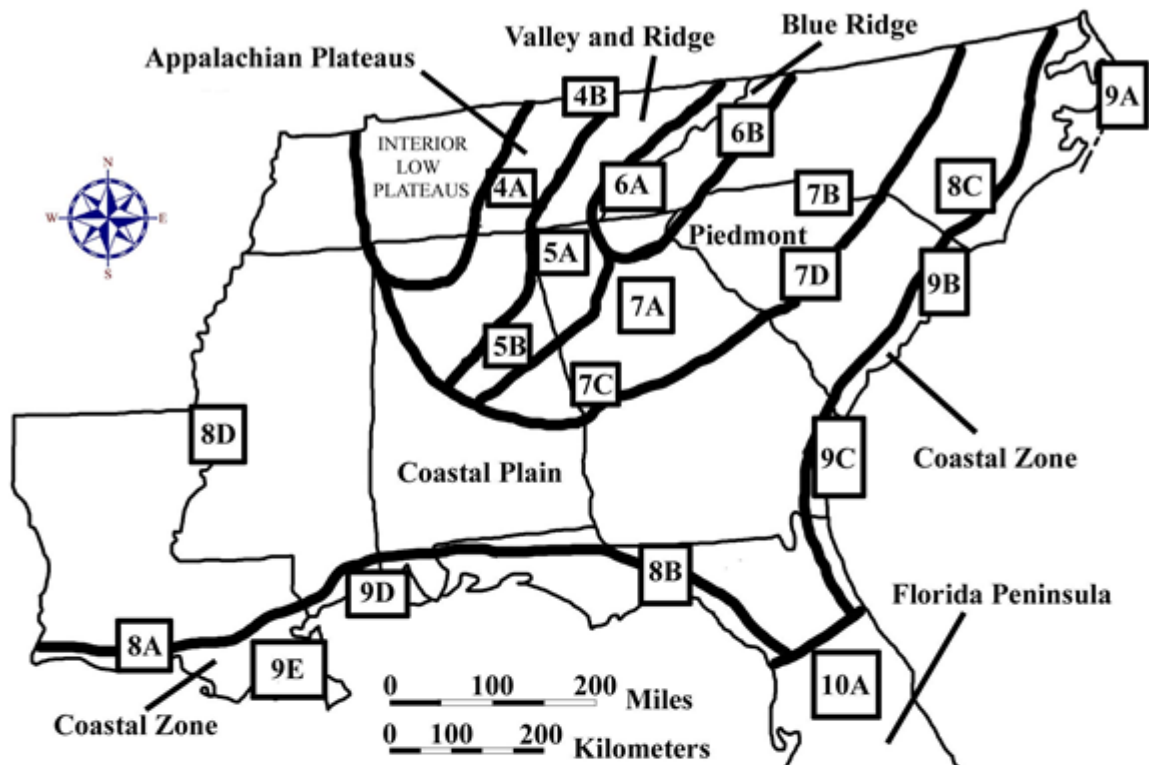


## CHAPTER 2

### INTERPRETATION OF MAPS AND REMOTELY SENSED IMAGES



**INDEX MAP TO STUDY AREAS**

|    |  |     |                                   |
|----|--|-----|-----------------------------------|
| 4A | Cumberland Plateau / Sequatchie Valley |     |                                   |
| 4B | Cumberland Gap                         |     |                                   |
| 5A | Lookout Mountain                       |     |                                   |
| 5B | Birmingham                             | 8C  | Carolina Bays                     |
| 6A | Great Smoky Mountains                  | 8D  | Mississippi River Alluvial Plain  |
| 6B | Blue Ridge Front                       | 9A  | Outer Banks                       |
| 7A | Metropolitan Atlanta                   | 9B  | Grand Strand                      |
| 7B | Kings Mountain Belt                    | 9C  | Georgia Coastal Corridor          |
| 7C | Pine Mountain Belt                     | 9D  | Mississippi Gulf Coast            |
| 7D | Columbia                               | 9E  | New Orleans to the Gulf of Mexico |
| 8A | Louisiana Salt Domes                   | 10A | Central Peninsula                 |
| 8B | Woodville Karst Plain                  | 10B | South Florida                     |

**DRAFT VERSION – updated 9-23-2020**



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John R. Wagner

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## PRIOR CONTENT KNOWLEDGE AND SKILLS REQUIREMENTS

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### General Concepts

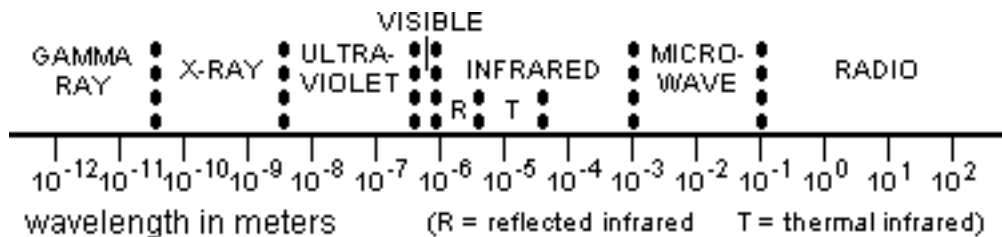
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The cartographic products used in the SE MAPS curriculum program were selected to give middle and high school students a special perspective on their world that can be attained in no other way. Recent advances in satellite and computer technology as well as in photographic and cartographic production provide remarkably high quality images, even considering the limitation that we gathered raw data mostly from products and databases available within the public domain. It was not possible to include samples from every single type of remote sensing technology, but we have tried to highlight a wide range of methodologies and products that will give students a good understanding of the types of data that are currently in use.

Remote sensing in its broadest definition includes any activity that gains information about an object without coming into physical contact with it. Students are already very familiar with this concept through the direct use of their own senses (sight, hearing, and smell) and through personal experience with photography and computers. They must also come to realize that data gathered by electronic sensors is an equally valid way to get information about the world in which they live. The role played by technology in increasing our knowledge base has accelerated greatly in recent years and will most likely continue this upward trend in years to come.

To fully appreciate the variety of remotely sensed images available in SE MAPS, students should already have a rudimentary understanding of the various components of the electromagnetic spectrum and the wave-like behavior of light. They should recognize that only a small portion of that spectrum is composed of visible light and that just as there are sounds so high-pitched or low-pitched that humans cannot hear, there are also wavelengths of light that we cannot see. Nevertheless, we can construct transmitters and sensors that can emit and detect these invisible wavelengths. The best and most common examples of this phenomenon are found in radio and television broadcasts and the microwave relay stations on which wireless (cell phone) technology is based. It is important for students to realize that just as they can tune a radio to bring in a particular station, remote sensing specialists can also tune a sensor to detect reflections or emissions at a particular wavelength of interest along any part of the electromagnetic spectrum.

**Figure 2-1: Regions of the Electromagnetic Spectrum**



Maps represent a convenient way to create visual models of the real world. As with any other model, the amount of detail shown will depend on the size and scale of the model as well as the use to which the information is to be put. Because maps provide a two-dimensional representation of a three-dimensional reality, certain distortions and misrepresentations are unavoidable. Students must realize these limitations as they study the way maps are produced and experience the problems associated with various map projections and surveying techniques. Students also must have mastered some basic map-reading skills to receive full benefit from the SE MAPS curriculum materials. A familiarity with spatial relationships such as compass directions, scale and proportion, linear and areal measurements, and the use of a grid system, such as latitude and longitude, for locating map features is of primary importance.

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### **Specific Skills Needed**

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No specific prior technical knowledge of aerial photography or satellite imagery is required to begin the SE MAPS lessons. Most students have taken pictures themselves and will understand the basic principles of photography. Many of these students will also have experienced airplane travel and will be familiar with the aerial perspective. They should be able to recognize and explain the difference between an oblique angle perspective and a view that is perpendicular to the earth's surface. The relationship of camera or sensor height to the scale of the resulting image is also important and can be related to students' perceptions of image size on a photograph diminishing with the object's distance from the camera. Although most satellite images are not technically photographs, the imaging process produces products that can be treated and analyzed in much the same way as pictures without appreciable loss of significance or information.

Before beginning work with the SE MAPS lessons, students should become familiar with a few of the most basic map symbols, such as representations for roads, railroads, rivers, swamps, political boundaries, and buildings. Most maps utilize a similar set of symbols to that which has been formally adopted by the United States Geological Survey for its standard topographic map series. That list (see Figure 2-2) may be referred to as needed, but students should have the basic symbols committed to memory to avoid confusion and delays while working through the performance task activities. Students should also know the difference between a fractional, verbal, and graphic scale, be able to use each type to measure distances, and be able to convert from one scale to the other. Many of the SE MAPS activities also call for measurement of surface area and the use of simplistic algebraic formulae such as  $D = R \times T$  (distance equals rate times time).

A working knowledge of contour lines is also important, although not necessarily essential. Several performance tasks in the SE MAPS activities require calculations based on contour line data and call for manipulation of this data, for example to construct topographic profiles. Even if students have not mastered the mathematical intricacies of modeling topography through contour line analysis or drawing profiles, they should nevertheless have an intuitive grasp of the basic concepts, for example, that contour lines drawn close together indicate steep slopes and that rivers always flow downhill.

