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Counter-GIS Experiments in Distance Interpolation with the Relational Reprojection Platform

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In this paper, we discuss the cartographic genealogy and prospective uses of the Relational Reprojection Platform (RRP), an interactive tool that we built to create custom azimuthal reprojections of spatial datasets with non-linear distance transformations. Building on prior examples of analytically rescaled azimuthal projections in the history of cartography and quantitative geography (from mid-twentieth-century efforts by Torsten Hägerstrand, Waldo Tobler, and William Bunge to more recent digital experiments), we show how our tool brings what were formerly custom artisanal projects into the reach of non-specialist cartographers. In order to illustrate the utility of this method, we highlight recent use cases for the RRP across multiple disciplines and subject areas. These use cases show the myriad ways in which a counter-GIS tool can enable new kinds of cartographic thinking, from visualizing relational spaces within a single context to other kinds of provocation, like presenting changes over time and bringing different relational spaces into dialogue with each other. We conclude with a rallying cry to digital geographers to create more experimental tools to challenge our established notions of visual spatial vernacular while still remaining committed to rigorous, reproducible data analysis.

INTRODUCTION

The much-vaunted "democratization of cartography" (see Crampton 2010; and Byrne and Pickard 2016 for critical perspectives on this trend) over the past fifteen to twenty years has made the production of technically competent maps within reach for many people not previously engaged with geographic visualization. As result, digital maps and map literacy have become a part of everyday life in ways not previously seen. While digital maps can now be found used in endless contexts, they are largely the same *kinds* of maps, produced with a small variety of geographic information system (GIS) software programs (e.g., Esri, QGIS) and websites (e.g., Google MyMaps, MapBox). Especially stark in web and mobile space, these "slippy maps" (Turner 2006) are generally yoked to the same web Mercator projection (Monmonier 2004), and thus the same kind of naïve representation of absolute space. The ubiquity of such maps is increasingly confounding, given the contemporary technical environment, full of powerful tools (the JavaScript libraries D3 and Proj4, to name two prominent examples) capable of projecting spatial data in myriad complex ways.

The **Relational Reprojection Platform (RRP)** is a small computational tool that we have been working on since 2018 to help draw users out of Euclidean space in order to consider the insights that can be drawn from examining data in *relational space*. Following David Harvey (1973) and his tripartite division of concepts of space into *absolute*, *relative*, and *relational*, we consider our platform as offering the opportunity to operationalize a move from absolute space to relative and relational space: relative since all of our data points are considered in their distance and bearing relative to a central point, and relational because the platform is used to convey the strength of relationships between places and the nature and scalar structure of that connection. Whereas a merely *relative* projection tool would only record different kinds of distances (for example, substituting time, travel cost, or other metrics for Euclidean distance) still in a linear fashion, it is this *relational* perspective that pushes the representation beyond what is possible with a linear distance scale.

In setting out to build what we refer to as a "counter-GIS" platform to take an approach to relative distance into the digital realm, we produced a computationally precise tool for heuristically exploring spatial relationships in point data sets. We do not use the term "counter" to signal a struggle *against* GIS, but rather as a *balance* of alternative approaches, like a counterweight to the inertia behind dominant mapping and spatial analysis logics codified into commercial software. While we dive into the computational mechanics of the RRP elsewhere (Payne and McGlynn 2024), the purpose of this piece is to illustrate the ways in which the RRP can change how we think about spatial data. There have also been several improvements made to RRP since the previous piece, most strikingly the ability to include polygon or line layers for contextual "basemap" purposes that are subjected to the same non-linear transformations as the main point data layers, which we illustrate through example data sets below.

In the following section, we sketch out our framework for thinking about GIS logic in cartography, which guided our approach to the RRP's development, lightly historicizing similar approaches in pre-GIS computational cartography. Following that, we present three contemporary case studies in which the RRP allowed us to illustrate relationships otherwise difficult to communicate in Euclidean space. Finally, we close the article with discussion about future directions for the RRP and more generally, the value of new tools with more capacious approaches to space.

BACKGROUND

The RRP was developed as a part of a workshop on "geographic imagination systems" hosted by David O'Sullivan and Luke Bergmann in 2018 (see also Bergmann and Lally 2021; Lally 2022a; Lally 2022b). Though we initially posed a version of the RRP method to solve a representational problem in showing qualitatively linked but physically distant data points, we were quickly confronted with the reality that mapping strategies from the pre-GIS era would have made this kind of experimentation easier. Our starting case was research on commercial gentrification in American cities, where one of this article's authors aimed to represent connections between distant urban neighborhoods that nonetheless had common qualities and linkages, like parts of Oakland, California and Brooklyn, New York. A traditional cartographic visualization with a standard projection would have thousands of miles of negative space between these two cities, and a network map would present their relationality in data space only, without considering physical location at all. What began as a visualization problem became an endeavor to build a rigorous analytical tool.

