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GROUNDWATER INPUTS TO REGIONAL EVAPOTRANSPIRATION IN THE NEBRASKA SAND HILLS

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1. INTRODUCTION

Climatically, the Nebraska Sand Hills are situated in a semi-arid region where evapotranspiration exceeds precipitation throughout most of the year. However, the high infiltration rates of the sandy soils has led to the accumulation of a large groundwater reservoir beneath this region. When the water table is at or near the surface, lakes, marshes and subirrigated meadows are formed (Figure 1). The presence of these wetland areas should be expected to significantly increase the rate of evapotranspiration from the Sand Hills region.

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2. METHODOLOGY AND RESULTS

The most recent version of MM5 includes a detailed land-surface model that represents a significant improvement in how MM5 computes surface fluxes and allows more realistic investigations of the effects of land surface characteristics on the atmosphere. Specifically, soil hydrology is now included explicitly, which vastly improves the utility of MM5 for hydrologic modeling. However, in the present form of the OSU land-surface model used in MM5, there is no provision for groundwater to interact with the atmosphere.

2.1 One-dimensional simulations

One-dimensional simulations with the OSU soil scheme, driven by observed atmospheric and soil

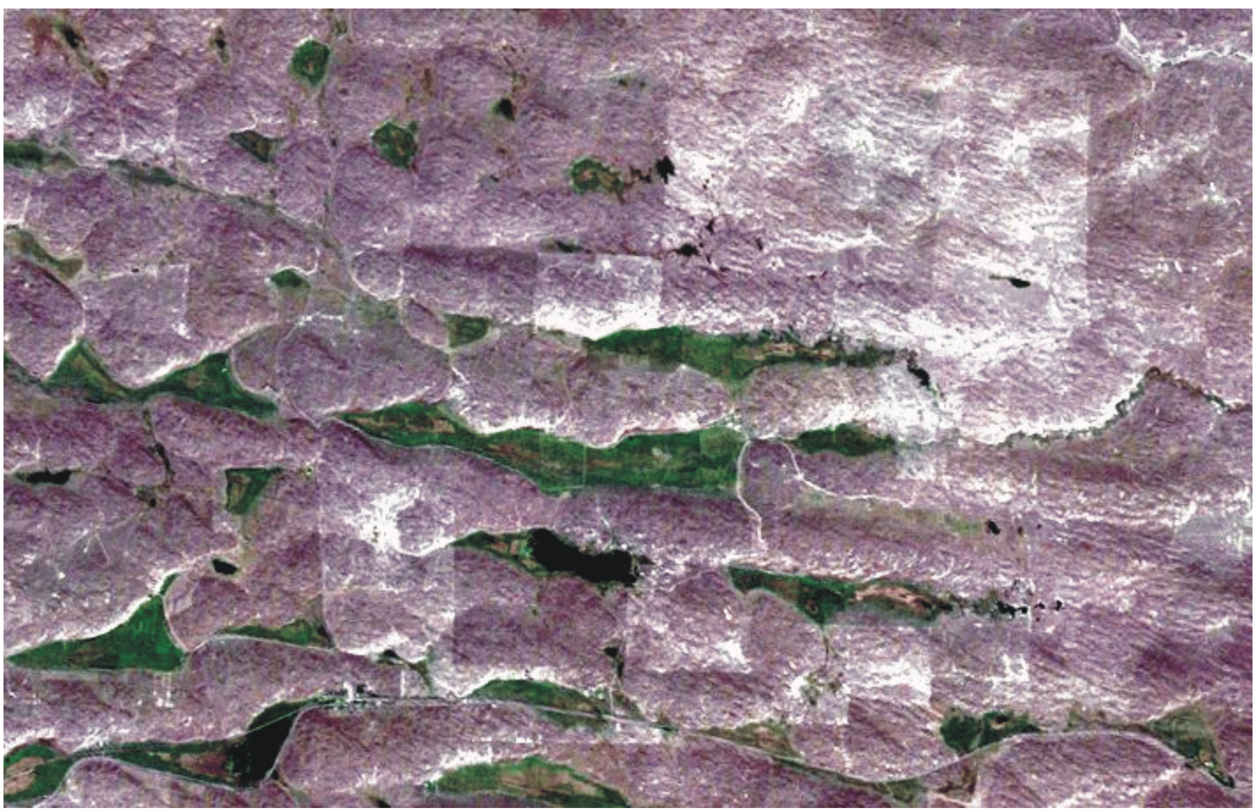

