

Geo/SAT 2



TROPICAL WET REALMS OF CENTRAL AFRICA, PART I

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INTRODUCTION:

Forests used to dominate the Earth's land surface. Covering an estimated 15 billion acres (6 billion hectares) these forests, with their dense canopies and little undergrowth, surrounded the islands of grasslands and deserts. Today, in many sections of the world the forests have become islands, encompassed by not only grasslands and deserts but also open lands due to deforestation for human endeavors. Tropical rainforests represent one of the last great forest areas in the world. They cover about 8.3 percent of the Earth's surface. These great forests are being cleared at an alarming rate to meet a variety of social and economic needs. The clearing of these forests can impact the world's hydrologic cycle and energy balance, the consequences of which we do not know.

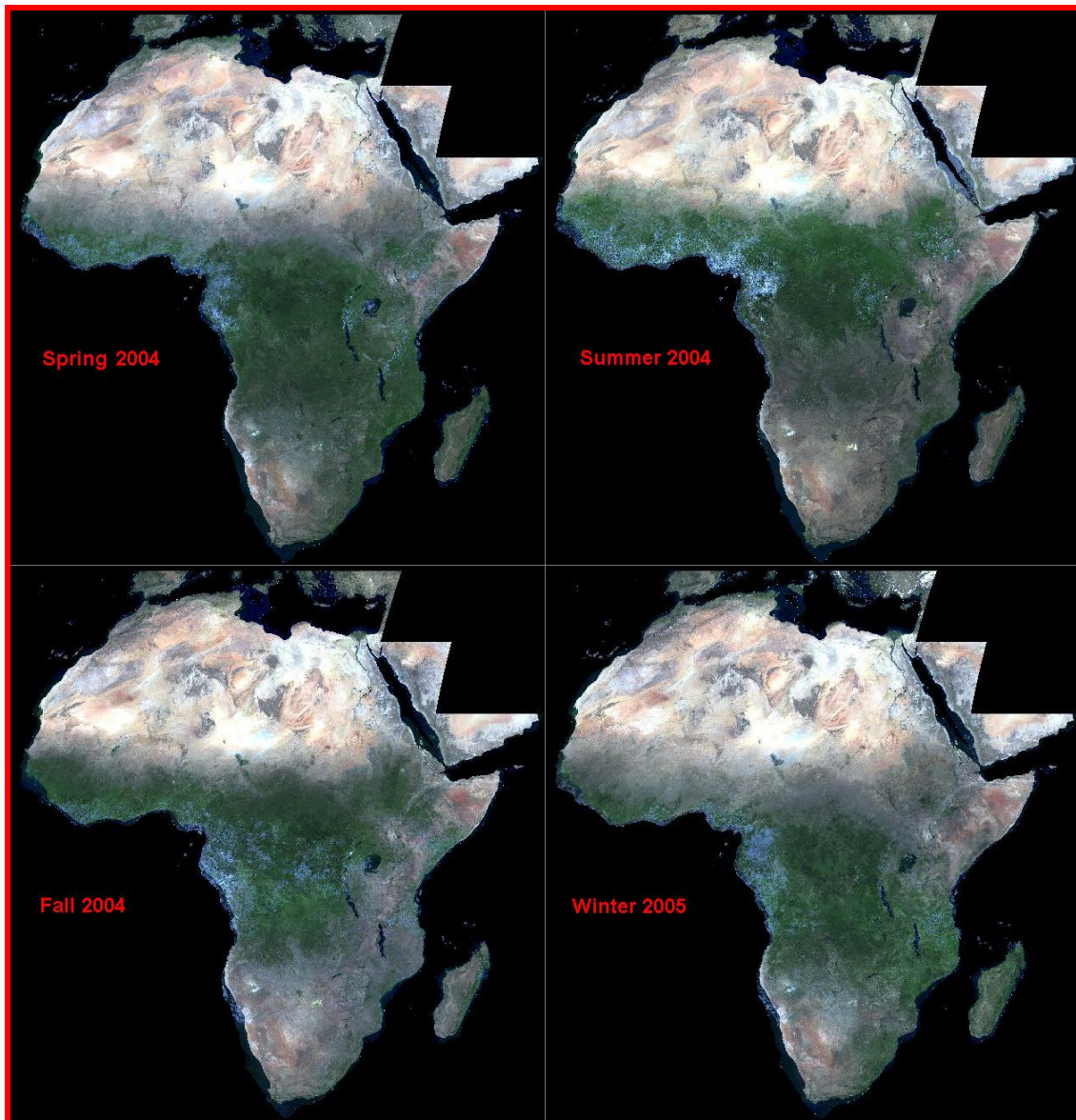


FIGURE 1: MODIS images of Africa.

This instructional module consists of two parts and centers on the tropical landscapes of Central Africa. The primary goal of the module is to use remotely sensed imagery to identify and measure the tropical wet regions. Part I discusses the world's tropical atmospheric patterns, the tropical regions of Central Africa, and the characteristics associated with the remote sensing scanner, MODIS (Moderate Resolution Imaging Spectroradiometer). It also deals with some preliminary analysis of four MODIS data sets covering the four seasons of the year in Central Africa. Part II examines two different ways to classify the four data sets and produce land cover images as well as acreage figures. Figure 1 shows four MODIS images covering all of Africa. The dark green areas identify the humid, tropical landscapes while the bright areas indicate dry realms.

BACKGROUND:

