Oluwakemi Izomo

Homework

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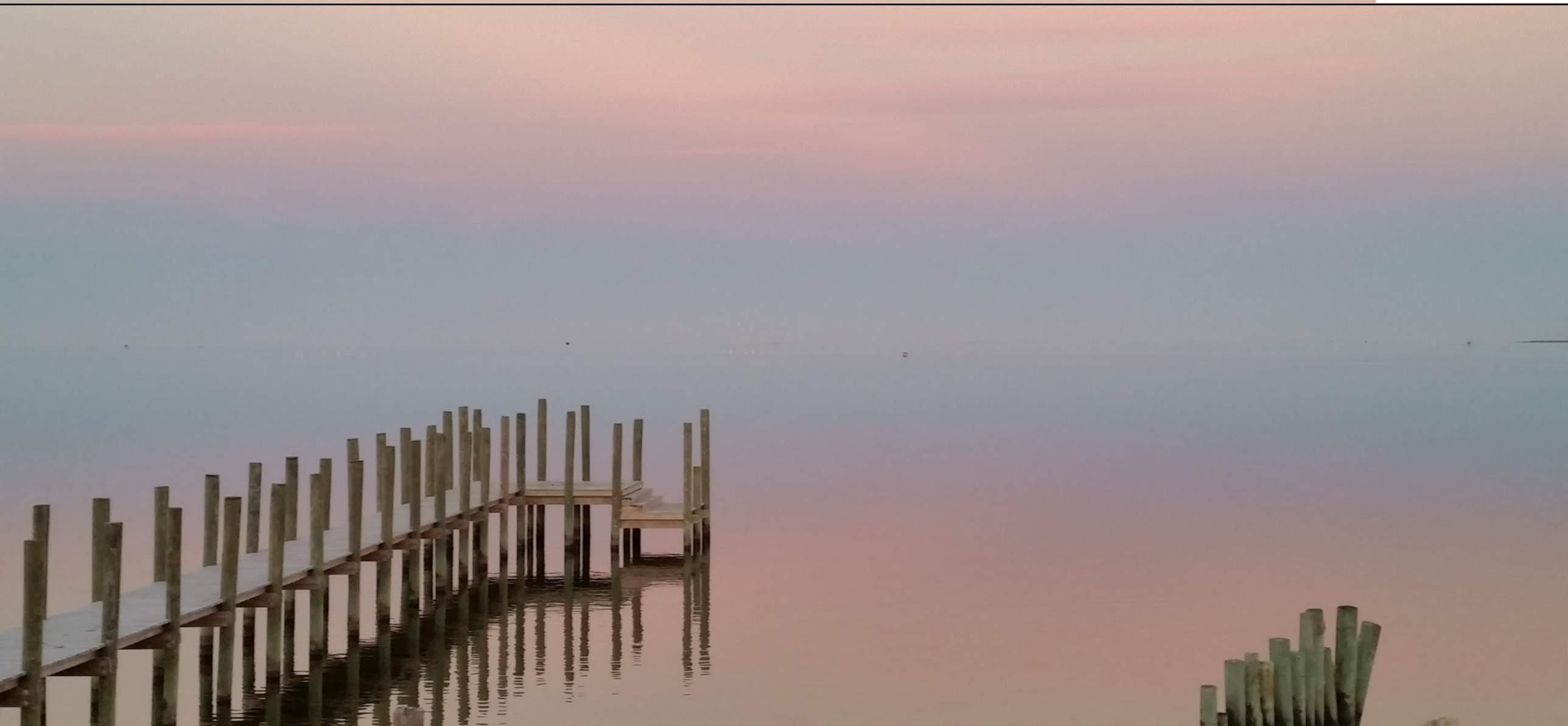
1 Why was the Holocene a “safe operating space for humanity”? Describe three aspects in which the Holocene was different, and favorable to humanity, from other geological epochs.
- stable climate, stable sea level, limited competition for the “social animal”
- Not key for SOSH: humanity was not much different then from today, and most people lived still in poverty; access to energy was limited.

2 What, in your opinion, is the key circumstance that allowed humanity in the last century to grow as fast as it did and push the planet outside of the Holocene?
- access to energy; economic model based on growth and wealth accumulation, particularly in the North-Atlantic culture; a mechanistic world view, advances in technology.
- the distinction between “natural” and “anthropogenic”: we are here, and the environment is there.

3 What, in your opinion, are the most likely consequences of leaving the Holocene and transitioning into a new epoch?
- a different dynamics of a warming planet, more extinction, food and water security, migration, social unrest …
- main cause of premature death

Mitigation and Adaptation Studies



Mitigation and Adaptation Studies

Class 2: The Baseline: Past Climate And Global Change

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Contents:

- Adaptation Science
- Baseline: climate and global change
- Outlook

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CLIMATE CHANGE

Hell and High Water: Practice-Relevant Adaptation Science

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Informing the extensive preparations needed to manage climate risks, avoid damages, and realize emerging opportunities is a grand challenge for climate change science. U.S. President Obama underscored the need for this research when he made climate preparedness a pillar of his climate policy. Adaptation improves preparedness and is one of two broad and increasingly important strategies (along with mitigation) for climate risk management. Adaptation is required in virtually all sectors of the economy and regions of the globe, for both built and natural systems (*1*).

However, without the appropriate science delivered in a decision-relevant context, it will become increasingly difficult—if not impossible—to prepare adequately (*2*). We suggest a number of measures to hasten the development of science to correct maladaptations to current climate variability and support society's increasing need to adapt to a changing climate, drawing on lessons from experience, insights from related endeavors such as sustainability science (*3*), and input from scientific and stakeholder communities.

The entrance to a garage in Lower Manhattan on 31 October, 2012, as New York City began clean-up after Hurricane Sandy.

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Adaptation Planning, Information Gaps, and the Need for Adaptation Science

Initial adaptation planning is occurring in some sectors, such as water resource management, forestry, insurance, and coastal zone management. A limited but growing number of states and cities are developing adaptation plans. U.S. federal agencies have implemented sustainability plans that include mitigation and adaptation (*4*).

There are serious science gaps, however (*5*, *6*). In many communities, decision-makers lack climate information or the means to apply it. In others, knowledge of current or potential future impacts exists, but not in a form or context that decision-makers can assimilate or act on in advance. In still others, engineering innovations are needed, as well as social science knowledge, to guide technology deployment and adjustments to management, investments, and public policy.

A key characteristic of emerging adaptation science is that it is both basic—in that it contributes to understanding fundamental physical, environmental, and socioeconomic research questions—and applied, because it is problem focused. Scientists and practitioners "coproduce" relevant research by jointly defining questions and maintaining frequent interactions (*7*). Coproduction is challenging to implement and sustain because participants often have different roles, vocabularies, interests, methods, and incentives. The effectiveness of communications and deliberative processes among scientists and practitioners requires empirical evaluation (*8*).

To support the wide range of necessary adjustments, we outline a comprehensive, integrated approach to research in social, physical, environmental, engineering, and other sciences. We describe adaptation science research needed to understand decision processes and information requirements, identify vulnerabilities, improve foresight about climate risks and other stressors, and understand barriers and options for adaptation.

Understand Decision Processes and Knowledge Requirements

Adaptation science research must clarify what types of scientific information are required for improved decision-making. Decision-makers are concerned with cost, feasibility, social acceptance, tradition, and other factors. To close a "usability gap," scientific information must fit into existing contexts (*9*). Organizational, cognitive, political, ethnographic, and decision sciences research is needed to clarify the problem, the values of participants, and the context in which the information will be applied. Understanding perception and apprehension of climate change risks is also a priority.

Identify Vulnerabilities

Research to characterize vulnerability and adaptive capacity focuses on pinpointing infrastructure, economic sectors, geo-

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There is an urgent need for "practice-relevant adaptation science"

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Identify climate thresholds in vulnerable systems. Knowledge of climate and related thresholds, points at which fundamental transformations occur in natural or human systems as climate changes, will improve resource management and inform debates about future atmospheric greenhouse gas stabilization. Coupled with time-dependent climate scenarios, improved knowledge of climate thresholds may help in estimating when effects could occur and thus facilitate setting adaptation priorities.

Improve Foresight About Climate Hazards and Other Stressors

Physical and biological scientists must study climate processes and develop models to deliver insights about climate features, including temperature and precipitation extremes, and related processes such as evolution of ecosystems, sea level rise, and other first-order effects. Social sciences can characterize human contributions to climate change through emissions and land use and inform mechanisms for improving interactions between climate scientists and potential users (*11*). Research challenges include:

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Improve integration of weather and climate information. Common elements of initializing predictions with observations and providing probabilistic weather and climate information across time scales can constitute a unified approach for weather forecasts and climate predictions (*13*, *14*). Decadal climate predictions with next-generation, high-resolution global climate models [e.g., (*15*)] have the potential to produce probabilistic near-term climate information over the next decade and improve insight into future conditions to which human societies will have to adapt (*16*). Research is needed to formulate methods for presenting global climate model information in probabilistic form and applying that information to risk assessment and management (*17*).