Figure 1: Quasi-true color rendering of Landsat 5 image of the Gudmundsen Sandhills Laboratory and vicinity in August 1997. Subirrigated meadows are green, indicating well-watered grasses, while dunes and non-irrigated interdunes appear reddish, indicating sparse or stressed vegetation.

Image courtesy G. Henebry, CALMIT/UNL

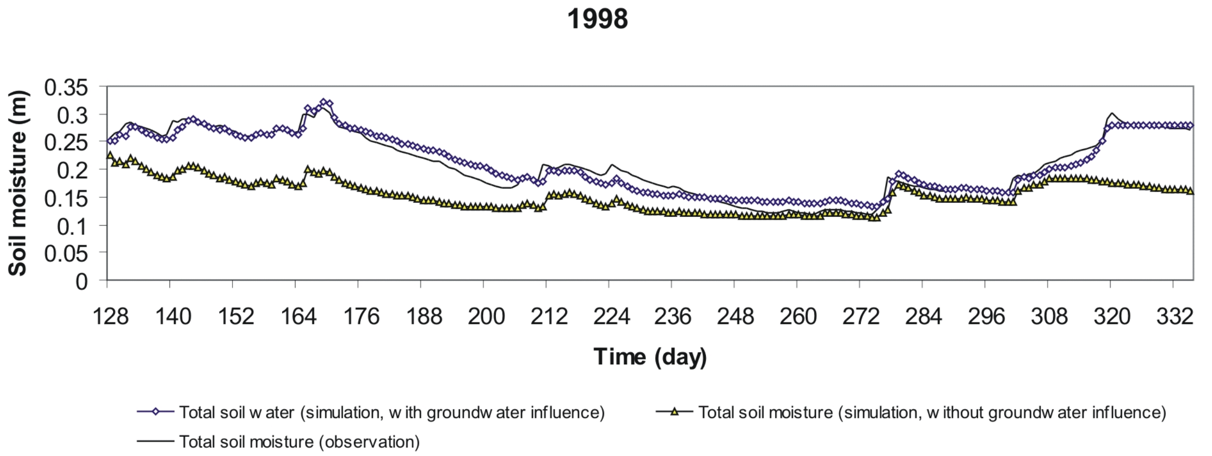

Figure 2: Results of one-dimensional simulations of soil moisture with and without groundwater interactions.

conditions, demonstrate the impact of groundwater inflow on the simulated soil moisture of a subirrigated meadow at the Gudmundsen Sandhills Laboratory in the northwestern Sand Hills (Figure 2). When the model is run without groundwater input, simulated soil moisture in the top 1m is considerably underestimated. However, when groundwater is incorporated into the simulations, the resulting soil moisture levels correspond well to the observations.

2.2 Simulations using MM5

To investigate the potential impact of near-surface groundwater on evapotranspiration, simulations were performed in which the lowest (hereafter referred to as the wet case) or the lowest two (referred to as the wetter case) soil layers in the MM5/OSU land surface model were kept saturated for all grid points within the Sand Hills (Figure 3). Extraction of moisture from the saturated zone by plant roots should contribute to an increase in regional evapotranspiration as compared to a simulation in which the lowest soil layer is allowed to drain freely (the control case). The case chosen for this experiment (0000 UTC 31 July 1986 - 0000 UTC 2 August 1986) exhibited weak northwesterly flow over the region at the 500 hPa level. Convection developed outside the Sand Hills and traveled over the region on 1 August 1986.

