Runway Friction Closure Prediction System (RFCPS)

Project Overview

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FPAW
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Outline

- Background
- About RFCPS
- System Overview
- Phase I Machine Learning
- Phase II Machine Learning
- Initial verification
- Output examples during storm
- Web-display
- Future Plans

Runway Friction Forecast and Closure Guidance

RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20200209 04:45

FORECAST LEAD TIME

	0445	0500	0515	0530	0545	0600	0615	0630	0645	0700	0715	0730	0745	0800	0815	0830	0845	0900	0915	0930	0945	1000	1015	1030	1045
FEC 12L/30R NW 1/3	0.26	0.28	0.23	0.23	0.22	0.22	0.21	0.2	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.25	0.25	0.25	0.25	0.43
FEC 12L/30R Center point	0.25	0.27	0.22	0.23	0.22	0.22	0.22	0.2	0.2	0.2	0.21	0.21	0.34	0.35	0.22	0.22	0.22	0.24	0.25	0.24	0.25	0.26	0.25	0.26	0.43
FEC 12L/30R SE 1/3	0.27	0.29	0.23	0.23	0.22	0.22	0.22	0.2	0.2	0.2	0.21	0.21	0.34	0.34	0.22	0.22	0.22	0.23	0.25	0.24	0.25	0.26	0.25	0.26	0.43
FEC 12R/30L NW 1/3	0.28	0.29	0.24	0.23	0.23	0.22	0.21	0.2	0.2	0.2	0.2	0.21	0.35	0.35	0.22	0.22	0.22	0.23	0.25	0.25	0.25	0.25	0.25	0.25	0.45
FEC 12R/30L Center point	0.28	0.29	0.24	0.23	0.23	0.22	0.21	0.2	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.26	0.25	0.25	0.25	0.45
FEC 12R/30L SE 1/3	0.31	0.32	0.26	0.25	0.23	0.22	0.21	0.2	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.26	0.25	0.25	0.25	0.45
17/35 N 1/3	0.36	0.35	0.21	0.22	0.22	0.21	0.21	0.2	0.2	0.2	0.2	0.21	0.34	0.34	0.22	0.22	0.22	0.22	0.22	0.24	0.25	0.25	0.25	0.25	0.43
17/35 Center point	0.35	0.35	0.21	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.24	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.25	0.43
17/35 S 1/3	0.36	0.35	0.21	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.24	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.25	0.45
4/22 SW 1/3	0.35	0.35	0.21	0.22	0.22	0.22	0.21	0.2	0.2	0.21	0.21	0.21	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.26	0.26	0.25	0.26	0.43
4/22 Center point	0.35	0.35	0.21	0.22	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.25	0.26	0.25	0.26	0.43
4/22 NE 1/3	0.36	0.35	0.21	0.22	0.22	0.22	0.21	0.2	0.2	0.2	0.2	0.2	0.33	0.33	0.2	0.2	0.2	0.21	0.21	0.21	0.21	0.21	0.23	0.23	0.39

No runway closure
Runway closure possible
Runway closure likely
Runway closure most likely

Background

- The airport community has relied on standard methods to relate weather data to the runway friction problem

- Minneapolis–Saint Paul International Airport experiences several winter storms each season where the runways must be closed due to a loss of friction

- MSP contacted the National Center for Atmospheric Research for help in automating the procedure for relating friction data to runway closure times

- The project would not be possible without support from **MAC** and folks at **MSP**: **Joshua Paurus, John Ostrom, Kyle Scapple, Renee Morafka**

Runway Friction Closure Prediction System

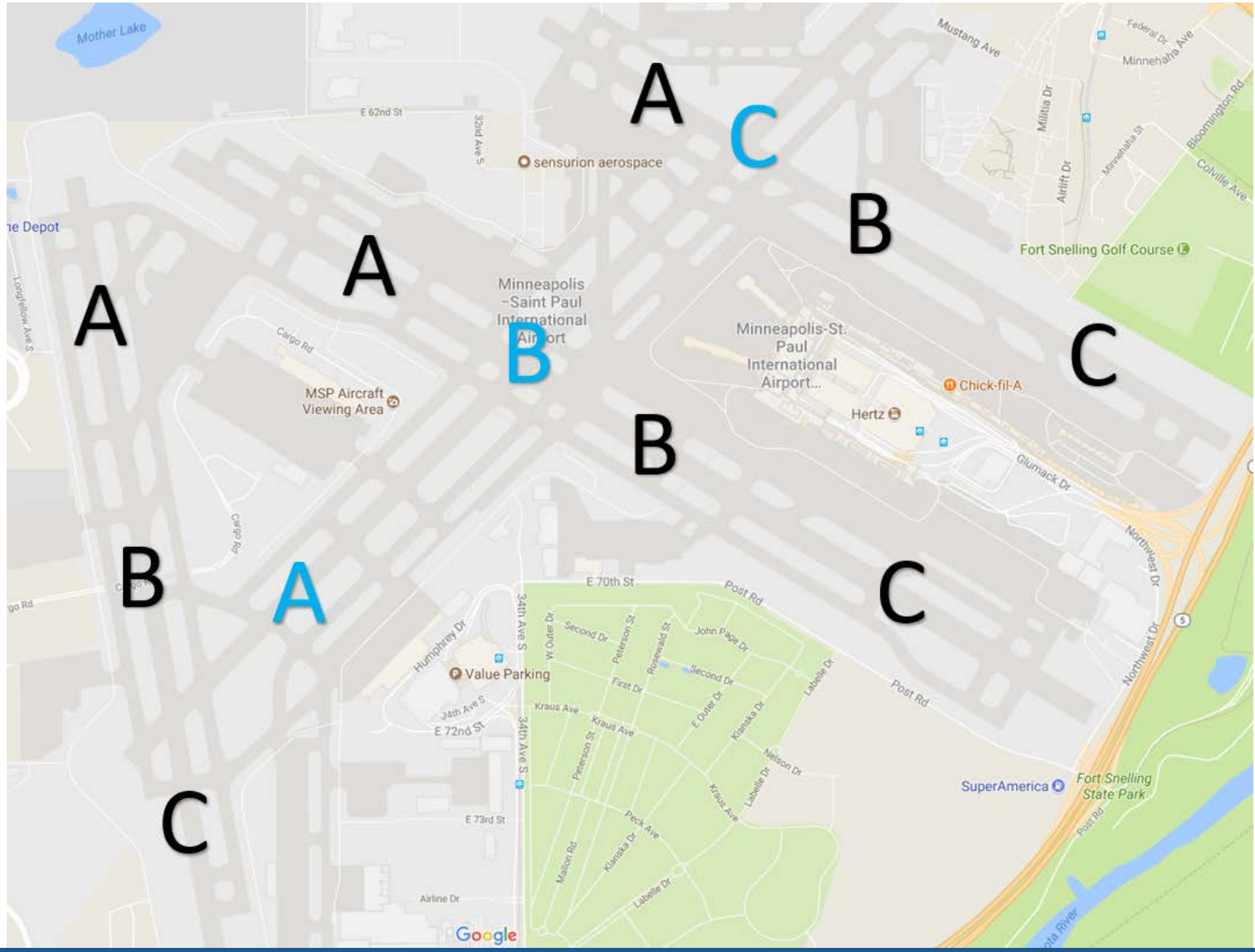
- The RFCPS combines machine learning models with a backend weather forecast to predict runway friction values and runway closure alerts

- The current system updates every hour using the latest available observation data, friction data and near-term forecast data.
  - Updates sub-hourly upon receiving real-time friction data

- RFCPS predicts frictions values from 0 to 6 hours into the future at 15-minute lead-times
  - Predicts friction Mu values between 0-1

- The friction values are combined with rules of practice to predict runway closure alerts

