Processing wind directions

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Let d be the meteorological wind direction in degrees, $d \in [0°, 360°]$, and φ the same in radians, $\varphi \in [0, 2\pi]$.

Note that we are disregarding the different orientation and offset for degrees and radians. Because we will transform all angles back to degrees in the end, orientation and offset would be flipped back to the original state anyway.

Averaging wind directions For all wind directions d, convert the angles from degrees to radians as

$$\varphi = d \cdot \frac{\pi}{180°}.$$

Using φ as angles of unit vectors[1], we can derive the cartesian components in East and North direction, respectively,

$$u = \sin\varphi$$
$$v = \cos\varphi \ .$$

The mean vector consequently has the components

$$\overline{u} = \langle u \rangle$$
$$\overline{v} = \langle v \rangle$$

and the mean angle is

$$\overline{\varphi} = \arctan\frac{\overline{u}}{\overline{v}} \ ,$$

where the four angular quadrants have to be considered separately. In Matlab the `atan2()` function does this automatically.

We obtain the mean angle in degrees as

$$\overline{d} = \overline{\varphi} \cdot \frac{180°}{\pi} \ .$$

[1] It can also make sense to use the complete wind vector including its absolute value for the averaging. In that case we would perform a weighted averaging over the angles. We use the unweighted approach here because it is common when anemometer and wind vane are present as separate instruments.

Standard deviation of wind directions For the angular fluctuations we substract the mean from all angles. Because we want to use the Matlab function `unwrap()` later, we work in radians:

$$\tilde{\varphi}' = \varphi - \overline{\varphi}$$

and map the values to the interval $[-\pi, \pi]$ as

$$\varphi' = \begin{cases} \tilde{\varphi}' & \text{if} \quad \tilde{\varphi}' \in [-\pi, \pi] \\ \tilde{\varphi}' + 2\pi & \text{if} \quad \tilde{\varphi}' < -\pi \\ \tilde{\varphi}' - 2\pi & \text{if} \quad \tilde{\varphi}' > \pi \; . \end{cases}$$

In Matlab this step is done by the function `unwrap()`. From the values of φ' the desired standard deviation can directly be computed and the value in degrees is obtained as

$$\sigma_d = \sigma_\varphi \cdot \frac{180^\circ}{\pi} \; .$$

An analogous approach has been published by Ackermann [1] using the weighted approach for $\overline{\varphi}$ (which we do not use in this course).

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References

[1] Ackermann, G.R., *Means and Standard Deviations of Horizontal Wind Components*, Journal of Climate and Applied Meteorology **22**, 959 (1983)