Vegetation Effects on Entrainment and Transport of Sand: Keeler Dunes

J.A. Gillies, N. Lancaster, E. Furtak-Cole
Desert Research Institute
Reno NV

Keeler Dunes Project Meeting
August 24, 2011, Keeler CA

Project Objectives

- This part of the Keeler Dunes study addresses two components of the larger study:

1. What is the nature of sand motion and dust emissions within the dunes?
2. What methods can be used for stabilization and control of the dunes and how can they be implemented?

Specific Objectives

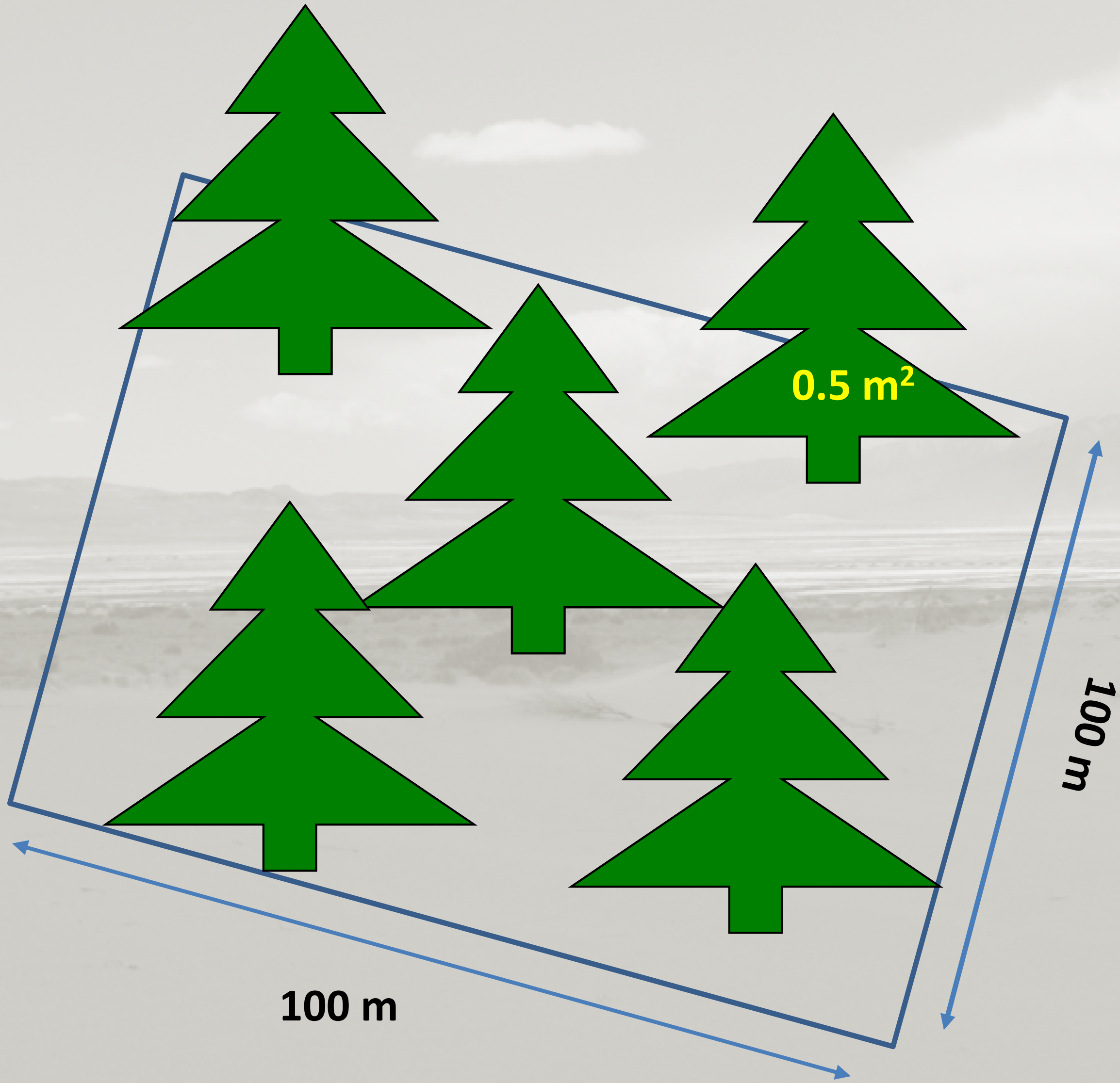
- Instrument different parts of the Keeler & Swansea Dunes to evaluate the effect different vegetation patterns have on sand movement threshold, sand transport, and by extension dust emissions (i.e., dust flux is proportional to wind speed and sand flux)
- Identify the relationships between vegetation and threshold and sand flux
- Evaluate directional wind effects on threshold and sand flux

Methods

- Sites were selected in Keeler Dunes based on available data on plant distributions and plant cover
- Wind speed, wind direction, and sand transport instrumentation were placed in the Keeler Dunes and Swansea at 17 locations
- Plant surveys were conducted to characterize the vegetation conditions at each monitoring site (height, width, number, in a known area surrounding the sensor station)

Vegetation Roughness Density λ=(# plants × mean frontal area)/surface area occupied by the # plants measured

Methods



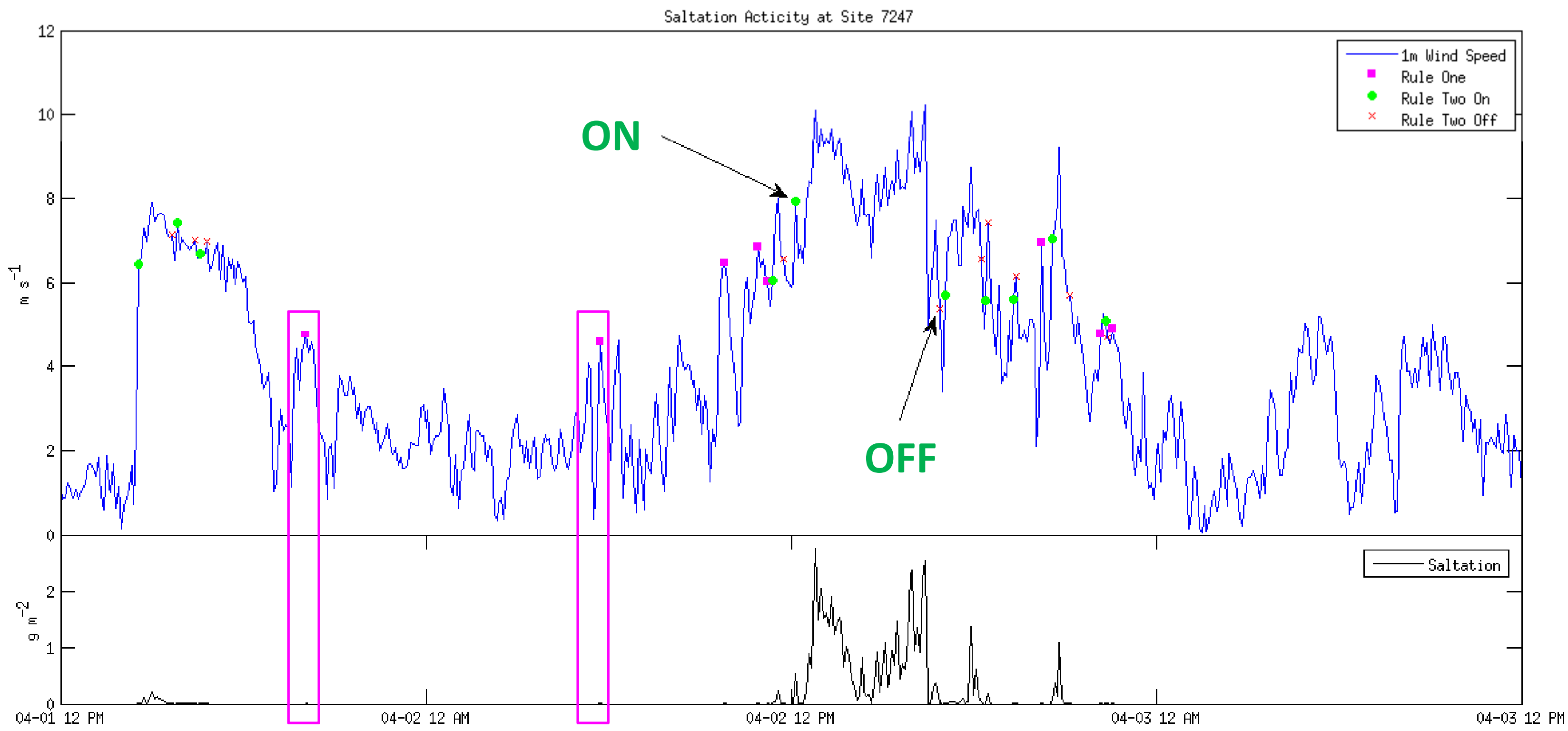
$\lambda = (5 \times 0.5\ m^2)/100\ m^2$

