4. Dmitrii Mendeleev and Russian Meteorology During the Second Half of the Nineteenth Century

Nathan M. Brooks

New Mexico State University

Dmitrii Ivanovich Mendeleev, who lived from 1834 to 1907, was one of the most important scientists and public figures in Russian history and the history of science. His fundamental work in postulating and developing the Periodic System of the Chemical Elements, expressed in the Periodic Table, brought him great fame not only in Russia but throughout the world as well. This achievement had an immense influence on the development of modern chemistry and physics, and it became part of the basic principles learned even today by every chemistry student. In Russia, Mendeleev's influence spread far beyond the discipline of chemistry. Mendeleev acted as a consultant and took an active role in many different fields of interest, including agriculture, industry, economic policies, and others. He served as an informal science advisor to many important officials in the Russian government and he headed the Russian Bureau of Weights and Measures for the last 15 years of his life.

Meteorology was one of the many fields that Mendeleev worked in during his life. However, Mendeleev was an "outsider" in this research area and his ideas met resistance from specialists in meteorology in Russia, at least partly because he did not approach the subject from the traditional ways of doing meteorology in Russia. In this paper, I will briefly discuss Mendeleev's work in meteorology and how it related to other work in meteorology in Russia.

As far back as the thirteenth century, there had been mentions of weather formations in the Russian Chronicles and other written sources.[1] However, the first real meteorological observations were conducted in the eighteenth in connection with Vitus Bering's expeditions to Siberia (1733-1739). Organized by the St. Petersburg Academy of Sciences, the leaders of the expedition were instructed to take measurements of temperature and barometric pressure, as well as to make non-instrumental observations of clouds, thunderstorms, and

other natural phenomena. In addition, the expeditions also set up a series of observations stations throughout Siberia, but these continued operating only until about the middle of the century.[2] While sporadic efforts were made to establish new observation stations during the rest of the eighteenth century and the first few decades of the nineteenth century, the first sustained meteorological observations were organized by Adolf Kupfer (1799-1865) beginning in the 1820s.[3] Kupfer, a Baltic German, received his higher education in Germany, but then returned to Russia and received an appointment as professor of chemistry at Kazan University in 1823. On a trip to Paris in that year to purchase equipment for the university, Kupfer became acquainted with Francois Arago and Alexander Humboldt, who stimulated his interest in terrestrial magnetism and meteorology. In 1828, Kupfer was elected to the Imperial Academy of Sciences and moved to St. Petersburg, where he began to organize a series of meteorological observation stations throughout Russia, to be supervised by a central observatory in the capital. In 1849, Kupfer was appointed director of this new central observatory, which was named the Main Physical Observatory [*Glavnaia Fizicheskaia Observatoriia*]. The local observation stations would take readings of temperature, pressure, and various other meteorological indicators, and then send them to the Main Physical Observatory, which was intended to coordinate the data received from the local observation stations and supervise their activities. Kupfer headed the Main Physical Observatory until his death in 1865, when Ludwig Kamtz (1801-1867), who had long experience in meteorology, took over this position. Upon Kamtz's death in 1867, Heinrich Wild (1833-1902) was appointed as director.[4] Wild re-energized the activities of the Observatory and supervised the organization and strengthening of the local observation stations, assisted by Mikhail Aleksandrovich Rykachev (1840-1919). By 1875, there were 118 local stations and 432 by 1890. In addition, the Main Physical Observatory conducted an active publication schedule. However, while the Main Physical Observatory and its network of observational stations collected large amounts of data, there was a lack of theoretical and experimental meteorology. While the research done in these institutions was valuable, Wild, Rykachev, and their co-workers did not go beyond gathering data and they devoted very little attention to providing any kind of scientific explanations of weather phenomena. Likewise, they were not interested in conducting experiments with aerostats or similar apparatus. On the other hand, Mendeleev, with his background in experimental as well as theoretical science, viewed these aspects as essential for a thorough understanding of the weather.

