# WATCHING OVER TEXAS FROM SPACE

**An Earth Observations education resource for grades 4 -12 in support of TEKS covering**

**Earth Science and Environmental Science Standards**

**Developed by TexasView with support from Grant Number G14AP00002 from the Department of the Interior,**

## Section 3.5 Monahans Sandhills State Park: Change Over Time Teacher's Guide

Texas Essential Knowledge and Skills (TEKS) standards address Earth's changing surface at multiple grade levels (Table 1). This lesson also addresses similar Next Generation Science (NGSS) standards at multiple grade levels (Table 2). With reference to erosion and deposition, sand dune landforms and the erosion and deposition of sand by the wind are recurring themes. In this lesson, Texas' Monahans Sandhills State Park serves as an excellent environment to demonstrate how the wind reshapes Earth's surface features.

| **GRADE LEVEL** | **COURSE** | **KNOWLEDGE** | **SKILLS** |
|---|---|---|---|
| Grade 4 Science | Earth and Space | (7) Earth and space. The students know that Earth consists of useful resources and its surface is constantly changing. The student is expected to: | (B) observe and identify slow ***changes to Earth's surface caused by*** weathering, erosion, and deposition from water, ***wind***, and ice |
| Grade 5 Science | Earth and Space | (7) Earth and space. The student knows Earth's surface is constantly changing and consists of useful resources. The student is expected to: | (B) ***recognize how landforms*** such as deltas, canyons, and sand dunes ***are the result of changes to Earth's surface by wind***, water, and ice |
| Grade 7 Science | Earth and Space | (8) Earth and space. The student knows that natural events and human activity can impact Earth systems. The student is expected to: | (B) analyze the effects of weathering, ***erosion, and deposition*** on the environment in ecoregions of Texas; and |
| Grade 8 Science | Earth and Space | (9) Earth and space. The student knows that natural events can impact Earth systems. The student is expected to: | (C) ***interpret topographic maps and satellite views*** to identify land and erosional features and predict ***how these features may be reshaped*** by weathering |
| High School | Earth and Space | (11) Solid Earth. The student knows that the geosphere continuously changes over a range of time scales involving dynamic and complex interactions among Earth's subsystems. The student is expected to: | (A) compare the roles of ***erosion and deposition*** through the ***actions of*** water, ***wind***, ice, gravity, and igneous activity by lava in constantly reshaping ***Earth's surface*** |

Table 1. Earth's changing surface features addressed across multiple grade levels in TEKS standards.

| **GRADE LEVEL** | **COURSE** | **DISCIPLINARY CORE IDEA** | **SKILLS** |
|---|---|---|---|
| Grade 4 Science | Earth's Systems | **4-ESS2-1:** Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. *Students who demonstrate understanding can:* | Make observations and/or measurements to provide evidence of the ***effects of weathering or the rate of erosion by water, ice, wind, or vegetation.*** [Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, ***relative rate of deposition,*** cycles of freezing and thawing of water, cycles of heating and cooling, and **volume of water flow**.] |
| Grade 4 Science | Earth's Systems | **4-ESS2-2:** The locations of mountain ranges, deep ocean trenches, ocean floor structures, earthquakes, and volcanoes occur in patterns. Most earthquakes and volcanoes occur in bands that are often along the boundaries between continents and oceans. Major mountain chains form inside continents or near their edges. ***Maps can help locate the different land and water features areas of Earth.*** *Students who demonstrate understanding can:* | ***Analyze and interpret data from maps to describe patterns of Earth's features.*** [Maps can include topographic maps of Earth's land and ocean floor, as well as maps of the locations of mountains, continental boundaries, volcanoes, and earthquakes] |
| Middle School | Earth's Systems | **MS-ESS2-1:** All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles ***produce chemical and physical changes in Earth's materials*** and living organisms. *Students who demonstrate understanding can:* | Develop a model to ***describe the cycling of Earth's materials*** and the flow of energy that drives this process. [Emphasis is on the processes of melting, crystallization, ***weathering, deformation, and sedimentation***, which act together to form minerals and rocks through the cycling of Earth's materials.] |

| | | | |
|---|---|---|---|
| Middle School | Earth's Systems | **MS-ESS2.2:** ***Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features*** and create underground formations. *Students who demonstrate understanding can:* | Construct an explanation based on evidence for how ***geoscience processes have changed Earth's surface at varying time and spatial scales.*** [Examples of geoscience processes include ***surface weathering and deposition by the movements of water, ice, and wind.***] |
| Middle School | Earth's Systems | **MS-ESS3-4:** Typically, as ***human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth*** unless the activities and technologies involved are engineered otherwise. *Students who demonstrate understanding can:* | Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Examples of impacts can include ***changes to the appearance, composition, and structure of Earth's systems*** as well as the ***rates at which they change.*** |
| High School | Earth's Systems | **HS-ESS2-1:** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. *Students who demonstrate understanding can:* | Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Emphasis is on how the appearance of ***land features (such as mountains, valleys, and plateaus)*** and sea-floor features (such as trenches, ridges, and seamounts) ***are a result of*** both constructive forces (such as volcanism, tectonic uplift, and orogeny) and ***destructive mechanisms (such as weathering, mass wasting, and coastal erosion).*** |
| High School | Earth's Systems | **HS-ESS2-2:** ***Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.*** *Students who demonstrate understanding can:* | Analyze geoscience data to make the claim that ***one change to Earth's surface can create feedbacks that cause changes to other Earth systems.*** [Examples could also be taken from other system interactions, such as |

| | | | |
|---|---|---|---|
| | | | ***how the loss of ground vegetation causes an increase in water runoff and soil erosion***; how ***dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion***; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.] |

Table 2. Earth's changing surface features addressed across multiple grade levels in NGSS standards.

All of the photographs in this lesson are posted on the

- Monahans SandHills Facebook page (https://www.facebook.com/monahanssandhills/).

Satellite images and maps can be found on the

- Monahans Sandhills State Park web site (http://tpwd.texas.gov/state-parks/monahans-sandhills)
- Texas Parks and Wildlife Department's Texas Watershed Viewer (https://tpwd.maps.arcgis.com/apps/Viewer/index.html?appid=2b3604bf9ced441a98c500763b8b1048)
- Texas Parks and Wildlife Department's Historical Imagery Viewer (http://tpwd.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=40c1b8be6fd1419f9d299103cc4241ca#)

Sand dunes are constantly changing, as the wind moves individual sediment grains across the landscape. The wind moves grains in a process called saltation, in which grains bounce or hop across the surface in the direction of wind movement (Fig. 1).

