Modeling Highway Speed Decreases During Winter Weather Events in Iowa

ZHENGYUAN ZHU

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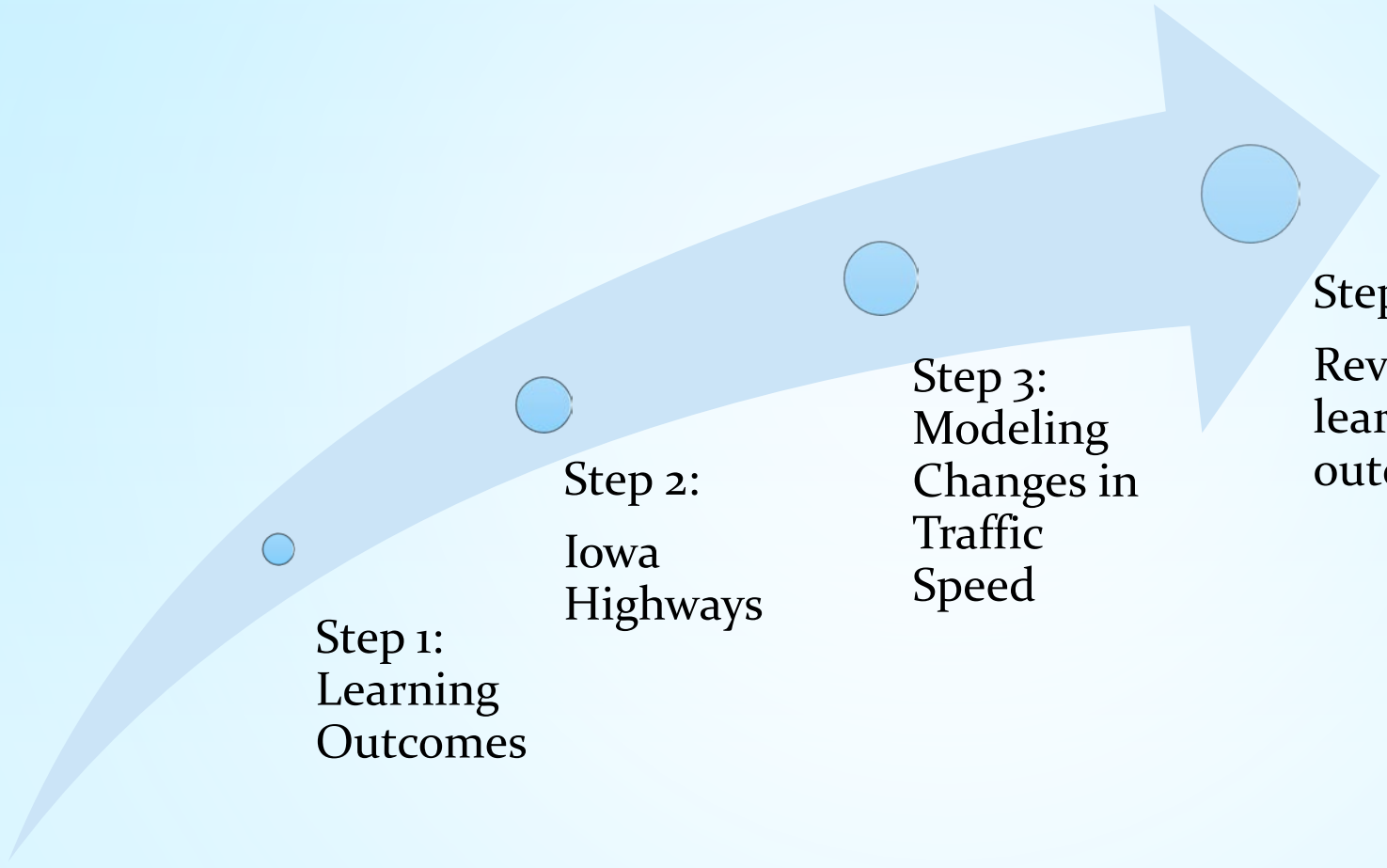


Learning Outcomes

- Measures of winter maintenance efficacy contain inherent variability and deficiencies of those procedures must be judged relative to that variability
- Variability in traffic speed changes during winter storm events can be modeled with stochastic processes
- Changes in traffic patterns should be judged relative to location-specific baseline traffic patterns
- Primary factors involved in decreased speeds in winter storm events include: lane conditions, wind speed, visibility, and absolute deviations in temperature from freezing point.

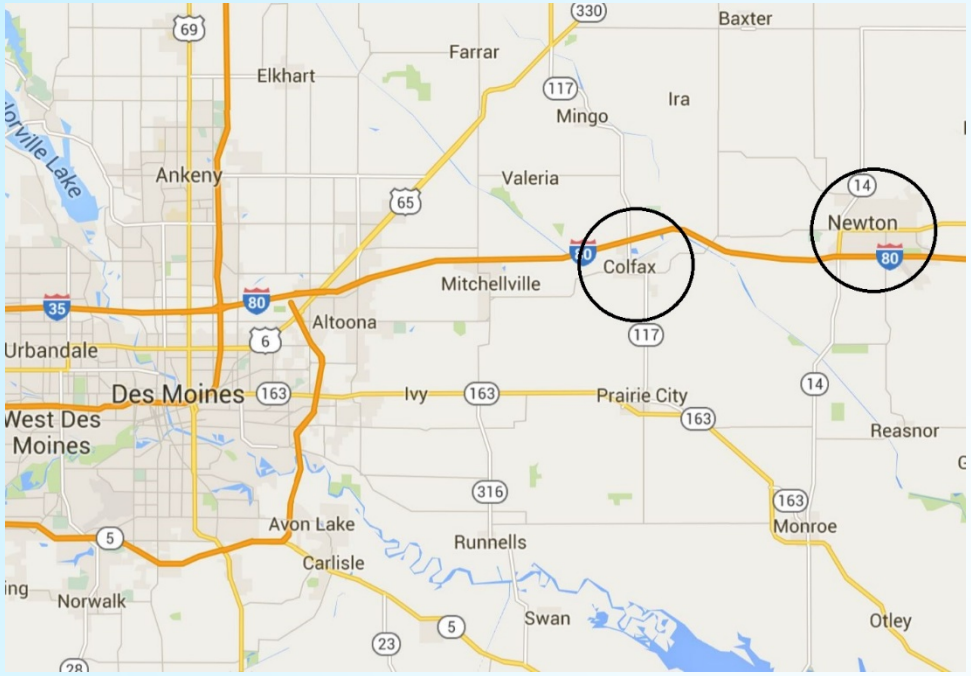
Iowa Highways

- Spend tens of millions of dollars every year clearing primary highways of ice and snow
- Winter weather events have an immediate and adverse impact on traffic flow
- Performance assessment of maintenance activities is challenging, partly due to the variability of nominal or expected effects of weather variables

Snowplow at work.

