Mapping the United States: Telling Stories with Statistics

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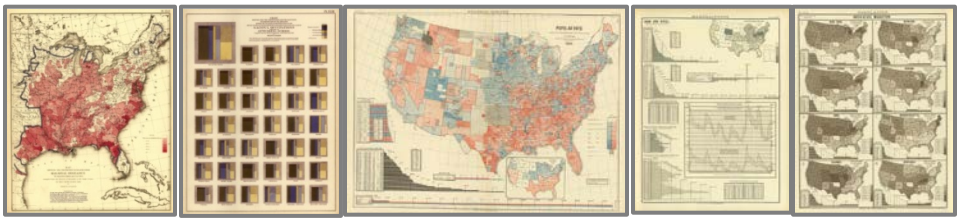
Abstract: The Census Bureau has been a leader in data visualization since the late 1870's. The production of statistical graphics and interactive tools for contemporary decision makers continues today. This paper reviews the Census Bureau's historical traditions of mapping and telling stories with statistics for the American public that reflect the important demographic, economic, and social issues of our time.

Keywords: Mapping, Visualization, Statistical Graphics, Census, History

Introduction

Telling stories with statistics has a long history at the Census Bureau. To those familiar with the maps and statistical graphics in Francis Amasa Walker and Henry Gannett's late-19th century editions of the *Statistical Atlas of the United States*, this brand of storytelling has stood the test of time. Statistical graphics from 1870 showing population density, foreign parentage, illiteracy, occupations, and wealth, altered the visual vocabulary of social scientists. **Abstract:** The Census Bureau has been a leader in data visualization since the late 1870's. The production of statistical graphics and interactive tools for contemporary decision makers continues today. This paper reviews the Census Bureau's historical traditions of mapping and telling stories with statistics for the American public that reflect the important demographic, economic, and social issues of our time.

These vibrant statistical graphics were new and unfamiliar in 1870. Today, most of us are accustomed to the many graphical forms that the Census Bureau and the statistical atlas popularized. Many iterations and spinoffs of this storytelling format evolved both inside and outside the Census Bureau through 14 decennials. Walker and Gannett's works have persisted as important forerunners of data visualization today [*Figures 1-5]*.



Figures 1-5. Examples from Census Office *Statistical Atlas* volumes, 1870 and 1880. David Rumsey Map Collection, www.davidrumsey.com

Visualizing the American Story

For the late-19th century world, maps and graphics showing statistics of U.S. demographic patterns, race, foreign-born compositions, and economic status were new, yet did not require much explanation. People understood them instantly. For a country that had barely recovered from the Civil War, the 1870 atlas was both a confirmation of everything that led up to that critical time in American history, and a road map for the future. For decision makers, the *Statistical Atlas* was an eye-opener. For every well-informed American citizen, it was their up-to-the-minute story—America in the present tense.

Ironically, statistical graphics using U.S. census data appeared initially in Europe. Prior to the publication of the 1860 map showing slave population as a percent of total population by county, the Census Bureau had not produced maps with geographic divisions below the regional level. J.D.B. DeBow, then Superintendent of the Census published a regional map in 1854 census report, *Statistical View of the United States [Figure 6]*. This report inspired August Petermann, a German cartographer to create a map showing slave populations in the U.S. (Schulten, 2010). Statistical maps were among the top-ranked statistical graphics—classified in European literature as *cartes figurative*, or *cartogrammes*--often symbolized in atlases with isopleth, choropleth, flow arrows, cross-hatch, dot, or spot map techniques (Funkhouser, 1938).

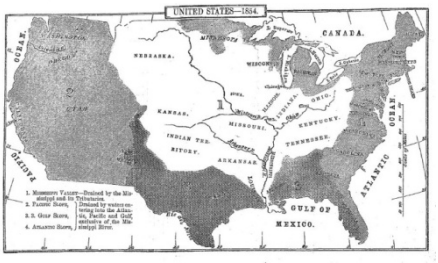


Figure 6. J.D.B. DeBow's 1854 *Map of the United States*. U.S. Census Bureau.

These resources and methods caught the attention of Francis A. Walker, the late-19th century economist, statistician, educator, and Superintendent for the Ninth Census, who quickly enacted a plan to create a national statistical atlas program for the United States. Together with his colleague Dan Coit Gilman (a geographer), Walker devised a program to create an additional volume of the 1870 Census to include a large collection of maps (50 total) and a new cadre of statistical graphics.

