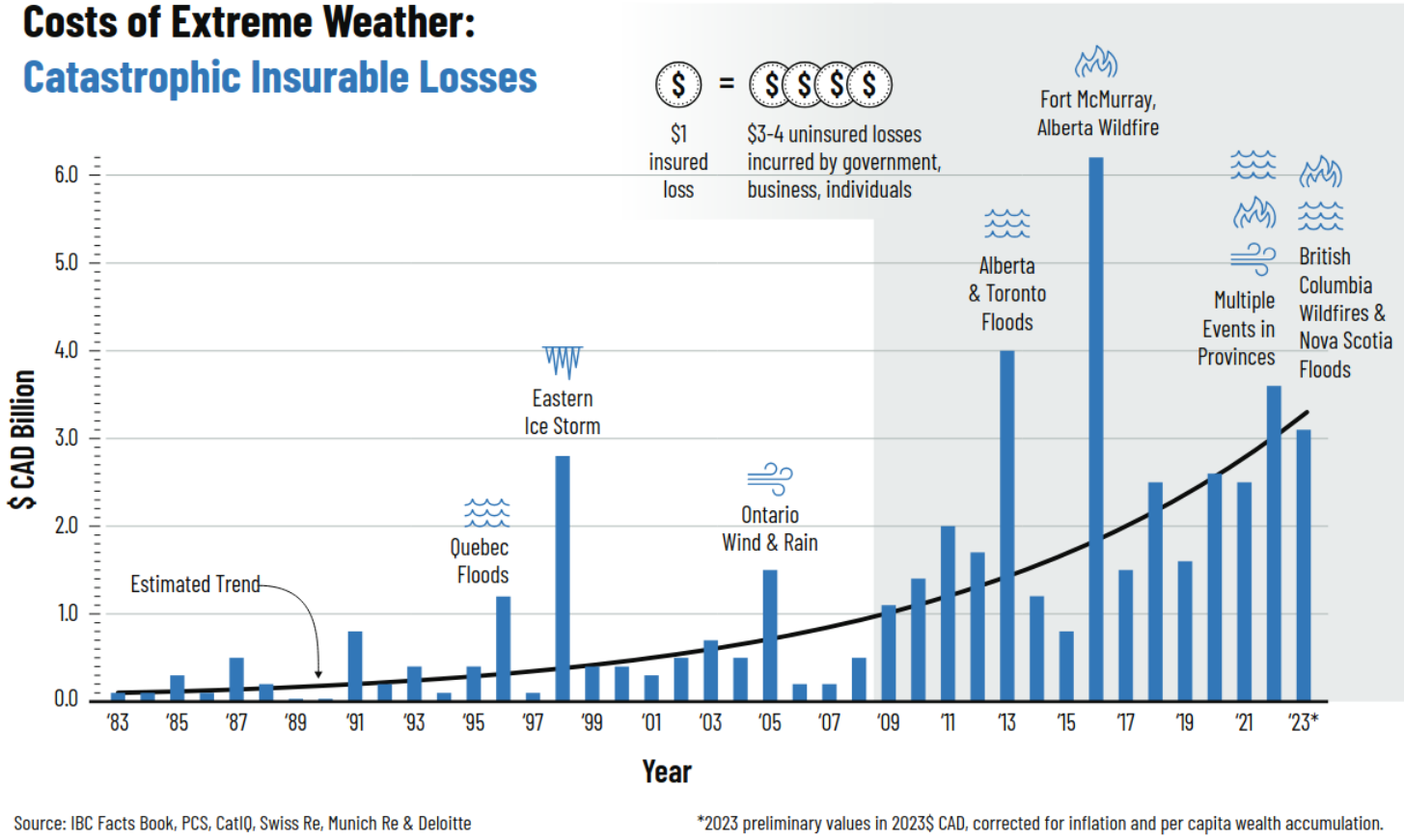
ISWMS: North America Wide Flow Prediction System

- Steven French
- Greenland International Consulting Ltd.

