Predicting Power Flow and Weather Stressors from Synthetic Grid Data

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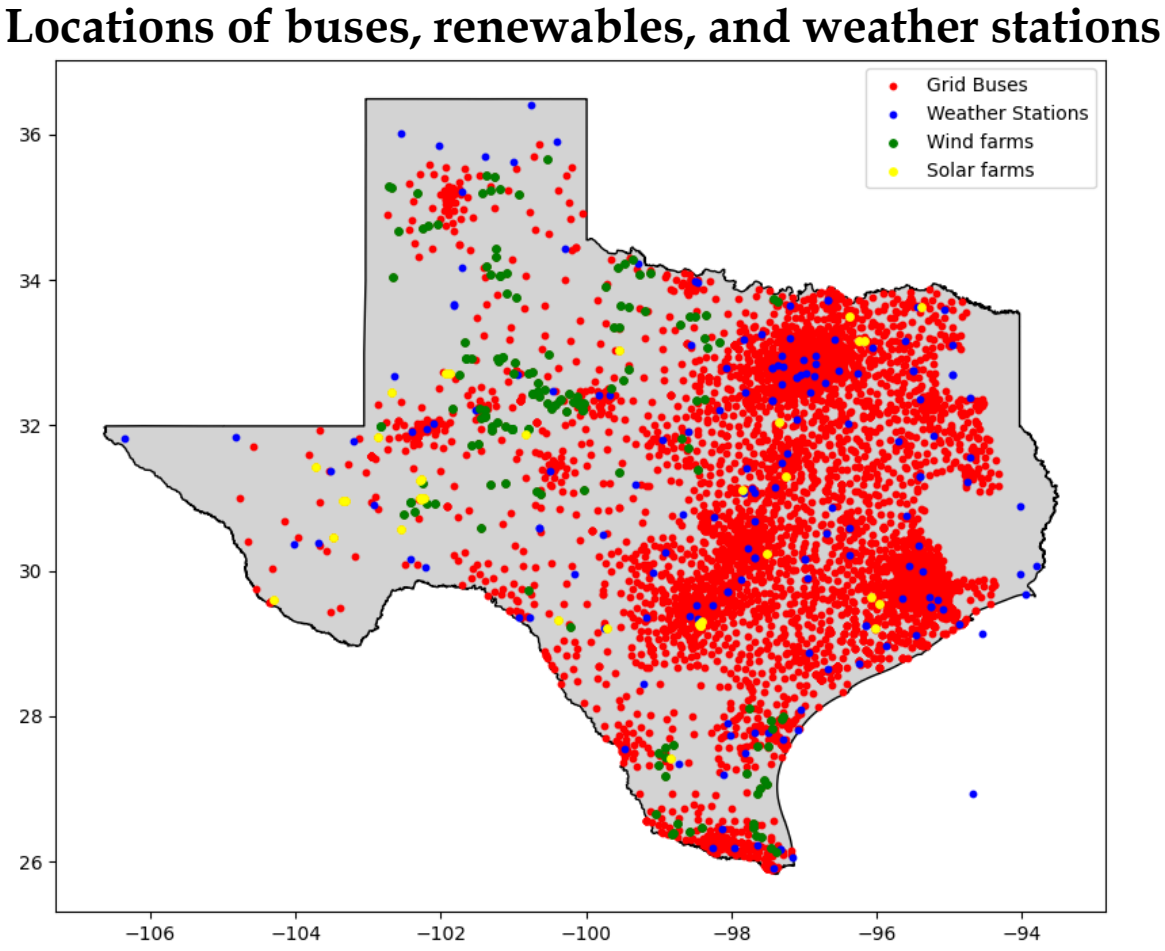
Weather-informed grid operations

- Motivation
  - Weather mostly used for long-term grid planning
  - Daily operations increasingly affected by weather
- Weather-power flow (PF) coupling
  - How to directly predict grid operational stress from weather forecast?
  - What are the key weather factors affecting grids?

