Please see the online version of this article for supplementary materials.

The First (Known) Statistical Graph: Michael Florent van Langren and the “Secret” of Longitude

Michael FRIENDLY, Pedro VALERO-MORA, and Joaquín IBÁÑEZ ULARGUI

A 1644 diagram by Michael Florent van Langren, showing estimates of the difference in longitude between Toledo and Rome, is sometimes considered to be the first known instance of a graph of statistical data. Some recently discovered documents help to date the genesis of this graphic to before March 1628, and shed some light on why van Langren chose to display this information in this form. In the process, we discovered three earlier versions of the 1644 graph and one slightly later reproduction. This article describes these early attempts on the solution of “the problem of longitude” from the perspective of a history of data visualization.

KEY WORDS: Data visualization; History of statistics; Longitude; Michael Florent van Langren; Selenography; Statistical historiography; Thematic cartography; Uncertainty.

1. INTRODUCTION

Every picture tells a story (Rod Stewart)

In the history of statistical graphics (Friendly 2008), as in other artful sciences, there are a number of inventions and developments that can be considered “firsts” in these fields. The catalog of the Milestones Project in the history of data visualization (Friendly and Denis 2001) lists 70 events that can be considered to be the initial use or statement of an idea, method, or technique that is now commonplace. Some early examples related to the theme of this article are:

- map projections of a spherical earth and use of latitude and longitude to characterize position (Claudius Ptolemy, c. 150 AD)
- the first modern atlas, *Teatrum Orbis Terrarum* (Abraham Ortelius 1570)
- first world map showing lines of geomagnetism (isogons), used in work on finding longitude by means of magnetic variation (Guillaume le Nautonier 1604).

Among these, there is also:

- first visual representation of statistical data: variations in determination of longitude between Toledo and Rome (Michael Florent van Langren 1644). (Like others in his family and in this time, his name was written in various forms and in different languages: Miguel Florencio, Michale Florent, etc. We use the English version here, abbreviated as MFvL where it serves in the following.)

If this is truly the first exemplar of a graph of statistical data, van Langren should be canonized in this history, along with the contributions of William Playfair (1786, 1801) (invention of the line graph, bar chart, and pie chart), Charles Joseph Minard (“the best statistical graphic ever drawn”), Florence Nightingale (1857) (the use of the “coxcomb,” or rose diagram for social and political advocacy), and others. Yet, van Langren and the history of his graph remain little known.

However, it is important to make clear (a) that many such “firsts” are relative rather than absolute and (b) that “priority chasing” for its own sake is often an unprofitable goal in historiography (May 1975). On the first point, many “first” developments in the history of data visualization were preceded by other contributions that count as a “first” under different specifications. For example, the idea of a system of latitude and longitude for a map of the world was first proposed by Eratosthenes in the third century BC; the idea of the “coxcomb”—a polar area chart—goes back at least to André-Michel Guerry (1829), and Nightingale almost certainly was introduced to this graphic form by William Farr (1852). On the second point, it is more useful to understand the context in which a significant historical event occurred.

This article describes the background and questions that led to van Langren’s graph (Figure 1), conventionally dated to a 1644 publication, *La Verdadera Longitud por Mar y Tierra* (The true longitude for sea and land). We show why using a graph was effective for van Langren to achieve his communication goals. More importantly, some recently discovered letters by van Langren and others help tell the story behind this early graph and serve to date its genesis to early 1628.

1.1 Other Early Graphs

We claim that this one-dimensional line graph by van Langren is the first known visual representation of statistical data (i.e., empirical data where uncertainty of the observations is

---

Michael Friendly is Professor of Psychology, **???**, York University, Toronto, Canada (E-mail: *friendly@yorku.ca*). Pedro Valero-Mora is Professor, Facultad de Psicologia, Universitat de Valencia, Spain (E-mail: *valerop@uv.es*). Joaquín Ibáñez Ulargui is Cientifico Titular del CSIC, Centro Nacional de Investigaciones Metalúrgicas, Madrid, Spain (E-mail: *jiu@cenim.csic.es*). This research was aided by the National Sciences and Engineering Research Council of Canada, grant OGP0138748 to the first author. We are grateful to Robert Karrow, Peter van der Krogt, Doug Sims, and other correspondents on the Map History discussion list for information related to van Langren and the topics discussed in this article.

 DOI: 10.1198/tast.2010.09154

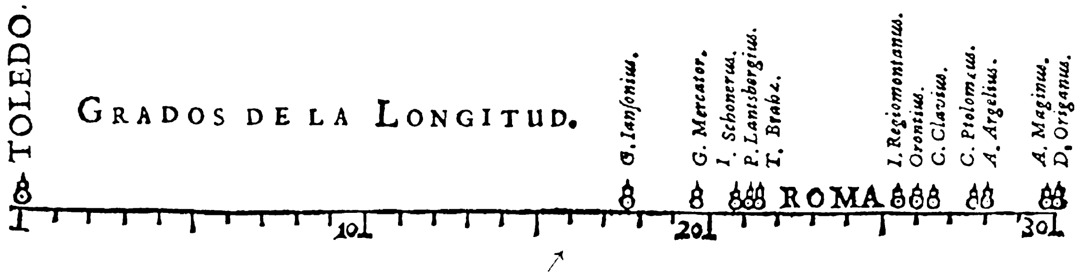

Figure 1. van Langren's 1644 graph of determinations of the distance, in longitude, from Toledo to Rome. The correct distance is 16.5°. *Source:* Tufte (1997, p. 15).

nonnegligible) and so a brief justification of this claim is necessary.

First, we can set aside all purely cartographic representations of geographical features (administrative boundaries, waterways, roads, cities, etc.) as outside the scope of the claim. Thematic maps, that *do* attempt to show something more than geographical features, did not arrive until the early 1700s (Friendly and Palsky 2007).

The first known graph of any sort is an anonymous tenth-century conceptual depiction of cyclic movements of the seven most prominent heavenly bodies through the constellations of the zodiac described by Funkhouser (1936) and reproduced in Tufte (1983, p. 28). Sometime around 1360, Nicole Oresme [1323–1382] conceived of the idea to visualize the way two physical quantities (e.g., time, velocity, distance traveled) vary in a functional relation. In the *Tractatus De Latitudinibus Formarum* (Latitude of forms), published only much later (Oresme 1482), he used the terms "latitude" and "longitude" in much the same way as we now use abscissa and ordinate, anticipating Descartes (1637) in this regard by over 250 years. His diagrams, shown in Figure 2, are the earliest abstract graphs we know of, but they were not based on any data. Funkhouser (1937, p. 277) said, "If a pioneering contemporary had presented Oresme with actual figures to work upon, we might have had statistical graphs 400 years before Playfair." But, empirical data that might have been displayed graphically were relatively unknown until around 1600.

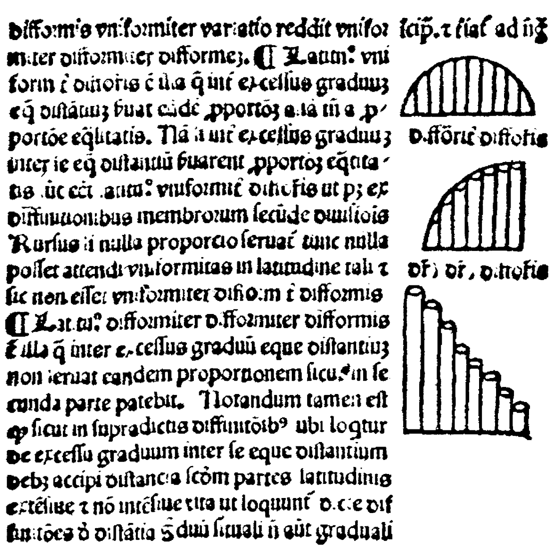

Figure 2. A page from Oresme's *Tractatus De Latitudinibus Formarum*, showing several graphical forms that might occur in a functional relation between physical variables.

