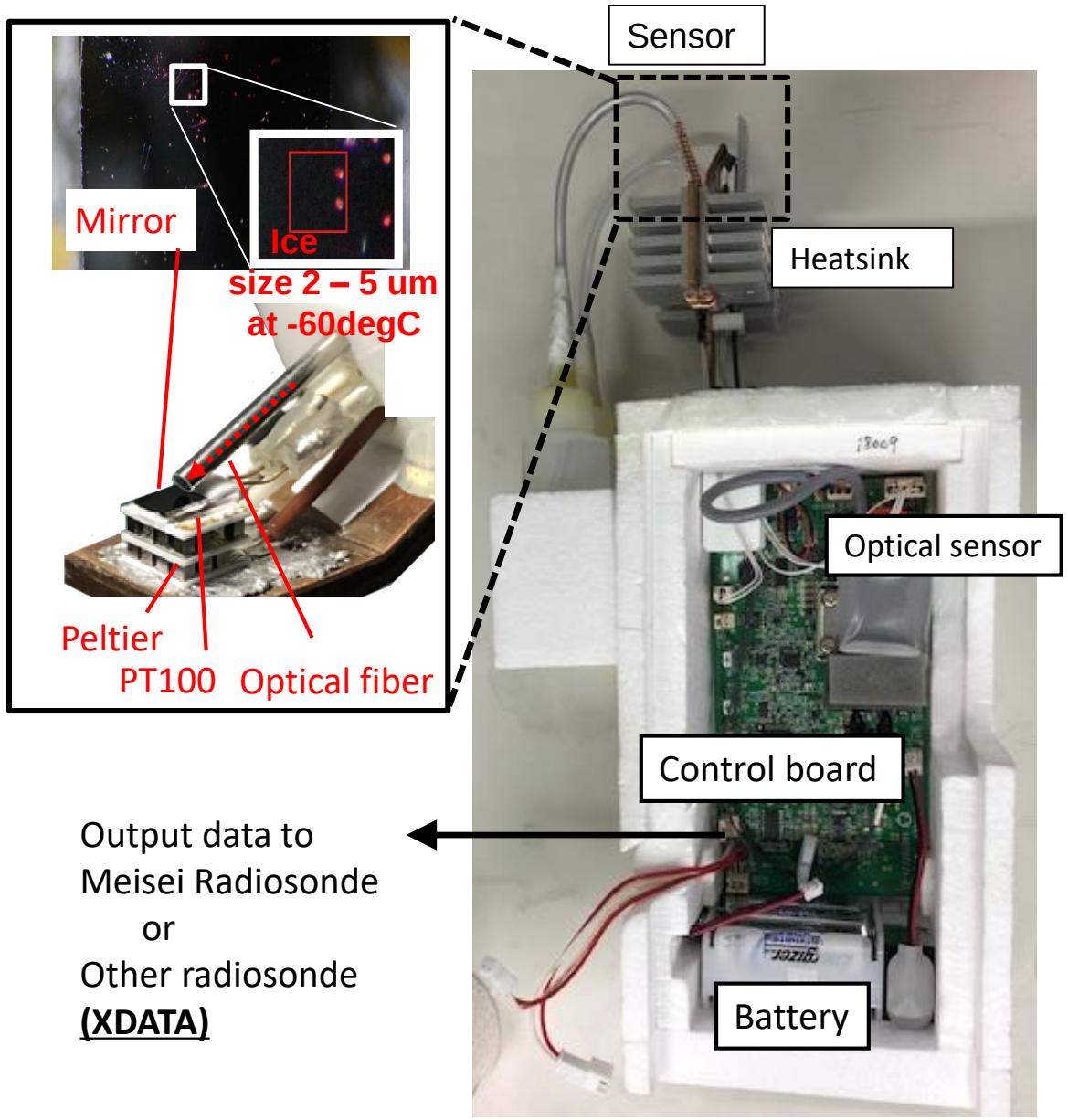
Status of the Meisei SKYDEW instrument

Takuji Sugidachi, (Meisei Electric Co. LTD., Japan)

Peltier-based chilled-mirror hygrometer “SKYDEW”



SKYDEW has been developed since 2009 by Meisei and Hokkaido university.

Features of SKYDEW hygrometer

1. Two-stage Peltier device
   No need to use cryogen material (CHF3)
2. Dew/frost detection by scattered light using an electronically modulated light
3. Digital controller (PID controller, gain scheduling depending on dewpoint)
4. Meisei original data format or XDATA format

History of SKYDEW development

2009 – 2014 Phase 1:
Several types of prototype
Lab tests and 9 test soundings

2016 – 2019 Phase 2:
Design of product model
20 test soundings including the comparison sounding with CFH

2019 – 2020 Phase 3:
Test of 2nd product model
Product release for domestic users (in Japan)

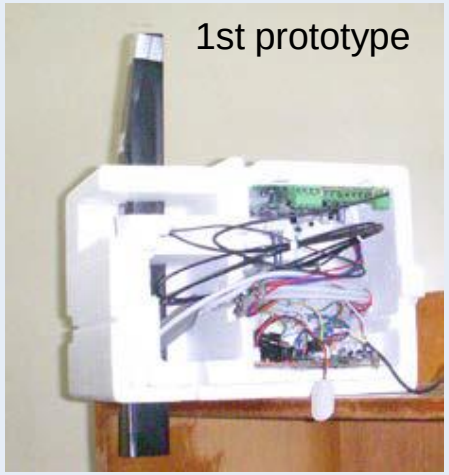
We have conducted many lab tests and test sounding with some type of prototypes.

Evaluation of the **Peltier cooling** performance, and development of an additional cooling system with **ethanol** evaporation

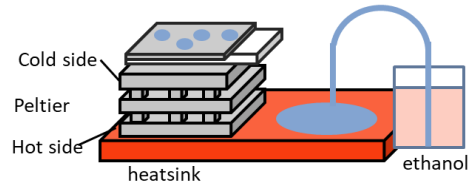
Tuning the feedback (**PID**) controller to maintain the constant dew/frost by trial & error, and the theoretical consideration.

9 test soundings in Japan and Indonesia.

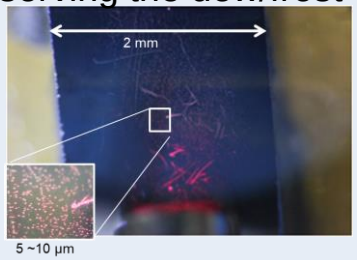
1st prototype



Cooling system with ethanol



Observing the dew/frost on the mirror



--> These results are described in Sugidachi, 2014, Ph. D paper at Hokkaido Univ. (https://eprints.lib.hokudai.ac.jp/dspace/bitstream/2115/55416/1/Takuji_Sugidachi.pdf)

History of SKYDEW development

2009 – 2014 Phase 1:
- Several types of prototype
- Lab tests and 9 test soundings

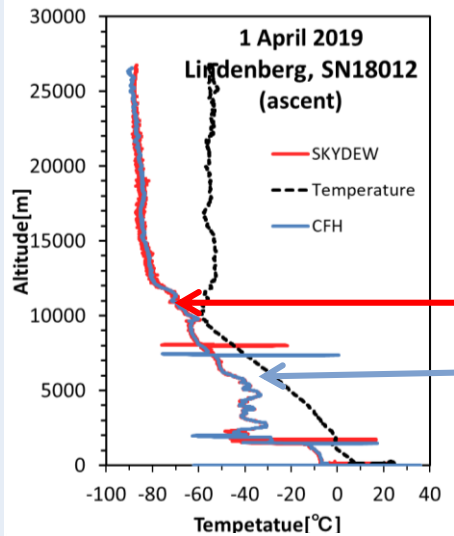
2016 – 2019 Phase 2:
- Design of product model
- 20 test soundings including the comparison sounding with CFH

2019 – 2020 Phase 3:
- Test of 2nd product model
- Product release for domestic users (in Japan)

20 test soundings with 1st product model
For the daytime, the measurement range is limited by the Peltier cooling performance.

