Mitigation of Heavy Snow Loads on PV Modules

to avoid the catastrophic damages

Tadanori Tanahashi (AIST, JP)

Contributors: Takahiro Chiba (Hokkaido University of Science),
Satoru Adachi (Nat. Res. Inst. for Earth Science and Disaster Resilience),
Yuki Tsuno, Kazuaki Ikeda, and Takashi Oozeki (AIST)

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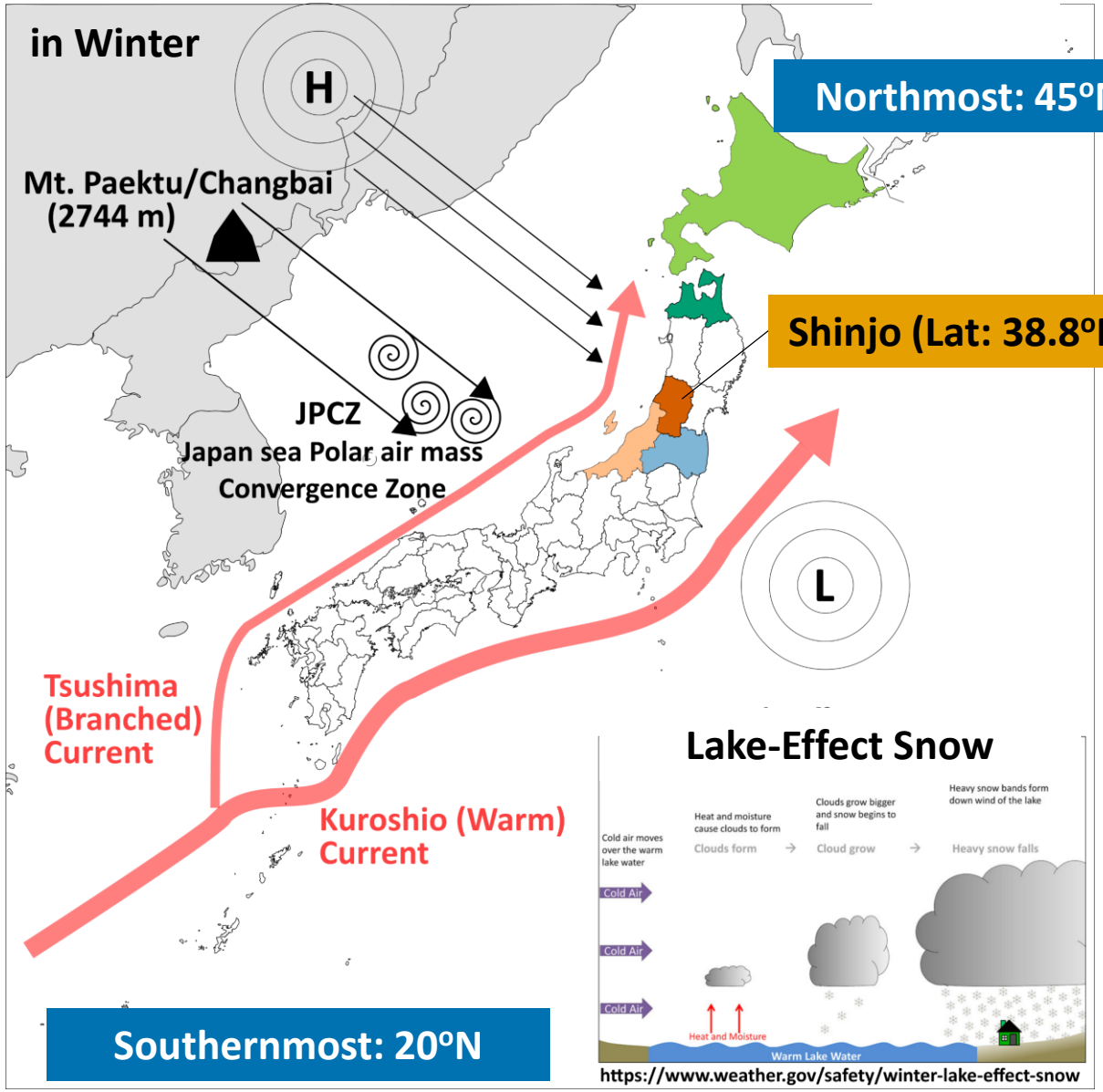
2024 High Latitude Photovoltaics Workshop, March 15, 2024
Piteå, Sweden

Background: Japan is not located at “High-Latitude Zone”, However

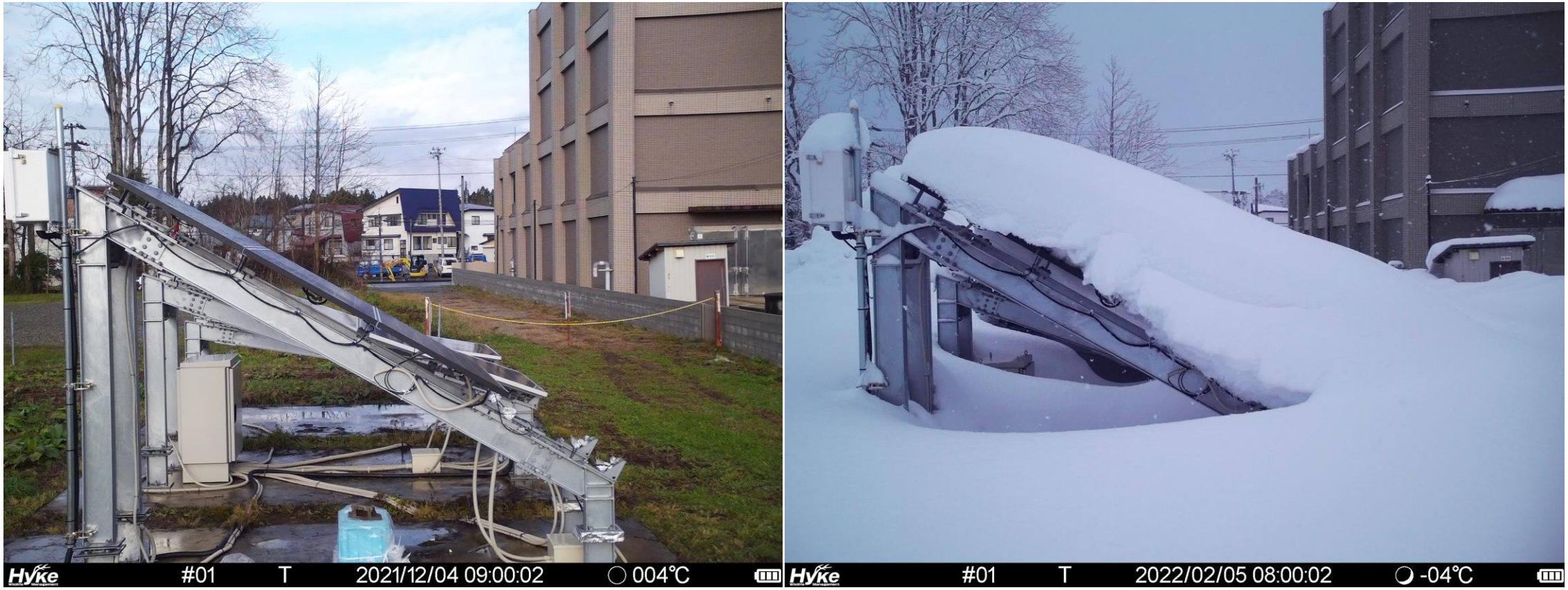


Source: JMA (Japan Meteorological Agency) →

	Prefecture	Observed Site	Max Snow Depth	
			cm	Date
1	Shiga	Ibukiyama	1182	1927/2/14
2	Aomori	Sukayu	566	2013/2/26
3	Niigata	Sumon	463	1981/2/9
4	Yamagata	Hijiori	445	2018/2/13
5	Niigata	Tsunan	419	2022/2/24
6	Niigata	Tohkamachi	391	1981/2/28
7	Niigata	Takada	377	1945/2/26
8	Niigata	koide	363	1981/2/28
9	Niigata	Sekiyama	362	1984/3/1
10	Niigata	Yuzawa	358	2006/1/28
11	Nagano	Nozawa Onsen	353	1984/3/22
12	Niigata	Yasuzuka	350	1984/3/8
13	Yamagata	Ohisawa	348	2000/3/1
14	Fukushima	Tadami	341	2013/2/25
15	Fukushima	Hinoemata	339	2015/2/15
16	Shizuoka	Mt. Fuji *	338	1989/4/27
17	Hokkaido	Horokanai	324	2018/2/25
18	Hokkaido	Kucchan	312	1970/3/25
19	Hokkaido	Shumarinai	311	1982/3/10
20	Niigata	Nou	309	1985/1/30

Heavy Snow Accumulation on PV Modules at Shinjo Test Site (JP)

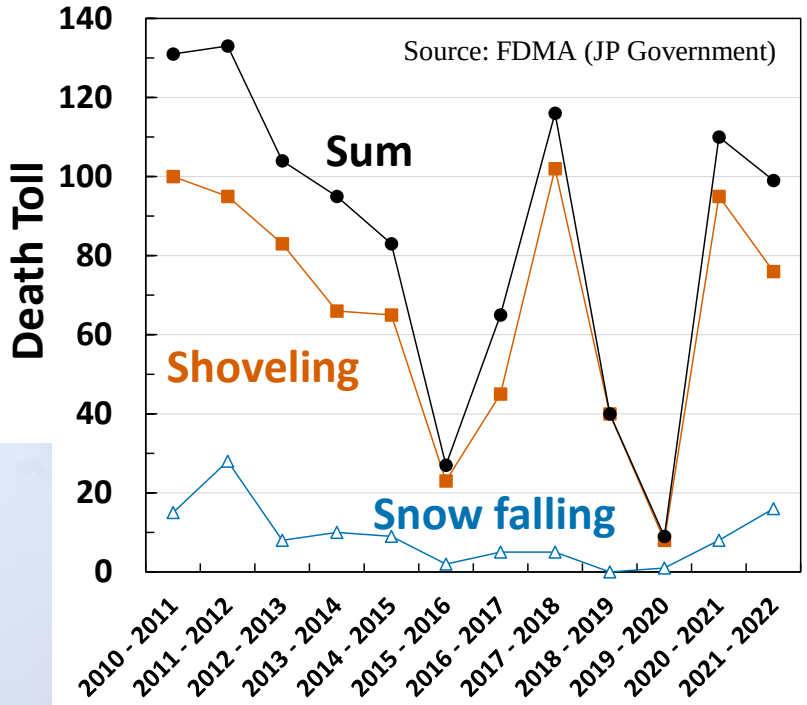
Heavy Snow Accumulation on PV Modules at Shinjo Test Site (JP)



