Introduction

The unjustified neglect of the *Meteorologica*

Rarely do scholars dismiss the value of their subject matter as frankly as has H. D. P. Lee:

> That the *Meteorologica* is a little-read work is no doubt due to the intrinsic lack of interest of its contents. Aristotle is so far wrong in nearly all his conclusions that they can, it may with justice be said, have little more than a passing antiquarian interest.[1]

Trends in the past three centuries of scholarship are consistent with this assessment. Historians of philosophy and science have never bestowed on the *Meteorologica* the attention they have lavished upon the *Physics* and the *de Caelo*.[2] And even in the last decades, when Aristotle's biological works have been scoured for evidence of his scientific practice, the *Meteorologica* has been largely ignored. With the exception of Hans Strohm's excellent but dated essay, there is no modern monograph in any language devoted to the treatise itself.[3] There has never been an English commentary, and much of the secondary literature is highly specialized and difficult of access.[4] More general treatments of ancient meteorology give invaluable overviews, but by their very nature they do not focus on Aristotle's theory and cannot explore all its relevant features.[5]

[1] Lee 1952: xxv–xxvi. Compare Usener's assessment of Epicurus: "Epicuro ut operam darem, non philosophiae Epicureae me admiratio commovit" (1887: v). Lewis 1996: 1–2 has given a defense of *Mete.* 4.

[2] Typical is Burnyeat's exhortation at the end of his introductory essay on *GC* 1, which entirely ignores the *Meteorologica*: "Read on. Read on to the *De Anima* and beyond" (2004: 24).

[3] Strohm 1936. Solmsen 1960 is first rate. I owe it a great deal both in content and method, but the *Meteorologica* is somewhat buried at the end of the book.

[4] Barthélemy St.-Hilaire's 1863 commentary is mediocre at best. Ideler 1834–6, now over 175 years old, is still useful on many points. Vicomercatus 1565 is not widely available or accessible.

[5] Ideler 1832. Gilbert 1907 is an excellent resource still but suffers from a sort of index-card quality, in which analysis is rather weak. Taub 2003 breaks new ground by setting various forms of meteorology in their appropriate epistemic and social contexts.

The treatise has not always been neglected, of course. Three at least partial Greek commentaries survive from antiquity.[6] Through a "paraphrasing compendium" the *Meteorologica* made its way into the Arabic tradition, from which it was translated into Latin by Gerard of Cremona.[7] Moerbeke produced the *translatio nova* based on the Greek text, and the Western tradition rapidly broadened out and deepened in sophistication.[8] The material here is vast and would require another lifetime to study, but my superficial acquaintance with it indicates that medieval and Renaissance scholars read the *Meteorologica* as part of an active pursuit of truth about the natural world. They rightly used Aristotle's work for their own purposes and did not restrict themselves to interpreting the text in its own right. With the rise of the new science, the treatise was plunged into an obscurity from which it has never emerged. It remains a strange testament to its faded fortunes in modern times that a disproportionate quantity of modern scholarship has been devoted to this rich commentary tradition.[9]

The *Meteorologica* is certainly "little-read," but Lee is also correct that Aristotle is "wrong in nearly all his conclusions." In fact, one can hardly help feeling embarrassed by the obvious mistakes about something so apparently straightforward as the role of rivers in the rain cycle, and it is particularly painful to watch Aristotle rejecting many fundamentally correct theories of his predecessors. With the possible exception of rain and snow, there is not a single theory in the *Meteorologica* that even comes close to the modern truth.

But it does not follow from this, of course, that the subject is intrinsically lacking in interest or merely of antiquarian value. If we took such a view,

[6] Alexander's, often little more than a paraphrase, is available for the whole treatise; Olympiodorus' is complete except for 2.7–9, the beginning of 3.1, and most of 4.10–12; Philoponus' is available for the first book only.

