Chapter 3
From Planetary Dynamics to Global Trade and Human Genetics: A Big History Narrative

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Abstract Big History is an academic enterprise engaged in combining many different fields within the sciences and humanities to provide a more complete, long time-frame perspective on human history. Such an interdisciplinary approach is particularly useful within education for providing teachers and students an interdisciplinary understanding of the causative processes behind major themes and trends of history. Presented here is a Big History narrative that explores the chains of cause and effect between intrinsic features of planet Earth and the course of global history from the early modern period. It traces the deep connections from the circulation dynamics of the Earth's atmosphere, to the trans-oceanic trade routes established during the Age of Exploration, and the pattern of European colonisation and empire-building in these earliest stages of globalisation that built our modern way of life, and finally to the genetic diversity of populations of people living across the Americas today. Along the way, it will also illustrate the links to seemingly-unrelated topics, such as why many industrial cities developed with an affluent, fashionable west-side contrasting against working-class slums in the East End, and why the Mason-Dixon line separating the Union and Confederate states in the American Civil War and the Great Wall of China both fundamentally follow ecological boundaries.

1 Introduction

Big History (Christian 1991), like astrobiology, is an inherently deeply interdisciplinary field of enquiry. It combines, for example, aspects of astrophysics, planetary sciences, geology, geography, evolutionary biology and anthropology to explore the

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ultra-*longue durée* of human history. It is 'Big' in many senses of the word: encompassing a broad diversity of related topics, operating across huge temporal scales and considering a global perspective, and dealing with profound, fundamental concepts. To consider these diverse factors in historical studies provides a richer and more complete understanding of why the past played out the way it did, and thus account for the state of the world we live in today, and inform us on the challenges and opportunities of the future.

Much of modern education is tightly compartmentalised; the class material prescribed by subject-focussed curricula without a great deal of discussion of common links or over-arching themes between different topics. History lessons are on a Monday, Geography on a Wednesday morning and Biology on Thursday, with minimal cross-fertilisation between departments, textbooks or coursework. This structurally-engendered discretisation of education today does not reflect the true interconnectedness of causative processes in science or history, and is in stark contrast to the wide-ranging interests and activity of the natural philosophers leading the Enlightenment and Scientific Revolution, and indeed to the way that much cutting-edge research is now being conducted in deliberately interdisciplinary teams.

Big History bridges across these divides between academic domains and so embraces a more all-encompassing narrative. Such a joined-up-thinking approach provides essential context and can deliver a much more representative and enriching perspective—an interdisciplinary gestalt—to education for both teachers and students.

What follows here is an example narrative within Big History. It traces the deep connections from the circulation dynamics of the Earth's atmosphere, to the trans-oceanic trade routes established during the Age of Exploration, and the pattern of European colonisation and empire-building in the earliest stages of globalisation that built our modern way of life, to the American Civil War, and finally to the genetic diversity of populations of people living across the Americas today. Along the way, it will also illustrate the links to seemingly-unrelated topics, such as why the Californian coast was so geostrategically critical for hundreds of years, or why many industrial cities developed with an affluent, fashionable west-side contrasting against working-class slums in the East End.

As an example of Big History, this tour therefore combines physics and planetary science, patterns persisting across centuries of early modern history, and human genetics. This account represents a more in-depth exploration and extension beyond the material covered in a chapter of the book *'ORIGINS: How the Earth Shaped Human History'* (Dartnell 2019). *ORIGINS* explores how different features of the planet we live on—from plate tectonics to the underlying geology and past climate change—have deeply affected the trends and themes of world history, and still influence current affairs and politics today. This is not to claim that human factors have not of course been crucial in our history, but to show that beneath these proximate drivers of human agency and cultural, social, economic and political factors there lay deeper strata of cause and effect that relate to planetary processes. All of the educational resources created alongside the published book are available at www.teachers.originsbook.com.

2 The Age of Exploration and Early Globalisation

The Age of Exploration, or the Age of Discovery, in European history (and the age of invasion and colonisation from the perspective of much of the rest of the world), began in the early fifteenth century. Navigators from the Iberian peninsula—the kingdoms that would become Portugal and Spain—ventured beyond the Mediterranean to discover the archipelagos of Madeira and the Azores, which served as stepping stones drawing sailors further out into the Atlantic ocean, and the coast of West Africa. Portuguese sailors were initially motivated by the search for the source of the gold being brought north across the Sahara by camel, and later in a determined effort to find the southern tip of Africa and thus a sea route to India and the riches of the spice trade.

After spending the best part of the century sending successive exploration missions progressively further down the western coastline of Africa, the Portuguese finally succeeded, with Vasco de Gama's 1497 expedition, in rounding the continent's southern tip and crossed the Indian Ocean, demonstrating the gateway for a maritime route between Europe and Asia. Christopher Columbus had in 1492 attempted to pioneer a western route to the Orient, but instead encountered the Americas and opened up a whole New World for exploitation by European powers. Where the Portuguese and Spanish had led the way, the Dutch, English and French were soon to follow, pursuing their own overseas ambitions in mercantilism, colonialism, and empire-building.

Within a generation, European sailors ventured across all the world's oceans and completed the first circumnavigation of the Earth. The trade routes they established spanned vast distances of ocean and knitted together the continents in a way that had previously never been seen—a revolution that heralded the birth of today's globalised economy.

All of this was made possible because mariners had begun to understand the global pattern of prevailing winds and ocean currents around the world, and how to link them together to plot reliable return routes across the seas (Paine 2013).

3 The Global Wind Machine

In simple terms, the global pattern of winds works like this. Sunlight warms the surface of the Earth around the equator, heating the low-lying air and evaporating a lot of water. This warm air rises and cools as it reaches higher altitudes. The moisture it holds condenses into clouds and falls as rain. This is why the tropical zone astride the equator is characterised by dense rainforests. At high altitude, the risen air mass diverges and splits to the north and south. Each of these arms travels around 3000 km before sinking back towards the ground again, at around 30° latitude—roughly one-third of the way between the equator and poles. Thus this solar-driven convection current creates two bands of 'subtropical highs' around 30° in the northern and southern hemispheres with the descending air, and leaves behind a region of low air pressure wrapped around the equator. The air descending back to the surface from high altitude is very dry, and cloudless, and so these two bands of subtropical highs are the major cause of deserts around the Earth: the Sahara, Arabian and Syrian deserts, and Mojave and Sonoran deserts in the northern hemisphere, and the Atacama, Kalahari and Australian desert in the southern hemisphere.

To complete this great convection current, the air must return to the equator from the subtropical highs at 30° north and south along the Earth's surface: what we know as winds. Thus, situated on either side of the equator are two immense atmospheric convection systems—the Hadley cells—like tubes wrapped around the planet, and rolling in opposite directions (Hadley 1735; Webster 2004).

