HOKKAIDO UNIVERSITY

Investigation of Road Visibility Conditions using Precipitation Intensity measured by Weather Radar during Winter Seasons

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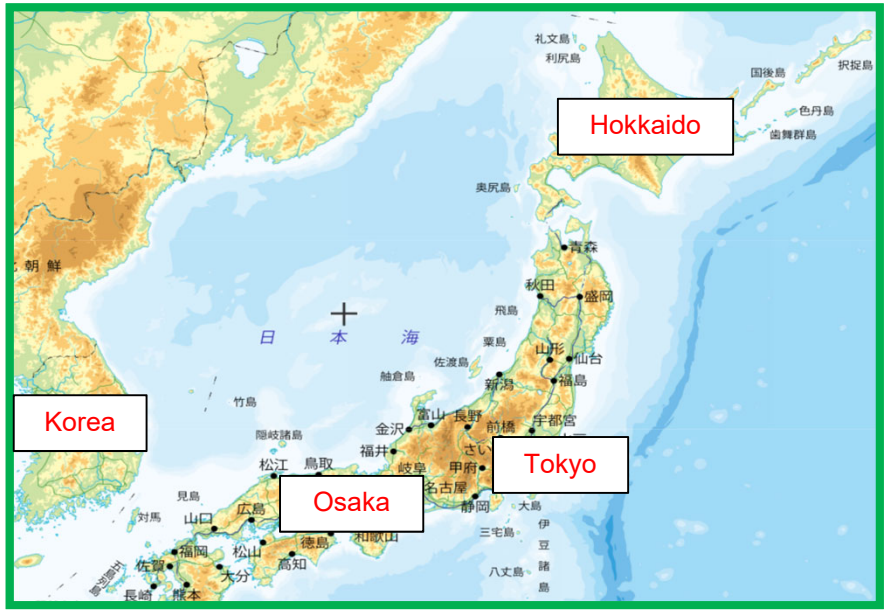
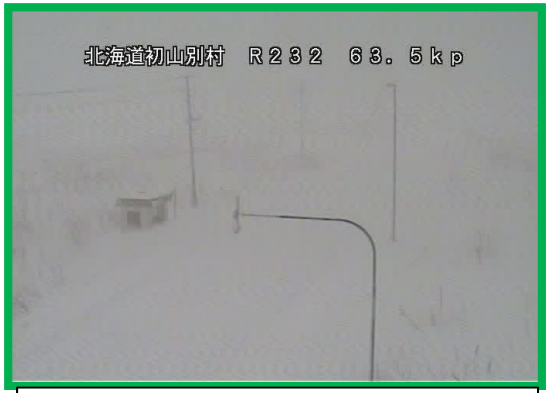
Introduction

- In Hokkaido, Japan, poor road visibility occurs during winter season.
- The risk of traffic restriction and crash increases. [1], [2]
- Poor road visibility suddenly occurs and changes rapidly.
- Quantitative evaluation is difficult.



Clear visibility condition



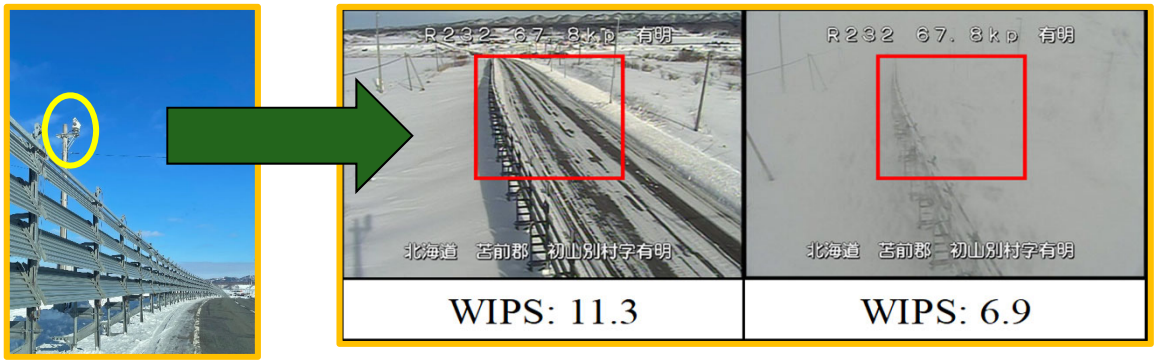
Poor road visibility condition

[1] Kajiya, Y., Kaneda, Y. and Tanji, K.: Factors Inducing Multi-vehicular Collisions During Visibility Reduced by Blowing snow, Transportation Research Record: Journal of the Transportation Research Board, Vol. 1745, pp. 61-66, 2001.
[2] Matsuzawa, M., Kajiya, Y. and Takeuchi, M.: The development and validation of a method to estimate visibility during snowfall and blowing snow, Cold Regions Science and Technology, Vol. 41, Issue 2, pp. 91-109, 2005.

