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THE SOCIETAL IMPACTS OF CLIMATE ANOMALIES DURING THE PAST 50,000 YEARS AND THEIR IMPLICATIONS FOR SOLASTALGIA AND ADAPTATION TO FUTURE CLIMATE CHANGE[1]

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[1] This paper does not deal with mitigating global warming and ocean acidification through limiting carbon dioxide and other greenhouse gases. It also does not deal with potential consequences of ocean acidification.

INTRODUCTION

The earth is warming, local climates are changing, and the weather is becoming more extreme.[2] These changes will continue until the level of greenhouses gases (GHGs) in the atmosphere is significantly reduced.[3] Even if the levels of GHGs are reduced to pre-industrial levels, it will take decades to centuries for the climate to stabilize and return to current conditions.[4] Within broad ranges, mathematical climate models can predict likely future climate scenarios as defined by metrological parameters–how hot, how wet, how dry–and the physical impact of future sea level rise scenarios.[5] The behavior of individuals and communities is less susceptible to predictive modeling than are climate systems. modeling of the climate. For example, while people in high risk flood zones might be expected to want to move to less dangerous areas, complex personal and societal factors make many unwilling to move.[6] One way to better understand how people will respond to future climate change threats is to look at behavior during previous times of climate change.

While we see current climate changes secondary to global warming as the disruption of a stable climate, the geologic record shows that the earth has oscillated from ice ages to greenhouse conditions for at

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[2] Caroline C. Ummenhofer & Gerald A. Meehl, *Extreme weather and climate events with ecological relevance: a review*, 372 PHIL. TRANS. R. SOC. B 20160135 (2017).

[3] Andrew P. Schurer et al., *Importance of the pre-industrial baseline for likelihood of exceeding Paris goals*, 7 NATURE CLIMATE CHANGE 563 (2017).

[4] *See* Benjamin H. Strauss et al., *Carbon Choices Determine US Cities Committed To Futures Below Sea Level*, 112 PROC. NATL. ACAD. SCI. 13508–13 (2015). *See also* Guojian Wang et al., *Continued Increase Of Extreme El Nino Frequency Long After 1.5[thinsp][deg]C Warming Stabilization*, NATURE CLIMATE CHANGE 568, 568–572 (2017).

[5] Gerald A. Meehl et al., *Trends in Extreme Weather and Climate Events: Issues Related to Modeling Extremes in Projections of Future Climate Change**, 81 BULL. AM. METEOROLOGICAL SOC'Y 427–36 (2000); Paul D. Williams et al., *Mathematics Applied To The Climate System: Outstanding Challenges And Recent Progress*, 371 PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOC'Y A: MATHEMATICAL, PHYSICAL & ENGINEERING SCI. (2013).

[6] *See* Edward L. Kick et al., *Repetitive Flood Victims And Acceptance Of FEMA Mitigation Offers: An Analysis With Community-System Policy Implications*, 35 DISASTERS 510–39 (2011). *See also* Celine S. Robinson et al., *Homeowner Acceptance Of Voluntary Property Acquisition Offers*, 31 INT'L J. OF DISASTER RISK REDUCTION 234–42 (2018).

least the past 2,700,000 years.[7] There have been significant climate anomalies—periods of deviation from the expected climate—during the last 25,000 years.[8] There are written and archeological records of the impact of climate anomalies on the health and culture of the communities what lived at the time of these changes.[9] This gives us a reference point for better understanding individual and societal response to the effects of future climate change. Other than the Syrian refugees,[10] we have limited contemporary experience with climate driven migration.[11] Thus, the response of communities to coastal flooding and climate change at the end of the last ice age may give us insight into the response to future sea level rise and climate change.[12]

This paper will first review the cultural basis for understanding climate and the mechanisms for climate impacts on society. The next section will look at the past impacts climate change and anomalies made on society. The third section will look at the special case of the effects of future warming, which are unprecedented for humans.[13] The final section will look at a unique problem of modern climate change—the availability of climate science and climate models that allow us to anticipate the future impacts of climate change rather than only learning about them as they happen.[14] This creates the unique new mental health risk of prospective fear of loss of place—the worry that you will

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[7] R. Bintanja & R.S. Van de Wal, *North American Ice-Sheet Dynamics And The Onset Of 100,000-Year Glacial Cycles*, 454 NATURE 869 (2008).

[8] Zhaohua Wu et al., *The Modulated Annual Cycle: An Alternative Reference Frame For Climate Anomalies*, 31 CLIMATE DYNAMICS 823–41 (2008).

[9] See, *e.g.* Alan N. Williams et al., *A Continental Narrative: Human Settlement Patterns And Australian Climate Change Over The Last 35,000 Years*, 123 QUATERNARY SCI. REVIEWS 91–112 (2015).

[10] Peter H. Gleick, *Water, Drought, Climate Change, and Conflict in Syria*, 6 WEATHER, CLIMATE, & SOC'Y 331–40 (2014).

[11] Miyuki Hino et al., *Managed Retreat As A Response To Natural Hazard Risk*, 7 NATURE CLIMATE CHANGE 364 (2017) (citing supplementary tables 1 and 2).

[12] Lawrence Guy Straus, HUMANS AT THE END OF THE ICE AGE: THE ARCHAEOLOGY OF THE PLEISTOCENE-HOLOCENE TRANSITION, 3 (Straus et al., ed., 1996), https://doi.org/10.1007/978-1-4613-1145-4_1.

[13] The last time the earth was as warm as it is today was about 120,000 years ago. Jeremy S. Hoffman et al., *Regional And Global Sea-Surface Temperatures During The Last Interglaciation*, 355 SCI. 277 (2017).

[14] K. Hayhoe et al., *2017: Climate models, scenarios, and projections, In Climate Science Special Report: Fourth National Climate Assessment, Volume I* 133-60 (D.J. Wuebbles et al., Maycock (eds.)).

suffer a climate related catastrophe or will have to migrate in the future. This concept has been termed *solastalgia*, which combines *solacium* (solace), *nostos* (return home), and *algos* (pain) to represent the emotional state of people whose sense of place is being destroyed because their environment is being destroyed.[15]

I. PRE-SCIENTIFIC KNOWLEDGE OF THE NATURAL WORLD

The societies affected by the climate anomalies discussed in this paper pre-dated modern science. They understood what we call climate through a combination of empirical observations of nature and myths. Each culture had a creation myth, which usually establishes the division between the sky, gods, the earth, and man.[16] Weather and its seasonal patterns are in the domain of the sky, of the gods.[17] These myths put bounds on the expectations for extreme weather, limiting the fear of the unknown, if one properly placated the gods. This reduced the fear of weather driven by the random whims of nature or of gods over which man had no control.[18] With the Neolithic Revolution, these groups transitioned from hunter-gatherers to subsistence agricultural societies.[19] Knowledge of weather and climate, at least as expressed in the seasons, became key to survival.

Timing the seasons was the most important climate information for subsistence agricultural societies, even those in equatorial areas with little change in day length or temperature during the seasons had other seasonal changes such as the monsoon or dry season.[20] Most had developed systems of astrology based on watching the heavens, mainly the movement of the stars, moon, and sun, for clues to

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[15] Glenn Albrecht, *Solastalgia: Environmental Damage Has Made It Possible to Be Homesick Without Leaving Home*, 32 ALTERNATIVES J. 34 (2006).

[16] John L. McKenzie, *Myth and the Old Testament*, 21 THE CATHOLIC BIBLICAL Q. 265 (1959).

[17] Simon D. Donner, *Domain of the Gods: an editorial essay*, 85 CLIMATIC CHANGE 231, 223 (2007).

[18] *Id*.

[19] Jacob L. Weisdorf, *From Foraging To Farming: Explaining The Neolithic Revolution*, 19 J. ECON. SURVEYS 561–86 (2005).

[20] *See* Barbara Bell, *The Oldest Records of the Nile Floods*, 136 GEOGRAPHICAL J. 569–73 (1970) (stating that the 5,000-year long record of the Nile floods is the best known record of river flooding.).

understanding what the gods wanted.[21] These also provided a reliable calendar system for marking the seasons and, for coastal communities, the tides.[22] These observational records of the heavens were the beginning of modern science and are among the oldest records we have of many cultures.[23]

Historical records, such as the Nile flood gauge records, show that the ancients could be accurate and care observers of the natural world. But these observations were in service of predicting and propitiating the gods, not in building a predictive theory of weather or climate in the modern sense.[24] Egypt was the longest lived and most stable of the ancient civilizations.[25] Egyptian religion saw time as running is cycles, as the Nile flood ran in a repeating cycle each year.[26] As discussed later, climate anomalies had profound effects on Egypt, but the Egyptians only saw them through the lens of their religious belief.[27] It was not until the Enlightenment that there was a bright line between astronomy and astrology.[28] The modern era of meteorology began in the late 1800s, with the formation of the International Meteorological Society in 1873[29] and the United State Weather Service in 1870.[30]

Moving from Recording Weather to Recognizing Climate Change

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[21] *See* Gustavo Zen de Figueiredo et al., *A Short Critical History on the Development of Meteorology and Climatology*, 5 CLIMATE 23, 24 (2017) (stating that the Egyptians had a religion based on weather by 3500 BCE).

[22] Ivan Sprajc, *Astronomy and its role in ancient Mesoamerica*, 5 PROCEEDINGS OF THE INT'L ASTRONOMICAL UNION 87–95 (2009).

[23] F. Richard Stephenson, *East Asian Astronomical Records*, 12 HIGHLIGHTS OF ASTRONOMY 317–21 (2002).

[24] J. Donald Hughes, *Sustainable agriculture in ancient Egypt*, 66 AGRICULTURAL HISTORY 12, 14 (1992).

[25] *Id.* at 14.

[26] As an equatorial nation, Egypt did not see the usual change of seasons, only the flood season of the Nile and a dry season between the yearly floods. *Id.* at 13.

[27] *Id.* at 14.

[28] Daryn Lehoux, *Observation and prediction in ancient astrology*, 35 STUDIES IN HISTORY AND PHILOSOPHY OF SCI. PART A 227, 233 (2004).

[29] WORLD METEOROLOGICAL ORG., *History of IMO,* WMO.INT, https://public.wmo.int/en/about-us/who-we-are/history-IMO (last accessed Nov. 4, 2018).

[30] NAT'L WEATHER SERV., *History of the National Weather Service,* WEATHER.GOV, https://www.weather.gov/timeline (last accessed Nov. 4, 2018).

