New Peltier-based chilled-mirror hygrometer "SKYDEW"

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Motivation

Meteolabor **Snow White** hygrometer is a Peltier-based, analog-controller hygrometer – its stratospheric performance was not satisfactory (Fujiwara et al., 2003; Vömel et al., 2003). Due to its mirror-cooling controller(?).

CFH/NOAA FPH can measure the tropospheric and stratospheric water vapor. They need a **cryogen material** (CHF_3) which is banned in near future.

History

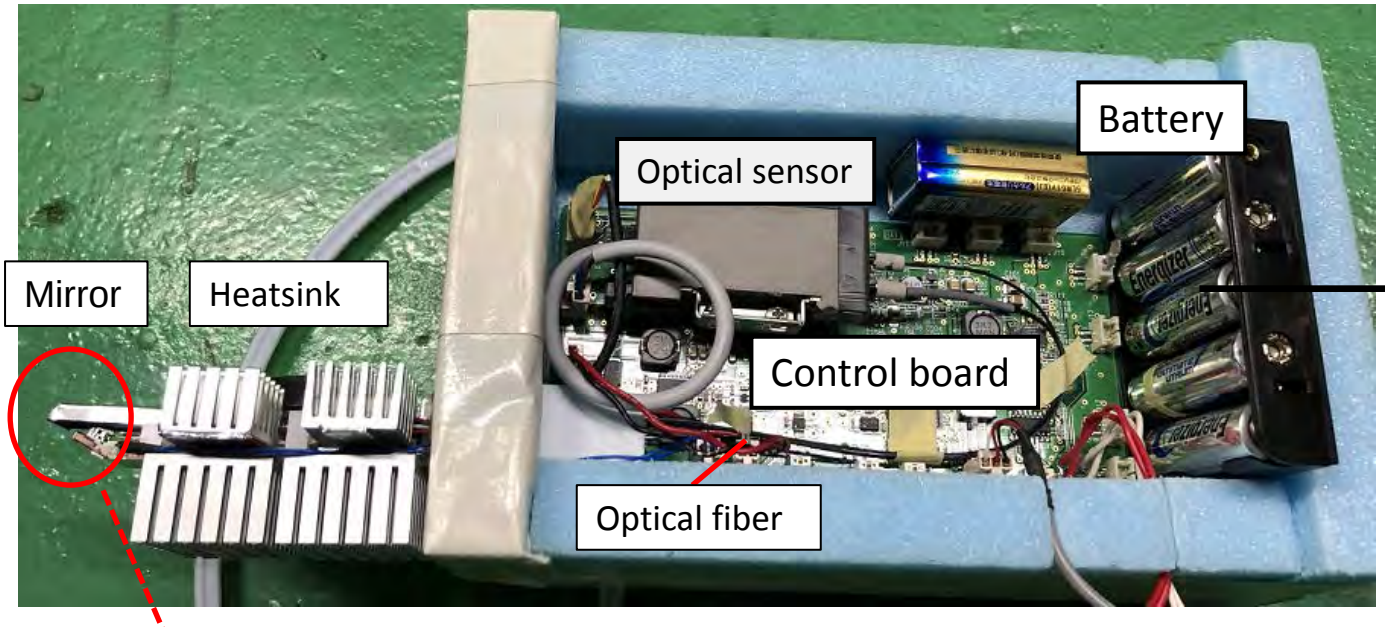
2009: We started to develop the Japanese dew/frost point hygrometer as my Ph. D thesis at Hokkaido university. We produced prototype model and conducted several **chamber tests** and 9 **flight tests**.

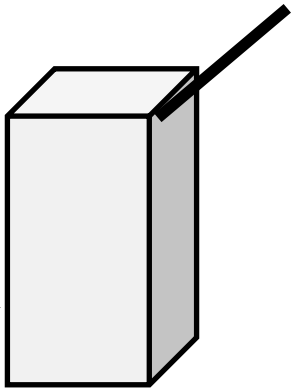
1st model

2014: I moved to Meisei electric co. ltd,.
We are developing the product model(**SKYDEW**)
(e.g., establishing a **manufacturing process**)

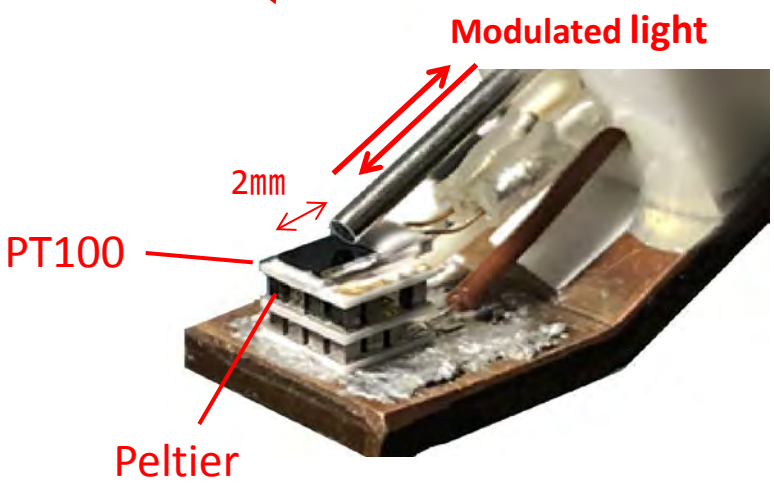
10th model (SKYDEW)

