

CHARACTERIZATION OF MODERN DUNE FIELDS IN CENTRAL AND SOUTHERN UTAH



H.S. Cornachione

CEE6440. GIS in Water Resources
Utah State University
Fall, 2016



Table of Contents

- 1.0 Why Sand Dunes?
- 2.0 Dune Formation
- 3.0 Study Objectives
- 4.0 Approach and Data Sources
- 5.0 Results
 - 5.1 Sevier Lake Dune Field
 - 5.1.1 Geology/ Physiographic Features
 - 5.2 Coral Pink Dune Field
 - 5.2.1 Geology/ Physiographic Features
 - 5.3 San Rafael Dune Field
 - 5.3.1 Geology/ Physiographic Features
- 6.0 Modern Dune Formation and Climate
- 7.0 Summary
- 8.0 Acknowledgements

List of Figures

- Figure 1. Coral Pink Sand Dunes
- Figure 2. Study sites and vicinity
- Figure 3. Sevier Lake area geologic map
- Figure 4. Coral Pink Sand Dunes area geologic map
- Figure 5. San Rafael area geologic map
- Figure 6 a, b, c. Sevier Lake area dune migration, wind patterns, precipitation
- Figure 7 a, b, c. San Rafael area dune migration, wind patterns, precipitation.
- Figure 8 a, b, c. Coral Pink Sand Dune area dune migration, wind patterns, precipitation.

Appendices

- Milford Municipal Airport Climate Data
- Sevier Lake Dune region – Active dune area through time using image classification

1.0 Why Sand Dunes?

Oh, the frivolity! Just the thought of sand dunes brings a lightness of heart typically accompanying thoughts of vacation, spring break, fun and relaxation. Unless, of course, one lives in an environment dominated by dunes, blowing sand and windstorms, lack of rainfall and faces the challenge of growing food or maintaining buildings or providing adequate water supply for a population. Sand dunes and dune fields are geographically widespread both in modern times and in the geologic record, occurring on every continent and from North to South poles. The increasing problem of desertification, global warming and climate change concerns have led to renewed studies of both modern dunes and ancient dunes in the geologic record.



Figure 1. Geologists hike First Dune, Coral Pink Sand Dunes State Park, October 2016.

2.0 Dune Formation

Sand dunes are formed by the action of wind on loose sediment, under arid climate conditions. Active dune formation and migration requires adequate wind strength and sediment sources, and is impeded (dunes are stabilized) by wetter, cooler periods. Accumulations of dune sand form around obstructions to the wind path, and take a variety of forms in response to wind patterns, sediment and surficial conditions. Over sufficiently long periods, vegetation and even soils (1000s of years) may develop, acting to stabilize the dune. Once stabilized, the reactivation energy required is higher than the threshold energy for moving sand particles.

Ancient dunes record climatic conditions of drought and desertification in the geologic record. With advances of optically stimulated luminescence (OSL), in concert with cosmogenic radionuclide and radiocarbon dating technologies, paleodune chronologies can provide a record of drought history. For the drought-ridden American west, investigations in the Great Basin areas from Minnesota to Idaho, Wyoming and the Colorado Plateau have developed records of drought periodicity through the Holocene (past 10000 years), and into the Pleistocene. Understanding of drought history in the arid western United States will benefit climate scientists, planners, engineers and others in more effectively responding to current climate changes.

3.0 Study Objectives

Investigation of several dune fields in south and central Utah is planned, using detailed field mapping, stratigraphy coupled with OSL and other age dating methods to develop a paleoclimate record for this area. Modern dune behavior and geometries in the same area will be useful to help interpret the ancient dunes. The purpose of this

investigation using Geographic Information Systems (GIS) is to obtain information on a variety of parameters impacting dune formation and stability in the Sevier Lake region, the entrance to the Grand Staircase region and San Rafael desert region to provide modern analogues for the upcoming study of older dunes and dune fields.

