

LiDAR Surveys of Gypsum Dune Fields in White Sands National Monument

Introduction

In 2008, the Chihuahuan Desert Network began supporting a three-year survey of the gypsum dune fields in White Sands National Monument (NM) by the University of Texas-Austin. The survey will produce the first LiDAR (Light Detection and Ranging) surveys, a highly accurate mapping method, of White Sands NM and provide the first 3-D topographic data of the dune fields. The purpose of this project is to collect data that will help determine similarities in shape and size of dunes, detect trends in the direction of migration, and observe interactions between dunes. By conducting multiple surveys, researchers can detect changes over time, including the migration rate of dunes, changes in shape related to the wind regime, and the dynamic exchange of sediment between dunes and the substrate (surface) they migrate over. The researchers will also determine the decadal dune dynamics and draft a protocol for monitoring dune dynamics. The study area is a representative strip of the dunes field, which is a wet aeolian (wind-related) system. The behavior of the substrate is a function of the water table.

Methods

LiDAR is an active remote sensing system that uses a laser scanner mounted to the bottom of an airplane with a Global Positioning System (GPS) unit and equipment to measure movement of the aircraft. LiDAR can produce highly accurate elevations and detect changes in land cover, such as vegetation, buildings, and vehicles. The researchers are using the LiDAR data to create an accurate digital elevation model (DEM) or 3-D map of the study area. The study will measure the height, shape, spacing, surface coverage, and volume of the dunes from the 3-D map and determine trends in the study area.



Researchers used aerial photos and field study in addition to the LiDAR surveys to determine changes in dune migration and behavior over decades.

Results

In June 2007, the researchers conducted the first LiDAR survey and basic data processing to create the 3-D map of the dunes and substrate, and collected auxiliary water table and wind data. The substrate, revealed with the LiDAR data, shows three terraces that correspond to the high-water levels of Lake Otero, an extinct Pleistocene lake, and subsequent wind events that eroded the gypsum into sand. The trend of small, dry interdune areas and large, wet interdune areas correspond to the terrace locations. In February 2008, a second LiDAR survey, separate from this study, was conducted by the National Center for Airborne Laser Mapping based at the University of Houston. The purpose of this survey was to compare the dune shapes to

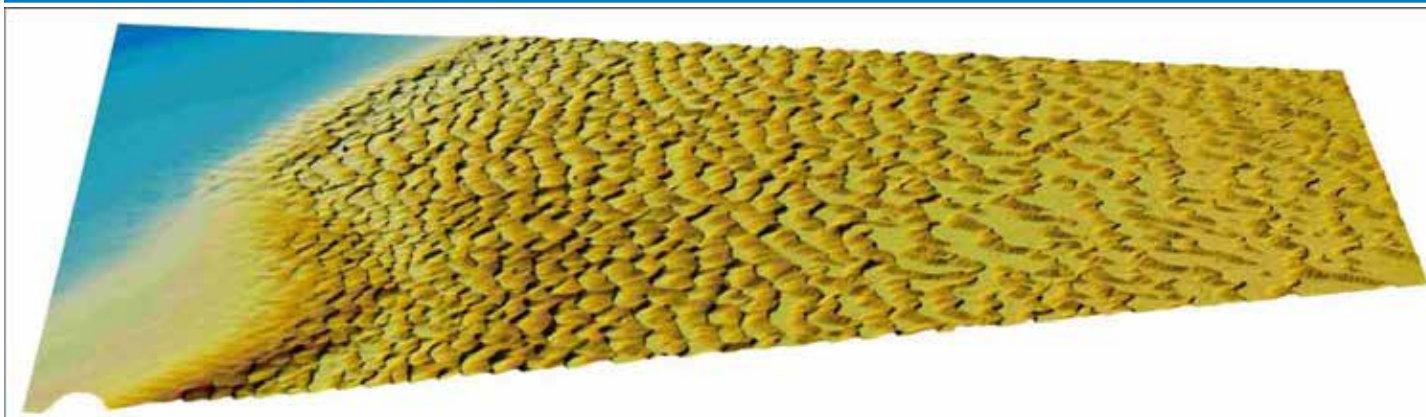
Objectives

By conducting multiple surveys, researchers can detect changes over time, including the migration rate of dunes, changes in shape related to the wind regime, and the dynamic exchange of sediment between dunes and the surface they migrate over.