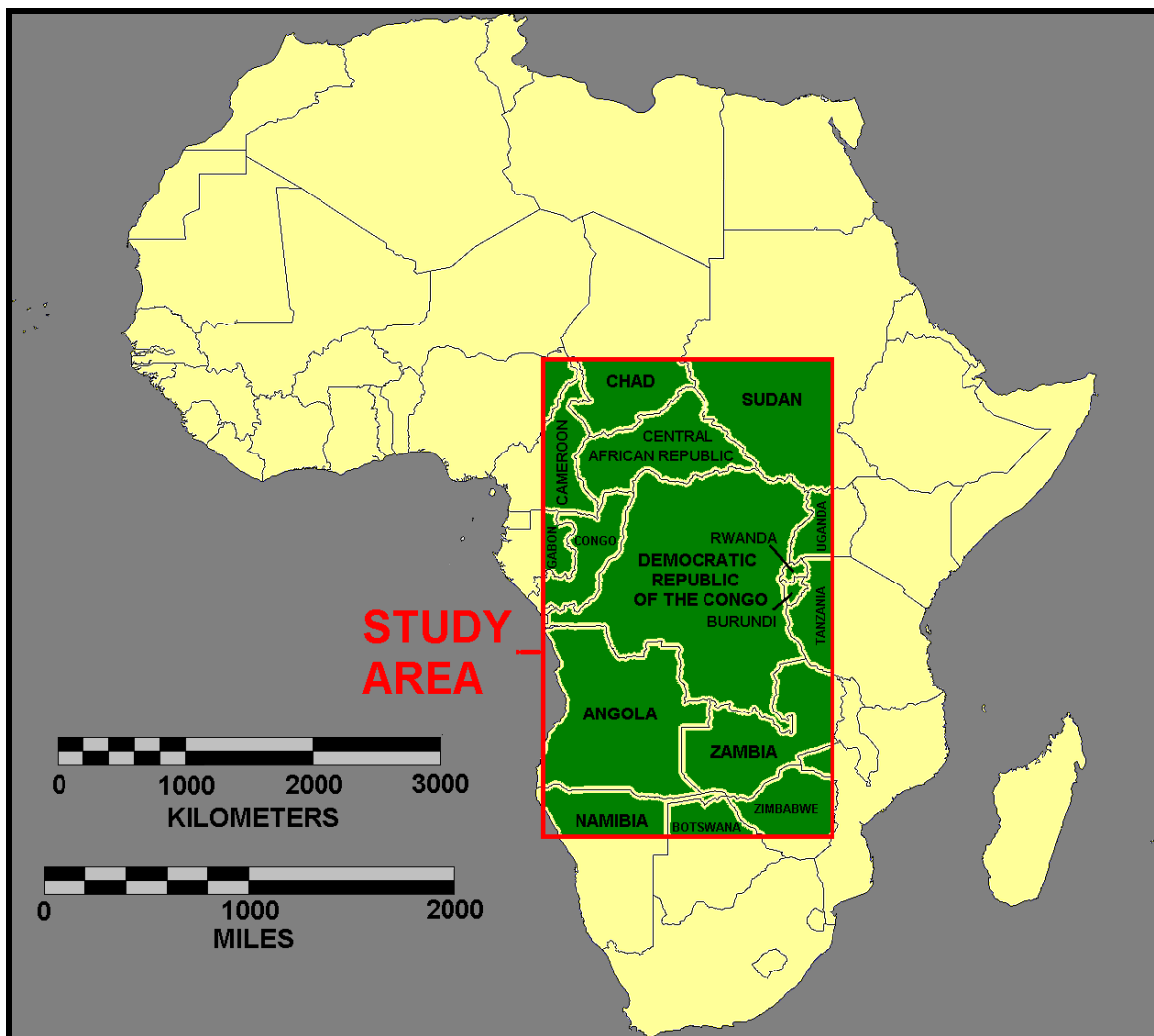


FIGURE 2: Study Area – Central Africa

Figure 2 outlines the area being studied in this module. The area is greater in size to the than the United States. Within this area is situated one of the world's largest tropical wet environments. As the following discussion will indicate, several different tropical realms

exist in this area, realms that range from year round heavy rainy conditions to those that have very distinct wet-dry seasons. To have some understanding about the climatic and vegetation conditions of these realms and to provide background knowledge for the remote sensing components of the modules, one needs to know something about the global atmospheric patterns as they relate to the tropics.

Tropical Atmospheric Patterns

The Earth's atmosphere is constantly in motion. Some major semipermanent wind and pressure conditions exist in this motion. In the tropics these semipermanent conditions are rather pronounced and are referred to as the Subtropical High Pressure, the Tropical Easterlies, and the Equatorial Low Pressure. Figure 3 provides a simplified arrangement of the semipermanent pressure zones and wind belts across the surface of the Earth.

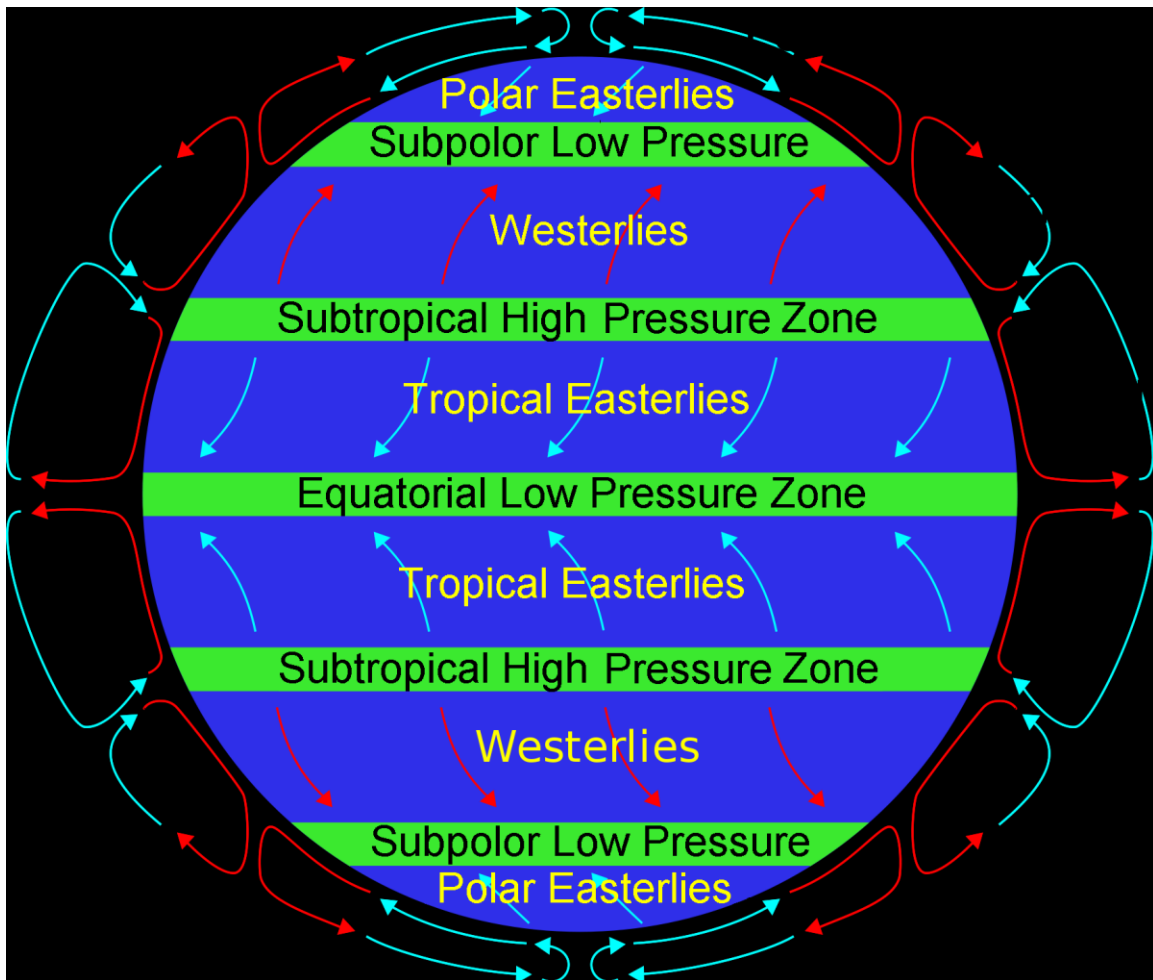


FIGURE 3: Generalized pressure zones and wind belts.

Subtropical High Pressure conditions form over cool surfaces and in the tropics such surfaces are generally found over the large ocean areas that are cooler than the adjacent land areas. Two Subtropical High Pressure zones exist, one in the northern hemisphere

and the other in the southern hemisphere. The zones vary between 25° and 35° latitude. Within the zones are high pressure cells, areas of greater intensity of high pressure. Five such cells occur, corresponding in location to five oceanic basins (North Pacific, South Pacific, North Atlantic, South Atlantic, and South Indian). These huge anticyclonic cells stretch nearly 2000 miles (3200 km) across in an east-west elongated pattern and tend to center on the east side of their respective ocean basin. The high pressures in the North Atlantic, South Atlantic, and South Indian play a key role in shaping the precipitation patterns over Africa. Air flows out of these cells in a clockwise circulation in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. Air flowing toward the Polar Regions form the Westerlies winds and those winds flowing toward the Equator are called the Tropical Easterlies. Tropical Africa receives the Tropical Easterlies.

The Tropical Easterlies are also called the Trade Winds, a name given to the winds in the 16th century by mariners sailing from Europe to America. These winds extend between 25° north latitude and 25° south latitude. As these winds start out of a subtropical high they are generally cool and dry but as they descend from the high and cross the water they warm up, which allows them to absorb enormous amounts of moisture from the oceans. Once they reach land they are generally moisture laden. Although called easterlies these winds are actually moving westward toward low pressure areas. The term Tropical Easterlies refers to their origin area. The winds are coming from the east out of a tropical source. At certain times of the year the winds cross the Equator at which point they turn eastward. This shift is due to what is called the “coriolis effect” which defects free moving objects as they move from one hemisphere to another hemisphere as the result of the Earth’s rotation. The flow patterns of the Tropical Easterlies into Africa determine the major precipitation patterns throughout the tropical portions of the continent.

The Tropical Easterlies from both hemispheres converged in the Equatorial Low Pressure zone, an area which nearly wraps around the Earth between 10° north latitude and 10° south latitude and is associated with warm, ascending air. This zone is also called the Intertropical Convergence Zone and the doldrums, the latter name relates to the very calm winds in the area resulting in many sailing ships being stranded for lengthy periods. Within this zone are Equatorial Low Pressure cells centered over large land masses that are warmer than water bodies at the same latitude. Warm, moist air converges into these cells and ascends vertically into towering thunderstorms. As the air rises, it cools and releases considerable amounts of rain.