Introduction

By utilizing the **image/signal processing** technologies such as value of the Weighted Intensity of Power Spectra (WIPS),

- visibility inspection system was developed. [3]
- Visibility based on WIPS is measured from the Closed-circuit Television (CCTV) Camera, actually. [4]



— For improve —

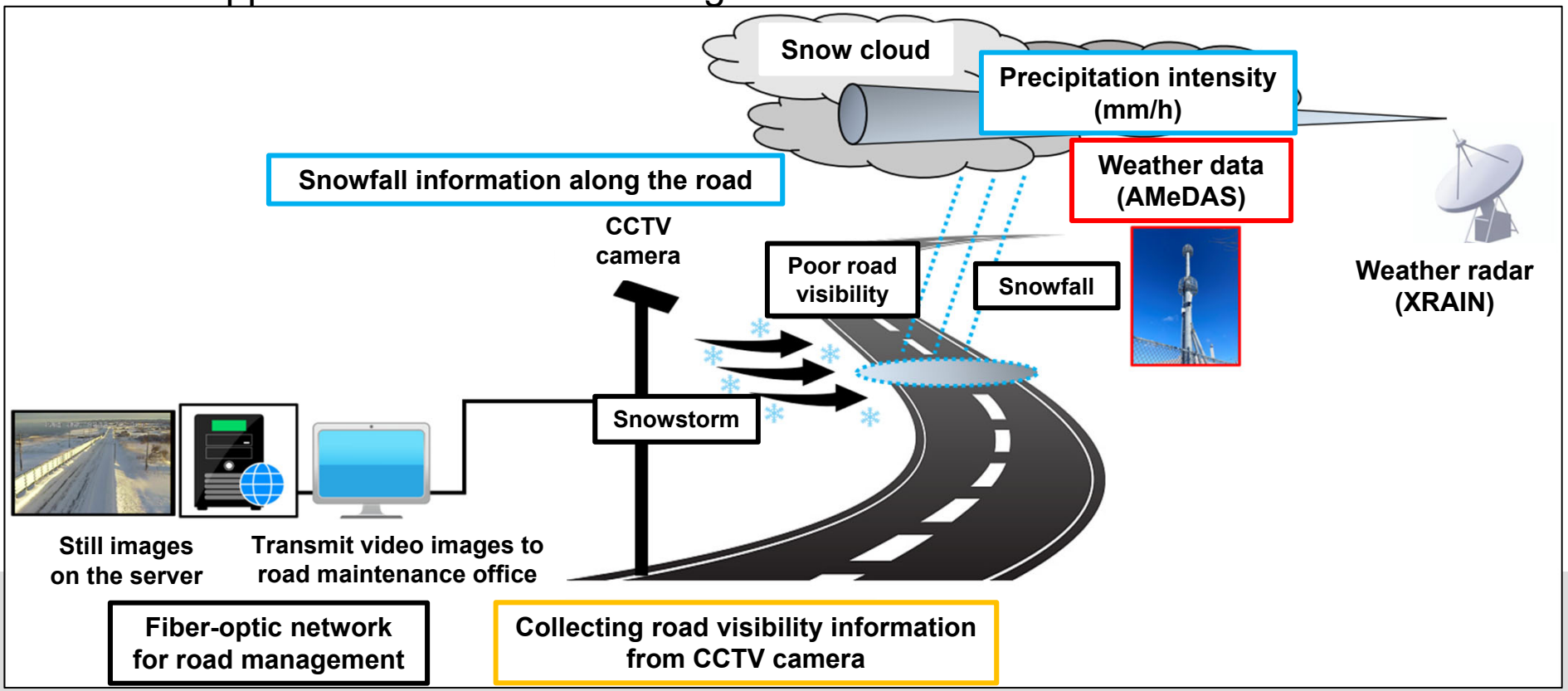
- By using snowfall information, the realization of more accurate/effective evaluation in real-time is expected.
- Precipitation intensity by weather radar might be available as snowfall information.
- XRAIN (Japanese weather radar by MLIT[5]) is available to observe precipitation with high spatio-temporal resolution: **250-meter square grid mesh, every 1-minutes**

[3] Nagata, Y., Hagiwara, T., Kaneda, Y., Araki, K. and Murakami, K. (2006) Simple way to use closed-circuit television road images for poor-visibility information. Transportation Research Record: Journal of the Transportation Research Board, Vol.1980, pp. 105-116.
[4] Hagiwara, T., Ota, Y., Kaneda, Y. and Araki, K. (2006) Method of processing closed-circuit television digital images for poor visibility identification. Transportation Research Record: Journal of the Transportation Research Board, Vol.1973, pp. 95-104.
[5] Kawasaki, A., Yamamoto, A., Koudelova, P., Acierto, R. A., Nemoto, T., Kitsuregawa, M., and Koike, T. (2017) Data Integration and Analysis System (DIAS) Contributing to Climate Change Analysis and Disaster Risk Reduction. Data Science Journal, 16: 41, pp. 1-17.

Objective

- To verify the applicability of precipitation intensity by XRAIN as snowfall information for poor road visibility evaluation.
  - The relationship between precipitation intensity and value of the WIPS is investigated by utilizing cross-correlation.

Considering snowstorm due to strong wind, the weather information by AMeDAS are used as support data for understanding and consideration.



Investigate Road Section and Weather Condition

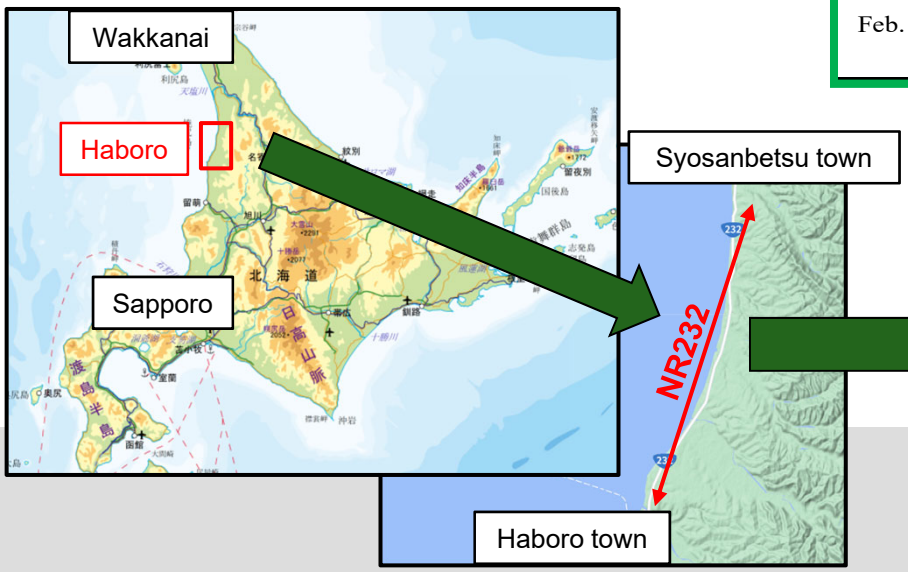
Investigate Road Section (22 km)

