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Supplementary Material

Fire emission uncertainties and their effect on smoke dispersion predictions: a case study at Eglin Air Force Base, Florida, USA

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Supplement: Adjustment of predicted winds

a. Methods

The Weather Research and Forecasting (WRF) modelling system was used at 1.3-km grid resolution. The modified WRF vertical profiles at the centre of the burn lot for every hour during the burn were used in plume dispersion modelling. The predicted atmospheric stability was in agreement with observations recorded around the burn site; however, Wind speed (WS) and wind direction (WD) needed to be modified to match the real-time wind measurements taken on site. The first set of wind velocity measurements was taken by a 3D sonic anemometer (Young 81000, R.M. Young Corp.) on the aerostat (Stevens, *et al*. 2013)[1], at its measurement height ranging from 38 to 280 m. The second set of wind measurements was taken at 10 m above ground at approximately the same location as the aerostat. The third measurement was taken at 2 m above ground at 4.0 km downwind of the centre of the burn lot.

The WS predicted for the burn site by WRF was evaluated against the three measured WSs. The WS ($\bar{u}$) at z meters above ground was corrected using logarithmic wind profile (Holton 2004):

$$\bar{u} = \frac{u_*}{k} \ln\left(\frac{z}{z_o}\right) \tag{1}$$

where z_o is the roughness length, u_* is the friction velocity and k is von Karman's constant. These three values were adjusted so the boundary layer theory profile in Eqn (1) became the least-square fit for the three measurements and the WRF prediction at planetary boundary layer (PBL) height. The values used to adjust WRF wind speed are listed hour by hour in Table S1. Since the smoke dispersion model's emission rate changed hourly, the WSs were corrected hourly as well.

[1] Stevens WR, Squier W, Mitchell W, Gullett BK, Pressley C (2013) Measurement of motion corrected wind velocity using an aerostat lofted sonic anemometer. *Atmospheric Measurement Techniques*, in press.

Table S1. The roughness length, z_o, the friction velocity, u_* and von Karman's constant, k, used for the least-square fit on wind speed from 1200 to 1400 hours CST

CST	z_o (m)	u_* (m s^{-1})	k
1200	6.1	0.5	1.8
1300	3.5	0.4	2.2
1400	0.3	0.3	4.8

Similar to the modification procedure with WS, WD was adjusted so the WD profile also became the least-square fit through the three measured WDs. The WD profile employed was the simplified Ekman spiral (Holton 2004). The directional wind vectors u_z and v_z at height z in Ekman spiral were simplified for the Northern Hemisphere as:

$$u_z = u_g\left(1 - e^{-\pi z/De}\cos\left(\pi z/De\right)\right),\ v_z = u_g e^{-\pi z/De}\sin\left(\pi z/De\right) \qquad (2)$$

where u_g is the geostrophic wind and De is the PBL layer depth, which is obtained from WRF.

The directional wind vectors were used to calculate the angle by which the wind rotates at height z with respect to the wind at ground level:

$$\Delta WD_z = \tan^{-1}\left(\frac{v_z}{u_z}\right) \times \frac{180}{\pi}, \qquad \Delta WD_0 = 0^\circ \qquad (3)$$

where ΔWD_z is wind rotation angle. WD at the ground level was obtained from least-square curve fit to the three measurements. The adjusted WD is the sum of wind rotation angle with the optimised WD at ground:

$$WD_{adjusted,z} = \Delta WD_z + WD_{ground} \qquad (4)$$

These hourly adjusted WS and WD were then input to Daysmoke.

b. Results

Fig. S1 shows the WSs measured and predicted at different times of the burn. The error bars represent the standard deviation of the measurements for each hour.