Tailor climate information to facilitate its application in decision-making. Sustained interactions among researchers and decision-makers are needed not only to understand how climate affects assets or resources but also to identify how climate information can be used in decisions (*18*). In addition to global climate models, other tools can produce relevant information, such as less computationally intensive intermediate-complexity models [e.g., to assess uncertainty (*19*)], qualitative scenario planning approaches (*20*), and decision-analytic approaches to use climate model information in ways that supplement conventional scenario-led studies [e.g., (*17*)]. Climate and decision scientists can tailor information for application through downscaling of climate model data [e.g., (*21*)] or running fully dynamical nested numerical models at regional or finer grid spacings [e.g., the North American Regional Climate Change Assessment Program (*22*)].

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nance, and incentives to facilitate adaptation. Four priorities are to:

Identify, explain, and explore opportunities to overcome barriers to adaptation. Existing laws, regulations, and other practices can limit adaptation. These include legal and financial mechanisms, from local to international jurisdictions. Research is needed to identify these barriers and develop solutions to minimize or surmount them.

Develop technologies and performance standards. A changed climate system with conditions never before experienced by human societies may alter effectiveness of historically successful adaptation approaches and limit types of adaptation (*27*). Adaptation options are needed that are robust to different climate and socioeconomic development pathways, and are thus effective in both the short-term and the long-term (e.g., improved water distribution or desalination systems, and advances in electricity generation, transmission, and distribution). Organizations and processes for establishing manufacturing, building, and other standards (e.g., the International Organization for Standardization) could contribute to the development of adaptation options.

Develop indicators and monitoring and evaluation systems. Monitoring and evaluation will help track progress in enhancing resilience, prioritizing adaptation funding, and evaluating effectiveness of adaptation options. For adaptation options related to infrastructure and some natural resources, relevant indicators are relatively easy to quantify. For measures focused on governance or livelihoods, indirect proxy variables must be defined. Case studies dominate adaptation evaluations, with little comparative research on implementation (*28*).

Learn from experience. A number of knowledge platforms are beginning to catalog and evaluate experiences to promote information exchange and learning. Learning and disseminating of lessons needs to be accelerated to improve decision-making. Enabling private companies to share experiences without damaging commercial interests is a particular challenge.

Measures to Establish Adaptation Science

First steps in establishing institutions to conduct and support adaptation science are taking place. In the United States, "mission" agencies—including the Environmental Protection Agency, the National Oceanic and Atmospheric Administration (NOAA), and the Department of the Interior—have supported the use of scientific information in adaptation. The Regional Integrated Sciences and Assessments Program, Climate Science Centers, and other efforts aim at developing a collaborative framework between research and practice (*29*). The European Union has provided research funding and launched an information portal (www.eea.europa.eu/themes/climate/european-climate-adaptation-platform-climate-adapt). Germany, the United Kingdom, and other countries are moving forward to establish services (e.g., www.climate-service-center.de). Australia has made adaptation a priority (www.csiro.au/Outcomes/Climate/Adapting.aspx).

Advances in adaptation science will not happen without two transformational changes: (i) an institutional structure to catalyze, coordinate, evaluate, and encourage the use of advances in adaptation science; and (ii) an increase in funding. National Research Council reports [e.g., (*6*)] and recommendations of a U.S. federal interagency committee (*30*) provide detailed recommendations that would help advance climate adaptation science.

One U.S. approach could be a national institute on climate preparedness composed of research and applications centers for adaptation in priority sectors or challenges. The institute would be geographically distributed and function in some ways similar to the National Institutes of Health. It would build on the current USGCRP, agency sectoral or regional research centers, and regional nodes for the National Climate Assessment's sustained assessment process. Providing sufficient resources for collaboration and learning would facilitate research on coupled systems and offer an opportunity to better connect adaptation science to interagency programs.

More broadly, sustained support for problem-oriented fundamental research on adaptation needs to be increased at research agencies. A particular challenge is to develop effective approaches to learn from adaptation practice as well as published research. Progress toward achieving the goal of adapting to changing climate will require demonstrating tangible benefits for society by connecting research and applications.

References and Notes

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Five Fields:

- Assessing the hazards
- Knowing the vulnerabilities
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The Baseline: Past Climate and Global Change

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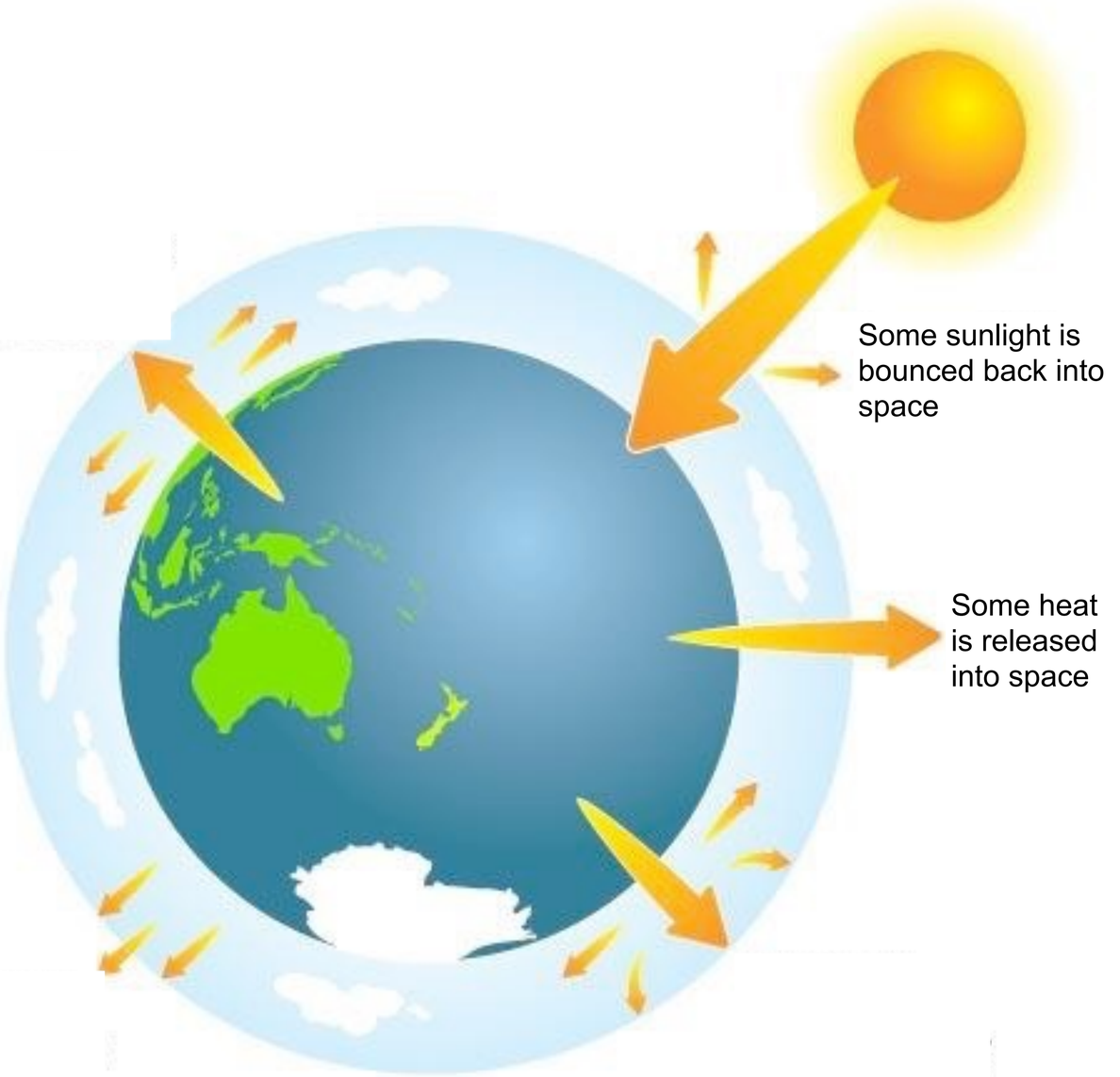
Climate depends on:
- available energy
- distribution of energy

Equilibrium: incoming radiation = outgoing radiation

Effective temperature depends only on incoming radiation; for Earth, it is -18°C.



