Introduction

In 1569, Dutch cartographer Gerard Mercator created a projection that allowed mariners to chart and follow a course based on a line of constant compass bearing over long distances. A little over three hundred years later, in 1900, German geographer Max Eckert and American geographer J.P. Goode criticized the misuses of the Mercator Projection on world maps for reference and thematic mapping (Scharfe 1986; Goode 1927). Between 1569 and 1900, the use of the Mercator Projection had spread from its intended nautical audience and often had been inappropriately used in reference and thematic mapping. The utilization of the Mercator Projection for reference and thematic mapping is a problem because the Mercator Projection is a rectangular projection with great areal exaggeration, particularly of areas beyond fifty degrees north or south (Greenhood 1964, Robinson 1990, Snyder 1994) . Despite this obvious flaw the Mercator Projection has been and is still widely used for world maps aimed at a general public audience (Dwyer 2017).

This article traces how the Mercator Projection spread from nautical cartography to most reference and thematic world maps in western European and United States cartography. As a result, the focus of this research is not on nautical cartography, rather it targets the moments when the projection moves away from nautical cartography and establishes itself into reference and thematic mapping. Examining the rise of the Mercator Projection sheds light on the complexities of mapping, the choice of map projection and the nuances of the role of maps in and throughout history. First, there is a gap in the literature that warrants further assessment of the Mercator Projection. Second, it reveals how the inappropriate use of the Mercator Projection in western cartography for reference and thematic world maps rose from early scientists' and explorers attempts to improve navigation and the publication of their work by geographic and scientific societies. Early thematic maps and the subsequent versions published in scientific journals and official government reports, created a connection between the Mercator Projection and science in western European cartography. It validated the perception to the western general public that the Mercator Projection was scientific.

Literature Review

The literature on Gerard Mercator and the Mercator Projection contextualizes and explains the significance of Mercator and his famed projection, it notes the failings of the projection for general reference and thematic maps, and suggests that the wide use of the projection has serious implications for the general populace's development of mental images of the world (Robinson 1990, Crane 2003, Taylor 2004, Brotton 2012, Monmonier 2004, Battersby 2014). However, the current literature fails to explain why and how it became a prevalent choice for world maps and atlases in western reference and thematic mapping.

The biographies of Gerard Mercator and other previous works contextualize Mercator and the Mercator Projection. Despite Gerard Mercator's significant contribution to cartography, few biographies have been written about him. Mark Monmonier stated that Mercator "distinguished himself at various times as a calligrapher, an engraver, a maker of scientific instruments, and a publisher. No less impressive were his discoveries in mathematics, astronomy, cosmography, terrestrial magnetism, history, philosophy, and theology" (Monmonier 2004, 31). Other biographers have expanded upon Mercator's life to portray him as an important voice in the scholastic socio-cultural times in the Spanish Dutch provinces (Crane 2002; Taylor 2004).

Unlike the Mercator Projection for navigational charts, no particular projection was designated, or identified as ideally suited, for reference and thematic maps. It should be briefly noted that in addition to navigation, Monmonier states the other appropriate uses for the Mercator Projection are weather maps and geophysics (Monmonier 2004, 14). It was not until the early twentieth century that cartographers began to construct projections specifically for thematic maps (Thrower 2005). Throughout history, alternatives have been presented to the Mercator Projection for reference and thematic maps at a world scale. The Globular, Eckert Projections 1-VI, Goode's Homolographic and Homolosine are a few examples (Eckert and Joerg 1908, Goode 1927, Goode 1933, Snyder 1993). Undoubtedly, the alternative projection that has spurred the greatest debate is the Gall-Peters projection, which resulted in the creation of the Robinson, and recently, the Patterson and Equal Earth projections (Peters 1983, Robinson 1990, Patterson, Savric and Jenny 2014, Patterson, Savric and Jenny 2015).

The history of cartography frames and helps to explain the repeated choice of using the Mercator Projection. Due to the influence of J.B. Harley, the discipline has shifted away from studying the technical history of maps to understand how humans use maps as tools to make sense of their surrounding environment at various scales (Harley 1987). In the 1980's, Harley created an epistemic break with the field. Foremost, Harley emphasized examining maps as social constructions, pushing for the writing of a relevant history of cartography that examined maps based on the context and policies that governed individuals and institutions in the content and production of maps throughout history (Harley 1987). Currently, the history of cartography is practiced throughout various fields. It's uniting scholastic core is that maps are intellectual constructions through which humans have organized, comprehended and manipulated spaces and places (Edney 2009).

The history of geography provides the next links in discovering the expansion of the Mercator Projection from nautical cartography. First, it expounds upon how the Mercator Projection spread from navigation charts to reference and early thematic mapping through the founding and growth of geographic societies. Second, it identifies the impact that Sir Edmund Halley, Captain James Cook, Charles Darwin, and Alexander von Humboldt had on changes in the display of geographic data, and by association the validation of the Mercator Projection for the display of that data. The history of geography reflects how the use of the Mercator Projection permeated throughout western European and United States mapmaking. Maps reflect cultural perception, and the use of the Mercator Projection for general reference and thematic maps became a norm, an integral part of the mathematical and scientific methodologies used to visualize the world (Thrower 2008).

