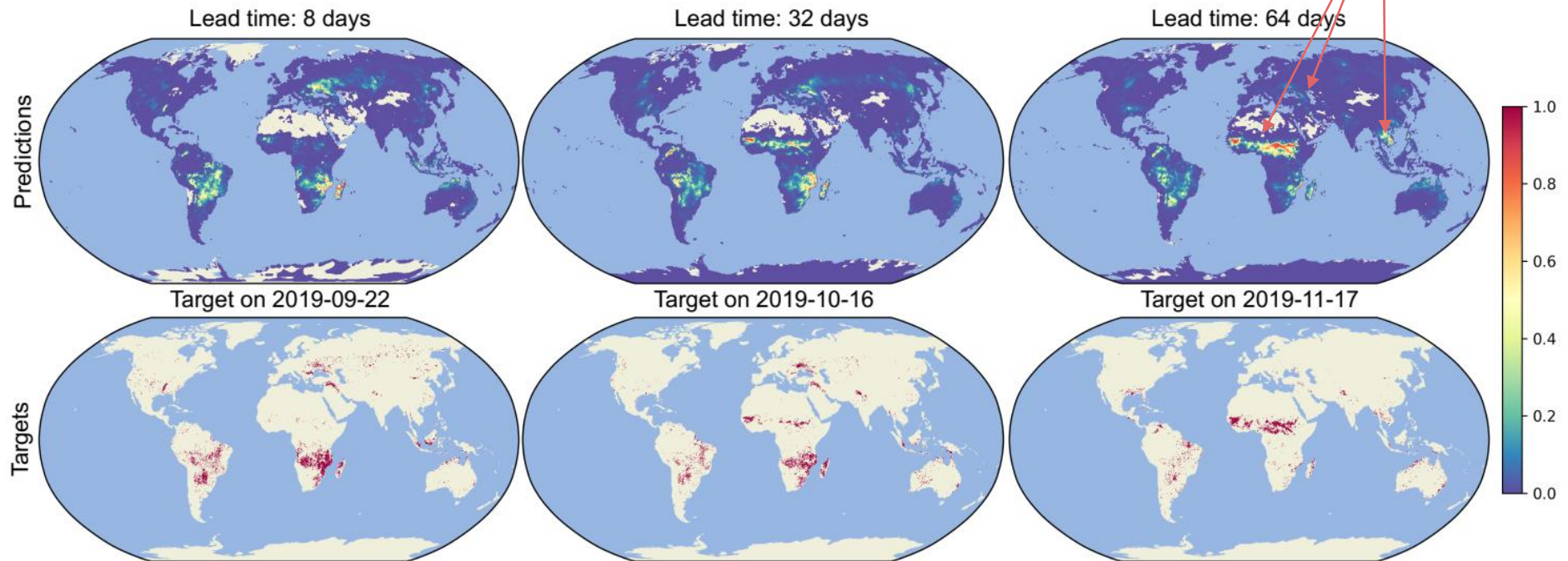# Wildfire forecasting as a segmentation task

- A U-Net model is trained to forecast the burned area pattern

- Input is formed from stacked fire driver variables

- Target: Presence of burned area at time t+h (h=8, 16, 32, 64 days)
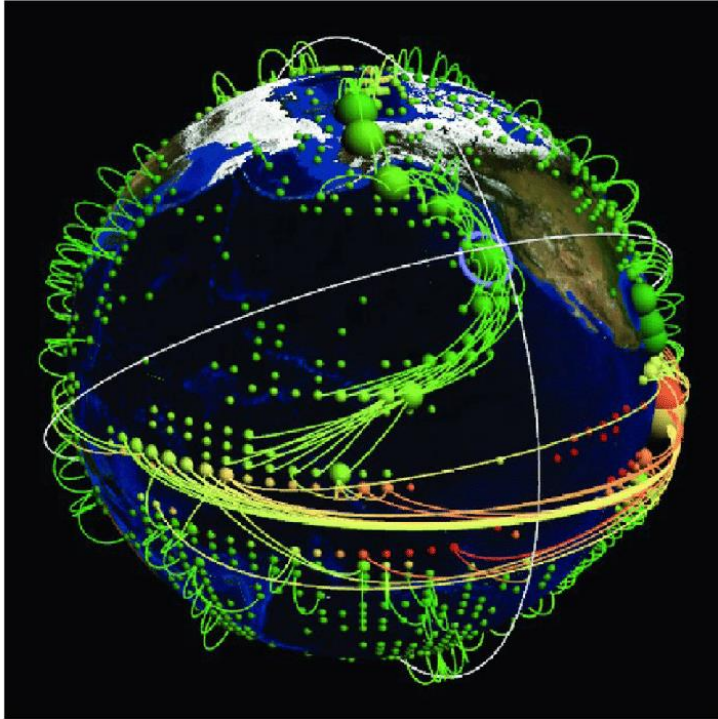
https://www.climatechange.ai/papers/neurips2022/52

Global prediction maps

- Good performance 2 months in advance
- Main patterns and shifts are captured
- Better than statistical baseline (mean seasonal cycle)

Captured change of fire activity in eastern Europe and south-east Asia, shift from the southern to the northern African savanna.

Earth is a complex inter-connected system

Source: Statistical physics approaches to the complex Earth system

- **Teleconnections** are long-range spatiotemporal connections in the earth system. "Arctic oscillation anomalies linked to extreme wildfires in Siberia" Kim et al. (2020)
- **Memory effects** refer to the influence of past events on current and future states of the Earth system. How past events such as fuel accumulation, drought conditions, and weather patterns can impact future wildfires.

Teleconnections modulate wildfires

ARTICLE **OPEN**

Check for updates

Arctic Oscillation and Pacific-North American pattern dominated-modulation of fire danger and wildfire occurrence

Flavio Justino[1], David H. Bromwich[2], Vanucia Schumacher[3], Alex daSilva[4] and Sheng-Hung Wang[2]

nature communications

Article

https://doi.org/10.1038/s41467-023-36052-8

Climate teleconnections modulate global burned area

Adrián Cardil[1,2,3], Marcos Rodrigues[4,5], Mario Tapia[2], Renaud Barbero[6], Joaquin Ramírez[2], Cathelijne R. Stoof[7], Carlos Alberto Silva[8], Midhun Mohan[9] & Sergio de-Miguel[1,3]

RESEARCH ARTICLE | CLIMATOLOGY

Extensive fires in southeastern Siberian permafrost linked to preceding Arctic Oscillation

Jin-Soo Kim[1,2], Jong-Seong Kug[3,*], Su-Jong Jeong[4,5], Hotaek Park[6] and Gabriela Schaepman-Strub[7]

+ See all authors and affiliations

Environmental Research Letters

PAPER

How much global burned area can be forecast on seasonal time scales using sea surface temperatures?