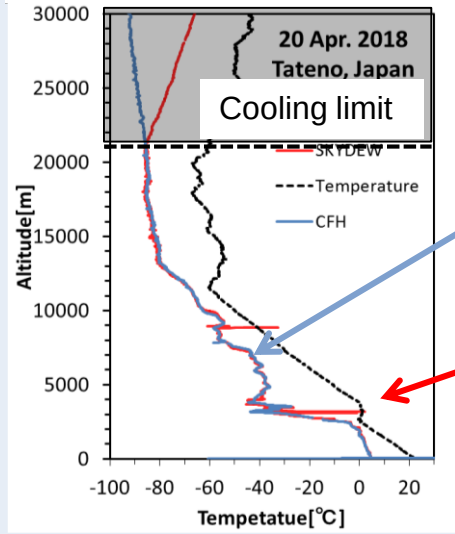
Nighttime

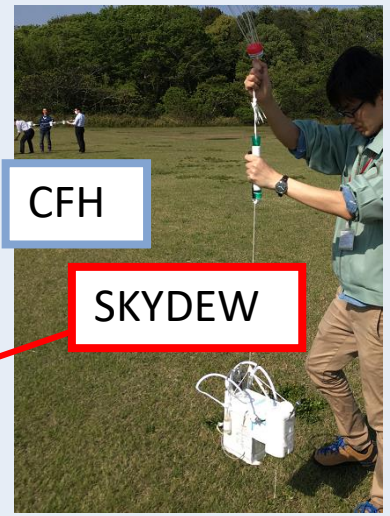
Lindenberg
1 April 2019



Daytime

Tateno
20 April 2019

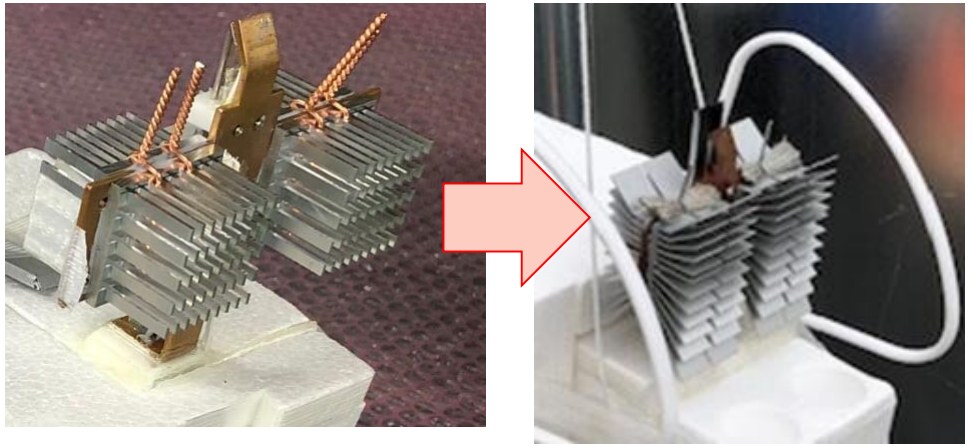




--> Refer to the presentations of ICM-10/11 by Sugidachi.

2nd product model

After the test sounding at Lindenberg in 2019, SKYDEW was redesigned for better performance and productivity.

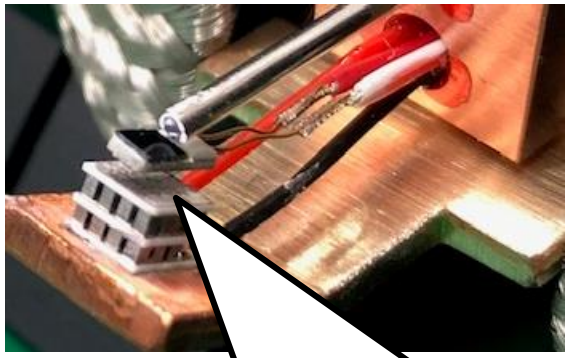


No ethanol

Performance: Cooling efficiency of heat sink for Peltier device.
Because of the improved Peltier cooling, SKYDEW can measure up to 30km without additional cooling by ethanol system.
We found that the **ethanol generate some harmful effects** for the stratospheric measurement. (e.g., contamination)

--> No ethanol model

Production issues solved:
Connection between a Peltier and a mirror part.
The incomplete connection leads the insufficient heat conduction, which cause the lower cooling limitation or unstable PID control.
This issue was solved by the original specialized soldering techniques



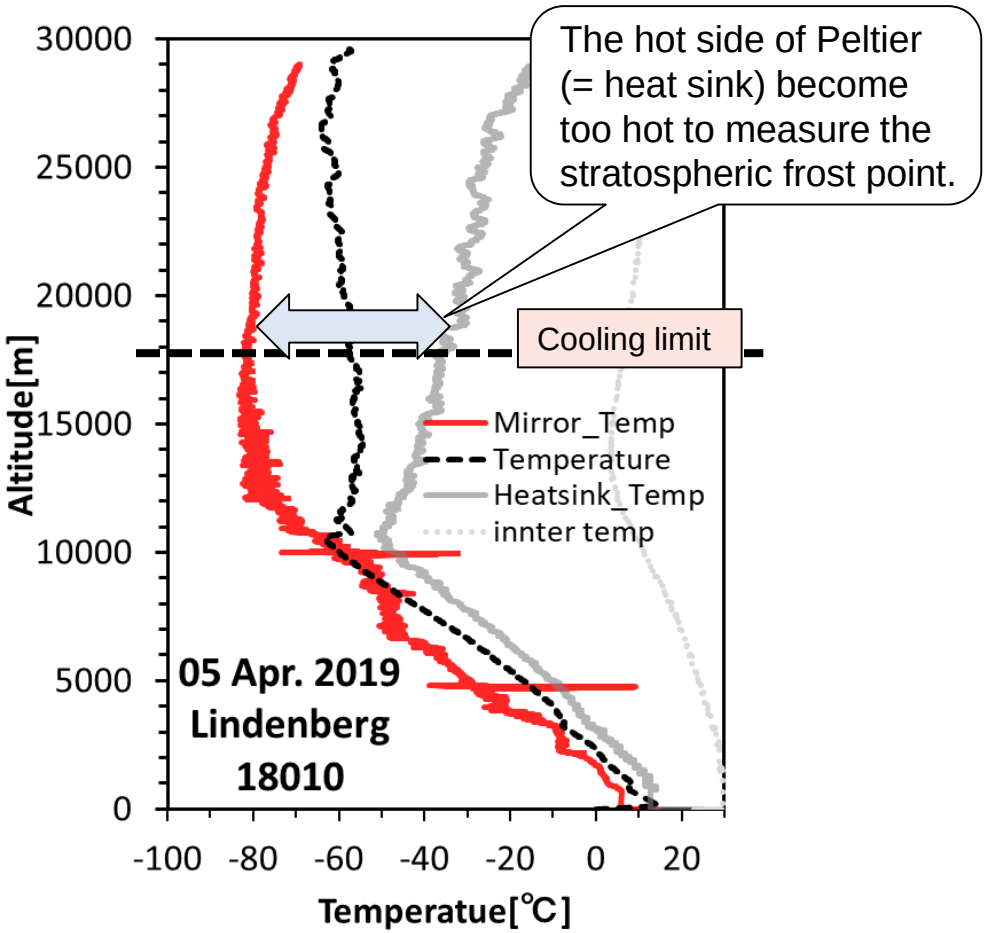
Specialized soldering method for the strong connection between Peltier and mirror.

