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IMPACT OF SAND HILLS' SOIL PROPERTIES ON SUMMER PRECIPITATION

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1. INTRODUCTION

The Nebraska Sand Hills are a unique part of the Missouri River Basin that can be expected to exert an influence on the local and regional atmospheric conditions. There has been little research to date that has focused on land surface-atmosphere interactions in this environment. Preliminary investigations at the Omaha/Valley WFO have shown that the Sand Hills acts as an orographic uplift area to initiate afternoon convection in the summer (S. Byrd, pers. comm., 1999). This was determined by analyzing surface wind fields just before, during and after convective events. However, the physical mechanism for this phenomenon was not determined. Since the highly permeable soils of the top layer of the Sand Hills quickly dry following precipitation events, contrasts between the Sand Hills and the surrounding plains may initiate a regional circulation in this part of the Great Plains. In the warm season, higher daily temperatures over the Sand Hills can cause rising motion and create a mesoscale pressure gradient towards the Sand Hills. This rising motion draws air into the Sand Hills region from regions to the south. In summer months, the low level jet has a diverted branch flowing into central Nebraska, very likely because of this heating effect of the Sand Hills. This southerly and southeasterly low level inflow of moist air to the region may result in enhanced precipitation over and around the Sand Hills. This enhancement is suggested by frequent severe storms, including squall lines and tornadoes, at preferred locations along the southern boundary of the Sand Hills. Land surface-atmosphere interactions in the Sand Hills are investigated through the use of sensitivity analyses with MM5 with a inner 4-km domain centered on the Nebraska Sand Hills. These interactions are investigated by comparing modeled surface fluxes and near surface temperature and moisture fields between Sand Hills locations and the surrounding plains and between control runs and runs with altered surface properties. The results presented here are for cases in a wet, a normal and a dry year for which soil type in the Sand Hills was altered during successive simulations with initial and boundary conditions derived from selected warm season precipitation events. These sensitivity runs yield estimates of the influence of the Sand Hills' soil characteristics on the atmosphere.

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2. MODEL CONFIGURATION

Simulations were performed using the latest release (version 3.50) of MM5 (Grell et al. 1994) to investigate the influence of the Nebraska Sand Hills on summer convection. Three two-way nested domains were defined with grid spacing of 36, 12 and 4 km, respectively, and with the inner grid centered on the Sand Hills. Model physics for all three domains include the MRF PBL scheme, explicit moisture with the Reisner ice physics. The 36km and 12km grids used the Grell cumulus parameterization; no cumulus parameterization was used for the 4km grid, so that cumulus processes are explicitly resolved at this scale. The OSU/Eta land surface model (Chen and Dudhia 2001a,b) was used to predict surface energy fluxes and soil temperature and moisture fields. The model was initialized at 0000 UTC of the first day of each selected case using initial and boundary conditions derived from NCEP/NCAR Reanalysis data obtained from CDC. The model was run for 48 hours with new lateral boundary conditions supplied every six hours. During preliminary model runs, it was found that the initial soil moisture specified for the region were much too high for the sandy soils present in the Sand Hills. This is primarily due to the fact that the NCEP/NCAR Reanalysis grid is too coarse to recognize this soil feature but is also likely a result of a well-know high precipitation bias of the reanalysis. In order to obtain more reasonable initial soil moisture values, the outer model domain was spun up for four days before the inner two domains were started.

3. RESULTS

Two simulations were performed for each case using the configuration outlined above. The only difference between the runs was that for the second (modified) run all grid points with sand soils were changed to a silt loam soil. This replacement was done for all three model domains, but only for those grid points located within the region defined by the innermost domain. Following a four-day spin-up period for each simulation, soil moisture values clearly show the Sand Hills as a region of low soil moisture throughout the upper 2 meters in the control run, but when the sandy soils are replaced by a silt loam, soil moisture levels are more consistent with the surrounding region.

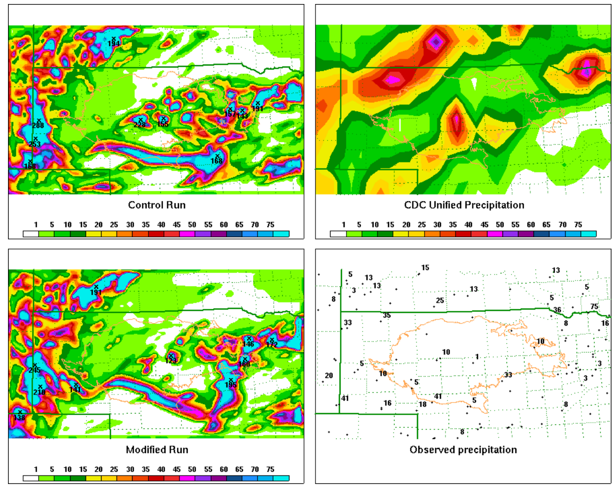

Figure 1 Precipitation totals for simulations and observations for the wet year (1983).

