Combined effect of the heating and the superhydrophhobic coating on the de-icing capability of the ultrasonic wind sensor

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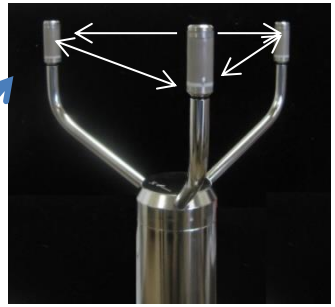
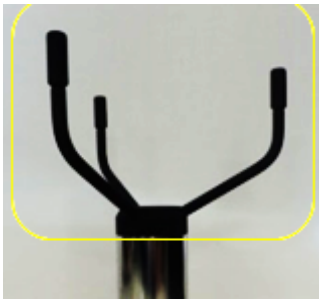
*4: Vaisala OYJ

Ultrasonic wind sensors

Ultrasonic transmission and reception

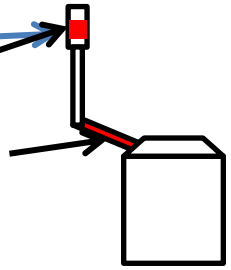


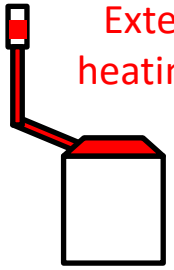


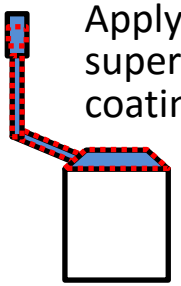
Model-I | Model-II | Model-III

Transducer

Heated area







	Model-I	Model-II	Model-III
Heated area	Transducer Lower arm	Transducer Whole arm Top Cover	Transducer Whole arm Top Cover
Coated area	X	X	Transducer Whole arm Top Cover

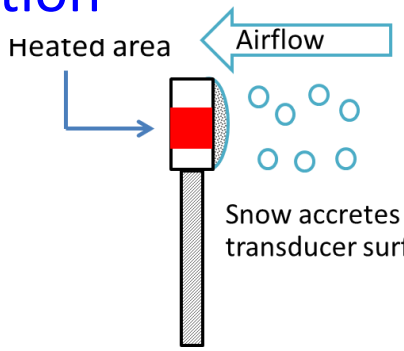
Agenda

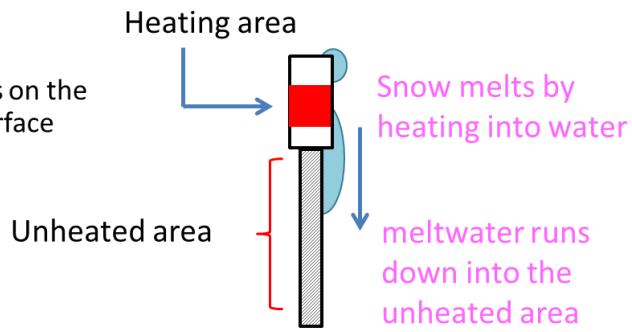
1. Motivation & Brief history of research
   - We experienced the erroneous wind measurement by the heated ultrasonic wind sensor in an icing climate
   - How we identified the cause of such events
2. Modification to Model-I
   - 2-1. Extending the heating area
     - Extending the heated area to prevent the secondary icing events
   - 2-2. Changing the surface property
     - Applying superhydrophobic coating to the hydrophilic surface
3. Snowing wind tunnel test
   - To confirm the effectiveness of modifications
4. Conclusions

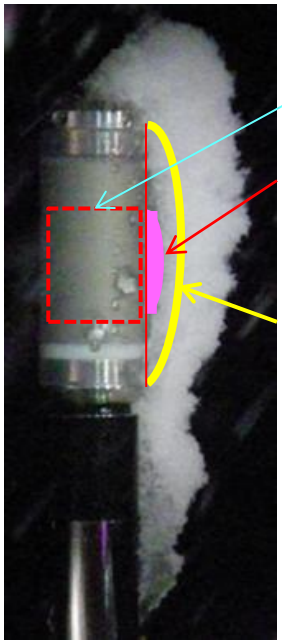
Icing process on transducer of Model-I

Scenario of ice bridge formation

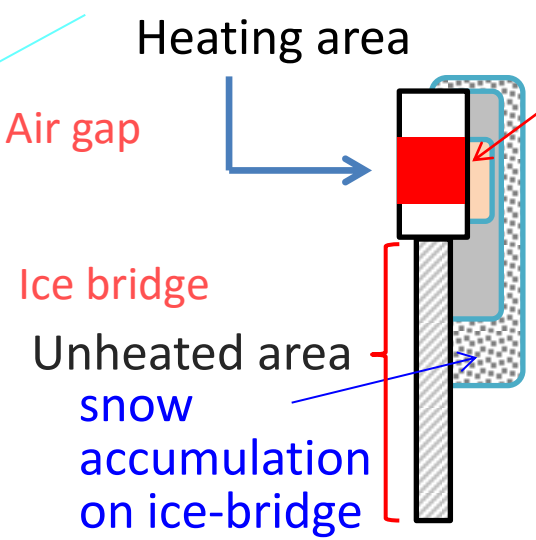
1. Snow accretes
2. melts due to heat
3. Melt water flows downward
4. freezes in unheated area (secondary icing process)
5. Ice grows and forms ice bridge



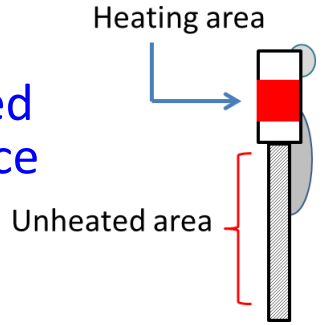




Transduser internal



Air gap because of heated transducer surface



Formation of ice-bridge due to secondary icing process

Ice occurred out of the reach of heated surface

⇨ Modification (Model-II & III)