Individuals who are not knowledgeable about meteorology and climate science experience weather and the seasons in the same way as did individuals in ancient cultures. While modern observers may not have an elaborate cosmology of gods to account for natural phenomena as did the ancients, they share the notion of climate as simply the experience of weather through time. As a prominent climatologist explained:

Climate is the ordinary man's expectation of weather. He knows that if he stays in one place there is a limit to the weather can put upon him, and he can predict what clothes he will need for each month of the year. Climate is not average weather to him, since averages mean little to the layman. Climate is made up of the succession of weather events he has learned to expect, and to resign himself.[31]

The meteorological concept of climate is a mathematical construct, the average and distribution of weather conditions over a specific time interval in a specific place. The most familiar climate reference is the plant hardiness zone map published by the United States Department of Agriculture (USDA).[32] These climate zone maps are the thirty-year average of the high and low temperatures across the United States.[33] The International Meteorological Organization (IMO) started the collection of national climate data with the request that member nations calculate 30 year averages, called climate norms, for the 1900-1930 period.[34] It was suggested as early as 1923 that while the long term climate had been stable for thousands of years, there were significant shorter term variations–climate anomalies.[35] Countries were mandated to update their climate maps at 30 year intervals, resulting in

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[31] F. Kenneth Hare, *The Concept of Climate*, 51 GEOGRAPHY 99, 99–100 (1966).

[32] U.S. DEP'T. AGRICULTURE, AGRICULTURAL RES. SERV., *USDA Plant Hardiness Zone Map*, http://planthardiness.ars.usda.gov/PHZMWeb/ (last accessed Nov. 4, 2018). These maps have been guiding gardeners for more than 90 years. Donald Wyman & Harrison L. Flint, *Plant Hardiness Zone Maps*, 27 ARNOLDIA 53–56 (1967). The Arnold Arboretum at Harvard University started publishing these maps in 1927. The USDA published its first map in 1960, and through time the USDA maps became the standard. *Id*.

[33] Anthony Arguez et al., *NOAA's 1981–2010 U.S. Climate Normals: An Overview*, 93 BULL. AM. METEOROLOGICAL SOC'Y 1687, 1687 (2012). Critically, they provide no information about other climate variables such as moisture.

[34] *Id*.

[35] Charles F. Marvin, *Concerning Normals, Secular Trends And Climatic Changes*, 51 MONTHLY WEATHER REV. 383 (1923).

1930-1960 and 1960 to 1990 norms.[36] The 30 year updates would identify climate anomalies. In 1956, the IMO recommended the 30 year average be updated every 10 years, but many nations continued to do 30 year updates.[37] These climate norms are not fundamentally different from the climate records maintained by ancient cultures. They assume that while there might be cyclical variations in the climate over a period of years, the long-term climate is stable. These 30 year climate norms are fundamentally descriptive, as were the records of meteorological phenomena compiled by ancient civilizations.

While it would be more than 100 years before the assumption of a stable climate would be eliminated in official climate normals, the first scientific predictions that carbon dioxide from burning fossil fuels was accumulating in the atmosphere and would warm the earth was made more than 100 years ago.[38] In a prophetic paper in 1956, Roger Revelle and Hans Suess – scientists at the Scripps Institution of Oceanography - proposed:

Thus human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future. Within a few centuries we are returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years. . . . This should certainly be adequate to allow a determination of the effects, if any, of changes in atmospheric carbon dioxide on weather and climate throughout the earth.[39]

The first edition of the journal, *Climate Change*, was published in 1977 and included an article predicting a warming climate and the progressive loss of artic ice over the next 50 years.[40] The

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[36] *Id.*

[37] *Id.*

[38] *See* Thomas Chamberlin, *An Attempt to Frame a Working Hypothesis of the Cause Of Glacial Periods on an Atmospheric Basis*, 7 J. GEOLOGY 545 (1899); *see also* Svante Arrhenius, *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground*, 41 LONDON EDINBURGH DUBLIN SCI. 237 (1896).

[39] Roger Revelle & Hans E. Suess, *Carbon Dioxide Exchange Between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 during the Past Decades*, 9 TELLUS 18, 19–26 (1957).

[40] Hermann Flohn, *Climate and Energy: A Scenario to a 21st Century Problem*, 1 CLIMATIC CHANGE 5 (1977).

Intergovernmental Panel on Climate Change (IPCC) was formed in 1988 and was charged to:

[A]address those knowledge gaps as they relate to the science, impacts and policy responses associated with the climate change problem. [] [T]…he Panel should, as a first step, identify the agreed facts and projections, separate them from mere speculations and bravely inform the world what ought to be done. [] …the Panel [should] [] …take account of work which has already been carried out by governments and international organizations in the field of climate change.[41]

By 2007, major meteorological organizations accepted that there was long-term global warming.[42] This meant that records that described the past 30 years of temperatures would not provide useful information on what the temperatures would be in coming years.[43] This was a fundamental break with the historic assumption that past temperatures are the best predictors of future temperatures.[44]

Developing a Broader Definition of Climate

The temperature normals used for the plant hardiness zone maps are a description of one parameter of climate. A full description of climate has to be include more variables, such as rainfall. Because they only include temperature, the plant hardiness maps make no distinction between planting in a desert and a swamp. The IPCC definition of climate is more complete:

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is 3 decades, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as

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[41] U.N. ENVTL. PROGRAMME INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Report of the First Session Intergovernmental Panel on Climate Change*, (TD-No. 267, 1988).

[42] Robert E. Livezey et al., *Estimation And Extrapolation Of Climate Normals And Climatic Trends,* 46 J. APPLIED METEOROLOGY & CLIMATOLOGY 1759, 1760 (2007).

[43] *Id.* at 1760.

[44] Anthony Arguez & Russell S. Vose, *The Definition of the Standard WMO Climate Normal: The Key to Deriving Alternative Climate Normals*, 92 BULL. AM. METEOROLOGICAL SOC'Y 699, 699 (2011). These climate norms are used for business purposes, as well as gardening and agriculture. *See* Seoung Joun Won et al., *Climate Normals And Weather Normalization For Utility Regulation*, ENERGY ECON. (2016).

temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.[45]

A deviation from the expected range of a climate variable for a given time of year is termed a climate anomaly.[46] For example, if the rainfall for a month is less than normal range of rainfall for that month, it would be an anomaly.[47] The expected climate range can include the expected frequency of extreme weather events.[48] Extreme events can be short-term, such as daily temperature or rainfall records and storms such as tornados.[49] They can also last for a period of time, such as a run of days at or near a temperature record.[50] Longer-term runs of extreme weather, especially droughts, can have profound effects through crop failure and the lack of drinking water.[51]

The climate anomalies discussed in this paper are as much as several hundred years long. An affected society, without knowledge of climate science, would have no way of knowing whether the change was permanent. Modern researchers see it as an after the climate has returned to normal. Climate skeptics focus on these previous long-term climate anomalies to argue that the current climate is not changing based on human activity, but is just another anomaly.[52] It is important to understand the reason climate scientists believe that the

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[45] Rajendra K. Pachauri et al., *Climate change 2014: synthesis report*, *in* CONTRIBUTION OF WORKING GROUPS I, II AND III TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 119 (2014).

[46] Wu et al., *supra* note 8, at 824.

[47] *Id.*

[48] TOM ROSS & NEAL LOTT, *A CLIMATOLOGY OF 1980-2003 EXTREME WEATHER AND CLIMATE EVENTS* (2003), https://www.ncdc.noaa.gov/monitoring-content/billions/docs/lott-and-ross-2003.pdf.

[49] Extreme weather is the most significant short-term threat to human health. *See generally* Sonia I. Seneviratne et al., *Changes in Climate Extremes and Their Impacts on the Natural Physical Environment*, *in* MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION, 109–230 (2012).

[50] Marc Poumadère et al., *The 2003 Heat Wave In France: Dangerous Climate Change Here And Now*, 25 RISK ANAL. 1483–94 (2005).

[51] In modern times, the Dust Bowl drought in the United States during the 1930s displaced 3.5 million people from the Midwest. Brian M. Fagan, THE GREAT WARMING: CLIMATE CHANGE AND THE RISE AND FALL OF CIVILIZATIONS 235 (2009).

[52] *See* Joel M. Kauffman, *Climate change reexamined*, 21 J. SCIENTIFIC EXPLORATION 723, 730–32 (2007). *See also* Patrick Frank, *A Climate of Belief*, 14 SKEPTIC 22–30 (2008).

current global warming represents persistent climate change, rather than being an anomaly like the previous Holocene climate anomalies discussed in this paper.

II. UNDERSTANDING CLIMATE CHANGE AND CLIMATE ANOMALIES

The thesis of this paper is that looking back at the effects of past climate anomalies on societies can help us understand the psychological impact of future climate change. While we describe what is going on now as climate change and what went on earlier in the Holocene as climate anomalies, the literature on climate change does not contain a bright line test for how long a climate anomaly has to persist to be called climate change. The fact that we could, at least theoretically, end the current warming and climate change further confuses the issue.[53] Understanding the factors that shape climate in the short and long term allow us to look at the impact of potential change without needing to distinguish between anomalies and persistent change.

The primary determinate of the earth's climate is how warm the sun makes the earth.[54] The sun's energy output cycles over time and the earth gets warmer or cooler as the amount of energy from the sun changes.[55] The earth's orbit around the sun varies over long periods of time, changing the distance between the earth and sun enough to affect the amount of solar energy reaching the earth.[56] These long cycles of varying solar energy reaching the earth are correlated with the onset

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[53] If greenhouse gas emissions were sufficiently reduced, and excess CO_2 was removed from the atmosphere, current global warming could be reversed, changing contemporary warming from climate change to a climate anomaly. *See* R. Socolow, *Wedges reaffirmed*, 27 BULL. ATOMIC SCIENTISTS, SEPTEMBER (2011), and Stephen Pacala & Robert Socolow, *Stabilization wedges: solving the climate Problem For The Next 50 Years With Current Technologies*, 305 SCI. 968–72 (2004).

[54] Dennis L. Hartmann et al., *Observations: atmosphere and surface, in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS: WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 181 (2013).

[55] V.M. Velasco Herrera et al., *Reconstruction And Prediction Of The Total Solar Irradiance: From the Medieval Warm Period to the 21st century*, 34 NEW ASTRONOMY 221–33 (2015).

[56] Stephen R. Meyers, *Resolving Milankovitchian: The Triassic Latemar Limestone and the Eocene Green River Formation*, 36 GEOLOGY 319 (2008).

of some of the ice ages.[57] These two processes determine the radiant energy that reaches the earth.

