Runway Friction Closure Prediction System (RFCPS)

Winter 2020-2021 Verification

Seth Linden
National Center for Atmospheric Research
Boulder, Colorado

Josh Paurus
Minneapolis–Saint Paul International Airport / MAC
Minneapolis, Minnesota

FPAW
April 28, 2021

NCAR

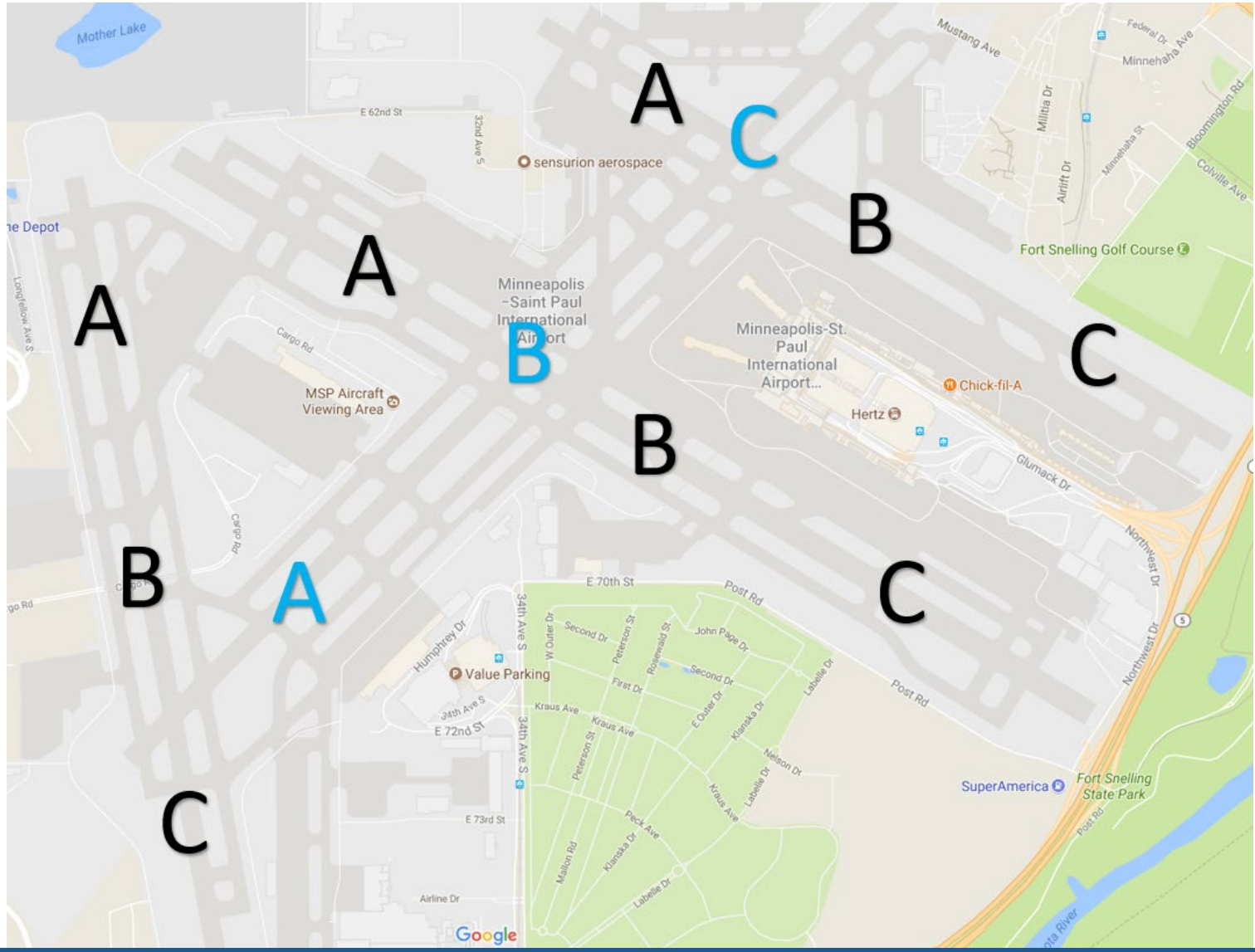
Outline

- What is RFCPS
- System Overview
- Phase II System Development
- Output examples
- **Verification of selected 2020-2021 cases**
  - December 23, 2020
  - December 29, 2020
  - January 23, 2021
  - October 20, 2020
  - November 10, 2020
  - February 4, 2021 (time permitting)
- Improving RFCPS

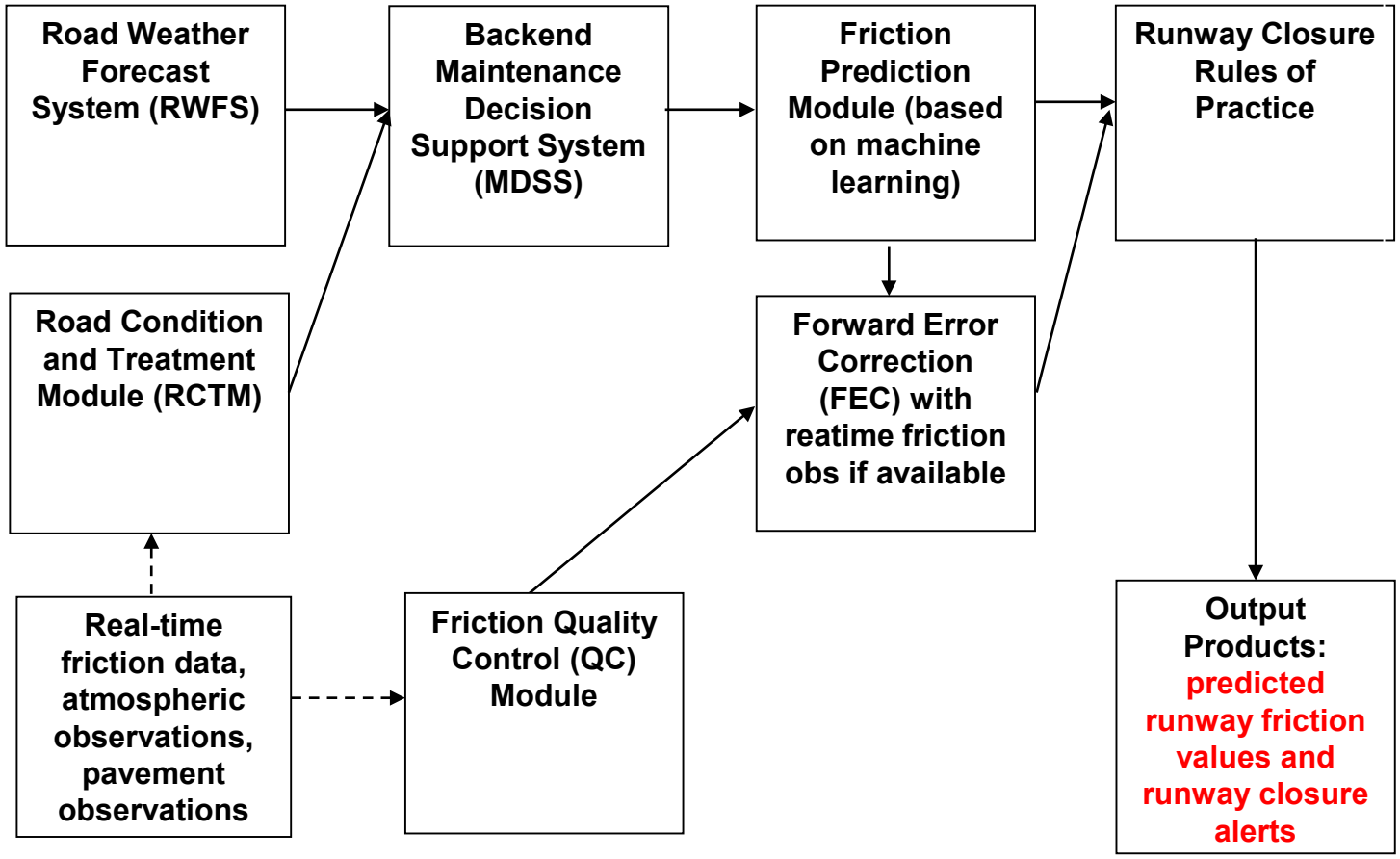
Runway Friction Closure Prediction System

- 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



RFCPS System Diagram



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**

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**)

