GRUAN ICM-11, Singapore, May 23, 2019

Meisei SKYDEW instrument: analysis of results from Lindenberg campaign

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

IHI GROUP
Realize your dreams

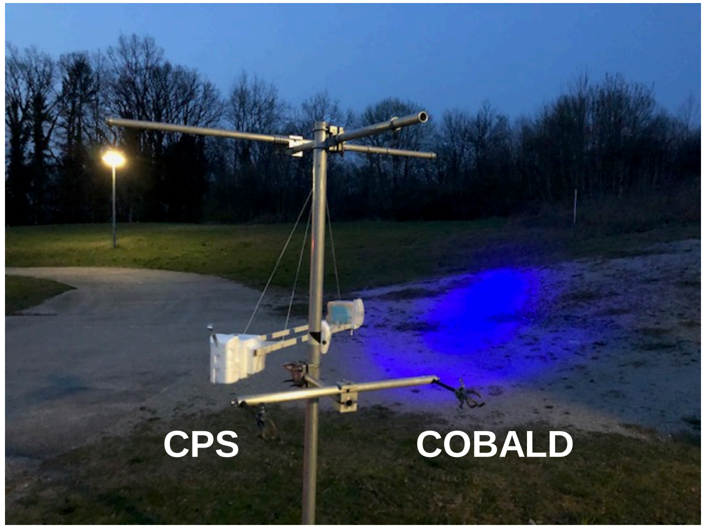
Overview

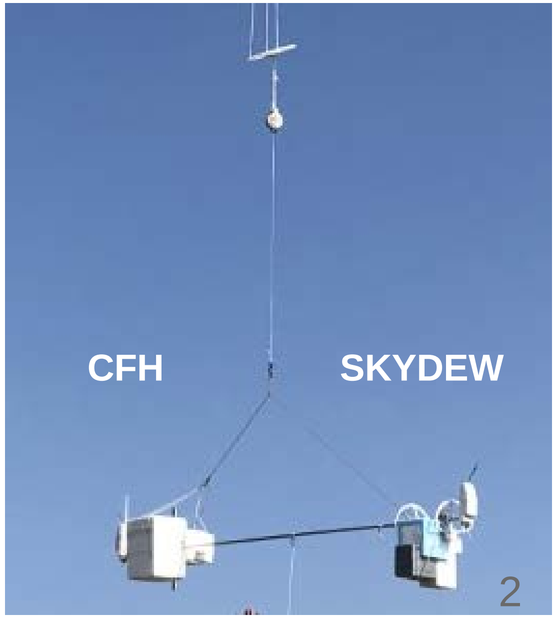
The test comparison campaign was conducted at Lindenberg, on April 2019

1) Chilled-mirror hygrometers
SKYDEW and CFH **4 soundings**

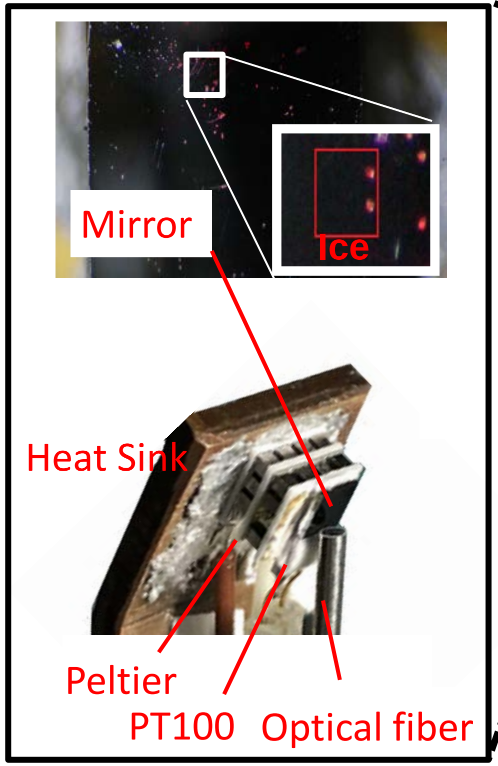
2) Cloud particle sensors
COBALD and CPS 1 sounding

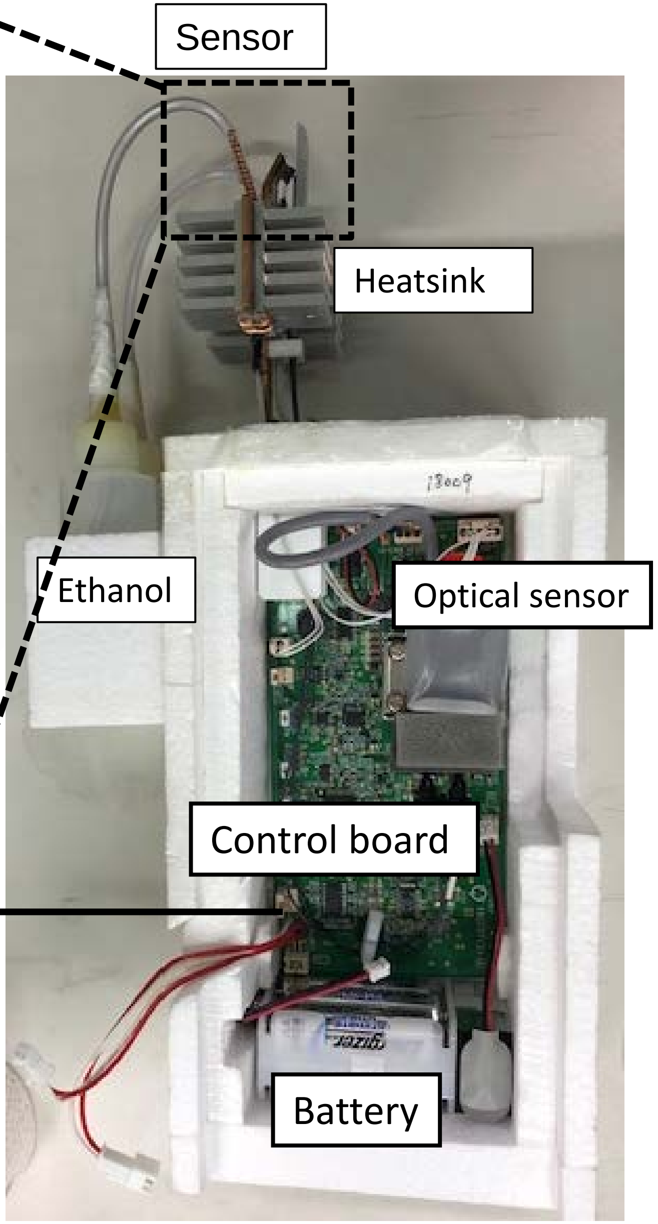
3) Operational radiosondes
Meisei iMS-100 and Vaisala RS41 12 soundings





Peltier-based chilled-mirror hygrometer “SKYDEW”





Output data to
Meisei Radiosonde
or
Other radiosonde
(XDATA)

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

Features of SKYDEW hygrometer

1. Two-stage Peltier device
   additional cooling system with the latent heat of evaporation for liquid ethanol
   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

Test flights & Comparison with CFH

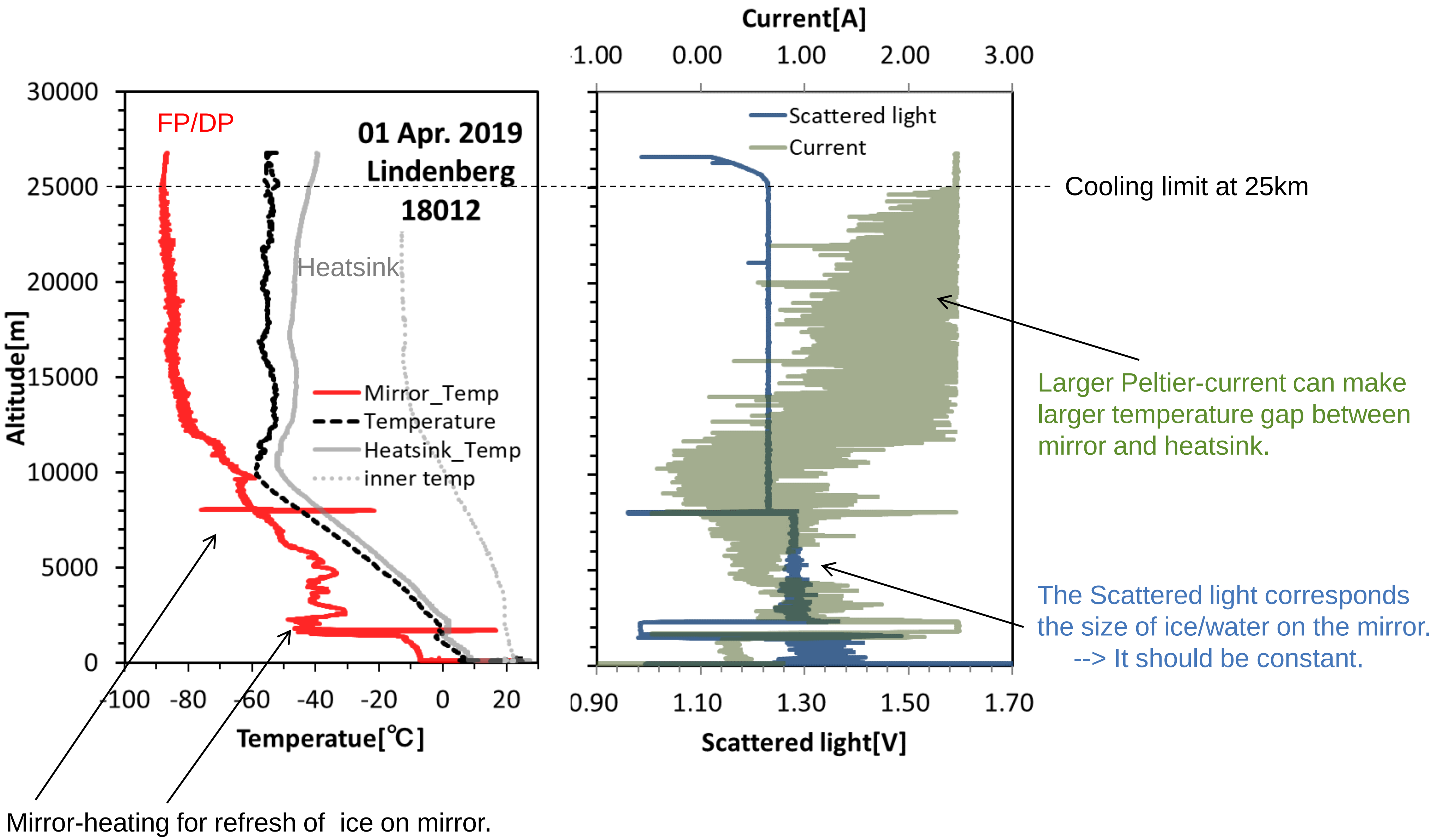
13 soundings of SKYDEW(product type) have been conducted since 2018.
The comparisons with CFH are10 times at Tateno, Lindenberg, and Kototabang.

1. Performance of SKYDEW (e.g., cooling limits)
2. Comparison results

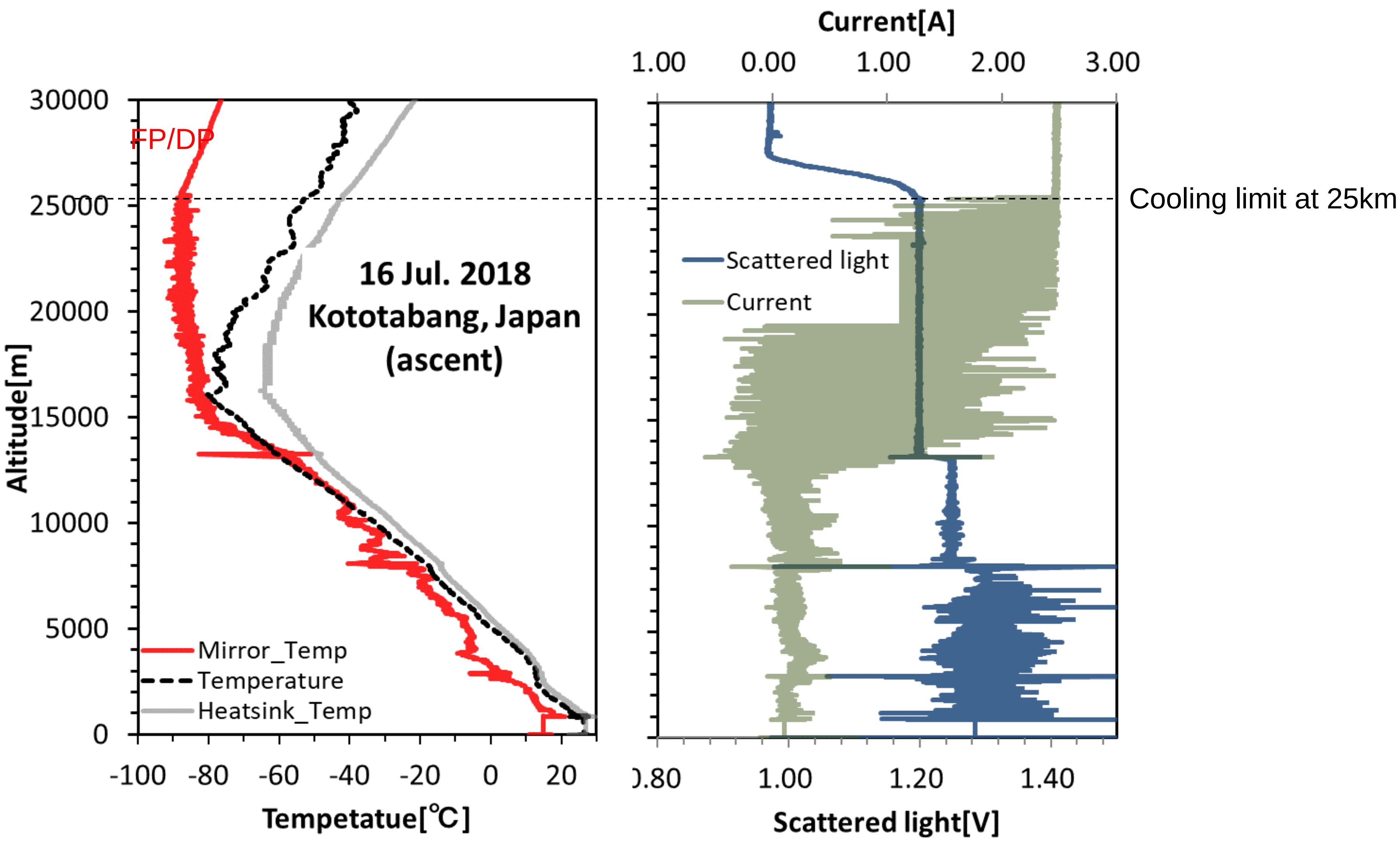
	Date	Place	SN	Comments
FL10	2018.01.29 17:30(LT)	Moriya , Japan	18002	
FL11	2018.02.27 17:30(LT)	Moriya , Japan	18003	
FL12	2018.04.20 14:45(LT)	Tateno , Japan	18001	with **CFH by JMA***
FL13	2018.07.15 16:46(LT)	Kototabang, Indonesia	18005	with **CFH by JAMSTEC***
FL14	2018.07.16 17:00(LT)	Kototabang, Indonesia	18006	with **CFH by JAMSTEC**
FL15	2018.07.19 20:40(LT)	Kototabang, Indonesia	18007	with **CFH by JAMSTEC**
FL16	2019.02.15 14:00(LT)	Moriya , Japan	18011	
FL17	2019.03.22 14:30(LT)	Tateno, Japan	18013	with **CFH by JMA**
FL18	2019.04.01 21:23(LT)	Lindenberg, Germany	18012	with **CFH by GRUAN LC***
FL19	2019.04.02 14:30(LT)	Lindenberg, Germany	18010	with **CFH by GRUAN LC**
FL20	2019.04.04 11:46(LT)	Lindenberg, Germany	18999	with **CFH by GRUAN LC**
FL21	2019.04.04 11:46(LT)	Lindenberg, Germany	18015	with **CFH by GRUAN LC**
FL22	2019.04.05 12:31(LT)	Lindenberg, Germany	18010	with **CFH by GRUAN LC**