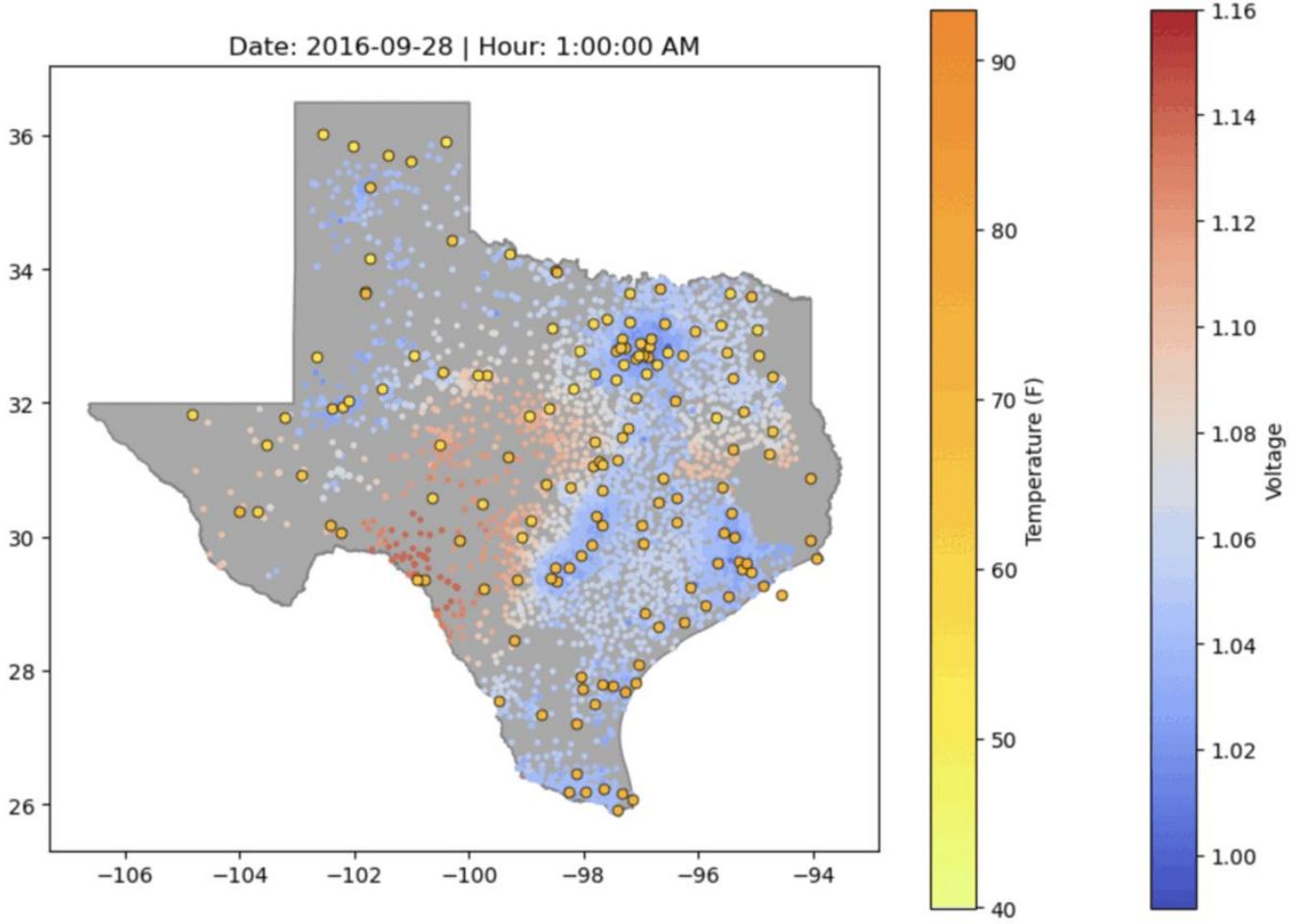
Synthetic grid dataset

- Texas synthetic grid 6717-bus case
  - ERCOT's full system with 8 regions
  - Renewable (wind/solar) generations
- Weather inputs [Overbye'23]
  - 137 weather stations
  - Temperature
  - Wind speed
  - Solar irradiance X cloud coverage