Modification of Model-I

Scenario

Snow accretes

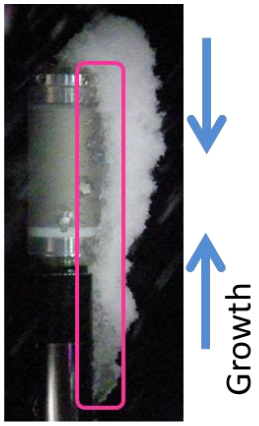
Melted by heat

Meltwater runs down to unheated area

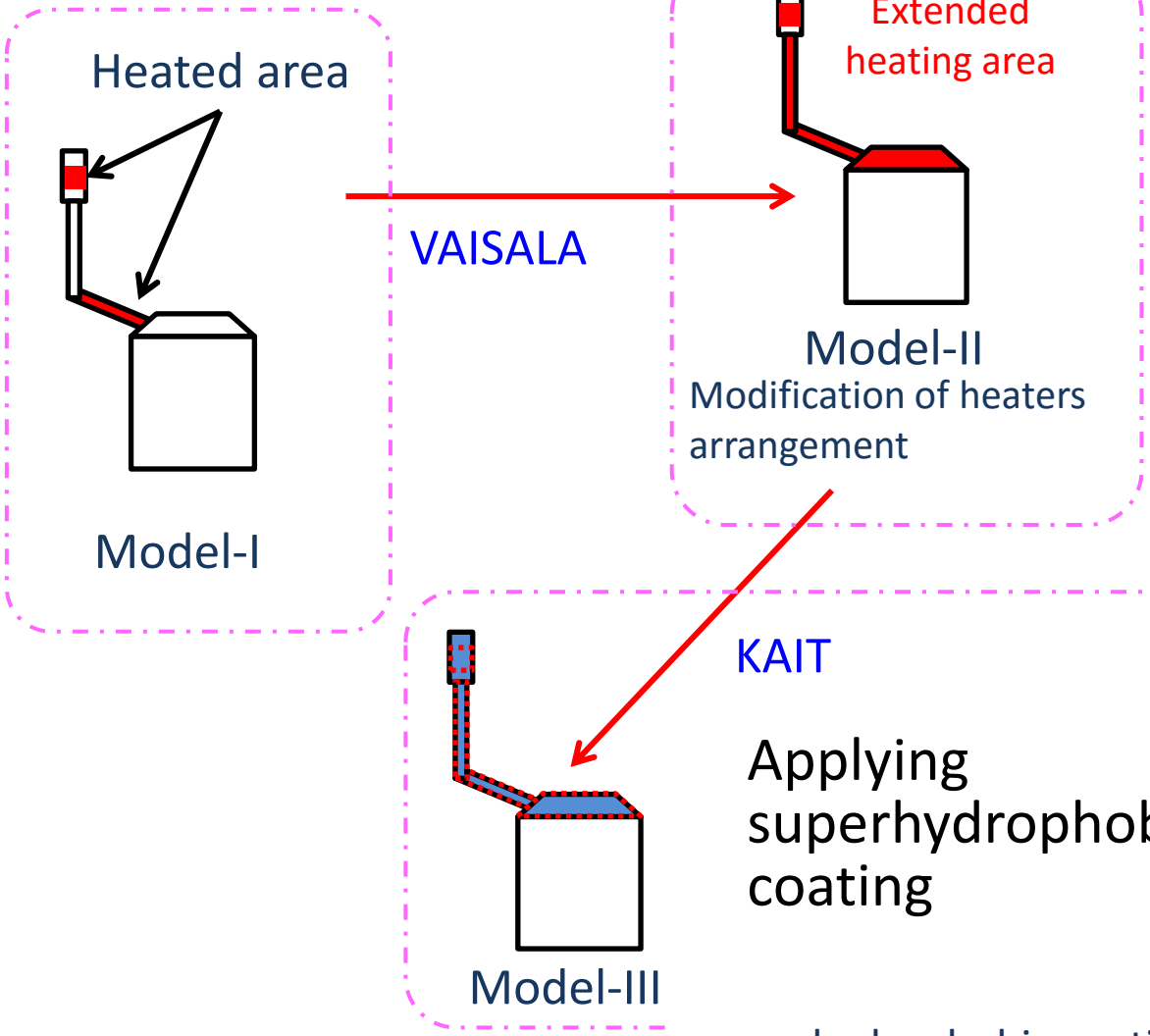
Secondary icing occurs

Ice grows from the upper and lower side

Ice-Bridge forms

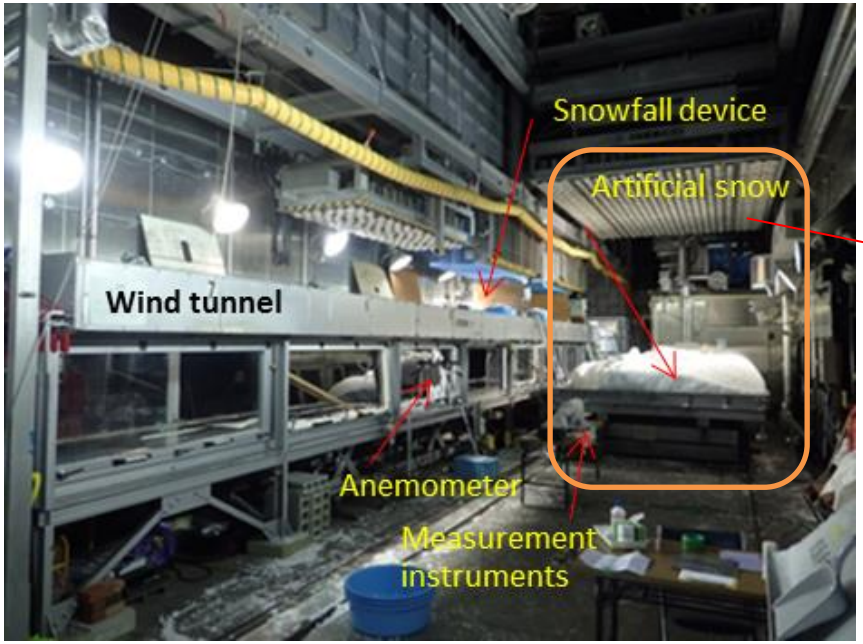


Secondary icing

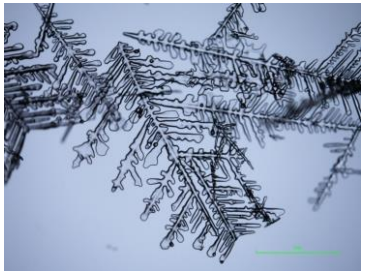


superhydrophobic coating (NTT-AT HIREC-100)

Snowing wind tunnel test



dendritic snow



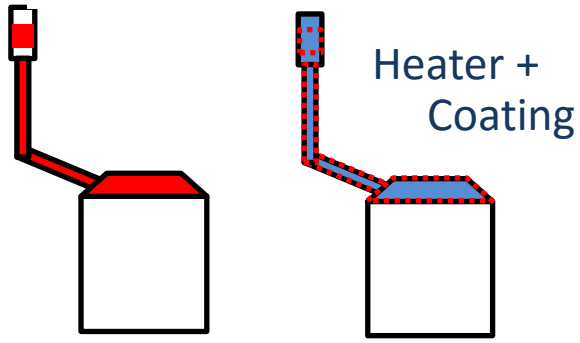
