Name:

LABORATORY

10 Arid Environments and Aeolian Geomorphology

Introduction

Desert environments are geographic regions where potential evapotranspiration normally exceeds precipitation. The distinction of this environment is usually drawn where precipitation is less than 500 mm per year. Many have drawn distinctions between extremely arid (consistently have 12 consecutive months without rainfall), arid lands (250 mm or less), and semiarid lands (250–500 mm). Regardless of the total rainfall the desert environment results in sparse vegetation, minimal animal habitation and human settlement. These harsh landscapes make up about 33% of the Earth's surface and exist in both warm and cold regions. They are not constrained by latitude, longitude or elevation. The reason for the geographical location of these deserts is driven by variables within the global, regional, and local climate systems, and this climatic regime ultimately influences the geomorphic processes that work within those environments.

A suite of geomorphic processes that is often associated with desert landscapes are Aeolian (wind-blown) processes. This is certainly not the only location where Aeolian processes occur. They can occur in coastal, fluvial, and even glacial landscapes. Although most deserts have less than 30% sand, Aeolian processes create relatively abundant features within the desert landscape, making them ideal laboratories for the study of Aeolian features.

Key Terms

Subtropical Desert
Mid-Latitude Desert
Mid-Latitude Monsoon Desert
Coastal Desert
Orographic/Rainshadow Effect
Orographic Desert
Polar Desert
Continentality
Intertropical Convergence Zone
Hadley Cell
Subtropical High Pressure
Sand Dunes
Barchan Dune
Transverse Dune
Parabolic Dune
Star Dune
Trade Winds
Physical Modeling
Slip Face
Saltation
Suspension
Creep

What Causes a Desert?

The causes of desert environments are directly related to climatic conditions and the physical landscapes within the region they are found. These climatic conditions have influences at varied scales from global to regional to local. Deserts can be designated subtropical, mid-latitude, mid-latitude monsoonal, orographic, coastal, or polar deserts. This first section of this lab will be looking at several examples of why deserts form where they do. *Keep in mind that many of these climatic influences work in harmony with other processes and, in combination, change the dynamics of the desert they create.* You can travel to any desert on Earth, but you will never find a desert that is the same. Each desert truly is a unique environment unto itself. In this lab you will investigate a few of these geographies and learn a little more about deserts.

Using Google Earth: One of the more revolutionary tools for investigating our planet's surface is the program Google Earth. Using this software, you can view the entire planet from a variety of different perspectives. The following questions will have you use the computers in the classroom and Google Earth in order to answer them.

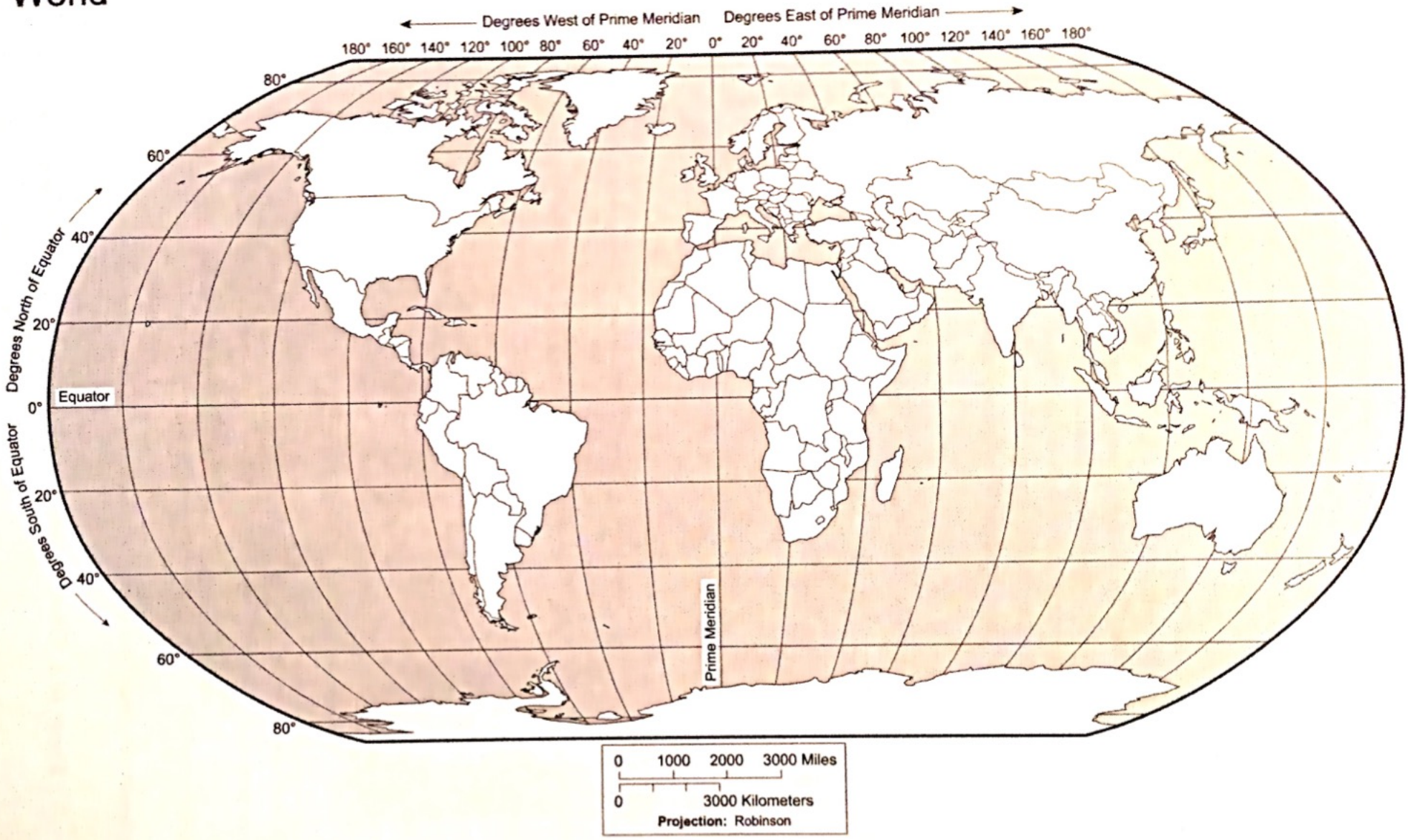
1. Given your knowledge of atmospheric processes and climate controls *and* using Google Earth, try to identify areas you think are deserts on Earth's surface. No need to zoom in too close, just locate them from the global view, but feel free to rotate the planet and zoom in if you think you've found one. Limit them to the largest and most obvious features from the global perspective.

   As you locate them, please draw a rough outline in these areas with a pencil on your blank world map.

2. What did you use to identify the deserts? In a few sentences, explain the criteria you used to distinguish them from non-desert areas.

