Development of a balloon-borne Peltier-based chilled-mirror hygrometer for the troposphere and the lower stratosphere

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1: Background

◆Atmospheric water vapor is important for climate dynamics. However, water vapor in the upper troposphere(UT) and lower stratosphere (LS) cannot be measured with normal sensors of operational radiosondes, thin-film capacitive RH sensors.

◆The measurement in the UT/LS needs to use the special sensor, such as a chilled mirror hygrometer. This sensor is generally very expensive, and is difficult to handle because this sensor needs cryogen.

In this study, we are developing a Peltier-based chilled mirror hygrometer without cryogen and ease-in-handling natures.

If the development of this hygrometer is accomplished,

(1) this hygrometer may be widely used with high frequency compared to the conventional chilled mirror hygrometer. This leads to the accurate detection of the water vapor fluctuation in time and space even in the UT/LS. Furthermore, the accumulation of these data over the long term will be helpful for detecting the decadal change of atmospheric water vapor.

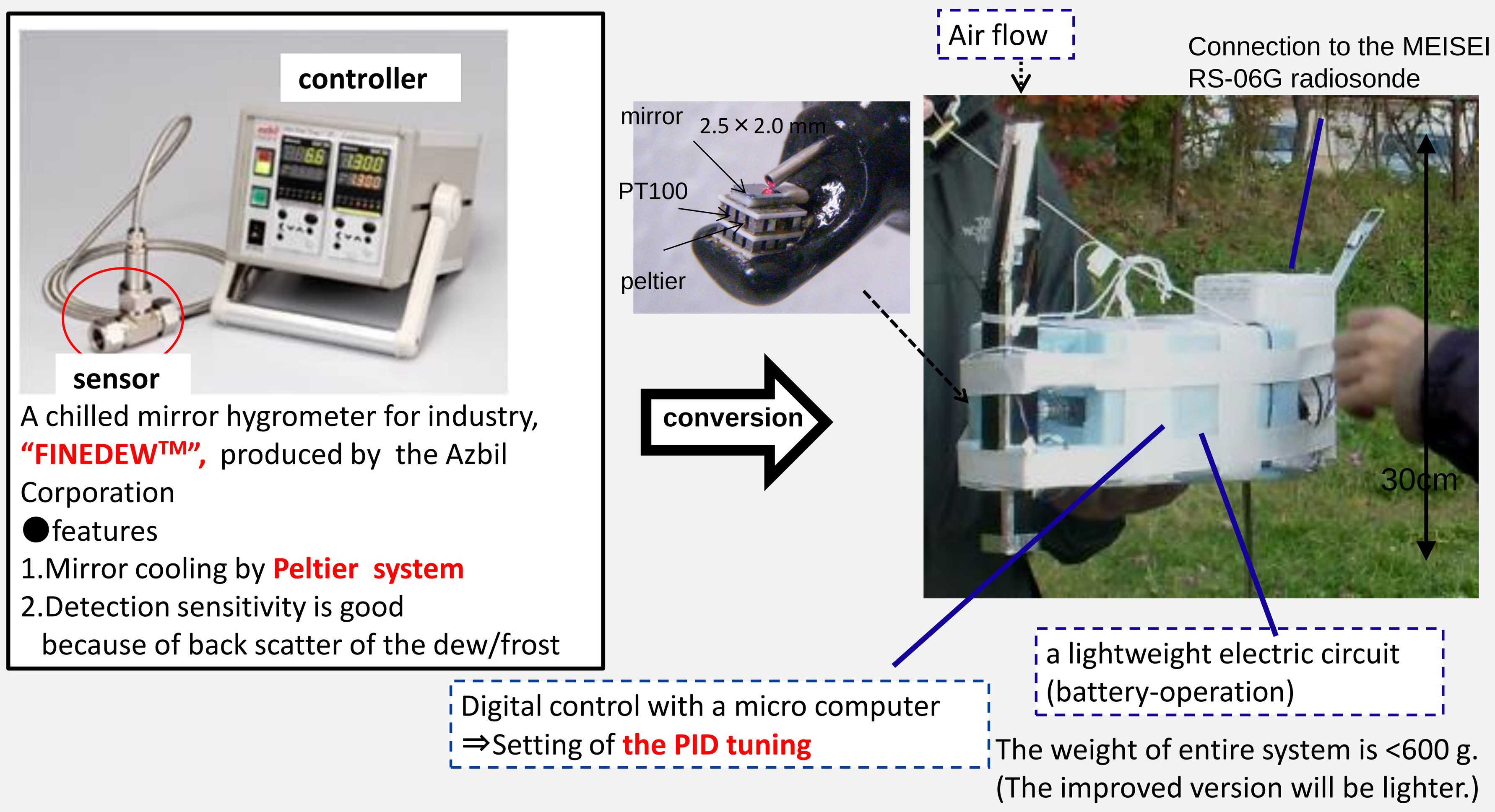
(2) our hygrometer will be able to measure the supersaturation in cloud without contamination error. For the conventional chilled mirror hygrometer, cloud particles and rain droplets attach the inlet tube and these water and ice may cause the contamination error.