The statistical atlas format persisted from 1870-1920 and the Census Bureau amassed an extensive archive of statistical maps with some minor variations with each decennial census. The maps and statistical graphics in these subsequent atlases revealed the many political, demographic, and economic stories of the American population previously hidden in data tables. The mandate of *scientific objectivity* was sometimes blurred by the controversial topics presented in some of the earliest volumes. Alongside these developments, Walker also established a mapping program to create the Census Bureau's

reference maps of enumeration districts for 1880 census operations (Anderson, 1988). Yet, none of his works has had more long-standing reputation than the 50 maps and innovative statistical graphics published in the 1870 atlas. This atlas became the *de facto* visual vocabulary for all future Census products and graphic summaries in census volumes, special publications, wall maps, and online formats.

A remarkable selection of over 400 statistical graphics in 1880 included the first use of multiple maps—"small multiples"—as well as treemaps (Friendly, 2006). A new map series showing the centers of population for the nation began in 1870, and later included centers within individual states (1910). The long shelf life of these graphics has set a precedent for further innovation and experimentation in statistical methodologies and cartography to represent continuous distributions and complex multivariate datasets. For instance, the methodology used to determine the centers of population, described in length in the introductory text for these late nineteenth century atlases, is now fully automated and each new "center" is officially celebrated on location after each decennial. These methodologies gave the U.S. Census Bureau and this American brand of storytelling a considerable "hometown" presence, but also extended to a large international following *[Figures 7- 10]*.

Figures 7-10. Examples from Census Office *Statistical Atlas* volumes, 1890. David Rumsey Map Collection, www.davidrumsey.com.

The Census Bureau in the Golden Age of Statistical Graphics

The statistical atlases of 1880 and 1890 documented the influx of European and Asian populations, the rapid growth of cities, and the expansion of transportation and manufacturing businesses. Data visualizations in these atlases tell the unfolding story of the American people through the late-19th century lens—stories about foreign-born populations, mines and quarries, cotton, railroads, cities, and land grants. Increasingly, "special inquiries of the bureau" were undertaken to summarize important demographic changes using new map types and statistical graphics designed to instantly prove a thesis. For example, Frederick Jackson Turner cited the Census Bureau's decision in 1890 to cease defining the frontier line, a decision illustrated by the map of population density [Figure 7], as the backdrop for his thesis on the role of the frontier in American history. Ongoing experimentations in other non-cartographic representations were equally informative, though their shelf-life was short in comparison to the maps. The brief appearance of radar [or spider] charts in 1900 to represent emerging diseases or the "ranked parallel coordinate plots" used in the 1890 and 1900 editions of the *Statistical Atlas* [*Figures 9-10, above]* to show ranks of the most populous cities at each census were considerably ahead of their time (Friendly, 2006).

Soon after the turn of the century this "golden age" of graphics and experimentation in these new methodologies decreased (Beninger, Robyn, 1978). In 1900, the production of reference maps for "the street book" showing the geographical composition of enumeration districts formalized census operations and ensured a more comprehensive coverage by census enumerators (Magnuson, King, 1995). The "special inquiries" census surveys expanded, and by 1905, the first *mail-out/mail* back census of manufacturing adopted a five-year cycle (quinquennial) separate from the decennial population census.

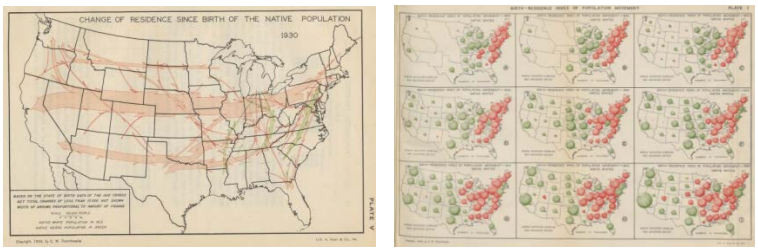
Beginning in 1915, stand-alone graphic summaries and miscellaneous publications on the economy and agriculture initially used data from the decennial census to produce statistical graphics, then eventually used intercensal survey data in 1925 (Wall, Engquist, 1938). From that point on, special surveys and supplemental questions on the decennial surveys collected data on the more sensitive topics of the American economy such as finance and commerce (mortgages, indebtedness) and unemployment.