3. Did you notice any commonalities about where these deserts were located? Feel free to zoom in and investigate the deserts you located to answer this. If yes, please explain. If no, describe why they are not similar. (Hint: Are there similar latitudes? Physical landscapes? Textures? Colors? Vegetation?)

World



ARIZONA GEOGRAPHIC ALLIANCE

Courtesy: Arizona Geographic Alliance **http://geoalliance.asu.edu/azga**
School of Geographical Sciences and Urban Planning
Arizona State University
Cartographer Terry Dorschied
World-at PDF

Subtropical (Trade Wind) Deserts

Some of the largest deserts of the world are located along somewhat distinct latitudinal bands around the globe. These deserts are primarily the result of the processes that redistribute energy from the Sun due to differential heating of the Earth's surface. These processes were highlighted in the Atmospheric Processes lab earlier in the course, so you may want to refer to that lab if you do not remember the details.

For a refresher, because the Earth is inclined at 23.5° from the plane of the ecliptic, the angle of the Sun's rays that strike any given location change throughout the year. If the Sun's rays strike a location from directly overhead the heating is the most intense, but as the angle decreases, the energy of incoming rays is more dispersed and thus less able to heat the surface. Because the Sun is only overhead between the tropics, the result is more intense heating between the tropics and less heating in the higher latitudes. This, in turn, results in a complex suite of global circulation systems both in the atmosphere and in the oceans. These systems help redistribute the energy from the equator to the poles (Figure 10.1).

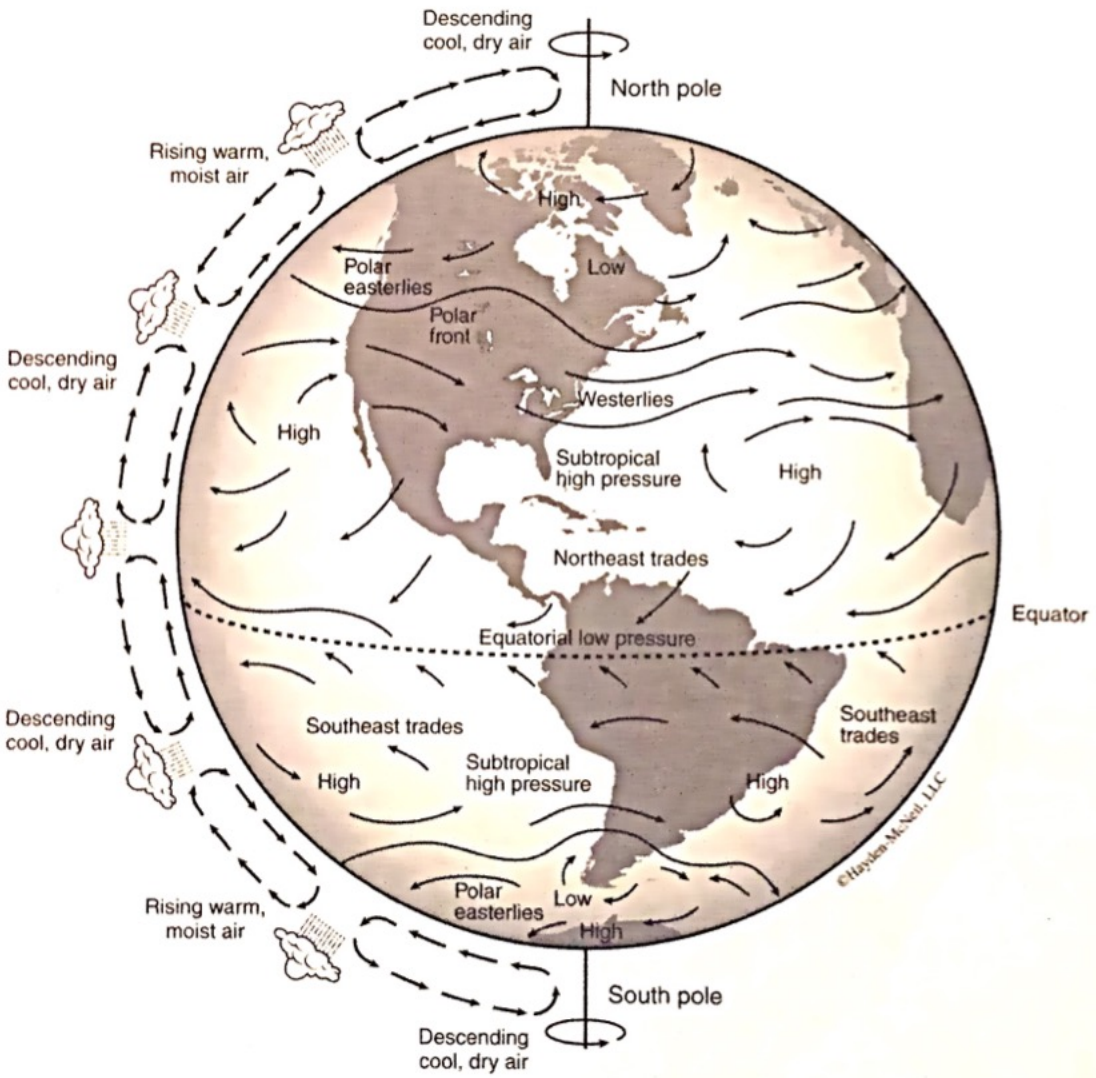


Figure 10.1. Global atmospheric circulation patterns. Source: Murck et al. (1997).

One of the primary mechanisms by which energy is transferred from the equator poleward is through atmospheric circulation cells (Hadley, Ferrell, and polar cells). For the subtropical (trade wind) deserts the Hadley cells play a vital role. Hadley cells start with rising air near the equator, or more specifically at the **Intertropical Convergence Zone (ITCZ)**, as heating builds low pressure at the surface. As this air rises it cools, condenses and rain/clouds often occur, and results in high pressure aloft. This zone is responsible for the majority of the Earth's rainforests. The air spreads out from the ITCZ toward the poles to ~30°N and S latitude. Because the moisture has largely been depleted as it moves away from the ITCZ, the air becomes very dry. It also descends back to the surface in this circulation. The result is a descending dry air mass, which creates high pressure at the surface, which helps establish an arid climate in that area. The result is hot/dry trade winds that blow from 30°N and S latitude toward the equator. As they approach the equator they heat further. With much of the cloud cover dissipated, further heating of the landmass occurs. Examples of subtropical (trade wind) deserts are the Simpson Desert of Australia and Rub ah Khali (see climograph, Figure 10.2) of the Arabian Peninsula.

