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Twentieth-Century Themes for the Progressive Map Collection

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Volume Six of the *History of Cartography*, which focuses on the twentieth century, was released in May 2015 as part of a massive, multi-volume reference work that covers cartography in all its forms across all eras, from prehistory through the end of the last century. At seventeen pounds, it's a big book—two books, actually—consisting of 1,954 large, double-column pages, with 529 encyclopedia entries written by over three hundred contributors and co-contributors, and including 1,153 illustrations, 5,115 bibliographic references, and 61 tables. In addition to serving scholars and interested lay users, it can help librarians organize a map collection to reflect the major revolutions that made the twentieth century arguably the most significant era in map history. Moreover, any one of the six themes that frame Volume Six could provide a coherent focus for an enlightening exhibition.

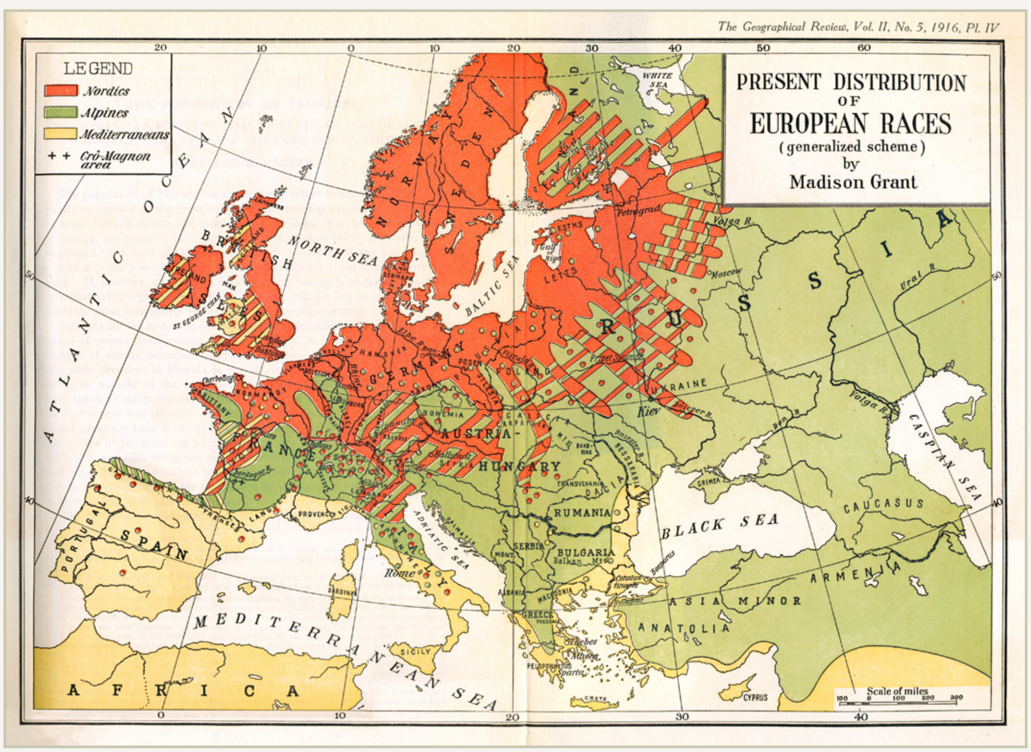

Figure 1. Map promoting scientific racism in the 1916 Geographical Review.

The first of these themes is the *Diverse Impacts of Mapping on Society*. Whether driven by technology, state formation, imperialism, or other forces, mapping assumed new or greatly enhanced roles in the twentieth century, notably in entertainment, environmental protection, growth management, weather prediction, hazard mitigation, and other arenas with clear social impact. Moreover, the century witnessed not only a relative "democratization" of map use and associated improvements in cartographic literacy, but also an increased awareness of ethical considerations in both the design and the use of maps.

By century's end maps and mapping were subject to unprecedented questioning; what came to be called counter-maps were challenging the authority of official delineations, and participatory mapping was a recurrent theme at academic conferences. Indeed, as mapping practices pervaded all parts of the globe and all levels of society, and as mapping became more important for coping with complexity, for organizing knowledge, and for influencing public opinion, scholars recognized the need (belatedly perhaps) for a critical appraisal of the use, misuse, and effectiveness of maps for exploration, regulation, management, planning, and persuasion.