Statistical mapping hiatus

In an ironic turn of events, an explosion of economic surveys of manufacturing, business, and agriculture, in the early- to mid-20th century was accompanied by a reduction in data visualization and statistical methodologies at the Census (Bachi, 1976). Early in the century, the statistical atlases for the 1910 and 1920 decennial censuses were drastically reduced in size and color folios perhaps reflecting the new austerity that had set in to the nation's economic recession of the 1920s following WWI (Dahmann, 2001). Shades of black-and-white became the favored color ramp for maps, and the simple solid and shaded bars were the most extensively used graphic device for most decennial volumes and graphic summaries from 1910s well into the 1950s. The age and sex pyramid almost entirely disappears from these volumes, and a few new uses of "orthodox frequency curves," treemaps, and small multiples, were introduced to show new topics such as interstate migration, marital status, school attendance and impacts of tuberculosis and typhoid fever. The innovative dot and circle maps used to portray agricultural data in 1914 was later adopted by the Department of Agriculture's *Graphic Summary* series (Dept. of Agriculture) as the primary map type used consistently well beyond the 1930s (Day, 1915).

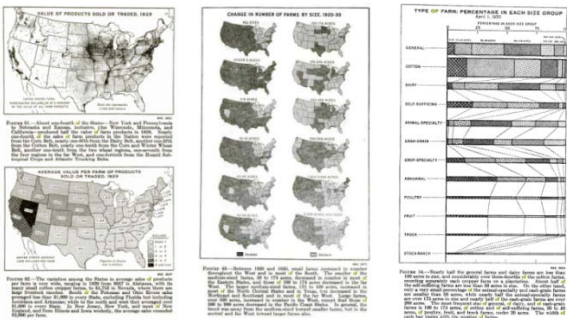
With resources and staff numbers reduced, it is not surprising that the most active experimentation in data visualization occurred outside the Census Bureau during the 1930s. Data visualizations thrived in academic institutions and government agencies using a smaller subset or special summary census data for analysis. Two notable examples are Charles Warren Thorntwhaite (University of Pennsylania's Wharton School of Finance and Commerce) and O.E. Baker (Department of Agriculture). Charles E. Thornthwaite's study of *Internal Migration in the United States* published in 1934 is a telling account of migration history, and American's "increasing sensitiveness to economic change" (Thornthwaite, 1934). His maps showed what most could only surmise from the waves of migrants leaving for California from "the Corn Belt and the Wheat Belt" (Thorntwaite, 1934). Thornthwaite also made note of a significant

movement into Michigan, Ohio, and Indiana as well as an eastward movement into New York and New Jersey *[Figures 11-12]*.



Figures 11-12. Maps from Charles E. Thornthwaite's *Internal Migration in the United States*, 1934. Harvard University Library. (http://pds.lib.harvard.edu/pds/view/4094194?n=3&imagesize=1200&jp2Res=.25&printThumbnails=no)

The devastating changes taking place on the agricultural and economic landscape from the Great Depression appeared on maps showing data for the critical years—1929-1934 and 1930-1935 (Wall, Engquist, 1938). Senior agricultural economist O.E. Baker's narrative in the introduction to the *Graphic Summary of the Number, Size and Type of Farm, and Value of Products* in October 1937 spelled out the worst impacts of the Great Depression with textual explanations and dozens of dot maps, pie charts, and bar graphs generated from 1935 census data *[Figures 13-14]*. Baker's maps and statistical graphics visualized regional patterns such as the increase or decrease in the numbers of farms and changes in sources of income for the American farmers (i.e. supplemental incomes of farmers) (Baker, 1937).



Figures 13-14. Page Excerpts from Department of Agriculture 1937-1938 *Graphic Summary* series. National Agricultural Library. (http://archive.org/details/graphicsummaryof105bake)

A New Statistical Era

During the 1930s and 1940s, statistical attention shifted to the American family, and the effects of the economy on unemployment and ability to work. With the economic downturn following the 1930 decennial census, maps and statistical charts were not

published in a separate statistical atlas but were distributed within single topic census volumes for Population, Metropolitan Districts, and Agriculture. The mapping program reflected a general trend in many statistical agencies toward less analysis and fewer resources to conduct surveys—and very sparse storytelling.

