Jonkers, A.R.T., 2005. "**Parallel meridians: Diffusion and change in early-modern oceanic reckoning**," in: *Noord-Zuid in Oostindisch perspectief*, ed. J. Parmentier. The Hague: Walburg, pp.17-42.

About six score years ago, the International Meridian Conference in Washington D.C. (1884) decided upon the meridian through the Royal Observatory at Greenwich as the universal reference datum for designating longitude on Earth.[1] Now marked by a brass ledge set in stone on the Observatory grounds, it provides food for thought to thousands of tourists and school children every year, enabling them to consciously straddle the divide between the eastern and the western hemisphere. On a more practical level, the Greenwich meridian pervades the work of many scientists, surveyors, mapmakers, and mariners alike, offering a world standard in positional information. Regardless of origin, language, or current location, X degrees of longitude refers to the same place for all concerned (given latitude), be it printed on an Admiralty Pilot chart or displayed by a handheld GPS receiver.

The implied benefits of a single prime meridian are indeed so obvious that it is easy to forget that these are proportional to the extent of uniform acceptance. Furthermore, the choice of Greenwich is rooted in political and maritime history; no physical or astronomical reason exists why the longitude of this leafy London borough should be favoured over any other. As long as a number of people agree on any common grid, each position contained therein is uniquely defined. However, when cartographic knowledge is scarce and incomplete, then strategic, commercial, and other considerations may induce separate groups to develop and maintain different solutions, either zealously preached, or jealously guarded. Rewind the tape of time, and that is exactly what one finds in early-modern western Europe, as French hydrographer Georges Fournier wrote in 1676:

> "Le monde estant rond, il n'y auoit pas plus d'occasion de mettre le premier meridien en un lieu qu'en un autre . . . Ptolemée et les Anciens le mettoient en l'extremité de l'Afrique, dans la Mer Atlantique, à 20 lieues à l'ouest des Isles Fortunées, d'autant qu'ils ne connoissoient aucune terre plus occidentale que ces isles . . . Abulfeda celèbre geographe, et tous les Arabes depuis l'ont mis à 8 degrez plus à l'orient que Ptolemée, et l'ont fait passer par les Colomnes de Hercule, Calpé et Adila au detroit de Gibraltar . . . François Sarzolus Aragonnois la fait passer par la ville de Paris; plusieurs de present le font passer par Uranibourg, Francfort sur l'Oder, Rome, et Venice. D'autres l'ont voulu reculer plus à l'ouest."[2]

Fournier could have added to this list, had he so desired. Other European cities referenced from in the sixteenth and seventeenth centuries include Bologna, Cracow, Lisbon, Nuremberg, Stettin, Toledo, and Ulm. Astronomers tended at this time to choose the meridian of their observatory as longitudinal zero, to facilitate their calculations, for instance, when drafting ephemerides. In such manner, the Alphonsine Tables (1272, reprinted up to 1641) spread the fame of the meridian of Toledo, whereas tabulated predictions by Johann Müller (Regiomontanus, 1474-1506) celebrated Nuremberg, David Trost's (Origanus, 1595-1630) ephemerides supported Frankfort, and Johann Kepler chose Ulm for his Rudolphine tables (1627). Nevertheless, in the maritime realm, usage of the above landlocked prime meridians has been quite limited; cartography and navigational practice have been far more influential in determining which meridian to reckon from.[3] Here, several Atlantic islands featured most heavily.

The Canaries (plus Madeira), the Azores (discovered 1427-52), and the Cape Verdes (discovered 1455-61) had much to offer to seagoing nations.[4] Volcanic in origin, they provided fertile soil for food (wheat from the Azores, wine from Madeira), timber (for ship maintenance), and trade (St. Michael produced the blue dyestuff woad, the Cape Verdes sold salt). From the seventeenth century they also functioned as entrepôt for textiles, African slaves, sugar from the West Indies, and spices from the East. From a navigational viewpoint, each group provided sheltered harbours, and spread over a wide area. Some individual islands (notably Pico, Tenerife, Gran Canaria, St. Antao, and Fogo) also had high peaks, visible over vast distances. No nearby ship would easily pass them without gaining a positional fix to correct the dead-reckoning.[5]

In addition, the islands became a springboard for oceanic voyages of exploration and trade throughout the next three centuries by all European maritime powers, aided by favourable winds and currents. For some vessels from the East Indies and the Americas, the Azores also provided a welcome geographical marker while homeward bound. Figure 1 (main chart, right) depicts the position of each archipelago relative to the Greenwich meridian, while the three smaller insets on the left identify those islands of particular relevance to this text. All labeled locations have been used in the past as longitudinal baseline, spanning over fourteen degrees from east to west.[6]

[FIGURE 1: Charts]

While Ptolemy's prime meridian west of the Canaries experienced a renaissance on some sixteenth-century European maps,[7] oceanic navigation became of age. Quadrennial solar declination tables combined with quadrant and astrolabe offered a reliable and accurate means of determining latitude; expedient traverses were found to and beyond the Cape of Good Hope; Magellan's expedition circumnavigated the globe; the route to the East Indies became codified in numerous roteiros. Manuscript (and later printed) charts had to be constantly updated in order to keep track of the latest discoveries. In these exciting times, many alternative Atlantic prime meridians were first put forward, destined to vie for dominance in the ensuing centuries. Some were promulgated through specific charts in use at the time, others were borne out of practical seafaring considerations. In analysing these developments, it is possible to trace distinct patterns of diffusion of nautical knowledge between countries. Prime meridians can sometimes serve the historian as a marker of the types and origins of the available information aboard ship, highlighting their evolution and exchange. Over thirteen hundred early-modern ships' logbooks were studied to find valuable clues pertaining thereto, yielding statistically robust results. In the context of this book, the significant rôle of the Southern and Northern Netherlands as agents of dispersion will be examined. It will be shown in the following two sections that beneath the bewildering array of competing meridians lie only a few guiding principles that have decisively shaped oceanic reckoning in the age of sail.

The Era of the Agonic Meridian (1500-1650)

In the sixteenth century, very little was known about the Earth's magnetic field. Magnetic declination, the variable angle between geographic and magnetic north, had been observed in Europe and at sea, and was increasingly considered a real phenomenon, rather than a measurement error. Sailors had experienced different magnetic variation (as they called it) during their journeys, and started recording these values in their journals and sailing directions for future reference. In order to steer a true course, they had to compensate their headings to counter local northeasting or northwesting of the compass. Their iron needles, magnetised by lodestone touch, were furthermore thought to point directly towards the nearest magnetic pole.[8] Whether the source of attraction was to be found in the heavens, a strongly magnetic Arctic island, or deep inside the planet's interior, was still open to substantial debate. The field's change over time (so-called secular variation) would remain unknown until the 1630s.[9]

The most common explanation of geomagnetism assumed some form of tilted dipole at work. A dipole constitutes the simplest possible magnet, with one north and one south pole, most easily pictured as a bar magnet. Medieval scholars had posited the Earth's field to be due to a dipole aligned with the planet's rotation axis, but since magnetic and geographic pole would then coincide, magnetic declination would be zero everywhere. Growing awareness of declination strengthened the conviction that the dipole apparently stood at some angle to the spin axis. Various postulates tried to define this orientation precisely, expressed in the (minimum) arc distance between geographical and magnetic pole and the meridian of the plane of tilt. Magnetic declination would be zero everywhere on this meridian, and on its direct opposite on the other side of the globe (that is, 180º of longitude distant); the shortest line from compass to magnetic pole at the surface would there also intersect the geographic pole. Such meridians are called agonic meridians (from the Greek for "no angle"). In the tilted dipole case, the two meridians formed a single agonic great circle, dividing the globe in a northwesting half and a northeasting half.

Elsewhere on Earth, needle deflection would vary predictably with position. An imaginary traveller circling the world on a constant latitude would see the difference between true and magnetic north increase from zero (at the dipole's meridian) to maximum northwesting (near 90º east longitude), then back to zero (at 180º), then reaching maximum northeasting (near 270º), and back to zero again. The actual maximum would be dependent on the dipole's tilt and the observer's latitude. In other words, a tilted dipole would offer a method of deriving ship's longitude from observed latitude and magnetic declination alone.

The first to commit such a longitude solution to paper was João de Lisboa in 1508. Based on measured northeasting at Lisbon (one quarter point, or circa 2º49') and zero declination near the eastern Azores (St. Michael and St. Maria), the Portuguese navigator surmised declination to be always constant along any given meridian, and that it would alter as a function of longitudinal distance travelled, from zero at the Azores to a maximum of four compass points (45º) at 90º to east and west of them. This progression would yield a value of one quarter point at a distance of 62½ leagues east, where Lisbon was placed. In his Tratado da Agulha de Marear (part of his 1514 Livro de Marinharia) de Lisboa also provided a table of the number of leagues travelled per degree of change in magnetic declination along different parallels of latitude (from 0º to 65º).[10]

Apart from the imagined practical solution to the longitude problem, the scheme's more lasting impact was due to the inherent conviction that Nature was not oblivious to the mariner's plight after all. Although no fixed point in the revolving sky had offered itself to suggest any particular choice of zero longitude, the Earth's magnetic field apparently did contain a "natural" indicator of the preferred meridian to reckon from. Many sixteenth-century voyagers sailing near the Azores, the Canaries, and the Cape Verdes had noted the absence of magnetic declination in these waters. At the time, needle deflection from true north was indeed very low throughout this region, and instrumental accuracy still left ample scope for improvement. Given the simplistic tilted dipole field description, could this be Nature's hidden clue as to where the longitudinal origin should lie? The ramifications of erroneously equating a meridian with an agonic line would have far-reaching consequences for navigation.

While providing false hope of lifting the uncertainty regarding a ship's easting and westing on the open ocean, the concept actually fuelled extensive confusion, as over the years the constantly changing, irregular field allowed null measurements to be associated with all three insular groups mentioned. Since at that time magnetic declination was still considered time-invariant, and recorded observations were therefore not associated with a specific date, conflicting claims eventually spanned the seas from Tenerife to Flores. Table 1 conveys some idea of the longevity of the controversy, based on navigation manuals, scientific tracts, and other texts discussing the various hypotheses.[11] It also shows that the idea caught on in Portugal, Spain, Italy, France, England, and the Low Countries, to which attention will presently be limited.

[Table 1: Agonic prime meridians 1500-1675]

Around the mid-sixteenth century, the repeated attempts by Flemish cartographer Gerard Mercator to calculate the north magnetic pole's exact coordinates may serve as a poignant example of Dutch efforts along these lines. Assuming a single point of magnetic attraction in the Arctic, all great circles aligned with compass needles anywhere in Europe would coincide at the magnetic pole. Given accurate coordinates of, and declination at, two places widely distant in longitude, spherical trigonometry could yield a cross-bearing of the point in question. In a letter of 23 Feb 1547 to his patron Antoon Perrenot de Granvelle, Mercator related his initial findings, based on observed northeasting in Danzig (14º) and Walcheren (9º). Remarkably, the placement of the pole (at 79º N, 168º E) he still expressed relative to a (non-agonic) prime meridian near the Canaries, twelve degrees to east of where the resultant agonic meridian was supposed to lie. This implied that Mercator's choice of prime meridian was at this time not yet burdened by geomagnetic concerns. However, in an instruction manual accompanying globes made for Emperor Charles V in 1552, the author did refer to the determination of longitude by magnetic means.[12]

Mercator returned to the issue seventeen years later, when he published his famous world map (1569), drawn on the projection that now bears his name. This time around, he explicitly interpreted the Atlantic agonic meridian as longitudinal reference. As earlier outlined, increasing traffic in the area had engendered conflicting reports that situated the zero line in the vicinity of Corvo (Azores) and the Cape Verde islands, a difference of about seven degrees. Rather than committing himself to either longitude, the cartographer chose not to choose, calculating instead the intersections of each agonic great circle with one aligned with magnetic north at Regensburg (Bavaria), where northeasting amounted to 16º44'. Not surprisingly, this exercise yielded two prospective magnetic poles, marked separately on the map. In the upper right legend, the cartographer furthermore stated his preliminary confidence in the Cape Verdes meridian, based on the magnetic observations by French master François de Dieppe. This prime meridian was later promulgated in the Low Countries by Mercator's son Rumold (world map, 1587), preacher-cartographer Petrus Plancius (world map, 1592), explorer Willem Barents (posthumous polar chart, 1598), and cartographers Willem Jansz Blaeu (world map, 1605) and Jodocus Hondius (world map, 1608).[13]

But Mercator's biggest champion was probably his compatriot Michiel Coignet. This versatile instrument maker, teacher of mathematics, and one-time engineer at the Spanish court is chiefly known for his Nieuwe Onderwijsinghe (1580), a nautical instruction appended to the Dutch translation of Pedro de Medina's Arte de Navegar (originally 1545, reprinted in Amsterdam in 1589, 1592, and 1598). Greatly expanded the following year, the book was also published separately in French, in Coignet's native Antwerp. Besides discussing tides, loxodromes, position finding, and various instruments, it is notable for its treatment of the longitude problem, and geomagnetic solutions in particular. After rejecting the opinions of Cortés, de Medina, and Cardano on the subject, Coignet successfully tested Mercator's postulate by comparing the declination at Antwerp as observed (9º NE) and predicted from his magnetic pole's position (8º58' NE). He then produced a diagram depicting how declination would vary along a parallel as a function of longitude. One major oversight was Coignet's attribution of de Dieppe's null observation to the Azores (St. Maria and St. Michael), although he mentioned the Cape Verdes (Boavista and Maio) further down the same paragraph.[14] Consequently, in later years, it was the Azores meridian that would travel farthest.

