Feasibility Study on Friction Mapping

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1. INTRODUCTION

Effective and efficient winter maintenance

- Correct understanding of road surface conditions is essential

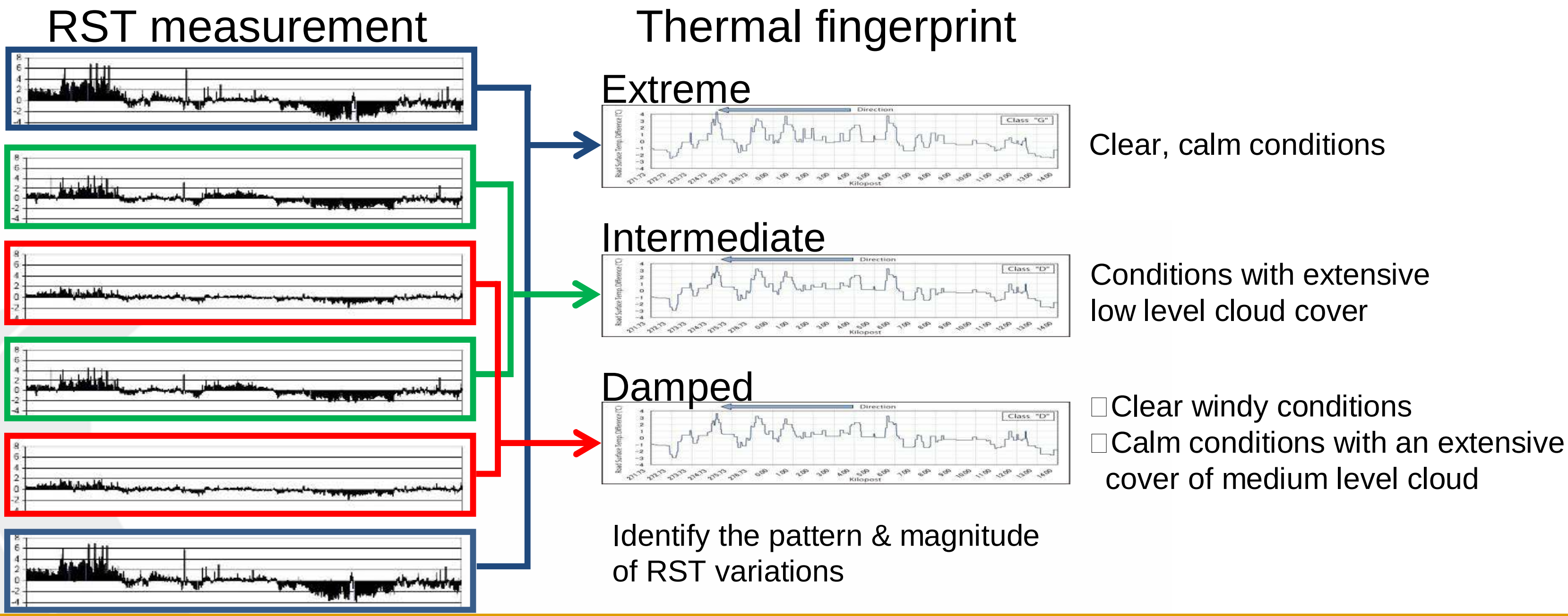
Thermal mapping

−Evaluate and refine chemical treatment strategies

−Measuring RST across an entire route

−Patterns of RSTs are reproducible (Shao *et al.*, 1996)

−Develops a unique RST pattern (*thermal fingerprint*) for each route



Friction measurement

- Used in the field.
- Various friction-measuring devices have been developed and tested.
- Facilitate planning, Evaluate the effectiveness, Enhance road safety
- Continuous measurement has expanded the use of friction indicators
- Impossible to constantly measure road surface friction

If the distribution of road surface friction is reproducible, road managers can reduce the need to conduct friction measurement.

Thermal mapping

RST measurement → Thermal fingerprint

Weather conditions

Friction mapping

Friction measurement → Friction fingerprint

Weather conditions

2. STUDY METHOD

Friction mapping ??