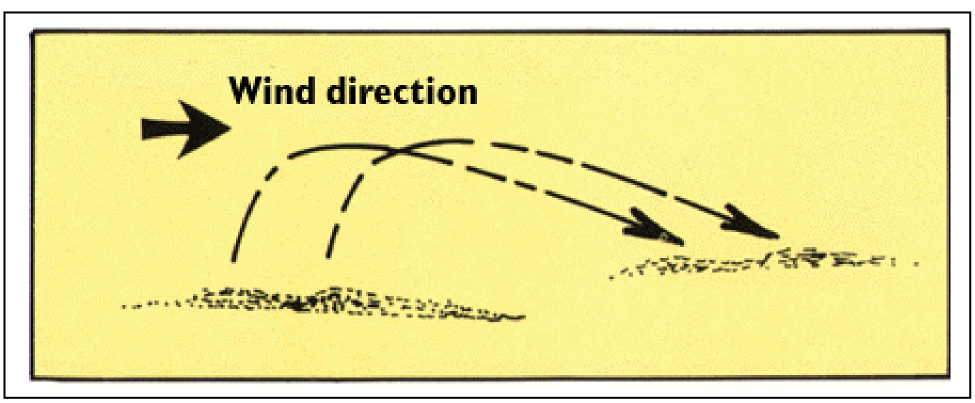


Figure 1. Saltation moves grains in the direction of wind motion, in a series of short bounces or hops. http://pubs.usgs.gov/gip/deserts/eolian/

Sediment may accumulate in mounds or ridges (Fig. 2; dunes) Dunes have gently-sloping faces towards the wind (the *windward slope*), and steeper faces downwind (the *leeward slope*; the *slipface*).

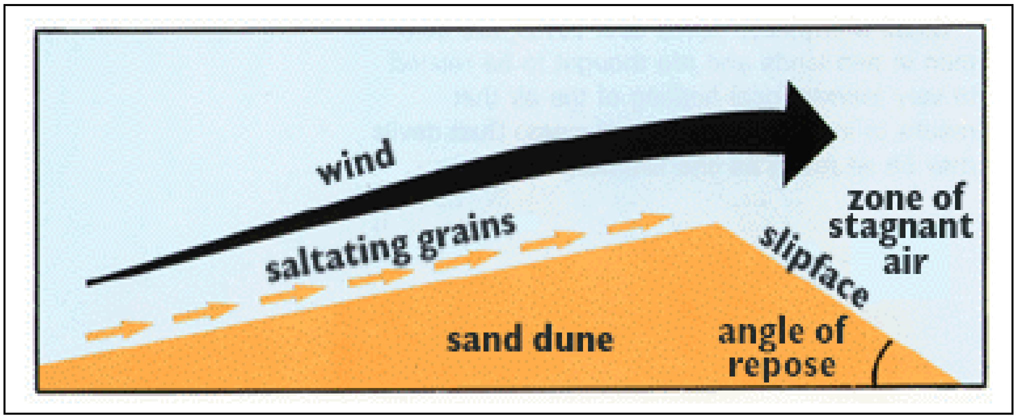


Figure 2. The wind blows sediment grains up the ***windward***, gentle slope grain-by-grain, by saltation. Grains accumulate at the top crest of the dune, and cascade down the steep ***leeward*** slipface. The dune moves downwind, grain by grain. (http://pubs.usgs.gov/gip/deserts/eolian/)

Figure 3 shows dunes' gently-sloping leeward faces on the right and the steep windward faces towards the left.

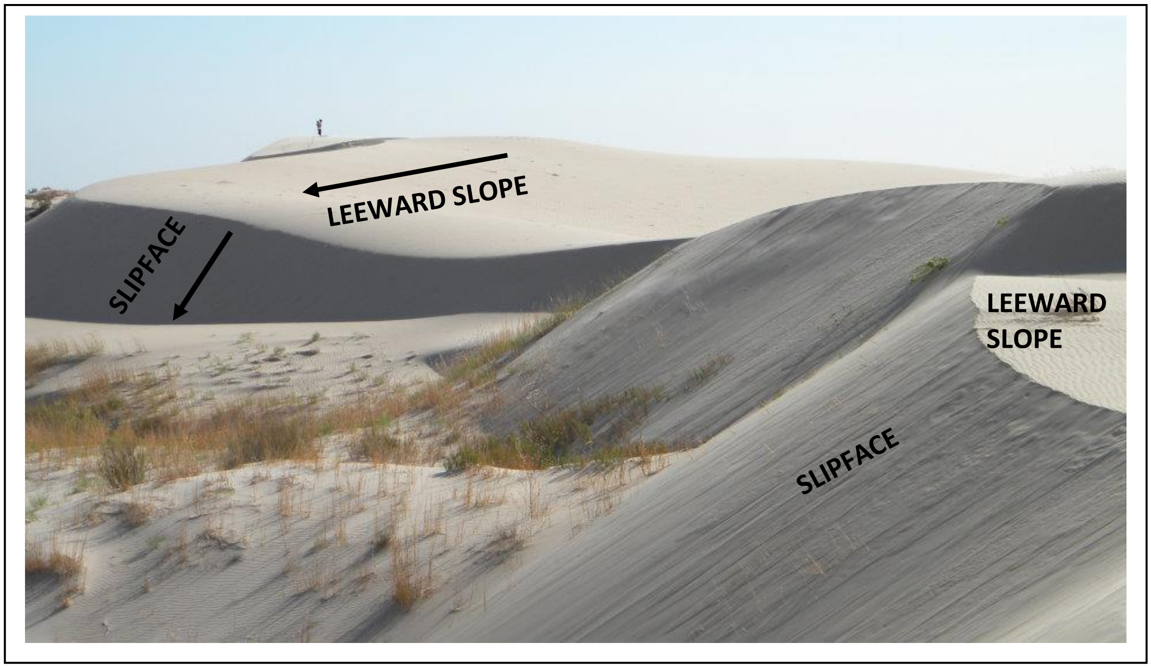


Figure 3. Wind direction is from the right; the long arrow shows the direction on the gentle leeward slope up which saltating grains move. Sand cascades down the steep leeward slope (slipface; short arrow) towards the right. The dunes are moving across the landscape towards the left.

***With this background information, follow along in the rest of the guide for activities and possible questions to use in developing your own assignment(s).***

To prepare for this exercise, visit the Monahans Sandhills State Park (MSSP) website (http://tpwd.texas.gov/state-parks/monahans-sandhills/map) and select the *Overview* tab (Fig. 4). Watch the video to see wind erosion in action.