→We will assemble the new hygrometer into the configuration not to contaminate from the attached water. The mirror of the hygrometer will be exposed in ambient air.

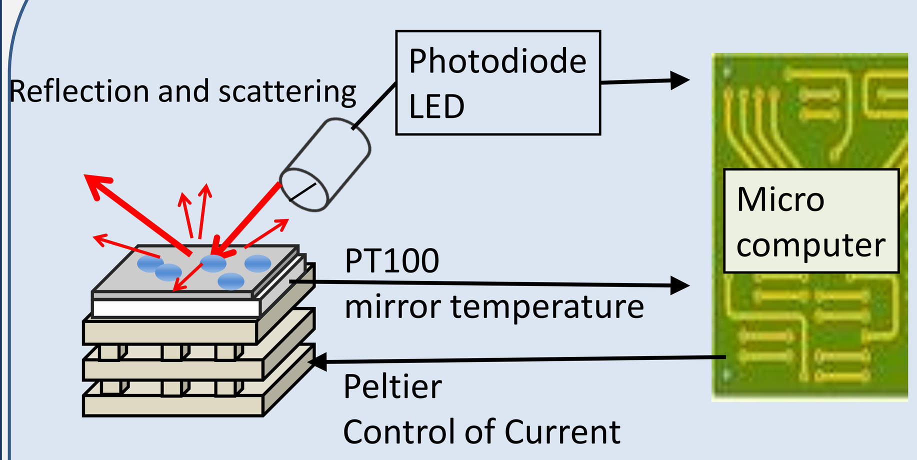
(In this poster, the pictures of our sensor have the inlet tube. We have improved it recently. The improved version is coming soon.

2: Instrument - A chilled mirror hygrometer for radiosonde -

A chilled mirror hygrometer is a high-accuracy sensor, which is known as a standard instrument. In this study, the chilled mirror hygrometer for industry, FINEDEW™, was converted into the chilled mirror hygrometer for radiosonde observations.



