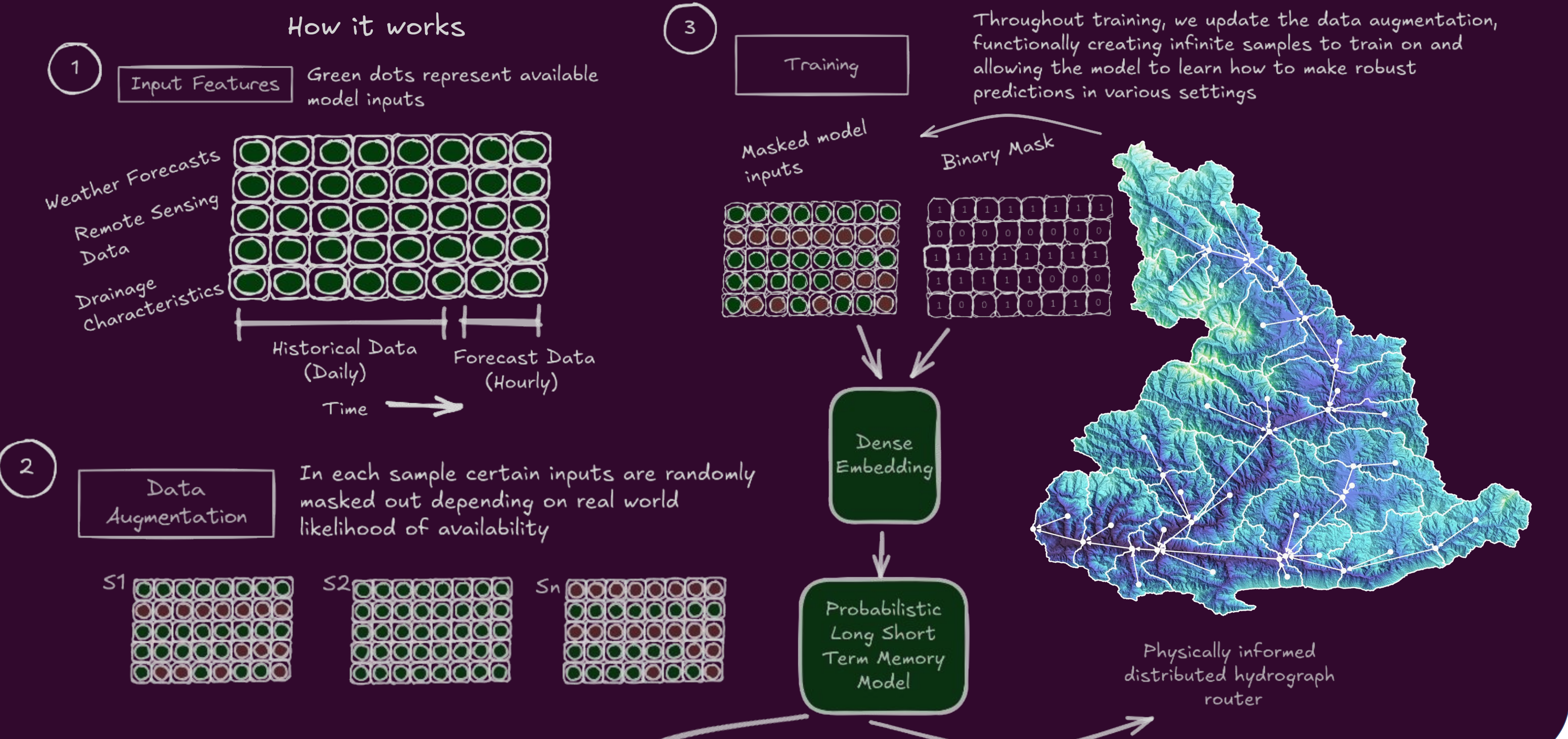
Data augmentation creates state-of-the-art hydrological forecasts using theory informed deep learning

