Data Use in an Undergraduate Remote Sensing Course: An Integrated Exploration of Geology, Hydrology and Vegetation in the Mono Lake Region of California

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Introduction

Data collected by satellite- and aircraft-mounted remote sensing instruments can be analyzed to gain useful insight into a wide variety of processes on Earth. In the course *Remote Sensing of the Earth's Environment* taught at Pomona College, which currently requires as a prerequisite only that those enrolling have taken any two science courses of their choosing, the material covered is pertinent to students studying a wide variety of disciplines, including geology, biology, chemistry, physics, environmental science/management and many of the social sciences. Students spend roughly ten weeks learning about the strengths and limitations of various common remote sensing datasets (e.g., multispectral, thermal, radar, etc.) via lectures and hands-on data analysis labs. Following this basic introduction, students spend five weeks analyzing the complex geology, hydrology and vegetation of the Mono Lake region of California in order to explore an overarching, open-ended question:

WHAT CONTROLS THE CHARACTER OF THE OBSERVED VEGETATION CYCLE(S) ACROSS THIS GEOGRAPHICALLY DIVERSE AREA?

Organization of the Mono Basin Project

During the project students are asked to characterize as fully as possible the behavior of the vegetation within an area of approximately 850 km^2, which includes Mono Lake and the area which surrounds it. Starting with a set of unifying questions, image processing software and several types of digital remote sensing data, the students and I work together in small groups and as a class to formulate, discuss and test reasonable hypotheses in order to address the central research question. Throughout the project the student groups have the freedom and responsibility to choose how best to process and integrate the available image data. In order to accomplish this effectively, the project is broken into three distinct parts.

PHASE 1 (~2 weeks)
Students work with a self-selected partner to make a start analyzing the geology, biology or hydrology of the study area. Project assignment is random (drawn out of a hat). In each instance, students will need to obtain additional information from outside sources.

- **GEOLOGY PROJECT: Characterize the geological setting of the Mono Basin within the study area. This can address rock/sediment types, may compare with existing geological maps, or address faults, lake history, topography, etc. Students need to develop ways to classify different rock types with confidence, which may mean explaining spectra, using spectral libraries, explaining features characteristic of different rock types, etc. This project is not as dependent upon the "temporal" nature of the data which will be provided, and thus I expect that the spatial analysis will be detailed, insightful and thorough.**
- **BIOLOGY PROJECT: Characterize the vegetation cycle and spatial distribution of vegetation in the Mono Basin area. This involves identifying vegetation, but students are able to take into account the variance as a function of time (seasonally, plus year to year) and must decide how to analyze and effectively present this information. They often find it useful to consider as well an elevation component, but need not worry about correlating with rock type or the hydrological cycle (they do this in Phase 2). Students must decide how to define the vegetation (green? what about other types?), characteristic spectral features using what they have learned and available spectral databases, how to handle displaying and analyzing the data, etc. While their spatial analysis needs to be thorough, the temporal component of this problem is particularly important as well.**
- **HYDROLOGY PROJECT: Characterize the hydrological cycle of the Mono Basin within the study area. This might involve such things as identifying areas which are snow covered at different seasons and for different years, evaluating rainfall (soil moisture?) as a function of time, thinking about changes in lake level as a function of time, evaluating volume differences in the lake, and comparing these data with rainfall information from the Mono Basin web site to figure out how much rainfall goes into the lake and how much ends up in groundwater or evaporating. When is the water available, where is it distributed, how crucial is soil moisture, etc.? This project is in some ways the most challenging, because it requires extensive use of remote sensing and non-remote sensing data, and involves both spatial and temporal components. Students must think about the broader question in Part 2, and focus their attention upon acquiring the information about the hydrological cycle which they feel is most pertinent -- remembering of course that use of remote sensing data must play a dominant role in whatever analysis they choose to perform!**

The initial phase of the project culminates when each student team submits a set of six powerpoint slides summarizing its key results from the Phase 1 analysis.

PHASE 2 (~3 weeks)
Existing student pairs are combined to form larger teams, each consisting of one pair of "geologists," a pair of "hydrologists" and a pair of "biologists" (I define the teams to help keep them as evenly balanced as possible). These larger teams, building upon the work performed in Phase 1, must integrate and expand upon their existing results in order to characterize the behavior of the vegetation in the study area. Given the limited time this treatment can't be comprehensive, but the elements upon which they choose to focus must be tackled thoroughly. For example, are there particular rock/soil types the vegetation likes to chew on, perhaps at different times of the year? What is the link to the hydrologic cycle seasonally and year to year, is there any elevation dependence, etc.?