Producing Forecasts at 1/3 Runway Segments



The Real-Time System

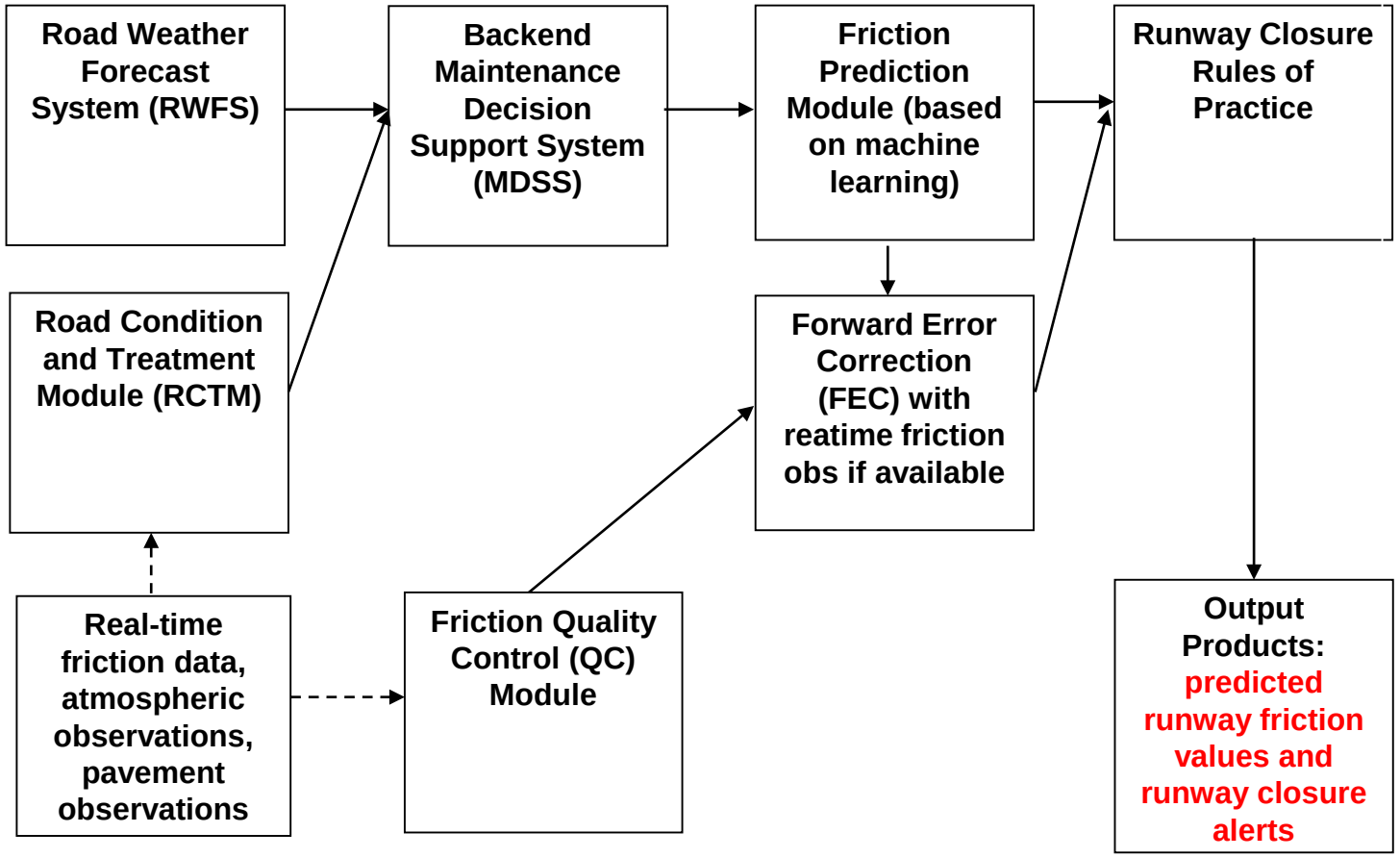
1. Backend forecast engine produces weather and road condition forecasts every hour for each runway segment

2. The friction prediction application reads in the forecast data and calls the different machine learning models

3. A separate application looks for real-time friction measurements from MSP and saves data in a file

4. Real-time application reads in latest weather forecast, latest friction forecasts, latest friction observations and produces the final output products
   - Applies Forward Error Correction (FEC) if applicable
   - Does time-conversions and formatting
   - Produces multi-panel plots, csv files and runway closure matrix
   - Very latest closure matrix and forecast plots available via web-display application (url based) for easy viewing

RFCPS System Diagram



Backend Road Weather Forecast System: MDSS

NOAA - NCEP
- •Numerical Weather Prediction Models
  - oHRRR
  - oNAM
  - oRGEM and GFS
- •Model Statistics
  - oLAMP-MOS
  - oMET-MOS
  - oMEX-MOS
- •Surface Obs (Metars)

NOAA Observations
- •RWIS Data via MADIS
- •Metar Data via NOAA

NCAR (Boulder, CO)
- Road Weather Forecast System (RWFS (DICast))
- Road Condition and Treatment Module (RCTM)
- Data Server

DOT / Airport Data
- •RWIS Sensor Info
- •Road characteristics
- •Route characteristics

Friction Prediction
- RFCPS

Maintenance Operations
- Web-display

Forecasts go out to 72 hour at 1-hour lead-times

NCAR

Phase I Machine Learning

- Created several different machine-learning models using historical friction data and RWIS observations
  - **Cubist (Regression)**
  - **Gradient Boosted Trees (GBT)**
  - **Random Forrest**
  - **Expert System (Rules) based algorithm**
- Models predict surface friction Mu values between 0-1
  - 0.2 would be very slick, 0.8 very tacky
- After analyzing initial results, modified the target data to get better results

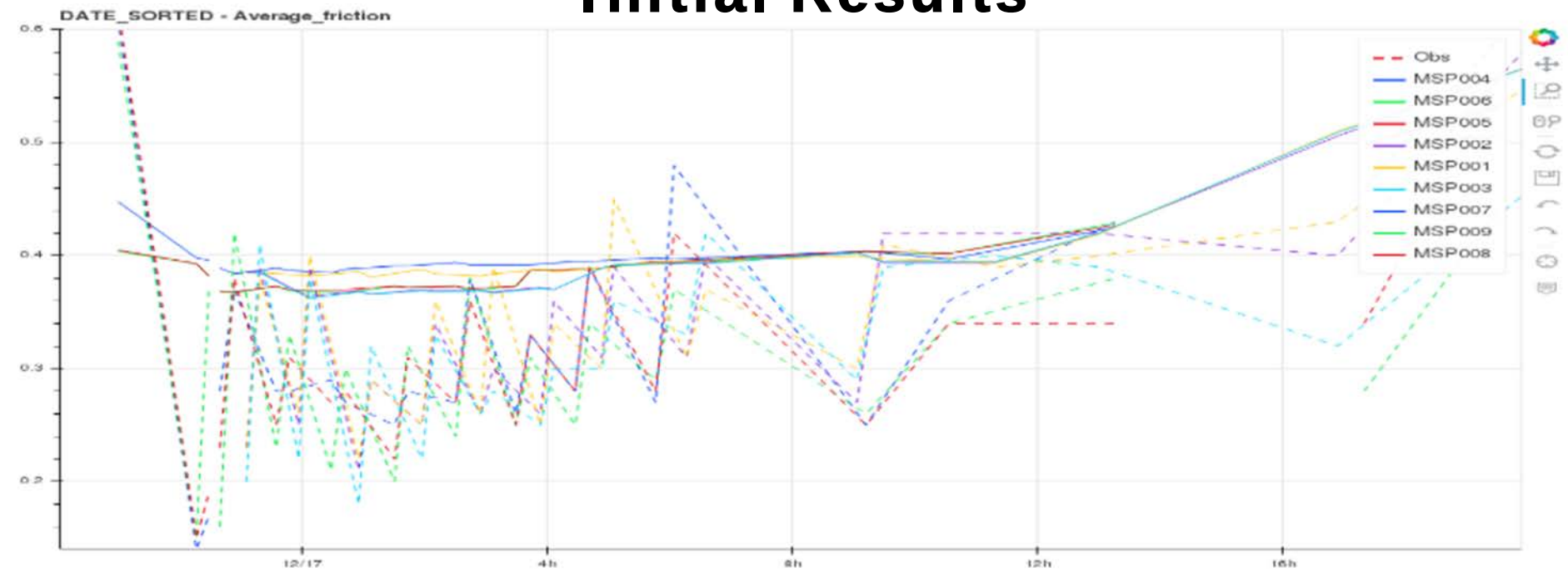
Data used for Phase I Machine Learning

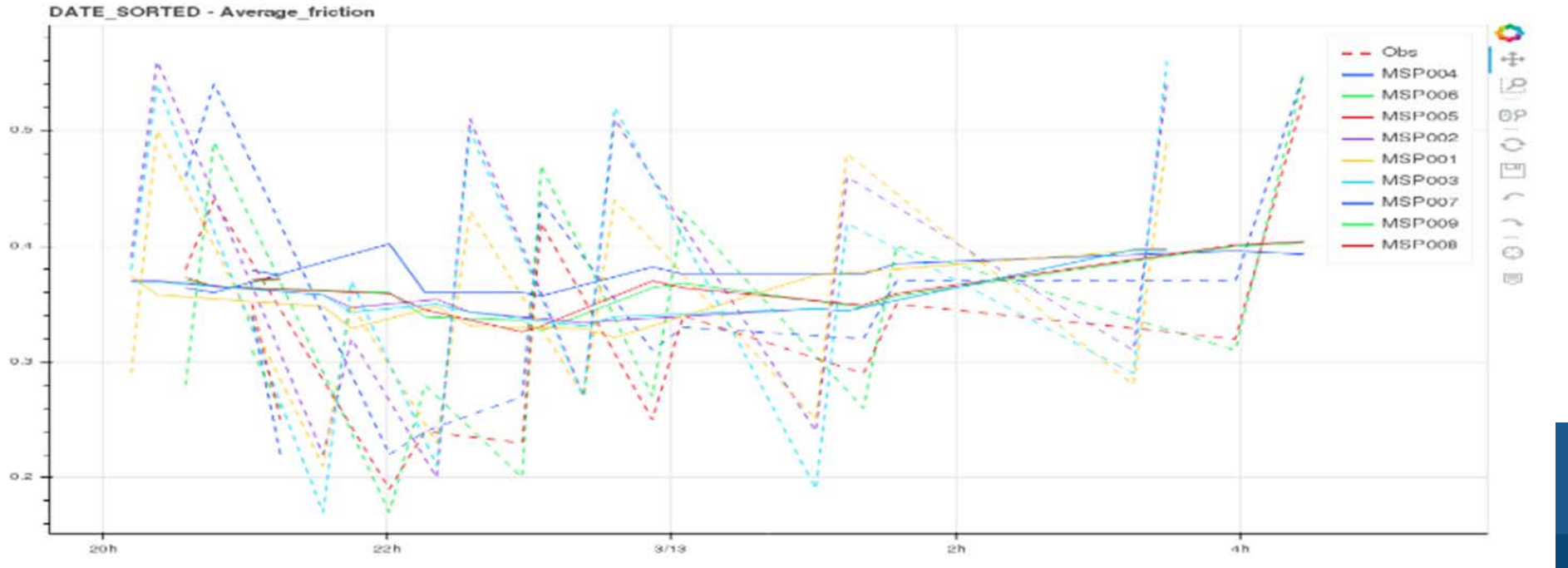
- All historical data is from Nov, 2014 – March, 2017
  - 3 winter seasons
- Friction Data from MSP
  - Measured by an Airport Surface Friction Tester
  - At inconsistent times when a storm was passing
- RWIS data
  - 5 minute surface and atmospheric data from multiple units at MSP
  - Surface Temp, Surface State, Air Temp, Dewpt, RH, Rain State, Wind Speed, Wind Dir, Chemical Factor / Concentration
- ASOS data
  - 1 minute data from the station at MSP
  - Visibility, Wind Direction, Wind Speed, Precip(mm), Present Weather (string), Temperature, RH, Dewpt