Understanding the importance of maps as tools also demanded a conscientious effort to disentangle significant, demonstrable impacts like those described in Volume 6 from assumptions based largely on theory or conjecture. During the twentieth century simplistic notions of the map as an objective representation of reality gave way to a broader grasp of how the map's respectability as a scientific tool makes it a target of political manipulation, particularly apparent in the geopolitics of Nazi Germany and the Cold War. The century also witnessed a broader and deeper appreciation of the diverse ways in which maps can be read and understood, a trend encouraged by the often-contentious intersection of cartographic scholarship and what's been called social theory. Also apparent was a broader, more nuanced understanding of the role of cartographic visualization in the packaging of ideas, explored under the interchangeable rubrics "propaganda maps" and "persuasive cartography," which mean pretty much the same thing.

The changing boundaries between cartography and other endeavors were also apparent in the growing participation of humanists, literary scholars, and art historians at academic conferences on map use and map history as well as in the adoption of geographic information systems as an analytical tool in archaeology, environmental biology, and public administration, among other fields.

The second key theme is *Overhead Imaging.* Technologies for imaging Earth from aircraft, satellites, balloons, and rockets not only enhanced the efficiency of mapping and surveillance but also had diverse scientific, social, military, and political impacts, exemplified in the early twenty-first century by an increased use of unmanned aerial vehicles as tools of surveillance and weapons of attack.

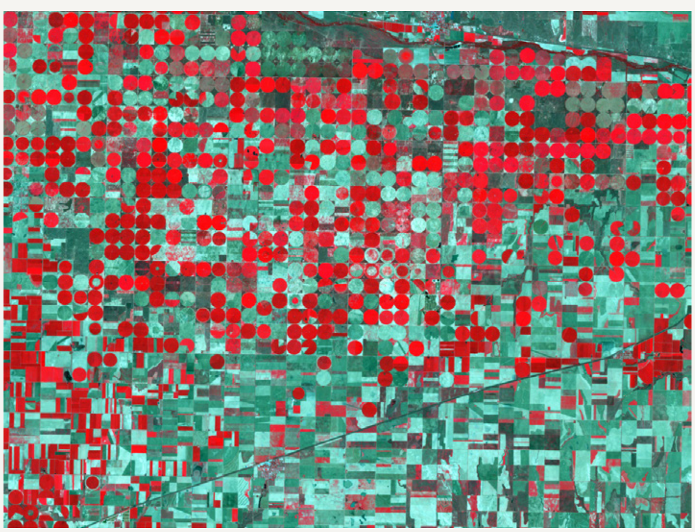

Figure 2. *Excerpt from a color-infrared image captured in 1988 by Landsat 5.*

Improved technologies for capturing image data and extracting cartographic features spearheaded a proliferation of geospatial databases, which in turn fostered a revitalized use of maps in older, more traditional fields of application such as energy exploration, transportation, and urban planning. During the twentieth century, aerial mapping and photogrammetry extended the reach of large- and intermediate-scale topographic mapping so effectively that the term *terrae incognitae* no longer meant the absence of any modern maps but rather a relative dearth of the censuses, detailed land use surveys, and environmental assessments essential to the Western World's managed spaces. In addition, remote imaging of other heavenly bodies helped redefine exploration.

The third key theme of cartography in the twentieth century is the *Electronic Transition*, whereby the dramatic and far-reaching conversion of geographic information to electronic media allowed the creation of interactive and dynamic maps. Although the products of this technology were not necessarily less expensive or more reliable, GIS and the Internet radically altered cartographic institutions and lowered the skill required to be a map author, and satellite positioning and mobile telecommunications

