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# Towards A Holistic View of Climate and Collapse

MA Dissertation

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# Ch. 0: Introduction

Rapid changes in climate, particularly changes towards aridity, are often viewed as catalysts for societal collapse. Most notably the Late Bronze Age Collapse (generally considered to occur within a 50-year period at approximately 3.15-3.1 KYBP ) in the Eastern Mediterranean, which saw the sequential fall of several civilizations across the Aegean, Levantine, Mesopotamian, and northwestern African regions, has recently been seen as a result of a rapid climate aridification event in these areas, occasionally known as the “3.2 ky Megadrought”. Sometimes this event is referred to as the “Late Bronze Age Drought,” but resolution between archaeology and paleoclimate is currently difficult (see Chapter 1 Section 1); throughout this paper references will follow the climatological nomenclature. Other such aridification events have been known throughout the Chalcolithic Bronze Age Eastern Mediterranean, such as the “4.2 kiloyear event”, sometimes referred to as the “Early Bronze Age Drought”, which was contemporaneous with the end of the Egyptian Old Kingdom and social decline into the First Intermediary Period. However, the direct association of these paleoclimatic events with their paired social collapses has recently been criticized in archaeological literature, most extensively by Knapp and Manning (an overview of Knapp and Manning’s criticisms are in Chapter 1 Section 1).A further aridity event at 5.2 KYBP, in contrast to the collapse events of 3.2 KYBP and 4.2 KYBP, however, is associated with the advent of state societies. The polarity of outcomes of climatically similar events is driven by human response and reaction to shifting climate. The human response, in turn, is influenced by cultural practices, social structure, political stability, and economic security; depending on a culmination of these factors, different societies at different times will be impacted differently by climate change.

An understanding of the impacts of climate change on humans must be predicated on several layers of foundational knowledge: an understanding of climatic processes as a whole, an understanding of climatic patterns and trends throughout time, and an understanding of human socio-politico-economical nuances at particular times. In this paper an overview of these three foundations is presented. Climate patterns and forcing mechanisms are defined on a basic level, Holocene (and late Pleistocene) climatic trends are outlined, and changes in human societies (from the Late Neolithic to the Early Iron Ages) at periods concurrent with known climatic shifts are examined.

# Ch. 1: Criticism of Climatological Causes of Collapse

Attributing societal collapse- particularly the Late Bronze Age Collapse- to extreme or dramatic climatic events has been a popular theme in Eastern Mediterranean Archaeology during the twentieth century (Carpenter 1966) and beyond, capturing public and professional interest particularly in recent decades due to parallels in modern anthropogenic climate shifts. Evidence of “sudden” drought in the constituent regions (and globally) during the Bronze Age, particularly towards its terminal end, have been linked to the known cultural shifts visible in the archaeological record, such as large-scale site abandonment and absence of written records, influencing a narrative that these cultural shifts were at least in part due to rapid (that is, commencing within a century) and insurmountable changes in climate patterns.

It is taken for granted (Kaniewski *et al.* 2010 and other authors discussed in Knapp and Manning 2016), and often considered to be common knowledge, that a sudden and extreme drought event, impacting the greater Eastern Mediterranean region, was crucial in the onset of the Late Bronze Age

Collapse. This particular drought, the so-called "3.2 ky Megadrought", expressed in waves across the region within a few decades, destabilized agricultural production and displaced peoples became the marauding "Sea Peoples" who further contributed to societal stress by disrupting trade networks and entering in conflict with other states. States facing agricultural losses fought to annex neighbors, or defended themselves from becoming annexed as such. One by one, the civilizations across the Eastern Mediterranean went dark, with cities abandoned, populations decimated, literature forgotten, trade networks destroyed (Stanton *et al.* 2012).

However, the idea of the 3.2 ky Megadrought as the catalyst for these events may not be as strongly supported as popular academic thought may want to believe. The timing of the Megadrought has recently been called into question (particularly by Knapp and Manning 2016, discussed further in Section 1 of this chapter), as has the primacy of climate change as a force of societal collapse. Furthermore, the definition of "collapse" needs to be addressed, as does the mystery surrounding the peoples living in the "Dark Ages" at the Bronze and Iron Ages boundary.

## 1.1 Dating Resolution

The work of Knapp and Manning (Knapp and Manning 2016) in particular details current problems in associating climatological perturbations with societal collapse events. Dating resolutions of perturbations, most notably droughts, are accurate only within one to two centuries, an as such cannot accurately be linked to fixed, archaeologically visible cultural shifts and events, which are more confidently dated. To cite an elucidating example: Kaniewski *et al.* 2010 (who draw a significant portion of the ire of Knapp and Manning) assert that climatic deterioration into extreme drought is evident beginning at 3.16 KYBP, almost perfectly concurrent with the lower boundary of the Late Bronze Age Collapse at 3.15 KYBP. However, in their rebuttal, Knapp and Manning draw attention to the fact that Kaniewski *et al.*'s date of 3.16 KYBP (1200 BCE) is only resolved within about two centuries, meaning that the date could be off by about one hundred years in either direction- Knapp and Manning give the largest possible range, based on one potential calculation, as 1310-1106 BCE. This severely skews the implied relationship with the Late Bronze Age Collapse dates- there is the potential that the identified event postdates the upper boundary of the Collapse (1250 BCE) by as much as 50 years.

Issues in dating chronology are particularly notable in short-term perturbations, such as the drought Kaniewski *et al.* sought to identify; uncertainties in dating resolutions in these short-term cases, which occur within a century or less, are often greater than the time frame of the event itself (Alley 1997). Only recently have higher-resolution dating studies for short-term events been published (Finne *et al.* 2017), largely in response to Knapp and Manning's work. With the higher resolution of more recent Late Bronze Age dates from the archaeological side, the abundance of low-resolution data from the climatological side creates uncertainty in interpreting climate data with respect to archaeological and historical evidence (Drake 2012).

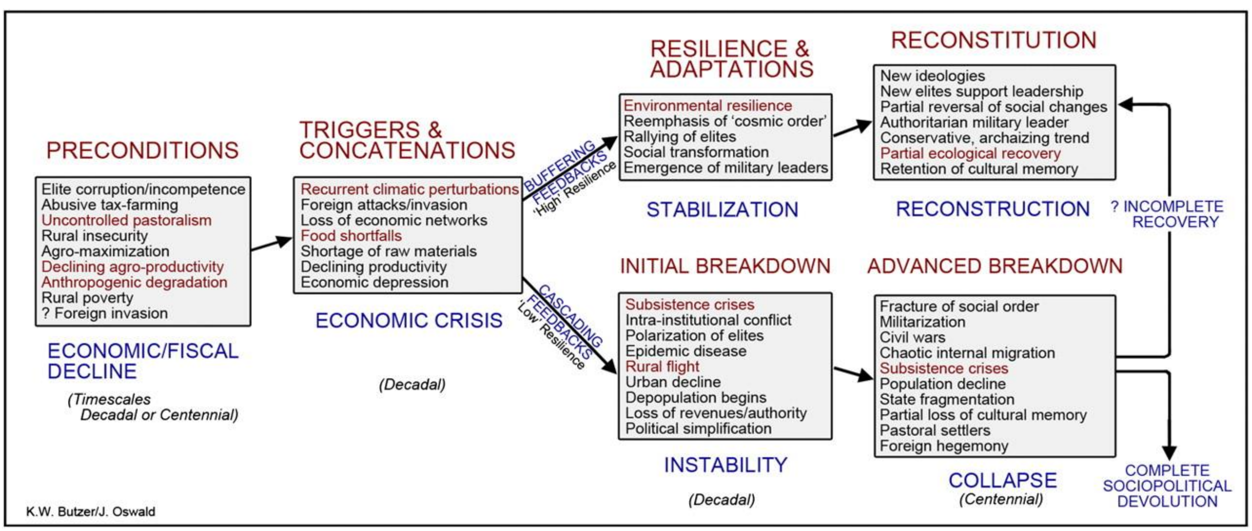
This is not to say that aridity at the end of the Late Bronze Age is a work of fiction; many proxy climate records from the Eastern Mediterranean regions do show that the climate at this time was more arid than at the beginning of the period, and that the mid to late Holocene climate as a whole was trending from moist to arid since the termination of the African Humid Period/Green Sahara (Kuzucoglu *et al.* 2009, Drake 2012, Knapp and Manning 2016); Holocene climate trends including the African

Humid Period are discussed below in Chapter 3. The problem is the onset date of the 3.2 KY Megadrought: did it, or did it not, occur before the decline of Eastern Mediterranean civilizations?

In lieu of a large database of accurately resolved dates, it becomes necessary to understand trends and patterns in climate change, particularly throughout the late Pleistocene and Holocene (the time following the Last Glacial Maximum). Sudden-onset arid perturbations, like the 3.2 KY Megadrought, are part of a longer trend towards arid climate conditions that have been occurring in stages or pulses throughout the mid- to late Holocene (Kuzucuoğlu 2009, Yeakel *et al.* 2014). The problems posed by the consideration of the 3.2 KY Megadrought dating can be alleviated if it is not viewed as a single event, but as a peak phase in a longer-scale trend. Too frequently this event is considered in isolation, which leads to the dilemma of whether or not the perturbation occurred before the Late Bronze Age Collapse. When it is considered in concert with other similar events and trends from the preceding few millennia, though, it becomes more evident that oscillating trends towards aridity did precipitate the Late Bronze Age Collapse; this "consideration in concert" (referred to in this paper as a "holistic view") of climate change is discussed further in Chapter 5.

## 1.2 Partial Responsibility

Climate in itself is only considered to be a partial factor in societal collapse, aggrandizing preexisting social, political, and/or economic stressors (Rosen 1994, Butzer 2012). The impacts of climate change on societies are contingent upon a number of human factors such as social, political, and religious organization and/or hierarchy of the society (Alland 1975, Kirch 1980, Butzer 1982). The nuances in these structures inform the society's response to climatic changes and perturbations. Different classes of the society might even respond differently, based on their own interactions- direct or indirect- with the environment (Rosen 1994).




