Meteorological Calculations

1.0 Horizontal Winds
The CPP supports both vector and scalar (unit vector) calculations for the horizontal wind speed and wind direction. The equations used in the CPP are from section 6, Meteorological Data Processing Methods, of the "On-site meteorological Program Guidance for Regulatory Modeling Applications" published by the U.S. Environmental Protection Agency.

1.1 Vector Averaging
From the sequence of N observations of A_i (instantaneous horizontal wind direction) and U_i, (instantaneous horizontal wind speed) the mean east-west, V_e, and north-south, V_n, components of the wind are,

$$V_e = \Sigma\,[U_i \sin(A_i)]/N \qquad (6.1.11)$$

$$V_n = \Sigma\,[U_i \cos(A_i)]/N \qquad (6.1.12)$$

The resultant mean wind speed and direction are,

$$UV = (V_e^2 + V_n^2)^{1/2} \qquad (6.1.13)$$

$$AV = ArcTan(V_e/V_n) \qquad (6.1.14)$$

The wind direction calculation is placed in a particular quadrant based on the signs of V_e and V_n. For easy referencing, the numbers to the right of the equations are the same equations numbers used in the guidance publication.

1.2 Scalar (unit vector)
In the calculation of scalar wind speed and wind direction, the horizontal wind speed U_i is set to a constant in equation (6.1.11) and (6.1.12). As a result of the division of V_e/V_n, the constant horizontal wind speed does not influence the calculation of the horizontal wind direction. The average horizontal wind speed is calculated by,

$$US = \Sigma\, U_i/N \qquad (6.1.1)$$

The horizontal wind speed is calculated using the same equation as before, but as stated above the weighing of the wind direction by the wind speed has been removed.

2.0 Sigma Theta Calculations
The CPP sets up three independent arrays for each channel set up as a sigma theta channel. One array is for the minute values, the other for the interim averages, and the third for the final averages. In most air quality applications hourly sigma thetas are of the most concern.

Each minute the CPP calculates and stores a one minute sigma theta. This calculation typically has 60 samples present in the sigma theta. At the selected interim averaging interval the CPP calculates and stores an interim sigma theta. For five minute interim averages there are typically 300 samples present in the sigma theta. At each final averaging interval the CPP calculates and stores a sigma theta. For hourly averages there are typically 3600 samples present in the sigma theta.

2.1 Standard Sigma Theta Calculation

The standard sigma theta calculation uses all samples collected over the time period to calculate the sigma theta. For hourly averages this is 3600 samples. For thirty minute final averages this is 1800 samples. For fifteen minute final averages this is 900 samples. At the end of each time interval the CPP calculates the sigma theta.

The guidelines recommend that sigma theta calculations use a scalar average to calculate the average wind direction used in the sigma theta calculation, as opposed to a vector wind direction average. In the initialization of the CPP, when any channel is set up as a horizontal wind direction channel, the CPP calculates a scalar wind direction average for this channel. If the user sets the channel up as a vector average, then the vector average is calculated as well as the scalar. If this channel is selected as the input for a sigma theta calculation, the CPP uses the scalar average for the sigma theta calculation.

This approach ensures adherence to the EPA guidelines and keeps from having to waste a channel to provide a scalar wind direction calculation should vector wind averages be desired.

The equation used to calculate the standard sigma theta is;

$$\sigma_A = [\,\Sigma\,(D_i^2 - AS^2)/N]^{1/2} \qquad (6.1.5)$$

Where AS is the average scalar wind direction for the time interval, and D_i is the individual wind direction samples. The mean horizontal wind direction (AS) is;

$$AS = \Sigma\, D_i\,(i)/N \qquad (6.1.4)$$

where

$$D_i = A_i\,(i) \quad for \;\; i = 1$$

and

$$D_i(i) = \begin{cases} D_i\,(i\text{-}1) + \Delta + 360 & if\ \Delta < -180 \\ D_i\,(i\text{-}1) + \Delta & if\ \Delta < 180 \\ D_i\,(i\text{-}1) + \Delta - 360 & if\ \Delta > 180 \end{cases}$$

$$\Delta = A_i(i) - D_i(i\text{-}1), \;\; for \;\; i > 1.$$

If the mean wind direction computed using (6.1.4) is not between 001 and 360 degrees, the increments of 360 degrees should be added or subtracted from the answer, as appropriate, until the result is between 001 and 360 degrees.

2.1 Revised Sigma Theta Calculation

To minimize the effects of meander under light wind speed conditions on the sigma theta calculation. it is recommended that four 15 minute values be computed and averaged as follows;

$$\sigma_A\,(1\text{-}hr) = [\,(\sigma^2_{A15} + \sigma^2_{A30} + \sigma^2_{A45} + \sigma^2_{A60})/4]^{1/2} \qquad (6.1.10)$$

The CPP breaks the hour up into four equal fifteen periods. The variance (Square of sigma theta) is calculated for each fifteen minute period. For hourly averages, the variance calculation for each fifteen minute period is averaged as given by (6.1.10) above and reported as the hourly sigma theta. For thirty minute final averaging intervals, periods 15 and 30 are used to calculate the sigma theta reported at the 30 minute boundary, and periods 45 and 60 are used to calculate the sigma theta reported at the hourly boundary.

With a single wind direction input, the CPP can be set up to calculate and provide both types of sigma theta calculations.

3.0 Vertical Winds

The CPP also provides interfacing to vertical wind sensors. Since there are some differences among manufacturers in sensor outputs, the manufacturer section should be referenced for proper sensor/CPP configuration. The CPP will provide average vertical wind speeds and wind directions, and sigma W calculations. The equation used to calculate and provide the standard deviation of the vertical wind speed or sigma W is;

$$\sigma_W = [\,\Sigma\,(W_i^{\,2} - WS^{\,2})/N]^{1/2} \qquad (6.1.8)$$

$$WS = (\,\Sigma\, W_i)/N$$

where W_i is the vertical wind speed instantaneous sample, and WS is the average wind speed.

4.0 Others

H2NS is committed to providing a comprehensive data collection platform. Please contact H2NS if you have an application that may require a special calculation.