Water vapor measurement in the tropical troposphere to lower stratosphere using a chilled-mirror hygrometer SnowWhite

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In the lower and middle troposphere, relative humidity sensors on radiosondes such as Vaisala Humicap thin-film capacitors are available. However, their performance is in doubt in cloud layers and above thick clouds, and this may cause very serious problems in some research topics. Above the upper troposphere, these relative humidity sensors do not work mainly due to their slow response at low temperatures. There are some balloon-borne and aircraft-borne sensors developed by researchers, but they have only been used in some special campaigns because of their great cost and complicated operation needed. Some ground-based and satellite-based remote sensing techniques are available for estimating the water vapor distribution in this height region, but the accuracy and precision of their measurements have not been validated well with in situ instruments.

Since 1996 a Swiss company Meteolabor has been developing and selling a hygrometer named SnowWhite, which is a low-cost, chilled-mirror, dew/frost-point sensor for radiosondes. SnowWhite measures a dew/frost-point temperature profile with a small mirror cooled by a Peltier device powered by a battery. The dew/frost on the mirror is monitored with a lamp, optical fiber, and phototransistor, and the feedback circuit automatically controls the strength of the Peltier cooler. The SnowWhite's mirror is made of two thin metals and is a component of a thermocouple, so that the mirror is at the same time a thermometer. Also, a heater is equipped at the sensor housing, so that SnowWhite measures total water content in clouds. Some research groups have already started to use SnowWhite because it has a potential to become a standard/reference instrument for all relative humidity sensors for radiosondes and/or because it may also work above the upper troposphere and even in the lower stratosphere where there is no commercial, reliable water vapor instrument at this moment.

The Soundings of Ozone and Water in the Equatorial Region Pacific Mission (SOWER/Pacific) has been running on a campaign basis since 1998. As a part of this mission, we have made a total of 54 soundings of SnowWhite at the Galapagos, Christmas Island (Kiribati), and Indonesia in different seasons since March 2000. Our system consists of SnowWhite, ECC ozonesonde, Vaisala RS80-15 radiosonde, and TMAX-C interface board. Therefore, we always have a simultaneous sounding of SnowWhite and Vaisala Humicap-A (22 soundings) or Humicap-H (32). To validate the SnowWhite performance above the upper troposphere, we also had two special campaigns in which we made simultaneous soundings with the NOAA/CMDL cryogenic frost-point hygrometer at the Galapagos in November-December 2000 and at Indonesia in November-December 2001. It should be noted that most of the SnowWhite soundings were conducted at night to minimize potential solar light contamination and water vapor contamination/out-gassing. Also, we made a chamber experiment at the Solar-Terrestrial Environment Laboratory, Nagoya University, in August 2000.

Previous studies suggest that the Vaisala Humicap-A sensor works down to -30 C air temperature (corresponding to about 10 km in the tropics) and that Humicap-H works down to -50 C air temperature (about 12 km). We calculate the relative humidity (RH) values with respect to liquid water from the SnowWhite measurements and compare them with Humicap measurements in the height ranges where Humicaps work. It is found that Humicap-A and SnowWhite agree well below 50% RH but that above 50% RH, Humicap-A tends to be drier as RH becomes higher (for example, Humicap-A is 5% drier at 80% RH), and that Humicap-H and SnowWhite agree well at all RH values.