It is recorded in the Milestones Project that around 1450, Nicholas of Cusa (Nikolaus von Kues) [1401–1464] proposed the idea of making a graph of the theoretical relation between distance and speed, but no sources are known. Of particular importance in this time were the laws of motion that governed falling bodies and projectiles. Albert of Saxony, Leonardo da Vinci, and others proposed different laws relating these quantities. Shortly after 1600, Galileo began the experimental study of the laws of relating time, distance, and speed of falling bodies, beginning with the (probably apocryphal) story of dropping a cannonball and a feather from the Tower of Pisa. In 1604 he conducted experiments using balls rolling down inclined planes, where he measured time with a water clock and surmised that the distance traveled was proportional to the square of the elapsed time.

Figure 3 compares the proposals of Albert, Oresme, Leonardo, and Galileo in graphical form (Frautschi 1986), but none of these actually made a graph of data, as far as is known. See the works of Frautschi (1986) and Wallace (1968) for more on the early history of laws of motion and the development of the correct idea of uniform acceleration of falling bodies.

As far as we know, the next early data-based graph, after van Langren, was a 1669 graph (image: *http://www.math.yorku.ca/SCS/Gallery/images/huygens-graph.gif*) by Christiaan Huygens (Boyer 1947) of the distribution of life expectancy at any age, derived by curve fitting and graphical interpolation (smoothing) from John Graunt's (1662) *Observations upon the Bills of Mortality*. Yet even this is essentially the graph of a functional relation.

1.2 Family History

The van Langren family is well known in the history of cartography. In the period from the mid 1500s through the end of the 1600s, three generations of this family achieved prominence as cartographers, globe makers, astronomers, and mathematicians, often with royal and state patronage. The genealogy of these individuals is shown in Figure 4. The brief description given here draws on the article by Keuning (1956) and the more recent and detailed studies in the book by van der Krogt (1993).

The van Langren family, starting with Michael's grandfather, Jacob Floris van Langren (or Jacobus Florentius), born ca.

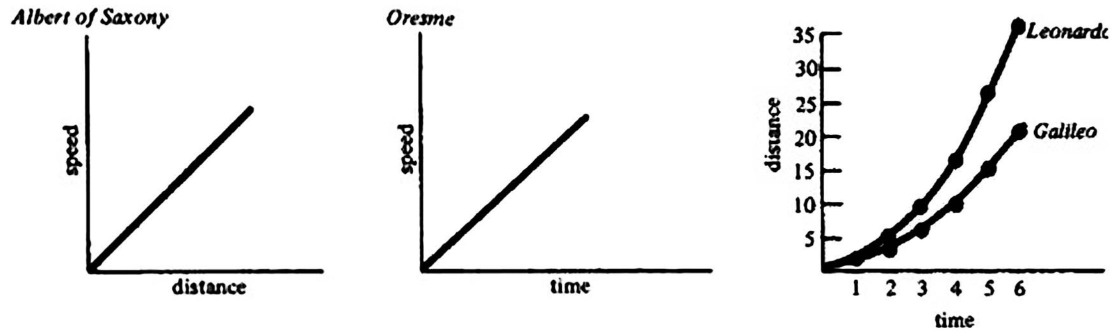

Figure 3. Laws relating time, position, and speed of falling objects, as proposed by Albert of Saxony, Nicholas Oresme, Leonardo da Vinci, and Galileo. The points shown on the rightmost graph were used only to show the difference in functional form between da Vinci and Galileo. *Source:* Frautschi (1986, fig. 2.2).

1525, together with his son Arnold Floris, born ca. 1571, made the first Dutch world globes, beginning around 1586 [dubbed "LAN IA" by van der Krogt (1993)]. In 1589, they produced a large version (52.5 cm diameter, "LAN II") that Jacob and Arnold continued to enhance over the next 50 years.

The salient points of this family history—only as they relate to our present account—are as follows.

First, the van Langren globes were significant in the development of Dutch sea-faring trade that arose largely in consequence of the Dutch revolt against Spanish rule (over matters of taxation, but principally of religion) that began under Philip II of Spain in 1568. This conflict, called the Eighty Years War, would last, on and off, for the next 80 years through the reigns of Philip II to Philip IV of Spain until 1648. In 1595, the first Dutch merchant fleet set out for the East Indies to circumvent the restrictions and blockades on the spice trade imposed by Spain. By 1602, the Dutch East India Company (*Vereenigde Oost-Indische Compagnie*) was established with a mandate to carry out trade and colonial activities against Spanish interests, and Dutch merchant ships would come to dominate world trade in the seventeenth century. Numerous sources were used by these early Dutch navigators, but the van Langren globes were particularly prized. In September 1592, Jacob Floris van Langren was granted a charter (monopoly) for 10 years on the production of globes in the Low Countries by the States General.

Second, the van Langren family enterprise of globe and map making, together with the copper plates and engraving tools, passed to his sons, Arnold Floris and Hendrick Floris van Langren, when the elder Jacob decided to retire at age 75 (van der Krogt 1993, p. 128). For navigational purposes, globes were often produced in pairs—a terrestrial globe, showing a map of the earth, and a celestial globe, showing a map of the heavens. But the initial van Langren globes of 1586 and 1589 had no celestial counterpart, so, in April 1590, Arnold was sent to visit Tycho Brahe on the island of Hven to make copies of Brahe's star catalog for the production of a celestial globe. The visit was evidently not particularly successful, and Hendrick was sent to complete the task in April 1593. A celestial companion to the 1586 globe (LAN IB) was produced in 1594; a mate to the larger 1589 globe did not appear until 1630.

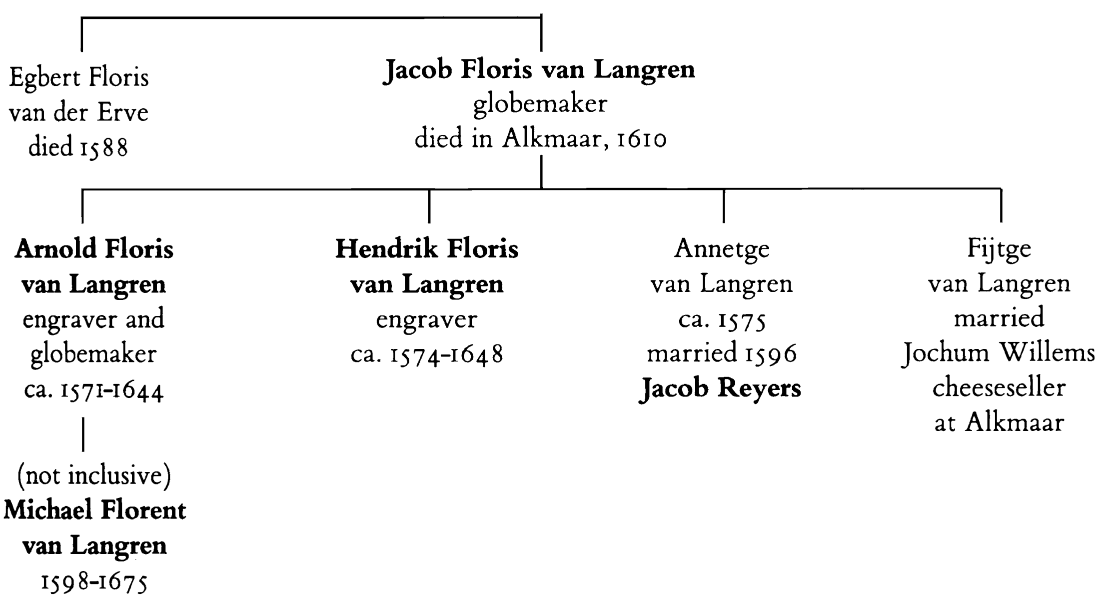

Figure 4. van Langren family genealogy. *Source:* van der Krogt (1993, p. 91).