Principle of a chilled mirror hygrometer

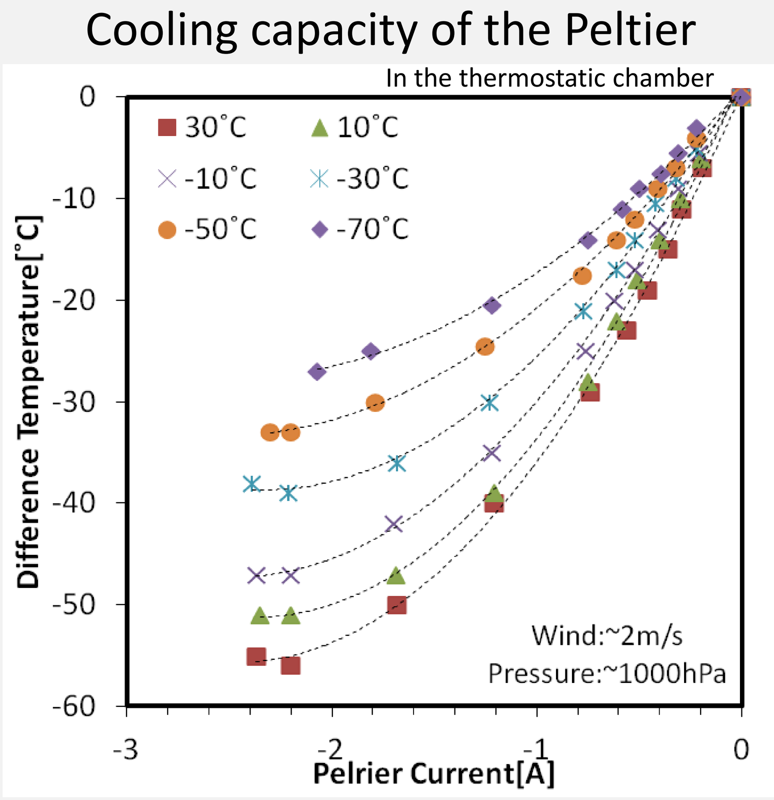


The amount of dew/frost on the mirror is kept constantly. Then, the temperature of the mirror is equal to the dew point. PID controller is used to keep the dew constantly. The Peltier current is defined by a following equation.

$$\text{Peltier current}[\%] = \frac{1}{PB}\left(e + Ti\int e\,dt + Td\frac{de}{dt}\right)$$

PB: Proportional Band, Ti: Integrated Time,
Td: Differential time, e: the deviation from target

