

Exploring the Earth with Remote Sensing: La Serena

Teachers' Guide

Project ASTRO Chile
April 2006

1. Introduction

This is a guide for instructors to accompany the image-based laboratory exercise “Exploring the Earth with Remote Sensing: La Serena”. It includes some suggestions for teaching the laboratory, additional explanatory material, pointers to further information available on the Web, and answers to the questions on the lesson worksheet.

Most of the questions in the laboratory call for description and/or analysis on the student’s part. Students must understand that there is no single “right” answer to many of the questions in the exercise. Answers given here are biased toward what I intend the student to learn, but probably won’t cover the full range of student responses. Interpretation of remote sensing images can be ambiguous; student answers may reflect this, and this is part of the point of this exercise.

The laboratory procedure assumes that the associated images are available to students electronically, so that they can be examined on a computer color display with pan and zoom features. This is necessary at various points to see details. I also assume that black and white printed copies of the images are provided to students, to mark up in Section 1, and to use as reference maps when they are exploring the digital images.

A digital image projector, “smart board”, or transparency projector is very useful to project enlarged images during the initial class introduction to the laboratory. This is also helpful if Section 2 is done as an in-class exercise (which I recommend).

If circumstances force the use of only printed copies, color copies are necessary for all the figures, and Figures 2 and 4 will have to be supplemented with some printouts of zoomed areas. Figure 3 could be omitted, and shared copies of the others (I suggest one set per 3 or 4 students) would help hold down the cost.

2. Orientation and scale

I recommend that this section be done as a group exercise in class, to be sure that all students develop the familiarity with orientation, scale, and use of the grid system necessary to do the subsequent sections.

2.1, 2.2., 2.3. The first three questions are answered by labelling the paper copy of Figure 1. I assume teachers are familiar with the locations of these major geographic features.

2.4 Students mark answers on the laboratory writeup, beginning with this question. This demonstrates the ability to use the locational grid. Student understanding of this is vital for successful completion of the lab.

The next three questions make use of the grid around the image to measure distances. Tip: place a slip of paper on the computer screen and use the grid to draw a distance scale on the paper. The paper can then be moved around on the image.

2.5 $32 \text{ km} \div 19.5 \text{ divisions} = 1.64 \text{ km}$ or 1640 m per division.

2.6 The answer depends on where the student judges the center of each city to be. The expected range of answers is 10 to 12 km.

2.7 The expected range of answers is 10 to 11 km from Port to Faro. To measure the distance along a curved line, transfer the grid to a slip of paper. The text is unclear. The mouth of the Elqui River is not at the Lighthouse. The distance from Port to river mouth is 12.5 km.

2.8 The expected range of answers is 16.500 to 18.500; or 20.800 if the distance from port to river mouth is used.

Teachers can expand on question 2.8 for further practice in estimation. For example, if each family of five tourists stays for a week, how many tourists in total will visit the beach during the summer tourist season? If they spend X \$Ch per family per day, for food and lodging, how much money will this bring to the local economy?

A useful analogy for the discussion of pixels is rounding off numbers with a calculator. The coarse pixel size of this image “rounds off” the information. For 2.9, it’s important to use a high zoom factor and really blow the image up to see the individual pixels.

2.9 30 pixels, +/- 1 or 2 depending on the student’s estimate of where the distance starts and stops. We count pixels in two kilometers and divide by two, to reduce this uncertainty.

2.10 33 meters per pixel. The pixels are 33 x 33 meters. The pixels are very coarse. These dimensions can be compared to your classroom, an entire school building, a basketball court, or some other large defined space that is at hand.

2.11 Good responses are things like: a car, a tree, a large truck, a house. This question is important preparation for image interpretation in the following sections. Students

are probably expecting to see fine detail in the zoomed image, but they can't. It may require some discussion to lead students to the desired result.

3. Relief

A quick, simple classroom demonstration of how shadows show relief is to put a crumpled towel on a desk top, and illuminate it from various directions with a desk lamp.

The purpose of the first question is to get the students to examine the image closely. The widest shadows will correspond to the highest mountains. This can be difficult to judge, so any reasonable answer should be accepted.

3.1 The highest point in the image is Cerro Cotun, above Las Rojas at L-19, 1131 m in altitude. Other high points that might be selected are Cerro Corazon, L-10/11, 724 m; and the ridgeline at F-11, 418 m. (Altitudes from Carta La Serena 2930-7030, Instituto Geografico Militar.)

3.2 A-D, 7-8, la zona color marrón, hay relieve pero no hay sombras.

3.3 From the right or east side.

The next question leads students to think about what the image does *not* show directly, regarding their physical environment.

3.4 Yes. La Serena has a range of elevations. The Plaza de Armas is elevated above the coastal plain. San Joaquin and Antena are higher than the Plaza, and there are hills such as Colina del Pino.