The only other important factor for understanding the global pattern of winds is that while the atmosphere is undergoing this great vertical circulation, the entire planet is rotating. Because the Earth is a solid sphere, this means that the surface at the equator is moving faster than that at higher latitudes. So as the air returns from the subtropical highs towards the equator the ground beneath turns eastwards faster and faster. In essence, the winds blowing towards the equator get left behind by the rotating surface with the result that they are effectively deflected in a smoothly curving path towards the west. This is known as the Coriolis effect, and it influences anything moving over the surface of a rotating sphere.

Figure 3.1 shows the circulation systems in the planet's atmosphere on either side of the equator that create the global pattern of alternating bands of easterly and westerly winds blowing across the Earth's surface.

3.1 Trade Winds, Westerlies, and the Doldrums

Winds blowing in the Northern Hemisphere are deflected by the Coriolis effect to their right, and those in the Southern to their left. Thus between the latitude of 30° north and the equator the prevailing winds follow a curved path towards the south-west, and so by the nomenclature for winds are called northeasterlies. And the same is true in the Southern Hemisphere: the air returning north along the surface to the equator is again deflected towards the west to produce prevailing southeasterly winds. These easterlies are known as the trade winds, and as reliable winds blowing through the tropics they have been absolutely crucial for mariners. Thus, the zone of prevailing trade winds either side of the equator has the same underlying cause as the bands of tropical rainforests and subtropic deserts around the planet: the Hadley cells of atmospheric circulation.

The band where the returning northeasterly and southeasterly trade winds meet each other around the equator is termed the Intertropical Convergence Zone (ITCZ) by modern atmospheric scientists. But sailors know this region of the sea by a different name: the doldrums. This region of low-pressure air, characterised by light winds or periods of dead calm, can prove disastrous for ships as they wait for the winds to pick up again or an ocean current to carry them out. A ship could be

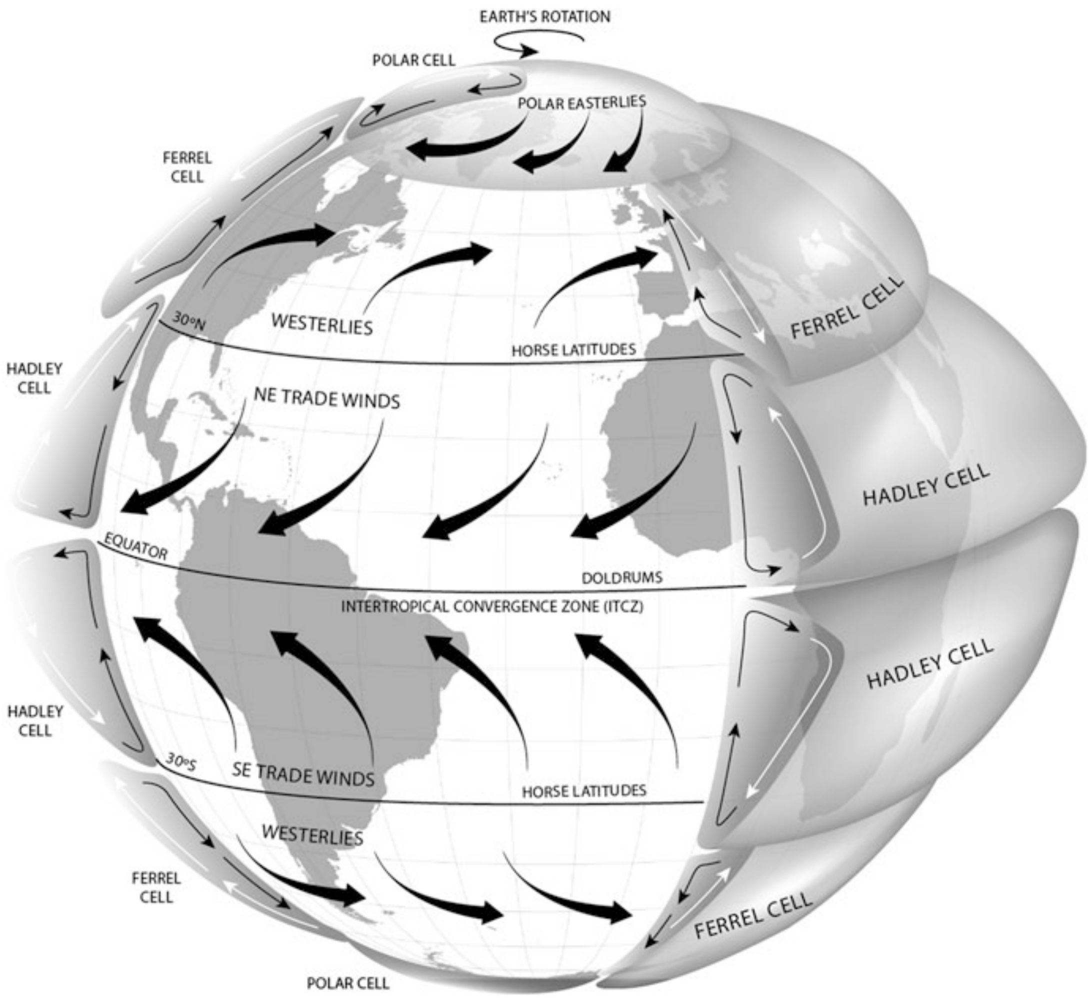

Fig. 3.1 The grand circulation currents in the Earth's atmosphere that create the global pattern of alternating bands of prevailing winds. (Figure designed by the author and drawn for *ORIGINS* by Matthew Broughton, based on Lutgens and Tarbuck 2000, and Wells 2012)

stuck becalmed in the doldrums for weeks, and in this equatorial region of hot and muggy climate it may mean not only a delay in delivering your cargo back to port but it can also spell death as onboard supplies of fresh water run out. The location of the ITCZ is determined by rising air warmed by the sun, and so it shifts north and south with the seasons. Furthermore, because land warms up more quickly than the ocean in summer, the ITCZ band is pulled further away from the equator by the continents. It therefore follows a decidedly sinuous, snakelike path around the waistline of the world. This makes the exact location and width of the ITCZ hard to predict, and increases the risk of sailors getting caught out in the doldrums.

Another pair of great convection cells in Earth's atmosphere are located beyond the Hadley cells, closer to the poles. At around 60° north and south the surface air, although cooler than at the equator, is still warm enough to rise into the atmosphere and drive another convection loop. Similarly with the Hadley cells, the surface winds blowing back towards the equator at the bottom of this loop are deflected to their right by the Coriolis effect, producing the band of winds called polar easterlies.

The third and final pair of grand circulation currents in the Earth's atmosphere are the two Ferrel cells, operating in the middle latitudes between 30° and 60°. Unlike the two already described, however, this Ferrel system is passive: it's not directly driven by its own rising warm air, but by the rolling of the Hadley and Polar cells it nestles between. It's analogous to a freewheeling gear being forced round by two powered cogs turning on either side of it. The descending arms of both the Ferrel and Hadley cells merge at around 30° north and south, forming two subtropical ridges of high pressure known as the 'horse latitudes'. These regions are also characterised by light, variable winds or calm conditions; and so, like the doldrums, sailors learned to be wary of them.

