File Revision Date:
September 24, 2025

Data Set Description:
PIs: Dr. Ruud Dirksen, Peter Oelsner
Instrument: Skydew, a peltier-based frostpoint hygrometer
Site: Lindenberg, Germany 52.21 N, 14.12 E, 112 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.

Lindenberg, Germany is also a GRUAN, as well as a, GAW site. Simultaneous ozone measurements on the same payload are considered ancillary data. The regular, weekly ozone data are submitted to the NDACC archive as we;;.

Contact Information:

| | |
|---|---|
| Name: | Dr. Ruud Dirksen |
| Address: | DWD, Meteorological Observatory Lindenberg<br>Am Observatorium 12, 15848 Tauche-Lindenberg, Germany |
| Phone: | +49 69 8062 5820 |
| Email: | Ruud.Dirksen@dwd.de |
| | |
| Name: | Peter Oelsner |
| Address: | DWD, Meteorological Observatory Lindenberg<br>Am Observatorium 12, 15848 Tauche-Lindenberg, Germany |
| Email: | Peter.Oelsner@dwd.de |


Reference Articles:

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.

Sugidachi, T. et al., Development of a Peltier- based chilled-mirror hygrometer, SKYDEW, for tropospheric and lower-stratospheric water vapor measurements, Atmospheric Measurement Techniques, 18(2), 509–531, doi:10.5194/amt-18-509-2025, 2025, URL https://amt.copernicus.org/articles/18/509/2025/.


Instrument Description:
[CFH] 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.

[Skydew]
The Meisei Skydew instrument is a lightweight balloon borne hygrometer that employs a Peltier element to cool the mirror instead of a cryogen. The measurement principle is basically identical to CFH, apart from the cooling method. Skydew's PID controller is more aggressive than that of CFH, leading to a higher frequency of the oscillations in mirror temperature.

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

$$H2O\ (ppmv) = ew/(P-ew)\ (\times 1e^6)$$

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.

$$RH = ew/es\ (\times 100\%)$$

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.

For Skydew's (not yet available) data processing, the so-called golden point method will be employed, which in essence is a filtering applied to the inevitable controller-induced oscillations in mirror temperature. The golden point method only uses the data associated with extremes in the mirror reflectivity, because the -temporarily- stable condensate layer belong to the actual dew/frost point

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

——
InterMet iMet-1-RSB Measurements of Pressure (after GPS correction), 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

——

Vaisala RS41 Radiosonde Measurements of Pressure, Temperature and Relative Humidity

Pressure:
Total uncertainty +/- 1 hPa (> 100 hPa)
Total uncertainty +/- 0.3 hPa (at 100 to 10 hPa)
Total uncertainty +/- 0.04 hPa (at < 10 hPa)

Air Temperature:
Total uncertainty +/- 0.4 K

Relative Humidity:
Total uncertainty +/- 4% RH

——

Geopotential Height:
Calculated using radiosonde GPS data.

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 | August 2006 |
| Regular observations started | October 2008 |
| Transition to InterMet iMet-1-RSB radiosonde | July 2009 |
| Switch from monthly to bi-weekly observations | April 2010 |
| Transition to Vaisala RS41 radiosonde | February 2016 |
| Switch from bi-weekly to monthly observations | May 2020 |
| Termination of R23-CFH measurements | November 2022 |
| Regular Skydew observations | April 2023 |