[7] This compendium is very different from the Greek text and has a complicated history of its own (Schoonheim 2000: xiv). The *translatio vetus* consists of *Mete*. 1–3 in Gerard's Latin translation based on Yahya ibn al-Bitriq's Arabic. To this is added Henry Aristippus' Greek–Latin translation of *Mete*. 4, and Alfred of Sareshel's translation of part of Avicenna's *Kitab al-Shifa* (*de Mineralibus* or *de Congelatione et Conglutinatione Lapidum*). See Schoonheim 2000: x–xx; Vuillemin-Diem 2008: 5–16. The other Arabic version, that of Hunayn ibn Ishaq, is even further removed from the Greek (Daiber 1975: 6) and did not influence the Latin translations.

[8] Vuillemin-Diem 2008: 17–41; 256–70 argues that Moerbeke relied mainly on manuscript J (Vindobonensis phil. gr. 100).

[9] Daiber 1975 produced an edition and translation of Hunayn ibn Ishaq's compendium of the *Meteorologica*. Lettinck 1999 contains an edition and translation of Ibn Suwar's *Treatise on Meteorological Phenomena* and Ibn Bajja's *Commentary on the Meteorology*. Schoonheim 2000 contains the Arabic version and Gerard of Cremona's Latin translation from the Arabic. Takahashi 2004 provides an edition of Barhebraeus. See Vuillemin-Diem 2008 for Moerbeke's translation and Rubino 2010 for Henry Aristippus' translation. It was the first Aristotelian treatise translated into Hebrew (Fontaine 2001: 102). Most recently on the Renaissance fortunes, see Martin 2011.

we would ignore perhaps everything in the corpus except Aristotle's logic and his ethics. In fact, a subject becomes antiquarian only if we divorce it from its intellectual or social context and fail to appreciate its broader historical significance. I hope to show that the *Meteorologica* was wrong in profoundly interesting and significant ways, and that it needs to be read carefully by anyone who is concerned with how the Greeks organize their rational thoughts about the physical world.

The place of *meteora* in Greek thought

Today, as in antiquity, our main contact with meteorology is practical: the daily weather, current conditions, predictions for the future. At a professional level too, much of the growth of the contemporary science concerned with climate change is focused on predicting what will happen and what can be done to prevent it. It must strike the reader as strange, then, that Aristotle shows almost no interest in prediction. It is not that these matters excited no interest in ancient times. There was, in fact, a whole literature of weather signs and prognostication. But this was not Aristotle's focus.[10] Instead he concerned himself exclusively with the universal and the theoretical, with the reasons why various phenomena arise, and to the extent that he discusses weather signs, it is always in the service of these causes.

Daily weather, with its observable phenomena and practical effects, always excites interest. Theoretical weather studies are a different matter. Although people talk about the weather every day, meteorology does not figure large in the organization of modern sciences. Few universities have Departments of Meteorology, and when they do, atmospheric studies and oceanography are sometimes joined, sometimes separated. The study tends to be squeezed between physics and chemistry on the one side and biology and environmental science on the other. As we shall see, Aristotle was faced with an analogous squeeze and confronted challenges on the related issues of the scope and integrity of the science. The title *Meteorologica* suggests that the treatise is concerned only with the weather but, in fact, Aristotle's compass is much broader, including some geology and what we take to be parts of astronomy. And broad as Aristotle's conception is, for the earliest Presocratics meteorology was much broader still: the study of things above the earth (*meteora*) was essentially identical with the study of cosmic nature,

[10] Taub 2003: 71. Lehoux 2007 for an excellent study and bibliography. Diogenes Laertius 5.26 credits Aristotle with a book on *Signs of Storms* (σημεῖα χειμώνων).

and though it did not include biology (a relatively late study), it sought ultimately to situate man's place in the universe as a whole. However, in the period of Aristotle's more recent predecessors, those who followed in the footsteps of Parmenides, the study of specific meteorological phenomena was losing ground and being reduced to the general laws of material change. One of Aristotle's main goals in writing the treatise was to find a stable compromise between the broad and the reduced version of meteorology, to fix its scope and purview, and provide it with a secure place in the physical world.