The publication record of the Mercator Projection reveals it as a tool and the map as a cultural artifact informing the wider story of why and how the Mercator Projection became a popular projection for world maps. Geographies of the book provides the mechanism for movement that traces the circulation and reception of knowledge in print through the making and movement of texts to inform the diffusion and the reception of knowledge and ideas (Keighren 2013). In Keighren's (2010) *Bringing Geography to Book,* the author questions the appropriateness of scale when investigating certain topics. Keighren analyzed the reception of Ellen Semple's *Influences* by utilizing social networks and hermeneutic communities, and noting their spatial and temporal scales provided a meaningful balance that connected commonalities in the reception of the work (Keighren 2010). This approach was applied to the Mercator Projection to convey how the adoption of the projection by the maritime community, and its progressive use by explorers, transitioned the Mercator Projection from navigation to reference and thematic mapping.

Maps were a commercial good which contributed to the economy of early modern Europe. The printing press provided an avenue for the increased publication and reception of maps. The printing press changed the availability of maps and other printable resources (Febvre and Martin 1976). Thrower also notes that the printing press facilitated the increase in scientific activity and interest (Thrower 2008). Mukerji (1983) argues that maps were essential for European participation in overseas expansion and aided how the European states defined themselves as geopolitical units in an emerging world system. Likewise, Benedict Anderson has argued that maps were a form of print capitalism illustrating a shared belonging and commonality between literate and economically powerful people and were part of creating and unifying 'imagined communities.' (Anderson 2006). Maps became an integral part of the inner workings of government and science, and simultaneously constructed a mental perception of power, dominance and ownership. Maps were not only a capital good but were decision-making artifacts for governments.

A map is often considered to be neutral. However, no map is neutral: maps are constructed by socio-cultural paradigms that typically reinforce norms (Cresswell 2013). While this study does not directly use deconstructionist theory, it does help interpret why the Mercator Projection was chosen to communicate data. Critical cartography originates from J.B. Harley's postmodern concept of 'deconstructing the map' which partially examined mapping as a representation of the construction of knowledge and power (Harley 2001; Cresswell 2013). Cresswell defined Harley's 'deconstructing the map' as postmodern because the map is a tool in a society's construction of knowledge (Cresswell 2013, 186-187). Harley draws upon the social theory of Derrida and Foucault to argue that maps and mapmakers are created and interpreted by cultural norms, and reinforce that society's norms and values (Harley 2001). According to Cresswell, a postmodernist engages in looking at the process of representation.

Critical cartography analyzes social and cultural ideologies, and the production, circulation, and consultation of maps, linking how the map and its power are tied to political and cultural values (Monmonier 2007; Edney 2014). Two different but fluid divisions within critical cartography arise: conceptual and contextual (Smith 1996; Edney 2005; Prior 2013). A conceptual approach to critical cartography is exemplified by Buisseret's application of how maps became tools of social and political power in early modern European empires (Buisseret 1992). A contextual approach is exemplified through Prior's dissertation. It focused on what maps were produced and by whom, when Britain was asserting imperial control over the 'Scramble for Africa' (Prior 2013). This study expands J.B. Harley's deconstructionist argument by focusing on how projection choice constructs the mental image, specifically of the world to a given audience. It also looks at how the map is constructed to be a tool that reflects collected information and knowledge.

Data and Methods

Archival data is combined with methodologies from the literature on geographies of the book to explain the diffusion of the Mercator Projection from navigation into reference and thematic maps. This creates a bibliographic record from the publication history of the Mercator Projection explaining the adoption and reception of the projection in western European and United States cartography. Anne Knowles states, **"s**cholars like to say that history is about time, geography about space. Tracing change through time leads to narrative, which is sequential, logical and verbal; geographical comparison over space produces maps, which are synoptic, simultaneous, and visual. The two ways of knowing, and the methods to which they have given rise, nest uncomfortably for many scholars" (Knowles 2015, 597-601).

The data itself is drawn from the cartographic publication record of world maps, and world maps in atlases, for content analysis. To trace the diffusion of the Mercator Projection, a total of five hundred and sixty-eight maps and atlases were reviewed for this study. The maps ranged in date from 1569, when Mercator published his projection, to 1900. They were found in archives located in the United States, and digital archives located in the United Kingdom, United States, Australia, New Zealand, the Netherlands, France and Germany. The archives consulted include: Bibliothèque Nationale de France, David Rumsey Map Collection, Folger Institute, John Carter Brown Library, Library of Congress, National Library of Australia, National Library of New Zealand, National Maritime Museum, Norman B. Leventhal Map Center, Osher Map Library, Cambridge University Digital Library, Royal Geographic Society, Royal Museums Greenwich, the British Library and Universiteitsbibliotheek Utrecht. The majority of the data was collected from archives that had uploaded scanned maps to their websites. Physical visits to archives were reserved for source materials that could only be accessed from in person visits.

From these archives, the maps were individually selected to be reviewed were those that had been scanned and uploaded to the digital archive for viewing at a global or near global scale and were available in high resolution through digital archives and within the study's 1569 to 1900 time frame. The maps were analyzed individually for their content and bibliographic information and the data for each was recorded into a spreadsheet database. In the case of atlases, all maps displaying global or near global coverage were included in the study.

All of the maps reviewed were categorized into four time periods: 1569-1699; 1700-1799; and 1800-1849 and 1850-1900. The 1569 to 1699 period was selected as it covered the period of early reception in nautical cartography of the Mercator Projection through Edward Wright's corrections, ending just before the publication of Edmund Halley's first thematic maps. The second time period, 1700 to 1799, covers early thematic cartography and the rise of cartography as a tool of science and government. The period 1800 to 1849 represents the rise of educational and popular cartography. The final period, 1850 to 1900, was the time when mass map production became dominated by large commercial cartographic firms like Rand McNally.

