Sonic Anemometer tilt correction

To ensure accurate alignment of the sonic anemometers, we applied the tilt correction algorithm of Wilczak et al. 2001 using the planar fit method, which I'll briefly describe below:

If *u,v*, and *w* are the velocity components in instrument coordinates (*u* is into the boom, *v* is to the left, and *w* is up, forming a right-hand coordinate system), the *u', v'*, and *w'* are the tilted velocities, rotated into the direction of the mean wind by rotation matrix **A**:

$$\begin{bmatrix} u' \\ v' \\ w' \end{bmatrix} = \mathbf{A} \begin{bmatrix} u_m \\ v_m \\ w_m \end{bmatrix}$$

where **A = BCD**, based on the pitch, α, roll, β, and rotation, γ, angles:

$$\mathbf{B} = \begin{bmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 0 \end{bmatrix} \mathbf{C} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\beta & -\sin\beta \\ 0 & \sin\beta & \cos\beta \end{bmatrix} \mathbf{D} = \begin{bmatrix} \cos\alpha & 0 & \sin\alpha \\ 0 & 1 & 0 \\ -\sin\alpha & 0 & \cos\alpha \end{bmatrix}.$$

For small inclination angles (in our case), the following relations are valid:

$$\tan\alpha = -b_1$$

$$\tan\beta = b_2$$

The formula for correcting for tilt (u_p, with no rotation) is $u_p = \mathbf{P}u_m$, where $\mathbf{P} = \mathbf{D}^T\mathbf{C}^T$ so the elements of **P** are dependent on b_1 and b_2. b_0, b_a, and b_2 are found using the observed winds and the technique of multiple linear regression, as detailed in the Appendix of Wilczak et al 2001.

Observations from the entire 3-month XPIA campaign were used in 30-munite averages to determine b_0, b_a, and b_2, and the tilt correction was applied to all velocities. (The velocities deemed as influenced by the tower wake we not included in the calculations.) Rather than using b_0 for the rotation, which was found from 3-months of velocities, the rotation was re-calculated for each 30-minute interval, and that rotation was used. Velocities are now aligned with the 30-minute mean direction (average *v* is 0), and corrected so *w* points in the actual, corrected vertical directions.

The values of the tilt matrices for the 12 sonics all corresponded to tilt corrections of less than 1.7 degrees.

Wilczak, J. M., Oncley, S. P., & Stage, S. A. (2001). Sonic anemometer tilt correction algorithms. *Boundary-Layer Meteorology*, *99*(1), 127-150.