01

GIS Provides a Common Visual Language

Transforming our understanding of the world

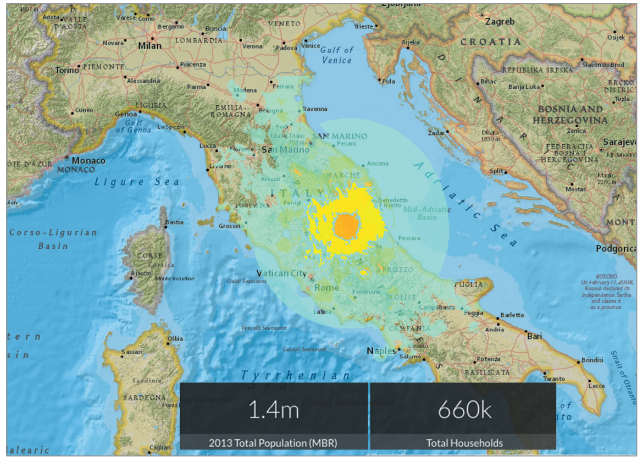
Maps and data underpin GIS, a technology that organizes information into all types of layers that can be visualized, analyzed, and combined to help us understand almost everything about our world. Web GIS connects and organizes many individual GIS systems into a collective GIS for the planet—available for use by anyone with an Internet connection. It's time to join and participate.

It's a Web GIS world

Mapping and analytics connect everyone

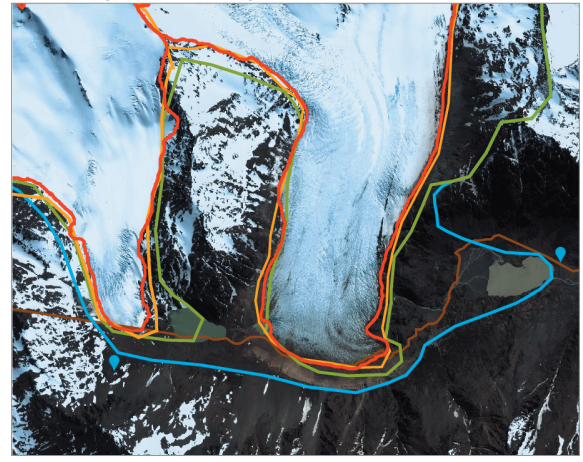
GIS has the extraordinary potential to touch every web-connected being through a common visual language that unites people across organizations and throughout the world. Today, hundreds of thousands of organizations in virtually every field of human endeavor are using GIS to make maps that communicate, perform analysis, share information, and solve complex problems. This is literally changing the way the world works. The power of this shift in the ways that people think about maps and geographic data is evident in this small gallery, which highlights some compelling examples.

GIS maps are uniquely of the moment



Published moments ofter the event, this shakemap portrayed the extent of area and people affected by the devastating 2016 earthquake in central Italy.