- October 2024
- Latornell Symposium

Importance of streamflow prediction



Infographic source: Intact Center on Climate Adaptation

Introduction

BACKGROUND

DATA SOURCES AND MODEL

RESULTS

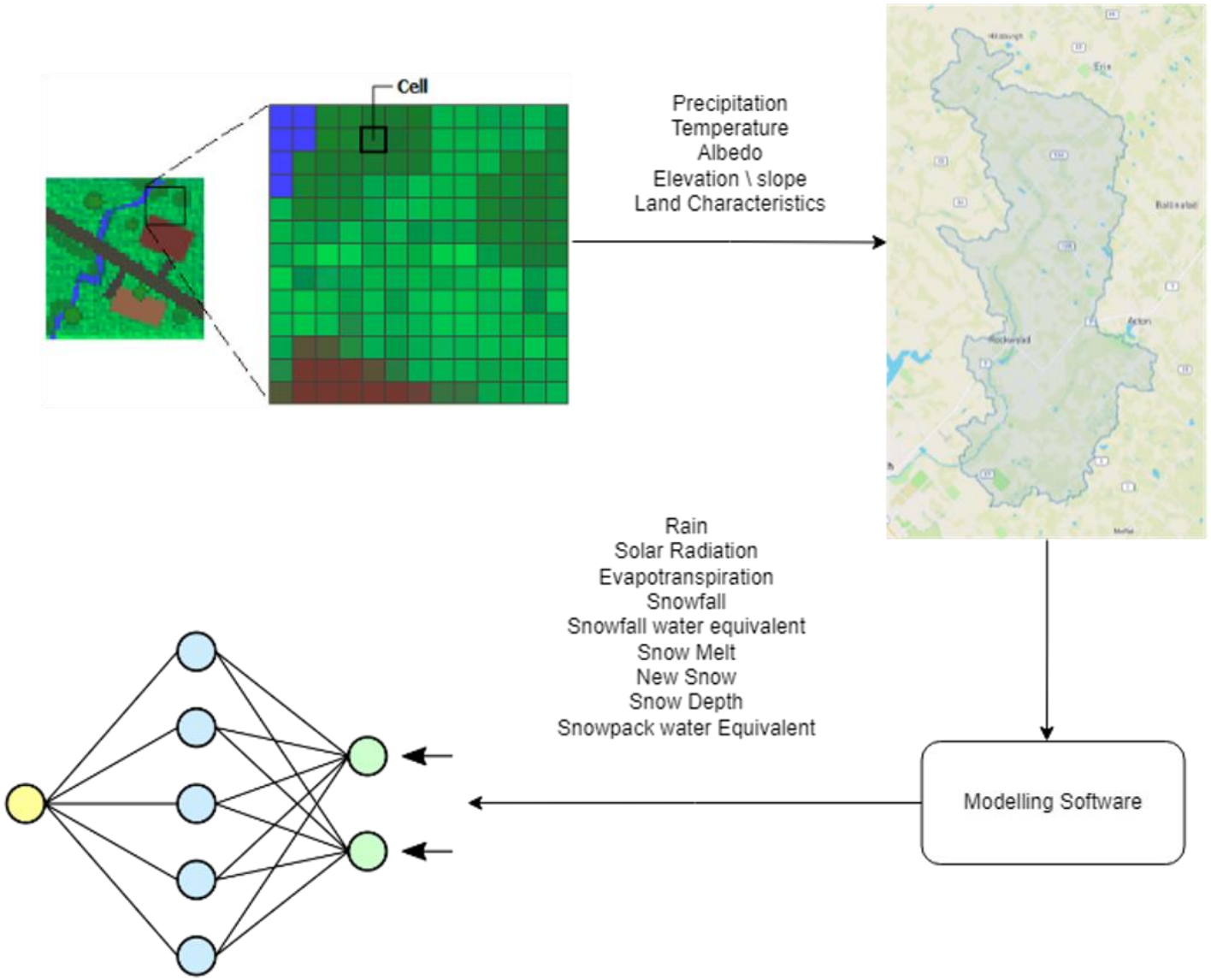
WEB INTERFACE

FUTURE DIRECTIONS

Methods of streamflow prediction

- Traditionally computed using physical models
- Physical models have limitations, and are difficult to use/extend
- Data driven models have been suggested as an alternative

Prediction system – High level

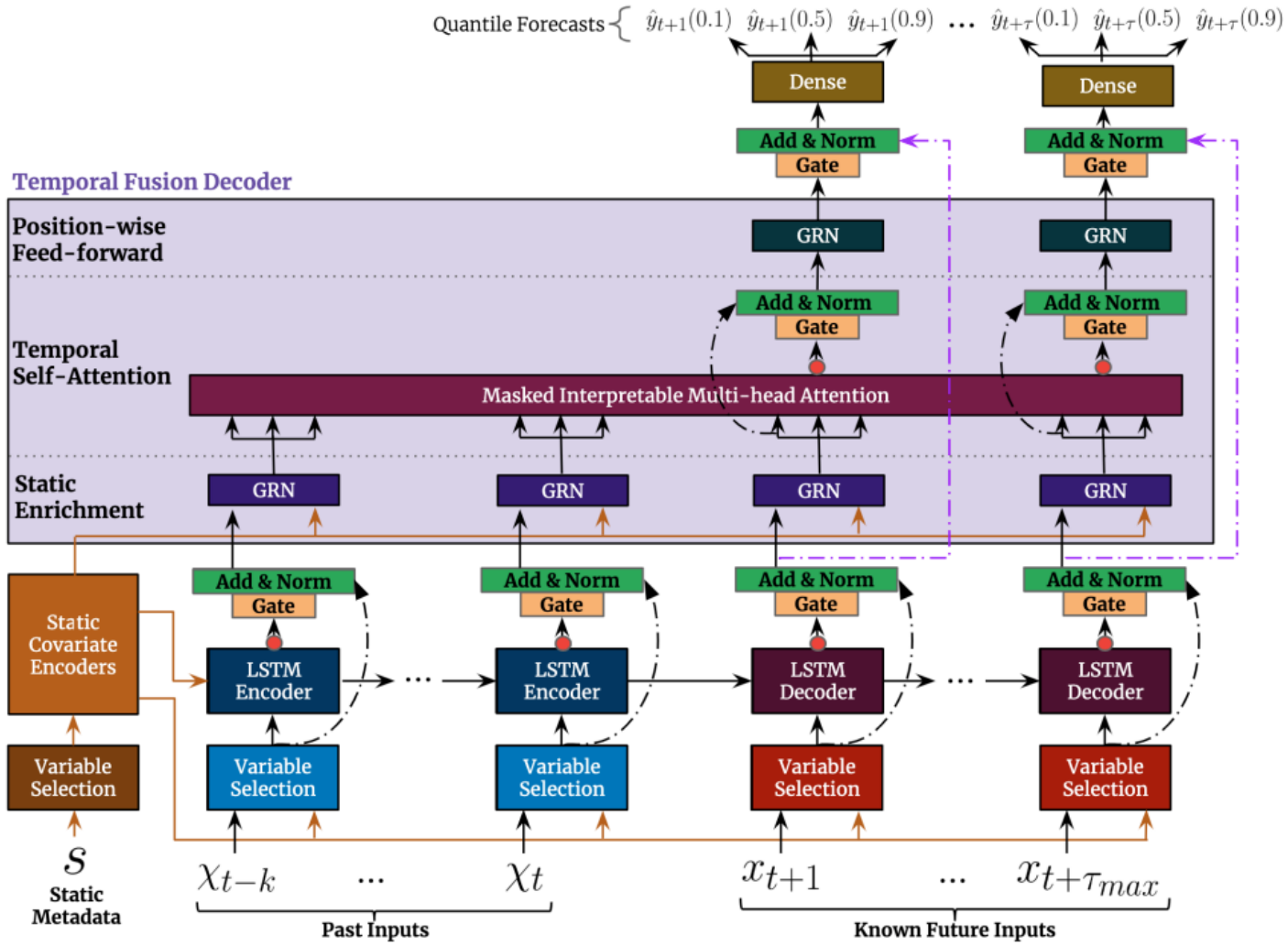


Challenges

- Weather forecasting data can be unreliable, so powerful models are needed to compensate
- Data is not evenly distributed
- Optimizing parameters can be time consuming and take computing resource
- Data storage requirement
- Ungauged locations are a lot more difficult than predicting for gauged
- Difficult to capture all catchment characteristics
- Human made structures

What is a transformer

- They are driving the current AI trends
- Uses multiple attention heads to scan over sequential data
- Finds patterns in data across variables and locations
- Their use in time series has been less explored
- Are extremely flexible for time series data
- Temporal Fusion Transformer is used in this research (pictured)



Temporal Fusion Transformer Advantages

- Quantile prediction gives margin of error
- Is built for sequential data
- Combines the strengths of LSTM and Transformers
- Uses GPU for training
- Can differentiate static and dynamic features
- Can produce interpretability statistics

