Making a Stable Sea: The Littorals of Eighteenth-Century Europe and the Origins of a Spatial Concept

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Abstract: Sea level has become the almost unavoidable reference point of the impending environmental cataclysm. While inherently variable, sea level has been naturalized, in the form of mean sea level, as the most reliable vertical datum. But for all its allure as a global baseline, mean sea level is the rather recent product of very specific local environmental and cultural conditions. Its exact definition in the early nineteenth century, built on the assumption of the reliability of littorals as reference points for heights, was preceded in the eighteenth century by lengthy and lively debates about perceived long-term variations of sea level, in which those who insisted on its rise or decline used local examples to bolster their generalizations. This essay explores these debates and lays out how they paved the way for the development of the ideas of a stable sea and of a measured mean sea level.

Global mean sea level is the most widely adopted metric for assessing long-term changes in the relative positioning of land and sea. It was first described as a crucial indicator of global environmental change in the early 1980s, but various locally and nationally defined mean sea levels served as the standard vertical datum long before that.[1] Its being so familiar means that sea level has become essentially naturalized—that is, we mention it, in daily life, without really thinking about what it truly means and tend to forget that mean sea level is a product of specific historically and culturally determined assumptions. Sea level and the scholarly debate about its long-term modification have a conceptual history, alongside a material history of changing landscapes, subsiding land, and rising water. As will be shown, at the local scale specific needs have determined which materially perceivable level of the sea ought to be used as a reference point, while on the global scale the inherent variability of the oceans has favored the development of the idea of an abstract

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[1] Robert Etkins and Edward S. Epstein, "The Rise of Global Mean Sea Level as an Indication of Climate Change," *Science*, 1982, *215*(4350):287–289; and "Key Indicators: Global Mean Sea Level," NASA Sea Level Change Portal, https://sealevel.nasa.gov/understanding-sea-level/key-indicators/global-mean-sea-level (accessed 29 Apr. 2020).

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and normalized mean sea level. These histories can be understood only in conjunction with each other. In this essay I aim to tell how the early history of the idea of sea level as a plausible reference point is rooted in a scientific debate about sea-level variations that predates anthropogenic climate change.

DEFINING SEA LEVEL

What sea level is, how it can be determined, how it can be compared diachronically, or which of its many incarnations it is best to refer to are all matters that for a long time have not been precisely defined or agreed on. While there has been a widespread tendency to refer to the average level of the sea, it was usually assumed—especially, but not exclusively, when measuring height by barometric means—that one would be able to determine it just by standing along the littoral, on a ship offshore, or on the frozen surface of a sound, without the need for any actual measurement.[2] Extremely rare were instances in which it was defined explicitly with more precision. As late as 1828, when the first interoceanic leveling in Panama was ordered by Simon Bolivar, the British surveyor John Augustus Lloyd—aware of the confusion around the exact definition of the mean level of the ocean—decided, rather than sticking to one specific point or average, to compare the levels of the Pacific and Atlantic oceans at various heights, registering how much they differed at both spring low and high tide and extrapolating from there the seas' average difference (see Figure 1).[3] High and low tides can in fact be—almost physically—appreciated in the moment. As potential reference points they have a haptic tangibility that went missing with the introduction in the early nineteenth century of the mathematized mean sea level.

Before self-registering tide gauges were introduced in the 1830s, and in many places of the world even afterward, keeping track of the variations of the level of the sea with any degree of precision presented major difficulties. Officers had, for instance, to be dispatched to measure the sea at regular, and possibly frequent, time intervals.[4] Part of the intrinsic imprecision of all measurements of the level of the sea is, indeed, due to the limits inherent in any attempt to produce knowledge in and from the field.[5] It was, for instance, simply the lack of anyone willing to attend to the gauge at the Royal Docks in Sheerness at night that drove the dockmaster to start developing a machine that would allow for a reduction in human participation in the data-gathering process (see Figure 2).[6] The most advanced theorizations of sea level developed at the time were completely uncoupled from the need to measure the sea physically. In his calculations on tides, Pierre-Simon Laplace defined the state of equilibrium of the sea as the level it would take if not subject to the influence of the Sun and the Moon. Friedrich Wilhelm Bessel invited his readers to imagine crossing the Earth with a network of canals connecting the oceans: the surface of still water in

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[2] See, e.g., Pierre-Simon Laplace, *Traité de mécanique céleste* (Paris: De l'Imprimerie de Crapelet, 1798), p. 147.

[3] John Augustus Lloyd, "Account of Levellings Carried across the Isthmus of Panama, to Ascertain the Relative Height of the Pacific Ocean at Panama and of the Atlantic at the Mouth of the River Chagres; Accompanied by Geographical and Topographical Notices of the Isthmus," *Philosophical Transactions of the Royal Society of London*, 1830, *120*:59–68.

[4] Michael S. Reidy, *Tides of History: Ocean Science and Her Majesty's Navy* (Chicago: Univ. Chicago Press, 2008), pp. 274–281.

