Colonizing the Free Atmosphere: Wladimir Köppen's 'Aerology', the German Maritime Observatory, and the Emergence of a Trans-Imperial Network of Weather Balloons and Kites, 1873-1906

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This article suggests that the meteorological science of 'aerology', the global study of the upper air with the help of balloons and kites, emerged most prominently in Imperial Germany in the first decade of the twentieth century as a consequence of trans-imperial networks and field work.

Although contemporaries and historians have often demoted aerology to the level of a *Hilfswissenschaft* to the emerging discipline of atmospheric physics, aerology was a top-down program of investing in scientific infrastructure to jumpstart, on the global stage, what contemporaries such as the Russian-German meteorologist Wladimir Köppen felt as long overdue: a German synoptic meteorology.[1] Newly established German weather balloon halls and kite stations became rivals in the field to metropolitan observatories and universities, assimilating data produced by expeditions and field work in general.[2] It was thanks to German aerologists, German meteorological stations and the German coordination of simultaneous European weather balloon ascents in the first decades of the twentieth century, that in the 1920s and 1930s both the Norwegian Bergen School and Lewis Fry Richardson were able to attempt

[1] Wladimir Köppen, "Die Wechselwirkung zwischen der maritimen und der Landmeteorologie in deren Entwickelung," *Meteorologische Zeitschrift* 26 (1909).

[2] On the role of stations and field laboratories in the life sciences, see: Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002); Jeremy Vetter, "Rocky Mountain High Science. Teaching, Research and Nature at Field Stations," in *Knowing Global Environments. New Historical Perspectives on the Field Sciences* (Piscataway NJ: Rutgers University Press, 2011), 108–134; Robert-Jan Wille, "The Co-Production of Station Morphology and Agricultural Management in the Tropics. Transformations in Botany at the Botanical Garden at Buitenzorg, Java 1880-1904," ed. Denise Phillips and Sharon Kingsland, *New perspectives on the history of life sciences and agriculture.*, Archimedes series in the history and philosophy of science (2015): 256–281; Raf De Bont, *Stations in the Field: A History of Place-Based Animal Research, 1870-1930* (Chicago: University of Chicago Press, 2015). For a meteorological case, see: Deborah R. Coen, "The Storm Lab: Meteorology in the Austrian Alps," *Science in Context* 22, no. 3 (2009): 463–486.

modelling weather.[3] Robert Friedman and Mott Greene have demonstrated the importance of aerology for later careers in meteorology and geophysics, not only contributing to the career of Vilhelm Bjerknes, but also to that of Alfred Wegener.[4]

For most historians, the crucial phase in the development of transnational atmospheric physics is the Cold War, when weather models and satellites emerged as tools. Paul Edwards has demonstrated how only between 1965 and 1975 did an interdisciplinary community succeed in tying together different research strands to create a transnational scientific and political community – or 'vast machine' – of climate sciences. In this machine the field of atmospheric physics had lead the way, with oceanography and ecology adopting its computer models and satellite data as shared 'boundary objects'.[5]

However, although Edwards did focus on the importance of infrastructural globalism before the Cold War,[6] he left it to other historians to analyze the emergence of atmospheric physics itself as a distinct field half a century before. Around the First World War, it entered the university curriculum in Germany.[7] There, a decade earlier, state observatories had started organizing regular balloon and kite ascents. This practice was exported to the Scandinavian countries when Bjerknes returned from Leipzig to Bergen before the War and created the Bergen School of atmospheric physics that became the dominant theory of meteorology after the 1930s, in the United States and the rest of the world.[8]

This article suggests that Germany's campaign in weather kites and balloons between 1900 and 1914 needs to be seen as a crucial (and heretofore missing) link or intermediary between two distinct periods and geographies in the history of meteorology. Whereas in the history of nineteenth century weather science the focus has mostly been on maritime meteorology, physical laws and weather prediction in Great Britain, its naval neighbors and to a

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[3] Robert Marc Friedman, *Appropriating the Weather. Vilhelm Bjerkness and the Construction of a Modern Meteorology* (Ithaca NY: Cornell University Press, 1989); Lewis Fry Richardson, *Weather Rediction by Numerical Processes* (Cambridge: Cambridge University Press, 1922); Peter Lynch, *The Emergence of Numerical Weather Prediction: Richardson's Dream* (Cambridge: Cambridge University Press, 2006).

[4] Friedman, *Appropriating the Weather*; Mott T. Greene, *Alfred Wegener: Science, Exploration, and the Theory of Continental Drift* (Baltimore: John Hopkins University Press, 2015).

[5] Paul Edwards, *A Vast Machine. Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA; London: MIT Press, 2010); Susan Leigh Star and James R. Griesemer, "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39," *Social Studies of Science* 19, no. 3 (1989): 387–420.

[6] Paul Edwards, "Meteorology as Infrastructural Globalism," *Osiris* 21, no. 1 (January 2006): 229–250.

[7] For a focus on the Interbellum and the infrastructure of British colonial developmental meteorology, see: Martin Mahony, "For an Empire of 'all Types of Climate': Meteorology as an Imperial Science," *Journal of Historical Geography* 51 (January 2016): 29–39.

[8] Friedman, *Appropriating the Weather*; Greene, *Alfred Wegener.*; James Rodger Fleming, *Inventing Atmospheric Science. Bjerknes, Rossby, Wexler, and the Foundations of Modern Meteorology* (Cambridge MA: MIT Press, 2016).

much lesser extent Austria-Hungary,[9] the focus in the twentieth century has been on thermodynamic modelling and the origins of atmospheric physics in Scandinavia and the United States.[10]

German aerology's intermediate position is manifold. First, aerology and weather ballooning formed a link between both centuries and specific epochal cultures of science, between Victorian networks of Humboldtian scientists calibrating instruments, mountaineering and collecting data globally and Cold War atmospheric physicists working with models and satellites.[11] Second, Germany formed a geographical link: between the land-based empires of the East, the British ocean and Scandinavia. Thirdly, Wilhelmine balloon halls and kite launching ships that collaborated and competed with Austrian mountain stations linked naval meteorology to the physics of the upper air. Fourth, Germany's imperial ambitions connected longer traditions of European imperial fieldwork in polar and tropical meteorology to the German system of research universities.[12]

Traditionally, the history of German science centers on the development (and sometimes its peculiar *Sonderweg*) of the German nation-state, in the form of the Imperial Germany formed by Bismarck between the Belt in the North and the Isar in the South, the Rhine in the West and the Memel in the East. Although this article also acknowledges the innovating impetus of the politics of German national science politics in the late nineteenth century and early twentieth century, it also emphasizes the importance of imperial dimensions and 'trans-imperial' networks in the history of German science. Thus, I relocate German science within the broader dynamics of an international and multidimensional history of the atmospheric sciences.

This article focuses on the embedding of Wladimir Köppen, a Russian-German scientist, into the meteorology of the new German state, a state that was focused on becoming both a maritime and a land empire, with Hamburg as an important center for the former and Berlin and Strasburg as centers for the latter. Out of this competition emerged a third dimension: the atmosphere. A new kind of German empire was born: an aerial empire, explored by a fleet of zeppelins and weather balloons. Nationalist and internationalist German scientists worked

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[9] Katherine Anderson, *Predicting the Weather. Victorians and the Science of Meteorology* (University of Chicago Press, 2010); David Moon, "The Debate over Climate Change in the Steppe Region in Nineteenth-Century Russia," *The Russian Review* 69, no. 2 (April 2010): 251–275; Deborah R. Coen, "Imperial Climatographies from Tyrol to Turkestan," *Osiris* 26, no. 1 (January 2011): 45–65; Azadeh Achbari and Frans van Lunteren, "Dutch Skies, Global Laws," *Historical Studies in the Natural Sciences* 46, no. 1 (February 11, 2016): 1–43.

[10] Friedman, *Appropriating the Weather*; Fleming, *Inventing Atmospheric Science.*

[11] For 'Humboldtian science', see: Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (Kent & New York: Dawson, 1978).

[12] See also Philipp Lehmann's contribution to this issue: "Losing the Field: Franz Thorbecke and (Post)Colonial Climatology in Germany," *History of Meteorology* 8 (2017): 145–158. Although several authors have also pointed at the important role of Germany in polar meteorology, much analysis on the national and imperial context of these aerological projects is still needed: Susan Barr and Cornelia Lüdecke, *The History of the International Polar Years (IPYs)* (Heidelberg: Springer, 2010).

together: the 'free atmosphere' was something that could be conquered but which left room for cooperation with other nations.

Köppen as world-meteorologist

Before the foundation of the Royal Aeronautical Observatory in Lindenberg in 1905, Wladimir Köppen's own kite station near Hamburg formed a key site for the new aerology. Thanks to Köppen's observatory and the weather kites produced and calibrated at the station, and in cooperation with the Lindenberg Observatory, German naval ships started collecting data in the tropics and the polar area.

Wladimir Köppen was chief meteorologist of the *Deutsche Seewarte* since its foundation in 1875, and later father-in-law of Alfred Wegener. In many ways, he was a 'go-between' between Russian, German and overseas meteorology.[13] It is tempting to call Köppen a generalist who was reluctant to pursue a further career in plant physiology, the topic of his dissertation, and who, through a detour, ended up as a meteorological climatographer famous for his maps and climate zones, which are still used today.[14] However, it is more accurate to describe him as a Humboldtian scientist who became a 'world meteorologist'. Recently, Katharine Anderson contrasted the Bergen School of dynamic meteorology and atmospheric thermodynamics to the earlier and much more comprehensive sphere of 'world meteorology' that had partly nurtured it. In particular, she offers two main examples: Napier Shaw's 'long involvement with the *Réseau Mondial*', the world network of meteorological stations, and Wladimir Köppen.[15]

World meteorologists such as Köppen and Shaw did not oppose the kind of focused thermodynamic modelling that later became the Bergen School of Vilhelm Bjerknes, Tor Bergeron and Jacob Bjerknes. Quite to the contrary, as my article will show, they played a vital role in making this influential school of dynamical meteorology possible, by offering data sets, critical support and most of all its infrastructure of observatories and academic expertise. At the same time, as Anderson has demonstrated, Shaw, Köppen and others worried about what the

[13] Following Kapil Raj, go-betweens have a crucial function in the development of modern science. Kapil Raj, "Go-Betweens, Travelers, and Cultural Translators," in *A Companion to the History of Science*, ed. Bernard Lightman (Chichester: John Wiley & Sons, 2016), 39–57, 44. Building on the German sociologist Georg Simmel, Raj distinguishes 'wanderers' from 'strangers': the first comes and goes, the second comes and stays. Meteorology was not only constructed by wanderers such as Alexander von Humboldt or Vilhelm Bjerknes, but maybe even more so by strangers such as Köppen, Jacob Bjerknes or Carl-Gustaf Rossby, the Scandinavians who brought the Bergen School to the United States. Of course, there is a large grey zone between wanderers and strangers. Rossby died in Sweden. For more on Rossby, see: Fleming, *Inventing Atmospheric Science*.