$= 0.025$

λ is a Frontal Area Index of Roughness

Data Analysis

- **Wind and sand transport data were collected during the period 01-22-2011 to 4-4-2011**
- **Wind speed and wind direction data for a consistent height of measurement (1 m) were compiled for the 17 sites**
- **Wind direction data from the instrumented sites were used to interpolate/extrapolate wind direction to the sites without wind vanes**
- **Threshold wind speed values for each site were calculated (for winds at 1 m height and the available Sensit data) using a new method developed at DRI for this project**
- **Threshold wind speeds for sites with wind speed measurements at 4 m height were calculated as well**



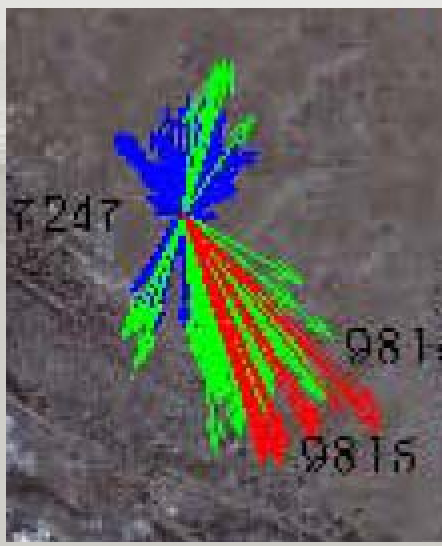
Threshold is defined as the mean of the wind speed at the time the Sensit registers activity and when activity ceases.

One rule: saltation events occurred within the 5 min. measurement period

Two Rule: saltation occurs for a minimum of 2 consecutive measurement periods (identify wind speed when saltation begins, identify wind speed when saltation ceases)

Data Analysis

- **Sand flux data were combined with the wind speed and wind direction data to produced sand roses for each of the test sites**



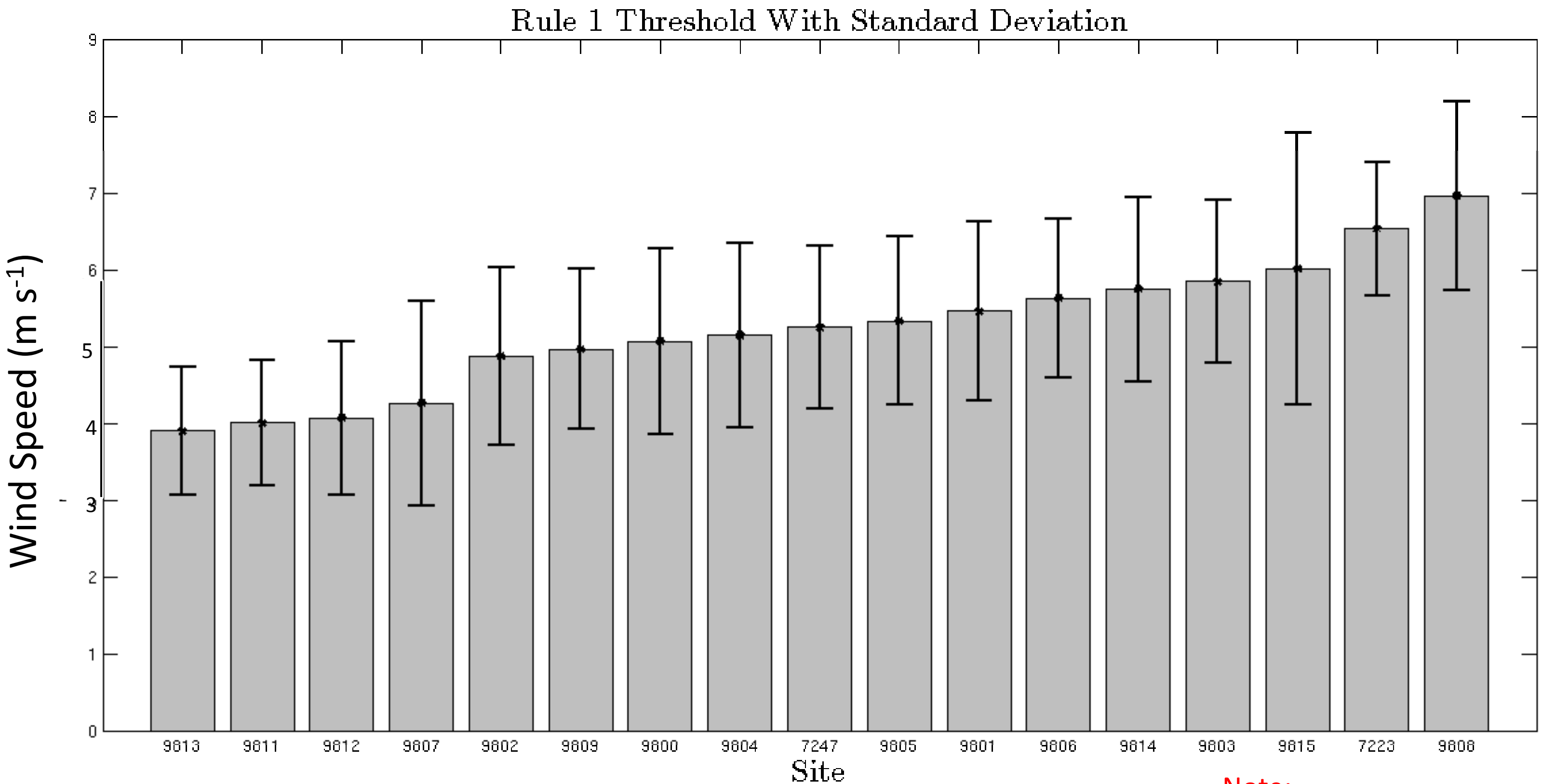
Each "arm" of the rose represents each 5 min. measurement of sand flux (g cm^{-2}) and points in the direction sand was moved