GIS maps reveal rapid global change

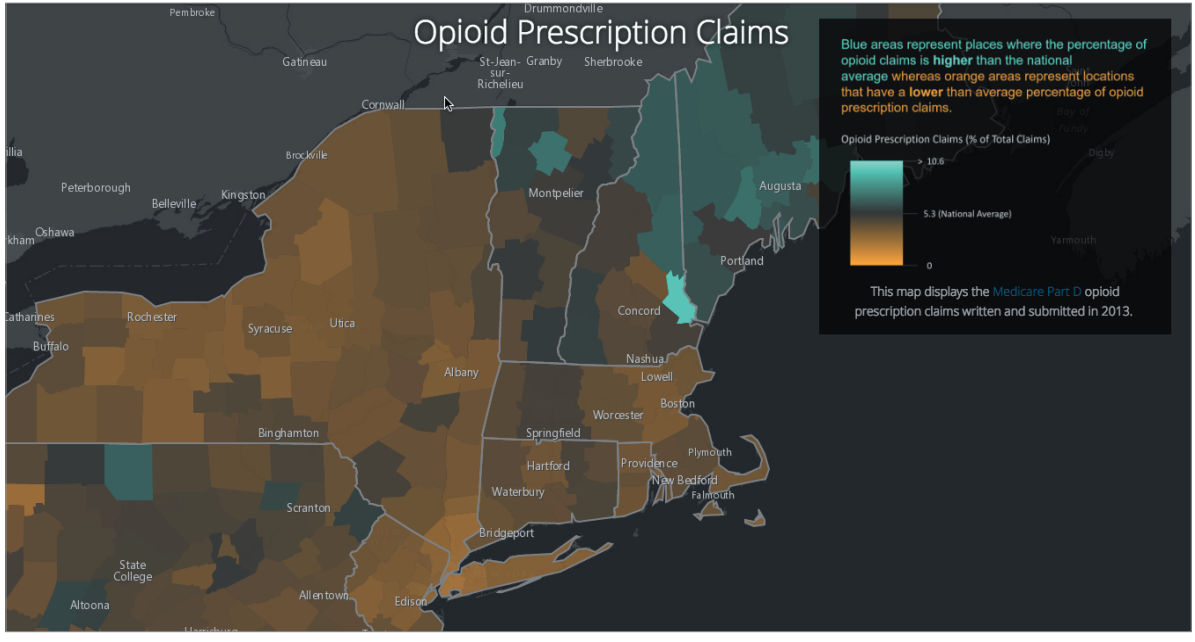


If a picture tells a thousand words, a map tells a thousand pictures. This map starkly reveals the disheartening extent of glacier retreat in the Southern Hemisphere.

GIS maps illuminate natural phenomena

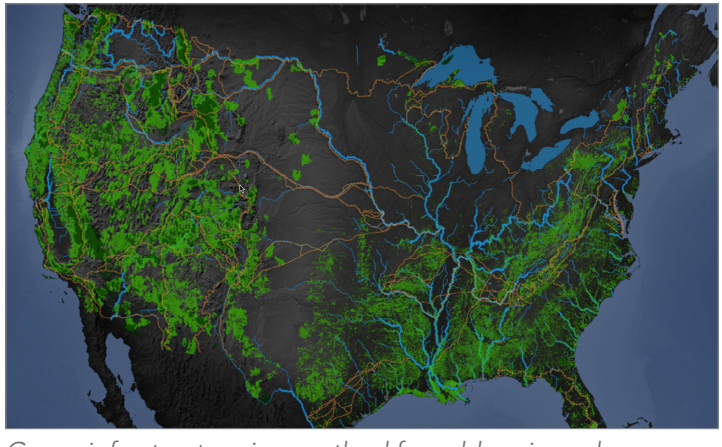
This interactive web app shows the path of the August 21, 2017, total eclipse of the sun. With totality literally reaching from coast to coast in the United States, this is the kind of information that is ideally suited for a map-based display.

GIS maps illuminate social issues



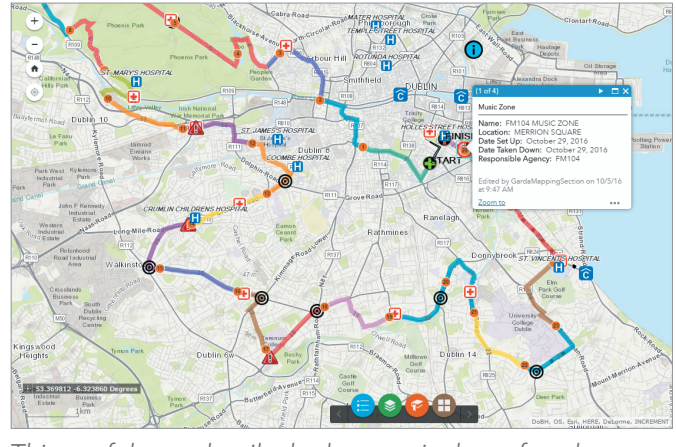
Social issues are driven by geography at global, national, and local levels. This interactive map of opioid prescription claims (zoomed into the Eastern Seaboard of the United States), reveals the subtle and often tragic geographic patterns that emerge when data is well-mapped.

GIS maps enable smart planning



Green infrastructure is a method for addressing urban and climatic challenges by building with nature. It is a way to view the land around us in a more holistic ecological manner.

GIS maps manage large events



This useful app details the key particulars of each segment on the route of the Dublin Marathon. The public now expects to find this depth of information for events of all kinds.

Thought leader: Jack Dangermond

GIS: Understanding The Science of Where

GIS is about uncovering meaning and insights from within data. It is rapidly evolving and providing a whole new framework and process for understanding. With its simplification and deployment on the web and in cloud computing as well as the integration with real-time information (the Internet of Things), GIS promises to become a platform relevant to almost every form of human endeavor—a nervous system for the planet. This system is now not only possible, but in many ways we believe it's inevitable. Why?

GIS integrates data about everything—and, at the same time, it provides a platform for intuitively understanding this data as an integrated whole. This GIS nervous system is providing a framework for advancing scientific understanding, and integrating and analyzing all types of spatial knowledge (all the "-ologies" such as biology, sociology, geology, climatology, and so on).

GIS provides a platform for understanding what's going on at all scales—locally, regionally, and globally. It presents a way to comprehend the complexity of our world as well as to address and communicate the issues we face using the common language of mapping. At Esri, we refer to this idea as The Science of Where.

