Icy Road Forecast and Alert (IcyRoad): Validation and Refinement Using MDT RWIS data

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Montana Department of Transportation

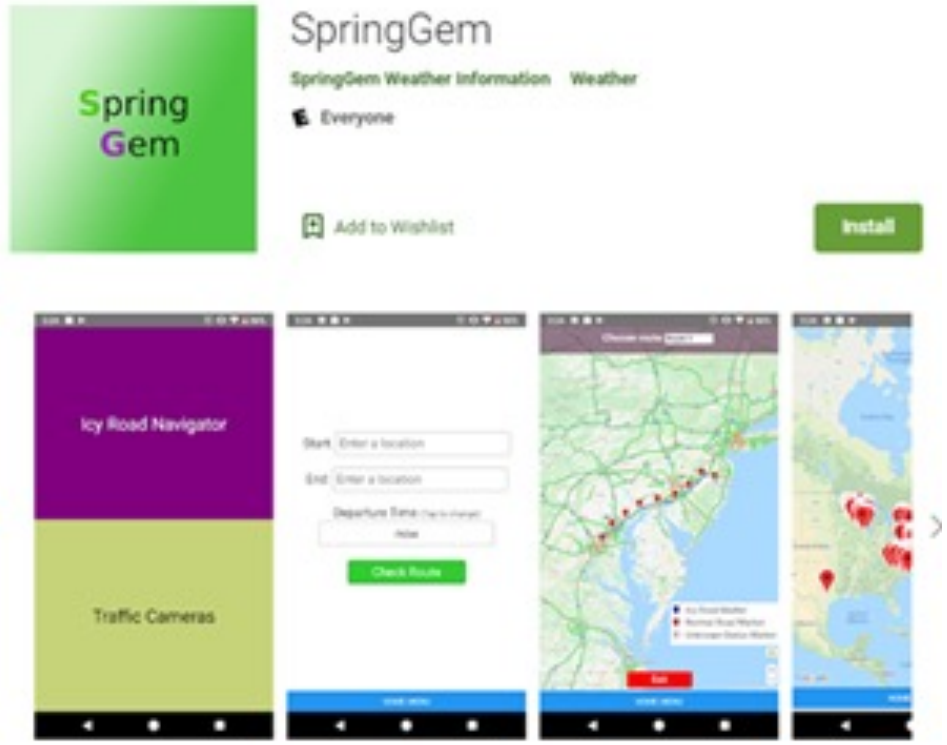
Project Budget and Duration

- July 1, 2020 – September 31, 2021 (research)

- October, 2021 – March, 31, 2022 (report)

Budget to SpringGem: $25,900

Pre-MDT IcyRoad



- Funded by Private invest and NSF SBIR Phase 1
  significant progress on IcyRoad
- Web app: https://sg-weather.com/weather/
- Mobile app:

Google Play: Download
https://play.google.com/store/apps/details?id=com.springgem

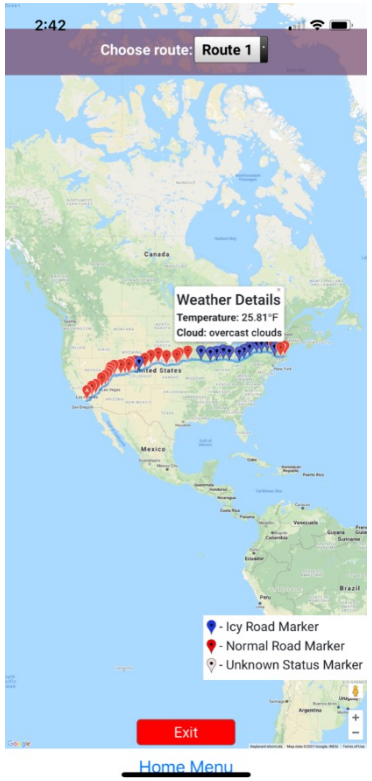
Apple App Store: Search “SpringGem”

Or scan the QR code From company website

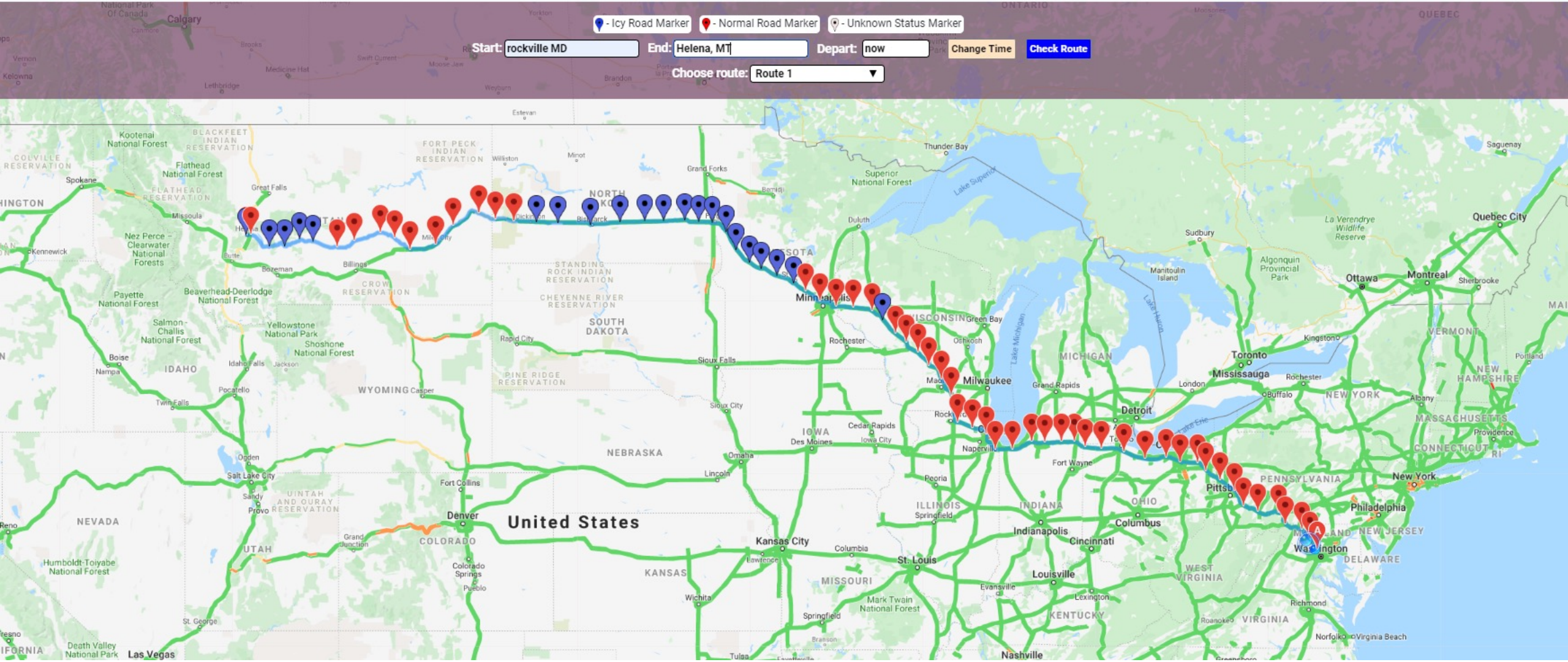
Current Status of IcyRoad

- Revised IcyRoad forecasting algorithm – IcyRoad2->IcyRoad3->IcyRoad3v2 ->IcyRoad3.4
- Developed IcyBridge and IcyCity, beside IcyRoad
- Published new web-app, and mobile app

ICYROADALERT
SAFETY FIRST

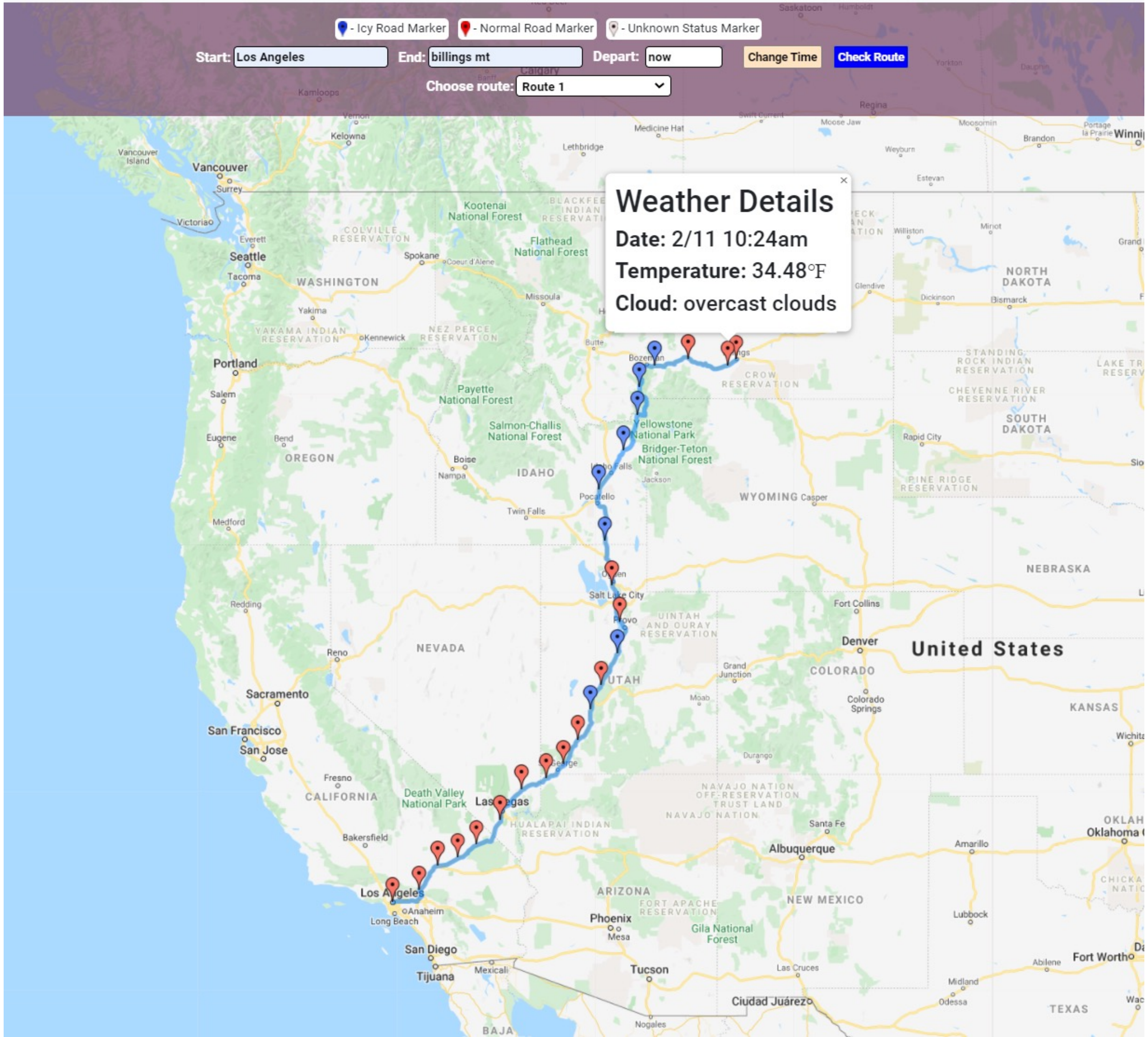


Speedy IcyRoad Forecast Across US

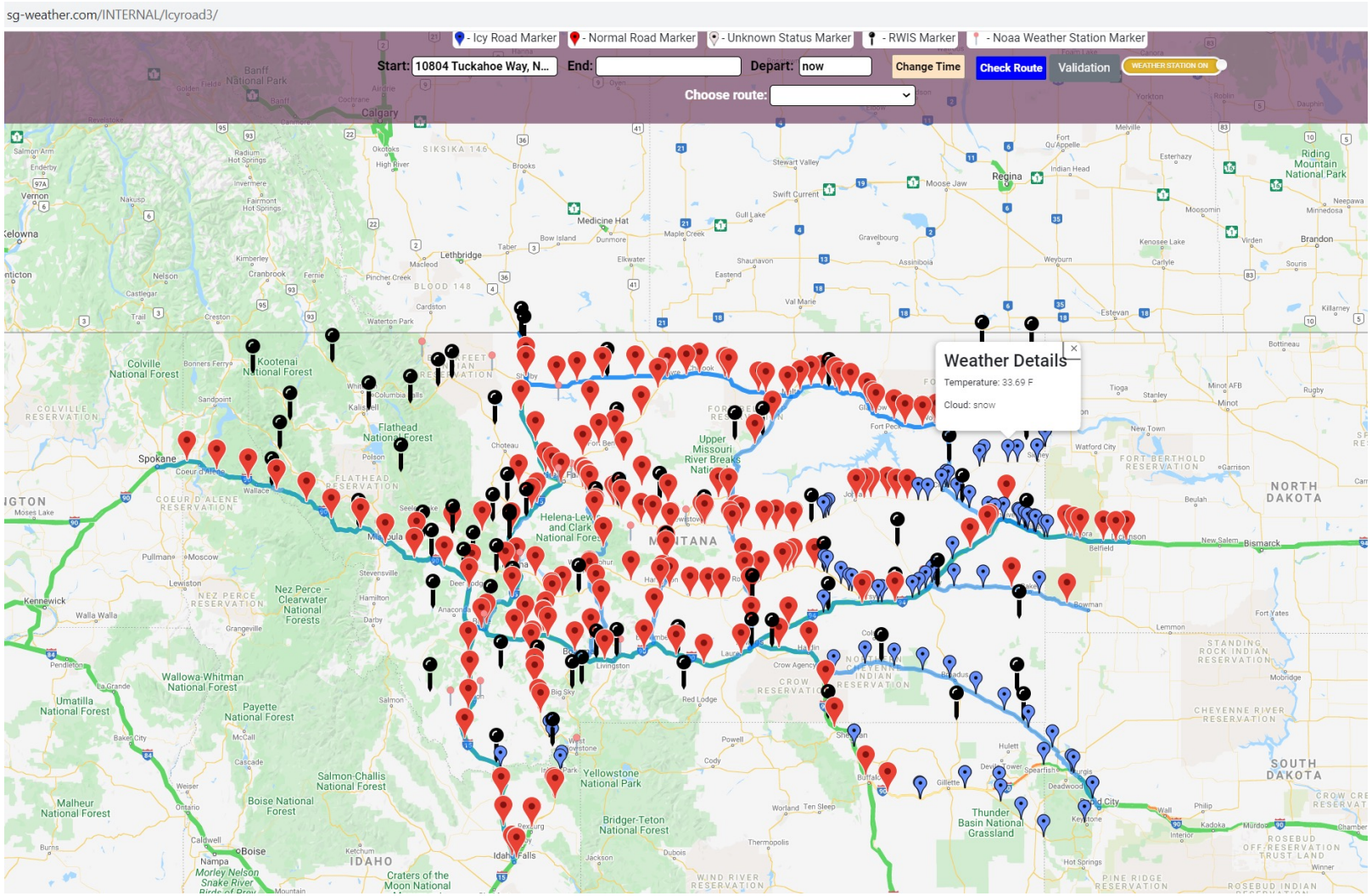


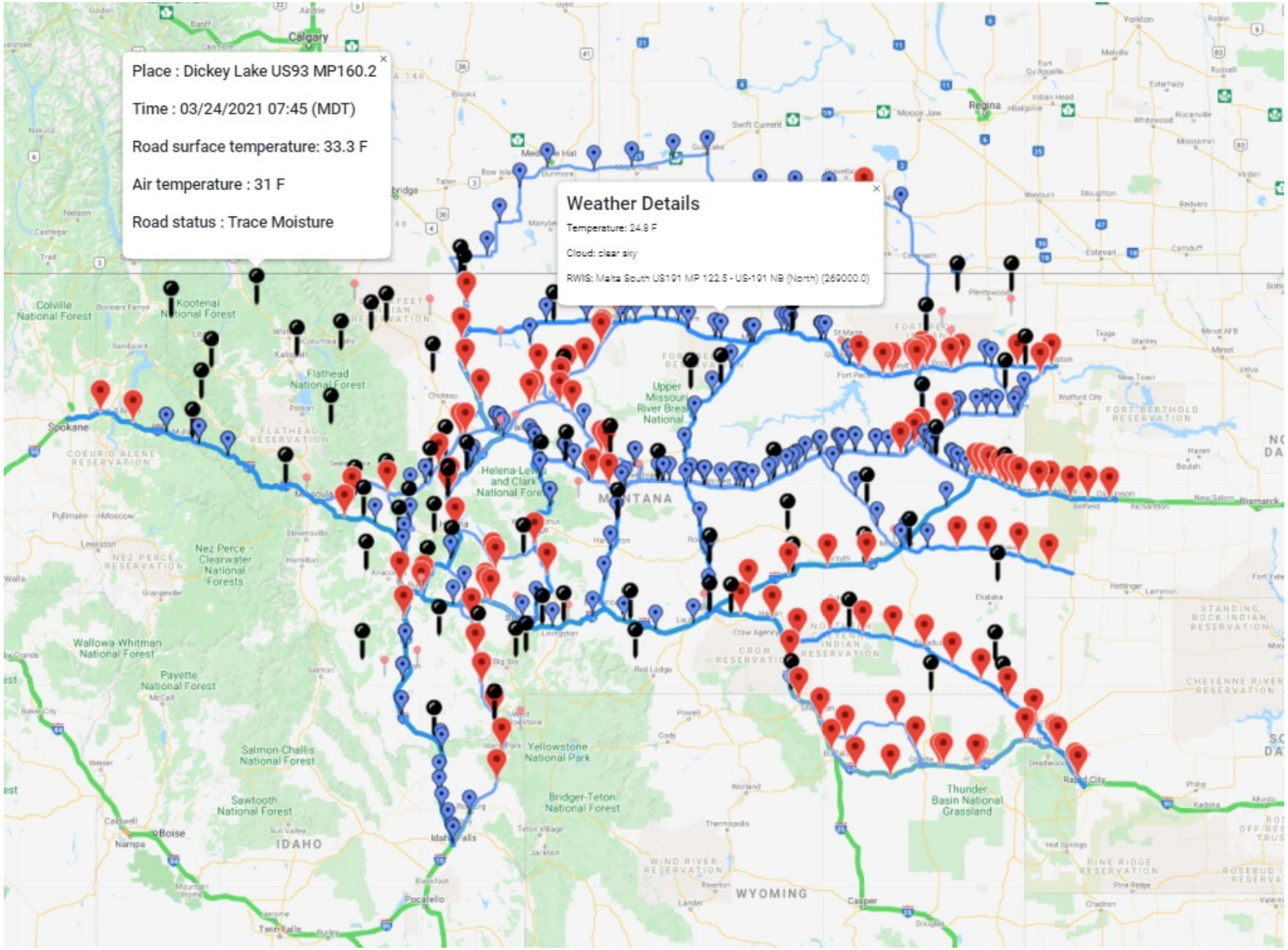
IcyRoad interactively sends forecast and alert of Icy Road status to users in 20 seconds, 24/7, across US and Canada

24-hr lead time

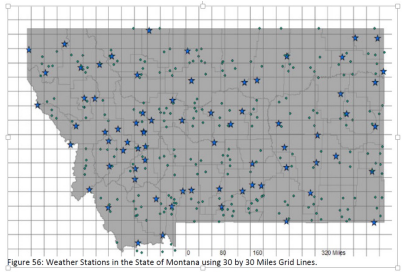

- Icy Road Marker
- Normal Road Marker
- Unknown Status Marker
Start: Los Angeles
End: billings mt
Depart: now
Change Time
Check Route
Choose route: Route 1
Weather Details
Date: 2/11 10:24am
Temperature: 34.48℉
Cloud: overcast clouds
United States

IcyRoad3 for MDT




Place : Dickey Lake US93 MP160.2
Time : 03/24/2021 07:45 (MDT)
Road surface temperature: 33.3 F
Air temperature : 31 F
Road status : Trace Moisture
Weather Details
Temperature: 24.8 F
Cloud: clear sky
RWIS: Malta South US191 MP 122.5 - US-191 NB (North) (269000.0)
Calgary
Regina
Spokane
Boise
Pocatello
Casper
Bismarck
MONTANA
IDAHO
WYOMING
Yellowstone National Park
Flathead National Forest
Kootenai National Forest
Colville National Forest
Helena-Lewis and Clark National Forest
Nez Perce - Clearwater National Forests
Wallowa-Whitman National Forest
Payette National Forest
Salmon-Challis National Forest
Sawtooth National Forest
Bridger-Teton National Forest
Thunder Basin National Grassland

