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Jornada Experimental Range and Sevilleta LTER: Unique Arid Rangelands to Study Changing Vegetation Cover Using Remote Sensing Systems

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ABSTRACT
The Jornada Experimental Range (Jornada) in southern New Mexico USA and the Sevilleta Long Term Ecological Research site (Sevilleta) in Central New Mexico provide unique opportunities to study changing vegetation patterns using remote sensing techniques. A research program began in 1995 to collect remotely sensed data from ground, aircraft, and satellite platforms to provide spatial and temporal data on the physical, vegetative, thermal, and radiometric properties of the ecosystems (grass, grass/shrub transition, and shrub) typical of arid rangeland of southwestern United States deserts. Data from these different platforms allow the evaluation of physical and vegetation change at different scales. These measurements are being used to quantify heat and hydrologic budgets and plant responses to change in components in the water and energy balance at the Jornada and Sevilleta.

RÉSUMÉ
La chaîne expérimentale de Jornada (Jornada) au New Mexico méridional Etats-Unis et la recherche écologique à long terme de Sevilleta (Seviletta) au New Mexico central fournissent des occasions uniques d'étudier les modèles changeants de végétation en utilisant des techniques de télédétection. Un programme de recherche a commencé en 1995 à se rassembler à distance a senti des données de la terre, d'avion, et de plateformes satellites pour fournir des données spatiales et temporelles sur les propriétés physiques, végétatives, thermiques, et radiométriques des écosystèmes (herbe, transition de herbe/arbuste, et arbuste) typiques du terrain de tir aride des déserts du sud-ouest des Etats-Unis. Les données de ces différentes plateformes permettent l'évaluation du changement de végétation à différentes scales. Ces mesures sont employées pour mesurer les budgets hydrologiques et les réponses d'usine au changement des composants dans l'eau et le bilan énergétique chez le Jornada et le Sevilleta.

INTRODUCTION

Arid and semiarid regions are sensitive to climate variations. Much research has been devoted to identifying changes in rangeland vegetation and vegetation patterns and attempting to link these changes to climate variations. Monitoring changes in these vast areas, which often have limited access, are difficult using conventional techniques. Remote sensing tools offer a unique capability to study and monitor these vast areas for changes and to assess rangeland health. A campaign named JORNEX (the JORNada EXperiment) was begun in 1995 to collect remotely sensed data from ground, airborne, and satellite platforms to complement the ongoing long-term research at the Jornada Experimental Range (Jornada) and to provide spatial and temporal data on the physical and biological state of the rangeland. In 1997, the experiment was extended to include the Sevilleta Long-Term Ecological Research site (Sevilleta). The Jornada Experimental Range is in the Chihuahuan Desert biome in southern New Mexico, USA (Lat. 32° 30' N, Long. 106° 48' W, El ~1300 m, 783 km^2). The Sevilleta is located on the Sevilleta National Wildlife Refuge (NWR) in central New Mexico, USA (Lat. 34° 21´ N, Long. 106° 41´ W, El ~1600 m, 3,600 km^2). The Sevilleta NWR straddles the Rio Grande River riparian corridor at the northern edge of the Chihuahuan Desert biome, the western edge of the Great Plains Shortgrass Prairie biome, and the southeastern edge of the Colorado Plateau Shrub-Steppe biome. The objectives of this study were to use remote sensing platforms (ground, aircraft, and satellite) to provide spatial and temporal data on the physical and biological states of the different biomes, to quantify plant responses to changes in components in the water and energy balance, and to evaluate techniques of scaling remote sensing data.

METHODS

Study sites typical of the major vegetation communities were chosen for intensive study. At the Jornada, grass [*Bouteloua eriopoda* (Torr.) Torr.], playa (grass) [*Hilaria mutica* (Buckley) Benth.], mesquite [*Prosopis glandulosa* Torr.], a grass/mesquite transition, creosote [*Larrea tridentata* (Sesse & Moc. ex DC.) Coville], and tarbush [*Flourensia cernua* DC.] vegetation communities were chosen as study sites. At the Sevilleta, mixed grass and creosote communities were chosen as study sites. Vegetation monitoring at the Jornada since 1912 and at the Sevilleta since 1988 indicates that shrubs (mesquite, creosote, and tarbush) are slowly encroaching into the original grass dominated communities. Ground, aircraft, and satellite measurement campaigns have been made in the Spring (May/June) and Fall (September/October) since 1995 centered on the date of an overpass of Landsat or ASTER satellites.

At each study site a 30x30 m grid and either a 150-m (Jornada) or a 400-m (Sevilleta) transect were established. Ground measurements of landscape surface temperature were measured using thermal infrared radiometer (IRT) at 5-m grid interval over the 30x30 meter grid. Radiance/reflectance of plant canopy and soil were measured using an Analytical Spectral Devices (ASD) full range (0.35 - 2.5 μm) spectroradiometer at the same 5-m interval on the grid and also at 5-m intervals along transects in each vegetation community. Leaf-area index (LAI) was measured with a LICOR LAI-2000 instrument along the transects.

