SURFACE WIND HETEROGENEITY FOR CASES-99

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1. INTRODUCTION

The Cooperative Atmosphere-Surface Exchange Study field campaign, conducted near Wichita, Kansas, in October 1999 (CASES-99) has provided a new data bank for boundary layer studies. In CASES-99, the 60 m main tower was surrounded by a dozen smaller towers within a radius of 2 km, including five towers from the Army Research Laboratory (ARL). Although the field campaign was conducted over relatively flat terrain, the wind data from the tower measurements often show significant micro-scale wind heterogeneity.

A high-resolution wind (HRW) model has been developed at ARL. This model is a two-dimensional, diagnostic atmospheric surface layer model with a horizontal grid spacing of the order of 100 m over a domain about 5 by 5 km. This model has been used to explain the micro-scale variability of wind fields over complex terrain. Using the CASES-99 data, a comparison between the measured and modeled winds has been carried out. Some of the results are presented here.

2. WIND HETEROGENEITY FROM MEASUREMENTS

Poulos et al. (2002) have provided a comprehensive description of CASES-99, including the instrumentation set-up and the measurements obtained. The National Center for Atmospheric Research (NCAR) deployed a 60 m tower and six smaller towers (stations) for CASES-99. All seven towers provide wind measurements at a height of 10 m above the ground and have been used for this study. Figure 1 shows the locations of the six stations relative to the main tower (37.64855° N, 96.73610° W). As can be seen from Fig. 1, all six stations are within 300 m of the main tower.

Figure 2 presents time series of the 30-minute average winds from the seven towers in Fig.1 for 16 October 1999. This figure provides an example of micro-scale wind heterogeneity, demonstrating that the 30-minute mean wind can vary significantly both in direction and in speed within a small area. Such micro-scale variability in the measured winds is thought to be due primarily to local micro-scale terrain effects even though the site was chosen for its relative flatness.

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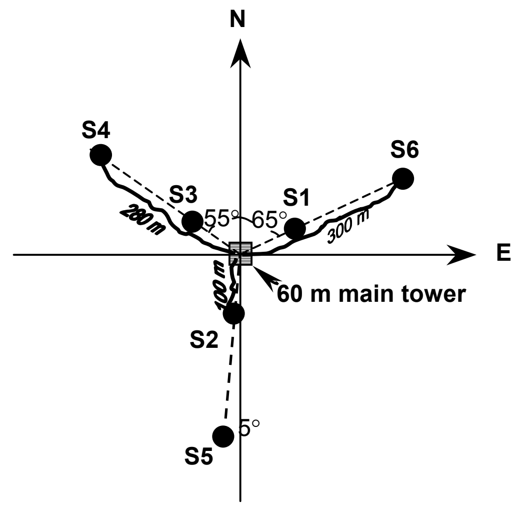

Figure 1. Location of the six NCAR measurement stations (S1…S6) relative to the 60 m main tower for CASES-99 (adapted from figure provided by Jeilun Sun).

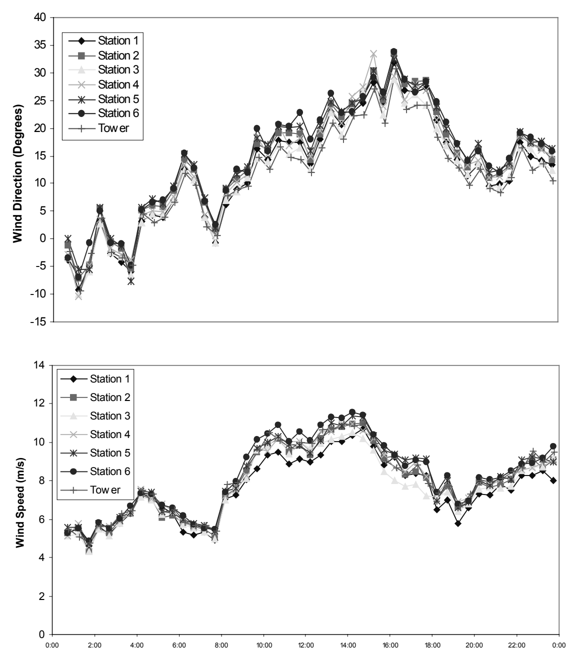

Figure 2. Time series of 30-minute average wind direction (upper panel) and wind speed (lower panel) at 10 m height above ground level from seven NCAR towers for 16 October 1999.