A crucial factor that enables long-range maritime trade routes—oceanic return-trips between the continents—is that because the Ferrel cell is driven by the Hadley and Polar cells on either side it turns in the opposite direction. The surface winds of the Ferrel cells blow not towards the equator but to the poles, and therefore the Coriolis effect deflects them in the opposite direction. The Ferrel cell provides a zone of westerly winds. Thus, the system of global atmospheric circulation provides two different latitude bands of surface winds blowing to the west—the trade winds of the Hadley cell and the polar easterlies—but if you want to sail back east again you can only do that within the realms of the two Ferrel cells and the westerly surface winds they produce. For example, Christopher Columbus complete his trans-Atlantic round-trip by following the trade winds from the Canary islands to landfall in the Bahamas 5 weeks later. To complete the return voyage he first needed to sail further north to encounter the band of westerlies that bore him back towards Europe.

3.2 Ocean Gyres and Currents

This system of alternating bands of winds between the equator and the poles also drives the grand patterns of surface currents in the world's oceans. These ocean currents have also been crucial for the establishment of global trade—because water is so much denser than air, even a gentle current can have a much greater effect on a sailing ship than the wind. The neighbouring zones of the easterly trade winds and the westerlies blow the surface water in opposite directions. This, coupled with the fact that the continents block the water from simply circling the world, and that water moving north or south across the globe also feels the Coriolis effect, creates great wheeling surface currents known as ocean gyres. There are five major gyres, in the North and South Atlantic, North and South Pacific, and in the Indian Ocean. These ocean gyres turn clockwise in the northern hemisphere, and anticlockwise in the southern, and like the direction of the wind bands they mirror each other over the equator.

The Canary Current coursing along the North African coast is the eastern arm of the North Atlantic gyre, and was well known to Phoenician and later Iberian sailors. The Gulf Stream, bearing warm waters from the Caribbean up to Northern Europe, forms the western arm of the same gyre. The Gulf Stream was discovered in 1513 when Spanish explorers sailing south along the coast of Florida realised they were being pushed backwards despite sailing with a strong wind. The commercial implications were immediately realised: heavily-laden galleons needed only slip into this wide, fast-flowing river within the ocean to be readily carried north and then round with the westerly winds back home (Winchester 2011). The Brazil Current, running along the east coast of South America, is the mirror-image counterpart of the Gulf Stream and carries ships south into the zone of the westerly winds which they then pick up for rounding Africa into the Indian Ocean.

The picture overall, therefore, is that in each hemisphere the atmosphere enveloping the planet is divided into three great circulation cells, like giant tubes wrapped around the world, each rolling in place and shifting north and south slightly with the seasons. These produce the major wind zones of the planet—easterly trade winds, westerlies and polar easterlies—which in turn drive the circulating ocean currents. The dominant pattern of winds around the Earth can therefore be explained with just three simple facts: the equator is hotter than the poles, warm air rises, and the world spins. (The seasonally-reversing system of monsoon winds is regionally important for the Indian ocean and south-east Asian archipelagos, but will not be discussed in greater depth here).

We are normally oblivious to this invisible churning of the planet's atmosphere high above our heads, but it can be discerned in a global view of the world. Fig. 3.2a shows an averaged view of the Earth (Kröger 2018) created from VIIRS weather satellite imaging data by taking the per-pixel median over the whole year of 2018. Snow and ice shows up clearly along mountain ranges like the Alps, Andes and Himalayas, as well as Siberia and Canada. Of most interest here are the regions of persistent cloud made starkly visible by this annual average. The relatively narrow equatorial band of rising air within the ICTZ is conspicuous across the Pacific and Atlantic oceans, as are the more nebulous cloudy regions over the Amazonian, central African and Indonesian rainforests. The trade winds are rendered visible as they blow this rainforest moisture off the western coasts. This is the rising arms of the Hadley convection cells made apparent by condensing water vapour in this averaged Earth view. Just as notable are the two bands where the planet's surface is clear, the manifest absence of clouds over the Sahara, Arabian, Kalahari and Australian deserts—marking the dry, descending arms of the Hadley cells around 30° north and south.

Another dataset makes clear how these systems of atmospheric circulation can be exploited by sailing ships taking defined routes between the bands of prevailing surface winds. We'll return in Sect. 4 to how these transoceanic trade routes were developed over the sixteenth and seventeenth centuries, but Fig. 3.2b shows a global picture for the early nineteenth century before steamships became dominant (Schmidt 2018). Each of the 950,000 points on this map represents the latitude and longitude coordinates of ships recorded in their logs, over the period 1784–1863. These numerous ships' logs entries, including wind, current and weather observations, were compiled by Captain Matthew F. Maury in the latter half of the nineteenth century, this collection then copied to microfilm in 1981, and digitised in the '90s as Deck 701 of the International Comprehensive Ocean-Atmosphere Data Set