Most of Mendeleev's work in meteorology was done in the 1870s, when he conducted large-scale investigations on the nature of gases.[5] This was a critical period in Mendeleev's life, both scientifically and personally. Mendeleev had been appointed as professor of chemistry at St. Petersburg University in 1865. Shortly after this time, while writing a textbook for his course in introductory chemistry, Mendeleev began to formulate his concept of the Periodic Law of the Chemical Elements. Mendeleev completed nearly all of his experimental and theoretical investigations on the Periodic Law during the short period from 1869 to 1871. However, by late December 1871, Mendeleev had fully switched his attention to the study of gases.[6]

Why would Mendeleev make such a shift in his research focus at this time? For one thing, we must remember that the Periodic Law had not attracted much attention by this

time. The Periodic Law would remain overlooked until after the mid-1870s, when the discoveries of gallium (1875), scandium (1879), and germanium (1886), all of whose properties were very accurately predicted by Mendeleev, demonstrated the usefulness of Mendeleev's concepts.[7]

By late 1871, Mendeleev felt that he had done sufficient work to establish the theory. More importantly, he decided at this time to look for the universal ether -- the substance that supposedly served as the carrier for all electric, optical, magnetic, and gravitational phenomena. Like many other scientists at this time, Mendeleev firmly believed that the ether existed and that it would help him unify all of the physical sciences, just like his periodic table unified all of chemistry.[8] He had been interested in various aspects of gases as far back as his student days and had even pointed out the inadequacies of the standard gas laws in an article in 1870.[9] The next year, Mendeleev decided to undertake very precise studies of the expansion and compressibility of gases in order to demonstrate the existence of the ether. He believed that if there were a limit to gas expansion under low pressure, then there would be a point when our atmosphere would stop expanding, which would leave room for the ether. To Mendeleev, the ether was still a gas, but it was a qualitatively different substance from the atoms that comprised our atmosphere. As he wrote in 1875: "Then one should also admit that the expansive luminiferous ether of celestial space is composed of a substance as different from the gases [of air] as one chemically simple body is from another, that is, they do not transition into each other...I do not dare hope that I will solve such fundamental questions, but as an approach to their resolution I will still continue to work out observations on the compression of gases under the smallest possible measurable pressures."[10] Mendeleev and his co-workers repeated the very exacting work on gases of Victor Regnault, but at more extreme conditions. They measured the temperature, pressure, and volume of various gases -- including air, hydrogen, carbon dioxide and others -- and they tried to determine the extent of deviations from Boyle-Mariotte or Gay Lussac's laws. By so doing, it was hoped, the ether could be identified by comparing the corresponding deviations across the various gases. However, despite huge amounts of effort and the expenditure of considerable amounts of money, by 1875, Mendeleev had failed to find solid evidence of the ether through these experiments. While Mendeleev believed he had uncovered serious errors in Regnault's work, his real goal -- the ether -- remained tantalizingly outside of his grasp.[11]

This failure to identify the ether in the laboratory induced Mendeleev to look at the behavior of gases in the upper levels of the earth's atmosphere. He reasoned that if he could not find the ether in the laboratory, he could turn to the "natural laboratory" and use it to examine the substance that so interested him. At first, he thought that there must be some source of heat in the upper atmosphere to produce the turbulence and atmospheric effects that we observe on earth. He noted that the air at high elevations was simply too thin to be the product of Boyle-Mariotte pressure reduction alone. Therefore, there must be a heat source in the upper atmosphere that was also expanding the gases.[12] At this time, it was generally believed that the air was entirely heated from below by sunlight reflected off the earth's surface. In several speeches and articles, Mendeleev proposed that water vapor in

the air was simultaneously heated by both sunlight from above as well as sunlight reflected off the earth's surface.[13] Mendeleev believed that research on this topic would bring him much closer to elucidating the nature of the boundary of the upper atmosphere with the ether. Moreover, it would also lead to a better understanding of the weather itself: "In order to establish a correct understanding of a large number of meteorological phenomena, in order to determine the refraction of light in the air, in order to conduct hypsometric measurements and for many other investigations it is necessary to know the law of the change of temperatures in different layers of air."[14]