Preparing Data for Machine Learning

- QC
  - Removed stuck values
  - Removed outlying Surface Temperature fields
    - If one station's Surface Temp differed greatly from the other stations at any given time, remove it.
- Combining the datasets
  - For any given friction measurement, take the most recent observation values from the RWIS or ASOS measurements.
    - For common fields use RWIS first, fall back to ASOS if RWIS is missing
- Adding combined/derived fields
  - Average value over last X minutes
  - Most severe value over last X minutes
  - Consolidated precip condition fields to match RCTM output

Initial Results



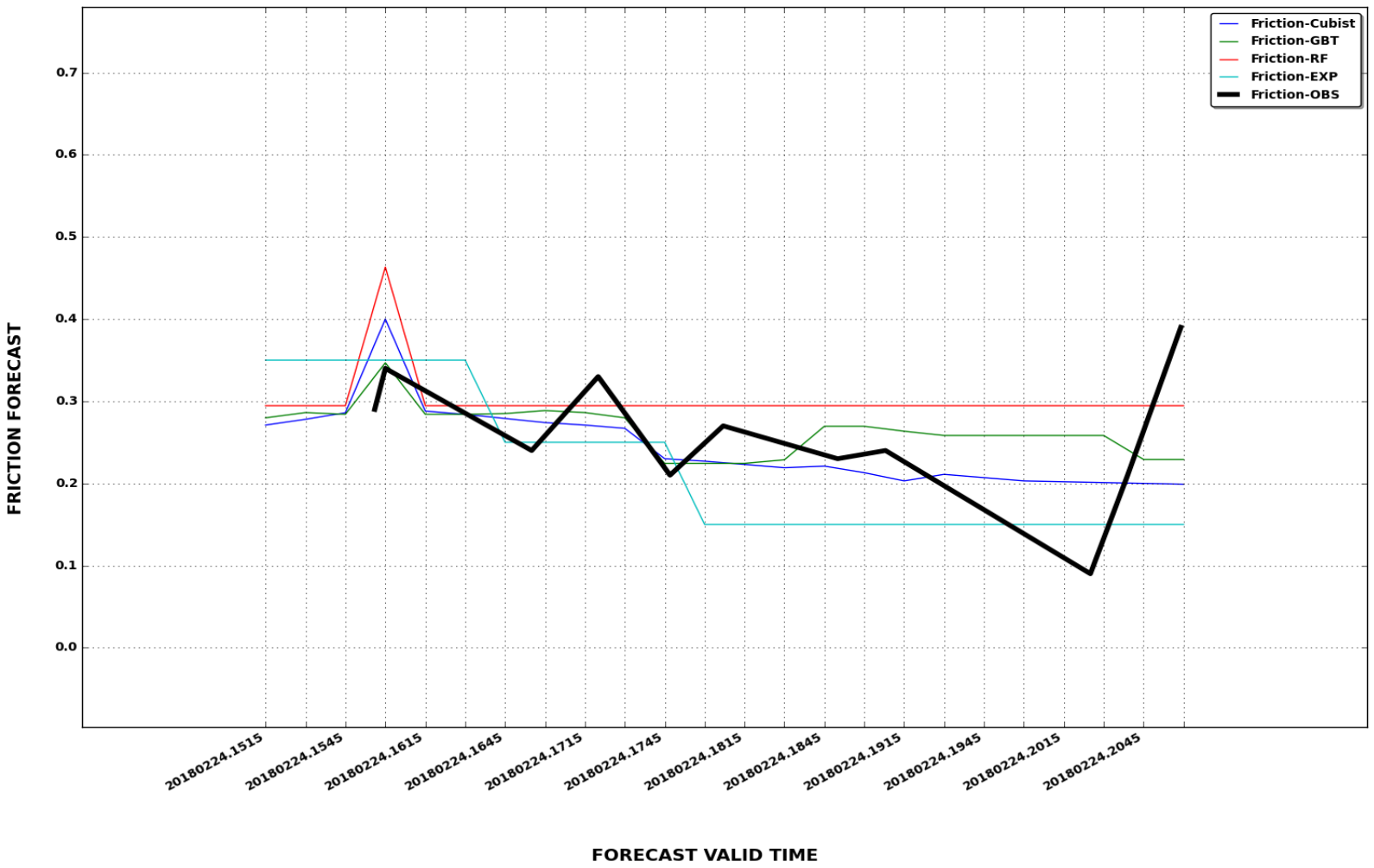


Change Target

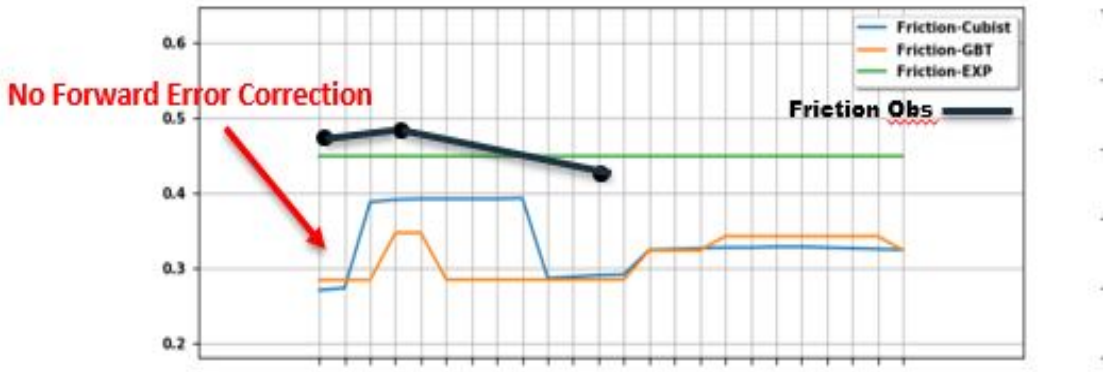
- Without historical and real-time treatment information cannot model the spikes
- Re-think problem
  - It would be meaningful if we could forecast the 'low' values in between the spikes. This would inform MSP when the friction values are likely to fall below some critical threshold.
- Solution: Change Target
  - Rather than training the models to target average friction, train them to target the worst friction value over last hour
- This produced much better results in Phase I
  - Still not capturing up and down in friction values due to runway treatments (that comes in Phase II)

Phase I: Target Lowest Friction Value

Initial Verification (after new target in ML)



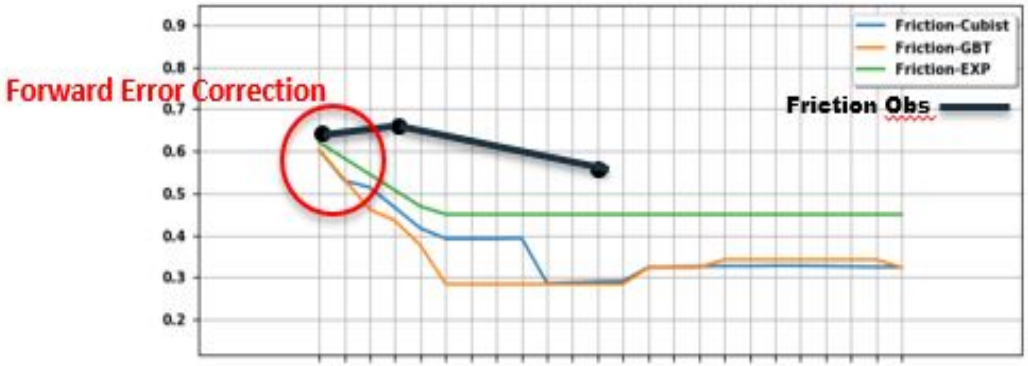
Initial Forward Error Correction



Gather friction measurements in real-time from MSP airport (these are the Friction Obs)