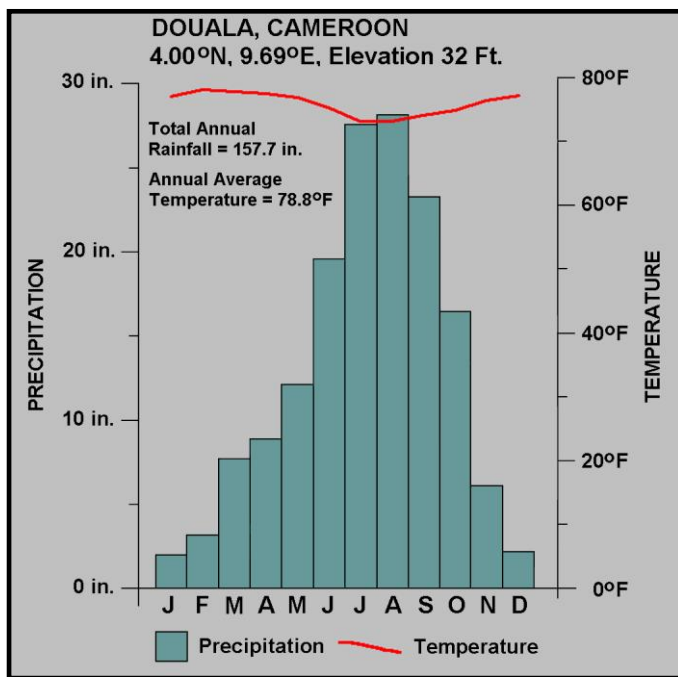
These three semipermanent atmospheric regions shift north and south throughout the year associated with high and low sun conditions. During the summer realm in the Northern Hemisphere the Equatorial Low Pressure cells are situated north of the Equator with the Northern Subtropical High Pressure cells moving pole ward and the Southern Subtropical High Pressure cells shifting toward the Equator. The reversed pattern occurs when it is summer in the Southern Hemisphere. Through this process the Equatorial Low Pressure cells cross over the Equator twice in a year creating heavy rain conditions throughout the

year in the equatorial regions. Central Africa provides the ideal area to observe this process.

Tropical Regions of Central Africa

Central Africa is basically a series of vast plateaus that range between 1,000 feet (305 m) and 3,000 feet (914 m) in elevation. These plateaus start from 20 to 100 miles (32 to 161 km) inland from the coasts with abrupt, ragged escarpments before the topography become predominately level to rolling. Several low, shallow river basins occupy these plateaus, of which the largest is the Congo River Basin. A highland region with a north-south arrangement is located in east Africa. The western section of this region forms the eastern edge of the study area. Here the highlands at over 5000 feet (1524 m) rim the Great Rift Valley. Just to the east of the valley is Lake Victoria at an elevation of 3720 feet (1124 m). With a surface area of 26,828 square miles (69,484 km²), it is over 4,000 square miles (10,360 km²) larger than Lake Michigan. Next are a series high mountain peaks with the largest being Mt. Kilimanjaro at 19,565 feet (5963 m) and Mt. Kenya at 17,040 feet (5193 m). Finally the highlands give way to narrow coastal lowlands. These surface features are important in the climatic and vegetation patterns of Central Africa.

Starting from the west coast and stretching across the Congo River Basin to the eastern highlands is one of the largest tropical rainforests in the world. Along the west coast a tropical monsoon type climate exists as the very moist Tropical Easterlies come in from the Atlantic Ocean and encounter the escarpments, resulting in orographic rainfall. If the escarpments did not exist, much greater amounts of precipitation would reach the central portion of the continent. The monsoon climate receives most of its rain during one season



but the amount that it does receive is able to maintain tropical rainforest vegetation throughout the year. Normally the Tropical Easterlies over the Atlantic would be flowing westward toward South America but depending on the season of the year some of these winds turn eastward as they cross the Equator and head to Africa. The changing of the Tropical Easterlies coming from the North Atlantic verses those coming from the South Atlantic determines when areas along the west coast of Africa receive large amounts of rain and experience a dry season.

FIGURE 4: Climograph for Douala, Cameroon.

Figure 4 is a climograph for the city of Douala, which is located on the west coast of Africa in Cameroon. Douala is only at 32 feet above sea level placing it below the plateau escarpments. It is located at 4.00° N. latitude, making it very near the Equator. The total annual average rainfall for Douala is 157.7 inches. New York City has an annual average rainfall of about 42 inches and Los Angeles about 12 inches. Based on these comparisons Douala receives a tremendous amount of rainfall. In fact, its peak month receives more rain than most places experience in a year. As Figure 4 illustrates most of the rain comes during the summer period in the Northern Hemisphere and the winter period is very dry. This pattern is associated with a typical tropical monsoon climate. During the summer period in the Northern Hemisphere the Southern Tropical Easterlies are flowing westward toward South America but as these winds cross the Equator they turn and head eastward to the west coast of Africa and places like Douala. The opposite occurs for places in the Southern Hemisphere. They would receive heavy rains during the winter season in the Northern Hemisphere, the summer season in the Southern Hemisphere. The temperature realm for Douala remains rather constant with monthly averages in the high 70s, typical of a tropical wet climate. Monthly averages do drop slightly during the wet season due to the heavy cloud cover.

Once the Tropical Easterlies cross the escarpments they move toward the Equatorial Low Pressure cell centered more over the middle of the continent where a convectional process starts moving the moist air upward into the atmosphere. The upward movement cools the air resulting in heavy amounts of rain. This movement generally produces large thunderstorms. A typical day starts with a bright, clear morning and as the day progresses the heat increases. As the temperature raises the evaporation rate increases, creating a high humidity level and an uncomfortable living condition. Eventually a large thunderhead develops from which a slight breeze and cooling occurs. This is a more pleasant time of the day. Generally by early afternoon the thunderhead reaches its maximum development and a heavy rainstorm occurs. By late afternoon the clouds disperse creating partly cloudy skies at sunset. This pattern is repeated basically every day of the year, resulting in tropical rainforest climates having no real seasonal variations and being viewed as monotonous in nature.

One might expect the Tropical Easterlies from the Indian Ocean would bring great amounts of rain into central Africa in addition to the Easterlies from the Atlantic but during the summer season (Southern Hemisphere) of the year the winds encounter the mountains on the island of Madagascar, the eastern escarpments and the eastern highlands. These topographic barriers force the air to rise and cool and keep most of the moisture in the air from reaching the center of the continent. During the winter season these winds cross the equator and flow toward the west coast of India. Figure 5 was taken during the December 1972 flight of Apollo 17 and shows the clouds from the Indian Ocean. Tropical Easterlies are stacking up against the northern mountains of Madagascar and the highlands of East Africa. The Equatorial Low Pressure cell is over the center of Africa, south of the Equator. During this period Lake Chad on the southern edge of the Sahara is experiencing its dry season.

Tropical rainforest climates have monthly average temperatures between 75° and 80° F, which provide for a high amount of energy for year-round plant growth. Annual rainfall is frequently between 70 and 90 inches with each month receiving enough moisture to support lush vegetation coverage.

