Reprinted from the Preprint Volume of the **Eighth Conference on Hydrometeorology**, October 22-26, 1990, Kananaskis Park, Alta., Canada. Published by the American Meteorological Society, Boston, Mass.

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INFLUENCE OF VEGETATION ON THE WATER AND HEAT DISTRIBUTION OVER MESOSCALE SIZED AREAS

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1. Introduction

Our presentation summarizes our research on the major role of landscape type on planetary boundary layer structure and associated mesoscale systems. Of specific focus is the difference in the partitioning of sensible and latent turbulent heat flux as a function of landuse, which can result, for example, in mesoscale wind circulations as strong as a sea breeze. Over irrigated areas and other areas of unstressed vegetation, boundary layer structure in the lower troposphere can be enhanced sufficiently to result in more vigorous cumulonimbus convection. Even slight differences in vegetation type, due to their different stomatal conductance and albedo characteristics, can cause substantial changes in the atmospheric response.

2. Discussion

Using modeling (e.g., Ookouchi *et al.*, 1984; Segal *et al.*, 1988; Avissar and Pielke, 1989; Pielke and Avissar, 1990; and Pielke and Segal, 1986) and observational studies (e.g., Segal *et al.*, 1989; Pielke and Zeng, 1989; and Pielke *et al.*, 1990a) we have demonstrated that the partitioning of sensible and latent heat fluxes into different Bowen ratios as a result of spatially varying landscape can significantly influence lower boundary layer structure and result in mesoscale circulations as strong as a sea breeze. Over and adjacent to irrigated land in the semi-arid west, for example, enhanced cumulonimbus convection can result as reported in Pielke and Zeng (1989). Schwartz and Karl (1990) document how the appearance of transpiring leaves on vegetation in the spring has the effect of substantially cooling (and thus moistening) the lower atmosphere. In their observational study, Rabin *et al.* (1990) demonstrate the effect on the formation of convective clouds of landscape variability. Dalu *et al.* (1990) have evaluated using a linear model how large these heat patches must be before they generate these mesoscale circulations, while Pielke *et al.* (1990b) present a procedure to represent this spatial landscape variability as a subgrid-scale parameterization in general circulation models.

These landscape variations result from a variety of reasons including:

i). man-caused variations

- agricultural practice (e.g., crop type, land left fallow, deforestation)
- political practices of land subdivision (e.g., inheritance laws, zoning)
- urbanization (e.g., housing developments)
- forest management (e.g., clear-cutting)
- irrigation

ii). natural variations

- fire damage to prairies and forests
- insect infestation and resultant damage to vegetation
- drought

Figure 1 and 2 illustrate observed variations in photosynthetically active vegetation, as measured by NDVI (Normalized Difference Vegetation Index) satellite imagery over the Great Plains of the U.S. Presumably, the active vegetation is transpiring efficiently during the daytime while the other areas, which are either nearly devoid of plants or involve vegetation under water stress, have most of their turbulent heat flux in sensible heat transfer. These two figures illustrate the large spatial <u>and</u> temporal variability of the photosynthetically-active vegetation (and therefore, of the sensible heat flux).

3. Model Results

To extend our study we have performed modeling and observational studies which demonstrate the major importance of vegetation and its spatial gradients on planetary boundary layer structure and mesoscale atmospheric circulations. Figure 3, for example, shows the results of a numerical model simulation with zero synoptic flow for the early afternoon in the summer for (i) a region in which a tall grass prairie is adjacent to a forest region; and (ii) the same as (i) except the tall grass prairie is replaced by wheat. For both simulations, the vertical velocity, east-west velocity, potential temperature, and mixing ratio fields are shown. Among the important results is the generation of a wind circulation as a result of the