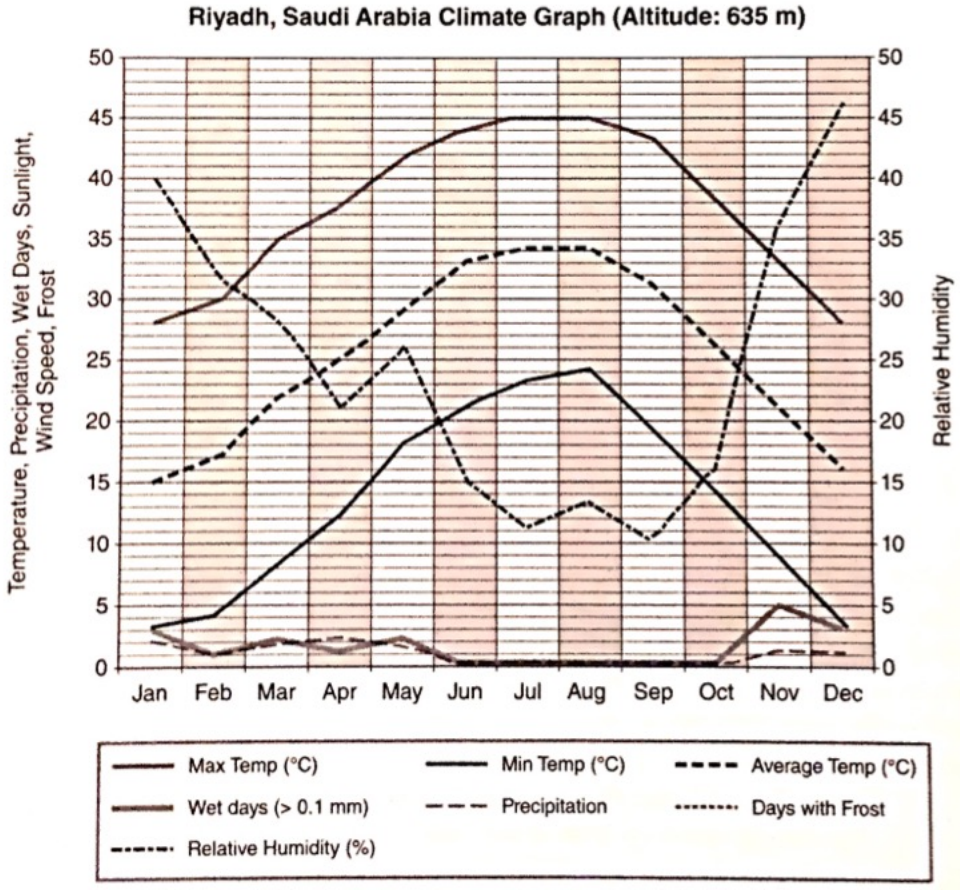


Figure 10.2. Climograph of Riyadh, Saudi Arabia. Source: http://www.climatemps.com/.

Mid-Latitude/Monsoon Deserts

It is also possible to have deserts in the mid-latitudes. These deserts occur between >30° and 50°N/S latitude. These deserts can be influenced by the subtropical high at lower latitudes, but are usually the result of being in the interior of continents far removed from moisture derived from oceans. This is known as **continentality**. Occasionally these types of deserts can be influenced by seasonal monsoonal conditions, as is the case in the southwestern United States and in western India/eastern Pakistan, and are sometimes classified as **monsoonal deserts**. Mid-latitude monsoonal deserts will experience seasonal precipitation increases. The archetypal example of a mid-latitude desert is the Gobi Desert of Mongolia (Figure 10.3). Phoenix, AZ, is also located in a monsoonal desert (Figure 10.4).

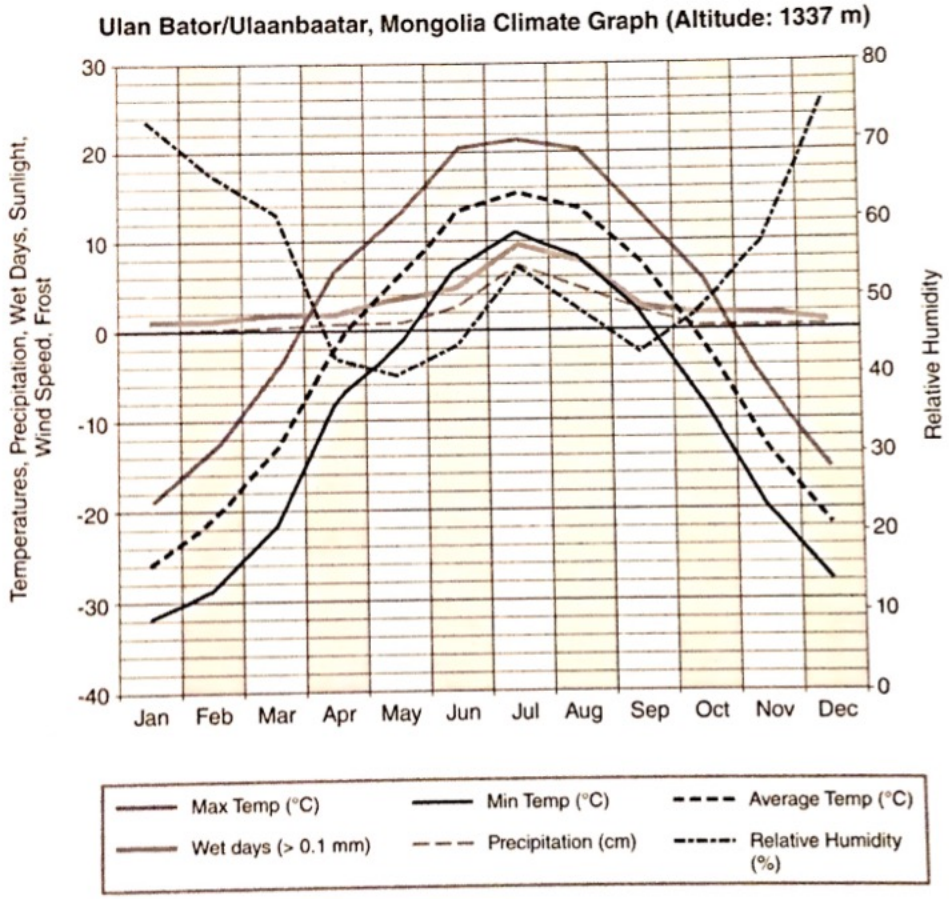


Figure 10.3. Although slightly higher in elevation and slightly north of the Gobi, this climograph is a close approximation of the climate in the Gobi Desert. This is a typical mid-latitude desert. Source: http://www.climatemps.com/.

