Aristotle's *Μετεωρολογικά*

Meteorology then and now

Anastasios A. Tsonis and Christos Zerefos

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Cover image: Mt. Olympus summit at 3.3 km height, a few hundred kilometers from Aristotle's birthplace at Stagira (courtesy of Stelios Zerefos)

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Prolegomena

Meteorology derives from the Ancient Greek word μετέωρος *metéōros* (*meteor*) which means 'things suspended high in the air'. *Μετεωρολογικά* (*Meteorologica*; on Meteorology) occupy a special place within the body of work by Aristotle. It is the only book dealing with many diverse areas such as astronomy, geometry, optics, geography, seismology, volcanology, chemistry, and today's aim of meteorology, weather forecasting and is divided into four books. Some of the features that Aristotle discusses in *Meteorologica* (for example, rivers and the seas), cannot be considered as suspended in the air. They are included in this book by virtue of their relation to moist and cold exhalation defined in Chapter 4 of Book A. Similarly, discussion on shooting stars, comets, and Milky Way has nothing to do with weather and meteorology. They are part of his discussion because they were thought as 'suspended' and products of the exhalation from the Earth. The four books are divided as follows:

Book A starts by considering the five fundamental elements: aether, fire, air, water, and earth, and their distribution in Aristotle's model of the universe. A supreme notion is then introduced, which he named αναθυμιαση or exhalation, which causes water and land to exhale vapour and dry air, respectively, after they are warmed by the Sun. The planet is warmed by solar radiation and then the air in contact with it warms up and rises. Aristotle then continues with a discussion about this rising motion and how it produces dew, frost, rain, snow, and hail. After that, the discussion moves to issues not directly related to weather such as stars, comets, the galaxy, etc. Aristotle discusses the phenomena of Aurora Borealis, which will be discussed in detail later in Book C, together with other optical phenomena such as rainbows. At the end of Book A, Aristotle touches on an important issue related to what today we would call global climate change, a topic of great interest and debate now-days. In this book, Aristotle also briefly talkes about winds, a topic that forms a major part of Book B with the detailed elaboration on wind formation and wind distribution on Earth. In Book B, Aristotle continues with the formation of lightning and thunder and subsequently touches on earthquakes, a topic again not much related to meteorology. In Book C,

Aristotle discusses in detail optical phenomena such as rainbow and halo where with the help of geometry he explains their formation. In this book, Aristotle also ventures into the creation of metals, which again is not much related to meteorology. In Book D, Aristotle classifies 'warm' and 'cold' as the two 'active' causes and 'dry' and 'moist' as the two 'passive' causes, and goes on to discuss how the active affect the passive and how their interaction affects our senses. This book is hardly related to meteorology; however, it appears that hidden in this discussion is the notion of (thermodynamic) equilibrium that is important in weather processes.

It is interesting to note that Aristotle did not provided titles for his works. The titles, including Μετεωρολογικά, were invented later for convenience by his publishers. The chronology of Μετεωρολογικά is not very clear, as it is one of his works that refers to very few historical events at the time of the writing. One such event is the fire of the temple of Ephesus in 356 BC. Another is the appearance of a comet in Athens in the time of ruler Nikomachus (around 341-340 BC). These two events suggest an interval of 16 years (356-340 BC) in which Μετεωρολογικά were written. In addition, it is worth mentioning that while the authenticity of the first three books is undisputed, some scholars have raised questions about the authenticity of the fourth book; however, most of the scholar agree that it is definitely a work of Aristotle, and that differences in style probably reflect the fact that in writing Book D, Aristotle used notes from his teaching students at the Academy.

While there are scientific issues behind Aristotle's writings, this book is written for non-specialist. We use simple examples which will be easily followed by general readers.

In this study we will consider only parts relevant to meteorological phenomena (for example, we will not deal with Aristotle's views on the stars or earthquakes) and we will compare Aristotle's arguments with the current knowledge of meteorology. The purpose of this book, however, is not a just a comparison between then and now. This book has an additional purpose, of bringing out the incredible deduction process that allowed Aristotle to make inferences about scientific ideas based on a few fundamental assumptions, on non-instrumental observations and on logic. In writing this book, we consulted two translations from Ancient Greek: one into English (*The Complete Works of Aristotle: The revised Oxford Translation, edited by* Janathan Barnes, Bollingen Series LXXI 2, Princeton University Press 1984) and one into modern Greek (*The complete Works of Aristotle,* Volumes 13 and 14*, edited by* H. P. Nikoloudis, Cactus Editions 1994). For our discussion of rainbows in Book C, we found the paper 'The Aristotelian Explanation of the Rainbow' by A. M. Sayili, *Isis* Vol. 30, No. 1: 65-83, 1939, to be a very informative reference. We note here that during the last 2,300 years and after two translations (to Arabic and Latin), some of the style and concepts have been naturally affected.