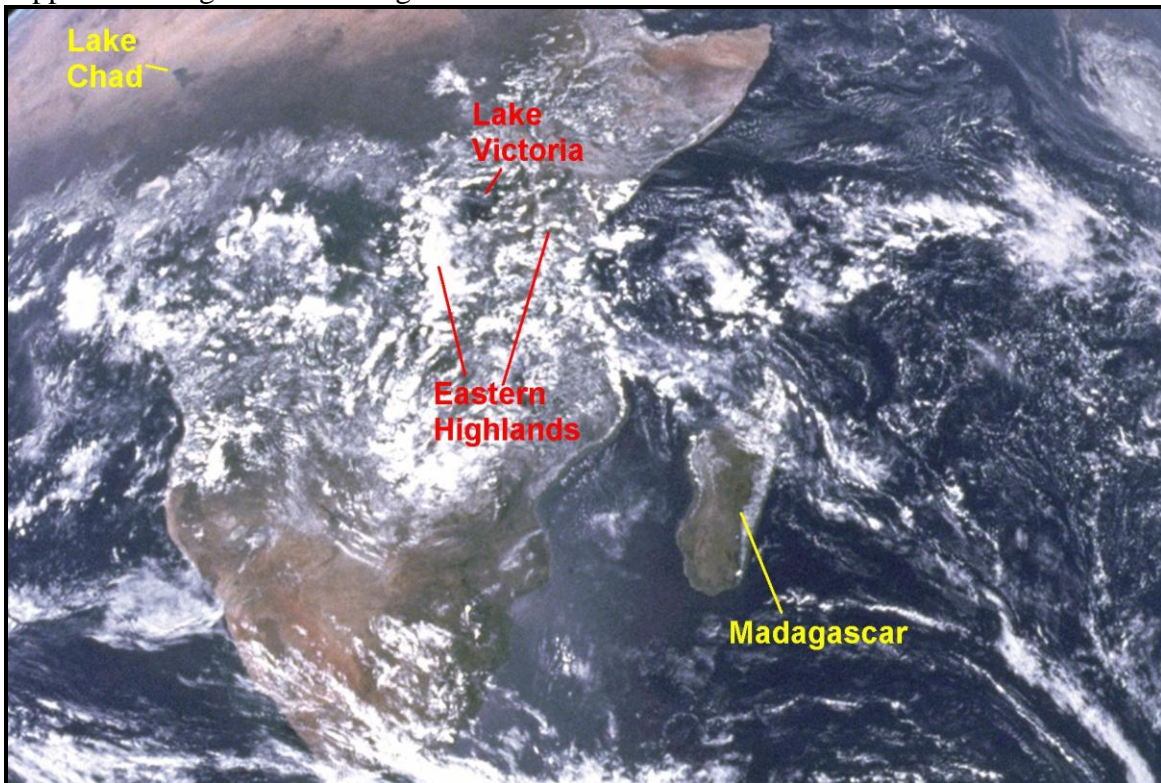


FIGURE 5: East Africa and the Tropical Easterlies from the Indian Ocean.
(Courtesy of NASA: Photo taken by Apollo 17 crew.)

Kisangani in the Democratic Republic of the Congo typifies a tropic rainforest climate with an annual average temperature of 76.1° F and an annual total rainfall of 72.5 inches (Figure 6). Kisangani is almost situated on the Equator. The two peak periods of rainfall correspond to the spring and fall equinoxes when the Equatorial Low Pressure cell should be crossing the Equator on its annual north-south cycle.

From these rainforest temperature and precipitation conditions a multistoried, broad-leaf evergreen forest exists, called a **selva**. Generally the trees grow between 70 and 120 feet high with

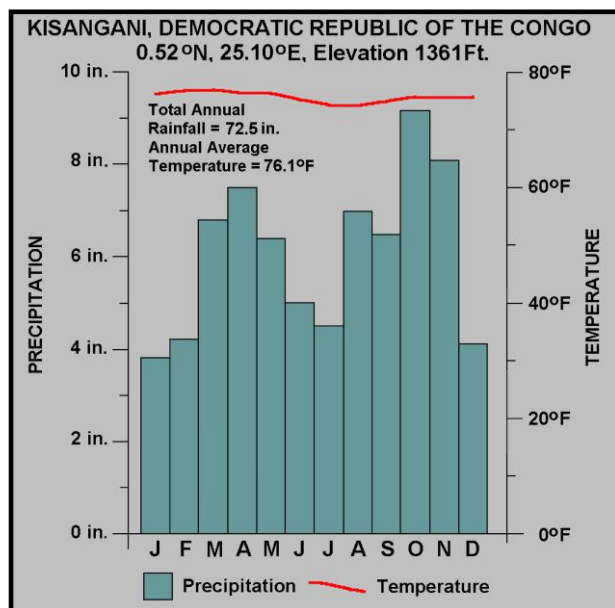


FIGURE 6: Climograph for Kisangani, Democratic Republic of the Congo.

overlapping crowns. The overlapping crowns and the broad leaves break the heavy rain drops from the daily thunderstorms and filter the moisture on its ways down to the forest floor, protecting the soil from erosion. These same conditions block much of the sunlight from reaching the forest floor. Little undergrowth is found in this type of forest. Along the edge of large rivers, the sun is able to penetrate to the forest surface resulting in heavy, densely tangled undergrowth called **jungle**. As people from the mid-latitudes first entered the selva, they traveled the rivers and concluded that jungle conditions existed throughout the entire forest. Today, deforestation is occurring in the selva, with large open areas being exposed to heavy rainfall and sunlight. These conditions have created soil erosion and higher ground temperatures. Temperature measurements above the overlapping tree crowns are comparable to those found in the hot desert regions but ground temperatures are generally 20 to 30 degrees cooler. The energy that reaches the forest floor does not easily make its way back into the evening atmosphere. With the trees removed higher temperatures are reaching the ground and like the deserts, large amounts of energy are being readily reflected back during the night hours. Under normal conditions the selva of the world act like large energy blankets. These blankets now have many large holes.

Similar forest conditions exist between the selva and the monsoon forests. The tropical monsoon climate has enough rain during its wet season to maintain the forests throughout the dry season. However, some differences do exist. The wetter margins of the monsoon forest resemble the selva but fewer species occur. In the drier sections of the forest the larger trees are more separated allowing for more sunlight. This situation results in jungle undergrowth developing on the forest floor. Monsoon climates are frequently associated with topographic barriers. The slopes from these barriers allow more sunlight to enter the forest floors and produce undergrowth. In comparison to the selva, the monsoon forests do not cover large areas.

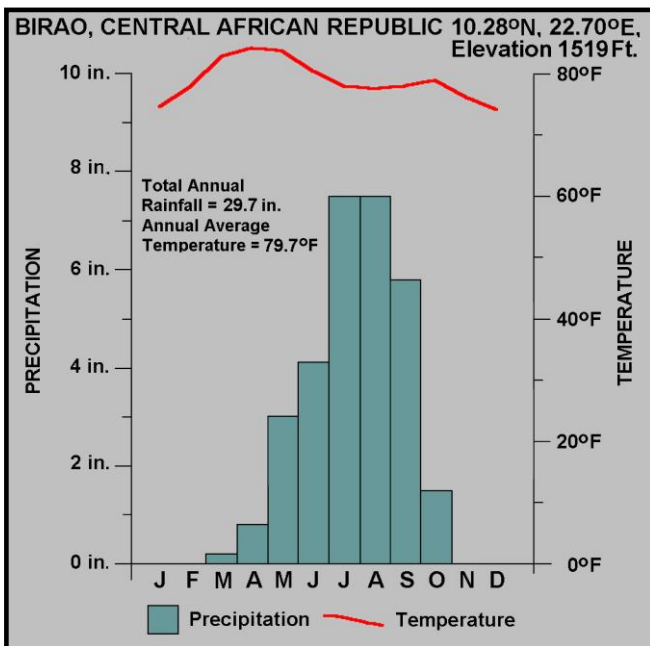


FIGURE 7: Climograph for Birao, Central African Republic.

Forming a horseshoe like pattern around the rainforest of Central Africa is a tropical realm that experiences a wet-dry seasonal pattern and a gradual decrease in amount of rain being received in comparison to the rainforest. This change in rainfall creates a landscape where trees are not as dense as they are in the selva and are designed to handle dry conditions. This landscape also has open grassland areas where the grass can grow quite high during the wet season and die down to low tufts in the dry period.

This climatic realm, referred to as a tropical savanna, has approximately six months of wet conditions when

the Equatorial Low is nearly overhead, providing convectional rainfall. This is the summer period. During the winter period the Equatorial Low has moved across the Equator into the other hemisphere and a dry, high pressure dominates the area. Tropical savanna belts occur on the pole ward sides of the tropical rainforest. A tropical savanna area exists also on the eastward side of the eastern highlands. As previously indicated during one season of the year the mountains on the island of Madagascar, the eastern escarpments and the eastern highlands block much of the rain coming from the Indian Ocean. Also, during one season the Tropical Easterlies coming across the South Indian Ocean turn away from Africa as they cross the Equator. These conditions create the savanna type climate in the curve of the horseshoe.

