Improvement of ILM calculation by pre-processing of the acquired data

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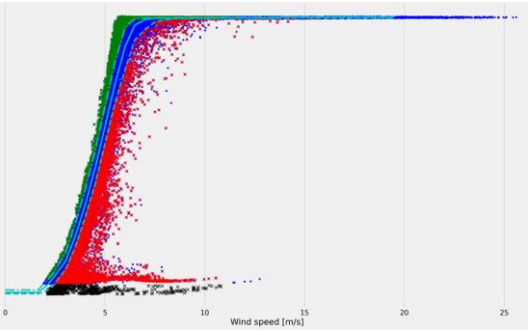
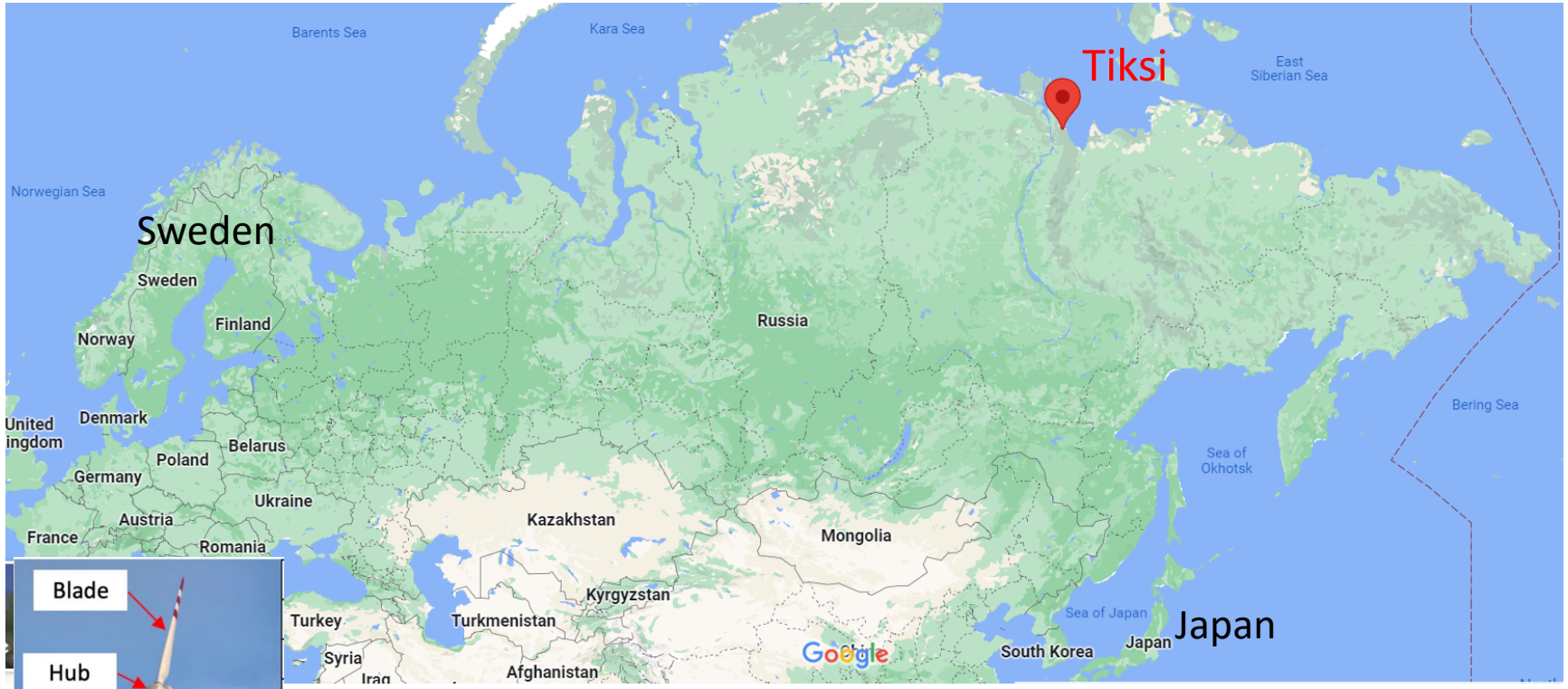
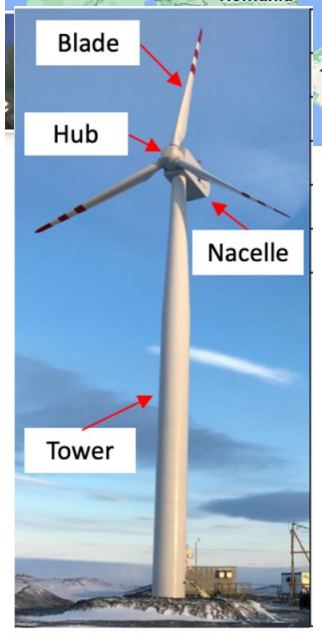


Introduction





About Tiksi

- A city facing the Arctic Sea of the Russian Federation
- Average temperatures are below freezing and cold regions

Climate of Tiksi

Wind speed [m/s]	Average	5.4
	Maximum	37.2
Ambient temperature [°C]	Average	-8.7
	Maximum	27.4
	Minimum	-35.6

Participated in a wind turbine operation project at Tiksi

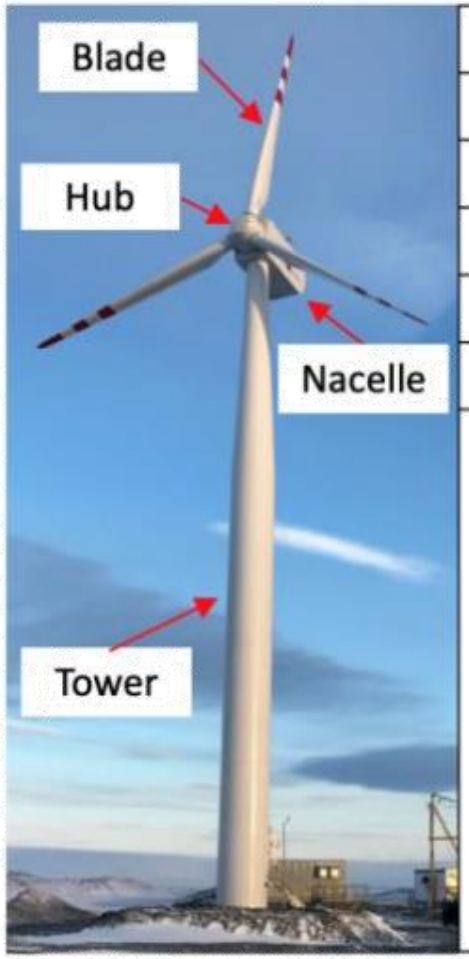
Necessary to evaluate the effects of icing on production losses

→IceLossMethod

- An open source code
- Need only standard data
- Applicable in any wind turbines