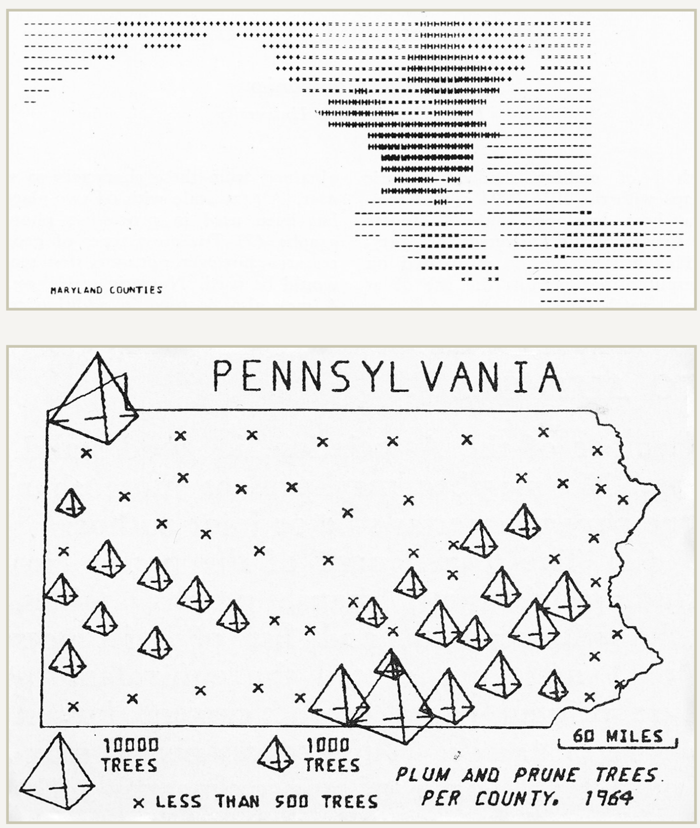

Figure 3. *Line-printer and pen-plotter maps in* The Professional Geographer, *1965 and 1968.*

revolutionized map-based wayfinding. Moreover, web-based technology not only undermined the traditional role of the state in topographic mapping but also made zooming in and out a widely pervasive and intrinsically interactive means of changing map scale—an extension to everyday use of the elegant but static bird's-eye views that had begun to proliferate in the nineteenth century.

Connections with earlier periods of map history are also apparent in the increased role of government in collecting, mapping, and using scientific data; the heightened concern for data quality; the rise and decline of truly mass production in the twentieth century; and the conflation of geographical, thematic, and topographic mapping whereby users could toggle between different layers or "coverages" while interactively manipulating map scale. Astute implementation of digital technologies, though never straightforward and far from complete by century's end, had moved cartography further beyond description and delineation and closer to the more ambitious goals of seeing and knowing.

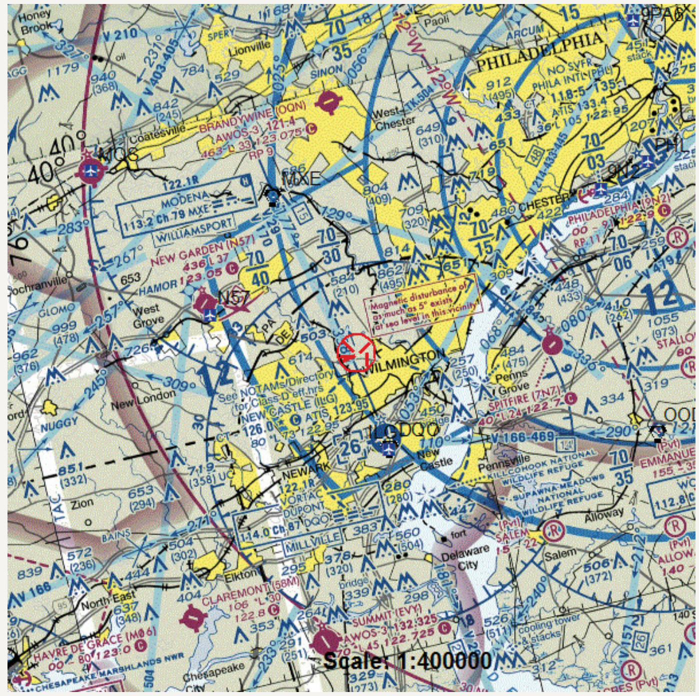

Figure 4. Online map of a "temporary flight restriction," identified by a red circle, over Vice President Biden's home, ca. 2009.

The fourth key theme is *Maps and Warfare*, noteworthy because the longstanding relationship between cartography and warfare became evermore prominent in the twentieth century. Along with the greater efficacy of precisely targeted cruise missiles and the trickle-down of military technology into civilian applications, this development brought impulsive aggression, the diversion of funds from beneficial public investment, and a reduced reliance on diplomacy. Accompanying this technology-inspired reconfiguration of military mapping were new notions of territory that a nation-state might claim as well as new prohibitive cartographies to protect these claims.

Chief among these prohibitive genres is aeronautical charting, which arose during the twentieth century to produce, reproduce, and regulate navigable airspace and later became a defensive strategy through the declaration of no-fly zones, actively enforced in some cases but largely rhetorical in others. Radar, a new mapping tool adept at tracking aircraft, became a strategy for enforcing other kinds of no-fly zones, including airspace restrictions above coastal waters and dynamic temporary flight restrictions (TFRs) that could emerge or expand suddenly in accord with the movements of top officials.

