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# JORNEX: A MULTIDISCIPLINARY REMOTE SENSING CAMPAIGN TO QUANTIFY PLANT COMMUNITY/ATMOSPHERIC INTERACTIONS IN THE NORTHERN CHIHUAHUAN DESERT OF NEW MEXICO

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## 1. INTRODUCTION

The Jornada Experimental Range in southern New Mexico provides a unique opportunity to integrate hydrologic-atmospheric fluxes and surface states, vegetation types, cover, and distribution, and vegetation response to changes in hydrologic states and atmospheric driving forces. As a National Science Foundation (NSF) Long-Term Ecological Research (LTER) site and a United Nations (UN) Man and the Biosphere (MAB) site, the Jornada Experimental Range has been recognized as a valuable location for long term ecological research programs to investigate the processes related to desertification. The ongoing investigations within the LTER have yielded a wealth of ground data about the basin vegetation characteristics, ecosystem dynamics, and vegetation response to hydrologic-atmospheric inputs. Measurements and studies at Jornada date back to 1912 (Ares, 1974).

In concert with the ongoing programs of ground measurements, a campaign named JORNEX (the JORNada EXperiment) was begun in 1995 to collect remotely sensed data from ground, airborne, and satellite platforms to provide spatial and temporal data on the physical and biological state of the rangeland. Data on distribution of vegetation state were measured on the ground with detailed vegetation surveys (cover, composition, height) at preestablished transects. Remotely-sensed data included ground- and aircraft-based visible, near infrared, and thermal infrared radiometers and airborne multispectral digital video and a laser altimeter. Satellite observations were from Landsat Thematic Mapper, NOAA-AVHRR, and GOES. Surface energy balance estimates were made using Bowen ratio and eddy correlation techniques. Different platforms (ground, aircraft, and satellite) allow the evaluation of landscape patterns and states at different scales. These measurements are being used as inputs to quantify the hydrologic budget and plant response to changes in components in the water and energy balance. This paper covers preliminary results from the 1995-1997 field campaigns.

## 2. STUDY AREA

The Jornada Experimental Range, the largest Agricultural Research Service (ARS) field station (783 km$^2$), is located 37 km north of Las Cruces, New Mexico and is about one-fourth the size of Rhode Island (Ares, 1974). Most of the Experimental Range is on the Jornada del Muerto Plain of the Chihuahuan Desert at about 1220 m elevation. It lies between the Rio Grande Valley on the west and the San Andres Mountains on the east in the northern part of the Chihuahuan Desert (see Figure 1). The crest of the San Andres Mountains is about 2440 m and coincides with the eastern boundary of the Experimental Range.

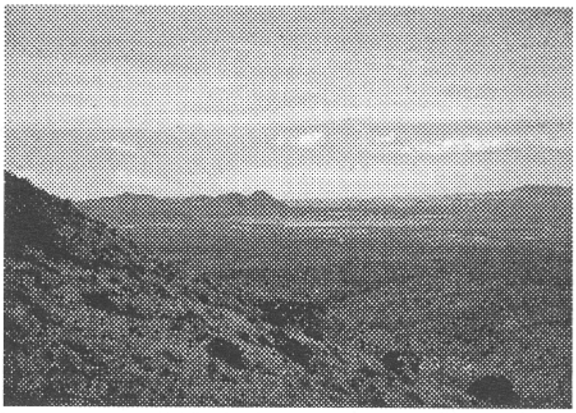

**Figure 1.** Looking west across the Jornada del Muerto Plain from the slopes of the San Andres Mountains.

The climate is characteristic of the northern region of the Chihuahuan desert, the most arid of the North American grasslands. Annual averages for precipitation

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and temperature are 241 mm and 15 C, respectively. Approximately 55% of the annual precipitation occurs as localized thunderstorms during July, August and September. Droughts (<75% of average annual precipitation) are common, and have occurred in 18 years from 1915-1995. The frost free period averages 200 days, but the effective growing season, especially for perennial grasses, is limited to the summer months. High temperatures, low humidities, and frequent winds (annual average wind movement is 17,346 km) result in large water losses by evaporation. Potential evaporation rates are approximately 10 times the average precipitation.