Use the friction observations to correct the friction forecast in the first 3-hours

The updated friction forecast is then used to produce the runway closure alerts



Phase II Goals

1. **Improve friction prediction models by incorporating actual treatment information**
   - Understand the MSP treatment data and how it relates to the friction values
   - Utilize new data to build new ML models
2. **Better Forward Error Correction**
   - Modify system to produce sub-hourly updates upon receiving real-time friction observations
     - Corrects latest forecast, updated to nearest 15minute start time and produces a new 6-hour forecast
3. **Update output and add forecast variables**
   - Runway Crosswind Potential
   - Runway Blowing Snow Potential
4. **Create web-display application (URL based) for easy viewing of the output products**

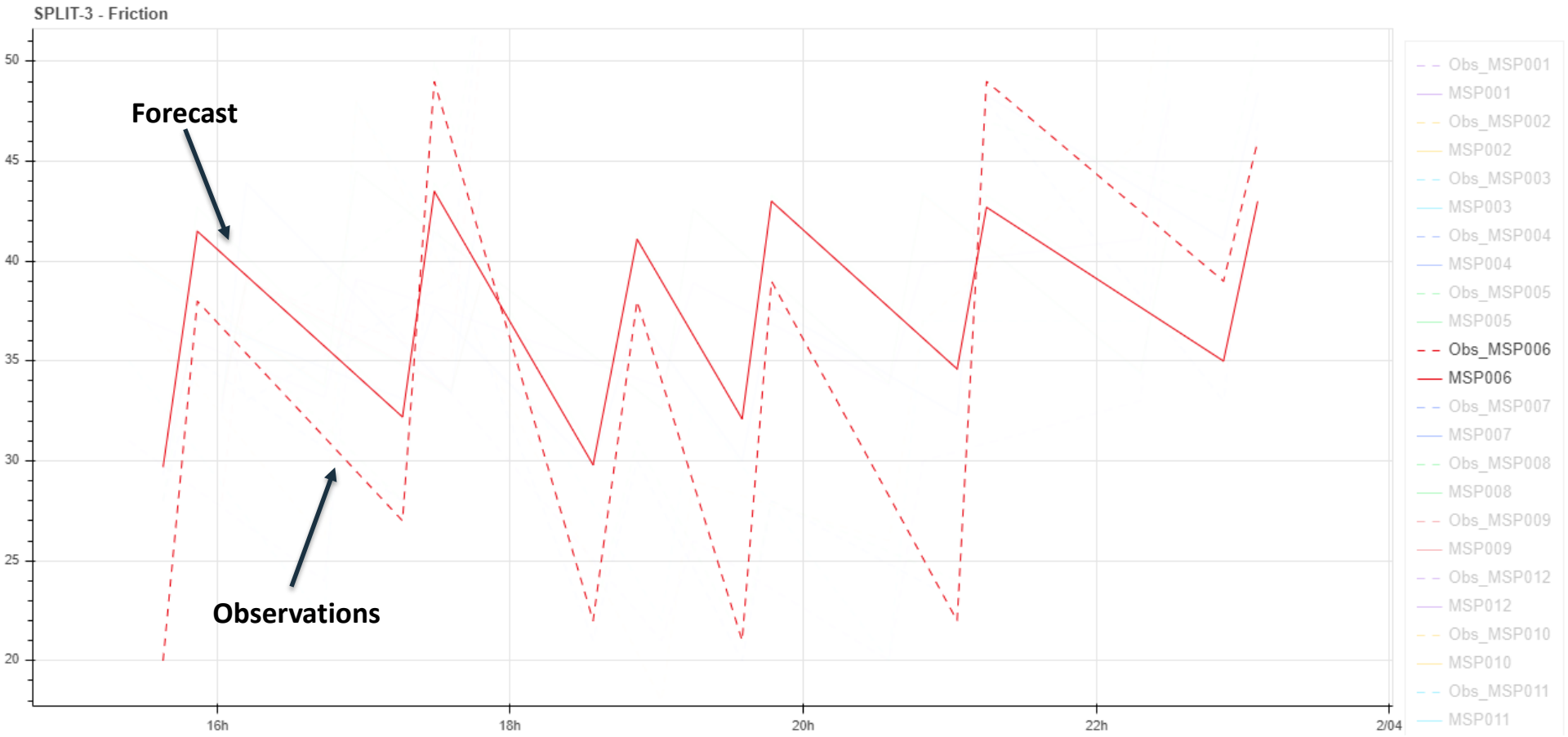
Preparing Data for Phase II Machine Learning

- Used more recent historical data
  - Winters of 2017/2018, 2018/2019 and early winter 2019
  - Same QC techniques to line up friction observations with RWIS / ASOS observations
- The updated historical data from MSP had indication of runway treatments
  - Spreadsheet indicates pre-run friction values and post-treatment friction values at certain times of the day
    - Also shows if treatment / plowing was done to the runway section
  - New QC was implemented to line up pre / post run friction values with actual treatments (yes = 1, no = 0)
    - QC'd out data where friction values went down after treatment (due to heavy snow)
    - Normally friction value increase (improve) after treatment

Phase II: Initial Machine Learning

- Worked on creating new machine-learning models that use actual treatment data
  - Initially developing models with treatment yes=1, no=0
- Then developed first model that takes into account all friction value and all treatment yes, no's
- A second model was developed using yes-treatment data only
  - Assume continuous treatment
- A third model was developed, for no-treatment data
  - Assumes no treatment at all
- Examined how these different models compare and how they can be used together

Phase II: Initial machine-learning models that use treatment data



Phase II Machine Learning Results

- New ML models developed
  - New Gradient Boosted Trees (GBT) model
  - New Neural Net Models
  - New optimized GBT model
  - New Cubist model

- NCAR did assessment of new friction models to determine what model is performing the best
  - Looked at both bulk statistics: Hit/Miss, MAE, RMSE
  - Also looked at several case-study plots

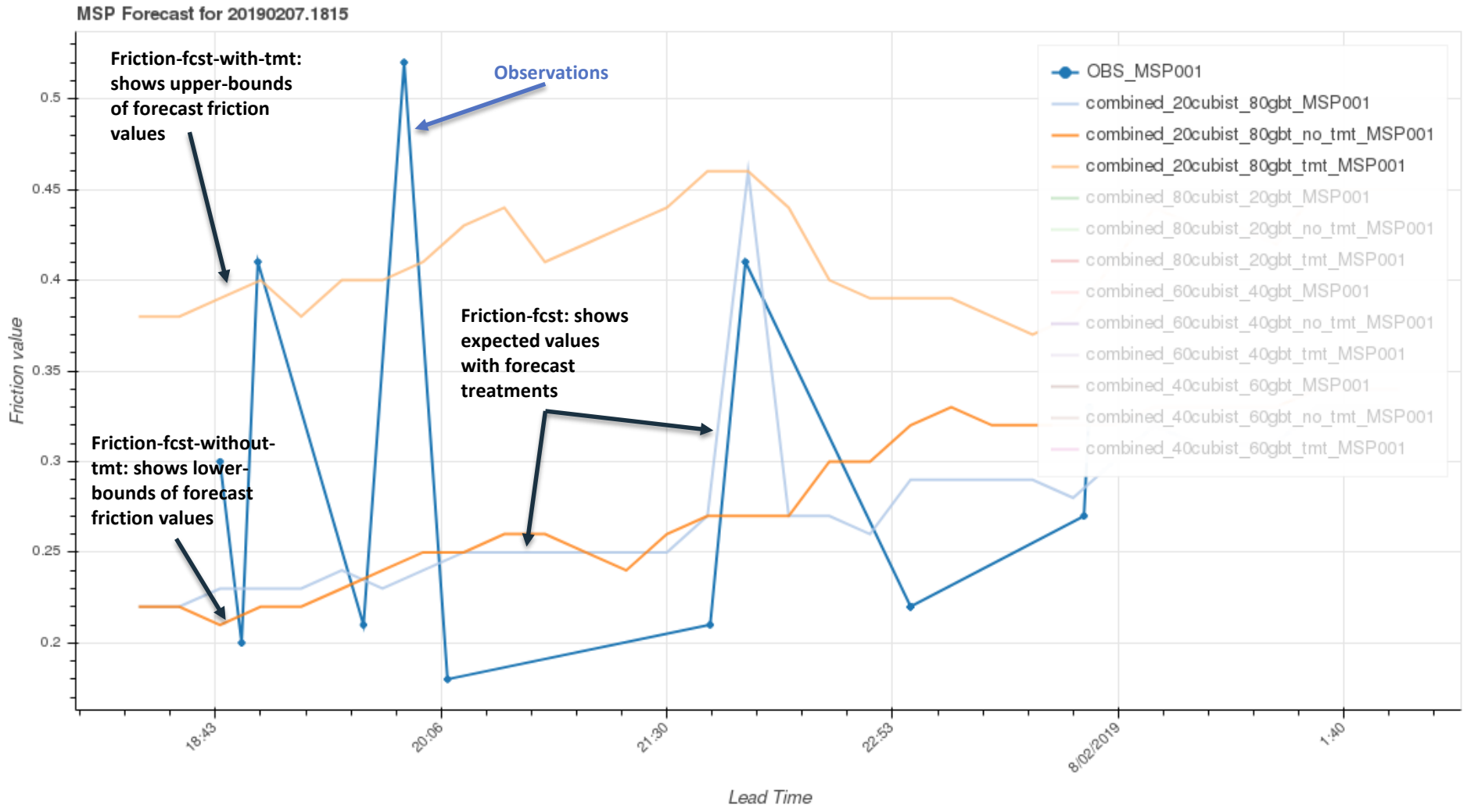
- Determined a model combination between the two best models gives the best overall results
  - Initial model **combination is 80% GBT / 20% Cubist**
  - Used this combination for all-three output models: Main Friction forecast (yes and no treatments), Friction forecast without treatment (based on no treatment), Friction forecast with treatment (based on yes treatment)