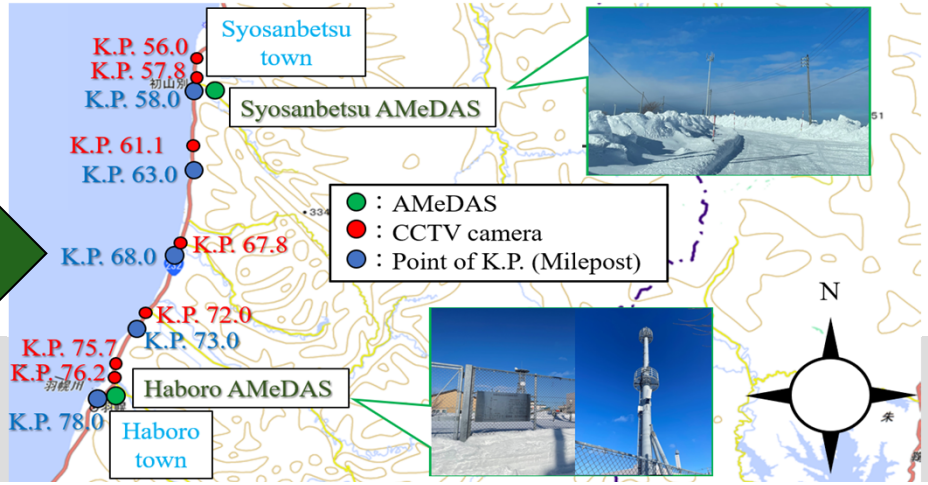
- NR232 [K.P. 56.0～K.P. 78.0]
  - West roadside：ocean
  - East roadside：high cliff
- Snowstorm tend to occur by West wind.

Weather condition (11 time periods)

- Major wind direction: West
- Wind velocity: over 6.0（m/s）

MM/DD/YY	No.	Time Period	Average Temperature (℃)	Average wind velocity (m/s)	Major wind direction
Dec. 26, 2020.	1	12:00-16:00	-5.7	10.5	West-Northwest
Dec. 27, 2020.	2	11:00-15:00	-4.5	8.0	West or West-Northwest
Dec. 29, 2020.	3	10:00-14:00	-5.4	9.7	West
Dec. 31, 2020.	4	12:00-13:30	-7.2	3.3	South-Southeast
	5	13:40-16:00	-6.6	11.9	West-Northwest
Dec. 28, 2021.	6	10:00-11:00	-9.4	1.8	East-Southeast
	7	11:10-14:00	-4.7	7.6	West-Northwest
Dec. 30, 2021.	8	8:00-12:00	-2.5	6.0	West-Northwest
Jan. 29, 2022.	9	11:00-15:00	-4.8	7.6	West or West-Southwest
Feb. 3, 2022.	10	12:00-13:20	-4.1	3.0	Nort or North-Northeast
	11	13:30-16:00	-3.6	6.8	Northwest





Obtained data: Precipitation intensity by XRAIN

Elevation angle (Hakodake Radar)

- In Hokkaido, elevation angle in summer and winter are different.
- From November 2021, winter elevation angle is adopted for observation.

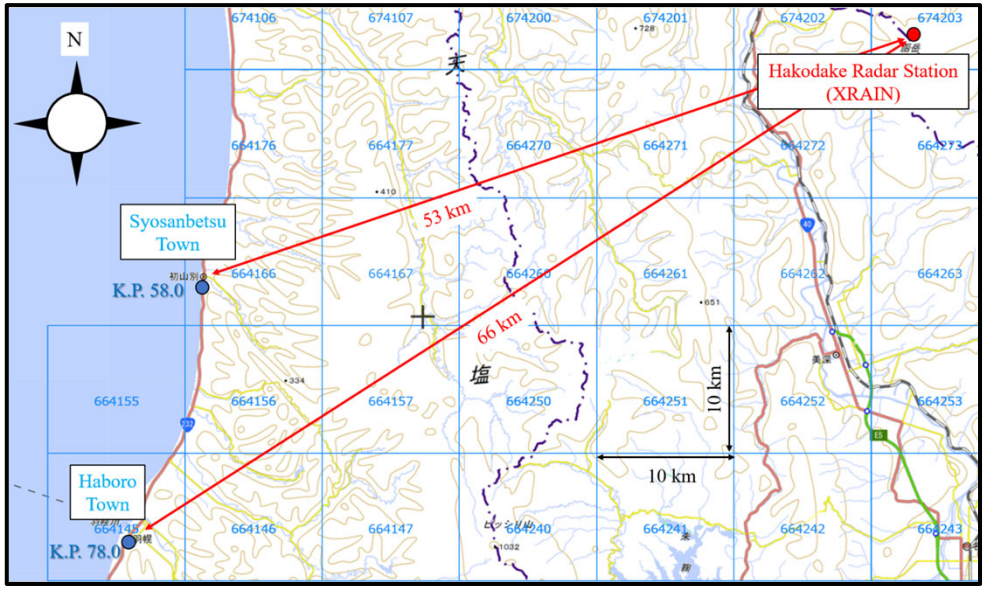
Reflection of snowfall in the air

- Altitude of Weather radar：1,149(m)
- Distance (Haboro⇔Hakodake)：60（km）
- Height for observing snow clouds: 700～1,600(m)
- Falling velocity (snow particles): 1.0～4.0 (m/s)