Finally, by all accounts, Arnold was a skilled engraver, but he was not highly possessed of financial and business acumen. By late 1607 or early 1608, he had accumulated sufficient debts that he was forced to flee from Amsterdam to the Spanish-ruled southern provinces—in such haste to escape the bailiff that he left behind his household goods and engraving tools. To re-establish himself, he offered a large terrestrial globe to the city of Antwerp. We surmise that his skills also included the social abilities to attract supporters in high places. In September 1609, he succeeded in being named official Spherographer to Archduke Albert of Austria and his wife, Infanta (Princess) Isabella Clara Eugenia of Spain (daughter of Philip II), rulers of the Spanish Netherlands.

After Albert died in 1621, Isabella was appointed governor on behalf of Philip IV and continued to support Arnold's work on terrestrial and celestial globes and the accompanying manuals that were needed for mariners at sea. In all probability some of this additional work was carried out by Arnold's son, Michael Florent van Langren, the subject of this essay.

1.3 The Problem of Longitude

In relation to the history of data visualization, the most important scientific questions of the sixteenth and seventeenth centuries were those concerned with physical measurement—of time, distance, and spatial location. These arose in astronomy, surveying, and cartography and related to practical concerns of navigation at sea, exploration, and the quest for territorial and trade expansions among European states. Here, we describe one of these—the problem of longitude—but only so far as it relates to, and provides context for, van Langren's graph. [See the work by Andrewes (1996) for a variety of perspectives (mathematics, cartography, navigation, etc.) on the history of the longitude problem and attempted solutions. Sobel (1996) provided a popular account (deprecated by historians) of the first accurate solution, the invention of the marine chronometer by John Harrison in 1765.]

Among the most vexing—and also consequential—problems was that of the accurate determination of longitude, both on land and at sea. Latitude, a N–S position relative to the equator, has a physical 0 point on the terrestrial sphere and a conventional range to $\pm 90°$ at the poles; this could easily be found with a sextant or other device for measuring the angle (declination) of the sun, moon, or given stars, using tables of these positions that had been common for many centuries. Longitude, the E–W position, has no natural 0 point, and no natural points of reference; the only physical fact is that the scale of $0°$–$360°$ around any parallel corresponds to the 24-hr rotation of the earth, or $15°$ per hour. Errors in navigation led at best to much longer travel times and short rations or starvation for seamen, at worst to numerous shipwrecks and maritime disasters.

For the present purposes, it is both convenient and historically appropriate to illustrate this with two diagrams van Langren used to explain the problem of longitude to the council of King Philip IV of Spain in 1632; the context in which this occurred is described in Section 2.2. In Figure 5 he says, in essence: consider trying to determine the location on earth of point D in relation to point B (say, Toledo), either on land or at sea. To determine the distance in longitude, you must refer point D to its meridian that passes through point E at the equator and refer point B to its meridian passing through point C on the equator. Then, you could calculate the distance between points B and D on land or at sea.

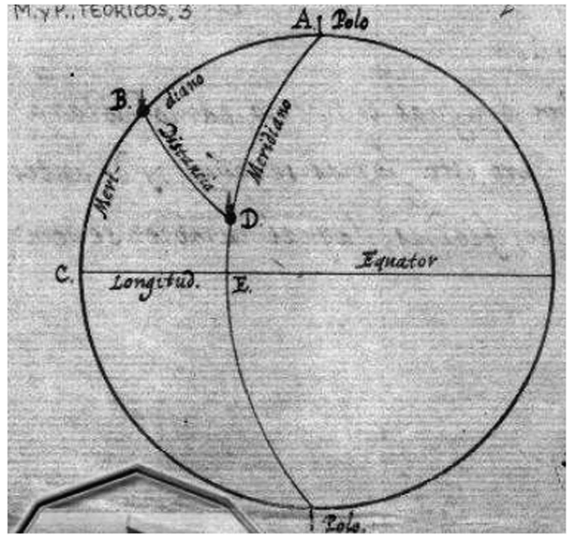

Figure 5. van Langren's 1632 first diagram, to explain the problem of determining longitude on land and at sea. *Source:* van Langren (1632).

But longitude at sea is a far more difficult and consequential problem. In Figure 6, van Langren shows the path of a ship that has left a port at F (with longitude at the equator, H) and has arrived at point L (longitude I), by traveling along the curved path shown from F to L. How can a navigator know how to return to port (F) or to sail further west to an island at point M?

What was needed for longitude was an accurate means to determine the difference in time between where you are and some fixed reference point. For example, if a navigator knew the time in Toledo at the *same instant* the sun reached its zenith (local noon), the difference between local noon and Toledo time would give the longitude difference, and similarly for any other celestial event. But, how could one know the time in Toledo when located at point D?

In the absence of accurate clocks, the problem was difficult on land, but even more so at sea, where celestial observations were subject to constant and changing motion and therefore more prone to error. As early as 1530, Reginer Gemma-Frisius [1508–1555] proposed a theoretical description—eventually proved to be correct—of how to determine longitude by a difference between clocks; but pendulum and other mechanical clocks (Galileo had used water clocks for his experiments in motion; Huygens obtained a patent for the pendulum clock in 1657) would remain insufficiently accurate for at least 100 years on land, and over 200 years for longitude at sea.

What else could serve as substitute for a reliable chronometer? Heavens above! In 1514, Johannes Werner [1468–1522] published a translation of Ptolemy's *Geographia*. In a commentary on Book I: Chapter IV, he proposed what became known as the lunar distance method, that is, determining longitude by measuring the angle between the moon and some star or the sun, with the use of a nautical almanac recording those positions at given dates and times at a fixed position.

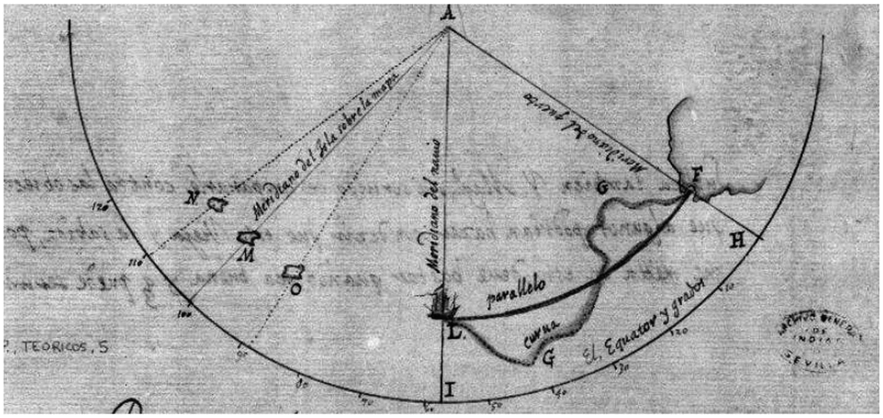

Figure 6. van Langren's second 1632 diagram, to explain the more specific problem of determining longitude at sea. *Source:* van Langren (1632).

