

The earth's climate has formed the constantly changing backdrop to all human endeavor. In late antiquity, the climate system had a decisive influence on agrarian subsistence – along with soil, labor, and technology, a prime determinant of what crops could be grown and overall productivity. The climate influenced demography and played a key role in health and disease. It stirred migrations – and it stirred the human imagination. In short, climate history is an integral part of environmental history, the study of humanity's changing relationship with the natural world. As historians, we live at an exciting moment for the study of the past climate, when the urgent need for a full understanding of climate dynamics has led to the recovery of natural archives that allow new insights into this dimension of environmental history.

Today I propose to leave entirely to one side questions of human impact and human response to climate change, which are keenly interesting but beyond the scope of what is treatable here. I will focus exclusively on the physical environment of the fifth century, trying to make a beginning of characterizing the main lines of change in the environmental background of a period that falls between more famous, or notorious, episodes of late Holocene climate history.

The climate is a large, complex, and purely physical system, and the parameters that interest us – such as temperature and precipitation – are the result of systems that involve features and processes at multiple scales. The study of climate, past and present, is always a question of scales, spatial and temporal.

[SLIDE] Many or most of us are students of the Mediterranean, and students of the Mediterranean are often intimately familiar with the importance of microclimates,

the sometimes exquisitely small-scale patterns of variation produced by the interaction of local features such as water, soils, vegetation, elevation, and orography.

[SLIDE] Microclimates can create distinct environments over small spatial scales, so that the leeward side of a mountain may present radically different prospects for agrarian production from the windward. Microclimates give us the amazingly rich texture of fine wine regions like Napa, where the slightest variations in moisture and temperature and wind and sun are worked into great art so that you can literally taste small-scale climate variation.

However intricate and colorful the mosaic of microclimates may be, though, they have no autonomy from larger-scale determinants of the climate. That is to say, local climates are always under the control of larger scale physical processes, including meso-scale or storm-scale climate processes, and especially synoptic and global scale determinants of climate.

[SLIDE] The dominant fact of global climate is the uneven heating of the earth's atmosphere, which creates the temperature gradients between the equators and the poles. Along with the oceans and topography of the continents, these gradients create the dominant circulation patterns that shape regional climate regimes. The climate in the tropical latitudes is dominated by the easterly trade winds, while the mid-latitude belt is under the control of the westerlies. In the northern hemisphere, maybe the most important mechanism of synoptic-scale climate variability is known as the North Atlantic Oscillation, or the NAO.

[SLIDE] The NAO is created by the permanent atmospheric pressure differences between a zone of high pressure over the Azores and a zone of low atmospheric pressure over Iceland. The intensity of the pressure gradient oscillates, and when it is elevated, the NAO is in a positive mode; the westerly wind flow is bent northward; low atmospheric pressure promotes precipitation over northern Europe while the high

pressure in the south 'blocks' precipitation. The effects are massive. In 2015-6, the NAO was frequently positive, contributing to record-setting rains in Britain and widespread drought in the western Mediterranean. In its negative mode, the effects are reversed: westerly storm tracks dribble across the Mediterranean, bringing abundant rains and potentially flooding.

[SLIDE] The Roman Empire straddled an unusually wide and diverse range of climate zones. The north-south range of the empire was historically rare. Moreover, the empire sat at the juncture of some of the most important climate gradients in the northern hemisphere. The western and northern parts of the empire were under the overarching influence of Atlantic climate mechanisms, which continued to exert an influence even into the central and eastern regions under Roman control. The Mediterranean sits along the border of the subtropics and the mid-latitude westerlies, while its southern rim is controlled by the ridge of subtropical high pressure along the line of 30 degrees north that squelches precipitation in the summer and progressively creates pre-desert and then desert along the southern and eastern edges of the empire.