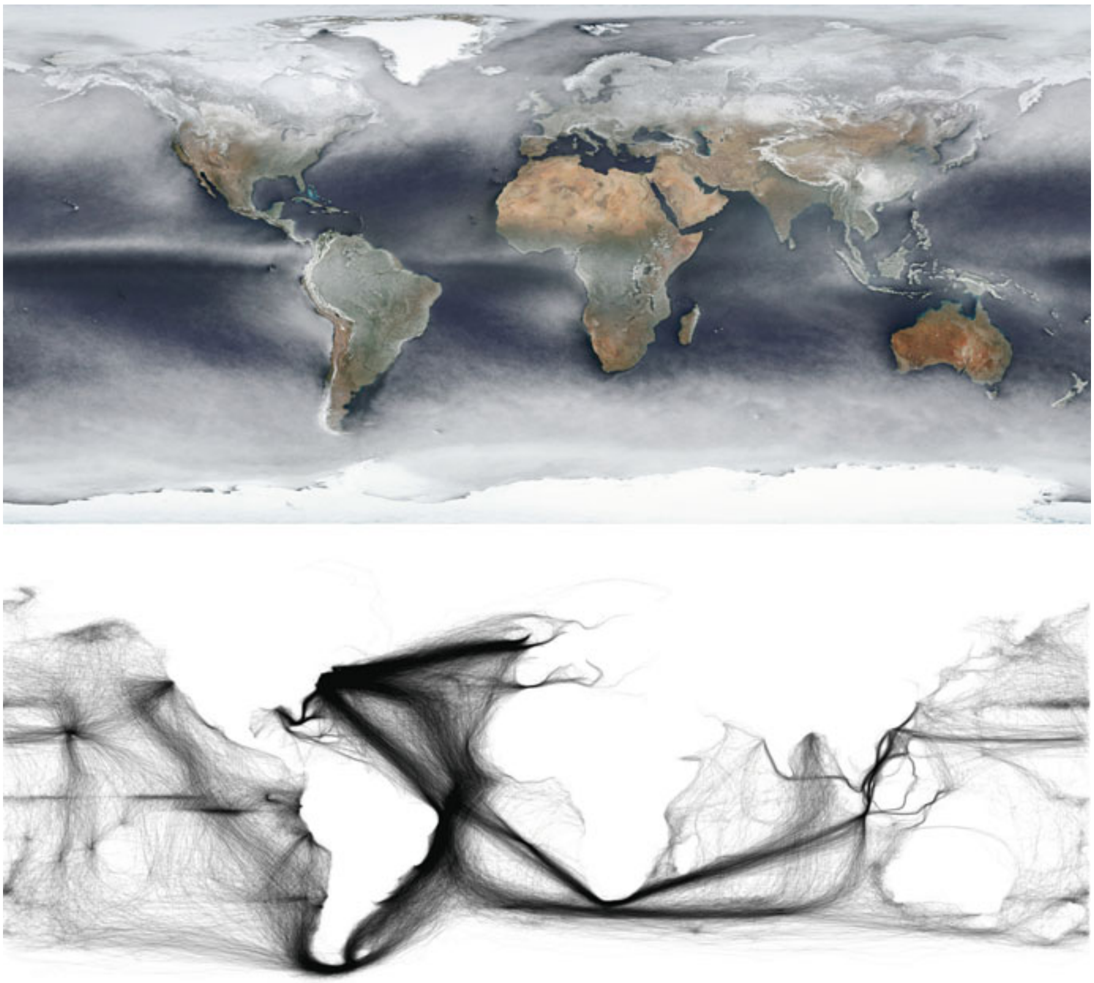

Fig. 3.2 (Top) The 'Average Earth' generated from a full year of satellite imagery. Persistent clouds along the equator, or their absence within the desert latitudes of 30° north and south, make visible the grand circulation currents within the Earth's atmosphere. (Bottom) Maritime trade routes during the Age of Sail as revealed by ships' positions recorded in captains' logs. ('Average Earth' created by Kröger 2018, using VIIRS weather satellite imaging data. Ships' logs map created by Schmidt 2018. Both reproduced with permission)

(ICOADS). This dataset is of US shipping (and so there is bias in the geographic spread of this dataset), but it nonetheless provides a clear demonstration of how the dense tracks of many ships reveal the global pattern of winds.

The outline of the continents are discernible in Fig. 3.2b from coastal shipping, and major ports like New Orleans, Portland, Callao, Liverpool, and Hong Kong are readily identifiable, as is the activity of whaling ships off the Alaskan coast. This plot clearly reveals the bustling route across the North Atlantic with the westerly winds, as well as ships heading down the West African coastline with the Canary current, or rounding Cape Horn between the Atlantic and Pacific (the Panama canal was not opened until 1914). The passage east to India can be seen taking a wide loop around the South Atlantic gyre, past Cape Town and then along the Brouwer route riding the Roaring Forties across the Indian Ocean; with the westward return route taking a much more northerly course with the trade winds. Traffic across the Indian ocean is funnelled through either the Sunda Strait between Java and Sumatra, or the Strait of Malacca to the north-west—the gateways into the East Indies and thus geostrategically critical chokepoints. Hawaii stands out in the mid-Pacific like a magnet governing field-lines of iron filings: shipping crossing to Japan and China with the trade winds, and returning again along a more northerly tract within the band of westerlies.

Also apparent are horizontal streaks running across the equatorial Pacific. Curiously, they don't seem to correspond to any particular port, island, or shipping route. In fact, these are the doldrums made visible—a trap for sailing ships, with the captains' logs recording many days spent becalmed in the unreliable winds of the ITCZ. The less prominent horizontal line much further south, off the western coast of Chile, relates to the Juan Fernández islands. This archipelago was a popular stop for British and American whaling ships (and incidentally was where Alexander Selkirk became marooned in 1704—the inspiration for Robinson Crusoe) after rounding Cape Horn. Even with chronometers for determining longitude, however, the islands were often difficult to find and so captains navigated to the correct latitude (easily calculated by sextant) and sailed along that parallel until they encountered the archipelago.

3.3 Prevailing Winds and Eastenders

Another enduring outcome of these wide bands of prevailing winds has been a clear east-west dichotomy in the development of cities across Britain and Northern Europe. For example, since the eighteenth century the disparity between the west and east halves of London has grown, with areas like Mayfair, Belgravia and Fitzrovia in the West developing as affluent, desirable places to live, characterised by spacious townhouses built around green squares, in stark contrast to the working-class slums of tenements and narrow streets in the East End of the city (Joyce 2003).

Northern Europe, which spearheaded the process of industrialisation, use of coal for domestic heating, and dense urbanisation, lies within the Ferrel cell of atmospheric circulation—the band of westerly prevailing winds—and so all of the smoke from factory stacks and household chimneys (and prior to the construction of underground sewer systems, the stench of effluence in the river as well) blew downwind towards the east. Those who could afford to do so lived in the west of the city and the working classes were left in the more polluted East End.

This argument linking the latitude and prevailing winds to social partitioning in industrialising cities may be slightly confounded in the case of London because the Thames also flows eastwards and thus the docklands and its workforce were located downstream where the river is wider. But this east-west pattern has been found in many other cities too. Heblich et al. (2016), for example, plotted the locations of industrial chimneys in 70 industrial English cities in 1880 and used an atmospheric dispersal model to map the spread of air pollution. They found that not only did the wind-blown pollution from smokestacks explain the deprivation of different neighbourhoods through the nineteenth century, but that these urban disparities persist today even though the smoke pollution has waned.

4 Transoceanic Trade Routes

The grand circulation cells in Earth's atmosphere and the bands of prevailing winds they generate were also critical to centuries of global development through the Age of Sail. As European navigators decoded the secrets of the planet's wind patterns and ocean currents they reached across the great expanses of the world's oceans, linked formerly unconnected regions of the planet, and began the process of globalisation (Paine 2013). The Age of Exploration was therefore not just a process of filling in the world map with strange new lands, but also of discovering invisible geographies. European sailors learned how to use the alternating bands of planetary winds and wheeling ocean currents like a great interlinked system of conveyor belts, to carry them where they wanted to go.

With their large, cannon-wielding ships and experience of building strong fortifications born of centuries of incessant warfare in Europe, the Portuguese rapidly asserted their dominance across the Indian Ocean and south-east Asian archipelagos. By 1520, the income from Portugal's control of the spice trade provided nearly 40% of the Crown's total revenue (Brotton 2013). Portugal had created a new kind of empire, made powerful and wealthy not through possession of large areas of territory but by the strategic control of sprawling oceanic trade networks on the other side of the world—an empire of water. The Spanish conquered the civilisations they encountered in the Americas and likewise grew rich on this plunder. The New World, and the new maritime routes to India and the Orient, offered Europeans access to a seemingly inexhaustible trove of territory and resources, wealth and power. And where the Spanish and Portuguese had led the way, the Dutch, British and French followed. The rivalry between these marine trading powers triggered colonial wars around the world as they attempted to eject each other from strategic ports and forts, and control chokepoints to dominate the critical sea passages.

