

Learning about your community and the world with GIS

Joseph J. Kerski

Geographer and Education Manager

1 GEOGRAPHY AND GIS: A SPATIAL RELATIONSHIP

For over 2500 years, people have been fascinated by geography, the study of our planet, its places, its processes, and its people. I would argue that geography can be thought of as a three-legged stool. The first leg is a rich body of content, including an understanding of river systems, biomes, climate, ocean currents, regional characteristics, natural hazards, energy, migration, and demographics, just to name a few. The second leg is composed of the skills that are inherent to geography, such as working with maps, satellite images, Geographic Information Systems (GIS), Global Positioning Systems (GPS), databases, scales, processes, spatial and temporal relationships, representing data, and other key skills necessary for the 21st Century. The third leg is the geographic, or spatial, perspective. The geographically-informed person sees the world from the viewpoint that phenomena interact and change over space, at local, regional, and global scales, and the resulting spatial relationships are important in nearly every aspect of our physical and cultural environment.

Fig. 1: What impact does deteriorating air quality from expanding urban areas in southern California have on Joshua Trees in the Mojave Desert? (Photo credit: Joseph Kerski)



Today, geography is more relevant than ever, as issues such as climate change, biodiversity loss, sustainable agriculture, water quality and quantity, political instability,

food, transportation, energy, and natural hazards grow in importance at the global scale but also increasingly affect our everyday lives. To effectively grapple with these complex issues, decision-makers need to see and understand geographic patterns and trends at anything from a global scale down to the level of a local community. To investigate such trends, geographers, and increasingly those outside of geography, rely on GIS (Gewin 2004). Unlike traditional maps, GIS goes beyond static, two-dimensional objects: instead, individual maps can be manipulated and combined with other maps, charts, databases, and multimedia, some in 3-D space.

The “G” in GIS represents geography – the map. The map could be a 2-D or 3-D topographic map, a map of soil pH, ecosystems, or watersheds, or a satellite image. The “I” represents the information behind the map, stored in a database. For rivers, the information could indicate perennial or intermittent, streamflow rate, or how conductivity or salinity varies with time or along its course. The “S” – the system – connects the map and the database. By selecting components on the map, the GIS analyst simultaneously selects the associated attributes in the database (and vice versa), allowing them to be changed, visualized, or classified. With the help of hundreds of tools in a GIS, spatial data can be manipulated and combined in many different ways. For example, the proximity tool could find all of the earthquakes that have occurred within 100 km of Charleroi, and the overlay tool could narrow down these earthquakes to those that have occurred under alluvium as the surficial deposit and that are on land containing high density residential development.

2 USING GIS IN EDUCATION

In primary, secondary, university, and informal education, GIS can be used to help students think critically, use real data, and solve problems. It appeals to today’s visual and technology-based learners. GIS is as fundamental a tool for teaching and learning geography as the periodic table of the elements is to a chemistry instructor or a microscope to a biology instructor. However, GIS can be used beyond geography to biology, chemistry, earth science, environmental science, history, mathematics, and in other subjects. GIS