The chart from Butzer 2012 details the progressive stages of economic societal crisis which may or may not end in a collapse event. "Recurrent climatic perturbations", likely encompassing of deterioration and desiccation trends, are only considered a trigger for potential collapse events in the presence of a collection of preconditions which largely could be categorized as "governmental failure." Elite corruption and tax farming are obviously governmental failure; uncontrolled pastoralism and agro-maximization (which can contribute to anthropogenic degradation, and it in turn to declining agroproductivity) are often driven by necessities of large states, who need surpluses to feed a large population of nonproducers. A society without internal political or social pressures function as equilibrium systems which are able to process and adapt to external pressures such as environment; however, in the presence of external aggravating factors, internal stressors boil over and steer a society towards a collapse event (Rosen 1994).

Many observations of paleoclimate and society forgo the social aspects in favor of the climatological aspects, seeking collapse causes that can be quantified with scientific inquiry rather than sociological interpretation; or, when considering social factors, considering them only as simplistic direct effects of climatic conditions (Trigger and Tainter 1988, Yoffee and Cowgill 1992). However, humans and societies are complex, and underlying social, political, and economic factors seem to be the primary movers of collapse events during times of climate stress. The importance of climate as humans respond to it, instead of climate factors in isolation, should be the focus of collapse event research.

Several of the scholars whose collapse theories are discussed in Chapter 4 of this paper saw the collapse event occur in the midst of some kind of social or political turmoil, such as declining power of the elites, labor riots, or unrest between constituent polities. Climate can easily be theorized to influence these issues, but the direct cause of the administrative dissolution is often human; hence, climate is a secondary factor, per Butzer's model. The final outcome of climatic change is dependent on the behaviors that the humans take in response to its shifts. In short, the effects of climate on societies is a factor of the choices that the societies make in response to it. The impacts of climate on society need to be viewed through this lens, instead of the simpler cause-and-effect paradigm that is prevalent- that it, something like a linear two-point model where climate directly impacts society without consideration of social response as a "middleman" instigating the changes.

An understanding of concurrent climate trends must be paired with more human-driven events, to paint a more accurate picture of societal decline. Often investigations into collapse events are focused on either the climatic or the sociopolitical factors leading up to the event; rarely are both aspects analyzed together. Further research should be inclusive of not only the climate trends occurring in an area, but also an overview of the known political climate and economic situation; understanding both aspects can help to isolate causes from effects, and understand how the climate impacts not the collapse event directly but the social and political nuances that lead up to the collapse event.

## 1.3 Collapses and Dark Ages

Further criticism has been directed at the very idea of societal collapse. Cultural "dark ages," the periods traditionally following collapse events, are usually marked by a disappearance of literature, lack of monumental construction, decline in trade, abandonment of urban centers, and a simplification of society. However, recent scholarship has indicated that the "social reduction" following known collapse events may not be entirely accurate. The Greek Dark Age and the Intermediate Periods of Egypt, for example, had small but thriving towns away from the abandoned or declining administrative centers (Dickinson 2007, Seidlmeyer 2014); these settlement patterns are discussed further in Chapter 4.

Within a single complex society, different class levels may have different strategies in response to environmental change. "Lower-order" citizens, inclusive of the the peasantry and agricultural producers, are more likely to enact adaptative strategies than "higher-order" authorities (Rosen 1994); however, the most successful agricultural responses- those which were associated with settlement and agricultural continuity during post-collapse periods- involved shifts *towards* small-scale subsistence farming and *away* from cash-cropping and surplus production strategies meant to sustain economic development. This is a strategy more beneficial for smaller communities than large urban networks, likely contributing towards the continuity of such smaller communities during times when cities were abandoned or production focuses were altered amidst climate shift.

Often, upon the dissolution of administrative or royal classes, or disruption of the elites, society becomes focused into smaller groups. Lower classes often either abandon urban centers for small communities in the hinterlands, or consolidate into provincial cities away from the administrative seat. In smaller communities, now focused on the needs of the individual settlement instead of the needs of the larger state, agricultural producers may shift their practice from one of copious surplus and luxury products to one of subsistence, no longer required to overproduce for large networks.

Collapse events have, historically, been identified with cultural discontinuities in the expressions and effects of administration centers, which control literature, manage monument construction, authorize trade, and organize large-scale settlements. Administration centers in Bronze Age times are extensions of the elite, ruling, or royal class, the top level of social hierarchy. The disproportionate association of social collapse with the discontinuity of social elites and hierarchical disruption has definitively informed how collapse and its aftermath is viewed.

"Social collapse," as it is used, refers more to a collapse of existing institutions of government; "dark ages" are the following periods in which the previous government has ceased to exist and projects like monumental construction cease (the requisite labor force of "monumental architecture" is considered to be attainable only by high-functioning administrations with control over large populations and land areas, and as such the absence of such monumental works is considered to indicate the absence of a widely-influential governing system). Society, particularly at the lower hierarchical levels, tends to persist following these "collapse events", often even maintaining cultural continuity of the "collapsed" society through the following "dark ages". Identification of collapses and dark ages, especially in context of Bronze Age societies, are skewed towards the happenings of elite levels of society, which is not reflective of the happenings of the society as a whole.

So, the historic idea of "collapse" leans too heavily on the expression of higher levels of society and the seat of administration (the capital), without much respect given to the majority of the population who belong to lower classes and live in other settlements.

In summation, dramatic perturbations, particularly aridification events, affect societies differently, discussed in further depth in Chapter 4; an aridification event in the sixth millennium BP was concurrent with formation of complex state societies, while aridification events in the fifth and fourth millenniums BP were concurrent with the decline and disappearance of such civilizations. However, problems in paleoclimatic dating resolutions prevent complete ascertainment that the climatic events predicated the collapse events. Additionally, the collapse events were largely declines in governmental and administrative functioning, and many of these "collapsed" societies had smaller but thriving branches of continuity into the following "dark age."

## Ch. 2: Agents of Climate Change

Climatic change is a complex and multifaceted process. Factors affecting the change of climate are referred to as climate forcing mechanisms (or simply forcing mechanisms), which includes internal processes occurring within the Earth system such as thermohaline and atmospheric circulation, in addition to external processes occurring outside of the Earth system such as orbital eccentricity and solar variability. Anthropogenic activities that result in climatic change are also external processes, as they are outside of the Earth system. The effect of a single forcing mechanism can be either compounded or mitigated by other mechanisms, and by the positive or negative feedback loops that the original mechanism sets in motion (Chiotis 2019). Additionally, onset of affects may be rapid or slow- often, compounding and positive feedback loops hasten the onset of climatic effects, while mitigating and negative feedback loops will cause effects to express later, perhaps up to centuries, after the initial forcing occurs.

Positive feedback mechanisms are those in which the effects of the mechanism hasten or intensify it, such as ice-albedo feedback: melting ice reveals water or soil, which have lower albedo than the ice, thus absorb more insolation, which heats the atmosphere, causing more ice to melt (further discussion on albedo as a forcing mechanism is found in Section 1 of this chapter). Negative feedback mechanisms are those in which the effects of the mechanism slow or mute it, such as cloud-heat interactions: warm temperatures during moist periods results in higher levels of evaporation, thus creating more cloud cover in the atmosphere, which reflect solar irradiance and decrease insolation, causing a decrease in global temperature.

While trends can be mapped on a general a global scale, regional deviations naturally occur. In addition to global location (affecting factors such as seasonal insolation, and susceptibility to atmospheric events such as the North Atlantic Oscillation and the Southern Oscillation), topography, limnology, and plant cover play factors in the local effects of worldwide events, enacting differing responses from different regions. The Eastern Mediterranean, despite the geographic closeness of its constituent zones (the Aegean, Anatolia, the Levant, Mesopotamia, and Egypt), is an interesting crux of these dividing regional effects- to use the atmospheric circulation pattern example from above, the Aegean and Anatolia are more affected by the North Atlantic Oscillation, while the Levant, Mesopotamia, and Egypt are more beholden to shifts in the Southern Oscillation (Kotthoff *et al.* 2008).

Highly individualized regional responses to global trends prevent trustworthy assertations that perturbations affect even nearby areas within the Eastern Mediterranean region concurrently and with similar strengths. It is not enough to say, for example, that the increase in seasonal rainfall known in northern Africa, southern Mesopotamia, and the Arabian Peninsula associated with the strengthening monsoon (DeMenocal 2000, Kennett and Kennett 2005) indicates greater moisture availability in the general Eastern Mediterranean; in fact, eastern Anatolia is suspected to have experienced much higher levels of aridity at this time (Roberts 2013). Thus an understanding of the underlying effects regionally are necessary to understand how a global trend, such as insolation, affects individual areas.

The interplay of multiple effects, muted or compounded by either their own effects or unrelated forcings, which may take a period of centuries to reflect in climate proxies- and all of these muting, compounding, and timing factors affected still by regional differentiation- make climate an incredibly complex subject to understand. However, an understanding of the complexity is necessary for an accurate understanding of the expression of climate change. While it is by no means an exhaustive list, an overview of some basic climate forcing mechanisms follow.

## 2.1: Insolation and Albedo

The initial forcing mechanism for climate shifts is, generally, insolation, or the amount of energy the Earth absorbs from the Sun through solar radiation. The energy absorbed by the Earth is displaced throughout the Earth system and expressed as weather patterns- and weather, averaged over time is climate (Chiotis 2019). Insolation is reliant on the Earth's distance from the Sun, the activity of the Sun itself, and by the Earth's planetary albedo.

The Earth's distance from the Sun is not a constant. While there are natural daily and seasonal changes in insolation of a particular area (creating the day-night and seasonal cycles of the planet), there are long-scale patterns (millennial to decamillennial) of changes in the eccentricity of Earth's orbit, the planet's obliquity, and precession of its equinoxes, which creates the astronomical patterns of Milankovitch cycles (Campisano 2012). Orbital eccentricity is the oscillation of Earth's orbital path around the Sun from more to less elliptic or oblong; obliquity is the shift in the angle axial tilt of the planet from more to less "upright" in respect to rotational-orbital axis; precession is a change in the direction of the rotational axis. Orbital forcing, as this mechanism is known, is constituted of these cyclic changes, and affects the absorbed solar energy of the Earth on a global and regional scale. (Campisano 2012, Chiotis 2019)

Activity on the Sun itself affects the radiation output of the star, or the total solar irradiance- which affects how much solar radiation is available for the Earth to absorb as insolation. Changes in solar output are driven by shifts in the magnetic field at the Sun's surface, expressed as phenomena such as sunspots and solar flares (Solanki *et al.* 2013). Solar output as a whole is theorized to vary on a handful of scales from decadal to millennial, and can be measured with some accuracy via cosmogenic isotopes related to solar magnetism; though cycles of the constituent phenomena are not fully understood before observational records began with Galileo (Solanki *et al.* 2013) Proxies of sunspots and solar flares are difficult to identify, and currently past reconstructions of these phenomena are unable to be accurately drafted (Krivova 2019).