In assessing Coignet's influence on contemporaries, one has to distinguish between the Dutch appendix and the French book. The former was found in Barents's shelter on Nova Zembla after the 1596-97 wintering. It was furthermore commented on by Dutch navigation experts Haeyen (1600), van den Brouck (1609), and Robbertsz le Canu (1612). In addition, near verbatim excerpts of Coignet's text can be found in the first part of W. J. Blaeu's Zeespiegel waggoner (1631), and in navigation manuals by de Graaf (1658) and Anhaltin (1659). The latter two specifically concern Mercator's agonic prime meridian.

As far as the French text is concerned, apart from English writers on navigation William Barlowe (1597) and Edward Wright (1599), who discussed Coignet's nautical hemisphere, William Borough's Discourse of the Variation of the Compasse (1581, 1585, 1596, 1614) is of interest due to the presented tilted dipole with agonic prime meridian over the Azores,[15] which the author compared to Mercator's observation at Regensburg (as reported by Coignet). An almost literal translation of the geomagnetic part of Coignet's Instruction can further be found in the Exercises of mathematician Thomas Blundeville (in eight editions over the period 1594-1631). The latter's agonic prime meridian once again crossed the Azores.[16]

The choice of this westernmost group of isles in general, and Corvo and Flores in particular, was additionally supported by Portuguese roteiros, many of which found their way northward in Europe despite an official embargo. The vital rôle played by Jan Huyghen van Linschoten of Enkhuizen in this respect is well-known; the navigational sources he compiled in Asia (1579-92, while in Portuguese service) would greatly facilitate the first Dutch East India ventures in the 1590s.[17] The Reys-geschrift van de Navigatien der Portugaloyers (part of his multi-volume Itinerario) would eventually go through five Dutch editions (1595-1644), two French ones (1619, 1638), and an English version (1598).

Some of the sailing directions contained therein had detailed descriptions of compass behaviour at sea. According to one by master Vicente Rodrigues de Lagos, the needle was supposed to point true between Flores and Fayal, while another suggested the longitude of St. Maria instead, shortly before explaining the concept of an agonic meridian, in van Linschoten's words:

> Om nu te verstaen het wraken ofte declineren van 't compas, so is te weten, dat alsmen is onder de Meridiaen, dat is: onder de linea ofte streeck die men verciert in den omloop van het firmament, van den eenen pool tot den anderen . . . so heeft men alle compassen (die goet en oprecht zijn) ficx ende ghelijck, sonder te wraken naer 't oosten ofte westen, ende wesende aen d'een of d'ander zyde, te weten, als men is aen de zyde van 't oosten, so wraect de lelie ofte naelde van 't compas naer 't westen, dat hieten wy noortwesteren, ende als men is aen de westzyde van de Meridiaen voorseyt, soo wraeckt ofte declineert de naelde van 't compas nae het oosten, dat hieten wy noordoosteren, waerme dit nu ghenoegh verstaen can worden om hen daernaer te reguleren.[18]

The Atlantic was not the only area where zero declination had been registered; Cape Agulhas (South Africa), and several locations in southeast Asia (notably Pedra Branca and Canton) and the Americas (Cartagena, Vilalobos, Acapulco) were also associated with agonic meridians from the 1590s onward. Since such a distribution is incompatible with a single tilted dipole, a four-pole arrangement was proposed instead, most often imagined as two tilted dipoles at right angles, generating two agonic great circles that evenly quartered the globe. Although the resultant progression of compass deflection from true north was doubled to four alternating sections of northeasting and -westing, the Atlantic longitudinal reference itself remained unchanged. Examples in the table include de Acosta (translated into Dutch by van Linschoten in 1598),[19] da Costa, de Saa, de Figueiredo, le Bon, de Mariz Carneiro, and Pimentel.

A more influential scheme was devised and avidly recommended to mariners by Flemish preacher Petrus Plancius. Based primarily on Spanish (rather than Portuguese) data, his four agonics divided the Earth's 360 degrees into one section of 60º (from Corvo to the next agonic over Cape Agulhas), and three of 100º (separated by meridional agonics over Canton and Acapulco). Each of these regions was additionally subdivided into two halves, of increasing and decreasing (wassende, afgaende) declination. This hypothesis was supported with a table of 43 compass observations at various landmarks (mostly in the Atlantic hemisphere), the longitudes of which (all relative to Corvo) had been "adjusted" to neatly fit the conjecture of regularity. Plancius had, for instance, placed Bantam (Java) nearly nineteen degrees west of its true longitude, which led to a dispute with van Linschoten on its position.[20]

The Calvinist cartographer's substantial contributions to Dutch navigation have been discussed by many scholars, and need not detain us here.[21] Less well-known is his impact as first hydrographer of the Verenigde Oostindische Compagnie (VOC) on the choice of prime meridian by its navigators. During the first four decades of the seventeenth century, those (sampled) Dutch navigators on East Indiamen that used a longitudinal measure of arc overwhelmingly reckoned from Corvo (see figure 2). Moreover, several VOC logbooks from this period not only used this meridian, but also explicitly stated observed magnetic declination in terms of Plancius's global partitions, such as the Griffioen (1608), the Zierikzee (1620), the Hollandia (1626), the Wapen van Hoorn (1627), the Zutphen (1632), the Amsterdam (1633, 1635), the Nieuw Amsterdam (1636), and the Banda (1637).[22] Given the Fleming's influence on a whole generation of Dutch masters since 1595, as teacher and examiner of navigation, and administering and correcting sailing directions (and possibly charts), it seems warranted to assume that the practical implementation of the agonic prime meridian over Corvo on Dutch routes to the East Indies was primarily his doing.[23] Other writers on navigation supporting his agonic-based reckoning include Simon Stevin (1599, 1608), Barent Evertsz Keteltas (1609), and Abraham Cabeliau (1617).[24]

[FIGURE 2: Dutch prime meridians in logbooks]

But it was not to last. Already severely criticised by contemporaries during his lifetime,[25] Plancius's longitude solution and associated prime meridian would be abandoned in navigational practice within two decades after his demise in 1622, due to two main reasons. First, cartographer W. J. Blaeu, one of the main adversaries of the theory, had become VOC hydrographer in 1633, the start of a lineage that would continue (with his son Joan from 1638, and grandson Joan from 1673) until 1705.[26] The Blaeus all championed the emerging new Dutch standard meridian that adorned their own globes and atlases alike, to be discussed in the following section. Secondly, Henry Gellibrand, a professor of astronomy at London's Gresham College, published his findings in 1635 (based on compass measurements around the English capital over the previous 54 years) that the Earth's magnetic field had been changing with time. This discovery had devastating consequences for time-invariant geomagnetic longitude schemes like Plancius's,[27] while simultaneously providing a hint as to why so many Atlantic isles had previously been thought Nature's unique favourite. More than any other factor, secular variation spelled the end for the agonic prime meridian. Despite a continuing trickle of such propositions by some land-based authors around the mid-seventeenth century, navigators of all nations quickly incorporated the notion of field change, which concurred with their own experience.[28]

In retrospect, individuals from the Southern Netherlands can be seen to have contributed most to the diffusion of agonic prime meridians in the Low Countries. Mercator's original lines of inquiry were widely distributed via Coignet in Antwerp to the Northern Netherlands, England, and France, while Plancius (born in Drenouter, near Belle) laid the foundations of his Corvo-based system with the aid of many gathered Iberian sources. Some of his ideas subsequently reached many foreign minds through the translated works of Stevin (born in Bruges). At the same time, direct and sustained communication with navigational practitioners ensured their (temporary) adoption in the maritime realm, at least as far as the VOC is concerned.

The Era of the Sea Atlas (1650-1750)

Figure 2 visualises the various prime meridians reckoned from aboard Dutch ocean-going vessels in the period 1598-1800. The total sample comprises 536 logs, from East India companies (249), Admiralties (123), merchants (153),[29] and whalers (11) based in the Northern Netherlands. Their navigators have relied upon all three archipelagos in the past, calculating ship's position relative to (C)orvo, (T)enerife, St. (J)ago, and (B)oavista. Nevertheless, even a perfunctory glance at this plot would suffice to ascertain that the meridian through the Canaries outnumbers all its competitors by a huge margin. This was not some belated honorary recognition of Ptolemy's work, but due to purely practical considerations. Tenerife's Teide volcano rises an impressive 3,718m above sea-level, making it by far the highest peak for hundreds of miles around, and more elevated than the next-tallest landmarks in the Azores (Ponta do Pico, 2,351m) and the Cape Verdes (Fogo's Pico, 2,829m). In addition, the Canaries had the advantage over the other two groups in being most easily reached from Europe, favoured by northeast tradewinds and Canaries Current, and ideally located as waystation for Atlantic crossings to north America and the West Indies, African destinations, and the routes to south America and the East Indies.

The reasons for Corvo's fall from grace have been outlined in the preceding section. The actual transfer from Corvo/Flores to Tenerife can be dated fairly accurately to around 1640. At this time, Amsterdam cartographer Jacob Aertsz Colom still graduated his West-Indische Pascaert relative to both Flores and Tenerife, indicating possible parallel usage. More revealing is a remark logged in the journal of the Dutch East Indiaman Pauw in Asian waters, expressing longitude relative to Tenerife, but adding an alternative coordinate shifted 13º to the east (i.e., using Corvo), stated as "following the old custom."[30] Furthermore, not a single sampled Dutch logbook after 1640 bears any evidence of lingering Azorean prime meridians. It therefore seems safe to assume that by the mid-seventeenth century Dutch mariners no longer tended to reckon from Corvo.

Nevertheless, the choice of Tenerife was somewhat tentative at first, being challenged by alternatives from the Cape Verdes in the 1660s and 1670s. Nine VOC journals from this period measured from St. Jago, and another three used nearby Boavista in this capacity. Belatedly, the Dutch private merchant Witte Lam, on a trip from the Dutch Republic to Cadiz and back in 1707-08 also defied the odds in favour of St. Jago.[31] But a closer look at the provenance of the VOC sources reveals that all except one of the St. Jago journals were kept by a single mate (Sipke Vis), and most of these concerned intra-Asian traffic only. Moreover, the three carriers using Boavista were written by one merchant (E. B. Verweij), on Indian Ocean itineraries commonly associated with the French Compagnie des Indes (CDI, see below), in ships such as the Sint Loowis, that may have been French as well. Despite first impressions based on the diagram alone, the challenge to Tenerife may thus very well have been almost negligible.[32]

From the earliest days, the VOC judged its charts to be of high strategical value. To avoid dispersal among rivals abroad, they were hand-drawn by Company hydrographers and their aides, and issued under embargo to its crews. But complaints about carelessness, theft, and abuse prompted the Directors in 1654 to impose tighter reins on the number and types of charts on board each vessel, through the introduction of inventory lists, to be signed by each navigating officer upon receipt and return of the stated items. The first version came into effect in 1655, to be updated in 1675, 1731, and 1747. These documents contain invaluable information regarding the actual charts used, not least because so few originals have survived. They show that throughout the studied period Dutch navigators en route to the East were fortunate in having sets of both Mercator (wassende GraedKaert) and plane charts (gelyckgradighe, Paskaert) for the same oceanic areas (north Atlantic, south Atlantic, and Indian Ocean).[33]

Each projection is suited to a particular type of navigation. Plane charts distort longitudinal degrees to be of equal (physical) length regardless of latitude (rather than diminishing from circa 111.24 km on the equator to zero at each pole). Therefore, plane charts are best employed to cover small areas, and tend to induce latitude sailing.[34] Mercator charts also depict meridians as straight lines, but vertically extend latitudinal degrees in exact proportion to the stretched horizontal dimension. Since all rhumbs thereby become straight lines as well, a ship's constant heading towards a destination can be simply drawn with a ruler, regardless of the size of the covered area.[35] In other words, the Mercator projection allows setting a course to pre-specified coordinates over large distances (providing winds and currents allow this).