Simulations were performed using the latest release (version 3.50) of MM5 (Grell et al. 1994). Three two-way nested domains were defined with grid spacing of 36, 12 and 4 km, respectively, 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

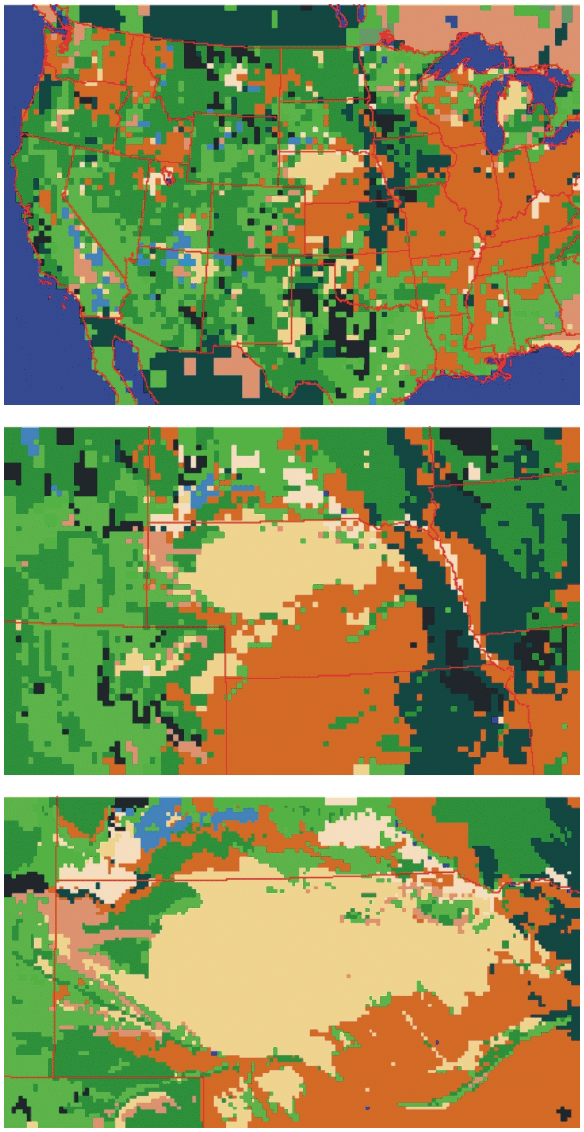

Figure 3: The Nebraska Sand Hills are readily identifiable in all three model domains as a contiguous region of sandy soils.