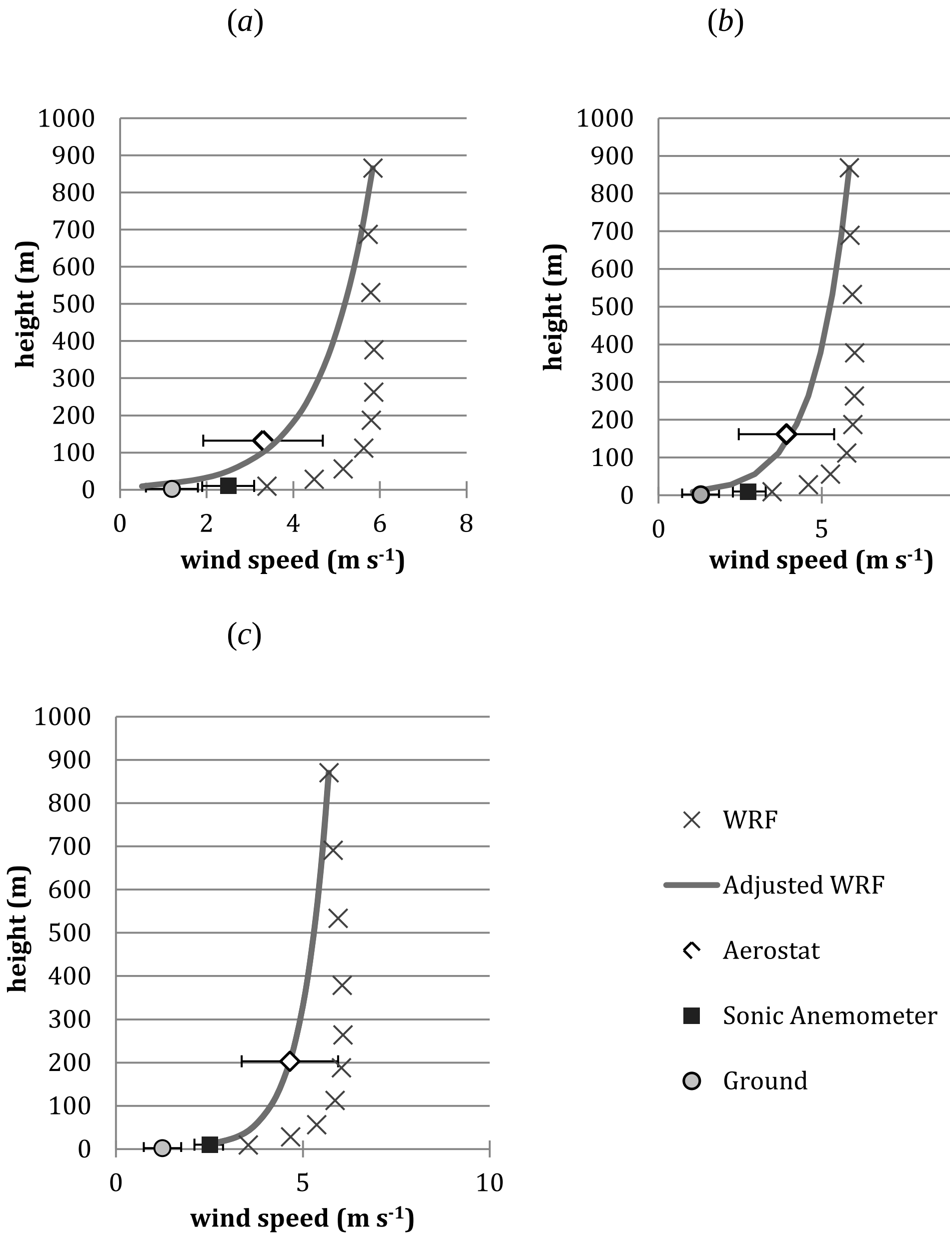

Fig. S1. Comparison of measured and Weather Research and Forecasting (WRF)-predicted wind speed at (*a*) 1200 , (*b*) 1300 and (*c*) 1400 hours CST. Measurements are at the ground (2 m), on a mast (10 m) and by the aerostat (hourly average ranging from 131 m to 203 m). WRF winds adjusted by the three measurements are also shown. Horizontal error bars represent standard deviation for each hour.

For the three hours of simulation, WRF over predicted WS in all vertical layers in the PBL. The adjusted WRF profile was within one standard deviation of the three measurements. For 1200–1400 hours CST, WRF winds were reduced near the ground. The adjusted WS maximum decrease was 2.9 m s^{-1}, which is an 85% reduction.

Fig. S2 shows the wind directions measured and predicted during the burn.