Description of “SKYDEW”





Meisei Radiosonde
or
Other radiosonde
(XDATA)



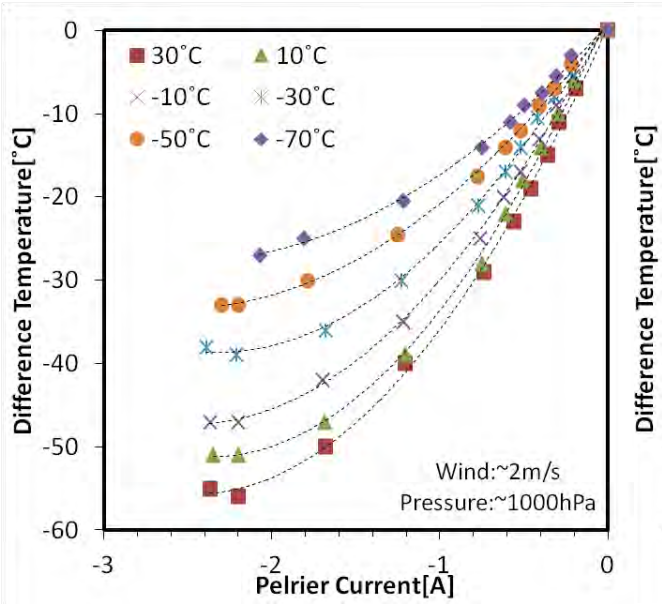
Features of SKYDEW hygrometer

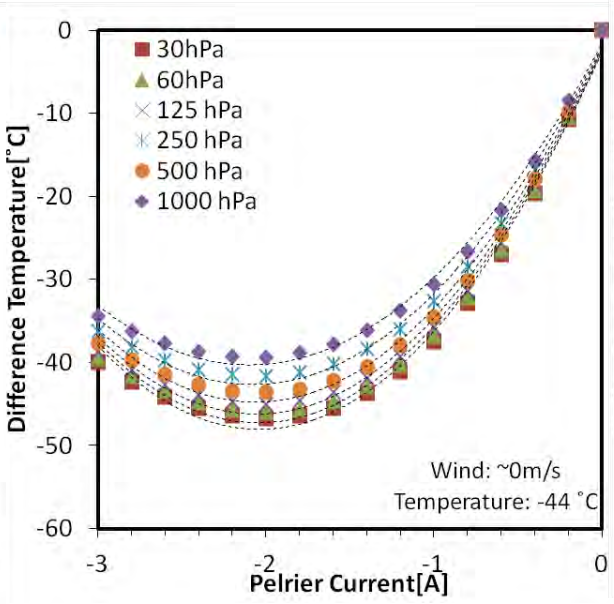
1. Two-stage Peltier device
2. Dew/frost detection by scattered light using an electronically modulated light
3. Digital controller (PID controller, gain scheduling depending on dewpoint)
4. Meisei original data format or XDATA format

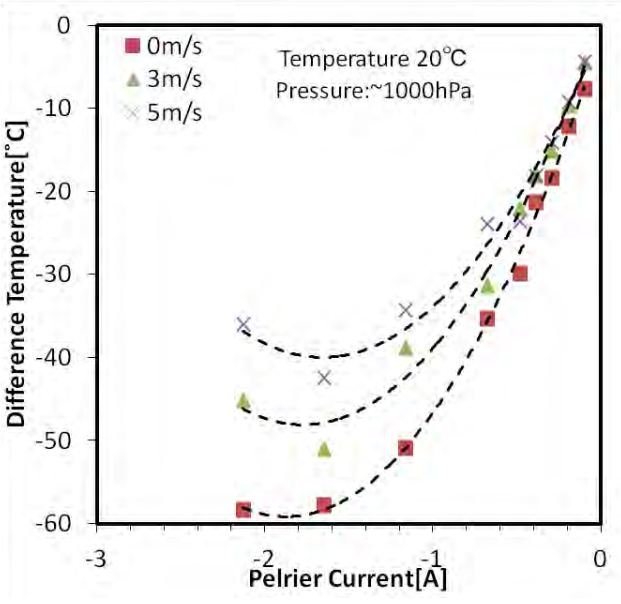
Cooling capability by Peltier device

Dependence on

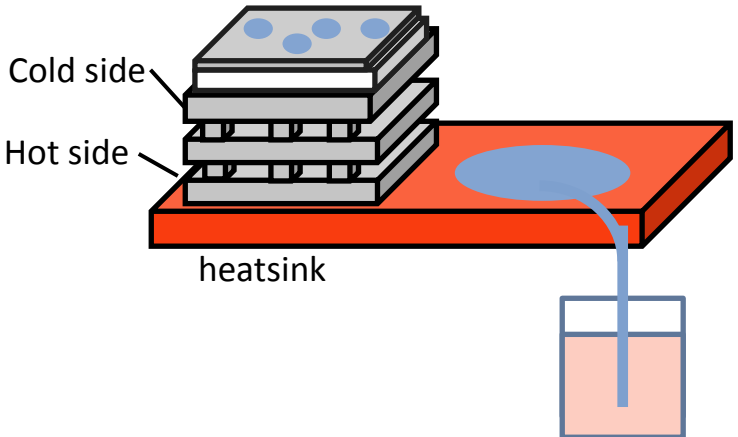
(a)air temperature, (b)pressure, (c) airflow







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



PAT. P.