Source:
https://commons.wikimedia.org/wiki/File:Snow_Plow_(10442280564).jpg#filelinks

Colfax/Newton Iowa



Source: Google maps

- Data for Colfax/Newton from 2012-2014
  - Road weather information system
  - Automated Weather Observing System
  - Maintenance crew notes

Modeling Traffic Condition Attempts

- Include expert opinion
- Model traffic speed directly
- Traffic Speed from Speed Limit
- Historic baseline: location-specific
- Account for storm type
- Snow intensity
- Rain previous to event

Model Selected

- Will model deviations in traffic speeds from historic baseline, rather than actual traffic speeds

- Partition data into 4-hour time blocks

- Use crew data to identify dates and times of a winter weather event

- Variables included:
  - Absolute deviation in temperature from freezing point
  - Wind speed, visibility, and lane condition (wet, ice, dry)

Model Details

$$y_t = h(\beta, x_t) + w_t$$
$$w_t = \gamma w_{t-1} + v_t$$

$w_0 = 0$ and v_t are independent, identically distributed random variables following a normal distribution with mean o and variance τ^2

$$h(\beta, x_t) = \beta_1\ x_{1,t} + \beta_2\ x_{2,t} + \beta_3\ x_{3,t} + \beta_4\ x_{4,t} + \beta_5\ x_{5,t} + \beta_6\ x_{6,t}$$

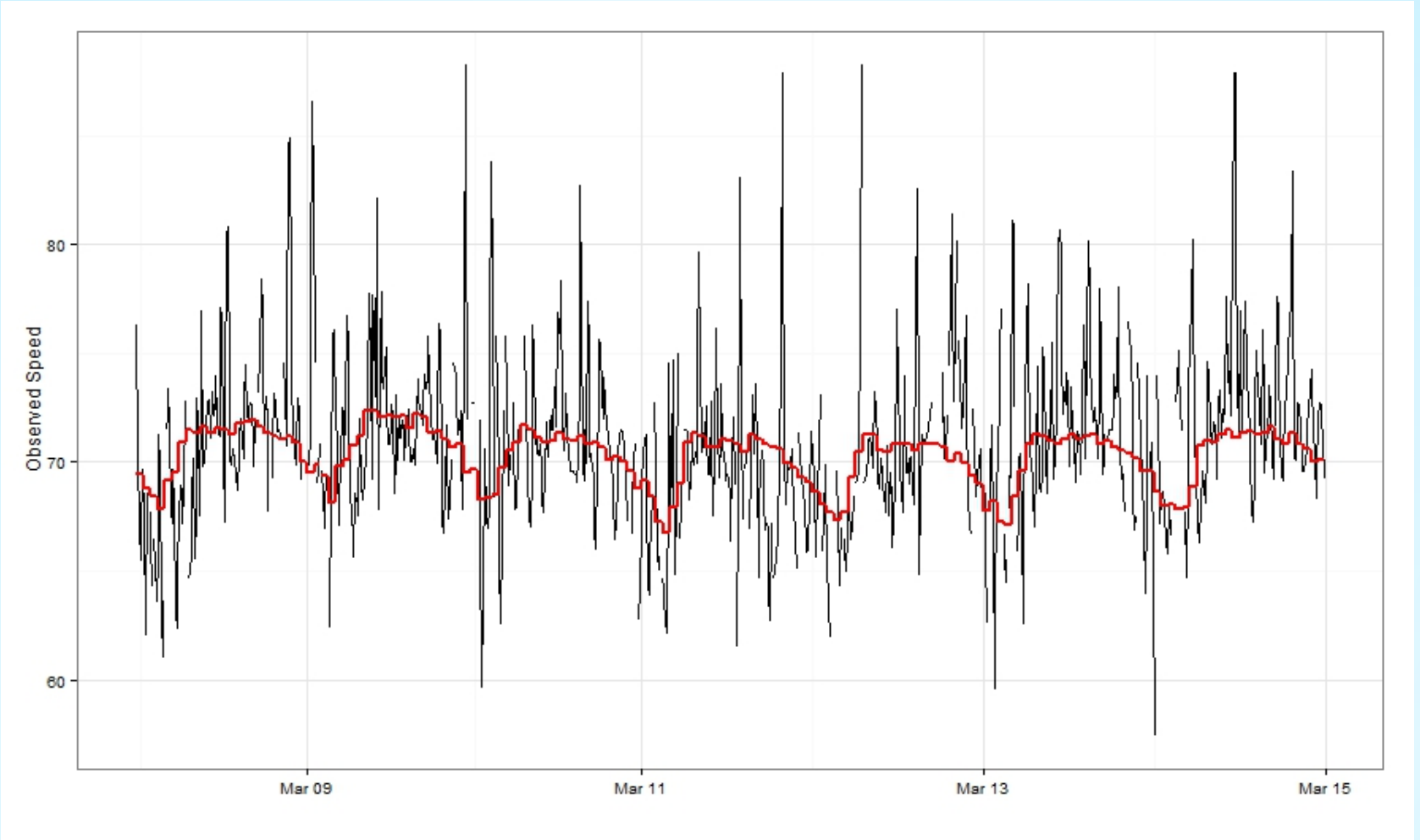
Priors:

$$\beta \sim N(0{,}100)$$
$$\gamma \sim Unif(-1,,1)$$
$$\tau \sim Inv\ Gamma(0.01, 0.01)$$