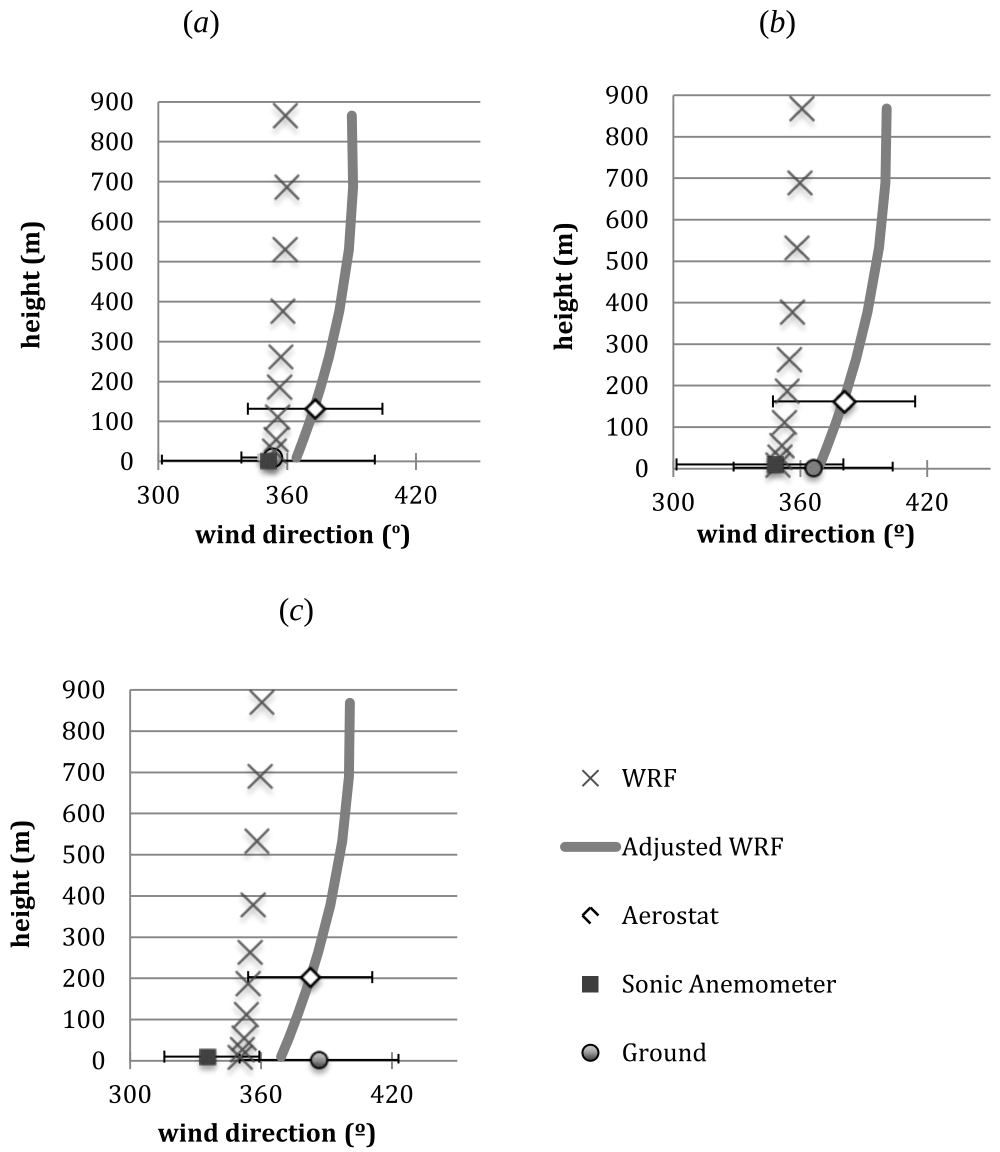

Fig. S2. Comparison of measured and Weather Research and Forecasting (WRF)-predicted wind directions at (*a*) 1200, (*b*) 1300 and (*c*) 1400 hours CST. Measurements are at the ground (2 m), on a mast (10 m) and by the aerostat (131–203 m). WRF winds adjusted by the three measurements are also shown. Horizontal error bars represent standard deviation of measurements during each hour.

WRF WDs were over-predictions (more easterly) at the ground (2 m) but under-predictions (more westerly) aloft (10 m and 131–203 m) for the majority of the burn period. Predicted winds from WRF generally were from the north-west, although the winds measured on and aboveground for 1300 and 1400 hours CST were from the north-east. WRF WD at the top of PBL rotated by only 11º with respect to the WD on the ground, but the adjusted WD at the top of PBL rotated 43º from WD at ground level.

Table 2 shows the WS and WD that WRF originally predicted and adjusted WS and WD at 850 m above ground for three different hours during the burn. Adjusted WS at this height did not deviate much from the originally predicted values but the WSs closer to the ground did get reduced greatly.

Table S2: Original Weather Research and Forecasting (WRF)-predicted wind speed (WS) and wind direction (WD) from 1200 to 1400 hours CST compared to WS and WD values adjusted to field measurements

	WRF original		***Adjusted***	
CST	**WS (m s^{-1})**	**WD (degrees)**	**WS (m s^{-1})**	**WD (degrees)**
1200	5.8	–1.0	5.8	20
1300	5.9	0.7	5.8	41
1400	5.7	0.3	5.7	55