[14] Wladimir Köppen, 'Wärme und Pflanzenwachsthum', *Bulletin de la Societé Impériale des Naturalistes de Moscou*, 43.3&4 (1870), 41–110.

[15] Katharine Anderson, "Marine Meteorology: Observing Regimes and Global Visions, 1918-1939," in *Soundings and Crossings. Doing Science at Sea, 1800-1970*, ed. Katharine Anderson and Helen Rozwadowski (Sagamore Beach MA: Science History Publications, 2016), 213–244.

Norwegian modelers were to abandon. Instead of studying the atmospheric interactions and meteorological phenomena of the globe as a whole, the Bergen School meteorologists focused 'on the collection of wind and temperature data within a tightly defined region, and interpreted through thermodynamic models of lines of convergence and fronts.'[16]

However, Köppen played an important role too in the meteorological studies of dynamical weather patterns in the upper atmosphere. It was Köppen who proposed the name 'aerology' for studies of the upper atmosphere in 1906, during a meeting of the International Commission for Scientific Aeronautics in Milan.[17] Köppen's new name capitalized on the recent designation of a new layer in the atmosphere by the Frenchman Leon Teisserenc de Bort together with Assmann: the stratosphere.

Köppen saw himself above all as a reformer. He himself wrote in 1909 that both the 1860s and the 1890s had seen important revolutions in the history of meteorology, in which he himself had played a large role in making Germany catch up with the rest.[18] He presented aerology as the fifth and possibly final phase in the progressive history of 'land meteorology', a phase which had started in the 1890s. According to Köppen, a first 'age of legends' had lasted from Babylonian to early modern times, followed by an era of quantification (1643-1817). Then came the periods of climatology (1817-1855) and synoptic meteorology (1855-1893). Gradually, land meteorology had increasingly connected to maritime meteorology and its science of storms.[19] According to Köppen, instruments and technologies had provoked these revolutions: barometers, isothermic maps, daily weather maps, weather kites and unmanned balloons. Balloons and kites had brought the third dimension of altitude and what would turn out to be a layered atmosphere into mapping global weather.

Köppen also was also reflective about financial resources. To his joy, in recent history the German state had finally followed where private American and French money had originally taken the lead. In the field of synoptic meteorology, Germans had only caught up decades later, with the establishment of the *Seewarte*. Now, Köppen was more confident about the important role of Germany in aerology.[20] Of course, his model above all legitimated the way he had innovated the field of meteorology himself. He had worked on climate statistics in the 1850s, exported the daily weather map from the Russian Empire to Imperial Germany in the 1870s and 1880s, and finally adopted weather kites around 1900. After that he had used his position at the Maritime Observatory to bring the new three-dimensional meteorology outside Europe, in order

[16] Ibid.
[17] Frederik Nebeker, *Calculating the Weather: Meteorology in the 20th Century* (San Diego: Academic Press, 1995), 48; Hugo von Hergesell, "The Development of Aerology. A Retrospect and a Glance into the Future," *Quarterly Journal of the Royal Meteorological Society* 53 (September 10, 1927): 78.
[18] Köppen, "Wissenschaftliche Luftschiffahrt," 105–106.
[19] Köppen, "Die Wechselwirkung," 19.
[20] Köppen, "Wissenschaftliche Luftschiffahrt," 105–106.

to connect maritime and continental meteorology. To do this, he used the 'free atmosphere' as a bridge.

Before analyzing the construction of meteorology as a discipline in imperial German discipline through Köppen's work, it is necessary to disentangle and recombine the twin pillars of this discipline: the German state and the German-speaking world.

The German state

Germany and the German-speaking world are somewhat underrepresented in the Anglophone histories of dynamic meteorology, climate science and atmospheric physics.[21] Although some historians have referred to the role of German meteorologists in designating the stratosphere in 1902 and establishing important meteorological institutes, they do so always in the context of other developments, such as the analysis of Germany's national culture of balloonists, or in the background of Vilhelm Bjerknes and Bergen School in dynamic meteorology.[22] However, recently, Mott Greene's biography of Alfred Wegener has created momentum for a more structural analysis of German aerology as a key field in the reformations in global meteorology: Wegener played a large role in the German academic landscape of 'cosmic physics' and ballooning.[23]

In the decade before the Great War, Germany played a key role in the new science of atmospheric physics because of its investment in a dense network of stations for unmanned balloons and kites. Between 1900 and 1914 several German state agencies started investing in global weather balloon ascents. The German navy invested in expeditions, a global network of measuring stations and a kite station near Hamburg. At the new meteorological institute of the Alsace *Reichsland* in Strasburg, the president of the International Committee of Scientific Aeronautics, Hugo Hergesell, coordinated international balloon ascents. He worked closely together with the Prince of Monaco on his ship the *Princesse Alice*, joined by the French and Italian navies; and in 1905 the Emperor Wilhelm II chartered the Royal Prussian Aeronautical Observatory under the directorship of Richard Assmann, who had emerged as an important figure in the Berlin campaigns for scientific ballooning in the 1890s.[24]

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[21] As are France and Soviet Russia, but I will leave this to others. For a German language overview of climate science, see: Matthias Heymann, "Klimakonstruktionen," *NTM* 17 (2009): 171–197.

[22] Sabine Höhler, *Luftfahrtforschung und Luftfahrtmythos: wissenschaftliche Ballonfahrt in Deutschland, 1880-1910* (Frankfurt am Main; New York: Campus, 2001); Friedman, *Appropriating the Weather*. Also, see footnotes below.

[23] Greene, *Alfred Wegener*.

[24] B. Tinz and G Rosenhagen, 'Archiv der überseeischen Stationen der Deutschen Seewarte', *ProMet. Meteorologische Fortbildung*, 37.1/2 (2011), 53–61; Alfred De Quervain, 'Über die Bestimmung der Bahn eines Registrierballons am internationalen Aufstieg vom 2. Juli 1903 in Strassburg', *Beiträge zur Physik der Freien Atmospäre*, 1.1 (1904); Richard Assmann, *Der Königlich Preussische Aeronautische Observatorium Lindenberg* (Braunschweig: Friedrich Vieweg & Sohn, 1915).

German weather ballooning was a form of Bismarckian *Realpolitik* that evolved into Wilhelmine *Weltpolitik*. he initiative did not only come top-down but was also the result of a global mindset of German institutions[25] enthusiastically taking up and expanding the politics and directives of unification and colonialism that emanated from Berlin. Scientists lobbied for national institutes on the level of the *Reich*, institutes that moved beyond the role usually taken up by the smaller state-based academies and *hilfswissenschaftliche Institute* ('assisting science institutes' such as observatories, gardens and collections) in the margins of German research university. After the unification of Germany, Bismarck supported scientific institutes that could help create legal structures for the *Reich* superseding the member states and the individual universities, such as the *Reichsgesundheitsamt* [Imperial Health Department] in 1870, the *Statistische Reichsamt* (1872), the *Monumenta Germaniae Historiae* 1886) and the *Physikalisch-Technischen Reichsanstalt* (1887).

With the *Reichsanstalt*, Germany also became an important global player in the standardization of instruments, with far reaching possibilities of imperial control; science, state and industry became more effective in coordinating their research agendas. In the board of the institute not only members of the government, the Army and the Navy took part, but in it meteorological instrument makers such as Rudolf Fuess collaborated with meteorologists such as Neumayer and Von Bezold: all three of them were board members of the *Reichsanstalt*. As a consequence, German meteorologists in Lindenberg and Berlin focused heavily on instrument-based research-technologies.[26] As Helmut Trischler has also shown, in a study on scientific aeronautics in general and engineering in particular, the supporting role of the German state and especially the military was pivotal in the development of twentieth century aviation research.[27] In this article the focus will be on the Navy; but the Army was a also large benefactor of aeronautics.

For the field of meteorology the year 1875 was crucial, when the *Norddeutsche Seewarte* [North German Maritime Observatory], financed by Hamburg and Bremen Chambers of Commerce, only three years old, became re-established as the *Deutsche Seewarte,* now as an imperial institute paid for by the Empire. Under Wilhelm II as emperor (1888-1918) these institutes became instruments for global expansion and he added many more scientific institutes, with the Kaiser Wilhelms Gesellschaft as its most famous legacy, but for meteorology especially

[25] On institutional agency, see: Mary Douglas, *How Institutions Think* (Syracuse NY: Syracuse University Press, 1986).
[26] Cahan, *An Institute for an Empire*, 75-76; Terry Shinn, *Research-Technology and Cultural Change* (Oxford: Bardwell Press, 2008). See also the many instruments in: Assmann, *Königlich Preussische Aeronautische Observatorium Lindenberg.*
[27] Helmuth. Trischler, *Luft- und Raumfahrtforschung in Deutschland: 1900-1970. Politische Geschichte einer Wissenschaft* (Frankfurt am Main: Campus, 1992).

important was the foundation of the Aeronautical Observatory under the emperor's patronage, the flagship of the new aerology.[28]

But the German culture of national science was also a bottom-up culture, in dialogue with top-down politics. Sabine Höhler has already demonstrated the surge in scientific ballooning in Germany between 1880 and 1910. According to her, this surge was the product of a culture of imperialism and nationalism organized from 'below', an alliance of national myth-making between individual scientific 'Daedalus-figures' on the one hand and a bourgeois culture of aeronautical societies on the other.[29] Höhler expanded Peter Fritzsche's notion of Germany as a 'nation of fliers' in the first three decades of twentieth century, a culture that produced Zeppelins and hang glider cults.[30] Although Höhler's focus on the importance of society and culture is vital for understanding the development of a German scientific lobby for meteorological ballooning, this article wants to bring back the imperial state in the global diplomacy of meteorological 'aeronautics', or to be more precise, the new global science of 'aerology'.[31] German meteorologists played a significant role in international committees that legitimized state institutes of science. Scientists in the International Meteorological Congresses and its aeronautics committees did not represent universities but national institutes.