[5] Jeremy Vetter, "Lay Observers, Telegraph Lines, and Kansas Weather: The Field Network as a Mode of Knowledge Production," *Science in Context*, 2011, *24*:259–280, https://doi.org/10.1017/S0269889711000093. See also Wilko Graf von Hardenberg, "Measuring Zero at Sea: On the Delocalization and Abstraction of the Geodetic Framework," *Journal of Historical Geography*, 2020, *68*:11–20, https://doi.org/10.1016/j.jhg.2019.12.004.

[6] Michael S. Reidy, "Gauging Science and Technology in the Early Victorian Era," in *The Machine in Neptune's Garden: Historical Perspectives on Technology and the Marine Environment*, ed. Helen M. Rozwadowski and David K. Van Keuren (Sagamore Beach, Mass.: Science History, 2004), pp. 1–31, esp. p. 11.

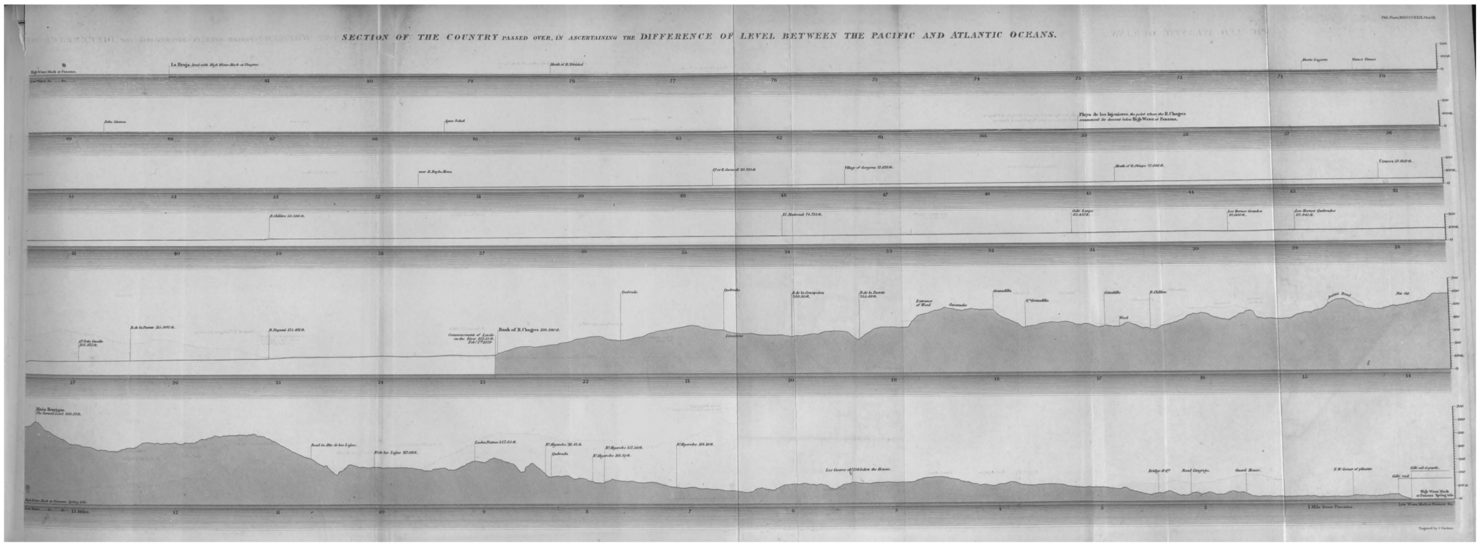

Figure 1. Lloyd's profile of the Isthmus of Panama. From John Augustus Lloyd, "Account of Levellings Carried across the Isthmus of Panama, to Ascertain the Relative Height of the Pacific Ocean at Panama and of the Atlantic at the Mouth of the River Chagres; Accompanied by Geographical and Topographical Notices of the Isthmus," *Philosophical Transactions of the Royal Society of London*, 1830, *120*:59–68. Courtesy of the Royal Society.