The growth of prohibitive cartography during the twentieth century is also apparent in increased maritime restrictions, including the widening of most territorial seas from three to twelve nautical miles and the delineation of Exclusive Economic Zones (EEZs), which gave coastal nations new authority over fishing and subsurface mining within two hundred nautical miles of their shoreline. The advent of offshore drilling and submarine warfare led to a broader, more intensive mapping of the sea floor as well as the discovery of a multitude of seamounts (submarine volcanoes), which triggered a round of aggressive naming reminiscent of the seventeenth century. Mapping had an inevitable if not indispensable role in dividing the seas and shrinking international waters.

New mapping technologies strengthened the bond between national defense and cartography and underscored the unintended consequences of technological innovation. Cold War fears of nuclear weapons and intercontinental ballistic missiles inspired the development of artificial satellites useful not only for monitoring weapons development and launch sites but also for mapping terrain and monitoring weather systems.

More exact representations of the planet's shape and gravity anomalies, originally intended to guide intercontinental ballistic missiles toward precisely pinpointed targets, provided a more accurate geodetic framework for geographic information of all types, civilian as well as military. In addition, the prospect of low-altitude unmanned bombers guided by the automated comparison of altimeter readings with onboard electronic terrain maps led to digital elevation models, which by century's end were supporting civilian applications as diverse as geographical mapping, landscape architecture, and commercial forestry. Moreover, the global network of seismographs sensitive to underground explosions—essential for ensuring compliance with nuclear test-ban treaties—proved useful in studying continental drift and modeling seismic risk.

And finally, the global positioning system, or GPS, intended as a more reliable way to route cruise missiles, became a commonplace tool for navigation, field measurement, land survey, and location tracking.

A fifth key theme is the *Paradox of Globalized Practices and Customized Content.* While the globalization of mapping technology and cartographic practice diminished international differences among cartographic products, fuller customization of map design and content fostered a broader range of cartographic applications, an unprecedented diversity of map types, significant changes in the form and appearance of maps, and the increased prominence of maps in the mass media. The globalization imperative was already apparent in commercial and institutional arenas at the end of the nineteenth century.

Perhaps the quintessential example of these is the "International Map of the World," proposed in 1891 by Albrecht Penck, at the Fifth International Geographical Conference in Bern. The movement toward global standardization intensified after World War II, and new cartographic genres emerged when distinct consumer communities adopted standardized aesthetics that ran from the highly formal designs of marine charts and orienteering

__Figure 5.__ Excerpt from Boston sheet (1912) of the "International Map of the World."

maps to the aggressively informal look of advertising maps and political cartoons.

Prominent examples of international standardization include soils maps and the “World Aeronautical Chart,” which outlived the comparatively purposeless “International Map of the World.” The coexistence of global standardization and increased customization is epitomized by infectiously innovative designs instantly recognizable to map collectors and cartophiles worldwide.

Distinctively functional examples include the “London Underground Map” and Erwin Raisz’s physiographic diagrams. Preeminently ideological examples include the Earth-from-space perspective of Richard Edes Harrison, whose dramatic illustration of the proximity of the United States and the Soviet Union fostered the notion of “Air-Age Globalism,” and the “Peters Map of the World,” which triggered a media scrum between Third World advocates and professional cartographers.

Digital technologies intensified these trends, but globalization often superseded customization. Although illustration and map projection software encouraged map authors to customize their designs for specific audiences, GIS software and web-based mapping typically constrained graphic style while simultaneously supporting flexibility in content and geographic scope. Maps produced using ArcInfo and other products of the Environmental Systems Research Institute (now known as Esri) had a distinctive look epitomized by line symbols in the key that resembled an italic letter *N*. No less distinctive was MapQuest.com, which introduced millions of do-it-yourself online mapmakers to the interactive, zoom-in / zoom-out graphic scale.

The growing ascendancy of digital technologies hastened the standardization of the data structures and the adoption of exchange formats required for efficient communication among data providers, software developers, and mapmakers. Stylistic homogeneity increased when new organizations emerged to promote data sharing both internationally and within governments. By century’s end online mapping applications with a rich toolbox of standardized symbols and layers promised unprecedented customization in content and relevance.