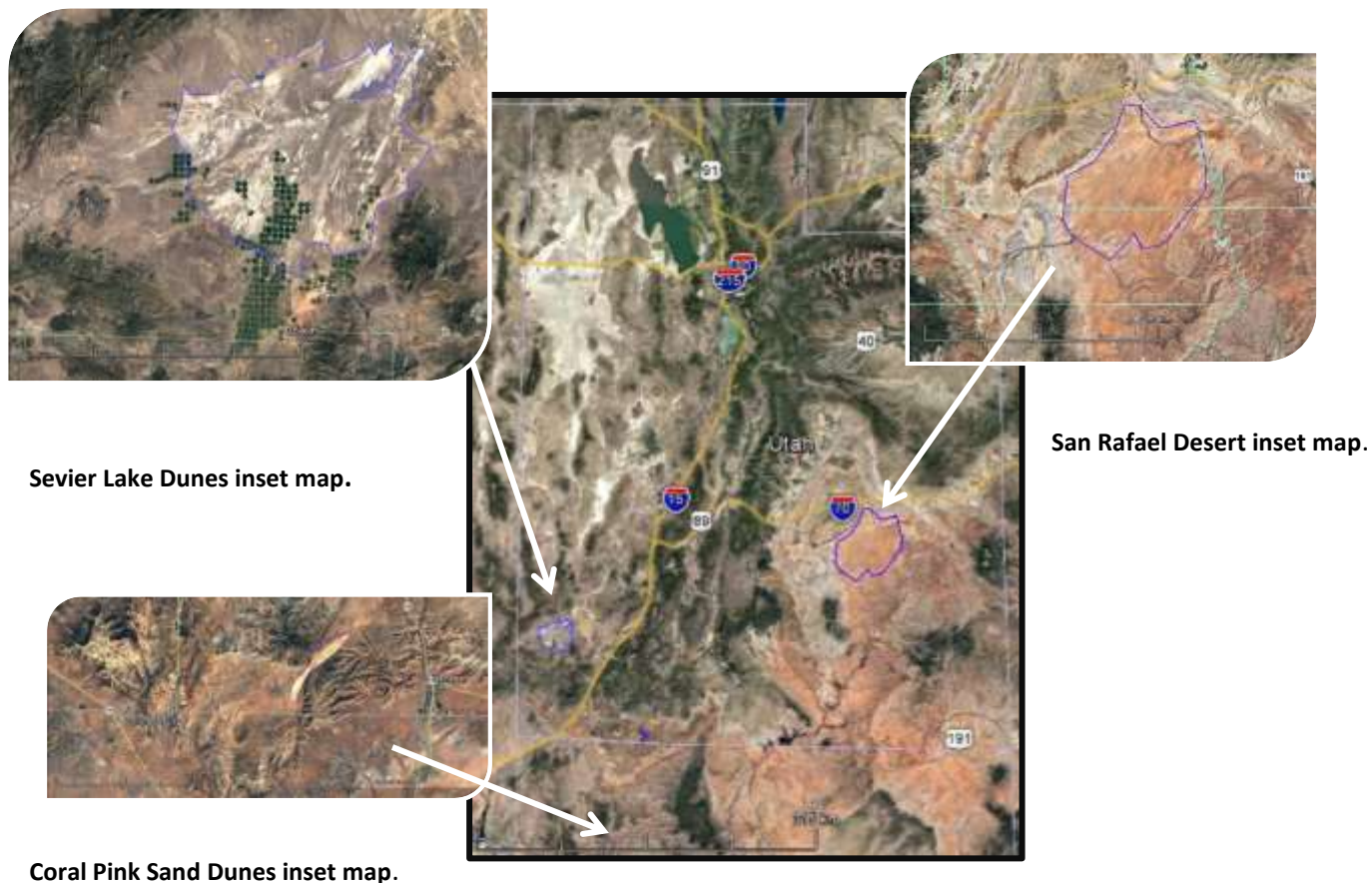


Figure 2. Project area map showing the subject study dune fields within the state of Utah. Source: Google Earth.

4.0 Approach and Data Sources

Dune field sites were identified using the historical imagery tool in Google Earth, and points of maximum extent for years available were identified, and changes in extent measured and recorded. Migration history based on change in maximum extent was calculated using Excel.

A wide variety of data sources were researched to determine the available options in the areas of physiographic data, imagery, climate data and mapping, geologic and soils mapping before selecting the data to be used for this project, which is the initial stage of the investigative effort. NAIP imagery was selected for the project, accessed from the State of Utah GIS portal. Rationale included accessibility, comparability for the historical records in Google Earth and particularly the ability to utilize the aerial photography for future field mapping efforts.

Physiographic information including digital elevation models (10 m DEMs), geologic and soils mapping was obtained through the Utah State Geologic Survey GIS portal, but is accessible from the US Geological Survey as well. Stream locations, groundwater aquifer recharge-discharge information was obtained through Arcgis servers and reviewed but is not used graphically. Precipitation and wind data was obtained from the Utah Climate Center, Utah State University (Schroeder, 2016), wind rose plots were obtained from the NOAA website via Iowa State University. Websites and data source links are provided in the list of references.

