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Roman Climate Awareness in Pliny the Elder's *Natural History*

This article examines the past and potential contributions of Pliny the Elder's *Natural History* (*NH*) on the subject of Roman perceptions and experiences of environmental change. It asks in particular how classicists, archaeologists, and environmental historians can responsibly use the *NH* as a source on ancient climate. First, it briefly reviews relevant topics in the paleoclimatology of the Roman world, a rapidly advancing discipline enabling the identification of ancient climate changes with increasing precision and confidence (I). The article then turns to the reliability of Pliny as an authority on ancient climate by examining his accuracy, objectivity, and use of source material in literary and historical context, including his rhetorical goals, which have gone understudied until quite recently (II). A close reading of passages on environmental and climate change follows, highlighting areas in which Pliny's observations are at odds with his source material. The examples discussed demonstrate the importance of phenology (III) and meteorology (IV) in Pliny's encyclopedic account of the natural world, one characterized by anthropocentrism, pragmatism, and an emphasis on local knowledge. The evidence for ancient climate change is plentiful but not conclusive on the details and timing, and further studies will continue to refine local records. Rather than presenting a synthetic reconstruction based on Pliny's observations, I argue that his encyclopedia offers an untapped resource on ancient climate and weather, not only by providing evidence of climate change, but also by recommending increased attention to seasonality, agricultural communities, and the lived experience of agricultural labor in order to better understand the effects of climate change on ancient populations.

KEYWORDS: Pliny the Elder, paleoclimatology, environment, natural history, Rome (Empire), climate, phenology, seasons, Roman literature, encyclopedia, agriculture, meteorology

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I. INTRODUCTION

Though major historical works have traditionally relegated the environment to their background and introductory chapters, it is becoming increasingly clear that environmental change impacted the Roman Empire at multiple levels, providing a dynamic medium for the lives of its people, aiding its growth, and exacerbating the conditions of its eventual decline.[1] Diverse populations living and working throughout the empire had profound effects on their local and regional environments, while experiencing a climate subject to its own dramatic shifts in temperature and precipitation.

Historians, archaeologists, and natural scientists have led recent interdisciplinary efforts to address the theoretical and practical issues of an integrated human, climate, and environmental history of the Mediterranean,[2] but the contribution of ancient literature remains undertheorized. The *Natural History* (*NH*), an attempt by Gaius Plinius Secundus (Pliny the Elder) to systematize all human knowledge about the natural world in the first century CE, has so far held a persistent place in the footnotes of studies on the physical realities of the Roman environment, particularly Italy.[3] But as advances in paleoclimatology enables scholars to identify ancient climate changes with increasing precision and confidence, Pliny's continued relevance is well worth revisiting. This article will explore the context of (II) and the evidence for (III) climate change in the *NH*, attempting to arrive at how modern scholars can responsibly use the encyclopedia as a source on ancient climate.

A secondary goal of the article is to consider the impact of climatic changes on the lives of ancient communities and individuals, one of the most vexing issues in current work on Roman climate. It has elsewhere been argued that Pliny's text can help make sense of the economic lives of ordinary Romans, if not through direct insight into their activities, then at least by revealing the dynamic constraints under which they operated.[4] I will show that in Pliny's advice to farmers, the population most immediately affected by fluctuations in the ancient climate, he offers valuable insights into the detection, management, and mitigation of climatic changes at a human scale (IV). Therefore, in addition to critically evaluating the evidence of environmental change in the *NH*, this paper aims to demonstrate Pliny's potential contributions to the ancient understanding and experience thereof, offering a framework for Roman climate awareness.

1. Climatic explanations for Roman economic decline and agricultural exhaustion are most popular, going back to Marsh 1864: 9–12, now revisited in light of new paleoclimatic evidence (e.g., Drake 2017; Harper 2017; Haldon, Elton, et al. 2018). Major works in the environmental turn of scholarship on the ancient Mediterranean include Horden and Purcell 2000 and Broodbank 2013. On climate and history, see Ingram et al. 1981; Lamb 1982; Le Roy Ladurie 2004–2009; and Brooke 2014. On the increasing role of the natural sciences in Roman history, Schrüfer-Kolb 2012 and Scheidel 2018.

2. E.g., Izdebski et al. 2016; Haldon, Mordechai, et al. 2018; McCormick 2019.

3. Cf. Doody 2010: 2, on the reception of the *Natural History*: "Pliny has had a long career in the footnotes of major historical studies, lending his weight to the substructure of the argument; it is in footnotes that many battles on the accuracy of Pliny's information have been lost and won."

4. Hollander 2019: 9, referring also to Cato the Elder, Varro, and Columella.

II. PLINY'S CONTEXT: NATURE, EMPIRE, AND THE ENCYCLOPEDIA

PALEOCLIMATOLOGY OF THE ROMAN WORLD

The climate record of the Roman world is a synthesis of increasingly high-resolution natural archives, "proxies" for ancient climate laid down in glaciers, seafloors, lake sediments, cave deposits, and tree-rings. Physically and chemically differentiated layers of deposits record vicissitudes of temperature and precipitation driven by the orbital, solar, and volcanic "forcings" (that is, drivers) of Earth's climate. Analysis of these records falls to paleoclimatology, an increasingly rigorous and quantitative discipline of earth science concerned with local, regional, and global climate patterns and their variability across time. Recent interdisciplinary research efforts have gathered multiproxy evidence throughout the Roman world, emphasizing regional differentiation across highly variegated microclimates of its vast geographical expanse, but also revealing a few general trends.[5]

Pliny's encyclopedia sought to encompass a vast and highly differentiated region, and it is essential to note at the outset that there can be no unified definition of a "Roman" or "pan-Mediterranean" climate, shaped as it was—and is—by local and global factors, stable geographical features and dynamic forces of weather.[6] The north-south expanse of the empire was unprecedented and almost unmatched, with highly variegated geographical features of the land and the dynamics of the *mare nostrum* enhancing local variability. Nevertheless, multi-proxy data converge to show that diverse regions, from the Alps to the Levant, enjoyed a period of warm, wet, and remarkably stable conditions contemporary with the rise and maximum extent of the Roman Empire. This period, commonly referred to as the Roman Climatic Optimum (hereafter the RCO), is widely acknowledged but poorly defined. Its extent is usually reckoned as ca. 200 BCE to 150 CE, but estimates range as far afield as 550 BCE to 350 CE, due to its varied expressions in temperature and precipitation patterns and the sensitivity of individual proxies to local conditions.[7] The relatively mild and predictable conditions of the RCO under which Pliny the Elder was writing did more than provide a scenic backdrop to the glory days of Rome: climate factors were deeply implicated in the empire's expansion and eventual decline, offering variable opportunities and constraints to its population. For the empire's sprawling agrarian economy, a more stable climate regime would have mitigated some of the usual uncertainty inherent in Mediterranean ecosystems, resulting for example in a more consistently

5. On paleoclimatology see Bradley 2015. For the most comprehensive—if by now somewhat dated—paleoclimatic syntheses for the Mediterranean see Luterbacher et al. 2012; McCormick et al. 2012, updated as Manning 2013; Brooke 2014: 317–49; and Harper and McCormick 2018.

6. Harper and McCormick 2018: 16. Even the Italian peninsula appears to have undergone contrasting patterns of climatic change in the north and south, as demonstrated by Peyron et al. 2013 through the use of pollen data.

7. Also known as the Roman Warm Period (Christiansen and Ljungqvist 2012). On dates see Harper 2017: 15; on proxy data, Harper and McCormick 2018: 33–35.

favorable Nile flood when compared to the Hellenistic period, adding to the breadbasket of the burgeoning empire and contributing to its structural resilience.[8]

The narrative is compelling, but characterizing the relationship between climate, environmental change, and past societies has proven persistently challenging. The nature of the paleoclimatic evidence suffers from three main issues: differences in scale, the visibility of crisis, and the uneven geographical distribution of proxy evidence. Firstly, natural archives running on geologic time scales rarely produce proxy data at the annual, decadal, or even centennial resolutions suitable to the work of historians and archaeologists, with significant margins of error too easily manipulated to fit existing narratives.[9] Secondly, the climate record tends to emphasize crisis over stability due to the nature of natural archives. Tree rings, for example, can reveal periods of life-threatening drought if they occurred during growth seasons, but responses to improved conditions are never so clearly represented. Finally, despite the publication of paleoclimate archives from the outer reaches of the Roman world, the Italian peninsula has yielded fewer high-resolution proxies and its climate history is not well understood. Though the situation is improving with the publication of new evidence from palynology and alluvial geoarchaeology,[10] climate proxies for the core of the empire remain relatively sparse and inconclusive.

Examples can be multiplied—for instance, paleoclimatic data has generally been collected and published by specialists without archaeological or historical research questions in mind, adding to difficulties in cross-disciplinary communication. The differential impact of climate change in its many forms is highly contingent on a number of social and historical factors. The upshot, for now, is this: due to the nature of the evidence, publications on the climate history of the Mediterranean have trended towards universal explanations, large-scale syntheses, and long-term trends, identifying periods of climatic anomaly and then seeking evidence of human reactions that affect the narrative of a given period.[11] Regional landscape studies and accounts of the rise and fall of societies tend to dominate, with fewer attempts to investigate the social and cultural dimensions of human-environment relationships. In sum, though indispensable for their record of general climate trends, natural archives and empire-wide syntheses do not offer

8. On relevant weather systems see McCormick 2013: 78–79; Manning et al. 2017 on the opposite trend, i.e., suppression of Nile floods during the Hellenistic period.