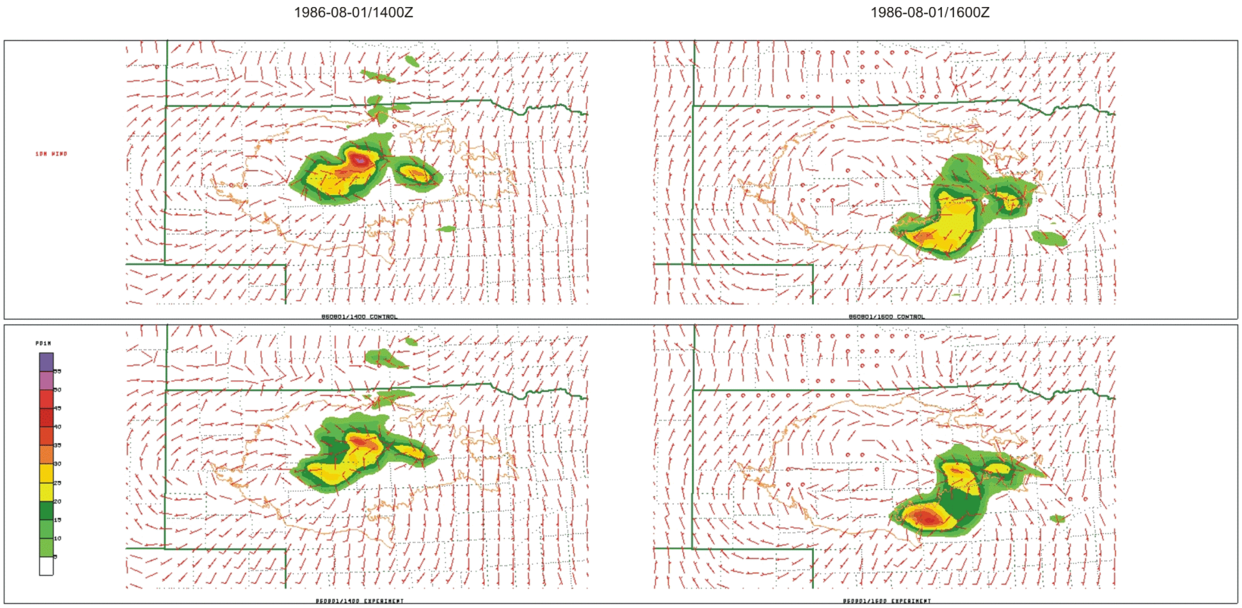

Figure 4: Hourly precipitation (mm) and 10 m winds for the control (top) and wetter soil (bottom) simulations. The earlier and more northerly displaced region of intense convection is apparent in the control case.

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 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 simulations using NCEP/NCAR Reanalysis data for initial soil moisture conditions, it was found that soil moisture levels in the Sand Hills were too high, resulting in unrealistically elevated latent heat fluxes through the entire simulation. By running the outermost domain for 4 days prior to the case study, more realistic soil moisture distributions were allowed to develop that are likely more representative of conditions in the sandy soils of the Sand Hills. In addition, this spinup may help to offset the effects of the well-known precipitation overestimate present in the reanalysis data.

On the day prior to the convective outbreak, daytime sensible heat flux (not shown) is 20-50 W m^{-2} higher in the control run than in the saturated soil runs. As the convective system traverses the Sand Hills in all three model runs, the convective development is delayed in the saturated soil simulations and the most intense precipitation develops along the southern edge of the system. In the control case, development is earlier and along the northern edge of the system (Figure 4).

Perhaps surprisingly, precipitation totals for the innermost domain for the 48 hour simulations decrease in both the wet and the wetter simulations, as compared to the control run. The decreases were less than 5% in each experiment and the cause of these decreases requires further investigation. However, when the domain is separated into Sand Hills and non-Sand Hills regions and the non-Sand Hill region is subdivided into four quadrants (northwest, northeast, southwest and southeast) spatial differences in the precipitation distribution can be noted (Table 1).

Because the deepest soil layer is not accessible to plant roots in the land surface model, saturating that layer has little impact on the precipitation generated by the model over the Sand Hills, with the exception of a 12% decrease in precipitation in the downstream (southeastern) quadrant. This decrease may be the result of reduced sensible heating over the Sand Hills causing a delay in the redevelopment of convection as the system exits the Sand Hills.

In the wetter case, plants have direct access to the saturated soil, increasing evapotranspiration and resulting in a small increase in precipitation over the Sand Hills (Table 1). Furthermore, the decrease in the southeastern quadrant is not as large as for the wet case, as the convection redevelops rapidly as

Table 1: Total precipitation during the 48 hour simulation for the Sand Hills (center box) and each of the four quadrants excluding the Sand Hills. The top number in each cell is for the control run, the second number is for the experiment run, and the third number if the difference between run expressed as a percentage.

Total Precipitation (mm)			
WET: Layer 4 Saturated		WETTER: Layers 3 & 4 Saturated	
17.12 17.29 +1.02%	2.30 2.49 +8.64%	17.11 16.66 -2.65%	2.30 3.06 +33.24%
17.40 17.10 -1.73%		17.40 17.45 +0.30%	
0.37 0.37 +0.32%	24.19 21.28 -12.01%	0.37 0.36 -3.32%	24.19 22.33 -7.70%

the system exits the Sand Hills.

3. SUMMARY

Simulations using MM5 and the OSU land surface model were conducted to investigate the potential for groundwater to interact with the atmospheric environment in the Nebraska Sand Hills by maintaining saturation within the root zone. Extraction of moisture from the saturated zone by plant roots enhances regional evapotranspiration and modifies the atmospheric boundary layer. Although there was little difference in the total precipitation over the Sand Hills and the surrounding region for the simulations presented here for a single convective system moving through the region, future work will investigate the impact of groundwater interactions on total warm-season precipitation in the region.

4. REFERENCES

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