Dust particles in the atmosphere reduce the amount of energy that gets through the earth's atmosphere and thus cool the earth.[58] Increases and decreases in air pollution from industry, such as sulfate emissions from burning coal have significant effects on solar radiation.[59] The major natural source of atmospheric particles is volcanic eruptions.[60] A volcanic eruption can blow megatons of rock and ash into the upper atmosphere, temporally blacking out the sun in the region of the volcano. The eruption will also put large amounts of sulfuric acid into the atmosphere.[61] The particles of rock and ash rapidly fall out of the atmosphere, but the acid reacts with water and forms microscopic particles of sulfate which can stay in the atmosphere for a long period of time. [62] These can cool the earth for periods of weeks to years, depending on the size of the eruption.[63] (It has been proposed to mimic this process by injecting sulfuric acid into the upper atmosphere artificially reduce solar radiation reaching the earth to offset GHG driven warming.[64])

Volcanic eruptions are linked to climate anomalies secondary to the cooling they cause by blocking solar radiation.[65] The 1783–1784 Laki eruption in Iceland has been linked to cooling in the Northern Hemisphere, which caused the monsoon that leads to the annual Nile flood to fail in subsequent years.[66] This leads support to proposals by

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[57] David A. Hodell, *The Smoking Gun Of The Ice Ages*, 354 SCI. 1235, 1236 (2016), http://science.sciencemag.org/content/354/6317/1235.

[58] Martin Wild, *Enlightening Global Dimming And Brightening*, 93 BULL. AM. METEOROLOGICAL SOC'Y 27, 30 (2012).

[59] *Id.*

[60] A. Robock, *Volcanic eruptions and climate*, 38 REVIEWS OF GEOPHYSICS 191–219 (2000).

[61] *Id.*

[62] Didier Swingedouw et al., *Impact Of Explosive Volcanic Eruptions On The Main Climate Variability Modes*, 150 GLOBAL AND PLANETARY CHANGE 24, 28 (2017).

[63] *Id.* at 29.

[64] Ulrike Niemeier & Simone Tilmes, *Sulfur injections for a cooler planet*, 357 SCI. 246–48 (2017), http://science.sciencemag.org/content/357/6348/246.

[65] Luke Oman et al., *High-Latitude Eruptions Cast Shadow Over The African Monsoon And The Flow Of The Nile,* 33 GEOPHYSICAL RES. LETTERS (2006).

[66] *Id.*

paleo climatologists that volcanic eruptions trigged climate anomalies that disrupted ancient civilizations.[67]

The geologic record includes volcanic eruptions 10,000 times the size of the Mt. St. Helens eruption, which may have rapidly cooled the earth by 10 degrees Celsius, with a ten-year recovery period.[68] An eruption of that sizes would cause catastrophic crop failures and worldwide starvation.[69] Volcanic eruptions have had major short-term effects on the climate throughout the historical and archeological record.[70]An asteroid or large meteoroid strike pushes more debris into the atmosphere than a super volcano, plus it causes massive heating of the earth over a period of hours.[71] An asteroid strike 66,000,000 years ago wiped out 76% of the species on earth.[72] After the initial heat surge, the climate is estimated to have cooled 10 °C for decades.[73]

Once the solar radiation reaches the earth, some is adsorbed and causes heating and the rest will be reflected back into space. The most extreme example is the Artic, where warming is melting highly reflective sea ice and allowing the radiation to be absorbed by the dark ocean waters.[74] On land, changes in land cover affect the climate through changing the adsorption and retention of solar radiation and by modifying the ability of the soil to hold water, which moderates temperature

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[67] Joseph G. Manning et al., *Volcanic Suppression Of Nile Summer Flooding Triggers Revolt And Constrains Interstate Conflict In Ancient Egypt*, 8 NATURE COMM. 900 (2017), http://dx.doi.org/10.1038/s41467-017-00957-y.

[68] Stephen Self, *The Effects Consequences Very Large Explosive Volcanic Eruptions*, 364 PHIL TRANS 2073, 2089 (2006).

[69] *Id; see also* Alan Robock et al., *Did the Toba volcanic eruption of~ 74 ka BP produce widespread glaciation?*, 114 J. GEOPHYSICAL RES.: ATMOSPHERES 1–9 (2009).

[70] Fabio Gennaretti et al., *Volcano-Induced Regime Shifts In Millennial Tree-Ring Chronologies From Northeastern North America*, PROC. NATL. ACAD. SCI. 201324220 (2014); AndrzeJ. Gala, *Impact of olcanic ruptions on the nvironment and limatic onditions in the rea of Poland (Central Europe)*, 162 EARTH-SCIENCE REVIEWS 58–64 (2016); M. Sigl et al., *Timing and imate orcing of olcanic ruptions for the ast 2,500 ears*, NATURE (2015).

[71] Christopher M. Lowery et al., *Rapid Recovery Of Life At Ground Zero Of The End-Cretaceous Mass Extinction*, NATURE 1 (2018), http://dx.doi.org/10.1038/s41586-018-0163-6.

[72] *Id.*

[73] Peter Schulte et al., *The Chicxulub Asteroid Impact And Mass Extinction At The Cretaceous-Paleogene Boundary*, 327 SCI. 1214–18 (2010).

[74] Syukuro Manabe & Ronald J. Stouffer, *Sensitivity Of A Global Climate Model To An Increase Of CO_2 Concentration In The Atmosphere*, 85 J. GEOPHYSICAL RES.: OCEANS 5529–54 (1980).

swings.[75] Deforestation and desertification are primary examples of changes in land cover that affect climate change. For example, 9,000 year ago, the Sahara Desert was a grassland with lakes and trees, which absorbed solar radiation.[76] Its transition to desert dramatically affected the local climate and atmospheric conditions, which in turn affected the larger climate system.[77]

Radiant energy that is reflected back into space does not warm the planet. Certain gases in the atmosphere trap this radiant energy and act like the glass in a greenhouse or car window that traps heat inside the structure.[78] The primary greenhouse gas (GHG) is water vapor and the other naturally occurring significant GHGs are carbon dioxide, methane, and nitrous oxides. [79] In the natural system, carbon dioxide controls the temperature because the concentration of water vapor follows the temperature.[80] If the atmosphere cools, water vapor precipitates out as snow, and if it warms, more evaporates from the ocean.[81] Carbon dioxide stays in the atmosphere and does not change concentration with temperature.[82] Models show that if carbon dioxide were completely removed from the atmosphere, the earth's temperature would drop by 21 °C in the first 50 years.[83] Two thirds of the ocean surface would be frozen, and the earth would be on the way to snowball earth.[84]

Carbon dioxide increased from 265 to 285 parts per million (ppm) in the atmosphere over the 6000 years before 1750.[85] While there were

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[75] Heinz Wanner et al., *Mid-to Late Holocene climate change: an overview*, 27 QUATERNARY SCI. REVIEWS 1791, 1804 (2008).

[76] *See generally* H. Renssen et al., *Simulation of the Holocene climate evolution in Northern Africa: the termination of the African Humid Period*, 150 QUATERNARY INT'L 95 (2006).

[77] J.G. Charney, *Dynamics of Deserts and Drought in the Sahel*, 101 Q. J. THE ROYAL METEOROLOGICAL SOC'Y 193 (1975).

[78] M. James Salinger, *Climate variability And Change: Past, Present And Future: An Overview*, 70 CLIMATIC CHANGE 9, 23 (2005).

[79] *Id.*

[80] Andrew A. Lacis et al., *Atmospheric CO_2: Principal control knob governing Earth's temperature*, 330 SCI. 356, 358 (2010).

[81] *Id.*

[82] *Id.*

[83] *Id.*

[84] *Id.*

[85] Wanner et al., *supra* note 75, at 1807.

climate anomalies during this time, the climate was fundamentally stable, returning to the same average temperatures after each anomaly.[86] Since 1750, fossil fuel burning, industrial development, and land use changes have increased atmospheric carbon dioxide to more than 400 ppm, with significant increases in methane as well.[87] This is a warming the earth to higher levels than have been seen since the last ice age, which is driving climate-related risks such as sea level rise and shifting rainfall patterns, as were seen during previous times of climate change and climate anomalies.[88]

While we talk about global warming, warming and climate effects are not uniform across the earth.[89] Most of the earth's surface heat energy is stored in the oceans.[90] The average depth of the ocean is about 12,100 feet.[91] Since cold water is heavier and sinks, the deep ocean is extremely cold, staying close to 0 Celsius. Ocean circulation patterns, such as La Nina, that mix the surface water more effectively with deep water cool the ocean and the atmosphere, causing droughts in the United States, floods in the western Pacific, and increasing Atlantic hurricanes.[92] When the circulation shifts to reduce mixing, a phenomenon called El Nino, the water warms and droughts turn to floods and Atlantic hurricanes are suppressed.[93]

Changes in ocean currents and mixing are a key driver of climate anomalies. For example, during the last deglaciation, there were several major cold periods during the interval from 16,000 years ago to 8,900

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[86] Joan Feynman & Alexander Ruzmaikin, *Climate Stability And The Development Of Agricultural Societies*, 84 CLIMATIC CHANGE 295 (2007).

[87] Lacis et al., *supra* note 80, at 359.

[88] *Id.*

[89] Marika M. Holland & Cecilia M. Bitz, *Polar Amplification Of Climate Change In Coupled Models*, 21 CLIMATE DYNAMICS 221 (2003).

[90] Yair Rosenthal et al., *A paleo-perspective on ocean heat content: Lessons from the Holocene and Common Era,* 155 QUATERNARY SCI. REVIEWS 1 (2017).

[91] NAT'L OCEAN SERV., *How Deep is the Ocean?*, NOAA.GOV, https://oceanservice.noaa.gov/facts/oceandepth.html (last accessed April 10, 2018).

[92] Antonietta Capotondi, *Atmospheric Science: Extreme La Nina Events To Increase*, 5 NATURE CLIMATE CHANGE 100–01 (2015).

[93] W. Cai et al., *Increasing Frequency of Extreme El Niño Events Due to Greenhouse Warming*, 4 NATURE CLIMATE CHANGE 111–16 (2014).

years ago.[94] These appear to be caused by to shifts in the flow of North American glacial meltwater between the Mississippi River, which carried the water to the Gulf of Mexico, and the St. Lawrence River, which carried it into the North Atlantic.[95] These changed the Atlantic Meridional Overturning Circulation, which affected global climate as does the El Nino/La Nina cycle today.[96]

Cultural and Demographic Impacts of Past Climate Anomalies and Climate ChangeGlobal warming is rapidly changing the local climate in many parts of the world, and sea level is increasing. This section looks at the societal impact of previous climate events to help us understand the potential impact of climate change on our societies. These nature of these impacts was described by Professor Kates, a pioneering demography scholar.[97] The first level is the effect of temperature, rainfall, and flooding on agriculture, fisheries, animals, housing and direct effects.[98] Secondary impacts are the results of the primary impacts and are anticipated to be the effects on human health, food supplies, transport, and energy supplies. [99] The third level impacts are on social order and society.[100] One of the key areas of vulnerability is human health and wellbeing.[101] In the worst case, climate anomalies can lead to societal collapse and even extinction.[102]

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[94] Paul Aharon, *Meltwater Flooding Events in the Gulf of Mexico Revisited: Implications for Rapid Climate Changes during the Last Deglaciation*, 18 PALEOCEANOGRAPHY (2003).