*The sounding data of CFH are provided by JMA, JAMSTEC, and GRUAN Lead center, respectively

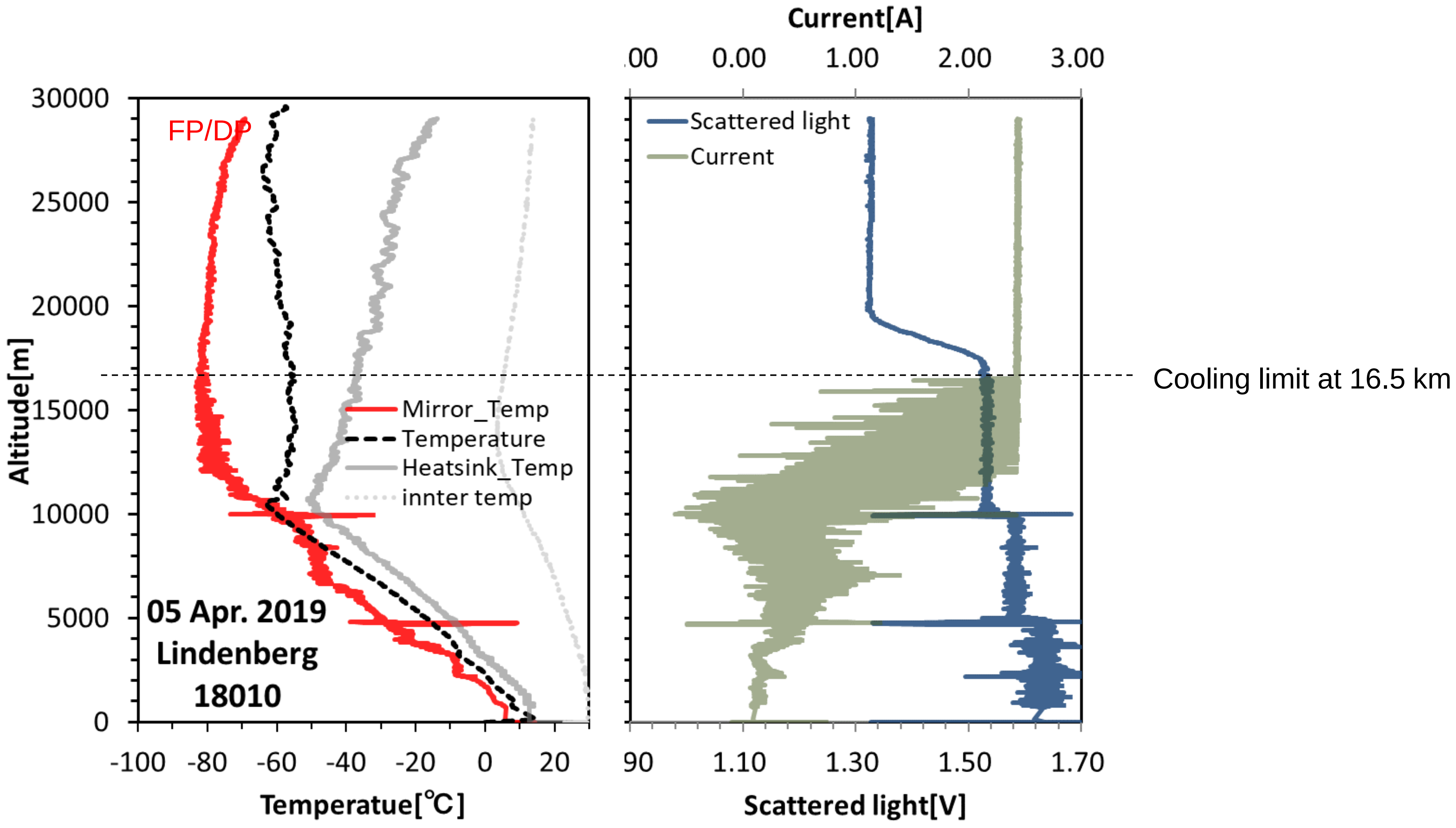
Performance at nighttime
(e.g., 1 April, 2019, Lindenberg)



Performance at daytime (e.g., 2018.07.16, Kototabang)



Performance at daytime
(e.g., 2019.04.05, Lindenberg)



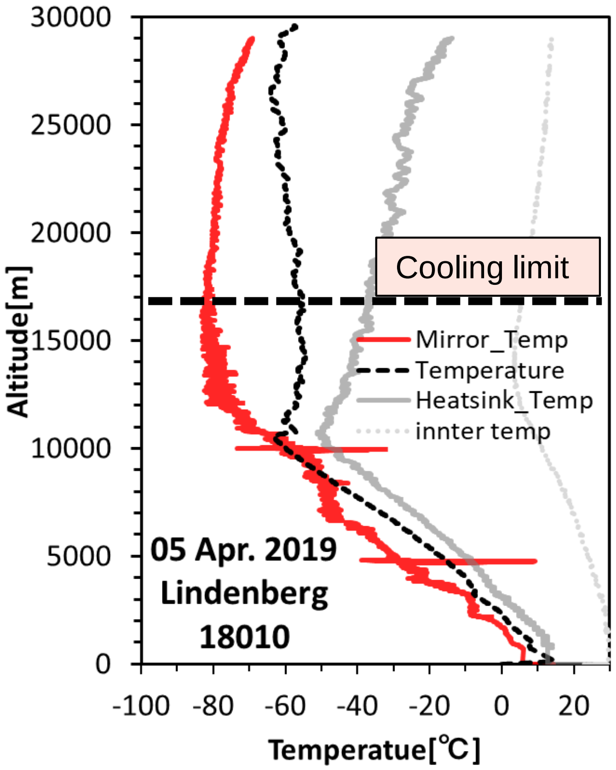
Performance at daytime (dependence on latitude)

The measurement range is restricted by the performance of Peltier cooling.

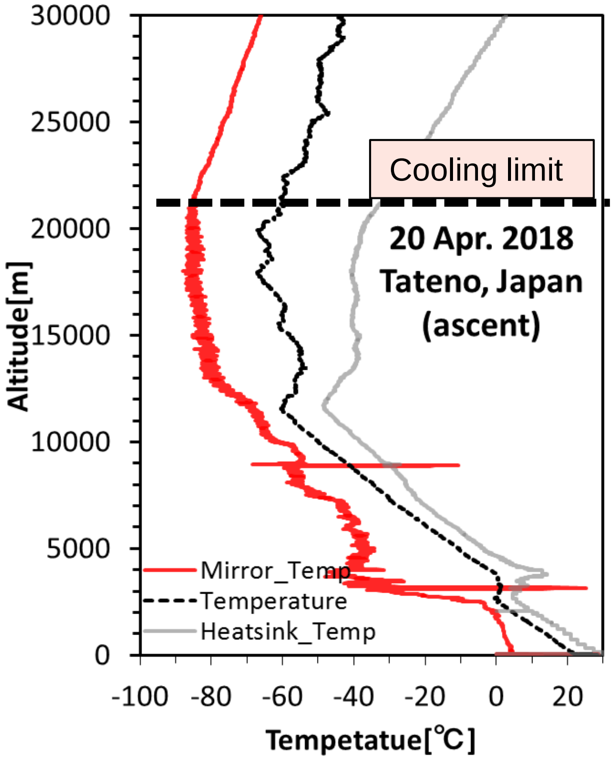
1. Daytime performance is limited as compared with nighttime performance, because the heatsink (hot side of Peltier) is heated by solar radiation.

2. The measurement at higher latitude is more difficult than that at tropics, because tropopause is lower and need to make temperature gap for longer time.

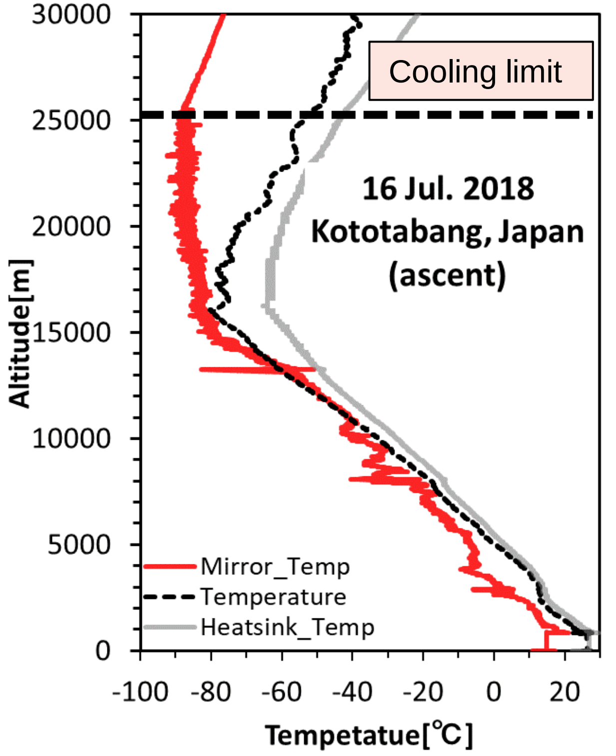
@Lindenberg (52N 14E)



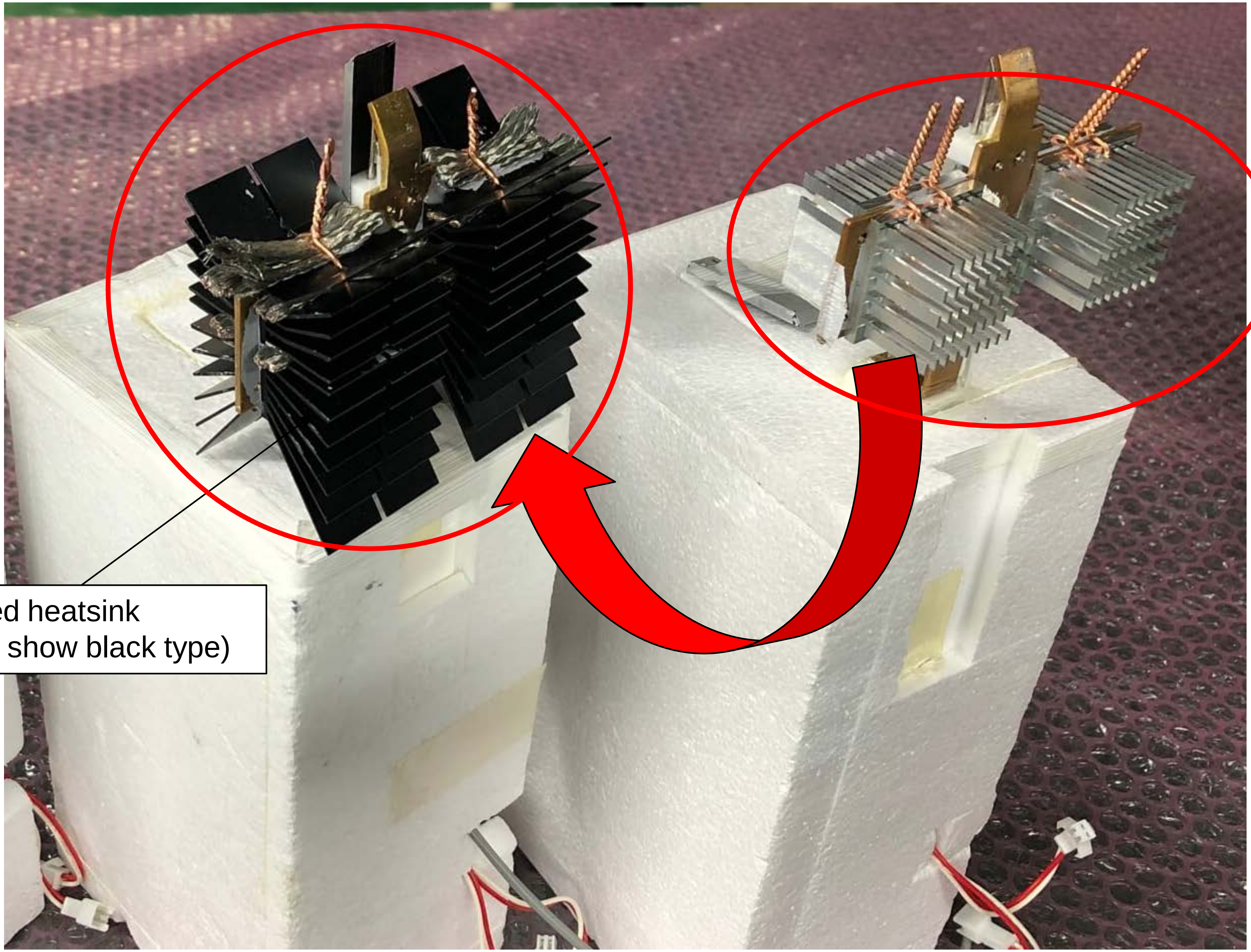
@Tateno (35N 140E)