We approach RRP's conceptual lineage through pre-GIS computational cartography and time geography, inspired by geographical researchers who created analytical graphics featuring non-linear distance scales that are deceptively difficult to produce with contemporary tools (Tobler 1976; Tobler 1987). Among the key works we've looked to during RRP's development, we have identified a collective emphasis on mobility and migration as the thematic ground on which distance experimentation is operationalized as a uniting thread, which in turn is reflected in our case studies. This attention to movement shows through in early representations of time geography, be it plotting the migration flows of residents of a small town in Sweden (Hägerstrand 1957) or warping the street grid of Seattle to reflect travel time from a central point rather than Euclidean distance (Bunge 1966). Bunge continues to use relative distance to dramatic effect in more explicitly political experiments, mapping the increasing "nearness" of a military nuclear catastrophe (Bunge 1988). Further, transport geographers have illustrated the time-space compression that goes along with different travel infrastructures through creative visualization of changing airline flight schedules in New Zealand (Forer 1978) or road construction in Venezuela (Marchand 1973) and South Africa (Pirie 1977). Critically engaging with movement and mobility enables broader thinking about distance, especially in the way that human movement patterns encode varying spatiotemporal scales, in which the probability of moving between places does not scale linearly with the distance between them (Alessandretti et al. 2020). Movement across space and time is thus a fruitful place to reckon with representing relative and relational space, as we demonstrate in our case studies in the next section.

The RRP is one contribution among multiple concurrent efforts toward breaking the over-determined Euclidean habits imprinted on us by GIS logic, and bringing disparate threads of geographic thought and practice together (Wilmott 2024; O'Sullivan 2024). Approaching RRP as a tool for both rigorous attention to uncertainty (Westerveld and Knowles 2021) while still maintaining what Nick Lally (2022b) calls the "expressive" character of the tool allows for playful exploration of spatial data, while explicitly breaking Euclidian standards (see also Hogräfer et al. 2020 on "map-like visualization"). Endeavors into time geography in the past few decades notwithstanding (L'Hostis 2009; Schwanen and Kwan 2012), the warping of space relative to travel time remains a task more easily accomplished without GIS, though easier now due to advances in software tools. We orient the RRP as part of the recent constellation of alternative tools built to challenge hegemonic logics.

Of course, de-emphasizing fidelity to linear distance scales in order to convey relationships is not new to cartography, nor is it scarce in our contemporary cartographic lives. Commonly seen specimens of relative distance in cartographic representation include tourism maps or public transit schematics. For example, a map of an amusement park or the downtown of a heavily touristed area prioritizes attractions rather than path length, while still giving a visitor ample information to navigate the park based on approximate bearing, milestones, and other "nodes" and "landmarks," in Kevin Lynch's framework from *The Image of the City*, that bear meaning in peoples' lived experience (Lynch 1960). Conversely, many subway and commuter rail maps explicitly attach a price to distance (through concentric fare zones) while simultaneously abstracting out the variation of Euclidean distance within those zones. However, for all the common literacy of these alternative distance representations and for their relatively common presence in our lives, relative distance in general has been left out of the cartographic democratization project. If you want a (beautiful, thoughtful) pin map, now anyone can do it; if you want a more complex approach to space, hire a professional cartographer, or just as likely a graphic designer working outside traditional digital mapping workflows.

WORKFLOW

The Relational Reprojection Platform is an interactive application built using the Shiny framework for the R programming language. Upon opening the application (see Figure 1 for a screenshot of the interface), users can upload their own point dataset containing one or more quantitative variables that relate back to a central point, specified in the dataset using an "Is_CTR" field, effectively creating a customizable azimuthal projection. Using the RRP is then a reflexive process for considering the way that places relate to each other, and selecting an