Insolation is further affected by planetary albedo, or how much solar radiation a planet reflects back into space without absorbing. Albedo is driven by topography and landscape on the planet's surface- higher-albedo coverage such as ice or sand, or even cloud cover (the most reflective, highest-albedo coverage) reflect more energy than water or forest cover, which absorb more energy (Chiotis 2019). Large-scale changes in surface cover at the planetary level (desertification, ice cap reduction, sea level rise, moisture availability) thus affects the radiation energy absorbed by the planet, which must then be displaced as weather (and so eventually climate) patterns. Aggregate albedo of the entire planetary surface produces global effects, but surface conditions within smaller regions can also have regional effects.

## 2.2: Intertropical Convergence Zone and the Monsoons

One of the most far-reaching weather and climate patterns on the planet is that of the monsoons, an atmospheric phenomenon driving rainfall seasons and patterns for constituent equatorial and low-latitude areas. The range of the monsoons vary in response to shifts in the location of the Intertropical Convergence Zone (ITCZ), the low-pressure intermediary zone of the equatorial-polar thermal gradient. The ITCA follows the thermal equator of the Earth and thus shifts in response to changing planetary heat distribution, which is affected by orbital forcing, regional albedo, and thermohaline forcing. Heat distribution is largely carried out by the thermohaline circulation (the thermohaline circulation is discussed further in Section 4 of this chapter).

The location of the ITCZ, and subsequently its strength, is driven largely by insolation, primarily through orbital forcing (though vegetation albedo is also crucial, discussed below). The displacement of heat throughout the globe by the thermohaline circulation creates a gradient from pole to equator, the center of which is the Intertropical Convergence Zone. Changes in insolation, and disruptions to the thermohaline circulation, affect the heat gradient and thus where the center (the ITCZ) sits.

Shifts in the Intertropical Conversion Zone affect the range and strength of the monsoon rains. Particularly susceptible to dramatic wet/dry oscillations are areas on the fringe of the monsoon zones, such as northern Africa, the Arabian Peninsula, and Mesopotamia. A northern shift in the ITCZ brings monsoon rains and thus moisture to these fringe areas in the Northern Hemisphere, while the ICTZ's southern retreat conversely causes aridification in these areas. In the Southern Hemisphere, the relationship is inverted (a northern shift of the ICTZ induces aridification, et cetera). Northern ICTZ shifts during the late Pleistocene and early Holocene are associated with the onset of the African Humid Period/Green Sahara, which is discussed further in Chapter 3 Section 3.

Paleoclimatic simulations of insolation-monsoon relationships in African contexts have recently revealed that vegetation cover, likely through its low albedo and surface moisture retention, is pivotal in calculations monsoon strength (DeMenocal 2000). Simulations of climatic conditions in the Sahara during the African Humid Period, relying on atmospheric models and orbital forcing cycles, showed that large standing bodies of water and thus the grassland biome they supported (which were known) were incapable of existing during this time. Adjusting the predictions with ocean and vegetation models found correct humidity levels allowing for the known Green Sahara. Thus, albedo effects from vegetation cover, in addition to orbital forcing effects, has profound effects on the strength of the monsoons.

## 2.3: Anthropogenic effects

Of much discussion in recent decades is the effects of human activity on climate forcing mechanisms. Generally, anthropogenic forcing mechanisms are only considered a primary factor of post-industrial climate change, but recent research has indicated that humans have had notable impacts on climate since at least the Neolithic.

Prehistoric climate forcings are generally thought to be confined to changes in surface landscapes (Roberts *et al.* 2011), which in turn affect regional (and eventually global) albedo. Landscape management, by accident or design, has been practiced by nomadic pastoralists and agriculturalists, as part of the very nature of these practices. Land surface changes by agriculturalists may seem understandable, as the conversion of natural landscapes to managed farmland necessitates such intentional land management, but the less obvious nature of changes by nomadic pastoralists is interesting.

The effects of nomadic pastoralists on vegetation cover was both positive and negative. The animal excrement, concentrated in the temporary camps where they were kept during nights and rests, created nitrogen hotspots which enriched the soil, encouraging vegetation growth (Marshall *et al.* 2018). However, browsing and grazing habits of the cows, sheep, and goats can be detrimental to vegetation cover. It has been suggested that overgrazing of the Sahara vegetation by the herds of nomadic pastoralists, during the insolation-driven terminal phase of the African Humid Period (terminal period approximately 6-5.5 KYBP; see discussion in Chapter 3 Section 3.1), helped to hasten the already-rapid desiccation of the Sahara (Wright 2017). “Natural” forcings of insolation and ITCZ shifts had placed the environment in a precarious balance, and the devegetation by nomadic herds pushed it over the tipping point.

As discussed above in Chapter 2 Section 1, shifts in surface cover cause resultant changes in the surface’s albedo, and the albedo effects of vegetation is a critical forcing mechanism for monsoon strength. Reduction of the low-albedo absorptive vegetation cover, revealing the high-albedo reflective sandy cover beneath, decreases the total insolation; over a large enough area, such as the Sahara belt, the albedo change can have global, in addition to regional, effects. Thus the devegetation reduced surface albedo throughout the region, which influenced a resultant decrease in insolation.

## 2.4: Heinrich, Bond, and the Thermohaline

Heinrich events are climatically notable phases of large-scale iceberg movement in the North Atlantic during glacial periods. Significant portions of glaciers collapse and form icebergs, which move into the North Atlantic and melt, introducing large quantities of cold fresh water into circulation. This raises sea level and lowers sea surface temperature, which drastically affects the Atlantic thermohaline circulation; debris from the iceberg melt may also displace salt in the water, further affecting water density. Heinrich events through the Pleistocene have been associated with dramatic cooling and aridification events in the Levant, reducing rainfall and evaporation by disrupting the thermohaline circulation and shifting the ITCZ (Bartov *et al.* 2003).

Bond events are similar but smaller scale events occurring during the current interglacial period. The final Heinrich event (H0) occurred around 12 KYBP (Hemming 2004), coincident with the onset of the Younger Dryas; the climatic shifts of the Bond events were not as dramatic as the Heinrich events in the Pleistocene (Bond *et al.* 1997). In the Holocene, these events generally coincide with a weakening of the monsoons and aridification in monsoon fringe regions in the Northern Hemisphere, as the ITCZ is driven south by disruptions to the thermohaline circulation.

| Bond Event | Time |
|---|---|
| 1 | 1.4 KYBP |
| 2 | 2.8 KYB |
| 3 | 4.2 KYBP |
| 4 | 5.9 KYBP |

| | |
|---|---|
| 5 | 8.1 KYBP |
| 6 | 9.4 KYBP |
| 7 | 10.3 KYBP |
| 8 | 11.1 KYBP |

Holocene ice raft debris events enumerated by Bond *et al.* 1997

The thermohaline circulation is a sensitive gradient-driven ocean circulation pattern which distributes heat around the planet, and the Atlantic Meridional Overturning Circulation is specifically the Atlantic expression of the phenomenon of thermohaline circulation (comprised of the equator to North Atlantic surface water, and the North Atlantic to Southern Ocean deep water). Density in seawater is a factor of temperature and salinity; saltier water is denser than fresher water, and colder water is denser than warmer water. Water temperature also affects the salinity of seawater; warmer temperatures allow more solute (in this case salt) to be dissolved in the water solvent. Warmer, lower-density surface water is carried from the equator to the poles via surface currents, driven by wind patterns, where it cools and sinks into the deep ocean. The deep water of the North Atlantic travels southward and upwells primarily in the Southern Ocean, though moderate upwelling occurs along currents near northwest and southwest Africa and long-scale upwelling occurs in the North Pacific.

The functioning of the thermohaline circulation, specifically the Atlantic Meridional Overturning Circulation (AMOC), is important for thermal regulation in the low-longitude Northern Hemisphere; disruption in the circulation, at least in premodern history, has caused relatively long-term cold events in the region (Chen & Tung 2018), and acceleration of the circulation is concurrent with warming events (McManus *et al.* 2004). One of the most common factors that disrupt the AMOC is cold freshwater influx, generally by glacial melt or large iceberg drift (Pleistocene Heinrich and Holocene Bond events) in the North Atlantic.

## Ch. 3: Holocene Paleoclimate in the Eastern Mediterranean

The geological period of the Holocene epoch is of most interest to the study of archaeology, particularly in the Mediterranean and the Near East, as the beginning of this postglacial world generally coincides with the known beginnings of Fertile Crescent agriculture. In particular, the Meghalayan Age constitutes the time period from approximately the Aegean and Near Eastern Middle Bronze Ages to the present, although the formations of early states are found early in the Northgrippian Age. The lower boundary of the Meghalayen is also coincident with a marked shift in cultures worldwide, making it the first geological boundary that is also associated with human events.

| | | |
|---|---|---|
| **Holocene** | Late Holocene (Meghalayan) | 4.2-0 KYBP |
| | Mid Holocene (Northgrippian) | 8.2-4.2 KYBP |
| | Early Holocene (Greenlandian) | 11.7-8.2 KYBP |

*Holocene dates and subdivision boundaries proposed by Walker et al. 2018; dates ratified and subdivisions renamed by the International Union of Geological Scientists June 2018*

| Period | Epoch | Age | Period | Duration (Age) | Duration (Epoch) |
|---|---|---|---|---|---|
| **Quarternary** | **Holocene** | Meghalayan | 4.2-0 KYBP | 4.2 KY | 11.7 KY |
| | | Northgrippian | 8.2-4.2 KYBP | 4 KY | |
| | | Greenlandian | 11.7-8.2 KYBP | 3.5 KY | |
| | **Pleistocene** | Tarantian | 126-11.7 KYBP | 114.3 KY | 2568.3 KY |
| | | Chibanian | 781-126 KYBP | 655 KY | |
| | | Calabrian | 1800-781 KYBP | 1019 KY | |
| | | Gelasian | 2580-1800 KYBP | 780 KY | |

*Holocene and Pleistocene subdivisions, as divided by the International Commission on Stratigraphy*

The climate of the Holocene is, in the most general terms, defined by a shift from humid to arid conditions. However, the transition was not smooth and stable; the drying trend was interrupted several times by pluvial phases, which in some areas lasted several kiloyears. The longest of these wet phases was the African Humid Period, terminating in the mid-Holocene, after which aridification pulses/cycles began to occur with greater frequency.