The dearth of extant manuscript charts used on Dutch East Indiamen prevents a quantified assessment as to what proportion of these had longitudinal degrees marked (along margins or equator), from which a possible active imposition of the Tenerife meridian of reference could perhaps be inferred. What limited evidence exists shows that, even well into the 18th century, many Dutch charts carried only a latitude scale, lacking longitudinal graduation altogether. However, those that did show longitude (both plane and Mercator) favoured Tenerife.[36] Moreover, all VOC sailing directions from the 1680s that incorporated longitudes did so relative to Tenerife, without exception.[37] This choice may have been additionally promoted through other means, such as navigation textbooks and teaching, printed tables of geographical coordinates of ports and landmarks, and oral tradition from master to mates. Whatever the means of diffusion, Dutch oceanic logbooks and journals support the assumption of global reckoning (i.e., all over the world, regardless of location), relative to a single prime meridian over Tenerife, at the latest from circa 1675 onwards.[38] It should therefore come as no surprise that the Amsterdam Admiralty officially endorsed this meridian in 1787, and that the translated Nautical Almanac (published for the first time that same year) had its zero meridian shifted nearly seventeen degrees westward. It would take until 1826 before Greenwich was officially adopted by royal decree in the Netherlands.[39]

But apart from thousands of anxiously guarded manuscript charts relied upon by VOC and Admiralties, a second Dutch source of hydrographic information did appear in print and spread widely among all that could afford it. The so-called sea atlas came into being in the 1650s. Unlike waggoners (which had been around since 1584), these cartographic compilations did not restrict their portfolio to European coastlines on a uniform scale, but covered the Atlantic and sometimes the Indian Ocean as well, in anything from a few dozen to several hundreds of charts, drawn on a wide variety of scales. Although most followed a plane projection with latitudinal graduation only, some carried an equatorial longitude scale as well, again relative to Tenerife. The number of Mercator charts in these atlases was initially very low, but increased from the 1680s.[40]

A handful of fiercely-competing chart publishers in Amsterdam have produced many editions of such maritime atlases, often enlarged, but otherwise very similar in title and content. After modest beginnings by Johannes Janssonius and Arnold Colom in the 1650s, the genre was more or less defined by Hendrick Doncker's 1659 Zee-atlas ofte Water-Waereld (initially containing a mere nineteen charts, later expanded to over seventy). The subsequent two decades saw rising competition from the likes of Pieter van Alphen, Jacob Aertsz Colom, Pieter Goos, Casparus and Jacob Lootsman, Arend Roggeveen, Johannes van Keulen (and successors), and Jacob Robijn. Regrettably for the mariner, the quantity in output and quality of printing was not matched in accuracy of the coastlines depicted. Some of the copper plates changed hands repeatedly, while others were simply copied from a competitor's original without acknowledgement. Many were recycled for decades, maintaining an outdated level of cartography for the general public.[41] Whereas an early eighteenth-century VOC manuscript chart might contain errors of less than a degree in, say, Madagascar's shape, its contemporary printed counterpart in Dutch sea atlases still kept a grossly inaccurate image alive, somewhat reminiscent of a shriveled balloon.

[FIGURE 3: Sea atlases from Amsterdam]

Yet despite these problems, the sea atlas not only proved an enduring commercial success at home, but also found an eager and appreciative audience elsewhere in Europe. Apart from a number of Latin, Spanish, and Italian editions, it was French and English translations that fared best abroad. Figure 3 plots Dutch, French, and English editions from the various publishing houses (identified by letter), next to comparable indigenous publications (symbols). It shows that some chart sellers targeted a specific market (Janssonius chose France; van Alphen, Lootsman, and Robijn preferred England), whereas other firms sold in both countries (foremost Doncker, Goos, and van Keulen). Furthermore, commercial impact appears more concentrated and constrained by local competition in England than in France.[42] Of course, the question then arises whether these Dutch publications and their derivatives significantly affected oceanic navigation in these two countries. Once again the historian can turn to the legacy of logbooks and journals for a complicated, but revealing answer. In the following brief assessment, the French case will precede the English one, and focusses attention once more on the longitudinal baseline.

On the first of July 1634, King Louis XIII decreed that the official French prime meridian, to be observed at all times by his chart and globe makers, hydrographers, and navigators, was to be the island of Ferro (see figure 1).[43] Apart from distant echoes of Ptolemy, this decision was perhaps also informed by prior French geomagnetic longitude solutions, which either included, or exclusively identified, this most westerly of the Canary isles in the geographical description of their agonic meridian (see table 1). A mere three decades hence, France experienced a "scientific awakening" under minister Colbert, who funded the building of the Parisian Observatory in 1667. Studies of the celestial sphere under astronomer G. D. Cassini resulted in the state-sponsored nautical almanac Connaissance des Temps from 1679, and established the longitude of the French capital more precisely. The latter became the foundation for a nationwide triangulation survey, under the aegis of the young Académie Royale de Sciences de Paris (founded 1666). This allowed the French coastline to be redrawn, for instance, in the 1693 Neptune François (29 Mercator charts of European Atlantic coasts); its preface also stressed the advantage of this projection to mariners.[44] A separate Mercator chart relative to Ferro, relied upon by French masters sailing to the East Indies, was probably drafted around this time by Georges Boissaye de Bocage.[45]

State influence also affected oceanic cartography. Although officially established in 1720, the French Dépot de Cartes, Plans, et Journeaux de la Marine actually dates back to the 1680s. Its main task was the collection, elaboration, and revision of French charts, and processing logbooks (and other sources) to extract valuable information pertaining thereto.[46] It provided French officials with yet another instrument to endorse a formally sanctioned prime meridian.[47] One would therefore expect foreign influences to be easily thwarted, and to have little effect on French oceanic navigation. However, the logs themselves tell an altogether different story.

[FIGURE 4: Charts and prime meridians referred to in French logbooks]

Figure 4 visualises charts (top layer) and prime meridians (bottom layer) referred to in 468 sampled French logbooks and journals over the period 1670-1789, consisting of 233 naval sources, 225 from the CDI, 2 by smaller merchant companies, and 8 unattributed ones.[48] Regarding prime meridians, the contrast with the Dutch situation is striking. Up to the mid-1750s, when (P)aris (see figure 1, top right) finally wiped out all competition, it was not (F)erro that predominated oceanic navigation (29 occurrences), but Dutch favourite (T)enerife (103), and St. (J)ago in the Cape Verdes (135), with small contributions from the (A)zores and (B)oavista, and a single instance of reckoning from (M)adagascar (to nearby Ile de Bourbon). To confuse matters further, thirteen logs (denoted with "X" in the figure) shifted (once) from one prime meridian to another during the voyage, which is commonly associated with a change in chart. So is it possible to uniquely identify cartographic sources and link these with an associated meridian?

For starters, some French navigators simply spoke of their reliance on "a Dutch chart", such as on the Sirenne in 1720: "je prend mon point départ sur une carte holandaisse qui prend son meridien au Teneriffe et qui est bien juste et fort bonne."[49] Such references have been marked in the top part of figure 4 as letters within a square, in this case (H)ollandois.[50] More specific are remarks identifying the actual chart publisher. Two names that occurred time and again are those of Pieter (G)oos (often written "Pietergoos") and van (K)eulen ("WanKeulen", "Van Queulen"), incidentally, concurring with figure 3. Some authors associated these names with the word "chart", others with "longitude" or "meridian". Disconcertingly, none profess a unique bond with either a particular meridian (Tenerife or St. Jago) or destination.[51]

By contrast, when examining particular null meridians, both Boavista and the "Azores" appear strongly correlated in the sample with specific routes or regions: all French masters estimating from the former were heading for the East Indies,[52] whereas the latter's usage was confined to the North Atlantic (between France and Canada,[53] and on the last homeward leg from the East, switching from either Tenerife or St. Jago).[54] But other instances when one meridian was exchanged at sea for another only serve to obfuscate attribution. Three voyages to the Americas all changed along the way from Tenerife to St. Jago; the first early on the outward voyage, the second while on the south American coast, the third in the last few days before reaching the home port again.[55] Two East Indiamen employed Tenerife in the Atlantic and St. Jago in the Indian Ocean, whereas two others used St. Jago all the way to reach Asia, and reckoned from Tenerife or Paris on intra-Asian passages thereafter.[56]

Underlying patterns only begin to emerge when recalling that most of the Dutch charts in question did not carry any longitude scale. Furthermore, those in Dutch sea atlases with east-west graduation used neither the Cape Verdes nor the Azores to calculate longitude. Yet the evidence strongly suggests that these sources pervaded French oceanic navigation; as late as 1764, Ingénieur Hydrographe de la Marine Jean-Nicolas Bellin complained about the Dutch charts "dont on etoit forcé de se servir, puisque personne en France ne s'étoit de ce siecle-ci, livré à l'étude et à la construction des cartes marines."[57]

Obviously, when a French Mercator chart was used to ply the Atlantic, one would expect to find reference to Ferro. Equally, mention of a "Dutch meridian" brings Tenerife foremost to mind. But detailed analysis of the French sample shows that in most cases, it was not the chart that determined the selected prime meridian, but the intended itinerary. Of 94 French East Indiamen, a mere 14 used Tenerife (and these passed the Canaries at close range), against 80 that reckoned from one of Cape

Verdes (the more obvious waystation to the East). French ships on triangular routes (France - west Africa - Americas - France) overwhelmingly chose the Canaries (Tenerife and Ferro, 36 times) over the other two archipelagos (a sighting of which would have implied a detour, 4 times only).

Interestingly, the choice was made long before the actual close passage at sea. French masters set out a course that would bring them near their chosen isle of zero longitude, there corrected their positional estimate, and then continued their journey while retaining their meridian of reference for the rest of the way. This forward looking method of oceanic navigation by advance selection of a waystation-based prime meridian can be called target reckoning. Even though Mercator charts were available, and translated Dutch sea atlases (plus the odd illegally obtained manuscript chart) were for sale, no single prime meridian ever reached the coveted status that Ferro was supposed to have, but never attained. In this respect, French navigational practice thus differed thoroughly from the Dutch example, up to the 1750s.

From then on, a number of new French charts and sea atlases managed to completely destroy the hegemony of the Atlantic isles. The aforementioned Bellin compiled the Atlas Maritime (1751), the comprehensive Hydrographie Française (1756-65), and the Petit Atlas Maritime (1764), which despite its title contained no fewer than 580 charts in five volumes. Although partly based on older material, all charts bore (added) longitude graduations. Despite carrying multiple scales relative to Paris, London, the Lizard, Ferro, and Tenerife, the logbooks show that only the Paris meridian was used; references to the "carte Francaise de la Marine", the "carte de la Cour", and the "carte de Maurepas" (marked as (N)aval in figure 4) are solely associated with longitudes relative to Paris.[58]

The second major agent of change was Jean-Baptiste Nicolas Denis d'Après de Mannevillette. Already in 1745, this hydrographer issued his Neptune Oriental ou Routier Général des Côtes des Indes Orientales et de la Chine (22 charts and sailing directions), greatly enlarged in 1775 (63 charts) and 1781 (supplement). He also produced a separate Mercator chart of the Indian Ocean (1753) and an abridged printed sailing direction for the East Indies (several editions in the 1760s).[59] All uniquely depended on the French capital's prime meridian. A navigator on board the CDI's Gloire in 1756, for example, honoured d'Après by reckoning "du meridien de l'observatoire Royal de Paris, me servant de la carte de M. D'après de Mannevillette Capitaine de V.aux de la Compagnie des Indes."[60] Consequently, no trace of either Tenerife, St. Jago, or Dutch sea atlases has been found in any sampled French navigational log or journal after 1760, at which time the transition from Atlantic target reckoning to global longitudes from Paris can be considered completed. More than a century was to pass before France eventually adopted Greenwich in 1884.

The situation across the Channel was somewhat different. Up to the 1660s, the English mariner mainly relied upon large-scale plane charts, manually drawn on parchment. These were produced throughout the seventeenth century by plattmakers in the Drapers' Company in London's docklands, collectively known as the "Thames school". Although these men incorporated hydrographical data from seafarers, most were themselves landlubbers; trained copyists, but without actual experience at sea. Their traditional manuscript latitude charts marked neither longitudinal degrees nor prime meridian.[61]

Early advocates of the nautical advantage of Mercator's projection were likewise little heeded. Edward Wright's 1599 Certaine Errors of Navigation even contained an example (with prime meridian over St. Jago), which probably did more to inspire Dutch cartographers (such as Hondius) than their English colleagues. Four decades later, Robert Dudley printed his Arcano del Mare in Florence (1646, 1661), the first English sea atlas. It contained over a hundred Mercator charts with longitudes relative to an agonic meridian over Pico (see table 1), but equally failed to rise to any prominence in England. Neither did Joseph Moxon's Book of Sea Plats (1657), the first such publication produced in England. As late as 1681, when a captured Spanish compendium of Pacific sea charts and sailing directions was translated as the Waggoner of the Great South Sea, the (coastal) charts were still reproduced only by hand.[62]

Returning one more time to figure 3, Dutch publishers of sea atlases (notably Doncker, Goos, Lootsman, and van Keulen) can be seen to have quickly exploited this commercial opportunity (1660-90), inundating the London market with English translations of their printed products. However, their reign was relatively short-lived, due to the efforts of two English hydrographers: John Seller, serving king Charles II and James II, and John Thornton, employed by the English East India Company (EIC) and the Hudson's Bay Company.