Runway Friction Forecast and Closure Guidance

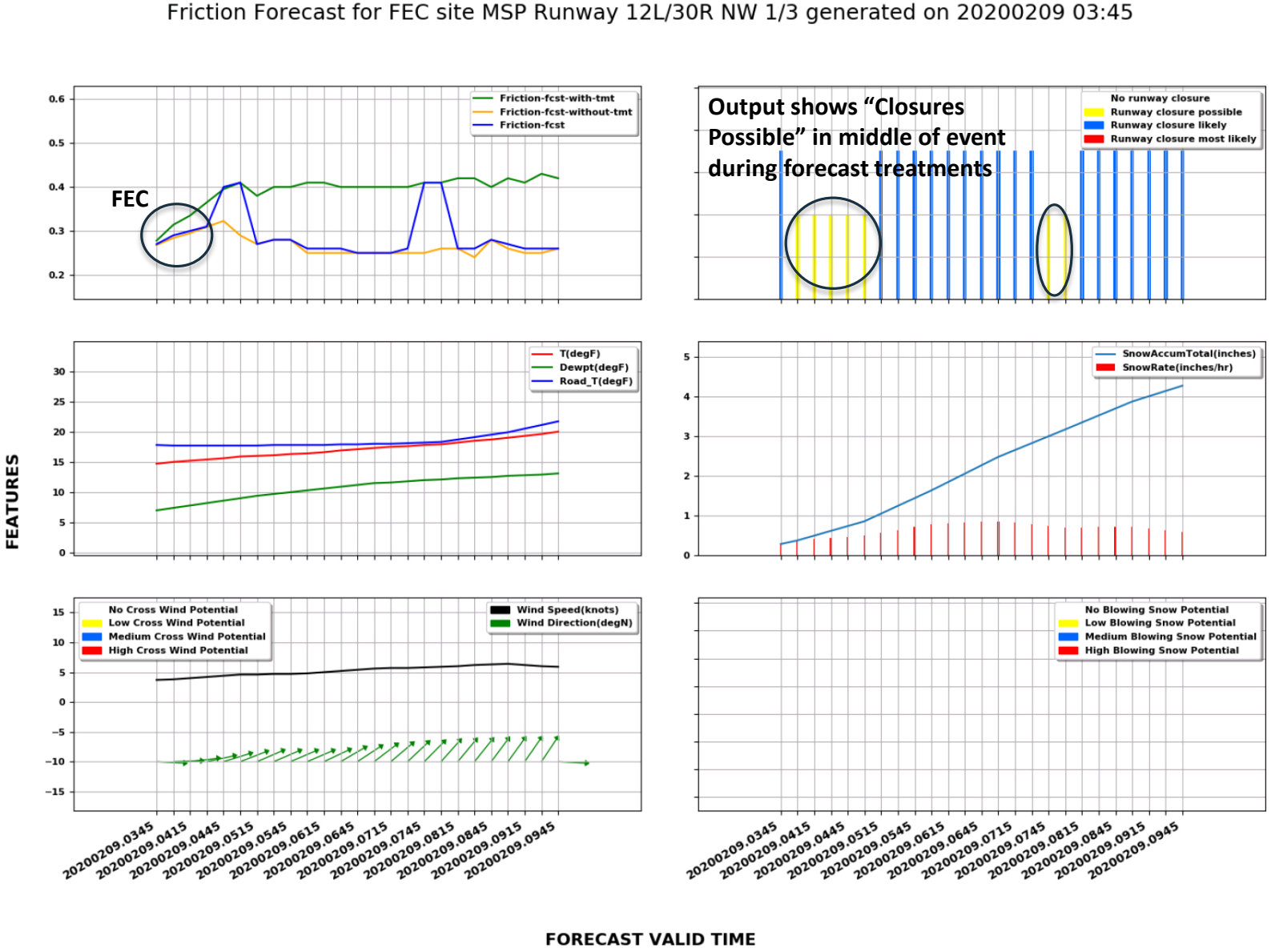
RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20200209 04:45

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

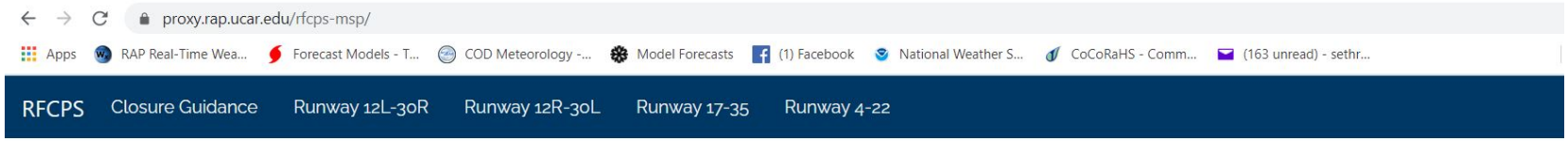
No runway closure
Runway closure possible
Runway closure likely
Runway closure most likely

Event getting started



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

RFCPS Weather Forecast 20201223 16z (10am CST)

December 23, 2020 case

Strong cold front with rain changing to snow.

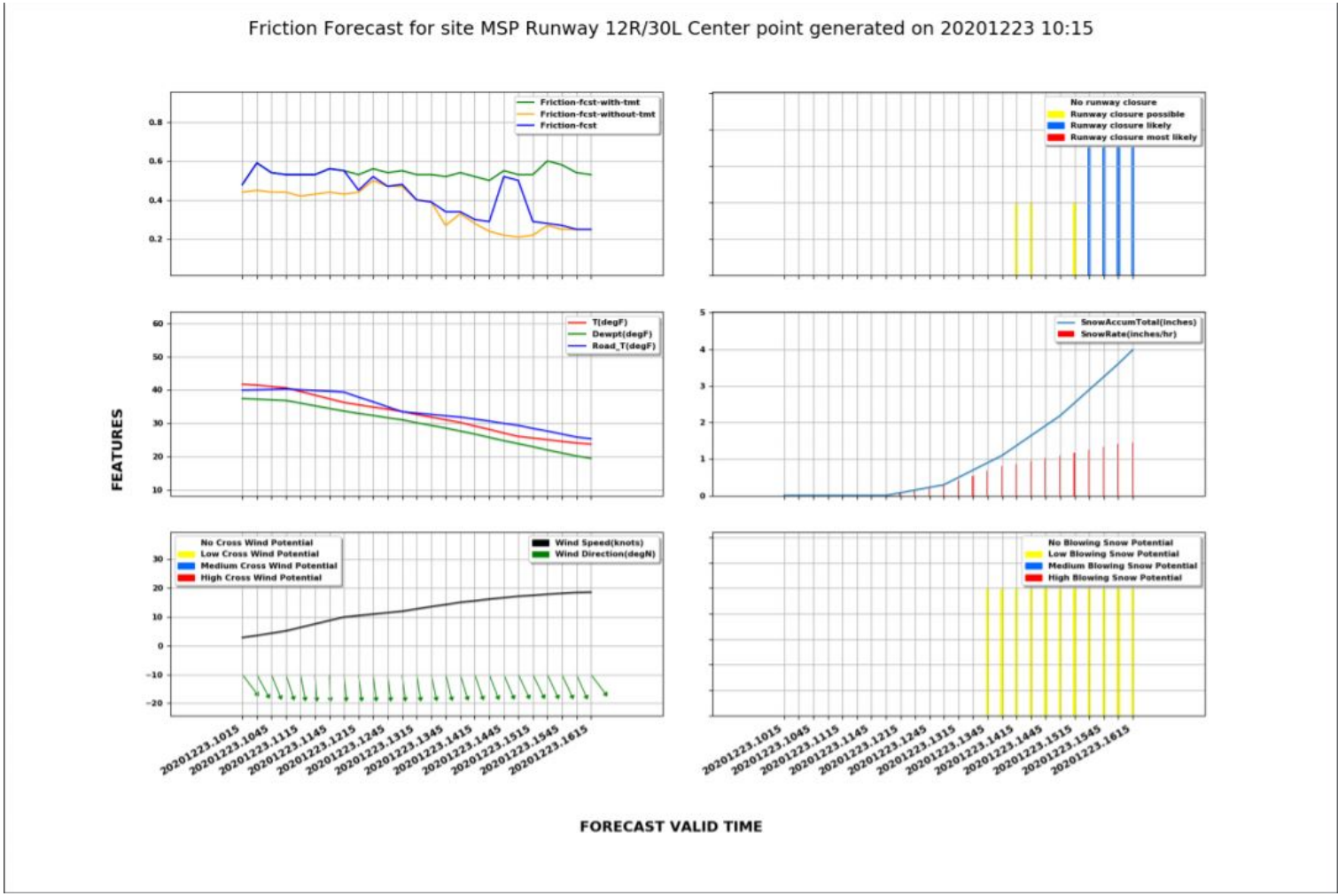
The temperature dropped from 47 degs to 7 degs

Precip start time: 20201223 17z (11am) (started as rain)

MSP measured 8.8” of snow

RFCPS weather forecast showed 8-10” at the airport

Forecast road-T a bit too warm initially



RFCPS Closure Matrix 20201223 16z (10am CST)

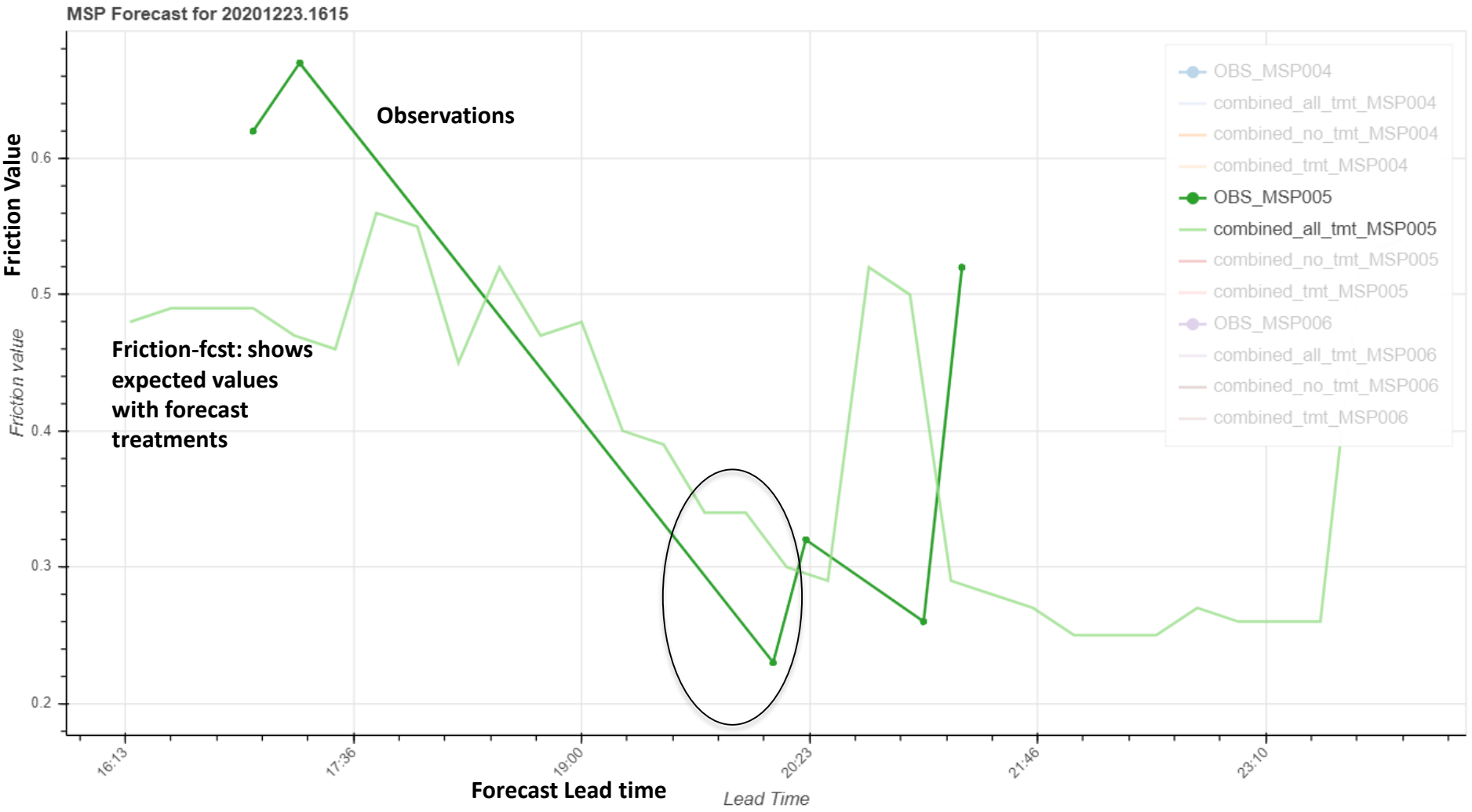
RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20201223 10:15

