XAI and Active Learning for Predicting Winter Weather Precipitation Type

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BACKGROUND

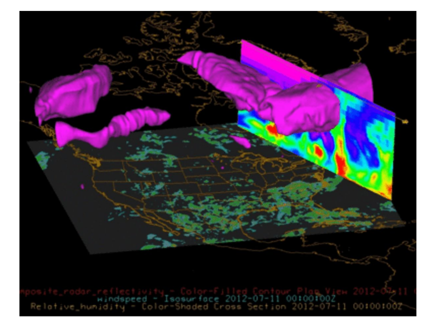
Motivation

- Winter precipitation causes 1.4 million accidents per year, $4.1 billion in damages per storm
- Accurate observation and prediction of winter precipitation is difficult
- Neural Networks are powerful but hard to interpret

Goal

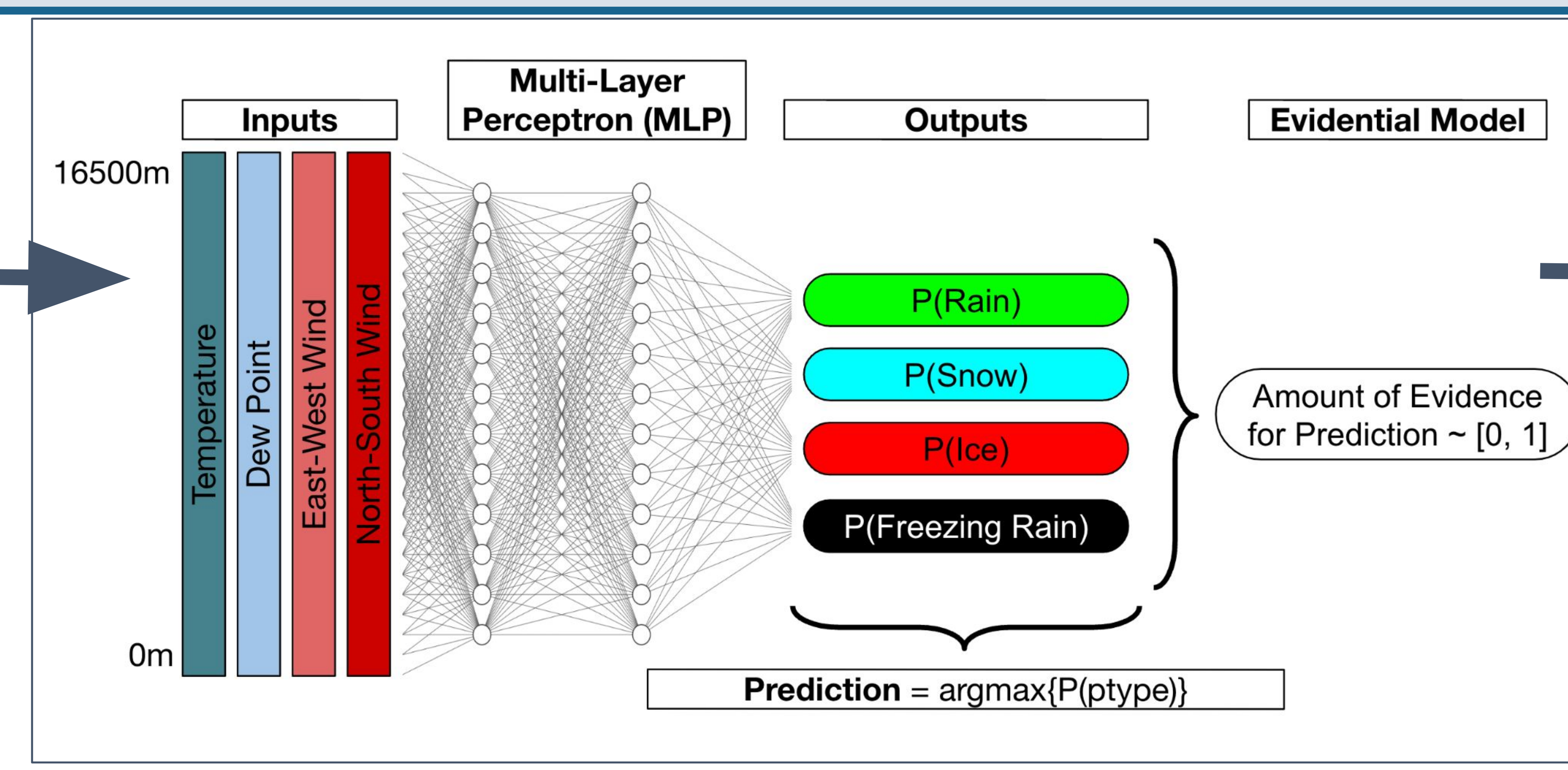
- Train deep learning models to predict winter p-type and **interpret** using **Explainable AI (XAI)** methods
- Implement **Evidential Active Learning** to improve **model performance** and **data efficiency**

