Initial Analysis of and Predictive Model Development for Weather Reroute Advisory Use

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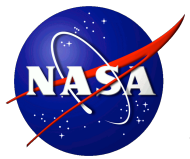

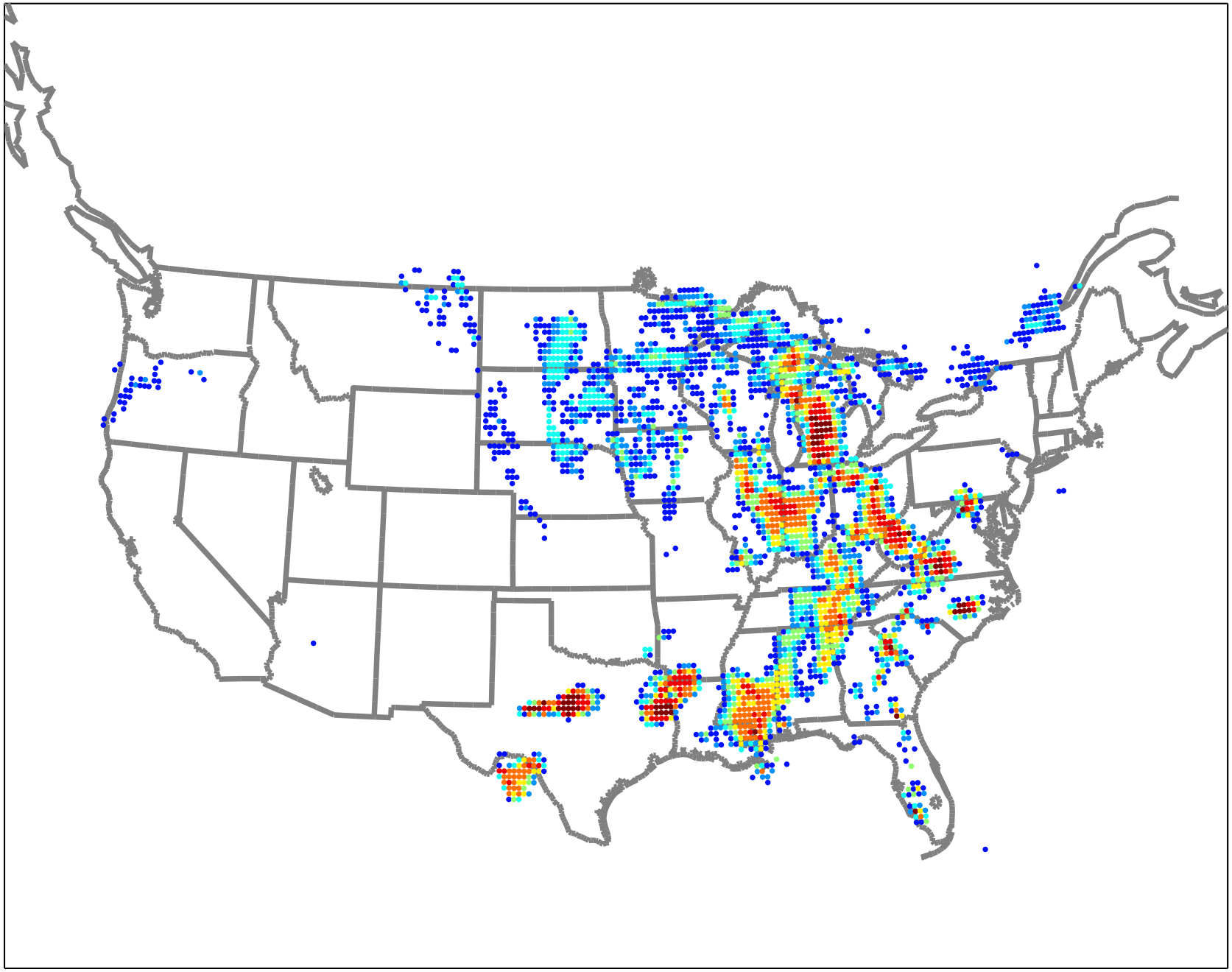

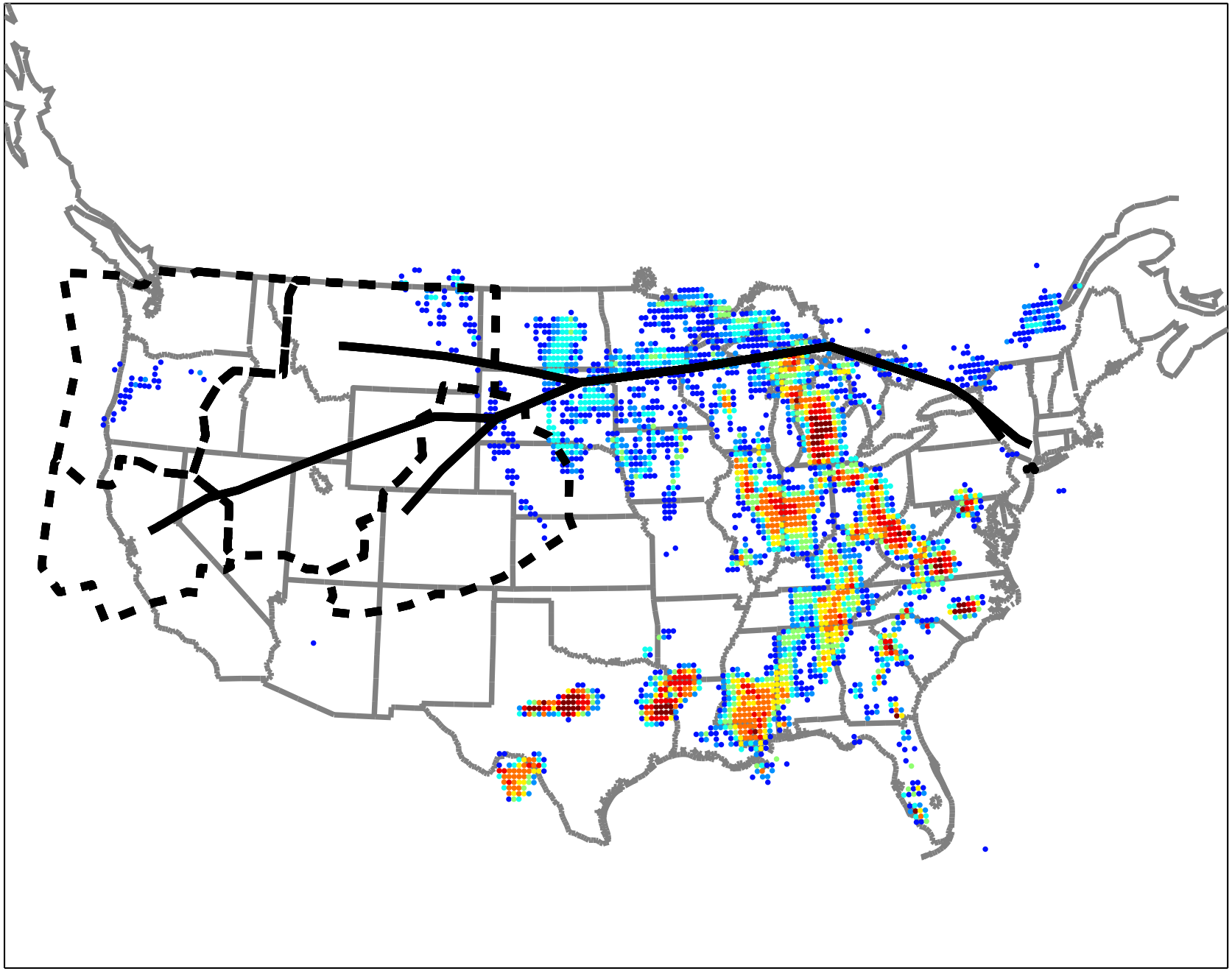

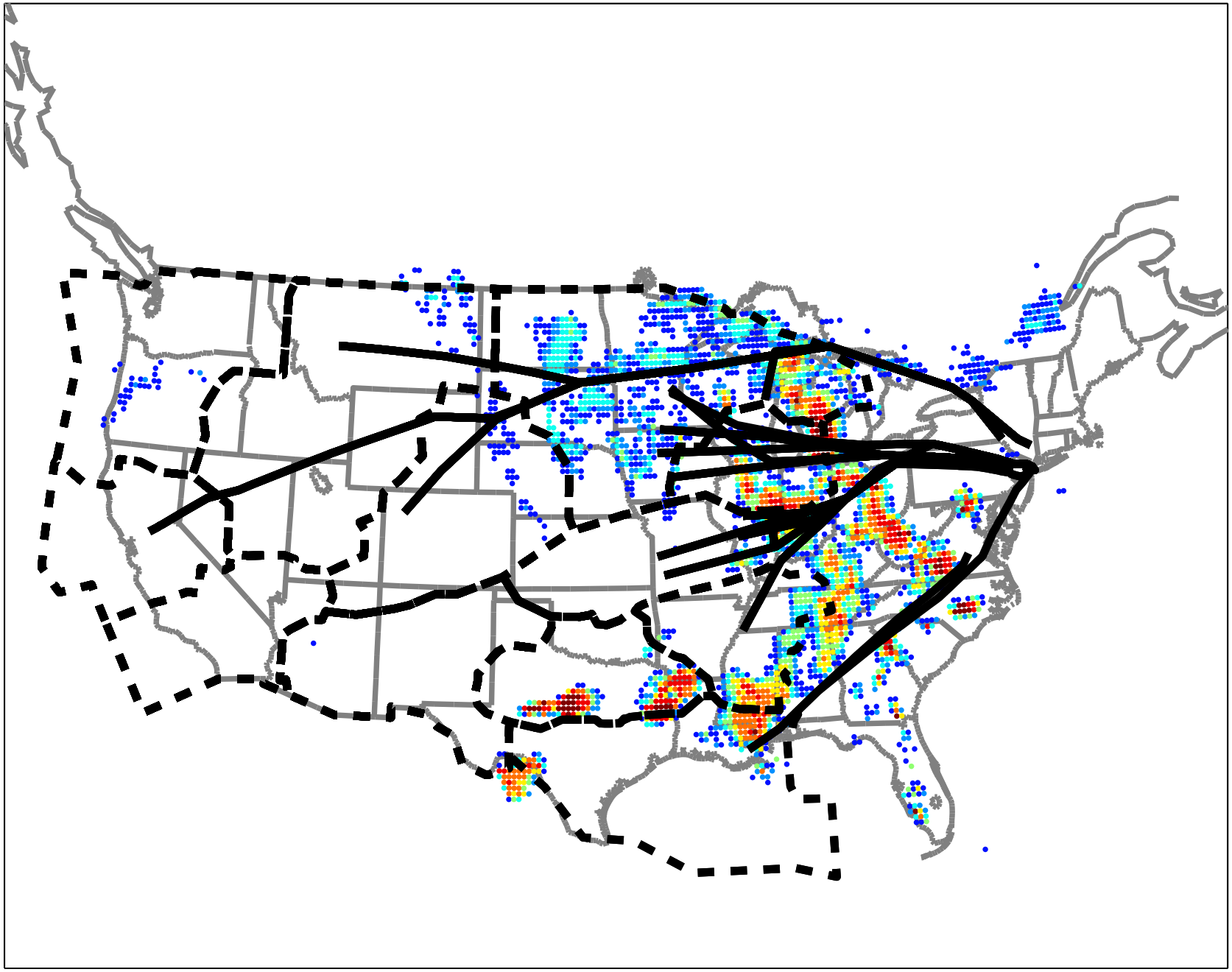

Approaches

Previous work and ongoing

- Focused on identifying similar weather days
- Analyzing reroutes used on similar days
- Difficult to generate meaningful clusters of days

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This work

- Build models to predict the use of reroutes based on weather data

Objective

Develop a framework and process to analyze the use of reroutes and develop models to predict reroute use.

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  $\Rightarrow$ difficult to extract relevant features

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  $\Rightarrow$ spatially similar routes with different descriptions

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- Large amount of weather data available
  $\Rightarrow$ difficult to extract relevant features
- Flexibility in route selection and descriptions
  $\Rightarrow$ spatially similar routes with different descriptions
- Routes used infrequently
  $\Rightarrow$ difficult to find similarities

Outline

- Advisory details
- Methodology
  - Identification of routes used by flights
  - Identification of similar routes
  - Weather feature extraction
  - Development of predictive models
- Prediction results
- Concluding remarks

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Advisories consist of . . .