Once selected, the maps were then categorized as Navigational, Reference or Thematic, based on what appeared to be their primary function. The recorded data included both bibliographic information and cartographic based information. The bibliographical information included Title, Year, Author, Place of Publication, Language, Archive and Location in Archive. The cartographic information included whether it was a single sheet map or found in an atlas, geographical coverage, scale, was it identified as a map or chart, projection used, map type, if thematic the type of data displayed and the cartographic symbology used to display the data, printing process and technique and any additional archival information to locate or further understand the document.

The framework for this study combines components of historical cartography's narrative with the record of map production as evidentiary artifacts, to illustrate how over a three-hundred-year period the Mercator Projection became utilized for general reference and thematic world maps. Multiple archives (including digital) were consulted for this study to trace the distribution and circulation of the Mercator Projection and its expanding realm of applications. The selection is not exhaustive and undoubtedly not entirely representative of map production for the time periods in question, as antique maps were often saved either for their importance, rarity or ornateness, leaving more mundane examples underrepresented. After creating large ornate maps or atlases, many publishers would then produce less expensive versions that were much smaller and less elaborate for a more general audience. However, publishers seldom changed the projection used for the ornate version on the simplified maps, as that would have added expense. It was standard publishing practice to produce both a high-end and cost-effective product (Karrow 2007).

It is important to note that the maps collected from archives may not be completely representative of all the maps published during the time frame of this study. Maps may have been saved for their importance, rarity or ornate nature and not as representative of what was typical of the time period (Thrower 2007). The earliest atlases were often quite elaborate and designed for the aristocracy, wealthy and educated elites (Wolter, Grim and Library of Congress, 1997). While many atlases have survived, navigational charts and maritime atlases were more difficult to locate. This may be due to the nature of the navigational chart being a working document subjected to much greater wear and tear. Navigational maps and charts as tools or working documents would have been less ornate and may have been seen as less deserving of being saved, or less important, because they were functional. Fortunately, some excellent examples of early navigational charts were located and analyzed.

Results and Discussion

At its creation in 1569, navigators were the intended audience for the Mercator Projection. Navigators were a highly skilled set of users whose sole purpose for using the Mercator Projection was to improve their ability to plan and follow routes at sea utilizing the nautical compass. From 1569 to 1900, the application of the Mercator Projection expanded from this specialized audience and function to the broader realm of general reference and thematic maps and atlases. The data present clear temporal trends in the purpose and intended audience of maps and atlases utilizing the Mercator Projection.

1569 – 1699

As expected, after its development in 1569 and until 1699, the Mercator Projection was widely used in the production of navigational charts. By the end of the seventeenth century, the data show that the Mercator Projection had become quickly adopted by navigators and became the dominant projection used for navigation. From 1569 to 1699, based on a review of sixty maps and atlases, 61% of navigational maps were created on the Mercator Projection. (See Figure 1.) The 39% of navigational maps that did not use the Mercator Projection were either portolan in style, or they were on an unidentifiable rectangular projection. General world reference maps during this time period also began to employ the Mercator Projection. Forty-three of the sixty maps reviewed from this time frame were reference maps found as individual sheets or in atlases, of which 85.71% applied a non-Mercator Projection while14.29% used the Mercator Projection. The most common non-Mercator Projection used for reference maps at this time was the Ptolemaic, followed by the Globular. However, a small handful of general reference maps utilizing the Mercator Projection were found for this time period.

The available data further show that in 1575, the Spanish first used the Mercator Projection to illustrate voyages to the Pacific Ocean. In 1582, the English used the Mercator Projection to arouse English interest in overseas enterprises. In Cologne, in 1600, the Mercator Projection was used in an atlas published by Matthias Quad as a less expensive alternative to the Ortelius or Mercator *Atlas*. In 1606, Blaeu published a hydrographic world map on the Mercator Projection in Amsterdam. Pierre Moullart-Sanson, in 1695, published a sea chart with an early crude theory for calculating longitude. In the Americas, the first example of a Mercator Projection was a 1791 hand drawn chart by a Boston schoolgirl from a pre-existing pattern. This indicates that the Mercator Projection was present before this data; however, there was no data found for an earlier date.

Initially, the Mercator Projection spread slowly because there were no clear instructions on how the average mariner could use or replicate the projection. After studying in Antwerp alongside Gerard Mercator, John Dee brought the Mercator Projection to England and introduced it to his colleagues, who helped spread it in English map publications (Taylor 1930; Crane 2003). Although Dee brought the projection to England, he did not contribute any clarifications as to how to best use or replicate the projection. A major problem with using the projection was that a mariner could be anywhere from two to three compass points off of their dead reckoning (Wright 1599). This was corrected by the work of English mathematician Edward Wright. In 1599, Wright published his *Certaine Errors of Navigation*, which provided a practical, useable and replicable method for constructing and using the Mercator Projection (Wright 1599). Wright's corrections to the Mercator Projection were reprinted in many sources because they worked. The number of these publications attest to the value that Wright's corrections to the Mercator Projection held for the nautical community. The seventeenth century saw the publication of a multitude of practical manuals on navigation, many of which explained how to use the Mercator Projection. Learning practical geometry from books was critical to mapmaking and navigation and to the recording of the voyages of discovery (Withers 2005). These include, Matthew Norwood's *System of Navigation* (1685), James Atkinson's *Epitome of the Art of Navigation* (1686) and multiple editions of *Certaine Errors*. It was after Wright's improvements that the spread of the Mercator Projection increased quickly and it effectively set the stage for the Mercator Projection t be used in the eighteenth century's reference and thematic mapping.