[95] *Id.*

[96] *See generally* Champoungam Panmei et al., *Bay of Bengal Exhibits Warming Trend During the Younger Dryas: Implications of AMOC*, 18 G^3: GEOCHEMISTRY, GEOPHYSICS, GEOSYSTEMS 4317 (2017).

[97] Robert W. Kates, T*he Interaction of Climate and Society*, 27 CLIMATE IMPACT ASSESSMENT 3, 11–12 (1985).

[98] *Id.*

[99] *Id.*

[100] *Id.*

[101] Rasmus Heltberg et al., *Addressing Human Vulnerability to Climate Change: Toward a "No-Regrets" Approach*, 19 GLOBAL ENVTL. CHANGE-HUMAN AND POL'Y DIMENSIONS 89–99 (2009).

[102] Guy D. Middleton, *Nothing Lasts Forever: Environmental Discourses on the Collapse of Past Societies*, 20 J. OF ARCHAEOLOGICAL RES. 257–307 (2012).

III. MEDIEVAL WARM PERIOD/MEDIEVAL CLIMATE ANOMALY IN THE AMERICAS

The Medieval Warm Period (MWP), now called the Medieval Climate Anomaly (MCA), was a period between 900 and 1350 AD that was significantly warmer than previous and later periods.[103] Modeling shows that the most likely trigger for the MCA was an increase in solar radiance,[104] which was likely amplified by effects on the ocean circulations.[105] While this event had global effects on precipitation, it was not a global warming event.[106] For the two cultures discussed in this section, its primary effect was through reduced rainfall. Two cultures in this section are in the American west, which has a long geologic history of megadroughts.[107] California is already experiencing droughts secondary to global warming.[108] The third was in Mexico, where Mexico city is facing water shortage issues from global warming.[109]

In the western United States, the MCA was accompanied by megadroughts, periods of reduced rainfall that lasted more than a decade, and, in some cases, more than a century.[110] Among indigenous peoples living on the California coast, periods of extended drought were associated with skeletal indices of poor health, such as reduced statute and osseous lesions.[111] It has been postulated that this lead to societal

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[103] Nicholas E. Graham et al., *Support for Global Climate Reorganization During the "Medieval Climate Anomaly*, 37 CLIMATE DYNAMICS 1217 (2011).

[104] Herrera, *supra* note 55, at 226.

[105] Gerard Bond et al., *Persistent Solar Influence on North Atlantic Climate During the Holocene,* 294 SCI. 2130–36 (2001).

[106] Nicolás E. Young et al., *Glacier Maxima in Baffin Bay During the Medieval Warm Period Coeval with Norse Settlement,* 1 SCI. (2015).

[107] Benjamin I. Cook et al., *North American Megadroughts in the Common Era: Reconstructions and Simulations*, 7 WILEY INTERDISCIPLINARY REVIEWS: CLIMATE CHANGE 411, 412 (2016).

[108] Michael E. Mann & Peter H. Gleick, *Climate Change and California Drought in the 21st Century*, 112 PROC. NATL. ACAD. SCI. 3858 (2015).

[109] Patricia Romero Lankao, *Water in Mexico City: What Will Climate Change Bring to Its History of Water-Related Hazards and Vulnerabilities?*, 22 ENV'T AND URBANIZATION 157–78 (2010).

[110] Scott Stine, *Extreme and Persistent Drought in California and Patagonia During Mediaeval Time*, 369 NATURE 546–47 (1994).

[111] L. Mark Raab & Daniel O. Larson, *Medieval Climatic Anomaly and Punctuated Cultural Evolution in Coastal Southern California*, 62 AM. ANTIQUITY NO. 2 319, 331 (1997).

reorganization competition and cooperation between tribes to deal with the water shortage.[112]

The droughts of this period were the most likely cause of the abandonment of the indigenous settlements in the Four Corners region, the intersection of Arizona, Colorado, New Mexico, and Utah.[113] The people who occupied this area prior to 1300 AD were known as the Anasazi.[114] The Anasazi build complex stone dwellings and had an elaborate cultural life. The best population estimate for the region at its most populous is 22,000, with others putting the range between 15,000-30,000.[115] The Anasazi disappeared over a short period of time, abandoning their cities and religious sites.[116] Climate reconstructions from tree rings show major droughts at 1150 AD and 1280 AD, dates that correspond to Anasazi migrations and abandonment of long house sites.[117]

The likely driver of the migration was the failure of the maize crop that provided the major food source. The normal rainfall for the area allowed for subsistence farming of maize, but any reduction in the rainfall would reduce the harvest below subsistence levels for the population.[118] Agricultural models estimate that even during the prolonged drought, the area could have supported as much as 40 percent of the population, yet everyone left.[119]

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[112] Douglas J. Kennett & James P. Kennett, *Competitive and Cooperative Responses to Climatic Instability in Coastal Southern California*, 65 AM. ANTIQUITY 379, 387–89 (2000).

[113] Terry L. Jones et al., *Environmental Imperatives Reconsidered: Demographic Crises in Western North America During the Medieval Climatic Anomaly*, 40 CURRENT ANTHROPOLOGY 137, 146 (1999).

[114] This is not specific tribal identification, but an archeological identification: the Anasazi pattern is defined by an emphasis on black-on-white painted ceramics, plain and textured gray cooking pottery, the development from pithouses to stone masonry and adobe pueblos, and the kiva as the principal ceremonial structure. Robert L. Axtell et al., *Population Growth and Collapse in a Multiagent Model of the Kayenta Anasazi in Long House Valley,* 99 PROC. NATL. ACAD. SCI. 7275–79 (2002).

[115] Andrew I. Duff & Richard H. Wilshusen, *Prehistoric Population Dynamics in the Northern San Juan Region*, AD 950–1300, 66 KIVA NO. 1, 167, 174 (2000).

[116] Axtell et al., *supra* note 114, at 7275.

[117] Larry Benson et al., *Anasazi (Pre-Columbian Native-American) Migrations During the Middle-12th and Late-13th Centuries – Were they Drought Induced?*, 83 CLIMATIC CHANGE 187, 190 (2007).

[118] Larry Benson & Michael S. Berry, *Climate Change and Cultural Response in the Prehistoric American Southwest*, 75 KIVA No. 1 87, 9 (2009).

[119] *Id*. at 199.

As with the indigenous peoples of California, there might have been health issues associated with the limited food that decimated the population. Alternatively, there might have been a collective decision to leave as a group to preserve critical mass to maintain the cultural roles and carry out religious rituals,[120] or there could have been a combination of causes, with a reduced population choosing to leave together to have the best chance of reestablishing their culture elsewhere. While it may be impossible to reconstruct the exact sequence of events that depopulated the areas, it is clear that the triggering event was a prolonged drought that reduced agricultural yields below those necessary to sustain the population.

The MCA deeply affected the lowland Maya civilization was centered around the Yucatan Peninsula in Mexico went through a series of collapses and recoveries that were likely driven by long term droughts.[121] The Maya developed a much more complex civilization than the Anasazi, with major cities and architectural structures, and a much larger population.[122] This complex society more closely resembles modern societies than does the subsistence level Anasazi culture. Two factors complicate the causal relationship between drought and cycles of the Maya civilization. The first is that there is not a robust tree ring record for the area of the Maya civilization during the critical periods.[123] The second is that the Yucatan receives more than a meter of rainfall in an average year,[124] and even severe drought years would receive many times the rainfall of good years in Anasazi country.[125]

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[120] *See* Axtell et al., *supra* note 114, at 7278.

[121] Sabin Roman et al., *The Dynamics of Human-Environment Interactions in the Collapse of the Classic Maya*, 146 ECOLOGICAL ECON. 312, 313 (2018).

[122] Larry C. Peterson & Gerald H. Haug, *Climate and the Collapse of Maya Civilization: A Series of Multi-Year Droughts Helped to Doom an Ancient Culture*, 93 AM. SCIENTIST 322 (2005).

[123] David W. Stahle & Jeffrey S. Dean, *North American Tree Rings, Climatic Extremes, and Social Disasters*, *in* DENDROCLIMATOLOGY 297–312 (2011). Trees produce a growth ring each year. These rings vary in width with growing conditions, providing the most direct record of paleo climate. *Id.* at 330. This requires the use of more indirect and less certain measures, such as analyzing lake bed sediments. *See* Martín Medina-Elizalde & Eelco J. Rohling, *Collapse of Classic Maya Civilization Related to Modest Reduction in Precipitation*, 335 SCI. 956 (2012).

[124] Michael P. Smyth et al., *The Perfect Storm: Climate Change and Ancient Maya Response in the Puuc Hills Region of Yucatán*, 91 ANTIQUITY 490, 494 (2017).

[125] Medina-Elizalde & Rohling, *supra* note 123.

The landscape and the climate provide part of the answer. 90 percent of the rain falls between May and December, leaving a prolonged dry period.[126] Much of the area is karst, a sinkhole ridden, eroded limestone geology that does not retain water and that has a thin soil cover subject to degradation through intensive agriculture.[127] The Maya built extensive waterworks to collect and manage the rainfall during the dry season.[128] This allowed the Maya to farm at a greater intensity than the subsistence farming of the Anasazi. During the latter years of the Maya civilization, starting about 550 CE, the population expanded, and the intensity of the agriculture increased to support the larger population. The skeletal remains from this period show progressive nutritional disease, consistent with declining food supply, which is consistent with an agriculture system challenged by the drought.[129] This weakened population was more susceptible to communicable diseases, which could catastrophically reduce the population in a short period of time.[130]

The lowland Maya civilization and the Anasazi were both destabilized by drought. Both where at the edge of the population they could support on their average rainfall. The Anasazi community was much smaller and simpler because it was in a very low rainfall region, limiting them to subsistence agriculture. The Maya had more water available, which allowed the development of a more robust agricultural system supporting a much larger population. but in a landscape that made it difficult to manage. Both failed when the amount of water available fell below the level necessary to sustain food production for their population. We know little about the details of the collapse of the Anasazi civilization because they left little behind.[131] The Maya left a record that indicates a complex societal collapse, triggered or exacerbated by drought,

[126] Nicholas P. Dunning et al., *Arising from the Bajos: The Evolution of a Neotropical Landscape and the Rise of Maya Civilization*, 92 ANNALS OF THE ASS'N OF AM. GEOGRAPHERS 267, 269 (2002).