Test flight of 2nd product model

The 2nd model does NOT need ethanol cooling system

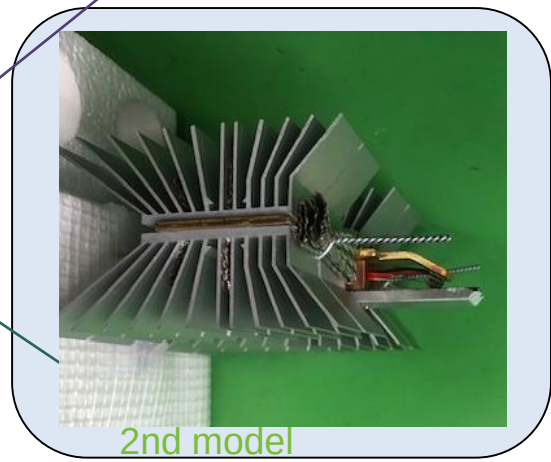
1st product model faced a challenge about the cooling limitation.
Even when the additional cooling by an ethanol evaporation is used, the daytime performance was limited by the Peltier capability.

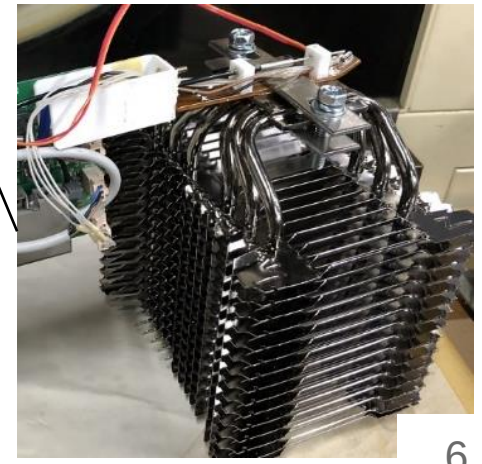
The sounding with 1st model @Lindenberg



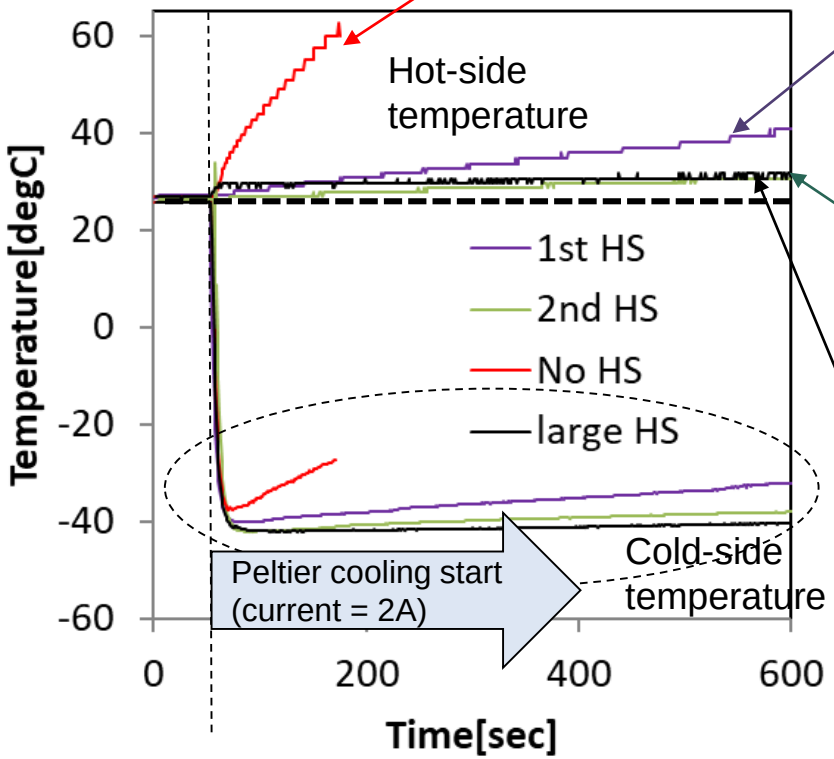

No Heat sink


1st model




Large heat sink

Test of heatsinks (in a chamber)