Motivation 01: Accidents resulting in injury / death, occurring while the shoveling off the snow accumulated on rooftop

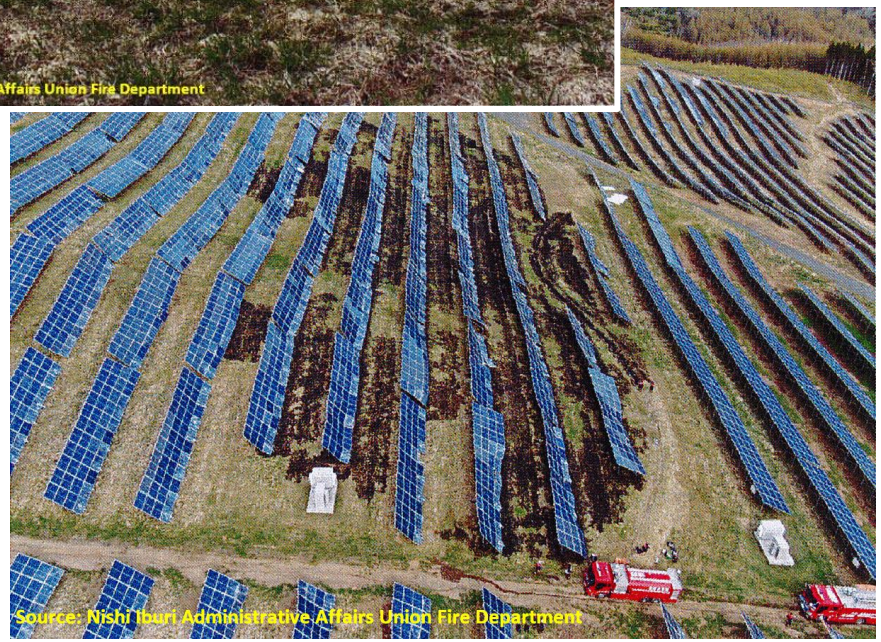
http://e-yanet.jp/snow09281452/

https://www.makuake.com/project/iguchi-ke/



In Japan, **ca. 800 people have died** during the shoveling off the snow, since 2010 snow season.

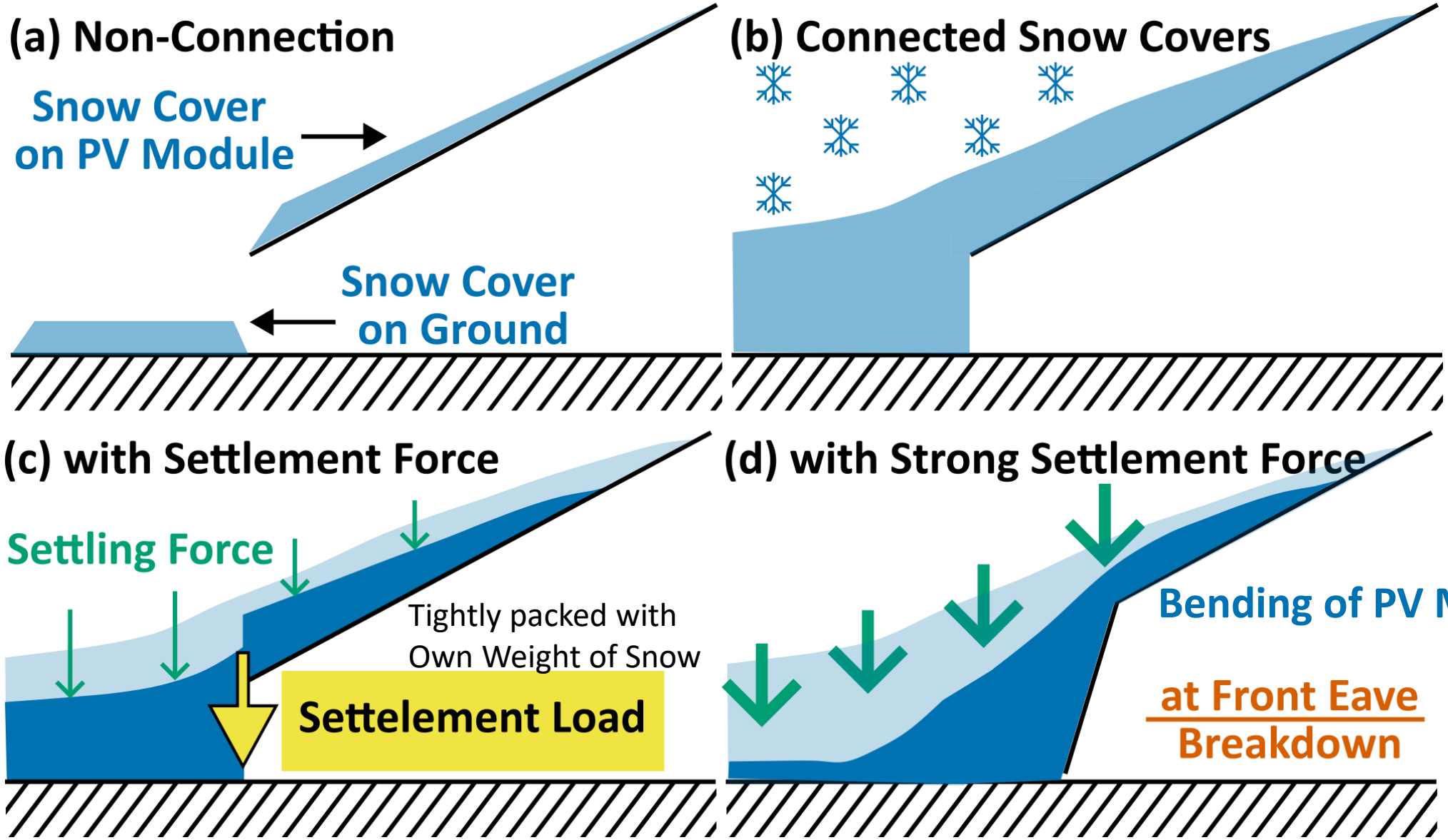
Motivation 02: Mechanical damages caused by heavy snow loads



After spring arrived, a bushfire occurred.

Even in the Elevated Mounting Structure (Bent failure of PV modules)

Impact of Heavy Snow Load



Snow Removal Technologies for PV Modules

1) Passive Technologies

- Surface Coating (Ice-Phobic / Hydro-Phobic / …)
- Surface Texture (Nano-Textured Glass / …)

2) Active (Melting / Thermal) Technologies

- Reverse Electrical Current (Bias) Applied to PV Cells
- **Encapsulated / Attached Electrical Resistance Heaters**

3) Mixed Technologies

- Heater
  + Rear Ventilation

Simple Configuration / Fabrication
(Easy Encapsulation)

Simple Identification of Heating Spec. for Design
(Resistance → Heating Ability)

Simple Control
(ON-OFF Control)

Commercially Available PV Module with a Built-in Film Heater

融雪 × 発電のハイブリッド誕生

太陽電池一体型ヒーターパネル

CSH-331B81BJ1（終端用）

CSH-331B81BJ2

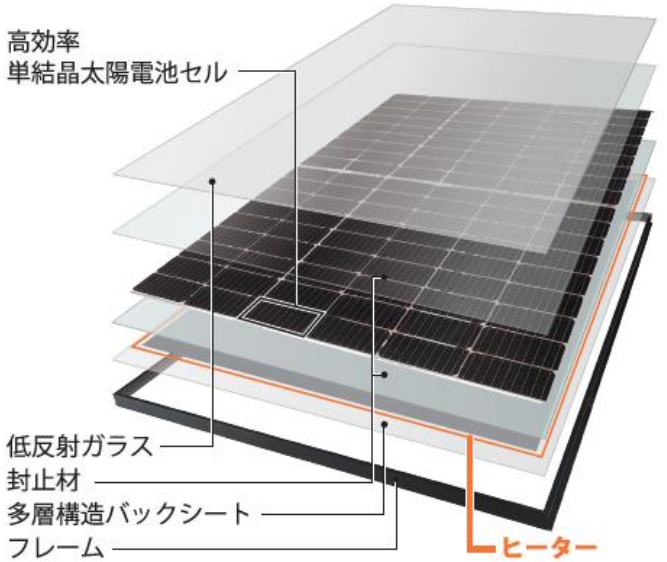
モジュール変換効率 19.4%※1

公称最大出力 331W※2

Made in Japan 信頼の日本品質

有機ELデバイスや半導体製造装置の開発、製造、メンテナンス事業も手がける長州産業。そこで培ってきた高度な装置技術は、太陽電池モジュールの製造にも確実にいかされ、高度な品質管理体制のもとで信頼性の高い製品を生産しています。
日本の厳しい気候条件の中で長期間にわたって性能を維持しなければならない太陽電池モジュール。長州産業では、そのために必要な信頼性を第一に考えています。