Mendeleev thought that the study of the upper layers of the atmosphere would lead him to the discovery of the laws of refraction, weather, astronomical observation, gases, and eventually, the ether. The problem was that the measurements could not be taken from the ground, of course. Furthermore, Mendeleev also insisted that measurements made on mountains did not accurately reflect the properties of the upper layers of the atmosphere away from the mountains. He believed that this would not allow observations of free-floating "oceans of air" without interference by the mountain itself.[15]

So how did Mendeleev propose to make the observations? He asserted that satisfactory results could be obtained using an aerostat -- a weather balloon -- operated by one scientist, together with the operator of the aerostat, to record observations of the gas expansion due to heating at various altitudes. He believed it was necessary to obtain measurements before theorizing. He stated: "Thus, if we want to arrive at an empirical law of meteorological changes in the layers of the atmosphere, we must rely almost exclusively on phenomena observed during aerostatic ascents."[16] Mendeleev knew of various previous aerostat ascents -- such as Gay-Lussac's in 1804 and James Glaisher's in the 1860s -- and that many of them were connected with meteorological observations. However, Mendeleev believed that Glaisher's data were suspect, due to certain methodological problems, such as placing the thermometer inside the cabin of the aerostat, which yielded higher temperatures than for thermometers placed outside the cabin.[17] In spite of his distrust of Glaisher's data, Mendeleev nevertheless used it in his own work. Mendeleev declared that "France and England have already done much for the resolution of this question; now it is the turn of other states to gather the necessary data in the greatest quantity...This country, thanks to its continental climate, is very appropriate for experiments of this sort."[18] The problem was that no one in Russia was willing to fund such balloon experiments. However, Mendeleev devised an ingenious way to obtain the needed funds. His work on gases was being funded by the state (Ministry of Finances, through the Russian Technical Society) and these officials were willing to let Mendeleev keep any profits from the publications of the results of his research. Mendeleev also devoted the profits from four other books published during the mid-1870s to financing a planned series of 15-20 aerostat flights. Unfortunately for Mendeleev, the aerostat was extremely expensive and the money he collected was insufficient for its construction. Mendeleev continued to advocate the benefits of an aerostat until the early 1880s when he turned his attention away from meteorology. He finally was able to take his flight in an aerostat in 1887, but the purpose of the flight was more connected with his growing interest in aviation than with meteorology.[19]

However, back in the mid-1870s, Mendeleev's hypotheses on what he might discover by means of these aerostat flights did not attract much attention from the Russian meteorological community.[20] One exception was M. A. Rykachev, who directed a harsh attack against Mendeleev's underlying conceptions in meteorology. Rykachev, Wild's assistant at the Main Physical Observatory, was offended that Mendeleev -- who was not a professional meteorologist -- would criticize the work of meteorologists like Glaisher without having done similar experimental work himself.[21] Mendeleev brushed aside such criticisms, believing that Rykachev simply wanted to maintain the authority of the Main Physical Observatory in meteorological research. Mendeleev also rejected Rykachev's criticisms of his concept of upper layers in the atmosphere. Rykachev believed that there were no distinct boundaries in the atmosphere and that the transitions were gradual. Mendeleev, on the other hand, insisted that there was a sharp transition between the top layer of the atmosphere and the ether.[22] This exchange soon sputtered out and no other professional meteorologist engaged Mendeleev in debate.