One reason for this great attention to the longitude problem was a series of substantial prizes offered by various European countries for "the discoverer of longitude." The first was offered by the Spanish King Philip II in 1567. After Philip III came to the throne in 1598, a prize of 6000 ducats, plus a pension of 2000 ducats for life was offered. Other rewards were offered by Holland and France, culminating in *The Longitude Prize*, begun in 1714 by the British government and resulting in awards totaling over £100,000 (O'Connor and Robertson 1997). [The proximal stimulus was one of the worst ever maritime disasters on 22 October 1707, in which five ships commanded by Admiral Cloudsley Shovel struck the Isles of Scilly, resulting in 2000 sailors killed. Various specific prizes were offered: £10,000 for a method accurate to within 1° of longitude (111 km, or 60 nautical miles) to £20,000 for accuracy within 0.5° (56 km, 30 nautical miles), plus other awards for contributions thereto.]

Over the next 200 years, problems that stemmed from attempts to solve the longitude problem by means of celestial observation and reference tables would occupy the attention of the best astronomers and mathematicians of the times. For example, in 1612 (shortly after the invention of the telescope) Galileo tabulated the orbits of the four largest moons of Jupiter and proposed that sufficiently accurate knowledge of their orbital periods could serve as a more precise celestial clock. Attempts to increase the precision of the lunar distance method were advanced by Edmund Halley around 1683 (times of occultations of a star by the moon).

After the publication of Newton's universal theory of gravitation in 1687 (*Principia mathematica*), the mathematical theory of planetary and lunar motion became more advanced. Tobias Mayer (1750), using maps of lunar features first developed by van Langren, made observations sufficiently precise to allow a mathematical and statistical account of the small perturbations ("librations") of lunar motion. This would serve as an early contribution to the theory of least squares as a method of combining observations subject to error (Stigler 1986, pp. 16–24).

This was the ring into which Michael van Langren threw his hat. A large part of his lifetime would be occupied by the problem of determining longitude. In this endeavor he was not particularly successful in providing a solution. Yet, along the way, he made a number of important contributions that we describe below, with a focus on his statistical graph and its wider context.

2. VAN LANGREN'S GRAPH

In this section we first consider the 1644 graph (Figure 1) from *La Verdadera* in relation to van Langren's presumed presentation goals and why this simple graph should be celebrated for graphical excellence, beyond just being a 'first.' We then describe the discovery of earlier letters by van Langren that (a) serve to date the origin of this graph to sometime before March 1628 and (b) provide a detailed history of the context and motivation that led him to adopt this graphic form.

2.1 Why the First Graph Got It Right

Van Langren's 1644 graph (Figure 1) was designed to contribute to a more precise determination of longitude, particularly for navigation at sea as noted above. There is, of course, a single, correct value for the distance in longitude between Toledo and Rome, but that value, 16.5°, would remain imprecisely known for over 100 years.

Looking at this graph, what can we see? On the graph, he shows 12 estimates of the longitude distance, on a scale of 0°–30°, each with a label (written vertically) for the name of the person who made that determination. This graph is remarkable in the history of data visualization for several reasons.

First, it would have been easiest for van Langren to present this information to the Spanish court in tabular form, showing (Name, Year, Longitude, Where), as suggested in Figure 7. Such a table could have been arranged to highlight authority (sorted by name), or priority (sorted by year), or the range of values (sorted by longitude value).

However, only a graph speaks directly to the eyes and shows the wide variation in the estimates; note that the range of values covers nearly half the length of the scale. It also appears from the graph that van Langren took as his overall summary the center of the range, where there happened to be a large enough gap for him to inscribe "ROMA."

Second, van Langren's graph serves as a compelling visual example of the idea of bias in statistical estimation. In Figure 1 a small arrow marks the true longitude distance (16.5°). This aspect can be seen more clearly by overlaying van Langren's

Sorted by Longitude

Longitude	Name	Year	Where
17.7	G. Iansonius	1605	Flanders
19.6	G. Mercator	1567	Flanders
20.8	I. Schonerus	1536	Germany
21.1	P. Lantsbergius	1530	Flanders
21.5	T. Brahe	1578	Denmark
25.4	I. Regiomontanus	1463	Germany
26.0	Orontius	1542	France
26.5	C. Clavius	1567	Germany
27.7	C. Ptolomeus	150	Egypt
28.0	A. Argelius	1610	Italy
29.8	A. Maginus	1582	Italy
30.1	D. Organus	1601	Germany

Sorted by Priority

Year	Name	Longitude	Where
150	Ptolomeus, C.	27.7	Egypt
1463	Regiomontanus,	25.4	Germany
1530	Lantsbergius, P.	21.1	Flanders
1536	Schonerus, I.	20.8	Germany
1542	Orontius	26.0	France
1567	Mercator, G.	19.6	Flanders
1567	Clavius, C.	26.5	Germany
1578	Brahe, T.	21.5	Denmark
1582	Maginus, A.	29.8	Italy
1601	Organus, D.	30.1	Germany
1605	Iansonius, G.	17.7	Flanders
1610	Argelius, A.	28.0	Italy

Figure 7. Two of the possible tables van Langren might have used. Left: sorted by longitude, to show the range. Right: sorted by year to show priority or trend. The Year given in these tables is approximate, as van Langren did not cite his sources by date.

graph on a modern map as shown in Figure 8: the previous estimates of longitude distance were extremely far from being correct and place Rome anywhere from the Adriatic Sea to Greece or Turkey.

Finally, van Langren's graph is also a milestone as the earliest known exemplar of the principle of "effect ordering for data display" (Friendly and Kwan 2003): graphs and tables are most effective when the information is arranged to highlight the features to be seen. In this case, it is clear that van Langren's main presentation goal was to show the enormous range of differences among the greatest known astronomers and geographers. As such, the graph is all the more remarkable for its focus on *uncertainty* or variability of observations, a topic that did not receive serious attention until roughly 100 years later (see Stigler 1986). Thus, we conclude that the first graph did indeed 'get it right.'

2.2 The 1628 Letters: Stake a Claim

Michael van Langren, like other scholars of his time, was a prodigious writer of letters. (For example, Quetelet 1864, pp. 247–248, described collections of letters to and from van Langren in several archives. Other collections of his letters were described or contained in Moreau 1957; de Vyver 1977.) Unlike those with independent means of support, and without a university education, van Langren had to depend on patronage to sustain his work and earn a livelihood. Most likely through his family connection (Arnold's son), in 1626, at age 28, he obtained a commission to make a map of the new canal constructed between the Meuse in Belgium and the Rhine in Germany. This map, titled *Fossae S. Mariae descriptio*... (Keuning 1956, fig. 1), was dedicated to Isabella Clara Eugenia, governor of the Netherlands, who would soon become his patron. Around this time, with the intercession of Isabel, he received an appointment as Royal Cosmographer and Mathematician to King Philip IV, for which he would come to receive an annual retainer of 1200 écus, apparently a considerable sum. Michael van Langren had arrived: financially, and in the Spanish court.

Recently, the third author found in the archive of his family some documents related to fray Íñigo of Brizuela, President of the Counsel of Flanders until 1629. These contain (a) an undated letter by van Langren to Isabella. In this, he requests that Isabella intercede on his behalf to King Philip to grant him a concession to make more accurate maps for navigation; (b) an undated letter from Isabella to King Philip giving reasons to support this concession; (c) a letter in French, dated March 9, 1628 by Dr. Jean Jacques Chifflet, in service to Isabella, written to fray Íñigo of Brizuela in support of van Langren's request.