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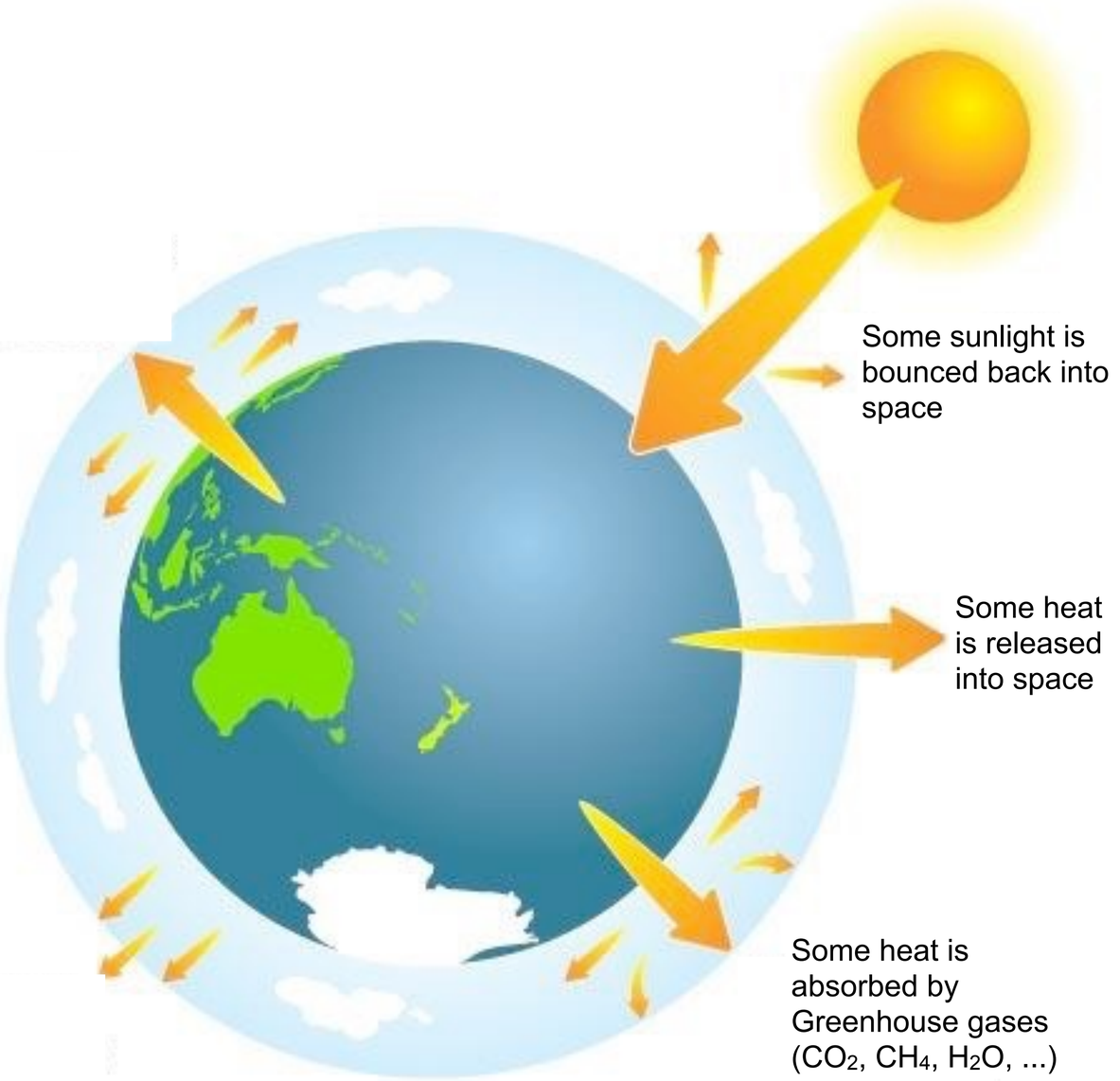

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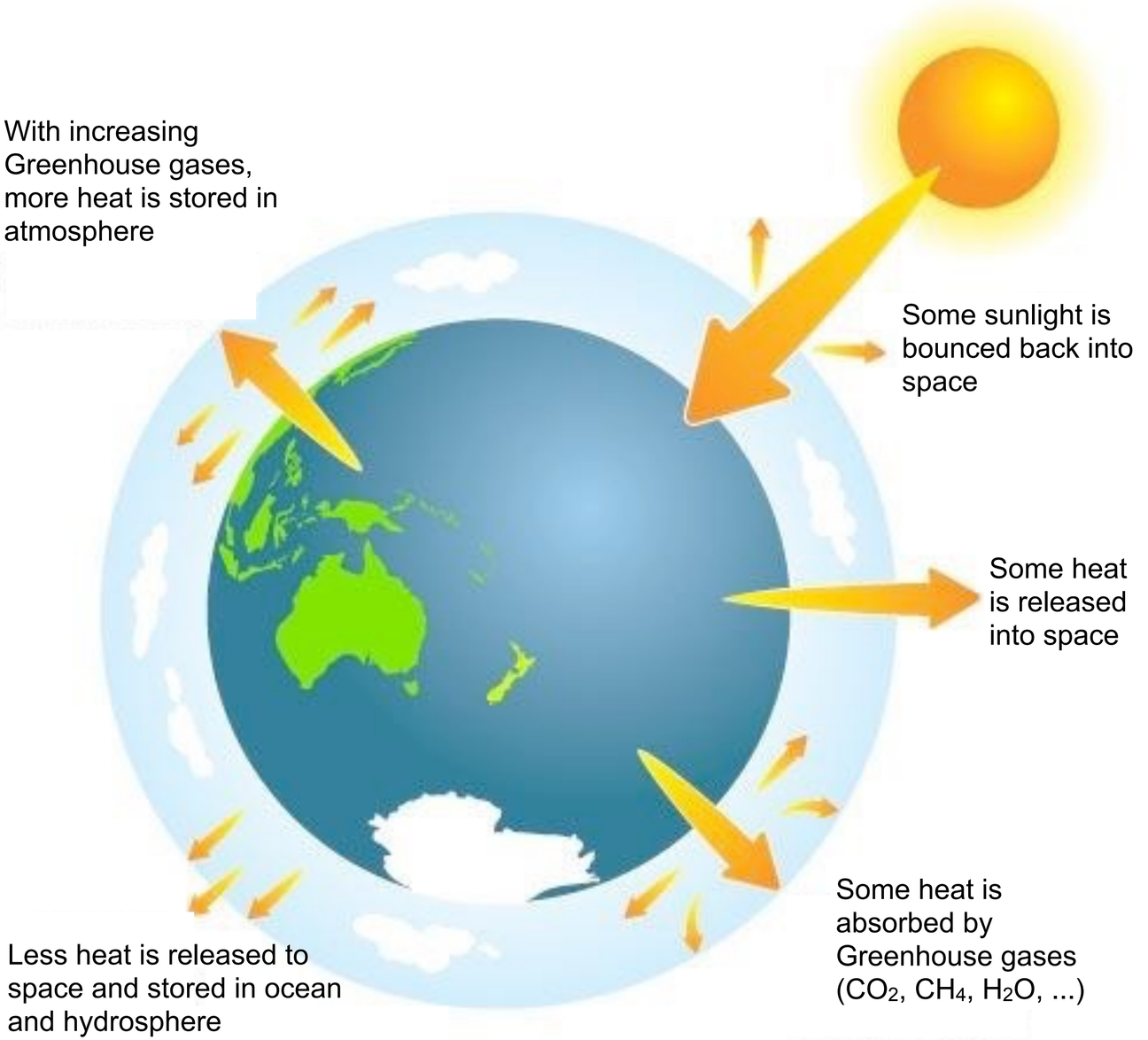

