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'BIG DATA' AND ALEXANDER VON HUMBOLDT'S APPROACH TO SCIENCE

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ABSTRACT

This article departs from the hypothesis that Alexander von Humboldt used 'Big Data' in order to bring new scientific evidence into the open. His method of measuring and combining temperature, humidity, altitude and magnetism in a geographical environment must be regarded as innovative, indeed, as the foundation of modern science. Although Humboldt lived in an analogue world and used the instruments of his time, his way of assembling information was not so different from what we are seeing in today's digitalised world. Information has no value unless it is shared. It does not say anything unless it is linked with other data. It cannot remain isolated but must be compared and interpreted. The generation of 'Big Data' was a pathway to Humboldt's concept of 'Kosmos' in much the same way as 'Big Data' today is the pathway to a virtual world. In this sense, Humboldt not only laid the foundation of modern science but anticipated the existence of a world where data and information are the source of everything when it comes to understanding the interconnectivity of the physical and the virtual world.

Dieser Beitrag geht von der Hypothese aus, dass Alexander von Humboldt 'Big Data' verwendet hat, um neue wissenschaftliche Erkenntnisse ans Licht zu bringen. Sein Ansatz, Temperatur, Feuchtigkeit, Höhe und Magnetismus in einer geografischen Umgebung zu messen und zu kombinieren, muss als innovativ, ja als Grundlage der modernen Wissenschaft angesehen werden. Obwohl er in einer analogen Welt lebte und die entsprechenden Instrumente benutzte, unterscheidet sich seine Art, Informationen zu sammeln, nicht so sehr von der in der heutigen digitalisierten Welt. Informationen haben keinen Wert, wenn sie nicht geteilt werden, sie sagen nichts aus, wenn sie nicht mit anderen Daten verknüpft sind, sondern müssen interpretiert werden. Die Erzeugung von 'Big Data' durch Alexander von Humboldt war ein Weg zum Konzept eines 'Kosmos', ähnlich wie 'Big Data' heute der Weg zum Konzept einer virtuellen Welt ist. Und doch ergänzen sich beide gegenseitig: der 'Kosmos' von Humboldt und die heutige virtuelle Welt gewinnen immer mehr an Bedeutung. In diesem Sinne hat Alexander von Humboldt nicht nur die Grundlagen der modernen Wissenschaft gelegt, sondern er hat die Existenz einer Welt vorweggenommen, in der Daten und Informationen die Quellen für alles sind, um die Wechselwirkung zwischen der physischen und der virtuellen Welt zu verstehen.

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INTRODUCTION

Alexander von Humboldt (1769–1859) is still a leading figure in science and research today. He became famous through his trip to America (1799–1804), travelling across the regions of South America, the Caribbean, Mexico and the USA which was followed twenty-five years later by a research trip lasting several months to Central Siberia, the Urals and the Altai Mountains. Humboldt was not alone on either of these expeditions. In the American continent he was accompanied by the French botanist Aimé Bonpland (1773–1858) and when in Russia he was joined by the biologist Christian Gottfried Ehrenberg (1795–1876) and the mineralogist Gustav Rose (1798–1873).

What has remained of his efforts above all is his central approach to exploring the world as a whole and its manifold connections. Observation of the interaction of nature and culture made him a pioneer in various directions of research. For this purpose, he wrote down his observations, took measurements and made experiments[1] and, at the same time, collected objects (plants, animals, cultural objects). He regarded his collections and the associated data as a knowledge base and point of reference for the manifold interdependencies within the cosmos.[2] The spectrum of his interest was so broad that he took a holistic approach. However, his holistic method by no means restricted itself to 'hard data' alongside art, history, literature and politics.[3] Rather, he collected everything as resilient material and the more of it he could collect, the better. 'Humboldt science', which was the result of the empirical viewpoint he gained on his trip to the American continent and the basis for his project of a 'new global modernity', would not have been possible without the enormous amount of data he extracted by observation and with the help of a multitude of instruments.[4] For example, Humboldt compared spaces ('Räume') in order to deal with the phenomenon of global interdependencies, and he tried to deal with global interactions with the help of rapidly growing and constantly new data.[5] The following article outlines the kind of data Humboldt was interested in, how he proceeded when collecting data, the technical assistance he used and the conclusions he drew from that data.

[1] Mario Ruiz Morales, *La aventura métrica de Alexander von Humboldt*, Granada 2012, p. 249–50, and Alexander von Humboldt, *Versuche über die gereizte Muskel- und Nervenfaser nebst Vermutungen über den chemischen Process des Lebens in der Thier- und Pflanzenwelt*, Posen and Berlin 1797, p. 2.

[2] Ottmar Ette, *Alexander von Humboldt und die Globalisierung. Das Mobile des Wissens*, Frankfurt a. M. 2009, p. 380.

[3] Andrea Wulf, *The Invention of Nature: Alexander von Humboldt's New World*, New York 2015, p. 335.

[4] Michael Zeuske, 'Humboldteanización del mundo occidental? La importancia del viaje de Humboldt para Europa y América Latina', HiN, IV/6, https://www.uni-potsdam.de/romanistik/hin/hin6/zeuske.htm (accessed 21 November 2019).

[5] Ette, *Alexander von Humboldt und die Globalisierung* (note 2), pp. 116–7.

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Humboldt's interest in data of all kinds stems from his curiosity and the desire to describe the complexity of the interwoven world. He was therefore interested in a broad scientific spectrum. Ottmar Ette[6] lists twenty-nine partly independent scientific disciplines:

•Ancient Studies	•Chemistry	•Social Science	•Literature	•Plant Geography
•Anthropology	•Dendrochronology	•Climatology	•Mathematics	•Linguistics
•Astronomy	•Geography	•Cultural History	•Meteorology	•Star Science
•Archaeology	•Geology	•Art	•Physics	•Volcanology
•Biology	•Geognosy	•Cameralistics	•Philology	•Zoology
•Botany	•History	•Cartography	•Philosophy	

This list shows the wide scope of the data Humboldt was concerned with, ranging from pure numbers (e.g. astronomy, geography, mathematics) to terms (e.g. art, cultural history, philosophy), physical objects (e.g. archaeology, geology, plant geography), pictorial representations (e.g. cartography, climatology, volcanology) and word lists (e.g. anthropology, linguistics, philology). His data and data aggregations can be found everywhere in his work. There are hardly any handwritten records or printed works that are purely descriptive. In most cases his continuous texts are supported or supplemented by tables with numbers or words as well as tableaus, graphics or illustrations (see Figures 1–9). The latter may have increased in the course of his scientific work.