1700 – 1799

Surprisingly, by 1700, the Mercator Projection had become the most commonly used projection for reference maps accounting for roughly half of the maps reviewed in this study. In addition, the Mercator Projection dominated use in early thematic mapping. This may well have been because the earliest thematic maps portrayed wind patterns, magnetic declination and ocean currents, or other information directly of use to navigators.

Based on the data, the 1700 to 1799 period appears to be a critical time frame for the dissemination of the Mercator Projection. Its widespread acceptance by the nautical community was undoubtedly the result of its superior usefulness in comparison to all other projections for navigation used at this time. It is also the time period when the Mercator Projection began to be used more frequently for reference and thematic maps. In reference mapping, 58% of thirty-eight maps and atlases used the Mercator Projection for world maps, with 42% using non-Mercator Projections, most notably the Globular Projection. (See Figure 2.) Having roughly half, or slightly more than half, of reference maps and atlases utilizing the Mercator Projection is a trend in the data that continues to the twentieth century.

The high use of the Mercator Projection for thematic data is undoubtedly related to early thematic mapping being tied to efforts at improving navigation. While the thematic map sample was small, it was heavily weighted toward the Mercator Projection, with nine of ten maps using the projection. The period of 1700 to 1799 saw the first identifiable thematic maps (Robinson 1982; Waters 1990). Most of these maps were created by navigators or by scientists recording and then portraying physical data, useful for sailing. This trend began with Edmund Halley mapping ocean currents, wind directions and compass magnetic variations on a Mercator Projection. Halley created a map of trade winds (1686) and the magnetic variations of the compass (1692-1698) both of which contributed to the publication of Halley's 1701 "A new and correct chart shewing the variations of the compass in the Western & Southern Oceans" (Halley 1686; Halley 1701; Waters 1990; Thrower 2007). Halley's findings became a milestone in the history of cartography as it is the earliest example of the use of isolines of any form (Thrower 2007). Halley's development of the isoline was greatly praised by German polymath Alexander von Humboldt. Humboldt later expanded upon Halley's work and followed Halley's lead by utilizing the Mercator Projection and isolines for the plotting of scientific data on the maps found in the field reports of his expeditions and in the subsequent publication of a series of popular/academic thematic atlases of the areas he explored (Thrower 2007). Isolines remain the most common method used on thematic maps portraying a host of phenomena including elevation, temperature, precipitation and barometric pressure.

Cook's voyages are of significance for the use and distribution of the Mercator Projection. Cook, his officers and Tupaia (a Polynesian priest and navigator whose skills and knowledge were utilized by Cook) created various charts, views and maps of his discoveries over his three voyages. Of the fifty-eight charts, views and maps printed by Cook, his officers and Tupaia, seven of them are labeled as the Mercator Projection, with one map being split between the Mercator Projection and a polar projection (Cook, Beaglehole and Skelton 1969). Upon returning to Britain, all of Cook's information was collected from him, his officers, and crew and was submitted to the Royal Society for inspection (Cook and Beaglehole 1969; Phillips 2017). The Admiralty then used their data to construct official charts from the voyage, which they then declared suitable for release (Phillips 2017). Captain James Cook's cartographic works furthered the tradition of using the Mercator Projection for the purpose of scientific knowledge. Cook's impact was profound, not only in the detailed charting of new lands but also through his role in the expansion of scientific societies. The output of maps portraying Cook's voyages utilizing the Mercator Projection and perhaps more importantly Cook's fame and prestige solidified the projections position as a favored choice for thematic and reference maps for generations to come.

1800 – 1849

Unfortunately, the precedent of using the Mercator Projection for the publication of navigational based thematic maps became the norm in the nineteenth century for all thematic maps, many of which were aimed at the general public and school children. In the nineteenth century many of the thematic maps, originally produced by academics, scientists and geographical institutions, were repackaged for a mass market. The information on these popular maps and atlases was not aimed at improving navigation but rather to illustrate what places were like: the crops grown, languages spoken, how much rainfall occurred, the type of government and a myriad of other phenomena. By 1900, the highly and unevenly distorted view of the world presented by the Mercator Projection may well have influenced the consciousness of 'what the world looks like' for millions.

From 1800 to 1849, the data show the tendency to use the Mercator Projection remained for thematic and general reference mapping. In reference mapping, 52% of one hundred and forty-three maps and atlases used the Mercator Projection for world maps, with 48% using non-Mercator projections (See Figure 3.) The most frequently used non-Mercator projection used was the Globular Projection. The same trend is reflected in the data for thematic maps, with 56% of forty-eight thematic maps and atlases using the Mercator Projection for world maps and 44% using a non-Mercator projection. The non-Mercator projections were typically the Globular and were often jointly published with the Mercator Projection map. (See Table 1.) This phenomenon indicates there were other projections to pick from and there was a popular secondary alternative, but the Mercator Projection was a clear preference over other projections to display world maps.

The early nineteenth century saw a dramatic rise in the number of maps designed for school age children from the primary level to the university. From 1800 to 1849, forty-one maps and atlases created for education-based purposes were reviewed. Of the forty-one maps, 53.66% used the Mercator Projection and 46.34% used a non-Mercator projection. This reflects the same trend seen for all reference maps. School maps and atlases were created for specific age audiences to communicate general geographic and thematic information. The increase in school maps coincides with the institutionalization of tax supported education in the United States and many European nations. In the United States, in 1796, the *Act to Establish Public Schools* was passed by Congress at the urging of Thomas Jefferson and led to greater access to education, at least for white males (Jefferson 1779). Schools for young women followed, but these "academies" seldom had taxpayer support. By the mid-nineteenth century, compulsory education laws for both boys and girls were being enacted on a state by state basis. The rise in student numbers was met with an increase in available textbooks and school atlases (Schulten 2001). Early in the nineteenth century, texts were created by individual authors who wrote, printed and marketed their work, but by the mid-century large publishing houses such as Rand McNally, Mitchell and the American Book Company began to dominate the market (Patton 1999). The Mercator Projection being shown to audiences early in their educational careers may have been instrumental in shaping their image of what the world looked like and, significantly, what a world map should look like.