3.1 Wet Year (1983)

Both the control and modified simulations produce a strong convective system that moves across the region and eventually splits into two separate cells (Figure 1). Total precipitation is higher than observed for both simulations but the path of the convective system conforms to the axis of highest observed precipitation totals. It should be noted that the density of reporting locations in the Sand Hills is very sparse and direct comparisons are difficult. In the control simulation, the convective systems travels across the Sand Hills more quickly than in the modified run. In addition, individual convective cells can be tracked by analyzing the hourly output of the simulations. A moisture convergence zone remains along the Sand Hills border in the control case (Figure 2), but is displaced eastward in the modified run. In each run, the cell travels along this convergence zone, resulting in a displacement of the precipitation path to the south in the modified run. In this case, convection is more intense over the Sand Hills in the modified run due to the additional moisture supplied from the wetter soil.

3.2 Average Year (1986)

Both simulations reproduce the 2-day total precipitation distribution and amounts quite well and there are only small differences between the two simulations (Figure 3). The control run shows some

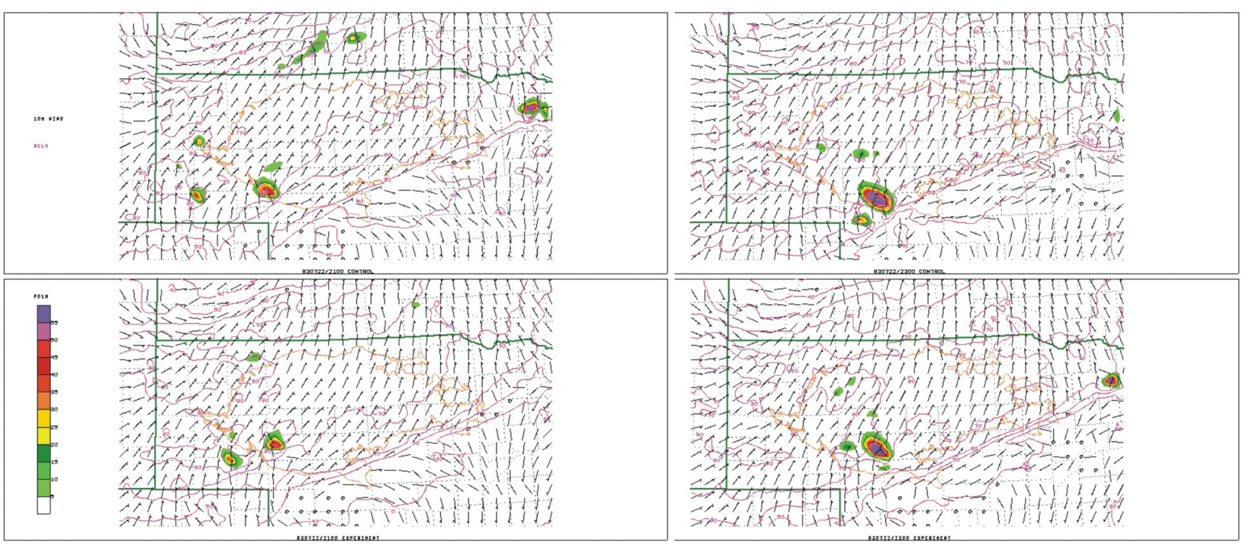

Figure 2 Control (top) and modified (bottom) simulations of hourly precipitation total (color filled), relative humidity (contours), and 10 meter winds (barbs) for the wet year (1983).

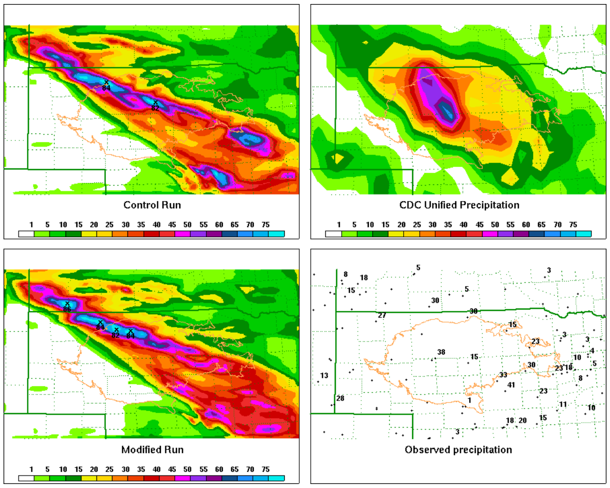

Figure 3 Precipitation totals for simulations and observations for the average year (1986).