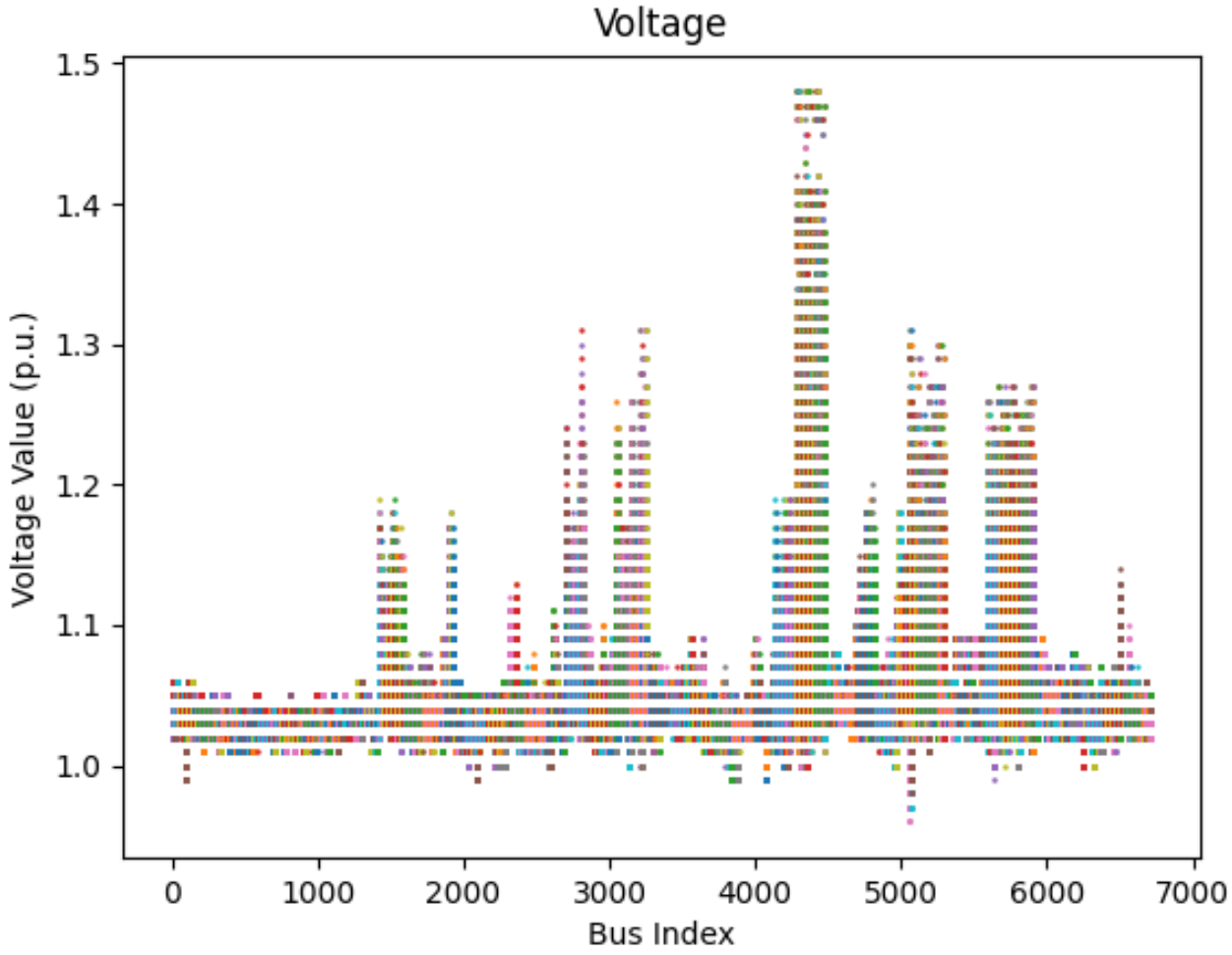
Weather-PF coupling

- Hourly PF outputs
  - Bus voltage
  - *Line flow (to be analyzed)*
  - PowerWorld OPF solver
- All the data in the year of 2016
  - 8784 samples in total
  - Per unit (pu) voltage [0.94, 1.48]



Voltage outputs

- Mostly > 1.0 pu
- Some extreme high values
  - Solver setup
- Variability of voltage still useful