The letter by van Langren contained the graph and table shown in Figure 9. Because of the sequence of the three letters, it is possible to date this letter to sometime before March 1628, possibly in the early part of this year. In the letter (below), he describes himself as "Mathematician to His Majesty," so this

Figure 8. van Langren's 1644 graph, linearly rescaled and overlaid on a modern map of Europe. Toledo is located at lat/long (+39.86°N, −4.03°W). Rome is located at (+41.89°N, +12.5°W), both shown by markers on the map. This image makes clear what van Langren wished to communicate: the wide variability of the estimates, but also shows how far the estimates were biased.

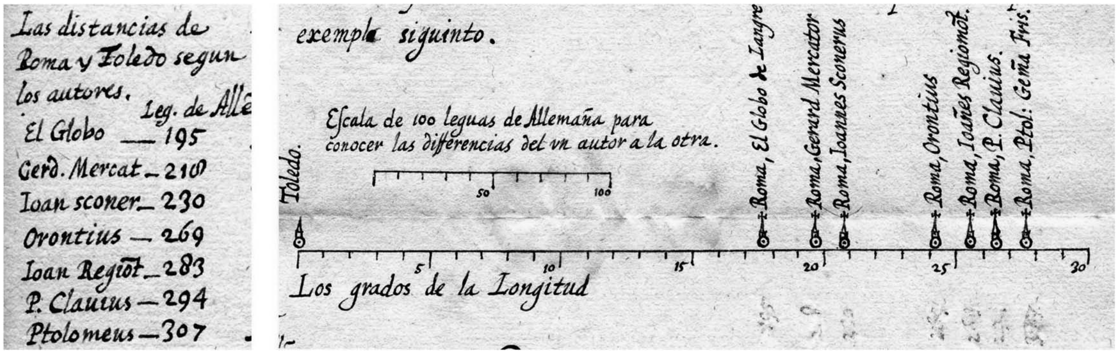

Figure 9. The graph and table of determinations of longitude, from the letter of van Langren to Isabella Clara Eugenia, ∼1628. *Source:* Archive of the counts of Castilfalé, Burgos, Spain.

could not date before 1626. Thus, van Langren's graph had its origin at least 16 years before the 1644 publication of *La Verdadera* that contained Figure 1.

Van Langren's letter to Isabella was transcribed from old to modern Spanish and then translated to English. It is worth printing the English translation to see the context and motivation for the graph. (Available online at *http://www.math.yorku.ca/SCS/Gallery/langren/VanLangren1628.pdf*.)

> Most Serene Highness
>
> Miguel Florencio van Langren, Mathematician to His Majesty, says that his Grandfather and his Father, Cosmographer to His Majesty, have been the first who have invented Globes for the direction of navigators, and the supplicant, emulating them has attained with great study and attention some fundamental and concealed aspects of the aforementioned art as well as others, and one of the main is that of Longitude, by which it is possible to lay out perfectly all the Terrestrial description, which has countless errors as can be seen in the writings of different authors, because comparing two maps or tables of longitude of different authors, by no means do they concur between them as Your Serene Highness will see in the following example.
>
> If the Longitude between Toledo and Rome is not known with certainty, consider Your Highness, what it will be for the Western and Oriental Indies, that in comparison the former distance is almost nothing. So to amend these deficiencies and to find the true distances of the towns of the Earth, it would be necessary that Your Serene Highness be pleased to supplicate to His Majesty (as in the example of the Queen Isabel of Castile) to dispatch a Patent so that he can send his corresponding and printed instructions for all the Earth, both to the East and to the West, ordering in it that all interested in the art observe what the supplicant advises them, promising that many benefits will derive for navigation, and eternal memory for His Majesty and Your Highness, for having ordered this general correspondence of the art, and Your Most Serene Highness will receive it very particularly.

Thus, he makes explicit that the purpose of drawing a graph is to show the "countless errors" in the determination of longitude distance between two relatively well-known locations. In its intent, the letter can be read as a classic example of the syllogism of grantsmanship as a patronage request:

1. Longitude distance between Toledo and Rome is subject to large errors.
2. By extension, the errors in longitude between Toledo and the Western and Oriental Indies must be far greater.
3. Therefore, grant me a Patent to sort this out, promising many benefits for navigation.

Viewed as a grant application, what is missing from this letter is a Method or Proposal paragraph indicating *how* he intends to solve the longitude problem. This would be a goal that occupied his attention over the rest of his life. Yet, perhaps fearing that others would steal his thunder or claim priority for his method, he intentionally kept the details secret. In *La Verdadera* (p. 8), Langren included a description of a new method to determine longitude, but in the form of a cipher whose meaning he said he will reveal to the king, presumably after suitable compensation. He claimed that this was communicated to the king via Isabel in 1625.

Some differences between this early graph (Figure 9) and the 1644 version (Figure 1) are worth noting:

- The most important difference is that in Figure 9, he includes a separate scale showing longitude distances in German leagues (Gl.), with a corresponding table of those values in the margin. The values in Gl. can also be seen faintly beneath the horizontal axis, as if he first recorded these values along the scale and then erased them. The use of double scales is common today (e.g., showing temperature in °F and °C), but it is remarkable that such annotations would appear on the first statistical graph.

  Why did he do this? First, it is reasonable to assume that he felt the need to show that the values on the graph were actually based on real data. A second inference is that the values shown were originally expressed in German leagues and then translated to degrees longitude. (A graphical conversion from his scales shows that 100 Gl. $= 8.9375°$, or 111.88 Gl. $= 10°$. Translation to modern units is more difficult to infer. As we note below, at the equator, $1°$ in longitude $= 111$ km, so, approximately, 1 Gl. $= 10$ km. However, at the latitude of Toledo, $1°$ in longitude $= 85.3$ km, so, approximately, 1 Gl. $= 7.62$ km.)
- The graph and table in Figure 9 show only 7 values instead of the 12 shown in Figure 1. Among these, Figure 9 contains a value 17.7° attributed to the "globe of Langren." Among all the images of van Langren's graph we have found, this is the only occurrence of an attribution that appeared just once. Yet, this value was off by only 7.2% in relation to all the other authorities named in all his graphs. (Among the five versions of

van Langren's graph we have found, this is the value with the second smallest positive bias, after those recorded for Iansonius (Jan Jansson [1588–1664]), for whom the average bias was 1.026°, or 6.2%. The particular van Langren globe referred to here is unknown. A close reading of van der Krogt (1993, chaps. 3 and 7) suggests the guess that this may be one of the large terrestrial globes ("LAN II") produced by Jacob and Arnold van Langren beginning in 1598 and modified in other copies over the next 50 years.)

- Moreover, the value ascribed to "Orontius" (Oronce Finé) here is located at 24° of longitude, rather than the value 26° in the 1644 version. We analyze differences among these and other versions in more detail in the online Appendix.
- Finally, the word *ROMA* is not inscribed in the convenient gap along the horizontal axis as in Figure 1, but it is written vertically in front of the name of each authority. Thus, the inference that the word *ROMA* in Figure 1 marked a central (typical, average, or best estimate) value for the true longitude distance is incorrect. (As far as is known, the idea of combining observations by averaging was first expressed in 1635 by the English astronomer Henry Gellibrand [1597–1636] (Gellibrand 1635). Later developments of this idea occurred only in the mid to late 1700s (Thomas Simpson, Tobias Mayer, Pierre Simon Laplace), finally arriving at the idea of the mean as a least squares estimate around 1800 (Adrien Legendre, Carl Friedrich Gauss).)