5.2.1 Grand Staircase Western Edge

Coral Pink Sand Dunes (CPSD) are located at the southern edge of Utah near the Arizona border (Figure 4), within a state park of that name. Formed as a fault bounded graben at the eastern edge of the Basin and Range province, the CPSD field is a long narrow band of thick sand with a central pivot in the center of the field where the north-northeast orientation curves to a northeast to east northeast trend.

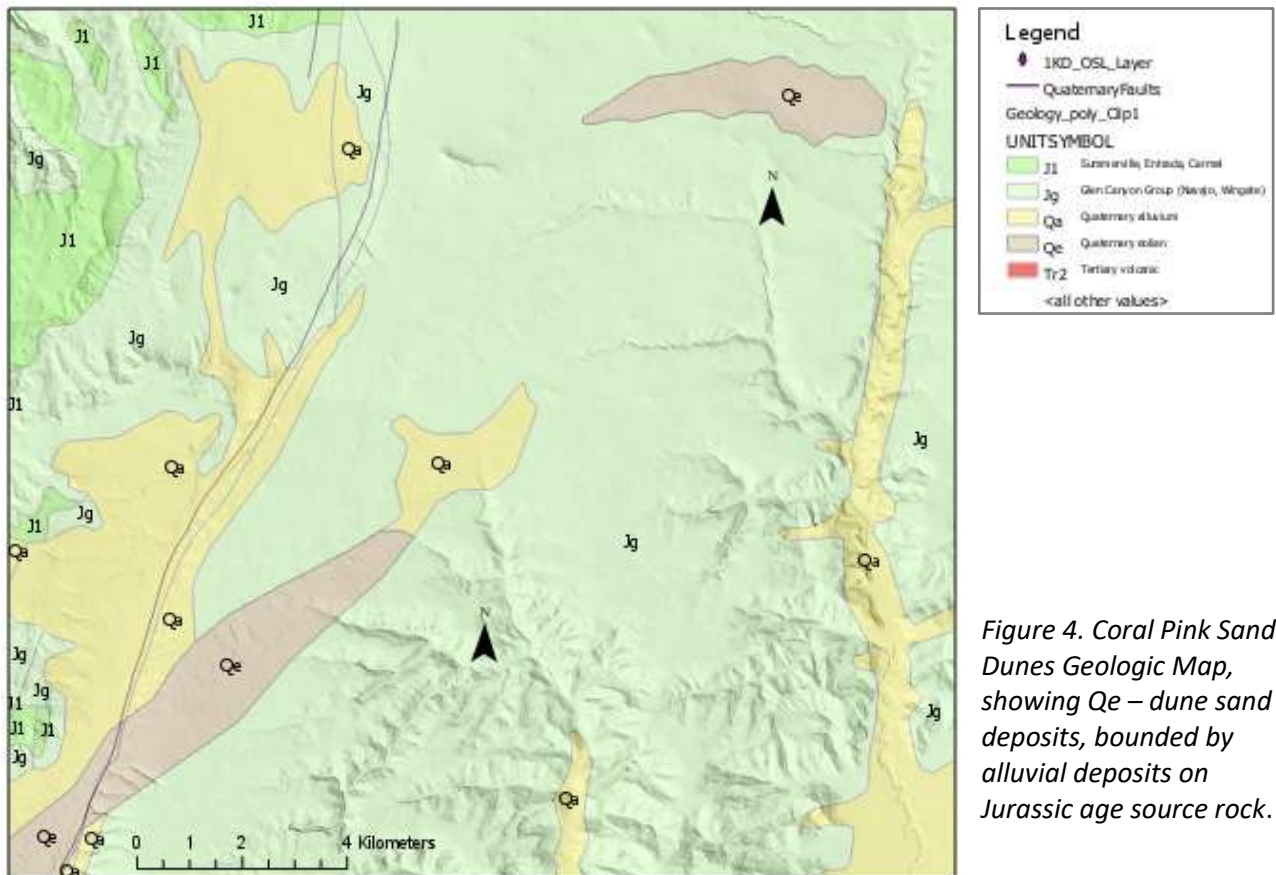


Figure 4. Coral Pink Sand Dunes Geologic Map, showing Qe – dune sand deposits, bounded by alluvial deposits on Jurassic age source rock.

The dune field crosses the Hurricane fault zone at this location, a quaternary fault the southern extension of the Wasatch fault zone. Ground penetrating radar studies (Ford, comm. 2016) suggest the depth of the sand exceeds 40 m, and sand has recently buried pinion pines of over 1700 years, at the southern end. Climbing dunes are forming across fault bounded slope to the east.