Our world is increasingly being challenged by expanding populations, loss of nature, environmental pollution, and the increasing dilemma of climate change and sustainability. My sense is that humans have never been more capable of sharing and addressing these issues. My belief is that GIS not only helps us increase our understanding, but it also provides a platform for collective problem-solving, decision-making, and perhaps most critical of all, collaboration. However, it's going to take all our best people, our most effective methodologies and technologies—scientists from many disciplines, our best thinkers, all our best design talent collaborating to create a sustainable future. GIS technology and GIS professionals will play an increasingly important role in how we respond to and confront our collective problems.

Jack Dangermond is president and founder of Esri, the world leader in GIS software development and its application in business, health, education, conservation, utilities, military and defense, oceanography, hydrology, and many other fields.

Video: GIS-Enabling a Smarter World

My hope is that by using GIS to apply The Science of Where, we can discover deeper insights, make better decisions, and take them to action.

Enabling a smarter world

GIS provides a framework and process

The Internet of Things is becoming real. We're learning how to measure virtually everything that moves and changes on the planet with a web of connected instruments that are gauging water flows, documenting changes in climates, and pinpointing where people and things exist. And this lattice of information is becoming available through the Internet, basically instrumenting our planet with GIS. Location mapping and GIS is becoming an essential framework or language to help us keep track of what's going on.

When fully realized, this framework allows a sort of virtuous cycle. GIS users, working in their localities—each contributing their small piece of the larger geographic puzzle—repeatedly apply the science of our world to collect and organize their geographic information into effective representations. They use maps along with interactive charts and graphs to visualize, portray, and share their results. With GIS, users go even further and ask deeper, more probing questions to model and test different scenarios. These GIS practitioners apply The Science of Where to inform the way that people make decisions and take action. Think about GIS users repeating this cycle over and over in hundreds of situations and locations worldwide—it adds up to science in action.

It all begins with a map

Web GIS revolves around the map. It's the framework for your data and the primary geographic container that gets shared and embedded in your apps. In ArcGIS it is called a "web map." The purpose of the web map below is simple enough: to show the last 120 days of earthquakes everywhere on Earth. (By the way, if you're reading the print edition, make sure you access the book on your computer as well to get the full, up-to-date experience.)

There are several points of interest right here on this map. First of all, it's navigable, which means you can pan and zoom. The map has many zoom levels built in, each one revealing more detail the closer you get. Click on any earthquake symbol to learn the magnitude and date of each event.

These little windows of information are called "pop-ups," and by the time you finish this chapter, you'll know how to configure them.

The map also has scaled symbols, showing the relative magnitude of each earthquake. The background map is symbolized as well, in this case in muted dark tones that set off the bright earthquake symbols.

This data, organized with this combination of symbology, reveals an interesting pattern: the well-known Ring of Fire. This map could be easily embedded on any web page or in an app. But where did it originate? It began life as a web map in the ArcGIS map viewer.

This simple live map shows earthquakes that occurred over the previous 120 days.

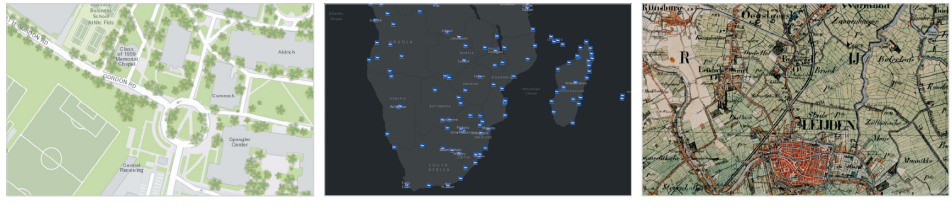
The expansive reach of Web GIS

Across organizations and beyond

The geographic organizing aspect of GIS has been part of the thinking from the beginning, but now factor in the impact of the web. Web GIS provides an online infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the web. This new vision of Web GIS fully complements, integrates, and extends the work of existing GIS professionals.

Web access to data layers is straightforward: every layer has a web address (a URL) making it easy to locate and share online. Because every layer is georeferenced, Web GIS becomes a system for integration that facilitates the access and recombination of layers from multiple providers into your own apps. This is significant for the millions of GIS professionals worldwide who are building layers that serve their individual purposes. By simply sharing these layers back into the online GIS ecosystem, they are adding to a comprehensive and growing GIS for the world. Each day, this resource grows richer and is tapped by ArcGIS users and shared on the web.