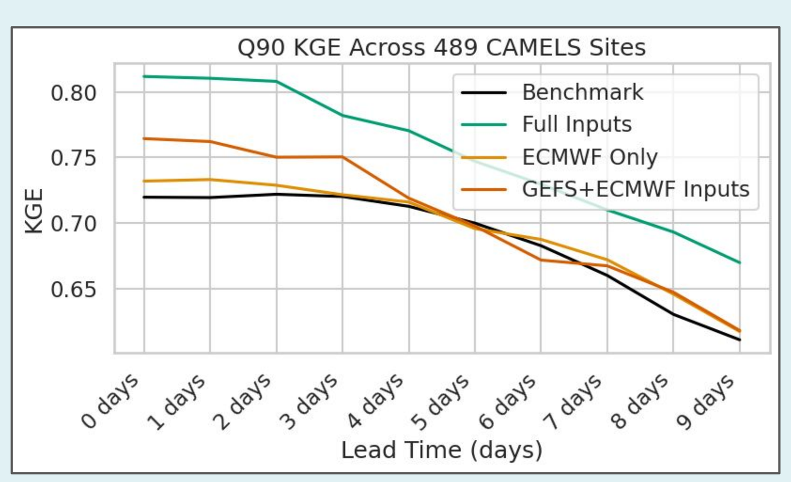
HydroForecast UPSTREAM TECH

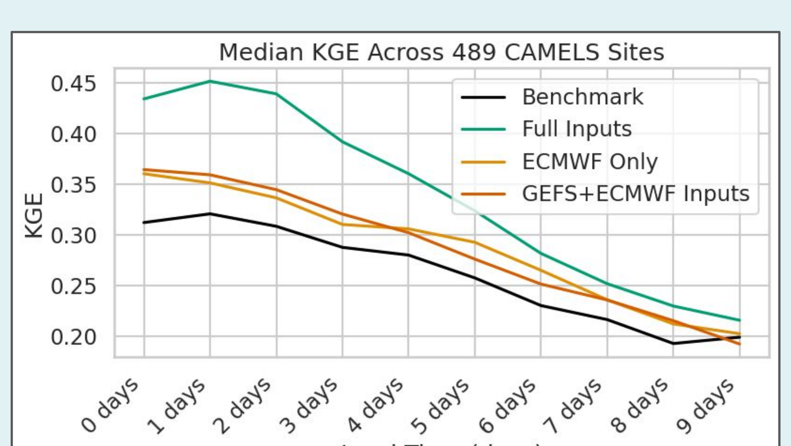


Background

Making **accurate, operational streamflow forecasts** is essential for effectively managing water resources. However, common input weather forecasts occur at varying resolutions and are subject to data outages from their providers. This work combines a **novel LSTM architecture** with a training routine focused on **data augmentation.** The result is **HydroForecast Short-Term 3 (ST-3)** a robust, flexible model that can learn from **mixed frequency** data sources, **maintain performance** in the event of an upstream data outage, and leverage **regional data** to make state-of-the-art streamflow forecasts

