GRUAN ICM-14, La Reunion, Nov. 28, 2022

Status of the Meisei SKYDEW instrument

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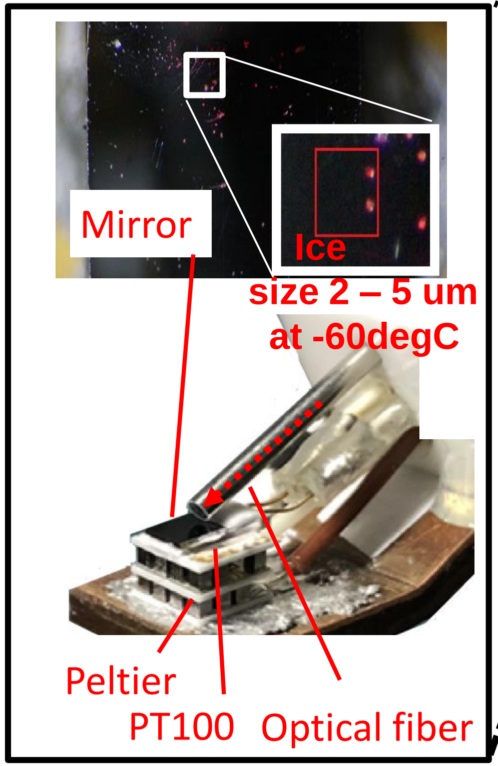
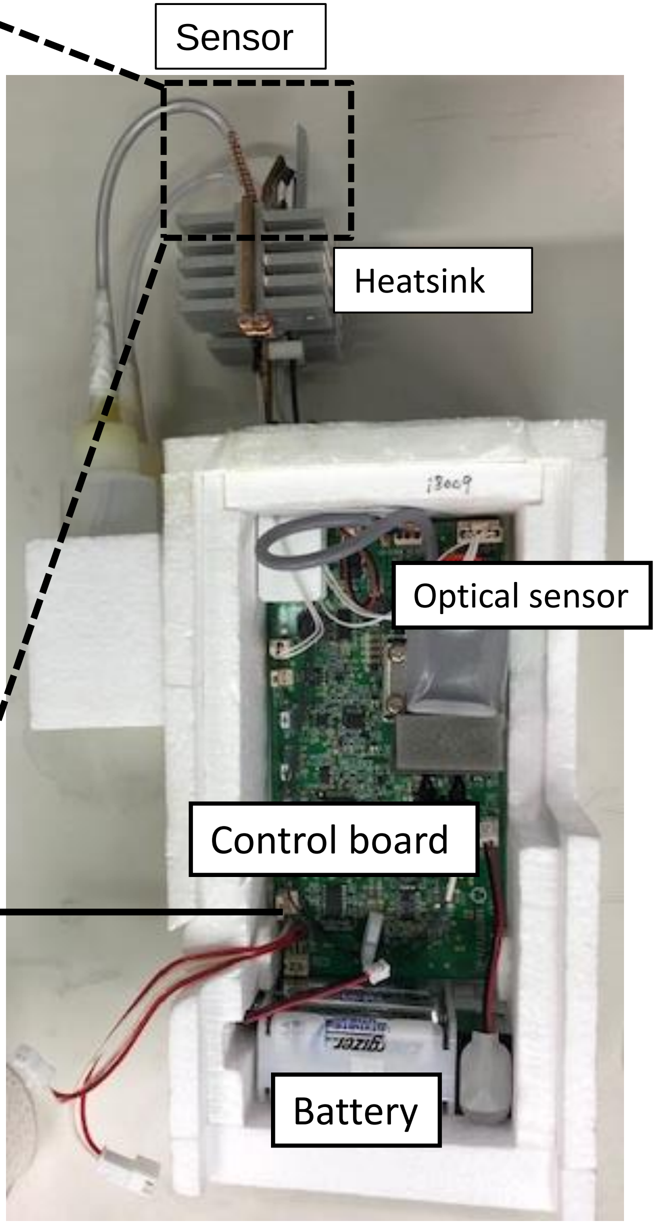
MEISEI

IHI GROUP
Realize your dreams

Peltier-based chilled-mirror hygrometer "SKYDEW"





Output data to
Meisei Radiosonde
or
Other radiosonde
<u>**(XDATA)**</u>

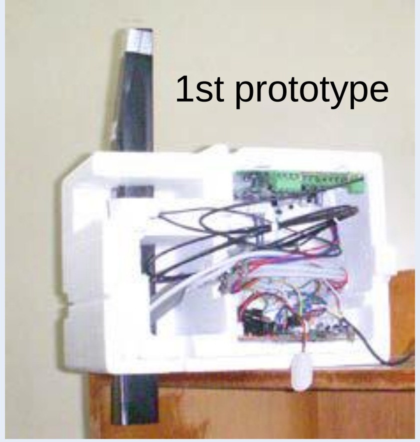
SKYDEW has been developed since 2009 by Meisei and Hokkaido university.

Features of SKYDEW hygrometer

1. Two-stage Peltier device
   No need to use cryogen material
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



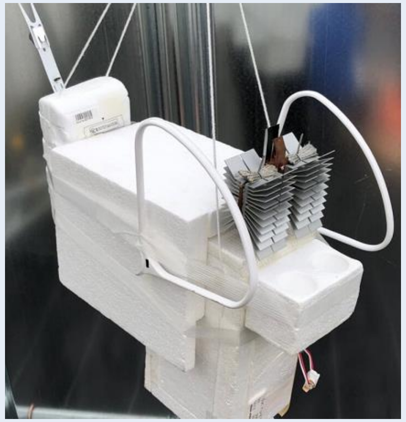
--> These results are described in Sugidachi, 2014, Ph. D paper at Hokkaido Univ. (https://eprints.lib.hokudai.ac.jp/dspace/bitstream/2115/55416/1/Takuji_Sugidachi.pdf)

ICM-9

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

The comparison results at Japan, Indonesia, and Lindenberg was reported at ICM-10, ICM-11.

2019 – 2021 Phase 3:
Test of 2nd product model
Product release for domestic users (in Japan)



The sounding with the product model started. Refer to the ICM-12, 13 presentation

2021 – Current Phase 4:
CE Certificate for EU users
Development of the SKYDEW GDP

Development of the frostpoint hygrometer GDP with SKYDEW

- Three types of the frostpoint hygrometer are currently used at the GRUAN sites.
  1. CFH
  2. FPH
  3. SKYDEW   Tateno, Showa, (Lindenberg)

- These are all chilled-mirror hygrometer using the same principle.
  But there are many differences. For example,
  thermometers (thermistor or PT100), cooling methods (Cryogen or Peltier),
  PID controller settings, mirror materials, etc. . .