The vegetation of the Jornada del Muerto Plain is characteristic of a subtropical ecosystem in the hot desert biome. Grasses are entirely C4 and principal dominants include black grama (*Bouteloua eriopoda* (Torr.) Torr.) mesa dropseed (*Sporobolus flexuosus* (Thurb. Ex Vasey) Rydb.) and three-awn (*Aristida purpurea* Nutt. and *Aristida pansa* Wooton & Standl.) . Shrubs and suffrutescents are commonly C3 and include honey mesquite (*Prosopis glandulosa* Torr.), Western honey mesquite (*Prosopis glandulosa var. torreyana* (L. Benson) M. C. Johnston), fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.), Broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britton & Rusby), and soaptree Yucca (*Yucca elata* (Engelm.) Engelm.). Seasonal rains can trigger flushes of both annual and perennial forbs such as spectacle pod (*Dithyrea wislizenii* Engelm.), Desert baileya (*Baileya multiradiata* Harv. & Gray) and leatherweed croton (*Croton pottsii* (Klotzsch) Muell. Arg.). Grass communities dominated by black grama have been susceptible to disturbances (such as prolonged drought and overgrazing), and encroachment by shrubs during the last century has been common.

Large areas of former grassland, including the northern portion of the study area, are now dominated by honey mesquite. This conversion on these deep, coarse-textured soils characteristically resulted in formation of coppice dunes, increasing spatial heterogeneity of critically limited nutrients (especially N) required for plant growth (Schlesinger et al., 1990), and increased wind erosion (Gibbens et al., 1993). It is unlikely that these vegetation conversions are reversible without substantial external inputs that could not be regarded as sustainable. The study area encompasses an ecotone between a remnant black grama grassland and a honey mesquite coppice duneland that developed in the past 80 years. Without subsequent intervention further desertification of this grassland is anticipated during the next century.

Within the large Jornada Experimental Range, three specific sites were chosen for intensive studies. Sites were selected to represent grass, shrub, and grass-shrub transition areas. Black grama dominates the grass site and is within a long term study area where grazing has been excluded. The site is relativity level (see Figure 2). Honey mesquite on coppice dunes dominates the shrub site. The dunes vary in height from 1 to 4 m with honey mesquite on each. The area between dunes is usually bare soil (see Figure 3). The grass-shrub transition site is an area between the grass and shrubs with vegetation components from both. Some dunes are present but are usually less than 1 m in height.

**Figure 2.** Radiometric measurements taken at the grass site using a backpack-yoke system in September 1996.

**Figure 2.** Mesquite coppice dunes at the shrub site with bare soil interdunal areas in September 1995.

## 3. METHODS

In order to expand the knowledge gained at Jornada from long-term studies at points, transects, and small plots, several remote sensing data platforms have been employed to evaluate the effects of scale. At sites where experiments have been conducted or where long-term monitoring has taken place, hand-held or ground-based remote sensing data have been acquired along with additional kinds of "conventional" measurements. In the grass, shrub, and transition sites, measurements of vegetation/soil reflectance and temperature are acquired along linear transects and at pre-established grid points using visible/near infrared radiometers, thermal infrared radiometers, and more sophisticated spectroradiometers. Ground surveys of vegetation type and height, leaf area index, and topographic variation are also made.

The ground measurements are coordinated with an airborne remote sensing campaign of three days centered on a Landsat overpass. The aircraft coverage is provided primarily by a remote-sensing equipped Aerocommander, but supplemented at different times by other remote sensing aircraft from other government agencies and private companies. The aircraft coverage is centered over the areas covered by the ground-based remote sensing as well as covering large portions of the Jornada adjacent to these sites. The Aerocommander acquires visible, near infrared, and thermal infrared radiometer data identical to the ground transect and grid measurements. It also acquires digital video data in three bands with a 92 m swath width along with integrated global positioning system (GPS) data.