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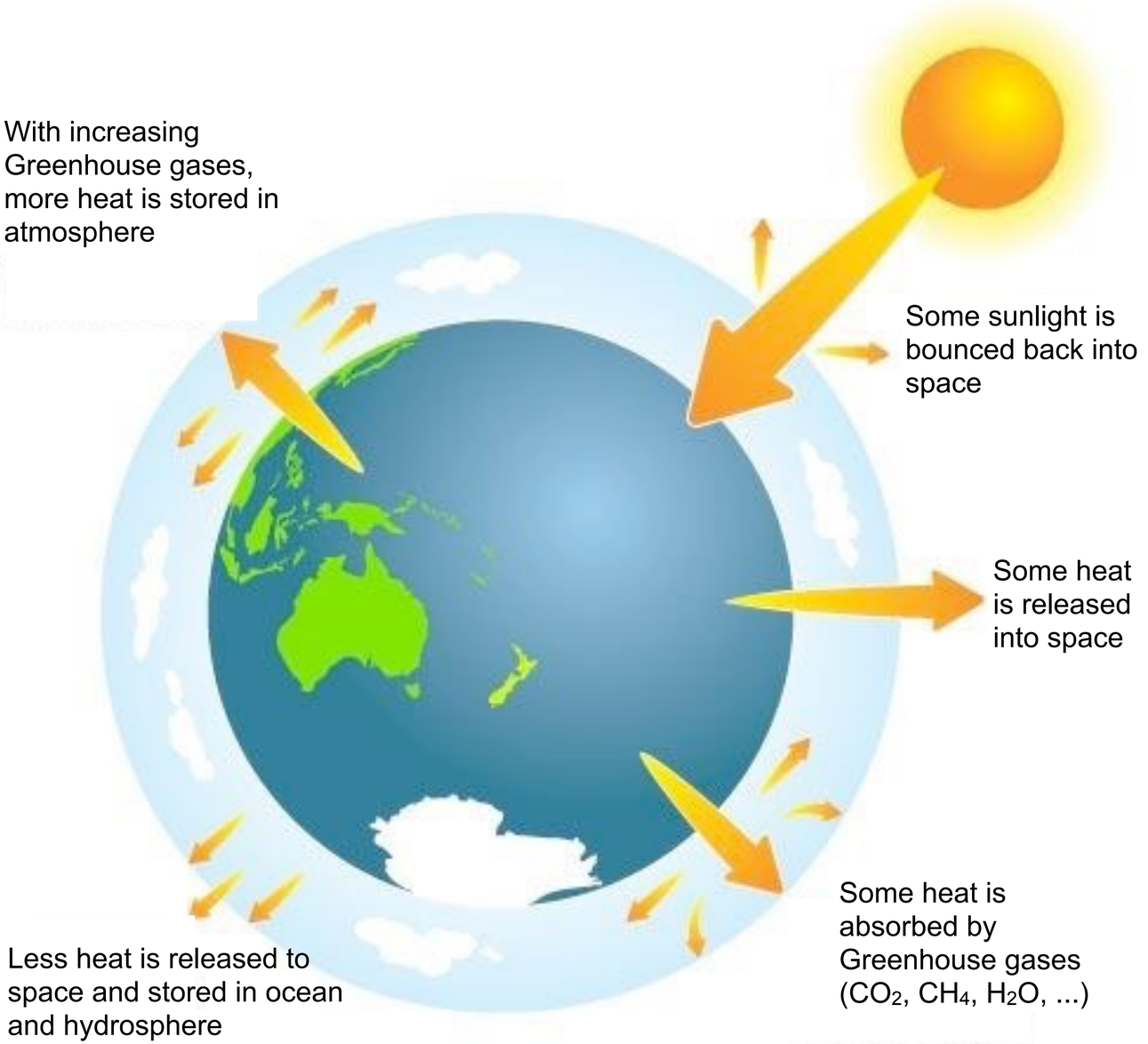

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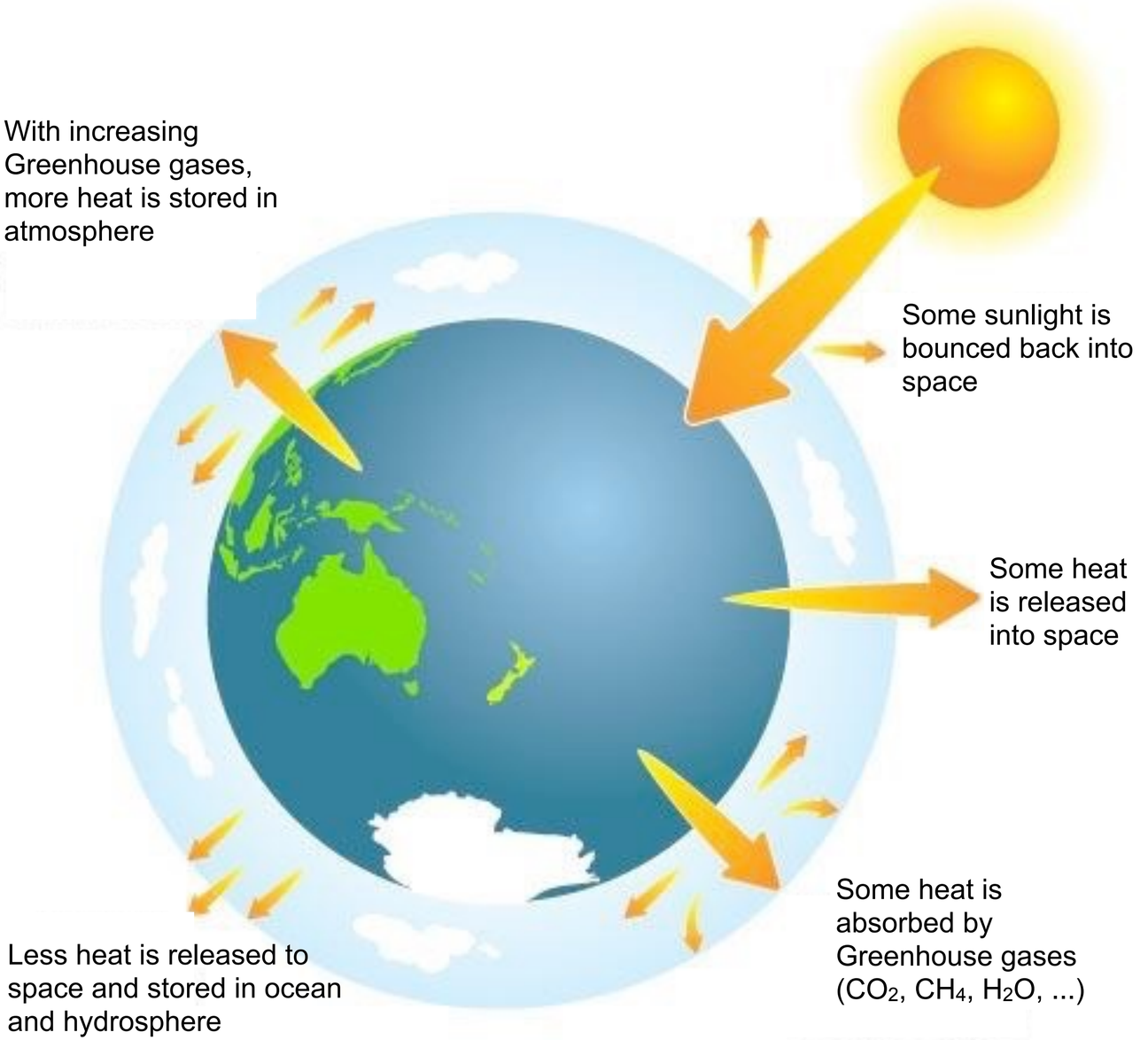

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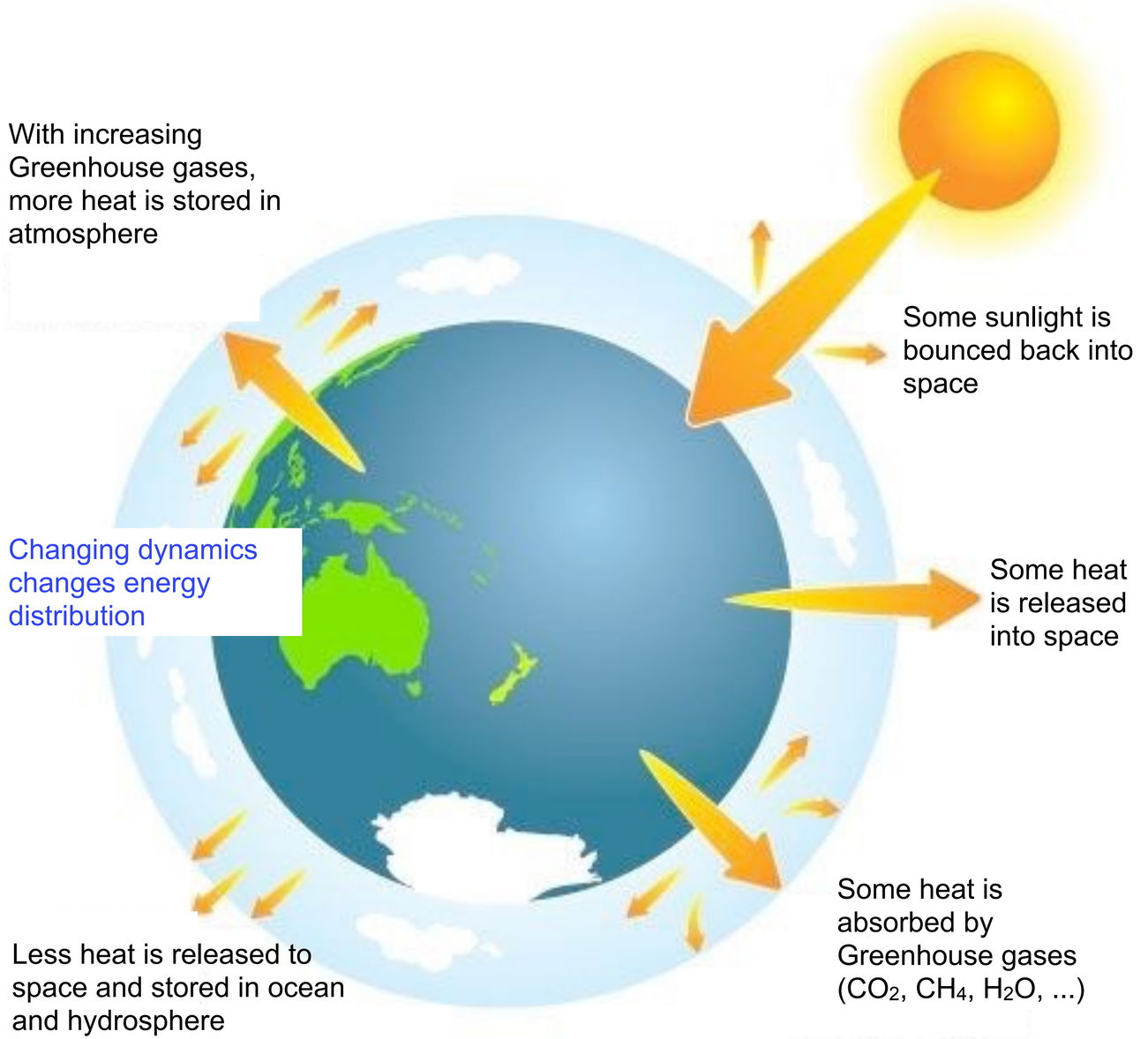