[127] *See* Eugene Perry, HYDROGEOLOGY OF THE YUCATÁN PENINSULA, New York 115, 11 (2003).

[128] Smyth et al., *supra* note 124.

[129] Roman et al., *supra* note 121, at 320.

[130] *See generally,* Rodolfo Acuna-Soto et al., *Drought, Epidemic Disease, and the Fall of Classic Period Cultures in Mesoamerica (AD 750-950): Hemorrhagic Fevers As a Cause of Massive Population Loss*, 65 MEDICAL HYPOTHESES 405 (2005).

[131] For an excellent attempt to reconstruct what happened to the Anasazi, *see* Craig Childs, *House of Rain: Tracking a Vanished Civilization Across the American Southwest* (2007).

but not solely due to drought.[132] This is more likely the failure mode for modern societies, where the climate impact creates a complex chain of adverse events.[133]

IV. IMPACT OF POST-LAST GLACIAL MAXIMUM SEA LEVEL RISE

Sea level rise is the best understood and easiest to observe threat from future climate change. This is not the first time that civilization has faced sea level rise. The last glacial maximum (LGM), the point at which the ice was thickest during the last ice age, occurred between 21,000 and 19,000 years ago.[134] Between 21,000 years ago and roughly 7,000 years ago, sea level rose 130 meters, over 425 feet.[135] During the glacial maximum, the shoreline was at the edge of what we now call the continental shelf, which is 100 or more miles offshore from many current coastlines. Many of these now submerged coastal areas were populated, as were islands that are now completely submerged. These populations were forced to migrate, just as contemporary populations on low-lying coasts will be forced to migrate in the future as sea level rises[136]

The rate of sea level rise during the glacial melt provides important information for adapting to future sea level rise. If the 130 meters of sea level rise were evenly spread over the 14,000 years, the average rate of sea level rise was about 9.3 mm a year, or a little less than a meter a century. Unfortunately, the melting came in pulses, with an event from 14,600-14,300 thousand years ago that saw 16 meters of sea level rise in 300 years, a rate of about 53 mm a year, or 5.3 meters a century. If this

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[132] *Id.* at 320.

[133] For example, drought was a major contributor the Syrian civil war. Francesca De Châtel. *The Role of Drought and Climate Change in the Syrian Uprising: Untangling the Triggers of the Revolution*, 50 MIDDLE EASTERN STUDIES 521 (2014).

[134] David Q. Bowen, *Last Glacial Maximum*, *in* ENCYCLOPEDIA OF PALEOCLIMATOLOGY AND ANCIENT ENVIRONMENTS 493 (Vivien Gornitz, ed., 2009), http://dx.doi.org/10.1007/978-1-4020-4411-3_122.

[135] Francesco Latino Chiocci et al., *Relative Sea Level Rise, Palaeotopography and Transgression Velocity on the Continental Shelf*, *in* UNDER THE SEA: ARCHAEOLOGY AND PALAEOLANDSCAPES OF THE CONTINENTAL SHELF 39 (2017).

[136] Jonathan T. Overpeck & Jeremy L. Weiss, *Projections of Future Sea Level Becoming More Dire*, 106 PROC. NATL. ACAD. SCI. U.S.A. 21461–62 (2009).

rate of rise were to be repeated in modern times, it would catastrophically flood most coastal areas.[137]

13,000 years ago, much of the southern North Sea between Britain and Europe was still dry land, open for settlement and use as a migration pathway.[138] By this time, the climate had warmed enough to make this area habitable; 1,000 years later, some 12,000 years ago, Britain and much of northern Europe were populated, including the area of the North Sea that is now underwater.[139] There were Neolithic villages and farming communities, which were then displaced as the land was resubmerged over the next 5,000 years. [140] While there may have been local catastrophes, in general, these populations adapted to the rising water, becoming mariners and moving to higher ground ahead of the rising waters.[141] We see this same pattern in Australia.

Australia has been populated for at least 50,000 years, which spans from before the LGM through post-LGM sea level rise.[142] As water was tied up in the building ice caps, sea level fell, thus putting the Australian shoreline farther offshore. Australia and New Guinea became a single land mass for several thousand years around the LGM.[143] Australia saw a temperature drop of 8-10 Celsius during the LGM and some glaciation in the mountains, but it was not covered with an ice sheet.[144] The climate

[137] Till Hanebuth, *Rapid Flooding of the Sunda Shelf: Late-Glacial Sea-Level Record*, 288 SCI. 1033–35 (2000).

[138] Garry Momber & Hans Peeters, *Postglacial Human Dispersal and Submerged Landscapes in North-West Europe, in* UNDER THE SEA: ARCHAEOLOGY AND PALAEOLANDSCAPES OF THE CONTINENTAL SHELF 321, 323 (2017).

[139] *See* Rebecca Miller, *Mapping the Expansion of the Northwest Magdalenian*, 272 QUATERNARY INT'L 209, 209–20 (2012).

[140] Fraser Sturt et al., *New Models of North West European Holocene Palaeogeography and Inundation*, 40 J. ARCHAEOLOGICAL SCI. 3963–76 (2013).

[141] *Id*. at 3975; Duncan Garrow & Fraser Sturt, *Grey Waters Bright with Neolithic Argonauts? Maritime Connections and the Mesolithic-Neolithicransition Within the "Western Seaways" of Britain, c. 5000-3500 BC*, 85 ANTIQUITY 59 (2011).

[142] *See* Richard G. Roberts et al., *Optical Dating at Deaf Adder Gorge, Northern Territory, Indicates Human Occupation Between 53,000 and 60,000 Years Ago*, AUSTRALIAN ARCHAEOLOGY 58 (1993).

[143] Sean Ulm, *Complexity and the Australian Continental Narrative: Themes in the Archaeology of Holocene Australia*, 285 QUATERNARY 182, 185 (2013).

[144] Alan N. Williams et al., *Human Refugia in Australia During the Last Glacial Maximum and Terminal Pleistocene: A Geospatial Analysis of the 25-12 ka Australian Archaeological Record*, 40 ARCHAEOLOGICAL SCI 4612 (2013).

became much drier, forcing the population to contract into refuges such as river valleys that had more water, including from glacial melt in the summers.[145] As the temperature and rainfall increased post-LGM, the population spread from the refuges, including into the large coastal areas created by the lower sea level.[146]

As the ice melted and sea level rose, the shoreline retreated inland. The rate and extent of the retreat is determined by the slope of the coast. This determines the velocity of the coastal retreat for a given rate of sea level rise, referred to as the transgression velocity.[147]On the northern coast of Australia, where the land bridge to New Guinee was created by the lowered sea level, the coast retreated as much as 300 km sea level rose.[148]

What is unique about Australia, and relevant to the final section on the psychology of climate threats, is that their aboriginal people's oral tradition—the Dreamtime legends—extend back in time to include the migration from the coastal lands exposed during the Ice Age as sea level rose again during the Holocene.[149] Scholars have collected stories from around the Australian coast telling separate of separate inundation events tied to specific local areas and landmarks and their presumption date of inundation.[150] Two persistent themes in these fundamental creation myths, which describe events more than 7,000 years ago, are that the process of migration inland, followed by the constant renegotiation of territories between tribal groups, and the impact of losing 1-5 km of land a year on some of the flat coastal plains.[151]

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[145] *Id*.

[146] Ingrid Ward & Peter Veth, *To the Islands: The Archaeology of the Archipelagos of NW Australia and Its Implications for Drowned Cultural Landscapes*, *in* UNDER THE SEA: ARCHAEOLOGY AND PALAEOLANDSCAPES OF THE CONTINENTAL SHELF 375 (2017).

[147] Chiocci et al., *supra* note 135, at 39.

[148] Alan N. Williams et al., *Sea-Level Change and Demography During the Last Glacial Termination and Early Holocene Across the Australian Continent*, 182 QUATERNARY SCI. REVIEWS 144 (2018).

[149] R.M.W. Dixon, *Origin Legends and Linguistic Relationships*, 67 OCEANIA 127 (1996). There has been an effort to match Dreamtime legends of meteorite falls with identified meteorite sites and through those to date the legends. Duane W. Hamacher, *Recorded Accounts of Meteoritic Events in the Oral Traditions of Indigenous Australians*, 25 ARCHAEOASTRONOMY – ASTRONOMY IN CULTURE 1 (2014).

[150] Patrick D. Nunn & Nicholas J. Reid, *Aboriginal Memories of Inundation of the Australian Coast Dating from More than 7000 Years Ago*, 47 AUSTRALIAN GEOGRAPHER 11, 40 (2016).

[151] *Id*. at 41.

There is also evidence that this experience of colonizing the newly exposed coast as the climate moderated after the LGM, then migrating inland as the land was drowned, created a culture that saw their territory as both the land and the water. This is most evident in Northwest Australia, where rising sea level created an archipelago of islands which were continuously part of the cultural space from before sea level stabilized.[152] One scholar termed this this the Aquapelago, to emphasize the continuity between the land and the water in the tribal culture:

> [A] social unit existing in a location in which the aquatic spaces between and around a group of islands are utilised and navigated in a manner that is fundamentally interconnected with and essential to the social group's habitation of land and their senses of identity and belonging.[153]

Current Australia is at least 20 percent smaller than the Australia that was populated after the climate moderated and before the sea level rise started after the LGM.[154] As with exploration of Neolithic culture during the period of inundation in Europe, this poses a challenge for anthropologists and archeologists because these sites are now drowned.[155] The data indicate that the original colonization of Australia by modern humanoids occurred more than 40,000 years, when sea level was high enough to require significant maritime skills.[156] While this was much earlier than the inundation period, it is assumed that these skills continued to inform the groups that lived near the coast and were useful in responding to changing sea level.[157]

The MCA and the post-LGM sea level rise are examples of the impact of previous climate anomalies and sea level rise on societies. There are several other important climate anomalies during the late Holocene, including three cold periods (Little Ice Ages) that caused crop failures

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[152] Ward & Veth, *supra* note 146, at 385.

[153] Philip Hayward, *Aquapelagos and Aquapelagic Assemblages*, 6 SHIMA: INT. J. RES. INTO ISLAND CULTURES 1, 5 (2012).

[154] Williams et al., *supra* note 148, at 151.

[155] Ward & Veth, *supra* note 146, at 385.

[156] Balme, *supra* note 118.