Humboldt thus stored his data (his 'collected experiences' and reliable data) in tables, maps, graphics and with the help of museum objects which he brought back to Europe. This knowledge base was a point of reference for him for the manifold interdependencies in the world: his cosmos or Kosmos as it is spelled in German. But what did these data mean for him and how did he link them to empirically underpin the interwoven world? For:

> [d]ie Vielheit der Erscheinungen des Kosmos in der Einheit des Gedankens, in der Form eines rein rationalen Zusammenhanges zu umfassen, kann, meiner Einsicht nach, bei dem jetzigen Zustande unseres empirischen Wissens nicht erlangt werden. Erfahrungswissenschaften sind nie vollendet, die Fülle sinnlicher Wahrnehmungen ist nicht zu erschöpfen; keine Generation wird je sich rühmen können, die Totalität der Erscheinungen zu übersehen. Nur da, wo man die Erscheinungen gruppenweise sondert, erkennt man in einzelnen gleichartigen Gruppen das Walten großer und einfacher Naturgesetze.[7]

[6] Ottmar Ette, 'Die Humboldtsche Wissenschaft', in *Alexander von Humboldt-Handbuch. Leben – Werk – Wirkung*, ed. Ottmar Ette, Stuttgart 2018, pp. 106–112 (p. 106).

[7] Alexander von Humboldt, *Kosmos. Entwurf einer physischen Weltbeschreibung, Erster Band*, Stuttgart und Tübingen 1845, p. 65.

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What Humboldt had in mind was an empirically oriented science founded on facts. Only facts, once they have been structured, can underpin theories and ideas. His aim was to empirically prove a global relativity.[8] And Humboldt made every effort to provide the necessary data. At a time, however, when electronic data processing was not yet available and the recording of such data had – laboriously – to be done manually, this was not an easy task. In this article I want to demonstrate that Humboldt was already thinking in 'Big Data' terms. For him, data had to be collected everywhere and at all times. These data were not intended to be just a snapshot, but to provide the basis for a moving image of linked areas that could be compared with each other.[9] His earth magnetic field measurements are an example of why Humboldt can be seen as a pioneer in the era of 'Big Data'; he produced countless measurement results not only alone but also with the help of others.[10] But it would be remiss of scholars to locate his 'Big Data' approach solely in the natural sciences. Even though he was able to operate primarily with numbers, he recognised that the cultural sciences and the humanities also had to be backed up with 'data'. These data were terms and word lists, time specifications and physical objects which revealed connections. And the data needed to be disseminated in the form of printed works and through his immense correspondence. However, Humboldt recognised the limitations of such data. For even innumerable and repeatedly obtained data cannot be combined to form a large whole, his *Kosmos*.

Humboldt collected data throughout his life using the resources available at the time. These included measuring instruments, which he carried around with him everywhere, as well as simple folders in which he stored information. He collected his material under certain categories such as 'telescopic vision', 'instruments', 'fog spots', 'black spots', 'holes', 'a ghost world' or 'world construction' and 'where we stand'. Such material consisted not only of numbers provided by measuring instruments but also of questions, ideas and evaluations. For his *Kosmos*, a five-volume work published between 1845 and 1862, the last volume posthumously, he sent comprehensive questionnaires to colleagues. He cut out relevant passages from letters containing the answers in order to file the information in his folders and boxes correctly.[11] *Kosmos* is thus an evaluation of gigantic data and information: 'Big Data', as one might call it today.

An example of the methods Humboldt used to condense data is within the so-called 'Nature Painting of the Andes' (1807) from his work on plant

[8] Ette, *Alexander von Humboldt und die Globalisierung* (note 2), p. 117.
[9] *Ibid.*, pp. 380–1.
[10] No author, 'Humboldt's legacy', *Nature Ecology & Evolution*, 3 (2019), 1265–6 (1265).
[11] Petra Werner, 'Kosmos', in Ette (ed.), *Alexander von Humboldt-Handbuch* (note 6), pp. 73–9 (p. 77); Wulf, *The Invention of Nature* (note 3), pp. 235–7.

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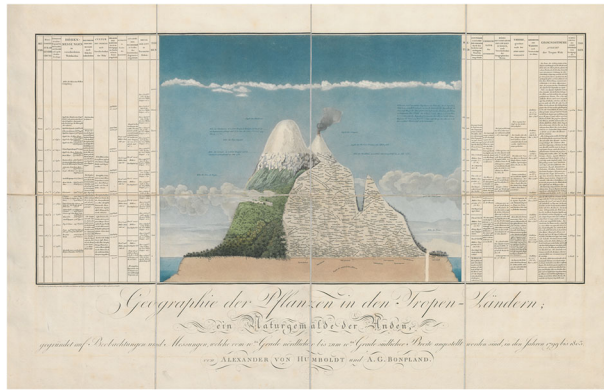

Figure 1. Alexander von Humboldt, 'Naturgemälde der Anden'. Universitäts- und Landesbibliothek Bonn, N 4' 632/15 Rara (Beil.).

geography, which he wrote together with his French travel companion, the botanist Aimé Bonpland.[12] The famous volcanoes of Ecuador, the Chimborazo and the Cotopaxi, both of which they climbed and the former of which was regarded as the highest mountain on Earth, are crammed into just sixteen columns of data (see Figure 1). For this, the authors gathered information on all physical phenomena between 10 degrees north and 10 degrees south latitude, and recorded everything in numbers in relation to the height. The columns themselves were the result of collaboration with other scientists, especially French scientists.[13] All these data, in both words and numbers, relate to the following different subject areas:[14]

•Vegetation	•Heights of other mountain peaks in comparison	•Boiling point of water at different heights	•Snow line
•Animal world	•Electrical voltage of the atmosphere	•Intensity of the colour blue in the sky	•Air density
•Farming	•Barometer reading	•Attenuation of light intensity	
•Temperature	•Decrease in gravity	•Radiation calculation on the horizon	

[12] Alexander von Humboldt and Aimé Bonpland, *Ideen zu einer Geographie der Pflanzen nebst einem Naturgemälde der Tropenländer*, Tübingen and Paris 1807.
[13] Eberhardt Knobloch, 'Naturwissenschaften', in Ette (ed.), *Alexander von Humboldt-Handbuch* (note 6), pp. 113–26 (p. 119).
[14] Ulrich Päßler, 'Im "freyen Spiel dynamischer Kräfte". Pflanzengeographische Schriften, Manuskripte und Korrespondenzen Alexander von Humboldts', in edition humboldt digital, ed. Ottmar Ette, https://edition-humboldt.de/v5/H0016431 (accessed 21 November 2019). No pagination.

