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RESPONSE OF THE ATMOSPHERIC MOISTURE FLUX TO THE SOIL MOISTURE

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1. INTRODUCTION

The response of the atmosphere to spatial variations of soil moisture has been mostly investigated with regional and large-scale numerical models (Entekhabi, et al. 1996). The Southern Great Plains (SGP) Experiment conducted in Central Oklahoma during June-July 1997 provides an unprecedented variety of quality data for examination of this subject.

2. DATA

The spatial variation of the atmospheric boundary layer data are from the Canadian Twin Otter aircraft. The Twin Otter aircraft executed many repeated flights over an east-west oriented flight track near El Reno, Oklahoma. The flight track is about 12 km long. The eastern third of the track consists of mostly grazed and ungrazed grass while the middle part of the track is mainly a mixture of mature winter wheat and bare soil. The western end of the track is partly managed pasture land. The spatial variation of the surface type is also shown from measurements of NDVI (normalized difference of vegetation index) on board the Twin Otter. The NDVI is derived from the reflectances at two channels centered at 730 nm and 660 nm.

The Twin Otter aircraft measures wind velocity, air temperature, humidity, carbon dioxide, and ozone at 32 samples per second. Using ground markers defined by the NDVI, the data for each pass are aligned and stretched according to the aircraft ground speed, allowing accurate compositing of sequential aircraft passes. Fluxes are calculated by averaging products of perturbations from moving windows of 1 km width.

The spatial variation of the surface soil moisture was retrieved from the Electronically Scanned and Thinned Array Radiometer (ESTAR) on board the NASA P-3 aircraft. Variations of radar backscattering from the ESTAR are related to the soil moisture from roughly the top 5 cm of the soil. The remotely sensed surface soil moisture was calibrated using ground in situ measurements (Jackson, et al. 1995). There are 7 days in which both the Twin Otter and the ESTAR data are available in the El-Reno region. The soil moisture along the El Reno track is extracted from the ESTAR images.

3. ATMOSPHERIC RESPONSE TO SPATIAL VARIATION OF SOIL MOISTURE

Our data analysis indicates that the spatial variation of the atmospheric moisture flux is only significant when the solar radiation is strong. During the evening transition period, the turbulence decay is not sensitive to the spatial variation of the soil moisture and vegetation. As the solar radiation increases with time in the morning, the spatial variation of moisture flux becomes most significant. As the atmospheric turbulence becomes strong close to noon, the size of turbulence eddies increases, which can reduce the influence of the spatial variation of the surface on small scales.

Since the atmospheric moisture flux varies with incoming available energy, the measured atmospheric moisture flux is normalized by the net radiation, i.e. the evaporative fraction (Mahrt et al. 1998).

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‡NCAR is sponsored by the National Science Foundation

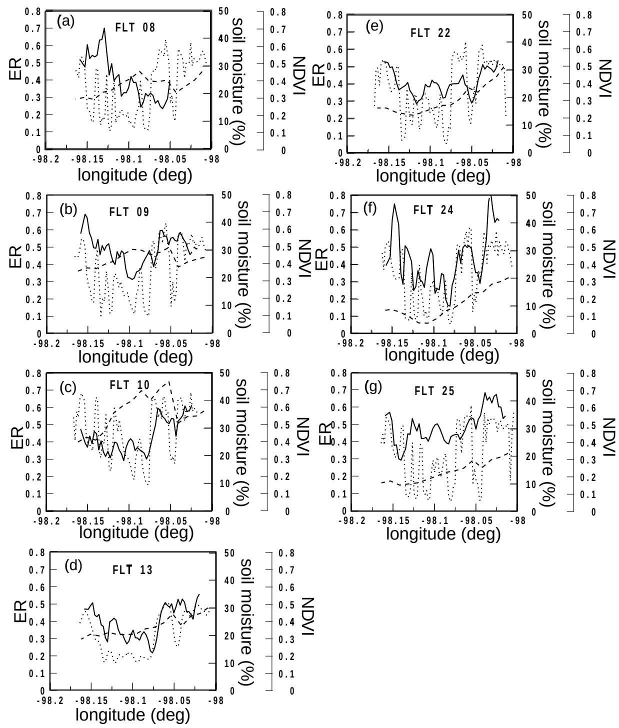

Figure 1: Spatial variation of evaporative ratio (solid lines), soil moisture (dashed lines), and NDVI (dotted lines) along the El Reno flight track for seven flights.