Yang Chen[1], Douglas C Morton[2], Niels Andela[2], Louis Giglio[3] and James T Randerson[1]

[1] Department of Earth System Science, University of California, Irvine, CA 92697, USA
[2] Biospheric Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[3] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA
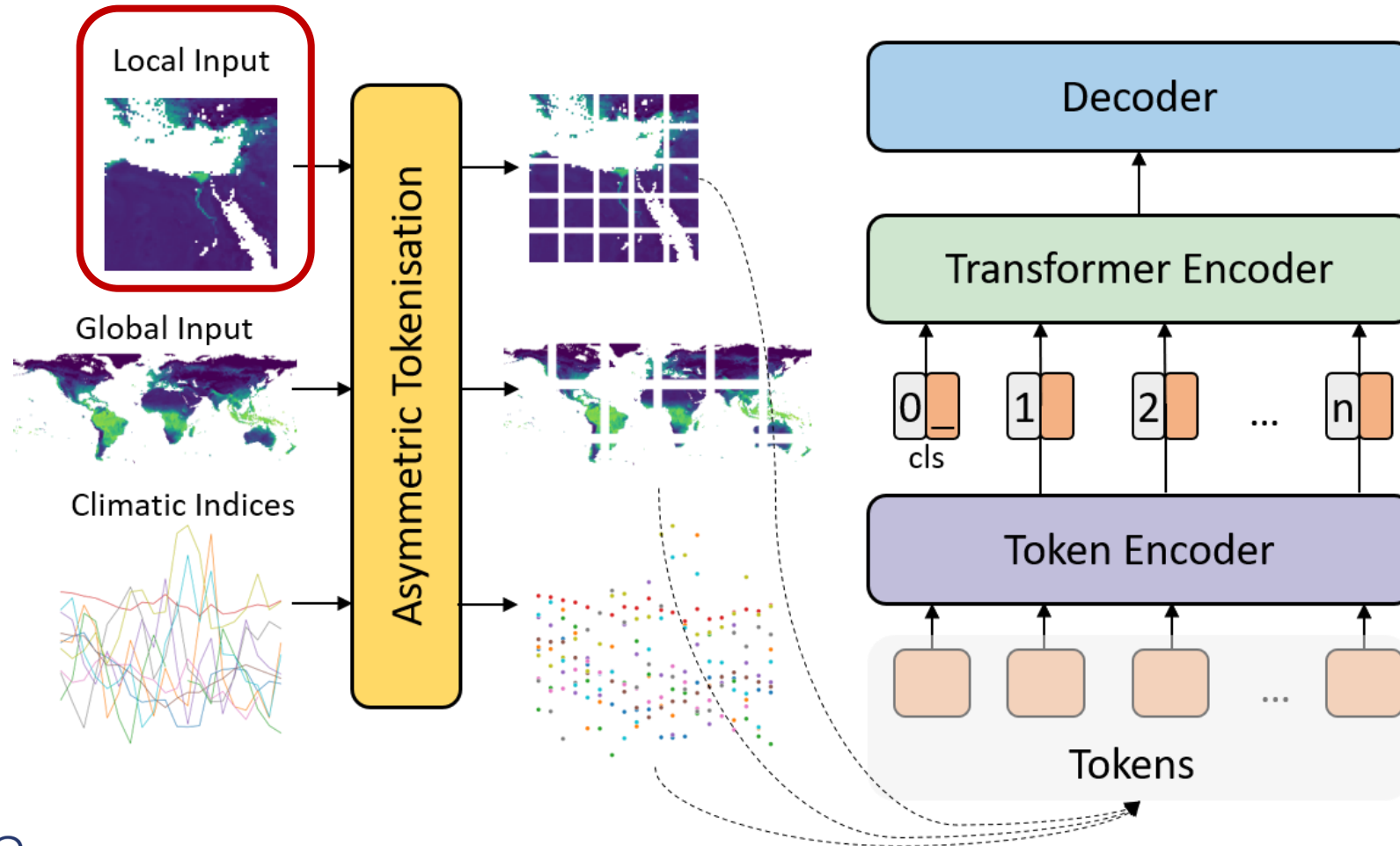
E-mail: yang.chen@uci.edu