While sand is clearly active, the dunes are a popular recreational resource for OHV use and hiking. A channel runs north along the hillslope to the east, the profuse alluvial fans seen in the Escalante Desert are not visible. Sediments appear to be sourced from the Mesozoic rock strata bounding the CPSD to the west and east.

No soils have been mapped by the NCRS in this area, suggesting it has been an active dune field through time, with very limited periods of moist or wet conditions to form soil layers. Dunes are formed in parabolic style, with sand collecting in an arcuate form around objects (frequently tree trunks). Linear dunes, such as seen at Escalante Desert, are not present, but a star dune has been observed forming at the southern end of the field, just north of the pinion forest boundary. Groundwater is either shallow or perhaps perched. Many areas of moisture ponded at the surface were observed during a recent field visit, after a series of heavy storm events.

5.3.1 San Rafael Desert

San Rafael Desert dune fields are located in the northern part of the Grand Staircase Escalante National Monument region (Figure 5) forming on a plateau bounded by incised meandering streams. Geologically, this area is known as the San Rafael Swell, considered a “monocline”, that is a region uplifted and folded on one side and sloped from that higher point.

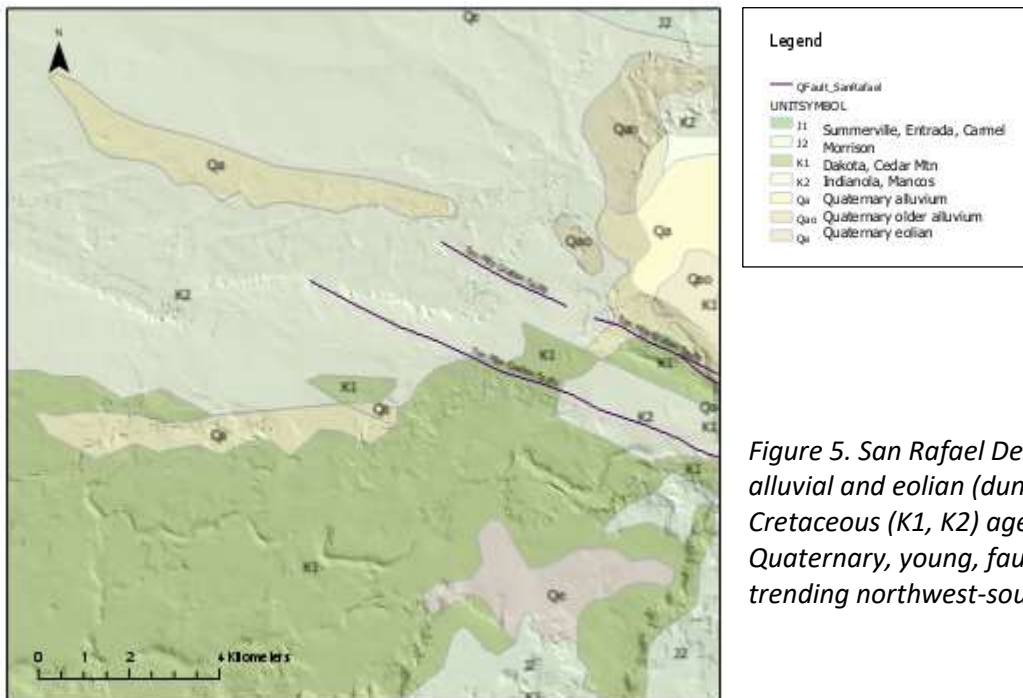


Figure 5. San Rafael Desert dune field. Quaternary alluvial and eolian (dune) sediments rest on Cretaceous (K1, K2) age sedimentary bedrock. Quaternary, young, faults impact surface elevation, trending northwest-southeast.

Dune ridges are somewhat more prominent than those in Sevier Lake region, mostly linear and oriented slightly north of east with some outlying parabolic stabilized (vegetated) dunes around the perimeter regions, especially to the south (Figure 8). Although soils have been mapped to the south of the field no soils are mapped interior to the dune field, indicating long term active dune migration.

Alluvial transport is limited, with some stream transport from uplands to the northwest and west. Sediment is the characteristic pink-orange of the Mesozoic sedimentary strata typical of the southwestern Utah and indeed USA regions. However a moderate amount of active sand appears to be forming linear ridges atop in situ bedrock, suggesting the primary source of sediment may be in situ, and primarily subject to eolian transport.

The San Rafael Desert belongs to Colorado Plateau physiographic province, rather than the Basin and Range. This impacts the sediment source, the nature, type and orientation of the dunes formed in this area. Sand accumulation is thick on linear ridges (see aerial photographs) and along the river margins than central Utah, Sevier Lake area the color contrasts indicating the different source, the Mesozoic sediments, particularly the massive, cliff forming Jurassic Navaho Sandstone, which is an ancient dune deposit now composed of white sands with pink and red beds reflecting post depositional oxidized iron leaching through the sandstone.