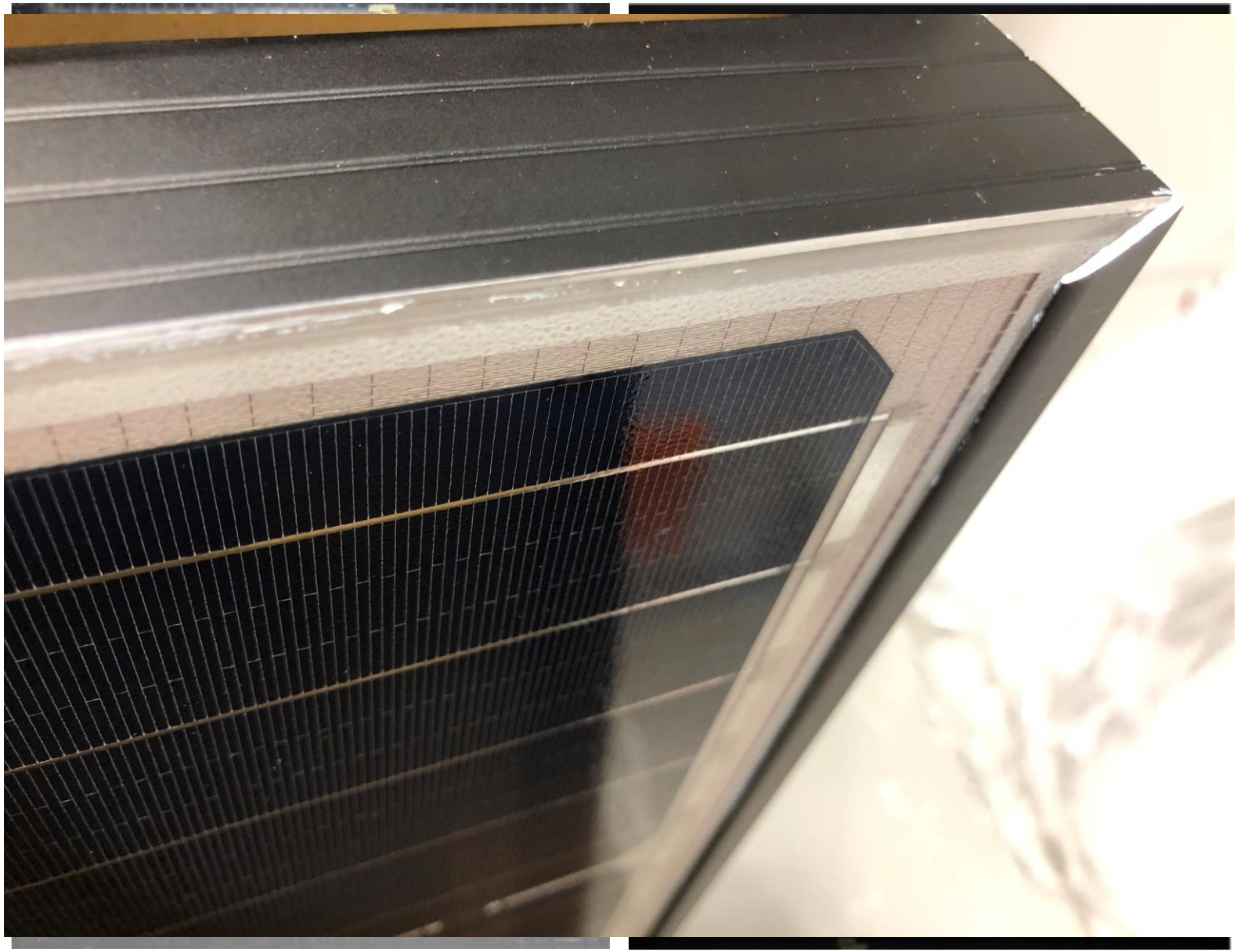
※1：太陽電池モジュールの変換効率（%）は $\frac{\text{モジュール公称最大出力（W）}}{\text{モジュール面積（㎡）}\times 1000\,(\text{W/㎡})}\times 100$ の計算式を用いて算出しています。
変換効率とは、太陽光エネルギーから電気エネルギーに変換したときの割合を表します。
※2：公称最大出力の数値は、JIS C 61215-2で規定するAM1.5、放射照度1,000W／㎡、モジュール温度25℃での値です。

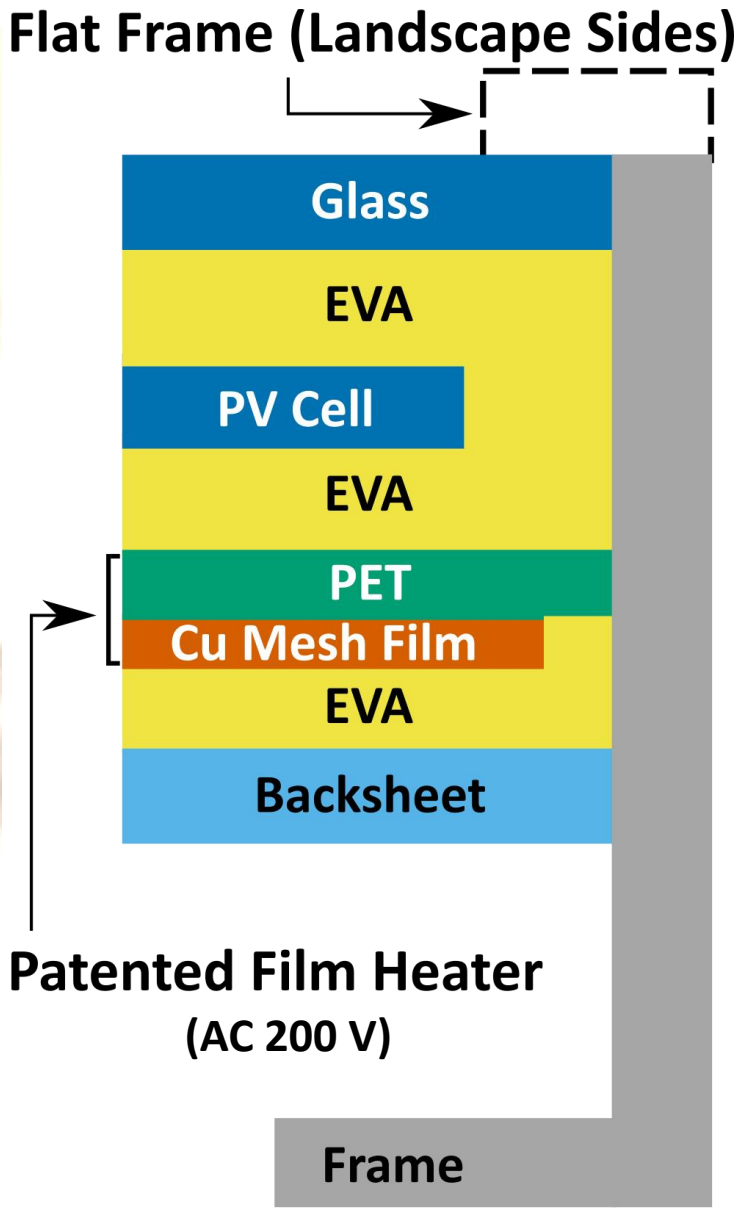


採用しているヒーターは異常発熱等を起こさない構造なので、安心してご利用いただけます。

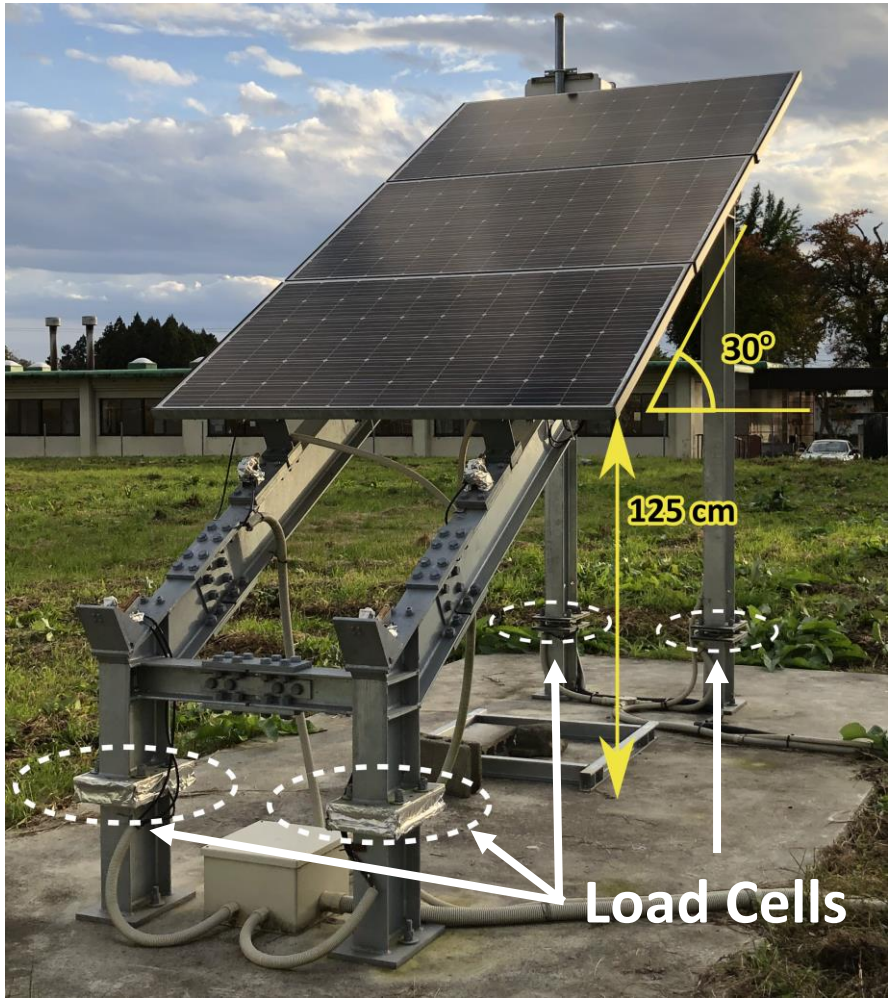
https://cic-solar.jp/catalog/hotpanel_2308/book/

PV Module with a Built-in Film Heater (*P*m = 280W)