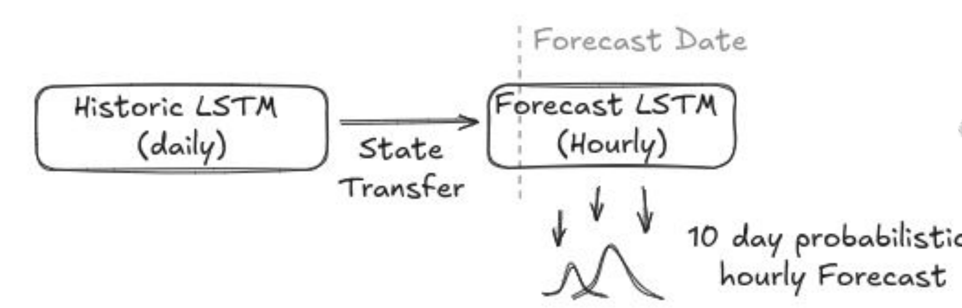
Validation

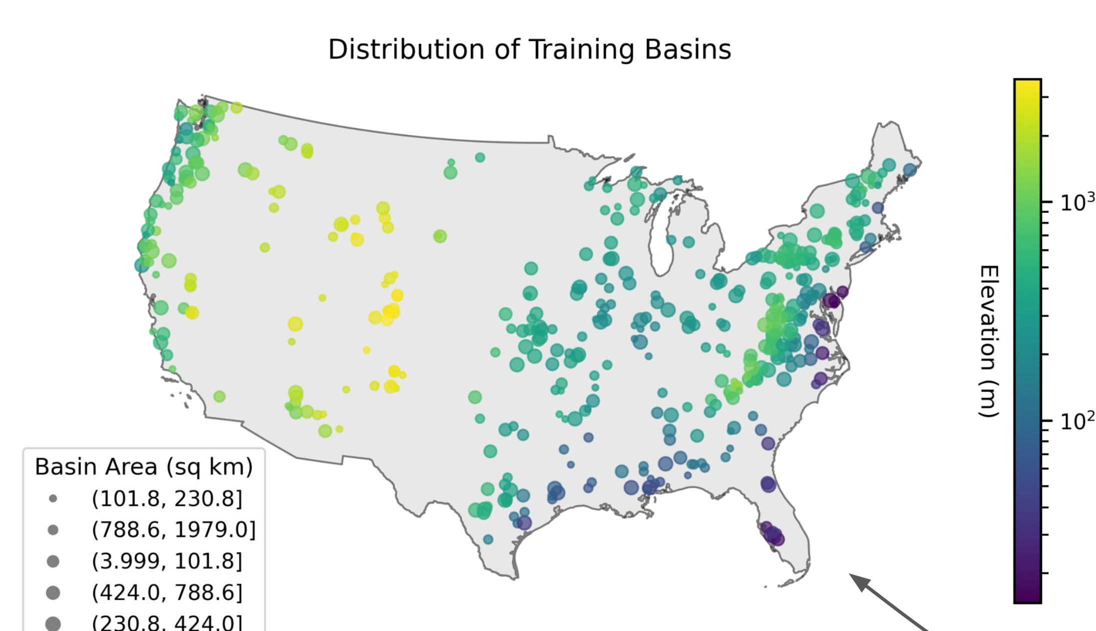




Metrics for streamflow forecasts on the test partition (WY 2020-2021) across 489 sites in the CAMELS dataset. Benchmark metrics represent a model trained without data augmentation or NOAA High Resolution Rapid Refresh weather inputs. Remaining metrics represent tuned model with varying sets of input weather sources.

The lumped model architecture helps the model **learn antecedent conditions** such as snow pack