6.0 Modern Dune Formation and Climate

In addition to sediment supply, with sources discussed in the previous section, dunes require wind to dislodge and carry the sediment and arid conditions. To characterize the dunes with respect to these climate factors, wind data and rainfall records were obtained for four locations in proximity to the three

dune fields of interest. These data are shown in Figures 6, 7 and 8, for sites Sevier Lake, San Rafael and Coral Pink Sands respectively, with additional data from central Utah following.

Particle size of sediment that can be transported by winds ranges from silt (.004 - .062mm) to fine sand (.062 - .125 mm). Threshold velocity of wind to pick up and carry sediment is 6 meters /second (13.4 miles/hour). Dune deposits, which can vary in shape depending upon local conditions leading to their deposition, are oriented in alignment with flow direction of wind. Speed and direction of wind is typically plotted on a diagram known as a wind rose, providing a quick visual guide to the variability of wind for the time period considered and the relative velocity of wind in any direction, as well as primary wind direction. Wind roses used for this study were constructed using the custom wind rose software provided by Iowa State University on the NOAA website.

While all three dune fields show some evidence of migration, it is not clearly correlated with annual rainfall nor apparently with wind strength. Based on the limited time of observation, approximately a 10-year period from 2006-2016 for each field, though rainfall is generally very low in all areas the aridity and wind speeds are clearly adequate to support active dunes. Active dune area was tracked for the Sevier Lake dunes and for Coral Pink Sand Dunes (Tables 1 and 2). Some variability is evident, but not a pattern.

7.0 Summary

Investigation of the modern dune fields for the Sevier Lake, Coral Pink and San Rafael dune fields provides some insights into models for ancient dunes to be studied in the future work for this project. Sevier Lake style dunes are formed in open, wide valleys, with fluvial and aeolian sources of transport for the dune sediments from outside the depositional area. Dunes are formed in sand sheets, relatively thin layers, with occasional thicker zones where obstructions have led to some barchanoid shapes. Dune sediment is not necessarily related to surrounding nor bedrock geology.

In contrast, both Coral Pink Sand Dunes and San Rafael dunes appear related to the bedrock and surrounding upland geologic formations as sediment sources. Channels are deeply incised in these regions, and aeolian transport appears significant in sediment movement and deposition. Dune thickness varies significantly, with Coral Pink region a thick deposit, moving in response to a wind tunnel, constrained by surrounding highlands and impacted by a cross cutting Quaternary (young) fault along with a stream channel constraining the east boundary. San Rafael dunes are longitudinal, with some parabolic and barchan shapes, but appear to be forming much thinner deposits, only slightly thicker than the Sevier Lake area.

Although based on short term (weather rather than climate time scales) data, dunes are actively forming in central and southern Utah under arid conditions, with sufficient wind speeds. To more fully characterize and certainly to quantify dune formation parameters, more detailed data would be required, obtained over longer time periods.