The rise of geographical societies in the nineteenth century coincided with geography's rise as an academic discipline. Shortly after the founding of geographical societies, geography as an academic discipline appeared first in French, Prussian and German universities and by mid-century in English and United States Universities (Stoddart 1986). Geographical societies, the new discipline of geography, and cartographic publishing houses all flourished as they attempted to meet the demand for geographic knowledge. Articles in the journals of geographic and other scholarly societies typically used the Mercator Projection for maps on a global or near global scale. The Royal Geographic Society (RGS) published the *Journal of the Royal Geographical Society of London* from 1831 to 1880. This journal was supported by the RGS, the British government, explorers and cartographers. John Murray and John Arrowsmith were the two most published cartographers in those early issues (*The Journal of the Royal Geographical Society of London 1-26* (1831-1856); *Proceedings of the Royal Geographical Society of London 27-50* (1857-1880). The Royal Geographic Society made an effort to create a map library and place maps in their publications. However, not all maps were included since there were many hand-made maps that were distributed in meetings (Herbert 1983). A survey of *The Journal of the Royal Geographical Society*, volumes one through fifty, revealed the maps that did make it to publication were often referred to as "sketch maps," based off the official records of the exploration or voyage. Most of these sketch maps were drawn on a cylindrical projection (typically the Mercator Projection) and the others were drawn on a conical projection (*The Journal of the Royal Geographical Society of London 1-50* 1831-1880; *Proceedings of the Royal Geographical Society of London 27-50* (1857-1880).

1850 – 1900

The 1850 to 1900 period was the final time frame reviewed for this study. The majority of maps and atlases found for review during this time were thematic rather than reference, reflecting what many cartographers have called the 'Golden Age of Thematic Mapping' (Thrower 2007). This has significant implications in that, not only were thematic maps becoming a widespread form of popular cartography, but the Mercator Projection was the leading projection used for these maps and atlases. The data shows, of the one hundred and seventy-two thematic maps surveyed in this time frame, 84.30% of them used the Mercator Projection. (See Figure 4). In reference mapping, the same trend persisted, as was established in the eighteenth century, with nearly half using the Mercator Projection: 48.94%. (See Figure 4.)

The second most popular projection was, again, the Globular Projection. Many of these maps and atlases were created by geographical institutions that noted scientific explorers or university faculty as the "authority" behind the map. For example, William Woodbridge cited the work of Alexander von Humboldt and others as the source for his maps in his publication *Universal Geography* (Woodbridge 1827). This connection between scientists, university faculty and geographical institutions, noted frequently on educational thematic maps, may have helped cement the perception that the Mercator Projection was superior to others as it was the projection of choice of the scientific elite.

The data reflect several forces driving the dissemination of the Mercator Projection, from navigational mapping into general use for thematic and reference mapping. The expanded use of the Mercator Projection followed a series of steps, beginning with its widespread utilization in navigation, then in use for plotting data during scientific explorations and subsequent reports to sponsoring governments or scientific societies. These reports were then published in scientific and geographic society journals. Finally, maps used in the academic journals became the basis and the authority for many maps and atlases marketed to schools and other general public audiences. In each instance, the Mercator Projection used in the earlier marketing or publication was retained.

Prussian explorer Alexander von Humboldt is a towering figure in the development of modern geography. His work contributed to the validation of the Mercator Projection as the projection of choice for science through his extensive use of it for his innovative thematic maps. Humboldt's travels to the Americas provided inspiration for cartographic innovations. Schulten writes that after 1804, Humboldt turned predominantly to geovisualization after his explorations in the Americas (Schulten 2018). During his explorations, Humboldt noted the difference in average temperature based on different climatic zones according to latitude and altitude. On his Isothermal map Humboldt plotted these isotherms against the plane of the Mercator Projection's rectangular grid and included a graph to explain the difference in varying temperatures based on altitude and latitude (Thrower 2007; Schulten 2018).

In reference to Humboldt's paper on isothermal lines, cartographic scholars Arthur Robinson and Helen Wallis consider, "this employment of the isarithm for spatial distribution by an outstanding natural scientist contributed largely to the widespread adoption of this technique in thematic cartography" (Robinson and Wallis 1967, 119-123). Humboldt acknowledged Halley's concept of isogones for the idea for isotherms (Thrower 2007). Humboldt adapted Halley's concept of 'curve lines' of equal compass declinations to show the distribution of temperatures, and he created the isotherms on the Mercator Projection to maintain angle accuracy (Robinson 1982). Humboldt continued using and perfecting plotting data on the Mercator Projection and used it in his *Atlas* to accompany his monumental work *Kosmos*. Humboldt's employment of isotherms for the visualization of temperature data, based on Halley's technique of using isolines to show lines of equal magnetic declination, was widely copied by others, most notably by Woodbridge in the United States and by Henrich Berghaus in his *Physikalischer Atlas* and the English version, *The Physical Atlas* (Scharfe 1986). Berghaus's *Physikalischer Atlas* was encouraged by Humboldt and despite its high price, was considered a scientific and economic success. The *Atlas* was another supplement to Humboldt's *Kosmos.* It was a challenge for cartographers as there were few examples of similar maps to draw upon and due to the vast amounts of data and the complexity of the spatial relationships that the maps were intended to convey. Berghaus, like Humboldt, used the Mercator Projection throughout his Atlas if displaying thematic data on a world map. The Mercator Projection is not the only projection in the Atlas; however, it is significant that these two dominant atlases maintained the Mercator Projection for the display of thematic data on a world map. Berghaus and Humboldt's influence was immediate and continuous throughout the cartographic and geographic fields. The Atlas became the model for other publications worldwide (Robinson and Wallis 1987; Thrower 2007). These atlases and those that quickly followed utilized Humboldt's isopleth technique as well as other thematic symbols that are still widely used today. These include, dot maps showing density, variable width flow lines showing the degree or amount of movement between places, and maps and choropleth shades for displaying classed sequential data by some geographic collection unit (i.e., population per state) (Robinson and Wallis 1987; Thrower 2007).