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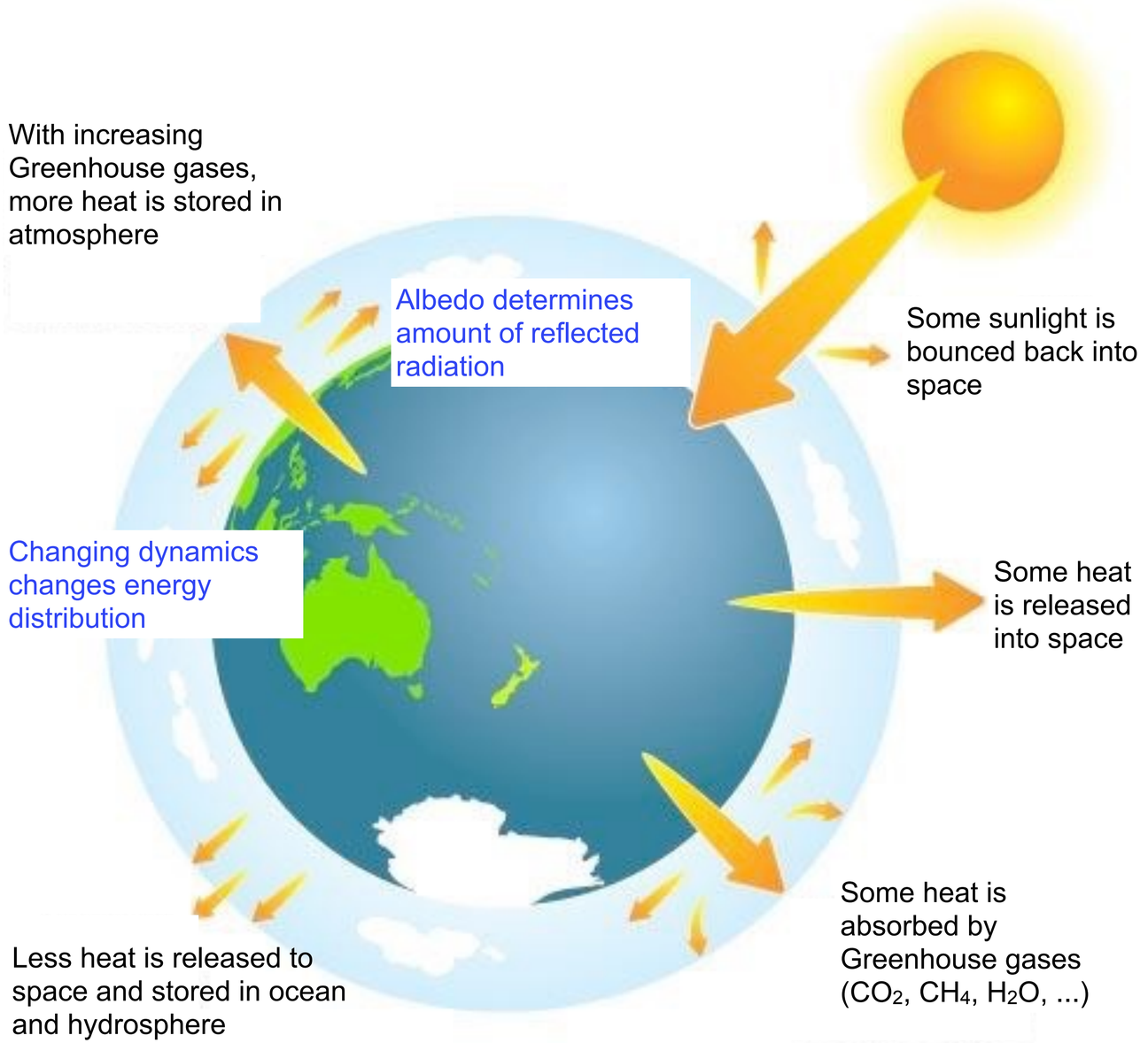

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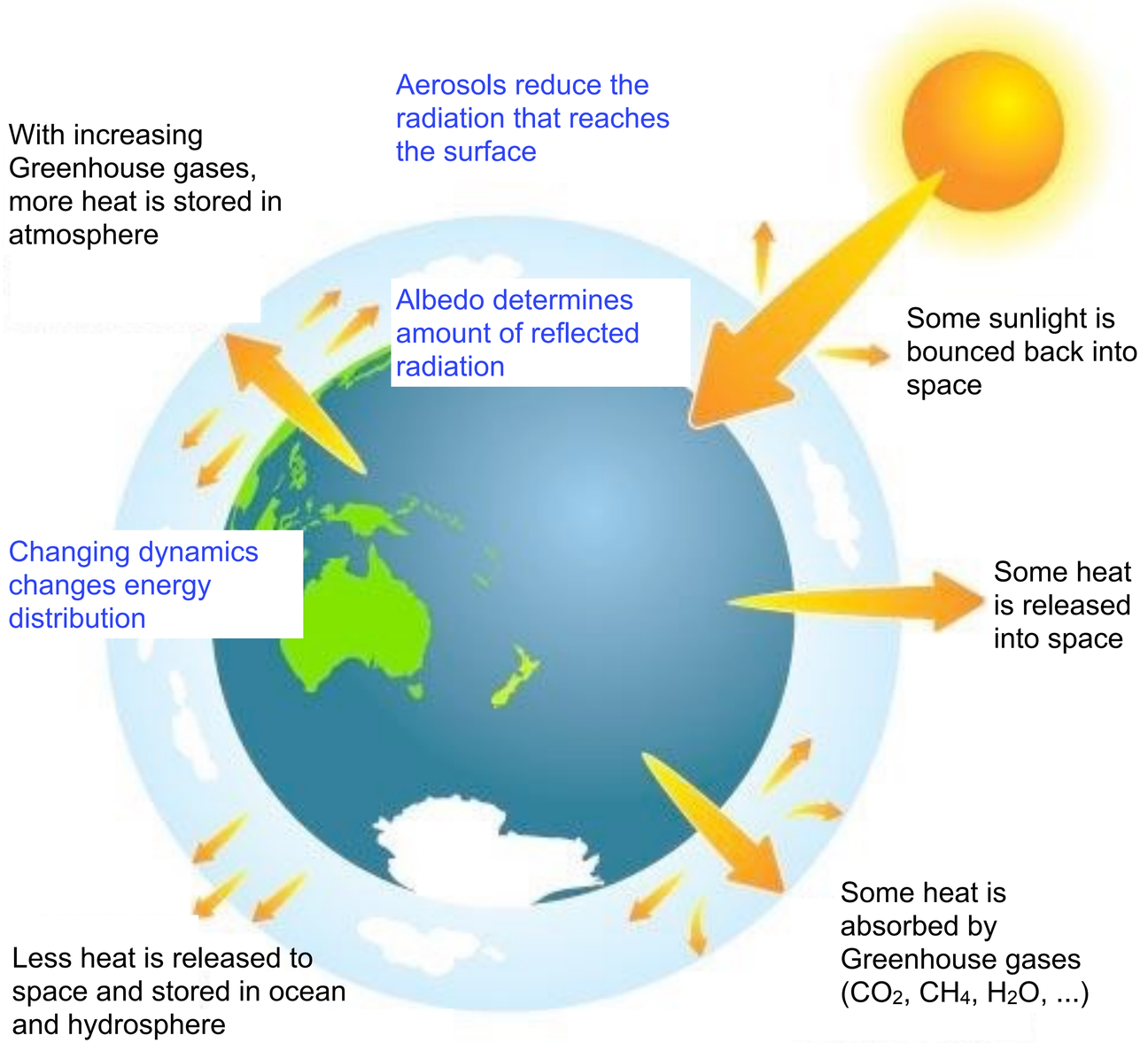