In 1937, the first *Enumerative Check Census of Unemployment* relied entirely on statistical sampling methods to estimate the scope of unemployment following the Great Depression (Biggers, 1938). This was the first scientifically constructed national sample conducted by the Census Bureau using postal workers as enumerators and the first report to include confidence intervals (Card, 2011). The maps in this report are a drastic change from the rich tradition of statistical mapping at the Census Bureau. Statistical data was shown on a very generalized regional scale.

The 1940 census included the first detailed inventory of housing. With a major push from the Works Progress Administration the sample survey continued to gain momentum to address persistent labor and economic issues. “Population problems” since the mid-1930s required additional data on the subcounty level (Anderson, 1988). Finer spatial resolution for data was particularly important for analyzing demographic and economic patterns within metropolitan districts. The need for greater spatial resolution required larger volumes of maps to support census operations, presaging the development of digital spatial databases later in the century.

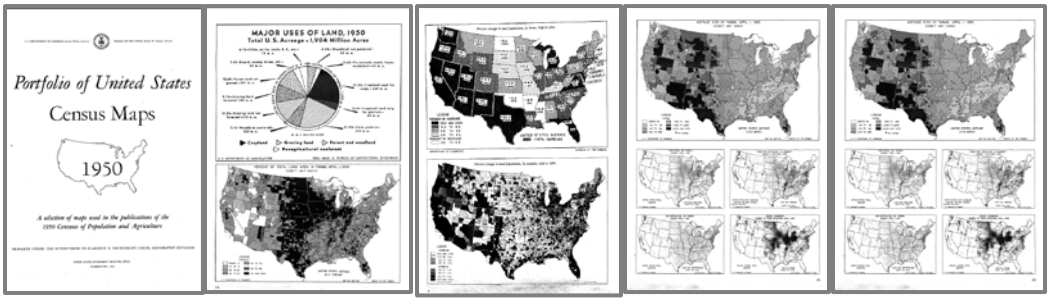
In preparation for the 1940 census, the Geography Division had increased the staff needed to update census maps, draw new enumeration district lines, and manually create three new geographic divisions used for tabulating census data at the subcounty level—the metropolitan districts, census tracts, and blocks (Anderson 1988). In very short order, however, the Census Bureau’s resources were allocated to the war effort as it took on defense-related work with specialized tabulations for projecting draft quotas and other national security concerns (Anderson, 1988). Its budgets were trimmed and remaining staff that had not been drafted were relocated to new defense agencies or moved to a new headquarters in Suitland, Maryland. Meanwhile, the publishing program to present 1940 census results was in full swing. Perhaps to prove its resilience in one of the most challenging times for data tabulation and map production, the downsized Geography Division produced an oversized map of United States population density by minor civil divisions, published in 1942 *[Figure 15]*.

Figure 15. *United States population density map by minor civil divisions: 1940* [1942]. Library of Congress. *American Memory* http://memory.loc.gov/cgi-bin/query/h?ammem/gmd:@field(NUMBER+@band(g3701e+ct003336))

Transitions in Cartography

The increase in surveys and types of data collected after the Great Depression and World War II created an opportunity for the Census Bureau to reclaim its position as a forerunner in data visualization. A booming information age was clamoring for the Census Bureau's official statistics on employment, unemployment, internal migration, and income. The government needed a central clearing-house for information on emerging industries such as petroleum and natural gas, automobiles as well as the dynamics of growing cities and new health concerns. Statistical mapping as well as a quality reference map inventory at the Census Bureau needed time to catch up.

Cartography as an academic discipline and a profession had broadened and matured after WWII as a method of analysis for world issues and events, as well as for homefront concerns. The Census Bureau increased its Geography Division staff and needed to get back to the business of producing hundreds of outline maps for the building blocks of census geography—counties, minor civil divisions, cities, boroughs, towns, and villages. Cartographers in the 1950s produced the black-and-white *Portfolio of the United States Census Maps* in 1955, two years after Arthur Robinson wrote the first edition of the *Elements of Cartography* (1953). The number of maps in the *Portfolio* paled in comparison to the exponential growth of statistical data taking place in all branches of the federal government *[Figures 16-20]*.