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The volcanoes in the centre of the picture 'Naturgemälde der Anden' (1807) are also stuffed with data. A total of 354 species of useful plants are marked on them at the respective altitudinal levels of their occurrence.[15] Humboldt was concerned with the distribution patterns of plants on Earth – an undertaking that undoubtedly required a large number of data references. The distribution of plants in America was also related to people's living conditions and compared to plants and cultural habits in Europe. In the German edition of his work 'Vues des cordillères et monumens des peuples indigènes de l'Amerique' (1810–13), Humboldt refers to the extent to which he is concerned not only with data in the natural sciences but also in cultural studies, when he writes: 'In diesem Werk habe ich alles versammelt, was mit dem Ursprung und den ersten Fortschritten der Künste bei den eingeborenen Völkern Amerikas in Beziehung steht.'[16]

As an empiricist, Humboldt considered that nature is based on laws which are created by nature itself.[17] This is perhaps the reason why he did not keep the individual items of data. While he searched for theories which would explain the numbers, he also saw advantages in collecting numbers so that he could link them together within a numerical framework. Humboldt had a hidden passion for numbers,[18] which included even mathematics. His way of penetrating the essence of things through numbers also meant that he appreciated Pythagoreanism,[19] which places emphasis on concepts such as laws, nature, order, number. At the same time Humboldt was concerned with determining exact numbers. However, he did not use numbers to perform arithmetical operations, but to visualise these numbers as lines.[20] For this reason, his description of the world is not rational, but according to Knobloch, a consideration of the phenomena given by empiricism.[21] It is above all the average numerical values and ratio numbers which form Humboldt's database that enable him to grasp the nature of things at a glance.[22]

Humboldt[23] not only collected and condensed data in the form of numbers and words, as in the 'Naturgemälde der Anden' (1807), he also attempted to reflect the 'whole material world' in *Kosmos* (1845–62). Yet his approach went far beyond numbers and words; it encompassed

[15] *Ibid.*

[16] Alexander von Humboldt, *Ansichten der Kordilleren und Monumente der eingeborenen Völker Amerikas*, ed. Ottmar Ette and Oliver Lubrich, Frankfurt a. M. 2004, p. 3.

[17] Knobloch, 'Naturwissenschaften' (note 13), p. 113.

[18] Michael Meier, 'Humboldts unbekannte Leidenschaft für Zahlen', *HumboldtKosmos*, 91 (2008), 16–17.

[19] Knobloch, 'Naturwissenschaften' (note 13), p. 114.

[20] *Ibid.*

[21] *Ibid.*, p. 115.

[22] Päßler, 'Im 'freyen Spiel dynamischer Kräfte' (note 14).

[23] Alexander von Humboldt, *Briefe von Alexander von Humboldt an Varnhagen von Ense aus den Jahren 1827 bis 1858*, Leipzig 1860 [1834], p. 20.

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physical objects in the same way as we find them in modern-day (university) collections and museums.[24] He brought numerous objects – archaeological artefacts, indigenous writings, minerals, fossils and plants – from America (and minerals also from Russia). Some of these have been lost over time (especially during the Second World War), others have fortunately survived.[25] However, despite the commemorations in 2019 of Humboldt's 250th birthday, and despite 'Big Data' being the basis of science and technology in the twenty-first century, there is still no comprehensive overview of all the physical objects he accumulated. The editing and processing of his preserved correspondence is still pending. In fact, his complete *oeuvre* has only just begun to be explored (e.g. the projects of the Berlin-Brandenburgischen Akademie der Wissenschaften on Alexander von Humboldt) and the recording of all the physical objects he collected is not even beginning to be envisaged. Humboldt has left behind more data than science will ever be able to process in a comprehensive way.

Humboldt even contributed to the new linguistics in Europe by collecting grammars and dictionaries of American languages for his brother Wilhelm's language project.[26] When this was not viable (partly because such writings had not survived due to tropical weather), Alexander himself created word lists of indigenous languages. It is of note that Wilhelm finally did not write the planned chapter on American languages in Alexander's travel work 'Reise in die Äquinoktial-Gegenden des Neuen Kontinents' (1859–60).[27] Alexander's American language material, however, did find its way into Friedrich Schlegel's comparative language observations. Humboldt did not share Schlegel's habit of belittling the indigenous peoples of America for their language, though.[28]

Humboldt's intention of using 'Big Data' as a scientific approach becomes even more apparent if you think of the connotations of the term. 'Big Data' refers to the large amounts of data collected for the purpose of

[24] Daniel Grana-Behrens and Karoline Noack, 'Objektwelten als Kosmos – Von Alexander von Humboldt zum Netzwerk Bonner Wissenschaftssammlungen', in *Objektwelten als Kosmos. Von Alexander von Humboldt zum Netzwerk Bonner Wissenschaftssammlungen*, Bonn 2019, pp. 8–12.

[25] Ferdinand Damaschun and Ralf Thomas Schmitt (eds), *Alexander von Humboldt – Minerale und Gesteine im Museum für Naturkunde Berlin*, Göttingen 2019; Beatrix Hoffmann, *Das Museumsobjekt als Tausch- und Handelsgegenstand. Zum Bedeutungswandel musealer Objekte im Kontext der Veräußerungen aus dem Sammlungsbestand des Museums für Völkerkunde Berlin*, Münster 2012; Walter Lack, 'Botanische Feldarbeit: Humboldt und Bonpland im tropischen Amerika (1799–1804)', *Ann. Naturhist. Mus. Wien*, 105 (2004), 493–514, http://www.biologiezentrum.at (accessed 25 November 2019); Glenn Penny, *Im Schatten Humboldts. Eine tragische Geschichte der deutschen Ethnologie*, Munich 2019; Ursula Thiemer-Sachse, 'Alexander von Humboldt, die Ureinwohner Lateinamerikas und das Problem des weltweiten Vergleichs', in *Alexander von Humboldt und das neue Geschichtsbild von Lateinamerika*, ed. Michael Zeuske and Bettina Schröter, Leipzig 1992, pp. 38–48 (p. 40).

[26] Jürgen Trabant, *Weltansichten. Wilhelm von Humboldts Sprachprojekt*, Munich 2012, pp. 68 and 73–4.

[27] *Ibid.*, p. 70.

[28] *Ibid.*, pp. 71–2 and 80–1.

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discovering cross-connections.[29] The term also often refers to structurally gigantic amounts of data obtained with the help of technical instruments of all kinds in an 'Internet of Things' (IoT) environment, which are then processed using parallel high-performance computers. These datasets are themselves often the result of science and technology based on data.[30] In other words, 'Big Data' today raises the issue of how to deal with it and subsequently directly returns to technology as the only solution.[31] The big difference between Humboldt's and today's understanding is that Humboldt regarded 'Big Data' as being the basis for empirical science to describe cross-connections for the first time, while today Big Data is used to calculate, manipulate and control cross-connections. Knowledge and technology are linked in such a way that new interdependencies merge into a virtual cosmos. The aim is to optimise business models in which work, health, finance, risk and trends are predicted.[32] These are the factors for which patterns are required in order to show innovation in the current age.[33] In this sense, 'Big Data' today also means turning to what Tom Boelstorff calls an 'algorithmic' way of life.[34] The new data practices will thus have an impact on future scientific cultures and epistemologies.