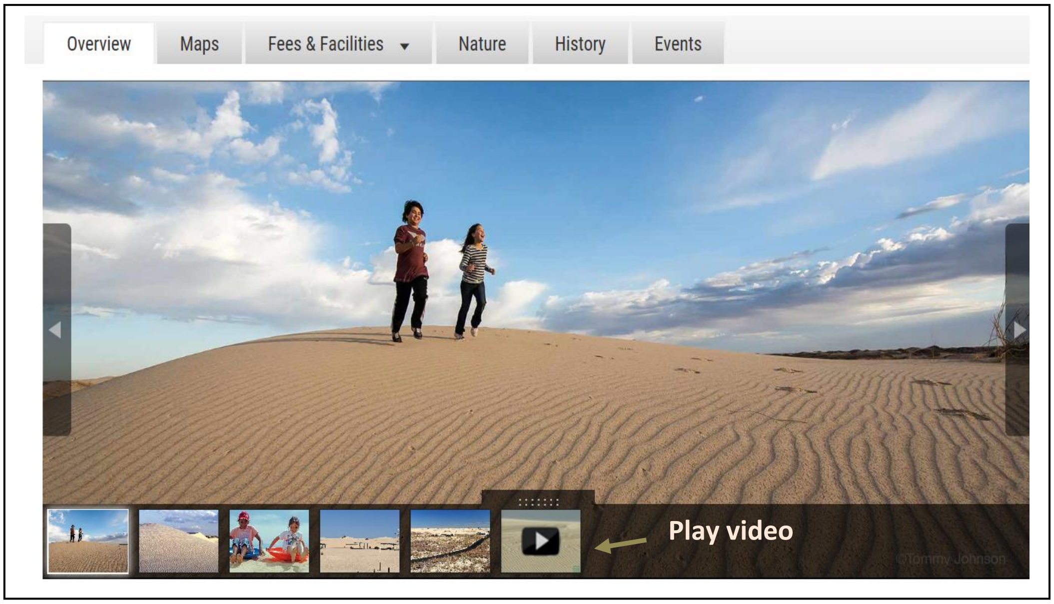


Figure 4. Monahans Sandhills State Park website. Select the arrow to play the video.

- The first moments of the video show wind moving sediment across the landscape, and also show the leeward and windward slopes of active dunes.
- A Park Ranger discusses the origin of the sand.
- Observe that vegetation tries to grow on the dunes (Fig. 5); this will be visible on the satellite imagery.

Figure 5. Grasses and shrubs may establish small, vegetated patches among the dunes. These are often ephemeral and become buried by the migrating dunes. If enough vegetation becomes established, dunes can become stabilized and stop migrating. (This is a still clip from the video posted on the MSSP web site).

Select the *Maps* tab on the park web site, and then select the *Satellite* button.  The dune fields appear as several separate bright areas along a northwest trend (Fig. 1).  You can zoom in and see multiple dunes.

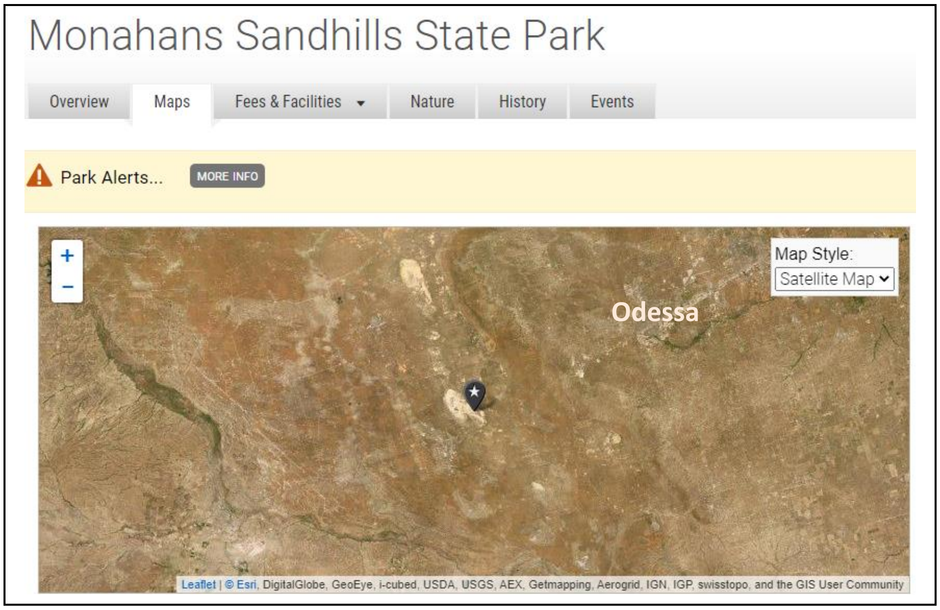


Figure 6.  Monahans Sandhills State Park is located southwest of Odessa, Texas.

Open the Texas Watershed Viewer, for better access to satellite imagery and higher-resolution photography (https://tpwd.maps.arcgis.com/apps/Viewer/index.html?appid=2b3604bf9ced441a98c500763b8b1048).  Search for Monahans Sandhills State Park and close the search result pop-up.  You are now viewing Landsat satellite imagery of the State Park and surrounding areas.  Center the park name in your viewer and zoom in until you see approximately the view in Figure 7.  Re-center with the Park name, if necessary.  You now have several features in the viewer, which we will observe changing over time.