The eastern Mediterranean is a truly global crossroads, where the influence of the Atlantic and the summer monsoons intersect. And we should not forget that the breadbasket of the empire, Egypt, depended on an annual Nile flood, discharging the runoff of the Ethiopian highlands, fed by summer monsoons off the Indian Ocean, pushed and pulled by the Pacific's great oscillation, El Nino. The Roman climate was truly global in its reach.

Understanding global and synoptic scale climate dynamics is of fundamental importance, particularly for the question of climate change. There is a scientific consensus that human activity over the last two centuries has loaded the atmosphere with greenhouse gases that trap heat and cause global-scale warming. Part of the reason that global warming is so alarming is that the magnitude of change – quite likely on

the order of a 2-degrees centigrade increase in average global surface temperatures over the next century – is so large *and* so fast. The study of the past climate only serves to heighten our anxiety and our sense of humanity’s vulnerability to environmental turbulence. History, in partnership with the natural sciences, can serve to deepen our sensibilities and sharpen our awareness of the importance of the environment. For though the causes, magnitude, and abruptness of modern, anthropogenic climate change are in combination novel and disturbing, climate change itself is not new. The climate is always changing due to natural causes. Even today, anthropogenic climate change operates on top of natural forces, but climate change per se did not begin with the exhaust fumes of the industrial revolution.

On scales that interest us, nature has four kinds of mechanisms that force climate change.

[SLIDE] First. *Orbital* forcing is caused by slight but hugely significant changes in the earth’s orbital parameters. The tilt of the earth oscillates between 22 degrees and 24.5 degrees on a 41,000 year cycle. The spin of the earth changes, as the axis wobbles like a top, on a 26,000 year cycle. And the gravitational pull of objects other than the sun ever so slightly tweaks the elliptical pathway of earth around the sun. The result of all this celestial swaying and wobbling is variability in the solar energy arriving on the planet. And even if the changes are gradual, the effects may not be, as complex feedback and threshold mechanisms produce ‘sudden’ jerks in the experience of parameters like temperature and precipitation.

[SLIDE] Second. *Solar* forcing is caused by changes in the amount of energy being emitted by the sun. The sun is a fairly constant star, but not perfectly changeless. Its solar dynamo pulses with energy on various timescales, the most famous of which is the 11-year sunspot cycle, and the most important of which may be a 2300-year cycle called the Hallstatt cycle.

[SLIDE] Third. *Volcanic forcing* is the earth's own contribution to climate change on small time-scales. Large eruptions spew sufficient ash into the sky to load the atmosphere with reflective sulfates, which in turn effects cooling of the earth's surface at magnitudes that can register as virtually instantaneous climate change, sometimes with long, lingering effects.

[SLIDE] Fourth and Finally. *Internal variability*. The climate system itself, in particular the all-important heat pump of the ocean's circulatory system, acts as an important and imperfectly understood source of unpredictability.

So, long before humans hijacked the earth's climate system, it changed on its own tempo and terms. The urgent need to understand the background of natural climate change has led earth scientists to scour the planet for what might be called *natural archives*.

[SLIDE] The history of the climate is being sketched thanks to the recovery of proxy evidence, physical records of past climate and climate change. Climate proxy records might inform us about the history of climate *forcing mechanisms* – like solar variation or volcanic eruptions – or about the history of climate *parameters* – temperature and precipitation. Climate parameter records, moreover, preserve information at different temporal resolutions and spatial scales. That is, some records – such as ice cores, tree rings, and some speleothems or cave mineral records – preserve data at a high temporal resolution, sometimes annual or even subannual. Other kinds of proxies – glacier history, pollen sequences, marine or lake sediments – can be just as valuable but often present lower chronological resolution. Further, some proxy evidence registers climate change at small spatial scales, while others have diagnostic value on much larger spatial scales. In general, it is the case that *temperature* changes are more spatially coherent, and *precipitation* changes are more spatially variegated. Changes in

precipitation, in other words, are more sensitive to global, synoptic, *and* microclimatic factors, but no level is autonomous of the others.