However, it is questionable whether the analysis of large amounts of data alone leads to knowledge, or might knowledge require more meaningful arguments which are cleverly combined?[35] Furthermore, the beginnings of a data-driven research perspective should, in my view, be traced to a much earlier point, as Humboldt was not the first exponent. In terms of the natural sciences, this data-led scientific approach was already deeply ingrained in work of innovators such as Francis Bacon and Isaac Newton. The same can be said of, for instance, Auguste Comte for the social sciences.[36] Thus, the term 'data' dates back to the seventeenth and eighteenth centuries. In 1788, Joseph Priestly, in his Lectures on History and General Policy, described facts of history as data and compiled over 2,000 personalities in a chronological grid chart of biography.[37] In the seventeenth century, the term 'data' was used in philosophy, mathematics and theology to denote indisputable facts and principles by common

[29] Ramón Reichert, 'Einleitung', in *Big Data – Analysen zum digitalen Wandel von Wissen, Macht und Ökonomie*, ed. Ramón Reichert, Bielefeld 2014, pp. 9–34 (p. 9).
[30] Klaus Mainzer, *Die Berechnung der Welt. Von der Weltformel zu Big Data*, Munich 2014, p. 18.
[31] Luciano Floridi, *The 4th Revolution. How the Infosphere is Reshaping Human Reality*, New York 2014, p. 15.
[32] Reichert, 'Einleitung' (note 29), p. 9.
[33] Floridi, *The 4th Revolution* (note 31), p. 16.
[34] Tom Boelstorff, 'Einleitung', in Reichert (ed.), *Big Data: Analysen zum digitalen Wandel von Wissen, Macht und Ökonomie* (note 29), pp. 105–13 (p. 107).
[35] Sarah Spiekermann, *Digitale Ethik. Ein Wertesystem für das 21. Jahrhundert*, Munich 2019, p. 209.
[36] Mainzer, *Die Berechnung der Welt* (note 30), p. 19.
[37] Daniel Rosenberg, 'Daten vor Fakten', in Reichert (ed.), *Big Data: Analysen zum digitalen Wandel von Wissen, Macht und Ökonomie* (note 29), pp. 133–56 (p. 133).

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agreement.[38] But the question is to what extent data can be differentiated from facts and evidence.[39] After all, data are not 'raw data', but already 'condensed', according to the anthropologist Clifford Geertz. This means that data exist in a cultural context and require interpretation, which is analogous to algorithmic interpretation.[40]

Whereas 'Big Data' today means gigantic amounts of information that are collected in order to predict (and thus manipulate) certain facts, at the beginning of the nineteenth century Humboldt did not have enough data to discover cross-connections. However, his limited resources for data acquisition and data processing did not stop him from collecting data via numbers, words and physical objects wherever possible. He certainly did not always know what the data were intended for, except to show cross-connections as part of a 'large whole'. In this sense Humboldt's obsession with data has much in common with today's data mania. Although data are not 'raw material' because they are already condensed, they can be 'processed' into ideas, arguments and even predictions (whether they are valid or not is a different issue). And this applies to numbers as well as to words and physical objects.

HUMBOLDT'S METHODS AND INSTRUMENTS OF DATA COLLECTION

Alexander von Humboldt documented a lot, and in several ways. He carefully documented his trip to America in several volumes as a diary (Figure 2). He stuffed his correspondence into folders and boxes or cut out important passages and pasted them onto relevant note sheets (Figure 3). He documented languages in word lists (Figure 4) and collected cultural data in the form of physical objects that he brought with him or as sketches and pictures together with descriptive texts (Figures 5 and 6). He documented plant information in the form of herbaria (Figure 7), geological information in the form of sketches (Figure 8), and information on geography and climate in the form of figures in tables (Figure 9). According to Knobloch, his scientific approach is holistic.[41] At the same time, Humboldt continued the French tradition of attaching importance to empirical data. The continuing accumulation of data in tables was not the purpose itself, but it reflected Humboldt's desire to be convincing. The data were intended to represent a coherent knowledge system – structures.[42]

[38] Rosenberg, 'Daten vor Fakten' (note 37), p. 138.
[39] *Ibid.*, p. 136.
[40] Boelstorff, 'Einleitung' (note 34), p. 124.
[41] Eberhardt Knobloch, 'Alexander von Humboldt und Carl Friedrich Gauß – im Roman und in Wirklichkeit', *Sitzungsberichte der Leibniz-Sozietät der Wissenschaften zu Berlin*, 109 (2011), 81–108 (92).
[42] Sylvie Romanowski, 'Humboldt's Pictorial Science: An Analysis of the Tablea physique des Andes et pays voisins', in *Essay on the Geography of Plants. Alexander von Humboldt and Aimé Bonpland*, ed. Stephen T. Jackson, Chicago and London 2009, pp. 157–97 (p. 171).

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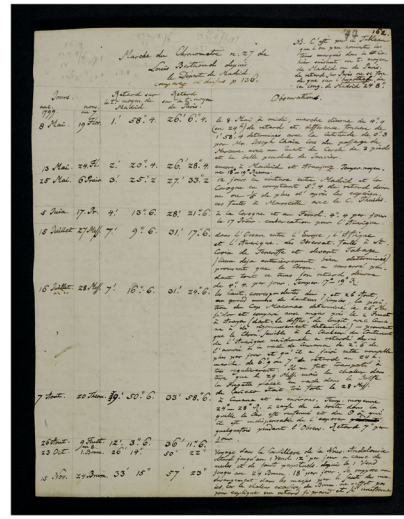

Figure 2. Chronometric information. Alexander von Humboldt, 'Amerikanische Reisetagebücher', 9 vols, I, folio 77r (http://resolver.staatsbibliothek-berlin.de/SBB0001527100000000).

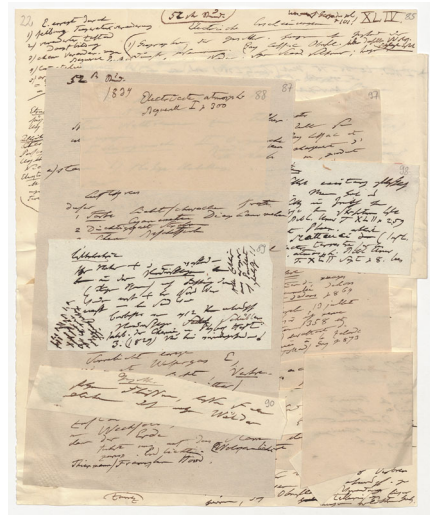

Figure 3. Alexander von Humboldt, 'Vorlesungsmanuskript zur Meteorologie o.D.', Blatt 206. Staatsbibliothek zu Berlin (http://resolver.staatsbibliothek-berlin.de/SBB0001A52B00000000).