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Goal: Use modeling that considers teleconnections and captures such large-scale Earth system dynamics
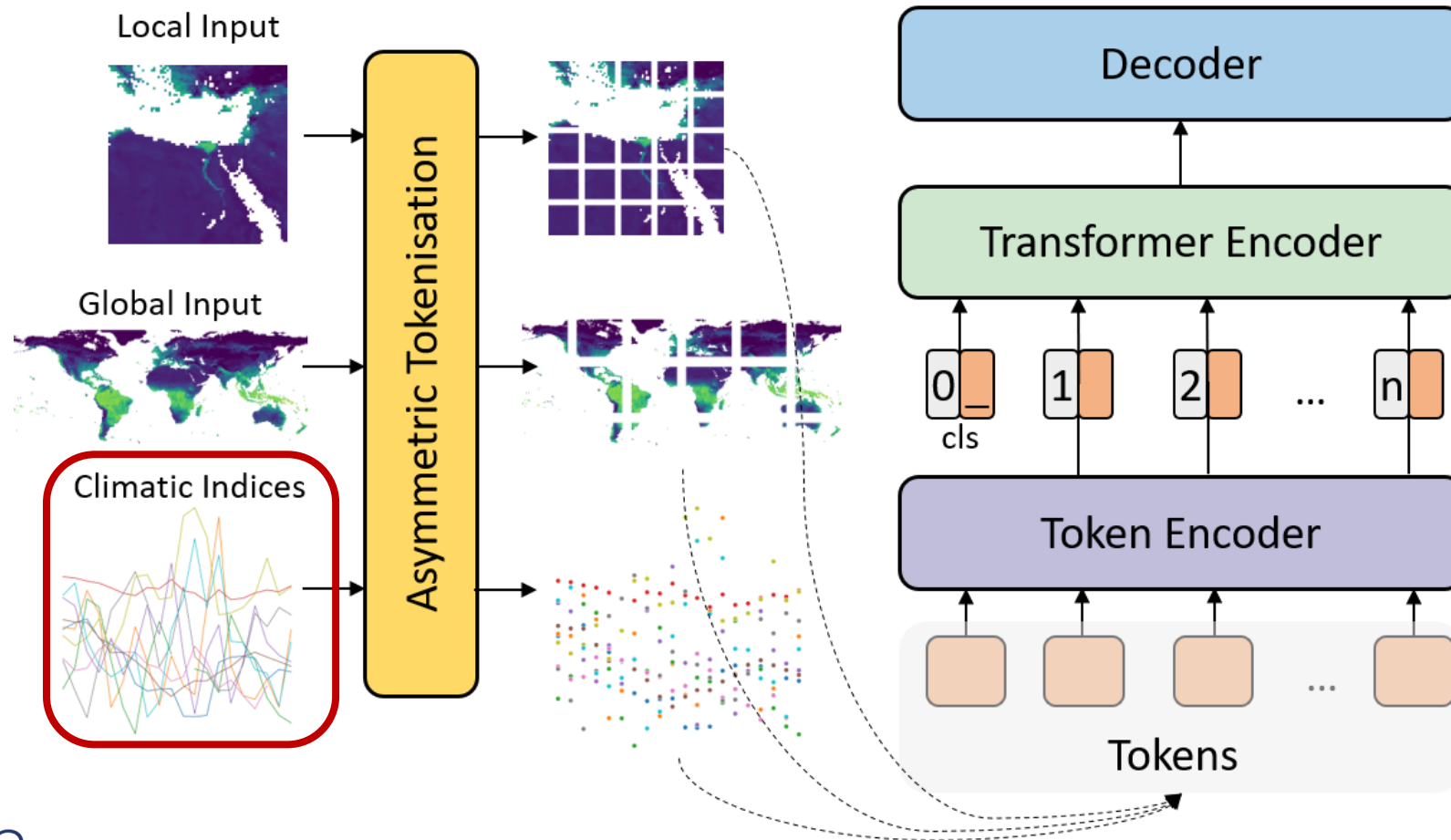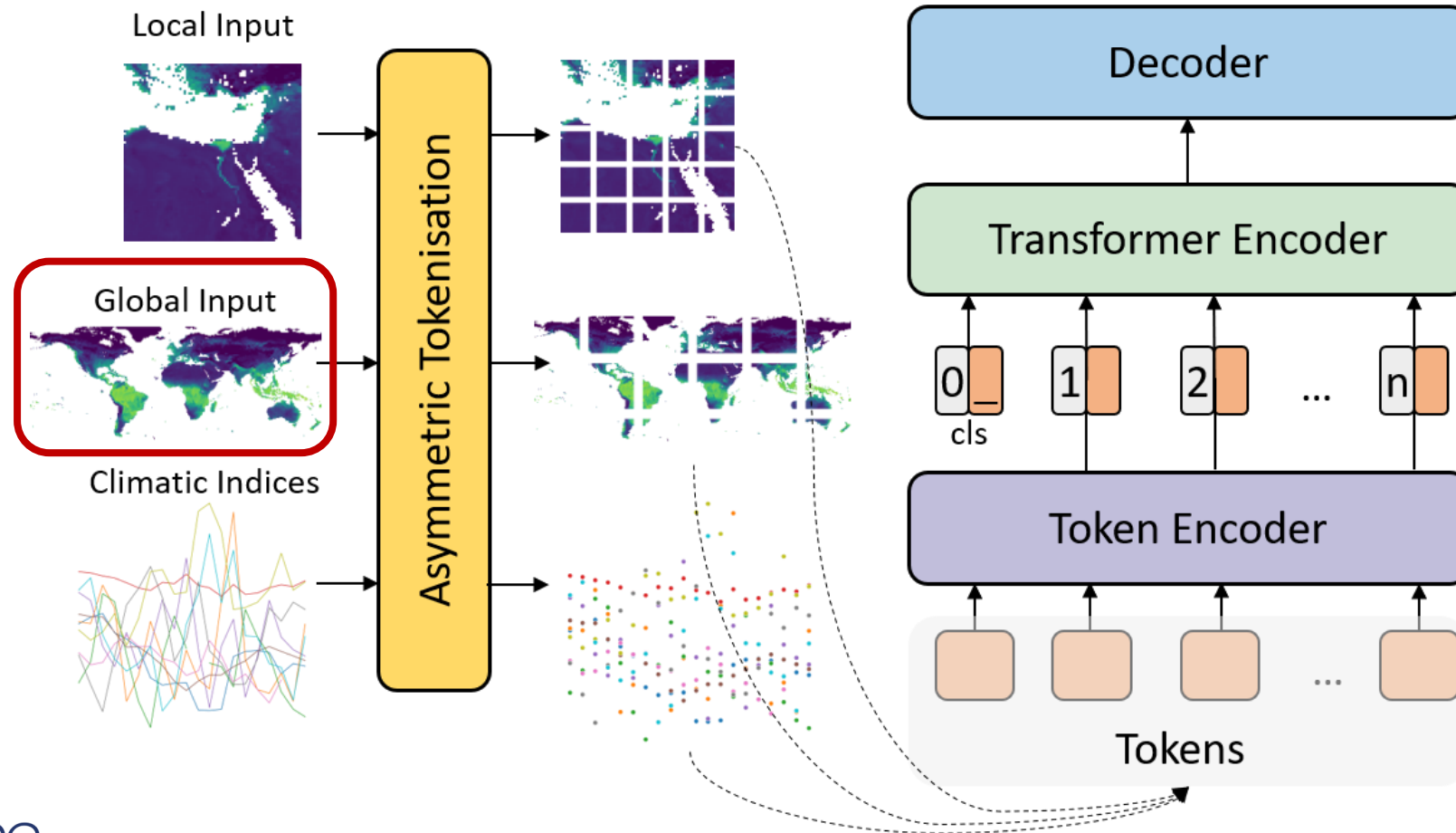
TeleViT: Teleconnection-driven Transformer
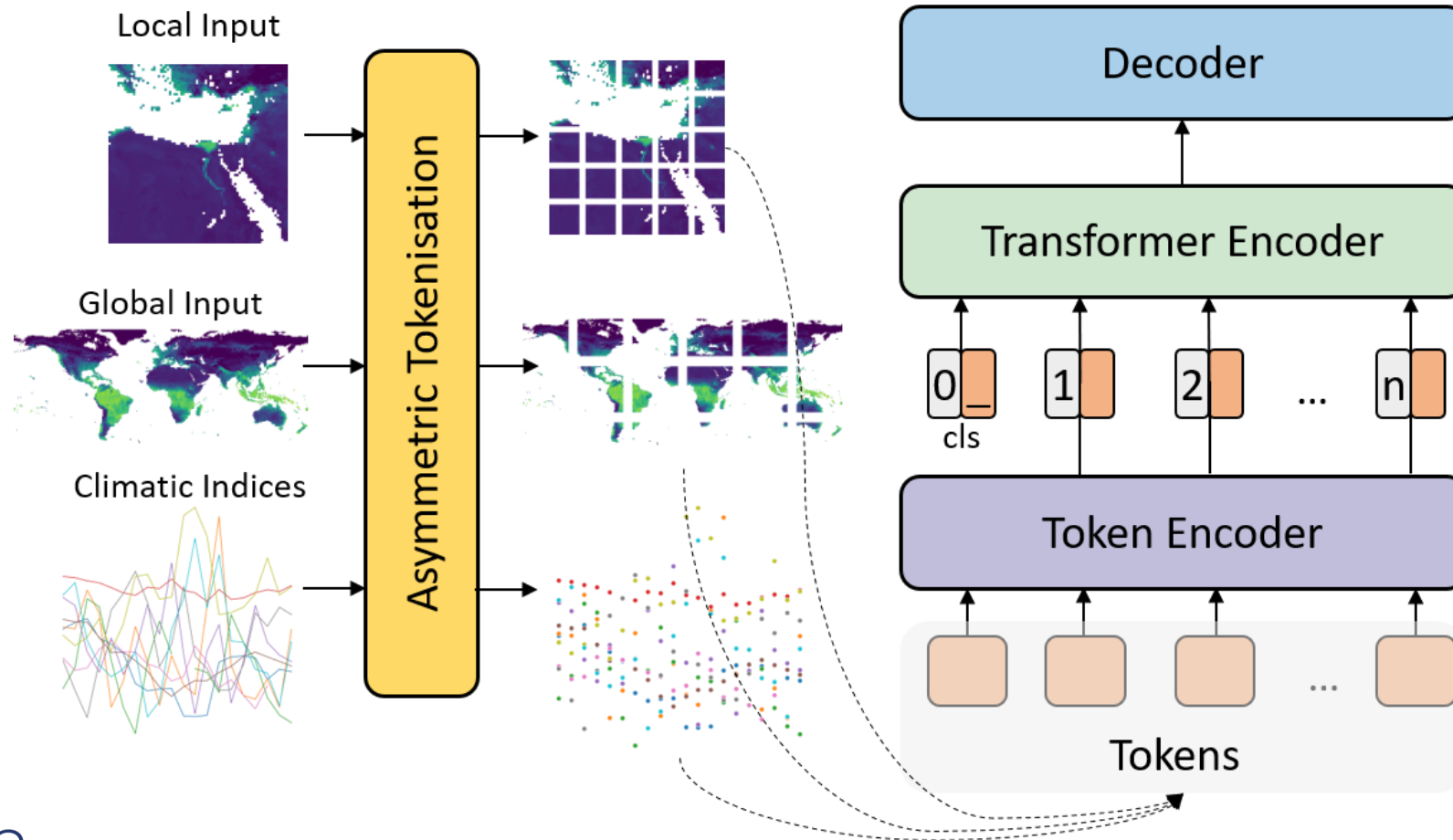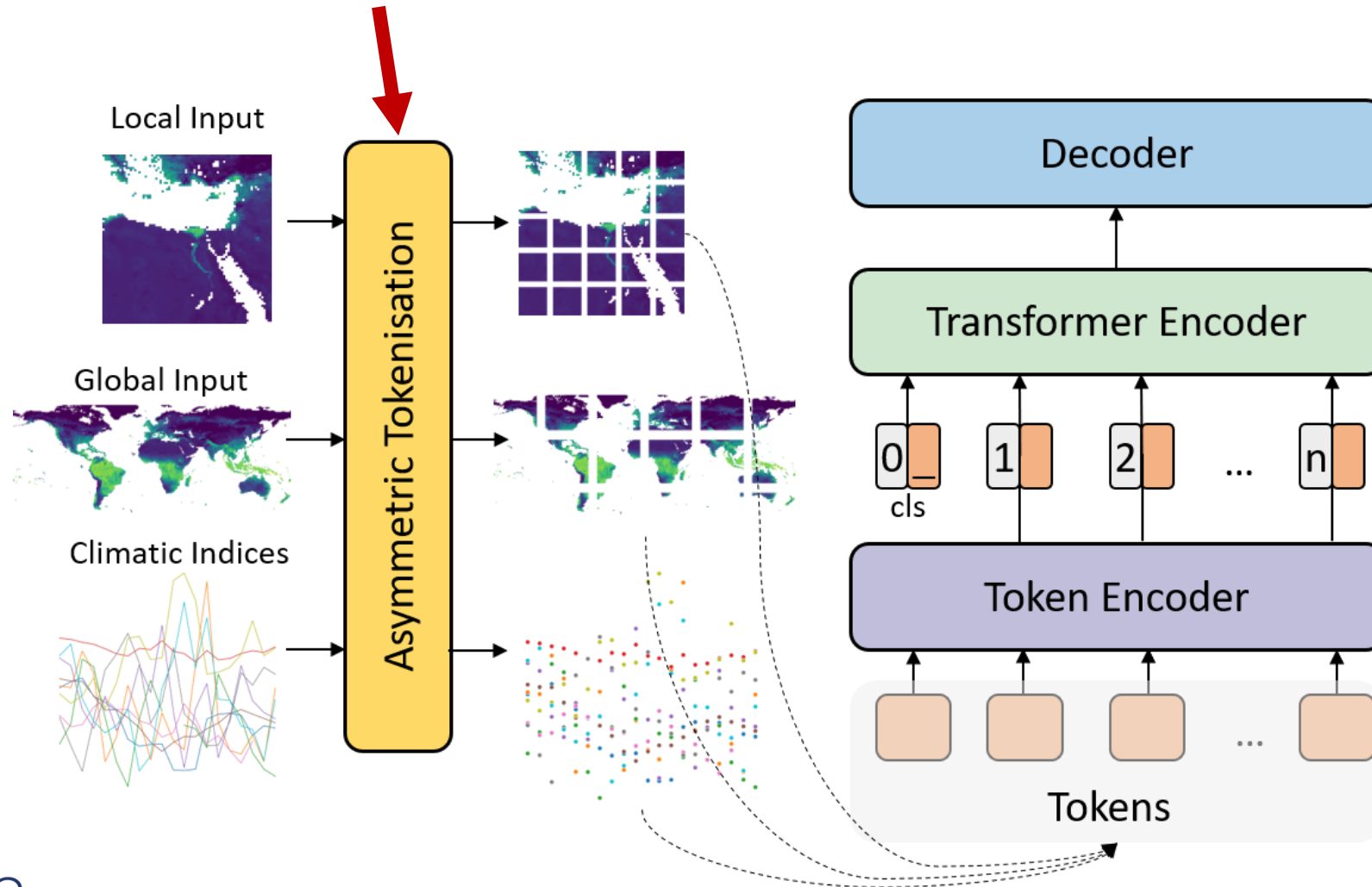
