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Esri and the Scientific Community

An Esri White Paper

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Introduction

At Esri, we are concerned with supporting basic and applied science, but we also recognize that there are many major themes of compelling interest to society that will drive scientific research for the next two decades. And thus we view science as helping us to understand not only how the Earth works but also how the Earth should look (e.g., by way of geodesign) and how we should look at the Earth (i.e., by way of Earth observation in varying forms and the accompanying data science issues of analyzing, modeling, developing, and documenting useful datasets for science, interoperating between these datasets and between various approaches) (figure 1).

![Figure 1](image)

**Figure 1:** There are many natural science domains in which GIS is being used effectively to understand how the Earth works, how the Earth should look, and how we should look at the Earth. These are the domains that Esri is particularly strong in.

In addition to supporting the science community (e.g., scientists within universities, research institutes, government agencies, and nongovernmental organizations [NGOs]), we seek to perform good science at Esri, as it underpins much of what we do as an organization. This is helping us to evolve ArcGIS® software into a comprehensive geospatial platform for science that supports research project management and collaboration, spatial analysis, visualization, open data, and communication of science—all at multiple scales (i.e., from individual researcher to lab workgroup to multidepartment, multiuniversity, university-to-agency collaboration to citizen engagement).
Figure 2: Main Components of Esri's Program to Support the Scientific Community

Figure 2 shows the various aspects of our comprehensive program to support the science community, showing the interlinkages between and among universities; government agencies; and various consultancies, nonprofit, for-profit, and other organizations focused on science. Program components include the following:

- **Paid internships for graduate and undergraduate students**, many positions with a science focus. Many of these lead to immediate employment with Esri thereafter. Consult esri.com/careers.

- **Visiting faculty/sabbatical program**. If considering an extensive time in residence at Esri headquarters, please see the guidelines at esriurl.com/sabbatical.

- **A new site license** (also known as the science kit) for stand-alone research organizations in the United States. See esriurl.com/sciencekit.

- Informal collaborations or partnerships on a range of research projects. See recent examples at esriurl.com/scicomm.

- App challenges. Recent competitions have been in the areas of climate resilience (esriurl.com/climateapp), global disaster resilience (esriurl.com/climateapp2), and data visualization. For future competitions, go to esri.com and search for "challenge."

- **Science books from Esri Press**. For example, *Mapping and Modeling Weather and Climate with GIS* (2015) features leading climatologists, meteorologists, and other experts sharing approaches to advance atmospheric and ocean science through GIS. *Ocean Solutions, Earth Solutions* (2015) is an externally peer-reviewed research monograph based on papers presented at the inaugural Esri Ocean GIS Forum. It is about use-inspired science and realistic solutions for mapping, monitoring, and protecting the ocean—hence, the entire Earth. It is also the first Esri Press book to employ digital object identifiers (DOIs) for citation of both chapter text and supplementary datasets (further reading on citations). *GIS Research Methods:
Incorporating Spatial Perspectives shows researchers how to incorporate spatial thinking and GIS technology into research design and analysis, and thus should be incredibly useful in the classroom. For more information, go to esripress.esri.com.

- **Apps for citizen science.** We have a range of apps to support citizen science projects and exciting implementations, including Collector for ArcGIS; GeoForm web app template; Survey123; Crowdsource Reporter for Citizen Science; Water Quality Status; My Hazard Information; and for your own customized apps from scratch, Web AppBuilder for ArcGIS. A prototype of the new Story Map Crowdsourse Builder for citizen science was used at the 2015 White House Science Fair. See esriurl.sci2015 for web links to these apps.

The most important aspects of the program are the software and data (content) stacks designed specifically for scientists and scientific problems. These include the following:

- **Multidimension tools and multidimension supplement tools** in ArcGIS Pro and ArcMap™ software. These tools allow the user to work with netCDF, HDF, and GRIB scientific data formats. A new geoprocessing tool accesses scientific data stored on a remote server via the OPeNDAP protocol and makes a raster layer.

- The **Scientific Data Workflows package** provides free examples to help jump-start the effective work with multidimensional datasets in ArcGIS. A Scientific Data Workflows.docx file goes through a number of general scientific examples. The workflows may be customized with the inclusion of one's own data. To download the package, go to esriurl.com/workflows.