Cooling capacity of the Peltier

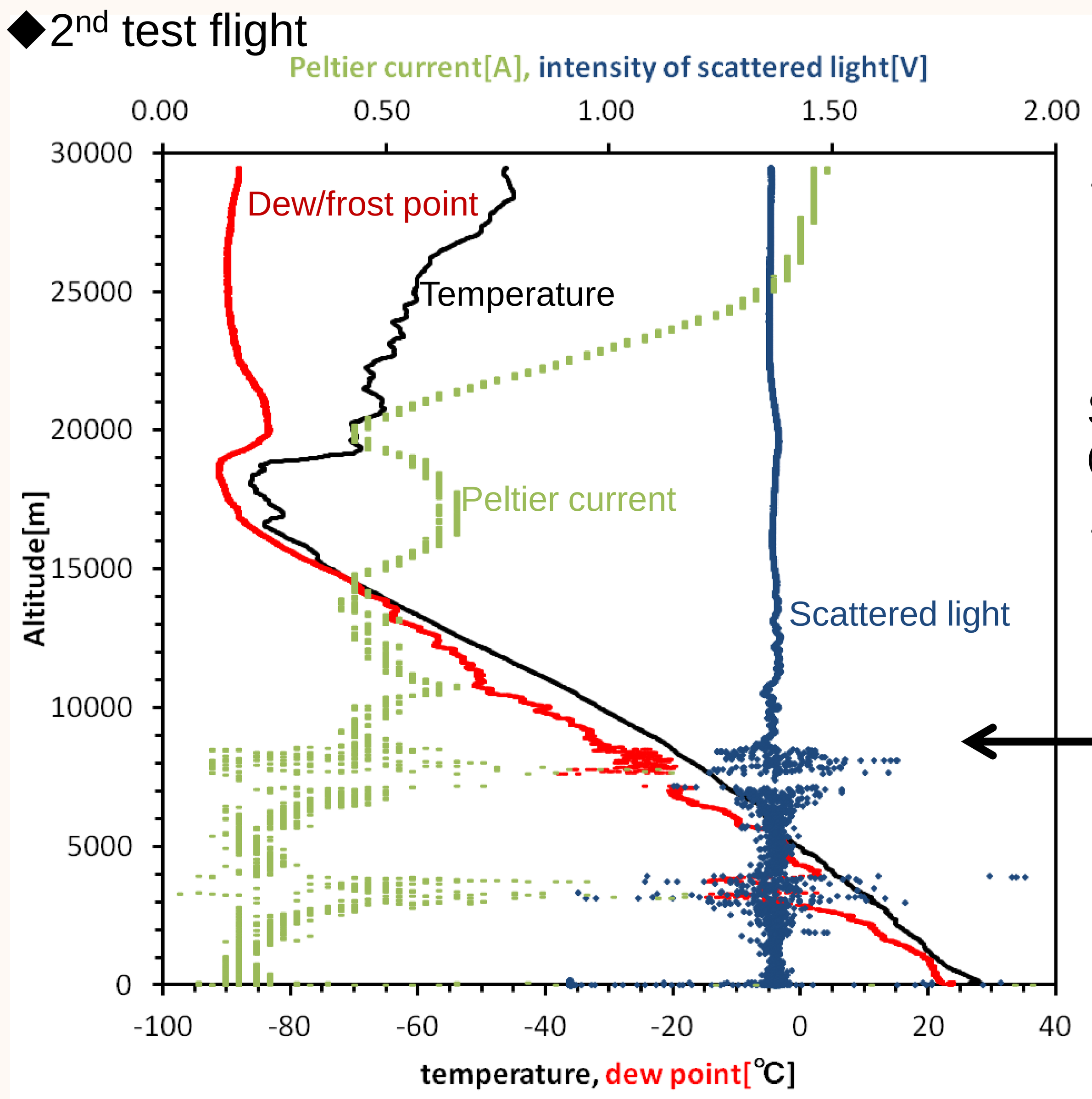


The cooling capacity is enough to measure the lower stratospheric water vapor.

3: Flight Test - Biak, Indonesia -

In January 2012, we have conducted flight tests three times at Biak, Indonesia. (In the 1st test flight, our hygrometer could not measure the water vapor in the upper troposphere due to the communication failure)

◆2nd test flight

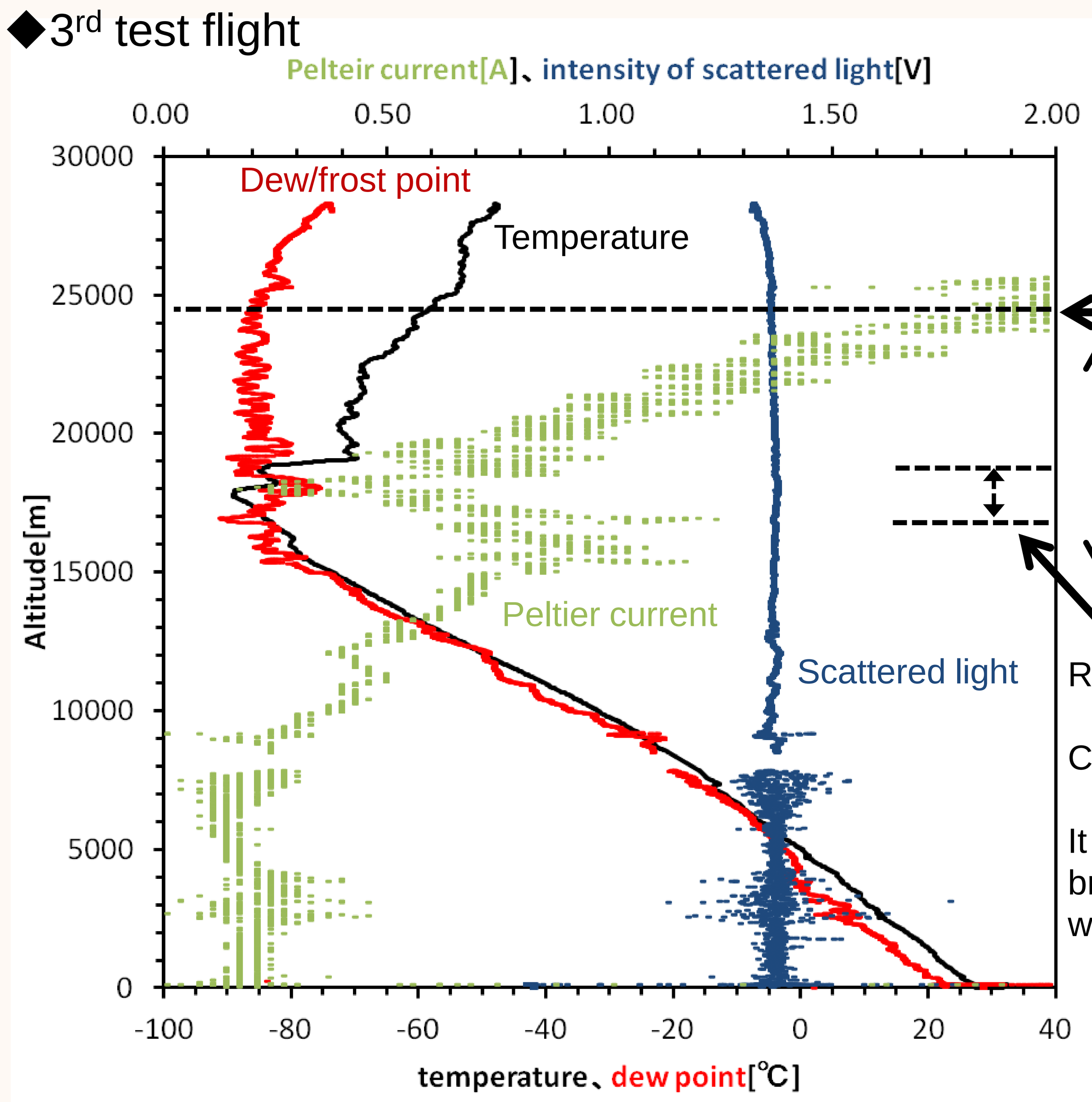


Slow response
(due to the imperfect PID tuning)

Dew on the mirror have changed to frost at this altitude.