**Figure 2-2: Standard USGS Symbols for Topographic Maps**

|               |  |
|---------------|--|
| <b>Black</b>  | Cultural features such as roads, buildings, and place names            |
| <b>Blue</b>   | Hydrographic feature such as oceans, lakes, rivers, and swamps         |
| <b>Brown</b>  | Contour lines and elevation values printed on index contours           |
| <b>Green</b>  | Forested areas and orchards  |
| <b>Red</b>    | Major roads, cities with large population, and public lands boundaries |
| <b>White</b>  | Open areas such as bare rock, agricultural fields, and pasture lands   |
| <b>Purple</b> | New features added during map revision from aerial photography data    |

**ELEVATION**

- bench mark BM  $\triangle$  123
- spot elevation  $\times$  123
- index contour line 50
- intermediate contour line
- depression contour line

**SURFACE FEATURES**

- sand dunes Sand or
- strip mine areas strip mine or
- quarry or open pit mine
- gravel or sand pit

**RIVERS, LAKES, WETLANDS**

- perennial stream
- disappearing stream
- intermittent stream
- waterfalls or rapids
- perennial lake
- intermittent lake
- well or spring
- marsh or swamp

**BOUNDARIES**

- political boundaries

**BUILDINGS AND FEATURES**

- occupied building or
- unoccupied building or
- school
- church
- airport or
- landing strip
- storage tank or
- landmark object Dixon
- cemetery or Cem

**ROADS AND TRAILS**

- primary highway or
- secondary highway
- light duty road or
- unimproved road or
- trail

**OTHER FEATURES**

- railroad
- power transmission line
- telephone line Telephone
- oil or gas pipeline Pipeline

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## **Resources for Aerial Photography, Satellite Imagery, and Cartography**

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- Fairey, Daniel A. (1989). South Carolina Cartographic Information Center. Columbia, SC: South Carolina Land Resources Conservation Commission.
- Steger, Theodore D. (1982). Topographic Maps. (0-383-966). Washington, DC: US Government Printing Office.
- National High Altitude Photography Program (NHAP). (1981). The Sky's the Limit. Sioux Falls, SD: United States Geological Survey.
- National High Altitude Photography Program (NHAP). (1982-83). US Department of Agriculture. Salt Lake City, UT: Agriculture Stabilization and Conservation Service.
- National Aerial Photographic Program (NAPP). (1989). US Department of Agriculture. Salt Lake City, UT: Agriculture Stabilization and Conservation Service.
- United States Geological Survey. (1981). Understanding Color-Infrared Photographs and False-Color Composites. Reston, VA: US Department of Interior.
- United States Geological Survey Topographic Maps. (USGS). US Department of Interior, Denver, CO: US Geological Survey Map Distribution Center.
- Ground Truth Studies Teacher Handbook. (1995). Aspen Global Change Institute, Aspen, CO.
- EarthSense (K-12 Environmental Education based on Remote Sensing and Hydrology). Institute for Global Change Research and Education, and the Division of Continuing Education, The University of Alabama in Huntsville.
- Barnaba, et. al., (2000). Explorations from an Aerial Perspective. Cornell University.
- Butler, B.C.M. and Bell, J.D., (1990). Interpretation of Geological Maps. John Wiley & Sons, Inc. New York, NY

Websites listing topographic map symbols:

United States Geological Survey: <http://www.mac.usgs.gov/pisb/pubs/booklets/symbols>



## READING AND INTERPRETING MAPS

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### Topographic Maps

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A topographic map is a graphical representation of a portion of the earth's surface that is plotted to a specific scale and printed in a quadrangle format that requires the map to be bounded on all sides by lines of latitude or longitude. Elevation and relief are portrayed using contour lines. Various physical and cultural characteristics of the landscape are marked on the map using a standard set of symbols. Different map series are printed at different scales. All of the topographic maps supplied with the SE MAPS portfolio were created from quadrangle maps produced by the United States Geological Survey's (USGS) National Mapping Program. All of the older series of USGS topographic maps use the English System of measurement (feet, miles, etc.). A newer series of maps, with a scale of 1:100,000 uses the metric system to label contour lines. The names of all original USGS reference maps from which sections were cut or from which mosaics were joined are listed in the box just below the map title on all SE MAPS cartographic products. The following chart lists the standard coverage of USGS maps. Note that the number of maps needed for statewide coverage is just an approximation and may vary widely depending on the size and shape of the state being sampled.

| Series<br>(Map Scale) | One Inch on Map<br>Represents Approx | Land Area<br>Covered            | # Maps Needed for<br>Statewide Coverage |
|-----------------------|--------------------------------------|---------------------------------|---|
| 1:500,000             | 8 miles                              | State Area                      | 1                                       |
| 1:250,000             | 4 miles                              | 2 <sup>0</sup> x 1 <sup>0</sup> | ~10                                     |
| 1:100,000             | 1.6 miles                            | 1 <sup>0</sup> x 30 min.        | ~30                                     |
| 1:62,500              | ~1 mile                              | 15 min x 15 min                 | ~175                                    |
| 1:24,000              | 2000 feet                            | 7.5 x 7.5 min.                  | ~600                                    |

Map scale is the relationship between the distance measured on a map and the corresponding real distance on the ground. The base map scale of 1:500,000 for example represents a dimensionless ratio in which one unit on the map is equivalent to 500,000 real units on the ground. Inches, feet, miles, millimeters or centimeters could be used with equal validity. The choice of map scale depends on how a particular map will be used and what level of detail or coverage is desired. The state base maps, for example, are considered "small scale" because they cover large land areas with less detail (everything on the map appears very small). Conversely, the 7.5 minute topographic maps are considered "large scale" because they show a greater amount of detail while covering a smaller land area (everything on the map appears very large). When measuring distances on a map, the fractional scale can be used to set up a numerical ratio that can be solved mathematically, or the graphic scale at the bottom of the map may be used to measure real distances directly from the map. Sometimes, it is easier to convert a fractional scale, such as 1:24,000 to a verbal scale of "1 inch equals 2,000 feet" because the smaller numbers are easier to handle when taking measurements from the map.

The portrayal of the shape of the earth's surface as depicted by contour lines is the most distinctive characteristic of any topographic map. Contours are imaginary lines which follow the land surface at a constant elevation above sea level. An alternate way of looking at contour lines is to see them as imaginary boundary lines, separating all points above a certain elevation from all points below that elevation. Usually, only thicker index contour lines are marked with elevation values. Contour intervals (the vertical difference in elevation between adjacent contour lines) vary from map to map depending on the topographic relief of the landscape and the amount of detail needed by the user. Too many contour lines on a map will obscure other features and make the elevation values themselves hard to read. Too few lines will not show enough detail and will therefore omit significant landform features. As a result, the contour interval on a particular map is very much influenced by the landform region in which the map is located. Contour intervals of five feet are common in the Coastal Zone, while Blue Ridge maps commonly use contour intervals of 40 feet or more.

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## **Regional Maps**

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Regional maps usually follow political boundary lines in their coverage outline and do not normally include contour lines. They may or may not use the standard USGS symbology or format. Such maps concentrate on placing major natural and cultural feature in their correct spatial and political context while naming important rivers, reservoirs, mountains, highways, cities, and other points of interest. Some regional maps do indicate major elevation differences by using variations of color in the landform representation or by detailed artistic renderings. When comparing several maps of the same region, it is important to note that different maps may have been drawn using different map projections. Because such maps try to represent a large segment of a three-dimensional spherical surface (the earth) on a two-dimensional piece of paper, distortions are inevitable. It is impossible to retain complete accuracy. Either equal areas are preserved, in which case directions and angles will be deformed, or the integrity of directions and angles is maintained, in which case some parts of a land area will appear much larger or smaller than expected.

SE MAPS has selected five regional maps to highlight topography, elevation, political features, and cultural features in the Southeastern United States. Four of these maps are drawn at the same scale for easy cross-referencing. MAP 3A, LANDSCAPES AND LANDFORMS is a shaded relief map, hand-drawn by Erwin Raisz, that emphasizes physiographic, or landform, features. An accompanying legend interprets the highly detailed and stylistic symbology used on the map. MAP 3C, LANDSCAPE PATTERNS contains a shaded relief image of the region that was computer generated. Elevation data from USGS topographic maps was digitized and then electronically converted into a range of grayscale values. MAP 3D, TOPOGRAPHY AND CLIMATE also illustrates elevation change, but this time using bands of different colors to indicate various ranges of height above sea level. MAP 3E, POLITICAL SETTING and MAP 3F, CULTURAL HERITAGE, both use United States Census data to display information of economic interest. These two maps also contain historical map insets of the region.

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## **Anaglyph Maps**

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People are used to seeing objects in the natural world appear in three dimensions. However, if a picture or drawing of that object is placed on a sheet of paper it can be perceived in only two dimensions. Likewise, a picture or image on a computer screen appears in only two dimensions. Normal stereoscopic vision is possible because our eyes occupy two different positions in space. They are separated by about 6.5 cm (2.5 inches) and therefore see real objects from a slightly different angle and send slightly different images to the brain. Depth perception is created when the brain uses the differences between those images to reconstruct a virtual stereoscopic image of the original object.