Friction measurement → Friction fingerprint

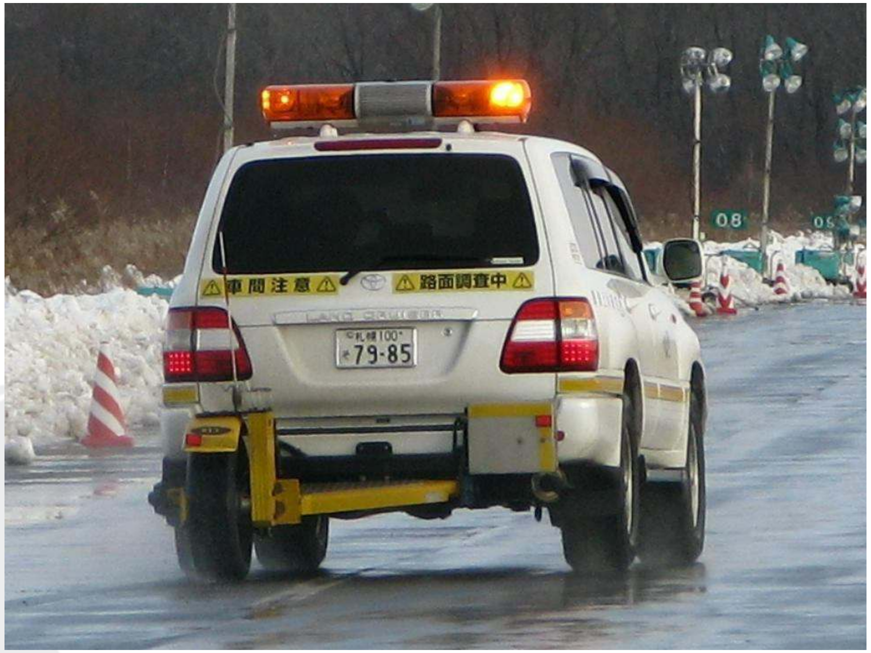
Weather conditions

1. Data collection
2. Verify reproducibility
3. Produce friction fingerprint
4. Verify reproducibility

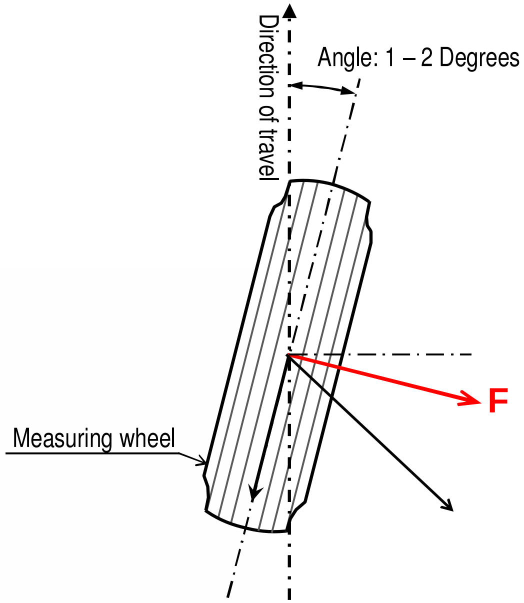
Friction Measuring Device

Continuous Friction Tester (CFT)

□Determine friction value by measuring the axial force on a measuring wheel offset by 1 - 2 degrees from the direction of travel
□Understand spatial changes in road surface conditions
(sampling rate: 10 Hz by default)



Continuous Friction Tester (CFT)



Halliday Friction Number (HFN)

□Ranges from 0 to 100.

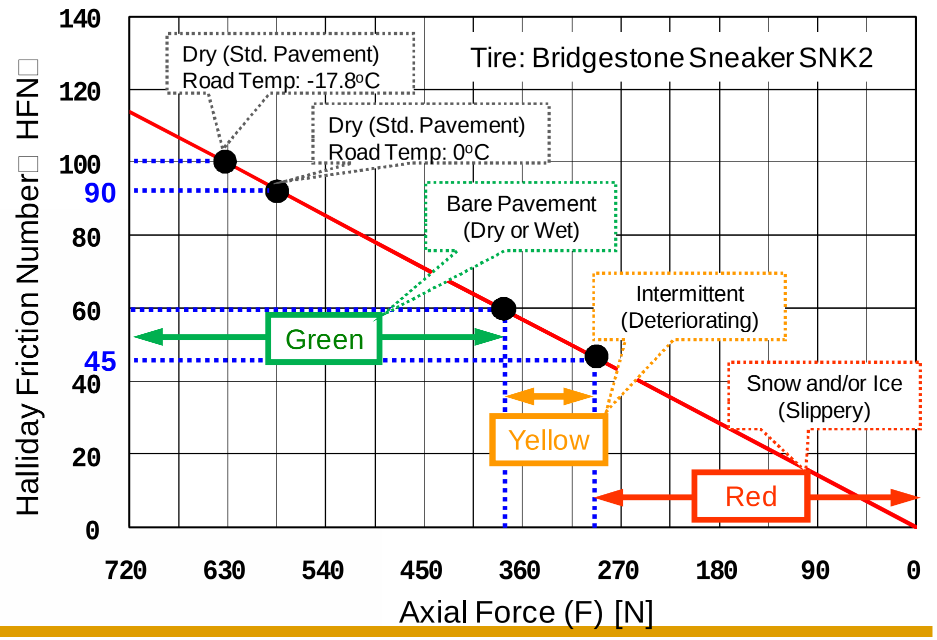
□Linear relationship links HFN values and axial force, and values are lower when the axial force is weaker.

* HFN = 0, no force between the tire and the road

100, lateral force on dry pavement (fine and gap-graded asphalt concrete) at -17.8 degrees Celsius.

□Convertible to coefficient of friction (μ) measured by standard device in Japan (Kiriishi *et al*., 2011)

$$\mu = 0.0124HFN - 0.0529$$



Data Collection

□Case study route:

18-km-long section of expressway in Hokkaido

□Friction Measurements: 92

1.Measurements in autumn: 2

✓ Conducted on a day when there was no snow cover and the road surface was dry

Run 0-1, *Run 0-2*

2.Measurements in winter: 90

✓ 5 days each in early winter (mid-Dec.), mid winter (late-Jan.) , and late winter (late-Feb.).