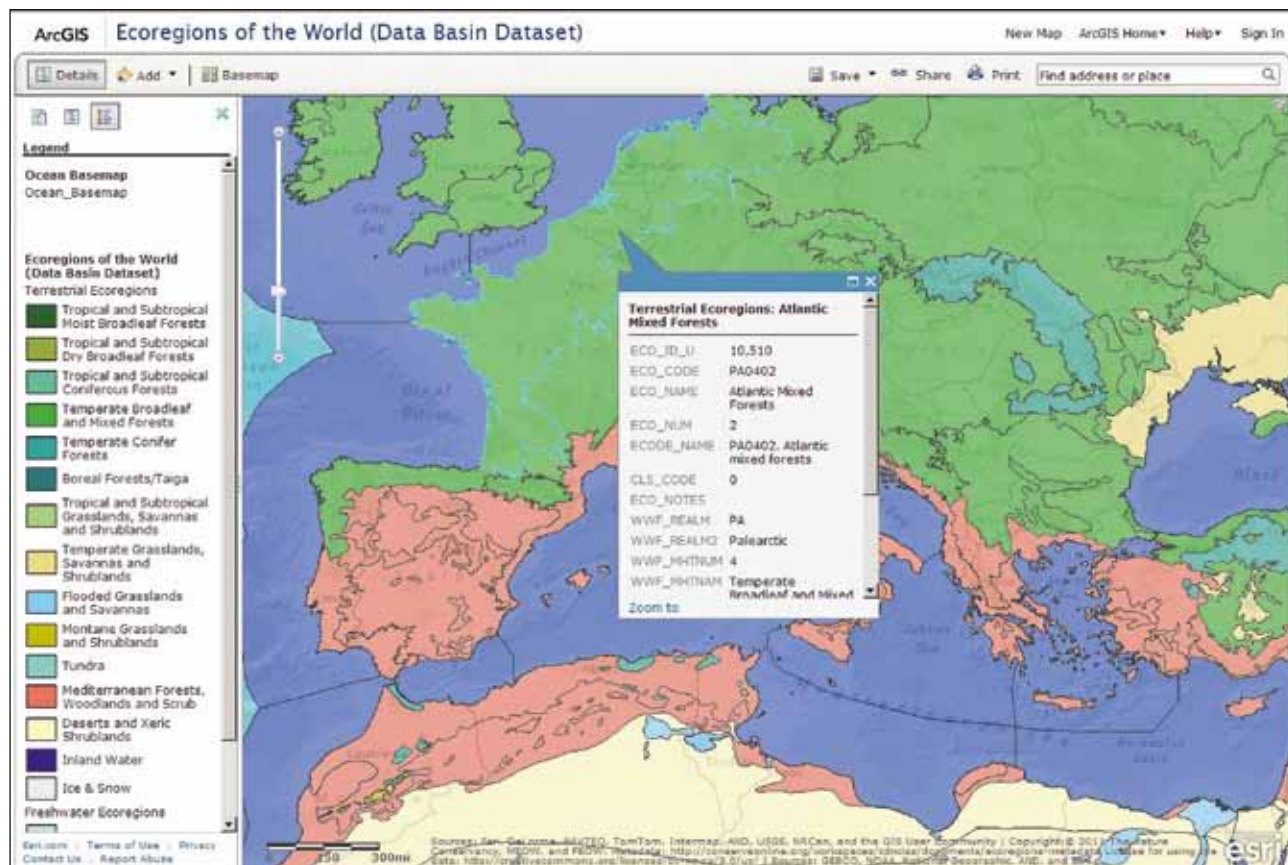
can be effectively used in combination with outdoor education (Louv 2005) and provides excellent career pathways for students. A wide variety of topics can be explored, such as the relationships between people, climate, land use, vegetation, river systems, aquifers, landforms, soils, and natural hazards. GIS inquiry begins with asking a geographic question. For example, how will climate change affect global food production? What is the relationship between birth rate and life expectancy? How does acid mine drainage in a mountain range affect water quality downstream? How does the changing demography associated with smaller household size affect urban sprawl? What is the best location for new wind energy farms? How will a proposed retail center affect community traffic patterns and land use?

In the classroom, GIS can be used in numerous ways (Kerski 2008). Using GIS tools such as ArcGIS (<http://www.esri.com/arcgis>) or ArcGIS Online (<http://www.arcgis.com>) and searching on “hurricane,” students can analyse the route, severity, and frequency of hurricanes and cyclones in the western Atlantic Ocean for the past 150 years. Are hurricanes becoming more or less frequent than they were during the 19th or 20th Centuries? Students can gather data on tree location, height, and species on their school campus using GPS receivers or even smartphones, build a spreadsheet, and then map those trees on top of a satellite image base map to analyze the pattern. Students can analyze the effects of the October 2010 toxic flood in Hungary on downstream communities and rivers ([nity.esri.com/arclessons/lesson.cfm?id=556\). Students can access the “This Dynamic Planet” map \(<http://mineralsciences.si.edu/tdpmap/>\) to study the relationship of earthquakes and volcanoes to plate boundaries and the rate of plate movement. Students can use Worldmapper \(<http://www.worldmapper.org>\) to analyse over 700 variables such as high-tech exports, forest loss, and mineral extraction as cartograms and spreadsheets. Through the use of ArcGIS, students can analyse the flood potential for rivers in their community and current wildfires around the world using real data and base maps in two or three dimensions. They can determine the mean center of population for an area, analyze how forests have changed in Brazil by analyzing satellite images from the 1970s to today, or determine how many cities in Belgium are within 25 km of the coast. Many other examples of using GIS in education exist, but let us select two and explore them in greater detail.](http://edcommu-</p>
</div>
<div data-bbox=)