My sixth key theme is *Maps as Tools of Public Administration*. Although maps were used in urban governance during the nineteenth century, they assumed greater importance during the twentieth century in local and national public administration, regional planning, and the representation of national identity. Key roles at the municipal level include land-use planning and code enforcement;

Figure 6. Excerpt from New York City “Use District Map” (1916). Solid, dashed, and blank street symbols represent business, “unrestricted,” and residential uses, respectively.

emergency response; the delineation and publication of election district boundaries; the delivery of regionalized municipal services; the assessment, taxation, and sale of real property; the design, management, and promotion of public transit networks; the analysis and control of crime; the management of networked infrastructure for electronic communication, energy distribution, water supply, and sewage; and the delineation of historic districts established to preserve a city's architectural heritage. Effective municipal administration came to depend heavily on reliable large-scale maps. At regional and national levels, mapping activities evolved during the twentieth century to include map-intensive systems for monitoring weather and water quality, for predicting environmental disasters, and for planning and orchestrating evacuations.

The twentieth century themes presented here run counter to the practice of most map collections, where acquisition strategies range from the systematic ingestion of topographic series maps through a government document depository program to the more eclectic accumulation of older, rarer maps purchased from dealers or donated by wealthy supporters seeking a tax advantage. Without a concerted effort, neither strategy is likely to yield a representative sampling of media maps and facility maps related to the city or the region, a representative sampling fundamental to a twenty-first century map collection. Of course, scanning and electronic media can fill many gaps, particularly with the assistance of a map society or knowledgeable and energetic volunteers, who need not be local. And networked catalogs can be avoid needless duplication as well as give distant users access to a rich diversity of materials, assuming support is available to refresh the electronic storage as needed, to avoid the ravages of disk rot.

Interactive and dynamic maps pose the greatest challenge for progressive map collections, particularly if the chosen strategy requires the concurrent preservation of working software and hardware, easily undermined by ephemeral operating systems. A more reliable and less costly approach to conserving dynamic cartographic artifacts might be to record interactive map use sessions with a variety of users and to maintain these recordings with whatever technology proves effective in conserving the cultural heritage of film, television, and artistic performances in general. This strategy has the added advantage of focusing on map use rather than graphic or physical objects. A still broader approach, designed to focus on impact, not mere objects, might employ documentary films to acknowledge the growing awareness among scholars of the map's value as an instrument of persuasion, empowerment, and resistance.

MAP CITATIONS

Figure 1. *Present Distribution of European Races*, plate iv accompanying Grant, M. 1916. "The Passing of the Great Race." *Geographical Review* 2: 354–60. doi: **10.2307/207903**.

Figure 2. NASA. 1988. Excerpt from color-infrared image, bands 4-3-2, captured in 1988 by Landsat 5. **http://www.nasa.gov/images/content/668535main_Garden_city_KS-1988.jpg**.

Figure 3 (top). Line-printer map from Monmonier, M. 1965. "The Production of Shaded Maps on the Digital Computer." *The Professional Geographer* 17(5): 13–14. doi: **10.1111/j.0033-0124.1965.013_r.x**.

Figure 3 (bottom). Pen-plotter map from Monmonier, M. 1968. "Computer Mapping with the Digital Increment Plotter." *The Professional Geographer* 20(6): 408–9. doi: **10.1111/j.0033-0124.1968.00408.x**.

Figure 4. Map of temporary flight restriction over Vice President Biden's home, Greenville/Wilmington, DE, first issued 27 January 2009, by the Federal Aviation Administration. **http://tfr.faa.gov/save_pages/detail_9_3124.html**.

Figure 5. US Geological Survey. 1912. Excerpt from "International Map of the World on the scale 1:1,000,000," Boston sheet. **http://ark.digitalcommonwealth.org/ark:/50959/x633f991m**.

Figure 6. City of New York, Board of Estimate and Appropriation. 1916?. Excerpt from "Use District Map Section No. 12." **http://digitalcollections.nypl.org/items/510d47e4-7681-a3d9-e040-e00a18064a99.**

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Mapping Temporal Datasets with D3

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INTRODUCTION

Many JavaScript libraries and APIs intended for mapping require long lines of code to perform even the simplest forms of animation. The Data-Driven Documents (D3) software library, however, offers a very simple option for quickly presenting a series of maps. D3's library contains various features that allow for geographic data to be bound to SVG objects in a webpage and presented chronologically. Animations can often be created with one short line of code.

ANIMATING WITH D3

D3 was developed primarily by Mike Bostock at Stanford University in 2011 with the intention of "bringing data to life." It offers a set of JavaScript functions for data visualization, which can be accessed by loading the *d3.js* library into an HTML document. These functions allow for the visualization of data sets by binding them to SVG objects and displaying them in a web browser. SVG is an XML-based format that allows for vector graphics to be grouped, styled, and transformed. After the data are tied to these objects, they may be animated using D3's *transition* method.