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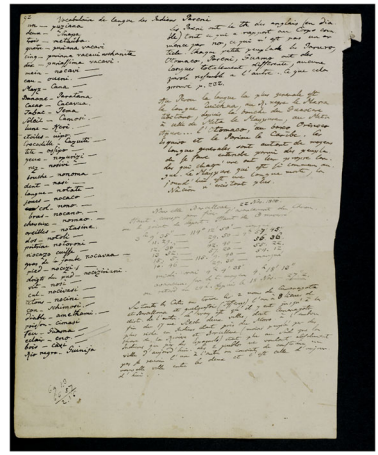

Figure 4. 'Vocabulaire de langue des Indiens Parensi'. Alexander von Humboldt, 'Amerikanische Reisetagebücher', 9 vols, III, folio 43v. Staatsbibliothek zu Berlin (http://resolver.staatsbibliothekberlin.de/SBB0001527400000000).

Figure 5. A replica of the so-called 'Humboldt Celt' (a 'celt' was used in neolithic cultures as an axe blade). Photograph by Daniel Grana-Behrens. Museum für Völkerkunde Dresden.

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Figure 6. Two fragments of indigenous manuscripts from Central Mexico. Alexander von Humboldt, *Vues des cordillères, et monumens des peuples indigènes de l'Amérique*, 1810. Planche XII. 'Généalogie des Princes d'Azcapozalco'.

Figure 7. Solarium lycopersicum L. [sub S. humboldtii]. Kolorierter Kupferstich von F. Guimpel, 1804. C. L. Willdenow, *Hortus berolinensis* [...], Berlin 1803–16. Botanisches Museum Berlin-Dahlem, Bibliothek. The image is also reproduced in Walter Lack, 'Botanische Feldarbeit: Humboldt und Bonpland im tropischen Amerika (1799–1804)', *Ann. Naturhist. Mus. Wien*, 105 (2004), 493–514 (507).

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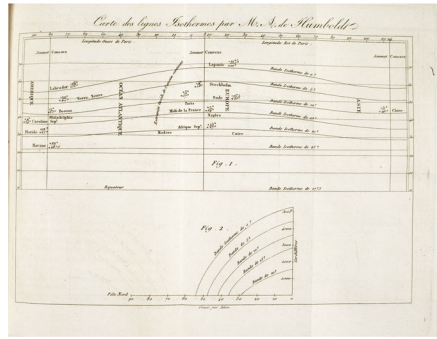

Figure 8. 'Carte des lignes isothermes par M. A. Humboldt'. This chart appears with Humboldt's essay 'Sur les lignes isothermes', in *Annales de chimie et de physique*, 5 (1817), 102–11.

Figure 9. 'Roches basaltiques et Cascade de Regla'. Alexander von Humboldt, *Vues des cordillères, et monumens des peuples indigènes de l'Amérique*, 1810. Planche XXII.

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Humboldt's scientific work ultimately led him to create his own kind of scientific procedure, Humboldtian science.[43] Humboldt's penchant for mean values runs like a thread through his works.[44] It is also only the average that makes laws stand out by means of numbers. There is no pure naked knowledge of nature.[45] This indicates that: 'Naturerkenntnis ergibt sich nicht unmittelbar wie der Naturgenuss, sondern wird über Zahlen vermittelt'.[46] This is not an arithmetic mean, but 'um die Veränderung einer variablen Größe an einem Ort in einem Zeitraum. Es geht um das Erkennen des Gesetzes, das der Änderung zugrunde liegt, wenn man Mittelwerte homogener Daten verschiedener Orte im gleichen Zeitraum miteinander vergleicht.'[47] As Knobloch remarks:

> Tatsächlich sind ja die von ihm verwendeten Daten nicht nur gemessene, sondern vor allem auch aus gemessenen Werten berechnete Werte. Denn wegen der Abnahme der Temperatur darf man mittlere Temperaturen von Orten nicht vermischen, die nicht auf demselben Niveau liegen, eine von Humboldt wiederholt betonte Forderung, die in der Forschungsliteratur oft nicht angesprochen wird […]. Für die Abnahme der Temperatur nahm Humboldt mit Ramond 1° pro 164 Höhenmeter an. Alle Mittelwerte müssen auf die Meeresfläche reduziert werden, bevor gleiche Werte durch Humboldts Iso-Linien miteinander verbunden werden.[48]

In general, Humboldt' works contain a wide range of numerical values:

•Longitude and latitude	•Distance	•Weight	•Angular distance (stars)
•Temperature	•Height	•Magnetic flux density	•Planetary orbit
•Humidity	•Brightness	•Quantity	
•Air pressure	•Speed	•Body height	

For him, measuring was an important undertaking and, indeed, an obsession.[49] He mentioned this in a letter to Johann Gotthelf Fischer von Waldheim: 'J'ai la fureur des chiffres exactes' or 'I am obsessed with exact numbers'.[50] Therefore, it is not surprising that nearly all the documents Humboldt left us are abundant in localisations, with geographical latitude

[43] Susan Faye Cannon, *Science in culture. The early Victorian period*, Folkstone and New York 1978, pp. 73–110; and Ette, 'Die Humboldtsche Wissenschaft' (note 6), p. 106.
[44] Knobloch, 'Naturwissenschaften' (note 13), p. 115.
[45] *Ibid.*
[46] Knobloch, 'Alexander von Humboldt und Carl Friedrich Gauß' (note 41), 97.
[47] *Ibid.*
[48] Knobloch, 'Naturwissenschaften' (note 13), p. 121.
[49] Daniel Kehlmann, *Die Vermessung der Welt*, Reinbek 2005, p. 39.
[50] Knobloch, 'Alexander von Humboldt und Carl Friedrich Gauß' (note 41), 88.

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and longitude recorded down to the smallest degree as well as temperature measurements. The main purpose was:

> […] mit Hilfe des Zahlenmaterials funktionale Zusammenhänge aufzudecken, das Bilden von Zahlenverhältnissen, wie es Humboldt nannte, das Zusammenwirken der Naturkräfte zu entschlüsseln. Das Zahlenmaterial stand im Dienste von Humboldts holistischer Weltsicht. Die Werte einer Größe blieben nicht isoliert, sondern wurden in Beziehung zu anderen Größen gesetzt. Messen war kein Selbstzweck, sondern für das zu gewinnende Weltverständnis unentbehrlich.[51]

Thus, the symbiosis of text and image also reflects an indissoluble whole of science, ethics and aesthetics for Humboldt.[52] Even some of his fleeting graphics combine image, text and numbers, such as the example of a geographical sketch with sticky notes, which is now in the Staatsbibliothek Berlin. The sketch, the subject of little research so far, compares various mountains around the world and their snowlines, as well as climatological data, in contrast to the 'Naturgemälde der Anden' (1807), which highlights botanical-geographical features.[53] But Humboldt not only collected and archived data or objects, he considered them carefully and investigated their complexity, thus creating an openness that, beyond a deterministic world (e.g. God-given, mechanistic), rather took on the character of 'a net-like intertwined fabric' according to Ette.[54] The accusation that the collection of empirical data is an inadmissible goal, a pure end in itself, unless it is supported by a general theory, which was Carl Friedrich Gauss's criticism,[55] is today, more than ever, relativised in the light of 'Big Data' as a 'commodity' of some kind, including science. Ultimately, contrary to Gauss's criticisms, Humboldt's measurements were noective, not even those from surveying the regions, but they were driven by his justified empiricism in order to ultimately describe global relations.[56] Neither were Humboldt's 'Big Data' an end in themselves – if you look at the ten dimensions of Humboldt's Science which can be extrapolated and for which the data served as a basis:[57]

[51] *Ibid.*

[52] Ottmar Ette, 'Eine "Gemütsverfassung moralischer Unruhe" – Humboldtian writing: Alexander von Humboldt und das Schreiben in der Moderne', in *Alexander von Humboldt – Aufbruch in die Moderne*, ed. Ottmar Ette, Ute Hermanns, Bernd M. Scherer and Christian Suckow, Berlin 2001, pp. 33–55 (p. 52).