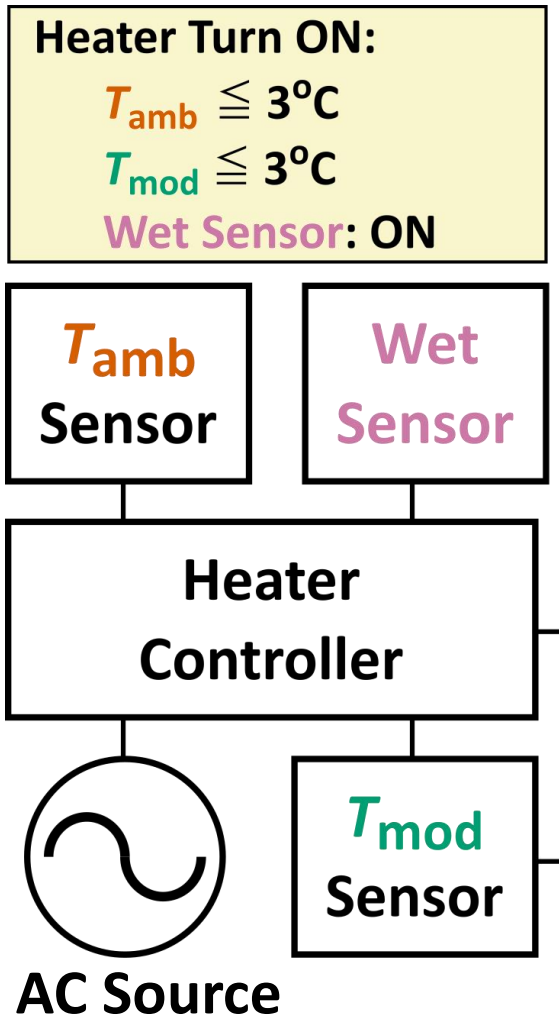


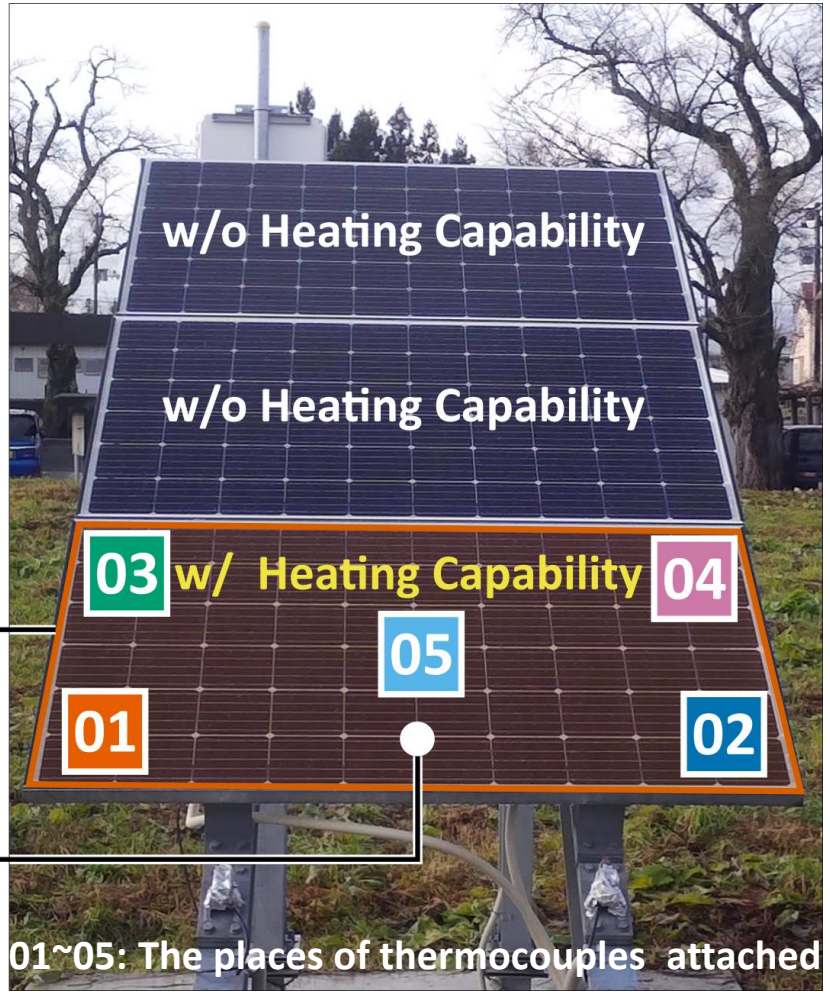


Setup to Evaluate the Effect of PV Module Heating



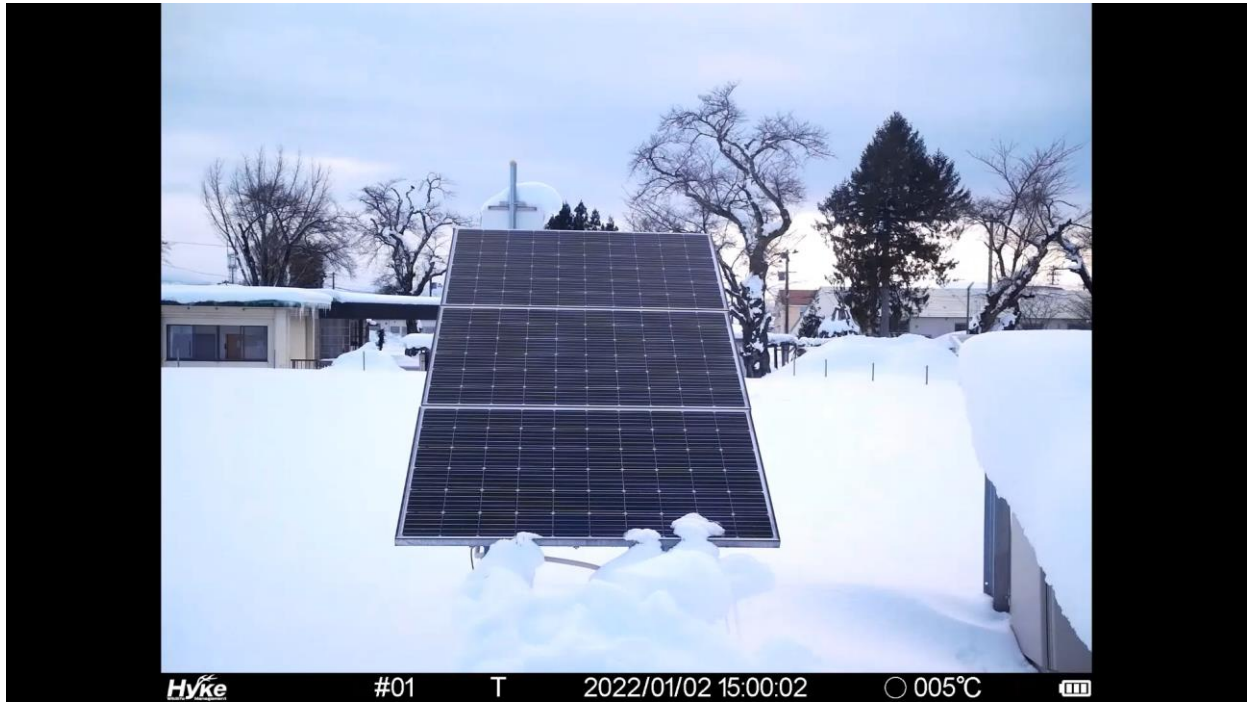
Mechanical Loads to the respective
4 pods were measured every 10 min.



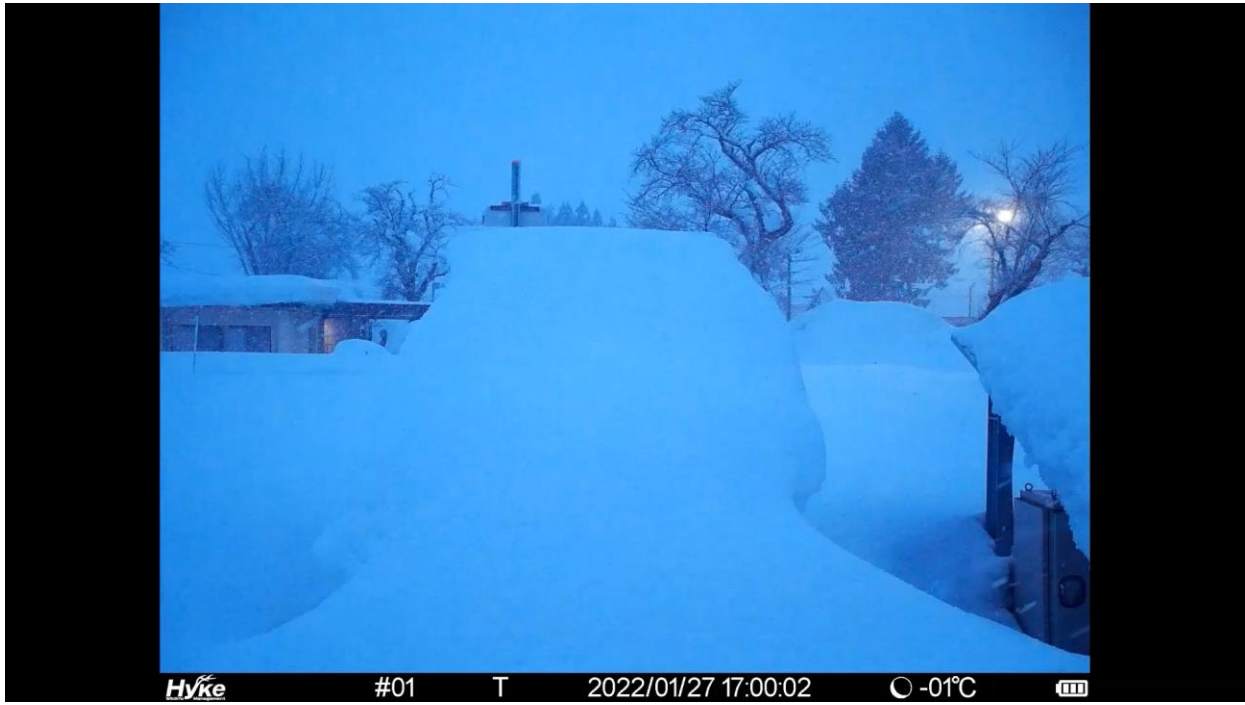


Control & Monitoring of Heating Ability

Evolution of Snow Coverage (2021-2022 Season)