- Name
- Valid time range
- Text description of several routes
  - From an origin Center or airport
  - To a destination airport

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June to August 2011

- 1,669 reroute advisories issued
- 735 unique advisory names
- 34,247 routes
- 2,770 origin-destination pairs

Example advisory

ATCSCC Advisory

ATCSCC ADVZY 062 DCC 06/21/2011 ROUTE RQD /FL

RAW TEXT:

```
ATCSCC ADVZY 062 DCC 06/21/11 ROUTE RQD /FL
NAME: TX_ZME_2_EWR_LGA
CONSTRAINED AREA: ZME
REASON: WEATHER
INCLUDE TRAFFIC: ZFW/ZHU/ZME DEPARTURES TO EWR/LGA
FACILITIES INCLUDED: /ZDC/ZFW/ZHU/ZID/ZME/ZNY/ZOB/ZTL
FLIGHT STATUS: ALL_FLIGHTS
VALID: ETD 211800 TO 220100
PROBABILITY OF EXTENSION: LOW
REMARKS: THIS REPLACES ADVZY033.
ASSOCIATED RESTRICTIONS:
MODIFICATIONS:
ROUTES:

ORIG                DEST                ROUTE
----                ----                -----
ZHU                 LGA                 >HRV J37 MGM AHN J208 HPW
                                        J191 PXT KORRY3<
ZHU                 EWR                 >HRV J37 SPA J14 CREWE J51
                                        FAK PHLBO2<
ZME ZFW(-BNA)       LGA                 >MEM J29 DJB CXR J146 ETG
                                        MIP3<
ZME ZFW(-BNA)       EWR                 >MEM J29 DORET J584 FQM