GIS is continually evolving. Its information model was originally centered around local files on a single computer. From there, it evolved into a central database environment based on clients and servers. The most recent evolutionary stride has taken it to a system of distributed web services that are accessible in the cloud. ArcGIS is now a Web GIS platform that you can use to deliver your authoritative maps, apps, geographic information layers, and analytics to wider audiences. You do this by using lightweight browser clients and custom applications on the web and on smart devices, as well as desktops, as you'll see in later chapters.



These three layers depicting Harvard University facilities, global airport locations, and Dutch historical maps, respectively, are among thousands available on ArcGIS Online.

Much of the work of traditional GIS users and experts has involved building and maintaining key foundational layers and basemaps—information products that support a particular mission. Huge investments have been made to compile these basemaps and data layers in great detail and at many scales. These include utility networks, parcel ownership, land use, satellite imagery and aerial photography, soils, terrain, administrative and census areas, buildings and facilities, habitats, hydrography, and many more essential data layers.

Increasingly, these information products are finding their way online as maps, comprehensive data layers, and interesting analytical models. This data comes to life for everyone as a living atlas, a collection of beautiful basemaps, imagery, and enabling geographic information, all of which are built into the ArcGIS platform. There, they are available for anyone to use, along with thousands of datasets and map services that have also been shared and registered in ArcGIS by users like you from around the world.

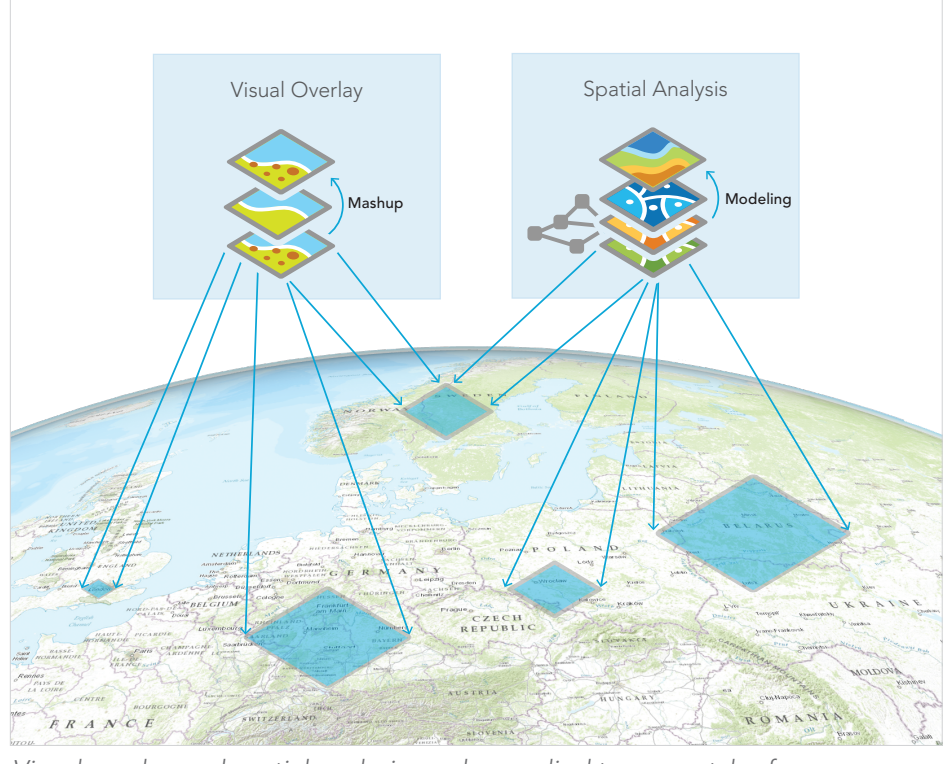
Web GIS is collaborative

Geography is the key, the web is the platform

Every day, millions of GIS users worldwide compile and build geographic data layers about topics critical to their work and for their particular areas of interest. The scope of information covers almost everything—rooms in a building, parcels of land, infrastructure, neighborhoods, local communities, regions, states, nations, the planet as a whole, and beyond, into other planetary systems. Web GIS operates at all scales, from the micro to the macro.

Geography is the organizing key; information in Web GIS is sorted by location. Because all these layers share this common key, any theme of data can be overlaid and analyzed in relation to all other layers that share the same geographic space.

This is a powerful notion that was well understood by mapmakers in the pre-digital era: tracing paper and later transparent plastic sheets were employed to painstakingly create "layer sandwiches" that could be visually analyzed. The desire to streamline this process using computers led to the early development of GIS. The practical term for this notion is "georeferencing," which means associating things using their locations in geographic space.



Visual overlay and spatial analysis can be applied to any patch of geography of any size on the planet.