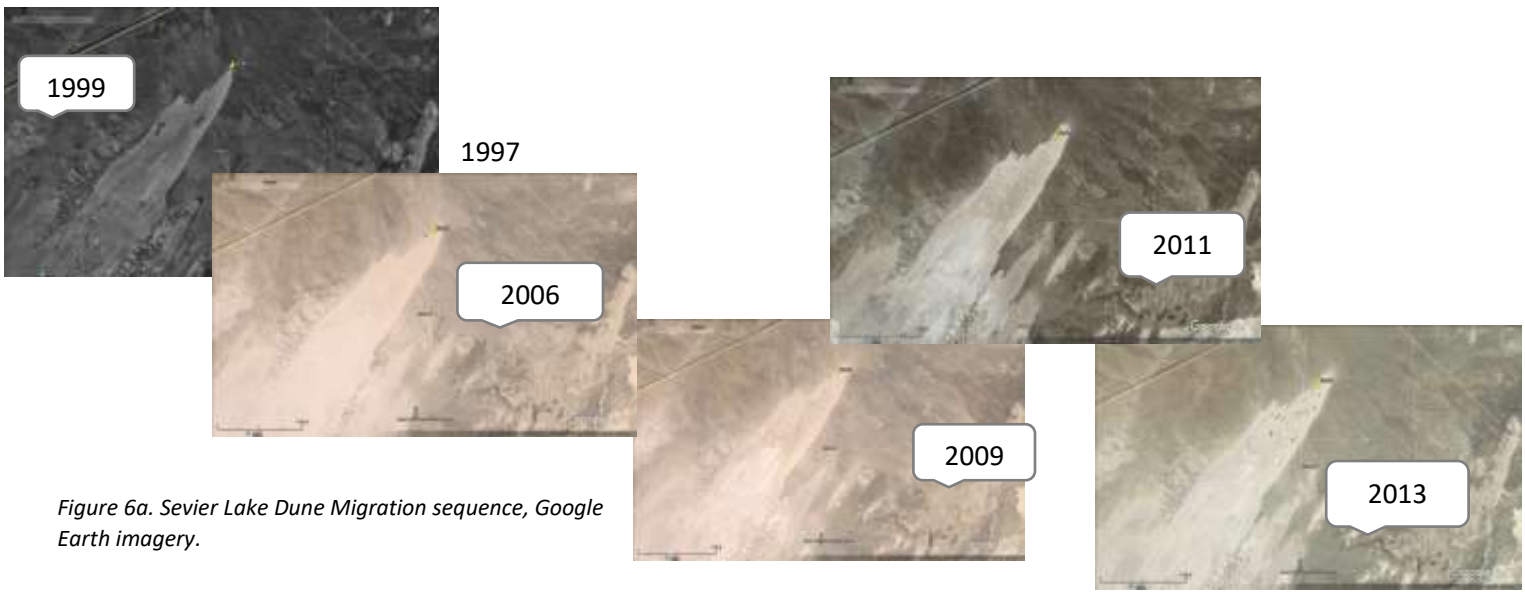


Figure 6a. Sevier Lake Dune Migration sequence, Google Earth imagery.

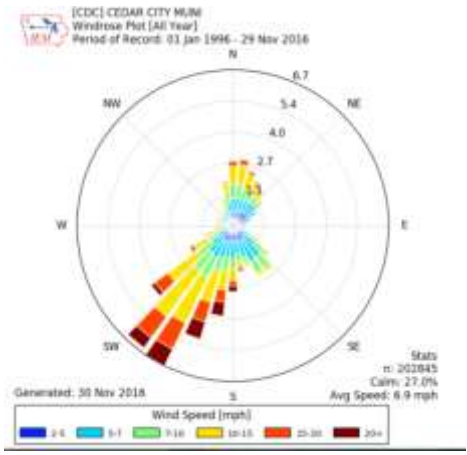
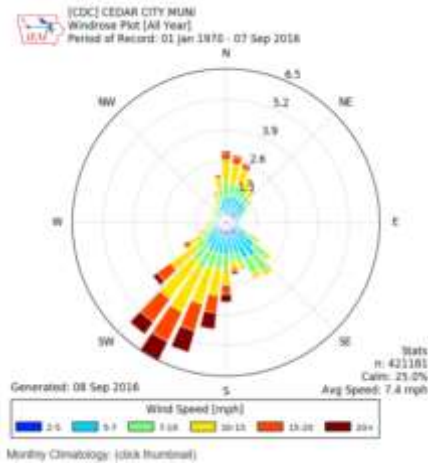


Figure 6b. Wind rose diagrams, Cedar City Airport, from 1970 – present and 20-year (1996-2016). Orange and brown carry sediment, transport direction south southwest. Source: Iowa State University, NOAA.

Annual Precipitation 1998-2016 Cedar City Regional Airport, Utah

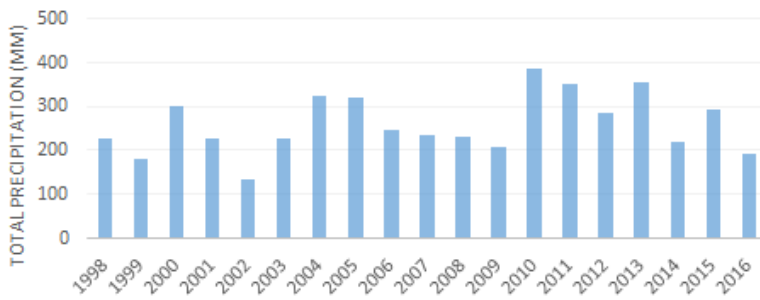


Figure 6c. Annual precipitation, Cedar City Airport, 1998-2006. Source: Utah Climate Center, USU.

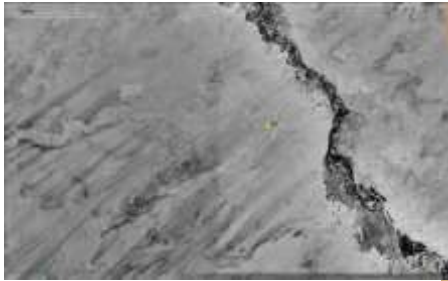


Figure 7a. San Rafael dune historical imagery showing dune formation, Google Earth.

