

# **Exploring the Earth with Remote Sensing: Tucson**

## **Teachers' Guide**

Project ASTRO Chile  
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### **1. Introduction**

This is a guide for instructors to accompany the image-based laboratory exercise “Exploring the Earth with Remote Sensing: Tucson”. 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 of Figure 2. Student understanding of this is vital for successful completion of the lab. The large, solid green rectangle at coordinates I-11 near map center is Randolph Golf Course.

The next three questions make use of the 1.6 x 1.6 km (1 x 1 mile) squares imposed on the image by the grid of major streets. Tip: place a slip of paper on the computer screen and use the street grid to draw a distance scale on the paper.

The answers to these questions aren't precise since Tucson isn't rectangular. The results will depend on the student's judgement in defining the boundaries of the urban area. If done in class, let each student or group of students work through the questions, then look at the range of results. This provides a class opportunity to discuss *estimation* and the use of *approximate results* as useful tools in science.

2.5 The expected range of answers is 19 to 22 km east-west, 13 to 19 km north-south.

2.6 Using the expected range from 2.5, the range of answers is 250 to 420 square kilometers.

2.7 Using the range of results from 2.6, the range of answers is 1200 to 2000 people per square kilometer.

2.8 Tucson is 5 to 10 times less densely populated than New York.

For a typical class size of about 25 students, population density can be demonstrated by placing four students in an open square representing Tucson's density, then filling in the square with the remaining students to show how much more densely populated New York is.

A useful analogy for the next part is rounding off numbers with a calculator, The coarse pixel size of this image "rounds off" the information. It's important to use a high zoom factor and really blow the image up to see the individual pixels. A 1.6 x 1.6 kilometer square in the image should just about fill the display screen.

2.9 56 pixels, +/-1 or 2 depending which part of the street grid is used to count.

2.10  $1600 \text{ meters} / 56 \text{ pixels} = 28.6 \text{ meters per pixel}$ . The pixels are 28.6 x 28.6 meters. The pixels are very coarse. These dimensions can be compared to your classroom, a basketball court, or some other large defined space that is at hand.

- 2.11 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. Good responses are things like: a car, a big tree, a small house, a swimming pool. Things of this size are *not* recognizable in the images.

### 3. Relief

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

The first question is a little tricky, since some of the dark areas in the Tucson Mountains are shadows but others are produced by dark mineral soil. The Catalina Mountains in the upper right corner of the image have clearly defined shadows, and I think it's apparent that these mountains are higher.

- 3.1 A-B, 18-19; upper right corner of the image
- 3.2 The shadows are wider here than in the Tucson Mountains, meaning that they are formed by higher peaks or ridges.
- 3.3 From the lower right, or over the viewer's right shoulder. This is a more difficult question, requiring some three dimensional geometric thinking.
- 3.4 The Tucson valley is relatively flat, without steep hills or canyons. This permits a very regular street grid.
- 3.5 From lower right (southeast) to upper left (northwest).
- 3.6 The Tucson valley is tilted from lower right (higher) to upper left (lower) since that is the direction that water flows across it.

### 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 Grass.

4.4 The mountain tops show the same intense green color as the golf course.

4.5 Trees. Not all students will know this. It helps to have been to the top of Mount Lemmon and experienced this much different environment.

4.6 Other examples are at E-7, G-6, I-8, J-12. There are many others.

4.7 There are many possible responses, including parks, athletic fields, cemeteries, lawns around public buildings, and heavily vegetated residential areas. The main thing is that students be thinking logically about size, shape, and location.

4.8 These are irrigated agricultural fields. An important clue is how a number of these vegetated areas, all strongly rectangular and of about the same size, cluster together.

Questions 4.9, 4.10, and 4.11 are follow-ons to the conceptual question 4.2 .

4.9 Deep purple to black.

4.10 Asphalt reflects poorly at infrared wavelengths.

4.11 Water is a poor reflector at all wavelengths, so it appears very dark.

4.12 These are parking lots. The rectangular shape and proximity to streets favors this explanation over bodies of water.

4.13 Light blue or turquoise color. This is an average of rooftops, greenery, bare soil, asphalt, vehicle roofs, etc. —the surfaces that are seen when looking straight down on the city.

4.14 White, or nearly white. Sandy soil reflects light at all wavelengths.

4.15 It would be very dark, like the lake in 4.11 .

Questions 4.16 through 4.19 prepare the students for interpretation of the La Serena image in Section 5. The area under investigation is El Con Mall and its surrounding parking lot.

4.16 The white object is about 17 by 13 pixels, or 490 meters east-west by 370 meters north-south. Size can also be estimated in terms of the fraction of the 1600 meter length defined by the surrounding major street grid.

- 4.17 Its outline is very regular and blocky, with straight sides and sharp corners.
- 4.18 The shape should suggest something artificial, and the color means the surface has to be highly reflective. Responses should account for both of these observations. It might be an excavation, such as a quarry or foundation work for a large building. It might be the roof of a large building, or some other kind of structure. In fact, it's El Con Mall.
- 4.19 Shape, size, and location suggest this is an area covered with asphalt—a parking lot.

Students may be aware that many buildings in Tucson have white roofs, at least to our eyes. That they are also white (highly reflective) in the infrared means they reflect heat effectively—so they are doing their job! An interesting comparison to El Con Mall is Park Mall, at H-13/14. It has a similar size, blocky geometry, and surrounding parking lot. Its roof is a darker color. This means the roof surface is a different material, and it does not reflect heat as well as the roof of El Con Mall. So it costs more to air-condition the inside of Park Mall.