- New output: **Use all three models for best guidance**
  - Friction-forecast (main model output: takes into account treatments and no-treatments, **gives expected values, closure guidance based on this model**)
  - Friction-forecast-without-tmt (model assumes no treatment being applied to runways, **gives lower bounds of friction values**)
  - Friction-forecast-with-tmt (model assumes treatment is applied at every lead-time, **gives upper bounds of friction values**)

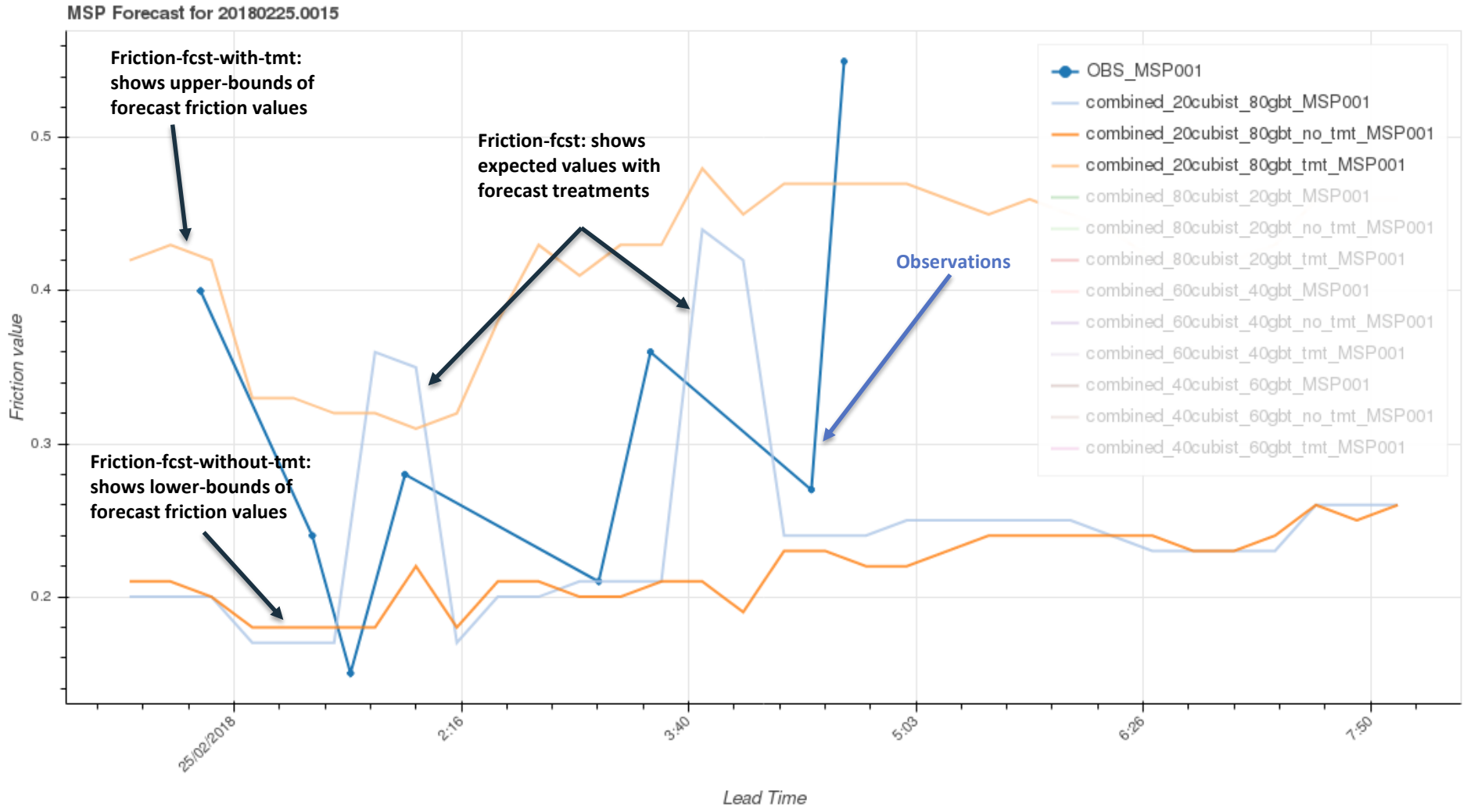
Verification

- NCAR created verification scripts for the RFCPS
  - Takes a date.hour range and can evaluate all friction forecasts over a given time-period or for a single forecast
    - Gives Average Hit %, Average Miss %, MAE, RMSE
    - Can compare ML models
- Also created a script to plot forecast time-series against the friction observations
- Ran some historical cases through the new friction models
  - 20180122-20180123
  - 20180224-20180225
  - 20180403-20180404
  - 20181226
  - 20190124
    - Using the verification script / plotting package to analyze the cases and model performance

New Model Output Examples



New Model Output Examples



Bulk Stats for February 9th case (00z to 23z)

80% GBT / 20% Cubist

ERROR STATISTICS :

HIT PERCENTAGE : 59.606

MISS PERCENTAGE : 40.394

MAE : 0.166

RMSE : 0.22

77% GBT / 23% NN

ERROR STATISTICS :

HIT PERCENTAGE : 57.847

MISS PERCENTAGE : 42.153

MAE : 0.175

RMSE : 0.231

Bulk Stats for January 23rd case (07z to 23z)

80% GBT / 20% Cubist

ERROR STATISTICS :

HIT PERCENTAGE : 61.111

MISS PERCENTAGE : 38.889

MAE : 0.188

RMSE : 0.225

77% GBT / 23% NN

ERROR STATISTICS :

HIT PERCENTAGE : 55.696

MISS PERCENTAGE : 44.304

MAE : 0.206

RMSE : 0.239

Final Fixes in Phase II

- Fixed a bug in the system related to generating the sub-hourly RFCPS runs upon receiving real-time friction observations
  - If system finds friction data during standard run, will wait to re-run and do Forward Error Correction (FEC)
    - to avoid stomping on initial output
  - Upon receiving friction data, output for all runway segments is re-generated, starting at nearest, last 15min time: 4:30, 4:45, 6:45, etc.
  - MSP should always use very latest output data for all runways
- Modified output such that during the middle of a storm, when runway closures are likely at surrounding lead-times
  - when a treatment is forecast, still color code matrix (and pdf plot) with some “yellow” indicating closures possible (instead of white / blank), this makes output look more reasonable during storms
  - Output now looks more reasonable during storms

Runway Closure Matrix Example

RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20190226 15:30

FORECAST LEAD TIME

	1530	1545	1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845	1900	1915	1930	1945	2000	2015	2030	2045	2100	2115	2130
12L/30R NW 1/3	0.4	0.4	0.39	0.38	0.43	0.44	0.46	0.38	0.37	0.36	0.37	0.36	0.36	0.31	0.31	0.3	0.3	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28
12L/30R Center point	0.42	0.41	0.4	0.39	0.44	0.46	0.47	0.41	0.4	0.39	0.4	0.39	0.39	0.35	0.35	0.34	0.34	0.33	0.32	0.32	0.31	0.31	0.31	0.3	0.3
12L/30R SE 1/3	0.4	0.42	0.41	0.39	0.44	0.46	0.47	0.41	0.4	0.39	0.38	0.39	0.39	0.35	0.35	0.34	0.34	0.33	0.33	0.32	0.32	0.31	0.31	0.3	0.3
12R/30L NW 1/3	0.39	0.42	0.41	0.39	0.43	0.42	0.45	0.37	0.35	0.34	0.33	0.35	0.34	0.34	0.29	0.28	0.28	0.27	0.26	0.26	0.21	0.21	0.22	0.22	0.22
12R/30L Center point	0.4	0.42	0.41	0.39	0.44	0.46	0.47	0.42	0.41	0.4	0.4	0.41	0.41	0.37	0.36	0.35	0.35	0.34	0.33	0.33	0.33	0.32	0.32	0.32	0.31
12R/30L SE 1/3	0.41	0.43	0.41	0.39	0.44	0.46	0.47	0.42	0.41	0.4	0.4	0.41	0.4	0.4	0.36	0.35	0.34	0.34	0.33	0.33	0.33	0.33	0.32	0.32	0.32
17/35 N 1/3	0.39	0.42	0.41	0.39	0.43	0.44	0.46	0.38	0.37	0.36	0.35	0.37	0.36	0.35	0.31	0.3	0.3	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28
17/35 Center point	0.41	0.4	0.42	0.4	0.44	0.44	0.46	0.46	0.4	0.39	0.38	0.37	0.38	0.37	0.32	0.32	0.31	0.31	0.3	0.3	0.3	0.3	0.3	0.3	0.3
17/35 S 1/3	0.4	0.4	0.39	0.37	0.43	0.46	0.41	0.41	0.4	0.39	0.4	0.39	0.35	0.34	0.33	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
4/22 SW 1/3	0.35	0.35	0.36	0.36	0.45	0.39	0.4	0.39	0.4	0.36	0.35	0.35	0.34	0.34	0.33	0.32	0.32	0.31	0.31	0.3	0.3	0.3	0.3	0.3	0.3
4/22 Center point	0.39	0.38	0.38	0.36	0.41	0.45	0.39	0.38	0.37	0.36	0.37	0.36	0.32	0.31	0.31	0.3	0.3	0.3	0.29	0.29	0.29	0.29	0.29	0.29	0.28
4/22 NE 1/3	0.41	0.41	0.4	0.38	0.43	0.44	0.46	0.38	0.37	0.36	0.35	0.36	0.36	0.31	0.31	0.3	0.3	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.28