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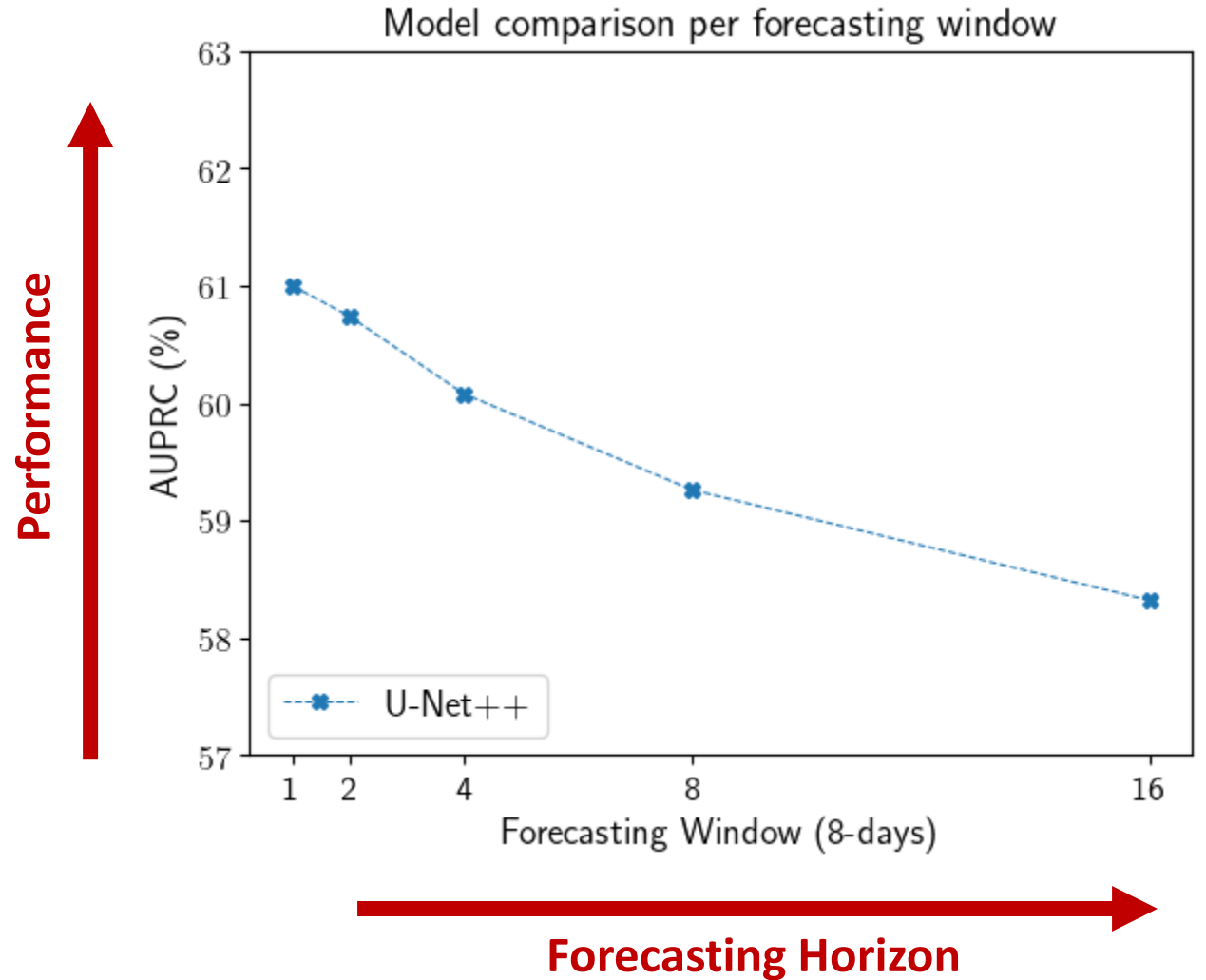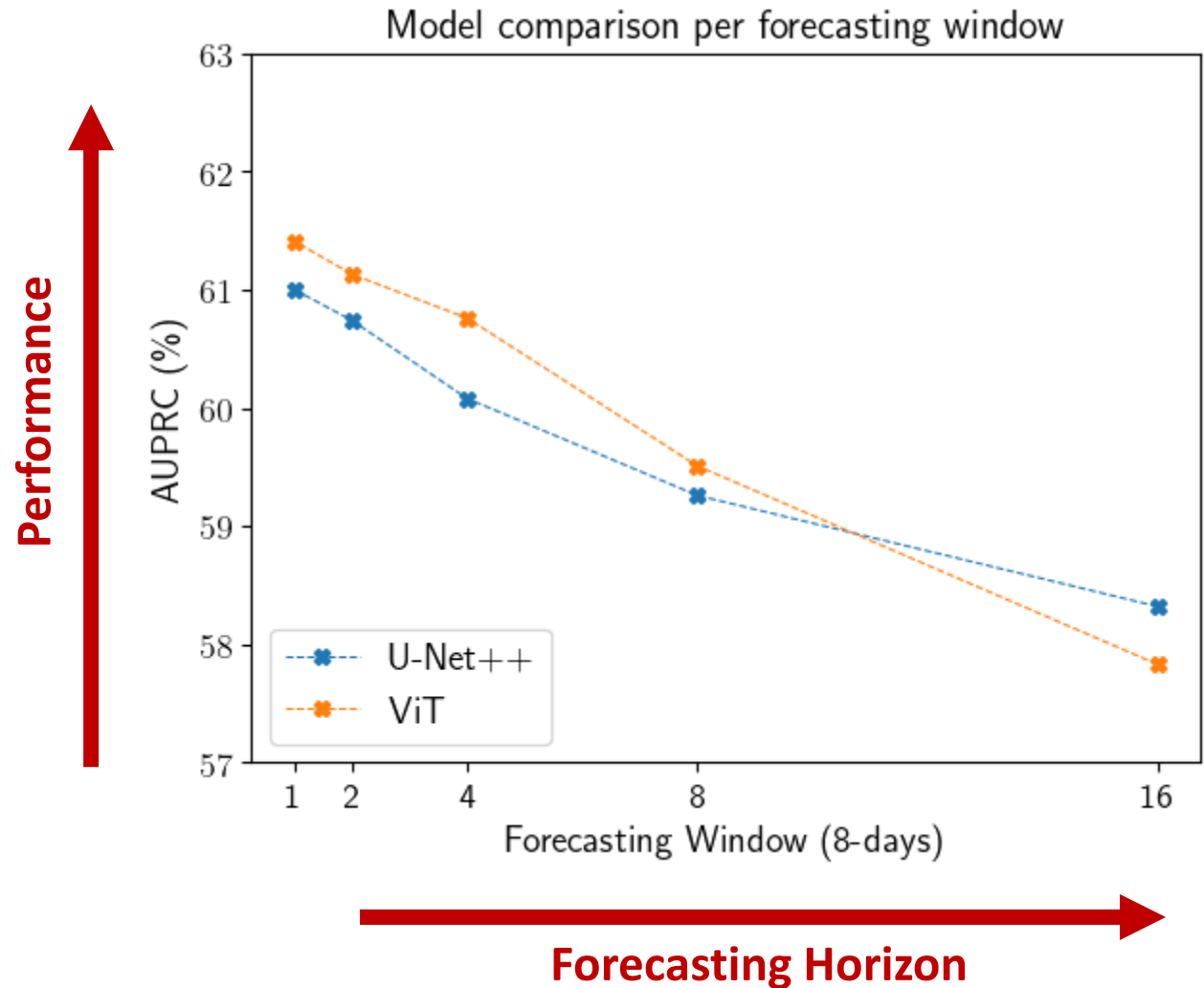
TeleViT: Teleconnection-driven Transformer