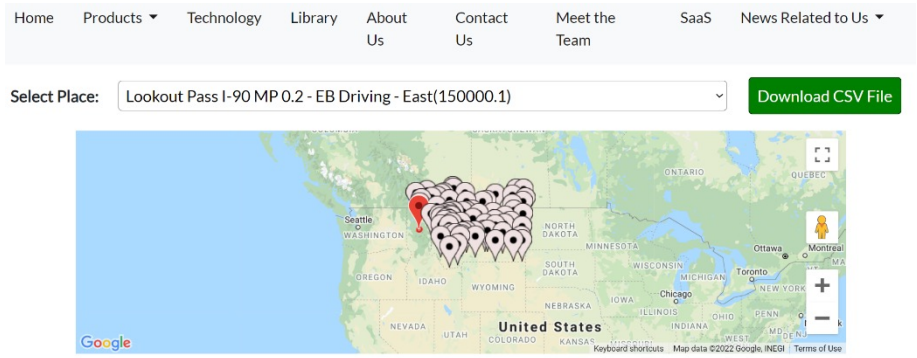
Validation of IcyRoad Using RWIS sites

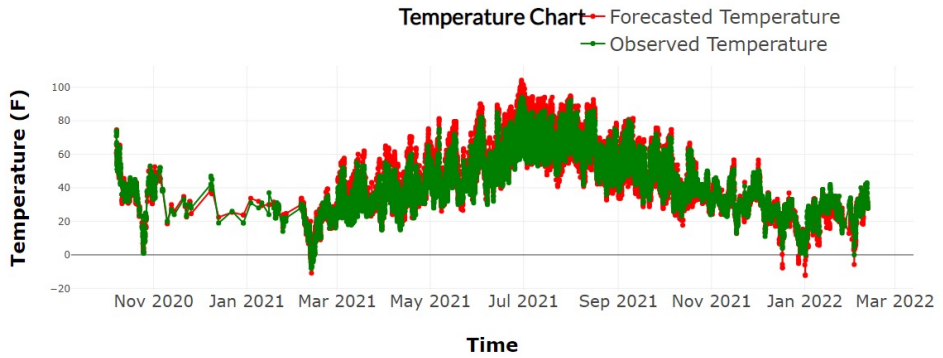


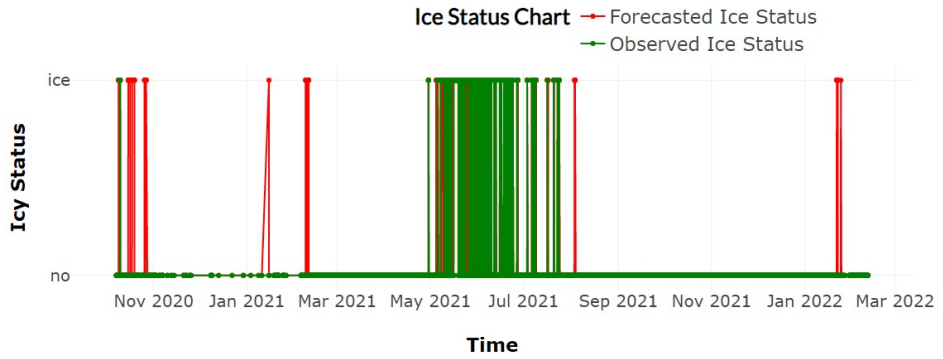
Weather stations in the state of Montana using the 30 by 30 mile grid lines. The stars refer to existing RWIS stations, while dots refer to other weather (MDT RWIS report, Ewan and Al-Kaisy, 2017)

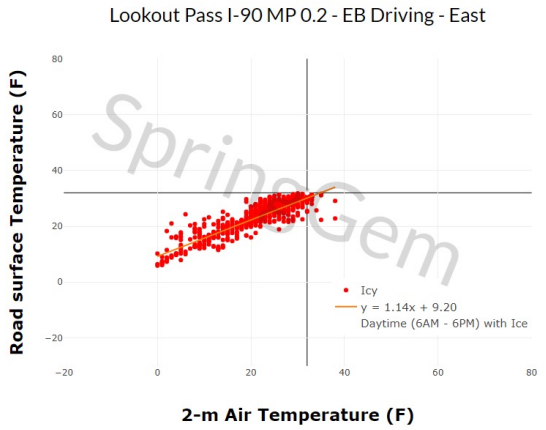
- Build online, automatic validation

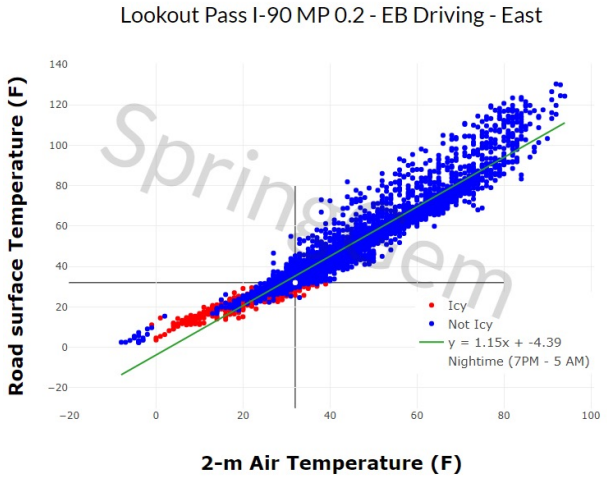
https://sg-weather.com/INTERNAL/IcyRoadValidation/

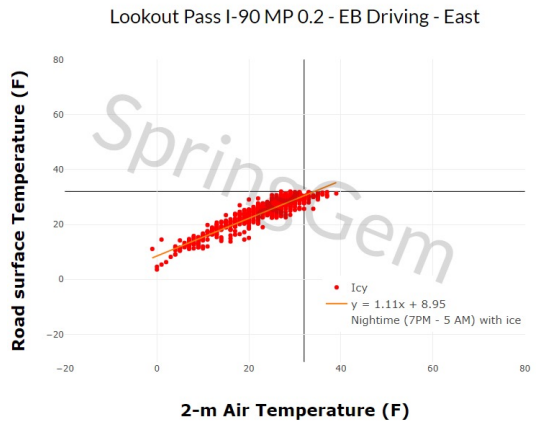




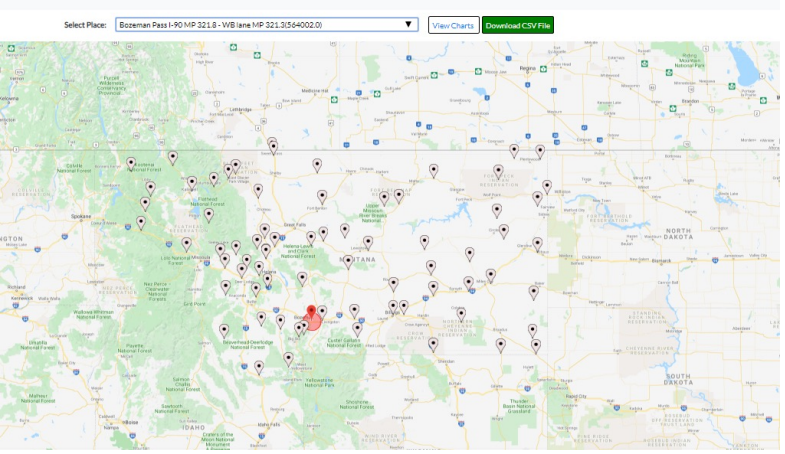






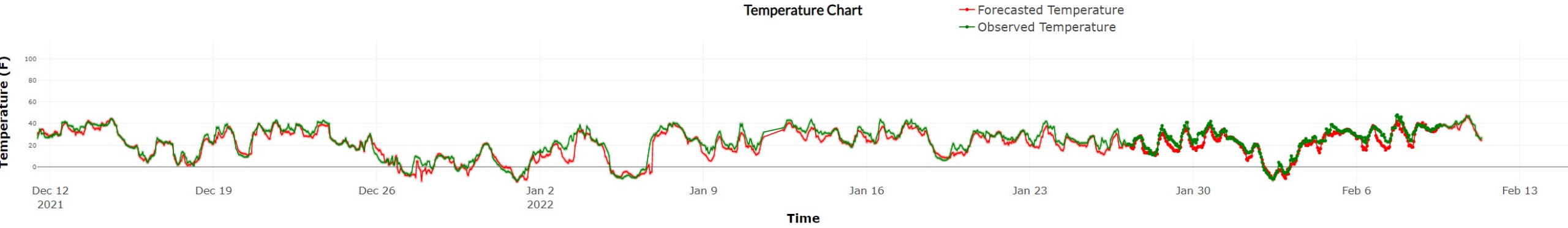


Similar to Figure 4 in Task 1 Report

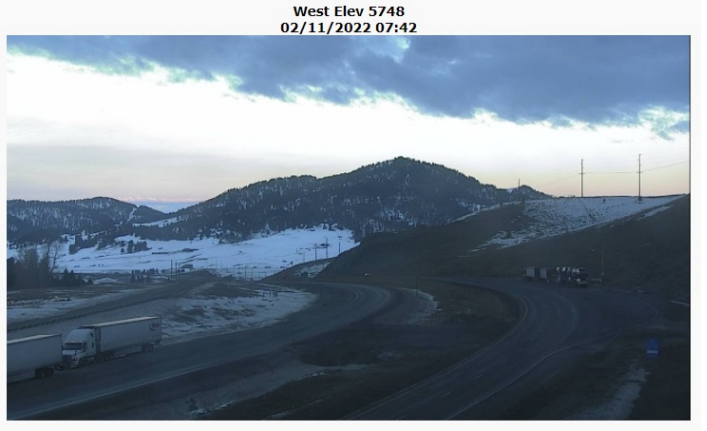


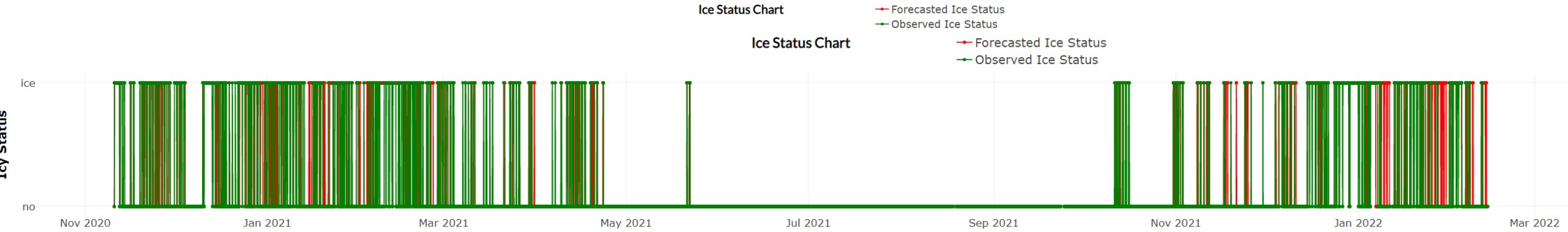
Example: Bozeman air temperature, IcyRoad 3 forecast vs RWIS

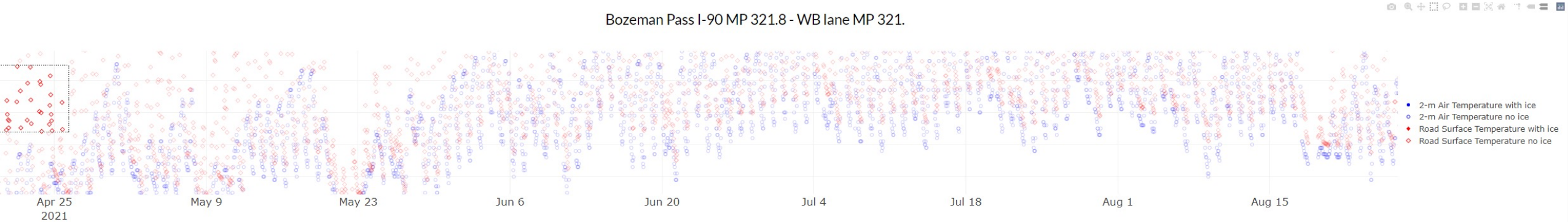
(results directly available at the online automated data analysis tool)



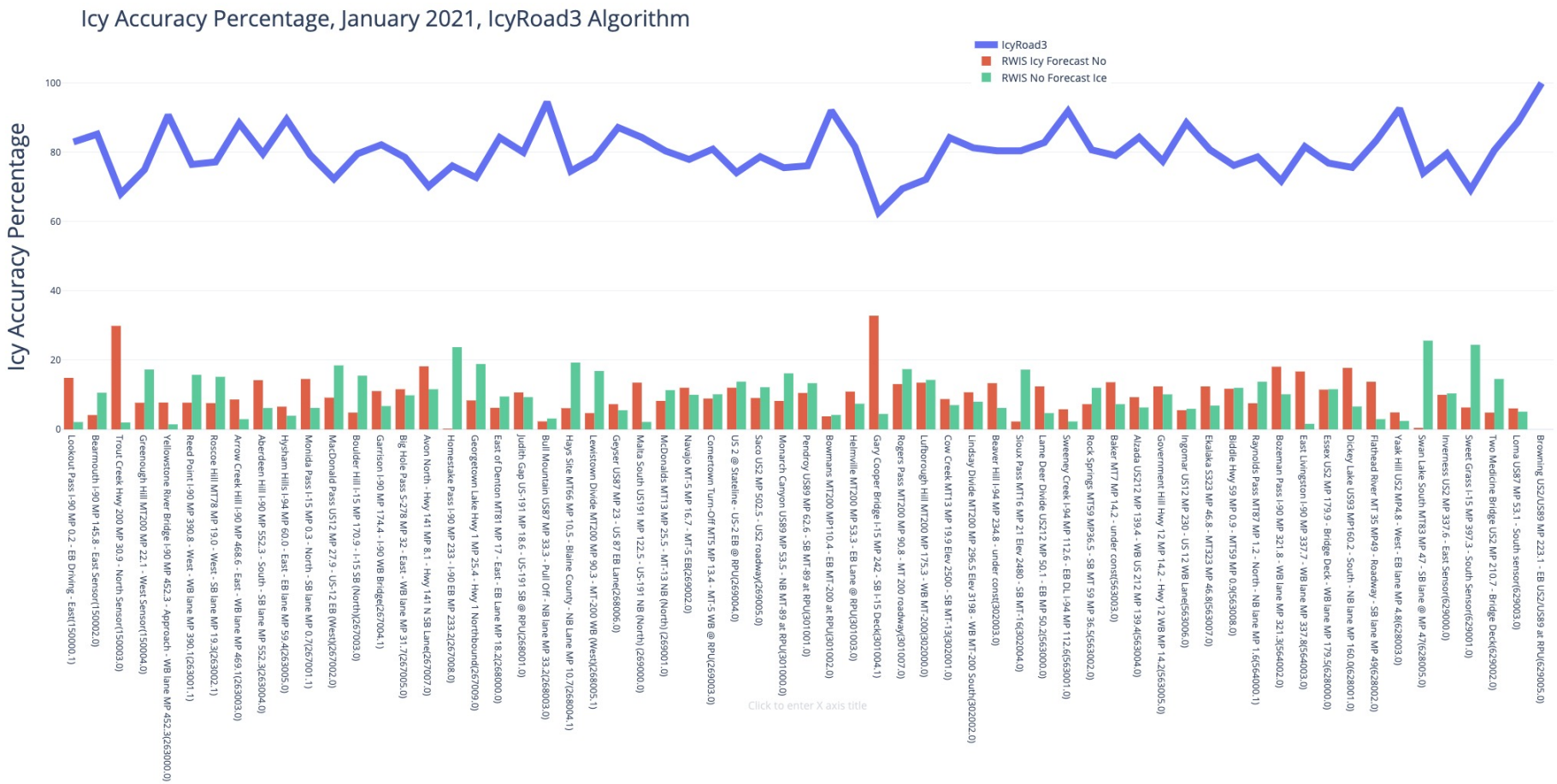
Bozeman IcyRoad3 forecast



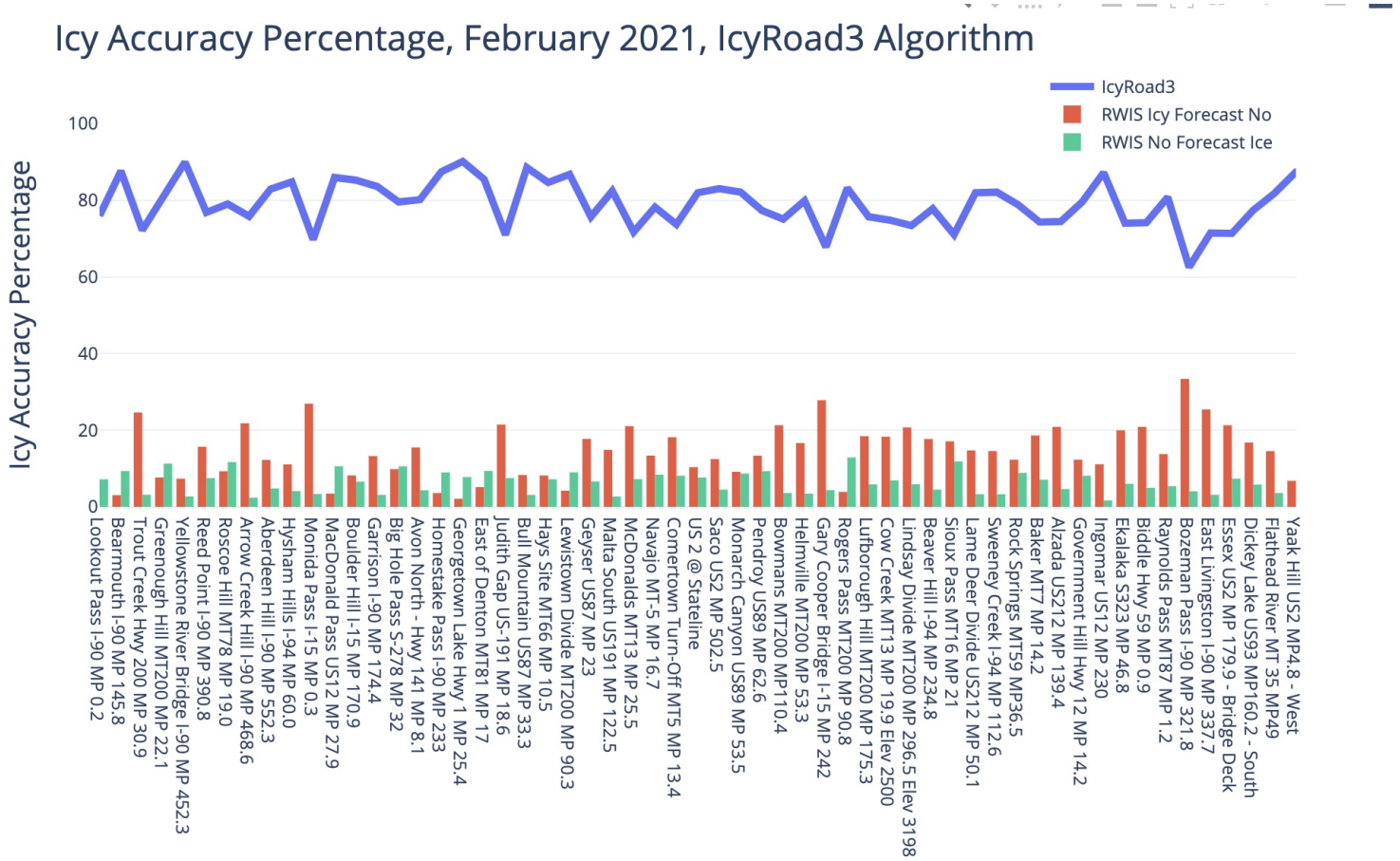




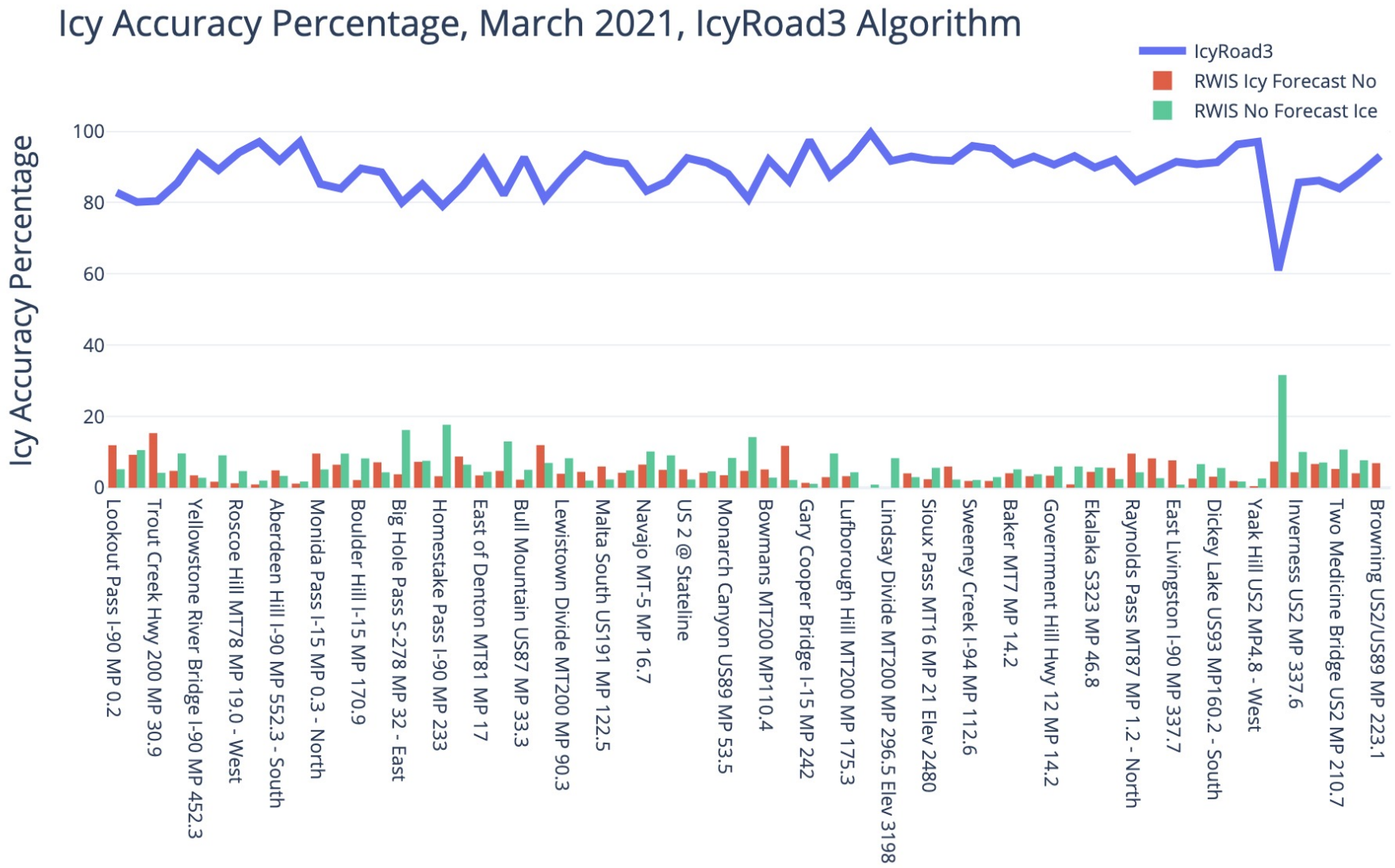
Validation, January 2021



Validation, February 2021



Validation March 2021



Scientific Understanding on Road Ice Formation

- Soil temperature vary less than pavement and air temperatures
- Soil temperature change ahs a lag phase delay (due to heat transfer to soil layer takes time)