In the absence of a large collection of accurately resolved dates for the occurrences of specific climatic perturbations, knowledge of general climatic trends can provide at least a rudimentary framework in which to work. For example, it may be impossible currently to date the beginnings of a drought event within a half-century of accuracy, but what is possible is seeing that for a century leading up to the presumed drought event was a period of increasing aridity, applying climatic stress to human populations which, when coupled with sociopolitical instability and economic failure, can reach a 'tipping point' for collapse events.

An understanding of long-term climate change as a whole, then, becomes a necessary foundation for the examination of human-climate interactions. So, following is a quick overview of key climatic effects known in the Eastern Mediterranean from the latest Pleistocene to the first quarter of the Meghalayan Age of the Holocene.

## 3.1: Pre-Holocene

The Holocene epoch was preceded by the Pleistocene, known colloquially as the Ice Age but was actually comprised of several glacial and interglacial phases. Glacial phases are coupled with general global aridity and low sea level; pollen records from the tropics and subtropics, in addition to the Mediterranean, indicate that these regions experienced severe forest decrease during glaciations (Roberts 2014). Each subsequent interglacial phase during the Pleistocene seemed to necessitate redevelopment and readvancement of vegetation, at least in Northern Europe (Roberts 2013) though the pattern of glacial-phase forest reduction in sub/tropical areas

The Last Glacial Maximum (LGM), peaking approximately 25-18 KYBP (Roberts 2014), occurred in the last quarter of the Tarantian Age. From this point until the Holocene Greenlandian Age was a shift towards warmer and more humid climates as the glacial bodies melted (a process that continued until approximately 7 KYBP, in the beginnings of Northgrippian Age). Interglacial transitional phases following the termination of the LGM were warmer and wetter than the arid glacial, with humid conditions in northern Africa and sea level rise in southern Mesopotamia commencing at approximately 14.6 KYB (DeMenocal 2000, Kennett and Kennett 2005), both of which persisted well into the middle Holocene. Several interruptions to the warming period from the LGM to the onset of the Holocene are known, though the most recent (Younger Dryas) is dated with any confidence, terminating at the Pleistocene-Holocene boundary at 11.7 KYBP (Roberts 2014).

## 3.2: Greenlandian Age (11.7-8.2 KYBP)

The effects of the melting of the glacial ice sheets dominated the Early Holocene following the Younger Dryas cold period at the terminus of the Pleistocene, releasing frozen water to create sea level rise and greater atmospheric humidity. Sea level rise persisted until about 8.5 KYBP; rapid sea level rise lasted until about 9 KYBP, then slow sea level rise occurred until 8.5 KYBP (Kennett and Kennett 2005).

At approximately 11-10 KYBP, Northern Hemisphere summer insolation peaked, coinciding with a northward shift of the Intertropical Convergence Zone and a strengthening of the monsoon season (DeMenocal *et al.* 2000, Kennett and Kennett 2005). Shortly following at 9 KYBP until about 5 KYBP was the Holocene Climatic Optimum; the delay between insolation optimum and climatic optimum is believed to result from a negative feedback loop with ice melt disrupting the thermohaline circulation.

The African Humid Period or Green Sahara began approximately 9 KYBP, coincident with the beginning Holocene Climatic Optimum, though the humid conditions had persisted since 14.6 KYBP (DeMenocal *et al.*2000). During this time, the modern Sahara was largely a grassland biome featuring lakes and rivers, sustained by the rainfall of the strong African monsoon. Seasonal rainfall across the Arabian Peninsula and southern Mesopotamia, also attributed to the strengthening monsoons, increased notably at approximately 10 KYBP (Kennett and Kennett 2005).

### 3.2.1: 8.2 KY Event

At the boundary between the Greenlandian and Northgrippian Ages is the global perturbation known as the 8.2 KY Event. This event is associated with Bond Event 5, the final collapse of the Laurentide Ice Sheet in Meltwater Pulse 1C and is known to have coincided with a period of aridity in Mesopotamia and Anatolia.

The 8.2 KY Event was a cold, dry interruption to the warm Holocene Climatic Optimum, lasting approximately two centuries in the Northern Hemisphere (Chiotis 2019). Disruption of the North Atlantic thermohaline circulation caused a temporary southward shift of the ITCZ and weakening in the monsoon in the Northern Hemisphere (Cheng *et al.* 2008), in addition to a reduction in the efficiency of heat transfer from the equator to the North Atlantic (Alley *et al.* 1997, Cheng *et al.* 2008). The thermohaline disruptions were caused by cold freshwater discharge pulses, related to both Meltwater Pulse 1C and Bond event 5; Meltwater Pulse 1C is the final stage of the collapse of the Laurentide Ice Sheet, beginning around 8.2 KYBP, which drastically altered the density and salinity of the Atlantic waters and thus disrupted the circulatory patterns.

## 3.3: Northgrippian Age (8.2-4.2 KYBP)

Following the onset of the 8.2 KY Event and containing the 6.5-5.9 KY aridification event (where the African Humid Phase undergoes a rapid end), this stage terminates at a further aridification event at 4.2 KYBP; this period is marked by aridification pulses throughout the Eastern Mediterranean, particularly following the termination of the African Humid Period around 5.9 KYBP. This period sees the rise of state societies in the Eastern Mediterranean, and terminates with a dramatic cultural shift in human society.

Just under two centuries after its onset, the 8.2 KY Event waned and warm, humid conditions temporarily returned to the Eastern Mediterranean. Throughout this event, the African Humid Period and Holocene Climatic Optimum were not considered to be terminated, though it entered a phase of decline around 6 KYBP, waning until its true terminus at around 5.5 KYBP (DeMenocal *et al.* 2000).

At about 8 KYBP was the peak of the Holocene Climatic Optimum, which, as a phase, lasted from around 9 KYBP to 5 KYBP. The Holocene Climatic Optimum was the warmest point of the Holocene based on global measurements, though it is associated with cooling in southern Europe (Davis *et al.* 2003), likely due to fluctuations in the thermohaline circulation due to glacial melt; Meltwater Pulse 1C is also centered around 8 KYBP (8.2-7.6 KYBP). Meltwater Pulse 1C is the final large-scale melt events of glacial retreat from the Last Glacial Maximum glacier caps, following Meltwater Pulse 1A at 14.6-14.3 KYBP and Meltwater Pulse 1B at 11.4-11.1 KYBP.

### 3.3.1: 6.5-5.9 KY Event

Bond Event 4 at 5.9 KYBP occurs within a further cool, dry event in the Northern Hemisphere lasting from 6.5-5.9 KYBP. This period is associated with another southward shift in the ITCZ and the paired weakening and shift of monsoonal rains in the Eastern Mediterranean. This event is also coincident with decreasing summer insolation in the Northern Hemisphere and decreasing vegetation cover in the Sahara, and the termination of the Holocene Climatic Optimum (DeMenocal *et al.* 2000).

The short terminal phase of the African Humid Period occurs during this event (African Humid Period terminal phase from 6 to 5.5 KYBP). The rapid onset of drier conditions is a factor of runaway positive feedback effects: the primary mechanism was a reduction of insolation driven by orbital forcing, which in isolation would have resulted in a gradual climatic shift. However, as the ITCZ slowly shifted south in response to insolation decrease, the reduction of precipitation began to help erode the vegetation cover in the Sahara, which additionally hastened through overgrazing by nomadic pastoralists (Roberts *et al.* 2011); a discussion of overgrazing as an anthropogenic climate forcing mechanism is found above in Chapter 2 Section 3. As the green wall collapsed into sandy soils, the higher-albedo surface contributed to even greater insolation reduction as it reflected even more solar energy. Internal insolation forcing, in concert with the external insolation forcing, accelerated the ITCZ shift and quickly ushered in arid conditions (DeMenocal *et al.* 2000).

The time around 5.2 KYBP has been identified independently by two researchers identifying aridity pulses; Kuzucuoğlu 2009, charting the progression of change from wetter to drier conditions in the Holocene, and Yeakel *et al.* 2014, who identify shifts in predator-prey ratio as a function of aridity in Egypt (charted as aridity pulses). Kuzucuoğlu identifies the first step in aridity at 5.3-5 KYBP; Yeakel *et al.* find a ratio shift and thus aridity pulse around 5 KYBP.

### 3.3.2: 4.2 KY Event

Bond Event 3 at around 4.2 KYBP coincides with a global climate shift towards aridity. In the Eastern Mediterranean, low Nile flow, lake level decrease in north Africa and the Levant, and reduced rainfall in Mesopotamia are thought to be related to a weakening monsoon at this time (Weiss 1993, Gasse 2000). The weak monsoon is likely related to the Bond Event, as these iceberg movements interrupt the thermohaline and shift the Intertropical Convergence Zone.

Both Kuzucuoğlu 2009 and Yeakel *et al.* 2014 identify an aridity step or pulse around this time. Kuzucuoğlu places the second step towards aridity at 4.5-3.9 KYBP, while Yeakel *et al.* 2014 identifies a second aridity pulse at about 4.17 KYBP.