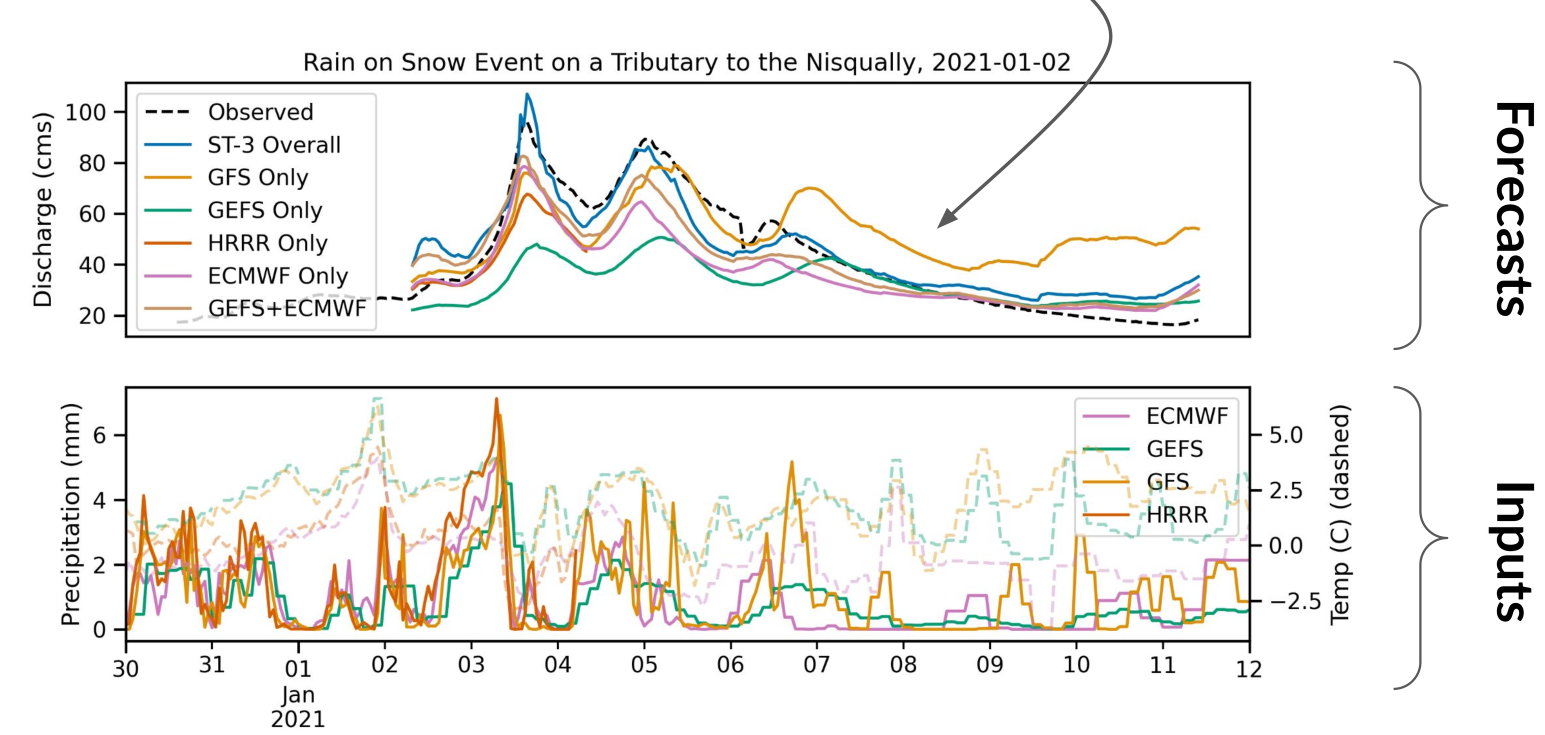




Training on a diverse array of basins allows ST-3 to **generalize** into a variety of hydrologic settings

HydroForecast ST-3 Results and Impacts

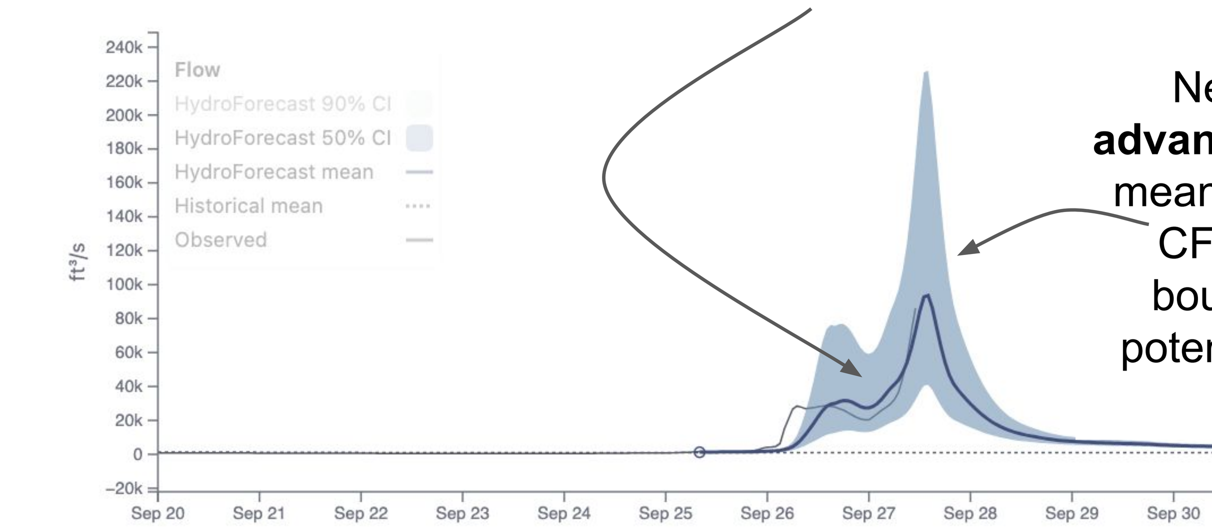
Data augmentation throughout training leads to **robust forecasts** regardless of regional **data availability** or upstream outages