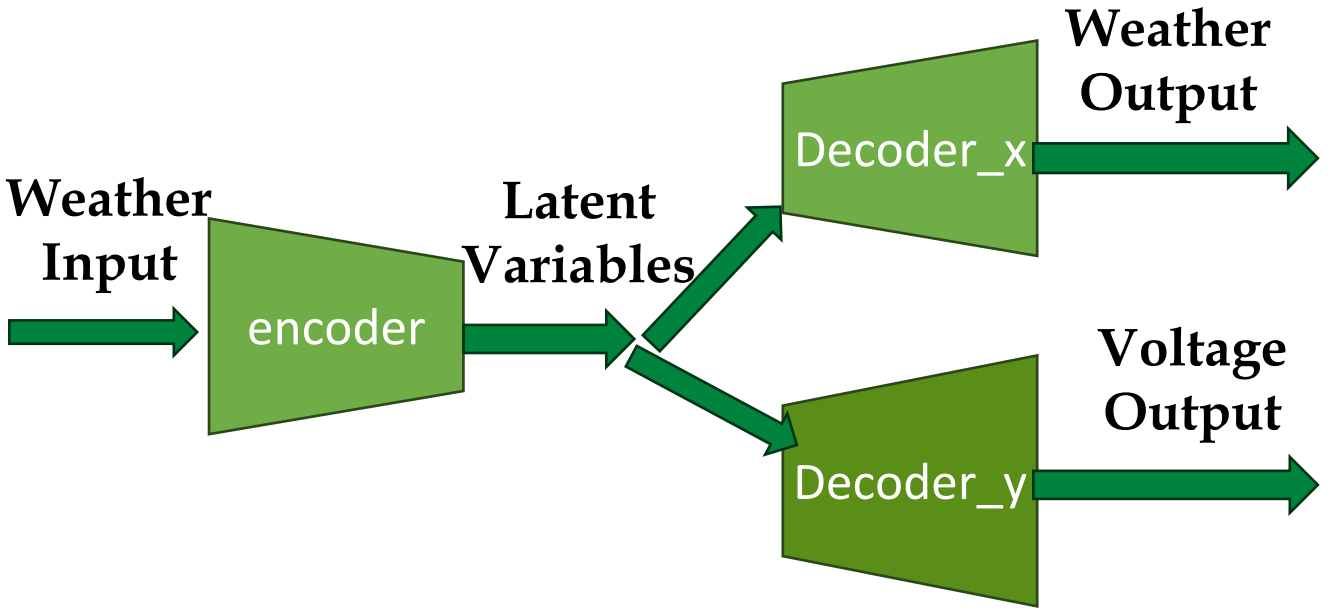
Voltage prediction

- Training/test split: 80%/20%
  - Graph neural network (GNN)
  - Autoencoder:

    best prediction
  - Sparse autoencoder:

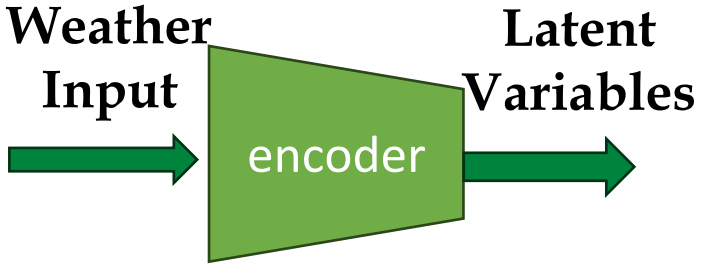
    for identifying stressors

  - *Why not use the load input?*

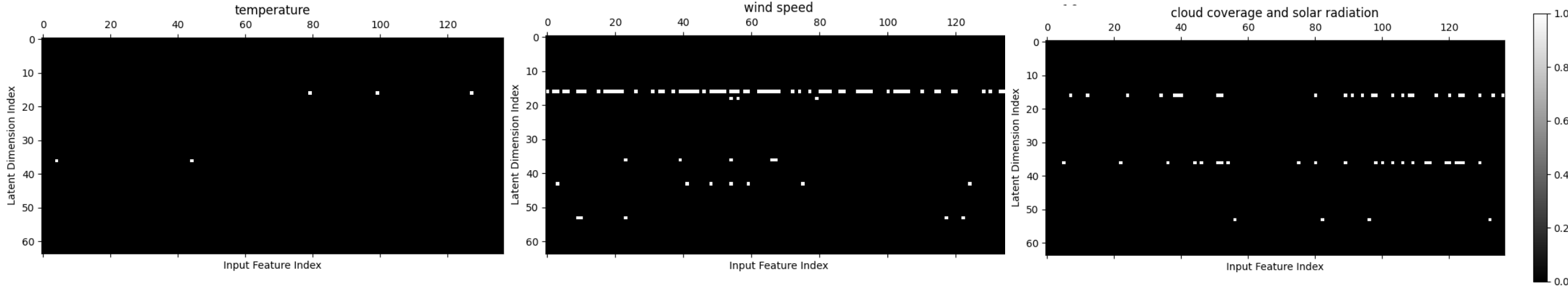


Error (pu)	GNN	Autoencoder	Sparse Autoencoder
Mean	0.028	0.0060	0.0084
Min	0.0016	2.3e-6	0
Max	0.098	0.018	0.12