## 3.4: Meghalayan Age (4.2 KYBP-Present)

With its lower boundary specifically selected at the 4.2 KY Event, the onset of the Meghalayan is the first geological age to coincide with climate-associated cultural change. After the Bond Event 3 at 4.2 KYBP, the following one, Bond Event 2, does not occur until the Iron Age at around 2.8 KYBP. The eruption of Thera occurred sometime between 3.6-3.45 KYBP; dating resolutions between radiocarbon and archaeological analysis differ (Ramsey *et al.* 2004, Manning *et al.* 2006)

### 3.4.1: 3.2 KY Megadrought

Centered around 3.2 KYBP, many climate records around the Eastern Mediterranean indicate a rapid-onset aridity pulse, lasting well into the Iron Age (Finné *et al.* 2011). Low sea surface temperatures and low evaporation rates in the Aegean are known from this period, which would have contributed to reduced rainfall in the region (Drake 2012). The length of the drought event varies by individual region, but it is generally thought to have lasted at least several centuries, and the conditions commencing at this time persisted well into the Iron Age; thus, whatever catastrophic desiccation was occurring continued to occur as new civilizations and empires emerged in the Eastern Mediterranean (Chiotis 2019).

Additionally, this is concurrent final Holocene aridity phases identified by Kuzucuoğlu 2009 and Yeakel *et al.* 2014; Kuzucuoğlu places the final step towards aridity at 3.2-2.8 KYBP, and Yeakel *et al.* find another aridity pulse at 3 KYBP. Interestingly, this is the only aridity pulse or step, and major aridity event in the Holocene, that is not also concurrent with a Bond Event. Lower sea surface temperatures, as occur in this period, can also be onset by Bond Events. This “para-Bond event” has often only been studied in the context of the Late Bronze Age Collapse, but the interesting climatic conditions known need further investigation on their own merit.

# Ch. 4: Civilization responses to climate patterns

A selection of several Eastern Mediterranean states has been selected for review. The selection focused on an intersection of climate and culture shift throughout the mid-Holocene; each selected society/state experienced an archaeologically noted shift in culture that was generally concurrent with shifts towards drier climate in the Northern Hemisphere.

## 4.1: Southern Mesopotamia (~5.5-5.2 KYBP)

Some of the first complex state-level societies emerged in Southern Mesopotamia around 5.5-5.2 KYBP (Rothman 2004) during the end of the Uruk Period and beginning of the Jemdet Nasr Period. This is following the termination of African Humid Period-related monsoon strength and pluvial period known in the region from 9-6 KYBP (DeMenocal *et al.* 2000) and during a shift towards a known phase of aridity from 5-4 KYBP (Sirocko *et al.* 1993, Kennett and Kennett 2005).

The foundations for state societies in Southern Mesopotamia appeared during a wet phase in the mid-Holocene. Large permanent settlements began to appear after 8 KYBP in the 'Ubaid Period, clustered around low-saline marine estuaries of the now-stable Ur-Schatt Delta (Kennett and Kennett 2005). Increased rainfall in the area from the strong monsoons sustained freshwater bodies like lakes and springs, diversifying the subsistence strategies available to peoples of the 'Ubaid Period (approximately 8-6.3 KYBP) (Sirocko *et al.* 1993, Kennett and Kennett 2005).

By 6 KYBP, humid conditions in the Eastern Mediterranean were terminating (Kennett and Kennett 2005). The reduction in rainfall due to the weakening of the Northern Hemisphere monsoons, reducing agricultural and pastoral capabilities across Mesopotamia, forced abandonment of smaller settlements and relocation of those peoples within the estuarine Ur-Schatt Delta, particularly at Uruk-Warka; population reduction in the north and population growth in the south (Kennett and Kennett 2005) support the trend of relocation to the Delta. Exploitation of the estuary via fishing, mollusk gathering, and canal irrigation would have provided food shelter during the aridification event. However, the regional Southern Mesopotamian climate began to desiccate around 5.2-5.1 KYBP (Bar-Matthews *et al.*1999). This aridity influenced a partial retreat of the delta, though the retreat was not total and is thought to have allowed agricultural advancement into the retreat zone with the help of irrigation technology while also maintaining a space for some estuarine exploitation (Brooks 2006).

The Delta settlements' population boom in the early sixth millennium BP urbanized the areas, and with larger populations came greater competition for the resources that many had relocated for. With larger populations now competing for resources, it became necessary to organize communities at a greater level than had existed in smaller non-urban settlements; fortifications began to appear around 5.3-5.1 KYBP, indicating conflict in the region likely due to the rarifying of estuarine resources resulting from the desiccation of the delta (Brooks 2006). Throughout the Jemdet Nasr period (5.2-5 KYBP), migration from the north to the south continued, as the emergent primary states and their comparatively higher availability of resources provided attractive options for rural peoples suffering from the impacts of the climate on their less-diversified economies. During this period the state societies also began to deviate from the once-uniform Uruk culture, a differentiation possibly tied to the conflicts that were occurring. These differentiations persisted and deepened throughout the following predynastic period as the primary states became city-states, and then eventually the Akkadian Empire.

Drying climates further afield allowed population aggregation in climate refugia in the Ur-Schatt Delta, and desiccation within the Delta, in concert with the increased competition that resulted from the population growth, created a context in which population and defense organization became necessary.

The drying trends during the terminal phase of the African Humid Period, precipitating the advent of Mesopotamian state society, were continuous through several centuries, though the peoples around the Ur-Schatt Delta were able to reap benefits from it. A flexible food economy and the use of artificial irrigation were adaptative strategies which allowed the peoples to not only survive but thrive.

## 4.2: Egypt (~5.2 KYBP)

The unification of Upper and Lower Egypt, and thus the beginnings of the Egyptian state, occurred at about 5.2 KYBP (Midant-Reynes 1992, Brooks 2006). This is coincident with the termination phase of the African Humid Period, marked by a decrease in monsoon strength across northern Africa; the related aridification of Africa and the eastern Sahara had persisted since around 7 KYBP (Brooks 2006). At this time, though, the Nile flow was not in decline, at a semipluvial phase between two low-flow events at around 5.5 and 5 KYBP (Bernhardt *et al.* 2012).

Following a shift to higher aridity and lower rainfall across northern Africa around 6 KYBP which marked the terminal phase of the African Humid Period, nomadic pastoralists in the region established traditions focused more on sheep and goat herding, as opposed to the cattle herding traditions that emerged slightly after 8 KYBP (Brook 2006). The short aridification pulse at 8.2 KYBP, an interruption to the otherwise moist pluvial African Humid Period, had influenced the emergence of cattle herding as a subsistence strategy in addition to the hunter-gatherer-forager strategies already in place. Cattle, as a subsistence strategy, provides reliable sources of nutrition for nomadic groups, though it is contingent upon adequate pasture availability; goats and sheep became a more logical alternative when long-term aridity began to disrupt vegetation growth patterns in the late seventh millennium BP. Some nomadic pastoralists likely participated in some sort of cyclic seasonal migration, re-visiting sites yearly depending on the season (Wilkinson 2003, Brooks 2006), though as seasonal rainfall patterns changed with the shifting monsoon in the sixth millennium BP and Saharan water sources disappeared, the viability of these patterns waned.

Continued climate stress and the desiccation of water sources and vegetation in the Sahara pushed nomadic peoples into fewer and fewer refugia, including the banks of the Nile in Upper Egypt, which may have been a yearly stop for pastoralists with a cyclic migration (Wilkinson 2003). While it survived as a strategy through the shorter-term aridification pulse at 8.2 KYBP, cattle herding waned around 5 KYBP (Brooks 2006) after the disappearance of Saharan vegetation. The “Nubian Exodus,” throughout 6-5 KYBP, with a peak at around 5.6 KYBP, was the onset of a sharp reduction of pastoralism. The adoption of agriculture by these peoples has been suggested to have begun as a strategy of herd upkeep compatible with the new sedentary lifestyle (Wengrow 2001). Additionally, it is possible that newer migrants to the Nile might have formed disadvantaged groups which earlier settlers could have exploited for labor, creating a social stratification; this elevation of the “proto-elites” led to the development of royalty (Midant-Reynes 1992).

Nile flow suffered from noted reductions at two phases bordering the advent of the Unified Egyptian state, at 6-5.5 KYBP and again at 5 KYBP (Bernhardt *et al.* 2012).The relative success of the river, especially in comparison to Saharan lake desiccation contemporaneous with it, likely provided trustworthy refugia for the pastoralists suffering from the vegetation reduction caused by the desertification event, and these climate refugees flocked to the banks and established permanent settlements. At the terminus of the sixth millennium BP, though, the pattern of fleeing climatic distress was no longer a popular strategy; the now-settled citizens of the Egyptian state had begun to manipulate the environment to buffer against perturbations. The use of artificial irrigation was known at least by the time of the reduced flow event at 5 KYBP, based on the dating of a mace head found depicting canal cutting (Midant-Reynes 1992)).

The desertification of the Sahara seems to have been the catalyst which eventually led to the formation of the Egyptian state. Fleeing the growing inhospitable conditions in the newly forming desert, climate refugees coalesced around the banks of the Nile, merging in some cases like water and oil and creating a breeding ground for stratification based on the disadvantage of more recently-come groups. The stratification soon gave way to the rise of elite and royal classes, and the groups along the Nile were soon unified as a single Egyptian State. The continuing climate desiccation began to affect the Nile refugia, but the fledgling state proved more resilient to the change than their nomadic ancestors.

## 4.3: Levantine Collapse (~4.2 KY)

Complex societies of the southern Levantine city-states disappeared as the large urban settlements were abandoned in favor of smaller lakeside villages around 4.2 KYBP. The abandonment event and shift in social complexity is concurrent with a global aridity pulse and North Atlantic cooling event associated with Bond Event 3.

Urban settlements had begun to appear around 5.2-5 KYBP in the southern Levant, following a moist phase in the region from 5.7-5.2 KYBP (Neev & Emery 1967, Rosen 1994). Subsistence was largely based on floodwater farming of cereals in the coastal alluvial plains, and commercial arboriculture and viticulture in the hill regions; cereal grain farming was for local food production, and the olives and grapes in the hills were for secondary production into oil and wine largely intended for trade as luxury goods by the elite.

Large settlements along the edge coastal plain, situated for the exploitation of both estuarine and higher-ground environments (Rosen 1997) continued to grow as many hill settlements were abandoned during the phase from 5-4.6 KYBP (Rosen 1994), likely in response to reduced rainfall in the region during this time; floodwater farming would have provided agricultural refugia during the pluvial termination, as a more reliable agricultural practice than rainwater farming. During this period and until about 4.2 KYBP, there was an increase in the construction of religious architecture; the increased focus of society on religion during a period of decline in both rainfall levels and climate conditions, and it is possible that the religious emphasis during this time was in response to the desiccating climate- either viewing the climate as some sort of punishment from above, or turning to religion to relieve the woes of the people.