9. Tree rings, some ice cores, and some lake varves are the exceptions, capable of offering annual and even sub-annual resolutions, though only tree rings can be absolutely dated, and these only with the aid of highly replicated and continuous regional series currently limited to northwest Europe, on which see Büntgen et al. 2011 and Manning 2013.

10. Mensing et al. 2015 on central Italy, Sadori et al. 2016 on southern Italy and Sicily, and Cremaschi et al. 2016 on the Po Plain. The empire's long-distance trade in timber means that even in the rare examples of wood suited for dendrochronological analysis found in the imperial core, tree-ring data may represent conditions elsewhere, on which see Bernabei et al. 2019.

11. Izdebski et al. 2016: 10; on current transdisciplinary research trends see McCormick 2019: 21–27.

a satisfactory impression of the nature and conditions of the RCO, much less the human experience thereof.

Fortunately, the story of Roman climate is not written only in the language of geochemistry. Contemporary treatises, letters, inscriptions, and papyri by attentive classical authors offer firsthand accounts of climate events.[12] Like natural archives, however, the documentary record is generally crisis-focused and conditioned by the highly subjective judgement of what was deemed worth recording, most often the anomalous or disastrous.[13] The different chronological resolutions and geographical sources of natural archives and written evidence make it difficult to demonstrate correlation, much less causality, between any given environmental crisis and historical developments. The temporal distribution of climate events can be informative to some extent on general climate trends, but ancient views on day-to-day conditions require an ancient author with an appreciation for the particular and the everyday.

Here we turn to Pliny the Elder and his *Natural History* (*NH*). Only rarely do his observations pertain to specific and dateable climate events plucked from the Roman annals, as when he reports remarkable Nile floods associated with portentous moments in Roman history (5.58), or the bountiful harvest enjoyed when the Phrygian Mater Deum was carried to Rome during the Second Punic War (18.16). Instead, taking all of nature as his subject, Pliny offers the kinds of granular data useful for reconstructing everyday conditions. When natural scientists and archaeologists quote Pliny, they tend to use him briefly as a purveyor of isolated facts. I will show that the *NH* still has untapped potential as a source on Roman climate change, and that it stands to cast a "flood of light" not only on the cultural world of first-century Rome, but also on its natural environment.[14]

THE ENCYCLOPEDIA: GOALS, USES, SOURCES, AND CONTEXT

The thirty-seven books of the *NH* make up the only surviving work of Pliny the Elder (23/24–79 CE), who wrote copiously throughout a distinguished military and administrative career.[15] His stated goal in the *NH* was to present a compendium of all knowledge about the natural world, having gleaned some 20,000 topics from 2,000 volumes by 100 authors, by his own reckoning (praef.17).[16] He assures

12. See Lamb 1982 for an early effort. More recently, hundreds of sources on Roman and early medieval climate events (ca. 100 BCE to 800 CE) have been gathered by researchers at the Initiative for the Science of the Human Past at Harvard. Their database is available for download at darmc.harvard.edu; see McCormick et al. 2013.

13. For Roman Italy, see Aldrete 2007 and Benito et al. 2015 on Tiber floods. Only in later periods, with the wine harvests in medieval France discussed below, do we get granular and diachronic accounts.

14. Wallace-Hadrill 1990: 81.

15. Healy 1999: 5–7. Most details of Pliny's life and works come from his nephew's letters (e.g., *Ep.* 3.5, 6.16, 6.20), on which see Gibson 2011. See also Conte 1994b: 498–504 on Pliny's lost works.

16. Quotations are numbered according to the conventions of the Budé editions (e.g., Le Bonniec 1972), the most recent authoritative publications of the *NH*. Translations are my own. On the preface see Howe 1985 and Morello 2011.

the reader, "I have not knowingly omitted any piece of information, if I have found it anywhere" (17.137). As published in 77 CE, the project was by the author's estimates unprecedented in scope and scale, attempted by neither Roman nor Greek before him, and covering all subjects encompassed by "what the Greeks called ἐγκυκλίου παιδείας" (praef.14).[17] Unlike Cato the Elder (234–149 BCE), Varro (116–27 BCE), and Celsus (ca. 25 BCE–50 CE), predecessors in the Roman encyclopedic tradition, Pliny was less interested in teachable skills (*artes*) than a large-scale enquiry into nature.[18] Pliny describes his topic as "the nature of things, that is, life (*rerum natura, hoc est vita*), and often its lowest department, so that in many cases I am obliged to use rude and foreign or even barbarous terms (*aut rusticis vocabulis aut externis, immo barbaris etiam*)" (praef.13). However apologetically, Pliny welcomes varied explanations for natural phenomena in the interest of breadth, sometimes citing the views of Babylonians (on earthquakes, 2.79) and Egyptians (on lunar orbits and stars, 2.23) alongside those of Greeks and his own countrymen, thereby adding to his own *auctoritas* by recognizing earlier writers, fewer than one third of whom would have written in Latin.[19] It is in terms of scope, not of ideas, that Pliny states his project's novelty, often downplaying his own contributions in favor of his sources. In this he is not unique among Roman technical writers, whose cultural emphasis on the *mos maiorum* and devotion to ancestors lent more weight to the words of past authorities than to those of their contemporaries (e.g., Vitr. *De arch.* 9.praef.17). Nevertheless, his own observations occasionally come to the fore, and these moments will prove most informative.

In the preface, Pliny's relationship to his sources is most relevant to the evidence he presents for ancient climate (section III). Despite the broad temporal and geographical range of source material, the *NH* is often characterized as a handbook for the Roman layman, important in its very "typicalness," inasmuch as it encompasses the average interests of a first-century Roman man.[20] Though perhaps only in a flourish of authorial modesty, Pliny himself identifies a lowly target

17. Here there are at least solid etymological grounds for calling the *NH* the first western encyclopedia, though the genre would not be self-consciously defined until the sixteenth century (Collinson 1966: 79–80). Given that the *NH* fulfills the basic modern requirements of an encyclopedia—it is a large-scale reference work equipped with retrieval devices—I will refer to it as such, but see Fowler 1997 and Doody 2010 on the appropriateness of the term.

18. Murphy 2004: 196–97, comparing cataloging tendencies in Vitruvius on architecture, Mela on geography, and Columella on agriculture. On Cato's lost *Praecepta ad filium*, Varro's *Disciplinae*, and Celsus' *Artes*, see Grimal 1965: 459–82.

19. French 1994: 218–22, only counting authors listed more than once in the *summarium.* Aristotle, Democritus, and Theocritus are his three most-cited sources, but these and many others might have been accessed in translation. On sources see also Beagon 1992: 18–20.

20. Doody 2010: 3–4. Beagon 2018: 656 doubts the extent to which Pliny's "often dense and occasionally rhetorical prose" would have been accessible to farm managers and herdsmen, but the extent of Roman literacy is beyond the scope of this paper. His rhetorical style, characterized as "torturous" (Norden 1909: 314) and "exasperating" (Duff 1966: 307–309), goes some way toward explaining the *NH*'s scholarly neglect until the 1990s and has led some to suggest that the *NH* was not yet revised at the time of Pliny's death.

readership, saying: "It is written for the common public (*humili vulgo*), the masses of farmers and workmen, and finally for those with the leisure time for study" (praef.6). At least in its stated purpose, then, the *NH* encompasses Roman society from its agricultural foundations to the lettered and landowning senatorial class, and it could offer some perspective on the experience of climate change at various levels of society.

Only recently have scholars begun to consider seriously the elements of literary form and authorial choice within ancient scientific and technical texts: in Pliny's case, how his goals affect his presentation of the subject matter and the strategies he employs.[21] Roger French identified three goals: 1) to instruct readers morally, with many major sections opening with a criticism of the moral laxity of man, especially in regard to proper use of natural resources; 2) to report wonderful things for the entertainment of the reading classes in the traditional of *mirabilia*; and 3) to serve as a broad reference work.[22] All three are relevant to an understanding of ancient climate, but readings of Pliny for environmental history have thus far considered only his third goal, citing the *NH* in specialist sections with short excerpts as relevant to particular studies.[23] It is in this vein that I first will present specific passages of the *NH* that offer evidence of climate change (III), but I also propose to address the first two goals. Pliny's attention to the marvelous and his moral instruction feature prominently in the Roman experience of climate and its effect on environmental change (IV). For its focus on the unusual and the exaggerated, his second goal—that of presenting wonderful things (*mirabilia*)—is of less relevance to the current project but deserves discussion here as an index of Pliny's reliability.

For its breadth and organization, the *NH* continues to be an invaluable compendium. But is Pliny a reliable source? His accuracy and objectivity have been open questions among scholars for decades, and that Pliny was a mere compiler, uncritical and derivative, is the most common critique of his work and remains largely uncontested.[24] Pliny himself was no expert in any particular area but a self-conscious popularizer, providing information to a broad audience, and his *NH* is the fullest expression of Roman imperial encyclopedism. This genre appeared in its earliest forms as didactic handbooks, growing in popularity with the expansion of the technical and professional classes.[25] Popular scientific curiosity drove also the

21. The important early monographs are Beagon 1992 and Healy 1999; further bibliography is reviewed in edited volumes by French and Greenaway 1986, Bipsham et al. 2007, and Gibson and Morello 2011.