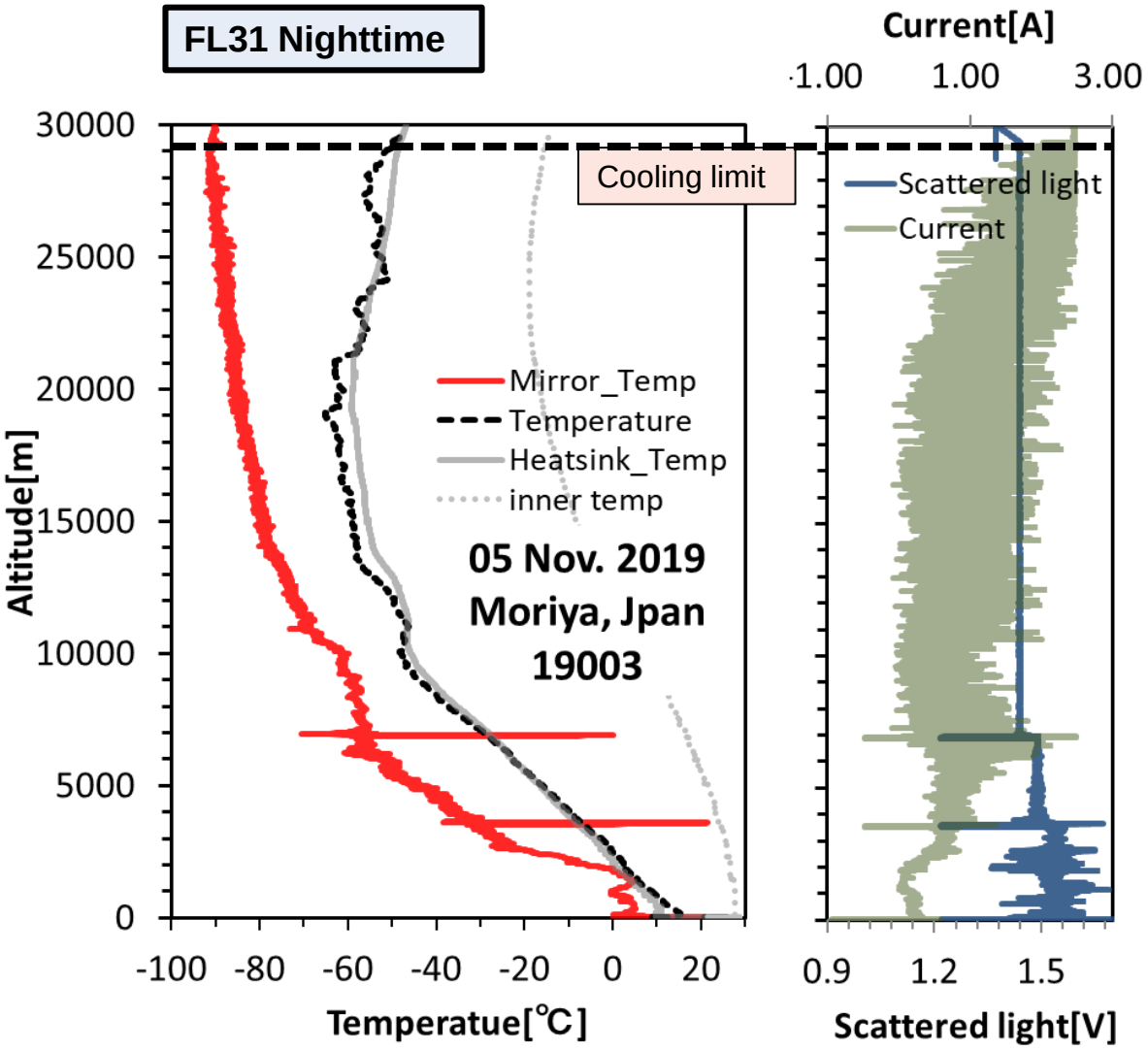


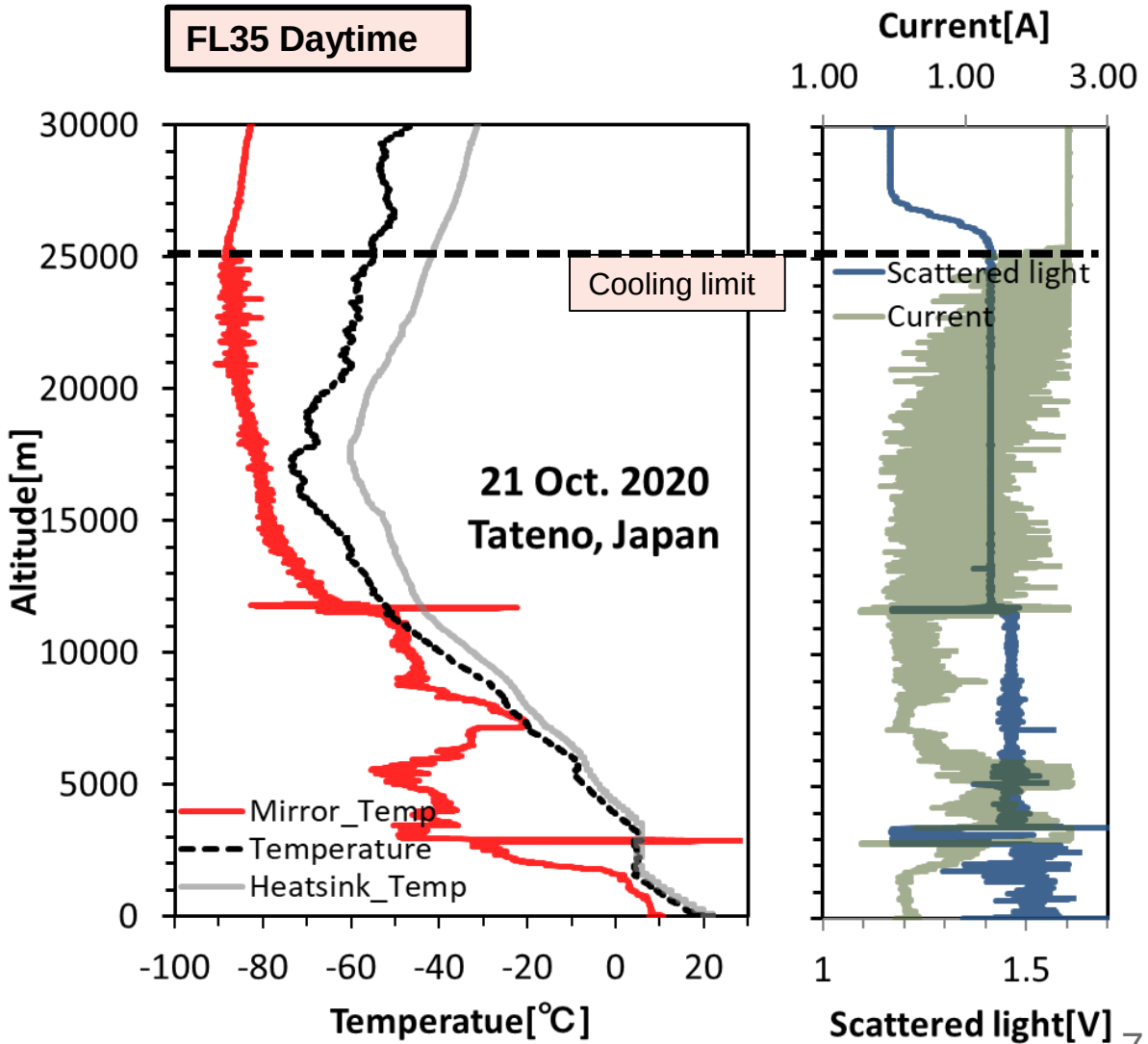
When Peltier current started, the heat sink temperature becomes gradually warmer than ambient air. The increase rate depend on the heat sink efficiency.

Performance of 2nd product model

No ethanol cooling system

The SKYDEW measured successfully up to 29km at nighttime, and up to 25km at daytime.
For both soundings, SKYDEW use no additional cooling with ethanol.