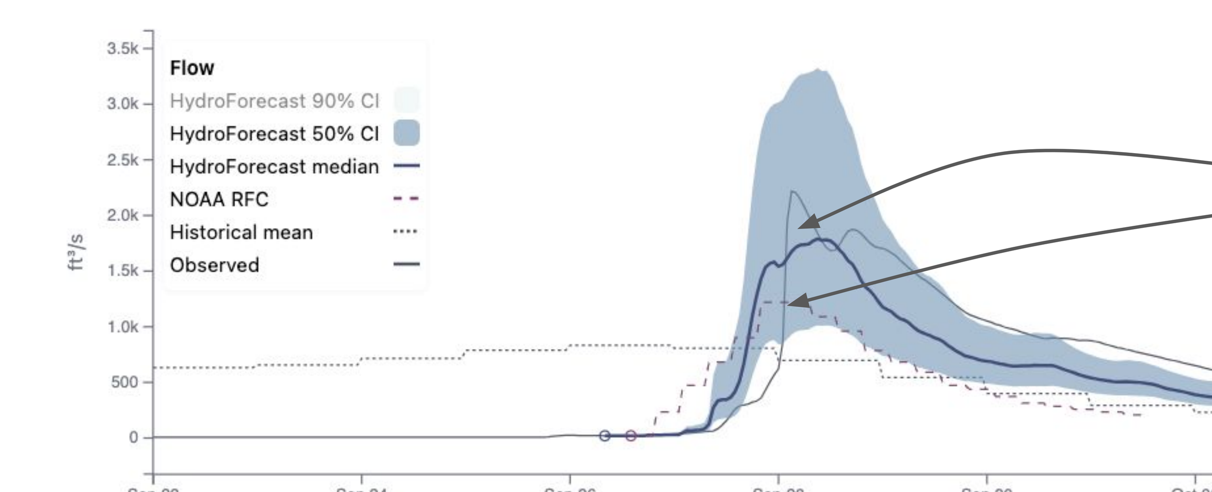
A rain on snow event on a tributary to the Nisqually. Notice how at later horizons, the forecast trace for GFS remains much higher than other traces. We can see that GFS forecasted temperatures remain above zero whereas other sources drop below freezing. This highlights that the model maintains physical fidelity even when forecasting using a single weather input.

A Case Study with Extreme Flows From Hurricane Helene

On Sept 27, the USGS gauge on the Nolichucky River in Tennessee **failed due to extreme flow** caused by Hurricane Helene, subsequently impeding emergency response planning