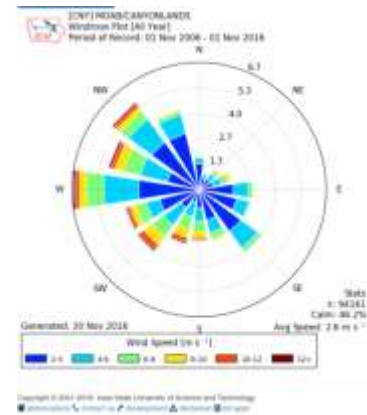
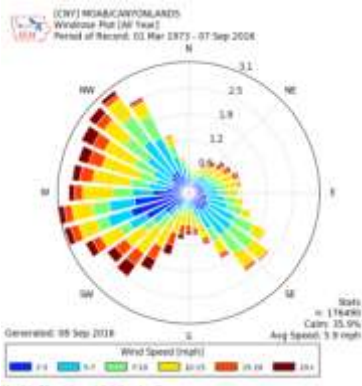


Figure 7b. Wind rose diagrams, Moab-Canyonlands Airport, 1973-2016, and 2006-2016: Iowa State University, NOAA. Wind direction dominant west southwest.

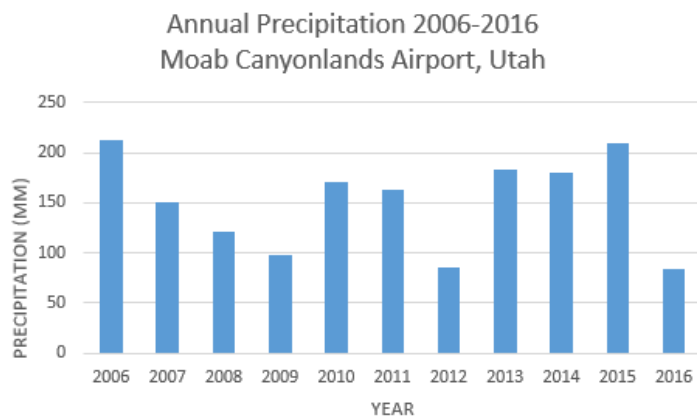


Figure 7c. Annual precipitation, Moab Canyonlands Airport, 1998-2006. Source: Utah Climate Center, USU.



Figure 8a. Coral Pink Sand dunes, imagery showing dune migration through historical imagery, Google Earth.

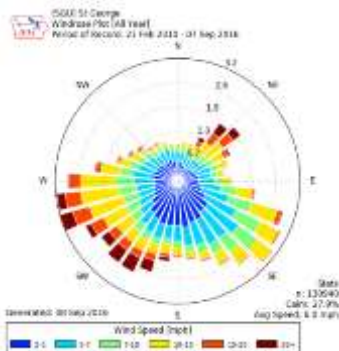


Figure 8b. Wind rose diagram for St. George Regional Airport, showing variable wind patterns, with transport-speed from west, to some southwesterly. Iowa State University, NOAA.

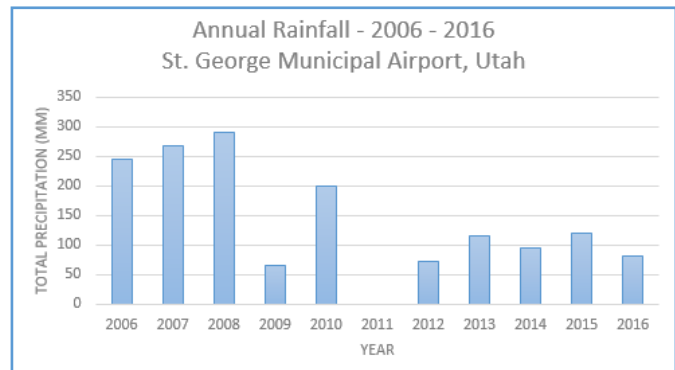


Figure 8c. Annual Rainfall, St. George Regional Airport, 2006-2016.