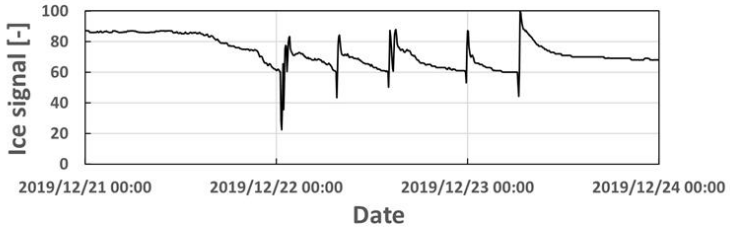
Specifications of the Tiksi wind turbine & the ice detector

Specification of the wind turbine



Wind turbine type	3-bladed upwind type
Rated power	300 kW
Cut-in wind velocity	3 m/s
Cut-out wind velocity	25 m/s
Hub height	41.5 m
Blade length	16.5 m
Sensors	- On the nacelle - Ultrasonic Anemometer Cup Anemometer Wind direction Ice Detector Precipitation Sensor(Only No.2) Vibrometer - Base - Thermometer Hydrometer

Ice detector



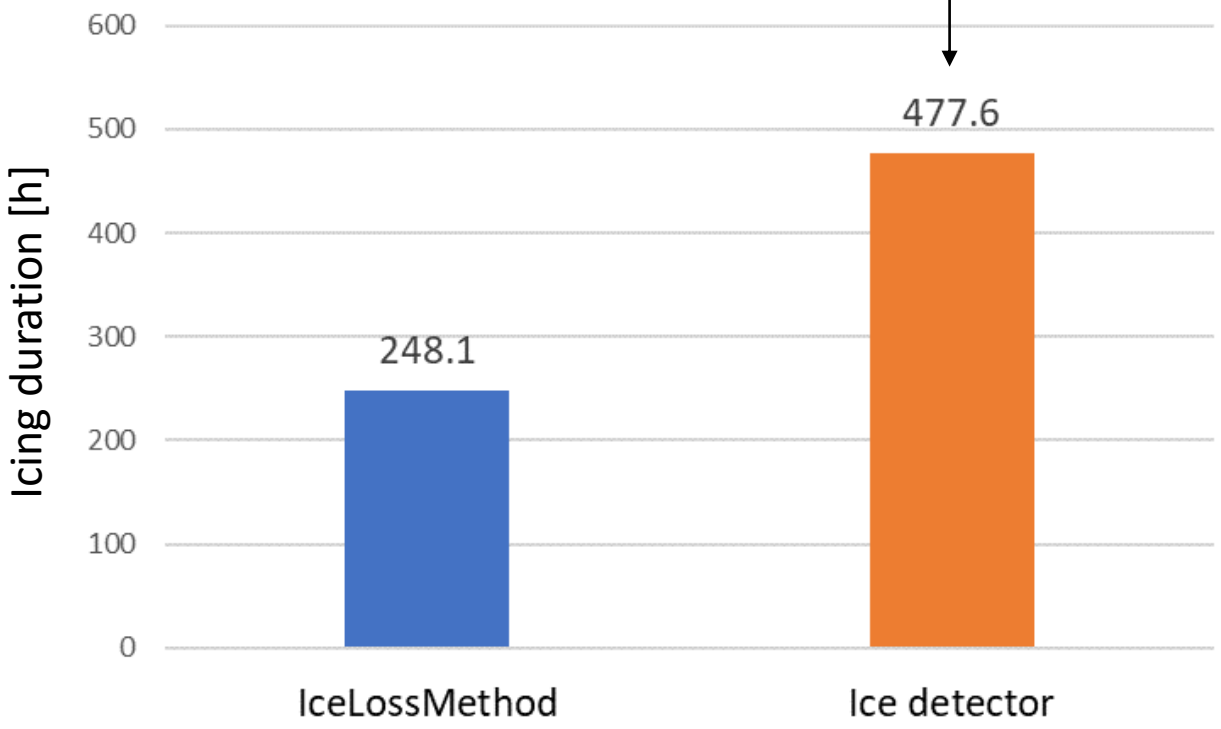
Normalize the natural frequency
of the aluminum stretched around it

Calculated the effect of icing by **IceLossMethod** and **ice detector**

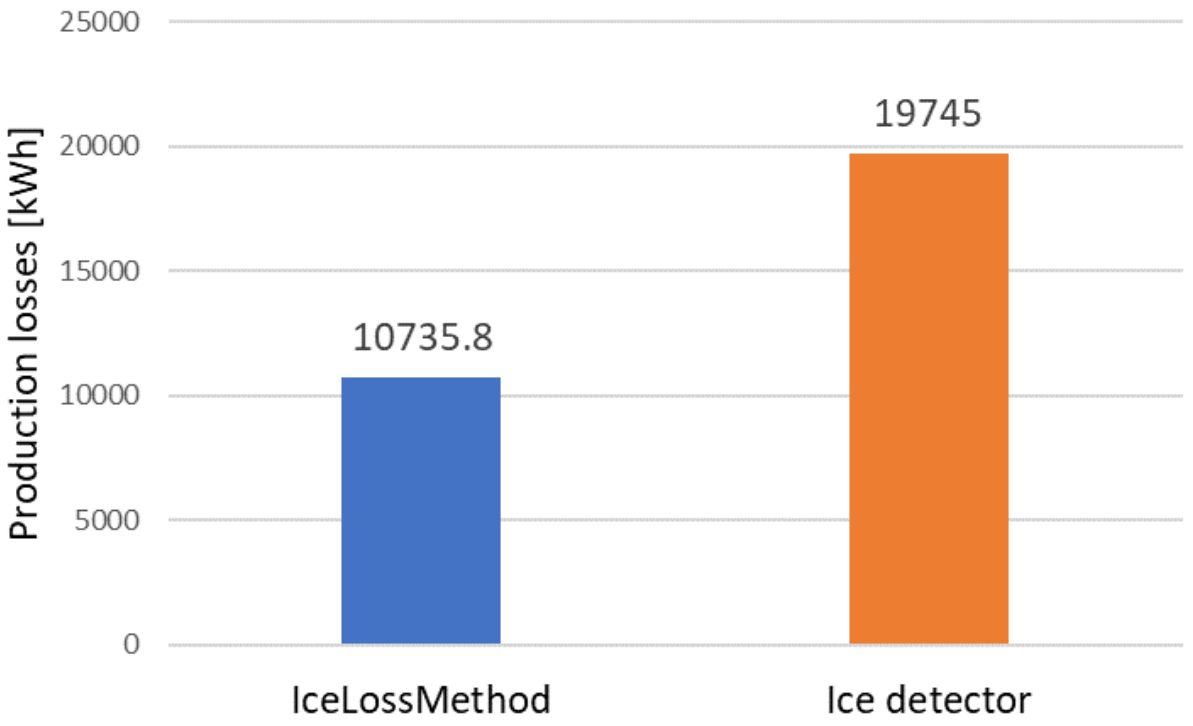
The result of IceLossMethod and the analysis with the ice detector