Conclusion: Soil temperature is NOT a good index for ice formation

Pavement temperature higher that air temperature at some time, lower than it at another time

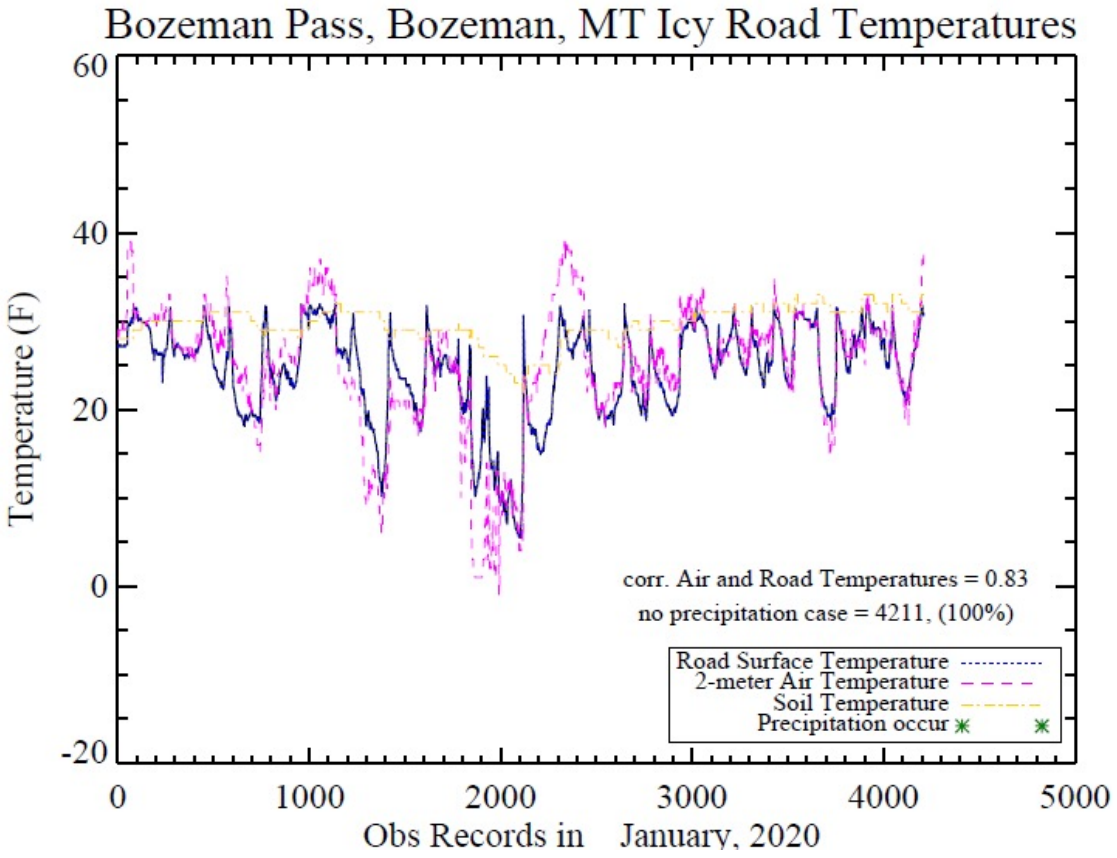


Figure 1 in Task 1 report

Bozeman (cont.)

- Pavement temperature and air temperature relations

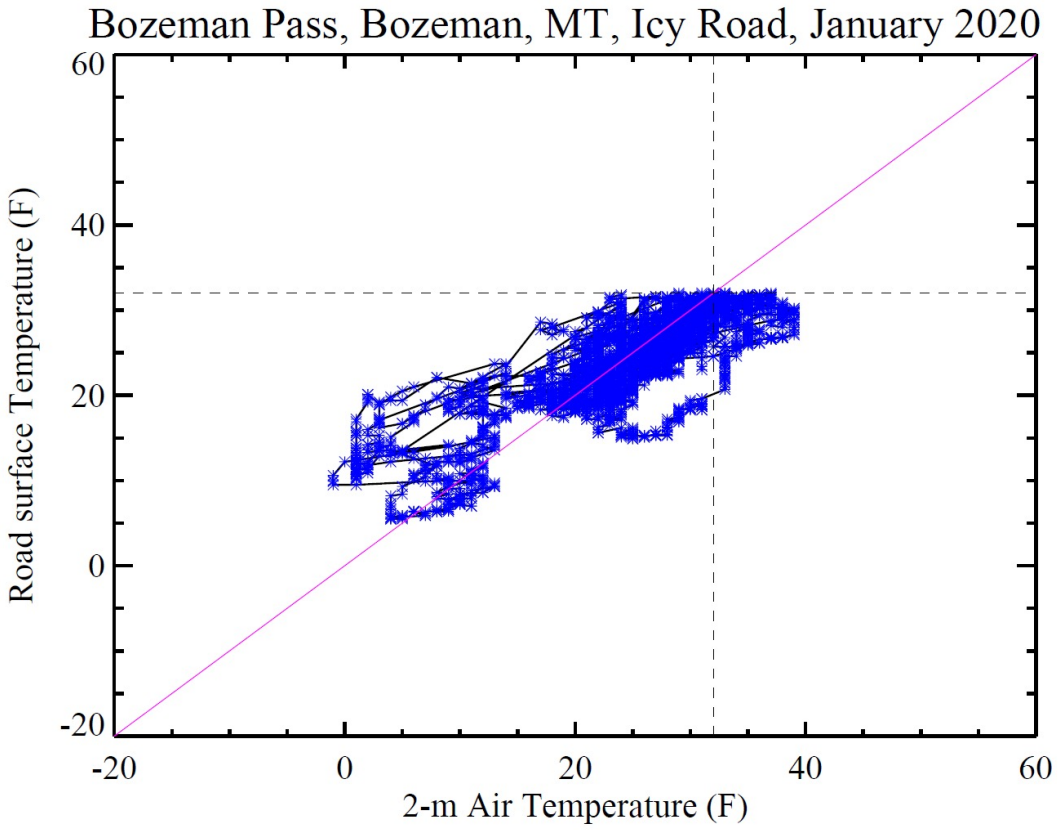


Figure 2 in Task 1 Report

MacDonald Pass, Butte (elevation above 1800 m)

- The road at this site was icy for >90% of days in January, 2020
- Snowfall was also monitored in most of the days there (77%), partly due to convection induced by orographic lifting and partly due to wind-blown snow from nearby regions being measured by the RWIS sensor
- Local calibration is needed in order to forecast road temperature correctly from Tair for a given region, since local elevation, cloud cover, and geographic conditions directly affect road/air temperature interactions

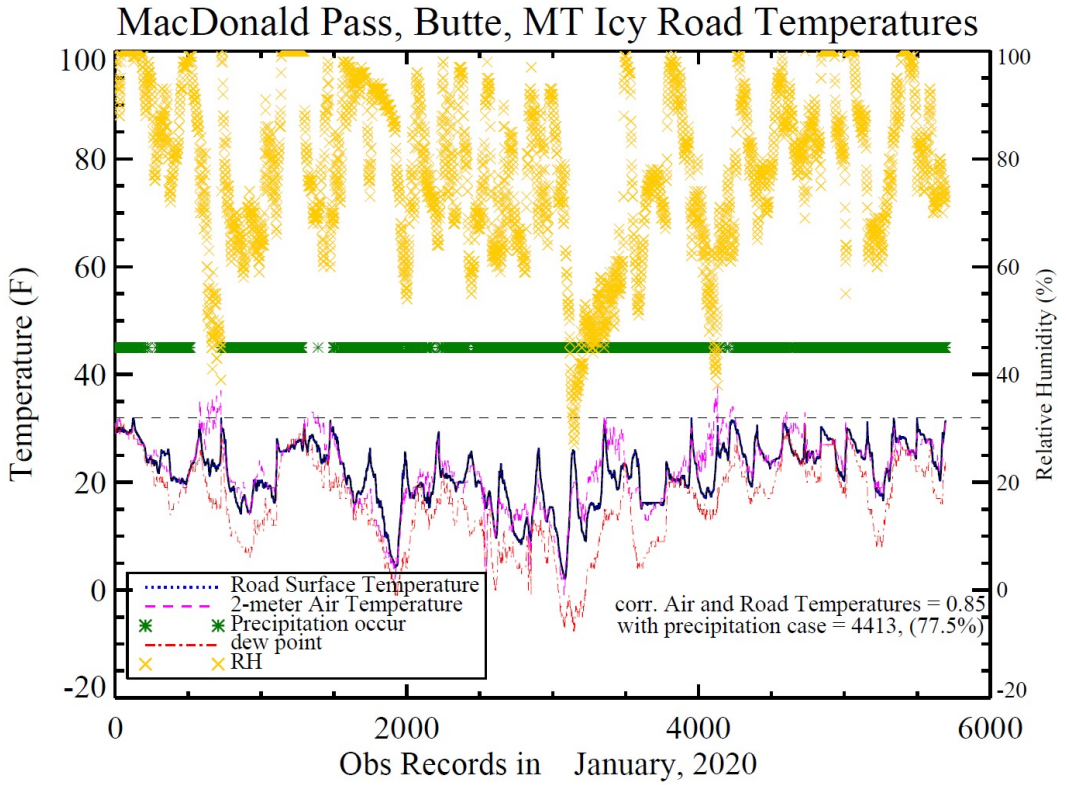
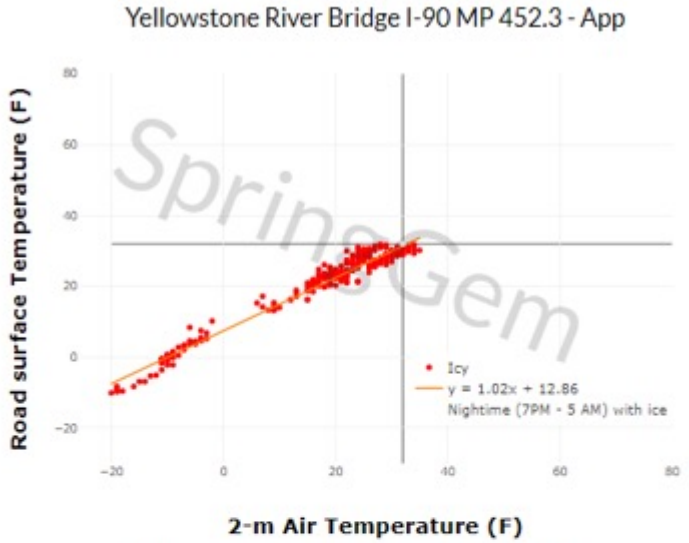


Figure 3 in Task 1 Report

Bridge – Yellowstone River Bridge

- Ice vs no ice has evident differences
- Daytime vs nighttime
- Regression gives first order relation between air and road pavement temperatures



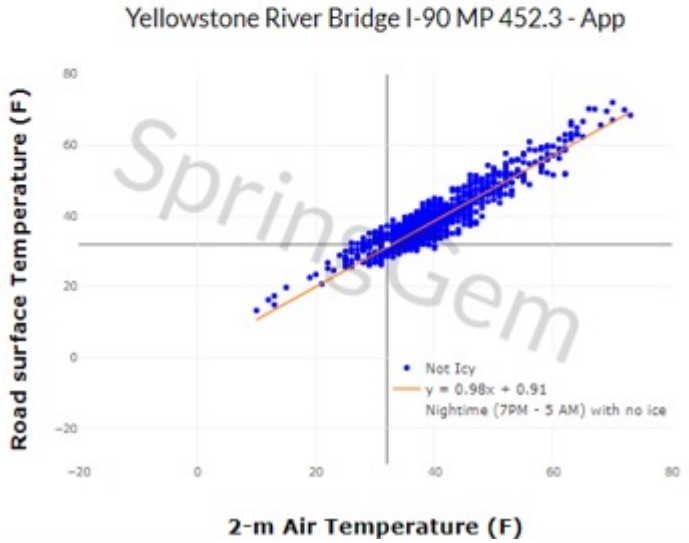


Figure 17 in Task 1 Report

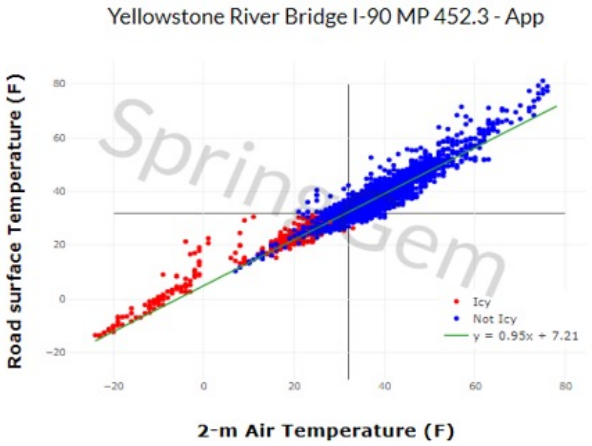
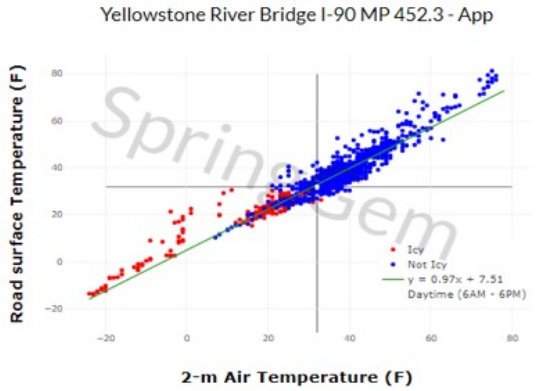


Figure 15. The 2-meter air temperature and road skin temperature relationships for Noverber 1, 2020 – to March 31, 2021, for Yellowstone Bridge (263000.0). The blue dot represent no-ice time, and the red dot represents for icy.



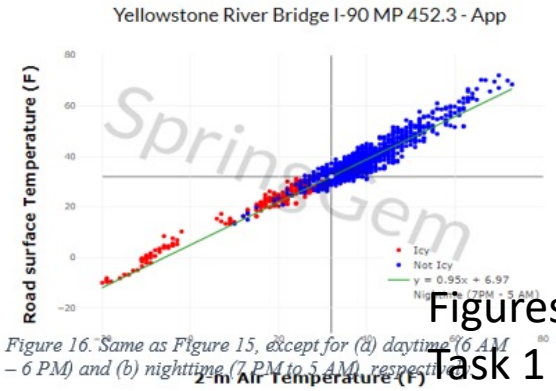
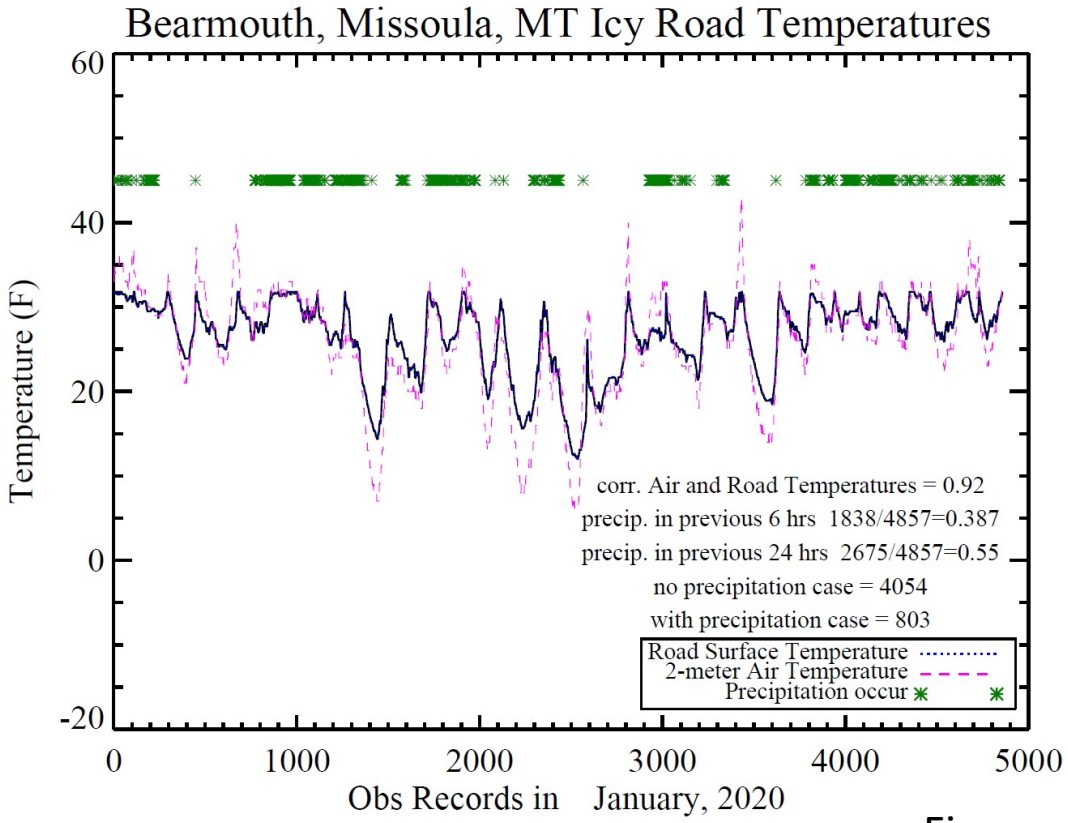
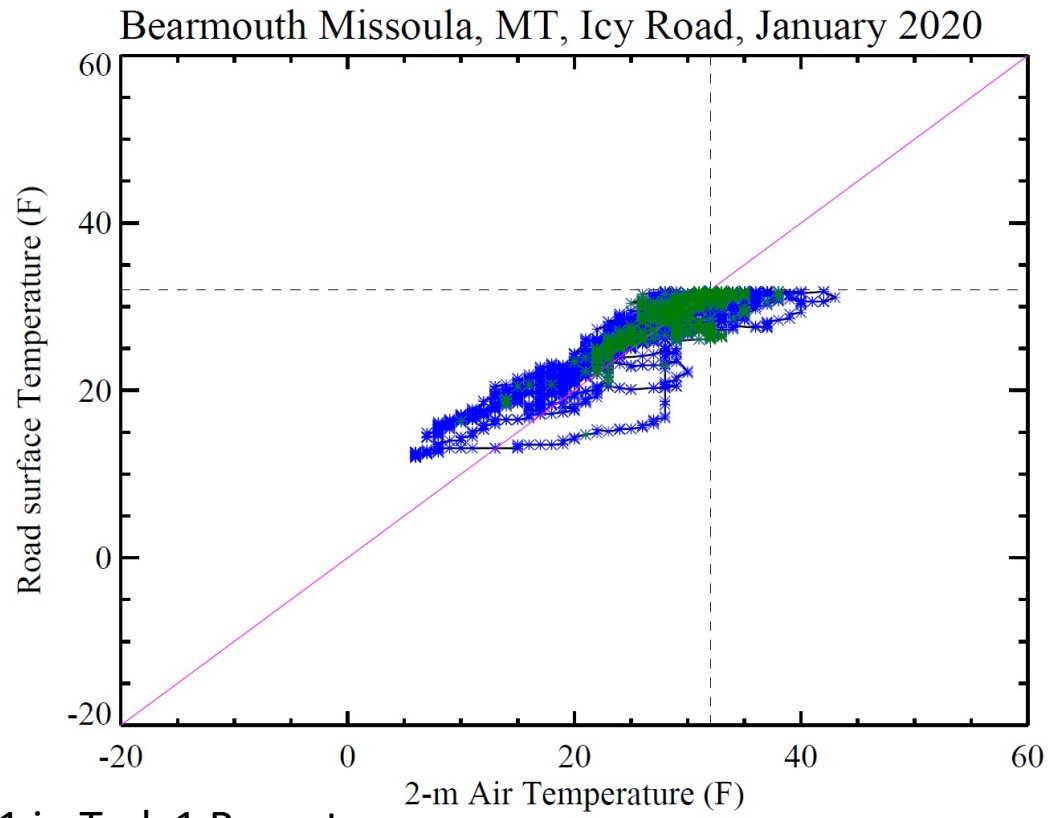


Figure 16. Same as Figure 15, except for (a) daytime (6 AM – 6 PM) and (b) nighttime (7 PM to 5 AM), respectively.