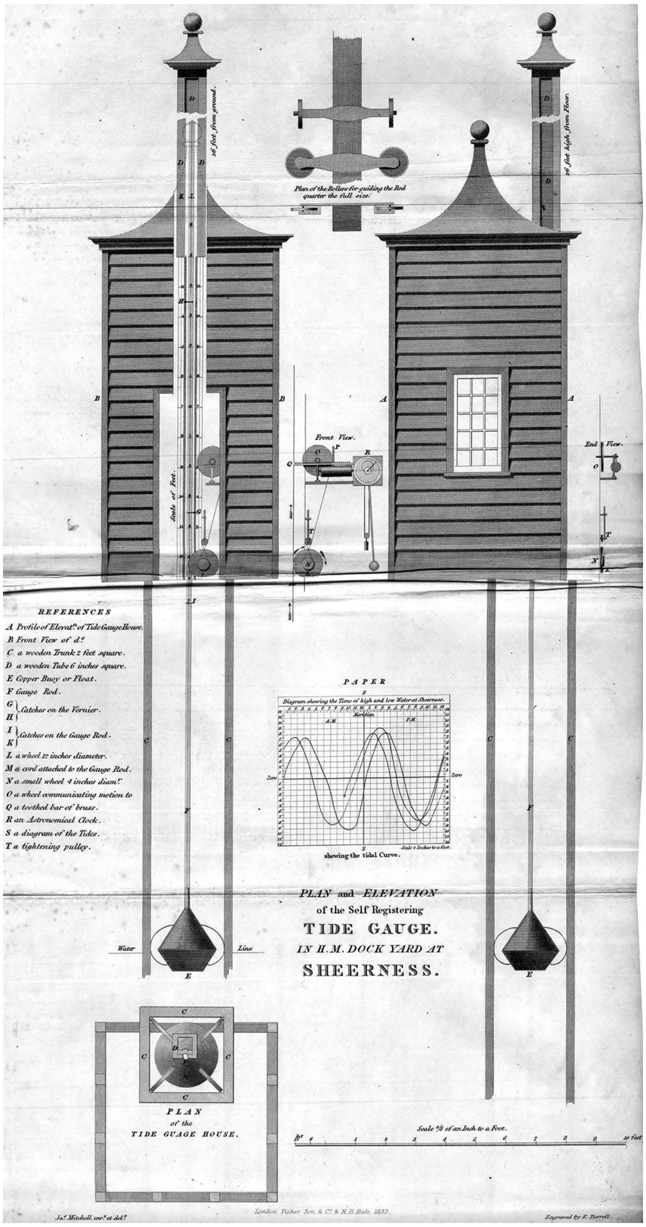

Figure 2. The first working automated tide gauge at the Royal Docks in Sheerness. From "The Tide Gauge at Sheerness," *Nautical Magazine*, 1832, *1*(8). Courtesy of Cambridge University Press.

the canals would, he explained, correspond to the geometrical surface of the planet. In both cases equations and abstractions had a more prominent role than gauges in determining the level of the sea.[7]

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[7] Nicolas Pouvreau, "Trois cents ans de mesures marégraphiques en France: Outils, méthodes et tendances des composantes du niveau de la mer au port de Brest" (Ph.D. diss., Univ. La Rochelle, 2008), p. 132, https://tel.archives-ouvertes.fr/tel-00353660

The choice of reference points for vertical measurements has traditionally responded to specific needs and local geomorphological features.[8] Nautical chart data, explicitly intended to facilitate navigation and in particular to prevent ships from running aground, thus usually refers to some iteration of average low, or lowest low, tide, so as always to indicate the minimum available depth of water. As pointed out in 1837 by the Cambridge don and renowned expert in the science of tides William Whewell, many practitioners in Britain erroneously assumed, in line with the country's drive toward the sea, that low water represented a surface level and thus the ideal reference point. In the same year a single measurement of low water at spring tide was adopted as the standard Irish datum.[9] And navigators had brought this assumption with them when setting up new colonial ventures. The earliest datum in India, since 1802 throughout the British East India Company's possessions, was, in fact, low water as recorded by various local tide gauges. As noted by the civil engineer Benjamin Bevan in a letter he sent in 1822 to the British Admiralty, surveyors, too, often preferred low water as a reference point because it allowed them to avoid, as far as possible, the use of negative elevations, thus simplifying calculations.[10]

When the aim was to keep the sea at bay, rather than moving on it, the primary interest would be to record sea level at high tide. This was particularly urgent in a couple of specific muddy, mostly man-made European coastal environments such as Venice and the Netherlands. In Venice the main vertical datum was, at least since 1440 and for many decades into the nineteenth century, the so-called *comune marino* (marine common), which referred to the level of high waters registered on the city's white stones by a thin blackish line of algal deposits. The materiality of this reference point made it difficult, however, to keep track of it over time: the datum was a living thing, moving with the tides and slowly shifting from year to year. Only much later was it made permanent by engraving a capital "C" into the stone. Measurements on land acquired long-term stability, but the consequence was that the marker was soon decoupled from the perceived sea level.[11] The Amsterdam Ordnance Datum, or Amsterdam Peil, is the oldest measured and registered vertical datum referring to sea level, dating back to the seventeenth century. Devised to ascertain flooding risks in an area reclaimed from the sea, it was as well a marker of average high tide, about 14 centimeters above the mean level.[12]

/document; Laplace, *Traité de mécanique céleste* (cit. n. 2), p. 250; and Friedrich Wilhelm Bessel, "Ueber den Einfluss der Unregelmässigkeiten der Figur der Erde, auf geodätische Arbeiten und ihre Vergleichung mit den astronomischen Bestimmungen," *Astronomische Nachrichten*, 1837, *14*(19–21):269–312, https://doi.org/10.1002/asna.18370141901, esp. p. 270.