- **Dimension Explorer** is a free tool that makes it easier to visualize and work with time-aware and multidimensional data in ArcMap by providing slider controls for navigation. See esriurl.com/dimension.

- **Spatial analysis tools** in ArcGIS Pro and ArcMap include scores of new functions for space-time pattern analysis and mining (including space-time cube visualization and analysis of changes in temporal trends at a location), raster segmentation and processing, working with 3D and LAS (lidar) datasets, pairwise feature processing, suitability modeling, cost-distance analysis, data review, and workflow management.

- **Integration of ArcGIS with the SciPy stack.** We seek to evolve ArcGIS into a comprehensive geospatial platform for science that supports research project management and collaboration, spatial analysis, visualization, open data, and communication of science—all at multiple scales. The inclusion of the SciPy stack supports this goal by expanding the number and type of analytical methods available to the science community. For context, see esriurl.com/scipy and the video at video.esri.com entitled "Python: Working with Scientific Data."

- **The inclusion of the netCDF4 Python library** allows users to build custom geoprocessing tools that analyze netCDF data, perform advanced slicing (subsetting) of a netCDF file (e.g., for creating climatologies), and reading netCDF files that contain groups.
- **The inclusion of Pandas**, a software library written for the Python programming language, offers data structures and operations for manipulating numerical tables and time series.

- **Integration with R** (aka as the R Project for Statistical Computing), an extremely popular environment for statistical computing, contains over 6,300 packages for solving a wide variety of statistical problems. R is commonly used by environmental scientists and statisticians. Although it contains a number of cutting-edge methods not implemented in any other environment, perhaps 95 percent or more of these packages are not explicitly spatial. Hence, many in the Esri user community have been asking for a mix of its functionality with ArcGIS, as well as better code-sharing interaction with the R community. A new open-source bridge library on GitHub will allow users of recent versions of ArcGIS for Desktop and ArcGIS Pro to directly build R into their workflows and to pass data between ArcGIS and R. An additional aim is to build a community of people who will develop R-based geoprocessing tools that are shared freely and openly, along with sample data. The community of tools will be user developed and user driven. Esri will not be developing sample toolboxes around R packages. Instead, our role will be to facilitate the community and help people build what they find useful and want to own and maintain. For context, see the comprehensive video at video.esri.com entitled "Integrating Open Source Statistical Packages with ArcGIS."

- **Benthic Terrain Modeler**, a free collection of open-source terrain analysis tools for ocean/coastal scientists and resource managers, is used in concert with bathymetric data for classifying and interpreting the benthic environment. See esriurl.com/btm.

- **ArcGIS for Maritime: Bathymetry** (free with all university site licenses) is a desktop extension for managing and mosaicking large volumes of data coming from multibeam bathymetric sensors, along with the associated metadata, and for producing and sharing bathymetric surface models and maps.

- New **Python raster functions**, a curated set of lightweight but powerful tools, are used for on-the-fly image processing and raster analysis in ArcGIS. Available from Esri's open-source community on GitHub at github.com/Esri/raster-functions.

- The open-source **Esri Geoportal™ Server** continues to be a popular and valuable contribution. The latest version, 1.2.6, includes increased support for the Project Open Data catalog format, various search and publication enhancements, and further integration options with ArcGIS Online/Portal for ArcGIS. You can access the release at github.com/Esri/geoportal-server/wiki.

- **GeoPlanner™ for ArcGIS** brings the power of ArcGIS Online and a geodesign workflow to land-based planning activities with a JavaScript-based web application that allows users to create, analyze, and report on alternative planning scenarios in support of better, more informed decision making. Universities and other organizations with campus site licenses already have access to this app via an ArcGIS Online organizational account. See esriurl.com/geoplanner.
GIS Tools for Hadoop is an open-source toolkit intended for big spatial data analytics. The toolkit allows users to leverage the Hadoop framework to do spatial analysis on spatial data. See esri.github.io/gis-tools-for-hadoop. Esri is pushing forward in the use of Spark as well (http://github.com/mraad/SparkProject).