Figures 15 and 16 in Task 1 Report

Bearmouth, Missoula (1189 m elevation)





Figures 10 and 11 in Task 1 Report

The road temperature and 2-meter air temperature correlation coefficient was 0.92.

Air temperature can be much higher than pavement temperature during the daytime, partly due to the fact that ice-covered road surfaces do not heat up quickly. Nevertheless, it can also be lower than the latter.

When roads were icy, the skin temperatures were always below 32°F (Fig. 11). Nevertheless, 2-meter surface air temperature could be above 32°F.

Model Forecast Uncertainty

- All model forecast has uncertainty, due to limited understanding on ice formation physical processes
- The longer the lead time, the less accurate the model forecast
- Assimilate ground observations with model forecast can improve forecast accuracy to an encouraging degree (icyroad3 80%)

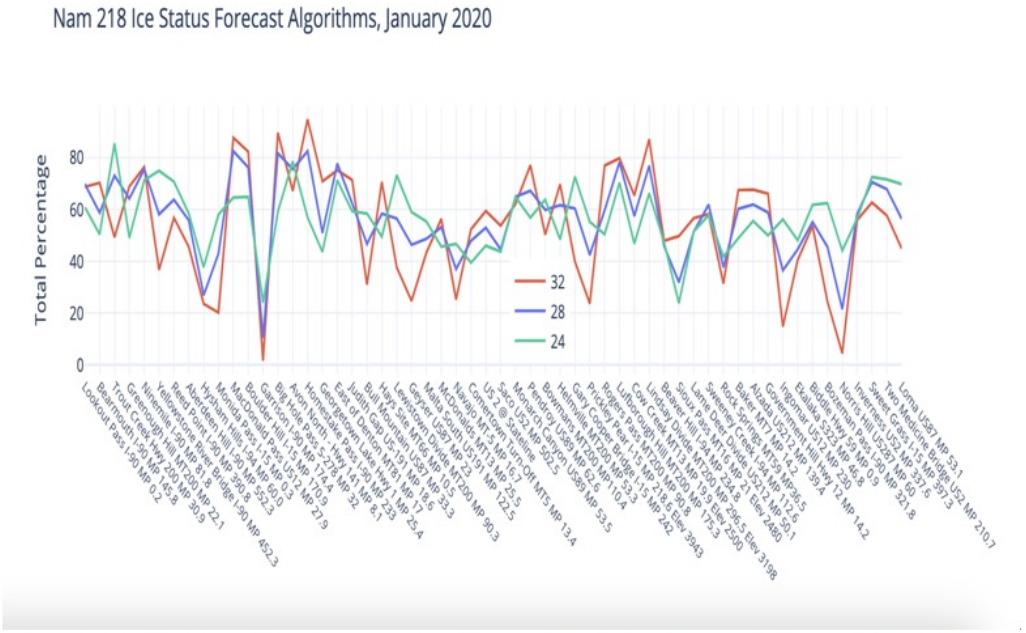


Figure 8: NAM-IcyRoad2 accuracy for road ice status forecast in January 2020 at RWIS sites. X-axis is the RWIS site names and y-axis is total accuracy percentage for ice status forecast. 32, 28, and 24 represent surface temperature thresholds at 32°F, 28°F, and 24°F, respectively.

Figure 8 of Task 1 Report

Elevation Impact on Model Forecast Accuracy

- a negative correlation coefficient of -0.25 between RWIS site elevation a icy status forecast for the site.
- Although this negative coefficient r not be statistically significant, elevation is still one of the seconda factors for ice formation on roadwa

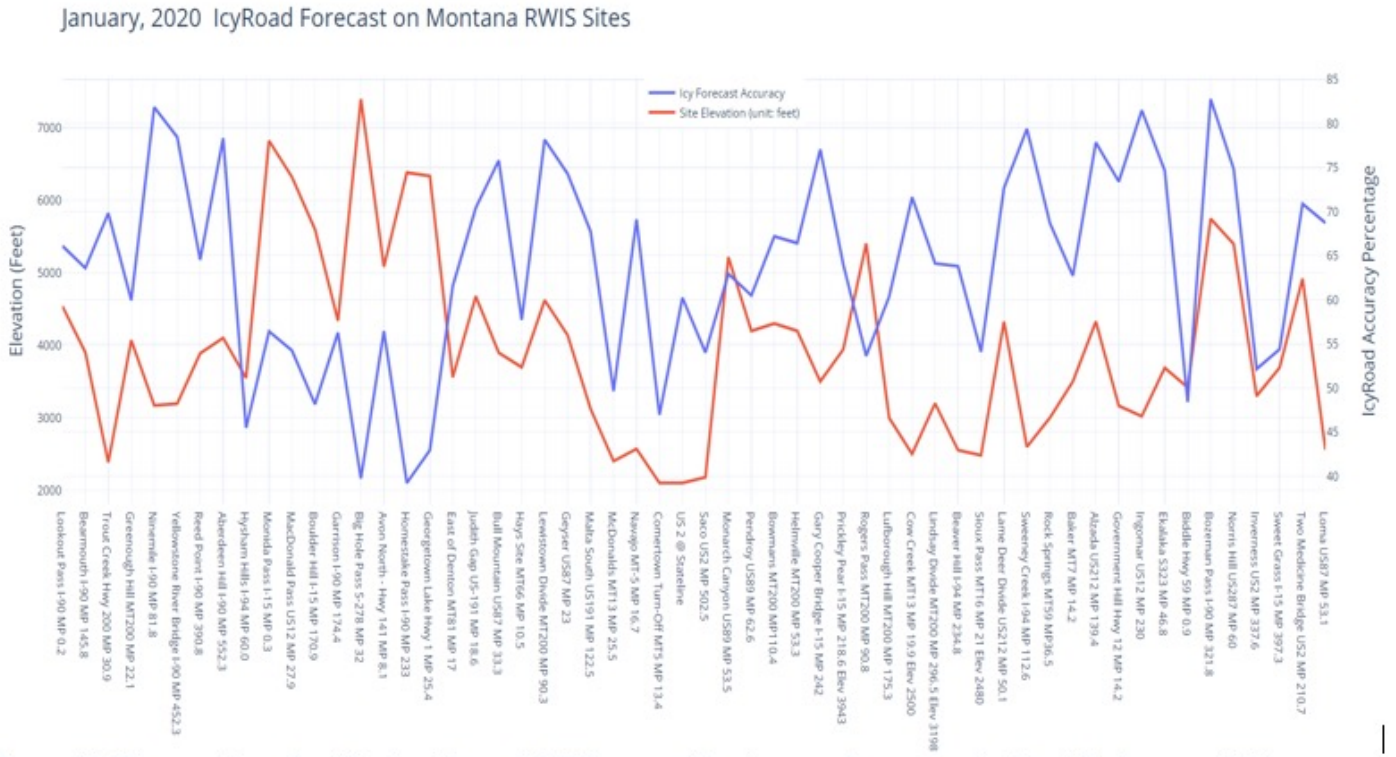


Figure 12. Elevation (unit: feet, blue line) for each RWIS site and Ice Accuracy Percentage (red line) for January, 2020 at temperature threshold t=24°F. IcyRoad2 algorithm was examined in this Figure.

IcyRoad3

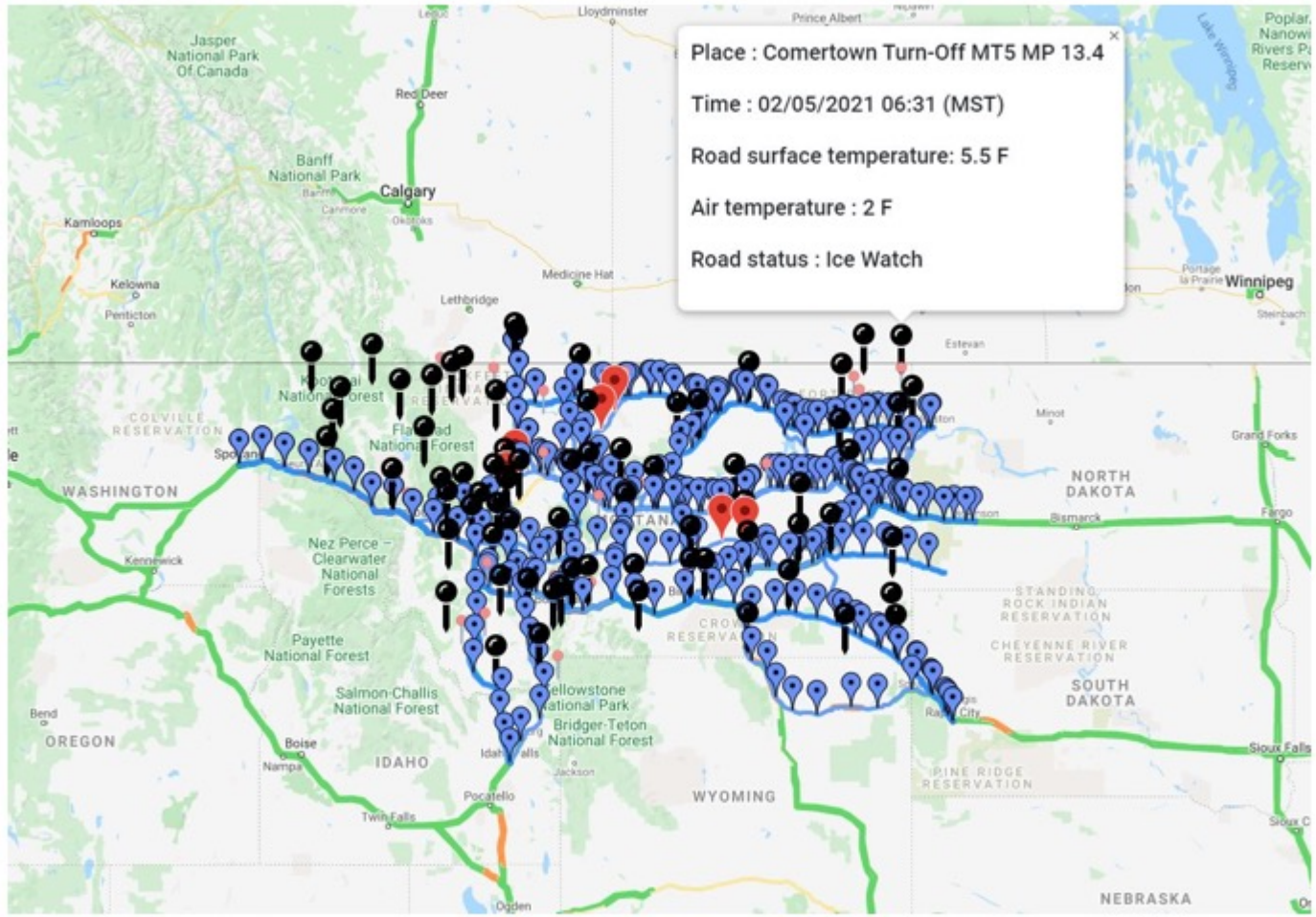
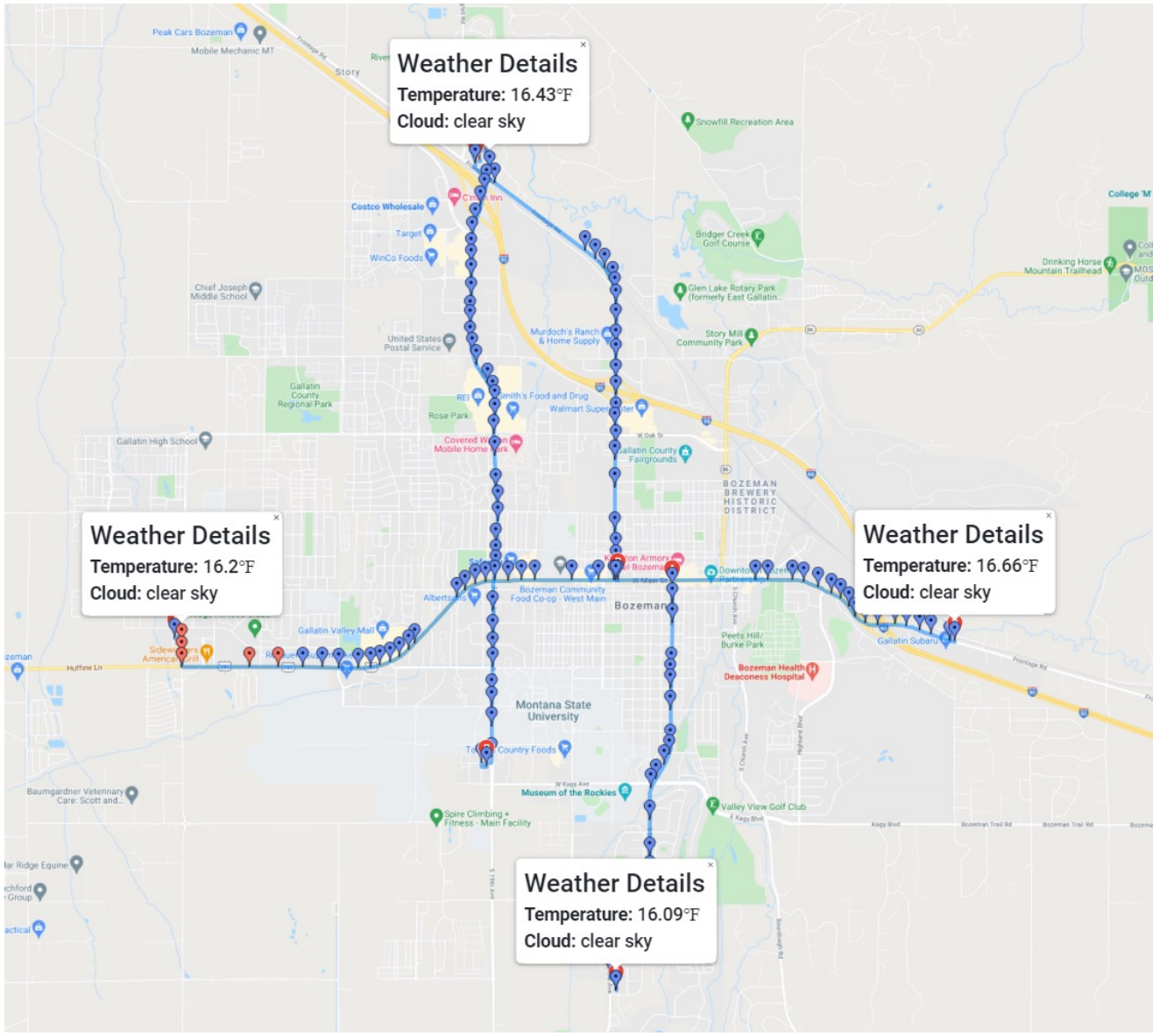


Figure 19. Sample of IcyRoad3 for state Montana highway ice status forecast for February 5, 2021. The blue marker is icy, the red marker is no ice, the black marker is RWIS sites location. Clicking RWIS sites shows observations. The small, pink pins are weather station locations and observations.

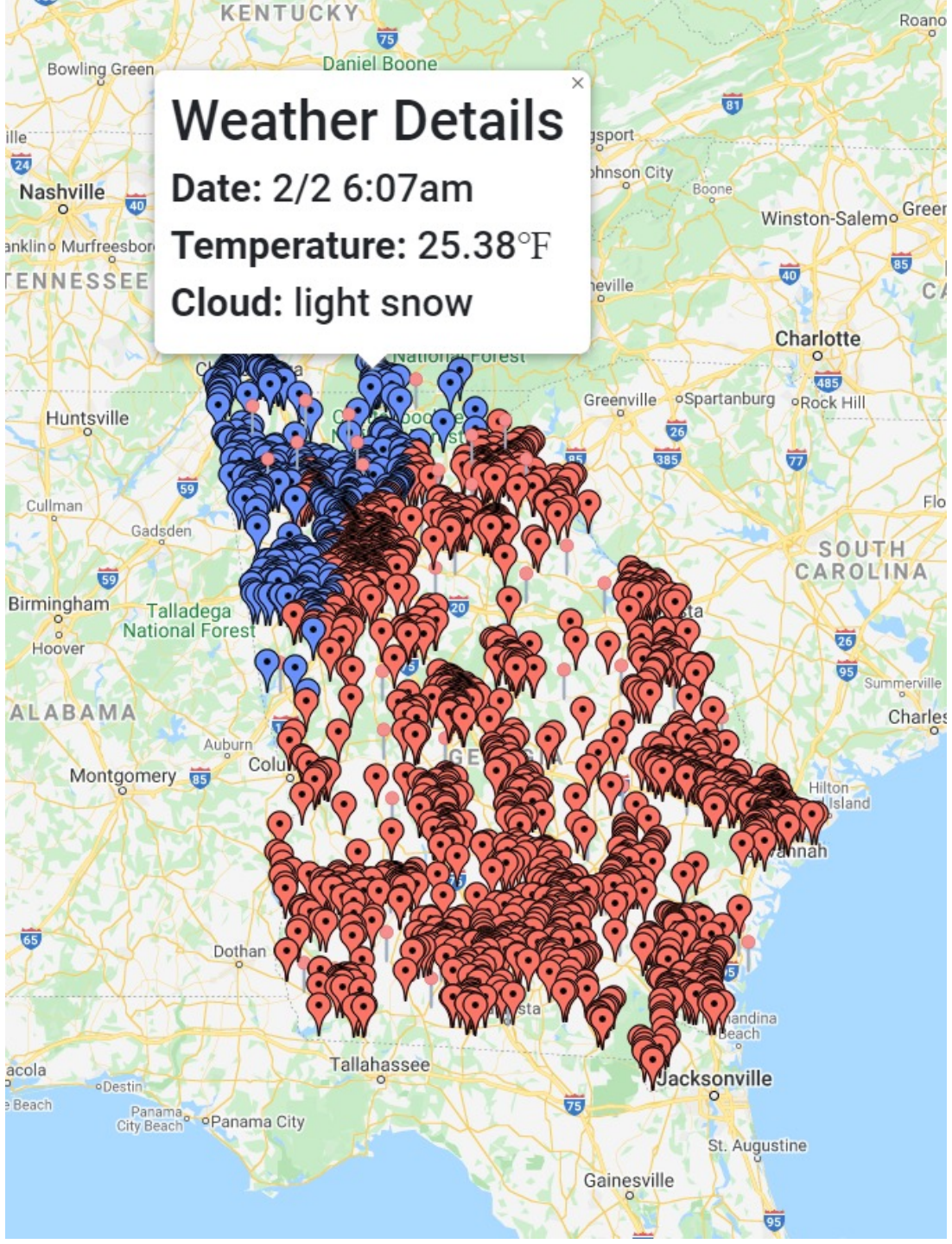
IcyCity

Funed by SringGem other project



IcyBridge

Funded by SringGem other project



RWIS site observation is not always correct

Bozeman (564000)
Site Summary Page
(Selected surface sensor may change based on conditions)
Current Time: 12/01/2019 18:03 MST