[8] Philip L. Woodworth, "High Waters at Liverpool since 1768: The UK's Longest Sea Level Record," *Geophysical Research Letters*, 1999, 26:1589–1592, https://doi.org/10.1029/1999GL900323.

[9] William Whewell, "Researches on the Tides, Seventh Series: On the Diurnal Inequality of the Height of the Tide Especially at Plymouth and at Singapore and on the Mean Level of the Sea," *Phil. Trans. Roy. Soc. London*, 1837, *127*:75–85, esp. p. 84; and Charles Close, "The Levels of Land and Sea: Great Britain," *Science Progress in the Twentieth Century (1919–1933)*, 1923, *18*(70):245–256, esp. p. 246 (standard Irish datum).

[10] Benjamin Bevan to Admiralty, 22 July 1822, Miscellaneous Tides and Trade Winds, RGO 14.51, Board of Longitude Papers, University of Cambridge Library. Regarding the British East India Company data point see Reginald Henry Phillimore, *Historical Records of the Survey of India*, Vol. 2 (Dehra Dun: Survey of India, 1950), pp. 17, 257–259; and William Lambton, "An Account of the Measurement of an Arc on the Meridian on the Coast of Coromandel, and the Length of a Degree Deduced Therefrom in the Latitude 12d 32f.," *Asiatick Researches*, 1808, 8:136–193.

[11] Francesco Carlo Rossi, "Il comune marino di Venezia," in *L'ingegneria a Venezia dell'ultimo ventennio* (Venice: Naratovich, 1887), pp. 42–48; and Antonio Rusconi, ed., *Il comune marino a Venezia: Ricerche e ipotesi sulle sue variazioni altimetriche e sui fenomeni naturali che le determinano* (Venice: Ufficio Idrografico del Magistrato alle Acque, 1983). Similar approaches, recording how living things, such as barnacles and oysters, register sea-level changes, have made a comeback more recently; see, e.g., Harold R. Wanless and Peter Harlem, "A Statement on the Evidence for and Implications of a Recent Rise in Sea Level" (Miami: Rosenstiel School of Marine and Atmospheric Science, Univ. Miami, 23 Apr. 1981).

[12] Herbert Heyde, *Die Höhennullpunkte der amtlichen Kartenwerke der europäischen Staaten und ihre Lage zu Normal-Null* (1923; rpt., Dortmund: Förderkreis Vermessungstechnisches Museum, 1999), p. 6.

The whole idea of keeping accurate and continuous track of the level of the sea—rather than just marking exceptional, catastrophic events or registering the times of tides—as a way to produce a stable reference point seems thus to have been the product of centuries of work to make the sea habitable for humans. It was, in other words, the product of an infrastructural turn that radically transformed certain European coastal landscapes and economies after the Middle Ages and throughout early modernity. The conceptualization of mean sea level as a long-term average of the various levels of the sea was the outcome of a century and a half of scientific research on tides. Ranging from Newton's theory of tides to Whewell's cotidal maps, passing through the efforts of the French Académie Royale to institutionalize the gathering of data to prove Descartes's tidal theory, this work led to the realization that none of the different, perceivable levels of the tide, such as high or low tide, could represent an actual surface level and thus that none of them could be reliably used to relate altitudes in topographical surveys undertaken in different lands separated by the sea. An increase in theoretical work on tides also made it clear that there was a lack of precise measurements of sea level and created momentum for an increase in the collection of raw data. Nonetheless, as exemplified by the many attempts made at the French port of Brest throughout the eighteenth century, in bouts of activism separated by many decades of inactivity, registering long-term variations of sea level remained a challenge.[13] This opened the way to a number of diverging theories, often defiantly uncoupled from the event they were supposed to explain.

A SURPRISING RISE

The Venetians had been the first to register a perceived rise in the level of the sea. As early as the thirteenth century it seemed to many that the city would inevitably be lost to the encroaching sea—owing to the combined effect of silting and subsidence, rather than sea rise—and multiple suggestions were made to move the town. In response, from the fourteenth century the city-state began various hydraulic works to balance the opposing impacts on its survival of sedimentation and relative sea-level change (more recently estimated at about 13 cm a century for the period from 400 to 1900 C.E.). For example, the Venetian authorities diverted the rivers that used to flow into the Venetian Lagoon and built seawalls to protect the city's buildings from the famous *acqua alta* (high water).[14]

Eustachio Manfredi, a professor of mathematics and Superintendent of the Waters in Bologna, was the first to try to formalize a theoretical explanation for the changes in the perceived level of the Adriatic Sea. In 1731 he was invited by Cardinal Bartolomeo Massei, the apostolic legate for Romagna, to visit Ravenna—150 kilometers south of Venice and part of the same complex system of lagoons spreading along the coast of northeastern Italy around the delta of the River Po. Here Manfredi and the Venetian hydraulic engineer Bernardino Zendrini were supposed to work on devising ways to protect the city from the flooding risk posed by the rivers Ronco and Montone (see Figure 3). They began by ascertaining the level of the city with respect to the surrounding