John Seller is chiefly known for his English Pilot waggoner (1671, and numerous subsequent editions) but also printed the Atlas Maritimus (1675, 1682) and Hydrographia Universalis (1690), which had a much wider geographical scope. The material for both was almost entirely of Dutch origin; Seller had obtained old copper plates sold for scrap in Amsterdam in the late 1660s, and had them re-engraved in London with anglicised nomenclature. He subsequently also copied preface and (plane) charts from an atlas by Pieter Goos and various other Dutch sources.[63] John Thornton was able to lay eyes on original manuscript (plane) charts by Joan Blaeu (as well as other Dutch sources), which he copied by hand before transferring them to copper plate for the third part of his 1703 English Pilot, for the East Indies. Following Seller's example, he had previously brought out an Atlas Maritimus (1685, 1700) as well. Similar sea atlases were published by P. Lea (1700), Knapton & Knapton (1728), and Mount & Page (1702, 1708, 1750, 1755). Most charts had latitudinal degrees, but some (especially large-scale ones) merely carried a scale bar in English leagues or miles. All perpetuated the mediocre standard of Dutch printed plane charts as earlier encountered.[64]

Nevertheless, the English borrowing practice failed to include the meridian of Tenerife as baseline.[65] Where longitudes did occur in print, for instance, in tabulated geographical coordinates of voyages and places (such as in Thornton's sailing directions in his 1703 Pilot) they often measured from Lizard Point in Cornwall (see figure 1, top right), the most southerly tip of the English mainland. Some plane charts drew this meridian as well, with parallel lines indicating the distance in leagues east or west of it.

In the 18th century, the meridian of London (passing through the dome of St. Paul's cathedral) was increasingly used by cartographers, but seafarers were initially far less eager to follow. After the advent of the Nautical Almanac in 1767 (which contained lunar tables to calculate longitude relative to the Greenwich Observatory), chart publishers and mariners also proved reluctant to change. It was left to a new generation of cartographers (such as Steele, Arrowsmith, and Norie) to spread this reform, aided by a growing number of chronometers at sea from the 1790s, and the founding of the naval Hydrographic Office on 1795, which exclusively used Greenwich.[66]

It would be tempting to conclude from the preceding that English navigators simply applied global reckoning in the Dutch sense, initially from the Lizard. It would also be incorrect. When examining English long-distance navigation in logbooks up to 1750, longitudes often appear as if only an afterthought. Moreover, a substantial number of East Indiamen apparently was able to do completely without them. And where longitudes were noted in these documents, those of faraway shores were rarely expressed relative to the Cornish headland. So how did English navigational practice differ from Continental means of reckoning?

The first part of the answer can be gleaned from Thornton's Pilot (1703), which contains a list of successive coordinates on a recent voyage to the East Indies and back.[67] It is subdivided into six smaller tables, each with its own heading. The first reads: "The Longitude Reckon'd from the Meridian of St. Jago", the second: "From the Meridian of Cape bona Esperance to Hughley". The next three (traversing the Indian Ocean) take Surat as longitudinal zero, while the last one uses the Cape again, on the passage to St. Helena. In the words of the contemporary nautical manuscript Sayling by the True Sea Chart: "our sea fareing men generaly speaking make the meridian they parted from the first meridian."[68]

Common English oceanic practice up to the 1750s thus renounced the supremacy of any prime meridian on formal or theoretical grounds. Instead, they applied the more utalitarian principle of taking the last land sighted. As soon as the next (recognised) waystation came into view, not only would the accumulated positional error be reduced to zero, but also the longitudinal parameter itself. In contrast to the Dutch choice of Tenerife, and French references to a handful of Atlantic isles, the English method of local reckoning relied on an ever-expanding array of hundreds of meridians, whose primacy was brief but recurrent.

A second major difference between English and Continental shipboard practice mostly concerns navigation to and from the East Indies. Rather than measuring easterly or westerly displacement in degrees of arc, masters on such journeys often only used meridian distance, i.e., physical distance stated in leagues or spherical degrees (of fixed length, irrespective of latitude).[69] Particularly in the first half of the eighteenth century, this was the method of choice in the EIC, as is evident from a sample of 345 English logbooks and journals, consisting of 119 from the EIC and 226 from the Royal Navy. Figure 5 depicts for both maritime organisations all sampled instances of (M)eridian distance reckoning (i.e., without longitudes calculated alongside), (A)rc measures of longitude (relative to multiple meridians), and the advent of global reckoning from (L)ondon (including Greenwich).

[FIGURE 5: Types of reckoning in English logbooks]

Naval sources are regrettably lacking for the first half of the seventeenth century, and remain sketchy at best for the second. Nevertheless, they show a marked difference with East India navigation, in that measures of arc dominate over meridian distances from the start. Furthermore, the latter have vanished from (oceanic) naval logs by the 1720s, while persisting in the EIC until circa 1760.[70] Similarly, the (global) prime meridian over London was making headway in the Royal Navy decades before EIC navigators followed suit.[71] This discrepancy between the two navigation traditions constitutes a third aspect in which English and Continental practice did not concur.

These findings have important implications for the type of chart used on board English ships, since tracing a course triangle based on meridian distance (rather than degrees of longitude) is eminently suited to large-scale plane charts. A Mercator grid, on the other hand, would be inappropriate, because the physical distance between meridians shrinks as a (cosine) function of latitude. It is therefore unlikely that EIC navigation up to 1750 depended on Mercator charts to any substantial extent, providing yet another explanation why no single prime meridian rose to early prominence in England. A series of non-overlapping plane charts on different scales tend to leave a decidedly fractured image of the world, confounding attempts to relate local landmarks to any global framework. It was initially the translated Dutch sea atlases, followed by English derivatives, which presented this multi-faceted, but myopic view to navigators, inducing a localised form of distance reckoning based upon frequent shifts in prime meridian.[72]

[TABLE 2: East India navigation 1650-1750]

When reflecting upon the covered developments, national differences in oceanic navigation during the era of the sea atlas (1650-1750) can be seen to have been most pronounced on the challenging routes to and from the East Indies (summarised in table 2). They show that each East India Company developed its own answers to the problem of measuring longitude, shaped by different sources, traditions, and techniques. Furthermore, navigational practice proved more influential in the choice of prime meridian than the charts that bore them. It also bears testimony to the success and spread of Dutch sea atlases, not just in a commercial sense, but strategically as well, providing foreign competitors with an easily procured, but inferior cartography, while superior manuscript sources were kept secret. In particular the Northern Netherlands can in this sense be considered a significant exporter of a particular level of nautical knowledge. Finally, the results underline the enduring historical value of ordinary nautical logbooks and journals, which can reveal a glimpse of what went on under the master's dividers.

Tables

Table 1. Agonic Meridians 1500-1700

Year	Proponent		Cape Verdes	Canaries	Azores
1508	de Lisboa	(Portugal)			S Michael, S Maria
1519	Faleiro	(Portugal)			Corvo
1522	Cabot	(Italy)			west of Flores
1542	de Santa Cruz	(Spain)	S Antao	Ferro	Corvo
------	Rotz	(France)		Ferro	
1545	Cortés	(Spain)			S Maria, Corvo
1547	Fernandez de Oviedo	(Spain)			Azores
1550	Cardano	(Italy)		Canaries	
1558	della Porta	(Italy)		Canaries	
1569	Mercator	(Flanders)	Sal, Boavista, Mayo		Corvo
1573	Menendez de Aviles	(Spain)			Azores?
------	Toussaints de Bessard	(France)	Cape Verdes	Ferro	S Michael
1581	Borough	(England)			Azores
------	Coignet	(Flanders)	Boavista, Mayo		S Maria, S Michael
1583	de Vaulx	(France)		west of Ferro	
1590	de Acosta	(Spain)			Corvo
1594	Wyatt	(England)			Pico
1596	da Costa	(Portugal)			Azores
1597	Blundeville	(England)			Azores
1598	Plancius	(Dutch Republic)			Corvo, Flores
1599	Stevin	(Dutch Republic)			Corvo, Flores
1602	de Syria	(Spain)			Terceira
1603	de Nautonier	(France)		western Canaries	
1607	Crescentio	(Italy)			S Michael, S Maria, Terceira
------	Davis	(England)			S Michael
1608	de Fonseca	(Portugal)			Terceira?
1609	Linton	(England)		west of Canaries	
------	Keteltas	(Dutch Republic)			Corvo, Flores
1615	Ferrer Maldonado	(Spain)			Corvo
1617	Cabeliau	(Dutch Republic)			Corvo, Flores
1621	Tarde	(France)	Cape Verdes	Canaries	Azores
1624	de Saa	(Portugal)			near Corvo
1625	de Figueiredo	(Portugal)			Corvo
1632	Aspley	(England)			S Michael
1640	le Bon	(France)			west of Corvo
1655	de Mariz Carneiro	(Portugal)			Azores?
1673	Pimentel	(Portugal)			Azores?

Table 2. Oceanic Navigation 1650-1750

		VOC	CDI	EIC
	production	manuscript	printed	printed
Charts	projection	plane/Mercator	plane/Mercator	mostly plane
	source	Hydrographic Office	Sea Atlas	Sea Atlas
	meridian	Tenerife	Atlantic isles	last sighted land
Reckoning	type	global	target	local
	measure	longitude (arc)	longitude (arc)	meridian distance (physical)

Figures

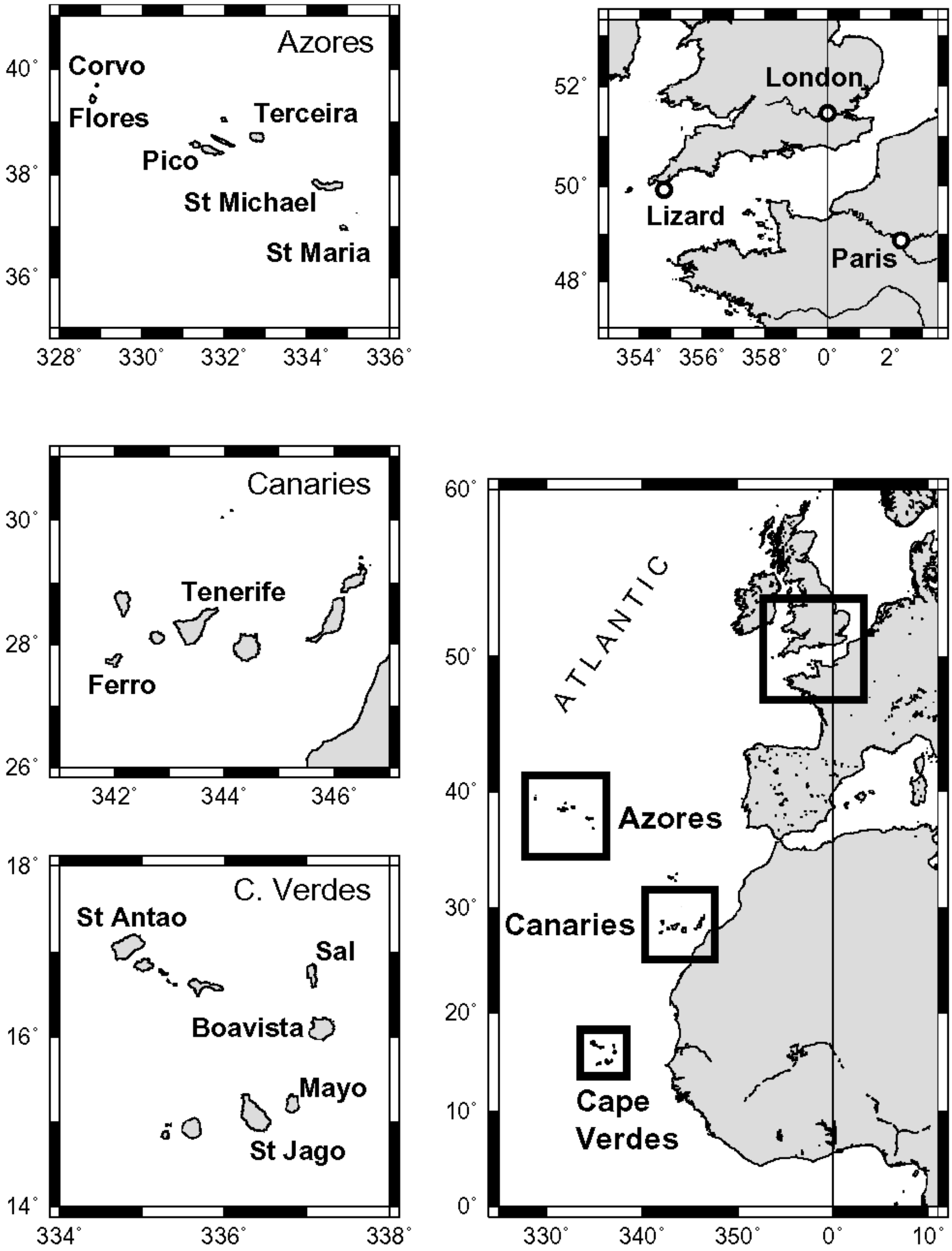

Figure 1. Early-modern maritime prime meridians relative to Greenwich. Main chart: North Atlantic Ocean. Top right: Channel. Top left: Azores. Middle left: Canary Islands. Bottom left: Cape Verde Islands. Only those locations relevant to the text have been labelled. Mercator projection.