Now extend the idea—of georeferencing shared data—onto the web. Suddenly it's not just your own layers or the layers of your colleagues that are available to you, it's everything that anybody has ever published and shared about any particular geographic area. This is what makes Web GIS such an interesting and useful technology; you can integrate any of these different datasets from different data creators into your own view of the world, overlay them and then perform spatial analysis.

How GIS works

The science of geography

GIS is both a technology and a science. It relies on a simple notion of organizing data into discrete layers that are aligned (georeferenced) in relation to one another in geographic space.

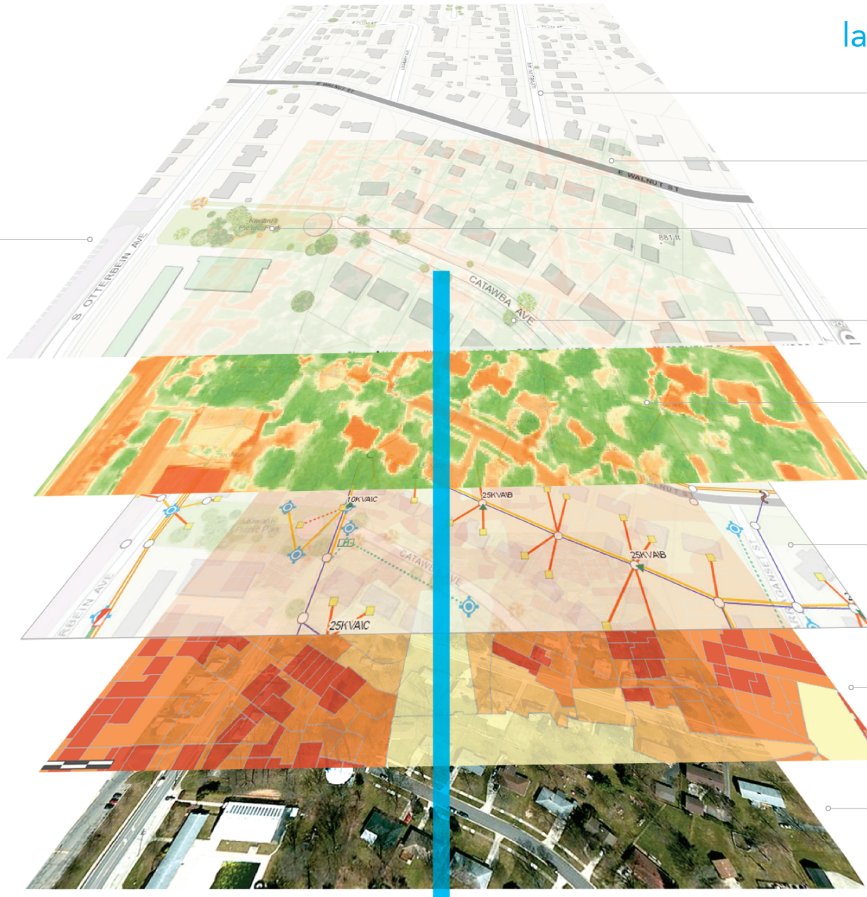
Map Layers: The secret advantage

Geographic datasets are presented in GIS as a series of dynamic, stacking map layers that cover a given extent (area). These layers can depict virtually any object (fixed or moving), boundary, event, or spatial phenomenon.

Layers line up on Earth

Georeferenced layers of information are the key characteristic of GIS that enable disparate types of data to be displayed, combined, and analyzed in common geographic space.

Things that map layers can represent



ArcGIS information items

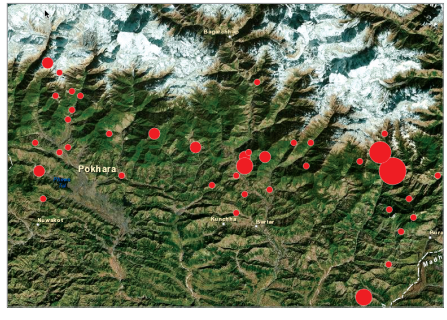
Layers

You can think of the items eligible to be stored in ArcGIS as different types of geographic information. Now you can examine the three most primary and commonly accessed items: layers, web maps, and scenes.

Layers are logical collections of geographic data. Think about any map. It might contain such layers as streets, places of interest, parks, water bodies, or terrain. Layers are how geographic data is organized and combined to create maps and scenes; layers are also the basis for geographic analysis.

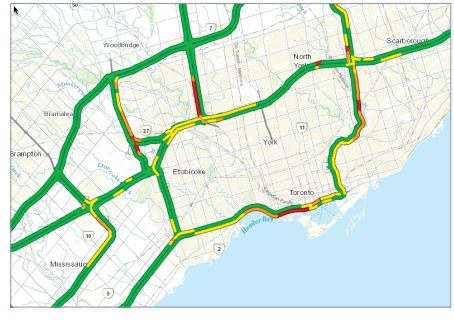
They can represent geographic features (points, lines, polygons, and 3D objects), imagery, surface elevation, cell-based grids, or virtually any data feed that has location (weather, stream gauges, traffic conditions, security cameras, tweets, and others). Here are a few examples of layers.