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[13] On the measurement attempts at Brest see Pouvreau, "Trois cents ans de mesures marégraphiques en France" (cit. n. 7), pp. 74–83. Regarding the momentum for increased collection of data on sea level see David Edgar Cartwright, *Tides: A Scientific History* (Cambridge: Cambridge Univ. Press, 1999); P. Goüye and M. de la Hire, "Memoire de la maniere d'observer dans les ports le flux et le reflux de la mer," in *Histoire de l'Académie royale des sciences: Année MDCCI* (Paris: Gabriel Martin, Jean-Bat. Coignard, & Hyppolite-Louis Guerin, 1743), pp. 12–13, http://gallica.bnf.fr/ark:/12148/bpt6k3503q; Pouvreau, "Trois cents ans de mesures marégraphiques en France," pp. 63–70; Guy Wöppelmann *et al.*, "Tide Gauge Datum Continuity at Brest since 1711: France's Longest Sea-Level Record," *Geophys. Res. Lett.*, 2008, 35(22), https://doi.org/10.1029/2008GL035783; and Reidy, "Gauging Science and Technology in the Early Victorian Era" (cit. n. 6), p. 11.

[14] Angelo Zendrini, "Sull'alzamento del livello del mare," *Giornale dell'Italiana Letteratura*, 1802, 2:11–45; and A. J. Ammerman *et al.*, "Sea-Level Change and the Archaeology of Early Venice," *Antiquity*, 1999, 73(280):303–312, https://doi.org/10.1017/S0003598X00088268.

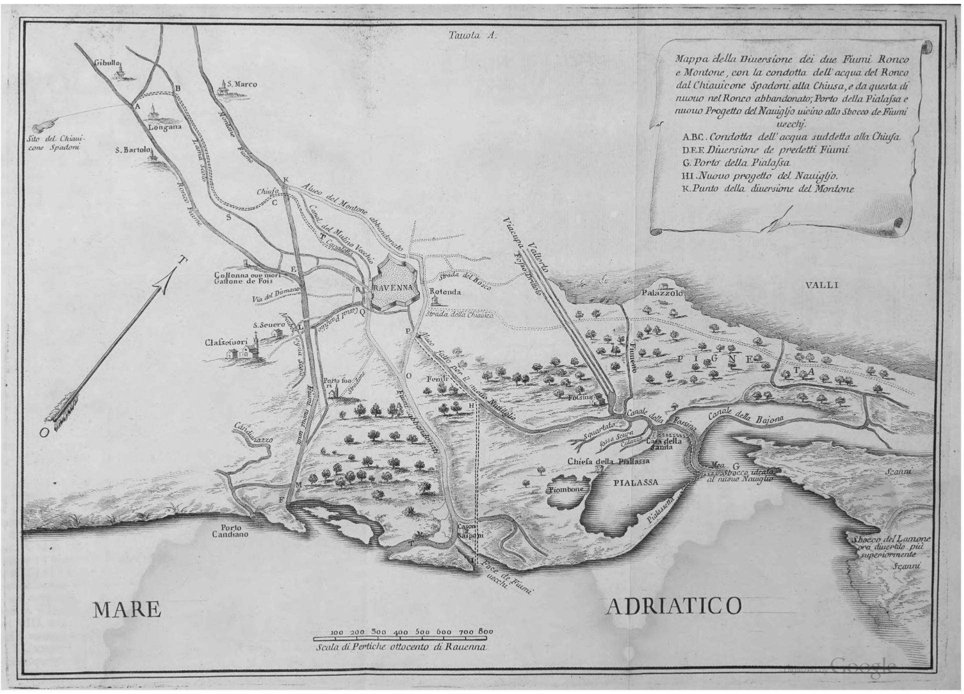

Figure 3. A map of the region surrounding Ravenna. From Bernardino Zendrini and Eustachio Manfredi, "Relazione per la diversione de' fiumi Ronco e Montone dalla città di Ravenna; Indirizzata del 1731: All'Eminentiss. e Reverendiss. Sig. Cardinale Bartolomeo Massei allora Legato della Provincia di Romagna," in *Leggi e fenomeni, regolazioni ed usi delle acque correnti* (Venice: Giambattista Pasquali, 1741), Tavola A. Public domain.

countryside and the nearby sea. Having accomplished this in just a couple of weeks, the two scholars got curious about the long-term history of the level of the city, known to have been raised multiple times.[15]

By a lucky chance, just as Manfredi and Zendrini were visiting, the city's archbishop ordered the start of work to rebuild the Ursian Basilica, first erected in the fifth century. During the excavation of its foundations a magnificent marble mosaic floor and the feet of numerous columns were found, 4 local feet and 7 inches (about 2.7 m) below the ground. Jumping at this fortuitous opportunity, Manfredi and Zendrini surveyed the ancient floor and calculated its position with respect to the level of the sea. To their great surprise, they found that it was just 6 local inches (35 cm) above low tide and 8 local inches (47 cm) below high tide.