7.0 Acknowledgements

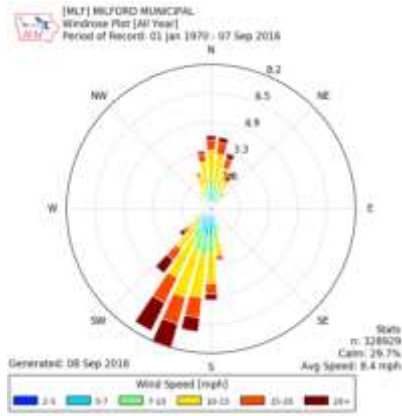
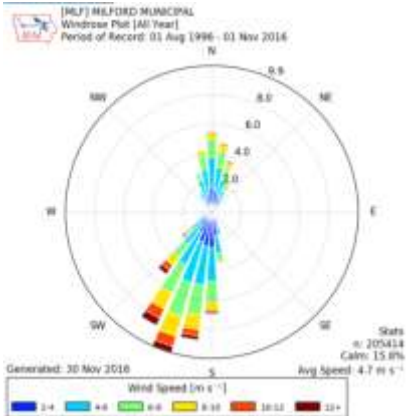
The following people provided invaluable assistance and support to this project, discussing data sources, methods and approaches and/or general guidance and support. The author is exceedingly appreciative of the support, and acknowledges the study is enhanced and benefited from their input.

- Dr. Tammy Rittenour, Geology Department, Utah State University
- Dr. David Tarboton, Civil & Environmental Engineering Department, Utah State University
- Martin Schroeder, Utah Climate Center, Utah State University
- James Mauch, Geology Department, Utah State University
- Alexander Short, Geology Department, Utah State University
- Egan, Matt, Kristen and Mike Cornachione for technical, editing and other advice

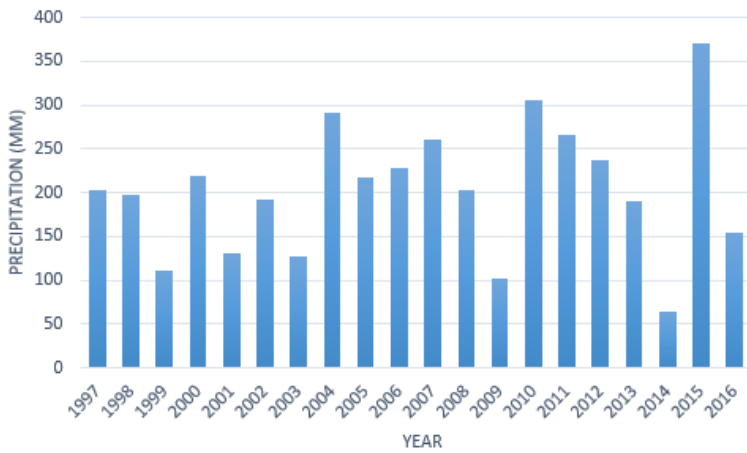


Appendix

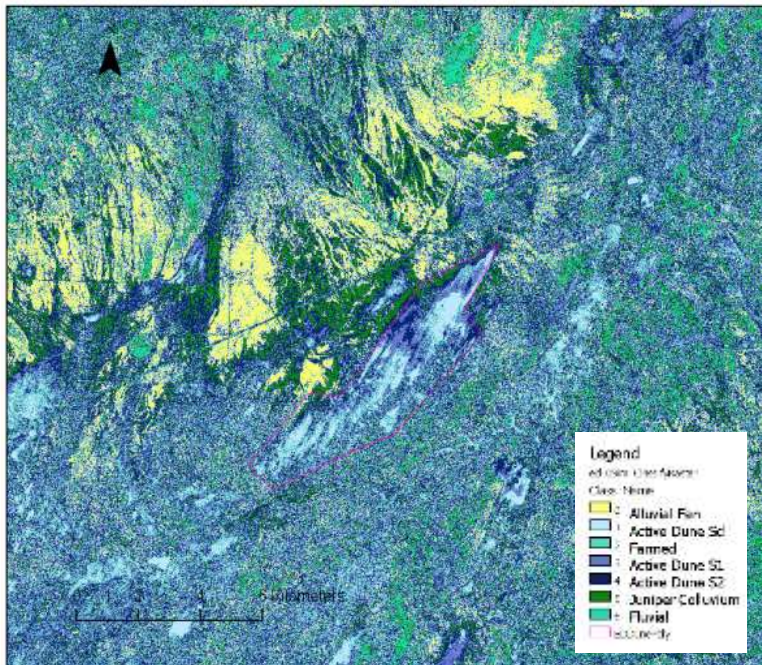
I. Additional Data from Milford Municipal Airport, north and east of the Sevier Lake Dune region, for comparison to dune orientation.



Annual Precipitation (1997 - 2016)
Milford Municipal Airport, Utah



II. Sevier Lake Dune area – active dune area through time, based on unsupervised image classification analysis.



Class	2014	2011	2009	2006
Active Dune (%)	81.96	68.14	76.35	67.38