@Kototabang(0S,100.3E)



Improvement of heatsink cooling

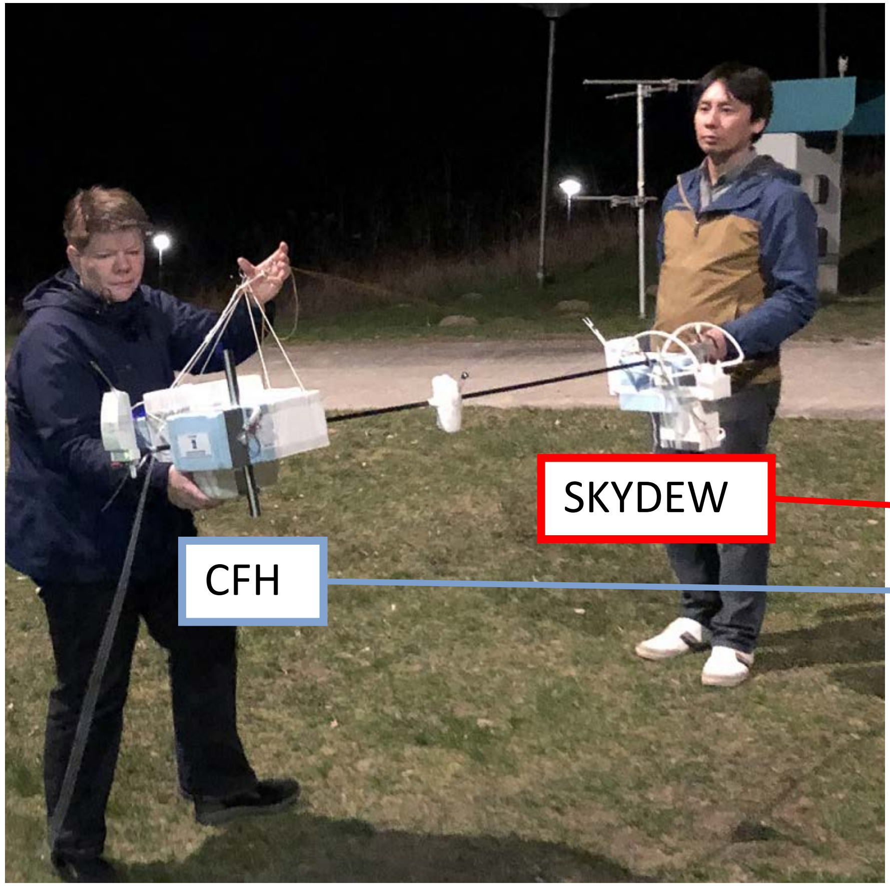


White-painted heatsink
(This picture show black type)

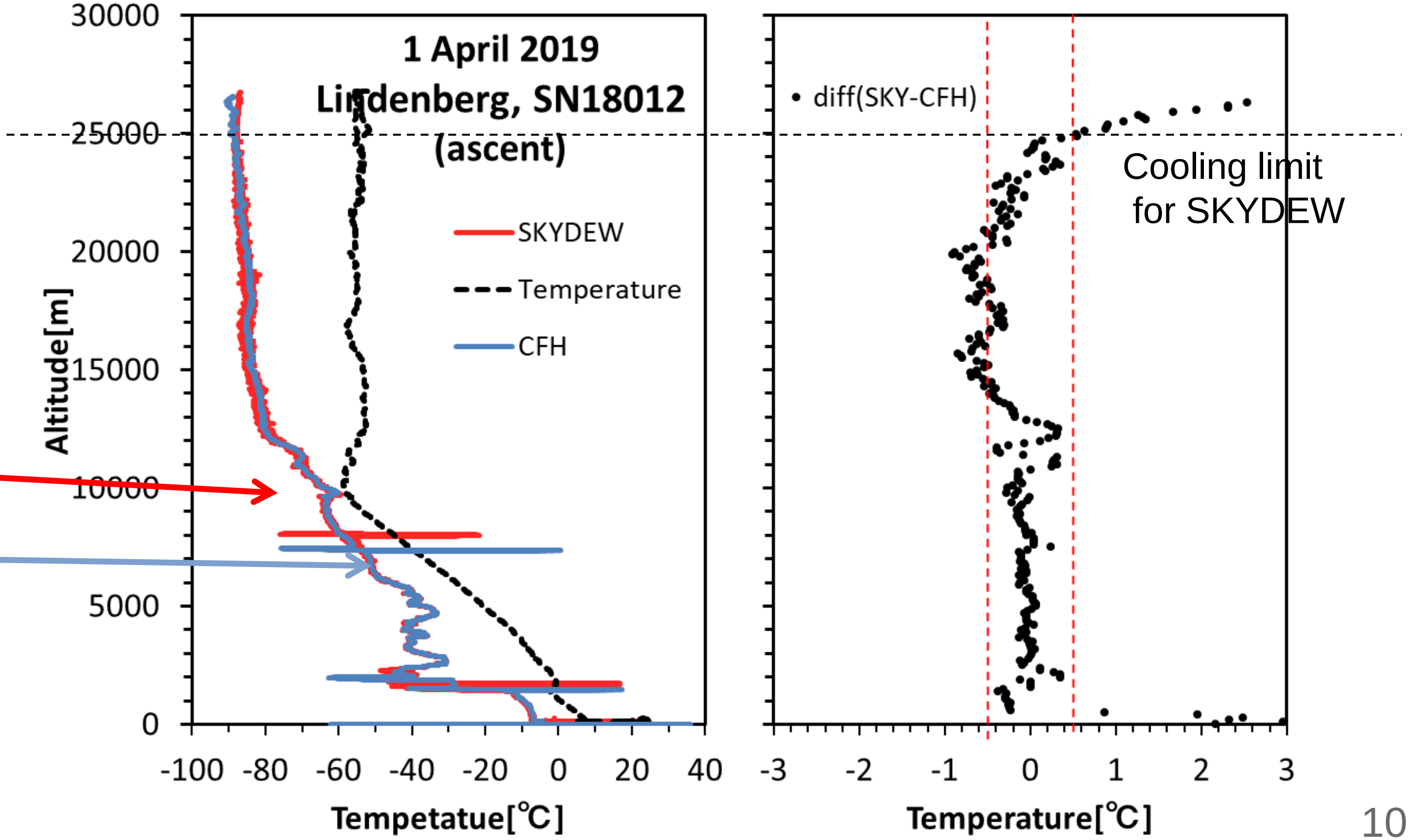
Comparison between SKYDEW and CFH

The comparison with CFH is total 10 sounding since 2018.

The mirror temperature of SKYDEW and CFH were compared at each 100m.



SKYDEW － CFH



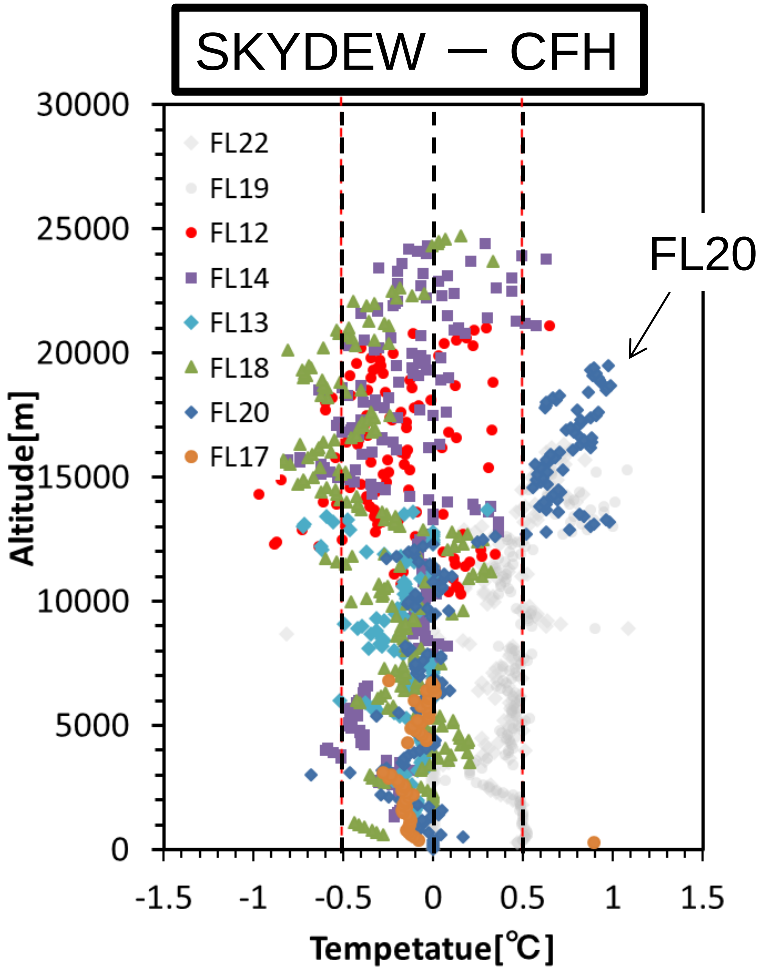
Comparison between SKYDEW and CFH

The temperature difference of total 8 sounding are plotted.
For troposphere, the difference is less than 0.3 K expect two soundings(FL19, FL22)

*There are possibility that the calibration of the SKYDEW used for FL19 and FL22 (SN18010) had small bias because of the calibration method.

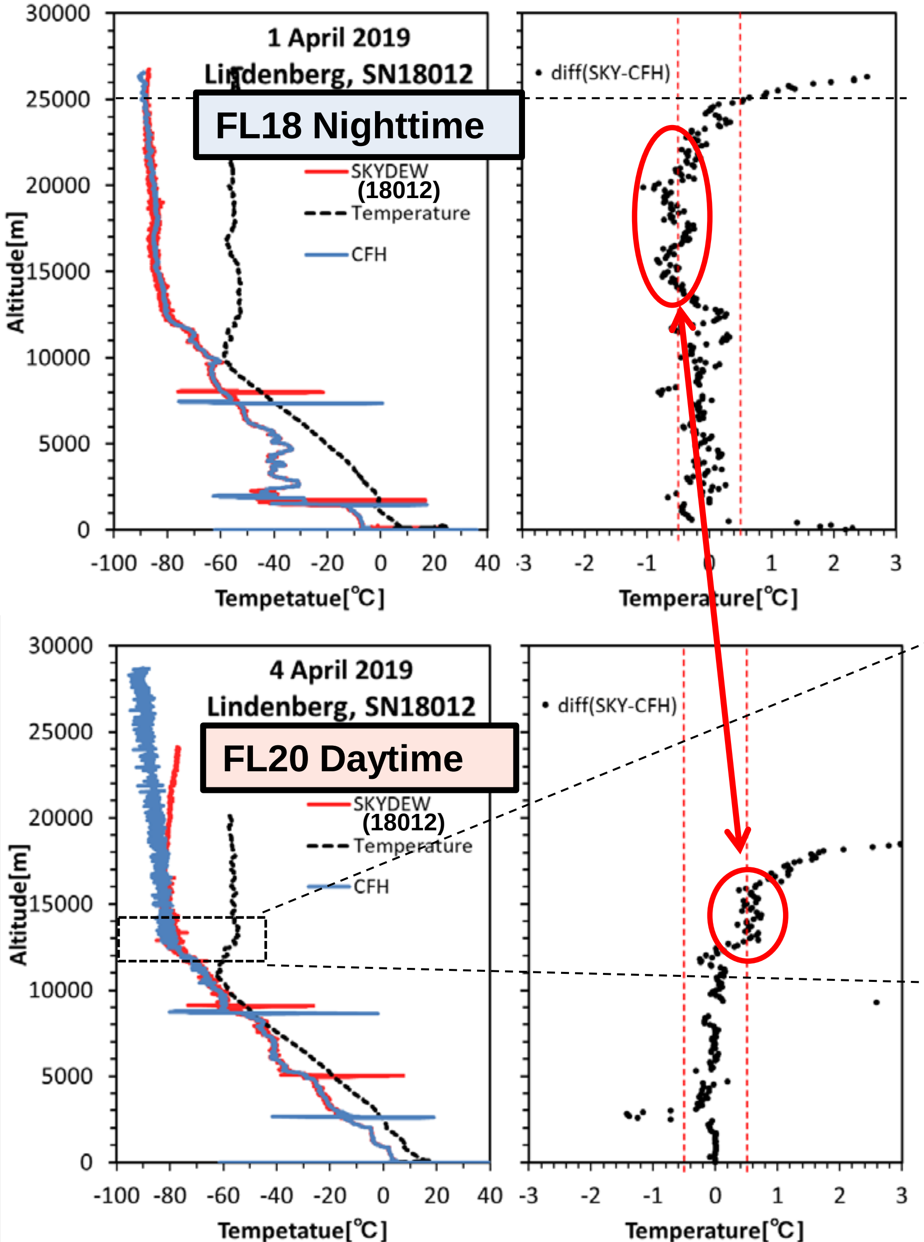
For stratosphere, the difference is over than 0.5 K. The bias of FL20 is positive, while the others are slightly negative.