The *transition* method is a special type of selector. Selectors allow objects in a webpage to be selected and then manipulated. Objects may be selected based upon their properties, such as tags, classes, attributes, or unique identifiers. Once a selection is made, operators may then be applied. These operators may manipulate an object's attributes, styles, or text content. They may also join data to the selected objects. By itself, an ordinary selector applies the subsequent operations instantaneously. By using the *transition* method, instead, the changes will occur gradually over time as opposed to immediately. When multiple transitions are

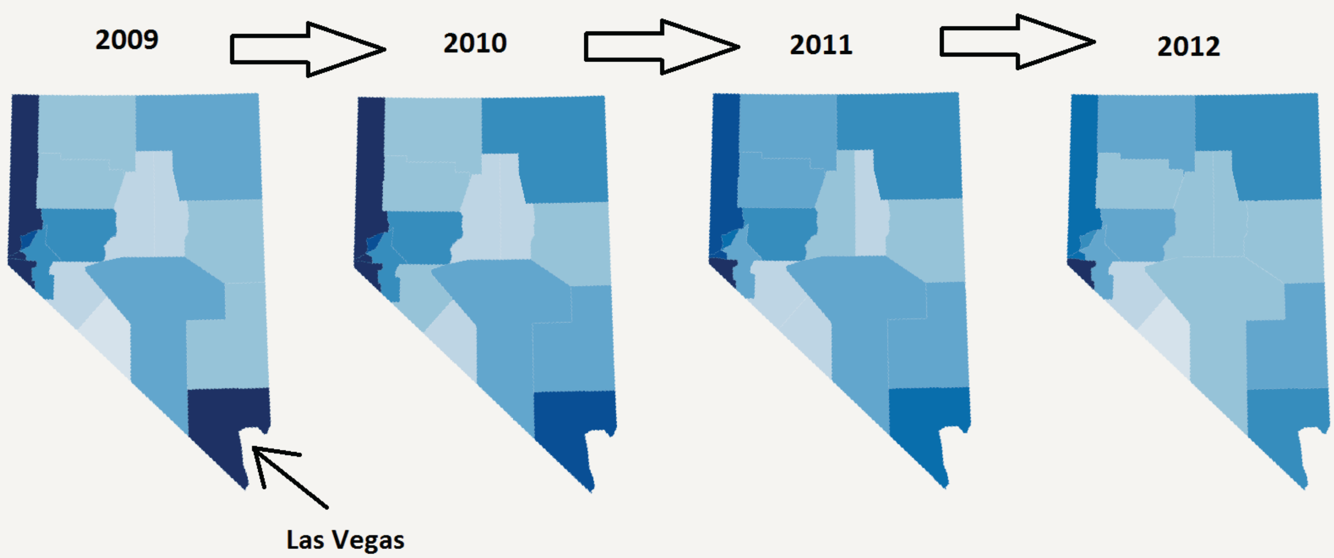

Figure 1. Nevada median home values from 2009 to 2012.

applied, the *delay* method may then be used to add separation between each transition. The *delay* constructor specifies, in milliseconds, how long the transition should wait to begin. By pairing each transition with a delay, the transformation may be specifically timed to string multiple maps together into a smooth animation (see Figure 1).

D3's user-friendly, minimalist approach allows for the easy borrowing of code. There are hundreds of examples of D3 maps on websites such as GitHub, and any example from the Web may be manipulated for use with another dataset with very little effort. Existing code examples demonstrate how to use D3 to take raw datasets and bind them to graphic elements for display in a browser (Figure 2). To add even more functionality, parts of various existing scripts can be combined.

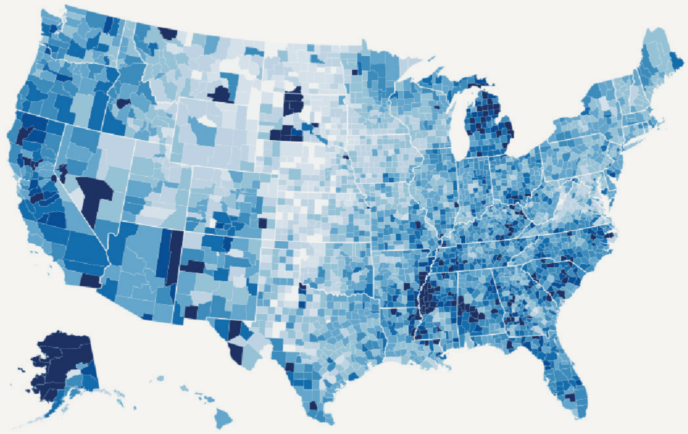

Figure 2. *Mike Bostock's choropleth map of US unemployment rates for 2008 demonstrates the binding of data to graphic elements using D3.*