3. THE HRW MODEL AND SIMULATIONS

The HRW model is described in Cionco and Chang (2000). Briefly, the model uses Gauss' principle of least constraint and a direct variational relaxation method to adjust an initially uniform wind field to conform to constraints imposed by topography, mass conservation, and buoyancy. One of the distinctive features of the HRW model is the use of a non-orthogonal, terrain-following, warped coordinate system. The model requires as inputs, digitized terrain elevations, surface meteorological observations, and upper air sounding data. The model output includes the surface (at 10 m above the ground) wind and potential temperature fields.

Figure 3 shows the site location and the terrain contours for the HRW model simulations. This domain of 5 by 5 km is centered at the NCAR main tower with a resolution of 100 m in both x and y directions. The topography of the area shows a general slope from southwest to northeast. The highest and the lowest points are 444.1 m and 408.7 m, respectively, with a standard deviation of terrain elevation equal to 7.4 m. The NCAR upper air sounding data from Leon, Kansas (96° 44.10' W, 37° 39.12' N, 442.6 m altitude) and the corresponding 10 m wind and temperature data from the 60 m main tower have been used as input data for model simulations. A total of 48 model runs (cases) have been carried out. The model-simulated winds have been compared with the measured winds from the six NCAR stations. The measured winds from the ARL towers and other towers have not been used for the current model evaluation since the measurement levels were different from 10 m. Some results of the model evaluation are reported in the following.

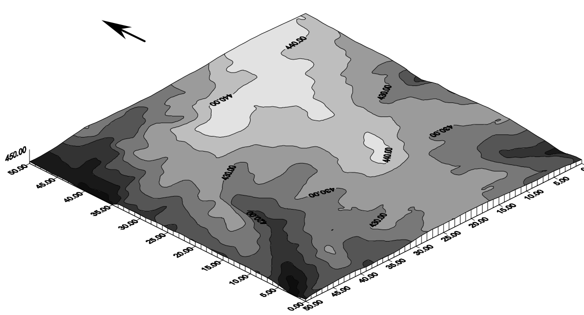

Figure 3. A three-dimensional representation of the terrain contours for the HRW model simulation domain. This domain of 5 by 5 km is centered at the NCAR 60 m main tower with 51 by 51 grid points. The arrow indicates North.

4. RESULTS OF THE MODEL EVALUATION

To compare the simulated and measured winds a simple linear regression analysis is used. Consider the following equation,

$$Y = aX + b, \qquad (1)$$

where X is the measured value of either wind speed or wind direction and Y is the corresponding simulated value from the model run. The correlation coefficient, R, is also calculated. Figures 4 and 5 present the simulated winds from 48 cases versus the measured winds in scatter diagrams with regression line (1) and the correlation coefficient value superimposed. Figure 4 shows the wind speed comparison, while Fig. 5 shows the wind direction comparison.

These two figures appear to indicate reasonably good agreement between the model simulations and the measurements for all six stations, with especially high positive correlation for the wind direction. The R-value is always greater then 0.915 for the wind speed and greater than 0.966 for the wind direction. For individual cases, however, the model can either underestimate or overestimate the measured wind speed at a particular station, as can be seen from the scattering in Fig. 4. Also there appears at times to be a systematic discrepancy between measured and modeled wind direction from station to station, as can be seen in Figure 5. Further in-depth study of the model performance as well as the micro-scale wind heterogeneity is being carried out.

5. REFERENCES

Cionco, Ronald M. and Sam S. Chang, 2000: Further evaluation of the HRW model using conditional sampling, *Proceedings of the 14th Symposium on Boundary Layer and Turbulence*, 7-11 August 2000, Aspen, Colorado.

Poulos, G., W. Blumen, D.C. Fritts, J.K. Lundquist, J. Sun, S. P. Burns, C. Nappo, R. Banta, R. Newsom, J. Cuxart, E. Terradellas, B. Balsley, and M. Jensen, 2002: CASES-99: A comprehensive investigation of the stable nocturnal boundary layer. *Bulletin of the American Meteorological Society*, submitted.