The climate desiccation occurring around 4.2 KYBP in the Southern Levant saw the retreat of the rivers in the coastal plains, and the elimination of simple floodwater farming as a viable subsistence strategy; the use of irrigation, known elsewhere in the world at this time, was not adopted to overcome this environmental stress. The end of the fourth millennium BP saw the abandonment of the cities in the Southern Levant, drastic population decrease, and a disappearance of the complex state societies there.

The emphasis on religion, extrapolated from the increase in construction of temple and shrine buildings, and refusal to adapt strategies such as irrigation, known at the time in places like Mesopotamia, were maladaptive strategies in the face of changing climate (Rosen 2004). These two factors particularly are interpreted at a sense of religious determinism, in which the worsening climatic conditions were insurmountable by human means or any human attempt to adapt was futile (hence the refusal to adopt known irrigation technology), and that prayer/faith/et cetera were the only ways to survive. The post-collapse Levantine social structures and subsistence strategies are unknown, but the severe population decrease following the collapse event likely means that only very small farming communities persisted for some time.

## 4.4: Akkadian Collapse (~4.2 KY)

A short time after 4.2 KYBP, during a known phase of global aridity associated with Bond Event 3 and low lake levels near the Tigris-Euphrates headwaters, the Akkadian Empire in Mesopotamia collapsed after about a century of rule during a period of widespread site abandonment and population reduction.

Settlement patterns in Southern Mesopotamia during the Predynastic Period were those of a few dozen city-states in constant states of shifting alliance. They were consolidated into a single state around 4.3 KYBP under Sargon of Akkad and the Akkadian dynasty he founded (Weiss 1993). North Mesopotamia, up to the Habur plains, was soon annexed into the empire. Agricultural production was intensified with imperialization of irrigation agriculture, in addition to intensification of rain-fed agricultural strategies used in the north; the agricultural productivity, particularly of the northern rain-fed plains, were crucial for food stability in the empire (Cullen and DeMenocal 2000).

The unification of greater Mesopotamia was fragile and superficial. The city-states heavily resisted the imperial control, frequently uprising into rebellion during changes of reign of the Akkadian kings and coming into conflict with royally-appointed governors; references of Akkadian kings and conquests of their own cities are known in the historical record (Weiss 1993, Yoffee 1995).

Towards the end of the reign of Shar-Kali-Sharri, an aridity pulse which onset at around 4.2 KYBP and lasted until 3.9 KYBP occurred (Cullen *et al.* 2000). The drought is associated with reduction of rainfall in Northern Mesopotamia and a resultant decrease in the productivity of the region’s rain-fed agricultural land; the widespread site abandonment in the north and mass migration towards centers in the south are likely due at least in part to this (Weiss 1993, Zettler 2003). The southern city-states, already in political stress, underwent further pressure upon the population boom from the new emigres and the new resource strain they created. Amidst this situation, Shar-Kali-Sharri’s reign terminated at around 4.15 KYBP, and was followed by a quick succession of short-lived and powerless kings.

Following the dissolution of the Akkadian Empire, the Mesopotamian city-states resumed their independence (at least for a time) and maintained individual cultural continuity of the kind they possessed prior to the unification by Sargon (Zettler 2003).

## 4.5: Old Kingdom Collapse (~4.2 KY)

The Egyptian Old Kingdom, consistent of the Third through Sixth Dynasties, declined into the First Intermediary Period following the death of Pepi II between 4.2-4.1 KYBP, coinciding with the global aridity phase known around 4.2 KYBP, reduction in Nile flow, and significant shift in predator-prey ratios (Yeakel *et al.* 2014). During the First Intermediary Period, Upper and Lower Egypt were disunified, and the period was said to be marked by famine, civil war, and a discontinuation of the monumental architecture projects known from the preceding unified period (Butzer 2012).

A period of poor Nile flow is believed to have begun onset around 4.4 KYBP, based on evidence from a pattern of channel incisions at Giza (Butzer 2012), before reaching a reduction peak around 4.2 KYBP (Bernhardt 2012). Chemical changes such as increased salinity and alkalinity from the Blue Nile is inferred from watershed proxy data around 4.3 KYBP, and a shift in predator-prey ratio, affected by a loss of Nile vegetation, has been calculated at around 4.17 KYBP; together, these factors are believed to indicate a subsistence crisis during this time period (Butzer 2012, Yeakel *et al.* 2014).

Economic and imperial decline became noted during the sixth dynasty, which lasted approximately 4.3-4.1 KYBP, concurrent with the disruptions to Nile flow; growing influence and privileges of members of the elite class along with disruption of trade by the Akkadian Empire contributed to a weakening of Pharaonic coffers and power (Butzer 2012). The near-centennial reign of Pepi II launched a dynastic crisis upon his death, essentially destroying any remnant authority of the royalty until the reunification of Egypt between 4-3.9 KYBP.

The decentralization of authority from the palatial center in Memphis began within the Fifth Dynasty (approximately 4.4-4.3 KYBP), as provincial governors began to reside full-time in the regions that they governed. With administration beginning to focus locally instead of at the capital, other institutions such as religion and cultural traditions began to diffuse into the periphery; in addition, the Pharaoh provided to these administrators staff (such as craftsmen and ritualists) and gifts (expensive luxury materials and consumables) to maintain their loyalty and bonds over the distance.

Economic decline in the Sixth Dynasty (approximately 4.3-4.1/4.2 KYBP) was partly resultant of such expenditures by the Pharaoh; similar expenditures contributed even more. Crown-funded monumental tombs, the central feature of mortuary cults once focused only on royalty, began to be offered to other non-royal elites in the court. The construction of the monuments and the religious staff who managed the cultic rituals were paid by the royal treasury, who also funded the upkeep and salaries involved with the older mortuary temples. These financial burdens were exacerbated by the destruction of Byblos, an Egyptian-controlled trade hub in the Levant, where timber and many luxury goods were exchanged.

Following the dynastic crisis after Pepi II, the unified Egyptian state was fractured into independent provinces. The dissolution of Unified Egypt, despite its concurrence with a global aridity pulse, is believed to have been primarily driven by social factors, with the environmental conditions as secondary driving forces galvanizing an economic collapse (Butzer 2012). Additionally, evidence indicates that this cultural shift was only a collapse for the imperial institution; peripheral towns exhibited continuity and, in some cases, even enrichment of social life into the First Intermediary Period, in contrast to the written accounts of the time (Seidlmayer 2014).

## 4.6: New Kingdom Collapse (~3.1-3 KY)

The Egyptian New Kingdom saw its end during the Twentieth Dynasty, particularly after the reign of Rameses III (the 'last great pharaoh') ended around 3100 YBP, though the dynasty technically persisted for another century until around 3010 YBP (Butzer 2012, Cline and O'conner 2012). The Twentieth Dynasty faded into the Third Intermediary Period. Like the event at 4.2 KYBP, reduction of Nile flow and an associated shift in predator-prey ratio is known around 3 KYBP, again generally contemporaneous with an aridity event, the '3.2 KY Megadrought' (Butzer 2012, Yeakel *et al.* 2014); though this aridification, unlike the global event at 4.2 KYBP, is concentrated in the Eastern Mediterranean. Additionally, the collapse of the New Kingdom is notably later than the collapse of other state societies in the constituent regions (Middleton 2019).

Around 3160 YBP, there is a record of 'foreign aid' in the form of grain shipments to the Hittite kingdom from the pharaoh Merenptah (Butzer 2012, Knapp and Manning 2016). Frequently this is interpreted as direct evidence for drought-induced famine in Anatolia and the persistence of the Egyptian state through the aridification known in the rest of the region; however, its meaning in this respect has been questioned (Middleton 2019). The Egyptian records were often skewed to illustrate the society's supremacy, and the shipment of grain to Hatti might have represented more of an Egyptian pride in their surplus productivity rather than a Hittite failure at productivity, or a subsistence redistribution problem in Anatolia driven more by internal conflict between the Hittite king and his deputy kings (Broodbank 2013, Knap and Manning 2016).

Rameses III's ascension to the Pharaonic throne around 3135 YBP was during a period of relative peace and stability, though the preceding Nineteenth Dynasty (around 3240-3140 YBP) terminated after several years of short-reigned kings and dynastic struggles, which created a breeding ground for corruption, particularly by the priesthood, which destabilized his and subsequent reigns (Van Dijk 2014). Land was acquired by the temples at an alarming rate, and by the end of Rameses III's reign over a third of arable land belonged to temples. The productivity surplus implied in Merenptah's time seemed to wane during Rameses III's rule, perhaps giving way to the beginnings of a subsistence crises; around 3130 YBP the pharaoh was recorded making an offering to the Nile to increase the river's floods (Butzer 2012). Soon after this, beginning around 3120 YBP, grain prices began to inflate, and peaked around 3080 YBP at twenty-four times standard price (Butzer 2012). At the very end of his reign just prior to 3105 KYBP, Rameses III faced a tumultuous series of riots and strikes by the royal labor forces. The workmen were demanding restitution for unpaid grain and coin wages; the crown had insufficient grain in storage to pay off the workers (Butzer 2012).

Rameses IV eventually succeeded his father upon his death around 3105 YBP; the office of the High Priest paid the striking workers their due grain, illuminating a power struggle between the temples and the state which must have been broiling for at least several decades. The usurpation of power by the priest class is especially evident just before 3060 YBP, when a High Priest depicted himself in the same size as the pharaoh; by around 3025, the pharaoh was a nominal leader in Lower Egypt controlled by Libyan allies, and the office of the High Priest separately governed Upper Egypt. Once more, the state had disunified.

Upper and Lower Egypt continued separately into the Third Intermediary Period, though the economic situations improved throughout this time. Surplus agriculture in Lower Egypt is implied by recorded land grants to temples, and smaller crafts like faience production and metalworking bloomed in lieu of monumental architecture (Taylor 2014) Though the unified Egyptian state had disappeared, civilization and culture persisted under changed governmental structures.