What appeared clear to the two scholars was that the level of the sea must have risen over time: it seemed unlikely that such an important cathedral, erected at the expense of the Byzantine emperor himself, had been built just at sea level, condemned to be flooded at regular intervals when the sea rose in its daily tidal cycle. The same might be said for the many other monuments in and around town that appeared to have been located at or below sea level in ancient times. They also thought it unlikely that the massive buildings had subsided so much and that such a momentous

[15] Eustachio Manfredi, "Sopra l'alzarsi che fa di continuo la superficie del Mare," in *Nuova raccolta d'autori, che trattano del moto delle acque*, ed. Giambattista Beccaria, Vol. 6 (Parma: Filippo Carmignani, 1768), pp. 195–212.

event had occurred so smoothly as not to affect the level of the surrounding streets in any way. Manfredi conjectured that sea rise was a product of rivers washing the sediments from land erosion into the Adriatic Sea.

At the time, however, the idea that the sea could rise was widely discredited. The most common theory about the relative position of sea and land was, in fact, that the level of the sea was falling.[16] The Swedish polymath Anders Celsius—better known for his temperature scale—intrigued by the many reported cases in which port towns along the coasts of the Baltic Sea had physically to be relocated closer to the sea, was the first to calculate a long-term rate of sea-level change in the Baltic. To do so he recorded the level of the water by having signs drawn on rocks; he then compared them with data he extracted from archival sources about seal hunting. Using the insight that the tops of so-called seal rocks scattered along the Baltic coast could only be reached by seals when they were close to the level of the sea, Celsius was able to create workable, if crude, historical series of the variations in the level of the water, highlighting the apparent lowering of the level of the Baltic Sea (see Figure 4).[17] Soon these local observations were transformed into assumptions about a global trend: limited knowledge about local environmental conditions gave shape to what became a universal theory.

Building on Celsius's example and driven by the desire to establish a way to measure future changes in the level of the sea, in April 1756 the mathematician Andreas Wykström engraved a permanent marker on the northernmost rock of the island of Kallo, just off Kalmar in southern Sweden. To establish the measurement he had set up a simple gauge and performed daily observations over the course of two years. He was able thus to calculate a rough mean level of the sea, the first ever based on instrumental data, almost a century before it became a common practice thanks to technical developments in the way data were gathered.[18]

FROM SILT TO COSMOS

Manfredi, however, believed that the distance between the sea and former ports had increased because the sediment washed into the sea by the world's rivers had cumulatively extended the landmasses. He claimed that, assuming a stable amount of water on Earth, the steady reduction in the sea's surface would necessarily cause sea level to rise. In an attempt at the experimental method, Manfredi also measured the amount of soil suspended in the waters of the local river Reno and made a rough estimate of the trend of sea rise. He came to the conclusion that, at a bare minimum, the level had risen about 16 centimeters in 348 years. Not being able to define the rate of the rise further, he complained that it would have been nice if the ancients had left clear markers of the level of the sea throughout history. Nonetheless, using the wharf of the Doge's Palace in Venice as a makeshift marker—at Zendrini's suggestion—he was able to estimate that the overall rise had probably been about 40 centimeters in 230 years and more than 2 meters since the basilica in Ravenna had been built.

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[16] An in-depth account of this theory is provided by Martin J. S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: Univ. Chicago Press, 2005), pp. 172–180.

[17] Anders Celsius, "Anmärkning om vatnets förminskande så i Östersjön som Vesterhafvet," *Kongliga Swenska Wetenskaps Academiens Handlingar*, 1743, *4*:33–50. See also Franz Xaver von Zach, ed., "Ueber Abnahme des Baltischen und Zunahme des Adriatischen Meeres," *Monatliche Correspondenz zur Beförderung der Erd- und Himmelskunde*, 1806, *13*:202–209, esp. pp. 204–205. For a detailed account of Celsius's sea-level measurements see also Martin Ekman, "An Investigation of Celsius' Pioneering Determination of the Fennoscandian Land Uplift Rate, and of His Mean Sea Level Mark" (Small Publications in Historical Geophysics, 25) (Åland Islands: Summer Institute for Historical Geophysics, 2013).

[18] Nicolas Desmarest, "Ferner: Précis de la discussion qui a eu lieu entre les savans de Suède & d'Italie, sur la diminution des eaux de la mer & ses progrès," in *Encyclopédie méthodique: Géographie-physique* (Paris: H. Agasse, 1795), p. 145; and Nils Bruncrona, "Beobachtungen und Angaben über die Verminderung des Wassers an der Schwedischen Küste," *Annalen der Physik und Chemie*, 1824, 2:308–328, esp. p. 322.