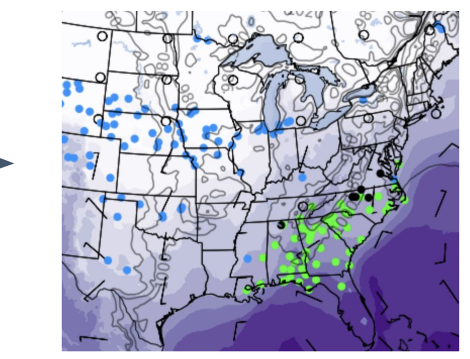
NEURAL NETWORK



Input

- RAP (Rapid Refresh) model
- **Temperature, Dewpoint, Wind Velocity** at 250m intervals in atmospheric column





Output

- **Rain/Snow/Sleet/Freezing Rain** Observations
- mPING → Crowd-Sourced
- ASOS → Fixed Monitors

MODEL AND RESULTS

Model	Loss Function	Hidden Layers	Nodes per Layer
Simple MLP	Cross Entropy	1	100
ECHO-Optimized MLP (ECHOMLP)	Cross Entropy	12	105
Simple Evidential MLP (EvidMLP)	Evidential Digamma	1	100

mPING Test Accuracies			
Rain	**Snow**	**Ice**	**FzRain**
94%	92%	41%	28%
88%	75%	65%	59%
94%	90%	17%	6%

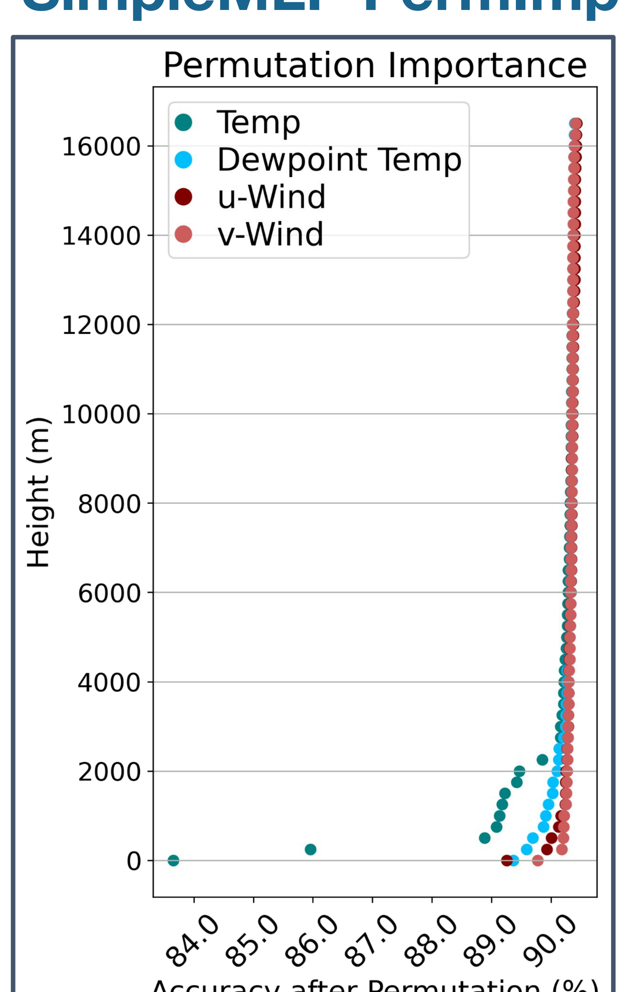
EXPLAINABLE AI (XAI)