FORECAST LEAD TIME

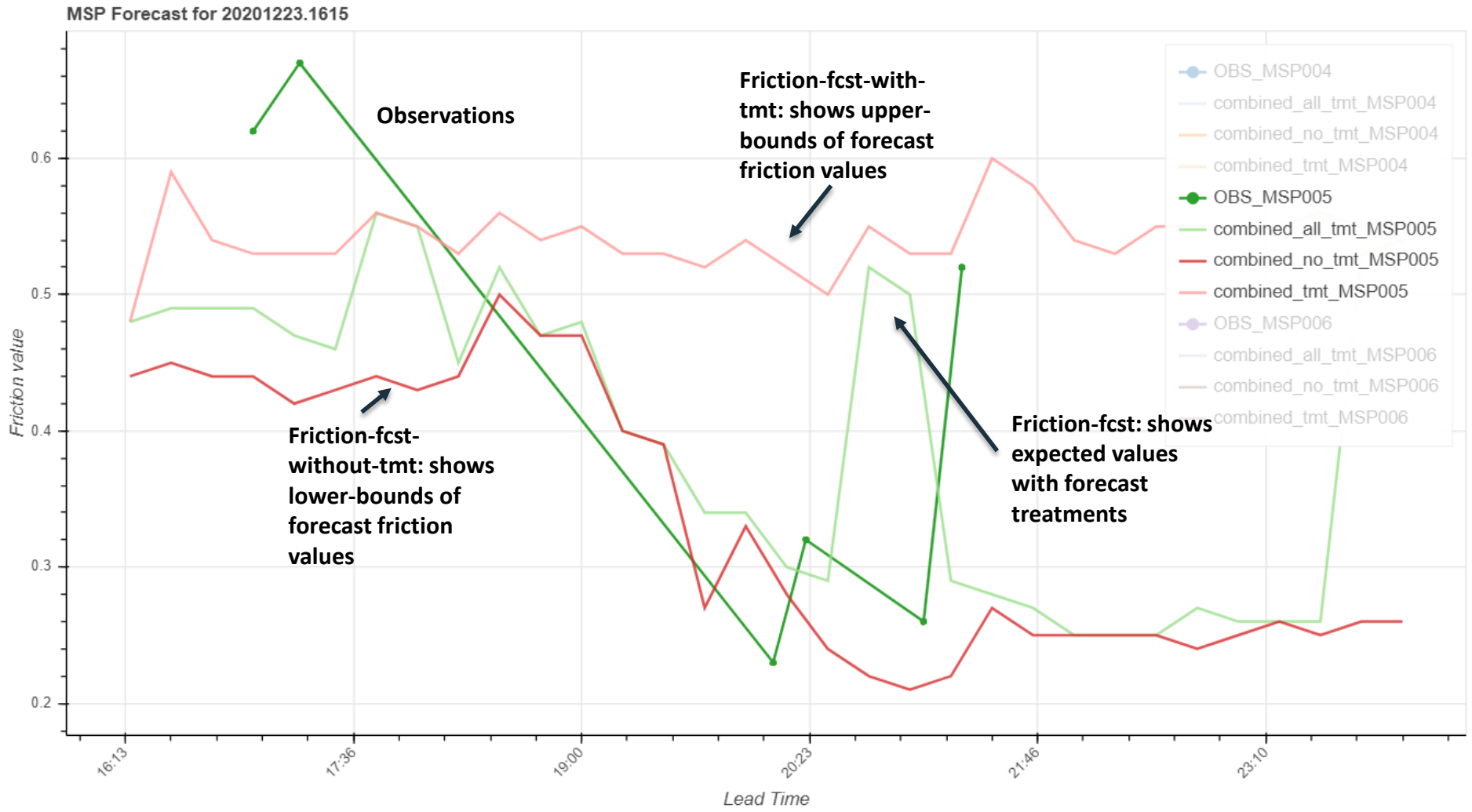
	1015	1030	1045	1100	1115	1130	1145	1200	1215	1230	1245	1300	1315	1330	1345	1400	1415	1430	1445	1500	1515	1530	1545	1600	1615
12L/30R NW 1/3	0.49	0.59	0.54	0.53	0.54	0.53	0.56	0.54	0.49	0.53	0.48	0.49	0.38	0.38	0.33	0.34	0.31	0.29	0.49	0.5	0.28	0.28	0.26	0.24	0.24
12L/30R Center point	0.49	0.49	0.54	0.54	0.53	0.53	0.53	0.53	0.46	0.53	0.48	0.49	0.38	0.38	0.53	0.55	0.31	0.29	0.25	0.26	0.28	0.28	0.26	0.24	0.23
12L/30R SE 1/3	0.5	0.49	0.54	0.54	0.53	0.53	0.53	0.54	0.46	0.53	0.48	0.4	0.38	0.33	0.34	0.33	0.29	0.29	0.47	0.5	0.26	0.28	0.27	0.25	0.24
12R/30L NW 1/3	0.47	0.59	0.54	0.53	0.54	0.53	0.56	0.55	0.45	0.52	0.48	0.49	0.4	0.39	0.34	0.34	0.3	0.32	0.58	0.58	0.29	0.28	0.26	0.25	0.25
12R/30L Center point	0.48	0.59	0.54	0.53	0.53	0.53	0.56	0.55	0.45	0.52	0.47	0.48	0.4	0.39	0.34	0.34	0.3	0.29	0.52	0.5	0.29	0.28	0.27	0.25	0.25
12R/30L SE 1/3	0.49	0.49	0.54	0.54	0.53	0.53	0.56	0.56	0.45	0.52	0.48	0.51	0.49	0.39	0.33	0.34	0.29	0.29	0.49	0.5	0.28	0.28	0.27	0.25	0.23
17/35 N 1/3	0.49	0.58	0.54	0.53	0.54	0.53	0.54	0.54	0.46	0.53	0.48	0.38	0.33	0.34	0.34	0.33	0.29	0.28	0.58	0.58	0.28	0.28	0.26	0.24	0.24
17/35 Center point	0.48	0.58	0.54	0.53	0.54	0.52	0.53	0.54	0.46	0.53	0.48	0.38	0.32	0.33	0.33	0.33	0.31	0.31	0.58	0.58	0.28	0.3	0.28	0.26	0.27
17/35 S 1/3	0.48	0.58	0.54	0.53	0.54	0.52	0.53	0.54	0.46	0.53	0.48	0.38	0.38	0.32	0.33	0.33	0.31	0.31	0.58	0.58	0.28	0.27	0.28	0.26	0.27
4/22 SW 1/3	0.49	0.58	0.53	0.54	0.54	0.53	0.56	0.56	0.47	0.52	0.47	0.48	0.4	0.39	0.34	0.34	0.3	0.3	0.59	0.59	0.29	0.29	0.27	0.26	0.25
4/22 Center point	0.48	0.58	0.53	0.53	0.54	0.52	0.54	0.54	0.46	0.53	0.48	0.38	0.38	0.33	0.33	0.34	0.29	0.29	0.5	0.5	0.28	0.28	0.26	0.25	0.24
4/22 NE 1/3	0.49	0.58	0.54	0.53	0.53	0.53	0.56	0.54	0.45	0.55	0.48	0.49	0.38	0.39	0.34	0.34	0.31	0.29	0.49	0.5	0.28	0.28	0.26	0.24	0.23

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

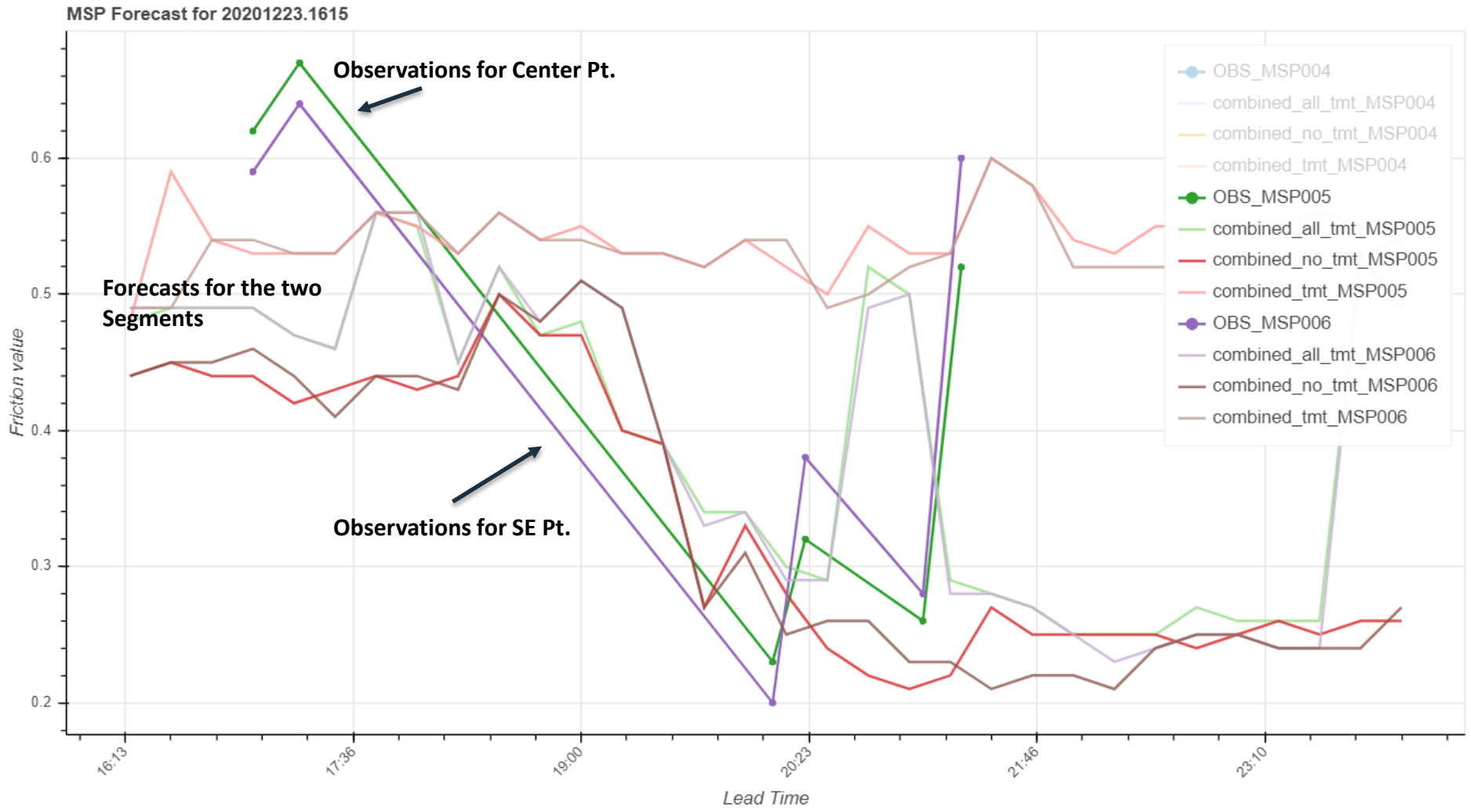
RFCPS Forecast 20201223 16z (10am CST)
Runway 12R/30L Center Segment