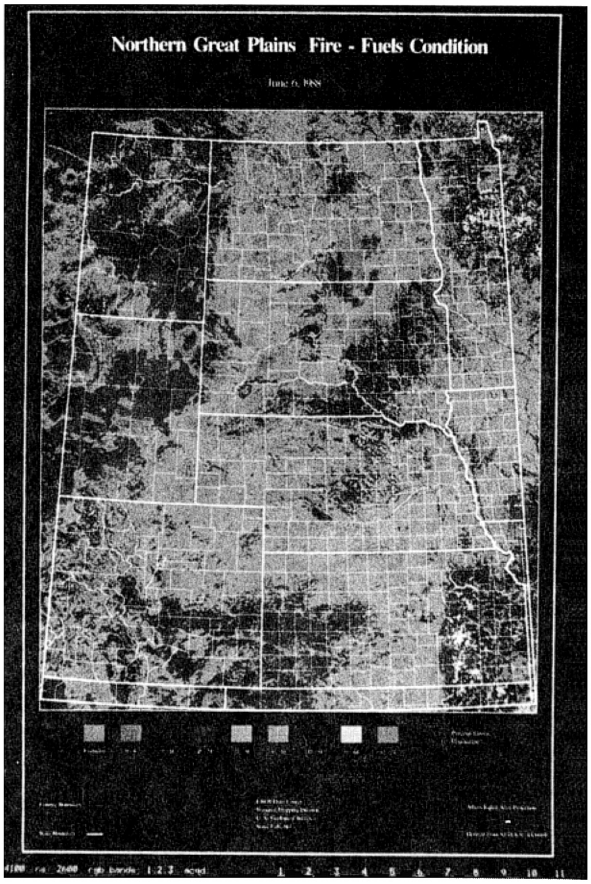

Figure 1. An example of NDVI satellite data for the week ending June 6, 1988, as a tool for assessing the spatial heterogeneity in vegetation state over a region for the northern Great Plains of the United States (photograph courtesy of EROS Data Center, Sioux Falls, South Dakota).

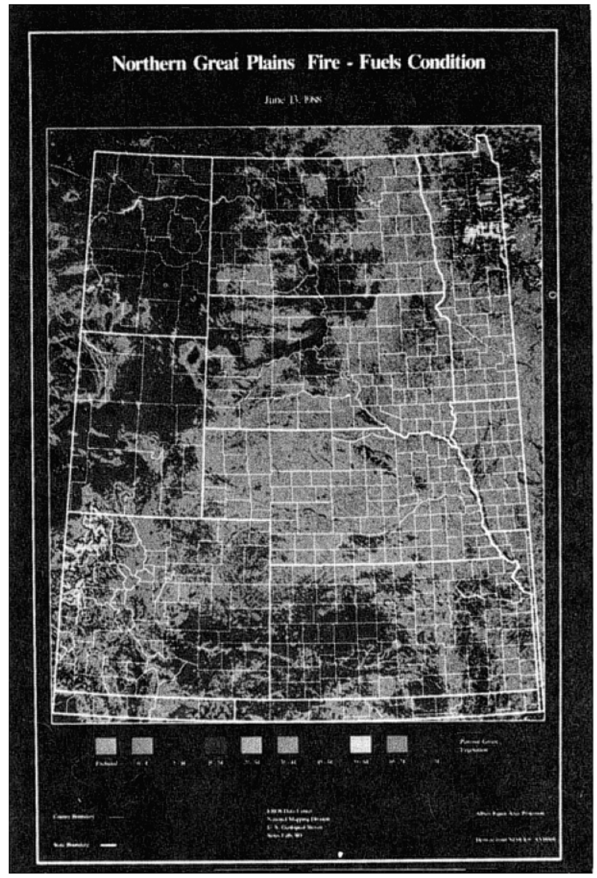

Figure 2. As in Figure 1 but for the week ending June 13, 1988.

juxtaposition of the two vegetation types, and the change in the intensity of this circulation when the prairie is replaced by wheat. Higher transpiration over the forest, in conjunction with the thermally-forced circulation which can advect the elevated low-level moisture into the resultant low-level wind circulation, can be expected to result in enhanced convective rainfall when the synoptic environmental conditions are favorable. Changes in convective rainfall resulting from the changeover of the natural prairie to wheat also seem possible – simulations which include deep convection will be presented at the conference. Note that similar model results were reported by Wetzel and Chang (1988).