Objective 1 - Help determine similarities in shape and size of dunes.

Objective 2 - Detect trends in the direction of migration over time.

Objective 3 - Observe interactions between dunes.



A 3-D map created using dune field data collected at White Sands NM.

the June 2007 survey to understand the type and degree of shape change in the dunes as a function of the winter wind regime.

The researchers conducted the third LiDAR survey of the study area in June 2008. The data were used in combination with 40 years of work on aerial photos to demonstrate dune migration rates over a year by creating the first of several difference maps for the project of the two June surveys. Difference maps will be the primary documentation of how the dunes change in shape as they migrate.

There was no consistent change in dune height in the survey area, but the erosion of the windblown side (stoss) and deposition side (lee) of the dunes demonstrated

the migration. The crescent-shaped dunes are actively migrating at rates that decrease sharply from the upwind area of the dune field and then remain relatively constant. The parabolic dunes, which are anchored on each end by vegetation, were the least active dunes. Deposition and erosion were inconsistent, which indicated a more random pattern than typical migrating dunes. The researchers are determining the impact of dune interactions on pattern evolution.

Interpretation of the LiDAR data indicates migration rates are impacted by the surface on which the dunes travel. The fastest migration rates occur where the dunes are higher, drier, and more closely spaced. Dunes in the wet interdune areas have the slowest migration. The rates of elevation

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This image from the National Aeronautics and Space Administration (NASA) shows a dust storm blowing across the gypsum dunes at White Sands NM.

change in the lee correspond with the angle formed between the dune's crest and the wind vector for the prevailing winds from the southwest (incidence angle). This is consistent with theory and published examples, though it is the first time this relationship has been documented systematically on whole dunes and documented by LiDAR results.

Researchers also documented new dune interactions using aerial photos and LiDAR images, significant bedform and defect repulsion, which were previously unrecognized in aeolian dunes. As defects (ends of dune crests) or main bedforms approach each other, the dunes rearrange by recombining and breaking away. This pattern occurs throughout the dune field. Other newly observed interactions include: merging, lateral linking, defect creation, and off-center collision. The differences in migration rate of the main dune and the defect are a function of differences in elevation.

Basic attributes about dunes and relationships between those attributes characterize the dune pattern. The researchers randomly selected 100 dunes and separated them from the substrate and collected these measures: dune area, dune volume, dune height, crest length, spacing, crestline sinuosity, dune surface area, crest orientation, and stoss slope. The researchers anticipate completing this aspect of the study by May 2010.

A fourth LiDAR survey of the study area was conducted in September 2009, from which the effects of the summer winds could be determined. High-resolution aerial photos (i.e., a visual spectrum survey) were also taken in July 2009. A fifth and final LiDAR survey was conducted in June 2010. A difference map of this and the June 2007 survey allowed the dune migration over three years to be determined.

Current Work

The researchers are conducting statistical processing of data from the June 2007 LiDAR survey. Data suggest that the relict shorelines control the spacing of the dune field. The researchers are also creating difference maps from the new LiDAR images. The June 2007 and 2008 maps can be used to determine net migration and behavior differences over a year. The June 2008 and January 2009 maps can be used to determine the impact of the winter wind regime. The researchers are also examining changes in the dune pattern and the correlation of changes in sand with the specific incidence angle made by the wind and the dune crest.

Discussion

Because the dune field is influenced by water, LiDAR surveys indirectly address groundwater issues at White Sands NM. The data from LiDAR and high-resolution photo surveys may also be used for educational purposes like flyover videos. The researchers are preparing manuscripts about bedform interactions and boundary conditions, statistical analysis of the dune pattern, and

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sediment flux over the field as reflected in the difference maps. These papers will contribute to advancing the body of knowledge in this field. The project will also support an upcoming hydrological ingestion for the monument.