* The FL35 data is provided by JMA

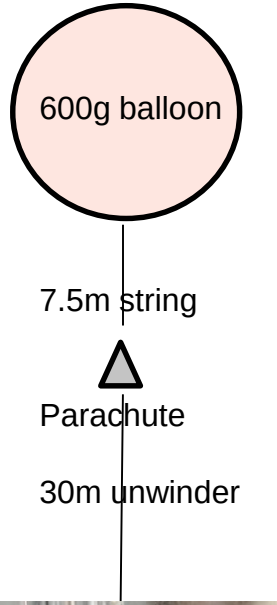
Specification

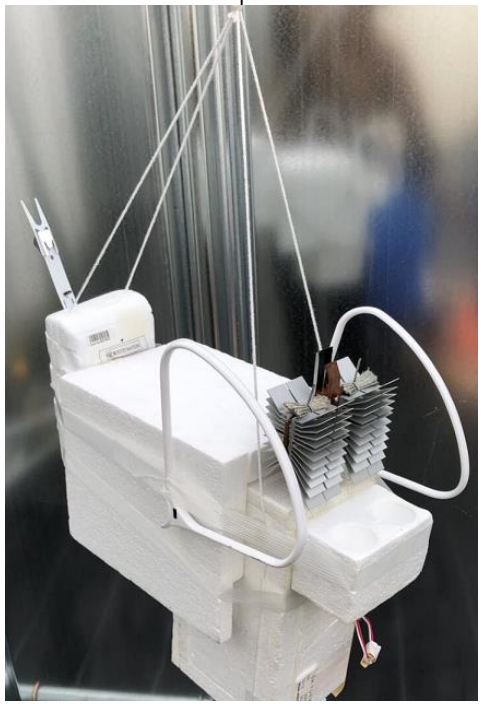
SKYDEW

Size & Weight	Dimensions	170(W) x 93 (D) x 318 (H) mm
	Weight	~700 g (including Battery, without radiosonde RS-11G)
Power Source	Voltage (Model)	9 VDC for Peltier device (Lithium battery (AAA) × 6) 9VDC for electric circuit such as optical sensor (Lithium battery (006P) × 1)

Typical configuration

In the case of no ozonesonde

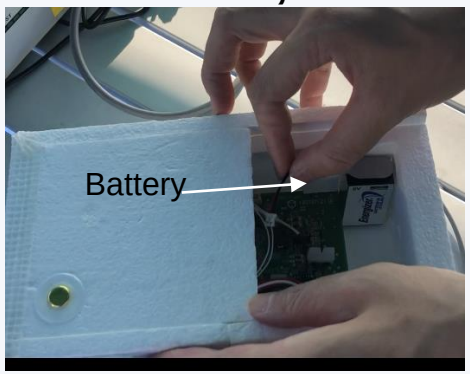


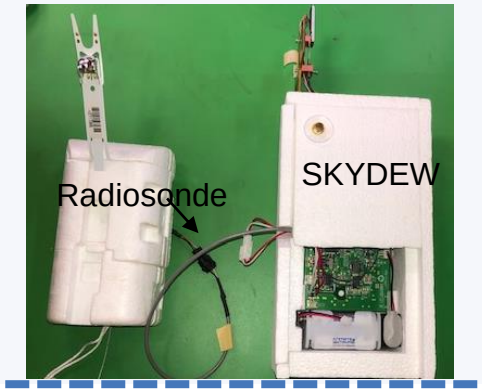


Operation flow

In the case with the Meisei radiosonde

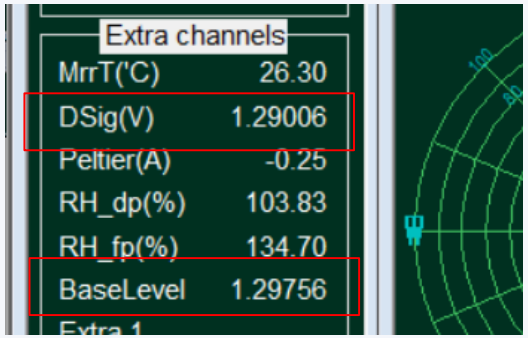
1. Connect the battery (006P) to start working for electric circuit, and connect the radiosonde



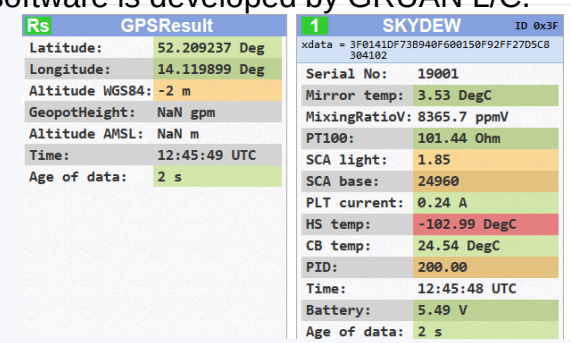


2. Check the level of scattered light signal to confirm the mirror condition.
(When the signal is higher than the defined value, the clean up of mirror is needed because the mirror may be dirty)

Meisei software



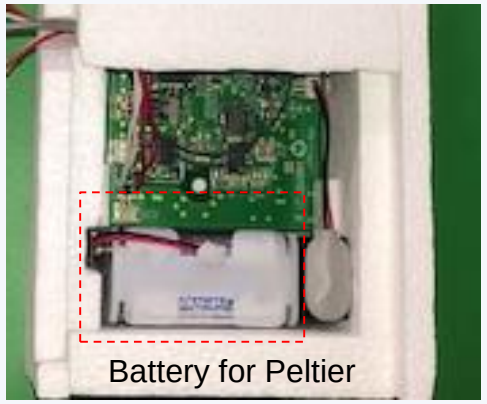
For XDATA version (RS41), the decoding software is developed by GRUAN L/C.

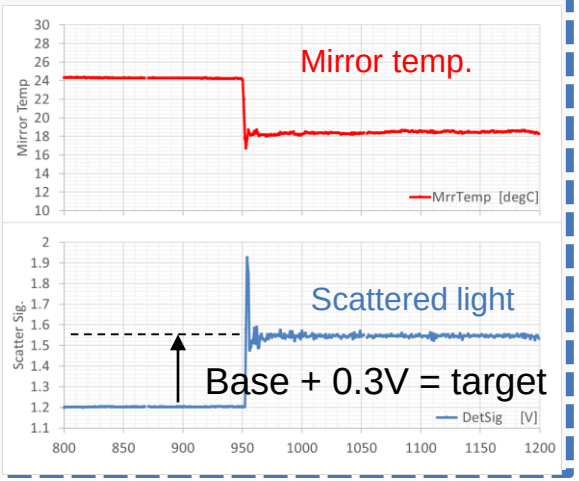


Rs GPSResult	
Latitude:	52.209237 Deg
Longitude:	14.119899 Deg
Altitude WGS84:	-2 m
GeopotHeight:	NaN gpm
Altitude AMSL:	NaN m
Time:	12:45:49 UTC
Age of data:	2 s

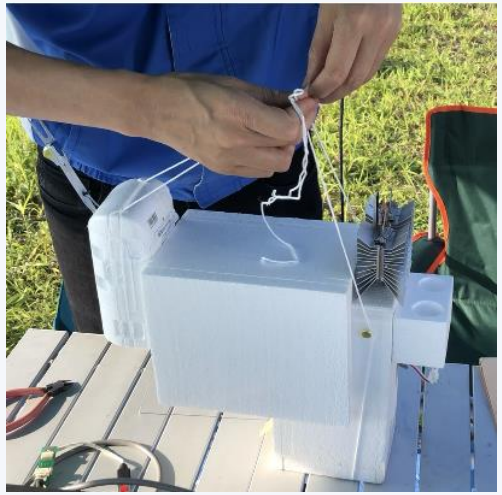
1 SKYDEW ID 0x3F	
xdata = 3F0141DF73B940F600150F92FF27D5C8304102	
Serial No:	19001
Mirror temp:	3.53 DegC
MixingRatioV:	8365.7 ppmV
PT100:	101.44 Ohm
SCA light:	1.85
SCA base:	24960
PLT current:	0.24 A
HS temp:	-102.99 DegC
CB temp:	24.54 DegC
PID:	200.00
Time:	12:45:48 UTC
Battery:	5.49 V
Age of data:	2 s