	Date	Place
FL12	2018.04.20 14:45(LT)	Tateno
FL13	2018.07.15 16:46(LT)	Kototabang
FL14	2018.07.16 17:00(LT)	Kototabang
FL15	2018.07.19 20:40(LT)	Kototabang
FL17	2019.03.22 14:30(LT)	Tateno
FL18	2019.04.01 21:23(LT)	Lindenberg
FL19	2019.04.02 14:30(LT)	Lindenberg
FL20	2019.04.04 11:46(LT)	Lindenberg
FL21	2019.04.04 11:46(LT)	Lindenberg
FL22	2019.04.05 12:31(LT)	Lindenberg



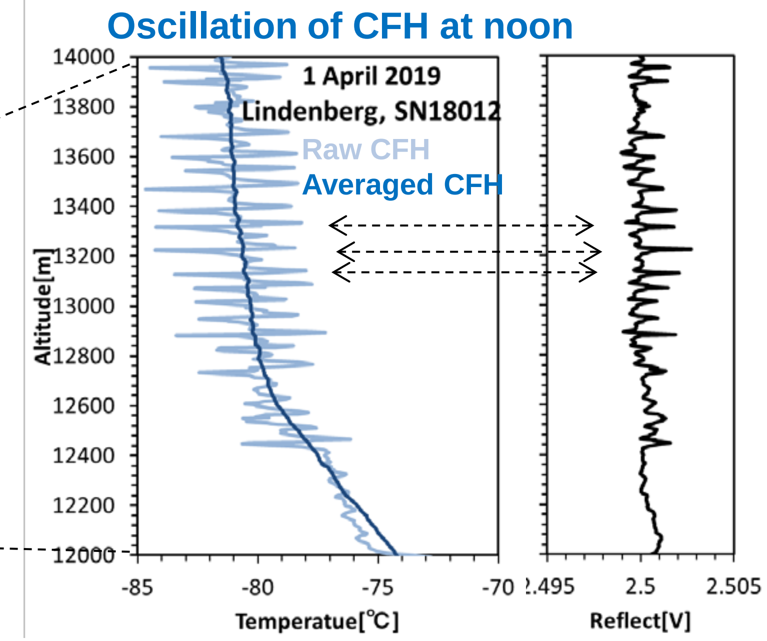
Comparison between SKYDEW and CFH

Same SKYDEW was used for the sounding of FL18 and FL20.



The payload of FL18 was recovered, and reused for the sounding of FL20.This means that this difference is not derived from the calibration error.

The CFH profile of FL 20 have large oscillation, which may be related to the solar contamination. However, it is considered that the oscillation does not generate bias.



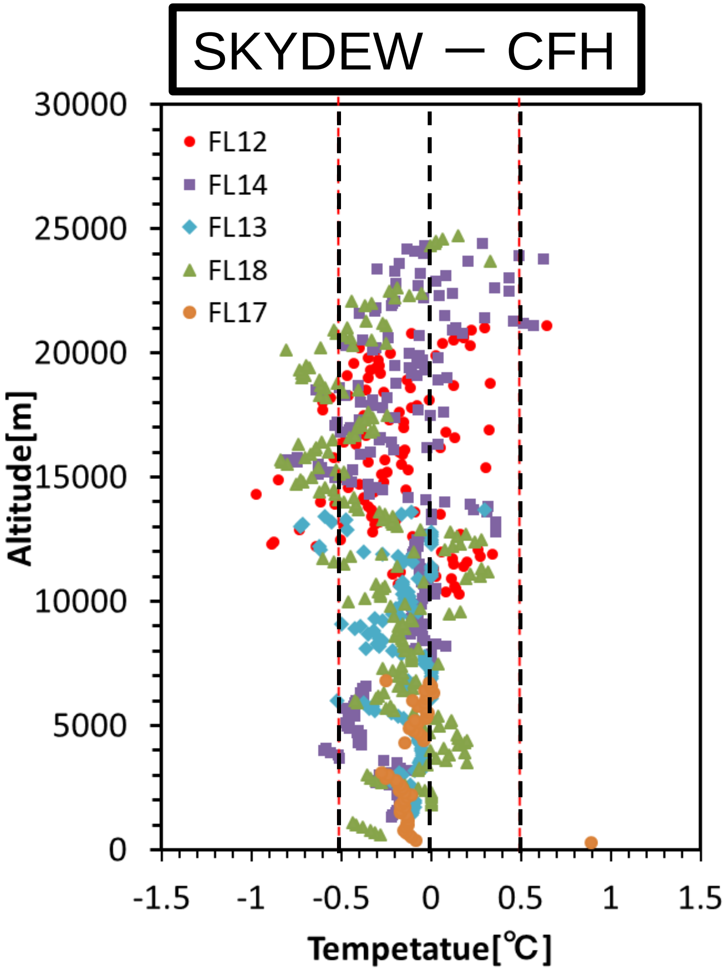
--> Regarding with this bias (FL20), further investigation is needed.

Comparison between SKYDEW and CFH

Excluding the doubtful sounding (contamination at cloudy condition) and the sounding of FL20, the difference temperature between SKYDEW and CFH is less than 0.5 K roughly.
At stratosphere, it seems that the SKYDEW are slightly negative in comparison with CFH.

--> Currently, the cause of this bias is under investigation.

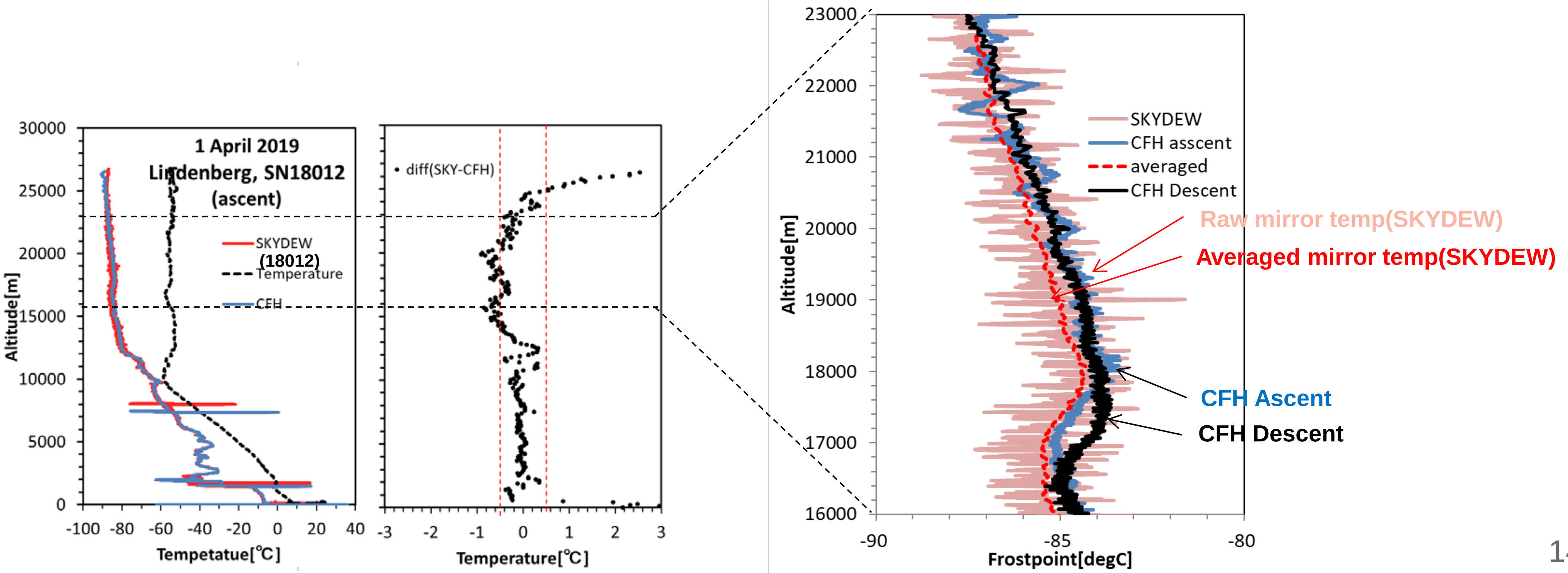
	Date	Place
FL12	2018.04.20 14:45(LT)	Tateno
FL13	2018.07.15 16:46(LT)	Kototabang
FL14	2018.07.16 17:00(LT)	Kototabang
~~FL15~~	~~2018.07.19 20:40(LT)~~	~~Kototabang~~
FL17	2019.03.22 14:30(LT)	Tateno
FL18	2019.04.01 21:23(LT)	Lindenberg
~~FL19~~	~~2019.04.02 14:30(LT)~~	~~Lindenberg~~
~~FL20~~	~~2019.04.04 11:46(LT)~~	~~Lindenberg~~
~~FL21~~	~~2019.04.04 11:46(LT)~~	~~Lindenberg~~
~~FL22~~	~~2019.04.05 12:31(LT)~~	~~Lindenberg~~



Comparison between SKYDEW and CFH

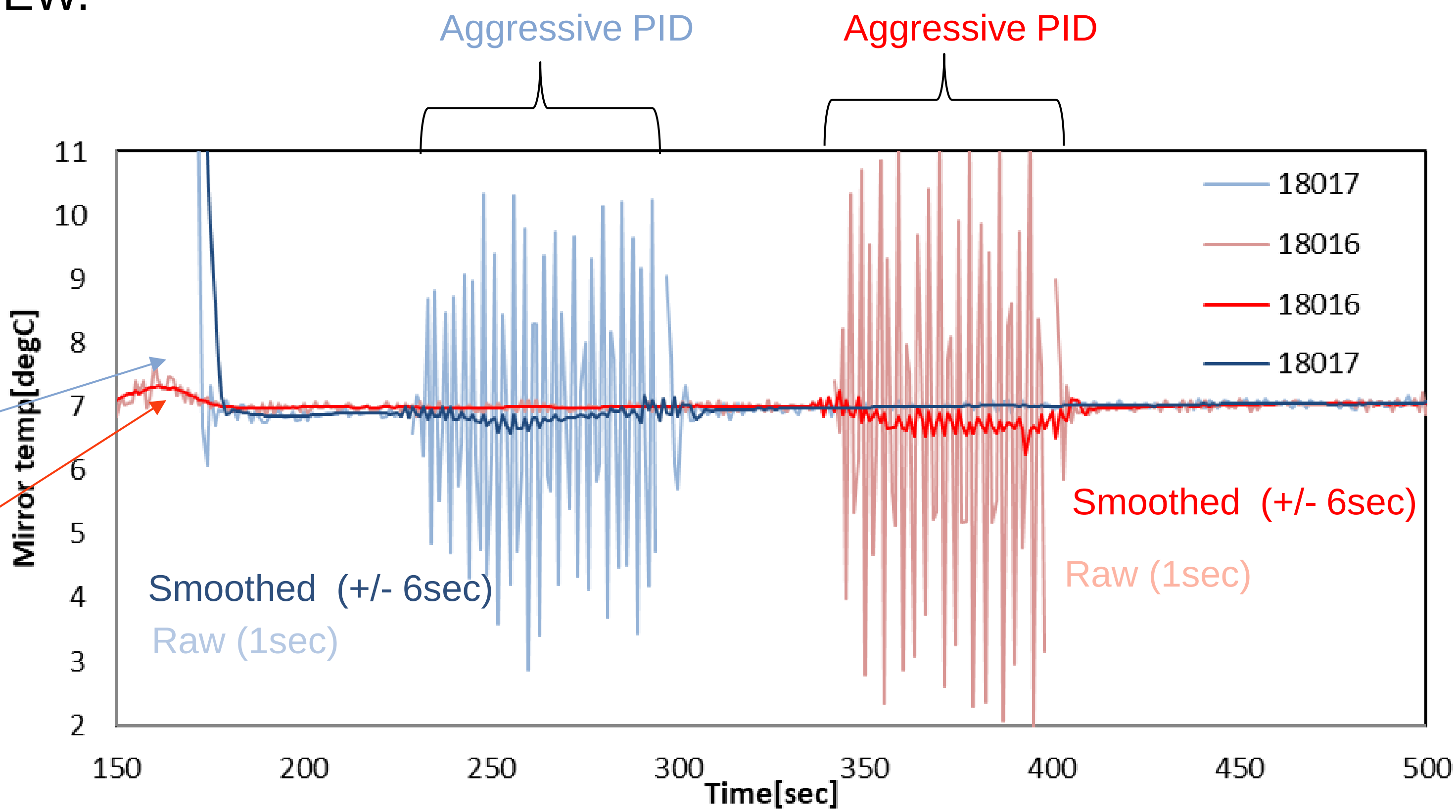
One of the possibility to derive this bias is the oscillation by the PID controller. The aggressive PID setting causes the larger oscillation. The oscillation can be smoothed out using appropriate filters (Vömel et al, 2016)

The oscillation may be too large for the SKYDEW, although the presence of slight oscillation is preferred. If the center of the oscillation is not true frostpoint, this smoothing of oscillation cause the bias.



Bias caused by PID oscillation ?