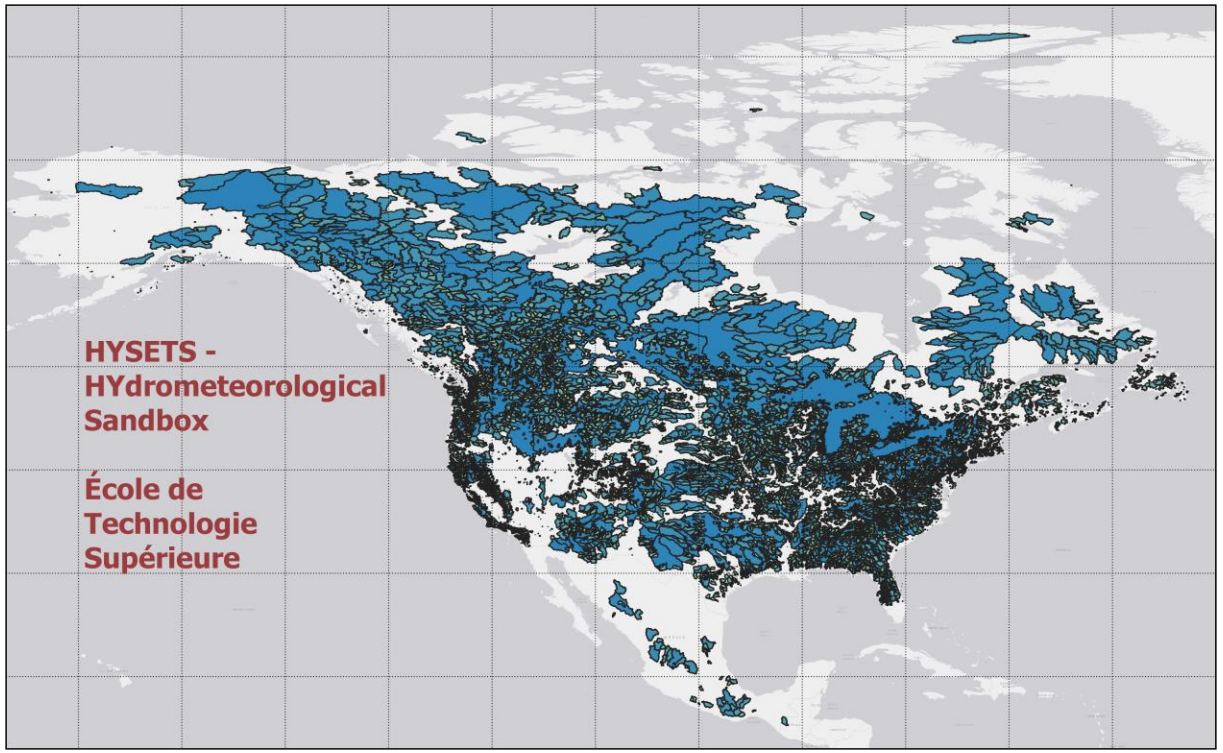
Data Sources

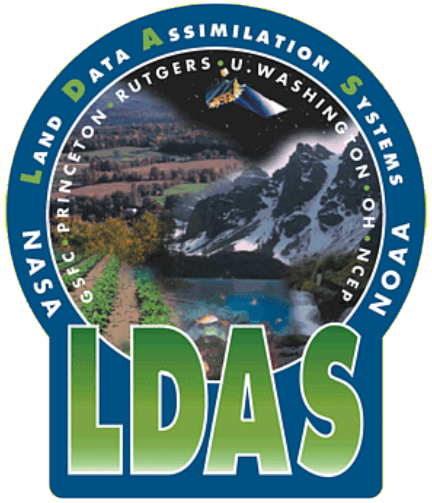
Dynamic

- HYSETS
- HYDAT/ USGS
- GLDAS
- High resolution local and longer term global forecasts

Static

- CARAVAN land characteristics





Iterative development process

- Encoder/ Decoder length
- Loss Function
- Precipitation/Temp Source
- Individual Scaling
- Adding GLDAS / Ecohydrology / Caravan
- Optimizing Hyperparameters

Testing Metrics

- NSE (Nash Suttcliffe)
- R-squared
- Percent Bias
- Kling-Gupta efficiency
- Importance statistics for variables

Validation of last 512 days for each time series

Continuous validation for flow prediction

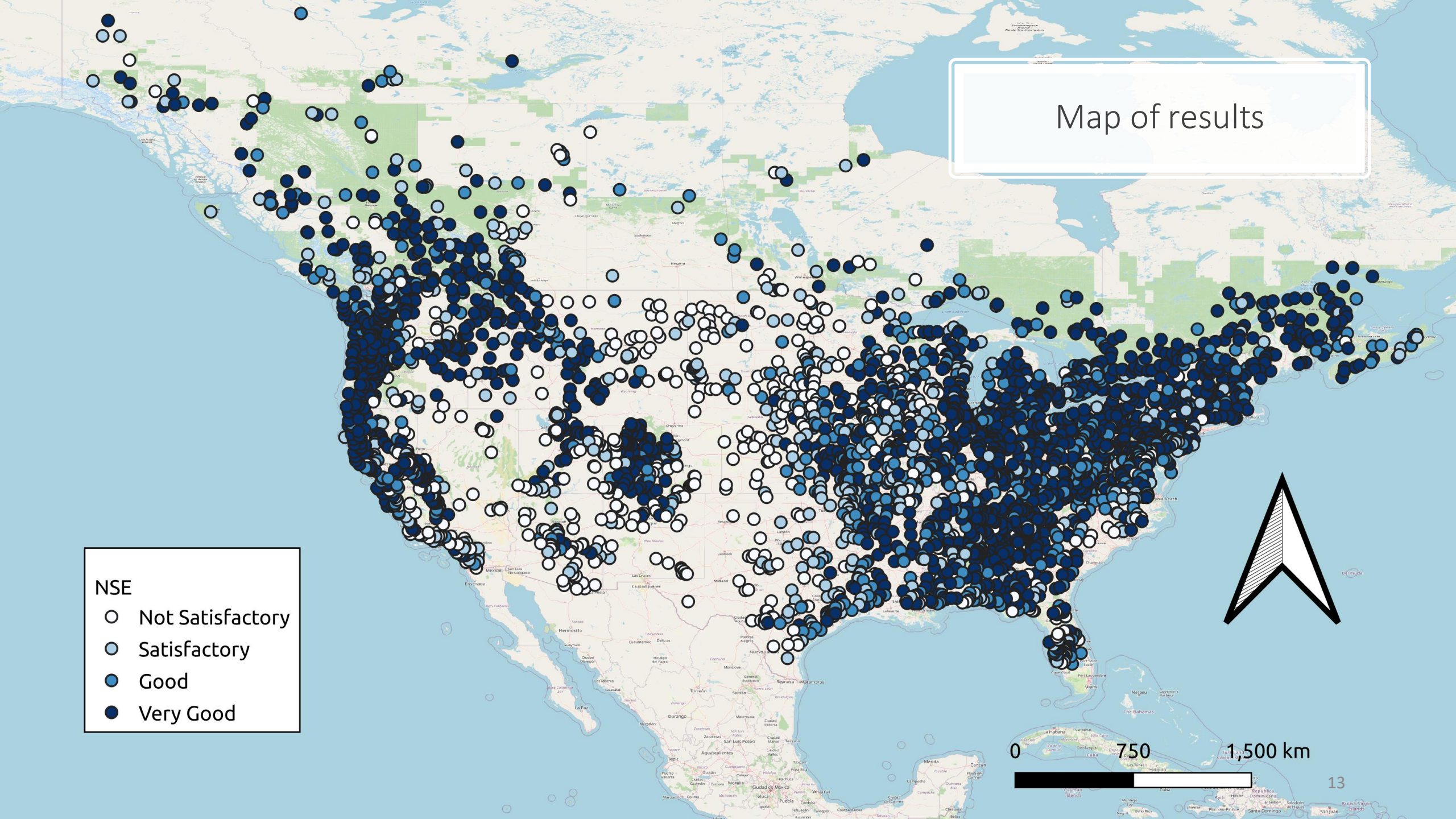
Metric	Not satisfactory	Satisfactory	Good	Very Good
R^2	≤0.60	(0.6,0.75]	(0.75,0.85]	>0.85
NSE	≤0.50	(0.5,0.7]	(0.7,0.8]	>0.8
PBIAS	$(-\infty, -15] \cup [15, \infty)$	(-15,-10] ∪[10, 15)	(-10,-5] ∪[5, 10)	(-5,5)