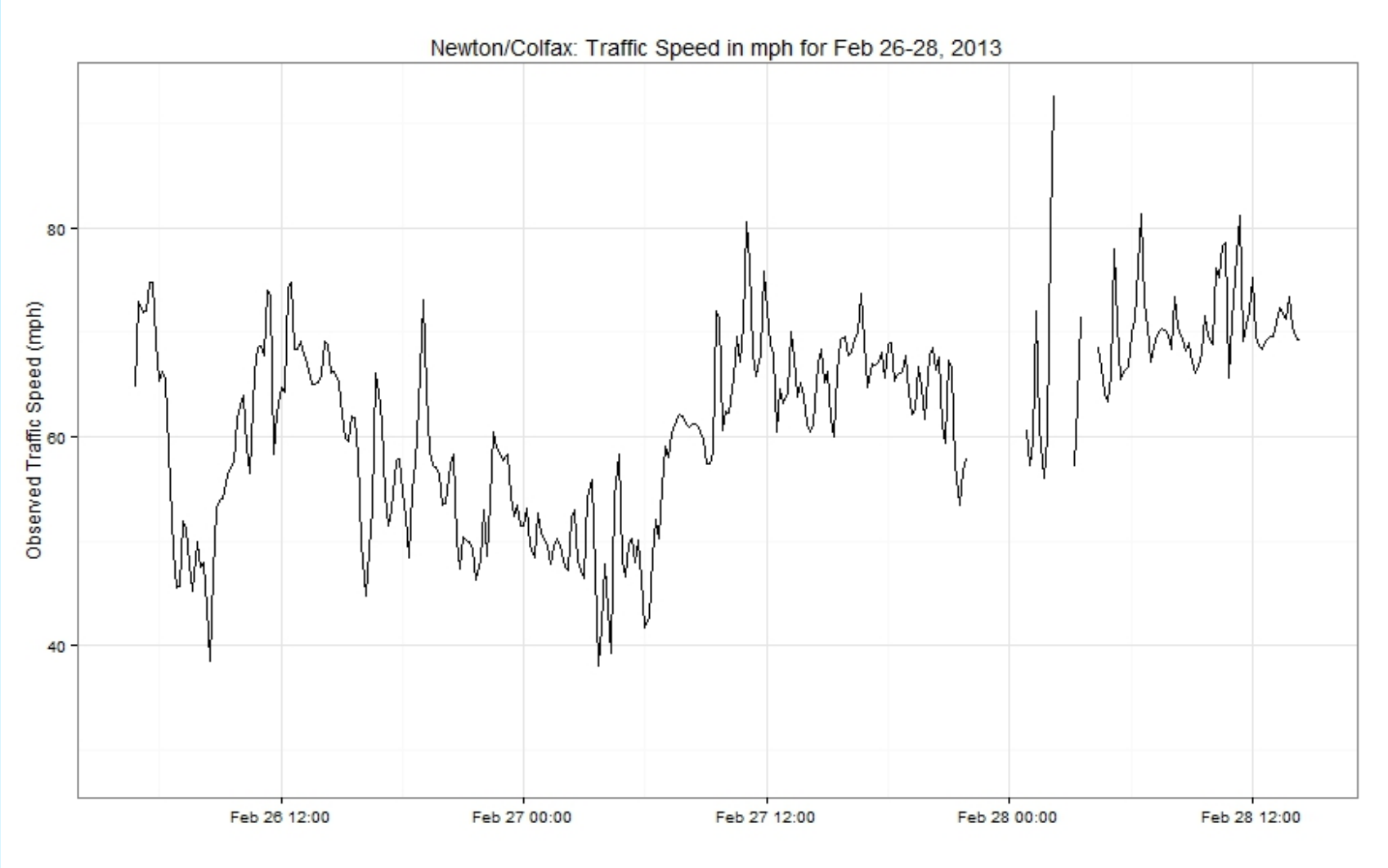
Algorithm for Sequential Modeling

1. Compute response variable y_t = observed speed– baseline speed
2. Segment data into N periods, with min. length (4-hours used here)
3. For lane condition in each segment, if less than 3 observations belong to one category (dry, wet, ice), treat corresponding entries as missing (i.e. no lane condition reported)
4. For first period, use diffuse priors for all parameters.
5. Using posterior draws from first period, update means and variances of priors, $p(\beta)$, of regression parameters, β, for estimation in second period.
6. Continue cycle of fitting model and using posterior draws to update priors for subsequent periods until model fit to the N^{th} data segment.

Baseline Speeds for Newton/Colfax, Iowa



Newton/Colfax: Feb 26-28, 2013



Data for one lane from Newton/Colfax on February 26-28, 2013.

Maintenance crew reported wet and blowing snow during this period.