Status	Sfc	Sub	Air	RH	Dew	BaroPs	Precip	Intens	Rat
Ice Warning	Bozeman Pass I-90 MP 321.8 - WB lane MP 321.3 (564002.0)								12/01/
	24.3F	25F	23F	79%	18F	-	None	None	-
Error	Deep Creek US-12 MP 23.5 - NB MP 60.0 (564005.0)								12/01/
	-	25F	24F	58%	12F	-	None	None	0.0 i
Ice Watch	East Livingston I-90 MP 337.7 - WB lane MP 337.8 (564003.0)								12/01/
	28.4F	-	34F	48%	16F	-	None	None	-
Error	Karst US191 MP 55.3 - sensor failure (564001.0)								12/01/
	-	28F	29F	53%	14F	-	None	None	-
-	Livingston Wind - I-90 MP 331.7 Elev 5401 (564006)								12/01/
	-	-	-	-	-	-	Other	Other	-
Dry	Norris Hill US287 MP 60 - North - NB lane MP 60.4 (564004.0)								12/01/
	23.2F	22F	27F	62%	16F	-	None	None	-
Ice Warning	Raynolds Pass MT87 MP 1.2 - North - NB lane MP 1.6 (564000.1)								12/01/
	21.4F	23F	23F	59%	10F	-	None	None	-

Norris Hill US287 MP 60

North Corner Elev 5400 — 12/01/2019 18:11

North Elev 5400 — 12/01/2019 18:10

Roadway Elev 5400 — 12/01/2019 18:09

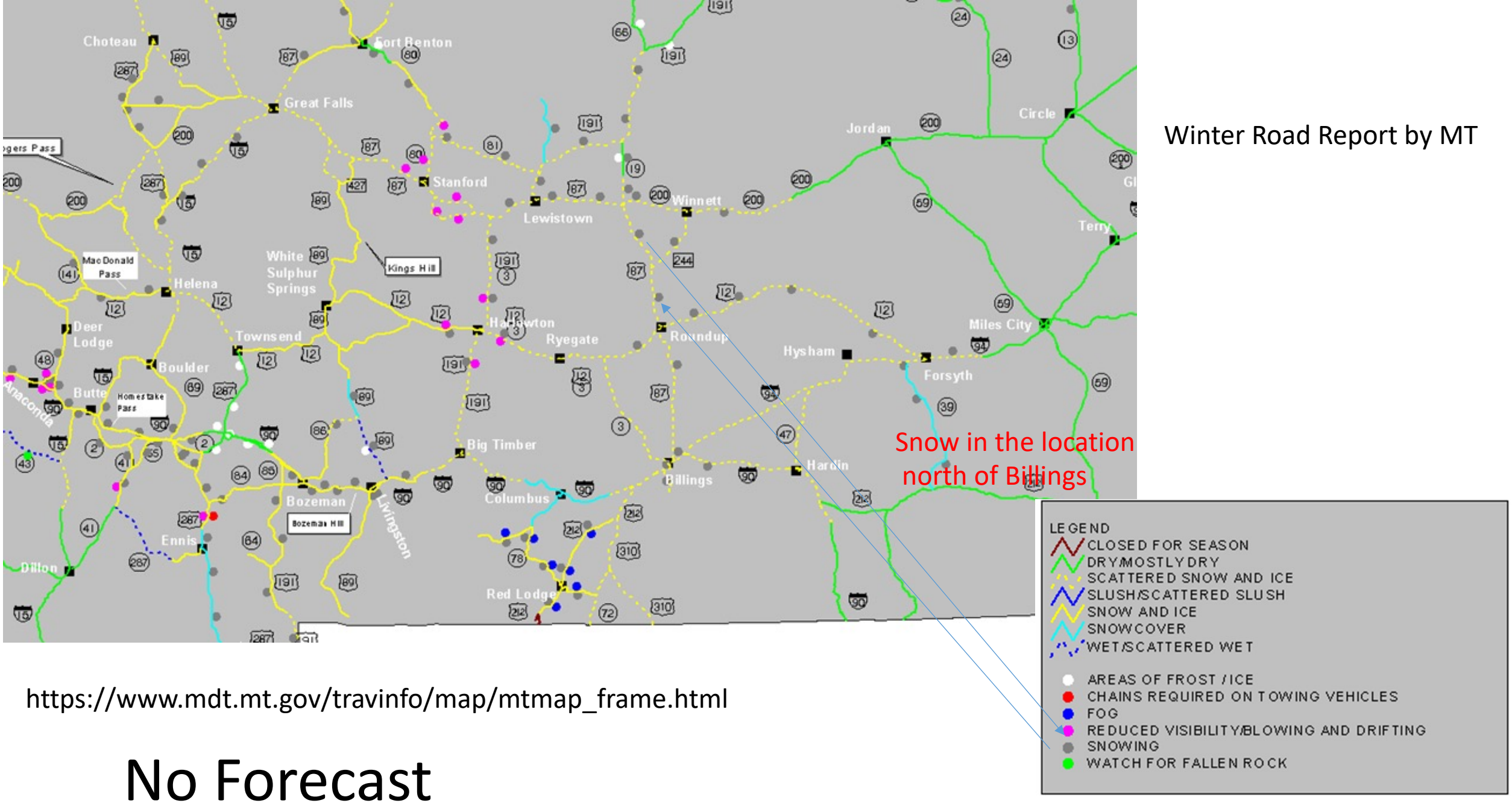
South Elev 5400 — 12/01/2019 18:08

12/01/2019 17:57 (MST) | History

Norris Hill US287 MP 60 - Roadway Elev 5400

Date/Time: 12/01/2019 18:09 — Loop

Available Images: Roadway Elev 5400



Winter Road Report by MT

Snow in the location north of Billings

https://www.mdt.mt.gov/travinfo/map/mtmap_frame.html

No Forecast

IcyRoad help!

1. IcyRoad3

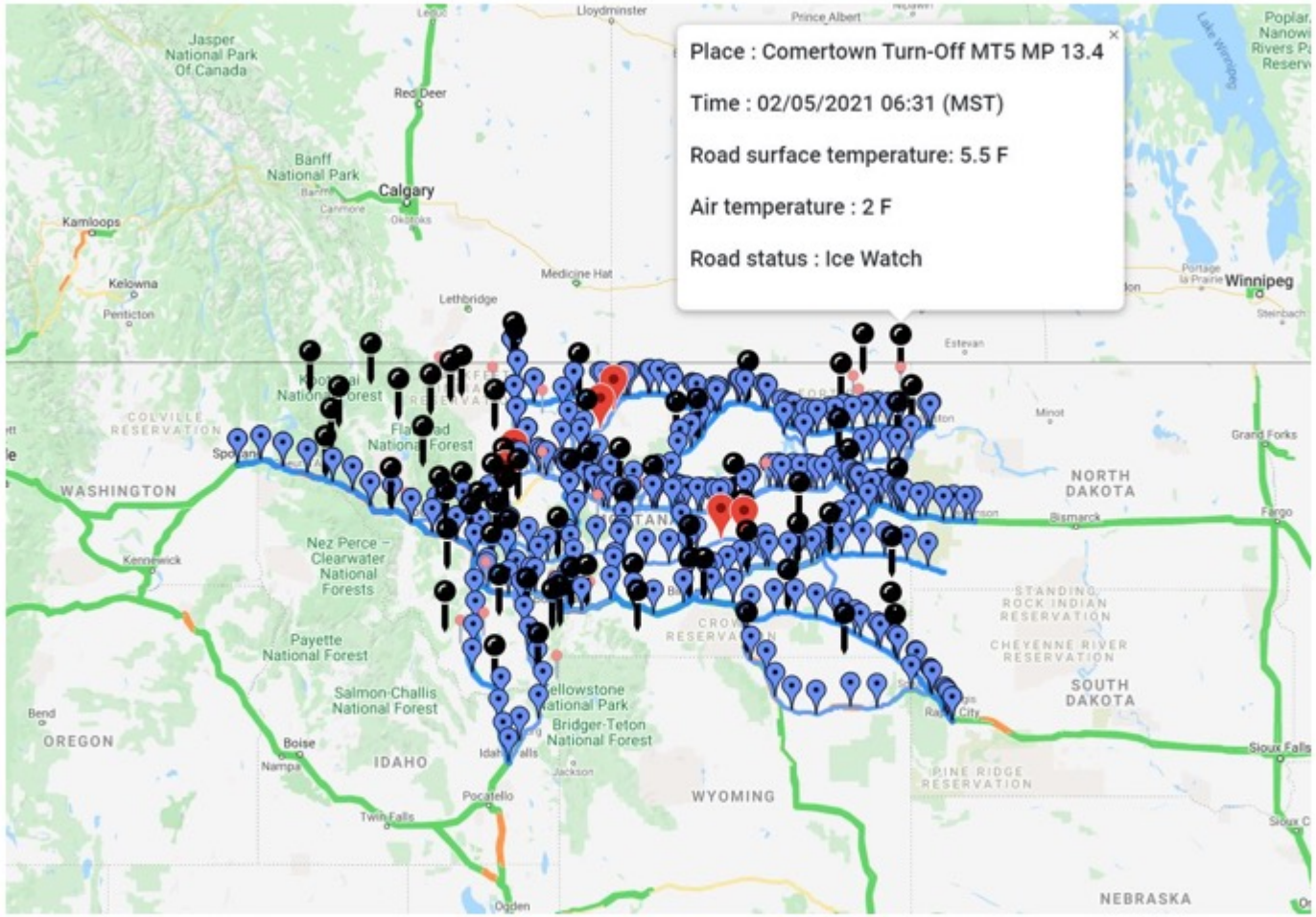
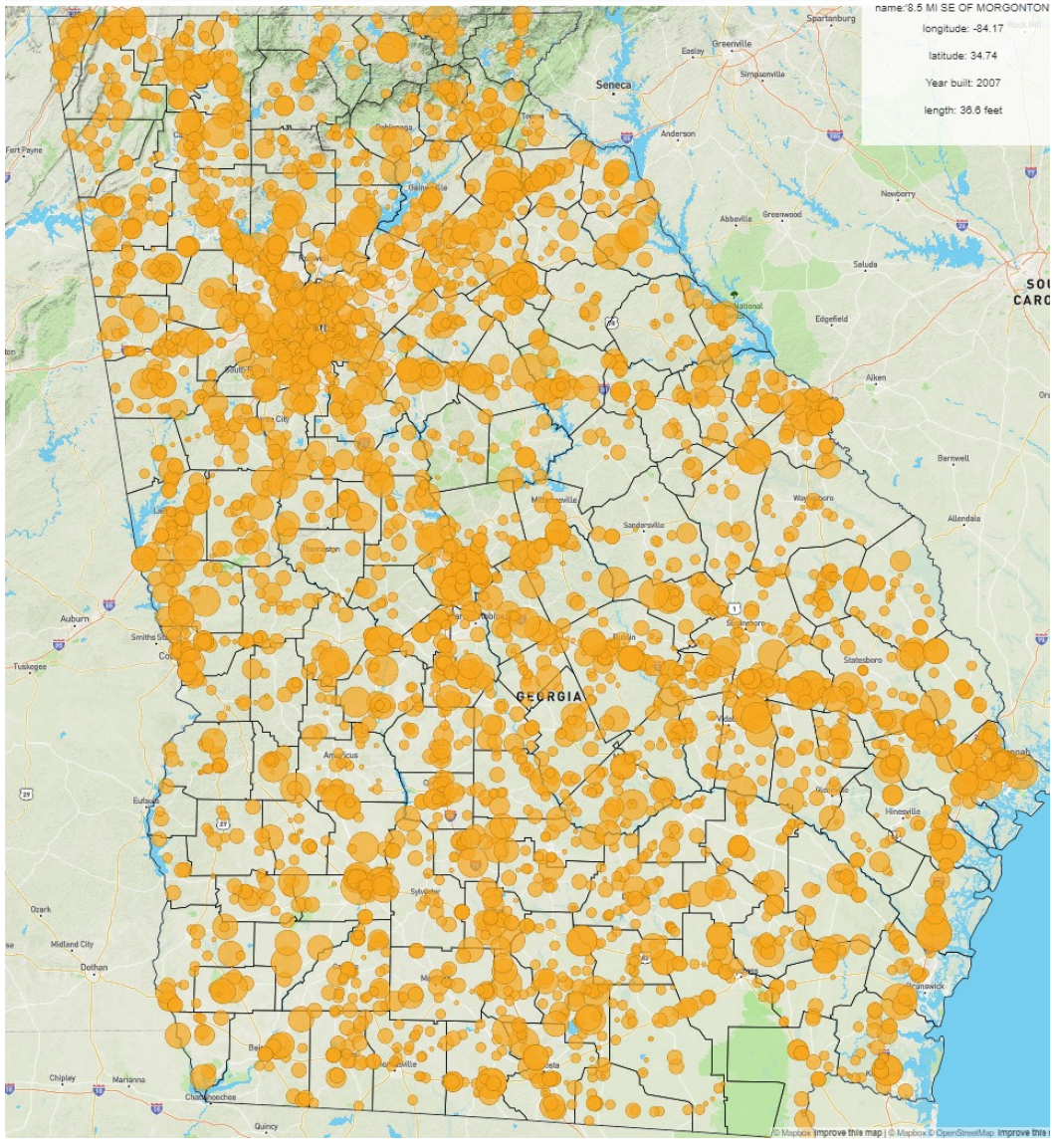
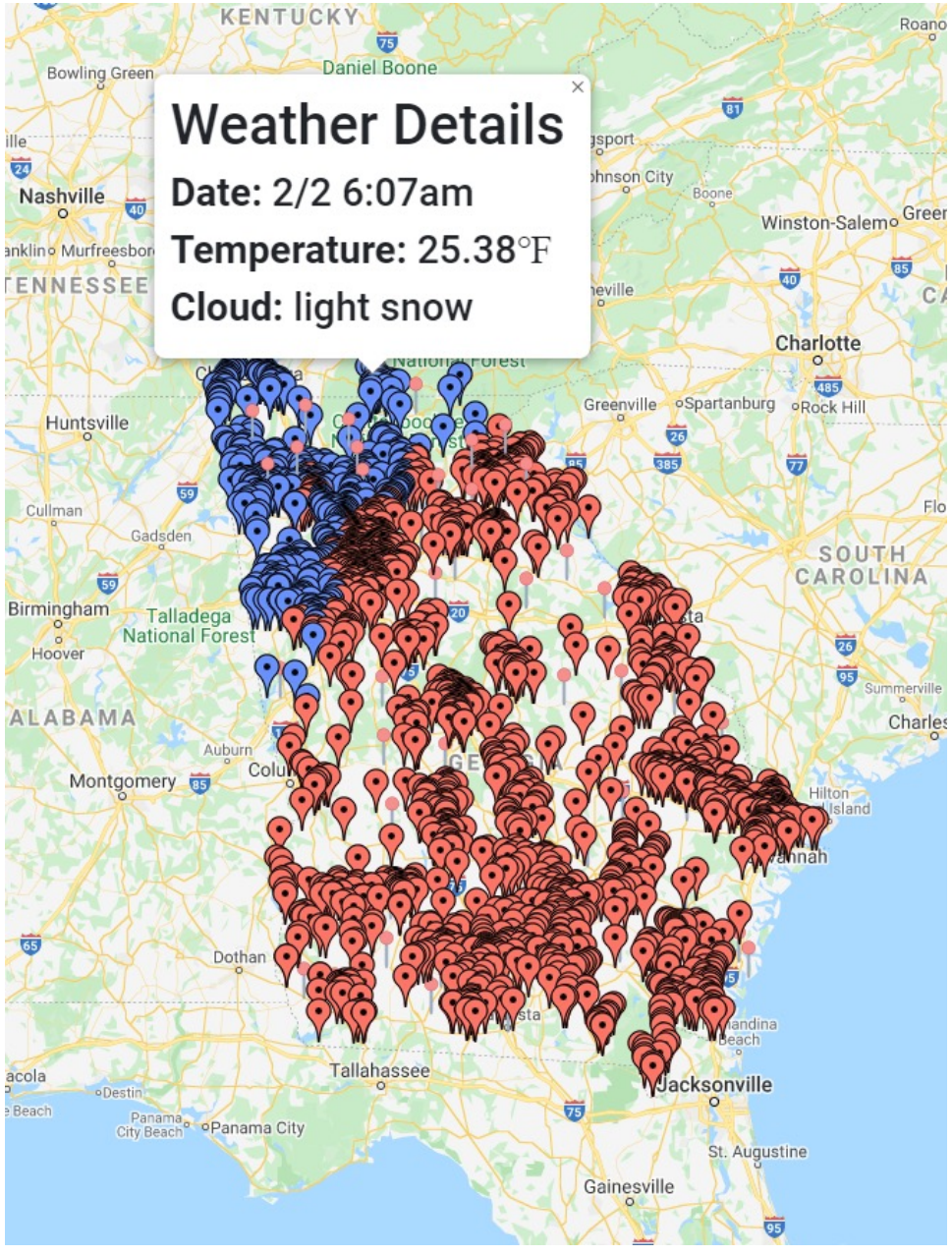


Figure 19. Sample of IcyRoad3 for state Montana highway ice status forecast for February 5, 2021. The blue marker is icy, the red marker is no ice, the black marker is RWIS sites location. Clicking RWIS sites shows observations. The small, pink pins are weather station locations and observations.

2. IcyBridge

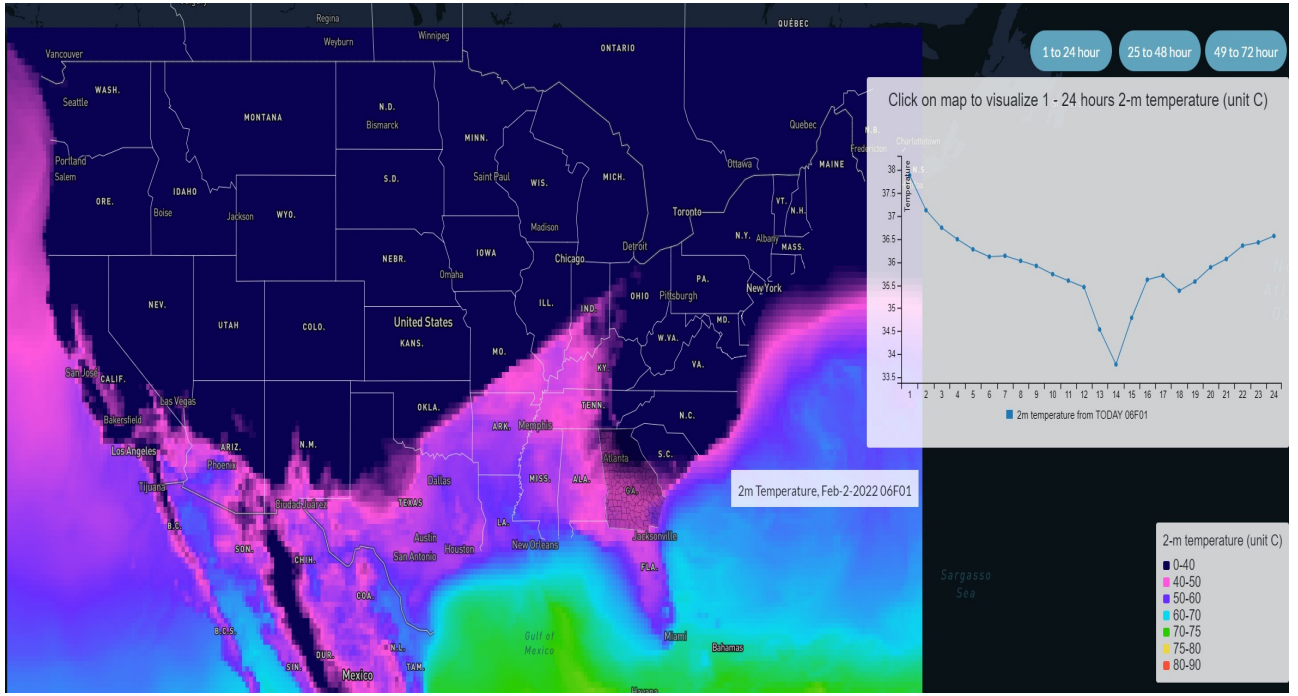

name:8.5 MI SE OF MORGONTON
longitude: -84.17
latitude: 34.74
Year built: 2007
length: 36.6 feet
GEORGIA