Nepal earthquake epicenters



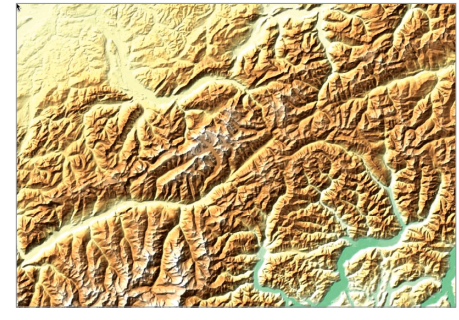
Feature point data from in-ground data sensors.

Toronto traffic



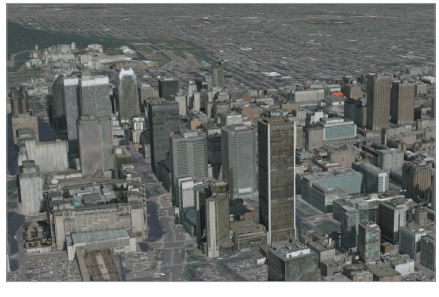
Cell-based raster using historical predictive data.

Terrain of the Swiss Alps



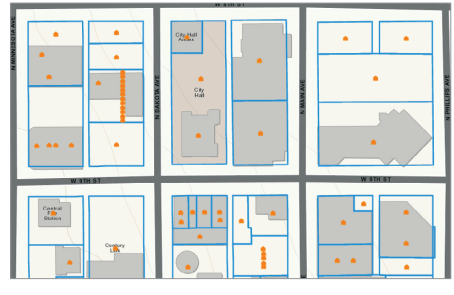
Tinted hillshade is a cell-based raster derived from an elevation surface.

Montreal, Canada, buildings



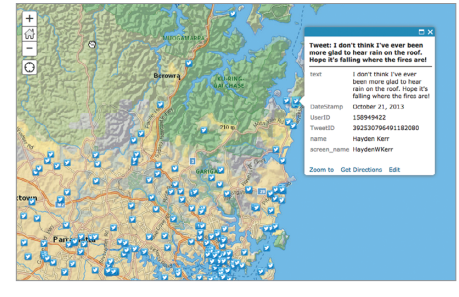
This 3D scene highlights layers for Montreal, Canada.

Sioux Falls parcels



Feature polygon data from cadastral surveys.

New South Wales wildfire tweets

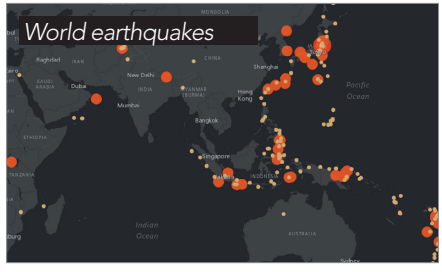


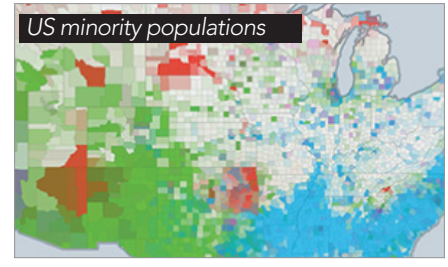
Feature point layer of tweets during 2013 New South Wales fires at #SydneyFires.

Web maps and scenes

Web maps

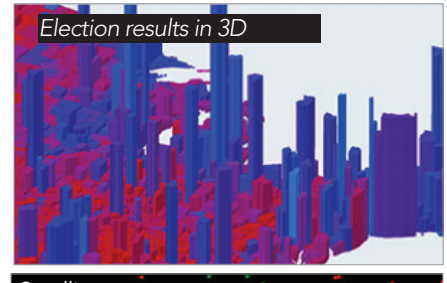
Web maps are the primary user interfaces by which work is done using ArcGIS. They contain the payload for GIS applications and are the key delivery mechanisms used to share geographically referenced information on the ArcGIS platform. Every GIS map contains a basemap (the canvas), plus the set of data layers you want to work with. If it's 2D, it's called a "web map." These are examples of two-dimensional web maps.