RFCPS Forecast 20201223 16z (10am CST)
Runway 12R/30L Center Segment



RFCPS Forecast 20201223 16z (10am CST) Runway 12R/30L Center and SE Segments



RFCPS Weather Forecast 20201229 19z (10am CST)

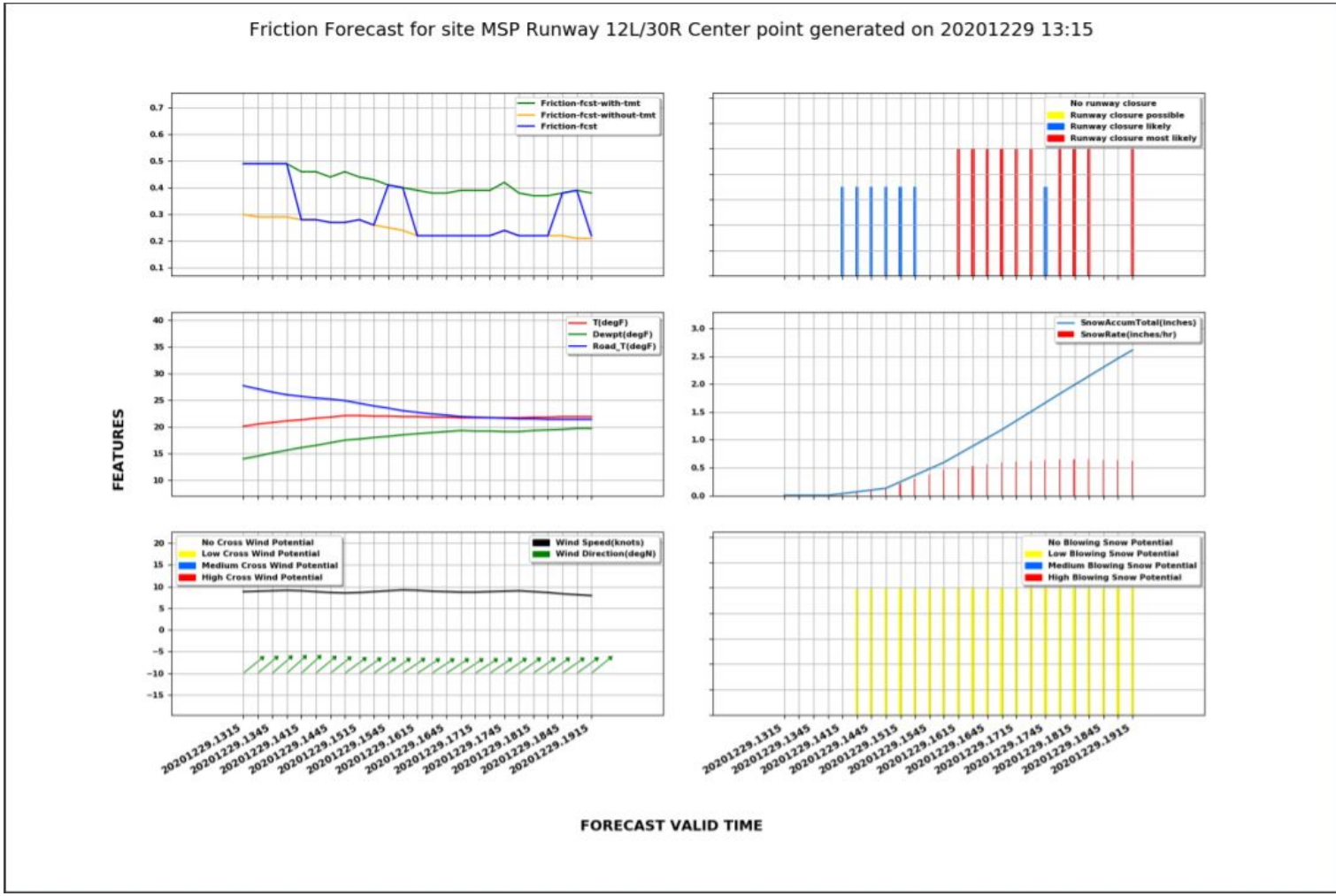
December 29, 2020 case

Moderately cold snow event (mid-winter)

Precip start time: 20201229 21z (3pm)

MSP measured 2.4” of snow

RFCPS weather forecast showed 3-4” at the airport



RFCPS Closure Matrix 20201229 19z (1pm CST)

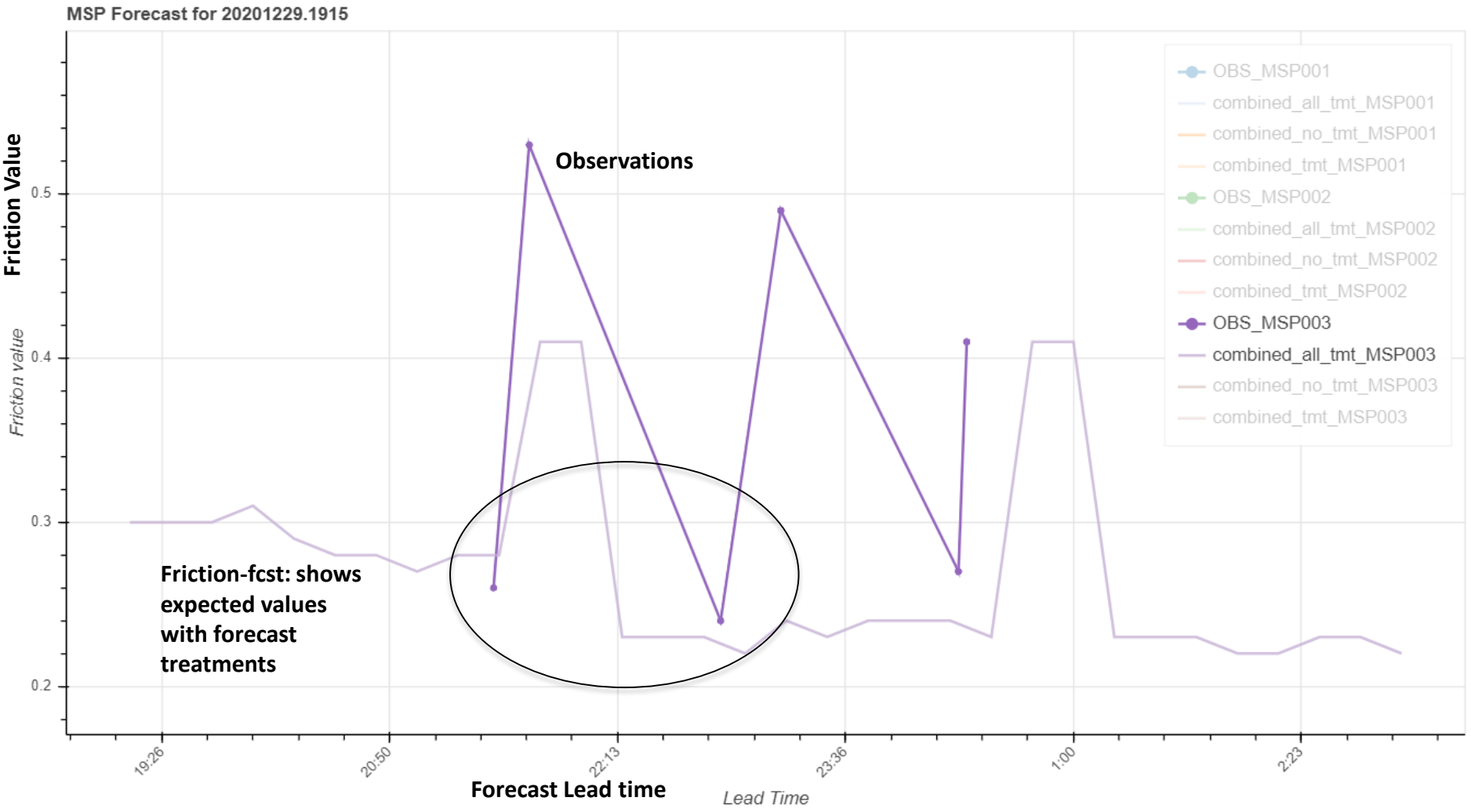
RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20201229 13:15