For us, who come from a modern perspective, Aristotle's theoretical study holds four major surprises. First, the modern world tends to value complexity and equate it with order. We marvel more at terrestrial life, at the diversity of living species, the sophistication of their behavior, the astounding complexity of their chemistry, and less at the monotony and simplicity of elemental and lifeless matter. For Aristotle, however, the simpler order is the better order. This peculiar feature of Aristotelian thought is alluded to in the subtitle of this book, "A More Disorderly Nature," which derives from Aristotle's comment in the first chapter of our treatise (1.1.338a26–b21): "these things [*meteora*] happen in accordance with a nature (κατὰ φύσιν), but one more disorderly (ἀτακτοτέραν) than that of the first material element [i.e., that of the heavens]."[11] In Aristotle's geocentric system, order decreases as we descend from the heavens into the sublunary world of fire, air, water, and finally earth. And the sublunary world displays a less orderly nature than the heavens in at least three ways: (a) in contrast with the simple rotary motion of the uniform celestial aether, the sublunary realm contains four different elements, which move in two opposite directions and which affect one another in new and complex ways;[12] (b) unnatural or forced motion is disorderly (*Cael.* 3.2.301a4–6), and there is an abundance of unnatural motion among the whirlwinds and other violent phenomena of the *Meteorologica*; (c) temporal cycles, precise and exact in the celestial realm, are much less precise in the sublunary. Though the cycle of evaporation and condensation follows certain regular periods (τισι τεταγμένοις χρόνοις 2.2.355a25–8), water vapor does not necessarily return in the same year or to the same place from which it has evaporated. And the sea's salinity "occurs according to a certain order

[11] Here and throughout the translations of Aristotle are my own, though with signficant debts to previous translators. The translators of other authors are indicated.

[12] Disorder is the state of the material world when separated from the work of the demiurge (κινούμενον πλημμελῶς καὶ ἀτάκτως –– Pl. *Ti.* 30a3–6). In the *Meteorologica* Aristotle does not discuss the deficiency of the material as a cause of the irregular motions, as he does in *GC* 2.10.336b21–4. Cf. Martin 2011: 42–3.

(τάξιν)," Aristotle says, "to the extent that things here [in the sublunary realm] can have a share in order" (2.3.358a25–6). The complexity of the sublunary world is not a sign of its excellence.

Modern readers may be surprised in a second way by the remarkable degree to which Aristotle's conception of the *meteora* forms an integrated unity, specifically, a unity of cause. Modern scientists, by contrast, invoke a wide variety of causes to explain these phenomena. They claim that the Milky Way is the appearance of our galaxy, a vast number of stars; that the aurora is caused by ionization of atoms in the upper atmosphere; that lightning is an electrical discharge; and that the salt of the sea is caused by the dissolution of minerals in it. Some of these phenomena just happen to take place within the same zone, but they are subject to very different causes, physical, chemical, sometimes even biological. For Aristotle, these phenomena all have a common origin in one of the two fundamental materials, the dry and the wet exhalations. Their shared location and the unifying agency of the sun serve as further assimilative causes. The application here of the principle of economy, usually considered a virtue in scientific explanation, is very powerful and clearly extends beyond what is indicated by the empirical evidence. Indeed, as we examine Aristotle's method more carefully, we find that he is less concerned with furnishing accurate and true causes of each phenomenon individually (something that gives modern meteorology its distinctive interdisciplinary character), and more concerned with how the causes of the *meteora* as a group form an integrated structure. Whereas modern science finds it sufficient to provide whatever happens to be the correct cause, Aristotle found it at least equally important to organize the causes. This is an ancient and medieval style of science very much in keeping with C. S. Lewis' "discarded image."