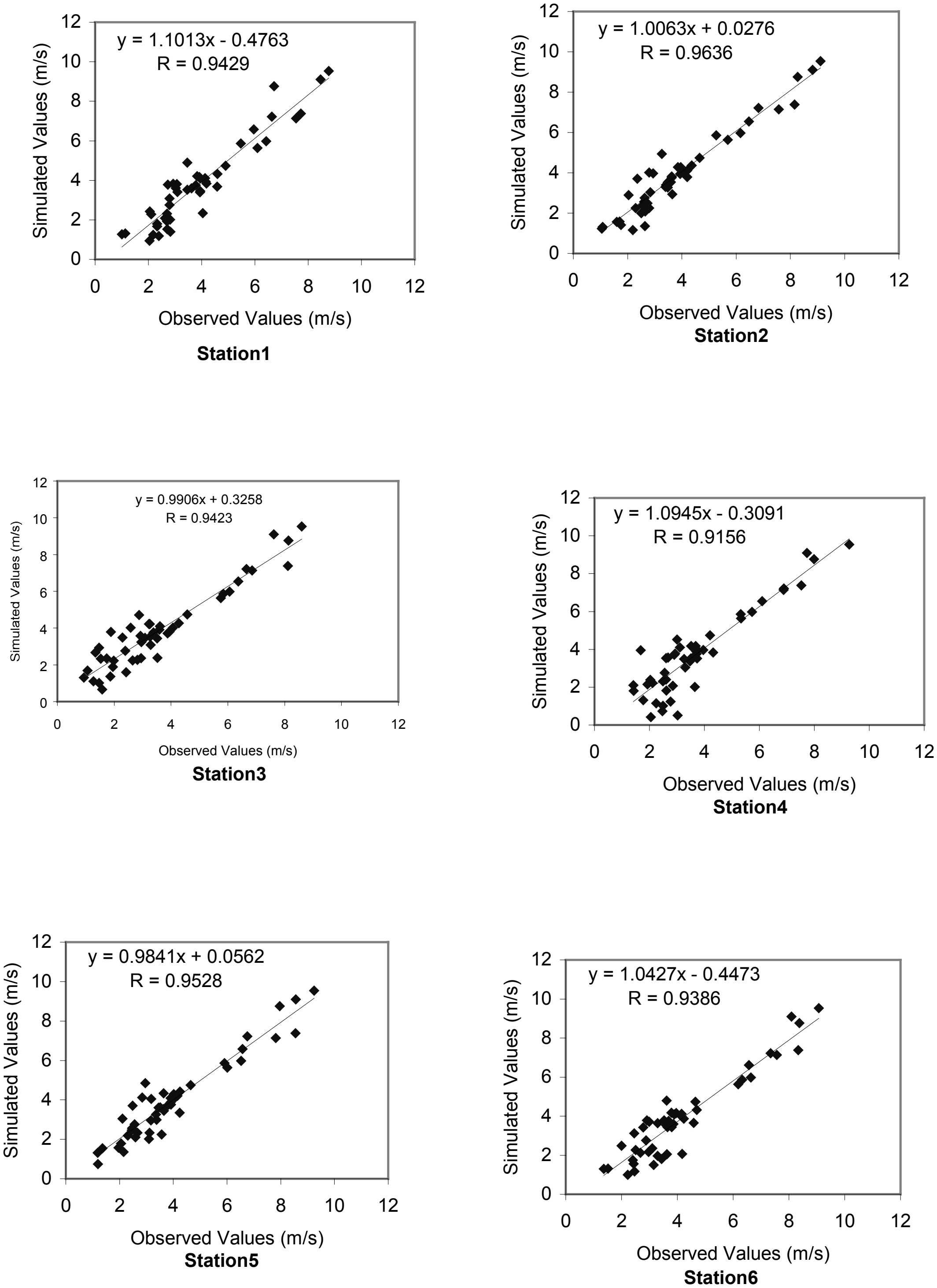

Figure 4. Scatter diagram for simulated (Y) wind speed versus measured wind speed (X). The straight line results from the linear regression analysis, (1).