Analyzing World Ecoregions With GIS

World ecoregions can be easily studied with the use of GIS. Start a web browser and access ArcGIS Online (<http://www.arcgis.com>). In the search box, enter “Ecoregions of the world” and pull up its legend. This map contains the three ecoregional boundary datasets used by The Nature Conservancy, including terrestrial ecoregions, marine ecoregions, and freshwater ecoregions covering the globe. How many ecoregions are on the map? Enable popups for these ecoregions and explore individual ecoregions around the

Fig. 2: Investigating world ecoregions, sea surface temperature, topography, and the ocean base map using ArcGIS Online.



world, clicking on them to obtain information about each of them. Move your mouse until it rests on the Equator, and describe how ecoregions and their vegetation change as you move across South America, Africa, and southeast Asia from west to east along the Equator. How do ecoregions and vegetation change as you move along the Prime Meridian from England south to Ghana?

What ecoregion is Belgium located in? Is there another part of the world that has a similar ecoregion to Belgium? If so, what is it? Which countries are comprised of a single ecoregion? Which countries are comprised of over 10 ecoregions? What three ecoregions predominate in Europe? What three ecoregions predominate in Africa in terms of land area? Select three ecoregions. Find some ground photographs that characterize these ecoregions and include your map and these photographs in an oral and written presentation on each of them.

Many factors help explain the size, shape, and distribution of ecoregions. Let us begin with two variables—the topographic base map and the ecoregions. Do this by toggling on and off ecoregions layer or by making the ecoregions layer semi-transparent. Investigate the Alps, the Andes, and the Himalaya. What effect do mountains have on ecoregions? Why? Does the effect of mountain ranges depend on how high the mountains are and where they are located around the planet?

Next, let us add population to our investigation. Use the Add function to search for “world population.” Add the Esri World Population layer. Either by toggling or making layers translucent, compare population to ecoregions. Name three ecoregions with a high population density. How can these ecoregions support a high population density? Name three ecoregions with a very low population density and explain why these ecoregions cannot support a higher population density. Based on what you know about population and ecoregions, and your GIS-based investigation, name three ecoregions that you believe are most under environmental pressure.

One additional factor influencing ecoregions is ocean currents and sea surface temperature. Using the Add function again, add the map “mean surface temperature 2003-2007”. Describe the pattern of sea surface temperature in the Atlantic Ocean. How does it affect the ecoregions in Europe, and why? Add the Ocean base map. What value does having a high resolution map of the ocean floor bring to your analysis?

3 ANALYZING RECENT EARTHQUAKES WITH GIS

Let us turn to another example and illustrate how spatial analysis through GIS can enhance teaching and learning. Let us say that you have read an article stating that the Haiti earthquake and its aftershocks in January 2010 were

unusual because they were large in magnitude and because earthquakes are rare in Haiti. You want to see if this is true. This can be done with desktop GIS software and data downloaded from the Internet.