An anaglyph is a composite picture produced by drafting two images, from slightly different perspectives and in contrasting colors, of the same object, and then superimposing them on each other. The resultant image displays a three-dimensional effect when viewed through glasses containing two correspondingly colored filters, one over each eye. Such glasses, by convention, place a red filter over the left eye and a blue or green filter over the right eye. The anaglyph process has been available for years, and has appeared in popular culture in such diverse applications as comic strips and motion picture films. Probably the most famous 3-D movie of all time, "The Creature From the Black Lagoon," filmed in 1953, used this technology. Red and blue filters were added to the cameras during filming and the audience was given the standard red-blue anaglyph glasses when they arrived at the theater.

Anaglyph images can be encoded in full color, grayscale, or in black and white. They have proven especially effective and impressive in modeling landscapes. The 3-D topographic maps used in SE MAPS are excellent teaching aids in the study of contour lines and also provide spectacular graphic renderings of the topography. Often times, seeing an image in 3D makes it much easier to interpret the data and distinguish the relative height of features such as mountain peaks, or the positions of river valleys. Topographic anaglyph maps are produced by generating both a blue and a red version of the contour line pattern on a topographic map and then adding shading derived from a digital elevation model dataset. The final anaglyph image is created by computing a trigonometric distortion or spatial shift on the data displayed in one of the color bands.

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## **Geologic Maps**

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A geologic map generally shows the age, lithology, orientation, and spatial coverage of various rock units that outcrop at the surface of the earth. The presence of a rock formation in a particular area means either that the rock is exposed at the surface or that it would be exposed if all of the soil and vegetation were removed. Such a map usually includes the locations of major faults, fold axes, and unconformities. Such maps may also highlight the location or distribution of various geologic resources. Geologic maps can be drawn at any size, shape or scale, but the data is almost always added onto a pre-existing topographic or other base map. Many, but not all USGS topographic quadrangle maps have corresponding geologic maps that can be obtained separately.

Besides recording the distribution of rocks of different ages and compositions, geologic maps also provide evidence of how a particular section of the earth has operated as a system throughout its long history. There is enough information given in most geologic maps to allow construction of a three-dimensional model of the rock geometry. Geologic cross-sections provide important information about the probable orientation of rock units below the surface. Major tectonic events and climatic upheavals leave evidence in the rocks formed at those times and cross-cutting relationships provide a mechanism for establishing relative time sequences. A close examination of patterns of rock distribution can also give valuable information about the depositional environments and geological processes that were at work during a particular geologic period.

The geologic maps used in the SE MAPS program vary from a sketch map of a local region around Pine Mountain, Georgia (MAP 7C) to a colorful state geologic map with accompanying cross section (IMAGE 8D) to a Southeast USA regional geologic map (MAP 3B). The level of detail shown on the local map is of course impossible to duplicate on the much smaller scale regional map, but it is at the local level that this information must be gathered first in order to produce any reliable state or regional geologic map. Many geologic maps use a standard set of symbols and colors to represent rock ages and formation names. With regional maps, individual rock formations usually cannot be identified and a particular color generally represents all the rocks formed during that entire geologic time period. The map legend will normally explain the meanings of the symbols and colors found on non-standard geologic maps.

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### **Other Special Purpose Maps**

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Other map types play important roles in SE MAPS. A special type of map called an orthophotomap includes many of the features of a topographic map superimposed on a series of distortion-free aerial photographs. Such maps are often multi-colored and show subtle topographic details in areas of very low relief, for example around marshlands, estuaries, and other coastal areas. Orthophotomaps are produced in a standard 7.5 minute quadrangle format (usually at a scale of 1:24,000). If such a map is printed without contour line information and lacks most other standard symbology, it is referred to as an orthophotoquad. Orthophotomaps and orthophotoquads are published by the United States Geological Survey (USGS) and are available primarily for selected areas along the Atlantic Ocean and Gulf of Mexico. SE MAPS uses these maps to highlight areas within the Georgia Coastal Corridor (IMAGE 9C).

National Park Service maps are highly accurate road and trail maps of a national park and its vicinity. They generally label significant topographic features such as mountains, rivers, and lakes, but do not usually include contour line data. These maps are less cluttered than most topographic maps and enable users to quickly find desired points of interest without having to wade through a maze of extraneous data. The Cumberland Gap National Park map (MAP 4B) is more recent than the USGS topographic map of the same area. It is included in SE MAPS to highlight the different traffic patterns before and after the Cumberland Gap Tunnel was completed.

Historical maps show features that were present at a particular location at a particular time. They represent a snapshot in history and afford a detailed look at change through time, specifically in reference to land use, land cover, and alterations in topography. Some historical maps are nothing but pictographs, such as the “Birds-Eye View of Columbia” (MAP 7D) and the “Birds-Eye View of Savannah” (MAP 9C). The scale factor is highest at the near edge of the sketch and lowest along the far edge. The addition of symbols for people, trees, boats, and railroad trains adds human interest to the sketches, but these features are usually drawn out of proportion to the rest of the landscape. The historical sketch map of Cocoonut Grove (IMAGE 10B) is different in one important aspect even though it also consists mostly of pictographs. This map has roads laid out to scale, as if the area were being viewed from a perpendicular aerial perspective, so it can be used to determine accurately the areas of land holdings and distances along roads and to the ocean. The Kings Mountain historical map (MAP 7B) consists of a portion of a modern topographic map with modern symbols erased and historical features inserted. This added detail makes it possible to reconstruct the actual series of events, in exactly the right locations, that influenced the results of that important Revolutionary War battle.

The digital elevation model (DEM) of Lookout Mountain (IMAGE 5A) shows what can be done when elevation data points gathered from contour line information on topographic maps are entered into a Geographical Information Systems (GIS) software program. In addition to the ‘flat’ view (overhead perspective) that we are used to seeing, the software can also display the same landscape image from a variety of oblique angles.

## READING AND INTERPRETING AERIAL PHOTOGRAPHY

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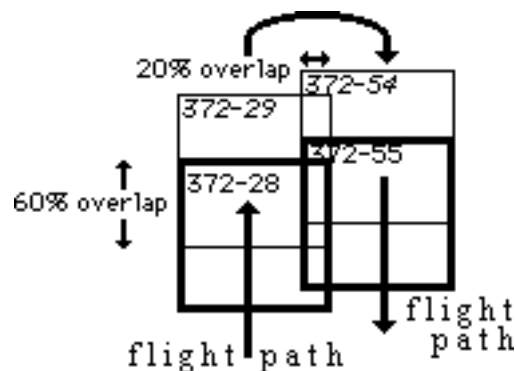
### Normal Aerial Photography

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Ground-based photographs provide only a limited and distorted picture of landscape features caught in the field of view. For example, mountains are defined by the skyline they create against the sky, while pictures of lakes and other large bodies of water are exaggerated laterally and compressed in the direction of view. Even photographs from high mountaintops tend to be primarily horizontal in orientation. Aerial photography provides a much broader perspective, covering a wide enough field of view that students not only see individual features from above, but also can recognize boundaries between regions dominated by different landscape processes. The horizon ceases to be a limiting barrier to information. Transition zones between terranes and subtle changes in structural trends and patterns are much more evident and lend themselves to speculation and debate over how such landscapes could have been produced and how they have changed over time.

Aerial photography existed even before there were airplanes or helicopters. The first documented hot-air balloon ride took place in 1783 in Paris, France. Once photography was invented in the early 1800s, balloonists routinely took pictures of points of interest from directly overhead. Some experimenters even strapped small cameras onto pigeons with widely varying results. Modern aerial photography is done in a much more systematic and orderly fashion. Airplanes fly at a constant elevation along a designated flight line, snapping pictures at regular intervals to achieve about a 60% overlap in photographic coverage. Once the airplane reaches the end of the designated flight path, it circles around and returns along a new flight path, slightly to one side of the original path, and takes a new set of pictures. Pictures from adjacent flight paths have about a 15% - 30% overlap. During processing, all photographs are labeled by roll number, strip (flight line) number, and exposure number, as well as with the date of photography. Most aerial photographs are taken on clear days between 10:00 AM and 2:00 PM in order to avoid the problems of ground shadows from low sun angles.

**Figure 2-3: Ground Coverage Pattern for Standard Aerial Photography**



The aerial photographs used in SE MAPS range from low altitude large scale images that show great local detail, to high altitude small scale images that cover a much greater ground area. Black and white film is standard for most aerial photography, but color film is used whenever the hue and intensity of the color of an object, such as for vegetation and soil, is important for interpretation. The photograph of the city of Savannah, Georgia (IMAGE 9C) was taken from an oblique angle. All the other aerial photographs in SE MAPS were taken from a vertical perspective. Because of the curvature of the earth, only the center point of each photograph is totally free of any distortion. Objects located away from the center in any direction appear to lean away from that center point. This effect is especially noticeable in low altitude photographs and in those areas containing tall buildings, but even large trees may appear to lean outward if they are far enough away from the center point. Some study areas utilize orthophotoquads that consist of a mosaic of aerial photographs chosen to cover the same area as a topographic quadrangle map. Such a mosaic has had all distortion eliminated.