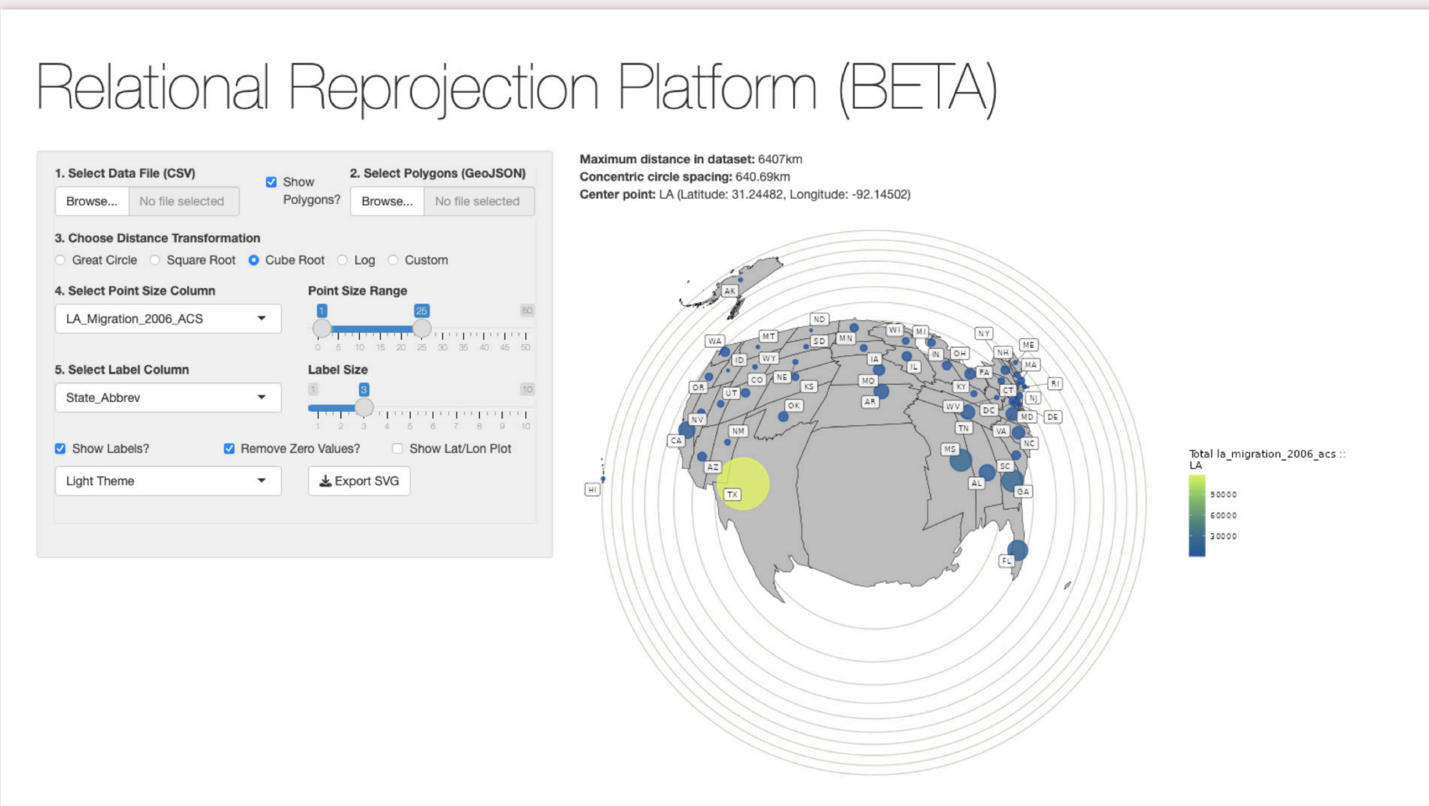


Figure 1. RRP workflow screenshot.

appropriate distance decay function for the phenomenon in question. For some uses, like international migration or tourist patterns, a simple linear or perhaps a square root distance decay are appropriate, but for mapping phenomena that have different underlying spatial logics, more extreme decays are required. A paradigmatic example of a situation lending itself to a logarithmic decay would be a classic from economic geography: the location of customers for a general retail business like a supermarket or a gym. Most customers for establishments like this are located very close to the business, with a quick drop-off in probability as you get farther away, but outliers from other cities/states/countries (e.g. tourists, visiting family members, people on business trips) will appear at the margins. Dropping a spreadsheet of customer locations into a standard GIS software suite would default to a projection that visually emphasizes the thousands of miles of negative space between a visiting Californian and a business in Boston, rather than showing the tightly focused underlying spatial pattern, the signal behind the noise of the pin map approach. The RRP's workflow allows users to start with this tightly focused approach, fine-tuning the results by modifying both distance and symbol interpolation settings (Figure 1).

CASE STUDIES

To illustrate a variety of possible use cases for RRP, this section will present three case studies, each of which demonstrates a different kind of comparison that this technique makes possible. First, we reproject American Community Survey (ACS) data on where Hurricane Katrina victims moved to, using our RRP version to show the advantages of a non-linear distance transformation in showing relational geographies across scales. Second, we look at migration data from the International Organization on Migration (IOM) over the course of several years to show how RRP allows for comparison of spatial relationships over time. Finally, we present a more speculative use of the software, based on a collaboration that aims to shed light on the importance of scarce water resources to coffee's global commodity chain.