✓ 6 measurements were conducted each day

Run 1 - *Run 30*

Run 31 - *Run 60*

Run 61 - *Run 90*

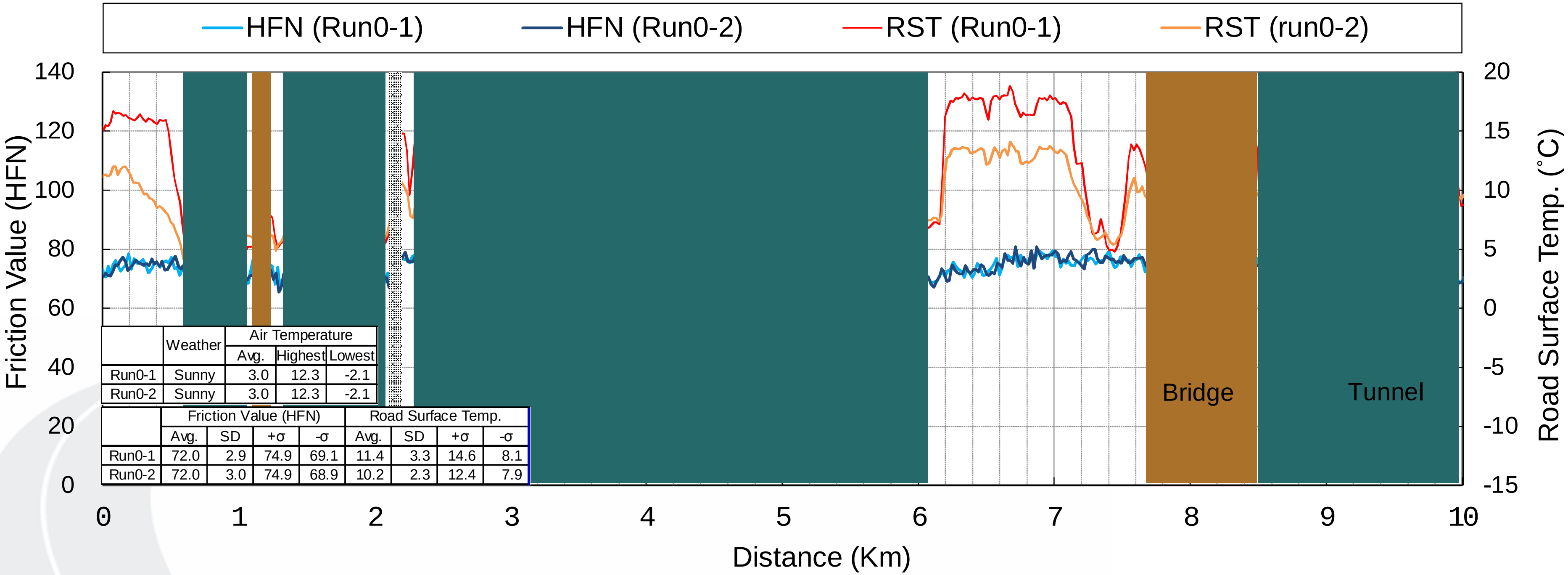
□Measurement start times: 9:30, 13:00, 17:00, 20:30, 00:00, 04:00

* subject to change upon consultation with road managers in relation to snow removal or other work.

3. STUDY RESULTS

Friction Distribution in the Snow-Free Season

- 10 km of the 18-km measurement length is shown for clearer visualization.
- Friction was consistent between the two measurements



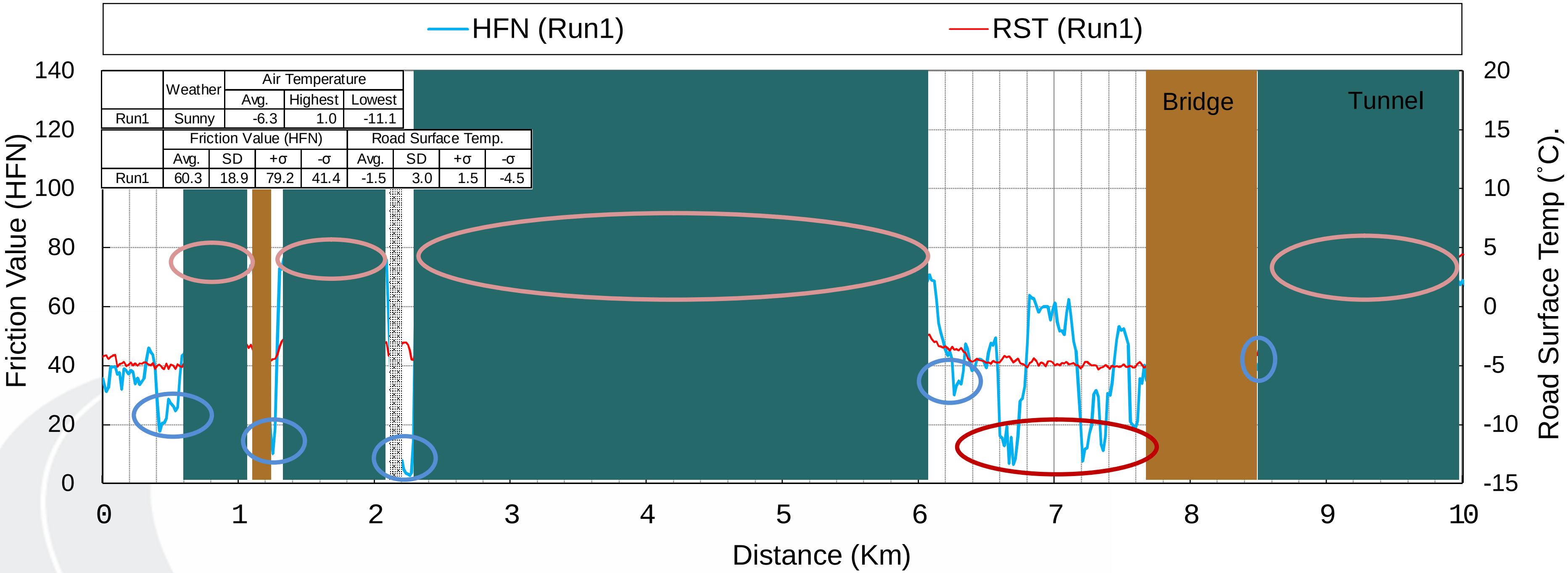
	Weather	Air Temperature		
		Avg.	Highest	Lowest
Run0-1	Sunny	3.0	12.3	-2.1
Run0-2	Sunny	3.0	12.3	-2.1

	Friction Value (HFN)				Road Surface Temp.			
	Avg.	SD	+σ	-σ	Avg.	SD	+σ	-σ
Run0-1	72.0	2.9	74.9	69.1	11.4	3.3	14.6	8.1
Run0-2	72.0	3.0	74.9	68.9	10.2	2.3	12.4	7.9

Measurement results conducted in autumn (Run 0-1, Run 0-2)

Example of Friction Distribution in Winter

- Friction values fluctuated greatly with distance
- Road surface friction was stable inside the tunnel, it was lower near its entrance/exit, at the ends of the bridge and in the cut section



	Weather	Air Temperature		
		Avg.	Highest	Lowest
Run1	Sunny	-6.3	1.0	-11.1

	Friction Value (HFN)				Road Surface Temp.			
	Avg.	SD	+σ	-σ	Avg.	SD	+σ	-σ
Run1	60.3	18.9	79.2	41.4	-1.5	3.0	1.5	-4.5

Example of measurement result conducted in winter (Run 1)