From the nineteenth century onward, maps were widespread cultural artifacts associated with the distribution of general and scientific knowledge. The rise of thematic cartography coincides with a time of increased demand for maps and a large decrease in the cost of map production. Cost reductions resulted from new innovations in printing and the cost of paper. Perhaps the most important changes in the printing of maps was the process of lithography, which was invented in 1798 by Alois Senefelder of Bavaria, and wax engraving (cerography) developed by Sidney Morse. Sidney Morse was the son of Jedidiah Morse (who published the first geography book in the United States, *Geography Made Easy* in 1784), and brother of Samuel Morse, inventor of the telegraph (Patton 1999). Coupled with a precipitous drop in the cost of paper (which occurred with the introduction of cheap pulp paper), books and maps became far more available (Febvre and Martin 1976).   Map production grew in the nineteenth century through innovation and an expanding market resulting from an increasingly literate population along with the expansion of empire and public interests in frontiers and colonies (Cain 1994).   Educational and family atlases provided a lucrative market. The thematic maps found on grade school wall maps, like the maps found in scientific journals, high school and university level atlases and popular "family" atlases, were almost always on the Mercator Projection. The rise of popular cartography and the widespread visibility it provided the Mercator Projection undoubtedly increased perception by the general public that the Mercator Projection was the 'accurate' map, and the choice of scientists, governments and educators.

During the nineteenth century, the United States followed the Europeans lead on the presentation and distribution of geographic information in academic or school-based texts. In the 1800s, geography was considered an essential subject taught in virtually all US schools (Schulten 2001). Many popular school atlases were mirrored after the European atlases, and prior to the American Revolution, geographical texts that circulated in the American colonies were written and published in Europe (Patton 1999). The first United States geography text, *Geography Made Easy,* was published by Jedidiah Morse, in 1784 (Patton 1999). The commercial success of Morse's geography text encouraged many others to write similar texts for school children. One of these was by William C. Woodbridge, whose text *Rudiments of Geography* relied heavily on an accompanying thematic atlas. Woodbridge had spent a year teaching in Switzerland. While in Europe he met Alexander von Humboldt. After returning to the United States, Woodbridge continued to correspond with Humboldt and incorporated many of Humboldt's ideas into his geographies (Calhoun 1984). In the introduction to his new geography text, Woodbridge thanked Humboldt and the Société de Géographie for their assistance (Woodbridge 1827). Both

Morse and Woodbridge used the Mercator Projection for their world maps. Even though other projections were available, only the Mercator and the Globular Projections were widely used for school atlases, with the Globular Projection more commonly used for world reference maps and the Mercator Projection being used for world thematic maps (Snyder 1993). The use of the Globular Projection for reference maps and the Mercator Projection for thematic data often occurred within the same atlas. This was a tacit acknowledgment from the atlas maker that they believed scientific data should be shown on the Mercator Projection.

In the nineteenth century, school maps became concerned with not only the ‘accurate’ delineation of territories and the location of places, but also in displaying data to convey what those places were like (Patton 1999). Particularly in the case of displaying scientific data, school atlases, geographies and atlases designed for a general public eager to learn of the far-off places explored by Cook, Humboldt, Darwin and others, relied on the Mercator Projection to display the science of the day. As Schulten emphasizes, “textbooks were among the most commonly read books in the nineteenth century and had influence beyond the schoolroom” (Schulten 2001, 94).

The use of the Mercator Projection in school atlases added legitimacy and a perception of accuracy to world maps. The Mercator Projection was not only being used in some of the most widely circulated books of the day, they were also texts that had the “official stamp” of the school system or of academia. The rectangular, gridded, highly distorted the Mercator Projection was now seen as the correct view. By 1900, the Mercator Projection had become firmly entrenched as a popular choice for world maps, even as academic cartographers began to argue against its use and suggested superior alternative projections. After 1900, academic cartographers began to create new projections to specifically address the shortcomings of the

Mercator Projection for general use and to urge their use as replacements of the Mercator Projection. The continued widespread use of the Mercator Projection reveals the general lack of success that the academic cartographic community has had in limiting the influence of the Mercator Projection.

The Mercator Projection provides a glimpse into the complexities of mapping, the choice of map projection and why the Mercator Projection changed human's ability of moving from one place to another, or, their perception of spatial arrangement of the globe. After 1569 and until 1700, the Mercator Projection was appropriately used for navigation. The misuses of the Mercator Projection began after 1700, when it was connected to scientists working with navigators and the creation of thematic cartography. During the eighteenth century, the Mercator Projection was published in journals and reports for geographic societies that detailed state-sponsored explorations. Western Europeans used the Mercator Projection as a tool in a specific scientific sense and as a tool for building their empires. In the nineteenth century, the influence of well-known scientists using the Mercator Projection filtered into the publications for the general public. These publications created the erroneous depiction of the way western European empires wanted their subjects to perceive the empire in the world.