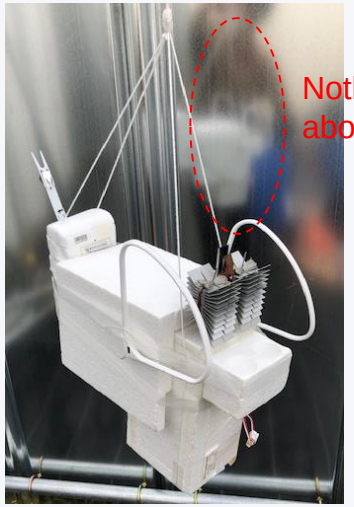
3. Connect the battery(AAA) for Peltier to start cooling mirror, and then mirror temperature become the dewpoint temperature.





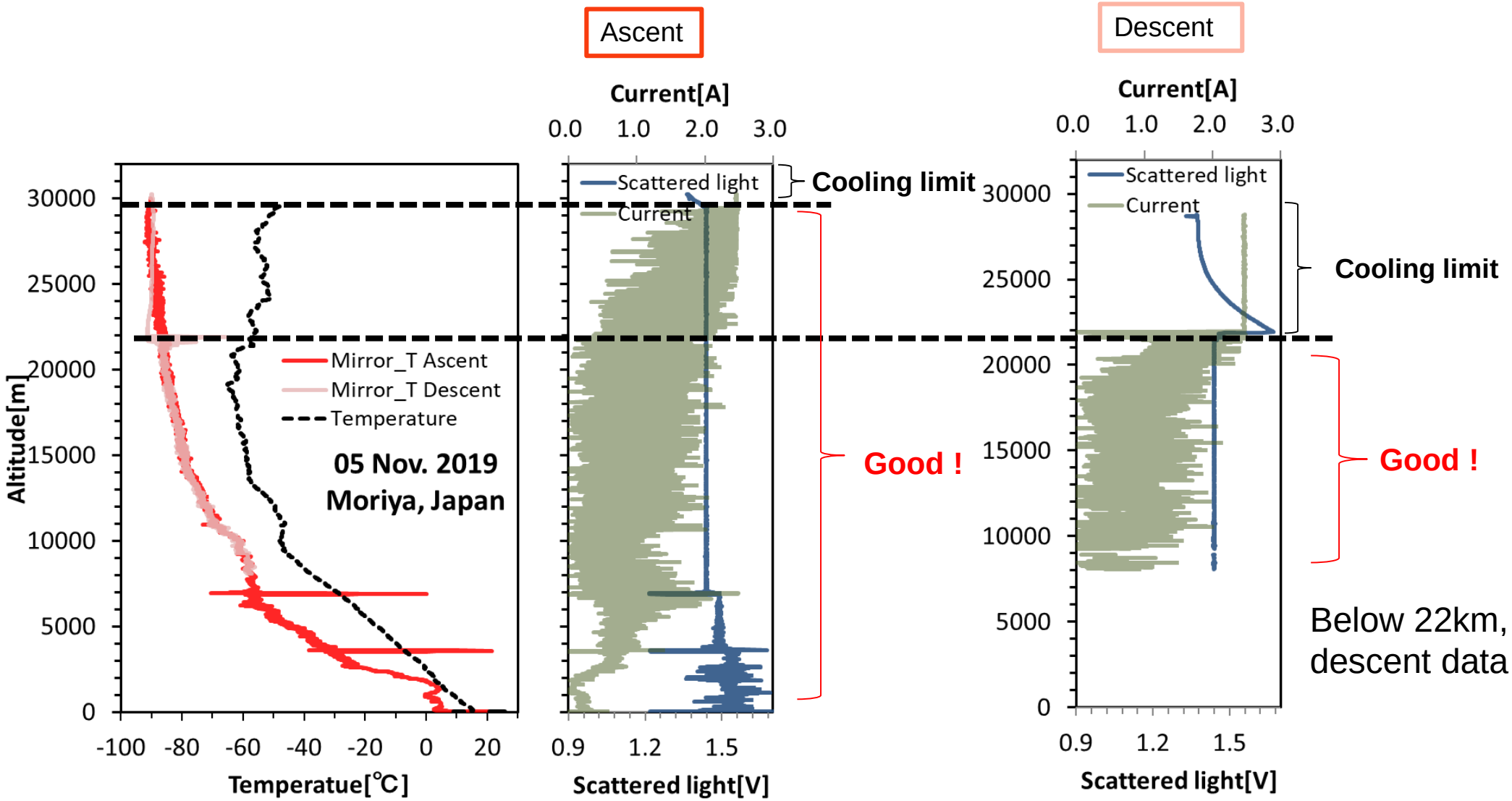
4. Build up the payload, and release





Data processing for SKYDEW toward GDP

The FL31 is a good sample for validation because this sounding obtained the descend data successfully below 22km.
By comparing the ascent and descent data, we have evaluated the performance at UTLS measurements.