Atmospheric icing (V ≥ 2.5 [m/s])

2019.4~2020.3



Icing duration [h]

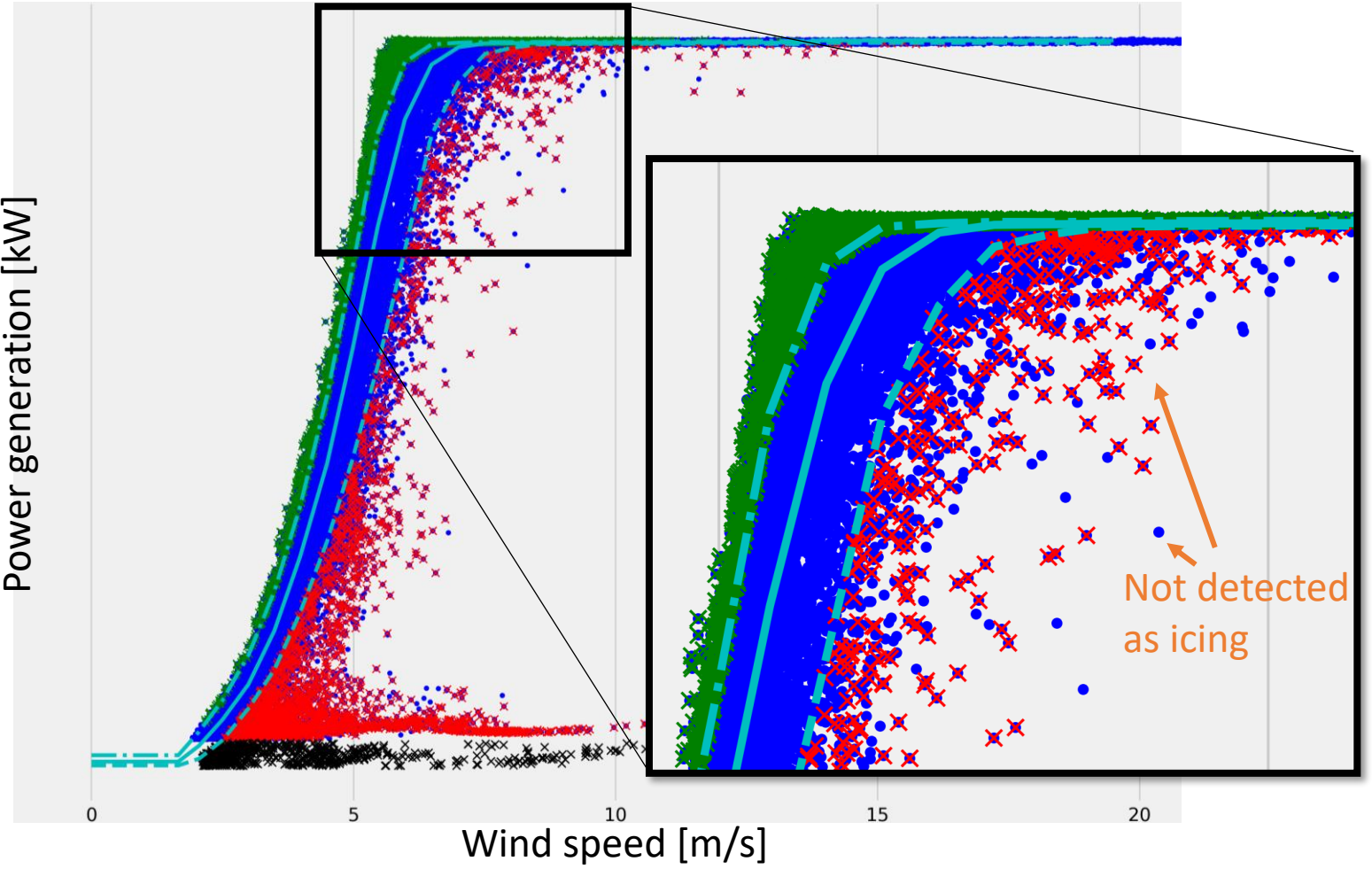


Production losses [kWh]

- Icing duration of Ice detector is taken as reference because the ice detector detects actual ice
- The results of IceLossMethod is greatly lower than Ice detector

IceLossMethod underestimate the effect of icing

Result of IceLossMethod



	Standard production
	Lost production due to icing
	Stops due to icing
	Over production due to icing
	Power curve by warm season data
	10 percenttile value (icing judgment value)
	90 percentile value

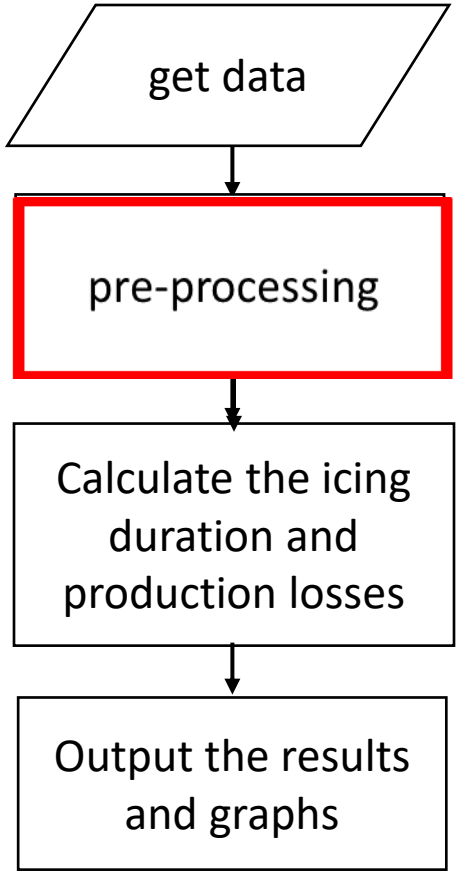
IceLossMethod underestimates

- Applicable for icing loss in any wind turbines as long as sufficient data
- The only standardized way to investigate the impact of icing on wind turbines