22. French 1994: 231.

23. For Pliny in environmental history, see, e.g., Allevato et al. 2016: 8 on the introduction of peaches to Italy; Harper 2017: 54 and Lamb 1982: 141 on beech trees, discussed below. Neumann 1985: 447 gives Pliny three sentences in his synthesis of ancient sources on climate change, only considering his quotations of Theophrastus.

24. E.g., Rose 1936: 347; Conte 1994b: 73–75; Hughes 2014: 231.

25. Beagon 2018; see also Jones 2018, arguing that encyclopedism functioned as an organizational principle throughout Roman culture by the first century BCE.

increasing popularity of miscellanies (*mirabilia*), authored by dilettantes whose interest in detail and exploration was not supported by a unified method.[26] The emphasis on wonder is one of Pliny's unscientific tendencies, along with his derivativeness and his untheoretical mindset, as he often includes material he may dispute (e.g., 29.61, 29.140, 30.98). As a compiler, however, and as a source on the ancient climate, his general lack of interest in advancing any particular argument contributes to the completeness of his work, even—some have suggested—bringing him closer to modern principles of unbiased data collection and preservation.[27] An important element in Pliny's reliability as a source on climate change is the extent to which he relies on his own observations of current conditions. Due to the encyclopedia's extensive use of references and quotations, modern scholars still generally characterize the *NH* as based upon reading rather than observation (autopsy),[28] but his statements pertaining to weather and climate often indicate the opposite, as discussed in the following sections. Pliny keeps an open mind, opining that "the more I observe nature the more do I consider no statement about her to be impossible" (11.6). In keeping with the scientific limitations of his era, he is most often noncommittal and leaves the assessment of veracity up to the reader. In short, Pliny is often only as reliable as his own sources. It is when he disagrees with them, or contrasts his own observations with those he compiles, that his work will prove to be most useful for the current study.

Pliny's approach was unscientific in the modern sense, but it was pragmatic, focused on information useful to the typical literate Roman man, one interested in understanding and making a living from the natural resources the encyclopedia brings together. In keeping with the Stoic worldview that the earth was designed for humans, who gave it significance and coherence, his presentation of the natural world is arranged around the extraction and utilization of its resources, just as his encyclopedic project is arranged to facilitate the extraction of information.[29] For its rhetorical emphasis on expansion, assimilation, and synthesis, his is also an unapologetically imperialist project. Characterized by Trevor Murphy as "an intellectual component of the spoils of war," the *NH* organizes the complex whole of nature with the confident order of the Roman governing class, at a time when they needed "storehouses rather than books" (praef.17) to showcase the resources and

26. Conte 1994a: 499–501 and Beagon 1992: 3, 8 emphasize the influence of Licinius Mucianus, a possible patron of Pliny and author of a *Mirabilia*. Healy 1999: 101–102 notes elements of *mirabilia* throughout. Beagon 2011: 76–83 proposes a rhetorical function, arguing that by encouraging "terrestrial curiosity" rather than the contemplation of the heavens or philosophy, Pliny emphasizes that even the mundane aspects of the physical word give his readers a chance to "rouse themselves from a complacent torpor and look again" at the world around them (83). See, e.g., *NH* 18.166, on the appearance of corn growing in trees when Hannibal was vanquished—though an early commentator notes that there is nothing so remarkable about this (Bostock and Riley 1855: 4:348).

27. Doody 2010: 22; Beagon 2018: 674.

28. E.g., Lloyd 1983: 135–49.

29. Doody 2010: 65. On *utilitas vitae* see Beagon 2018: 600: "The entire work is shaped by humanity's life in nature; nature is nature as viewed and used by the human race."

wonders under imperial control.[30] Along with superiority of the imperial core, an unsubtle strand of old-fashioned moralizing and Italian exceptionalism runs throughout the *NH*. At times the sun shines on Pliny's Italy more kindly even than the most optimistic readings of paleoclimate proxies suggest:

> Iam vero tota ea vitalis ac perennis salubritas, talis caeli temperies, tam fertiles campi, tam aprici colles, tam innoxii saltus, tam opaca nemora, tam munifica silvarum genera, tot montium adflatus, tanta frugum vitiumque et olearum fertilitas.... tamquam iuvandos ad mortales.... !
>
> Plin. *NH* 3.41
>
> This [country] so replete with life-giving and everlasting vitality, such serenity of climate, fields so fertile, hillsides so sunny, glades so free from danger, groves so shady, forest products so bountiful, breezes from so many mountains, such a bounty of grain, vines, and olives... as if to aid [the endeavors of] men!

Such passages are in the tradition of *laus Italiae,* which famously suffuses the Italian landscape in the optimistic passages of Vergil's *Georgics* (29 BCE). It should not, therefore, be taken as evidence for a more congenial climate under the RCO.[31] This excerpt illustrates how Pliny's use of both ideological and prosaic language and themes offers diverse representations of the ancient climate, sometimes in a single passage. It also raises some terminological questions. In the following section, before moving on to *loci* for climate change, I will attempt to arrive at a definition of climate in Pliny's vocabulary.

DEFINING CLIMATE IN THE *NATURAL HISTORY*

In the passage quoted above, I have translated *caelum* as climate, and this is the word used throughout the work to describe the source of the atmospheric conditions of temperature and weather, approaching most closely our modern definition, the average pattern of weather conditions in a particular area.[32] *Caelum* can also refer more broadly to the heavens and is not without religious implications, as in the opening to Book 2, on the heavens and cosmological phenomena:

30. "Spoils of war": Murphy 2004: 195. Naas 2002 and Murphy 2004 have been particularly influential in their arguments for an imperialist reading, building on seminal studies of the 1990s: Wallace-Hadrill 1990, Beagon 1992, and French 1994.

31. In such hyperbolic passages, it is important to ask whether the author's goal is truly to accurately portray the contemporary local climate or to assert a moral or ideal point, as for example when Hesiod (ca. 700 BCE), lamenting the difficulties of agriculture, describes Ascra in Boeotia as "bad in the winter, sultry in summer, and good at no time" (*Op.* 640).

32. *OED* online, s.v. "climate" 2a: "The characteristic weather conditions of a country or region; the prevalent pattern of weather in a region throughout the year, in respect of variation of temperature, humidity, precipitation, wind, etc., esp. as these affect human, animal, or plant life." Pliny (*NH* 2.28) quotes Varro (*Ling.* 5.18) to explain the word's "undoubted"—though, ultimately, mistaken—origins in *caelatus*, "engraved." See also Quint. *Inst.* 10.3.18.

"the world (*mundum*), and whatsoever by another name may be called the heavens (*caelum*), in whose vault all things exist, we must hold equal to a deity, eternal and immeasurable (*aeternum, inmensum*)" (2.1). Just as *mundus* can mean the earth and its immediate surroundings or the entire universe, *caelum* describes both the visible firmament of the heavens and celestial regions more generally, like the Greek οὐρανός.

These heavens rotated around the immobile globe, which served as the pivot of the world. In the context most relevant to the current study, *caelum*—or sometimes *aer*—is the source of weather and the sum of its expressions: "hence clouds, thunder and lightning; hail, frost, rains, storms, and whirlwinds" (2.102). Pliny explains the mechanisms of causation, such as they were understood to function, as follows:

> Tempestatum imbriumque quasdam statas esse causas, quasdam vero fortuitas aut adhuc rationis inconpertae, manifestum est. Quis enim aestates et hiemes quaeque in temporibus annua vice intelleguntur siderum motu fieri dubitet? Ergo ut solis natura temperando intellegitur anno, sic reliquorum quoque siderum propria est cuiusque vis et ad suam cuique naturam fertilis.
>
> Plin. *NH* 2.105

> It is clear that certain causes of the seasons and precipitation are fixed, but others happen by chance or for a reason as yet undiscovered. For who could doubt that summer, winter, and the annual turn in seasons are understood to be caused by the motion of the stars? Therefore, as the nature of the sun is understood to influence the temperature of the year, so also each of the other stars has its own power, [one which is] productive in terms of its own nature.

In addition to the effects of the sun and stars, winds—especially the west wind, Favonius—served as an enlivening principle for the world, similar to the Stoic *pneuma,* as the "generative spirit of the nature of things" (*ille generabilis rerum naturae spiritus*, 2.116). These mid-latitude westerlies still arrive in winter to start the Mediterranean rainy season, now understood to originate in a low-pressure zone over Iceland, while a subtropical high pressure is responsible for summer aridity.[33] Pliny is careful to leave room for variation, acknowledging the possibility of other causes for rains and winds (2.111). In addition to weather, the various expressions of *caelum* affect the productivity of the earth and the nature of its people. Like Vergil (*G*. 1.233–39) and Ovid (*Met*. 1.45) before him, in a horizontal partitioning that characterizes ancient and medieval geography, Pliny divides the globe into five parts (*zonas*, 2.172) by climate regime: a central band of extreme heat, frigid poles, and the two habitable zones in between.