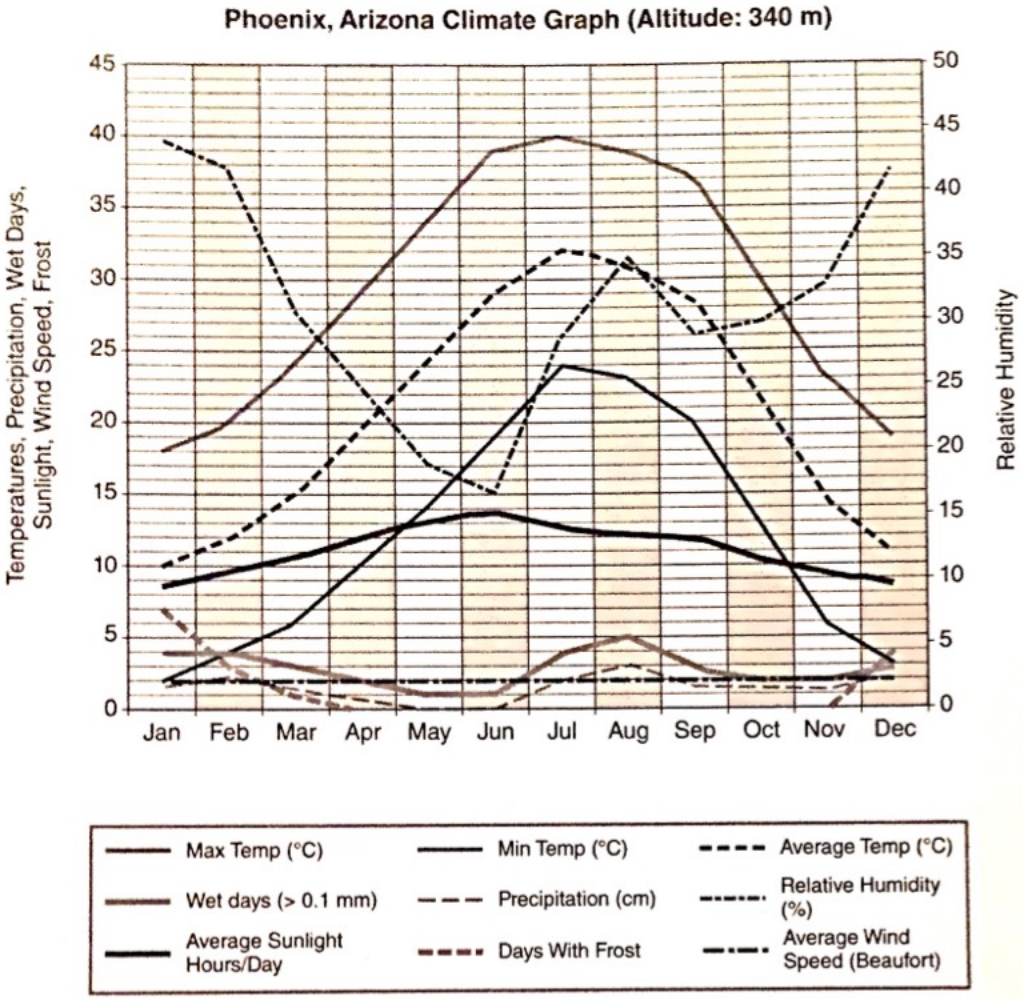


Figure 10.4. *Phoenix, Arizona represents a mid-latitude monsoonal desert. Source: http://www.climatemps.com/.*

Coastal Deserts

Coastal deserts are often the most complex desert environments to grasp. The complexity is derived from coastal deserts existing where atmospheric, terrestrial, and oceanic processes interact with one another. They generally occur where cold ocean currents border a warm land mass and where cold water upwelling along the coast creates stable atmospheric conditions. Fog often occurs in these areas as the only form of condensation that develops on a relatively regular basis. Because of the complex interactions within these deserts, they are often the driest areas on our planet.

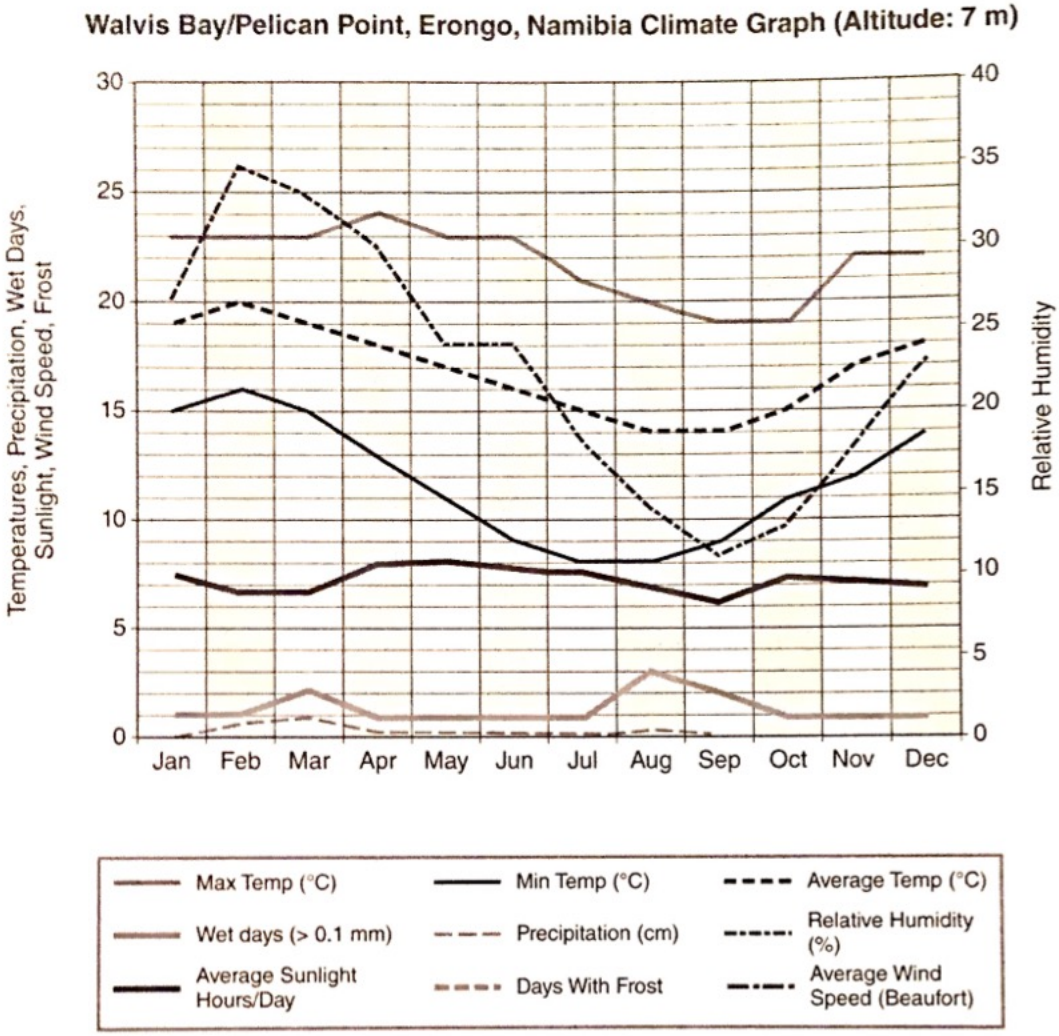


Figure 10.5. Walvis Bay, Namibia. Namib desert climograph. Source: http://www.climatemps.com/.