D3 is very efficient, often requiring less code than other software libraries to accomplish the same task. The selection methods, for example, allow for elements of a webpage to be selected and manipulated either individually or all at once using a single line of code, whereas other libraries often require a *for* loop just to select an element and change one attribute. In addition to these efficiencies, D3 also offers options such as shape generators, scale constructors, and a variety of map projections.

DATA SOURCES

Data may be loaded into a webpage via D3 in multiple formats. D3 can accept GeoJSON and TopoJSON data, which store the coordinates of geographic features, and are variants on the JSON (JavaScript Object Notation) format, which uses simple text to pass attribute data in pairs. JSON files offer a simple way to organize and store data into variables and load them quickly in the background of a webpage. GeoJSON and TopoJSON can also include non-geographic attributes for each feature. Attribute data may also be stored separate from geographic data, in a comma-separated values (CSV) or tab-separated values (TSV) file. In Example 1, used to create Figure 2, a JSON file is loaded in which contains the outlines of US counties.

The United States Census Bureau's American FactFinder is a great resource for finding datasets with a temporal component, with thousands of different categories of statistical data at various levels of spatial resolution. Once downloaded, some manipulation is necessary for the data to be properly read by the specific code in Example 1: it is important to rename the FIPS code field to "id" and the statistic field title to "rate." The data can be saved as a tab-separated file using the extension ".tsv."

MAPPING AND ANIMATION

Once the data files are in the correct format, they may be bound to an SVG element and visualized using D3. SVG uses the *path* variable to bind it to the county geometry defined in the JSON file and draw the counties in a webpage. D3 then uses what it calls a *dictionary* to relate the unemployment values in the TSV file to their respective counties. After data classification using the *quantize* function, D3 uses inline CSS, a computer language used for manipulating the presentation of a webpage, to color each class (see Example 1). CSS offers many advantages to web design because it separates the content of a webpage from its styling.

The animation process begins by drawing the first map. After this is completed, the map may be redrawn multiple times and staggered with the delay function. This can be

```
//Creating choropleth map of U.S. unemployment rates

                                                        //Define fill colors for 9 possible classes
.q0-9 { fill:rgb(247,251,255); } .q1-9 { fill:rgb(222,235,247); } .q2-9 { fill:rgb(198,219,239); }
.q3-9 { fill:rgb(158,202,225); } .q4-9 { fill:rgb(107,174,214); } .q5-9 { fill:rgb(66,146,198); }
.q6-9 { fill:rgb(33,113,181); } .q7-9 { fill:rgb(8,81,156); } .q8-9 { fill:rgb(8,48,107); }
</style>
<body>
<script src="http://d3js.org/d3.v3.min.js"></script>    //Load D3 libraries
<script src="http://d3js.org/queue.v1.min.js"></script>
<script src="http://d3js.org/topojson.v1.min.js"></script>      //Imports external JavaScript file of
                                                                //reusable functions
<script>
  var width = 960, height = 600;                                        //Set size of map in pixels

  var rateById = d3.map();              //Create dictionary to relate counties in JSON to respective values in TSV

  var quantize = d3.scale.quantize()                   //Determine 9 possible classes
    .domain([0, .15])                                  //Set domain with maximum and minimum values of dataset
    .range(d3.range(9).map(function(i) { return "q" + i + "-9"; }));

  var projection = d3.geo.albersUsa()          //Set projection to Alber's Equal Area Conic
    .scale(1280)                               //Preserves area proportionally between two parallels
    .translate([width / 2, height / 2]);       //Ideal for large areas running east-west, such as U.S.

  var path = d3.geo.path()                     //Create path generator, for JSON geometries to be drawn
    .projection(projection);

  var svg = d3.select("body").append("svg")                    //Select body of DOM, append to SVG element
    .attr("width", width)
    .attr("height", height);

  queue()                                              //Load files, wait for ready function
    .defer(d3.json, "/mbostock/raw/4090846/us.json")
    .defer(d3.tsv, "unemployment.tsv", function(d) { rateById.set(d.id, +d.rate); })
    .await(ready);                                     //Populate dictionary with id and rate fields from TSV

  function ready(error, us) {                          //Call JSON file, bind to SVG
    svg.append("g")
    .attr("class", "counties")
    .selectAll("path")
    .data(topojson.feature(us, us.objects.counties).features)                 //Convert JSON to GeoJSON
    .enter().append("path")                                                   //Bind county data to path
    .attr("class", function(d) { return quantize(rateById.get(d.id)); })        //Determine each county's class
    .attr("d", path);                                                         //Draw counties

    svg.append("path")
    .datum(topojson.mesh(us, us.objects.states, function(a, b) { return a !== b; }))
    .attr("class", "states")                  //Mesh state boundaries to prevent duplicate paths for borders
    .attr("d", path); }                       //Draw states

  d3.select(self.frameElement).style("height", height + "px");
</script>
```