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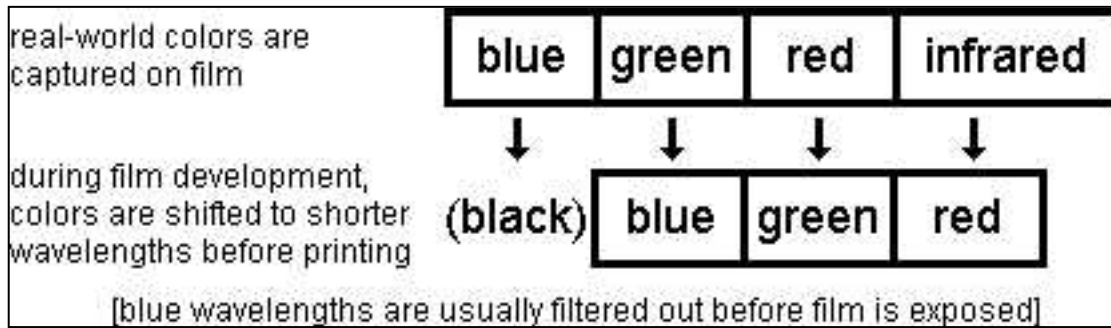
### **Infrared Aerial Photography**

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The cartographic products for some study areas in SE MAPS feature a variety of false-color infrared aerial photographs. Infrared film is sensitive to longer wavelengths (beyond the red color band) of the electromagnetic spectrum and can collect information that is not detectable in normal aerial photography. Infrared images often are sharper and clearer than those obtained with visible light because the longer wavelengths penetrate haze better. Many insects have a broader range of vision and can see wavelengths in the infrared band undetected by the human eye, just as dogs can hear higher frequency sounds than humans. Black and white infrared photographs record the degree of reflectance in a grayscale format. Internal leaf tissues associated with healthy vegetation are very strong infrared reflectors. This causes farm fields and woodlands in a picture to appear very light. In general coniferous trees appear lighter than deciduous trees. Clear water has very low reflectance values for infrared wavelengths and so appears nearly black. For the same reason, wetlands also appear darker than normal land surfaces. Infrared color photographs allow us to detect more variations in color hues than a regular color photograph, thereby providing more data on the relative health of vegetation.

The photographs are called “false color” because the colors of the features we see printed on the picture are not the same as the colors of the same features in the real world. In order to get any information from the infrared photographs, the invisible (to our eyes) infrared reflectance data must be printed in a color we can see. A color shift is performed during the printing process so that infrared objects are shifted to a red coloration, red objects are shifted to a green coloration, and green objects are shifted to a blue coloration. Blue objects would be shifted to a violet or even black coloration, but these shorter wavelengths are usually filtered out completely even before the image is captured on film. The colors “red,” “green,” and “blue” are significant because these are the primary additive colors used in all lithographic printing, regardless of the source of the data. In the same way, a color television set combines broadcast beams of red, green, and blue color to create the color image you see on your TV screen.

**Figure 2-4: Color Shift Chart for Infrared Photographs**



An understanding of the actual mechanics of developing and printing infrared color photographs relies heavily on the basic principles of color science. All color films have three distinctive layers or emulsions, each sensitive to different wavelengths of reflected light. Standard color film is sensitive to the visible reflected wavelengths of red, green, and blue light. Processing the film generates cyan, magenta, and yellow dyes in proportion to the amount of exposure each emulsion received when the picture was taken. When these layers are combined during the printing process, they produce a color picture very close to what we observe in nature. Color infrared film has a yellow filter over all three emulsion layers to block ultraviolet and blue wavelengths from ever reaching the film. The emulsions on color-infrared film are sensitive to green, red, and near-infrared wavelengths. The processing of the film again produces yellow, magenta, and cyan dyes. When these layers are combined during printing, they produce a color photograph, but one in which the colors are very different from the original features. In processing a series of infrared photographs, care is taken to maintain a color balance between different negatives. This gives a greater consistency and degree of confidence to interpreting differences detected in color hues from one picture to another.

**Figure 2-5: Color Key for Infrared Photographic Interpretation**

| <u>COLOR</u>                 | <u>MEANING</u>   |
|------------------------------|--|
| shades of red                | healthy vegetation                                       |
| bright red                   | vigorous growth, winter rye, oats, wheat, in fields      |
| darker red                   | evergreen -- pine, other conifers, scrub vegetation      |
| very dark red or greenish    | cypress, tupelo swamps or other wetland areas            |
| bluish-gray or greenish-gray | dormant vegetation (deciduous – leaf off), fallow fields |
| pink                         | vegetation in early stage of growth, suburban lawns      |
| white                        | sandy beaches, rock outcroppings, no vegetation          |
| gray to steel blue-gray      | cities, towns, concrete and asphalt roads, paved areas   |
| shades of blue to black      | bodies of water -- lakes, rivers, streams, oceans        |
| light blue                   | water with heavy sediment load                           |
| dark blue to black           | clear water with little sediment                         |

All of the SE MAPS infrared color photographs came either from the National High Altitude Photography (NHAP) program, flown at an elevation of 40,000 feet, or the National Aerial Photographic Program (NAPP), flown at an elevation of 20,000 feet.



These federal programs provide complete coverage to participating states and commonly utilize a specially equipped Lear Jet with a camera mounted on its underside to obtain the photographs. Infrared photographs are almost always taken during the winter months when deciduous trees are in their dormant or leaf-off stage. This type of photography is used widely in agriculture, forestry, archeology, and hydrology, as well as geology.

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### **Stereoscopic Viewing of Aerial Photographs**

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Most students are familiar with Viewmaster<sup>®</sup> reels and viewers that give a three dimensional appearance to cartoon characters, movie scenes, prehistoric animals, or scenic vistas. In much the same way, students can use a stereoscope to view aerial photographs and recreate a three dimensional image of the landscape. The key to such depth perception is an ability called binocular vision through which each of our two eyes sees objects from a slightly different angle (this is because our eyes are separated by a distance of approximately 5.7 centimeters [2.25 inches]). In people with normal vision, the two independent and slightly different views from each eye are sent to the brain and merged into a single three dimensional image. The degree of depth perception is greatest for nearby objects and decreases with distance until it is lost completely for objects located farther than 600 meters (2,000 feet) from the observer.

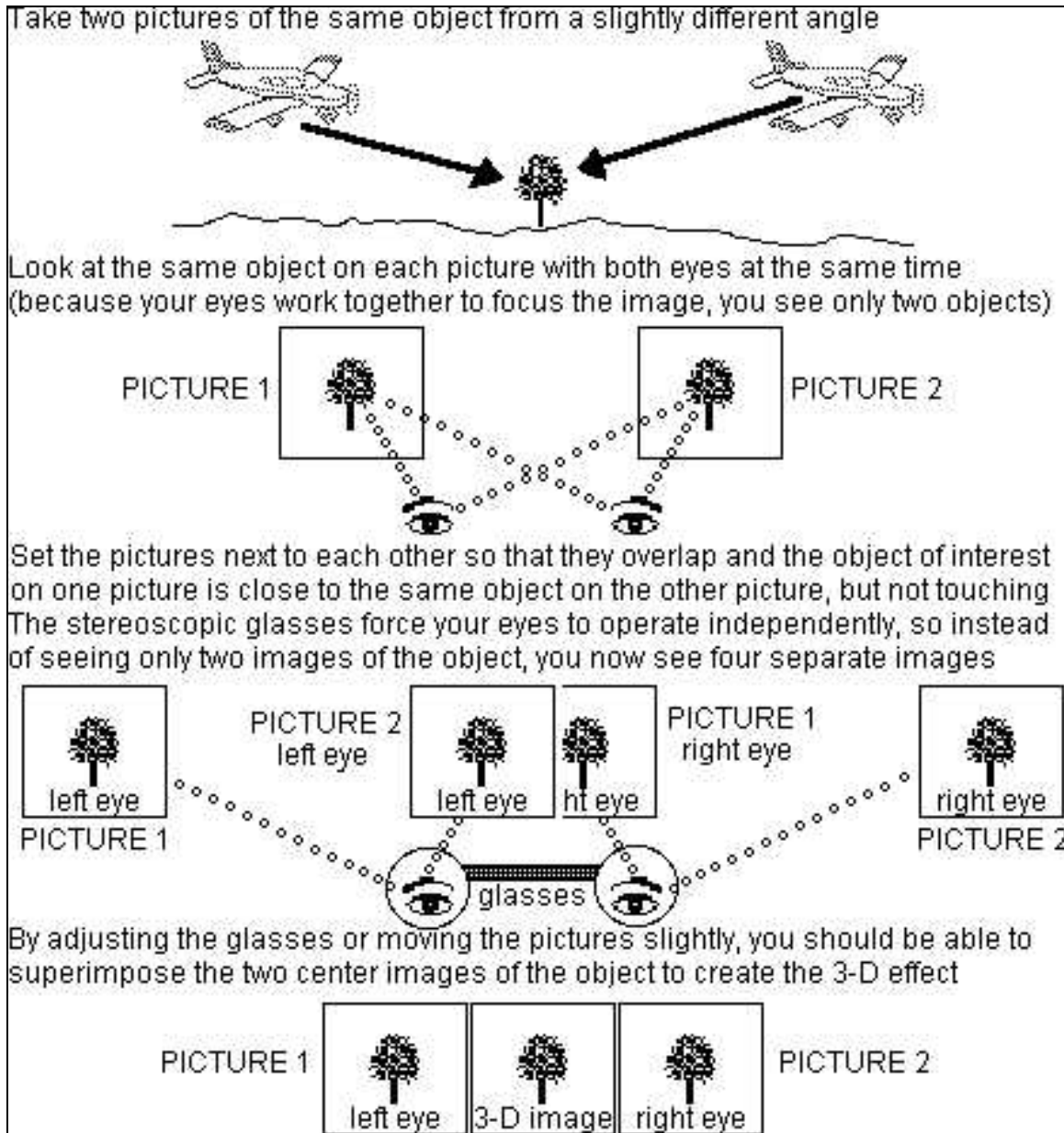
To view aerial photographs stereoscopically, it is necessary to select two adjacent pictures with significant overlap. Most modern aerial photographic programs build in an overlap of about 60% along the flight line and from 15% to 30% along adjacent sides (see Figure 2-3). Within the overlap area, specific features will appear on both images, but the angle at which the object was photographed will differ from one picture to the other. The lenses of the stereoscope force each eye of the viewer to focus on a different photograph, so that a building on one photograph is viewed only by the left eye and that same building on the second photograph is viewed only by the right eye. The two pictures must be overlapped exactly the right amount in order for the stereo image to appear, or alternatively, the distance between lenses may be adjusted on some stereoscopes to achieve the same effect. The result is a three dimensional view of the overlap area only. Even with the stereoscope, the remaining areas of both pictures will appear as flat images.