Figures 16-20. Page excerpts from *Portfolio of United States Census Maps, 1950*. 1955. U.S. Census Bureau. http://www2.census.gov/prod2/decennial/documents/00642062_TOC.pdf

Meanwhile, the Census Bureau needed to assemble the critical mass of maps to support their rapidly growing mapping programs. Coincidently, in short order, the ENIAC and UNIVAC computers at the Census Bureau began the transformation of reference map production and statistical mapping to automated methods. The statistical mapping process was "computer assisted" at the start of the GE-50 (Geography Series 50) wall-map series (1:5,000,000) scale in the early 1960s *[Figure 21]*. Cartographers revived the *colorized* format (choropleth mapping) with 62 different thematic maps showing demographic,

housing, and economic data for county and standard metropolitan statistical areas (Meyer *et al*, 1975; Bower, 2010). An automated system called the "micrographics technique" processed the data and matched up the geographic codes to a particular class interval. Each class interval was associated with a digital file of the county boundaries, and these boundaries were plotted on color-separated films through a "computer-output-on-microfilm" (COM) device (Meyer *et al*, 1975).



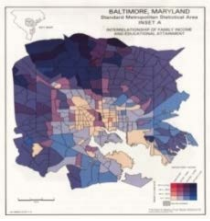


Figure 21. *Population Distribution, Urban and Rural: 1960* (GE-50 series). U.S. Census Bureau. Figure 22. 1970 Population Distribution in the United States (GE-70 series) U.S. Census Bureau; Figures 23-24. *Baltimore Urban Atlas*. 1974. (GE-80 series). JScholarship website. (https://jscholarship.library.jhu.edu/handle/1774.2/34138)

For the 1970 census, the highly successful GE-70 map series (1:7,500,000) featured new thematic map designs such as the depiction of U.S. population as a dot distribution with white dots concentrated and interspersed on a black background *[Figure 22]*. The GE-80 Urban Atlas series published in 1970 featured tract-level data for individual Standard Metropolitan Statistical Areas and multivariate symbology *[Figures 23-24]*. Statistical mapping methods such as graduated circles, dot density distributions, choropleth, and multivariate analysis were incorporated into automated Geographic Information Systems (GIS) designed to process large datasets of tabular information and link individual values and cells to a particular geographic entity. To support the continuously expanding enumeration process and statistical mapping program, the Census Bureau needed a comprehensive, nested, nationwide geospatial database that contained latitude/longitude (x,y) coordinates for every geographical entity that could be continuously updated and instantly linked to statistical data tabulated from the decennial survey.

TIGER in the making

For nearly 20 years prior to its release in 1990, TIGER (Topologically Integrated Geographic Encoding and Referencing) had been looming on the horizon. TIGER an ingenious homegrown system designed to geocode reference information and link geospatial data to statistics was the logical next step in the digital transformation of Census mapping. During the planning stages for the 1970 census, the Census Advisory Committee on Small-Area-Data outlined the initial stages of the GBF-DIME (Geographic Base File-Dual Independent Map Encoding) program. In 1980, the primary goal of the Interagency Technical Coordination Task Force made up of Census Bureau and U.S. Geologic Survey was simply to produce a "digital map of the nation." This digital database combined the Census Bureau's GBF_DIME geographic base files along with the USGS 1:100,000-scale Digital Line Graphs (DLGs), and the USGS 1:24,000-scale quadrangles to lay the foundation for the next thirty years (Bower, 2010). The result was

an accurate and digital base map of x,y coordinates for all the boundaries and geographic entities of the United States to support the enumeration process and to link to the massive amounts of statistical data collected and tabulated by the Census Bureau through a geocoding system.

The TIGER data opened a new world of business opportunities to integrate census data with massive amounts of geospatial information using GIS available to the public as TIGER/Line files in ASCII format. In the 1990s GIS businesses used TIGER data as a primary source of geospatial information for the U.S., and in turn, census operations using TIGER data adapted to changes in GIS technology. In 1990 all maps were produced using automated methods to represent every level of collection geography (i.e. census tract/block numbering areas, block maps, etc.) delineated, geocoded, and stored within the Census Bureau's TIGER database. In 2000, refinements to an automated-address matching capability were added to geocode over 59 million residential addresses to the correct collection geography to create what we now know as the MAF/TIGER[ii] (MTDB) database. Further innovations in digital mapping programs developed by the Census Bureau and the GIS community over the past thirty years have substantially reduced processing time for large datasets from weeks, to days, to hours, to minutes. The Census Bureau produced tens of millions to support census field operations and data dissemination. Statistical mapping as a primary method of data visualization is now an "on demand" process. TIGER/Line shapefiles have been available to the public since 2007.