Third, this structured unity of cause seems to be in conflict with what appears to be a thoroughgoing empiricism. As I argue in my first chapter, when Aristotle reports and refutes the theories of his predecessors (and these reports are reminiscent of modern literature reviews), overwhelmingly his arguments are empirical in nature, that is to say, he characteristically cites observational evidence that conflicts with their theories. In support of his own theories, too, he often provides confirmatory signs drawn from simple observations. This empirical tendency has been regularly noted, but if we suppose that it implies a disciplined, even-handed, and critical scrutiny of meteorological theories, we would be mistaken. Two features of Aristotle's account tell against the empirical character of his method in this modern sense. (i) As just mentioned, Aristotle regularly tailors his evidence to suit both his specific theory and the general principles

of the whole discipline. The empirical evidence is present in abundance, but it has already been pre-selected to fit the theory. The structure of the discipline, then, is more important than the individual parts, and rarely do we see Aristotle examining obvious contradictory evidence that might undermine his general principles. (ii) Aristotle composed the *Meteorologica* to stand within a sequence of physical lectures. By using both empirical and philosophical methods of high generality, he had already laid down his groundwork in the *Physics*, *de Caelo*, and *de Generatione et Corruptione* and had drawn conclusions there that he now takes for granted.[13] As a result, when he argues against his predecessors on the basis of empirical evidence rather than theory, it is because he has already put the more general arguments to rest. The upshot is that the *Meteorologica* has an empirical character, only because the basic parameters and foundations of the discipline have already been established by a more general philosophical method elsewhere. Aristotle's empiricism here is not to be mistaken for its modern counterpart.

A final surprise comes from teleology. In view of the integrated place of the *Meteorologica* in the physical works, the modern reader acquainted with ancient teleology will find it strange that the *Meteorologica* is utterly devoid of reference to teleology and the final cause. It is not the purpose of the sun, the rain, the rivers, or the sea to support life on earth or sing the praises of God in heaven. In this respect, Aristotle seems to present a remarkably modern conception of an earth that is an accidental environment, where living things must struggle to make their way if they are to exist at all. But again the modern comparison is deceiving, as I shall argue in Chapter 5; for, while it is true that teleology plays no direct role in the treatise, we shall find that the lack of teleology here merely reflects the *Meteorologica*'s role in the grander cosmic teleological scheme, one that positions it between the celestial teleology of the divine mind (νοῦς) on the one hand and the teleology of terrestrial living organisms on the other. The non-teleological character of the *Meteorologica* cannot be understood apart from the play of teleology around it.

The method and organization of the book

I had long noticed the lack of an English commentary on the *Meteorologica*, and my initial intention when beginning this project was to supply one.

[13] For the argument that even Aristotle's highly general physical works proceed by a largely empirical method, see Bolton 1991 and 2009.

But as I proceeded, Aristotle's hierarchical and integrated causal structure persuaded me that this was a poor strategy: it has been precisely the commentary format that has prevented scholars, from antiquity onward, from understanding the treatise's basic architecture and its significance. It was also clear to me that students of the history of meteorology and geography might be benefited by a guide from outside their discipline, one with broader experience in Aristotle's own habits of thought, one who could provide them with a context in which to understand his peculiar and often flawed arguments.

These considerations and goals have produced a book that falls into two unequal parts (I provide a somewhat more detailed précis below). The first part (Chapters 1 to 5) deals with the context of the treatise and issues of a general nature. I first situate the *Meteorologica* diachronically among the theories of early Greek meteorology (Chapter 1) and synchronically within Aristotle's more general physical works, especially the *de Caelo* (Chapter 2). Then I turn to the material principles, the exhalations (Chapter 3), to the complex causal structure of the whole (Chapter 4), and finally, through a consideration of teleology and the final cause, to the treatise's intermediate position between cosmic and biological nature (Chapter 5). These last two chapters form the core of my argument.

The second part (Chapters 6 to 13) deals with the meteorological phenomena in the order in which Aristotle presents them. The chapters of this section may be read separately, though I do not intend them merely as an independent overview of the several topics of the treatise. I endeavor throughout the second part to stress the major themes of the first, provide amplification and nuance, and show in detail how Aristotle conceives of the meteorological phenomena as a unified whole. In each chapter I focus on one or two problems that have been neglected or unsolved. For these reasons, my treatment of passages is selective and problem-oriented. It is my hope that these discussions will be of aid to historians of science less familiar with the intricacies of Aristotle's thought-patterns and will show students of Aristotle that careful attention to the treatise is worthwhile.