The stereoscope lenses must be placed over a common point on each picture, and must be kept either parallel to or perpendicular to the flight line of the two photographs to produce a usable image. Any other position may cause eyestrain and will produce a distorted image. Many stereoscope lenses also serve as magnifiers that enlarge features up to two or four times their original size on the photographs. Pocket stereoscopes are fairly inexpensive and will work well enough for the stereo photographs used in SE MAPS, even though the field of view is limited. More expensive stereoscopes use sets of mirrors that enable the user to see much more of the stereo image at one time.

Using a stereoscope to view the overlap areas of adjacent aerial photographs enables the viewer to perceive a stereo image at distances far beyond the normal limits

for depth perception. An unexpected benefit to this setup is that, for most viewers, the stereo image also exaggerates the topographic relief by a factor of about four. So mountains and buildings look much taller, valleys look much deeper, and slopes look much steeper than they really are. Although this exaggeration may at first be confusing, it is actually of great benefit to the viewer because it provides additional and more detailed information about the landscape, especially in areas consisting of mostly flat terrain. It is important to note again that only the overlap area can be viewed in stereo.

**Figure 2-6: Using a Stereoscope to Obtain a 3-D Image**



## READING AND INTERPRETING SATELLITE IMAGERY

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### Landsat Data

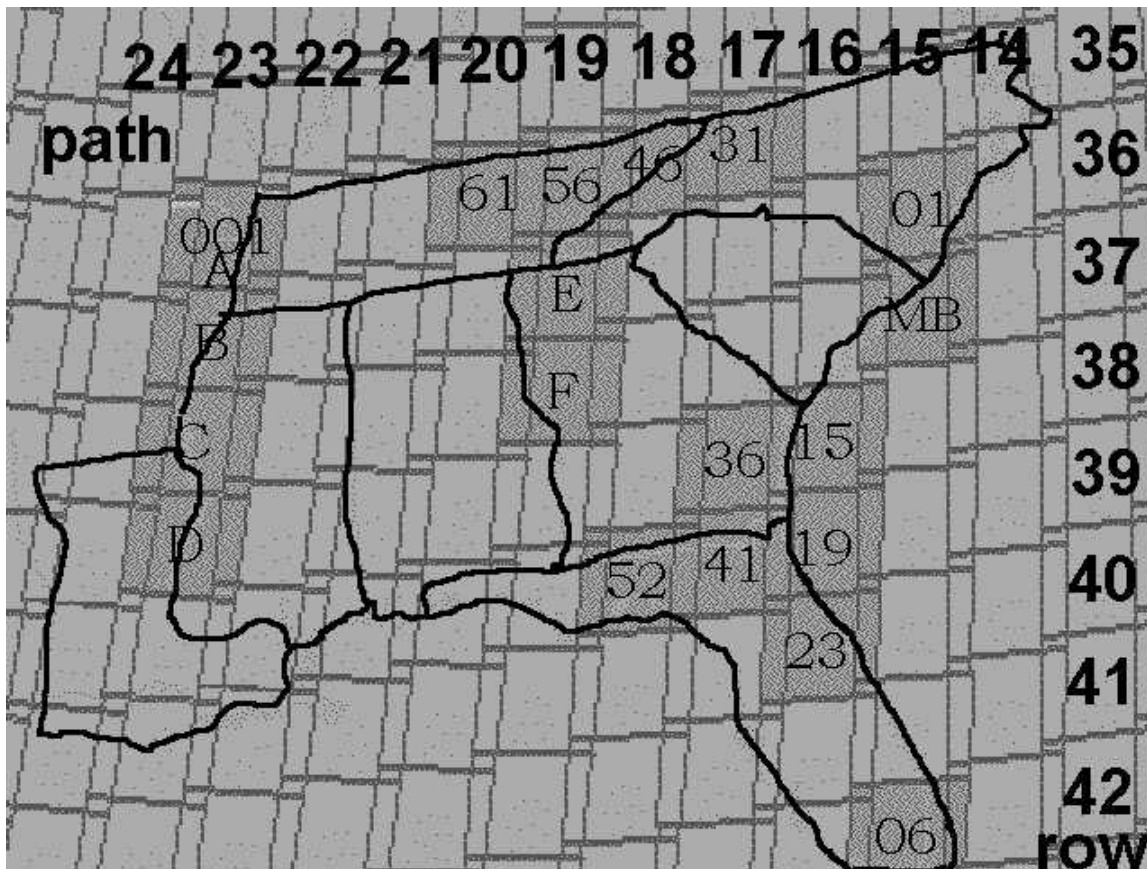
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Rocket ships provided the earliest opportunity to picture earth from space, but the resulting photographs were generally of poor quality and unpredictable coverage. Early meteorological satellites like TIROS-1, launched in 1960, displayed cloud cover and weather patterns well enough, but provided little or no detail about the earth's surface. The publication of hundreds of high resolution photographs of earth taken by astronauts during the Mercury and Gemini manned space programs run by NASA (National Aeronautics and Space Administration) finally gave space photography the recognition it deserved as a potentially valuable tool for geologic and earth resource applications. The subsequent Apollo space program and the earth-orbiting Skylab included multi-spectral cameras in some of their orbital missions and NASA began planning for an orbiting imaging system that would cover the entire globe.

The first Earth Resources Technology Satellite (ERTS) was launched on July 23, 1972. Just before the second ERTS satellite was scheduled to be launched, NASA renamed the entire project and all ERTS satellites became part of the Landsat Program. A total of seven Landsat satellites have been launched, most recently in 1999. The first three contained multi-spectral scanners as well as Return Beam Vidicon (RBV) cameras. Landsat 4, 5, and 7 contain various types of Thematic Mappers, and Landsat 6 never functioned due to launch failure. All Landsat satellites follow sun-synchronous orbits that pass over both the north and south poles of the earth. They make fourteen orbits per day and each orbit crosses the equator a little further westward of the preceding orbit so that this displacement exactly keeps pace with the sun's apparent movement across the sky. As a result, the satellite (as it passes over the day side of the earth) always sees the sun from about the same angle and always re-crosses the same surface data point at the same local sun time. The satellite requires 16-18 days and over 200 orbits before it revisits a particular point on the globe.

Both the multi-spectral scanners and the thematic mappers gather data at several different wavelength categories, or spectral bands, of the electromagnetic spectrum. Multi-spectral scanners record data in the green, red, and near-infrared portions of the spectrum. Thematic Mappers use seven spectral bands, spanning the visible, infrared, and thermal infrared categories. Unlike photographs, the different spectral signatures of separately scanned images can be combined in a number of ways to provide customized color composite images. The most common format for printing, however, uses data from the green, red, and near-infrared sensors to produce a false-color product resembling small scale infrared aerial photographs. Even though the data acquisition methods are different, the resulting cartographic products can be analyzed using the same procedures. Due to the overlap in orbital paths (from 14% at the equator to 85% at the poles), stereo viewing is theoretically possible, but because of the high altitude, the vertical exaggeration is too small to make such viewing useful, except in very mountainous areas.