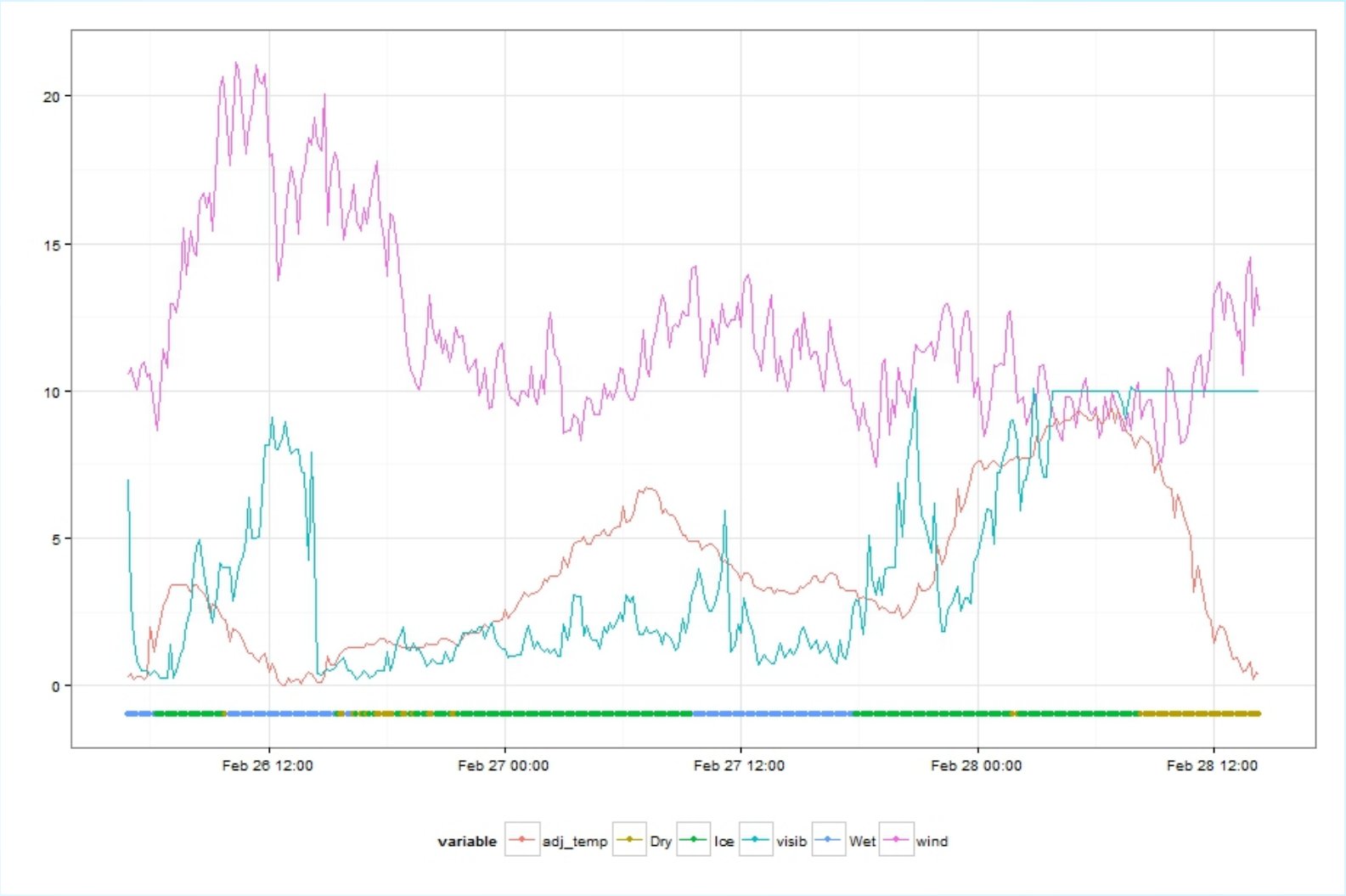
Some missing data.

Event 1: Feb 26-28, 2013

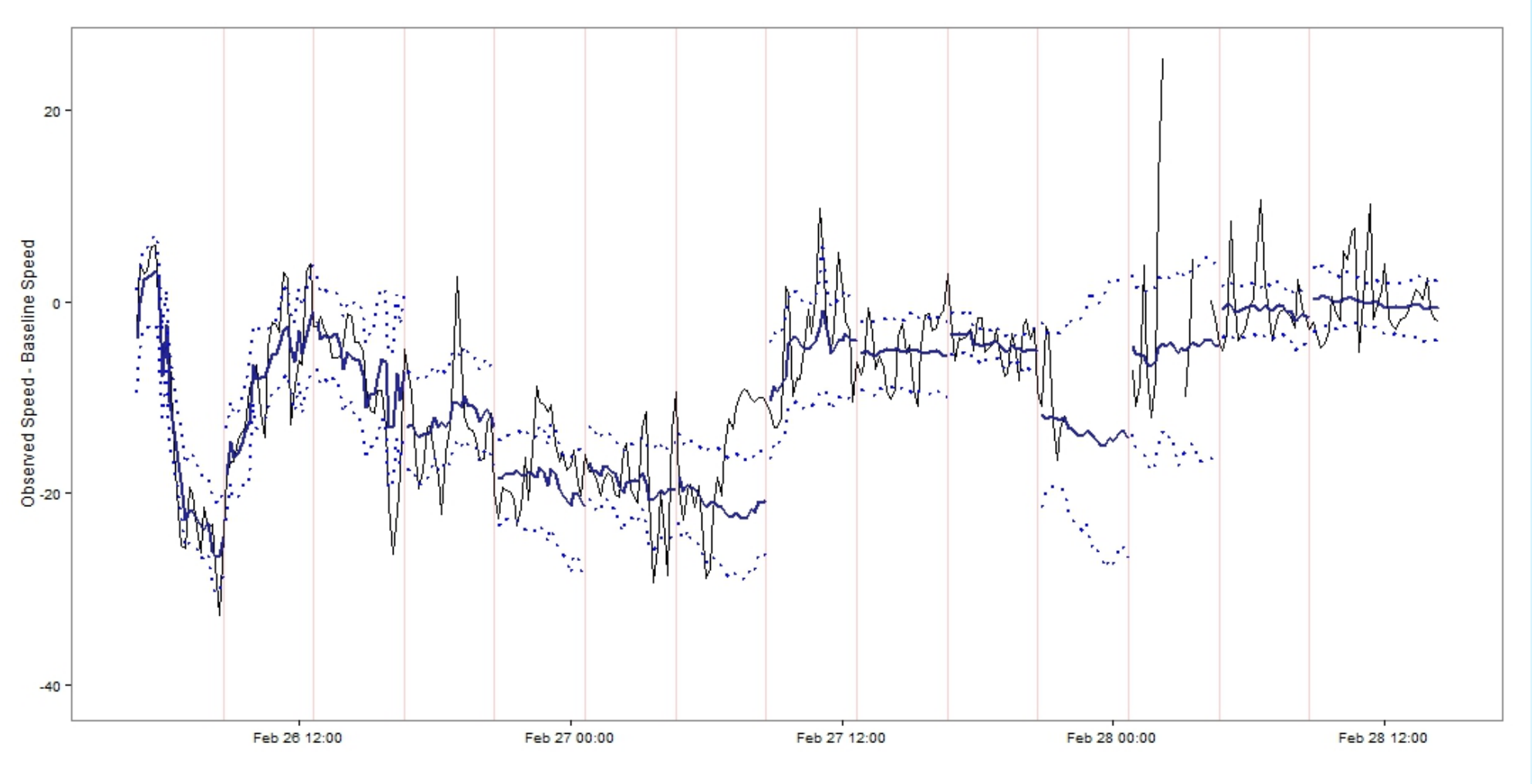
Plot of wind speed, absolute deviation in temperature from 32° F, visibility, and lane conditions: wet, ice, or dry.