The early exploration ships were slender-hulled and rigged for the greatest manoeuvrability around unknown coastlines, and in particular for beating into the wind. But these small caravels with triangular 'lateen' sails required large numbers of expert crew and had little stowage space for cargo alongside the necessary provisions. The ideal design for transoceanic trade, on the other hand, is a broad ship rigged with large square sails, which is much simpler to handle and so minimises the crew size whilst maximising the hold space for supplies and profit-making cargo. These square-rigged ships, exemplified by the Spanish galleons, catch a great deal of motive force but can only ever ride with the wind: beating against the breeze is virtually impossible (Rodger 2012). This meant that in contrast to the early years of exploration, the trade routes that came to establish the European imperial presences overseas were strongly dictated by the direction of the prevailing winds,

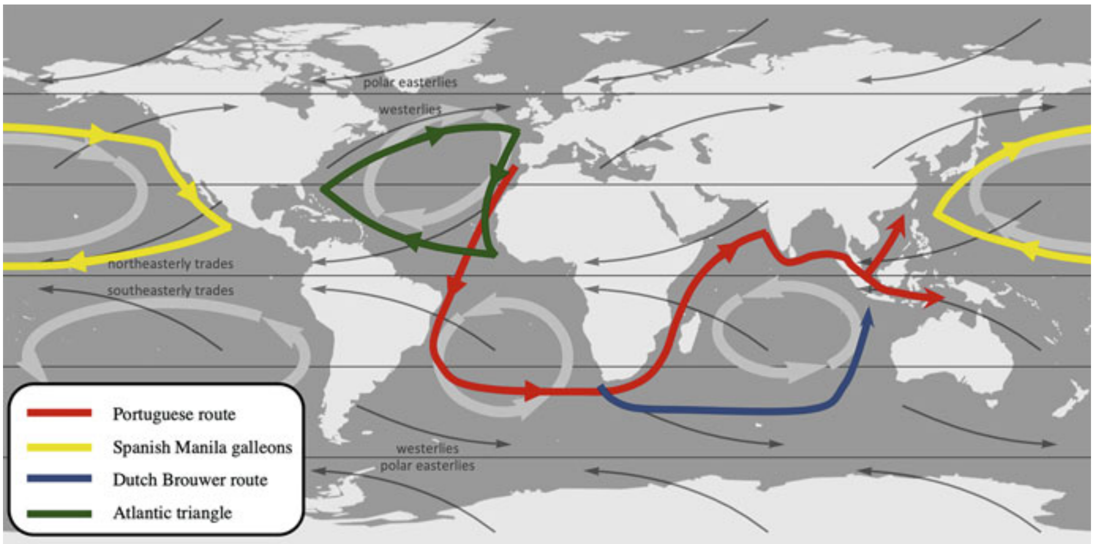

Fig. 3.3 The major European oceanic trade routes during the Age of Sail, navigating between different bands of prevailing winds and currents of the ocean gyres. (Figure created by the author using information from Jones et al. 2004; Bernstein 2009; Winchester 2011; Wells 2012)

and this had profound implications for patterns of colonisation and the subsequent history of our world. The three most important of these were the Manila Galleon Route, the Brouwer Route and the Atlantic Trade Triangle, depicted in Fig. 3.3.

4.1 Manila Galleon Route

While the Portuguese were establishing their trade empire in South East Asia, the Spanish were exploring their possessions in the Americas. By 1513 a Spanish explorer had trekked across the Panama isthmus and became the first European to set eyes on the ocean on the far side: *Mare Pacificum*—the Peaceful Sea (Brotton 2013). The Spanish began looking for their own westward maritime route to the Orient from the Americas. From Central America, ships can follow the trade winds across the Pacific to the Philippines and Spice Islands, or to trade with China. Realising that the pattern of winds in the Pacific replicates that of the Atlantic, Spanish navigators sailed north from the Philippines as far as the coast of Japan before picking up the band of westerlies (in the Ferrel circulation cell of the atmosphere) that carried them back across the Pacific (Bernstein 2009). This discovery enabled the Spanish to bridge the vast Pacific Ocean with regular round-trip shipping, the Manila Galleon Route. This ran between the colonies of New Spain in Acapulco, in present-day Mexico, and Manila in the Philippines for 250 years—from 1565 to 1815, ending with the Mexican War of Independence (Fish 2010).

The main cargo carried west across the Pacific on this route was silver. In the 1540s the Spanish discovered rich silver veins in Mexico, as well as the 'silver mountain' of Potosí high in the Andes (Bernstein 2009; Frankopan 2016; Paine

2013). Most of this silver was sailed up the South American coast on the Humboldt Current (the eastern arm of the South Pacific gyre) to the Panama Isthmus, carried across this narrow land bridge by packs of mules and then loaded onto ships bound for Spain. But about a fifth of the mined American silver was sent across the Pacific aboard Manila Galleons and in the Philippines it was traded for Chinese luxuries: silk, porcelain, incense, musk and spices (Bernstein 2009; Frankopan 2016; Paine 2013).

The westerly winds across the Pacific delivered the galleons to the coast of California, where they needed way stations to be resupplied after this long oceanic crossing and before setting off on the last leg of their journey south down the coast to Mexico. This is why California was so geopolitically significant—it's where the winds deliver you to after crossing the Pacific—and the names of the major cities of San Francisco, Los Angeles and San Diego still recall this Spanish influence today.

4.2 Brouwer Route

The maritime route to India pioneered by the Portuguese involved heading down the West African coastline with the Canary current, crossing the equator, and then using the South Atlantic gyre to carry ships across the band of southeasterly trade winds until they entered the zone of the westerlies. This then carried them past the southern tip of Africa and into the Indian Ocean and the realm of the seasonally-reversing monsoon winds. From the year after da Gama's triumphant return, the Portuguese began sending annual expeditions along this new sea route to India. The very first fleet that followed took such a wide loop through the South Atlantic to meet the necessary westerly winds that they encountered the eastern bulge of South America. Thus the reason that Brazil today speaks Portuguese but the rest of Latin America speaks Spanish is a colonial consequence of the wind patterns (Crowley 2016).

This mid-latitude band of westerly winds is the southern-hemisphere mirror image of the westerlies that the Spanish learnt to ride across the north Pacific from Japan to California on the Manila Galleon Route. The band of westerlies in the southern hemisphere, however, tend to blow far harder than their northern equivalent. After the break-up of the supercontinent Pangea over 200–150 million years ago (Frizon de Lamotte et al. 2015) the vagaries of continental drift have rearranged the Earth's face so that today two-thirds of the landmass—and mountain ranges which disrupt the flow of winds—lies in the northern hemisphere. The southern hemisphere of the planet, however, is dominated by open ocean, free of windbreaks. In particular, below about 40° only the bottom tip of South America and the two islands of New Zealand impede the uninterrupted rush of the westerly winds all the way around the world, and sailors came to call this zone the Roaring Forties. And if they dared to push even further south, risking fierce wind and waves, frigid climate and threat from icebergs, navigators could take advantage of the even stronger Furious Fifties or Shrieking Sixties.