CASE STUDY 1: NON-LINEAR RELATIONAL GEOGRAPHIES

Making landfall in 2005, Hurricane Katrina was one of the deadliest and most costly natural disasters in American history. In the years since, many maps and visualizations of the storm's damage have been produced, including some that take a relational approach, showing how the impact of this event was felt far beyond the Gulf Coast that was the hardest hit region. Originally produced for an article in *Smithsonian* Magazine, the Smithsonian Institution in partnership with Esri gathered ACS data from 2006 about state-to-state migration in the wake of Katrina, representing the movement pattern through proportional symbols atop a choropleth map of number of migrants per state (see Figure 2). While the map effectively communicates the mass movement the disaster instigated, it does little to contextualize the differences in regional impact of such movement. It also commits the cardinal cartographic sin of representing raw counts on a choropleth map, though the proportional circle overlay of the same information is a more appropriate choice.

To show how RRP can address some of these limitations, we have recreated the map using the same data (Figure 1 shows the dataset loaded into the RRP; see Figure 3 for a cleaned-up version based on the SVG export from RRP). One limitation of the existing map is that only the lower 48 states are shown in the default view; while map users can scroll around and zoom in and out to see Alaska and Hawaii, there is no guarantee that they will. This may seem unimportant for something like migration after a disaster, since a reasonable first assumption would be that neither state received many Katrina migrants given their vast geographic distance from Louisiana. On

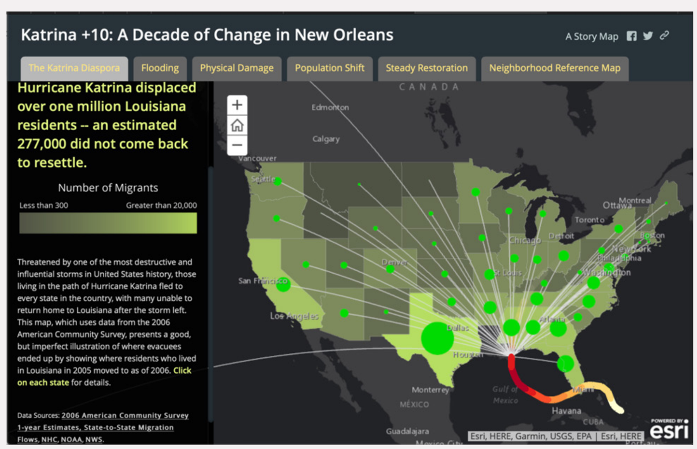


Figure 2. The **Katrina Diaspora webmap**, by Esri and Katie Nodjimbadem, 2015.