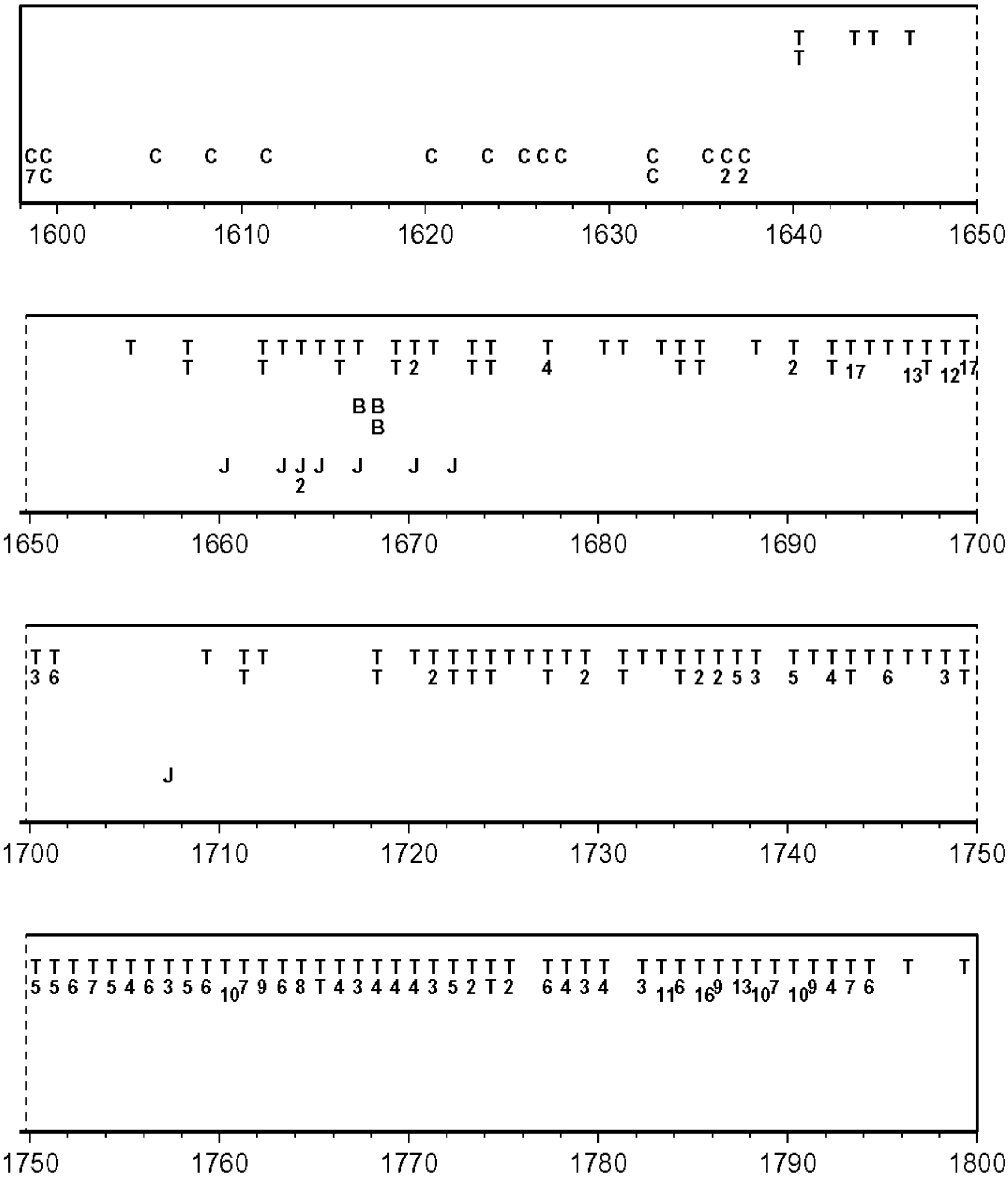

Figure 2. Prime meridians in sampled Dutch logbooks (1598-1800). B = Boavista; C = Corvo; J = St. Jago; T = Tenerife. Numbers indicate additional instances in the same year of the adjacent meridian.

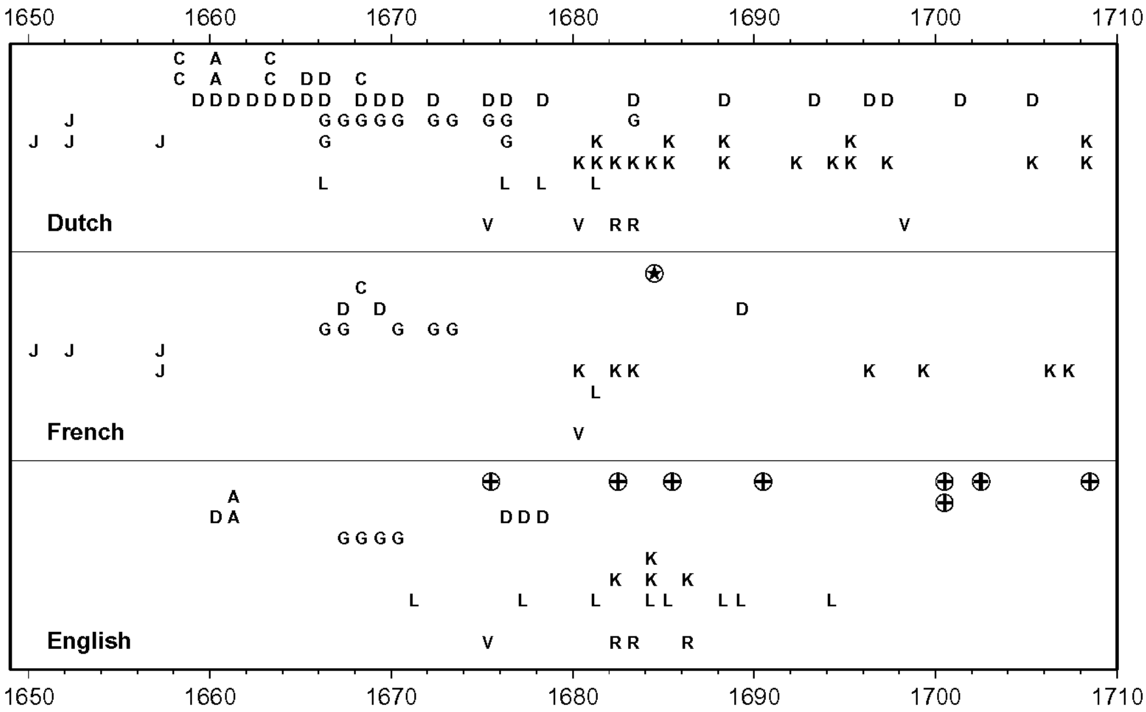

Figure 3. Sea atlases from Amsterdam publishers (1650-1710), in Dutch (top), and in French (middle) and English translation (bottom). A = Pieter van Alphen; C = Arnold and Jacob Aertsz Colom; D= Hendrick Doncker; G = Pieter Goos; J = Johannes Janssonius; K = Johannes van Keulen (and family); L = Casparus and Jacob Lootsman; R = Jacob Robijn; V = Arend Roggeveen. Source: Koeman, Atlantes Neerlandici, vol. 4. Circled star: French sea atlas. Circled cross: English sea atlas.

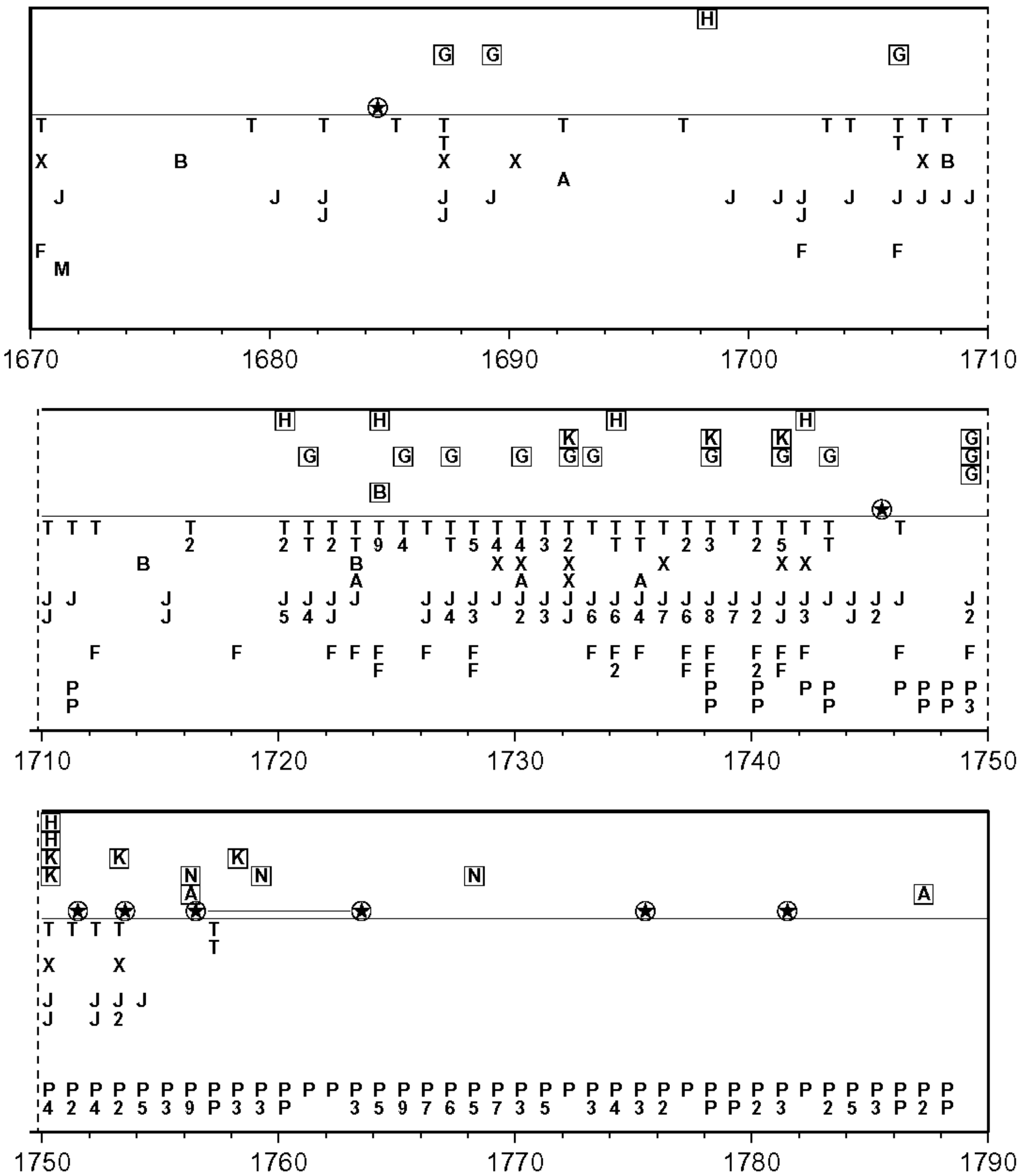

Figure 4. Charts (top, in squares) and prime meridians (bottom) referred to in sampled French logbooks (1670-1789). Charts: A = d'Après de Mannevillette; B = Bocage; G = Goos; H = Hollandois (Dutch); K = van Keulen; N = Naval. Meridians: A = Azores; B = Boavista; F = Ferro; J = St. Jago; M = Madagascar; P = Paris; T = Tenerife; X = shifting. Circled star: French sea atlas. Numbers indicate additional instances in the same year of the adjacent meridian.