[157] Ward & Veth, *supra* note 146, at 386.

and famines.[158] The Neolithic cultures that faced the post-LGM sea level rise were highly adaptable, colonizing new land as the warming climate allowed, and giving it back up as sea level rose. They had maritime practices before the colonization or developed them during the migration period and those practices stayed part of their cultures. Their sites were flooded and there has been relatively little underwater archeology done on them, and they were pre-literate societies, so we cannot know how much dislocation accompanied their migrations. Prolonged drought forced the migration of the Anasazi and contributed to the destabilization of the Maya culture. We have only seen drought in modern times, and it has led to famine and political instability, just as in the past.

V. THE NEW THREAT: HEAT

The earth has been much warmer than it is today, as warm as the worst-case projections of future climate change.[159] But this was 56 million years ago, long before humans, so as a species we have no evolutionary experience of a significantly warmer climate. The MCA was only warm in comparison to the colder post-LGM period, not compared to today, much less the projected global temperatures from current levels of GHGs in the atmosphere.[160]

Humans are mammals, and as such, are endothermic–warm blooded–and homeothermic–they maintain a constant body temperature.[161] The average core temperature for human is 98.6 degrees Fahrenheit or 37 degrees Celsius, which is higher than the average environmental temperature for most parts of the earth.[162] Mammals maintain a

[158] Christian Pfister & Rudolf Brázdil, *Social Vvulnerability to Cclimate in the " Little Ice Age": Aan Eexample from Central Europe in the Eearly 1770s*, 2 CLIMATE OF THE PAST 115, 120 (2006).

[159] Francesca A. McInerney & Scott L. Wing, *The Paleocene-Eocene Thermal Maximum: A Perturbation of Carbon Cycle, Climate, and Biosphere with Implications for the Future*, 39 ANN. REV. EARTH PLANET SCI. 489 (2011).

[160] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: WORKING GROUP I: THE PHYSICAL SCIENCE BASIS, *Projections of Future Changes in Climate*, IPPC.CH, https://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html

[161] Aviv Bergman & Arturo Casadevall, *Mammalian Endothermy Optimally Restricts Fungi and Metabolic Costs*, 1 MBIO e00212–10 (2010).

[162] Margaret V. Savage & George L. Brengelmann, *Control of Skin Blood Flow in the Neutral Zone of Human Body Temperature Regulation*, 80 J. APPLIED PHYSIOLOGY 1249 (1996).

higher temperature than their environment through retaining the metabolic heat produced by converting food into energy in the body.[163] Mammals lose or gain heat to the environment through radiation, and transfer to the air or other media through convection.[164] They cool their bodies though evaporative cooling, generating sweat or saliva to evaporate if the air is dry enough.[165]

Mammals can only survive in a temperature range that allows them to maintain their body temperature within a few degrees of normal.[166] As they lose more heat to the environment, their metabolism increases to produce more heat and they begin behaviors to retain or gain heat.[167] If they lose too much heat, they develop hypothermia. When humans become hypothermic, they first shiver involuntarily and uncontrollably as a way to increase their internal heat production.[168] As they continue to cool, they lose consciousness and their organ systems slow and begin to fail.[169] Their hearts will eventually stop, and they will eventually die from organ failure.[170] But the cold also preserves body tissue, and patients are often put into deep hypothermia to allow more time to treat certain medical conditions.[171] It is not unusual for a patient found without a heartbeat from deep hypothermia to be warmed and revived without permanent injury.[172] While people and animals do die from cold, there is a wide range of survivable temperatures below body temperature.[173] In contrast, excess heat is rapidly fatal.

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[163] Duncan Mitchell et al., *Revisiting Concepts of Thermal Physiology: Predicting Responses of Mammals to Climate Change*, 87 J. ANIMAL ECOLOGY 956, 963 (2018).

[164] *Id.*

[165] *Id.* at 962.

[166] *Id.* at 965.

[167] *Id.*

[168] Patrizio Petrone et al., *Management of Accidental Hypothermia and Cold Injury*, 51 CURRENT PROBLEMS IN SURGERY 417, 420 (2014).

[169] *Id.*

[170] *Id.*

[171] Kees H. Polderman, *Mechanisms of Action, Physiological Effects, and Complications of Hypothermia*, 37 CRITICAL CARE MEDICINE S186 (2009).

[172] Petrone et al., *supra* note 169, at 422.

[173] Mitchell et al., *supra* note 163, at 958-63. There is evidence that under normal conditions, rather than extreme events, cold kills more people than heat. *See* A. Gasparrini et al., *Mortality*

When it is too hot for mammals to transfer enough metabolic heat to the environment to maintain their core body temperature, they slow their metabolism and start behaviors such as looking for shade and sweating to reduce their temperature.[174] Large animals such as elephants and people can stand very hot temperatures for a short period, *e.g.* enjoying a sauna, but not if they are prolonged.[175] Unlike hypothermia, which does minimal permanent tissue damage until extreme levels, hyperthermia starts killing tissue and causing permanent injury when core temperature hits 104 °F (40 °C)—just a few degrees above normal body temperature.[176] Once this process begins, the body loses its ability to manage heat and the core temperature can quickly rise, leading to heat stroke and death if the patient is not quickly cooled.[177] Brain tissue is sensitive to heat and shows massive damage in autopsies of patients who died of hyperthermia.[178] Patients who survive heat stroke often have long-term neurologic damage.[179] While there is limited cross-species comparative data available, what there is shows a similar tissue damage temperature for other animals.[180] This relative intolerance to heat as compared to cold, combined with the difficulty of shedding excess heat, as opposed to generating additional heat, means that the survival zone for mammals is much narrower for temperatures at or near body temperature.[181] The 2003 heat in Europe and Asia shows the risk of excess heat—as many as 70,000 people died in Europe,[182] and an

Risk Attributable to High and Low Ambient Temperature: A Multi-Country Study, THE LANCET (2015).

[174] Mitchell et al., *supra* note 163, at 956–973.

[175] *Id.*

[176] Jonathan A. Becker & Lynsey K. Stewart, *Heat-Related Illness.*, 83 AM. FAM. PHYSICIAN 1325 (2011).

[177] *Id.* at 1326.

[178] L.F. Fajardo, *Pathological Effects of Hyperthermia in Normal Tissues*, 44 CANCER RES. 4826s, 4827s (1984).

[179] Heidi Grogan & Philip M. Hopkins, *Heat stroke: Implications for Critical Care and Anaesthesia*, 88 BRIT. J. ANAESTHESIA 700, 702 (2002).

[180] Mark W. Dewhirst et al., *Basic Principles of Thermal Dosimetry and Thermal Thresholds for Tissue Damage from Hyperthermia,* 19 INT'L J. HYPERTHERMIA 267, 269 (2003). This is to be expected—the enzyme systems that fail from heat are nearly identical across all mammals.

[181] Mitchell et al., *supra* note 163, at 965.

[182] Jean-Marie Robine et al., *Death Toll Exceeded 70,000 in Europe During the Summer of 2003*, 331 COMPTES RENDUS BIOLOGIES 171 (2008).

undetermined number in Asia.[183] The number of hot days, the individual highs, and, most importantly, for relief at night, the record high daily low temperatures, made this the hottest period since the 1500.[184] This was the first extreme weather event to be partially attributed to climate change.[185] One of the highest risk areas for climate change driven extreme heat events is India, which is densely populated and whose summers are already very hot and humid.[186] In addition to the toll on human health, heat is increasingly linked to drought, as the high ground temperatures dry out soil moisture, exacerbating drought conditions.[187]

The past tells us little about the future impact of heat on society. It will likely exacerbate class and race differences, both for individuals and nations, because heat risk to humans can be solved with air conditioning.[188] The hardest challenges will be in hot, densely populated nations such as India and China.[189] It is expected that, as income allows, air conditioning use will expand dramatically.[190] Air conditioning poses its own climate threats. There will be a huge increase in the demand for electricity, which will increase with the local temperature.[191] In crowded cities, where the heat island effect already raises the temperature as much as 15 degrees Celsius,[192] the exhaust air from air conditioning

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[183] Wei Huang et al., *The Impact of the 2003 Heat Wave on Mortality in Shanghai, China*, 408 SCI. TOTAL ENVT. 2418–2420 (2010).

[184] Poumadère et al., *supra* note 50, at 1484.

[185] Peter A. Stott et al., *Attribution of Extreme Weather and Climate-Related Events*, 7 WILEY INTERDISC. REVIEWS.: CLIMATE CHANGE 23, 24 (2016).

[186] *Id.* at 366; Geert Jan van Oldenborgh et al., *Extreme Heat in India and Anthropogenic Climate Change*, 18 NATURAL HAZARDS & EARTH SYSTEM SCI. 365 (2018). While the death count is much lower than in the 2003 European heat wave, this is likely due to the difficulty of counting and attributing deaths to heat in India.

[187] Zengchao Hao et al., *Compound Extremes in Hydroclimatology: A Review*, 10 WATER 1, 2 (2018).

[188] Marie S. O'Neill et al., *Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence,* 82 J. URBAN HEALTH 191 (2005).

[189] Lucas W. Davis & Paul J. Gertler, *Contribution of Air Conditioning Adoption to Future Energy Use Under Global Warming*, 112 PROC. NATL. ACAD. SCI. 5962 (2015).

[190] *Id.*

[191] *Id.*

[192] Brice Tremeac et al., *Influence of Air Conditioning Management on Heat Island in Paris Air Street Temperatures,* 95 APPLIED ENERGY 102 (2012).

units will further raise the temperature.[193] The refrigerants used in air conditioners in developing countries are potent GHGs, up to 10,000 times as potent as carbon dioxide at causing global warming.[194] The first study of leakage of refrigerants was done in China and found significant leakage into the atmosphere.[195] Dealing with global warming in cities will require new ideas for sustainable cooling.[196]

VI. SENSE OF PLACE AND CLIMATE CHANGE DRIVEN MIGRATION

This section focuses on the most disruptive impact of climate change—forced migration because your home is no longer livable.[197] Forced migration destroys communities and has profound mental health consequences.[198] As discussed below, these real threats, combined with the sense of place—an attachment to one's physical location—complicate rational climate adaptation. Even before the conditions are bad enough to force migration, populations can suffer from *solastalgia*—the fear of loss of home. Sea level rise, drought, and heat are the long-term primary climate change risks that force migration.[199] Sea level rise is the most predictable threat, least as to the populations at risk.

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[193] *Id.* at 103. Air conditioning units generate net heat to the environment, they just move the heat from the inside to the outside.

[194] Yanli Zhang et al., *Leakage Rates of the Refrigerants CFC-12, HCFC-22 and HFC-134a from Operating Mobile Air-Conditioning Systems in Guangzhou, China: Tests Inside a Busy Urban Tunnel Under Hot and Humid Weather Conditions*, 4 ENVTL. SCI. & TECHNOLOGY LETTERS 481 (2017).

[195] *Id.* at 484.