Aggressive cooling of the hot side

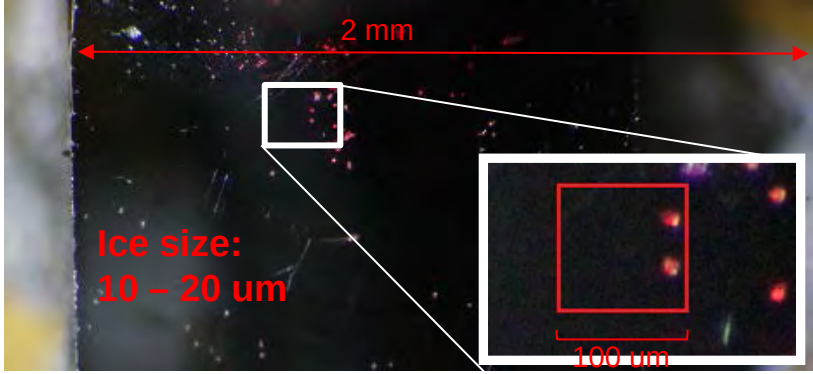
In addition to Peltier cooling , we use liquid ethanol for cooling of the heatsink. When ethanol evaporates on surface of the heatsink, the latent heat of evaporation can provide additional cooling effect of heatsink.

Ice on the mirror

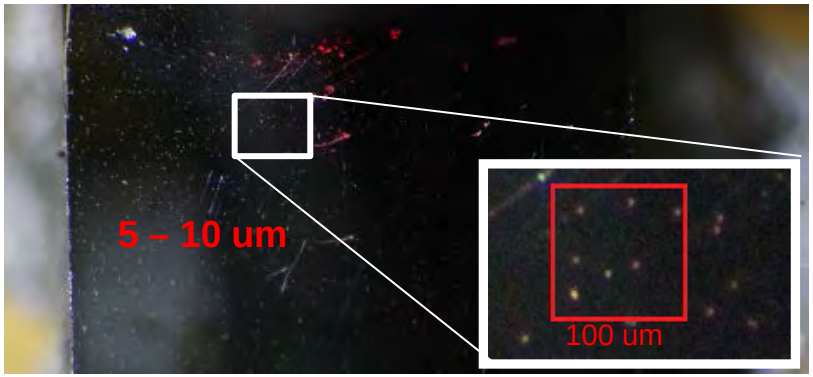
The ice size and density on the mirror depends on the mirror temperature.
> large ice and low density for high T
small ice and high density for low T

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

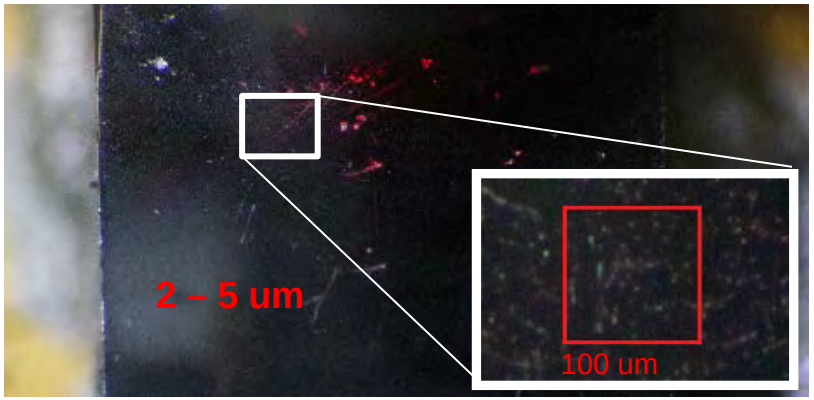
Ice on mirror need to be refreshed by heating mirror in cold enough conditions in a similar to the CFH.



(T=-21℃、-31℃FP)



(T=-39℃、-45℃FP)