- Until snowfall reflected on the ground, time lag might be occur.
  - 5 ～15 minute

Precipitation intensity by XRAIN

- We used precipitation intensity per 1-kilometer square grid mesh.
- We adopted average 10-minute value of it at the current time.

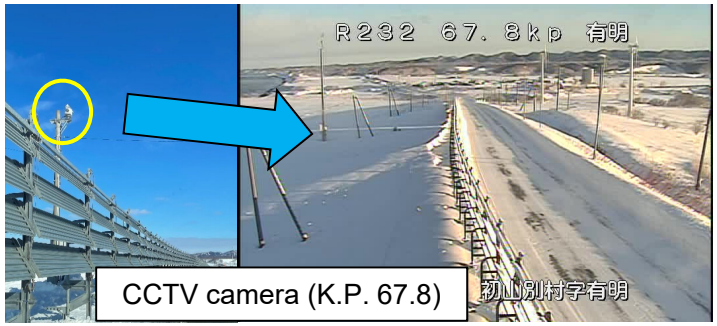


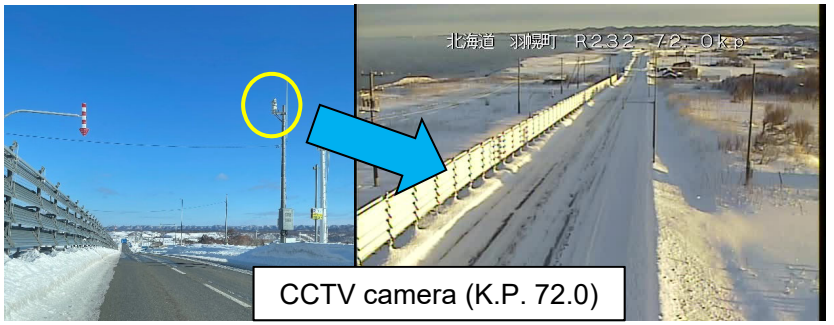
Angle of Elevation		Altitude	Height from Ground
θ0	θ1	Hakodake：1,129(m)	1,251(m)：0.1°
0.1°	0.4°	Weather Radar：1,149(m)	1,569(m)：0.4°
(-0.4°)	(0.1°)		729(m)：-0.4°

Obtained data: Visibility Information – CCTV camera images

Still images captured by the CCTV camera

- In the 22-km/section, there are seven CCTV cameras. (SD quality: 720 × 480)
- CCTV captures still image every 5-minutes.
- We used still images captured by two CCTV cameras (K.P. 67.8 and K.P. 72.0) for road visibility evaluation.
- Other five cameras sometimes occurred heavy adhesion of snow/ice, and changed the shooting direction in winter season.





Specification of CCTV camera

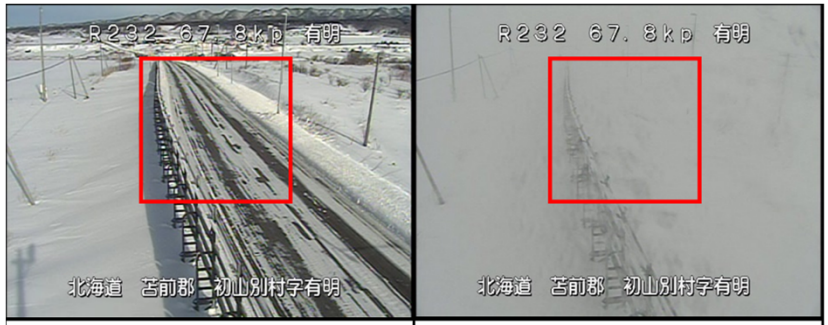
Image Sensor	**Veneer CCD (Color)**
Valid Pixels	**About 380,000 pixels or more**
Definition	**Horizontal: 480 or more**
S/N	**47dB or more**
Minimum Illuminance Level	**Electronic Sensitivity OFF: 0.4 lux or less** **Electronic Sensitivity ON: 0.007 lux or less**
Camera Case	**Installed Wiper and Defroster**

Obtained data: Visibility Information – WIPS values

Value of the WIPS

- WIPS is image/signal processing-based criterion.
- WIPS represents road visibility condition.
  - Clear road visibility: Large value
  - Poor road visibility: Small value

- Value of the WIPS focused on subjective visibility by human eyes.
  - It doesn't classify the factors of poor road visibility. (such as dense or fog)