⇒ The PID tuning was changed to get a faster response in the upper troposphere and lower stratosphere in the 3rd test flight.

◆3rd test flight



Cooling limit by this sensor

Slight oscillation
(due to the imperfect PID tuning)

RHi > 200% in this region

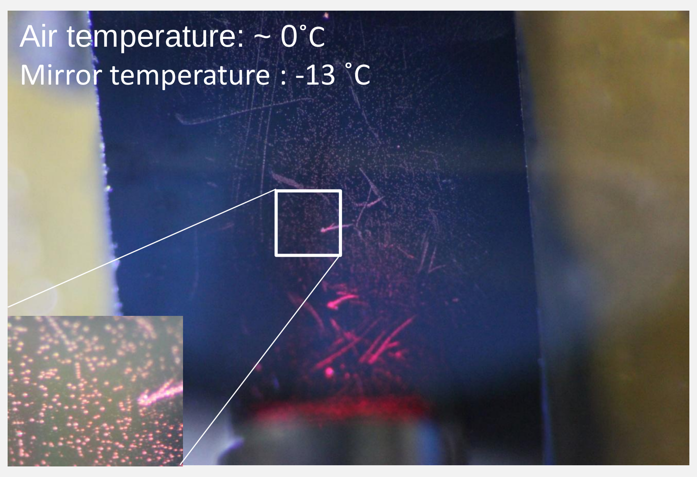
Contaminations or supersaturation?

It is thought that the inlet tube brings the contamination error in wet conditions.

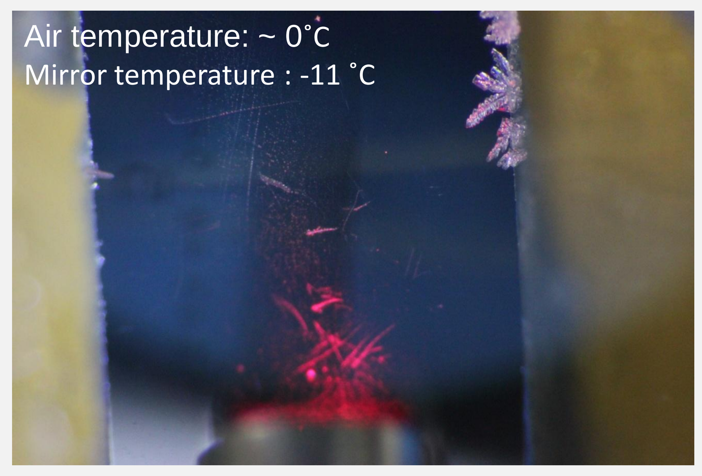
◆This result shows that our hygrometer can measure the stratospheric water vapor without cryogen at ~25 km, if we succeed in the PID tuning.

4. Laboratory experiment

How much is the amount of dew/frost on the mirror suitable for the stable control?
⇒ We are investigating the state of frost/dew on the mirror by watching through a microscope. Also, we will see how shapes of the frost vary by air temperature.



The diameter of dew is about 5 ~10 μm during operation



In this case, the frost at the edge of the mirror grow larger. we think that this ice is unsuitable for the good PID control, Ice should be uniform on the mirror.

5.Outlook

The challenges now are below:

(1) the PID tuning for stable control; →We will continue the flight test and the laboratory experiment. In January 2013, we will conduct the test flights of the improved version in Biak, Indonesia.

(2) the estimation of the measurement uncertainty; and →This need the comparisons with other sensors . In January 2013, the comparison with the CFH and the FLASH-B will be conducted.

(3) reducing the cost. → The cost of the sensor is not clear yet because this hygrometer is under development. We are working on reducing the cost now.

Acknowledgments

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