FORECAST LEAD TIME

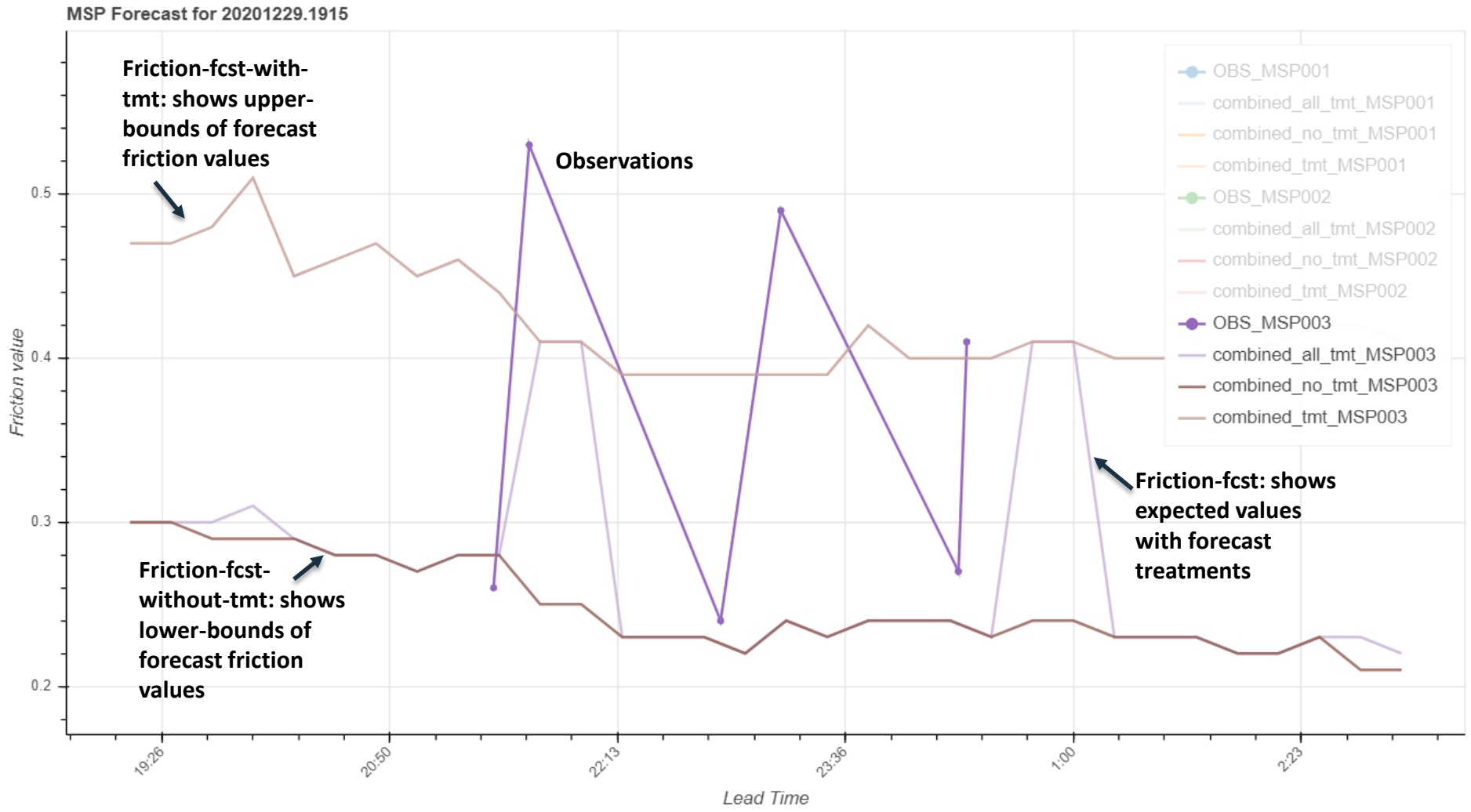
	1315	1330	1345	1400	1415	1430	1445	1500	1515	1530	1545	1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845	1900	1915
12L/30R NW 1/3	0.49	0.49	0.49	0.49	0.28	0.28	0.26	0.27	0.28	0.27	0.41	0.41	0.23	0.22	0.22	0.22	0.22	0.22	0.24	0.22	0.22	0.22	0.38	0.39	0.22
12L/30R Center point	0.49	0.49	0.49	0.49	0.28	0.28	0.27	0.27	0.28	0.26	0.41	0.4	0.22	0.22	0.22	0.22	0.22	0.22	0.24	0.22	0.22	0.22	0.38	0.39	0.22
12L/30R SE 1/3	0.47	0.47	0.48	0.51	0.29	0.28	0.28	0.27	0.28	0.28	0.41	0.41	0.23	0.23	0.23	0.22	0.24	0.23	0.24	0.24	0.24	0.23	0.41	0.41	0.23
12R/30L NW 1/3	0.47	0.48	0.47	0.49	0.27	0.28	0.28	0.29	0.28	0.28	0.43	0.41	0.23	0.23	0.23	0.22	0.23	0.23	0.24	0.24	0.23	0.23	0.4	0.41	0.23
12R/30L Center point	0.46	0.49	0.48	0.49	0.28	0.28	0.26	0.27	0.28	0.28	0.41	0.41	0.23	0.23	0.23	0.22	0.23	0.23	0.24	0.24	0.23	0.23	0.4	0.41	0.22
12R/30L SE 1/3	0.46	0.49	0.48	0.49	0.28	0.28	0.28	0.27	0.28	0.26	0.41	0.4	0.22	0.22	0.22	0.22	0.22	0.22	0.24	0.22	0.22	0.22	0.38	0.38	0.22
17/35 N 1/3	0.48	0.48	0.46	0.5	0.27	0.27	0.27	0.28	0.27	0.26	0.41	0.41	0.23	0.23	0.22	0.22	0.23	0.23	0.24	0.23	0.23	0.22	0.4	0.4	0.22
17/35 Center point	0.48	0.46	0.47	0.5	0.26	0.27	0.27	0.28	0.26	0.26	0.41	0.41	0.23	0.23	0.22	0.22	0.23	0.23	0.24	0.24	0.23	0.23	0.4	0.4	0.22
17/35 S 1/3	0.47	0.46	0.47	0.5	0.26	0.28	0.28	0.28	0.27	0.26	0.41	0.41	0.23	0.22	0.22	0.22	0.23	0.23	0.24	0.24	0.23	0.23	0.4	0.4	0.22
4/22 SW 1/3	0.47	0.47	0.46	0.5	0.29	0.29	0.28	0.28	0.28	0.28	0.41	0.41	0.23	0.23	0.22	0.22	0.22	0.22	0.24	0.23	0.22	0.22	0.38	0.38	0.22
4/22 Center point	0.46	0.46	0.47	0.51	0.28	0.28	0.28	0.28	0.27	0.28	0.43	0.42	0.24	0.24	0.23	0.23	0.24	0.23	0.24	0.24	0.24	0.23	0.4	0.41	0.23
4/22 NE 1/3	0.46	0.48	0.47	0.49	0.28	0.28	0.26	0.27	0.28	0.26	0.41	0.4	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.22	0.22	0.22	0.38	0.39	0.22

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

RFCPS Forecast 20201229 19z (1pm CST)
Runway 12L/30R SE Segment



RFCPS Forecast 20201229 19z (1pm CST)
Runway 12L/30R SE Segment



Bulk Stats for 20201229 case

80% GBT / 20% Cubist

ERROR STATISTICS :
HIT PERCENTAGE : 53.5
MISS PERCENTAGE : 46.5
MAE : 0.156
RMSE : 0.188

RFCPS Weather Forecast 20210123 21z (3pm CST)

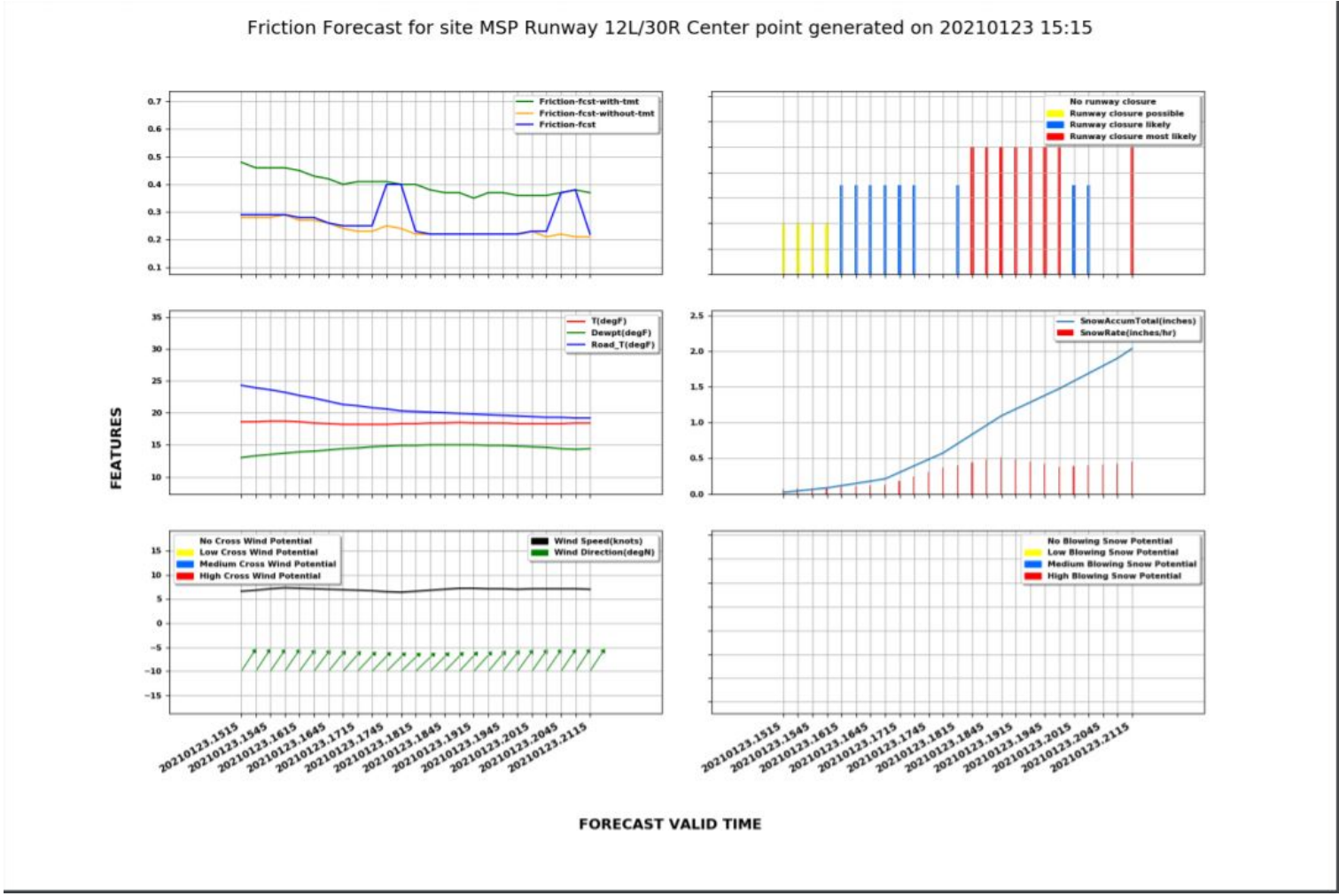
January 23, 2021 case

Moderately cold snow event (mid-winter)