Figures 7 and 8 reflect the summer wet – winter dry pattern associated with the tropical savanna climate. Birao of the Central African Republic is located at 10.28° N. Latitude. Since it is in the northern hemisphere, the rainy period occurs between May and September. Mongu, Zambia, is situated at 15.25° S. Latitude and has its rainy period between November and March. The monthly temperatures for both places fluctuate more than that found in the tropical rainforest climates, with higher temperatures during the summer periods and lower temperatures during the winters.

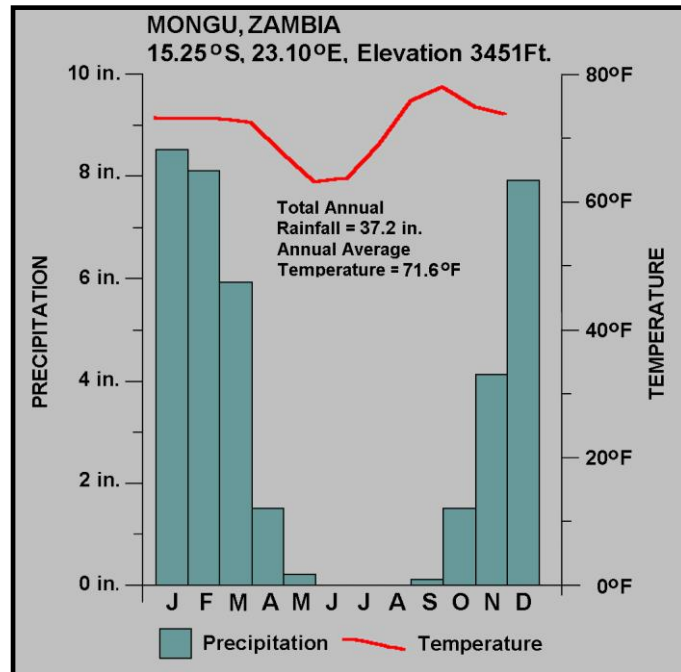


FIGURE 8: Climograph for Mongu, Zambia.

The savanna is a transitional zone of vegetation between the wet tropics and the dry deserts. The rainfall during the wet season is not enough to maintain the vegetation in the dry season; consequently, vegetation goes through a noticeable change. The wet season is green and the dry season brown. Trees are between 30 and 35 feet in height with thick barks and waxy leaves to reduce moisture loss due to evaporation. They also have thorns to make it difficult for animals to break into the moist inner core of the trees. A great amount of open space exists between trees. Grasses and low bushes occupy these open spaces. During the wet season the grasses grow quite dense and to considerable heights. In the dry season these grasses turn brown and fall over. Fires burn much of the grass and leave behind a scorched landscape waiting for the next wet season. In some portions of the savanna the grasses dominate with a few scattered trees. Savannas cover major portions of the Earth’s land surface and Africa has the largest area of this biome.

The final climatic realm within the study area is a semiarid region that is generally found around the periphery of a desert. One of these realms is located at the northern edge of

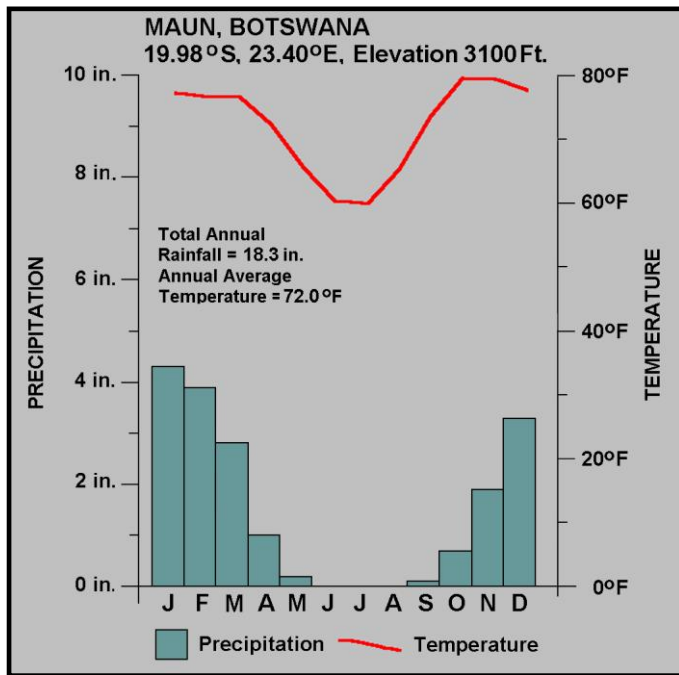


FIGURE 9: Climograph for Maun, Botswana

the study area and is associated with Sahara. It is part of the Sahel. A second semiarid region is situated at the southern end of the study area and is on the edge of the Kalahari and Namib Deserts. These semiarid regions are not part of the tropical wet climates in Central Africa. They were included in the study area to provide contrast between the dry and wet regions.

Maun, Botswana provides an example of a semiarid climatic realm (Figure 9). Although it has the same rainfall pattern as seen in the Mongu, Zambia climograph, its total annual rainfall is considerably less. Potential evaporation exceeds precipitation in semiarid regions.

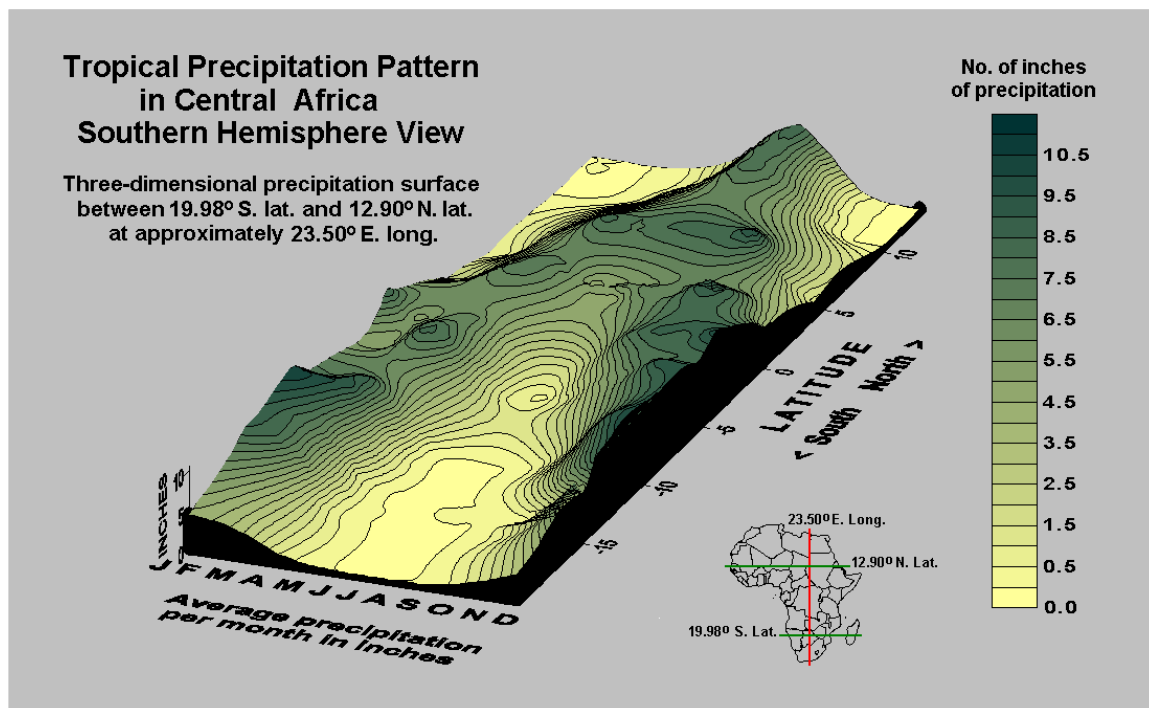


FIGURE 10: Three-dimensional precipitation profile of Central Africa.

Figure 10 shows a three-dimensional surface that provides a precipitation profile through the center of the study area along a south-north axis (23.50° E. long.). The other axis

displays average monthly rainfall for the 12 months. Around the Equator the rainfall is heavy through the year. Moving away from the Equator the rainfall becomes more seasonal and less than found in the rainforest. In studying this profile one must keep in mind the differences between the Northern and Southern Hemispheres with respect to summer and winter. This profile summarizes the precipitation patterns through the center of the study area.