PROJECT CONCLUSION
Each team submits a set of 24 polished, thoroughly annotated powerpoint slides targeted to be suitable for use as a stand-alone product in a high school science course; the slides and their annotation are placed on the course web site. In addition, each team gives a 20-minute oral presentation using the slides and materials they have prepared.

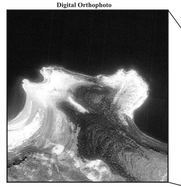
Tools and Data

For the most recent iteration of the course students worked with the ENVI 3.5 remote sensing software package written by Research Systems Inc. I have also used ER Mapper. The key is to employ a user-friendly package capable of allowing the students to explore a diverse array of different data types, spectral libraries, etc., so that time and the students' skills become the limiting factors, not the abilities of the software.

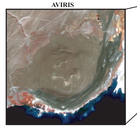
I provide students with access to many different satellite and aircraft remote sensing datasets, enabling them to explore questions using data collected at different wavelengths and variable physical and temporal scales. These include data from: Landsat 5 TM; AVIRIS; DEM; DOQ; SPOT; TIMS; AirSAR; and, most recently, bathymetry. Some data were obtained upon request from scientists at JPL, while the rest were acquired a bit at a time over a period of years. My intent, before the class is next taught, is to add Landsat 7 data, SRTM topography, ASTER imagery, and various GIS vector datasets, and ultimately my goal is to expand the scope by adding a field component to the project.

MONO BASIN STUDY AREA

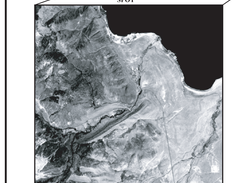
Digital Orthophoto

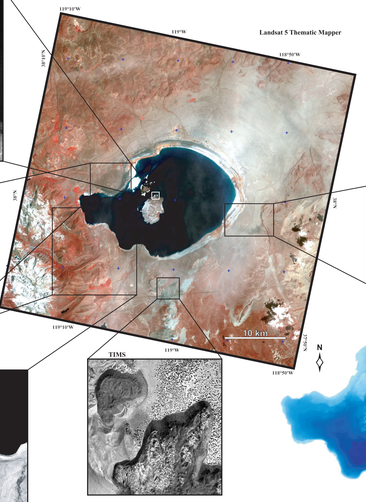


AVIRIS



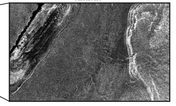
SPOT





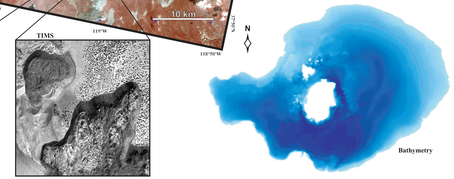
Mono Basin Location

AIRSAR



TIMS

Bathymetry



3D Perspective Overlay, ~5x V.E.

Examples of Student Products

Sample of an Annotated Slide

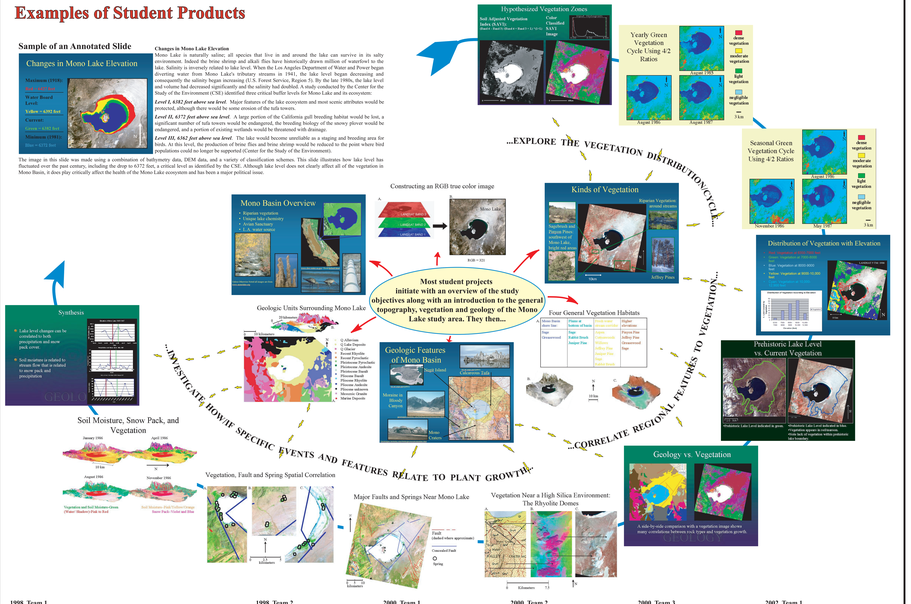
Changes in Mono Lake Elevation
Mono Lake is naturally saline; all species that live in and around the lake can survive in its salty environment. Indeed the brine shrimp and alkali flies have historically drawn million of waterfowl to the lake. Salinity is inversely related to lake level. When the Los Angeles Department of Water and Power began diverting water from Mono Lake's tributary streams in 1941, the lake level began decreasing and consequently the salinity began increasing (U.S. Forest Service, Region 5). By the late 1980s, the lake level and volume had decreased significantly and the salinity had doubled. A study conducted by the Center for the Study of the Environment (CSE) identified three critical buffer levels for Mono Lake and its ecosystem:

Level I, 6392 feet above sea level: Major features of the lake ecosystem and most scenic attributes would be protected, although there would be some erosion of the tufa towers.

Level II, 6372 feet above sea level: A large portion of the California gull breeding habitat would be lost, a significant number of tufa towers would be endangered, the breeding biology of the snowy plover would be endangered, and a portion of existing wetlands would be threatened with drainage.

Level III, 6362 feet above sea level: The lake would become unsifiable as a staging and breeding area for birds. At this level, the production of brine flies and brine shrimp would be reduced to the point where bird populations could no longer be supported (Center for the Study of the Environment).

The image in this slide was made using a combination of bathymetry data, DEM data, and a variety of classification schemes. This slide illustrates how lake level has fluctuated over the past century, including the drop to 6372 feet, a critical level as identified by the CSE. Although lake level does not clearly affect all of the vegetation in Mono Basin, it does play critically affect the health of the Mono Lake ecosystem and has been a major political issue.



1998, Team 1

Conclusions

- The vegetation is concentrated on volcanic rock, particularly on the Quaternary pyroclasts.
- Vegetation is shown only on the east side of the fault located to the south of the lake. Vegetation is also bounded on the west side of the lake by another fault.
- Vegetation changes seasonally; it is concentrated to the south in November, and along the lake and to the west in August.
- There is little annual change in vegetation from 1985 to 1987. A longer span of time is necessary to see broad scale changes.
- Vegetation follows streams to a minimal extent.
- Vegetation is more highly concentrated along the streams in November than in the spring and summer months.
- The Mono Lake ecosystem can only be maintained through education and successful water management programs.

1998, Team 2

Conclusions

- Vegetation decreases with elevation and along meander drainages.
- Vegetation avoided directly with rock and quartzose clast dry conveyances.
- Vegetation was found predominantly growing on volcanic rocks.
- Decreasing water levels can vary from year to year, causing some fluctuations in growth patterns.
- Carbonate(alk), vegetation also varies from aspects to sources, with the greatest concentrations in the east slope.
- Vegetation varies seasonally, with greatest concentrations in the south in November and along the lake and to the west in August.

2000, Team 1

Conclusions

Vegetation in Mono Basin is controlled by

- **Closed basin topography / orographic effect**
- **Location and amount of precipitation**
- **Location of lake deposits and volcanic soils**
- **Drops in lake level**

2000, Team 2

Conclusions

- Aspect as a local orographic effect.
- In general, higher elevations receive more vegetation cover.
- Elevation controls vegetation patterns such as that and decreasing density of vegetation with elevation.
- Lake conservation levels have had a negative impact on vegetation.

2000, Team 3

Conclusions:

- Clear correlation between brightness of vegetation reflectance and the hydrologic cycle.
- Direct relationship between elevation and vegetation.
- Circular relationship between lithology and vegetation.
- Ground truth points and field research.

2002, Team 1

Conclusions

- Vegetation is concentrated on the eastern regions of the Mono Basin.
- Vegetation is concentrated on the volcanic rocks and on the Quaternary and Tertiary sediments.
- Vegetation is concentrated on the lake and streams.
- Vegetation varies seasonally, with greatest concentrations in the south in November and along the lake and to the west in August.
- Vegetation varies with elevation, with greatest concentrations between 6400 and 6450 feet.
- Vegetation varies with aspect, with greatest concentrations on the east slope.
- Vegetation varies with carbonate(alk), with greatest concentrations on the east slope.

<<< For further details about the Mono Basin project and to see more student results, see http://www.geology.pomona.edu/Classes/Geo110/Geo110.html >>>