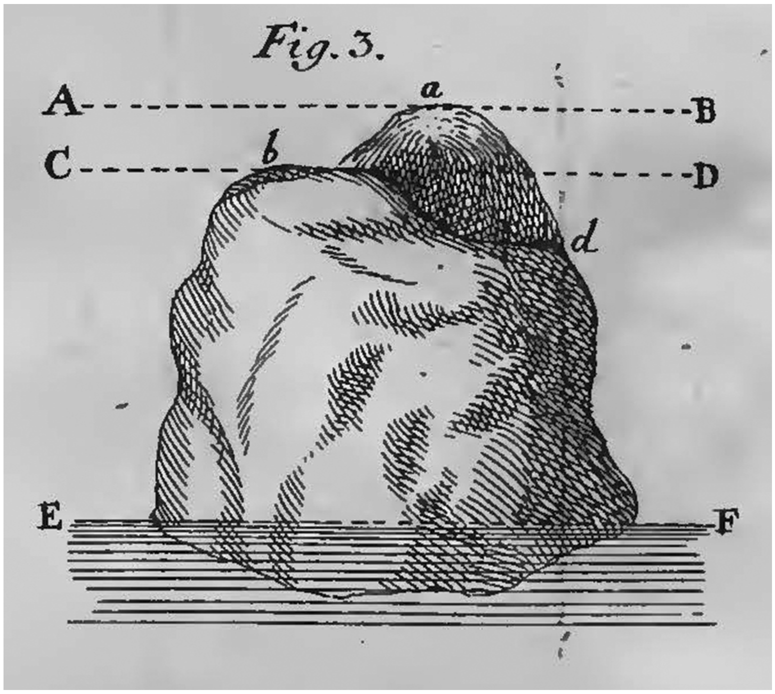

Figure 4. Illustration of a seal rock used by Celsius to determine the relative change of sea level in the Baltic Sea. From Anders Celsius, "Anmärkning om vatnets förminskande så i Östersjön som Vesterhafvet," *Kongliga Swenska Wetenskaps Academiens Handlingar*, 1743, *4*:33–50. Public domain.

A similar logic was followed, at about the same time, by the Dutch scholar Nicolaas Hartsoeker. The idea that the sea was constantly rising appeared to be commonplace in the Netherlands, where the continuous need to heighten and repair the country's many dams and dikes seemed to provide continuous proof of it. By measuring the amount of dirt suspended in the Rhine, Hartsoeker estimated that the level of the sea rose by about 30 centimeters every century and predicted that within ten thousand years all the fertile land would have been eroded and the sea would have covered most of the planet, with the exception of a few barren peaks.[19]

Notwithstanding the international scholarly network linking the practical experiences of the Venetians and the Dutch with rising water in muddy coastal regions, the idea that the overall level of the sea was decreasing remained the most recognizable product of this eighteenth-century debate, memorialized by the French diplomat and natural historian Bênoit de Maillet's take on Neptunism.[20] In his controversial posthumous work *Telliamed* de Maillet theorized that the whole planetary geomorphological process was, in fact, produced by the constant diminution of the seas'

[19] Nicolaas Hartsoeker, *Cours de physique, accompagné de plusieurs pièces concernant la physique qui ont déja paru, et d'un extrait critique des lettres de M. Leervenhoek, par feu M. Hartsoeker [Eloge de Hartsoeker par Fontenelle]* (Den Haag: Jean Swart, 1730), pp. 317–318.

[20] On the dominance, well into the nineteenth century, of geological theories claiming that the primordial Earth was covered with water (here, for the sake of brevity, referred to as Neptunism) see Rachel Laudan, *From Mineralogy to Geology: The Foundations of a Science, 1650–1830* (Chicago: Univ. Chicago Press, 1987), pp. 87–94.

waters, which had once covered the whole planet but whose decrease was destined to leave the Earth barren and dry. This prospect was apparently attractive to some: the idea that someday you could walk from Calais to Dover appealed to at least one of de Maillet's readers.[21]

Since the Dutch and Italian calculations showed a regular increase in sea levels, thus contradicting the diminution theory, proposals were soon made to explain how the decrease of the Baltic and the rise of the Adriatic could occur at the same time. The renowned natural historian Georges-Louis Leclerc, Comte de Buffon, while endorsing the idea that the sea was diminishing on a global scale, also registered in his writings a number of cases in which the level of the sea had apparently risen because of peculiar local conditions. As an example of the latter he mentions the oceanic expanses around the southern tip of India: for Calicut, Ceylon, and the Maldives he reported accounts that all had experienced a significant sea rise. The Baltic itself, he claimed, had risen along its southern shores while diminishing along the coast of Sweden.[22]

Johan Browallius, Bishop of Åbo/Turku, was one of the most severe critics of Celsius's theory of the diminution of the sea. Pointing to a multiplicity of examples, he too claimed that along each coast the sea varied in different ways, rising here and decreasing there while remaining altogether stable elsewhere. All changes, he claimed, were relative to each other, just like the tides: what was gained in one place had to be lost somewhere else. As an explanation for this variety, the Italian physicist Paolo Frisi and others suggested that because of the centrifugal force caused by Earth's rotation the global sea tends to grow toward the equator, its level decreasing over time closer to the poles and rising the more you move away from them.[23] The Venetian historian Giacomo Filiasi, highlighting the impact of local conditions on the measurability of general trends, wrote that the rise of the Adriatic was not in opposition to the general decrease of the worlds' seas: "general effects always vary in some place and time for particular, or local, causes. . . . Nature does not know our measures and our mathematical calculations."[24]