WIPS: 11.3	WIPS: 6.9

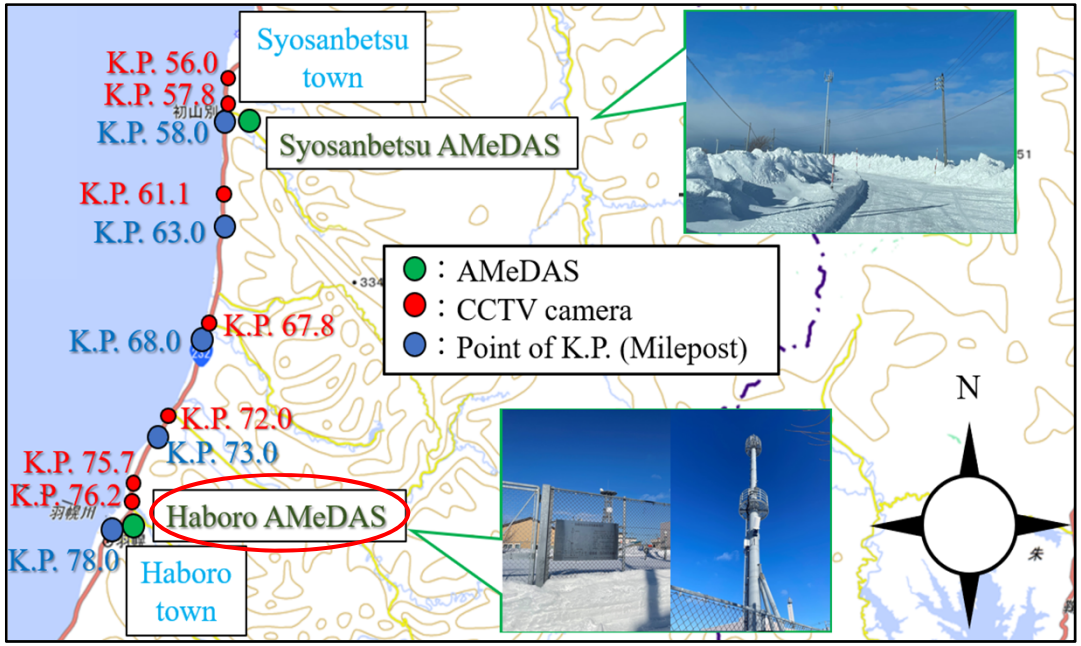
WIPS is actually used for measuring road management as visibility assessment value.

Related data: Weather Information

Weather data by Haboro AMeDAS

- Haboro AMeDAS is located near Haboro town.
  (AMeDAS: Automated Meteorological Data Acquisition System)

- We collected followings (every 10-minutes):
  - Temperature
  - Wind velocity and direction



Evaluation method: Cross-Correlation between Precipitation Intensity (XRAIN) and Value of the WIPS

Calculation and unit of time interval

- Cross-correlation calculated from equation (1).
  - Value of the WIPS as y_i and precipitation intensity as x_i.
- Sign of cross-correlation was negative:
  - WIPS changes with a time lag in response to changes in precipitation intensity.
  - Unit of time interval: 5-minute.

- This case shows WIPS changes with a time lag (5-minute) in response to changes in precipitation intensity.

Covariance

$$C(\tau) = \frac{\sum_{i=1}^{N-\tau} (x_i - \bar{x})\,(y_{i+\tau} - \bar{y})}{\sqrt{\left\{\sum_{i=1}^{N} (x_i - \bar{x})^2\right\}\left\{\sum_{i=1}^{N} (y_i - \bar{y})^2\right\}}} \quad (1)$$

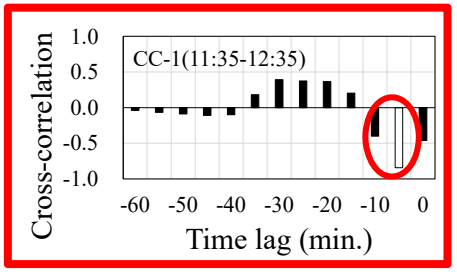
Standard deviation

Calculate

τ (min.)		0 (min.)			5 (min.)			10 (min.)	
Time	N(i)	PI	WIPS		PI	WIPS		PI	WIPS
11:35	1	x1	y1		x1	y1		x1	y1
11:40	2	x2	y2		x2	y2		x2	y2
11:45	3	x3	y3		x3	y3		x3	y3
11:50	4	x4	y4		x4	y4		x4	y4
						y5			y5
~		...	...		...	...		...	...
12:30	12	x12	y12		x12			x12	
12:35	13	x13	y13		x13	y13		x13	y13

Slide the data in 5-minute.

Result



The highest cross-correlation was about -0.80.
(Time lag was 5 minute)

$C(\tau)$: Cross-correlation, τ : Time lag (min.), N : Number of data $(i = 1, \ldots, N)$,
x_i : Precipitation intensity (mm/h), y_i : Value of the WIPS,
$\bar{x}$: Average value of the precipitation intensity, $\bar{y}$: Average value of the WIPS

Results of Cross-Correlation: Three categories

Results of 11 time periods could be classified into **three categories** depending on the cross-correlation value and time lag.

Category 1 and Category 2

[Category-1]

- Precipitation intensity:
  - almost 0.0 (mm/h)
- **Clear road visibility condition**

[Category-2]

- Visibility and weather were **related**.
- The sign of cross-correlation:
  - **Negative**
- The highest Cross-correlation value:
  - **Larger than 0.4**
- Time lag was **relatively small**.