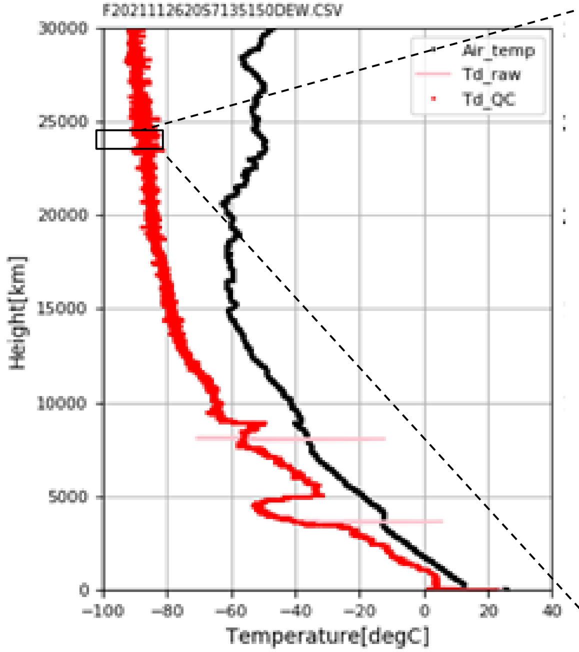
- The characteristics of the data seems to be slightly different.
  I don't know yet that one GDP for all model of FP is suitable.
  The data processing and uncertainty estimation for the SKYDEW was created
  toward the frost point GDP.

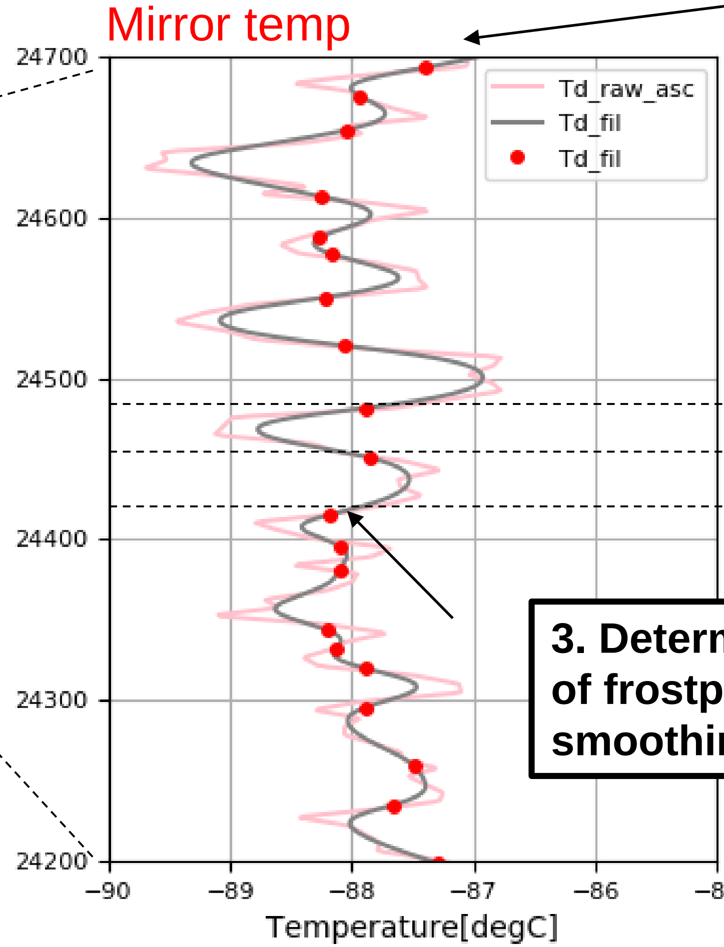
Data processing for SKYDEW toward GDP

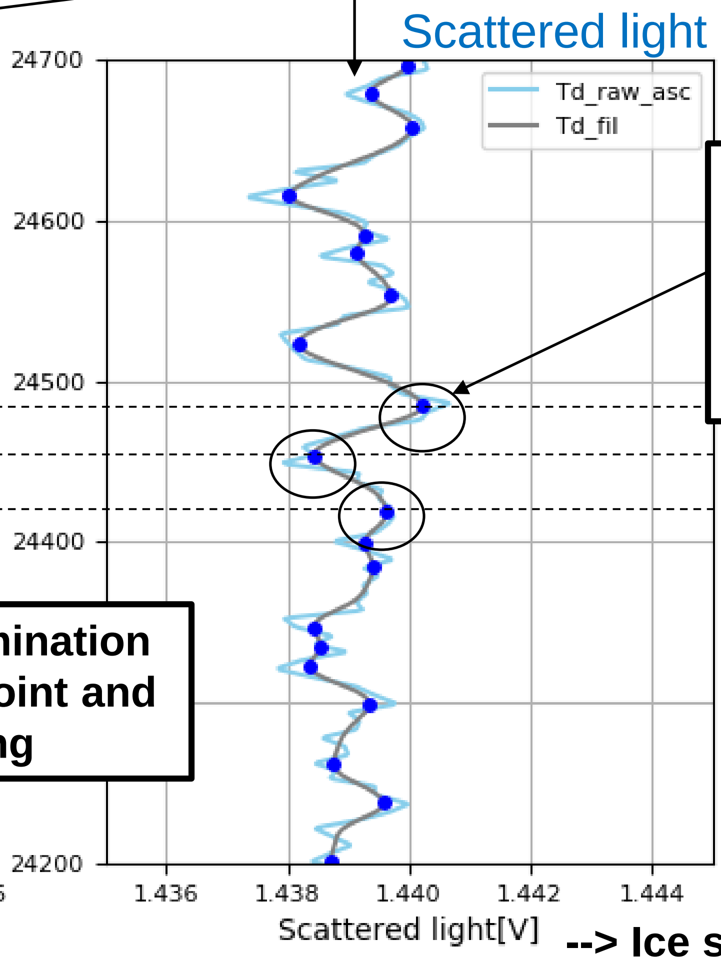
Poltera (2021) at ICM-13 proposed the golden point method, which is smoothing method based on the measurement principle of a chilled-mirror hygrometer. The golden point method is applied to the SKYDEW profile.

