## Reconciliation of sensor height measurements

Steve Oncley and I are reviewing the measurement of sensor heights with the goal of perhaps reconciling ambiguities in the sensor heights.

## Configuration 1 dimensions

The horizontal arrays sonic heights were measured relative to the mean of the heights agl of the reference marks for both the upwind (1.534 m ) and downwind ( 1.53 m ) arrays. The profile heights appear to have been measured relative to the height of the reference mark on the profile towere ( 1.52 m ).

## Configuration 2 dimensions

The reference mark height for all configuration 2 sensor heights was measured at the NE tower of the downwind horizontal array (goalposts) $=1.76$ m . Sonic 1 b at the NE end of the array was $1.91 \mathrm{~m}+0.05 \mathrm{~m}=1.96 \mathrm{~m}$ above the reference mark and sonic 12 b at the SW end of the array was $1.92 \mathrm{~m}+0$. $05 \mathrm{~m}=1.97 \mathrm{~m}$ above the reference. Sonic spacing was 1.29 m .

The mean heights above the reference mark of the upwind sonics was $1.92 \mathrm{~m}+0.05 \mathrm{~m}=1.97 \mathrm{~m}$. The heights agl of the upwind reference marks or the profile reference marks do not appear to have been measured. Assuming a reference height of 1.76 m for the horizontal arrays, gives array heights of 1.76 $\mathrm{m}+1.97 \mathrm{~m}=3.73 \mathrm{~m} \mathrm{agl}$

Following are the new profile sensor heights.

| nominal <br> height | sonic $^{\star}$ | +1.76+0. <br> $\mathbf{0 5 3 m}$ | +1.68+0. <br> $\mathbf{0 5 3}$ | SHT $^{\star}$ | $\mathbf{+ 1 . 7 6 - 0 . 3 7}$ <br> $\mathbf{m}$ | $\mathbf{+ 1 . 6 8 - 0 . 3 7}$ <br> $\mathbf{m}^{\star *}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 3 m | 1.96 m | 3.77 m | 3.69 m | 2.36 m | 3.75 m | 3.67 m |
| 4 m | 2.90 m | 4.71 m | 4.63 m | 3.33 m | 4.72 m | 4.64 m |
| 5.5 m | 3.99 m | 5.80 m | 5.72 m | 4.43 m | 5.82 m | 5.74 m |

* heights above configuration 2 reference mark
** corrected reference mark height implied by continuity of 3 m profile sensors through configurations 2-4 (see Discussion at end).


## Configuration 3 dimensions

The reference mark height for configuration 3 was not measured agl, but was measured to be 15.2 cm below the reference mark for configuration 2 or 1.76 $\mathrm{m}-0.15 \mathrm{~m}=1.61 \mathrm{~m}$. (BUT the height of the configuration 3 reference mark on the profile tower was later measured to be either 1.51 m or 1.53 m !) The heights of the downwind array sonic booms above the reference mark were measured to be

| 5b | 6t(?) | $\mathbf{6 b}$ | $\mathbf{1 2 b}$ |
| :--- | :--- | :--- | :--- |
| 3.254 <br> $m$ | $3.252 m$ <br> $(?)$ | 3.250 <br> m | 3.275 m |

These heights were measured again on Aug 4 :

| $\mathbf{1 b}$ | $\mathbf{5 b}$ | $\mathbf{5 t}$ | $\mathbf{7 b}$ | $\mathbf{7 t}$ | $\mathbf{1 1 b}$ | $\mathbf{1 1 t}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 3.263 | 3.262 | 4.260 | 3.261 | 4.264 | 3.262 | 4.264 |

for mean sonic heights of $3.262 \mathrm{~m}+1.61 \mathrm{~m}+0.053 \mathrm{~m}=4.93 \mathrm{~m}$ and 5.93 m agl. The heights of the upwind sonics appear to be $3.254 \mathrm{~m}+0.053 \mathrm{~m}+1.61 \mathrm{~m}=$ 4.92 m agl.

The profile sonic (?) heights were measured on Aug 3:

|  | $\mathbf{8 / 3 / 0 8}$ boom <br> hts $^{*}$ | $\mathbf{+ 1 . 6 1 m}$ <br> $\mathbf{0 5 m}$ | $\mathbf{+ 0 .}$. <br> $\mathbf{0 5 m}$ | $\mathbf{+ 1 . 5 3 m} \boldsymbol{+ 0 . 0 .}$ <br> $\mathbf{0 5 m}$ |
| :--- | :--- | :--- | :--- | :--- |
| 8 m | 6.468 m | 8.13 m | 8.03 m | 8.05 m |
| 7 m | 5.544 m | 7.20 m | 7.10 m | 7.12 m |
| 5.8 m | 4.256 m | 5.92 m | 5.82 m | 5.84 m |
| 4.8 m | 3.316 m | 4.98 m | 4.88 m | 4.90 m |
| 3.3 m | 2.110 m | 3.77 m | 3.66 m | 3.68 m |
| 1.5 m | -0.026 m | 1.63 m | 1.53 m | 1.55 m |

## Configuration 4 dimensions

There are several statements about the heights of the reference marks in this logbook entry. It is stated that the profile reference mark for configuration 3 $=1.505 \mathrm{~m}$ agl, but also that it is 0.027 m "above top of 1.55 m sonic" (boom?), implying a height of $1.50 \mathrm{~m}+0.027 \mathrm{~m}=1.53 \mathrm{~m}$ agl. Then it says the reference mark for configuration 4 is 0.040 m above the reference mark for configuration 3 , which could be $1.65 \mathrm{~m}, 1.55 \mathrm{~m}$ or 1.57 m agl.