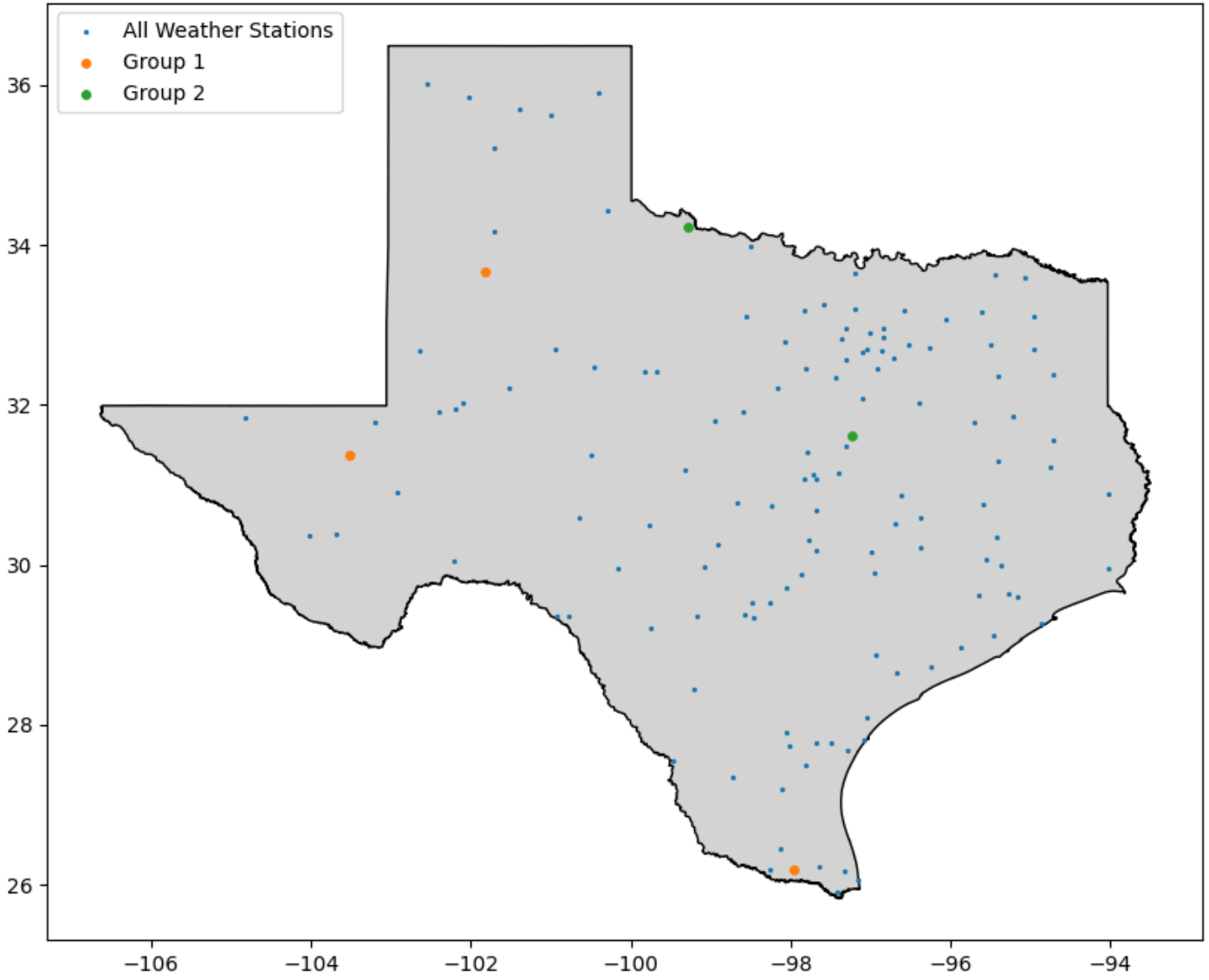
Identifying weather stressors

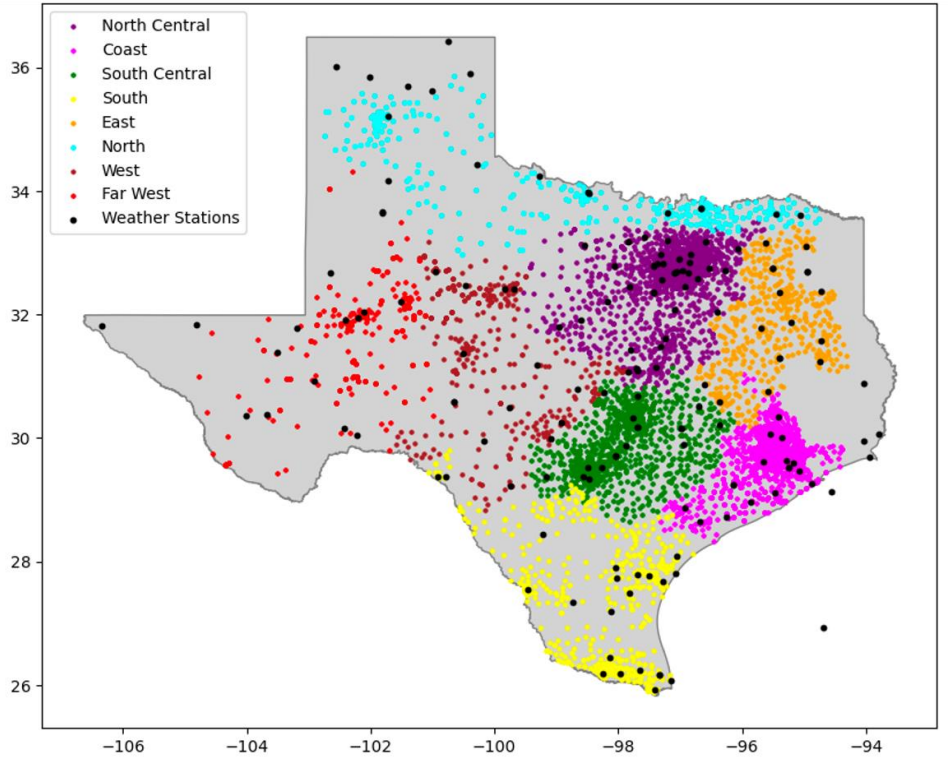


- Sparse autoencoder: promote 0's in encoder matrix
  - Highly correlated weather features
  - Very few underlying stressors (latent variables)
  - Sparse mapping from weather input