There is also a pulsed gallium-arsenide diode laser altimeter mounted in the Aerocommander to measure distance from the airplane to the landscape surface. Differences between bare soil and vegetation are easily distinguished as are changes in topography and canopy height.

Landsat Thematic Mapper data are acquired for the overpasses coincident with the field campaigns. Selected SPOT, NOAA-AVHRR, and GOES data are also acquired to provide a wider range of resolution coverage for the Jornada. Upscaling of the ground-based and aircraft data to the satellite resolutions are being attempted. In addition, combination of various data types, such as, Landsat TM and aircraft laser data, is being attempted to increase information content.

To complement the remote sensing measurements, surface energy fluxes have been monitored continuously since May 1995 using the Bowen Ratio energy balance method and periodically (during intensive field campaigns) with eddy correlation systems. The Bowen Ratio measurements have been made at the grass and shrub sites while the eddy correlation measurements have been made at numerous sites at heights ranging from 2 m to 25 m through the use of towers.

Intensive ground and airborne campaigns have taken place during dry seasons (May 1995, 1996, and 1997), wet seasons (September 1995 and 1996 and October 1997), and one dormant season (February 1996). During one or more campaigns, additional ground or aircraft data have been acquired by the following instruments: AVIRIS, TIMS, TMS, CIMEL, and PARABOLA.

## 4. RESULTS

As the data set continues to build in size, methods are currently being developed to distribute the data to JORNEX participants and eventually to other investigators. The data set should be of interest to those studying arid regions, vegetation change, and climate processes. A web site will eventually be used for data distribution.

Some early results have been generated by the investigative team. Figure 4 shows a comparison between aircraft-based surface temperatures measured on May 21, 1995 and September 25, 1995 from the Aerocommander with an 80 m footprint over the shrub site. The airborne temperatures correspond closely with the ground measurements. The aircraft-based surface temperatures for the May transect illustrated in Figure 4 range from 52.6 to 37 C with an average for the line of 46.8 C. For the September transect the airborne temperatures range from 45.9 to 36.8 C with an average of 42.7 C. Higher surface temperatures observed for the May flight reflect higher radiation and drier moisture conditions than in September after the rainy season. With observations of air temperature and windspeed over the shrub site, an estimate of sensible heat flux, H, was computed for each surface temperature pixel by assuming air temperature and windspeed remained uniform over the transect (see Kustas et al., 1990 for details). The resulting sensible heat flux transects for May and September are illustrated in Figure 5. For the May transect, H ranges between 350 to 125 W/m$^2$ with the average being approximately 270 W/m$^2$. For September, H ranges from 220 to 115 W/m$^2$ with the average being approximately 185 W/m$^2$. Surface flux observations indicate H of 300 W/m$^2$ for May and around 250 W/m$^2$ for September. The latent heat flux, $\lambda E$, measured at the shrub site was 50 W/m$^2$ for May and 85 W/m$^2$ for September yielding Bowen ratios (i.e., $H/\lambda E$) of 6 and 3 for May and September, respectively. This indicates more of the available energy ($Rn$ - $G$) was being partitioned into evapotranspiration in September than in May. Methods to derive spatially distributed evapotranspiration maps with the remotely sensed data for the different campaigns are underway.

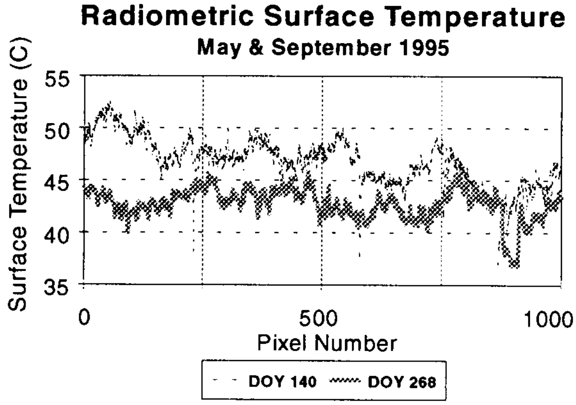

**Figure 4.** Surface temperature measured with an infrared radiometer mounted on the Aerocommander aircraft May 21, 1995 (DOY 140) and September 25, 1995 (DOY 268).