Satellite observations support the existence of large gradients in atmospheric conditions across a forest – grassland boundary in the United States, as illustrated in Figure 4 where the highest satellite measured surface skin temperature irradiances are presented for a five week period in 1986 (July 24-August 31) as measured by the GOES geostationary satellite. Temperatures are over 10° C cooler over the forest as contrasted with prairie regions even short distances away (~30 km), as suggested to be the case by the modeling study.

4. Conclusions

This study documents further the major role of landuse on atmospheric boundary layer structures and mesoscale circulations. Even vegetation types as similar as natural tall grass prairie and wheat result in different atmospheric responses. This suggests that man's modification of landscape has had a major role in local climate and, since man has altered vast areas of the land surface, a global response to man-caused land-use changes should be expected.

5. Acknowledgements

The work was sponsored under NSF grant #ATM-8616662 and NOAA/ERL grant #NA85-RAH-05045. The authors would like to thank Jeff Eidenshink from the EROS Data Center in South Dakota for his assistance. The editorial preparation of this paper was ably handled by Dallas McDonald and Bryan Critchfield.

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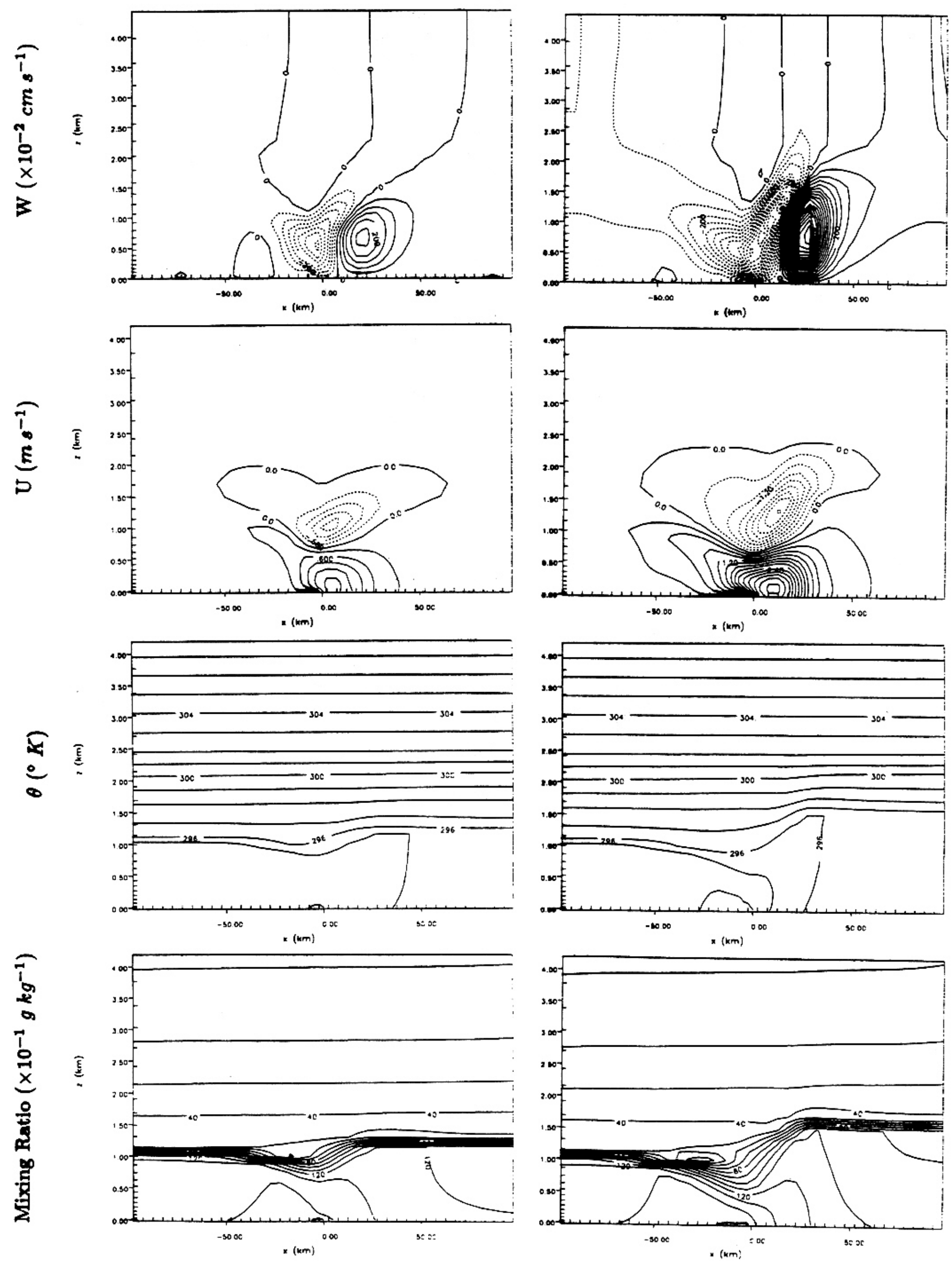