Objective

Aim to improve the accuracy of IceLossMethod by processing the data

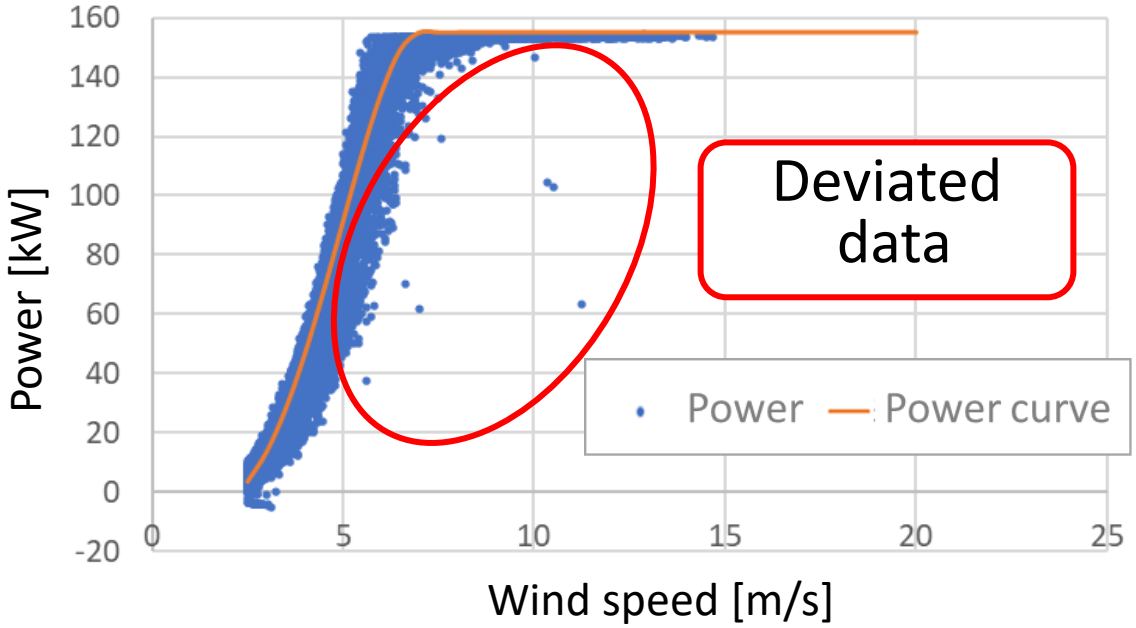
Causes of underestimation



Calculate non-iced output curve with warm season data

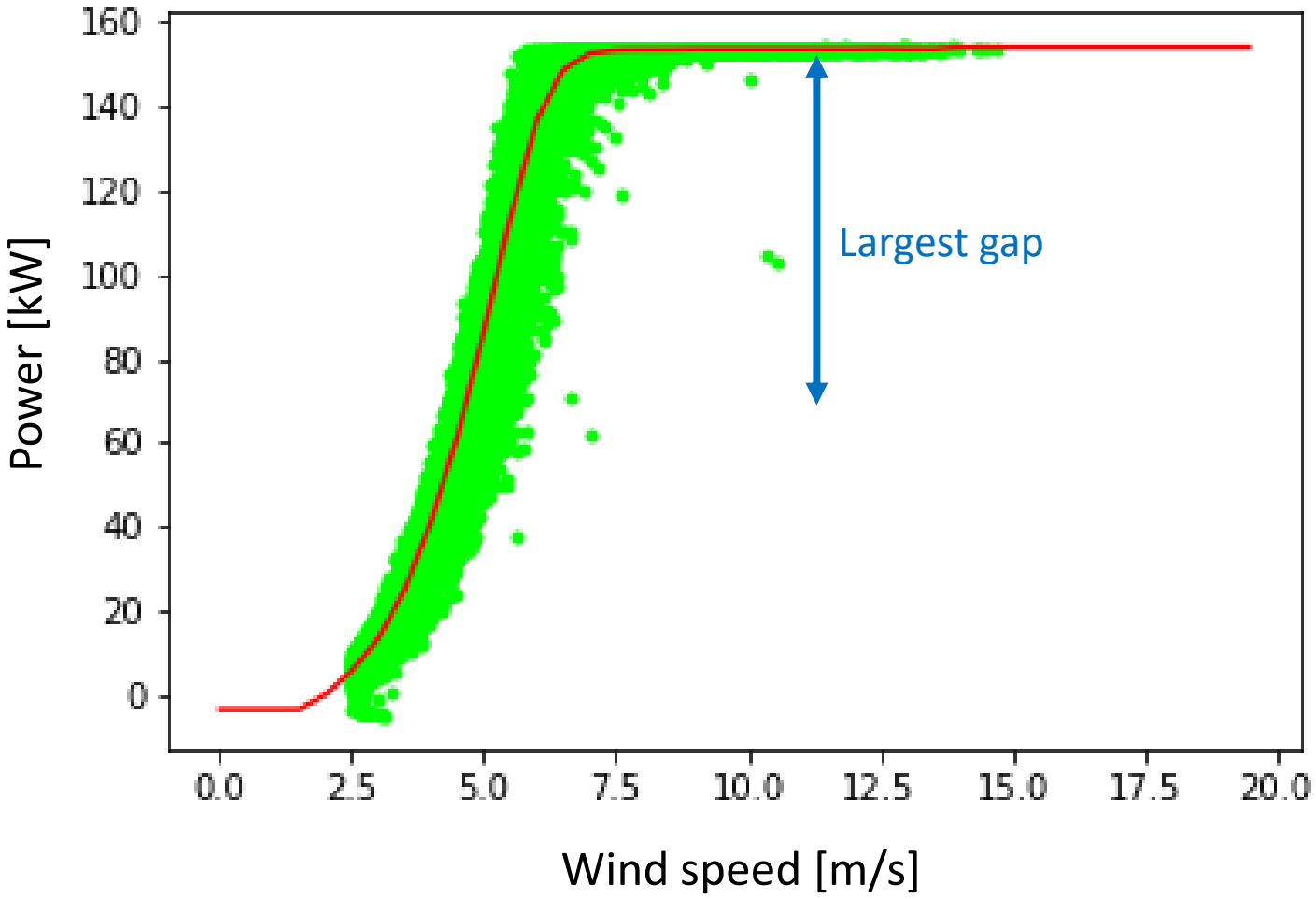
→ The accuracy of IceLossMethod depends on the degree of scattering of the data acquired in the warm season data