Artificial snow

At Shinjo CES Laboratory,
National Research Institute for Earth Science and Disaster Prevention

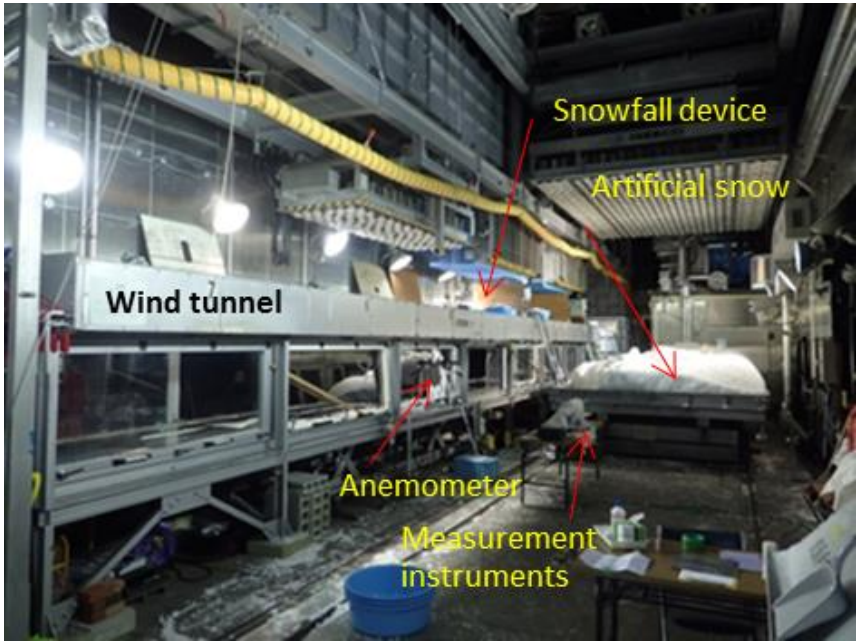
Tests conditions

Temperature [deg C]	-12	
Wind speed [m/s]	1	6
Snow flux [g/m^{2}s]	3.75	3.74
Snowfall intensity [mm/h]	13.5	13.5

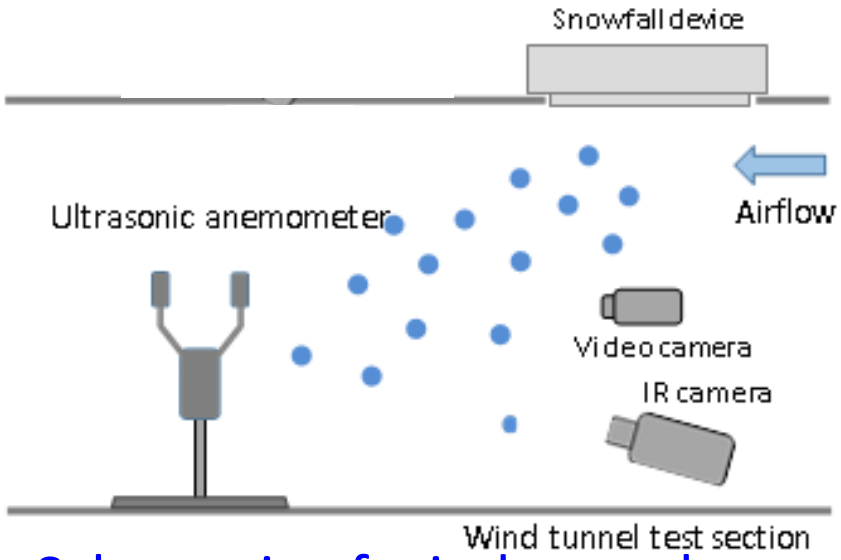
Test models



Snowing wind tunnel test



At Shinjo CES Laboratory,
National Research Institute for Earth Science and Disaster Prevention