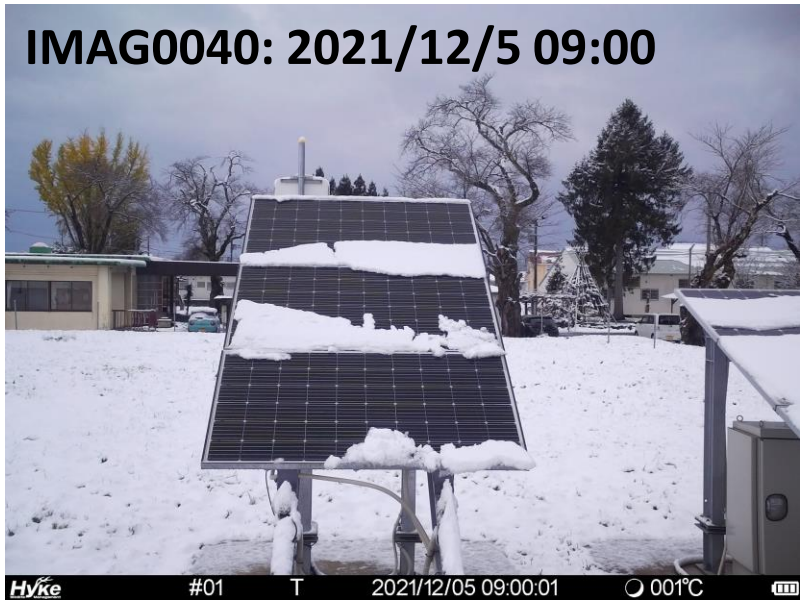


Facilitation of Snow Shedding
Formation of Snow Connection



Further Accumulation of Snow

Snow Coverage Estimation



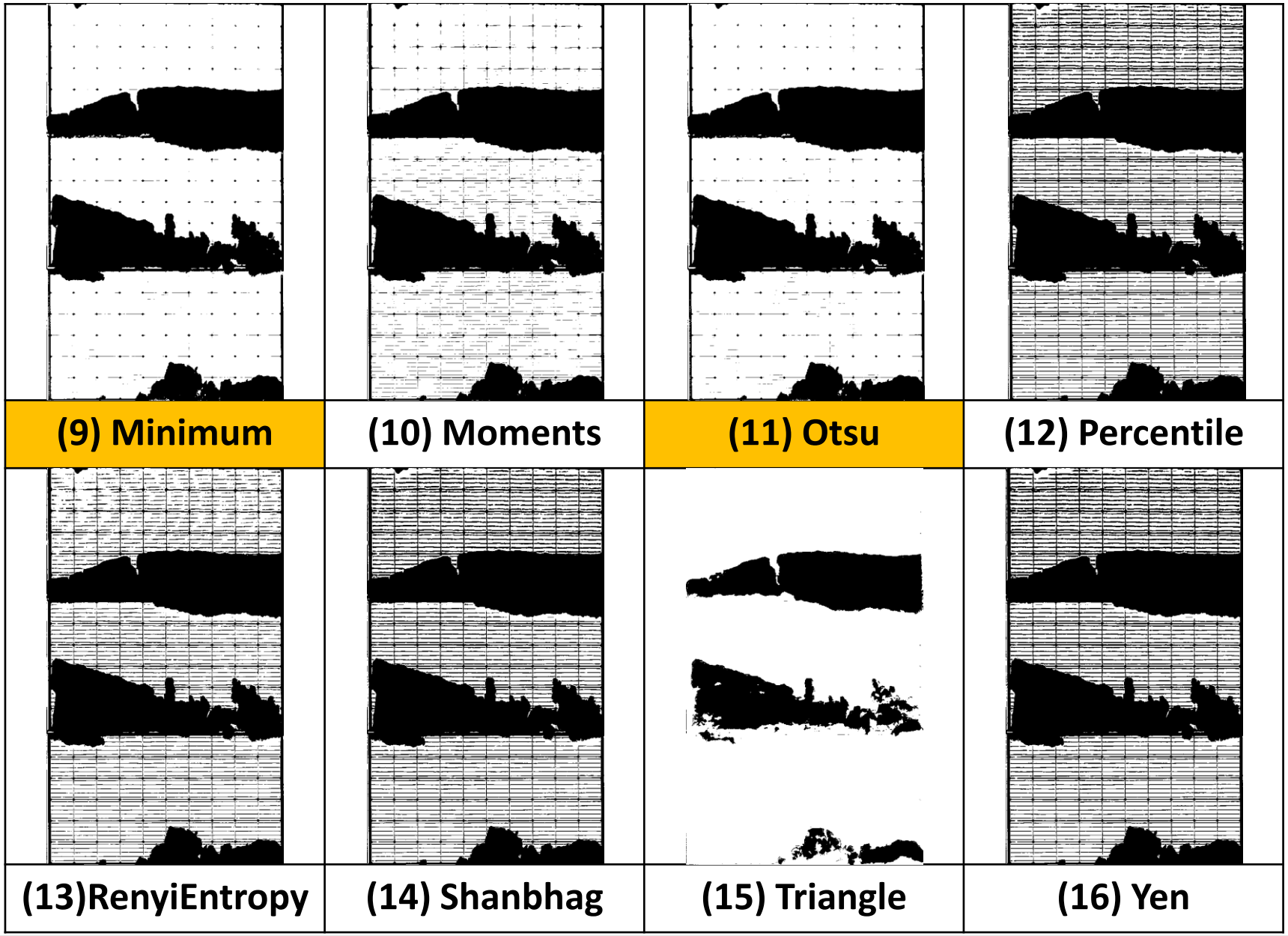
OpenCV / python

- ROI Clipping
- Perspective Correction

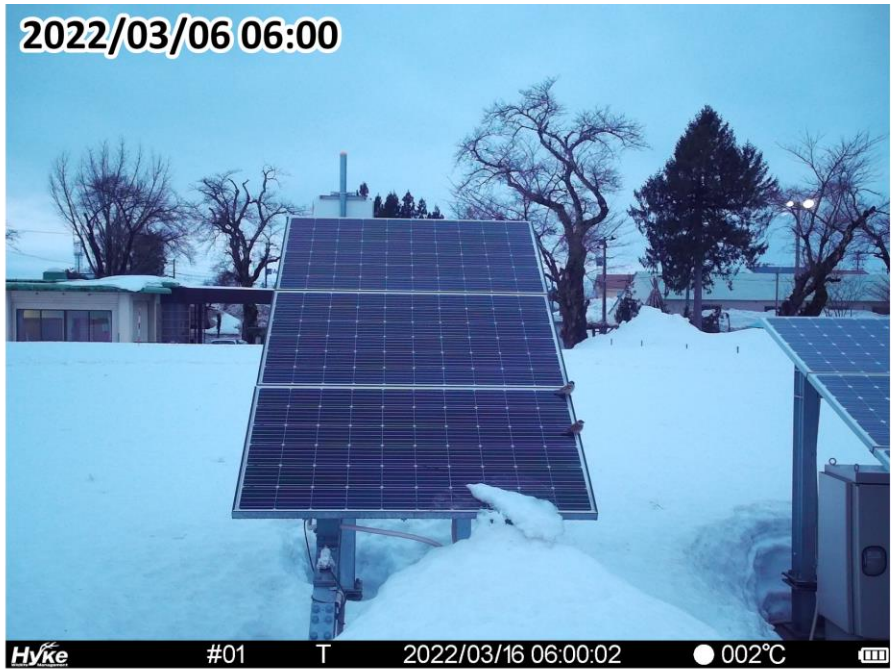
python on ImageJ/JAVA

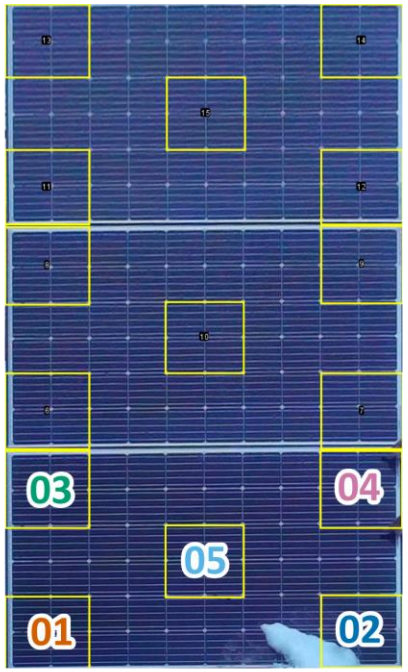
- Binarize
- Threshold Selection

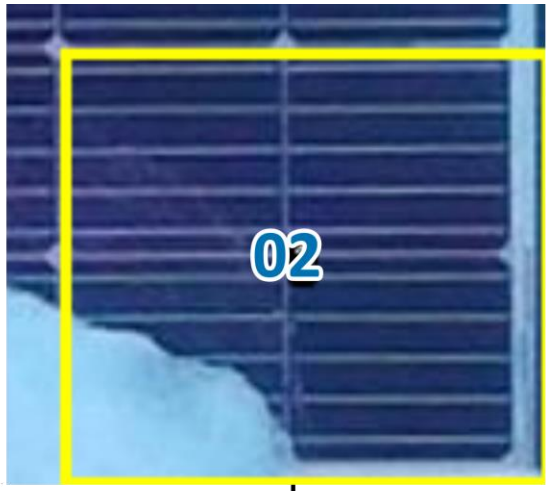
https://imagej.net/plugins/auto-threshold

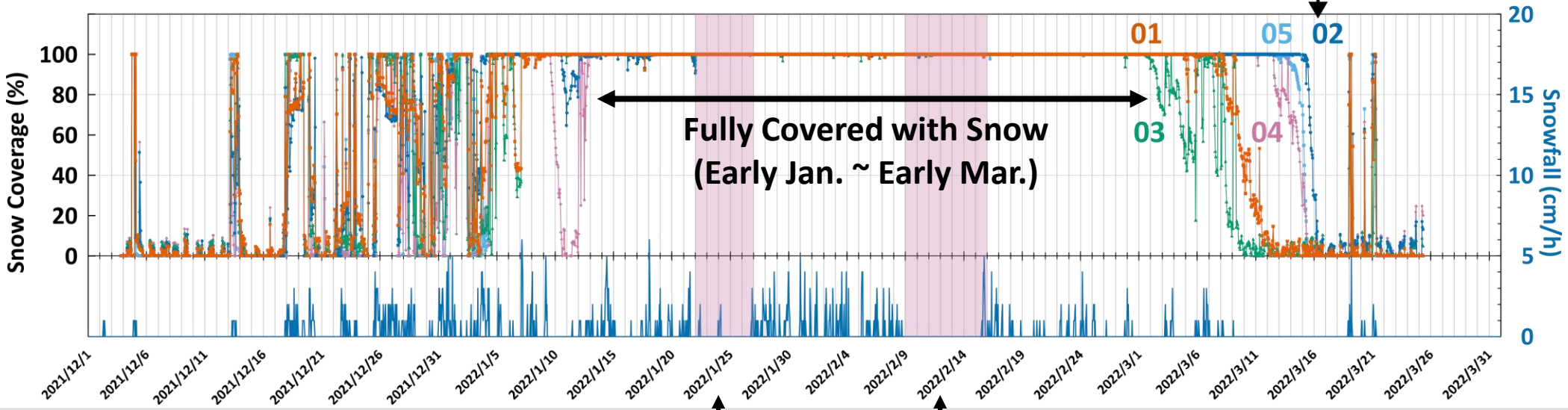


Evolution of Snow Coverage (2021-2022 Season)