It was a Dutch navigator who pioneered the use of the Roaring Forties as a short-cut from the Portuguese route around the Indian Ocean. In 1611, Captain Henrik Brouwer of the Dutch East India Company passed the Cape of Good Hope and instead of heading north-east towards India he turned south, deeper into the westerlies. These carried him fully 7000 km east before he exited this fast-moving ocean freeway and turned north again towards Indonesia and the spice islands. The Brouwer Route, making use of the Roaring Forties, took less than half the time of the traditional passage—not least because it obviated the need to wait for the monsoon winds in the Indian Ocean.

The development of the new passage had a number of profound historical consequences. It was sailors taking the Brouwer Route who became the first Europeans to sight Australia, spurring further exploration and then colonisation. Furthermore, the Brouwer Route detouring south across the Indian Ocean meant that the Sunda Strait between Java and Sumatra became the crucial gateway into the East Indies, rather than the Strait of Malacca that the Portuguese had controlled. This caused a significant geostrategic shift, and the Dutch founded Batavia—present-day Jakarta—in 1619 as their operational centre in the region and to command this key strait. This zone of strong winds was also the reason behind the founding of Cape Town: the Dutch needed a resupply port for ships before the long final leg of their voyage to the East Indies. The Roaring Forties wind belt is therefore the reason why Afrikaans is spoken today in South Africa.

4.3 Atlantic Trade Triangle

Although it was spices that drove the early years of the Age of Exploration and the global oceanic trade carried by European ships, by the beginning of the eighteenth century new commodities had come to dominate demand. Crops indigenous to Africa and India had been transplanted to the New World and large amounts of coffee were now being produced in Brazil, sugar in the Caribbean, and cotton in North America (Bernstein 2009). The colonists' demand for labour needed to cultivate these commodities for the European markets led to another transcontinental trading system, which has arguably been the most significant for the shape of the world today.

In simple terms, the Atlantic Trade Triangle linked Europe, Africa and the Americas to serve Europe's insatiable hunger for cheap cotton, sugar, coffee and tobacco, at the expense of the inhuman suffering inflicted on the slaves exploited in the process. The Industrial Revolution, begun in Britain but soon spreading through Europe, saw the use of powered machinery to mass-produce wares like fabrics. This in turn drove a surge in demand for the raw materials needed for their manufacture, such as cotton fibres. Cotton is a tropical shrub that can't be grown in the European climate and so provided a large cash crop opportunity for plantations in the Americas. Due to the pattern of global winds, European ships bound for the

Americas must first sail down to the West African coast before they can catch the necessary trade winds for the trans-Atlantic crossing.

Ships sailed from Europe with industrially-manufactured goods such as textiles and weapons down to the western African coast. Here they were traded with local chiefs for slaves they had captured, who were then transported under brutal conditions across the Atlantic (along the 'Middle Passage' with the trade winds) to sell to plantation owners in Brazil, the Caribbean and North America. The capital raised by selling this human cargo was used by the captains to purchase the plant commodities grown on the plantations, the produce of the slaves' labours. These raw materials were then sailed with the westerlies back to Europe for manufacturing, and so completing the loop (Jones et al. 2004). There were variations on the exact routes sailed and the wares transferred at each leg in overlapping circuits, as well as short hops shuttling goods along certain stretches of coastline (Bernstein 2009; Morris 2011), but this was the core of the Atlantic Trade Triangle that operated between the European homelands and their colonial territories from the late sixteenth to the early nineteenth centuries.

The shipping merchants sold their cargo for a profit at each stage of the triangle and so like an economic cog sat across the Atlantic, being blown round and round by atmospheric circulation, the system generated huge financial gains for its masters with each turn, but at an incalculable cost of suffering for the slaves involved. While the European nations began to use waterwheels and then steam engines to power their mills and factories, the enslaved human workforce overseas providing the raw materials was an equally important component of the machinery driving the economics of industrialisation.

5 Transatlantic Slavery and the US Today

The Spanish, and later English and French, slave traders crossed to their colonial possessions in the Caribbean islands and mainland central and north American, whereas Portugal transported captive labour to Brazil. While exact totals will never be known, overall the transatlantic slave trade forcibly transported over ten million people—and possibly as many as 12.5 million—from their homes in Africa to labour on plantations and mines in the Americas. The Transatlantic Slave Trade Database, hosted by Emory University (www.slavevoyages.org), reports data covering the years 1510–1870 of 9.98 million slaves embarked in African ports and 8.68 million arriving in the Americas. The discrepancy between these numbers itself exposes the abhorrent reality of this transatlantic trafficking of human life: over 1.3 million people died in transit under barbaric conditions aboard the slaver ships.

5.1 Atmospheric Dynamics and Transport Routes

Of the ~10 million total slave embarkations tracked on the Transatlantic Slave Trade Database, 3.5 million were shipped to Brazil, 5.1 million were transported to the Caribbean islands (over a million were taken to labour on the sugar plantations of Jamaica alone), and half a million to Spanish central America. Slaves transported to the North American mainland—what would become the US—represented only about 3.5% of the total trans-Atlantic trade.

There was also great variance in the regions of Africa that suffered most severely from their population being captured and sold to slavers. Before being loaded onto ships for the transatlantic crossing, African slaves were held in coastal forts, known as factories. These had mostly been established at the mouth of rivers as this offered the easiest way for moving captives from further inland. Over the duration of the transatlantic slave trade, most captives came from West Central Africa around the Congo river, with many also taken from Senegambia—the area between the Senegal and Gambia Rivers—and also the coastline around the Gulf of Guinea: the Bight of Biafra, Bight of Benin, and the Gold Coast. Figure 3.4a displays a schematic of the major transatlantic slave routes, with the ethnic group regions of Africa colour-coded for the number of slave exports (Nunn and Wantchekon 2011).

Although slaves captured in Africa could end up being trafficked anywhere in the Americas, there were nonetheless strong connections between the embarkation point and destination. Figure 3.4b plots data extracted from the Transatlantic Slave Trade Database to show where slaves arriving in Brazil, the Caribbean islands, and the North American mainland, had originally embarked in Africa. The majority of slaves sent to Brazil were from West Central Africa (57%), with a notable fraction from Southeast Africa (8%) that had been sailed around the Cape of Good Hope and across the South Atlantic, but only a minor input from Senegambia (3%). The Caribbean islands and mainland North America, on the other hand, both received about a fifth of their slaves from West Central Africa, but most of the slave labour arriving on the plantations of the North American mainland (24%) had set sail from Sierra Leone and Senegambia.