Weather Details
Date: 2/2 6:07am
Temperature: 25.38°F
Cloud: light snow
KENTUCKY
Bowling Green
Daniel Boone
Nashville
Winston-Salem
Charlotte
Greenville
Spartanburg
Rock Hill
Huntsville
Cullman
Gadsden
Birmingham
Talladega National Forest
Hoover
ALABAMA
SOUTH CAROLINA
Montgomery
Auburn
Dothan
Tallahassee
Jacksonville
Panama City
Gainesville
St. Augustine

3. Localized weather information – current and 8-day forecast based on weather forecasting model

- Provide localized weather forecast
- Include
  - 2-meter air temperature
  - wind speed and direction
  - Precipitation
  - Soil moisture
  - Clod cover
  - Relative humidity
  - more…

. At hourly, for 10-day lead time

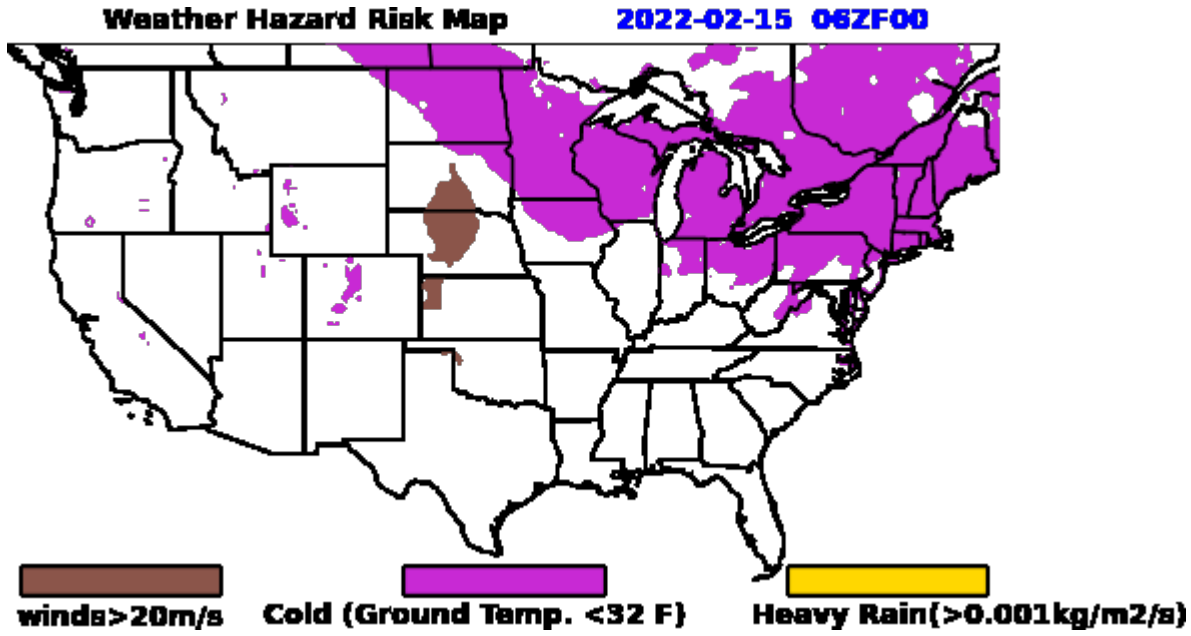


Hourly Temperature forecast for Vancouver, 2/2/2022

https://sg-weather.com/mapboxTemperatureMinshapeWithTimeSeries - for 2-meter surface air temperature
https://sg-weather.com/mapboxRainMinshapeWithTimeSeries - for rainfall

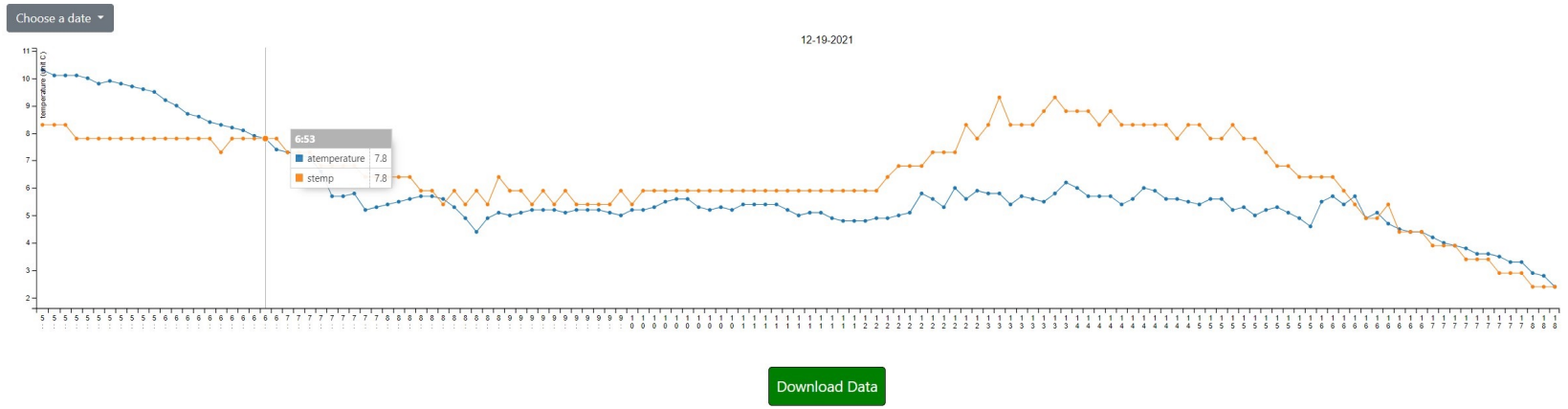
4. Hazard

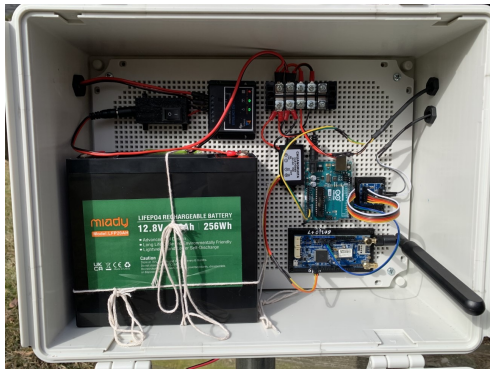
- https://sg-weather.com/weatherforecast



Weather Service for Local Farm

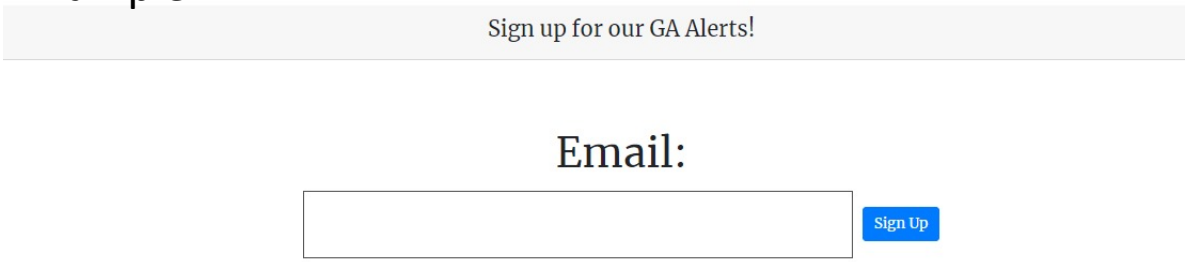
5. Sensor of pavement temperature, air temperature, relative humidity and wind – based on Internet-of-Things automated collect, transmit, and display data on web-server for more locations



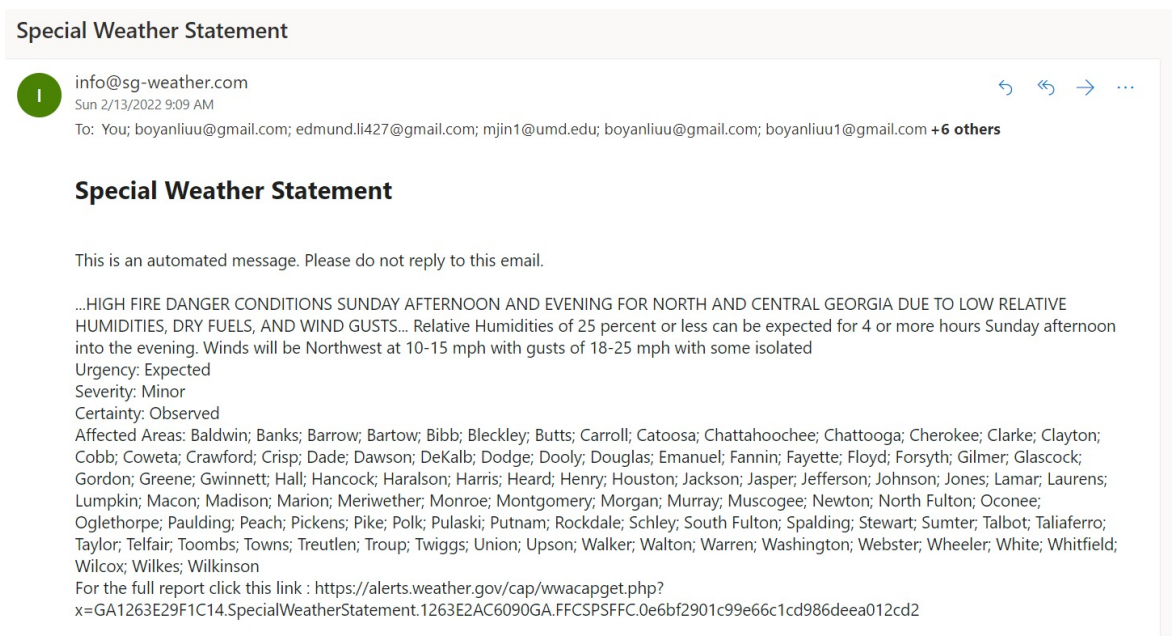


6. NWS Montana Alert

Example:



Automatically receive alert issued by NWS for Montana



7. 8-day forecast in Table from DIFFERENT sources

8-Day Forecast (from NOAA GFS forecast)

Cloud cover > 40% | Wind speed (U or V) > 10 m/s | Rain | Daytime clear sky | Nighttime clear sky | Snow

	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022
(UTC)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	15	18	21	0	3	6	9	12	15	18	21	0	3	6	9	12	15	18	21	0	3	6	9	12	15	18	21
(EST)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	11	14	17	20	23	2	5	8	11	14	17	20	23	2	5	8	11	14	17	20	23	2	5	8	11	14	17
1.9 MI SW OF RINGGOLD	55.09	52.54	50.22	48.87	47.97	46.87	44.94	43.12	42.44	41.61	41.56	41.18	41.85	42.19	42.19	41.81	40.62	38.50	36.55	35.02	33.94	33.06	30.99	30.27	30.09	28.80	27.61	26.67	25.84	25.09	24.49	29.88	38.48	41.04	32.20	28.80	28.09	27.93	27.57	37.92	48.00	49.89	37.58	33.82	31.91	35.38	36.12	41.11	49.55	49.93
3 MI W OF SUMMERVILLE	51.78	49.68	48.15	47.21	46.58	44.15	41.88	41.14	40.64	41.27	42.51	42.95	44.51	44.94	44.04	41.99	40.73	37.71	35.46	34.18	33.55	33.40	31.30	29.92	29.17	28.65	27.88	27.41	26.80	26.26	25.41	30.96	40.41	42.58	32.36	29.44	28.51	28.58	28.22	37.35	47.05	50.02	37.62	34.39	33.15	36.99	37.26	41.82	49.48	48.90
IN SOUTH EAST CALHOUN	56.66	53.56	51.40	50.05	48.79	47.71	46.60	46.28	45.68	45.14	45.72	45.54	44.42	44.08	44.46	43.86	42.60	41.22	39.51	37.60	36.00	34.66	33.15	31.35	30.24	29.80	29.07	28.13	27.16	26.38	25.68	30.81	40.35	43.20	33.22	29.89	30.15	30.25	29.59	39.42	48.20	50.22	38.28	34.41	37.89	38.73	38.26	41.04	48.70	51.60
2.7 MI S OF EMERSON	59.94	57.34	53.64	51.06	49.73	49.62	47.75	44.71	43.77	44.10	43.81	44.38	45.18	45.10	44.92	44.74	43.81	42.64	40.93	38.91	36.93	35.62	34.47	32.85	31.12	29.98	29.25	28.72	27.88	27.01	26.37	31.26	40.78	44.10	34.41	32.05	32.51	33.35	31.77	38.79	47.91	51.03	40.48	40.87	41.59	40.80	40.08	41.40	45.88	49.84
3.2 MI NE OF CANTON	60.12	58.92	55.47	52.02	50.38	49.78	48.24	45.90	45.07	45.19	44.83	45.57	45.57	44.46	42.76	43.00	41.99	40.75	39.56	38.08	35.71	33.71	32.09	30.92	29.93	29.01	28.42	28.09	28.11	27.66	26.80	33.89	44.35	47.43	34.65	32.94	32.04	30.76	29.91	37.71	47.07	49.32	37.69	37.11	38.86	38.23	37.98	40.26	45.14	49.48
2.5 MILES EAST OF SUWANEE	61.63	60.84	60.33	58.66	55.94	53.65	53.22	52.34	47.86	47.64	48.22	48.96	49.23	49.19	48.20	46.31	45.27	44.04	42.69	41.05	39.85	38.10	35.85	34.45	33.30	32.47	31.93	31.35	30.49	30.65	30.51	35.85	45.81	48.70	40.78	37.04	33.71	31.24	30.11	37.11	46.47	49.50	42.29	41.92	41.07	40.12	39.85	40.05	42.78	47.95
4.5 MI S OF TALLAPOOSA	56.88	54.75	51.89	49.96	49.26	49.05	45.90	42.78	41.52	41.79	42.03	43.25	42.64	43.81	42.62	42.26	40.93	39.38	38.39	37.26	35.60	34.29	33.22	30.97	29.35	28.22	27.63	27.10	26.69	26.44	26.49	31.66	40.69	43.36	33.55	30.70	30.60	31.06	30.22	39.09	48.69	51.03	39.04	39.29	38.91	38.84	39.24	41.43	49.50	48.15
1.5 MI S OF ATHENS SQ	62.37	63.05	62.55	62.14	62.38	59.54	57.97	57.32	56.79	53.21	49.91	50.05	51.72	52.57	52.41	50.20	48.13	46.02	45.00	43.92	42.80	41.14	39.27	38.61	36.73	35.22	34.66	33.71	32.70	31.59	30.60	38.26	47.92	48.97	39.02	34.84	32.04	28.96	28.49	38.35	47.98	50.25	41.99	41.81	41.31	40.22	40.01	40.64	42.94	45.79
IN ATLANTA	62.76	61.77	59.95	58.71	56.52	55.60	55.02	53.31	48.61	47.91	48.18	49.10	49.30	49.60	48.12	47.86	46.87	46.20	45.32	43.77	41.74	39.85	38.55	36.97	35.40	34.03	33.01	32.25	31.51	31.06	30.74	34.47	44.08	48.78	43.32	40.15	38.07	35.19	33.12	38.61	48.20	52.07	48.20	46.13	44.56	43.77	43.05	42.82	45.28	49.24
2 MI W OF STOCKBRIDGE	62.05	62.71	62.39	61.34	58.28	57.21	56.46	55.67	53.08	49.87	48.58	49.37	49.91	51.12	48.70	48.13	46.89	45.70	44.94	44.01	42.60	40.62	38.82	37.78	36.27	35.06	33.87	33.12	32.04	31.59	31.17	36.21	45.19	49.14	41.38	37.83	35.08	32.50	30.63	38.46	48.60	50.61	45.30	43.72	43.00	42.10	41.77	42.58	45.90	48.00

4-Day Precipitation Forecast (based on OpenWeather)

Rain | Snow | None

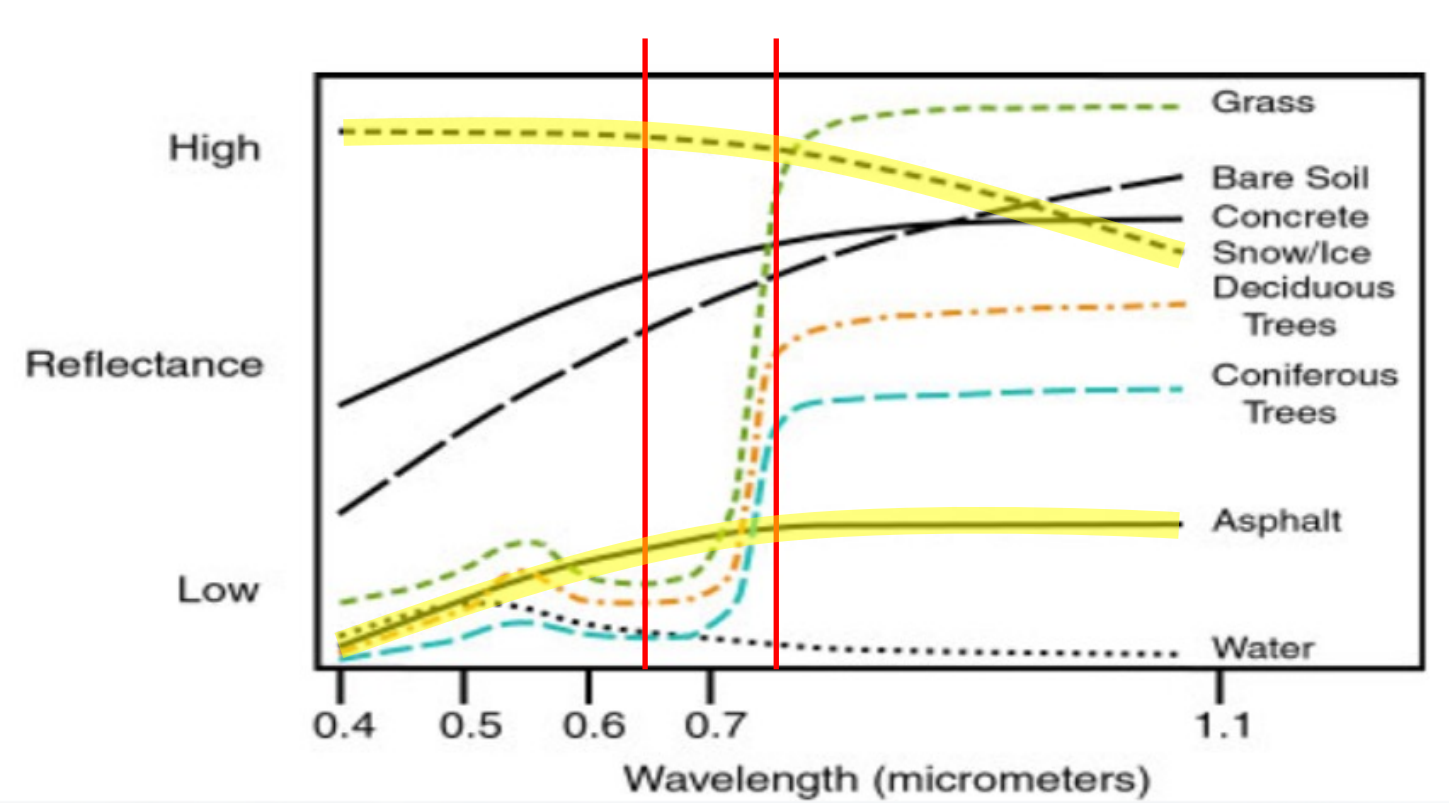
	Su, 2/13/2022	Su, 2/13/2022	Su, 2/13/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	M, 2/14/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	Tu, 2/15/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	W, 2/16/2022	Th, 2/17/2022	Th, 2/17/2022	Th, 2/17/2022	Th, 2/17/2022	Th, 2/17/2022	Th, 2/17/2022
(UTC)	15	18	21	24	3	6	9	12	15	18	21	24	3	6	9	12	15	18	21	24	3	6	9	12	15	18	21	24	3	6	9	12	15	18	21	24	6	9	12	15
(EST)	11	14	17	20	23	2	5	8	11	14	17	20	23	2	5	8	11	14	17	20	23	2	5	8	11	14	17	20	23	2	5	8	11	14	17	20	2	5	8	11
1.9 MI SW OF RINGGOLD																													0.11 mm				1.35 mm						
3 MI W OF SUMMERVILLE																																	0.16 mm	3.02 mm					
IN SOUTH EAST CALHOUN																													0.11 mm				0.14 mm	2.19 mm					
2.7 MI S OF EMERSON																																		1.09 mm					
3.2 MI NE OF CANTON																																		1.12 mm					
2.5 MILES EAST OF SUWANEE																																	0.11 mm						
4.5 MI S OF TALLAPOOSA																												0.13 mm						0.87 mm				
1.5 MI S OF ATHENS SQ																															0.11 mm		0.19 mm						
IN ATLANTA																																							
2 MI W OF STOCKBRIDGE																												0.11 mm											

Task 2 Validation of the Ice Formula

- 1st time that an unmanned aerial vehicle (UAV)-based hyperspectral sensor will be used for road ice detection.
- High-risk drone-based remote sensing technology.
- Challenge to distinguish snow, ice, dry and wet roads with remote sensor.