Reproducibility of Friction Distribution

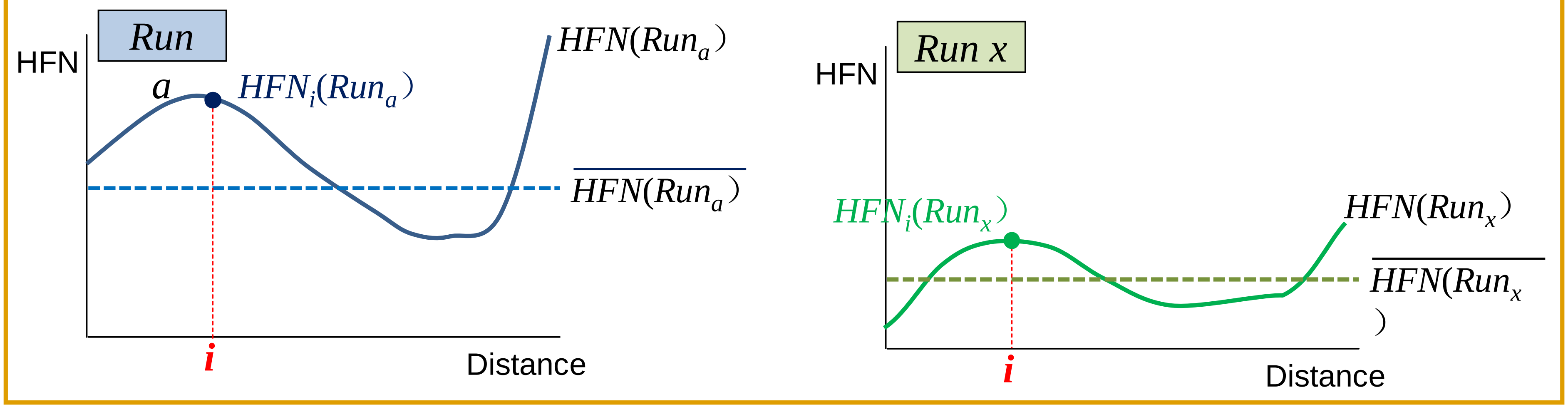
- Road surface friction varies more significantly in winter than in non-winter season
- Does friction distribution have reproducibility like RST under certain conditions?

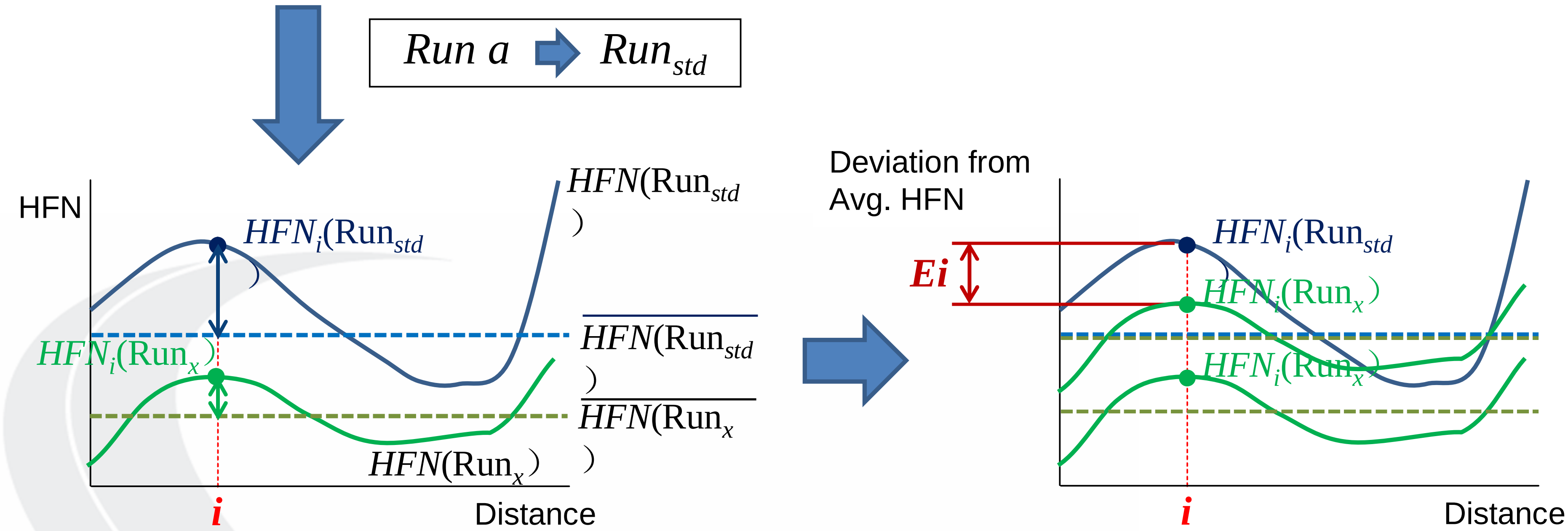
Ei : Difference in friction distribution at point ***i***

$$E_i = HFN_i(\mathrm{Run}_{std}) - HFN_i(\mathrm{Run}_x) - \left\{\overline{HFN(\mathrm{Run}_{std})} - \overline{HFN(\mathrm{Run}_x)}\right\}$$

Run_{std} : standard measurement,
Run_x : control measurement,
$HFN_i(\mathrm{Run}_{std})$: friction at point *i* of Run_{std},
$HFN_i(\mathrm{Run}_x)$: friction at point *i* of Run_x,
$\overline{HFN(\mathrm{Run}_{std})}$: average friction of Run_{std}, and
$\overline{HFN(\mathrm{Run}_x)}$: average friction of Run_x.