The German-speaking world

However, these national institutes had freely exchanged German-speaking scientists with different kinds of historical affiliations. Existing national histories have not, however, been able to fully explain the international commitment of German scientific ballooning and its role in

[28] Georg Schreiber, *Deutsche Wissenschaftspolitik von Bismarck bis zum Atomwissenschaftler Otto Hahn*, Arbeitsgemeinschaft für Forschung des Landes Nordrhein-Westfalen. Geisteswissenschaften (Cologne & Opladen: Westdeutscher Verlag, 1954), 26–27. More on German science policy and academic disciplines: Peter Lundgreen et al., *Staatliche Forschung in Deutschland* (Frankfurt am Main: Campus Verlag, 1986); David Cahan, *An Institute for an Empire: The Physikalisch-Technische Reichsanstalt, 1871-1918* (Cambridge & New York: Cambridge University Press, 1989); Timothy Lenoir, *Instituting Science: The Cultural Production of Scientific Disciplines* (Stanford CA: Stanford University Press, 1997).

[29] Höhler, *Luftfahrtforschung und Luftfahrtmythos*, 33; 298.

[30] Peter Fritzsche, *A Nation of Fliers. German Aviation and the Popular Imagination* (Cambridge MA: Harvard University Press, 1992); Christoph Rosol, "Rotoren und Leewellen. Figuren der (In-)Stabilität Um 1937," *iLinx. Berliner Beiträge zur Kulturwissenschaft*, no. 1 (2010): 71–97.

[31] Theda Skocpol, "Bringing the State Back in: Strategies of Analysis in Current Research," in *Bringing the State Back in*, ed. Peter B. Evans, Dietrich Rueschemeyer, and Theda Skocpol (Cambridge & New York: Cambridge University Press, 1985), 3–43. More on nationalism, international committees and discipline building: Robert-Jan Wille, "Stations and Statistics. Paulus Hoek and the Transnational Discipline of Ocean Biology," in *Soundings and Crossings. Doing Science at Sea, 1800-1970*, ed. Katharine Anderson and Helen M. Rozwadowski (Sagamore Beach MA: Science History Publications, 2016), 179–212.

international commissions. They explain why German scientists wanted to compete with Britain, but not why they also chose to collaborate.[32]

What does explain Germany's international commitment is its imperial dimension, not just Germany's colonial ambitions, but also Germany's place in the European balance of imperial powers and Germany as Europe's academic powerhouse. Not only did many students from neighboring countries go to study in Germany, but groups of German-speaking scientists who used to work for other empires were more and more drawn in, for now they had another ambitious empire to work for.[33] Germany became the stage for multi-national science workers.

Of course, between the Congo Conference of 1884 and the First World War, Germany had a colonial empire, but even before Bismarck's 'Scramble for Africa' and even before his unification of Imperial Germany, Germans had formed part of a global scientific network of ethnic Germans and German-speaking scientists from Russia to South America and from the North Pole to Africa. By 1850, the community of German meteorologists had already become a community with a global outlook, maybe even more due to Germans travelling between the central European empires and the Americas in the nineteenth century than due to earlier research in the British and Dutch colonies.

Indeed, many German-speaking scientists had worked for the older sea-based empires in the Early Modern Age. But even ignoring the many Germans that worked in the maritime empires of the Dutch and British in the seventeenth, eighteenth and nineteenth centuries[34], many were also actively helping the geographical and scientific expansion of the great land empires after 1800, old and new. Of course, Austria-Hungary was such an empire, and the scientific imperialism of the Habsburgs inspired Germans working in Prussia, Bavaria and the smaller German states in the north.[35]

These were not just empires in Europe. While German-speaking scientists worked for the expansion of Russia in the nineteenth century, others helped the new state of Argentina research, conquer and battle the 'deserts' and violently bring under state control the natives of Patagonia in

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[32] Kärin Nickelsen and Fabian Krämer, "Introduction: Cooperation and Competition in the Sciences," *NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin* 24, no. 2 (2016): 119–123.

[33] For a global history of the nineteenth century with a large role for the German-speaking world as a center of academic expertise, but with an emphasis on its *export* instead of import, see: Jürgen Osterhammel, *The Transformation of the World. A Global History of the Nineteenth Century* (Princeton: Princeton University Press 2015). For a recent article on meteorology and climatological data collecting as a form of state and nation building in Switzerland (in the context of its neighboring countries), and for more about the Swiss meteorologist in Russia Heinrich Wild, see: Franziska Hupfer, "Ein Archiv für Wissenschaft, Staat und Nation. Klimatologische Datenpraktiken in der Schweiz, 1860-1914", *NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin* 25, no. 4 (2017): 435 – 457.

[34] Thomas Biskup and Martin Kohlrausch, "Germany: 2. Colonial Empire," *The Encyclopedia of Empire*, 2016, 1–16, 3.

[35] See for example Coen, *The Storm Lab*, 479.

the *Conquista del Desierto* between 1878 and 1885.[36] Some of these German-speaking scientists would move back to Germany, and many of them corresponded with scientists there. For German scientists in the nineteenth century, competition or cooperation were in the end just co-existing modes of reproduction of global knowledge. Some felt that Germany's mission was to become a global center of academic accumulation and to bring academic technocracy to the globe, whether it was through peaceful and transnational cooperation, or through wars and competitive statecraft. Köppen was one of them, although he preferred the mode of international cooperation.

Between state, reform and statistics: a German Russian from Russia to Germany

Köppen exemplified the global German scientific explorer-bureaucrat because he himself came from a family of travelling technocrats. He was born in 1846 in St. Petersburg. His grandfather had been a German doctor reorganizing the Charkov state health department under Czarina Katharina II; his father worked for the state's Domains, worked in statistics, ethnography and archaeology, and he was a member of the Petersburg Academy of Sciences. Together with a group of other scientists, military officers and civil servants, among them many Baltic Germans[37], Peter von Köppen had founded the Russian Geographical Society in 1845.[38] Wladimir later wrote that he had been raised by a *Russian* patriot in a *German* house; he spoke Russian, German, French and Tatar fluently, with a family house on the Krim, where his father had done geographical and statistical field work.[39]

The Köppen family adhered to an ideology of liberal reform and national unity.[40] Because of the Russian reform movement in the 1860s, his father acknowledged his son's wishes to study the natural sciences, because 'Russia will have need of natural scientists' to 'exploit its natural riches', and Wladimir was first sent to St. Petersburg to study, at the university.

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[36] Pedro José Depetris, "Las Ciencias de la tierra en la FCEFyN: breve historia de la investigación científica," *Revista Faculdad de Ciencias Exactas, Fisicas Y Naturales* 1, no. 1 (2014): 99–111.

[37] Such as the zoologist Karl Ernst von Baer, the astronomer Friedrich Georg Wilhelm Struve and the admiral-explorer Adam Johann von Krusenstern

[38] The Geographical Society was an organization that united the opposition to the Vienna Congress conservatism Czar Nicholas I and united the forces of progressive nationalism, both panslavic Russians and reform-oriented Baltic Germans in coordinating and expanding the scientific exploration of Russia, a country large enough to turn studying national geography into the study of global climates. For more on the society's history, tensions between the Baltic Germans and the panslavic Russians, and the exploration of Siberia, see: Mark Bassin, "The Russian Geographical Society, the 'Amur Epoch,''and the Great Siberian Expedition 1855–1863," *Annals of the Association of American Geographers* 73, no. 2 (June 15, 1983): 240–256.

[39] Else Wegener-Köppen, *Wladimir Köppen. Ein Gelehrtenleben für die Meteorologie*, Grosse Naturforscher (Stuttgart: Wissenschaftliche Verlagsgesellschaft M. B. H., 1955), 20–23.

[40] He himself thought himself lucky to have lived in two *begeisterungsreiche Zeiten*, 'spirited times'. The first was the period of Russian reforms between 1860 and 1864, under Czar Alexander II, in the aftermath of the lost Crimean War, with the abolishment of serfdom and significant reforms of education, government and the legal system. The second was the unification of Germany under Bismarck between 1867 and 1870. Ibid., 17.

However, Köppen had to learn to value meteorology as an interesting technocratic field in itself first. After the death of his father, his older brother Theodor sent Wladimir to Germany to study in Heidelberg, and after visiting the meteorologist Julius von Hann in Vienna, he started to study zoology and botany with Wilhelm Hofmeister, because he feared that his meteorology was a *schädliche Liebhaberei*, a 'harmful hobby'. He later realized however that through his meteorology he had learnt to practice 'the mathematical method', which he had used as a *Hebel*, a 'lever' for the 'progress' of the other sciences, and especially his plant physiological dissertation.[41]

Because of his family home in the Krim, Köppen had learnt to appreciate the climate differences in Russia which were 'larger than in the West of Europe'. Together with his father and his siblings, Theodor and Natalie, he took meteorological measurements at home and studied plant and animal life. His sister Aline married the director of the Imperial Acclimatization Garden in Jalta, not far from home.[42] In Heidelberg, Köppen first focused on biological and geological studies and only in the margins of his studies did he write a few first meteorological articles (on Crimean weather or rainfall in the Heidelberg region, for example) in the *Zeitschrift der Österreichischen Meteorologischen Gesellschaft* (hereafter the *Zeitschrift*), thanks to the connections he had made during his Vienna visit. As a typical German student, he travelled to other German cities for additional *Bildung*, including Leipzig, where he studied with the developmental zoologist Rudolf Leuckart.

In his 1870 dissertation he studied the relationship between plant development and warmth, focusing on maize, wheat, peas, broad beans and lupins. Thus, he was able to combine his own interest in meteorology with the new plant physiology made popular by German botanists such as Julius Sachs[43] Köppen wanted to answer 'questions plant geographers ask plant physiology': the interaction between organism and environment, questions that would later be taken up by German colonial botanists and ecologists.[44] In the 1860s, Charles Darwin, the laboratory, instrumental precision and statistical technologies had created a culture of exchange between the natural sciences, the life sciences and meteorology. In that decade Darwin's half-cousin Francis Galton moved from weather maps to the study of life, but Köppen went the other way.[45]

In 1872 Köppen published a long article in the St. Petersburg Academy journal *Repertorium der Meteorologie*, in which he used laws of probability of specific weather types,

[41] Ibid., 27–37.
[42] Ibid., 24–26.
[43] Köppen, "Wärme Und Pflanzenwachsthum."
[44] Köppen, "Wärme und Pflanzenwachsthum," 42; Eugene Cittadino, *Nature as the Laboratory: Darwinian Plant Ecology in the German Empire, 1880-1900* (Cambridge: Cambridge University Press, 1991).
[45] Nicholas W. Gillham, *A Life of Sir Francis Galton: From African Exploration to the Birth of Eugenics* (New York, N.Y.: Oxford University Press, 2001), 140–151.

based on past weather. Köppen's work was praised for its effort to tackle a challenging new field, connecting data for the benefit of weather prognostication, and an excerpt was published in the *Zeitschrift*.[46] Having returned to Russia in 1872, he wrote to Heinrich Wild, the Swiss director of the St. Petersburg Central Observatory, inquiring for positions. Wild gave him a job as assistant.