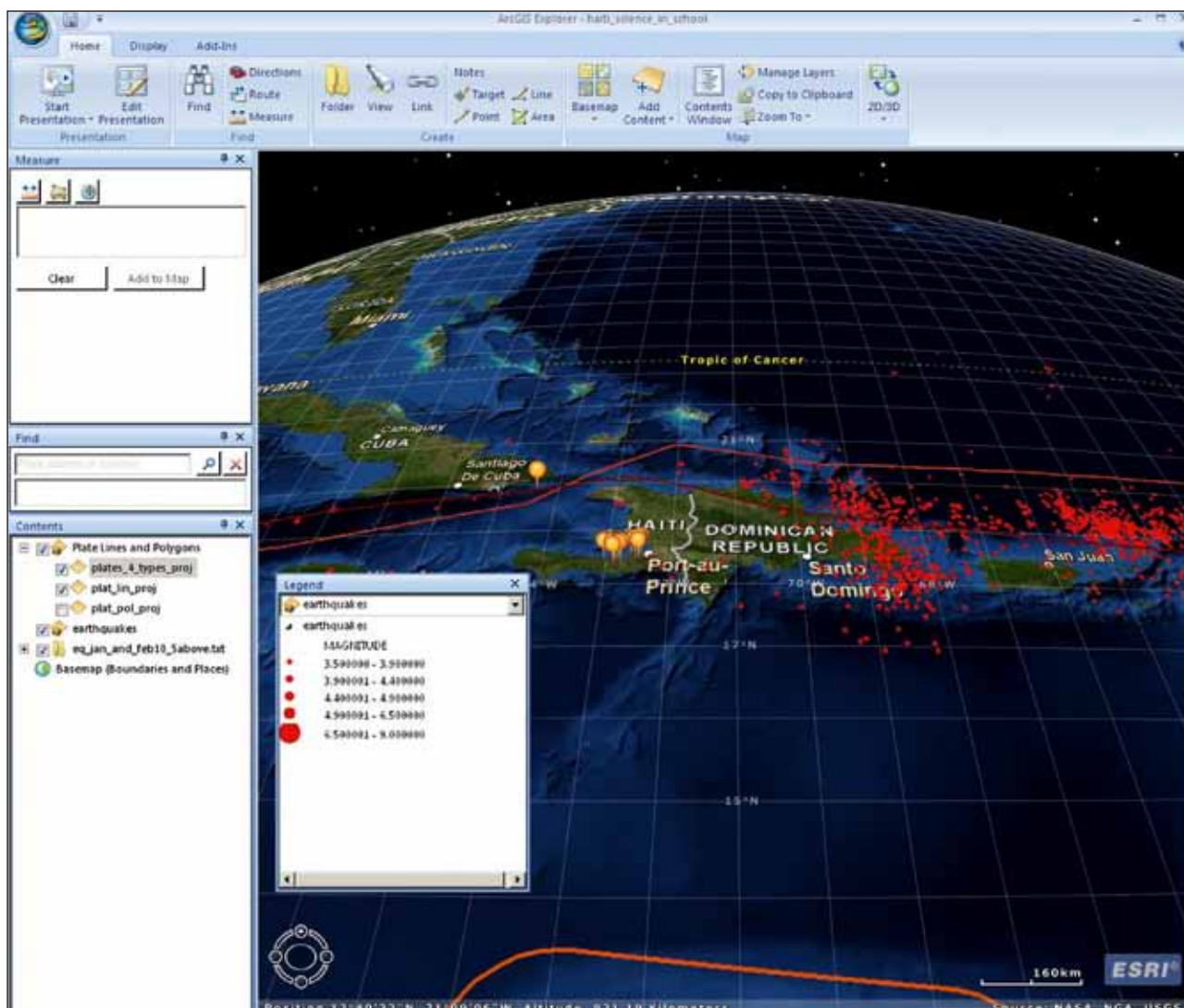
Because earthquakes are inherently three-dimensional phenomena, download 3D GIS software called ArcGIS Explorer, freely available from Esri. Once installed, access the software. You will see that it is a 3-D virtual globe into which you can add your own data. Access a web browser. From the seismic catalog from the US Geological Survey (<http://earthquake.usgs.gov>), download a comma-separated text file of earthquake data covering January and February 2010. Do this by selecting Earthquakes on the left panel, and then “Search for an earthquake.” Run a global search and select spreadsheet format, comma delimited, with magnitudes 6 and above, from 01 January to 28 February 2010. Save your resulting file in CSV (comma separated value) format which will include the dates, locations, magnitudes, and depths of earthquake epicenters around the world. In a text editor, strip off lines above and below the data except the header line. In the header line, remove the parenthesis and re-save the file. In ArcGIS Explorer, use the Tools menu to add your earthquake data as X-Y coordinates in their correct locations.

What do you notice about the spatial pattern of global earthquake locations? Why are earthquakes not distributed evenly around the world? From ArcGIS Online, add the plate boundaries layer and the Earthquakes January 2004 to April 2007 layer, so that you can investigate the relationship between plate boundaries and over 60,000 historical earthquake locations, magnitudes, and depths. Why are some plate boundaries frequented by earthquakes while others are relatively quiet? Along what type of plate boundaries are the deepest and the shallowest earthquakes? Why?

You will see that mid-ocean ridges have a moderate number of earthquakes that are less than 10 km deep, while subduction zones (where one plate sinks beneath the other) are associated with more frequent earthquakes that are at the same time deeper and more intense. Zoom to Haiti and you will see that the newspaper article was correct: Most earthquakes in the region over the three year period occurred in a wide, scattered pattern off the northeast coast of Hispaniola (shown by the red dots) but the January and February 2010 earthquakes were focused in a narrow cluster on the western side of the island, in Haiti (shown by the yellow pushpins). Which earthquakes would you consider aftershocks, and why?