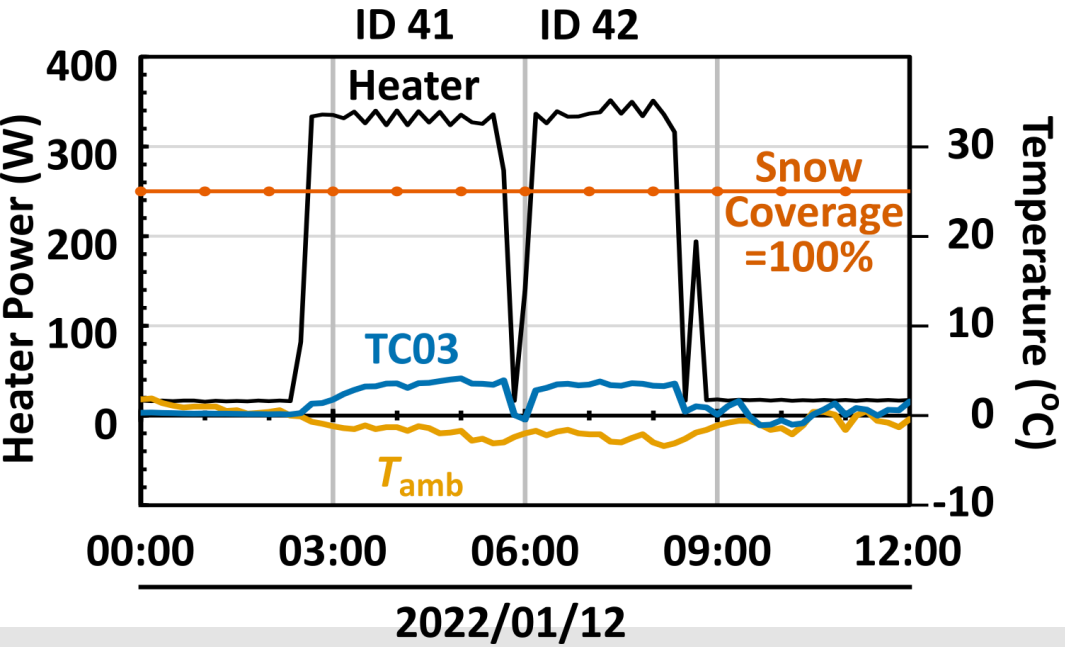








Estimation of Attained/Reached Module Temperature

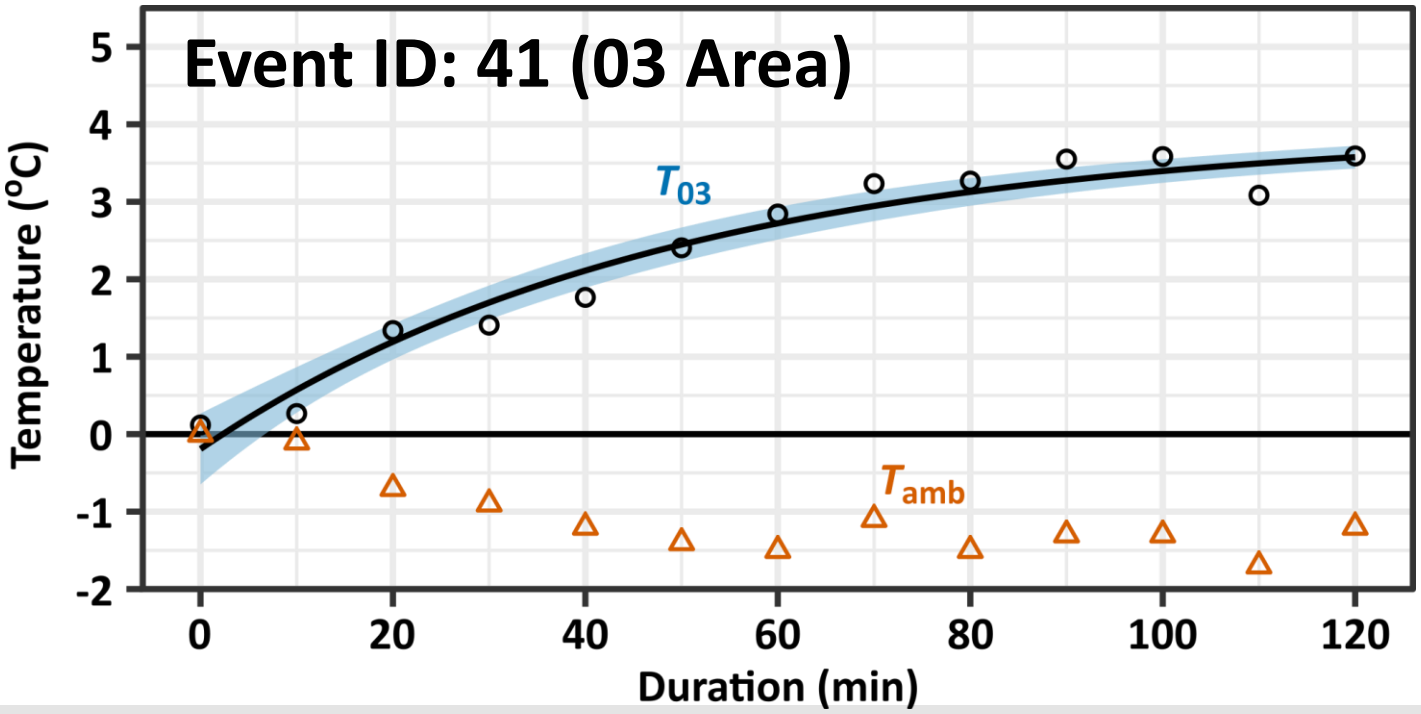


Fitting to Simple Exp. Curve

$$T_{mod-obs} = \alpha \cdot exp(-\beta \cdot t) + T_{mod-att}$$

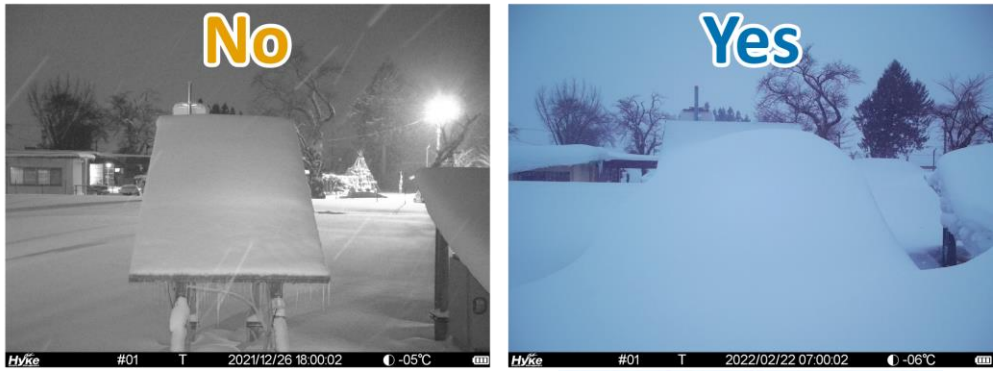
$T_{mod-obs}$: Observed Module Temperature

$T_{mod-att}$: Attained Module Temperature

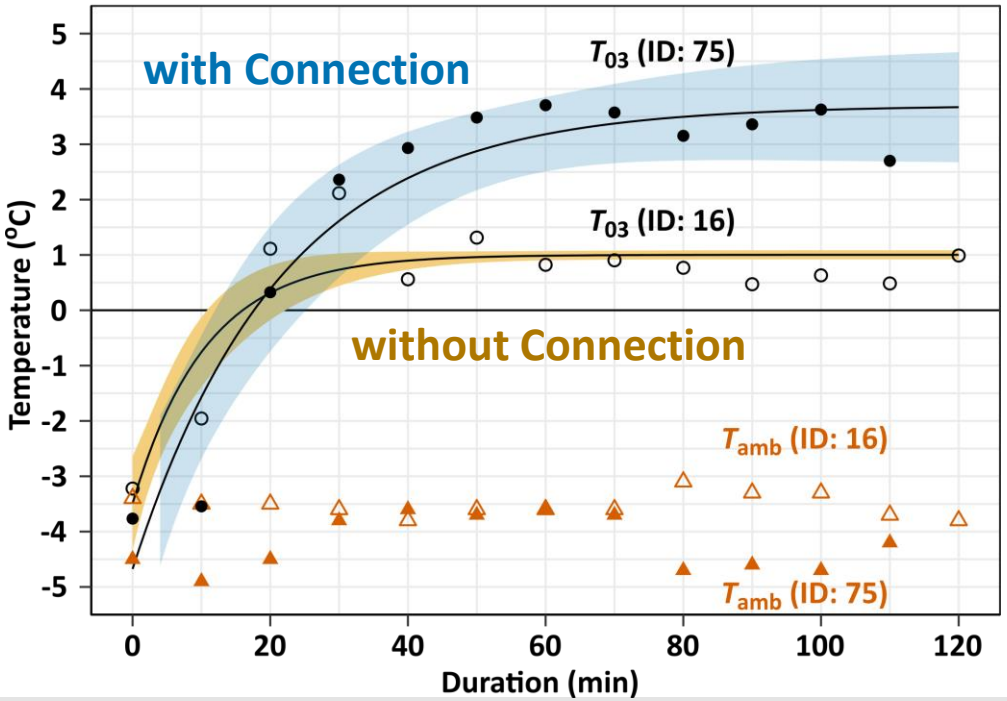


Effects of Snow Covers Connection

Connection of Snow Covers



ID: 16 (2021/12/26 18:00)　　ID: 75 (2022/02/21 07:00)