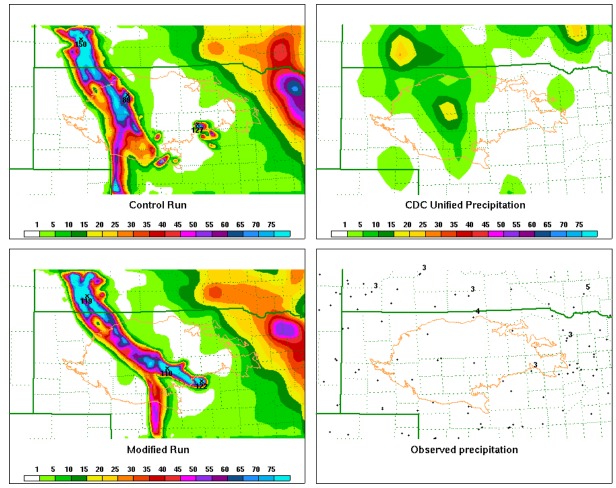

Figure 5 Precipitation totals for simulations and observations for the dry year (1989).

redevelopment, as the system leaves the Sand Hills and travels over the moister surface to the southeast, resulting in higher precipitation totals in this part of the domain. In this case, convection is more intense over the Sand Hills in the modified run (Figure 4) due to the additional moisture supplied from the wetter soil. Once the convection exits the Sand Hills and begins to travel over the moister soils outside the region, the control run intensifies, while the modified run weakens as there is no soil moisture increase.

3.3 Dry Year (1989)

The control and modified simulations produce precipitation amounts generally consistent with observations outside the Sand Hills (Figure 5) but the control run produces much more widely scattered precipitation over the eastern and central Sand Hills than does the modified run. This case shows significant differences in the path that the convective system takes across the Sand Hills between the two runs (Figure 6). In the modified run, the path is aligned with the 500 hPa winds (center and right panels) throughout the simulation period. However, in the control run, as the system

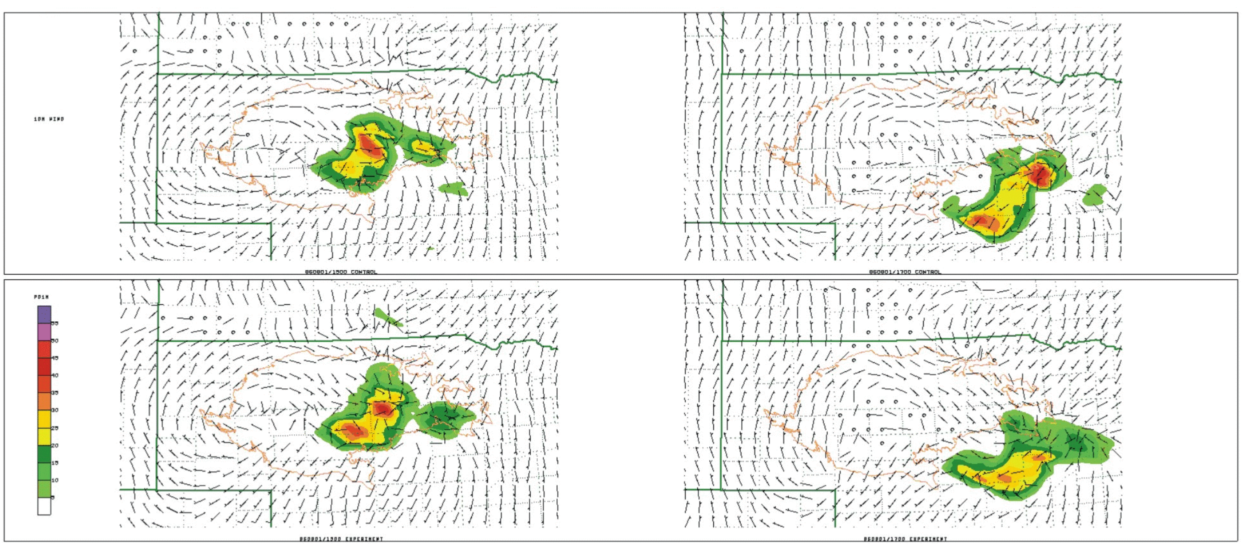

Figure 4 Control (top) and modified (bottom) simulations of hourly precipitation total (color filled), relative humidity (contours), and 10 meter winds (barbs) for the average year (1986).