Schematic of wind tunnel test

Tests conditions

Temperature [deg C]	-12	
Wind speed [m/s]	1	6
Snow flux [g/m^{2}s]	3.75	3.74
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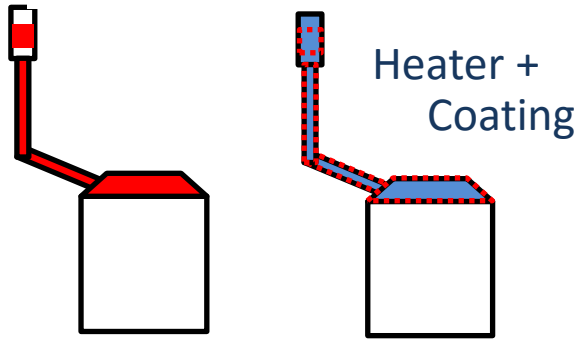
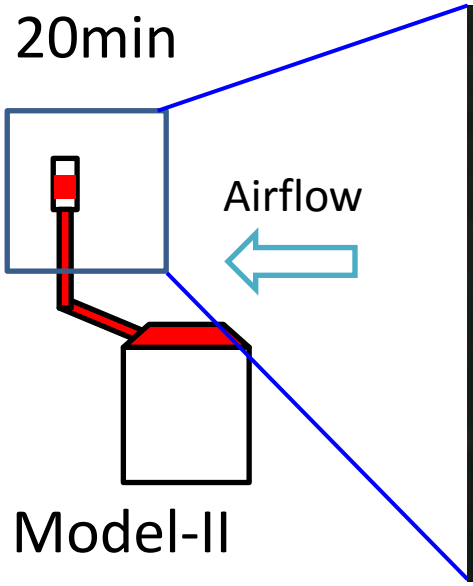
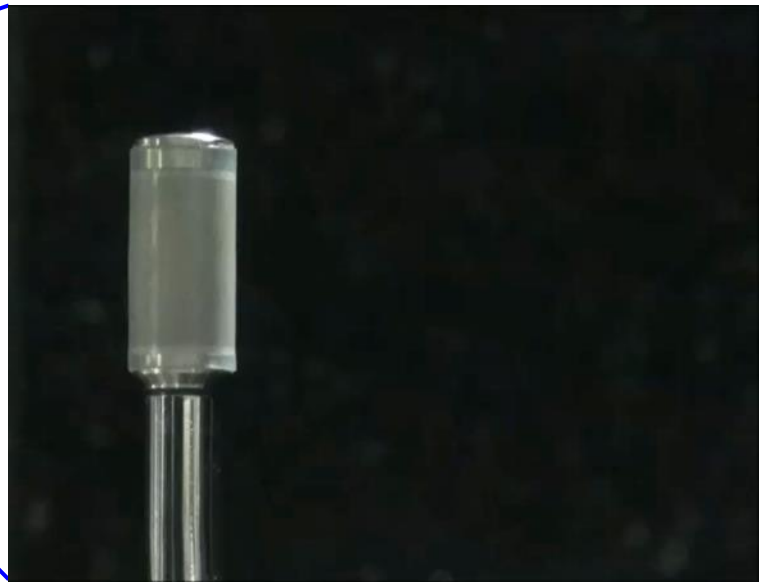
Test models



Test results at 6 m/s





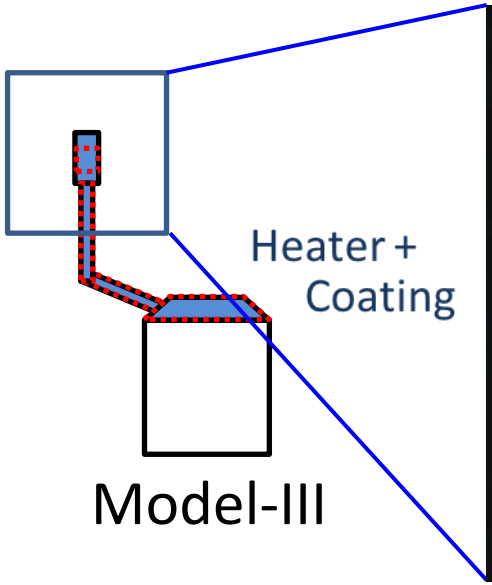
Test conditions

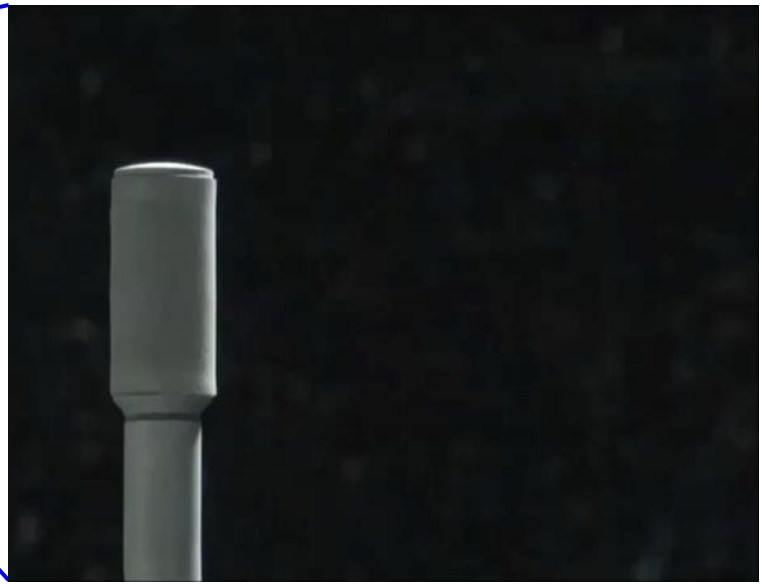
Airspeed: 6 m/s

Ambient temp: -12 deg C

Snow flux: 3.74 g/m^{2}s

- Snow melts and melt water runs downward on transducer surface



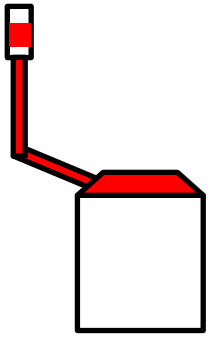


- No snow/ice accretion occurs in the course of the test run
- Snow melts upon impact on the coated surface
- Some snow flakes are bouncing on the surface