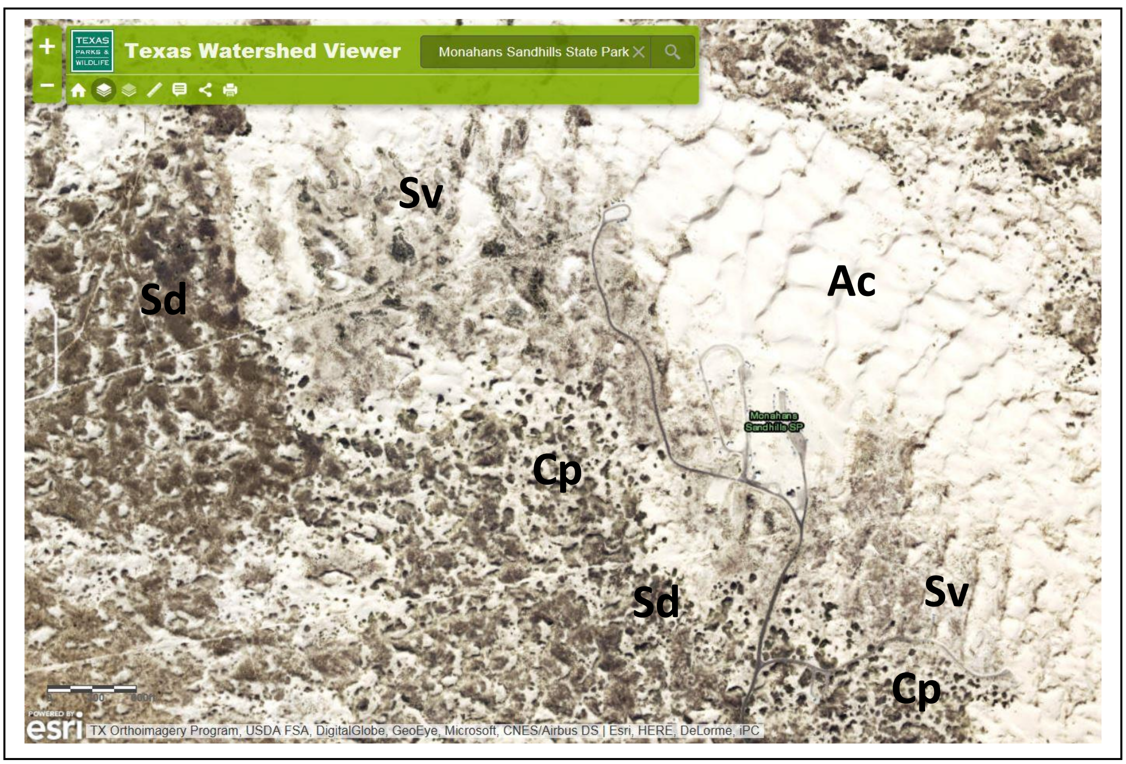


Figure 7.  Monahans Sandhills State Park.  Several types of landcover include active dunes (Ac), sparsely-vegetated dunes (Sv), isolated coppice dunes (Cp), and stabilized dunes (Sd).

Active dunes (Ac)

Sparsely-vegetated dune (Sv)

Isolated coppice dunes (Cp), below anchored by Shin Oak trees, which have roots up to 30 feet deep.

Stabilized dunes (Sd) have several species of shrub and tree cover.

Figure 8. Surface views of landcover on dunes in Monahans Sandhills State Park.

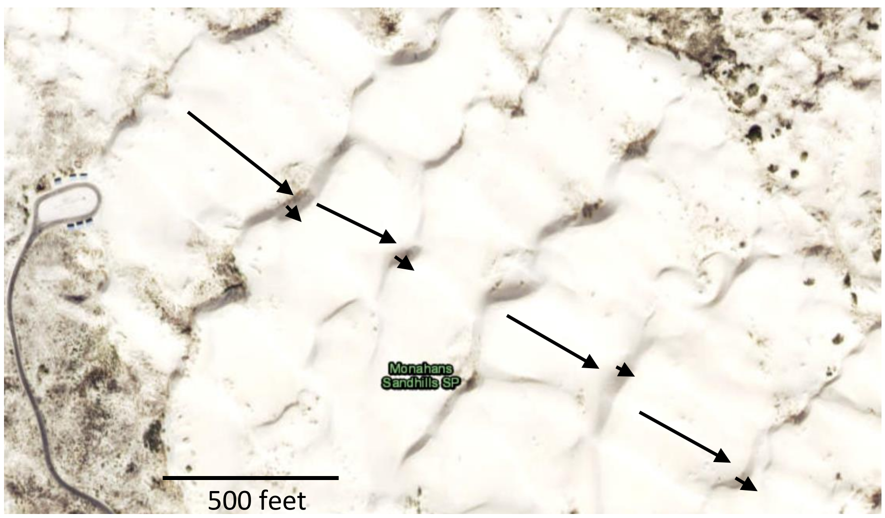


Figure 9. Migrating dunes in the active dune field area. Long arrows indicate the more gently-sloping windward slope leading up to the crest of the dune; short arrow the steeper leeward slope of the dunes.

- Center on the area mark "Ac" (Fig. 7; active dunes) and zoom in until you see approximately the view in Figure 9. The active dunes have little to no vegetation cover and migrate under the influence of the wind. What direction is the wind blowing? *Students should be able to recognize the longer, gentle slope of the windward side of these dunes, leading up to the shorter, steeper slope of the leeward side (Fig. 2). The wind is blowing predominantly from the northwest in these images acquired in mid-November, although it changes with the seasons.*
- Which direction should the dunes be migrating? *Students should recognize that because the wind is predominantly blowing from the northwest, the dunes can be predicted to migrate towards the southeast*

Grasses and shrubs can take root on active dunes. If dune migration is slow enough, and sand movement does not bury such vegetation, the dunes may become stabilized. However, small areas of sparse vegetation may be easily buried by fast-migrating

Figure 10. Sparsely vegetated dunes adjacent to the active dune field.

Center on the area marked “Sv” (sparsely vegetated dunes) in Figure 7 and zoom in until you see approximately the view in Figure 11.

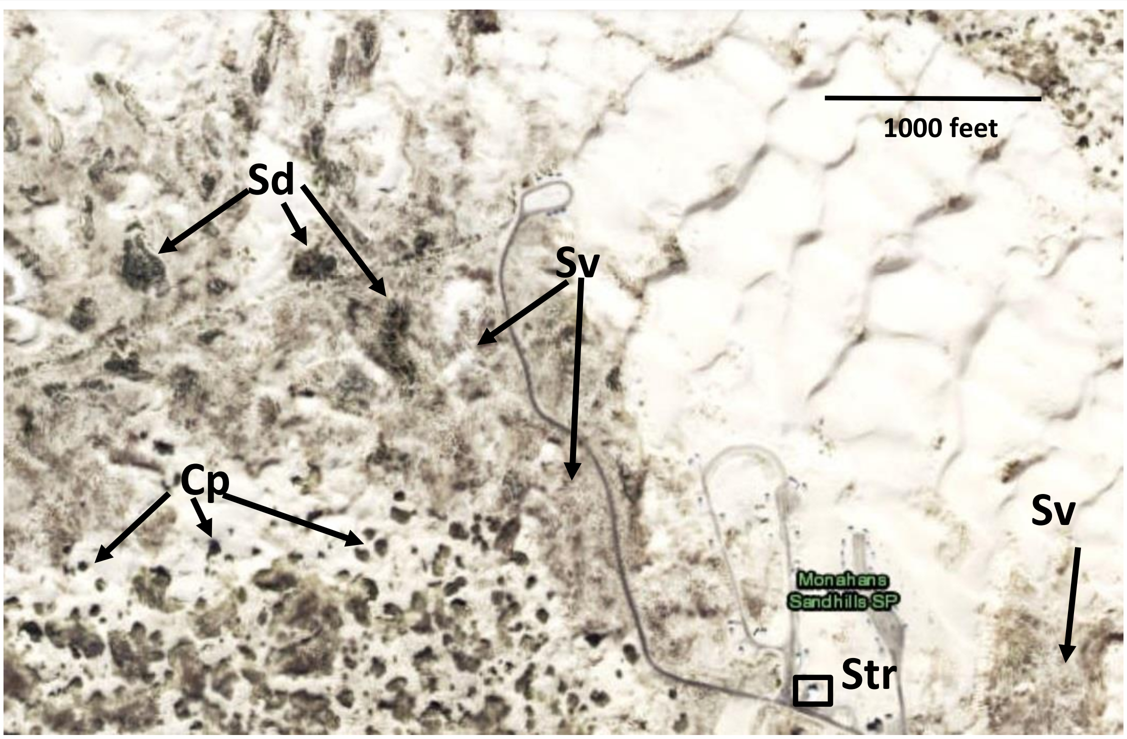


Figure 11. Sparsely-vegetated dunes with scattered coppice dunes.