ANALYSIS:

MODIS

MODIS is one of several scanning instruments aboard the Terra and Aqua satellites (Figure 11). Terra orbits the Earth passing from north to south across the equator in the morning; while, Aqua

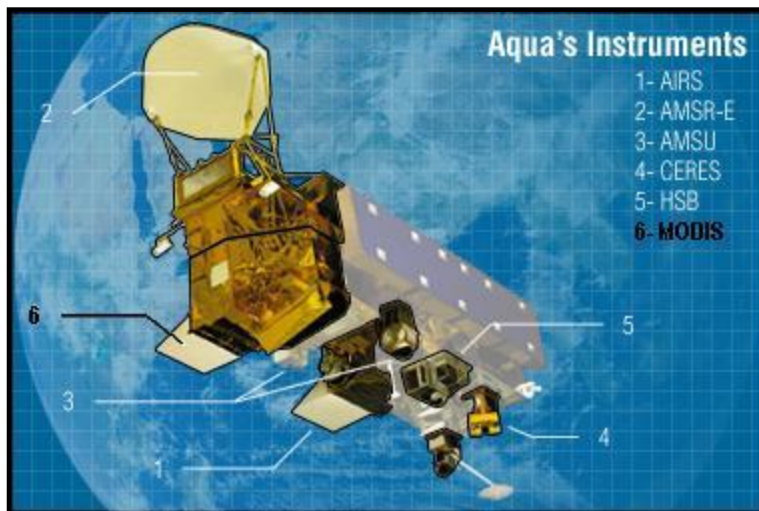


FIGURE 11: Artist view of Aqua satellites with its various recording instruments.

moves south to north over the equator in the afternoon. Between the two satellites MODIS imagery can be obtained for the Earth's entire surface every 1 to 2 days. MODIS acquires data in 36 spectral bands at three spatial resolutions -- 250m, 500m, and 1,000m. The bands relate to different environmental conditions.

The data sets being used in this module covers bands 1-7 (Table 1). These bands

are best suited for land surface studies.

MODIS's viewing swath width is 1,421 miles. (2,330 km); thus, within two swaths MODIS can view an area the size of the 48 contiguous states of the United States. With respect to land studies such a wide swath can create a problem. Trying to find a land area the width of a swath without any cloud cover is nearly impossible. This is especially true in tropical wet Africa where cloud cover conditions prevail. To partially overcome this problem, composite data sets are prepared for bands 1-7 based on a 32 and 16 day cycles. In other words the cloud free sections of several data sets within a given 32 or 16 day period are merged together to make one fairly cloud free data set. It is not always possible to have a completely cloud free data set. The west coast of Central Africa has a tremendous amount of cloud cover associated with the monsoon conditions; thus, some cloud cover over this area exists on the data sets being used with this module.

Table 1: MODIS Bands 1-7

Band	Spectral Range	Spectral Level	Pixel Res.
1	620-670 nm	Red visible	250 m
2	841-876 nm	Near Infrared	250 m
3	459-479 nm	Blue visible	500 m
4	545-564 nm	Green visible	500 m
5	1230-1250 nm	Mid Infrared	500 m
6	1628-1652 nm	Mid Infrared	500 m
7	2105-2155 nm	Mid Infrared	500 m

Along with data from other instruments on board the Terra and Aqua satellites, MODIS data are transferred to ground stations in White Sands, New Mexico, via the Tracking and Data Relay Satellite System. The data are initially sent to the Earth Observing System's Data and Operations System at the Goddard Space Flight Center for further processing. The data are then parceled out to three Distributed Active Archive Centers (DAACs) for distribution. Land data sets are available through the Land Processes DAAC at the U. S. Geological Survey EROS Data Center. Users with an appropriate x-band receiving system may capture regional data directly from the spacecraft using the MODIS Direct Broadcast signal.

The MODIS instrument records data as 12 bit values. Thus, reflective information from the Earth's surface can be recorded in a numerical range from 0 to 4095. A normal computer byte is 8 bits. Two bytes are required to hold a 12 bit value. Therefore, for every MODIS pixel in a data set, two bytes are needed. Most remote sensing software packages are designed to read one byte for every pixel. A two byte configuration creates a problem for these packages. For this module it will be necessary to reduce the 12 bit values down to 8 bits. The procedure for handling this conversion will be discussed latter.

Bands 1 and 2 have a pixel resolution of 250 meters; whereas, bands 3-7 have resolutions of 500 meters. However, the data sets were provided with all of the bands at a 500 meter resolution. This makes it possible to use all of the bands and not be limited to only two of them.

Preprocessing Data Sets

Four MODIS data sets are used in this module. They cover the Spring 2004, Summer 2004, Fall 2004 and Winter 2005 periods. These four time periods will show the changes in the geographic condition of the tropical vegetation in Central Africa, changes that correspond to the annual movement of the Equatorial Low Pressure zone. These data sets were downloaded from the Global Land Cover Facility (GLCF) at the University of Maryland.

A data set covering the entire continent of Africa is 16,700 pixel elements wide by 17,352 lines. Each band with a 500 meter pixel resolution and two bytes per pixel is a file

of 552 Mbytes in size. One data set requires 3.8 Gigabytes of storage. To convert the 16 bit data values into 8 bit values and reduce the storage size of a band, the bands are loaded into Photoshop. The first step in Photoshop is to adjust the gray level range of a band using the Image\Adjust\Level function. A window appears showing the distribution of the data over the 12 bit range. Most of the data was concentrated in the lower end of the range indicating that the few values in upper portion of the range could be shifted down. This could be done by moving the graph's right-handed arrow to almost the left side of the graph. This process results in all of the values being placed in an 8 bit range, one byte. The few values in the upper level of the 12 bit range are changed to the value of 255. The next step uses the Image\Mode\8 bits/channel function. This step converts a band so that each pixel value has one byte rather than two. This step also reduces the size of a band file to 276 Mbytes.

Again, using Photoshop the bands are cropped to 4760 pixel elements by 8117 lines to cover the study area of Central Africa. By converting the data to one byte per pixel and cropping a data set the file size per band decreases to 36.8 Mbytes, a more manageable size for this instructional module. Finally, the seven bands of a data set were loaded into EarthScenes, the image processing software package used in all of the Geo/SAT 2 modules. This process was repeated for each data set. This preprocessing procedure requires several work days to complete. This brief description of the procedure is being provided in order to make the users of this module aware of the amount of time involved in getting a data set prepared for the analysis stage.

Preliminary Analysis

Part I of this instructional module deals with some preliminary analysis of the four MODIS data sets. Using EarthScenes color images can be made that allow one to study the seasonal changes in vegetation in Central Africa. These changes can relate to the materials previously presented in the Background section.

The first images made were true color composites (TCCs), one for each of the four seasons. A TCC is an image that relates to the normal colors seen by a human eye. Bands 1,4,3 were used to make the TCCs. These bands correspond to the three basic colors (red, green, and blue) in the visible portion of the electromagnetic spectrum. Figure 12 displays the TCCs for the four seasons. These images have been greatly reduced in size and do not contain the detail that one might see if viewing them using EarthScenes.