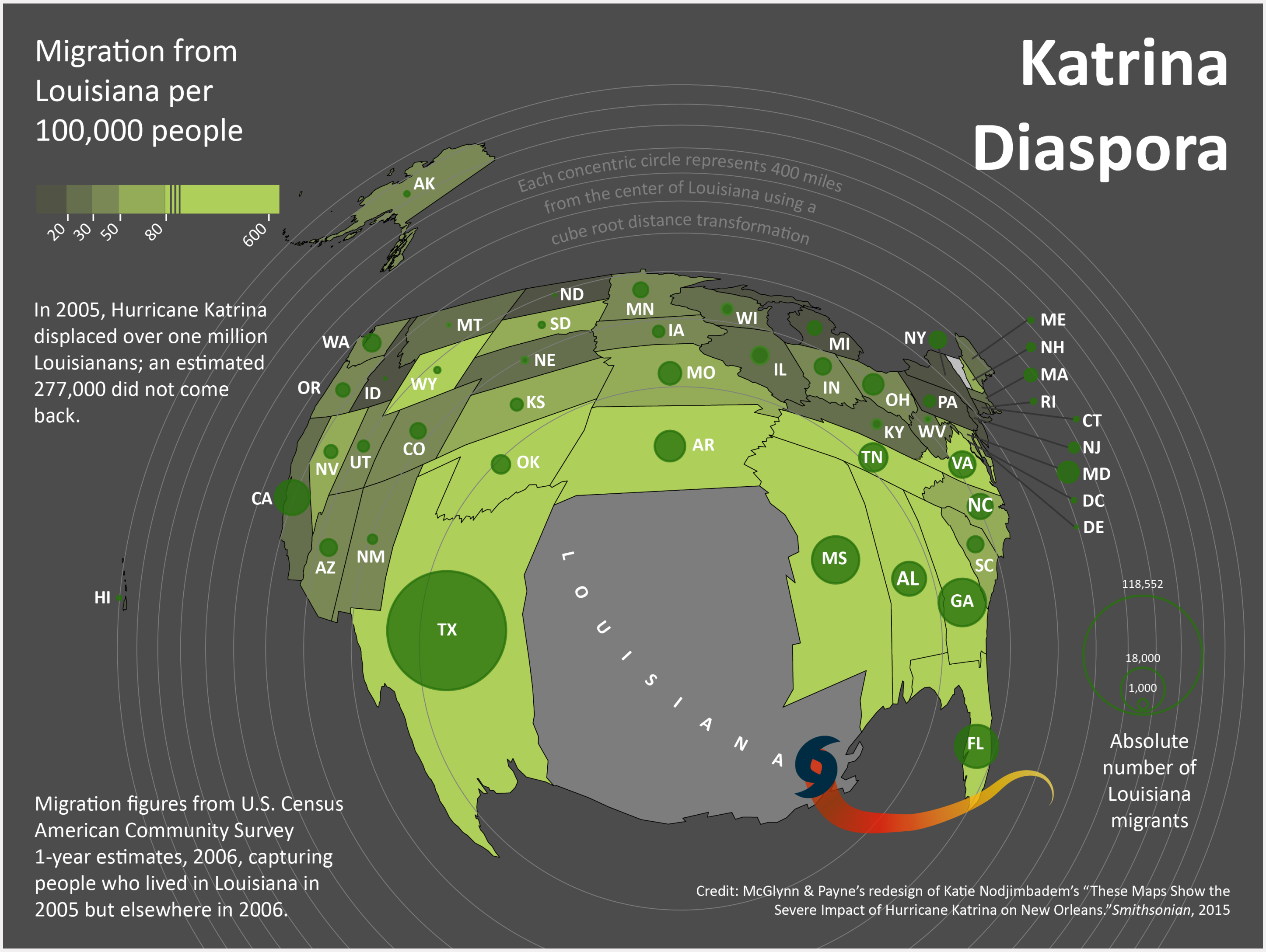


Figure 3. Our version of the same dataset using RRP.

inspecting the data, however, Alaska in particular had a sizable migration number for its population, with a tally of 50 ex-Louisianans per 100,000 state residents, higher than the proportion, 29/100,000, in California, and even higher than many densely populated Northeastern states like Massachusetts (24 per 100K), New York (13), New Jersey (12), or Pennsylvania (10). One potential reason for this discrepancy is the prominence of the fossil fuel sector and other extractive industries in both Louisiana and Alaska; displaced residents with work experience in oil and gas may have taken jobs on the fields of the North Slope instead of offshore in the Gulf. For the same reasons related to the fossil fuel sector, Wyoming stands out on our map (but not on the original map, due to its lack of relative comparisons) compared to its neighbors, with a proportion of 85 ex-Louisianans for every 100,000 state residents, almost as high as Florida's rate of 90 per 100,000. Clearly proximity on the Gulf Coast and total population matter in terms of post-Katrina migration patterns, but they are not the whole story.

In the RRP version, we have also normalized the raw number of migrants per hundred thousand people in the receiving state. We did this in order to bring out the regional relationship further, supplementing the raw numbers in the proportional symbols with normalized data represented as quintiles on a choropleth. In our version of the map, the influence of the disaster on large population states like California and Texas are tempered by the normalization. California's importance fades while the importance of Texas as a receiver state is still emphasized. Similarly, smaller Gulf-adjacent states like Arkansas emerge as important host communities, accepting many more disaster migrants relative to their population than larger population centers. Though these initial observations are in part an argument for better normalization practice in cartography, we contend that the greater regional focus provided by our RRP map of migration out of Louisiana makes it especially important to consider relative, not absolute, rates of emigration.

CASE STUDY 2: TIME COMPARISONS

This case study extends the concept behind the first example, migration mapping. Whereas in the Katrina example, the main focus was the spatial pattern of the disaster diaspora in a single moment of time, the second case study is a comparative case meant to investigate the impact of a different disaster, the COVID-19 pandemic, on migration into Italy.

In 2015, more than a million people crossed into the European Union (EU) with the intention of petitioning for asylum. The bump in migration to the region was instigated by not only the worsening Syrian war, but also many other instances of localized political and economic instability across the world. Following this so-called "migration crisis," various EU countries made serious changes to their migration policy, tightening control of both land and sea borders, resulting in a severe drop of arrival figures initially, but one that has been steadily rising again each year since. In parallel, the United Nations IOM began tracking mixed migration to the EU through major receiver countries. Mixed migration flows, by their definition, are made up of people "travelling together, generally in an irregular manner, using the same routes and means of transport, but for different reasons," including "asylum seekers, refugees, trafficked persons, unaccompanied/separated children, and migrants in an irregular situation" (IOM 2019, 141–2). Chief among these arrival countries is Italy, a country with many islands adjacent to North Africa, making informal entry by boat more feasible than many other EU countries.