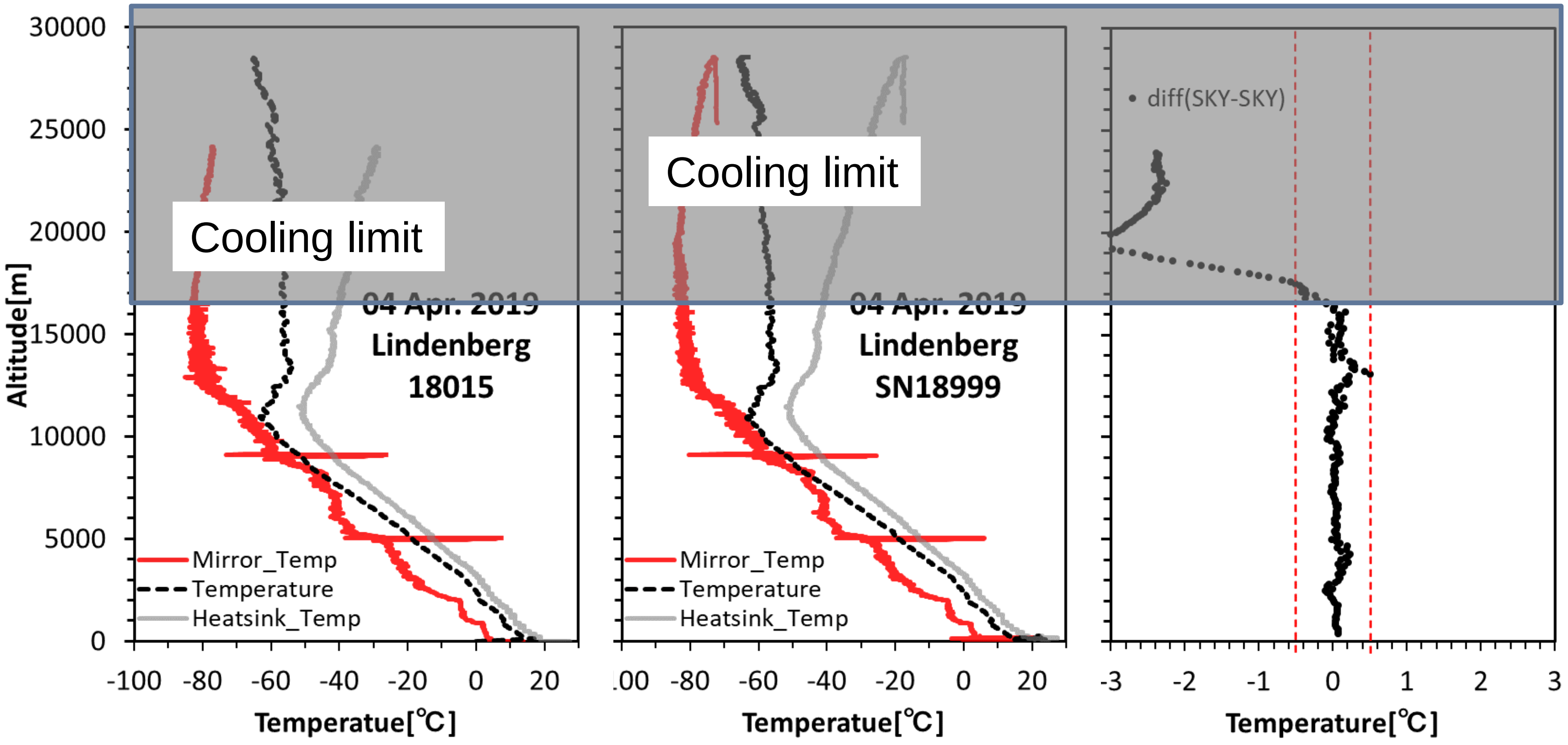
The experiment was conducted to investigate the negative bias.
Two SKYDEWs measure same air, and the PID parameter for one SKYDEW was changed to make oscillation for a minute. When the oscillation is large, it seems that the averaged mirror temperature indicates lower than the other SKYDEW.

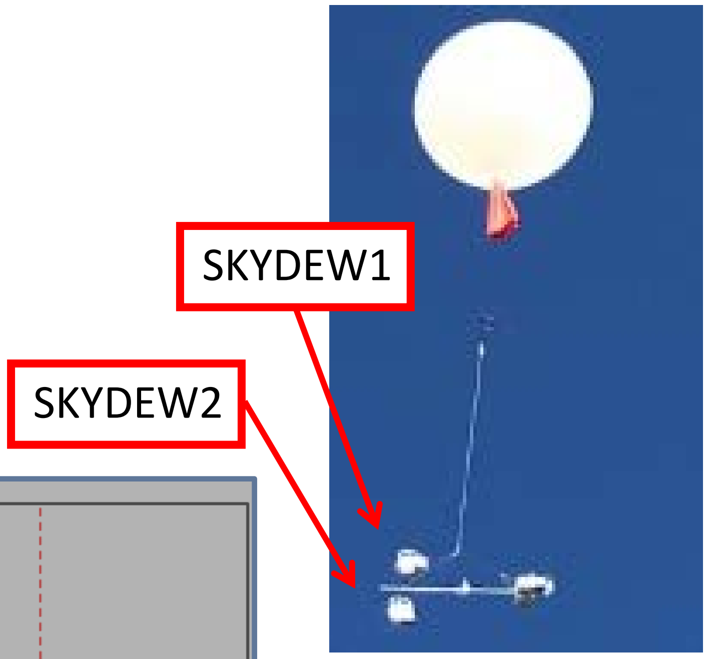


Is this systematic bias or random error?
--> Further investigation is needed.

Dual sounding of SKYDEW

At 4 April 2019, two SKYDEW instruments were flown on the same payload to evaluate the reproducibility. The difference between the measured frost point temperatures is almost less than +/-0.2 K up to 16.5km (cooling limit)





Summary

1. SKYDEW can measure dewpoint/frostpoint up to 25 km at nighttime, and up to 15-25 km at daytime depending on locations.

2. The comparison with CFH shows good agreement at troposphere. The SKYDEW has slightly bias as compared with CFH at the stratosphere. The cause of this bias is still under investigation.

3. The dual sounding with two SKYDEW shows good agreement. The difference between the measured frost point temperatures is almost less than +/-0.2K.

4. The product model of SKYDEW will be released on October 2019.

We thank JMA (Japan metrological agency) for providing the CFH data at Tateno, Dr. J. Suzuki at JAMSTEC (Japan Agency for Marine-Earth Science and Technology) for providing the CFH data at Kototabang, and the GRUAN lead center and the staffs at the Lindenberg observatory for the support of the observations at Lindenberg

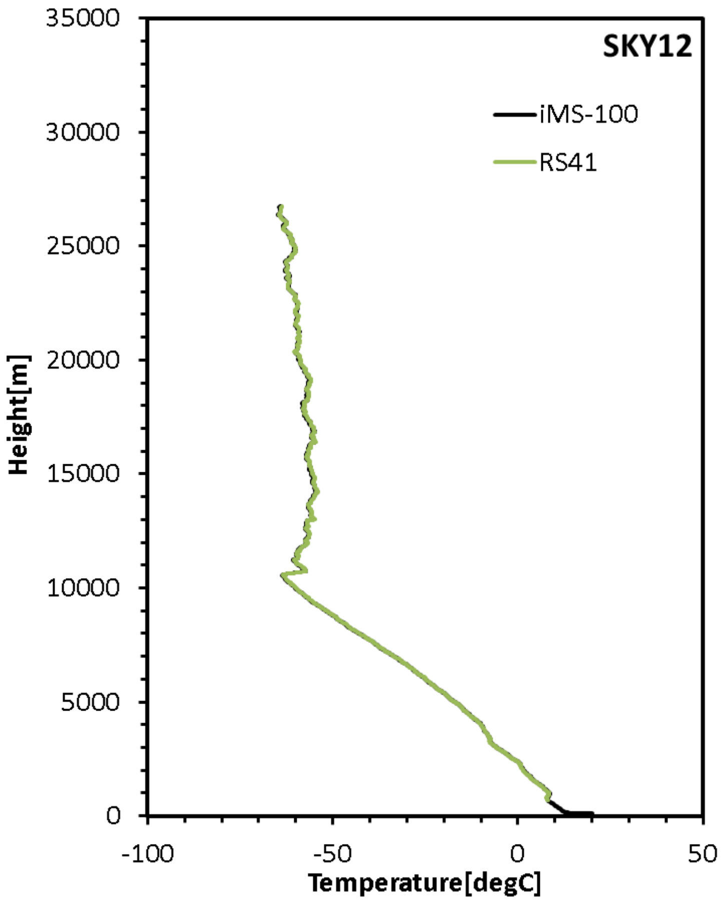
Thank you for your kind attention.

For more information, contact “sugidachit@meisei.co.jp”

Comparison flight with CFH

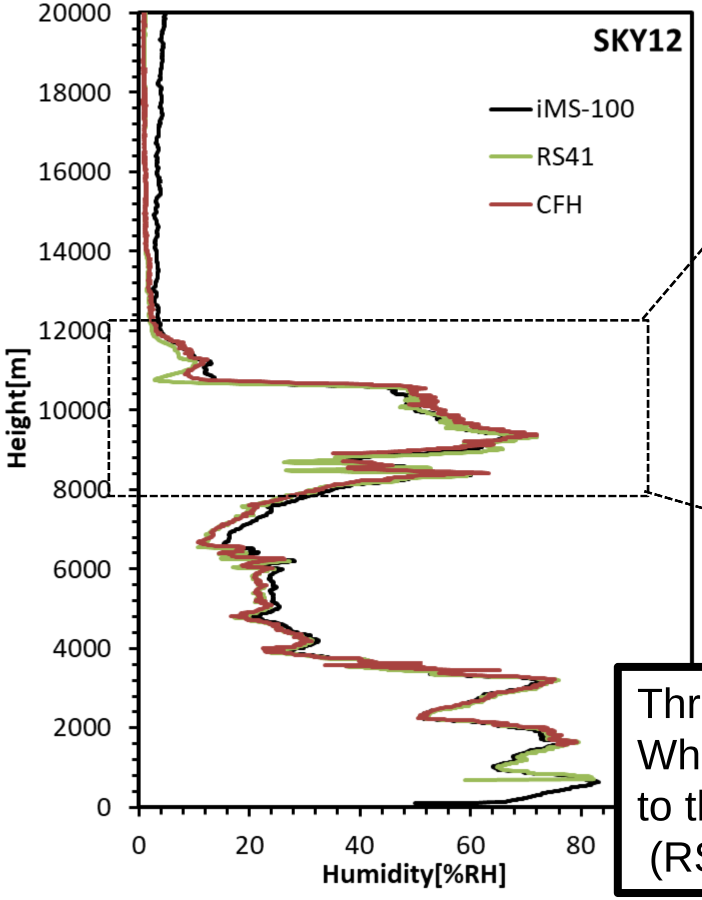
The iMS-100 and RS41 are flown with the CFH.