The Living Atlas of the World (esriurl.com/livingatlas) features beautiful and authoritative maps, satellite imagery feeds, and demographic data on hundreds of topics relating to people, the Earth, and life. This includes a rich collection of Earth and ocean observation layers describing current conditions such as severe weather and hurricanes. To enhance and expand this collection, Esri has recently published a new set of live feeds layers featuring frequently updated data from several sources, including NOAA, NASA, and US Geological Survey. The Living Atlas also includes layers from a new map of global terrestrial ecosystems for a host ecosystem research and management application, including assessments of climate change impacts to ecosystems, economic and noneconomic valuation of ecosystem services, and conservation planning. This map of ecological land units (ELUs) represents the most current, accurate, comprehensive, and finest-resolution data available at a global scale for each of the four inputs: bioclimate, landform, lithology, and land cover. To access this content, see the Esri white paper at esriurl.com/eluwhite.

For many years, Esri has been compiling a human geography database of demographics and statistics about all countries in the world and mapping these datasets using an innovative methodology. The Esri World Population Estimate, a new probability surface that estimates the location and count of people throughout the world, is now available to researchers and others online. See esriurl.com/population.

Other Initiatives

Open source, open data, standards, and interoperability: Leveraging open-source code and solutions with Esri® technology is something that the scientific community is very much interested in. However, many in the science community are still surprised to hear that Esri produces free, open-source products, such as Geoportal and ArcGIS Editor for OpenStreetMap, or maintains a significant presence on GitHub (esri.github.io with additional resources at developers.arcgis.com). Esri is also committed to building and supporting an open and interoperable platform that in turn supports many relevant standards, including those from ISO TC 211 and the Open Geospatial Consortium, Inc. (OGC). In any platform strategy, being open and interoperable actually makes very good business sense. In the Esri space, a successful platform is not only open and interoperable but standards compliant as well. For more information, see esriurl.com/scicomm.

Spatial statistics: See the Spatial Statistics Resources page, frequently updated at esriurl.com/spatialstats.

Imagery: ArcGIS provides a comprehensive platform for working with imagery and making your imagery useful, including advanced image management and processing and robust analysis tools. As an example, see how the NASA Langley Atmospheric Science Data Center (ASDC) Distributed Active Archive Center (DAAC) is
improving the accessibility and use of Earth science data with this platform (esriurl.com/nasa and esriurl.com/nasavid). And for over 9,000 universities across the world, this imagery platform and a wealth of imagery data are already freely available under their campus site licenses. See esriurl.com/imagery and some pretty amazing explorations of Landsat at esriurl.com/secrets.

- **Big data:** Researchers today need to deal with an avalanche of data—from environmental sensor networks (both on land and at sea), social media feeds, lidar, and outputs from global- and regional-scale atmospheric circulation and general climate models and simulations. Because of this, big data has emerged as a major research theme for the academic community. To see what Esri is doing in this space, visit esri.com/products/technology-topics/big-data.

- **Basemaps:** Many in the scientific community are interested in and participate in our Community Maps Program (esriurl.com/cmaps). This is in the spirit of crowdsourcing authoritative content from the community that Esri then hosts free in the cloud and of which contributors retain ownership and are acknowledged. In terms of GIS analysis directly within the web browser, the geoanalytics web services that Esri offers for hydrologic science are the most advanced thus far.

- **Story Maps:** Story maps allow scientists to make their data and analyses more accessible to their colleagues as well as to policy makers and citizens (example). Think of the power of telling a 30-second elevator speech about your research to a funder or policy maker as a story map! Templates and tutorials are available at storymaps.esri.com. Related resources: An Ocean of Story Maps (esriurl.com/ocnstories) and Speaking the "Language" of Spatial Analysis via Story Maps (esriurl.com/analyticalstories).