（T=-60℃、-61℃FP）

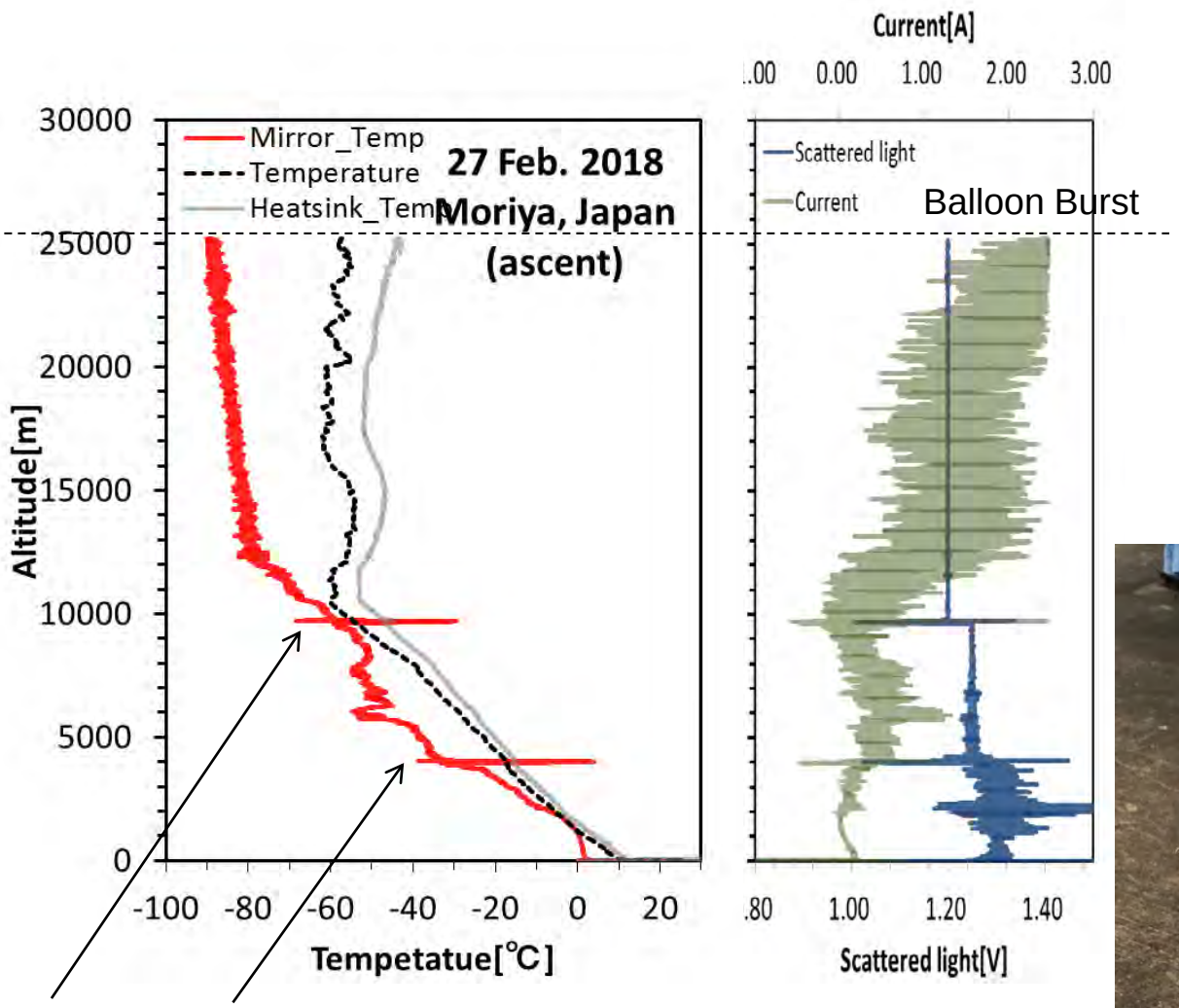
Test flights

	Date	Place	Results	Comments
1	2011.01.28 daytime)	Moriya , Japan	0 - 10km	Due to bug of F/W
2	2011.11.04 14:01(LT)	Sapporo, Japan	0 - 20km	Cooling limit Slow response
3	2011.12.01 17:41(LT)	Moriya , Japan		Contamination error
4	2012.01.09 17:27(LT)	Biak, Indonesia	0 – 15 km	Comparison with **CFH** Unwinder trouble
5	2012.01.10 18:42(LT)	Biak, Indonesia	0 - 25km	Comparison with **CFH, FLASH-B** Slow response
6	2012.01.13 15:49(LT)	Biak, Indonesia	0 - 25km	Oscillation in LS
7	2013.01.10 18:00:(LT)	Biak, Indonesia	2 - 15km	Good agreement with **CFH**
8	2013.04.25 16:40(LT)	Moriya , Japan	0 - 7km	Hardware trouble
9	2013.10.27 9:10(LT)	Moriya , Japan	0 – 9 km	too dry condition
10	2018.01.29 17:30(LT)	Moriya , Japan	0 - 18km	
11	2018.02.27 17:30(LT)	Moriya , Japan	0 - 25km	
12	2018.04.20 14:45(LT)	Tateno , Japan	0–21.5km	