Warm season data：temperature is higher than 3℃



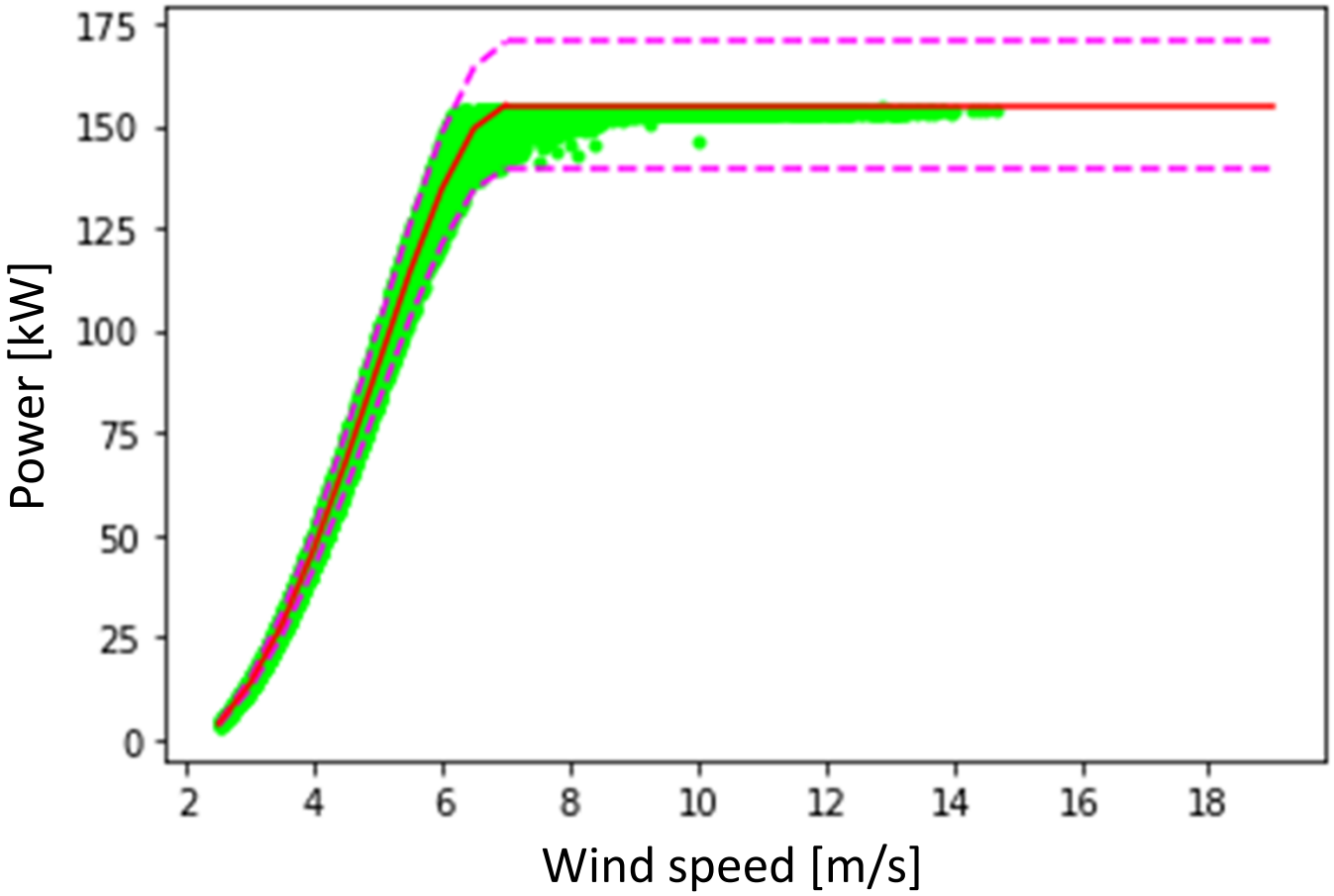
Perform pre-processing to remove deviated data

How to remove the deviated data



- Some data cannot generate power as usual
- Data is removed in order from the data with the largest gap
- Remove deviated data until all data is within 5-20% above and below the approximation formula

How to remove the deviated data



+10% of output curve

-10% of output curve

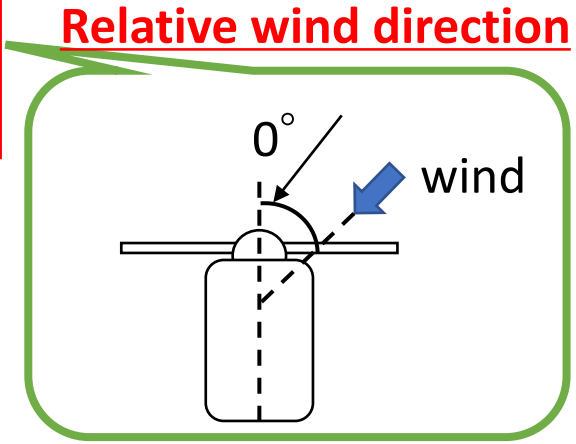
Change this line to ±5, ±10, ±15, and ±20%

- Some data cannot generate power as usual
- Data is deleted in order from the data with the largest gap
- Remove deviated data until all data is within 5, 10, 15, and 20% above and below the approximation formula

The feature of deviated data

①Relative wind direction deviation is big

	Ultrasonic relative wind direction 3 seconds average[°]				Ultrasonic relative wind direction 30 seconds average			
	average	minimum	maximum	deviation	average	minimum	maximum	deviation
2019/6/11 12:35	12.271	-18.9	49	14.756	11.867	-12.9	34	12.199
2019/6/16 11:40	3.875	-22.9	63	19.352	4.697	-17.9	47	17.862



Because of the turbulency of wind

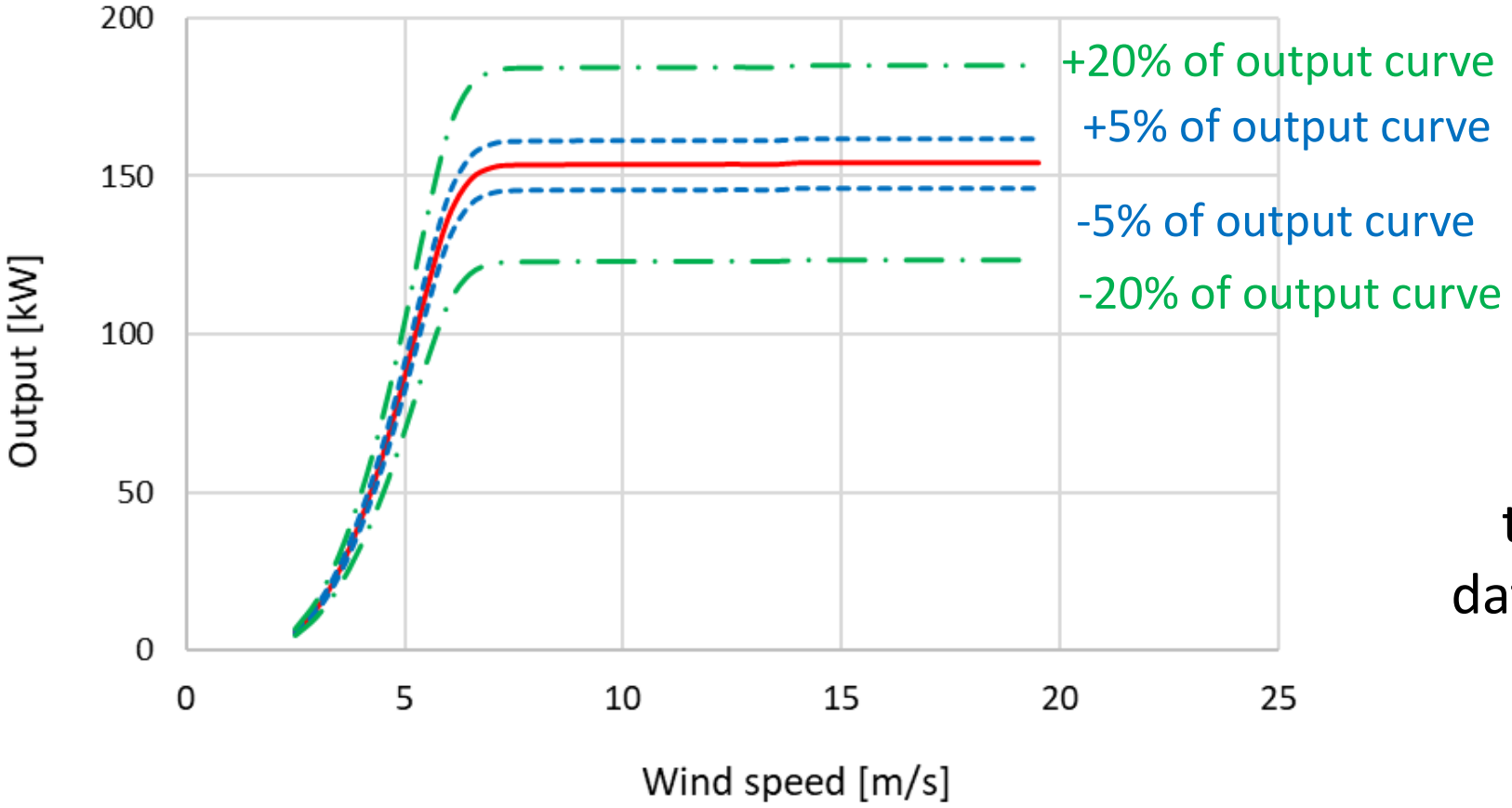
② The change in the generator speed is large in 5 minutes