Validation Results

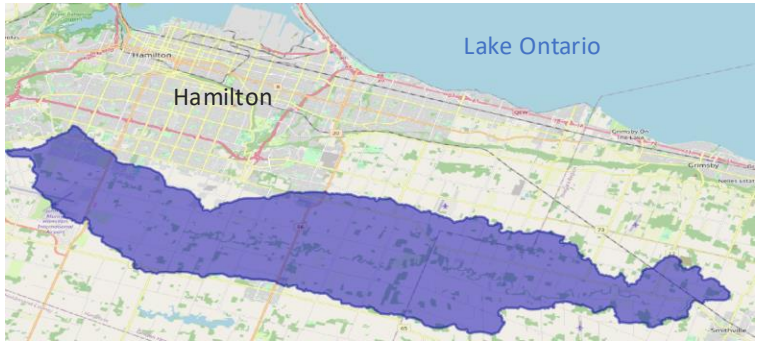
R^2 Median	NSE Median	PBias Median	KGE Median
0.86	0.81	-3.25	0.78

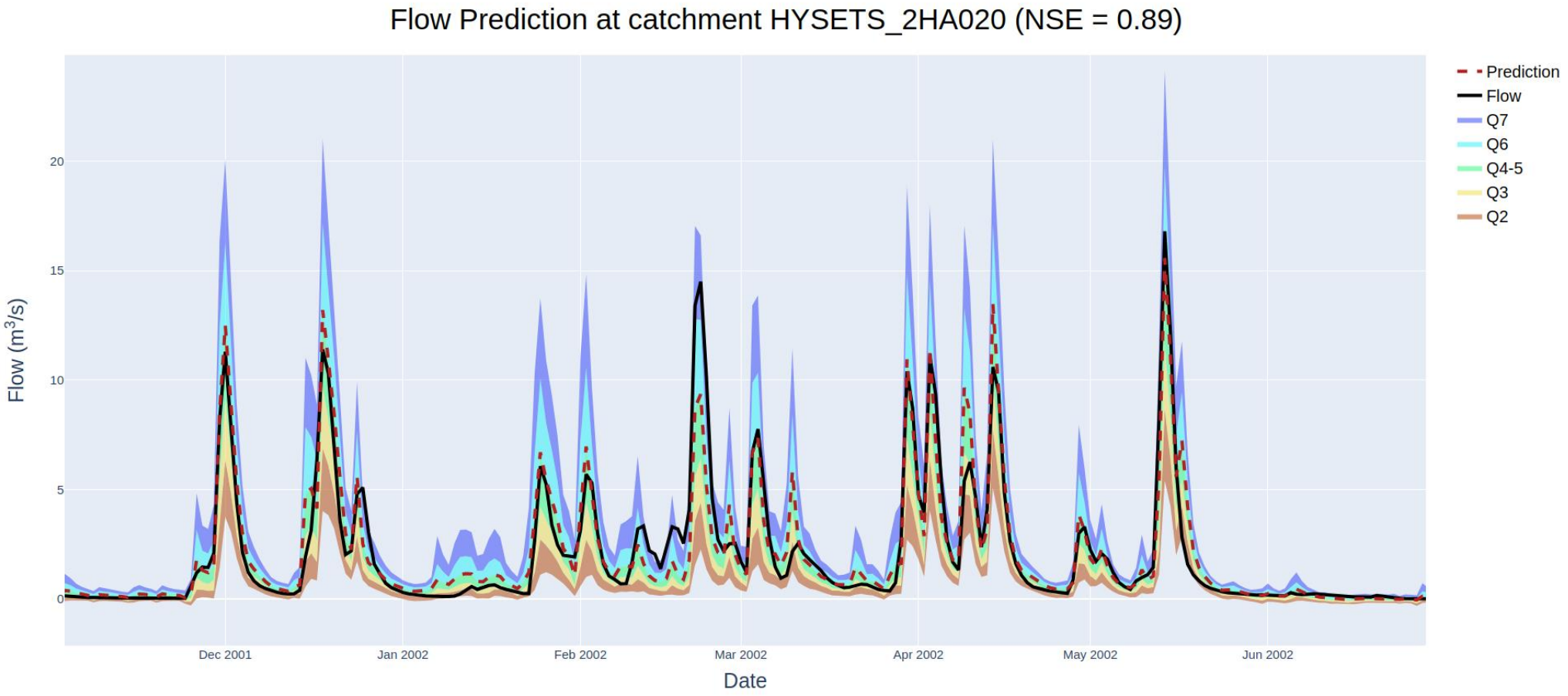
Statistic	Unsatisfactory	Satisfactory	Good	Very Good
R^2	12%	13%	22%	53%
NSE	15%	14%	17%	54%
PBias	35%	15%	22%	28%