Orographic Deserts

Orographic deserts occur where the dominant winds in a region are blocked by mountain ranges. On the windward side of these ranges the air mass is forced up over the range losing the majority of the moisture through **orographic processes** and resulting in very dry/arid conditions on the lee side of the range (Figure 10.7). These processes were discussed in the Climate Controls lab in your lab manual. If you need a refresher, it may be helpful to look at that again. An example of this sort of desert exists on the eastern side of the southern Andes Mountains in Argentina.

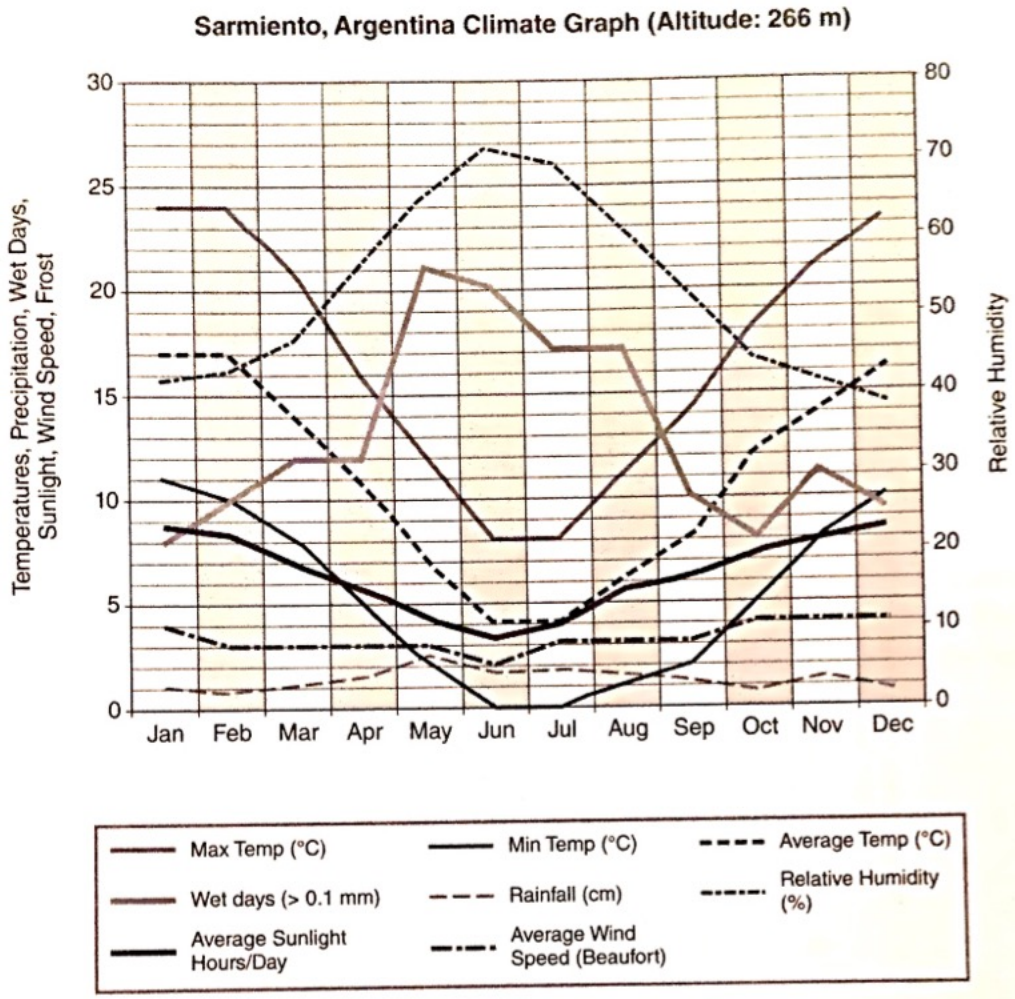


Figure 10.6. *Climograph of Sarmiento, Argentina in the Patagonian Desert of Argentina. This desert sits in the rain shadow of the Andes Mountains. Source: http://www.climatemps.com/.*

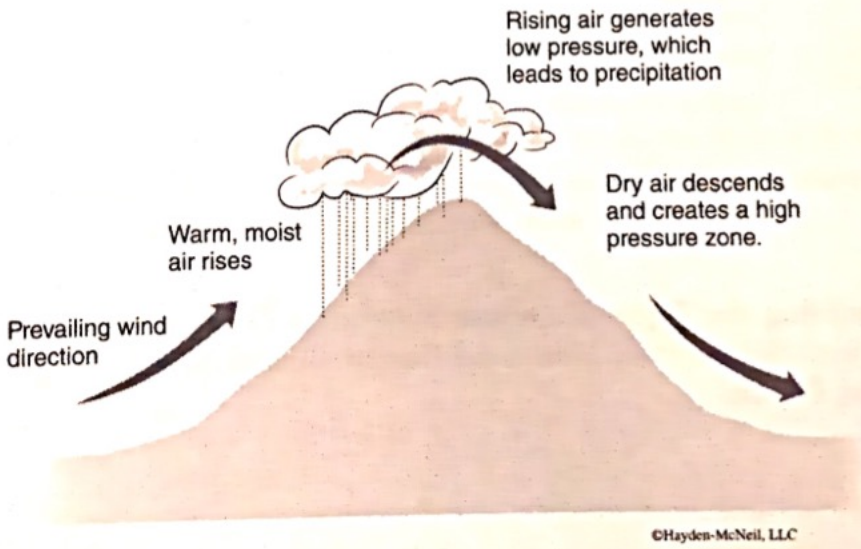


Figure 10.7. *Orographic effect producing arid conditions on the lee side of the mountains. Source: http://imnh.isu.edu/digitalatlas/clima/general/genfr.htm.*

Polar Deserts

Polar deserts occur in areas where the warmest month is less than 10°C and are largely located above 50°N/S latitude. These deserts are very cold as their temperatures rarely rise above the freezing point of water. Sand dunes are not found in these environments and are often rocky areas like the ice-free areas of Antarctica. There can also be glacial ice that has very slowly accumulated over tens of thousands of years in these deserts.