## 4.7: Mycenaean Collapse (~3.2 KY)

The collapse of Mycenaean civilization in mainland Greece and the subsequent cultural descent into what is known as the 'Greek Dark Age' occurred shortly after 3.2 KBP, concurrent with a known shift towards climate aridity in many areas of the Eastern Mediterranean. The abandonment of multiple palatial centers, disappearance of literacy, and sharp decline in external and internal trade over a relatively short period of time is often associated with a rapid-onset drought known across the region (Stanton *et al.* 2012).

Mycenaean city-states and their political polities were established on the Greek mainland within the time period 3.4-3.3 KYBP (Middleton 2019), adopted from the earlier palatial systems of Minoan Crete; the structure was of an administrative palatial center which exercised control over smaller settlements organized into provinces. The palatial center was the nexus of the redistributive economical system the states practiced. The provincial settlements produced agricultural goods and were responsible for processing some of them; more processing occurred in the palatial center, where the products were managed and redistributed among the provincial settlements. Labor and military forces were likewise drawn from the provinces to the palatial center (Dickinson 2006).

The palace also managed trade. Raw goods would be imported and processed by royal craftsmen; and then the palace exported the worked products in addition to processed goods made from locally produced agricultural goods, such as olive oil and wine. Mycenean trade partners were located throughout the Mediterranean, and strong trade networks were established between many of the Eastern Mediterranean states. Trade became a primary feature of the Mycenean palatial societies, and the profit and status were largely reserved for the palatial elite.

Some "independent" settlements existed outside of palatial control (Foxhall 1995, Finné *et al.* 2017). These villages are believed to have been largely in control of their agricultural activities, making their own decisions about crop selection, largely cereals, but still engaging economic relations with the palace administration. Large amounts of administrative food stores used for redistribution are thought to have originated from these semi-independent settlements instead of incorporated palace territory (Foxhall 1995). In fact, it would seem that the palatial interests were largely in luxury crops (and livestock), preferring to use their influence in the provinces to dedicate land to economically favorable crops and livestock (oil, linen, and sheep) which could be processed into valuable trade goods (Foxhall 1995).

Recent investigations of Pylos have been conducted with respect to the low-resolution dating problem of paleoclimate (see Chapter 1 Section 1). Several short-term aridity events since 3800 YBP are recorded with relatively low uncertainty in dating. A rapid-onset dry phase from 3550-3400 YB is followed by a return to moister conditions, interrupted by a very short two-decade semiarid perturbation centered around 3200. Then a temporary return again to the moister conditions until a transitional phase begins at 3150 YBP towards arid conditions which fully onset at 3100 until 2950 YBP. (Finné *et al.* 2017).

The destruction of the palace of Pylos (occasionally referred to as the Palace of Nestor) is dated between around 3150-3130 YBP, during the transitional phase identified before the final late third millennium aridity pulse. The immediate decades predating the collapse of the palace were comparatively wet, and the short pulse around 3.2 KYBP was mild in comparison to the conditions at 3100 YBP. Thus, the Pylos palace seems to have not experienced its collapse during a drought phase; with a sharp dating resolution, the 3.2 short event is dated two to eight centuries *before* the palatial collapse. However, the preceding periods of dryness may have contributed to a social destabilization which prevented recovery following the palace's destruction.

The Pylian state agriculture was uniquely suited for the production of crops with high water requirements, as the Messenian Plain received a relatively high level of rainfall comparative to the rest of the Peloponnese, and the aridity pulses likely caused temporary disruption of agriculture in this area (Foxhall 1995, Finné *et al.* 2017). The events at 3550-3400 YBP and 3200 YBP possibly caused at least minor subsistence crises that led to social unrest. Just prior to the palace's destruction around 3150 YBP, architectural projects expanding the storage capacity were undertaken, in addition to reduction of palace accessibility; these changes indicate a danger to the palace and intention by the palatial administration to collect more surplus. The preceding two climatic disturbances likely brought the palace stores to a dangerously low point, and the palatial elite might have been actively attempting to prevent such a problem in future events.

However, after the destruction of the palace by fire around 3150 YBP, the new storage facilities would not have a chance to be filled. The causes of the immolation are unknown, but the fact that Pylos was not rebuilt, or the administration reconstructed, following the destruction is likely an indicator of the political condition of the time. The failure of the administrative systems prior to the 3150 YBP immolation likely destabilized its power and prevented its reconstruction, especially as dryer conditions began to onset again around the same time (Finné *et al.* 2017).

The Late Helladic IIIB-IIIC boundary at around 3.1 KYBP saw the abandonment and destruction of many of the palaces that characterized the Late Bronze Age on mainland Greece, and very few of the centers saw reoccupation and inhabitation into the Greek Dark Ages. Those who maintained continuity, such as Argos or Athens, saw a drastic reduction in both population and size of polities (Bennet 2013). Though there was a decline of population into the Dark Ages, and an abandonment of most palatial centers, many towns and villages in the provincial periphery were able to maintain continuity. Small-scale building projects were undertaken (Dickenson 2006), regional elites began to appear in the power vacuum, and agricultural patterns shifted away from old palatial focuses like linen and towards subsistence strategies like cattle (Foxhall 1995).

## 4.8: Hittite collapse (~3.2 KY)

Amidst a period of aridity within the Eastern Mediterranean and a series of societal collapse events in the region, the Hittite Empire of Anatolia was likewise faced with widespread site destruction and disappearance of literature (Drake 2012).

The Hittite kingdom emerged shortly after 3.6 KYBP, around the onset of a warm wet period which lasted approximately two centuries (Müller-Karpe 2009). The kingdom was centered on the capital city of Hattusa, which had been captured by the first king Hattusili I; the relocation of the Hittite administrative capital from the Early Period site of Nessa to the new capital of Hattusa marks the beginning of the Hittite Kingdom proper. Hattusili I continuously campaigned through his reign, extending the borders of the kingdom and leading military forces to the lands south of the Taurus Mountains; his successor, Mursili I, likewise carried out a reign of conquest, campaigning as far south as Babylon in Central Mesopotamia. Many of Mursili I's excursions, like the Babylonian one, did not add territory to the kingdom; additionally, his extensive campaign to Southern Mesopotamia was costly for the state's resources. With Hattusa close to revolt, the second king was assassinated shortly after returning, and the kingdom remained confined to central Anatolia, losing its trans-Tauros territories. Though a few campaigns were carried out in the Middle Hittite Period, the territories were soon lost again (Klengel 2011), and expansion was not a major concern for the Hittites again until the reign of Tudhaliya I and the imperial age. The close of Mursili II's reign around 3490 YBP roughly coincided with the termination of the dendrochronologically defined warm wet period in Anatolia at approximately 3450 YBP (although this terminus more closely aligns with the ascent of Telepinu I).

The post-Mursili I empire was politically and socially tumultuous, with royal authority undermined by dynastic struggles fueled by several assassinations. Royal decree- the Edicts of Telepinu, named for the king who set them down- set down succession laws and tax reform, in addition to seeing the construction of state grain storage facilities during the reign of Telepinu I. The succession laws, applicable to not only royalty but even common families, standardized the process throughout the kingdom; the grain storage units, a novel structure for Anatolia at this time, were able to protect against famine years (once filled) with their great capacities- one silo from Büyükkale could, when filled, feed 23,000-32,000 people for a year (Müller-Karpe 2009). The Edicts of Telepinu likely addressed some of the sociopolitical issues that had caused unrest in the later part of Mursili I's reign and the period between the reigns of Mursili I and Telepinu I, giving insight into the most concerning issues of the time and implying the level of social unrest occurring. (Klengel 2011)

Beginning with the reign of Tudhaliya I at approximately 3350 YBP, the Hittite state begins to be considered as an empire. Precedents set by Telepinu I, particularly the grain storage constructs, made feasible- or possibly just easier- the construction of an empire. With expansive grain storage capacities to protect against subsistence crisis, which possibly caused (or partially caused) the unrest towards the end of Mursili I's reign, long campaigns would be theoretically less stressful on state food resources.

# Ch. 5: Holistic View of Climate Change

Many dates used throughout this paper are estimates. Archaeological dates are generally resolved with more accuracy than paleoclimatic ones, and recent dates more so than older ones. The low resolution for the onset of sudden drought perturbations, particularly at 3.2 KYBP, makes it impossible to claim with any certainty that these droughts precipitated the sharp cultural shifts within the following century; without more accurate dating, the current claim can only be that these events happened at *around* the same time. Imprecise resolution, however, does not render the data completely useless; using a more holistic view of climate change throughout the Holocene, and the use of trends in lieu of individual perturbations, it may be possible to create a link between climate change and 'collapse' events.

Climate is made up of many interconnected mechanisms and effects, interwoven into patterns and perturbations that express themselves at the regional and global level. None of the forcing mechanisms occur in isolation; they are always partnered with other mechanisms, and always interacting even with their own effects. The Earth's climate system is stacked precariously, and ripples on one level cause ripples on other levels. Climate, as a phenomenon, *exists* holistically, and as such must be *understood* holistically. Understanding climate as the complex network that it is may be challenging, but the implications of untangling the threads may help us better understand its effects in areas which have not benefitted from intense study.

Likewise, on a more longitudinal level, climate patterns throughout Earth's history must be understood as a single system, which can be subdivided into trends or phases for more micro-level analysis. Holocene climate (in addition to late Pleistocene following the termination of the Last Glacial Maximum) is a piece of this whole, and within this piece the constituent sub-pieces must be understood as interconnected within the system. Understanding long-scale climate patterns can perhaps serve as a surrogate, without the availability of accurate, high-resolution data. While the precise onset date of a particular perturbation may not be available, a series of droughts or gradual aridity trend known in the centuries preceding the event of interest may allow researchers to extrapolate climatic stress at that particular time. In this example, too, it might benefit research to consider the perturbation of interest not as a single event, but as a peak phase of the drought trend of the preceding centuries.

The complexity of climate is itself only a small factor in the complex processes leading to social collapse events. The nuances of human populations as they respond to climate change are what dictates the direction of adaptation- towards reconstruction (or construction, in the case of the 5.2 KYBP Event), or towards collapse. An understanding of the political, social, and economic situations of a group at a given time will help determine the effects that climate change will have.