[53] Birgit Schneider, 'Berglinien im Vergleich – Bemerkungen zu einem klimageografischen Diagramm Alexander von Humboldts', HiN, XIV/26 (2013), 26–43 (34).

[54] Ette, 'Die Humboldtsche Wissenschaft' (note 6), p. 106.

[55] Knobloch, 'Alexander von Humboldt und Carl Friedrich Gauß' (note 41), 86–7.

[56] Manuel Puig-Samper, 'La medida de América: de la observación métrica ilustrada española al empirismo razonado humboldtiano', *Historia Mexicana*, LXVII/2 (2017), 907–63 (953).

[57] Ette, 'Die Humboldtsche Wissenschaft' (note 6), pp. 107–112.

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•Transdisciplinary science	•Networking science	•Democratization of knowledge
•Life science	•Fractal science (arrangement of images, texts, fragments, chaos)	•Inter- and transmedial (interlocking of image-text, text-image, text-image and image-writing)
•Transareal science	•Cosmopolitan science	•Science policy dimension

For example, Humboldt's approach to the aforementioned 'Naturgemälde der Anden' (1807) is multi-layered.[58] It is comparative, causal, integrating (in terms of evidence) as well as multidimensional and documentary. In general, Humboldt's 'Big Data' approach meant trying to think both along both horizontal lines, i.e. the differentiation of the sciences; and vertical lines, i.e. specialisation guided by scientific networking possibilities.[59] Humboldt was thus a lateral thinker, '[der sich] nicht in Messungen, Datenerhebungen und Statistiken verlor, sondern aufs Ganze und damit auch das Zusammenleben unterschiedlicher Kulturen meinte'.[60]

From 1814 to 1828 Humboldt was increasingly concerned with the arithmetic of plant geography. As early as 1796 Humboldt had formulated his idea of a 'physique du monde', according to which nature represents the unity of all phenomena (including all living beings and substances). When developing his ideas on plant geography, he assumed that nature as a whole was not static, but emerged from the free play of dynamic forces.[61] For as far as plants were concerned, he assumed geographical and climatic conditions to be forces of variation of forms and physiognomy, which he examined by means of numerical systematics.[62] Thus, he became the 'measuring botanist' that he felt plant geography called for.[63]

An approach to plant geography comparable to Humboldt's can be found in the work of Francisco José de Caldas, who created Andean profiles between 1802 and 1809, and indicated the dimensions of some useful plants and their areas of distribution.[64] Humboldt and Caldas met in 1801. Their relationship was characterised by mutual respect and recognition: Caldas copied Humboldt's elevation profiles between Cartagena and Bogotá, while Humboldt took a closer look at Caldas' astronomical positions and field notes. Humboldt's 'botanical arithmetic' and the underlying data networking took place after his return to Paris.[65] In addition to the usefulness of his data, Humboldt's work inspired ideas on plant geography in other people like Göran Wahlenberg (Switzerland,

[58] Romanowski, 'Humboldt's Pictorial Science' (note 42), pp. 165–7.
[59] Ette, 'Die Humboldtsche Wissenschaft' (note 6), p. 107.
[60] *Ibid.*, p. 109.
[61] Päßler, 'Im 'freyen Spiel dynamischer Kräfte' (note 14).
[62] *Ibid.*
[63] Humboldt, *Ideen zu einer Geographie der Pflanzen* (note 12), p. 86.
[64] Päßler, 'Im 'freyen Spiel dynamischer Kräfte' (note 14).
[65] *Ibid.*

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Lapland) and Leopold von Buch (Norway). He also profited from his correspondence with Robert Brown (Madeira, Cape of Good Hope, Australia). And it was Humboldt who supported Franz Julius Ferdinand Meyer in his circumnavigation of the world (1830–2) on behalf of Prussia. Humboldt's vision of a botanical-geographical science network can be found in his 1814 lecture 'Considérations générales sur la végétation des îles Canaries'. In the lecture he compares his data with those of other scientists. Humboldt combines temperature data with barometric height measurements as well as botanical and plant physiological findings paired with average temperatures and limits of vegetation and eternal snow. The ideas of expressing distances of vegetation and snow heights in different regions by a numerical ratio is a concept of botanical arithmetic. The relationship between the natural plant families and the genera and species should, he thought, be determined in relation to the different widths. Thus, Humboldt's statistical method was also a way of coping with the flood of botanical data.[66]

To visualise such data, Humboldt not only condensed image, text and numbers, as in the case of the 'Naturgemälde der Anden' (1807), but also used a variety of graphic methods, many of which he developed himself, in order to make his research findings visible. In his 'country map', for example, he combined the graphic representation of a map with the method of isolines (contours) instead of representing this information in tabular form, which was customary at the time.[67] Humboldt's famous 'Cartes des lignes isothermes' (1817), on the other hand, dispenses with the country contours and shows only the lines (Figure 8). It is to Humboldt's credit that he methodically grouped the temperature distribution on Earth for the first time. To do this, he used his own data from his trip to America, as well as data from fellow researchers and from books, and found fifty-eight locations that were useful, of which he considered only those in the northern hemisphere (between Florida in the West and China in the East). He calculated the mean value as well as temperature, longitude, latitude and altitude, and provided further information on the measured values.[68] He assumed that the temperature would decrease by 1 degree per 164 metres of altitude. However, his idea concerning temperature and heat in numerical proportions was formulated as a theory by Juan Baptiste Joseph Fourier, who developed it without reference to Humboldt.[69]

Humboldt's above-mentioned data are usually available in two forms: as a written map in tabular form and as a graphical conversion of the

[66] *Ibid.*

[67] Birgit Schneider, 'Linien als Reisepfade der Erkenntnis. Alexander von Humboldts Isothermenkarte des Klimas', in *Karten Wissen. Territoriale Räume zwischen Bild und Diagramm*, ed. Stephan Günzel and Lars Nowak, Wiesbaden 2012, pp. 175–99 (pp. 177 and 192).

[68] *Ibid.*, p. 180.

[69] Knobloch, 'Naturwissenschaften' (note 13), p. 121.