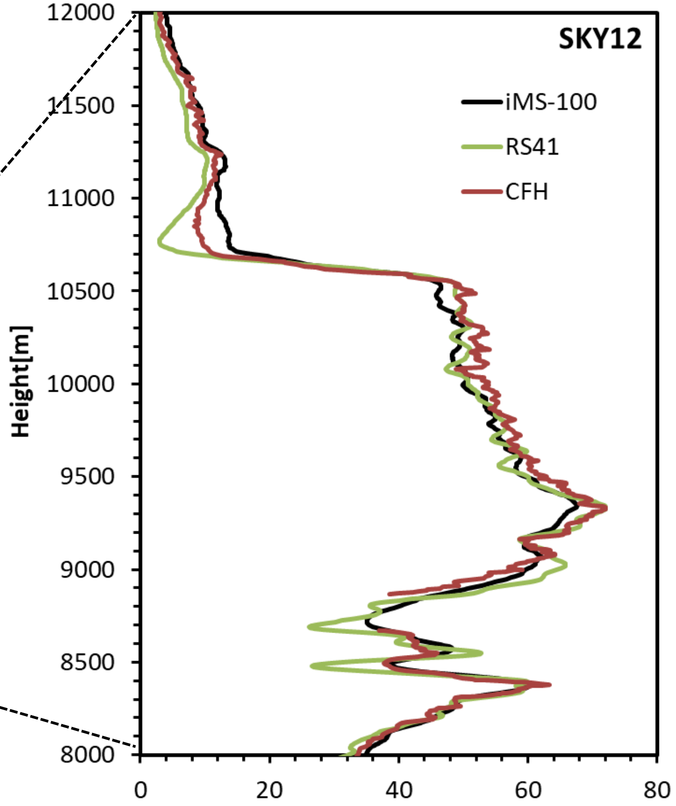
Temperature



Relative humidity

+CFH

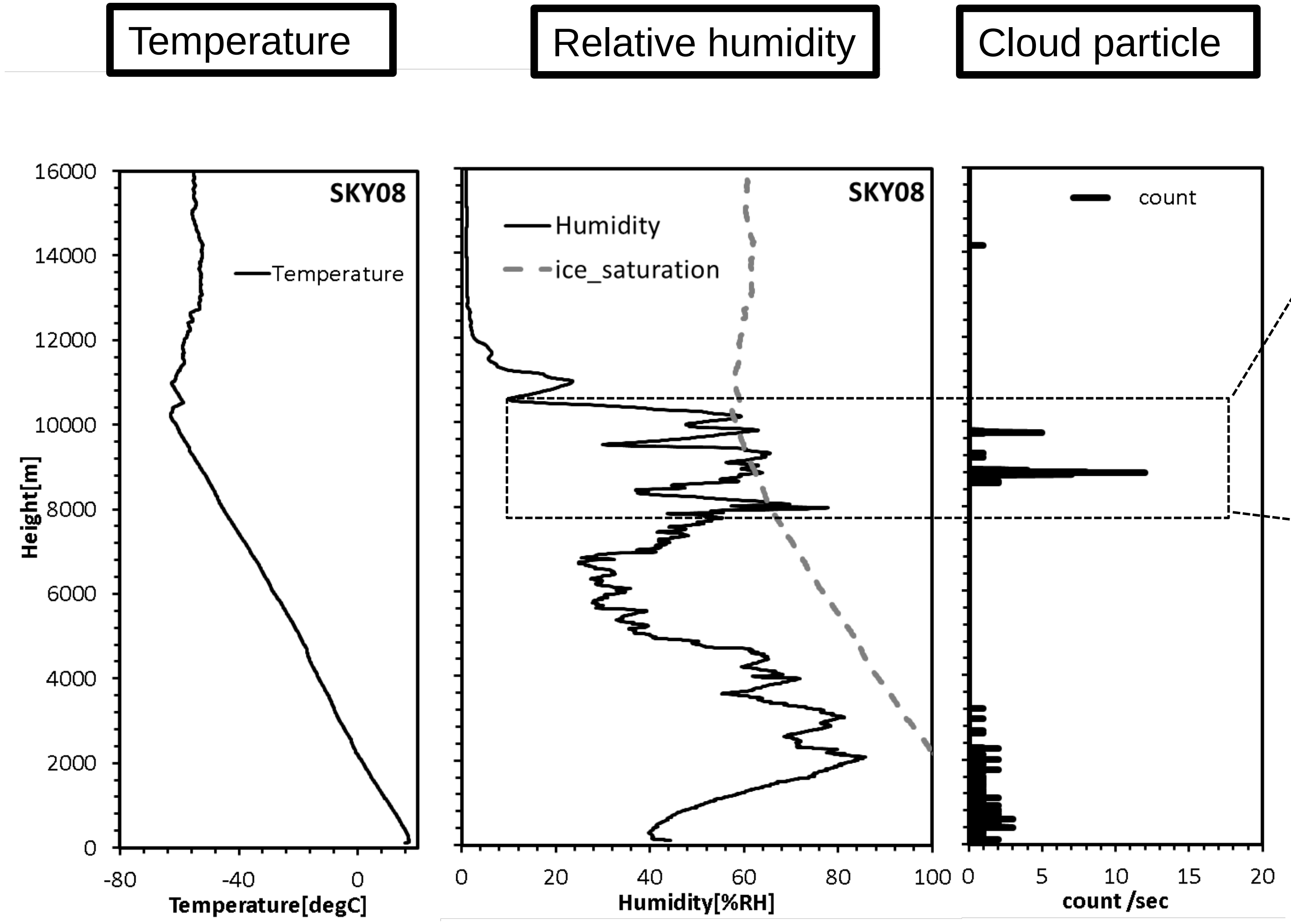


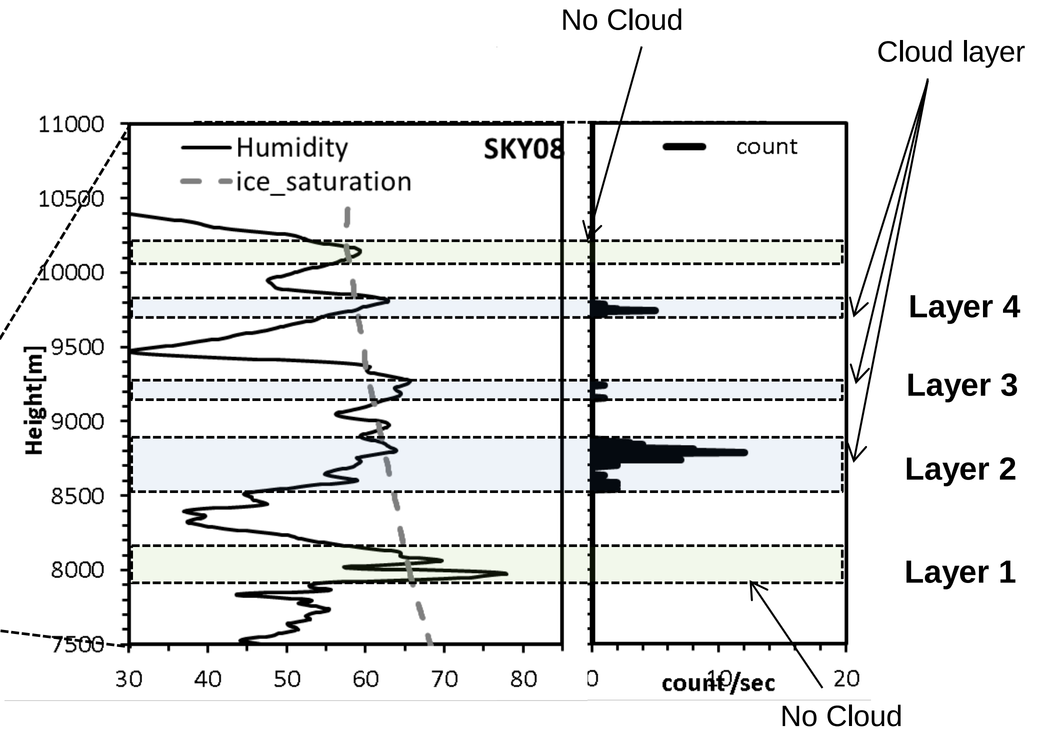


Three RH profiles have good agreement basically. When changing RH, the difference becomes large due to the response time or the tuning of TL correction.
(RS41 > CFH > iMS-100)

Comparison flight with cloud particle sensors

The iMS-100 and RS41 are flown with the particle sensors, COBALD and CPS(Cloud particle sensor) produced by Meisei.





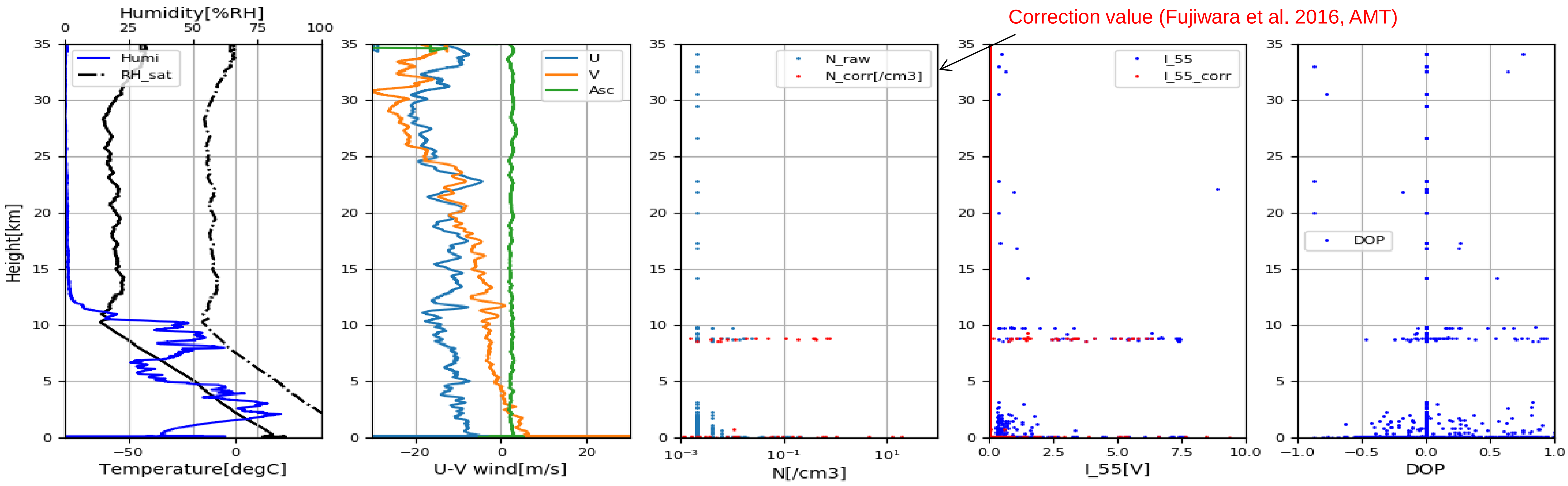
<u>Layer 1 (no cloud layer):</u>
The RH profile shows high supersaturation.

<u>Layer 3,4 (could layer):</u>
The RH profile shows slightly supersaturation.

The information about existence of cloud is useful for the evaluation of RH value.

Result of CPS Ascent

T, RH, U/V, Particle Number, Particle size, Particle shape



Number concentration from number of count per second (>2 μm)

I55 ,
Scattered light level
---> particle size
(2um – 140um)

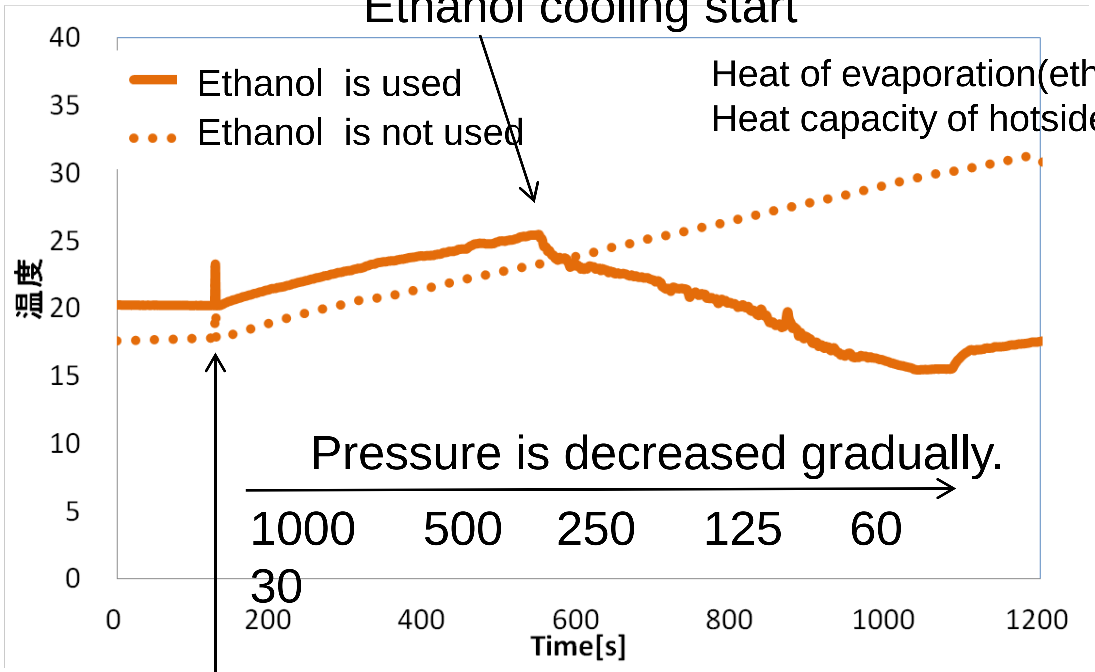
The degree of polarization (**DOP**)
---> particle shape

●innovation of hotside cooling

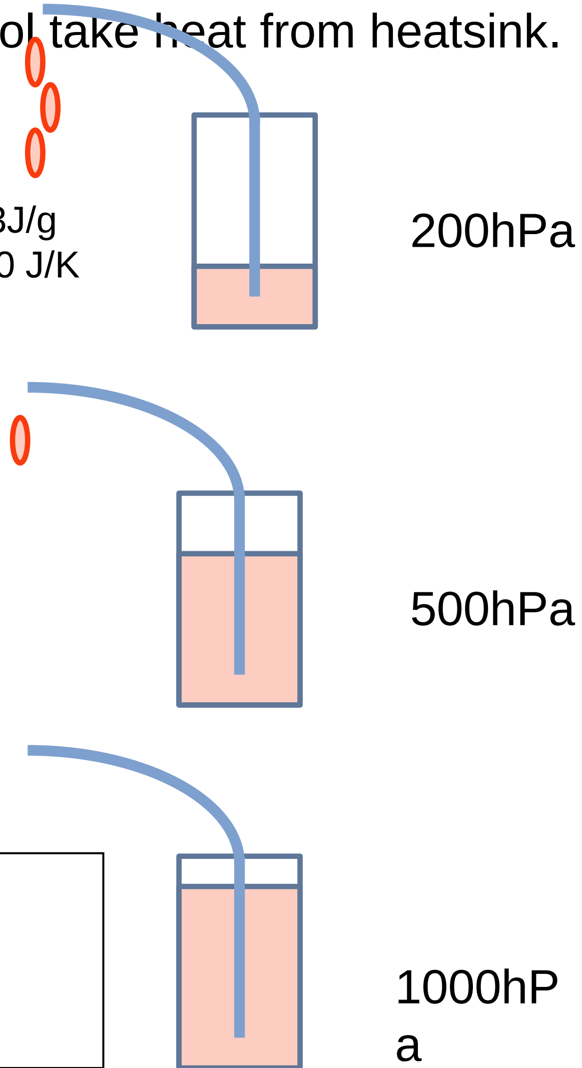
A chilled-mirror hygrometer by peltier cooling is needed to cool hotside effectively.
But, air cooling are not expected because of a little air in upper air, in particular stratosphere.
This sensor use cooling by heat of evaporation.
When ethanol evaporate, it take heat from air. In this case, ethanol take heat from heatsink.