**Figure 2-7: NALC Coverage Map, Southeastern United States**



A major advantage to satellite imagery is that large areas can be scanned at one time, so researchers and students can see the "big picture." This large areal coverage permits easy comparison with similarly scaled state base maps and regional maps. Individual scenes are categorized and identified by path and row number. Paths are the southbound segments of the orbital path traced by the satellite. Rows run east-west and are spaced 165 km (100 mi) apart to create a roughly equi-dimensional (rhombic) image area. Most of the satellite imagery used in SE MAPS is part of the North American Landscape Characterization (NALC) project, co-sponsored by NASA, the USGS (United States Geological Survey), and the EPA (US Environmental Protection Agency). NALC images are generated through NASA's Landsat Pathfinder Program which utilizes remote sensing technologies to investigate global change. These images, under the most favorable circumstances, will only provide a ground resolution of 100 meters (300 feet), meaning that any object smaller than that size will not usually show up on the NALC image.

Four of the satellite images used in SE MAPS have much better resolution than the NALC images. The South Florida mosaic (MAP 10B), Central Peninsula mosaic (IMAGE 10A), Lookout Mountain region (IMAGE 5A), and the Mississippi Delta area (IMAGE 9E) were all derived from the more sophisticated Thematic Mapper system first used on Landsat 5. The Thematic Mapper is an advanced scanning instrument mounted

on the satellite, orbiting about 400 miles above the earth, which is able to distinguish features on the earth's surface as small as 30 meters (98 feet) across. Each full image is almost square and covers approximately 10,000 square miles. Continuous strips of imagery are acquired along the orbital path and transmitted to a ground receiving station where the data is stored on magnetic tapes. In that form, the data can be manipulated digitally by computers to produce the exact blend of spectral bands required for a particular study.

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### **Thermal Infrared Imagery**

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Although many people equate the term “infrared” with “heat” radiation, the reality of the situation is a little more complex. Most infrared sensors actually operate in the reflected energy portion of the infrared region, from .7 micrometers (microns) to 3 micrometers in wavelength. They can detect the amount of solar radiation in that particular wavelength range that has bounced off objects on the surface of the earth before reaching the sensing instrument. A great deal of important geologic and hydrologic information can be gained from this portion of the spectrum. For this reason, the thematic mapper instruments used in Landsats 4, 5, and 7 allocated three of their seven spectral sensors to target the reflected infrared range. Photography using infrared-sensitive film is possible only within the range of .7 micrometers to .9 micrometers.

The thermal infrared portion of the spectrum, in contrast, begins at 3 micrometers and usually extends to the 15 micrometer mark, although the infrared region continues all the way to the 1,000 micrometer (1 millimeter) mark. The energy picked up by sensors in this range has not been reflected off of anything, but rather is radiant energy that has been emitted by objects on the earth's surface and traveled directly to the sensing instrument. Photographic film cannot detect thermal infrared radiation, so special detectors have to be used. The thematic mappers on Landsat each allocate one sensor, Band Six, to record thermal infrared data. Each type of different surface or material has its own characteristic emissivity value or percentage. In general, dark objects absorb energy better and therefore emit more radiant energy. Light colored objects absorb less energy and therefore have less radiant energy to emit. Variations in density, thermal conductivity, and surface roughness of objects also effect their emissivity values.

The laws of physics tell us that every material object with a temperature above absolute zero will give off radiant energy at a predictable wavelength and intensity. Objects raised to a higher temperature will emit more energy and the characteristic wavelength of that energy will become shorter. Because the temperature of the earth's surface (and most everything on it) averages about 25° C (77° F), the radiant energy emitted from the earth's surface peaks at a wavelength of approximately 9.7 micrometers, which is right in the middle of the thermal infrared portion of the spectrum. Unfortunately for the remote sensing industry, gases in the atmosphere, especially greenhouse gases like carbon dioxide, methane, water vapor, and ozone, immediately absorb most of this thermal infrared energy, so it is not possible to record the majority of these emissions using satellites. There is however a small part of the thermal infrared

region, from 10.5 micrometers to 12.5 micrometers, which transmits infrared energy without interference and it is in this range that most satellite infrared systems operate.

SE MAPS uses two thermal infrared images, the AVHRR (Advanced Very High Resolution Radiometer) regional image on MAP 3C and the Lower Mississippi River Delta print on IMAGE 9E. In almost all thermal images, warmer radiant temperatures are denoted by brighter areas. The notable exception is weather satellite images, where the grayscale sequence is reversed to prevent colder clouds from appearing black and warmer ground from appearing white. Sometimes, the grayscale image data is processed by a computer and different temperature regions are printed using a color code, generally assigning red to indicate higher temperatures and blue or purple to represent cooler temperatures. It is important to refer to the legend before interpreting color contrasts on any thermal infrared image. The disadvantage to color coding is that temperature boundaries appear artificially sharp. In fact, these values tend to vary continuously across a region rather than changing in sudden jumps.

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### **Land Use / Land Cover Analysis**

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Land use and land cover maps can be generated from a variety of different data sources. For local areas, topographic maps and aerial photographs are the customary sources; for statewide or regional coverage, satellite images provide the best data. The term “land use” emphasizes human impact on the land. General categories of coverage include residential, agricultural, commercial, industrial, recreational, and institutional. The term “land cover” is reserved for natural features such as vegetation, water, rock outcroppings, forested areas, or meadowlands. These types of maps are often printed in two colors, using black for boundaries and labels, and green for the base map or image. Occasionally, they are printed in full color format, especially for large regional coverage. Most of these maps include standard base map features such as political boundaries, roads, railroads, and rivers/lakes; but they do not normally include contour lines.

Landsat imagery is frequently utilized as a primary database because the original scanned image is transmitted from space down to earth in a digital format that is ideal for computer processing. Each image is made up of large numbers of extremely small picture elements called “pixels.” The computer program classifies each pixel according to the categories that will be displayed in the final product. Two of the SE MAPS cartographic products were produced in this way, the habitat change sketch maps (MAP 8A) and the wetland distribution maps (MAP 9E). Both can be categorized as land cover maps, because the computer program assigned certain colors to certain ranges of environmental divisions in the database. Such maps are best used to describe the changes in distribution of vegetation types, water resources, and similar surface features for a particular land area over long or short spans of time. The simplicity of these maps makes it easy to see where and especially when major changes in land cover occurred.

## READING AND INTERPRETING RADAR AND OTHER IMAGERY

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### Radar Imagery

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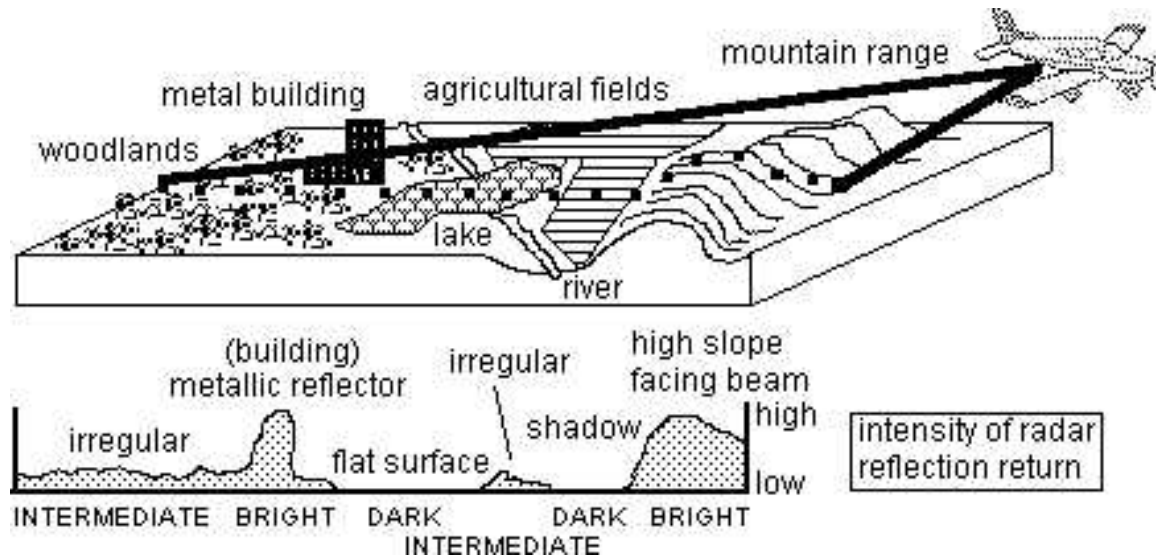
Although the word “radar” is really an acronym that stands for “Radio Detection and Ranging,” almost all radar technology today uses the microwave portion of the electromagnetic spectrum (wavelengths between .8 and 68 cm) instead of the radio waves that characterized the earliest designs during World War II. For security reasons, military developers assigned random code letters (K, X, C, L, P) to the various wavelength bands. These same code designations continue to be used today. The longer wavelength microwave bands are utilized most often in remote sensing applications because the atmosphere is completely transparent at these wavelengths and the radar pulses are unaffected by clouds and precipitation. Under ideal conditions, these longer wavelengths are capable of penetrating vegetation canopies, dry sand, or other thin surface cover to reveal topographic structures that lie hidden from the view of other imaging systems.