The correlation between the evaporative fraction and soil moisture indicates that the vegetation at both ends of the flight track has strong influence on the atmospheric moisture flux (Fig. 1). The relatively large atmospheric moisture flux at both ends is independent of the surface soil moisture. Evapotranspiration from the vegetation using moisture from the deep root zone may contribute to this result. The root zone never dried out during this experiment.

Since the central part of the El Reno track is dominated by bare ground, and mature winter wheat, variations of the soil moisture between days are correlated to the atmospheric moisture flux, atmospheric water vapor concentration, and surface radiation temperature (Fig. 2). Figure 2a indicates that the atmospheric moisture flux increases with the surface radiation temperature, which is directly related to the sensible heat flux or the buoyancy flux. In other words, the atmospheric moisture flux is dominated by the dynamical aspect of turbulence through the strength of the buoyancy flux, not the availability of the water vapor, at least during this field experiment. The increase of the surface soil moisture leads to reduction of the surface temperature (Fig. 2b), and reduction of the buoyancy flux.

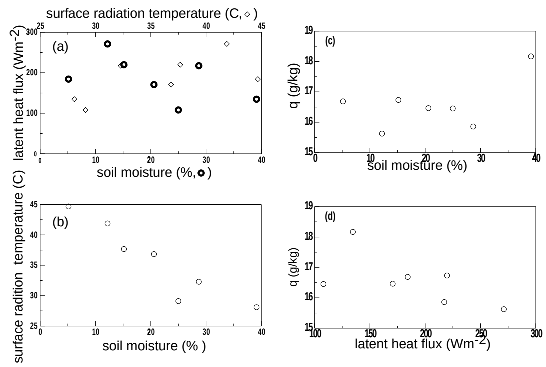

Figure 2: Correlations between the latent heat flux, soil moisture, and surface radiation temperature (a), between surface radiation and soil moisture (b), between the water vapor specific humidity and the soil moisture (c), and the latent heat flux (d). Each symbol represents variables averaged over the central part of the El Reno track from each flight.

As a result, the atmospheric moisture flux is inversely correlated with the soil moisture. Since the atmospheric moisture flux is also driven by the difference between the atmospheric water vapor and the available water vapor at the ground surface, Figure 2d indicates that the moisture flux is inversely correlated with the water vapor mixing ratio in the air. Figure 2d implies two aspects: 1) dry air leads to larger vertical vapor pressure gradient, and enhances the evaporation; 2) the small concentration of the water vapor implies dry soil, which leads to large buoyancy flux, and strong turbulence. As a result, the large moisture flux is related to the lower water vapor specific humidity.

4. SUMMARY

The spatial variation of the atmospheric moisture flux responds to the spatial variation of surface type during the early morning if the wind is not strong. This spatial response stops during the turbulence decaying period in the afternoon. Large turbulence eddies around noon and early afternoon can also reduce the influence of the spatial variation of surface type on the atmospheric moisture flux. The spatial variation of the atmospheric moisture flux is more sensitive to the spatial variation of vegetation than the spatial variation of soil moisture for this experiment. The strength of the atmospheric moisture flux may be inversely related to the soil moisture if the atmospheric moisture flux is dominated by the turbulent strength or buoyancy flux. The relationship between the response of the atmospheric boundary layer to the spatial variation of soil moisture will be further examined over additional flight tracks. These results need will be interpreted in a model setting.

5. ACKNOWLEDGEMENTS

This work is supported by NASA grant NAG-5-8765.

6. REFERENCES

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