The green areas identify vegetation that is receiving adequate amounts of moisture and heat. The spring and fall images have the green areas centered over the Equator, relating to the spring and fall equinoxes. The summer and winter images show the green areas extending northward and southward, respectively, from the Equator. This change relates to the movement of the Equatorial Low Pressure over Central Africa. All four images show green areas around the Equator, the selva and monsoon forests. The bright blue

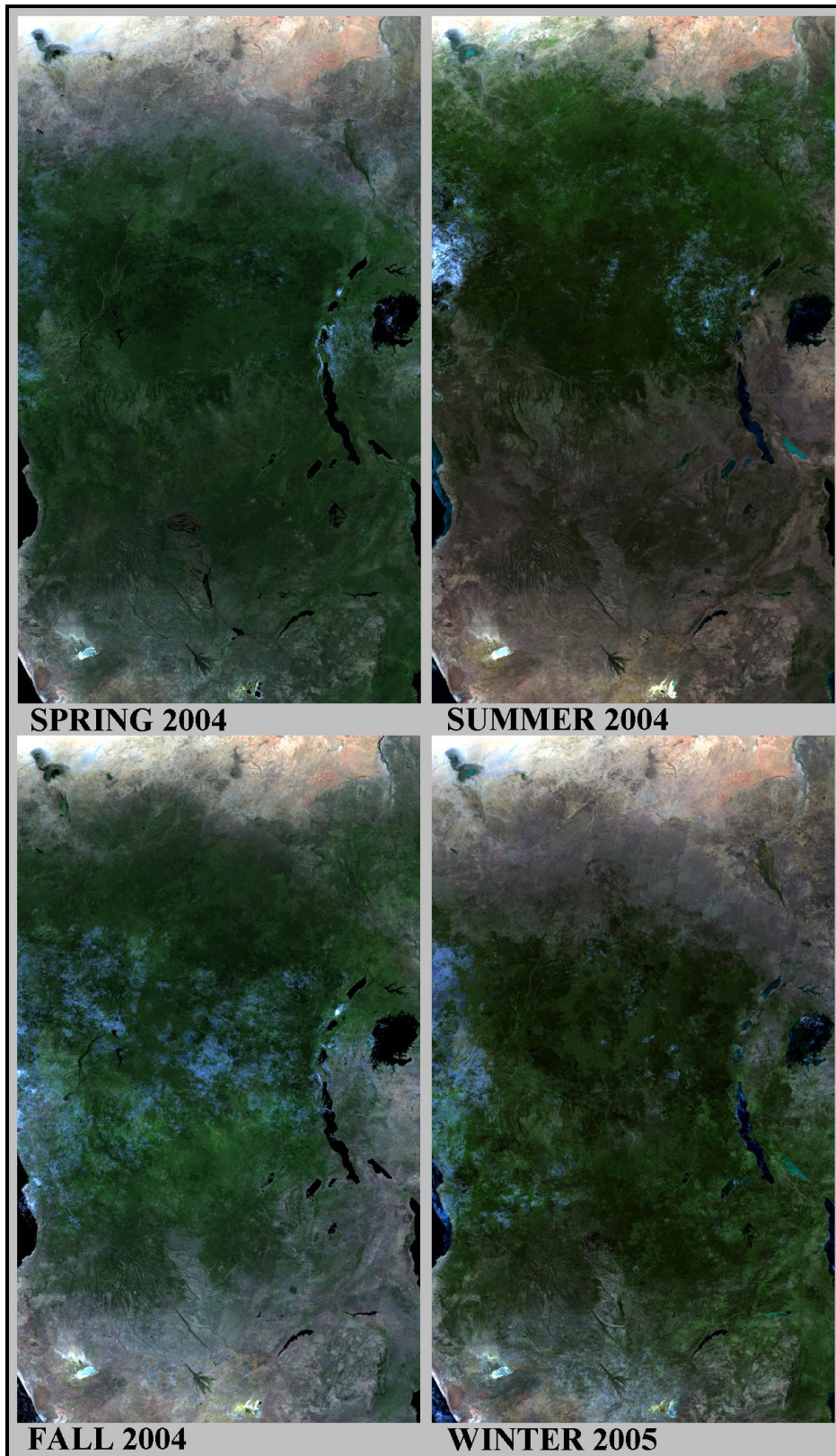


FIGURE 12: True color composites of the four seasons over Central Africa.

colors are clouds, which are mainly located along the west coast plateau escarpments and the eastern highlands adjacent to the Great Rift Valley. As previously indicated, it is nearly impossible to have cloud free data sets over the wet tropics for any 32 day period. The gray-brown areas are experiencing little rainfall, which is reflected in their dry vegetation. Many of these areas are green in the opposite season. Compare the green and gray-brown areas north of the Equator in the summer and winter images. These areas are mainly the tropical savannas. The reddish-brown and bright white areas are the semiarid regions.

The green band dominates throughout most of area shown by the TCCs. This can be verified by using the Pixel Read-out function in EarthScenes. Figure 13 shows a small section of the study area being displayed using the Pixel Read-out function. The pixel values for the red, green, and blue bands are shown at the top and are based on the pixel located at the point of the arrow. The green band has a data value of 34, more than twice the amount of the value levels for the red and blue bands. Figure 13 also provides an example of the detail not apparent in the images shown in Figure 12. One can see the bright rectangular-shaped green areas that are fields cut out of the forest.

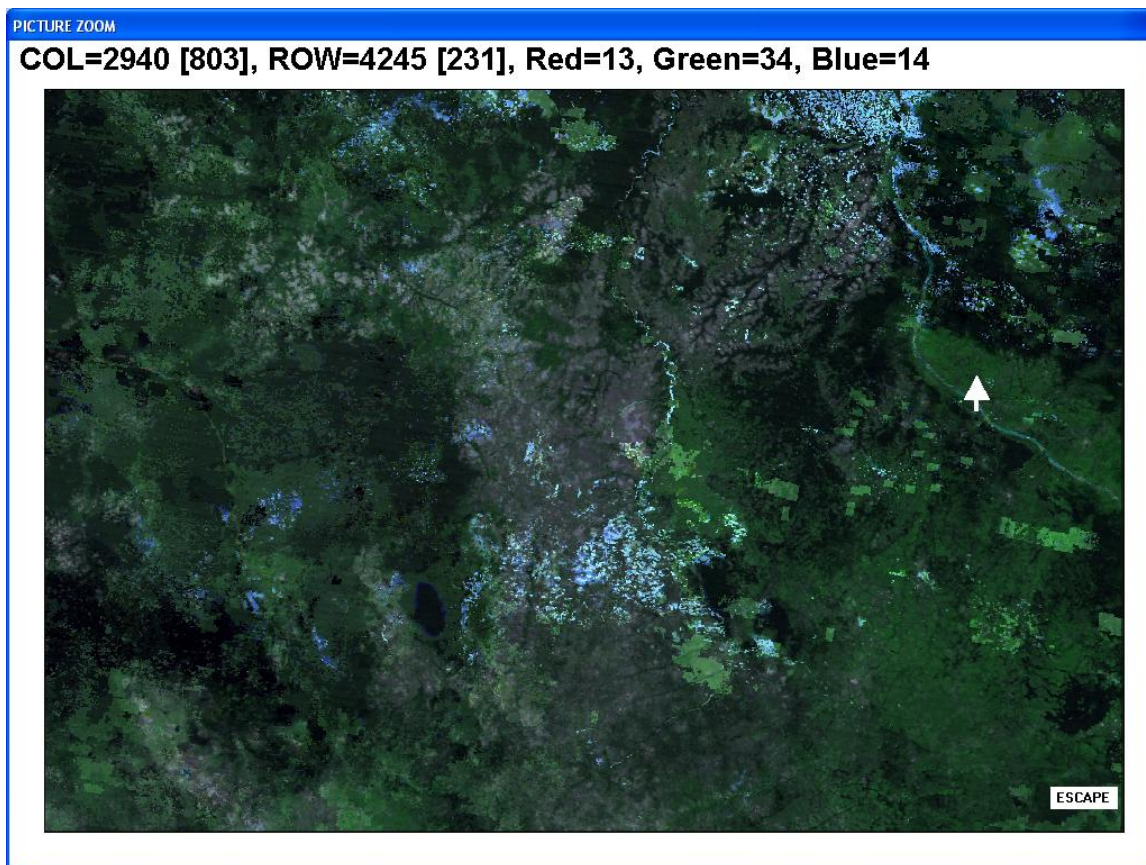


FIGURE 13: A pixel read-out of a true color composite.