Temperature

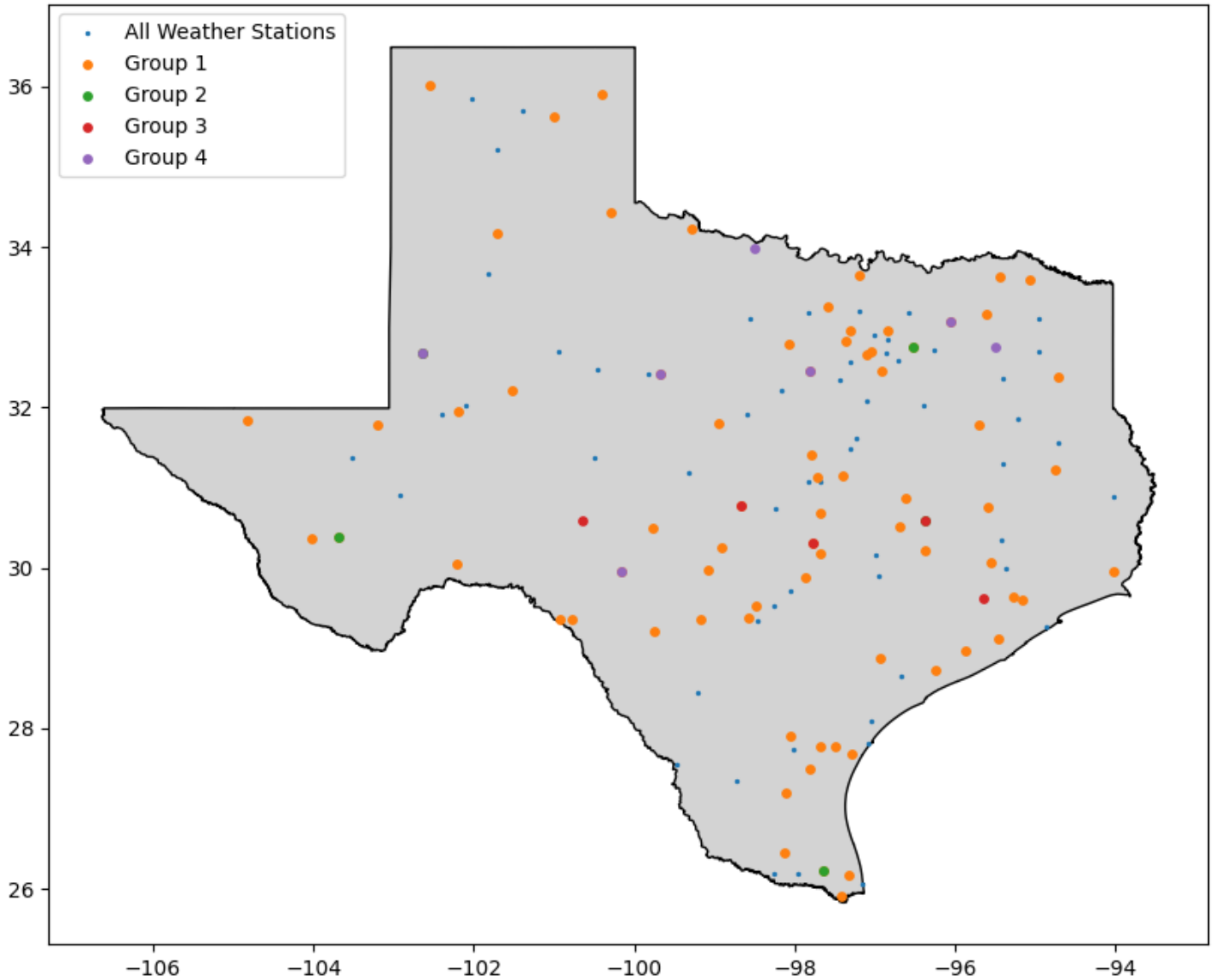


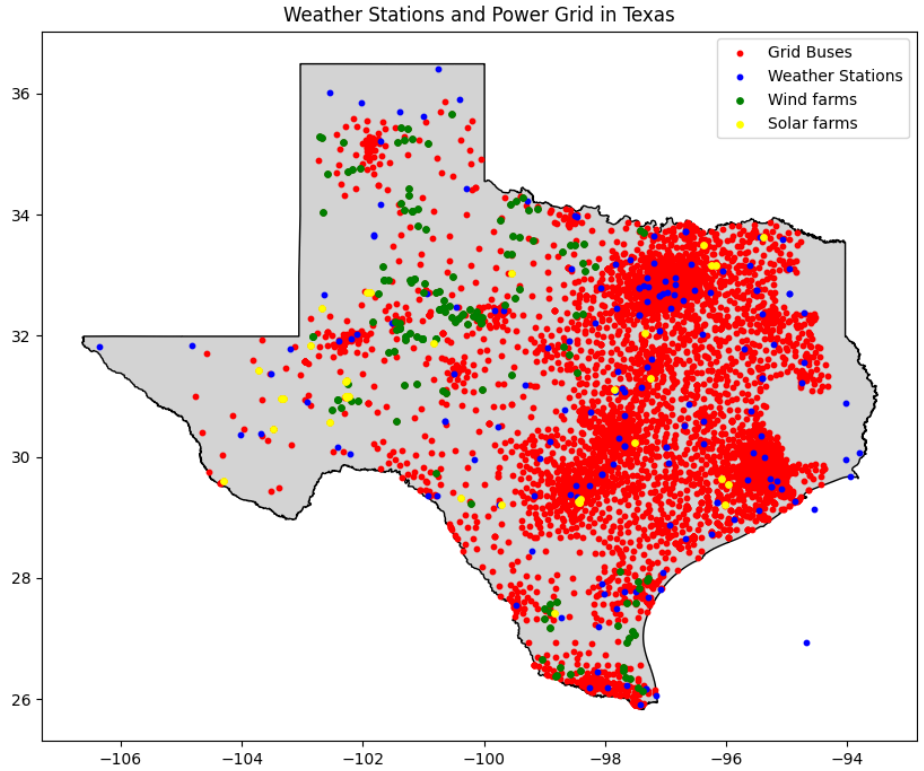


- 5 active temperature locations
  - Similar temp. across the state
  - Cover ERCOT regions in:

North, Farwest, Central, South

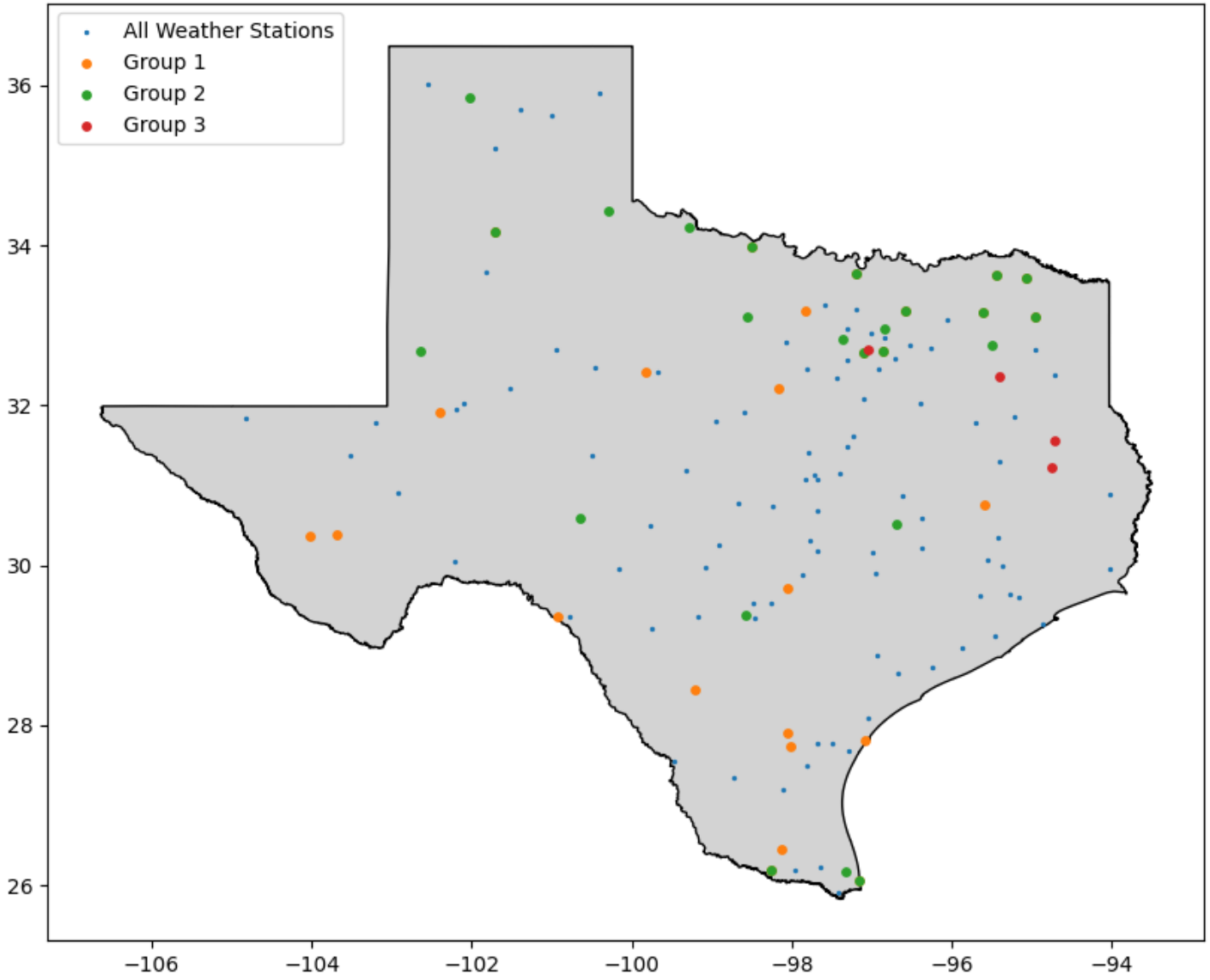
Wind speed

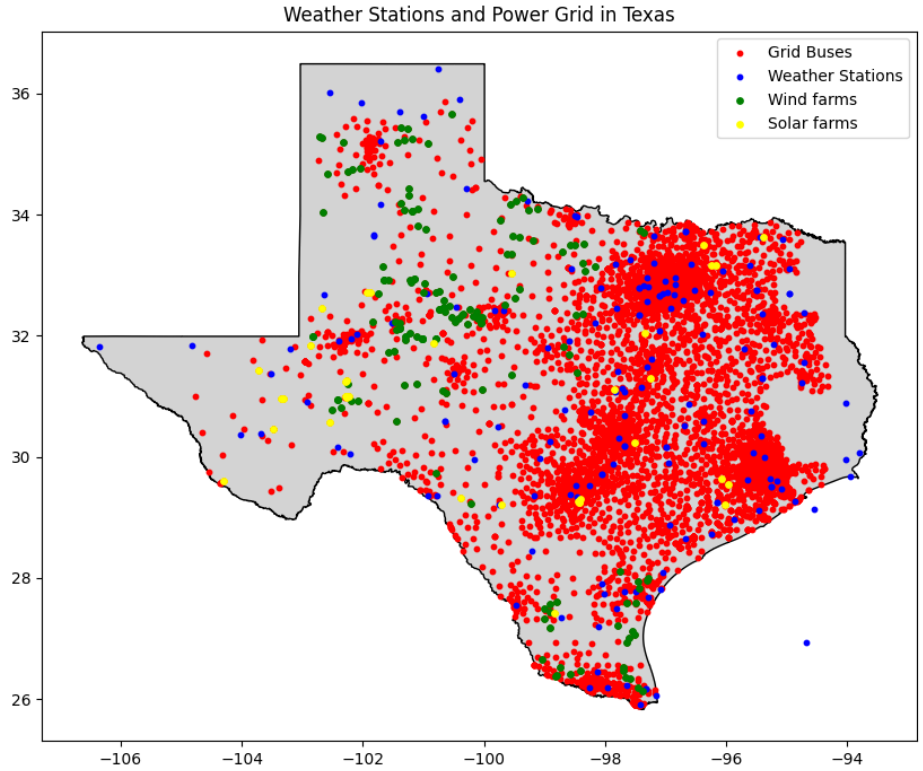




- Multiple wind locations
  - Wind patterns very diverse
  - Related to wind farm locations

Solar input





- A dozen of solar locations
  - Related to solar farm locations
  - Possibly affecting load demand

Conclusions

- Weather-aware grid operations
  - Predictive modeling of PF outputs
  - Identifying weather stressors

- Ongoing directions:
  - General PF outputs (line flow?)
  - Detailed ERA5 weather data

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