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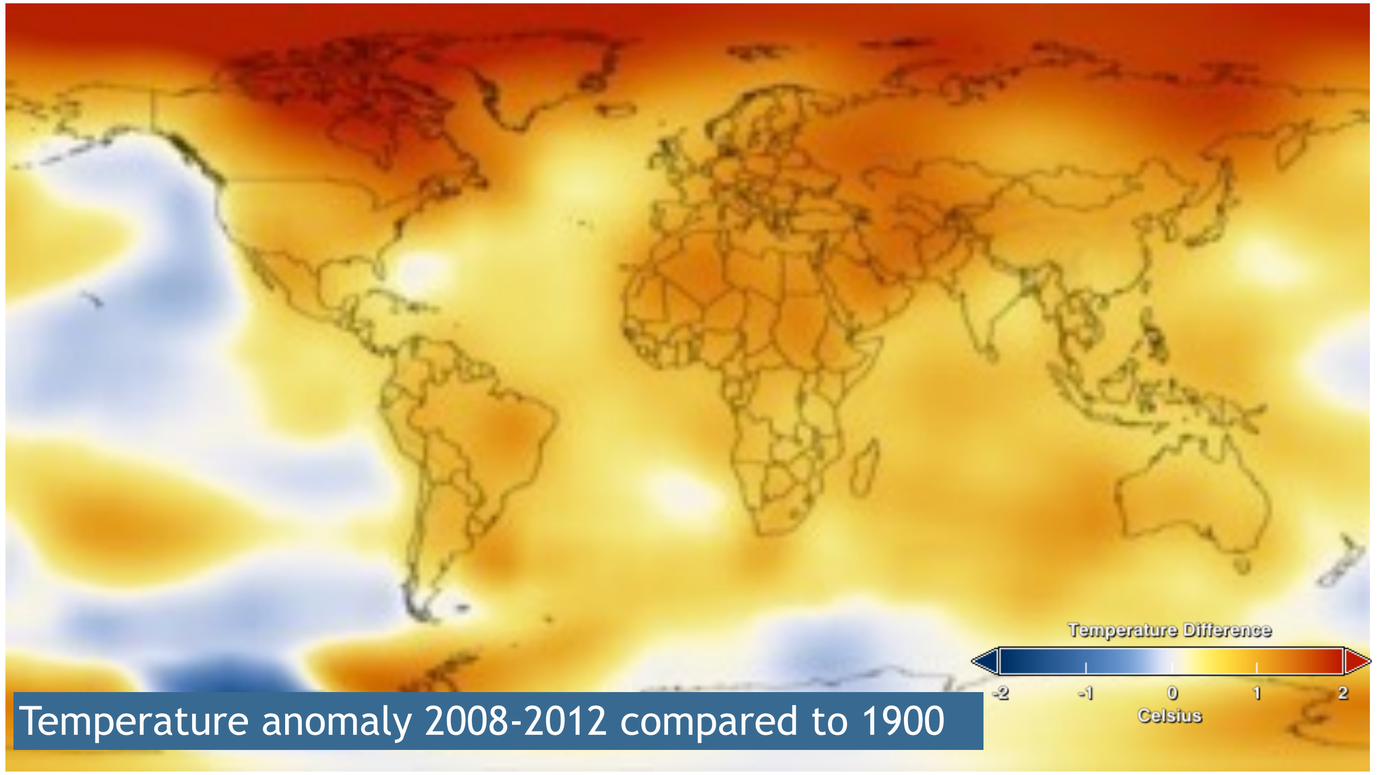


Temperature anomaly 2008-2012 compared to 1900

The Baseline: Past Climate and Global Change

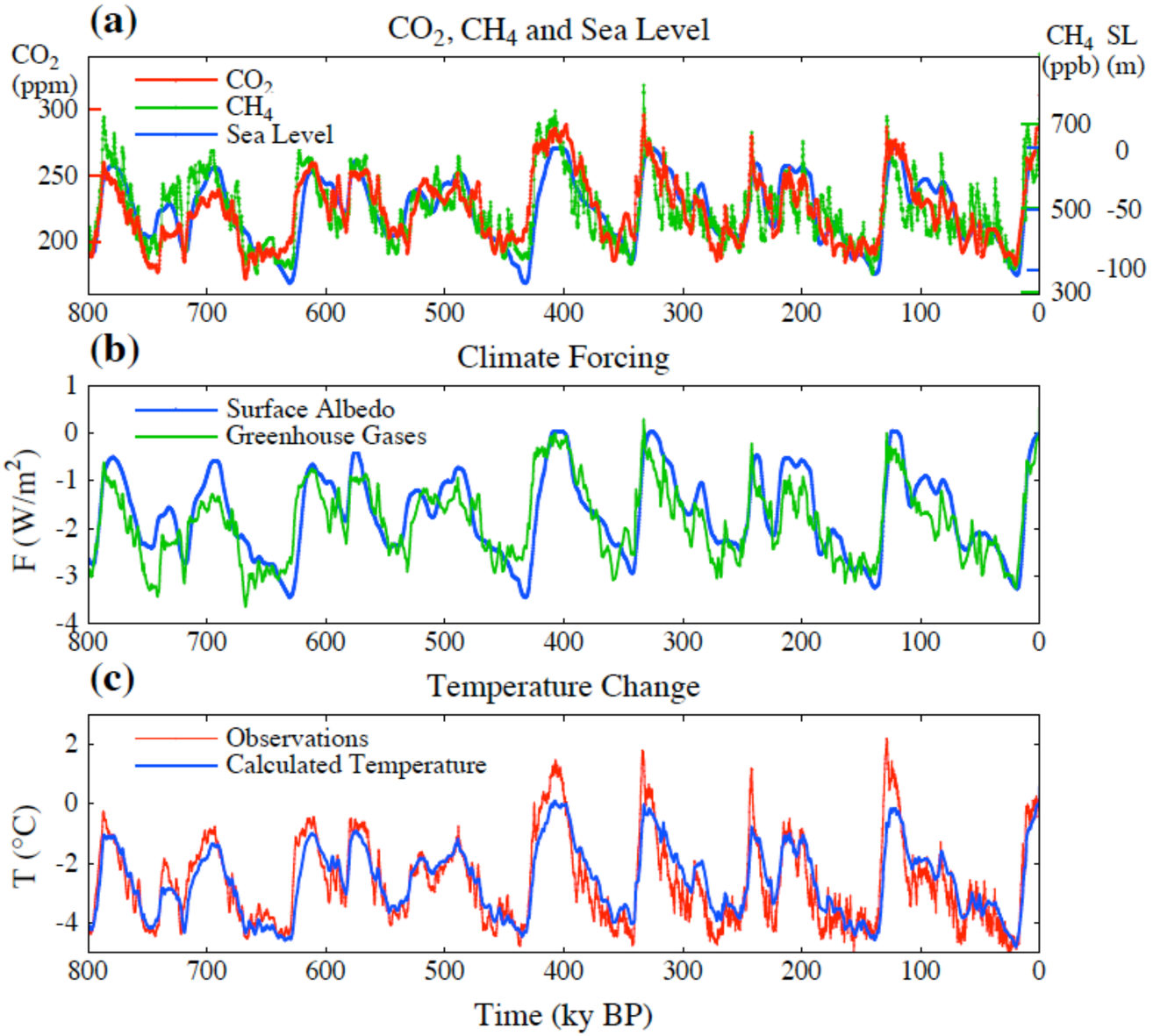
Climate Change is a long-term shift in the statistics of weather - averages, frequency and magnitude of extremes.

Climate is determined by:

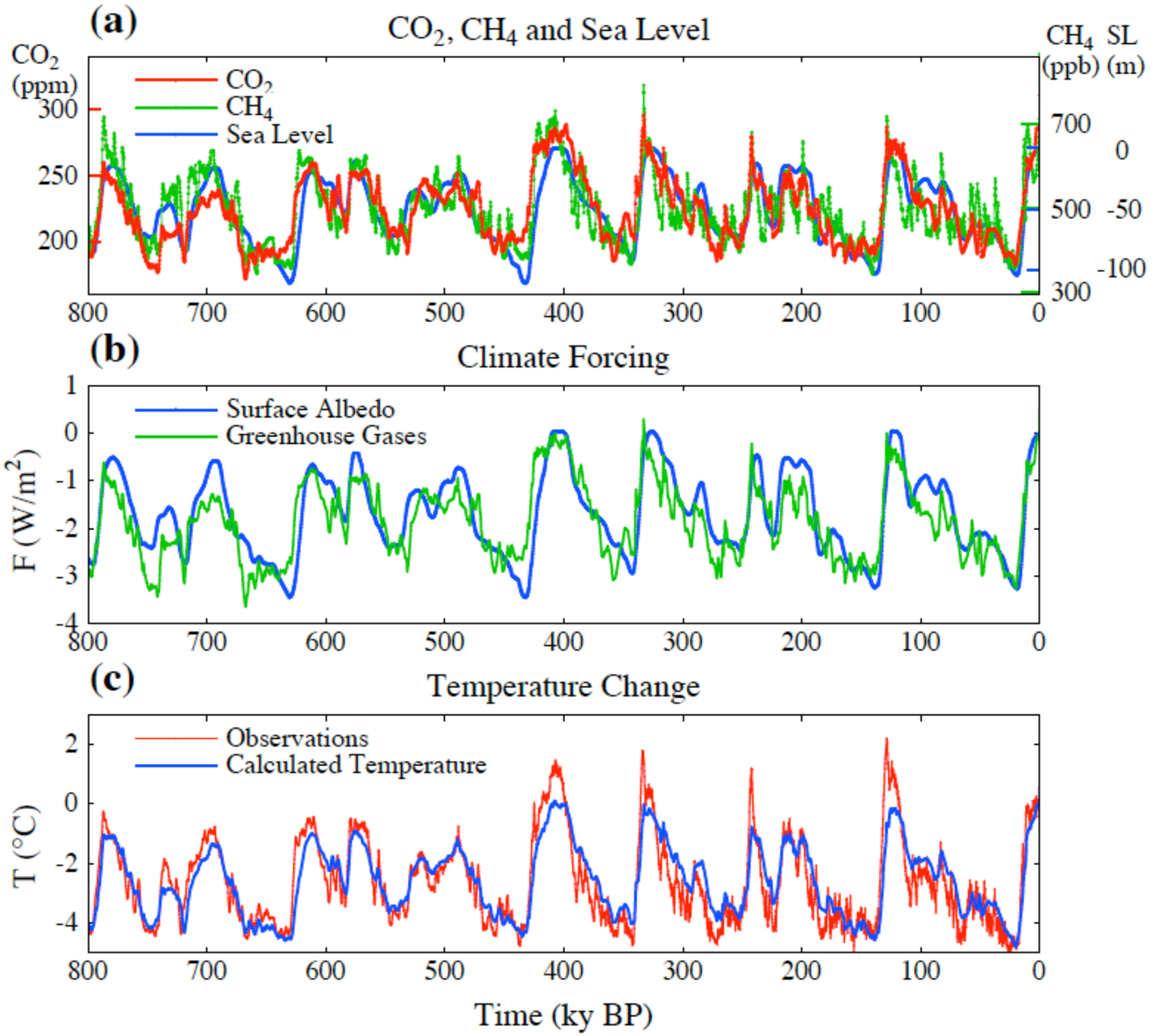
- incoming radiation (sun)
- reflected radiation (albedo)
- retained heat (Greenhouse gases)

Climate can change from local to global scales.

Climate can change a lot over time.



The Baseline: Past Climate and Global Change



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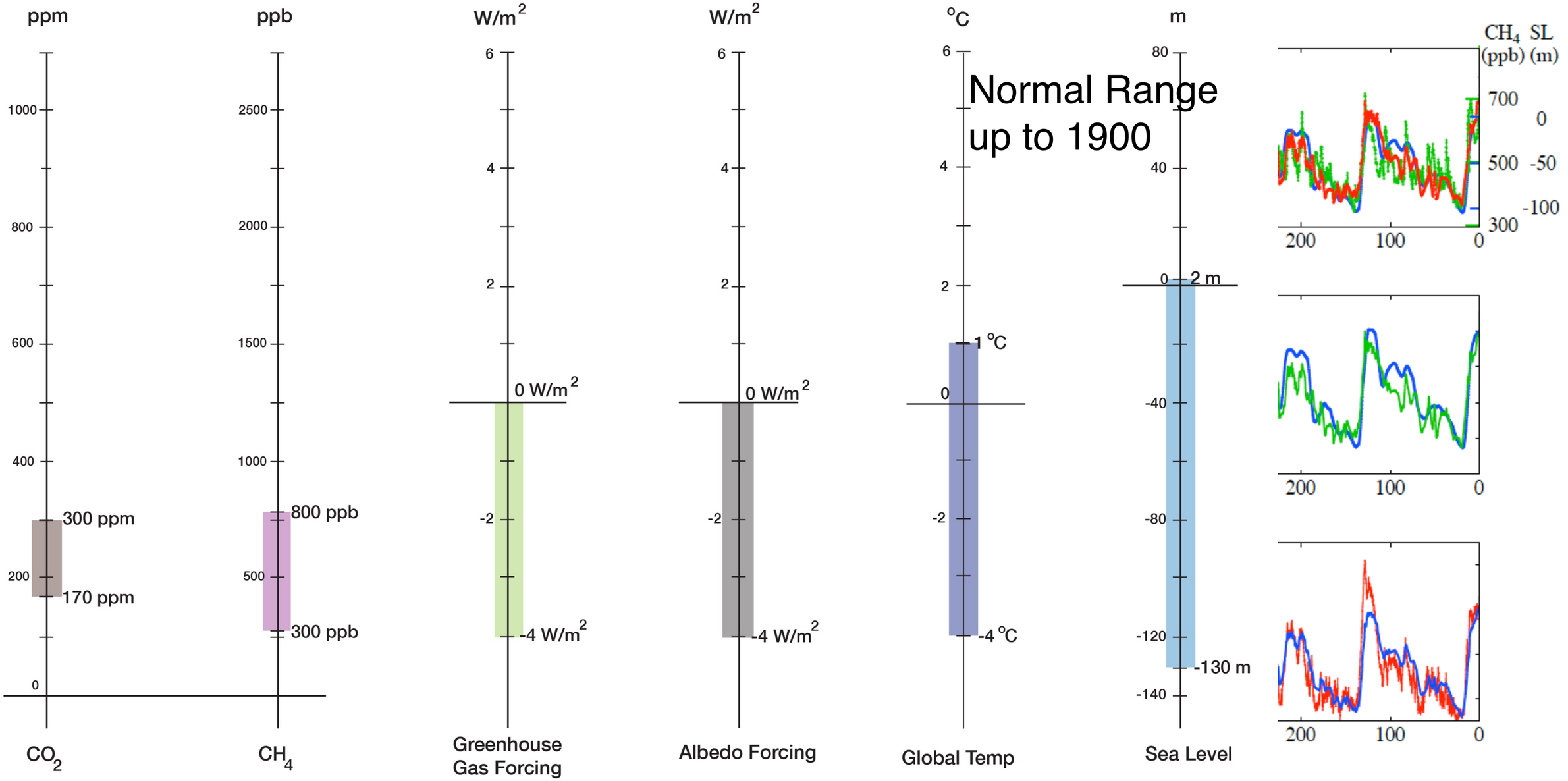

The Baseline: Past Climate and Global Change

Long-term (centuries to millennia) correlations:

- 130 ppm CO
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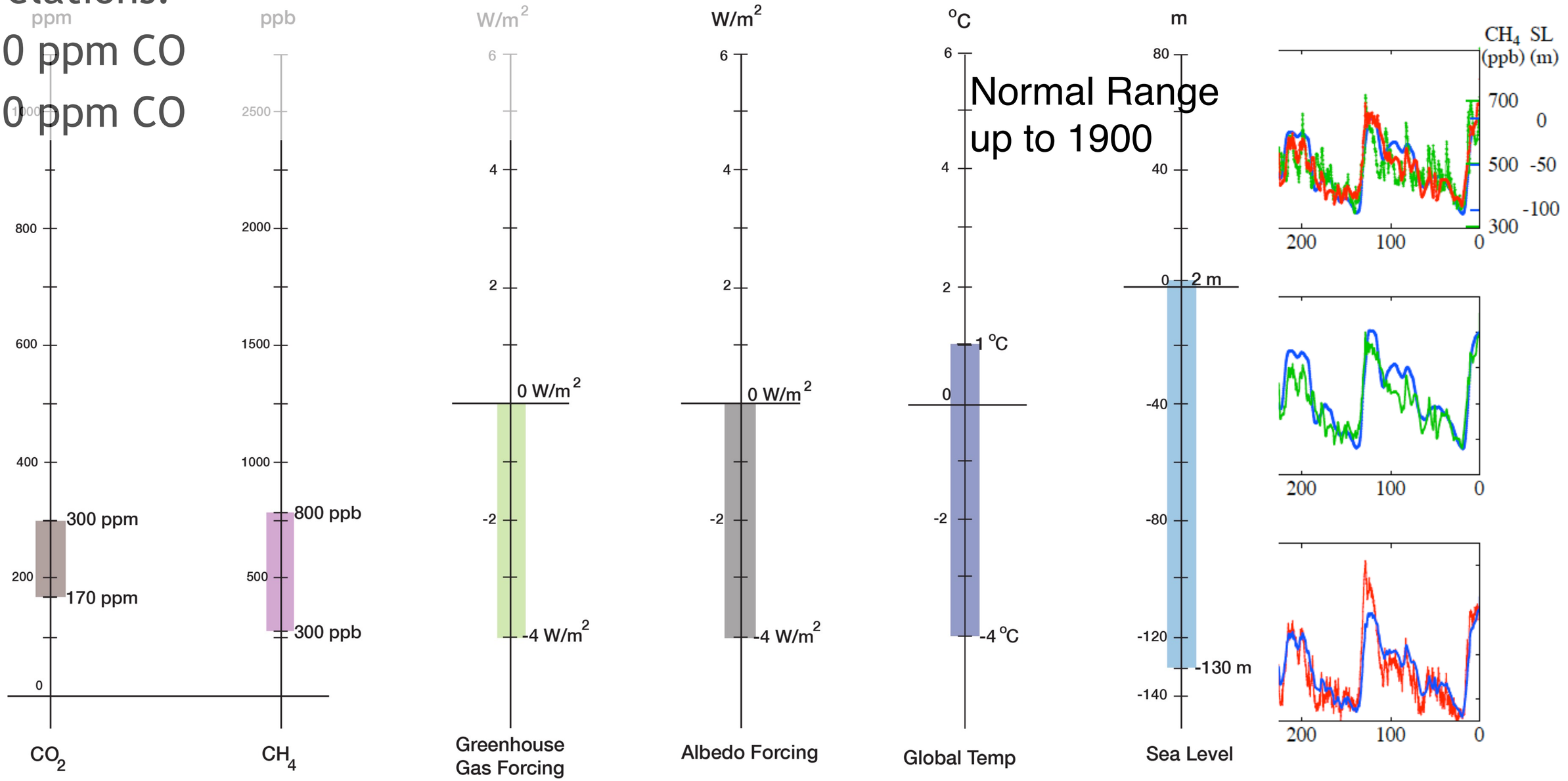