Radar is unique because it is an active system in which a pulse of energy is sent out from an antenna and a portion of that energy (sometimes called an echo) is reflected back to the same antenna to be recorded. Different intensities of energy reflection (Figure 2-8) give valuable information about the texture and orientation of various objects the beam encounters in its field of view. Slopes facing the radar source generally send a strong return signal, slopes facing away from the source, or smooth flat surfaces such as lakes or ponds, will show little or no reflectivity. Sharp corners, especially on metal structures such as bridges or buildings, generate very strong reflections. Radar can also be used to calculate the distance of an object or surface feature by multiplying the speed of light (in the atmosphere) by half the time elapsed between the sending of the pulse and the receiving of the reflection. Many radar systems used in weather forecasting, air traffic control, and navigation rely on a rotating antenna that sweeps a circular path through the sky and sends back positional data on thunderstorms, airplanes, or tall buildings. Doppler radar can detect frequency differences indicating whether an object is approaching or receding from the radar location. Because radar is an active system, and doesn't depend on reflected sunlight, it can be utilized both day or night.

Most modern applications of radar in the field of remote sensing rely on a technique called Side Looking Airborne Radar (SLAR). This technological advancement was pioneered by the United States military in the early 1950's as a reconnaissance tool to gather information about enemy terrain that aircraft could not fly over directly. In a SLAR system, the radar pulse is sent out at a fixed angle (the depression angle) from an airplane flying in a straight line and the pulse returns (echoes) are continuously monitored and can be displayed on film as a strip image. Image strips can be combined to form a radar mosaic that can cover a fairly large area with excellent resolution. A lower depression angle produces higher resolution radar images because the presence of shadows enhances any slight differences in topographic relief. Radar pulses can also be

generated above the earth's atmosphere from satellites, space shuttles, or space stations. Such systems are known collectively as Spaceborne Imaging Radar (SIR).

**Figure 2-8: Effect of Topography on Radar Echoes**



All radar images appear initially as black and white (grayscale) pictures. The brightest areas represent features that have the highest reflectance. The darkest areas represent areas in shadow or flat surfaces (lakes, parking lots) from which there is little or no pulse return. Intermediate returns indicate terrain that is not flat, but also not excessively steep. Any radar picture that is printed in color must have been generated by a computer program that assigns particular colors to particular brightness (grayscale) values. Radar wavelengths can have no color, only the visible portion of the electromagnetic spectrum possesses natural color. The SLAR images used in SE MAPS (IMAGE 4A – Sequatchie Valley; IMAGE 4B – Cumberland Gap; IMAGE 6A – Great Smoky Mts; and IMAGE 7C – Pine Mountain) are all grayscale mosaic radar images produced by the United States Geological Survey (USGS). By carefully analyzing the position of shadows, it is possible to determine both the flight direction of the airplane and the look (range) direction in which the radar pulse was beamed. The look direction is always perpendicular to the flight path.

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### Side-Scan Sonar Imagery

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Side-scan sonar is different from most other remote sensing methods because it does not use radiation from the electromagnetic spectrum. Instead, it uses sound waves to determine the shape and hardness of the ocean floor. As sound waves hit the sea floor, some of the energy passes from the water into the bottom materials, but a portion of the energy is reflected back towards the surface as an echo and is recorded by a microphone. Different seabed materials (sand, rock, mud, shells) reflect and absorb sound differently and these variations in bottom type appear as light/dark shades of gray in the digital sonar record. For instance, a rocky, hardbottom area would reflect sound back to the



microphone very quickly and with greater intensity than sound bounced off a flat, muddy area of the seafloor. The mud is softer and does not bounce the sound back to the microphone nearly as quickly. The fine sandy areas show up on the recorded image as dark (low backscatter) areas. Shelly and rocky areas that reflect more of the energy from the sound wave show up on the recorded image as very light (high backscatter) areas.

Sonar allows scientists to take an acoustic photograph of the seafloor. Sound waves are emitted as “clicks” or pulses from a transducer that is dragged through the water behind a ship. This trailing apparatus is sometimes called a “towfish” and also includes a microphone to record sound reflections or echoes. The sound waves travel through the water, but bounce off everything in their path (including the seafloor, debris, fish, etc.). When sound encounters solid objects standing in relief or in the water column (like rocks on the bottom, wooden structures, or fish) the sound casts a shadow (like a flashlight would) behind the object. Side scan sonar data can be collected from either large ships or small boats, depending on the duration of the cruise and the expected weather. A sonar mosaic is a picture of a wide area of the seafloor made by combining a succession of individual narrow strip images recorded during successive passes of the ship and towfish..

Although sound waves travel well under water, the acoustical energy tends to spread out and become fainter the further it travels. For this reason, scientists can only obtain reliable sonar data for a short distance on either side of the ship’s path through the ocean. This is why side scan sonar surveys are sometimes said to be “mowing” the ocean. Much like we would mow grass in rows with a lawn mower to make sure we cover every square inch of the yard, the boat must travel back and forth many times to completely cover a study area. Sometimes a lawn mower will miss a small section of grass during the mowing process. Likewise, side scan sonar will sometimes skip small areas in a mosaic which then have no data recorded.

Seafloor mapping with sonar is important to scientists and engineers who may want to find a source for sand - perhaps for future beach renourishment. Another use for seafloor mapping is to monitor hardbottom (reef) communities in the nearshore zone. Recreational and commercial fishing activities are very dependent on these hard bottom communities as productive resource sites. An increasingly important role for side scan sonar is in underwater archeology. This technique is especially appropriate for locating and identifying wooden structures (such as shipwrecks) over large areas of ocean floor. In SE MAPS, side scan sonar images appear in MAP 9B and IMAGE 9B (Grand Strand). Individual images highlight bridge pilings and sunken ships, while larger area mosaics illustrate the varied bottom conditions off the coast of Myrtle Beach, South Carolina.

## CONTENTS OF THE PORTFOLIO OF CARTOGRAPHIC PRODUCTS

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The complete SE MAPS portfolio contains six copies of each cartographic product (printed back to back) and six transparent plastic grids with one-inch squares. Each of the 21 designated SE MAPS study areas is associated with two large-format sheets that display all the maps and images required by students to do the activities contained in the SE MAPS Teaching Manual. There are also six regional maps that are used in connection with all study areas, giving a total of 48 separate products printed on 24 laminated sheets. The total package of 288 products and 6 plastic grids is accommodated in three large cardboard portfolios, 44 inches by 31 inches in dimension. All lamination is .3 mils. Products are designed for continuous student use with wipe-off pens and are sufficient in number for groups of 3 to 5 students to share map sets while working in a cooperative learning format within the typical middle school classroom.

### List of SE MAPS Lithographs and Individual Cartographic Products

#### MAP 3A – LANDSCAPES AND LANDFORMS

- \* Landforms of the Southeastern United States (sketch map)
- \* Physiographic Divisions (line drawing)

#### MAP 3B – GEOLOGICAL SETTING

- \*Surface Geology of the Southeastern United States (geologic map)
- \*Tectonic Map (geologic map)

#### MAP 3C – LANDSCAPE PATTERNS

- \*AVHRR Mosaic of the Southeastern United States (thermal infrared)
- \*Shaded Relief Image of the Southeastern United States (regional map)

#### MAP 3D – TOPOGRAPHY AND CLIMATE

- \*Digital Elevation Map of the Southeastern United States (regional map)

#### MAP 3E – POLITICAL SETTING

- \*Political Base Map of the Southeastern United States (regional map)
- \*The Southeastern United States before 1800 (historical map)

#### MAP 3F – CULTURAL HERITAGE

- \*Cultural Base Map of the Southeastern United States (regional map)
- \*Native American Cultures and Early Settlement Patterns (regional map)

#### MAP 4A – CUMBERLAND PLATEAU / SEQUATCHIE VALLEY

- \*3-D Topographic Section Map: Sequatchie Valley, TN (anaglyph map)
- \*Grassy Cove, TN (anaglyph map)
- \*Raccoon Mountain, TN (topographic map)

#### IMAGE 4A – CUMBERLAND PLATEAU / SEQUATCHIE VALLEY

- \*Sequatchie Valley, TN (SLAR [radar])
- \*Sequatchie Valley, TN (NALC [satellite])
- \*Grassy Cove, TN (NHAP [air photo] triplet)

#### MAP 4B – CUMBERLAND GAP

- \*Cumberland Escarpment, TN (topographic map)
- \*Cumberland Escarpment, TN (NALC [satellite])
- \*Cumberland Gap National Historical Park (National Park Service map)

IMAGE 4B – CUMBERLAND GAP

- \*Cumberland Escarpment, TN (SLAR [radar])
- \*Cumberland Gap, TN (topographic map)
- \*Cumberland Gap, TN (NHAP [air photo] stereopair)

MAP 5A – LOOKOUT MOUNTAIN

- \*Lookout Mountain, AL-GA (topographic map)
- \*Little River Canyon, AL (topographic map)

IMAGE 5A – LOOKOUT MOUNTAIN

- \*Lookout Mountain, AL-GA (TM [satellite])
- \*Little River Canyon, AL (NHAP [air photo] mosaic)
- \*Lookout Mountain, AL-GA (DEM [digital elevation model])