A word about my general approach to the text is necessary, since it might strike some as occasionally more literary than philosophical. As I mentioned above, I have been impressed by the coherence of the grand organizational structures in the *Meteorologica*. I have been much less impressed by the individual arguments, which often seem *ad hoc* and arbitrary. This contrast has led me to conclude that Aristotle's primary interest was the organization of the whole and that the arguments are more or less ancillary to that purpose. For this reason, I have found it profitable to seek Aristotle's

motivation for making an odd observation or bad argument in his conception of the whole discipline. I prefer to diagnose rather than to remedy his specific arguments. The reader will quickly detect the pervasive use of the simple techniques of polarity and analogy in my analysis. This is, of course, because they are Aristotle's basic structuring techniques, and their unmistakable similarity to the oppositional structures of Homeric composition confer upon the *Meteorologica* a kind of awesome and epic grandeur, which Aristotle is more than willing to exploit. But they are not for him merely the pattern of folk thought so beloved of structuralists; they are instead highly refined techniques of taxonomy and division joined to a sophisticated apparatus of causation.

My primary interest is the way in which Aristotle's method contributes to the unity of the science of meteorology. When I began this project, I intended to use the *Meteorologica* as a case study in the techniques of "scientific unification" that had been the subject of my previous book. I was especially interested in how Aristotle's construction of the subject genus of meteorology might inform our understanding of his theory of the subject genus in the *Posterior Analytics*. The *Meteorologica* provides ample material to this end, but I found that such a project, whether and how the practice of the *Meteorologica* corresponds or fails to correspond to the theory of the *Posterior Analytics*, became less interesting than the theory of unity implicit in the *Meteorologica* itself. I found that Aristotle's practice here runs far in advance of his theory in the *Analytics*, and for this reason I have not engaged the *Analytics* in any sustained or systematic way. I think it will be clear, however, that the issue of scientific unity and what constitutes a subject genus is always a present concern.

Meteorologica 4 and the date of the work

I do not, of course, discuss the fourth book of the *Meteorologica*, which deals with the transformation of various homeomerous bodies. The textual tradition has always given it a secure place at the end of the *Meteorologica*, but its role in the course of physical lectures has been disputed from antiquity.[14]

[14] Alexander 179.3–11 (cf. Olympiodorus 273.27–9), noting especially its reliance on active and passive powers, sees it as a continuation of the *GC* rather than of *Mete.* 1–3. According to Olympiodorus 272–3, *Mete.* 3.6 treats lifeless homeomeries (metals and minerals), which prompts Aristotle to take up the question of homeomeries in general in *Mete.* 4. *Parts of Animals*, then, treats ensouled homeomeries. Philoponus 3.14–19 likewise sees a continuity between the study of metals (3.6) and Book 4. Lewis 1996: 9–15 argues on a similar basis that *Mete.* 4 follows naturally from the first three books. See Viano 2006: 17–23 for an excellent discussion of the continuities and breaks between 1–3 and 4.

The project of the first three books is left incomplete with Aristotle's hasty and general discussion of metals and minerals, and though he promises an account of their species at the very end of Book 3 (3.6.378b5–6), Book 4 does not provide what we are promised.[15] Whatever continuities may be found, *Meteorologica* 4 is obviously based on different principles and methods from those of the first three books. Not only are the exhalations, so characteristic of the first three books, absent, but the entire structure of cosmic place between the moon and the earth (and below the surface of the earth) has completely disappeared. The agency of the sun and the heavens plays no role. The fourth book carefully straddles the provinces of inorganic and organic matter. In certain respects it continues the work of the *de Generatione et Corruptione* in studying the qualitative changes of matter, and for this reason it has been called the "Chemical Treatise"; in others it prepares the way for the tissues of organic bodies, which require homeomerous materials significantly more complex than the simple elements that are the materials of the cosmos as a whole.[16] Occasionally the fourth book may shed light on problems in the previous three, but for our interests there is little direct interaction. I see no reason to doubt the authorship of either treatise; certainly the authenticity of the first three books has never been seriously doubted.[17]