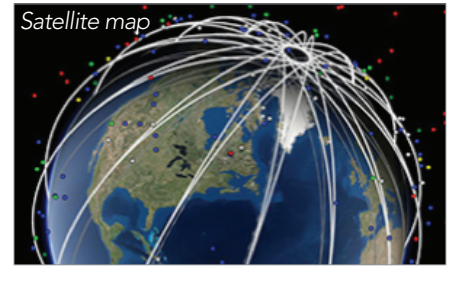




Scenes

The 3D counterpart to a web map is a scene. Scenes are similar to web maps (they combine basemap layers with your operational overlays), but scenes bring in the third dimension, the z-axis, which provides additional insight to study certain phenomena. These are examples of scenes.



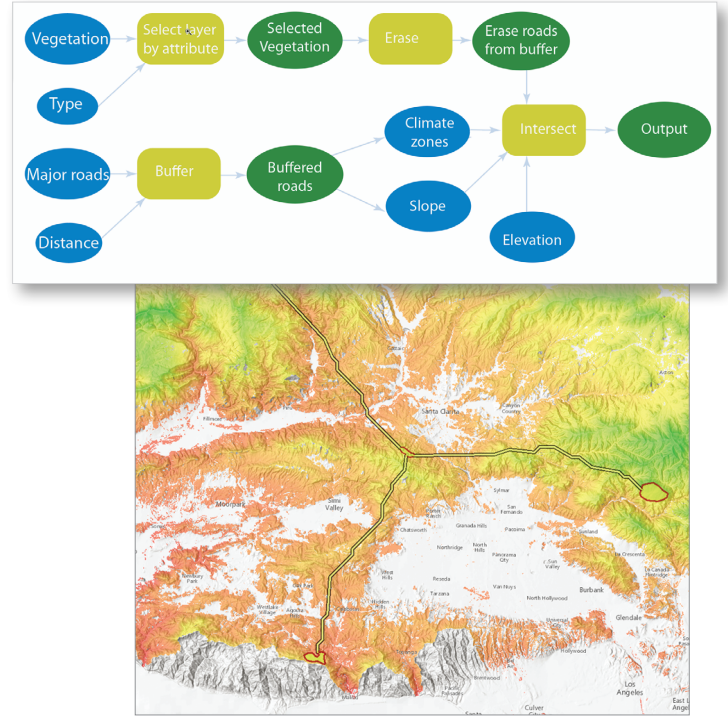


Geospatial analysis yields insights

GIS analysis is the process of modeling spatially, deriving results by computer processing, and then examining and interpreting those model results. Spatial analysis is useful for evaluating suitability and capability, estimating and predicting, interpreting and understanding, and much more.

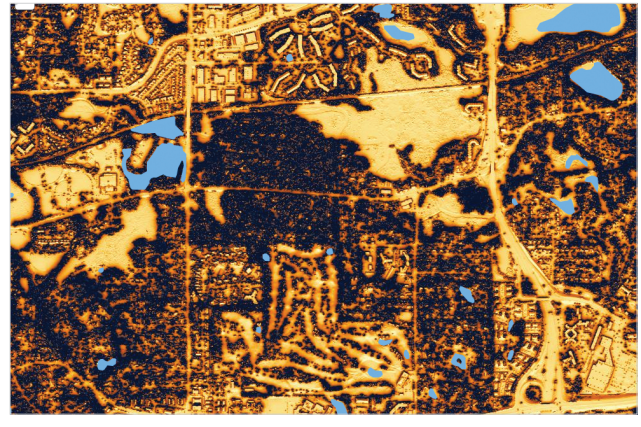
ArcGIS provides a large set of modeling functions that produce analytical results. These functions typically generate new data layers and associated tabular information, enabling you to use ArcGIS to model just about any kind of spatial problem you can think of. (Chapter 5 delves into this area of ArcGIS in more detail.)

Sometimes analysis functions are built into the system. In many other situations, experienced users create their own models as analysis tools that can be shared with other ArcGIS users. These models can also be used to create new geoprocessing tasks in ArcGIS Enterprise (an advanced GIS server). So advanced users can create sophisticated analytical models that can be shared and accessed by other users who can work with their results.



This shows a GIS workflow and resulting map used to model cougar habitat in the mountains and wildlands near Los Angeles.

Even beginners can apply spatial analysis. Practice and experience will help you expand the level of sophistication of your spatial analysis and modeling. The good news is that you can begin applying spatial analysis right away. The ultimate goal is to learn how to solve problems spatially using GIS.



Minnesota models solar potential for the whole state by deriving expected solar radiation from critical raster and imagery layers. This enables citizens to perform a quick, high-level assessment of where solar power might be a practical alternative.