Conclusion

By uncovering how the Mercator Projection moved from a navigational tool to a way of displaying the world, this dissertation offers a glimpse into how it was championed, challenged, accepted and changed throughout time. The legacy of the Scientific Revolution allowed the geographic discipline to develop into a more theoretical and data-driven science. The Mercator Projection was indirectly validated by science, as navigators and scientists worked together to make navigation more efficient. The rise of thematic cartography, and the increase of literacy and availability of knowledge to the public further propelled the distribution and diffusion of the Mercator Projection. It became a widely used projection for world maps and atlases, for which it was ill-suited, but also because it had a reputation of being used by professional and intellectual communities. As a result, the Mercator Projection was published in maps, atlases and school atlases for the general public, which influenced how the majority of people using these resources would come to conceptualize the world. By conceptualizing how the Mercator Projection moved as a physical and ideological tool through space and time within world maps and atlases, this dissertation has offered a glimpse into how the Mercator Projection became a popular envisioning of the world.

References

Anderson, Benedict R. O'G. 2006. *Imagined Communities: Reflections on the Origin and Spread of Nationalism*. Revised edition. London; Verso.

Buisseret, David. 1992. *Monarchs, Ministers, and Maps: The Emergence of Cartography as a Tool of Government in Early Modern Europe*. Chicago, Illinois: University of Chicago Press.

Cain, Mead T.1994. "The Maps of the Society for the Diffusion of Useful Knowledge: A Publishing History." *Imago Mundi* 46: 151–67.

Calhoun, Daniel H. "Eyes for the Jacksonian World: William C. Woodbridge and Emma Willard." *Journal of the Early Republic* 4, no. 1 (1984): 1–26.

Cook, James, J. C Beaglehole, and R. A Skelton. 1969. *The Journals of Captain James Cook on His Voyages of Discovery: Charts & Views. Cambridge* [Cambridgeshire: Published for the Hakluyt Society at the University Press.

Crane, Nicholas. 2003. *Mercator: The Man Who Mapped the Planet*. New York, New York: Henry Holt and Company.

Cresswell, Tim. 2013. *Geographic Thought: A Critical Introduction. 1 online resource. vols. Critical Introductions to Geography*. Chichester, West Sussex, UK: Wiley-Blackwell.

Edney, Matthew H. 2005. “Putting ‘Cartography’ into the History of Cartography: Arthur H. Robinson, David Woodward, and the Creation of a Discipline.” *Cartographic Perspectives* 51: 14–29.

Edney, Matthew. 2009. “Cartography, history of” In Gregory, D., Johnston, R., Pratt, G., Watts, M.J., and Whatmore, S. [Eds.] *The Dictionary of Human Geography*, 5th Edition (Hoboken: John Wiley & Sons, Incorporated): 69-72.

Edney, Matthew H. 2014. “Academic Cartography, Internal Map History, and the Critical Study of Mapping Processes.” *Imago Mundi* 66, no. sup1: 83–106.

Febvre, Lucien and Martin, Henri-Jean. 1976. *The Coming of the Book: The Impact of Printing, 1450-1800*. [New ed.] edn. London: N.L.B (The foundations of history library).

Herbert, Francis. 1983. “The Royal Geographical Society’s Membership, the Map Trade, and Geographical Publishing in Britain 1830 to Ca 1930: An Introductory Essay with Listing of Some 250 Fellows in Related Professions.” *Imago Mundi* 35: 67–95.

Jefferson, Thomas. 1779. “79. A Bill for the More General Diffusion of Knowledge,” June 18, 1779. Founders Online: National Archives. https://founders.archives.gov/documents/Jefferson/01-02-02-0132-0004-0079#document_page.

Monmonier, Mark. 2004. *Rhumb Lines and Map Wars: A Social History of the Mercator Projection*. Chicago, Illinois: University of Chicago Press.

Monmonier, Mark. 2007. “Cartography: The Multidisciplinary Pluralism of Cartographic Art, Geospatial Technology, and Empirical Scholarship.” *Progress in Human Geography* 31, no. 3 (June): 371–79.

Goode, J Paul. 1927. “The Map as a Record of Progress in Geography.” *Annals of the Association of American Geographers* 17, no. 1: 1–14.

Halley, E.1686. “An Historical Account of the Trade Winds, and Monsoons, Observable in the Seas between and Near the Tropicks, with an Attempt to Assign the Phisical Cause of the Said Winds, By E. Halley.” Philosophical Transactions of the Royal Society 16: 153–68.

Halley, Edmund. 1701. “A New and Correct Chart Shewing the Variations of the Compass in the Western & Southern Oceans as Observed in Ye Year 1700 by His Ma:Ties Command by Edm. Halley - JCB Map Collection.” London: W. and J. Mount, and T. Page. John Carter Brown Library. https://jcb.lunaimaging.com/luna/servlet/detail/JCBMAPS~1~1~3540~101701:A-new-and-correct-chart-shewing-the?qvq=q:Edmond%2BHalley&mi=1&trs=4#. John Carter

Brown Library. https://jcb.lunaimaging.com/luna/servlet/detail/JCBMAPS~1~1~3540~101701:A-new-and-correct-chart-shewing-the?qvq=q:Edmond%2BHalley&mi=1&trs=4#.