33. On Mediterranean climate and the North Atlantic Oscillation (NAO) mentioned here, see Brandimarte et al. 2011.

According to Pliny, only the regions between the heat and cold gave rise to people (Romans, that is) capable of conquering the rest, so climate is not an altogether apolitical subject. After his ethnographic excursus in Books 3–6, Pliny spends most of the *NH* in the *fertiles tractus* (2.190) of the central Mediterranean, with reference to exotica only for contrast.[34] Nature produces "skewed fertility" in far places where the elements are out of balance, like the heat-loving cedar growing in the mountains of Lycia and Phrygia (16.136).[35] Pliny attributes much of the adaptability of foreign flora to human cultivation, marveling at the soil management techniques that enable such exotic transplants to survive and thrive, but adding conscientiously that human ingenuity can only go so far: climate cannot be changed (*caelum nullo modo flecti*, 16.136). However, the content of Pliny's borrowings creates tension with his professed philosophy, especially when he pairs earlier sources with observations of conditions in contemporary Roman Italy. His self-conscious comparisons of information gained through autopsy with readings of his predecessors reveal changing environmental conditions over the centuries and across the Mediterranean. Some changes he attributes to human action, but others are without any anthropogenic explanation and, especially when paired with archaeological and paleoclimatological information, point to a changing climate.

III. *LOCI* FOR CLIMATE CHANGE IN THE *NATURAL HISTORY*

To identify environmental changes in Pliny's text, I have adapted a methodology developed by the Intergovernmental Panel on Climate Change (IPCC) to interpret phenological data as indices of climate change. Phenology (from φαίνω, "to show or appear") is the scientific study of plant and animal life cycle events triggered by seasonal changes, which include exposure to light, temperature changes, and moisture availability.[36] The field emerged as an environmental science in the mid-1990s and is experiencing a revival in light of current global changes, though its history goes back much farther, with the earliest networks and continuous records in Europe.[37]

IPCC scientists identified the biological fingerprint of climate change in range shifts and the advancement or delay of phenological events.[38] Range shifts refer to changing habitat boundaries, such as tree lines moving higher under warmer

34. Descriptions of climate are a basic feature of Roman ethnography as defined by Thomas 1982: 1, but in Pliny's geographical chapters (3–6) these are focused on otherness and the sensational. In Bactria and Cyrene, for example, the climate is so congenial that weeds do not spring up and hoeing is unnecessary (18.186).

35. Beagon 2007: 22.

36. On the discipline of phenology see Leith 1974 and Schwartz 2013.

37. See Menzel 2013 for the development of phenology in Europe as well as current networks. Italy maintains regional networks, but there is no nationwide database available.

38. For the "fingerprint" see meta-analyses by Parmesan and Yohe 2003 and Root et al. 2003, the former based on observations of over 1,700 species worldwide and foundational for IPCC 2014. The next IPCC Synthesis Report is due for release in 2022.

conditions or the changing routes of migratory birds. Phenological events are seasonal changes in plant and animal behavior—for example, leaves opening and falling, birds or insects hatching and migrating—which do vary from year to year but exhibit convincing trends in aggregate. Modern phenological syntheses have shown that the flowering, fruiting, and leaf emergence in agricultural as well as wild plants demonstrates high correlation with temperature change. Only the emergence and sprouting of winter crops in autumn is more related to the farmer's activities, in this case planting dates. These and other activities such as tilling and harvesting are known as "false phases," less responsive to climate than plant and animal species but nevertheless shown to correlate with temperature change.[39]

Both range shifts and the timing of phenological events carry wide-reaching ecological implications and are key indicators for the impacts of climate change on the biosphere today, and both appear in the *Natural History*.[40] Pliny reports phenological information most often as the times for sowing, flowering, and harvest, and notes differences among his sources: principally Hesiod, Cato, Caesar, and Vergil. What follows is not a comprehensive catalog of phenological observations in Pliny, with which his agricultural book (Book 18) is replete, but a focused account of passages that suggest range shifts and changes in the timing of phenological events, based on comparison of Pliny's observations with those of his sources.

RANGE SHIFTS

Olives: The habits and habitats of mid-latitude trees and shrubs are the traditional focus of modern phenological research, and Pliny's observations are similarly focused. On the changing range of the olive tree (*Olea europaea*), Pliny pulls together the testimony of earlier authors, and his remarks testify to a warmer climate in the first century CE. In the opening of Book 15 Pliny quotes Theophrastus (ca. 372–288 BCE), the most consistently ecological of his sources, who assigns each plant an οἰκεῖος τόπος in the microclimates of the Mediterranean.[41] Recognizing Theophrastus as the supreme authority on plants, he compares the Greek botanist's fourth-century views on the olive's range to those of his own predecessors, including the antiquarian annalist Fenestella, whose death Pliny placed at the end of Tiberius' reign (ca. 19 CE, *NH* 33.146). Fenestella's work survives only in fragments, but in the *NH* he is cited as an authority on such diverse subjects as art history, metallurgy, and zoology, in addition to arboriculture.

39. Menzel et al. 2006: 1971–74.

40. For Europe, Menzel et al. 2006 was a major publication, finding a mean advance of spring and summer events by 2.5 days and delay of fall events by 1 day, based on observations from 1971 to 2000 of 542 plant and 19 animal species in 21 European countries.

41. Hughes 1985: 297. Recognizing Theophrastus' supreme authority on plants, Pliny lists him first among foreign sources (*externis*) in ten cases, second after the more ancient Hesiod, Herodotus, or Democritus in the other six (Morton 1986: 89).

Comparing the accounts of these two venerable sources, Pliny observes that the frost-averse olive tree had made some striking progress:

> Oleam Theophrastus e celeberrimis Graecorum auctoribus urbis Romae anno circiter CCCCXL negavit nisi intra XXXX passuum ab mari nasci, Fenestella vero omnino non fuisse in Italia Hispaniaque aut Africa Tarquinio Prisco regnante, ab annis populi Romani CLXXIII, quae nunc pervenit trans Alpis quoque et in Gallias Hispaniasque medias.
>
> Plin. *NH* 15.1
>
> Theophrastus, among the most famous Greek writers, around the year 440 of the city of Rome [314 BCE] denied that the olive grew more than forty miles from the sea; indeed, Fenestella [tells us that] it did not exist at all in Italy, Spain, or Africa in the reign of Tarquinius Priscus in the year 173 of the Roman people [581 BCE], whereas now it has crossed even the Alps, into Gaul and the middle of Spain.

The genus *Olea* is often cited as a Mediterranean climate indicator, thriving in rocky calcareous soils near the sea and able to endure long droughts but not harsh winters.[42] During the RCO the olive and its fellow cash crop, the grapevine (*Vitis vinifera*), traveled farther inland and uphill than ever, into areas where the "unremitting severity of winter" prevented cultivation before.[43] Here Pliny's testimony, which might plausibly have been based on his own observations during his military service as procurator in Gaul and Spain (70–76 CE), is mostly supported by archaeobotanical studies. Macrobotanical evidence (preserved wood and pits) has been used to suggest the cultivation of olive trees spread from eastern Spain to central and northern Italy around the first century BCE, thereafter spreading to France.[44] Recent pollen studies suggest a considerably longer history of olive trees in Italy, but because wild and domestic subspecies hybridize easily and their pollen is indistinguishable, it can be difficult to get a clear picture from palynological or

42. Moriondo et al. 2013; Mercuri et al. 2013.

43. Columella, *Rust.* 1.1.4–5. This passage cites the lost author Saserna to offer as convincing an ancient account of climate change as anywhere in Pliny, though Columella ultimately defers to the astronomers: "I have found that many authorities now worthy of remembrance were convinced that with a long lapse of time the nature and conditions of the climate are changed; and that among them the most learned professional astronomer, Hipparchus, has asserted that there will come a time when the earth's poles will change position, a statement to which Saserna, no mean authority on rural affairs, seems to have given credence. For in that book on agriculture which he has left behind, he concludes that the position of the heavens had changed, *since regions which formerly, because of the unremitting severity of winter, could not preserve any shoot of the vine or the olive planted in them, now with the early coldness having abated, and the weather becoming more clement, abound in plentiful olives and the vintages of Bacchus*. But whether this theory is true or false, we should leave it to the writings of astronomy." The changing position of the poles comes tantalizingly close to the phenomenon of orbital precession, which combined with orbital tilt is a major driver for global climate change, but not believed to have been widely known in antiquity. This is further discussed in section IV.

44. See Leveau et al. 1991 on the olive in France, Terral and Arnold-Simard 1996 in Spain, and Castelletti et al. 2001 in Italy, but cf. Fugazzola Delpino 1982: 133–34.

genetic evidence alone.[45] Later, Pliny mentions in passing wheat grown in the mountains (18.63), suggestive of new high-altitude landscapes of cultivation,[46] and *cassia* on the banks of the Rhine (12.98). Commentators identify the latter not as true *Cinnamomum cassia* but as *Daphne gnidium*, a similar Mediterranean ornamental which in the twentieth century survived to about 47° N, within the latitudinal range of the Rhine.[47] To a greater extent than forest trees like beeches, cultivated plants expanded their range due to human action as well as more accommodating climatic conditions, as interconnectivity and a growing population incentivized economic growth through expanded agricultural production.

In certain regions the conditions that enabled botanical migrations appear to have been rather extraordinary. Evidence for Alpine glacier retreat and tree-ring growth patterns, while not directly informative about conditions on the other side of the Alps, suggests that central European temperatures were higher even in the first century CE than in the previous 150 years.[48] This has been seen as highly significant, since an increase of just one degree Celsius from the last centuries BCE would have rendered, conservatively, another five million hectares of arable land suitable for cultivation.[49] If this is the case, the RCO facilitated dramatic expansion and increasing production in the agricultural landscapes of the Empire, and Pliny was right to take notice through observing his surroundings and comparing contemporary evidence with his sources. In the case of olive trees, he offers a *locus* for climate change by accepting the validity of both past authors and his own observations, but in the following examples sources and observation are in conflict, so that the nature of change is left for the reader to judge.