Whilst steamships or modern freighters can steer the most direct course to their target port, sailing ships are highly constrained by the global pattern of winds and the ocean gyres they create, and in particular prefer not to cross the equator and risk being becalmed in the doldrums. For example, the 'direct' distance (the Great Circle geodesic) from Senegambia to Pernambuco, the western tip of Brazil, is 3250 km, and from the mouth of the Congo river to Pernambuco is 5220 km. The Brazilian coast is significantly closer to Senegambia than the Congo, and yet received a much greater proportion of its imported slaves from West Central Africa. From West Central Africa a reliable sailing route follows the southeasterly trade winds and then around the south Atlantic gyre along the Brazilian coast to serve the coffee plantations. Whereas from Senegambia and the coastline of the Guinean Gulf, all situated north of the equator, ships can ride with the northeasterly trade winds and ocean current to the sugar plantations of the Caribbean islands, the cotton plantations

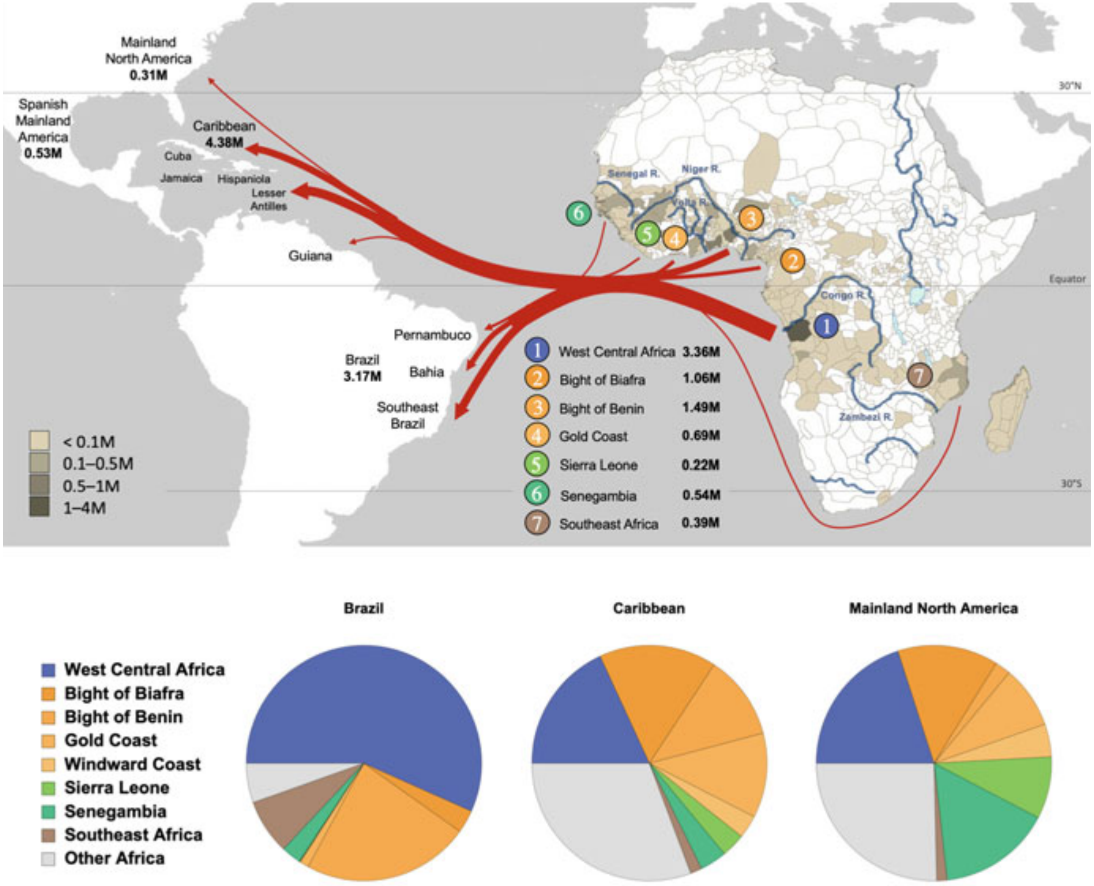

Fig. 3.4 The Transatlantic Slave Trade. (**a**) Top map shows number of millions of people captured into slavery in different regions of Africa (colour-coding). Captives were moved to coastal factories, often along rivers, before being loaded onto ships for the transatlantic crossing (red arrows). Numbers in millions disembarked at major colonial destinations in the Americas also shown. (**b**) Bottom diagram shows the pattern of winds and currents for the transatlantic passage created strong associations between particular loading and disembarkation locations. Pie charts show where slaves arriving in Brazil, the Caribbean islands, and the North American mainland where originally embarked in Africa. (Figure created by the author using data extracted from The Transatlantic Slave Trade Database, publicly-available river data, and overlaid with colour-coded Africa map from Nunn and Wantchekon 2011, reproduced with permission)

of Alabama and Carolina, or further to the tobacco plantations of Virginia. Thus it is environmental causes, ultimately rooted in the circulation dynamics of Earth's atmosphere, that defined two partially distinct slave-trading systems: North America and Brazil (Domingues da Silva 2008).

5.2 *American Civil War*

The Atlantic slave trade was banned by the British in 1807, but smuggling continued to North America until the abolition of slavery after the conclusion of the American

Civil War in 1865. The Mason-Dixon line was originally surveyed in the 1760s to resolve a border dispute between Pennsylvania, Maryland, Delaware, and West Virginia, but later came to denote the division between the Union and Confederate States. The climate of the southern states enabled them to grow cotton and tobacco as cash crops, and thus their economic system became dependent on plantations and slave labour. Whereas the economies of the more northerly, cooler, Yankee states were based on agriculture of staple cereal crops and industrial manufacture. Thus, although the Mason-Dixon line marked the cultural boundary between the southern slave states and northern free states, it ultimately represents an environmental distinction between warmer and cooler climates and modes of agriculture. (Similarly, the Great Wall of China follows an ecological boundary, between wetter latitudes capable of supporting agriculture and thus agrarian civilisation, and the dry steppes to the north suitable only for nomadic pastoralists: 'barbarian' raiders like the Scythians, Xiongnu or Mongols) (Fernandez-Armesto 2002).

5.3 Population Genetics Today

Even after the Confederacy lost the Civil War and slavery was abolished across the southern states, there was no sudden change in the demographics or indeed in the economic focus of this region. The former slaves continued to work on the same cotton plantations, but now they were sharecropping as freedmen. However, the economic fortunes of the Deep South began to slump with falling cotton prices followed by the infestation of the boll weevil in the 1920s. Several million African-Americans migrated from rural areas in the southern states to the major industrial cities of the north- eastern and midwestern United States, especially after the Great Depression of the 1930s.