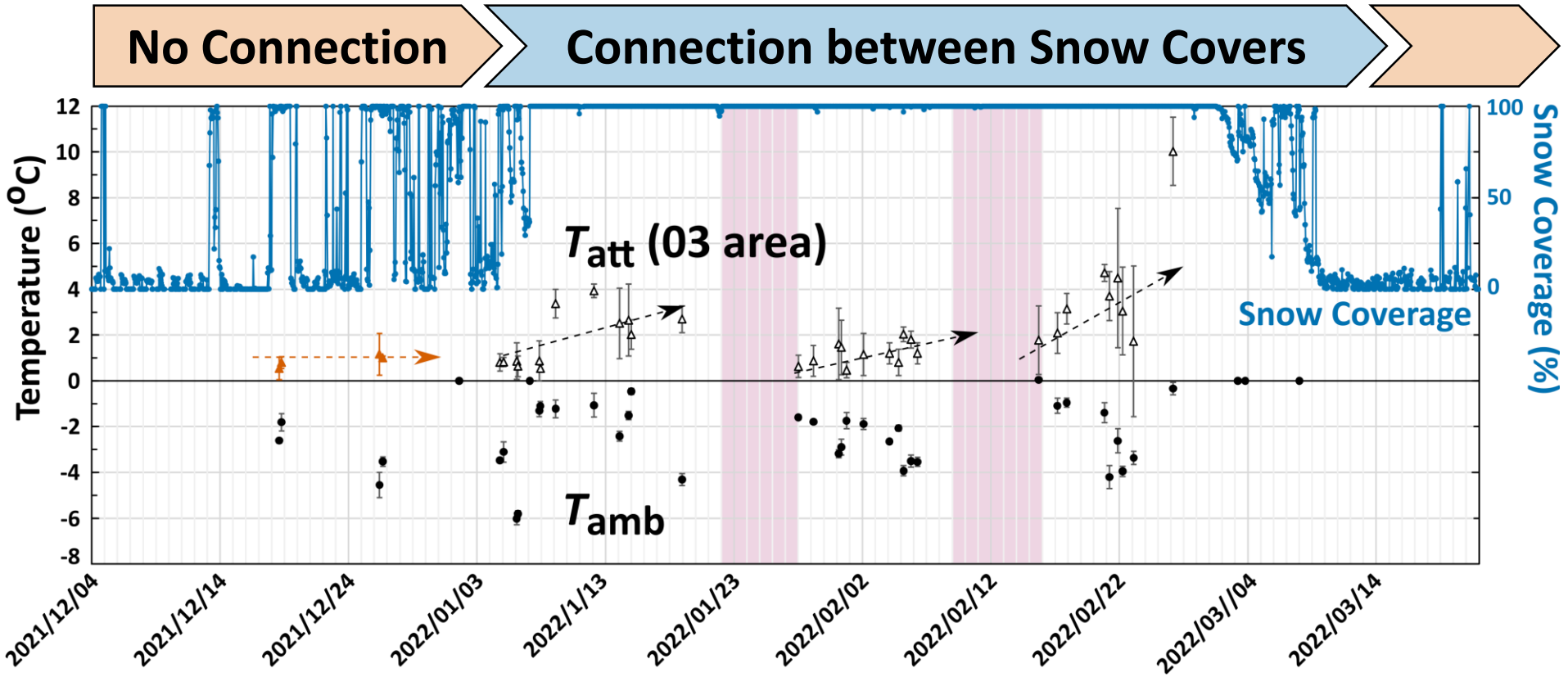
Elevation of
Attained Module Temperature

with Snow Connection:
← Evolution of Thermal-Property in the Interface
(between Acc. Snow and PV Module Surface)

← **without Snow Connection**:
Direct Contact of Water / Ice to PV Module

← Similar T_{amb}

Evolution of Attained Module Temperature

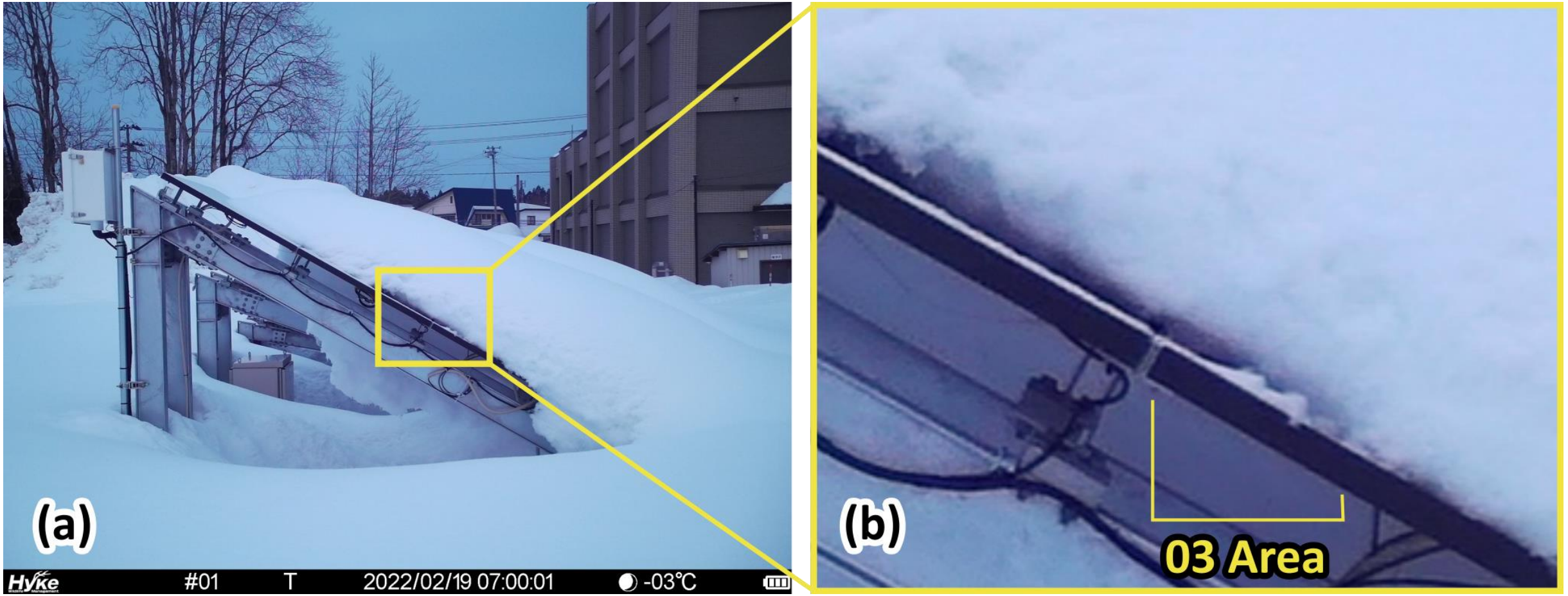


Connected Period: Gradual Increase in $T_{mod\text{-}att}$ (Attained Module Temperature)

➔ Ballooning Size of a Material(s) with Low Heat Capacity, which is placed at the Interface between Accumulated Snow and PV Module Surface.

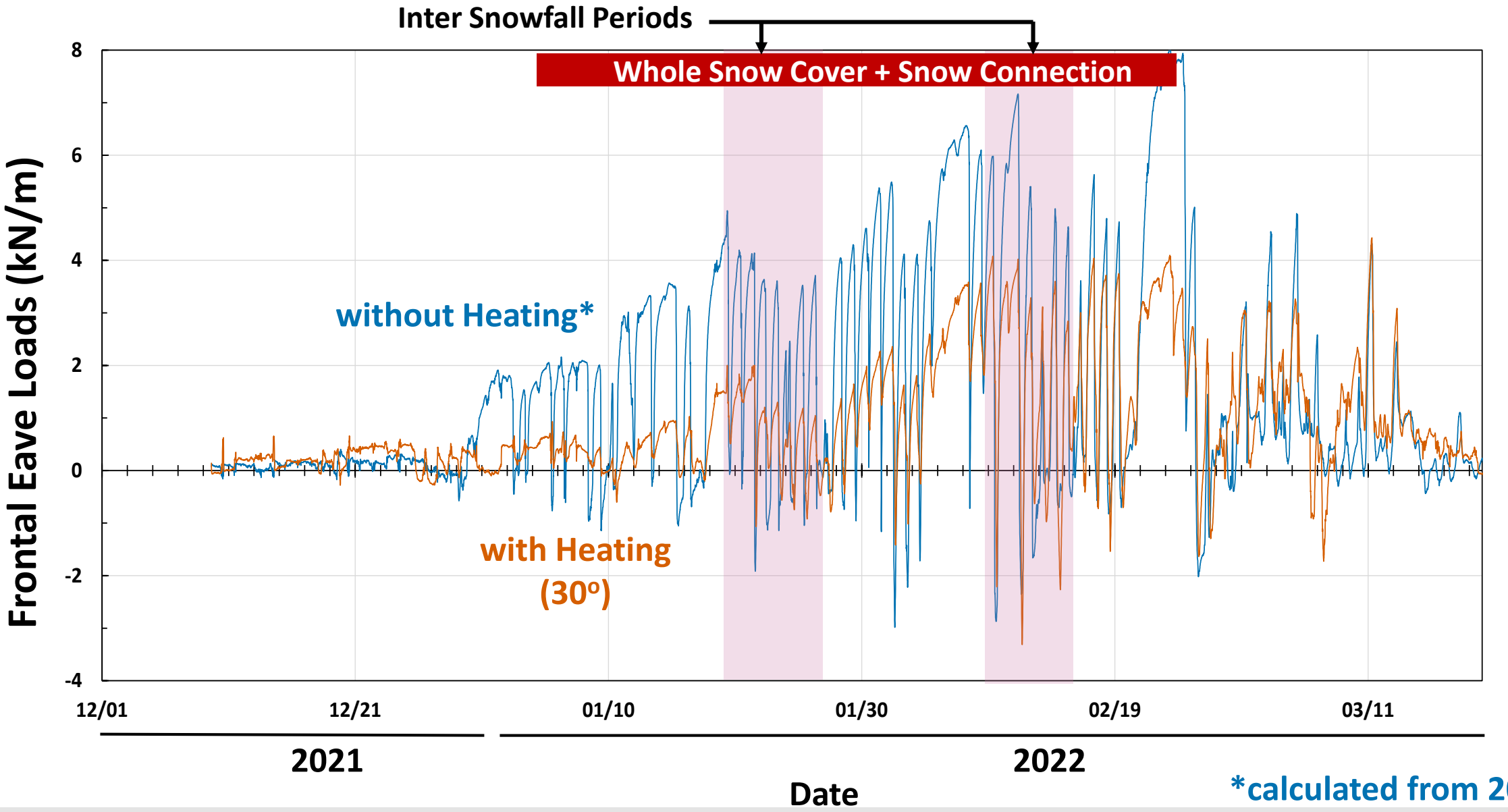
Non-Connected Period: Constant $T_{mod\text{-}att}$ with Low Temp. ➔ Direct Contact