No, this question can't be answered from the Landsat image, because the vertical relief is insufficient to produce shadows. The urban area of La Serena appears flattened. Notice that because the hills of Coquimbo are steeper and more abrupt, one can tell from the image that Coquimbo is hilly.

Now we see how questions like this can sometimes be answered using indirect evidence. For example, the fact that water flows downhill.

3.5 To the west, or left side of the image, towards the ocean.

3.6 The valley must rise towards the east, with the highest part of the image in the southeast corner, M/N-19.

4. False color

The use of false color (sometimes called *representational color*) may be a difficult concept for some students. A computer-oriented demonstration is to change the color map of the display for images of everyday scenes or objects.

An important implicit result of Secs. 4 and 5 is for students to realize the limitations of remote sensing images. The information they give is imperfect, and image interpretation may be ambiguous, uncertain, or just wrong.

4.1 Bright red, in the Landsat image

4.2 Black. The idea that “black” is the absence of reflected light, rather than a “color” itself, can be difficult to grasp. Previous instruction about the nature of light and color is helpful.

4.3 Yes, this area has a similar green color.

4.4 Plants: grass, shrubs, trees, and crops.

4.5 These areas are a reddish brown color in the true color image. They are generally rectangular, large (hundreds of meters), and located in the countryside. They are fields of mostly bare soil; for example, potato fields.

The next question illustrates how false color images can be equivocal or misleading, by overemphasizing some characteristic of the terrain.

4.6 The bright green area in the false color image isn't green in the true color image. It has a color similar to that of the bare fields in Question 4.5. There must be enough vegetation present to strongly reflect near infrared light, and produce green in the false color image, but not enough to reflect a lot of visible light and dominate the true color.

The remaining questions in this section are preparation for examining the image of a remote location in Section 5.

4.7 Focus on Route 5 to answer this question. In Figure 1, dark purple to black. In Figure 2, dark grey to black.

4.8 Asphalt is a poor reflector of infrared light. It absorbs both visible and infrared light.

4.9 Water is a very poor reflector of visible and infrared light.

4.10 The Elqui has water in it, where it runs between Las Companias and La Serena. One can tell this because it is a very dark color.

4.11 The entire shape is about 500 m N-S and 100 m E-W (15 pixels by 3 pixels).

- 4.12 Its outline is very regular and blocky, with straight sides and sharp corners. On close inspection it is actually two rectangular shapes with a dark area in between.
- 4.13 Asphalt—since this would be a strange place to find a lake!
- 4.14 A pair of large buildings surrounded by a parking lot. In fact, this is Centro Lider-Sodimac, a shopping center. It should be emphasized that the white color represents the reflectivity of the roofs of these building, not the color of their walls.
- 4.15 Medium purple.

4.16 Here is the summary table, filled in with desired responses. Student answers will probably vary. This exercise reinforces the interpretive lessons of Section 4, in preparation for Section 5.

Color	Shape	Size, meters	Location	Surface	Target
Very dark purple	thin straight line	1000's	in city	asphalt	Streets, roads
	Smooth curve	1000's	Bordering the city	water	ocean
	Thin wavy line	1000's	Outside the city	water	river
	irregular	100 's - 1000's	in mountains	not a surface	shadows
Bright green	Continuous, no boundaries	1000's	in the valley	vegetation	Pastures, orchards, crops
	irregular	1000's	in mountains	vegetation	Grass and brushwood
White	rectangular	100's	In city	Building roof	Shopping center
Red-brown	rectangular	100's	Outside city	Bare soil	Plowed field
Medium purple	Block shapes	100	In city	mixture	Mixed urban area

5. Exploring a remote location

Some things in this image have La Serena analogs, while others don't—for example, the large number of golf courses and the absence of an ocean.

5.1 Upper right, right side, and middle left side.

5.2 These could be vegetated areas of brush or trees. In fact, this is a pine forest.

5.3 The most obvious river in the image is the Rillito River. It runs from middle right to upper left corner.

5.4 The river was dry, since it is a bright color, not dark like water. Quebrada de Santa Gracia is a similar example in the La Serena image.

5.5 Interstate Highway 10 runs diagonally across the image, from bottom right to top left. I-10 runs from the Atlantic Ocean (Jacksonville, Florida) to the Pacific Ocean (Los Angeles, California) across the southern border of the U. S.

5.6 The area around La Serena is irrigated farmland. The area around Tucson is not irrigated, so it is barren desert. The annual rainfall is the same for both locations, about 0.3 m per year. The Andes supply irrigation water in the Elqui Valley. The mountains near Tucson are not high enough, or extensive enough, to be a source of irrigation water for farming.

It's important to emphasize that the per pixel scale and the overall size of the Tucson image Figure 4 is the same as for La Serena Figure 1.

