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The invention of atmosphere

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ABSTRACT

The word "atmosphere" was a neologism Willebrord Snellius created for his Latin translation of Simon Stevin's cosmographical writings. Astronomers and mathematical practitioners, such as Snellius and Christoph Scheiner, applying the techniques of Ibn Mu'ādh and Witelo, were the first to use the term in their calculations of the height of vapors that cause twilight. Their understandings of the atmosphere diverged from Aristotelian divisions of the aerial region. From the early years of the seventeenth century, the term was often associated with atomism or corpuscular matter theory. The concept of the atmosphere changed dramatically with the advent of pneumatic experiments in the middle of the seventeenth century. Pierre Gassendi, Walter Charleton, and Robert Boyle transformed the atmosphere of the mathematicians giving it the characteristics of weight, specific gravity, and fluidity, while disputes about its extent and border remained unresolved.

1. Introduction

Today the earth's atmosphere along with the other planets' atmospheres form the subject matter of an independent field of science that uses expensive, sophisticated tools and advanced mathematics. The atmospheric sciences have their own departments, journals, and government funding (Conway, 2008; Harper, 2008; Yeang, 2013). The changing conditions of the atmosphere can cause public anxiety, provoke state action, and engender global debate. The atmosphere itself might seem like a given, a universally recognized phenomenon that transcends eras and cultures. Yet, like many seemingly universal ideas tied to the history of science – for example, the concepts of observation, fact, or gas – the word "atmosphere" emerged at a particular historical moment (Daston, 1991; Pagel, 1982; Park, 2011). Strictly speaking, before 1600 no one used the word or conceived of the atmosphere or atmospheres as objects of philosophical or mathematical analysis.

Two Greek words "ἀτμός," meaning vapor, and "σφαῖρα," meaning sphere, form the word "atmosphere," or "atmosphaera" in Latin, giving it the flavor of a classical term. It is not. The word initially appeared at the beginning of the seventeenth century, first in Latin and then quickly afterward in other European languages. The neologism first emerged from those swayed by linguistic patriotism and humanists' concerns with the history and origins of language. Transformed into Latin, the word *atmosphaera* spread rapidly through Europe's networks of learned culture. By the middle of the seventeenth century, vernacular writings of virtuosi established cognates in English, French, and Italian.

That the diffusion of the word and the acceptance of the atmosphere as a concept of natural philosophy corresponded to alterations of and adjustments to traditional Aristotelian natural philosophies is not obvious. No polemicists railed against innovators who investigated the atmosphere. No church banned or jailed scholars because they asserted its existence. Some thinkers, emblematic of the new sciences, such as Galileo Galilei and René Descartes, seem not to have used the term. Yet, by the end of the seventeenth century, "the atmosphere," or rather simply "atmosphere," was a term used in multiple fields of research, not just cosmology and meteorology but botany and medicine as well. And despite the lack of polemics surrounding the atmosphere, its employment signified an understanding of the world that differed from that of the traditional natural philosophies and middle sciences of the Middle Ages and Renaissance.

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2. The aerial region in Aristotelian meteorology and the optical tradition

The seventeenth-century conceptual and linguistic origins of the atmosphere has been obscured by the widespread conflation of ancient and medieval conceptions of the region between the earth and moon with the atmosphere.[1] Sixteenth-century understandings of the composition of the region between the earth's surface and the lunar orb were based on two interelated traditions: Aristotelian natural philosophy and Ptolemaic middle or mixed sciences. Aristotle's account of the sublunary region played an outsized role in early modern natural philosophy. His writings, including the *Meteorology*, formed a starting point for university lectures throughout the Middle Ages and early modern period. Without describing an atmosphere per se, the *Meteorology* gave an account of the region between the earth's surface and the moon. Recent interpretations of the *Meteorology* have found only two aerial regions above the earth and below the sphere of fire that forms a border with the lunar orb. One aerial region reaches to the top of mountains, where the cycles or rain takes place, and a drier region sits above (Lee, 1952, pp. 24-27; Taub, 2004, p. 90; Wilson, 2013, pp. 117-55).

Unlike modern interpreters, medieval and early modern followers of Aristotle separated this aerial zone below the sphere of fire into three strata. For medieval and early modern Aristotelians, the uppermost layer is hot and dry, largely composed of fiery exhalations. The middle region is cold and wet, typically filled with vapors and clouds. The lowest region is hotter than the middle region; the reflection of sunlight on the earth's surface warms it. This region is also wet from the vapor that rises from the terraqueous globe, that is, the earth and its bodies of water (Martin, 2011, 8-9).[2] Nearly all wet and vaporous exhalations circulate within the two lower aerial strata as they intermittently form clouds and rainfall. The division of air into three regions ordered and defined species of meteorological phenomena, tying closely to the Aristotelian doctrine of place. Just as the elements' gravity and levity result from natural place, the exhalations, and their varieties, naturally moved to the regions of the air, which conformed to their composition (Wilson, 2013, pp. 35-92). The dry exhalation has the power of fire and the tendency to rise toward the moon. The heavier vaporous exhalations are potentially water and remains in the lower regions (340b23-341a9).