K.P. 67.8					
Date	**Time Period No.**	**Time Period**	**The Highest Cross-Correlation**	**Time lag (min.)**	**Category**
Dec. 26, 2020.	No. 1	12:00-13:00	-0.79	5	2
		12:15-13:15	-0.74	5	2
		12:55-13:55	-0.64	0	2
		14:55-15:55	-0.74	0	2
Dec. 27, 2020.	No. 2	No precipitation			1
Dec. 29, 2020.	No. 3	10:00-11:00	-0.57	5	2
Dec. 31, 2020.	No. 4 and No. 5	13:10-14:10	-0.52	10	2
	No. 5	14:40-15:40	0.50	25	3
Dec. 28, 2021.	No. 6	10:25-11:25	0.47	10	3
	No. 6 and No. 7	10:45-11:45	-0.60	0	2
Dec. 30, 2021.	No. 8	8:00-9:00	-0.35	35	3
		8:25-9:25	0.34	35	3
		11:00-12:00	-0.68	10	2
Jan. 29, 2022.	No. 9	12:25-13:25	-0.75	0	2
		13:35-14:35	-0.78	5	2
Feb. 3, 2022.	No. 10	12:20-13:20	-0.70	5	2
	No. 11	14:35-15:35	0.53	0	3

Results of Cross-Correlation: Three categories

Results of 11 time periods could be classified into **three categories** depending on the cross-correlation value and time lag.

Category 3

- Visibility and weather were **complex**.
- The sign of cross-correlation:
  - **Positive**
- Time lag was large.
  - **Over 15.0 (min.)**

[Cause of these results]

- Advection of snow particle
  - Falling speed and non-vertical fall
- Time lag occur until snowfall reflected on the ground. [6]

K.P. 72.0					
Date	Time Period No.	Time Period	The Highest Cross-Correlation	Time lag (min.)	Category
Dec. 26, 2020.	No. 1	12:15-13:15	-0.80	5	2
		12:55-13:55	-0.59	0	2
		14:55-15:55	-0.72	5	2
Dec. 27, 2020.	No. 2	11:35-12:35	-0.84	5	2
Dec. 29, 2020.	No. 3	10:00-11:00	-0.71	0	2
		11:05-12:05	-0.72	0	2
Dec. 31, 2020.	No. 4	12:55-13:55	-0.81	15	3
	No. 5	14:35-15:35	0.59	25	3
Dec. 28, 2021.	No. 6	10:15-11:15	0.60	10	3
Dec. 30, 2021.	No. 8	8:50-9:50	-0.70	0	2
		11:00-12:00	-0.84	10	2
Jan. 29, 2022.	No. 9	12:25-13:25	-0.79	10	2
		13:35-14:35	-0.59	0	2
Feb. 3, 2022.	No. 10	12:20-13:20	-0.71	0	2
	No. 11	14:35-15:35	0.47	15	3

[6] Derin, Y., Anagnostou, E., Anagnostou, M. and Kalogi-ros, J.: Evaluation of X-Band Dual-Polarization Radar-Rainfall Estimates from OLYMPEX, Journal of Hydro-meteorology, Vol. 20 (9), pp. 1941-1959, 2019.

Results of comparing with XRAIN, WIPS and Weather data: Category 1 [No.2 time period]

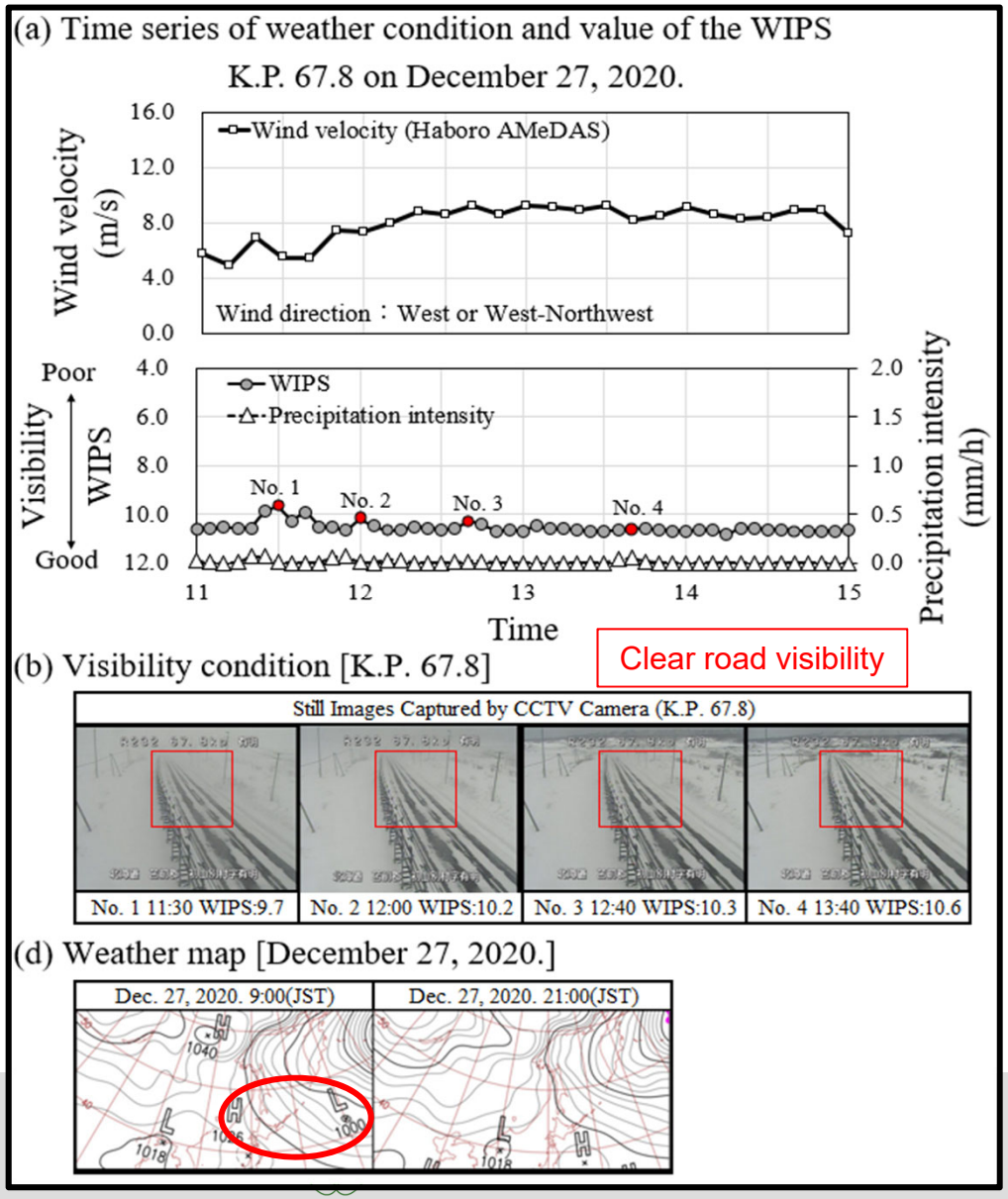
Dec. 27, 2020. [K.P. 67.8]