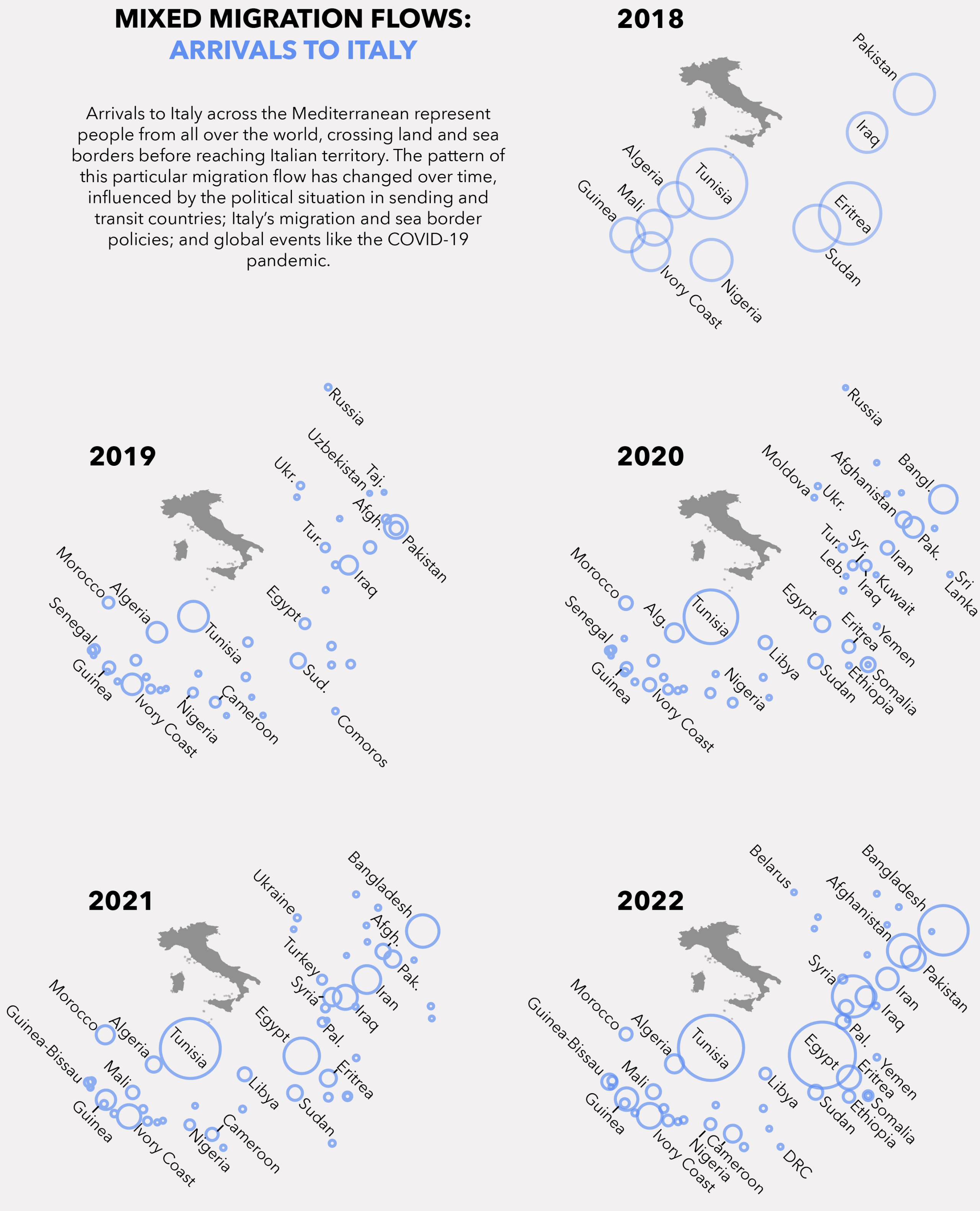
This case study proved an exercise in data exploration as well as time comparison. Initially setting out to compare migration pre- and post-COVID-19, the dampening effect of the pandemic on migration was belied by a larger story of Italian internal politics and changing migration policy. Whereas COVID-19 border closures make less difference on mixed migration flows, dependent on informal modes of arrival, Italy's changing policies toward Mediterranean ships are more visible through RRP.