An alliance between empires: the Vienna international conference of 1873

Put in charge of the meteorological library, Köppen learned to create synoptic weather maps, the daily production of which started in 1873.[47] In the same year he accompanied Wild as the Russian delegate to the first International Meteorological Congress in Vienna, organized by Wild, the Austrian meteorologist Karl Jelinek in Vienna and the German meteorologist Carl Bruhns in Leipzig, a follow–up to a meeting between the Russians, Germans and Austrians held in Leipzig in 1872.

This alliance between the meteorological institutes of the large land-based empires mirrored the international shifting balance of power of that time. In the same year that the meteorologists assembled at Vienna, Bismarck formed the *Dreikaiserabkommen*, a treaty that later resulted in a league (*Bund*) between the three emperors Wilhelm I of Germany, Alexander II of Russia and Franz Joseph of Austria-Hungary. Only two years before, after the defeat of France and the German unification in Versailles, Wilhelm had been elevated from king to emperor. As his chancellor, Bismarck now tried to rebalance Europe around a new and more powerful German Empire.[48]

In the same way, meteorologists from Leipzig, Vienna and St. Petersburg unified a fragmented landscape of German, Austrian and Baltic German meteorologists, but did so under the flag of international cooperation instead of German power play.

To Vienna came representatives of state meteorological observatories from the whole of Europe, including the Ottoman Empire. Furthermore, the United States and China were represented by a delegate. Only France was notoriously absent; French scientists in this period

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[46] Wladimir Köppen, 'Die Aufeinanderfolge der unperiodischen Witterungserscheinungen nach der Wahrscheinlichkeitsrechnung untersucht', *Meteorologicheskii Sbornik - Repertorium für Meteorologie*, 2 (1872), 187–238; Wladimir Köppen, 'Auszuge aus die Aufeinanderfolge der unperiodischen Witterungserscheinungen nach der Wahrscheinlichkeitsrechnung untersucht', *Zeitschrift der Österreichischen Gesellschaft für Meteorologie*, 7.22 (1872), 369–75. This article was also noticed by Nebeker, *Calculating the Weather: Meteorology in the 20th Century*, 44.

[47] Wegener-Köppen, *Wladimir Köppen*, 44; Napier Shaw, *Manual of Meteorology 1. Meteorology in History* (Cambridge: Cambridge University Press, 1942), 287.

[48] The classic texts here are: Golo Mann, *Deutsche Geschichte des 19. und 20. Jahrhunderts*, 13th ed. (Frankfurt-am-Main: Fischer Taschenbuch Verlag, 2011), 455; Hajo Holborn, *A History of Modern Germany: 1840-1945*, 2nd ed. (Princeton N.J.: Princeton University Press, 1982), 237.

were actively avoiding the German-speaking community after the Franco-Prussian war of 1871.[49] However, the 'enormous British Empire' (in the words of Köppen) was underrepresented as well. Only two meteorologists came, the Scottish Alexander Buchan of Edinburgh and the director of the Meteorological Office, the Irish Robert Henry Scott.[50] Scott himself was not a stranger to Germany: he had studied chemistry and meteorology among others with Heinrich Dove in Berlin and Justus von Liebig in Munich. Another meteorologist with a German background was Johan Friedrich Julius Schmidt who represented the observatory at Athens. From the 31 official delegates, seven each came from the German Empire and Austria-Hungary. Along with the UK, Italy and Belgium also sent two meteorologists each.[51]

Thus, although Alexander von Humboldt had written most of his works in French in the first half of the century, the geopolitics of international meteorology became more and more written and practiced in German. This was a remarkable change in the balance of power; more than twenty years earlier, in 1853, the first international conference on maritime meteorology had been organized in Brussels by Western powers (American, British, Belgian and Dutch naval officers and scientists) and although it was visited by Russians and Scandinavians, neither German nor Austrian meteorologists take part.[52] It had partly to do with the distinct communities of maritime and land-based meteorology, but as they were merging, these communities were also fighting for ascendancy within meteorology as a whole.

In Vienna, the focus was more on the land than on the sea, and the land-based empires dominated. However, just as in other spheres of diplomacy, the balance would shift back again. Christophorus Buys Ballot from the Dutch Royal Meteorological Institute in Utrecht, active behind the curtains of the organization of 1853 and very vocal at the Vienna Conference, had proposed in advance a series of observation stations in distant areas and also a central office for the exchange of publications; his proposal was not adopted but would become a *Leitmotiv* for the next decades.[53] Buys Ballot represented the maritime wing of the international community.

Christophorus Buys Ballot was not the only one to propose an international plan. In Vienna, Wild suggested that 'in order to investigate the weather phenomena of the higher strata of the atmosphere, more numerous observations should be made on isolated mountain peaks, as

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[49] *Report of the Proceedings of the Meteorological Congress at Vienna. Protocols and Appendices. Translated from the Official Report* (London: Her Majesty's Stationery Office, 1874).
[50] Wegener-Köppen, *Wladimir Köppen,* 45.
[51] One was sent by Norway, Sweden, Denmark, the Netherlands, Switzerland, Spain, Portugal, Greece, China, Russia and the United States. Next to the official guests were the visitors: all of them Austrians, except for Köppen and August Petermann from the Justus-Perthes publishing house in Gotha, Germany.
[52] Azadeh Achbari, "Building Networks for Science: Conflict and Cooperation in Nineteenth-Century Global Marine Studies," *Isis* 106, no. 2 (June 2015): 257–282; Azadeh Achbari, Rulers of the Wind. How Academics Came to Dominate the Science of Weather, 1830-1870 (Dissertation Free University of Amsterdam, 2017), 57-64. See also Kevin Donnelly's contribution to this issue: "Redeeming Belgian Science: Periodic Phenomena and Global Physics in Brussels, 1825-1853," *History of Meteorology* 8 (2017): 54–73.
[53] *Report of the Proceedings*, 38, 49; Edwards, *A Vast Machine*, 53.

well as in captive balloons', a proposal which everyone could agree on and which was adopted right away.[54] However, it would take another twenty years before international coordination of scientific ballooning would take place. Other Russians had plans too. Wild's assistant Mikhail Rykachev came that year with an eight-points plan of coordinating international data, including the establishment of balloon stations. The editors of the *Zeitschrift* thought his last point on balloons so important that it added a footnote prioritizing this.[55]

More striking was that in the beginning of the year Köppen himself had also presented a plan in that journal, proposing the foundation of an International Meteorological Institute, most likely in the Netherlands, a small, neutral and 'advanced' country, where life was cheaper than in England and the location central. European countries then needed to build more than 200 observation stations, with European Russia alone signing up for one hundred. This was clearly the plan of a too ambitious young idealist, and the conference members chose to focus on other plans.[56]

It was Buys Ballot's plan that had a bigger afterlife. He became the president of the next foundational meeting in Utrecht of the International Meteorological Committee, after which Wild became president and Scott secretary of the Committee. During the meeting of 1879 the Committee became permanent and an International Polar Year was organized at the instigation of the Austrian naval officer Karl Weyprecht, with the Austrian Navy establishing itself as a colonial power in the Arctic. Through Austria, the sea came back with a vengeance, although the conference also saw Hann pleading for building chains of mountain stations, as better alternatives to Wild's balloons.[57] Parallel to this development, Imperial German meteorology would soon move from a fragmented and state-based orientation on land meteorology, with all its observatories before 1870 inland, towards a more expansive policy of coastal meteorology, following the establishment of the *Seewarte*.[58]

In 1875 Georg Neumayer (who only became *Von* Neumayer in 1900), who had visited Vienna as the official hydrographer of the German Navy, but who had travelled all over the world focusing on terrestrial magnetism and had even worked in Australia, became the new director of the German Maritime Observatory.[59] He asked Köppen, whom he had met in Vienna and was already 'gloriously known' (*rühmlichst bekannt*), to come and join him there.[60] Köppen

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[54] *Report of the Proceedings*, 58.
[55] Mikhail Aleksandrovich Rykachev, "Weitere Fragen zur Verhandlung für den Meteorologen-Congress zu Wien," *Zeitschrift der Österreichischen Gesellschaft für Meteorologie* 8, no. 13 (1873): 193–203.
[56] Wladimir Köppen, "Über die Errichtung eines Internationalen Meteorologischen Institutes. Vorschlag an den Wiener Meteorologischen Congress," *1873* 8, no. 2 (1873): 17–26; Wegener-Köppen, *Wladimir Köppen,* 46.
[57] Coen, "The Storm Lab," 469.
[58] Barr and Lüdecke, *The History of the International Polar Years (IPYs)*.
[59] W. Schröder, K. H. Wiederkehr, and K. Schlegel, "Georg von Neumayer and Geomagnetic Research," *History of Geo- and Space Sciences* 1, no. 2 (2010): 77–87.
[60] Wegener-Köppen, *Wladimir Köppen,* 51–43.

already had a reputation: at that time he had published more than twenty meteorological and climatological articles in Russian and Austrian journals in his 'spare time'.[61] From 1876 onwards, he would be responsible for the daily synoptic weather map of Imperial Germany.[62]

The *Seewarte*: a new German center for meteorology

The Seewarte was founded as a *Centralstelle* that serviced the whole of the German Empire with gathering data and doing scientific studies benefiting maritime meteorology (the first department), meteorological instruments (the second department) and storm warnings.[63] In the first years Köppen was active in gathering meteorological data, constructing weather maps and directing the third department for storm warnings.[64] Right from the beginning the Observatory recognized the importance of international networks, meetings and cooperation: the Germans worked together with the Dutch and Danish navies in making and exchanging data. A Danish series of daily charts of the Atlantic now became a dual German-Danish project that would last until the First World War.[65] The director and his staff members would report from visits to different formal and informal conferences and publish these in the annual reports. Köppen attended many of these meetings.[66]

In 1879 Köppen was promoted to the Observatory's leading meteorologist, and from that time on Köppen had more space to expand what he saw as a more *Wissenschaftliche* meteorology. It was a crucial year in German meteorology, because the second International Meteorological Conference in Rome produced a formalized organization, in which Neumayer took over from Bruhns the position of member in the International Committee, moving meteorological leadership from Leipzig to Hamburg. In the same year, the eminent Humboldtian Heinrich Wilhelm Dove of Berlin died, an important German meteorologist in the 1840s but a conservative factor in the 1870s, according to many of his contemporaries.[67] Because it would take until 1885 until a permanent successor was found for Dove, and because Dove had been suffering with health problems from the early 1870s, Hamburg took over the German initiative.