Map of results



Hindcasting



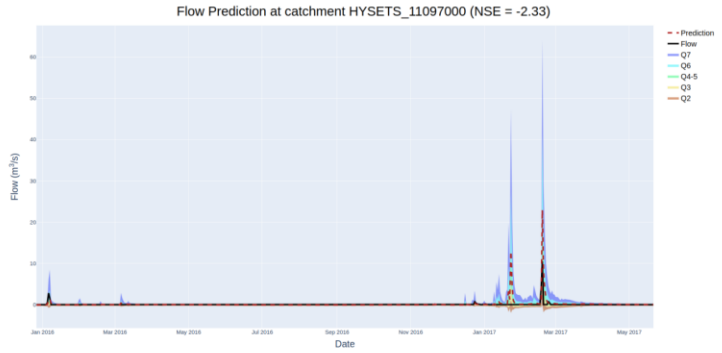


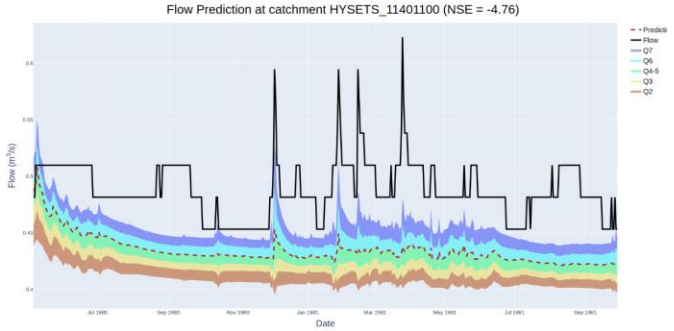
Prediction Challenges

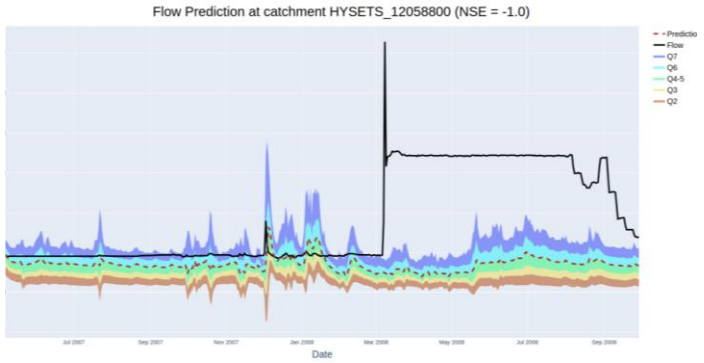
- Model struggles with unpredictable patterns that can appear at monitoring stations
- Can be difficult to detect these locations

Some difficult scenarios

- Locations with dams, and other structures
- Locations with zero flows the majority of the time
- Locations with excessive water taking

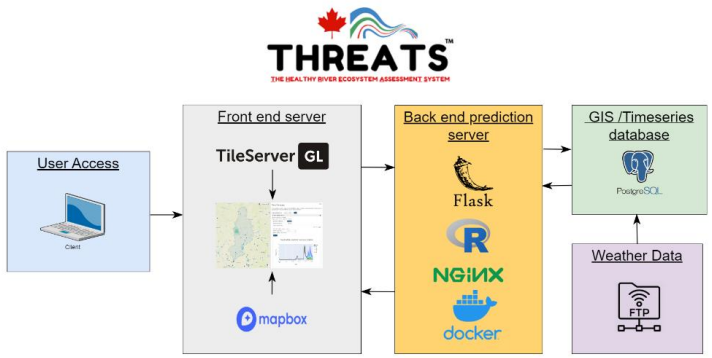


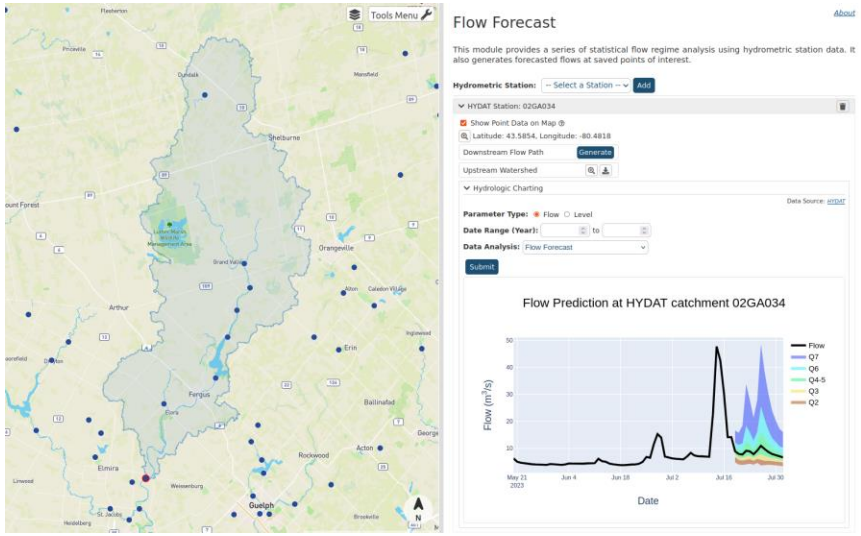


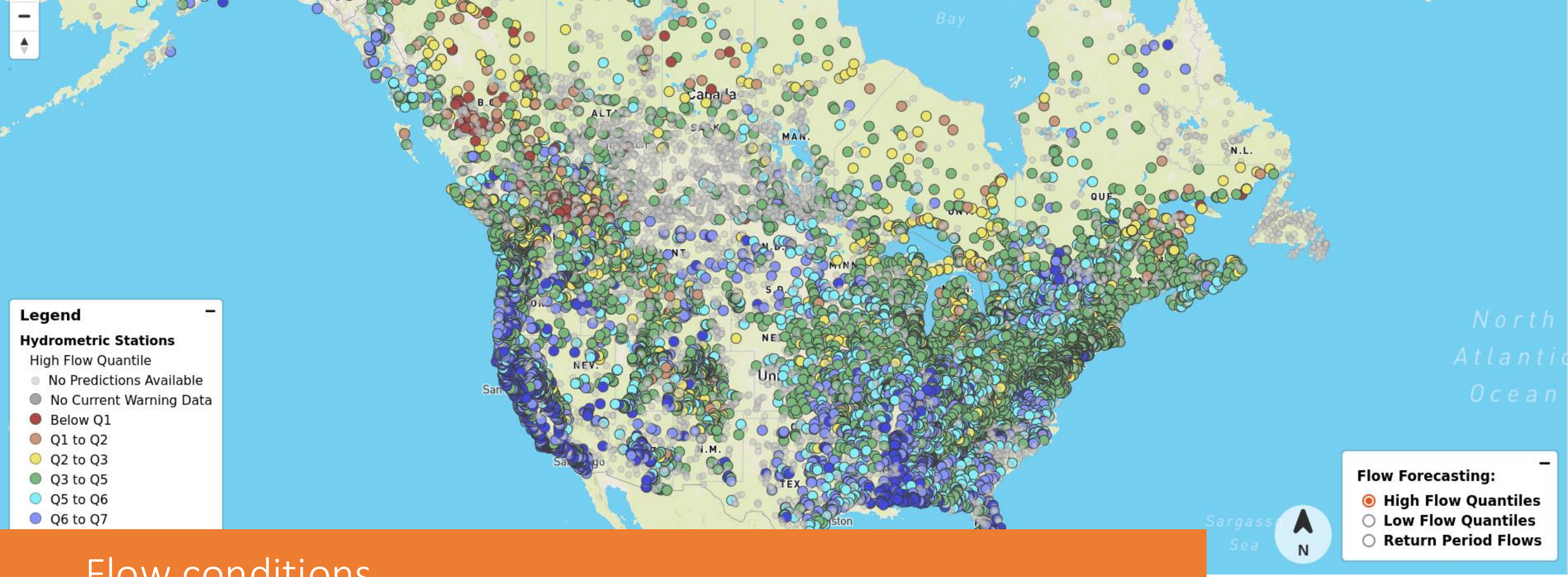


THREATS

- Web based interface
- Has many integrated tools for environmental data analysis
- Backend uses APIs, docker containers, load balancing, efficient databases to effectively analyze large amounts of data
- User will be able to identify forecasting stations, view performance of past streamflow predictions, view other hydrometric analysis