Data Analysis

- **The threshold wind speed data and sand flux data were used to evaluate relationships between vegetation and the magnitude of the local threshold wind speed and saltation flux**

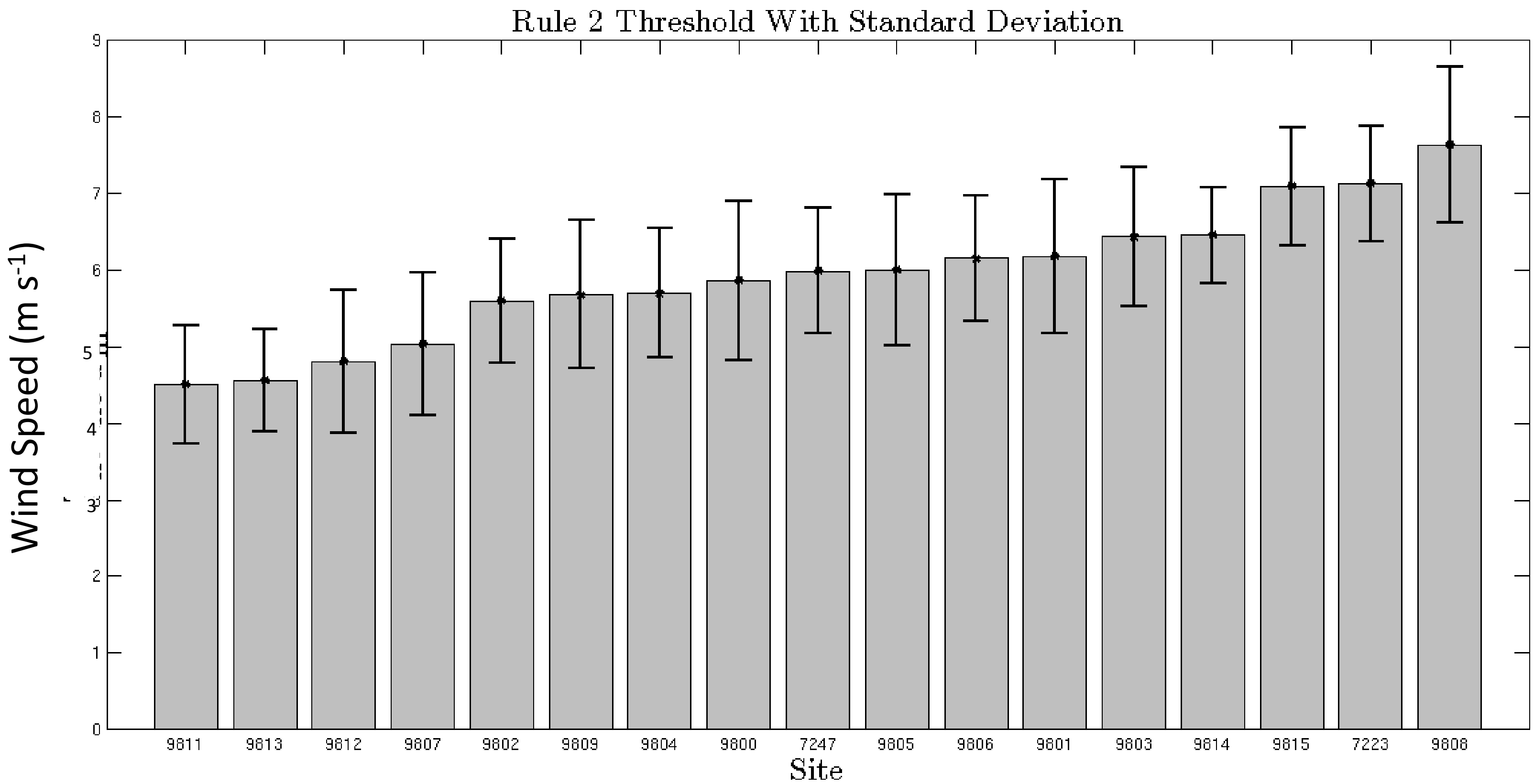
Results

- **1 m Threshold Wind Speed at the Sites**



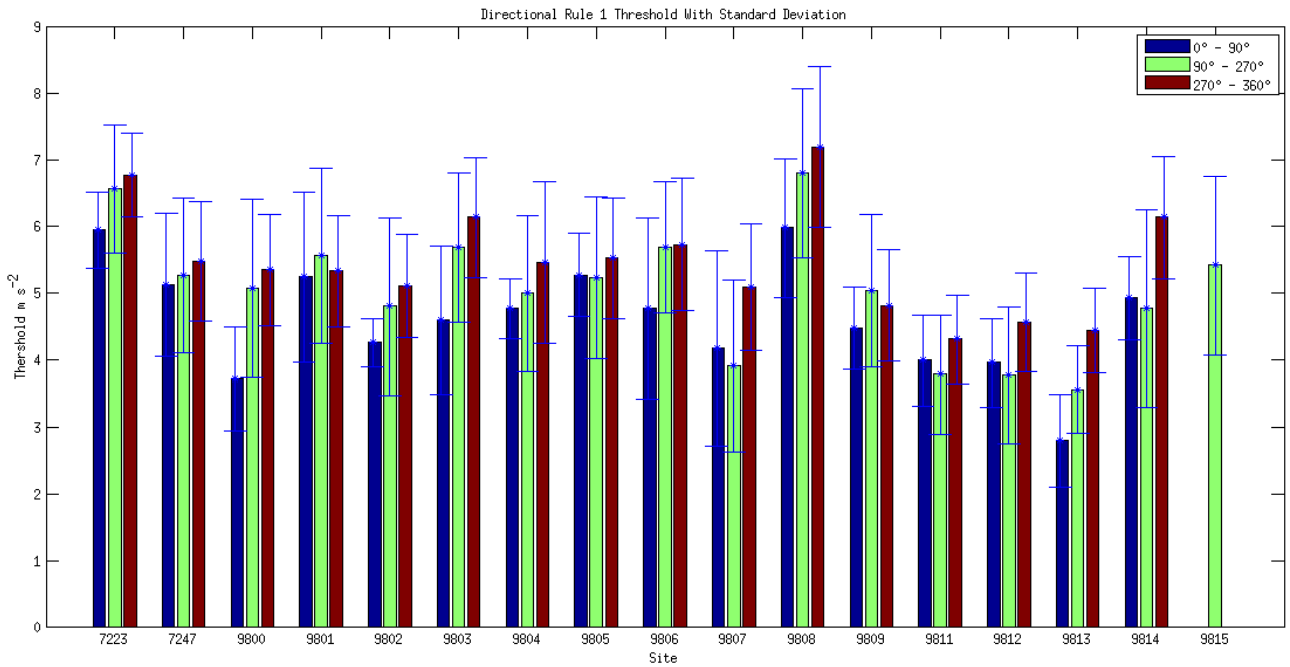
Note:
The threshold analysis is preliminary and is being re-evaluated.