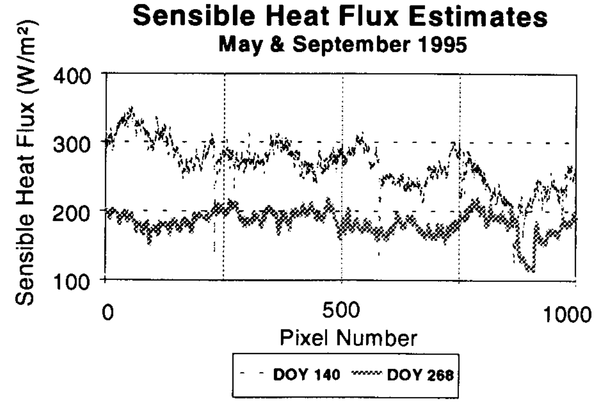

**Figure 5.** Sensible heat flux estimates using airborne surface temperatures and ground observations of air temperature and windspeed at the shrub site for May 21, 1995 (DOY 140) and September 25, 1995 (DOY 268).

Figure 6 and 7 show the roughness differences between the grass and shrub sites. Both general topographic differences (level grassland and rolling duneland) and vegetation differences (smoother grassland and rough mesquite dunes) are evident from the laser altimeter data. The laser data is being used to calculate the aerodynamic roughness similar to Menenti and Ritchie (1994).

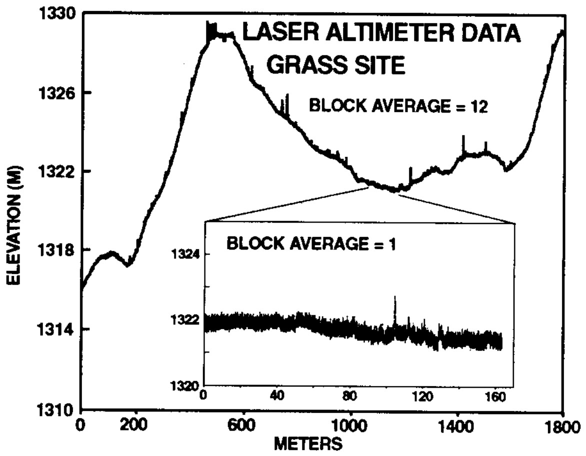

**Figure 6.** Laser altimeter measurement of topography and surface roughness at the grassland site on May 19, 1995 and displayed using a 12-measurement block average.

## 5. ACKNOWLEDGEMENTS

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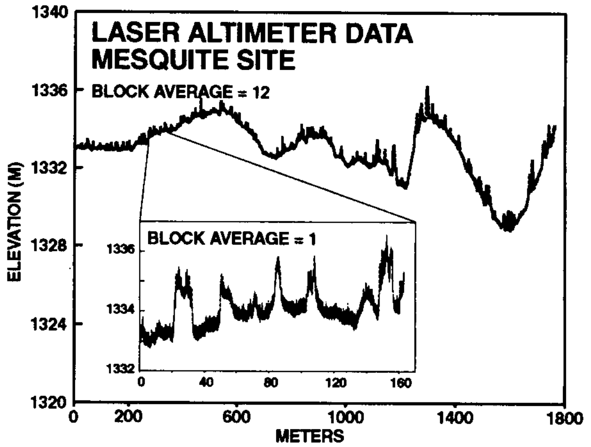

**Figure 7.** Laser altimeter measurement of topography and surface roughness at the shrub (duneland) site on May 19, 1995 and displayed using a 12-measurement block average.

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