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values as a map.[70] Given Humboldt's preferences, it is not surprising that Heinrich Berghaus' *Physical Atlas* (1838–48), which was supposed to appear together with Humboldt's *Kosmos* (1845–62) but failed due to a quarrel with the publisher, is also oriented towards reproducing observations and data graphically.

Furthermore, Humboldt's political interest in conditions in the Viceroyalty of New Spain, for example, shows how much he relied on a plethora of data to support his observations. In his work *Essai politique sur le royaume de la Nouvelle-Espagne* (1809–14) there are about three dozen tables which contain figures on demography, the census of clergy and monks, the number of schools, hospitals, prisons, customs receipts, imports, tonnages of ships and the political-geographical subdivision of the Viceroyalty together with the number of inhabitants. Even in letters, Humboldt does not abandon his principle. For example, in his 'Letter to a clergyman in Amsterdam'[71] he correlates American population figures and language affiliation. Sometimes one wonders how he got hold of these numbers in the first place.

Humboldt compared many things with one another, including cultural artefacts or phenomena.[72] According to Ette, the comparison served him as a kind of instrument for putting everything in relation (and in motion) with everything as far as possible.[73] Sometimes such comparisons, as Ette further explains, seem quite arbitrary, for example, the comparison between Cuba and Prussia with regard to agriculture. However, Humboldt's comparisons must be regarded as a rhetorical-literary method that enables him to relate what at first glance seems incomparable to anything else. In this respect, Humboldt is more concerned with the attempt to achieve what Ette calls a worldwide comparability.[74] One must bear in mind that today's 'Big Data' initiatives have no other purpose than to enable such a comparability, even between things that are not comparable with one other. Humboldt used statistical data to compare population trends with a view to agriculture in the Viceroyalty of New Spain and Prussia, but in this case the comparison is less a rhetorical-literary means to surprise and rather more due to ways of thinking which aim: 'Entwicklungen weltweit miteinander in Beziehung [zu setzen] und allgemeine und allgemeingültige Regeln und Gesetzmäßigkeiten daraus [abzuleiten].'[75] For this reason, too, everything is now recorded in the form of 'Big Data'. Ette's conclusion from

[70] Schneider, 'Linien als Reisepfade' (note 67), p. 192.
[71] Alexander von Humboldt, 'Letter to a clergyman in Amsterdam', in *Der andere Kosmos*, ed. Oliver Lubrich and Thomas Nehrlich, Munich 2019, pp. 261–3.
[72] Ursula Thiemer-Sachse, 'Alexander von Humboldt, die Ureinwohner Lateinamerikas und das Problem des weltweiten Vergleichs', in *Alexander von Humboldt und das neue Geschichtsbild von Lateinamerika*, ed. Michael Zeuske and Bettina Schröter, Leipzig 1992, pp. 38–48 (p. 40).
[73] Ette, *Alexander von Humboldt und die Globalisierung* (note 2), p. 152.
[74] *Ibid.*, p. 153.
[75] *Ibid.*

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Humboldt's urge to compare is that he makes the reader a 'citizen of the world', who then looks at his own circumstances as a citizen:

> So setzt die Humboldt'sche Wissenschaft als Weltwissenschaft mit Hilfe des Vergleich – und speziell des kühnen Vergleichs – ein Weltbewusstsein in Gang, das den Weltbürger nicht in einem kosmopolitischen Nirgendwo belässt, sondern zu einem Staatsbürger macht, der aus dem Blickwinkel einer Kosmopolitik die Verhältnisse nicht zuletzt in seinem eigenen Staatswesen betrachtet. So konnte aus dem Weltbürger ein doppelt nützlicher Staatsbürger werden.[76]

Humboldt used the analogy to create connections that are not easily observable.[77] He also relied on such an analogy in cultural studies:

> Die Gegenüberstellung der Kunstwerke Mexikos und Perus mit denen der alten Welt, die ich vorhabe, ist für meine Forschungen und den Pittoresken Atlas, der die Ergebnisse enthält, von einigem Interesse. Fernab von jedem Systemdenken werde ich die Analogie aufzeigen, die sich zwanglos anbieten, und dabei diejenigen, die eine Identität der Rasse zu beweisen scheinen, von denen unterscheiden, die wahrscheinlich nur auf inneren Ursachen beruhen, auf jener Ähnlichkeit, welche alle Völker in der Entwicklung ihrer Verstandskräfte aufweisen.[78]

Once again, his emphasis is on creating interconnections:

> Indem ich in ein und demselben Werk die rohen Monumente der eingeborenen Völker von Amerika und die malerischen Ansichten des Gebirgslandes vorstelle, das diese Völker bewohnt haben, glaube ich Gegenstände zu vereinigen, deren wechselseitige Beziehungen dem Scharfsinn jener, die sich dem philosophischen Studium des menschlichen Geistes widmen, nicht entgangen sind.[79]

Humboldt used numerous instruments on his America trip to obtain numbers relating to the above-mentioned fields of knowledge.[80] In the Instrument Index 'Hidden Kosmos',[81] all the instruments used by Humboldt on his trip to America are listed, as well as those he named in his so-called 'Kosmos Lectures' at Berlin University (1827) and at the Berlin Singakademie (1828). There are sixty-four instruments in total:[82]

[76] *Ibid.*, p 159.
[77] Romanowski, 'Humboldt's Pictorial Science' (note 42), p. 186.
[78] Humboldt, *Ansichten der Kordilleren* (note 16), p. 18.
[79] *Ibid.*
[80] Alexander von Humboldt, *Reise in die Äquinoktial-Gegenden des Neues Kontinents*, ed. Ottmar Ette, 2 vols, Frankfurt a. M. and Leipzig 1999, I, pp. 63–4.
[81] http://deutschestextarchiv.de/kosmos/instrument (accessed 6 November 2019).
[82] See Friedrich L. Brand, *Alexander von Humboldts physikalische Messinstrumente und Messmethoden*, Berlin 2001; and Max Seeberger, 'Humboldt y sus instrumentos científicos', in *Alejandro de Humboldt en México*, ed. Frank Holl, Mexico 1997, pp. 55–65.