That is why we combined the English and Greek translations and our familiarity and knowledge of ancient and modern Greek and meteorology to present accurately the writings of Aristotle. Our version of Aristotle's writing may at times appear 'exotic', partly because the style of expressing in Ancient Greek (like any other ancient language) was very different to the style used today, much like today's English differs from Shakespearean English. In Greek language, for example, it is very common (even today) that several tenses will be used in one sentence. Nevertheless, we think that our version has a flavour to it, and we hope the reader will adapt it without much effort.

Anastasios Tsonis and Christos Zerefos
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Introduction: about Aristotle

His life

Aristotle, son of Nicomachus, was born in 384 BC in Stagira of Macedonia, about 55 km east of today's Thessaloniki. He died in Chalcis, a city on the island Euboea (Evia) just west of Attica, in 322 BC. His father was the doctor to Amyntas II, the king of Macedonia, who was the father of Phillip II and grandfather of Alexander the Great. His mother, Phaistis, descended from Chalcis. Both his father and mother belonged to the family of Asclepius. Aristotle's parents died when he was about thirteen and Proxenus of Atarneus became his guardian. Very little is known about Aristotle's early life. It is not even certain how much time he spent within the Macedonian Palace. At the age of 17, Proxenus sent him to Athens to study at the Academy, the school established by Plato. There Aristotle remained for 20 years. In 348 BC Plato died and was succeeded by the son of his sister Potonis Speusippus. For this reason, as well because the relations between the Athenians and Phillip II had worsen, Aristotle and his friend Xenokrates, left Athens and settled in Assos (Asia Minor), south of the Trojan coast across the island of Lesbos. There Aristotle met Hermias of Atarneus whom he initiated to Platonian philosophy, and who became a very close friend. Aristotle stayed in Assos for three years (348-345 BC) and then, after an invitation by Theophrastus, moved across to Mitilini where he stayed until 342 BC. That year he was invited to take over the education of young Alexander, who later became Alexander the Great.

Aristotle remained in Macedonia until 335 BC. During this time, in addition to educating Alexander, Aristotle embarked on to theoretical studies, which were interrupted in 341 BC by the death of his friend Hermias. "In his honour Aristotle wrote his only surviving poem *Ode to Virtue* (*Αρετα πολυμοχθε...*).[1] After 335 BC, Alexander now being the King of Macedonia, Aristotle moved to Athens again, and established the Lyceum (or Peripatetic School). He stayed there teaching and writing until Alexander's death

[1] The poem is included in the Appendix I at the end of the book

in 323 BC. Subsequently, his position in Athens became difficult (among other things he was accused of insulting the Gods). Aristotle was forced to leave and went to Chalcis where he died the next year at the age of 62. The Stagirites moved and buried his body in his birth place.

His works

Aristotle wrote about basically everything. The complete catalogueue of Aristotle's work, accepted today, is by August Immanuel Bekker of Berlin University, published in two volumes in 1831. Three more volumes were added at a later date. Bekker based his work on three ancient catalogues by Diogenes Laertius, Ptolemy Henou (most likely a student of the Peripatetic school), and Isychios. Not all the works by Aristotle are listed in this book; Aristotle wrote tens of titles, which account for about half a million lines.

In his books Aristotle covered all philosophical topics and questions: nature, being, virtue and ethics. These subjects were studied in combination with the critical research of the political evolution of Greek city-states. However, Aristotle did not act only as a philosopher, he went a long way from supernatural explanations and beyond superstition. He was a master of inductive, systematic, and practical thinking, and was unparalleled in his ability to organise events and evidence. He contributed immensely to Plato's ideas and was determinative in the development, evolution, and application of the philosophical systems, that have influenced and still influence the world today. For Aristotle, there is no 'ideal' society, but only 'noble' (best possible) society within human capabilities. He considered education and virtuous upbringing as the best means for survival and progress.

The works of Aristotle were transferred from the Library of Alexandria to the Library of Antioch after the fall of Alexandria to the Arabs in AD641. After the conquest of Antioch most of the Alexandrian philosophers were converted to Islam and a large number of them immigrated to Spain. As early as the 9th century AD, these works were translated first into Arabic and later into Latin. They spread all over Europe. Aristotle's works were not studied only by philosophers but also by renowned scientists such as Galileo, Newton, Keppler, among many, who took counsel from his works and methods. Aristotle's views were adapted both by Christianity and Islam, as seen by miniatures in ancient theological manuscripts from major Christian and Islamic sources, such as *Sinaitic Codices* and *Islamic Codices* at Azhar Cairo (the first Islamic University in the world). Aristotle's views formed the basis for the study of physics and natural sciences for more than 1500 years and were adapted by both Christianity and Islam. Since the 19th century, no education could be considered complete without a reference to this great man from Stagira, the father of philosophy, and one of the greatest (if not the greatest) minds of all time.