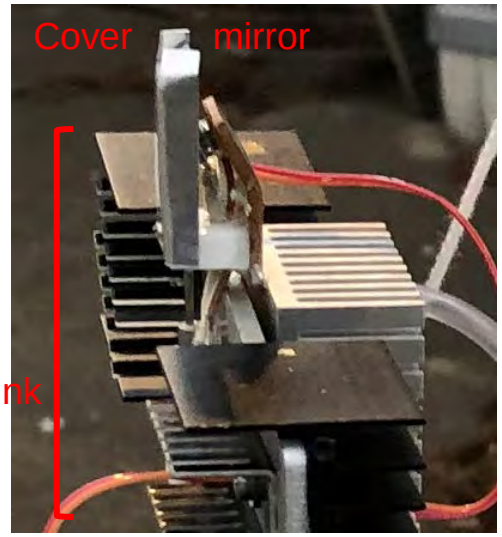
Prototype model

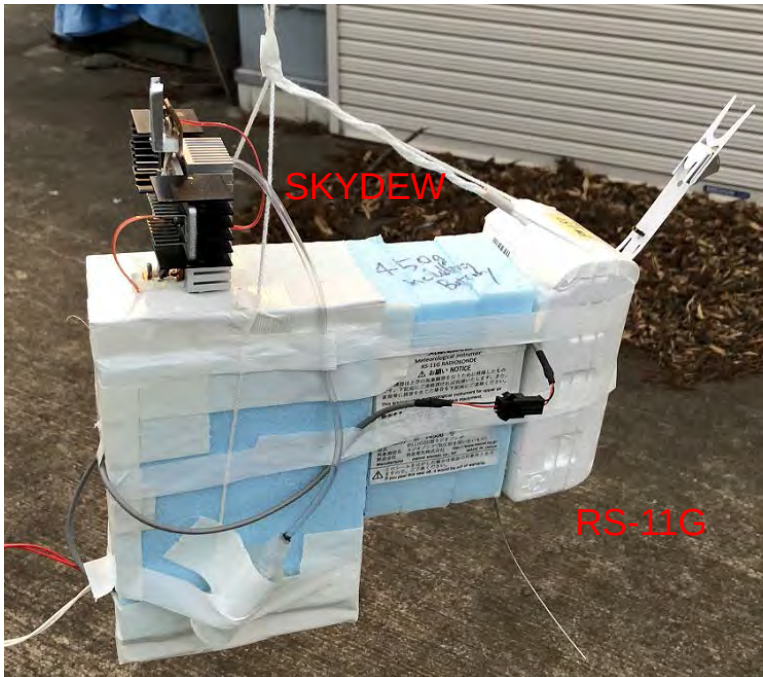
product model

11th test flight
(2018.02.27 nighttime, Moriya 36N 140E)



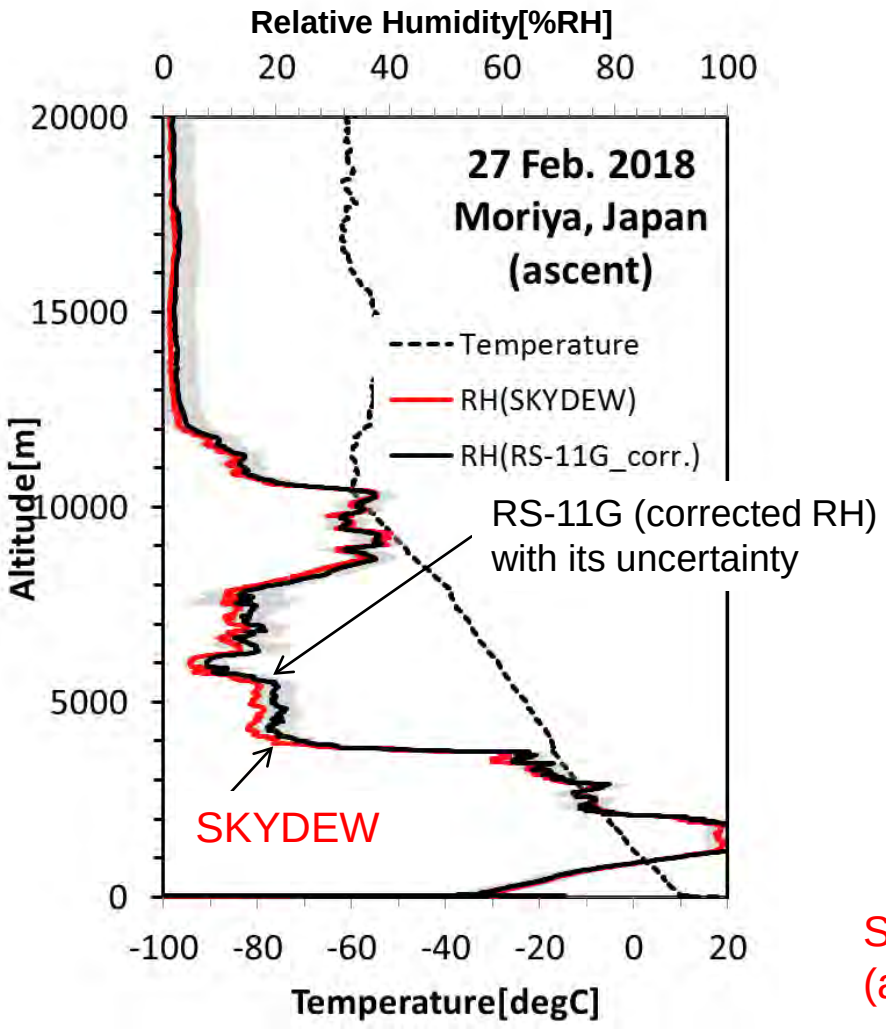
Mirror-heating for refresh of ice on mirror.