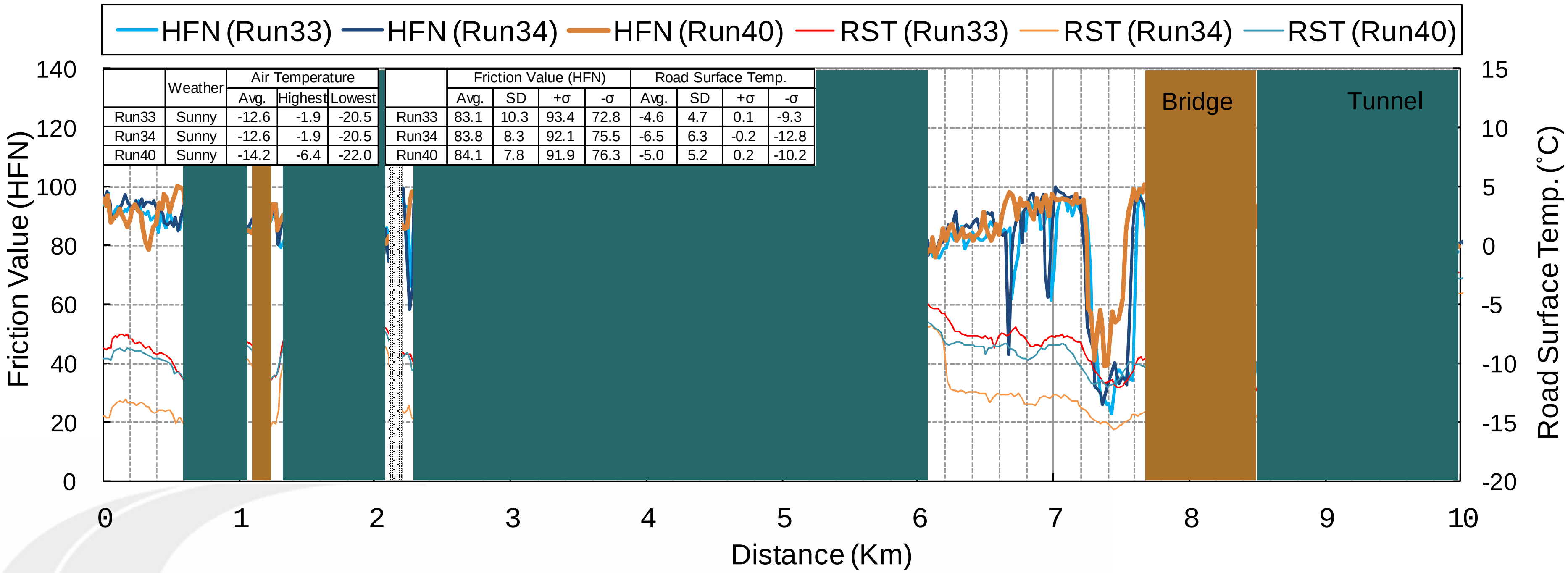
Measurement results conducted under the same condition





Reproducibility of the Surface Friction in the Winter Season

- The large max. and min. error values were partly a result of differences of several to ten meters in points of sudden changes in friction.
- Necessary to determine points where friction changes suddenly



	Weather	Air Temperature Avg.	Air Temperature Highest	Air Temperature Lowest
Run33	Sunny	-12.6	-1.9	-20.5
Run34	Sunny	-12.6	-1.9	-20.5
Run40	Sunny	-14.2	-6.4	-22.0

	Friction Value (HFN) Avg.	SD	+σ	-σ	Road Surface Temp. Avg.	SD	+σ	-σ
Run33	83.1	10.3	93.4	72.8	-4.6	4.7	0.1	-9.3
Run34	83.8	8.3	92.1	75.5	-6.5	6.3	-0.2	-12.8
Run40	84.1	7.8	91.9	76.3	-5.0	5.2	0.2	-10.2

Measurement results from clear days when RST dropped dramatically at night

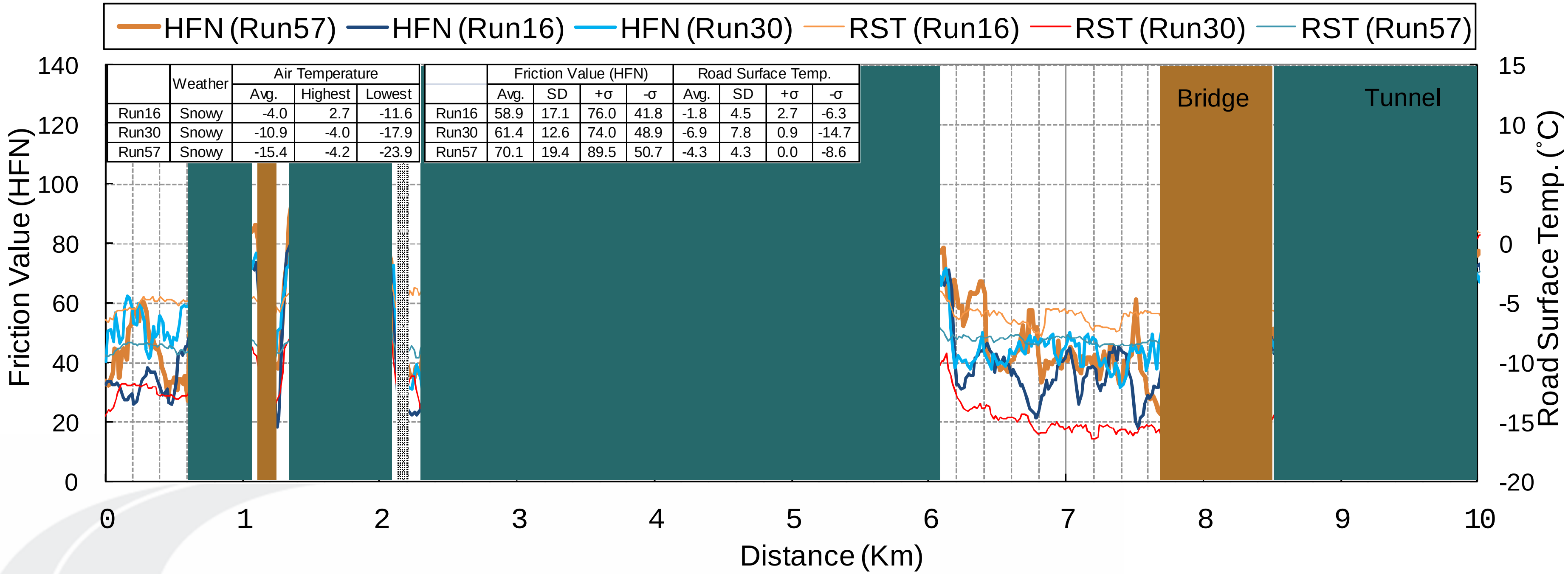
Results of error calculation performed by taking Run 33 as Run_{std}