Collapse event research generally divorces climatic from human factors, attributing collapse to either one factor or the other. However, the intricate nature of human-climate interaction means that this approach will never resolve satisfactorily. An understanding of climate forcings, of climate trends, of climate regionality, and of human socio-political-economical nuances must be further bundled holistically into an understanding of human-climate interactions. Neither the climate, nor humanity, exists in a vacuum; they are intertwined, and must be understood as such to be understood to any satisfactory level.

## 5.1 Forcings

A holistic view of climate change should be set in a foundation of at least a basic understanding of climatic forcing mechanisms. Several main mechanisms have been discussed throughout Chapter 2; many of these forces, such as insolation and albedo, trigger further effects, such as ice melt, which triggers yet further effects, such as interruption of the thermohaline circulation. An understanding of the effects of climate forcing mechanisms and their interconnected positive and negative feedback loops can inform theoretical modeling at a deeper level that is necessary for any meaningful investigation into the relationship between climate and humans.

In particular, as an example, the complex nature of the African monsoons. The monsoon's strength and area of effect are driven by the location of the Intertropical Convergence Zone, which is altered by insolation, which is itself is affected by local and global surface conditions in addition to Earth's distance from the sun (via the Milkanovitch Cycles). Here, the strength and area of the monsoons are the proverbial tip of the iceberg, driven by a series of underlying causes which each have additional effects, globally and regionally.

The complexity of climate research is daunting, but the complex networks constituting it are important to consider when studying the human responses to climate change. While the overall composite effect is generally of the most concern, understanding the constituent factors that constitute the climate may be able to inform of nuances in responses.

### 5.1.2 Trends

Climate through time also must be understood holistically. The climatic events through the Holocene- particularly the events at 5.2 KYBP, 4.2 KYBP, and 3.2 KYBP- are not isolated events, but part of a greater global trend towards aridity during this epoch. The timeline of the climate naturally consists of peaks and valleys as conditions oscillate, but on a simple linear scale, from the beginning of the Holocene to the present date, the climate moves from humid to arid. The greater events listed above are aridity peaks, interspersed by pluvial valleys; the peaks and valleys, on a smaller scale, also contain peaks and valleys of their own.

Discrepancies in dating resolution, particularly surrounding the 3.2 KY Megadrought, can be temporarily bridged by a holistic understanding of climatic trends. While the drought is considered "sudden onset", the global trend towards aridity means that before its occurrence the climate was still approaching aridity and exerting that stress on biotic populations. So while the 3.2 KY Megadrought may have occurred either before, or after, the collapse of Eastern Mediterranean civilizations at the end of the Bronze Age, it can be stated definitely that prior to the widespread collapse event the climate was drying.

## 5.2 Regionality

Further understanding of the regionality of climate change can also be illuminating. Understanding how climate affects one area, with its specific topographic, vegetative, and hydrological features, in addition to knowledge about the underlying forcing mechanisms at play, may be useful to 'work backwards' to better understand how these mechanisms are affecting a different area. Unpacking the constituent pieces of regional climate, they may be reconstituted with the individual pieces of another region to further inform about climate patterns in a specific location.

"Reverse-engineering" climate in an unknown area may be possible with a greater understanding of regional effects. Taking a known climatic condition at a particular place in time and divorcing the regional effects from the global ones, the global effects might be applied to regional factors in an unknown area to create a working theoretical model for conditions in the unknown region at that time.

A deeper understanding of climate forcing mechanisms and regionality grants a greater understanding of the global trends identified through wide-scale proxies like ice cores. Global trends can be combined with regional variables such as topography, ground cover, and hydrology to contextualize the effects in respect to a particular region and create a working theoretical model for unknown areas where paleoclimatic studies have not been carried out.

### 5.3 Towards holistic

When climate is understood holistically on a longitudinal and latitudinal level, it then must be combined with a further understanding of human sociopolitical complexity. In each of the discussed collapse events, political and economic stressors were present in addition to climatic desiccation, and were likely the direct cause of the dissolution of the respective administrations. However, the climate factors likely influenced the political and economic stressors- in the example of the Egyptian New Kingdom at 3.2 KYBP, the social unrest that gave way to riots at the end of the period were partially due to a depletion of food stores, which was likely a result of decline in agricultural output from poor Nile flow and reduction in rainfall at the time. The climate in this case aggravated social unrest, which contributed to the decline of pharaonic power and eventual dissolution of the administration.

To understand social impacts of climate change, an understanding of both social and climatic (forcings, trends, and regionality) factors must come first. Each factor needs to be understood individually and in the contexts of the others- as a whole, because the factors intertwine and affect each other. A totally holistic view of climate change draws on all of these parts, and understands each on an individual and combined level.

## Ch. 6: Responding to Changing Climate

One of the most interesting questions about the response of societies to climate events is regarding the varying responses to similar events. Late sixth millennium BP Egyptian and Southern Mesopotamian peoples, during a period of climate desiccation, coalesced into state societies; these same areas, during a similar period of aridity in the late fifth millennium BP, saw these states decline. Further aridity trends in the late fourth millennium BP were concurrent with further collapse events, yet these same arid conditions persisted during the advent of the Iron Age successors of such societies. The differing responses between each of these societies is driven by particular and varying human response choices made by each society in response to changing climate.

The human response is a function of an overlay of multiple social factors and forms of organization. Social structure, political organization, belief system, and human perception of the environment inform the response to changing environmental conditions, which may vary even at the hierarchical level. Differing strategies in response to climate change thus vary across time and space, resulting in differing outcomes, and even within collapse events resulting differently in declines, post-collapse conditions, and recoveries.

Drawing from Butzer’s model of historical collapse, the primary driving factor precipitating social collapse is, generally, government failure. Changing climate only becomes a disaster in the presence of preexisting sociopolitical issues indicative of highly stratified society, and this can be seen in many of the illustrated collapse events discussed in Chapter 4 Sections 3 through 8. Droughts and associated subsistence crises galvanize a populace already facing budding conflicts with their elites and governments, in addition to weakening the position of an already-fragile governments. As an example, the New Kingdom collapse: where a pharaoh with waning power found his grain stores empty, and subsequent riots from the laborers who were to be paid from those stores. Weak faith of a populace in their government begins to reach a critical point once food availability is threatened.

Lower-class peasants, including farmers, are generally more predisposed towards the adoption of successful strategies for long-term climate change adaptation than are elites; following the dissolution of government and administration, smaller communities focused on subsistence agriculture persist into the proceeding 'dark age' and, while on a reduced scale, still maintain some cultural continuity as they adapt to the loss of the previous hierarchy. Smaller communities, which need to produce less surplus than larger states, are already predisposed towards more effective adaptation to climate change. Without an administrative push to dedicate precious land to luxury goods which royals and elites use for long-distance trade and status, small farming communities are able to focus extra land on smaller surpluses to act as a buffer for inevitable crop failures.

Large communities can also survive into a dark age, when they still retain cultural memory of their individualized existences. In the case of the Akkadian Empire, particularly, the individual city-states simply revert back to their pre-unified states upon the dissolution of the dynasty. As a smaller unit, similar to the small farming villages, city-states are able to focus production on the needs of the individual city.

Decentralized governments seem to predicate a stronger adaptational response to climate stress. Interestingly, the weakening of central government in favor of regional governors, such as in the case of Old Kingdom Egypt, is indicative of a decline of state power (possibly leading to eventual collapse) but *also* indicative of a more favorable survival capacity. The waning power of the pharaoh is likely a factor in the dissolution of the 'Old Kingdom' but the presence of local administration who live and reside in their districts is what, at least in part, helped maintain thriving culture and continuity through the First Intermediary Period. In this case, then, one of the factors that caused a 'collapse event' is one that also protected the existence of smaller-scale societies following that very collapse.

This is quite indicative of the general criticisms laid at the idea of 'collapse.' The dissolution of an administrative or elite class does not necessarily imply the dissolution of the entirety of a society, although this has often been the association throughout the history of archaeological study. The particular case of the Old Kingdom refutes the traditional idea that governmental failure is equivalent to social failure, as a large factor indicative of the governmental failure was also key to the survival of society following the fall of the government. Collapse events are, more plainly, collapses of *governments*- of the administrative, ruling, and/or elite classes.

In this respect, then, it would seem that complex hierarchies and high stratification are predicating factors of social collapse. Were complexity of social hierarchy able to be quantified, it seems likely that a "highly complex or stratified" society would be more likely to undergo a collapse event (of government and administration) than a society with less complexity and stratification. The "downgrade" from complex to simpler societies, often a negative feature and seen as a key marker of "dark ages," may actually be an adaptational advantage to both climate change and the socio-political-economic problems that it highlights.

Interesting that higher classes are both less likely to positively adapt to climatic change and less likely to survive climate-affected collapse events, and that "simpler" societies thrive in the following “dark ages.” It would seem that the adaptational advantage of (relative) social simplicity might provide higher resilience to the effects of climate change on societies. Further research might be beneficial to determine if such a quantifying model of complexity and hierarchy could be established, then to assign values to particular societies to see if any trends appear in the context of collapse events. This scale could possibly be altered or amended to quantify the complexity of different levels of society, and see if further trends appear in “dark age” continuity.

## Summation

The cultural shift at around 5.2 KYBP resulted in the appearance of state societies; the cultural shifts at around 4.2 KYBP and 3.2 KYBP resulted in the disappearance of state societies. Each of these three periods were also generally concurrent with measured environmental changes in their respective regions, and the events at 4.2 KYBP and 3.2 KYBP are also concurrent with social, political, and economic issues becoming notable within these societies.

To understand the effects of climate change on these societies, though, the climate must first be understood: the factors that impact climate, and climate trends through time. Understanding these factors, in addition to understanding the social nuances occurring in the societies at this time, are necessary for a holistic view of humans and climate change, and this holistic view is necessary to unpack the complexities involved in each factor both individually and in context with the other factors.

Though dating resolution is criticized and paleoclimate data is not expansive, holistic views of climatic trends, regional effects, and climatic forcing mechanisms may help bridge gaps in knowledge and build working models and theories for the direct environmental effects of climate change. An understanding of social responses and their constituent factors can help understand how a society responds to climate change. The response of the society, then directly influences either adaptation or collapse. A holistic view comprising each of these factors is necessary to understand completely how climate change and society are interwoven.

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