                                        FQM1<


TMI ID: RRDCC062
211728-220100
11/06/21 17:28  DCCOPS./nfs/lxstn18
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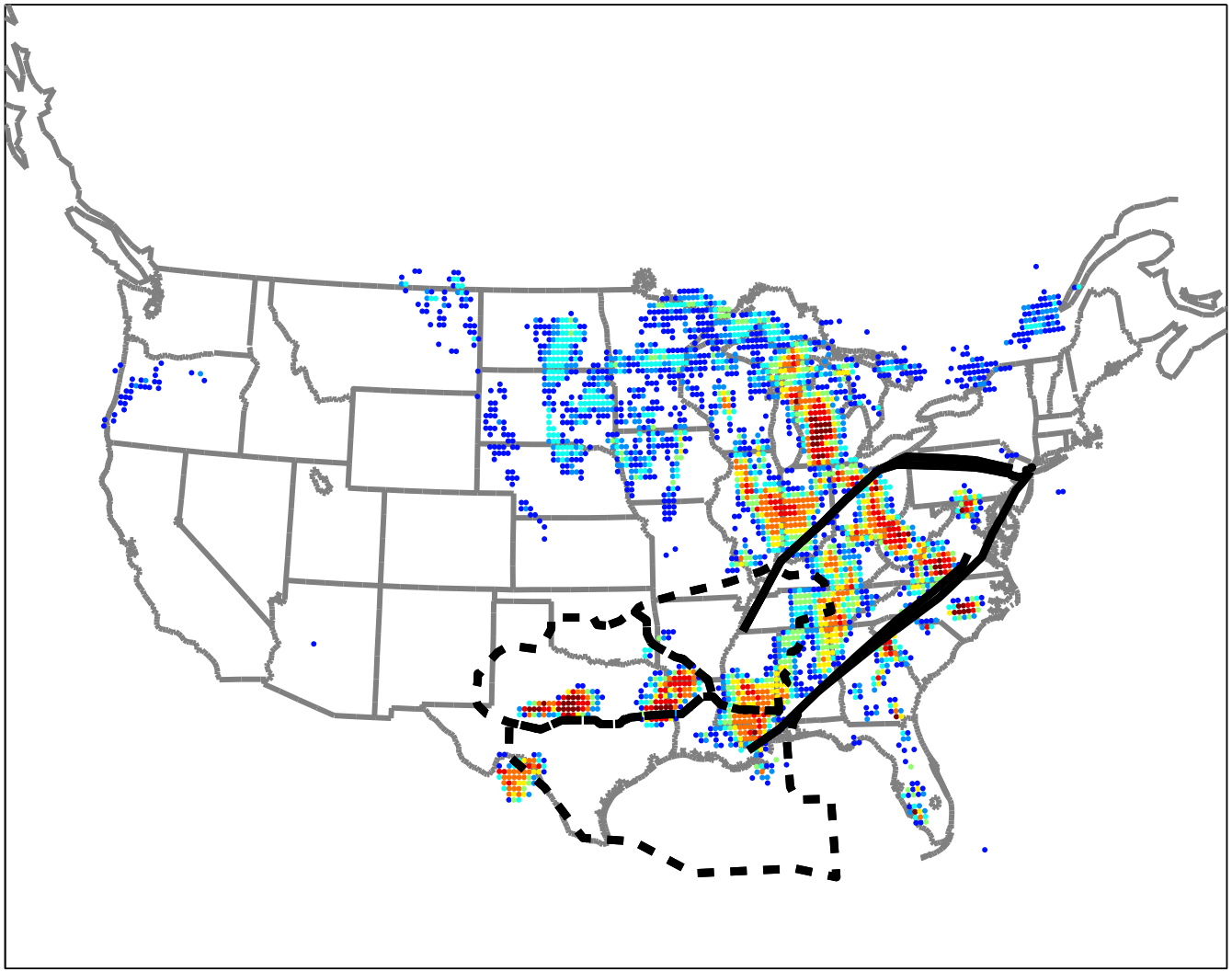

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- Identification of routes used by flights
  requires distance metric to compare routes and flight tracks
- Identification of similar routes

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  requires distance metric to compare routes and flight tracks
- Identification of similar routes
  requires distance metric to compare routes
- Weather feature extraction
  requires domain knowledge
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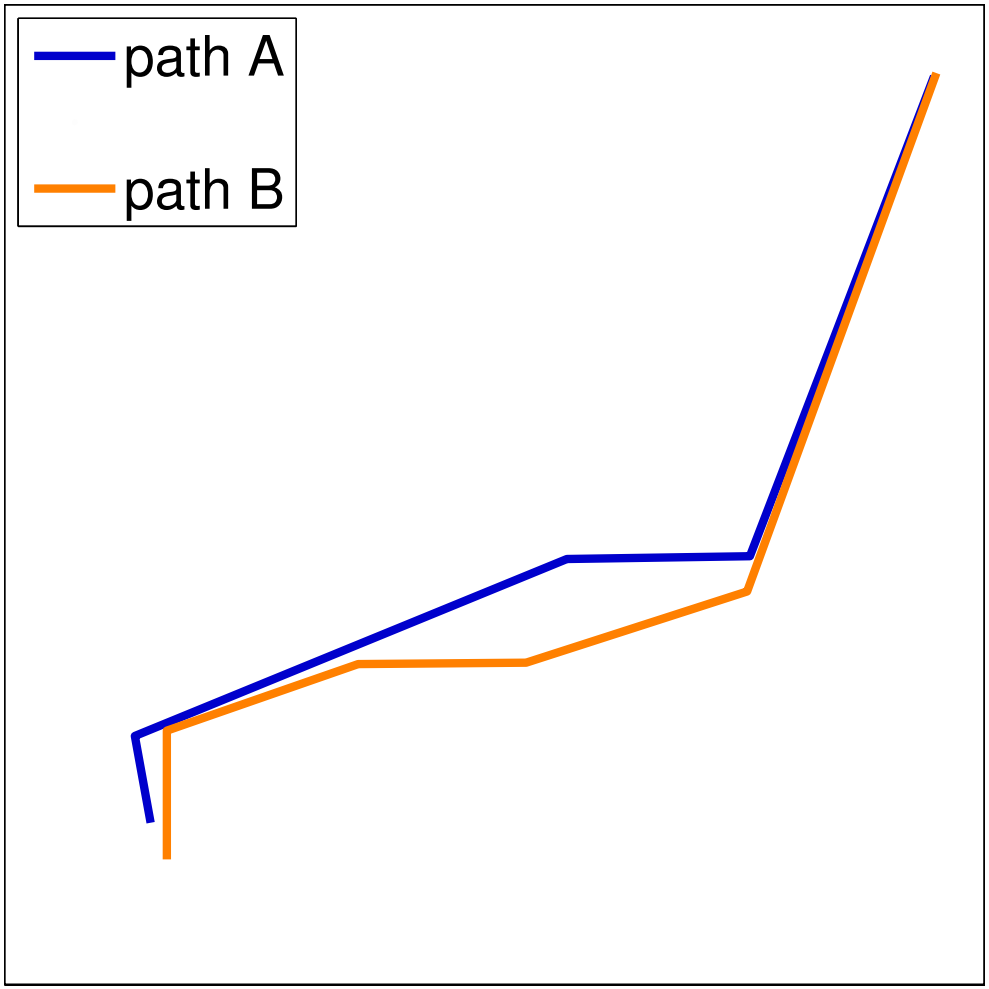

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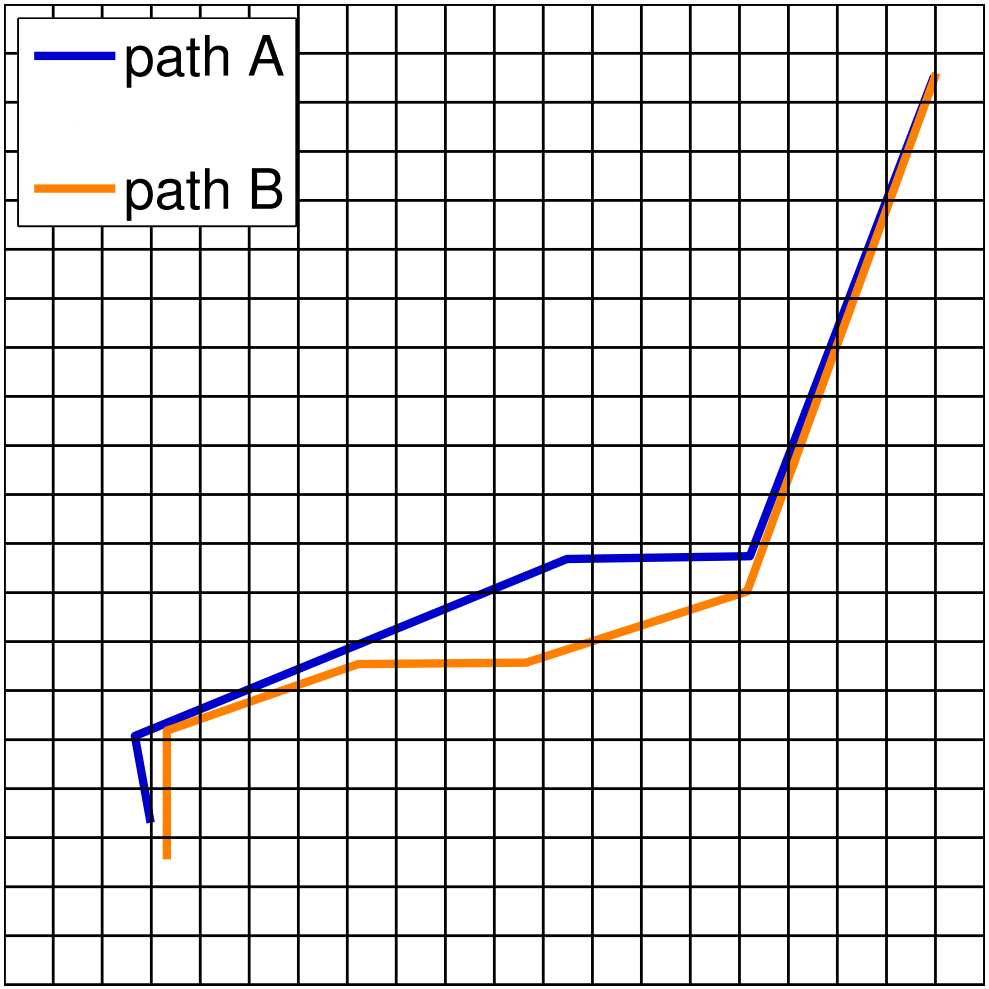

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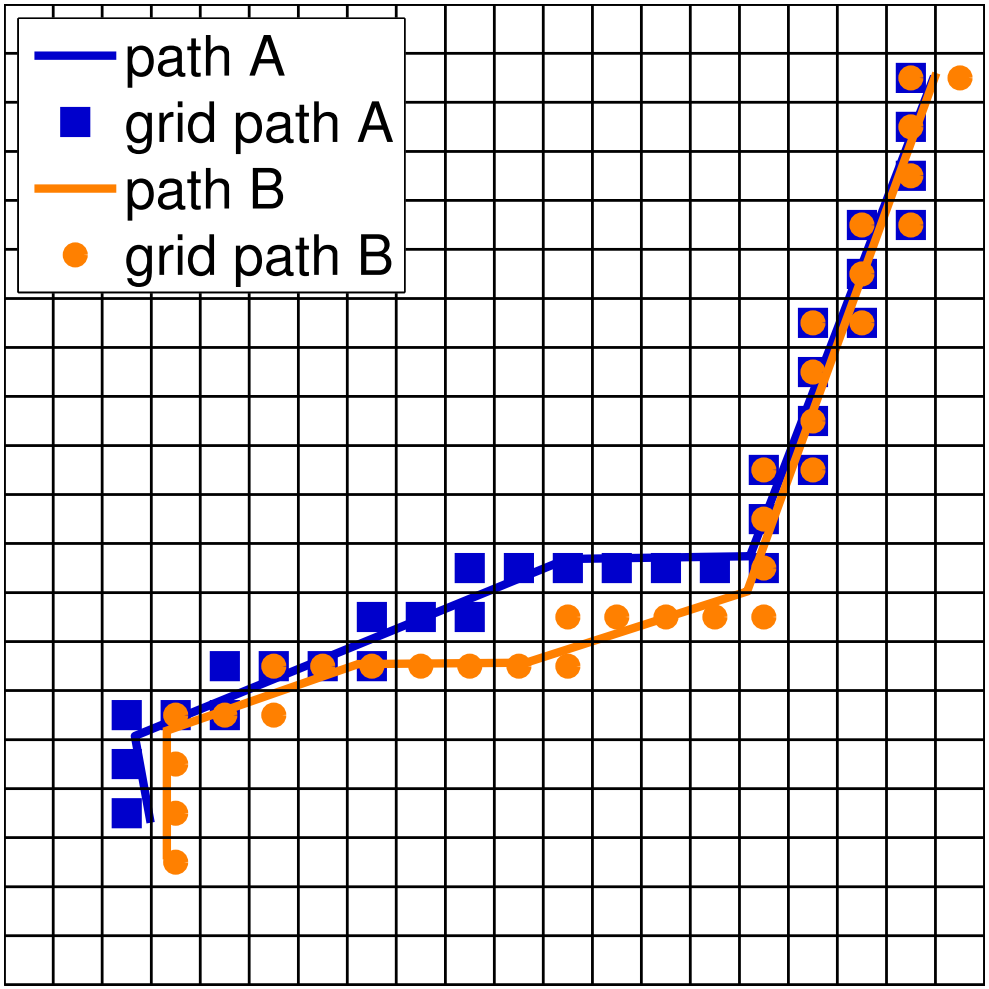

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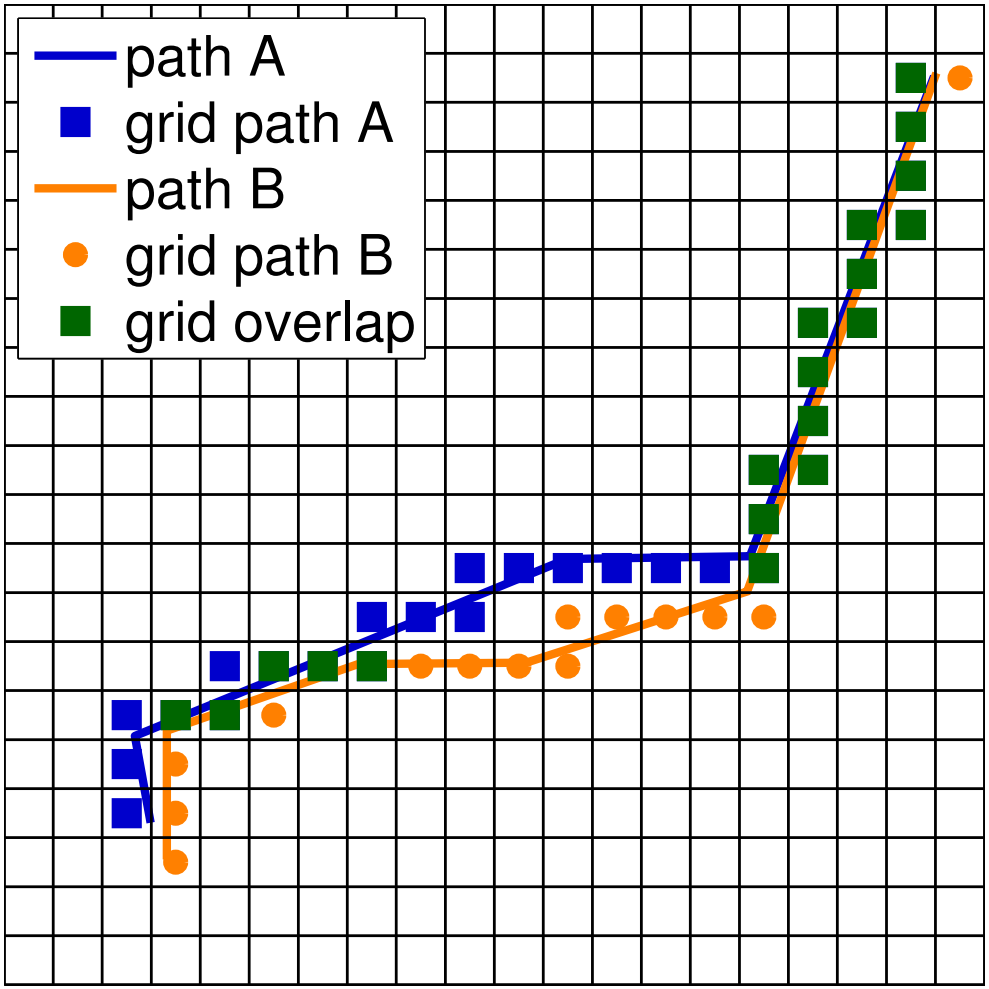
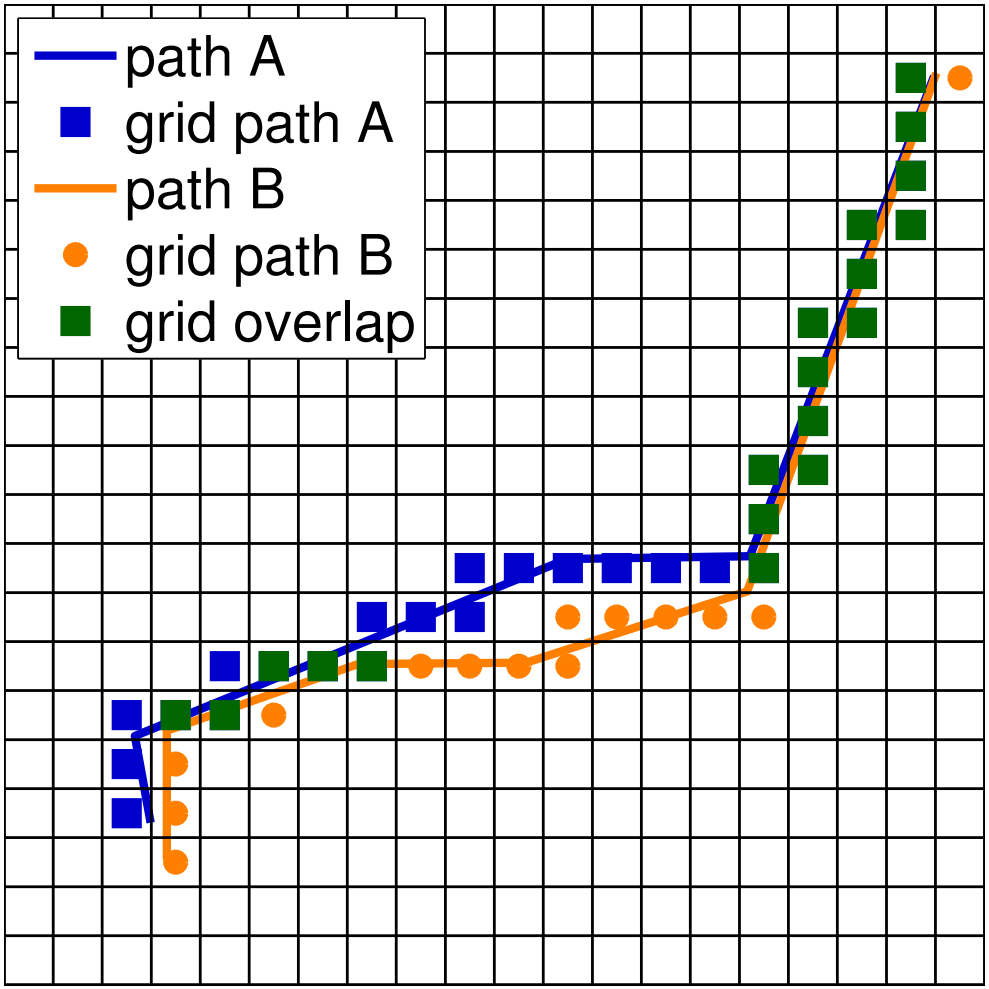


Distance metric

$$\text{distance}(\text{path A}, \text{path B}) = 1 - \frac{\text{length}(\text{grid overlap})}{\min(\text{length}(\text{path A}), \text{length}(\text{path B}))}$$



Route usage

- June through August 2011