The last decade or two has witnessed a remarkable bonanza of new paleoclimate evidence. For the historian, this goldrush of new data is a thrilling opportunity to enrich the long and distinguished tradition of environmental history, with novel insights on the large-scale mechanisms and dynamics of climate change. We have long known about the rich, small-scale stories of the Mediterranean landscape. Now we are starting to see the big picture. It is akin to having known the finely drawn character sketches of the *Iliad*, and belatedly learning the whole epic of the Trojan War.

Maybe the single greatest revelation has been the mere fact of rapid and large-scale climate change in the Holocene. Humans have existed for around 200,000 years. For most of this history, we lived in the wild times of the late Pleistocene. On a millennial timescale, orbital forcing mechanisms drove profound shifts in the earth's climate, creating full-scale ice ages. The Pleistocene has been called the "reign of chaos," for good reason. Then, around 12,000 years ago, the ice melted for good, and the chaos subsided, as the climate epoch known as the Holocene began. The Holocene - warm and stable - was the necessary backdrop to the rise of agriculture and civilization. It has been a hospitable setting for the extraction of greater levels of energy from the environment and the construction of large, complex societies. But, it turns out, even the Holocene has seen climate change on scales that have entailed massive consequences for human social development.

[SLIDE] Holocene climate change proceeds on decadal, centennial, and millennial scales. Always in the background, and driving the most important millennial scale changes, has been the continuing operation of orbital forcing. After reaching a peak in the early to mid Holocene, around the beginning of the Neolithic, levels of insolation have persistently declined. The mid-Holocene was something of an optimum,

warm, humid, and stable. The ensuing late Holocene, the last four thousand years, has seen progressively lower insolation and consequent cooling, with other synoptic-scale effects, including the desertification of the Sahara, the weakening of the monsoons, greater frequency of El Ninos, sharper seasonal differences in the Mediterranean (with its now pronounced dry summers and wet winters), and weaker pressure differences over the Atlantic. These changes have been inexorable, but not smooth and continuous. Rather, on decadal and centennial scales, the climate has rocked and swayed on its bumpy path toward the late Holocene.

[SLIDE x 2] In a forthcoming book, I synthesize recent paleoclimate work and advocate for characterizing the centuries of Roman rule by division into three separate eras of late Holocene climate, defined by changes on submillennial scales.

[SLIDE] The first is a phase of climate history that is widely recognized in the literature, if poorly defined in time and space, known as the Roman Climate Optimum. It properly describes a phase lasting ca. 200 BC to 150 AD, noted for warmth, humidity, and stability in broad stretches of the empire's territories. The Roman Climate Optimum experienced persistently elevated levels of solar output, between two grand solar minima on either side of the long Roman era. Moreover, with the exception of a huge explosion in the year Julius Caesar was assassinated, the period was spared any volcanic events that were catastrophic on a global scale. The consequence was a phase of climate history that, I argue, looked back to the gentler and qualitatively different mid-Holocene. The combination of warmth *and* humidity (including, notably, summer precipitation) – from Spain and Italy to North Africa and the Levant – was somewhat unusual but well attested in variety of records. The Roman Climate Optimum pushed back, so to speak, against the tide of late Holocene change, restoring conditions that appeared really for the last time. It also seems that El Ninos were quiescent and rare, while the Nile flood was extraordinarily dependable.

This phase came to an end in the middle of the second century, which marked the beginning of what I call the Late Roman Transitional Period. This phase of some three centuries is notably incoherent, disorganized. I will try to zoom in on it in a moment, to look more closely at the fifth century, but for now suffice it to say that the entire period is marked by signals of stronger variation than the preceding centuries.

Finally, from the AD 530s onward, there is significant evidence for climate reorganization, in a period that is justly starting to be called the Late Antique Little Ice Age. A combination of volcanic activity – the most important sequence of eruptions in the last several thousand years, kicked off by the famous “Year without Summer” in AD 536 – and declining insolation forced a global-scale cooldown. It wasn’t merely colder; it was suddenly and massively colder, with a decline in average temperatures of 2 degrees in the space of a decade, lasting a century and a half. It was probably colder than during the more famous “Little Ice Age” centered on the 17<sup>th</sup> century.