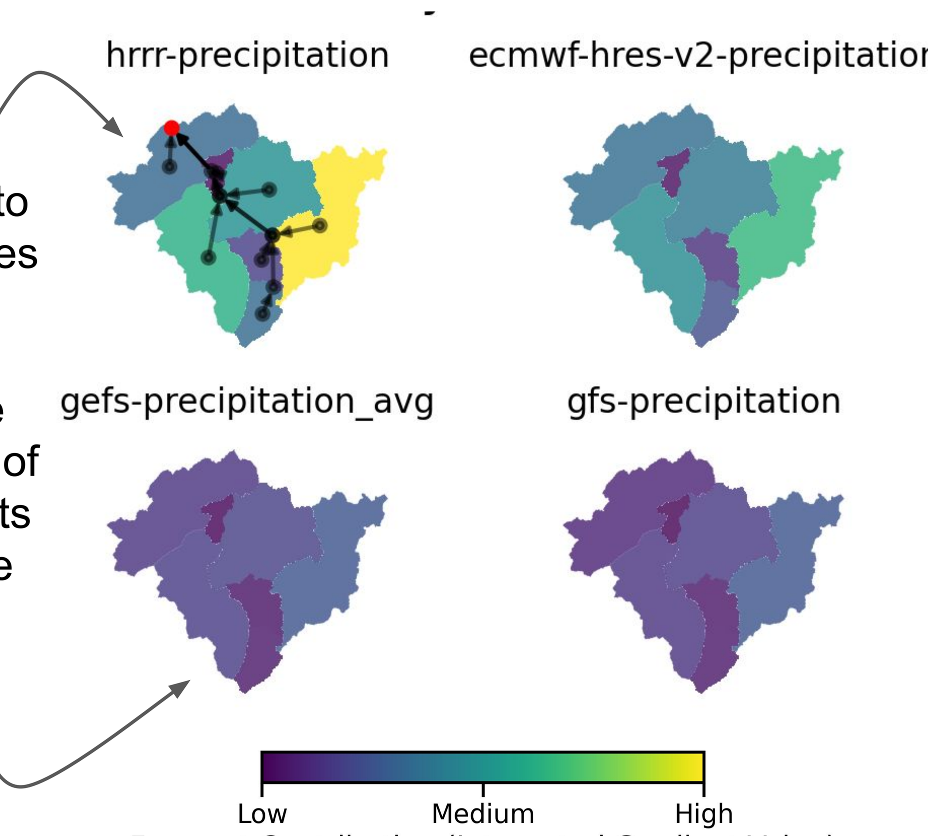


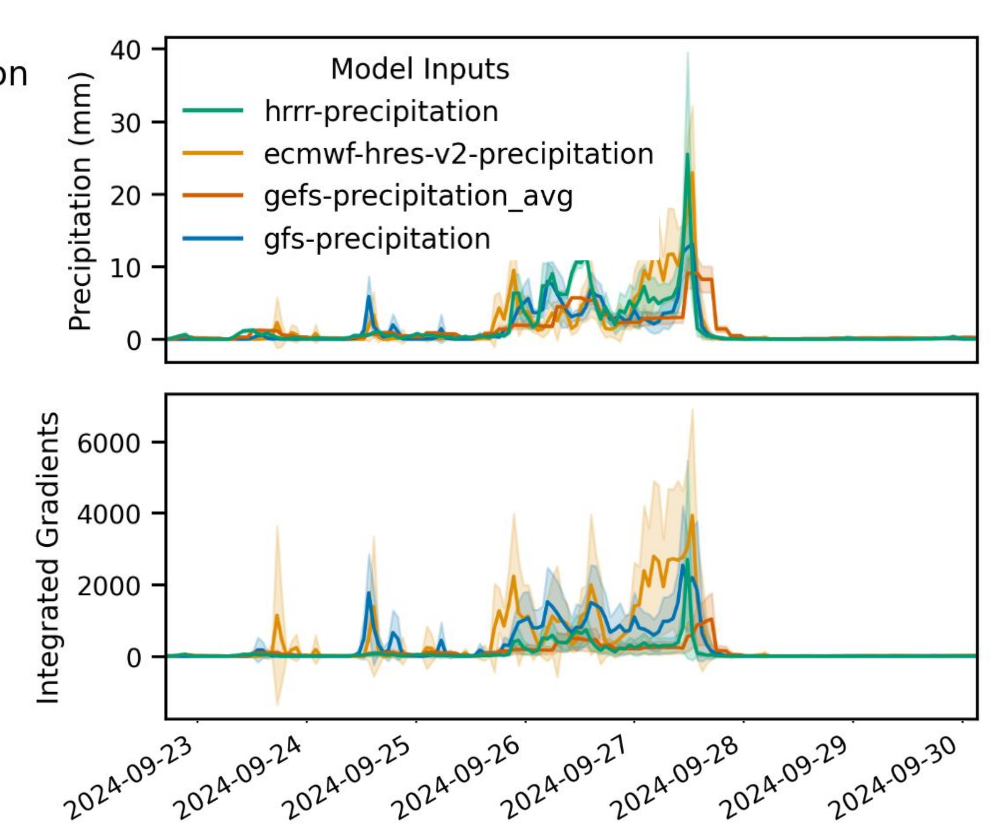
Nearly **48 hours in advance** ST-3 forecasted a mean flow of over 90,000 CFS with confidence bounds indicating the potential for catastrophic flooding.



A nearby gauge on the Emory River highlights that ST-3 **substantially outperformed NOAA's RFC** when forecasting the extreme event

Fine tuning to individual sites allows the model to **weight the importance** of varying inputs to maximize forecast accuracy





Above, ST-3 forecasts during extreme flows caused by hurricane Helene. Below, integrated gradients across space and time highlighting the importance of precipitation from various weather sources with regards to forecasts during the extreme flow event.

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