Beeches: Beech trees (*Fagus* sp.) present a somewhat less certain example of a range shift, still worth mentioning as one of a few passages from the *NH* cited by modern environmental historians as evidence for Roman-period climate change. H. H. Lamb compares Pliny's characterization of beeches as a mountain tree to earlier reports (i.e., Livy) that they grew along the Tiber around 300 BCE, concluding that the climate had grown too warm for them by the first century CE.[50] However, Pliny also lists beeches among trees that "descend to the plain" (*descendunt et in plana*, 16.74), and the pollen record goes some way to support this. With their analyses of the waterlogged sediments of Roman harbors, Laura Sadori and colleagues report higher than expected levels of beech pollen—as well as wood and leaf fragments—in the pre-Roman and early Roman period, and suggest that cooler and wetter climatic conditions forced mountain taxa to lower altitudes in the final

45. Mercuri et al. 2013; Langgut et al. 2019, showing established *Olea* sp. from the mid-second millennium BCE.

46. Hin 2013: 85 discusses the implications for Roman population growth.

47. Bostock and Riley 1855: 3:141n.151; Tutin et al. 1968: 257.

48. Büntgen et al. 2011; Harper 2017: 46. Generally speaking, warmer northern-central European temperatures correlate with a cooler Mediterranean; see, e.g., Rousi et al. 2020.

49. Lo Cascio and Malanima 2005: 27; Christiansen and Ljungqvist 2012.

50. Theophrastus, writing in the third century BCE, also noted beeches of exceptional size on the plain of Latium, around Rome (*Hist. pl.* 5.8.3) (Lamb 1982: 141).

centuries BCE.[51] Beech pollen can travel far by wind and water, however, so its presence in harbors does not necessarily indicate that these trees grew anywhere near the sea. As a long-lived species characteristic of mature forest, beeches are generally less responsive to environmental variability than opportunistic weeds, shrubs, and small trees from warmer climates, such as the olive, which respond more readily to changes in temperature, though recent research has challenged this in regards to phenological phases.[52] Low-altitude beeches, which today grow above elevations of 800 meters in Italy, might be survivors of a cooler period in central Italy, their continued presence owed to the wetter summers of the RCO.

Frost Hollows: Pliny also describes range changes with negative impacts for cultivation, citing some remarkable transformations to agricultural landscapes in Book 17, in a passage on the effect of local climate and soils on trees:

> Quid quod mutantur saepe iudicata quoque et diu comperta? In Thessalia circa Larisam emisso lacu frigidior facta ea regio est, oleaeque desierunt, quae prius fuerant, item vites aduri, quod non antea. ... et circa Philippos cultura siccata regio mutavit caeli habitum.
>
> Plin. *NH* 17.30

> Do we not find that [soils] appraised over a long period are often changed? In Thessaly, in the vicinity of Larisa, after the lake was drained, the district became much colder, and the olive trees which had been there formerly perished, and likewise the vines were frostbitten, which never happened before. ... and in the vicinity of Philippi, after the country was drained for cultivation, the nature of the climate changed.

Here Pliny is quoting Theophrastus on the creation of frost hollows in Larisa (*Caus. pl.* 5.14.2–3) and Philippi (*Caus. pl.* 5.14.5). Frost hollows form when features of the local geography—in these cases, depressions left by drained lakes—cause cold air to sink in and accumulate. Pliny's direct reproduction of source material without reference to his own observations means this passage should not be taken as evidence of first-century conditions. It is, however, a useful reminder of the intensity of hyperlocal conditions, which could mitigate or even run counter to regional trends.[53]

51. Sadori et al. 2015: 222–27, also citing the results of pollen cores from nearby Lago di Massaciuccoli and Lago dell'Accessa in southern Tuscany. Plant macroremains—seeds, fruits, wood, and leaves—are generally indicative of local flora, but since the wood in harbor sediments might have been brought some distance as building material, and the leaves and other macroremains deposited by fluvial activity, I do not discuss them here.

52. Vilhar et al. 2018: 45; cf. Flexas et al. 2014.

53. Grove and Rackham 2001: 142. Some authors have suggested far-reaching climatic effects caused by human activity in the Roman period, e.g., Reale et al. 2000, using atmospheric modeling to suggest widespread aridity caused by deforestation.

PHENOLOGICAL EVENTS

Bees: For our next examples of climate change, we move to phenological changes in the timing of seasonal plant and animal behaviors and the complex interactions between them. Two passages concern the emergence of bees around the rising of the constellation Vergiliae, which we know as the Pleiades, in mid-May.[54] Pliny and his sources associate the rising of the Pleiades with rainy weather, making it a dangerous time for vines and olives as well as bees, whose fertilization processes are impaired by precipitation (17.11). In both examples below, the emergence of the bee (*Apis mellifera*, the European honeybee) is linked to blossoming of the bean. First, Pliny makes one of his more dismissive statements against the testimony of his sources:

> Circa apes aut temporum locorumve ratio mutata est, aut erraverunt priores. Conduntur a Vergiliarum occasu et latent ultra exortum; adeo non ad veris initium, ut dixere, nec quisquam in Italia de alvis existimat ante fabas florentes.
>
> Plin. *NH* 11.13
>
> With reference to bees, either the reckoning of seasons and conditions has changed, or else former [writers] have been mistaken. [Bees] are out of sight from the setting of the Vergiliae [November 11] and stay hidden past their rising [May 10]; not till the beginning of spring, as some have said, does anyone in Italy consider [releasing them] from the hives, nor before the beans blossom.[55]

The seasonal habits of bees, which Pliny later describes as "wonderful and worthy of recording" (21.73), are highly sensitive to patterns of flower opening in the plants they pollinate. If we interpret this passage as a delayed emergence of bees compared to that observed by Pliny's sources, one explanation could be the higher levels and longer duration of spring precipitation characteristic of the RCO, suggested by isotopic evidence from Italian lakes, which could keep bees in their hives longer.[56] This might be taking the comment too far, and much depends on the location of hives, their elevation, slope aspect, hours of sunlight received, local plants available, and myriad other factors. Pliny's denial that any *Italian* beekeeper would open his hives before the appropriate time could imply that this apiary misinformation comes from a foreign source, perhaps referring not to Italy's *Apis mellifera ligustica* but to the subspecies *cecropia* native to Greece. The several subspecies were highly sensitive to changes in climate, and Columella warns against long-distance trade in swarms for this reason (*Rust.* 9.8.3).

54. See below, pp. 271–72, on astronomical calculations and the seasonal association of constellation risings and settings, which change over time.

55. Pliny refers here to the first honey harvest; another in summer produced the best honey (Varro, *Rust.* 3.16.34; Columella, *Rust.* 9.14.10).

56. On the isotopic evidence see Sadori et al. 2016: 180.

This and a later passage on bees demonstrate Pliny's awareness of deeply intermixed phenological patterns. Returning to the rising of the Pleiades to describe associated agricultural tasks, Pliny says that the arrival of a little bee marks the imminent blossom of the bean, the flower which "calls it forth": *Hoc intervallo et apicula procedens fabam florere indicat, fabaque florescens eam evocat* (18.253). Pliny's use of *apicula* rather than *apis* may suggest that he is describing a small native bee rather than the European honeybee, which is more resilient than other species thanks to its wide geographic range and long history of cultivation. From remarks like this, it is clear how the changes in the timing of seasonal events could lead to a mismatch of seasonal pollinator patterns with their respective flora. Indeed, such phenological mismatches are the best studied and most worrisome aspects of current climate change. One temporal mismatch can have trickle-down effects, in this case leaving bees without an important food source and plants without pollinators.[57] Because the overwhelming majority of flowering plant species, including most crop species, rely on animal (especially insect) pollinators, synchrony in phenological events is crucial to agroecosystem health.[58] In the next passage, Pliny records an observation of changes in the timing of seasonal events with adverse effects for pollinators.

Butterflies: Climate-driven mismatches like these are the main source of adverse biological effects in modern climate change. For example, current trends in southern Europe are consistent with higher global temperatures, affecting for example the arrival of butterflies, recorded eleven days earlier between 1952 and 2000 near Barcelona, Spain.[59] This insect provides our next *locus* for climate change in the *NH*, a case of phenological change creating a mismatch in spring events:

> Sunt qui certissimum veris indicium arbitrentur ob infirmitatem animalis papiliones. Id eo ipso anno, cum commentaremur haec, notatum est proventum eorum ter repetito frigore extinctum advenasque volucres a. d. VI. kal. Febr. spem veris adtulisse, mox saevissima hieme conflictatas.
>
> Plin. *NH* 18.209–210

57. Kehrberger and Holzschuh 2019. Current honeybee mortality in Italy, with colony losses averaging 19% in 2009/2010, has been linked to pesticides rather than climate (e.g., Porrini et al. 2016), but pollinator function in relation to changes in climate is well-attested in other parts of the world (Burkle et al. 2013).

58. Klein et al. 2007 on food crops and pollinators. On climate change and the disruption of plant-pollinator interactions see Memmott et al. 2007, modelling interactions between 1420 pollinator and 429 plant species; see also Holden 2006 for the initial proposal of a twenty-first-century "pollination crisis." The effects of desynchronizations in bee-plant interactions were recently studied with reference to solitary bees by Schenk et al. 2018.