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•Hydrometers	•Heliotrope	•Micrometers	•Plummet	•Watch (chronometer)
•Barometer	•Horizon (artificial)	•Microscope (composite)	•Sextant	•Clock (half-chronometer)
•Bussole (declination)	•Hyetometers	•Multiplications (mirror circle)	•Sextant (canned)	•Clock (length-)
•Bussole (inclination)	•Hygrometer	•Multiplier (electromagnetic)	•Mirror	•Clock (pendulum)
•Cyanometer	•Hygrometer (fish bone)	•Night scope	•Telescope	•Clock (Sea-)
•Distillation apparatus	•Hygrometer (hair)	•Normal metre	•Theodolite	•Clock (Sun-)
•Electroscope	•Infinitesimal calculus	•Octant	•Thermometers	•Volta (ash column)
•Eriometer	•Compass	•Pendulum (fixed)	•Thermometer (maxima)	•Libra
•Eudiometer	•Leidener bottle	•Photometers	•Thermometer (with double vernier)	•Balance (rotary)
•Telescope	•Ruler	•Quadrant	•Thermometer ball	•Balance (rotary)
•Telescope (achromatic)	•Magnetic needle	•Refractometer	•Therm om etricprobe	
•Telescope (magnetic)	•Magnetometers	•Refractor	•Thermometrograph	
•Graphometers	•Magnetoscope	•Repetition circle	•Therm oscope	

Humboldt was always up to date and invested considerable amounts of money in the latest instruments:

> Sextant von Jesse Ramsden, Künstlicher Horizont von Noël Simon Caroché, kleiner Quadrant von John Bird, Repetitionskreis, Theodolit von Johann Heinrich Hurter, Sextant von Edward Troughton, Korrekturfernrohr, achromatisches Fernrohr von Peter Dollond, anderes achromatisches Fernrohr von Caroché, Graphometer von Ramsden, Längenuhr von Louis Berthoud, Semichronometer von Johann Heinrich Seiffert, Inklinationsboussole von Paul Étienne Le Noir, große Magnetnadel aufgehängt nach Charles Augustin de Coulomb, Magnetometer von Horace Bénédicte de Saussure, Deklinationsboussole von Le Noir, Barometer, Hygrometer, Hyetometer, Thermometer, Cyanometer, thermometrische Senkbleis, Feldmess-Ketten, metrische Normalgewichte.[83]

Humboldt's urge for surveying and for accuracy, however, must be seen in the context of the eighteenth century, with many other scientists assuming that even minor deviations in the physical and chemical system would bring new insights. At the same time, it must be borne in mind that many instruments used by Humboldt (such as the eudiometer or air quality meter) were not capable of delivering such fine results, so Humboldt's efforts actually generated 'meaningless numbers'.[84] Humboldt essentially

[83] Knobloch, 'Naturwissenschaften' (note 13), p. 117.

[84] Stephen T. Jackson, 'Instruments Utilised in Developing the Tableau physique', in *Essay on the Geography of Plants*, by Alexander von Humboldt and Aimé Bonpland, ed. Stephen T. Jackson, tr. Stephen Romanowski, Chicago and London 2009, pp. 221–6 (p. 221).

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measured, among other things, degrees of longitude, latitude and altitude, temperature, humidity, electrometry, the intensity of the blue in the sky, the chemical composition of the atmosphere and gravity.[85] But since he did this with such constancy, in comparison to what we experience today, his efforts must be seen as a first attempt to generate 'Big Data', in which he was also feverishly interested.

HUMBOLDT'S CONCLUSIONS FROM 'BIG DATA'

Humboldt's *Kosmos* approach – that all things depend on each other in equal measure and that heeding this fact is essential to gaining knowledge and understanding – helps us to understand the purpose of all the data and all the physical objects (plants, cultural assets) that he collected. Both are necessary to verify existing knowledge, as the most recent example of Humboldt's data on the 'Naturgemälde der Anden' (1807) demonstrates. Researchers have shown that the data in the above-mentioned tables contain deviations from those in his American diaries.[86] On the other hand, the diversity of species in the tropical mountains referred to by Humboldt himself in the form of the 'Naturgemälde der Anden' is considered a 'mystery' or a 'secret' even today.[87] Humboldt was wise enough to remain modest in his 'Big Data' approach. However, according to his own judgment, he considered three scientific areas to be particularly relevant: (1) Geography of plants (including nature paintings of the tropics), (2) Isothermal lines and (3) Earth magnetism.[88]

His core idea on plant geography was the linking of history and plants, in which the distribution of species is recorded by biostatistics, as is also known from the 'Naturgemälde der Anden' (1807). Humboldt discussed this idea in detail in his introduction to *De Distributione geographica plantarum secundum coelotemperiem et altitudinem montium, prolegomena* (1817) and related the mean temperatures in the regions of the world with the occurrence of plants in twenty-one tables. According to Knobloch, the focus was on the connection between climatology, plant physiology and plant systematics as well as on the extent to which the distribution of plants influenced humans and their sense of art.[89] The isothermal lines (Figure 8) are the result of statistical methods which Humboldt used to develop 'meteorology to climatology'.[90] The aforementioned famous illustration of

[85] *Ibid.*, pp. 222–6.
[86] See Pierre Moret, Priscilla Muriel, Ricardo Jaramillo and Olivier Dangles, 'Humboldt's Tableau Physique revisited', PNAS, 116/26 (2019), 12889–94.
[87] Carsten Rahbek *et al.*, 'Humboldt's enigma: What causes global patterns of mountain biodiversity?', in *Science*, 365 (2019), 1108–13.
[88] Knobloch, 'Naturwissenschaften' (note 13), p. 118.
[89] *Ibid.*, p. 119.
[90] *Ibid.*, p. 120.

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the isotherm shows that isotherms intersect the latitudes, and that maxima and minima depend on the longitude. Humboldt attributed the curvature to the shape of the continents.[91]

In his *Kleinere Schriften* (1853), Humboldt writes on the distribution of heat: 'Erfahrung und Beobachtung die Data an die Hand geben, aus welchen die Theorie die Berichtigung der verschiedenen in Anwendung gebrachten Elemente schöpfen kann. Es ist der Zweck dieser Abhandlung: die Vereinigung dieser Data zu erleichtern.'[92] He studied the heat distribution in four areas (surface of the Earth, slope of mountains, oceans, interior of the Earth) and made 127,000 thermal observations with sixteen thermometers, which allowed him to determine the mean annual temperatures as well as the mean winter and summer temperatures regardless of the inaccuracy of the instruments he used.[93]

Humboldt considered the law of the decrease of geomagnetic force from the magnetic North Pole to the magnetic equator to be the most important finding of his American journey. In no more than two years, from 1805 to 1807, Humboldt made 6,000 earth magnetic measurements at Friedrichstraße in Berlin. Shortly before 1805, he travelled to Italy to join Joseph Louis Gay-Lussac in examining the influence of mountains on Earth's magnetism. His geomagnetic observations on his journey to Russia in 1829, on 134 sheets of the third volume of the Russian diary, have not yet been analysed.[94] Carl Friedrich Gauss (1777–1855), who published his 'General Theory of Earth Magnetism' with a better method and better instruments in 1839, relied on data from ninety-one places in the world, some of which came from Humboldt.[95] Is Humboldt's research path not analogous to what is happening today: the path of conscious compilation not just of individual items but of facts and data which help discover and explain areas of mutual dependencies? Isn't that 'Big Data'?

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[91] *Ibid.*, p. 122.
[92] *Ibid.*, p. 120.
[93] *Ibid.*
[94] *Ibid.*, p. 123.
[95] *Ibid.*, p. 124.

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