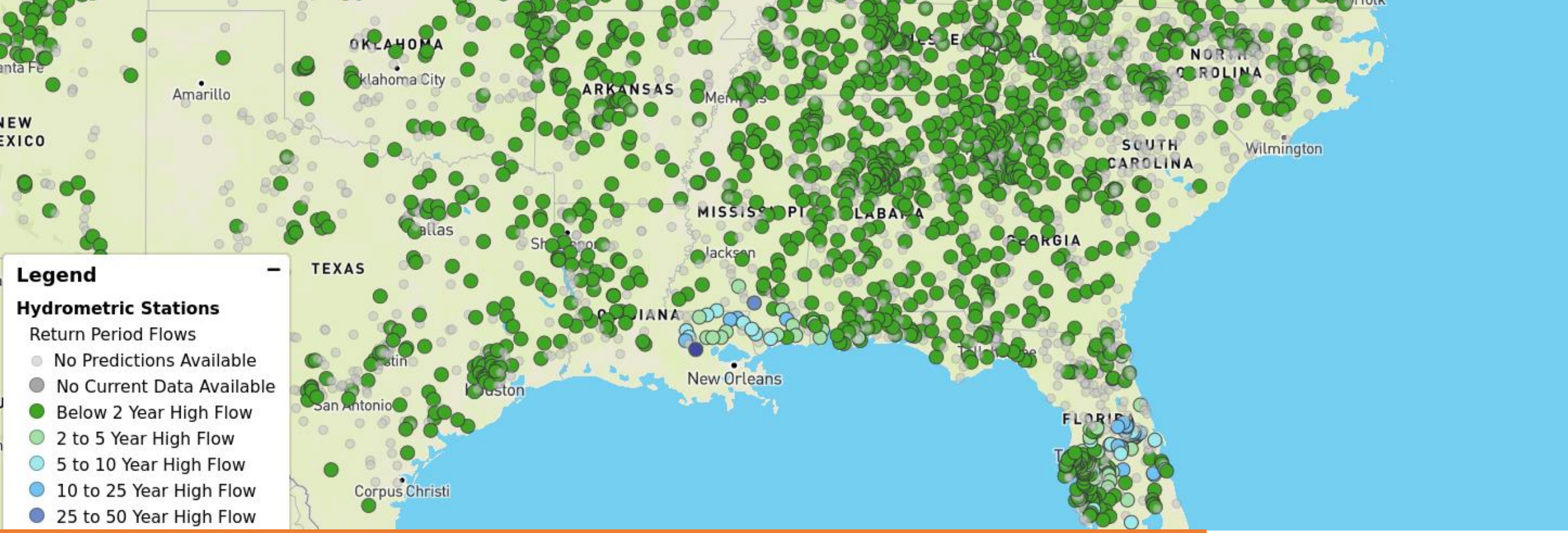






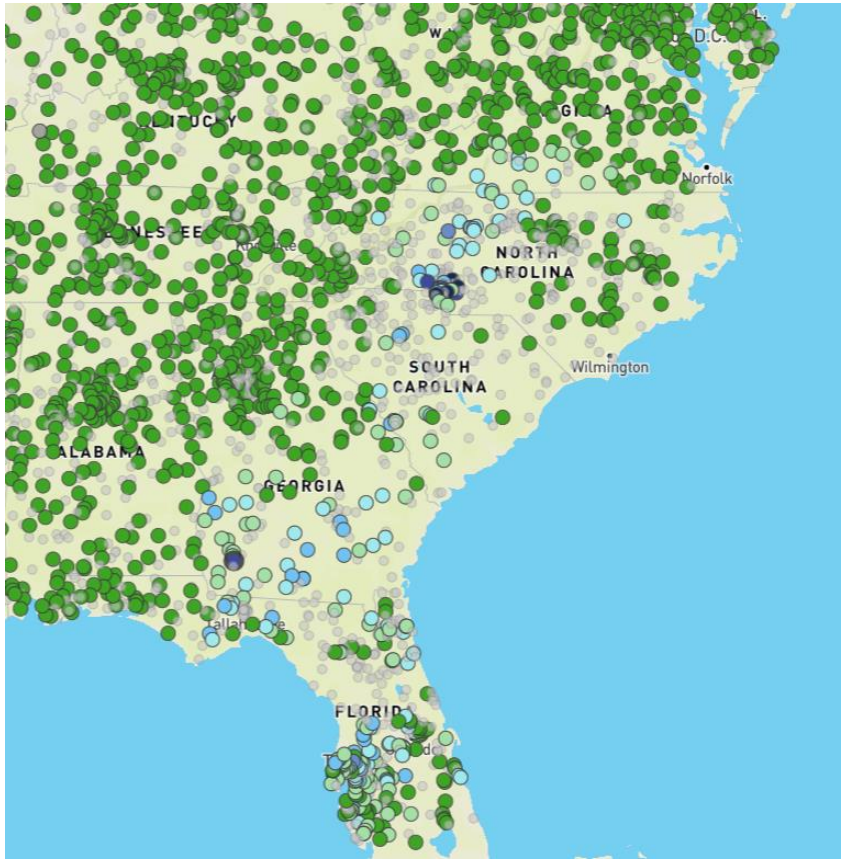
Flow conditions

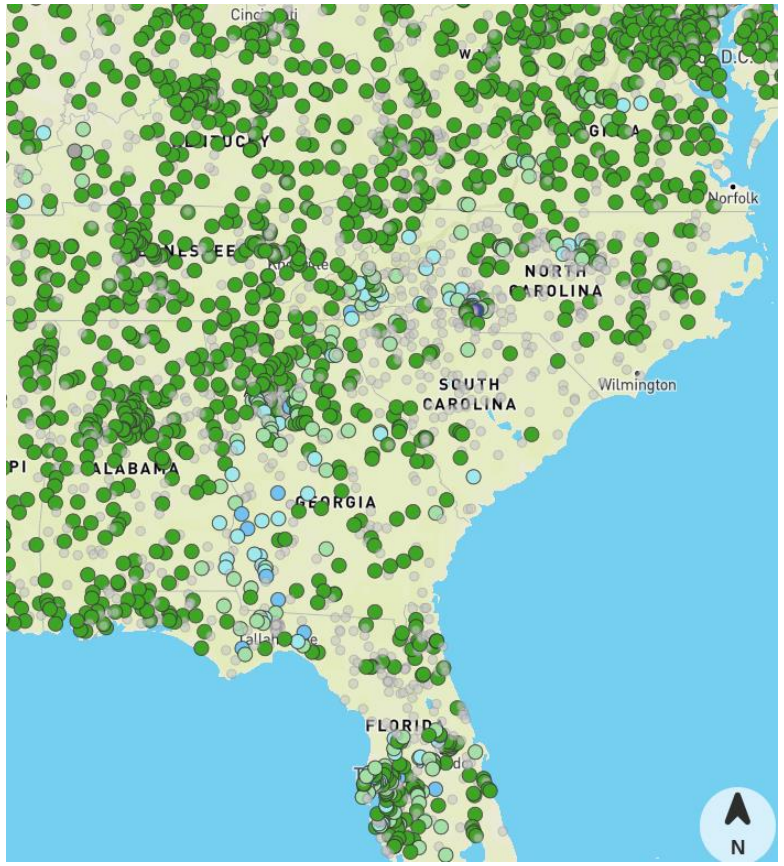
- Compare against normal flow conditions for that time of the year
- Where do the predicted flows rank among the quantiles for that day?