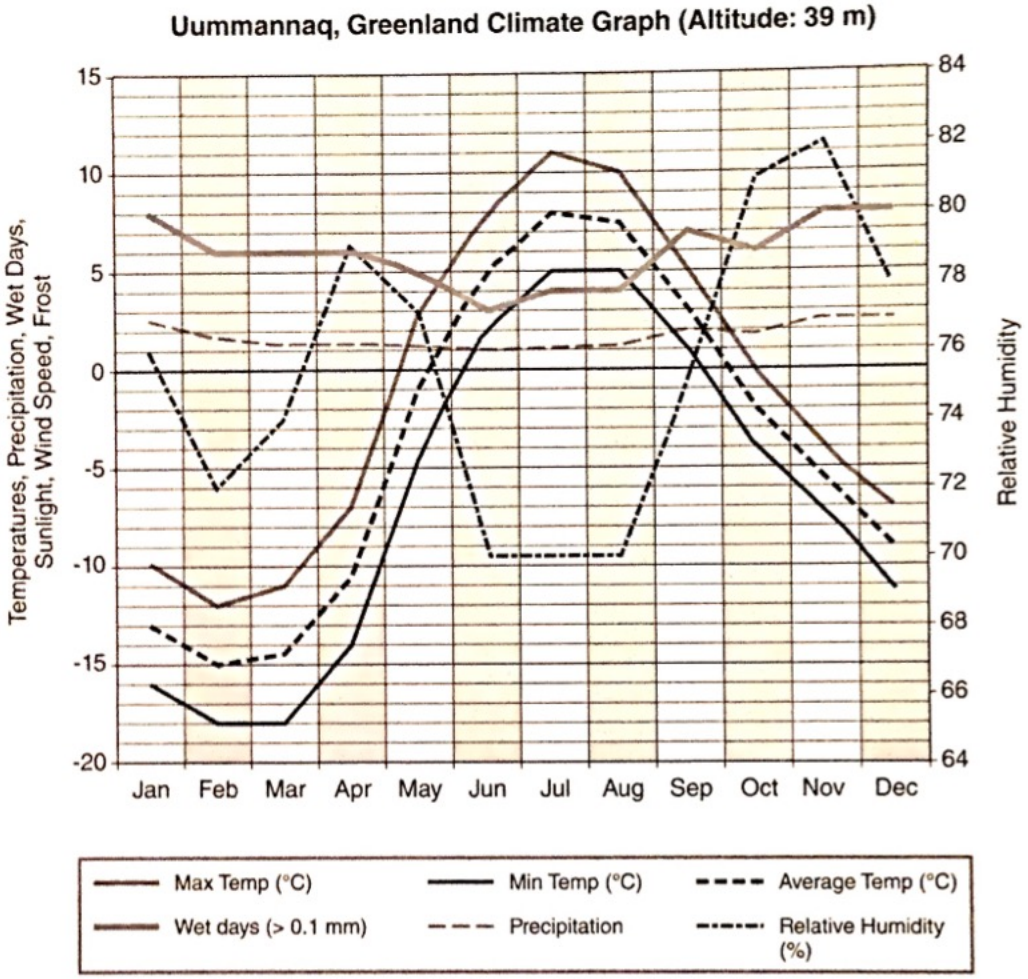


Figure 10.8. *Uummannaq, Greenland. This climograph is a close approximation of a typical polar desert. Source: http://www.climatemps.com/.*

Identifing the Types of Desert: Subtropical (Trade Wind) Deserts, Mid-Latitude Deserts, Mid-Latitude Monsoonal Deserts, Coastal Deserts, Orographic Deserts, and Polar Deserts.

Using the descriptions of the various desert types on Earth, the information from the USGS website http://pubs.usgs.gov/gip/deserts/types/, and your understanding of global atmospheric and oceanic circulation systems and physical landscapes, answer the following questions using Google Earth. In each you will have to identify what kind of desert you are looking at. Please choose between subtropical, mid-latitude, mid-latitude monsoon, orographic, coastal, and polar deserts. ***Remember**: In most cases there are several mechanisms responsible for a desert's formation!*

In Google Earth, go to and begin to explore the Sahara Desert. Also refer to a climograph from the region (Figure 10.9) to help you answer these questions.

4. What kind of desert do you think the Sahara Desert is?

5. Why do you think this? In a paragraph, describe what you think the dominant processes are that are responsible for the arid environment that exists here. Do not be general about this. Try to be very specific for this desert given what you know.

6. The Sahara is the largest desert in the world. Why do you think it is so large?

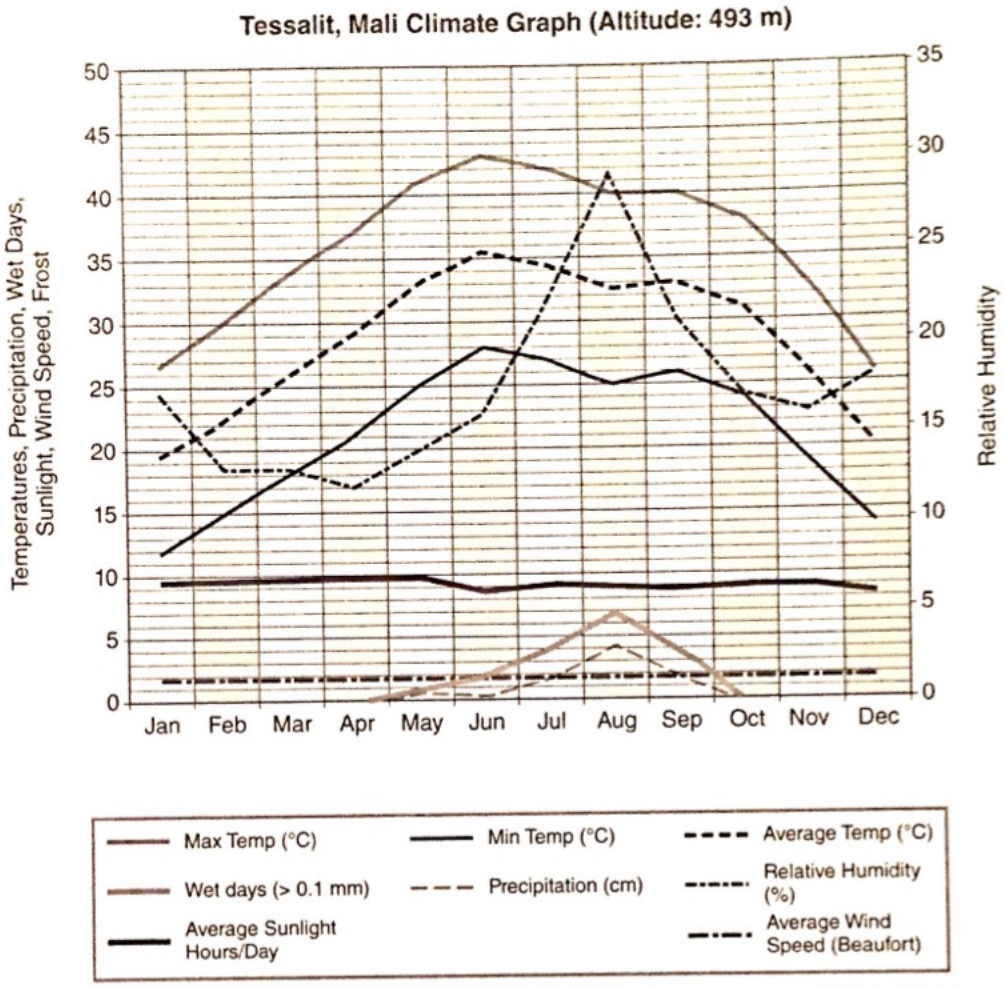


Figure 10.9. *Tessalit, Mali. A typical climograph of the Sahara Desert region. Source: http://www.climatemps.com/.*

Using Google Earth and the climograph that follows (Figure 10.10), search for and explore the Atacama Desert.