No runway closure
Runway closure possible
Runway closure likely
Runway closure most likely

Runway Closure Matrix Example

RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20200209 04:45

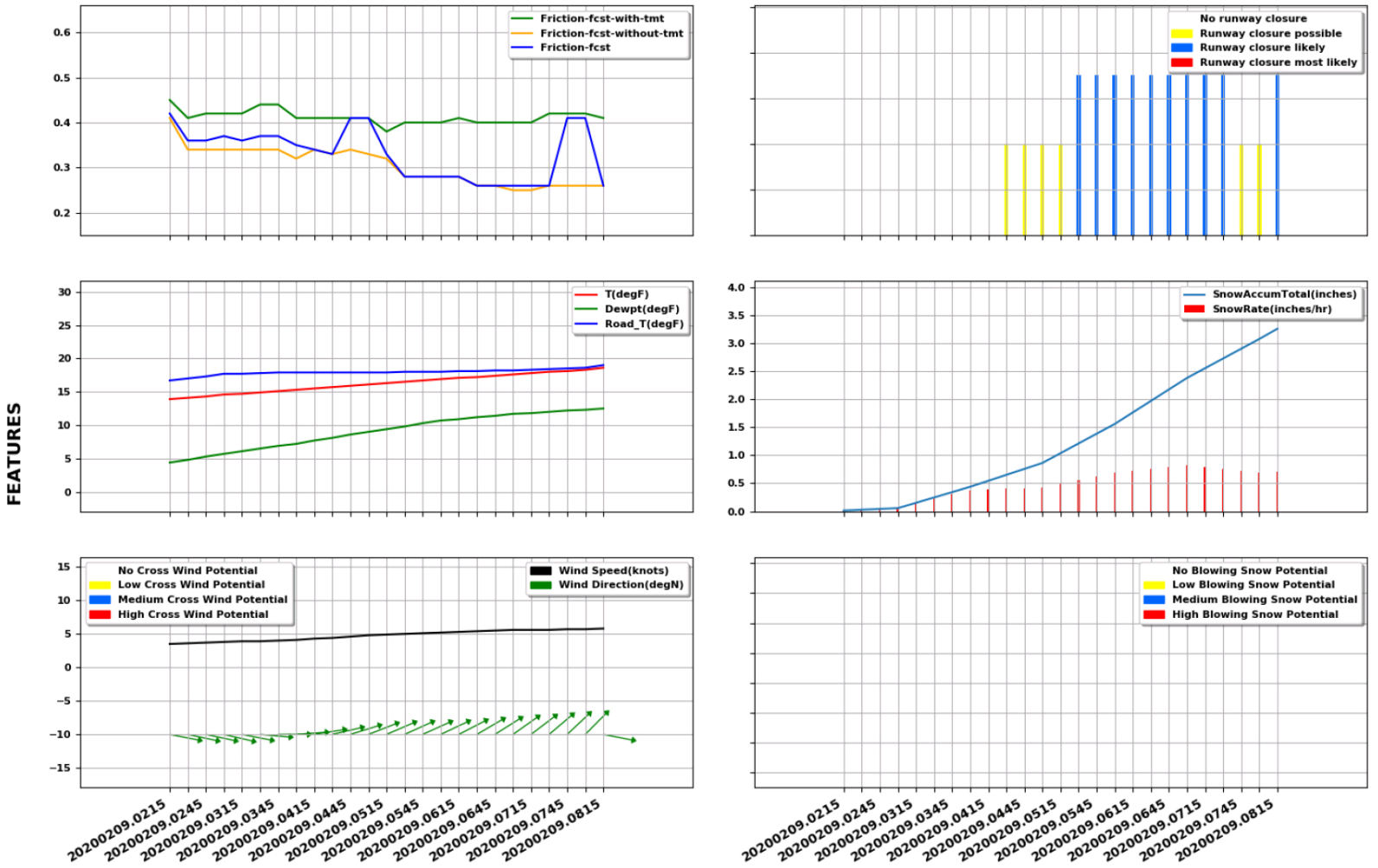
FORECAST LEAD TIME

	0445	0500	0515	0530	0545	0600	0615	0630	0645	0700	0715	0730	0745	0800	0815	0830	0845	0900	0915	0930	0945	1000	1015	1030	1045
FEC 12L/30R NW 1/3	0.26	0.28	0.23	0.23	0.22	0.22	0.21	0.2	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.25	0.25	0.25	0.25	0.43
FEC 12L/30R Center point	0.25	0.27	0.22	0.23	0.22	0.22	0.22	0.2	0.2	0.2	0.21	0.21	0.34	0.35	0.22	0.22	0.22	0.24	0.25	0.24	0.25	0.26	0.25	0.26	0.43
FEC 12L/30R SE 1/3	0.27	0.29	0.23	0.23	0.22	0.22	0.22	0.2	0.2	0.2	0.21	0.21	0.34	0.34	0.22	0.22	0.22	0.23	0.25	0.24	0.25	0.26	0.25	0.26	0.43
FEC 12R/30L NW 1/3	0.28	0.29	0.24	0.23	0.23	0.22	0.21	0.2	0.2	0.2	0.2	0.21	0.35	0.35	0.22	0.22	0.22	0.23	0.25	0.25	0.25	0.25	0.25	0.25	0.45
FEC 12R/30L Center point	0.28	0.29	0.24	0.23	0.23	0.22	0.21	0.2	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.26	0.25	0.25	0.25	0.45
FEC 12R/30L SE 1/3	0.31	0.32	0.26	0.25	0.23	0.22	0.21	0.2	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.26	0.25	0.25	0.25	0.45
17/35 N 1/3	0.36	0.35	0.21	0.22	0.22	0.21	0.21	0.2	0.2	0.2	0.2	0.21	0.34	0.34	0.22	0.22	0.22	0.22	0.22	0.24	0.25	0.25	0.25	0.25	0.43
17/35 Center point	0.35	0.35	0.21	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.24	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.25	0.43
17/35 S 1/3	0.36	0.35	0.21	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.24	0.25	0.25	0.25	0.25	0.26	0.25	0.25	0.25	0.45
4/22 SW 1/3	0.35	0.35	0.21	0.22	0.22	0.22	0.21	0.2	0.2	0.21	0.21	0.21	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.26	0.26	0.25	0.26	0.43
4/22 Center point	0.35	0.35	0.21	0.22	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.22	0.35	0.35	0.22	0.23	0.24	0.25	0.24	0.25	0.25	0.26	0.25	0.26	0.43
4/22 NE 1/3	0.36	0.35	0.21	0.22	0.22	0.22	0.21	0.2	0.2	0.2	0.2	0.2	0.33	0.33	0.2	0.2	0.2	0.21	0.21	0.21	0.21	0.21	0.23	0.23	0.39