- Routes and flights inbound to New York Center (ZNY)
- Define use:
  flight track and reroute overlap for at least 85% of shorter path
- Of 4,476 issued routes, 905 were used by at least one flight

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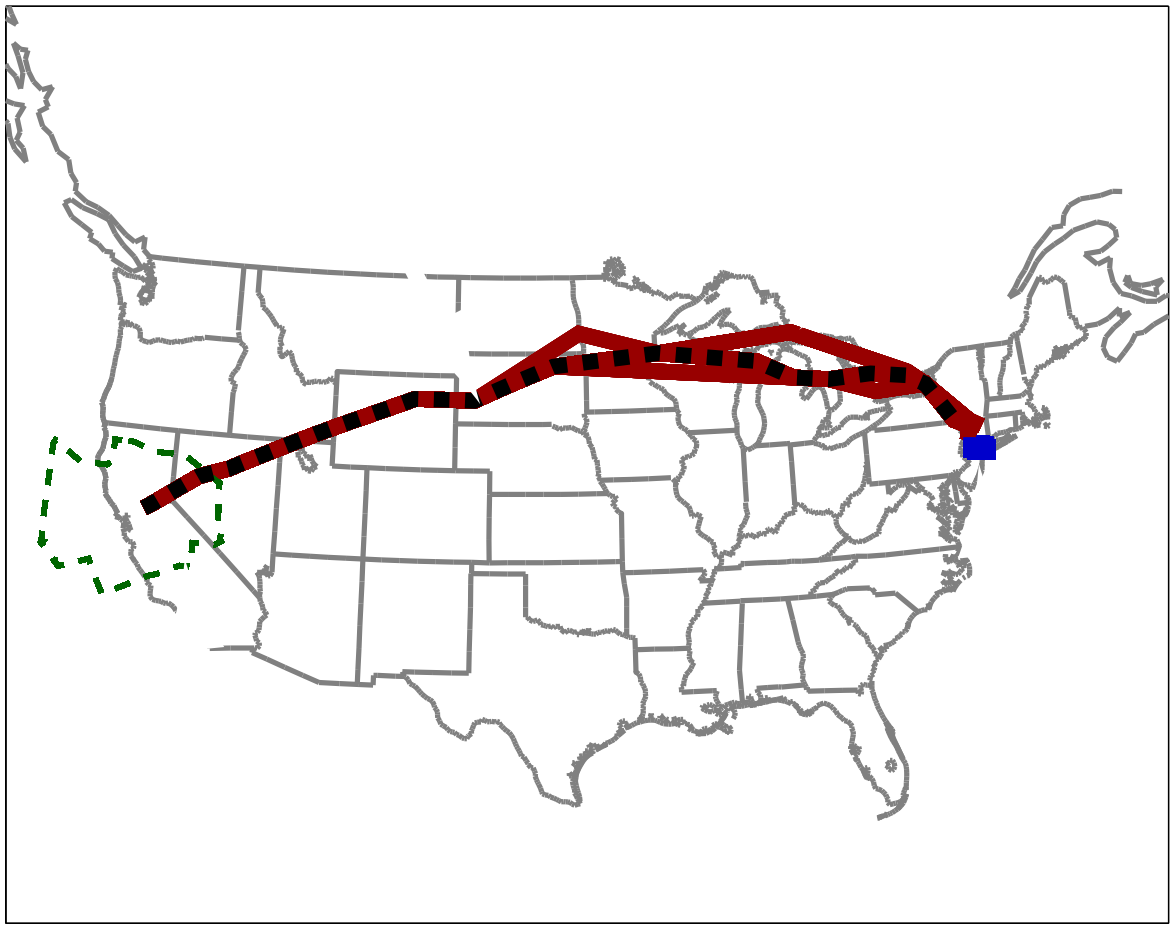
Cluster routes

905 used routes grouped into 253 clusters

Example cluster



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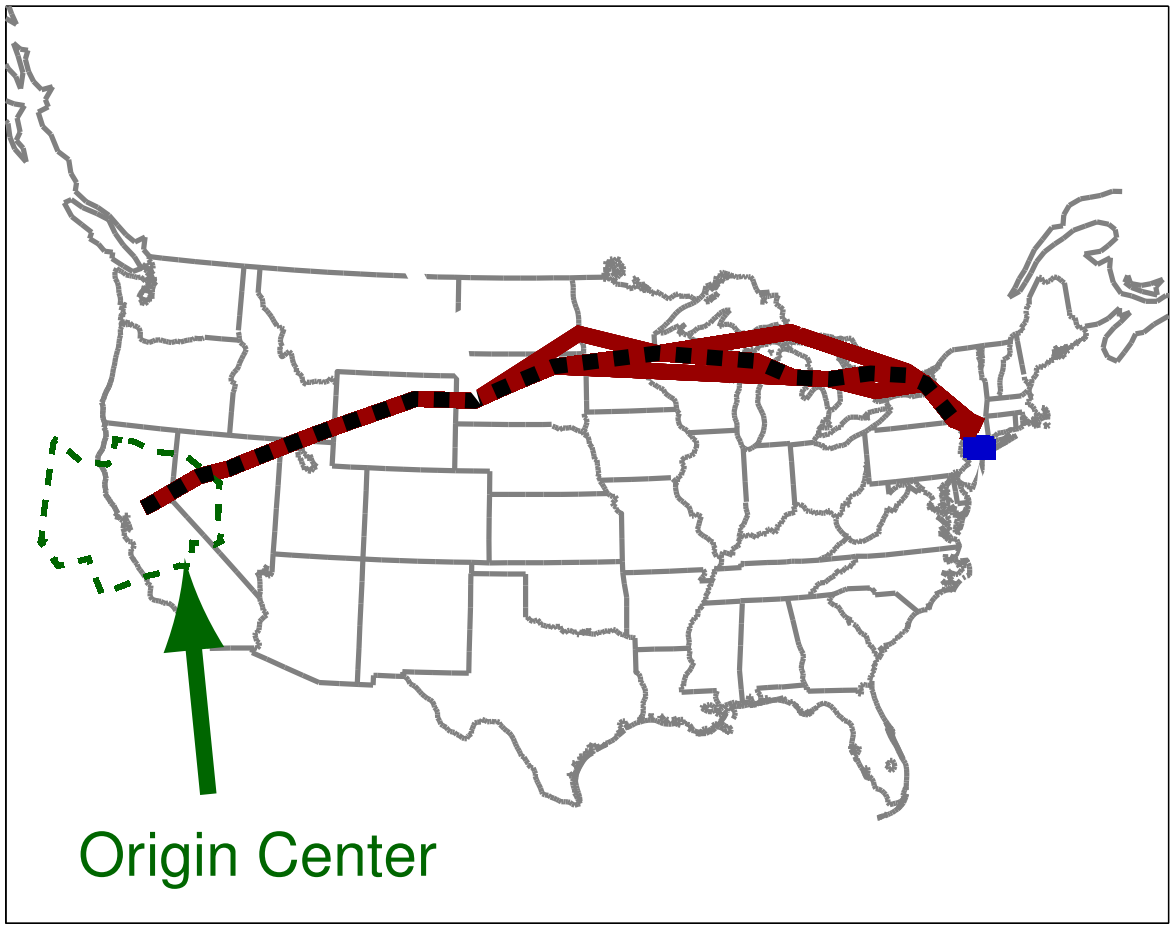

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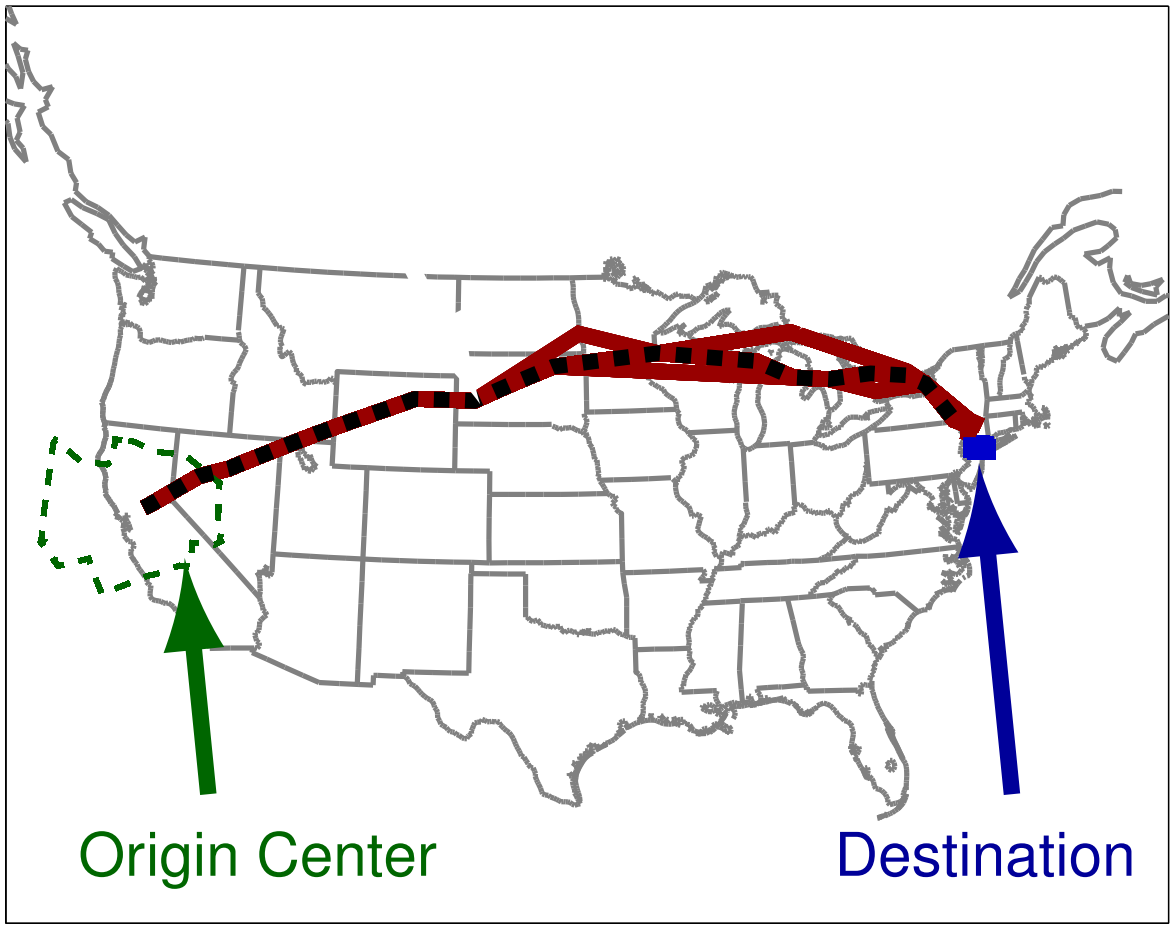

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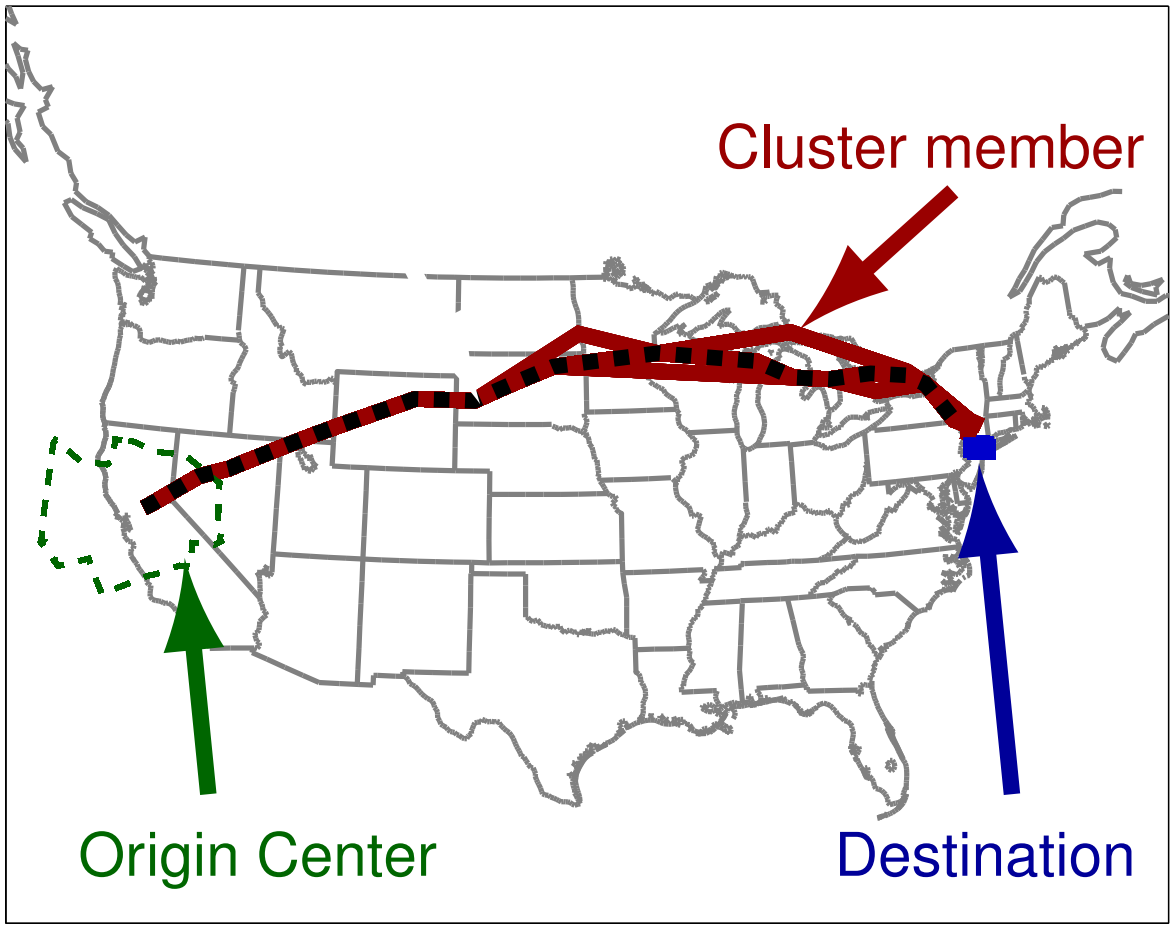

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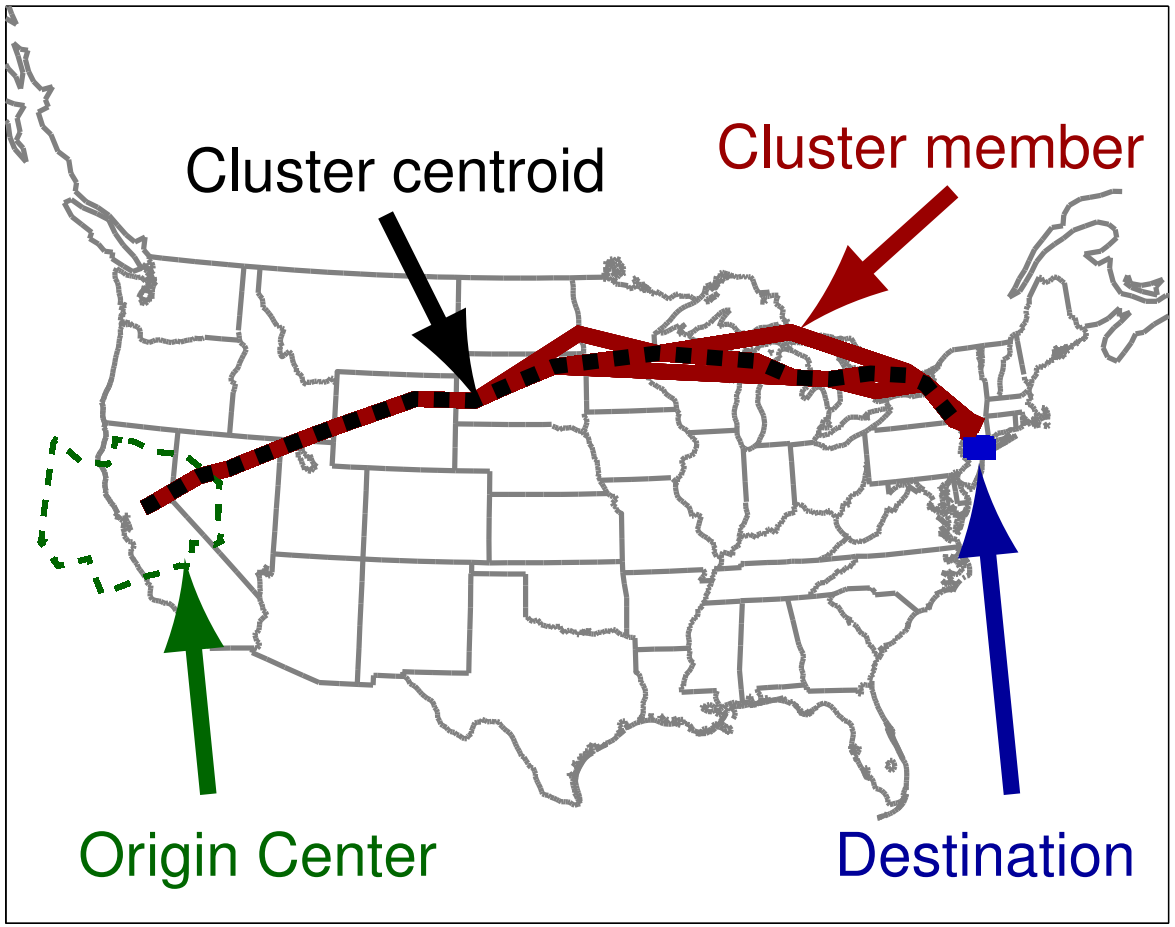

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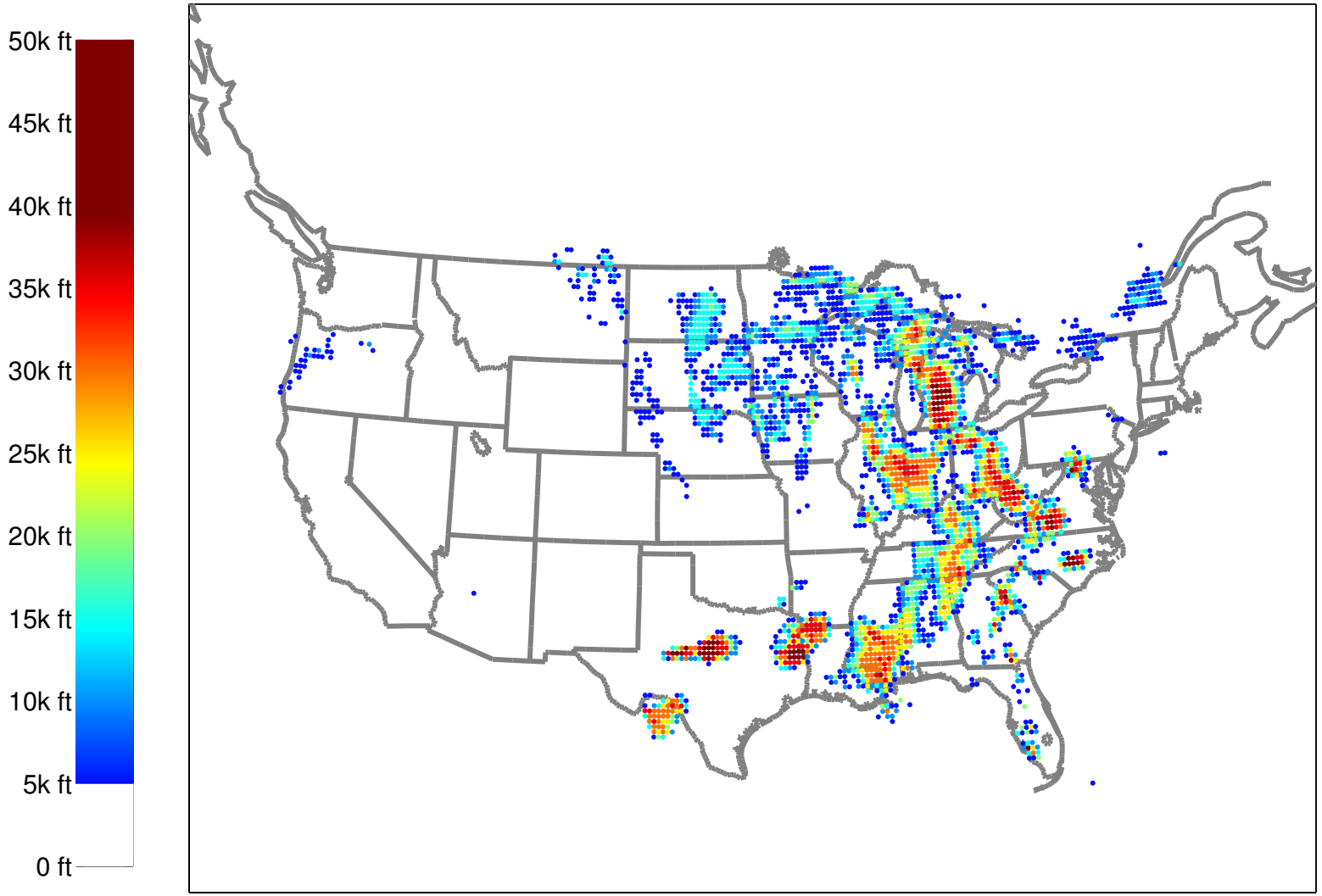
Grid

- Spatial resolution of 75 nmi by 58 nmi
  (1.25° lat by 1.25° lon)
- 1,000 grid elements cover the continental US
- Temporal resolution of one hour
- 1,000 averaged echo top values per hour

High resolution weather data



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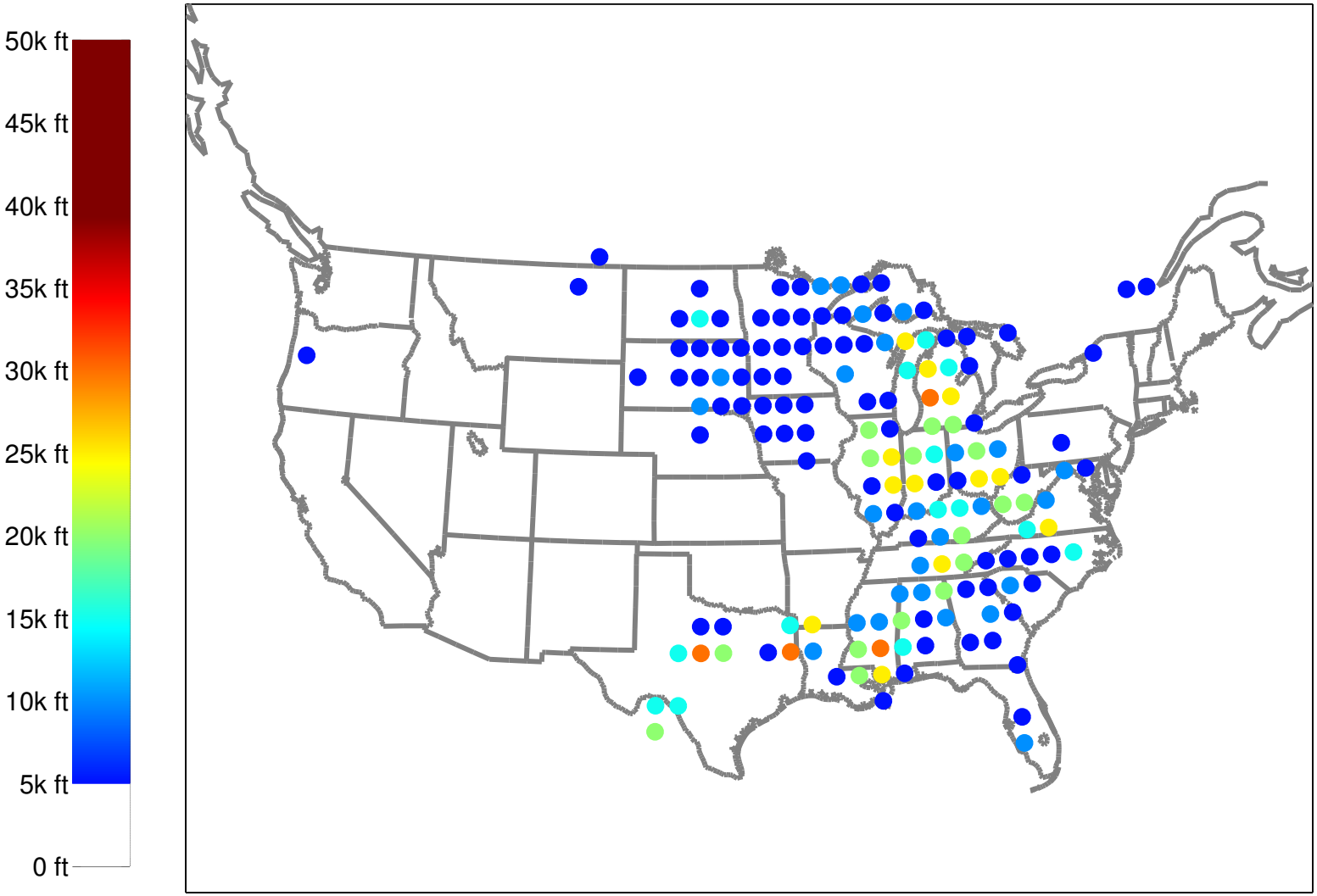

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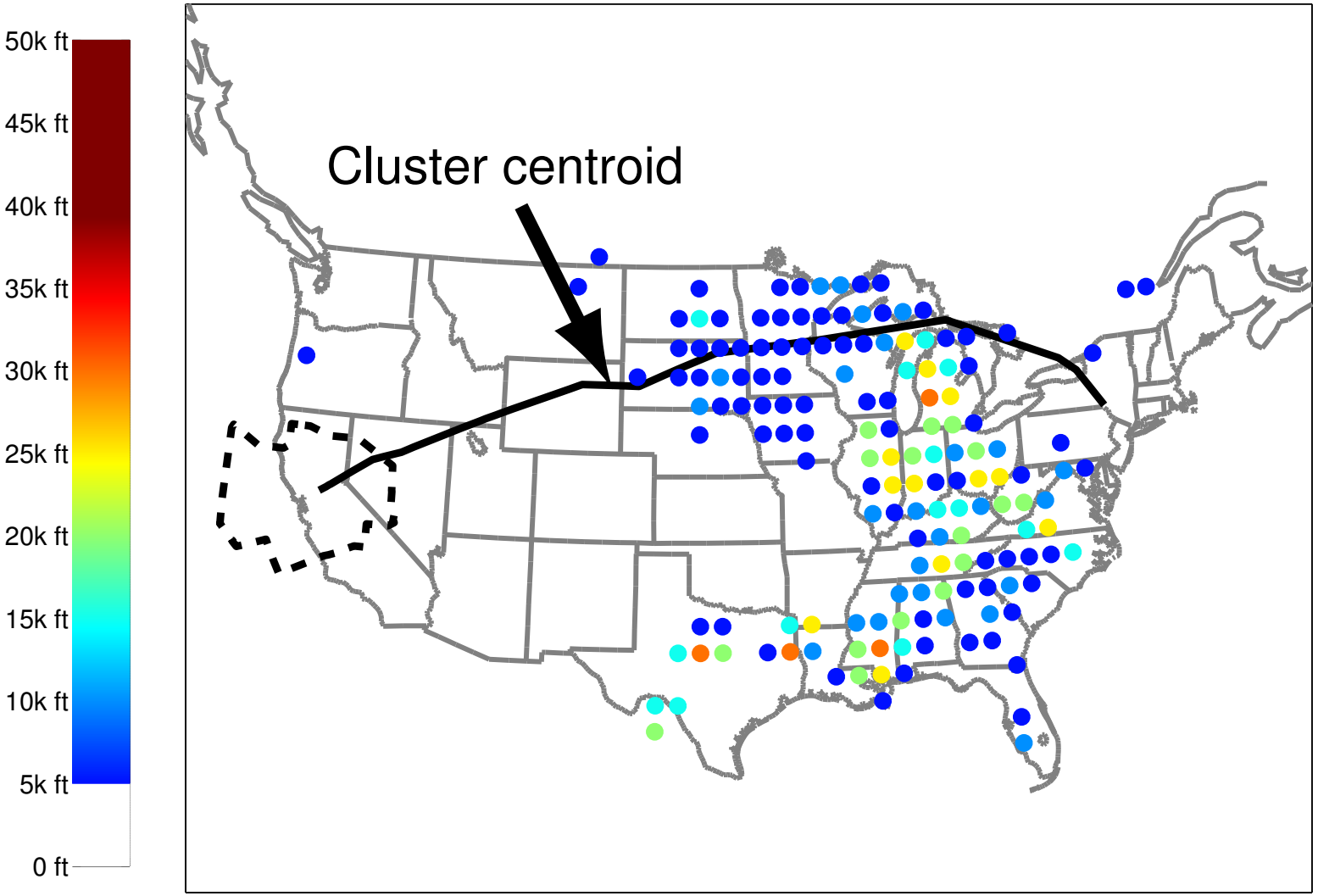