Comparing between time slices, mixed migration arrivals to Italy in 2018 (as recorded by IOM) are greater than in 2022, and only from a handful of countries—mostly in North Africa, and particularly Italy's nearest Mediterranean neighbor, Tunisia. There is a precipitous drop in numbers from individual countries' arrivals not during the COVID-19 peak but the year before, where the large North African figures plummet and single-digit numbers of arrivals from other farther-flung countries emerge. This pattern change is almost certainly illustrative of the 2018 closure of Italy's ports and then Minister of the Interior Matteo Salvini's drastic attempts to shun Mediterranean rescue boats. Further, in 2020, while arrivals to Italy were still representing a variety of countries in small numbers, the resurgence of Tunisia is significant: migration from countries where several land borders would have to be crossed (not an easy proposition in the pandemic era) before taking a boat did not have a resurgence until later. However, for those in Tunisia the route to Italy was more straightforward, though still more dangerous. In the context of mixed migration, whether the Italian border was closed meant less than the number of additional places migrants might have to pass through. In the post-COVID-19 moment, the migration story is one of a diversifying immigrant population to Italy, more willing to cross land borders before approaching Italy by sea.

The square root distance interpolation allows us to keep far flung places like Bangladesh and Russia in the narrative without losing sight of the importance of the enduring relationship between Italy and North Africa. While it's possible to add the country outlines to this graphic, we opted not to, in order to instead lay bare the widening impact of an increasingly cloistered Italy in what could be a borderless world. To build a more polished illustration to go with our observations, we used the size controls for the proportional symbols to standardize symbol size across time slices based on the peak arrival figures (2018). RRP's export function then provided an SVG with all of the adjusted proportional symbols, ready to edit into a custom graphic (Figure 4). More effectively than iterating through choropleth maps on the same data, RRP allows for an exploratory analysis of a data set revealing the unevenness of mixed migration flows over time.

CASE STUDY 3: CONTEXT COMPARISONS

The final case study we present draws from a University of California, Berkeley research project that we used RRP to assist on. The researcher, Berkeley professor of New Media



Source:
UN International Organization on Migration's databank.
Symbol size reflects the number of arrivals to Italy per country of origin in Q3 (July-Sept) for 2018-2022.

Figure 4. Our visualization of mixed migration flows to Italy.

Greg Niemeyer, was doing preliminary work for a project on hydrocolonialism in the context of the massive in-progress Thwake dam project in Kenya that will displace large numbers of regional farmers. Niemeyer wanted to make a visualization showing the locations of all Starbucks locations in San Francisco compared to all of the water boreholes in the same amount of land in Makueni County, Kenya, a region affected by the dam project. The dam, meant to serve both agricultural and domestic use, exists in an agricultural zone that also experiences poor water access. By overlaying the boreholes—three of which have already run dry—the map shows how much farther people in Makueni County have to travel for drinking water than someone on the street in San Francisco craving an expensive cup of coffee. The juxtaposition is meant to highlight the disparities underwritten by such a water-intensive crop as coffee. This visualization set the stage for a more engaged projected on the futures of the Makueni region in light of a huge infrastructural change (Niemeyer 2023).

In this case, we decided to keep the distance decay linear, rather than transform distance in a non-linear fashion, so the main contribution of RRP was in quickly being able to create point layers around a central location. Because the "custom" option for distance calculation is actually a stepwise function of three linear decay functions, reproducibly creating the same customized distance decay on multiple data sets is possible with RRP. The resulting graphic (Figure 5), tells a small but powerful story about water access and privilege.

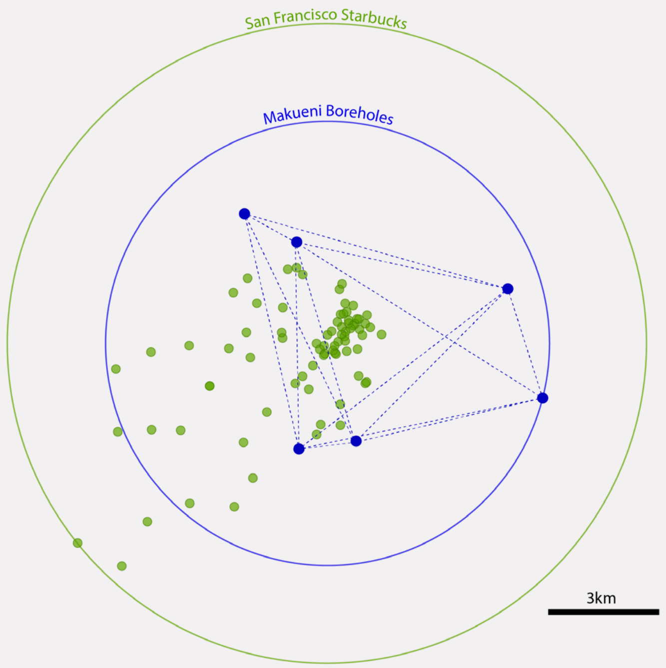


Figure 5. Our visualization in support of Greg Niemeyer's project.