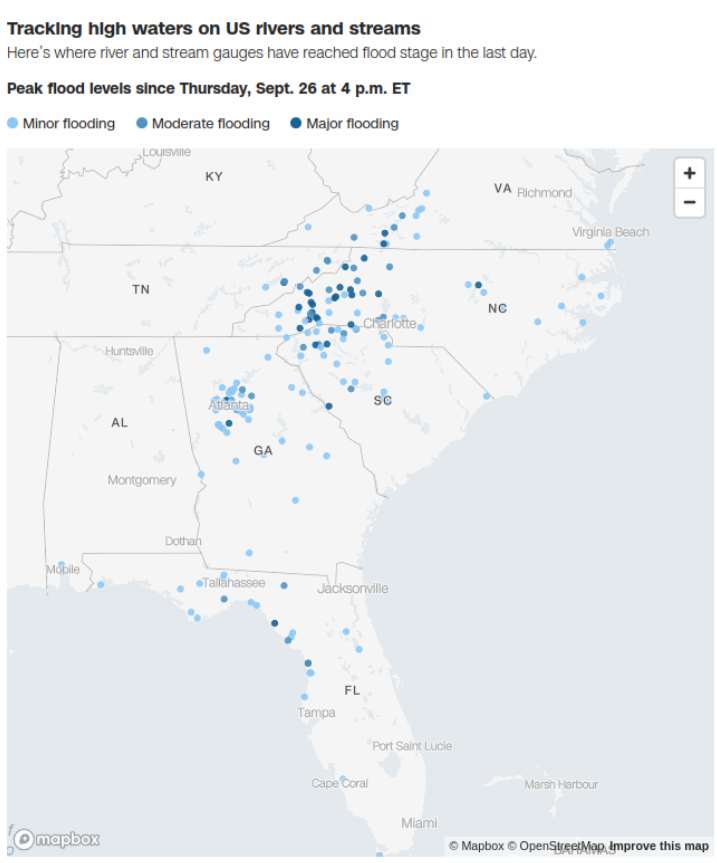


Return Periods

- Forecast compared against return periods
- Computed using Pearson 3
- Compare against historical high flows, how likely is a flooding event