1. Smoothing for removing electric noise

SKYDEW at Tateno, 26 Nov 2021, nighttime

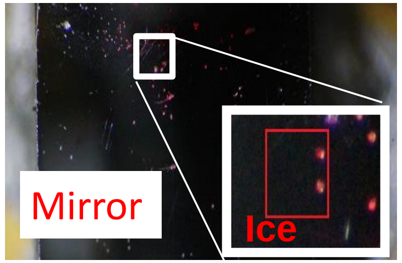






2. Detection of the equilibrium points (Growth/evaporation rate is zero at Inflection points.)

3. Determination of frostpoint and smoothing



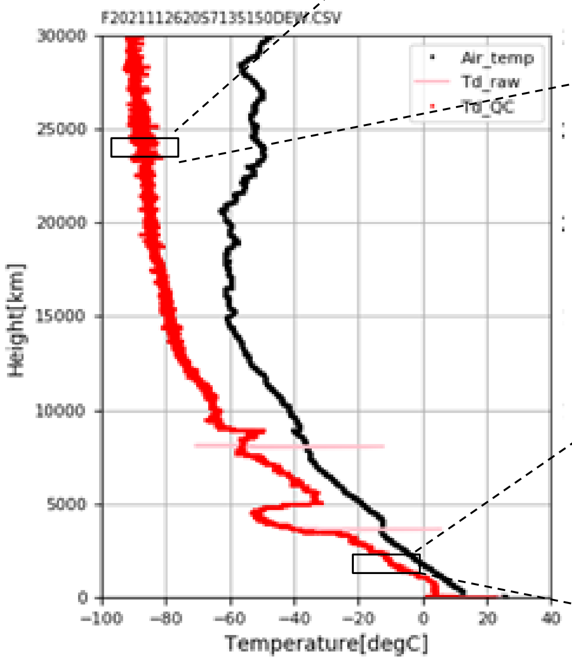
--> Ice size on the mirror

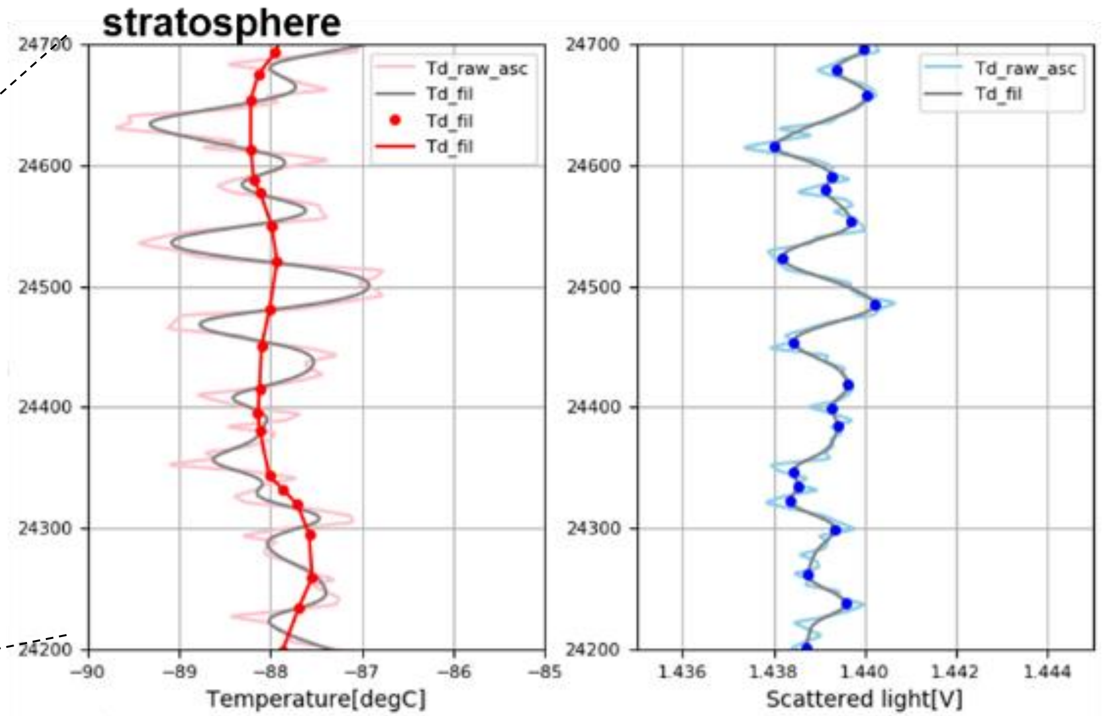
small **large**

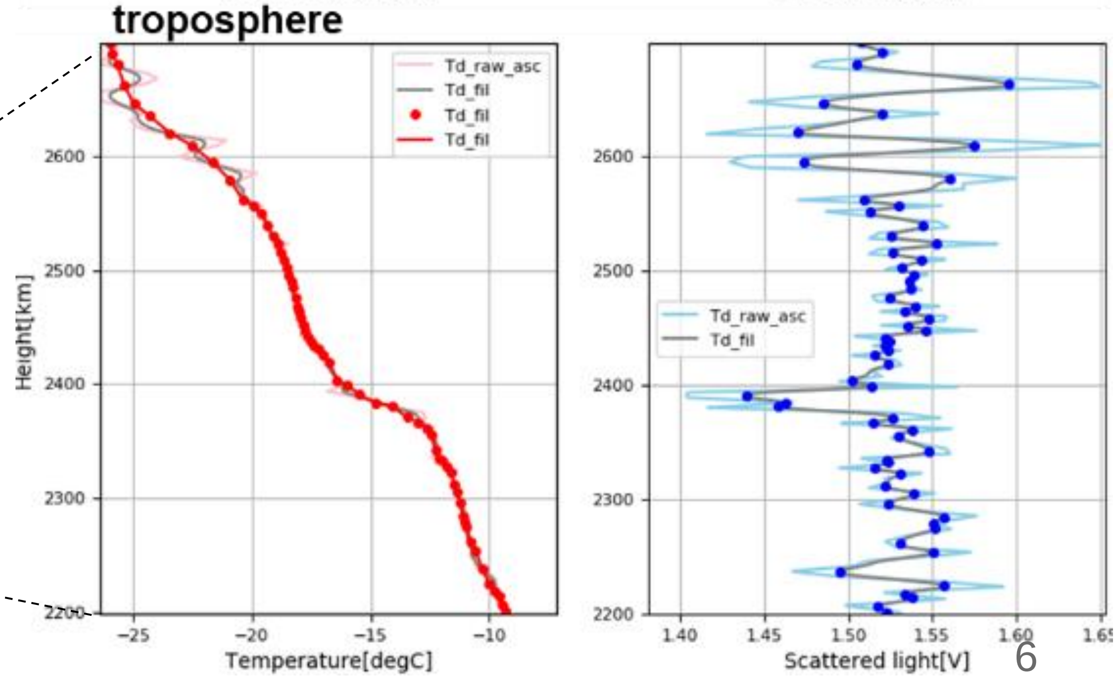
Data processing for SKYDEW toward GDP

The golden points cause low vertical resolution comparing with raw data. This resolution depends on the oscillation period.
Oscillation periods is related to the particle size on the mirror, the PID controller, water vapor concentration.