Event characterized by icy and wet lane conditions, some dry intermixed and dry at the end.

Periods of low visibility, higher winds, temperatures close to freezing point in beginning



Event 1: Feb 26-28, 2013



Plot of fitted model results (in blue) with 90% credible intervals.

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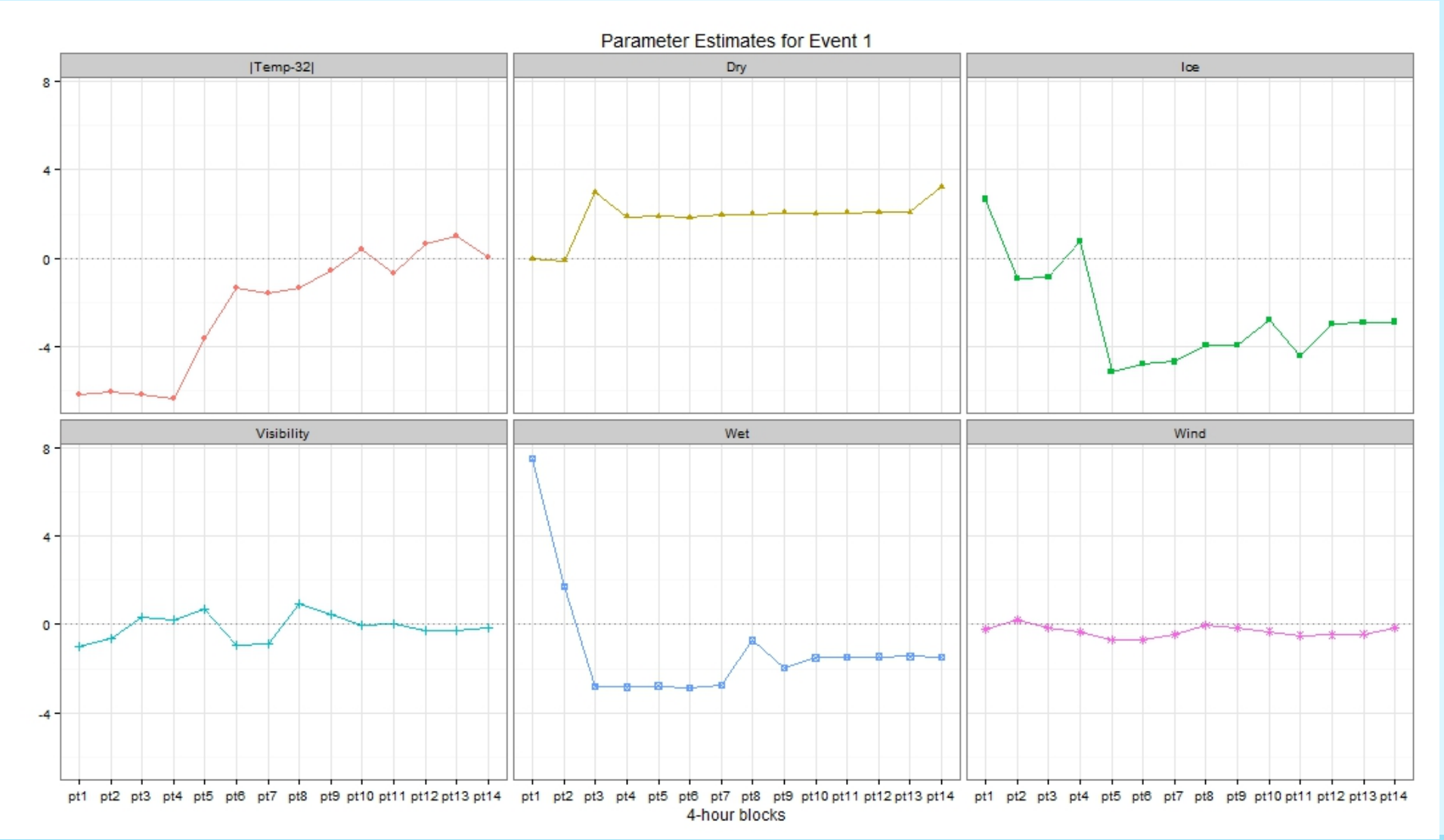