Figure 3. Atmospheric circulation at 1400 LST due to the contrast between a forest (left-hand side) and tall grass prairie (left panels) and a forest and wheat farming (right panels). Contour intervals are (i) 0.5 cm s^{-1} for W; (ii) 0.3 cm s^{-1} for U; (iii) 1 K for θ; and (iv) 1 g kg^{-1} for mixing ratio.

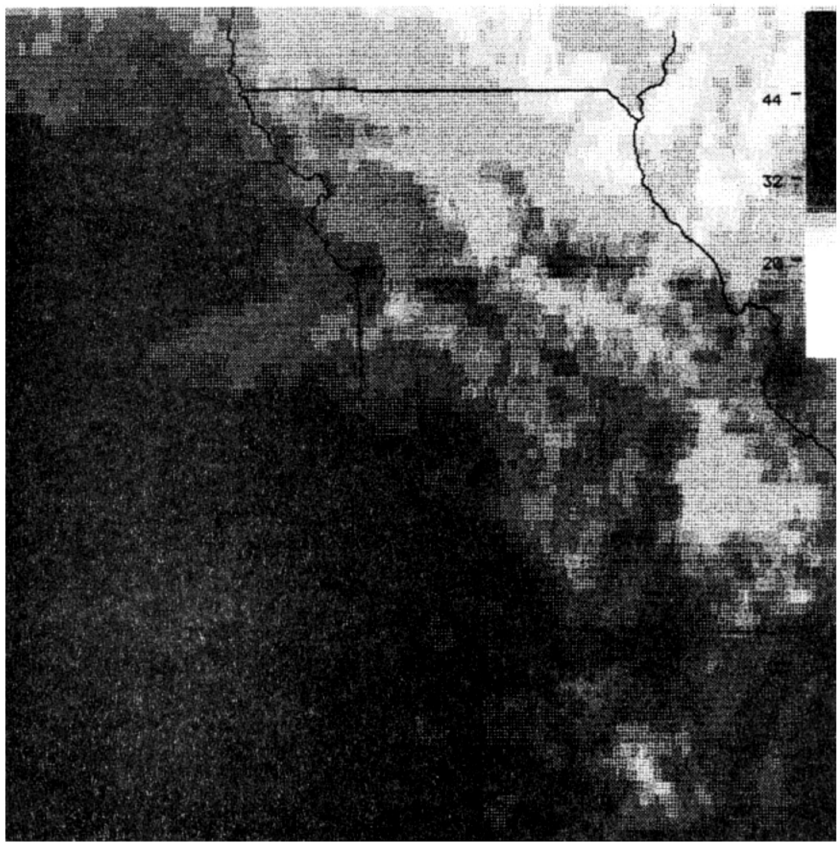

Figure 4. Plot of the highest measured surface skin temperature irradiance in °C as measured by the GOES geostationary satellite from July 24 – August 31, 1986 for a region centered on eastern Kansas and western Missouri.

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