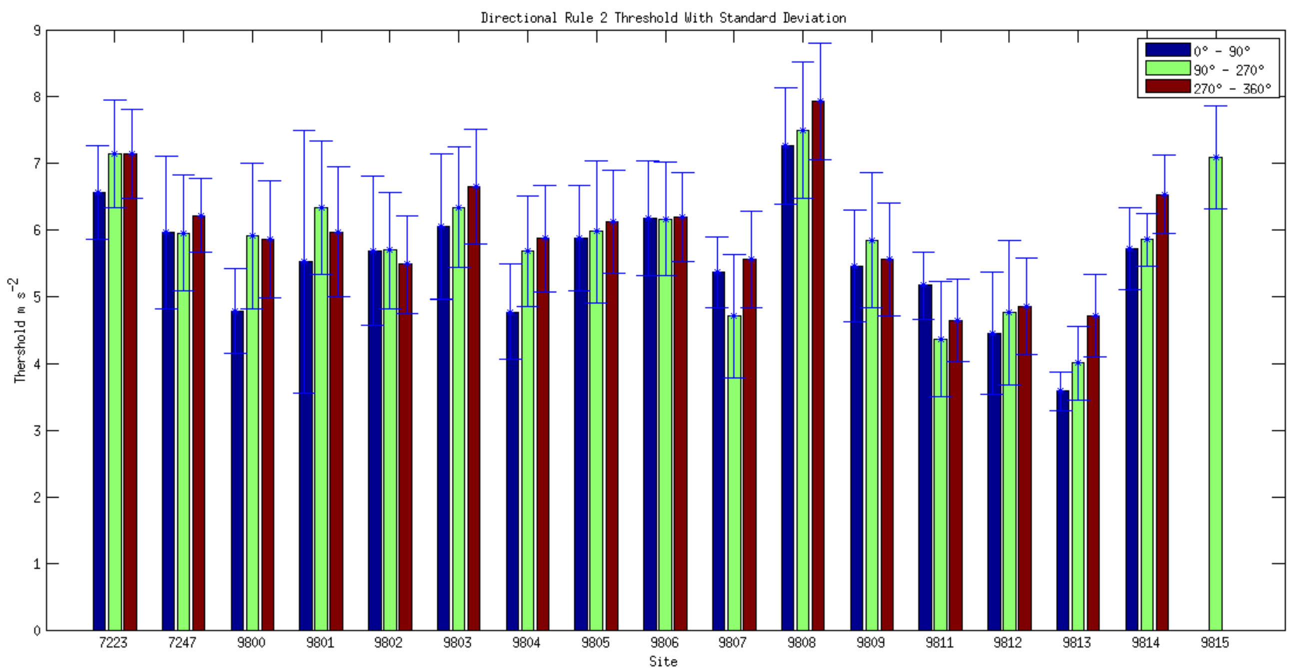
Number of observations range from 5 (Site 9815) to 238 (Site 9800)



Number of observations range from 2 (Site 9815) to 532 (Site 9812)

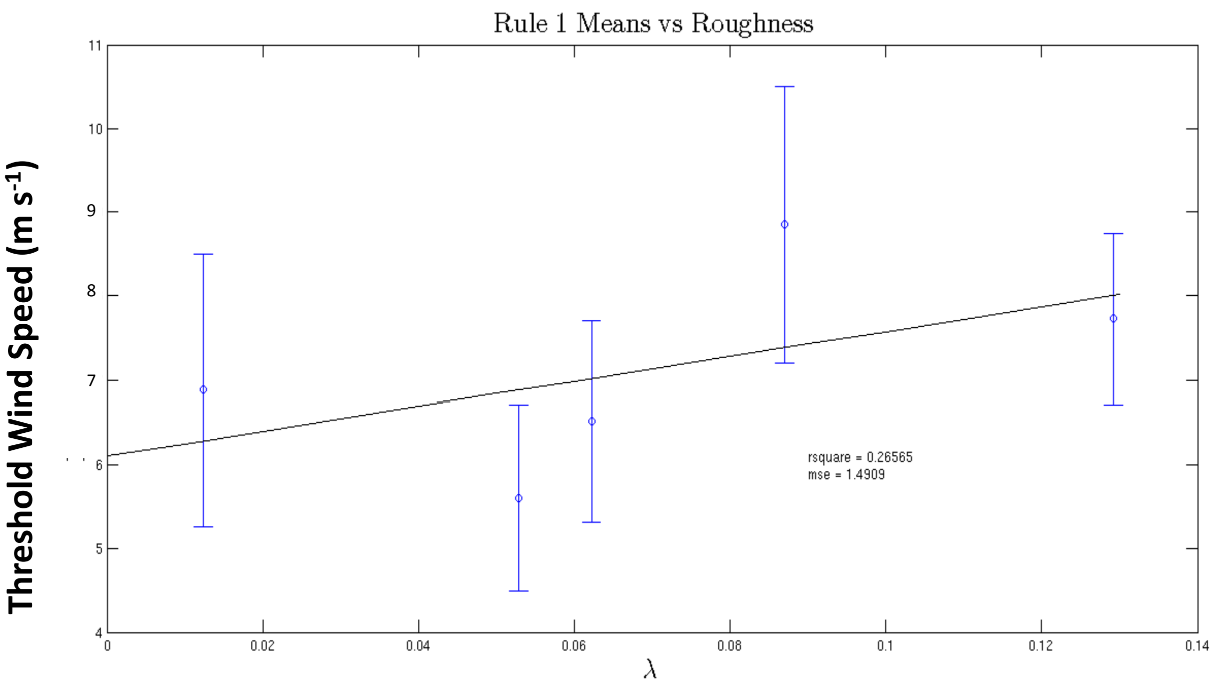
Note:
The threshold analysis is preliminary and is being re-evaluated.