Apps extend the reach of GIS

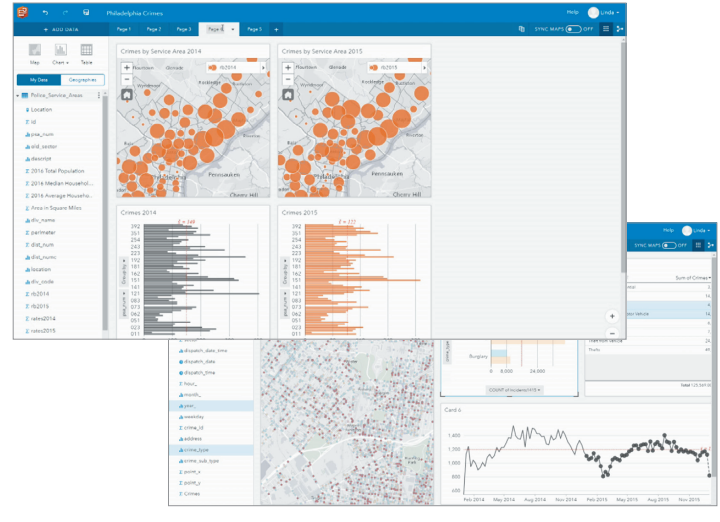
Every GIS map has an interface—a user experience for putting that map to use. These experiences are called "apps," and they bring GIS to life for all kinds of people. And like other apps, these work virtually everywhere: on your mobile phones, tablets, in web browsers, and on desktops.

You'll learn much more about apps, these lightweight map-centric computer programs, in chapter 7, but for now you should know that as a publisher in ArcGIS, you can configure an app for specific users you want to reach by including a certain map or scene, and data layers, and setting other app properties. These configured apps are what you can save and share with selected users. And you can manage these apps as items in your ArcGIS account.

People have embraced the concept of apps. They get it. Many already use and value basic personal navigation maps, but expectations have been raised, and people increasingly want map apps that "do more."

The result is that map-based apps are the way that organizations extend the reach of their GIS in significant ways.

GIS on mobile devices is changing how we interact with geography. With your phone, you can access GIS maps and data anywhere, positioning you and your organization to leverage full GIS capabilities in the field. A GIS-enabled smartphone is also an advanced live data sensor.



Insights is a new Esri app designed to explore and interpret GIS data layers using maps and charts. You can integrate additional rich layers to help investigate your data more deeply while discovering new patterns.

QuickStart

Connect to the ArcGIS platform online and on the desktop

Now it's time to get your hands on ArcGIS. If you're an existing user and already have an ArcGIS subscription (with Publisher privileges), as well as the ArcGIS Pro desktop application installed on your local machine, you're good to go and can skip to the next page. If you don't have these two things, read on.

Join the free Learn ArcGIS organization

The majority of lessons in this book are carried out on the ArcGIS platform (in the cloud), and many require membership (with Publisher privileges) in an ArcGIS organization. Think of this as a data-rich learning sandbox available for students and others to practice with ArcGIS. With your membership, you can immediately begin to use maps, explore data, and publish geographic information to the web. Go to the Learn ArcGIS Organization link (http://go.esri.com/LearnOrg) and click the Sign Up Now link to activate a 60-day membership.

Install ArcGIS Pro

ArcGIS Pro is a desktop application that you download and install on your local computer. If you don't already have ArcGIS Pro, you can get a limited-time license when you join the Learn ArcGIS organization. Check the system requirements, and then use the download button below to install the software on your local machine.

ArcGIS Pro is a 64-bit Windows application. To see if your computer will run ArcGIS Pro, check the system requirements.

Download ArcGIS Pro

The Learn ArcGIS organization is set up specifically for educational use. It includes all the data required to complete the lessons found at Learn.arcgis.com. You can join this organization even if you already have another ArcGIS account.

Learn ArcGIS lesson

Demographic Analysis and Smart Mapping

The best way to get familiar with ArcGIS is to just dive in. In this Learn ArcGIS lesson you'll create a map of Detroit, Michigan, by adding and enriching a layer of ZIP Codes with demographic data from ArcGIS Online. You'll also apply smart mapping to style the layer, configure pop-ups to make the demographic information easier to read, and finally you'll report your findings by configuring a web app that tells a clear story based on your data.

Overview

More children live in poverty in Detroit, Michigan, than in any other city in the United States. You work for a charity that supports community programs and poverty relief efforts. This year, the charity wants to direct its funding toward resources to help at-risk kids in Detroit. Your objective is to ensure the programs are offered where they're most needed.

Build skills in these areas:

- Adding layers to a map
- Enriching layers with demographic data
- Styling layers with smart mapping
- Configuring pop-ups
- Editing item details
- Configuring a web app

Start Lesson

What you need:

- Membership in the Learn ArcGIS student organization (or another organization with publisher privileges).
- Estimated time: 30 minutes to one hour