	Error (HFN)			Appearance Ratio (%)	
	Avg.	Max.	Min.	±6	±12
Run34	0.0	44.3	-50.1	90.6	96.2
Run40	0.0	32.0	-60.4	83.7	94.0

Reproducibility of friction data on snowy days without sunshine

□The margin of error was larger and the percentage of data within a ±6 margin of error on the HFN scale fell to 70%

□Approx. 90% of data are still within a ±12 margin of error



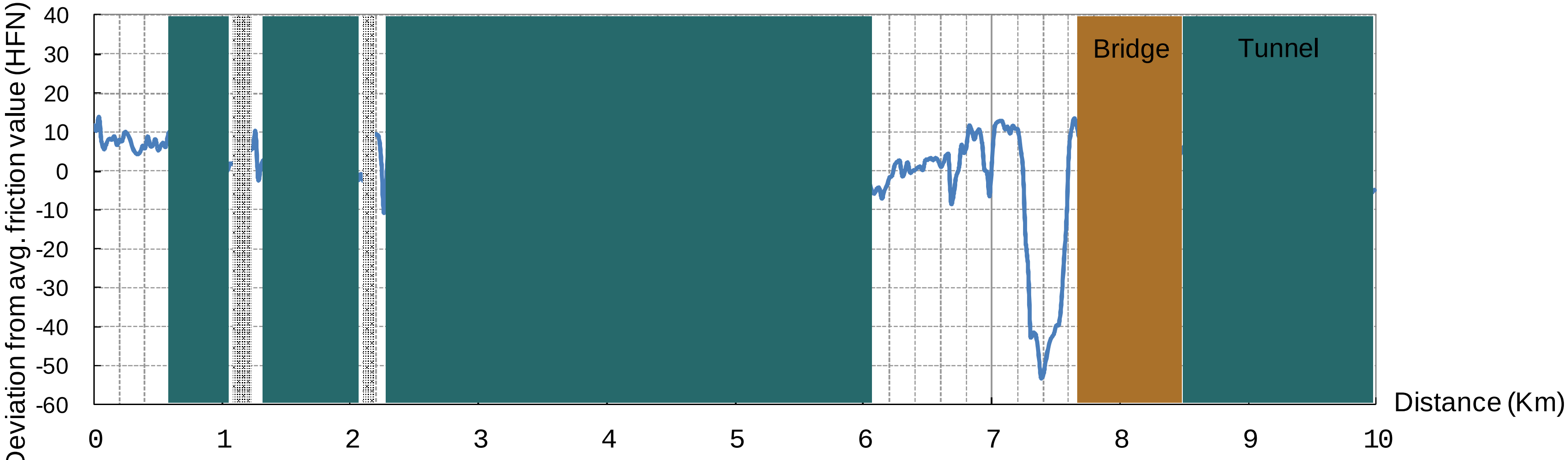
Measurement results from snowy days without sunshine

Results of error calculation performed by taking Run 16 as Run_{std}

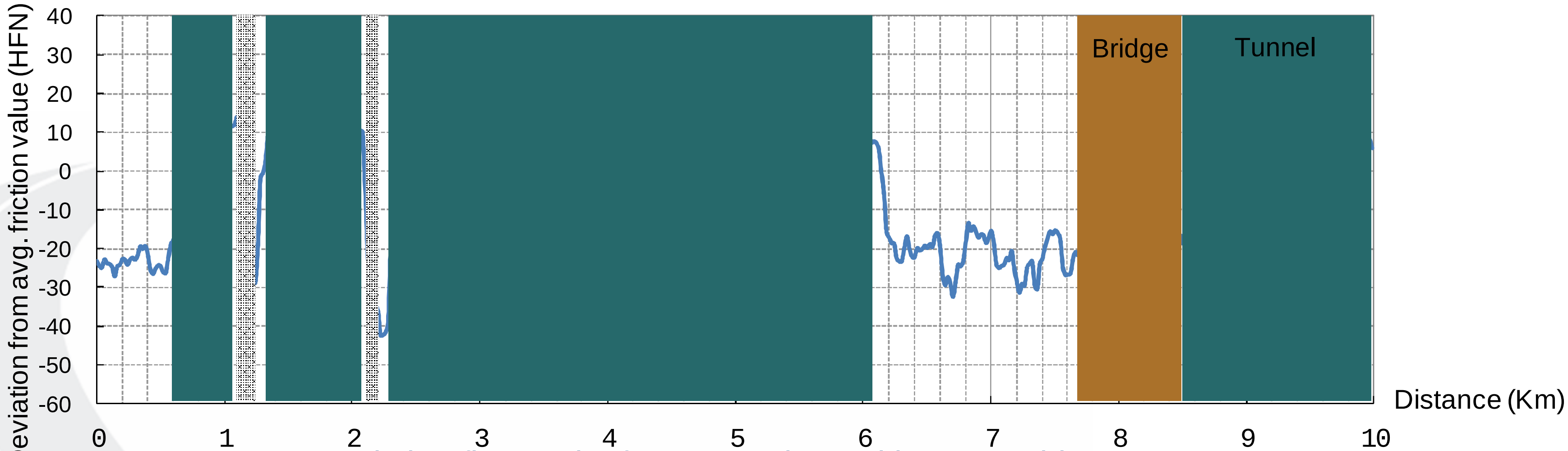
	Error (HFN)			Appearance Ratio (%)	
	Avg.	Max.	Min.	±6	±12
Run30	0.0	35.5	-32.4	72.4	90.4
Run57	0.0	28.9	-28.5	77.6	90.8

Production of Friction Fingerprints

−Averaging the deviation from the avg. friction for each measurement.