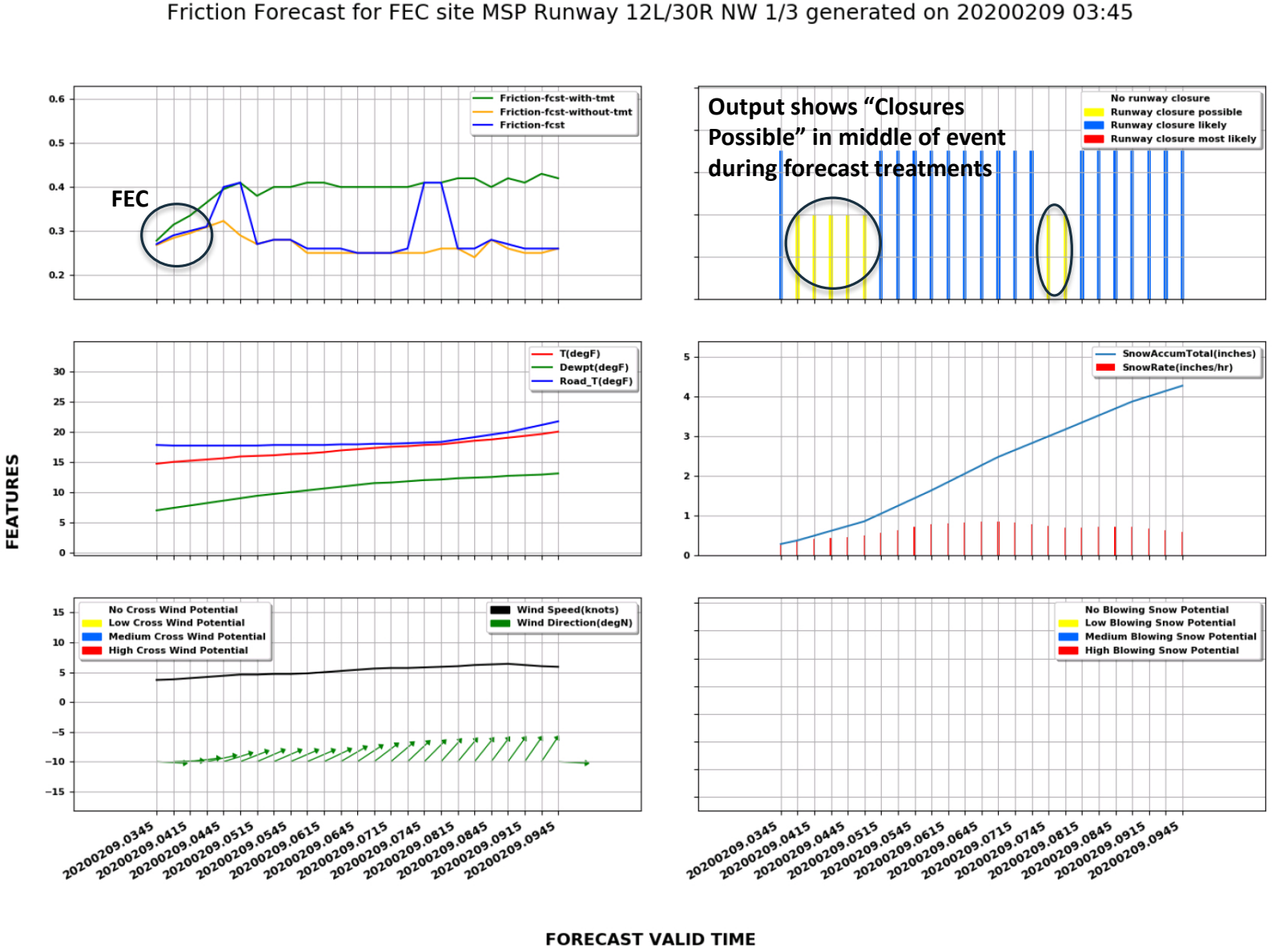
No runway closure
Runway closure possible
Runway closure likely
Runway closure most likely

Just Before Event starts

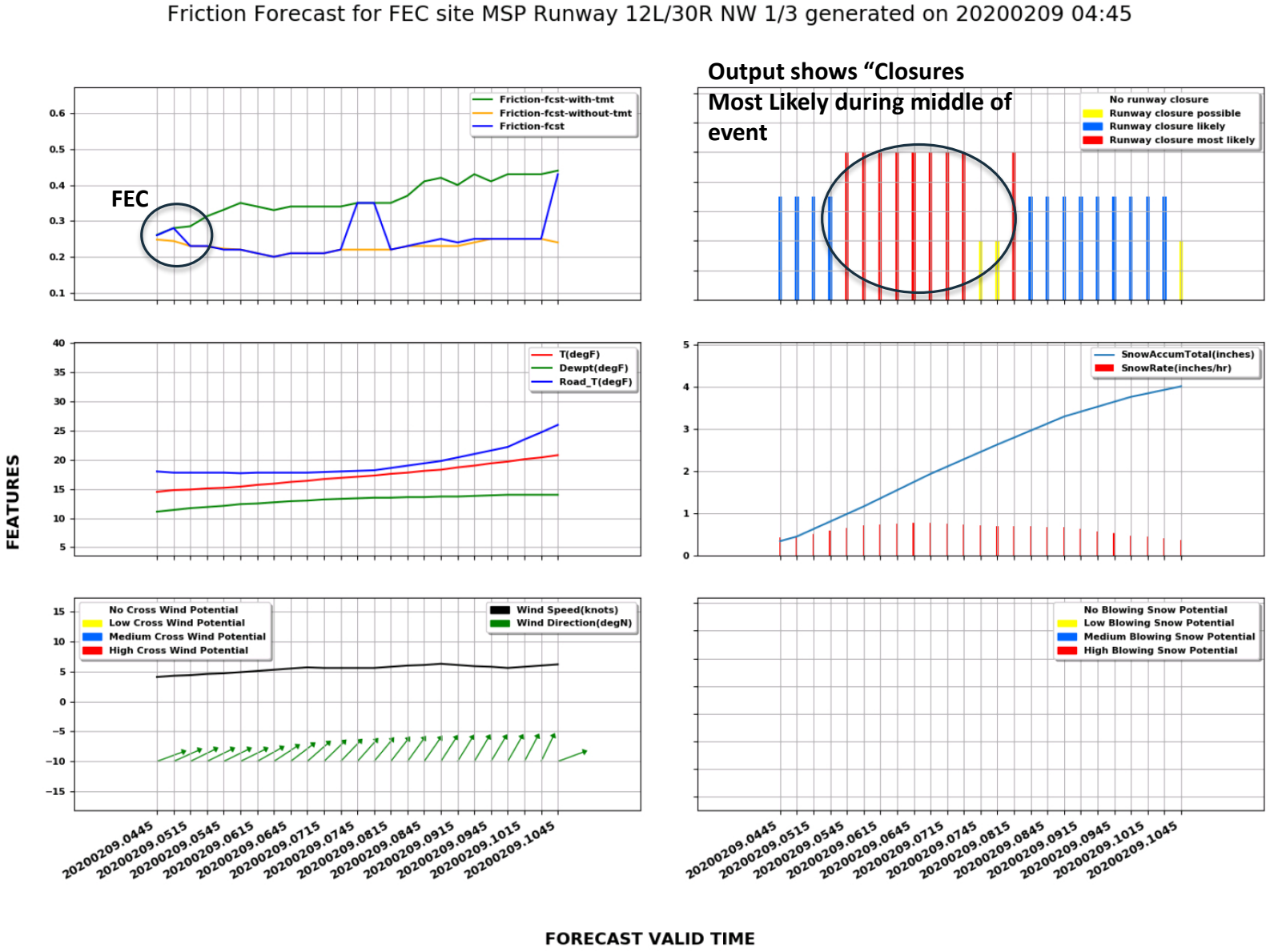
Friction Forecast for site MSP Runway 12L/30R NW 1/3 generated on 20200209 02:15