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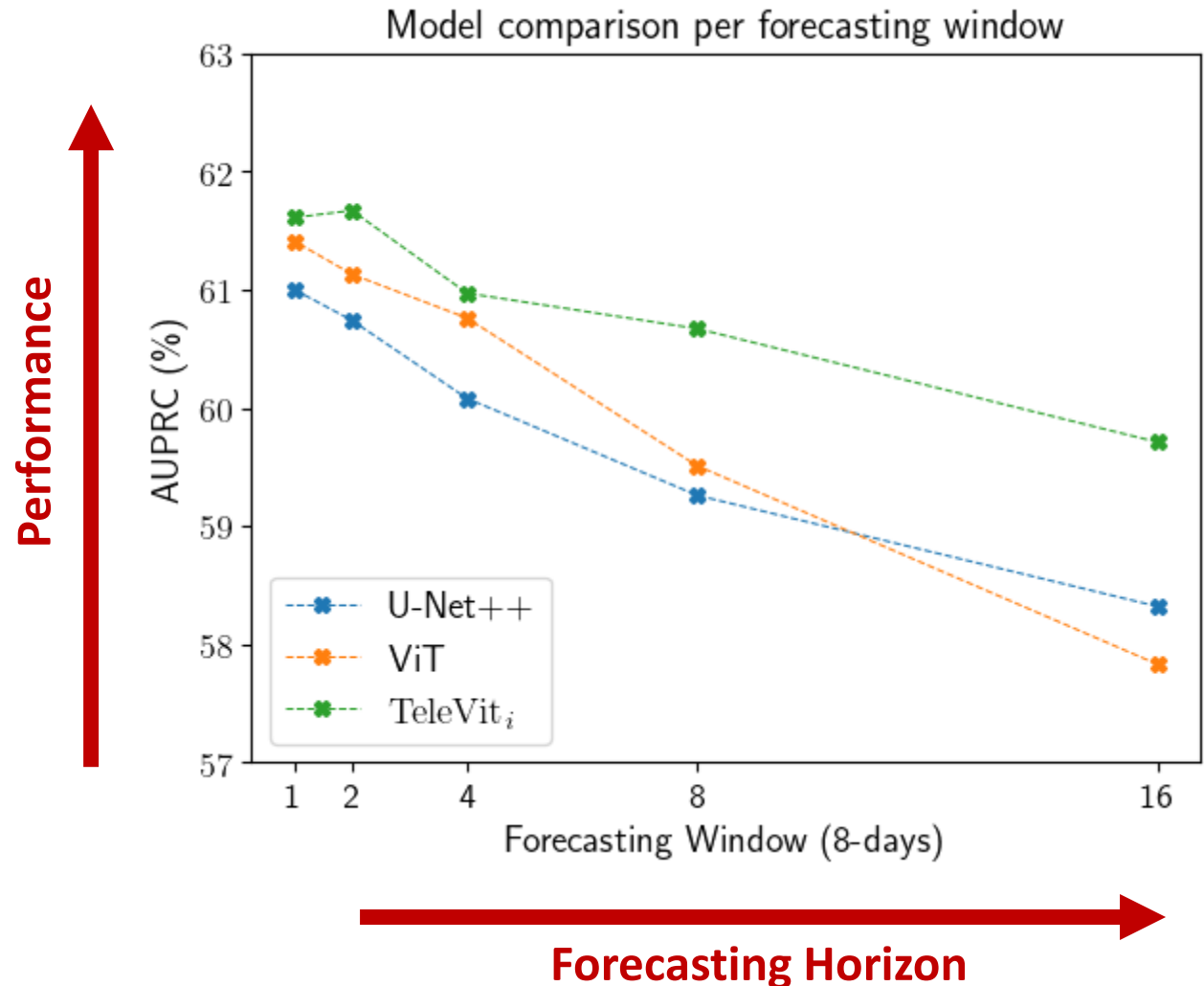# Results