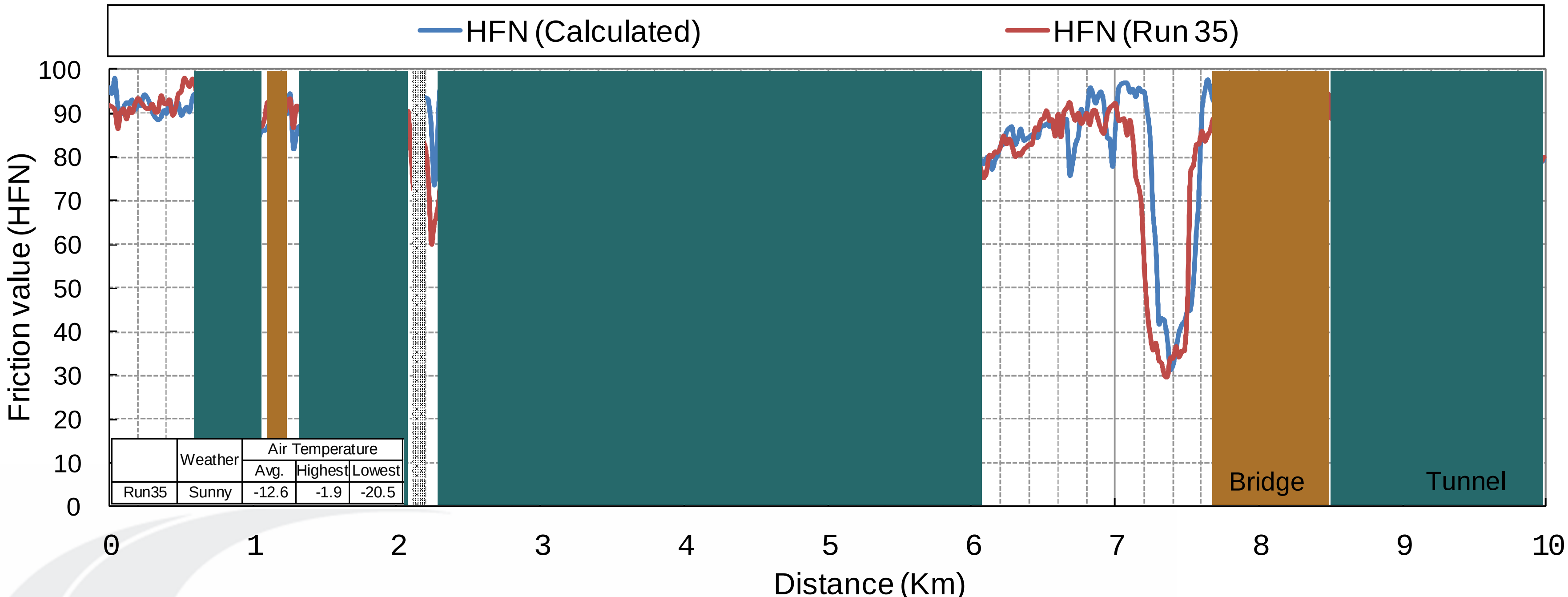
Friction fingerprint for cases where the weather is clear and RST drops dramatically at night



Friction fingerprint for snowy days without sunshine

Reproducibility of the Friction Fingerprints (1)

- Verified by comparing the results with those of Run 35.
- Calculated friction values were determined by adding the avg. friction value of Run 35 to the friction fingerprint



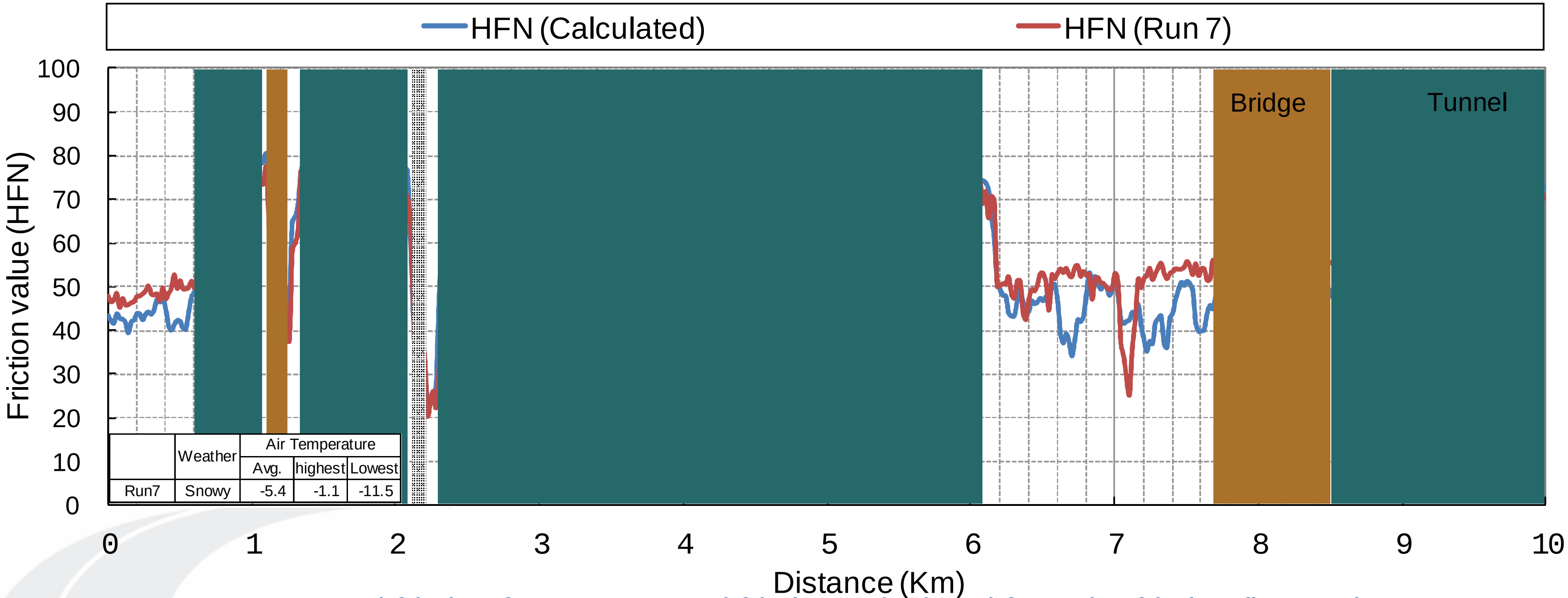
Measured friction from Run 35 and calculated friction from the friction fingerprint for cases where the weather is clear and RST drops dramatically at night