Task 2 Validation of the Ice Formula

- Road Ice Index θ = (NIR-RED)/(NIR+RED)

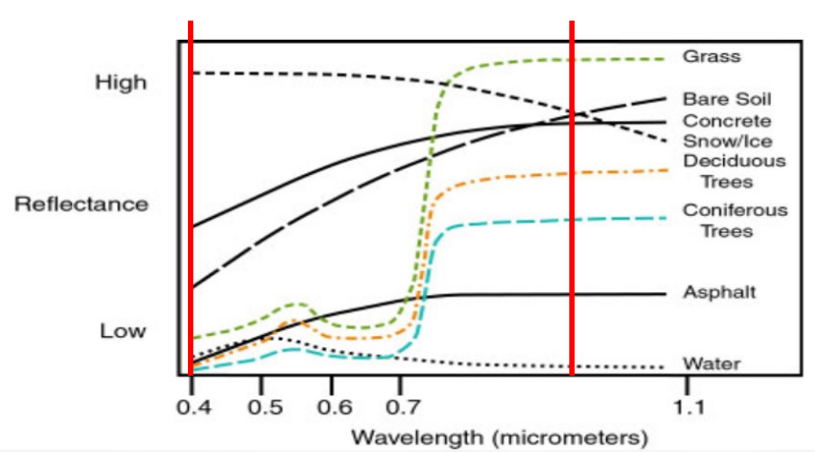


Task 2 Validation of the Ice Formula

- Data collection
  - Sensors
  - Data Collections
  - Experimental Setup
  - Data Analysis Methods
- Results
  - Sub-Zero Lab
  - Airport
  - UM Campus UAS Flight
- Implementations
  - Conclusion
  - Implementation
  - Cost
  - Barriers

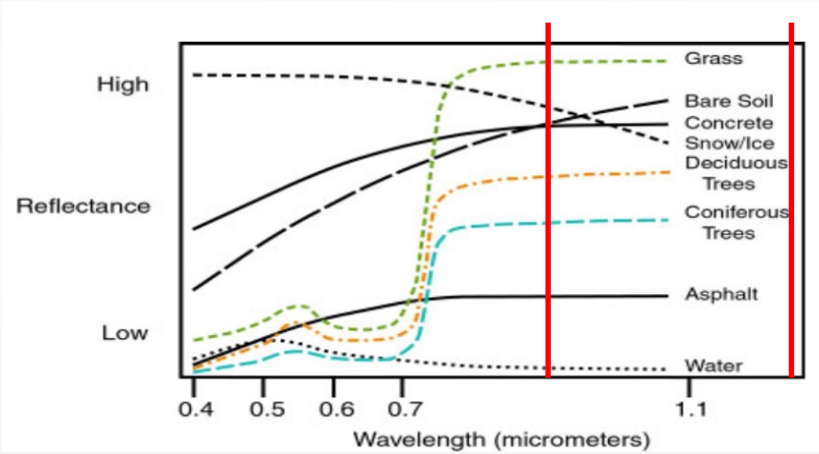
Sensor

- Pika L
  - 400-1000 nm
  - 2.1 nm band
  - 281 channels
  - 1.55 kg (3.41 lbs.)



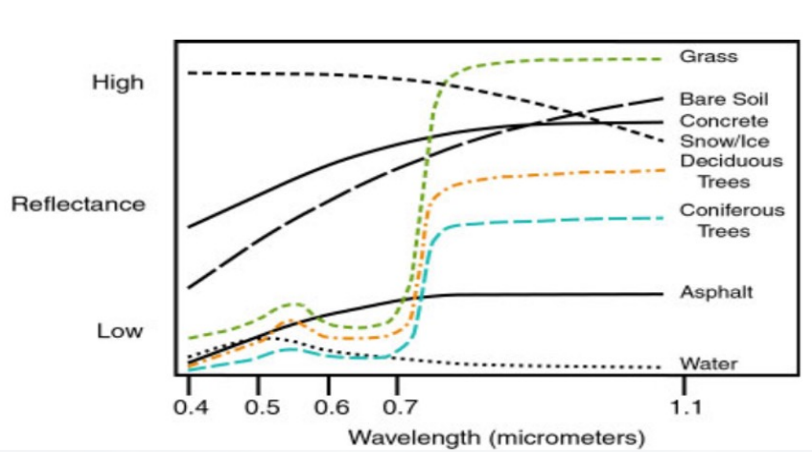
Sensor

- Pika NIR-320
  - 900-1700 nm
  - 4.9 nm band
  - 164 channels
  - 4.31 kg (9.50 lbs.)



Sensor

- ADS FieldSpec 3
  - 350-2500 nm
  - 2nm band
  - 2151channels
  - 5.44 kg (11.99 lbs.)
    - without computer



Data Collection

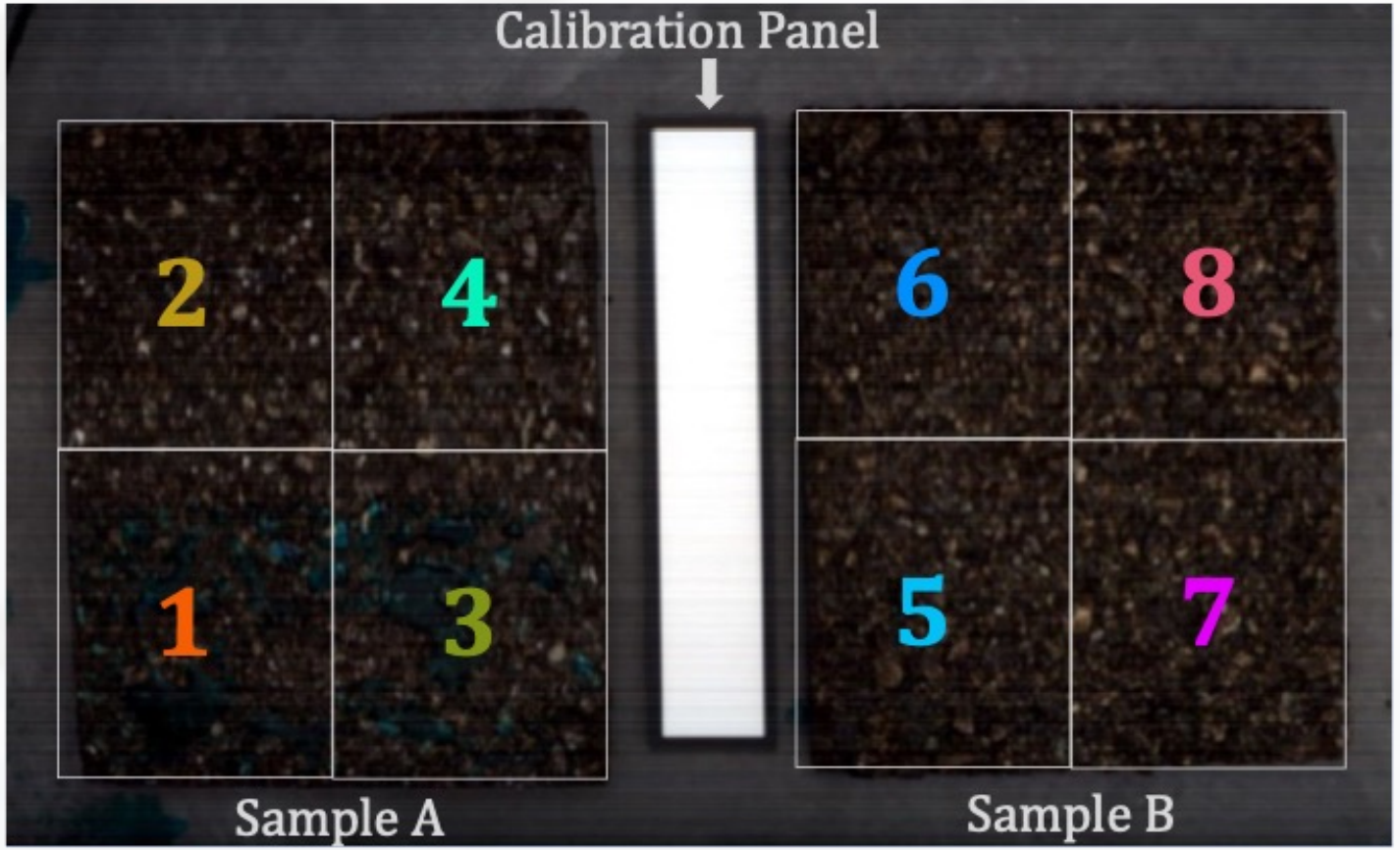
- Montana State University, Sub-zero Lab
  - Pika L
  - NIR 320
- Missoula International Airport, Runway 26/8
  - Pika L
  - ADS FieldSpec 3
- University of Montana
  - M-600 UAS
  - Pika L

Experimental Setup

- Sub-Zero Lab
  - -4.4°C up to 4.4°C
    - 2° increments
  - Pika L
  - NIR 320

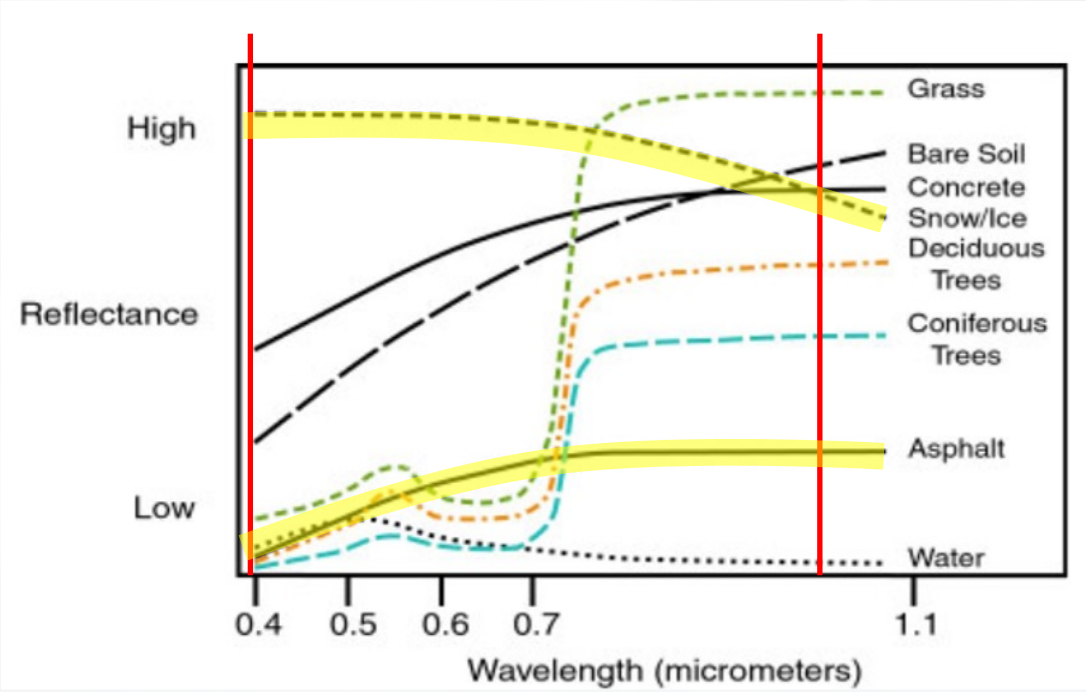
Experimental Setup

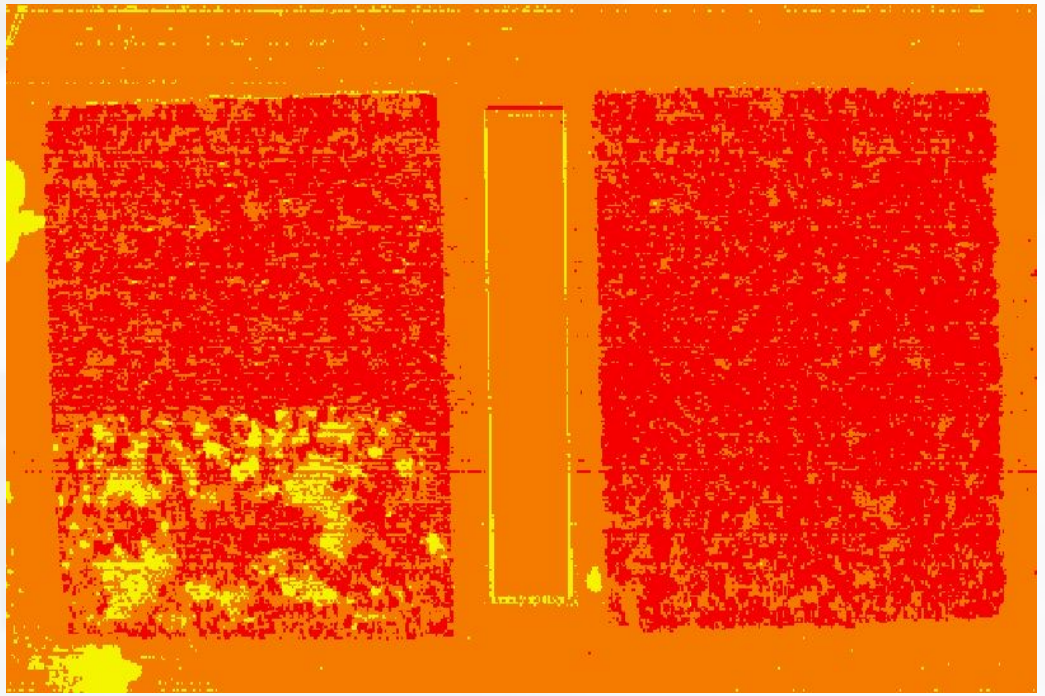
- Sub-Zero Lab
  - Sample Preparation
  - Numbering is for reference only



Data Analysis Methods

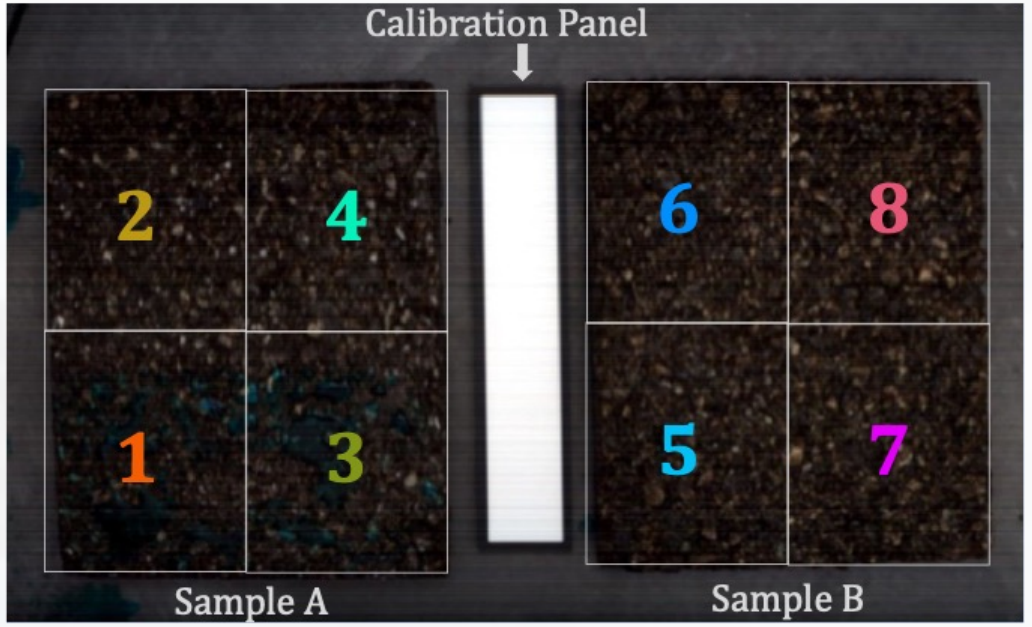
- Road Ice Index θ= (1025nm-389nm)/(1025nm+389nm)