Resolution: 10-20m@troposphere, 20-40m@strasophere

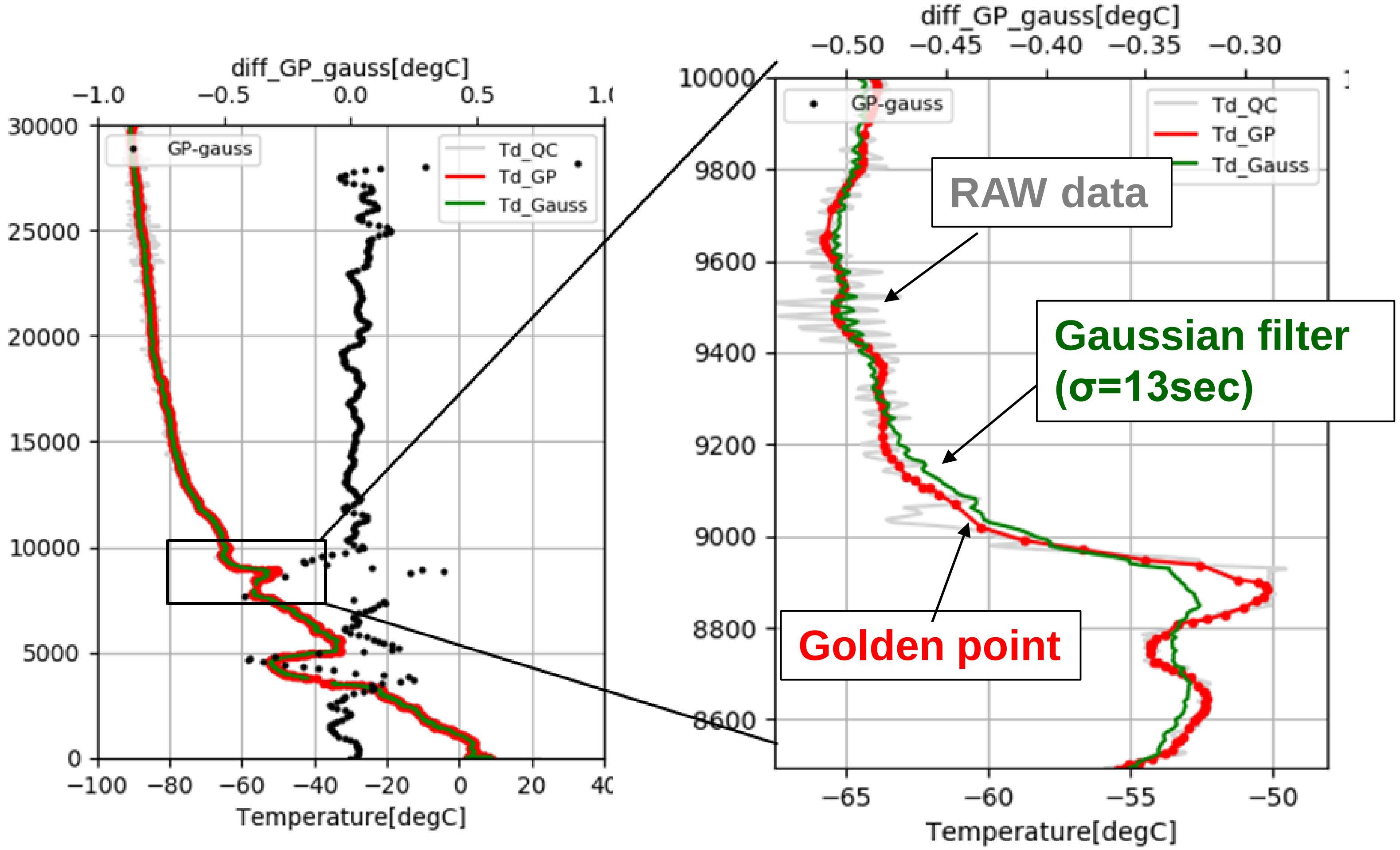






the golden point methods v.s. gaussian filter.

Frost point profiles smoothed by the golden point methods and gaussian filter were compared.



When using a Gaussian filter, if we do not choose an appropriate window size, the smoothed profile will still have oscillations or will be over-smoothed.

In particular, the SKYDEW have aggressive PID tuning and stronger oscillation on mirror temperature.

Uncertainty budget for SKYDEW toward GDP

In a measurement with a chilled-mirror hygrometer, there are several sources of uncertainty. The uncertainty parameter is similar with all model of FP. (Vömel et al. 2016 and Hall et al. 2016)