The structure to the left of the road in figure 10 is marked as “Str” in figure 11. Dunes on either side of the road through the center of the image are covered with primarily sparse grass and shrub vegetation (Sv), as shown in Figure 9. Several isolated areas with denser vegatation are indicated by “Sd”. These patches of dense vegetation are 150 feet wide and up to 300 feet long. Smaller coppice dunes (Cp) are scattered to the southwest of the sparsely-vegetated dunes.

- What sort of changes might result in changes in vegetation cover adjacent to and within the active dune field?
    - *Answers may vary, but students should hypothesize that*
        - *An increase in wind activity could reactivate sparsely-vegetated dunes and the active dune field would grow.*
        - *A decrease in wind activity would have the opposite effect; vegetation cover could expand and become denser.*
        - *An increase in sand supply could rejuvenate and expand the dune field, burying vegetation.*
        - *An increase in moisture could expand the vegetation cover.*
        - *Vegetation on coppice dunes could expand and merge, better anchoring sand dunes.*

Center on the area marked "Sv" (sparsely vegetated dunes) in Figure 7 and zoom in until you see approximately the view in Figure 12.

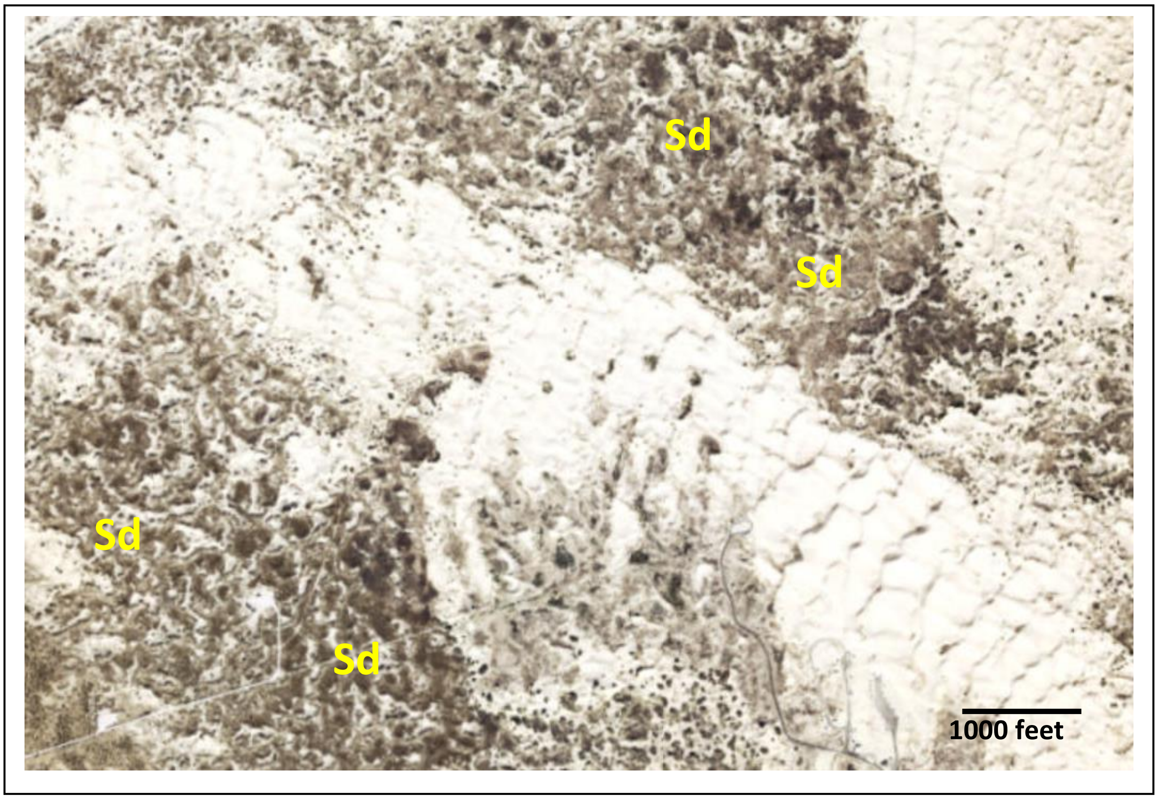


Figure 12. Stabilized dunes (Sd) flank the actively-migrating dune fields (Ac).

A variety of vegetation has stabilized dunes within the dune fields (Figure 13), including mesquite trees, shin oak trees, cacti, willows, salt bush, and sage.