While Mendeleev was responding to Rykachev in a professional arena, Mendeleev also wanted to create a greater audience for meteorology among the general educated public. In order to accomplish this, Mendeleev had two of his assistants translate Henrik Mohn's book *Meteorology* (first published in German in 1872) into Russian (1876).[23] Mohn's book was a general textbook that focused on the science of weather prediction, rather than on climatology, the study of average conditions of the weather in different regions. Mendeleev wrote the preface for the book and added numerous footnotes. Mendeleev paid little attention to the theoretical aspects of Mohn's book and instead focused on the institutional organization he would like to see for meteorology in Russia. In essence, Mendeleev's plan was to create another organization that would duplicate the observational network of the Main Physical Observatory. Since the professional meteorologists at the Main Physical Observatory paid no attention to his ideas about meteorology, Mendeleev apparently began thinking of ways to circumvent this roadblock. He focused his attention on the new *zemstva*, local self-governing bodies in rural areas, which were becoming interested in weather prediction as an aid to agriculture. Mendeleev proposed that these rural observers could collect data and send them to an expert (like Mendeleev), who would then process and organize the masses of information. Mendeleev even saw the *zemstva* using aerostats to collect data, although he acknowledged that many *zemstva* would have to band together to purchase an aerostat, since the cost was so great. However, Mendeleev never followed up on these ideas about organizing a parallel organization to the Main Physical Observatory for collecting meteorological data. As with many of his other schemes over the course of his entire life, Mendeleev did not maintain an interest long enough to bring this idea to fruition.

Mendeleev's varied activities during these years had yet another link to meteorology. In 1875, Mendeleev orchestrated the convening of a Commission to study Spiritualistic phenomena.[24] The Commission was formed in order to examine scientifically these phenomena and -- Mendeleev evidently hoped -- the results would clearly debunk the claims of the Spiritualists that Spiritualist phenomena were real. Although there were other motivations for Mendeleev's interests in Spiritualism at this time, one of the reasons that

Mendeleev became so concerned about Spiritualism was its close connection to his work on gases and meteorology. Some people were beginning to claim that the ether could function as a carrier for Spiritualistic phenomena, as well as for gravitational, electrical, magnetic, and other phenomena. If we recall that the ether was the central point of Mendeleev's work on gases and meteorology, it is easy to understand his concern that if the ether became linked to Spiritualism, it would lose its status as a serious problem of scientific research. For this and other reasons, Mendeleev was eager to debunk the Spiritualists. Mendeleev defined Spiritualist phenomena as "those which occur at séances, happening usually in the evening, in darkness or twilight, in the presence of special persons who are called mediums," and hypothesized that these phenomena might be analogous to the weather, since atmospheric phenomena were not phenomena created by a specific force, but simply phenomena that occurred in the atmosphere.[25] At the time of the séances observed by the Commission, Mendeleev made copious notes on the weather conditions. Evidently, he wanted to test his ideas about the connection of Spiritualistic phenomena with the weather. Mendeleev soon convinced himself that the mediums were faking the Spiritualistic phenomena, and he stopped further investigations along this line.

By the late 1870s, Mendeleev's interest in meteorology had waned and he began to turn his attention to other activities. His work on gases was left unfinished and he never obtained sufficient funding to purchase even one aerostat for meteorological experimentation. While Mendeleev continued to hold a belief in the existence of the ether, he no longer explored ideas of how to investigate it in the upper atmosphere. His work in meteorology left barely a trace in the history of Russian meteorology.

Endnotes

1 D. F. Nezdiurov, *Ocherki razvitiia meteorologicheskikhnabliudenii v Rossii*, Leningrad, Gidrometeoizdat, 1969, pp. 9-11.

2 *Ibid*., pp. 15-22.

3 For information about Kupfer, see: V. M. Pasetskii, *Adolf Iakovlevich Kupfer, 1799-1865*, Moscow, Nauka, 1984. Also see D. F. Nezdiurov, *op. cit.*, pp. 39-67.