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An ARS aircraft stationed at Weslaco, Texas was used to collect thermal (IRT), 4-band spectral radiance (Exotech), multispectral digital images, and Global Positioning System (GPS) data at 100 and 300 m AGL (Above Ground Level) along flight lines crossing all the selected study sites. Flights of the Thematic Mapper Simulator (TMS) or MASTER (MODIS/ASTER Airborne Simulator) instrument were made from 1998 to 2003.

Satellite data from Landsat Thematic Mapper (TM) and ASTER have been acquired for the cloud free days during the campaigns to be used for scaling ground and aircraft measurements to larger areas. AVHRR and GOES satellite data are also available to assess the value of different resolution data sets. More details on methods, instrumentations, and data are discussed in Rango *et al.* (2006).

RESULTS

Leaf area index (LAI) has been measured with a LAI2000 along the linear transects at the Jornada and Sevilleta has varied greatly over the time period. In general at the grass site, LAI is higher in the Spring than in the Fall. While at the transition site the reverse is generally true, namely, the LAI is higher in Fall than in Spring. The mesquite site LAI has no consistent pattern, whereas the creosote and tarbush sites generally had a greater LAI in Spring. LAI was low at all sites in September 2001 due to low rainfall in the Spring and Summer. Variability in the range of LAI has increased since 1995, with greater fluctuations in measurements in recent years. In general LAI tended to decrease with increasing shrubs and decreasing grass.

Radiance data measured at 1-m above the landscape surface with the ASD Full Range Spectroradiometer and averaged for 49 measurements made at 5-m intervals on a 30 x 30m grid showed total radiance (0.35 - 2.5 μm) to be 12 to 40% higher at shrub sites than the grass sites. Differences between years, seasons, and vegetation were found but the shrub sites always had higher radiance values. Radiance measured from the aircraft at 100 and 300-m AGL with an Exotech 4-band radiometer with filters for the first 4-bands of the Landsat TM showed greater variability and higher radiance at the shrub sites than at the grass sites. The higher radiance and variability over the shrub site would be due to the patchy nature of the shrubs. The higher radiance measurements both from the ground and aircraft were probably due to the lower surface cover (LAI) at the shrub sites giving a higher soil contribution to the total radiance measured.

Aircraft data from digital images, Thematic Mapper Simulator (TMS), and MASTERS instruments also measured higher radiance over the shrub sites when compared to the grass sites. Only the grass community spectrum showed a significant change in between Spring and Fall campaigns. The reduction in the magnitude of the grass community radiance spectrum in the Fall campaign would be related to the increased biomass of grass caused by the Fall monsoonal rain patterns in the region. This increase in biomass would increase ground cover and reduce soil contribution to the measured radiance spectrum thus lowering the total radiance spectra.

A comparison of reflectance measurements from the ASD, MASTER, and ASTER instruments showed that reflectance increased from grass to transition to mesquite communities from all three platforms. Patterns of reflectance were similar from the three platforms with MASTER and ASTER having similar absolute values (Fig. 1). Comparison of absolute values of ASD ground measurements with MASTER and ASTER measurements differed with different vegetation communities but in general ASD reflectance measurement were slightly lower than MASTER or ASTER measurements. These differences are assumed to be related to the integrated measurement of different sized footprints of the instruments and probably the lower soil cover in the ASD footprint.

In general, as canopy ground cover decreased from grass to transition to shrub communities, radiance/reflectance measured from all instrument increased, indicating a potential for change in heat and water balance of these ecosystems if shrubs continue to expand into the grass communities. These data suggest that changes of vegetation from grass to shrub communities could have significant effects on the albedo, the surface temperatures measured at the different sites, and the overall water and heat balances in these communities.

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Landscape surface temperatures measured from the aircraft and on the ground with IRTs were 3 to 5° C higher at the shrub communities than the grass communities on clear days at 1 p.m. local time following the pattern of the radiance. MASTERS and ASTER measured temperatures were also 2 to 4° C higher at the shrub site. Good agreement was found between ground, MASTER, and ASTER data for the measurement of landscape surface temperature.

These results indicated that a temperature emissivity separation algorithm developed for use of MASTER data appears to work as well with the data from ASTER. This is encouraging for the application of the technique for mapping emissivity over large areas.

CONCLUSIONS

A unique remote sensing data set to measure change in semiarid grass and shrub communities is being collected at the Jornada and Sevilleta in New Mexico, USA. Radiance measured at ground and aircraft platforms was 12 to 40% higher for a 30 x 30m grid area at shrub sites than at the grass sites. Landscape surface temperatures were 3 to 5 °C higher temperatures for a 30 x 30m grid area at the shrub site than the grass site by 1 p.m. local time. These differences in surface radiance and temperature between shrub and grass sites could have significant effects on the energy and water balances of the Jornada and Sevilleta as shrubs continue to expand at the expense of the grassland.

REFERENCES

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Figure 1. Comparison of Ground (ASD), Aircraft (MASTER), and Satellite (ASTER) reflectance data.