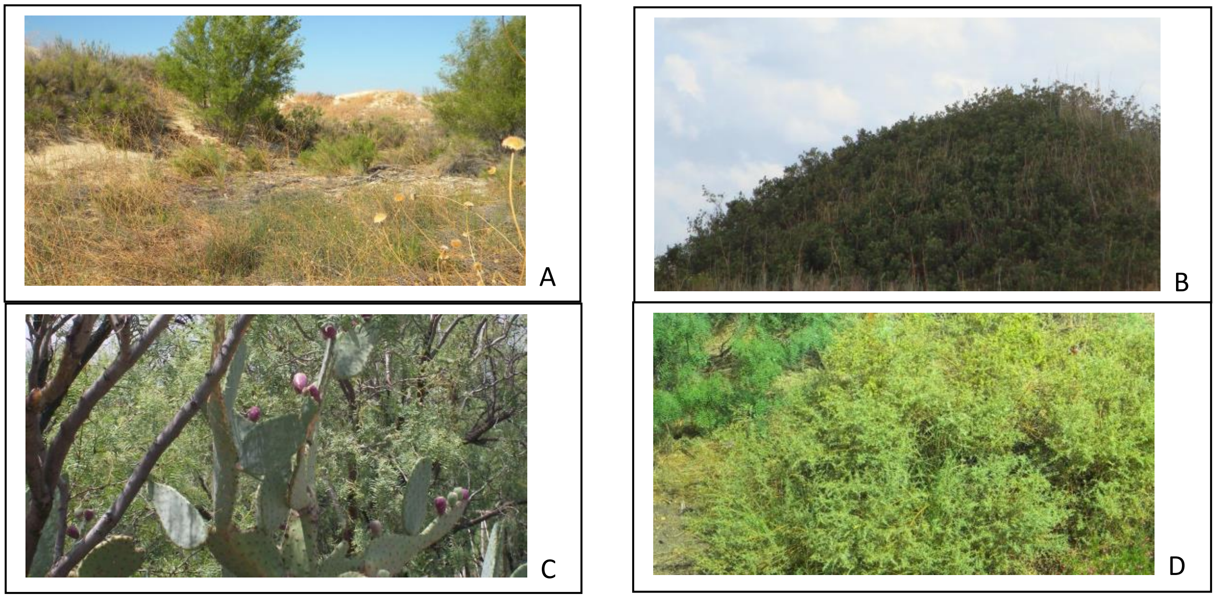


Figure 13. Vegetation cover on stabilized dunes. A. Black willows. B. Shin Oaks. C. Cacti and Mesquite. D. Four wing saltbush and mesquite.

- **Open the Historical Imagery Viewer** and select the “2” button (Figure 8).
- (http://tpwd.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=40c1b8be6fd1419f9d299103cc4241ca#) .
- In this viewer (Fig. 13) you are seeing the same Landsat image of Monahans Sandhills State Park that you saw in the Texas Watershed Viewer (Fig. 7).

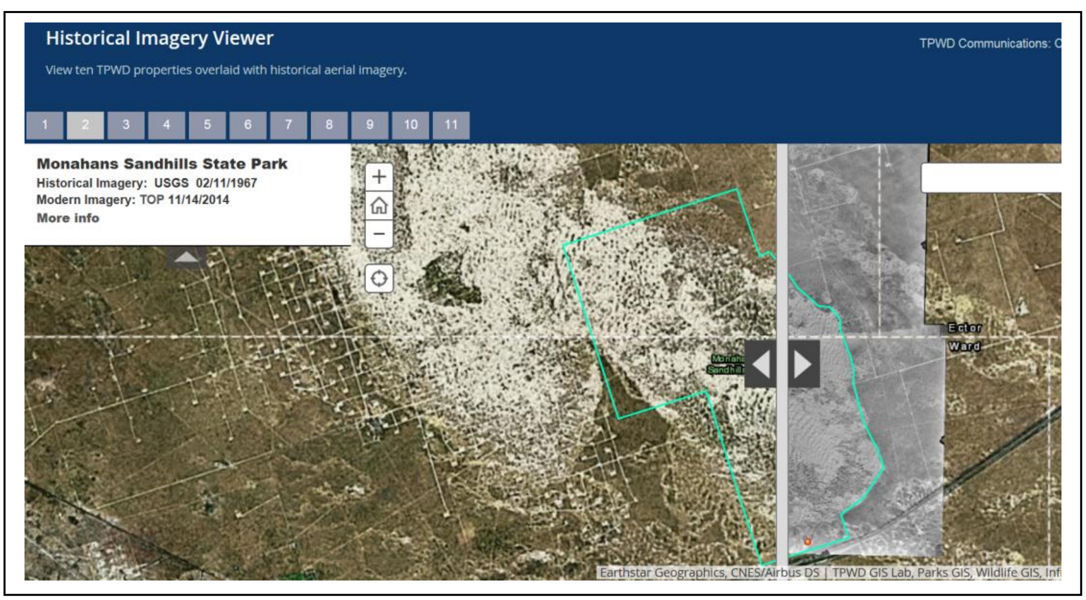


Figure 14. Historical Imagery Viewer.

- There is a vertical "slider bar" that allows you to "swipe" a 1967 aerial photograph of the same area over a December 2nd, 2018 Landsat image. Grab the bar with your mouse, pull it to the left, and cover the state park with the older image.
- At this zoom level, changes may not be obvious, so re-center your view on the words "Monahans Sandhills SP and zoom in until you see approximately the view in figure 15.
- Pull the slider bar all the way to the left. You will see:

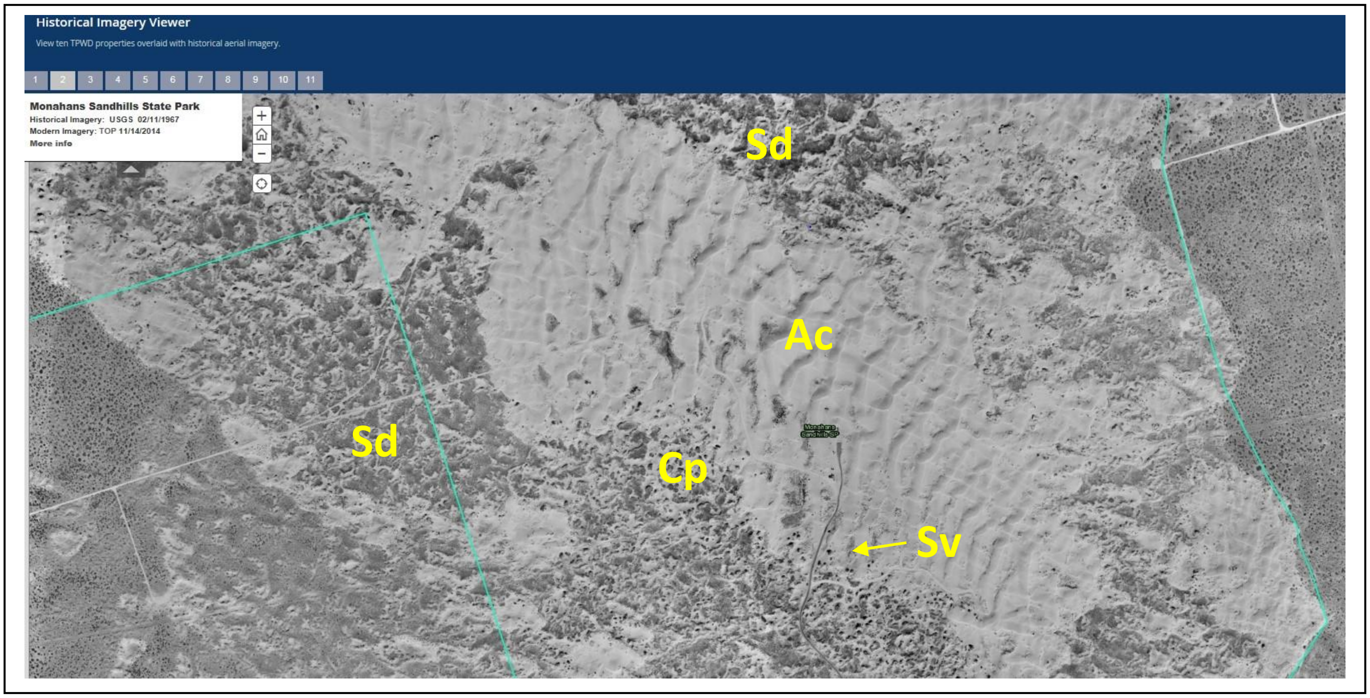


Figure 15. Ac = Active dunes. Sv = sparsely-vegetated dunes. Cp= Coppice dunes. Sd = Stabilized dunes

You can now zoom into several of these areas and view changes over time in the different parts of the MSSP.