The 1 b sonic boom was measured to be 5.37 m above the reference mark for configuration 4 .
This logbook entry also measures the sonic and SHT heights wrt the 1.55 m sonic boom. Note that these heights were not changed between configurations 3 and 4 , and are consistent within 1 cm of the last column of the preceding table.

| nominal <br> ht | sonic $^{\boldsymbol{*}}$ | +1. <br> 55m | SHT $^{\boldsymbol{*}}$ | +1.55m-0.42 <br> $\mathbf{m}$ |
| :--- | :--- | :--- | :--- | :--- |
| 8 m | 6.508 m | 8.06 m | 6.878 | 8.01 |
| 7 m | 5.582 m | 7.13 m | 5.886 m | 7.02 m |
| 5.5 m | 4.286 m | 5.84 m | 4.710 m | 5.84 m |
| 4 m | 3.352 m | 4.90 m | 3.749 m | 4.88 m |
| 3 m | 2.140 m | 3.69 m | 2.542 m | 3.67 m |
| 1.5 m | 0.0 m | 1.55 m | 0.376 m | 1.51 m |

- measured wrt the 1.5 m sonic boom (at 1.50 m agl )


## Discussion

The 3 m profile sensors were not moved through configurations $2-4$, so that a discrepancy remains between the heights of the 3 m profile sensors during configuration 2 (sonic: $=3.77 \mathrm{~m}$ and $\mathrm{SHT}=3.75 \mathrm{~m}$ ) and those for configurations 3 and 4 (sonic $=3.69 \mathrm{~m}$ and $\mathrm{SHT}=3.67 \mathrm{~m}$ ). This implies that the reference mark height for configuration 2 , measured at the NE horizontal array tower to be 1.76 m , did not apply at the profile tower, but should rather have been 1.68 m . (Note that simple transposing the last two digits of 1.76 m gives 1.67 m , which is within 1 cm of the implied value.) Kurt very carefully kept the baseplates of the 6 towers for the horizontal array at the same elevation using a $4^{\prime}$ carpenters level and presumably did the same for the profile tower. It seems unlikely that there was an 8 cm difference between the elevations of the 7 AHATS Roan towers. Assuming 1.67 m for the height of the reference mark for configuration 2 gives the following heights:

|  | Sonic $1$ | $\begin{aligned} & \text { SHT } \\ & 1 \end{aligned}$ | Sonic | $\begin{aligned} & \text { SHT } \\ & 2 \end{aligned}$ | $\begin{aligned} & \text { Sonic } \\ & 3 \end{aligned}$ | $\begin{aligned} & \text { SHT } \\ & 3 \end{aligned}$ | $\begin{aligned} & \text { Sonic } \\ & 4 \end{aligned}$ | SHT |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| reference <br> ht | 1.52 m | 1.52 m | 1.67 m | 1.67m | 1.52 m | 1.52 m | 1.56 m | 1.56m |
| upwind | 3.74/3.24 | na | 3.64 | na |  | na | 6.98 | na |
| top | 4.24 | na | 4.64 | na | 5.83 | na | 7.98 | na |
| bottom | 3.24 | na | 3.64 | na | 4.83 | na | 6.98 | na |
| 8m | 8.05 | 8.01 | unch | unch | 8.04 | 8.01** | 8.06 | 8.01 |
| 7 m | 7.08 | 7.01 | unch | unch | 7.12 * | 7.02** | 7.13 | 7.02 |
| 5.5 m | 5.53 | 5.47 | 5.71 | 5.73 | 5.83 | $5.84 * *$ | 5.84 | 5.84 |
| 4 m | 4.24 | 4.23 | 4.62 | 4.63 | 4.89 | $4.88{ }^{* *}$ | 4.90 | 4.88 |
| 3 m | 3.30 | 3.26 | 3.68 | 3.66 | 3.68 | 3.67 ** | 3.69 | 3.67 |
| 1.5 m | 1.55 | 1.51 | unch | unch | 1.55 | 1.51 ** | 1.55 | 1.51 |

unch: Profile heights not measured for configuration 2, but same as configuration 1
Height changed for profile sensors at start of configuration

* 7 m sonic moved up on Aug 3 at 09:41
** The configuration 3 SHT heights were not measured, but copied from configuration 4