59. Peñuelas et al. 2002, also observing that on average, between 1952 and 2000, leaves unfolded sixteen days earlier and fell thirteen days later, and spring migratory birds arrived fifteen days later. The responses and adaptations of butterflies to climate change were the subject of a book-length investigation over twenty years ago (Dennis 1993) and reports continue to emerge on the vulnerability of European (Heikkinen et al. 2010) and Mediterranean species (Zografou et al. 2014).

> There are some who judge butterflies to be the surest sign of spring, because of the animal's delicacy. In this present year, when we are writing, it has been noted that their arrival has been cut off three times by as many returns of the cold; while the foreign birds, which brought hope of early spring by the sixth day before the calends of February [January 27], were then struck by a most severe winter.

Pliny uses this example to illustrate the uncertainty in the timing of seasons, such as wintry weather preceding the beginning of winter (he uses the Greek προχειμάζειν) or lasting longer (ἐπιχειμάζειν), or the interruption of unseasonal storms (18.207). The winter storms described as playing havoc with animal populations were most likely related to the strongest pattern of large-scale climate variability in the western Mediterranean, the North Atlantic Oscillation (NAO).[60] Subject to decadal shifts in atmospheric pressure, the NAO either drives winter storms north into central Europe, which can result in a drier Mediterranean, or moves westerlies directly through Italy, bringing more precipitation in the wet season. Such decadal fluctuations and their disruptive potential are a popular current focus of environmental historians,[61] but Pliny does not note them as exceptional in his own day. In this case, his observation of variability cannot confirm that the NAO was fluctuating more frequently in the first century CE, but serves to remind us that interannual variability continued to be an important factor even in the relatively stable conditions of the RCO.

The Grape Harvest: Pliny notes a major discrepancy between past and present conditions in the timing of the vintage (grape harvest and processing). Harvest dates for grapevines make up a significant class of climate historical documentary data: records extend back to the medieval period in the parish and municipal archives of Europe, recording hot summers or poor yields, and showing that harvest dates are strongly linked to temperature.[62] Nowhere are changing practices over time clearer than in Pliny's comments on the Robigalia, Floralia, and Vinalia, ancient festivals that he observes have no significant relationship to actual harvest dates (18.284–89). He also observed the vintage being gathered much earlier than his sources recommended, and intended accordingly to update his readership:

> Vindemiam antiqui numquam existimavere maturam ante aequinoctium; iam passim rapi cerno. Quamobrem et huius tempora notis argumentisque signentur.
>
> Plin. *NH* 18.315

60. On the NAO see Xoplaki et al. 2004, and on its variability, Olsen et al. 2012.

61. Drake 2017; Harper and McCormick 2018: 15. More regional studies are needed to refine correlations.

62. E.g., Le Roy Ladurie and Baulant 1980; Chiune et al. 2004; but see recent critique by Labbé et al. 2019. See also García de Cortázar-Atauri et al. 2010; Daux et al. 2012.

> The ancients held the opinion that the vintage was never ripe before the equinox; but now I observe that it is gathered in at different times. On that account, its correct season should be designated by signs and indications.

What follows is a long list of considerations—the weather must not be too dry, nor should the grapes be covered in dew or still growing, and the moon should be waxing (18.316). All this gives some sense of the seasonal variations that governed harvest dates. On the other end of the season, he also observes (*vidi*, 18.319) the vintage being gathered as late as the beginning of January.[63] Pliny attributes this to carelessness and a lack of preparation and not to different climatic conditions, though the survival and fruiting of grape vines into winter certainly speaks to milder temperatures.

Pliny does not refer specifically to his sources in this passage, nor to the region they described. Harvest can vary significantly with the permanent conditions of the vineyard—elevation and soil—as well as precipitation and temperature, not to mention the grape variety and the type of wine being produced. Reading this passage in context suggests that we are still in Italy, with adjacent references to the Vulcanalia (18.314) and the recommendations of augurs (18.316). It seems likely that Pliny is drawing from Cato the Elder, since he quotes the Republican author as the first to write about viticulture, though Cato himself described only a few varieties of wine. Pliny notes that the number of varietals cultivated in Italy had greatly increased since (14.44–46) and that yields per acre had greatly exceeded anything Cato described.[64] In addition to greater variety, an earlier autumn harvest would add to this broader transformation of viticulture, suggestive of the RCO's mild climate and warmer temperatures, which would enable earlier planting and faster ripening with the accumulation of more growing degree days by the autumnal equinox.[65]

The *NH* is replete with phenological information, but this section has focused only on those cases where Pliny—or, in the case of beeches, modern scholars—have noted differences or disruption between source material and current conditions. Meticulous comparison of the "absolute" flowering dates given by Pliny to current equivalents—as, for example, has been done for the observations of Henry David Thoreau around Concord[66]—remains a potentially rewarding avenue, though beset by uncertainties regarding ancient plant identifications and the translation of ancient calendrical dates.

63. This might refer to the production of ice wine from frozen grapes, to which Pliny seems to allude when he describes the Allobrogian vine as "ripened by frost" (*gelu maturescens*, 14.26) and grapes as gathered after the first frost at Thurii (*non ante demetuntur quam gelaverit*, 14.39).

64. French 1994: 215.

65. Growing degree days (GDDs) are a phenological unit for heat accumulation, used to predict stages of development like blooming and—in this case—harvest date. More productive viticulture owes much to human decisions and industry, so this should not be interpreted as positive climate change alone.

66. Miller-Rushing and Primack 2008.

IV. METEOROLOGY AND THE EXPERIENCE OF CLIMATE CHANGE IN BOOK 18

In this final section, I will examine Pliny's presentation of climate and seasonal signs in Book 18, on arable farming, using practical meteorology as a framework to discuss Roman perceptions and experiences of climate. Book 18 shares many similarities in style, form, and content with the agronomic works of Cato, Varro, and Columella, whom Pliny cites often and against whom he may have felt the need to justify his own account.[67] I will attempt to show that these distinctions go beyond literary self-consciousness and can serve as useful markers towards the awareness of seasonal and climatic changes.[68] Farming depends on climate and its expressions in weather, a factor over which individuals have no control, except by choosing when and how to plow, to sow, and to harvest. After presenting various methods from different sources for a given task, Pliny often concludes that timing is the most important factor.[69] Pliny's recommendations for the timing of these "false phases" (see above) not only offer further evidence for Roman-period climate change, but will also serve to move the discussion toward its human and social effects, which have received too little attention in favor of large-scale climate syntheses.

PRACTICAL METEOROLOGY: THE CALENDAR AND THE ALMANAC

By highlighting passages where Pliny's observations of the present are in conflict with his sources, the previous section illustrated the tension between the two fundamental methodologies of ancient science: reading and observation. Liba Taub has argued that Pliny proves his originality at this intersection, specifically in the field of practical meteorology, which she describes as the study of weather processes and forecasting as pertaining to their benefits for agriculture.[70] A practical understanding of climate and the seasons was essential to farmers around the Mediterranean, and

67. Pliny uses imperative verbs only in Book 18, apparently in imitation of the agronomic authors' didactic habit. On style see Hine 2011: 646–49; on shared ideology see Beagon 1992: 161–64, describing an "ideology of the soil" with plentiful ancient examples, i.e., Cic. *Off.* 1.42.150–51; Cato, *Agri.* praef.; Columella, *Rust.* 1.praef.12–17; Varro, *Rust.* 2.praef.3, Verg. *G.* 2.458–74, 2.513–42.

68. In Book 18, other instances in which Pliny explicitly notes differences between his observations and previous ones, not discussed for reasons of length, include the following: 18.6 (Cato and Atilius Regulus), 18.30 (Vergil), 18.125 (the importance of *rapum*), 18.285 (Varro, the appearance of mildew in summer), 18.289 (Varro, astronomical phenomena associated with the second Vinalia), 18.295 (Cato and Vergil, field preparation), 18.296 (the disadvantage of uprooting crops). The last, advocating green manuring, is sound advice and apparently was widely applied in the Roman period. Passages like these temper Thurmond's assessment that Pliny is incorrect "with frustrating regularity" when it comes to agricultural matters (2006: 22). Beagon (1995: 121) notes that "literary self-consciousness" seems to affect Pliny most acutely in the agricultural sphere.

69. E.g., on the storage of grain: *Nobis referre plurimum tempestivitas condendi videbitur* (18.303), echoing the flexible strategies of traditional Mediterranean farmers interviewed by Halstead 2014.

70. Taub 2017: 78–85; see also Murphy 2004: 15, on Pliny's combination of new and traditional knowledge.

in attempting to portray it Pliny combines two parallel traditions in ancient meteorology. The first, associated with Greek philosophy and science, is explanation, the focus of Book 2 from which I drew Pliny's definition of climate. In the spirit of explanation, he compels readers to submit to "the difficulties of astronomy" (*sideralis difficultas*, 18.206) and cautions that his conclusions are not straightforward—a similar disclaimer to those which now feature in paleoclimate reconstruction studies. The second tradition is prediction, which characterizes Book 18 and is often attributed to Roman folk wisdom.[71] For the purposes of this discussion, three aspects of Pliny's practical meteorology are important to an understanding of ancient climate: differences in ancient agrarian calendars, the importance of phenological signs, and adjustments for local conditions.