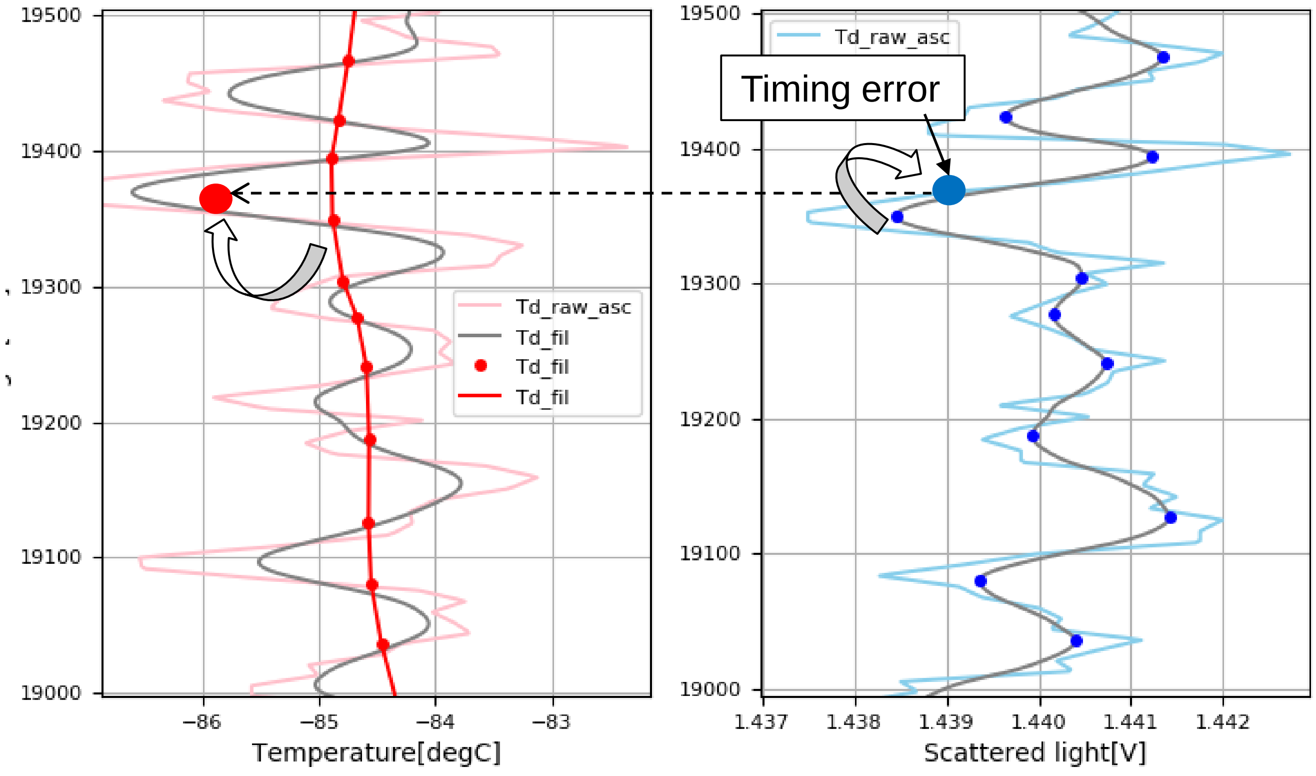
How to estimate the uncertainty derived from the golden point was considered

Uncertainty parameter	Value (k=1)	(Un)/correlated
Mirror_temp measurement, u_mirror	**0.052=(u_mrr1^2+u_mrr2^2+u_mrr3^2)$^{0.5}$**	**correlated**
PT temperature calibration, u_mrr1	$\mathbf{0.07/\sqrt{3}}$	**correlated**
Resistance measurement u_mrr2	$\mathbf{0.005\sqrt{3}}$	**correlated**
Thermal gradient of mirror, u_mrr3	$\mathbf{0.015/\sqrt{3}}$	**correlated**
GP detection error, u_GP_error	**~0.6 at max**	**uncorrelated**
Filtering deviation, u_filter	**~1.0K at max**	**uncorrelated**
Contamination by cloud	**Depend on the situation strongly.**	**correlated**
Aerosol effect and curvature effect	**negligible**	**correlated**
Total uncertainty, u_SKYDEW	**=(u_mirror^2+u_GP_error^2+u_filter^2)$^{0.5}$**	

Uncertainty budget for SKYDEW toward GDP

Error of golden point selection (timing error)

Accuracy of golden point selection is critical for accurate frostpoint estimation. The timing error of golden points depends on the oscillation period, amplitude and electrical noise. Here, the uncertainty is calculated on assumption that the timing error of golden point selection is 1 second at max.



The sampling rate is 1Hz for SKYDEW.
Oscillation period is ~5sec@LT, ~10sec@UT

The smaller amplitude of PID oscillation brings better estimation of frostpoint. The shorter oscillation period brings higher vertical(time) resolution. This uncertainty is considered to be originally derived from an electrical noise on the control circuit board.

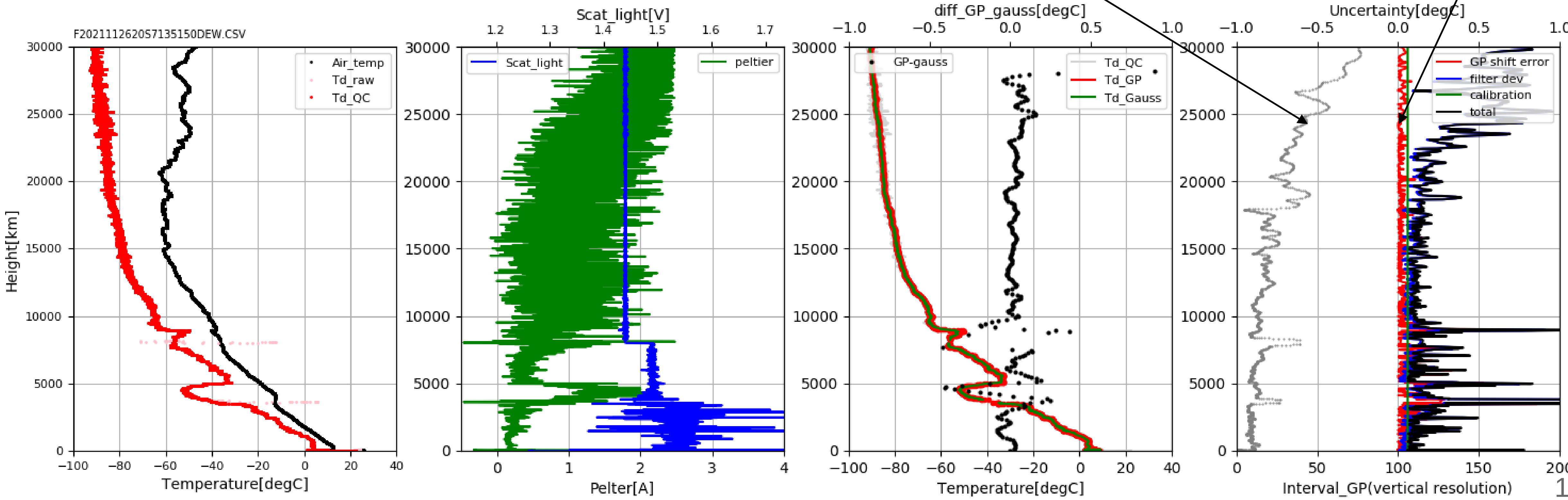
Uncertainty budget for SKYDEW toward GDP

The profile of the frost point and uncertainty on 26 November 2021 in Japan. Right panel shows the uncertainty(k=1) for this sounding. When the oscillation is enough small, the uncertainty is less than 0.2K. However, the uncertainty is larger for the stronger oscillation above 23km and sharp gradients of frost point for this sounding.
The vertical resolution is larger at higher altitude.