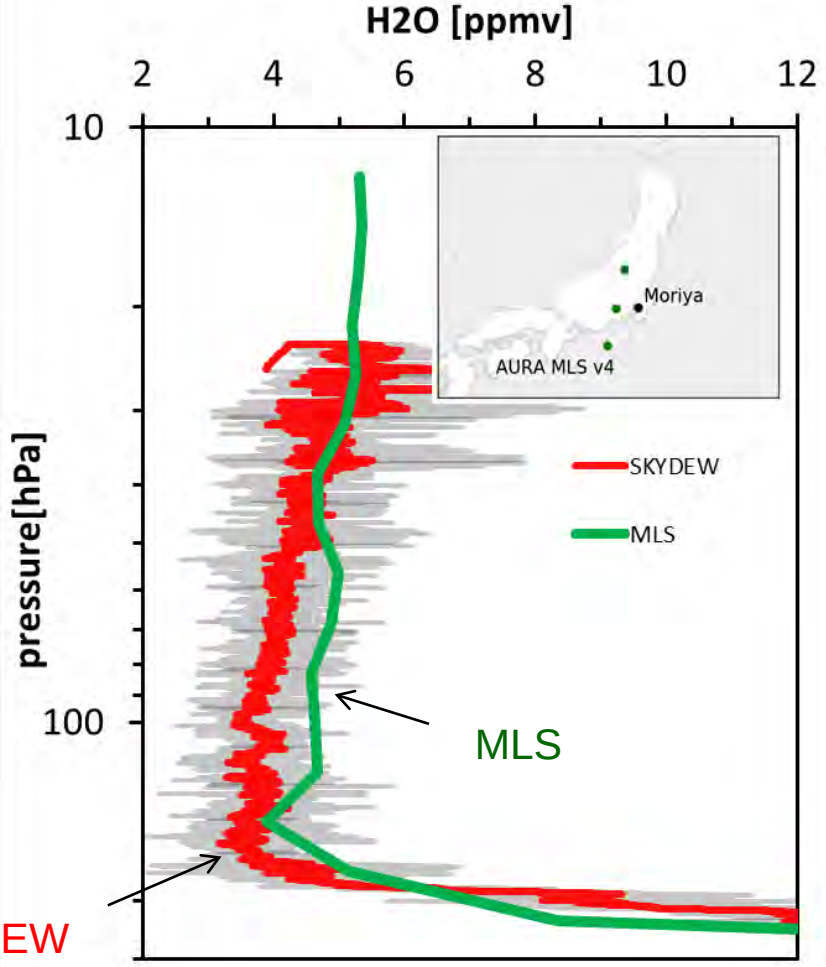
Test flight 2018.02.27

Tropospheric RH
(comparison with operational radiosonde)



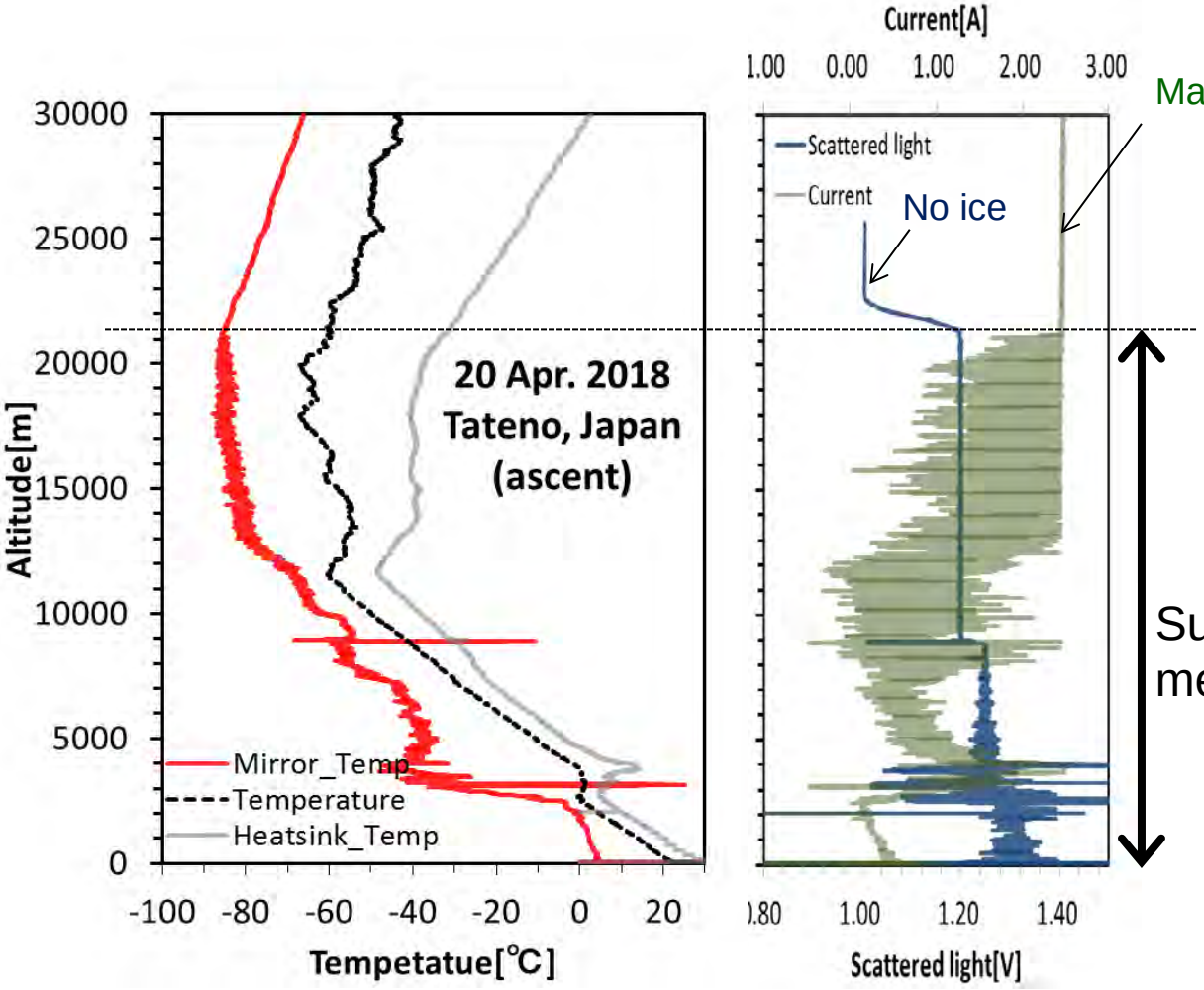
Good agreement within 3%RH
(slightly difference, SKYDEW<RS-11G@~5km)