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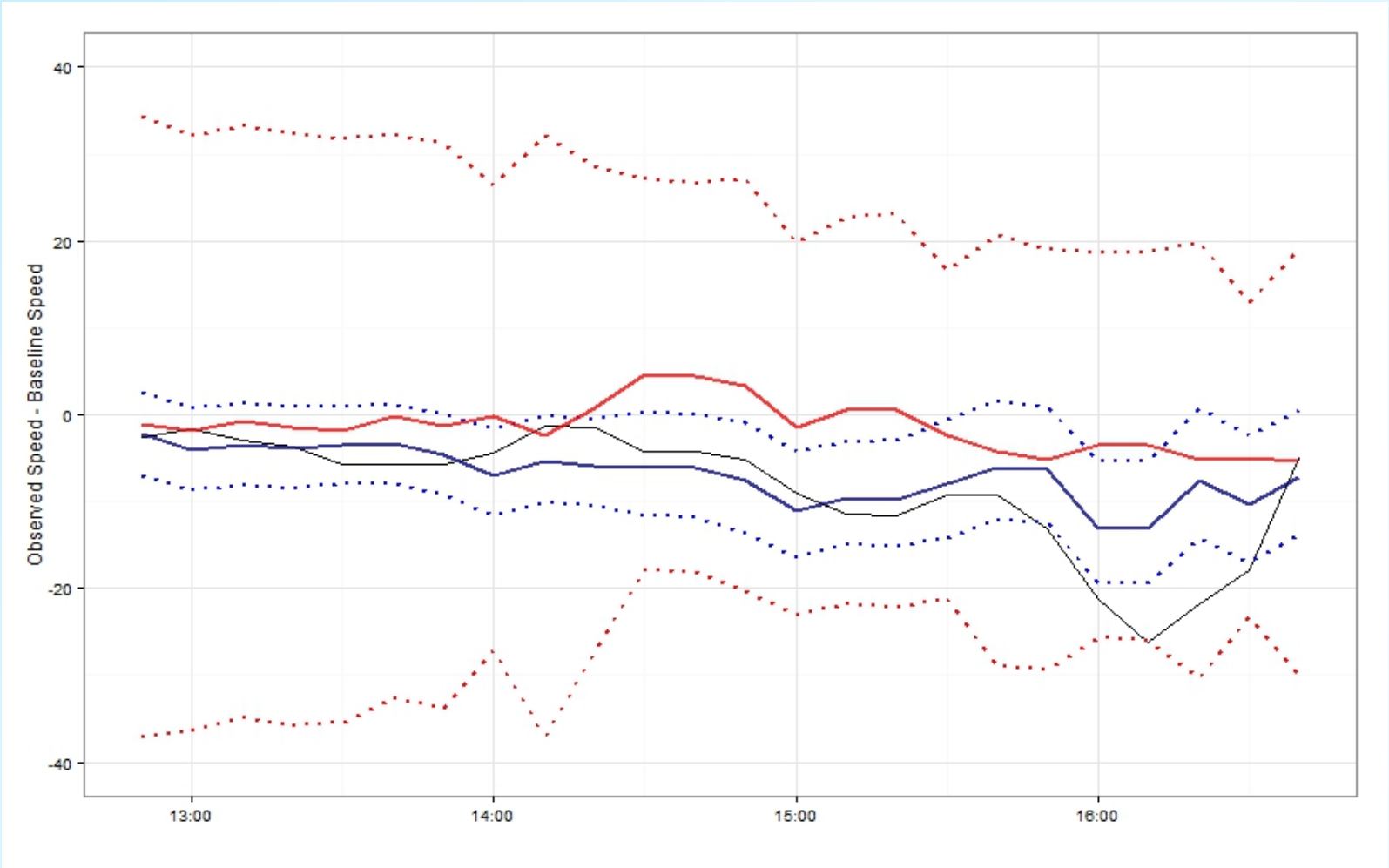
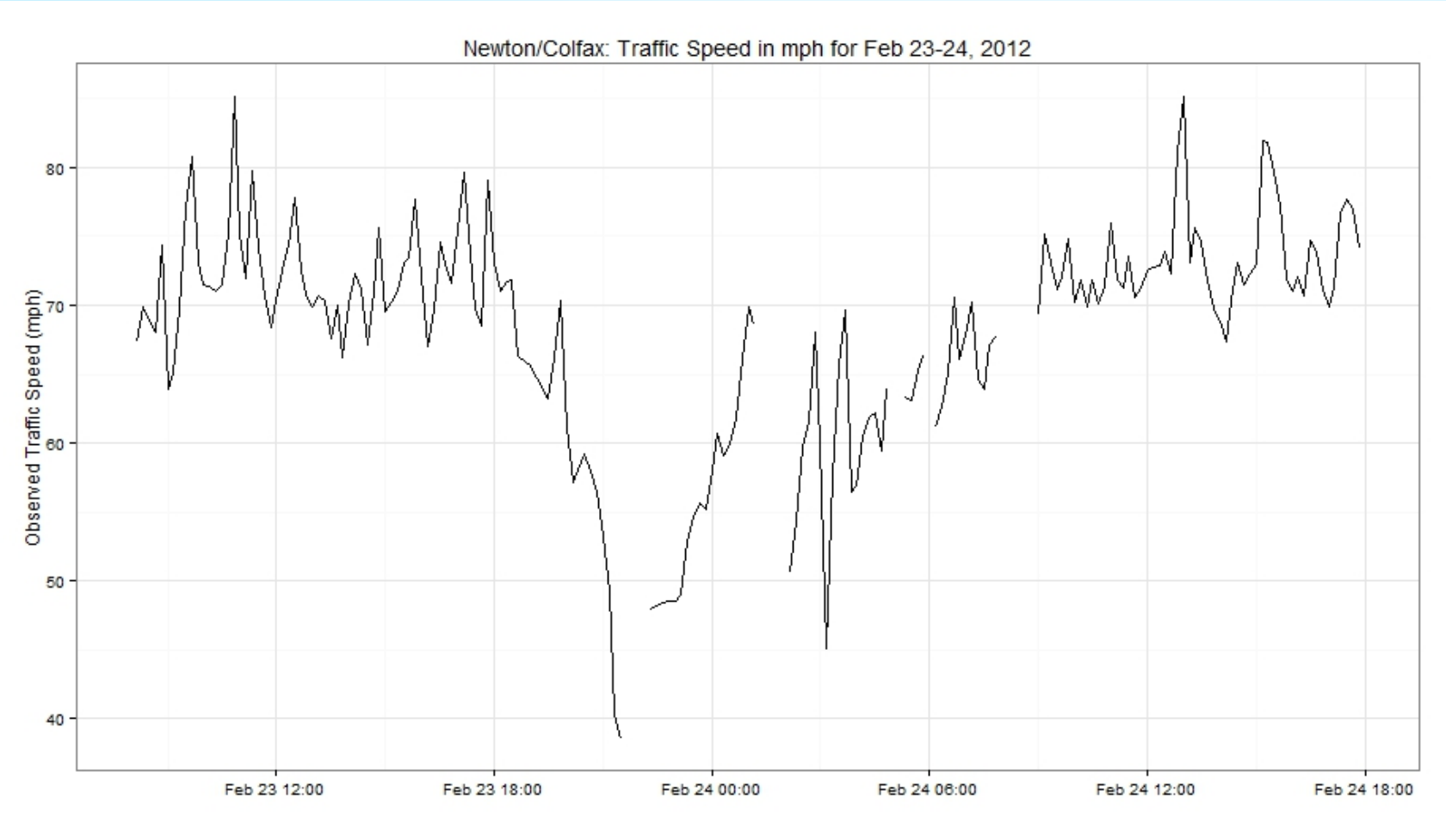


Sample forecast (in red) for one 4-hour time block with 90% credible intervals.