METHODS AND RESULTS

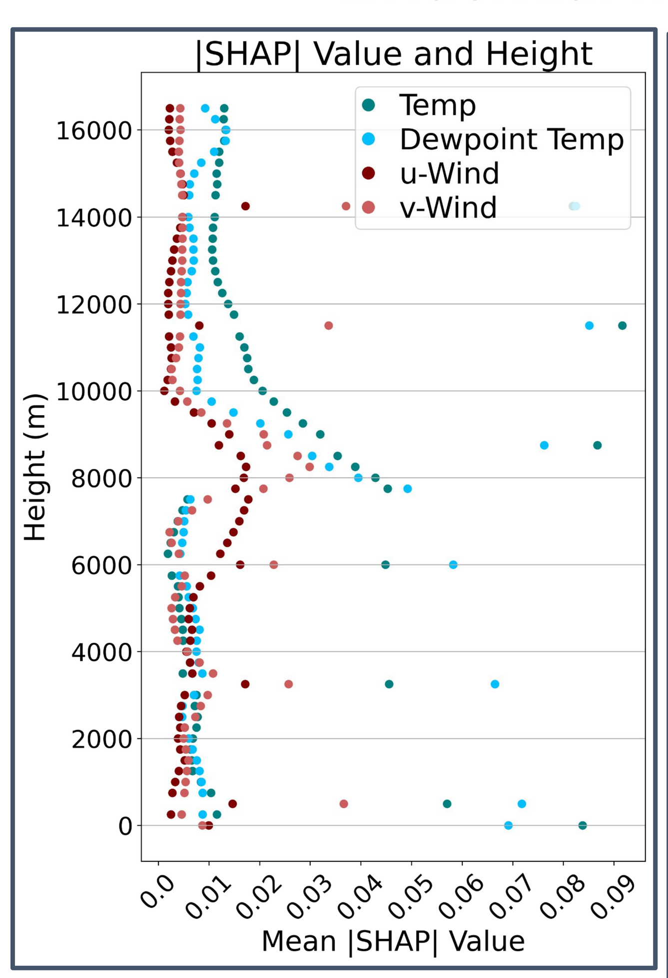
Permutation Importance: Change in prediction accuracy from original model after randomly shuffling each input feature one-by-one

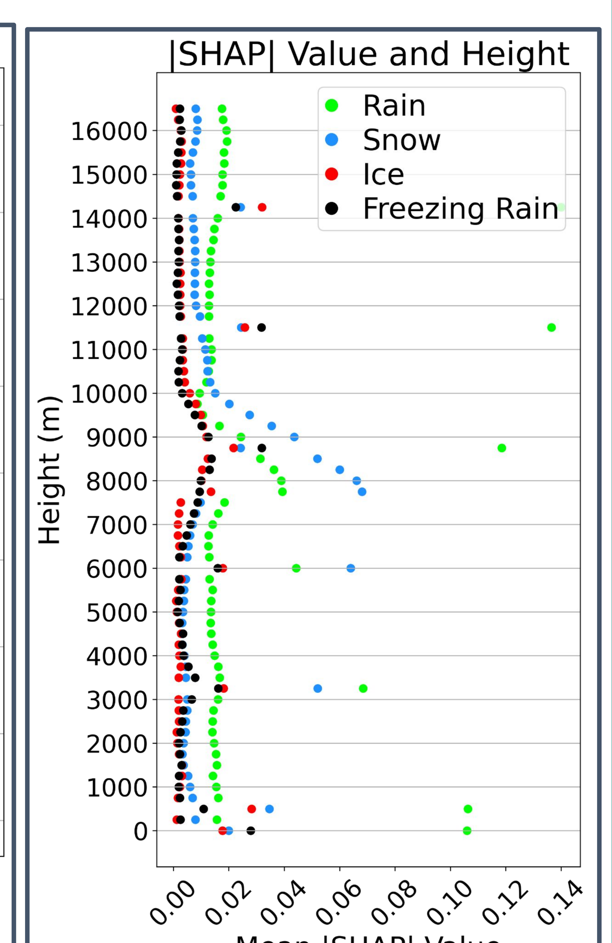
SHAP (SHapley Additive exPlanations): Computes contribution of each feature towards each model prediction