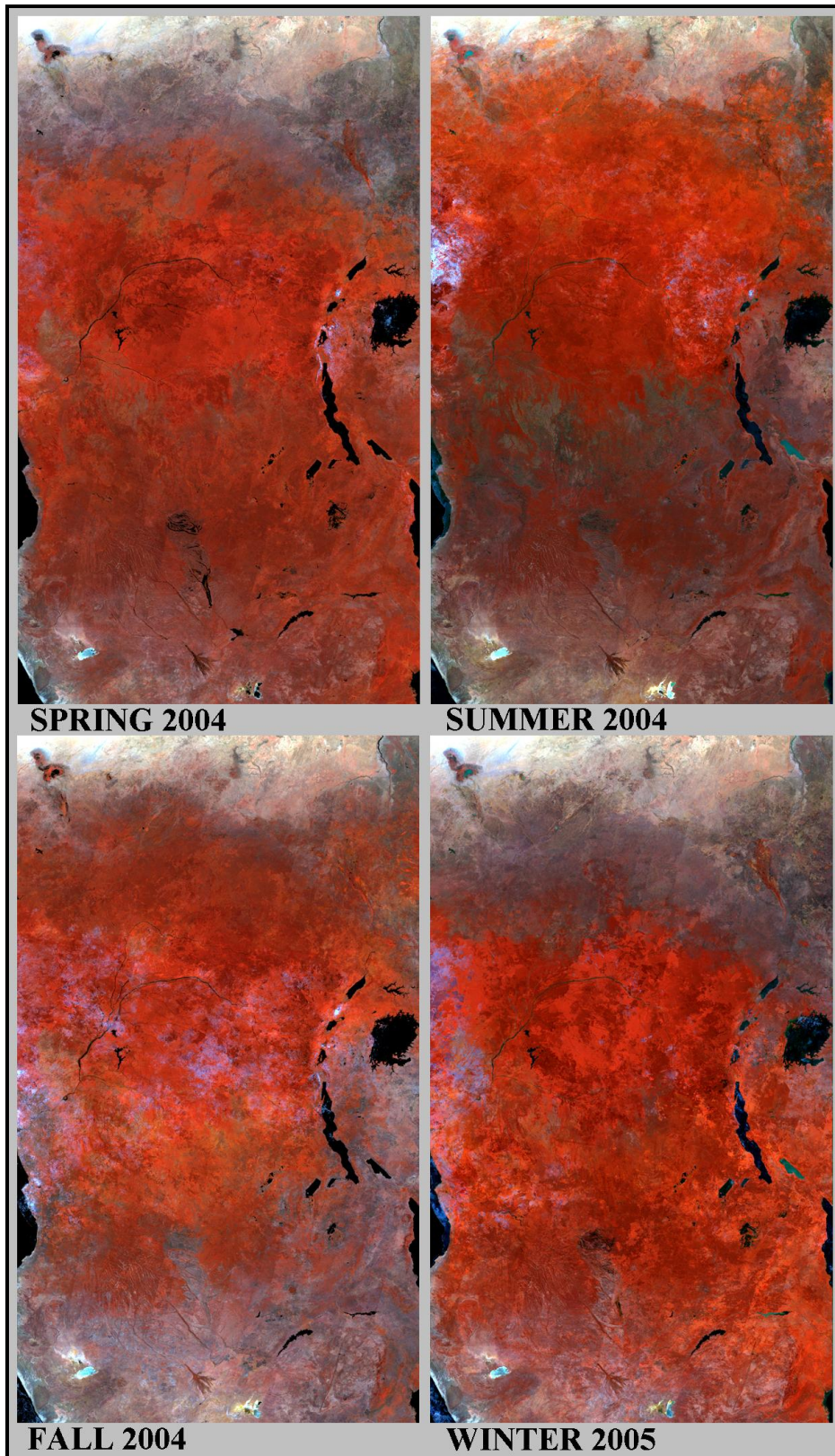


FIGURE 14: False color composites of the four seasons over Central Africa.

Figure 14 is a set of false color composites (FCCs) of the four seasons. These FCCs are based on bands 2, 4, and 3 that relate to the near infrared, green visible, and blue visible sections of the spectrum. The near infrared band was assigned to the red color.

The four FCCs shows generally the same changes in the vegetation patterns as seen in Figure 12 based on the north-south movement of the Equatorial Low Pressure. However, the near infrared band helps to reduce the amount of cloud cover and better defines water conditions than the red visible band. A comparison to the TCCs shows that the clouds in the FCCs are thinner. Water areas stand out. The Congo River can be seen on the FCCs in comparison to the TCCs. Also, the seasonal disappearance and reappearance of water bodies in the southern portion of the images is more apparent in the FCCs. Figure 15 is an enlargement of the Congo River Basin based on the summer FCC. The river with its major tributaries can be clearly observed.

It is possible to make many more FCCs based on different band combinations. Each FCC can provide additional information. One might like to try some other FCC combinations. Part II of this module will deal with the classification and areal measurements of the major tropical vegetation regions of Central Africa.

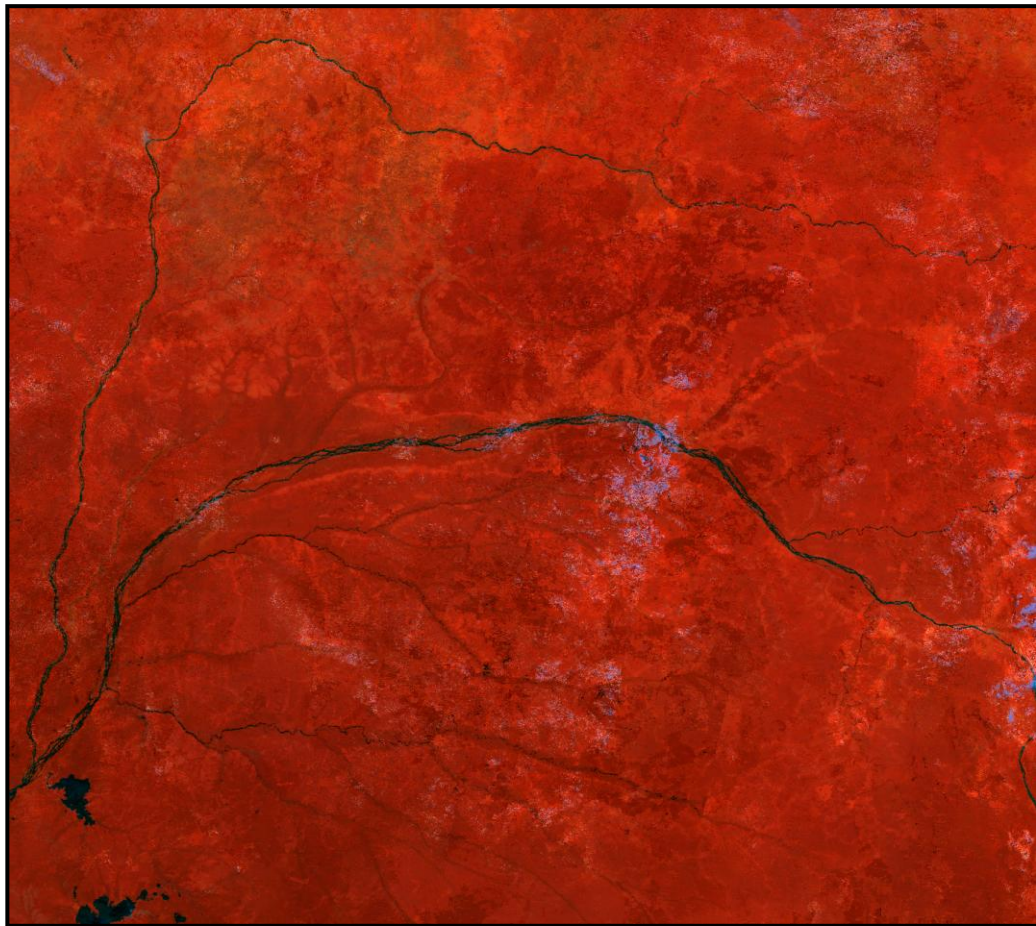


FIGURE 15: Summer false color composites of the Congo River Basin.

Suggested Books:

Christopherson, Robert W. 1994. *Geosystems: An Introduction to Physical Geography*, 2nd ed. New York: MacMillan College Publishing Company.

Gabler, Robert E., et al. 1999. *Essentials of Physical Geography*, 6th ed. Forth Worth: Saunders College Publishing, Harcourt Brace College Publishers.

Jensen, John R. 2000. *Remote Sensing of the Environment: An Earth Resource Perspective*, Upper Saddle River, New Jersey: Prentice Hall

McKnight, Tom L. 1994. *Physical Geography: A Landscape Appreciation*, 4th ed. Englewood Cliffs, New Jersey: Prentice Hall