File Revision Date:
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Data Set Description:

PI: Dr. Rigel Kivi, Dr. Holger Vömel
Instrument: Cryogenic Frostpoint Hygrometer (CFH)
Sites: Sodankylä, Finland 67.370 N, 26.630 E, 179 msl

Measurement quantities: pressure, temperature, relative humidity, geopotential height, frost point temperature, water vapor mixing ratio, mixing ratio uncertainty, vertical resolution, ozone mixing ratio, ozone partial pressure, gps altitude, latitude and longitude, horizontal wind speed and direction.

Sodankyla, Finland is also a GAW and GRUAN site. Simultaneous ozone measurements on the same payload are considered ancillary data.

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Reference Articles:

Kivi, R., Dörnbrack, A., Sprenger, M., & Vömel, H. (2020). Far-ranging impact of mountain waves excited over Greenland on stratospheric dehydration and rehydration. *Journal of Geophysical Research: Atmospheres*, 125, e2020JD033055. https://doi.org/10.1029/2020JD033055

Thölix, L., Backman, L., Kivi, R., and Karpechko, A. Yu.: Variability of water vapor in the Arctic stratosphere, Atmos. Chem. Phys., 16, 4307-4321, doi:10.5194/acp-16-4307-2016, 2016.

Vömel, H., T. Naebert, R. Dirksen, and M. Sommer, (2016): An update on the uncertainties of water vapor measurements using Cryogenic Frostpoint Hygrometers, Atmos. Meas. Tech., 9, 3755-3768, doi:10.5194/amt-9-3755-2016.

Vömel, H., D. E. David, and K. Smith (2007), Accuracy of tropospheric and stratospheric water vapor measurements by the cryogenic frost point hygrometer: Instrumental details and observations, J. Geophys. Res., 112, D08305, doi:10.1029/2006JD007224.

Vömel, H., M. Rummukainen, R. Kivi, J. Karhu, T. Turunen, E. Kyrö, J. M. Rosen, N. T. Kjome, and S. J. Oltmans (1997), Dehydration and sedimentation of ice particles in the Arctic stratospheric vortex, Geophys. Res. Lett., 24, 795-798, doi: 10.1029/97GL00668.

Vömel, H., J. E. Barnes, R. N. Forno, M. Fujiwara, F. Hasebe, S. Iwasaki, R.Kivi, N. Komala, E. Kyrö, T. Leblanc, B. Morel, S.-Y. Ogino, W. G. Read, S. C. Ryan, S. Saraspriya, H. Selkirk, M. Shiotani, J. Valverde Canossa, D. N. Whiteman, (2007), Validation of Aura/MLS Water Vapor by Balloon Borne Cryogenic Frostpoint Hygrometer Measurements, J. Geophys. Res., 112, D24S37, doi:10.1029/2007JD008698.

Instrument Description:

The Cryogenic Frostpoint Hygrometer (CFH) is the first lightweight digital balloon-borne hygrometer based on the original NOAA analog Frostpoint Hygrometer. The CFH uses the chilled-mirror principle, in which a water condensate is formed on a small temperature-controlled mirror, which is exposed to ambient air flowing across the mirror. An optical detector senses the condensate by measuring the amount of light that is reflected off the mirror and a digital controller regulates the temperature of the mirror in order to maintain a constant reflectivity of the condensate covered mirror surface. To the extent that the reflectivity is constant, the condensate on the mirror is assumed to be in equilibrium with the gas phase. The temperature of the mirror is measured using a small individually calibrated thermistor. Under the condition of equilibrium it is considered to be equal to the ambient dew point or frost point temperature, depending on whether the condensate phase is liquid or ice.

Algorithm Description:

The partial pressure of water vapor (ew) is calculated directly from the measured frost point temperature using the Goff-Gratch equation, which relates the saturation vapor pressure over ice or over liquid to the condensate temperature. The Goff Gratch equation corresponding to the correct phase of the condensate (liquid or ice) has to be used to calculate the partial pressure. The water vapor mixing ratio (H2O) in dry air is calculated from ew using

H2O (ppmv) = ew/(P-ew) (x1e^6)

where P is the measured atmospheric pressure.

Frost point temperatures are converted to relative humidity values by dividing the water vapor partial pressure by the saturation water vapor pressure (es) at the measured atmospheric temperature.

RH = ew/es (x100%)

The uncertainty of RH values calculated in this way depends on the uncertainty of the frost point temperature measurements and the radiosonde measurements of temperature that determine es.

Expected Total Uncertainty of Instrument:

Vaisala RS80 Radiosonde Measurements of Pressure, Temperature and Relative Humidity

Pressure:

Total uncertainty +/- 1 hPa (at 100 hPa)
Total uncertainty +/- 0.1 hPa (at 10 hPa)

Air Temperature:
Total uncertainty +/- 0.3 K

Relative Humidity:
Total uncertainty +/- 5% RH

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

Pressure:
Total uncertainty +/- 2 hPa (at 1000 hPa)
Total uncertainty +/- 1 hPa (at 100 hPa)
Total uncertainty +/- 0.1 hPa (at 10 hPa)

Air Temperature:
Total uncertainty +/- 0.3 K

Relative Humidity:
Total uncertainty +/- 5 % RH

Geopotential Height:
Calculated using radiosonde PTU measurements.

Frost Point Temperature:
Total uncertainty +/- 0.1 K

Water Vapor Mixing Ratio:
Total uncertainty typically +/- 2 % (1 sigma)
The total uncertainty is provided as additional column within the data.
The vertical width of the smoothing kernel for which this uncertainty applies is also provided as part of the data.
For the algorithm to estimate the water vapor uncertainty see Vömel et al., (2016)

<u>Measurement History:</u>

First observation	January 1996
Regular winter observations started	December 2002
Year round observations started	July 2007
Transition to InterMet iMet-1-RSB radiosondes started	January 2010