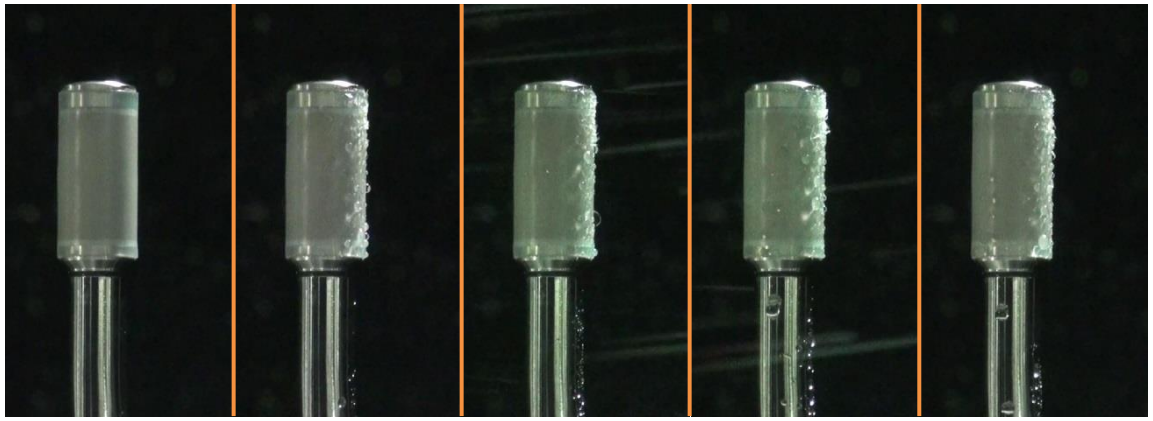
Results of snowing test- at 6m/s

Snow flux: 3.74 g/m^{2}s

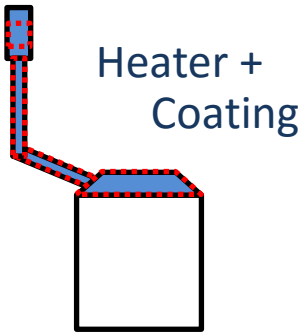
Airflow



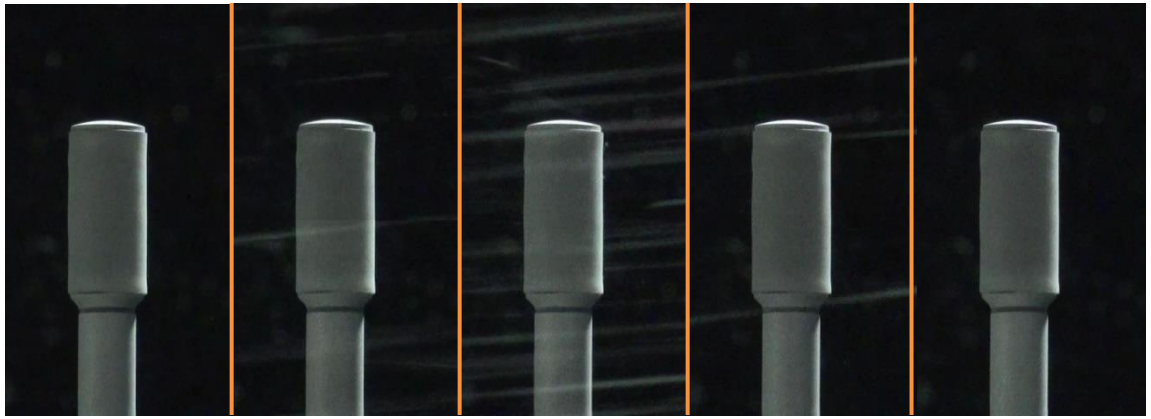
Model-II



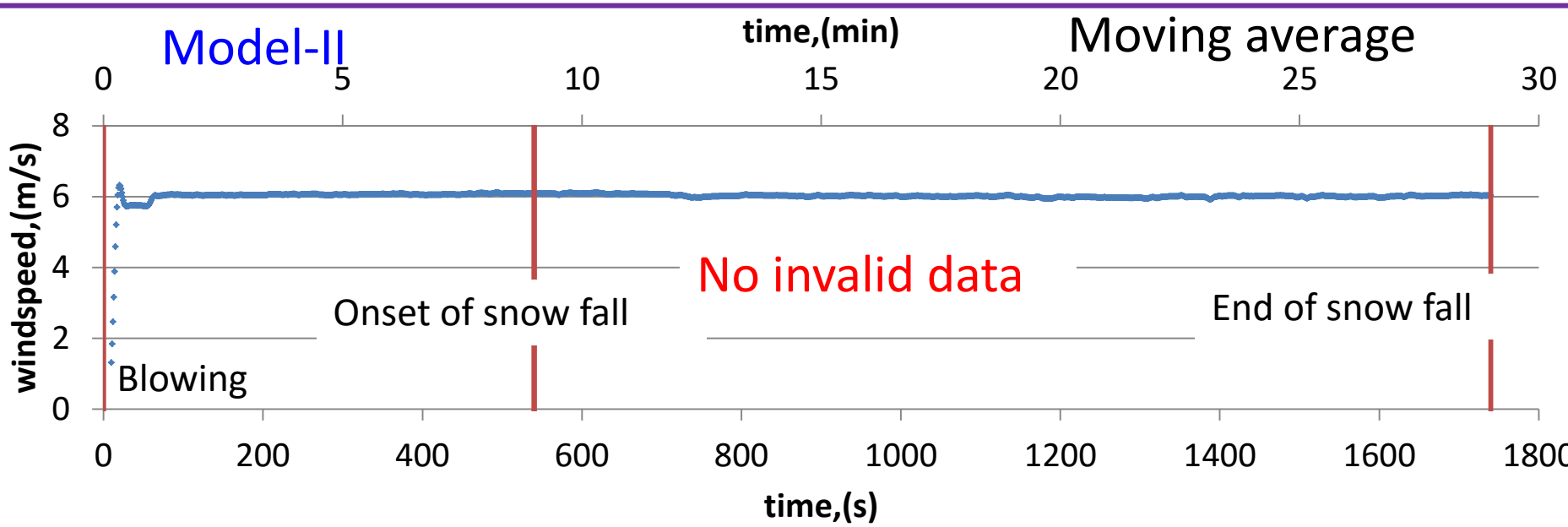
0min 5min 10min 15min 20min

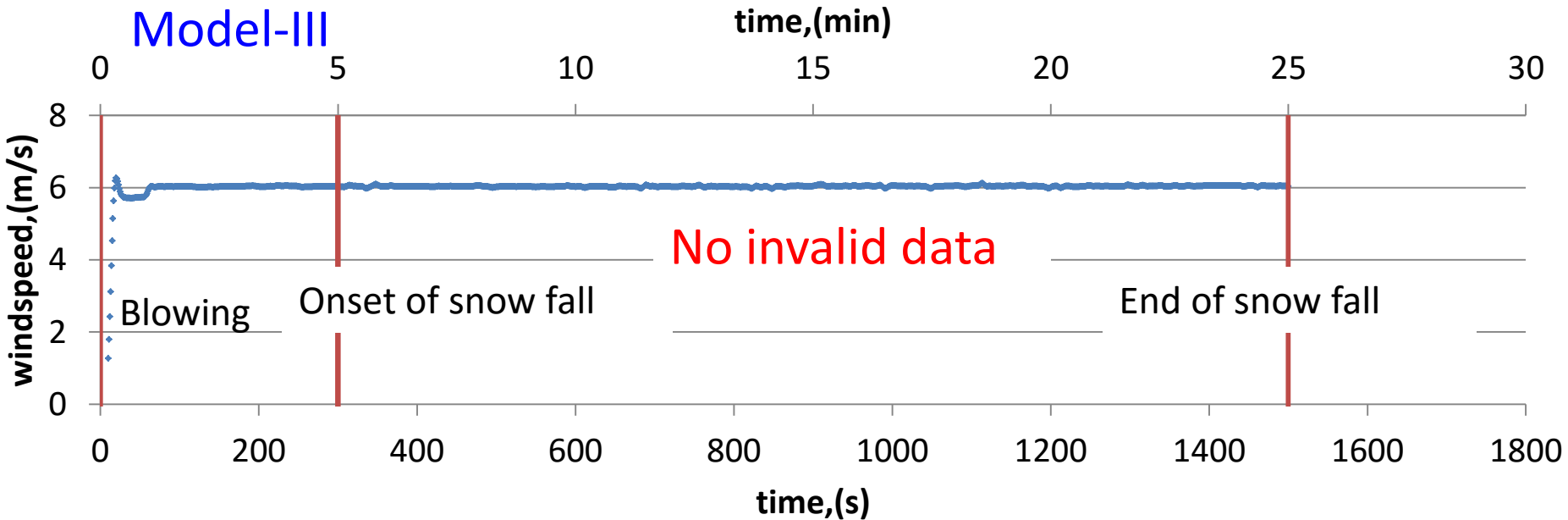


Model-III



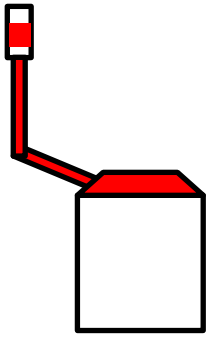
Results of snowing test- at 6m/s



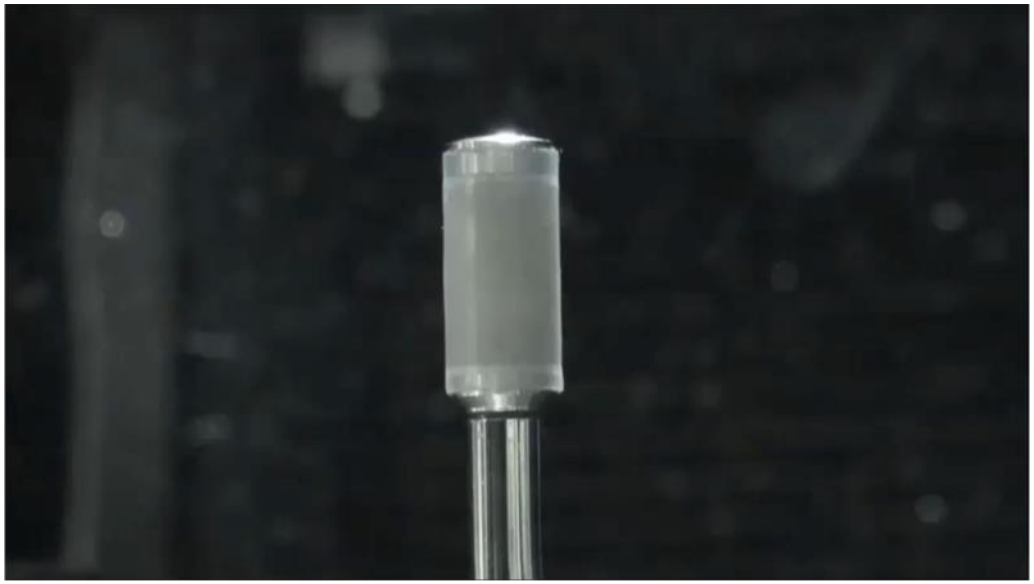


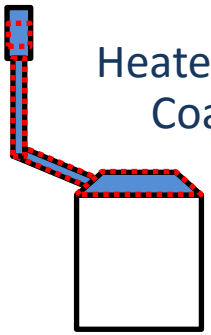
Results of snowing test- at 1m/s

Snow flux:
3.75 g/m^{2}s

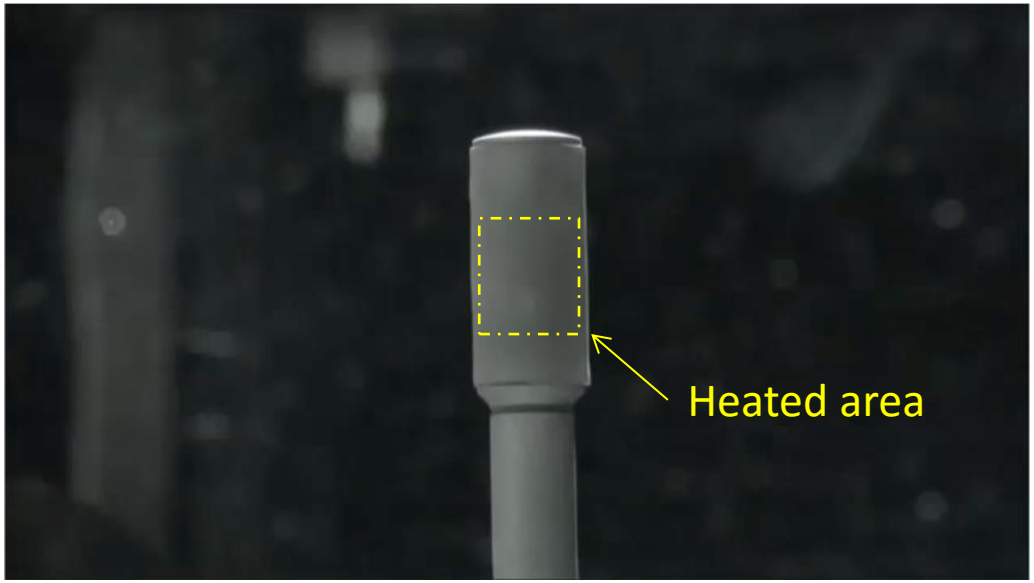


Model-II