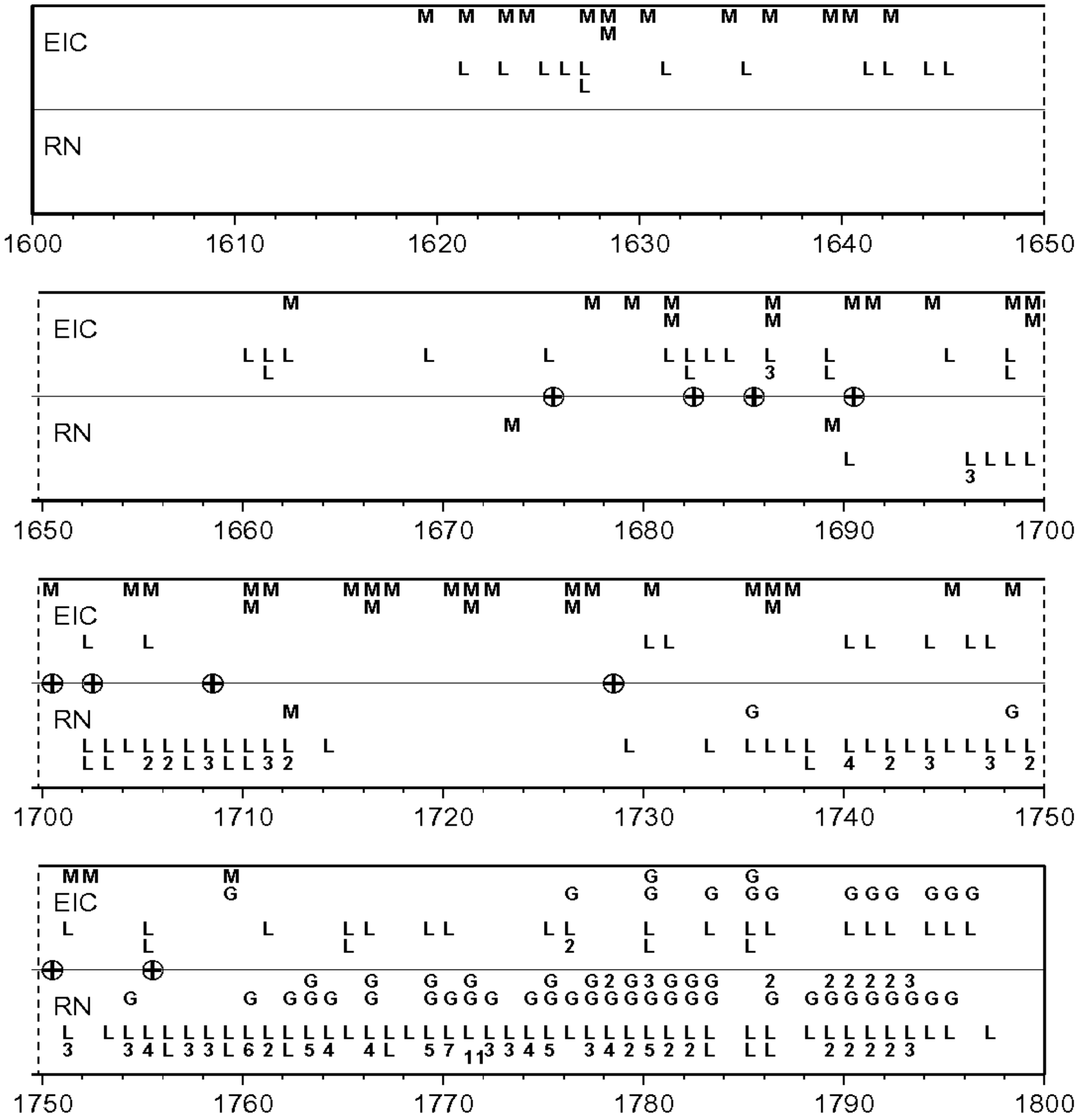

Figure 5. Types of reckoning in sampled English logbooks (1600-1800) from East India Company (top) and Royal Navy (bottom). A = Arc measure of longitude (local); L = London and Greenwich (global); M = meridian distance (local). Circled cross: English sea atlas. Numbers indicate additional instances in the same year of the adjacent meridian.

Notes

1. At the time, about two thirds of world shipping already relied upon the Greenwich meridian; Howse, D. "1884 and Longitude Zero." Vistas in Astronomy 28 (1985) 11-19; Howse, D. and M. Sanderson. The Sea Chart: An Historical Survey Based on the Collections in the National Maritime Museum. Newton Abbot: 1973. 101.

2. Fournier, G. Hydrographie Contenant la Théorie et la Pratique de Toutes les Parties de la Navigation. 2d ed. Paris: 1676, 425. Some Arab geographers actually kept Ptolemy's prime meridian; Kennedy, E. S. and M. H. Regier. "Prime Meridians in Medieval Islamic Astronomy." Vistas in Astronomy 28 (1985), 29-32.

3. Waller, R. The Posthumous Works of Robert Hooke . . . London: 1705, 480-81; Markham, A. H. The Voyages and Works of John Davis the Navigator. Hakluyt Society Publications, series I, no. 59a. London: 1880, 341; Mercier, R. "Meridians of Reference in Pre-Copernican Tables." Vistas in Astronomy 28 (1985) 23-27; Gingerich, O. "The Accuracy of Ephemerides, 1500-1800." Vistas in Astronomy 28 (1985) 339-42; Sarton, G. Six Wings: Men of Science in the Renaissance. London: 1957, 90; rare evidence of the meridian of Frankfort used at sea in Gosch, C. C. A. (ed.) Danish Arctic Expeditions, 1605 to 1620. 2 vols, Hakluyt Society Publications, series I, no. 96, 97. London: 1897, 2: 71 (voyage Jens Munk, 1609).

4. Bentley Duncan, T. Atlantic Islands: Madeira, the Azores and the Cape Verdes in Seventeenth Century Commerce and Navigation. Chicago, Ill.: 1972, 7-19. The Azores were also known as the "Flemish Islands", because in 1466 the island of Fayal had been given to Isabella of Burgundy as part of a treaty settlement. Later, the whole group came under Portuguese control; Howse and Sanderson, Sea Chart, 71. In addition, the "Salvages" are two small rocky islands, about halfway between Madeira (which owns them) and the Canaries.

5. Williamson, J. A. The Cabot Voyages and Bristol Discoveries under Henry VII. Hakluyt Society Publications, series II, no. 120. Cambridge: 1962, 14, 15; Bentley Duncan, Atlantic Islands, 3-4, 23.

6. Godinho V. M. "The Portuguese and the `Carreira da India' 1497-1810", in Ships, Sailors and Spices: East India Companies and their Shipping in the Sixteenth, Seventeenth, and Eighteenth Centuries, ed. J. R. Bruijn and F. S. Gaastra. Amsterdam: 1993, 24; Williamson, Cabot Voyages, 14. Columbus, for instance, used Ferro in the Canaries as last stop before his Atlantic crossing; Marguet, F. Histoire de la Longitude à la Mer au XVIII Siècle en France. Paris: 1917, 2.

7. Refugees from the Ottoman conquest of Constantinople (1453) brought Ptolemy's Geography to western Europe, where the newly invented printing press assured its rapid distribution from 1470 onwards. thereafter. Ptolemy's legacy thus served as a model for other map makers, many of whom initially followed his meridian choice as well. A century later, the first modern atlas, Abraham Ortelius's Theatrum Orbis Terrarum (Antwerp, 1570) continued this tradition, albeit with the addition of the western hemisphere (measured up to 180≡ west). Cotter, C. H. A History of Nautical Astronomy. London: 1968, 181; Sanson d'Abbeville, N. Atlas du Monde. Paris: 1665. Facs., intro. M. Pastoureau. Amsterdam: 1988, 29; Martinez-Hidalgo y Teran, J. M., Historia y Leyenda de la Aguja Magnetica: Contribución de laos Españoles al Pregreso de la Nautica. Barcelona: 1946, 117.

8. In reality, a magnetised needle will attempt to align itself with the local magnetic flux lines, which are, more often than not, oriented elsewhere, due to the complex fluid nature of the geodynamo.

9. For a detailed analysis of the evolution of geomagnetic hypotheses, please consult my forthcoming book: Earth's Magnetism in the Age of Sail, Baltimore, MD: Johns Hopkins University Press.

10. De Lisboa, J. de. "Tratado da Agulha de Marear" in Livro de Marinharia: Roteiros, Sondas e Outros Conhecimentos Relativos á Navegaçao (1514). Facs. ed. J. I. de Brito Rebello. Lisbon: 1903, 18-24; Albuquerque, L. M. de. O Livro de Marinharia de André Pires. Agrupamento de Estudos de Cartografia Antiga 1 (1963), 10-12, 124-28, 132; Albuquerque, L. M. de. Contribuicao das navegaçoes do sec. XVI para o conhecimento do magnetismo Terrestre. Agrupamento de Estudos de Cartografia Antiga 44 (1970) 7-8, 19; Crone, E. "Het Aandeel

van Simon Stevin in de Ontwikkeling van de Zeevaartkunde." Mededelingen van de Marine Academie 15 (1963), 8; Crone, E., E. J. Dijksterhuis, and R. J. Forbes. The Principal Works of Simon Stevin, vol. 3. Amsterdam: 1961, 393-94; Davids, C. A. "Finding Longitude at Sea by Magnetic Declination on Dutch East Indiamen, 1596-1795." The American Neptune 50 no. 4 (1990), 281; Keuning, J., De Tweede Schipvaart der Nederlanders naar Oost-Indië onder Jacob Cornelisz van Neck en Wybrant Warwyck 1598-1600, vol. 2. Werken der Linschoten Vereniging 44. The Hague: 1940, xxx-xxxi; Keuning, J. Petrus Plancius, Theoloog en Geograaf 1552-1622 Amsterdam: 1946, 123.

11. De Lisboa, "Tratado da Agulha", ch. 7; Faleiro, F. Tratado del Sphera del Mundo y del Arte de Navegar. Seville: 1535, ch. 8; Sanuto, L. Geografia dell'Africa. Venice: 1588. Facs. intro. R. A. Skelton. Amsterdam: 1965, vii-viii, 5v; Santa Cruz, A. de. The Book of Longitudes (Libro de las Longitudines, Seville: 1542). Transl. J. Bankston. Bisbee, Ariz.: 1992, ch. 4; BL MS Regal 20 B VII, f.16v; Cortés, M. Breve Compendio de la Sphera y de la Arte de Navegar. Seville: 1551, ch. 5; Oviedo, G. F. de. La Hystoria General de las Indias. (n.p. 1547), f.16v; Cardano, H. Opera Omnia, Aucta et Emendata. Leyden: 1663, pt. 3, bk. 12, ch. 60; Porta, G. della, Natural magick. Transl. R. Eden. London: 1658. Facs., introd. D. J. Price. Washington DC: 1957, bk.7, ch. 38; Archivo General de Indias, Seville (AGI), Indiferente 426, bk. 25, f.226r-227v; Toussaints de Bessard. Dialogue de la Longitude Est-Ouest. Rouen: 1574, 30; Borough, W. A Discourse of the Variation of the Compasse, or Magneticall Needle 2d ed. London: 1596, 146; Coignet, M. Instruction Nouvelle de Poincts Plus Excellents et Necessaires, Touchant l'Art de Nauiger. Antwerp: 1581, 11-12; Bibliothèque Nationale, Paris (BNP) MS FR 9175, f.3v, 19r; Acosta, J. de. Historia Natural Moral de las Indias. Seville: 1590, bk. 1, ch. 17; Warner, G.F. (ed.), The Voyage of Robert Dudley . . . to the West Indies, 1594-1595. Hakluyt Society Publications, series 2, no. 3. London: 1899, 91; Dudley, R. Arcano del Mare. Florence: 1646, passim; National Maritime Museum, Greenwich (NMM) MS NVT/7, ch. 31; Blundeville, T. His Exercises, Containing Eight Treatises . . . 2nd ed. London: 1597, ch. 25-26; Rouffaer, G. P. and J. W. IJzerman. De Eerste Schipvaart der Nederlanders naar Oost-Indië onder Cornelis de Houtman, 1595-1597. Werken der Linschoten Vereniging 7, 25, 32. The Hague: 1915, 1925, 1929, 3: 411-12, 415; Crone, Dijksterhuis, and Forbes, Principal Works, 420-75; Syria, P. de. Arte de la Verdadera Navegacion. Valencia: 1602, 54, 60; Nautonier, G. de. Mecometrie de l'Eymant. Venes: 1603, bk. 1, 21; Crescentio, B. Nautica Mediterranea. Rome: 1607, 225, 229, 236-37; Markham, John Davis, 284; AGI Patronato 262 R.4 imagen 15, 29-31, 33-40, 52-53, 60, 63, 80-82, 84, 98-103, 116-17; Linton, A. Newes of the Complement of the Art of Navigation. London: 1609, 16; Keteltas, B. Het Ghebruyck der Naeld-Wiisinge. Amsterdam: 1609, dedication; AGI Patronato 262 R.6 im. 2, 4-5, 28-30; Cabeliau, A. Reken-Konst van de Groote See-vaert. Amsterdam: 1617, ch. 7 (nota); Tarde, I. Les Usages du Quadrant à l'Esguille Aymantee. Paris: 1621, 20, 68; Saa, V. de. Regimento de Navegaçam. Lisbon: 1624, 20v; Figueiredo, M. de. Hidrographia Exame de pilotos . . . Lisbon: 1625, 15-16; Aspley, I. Speculum Nauticum. A Looking Glasse for Sea-Men. 2d ed. London: 1632, 39; Figueiredo, M. de. Hydrographie ou Examen, Traduit . . . et Augmenté . . . Dieppe: 1640, 23; Carneiro, A. de Mariz. Regimento de Pilotos e Roteiro da Navegaçam. Lisbon: 1655, 8, 11, 207.

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14. Coignet, M. Instruction Nouvelle de Poincts Plus Excellents et Necessaires, Touchant l'Art de Nauiger. Antwerp: 1581, 11-16; Meskens, A. J. "Michiel Coignet's Nautical Instruction." Mariner's Mirror 78 no. 3 (1992), 257-70; Crone, "Aandeel van Simon Stevin", 9-10.