Event getting started

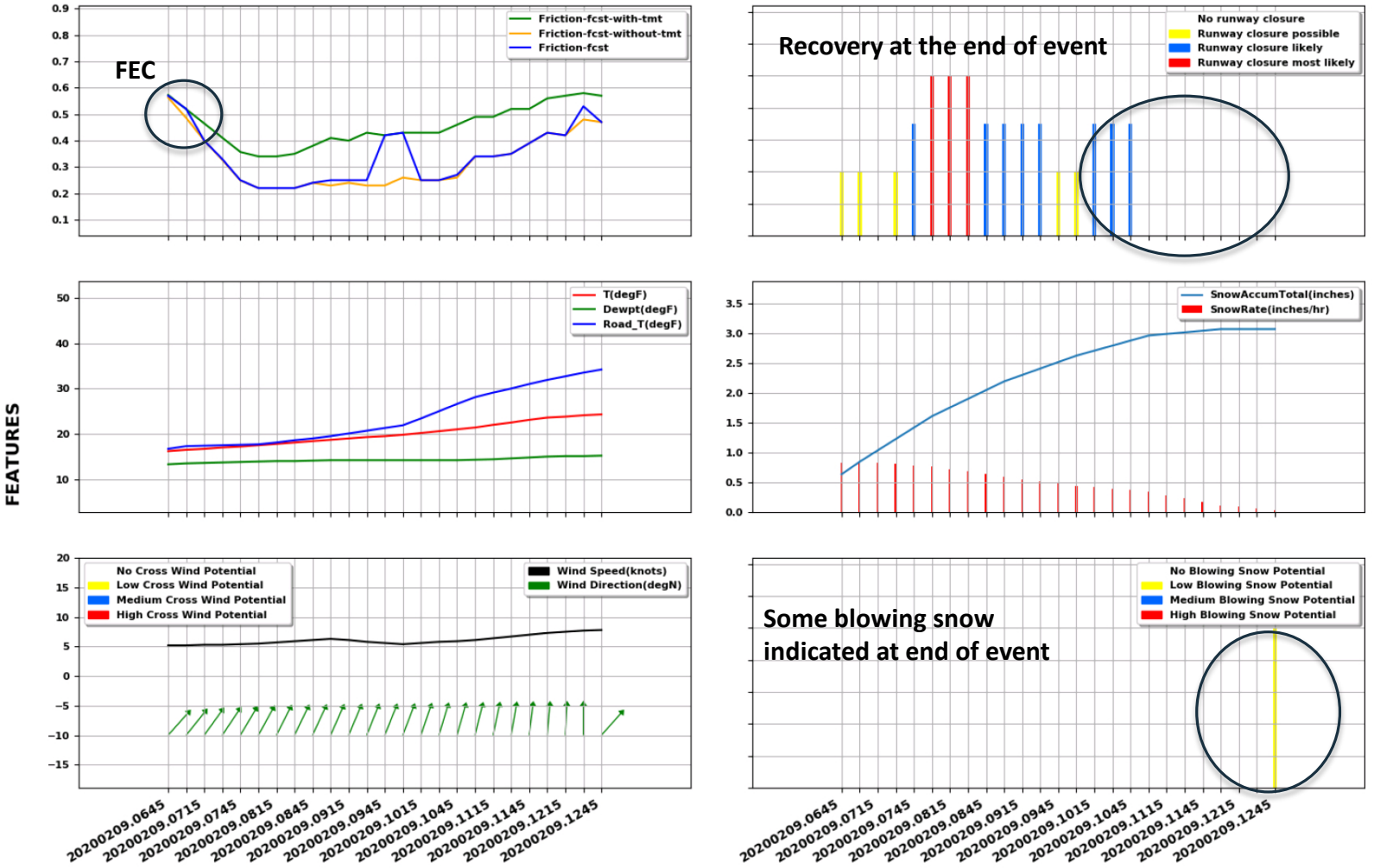


Middle of Event



End of Event

Friction Forecast for FEC site MSP Runway 12L/30R NW 1/3 generated on 20200209 06:45



New output: Blowing Snow Potential

NCAR blowing-snow algorithm:

- looks at age of last snowfall, wind-speeds, temperatures, current precip (snow or liquid)
- derives blowing-snow values between 0-1. Then apply a set of thresholds to come of with blowing-snow potential (integer values between 0-3):

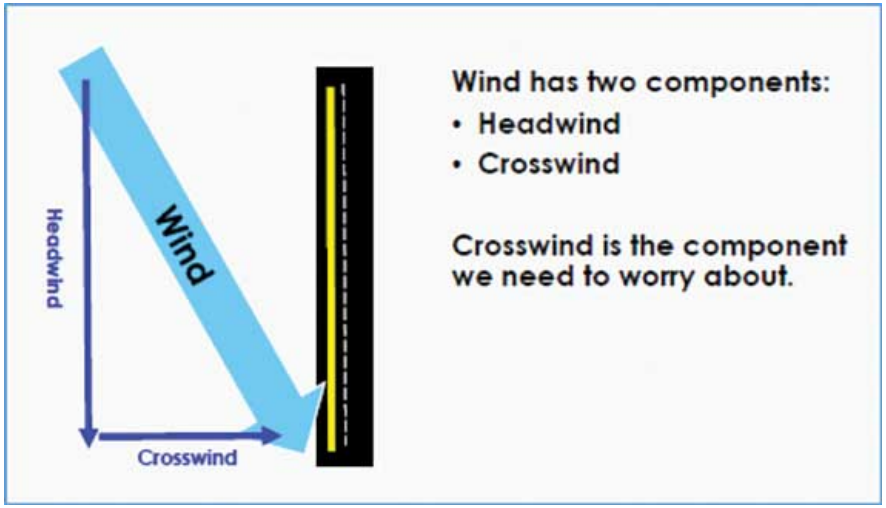
0: No blowing snow
1: Blowing snow potential: Low
2: Blowing snow potential: medium
3: Blowing snow potential: high

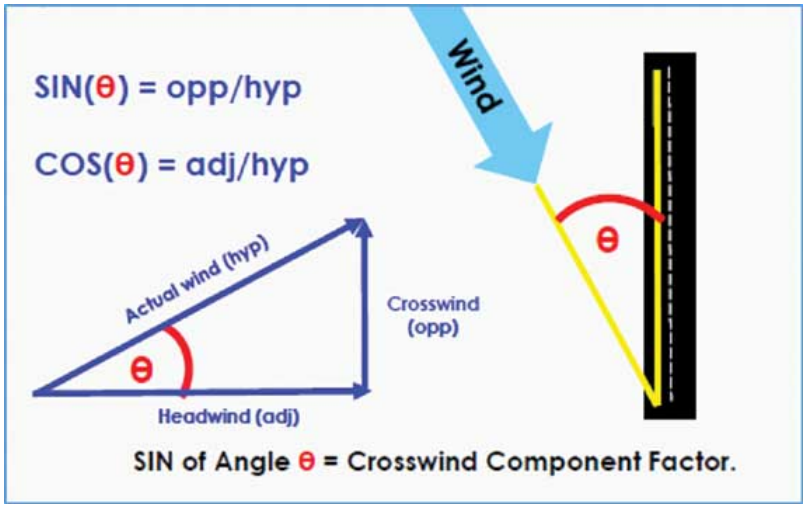
```
if( val >= 0.0 && val <= 0.05 )
  return( 0.0 );
else if( val > 0.05 && val <= 0.333 )
  return( 1.0 );
 else if( val > 0.333 && val <= 0.667 )
  return( 2.0 );
 else if( val > 0.667 && val <= 1.0 )
  return( 3.0 );
```

- NCAR producing new output variable: blowing-snow-alerts for MSP
  - Providing Blowing-Snow Potential (integers 0-3)
  - 0=None, 1=Low, 2=Medium, 3=High
- Added blowing-snow potential (values 0-3) to output csv file
  - Added to the 15min csv output and new multi-panel plots

New output: Crosswind Potential

- NCAR developed Runway Crosswind Warning variable





Crosswind = WindSpeed * Sin(θ)

Any wind beyond 60 degrees off the runway heading should be considered as all crosswind

New output: Crosswind Potential

- NCAR created new forecast output product for MSP: Crosswind Potential
  - First derive crosswind-speed, then threshold to get potential
    - low_thresh = 25 knots
    - medium_thresh = 30 knots
    - high_thresh = 35 knots
  - Crosswind Potential: 0 = None, 1 = some crosswinds, monitor, 2 = crosswinds likely but not as strong, monitor, 3 = crosswind warning, runway closure likely
- Crosswind has been added to 15min output csv files and new multi-panel plots

Web-display for viewing output

- Built a simple web display for viewing the latest output from the RFCPS
- The web page is both desktop compatible and mobile phone compatible.
  - The display is rendered automatically for each version.
  - For the desktop version, you see the latest Matrix and then below that the latest forecast plots for each runway.
  - For each of the runway plots, there is a carousel feature where you can either swipe left or right to see all the runway section plots or use your mouse to click back and forth. Each runway has 3 plots (A, B,C).
- The mobile version shows the matrix first and then the 12 multi-panel plots are below it and you can use scrolling (with fingers) to see the plots below
- The web display always shows the very latest forecast (the Closure Matrix and plots are all from the very latest, same run).

Web-display for viewing output

- The web page is password protected

  https://proxy.rap.ucar.edu/rfcps-msp/

Closure Guidance

RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20200901 15:15

FORECAST LEAD TIME

	1515	1530	1545	1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845	1900	1915	1930	1945	2000	2015	2030	2045	2100	2115
12L/30R NW 1/3	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.58	0.59	0.59	0.59	0.59	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.63	0.63	0.64	0.64
12L/30R Center point	0.6	0.6	0.59	0.59	0.59	0.59	0.59	0.6	0.59	0.59	0.59	0.59	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.62	0.63	0.63	0.63	0.64	0.64
12L/30R SE 1/3	0.6	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.62	0.63	0.63	0.63	0.64	0.64
12R/30L NW 1/3	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.6	0.6	0.6	0.6	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.62	0.63	0.63	0.63	0.64	0.64
12R/30L Center point	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.58	0.59	0.59	0.59	0.59	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.62	0.64	0.64
12R/30L SE 1/3	0.6	0.6	0.6	0.6	0.6	0.59	0.59	0.6	0.6	0.6	0.6	0.6	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.63	0.63	0.63	0.63	0.65	0.65
17/35 N 1/3	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.58	0.59	0.59	0.59	0.59	0.63	0.64	0.64	0.62	0.62	0.62	0.62	0.64	0.62	0.62	0.63	0.64	0.64
17/35 Center point	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.6	0.6	0.6	0.6	0.64	0.64	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64

Future Plans for Phase II

- Extend forecast window to 72 hours
  - MDSS forecast data goes out 72 hours
  - Utilize forecast data to produce a 72 hour friction and runway closure forecast
- Port RFCPS system to the cloud
  - Install on Amazon (AWS) cloud instance
  - Better up-time, easy to add space and memory, easy to expand system to other states
- Utilize real-time runway treatment data to improve friction forecast
  - Use this data to change forecast treatments from MDSS
  - Will make the friction forecast more accurate, reflecting correct up/down in values due to treatments

Questions