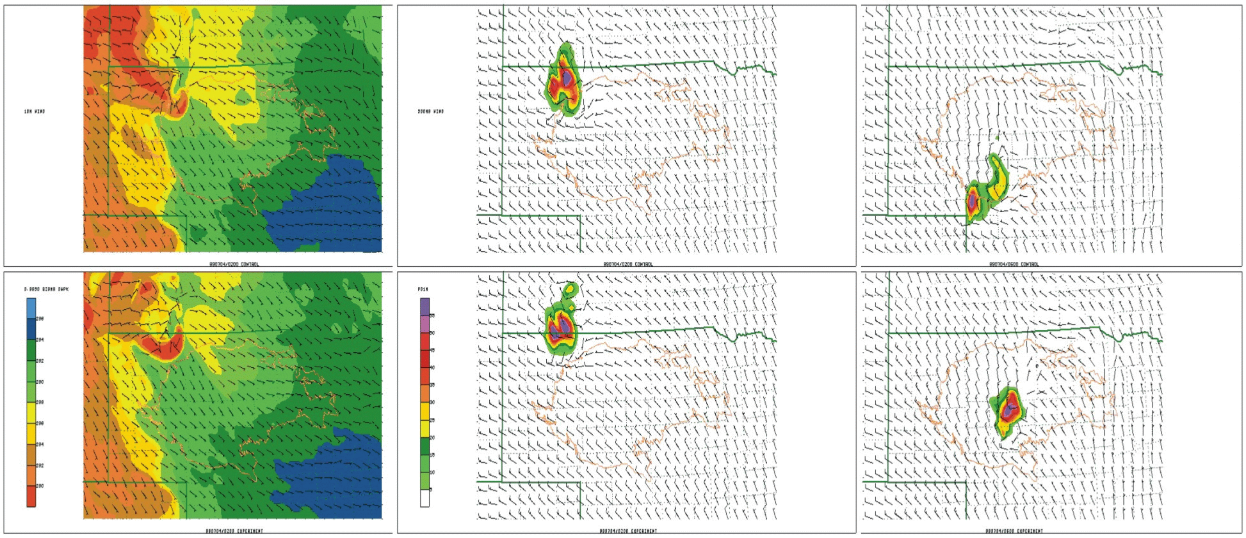

Figure 6 Control (top) and modified (bottom) simulations of hourly dewpoint temperatures (left column), precipitation total (color filled), and 500 hPa winds (barbs) for dry year (1989).

enters the Sand Hills, it begins to deviate to the right with respect to the upper level flow. The southeasterly flow at the surface brings moister air farther north in the modified run, keeping the drier air over the north central Sand Hills from penetrating southward as it does in the control run (left panels). The convection follows the moist tongue in each run, so that in the modified run does not deviate from the upper level flow in order to remain in moist air.

4. SUMMARY

For the cases studied, both the control and modified simulations reproduce the observed 2-day total precipitation distribution and amounts quite well, with only small differences between the two simulations. However, analysis of the hourly results leads to several generalizations concerning the differences between the control and modified run. First, the timing and strength of individual convective cells differs between runs. Second, there is some indication of weakening of cells entering the Sand Hills in the control cases and redevelopment of these cells as they exit the Sand Hills and travel over the surrounding moister surface. Finally, in several of the cases studied, there appears in the control cases to be preferred paths for convection along the Sand Hills' boundaries, where there is a significant soil moisture discontinuity.

5. REFERENCES

Chen, F., J. Dudhia, 2001a: Coupling an Advanced Land Surface–Hydrology Model with the Penn State–NCAR MM5 Modeling System. Part I: Model Implementation and Sensitivity. Monthly Weather Review: Vol. 129, No. 4, pp. 569–585.

Chen, F., J. Dudhia, 2001b: Coupling an Advanced Land Surface–Hydrology Model with the Penn State–NCAR MM5 Modeling System. Part II: Preliminary Model Validation. Monthly Weather Review: Vol. 129, No. 4, pp. 587–604.

Grell, J.A., J. Dudhia and D.J. Stauffer, 1994: A description of the fifth generation Penn State/NCAR mesoscale model (MM5). NCAR Tech Note NCAR/TN-398+STR, 138 pp.