4 For information about Wild and his activities at the Main Physical Observatory, see D. F. Nezdiurov, *op. cit.*, pp. 68-123. Also see A. Kh. Khrgian, "Istoriia meteorologii v Rossii", *Trudy Instituta Istorii Estestvoznaniia it Tekhniki*, 2 (1948): 71-104.

5 Surprisingly, little adequate research has been conducted on Mendeleev's work on gases. The most sophisticated treatment is L. S. Kerova, V. A. Krotikov, and R. B. Dobrotin, "Issledovaniia D. I. Mendeleev v oblasti fiziki gazov", *Voprosy Istorii i Metodologii Khimii*, 2 (1978): 73-96.

6 See Michael Dan Gordin, "The Ordered Society and Its Enemies: D. I. Mendeleev and the Russian Empire, 1861-1905", Ph.D. dissertation, Harvard University, 2001, p. 101.

7 Stephen G. Brush, "The Reception of Mendeleev's Periodic Law in America and Britain", *Isis*, 87 (1996): 595-628.

8 For a cogent argument about the centrality of the ether in Mendeleev's research, see Gordin, *op. cit.*

9 D. I, Mendeleev, "Zamechaniia po povodu raboty Endriusa nad szhimaemostiu uglekisloty", (1870), *Sochineniia*, 5, Leningrad-Moscow, Akademiia Nauk SSSR, 1947, pp. 110-111.

10 D. I. Mendeleev, "Ob uprugosti gazov", 1 (1875), *Sochineniia*, 6, Leningrad-Moscow, Akademiia Nauk SSSR, 1939, p. 227.

11 For Mendeleev's summary of his work on gases, see *ibid*.

12 D. I. Mendeleev, "O temperature verkhnikh sloev zemnoi atmosfery", (1875), *Sochineniia*, 7, Leningrad-Moscow, Akademiia Nauk SSSR, 1946, pp. 15-20.

13 In addition to *ibid*., also see D. I. Mendeleev, *Sochineniia*, 7, pp. 23-50.

14 *Ibid*., p. 35.

15 D. I. Mendeleev, "O temperature verkhnikh sloev zemnoi atmosfery", *op. cit.*, p. 15.

16 D. I. Mendeleev, "O temperature verkhnikh sloev atmosfery", (1876), *Sochineniia*, 7, p. 36. Emphasis in original.

17 See *Ibid*., pp. 37, 39.

18 *Ibid*., p. 48.

19 V. N. Vorobev, *Geneziz russkoi vozdukhoplavatelnoi mysli v trudakhh D. I. Mendeleeva*, Moscow, Akademiia Nauk SSSR, 1965.

20 In fact, most histories of Russian meteorology barely even mention Mendeleev. For example, see Nezdiurov, *op. cit*.; and Khrgian, *op. cit*.

21 M. A. Rykachev, "Nekotoryia zamechaniia na soobshchenie D. I. Mendeleeva 'O temperature verkhnikh sloev atmosfery'", *Zhurnal Russkogo fiziko-khimicheskogo obshchestva, ch. fizika*, 8 (1876): 10-18.

22 D. I. Mendeleev, *Sochineniia*, 6, *op. cit.*, p. 240.

23 Henrik Mohn, *Meterologiia ili uchenie o pogode*, tr. N. Iordanskii and F. Kapustin, ed. D. I. Mendeleev, St. Petersburg, Obshchestvennaia Polza, 1876. Mendeleev's preface and footnotes to this volume are reprinted in D. I. Mendeleev, *Sochineniia*, 7, *op. cit.*, pp. 201-237.

24 See Richard E. Rice, "Mendeleev's Public Opposition to Spiritualism", *Ambix*, 45 (1998): 85-95; and Michael Dan Gordin, *op. cit*., pp. 167-241.

25 D. I. Mendeleev, *Materialy dlia suzhdeniia o spiritizme*, St. Petersburg, Obshchestvennaia Polza, 1876, p. 308.