	Control zone[-]				Power [kW]			
	average	minimum	maximum	deviation	average	minimum	maximum	deviation
2019/7/20 10:55	2.517	1	3	0.51	135.674	58.146	165.534	24.866
2019/7/23 8:05	2.489	1	3	0.597	127.306	45.208	163.486	36.814

The reason is not yet clear

The output may be low for a reason other than the wind speed

The result of Icing duration and production losses after pre-processing



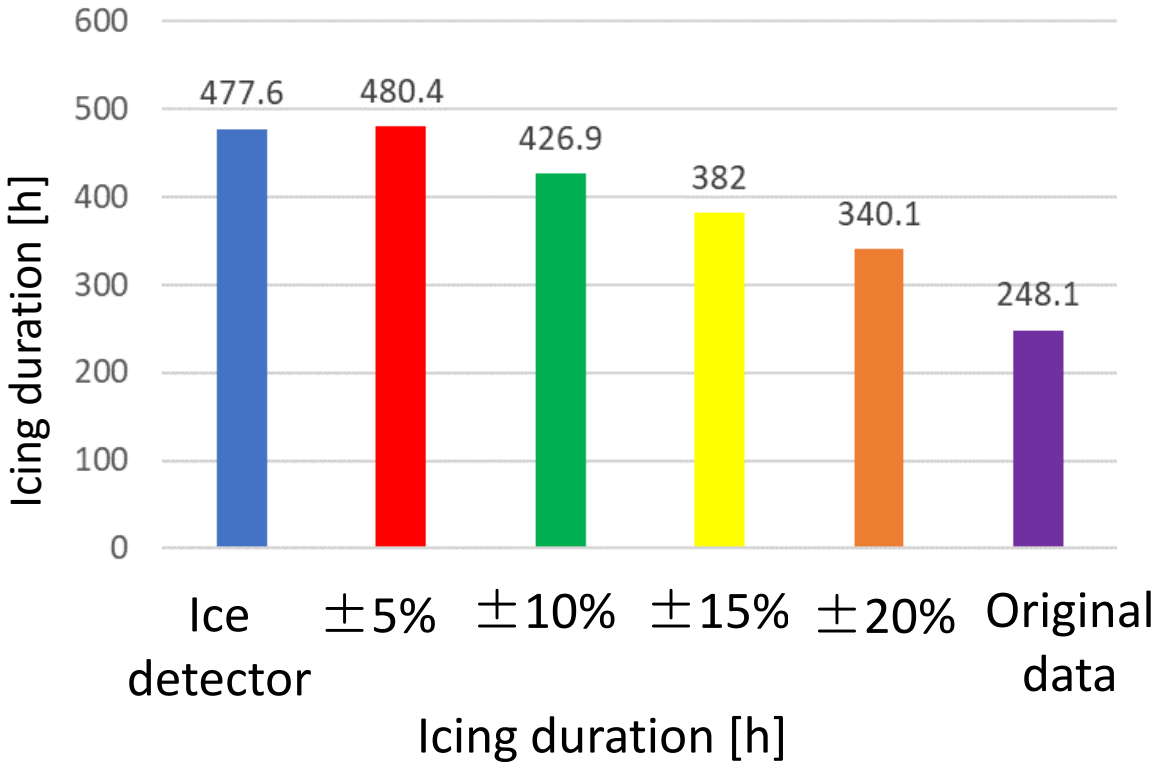
±5, 10, 15 and 20% of output curve

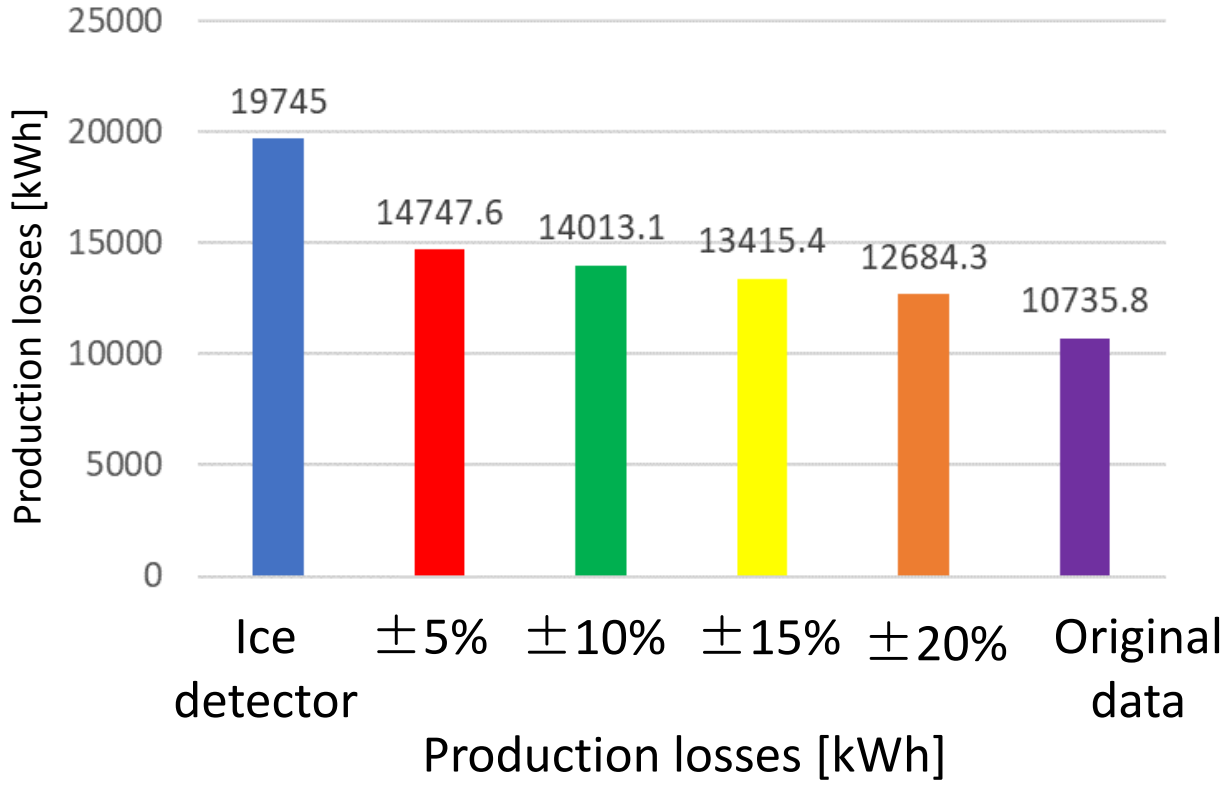
Remove the deviated data until certain range