Ethanol cooling start

Heat of evaporation(ethanol) : 853J/g
Heat capacity of hotside : about 30 J/K



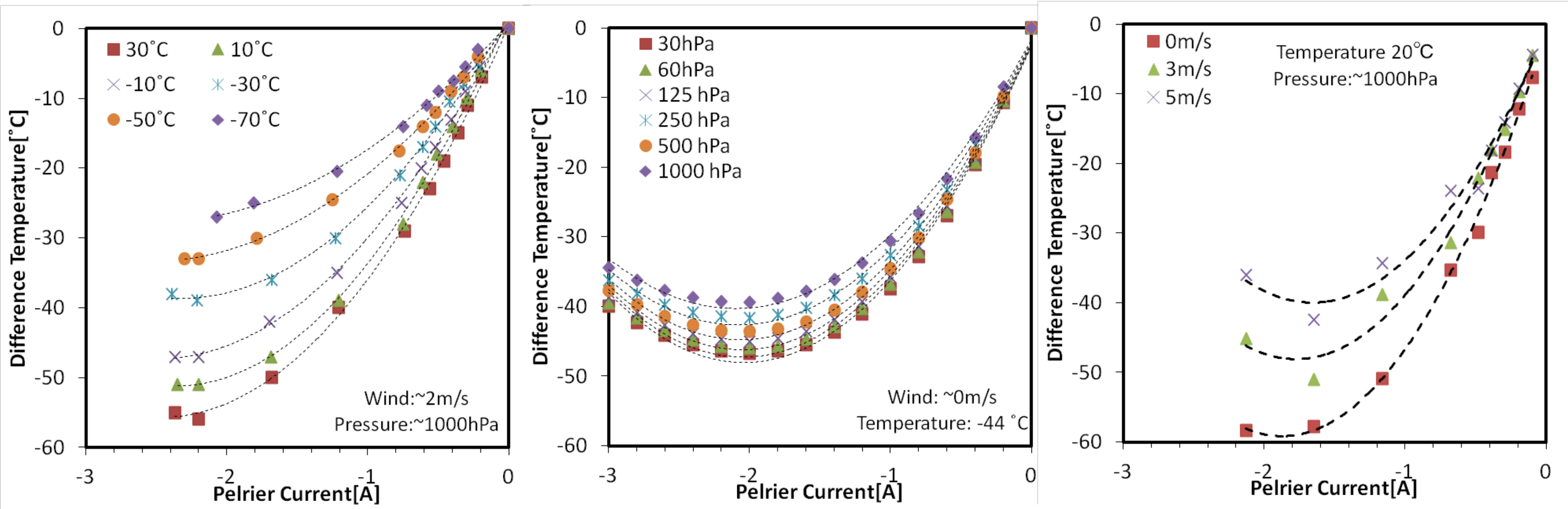
Peltier current ON
(constant 1.2A)



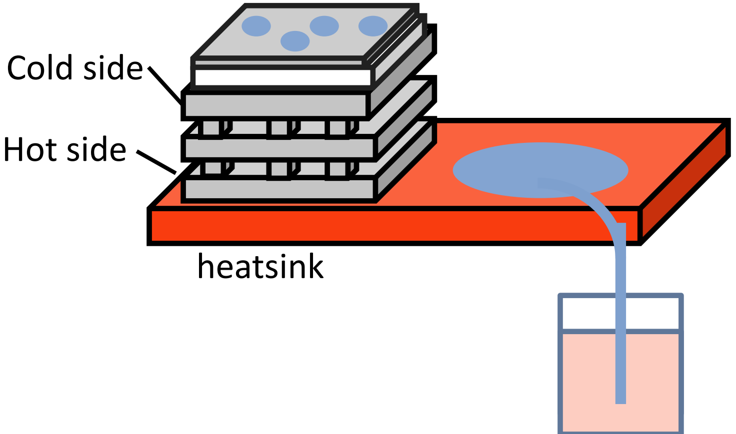
Ethanol(15g) cool hotside 15℃
Condition
peltier current: 1.2A (constant)
Pressure :1000hPa ⇒30hPa(during 1200sec)

Cooling capability by Peltier device

Dependence on
(a)air temperature, (b)pressure, (c) airflow



We estimate that ΔT>30@LS, ΔT>55@surface.



PAT. P.

Aggressive cooling of the hot side

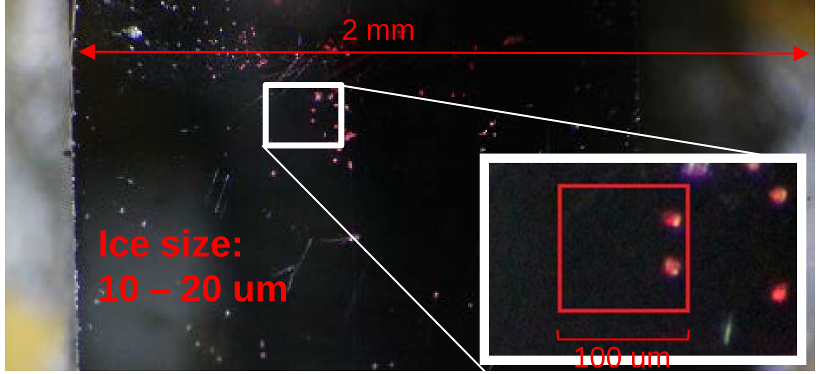
In addition to Peltier cooling , we use liquid ethanol for cooling of the heatsink. When ethanol evaporates on surface of the heatsink, the latent heat of evaporation can provide additional cooling effect of heatsink.

Ice on the mirror

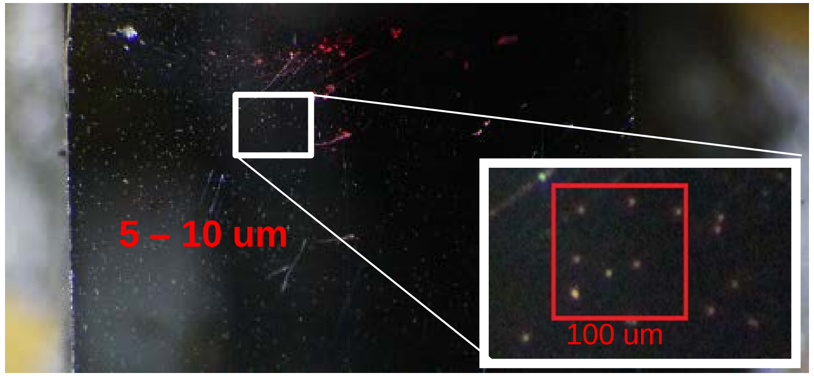
The ice size and density on the mirror depends on the mirror temperature.
> large ice and low density for high T
  small ice and high density for low T

The growth/evaporation rate of larger ice is lower, which cause slower response particularly in UT/LS.

Ice on mirror need to be refreshed by heating mirror in cold enough conditions in a similar to the CFH.

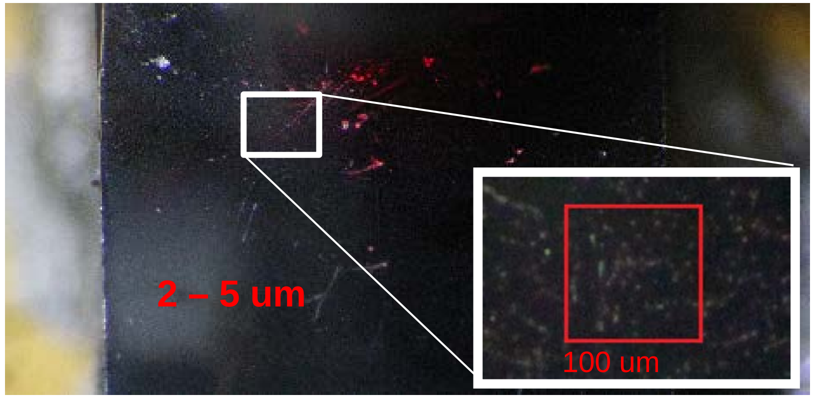


(T=-21℃、-31℃FP)



R= 4 um
ISL =80 mW
400 個/mm2
→ 32 W

(T=-39℃、-45℃FP)

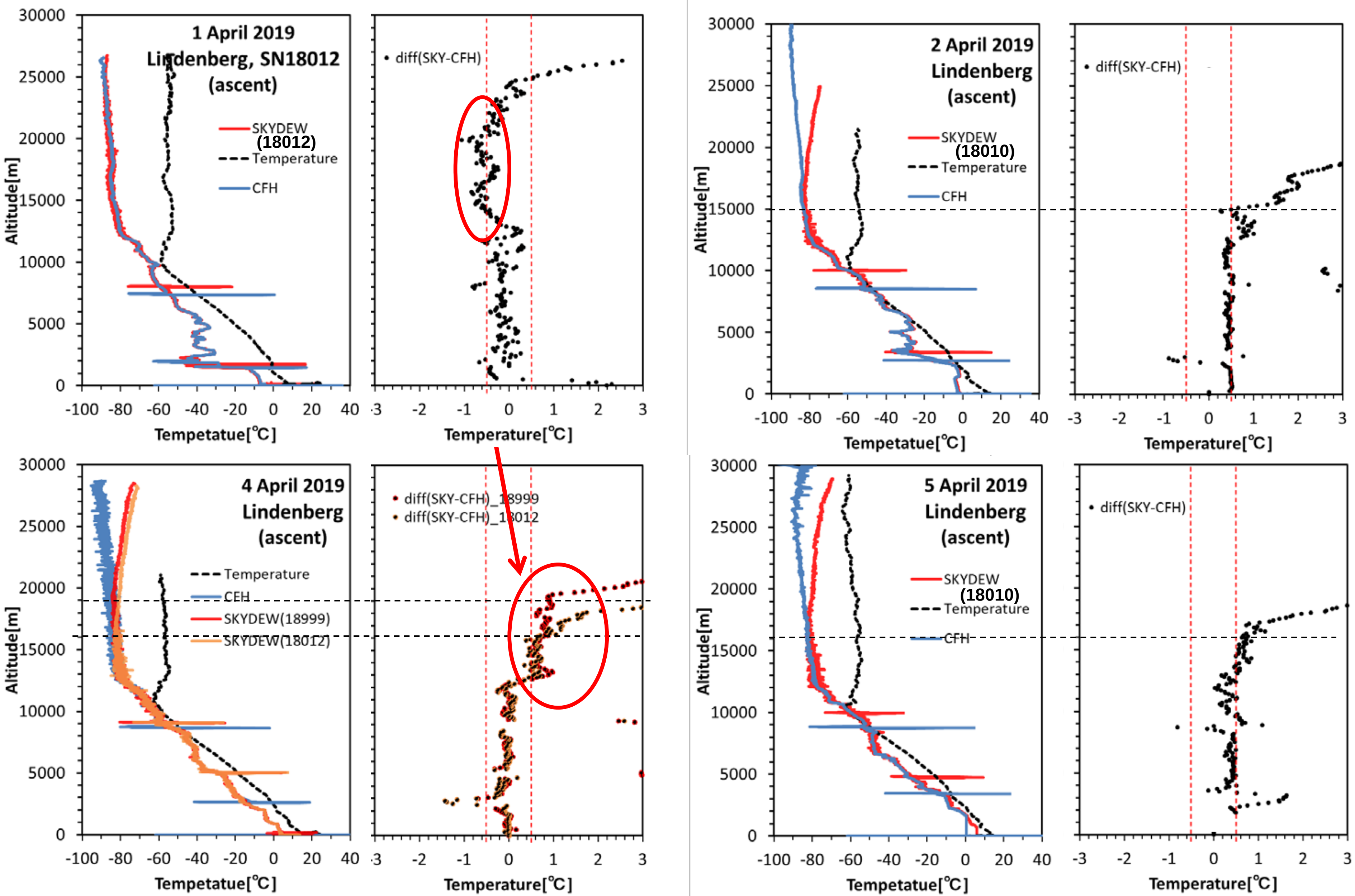


R= 2 um
ISL =10 mW
2880個/mm2
→ 28.8 W

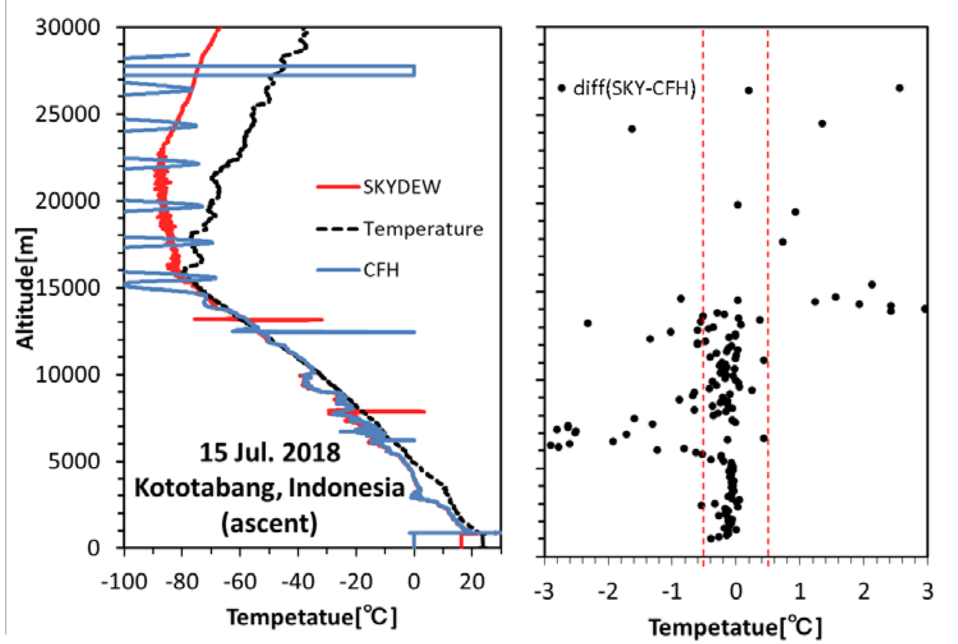
(T=-60℃、-61℃FP)

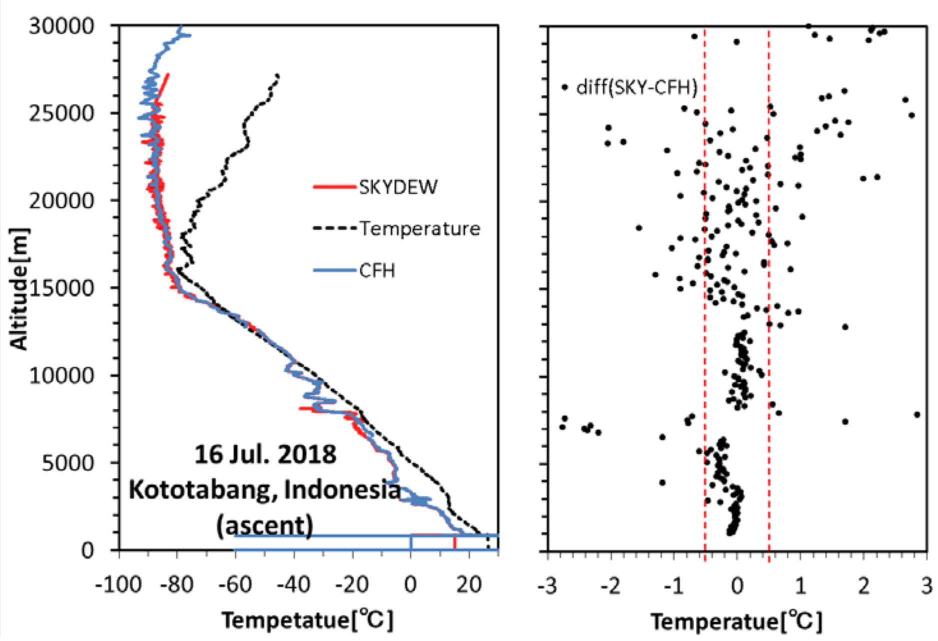
Comparison between SKYDEW and CFH @ Lindenberg, 20190401-05

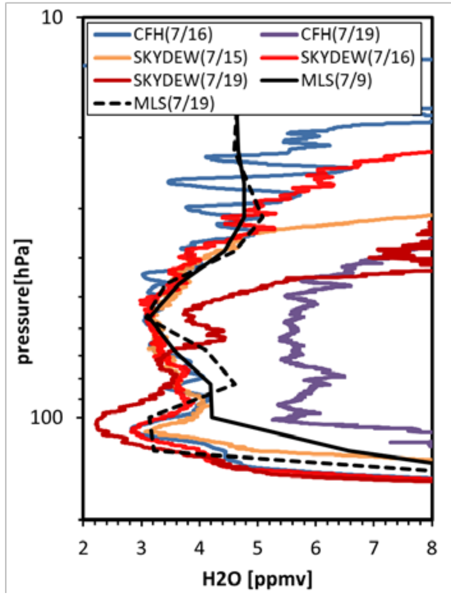
SKYDEW and CFH have a good agreement (+/- 0.5degC) at troposphere.
The measurement biases are over than 0.5degC at stratosphere.