7. What kind of desert do you think the Atacama Desert is?

8. Why do you think this? In a paragraph, describe what you think the dominant processes are that are responsible for the arid environment that exists here. Do not be general about this. Try to be very specific for this desert given what you know.

9. The Atacama is the driest desert in the world. Why do you think this desert is so extremely arid?

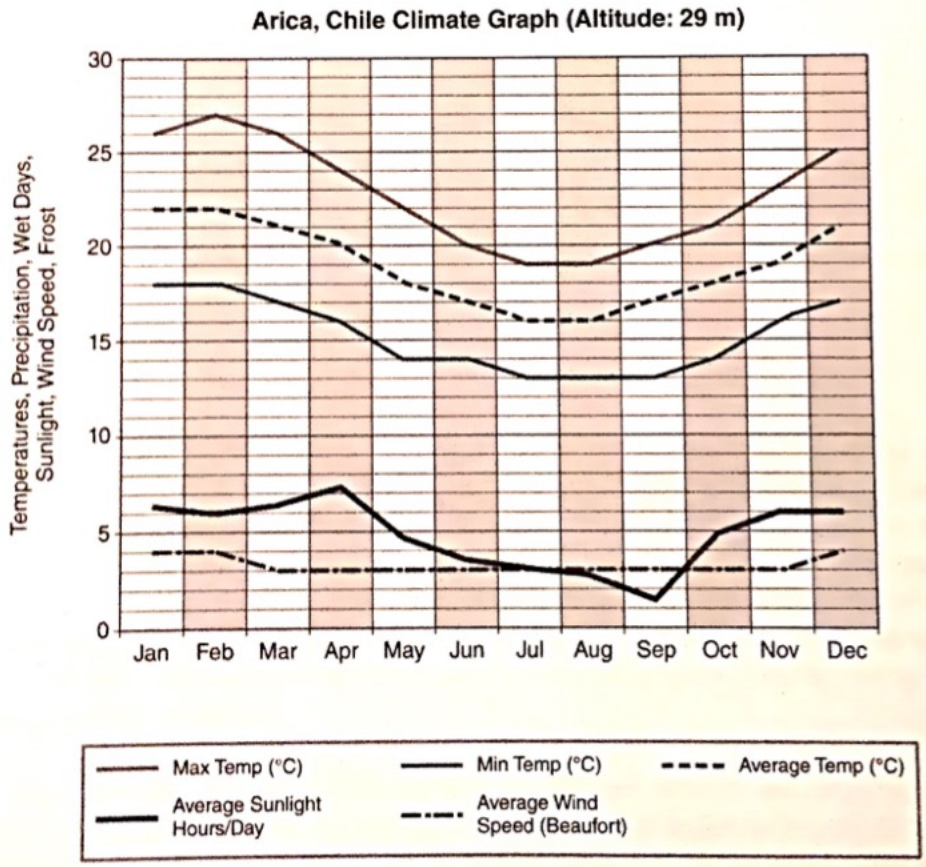


Figure 10.10. *Arica, Chile. Further inland temperatures would be slightly warmer than in Arica, but this is typical of the Atacama Desert. Source: http://www.climatemps.com/.*

Using Google Earth and the climograph that follows (Figure 10.11), search for the Sonoran Desert and explore this desert.

10. How would you classify the Sonoran Desert?

11. In a paragraph, describe what you think the dominant processes are that are responsible for the arid environment that exists here. Do not be general about this. Try to be very specific for this desert given what you know.

12. The Sonoran Desert is home to some unique species of large vegetation like the Saguaro Cactus. Why do you think this desert is able to support such vegetation? Explain using the climograph of Tucson that follows (Figure 10.11).

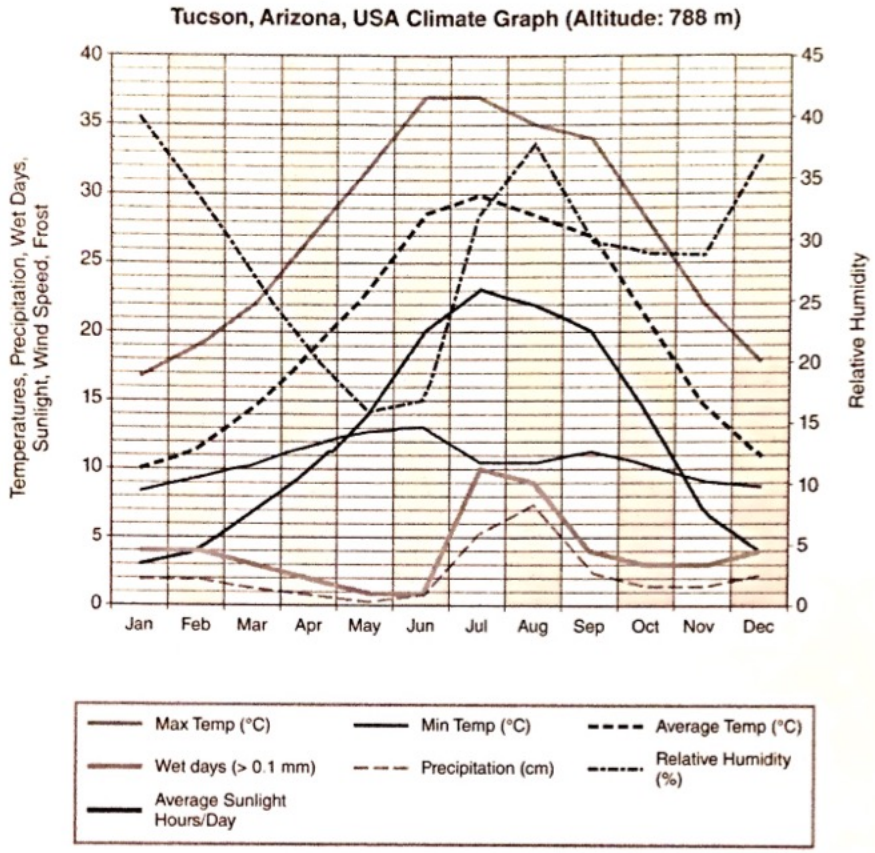


Figure 10.11. Tucson, Arizona. This is a typical climograph from the Sonoran Desert. Source: http://www.climatemps.com/.