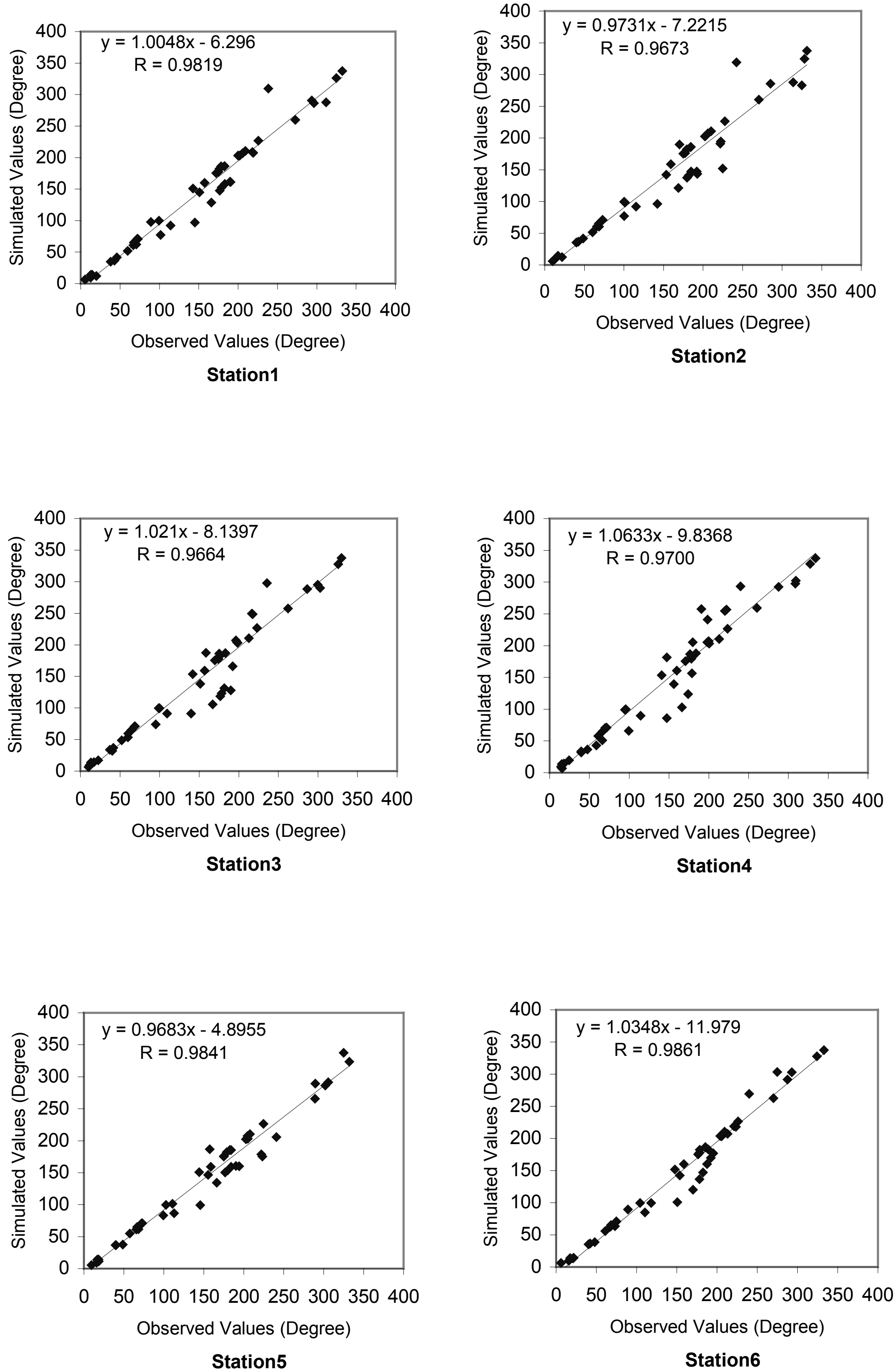

Figure 5. Same as Fig. 4 except for wind direction.