A STABLE SEA

The idea that the level of the sea might be much more stable than that of the continents was first proposed, as a way to overcome the many contradictions of the scientific debate about relative sea changes, at the dawn of the nineteenth century by John Playfair. A few decades later Charles Lyell bolstered the idea that it was time to overturn the standard model: building on the work of the German geologist Leopold von Buch, he asserted that the relative changes in the level of land and sea in the Baltic could more appropriately be explained by movements of the land rather than

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[21] Bênoit de Maillet, *Telliamed, ou entretiens d'un philosophe indien avec un missionaire françois sur la diminution de la Mer, la formation de la Terre, l'origine de l'Homme, &c.*, ed. Jean-Antoine Guer (Amsterdam: L'Honoré & Fils, 1748). See also Rhoda Rappaport, *When Geologists Were Historians, 1665–1750* (Ithaca, N.Y.: Cornell Univ. Press, 1997), p. 232.

[22] Georges Buffon, *Oeuvres d'histoire naturelle*, Vol. 1: *Histoire et théorie de la Terre* (1749; rpt., Bern: Nouvelle Société Typographique, 1792), https://www.e-rara.ch/zut/5138380, pp. 242–245.

[23] For Browallius's view see Desmarest, "Ferner: Précis de la discussion qui a eu lieu entre les savans de Suède & d'Italie" (cit. n. 18), p. 145. Frisi's calculations of the level of sea rise at different latitudes are quoted in Zendrini, "Sull'alzamento del livello del mare" (cit. n. 14), pp. 5–6, 28.

[24] Giacomo Filiasi, *Memorie storiche de' Veneti primi e secondi*, Vol. 1 (Venice: Modesto Fenzo, 1796), pp. 400–401 (my translation). For an introduction to the role of place in the history of science see David N. Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago: Univ. Chicago Press, 2003). For an example of the eighteenth-century debate about the viability of absolute generalizations see Marie-Noëlle Bourguet, "Landscape with Numbers: Natural History, Travel, and Instruments in the Late Eighteenth and Early Nineteenth Centuries," in *Instruments, Travel, and Science: Itineraries of Precision from the Seventeenth to the Twentieth Century*, ed. Bourguet, Christian Licoppe, and Heinz Otto Sibum (London: Routledge, 2002), pp. 96–125.

the sea.[25] This explanation, indeed, would not require a search for supporting examples all over the world but could easily accommodate the fact that change in the relative level of land and sea was occurring in exactly the opposite direction in the Adriatic Sea. Further geological research in the course of the nineteenth century would allow explanations of the perceived variations in the relative positioning of land and sea in the Baltic and the Adriatic by means of, respectively, glacial rebound lifting the coasts of Sweden and subsidence slowly sinking the coasts of northeastern Italy. A reliably stable sea thus became the standard theory. This veritable paradigm shift in the way in which the relative movements of land and sea were considered would hugely affect the way in which sea level was conceptualized in the following decades as the reliable standard reference point for all altitude measurements.

Prompted by a search for ways to explain discrepant data about relative sea changes, the eighteenth-century debate discussed in this essay thus led to the abandonment of the idea of long-term variability of sea levels—an idea that would only return almost two centuries later, in response to completely new developments due to anthropogenic climate change. That debate is exemplary of the complexities of any discourse about sea-level rise and of the fact that any human understanding of sea levels is a product of specific historically and culturally determined assumptions. It also highlights the continuity and liveliness of conceptual debates about global change beyond and across traditional periodizations.[26] As spaces of constant transformation, in which movement is immediately perceivable but trends can only be seen through measurement and explained historically, littorals offer an ideal case study of how ideas of global change have been construed and discussed throughout human history.

[25] John Playfair, *Illustrations of the Huttonian Theory of the Earth* (Edinburgh: William Creech, 1802), pp. 441–457; Leopold von Buch, *Reise durch Norwegen und Lappland*, 2 vols., Vol. 2 (Berlin: G. C. Nauck, 1810), p. 291; and Charles Lyell, "The Bakerian Lecture: On the Proofs of a Gradual Rising of the Land in Certain Parts of Sweden," *Phil. Trans. Roy. Soc. London*, 1835, *125*:1–38.

[26] For an introduction to this historiographical debate see Alan Mikhail, "Enlightenment Anthropocene," *Eighteenth-Century Studies*, 2016, *49*:211–231, https://doi.org/10.1353/ecs.2016.0002; and Lydia Barnett, *After the Flood: Imagining the Global Environment in Early Modern Europe* (Baltimore: Johns Hopkins Univ. Press, 2019).