Results of error calculation performed by taking the calculated friction values as Run_{std}

	Error (HFN)			Appearance Ratio (%)	
	Avg.	Max.	Min.	±6	±12
Run35	0.0	31.5	-45.8	86.0	95.8

Reproducibility of the Friction Fingerprints (2)

- There is some margin of difference in friction values, the friction values show a similar distribution.
- Calculated friction values also show high reproducibility.



Measured friction from Run 7 and friction calculated from the friction fingerprint for snowy days without sunshine

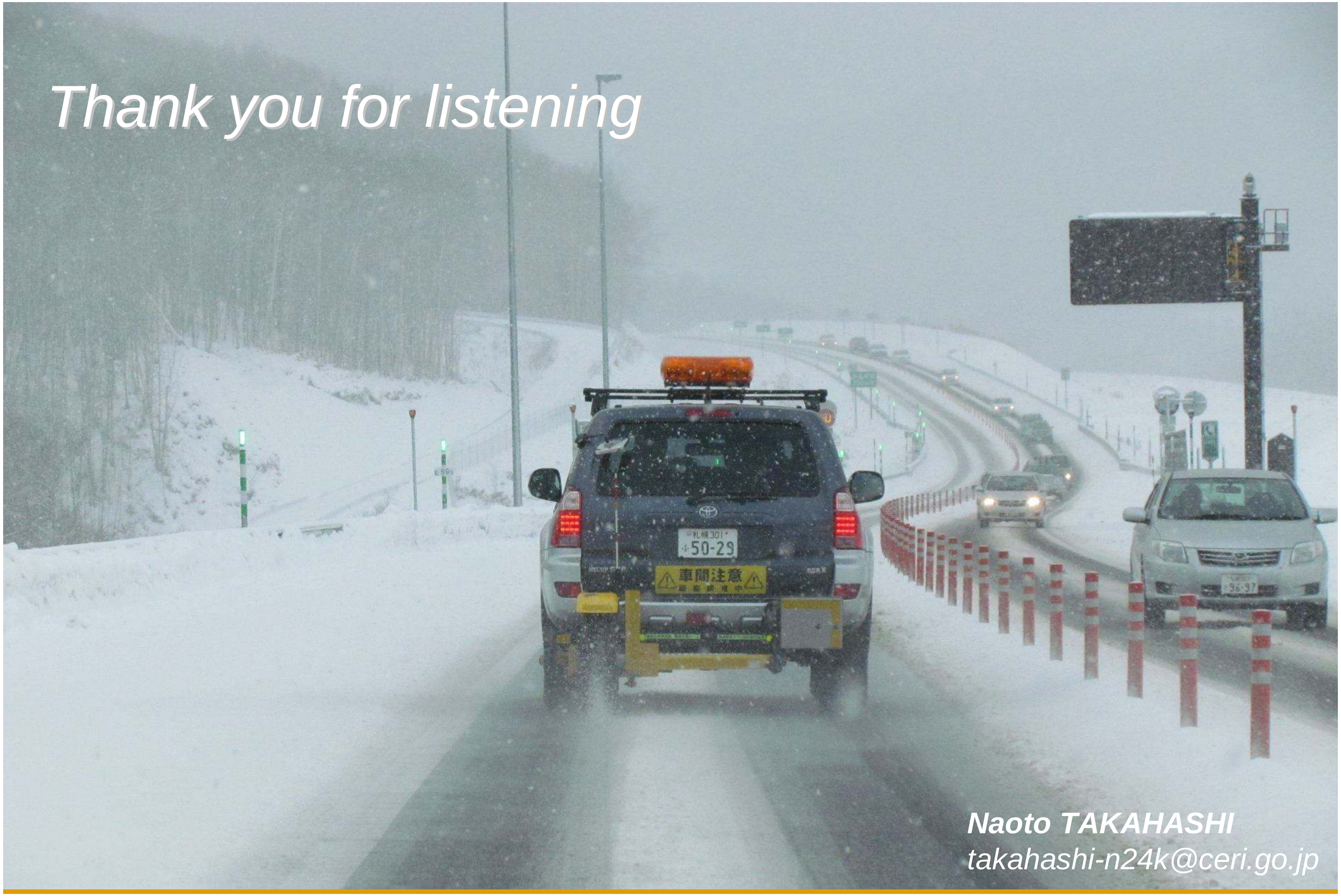
Results of error calculation performed by taking the calculated friction values as Run_{std}

	Error (HFN)			Appearance Ratio (%)	
	Avg.	Max.	Min.	±6	±12
Run7	0.0	18.3	-16.9	86.6	95.6

4. CONCLUSIONS

- Reproducibility of friction distribution was verified.
- It was confirmed that the friction distributions show high reproducibility even in winter under similar conditions.
- It was also found that the friction value derived from the friction fingerprints produced using friction data collected under snowy conditions also shows high reproducibility.
- The conditions under which the reproducibility of friction data was confirmed are limited, it was confirmed that creating friction fingerprints is effective in estimating the distribution of road surface friction.
- The authors plan to further accumulate and analyze friction data to clarify and schematize the conditions under which the distribution of friction data is reproducible.

Thank you for listening



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