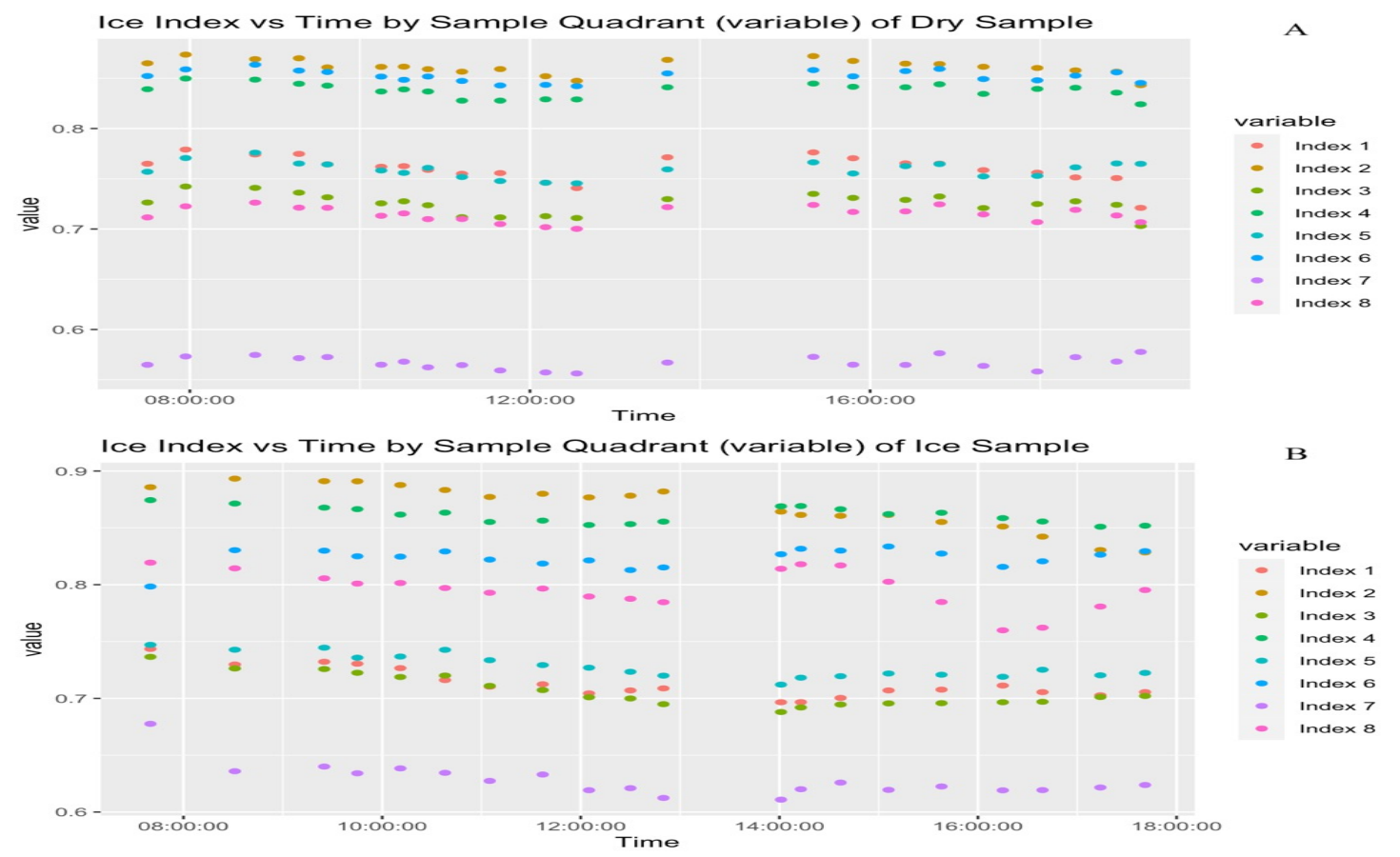
Data Analysis Methods

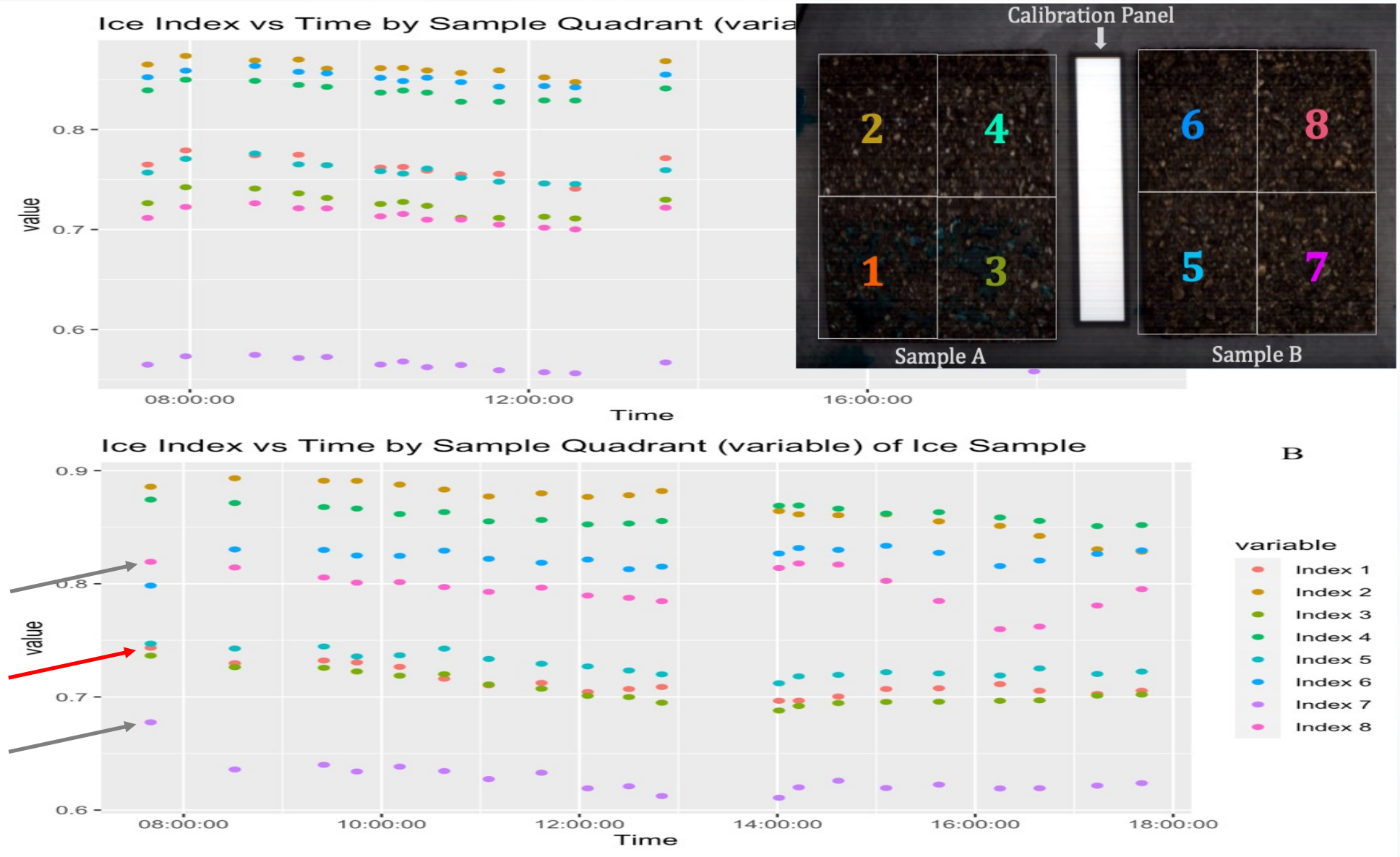
- Principal Component Analysis
  - Hyperspectral
- Python
  - https://github.com/jfowler9/MDT_Icy_Roads.git
  - Data cube
  - Pulls specific wavelengths
  - Remove calibration panel
  - Runs index and averages by quadrant



Results

- Road Ice Index θ = (NIR-RED)/(NIR+RED)

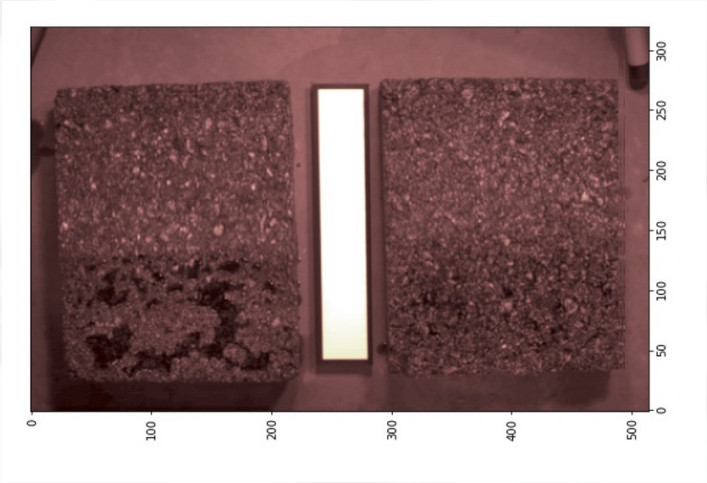


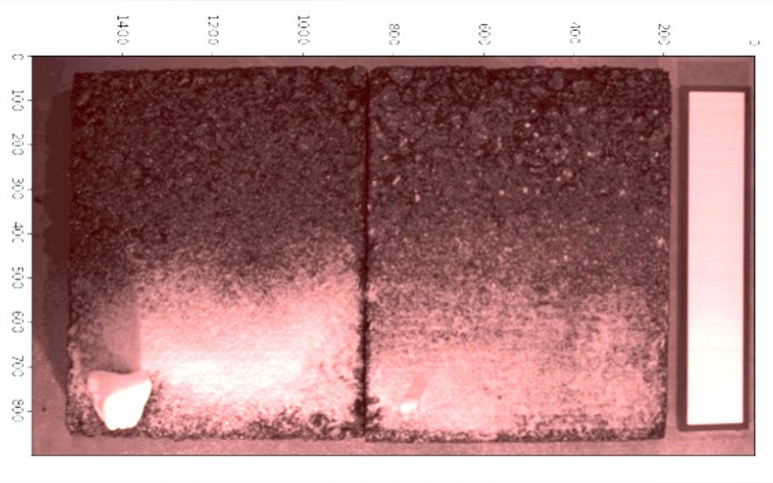

Ice Index vs Time by Sample Quadrant (varia
value
0.8
0.7
0.6
08:00:00
12:00:00
16:00:00
Time
Calibration Panel
2
4
6
8
1
3
5
7
Sample A
Sample B
Ice Index vs Time by Sample Quadrant (variable) of Ice Sample
B
value
0.9
0.8
0.7
0.6
08:00:00
10:00:00
12:00:00
14:00:00
16:00:00
18:00:00
Time
variable
Index 1
Index 2
Index 3
Index 4
Index 5
Index 6
Index 7
Index 8

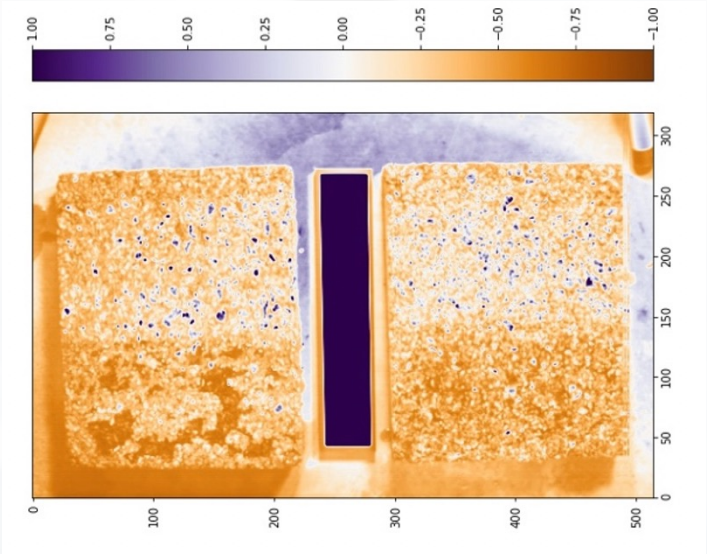
-4° → 4° → -4°

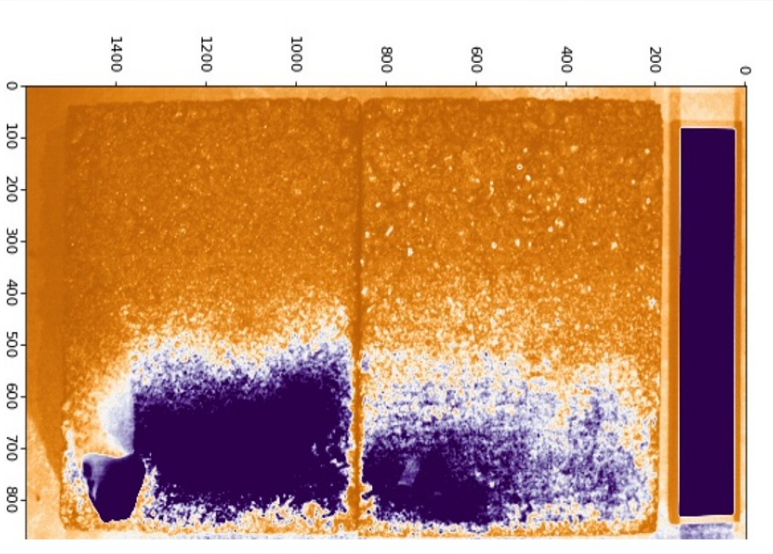
Results

- Pika L
  - 400-1000 nm
- PCA
  - Resonon
  - ArcGIS
  - Python



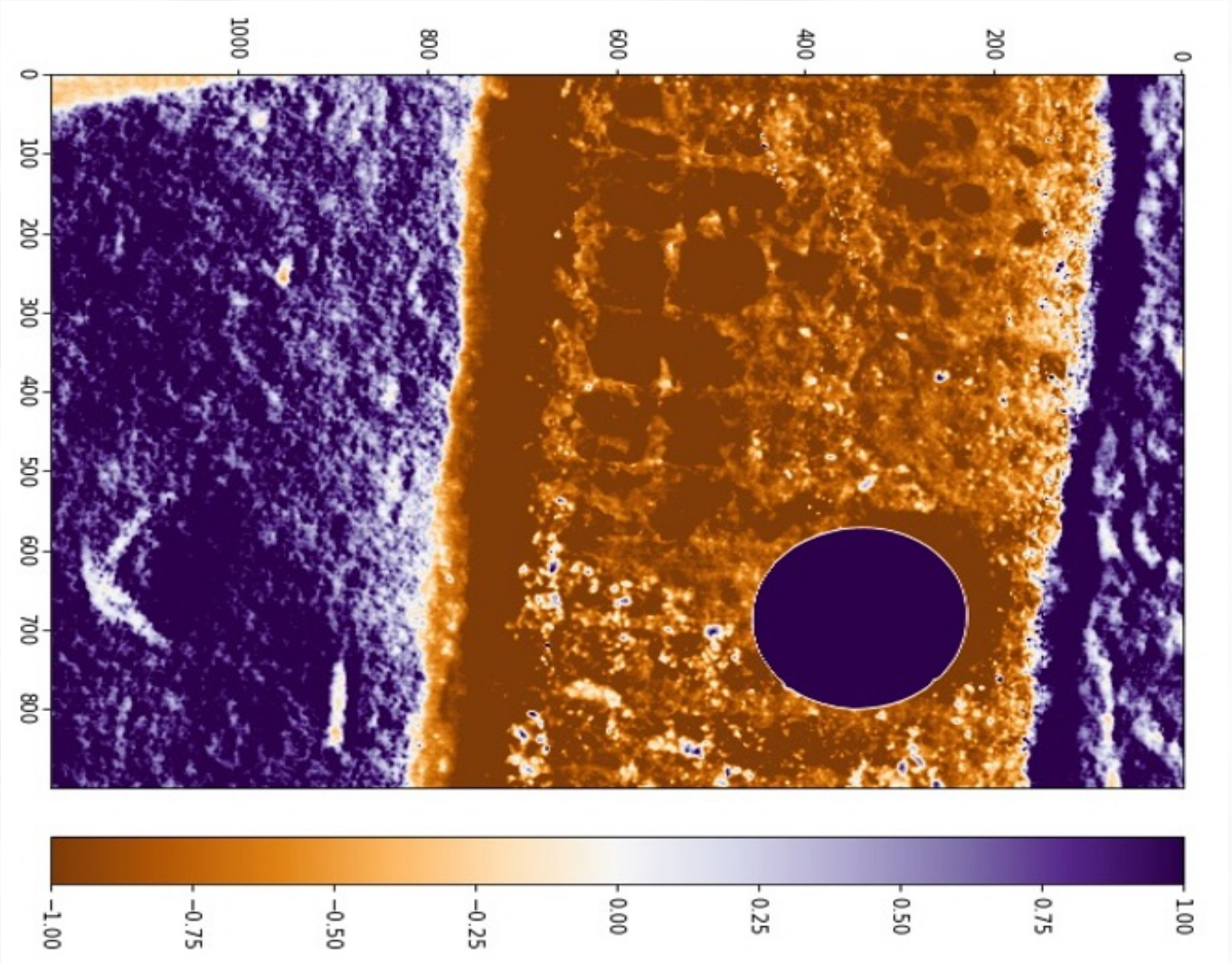






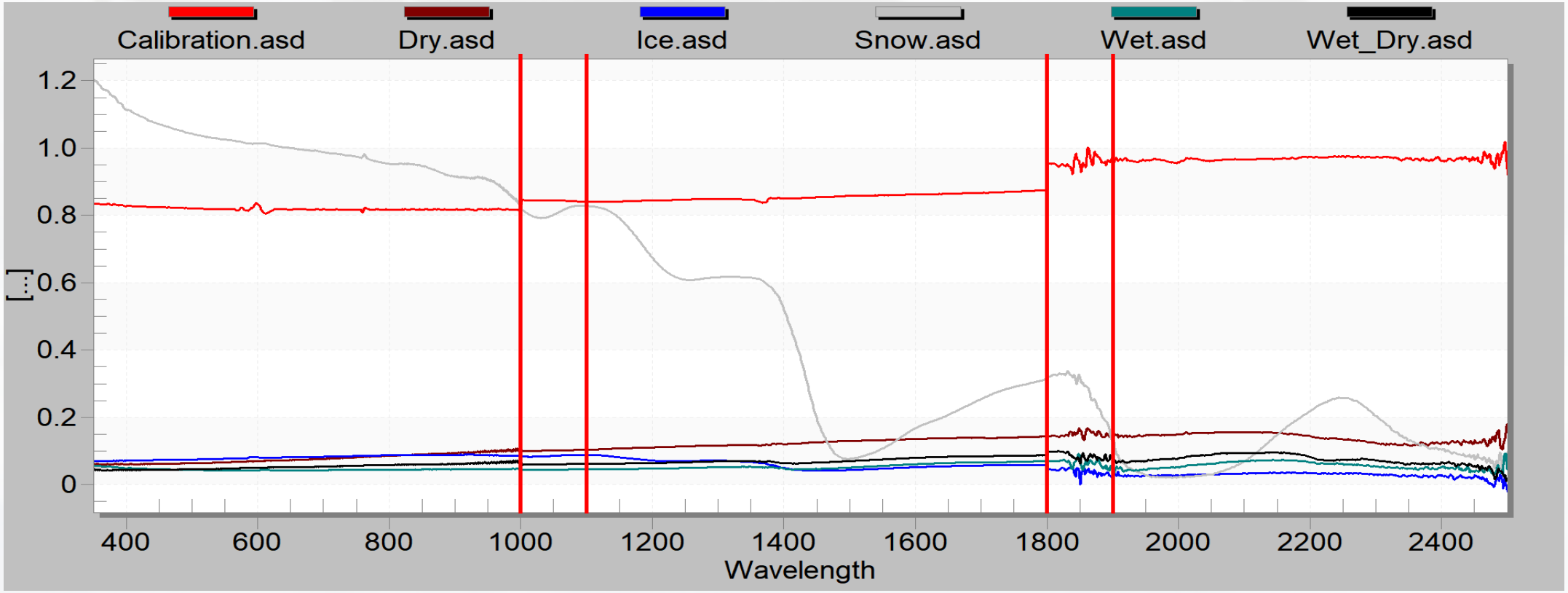
Airport

- Pika L
- PCA



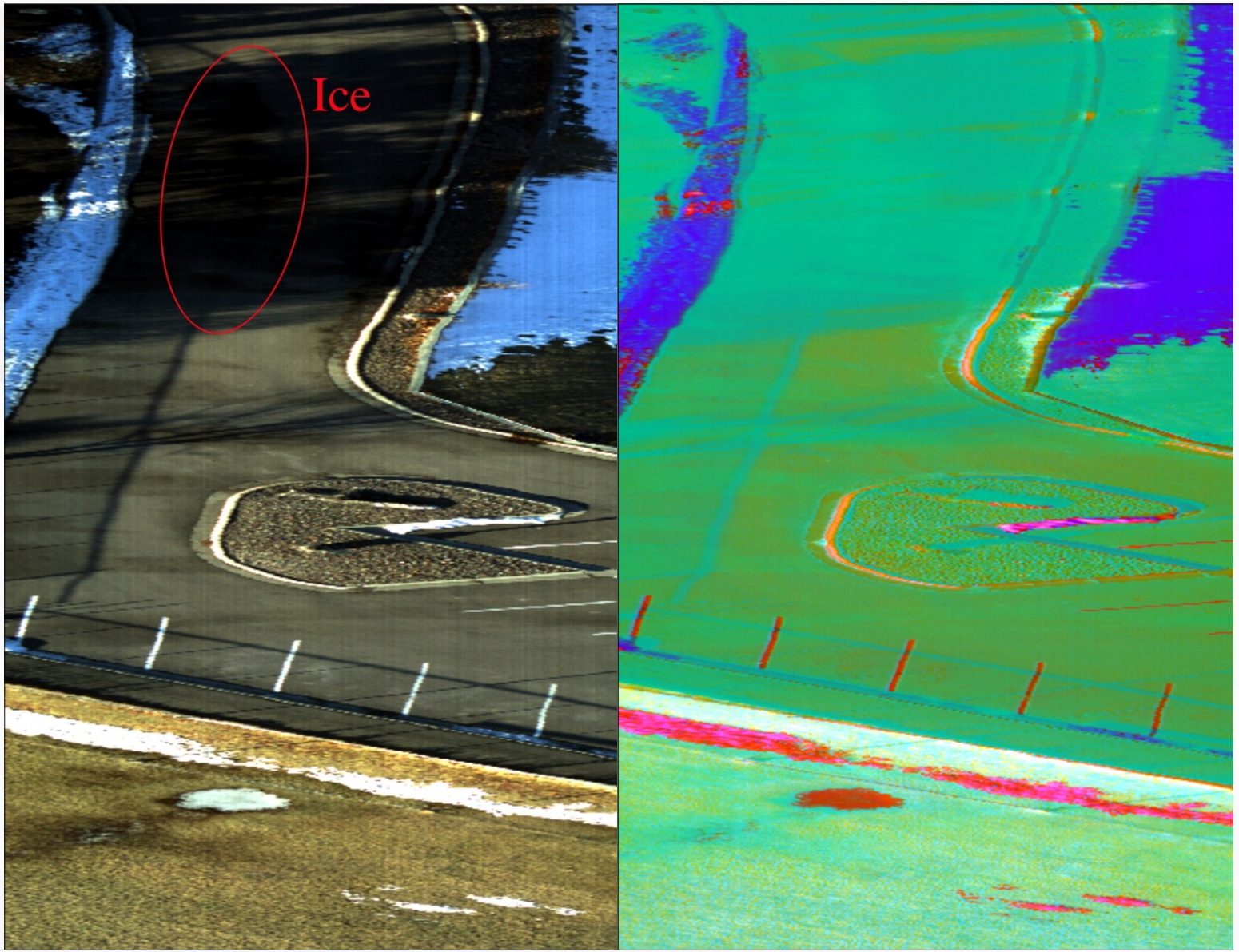
Airport

- ASD Spectrometer
  - 350-2500 nm



UM UAS Flight

- Pika L
  - 400-1000 nm
- No visible ice



Conclusion

- Road Ice Index θ = (NIR-RED)/(NIR+RED) is not definitive in this study
- Pika L is capable of differentiating
  - Dry asphalt/water/snow/ice
  - PCA/Supervised classification/Road Ice Index*
- ADS Spectrometer shows some promise in specific bands
  - 1,000 -1,100 nm
  - 1,800 – 1,900 nm

Implementation

- Equipment
  - Hyperspectral Sensor
  - Platform
  - Computing/Storage
- Personnel
- Training/Certification
  - Program Specific
  - FAA Licensing

Cost

- Cost ~$42,000 per unit
- Personnel
  - Training
  - Certification (Part 107)
- Liability
- FAA regulation/waivers
  - Flights over people and vehicles
  - BVLOS

Barriers to Implementation

- Cost per unit ($42K)
- High risk of UAS failure due to propeller icing
- Flight time
- Flight distance (line of sight)
- Data storage/processing/availability
- Work force
- FAA Regulations

Possible Future Directions

- Sensor Platforms
  - Stationary
  - Ground Vehicles
- PCA of hyperspectral data
- Machine Learning
  - Training Data
- Passive Sensor vs Active Sensor

Questions?