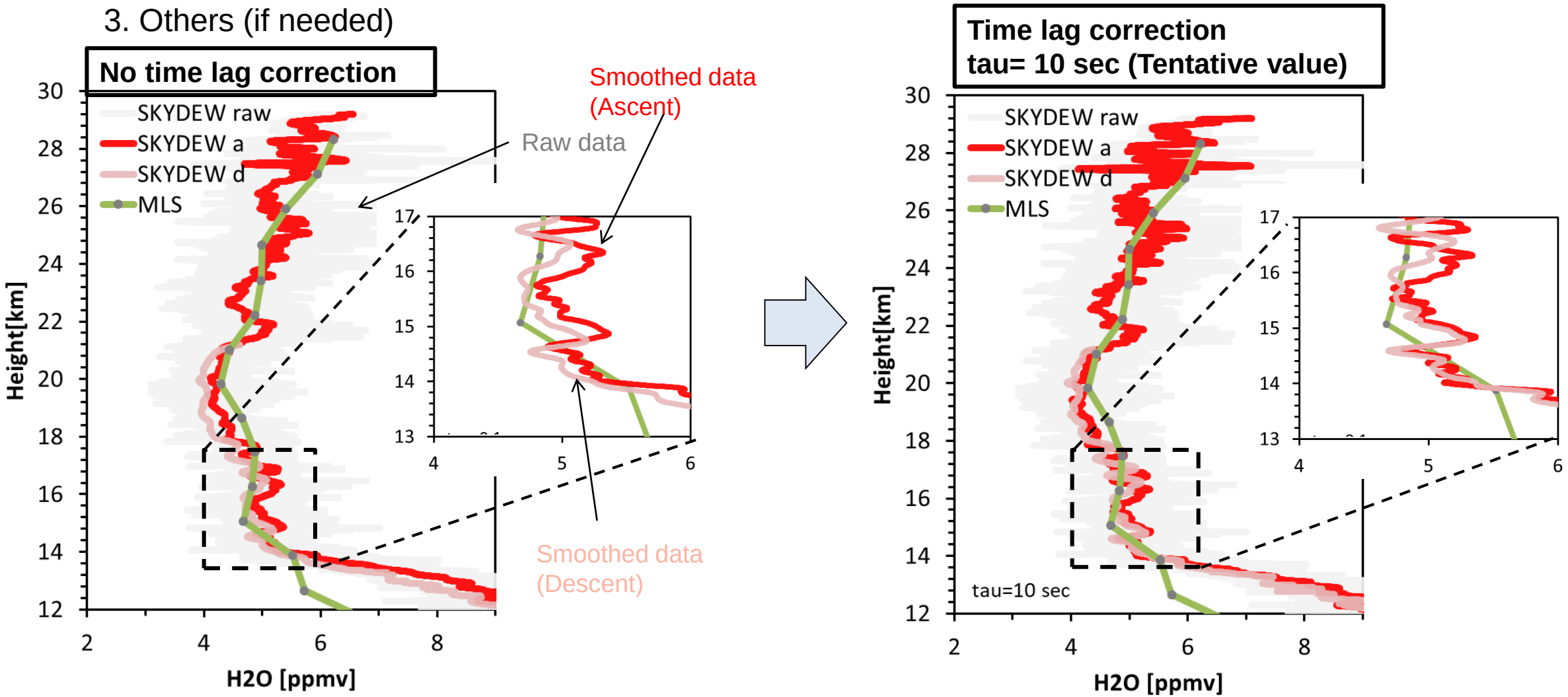


Below 22km, both ascent and descent data are available.

Data processing for SKYDEW toward GDP (under consideration)

A raw mirror temperature measured by chilled-mirror hygrometers often has oscillations by the PID controller to maintain a constant frost layer. These oscillations should be smoothed out by an appropriate filter (Vömel et al., 2016)
The required data processing:

1. Smoothing such as Gaussian filter
2. Time lag correction (Further evaluations are needed)
3. Others (if needed)



Uncertainty budget for SKYDEW toward GDP(under consideration)

(1) Calibration of temperature sensor (PT100) **<0.06 K**, calibration point -95, -45, 0, 40 degC

(2) Instability of PID controller **< ?? K**

Does a large oscillation cause the bias by unbalance of cool/heat power? (--> refer to the ICM-11 ppt)

(3) Time lag effect **?? sec**

Delay by an evaporative/condensation rate of ice. Negligible for SKYDEW, depending on ice size.

Effect of slight residual water/ice attached on the sensor cover.

(4) Contamination error under cloudy condition

The clear sky condition is recommended for stratospheric measurement. (--> next slide)

(5) Others

ambiguity of the condensate phase (frost or dew, cubic ice)