[Category-1]

- Precipitation intensity was slight.
  - Almost 0.0 (mm/h)
- Wind velocity was strong.
  - Around 8.0 (m/s)

- In the day time, there was a low pressure around Hokkaido.
- Poor road visibility might be occur due to snowstorm.

- However, snowstorm didn't occur.
- Clear road visibility conditions
- Value of the WIPS and precipitation intensity were **related**.



Results of comparing with XRAIN, WIPS and Weather data: Category 2 [No.9 time period]

Jan. 29, 2022. [K.P. 67.8]

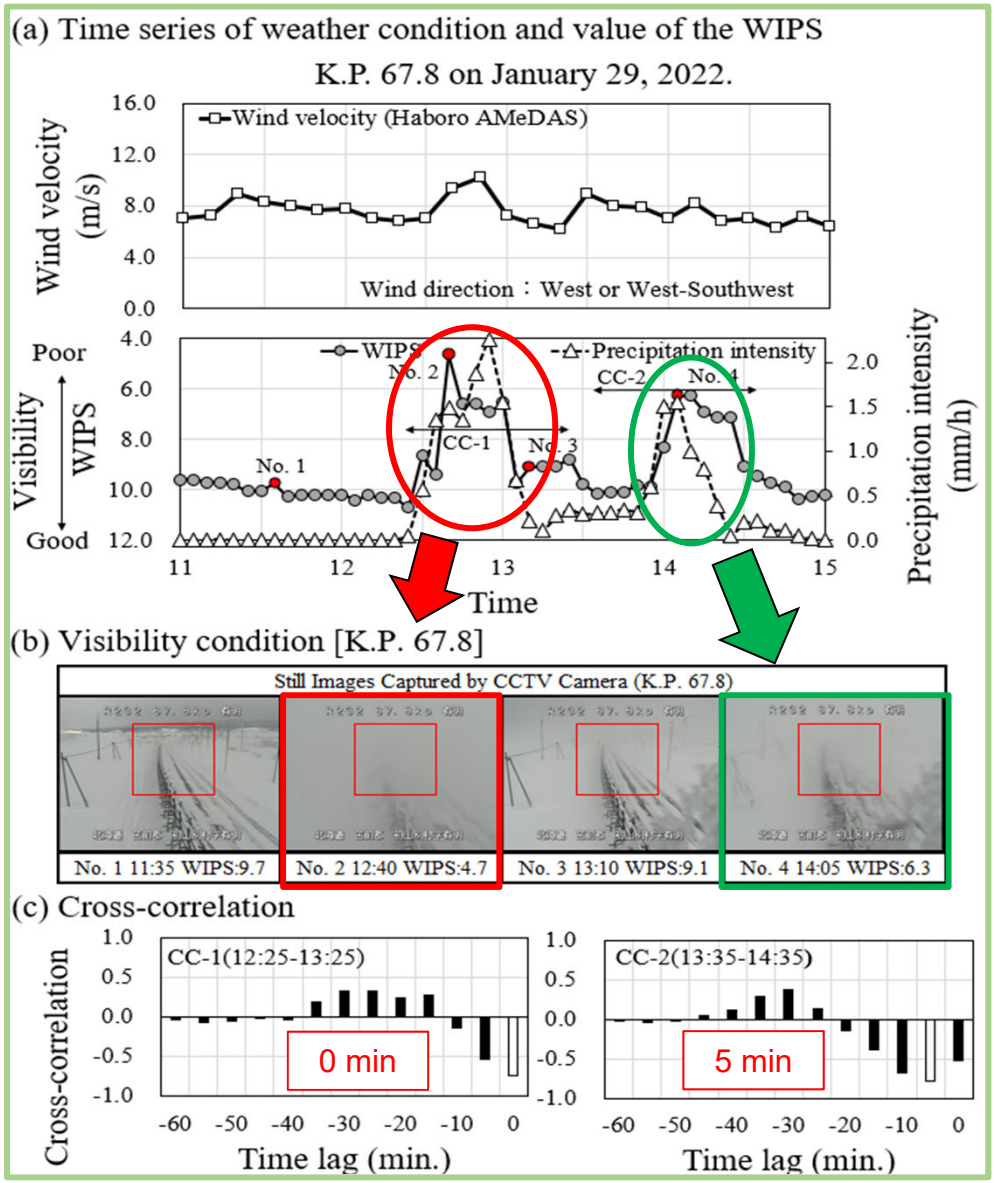
[Category-2]

- Low pressure around Hokkaido.
- Precipitation intensity increased.
- Poor road visibility occurred.