15. but placed at 23≡30' W of London, coinciding with St. Jago in the Cape Verdes.

16. Meskens, "Coignet's Nautical Instruction", 271-77; Blundeville, His Exercises, 1597, ch.25; Blundeville, T. "A New and Necessarie Treatise of Nauigation" in A Most Plaine and Easy Way for the Finding of the Sunnes Amplitude and Azimuth, ed. J. Tapp. London: 1630, 331v; Graaf, A. de. De Seven Boecken van de Grootte Zeevaert. Amsterdam: 1658, 45; Anhaltin, C. M. Slot en Sleutel van de Navigatie ofte Groote Zeevaert. Amsterdam: 1659, 47-48; Borough, Discourse, 154.

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18. WLV 43, p.44, 369-70; Rodrigues's instructions would also be echoed in seventeenth-century Portuguese roteiros by Joao Baptista Lavanha, and in navigation manuals by Manuel de Figueiredo and Antonio de Mariz Carneiro; Leitao, H. (intro.) Dois Roteiros do Seculo XVI, de Manuel Monteiro e Gaspar Ferreira Reimao, Atribuidos a Joao Baptista Lavanha. Lisbon: 1963; Figueiredo, Hidrographia, passim; Carneiro, Regimento de Pilotos, passim.

19. Pos, "So weetmen", 145; Crone, Dijksterhuis, and Forbes, Principal Works, 403. A second edition of the Dutch translation followed in 1624.

20. Rouffaer and IJzerman, Eerste Schipvaart, 2: 229, 3: 411-22; Keuning, Tweede Schipvaart, 236-43; Keuning, Petrus Plancius, 141-42.

21. Davids, C. A. Zeewezen en Wetenschap: de Wetenschap en de Ontwikkeling van de Navigatietechniek in Nederland tussen 1585 en 1815. Amsterdam: 1986; Davids, "Finding Longitude"; Crone, E. "De Vondst op Nova Zembla: een Hernieuwd Onderzoek der Navigatie Instrumenten." Bulletin Rijksmuseum 14 no. 2 (1966), 71-85; Struik, D. J. The Land of Stevin and Huygens: A Sketch of Science and Technology in the Dutch Republic during the Golden Century. Studies in the History of Modern Science 7. Dordrecht: 1981; Schilder, G. and W. F. J. Mörzer Bruyns. "Zeekaarten en Navigatie." in Maritieme Geschiedenis der Nederlanden 1. Bussum: 1976, 239-48; Schilder, G. and W. F. J. Mörzer Bruyns. "Navigatie." in Maritieme Geschiedenis der Nederlanden 2. Bussum: 1977, 159-99; Keuning, Tweede Schipvaart; Keuning, Petrus Plancius; Naber, Reizen 1594-1597.

22. Algemeen Rijksarchief, The Hague (ARA) 1.11.01.01/1137 logbook Griffioen (e.g. 15-16 Apr, 2 May 1608); ARA 1.10.30/309 logbook Zierikzee (e.g. 9 Feb 1620 in table); ARA 1.04.02/5050 logbook Hollandia (e.g. 5 Oct, 4 Nov 1626); ibidem /14345 logbook Wapen van Hoorn (e.g. 18 June, 11-12 Aug, 1 Sept 1627); ibidem /1105 logbook Zutphen (14, 27 June, 4-5 July 1632); ibidem /1110 logbook Amsterdam (14, 27 June, 4-5 July 1633); ARA 1.10.30/75 logbook Amsterdam (e.g. 26, 28 Feb, 1-2, 7, 12, 28 Mar, 1, 17, 26-27 Apr 1635); University Library Leyden (UBL) BPL 127 E logbook Nieuw Amsterdam (e.g. 15 Jan, 9 Feb, 8 Apr, 8 June, 2 July 1636); ARA 1.04.02/1120 logbook Banda (24 Feb, 7 Mar 1637). Other VOC logbooks from this period still lacked arc measures of longitude; among these, some nevertheless contained references to the Plancius concept, such as ARA 1.04.02/1132 logbook Engel (9 Sept 1639), ibidem /1089 logbook Leijden (31 dec 1625, 12, 23 Jan 2, 19 Apr, 5, 10, 15 May 1626), and ibidem /1095 logbook Nassau (1 dec 1628).

23. Ten sampled logbooks from 1598-1600 of the Dutch Oude Oostindische Compagnie (one of the companies that

preceded the VOC) likewise reckoned from the Corvo meridian; ARA 1.04.01/51 Gelderland (1598-1600); ibidem /62 Utrecht (1598-1600); ibidem /53 Vriesland/Zeelandia (1598-1600); ibidem /46 Amsterdam/Vriesland (1598-99); ibidem /44 Hollandia (1598-99); ibidem /43 Mauritius (1598-99); ibidem /60 Vriesland (1598-99); ibidem /54 Zeeland (1598-99); ibidem /45 Hollandia (1599); ibidem /60 Amsterdam (1599-1600).

24. Stevin, S. De Havenvinding. Leyden: 1599, passim; Stevin, S. Wisconstighe Ghedachtenissen. Leyden: 1605-08, pt. I, bk. 5, 164-74; Struik, Land of Stevin, 58; Davids, Zeewezen en Wetenschap, 72, 287; Dijksterhuis, E. J. Simon Stevin: Science in the Netherlands around 1600. The Hague: 1943 and 1970, 77, 83, 91, 186-88; Davids, "Finding Longitude", 283-84; Balmer, Beiträge, 128-33; Crone, Dijksterhuis, and Forbes, Principal Works, 253-54, 365, 368-72, 377-79. Stevin's 1599 Havenvinding contained the Plancius table, and appeared in Latin translation (by Hugo de Groot) and in English (by Edward Wright) the same year; a Latin publication of Stevin's 1608 work on mathematics (which incorporated an edited version of the 1599 treatise) was undertaken by Rudolf Snell(ius) van Roijen, while a French translation by Albert Girard appeared in 1620. Thompson, William Gilbert, 7; Sarton, Six Wings, 94; Taylor, E. G. R. Mathematical Practitioners of Tudor and Stuart England. Cambridge: 1954, 47; Waters, D. W. The Art of Navigation in England in Elizabethan and Early Stuart Times. London: 1958, 229.

25. A trial at sea by the Amsterdam Admiralty in 1611 resulted in a negative report. Plancius's rationale was moreover rejected by cartographers Hondius and Blaeu, the earlier-mentioned Haeyen and Robbertsz, and mathematics professor Adriaen Metius (who did copy part of the Plancius table of observations, as did Anhaltin). Hondius, J. Tractaet ofte Handelinge van het Gebruyck der Hemelsche en Aertschen Globe. Amsterdam: 1597, 50-51; Haeyen, Een Corte Onderrichtinge Belanghende die Kunst vander Zeevaert. Amsterdam: 1600, 10, 16; Blaeu, W. J. Licht der Zeevaart. Amsterdam: 1608, preface; Robbertsz, R. Numeratio: Het Eerste ABC der Tal-konst. n.p. 1612, preface, 16, backpage; Metius, A. Nieuwe Geographische Onderwysinghe . . . Franeker: 1614, 10-11, 43-44; Anhaltin, Slot en Sleutel, 56; Muller, S. De Reis van Jan Cornelisz May naar de IJszee en de Amerikaansche Kust 1611-1612. Werken der Linschoten Vereniging 1 The Hague: 1909, 16; Davids, Zeewezen en Wetenschap, 76-77, 285-87, 313, 355; Davids, "Finding Longitude", 284-87; Crone, Dijksterhuis, and Forbes, Principal Works, 407-9; Keuning, Petrus Plancius, 131-35; Naber, Reizen 1594-1597, xxii-iii, xxix-xxx, 51; Crone, "Aandeel van Simon Stevin", 10.

26. Schilder, G., "Organization and Evolution of the Dutch East India Company's Hydrographic Office in the Seventeenth Century." Imago Mundi 28 (1976), 61-65.

27. The first static geomagnetic longitude solution after 1635 (by Gabriel Grisly van Offenburg, in 1647) submitted to a Dutch committee (VOC examiner of masters Cornelis Jansz Lastman, Joan Blaeu, and hydrographer Sybrand Hansz Cardinael) was explicitly rejected because secular variation had not been accounted for; Dam, P. van. Beschryvinge van de Oostindische Compagnie. ed. F. W. Stapel and C. W. Th. Baron van Boetzelaer van Asperen en Dubbeldam. 7 vols. Rijks Geschiedkundige Publikatiën 63, 68, 74, 76, 83, 87, 96. The Hague: 1976, bk.1, II: 681; Davids, Zeewezen en Wetenschap, 77-80; Davids, "Finding Longitude", 288.

28. Gellibrand, H. A Discourse Mathematical on the Variation of the Magneticall Needle. London: 1635. Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus 9, ed. G. Hellmann. Berlin: 1897, repr. Nendeln: 1969, 19; Fournier, Hydrographie, 415-16; Malin, S. R. C. and E. C. Bullard. "The Direction of the Earth's Magnetic Field at London 1570-1975." Philosophical Transactions of the Royal Society A 299 (1981), 364-66, 384-87; Mason, S. F. A History of the Sciences. New York: 1962, 253; McConnel, A. Geomagnetic Instruments before 1900: An Illustrated Account of Their Construction and Use. London: 1980, 5; Feingold, M. The Mathematicians' Apprenticeship: Science, Universities and Society in England, 1560-1640. Cambridge: 1984, 11; Cotter, C. H. "Edmund Gunter (1581-1626)." Journal of the Institute of Navigation 34 (1981), 367; Goodman, D. and C. A. Russell, eds. The Rise of Scientific Europe 1500-1800. Sevenoaks: 1991, 206-7; Malin, S. R. C. "Historical Introduction to Geomagnetism." in Jacobs, J.A. (ed), Geomagnetism vol. 1, ed. J. A. Jacobs. London: 1987, 19-20; Taylor, E. G. R. The Haven-Finding Art. London: 1957, 232; Benjamin, P., The intellectual rise in electricity: a history (New York, NY 1895), 447; Crombie, A. C. Styles of Scientific Thinking on the European

Tradition: The History of Argument and Explanation. 3 vols. London: 1994, 636; Sarton, Six Wings, 94; Taylor, Tudor and Stuart England, 38, 62-63, 72-73.

29. The merchants category comprised the Dutch West India Compagnie, Middelburgsche Commercie Compagnie, and some small private ventures.

30. Mörzer Bruyns, W. F. J. "Prime Meridians used by Dutch Navigators: A Survey of the Prime Meridians Used by the Dutch for Navigation and Hydrography, prior to 1884." Vistas in Astronomy 28 (1985), 33; ARA 1.10.30/131 logbook Pauw (16 June 1640): "de lengte van 110.57 ofte naer 't oude gebruyck 123 gra. 57 min becomen te hebben."

31. Archives Nationales, Paris (ANP) MAR 4JJ/144 logbook Witte Lam (1707-08).

32. The nine VOC journals using St. Jago are all kept in ANP MAR 4JJ/144; the eight by first mate Sipke Vis concern an anonymous vessel (1660) and the ships Rijsende Son (1663), Casteel Rammekens (1664), Cogge (1664), Lantsmeer (1664-65), Alphen (1665-66), Amersfoort (1667), and Vrijheijt (1670). Of these, only the anonymous ship and the Amersfoort described voyages from and to patria. In addition, Sipke Vis also left journals (under the same archival reference) from his intra-Asian travels aboard the Naarden (1662), Anckeveen (1662-63), and Canae (1665), but none of these carried sufficient longitudinal data to determine which prime meridian was used (and have thus been omitted from the sample). The other VOC log using St. Jago, from an unknown navigator, is ANP MAR 4JJ/144 Bock (1672), travelling from Cochin to Batavia. Verweij's three voyages relative to Boavista concern the ships Sint Loowis (1667), Sint Jan (1668), and Vergulden Arent (1668-69), in British Library, London (BL) MS Sloane 3673.

33. Schilder, G., "Organization and Evolution", 61-67.

34. Latitude sailing is the method of making a desired latitude in good time on the open sea, and then heading east or west on that parallel ("running down the latitude") until landfall is made.

35. Note, however, that a constant heading is not the same as a great circle course towards a destination (the shortest route between points on a sphere).

36. Mörzer Bruyns, "Prime Meridians", 33.

37. Examples in ARA 1.04.02/1431, f.618 (1688), ibidem /1831, f.857 (1713), ibidem /1953, f.2053 (1722), ibidem /2304, f.221 (1734), ibidem /2489, f.317 (1740), ibidem /2711, f.137 (1749), ibidem /3250, f.474 (1769), and ibidem /2617, f.195 (1795).

38. It is tempting to associate a VOC clampdown on non-Tenerife meridians in the 1670s with the advent of Joan Blaeu II (1673) as Company hydrographer, and/or with the new navigation equipment list of 1675. However, no evidence to this effect has so far come to light.