Uncertainty estimation
1. GP estimation
2. Filtering deviation
3. Calibration error

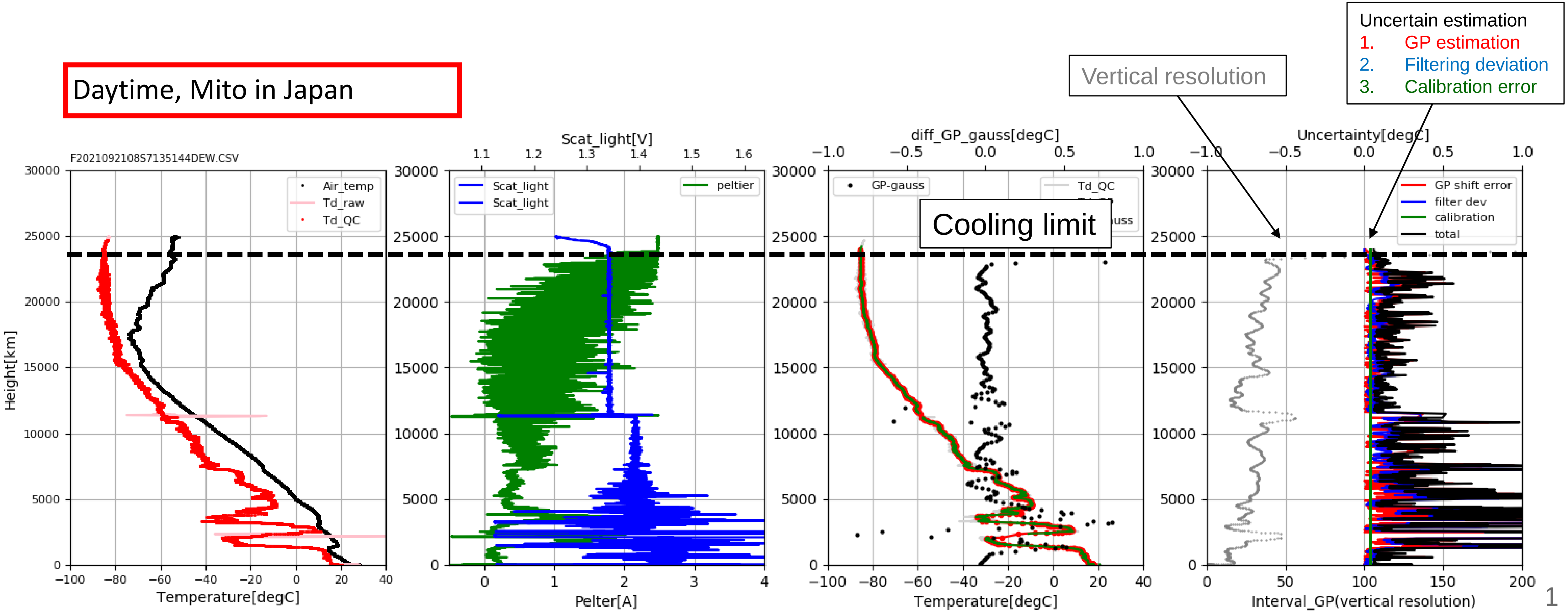
Nighttime, Tateno in Japan

Vertical resolution



Uncertainty budget for SKYDEW toward GDP

The profile of the frost point and uncertainty on 21 September 2021 in Japan. Right panel shows the uncertainty(k=1) for this sounding. In the troposphere, the large oscillation causes the large uncertainty.



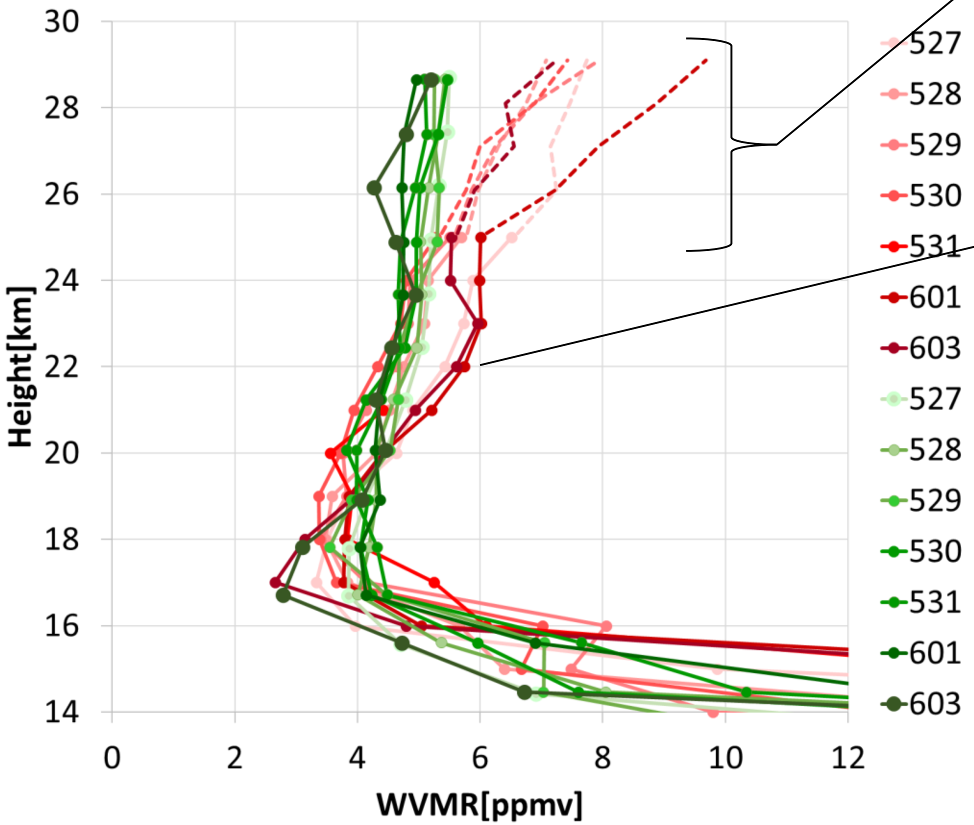
Uncertainty budget (Contamination error)