Differences in agrarian calendars: Pliny devotes a substantial section of Book 18 to his agrarian calendar. When he provides calendrical dates, he derives them mostly from the Julian calendar, which the Greek astronomer Sosigenes developed under Caesar.[72] He quotes earlier authors extensively in correlating seasons, weather, and agricultural tasks with the timing of astronomical events, particularly the heliacal rising and setting of certain stars, solstices, and equinoxes, citing a long tradition of astrometeorological texts that Hesiod began with the final section of the *Works and Days* (ca. 700 BCE).[73] Pliny tells the reader that "the proper times for sowing depend to a very great degree upon the stars" (18.201), and for that reason the exact dates of their rising and setting are of great importance (18.202). He also acknowledges that the appearance or disappearance of constellations varied geographically, citing examples in Egypt, Italy, Rhodes, and Pontus (2.178). Indeed, when multiple authors do agree on the date of a given celestial event, it is worthy of comment (*rarum*, 18.312). For the setting of the Pleiades, which governed the sowing of winter wheat, spelt, and barley in Italy, and all grains in Greece and Asia Minor (18.49), he lists several disagreements:

> Eorum qui in eadem regione dissedere, unam discordiam ponemus exempli gratia: occasum matutinum Vergiliarum Hesiodus —nam huius quoque nomine exstat astrologia —tradidit fieri, cum aequinoctium autumni conficeretur, Thales XXV die ab aequinoctio, Anaximander XXXI, Euctemon <XLIIII, Eudoxus> XLVIII.
>
> Plin. *NH* 18.213

71. *Rudis fuit priscorum vita atque sine litteris. Non minus tamen ingeniosam fuisse in illis observationem apparebit quam nunc esse rationem* (18.284). The prediction element is especially prevalent at the end of Book 18, when Pliny describes weather signs provided by astronomical phenomena, birds, and aquatic animals, land animals, and plants, an order that echoes the organization of the *NH* as a whole.

72. Lehoux 2007; Taub 2017: 81.

73. On ancient meteorology see Taub 2003 and, specific to Pliny, Taub 2017: 78–85.

> But with reference to those who, in the same country, disagree, we shall mention one instance of discrepancy by way of illustration: Hesiod—for a *Science of the Stars* under his name also survives[74]—has stated that the morning setting of the Vergiliae [Pleiades] takes place when the autumnal equinox is complete; but Thales [makes it] the twenty-fifth day after the equinox, Anaximander the thirty-first, Euctemon the forty-fourth, and Eudoxus the forty-eighth.

Pliny attributes most differences to geography (18.201), but the distance of seven centuries between the authors also plays a role. Part of the explanation lies with a phenomenon that was never fully understood in antiquity but was very important for long-term or "orbital-scale" climate change, the precession of the equinoxes and orbital tilt.[75]

Orbital precession tilts the earth on its rotational axis over intervals of about 26,000 years. At the same time, the globe oscillates between a 22- and 24.5-degree tilt on a 41,000-year cycle. Based on recent modeling of these synchronous effects, the date of the autumn setting of the Pleiades changed by about eleven days between the eighth century BCE and first century CE.[76] Given the far removal in time as well as geography, then, it is only to be expected that Pliny differs from Hesiod, the pre-Socratic philosophers Thales and Anaximander, the fifth-century BCE Athenian astronomer Euctemon, and the fourth-century BCE Eudoxus of Knidos.[77] The phenomena of orbital precession and tilt are important to long-term climate change because they affect insolation—the amount of solar radiation that reaches parts of the globe, and for how long, each year.[78] The fact that Pliny observes their effects is interesting, but because these processes operate at scales of tens of thousands of years, orbital-scale climate change is difficult to relate to historical processes, much less so to the lives of Roman people and the timing of agricultural tasks.[79]

Looking to the Roman agronomists as closer contemporaries, Pliny provides examples from Vergil (*G.* 1.208, 1.227), Columella (*Rust.* 2.8), and Favonius (2.47) on varying sowing dates depending on soil quality, climate, and the crop in question (18.202–203). Geographical climatic variability was of clear importance to the

74. This work no longer survives.

75. Evans 1998: 262. The Greek astronomer and mathematician Hipparchus (ca. 190–120 BCE) did author a treatise *On the Precession of the Equinoxes*, preserved in part in the *Almagest* of Claudius Ptolemy (ca. 100–170 CE).

76. Antonello 2016: 7. See also disagreement with Varro on the date of the second Vinalia (*NH* 18.289).

77. The fact that Pliny observes those differences is to his credit; by late antiquity, farmer's almanacs had become more rhetorical exercises than practical handbooks: the tenth-century *Geoponika* reproduces agronomists' dates and recommendations to the letter, apparently more indifferent to contemporary farming practices (Antonello 2016: 9).

78. These are the solar "forcings" mentioned at the beginning of section II; see Ruddiman 2013: 159–76.

79. On types of climate change see Bradley 2015: 14–16.

Roman agronomic authors: as quoted by Pliny (18.163), Cato recommends noting climate (*caelum*), weather, soil, relief, aspect, water availability, connectivity, and available labor (*Agr.* 1.2–3). Varro discusses regional differences in climate through the interlocutor Scrofa (*Rust.* 1.6). But what about differences in climate over time, at scales which were relevant to the Roman population? Pliny proves his usefulness on this front in the second element of his practical meteorology, adjusting the timing of agricultural tasks for local conditions and allowing for seasonal variability.

Importance of phenological signs: Skeptical of calendrical dates with their myriad inconsistences, Pliny rejects as impractical Vergil's designation of tasks by numbered days on the lunar calendar (18.205–206). Instead, he encourages the independent farmer to look for terrestrial signs and make his own observations. This aspect of practical meteorology, relying on observation over the word of authorities and astronomers, returns us to the topic of phenological signs.

Pliny argues that seasonal events like leaf emergence—proven to be closely linked with temperature[80]—are a better indicator of weather and agricultural activities than the constellations. Rather than giving calendrical dates for the solstices, he notes their associated phenological events: "The turning leaves of olive, white poplar, and willow mark the summer solstice, blooming pennyroyal (*pulei*) the winter solstice" (2.108). He marks the time for plowing by the fruiting of the lentisk (or mastic)[81] and the blossoming of the pear, squill, and narcissus (*Ergo haec aratio has habebit notas*, 18.244). He tells us that the Roman peasant (*vulgus agreste*) knew not to sow after the departure of the stork (*ciconiae*, 18.314).[82] On the topic of winter sowing, after faithfully listing the celestial markers recommended by Xenophon and Cicero, he informs the reader that the true method to be adopted is not to sow until the leaves begin to fall (*cum sit vera ratio non prius serendi quam folia coeperint decidere*, 18.224), apparently in contrast to the Italian folk saying, quoted in earlier works on Roman agriculture, that "early sowing is rarely a mistake."[83] He repeats the caution with reference to winter sowing, urging readers to judge celestial dates by their results and not expect the timing of seasonal changes to be exact or consistent (*ex eventu significationum intellegi sidera debebunt, non ad dies utique praefinitos expectari tempestatum vadimonia*, 18.231). In one of his most picturesque examples, Pliny recommends watching for the appearance of glowworms (*cicindelae*) as a sign for sowing millet (*panici miliique*, 18.250). Alluding

80. Keenan 2015: 48; Vilhar et al. 2018: 45.

81. In reference to Cicero: *Iam vero semper viridis semperque gravata / lentiscus triplici solita est grandescere fetu / ter fruges fundens tria tempora monstrat arandi* (*Div.* 1.15, a translation from Aratus). Theophrastus also describes the mastic as bearing three crops of berries (*Hist. pl.* 7.13.6).

82. Similarly, for Hesiod, migrating cranes marked the time for plowing: φράζεσθαι δ', εὖτ' ἂν γεράνου φωνὴν ἐπακούσῃς / ὑψόθεν ἐκ νεφέων ἐνιαύσια κεκληγυίης (*Op.* 448–49).

83. Spurr 1986: 42.

again to the Pleiades, called Vergiliae by the Romans, he compares the inconvenience of staying up to watch the stars with the ease of noticing the seasonal changes on the ground, comparing the lights of bioluminescent beetles winking on at twilight to constellations scattered in the grass:

> Iam Vergilias in caelo notabiles caterva fecerat; non tamen his contenta terrestres fecit alias veluti vociferans: "Cur caelum intuearis, agricola? Cur sidera quaeras, rustice? Iam te breviore somno fessum premunt noctes. Ecce tibi inter herbas tuas spargo peculiares stellas easque vespera et ab opere disiungenti ostendo ac, ne possis praeterire, miraculo sollicito.... Cur etiamnum altius spectes ipsumque caelum scrutere? Habes ante pedes tuos ecce Vergilias."[84]
>
> Plin. *NH* 18.251–52

> Nature had already formed the Vergiliae, a noble group of stars, in the heavens; but not content with these, she made others for the earth, as if crying aloud: "Why do you contemplate the heavens, farmer? Why look up at the stars, rustic? Already the nights oppress you, wearied with sleep too brief. Look! For you I scatter stars amid the grass and reveal them to you in the evening, unyoked from your work, and lest you disregard them, I call your attention to this marvel.... Why then do you still look higher and scan the sky? See, you have before your feet your Vergiliae."

When it comes to relying on personal observation rather than reading, it is impossible to know for certain to what extent Pliny followed his own advice. However, parts of the *NH* concerning climate and agriculture clearly draw on personal experience, often from his administrative and military postings, which serve to bolster his reliability as an authority on Roman climate.[85]

Adjustments for local conditions in the performance of agricultural tasks: In a rare case of mentioning a particular weather event, though not in terms specific enough to date, Pliny describes a severe winter in the territory of the Treveri, near modern Trier in southwest Germany, just the year before his writing. Here, after losing their winter crop in the unexpected weather, the farmers sowed again in March

84. On this passage commentaries defer to Sillig (1851–1858), who attributes the prosopopoeia to an unknown poet. Personification is not so unusual in Pliny, however, that it could not be an original composition, given his characterization of *divina Natura* (e.g., 2.157) and a similar passage (18.265–67). On the rhetorical function of *mirabilia*, see n.26 above.