Precip start time: 20210123 22z (4pm)

MSP measured 4.4” of snow

RFCPS weather forecast showed 4-5” at the airport



RFCPS Closure Matrix 20210123 21z (3pm CST)

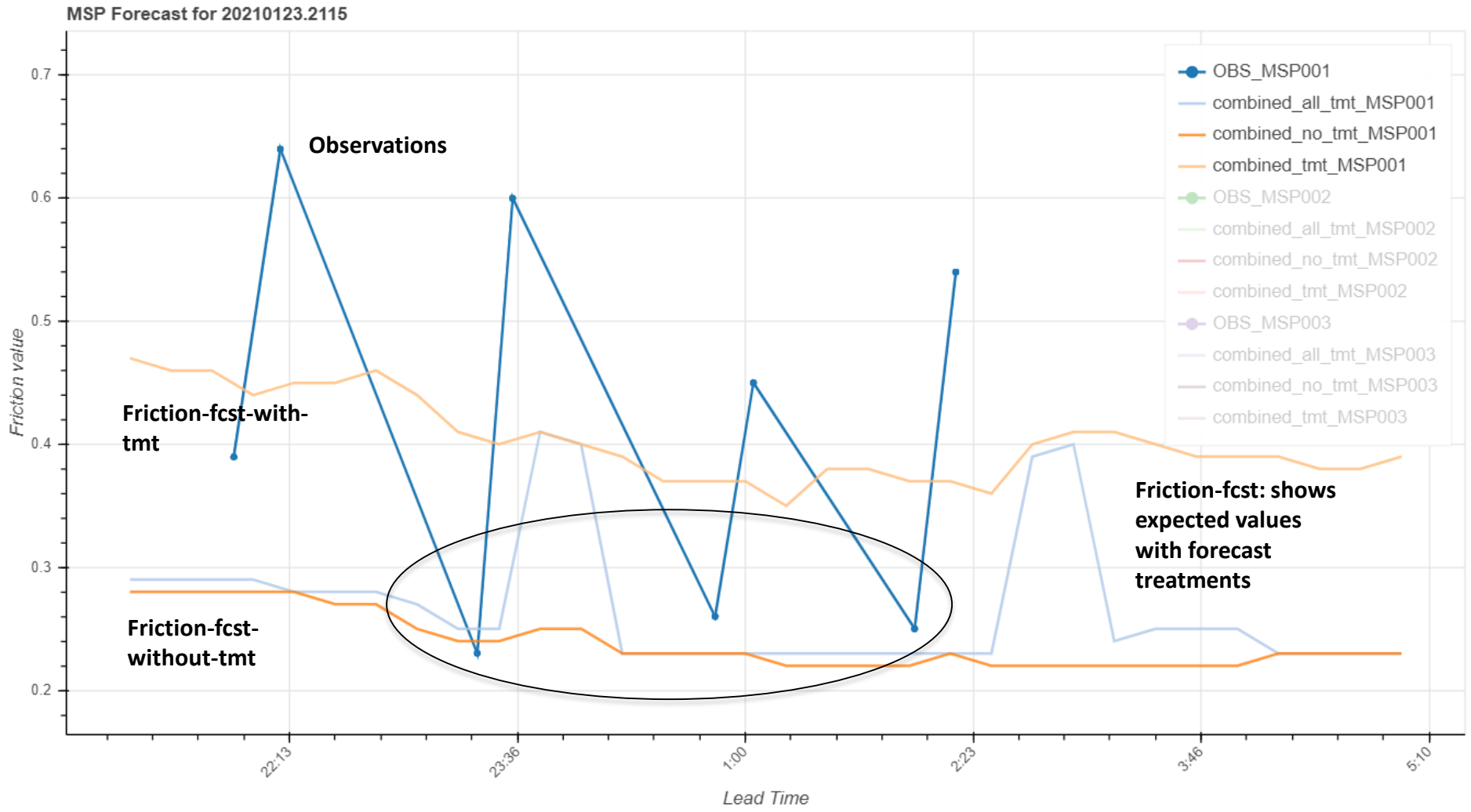
RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20210123 15:15

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	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.27	0.25	0.25	0.41	0.4	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.39	0.4	0.24
12L/30R Center point	0.29	0.29	0.29	0.29	0.28	0.28	0.26	0.25	0.25	0.25	0.4	0.4	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.37	0.38	0.22
12L/30R SE 1/3	0.28	0.28	0.28	0.28	0.28	0.26	0.26	0.26	0.25	0.25	0.4	0.4	0.23	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.41	0.43	0.24
12R/30L NW 1/3	0.28	0.28	0.29	0.28	0.28	0.28	0.28	0.27	0.27	0.27	0.43	0.41	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.26	0.44	0.44	0.25
12R/30L Center point	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.27	0.43	0.42	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.43	0.41	0.24
12R/30L SE 1/3	0.29	0.29	0.29	0.29	0.27	0.28	0.27	0.26	0.25	0.25	0.41	0.4	0.23	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.25	0.41	0.41	0.24
17/35 N 1/3	0.28	0.27	0.27	0.28	0.28	0.28	0.26	0.25	0.25	0.25	0.4	0.37	0.23	0.23	0.23	0.24	0.25	0.25	0.25	0.25	0.25	0.26	0.43	0.44	0.25
17/35 Center point	0.28	0.28	0.28	0.28	0.28	0.27	0.26	0.25	0.25	0.25	0.41	0.37	0.23	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.43	0.44	0.26
17/35 S 1/3	0.28	0.28	0.28	0.28	0.28	0.27	0.26	0.25	0.25	0.25	0.41	0.37	0.23	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.26	0.26	0.43	0.44	0.26
4/22 SW 1/3	0.29	0.28	0.29	0.28	0.28	0.28	0.28	0.26	0.25	0.25	0.41	0.38	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.25	0.25	0.25	0.42	0.43	0.24
4/22 Center point	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.27	0.25	0.25	0.41	0.38	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.39	0.39	0.22
4/22 NE 1/3	0.29	0.29	0.29	0.29	0.27	0.28	0.27	0.26	0.25	0.25	0.41	0.4	0.23	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.24	0.25	0.41	0.41	0.24

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

RFCPS Forecast 20210123 21z (3pm CST)
Runway 12L/30R NW Segment



Bulk Stats for 20210123 case

80% GBT / 20% Cubist

ERROR STATISTICS :
HIT PERCENTAGE : 53.7
MISS PERCENTAGE : 46.3
MAE : 0.136
RMSE : 0.173

RFCPS Weather Forecast 2021020 18z (12pm CST)

October 20, 2020 case

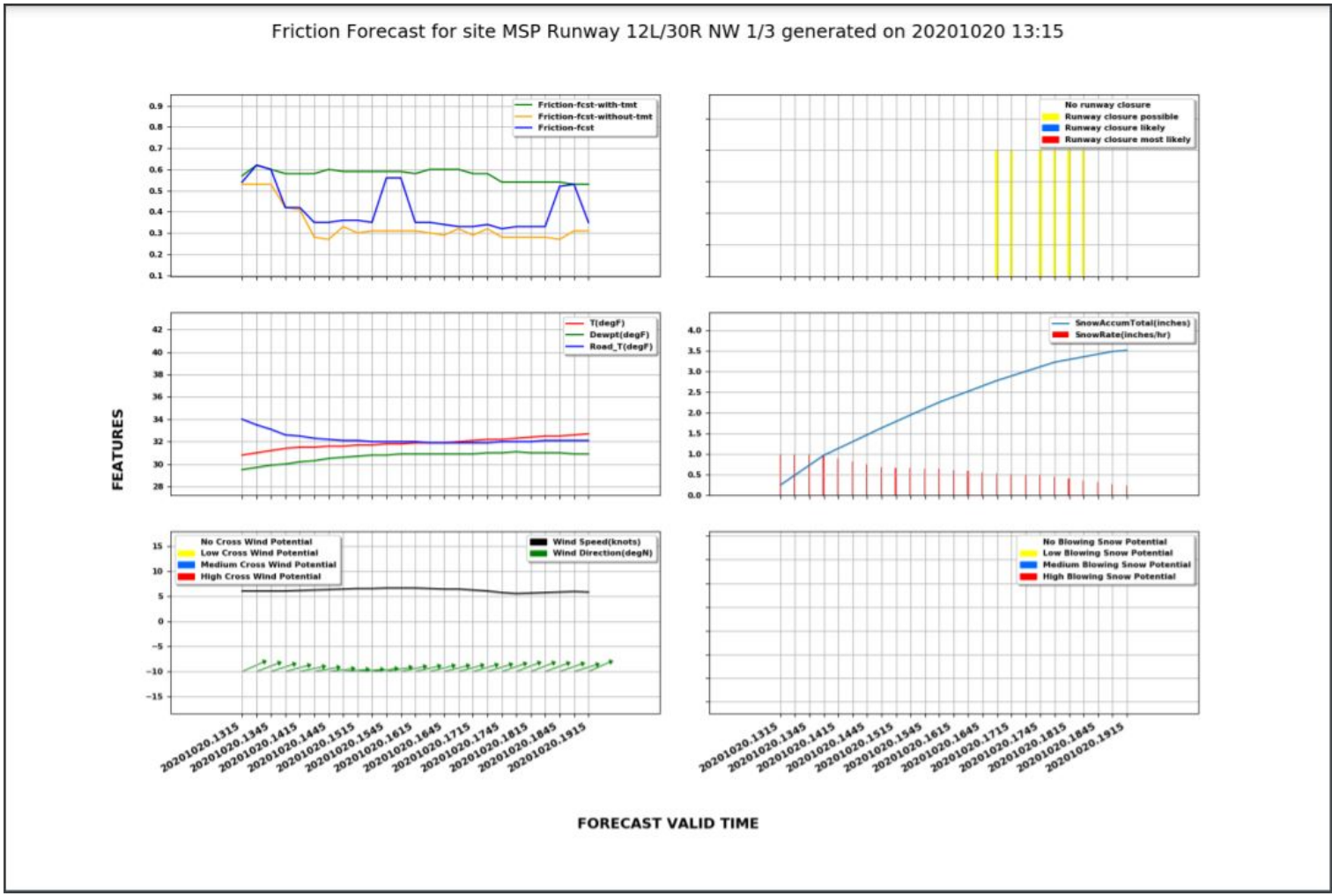
Fall storm that started warm (rain to snow)