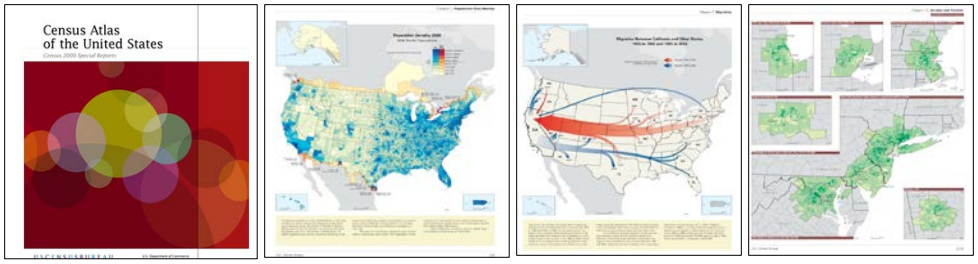
Reviving the storytelling tradition

Though the period between the 1920s and 1960s witnessed a noticeable "stagnation" in statistical mapping, some would consider this a period of "retooling." Statistical mapping at the Census Bureau revamped its operations to handle "big data. During this "retooling" thematic cartography adopted new statistical methodologies that had been developing in academic communities. The GE-50, -70, and -80 series reflected these developments, but only represented a small portion of the data collected and tabulated by the Census Bureau. The storytelling narrative was blatantly missing from these products. Small amounts of introductory text were included with the *Urban Atlas* to describe the methods used to produce the maps, and define the geographic entities and terms included within the individual plates. What was absent was the interpretive text to describe the patterns and processes revealed by the data analysis. The storytelling format of the late nineteenth and early-20th century statistical atlases and graphic summaries had essentially disappeared in Census Bureau mapping products.

Outside the Census Bureau, the statistical atlas storytelling tradition was temporarily revived by the *National Atlas* project. After a series of false starts from 1954-1970, the *National Atlas of the United States* (1970) was again mobilized by a cross-agency working group centralized at the U.S. Geological Survey to create a statistical mapping tome organized by theme. The atlas began as major collaborative project to present large number statistical maps representing contributions from over 84 federal agencies and

bureaus within a single print volume. The atlas was published in 1970 after nine years of concentrated effort, and is the last of its kind to assemble such a comprehensive story of the U.S. in one bound volume. In 1997, a digital version of the *National Atlas* was created.

The making of *Mapping Census 2000* (2001) and the *Census Atlas of the United States* (2007) based upon Census 2000 data ushered a new era of data visualization and statistical storytelling. It was a spectacular revival of the Walker and Gannett statistical atlases, and a culmination of the statistical and survey methods that had evolved over the course of the twentieth century. The maps and statistical graphics in the *Census Atlas of the United States* visualized the nation's past, present, and future with stunning color palettes and detailed thematic data for states, counties, and census tracts *[Figures 25-28]*. The fourteen narratives at the beginning of each thematic chapter were comprehensive and informative. This atlas proved that the storytelling format that had originated at the Census Bureau nearly 130 prior had been revamped for the 21st century. Little did Walker and Gannett know that their mapping techniques and themes could be recreated instantaneously with GIS software and a with powerful geospatial database at its core.



Figures 25-28. Page excerpts from *Census Atlas of the United States*, 2000. 2007. U.S. Census Bureau

Online mapping tools and viewers and beyond

Today, if you can think it, you can map it. Data exploration, data visualization, data mining of census statistics has gone well beyond the storytelling traditions of 1870. New themes of migration, journey-to-work, emergency response, are the focus of new online mapping tools and data viewers available on the Census.gov website. The American Community Survey is a new source of data providing annually updated estimates of demographic and housing characteristics, and has introduced new challenges for mapping confidence intervals or measures of uncertainty. TIGER/Line shapefiles and geodatabases combined with the Census Bureau's statistics have created entirely new business models for map producers to transition from print to web-enabled products. Application programming interfaces (APIs), open-source technology, and web services have enabled users to participate in data mining with new interactive mapping tools. This would not be possible without the last 140 years of innovation at the Census Bureau.