4.20 Here is the summary table, filled in with desired responses, including suggested optional additions by students. Student answers will probably vary. This exercise reinforces the interpretive lessons of Section 4, in preparation for Section 5.

<b>Color</b>	<b>Shape</b>	<b>Size, meters</b>	<b>Location</b>	<b>Surface</b>	<b>Target</b>
Very dark purple	thin straight line	1000's	in city	asphalt	streets
	round or irregular	about 100	edges of city	water	small lakes
	rectangular	50-200	in city next to streets	asphalt	parking lots
	irregular	100 's - 1000's	in mountains	not a surface	shadows
	Thin wavy line	1000's	NW corner of image	water	river
	irregular	1000's	Tucson Mtns.	soil	Rocky ground
Bright green	rectangular	1000	in city	grass	Golf course
	irregular	100's	in city	Grass, trees	Vegetated neighborhood
	irregular	1000	edges of city	grass	Golf course
	rectangular	100's	In city	grass	Small parks
Whitish	long, thin, wavy	Many 1000's	Edge of urban area	Bare sandy soil	Dry river bed
	rectangular	100's	In city	rooftop	mall
	Long, straight	1000	In city	Concrete pavement	Airport runway
Light blue	can't tell	fills many pixels	In city	mixture	Mixed urban area
	Blocky, rectangular	1000	Outside city to west	mixture	Housing development

## 5. Exploring a remote location

Some things in this image have Tucson analogs, while others—such as the Pacific Ocean—don't. It's important to emphasize that the scale, 28.6 meters per pixel, and the overall size of the La Serena image is the same as for Tucson Figure 2. If students have made a ruler on a slip of paper as suggested for Question 2.4, they can use it also on the La Serena image.

5.1 Mountains cover most of the right half of the image.

5.2 G-6 to M-19, and A-17 to G-11. These are the Rio Elqui and Quebrada Santa Gracia. The Elqui flows generally west, into the ocean. Quebrada Santa Gracia flows southwest, into the Elqui. "Quebrada" is a Chilean geographic term denoting a ravine or steep valley, usually containing an intermittently flowing stream.

5.3 The Elqui contained water, at least in its western part, because it appears as a thin dark line. Quebrada Santa Gracia was dry, since it appears as a network of thin whitish lines.

5.4 The logic I am looking for is that dark areas are either asphalt or water, and this area is far too large to be a parking lot—so it is probably a very large body of water. This is the Pacific Ocean.

5.5 The dominant color is green, which suggests lots of vegetation of some kind.

5.6 Students have to take my word for it that this area is a desert. The annual rainfall is the same as for Tucson, about 0.3 meters. The presence of vegetation suggests that water is being supplied artificially, i.e. these areas are irrigated. One might expect to find farms, producing food, surrounding a city.

5.7 The urban areas lie in an arc near the ocean, roughly E-L, 1-8. Their total area is much smaller than the urban area of Tucson. The central part of La Serena is at G-H, 6-7. Coquimbo is on the peninsula at J-L, 1-2. Other areas are suburban housing developments.

5.8 Qualitatively, we expect the population in La Serena to be much less since it's a lot smaller in area. This question can be answered quantitatively by using the grids to count squares containing the urban areas in each image. I get about 20 squares for La Serena-Coquimbo, and about 120 for Tucson. This suggests that La Serena has 1/6 the population of Tucson. This assumes that the population density is about the same. Chilean census data give a population of about 100,000 people for this region.

5.9 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. Going a step further, 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.

5.10 The Panamerican Highway, which runs north to south the length of Chile and links all the major cities, runs along the coast from A-6 to N-1.

Questions 5.11 through 5.15 lead the students toward selecting “mystery” features to be investigated further in 5.16 through 5.18.

5.11 Being outside the city in farming areas, large, rectangular, but not green, suggests these are agricultural fields of bare soil. From local knowledge, I suspect these are potato fields.

5.12 This is similar to El Con Mall in the Tucson image: blocky geometry, large size, in an urban area. It is a shopping mall.

5.13 This target is deliberately chosen to be ambiguous, and I don’t want to give away the answer here. By analogy with the Tucson image, the white color could be bare sandy soil, perhaps an excavation, or a building roof (although it is not sharp-edged). The dark area might represent water, pavement, or perhaps a shadow.

5.14 There is a roughly similar feature in the Tucson image at I-J, 9-10; although this is wider and straighter than the La Serena feature. Some kind of water feature or asphalt construction is possible—such as a ditch, or airplane runway. The direction that shadows fall in the mountains around La Serena, together with close inspection of this feature and the surrounding topography, suggest it might be a shadow.

5.15 This requires careful, close inspection of the image. The golf course is at B-5. It is a snakey green feature, similar to the golf courses outside the city in the Tucson image. It is hard to pick out of the general green background of the image.

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.

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 La Serena image:

E-9: large scale linear features on the edge of an urban area

G-8: small round blobs near the Elqui River

M-2: peculiar large semicircular shape, dark red color

H-10: arrangement of thin dark linear features

I/J-8: small irregular blue patch

B-G, 5: bright blue irregularity along the border between land and ocean

G/H-8: small dark rectangular feature bordered by a white 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. 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.