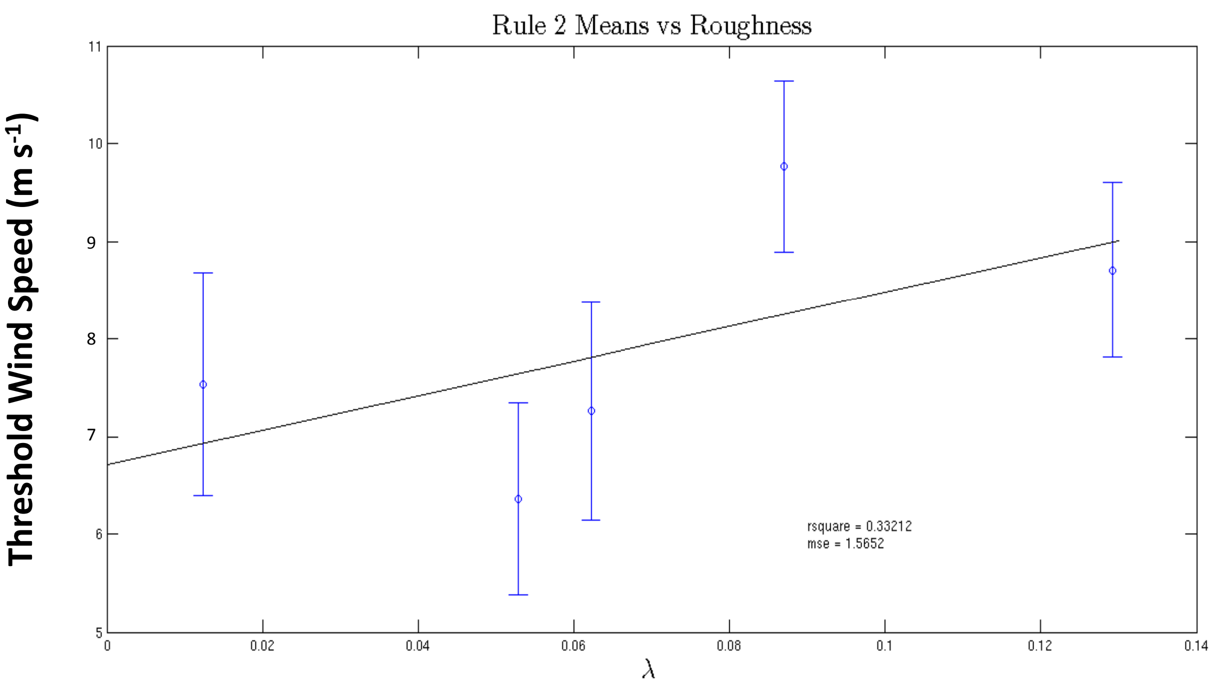




Wind direction affects threshold (suggesting a local plant distribution effect)

Note:
The threshold analysis is preliminary and is being re-evaluated.



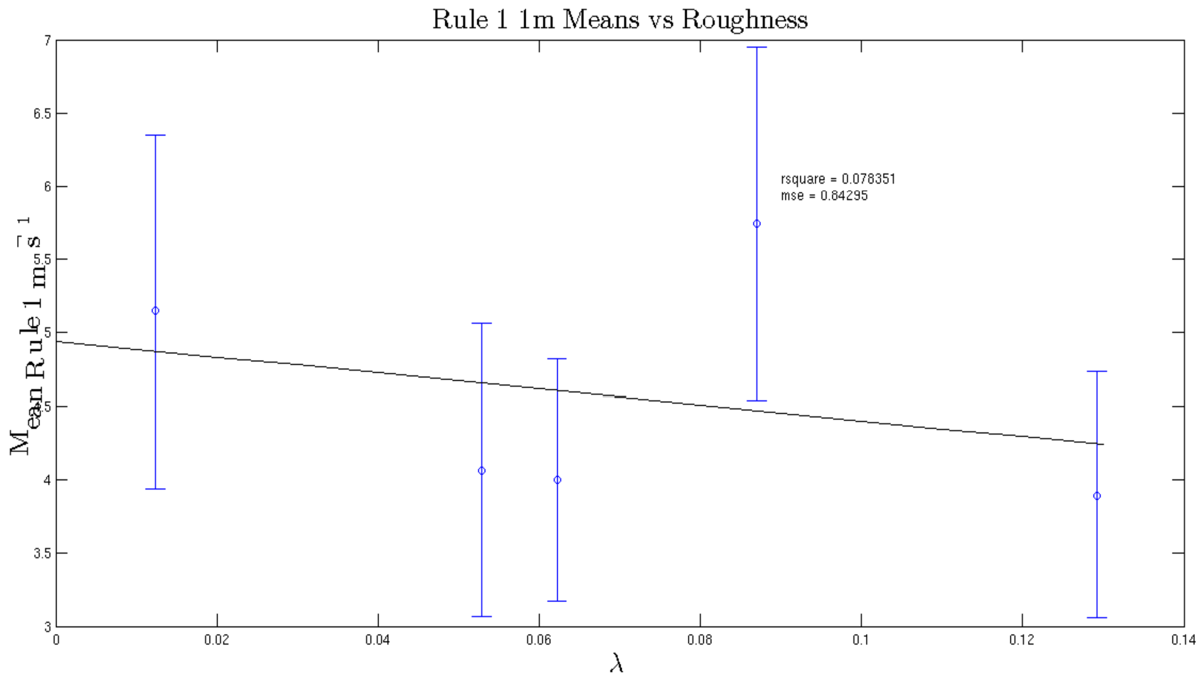


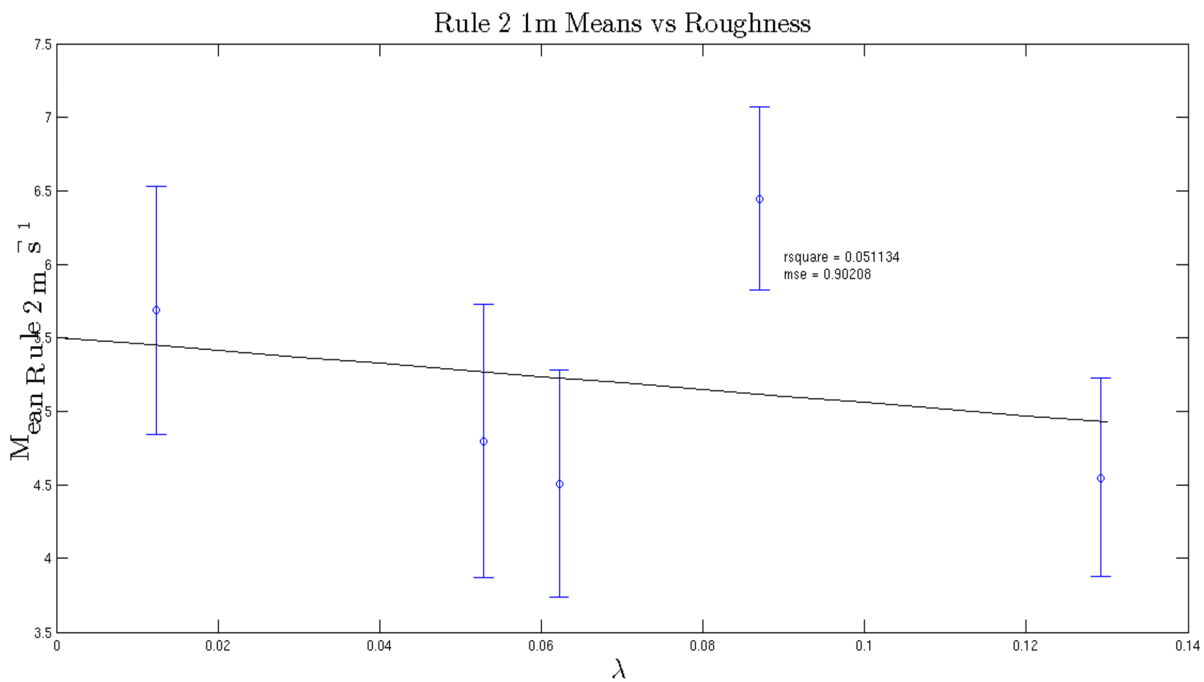
In general an increase in threshold wind speed is observed (for 4 m WS)