Mapping tools scripted from computer code (i.e., HTML, JavaScript, CSS, Flex) combined with the Census Bureau's API (containing data from the 2010 Census and

American Community Survey) have enabled a new generation of storytelling and data exploration. Tools such as the *Census Data Mapper* enable users to create county-based maps of population, race, ethnicity, family, and households from the 2010 Census. The *Census Flows Mapper* provides an interface to visualize county-to-county migration patterns based on data from the American Community Survey *[Figure 29]*.

The *Metropolitan/Micropolitan Thematic Map Viewer* visualizes demographic variables by census tract from a 2010 special report on the largest U.S. centers of population and economic activity *[Figure 30]*. The *Small Area Income and Poverty Estimates (SAIPE) Interactive Data Tool* visualizes data for annual income and poverty by age for states, counties, and school districts. The Census Bureau's *OnTheMap for Emergency Management* web application provides first responders with tools to analyze employment and demographic data in association with hurricanes, wildfires, floods, disaster declaration areas, and winter storms *[Figure 31]*. The *2011 Language Mapper* is most recent of the interactive map viewers based on American Community Survey data on Language Use in the United States for nation States, and metropolitan and micropolitan areas. It details the number of people speaking languages other than English at home and their ability to speak English, by selected social and demographic characteristics *[Figure 32]*.

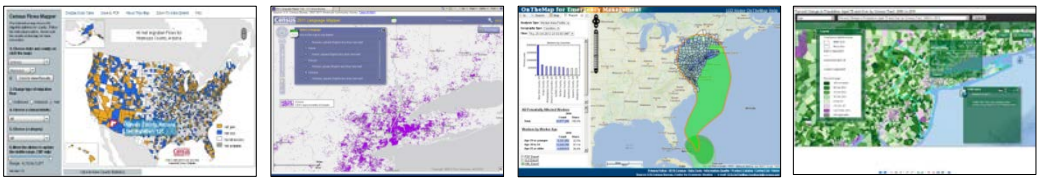


Figure 29. *Census Flows Mapper*; Figure 30. *Metropolitan/Micropolitan Thematic Map Viewer*; Figure 31. *OnTheMap for Emergency Management*. Figure 32. *2011 Language Mapper*. *Census.gov website*

TIGERWeb and Challenges for the Future

Today, TIGER/Line shapefiles are still the Census Bureau's primary product providing geospatial data for use in a variety of GIS-based mapping applications. TIGERWeb is a new extension of the TIGER database featuring an on-line viewer for all features, geographic entities, boundaries, and attributes (such as population and housing unit counts) as well as a web mapping service designed for use with a wide variety of web apps. Reference map and thematic map programs rely heavily upon the accuracy of the MTDB, and the power of GIS to analyze and enable the dissemination of data. Most recently, the Census Bureau has produced TIGER/Line shapefiles pre-joined with demographic data for use in geospatial analysis.

Conclusion:

The MTDB has opened up more opportunities for statistical mapping and analysis, and accuracy standards have improved far beyond what was envisioned in the past. Today,

the data visualization world acknowledges its deep roots at the Census Bureau. Though data mining is much different today than it was in 1870, statistical graphics produced by digital mapping tools and applications have become more crucial for today's decision makers. Census APIs and geospatial data enable users to mine data and create new cartographic analysis from multiple sources to correlate, detect, and derive information and knowledge from large statistical datasets. The MTDB has grown to over 25 terabytes. Public access to the Census Bureau's big data along with open-source technology has continued to transform business models and enabled skilled computer programmers to achieve powerful results. Knowledge and understanding of today's world has also grown as a result. What started with fifty maps in 1870 is now an amazing archive of America's demographic and economic history, and has evolved as an ever-expanding geospatial resource to tell the American story for years to come.

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[i] The views expressed are those of the authors and not necessarily those of the US Census Bureau or Department of Commerce.
[ii] Master Address File (MAF)/Topologically Integrated Geographic Encoding and Referencing (TIGER)