Stratospheric WVMR
(comparison with AURA MLS)



~1 ppmv difference @ 50 ~100hPa
Bias of MLS ?

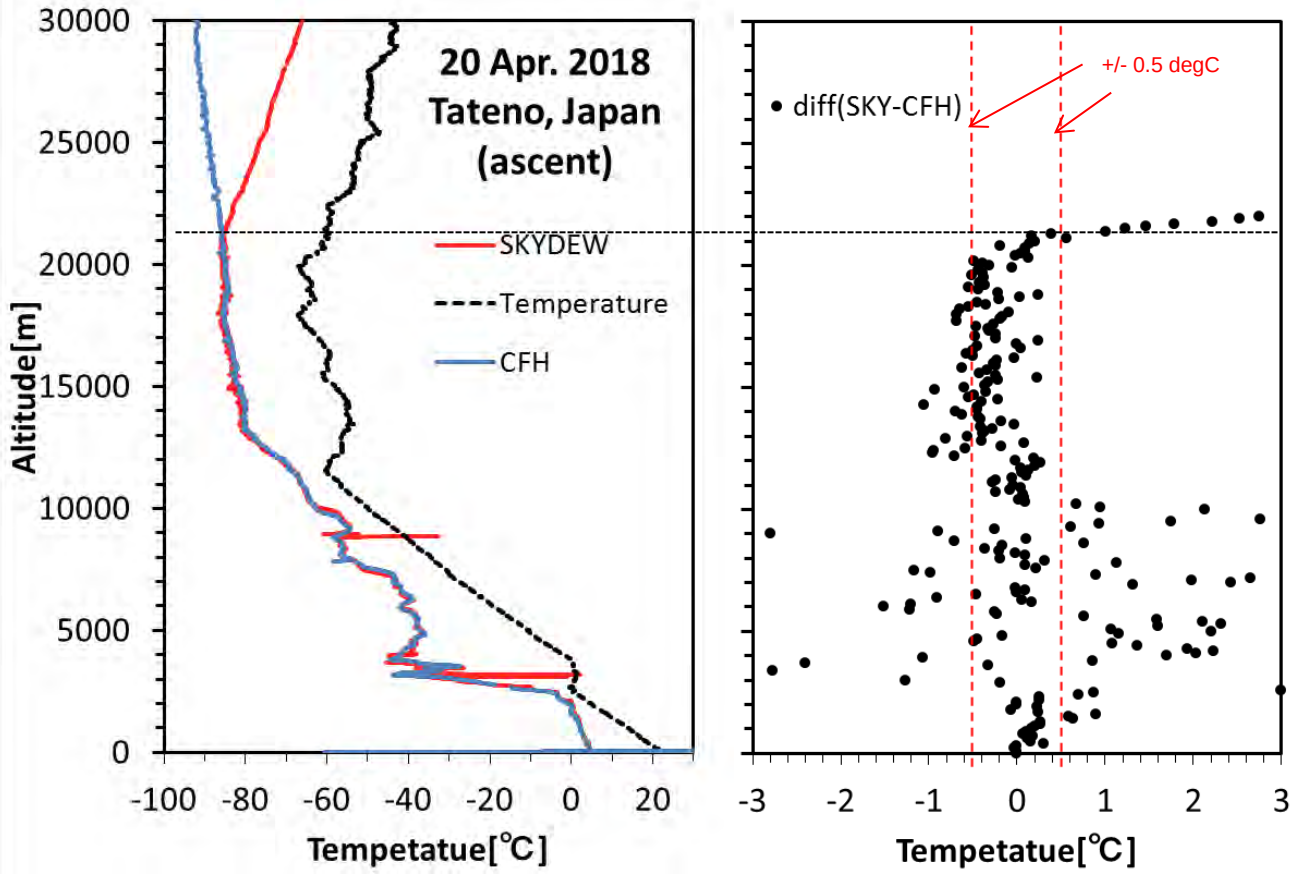
12th test flight , simultaneous sounding with the CFH (JMA) (2018.04.20 daytime, Tateno 36N 140E,)