This trend is not observed for the 1 m WS

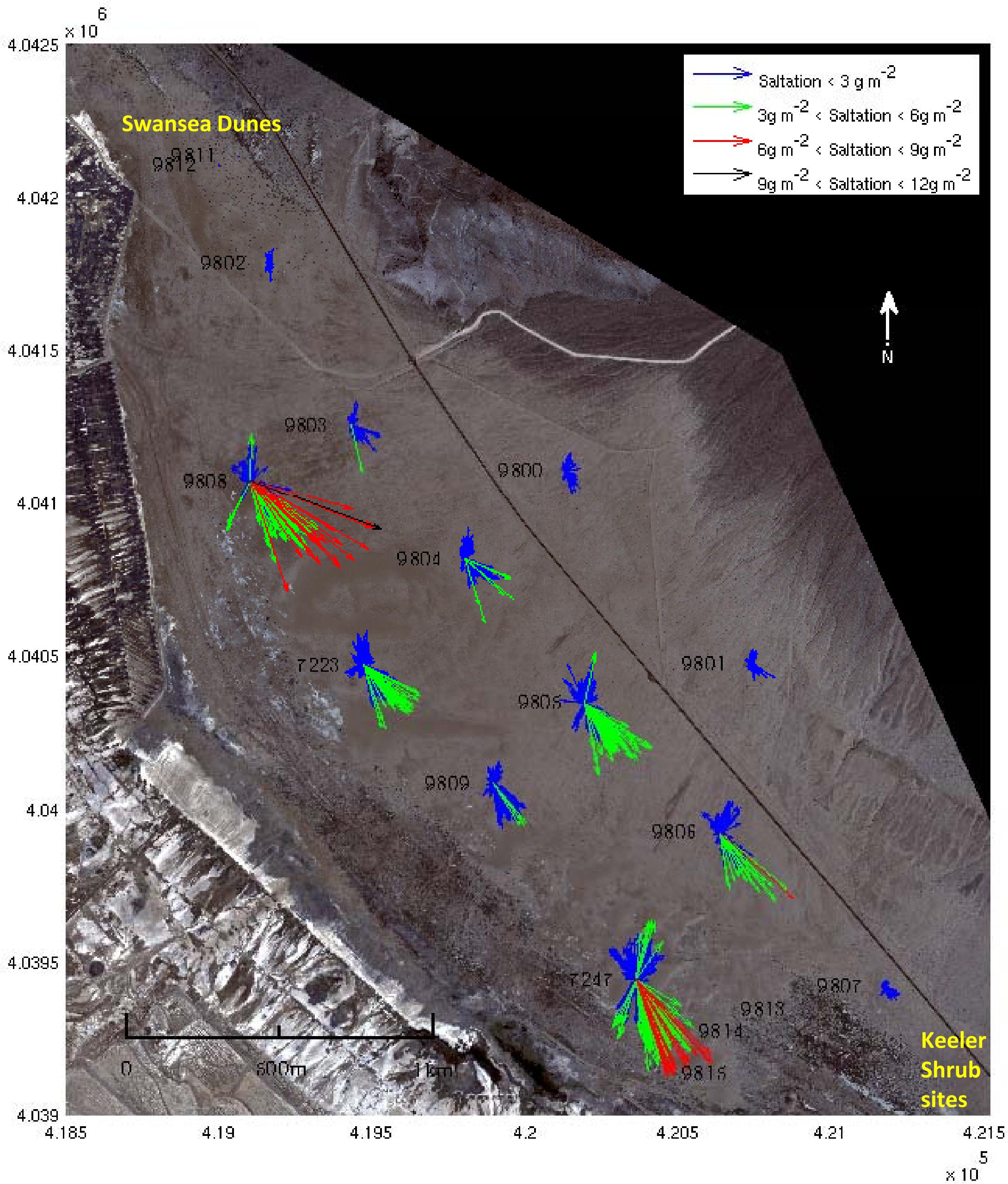
Threshold signal was not clear for the sites with the highest roughness densities

Note:
The threshold analysis is preliminary and is being re-evaluated.





For 1 m wind speed measurements there is too great an effect on local wind speed below the height of the vegetation, which affects the expected relationship (i.e., as λ increases, threshold increases)



Sand transport was observed for three wind direction ranges:

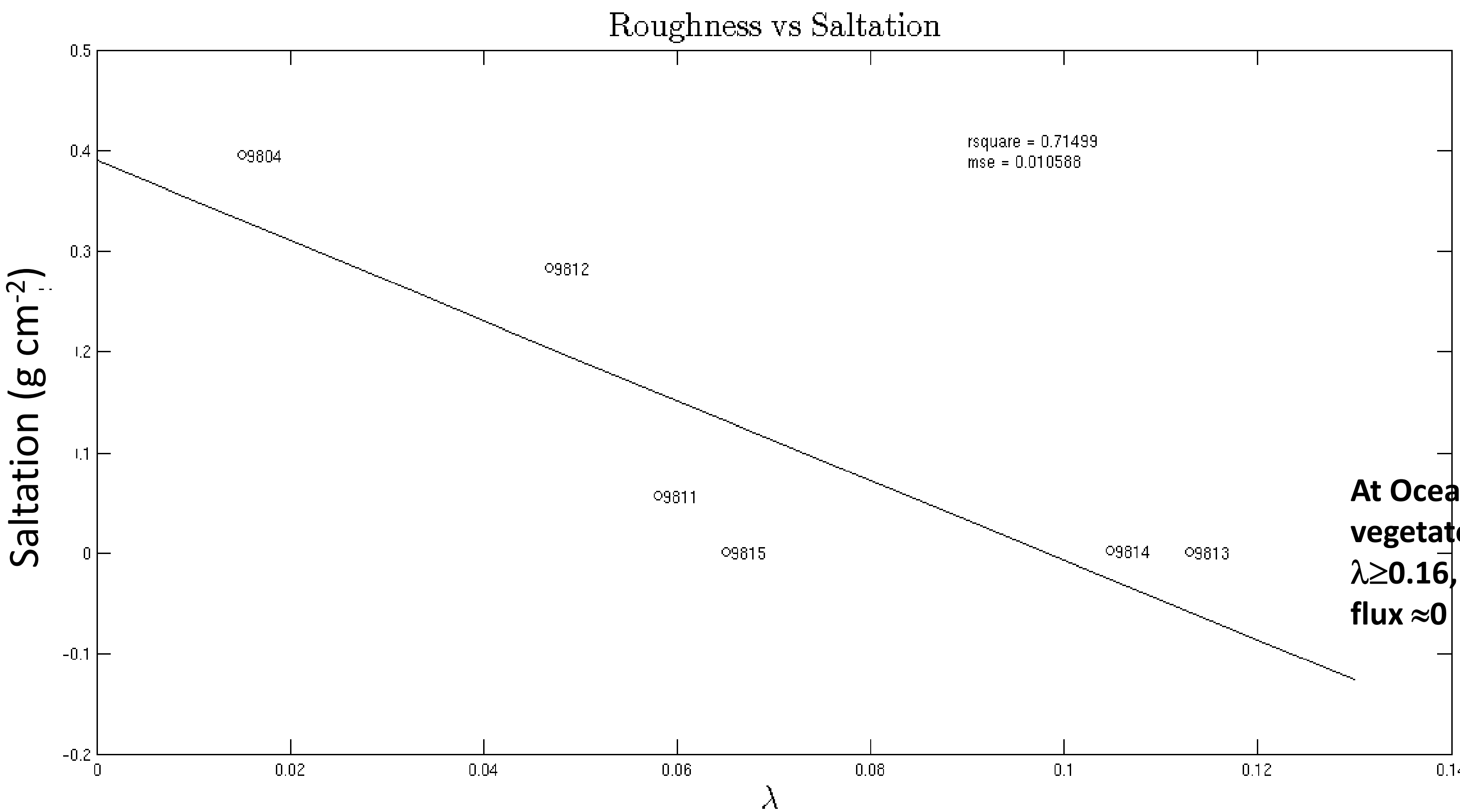
0° - 90°
90 ° - 270 °
270 ° - 360 °

Highest measured fluxes were observed with:

1) **northerly winds**

Results

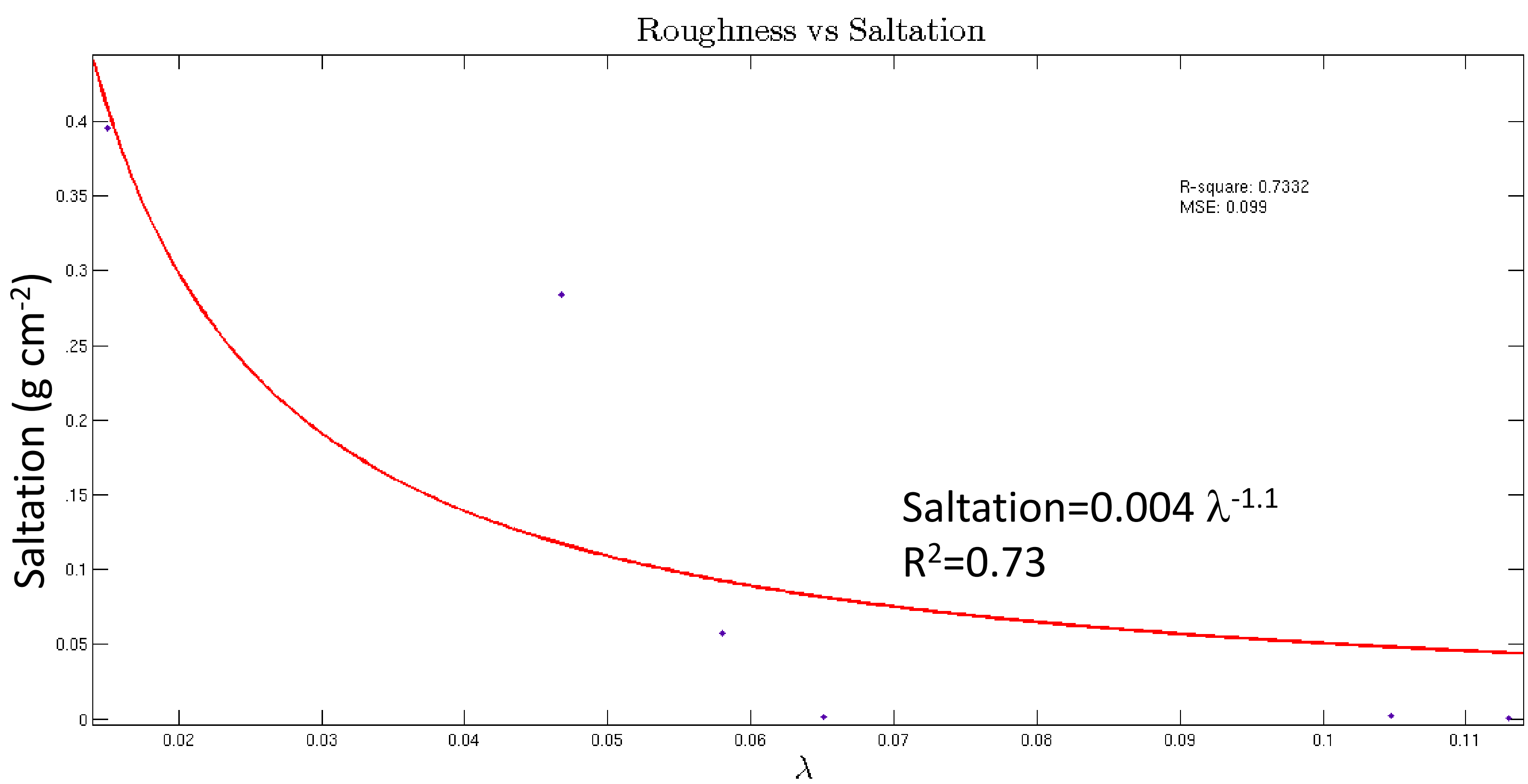
- **Vegetation effect on sand transport rate**