[196] Karin Lundgren-Kownacki et al., *Challenges of Using Air Conditioning in an Increasingly Hot Climate*, 62 INT'L J. BIOMETEOROLOGY 401, 406 (2018).

[197] Migration is seldom driven solely by environmental concerns, even when they are the driver of the failing community. Elizabeth Marino & Heather Lazrus, *Migration Or Forced Displacement?: The Complex Choices of Climate Change and Disaster Migrants in Shishmaref, Alaska And Nanumea, Tuvalu*, 74 HUMAN ORG. 341 (2015).

[198] James M. Shultz et al., *Public Health and Mental Health Implications of Environmentally Induced Forced Migration*, DISASTER MEDICINE AND PUB. HEALTH PREPAREDNESS 1 (2018).

[199] This excludes short-term extreme weather risks, which are exacerbated by sea level rise and heat.

Sea level rise has been going on for more than 100 years, and the rate is increasing.[200] Some of the largest cities and most densely populated areas in the world are located on low, flat river deltas.[201] Most of these deltas are subsiding from geologic processes, exacerbated by ground water pumping, which increases the rate of relative sea level rise.[202] Areas such as south Florida, Louisiana, and the Newport News/Richmond, Virginia area are already experiencing routine flooding when there is an especially high tide or a winter storm.[203] The Louisiana coast is being inundated at a rapid rate[204] and is subject to frequent hurricane flooding.[205]

As we saw in the discussion of the impact of sea level rise after the LGM, populations settled in low lying coastal areas in Northern Europe and Australia had to migrate as the rising sea pushed the coastline inland.[206] The sea level rise was slow enough on a year to year basis that they would have seen the same patterns of gradually increasing nuisance flood and worsening storm flooding. At some point they were driven inland, either by the increasing toll of nuisance flooding or after catastrophic storm flooding. In today's world, the predicted sea level rise if current levels of GHG emissions continue is 4.3 – 9.9 meters (14-32 feet) over the next several hundred years.[207] This would displace 20,000,000 in the United States alone, based on the current coastal population.[208] While this could be cut in half if emissions are quickly cut to

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[200] Sean Vitousek et al., *Doubling of Coastal Flooding Frequency Within Decades Due to Sea-Level Rise*, 7 SCIENTIFIC REPORTS 1399 (2017).

[201] Ivan Sekovski et al., *Megacities in the Coastal Zone: Using a Driver-Pressure-State-Impact-Response Framework to Address Complex Environmental Problems*, 96 ESTUARINE, COASTAL & SHELF SCI. 48 (2012).

[202] *See* Tom Clarke, *Delta Blues*, 422 NATURE 254 (2003); *see also* Charles W. Schmidt, *Delta Subsidence: An Imminent Threat to Coastal Populations*, 123 ENVTL. HEALTH PERSPECTIVES A204 (2015)

[203] *See* Hamed R. Moftakhari et al., *Cumulative Hazard: The Case of Nuisance Flooding*, 5 EARTH'S FUTURE 214 (2017). *See also* Benjamin H. Strauss et al., UNNATURAL COASTAL FLOODS: SEA LEVEL RISE AND THE HUMAN FINGERPRINT ON US FLOODS SINCE 1950 (2016).

[204] Brady R. Couvillion et al., *Land Area Change in Coastal Louisiana from 1932 to 2010*, U.S. GEOLOGICAL SURVEY SCIENTIFIC INVESTIGATIONS MAP (2011).

[205] David Roth, NAT'L WEATHER SERV., LOUISIANA HURRICANE HISTORY (2010).

[206] See *supra* accompanying note 140.

[207] Strauss et al., *supra* note 4, at 13508.

[208] *Id.*

much lower levels, it would still displace approximately 10,000,000 people in the United States.[209] This would profoundly affect the US population distribution.[210] Globally, such sea level rise would affect hundreds of millions of people.[211]

As we saw with the Anasazi, prolonged drought is also a driver of migration.[212] Unlike the gradual onslaught of sea level rise, drought, especially if complicated by heat, is felt quickly and can drive massive dislocations.[213] The Syrian refugee crisis may be a harbinger of future heat and drought forced migrations. In 2017 there were 6,300,000 people displaced from the Syrian Arab Republic (Syria).[214] The primary driver of displacement is the civil war, but there is a strong argument that a multi-year drought contributed to the civil war.[215] Climate change likely made the drought worse, but attribution is difficult because Syria has a long history of droughts with political consequences.[216] Given the frequency of droughts in the region, and that surrounding countries who suffered from the same drought did not fall into civil war, there is a strong argument that it was the failure of the Syrian government to respond to the drought with aid that fueled the

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[209] *Id.*

[210] Mathew E. Hauer, *Migration Induced by Sea-Level Rise Could Reshape the US Population Landscape*, 7 NATURE CLIMATE CHANGE 321 (2017).

[211] ANTHONY OLIVER-SMITH, SEA LEVEL RISE AND THE VULNERABILITY OF COASTAL PEOPLES: RESPONDING TO THE LOCAL CHALLENGES OF GLOBAL CLIMATE CHANGE IN THE 21ST CENTURY 9 (2009).

[212] See *supra* accompanying note 150.

[213] The United States Dust Bowl drought and heat event displaced millions from the Midwest. Gabriele C. Hegerl et al., *The Early 20th Century Warming: Anomalies, Causes, and Consequences*, 9 WILEY INTERDISC. REVIEWS: CLIMATE CHANGE 11, https://onlinelibrary.wiley.com/doi/abs/10.1002/wcc.522.

[214] THE UNITED NATIONS REFUGEE AGENCY, GLOBAL TRENDS: FORCED DISPLACEMENT IN 2017 2 (2018), http://www.unhcr.org/en-us/statistics/unhcrstats/5b27be547/unhcr-global-trends-2017.html.

[215] Gleick, *supra* note 10, at 331–40.

[216] *See* David Kaniewski et al., *Drought and Societal Collapse 3200 Years Ago in the Eastern Mediterranean: A Review*, 6 WILEY INTERDISC. REVIEWS: CLIMATE CHANGE 369 (2015). *See also,* Karl W. Butzer, *Sociopolitical Discontinuity in the Near East c. 2200 BCE: Scenarios from Palestine and Egypt, in* THIRD MILLENNIUM BC CLIMATE CHANGE AND OLD WORLD COLLAPSE 245 (1997).

uprising.[217] There is no way to clearly attribute the Syrian civil war solely to climate change, or even to drought.[218] But, as climate change leads to economic and social damage, it is reasonable to assume that the political consequences will be worse in politically unstable countries.

When there is time, as with sea level rise, managed retreat—the strategic relocation of a community or the intentional abandonment of a threatened area—is preferable to a chaotic last minute migration.[219] A successful relocation requires funding, buy in from the community, new places to live, jobs, and frequently significant coercion, such as only providing benefits after a disaster if you migrate, or the threat of drowning as the water level rises in a new dam.[220] Even well-funded, small scale relocation efforts, such as moving a small Alaskan village inland have proven very difficult to do.[221] Kivalina is small coastal indigenous community in Alaska that is being eroded by winter storms that were once blocked by Artic ice.[222] It was estimated in 2006 that it erosion protection measures would cost $15,000,000 and that relocation of the community of 400 would cost between $95 and 125,000,000.[223] Since 2006, temporary erosion control measures and limited relocation has not worked, and the cost estimates for relocation have risen to $100-

[217] *See* De Châtel, *supra* note 133, at 522. *See also* Colin P. Kelley et al., *Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought*, 112 PROC. NATL. ACAD. SCI. 3241 (2015). Another view is that the drought was so disruptive because government policies had undermined the agricultural economy, rather than being worsened by climate change. Jan Selby, *Climate Change and the Syrian Civil War, Part II: The Jazira's Agrarian Crisis*, GEOFORUM (2018), http://www.sciencedirect.com/science/article/pii/S0016718518301829.

[218] At least one scholar argues that severe drought so debilitates the country that it is less like to have a revolution. Revolutions flow from increased water, which allows the rebels sufficient food and assets to have a revolution. Idean Salehyan & Cullen S. Hendrix, *Climate Shocks and Political Violence,* 28 GLOBAL ENVTL. CHANGE 239–50 (2014).

[219] Hino et al, *supra* note 11, at 364.

[220] *Id.*

[221] Robin Bronen, *Forced Migration of Alaskan Indigenous Communities Due to Climate Change*, ENVT., FORCED MIGRATION AND SOC. VULNERABILITY 87 (2010).

[222] U.S. CLIMATE RESILIENCE TOOLKIT, *Climate Stressors and impacts*, CLIMATE.GOV, https://toolkit.climate.gov/case-studies/relocating-kivalina (last accessed Nov. 4, 2018).

[223] ARMY CORPS OF ENGINEERS, ALASKA VILLAGE EROSION TECHNICAL ASSISTANCE PROGRAM, AN EXAMINATION OF EROSION ISSUES IN THE COMMUNITIES OF BETHEL, DILLINGHAM, KAKTOVIK, KIVALINA, NEWTOK, SHISHMAREF, AND UNALAKLEET 2 (2006), http://66.160.145.48/coms/cli/AVETA_Report.pdf.

400,000,000. There is no timeframe to complete relocation or a firm location.[224] Previous efforts to buy out small communities rather than relocate them have had mixed success.[225]

One of the complicating factors to a managed retreat is an individual and community sense of place. "Sense of place" is the psychological term for an individual's or community's interconnection through social networks and its connections to its physical environment.[226] When a person with a strong sense of place is away from their home environment, they have a strong sense of loss. The severity of this loss of sense of place was captured in the old meaning of nostalgia, which was inspired by Odysseus and his relentless trek homeward after the Trojan War.[227] The original clinical meaning of nostalgia as a mental illness was a specific sense of homesickness, especially in persons involuntarily away from home such as soldiers.[228] It was recognized as potentially so severe as to cause life-threatening depression.[229] In modern usage, the term "nostalgia" has been replaced by "homesickness" as the psychological term for missing place and its connections, while nostalgia is used for the broader notion of longing for better times.[230]

Sense of place, and the feeling of homesickness when out of place, complicates relocating people from dangerous places, even in the wake

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[224] Isle de Jean Charles, a small indigenous community in Louisiana, has been disappearing due to subsidence and sea level rise. It has been given a $48,300,000 grant to relocate and has finally agreed on a new location for the community. Mark Schleifstein, *State is buing Isle de Jean Charles relocation site for $11.7 million,* NOLA.COM (Mar. 20, 2018), https://www.nola.com/environment/index.ssf/2018/03/state_is_buying_isle_de_jean_c.html.