How and why do plate boundaries differ, and how do their movements result in different kinds and numbers of earthquakes? How do plate movements impact populations living in close proximity, but also those far away, such as a result of tsunamis? Use the measure tool to answer the following question: What is the average distance that most earthquakes occur from the subduction zone along the western edge of South America? What does this distance, and

Fig. 3: Investigating earthquakes from January and February 2010, historical earthquakes, and plate boundaries in ArcGIS Explorer.



earthquake depth, tell you about the type of plate boundary that exists there? Do you think that the fact that there had been no small historical earthquakes in Haiti contribute to tectonic pressure that resulted in the 7.0 earthquake of January 2010? How common are aftershocks? The earthquake a month later in Chile was much larger than the Haiti earthquake, but the death toll was much less. What affect do building codes have on earthquake damage in a region? What affect does population density have on earthquake damage, injuries, and fatalities?

4 SUMMARY AND NEXT STEPS

Each of the two detailed examples uses all three legs of the geography education stool. In each, content knowledge was critical—students need to at least understand the fundamentals of what an ecoregion is, or what a plate boundary is, before embarking and while embarking on these activities. GIS does not replace learning content, but allows students to be scientists and geographers as they investigate the phenomena under study. Skills are important, including changing the symbology, scale, and data layers on

the maps, whether they are in a desktop GIS or an online GIS environment. Students are solving problems using the same tools used in the workplace. They are applying geography in a data rich and technology rich environment. They build more than GIS skills and problem solving strategies such as critical thinking skills. These are the skills embedded in knowing when and how to use data, and evaluating data to determine its suitability for each project and to answer each question. The effective use of GIS depends on and builds personal, academic, workplace, industry, management, and occupational competencies (DiBiase et al. 2010). The geographic perspective is also important, for this perspective is what drives the investigation forward, seeking to make connections between variables across space and time. But this is not the complete picture: The educator has a critical role here. The educator models what geographic inquiry is, from asking geographic questions to gathering and analyzing data, to reaching conclusions, and bringing in additional variables, scales, and considerations.

GIS is comprised of maps and data that work as a system. The most critical part of that system is people. Networking with other educators who use GIS is critical to its succes-

sful use in educators. Connect with other educators using GIS around the world, and find lessons, data sets, online mapping tools, software, events, and more, via the ESRI Education Community: <http://edcommunity.esri.com> and through the Digital Earth EU Project (<http://www.digital-earth.eu/>). Educators can share and use lesson plans for using GIS via the ArcLessons library, on <http://edcommunity.esri.com/arclessons/arclessons.cfm>.

Four books contain lessons, data, software, and assessments for students of all levels. The lessons include topics in biodiversity, natural hazards, climate, and others. To learn more about these books, see: www.esri.com/ourworldgiseducation.

References

DiBiase, D., T. Corbin, T. Fox, J. Francica, K. Green, J. Jackson, G. Jeffress, B. Jones, Br. Jones, J. Mennis, K. Schuckman, C. Smith, and J. Van Sickle. 2010. The New Geospatial Technology Competency Model: Bringing Workforce Needs into Focus. *URISA Journal* 22(2): 55-72.

Gewin, V. 2004. Mapping opportunities. *Nature* 427: 376-377.

Kerski, J. 2008. The role of GIS in digital earth education. *International Journal of the Digital Earth* 1(4): 326-346.

Louv, R. 2005. *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*. Algonquin Books.

National Academy of Sciences. 2006. *Learning to Think Spatially—GIS as a Support System in the K-12 Curriculum*. Washington DC, USA: The National Academies Press.

Sui, D. 1995. A pedagogic framework to link GIS to the intellectual core of geography. *Journal of Geography* 94: 578-591.

Joseph Kerski serves as Education Manager at Environmental Systems Research Institute (Esri), where he develops GIS-based curriculum, conducts professional development for educators, develops and nurtures educational partnerships for the advancement of spatial analysis in education, and conducts research in the implementation and effectiveness of GIS in education. Joseph also teaches GIS at the University of Denver, in Colorado USA. Prior to joining Esri, Joseph served as geographer at the US Geological Survey and the US Census Bureau, and taught GIS and geography at several secondary schools and in other universities. Esri is a company dedicated to the development of GIS software that millions of people around the world use daily to make better decisions in government agencies, nonprofit organizations, private industry, and in academia. The Esri Education Team supports GIS at all levels of education, in instruction, educational policy-making, and educational administration.