DISCUSSION

The above examples have shown some of the potential we believe that the RRP has to facilitate the creation of the kinds of non-linear distance scales and relational maps that have seldom been seen since the early days of computational geography. While we were sure to present examples where RRP output contributed to a polished product, we also see RRP as a contribution to exploratory data analysis workflows, wherein RRP is a tool for thinking through the spatial relationships in a data set. There are likely many other uses for this technique that we have not identified, and our hope is that by providing this as free and open-source software (FOSS), cartographers will be empowered to use this tool in unexpected ways.

In a more general sense, RRP represents the quiet power of small tools. While at heart RRP is a simple tool for customizing an azimuthal projection, as we've explained above, that one function can be used in sophisticated ways to learn more about data sets and to tell complex stories about them. In presenting case studies of RRP with different datasets, we are advocating for adoption of a program we find useful. Alongside our own tool, we hope to rally our colleagues across cartography and digital geography to continue to temper contemporary over-determined spatial vernacular by building still more counter-GIS tools to analyze spatial data and to change the way eager map readers see the world by changing how it is represented.

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Robinson, Arthur H., Joel L. Morrison, Phillip C. Muehrcke, A. Jon Kimerling, and Stephen C. Guptill. 1995. *Elements of Cartography, 6th Edition.* New York: John Wiley & Sons.

Articles in Periodicals: Author's or authors' names as in *Books,* above. Year. "Title of Article." *Title of Periodical,* volume number, page numbers, DOI if available. Follow punctuation and spacing shown in the following example.

Peterson, Michael. 2008. "Choropleth Google Maps." *Cartographic Perspectives* 60: 80–83. http://doi.org/10.14714/CP60.237.

Articles in edited volumes: Name of author(s). Year. "Title of Article." In *Title of Edited Volume*, edited by [Editor's or Editors' names, not inverted], page numbers. City of Publication: Publisher's Name.

Danzer, Gerald. 1990. "Bird's-Eye Views of Towns and Cities." In *From Sea Charts to Satellite Images: Interpreting North American History through Maps*, edited by David Buisseret, 143–163. Chicago: University of Chicago Press.

Websites: Websites should generally be referenced in running text with a hyperlink ("On its website, the Evanston Public Library Board of Trustees states…"). If a more formal citation is necessary, use: Name of author(s). Year. "Title of Document." *Title of Complete Work (if relevant)*. Access date. URL.

Cartography Associates. 2009. "David Rumsey Donates 150,000 Maps to Stanford University." *David Rumsey Map Collection*. Accessed January 3, 2011. http://www.davidrumsey.com/blog/2009/8/29/david-rumsey-donates-150-000-maps-to-stanford.

Maps: Maps should be treated similarly to books, to the extent possible. Specific treatment may vary, however, and it is often preferable to list the map title first. Provide sufficient information to clearly identify the document.

A Plan of the City of New York and its Environs. P. Andrews, sold by A. Dury in Dukes Court, St. Martins Lane, surveyed by John Montressor, 1775.

E-mail correspondence: E-mail messages may be cited in running text ("In an e-mail message to the author on October 31, 2005, John Doe revealed…") instead of in a note or an in-text citation, and they are rarely listed in a bibliography or reference list.

Additional examples: For additional examples, please consult the latest edition of *The Chicago Manual of Style*, (chicagomanualofstyle.org).

DOI NUMBERS: DOI numbers for references must be included whenever available. You can look up DOIs at www.crossref.org/SimpleTextQuery.

REFERENCES LIST: The list of references should begin in a separate section, immediately after the text. Entitle the section "References" and list all references alphabetically by the author's last name, then chronologically. Provide full, unabbreviated titles of books and periodicals.

FOOTNOTES: Footnotes should be used sparingly: i.e., only when substantive enough to amplify arguments in the text. They should be addressed to a single point in the manuscript.

UNITS OF MEASURE: *Cartographic Perspectives* uses the International System of Units (metric). Other units should be noted in parentheses.

EQUATIONS: Equations should be numbered sequentially and parenthetically on the right-hand edge of the text. If special type styles are required, instructions should be provided in the margin adjoining the first case of usage. Authors should carefully distinguish between capital and lower-case letters, Latin and Greek characters, and letters and numerals.

TABLES: Tables should be discussed in the text and denoted by call-outs therein, but the meaning of a table should be clear without reading the text.