Early modern Aristotelians were diverse, but there was widespread agreement about the existence of three regions of air. Many of the most influential Aristotelian textbooks and treatises on meteorology printed during the seventeenth century, such as those of Giacomo Zabarella, the Collegium conimbricense, Daniel Sennert, and Libert Froidmont, which differed from each other in many aspects and doctrines, nevertheless sustained the tripartite division of air (Collegium conimbricense, 1606, col. 8; Froidmont, 1627, p. 3; Sennert, 1618, pp. 273-74; Zabarella, 1617, pp. 341-42).

While natural philosophers theorized about the region of air based on their experiences and understanding of Aristotle, a number of medieval and early modern astronomers calculated the height of these vapors.[3] These calculations were made as part of the middle or mixed sciences, or what would later be referred to as mixed mathematics (Brown, 1991; McKirahan, 1978; Weisheipl, 1965). For the most part, these medieval calculations of the height vapors did not directly challenge Aristotle's understanding of the sublunary region. Potentially, they even confirmed the existence of divided aerial regions and that vapors occupy the lower sublunary regions.

This technique relies on the matter of the sublunary region affecting the light of the sun and other heavenly bodies, a phenomenon recognized in antiquity. In the *Almagest*, Ptolemy (1984, 1.3, p. 39) weighed the possibility of vapors altering celestial light, attributing the large appearance of the setting and rising sun and moon to the "exhalation of moisture surrounding the earth," although elsewhere he considered this phenomenon to be entirely perceptual or psychological.[4] In the *Almagest*, as well as in the *Optics*, he discussed the air's distortion of observed positions of stars, believing that the refraction of starlight occurs at the point where air meets the celestial ether. This explanation left out the sphere of fire and assumed a uniform density for the aerial region (Ptolemy, 1903, p. 203, 13-18: Ptolemy, 1984 8.6, p. 416; Ptolemy, 1996, pp. 238-40; Smith, 2015, 122-23). He apparently did not calculate the angle of solar depression, that is, the angle between the horizontal line of sight of an observer and the position of the sun, at twilight, but the ancient geographer Strabo (2, 5, 42) possessed an accurate figure (Goldstein, 1976, 105). Strabo, however, did not use this angle to calculate the height of vapors.

Islamic astronomers gave great attention to questions surrounding twilight, in part because of the need to establish precise times for prayer (Yazdi, 2004). Ibn Muʿādh, in his eleventh-century *Liber de crepusculis*, which Gerard of Cremona translated into Latin in the twelfth century and was widely and incorrectly attributed to Alhazen, attempted to calculate the height to which "subtle vapors ascend" from the earth's surface (Smith, 1992, p. 96).[5] Ibn Muʿādh, a jurist and Koranic scholar, was active in eleventh-century Cordoba and wrote several works on astronomy and mathematics in addition to the *De crepusculis* (Smith, 1992, pp. 83-84). He reasoned that the sun's rays must be affected (*suspenditur*) by "some body denser than air" and that above the earth's surface "there is nothing more dense than air, except ascending vapors (*vapores*)." Therefore, it is these denser vapors, not the entire sphere of air that the setting or rising sun illuminates (Smith, 1992, pp. 98-99). Accepting that the angle of solar depression at twilight is 19° and the earth's circumference is 24,000 miles, he calculated the height of the highest vapors to be just below 52 miles [see Fig. 1] (Smith, 1992, 114-15).

Witelo, the thirteenth-century author on optics, whom Alhazen greatly influenced, closely followed Ibn Muʿādh's reasoning. Witelo contended that the reflection of sunlight creates twilight. Simple air is transparent and does not reflect light. Rather only air thickened by vapors can. Using the same geometrical methods as Ibn Muʿādh, he calculated the "elevation of vapors that thicken the air" to be approximately 48 miles.[6] In the late Middle Ages, at least a few scholars knew these calculations. For example, Nicole Oresme, the French philosopher and advisor to Charles V, cited Ibn Muʿādh's result, although, unlike Witelo, he did not know the true author. Oresme described the *Liber de crepusculis* as finding "the summit of the gross vaporous air" (Oresme, 2007, p. 138).

Since Ibn Muʿāhd, Witelo, and Oresme accepted that simple or pure air filled the region above the vapors, these medieval mixed-mathematical determinations potentially conformed to Aristotelian

[1] For example, prominent textbooks in the history of science and works on the history of meteorology refer to the atmosphere in ancient and medieval thought. For the textbooks see Lloyd (1970), p. 110; Lindberg (2007), pp. 66, 121, 128. For the histories of meteorology see Taub (2004), pp. 36, 75, 147, 153; Ducos & Thomasset (1998); Martin (2011), 108-9.

[2] For a clear and influential medieval account of these regions see Albertus Magnus (2003), 1.1.8, pp. 11-12.

[3] For an example of the role of experience in understanding these regions see Zabarella (1617), pp. 341-42; Schmitt (1969).

[4] Ptolemy (1898), 13, 5-6: ἡ τοῦ ὑγροῦ τοῦ περιέχοντος τὴν γῆν ἀναθυμίασις."

[5] For the identification of the author see Sabra (1967).

[6] Witelo (1535), 10,60, fols. 282v-83r: "elevatio vaporum aerem inspissantium."