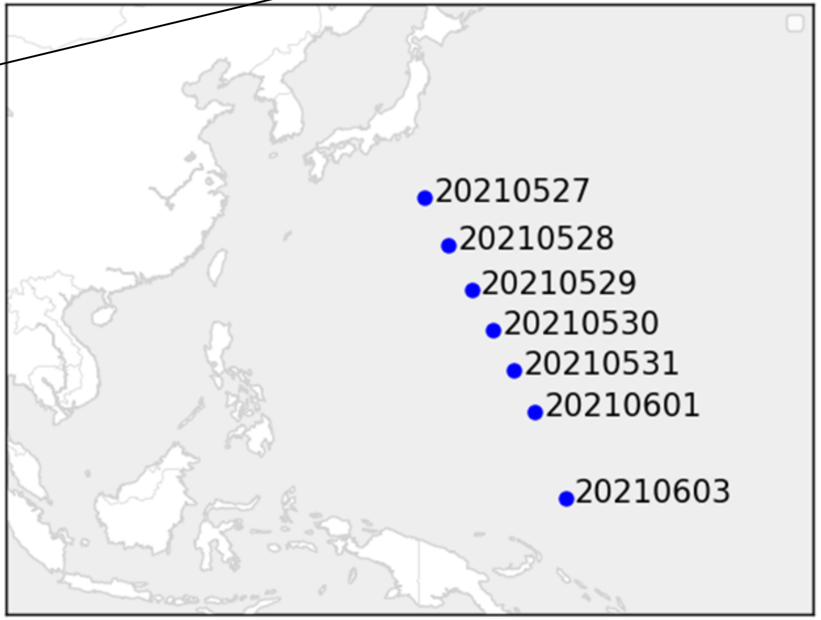
Water vapor mixing ratio calculated from SKYDEW and RS-11G pressure measurement was compared with water vapor mixing ratio from Aura MLS for the validation of stratospheric water vapor measurement.

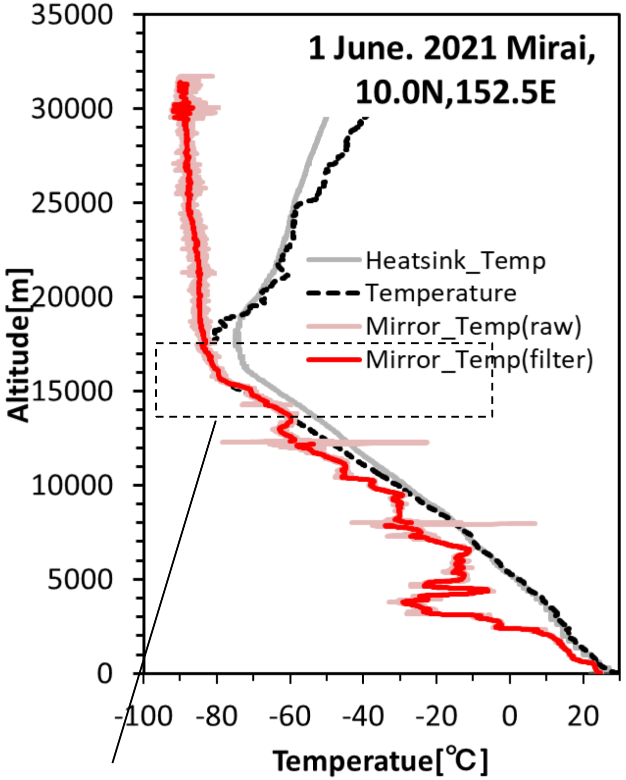
7 profiles of SKYDEW and Aura MLS.

contamination from outgassing of balloons and flight trail above 25km

For 3 profiles, positive bias above 20km.





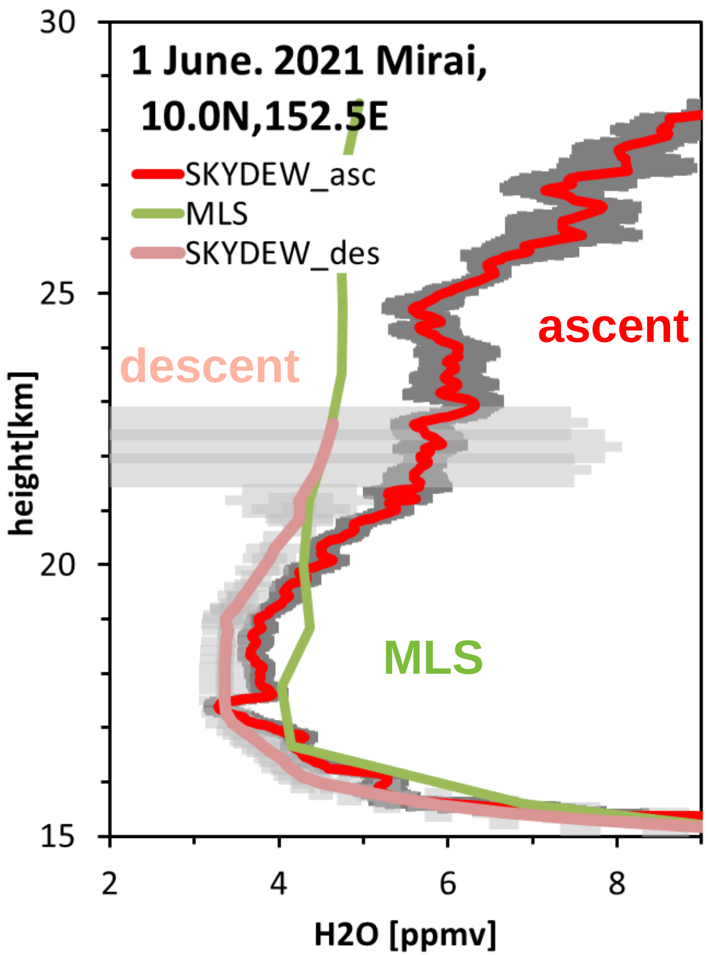


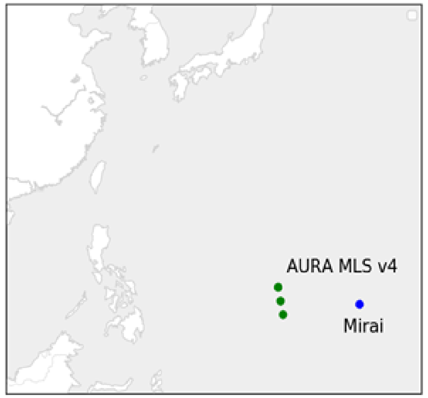
All sounding was conducted after sunset with the product model of SKYDEW. The cooling limit is enough up to 30km.

the SKYDEWs passed through the saturated air at upper troposphere.