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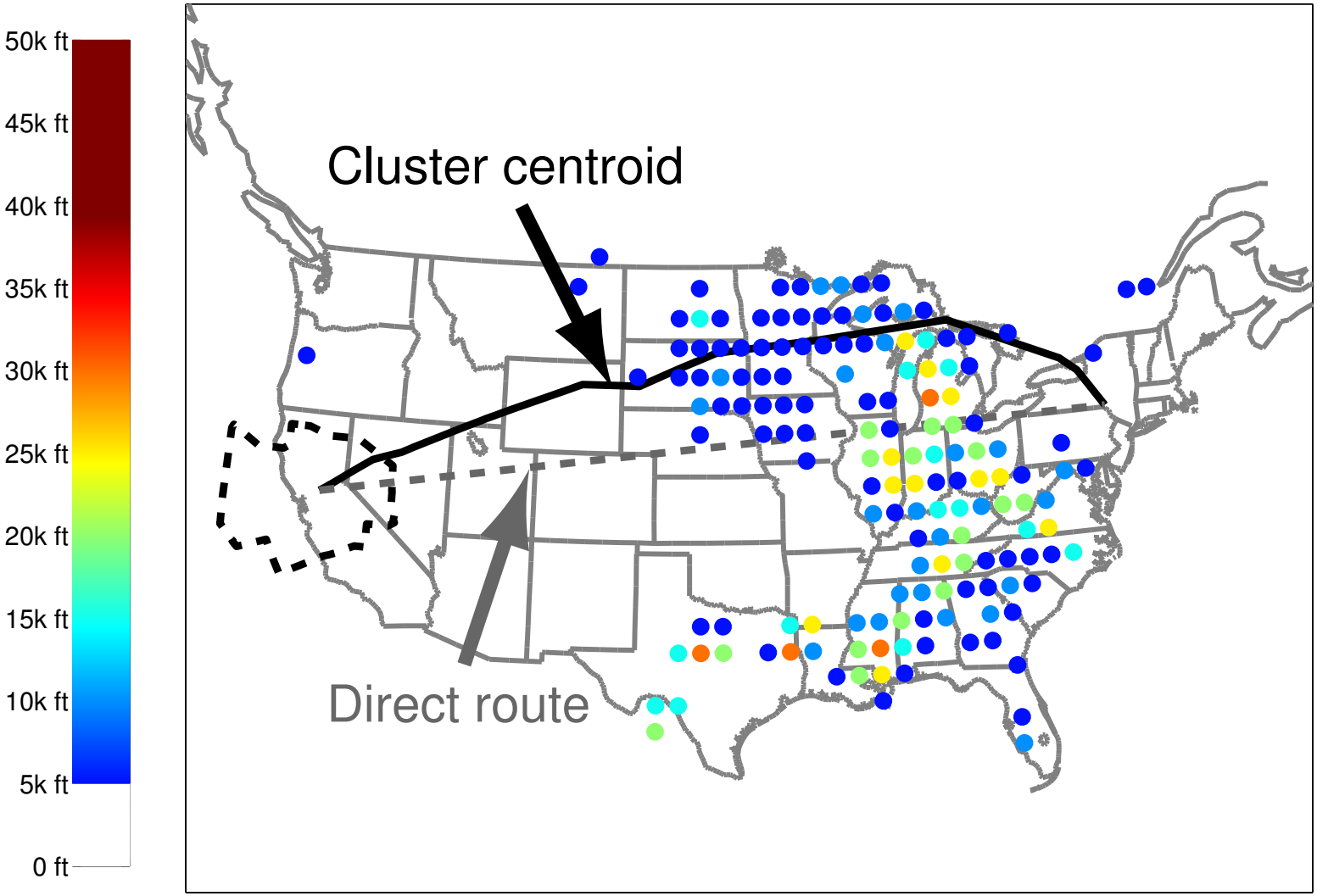

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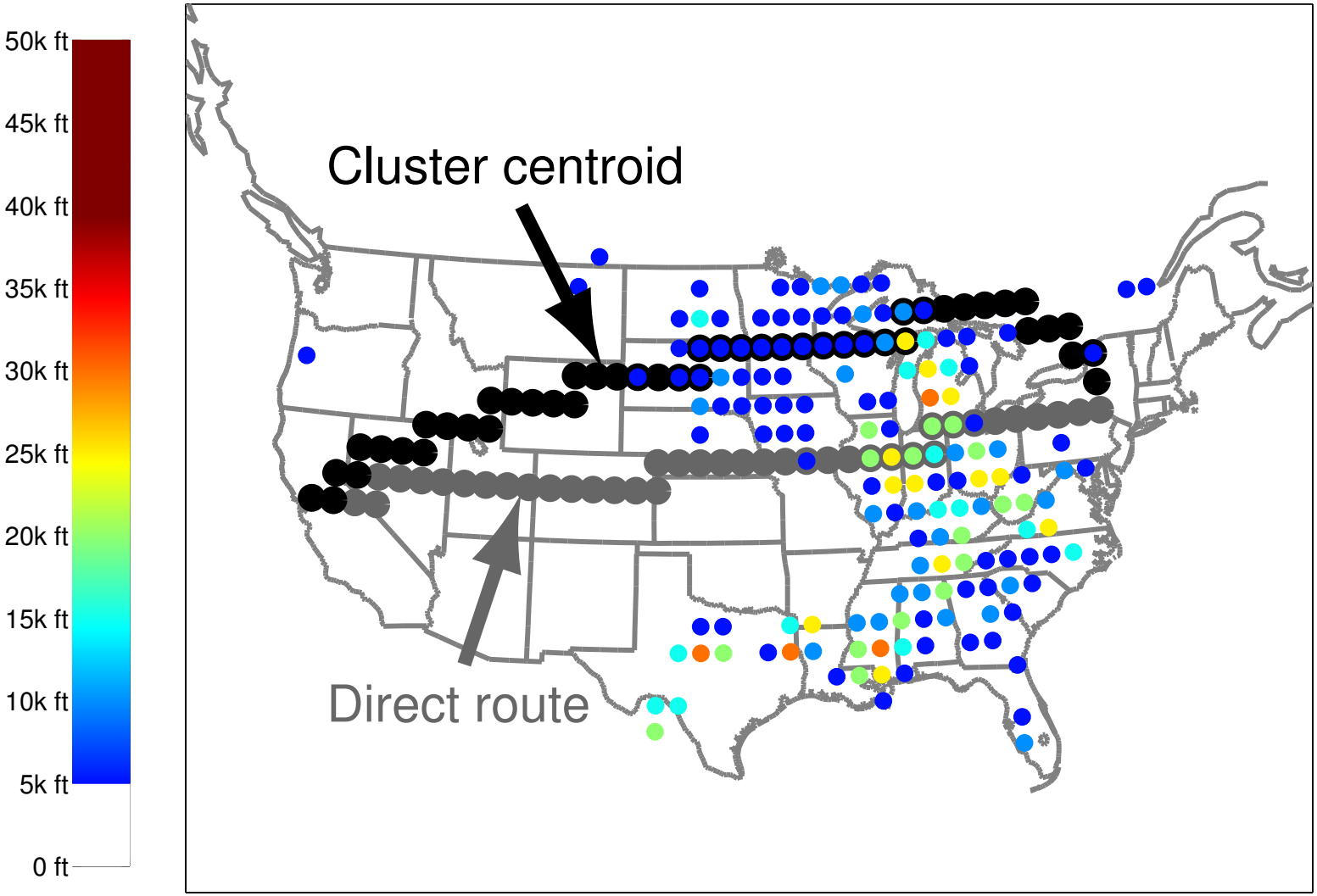

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Data summary

Reduced data

- June to August 2011
  $\Rightarrow$ **2,208 one-hour time windows**
- 905 ZNY-bound routes used
  $\Rightarrow$ 253 reroute clusters
  $\Rightarrow$ **20 most frequently used clusters**
  (used 50 to 240 times)
- 2,614,920 echo top data points per hour
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  $\Rightarrow$ **34 created features per hour per cluster**

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Data for model development for one cluster

- 2,208 observations
- 34 created features
- class label
  $+$ reroute cluster used
  $-$ reroute cluster not used

Classification error

$$\varepsilon = \frac{\text{\# incorrectly predicted observations}}{\text{total \# observations}}$$

Model performance metrics

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True positive rate

$$\text{TPR} = \frac{\text{\# of correctly predicted positive observations}}{\text{total \# of positive observations}}$$

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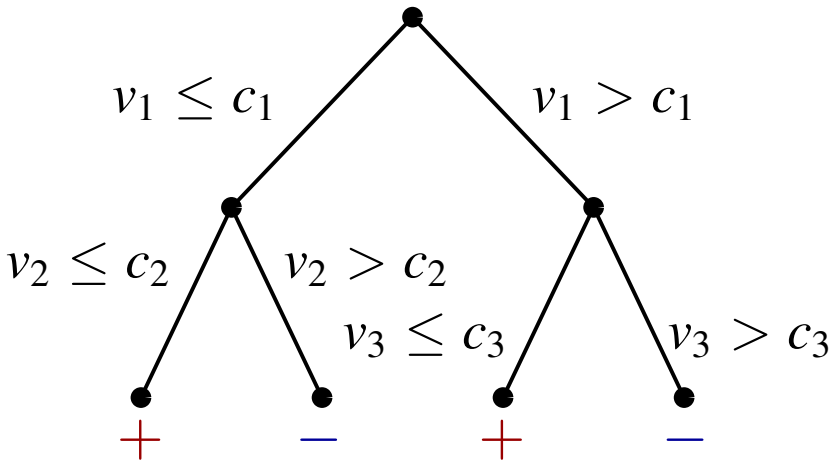
Decision tree