MAP 5B – BIRMINGHAM

- \*Birmingham, AL (topographic map)

IMAGE 5B – BIRMINGHAM

- \*Birmingham, AL (NHAP [air photo] mosaic)
- \*Sloss Furnaces National Historic Landmark (NAPP [air photo])

MAP 6A – GREAT SMOKY MOUNTAINS

- \*3-D Topographic Section Map: Gatlinburg, TN (anaglyph map)
- \*Gatlinburg, TN (NHAP [air photo] stereo triplet)

IMAGE 6A – GREAT SMOKY MOUNTAINS

- \*Great Smoky Mountains, TN-NC (topographic map)
- \*Great Smoky Mountains, TN-NC (SLAR [radar])
- \*Great Smoky Mountains, TN (NALC [satellite])
- \*Ducktown, TN (NHAP [air photo])
- \*Ducktown, TN (MSS [satellite])

MAP 6B – BLUE RIDGE FRONT

- \*Blue Ridge Front, NC (topographic map)
- \*Mount Mitchell, NC (topographic map)
- \*Grandfather Mountain, NC (topographic map)

IMAGE 6B – BLUE RIDGE FRONT

- \*Blue Ridge Front, NC (NALC [satellite])
- \*Mount Mitchell, NC (NHAP [air photo] mosaic)
- \*Grandfather Mountain, NC (NHAP [air photo] stereopair)

MAP 7A – METROPOLITAN ATLANTA

- \*Atlanta, GA (topographic map)
- \*Soapstone Ridge, GA (topographic map)
- \*Stone Mountain, GA (topographic map)

IMAGE 7A – METROPOLITAN ATLANTA

- \*Atlanta, GA (NALC [satellite])
- \*Stone Mountain, GA (DOQ [air photo])
- \*Soapstone Ridge, GA (DOQ [air photo])
- \*De Kalb County Sewage Plant (DOQ [air photo])
- \*De Kalb County Landfill (DOQ [air photo])

MAP 7B – KINGS MOUNTAIN BELT

- \*Kings Mountain, NC-SC (topographic map)
- \*Kings Mountain National Military Park (historical map)

- IMAGE 7B – KINGS MOUNTAIN BELT
- \*Kings Mountain, NC-SC (NHAP [air photo] mosaic)
  - \*Grover Quarry, SC (NAPP [air photo])
- MAP 7C – PINE MOUNTAIN BELT
- \*Pine Mountain, GA (topographic map)
  - \*Geologic Map of Harris County, GA (geologic map)
- IMAGE 7C – PINE MOUNTAIN BELT
- \*Pine Mountain, GA (SLAR [radar])
  - \*Pine Mountain, GA (NALC [satellite])
  - \*Lake Florence, GA (topographic map)
  - \*Lake Florence, GA 1938 (B&W air photo)
  - \*Lake Florence, GA 1964 (B&W air photo)
- MAP 7D – COLUMBIA
- \*Columbia, SC (topographic map)
  - \*Downtown Columbia, SC (historical map)
- IMAGE 7D – COLUMBIA
- \*Columbia, SC (NHAP [air photo])
  - \*Downtown Columbia, SC (NAPP [air photo])
- MAP 8A – LOUISIANA SALT DOMES
- \*Avery Island, LA (topographic map)
  - \*Avery and Weeks Islands Habitat Maps (land use / land cover map)
- IMAGE 8A – LOUISIANA SALT DOMES
- \*Avery Island, LA (photoquad [air photo])
  - \*Salt Domes, LA (TM [satellite])
- MAP 8B – WOODVILLE KARST PLAIN
- \*Woodville Karst Plain, FL (topographic map)
  - \*Leon Sinks, FL (topographic map)
  - \*Wakulla Springs, FL (topographic map)
  - \*Spring Creek, FL (topographic map)
- IMAGE 8B – WOODVILLE KARST PLAIN
- \*Woodville Karst Plain, FL (NAPP [air photo] mosaic)
  - \*Leon Sinks, FL (NAPP [air photo])
  - \*Wakulla Springs, FL (NAPP [air photo])
  - \*Spring Creek, FL (NAPP [air photo])
- MAP 8C – CAROLINA BAYS
- \*Bladen Lakes, NC (topographic map)
- IMAGE 8C – CAROLINA BAYS
- \*Bladen Lakes, NC (NHAP [air photo] mosaic)
  - \*Bladen Lakes, NC (NALC [satellite])
  - \*Bladen Lakes, NC (B&W photomosaic [air photo])
- MAP 8D – MISSISSIPPI RIVER ALLUVIAL PLAIN
- \*Yazoo Basin, MS (topographic map)
  - \*Yazoo City, MS (topographic map)
  - \*Vicksburg, MS (topographic map)
  - \*Vicksburg Profile Line (topographic map)

IMAGE 8D – MISSISSIPPI RIVER ALLUVIAL PLAIN

- \*Yazoo Basin, MS (NALC [satellite])
- \*Vicksburg, MS (NAPP [air photo])
- \*Geologic Map of Mississippi (geologic map)
- \*Geologic Cross Section of Eastern Mississippi (geologic map)

MAP 9A – OUTER BANKS

- \*Outer Banks, NC (topographic map)
- \*Cape Hatteras, NC (topographic map)
- \*Oregon Inlet, NC (topographic map)
- \*Kitty Hawk, NC (topographic map)

IMAGE 9A – OUTER BANKS

- \*Cape Hatteras, NC (NHAP [air photo])
- \*Oregon Inlet, NC (NHAP [air photo])
- \*Kitty Hawk, NC (NHAP [air photo] mosaic)

MAP 9B – GRAND STRAND

- \*Grand Strand Bathymetry (topographic map)
- \*Myrtle Beach, SC (topographic map)

IMAGE 9B – GRAND STRAND

- \*Grand Strand, SC (NALC [satellite])
- \*Myrtle Beach, SC (NAPP [air photo])
- \*Myrtle Beach, SC (side scan sonar)
- \*Bridge Pilings (side scan sonar)
- \*Dock Pilings (side scan sonar)
- \*Small Boat (side scan sonar)
- \*Sunken Boat (side scan sonar)

MAP 9C – GEORGIA COASTAL CORRIDOR

- \*Georgia Sea Islands, GA-FL (topographic map)
- \*Georgia Sea Islands, GA-FL (ERTS [satellite])

IMAGE 9C – GEORGIA COASTAL CORRIDOR

- \*Altamaha River Wetlands, GA (orthophotoquad mosaic)
- \*Savannah, GA (NALC [satellite])
- \*Savannah, GA 1734 (historical map)
- \*Savannah, GA 1998 (B&W oblique air photo)

MAP 9D – MISSISSIPPI GULF COAST

- \*Mississippi Sound, MS (topographic map)
- \*Ship Island, MS 1950 (topographic map)
- \*Ship Island, MS 1970 (topographic map)

IMAGE 9D – MISSISSIPPI GULF COAST

- \*Mississippi Sound, MS (CIR [air photo] mosaic)
- \*Ship Island, MS 1952 (B&W air photo mosaic)
- \*Ship Island, MS 1966 (CIR [air photo] mosaic)
- \*Ship Island, MS 1997 (CIR [air photo] mosaic)
- \*Ship Island, MS 1998 (CIR [air photo] mosaic)

MAP 9E – NEW ORLEANS TO THE GULF OF MEXICO

- \*New Orleans, LA (topographic map)
- \*New Orleans, LA (historical map)
- \*Habitat Change, Lower Mississippi Delta (land use / land cover map)

IMAGE 9E – NEW ORLEANS TO THE GULF OF MEXICO

- \*Lower Mississippi River Delta, LA (TM [satellite])
- \*New Orleans, LA (CIR [air photo] mosaic)
- \*Lower Mississippi River Delta, LA (thermal infrared)

MAP 10A – CENTRAL PENINSULA

- \*Central Peninsula, FL (topographic map)
- \*Phosphate Region, FL 1952 (B&W air photo)
- \*3-D Topographic Section Map: Lake Wales Ridge, FL (anaglyph map)
- \*Disney World, FL 1947 (B&W air photo)
- \*Cape Canaveral, FL 1943 (B&W air photo)

IMAGE 10A – CENTRAL PENINSULA

- \*Central Peninsula, FL (TM [satellite])
- \*Phosphate Region, FL (NAPP [air photo])
- \*Lake Wales Ridge, FL (NAPP [air photo] mosaic)
- \*Disney World, FL (NAPP [air photo])
- \*Cape Canaveral, FL (NAPP [air photo])

MAP 10B – SOUTH FLORIDA

- \*South Florida, FL (topographic map)
- \*South Florida, FL (TM [satellite])
- \*Windley Key, FL (topographic map)

IMAGE 10B – SOUTH FLORIDA

- \*Fort Mayaca, FL (NAPP [air photo])
- \*Cocoanut Grove, 1896 (historical map)
- \*Coconut Grove, FL (NAPP [air photo])
- \*Coconut Grove, FL 1896 (land use / land cover map)
- \*Windley Key, FL (NAPP [air photo])
- \*Windley Key, FL 1951 (B&W air photo)