aerosol effects

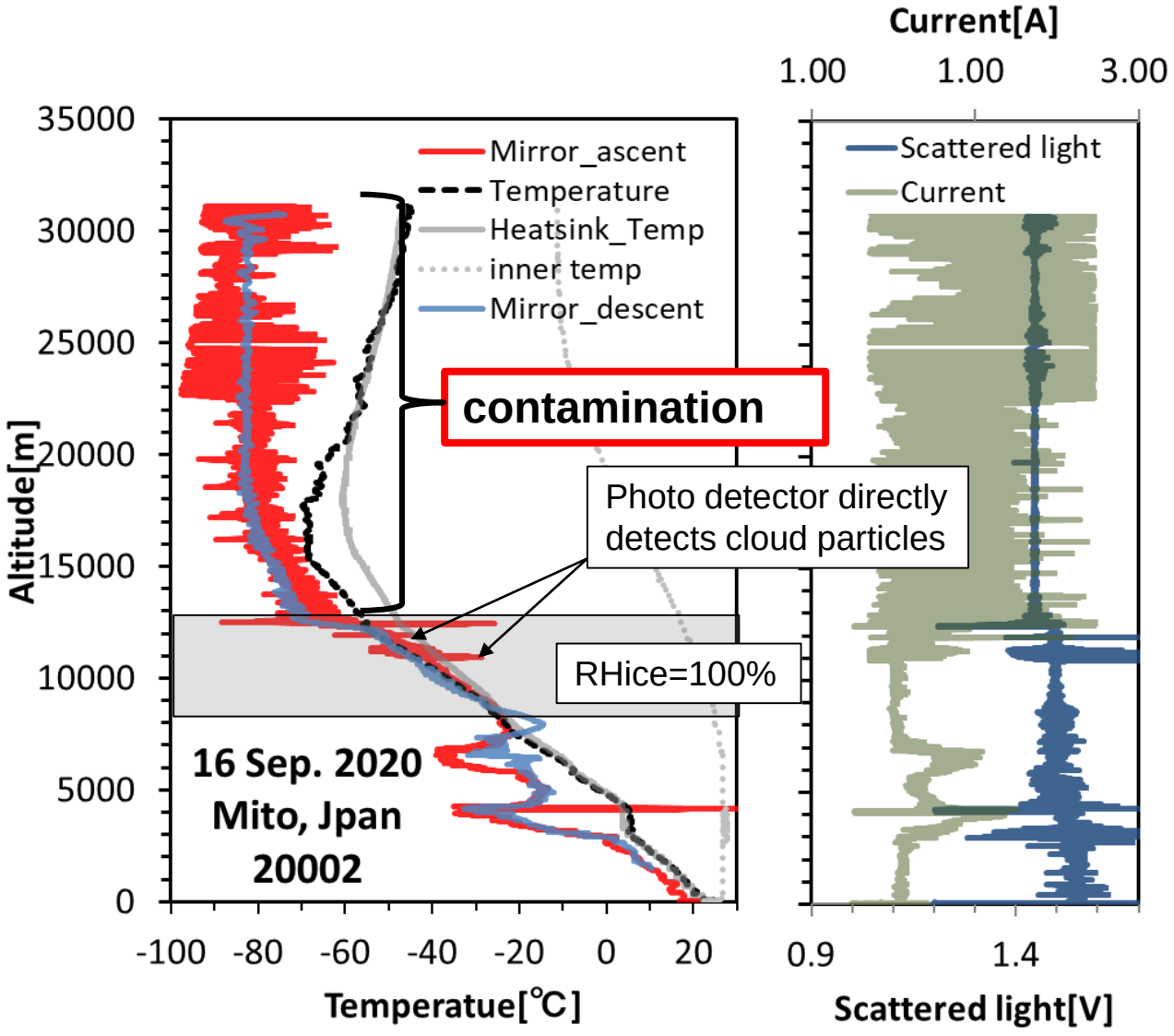
curvature effects

slow drift by changing the ice shape/amount

slow drift of detector signal

Example sounding of contamination at cloudy condition

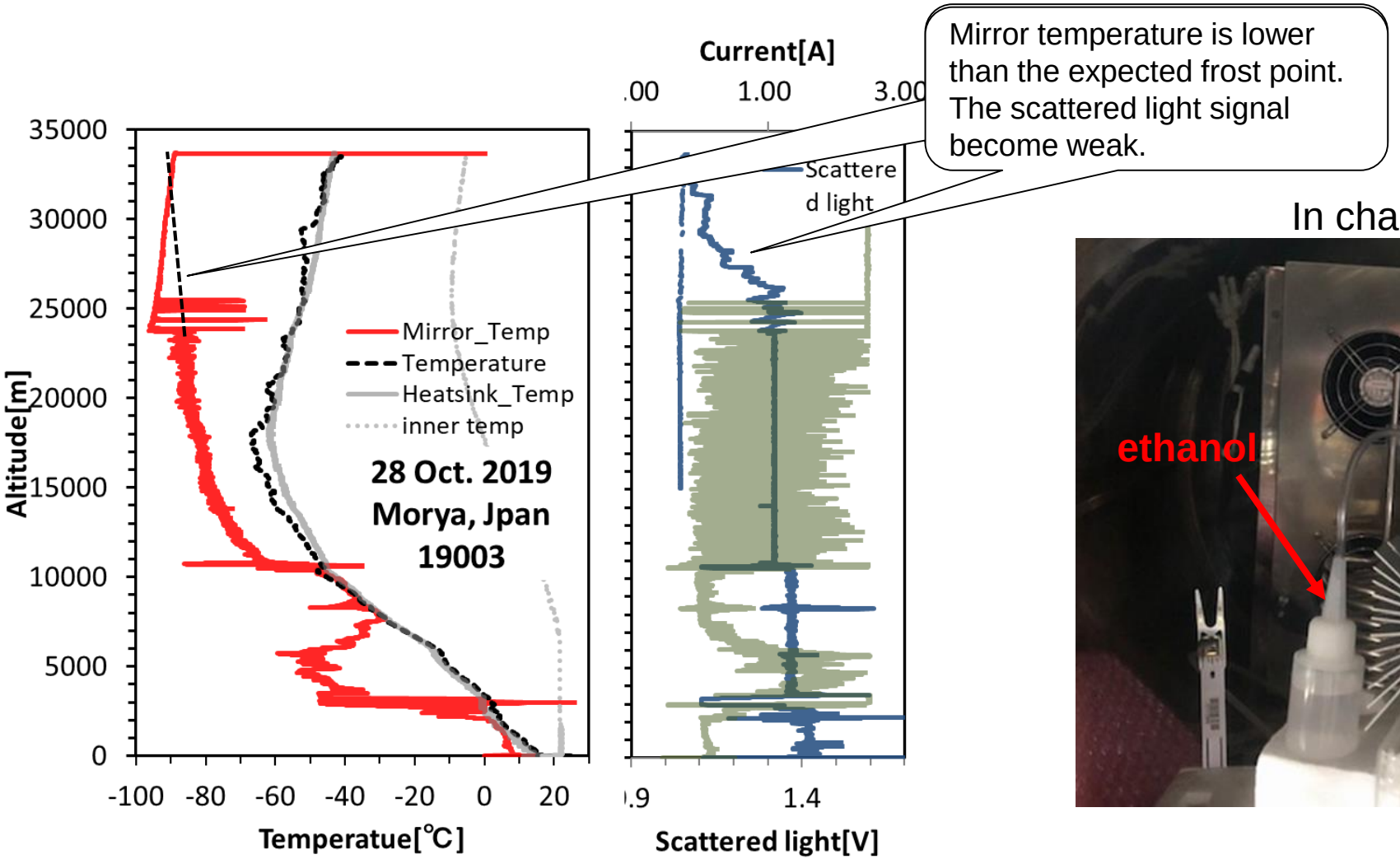
A thick cloud causes the contamination. After passing the cloud, the oscillation is caused because the contaminated air flow into the mirror.
It seems that descent data also indicate higher frost point than an expected value.



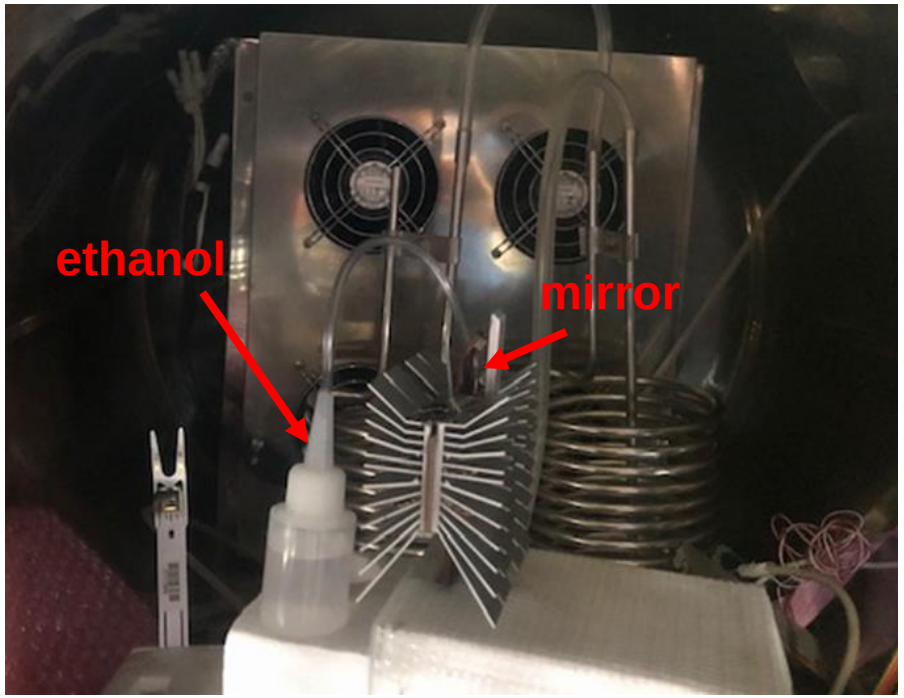
Cloud condition at release time

Example sounding of contamination by ethanol

An ethanol to cool the heatsink (hot side of Peltier) can cause the contamination.
It is suspected that the evaporated ethanol breaks frost layer on the mirror. The mechanism of this behavior is not clear, but this behavior is reproducible in chamber.
We decided that we do not use ethanol for the additional cooling.



In chamber



Summary

1. Performance of SKYDEW(2nd product model)
   SKYDEW can measure dewpoint/frostpoint up to 30 km at nighttime, and up to 25 km at daytime (depending on the cooling limitation by Peltier)

2. The product model of SKYDEW is presale in Japan at present.
   Only JMA has conducted the sounding with SKYDEW. Because several projects in Japan are postponed because of COVID-19, many soundings with SKYDEW will be conducted at tropic and at Antarctica (Syowa station) next year.

3. Action item toward GDP
   Data processing, smoothing and time-lag correction (under consideration)
   Uncertainty budget (under consideration)

For more technical information, contact me, "sugidachit@meisei.co.jp"
If you have interest in purchasing SKYDEW, access the Meisei web site below
https://archive.meisei.co.jp/english/support/contact/

Acknowledge
We thank JMA (Japan metrological agency) for providing the SKYDEW data at Tateno, 21 October 2020.