Uncertainty budget for SKYDEW toward GDP

The descend data is useful for judging the contamination during ascent.
For the sounding on 1 June 2021, the SKYDEW could measure frost point below 23km during descent. The descent measurement indicates lower water vapor mixing ratio than ascent measurement around 21~23km. SKYDEW is deigned for the ascent measurement. Availability of descent data depends on the sounding situation.



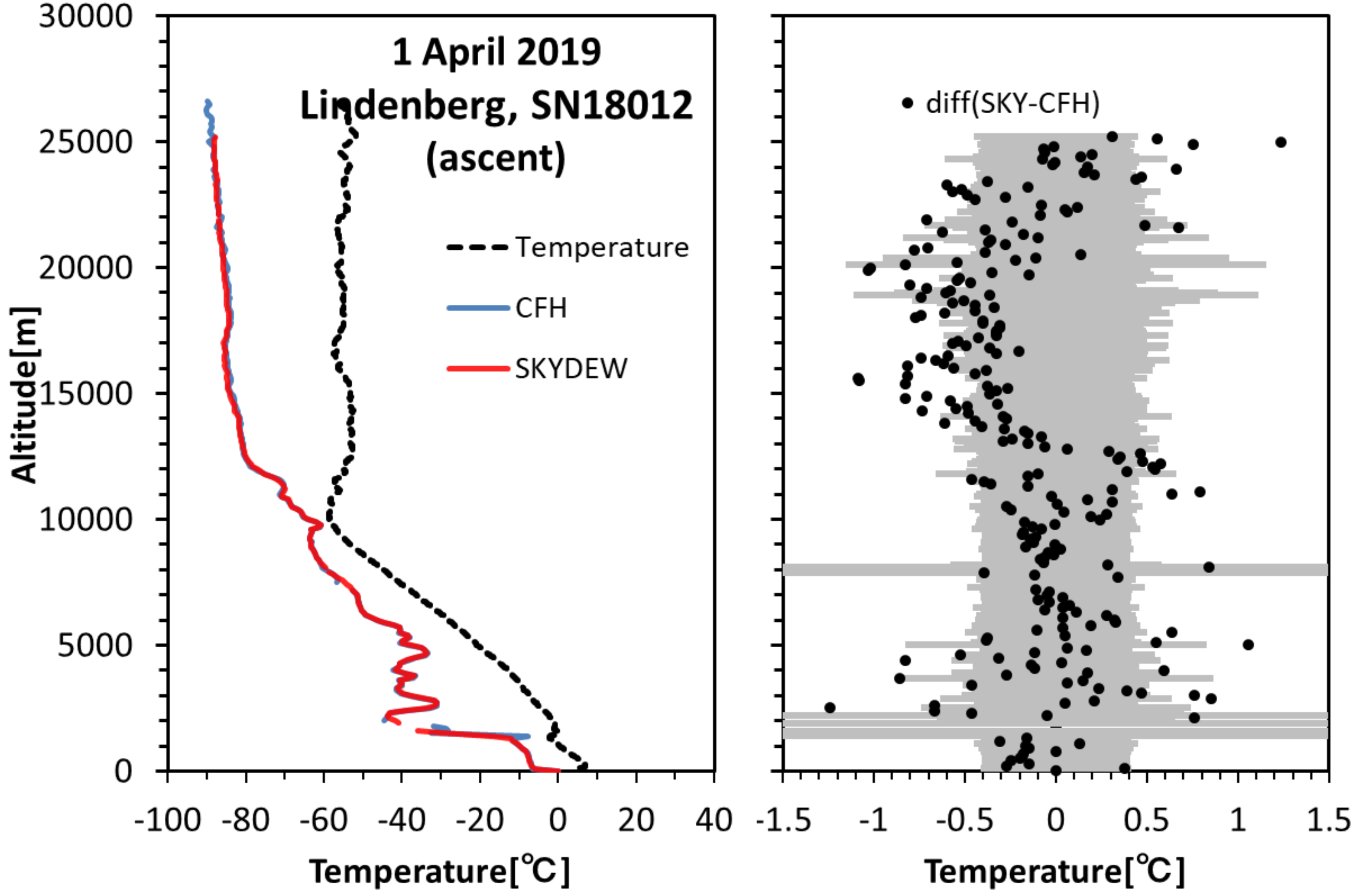


Water vapor mixing ration from SKYDEW and MLS at 1 Jun 2021. Red line is the ascent profile and pink line is descent profile. Gray shadow indicates the uncertainty(k=2).

Note that the descend data is not always available because SKYDEW is sometime out of PID control due to cooling limit at stratosphere.

Verification

The profiles from the SKYDEW (**older model**) and the CFH using a single balloon on 1 April 2019.
The values are averaged at each 100m for both instruments. The dew/frost point temperature from SKYDEW is consistent well with that from CFH below ~13 km. However, there is difference reaching up to ~0.5K at stratosphere, which values is sometimes over than the combined uncertainty (k=2). Here, we assume the CFH uncertainty is 0.2K through whole profiles



Unknow bias
(within uncertainty=2)

--> Further evaluation is needed.

This sounding is conducted at nighttime, with the old model of SKYDEW.

Summary

1. The data processing with the golden point methods toward SKYDEW GDP was created.

2. The measurement uncertainty for SKYDEW is less than 0.2K during the stable measurement, but sometimes over 0.5K

We prepare the AMT paper about this data processing and verification.

Future task

3. **The RH and WVMR uncertainty** combined with the uncertainty of temperature and pressure.

4. Comparison with other hygrometers such as CFH to verify the measurement performance (especially at stratosphere).

5. Where is the data processing center for SKYDEW ?

My concerns

6. The stable production of SKYDEW is currently not easy because of the semiconductor shortage. We will take measures (e.g., redesign of the electric circuit) according to future purchase requests.

We thank Dr. J. Suzuki at JAMSTEC (Japan Agency for Marine-Earth Science and Technology for providing the SKYDEW data on Pacific, Dr. Tomikawa at NIPR(National Institute of Polar Research) for providing the SKYDEW data.

Thank you for your attention!