Paroscientific, Inc.
Digiquartz® Pressure Instrumentation

MET4 AND MET4A CALCULATION OF DEW POINT

Summary

This report describes the calculations required for determining the dew point temperature, using the measured air temperature and relative humidity provided by the MET4 or Fan-Aspirated MET4A.The algorithm is based on the Magnus-Tetens formula, over the range

$$0° C < T < 60° C$$
$$0.01 < RH < 1.00$$
$$0° C < T_d < 50° C$$

where T is the measured temperature [°C]

RH is the measured relative humidity

and T_d is the calculated dew point temperature [°C]

The dew point temperature is

$$T_d = \frac{b \cdot \alpha(T, RH)}{a - \alpha(T, RH)} \quad (1)$$

$$\alpha(T, RH) = \frac{a \cdot T}{b + T} + \ln(RH) \quad (2)$$

with a = 17.27

and b=237.7 [°C]

The uncertainty in the calculated dew point temperature is ±0.4° C.

Background

The MET4 and MET4A provide three measured meteorological parameters: the atmospheric pressure, the temperature and the relative humidity. A fourth parameter is often requested, the dew point temperature. This quantity can be calculated from the three measured parameters.

The measured atmospheric pressure is the sum of two terms, the partial pressure of dry air (p_a) and the partial pressure of water vapor (p_w). The water vapor pressure is a function of temperature, and the dew point temperature (T_d), which is defined as the temperature at which the air is saturated with water vapor.

Given the measured temperature (T) and the measured relative humidity (RH), it is possible to calculate the dew point temperature. The present calculation limits the dew point to values above freezing. This provides for a more efficient calculation, although over a limited range.

Dew Point Calculation

T	The measured temperature; 0° C < T < 60° C
T_d	The calculated dew point temperature; 0° C < T_d < 50° C
RH	The measured relative humidity; 0.01 < RH < 1.00
p_{ws}	The vapor saturation pressure
p_w	The vapor pressure

Derivation

The Magnus-Tetens formula for the vapor pressure is given by 1[1]

$$p_w = 0.6105 \cdot e^{(aT/(b+T))} \quad [kPa]$$

with a=17.27

b=237.7

and T_d is in °C.

The vapor pressure is related to the relative humidity and vapor saturation pressure by

$$p_w = RH \cdot p_{ws}$$

When the air is saturated the relative humidity is equal to 100%, and the temperature is equal to the dew point temperature, which allows us to solve for the dew point temperature.

$$p_w = RH \cdot p_{ws}$$

$$\Rightarrow 0.6105 \cdot \exp\left[\frac{a \cdot T_d}{b + T_d}\right] = 0.6105 \cdot RH \cdot \exp\left[\frac{a \cdot T}{b + T}\right]$$

$$\Rightarrow T_d(T, RH) = \frac{b \cdot \alpha(T, RH)}{a - \alpha(T, RH)}$$

where

$$\alpha(T, RH) = \ln(RH) + \frac{a \cdot T}{b + T}$$

Uncertainty of Dew Point

The uncertainty in the measured dew point temperature is a function of the measured temperature and relative humidity and the uncertainties associated with those measurements.

The uncertainty in the measured dew point temperature is

$$\sigma^2_{Td} = \sigma^2_{T}\left(\frac{\partial T_d}{\partial T}\right)^2 + \sigma^2_{RH}\left(\frac{\partial T_d}{\partial RH}\right)^2$$

where σ^2_{Td} is the uncertainty in the calculated dew point temperature

σ^2_{T} is the uncertainty in the measured temperature

σ^2_{RH} is the uncertainty in the measured relative humidity

and assuming no cross-correlated uncertainties.

Taking the appropriate derivatives and collecting the terms, we find the uncertainty in the calculated dew point temperature to be

$$\sigma^2_{Td} = \sigma^2_{T}\left(\frac{a\cdot b}{a\cdot b-(b+T)\ln(RH)}\right)^4 + \sigma^2_{RH}\left(\frac{a\cdot b(b+T)^2}{RH\cdot(a\cdot b-(b+T)\ln(RH))^2}\right)^2$$

Letting the parameters be

T = 60° C, temperature range

RH=1.00 (100%), relative humidity range

σ_T = 0.1° C, uncertainty in the measured temperature

σ_{RH} = 0.02 (2%), uncertainty in the measured relative humidity

we calculate the one sigma uncertainty in the dew point temperature

s_{Td} =

0.4deg C

1[1] Barenbrug, A.W.T., *Psychrometry and Psychrometric Charts*, 3rd Edition, Cape Town, S.A.: Cape and Transvaal Printers Ltd., 1974