About the date of composition, I have little to say. The *Meteorologica* was clearly part of a rotating series of lectures (1.1), and that series was undoubtedly delivered more than once in Aristotle's lifetime.[18] We are better supplied for *termini post quem* here than for any other physical treatise. An early datable event is the burning of the temple of Ephesus (3.1.371a31), described as having taken place "now" (νῦν), and dated to 356 BC. A comet is said to have appeared in the archonship of Nicomachus (1.7.345a1) dated to 341/0 BC. The conjunction of Jupiter with one of the stars of Gemini, which "we ourselves have seen" (1.6.343b30) has been dated in recent years to December 337 BC.[19] The second moon-rainbow

[15] *Mete*. 4.8 discusses metal formation, but on the basis of different principles (see Chapter 13). A section in Avicenna's *Kitab al-Shifa* is an attempt to fulfill this promise and for this reason becomes attached in translation to the *translatio vetus* of the *Liber Metheorum*.

[16] Düring 1944: *Aristotle's Chemical Treatise*; for biological connections, see Furley 1983; Gill 1997.

[17] Alexander 179.3–4 affirmed its Aristotelian authorship. Louis 2002: vii–xviii. On the authenticity of 4, see Strohm 1984: 216–18, and at length, Viano 2006: 79–113.

[18] Lee 1952: xxiii–xxv; Louis 2002: xviii–xx.

[19] Poss 1980 for the occultation of 1 Geminorum. Cohen and Burke 1990, with a somewhat more elaborate study, concur on the star and the date (though ignorant of Poss' contribution). The evidence of Corona being overhead (2.5.362b10) and therefore suggesting an Athenian observer, and therefore Aristotle at Athens, is too ambiguous and imprecise to be useful.

"we have met with in over fifty years" (3.2.372a28–9) could arguably have been observed in the very late 330s.

Stylistically, the treatise has a coherence and uniformity of vision that might suggest a brief period of intense work, but this can hardly be proved. As will become clear, I do think that the treatise in its current form was based on a plan worked out in advance, most likely in a notebook shorter than, though similar to, the *Historia Animalium*. This conjectural *Historia Meteorōn* may have contained a list of problems and predecessors' theories but certainly would have described the phenomena and, most importantly, the list of their differentiae, such as we find in the *Historia Animalium*. This list need not have been the chronological first step toward the composition of the earliest version of the *Meteorologica*, but it was almost certainly drawn up before our *Meteorologica* was completed.[20] At the same time, it is clear that the treatise was not written in isolation from the rest of the physical works. The overall conception of the *Meteorologica* is crucially dependent upon the *Physics*, *de Caelo*, and *de Generatione et Corruptione* on the one side and the *de Anima* and the biological works on the other. The synthesis of the whole set of lectures must have begun early and was certainly the work of a lifetime.

Overview of the argument and claims of the book

Chapter 1 begins by examining the place of the *Meteorologica* in the tradition of early Greek physical investigation. I argue that Aristotle inherited a science in decline and was eager to reinvigorate it. Most controversially, I claim that he attributed meteorology's decline (and since Aristotle largely wrote the history of early Greek philosophy, we have little independent counter-evidence) to the obsession with the general problems of change, which occupied thinkers in the aftermath of Parmenides and which led them to consider the fundamental nature of matter more important than the independent study of meteorology. The neglect of meteorology reached an extreme in Plato's manifest contempt for it even in the physically oriented *Timaeus*. I show that Aristotle aimed his refutations of his predecessors largely at a specific rather than a general level and that he did so because of his desire to avoid engaging with their most general principles and to keep meteorology at the appropriate level of specificity. In this way he prevented meteorology from being reduced to general physics.

[20] There may be traces of it incorporated directly into the *Meteorologica* at 3.2. For the practice of ancient writers, see Dorandi 2007, especially Chapter 2.