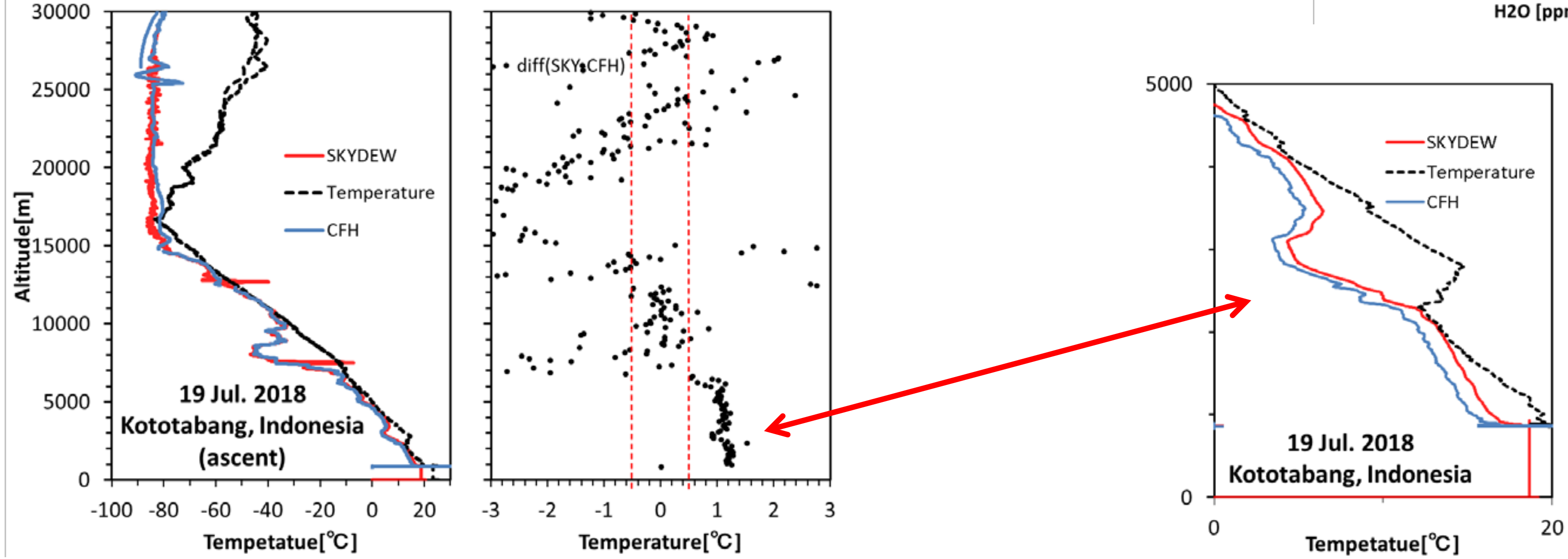


Comparison between SKYDEW and CFH @ Kototabang



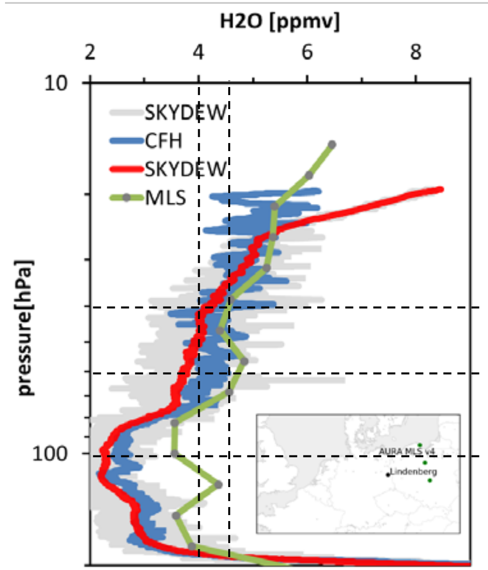




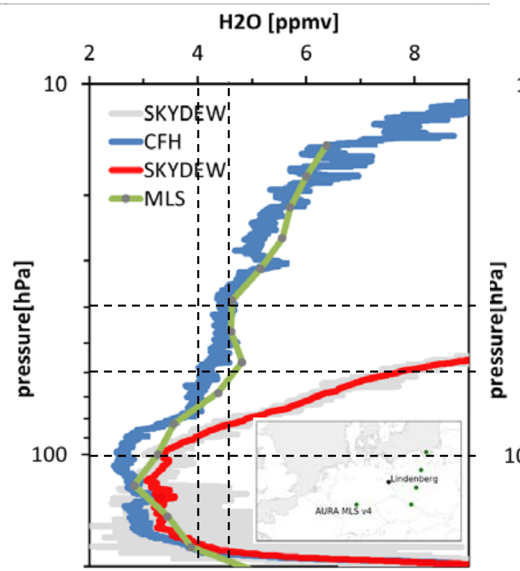


Water vapor mixing ratio of SKYDEW, CFH, and AURA MLS

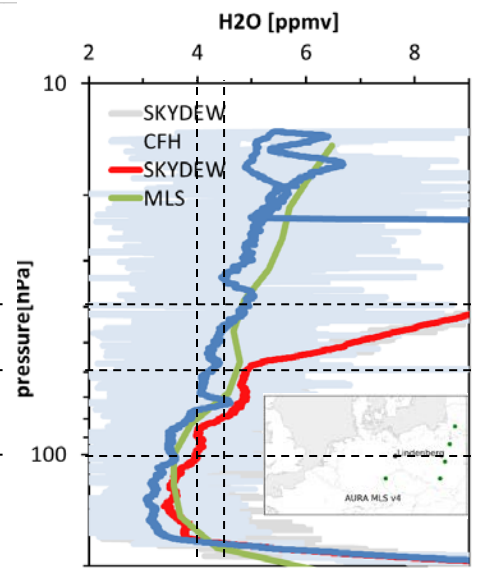
2019.4.1

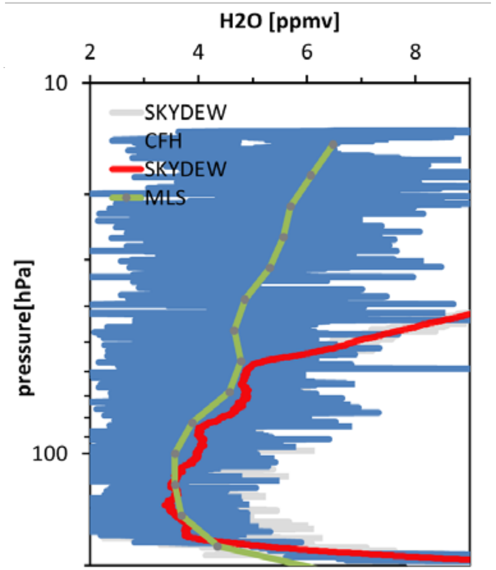


2019.4.2

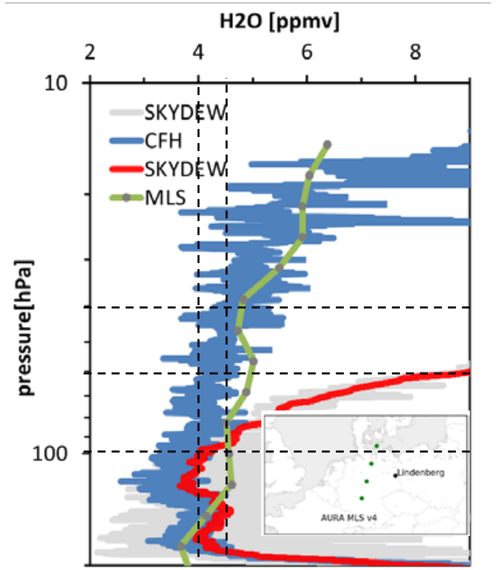


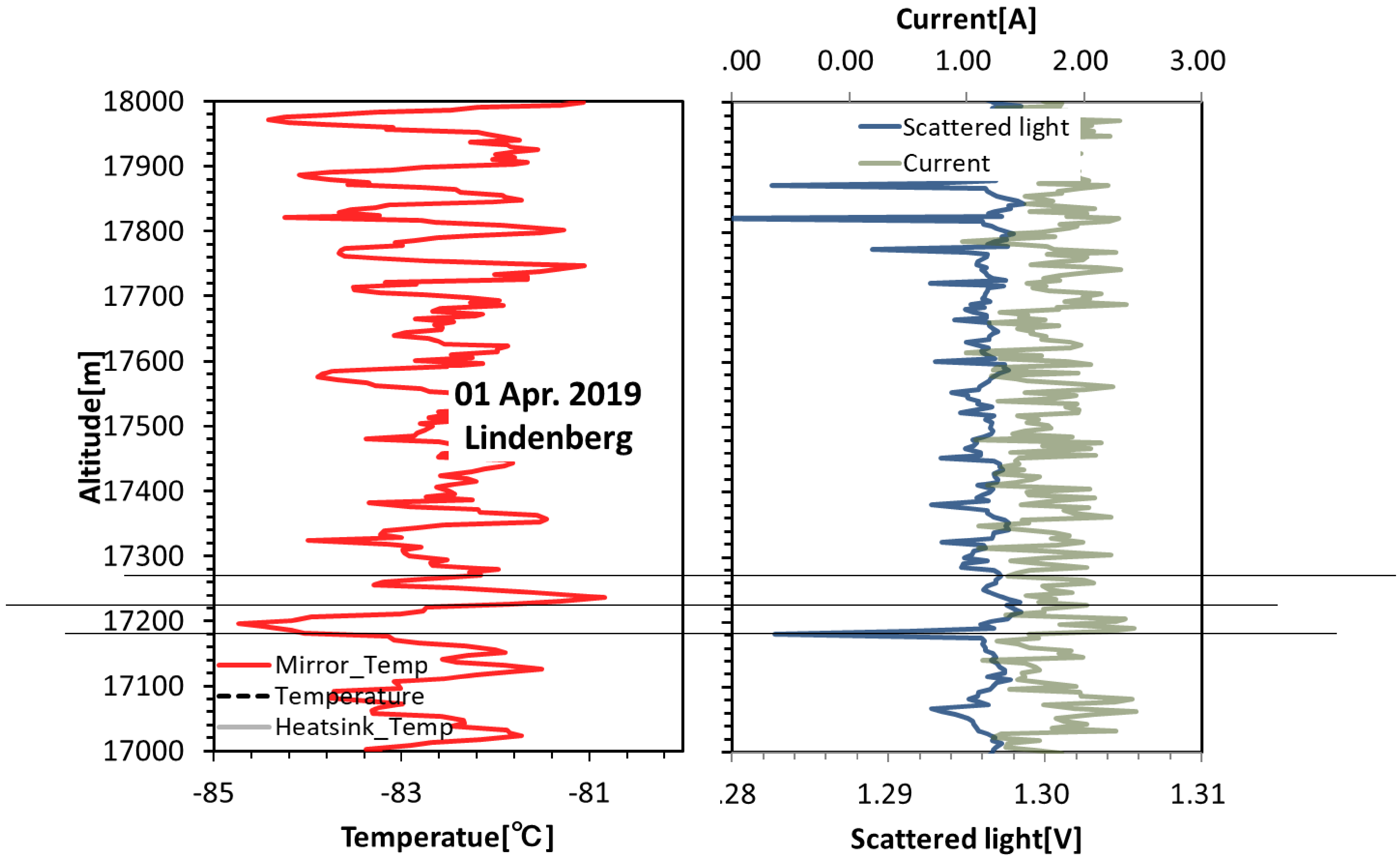
2019.4.4





2019.4.5





Current[A]
.00
0.00
1.00
2.00
3.00
Scattered light
Current
18000
17900
17800
17700
17600
17500
17400
17300
17200
17100
17000
Altitude[m]
01 Apr. 2019
Lindenberg
Mirror_Temp
Temperature
Heatsink_Temp
-85
-83
-81
Temperatue[℃]
.28
1.29
1.30
1.31
Scattered light[V]