Example 1. *Code for Mike Bostock's U.S. unemployment map.*

done by creating an update function that includes some of the same code from Example 1, but with a different year's dataset (see Example 2). The *transition* method creates a pause between the drawings of the two maps. The standard transition time is 250 milliseconds. By using the *delay* method after each transition, that time can be lengthened, adjusting the speed of the animation.

The addition of the *transition* and *delay* components to each update create the animation. The data update function may be repeated for the number of time periods present in the time series. It is important to include the minimum and maximum values that would be appropriate for the entire series of datasets in the original *quantize* function, so that each set is classified in the same way. The delay time must also be incremented in equal intervals to form a consistent animation.

The animated map still needs to be paired with a dynamic title. To do this, the *span* HTML element can be used (see Example 3). *Span*, short for spanning, is similar to the *div* element, as both are used for organizing and styling particular pieces of a webpage. The *div*, or division, element is typically for larger areas of a webpage, and may be made up of many different spans. The *span* element is for smaller areas of text. Both allow for specific parts of an HTML page to be grouped together and easily referred to later in the document. By adding a span to the *h2* element,

```
//Creating update function

function updateData() {

  queue()
  .defer(d3.json, "us.js")
  .defer(d3.tsv, "unemployment2.tsv", function(d) { rateById.set(d.id, +d.rate); })
  .await(ready);                    //Update script with new dataset

function ready(error, us) {

  svg.append("g")
  .attr("class", "counties")
  .selectAll("path")
  .data(topojson.feature(us, us.objects.counties).features)
  .enter().append("path")
    .transition()                          //Create a brief pause between redrawing of map
    .delay(750)                            //Extend pause to 3/4 of a second, increase by
                                           //equal intervals each update

  .attr("class", function(d) { return quantize(rateById.get(d.id)); })
  .attr("d", path);

  svg.append("path")
  .datum(topojson.mesh(us, us.objects.states, function(a, b) { return a !== b; }))

  .attr("class", "states")
  .attr("d", path);

  updateData();                     //Add to each ready function preceding an update function

}
```

Example 2. *By creating an update function that includes a transition and delay constructor, the map may be continually redrawn using a new dataset.*

```
<h2>
    <span> </span> //Add to beginning of body
</h2>

d3.select("h2 span").text("U.S. Unemployment Rates 2010"); //Add to end of ready function
```

Example 3. *By adding a span to the h2 element, the space may be selected in each update function and a dynamic title may be inserted.*

which indicates header text, a new title may be inserted each time the update function is called. In order to create the same animated effect displayed by the map itself, the transition and delay parameters must be added to each title as well. By using the same delay timings from each update function, the titles stagger at the same intervals as their respective maps.

CONCLUSION

D3 NOT ONLY transforms raw datasets into static graphics, but also graphics with movement and interactivity. By using D3's animation capabilities, a sense of change over time may be conveyed. Applying a custom dataset to one of the many D3 map examples on the web is easy; an update function can then be assembled to reload the existing script with new data. The *transition* method is used to redraw the map after the update, and the *delay* operator adds timing to the animation to generate a smooth progression of graphics. The library is simple enough to use so that anyone with a basic understanding of HTML and JavaScript can easily turn almost any time series dataset into an animated map.

A sample animated map, based upon this article, can be viewed at **http://pjbutler.podserver.info/test.html**.

SUGGESTED RESOURCES

Bostock, Mike. 2012. "Choropleth." *Bl.ocks.org*. **http://bl.ocks.org/mbostock/4060606**.

Maps on D3 — Tutorial. 2013. *Social Innovation Simulation*. **http://socialinnovationsimulation.com/2013/07/11/tutorial-making-maps-on-d3**.