The lower the percentage, the closer to the output curve data is used to calculate the effect of icing.

The result of Icing duration and production losses after pre-processing

2019.4~2020.3

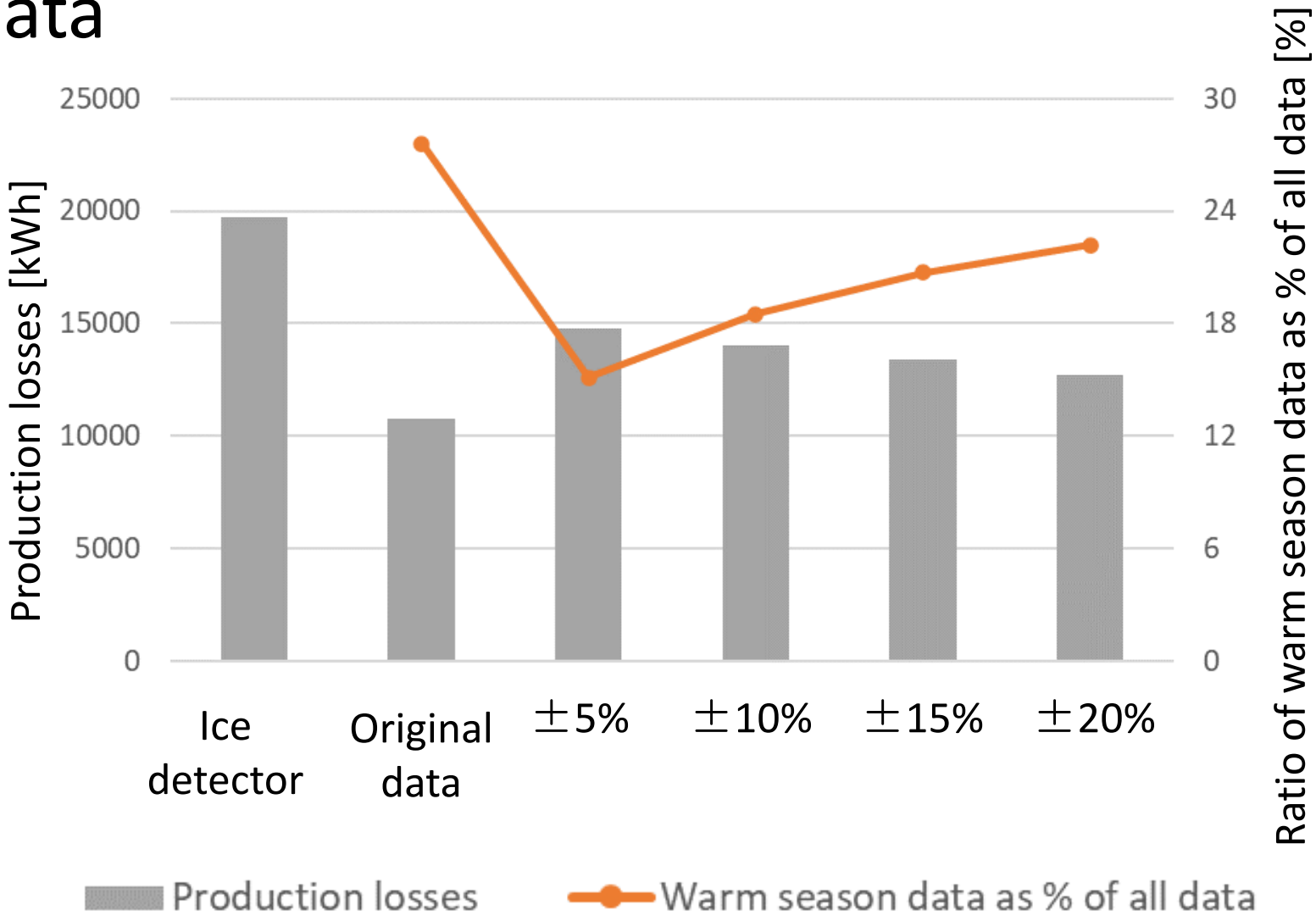




- Icing duration and production losses were increased at any percentage compared to original data
- 5 and 10% were close to the value of the icing detector, which is considered to be reliable