Confirmation of Air Slit / Gap



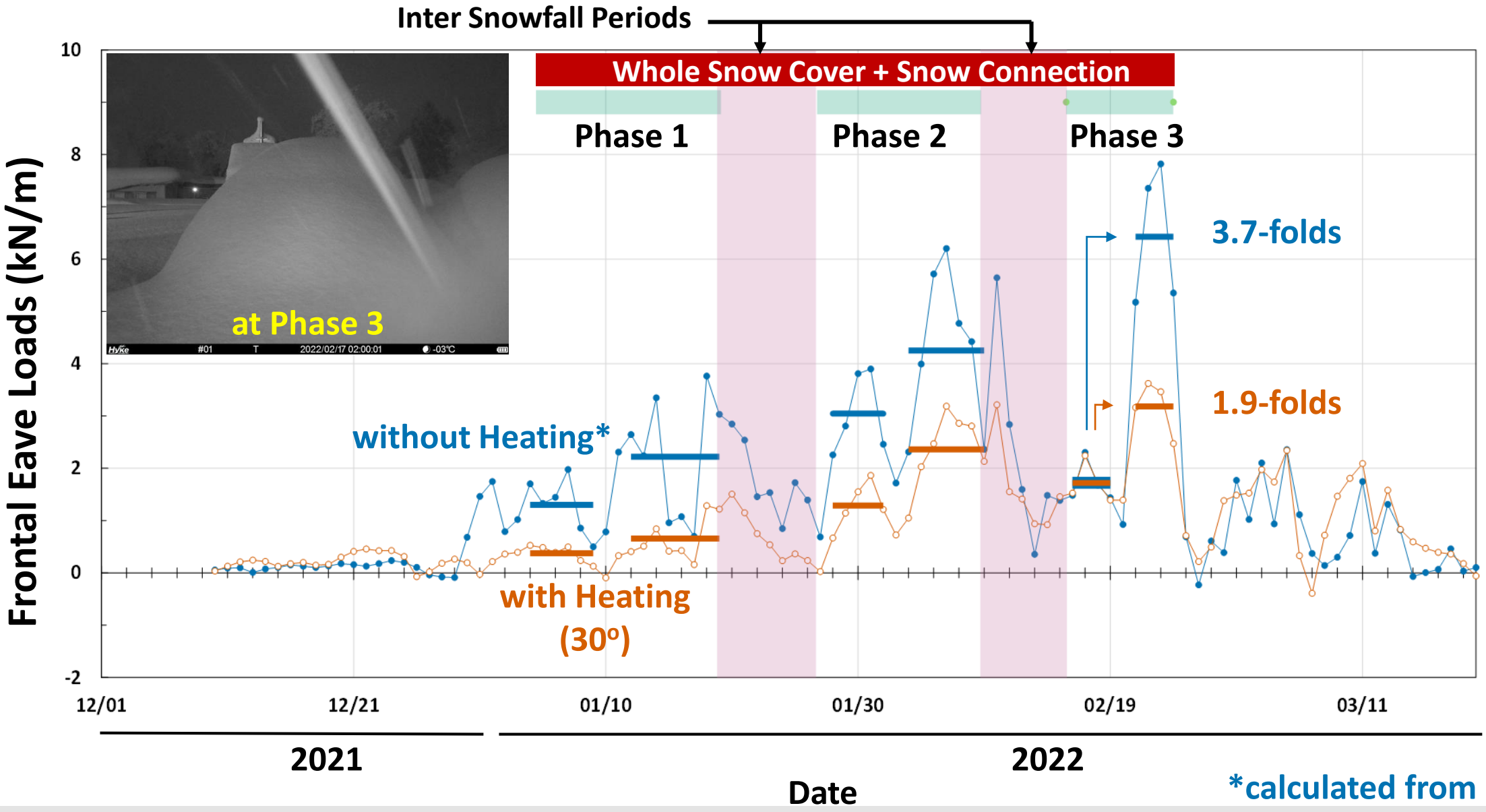
When the Snow Cornice (Snow Ledge) was Shed/Dropped by Coincidence,
the Air Slit / Gap was Confirmed at 03 Area.

Evolution of Frontal Eave Loads (10 min Interval)



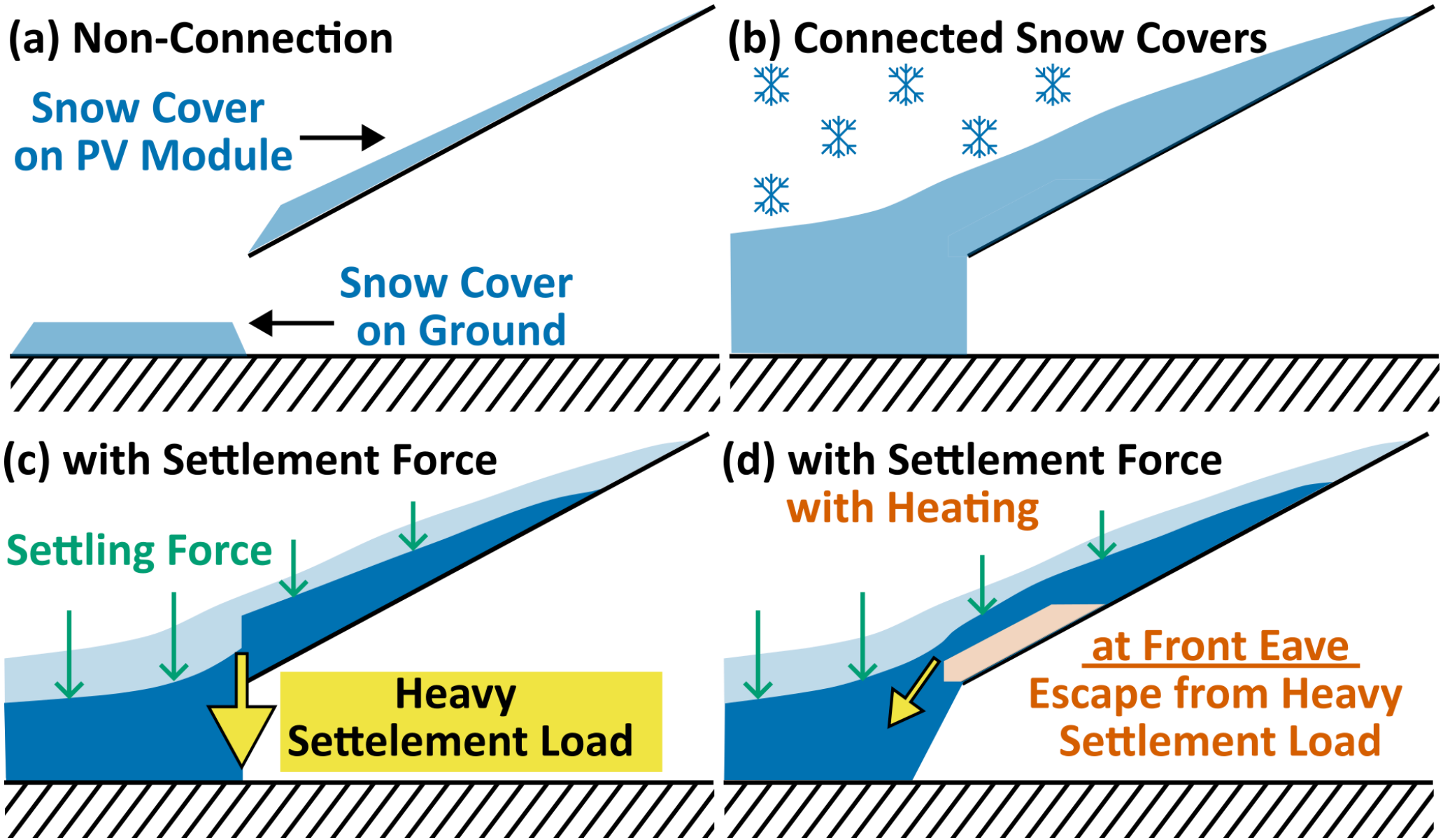
*calculated from 20° data

Evolution of Frontal Eave Loads (Daily Mean)



*calculated from 20° data

Impact of PV Module Heating on Heavy Snow Load



Summary

Mitigation of Heavy Snow Loads

PV-module heating contributes to the reduction of the settlement load at front eave, through the conversion of thermal properties at the interface between PV-module surface and accumulated snow.

Other Topics

01: Impacts of Snow-Melting on PV Performance

Less or no need for shoveling on the rooftop.

02: Optimization of Electric Power Consumption for Heating

Low-cost operation

03: Safety Aspect of Snow-Melting PV with Heater

Even under the worst-case scenario (hot summer, maximum heater-output, and shading [hotspot endurance conditions]), PV-module safety can be ensured.

The electrical safety standard for Snow-Melting PV Modules is discussed in IEC TC82/WG2 (NP approval).

Thank you for your attention!

Contact: tadanori.tanahashi@aist.go.jp