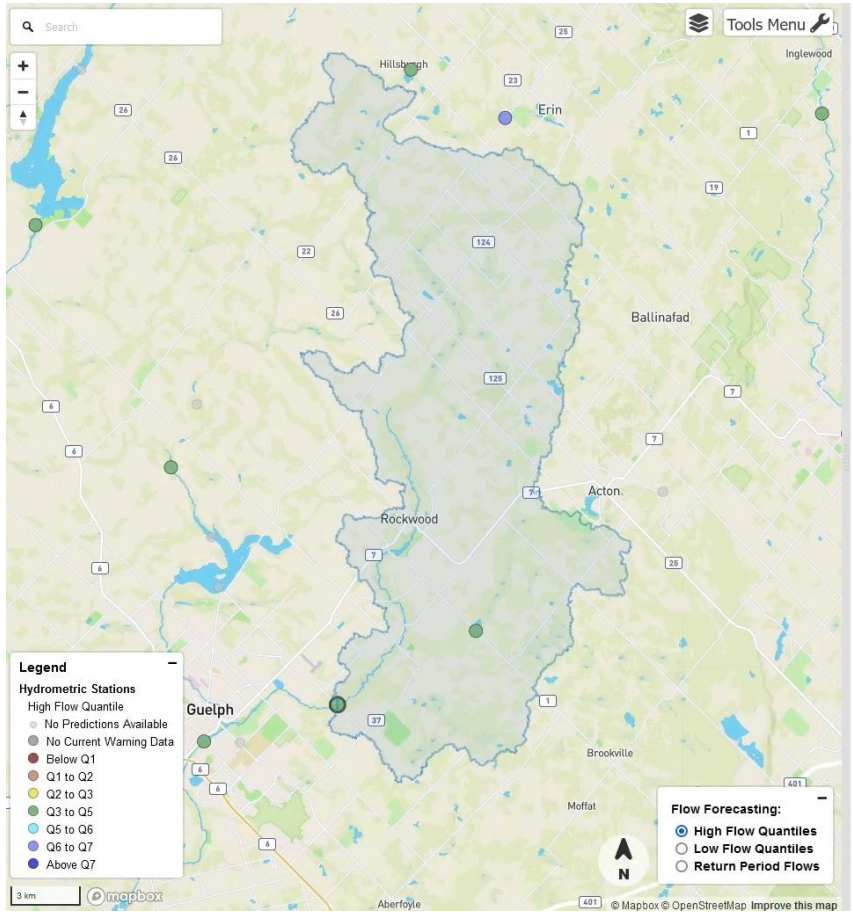


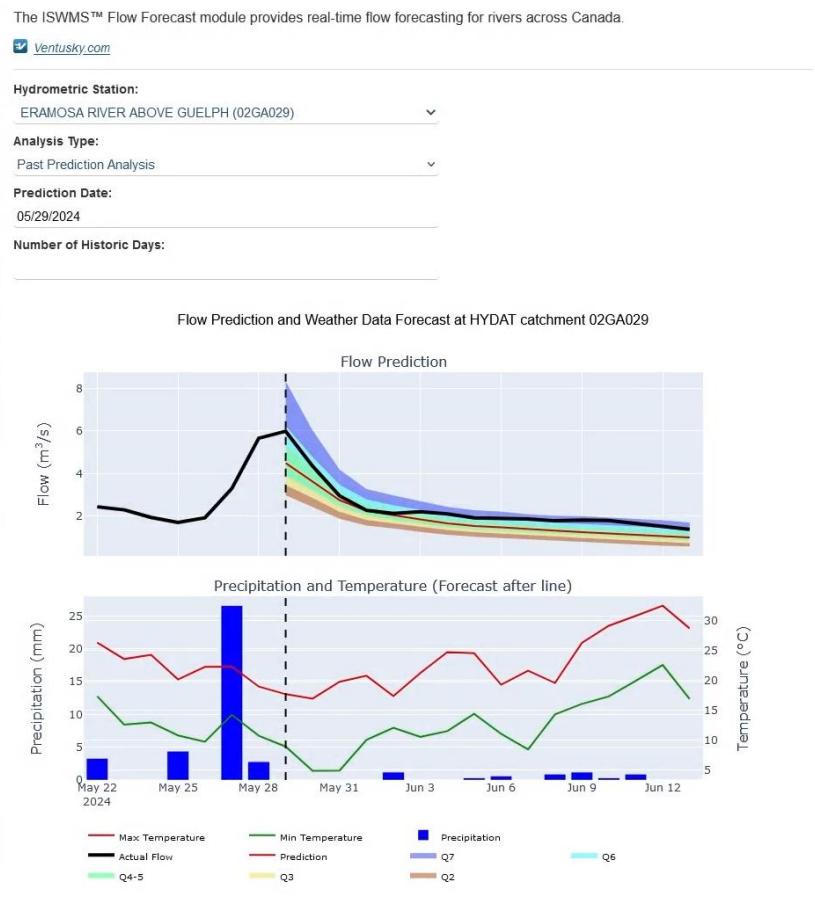


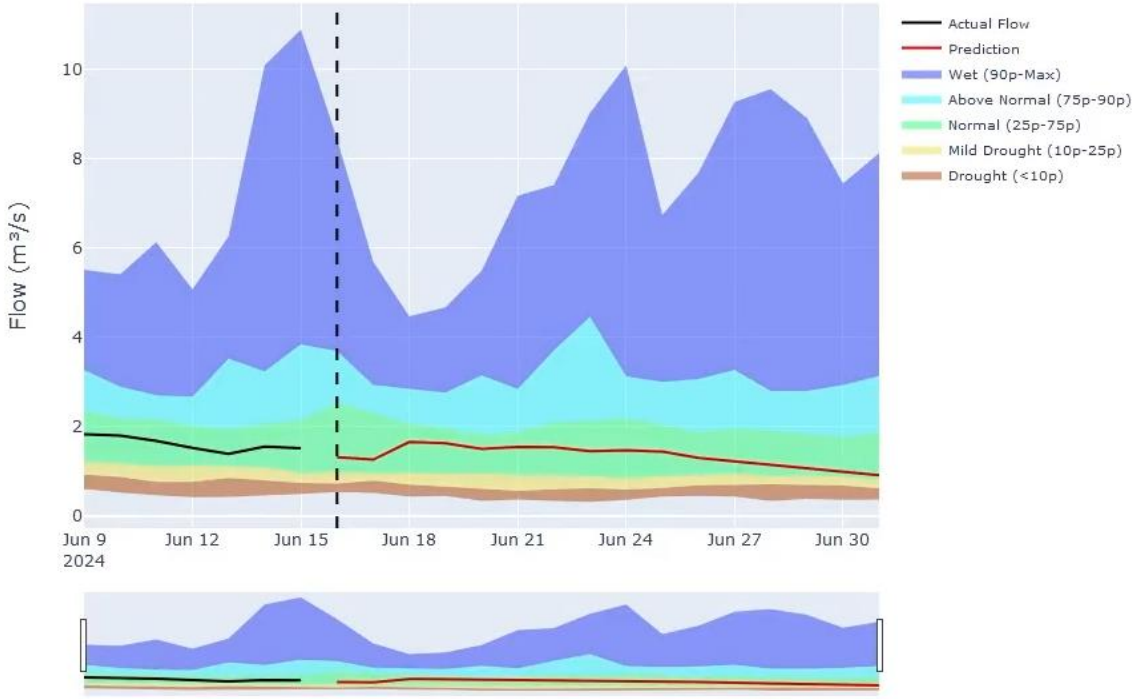
Hurricane Helene – 1 (left) and 2 (middle) days before predictions vs actual flooding* (right)

Flood map source: CNN News

Viewing Predictions

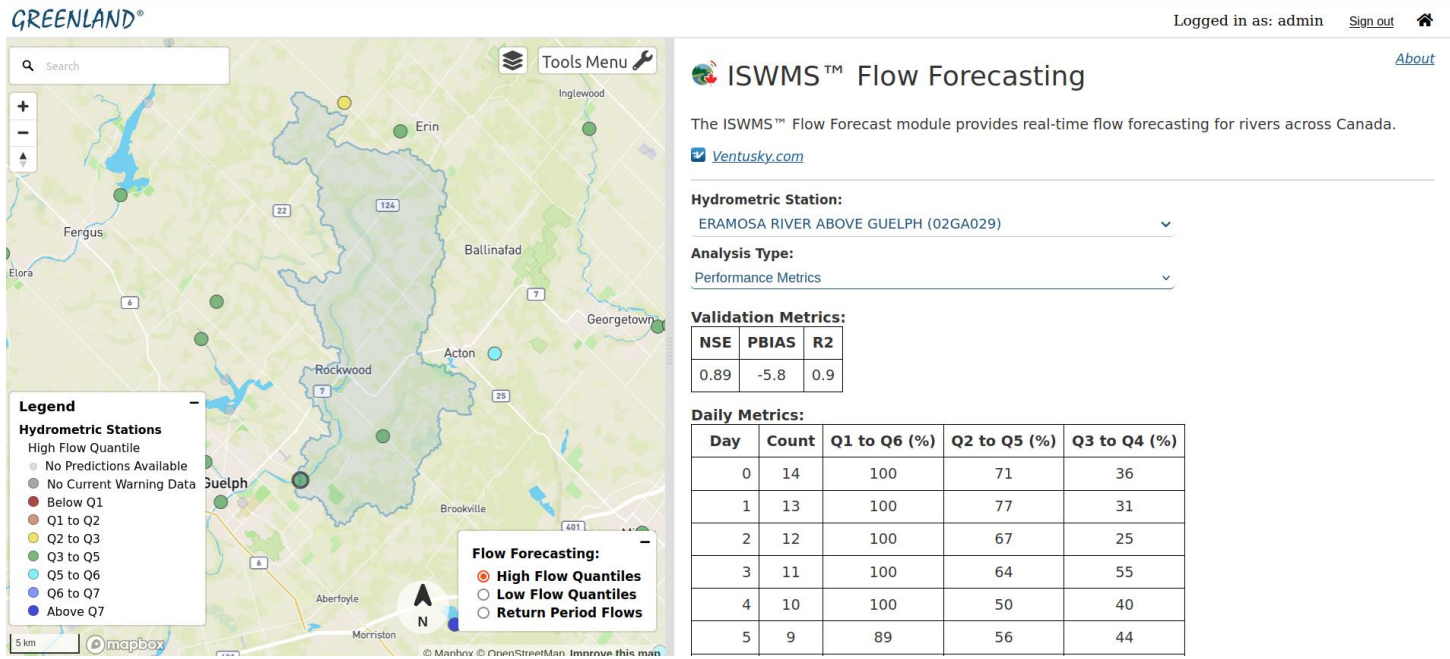






Return period, and flow condition charts

Continuous Validation



- Continuously tracks the performance of past predictions
- What percentage were predicted within the prediction intervals by day of prediction

Future Work

- Interpolation to provide more training data
- Consider training on forecasting data
- Sub daily predictions
- Detecting problematic catchments
- Ungauged predictions
- Investigate ensemble weather forecasts
- Finding improvements in compute time

For more information

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