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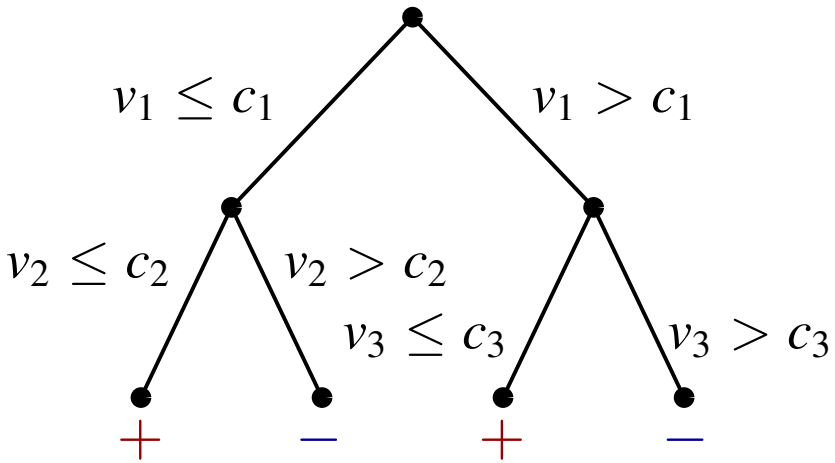

- Shallow trees cannot capture more complex connections
- Deep trees tend to overfit

Random forest

- Consists of many weak learners (shallow decision trees)
- Each decision tree is built with:
  - Randomly selected subset of observations
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- Ensemble prediction: weighted vote of each weak learner

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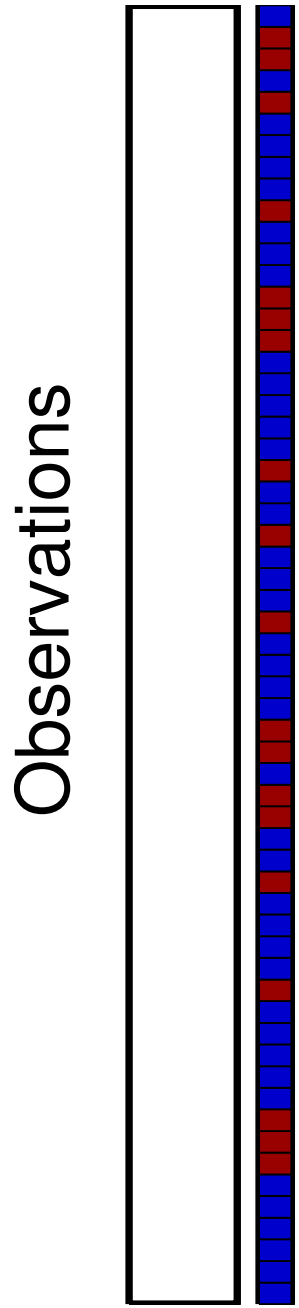
$\Rightarrow$ Advantage: reduce sensitivity to noise $\Rightarrow$ reduce overfitting

Model development



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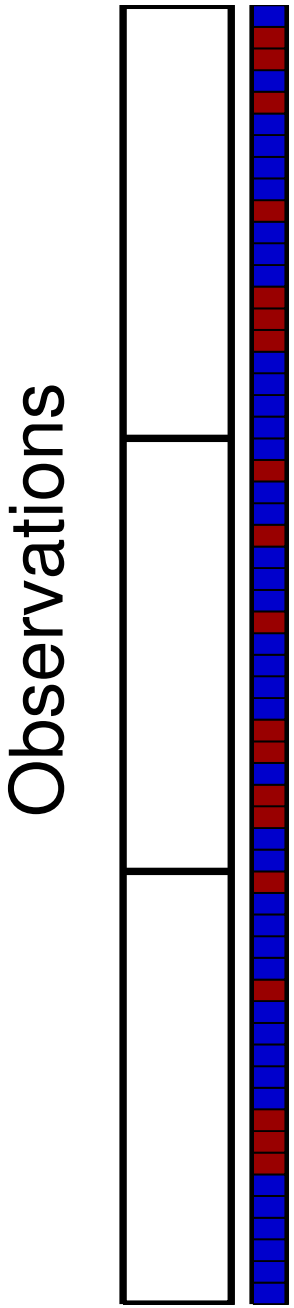

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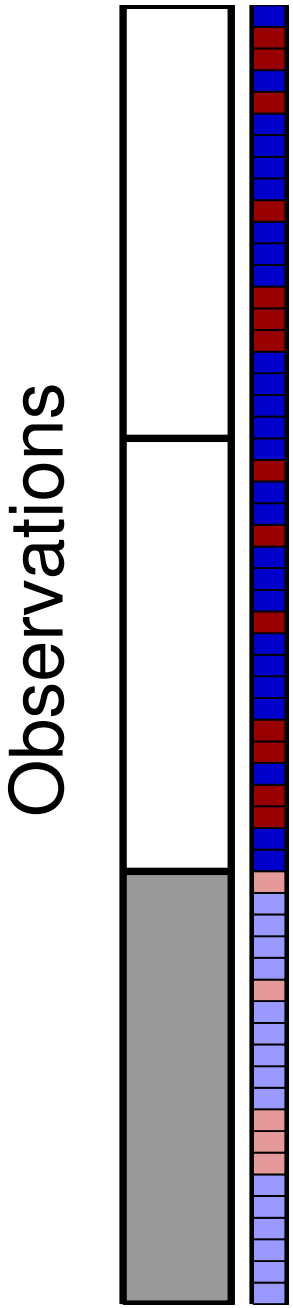

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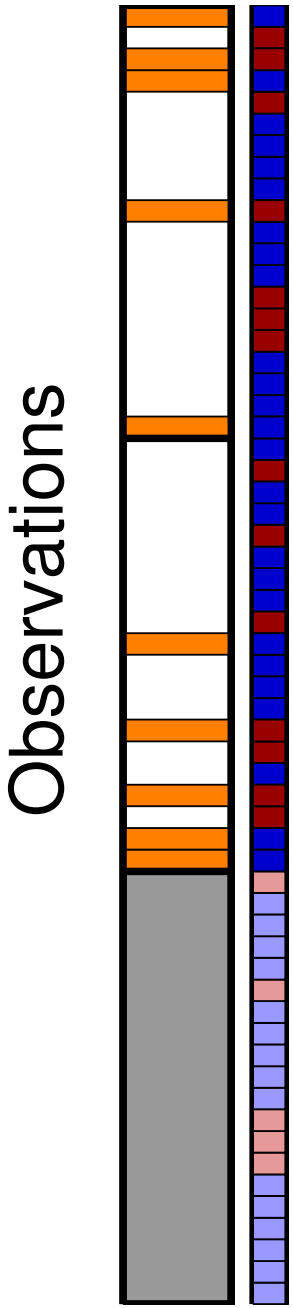

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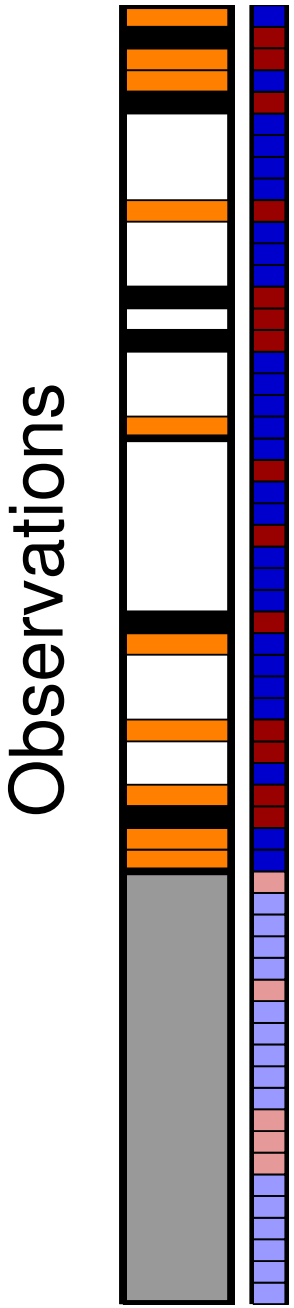

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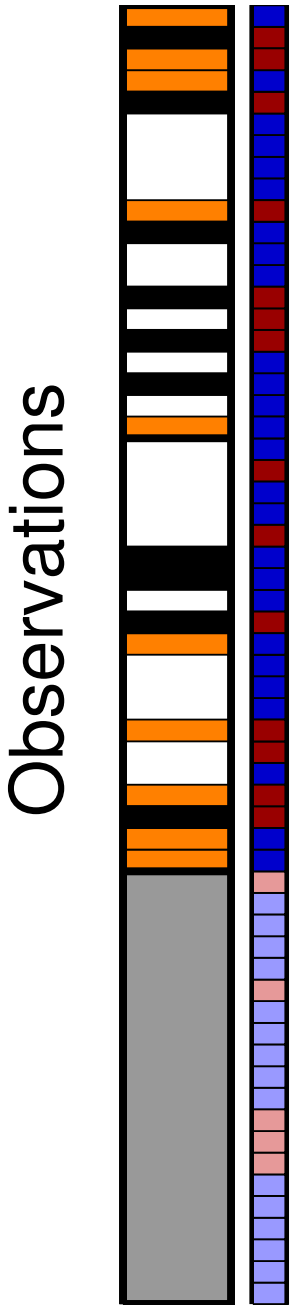

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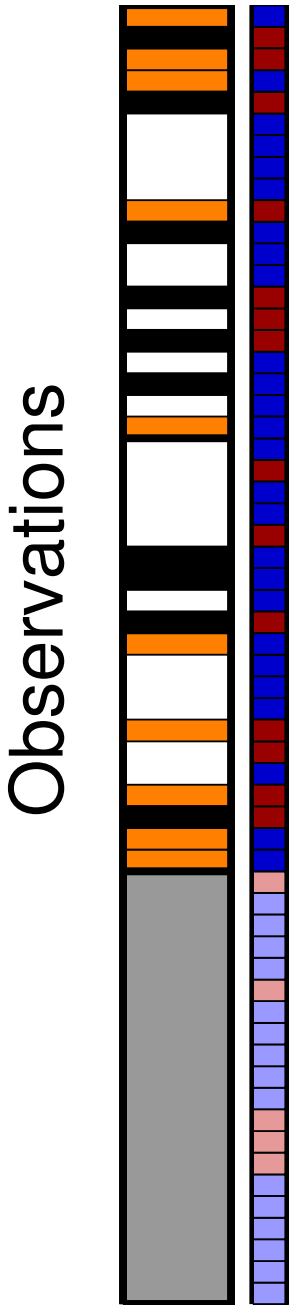
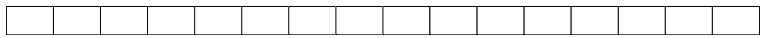
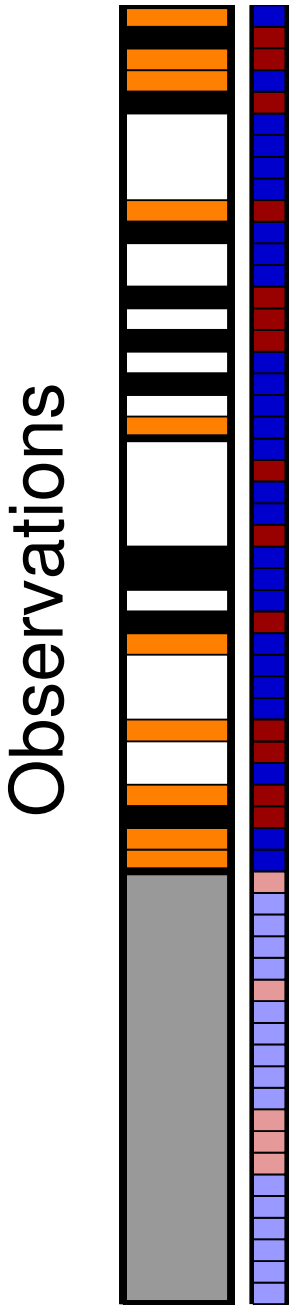