Was Hamburg a center of national renewal? After a visit of Köppen in 1875, Dove had told him he would gift his library to the Observatory, but Köppen used his new position to

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[61] Ibid., 160–161.: Georg Neumayer, 'Erster Jahresbericht über Organisation und Thätigkeit der Deutschen Seewarte, umfassend den Zeitraum vom 1. Januar 1875 bis Schluss des Jahres 1878', *Aus dem Archiv der Deutschen Seewarte*, 1.1 (1878), p. 6.
[62] Shaw, *Manual of Meteorology 1*, 287.
[63] Neumayer, "Erster Jahresbericht," 4–10.
[64] Wegener-Köppen, *Wladimir Köppen,* 50.
[65] Shaw, *Manual of Meteorology 1*, 166.
[66] Neumayer, "Erster Jahresbericht," 10.
[67] Georg Neumayer, "Zweiter Jahresbericht über die Thätigkeit der Deutschen Seewarte für das Jahr 1879," *Aus dem Archiv der Deutschen Seewarte* 2, no. 3 (1879). See also Achbari, Rulers of the Winds.

challenge Dove's mechanical theory of wind directions.[68]. For Dove wind direction formed the most important factor in weather characteristics, and he had therefore not needed synoptic charts, and extrapolated the weather from local measurements. [69]

However, this image ignores the important groundwork in meteorological cartography that was lead in the 1880s and 1890s by Köppen, his fellow staff members at the *Seewarte* and contemporaries such as Hann; Köppen was by far not the only one aiming at moving synoptic meteorological map-making to frontstage. However, from his unique position at the *Seewarte* Köppen was able to work hard to put Germany on the map as a major power in meteorology in these decades. He played a major and decisive role in the foundation of the *Deutsche Meteorologische Gesellschaft*, the German Meteorological Society in 1883, as a consequence of the responsibilities taken up by the Germans in the International Polar Year. Until 1889, the society would be based at the *Seewarte* in Hamburg, after which it would move to Berlin.[70]

In this decade with Hamburg as Germany's meteorological center, Köppen himself would try to combine all the different meteorologies that existed at that time, publishing 200 articles in the next 25 years and monographs in synoptic meteorology, climatology, cloud studies, atmospheric circulation above the oceans, cyclone dynamics, plant geography and maritime meteorology; from 1905 to 1940 he would write another 300. Most of his articles were written for two journals: the half of it appeared in the *Meteorologische Zeitschrift*, the successor to the Austrian *Zeitschrift,* now aimed at the whole German-speaking world, of which he became editor in the year of its foundation, together with Julius von Hann, and another third appeared in the Maritime Observatory's own *Annalen der Hydrographie und Maritimen Meteorologie*.[71]

His most important monographs in this period were the 1890 *Cloud Atlas* under the auspices of the International Meteorological Conference, edited together with the Swedish Hugo Hildebrand Hildebrandsson and Neumayer, the 1899 handbooks *Klimalehre* and *Grundlinien der maritimen Meteorologie*, and his two attempts in 1884 and 1900 at a map classifying the world's

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[68] Köppen, "Wissenschaftliche Luftschiffahrt," 105; Wegener-Köppen, *Wladimir Köppen,* 47–54; Gisela Kutzbach, *The Thermal Theory of Cyclones: A History of Meteorological Thought in the Nineteenth Century* (Boston: American meteorological Society, 1979). More on Dove and earlier attacks by Buys Ballot, see: Azadeh Achbari, Rulers of the Wind, 119-177.

[69] This resistance against synoptic maps has become a topic in the history of meteorology, a topic Köppen would contribute to himself. According to Köppen, through Dove meteorology and especially German meteorology had entered a phase of stagnation. Later propagators of the Bergen School extended this phase of stagnation to the 1880s and 1890s in their own accounts of the history of meteorology: only after 1900, when aerological measurements became less sporadic, did meteorology progress again. Tor Bergeron, "Methods in Scientific Weather Analysis and Forecasting. An Outline in the History of Ideas and Hints at a Program," in *The Atmosphere and the Sea in Motion. Scientific Contributions to the Rossby Memorial Volume*, ed. Bert Bolin (New York & Oxford: The Rockefeller Institute Press & Oxford University Press, 1959), 451–452.

[70] Cornelia Lüdecke, "Gründung der Deutschen Meteorologischen Gesellschaft (Ära Neumayer 1883-1889)," in: Gerd Tetzlaff, Cornelia Lüdecke, and Hein Dieter Behr, eds., *125 Jahre Deutsche Meteorologische Gesellschaft. Festveranstaltung am 7. November 2008 im Hamburg* (Offenbach: Deutscher Wetterdienst, 2008), 41-47.

[71] Wegener-Köppen, *Wladimir Köppen,* 160–193.

climates combining quantitative meteorology and plant geography, a 'map of maps'.[72] Köppen accumulated data, statistics, maps and subdisciplines to create a multidimensional synoptic meteorology. Later, in the 1920s, retired and living in the Austrian university city of Graz where his son-in-law Alfred Wegener worked, he would with the same mentality absorb Wegener's theory of shifting continents into the new field of paleoclimatology.

Mapping storms and plants

In Hamburg Köppen developed a third-dimensional look on weather in the process of extending the two-dimensional cartographical method. One of the first important transcontinental synoptic maps he made in 1881 was based on years of data (1873-1879), collected by him or collected and published earlier by, among others, American and Danish meteorologists, on monthly barometric minima and its *Zugstrassen* (a term derived from the American 'tracks of movement'), a term still used today, although his fellow coworker Wilhelm Jacob van Bebber later also used the term *Zyklonbanen* or 'cyclonic paths'. This map encompassed the whole North Atlantic and the half of the neighboring continental masses, from the Rocky Mountains (*Felsengebirge*) to the Ural Mountains.[73] It combined synoptic meteorology with a thermal theory of storms, with the arrows as an extra interpretive layer over a continental plotting of barometric minima obtained by a form of extensive data crunching that was reserved for state bureaucracies or commercial cartography firms.

Köppen's maps were appreciated by eminent meteorologists. His map was used in Hann's *Meteorologischer Atlas*, a series of maps published in the third edition of the renowned *Berghaus Physikalischer Atlas*, together with another of his maps of rainfall areas in the world which resulted from his climatological map project.[74] Hann preferred Köppen's cyclonic path map to that of Van Bebber's. In general, Hann was impressed by the way German cartography had developed in the last decade, referring not only to the maps of the commercial publishing house of Justus Perthes, but also to that of institutes such as the Deutsche Seewarte, which also

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[72] Wladimir Köppen, "Die Wärmezonen der Erde, nach der Dauer der heissen, gemässigten und kalten Zeit und nach der Wirkung der Wärme auf die organische Welt betrachtet," *Meteorologische Zeitschrift* 1 (1884): 215–226; Wladimir Köppen, "Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt," *Geographische Zeitschrift* 6 (1900): 593-611-679. On German plant geography in the nineteenth century, see: Nils Güttler, *Das Kosmoskop: Karten und ihre Benutzer in der Pflanzengeographie des 19. Jahrhunderts* (Göttingen: Wallstein Verlag, 2014).

[73] Wladimir Köppen, "Die Zugstrassen der barometrischen Minima in Europa und auf den Nordatlantischen Ocean und ihr Einfluss auf Wind und Wetter bei uns," *Mitteilungen der Geographischen Gesellschaft in Hamburg* 4 (1881): 76–97; Wladimir Köppen, "Erläuterung zur Karte der Häufigkeit und der mittleren Zugstrassen barometrischer minima zwischen Felsengebirge und Ural," *Zeitschrift der Österreichischen Gesellschaft für Meteorologie* 17 (1882): 257.

[74] Julius von Hann, *Atlas der Meteorologie. Berghaus' Physikalischer Atlas, Abteilung III* (Gotha: Justus Perthes, 1887).

functioned as the national scientific naval cartography bureau.[75] Cartographic practice restructured meteorological thinking.[76]

Köppen was transformed by his map and atlas making process: it not only forced him to collect data more globally in pursuit of geographical symmetry, with areas that had seen either intensive or extensive data hoarding, but it also made him appreciate comparison as a visual tool.[77] Köppen referred to the clarity and symmetries maps create, especially the Humboldtian plant geography map of August Grisebach that appeared in 1867 in *Petermanns Geographische Mitteilungen* [*PMG*], a very Humboldtian journal, in which he saw all kinds of processes 'working together'.[78] His later, more complete and well-known climate classification map also appeared in *PMG*, after an attempt to publish his 1900 article there as well had failed.[79]

Köppen practiced the kind of Humboldtian science advocated by William Whewell and which was practiced by the British tidologist and others, such as Köppen's main inspirations Alfred Russel Wallace and Darwin: science progressed when inductions from different classes of knowledge 'jumped together'.[80] In the library of the *Seewarte* the works of Humboldt, Darwin, Wallace and Whewell were in the collection, from the latter both his many studies on tides as a volume of his *History of the Inductive Sciences*.[81]

Köppen did connect several 'classes of knowledge', but mostly he jumped together the many dimensions of meteorology itself. His meteorology and climatology went beyond the second dimension. First, it wanted more than just to map global climate and predict local weather: Köppen looked for mathematical theories of large systems, such as cyclones and other storms, to which he devoted the most of his articles, as did many of his contemporaries, including Hann.[82] Second, it wanted to go beyond the separation of land-based and maritime

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[75] Letters Julius von Hann to Hermann Berghaus, January 31st, 1885 (pages 67-68) and March 3rd, 1886, SPA ARCH MFV 19B/1 (nos. 108-109), Gotha Perthes Collection (GPC), Gotha Research Library (GPL). I wish to thank Nils Güttler for pointing me at the Hann collection and these letters particularly.

[76] Güttler, *Das Kosmoskop*. See also: Katharine Anderson, "Mapping Meteorology," in *Intimate Universality: Local and Global Themes in the History of Weather and Climate*, ed. James Rodger Fleming, Vladimir Jankovic, and Deborah R. Coen (Sagamore Beach MA: Science History Publications, 2006), 69–91.

[77] See also letters Wladimir Köppen to Hermann Berghaus, SPA ARCH MFV 19N/7 (nos. 108-109), GPC, GPL. Other letters, addressed to Alexander Supan, are in the Gustav Radde Collection, SPA ARCH PGM 026/2, GPC, GPL.