2.3 Letters of 1632–1633: Eyes on the Prize

We are not quite done with the analysis of van Langren's early letters related to this graph of longitude. In the course of research for this article, another similar collection of letters (van Langren 1632) was found in the *Archivo General de Indias* (General Archives of the Indies) in Seville, and cataloged as *Estudios Sobre la Longitud*, Patronato, 262, R.7. There are five letters, including two by van Langren describing his ideas for the determination of longitude, (these may be accessed online through the Portal de Archivos Españoles, *http://pares.mcu.es*, searching for "van Langren"), with supporting letters by a Juan Osvaldo de Brito. The first of these, by de Brito, is dated February 28, 1632 and is essentially a cover-memo to the War Subcommittee of the Council to Philip IV, concerning the attached proposal by MFvL that had been presented to the Council January 7 of that year.

Both letters by van Langren contain slightly different versions of the graph of longitude distances. Figure 10 shows the version contained in the 1632 letter. Here, for the first time we know of, he attempts to deal with the general problem of mapping a spherical earth in terms of latitude and longitude, described earlier (see Figure 5). Consequently, in the 1632 version of the graph, he explicitly represented the estimates for Rome along a separate line for the parallel of Rome.

In addition, he showed 13 separate points on the graph, but a close inspection shows that two of the points each cite two authorities ([Ptolomeus, Orontius]; [Leonitrus, Origanus]), for a total of 15 citations. These include five sources [Algunas ("Algunas" here refers to "various" sources that he could not or did not want to disclose) maps, Bertius, Algunas map & globe, P. Apianus, Leonitrus] not seen in any other versions of the graph. The letter of 1633 uses the same data, but omits the separate parallels for Toledo and Rome.

Beyond the details of differences among these graphs, the texts of these letters give further insight into van Langren's motivation for writing them. He begins with the statement that MFvL, mathematician to His Majesty, has uncovered some "very important secrets" with regard to the computation of longitude, on land and at sea. There follows a presentation of the general longitude problem (Figure 5) and the additional problems for longitude at sea (Figure 6). In this, he illustrates the habitual errors of navigators that result from inaccurate maps and charts, using his current version of the graph of longitude determinations, now with additional sources (Figure 10), and reminds His Majesty that he has been granted a royal mandate to carry this out.

The final paragraphs get to the main points:

> And in this regard His Majesty offered to the Inventor of such solution great rewards, and in particular to Luis Fonseca 6000 ducats every year, and then to Juan Arias, 2000 ducats every year for a lifetime; so if his Majesty sends to this Supplicant the assurance of a prize that his Royal Highness judges appropriate, he (the Supplicant) will report the aforementioned secret to His Majesty, because finding this invention and not getting any reward would be honorless.
>
> (My person) also supplicates that His Majesty shelters him against the objections that some could put, saying that my invention is old and known and that I should not interfere in this, as I think that it must be sufficient if it is good and useful.

Evidently, after these two letters for support, he was successful on both accounts, without even revealing the "secret." He

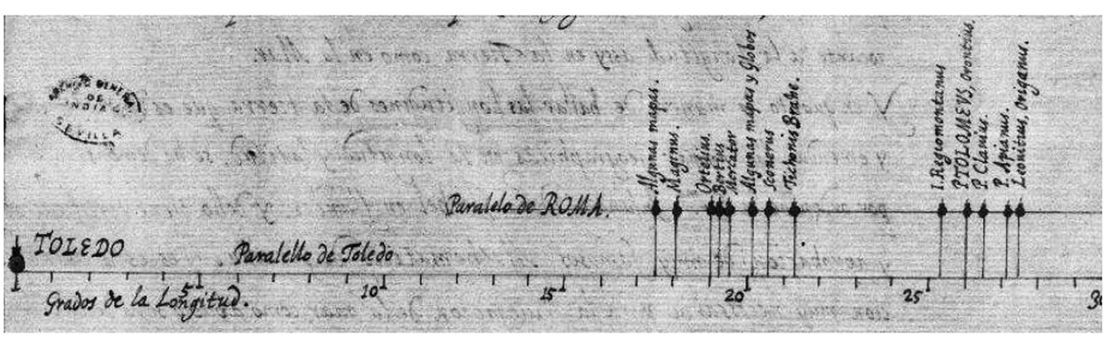

Figure 10. van Langren's 1632 graph of determinations of longitude. Here, he cites additional sources and makes clear that Toledo and Rome are located on slightly different parallels of latitude. *Source:* van Langren (1632).

received some unknown but handsome compensation, and, in the following year (van Langren 1634), he felt free to announce "to all the professors and lovers of mathematics, on the proposition of longitude, by sea and land": it has been done by MFvL, mathematician to his Catholic Majesty.

3. VAN LANGREN'S DATA

At least four questions naturally arise from the above discussion: (a) What were the sources of the estimates of longitude that van Langren displayed in these graphs? (b) Why did he choose Toledo and Rome? (c) How did the authorities and values displayed differ across the versions of the graph? (d) Why were the estimates so biased upward? These questions take us into the realm of statistical historiography (Friendly 2005), that is, the use of statistical thought in the analysis of historical sources. For reasons of length, these topics are discussed in the online Appendix included in our supplementary materials.

4. OTHER WORK: LONGITUDE AND SELENOGRAPHY

Although van Langren's cipher remains undecoded, the "secret" that van Langren alluded to in his 1632/33 entreaties to the Spanish court is related to a possible improvement in the lunar method that he surmised from telescopic observations. This would turn out to be his principal contribution to astronomy, wherein he is better remembered than in the history of statistical graphics.

As early as 1628, he conceived the idea of using the rotation of the moon—rather than its mere position in the sky—as a more accurate celestial clock. By timing the occurrence of sunrise or sunset on identifiable lunar peaks and craters, one would have a nearly continuous set of reference events with which local time could be accurately determined.

Two things were needed to make this idea practical for the determination of longitude at sea. First, it required an accurate lunar globe or set of maps that named the peaks, craters, and other lunar features so that they could be easily recognized. Second, it required a set of ephemeris tables, recording the onset in standard time of sunrise (lightening) and sunset (darkening) events on the days of the lunar cycle.

Van Langren spent a few years in the early 1630s at the court in Madrid, during which he attempted to enlist support for this project and made plans for the preparation of a collection of lunar maps and diagrams, together with a "user guide" containing instructions for the calculation of longitude from observations of the lunar features he would catalog. Because he would be the first to comprehensively map the lunar features, he proposed to have "the names of illustrious men applied to the luminous and resplendent mountains and islands of the lunar globe," a prospect that evidently pleased King Philip.

In a letter dated May 27, 1633 (de Vyver 1977; Whitaker 2004), Philip encouraged Princess Isabella (van Langren's patron) to fund this project. Isabella's death in December of this year delayed both his source of funds and enthusiasm for timely completion of this work. Over the next decade he produced 30 sketches of lunar features in different phases of its cycle.