Plot:
Blue – fitted model
Red – forecast

Newton/Colfax: Feb 23-24, 2012



Data for one lane from Newton/Colfax on February 23-24, 2012.

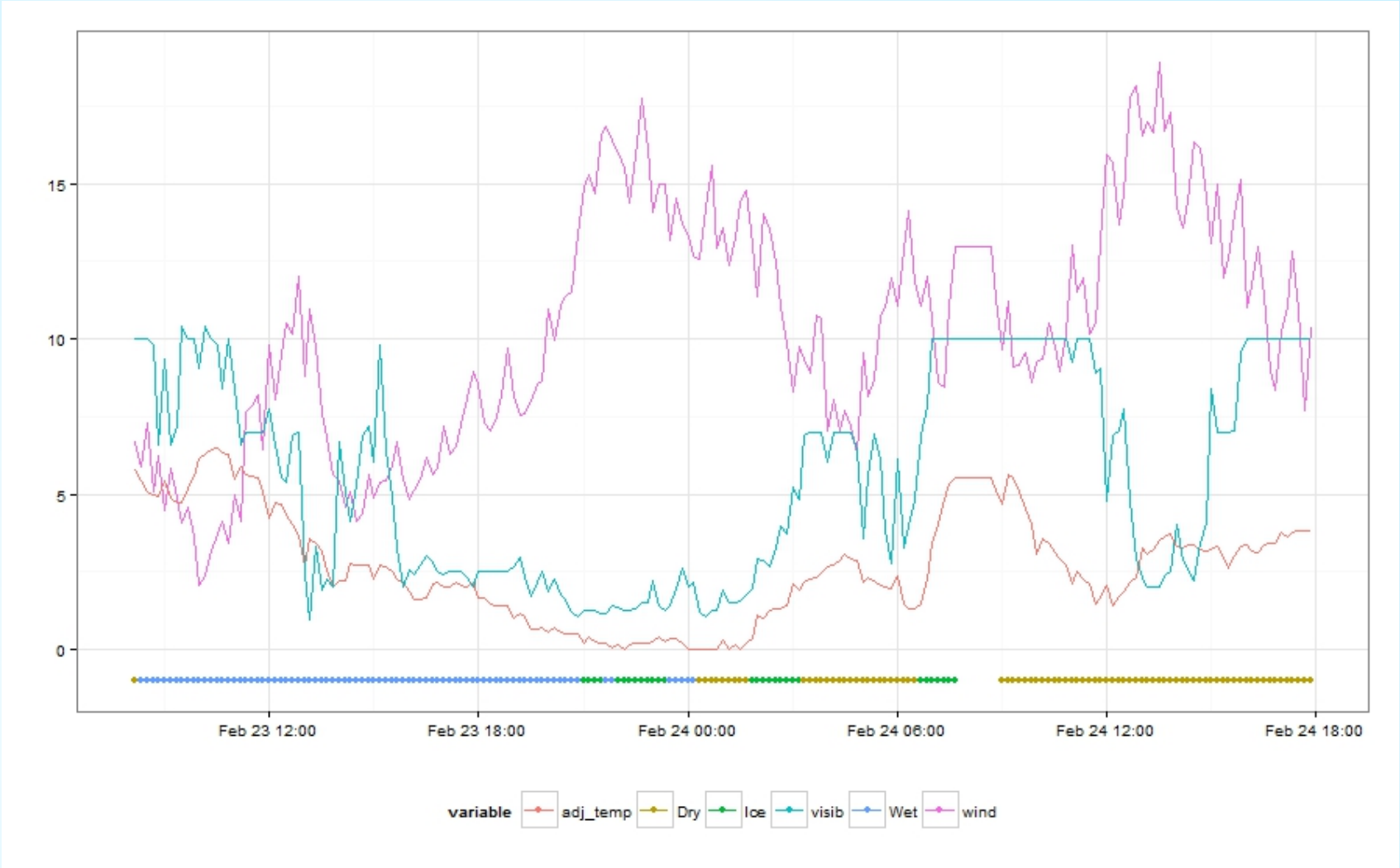
Maintenance crew reported rain at beginning of event, then transition to wet snow, followed by blowing snow.

Again, some missing data.

Event 2: Feb 23-24, 2012

Plot of wind speed, absolute deviation in temperature from 32° F, visibility, and lane conditions: wet, ice, or dry.

Event characterized by mostly wet lane condition in beginning, a lot of 'dry' recorded toward end.