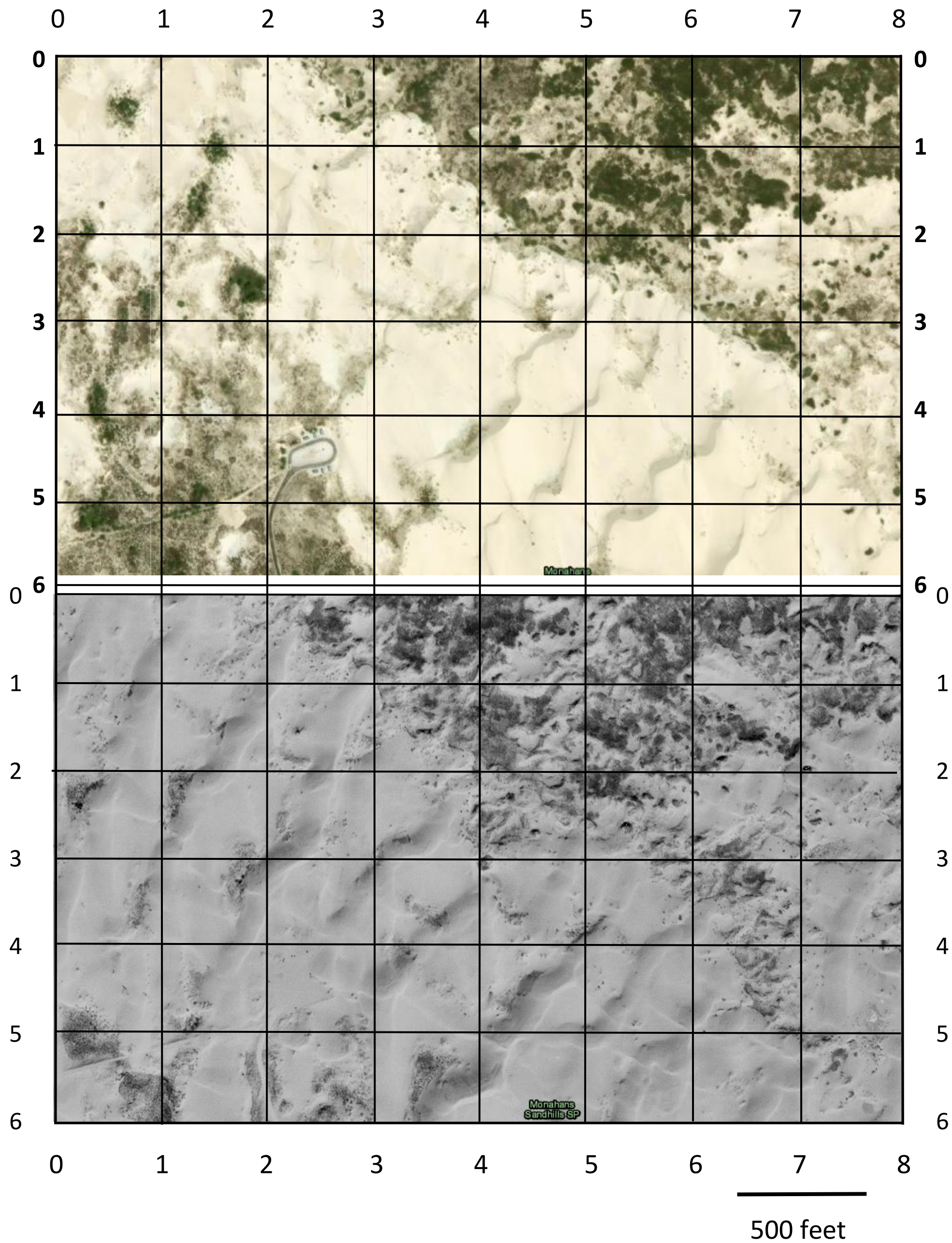


Figure 16. Migrating dunes in the active dune field area, circa 1967 (bottom image; 02/11/1967) and 2018 (top image; 12/02/2018). Students will investigate specific locations with reference to the gridded images above. The “X” axis numbers are referenced first for location purposes, followed by the “Y” axis numbers. For example, there is a “loop” road centered at grid point (2.4, 4.6) in the 2014 scene. The word “Monahans” on the bottom of the images is split by the gridline at (5, 6). “Columns” of grids run from north to south; “rows” of grid units run east-west.

Zoom in to the area shown in Figure 16.

- Swipe the 1967 image back and forth over the 2018 image. Have the dunes migrated? Are there other changes?
  - Observe the large northeast-trending dune centered at (4.5,4.5) in the 1976 image. How many dunes are in that grid square now?
    - *There are now two dunes in that grid square, neither of which is in the same location as the 1967-era dune.*
  - Observe the adjacent grid square to the east. Has the central dune (centered at 4.5, 5.5) from the 1967 image changed?
    - *The central dune appears to have moved towards the southeast, almost out of the grid square.*
    - *Another dune is encroaching from the northwest; its slip face is just entering the grid square.*
  - Observe the grid square centered at (3.5, 1.5). How has the size of active dune cover in the grid changed between 1967 and 2014?
    - *The boundary between sparsely-vegetated dunes and active dunes has shifted towards the northeast approximately 200 feet.*
  - Locate another grid where the active dunes have moved over sparsely-vegetated dunes.
    - *The grid centered at (4.5, 2.5) was almost totally covered with sparse vegetation in 1967. By 2014 the active dunes cover almost 75% of the area within the grid unit.*
    - *Similar advance of the active dunes can be seen in the grids centered at (3.5, 6.5) and (4.5, 6.5).*
  - Observe the sparsely-vegetated dunes centered at (0.5, 5.5) and (0.8, 5.8). Have these dunes migrated?
    - *No. In fact, they seem to be more heavily-vegetated in the more recent image.*
  - Do there appear to be any other areas where vegetation cover has increased, as opposed to being covered by migrating sand?
    - *Yes. the entire south western 1/3 of the 2018 image has significantly more sparsely-vegetated sand dunes.*
    - *Several large dunes appear to host dense vegetation in areas that were formerly bare sand (e.g. (0.4, 4), (0.8, 3), (1.9, 2.8), and (1.5, 1.2).*