5.7 Qualitatively, the urban area of Tucson is much larger. To answer the question quantitatively, count the grid squares containing urban areas in Fig. 1 and in Fig. 4. I count about 20 squares for La Serena-Coquimbo, and about 120 for Tucson, so Tucson is about six times larger. Student results may be somewhat larger or smaller.

5.8 If Tucson is about six times larger, it may have six times as many people, or about 600,000. This assumes that the population density is about the same for both areas. Census data indicate that this number is about right for urban Tucson.

While working on 5.7 and 5.8, students may notice that Tucson is a bluish color, while La Serena is a light purple. This suggests that the mixture of surfaces seen looking down from above is different. Since grass and asphalt will contribute the same colors to each image, this suggests that rooftops and streets are made of different materials in the two cities, and perhaps the proportion of vegetation is different.

Questions 5.9 through 5.15 lead the students toward selecting “mystery” features to be investigated further in 5.16 through 5.18.

- 5.9 Other examples are at E-7, H-9, I-8, J-12. There are many others.
- 5.10 Possible responses include parks, athletic fields, cemeteries, lawns around public buildings, and heavily vegetated residential areas. All of these can be found in Fig. 4. The main thing is that students be thinking logically about size, shape, and location.
- 5.11 Examples are at D-4, E-5, I-10, K-6, and K-16. A hint is that bodies of water will be small. They are also located in small green areas. These are decorative ponds in parks, water hazards in golf courses, and in the case of D-4, a sewage treatment lagoon.
- 5.12 These are parking lots for businesses and workplaces. Private cars are the dominant form of transportation in the Tucson.
- 5.13 This is a mall, similar to Centro Lider-Sodimac. The location, size, color, and surrounding rectangular dark area are clues that should lead students to this conclusion.
- 5.14 I won't give away the identity of this feature here. I am looking for logical thinking. Students have learned that dark areas are usually either water or asphalt. The area is in the city and appears to have roads leading to it. Perhaps it is a very large parking area, an airport runway, or a large body of water with some industrial purpose.
- 5.15 These are golf courses. The fairways are irrigated and covered in grass. Since water in the desert is expensive, the roughs aren't irrigated. Students might also conclude that these are agricultural areas, with irregular outlines dictated by topography.
- 5.16, 5.17, 5.18. The final three questions require interaction between classes at the two locations. This part is experimental, and the best way to define, request, collect, and exchange digital camera images will be shaped by experience. The key requirements for the "robot" images are that they be taken close up and from a horizontal perspective at ground level. They don't have to be taken at a particular time, and the direction will depend on circumstances of access.

As with planetary missions, "Mission Control" in the form of the teachers involved may deem that some locations can't be explored for reasons of distance, time involved, or other problems related to access. In particular, the area at K-L, 12-13 is an air force base. Civilian access and photography are not permitted.

Some potential targets have been suggested in the previous questions. Generally, targets in the urban areas will be more feasible for investigation. Targets in the surrounding countryside may or may not be, depending on the time and effort required to get to them. Targets in mountainous areas are out of bounds. These areas are rough and inaccessible.

Teachers may need to lead students to choice of appropriate mystery targets. In addition to the ones suggested by previous questions, here are some other curious or ambivalent features in the Tucson image:

H-14: blocky blue shape in a dark rectangle

I-8: large rectangular white area

D-7: collection of dark shapes adjoining the Rillito River

H-9: small white U shape in green area

Extra credit question: suitable for independent thinking by the brighter students, or for classroom discussion. If we were visitors from outer space, could we tell from these images alone that these areas are home to a technically advanced society? If not, what additional information would we need to have?

This question has two parts to consider. First, what constitutes a technically advanced society? Answers may include the use of machines not powered by animals; the ability to store and transmit power for use at any time, for example burning coal to generate electricity; and the ability to transmit information over long distances. Second, can activities of this kind be detected in images of 30 meters resolution? Power lines and most vehicles can't be seen, but trains or large ships might be detectable as moving features if we had a set of images spaced over time. I expect that students will come up with many other thoughtful, imaginative responses.

The existence of large urban concentrations, including roads and large buildings, is insufficient evidence. At the time of the Spanish conquest, the Aztec capital of Teotihuacan was larger than any city in Europe, and laid out with large buildings, thoroughfares, and a canal system. Objections from human history can be raised to the other responses also. The Dutch used wind powered machines to pump vast quantities of water (admittedly, only when the wind was blowing). Signal towers of various kinds have been used since ancient times to transmit messages quickly. The Chinese built vast fleets of giant rafts and sailed long distances. Many societies have built large structures or laid out giant patterns on the ground for religious purposes. Examples are Inca temples and the Nazca lines in Peru. Our visiting aliens would likely need images of much higher spatial resolution to detect high technology artefacts. And of course detecting our communications and other electromagnetic emissions would be a dead giveaway.