[225] The Brownwood subdivision in Baytown, Texas had become a high-risk flood zone due to groundwater pumping. Congress authorized funds for a buyout after repeated floods. The community declined to pay the local match on the buyout, only to be washed away by a hurricane. *See* FEMA, NAT'L FLOOD INSURANCE PROGRAM COMMUNITY RATING SYSTEM, SPECIAL HAZARDS SUPPLEMENT TO THE CRS COORDINATOR'S MANUAL 9 (2006), https://www.fema.gov/media-library-data/20130726-1557-20490-7343/specialhazards2006.pdf.

[226] Marco Antonsich, *Meanings of Place and Aspects of the Self: An Interdisciplinary and Empirical Account*, 75 GEOJOURNAL 119, 129 (2010).

[227] Constantine Sedikides et al., *Nostalgia: Conceptual Issues and Existential Functions*, *in* HANDBOOK OF EXPERIMENTAL EXISTENTIAL PSYCHOLOGY 200 (J. Greenberg et al., eds., 2004).

[228] *Id.* at 201–02.

[229] *Id.*

[230] *Id.* at 304.

of a disaster. The sense of place, expressed as the right of return,[231] made it politically impossible to rethink the geography of New Orleans after Hurricane Katrina in a way that would have limited redevelopment in the highest risk neighborhoods.[232] One of the first studies about the factors that influence relocation decisions in communities offered a viable, funded relocation program was done after Hurricane Sandy. It supported the importance of the sense of place, finding that an individual's decision to take a buyout was highly dependent on the decision of his/her neighbors—no one wanted to left alone in an abandoned community, or to leave an intact community.[233] Many who choose to return to or stay in a high risk flood area suffer from long term mental health[234] and physical health problems.[235] These individuals may also suffer from the more contemporary notion of nostalgia—a longing for the past—if their community is fundamentally transformed by the flood.[236] This well known sense of loss of place because the place itself has changed leads to the question—can there be an anticipatory sense of loss of place because of future environmental risks?

[231] *See* Lolita Buckner Inniss, *Domestic Right of Return: Race, Rights, and Residency in New Orleans in the Aftermath of Hurricane Katrina*, 27 B.C. THIRD WORLD L. J. 325 (2007); *see also* Chris Kromm & Sue Sturgis, *Hurricane Katrina and the Guiding Principles on Internal Displacement*, 36 INST. SOUTHERN STUD. 1 (2008).

[232] Marla Nelson et al., *Planning, Plans, and People: Professional Expertise, Local Knowledge, and Governmental Action in Post-Hurricane Katrina New Orleans,* 9 CITYSCAPE 23–52 (2007). By 2015, ten years later, the city had rejected any plans that required not rebuilding, even in the highest risk neighborhoods. Richard Campanella, *The Great Katrina Footprint Debate 10 Years Later*, NOLA.COM (May 29, 2015), https://www.nola.com/katrina/index.ssf/2015/05/footprint_gentrification_katri.html.

[233] Sherri Brokopp Binder et al., *Rebuild or Relocate? Resilience and Postdisaster Decision-Making After Hurricane Sandy,* 56 AM. J. COMMUNITY PSYCHOL. 180, 191–93 (2015).

[234] Jessica Elizabeth Lamond et al., *An Exploration of Factors Affecting the Long Term Psychological Impact and Deterioration of Mental Health in Flooded Households*, 140 ENVTL. RES. 325, 333 (2015).

[235] Shuang Zhong et al., *The Long-Term Physical and Psychological Health Impacts of Flooding: A Systematic Mapping*, 626 SCI. TOTAL ENV'T 165, 174 (2018).

[236] Sedikides et al., *supra* note 234.

VII. SOLASTALGIA AND FUTURE ENVIRONMENTAL RISK

Persons who returned after Hurricane Katrina had significant short-term mental health problems, which have been attributed to the trauma of the storm, if they stayed during the storm, or of having their property and community damaged if they evacuated and returned.[237] There is also evidence of long-term health problems in those who either returned to the community or stayed during the storm and never left.[238] These effects were most pronounced in those with less social capital (community and financial resources).[239] While the role of fear of future flooding has not been studied in Katrina survivors, there are recent studies that look at this in the context of the effect of flood mitigation measures on mental health.[240] The first study to look at mitigation efforts, which would reduce the change of future flooding, found that they significantly reduced mental health problems.[241] A study on flooding in France found that there was a significant impact on subjective well-being (SWB) of persons who were at flood risk in a flooded region, but were not flooded themselves.[242] This study found:

> Living in a flooded community also reduces the SWB of a respondent even when they themselves have not been flooded. The (direct and total) effect is smaller than when an individual is flooded themselves, perhaps because of the relief from being spared tangible damage. Out of the set of risk perception variables there are two variables with negative statistically significant total effects ($p < 0.05$): worrying about flooding and expecting flood risk to increase. Overall, these subjective perceptions may place a larger downward pressure on SWB as compared to flood experiences when they are not attenuated over time.[243]

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[237] Jean Rhodes et al., *The Impact of Hurricane Katrina on the Mental and Physical Health of Low-Income Parents in New Orleans*, 80 AM J. ORTHOPSYCHIATRY 237, 243 (2010).

[238] Francis O. Adeola & J. Steven Picou, *Race, Social Capital, and the Health Impacts of Katrina: Evidence from the Louisiana and Mississippi Gulf Coast*, 19 HUMAN ECOLOGY REV. 10, 20 (2012).

[239] *Id.*

[240] Lamond et al., *supra* note 234, at 325 (2015).

[241] *Id.* at 333.

[242] Paul Hudson et al., *Impacts of Flooding and Flood Preparedness on Subjective Well-Being: A Monetisation of the Tangible and Intangible Impacts*, J. HAPPINESS STUD. 1 (2017), https://link.springer.com/article/10.1007%2Fs10902-017-9916-4.

[243] *Id.* at 10.

This study assigned an income adjusted compensation value (the amount necessary offset the loss of SWB) to this fear of increasing flood risk.[244] For the mean income, the average compensation value was 79,000 Euros, with 90% confidence levels of 63,000 to 97,000 Euros.[245] This was a study of French households subject to river flooding as France faces significant increases in river flooding from climate change.[246] It is logical to conclude that the increased risk of flooding that is worrying the surveyed individuals is caused by climate change.[247] SWB is not a rigorously defined term, but is meant to capture an individual's overall feelings about his/her situation.[248] In this case, this specifically includes fear of future climate change driven environmental risk.

The psychological literature did not have a term for this fear of future environmental risk. The environmental philosopher Glenn Albrecht proposed *solastalgia* as a term to describe the fear of the future environmental damage and damage to their personal identity as defined by their environment, that he saw in environmental activists with whom he worked.[249] Nostalgia, as described previously, did not really fit as the fearful environmentalists had not been removed from their homes and their fear was about the future, not about the loss of the good old days:

Solastalgia has its origins in the concepts of 'solace' and 'desolation'. Solace is derived from solari and solacium, with meanings connected to the alleviation of distress or to the provision of comfort or consolation in the face of distressing events. Desolation has its origins in solus and desolare with meanings connected to abandonment and loneliness. …algia means pain, suffering or sickness …the concept has

[244] *Id.* at 11.

[245] *Id.*

[246] *See generally* Hudson, *supra* note 242 (citing Patrice Dumas et al., *The Influence of Climate Change on Flood Risks in France-First Estimates and Uncertainty Analysis,* 13 NATURAL HAZARDS AND EARTH SYS. SCI. 809 (2013).

[247] While Hudson does not explicitly discuss the origin of the risk, the author assigned key words for the paper include "climate change," "adaptation," and "climate change adaptation." *Id.* at 2.

[248] George MacKerron, *Happiness Economics from 35 000 Feet*, 26 J. ECON. SURVEYS 705, 707 (2012).

[249] Albrecht, *supra* note 15, at 32.

been constructed such that it has a ghost reference or structural similarity to nostalgia so that a place reference is imbedded. …solastalgia is the pain or sickness caused by the loss or lack of solace and the sense of isolation connected to the present state of one's home and territory. …It is the pain experienced when there is recognition that the place where one resides and that one loves is under immediate assault (physical desolation). …In short, solastalgia is a form of homesickness one gets when one is still at 'home'.[250]

While coined in the context of traditional environmental fights over coal mining and a power plant, solastalgia is a powerful concept for thinking about the mental health consequences of climate change. It is not a well-defined term, even Glenn Albrecht himself seems to equate it with nostalgia when it applies it to the folks living in New Orleans after Hurricane Katrina who are suffering mental illnesses related to the loss of their homes and community and the slow pace of recovery.[251] But in its prospective sense, it is useful it to describe the fear of future harm from climate change and helplessness to affect that change.

The fear of climate change—solastalgia—stands in opposition to the sense of place, at least in situations such as sea level rise where the best adaptation course is relocation. These cannot be resolved by simple risk analysis because both solastalgia and the sense of place have strong emotional components. As long as the individual stays in place, solastalgia will be a source of stress and potentially mental illness. But if the individual is forced to migrate, the more traditional nostalgia may displace solastalgia, maintaining the stress and the risk of mental health problems. This tension between solastalgia and nostalgia will be an increasing source of mental health problems as climate change continues.

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[250] *Id*. at 48.

[251] Glenn Albrecht, *Chronic Environmental Change: Emerging "Psychoterratic" Syndromes*, *in* CLIMATE CHANGE AND HUMAN WELL-BEING 43, 53 (Inka Weissbecker, ed., 2011).

CONCLUSION

Humankind has faced climate anomalies, climate change, and associated sea level rise and fall over the last 20,000 years since the LGM. We will face these same risks going forward, with a new risk of warming beyond historic levels and perhaps, in places, beyond the ability to adapt. In previous eras, future climate was a mystery. Cultures had a strong observational knowledge of past climate, but no ability to predict the beginning, magnitude, or duration of an anomaly. When it became too dry, too cold, or sea level was encroaching, they accommodated the current conditions as best they could. Sometimes they migrated and sometimes they died. They prayed and sacrificed to their gods for better weather. To them, we would be like gods because we can see, however darkly, into the future and predict the climate. The most fundamental risks will be sea level rise, drought, and heat beyond the survival envelop for human society. Adaptation to these risks will include migration, which is itself difficult to accomplish without risks and long term mental health issues. Unlike ancient peoples, we can even change the course of the climate with sufficient willpower and cooperation. Still, like Cassandra who was cursed to see the future but who would never be believed, we will suffer the fear of future threats and the fear that we are helpless to prevent them.[252] Resolving the tension between solastalgia and nostalgia may prove as difficult as reaching a meaningful international agreement to limit global warming.

[252] Kent A. Sepkowitz, *Cassandra and Ignaz Semmelweis*, 1 INTL. J. INFECTIOUS DISEASES 57 (1996).