- U-Net++ provides the baseline

Model comparison per forecasting window

Results

- U-Net++ provides the baseline, plain ViT achieves a similar performance

Model comparison per forecasting window

Performance

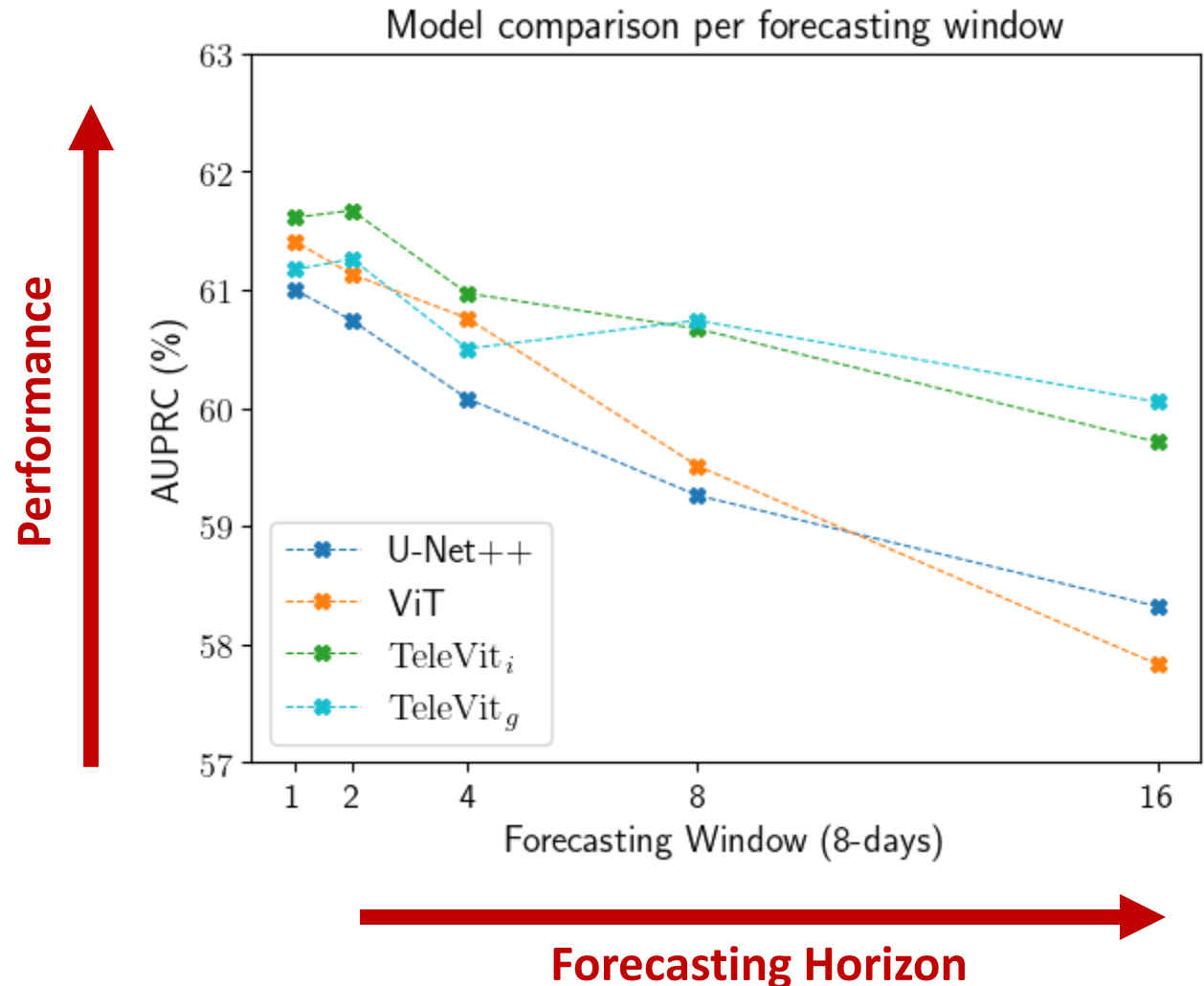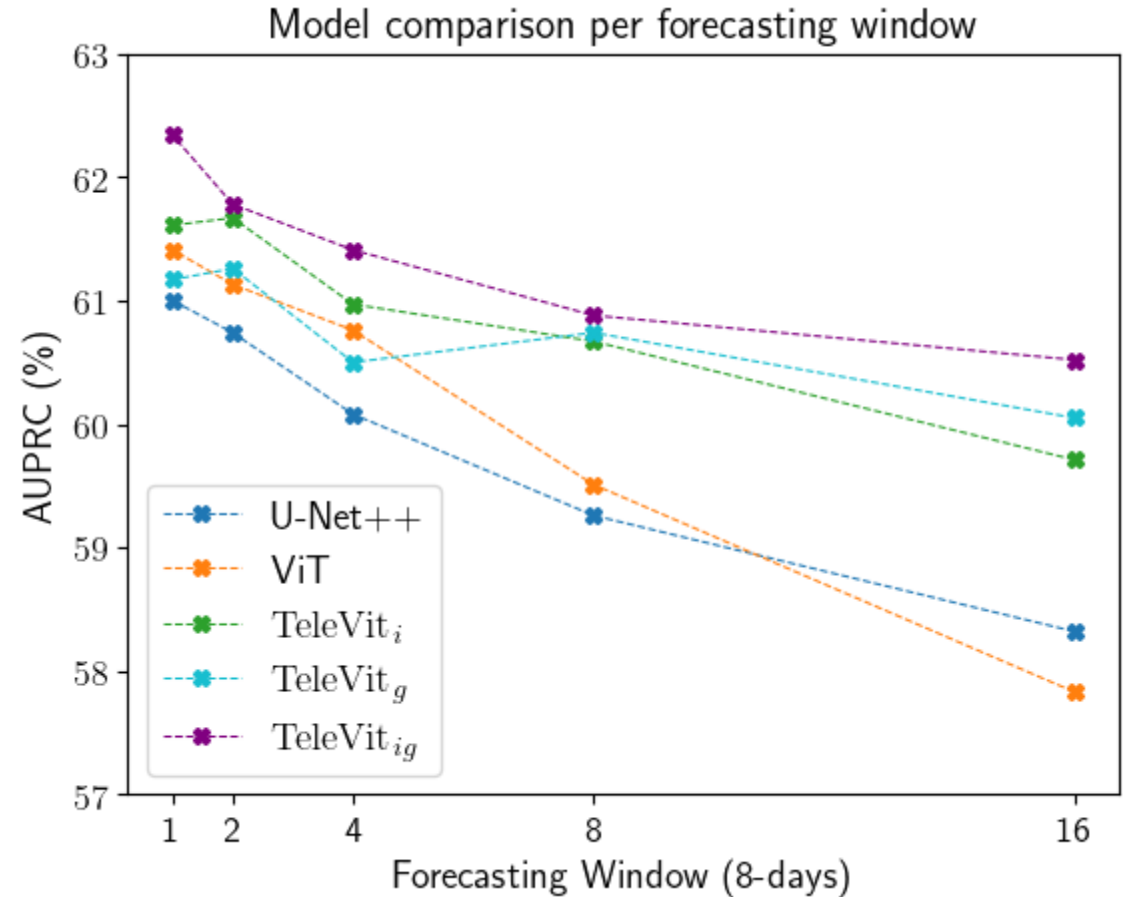Forecasting Horizon

Results

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- Teleconnection indices alone improve performance, especially for long-term forecasting

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- Global input similar to teleconnection indices

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Results

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- Global input similar to teleconnection indices