Features

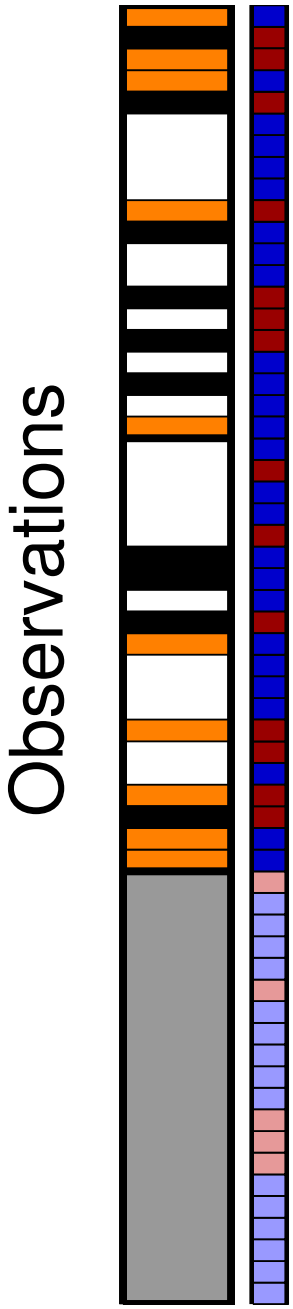


Model development



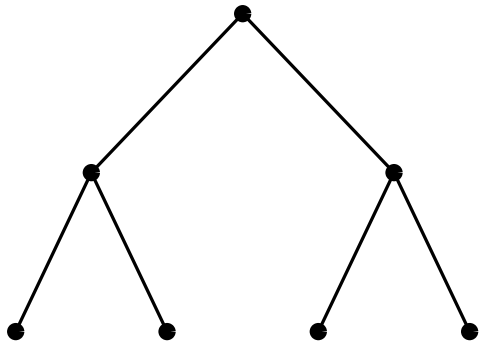
Features

Model development

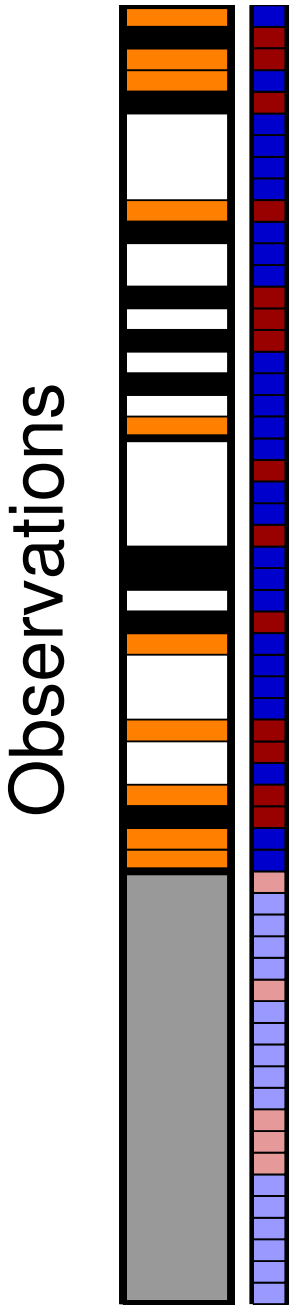


Features

Weak learner

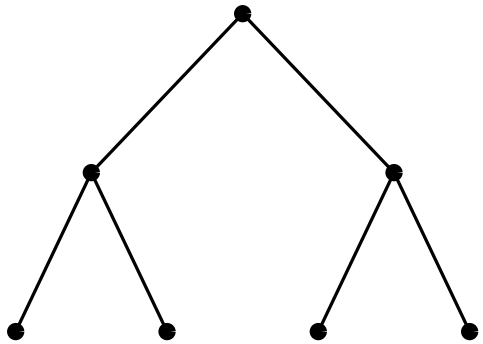


Model development



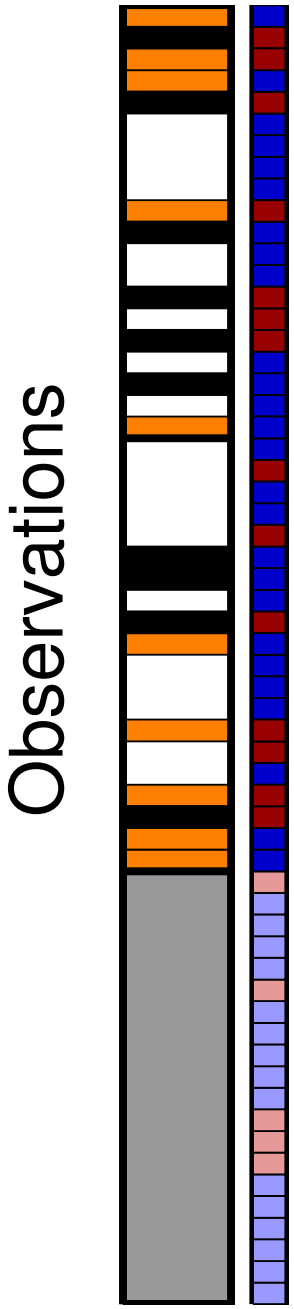
Features

Weak learner



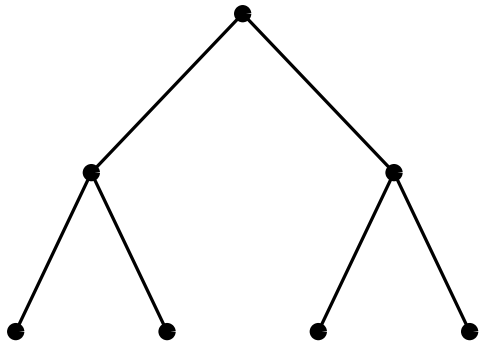
$\varepsilon =$ sub test prediction error

Model development



Features

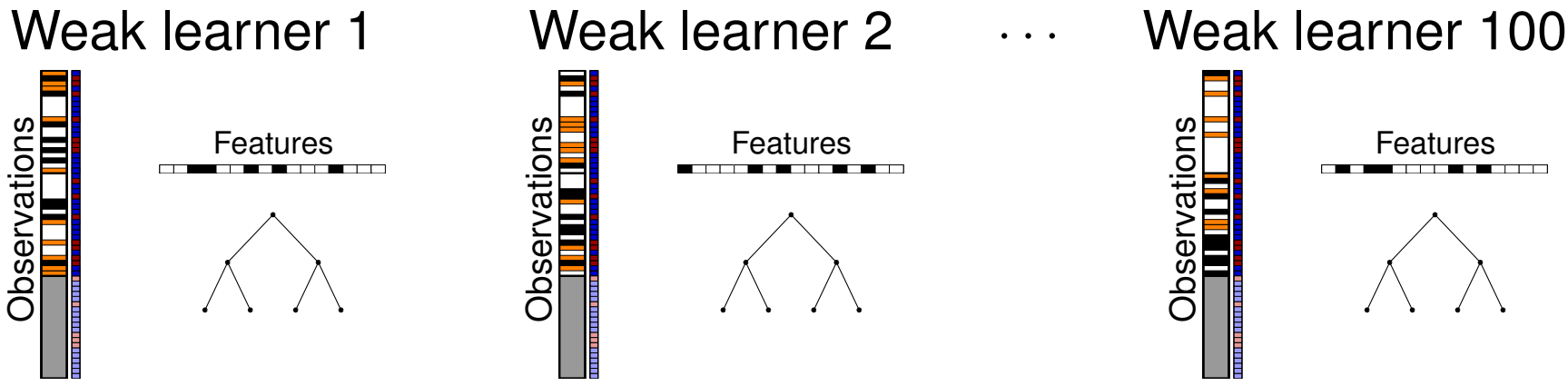
Weak learner



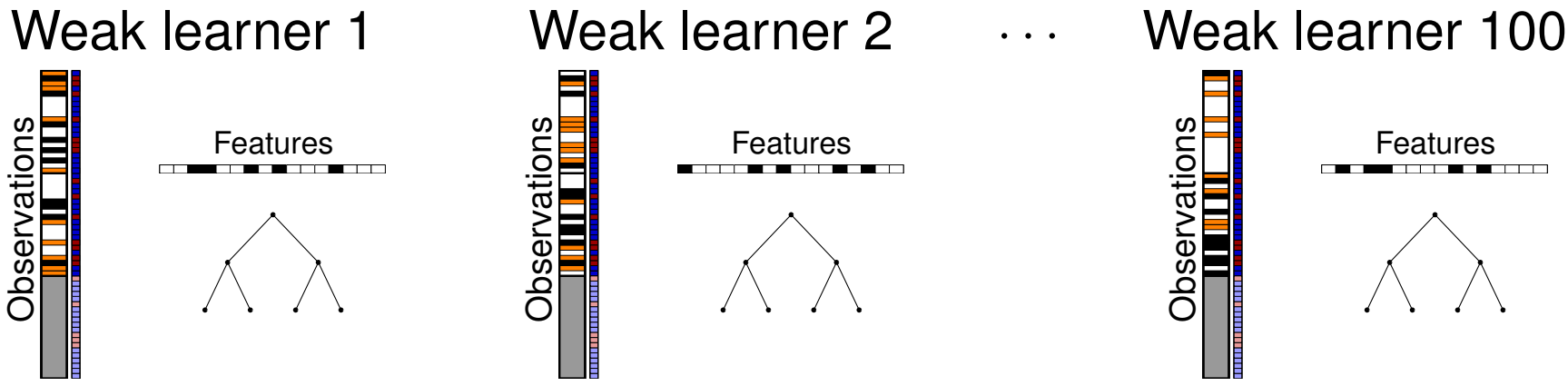
$\varepsilon =$ sub test prediction error

$$\alpha = \begin{cases} \nearrow \text{ as } \varepsilon \searrow, \varepsilon < 0.5 \\ 0, \text{ otherwise} \end{cases}$$

Model development



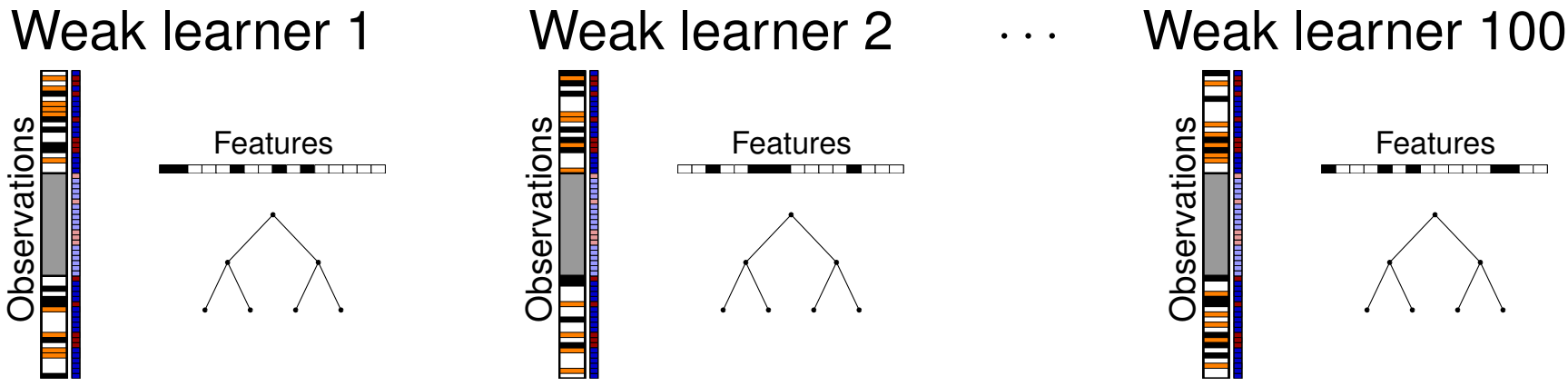
Model development



Ensemble prediction:

Weighted vote from each weak learner

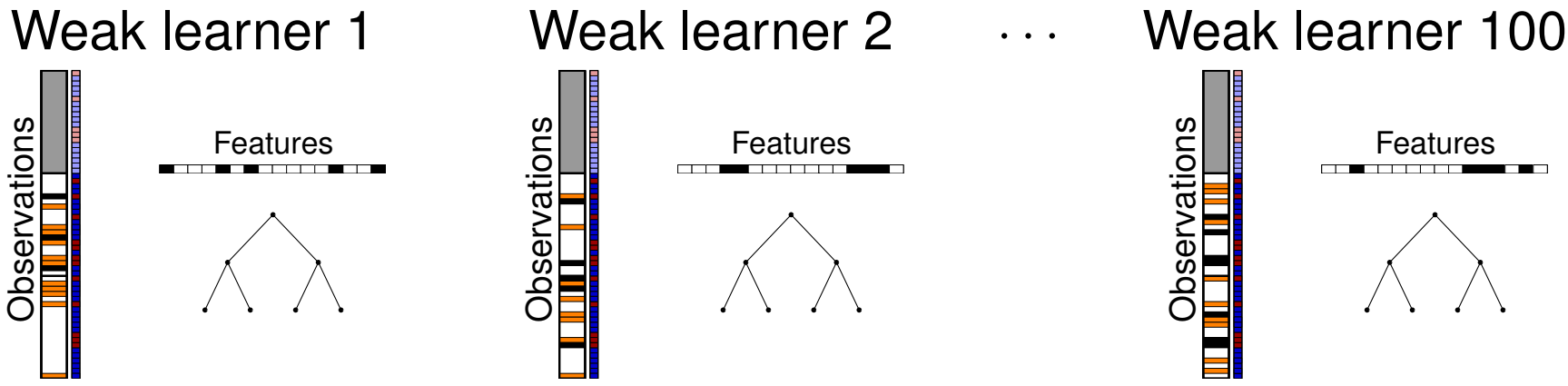
Model development



Ensemble prediction:

Weighted vote from each weak learner

Model development



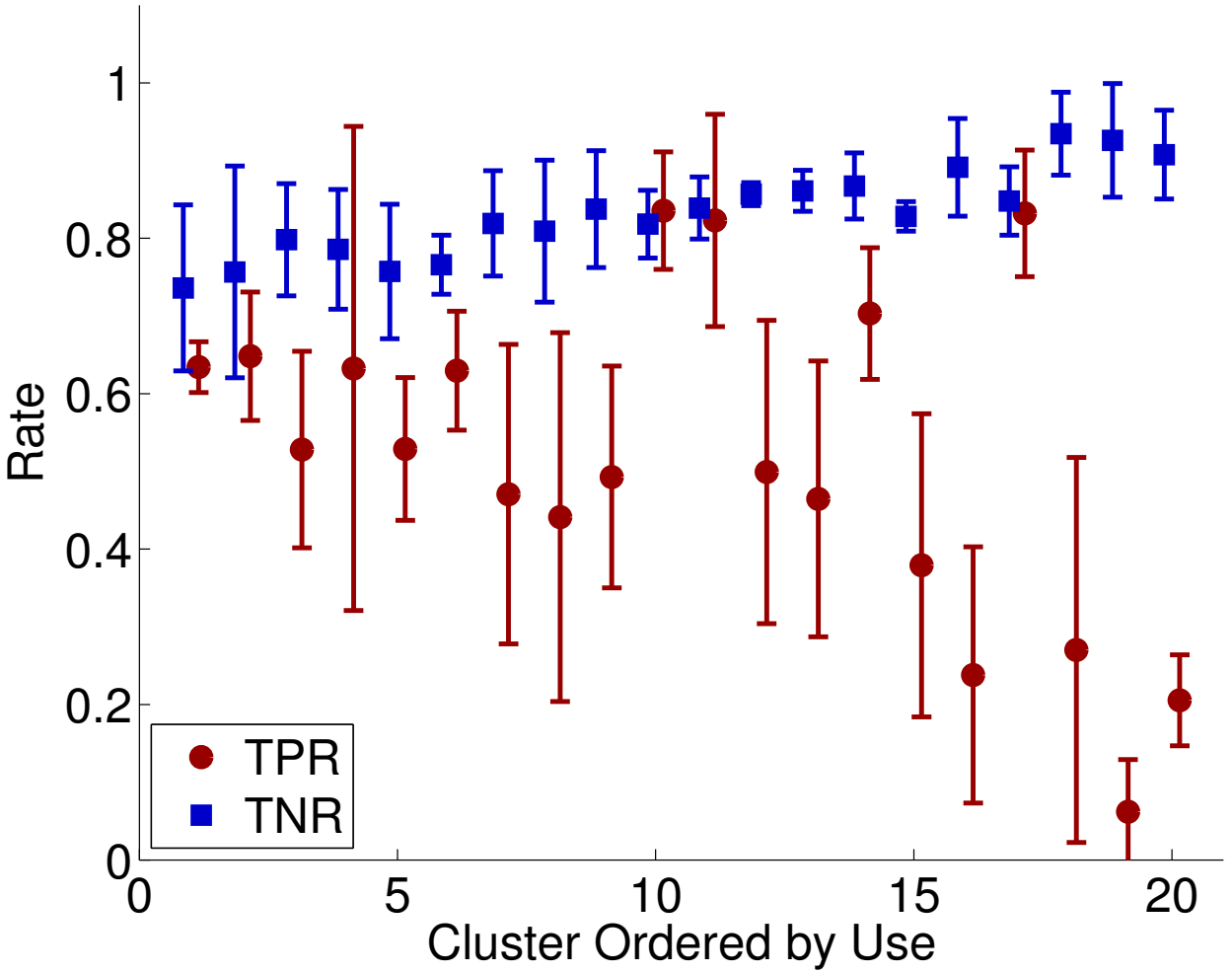
Ensemble prediction:

Weighted vote from each weak learner

Outline

- Advisory details
- Methodology
  - Identification of routes used by flights
  - Identification of similar routes
  - Weather feature extraction
  - Development of predictive models