Precip start time: 20201020 18z (12pm) (started as rain)

MSP measured 7.9” of snow

RFCPS weather forecast showed 3-5” at the airport

Forecast road-T too warm initially



RFCPS Closure Matrix 20201020 18z (12pm CST)

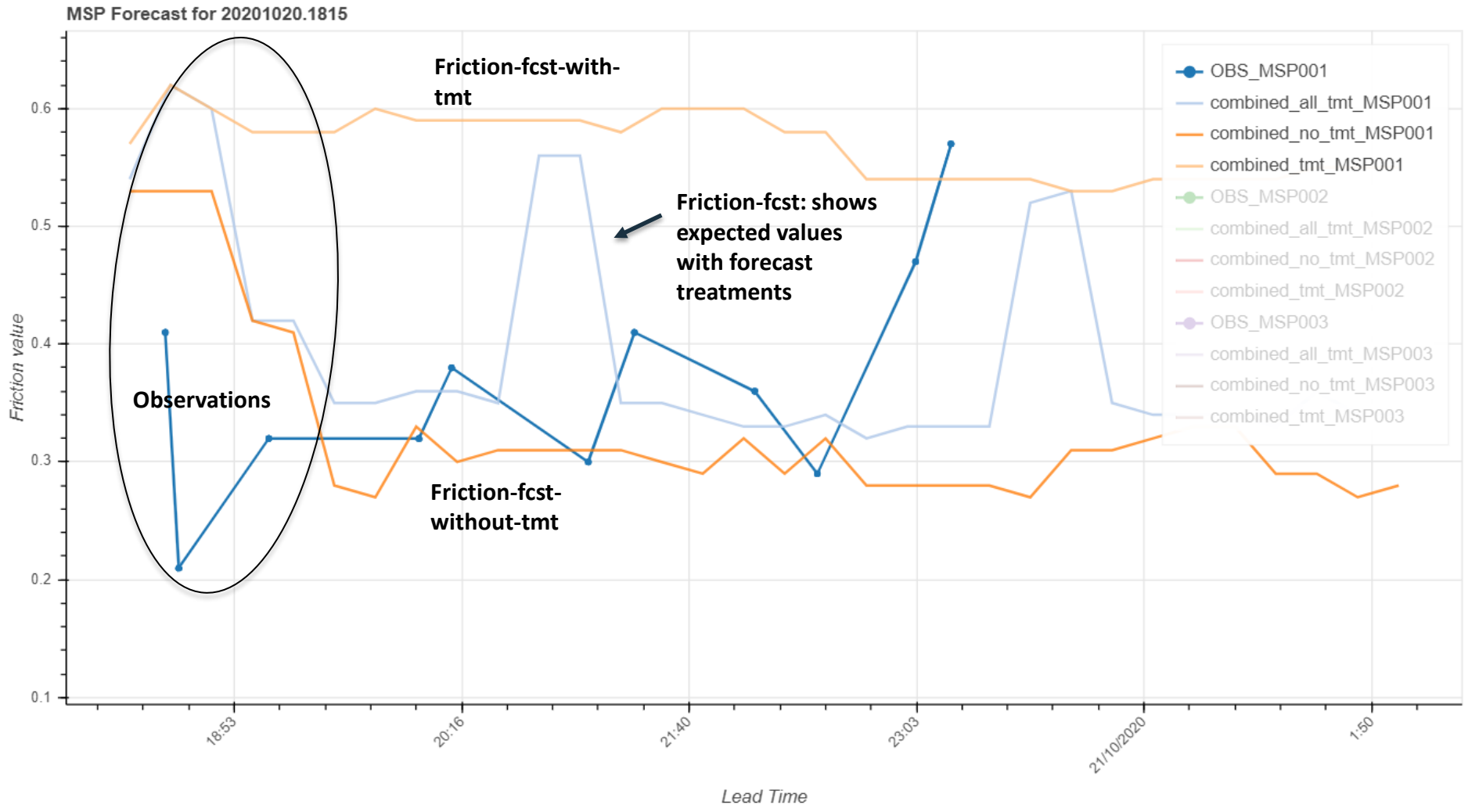
RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20201020 13:15

FORECAST LEAD TIME

	1315	1330	1345	1400	1415	1430	1445	1500	1515	1530	1545	1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845	1900	1915
12L/30R NW 1/3	0.54	0.62	0.6	0.42	0.42	0.35	0.35	0.36	0.36	0.35	0.56	0.56	0.35	0.35	0.34	0.33	0.33	0.34	0.32	0.33	0.33	0.33	0.52	0.53	0.35
12L/30R Center point	0.62	0.6	0.42	0.37	0.36	0.36	0.36	0.36	0.35	0.34	0.55	0.54	0.34	0.35	0.34	0.33	0.33	0.35	0.32	0.33	0.33	0.33	0.52	0.53	0.35
12L/30R SE 1/3	0.33	0.35	0.58	0.58	0.36	0.37	0.36	0.36	0.36	0.35	0.35	0.34	0.34	0.34	0.55	0.55	0.33	0.35	0.35	0.35	0.35	0.35	0.34	0.33	0.35
12R/30L NW 1/3	0.33	0.33	0.37	0.37	0.37	0.37	0.57	0.57	0.37	0.34	0.34	0.34	0.36	0.35	0.35	0.34	0.34	0.35	0.53	0.53	0.34	0.34	0.33	0.34	0.35
12R/30L Center point	0.37	0.37	0.37	0.38	0.37	0.37	0.57	0.57	0.37	0.35	0.35	0.35	0.35	0.35	0.36	0.34	0.34	0.35	0.53	0.53	0.33	0.34	0.33	0.34	0.35
12R/30L SE 1/3	0.62	0.6	0.42	0.37	0.37	0.37	0.36	0.36	0.36	0.34	0.55	0.55	0.34	0.34	0.35	0.34	0.34	0.34	0.32	0.32	0.33	0.33	0.52	0.53	0.35
17/35 N 1/3	0.37	0.37	0.37	0.37	0.37	0.36	0.58	0.57	0.36	0.35	0.35	0.33	0.34	0.34	0.34	0.34	0.34	0.35	0.57	0.56	0.35	0.35	0.34	0.34	0.35
17/35 Center point	0.6	0.44	0.43	0.43	0.42	0.36	0.57	0.58	0.36	0.35	0.34	0.34	0.33	0.33	0.35	0.34	0.34	0.35	0.57	0.56	0.35	0.35	0.34	0.33	0.35
17/35 S 1/3	0.42	0.37	0.37	0.37	0.37	0.37	0.57	0.58	0.36	0.35	0.35	0.35	0.34	0.34	0.35	0.35	0.35	0.35	0.57	0.56	0.35	0.35	0.34	0.35	0.35
4/22 SW 1/3	0.38	0.38	0.38	0.37	0.37	0.37	0.57	0.57	0.37	0.35	0.35	0.35	0.35	0.35	0.35	0.34	0.34	0.35	0.56	0.56	0.35	0.35	0.34	0.34	0.35
4/22 Center point	0.37	0.37	0.37	0.37	0.36	0.36	0.57	0.57	0.36	0.35	0.35	0.34	0.34	0.36	0.35	0.35	0.35	0.35	0.53	0.53	0.33	0.34	0.33	0.34	0.35
4/22 NE 1/3	0.62	0.6	0.42	0.37	0.37	0.36	0.36	0.36	0.35	0.34	0.54	0.54	0.35	0.35	0.35	0.33	0.34	0.35	0.32	0.32	0.32	0.33	0.52	0.53	0.35

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

RFCPS Forecast 20201020 18z (12pm CST)
Runway 12L/30R NW Segment



Bulk Stats for 20201020 case

80% GBT / 20% Cubist

ERROR STATISTICS :
HIT PERCENTAGE : 56.6
MISS PERCENTAGE : 43.4
MAE : 0.136
RMSE : 0.172

RFCPS Weather Forecast 2020110 20z (2pm CST)

November 10, 2020 case

Fall storm: very warm to cold (strong cold-front on the 10th)