85. Pliny argues against (unnamed) sources in his attribution of blight not to scorching by the sun but to nighttime chill, evident to anyone who pays attention (*Id manifestum fiet adtendentibus*, 18.275). He also claims to have personally examined all but a very few (*exceptis admodum paucis*, 25.9) medicinal plants in the garden of Antonius Castor, and to have had others sent to him (25.18, 25.27, 27.99). According to Morton (1986: 91) Pliny is the first to mention the exclusively maritime pea (*Pisum maritimum*, 17.30) and to distinguish the two plants used for rope-making in Spain (19.26, 24.65), which he attributes to observations during postings in Spain.

and reaped an abundant harvest (18.183). This example serves to introduce the final feature of practical meteorology important to ancient climate: adjustments for local conditions.

In spring, acknowledging variability in the beginning of prevailing west winds, Pliny advises that the farmer "should start spring tasks not when the west wind ought to blow, but when it does blow" (*Neque enim eo die vocantur ad munia, quo favonius flare debeat, sed quo coeperit*, 18.238). Not unlike paleoclimate proxies, phenological changes are highly contingent on local conditions. Making the necessary adjustments for seasonal variability and change over time required close attention to local conditions, at least as important, if not much more so, than a working knowledge of astronomy. Unlike Columella, who doubted whether mastery of meteorological knowledge was possible "without the light of intelligence and the most expert instruction" (*Rust.* 1.praef.22–23), Pliny offers the observation of nature as a perfectly acceptable substitute:

> Sed ille indocilis caeli agricola hoc signum habeat inter suos vepres humumque suam aspiciens: cum folia viderit decidua. Sic iudicetur anni temperies, alibi tardius, alibi maturius. Ita enim sentitur ut caeli locique adficit natura, idque in hac ratione praecellit, quod eadem et in mundo publica est et unicuique loco peculiaris.
>
> Plin. *NH* 18.226
>
> But that farmer unschooled in astronomy may find this sign [for sowing] among his brambles, looking at his own land: when he has seen the leaves fall. In that way the year's weather may be estimated, [since they fall] earlier in one place, later in another; for so [the weather] is understood as the nature of climate and locality affects it, and this method excels in this regard, because it is both common to the whole earth and peculiar to each place.

What does all this have to do with climate change? By being both universal (*in mundo publica*) and particular (*unicuique loco peculiaris*), Pliny's method allows room for interannual and geographical variability. The farmer experienced climate as weather, and weather events often "disturb the regularity of our expectations" (18.208). Nevertheless, Pliny understood climate and geography to affect (*adficit*) those unpredictable expressions, allowing local knowledge and attentive observation—his *ratio* of choice—to fill in the gaps.

Pliny's practical meteorology advocates a place-based approach, relying on local knowledge based in diachronic experience to properly interpret seasonal signs.[86] His emphasis on attention to and knowledge of local conditions is an

86. Local knowledge in agriculture is an important theme that did not garner full exploration in this article. After quoting Theophrastus on frost hollows, as discussed in section II, Pliny continues: "In Syracusan territory, an immigrant farmer (*advena cultor*) lost his crops to mud after clearing the soil of stones, until he put the stones back again (*donec regessit lapides*)" (17.30). Here, the detail that

essential attribute of his treatment of climate in the *NH*. When it comes to agriculture Book 18 advocates a more flexible practice, one that could be responsive to climate change, and was probably more representative of the agricultural non-elite.

EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL POPULATIONS

Suggesting that the writings of Roman agronomic authors reflect the views of the population as a whole has long been out of fashion, so we need not do so for Pliny. It is probably safe to assume that the practical meteorology in Book 18 would have been more widely relevant to the lives of ordinary Romans than the somewhat half-hearted philosophical attempts to define climate in Book 2. Beyond that, identifying the agricultural advice of an equestrian encyclopedist with the realities of Roman agriculture is a risky proposal, but one worth exploring nevertheless, as it pertains to the Roman experience of climate.

Like the Roman agronomists he frequently cites, Pliny suggests that farms prosper with the most attentive farmers (*diligentia ... curiosius*, 18.19).[87] Unlike them, with the exception of Cato the Elder, Pliny at least ostensibly tries to address the smallholders of the *humili vulgo* (praef.6). By contrast, Varro, Vergil, and Columella wrote for the owners of large estates of perhaps 50–60 hectares, a world away from the modest allocations granted to resettled colonists in Italy, which measured closer to 1.25–2.5 hectares (5–10 *iugera*).[88] On smallholdings like this, and on marginal land, flexible sowing dates informed by phenological changes and local conditions allowed cultivators to adapt more easily to changing climatic conditions.[89] Of course, not only weather conditions but also uneven land ownership and access to work animals could affect the timing of tilling and sowing.[90] Much more work is needed to understand how effects of climate change were mitigated or intensified by

the farmer was a newcomer (*advena*) seems to have been offered by way of explanation for his misuse of the land, which he warns elsewhere must not be too deeply tilled (18.38). On the formation of local environmental knowledge see Butzer 2005; 2011: 12–13.

87. He also quotes the old adage that "the best fertilizer is the master's eye" (*ideo maiores fertilissimum in agro oculum domini esse dixerunt*, 18.43) at the end of the anecdote of the hardworking C. Furius Cresimus. This character was brought up on charges of magic when his fields yielded more than his neighbors', a good example of differential production of farms even in the same region. Pliny takes the story from L. Calpurnius Piso Frugi, consul 133 BCE and annalist (fr. 33 Peter = 43 Forsythe = 36 Chassignet = 36 Beck-Walter).

88. Hopkins 1978: 57n.81, citing figures for the second century BCE; Halstead 2014: 61.

89. For a contemporary example, Halstead 2014: 27 observed the winter sowing of spelt and emmer in Asturias, northwest Spain, shifting from December to January or even February to reduce the risk of lodging (stem collapse) by shortening the growing season. The risk of lodging is one example of why assigning terms of qualitative value to climatic change such as the RCO can be problematic. Advantageous conditions for some—mild winters, more precipitation—could still present challenges in other areas.

90. Halstead 2014: 23–24.

the social statuses of the farmer, available technology, and economic and political structures.[91]

Thus far, climate research has centered on causal links between increasingly unpredictable climate and resource stress, thus tending towards grand narratives of decline, collapse, or, more recently, resilience. Historians studying the societal impact of climate change rarely aim to establish general laws that govern how people respond to it.[92] The examples in the past section should show that the length, beginning, and end of the growing season was of much greater relevance to the livelihoods of Roman agriculturalists than the average temperatures. Farming in the preindustrial Mediterranean came with significant—or as Horden and Purcell put it, predictable—unpredictability, leading to a host of well-studied risk management behaviors.[93] Macroscale climate histories miss the wide range of adaptive strategies available to ancient farmers—the Italian farmer watching for the first leaves to emerge and adjusting his planting schedule (18.226), or the those in southeast Germany sowing again after a severe winter and bringing in an abundant harvest (18.183). A major challenge facing climate history studies is how to allow the individual back into the picture, and here Pliny illustrates how the literary record stands to greatly enhance our understanding of Roman responses to environmental change.

V. CONCLUSIONS

Viewed in the literary, social, and environmental context of the first century CE, the *NH* has current potential by recommending increased attention to seasonality, agricultural communities, and the lived experience of agricultural laborers in order to better understand the effects of climate change on ancient populations. The environmental legacy of the Roman Empire remains contested, and further close regional studies are needed. With his granular attention to detail and the breath of his encyclopedic project, Pliny records evidence of range shifts and changes in the timing of phenological events that both challenge and complement current paleoenvironmental data.

The proliferation of interdisciplinary studies on the past Mediterranean environment will continue to create opportunities for dialogue with authors like Pliny. Ongoing debates and uncertainty due to the differential impacts, perceptions, and challenges of the current climate crisis complicate the development of any single

91. See Harper and McCormick 2018: 40; Hollander 2019. See also Rosenzweig and Marston 2018, on using resilience theory to examine long-term sustainability in the context of climatic and economic pressures.

92. Izdebski et al. 2016: 7. See Harris 2013: 7: "We need more data, obviously, but, more importantly still, we need better thinking about the possible range of differences between local climates within the same region and within the Roman Empire (Mediterranean and otherwise) as a whole; and we also need better thinking about the likely effects of climatic change on human, or rather Roman, behavior."

93. On agricultural risk management see Garnsey 1988; Halstead and O'Shea 1989; Gallant 1991.

narrative, and understanding of global change and its local effects remains to some extent both privileged and politicized.[94] Acknowledgement of similar complexity in the Roman world need not preclude its investigation. Climate is not merely the aggregate temperature and precipitation data for a given region; it is also a historically and culturally constructed idea, one which mediates what people expect of their surroundings.[95] By codifying those expectations in his own particular—and particularly Roman—way, Pliny's *Natural History* offers a unique perspective on Roman climate, its changes, and the experience thereof.

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94. See Popovich et al. 2017, mapping American positions on climate change.
95. For some recent anthropological approaches see Barnes and Dove 2015 and Hulme 2015.

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