- Prediction results
- Concluding remarks

Prediction results



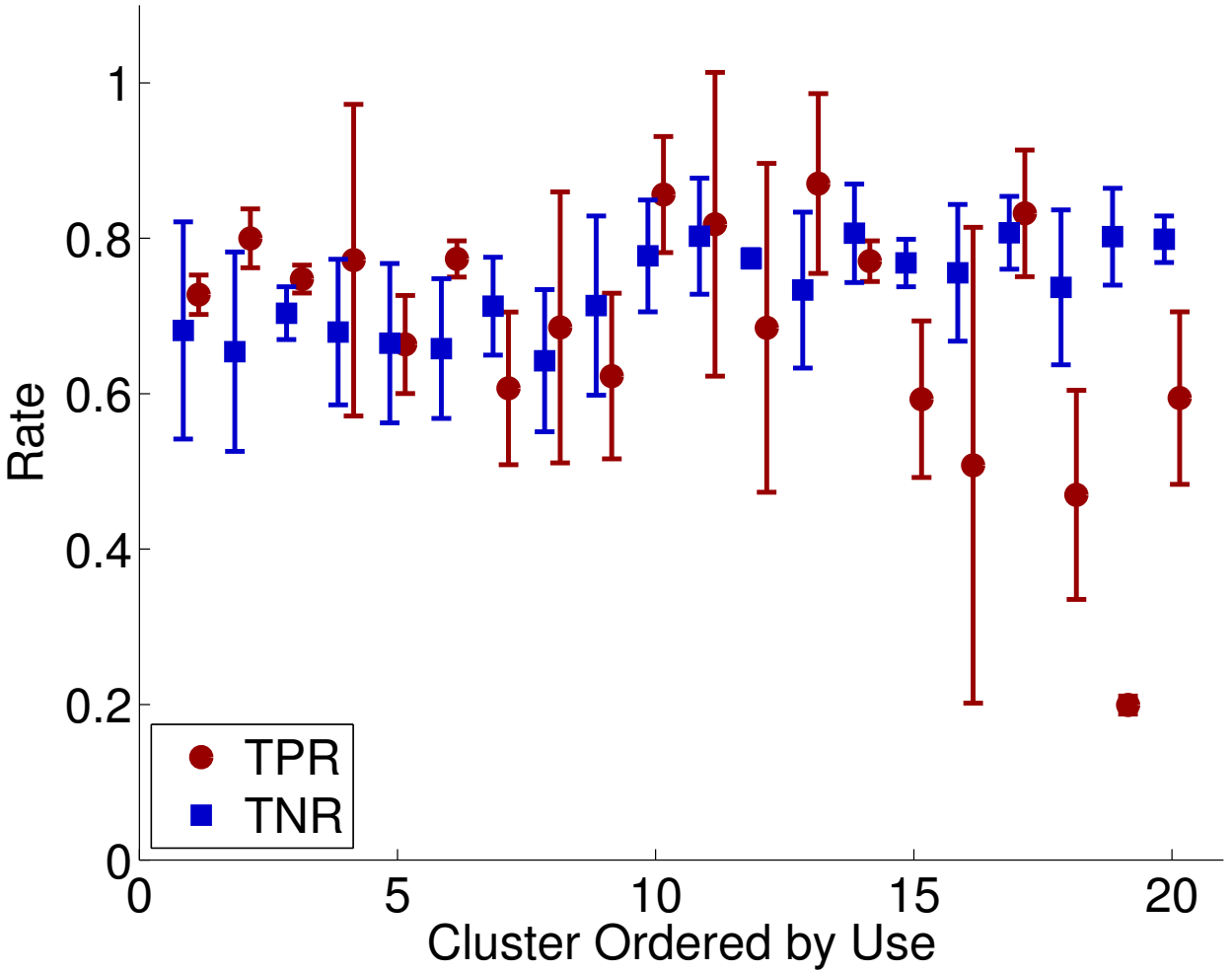
Synthetic Minority Oversampling Technique (SMOTE)

Within the training set:

- Select a positive observation
- Select one of its nearest neighbors
- Create a new observation:
  Convex combination of these two observations

Chawla, N. V., Bowyer, K. W., Hall, L. O., and Kegelmeyer, W. P., SMOTE: Synthetic Minority Over-sampling Technique, *Journal Of Artificial Intelligence Research*, Vol. 16, 2002, pp. 321 357.

Prediction results with SMOTE



Outline

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Conclusions

- Developed a framework to
  - analyze the historical use of reroutes
  - develop models to predict reroute use
- With improvements, this approach could provide insight into advisory use

Conclusions and future work

Conclusions

- Developed a framework to
  - analyze the historical use of reroutes
  - develop models to predict reroute use
- With improvements, this approach could provide insight into advisory use

Future work

- Include weather conditions at fixes and along jet routes
- Use Convective Weather Avoidance Model (CWAM)
- Use Collaborative Convective Forecast Product (CCFP)

Questions?

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