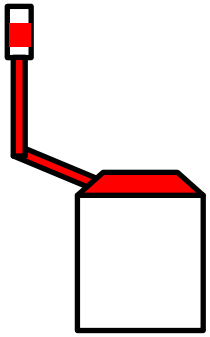
Model-III



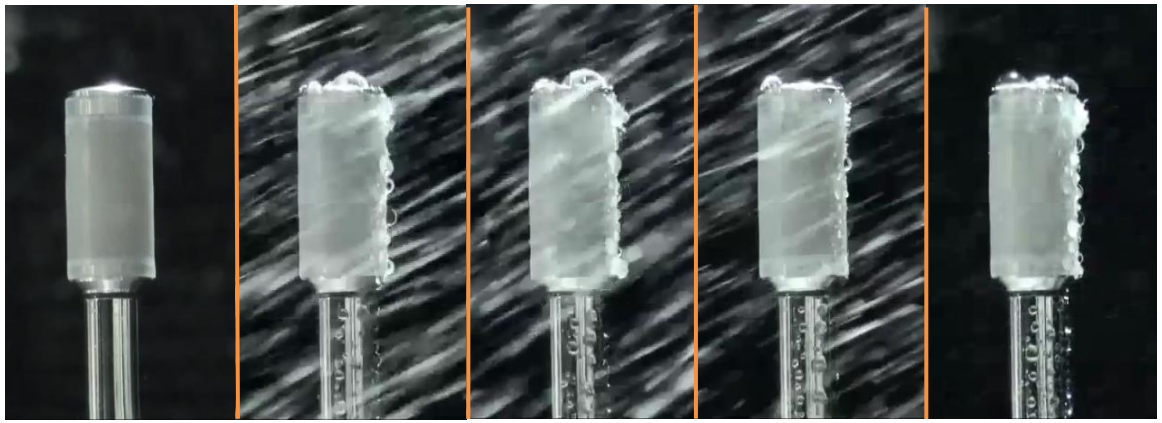
Results of snowing test- at 1m/s

Snow flux: 3.75 g/m^{2}s

Airflow

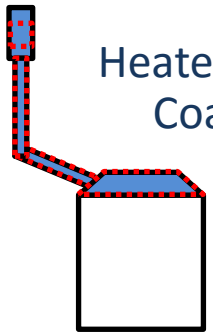


Model-II

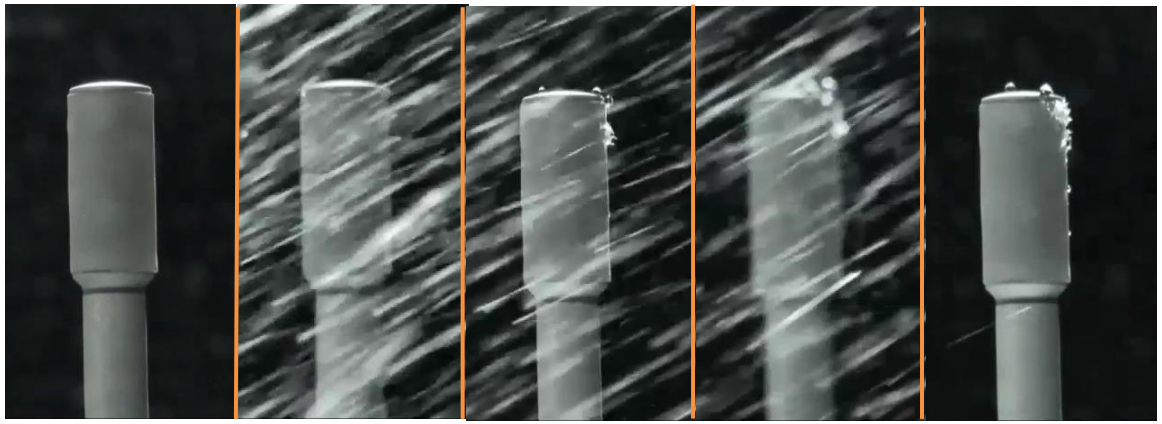


0min 5min 10min 15min 20min

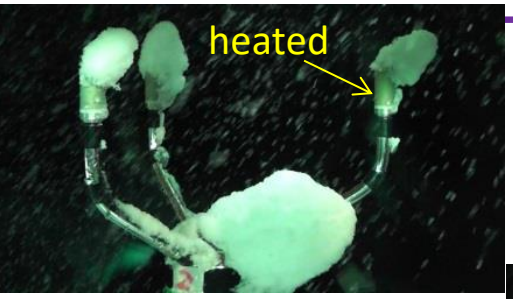
Heater + Coating



Model-III

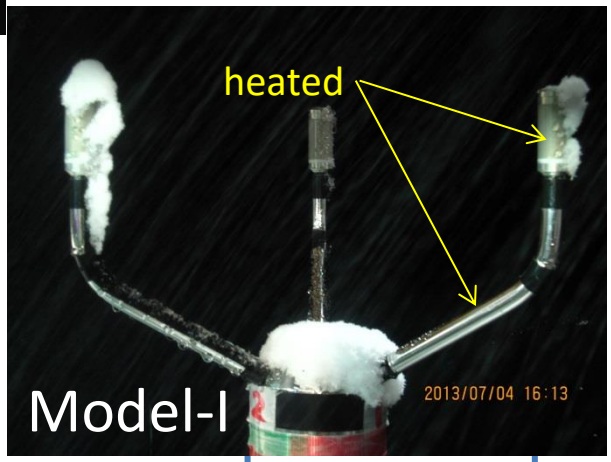


Results of snowing test- at 1m/s



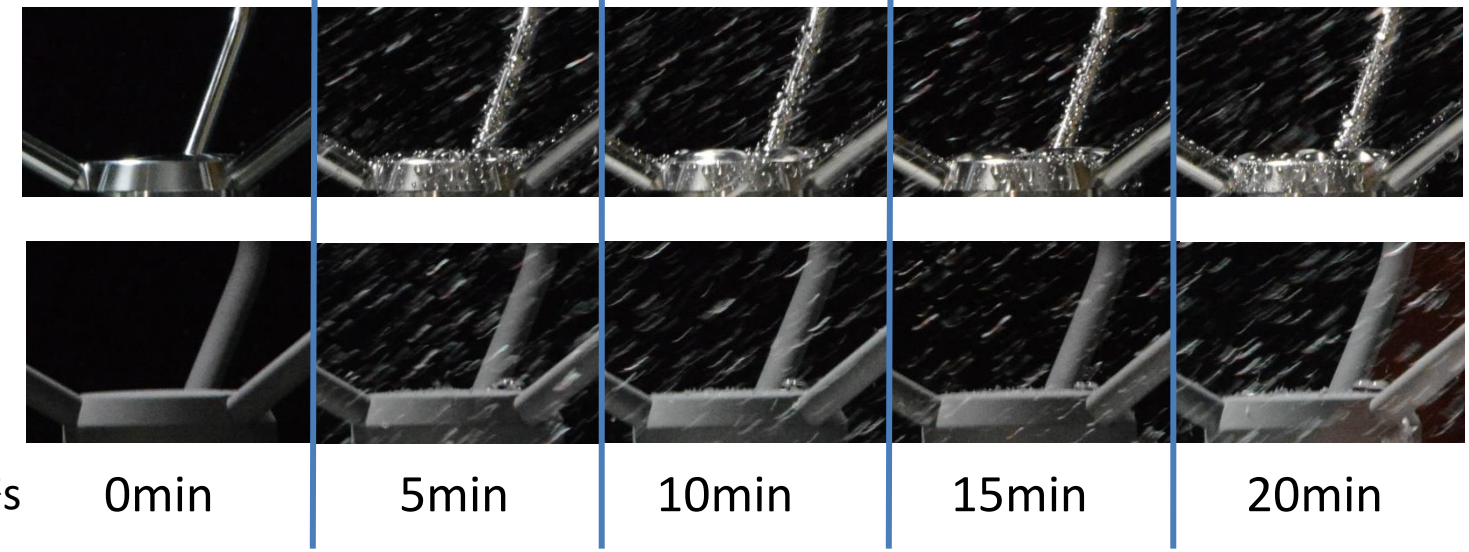
Snow accumulation on the top cover and the lower arms of the previous model (no heated arms & top cover)

Preventing snow accumulation on the top cover by heating & heating+coating



Model-II

Model-III



Snow flux: 3.75 g/m^{2}s

0min 5min 10min 15min 20min

Concluding remarks

- The primary findings obtained by the previously conducted research
  - An ice-bridge with an air gap forms on the heated cylindrical transducer surface of the wind sensor due to the secondary icing process in snowing conditions, which may be the main cause of incorrect wind measurement.
  - Prevention of freezing of meltwater on the transducer or acceleration of removal of liquid water from it can be the best way for stable measurement.
- Modification of the ultrasonic wind sensor
  - Extending the heating area: leads to avoidance of refreezing of meltwater
  - Metamorphosing the surfaces into being superhydrophobic (+ extended heating area): leads to quick removal of water from the body surface
- Verification of modifications by snowing wind tunnel test
  - Both modifications work well to prevent the sensor from icing and snow accumulation. In particular, coating achieves its water repellency.
- Future research
  - The durability of superhydrophobic paint has to be evaluated by the field test throughout winter where the coated surface is exposed to the harsh icing and/or snowing conditions.