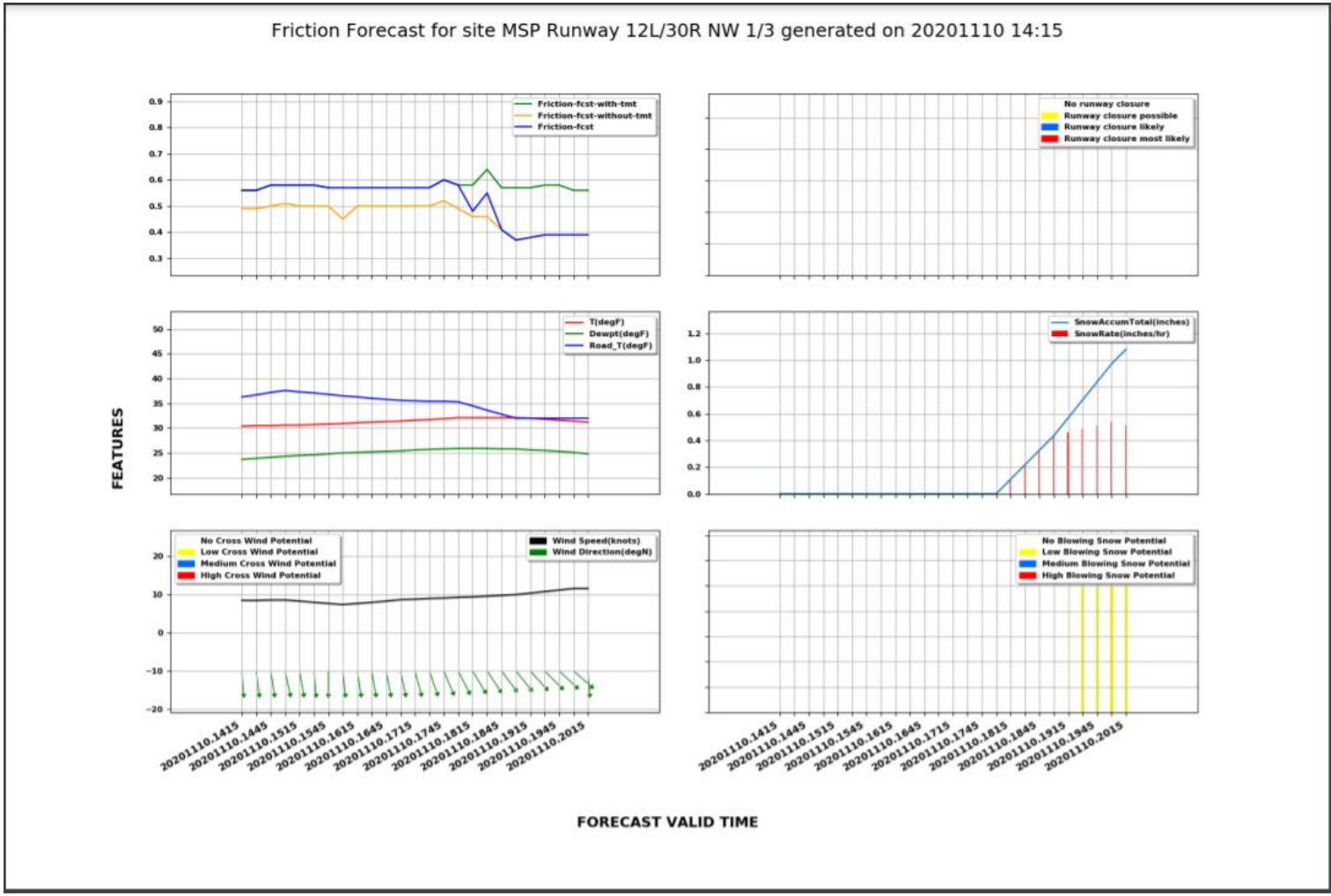
Precip start time: 20201110 18z (12pm) (started as rain)

MSP measured 5.5” of snow

RFCPS weather forecast showed 1-3” at the airport

***Fixed Forecast precip-type during this event (weather forecast had too much rain vs snow)**

Forecast road-T too warm



RFCPS Closure Matrix 20201110 20z (2pm CST)

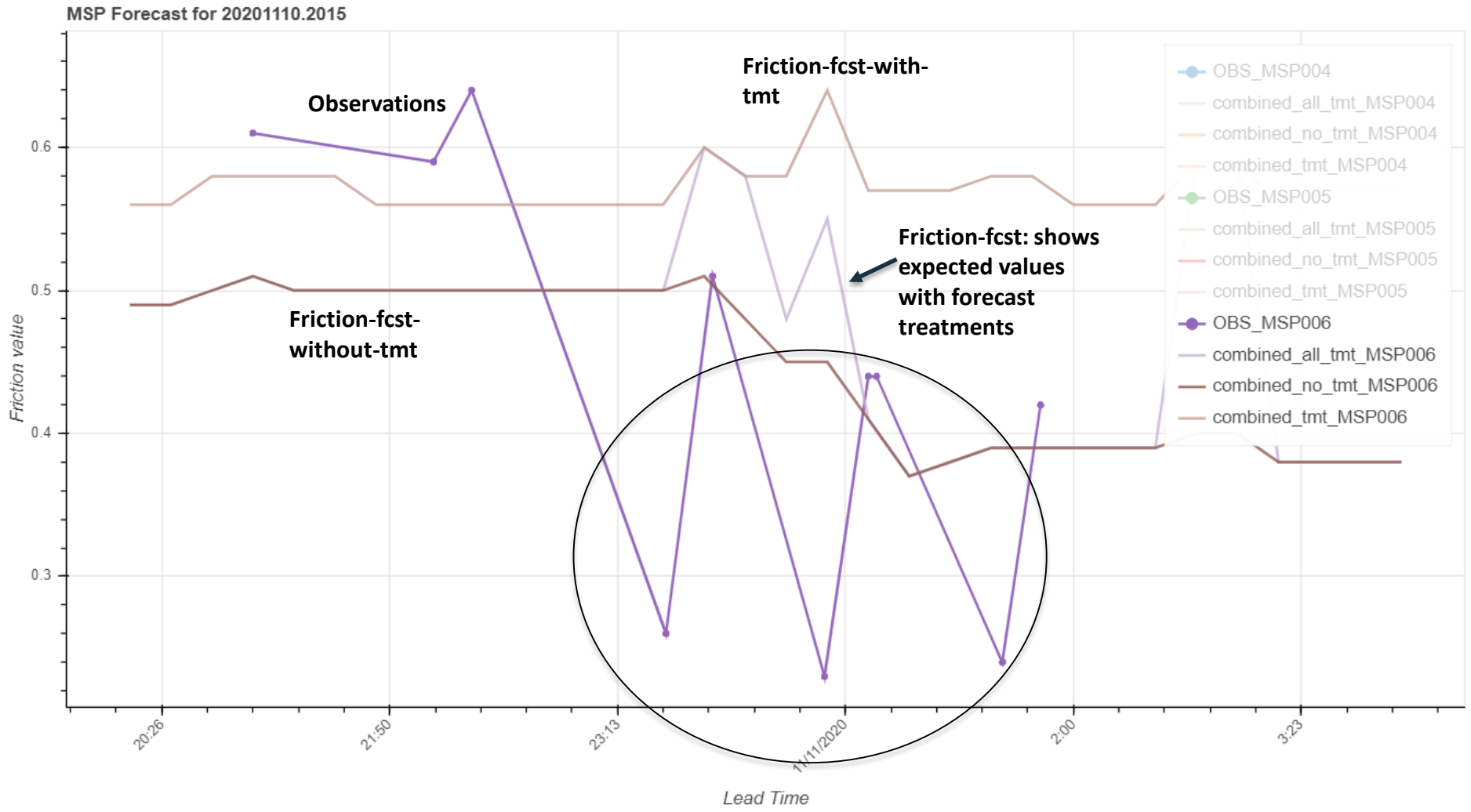
RUNWAY CLOSURE GUIDANCE MATRIX GENERATED ON 20201110 14:15

FORECAST LEAD TIME

	1415	1430	1445	1500	1515	1530	1545	1600	1615	1630	1645	1700	1715	1730	1745	1800	1815	1830	1845	1900	1915	1930	1945	2000	2015
12L/30R NW 1/3	0.56	0.56	0.58	0.58	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.6	0.58	0.48	0.55	0.41	0.37	0.38	0.39	0.39	0.39	0.39
12L/30R Center point	0.56	0.58	0.58	0.58	0.58	0.56	0.56	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.58	0.58	0.48	0.55	0.41	0.37	0.38	0.39	0.39	0.39	0.39
12L/30R SE 1/3	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.57	0.57	0.57	0.57	0.58	0.61	0.5	0.57	0.45	0.44	0.46	0.46	0.46	0.46	0.46
12R/30L NW 1/3	0.58	0.58	0.58	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.58	0.59	0.5	0.56	0.45	0.44	0.46	0.46	0.46	0.46	0.46
12R/30L Center point	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.57	0.57	0.57	0.57	0.57	0.58	0.59	0.5	0.56	0.45	0.44	0.46	0.46	0.46	0.46	0.46
12R/30L SE 1/3	0.56	0.56	0.58	0.58	0.58	0.58	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.6	0.58	0.48	0.55	0.41	0.37	0.38	0.39	0.39	0.39	0.39
17/35 N 1/3	0.56	0.56	0.56	0.58	0.56	0.55	0.56	0.56	0.55	0.55	0.55	0.57	0.57	0.55	0.58	0.59	0.5	0.58	0.45	0.44	0.46	0.46	0.46	0.46	0.46
17/35 Center point	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.57	0.57	0.57	0.57	0.58	0.59	0.5	0.56	0.45	0.44	0.46	0.46	0.46	0.46	0.46
17/35 S 1/3	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.57	0.57	0.57	0.57	0.58	0.59	0.5	0.56	0.45	0.44	0.46	0.46	0.46	0.46	0.46
4/22 SW 1/3	0.58	0.56	0.56	0.56	0.56	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.58	0.59	0.5	0.56	0.45	0.44	0.46	0.46	0.46	0.46	0.46
4/22 Center point	0.58	0.58	0.58	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.59	0.6	0.51	0.58	0.46	0.45	0.47	0.47	0.47	0.47	0.47
4/22 NE 1/3	0.56	0.56	0.58	0.58	0.58	0.58	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.6	0.58	0.48	0.55	0.41	0.37	0.38	0.39	0.39	0.39	0.39

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

RFCPS Forecast 20201110 20z (2pm CST)
Runway 12R/30L SE Segment



Improving RFCPS (Lessons Learned)

- The ML Friction Forecasts are highly dependent on having a good road-T forecast along with a good precip-type and snowfall forecast
  - Fixed issue with the precip-type forecast during the November 10th event (too much rain vs snow)
  - Fixe issue with road-T forward-error-correction (FEC) for several runway segments that were not getting observations
- The road-T forecast can be too warm during the fall and spring
  - This causes the forecast friction values to be too warm
  - Typically not as much of an issue during the heart of winter when it's cold

Improving RFCPS (Lessons Learned)

- When the road-T forecast, precip-type and the snowfall forecast are close to reality, the Friction Forecast is quite good at predicting the low values (before treatment)
- Hard to match forecast treatments with actual treatments
  - The up/down in forecast friction values may be off because of forecast treatment doesn't line up with actual treatment
  - Future work is proposed to address this by taking into account actual treatments (Phase III?)
- The Friction-fcst-with-tmt (shows upper-bounds of forecast friction values) is typically a little too low compared to observations
  - But this typically is not an issue since the values are usually all above 0.40 (so no issues on the runways)

Questions