[78] Köppen, "Versuch," 41. More on printed maps changing the way scientists looked at their own field:Nils Güttler, "Scaling the Period Eye: Oscar Drude and the Cartographical Practice of Plant Geography, 1870s–1910s," *Science in Context* 24, no. 1 (February 3, 2011): 1–41.

[79] Wladimir Köppen, "Klassifikation der Klimate nach Temperatur, Niederschlag und Jahresablauf," *Petermann's Geographische Mitteilungen* 64 (1918): 193-203-248. See letter Wladimir Köppen to Alexander Supan, April 28, 1900 (no. 356), SPA ARCH PGM 026/2, GPC, GPL.

[80] William Whewell, *Novum Organon Renovatum, Being the Second Part of the Philosophy of the Inductive Sciences*, 3rd ed. (London: John W. Parker and Son, 1858), 88.

[81] See author index of *Katalog der Bibliothek der Deutschen Seewarte* (Hamburg: Hammerich & Lesser, 1890).

[82] Kutzbach, *The Thermal Theory of Cyclones*, 90, 150; Coen, "The Storm Lab," 469.

meteorology.[83] Third, it combined meteorology and climatology with the study of biology, geology and historical development.[84] In 1898, after starting his first kite experiments, the third dimension for Köppen became the study of the upper atmosphere, as an important 'layer' to study atmospheric circulation, a topic that was related to cyclogenesis.[85]

For Köppen cloud-atlases were different from meteorological maps, as they were not so much atlases demonstrating models, theories and data, but important instruments for measuring travelling clouds. They were the first global standardized tools for studying the upper atmosphere. According to an 1890 atlas 'observations taken at the bottom of the atmospheric ocean are plainly insufficient to determine its circulation'.[86] According to meteorologists such as Hann, circulation of the atmosphere at lower heights must be influenced by atmospheric movement at higher altitudes, especially because of the big temperature differences between the poles and the equator, but it was hard to observe circulation at higher altitudes. In 1888 Köppen had already written about the importance of air balloons, next to measuring the speed of cirrus clouds visible from the ground (for which a standardized terminology and an extensive network of telegraphs was needed), for studying the circulation of the atmosphere in temperate zones.[87] Others had picked up this theme too in the same year. Among them was Wilhelm von Bezold, the new director of the Royal Prussian Meteorological Institute in Berlin since 1885.[88] In the 1890s a new, more aggressive culture of scientific ballooning emerged in Germany, especially in Berlin and the larger cities of the south of Germany. In 1902 Köppen found a way to take part: his weather kites.

Joining Von Bezold's culture of scientific ballooning: a kite station

Von Bezold knew what to do: claim back the German pole position in meteorology from the *Seewarte*. Coming from Munich and being very interested in the atmospheric circulation above and around the mountains, he had made a pact with a new kind of 'shipmen', the *Luftschiffer*, the 'airshipmen' manning balloons. At the hundredth meeting of the *Deutsche Verein zur Förderung der Luftschiffahrt* ('German Society for the Advancement of Ballooning') he proposed cooperation between this Society and his Meteorological Institute, creating a new field and

[83] Köppen, "Die Wechselwirkung."
[84] Köppen, "Versuch," 41.
[85] Later, he would refer to the German-British astrophysicist Arthur Schuster, who mused about changing a two-dimensional meteorology into a three-dimensional one: Köppen, "Wissenschaftliche Luftschiffahrt," 105.
[86] Hugo Hildebrand Hildebrandsson, Wladimir Köppen, and Georg Neumayer, *Wolken-Atlas. Atlas des nuages. Cloud Atlas. Moln-atlas.* (Hamburg: Gustav W. Seitz Nachf. & Besthorn Gebr., 1890).
[87] Wladimir Köppen, "Die allgemeine Cirkulation der Atmosphäre," *Humboldt. Monatsschrift für die gesamten Naturwissenschaften* 7 (1888): 449, 452.
[88] Wilhelm von Bezold, "Die Bedeutung der Luftschiffahrt für die Meteorologie," *Naturwissenschaftliche Wochenschrift* 3, no. 11 (1888): 81–86; Wilhelm von Bezold, *Das Königliche Preussische Meteorologische Institut in Berlin und dessen Observatorium in Potsdam* (Berlin: Mayer & Müller, 1890).

decade of scientific ballooning.[89] Support from the Emperor and the army resulted in 75 flights with manned balloons and a three-volume work, in which Richard Assmann and Arthur Berson took over the practical initiative from Von Bezold.[90]

The power of the society movement and of the nationalist ideology supporting the scientific campaign has already been demonstrated by Höhler,[91] but it is important to realize that the meteorologist's nationalism was more a form of imperialism combined with what Paul Forman and Geert Somsen have called 'olympic' internationalism, [92] a firm belief by contemporaries in the universality of science and in nations as mere vehicles of a noble battle on a global stage.

However, national mythologies were created, both by German scientists and their competitors. In order to legitimate the Berlin campaign, Assmann turned to the lack of systematic scientific ballooning in the past: here was a mission for Germany's airshipmen. He categorized their French predecessors, from Louis Gay-Lussac to Albert Tissandier, as sharp observers, but somewhat impressionable and prone to fantasy, whereas the British balloonists such as James Glaisher had done their measurements in the 1850s in a more machine-like mode, without observing the clouds. Of course, the country of philosophy and precision technology had to save the day.[93]

Most of the speeches made by German meteorologists on aeronautical research, either for an international or a national audience, focused on national policy and the build-up of empire as mere practical resources for their kind of science. As soon as the cooperation with the aeronautical societies became less necessary with the coming of unmanned balloons, national identity building in meteorology became less important. National pride was often trumped by global disciplinary pride: Assmann wrote elsewhere that he wanted to use balloons to change meteorology from a statistical science into a more prestigious science of physics.[94]

Moreover, Von Bezold's alliance with the military does not so much reveal a new wave of military nationalism in meteorology, but an appropriation of an alliance that had been normal in maritime meteorology. Air balloon meteorology would become as important for the army (a distinct air force would only emerge decades later) as maritime meteorology for the navy. The alliance between Von Bezold, the emperor and the army was above all strategic.

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[89] Von Bezold, "Die Bedeutung der Luftschiffahrt."
[90] Otto Baschin et al., *Wissenschaftliche Luftfahrten ausgeführt vom Deutschen Verein zur Förderung der Luftschiffahrt in Berlin,* 3 volumes, ed. Richard Assmann and Arthur Berson (Braunschweig, 1899).
[91] Höhler, *Luftfahrtforschung und Luftfahrtmythos*.
[92] Paul Forman, "Scientific Internationalism and the Weimar Physicists: The Ideology and Its Manipulation in Germany after World War I," *Isis* 64 (1973): 154; Geert J. Somsen, "A History of Universalism: Conceptions of the Internationality of Science from the Enlightenment to the Cold War," *Minerva* 46, no. 3 (September 24, 2008): 366.
[93] Baschin et al., *Wissenschaftliche Luftfahrten* 1, 91.
[94] Richard Assmann and Arthur Berson, *Ergebnisse der Arbeiten am Aëronautischen Observatorium in den Jahren 1900 und 1901* (Berlin: A. Asher & Co, 1902), 1.

But martial nationalism was a factor not to be ignored. It partly explains why Köppen may have been hesitating to take full part in the balloon movement right away at the outset, as opposed to his future son-in-law Wegener who partook enthusiastically as a young man in that period.[95] Köppen was an active internationalist. At that time he had felt very uncomfortable with the situation in his native Russia, where the reactionary Czar Alexander III in the 1880s and 1890s tried Russifying the country.[96] Köppen did not only contribute to global standards for meteorology and geography, but also joined the Esperanto movement founded by the Russian-Polish-Jewish Ludwik Zamenhof. He translated his own meteorological articles for the Esperanto *Internacia Science Revuo*, including an 1893 article of his on geographical names, always a problem for meteorologists dealing with several languages and scripts (especially Latin and Cyrillic).[97] Köppen felt more comfortable welding and extending empires at the border than marching to the drums in the interior.

But when the Berlin meteorologists slowly moved away from manned balloons launched on public sport terrains and started developing cheaper technologies such as unmanned balloons and kites, and were taking experiments in private institutes in the United States and France as a more interesting model, Köppen jumped aboard.[98] In 1896 Abott Rotch, who had visited Köppen's Seewarte in 1894,[99] had started launching a series of kites carrying self-recording instruments in Blue Hill in Massachusetts, and in the same year Léon Teisserenc de Bort established a private observatory in Trappes, near Paris.[100] Kites formed a good and relatively cheap technology to study the temperature, humidity and movement of air in the 'free atmosphere' at different heights.[101]

A third player: Hergesell, Strasburg and rapprochement between France and Germany

Köppen was not the only German who had wanted to jump aboard Von Bezold's balloon and kite movement. A new person to play a big role was Hugo Hergesell, who worked at the meteorological institute of Strasburg in the German-occupied Alsace. But Hergesell was a smart diplomat who invested a lot in cooperating with his French colleagues. His attempts mirrored an

[95] Wegener became a balloonist in 1905 during his Berlin study period, where Von Bezold had motivated his students become a member of the *Deutsche Verein*: Greene, *Alfred Wegener*, 82.
[96] Wegener-Köppen, *Wladimir Köppen,* 31.
[97] Wladimir Köppen, "Pri la skribado de la nomoj geografiaj en la kartoj diverslandaj," *Internacia Scienca Revuo* 5, no. 56 (1908): 229–231.
[98] G. Lachmann, "Neue Drachenexperimente," *Zeitschrift für Luftschifffahrt und Physik der Atmosphäre* 13 (1894): 301–303.
[99] Wladimir Köppen, "Bericht über die Erforschung der freien Atmosphäre mit Hülfe von Drachen," *Aus dem Archiv der Deutschen Seewarte* 24, no. 1 (1901): 4.
[100] Shaw, *Manual of Meteorology 1*, 224.
[101] Georg Neumayer, "Einundzwanzigster Jahresbericht über die Tätigkeit der Deutschen Seewarte für das Jahr 1898," *Annalen der Hydrographie und Maritimen Meteorologie*, no. 2 (1899): 52.

earlier period of official *rapprochement* between Germany and France in the 1880s, when Bismarck had actively supported a new wave of active French colonialism, to divert France from thinking about the loss of Alsace-Lorraine.[102]

Just like Köppen, Hergesell found out while working in the French Vosges mountains, close to his Alsace station, that kites were ideal instruments for places that received wind from the sea.[103] When in September the International Meteorological Conference came to Paris, the question of scientific balloons and kites was added last-minute, so that only Von Bezold and the new directors of state meteorological institutes in Strasburg and Munich, Hergesell and Fritz Erk were able to attend, with many others absent. After negotiations between the French, the Germans, the American Rotch and the Russian Rykachev, a technological committee coordinating international balloon and kite soundings was established: Von Hergesell became its president. After Berlin, Strasburg became a second point of gravity in German sounding of the upper atmosphere, at the border with France.[104]