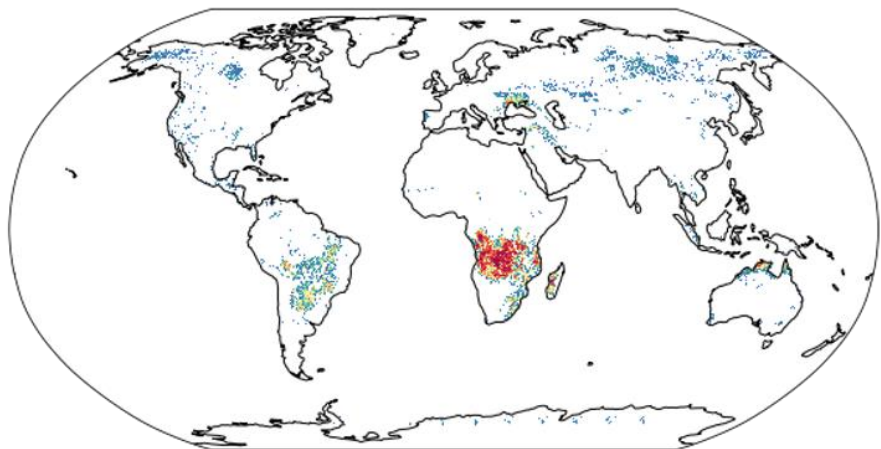- Combination of local input, teleconnections indices and global input is always best
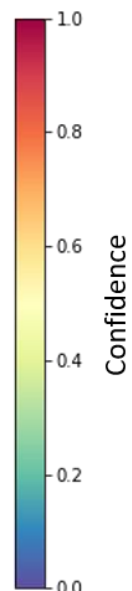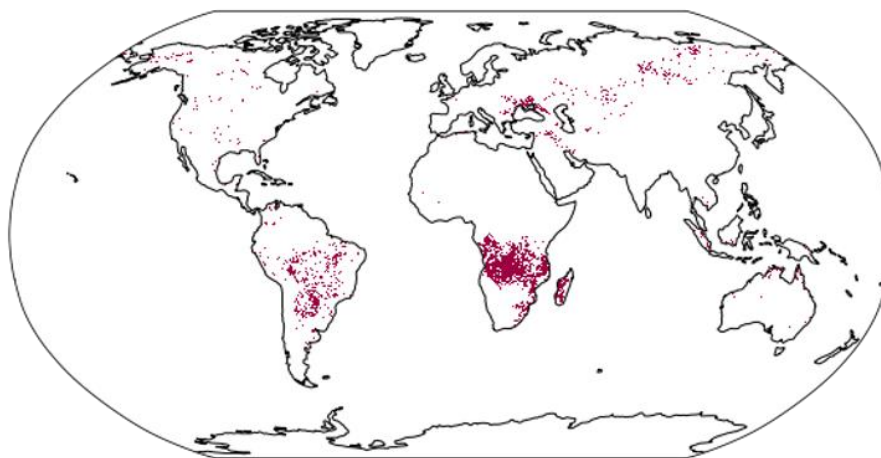

Model comparison per forecasting window

Performance → (vertical axis)

Forecasting Horizon → (horizontal axis)

Legend:
- U-Net++
- ViT
- TeleVit_i
- TeleVit_g
- TeleVit_{ig}

Y-axis: AUPRC (%)
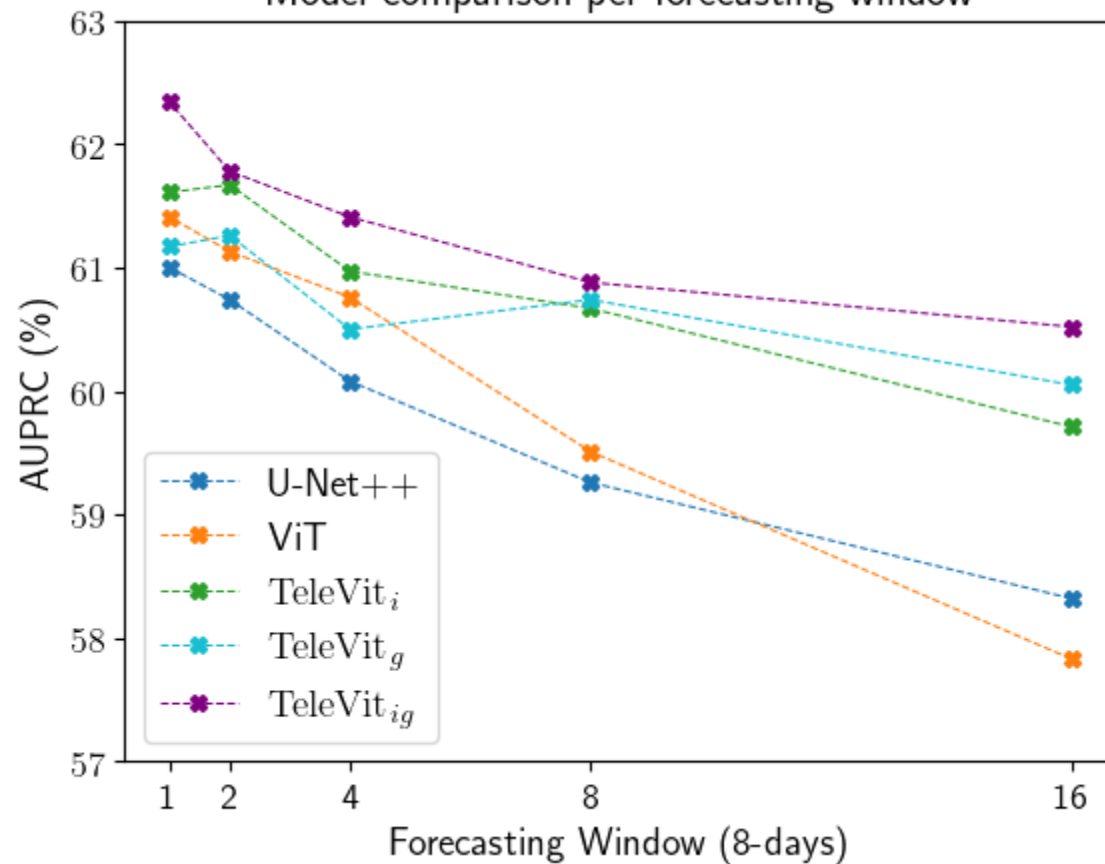X-axis: Forecasting Window (8-days)

Results

Forecasted Burned Area Pattern Lead Time 4x8-days

Target Burned Area Pattern

Conclusion

- TeleViT effectively combines multimodal Earth system variables, i) local input, ii) global input, and iii) teleconnection indices

- Teleconnection-driven modeling improves forecasting capabilities, especially long-term forecasting

- Exciting future work
  - Understand performance gain. Explain model to elucidate known/unknown teleconnections
  - Exploit temporal context for local/global input
  - Beyond wildfire forecasting

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