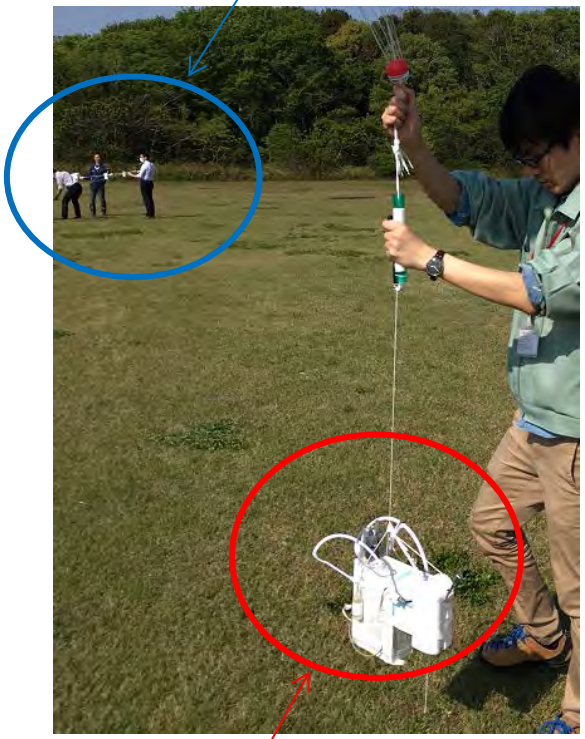
Cooling limit at 21.5km
---> The heat sink become too hot at daytime observation.

Successful measurements

12th test flight , simultaneous sounding with the CFH (JMA) (2018.04.20 daytime, Tateno 36N 140E,)



CFH vs RS92, iMS-100, RS-11G by Japan Meteorological Agency

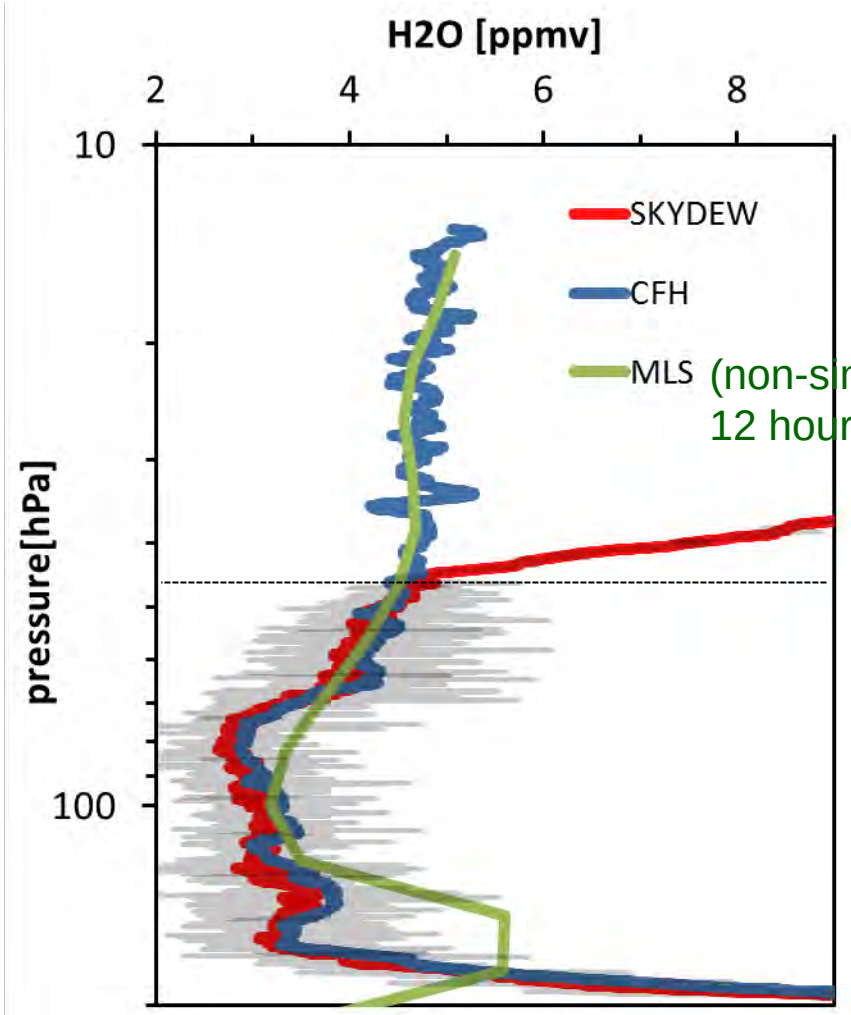


SKYDEW with RS-11 (by Meisei)

Above tropopause level,
approximately agreement (but, difference of ~0.3 degC, SKYDEW<CFH)

12th test flight

Stratospheric WVMR
(comparison with CFH, AURA MLS)



(non-simultaneous 12 hours ago)

SKYDEW(averaged +/- 15 second data)

CFH(averaged +/- 15 second data)

Summary

1. A Peltier-based chilled-mirror hygrometer
   battery-operated instrument, without cryogen
2. Performance: SKYDEW measured tropospheric and stratospheric WV
   from the surface up to 25 km.
3. Cost: target price is comparable as CFH

Schedule

by autumn of 2018: improved prototype model

*comparison with other hygrometers (CFH, AURA MLS …)
*test flight in tropics and other sites
*evaluation of XDATA output version
*improving the heatsink cooling

We are waiting for the pilot users.

by the end of 2018: product model will be released

2019 or 2020(?) : radiosonde intercomparison campaign

Thank you for your kind attention.

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