Just as in the *Seewarte*, international exchange prompted national innovation. It was on a visit to St. Petersburg and the magnetic observatory at Pavlovsk that Köppen for the first time saw a Hargraves at work, one of the better functioning kites.[105] During these years he started communicating with Rotch and Teisserenc de Bort on building kites and visited Teisserenc de Bort at his new international 'Franco-Scandinavian' kite station in Danish Hald.[106] In 1902 he prepared a 100 page report on American, Russian and French practices, the use of different types of kites (Malay or Hargraves, for example), attaching specific lightweight instruments to them, working with lyres, finding an area far away from tramways and electric wires. He soon became the central kite expert, creating his own kite models, and in 1901 he organized kites for the German Antarctic Expedition of 1901.[107]

When in 1902 Hergesell's International Aerological Committee met in Berlin, for five days, including presentations on balloons by Rykachev, Teisserenc de Bort, Von Bezold,

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[102] Also, Bismarck had wanted to drive a wedge between France and England. Later, the German-French relationship became somewhat more strained again, but the French would not again disappear from the international stage of science. Nathan Orgill. "Between Coercion and Conciliation; Franco-German Relations in the Bismarck Era, 1871-1890", in: Carine Germond and Henning Türk, *A History of Franco-German Relations in Europe; From 'Hereditary Enemies' to Partners* (Basingstoke: Palgrave Macmillan, 2008): 49-60, 55.

[103] Hugo Hergesell, 'Report of the Proceedings of the International Committee for Scientific Aeronautics', appendix II, *Report of the International Meteorological Committee, Southport 1903* (London: His Majesty's Stationery Office, 1904), 29; hereafter Report ICSA.

[104] Hugo Hergesell, "Die Wissenschaftliche Luftschiffahrt auf der Internationalen Meteorologenconferenz in Paris," *Zeitschrift für Luftschifffahrt und Physik der Atmosphäre* 15 (1896): 241–245.

[105] Köppen, "Bericht über die Erforschung," 5.

[106] See for example letters Lawrence Abott Rotch to Wladimir Köppen, July 8th 1901, no. 1377; Léon Teisserenc de Bort to Wladimir Köppen, October 20th, 1899, no. 1745 and August 11, 1902, no. 1747, Köppen Correspondence (Ms 2054), University Library Graz (UBG); [Léon Teisserenc de Bort], *Travaux de la station franco-scandinave de sondages aériens à Hald 1902-1903* (Viborg: E. V. Backhausens Bogtrykkeri, 1904), 6.

[107] Köppen, "Bericht über die Erforschung," 10.

Assmann and Hergesell himself, Köppen joined the committee in a session on kites. In this session, Rotch and Berson also presented. On this committee, a new entente was organized between the Germans, the Russians and the French. After more than a decade of diplomatic talks, Hergesell and Von Bezold had succeeded in bringing the French into a new campaign of international balloon ascents. Because they had to find common standards, only after which they could start coordinating the ascents, the Germans had abandoned manned balloons in the period 1896-1900 for the *ballon-sonde* that was much more popular in France.[108] Also, a year before, Assmann had invented a new type of rubber balloon that was able to expand, keeping a relatively constant velocity of ascent, delivering more reliable data, and which was easier to recover because it burst at maximum height.[109]

Now, when Köppen took to the stage and spoke about his 100-page report and his years of kite experiments, Hergesell immediately decided to appropriate his work for the Committee and sent a telegram to the vice-admiral of the Navy, Alfred von Tirpitz, thanking him for the support of Köppen's experiments ('the most important experiments that have come out of maritime meteorology recently') and the wish of the international committee for more structural support for Köppen's new Hamburg kite station.[110] Other resolutions of the conference were aimed at extending the European networks of simultaneous ascents to the other large continental masses such as North America, as well as the large mass of British India. It must have had a certain effect: in 1905 Köppen was able to send a fellow staff member, Wilhelm Brennecke, with his kites on the SMS *Planet* on a scientific expedition to the South Atlantic and the Pacific.

The *Planet* expedition and Germany's new oceanic empire

The *Planet* was the second substantial scientific expedition organized by the German Navy, and the first in which the *Seewarte* played a large role. In 1874, only a year after the British *Challenger* started sailing around the world, the young state of Germany had sent the *Gazelle* for an expedition around the world, a Prussian warship rebuilt into an Imperial vessel with a research mission, with one official scientist added. It was also a reconnaissance mission: it had anchored at several places at the Eastern shores of New Guinea. Ten years later, during the Berlin Conference of 1884, it was not just Africa that was carved up by the European imperial powers under the leadership of Bismarck. Western Melanesia also became the subject of a scramble: in

[108] *Protokoll über die vom 20. bis 25. Mai 1902 zu Berlin abgehaltene dritte Versammlung der Internationalen Kommission für Wissenschaftliche Luftschiffahrt* (Strasburg: M. DuMont-Schauberg, 1903), 14–17.
[109] Paul Beelitz, *Radiosonden* (Berlin: Verl. Technik, 1954), 90; John L. DuBois, Robert P. Multhauf, and Charles A. Ziegler, *The Invention and Development of of the Radiosonde with a Catalog of Upper-Atmosphere Telemetering Probes in the National Museum of American History, Smithsonian Institution* (Washington DC: Smithsonian Institution Press, 2002), 8.
[110] *Protokoll*, 61.

1886, Gustav von Schleinitz, captain of the *Gazelle*, became the first *Landshauptmann* of German New Guinea.

Between the *Gazelle* and the *Meteor* expedition organized between 1925 and 1927, the subject of Penelope Hardy's article in this issue of the *History of Meteorology* and a product of Weimar nationalism,[111] two other ships were sent out by the German Navy for official scientific expeditions large enough to publish results afterwards. One was the *Planet* expedition of 1906-1907 and the other the *Möwe*-expedition of 1911. Other high-profile scientific expeditions sent out by Germany between the *Gazelle* and the *Meteor* used civilian ships specially purchased for the projects and sold afterwards: the *National* (Plankton Expedition, 1898-1899), and the two Antarctic expeditions with the *Gauss* (1901-1903) and the *Deutschland* (1911-1912). Of all these expeditions, the *Valdivia* and *Meteor* expeditions had commanded the most scientists: 10 and 11 respectively. However, the *Planet* was exceptional too: already two years after its homecoming the results were published.[112] The *Planet* would set a new model, in an age of faster science, focused more on oceanography and meteorology than on marine biology.

This development coincided with the growth of observation stations 'of the second and third order' outside Europe sending data to the *Seewarte*. There were fewer than 10 stations before the 1880s, mainly sending data out of South America; ten more stations in Labrador and Southwest Africa were added in the 1880s; and ten more in East Africa in the 1890s, when German activity in the North Pole and the new colonies grew. The boom came between 1900 and 1914, with more than 180 stations reporting in 1910, almost all of them from Africa and to a lesser extent the Pacific.[113] The *Planet* (and later the *Möwe*) travelled through all these areas of the new German empire: the African coast and through the Indian Ocean to the Bismarck archipelago, not only doing aerological research but also collecting ethnographical objects.

However, the *Planet* expedition should not only be seen within the context of a series of national expeditions sent out by Imperial Germany and as an extension of the German Navy into its expanding colonial empire. The *Planet* was also an instrument of the new transnational aerology of the time.

The trans-imperial expedition

[111] Penelope K. Hardy, "Meteorology as Nationalism on the German Atlantic Expedition, 1925-1927," *History of Meteorology* 8 (2017): 124–144.

[112] The early expeditions organized before the Planet took on average almost 28 years to fully publish their results, although this often depended on the last marine biologist describing all the caught specimens. The three expeditions after the Planet took on average a little more than six years: here, oceanographers and meteorologists working closely with the Navy to get the data out relatively fast. H. G. Gierloff-Emden, *Lehrbuch der allgemeinen Geographie. Geographie des Meeres, Ozeane und Küsten 1* (Berlin & New York: Walter de Gruyter, 1980), 123–125. Gierloff-Emden also mentions the three private German expeditions to the North Pole in the 1860s before the unification, the *Grönland*, *Germania* and *Hansa*.

[113] Tinz and Rosenhagen, "Archiv der Überseeischen Stationen der Deutschen Seewarte."

Between 1896 and 1902 the network of weather balloons had focused on Europe, Russia and the United States; in 1902 Assmann's aeronautical institute in Berlin started daily ascents, as well as daily telegraphing the weather data to the *Seewarte* so that Köppen could process these together with his own kite measurements in his daily weather maps and reports. Three years later, Assmann would move to a new observatorium in Lindenberg.

Over the next ten years, Europeans and Americans joined hands in bringing these networks to the oceans and other continents. Hergesell had been able to borrow the *Princesse Alice* of the Prince of Monaco and the *Sleipner* of the German Emperor in these years to study the upper atmosphere in the Mediterranean and the Atlantic; he also went to Spitzbergen; Rotch and Teisserenc did the same on the *Otaria* in others parts of the Atlantic; in 1905 and 1906 Alfred Wegener had left Lindenberg Observatory as an assistant to aerological measurements as the official meteorologist on the *Danmark* expedition to Greenland and asked Köppen to send some of his kites; later, he would rent a cabin on the steamship *Tübingen* to Montevideo and Buenos Aires; Italian ships had gone to the Indian Ocean; Lindenberg sent Arthur Berson to Lake Victoria and Nyassa; Willem van Bemmelen would do measurements at the Royal Magnetic and Meteorological Laboratory in Batavia, and connected his findings on 'westerlies' to those of Lindenberg in Africa.[114]

The practice of kite science in the tropical seas

The *Planet* was in 1906 the first to extend aerological measurements to the South Atlantic, Indian and Pacific Oceans. The ship was equipped with the most modern instruments, with the *Seewarte* organizing all meteorological and oceanographic instruments. The ship had an electric motor lyre (Köppen himself had at the Seewarte only one that burned on denatured alcohol),[115] thirty kites, 48 balloons, nine kite meteorographs (or baro-thermo-hygrographs), six anemometers and a Fuess 'aspiration psychrometer', among others. Especially the psychrometer was important: it was developed by Richard Assmann and the Berlin instrument maker Wihelm Fuess and had by then become a key instrument in the international aerology campaigns.[116] Köppen's kite report was also in the ship's library, as was his *Maritime Meteorologie*, Hann's

[114] Höhler, *Luftfahrtforschung und Luftfahrtmythos*, 296–304; Shaw, *Manual of Meteorology 1*, 224; Alfred Wegener, *Thermodynamik der Atmosphäre* (Leipzig: Johann Ambrosius Barth, 1911); Willem van Bemmelen, *Die Erforschung des Tropischen Luftozeans in Niederländisch-Ost-Indien. Luftfahrt und Wissenschaft 5* (Berlin: Julius Springer, 1913); Adolf Miethe, Hugo Hergesell, and Prinz Heinrich, *Mit Zeppelin Nach Spitzbergen: Bilder von der Studienreise der Deutschen Arktischen Zeppelin-Expedition* (Berlin: Bong, 1911). On the Danmark expedition and the first letter of Alfred Wegener to Wladimir Köppen, March 28th, 1906, no. 1, Wegener-Köppen Archive HS 1968 595 (WK), Deutsches Museum (DM), Munich; on the Montevideo trip, see, December 14h, 1909, no. 7. See also ICSA Reports Southport 1903, Paris 1907 and Berlin 1910.

