

File Revision Date:

October 4, 2016

Data Set Description:

PI: Dr. Dale Hurst
Instrument: NOAA Frost Point Hygrometer (FPH)
Sites: Boulder, CO USA 39.949°N, 105.197°W, 1743 masl
Hilo, HI USA 19.717°N, 155.049°W, 10 masl
Lauder, NZ 45.038°S, 169.683°E, 370 masl

Measurement Quantities: Pressure, Temperature, Relative humidity, Geopotential height, Frost point temperature, Water vapor mixing ratio, GPS Altitude, Latitude and Longitude of payload (for most soundings since Oct 2002), Horizontal wind speed and direction (for most soundings since Oct 2002).

NOTE: Most FPH soundings are archived under the instrument name WVSONDE and have filename extensions ".w[HH]" where [HH] is the hour of balloon launch (UTC). For some Boulder soundings two FPHs were flown on the same balloon. To differentiate between the two instruments the second FPH sounding is archived under the instrument name WVSONDE2 with the filename extension ".h[HH]".

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Reference Articles:

Mastenbrook, H. J. and Dinger, J. E.: Distribution of Water Vapor in the Stratosphere, *J. Geophys. Res.*, 66, 1437–1444, 1961.

Mastenbrook, H. J. and Oltmans, S. J.: Stratospheric water vapor variability for Washington, DC/Boulder, CO: 1964–82, *J. Atmos. Sci.*, 40, 2157–2165, 1983.

Oltmans, S. J.: Measurements of water vapor in the stratosphere with a frost-point hygrometer, *Moisture and Humidity-1985-Measurement and Control in Science and Industry*, 251–258, 1985.

Oltmans, S. J. and Hofmann, D. J.: Increase in lower-stratospheric water vapour at a mid-latitude northern hemisphere site from 1981 to 1994, *Nature*, 374, 146–149, doi:10.1038/374146a0, 1995.

Oltmans, S. J., Vömel, H., Hofmann, D. J., Rosenlof, K. H., and Kley, D.: The increase in stratospheric water vapor from balloonborne, frostpoint hygrometer measurements at Washington, D.C., and Boulder, Colorado, *Geophys. Res. Lett.*, 27, 3453–3456, doi:10.1029/2000GL012133, 2000.

Scherer, M., Vömel, H., Fueglistaler, S., Oltmans, S. J., and Staehelin, J.: Trends and variability of midlatitude stratospheric water vapour deduced from the reevaluated Boulder balloon series and HALOE, *Atmos. Chem. Phys.*, 8, 1391–1402, doi:10.5194/acp-8-1391-2008, 2008.

Hurst, D. F., Oltmans, S. J., Vömel, H., Rosenlof, K. H., Davis, S. M., Ray, E. A., Hall, E. G., and Jordan, A. F.: Stratospheric water vapor trends over Boulder, Colorado: Analysis of the 30 year Boulder record, *J. Geophys. Res.*, 116, D02306, doi:10.1029/2010JD015065, 2011.

Hall, E. G., Jordan, A. F., Hurst, D. F., Oltmans, S. J., Vömel, H., Kühnreich, B. and Ebert, V.: Advancements, measurement uncertainties and recent comparisons of the NOAA frost point hygrometer, *Atmos. Meas. Tech.*, 9, 4295–4310, doi:10.5194/amt-9-4295-2016, 2016.

Instrument Description:

The NOAA FPH is a compact and lightweight balloon-borne chilled mirror hygrometer first developed in the 1960s at the Naval Research Laboratory, Washington, D.C., then routinely flown from Boulder starting in 1980. The instrument measures the frost point temperature of the air stream flowing through it. First, a thin layer of frost is grown on a small reflective mirror continuously in thermal contact with a cold bath. The frost layer is then stably maintained by a micro-controller, using Proportional-Integral-Derivative (P-I-D) logic, that applies pulses of heat to the mirror to counteract the persistent cooling by the cold bath. The surface frost coverage is monitored by a small infrared beam (LED) that reflects off the mirror to a photodiode detector. When changes in frost coverage are sensed the heating pulses are rapidly adjusted to re-stabilize the frost layer. When the frost layer is stable it is in equilibrium with the moisture in the air stream flowing over the mirror, and the frost point temperature is equal to the mirror temperature.

Algorithm Description:

The partial pressure of water vapor (P_w) in the flowing air stream is calculated directly from the measured frost point temperature using the well-established Goff-Gratch equation that relates the saturation vapor pressure over ice to the ice surface temperature. The water vapor mixing ratio (H_2O) is calculated from P_w using

$$H_2O \text{ (ppmv)} = P_w / (P_a - P_w) \times 10^6$$

where P_a is the measured atmospheric pressure. Mixing ratios are defined as mole fractions in dry air so it is necessary to subtract the water vapor partial pressure from the measured atmospheric pressure. Water vapor mixing ratios in units of ppmv (parts per million by volume) are similar to mole fraction units (micromoles water vapor per mole dry air). The accuracy of water vapor mixing ratios calculated in this way depends on the accuracies of the frost point temperature measurements and the radiosonde measurements of P_a .

Frost point temperatures can also be converted to relative humidity values by dividing the water vapor partial pressure by the saturation water vapor pressure (P_{ws}) at the measured atmospheric temperature.

$$RH = P_w/P_{ws} (x100\%)$$

The accuracy of RH values calculated in this way depends on the accuracies of the frost point temperature measurements and the radiosonde measurements of temperature that determine P_{ws} .

Expected Precision/Accuracy of Instrument:

Vaisala RS80 Radiosonde Measurements of Pressure, Temperature and Relative Humidity

Pressure:

Resolution 0.1 hPa

Accuracy +/- 0.5 hPa

Temperature:

Resolution 0.1 K

Accuracy +/- 0.2 K

Relative Humidity:

Resolution 1% RH

Accuracy +/- 2% RH

InterMet iMet-1-RSB Measurements of Pressure, Temperature and Relative Humidity (PTU)

Pressure:

Resolution 0.01 hPa

Accuracy +/- 0.5 hPa

Temperature:

Resolution 0.01 K

Accuracy +/- 0.2 K

Relative Humidity:

Resolution 0.1% RH

Accuracy +/- 5 % RH

Geopotential Height:

Calculated using radiosonde PTU measurements.

Errors due to uncertainty in the PTU values.

Frost Point Temperature:

Resolution 0.01 K

Accuracy +/- 0.1 K

Water Vapor Mixing Ratio:

Resolution 0.01 ppmv (<10), 0.1 ppmv (10-99.9), 1 ppmv (100-999), 10 ppmv (1000-9990), 100 ppmv (10000-30000)

Accuracy +/- 1 % (below 20 km), 1-3 % (above 20 km*)

*due to increasing relative accuracy estimates for radiosonde pressure measurements as atmospheric pressure decreases

Instrument History:

Boulder:

Start date using VIZ "A" radiosondes and analog data recording: April 1980*

*Note that data from Apr 1980 to Feb 1991 are available from the PI only as 250-m vertical averages

Upgrade to Vaisala RS80 radiosondes and digital data acquisition: February 1991

Upgrade to modern electronics board and temperature-controlled optics block: March 2004

Upgrade to InterMet iMet-1-RSB radiosondes and digital frost control: May 2009

Hilo:

Start date using InterMet iMet-1-RSB radiosondes: December 2010

Lauder:

Start date using Vaisala RS80 radiosondes and modern electronics board : August 2004

Upgrade to InterMet iMet-1-RSB radiosondes and digital frost control: September 2009