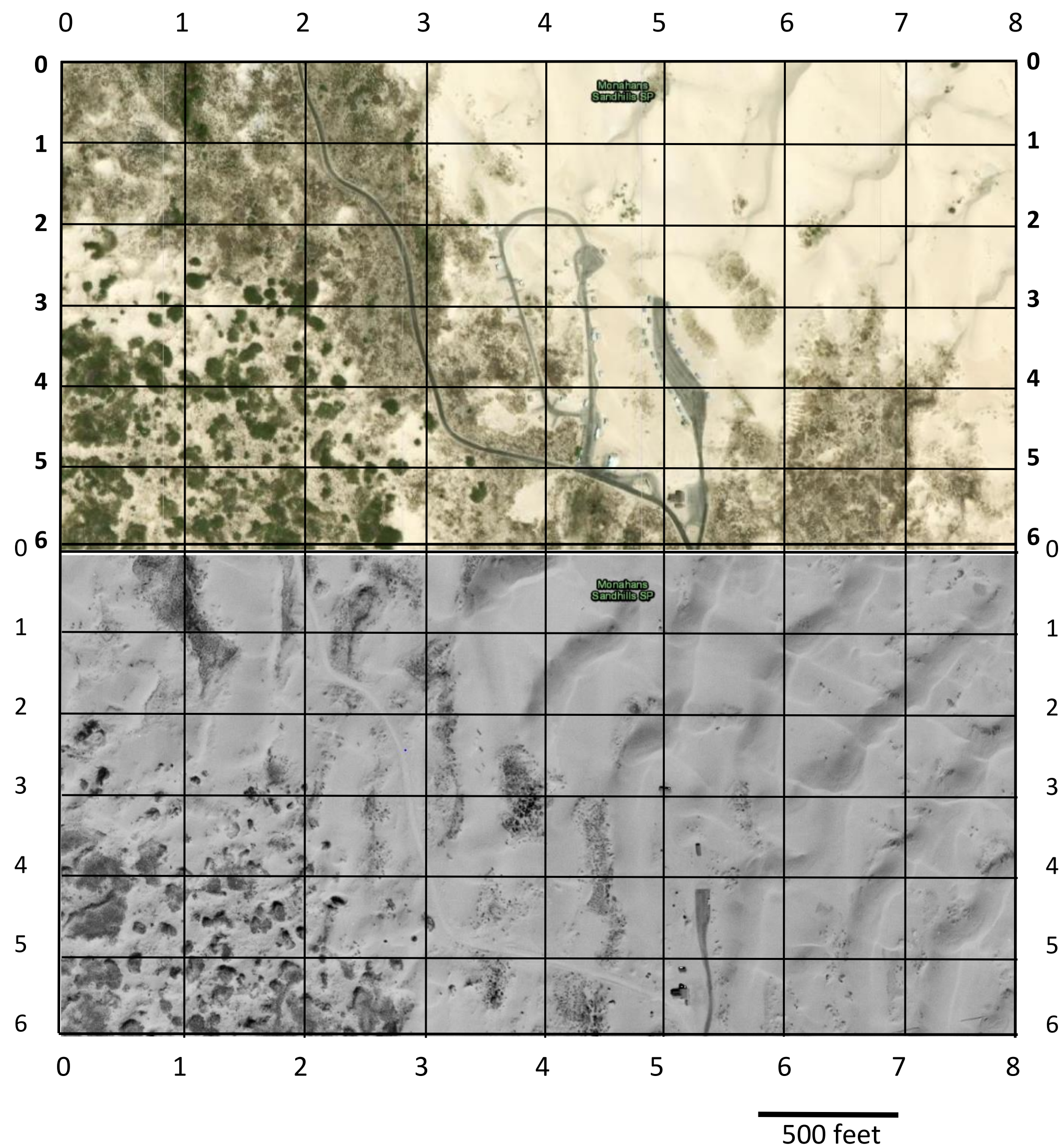


Figure 17. Migrating dunes in the active dune field area, circa 1967 (bottom image; 02/11/1967) and 2018 (top image; 12/02/2018). Students will investigate specific locations with reference to the gridded images above.

Zoom in to the area shown in Figure 17.

- Swipe the 1967 image back and forth over the 2018 image. Have the dunes migrated? Are there other changes or features that differ between the two images?
    - Observe the northwest-trending bright features in the eastern two columns of the 1967 image, in particular those centered at (6.5, 1.5) and (6.4, 2.0). What are these features?
        - *These are slip faces on small dunes that are migrating towards the northeast. The short, steep faces of the dunes appear as bright, northwest-trending lines on the image. This would indicate the wind direction creating these dune forms is coming from the southwest. These dunes are superimposed on the larger, northeast-trending dunes that dominate the topography in this part of the park.*

        - *The winds in MSSP area change direction with the seasons.*
            - *During the summer winds blow from the southeast*
            - *During the winter winds blow from the northwest (e.g. the 2018 image)*
            - *During the spring winds blow from the southwest (e.g. the 1967 image)*
    - How about the northeast trending, large dunes? Have they migrated as you observed in the previous scene?
        - *Yes. None of these dunes are in the same location.*
    - Observe the area surrounding the road that enters the scenes on the south at (5.3, 6) and exits on the north at (2.0, 0.0). How has the vegetation cover changed between 1967 and 2018?
        - *The area adjacent to the road had a mixture of sparsely-vegetated dunes and active dunes in 1967. By 2014 the had much more land covered with sparse vegetation, extending all the way to the northwest corner of the scene.*
    - Observe the area in the southwest corner of the scene. How has the vegetation cover changed?
        - *Some areas have changed very little. The grid units centered at (0.5, 3.5), (0.5, 4.5) and (0.5, 5.5) have changed very little. Many of the densely-vegetated dunes and coppice dunes are stabilized, and have changed location and configuration very little between 1967 and 2018.*
        - *Coppice dunes have expanded towards the north and east on the western side of the road.*
    - Identify other areas in the scene affected by significant change in vegetation cover.
        - *The grid units centered at (6.5, 4.5) and 6.5, 5.5) were unvegetated, active dunes in 1967 and by 2018 have been covered with sparse vegetation.*
    - Are there other significant changes in land cover evident in the scene?
        - *Yes, roads have been developed within the central part of the scene. These are picnic areas that are part of the State Park infrastructure.*