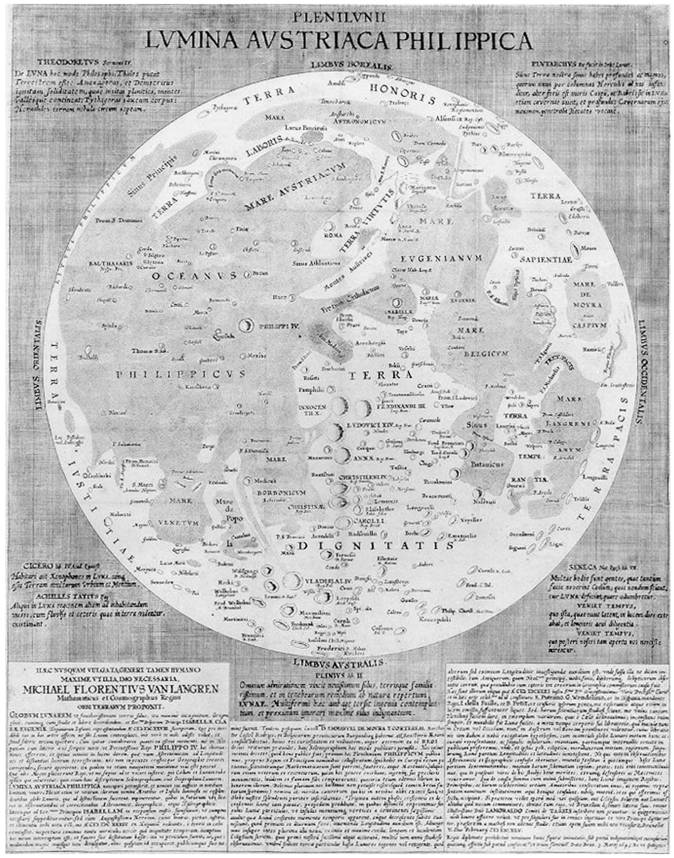

Figure 11. van Langren's 1645 map of the moon, *Plenilunii Lumina Austriaca Philippica*, dedicated to King Philip and showing 325 topographic names he had assigned to lunar features. *Source: http://www.lpod.org/?m=20060128*.

News that others (Johannes Hevelius and P. Juan Carmanuel y Lobkowitz) were planning their own projects in mapping the lunar surface propelled him to complete what is now regarded as the first comprehensive lunar map.

In early 1645 he produced a manuscript version (Whitaker 2004, fig. 25) showing 48 named topographic features. Correspondence among van Langren, his friend E. Puteanus, and others in the Spanish court (Bosmans 1903) date this to early February of this year. The final version, engraved in copperplate in March 1645 (Figure 11) identifies 325 named locations. [Of the manuscript version, only three copies were known to exist by Bosmans (1903, p. 110); Whitaker (2004, p. 40) could locate only four extant copies of the engraved version.] Having exhausted his list of "illustrious men," and even adding several saints, he still had more features than names. Beyond the titular dedication to King Philip (*Plenilunii ... Philippica*), the Infanta Isabella Clara Eugenia appeared three times in his nomenclature, in recognition of years of patronage. See the book by Whitaker (2004) for a comprehensive account of the naming of lunar features.

Van Langren never completed the manual and tables describing exactly how his lunar map could be used. Moreover, although his scheme for longitude determination based on a detailed lunar map did offer the opportunity for greater precision than previous lunar methods, the relatively slow speed with which the lunar peaks became illuminated or vanished set hard limits on the precision this method could achieve. Nevertheless, he was the first to produce a comprehensive lunar map, and his own toponym for the crater *Langrenus* survives to this day, along with about half of his other names.

Michael Florent van Langren died in Brussels in May 1675, long before his ideas for the determination of longitude could be improved upon by others. Variations of the lunar method advanced considerably over the next 100+ years, providing greatly improved accuracy based on more detailed and precise observations and mathematical theory to account for the librations of the moon. As noted earlier, Tobias Mayer (1750) made significant contributions in this regard. In this, he used a lunar map of greater precision (Whitaker 2004, fig. 52), the first to be based on accurately measured positions on the lunar surface. His tables and calculations offered the prospect of accuracy to within the 1° (111 km) range for at least the smallest prize designated by the British *Board of Longitude*. Mayer died in 1762, but his work would ultimately earn his widow a £3000 prize in 1765, and smaller prizes of £300 were awarded to both Gottfried Leibnitz and Leonhard Euler as contributions to Mayer's work.

5. CONCLUSIONS

As in the opening quotation, "Every picture tells a story," the aim of this article has been to uncover the larger history behind van Langren's 1644 graph (Figure 1), often considered the first exemplar of a graph of statistical data. From the discovery of his early letters, we have learned that the origin of this first one-dimensional graph goes back at least 16 years earlier, to the letter dated before March 1628 to Isabella Clara Eugenia (Figure 9). Moreover, the sequence of development of the earlier versions of this graph helps to shed some light on aspects of the determination of longitude in his time.

We have shown that, at the time of the earliest (1628) version, he already had in mind a possible and more accurate solution to the longitude problem, based on lunar rotation and the lunar maps he had begun to contemplate. He did not complete the lunar map until 1645, and never finished the remaining parts (tables and instructions for their use) to make this a practical method. Consequently, he is better remembered in historical studies for his lunar maps than for his contributions to the longitude problem in his time.

Nevertheless, we have also shown that Michael Florent van Langren should be remembered as well for his contributions to statistical graphics and data visualization. His one-dimensional graphs, showing the wide variability in the previous determinations of longitude distances between Toledo and Rome, are outstanding to this day as examples of clear visual presentation, from a time before the ideas of uncertainty of empirical estimates or even of representation of empirical data values along an axis were known.

SUPPLEMENTAL MATERIALS

Beyond this, we hope that we have left some interesting open questions for others to examine. To this end, supplementary materials related to this article include:

Appendix A: Some answers to the questions posed in Section 3. (langren-app.pdf)

La Verdadera: A transcription and English translation of *La Verdadera Longitud por Mar y Tierra*. (verdadera.pdf)

These and other documents related to van Langren's cipher, his "secret of Longitude," have also been deposited at *http://www.math.yorku.ca/SCS/Gallery/langren/*.

[Received August 2009. Revised February 2010.]

REFERENCES

A few items in this reference list are identified by shelfmarks or call numbers in the following libraries: BeNL: Belgium National Library, BL: British Library, London, BNF: Bibliothèque Nationale de France, Paris (Tolbiac), LC: Library of Congress, MMR: Maritime Museum, Rotterdam.

Andrewes, W. J. H. (ed.) (1996), *The Quest for Longitude: Proceedings of the Longitude Symposium, Harvard University, November 4–6, 1993*, Cambridge, MA: Collection of Scientific Instruments, Harvard University. [4]

Bosmans, H. (1903), "La carte lunaire de van Langren conservée aux archives générales du royaume à Bruxelles," *Revue des Questions Scientifiques*, 3rd Series (4), 108–139. [9]

Boyer, C. B. (1947), "Note on an Early Graph of Statistical Data (Huygens 1669)," *Isis*, 37 (3/4), 148–149. [2]

de Nautonier, G. (1602–1604), *Mecometrie de l'eymant, c'est a dire la maniere de mesurer les longitudes par le moyen de l'eymant*, Paris: R. Colomies. BL: 533.k.9; BNF: RES-V-432; LC: QB225.N3. [1]

de Vyver, O. V. (1977), "Lettres de J.-Ch. della Faille S.I., cosmographe du roi, Madrid, M.-F. van Langren, cosmographe du roi, Bruxelles, 1634–1645," *Archivum Historicum Societatis Iesu*, 46, 73–183. [6,9]

Descartes, R. (1637), "La Géométrie," in *Discours de la Méthode*, Paris: Esseller. [2]

Farr, W. (1852), *Report on the Mortality From Cholera in England, 1848–1849*, London: HMSO. Also published as Farr, W. (1852), *Registrar General's Report on Cholera in England 1849–1850*, London: W. Clowes & Son. [1]

Frautschi, S. C. (1986), *The Mechanical Universe*, Cambridge, U.K.: Cambridge University Press. [2,3]

Friendly, M. (2005), "Milestones in the History of Data Visualization: A Case Study in Statistical Historiography," in *Classification: The Ubiquitous Challenge*, eds. C. Weihs and W. Gaul, New York: Springer, pp. 34–52. [9]

——— (2008), "A Brief History of Data Visualization," in *Handbook of Computational Statistics: Data Visualization*, Vol. III, eds. C. Chen, W. Härdle, and A. Unwin, Heidelberg: Springer-Verlag, Chap. 1, pp. 1–34. [1]