Since the abolition of slavery, therefore, there has been a lot of population movement within the Americas as well as interbreeding and genetic admixture. Slave traders and owners kept few records, but DNA studies have begun shining light on family ancestry and how this regime of forced migration from different regions of Africa has shaped the genetic structure of modern populations across the Americas.

For example, a recent research programme led by Gouveia et al. (2020) sequenced the genes of over 6000 individuals with African ancestry across the Americas. They found that West African ancestry is the most prevalent in African-Caribbeans and US African-Americans today, whereas African-Americans in south-eastern Brazil show a high degree of ancestry from south/east Africa. This is believed to be due to the fact that after the British abolished the slave trade in 1807 and the Royal Navy closed the slave transport routes in the North Atlantic, Portuguese traders came to rely on slaves captured in southeast Africa for their Brazilian plantations. This south/east African ancestry in modern Brazilians could also be differentiated into two different sources of gene flow through Africa, from the western and eastern Bantu populations. These distinct populations descend from two streams of migrations that expanded out of the Nigeria-Cameroon region over 5000–2000 years ago to cover much of sub-Saharan Africa (Bostoen 2018)—Bantu farmers who displaced the previous hunter-gatherer populations. These DNA markers, therefore, track the ancient expansion of farmers across Africa, and then the forced migration of people to southeast Brazil in the holds of slaver ships (with a much smaller flow going to the Caribbean or North America).

Gouveia et al.'s analysis also indicates that African ancestry has become far more homogeneously distributed in the American gene pool than is found in the native populations in Africa. This greater admixture is due to the fact that plantation owners often deliberately sourced slaves who spoke different language and therefore were from different geographic origins, so as to minimise the risk of organised uprisings—as well as the far greater levels of mobility and intermarrying within America over the last 150 years than across the long stretch of western Africa.

So although the ancestral roots of African-Americans today reveal the signature of both planetary factors (wind patterns favouring particular sailing routes) and historical geopolitical influences (such as the abolition of slavery by the British in 1807 forcing Brazil to rely on slaves brought across the south Atlantic), there has been a much greater degree of subsequent genetic admixture in America than in Africa (Gouveia et al. 2020).

6 Summary

Big History is an academic enterprise committed to combining many different fields within the sciences and humanities to produce a broadly-encompassing, long-term perspective on the human past, present and potential futures. Such an approach holds great promise within education for providing teachers and students an interdisciplinary understanding of the causative processes behind major trends and themes of history.

The Big History narrative offered here explored the chains of cause and effect from the fundamental modes of circulation in Earth's atmosphere, to the long-range maritime trade routes established during the Age of Exploration that harnessed knowledge of the global system of prevailing winds and oceanic currents, to the pattern of European colonisation, exploitation and empire-building in these earliest stages of globalisation that built our modern way of life, and finally to the genetic diversity of populations of people living across the Americas today. The surprising connections were also drawn to seemingly-unrelated topics, such as why many industrial cities developed with an affluent, fashionable west-side contrasting against working-class slums in the East End, and why the Mason-Dixon line separating the Union and Confederate states in the American Civil War and the Great Wall of China both fundamentally follow ecological boundaries.

This has been just one illustrative example, but hopefully serves to demonstrate how fundamental features of the planet have profoundly influenced centuries of modern history and the shaping of the world we live in today.

References

Bernstein, W.L.: A Splendid Exchange: How Trade Shaped the World. Atlantic Books, London (2009)
Bostoen, K.: The Bantu Expansion. Oxford Research Encyclopedia of African History. Oxford University Press, London (2018)
Brotton, J.: A History of the World in Twelve Maps. Penguin, London (2013)
Christian, D.: The case for 'big history'. J. World Hist. **2**, 223–238 (1991)
Crowley, R.: Conquerors: How Portugal Forged the First Global Empire. Faber & Faber, London (2016)
Dartnell, L.R.: ORIGINS: How the Earth Shaped Human History. Bodley Head, London (2019)
Domingues da Silva, D.B.: The Atlantic slave trade to Maranhão, 1680–1846: volume, routes and organisation. Slav. Abolit. **29**(4), 477–501 (2008)
Fernandez-Armesto, F.: Civilizations: Culture, Ambition, and the Transformation of Nature. Free Press, New York (2002)
Fish, S.: The Manila-Acapulco Galleons: The Treasure Ships of the Pacific. AuthorHouse, Bloomington (2010)
Frankopan, P.: The Silk Roads: A New History of the World. Bloomsbury, London (2016)
Frizon de Lamotte, D., Fourdan, B., Leleu, S., Leparmentier, F., de Clarens, P.: Style of rifting and the stages of Pangea breakup. Tectonics **34**, 1009–1029 (2015)
Gouveia, M.H., Borda, V., et al.: Origins, admixture dynamics and homogenization of the African gene pool in the Americas. Mol. Biol. Evol. **37**(6), 1647–1656 (2020)
Hadley, G.: Concerning the cause of the general trade-winds. Philos. Trans. R. Soc. Lond. **39**, 58–62 (1735)
Heblich, S., Trew, A., Yanos, Z.: East Side Story: Historical Pollution and Persistent Neighborhood Sorting. CESifo Working Paper Series No. 6166 (2016)
ICOADS: About the Maury Collection. https://icoads.noaa.gov/e-doc/other/transpec/maury/about.txt
Jones, M., Jones, R., Woods, M.: An Introduction to Political Geography: Space, Place and Politics. Routledge, London (2004)
Joyce, S.: Capital Offenses: Geographies of Class and Crime in Victorian London. University of Virginia Press, Charlottesville (2003)
Kröger, J.: Average Earth from Space 2018. https://hannes.enjoys.it/blog/2019/01/average-earth-from-space-2018 (2018)
Lutgens, F.K., Tarbuck, E.J.: The Atmosphere: An Introduction to Meteorology, 8th edn. Prentice Hall, Upper Saddle River (2000)
Morris, I.: Why the West Rules—for Now: The Patterns of History and What They Reveal About the Future. Profile Books, London (2011)
Nunn, N., Wantchekon, L.: The slave trade and the origins of mistrust in Africa. Am. Econ. Rev. **101**(7), 3221–3252 (2011)
Paine, L.: The Sea and Civilization: A Maritime History of the World. Knopf, New York (2013)
Rodger, N.A.M.: Atlantic seafaring. In: Nicholas, C., Philip, M. (eds.) The Oxford Handbook of the Atlantic World, pp. 1450–1850. Oxford University Press, London (2012)
Schmidt, B.M.: Creating Data [Digital Monograph]. http://creatingdata.us (2018–present)
Webster, P.J.: The elementary Hadley circulation. In: Diaz, H.F., Bradley, R.S. (eds.) The Hadley Circulation: Present, Past and Future, pp. 9–60. Springer, Netherlands, Dordrecht (2004)
Wells, N.C.: The Atmosphere and Ocean: A Physical Introduction, 3rd edn. Wiley, New York (2012)
Winchester, S.: Atlantic: A Vast Ocean of a Million Stories. Harper Press, Manhattan (2011)