SimpleMLP PermImp



Evidential MLP SHAP

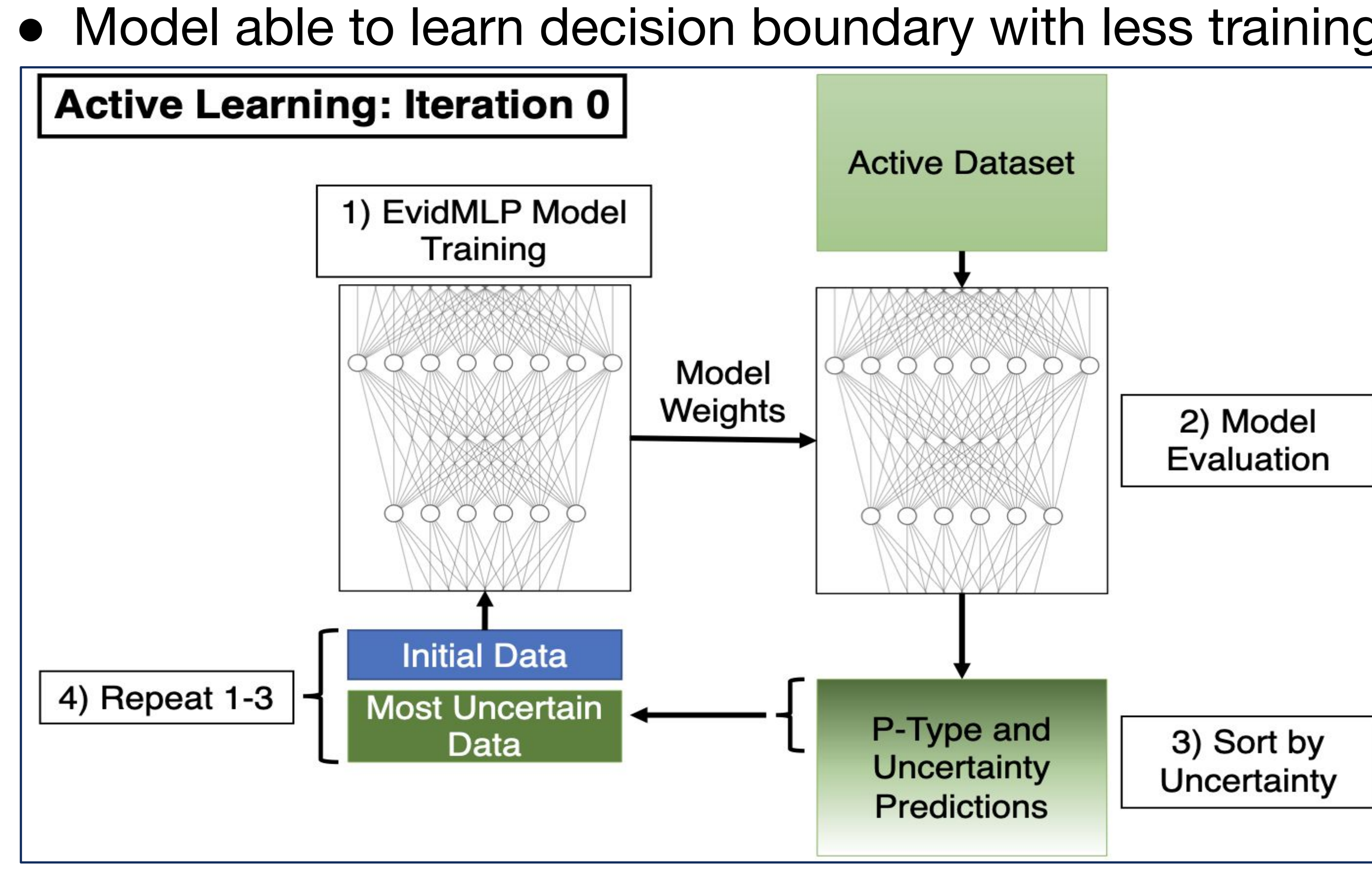




ACTIVE LEARNING

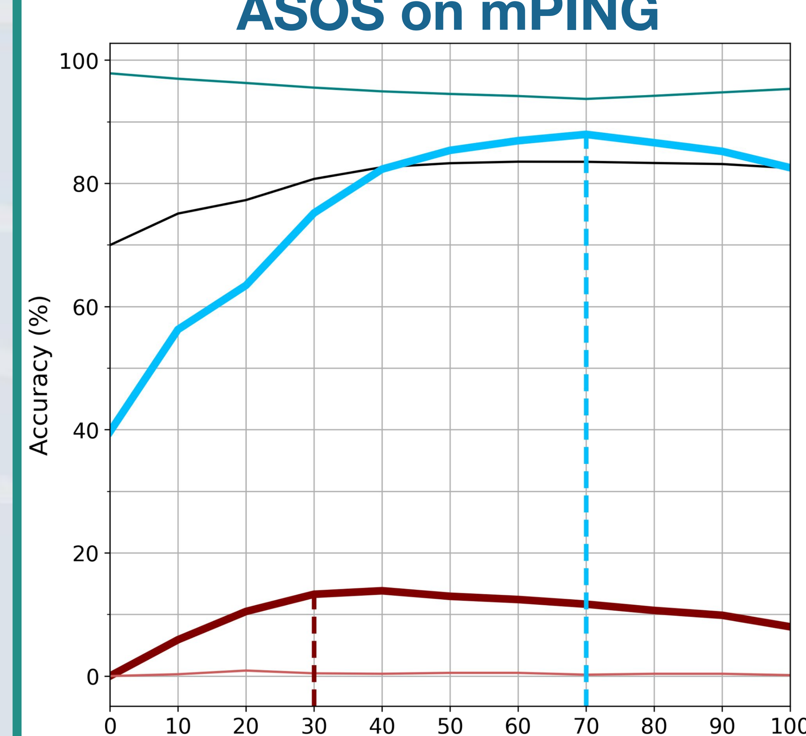
METHODS AND RESULTS

- Iterative training on uncertain training examples using Evidential MLP
- Model able to learn decision boundary with less training examples

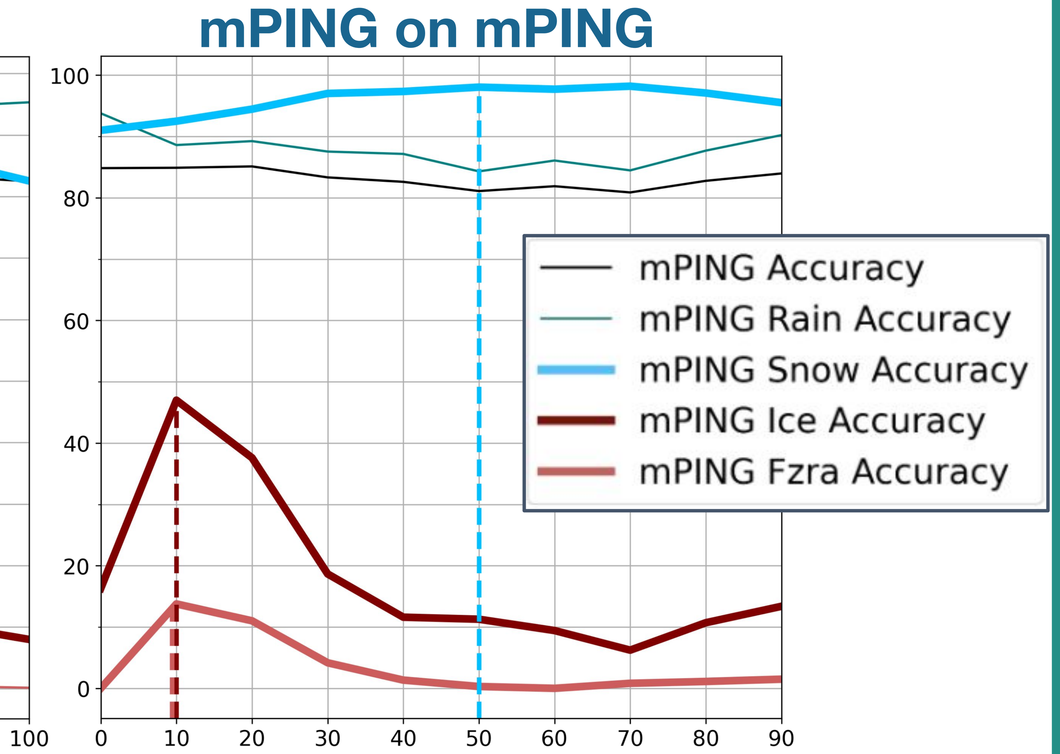


Experiments	
Initial (% Full)	**Active (% Full)**
ASOS (10%)	ASOS (90%)
ASOS (100%)	mPING (100%)
mPING (10%)	mPING (90%)

ASOS on mPING



mPING on mPING



CONCLUSIONS

Explainable AI

- Simple MLP learned important features at lower elevations in atmospheric column
- Evidential MLP learned important features at lower elevations and near tropopause

Active Learning

- Sleet accuracy improves significantly over baseline with just the most uncertain 20% of full dataset added
- Able to improve accuracy for most difficult labels while maintaining performance for other labels

FUTURE WORK

Active Learning

- Compute baselines for comparison
- Use Model Ensembles and Dropout Sampling in addition to Evidential Uncertainty

Analysis

- Apply model to RAP grids across US, beyond mPING and ASOS observation points
- Implement model architectures with spatiotemporal components (CNN, RNN, etc.)
- Analyze consistency with physical knowledge

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