[Two cross-correlations]

- The sign of cross-correlation:
  - Negative
- The highest value:
  - Large
- Time lag:
  - Small (0.0 or 5.0 (min.))

- Value of the WIPS and precipitation intensity were **related**.
- Poor road visibility due to snowfall.



Results of comparing with XRAIN, WIPS and Weather data: Category 3 [No.4 and No.5 time periods]

Dec. 31, 2020. [K.P. 72.0]

[Category-3]

- Low pressure around Hokkaido.
- Interval of isobars was narrow.

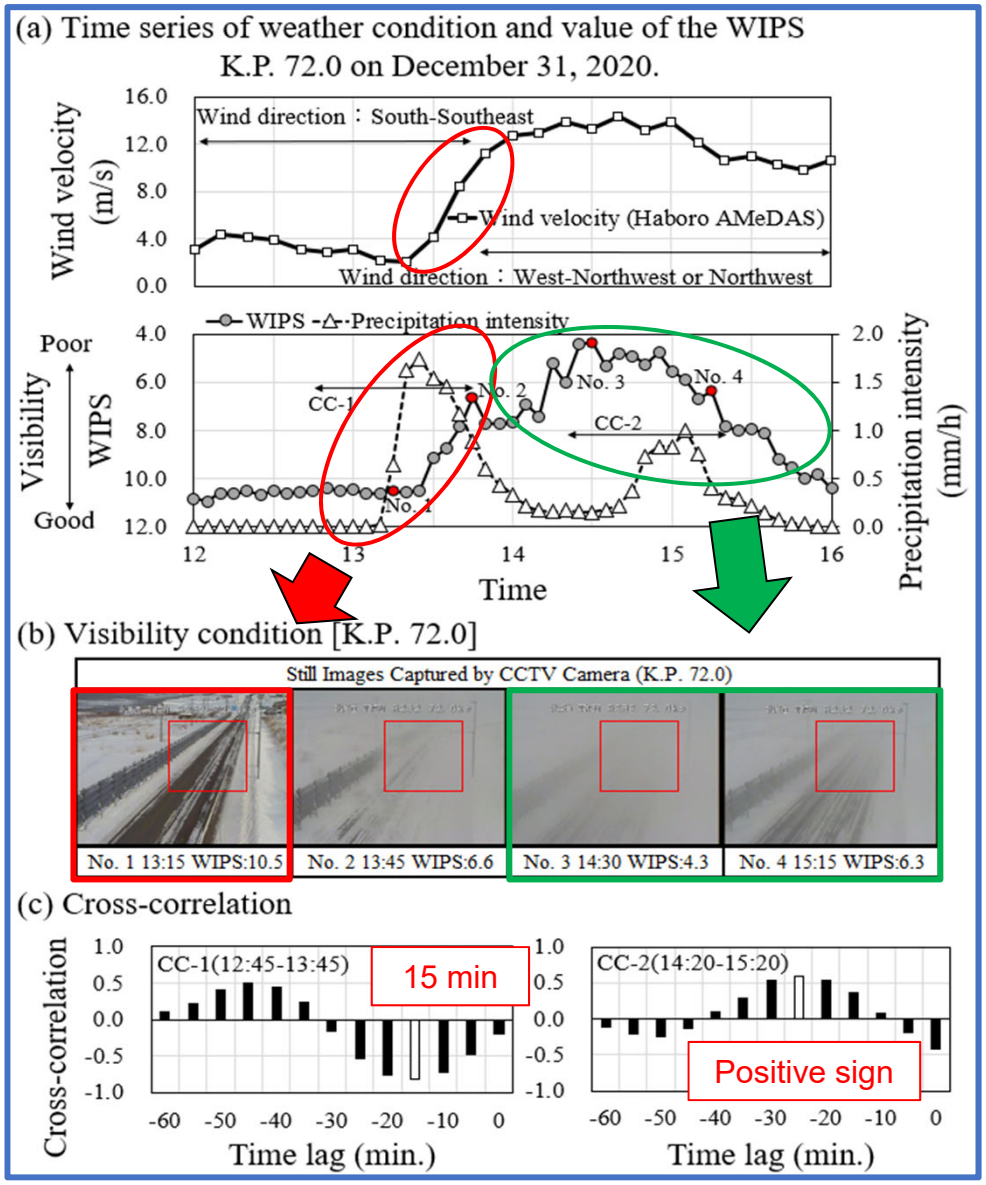
[13:00 – 14:00]

- Precipitation intensity increased.
  - However, clear road visibility conditions.
- After, precipitation intensity decreased.
  - Poor road visibility due to strong wind.

[14:30 – 15:30]

- Precipitation intensity increased again.
  - From 14:30, poor road visibility continued.
- Visibility and XRAIN were **different**.
  - Visibility changed due to snowstorm caused by strong wind.

The possibilities of **the advection of snow particle** is expected.



Conclusions

Objectives of the present study

- To verify the applicability of precipitation intensity by XRAIN as snowfall information for poor road visibility evaluation.
  - The relationship between precipitation intensity and value of the WIPS is investigated by utilizing cross-correlation.

Results in **Category-1** and **Category-2**

- Both conditions (visibility and weather) were **related**.
- Applicability of road visibility estimation by precipitation intensity was indicated.

Results in **Category-3**

- Both conditions were **different**.
- Under strong wind, we should consider **the advection of snow particles** in the air.

— For future works and to develop road monitoring system —

In order to use the precipitation intensity by XRAIN as snowfall information for evaluating snow condition, followings should be considered.

- Accuracy of snow particle observation by weather radar
- Falling velocity and advection of snow particles

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Outline

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