Friendly, M., and Denis, D. J. (2001), "Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization," web document, available at *http://www.math.yorku.ca/SCS/Gallery/milestone/*. [1]

Friendly, M., and Kwan, E. (2003), "Effect Ordering for Data Displays," *Computational Statistics and Data Analysis*, 43 (4), 509–539. [6]

Friendly, M., and Palsky, G. (2007), "Visualizing Nature and Society," in *Maps: Finding Our Place in the World*, eds. J. R. Ackerman and R. W. Karrow, Chicago, IL: University of Chicago Press, pp. 205–251. [2]

Frisius, R. G. (1530), *Principiis Astronomiae Cosmographicae*. [4]

Funkhouser, H. G. (1936), "A Note on a Tenth Century Graph," *Osiris*, 1, 260–262. [2]

——— (1937), "Historical Development of the Graphical Representation of Statistical Data," *Osiris*, 3 (1), 269–405. Reprinted Brugge, Belgium: St. Catherine Press, 1937. [2]

Gellibrand, H. (1635), *A Discourse Mathematical on the Variation of the Magneticall Needle. Together With Its Admirable Diminution Lately Discovered*, London: n.p. [8]

Graunt, J. (1662), *Natural and Political Observations Mentioned in a Following Index and Made Upon the Bills of Mortality*, London: Martin, Allestry, and Dicas. LC: HB1416.L8 G7 1665. [2]

Guerry, A.-M. (1829), “Tableau des variations météorologique comparées aux phénomènes physiologiques, d’aprés les observations faites à l’obervatoire royal, et les recherches statistique les plus récentes,” *Annales d’Hygiène Publique et de Médecine Légale*, 1, 228–. [1]

Keuning, J. (1956), “The van Langren Family,” *Imago Mundi*, 13, 101–109. [2,6]

May, K. O. (1975), “Historiographic Vices: II. Priority Chasing,” *Historia Mathematica*, 2, 315–317. [1]

Mayer, J. T. (1750), “Abhandlung über die umwälzung des Monds und seine Axe,” *Kosmographische Nachrichten un Sammlungen*, 1, 52–183. [5,10]

Moreau, J. (1957), *Honderd veertien Nederlandse brieven van Erycius Puteanus aan de astronoom Michael Florent van Langren*, Antwerp: De Seven Sinjoren. [6]

Nightingale, F. (1857), *Mortality of the British Army*, London: Harrison and Sons. [1]

O’Connor, J. J., and Robertson, E. F. (1997), “Longitude and the Académie Royale,” web article, MacTutor History of Mathematics. Available at *http://www-groups.dcs.st-and.ac.uk/~history/PrintHT/Longitude1.html*. [5]

Oresme, N. (1482), *Tractatus de latitudinibus formarum*, Padova. BL: IA 3Q024. [2]

Ortelius, A. (1570), *Theatrum Orbis Terrarum*, Antwerp: Coppenium Diesth. 53 maps in coperplate, 41 × 29 cm.; LC: G1006.T5 1570. [1]

Playfair, W. (1786), *Commercial and Political Atlas: Representing, by Copper-Plate Charts, the Progress of the Commerce, Revenues, Expenditure, and Debts of England, During the Whole of the Eighteenth Century*, London: Debrett, Robinson, and Sewell. Republished in Wainer, H., and Spence, I. (eds.) (2005), *The Commercial and Political Atlas and Statistical Breviary*, Cambridge University Press. [1]

——— (1801), *Statistical Breviary; Shewing, on a Principle Entirely New, the Resources of Every State and Kingdom in Europe*, London: Wallis. Republished in Wainer, H., and Spence, I. (eds.) (2005), *The Commercial and Political Atlas and Statistical Breviary*, Cambridge University Press. [1]

Quetelet, A. (1864), *Histoire des Sciences Mathématiques et Physiques chez les Belges*, Brussels: Hayez. [6]

Sobel, D. (1996), *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time*, New York: Penguin. [4]

Stigler, S. M. (1986), *The History of Statistics: The Measurement of Uncertainty Before 1900*, Cambridge, MA: Harvard University Press. [5,6]

Tufte, E. R. (1983), *The Visual Display of Quantitative Information*, Cheshire, CT: Graphics Press. [2]

——— (1997), *Visual Explanations*, Cheshire, CT: Graphics Press. [2]

van der Krogt, P. (1993), *Globi Neerlandici: The Production of Globes in the Low Countries*, Utrecht: HES Publishers. [2,3,8]

van Langren, M. F. (1632), “Estudios sobre la longitud,” manuscript, Archivo General de Indias, Patronato, 262, R.7. [4,5,8]

——— (1634), *Advertencias De Migvel Florencio Van Langren Matematico de su Magestad, a todos los professores y amadores de la Matematica, tocantes a la proposicion de la longitud, por mar y tierra, que ha hecho a su Magestad Catolica*, Brussels: Jean Momartre. MMR: S.4793(477). [9]

——— (1644), *La Verdadera Longitud por Mar y Tierra*, Antwerp: (n.p.). Ii + 14 pp., folio; BL: 716.i.6.(2.); BeNL: VB 5.275 C LP. [1]

Wallace, W. A. (1968), “The Enigma of Domingo de Soto: *Uniformiter difformis* and Falling Bodies in Late Medieval Physics,” *Isis*, 59 (4), 384–401. [2]

Whitaker, E. A. (2004), *Mapping and Naming the Moon: A History of Lunar Cartography and Nomenclature*, Cambridge, U.K.: Cambridge University Press. [9,10]

META DATA IN THE PDF FILE

Following information will be included as pdf file Document Properties:

Title : The First \(Known\) Statistical Graph: Michael Florent van Langren and the "Secret" of Longitude
Author : Michael Friendly, Pedro Valero-Mora, Joaquin Ibanez Ulargui
Subject : The American Statistician, Vol.0, No.0, 2010, 1-12
Keywords: Data visualization, History of statistics, Longitude, Michael Florent van Langren, Selenography, Statistical historiography, Thematic cartography, Uncertainty

THE LIST OF URI ADRESSES

Listed below are all uri addresses found in your paper. The non-active uri addresses, if any, are indicated as ERROR. Please check and update the list where necessary. The e-mail addresses are not checked – they are listed just for your information. More information can be found in the support page: *http://www.e-publications.org/ims/support/urihelp.html*.

```
--- mailto:friendly@yorku.ca [2:pp.1,1] Check skip
--- mailto:valerop@uv.es [2:pp.1,1] Check skip
--- mailto:jiu@cenim.csic.es [2:pp.1,1] Check skip
200 http://www.amstat.org [2:pp.1,1] OK
200 http://dx.doi.org/10.1198/tast.2010.09154 [2:pp.1,1] OK
302 http://pubs.amstat.org/loi/tas [2:pp.1,1] Found
200 http://www.math.yorku.ca/SCS/Gallery/images/huygens-graph.gif [2:pp.2,2] OK
200 http://www.math.yorku.ca/SCS/Gallery/langren/VanLangren1628.pdf [2:pp.7,7] OK
200 http://pares.mcu.es [2:pp.8,8] OK
200 http://www.lpod.org/?m=20060128 [2:pp.9,9] OK
200 http://www.math.yorku.ca/SCS/Gallery/langren/ [2:pp.9,9] OK
200 http://www.math.yorku.ca/SCS/Gallery/milestone/ [2:pp.9,9] OK
200 http://www-groups.dcs.st-and.ac.uk/~history/PrintHT/Longitude1.html [2:pp.11,11] OK
```