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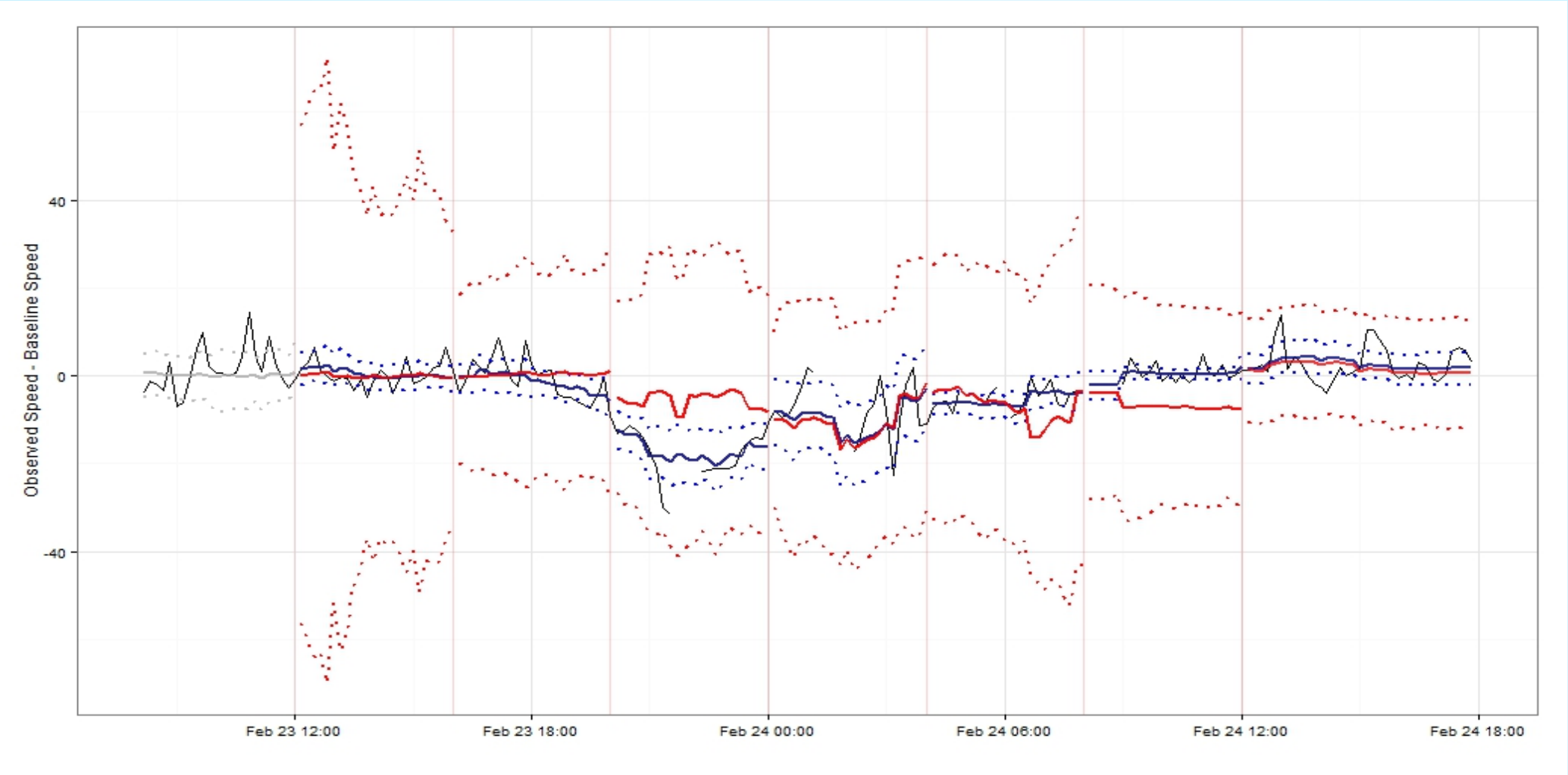

Plot of fitted model (blue) and forecast (red) results with 90% credible intervals.

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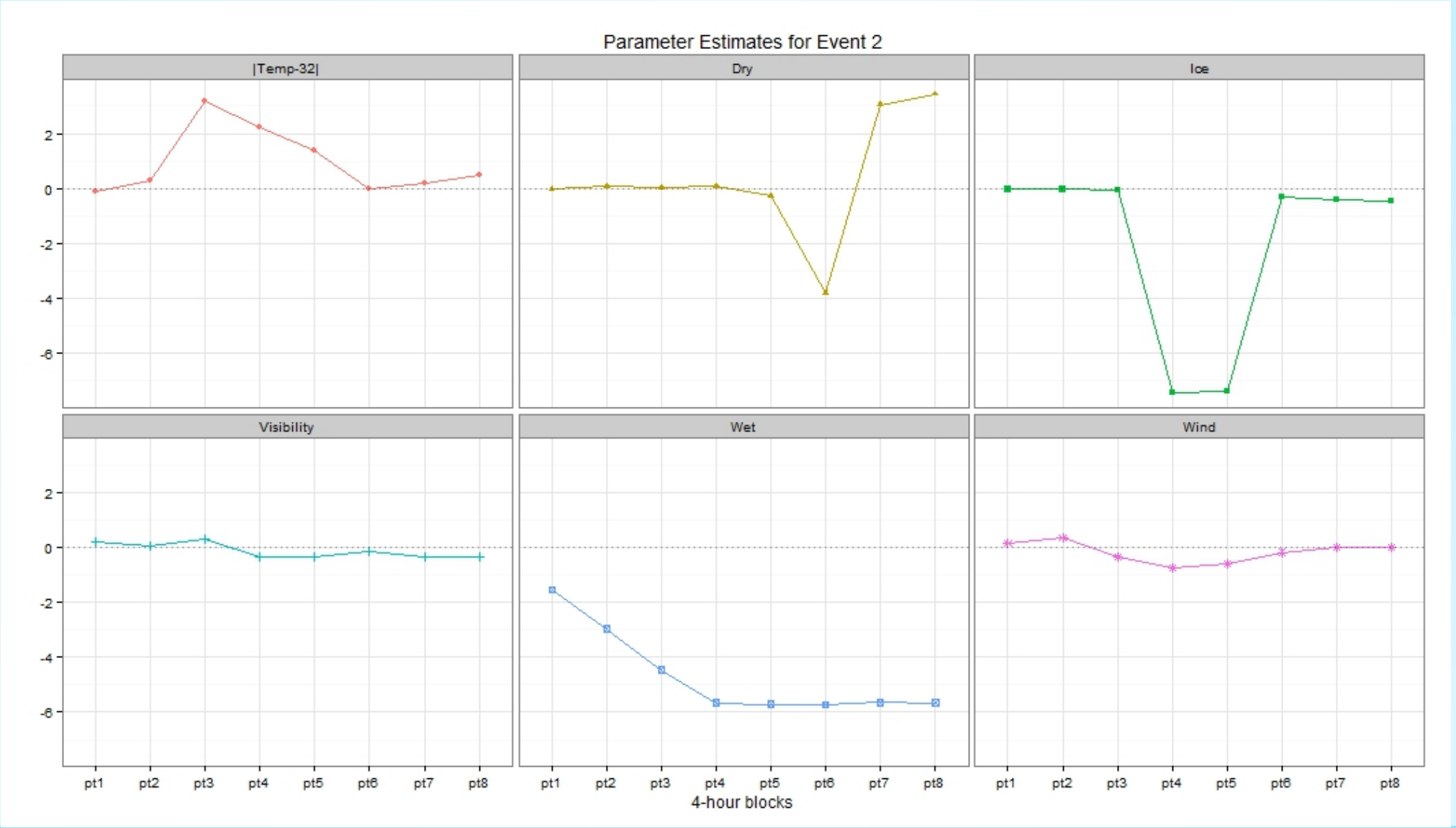

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Contact Information:

Zhengyuan Zhu

e-mail: zhuz@iastate.edu