Underestimate is solved by pre-processing

Production losses and warm season data as % of original data



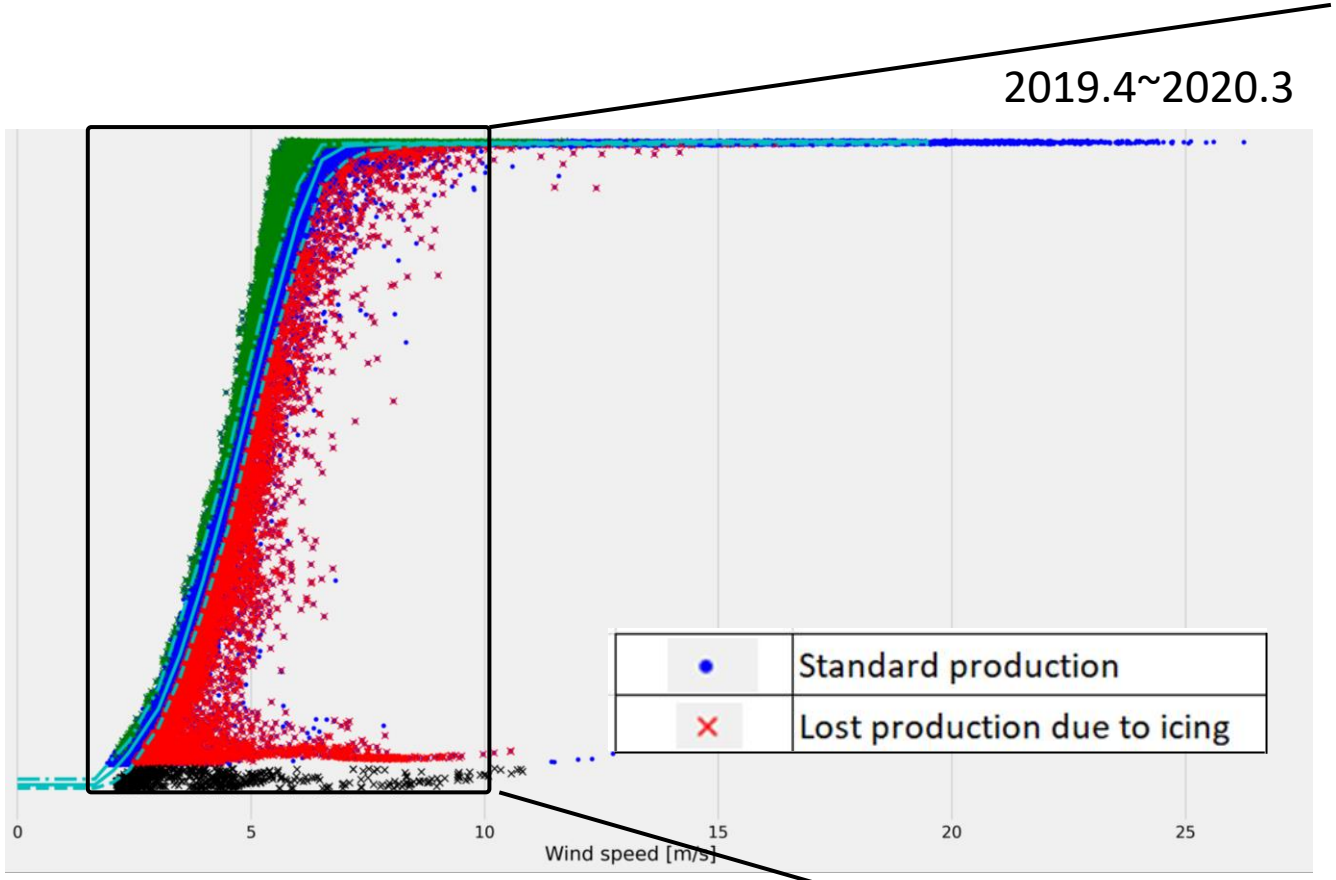
If you remove the deviated data from the dataset

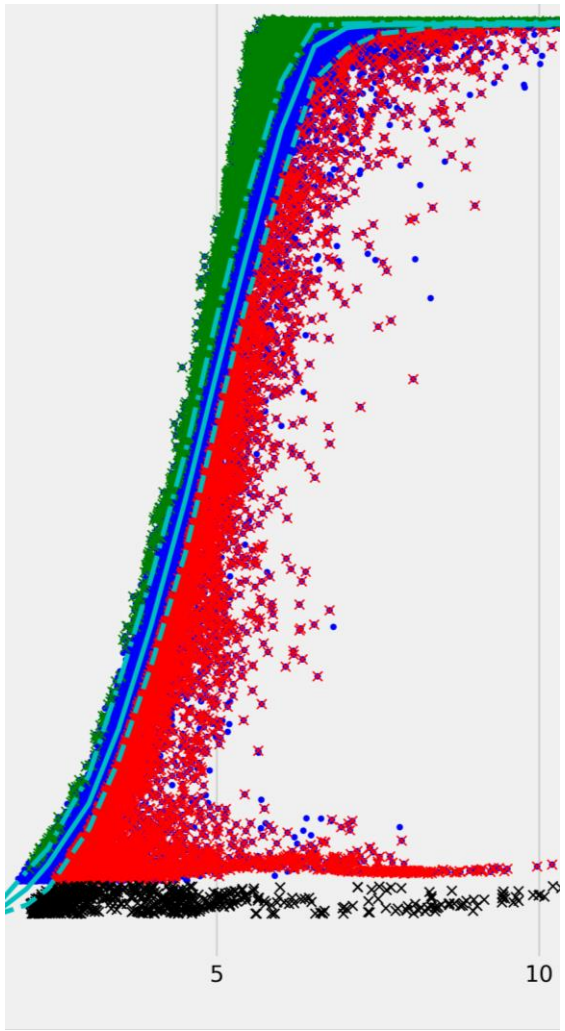
you will have more accurate result

↕

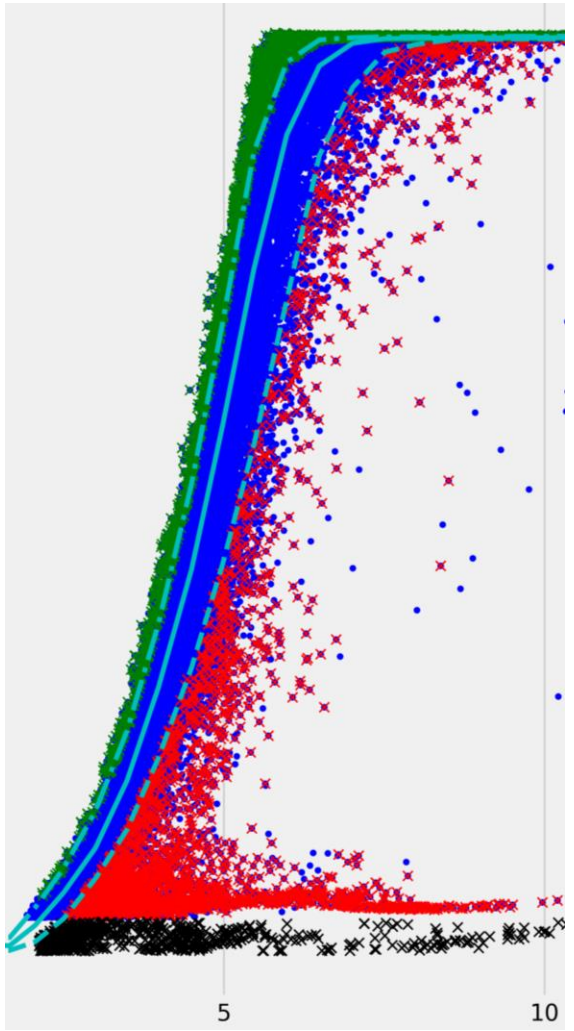
The rate of warm season data volume to the whole will be low

The results of pre-processing





pre-processing



Original data

- The number of red dots increased
- Pre-process contributed to improve the accuracy of the IceLossMethod

Conclusion

Incorporating new ideas into the ILM approach has improved the accuracy of icing duration calculations. Some findings and ideas are as follows.

- The duration of the icing events calculated by the ILM approach was evaluated by the comparison with the analytical results of the ice sensor outputs. As a result, it turned out that the ILM approach would tend to underestimate the duration.
- Since the criterion of the icing events in the cold season are determined by the power data in the warm period in the ILM approach, the accuracy of analysis for the icing duration and the energy loss depends strongly on the degree of scattering of the data acquired in the warm period.
- The process of removing data with a large deviation from the expected power at the respective wind speeds in the warm season prior to conducting the ILM analysis contributed greatly to improved calculation of the icing duration.

Thank you for your attention.