Esri is well-known as a vendor of GIS technology to research labs, universities, and other places where great science is done, providing a catalyst toward geoenabling the scientific process (figure 3). However, Esri continues to work toward contributing as a member of the scientific community as well. As such, Esri maintains objective scientific representation on various scientific **boards and councils**, including several of the committees that do the work of these bodies over the long term. Examples include the Science Advisory Boards of NOAA, the EPA, and the US Census Bureau; the Federation of Earth Science Information Partners (ESIP); various committees and the Board of Directors of the OGC; the Consortium for Ocean Leadership, the National Academy of Sciences Ocean Studies Board; and the board of the Citizen Science Association.
Figure 3: This generalized scientific process diagram shows one way of looking at a cycle for conducting both physical and social science research and answering research questions such as How and where will climate change impact forest composition, coastal habitats, etc.? What factors most affect the spread of infectious diseases or invasive species? and How much will sea level change on a range of spatial and temporal scales?

**Staying Connected** To keep abreast of the latest science developments at Esri

- Bookmark the web catalog (esriurl.com/scicomm) that is continually updated and provides more in-depth information on our various services to and collaborations with the scientific community.

- Follow several of the ArcGIS Resources communities at resources.arcgis.com/en/communities. These resources are organized by application domain (industry) or by technical approach, all with content provided solely by Esri staff. Each contains blogs, Twitter streams, discussion forums, videos, case studies, maps, apps, data, and documentation preselected to help users in that domain complete their work, without having to search through large volumes of content to find what best applies to their application domain. Examples are the following:

  - Bookmark the Oceans Resource Center (esriurl.com/ocnres), particularly the blog post section, where updates are posted all the time, including results of the annual Esri Ocean GIS Forum conference series.

  - Bookmark the Hydrology, Soils, Mapping, Community Analyst, Health, Imagery, and 3D Resource Centers for the same reasons. All contain significant content for the science community (i.e., scientists within universities, research institutes, government agencies, NGOs).

  - Bookmark the Analytics Case Studies site (esriurl.com/case) to view various modes of analysis from exploration to decision making as demonstrated by
examples and where processes are shown, results are interpreted, and data and models can be downloaded.

- Get involved in a GeoNet community (geonet.esri.com/welcome). This is a different kind of resource center where you can provide content as the user and have an opportunity to interact directly with Esri staff or other users who can answer technical how-to questions. This gives us at Esri an opportunity to not only listen to you but ask you questions as well. See also the helpful video Getting Your Questions Answered Quickly on GeoNet at esriurl.com/geonet.

- Bookmark the ArcGIS Pro web site (pro.arcgis.com) that has significant content for the science community, particularly regarding geoprocessing and spatial analysis across many science domains.

- Follow Esri chief scientist Dawn Wright on Twitter (@deepseadawn) where she makes science and ocean-related postings daily or @gisandscience.

- Follow the GIS and Science blog (gisandscience.com) of Matt Artz, Esri GIS and science manager, to see the fascinating array of journal articles, books, and scholarly events showing how GIS technology is being used to advance scientific understanding.

- Attend the Esri International User Conference, where there are always high-quality paper sessions and Map Gallery presentations focused on a wide array of scientific themes (including the annual GIScience Research or Frontiers in GIScience sessions and the new Science Symposium). In addition, there is a large Environment Showcase in the Exhibit Hall (with several booths hosted by research labs, agencies, and initiatives), special interest group (SIG) meetings, and science-related demo theaters (e.g., demo theaters by the wizards in our Applications Prototype Lab are always a treat for scientists).

- Attend upcoming Esri events with science themes (e.g., Geodesign Summit and Geodesign Summit Europe, the Health and Human Services GIS Conference, and the Esri Ocean GIS Forum). Consider the Esri Developer Summit as well. Information on all Esri events is available at esri.com/events.

- Esri staff also do great science themselves, and you are welcome to visit our online Zotero library (esriurl.com/zotero) showcasing our publications.
Esri inspires and enables people to positively impact their future through a deeper, geographic understanding of the changing world around them.

Governments, industry leaders, academics, and nongovernmental organizations trust us to connect them with the analytic knowledge they need to make the critical decisions that shape the planet. For more than 40 years, Esri has cultivated collaborative relationships with partners who share our commitment to solving earth’s most pressing challenges with geographic expertise and rational resolve. Today, we believe that geography is at the heart of a more resilient and sustainable future. Creating responsible products and solutions drives our passion for improving quality of life everywhere.

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