Aeolian Processes

Aeolian processes are those that shape the surface of the Earth over time by wind. Wind can shape the Earth's surface by eroding (although this is usually very minimal in impact), transporting, and depositing sediment across landscapes. There are many different Aeolian landforms (yardangs, ventifacts, etc.) that have been discussed and researched in the field of Aeolian Geomorphology, but the most classic form that is often associated with desert/arid environments are sand dunes. The focus of the remainder of this lab will be examining various sand dunes, interpreting them, and recreating them through **physical modeling**.

Sand dunes are depositional landforms that are formed when a sediment supply is subject to prevailing winds for a given period of time. If the sediment supply is of small enough grain size (e.g., sand, silt, clay), it can be entrained by the wind. This occurs when the lifting force exceeds that of the forces of gravity and friction on the grain (Figure 10.12). If this occurs the sediment is then carried through **suspension** in the air, bouncing across the surface through the process of **saltation**, or at the surface through the process of **creep** (Figure 10.13). The sand dunes will accumulate where the energy needed to maintain sediment transport has dissipated.

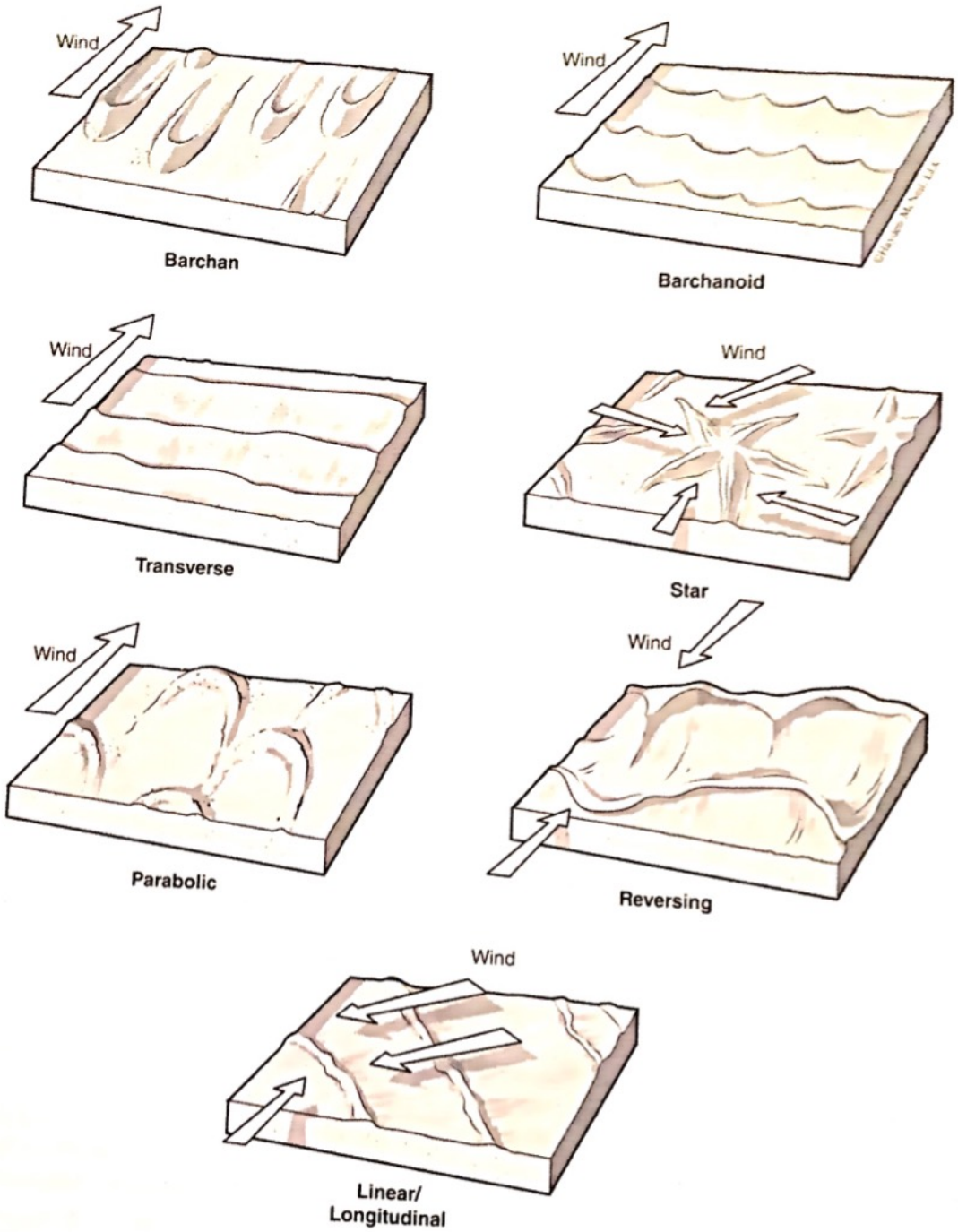


Figure 10.15. The most recognized dune forms with arrows showing wind direction.

Identifying Different Sand Dune Morphologies (Forms) on Google Earth

White Sand Dunes, New Mexico, USA

13. Using Google Earth, go to White Sand Dunes, New Mexico, in the Search Box in the upper left of the screen. This is one of the most spectacular sand dune fields on Earth. When you have located the White Sand Dunes please look over the entire sand dune field. Look for locations that have barchan dunes and point the map over that area. Write down the latitude and longitude of a (or a group of) barchan dune.

14. Now that you have located barchan dunes, see if you can find parabolic dunes. If you are not sure of the difference, please see the diagrams in Figure 10.15 and the previous description. Once you find parabolic dunes, please write down the latitude and longitude of that location.

15. Which way is the dominant wind blowing across these sand dunes?

Namib Desert, Namibia, Africa

16. Using Google Earth, go to the Namib Desert. You will immediately notice that it is a very strange landscape. Sand dunes are everywhere! This is one of the largest sand seas in the world. What kinds of sand dunes do you notice? Please write the latitude and longitude next to the different dune type or types you observe. You may notice more than one kind, and that is OK.

17. What do you think the dominant wind directions are based on what you can see in the sand dunes?

18. Why do you think the Namib Desert exists in this location? Think of the atmospheric circulation, oceanic circulation and physical landscapes in and surrounding the area. In a few sentences, describe why this desert exists.

Grand Erg Oriental, Sahara Desert, Africa

19. Using Google Earth, go to the Grand Erg Oriental. This is a section of the Sahara Desert in northern Africa. You are going to have to zoom in very close and go slightly north on the map until you see a bunch of small dots or hills on the landscape. These dots/hills are individual sand dunes. What kind of dunes are these?

20. What do you think the dominant wind directions are here?