39. Mörzer Bruyns, "Prime Meridians", 34; Schilder, G. and W. F. J. Mörzer Bruyns. "Navigatie." in Maritieme Geschiedenis der Nederlanden 3. Bussum: 1977, 216.

40. Whitfield, P. The Charting of the Oceans: Ten Centuries of Maritime Maps. London: 1996, 74, 91. Longitudinal scales for example on the chart of the East Indies (eastern part) in Doncker, H. Zee-atlas ofte water-waereld Amsterdam: 1661; an example of Mercator projection is the "Nieuwe Pascaert van Oost Indien" in Keulen, J. van. De Groote Nieuwe Vermeerderde Zee-Atlas ofte Water-Werelt . . . in Seer Nette Kaerten, Soo Platte als Wassende Graden. Amsterdam: 1682. By the mid-eighteenth century, almost all van Keulen's charts used Mercator's projection.

41. Doncker's originals, the most up to date sea atlas plates in the second half of the seventeenth century, were blatantly copied by Goos, whose widow sold the publishing rights to Jacob Robijn. Johannes van Keulen in turn bought Doncker's entire stock-in-trade in 1693, and inserted Goos's intoduction and index in a French edition of his own sea atlas in 1680. Koeman, C. Atlantes Neerlandici: Bibliography of Terrestrial, Maritime, and Celestial Atlases and Pilot Books, Published in the Netherlands up to 1880. vol. 4 Amsterdam: 1970, 154-197; Expositie Amsterdamse Kaartmakers 1544-1975. Amsterdam: 1975, 17, 19, 25-26; Howse and Sanderson, Sea Chart, 60-61, 71; Schilder, G. "A Manuscript Sea Atlas, Drawn by Romeyn de Hooghe in 1681." Centro de Estudos de Cartografia Antiga 130 (1981), 7.

42. Koeman, Atlantes Neerlandici, 4: passim. French competition by Bougard, R. Le Petit Flambeau de la Mer, ou le Véritable Guide des Pilotes Côtiers. Havre de Grâce: 1684, was based on the author's voyage to the East Indies in 1682-83. It combined navigational instruction with 64 charts for coastal navigation from France to South Africa, and went through 13 editions until 1817. English competition by chart sellers John Seller (1675, 1682, 1690), John Thornton (1685, 1700), P. Lea (1700), and Mount & Page (1702, 1708) was usually entitled Atlas Maritimus or Hydrographia Universalis; Pastoureau, M. "Les Atlas Imprimés en France avant 1700." Imago Mundi 32 (1980), 64; Anthiaume, A., "L'Enseignement de Science Nautique au Havre de Grâce pendant les XVIe, XVIIe et XVIIIe Siècles." Bulletin de Géographie Historique et Descriptive 1-2 Paris: 1911, 19; Tooley, R. V. Maps and Map-makers. 6th ed. London: 1978, 44, 61-62.

43. Fournier, Hydrographie, 425; Sanson, Atlas du Monde, 33.

44. Howse and Sanderson, Sea Chart, 12, 79; Whitfield, Charting of the Oceans, 82, 95-96; Raynaud-Nguyen, I. "Longitudes and Meridians on French Charts of the Merditerranean in the 17th and 18th Centuries." Vistas in Astronomy 28 (1985), 49-60; Pastoureau, "Les Atlas Imprimés", 65. The Neptune mainly contained charts by hydrographers Saveur and de Chazelles, edited and published by Charles Pène in 1693. The same year, Alexis Hubert Jaillot (Paris) and Dutch publisher Pierre Mortier had all plates re-engraved in Amsterdam for three pirate editions in Dutch, English, and French.

45. It is unknown whether the chart was made by father de Bocage (the first professeur royal d'hydrographie in Havre de Grâce from 1666) or son (author of Explication et usage d'une partie du cercle universel (Paris 1683, 1689, 1695). The chart was still in use in the 1720s as the master of the CDI's Lenguedocien (ANP MAR 4JJ/69) asserted upon departure for the East in 1724: "me servant de la carte reduitte faite par Mr. de Bocage sur laquelle il fait passée le p.re meridien a l'isle de Fer."

46. Raynaud-Nguyen, "Longitudes and Meridians", 49; Whitfield, Charting of the Oceans, 96. The French sample is largely based on the Dépot's collections; the number of sampled logbooks can be seen to greatly increase from 1720.

47. In 1724 hydrographer père Feuillée (SJ) sailed to Ferro to determine the longitudinal distance between the isle and the Paris Observatory, to which it was intended to transfer it; Raynaud-Nguyen, "Longitudes and Meridians", 55.

48. There appears to be no distinction in navigational practice as related in the following, between French Navy and Compagnie des Indes (other than in destinations).

49. ANP MAR 4JJ/90 logbook Sirenne (7 May 1720); similar examples using Tenerife in ibidem /69 logbook Africain (1724-25) and ibidem /66 logbook Henriette (1742); however, compare ibidem /48 logbook Victorieux (1750), which identifies St. Jago as "meridien Hollandois".

50. The first (1698, BNP MS FR 21690, f.338) and third occurrence (1734, ANP MAR 3JJ/330 "Mer des Indes", no. 15) stem from French sailing directions, rather than logbooks; the former even identified the VOC as source, speaking of: "les veritables cartes de la compagnie de Hollande".

51. References to Pieter Goos can be found in ANP MAR 4JJ/74 logbook President (1687), ibidem /90 logbook Jeux (1689), BL Add. MS 34246, logbook Patriarche (18 June 1706), ANP MAR 4JJ/47 logbook Toison d'Or (13 Jan 1708), ibidem /21 logbook Dromadaire (21 Apr 1721), ibidem /69 logbook Méduse (1725-26), ibidem /70 logbook Duc de Noailles (3 Jun 1728), ibidem /74 logbook Lys (4 May 1730), ibidem /11 logbook Rubis (1732), ibidem /114 logbook Philibert (22 Apr 1734), ibidem /131 logbook Penthièvre (1738-39), ibidem /66 logbook Henriette (1741) and logbook Aurore (1741-42), ibidem /71 logbook Vestale (22 Sept 1743), ANP MAR 3JJ/333 no. 13 logbook Les 13 Cantons (1749), and ANP MAR 4JJ/71 logbook Triton (1749-50). References to Van Keulen reside in ANP MAR 4JJ/74 logbook Badine (2 Mar 1734), ibidem /61 logbook Dryade (1738), ibidem /65 logbook Astrée (1738-39), ibidem /115 logbook Fulvy (1741), ibidem /43 logbook Amérique (27 May 1750), ibidem /34 logbook Parham (1753), and ibidem /48 logbook Victorieux (4 Sept 1758).

52. ANP MAR B^4/7 logbook Vautour (1676-80); ANP MAR 4JJ/88 logbooks Diligent (1708-10), Chasseur (1714-16), and Royal Philippe (1723-25).

53. ANP MAR 4JJ/7 logbook Aimable (1692); ibidem /69 logbook Annibal (1723); ibidem /34 logbook Amitié (1730); ibidem /44 logbook Courier d'Orleans (1735).

54. ANP MAR 4JJ/90 logbook Jeux (1690-91); ibidem /89 logbook Maurepas (1736-38).

55. ANP MAR 4JJ/11 logbook Arc en Ciel (1687-88); ibidem /44 logbook Charente (1732-33); ibidem /11 logbook Elephant (1729).

56. ANP MAR 4JJ/88 logbook Royal Philippe (1732-34); ibidem /115 logbook Fulvy (1741); ibidem /112 logbook Argonaute (1730-31); ibidem /132 logbook Mars (1742-44). Compare the first Mercator chart of the Mediterranean (1737, by the Marquis d'Albert, then head of the naval Dépot), which depicted parallel longitude scales relative to Ferro, Paris, Tenerife, and London; Raynaud-Nguyen, "Longitudes and Meridians", 55.

57. Bellin, J.-N. Le Petit Atlas Maritime: Recueil de Cartes et Plans des Quatre Parties du Monde. 5 vols. Paris: 1764, 2-3. Actually, French hydrography had by this time already produced a number of high quality alternatives.

58. References to the naval charts in ANP MAR 4JJ/22 logbook Atalante (1749-50), ibidem /34 logbook Galatée (1750), ibidem /86 logbook Bot le Favori (1756-57), and ibidem /92 logbook Condé (1768). The Count de Maurepas was a French Minister of the Navy and Secretary of State.

59. D'Après was a navigator, captain, hydrographer, and from 1762 director of the Dépot de Tous les Journeaux, Cartes et Plans Relatifs à la Navigation des Vaisseaux de la Compagnie des Indes. His successful Mémoire sur la Navigation de France aux Indes (Paris: 1765) was reprinted in 1768, and translated into English the year after; Haudrère, P. La Compagnie Française des Indes au XVIIIe siècle (1719-1795). Ph.D. thesis. Paris: 1989, 81; Howse and Sanderson, Sea Chart, 103; Hoefer, Nouvelle Biographie Générale Paris: 1852-77, 2: 932.

60. ANP MAR 4JJ/87 logbook Gloire (16 Jan 1756).

61. Whitfield, Charting of the Oceans, 92; Howse and Sanderson, Sea Chart, 59. Among te most notable members of the school were John Daniell, Nicholas Comberford, John Burston, John Thornton, and Joel Gascoyne.

62. The prize was obtained by captain Bartholomew Sharpe in the Trinity, upon taking the Spanish vessel Rosario off Ecuador. Some fourteen manuscript copies of the English version are known. Tooley, Maps and Map-Makers, 52; Whitfield, Charting of the Oceans, 81-82, 92-93; Howse and Sanderson, Sea Chart, 65, 73.

63. Koeman, Atlantes Neerlandici, 4: 193; Howse and Sanderson, Sea Chart, 11-12, 65, 67. According to Tooley, Maps and Map-makers, 53, Seller also copied from Dutch publishers de Wit, de Ram, Danckerts, Allard, and

Visscher.

64. Seventeen of Thornton's manuscript copies can be found in the BNP; among the other sources are marine surveys of the Persian Gulf by Cornelis Cornelisz Roobacker (1645). Detailed descriptions in Roncière, M. de la. "Manuscript Charts by John Thornton, Hydrographer of the East India Company (1669-1701)." Imago Mundi 19 (1965), 46-50. According to Whitfield, Charting of the Oceans, 93, it was Thornton's work which finally "killed" the anachronistic manuscript chart tradition.

65. Rare English usage of Tenerife in geographical tables in Gellibrand, H. Epitome of Navigation. ed. E. Speidell. London: 1698, tables.

66. Thornton, J. The English Pilot: The Third Book. London: 1703. Facs. introd. by C. Verner and R. A. Skelton. Amsterdam: 1970, 15-16. Harrison, E. Idea Longitudinis: Being a Brief Definition of the Best Known Axioms for Finding the Longitude. London: 1696, 4; Terrell, C. "The Adoption of the Greenwich Meridian by the British Map Trade." Vistas in Astronomy 28 (1985) 211-14. The first English sea atlas uniformly graduated for both latitude and Greenwich longitude (in Mercator projection) was The Atlantic Neptune (London: 1777) by marine surveyor Joseph Frederick Wallet Des Barres, published for the Royal Navy at government expense.

67.Thornton, English Pilot, 29.

68. BL MS Sloane 3143, f.65.

69. Williams, J. E. D. From Sails to Satellites: The Origin and Development of Navigational Science. Oxford: 1992, 42-43; Cotter, C. H. "Nautical Astronomy and the Mercator Principle." Journal of the Institute of Navigation 29 (1976), 15.

70. Early EIC occurrences of meridian distance in India Office British Library, London (IOBL) L/MAR/A /29 logbook Charles (1619-20), ibidem /37 logbook Hart (1623), and ibidem /45 logbook William (1627). Late EIC meridian distance in IOBL L/MAR/B /549 C logbook Anson (1751), ibidem /164 E logbook Onslow (1748), and ibidem /320 E logbook Diligent (1759-60). Meridian distance in Royal Navy ships (only) in NMM DAR/8 logbook Assistance (1673), Public Record Office, Kew (PRO) ADM 52/112 logbook Tyger Prize (1689-91), and ibidem /309 logbook Tygar (1712). Early EIC arc measures of longitude in IOBL L/MAR/A /34 logbook Jonas (1621), ibidem /29 logbook Charles (1623-24), and ibidem /42 logbook Falcon (1625).

71. Early occurrences in naval sources of the Greenwich meridian (global reckoning) in PRO ADM 52/484 logbook Seahorse (1735-38), ibidem /531 logbook America (1748), and ibidem /557 logbook Centurion (1754-55). The earliest Royal Navy voyage to the East Indies using Greenwich in the sample is ibidem /490 logbook South Sea Castle (1760). Early instances of the Greenwich meridian (global reckoning) used on East Indiamen in IOBL L/MAR/B /488 I logbook Greenwich (1776), ibidem /531 logbook Lively (1780-81), and ibidem /98 F logbook Neptune (1780-81).

72. This may provide part of the reason why English East Indiamen sailed to India via East Africa, and were among the last to exploit the advantages of a more southerly, oceanic passage along the "roaring forties" to the East.