At Oceano Dunes vegetated site, $\lambda \geq 0.16$, saltation flux ≈ 0

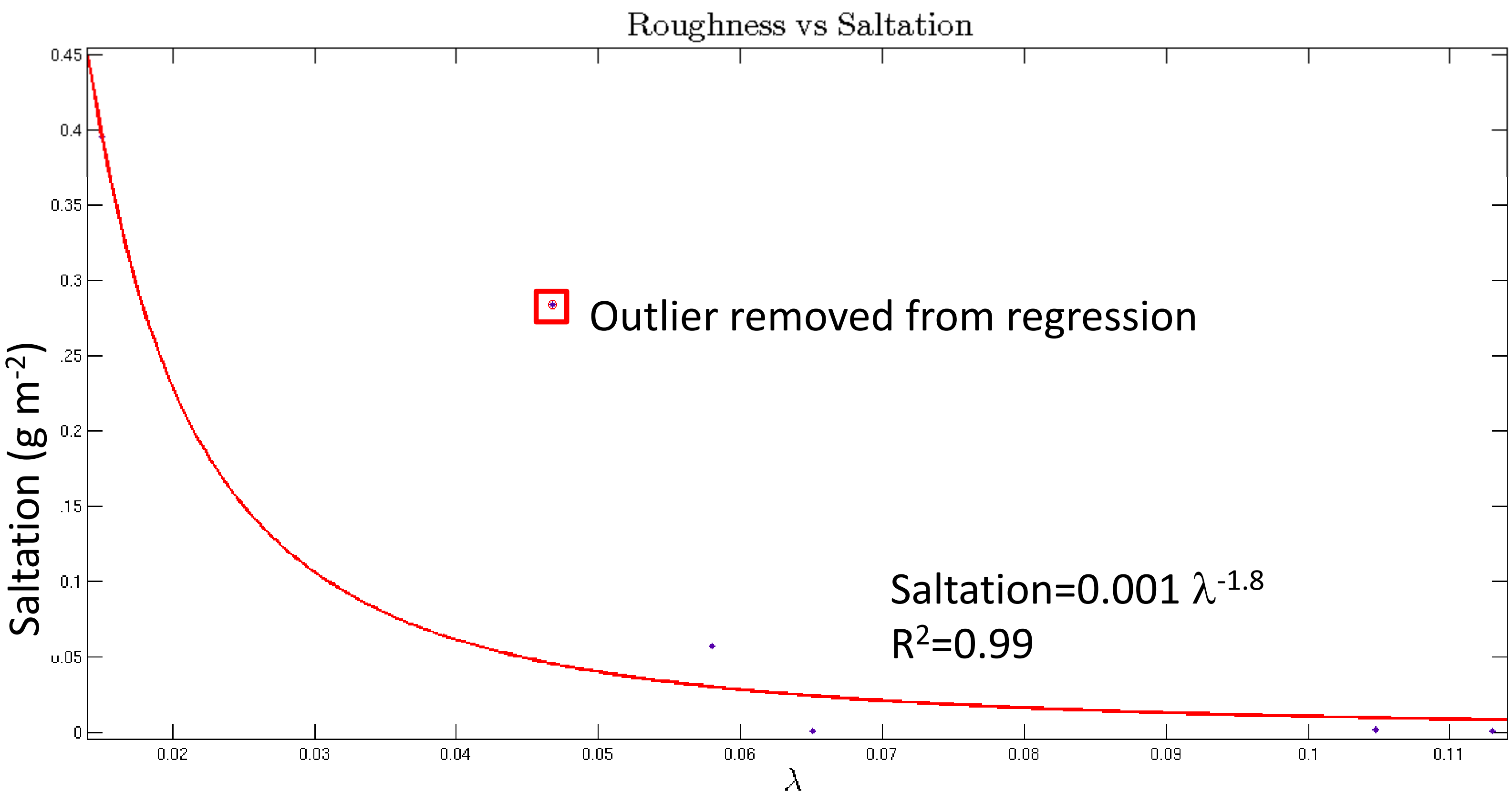
Results

- **Vegetation effect on sand transport rate**



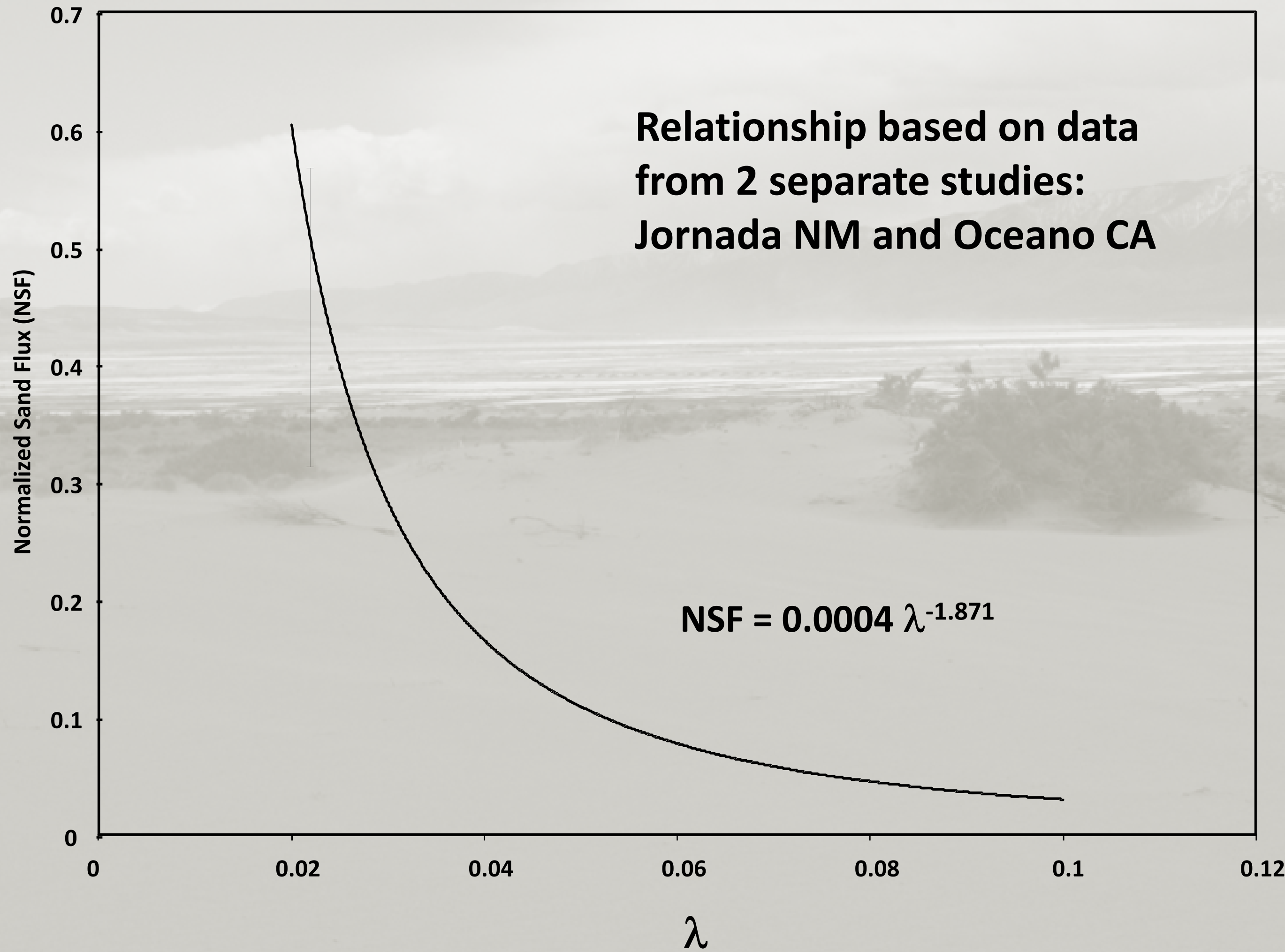
Results

- **Vegetation effect on sand transport rate**



Results

- **Vegetation effect on sand transport rate (for roughness elements >0.38 m)**



Conclusions

- **1 m threshold wind speeds for sand transport range from 4 – 7.5 m s^{-1}**
- **4 m threshold wind speeds for sand transport from 6 – 10 m s^{-1}**
- **Threshold scales with λ (4 m wind speed)**

Note:
The threshold analysis is preliminary and is being re-evaluated.

Conclusions

- Sand transport on the dunes occurs for three wind direction ranges
- During the monitoring period the highest sand fluxes were observed for northerly winds (transport towards the south)
- Saltation flux decreases with increasing λ
- Decrease in flux with increasing λ is defined by a power function
- $\lambda > 0.15$ will essentially stop sand movement if plants are sufficiently tall (>0.3 m)
- Using plants to control sand transport and associated dust emissions offers an effective strategy