The Late Roman Transitional Period, then, is the relatively incoherent and highly variable phase of late Holocene history *between* the more sharply pronounced Roman Climate Optimum and Late Antique Little Ice Age. Precisely because it was more changeable, more muddled, it will require the continued collection and analysis of climate proxies to reconstruct these centuries in more granular detail. But already, we can say that the Late Roman Transitional Period was not simply a straight line from the warmer, wetter, and stable optimum to the icy age of the sixth and seventh centuries. It was a period full of twists and turns, and we can already start to see some of them, if only in broad outline. I would like to note, briefly, four large-scale features of the fifth-century climate.

[SLIDE] First, the best solar activity record (based on beryllium isotopes in ice cores) reveal a definite increase in the levels of solar energy reaching earth across the

fifth century. The fifth century, here and in the following slides, is highlighted in yellow.

[SLIDE] Second, the best study of volcanic forcing, an important new work by Sigl et al, reveals the fifth century as a time of relative absence of major volcanic activity. This does not mean there weren't volcanic eruptions, just that these had little global-scale effect. Certainly, fifth-century volcanism pales in comparison to the impending explosions of the sixth century, a period of notable seismic and volcanic activity.

[SLIDE] Third, the best temperature records are neither dramatic nor particularly consistent. An important new temperature reconstruction by Ulf Buentgen, based on high-resolution tree rings, shows slight warming in central Europe but cooling in central Asia. These regions were moving in different directions before the coordinated plunge into the late antique little ice age.

[SLIDE] The Alpine trees agree with a speleothem record from Austria, also showing warming across the fifth century.

[SLIDE] Fourth, and what I think is maybe the most exciting, at first glance the precipitations records of the fifth century might seem inconsistent. But in fact they tell a consistent story of a major phase shift in the mode of the North Atlantic Oscillation, from strongly positive to strongly negative. A tree-ring record from central Europe shows that the heart of the continent received *decreasing* amounts of rainfall across the fifth century.

[SLIDE] By contrast, a range of records from Anatolia, including the Sofular Cave speleothem, show the fifth century as a period of transition toward a more humid climate.

[SLIDE] This is coherent with a wide range of evidence, including a new multiproxy study from Sicily, showing that a period of wetter climate was initiated in the mid-fifth century.

[SLIDE] And, an effort to reconstruct the history of the NAO from Greenland records also suggests the fifth century as a time of change from a positive to a negative NAO. I would argue that we have the evidence to posit a major, enduring shift in the middle of the fifth century toward a negative NAO, steering the westerly storm tracks southward, delivering greater precipitation over the Mediterranean, from Italy to eastern Turkey.

[SLIDE] In conclusion, we have much to learn about the climate of the fifth century, and we have much reason for hope that the future will continue to deliver us paleoclimate records that enhance our knowledge and understanding of environmental history in this period. From a millennial-scale perspective, the fifth century climate lacked drama, especially relative to what immediately followed. But, to adapt what Keynes said, in the millennial scale, we are all dead. Those who lived in the fifth century were deeply influenced by the smaller, fine-grained changes that are smoothed out in the longer perspective. Even small climate changes can have large repercussions, under the right circumstances. Human societies are variously resilient or fragile to the instability of the environment, and the magnitude of climate change is not always a certain predictor of its human impact. Future work might focus in on smaller geographic scales and explore the complex relationship between climate change and human social response in the specific conditions of the fifth century.

No matter what, though, we must try to appreciate the inseparability of local, regional, and global scale processes, and to situate more focused studies within larger frameworks that recognize the overwhelming power of climate mechanisms like the

North Atlantic Oscillation. The fun of history is trying to think big and small, simultaneously, in both time and space --- whether we are thinking of the earth's climate or human societies. Thank you.