Harley, J.B. 1987. "Preface." In *The History of Cartography, 1, Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean*. Chicago, Illinois; London, UK: University of Chicago Press: xv-xxi.

———. 1987. "The Map and the Development of the History of Cartography." In *The History of Cartography, 1, Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean*. Chicago, Illinois; London, UK: University of Chicago Press: 1-42.

———. 2001. *The New Nature of Maps*. Edited by Paul Laxton. Baltimore, Maryland: Johns Hopkins University Press.

Karrow, Robert. 2007. "Centers of Map Publishing in Europe, 1472-1600." In *The History of Cartography*, edited by David Woodward, Vol. 3, Cartography in the European Renaissance. Chicago, Illinois; London, UK: University of Chicago Press.

Keighren, Innes M. 2010. *Bringing Geography to Book: Ellen Semple and the Reception of Geographical Knowledge*. London: I.B. Tauris.

Keighren, Innes M. 2013. "Geographies of the Book: Review and Prospect." *Geography Compass* 7, no. 11 (November): 745–58.

Knowles, Anne Kelly. 2015. "Historians and Cartography." In *History of Cartography, 6, Cartography in the Twentieth Century*. Chicago, Illinois; London, UK: University of Chicago Press: 597–601.

Mukerji, Chandra. 1983. *From Graven Images: Patterns of Modern Materialism*. New York, New York: Columbia University Press.

Patton, Jeffrey C. 1999. "The American School Atlas: 1784-1900." *Cartographic Perspectives* 33: 4–32.

Phillips, Eóin.2017. "Astronomical Observations Made during Captain Cook's Last Voyage (RGO 14/61)," n.d. https://cudl.lib.cam.ac.uk/view/MS-RGO-00014-00061/5.

Prior, Amy Dawn. 2013. "British Mapping of Africa: Publishing Histories of Imperial Cartography, c.1880-C1915." Ph.D., The University of Edinburgh (United Kingdom).

Robinson, Arthur Howard. 1982. *Early Thematic Mapping in the History of Cartography*. Chicago: University of Chicago Press.

Robinson, Arthur Howard, Helen Wallis, and International Cartographic Association. 1987. *Cartographical Innovations: An International Handbook of Mapping Terms to 1900*. Tring, Herts: Published by Map Collector Publications in association with the International Cartographic Association.

Scharfe, Wolfgang. 1986. “Max Eckert’s ‘Kartenwissenschaft’. The Turning Point in German Cartography.” *Imago Mundi* 38: 61–66.

Schulten, Susan. 2001. *The Geographical Imagination in America, 1880-1950*. Chicago: University of Chicago Press.

Schulten, Susan. 2018. “Alexander von Humboldt: Master of Infographics.” *Mapping the Nation: A Companion Site to Mapping the Nation by Susan Schulten*. Accessed November 26, 2018. http://www.mappingthenation.com/blog/alexander-von-humboldt-master-of-infographics/.

Smith, Catherine Delano. 1996. “Selected Papers from the 16th International Conference on the History of Cartography: Theoretical Aspects of the History of Cartography: Why Theory in the History of Cartography?” *Imago Mundi* 48, no. 1 (January): 198–203.

Snyder, John P. 1993. *Flattening the Earth: Two Thousand Years of Map Projections*. Chicago, Illinois: University of Chicago Press.

Stoddart, D. R. 1986. *On Geography and Its History*. New York: B. Blackwell.

Taylor, E.G.R. 1968. *Late Tudor and Early Stuart Geography, 1583-1650.* New York, New York: Octagon Book.

———. 1930. *Tudor Geography, 1485-1583*. London, UK: Methuen & Co. LTD.

Taylor, Andrew. 2004. T*he World of Gerard Mercator: The Mapmaker Who Revolutionized Geography*. New York, New York: Walker & Co.

Thrower, Norman J. W. 2008. *Maps & civilization: cartography in culture and society*. Chicago, Illinois; London, UK: University of Chicago Press.

Waters, D.W. 1990. “Captain Edmond Halley, F.R.S., Royal Navy and the Practice of Navigation.” In *Standing on the Shoulders of Giants*, edited by Norman J. W Thrower, 171–202. Berkeley and Los Angeles, California; Oxford, England: University of California Press, 1990.

Withers, Charles W. J. 2005. “Geography, Science, and the Scientific Revolution.” In *Geography and Revolution*, edited by David N Livingstone and Charles W. J. Withers, Chicago: University of Chicago Press: 75-105.

Wolter, John, Grim, Ronald and Library of Congress. 1997. *Images of the World: The Atlas through History*. New York: McGraw-Hill.

Woodbridge, William C. 1827. *A System of Universal Geography: On the Principles of Comparison and Classification*. 2nd ed. Hartford, Connecticut: Oliver D. Cook & Co, 1827. Hathi Trust Digital Library. https://babel.hathitrust.org/cgi/pt?id=hvd.32044097022131;view=1up;seq=9.

Wright, Edward. 1599. *Certaine Errors in Nauigation, Arising Either of the Ordinarie Erroneous Making or Vsing of the Sea Chart, Compasse, Crosse Staffe, and Tables of Declination of the Sunne, and Fixed Starres Detected and Corrected*. London: Valentine Sims and W. White. Early English Books Online. http://eebo.chadwyck.com/search/full_rec?SOURCE=pgthumbs.cfg&ACTION=ByID&ID=99837677&FILE=../session/1508339433_10560&SEARCHSCREEN=CITATIONS&SEARCHCONFIG=var_spell.cfg&DISPLAY=AUTHOR.