[115] Köppen, "Wissenschaftliche Luftschiffahrt," 108.

[116] Höhler, *Luftfahrtforschung und Luftfahrtmythos*, 223.

Klimatologie and the first issue of a new journal founded by Hergesell and Assmann, the *Beiträge zur Physik der freien Atmosphäre*.

It was not Brennecke but the *Planet*'s young officer Schweppe who was taught how to use kites by Köppen at the Seewarte, and instructed in using balloons by Hergesell in Strasburg. After arriving in the Pacific officer Schlenzka then took over.[117] The crew had to practice regularly, because the 'method of kite and balloon work on board was still in a stage of development' and they had to practice in the Bay of Biscay. At the first 'station', with 5 kites attached to an 8 kilometers line, albeit invisible because of a cloud deck at 400 meter altitude, the line broke, and they lost 1 km of wire and one kite.

Aerology on a ship was a different endeavor. The person in charge of the kite ascent also needed to be in charge of the ship's maneuvering. The ship had to find a good position in the wind to get the kite up in the air (with the help of a lyre), with the kite attached to the mast at first. They found that there were no rules for the ship's ideal speed. The ascent of balloons was another thing: special diagrams and formulas were needed to fill the balloons with the right amount of gas, so that – with the ship's speed and the weight of the instruments in mind – the ascent and descent were relatively stable. The ship also had to retrieve the balloon again at sea; most of the time quite soon after the ascent the balloon was lost out of sight, even with clear skies.[118] Kiting on water meant paying less attention to the wire – the free oceanic space was less destructive – but more to the kite itself, which often did not survive a crash in the ocean.[119]

Opening up colonial skies

Having travelled further to Lisbon's Torre de Belem, the officers mused about Vasco da Gama and Humboldt who had travelled to the Cape of Good Hope, India and America, and concluded that the 'scientific disclosure' of the world was still not finished. On the first Thursday of the month, an 'international day' on which meteorological observations were made across the world, they tried to raise their kites into the air as well. This international day had started as a structural project at the Milan conference of the International Commission for Scientific Aeronautics.[120]

The map in the final travel report showed two things. It first showed the route that the *Planet* took, following the African coast, going south from Cape Town almost twenty degrees, then back north, over Madagascar and the Maldives to British Ceylon. From Ceylon they went to the Dutch Indies, south of Sumatra and Java, turning between Bali and Lombok towards the

[117] Korvetten-Kapitän Lübbert, ed., *Forschungsreise S. M. S. "Planet"1906/7 I. Reisebeschreibung* (Berlin: Karl Siegismund, 1909), i–xviii.
[118] Hugo Hergesell et al., eds., *Forschungsreise S.M.S. "Planet" 1906/7, II. Band Aerologie* (Berlin: Karl Siegismund, 1909), 50–60.
[119] Köppen, "Wissenschaftliche Luftschiffahrt," 108.
[120] Ibid., 3.

Moluccas and the Bismarck Archipelago. From their German colony they went to the American Philippines and Hong Kong.

Second, the map also showed the cities of the Eurasian continent that took part in the monthly ascents, with South Asia and Africa – except for Cairo – empty, and an impressive string of Russian cities from St. Petersburg to Omsk. West of this string there were almost thirty stations, mostly in Germany, Russian Poland and the Alps, and interestingly, Great Britain, which had suddenly caught up with the other great powers in aerological soundings. By pairing the strings of European land observatories to the route of the *Planet*, the goal of the map was to demonstrate the pioneering mission of the *Planet* and the 'blank spot' it had to fill; the tropical atmosphere that hung above the maritime and land economies of Asia. While imperial powers competed in getting political and economic access or even hegemony in these economies, the German meteorologists contributed to opening up the tropical skies.[121]

From this first trip, Köppen drew two general conclusions from the data: first, above the oceans, just as on the land, the atmosphere changed from one *mächtige* (mighty) layer to another, from one where the temperature dropped at higher altitudes to one where it rose (a so-called 'inversion'), or one where it stayed constant (a so-called 'isotherm'). Second, the atmosphere above the inversion layers above the sea were normally as dry as the atmosphere at the immediate surface of deserts – a phenomenon only known from winters in moderate zones, whereas Köppen expected the conditions in the tropics to be more like the summers in Europe. This begged for more measuring.

All in all, the *Planet* was a first act in tropical aerology. It was a pilot. Other Europeans would take it up, among them the Dutch meteorologist Willem van Bemmelen, who started soundings with manned and unmanned balloons in Batavia from 1910 onwards. Van Bemmelen had already visited Strasburg. Outside Europe, the first colonial bureaucrats started to take over from the occasional visiting ship.[122] In Germany, Köppen continued working on kites until 1913, when the kite station burned down and the First World War broke out. This was the end of the German imperial dream, at least for Köppen. In 1919, a year after the fall of the Empire, Köppen retired, and in 1924 he moved to Austrian Graz to live with his daughter and son-in-law. Alfred Wegener had a position as meteorologist and geophysicist at the university there, and Köppen continued cooperating with Wegener on his theory of continental movement and paleoclimatology. Köppen would keep publishing works in 'dynamical climatology' until 1940, when he died of old age in the first year of the Second World War.

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[121] During the journey, the members of the *Planet* observed the power struggles of other colonial nations: in the harbor of Batavia, for example, they encountered only one Dutch warship, and found out that all other warships were sent to Lombok and Bali to wage a colonial war against the Rajah of Bali, which ended with a ritual suicide, *puputan*, or in the words of the German officers, a 'heroic fight to the death' of the Rajah of Denpasar and many hundreds of his followers mown down by Dutch gunfire. Ibid., 67–70.

[122] Mahony, "For an Empire of 'all Types of Climate': Meteorology as an Imperial Science."

Conclusion

This article has demonstrated the role of Germany and the German-speaking world in the imperial construction of global aerology, and especially the role of Wladimir Köppen and his kite work at the *Deutsche Seewarte*, working closely together with German-speaking meteorologists such as Wind, Hann, Von Bezold and Hergesell. Köppen was a 'Baltic German' migrant *in* Germany operating in a world of competing empires. Both land empires such as Russia and Austria-Hungary and maritime empires such as Great Britain, France and the Netherlands had created a stage for global meteorology, in which a race was imagined between imperial science programs. Germany played the role of global middle man, concurrently a continental empire and an aspiring maritime empire.

It is important that the social and imperial history of the German scientist does not focus on the German state alone, but focuses on the German-speaking community as a transnational scientific force of science and state formation. German scientists had created a niche for themselves in the nineteenth century (and even before), as civil servants in an emerging world of high imperialism, competing for ascendancy in the technosphere, with the 'free atmosphere' as a trans-imperial space.

The problematic figure of the German apolitical opportunistic migrant-scientist, selling their work to different governments and political regimes, each with their own imperial ambitions, was made famous as a trope by the Cold War Hollywood blockbuster *The Right Stuff*, directed by Philip Kaufman in 1983. This movie was an adaptation of Tom Wolfe's 1979 novel of the same name dealing with the American-Russian space race in the 1950s.[123] When in one of the movie's scenes senator Lyndon B. Johnson complains about the Germans helping the Soviets building satellites, gaining 'the high ground', and surpassing the Roman and British Empires with their roads and ships, but most of all the Americans with their air planes, a fictional version of Wernher von Braun, the German architect of the American space program, steps forward and replies to the senator with a heavy accent: 'no, […] our Germans are better than their Germans'.[124]

Just like all other scientists, German meteorologists were very political and not just opportunistic: many of them invested a lot in empire-making. However, these empires were often, but not always, organized around the specific nation-state of Germany: more important 'empires' formed the wider German academic community and the global community of meteorology. For these two communities they were willing to strategize, whether that meant organizing kite stations or mounting large expeditions to the South Seas.

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[123] See also: Tom Wolfe, *The Right Stuff* (London: Vintage Books, 2005 [1979]).

[124] This quote may reflect a historical anecdote. Andrew Roberts wrote that Ian Jacob, Churchill's military assistant in the British War cabinet had said something similar once to him in person on Britain winning the war because of 'their Germans' being better. However, Jacob made the remark decades after the War and it is unclear whether it was Jacob or Kaufman who came up with this. See also Andrew Roberts, *A history of the English-Speaking Peoples since 1900* (New York: Harper Collins, 2008).

The story of meteorology around 1900 was one of a global alliance of Germans working for and moving between different governments and science institutes: a history of cooperating Germanophones. After 1871, Bismarck's German Empire would indeed form a new beacon for German-speaking scientists, and its government a very interesting new supplier of science jobs. Imperial Germany needed all kinds of German-speaking scientists for its new project of empire-building, at first in Europe and later in Africa and Melanesia too. Köppen himself was drawn to a government position in Hamburg. His family had worked for the Russian Empire, he had been educated in German universities and he had worked together with Swiss and Austrian meteorologists, both in Russia and in Germany. He was an ideal candidate to work for the *Seewarte* and expand Germany's meteorology.

With the balance of power in Europe shifting, Germany was able to take the lead in the build-up of global aerology, in a period in which a German-Austrian-Russian *entente* and a German-French *rapprochement* under the leadership of Bismarck created opportunities for international cooperation that were not directly abandoned when these relationships became strained again, at least not in the years before the Great War. And at sea the Germans cooperated with the Dutch and the Danish. It was a golden age for German aerology: in the years that Bismarckian *Realpolitik* gave way to Wilhelmian *Weltpolitik*, partly thanks to Köppen German aerology became even transcontinental, resulting in a global scramble for the 'free atmosphere'.

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