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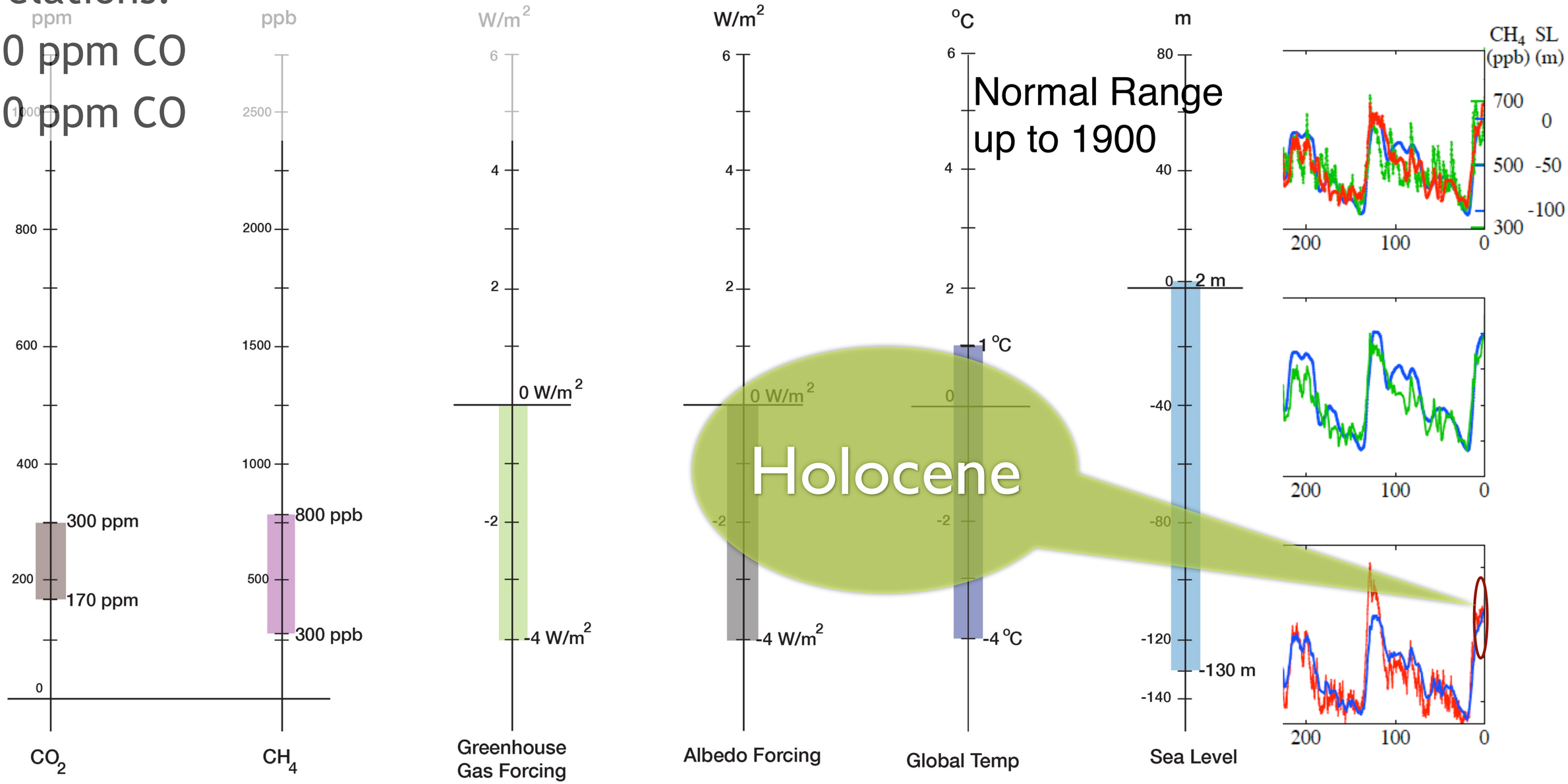
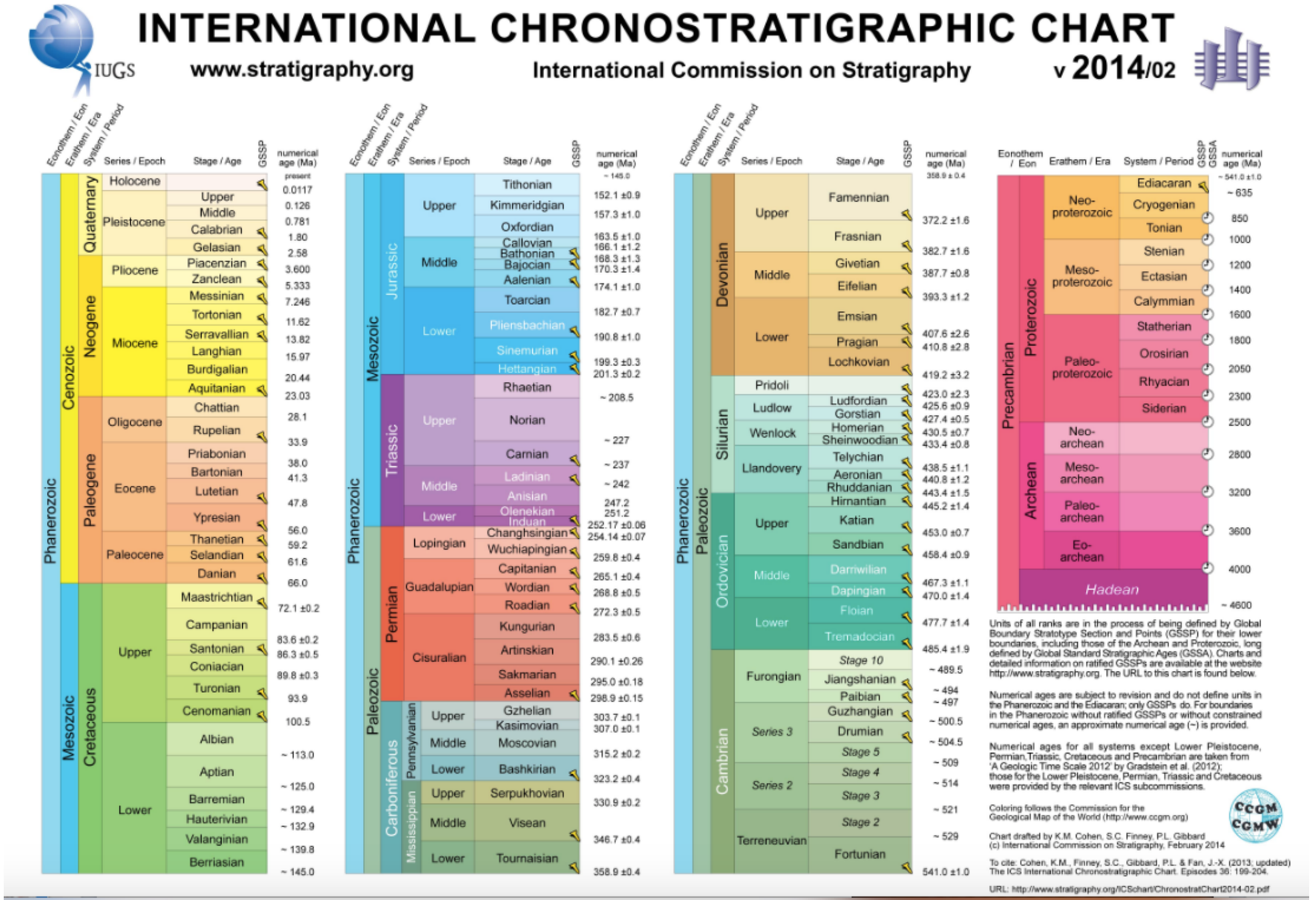
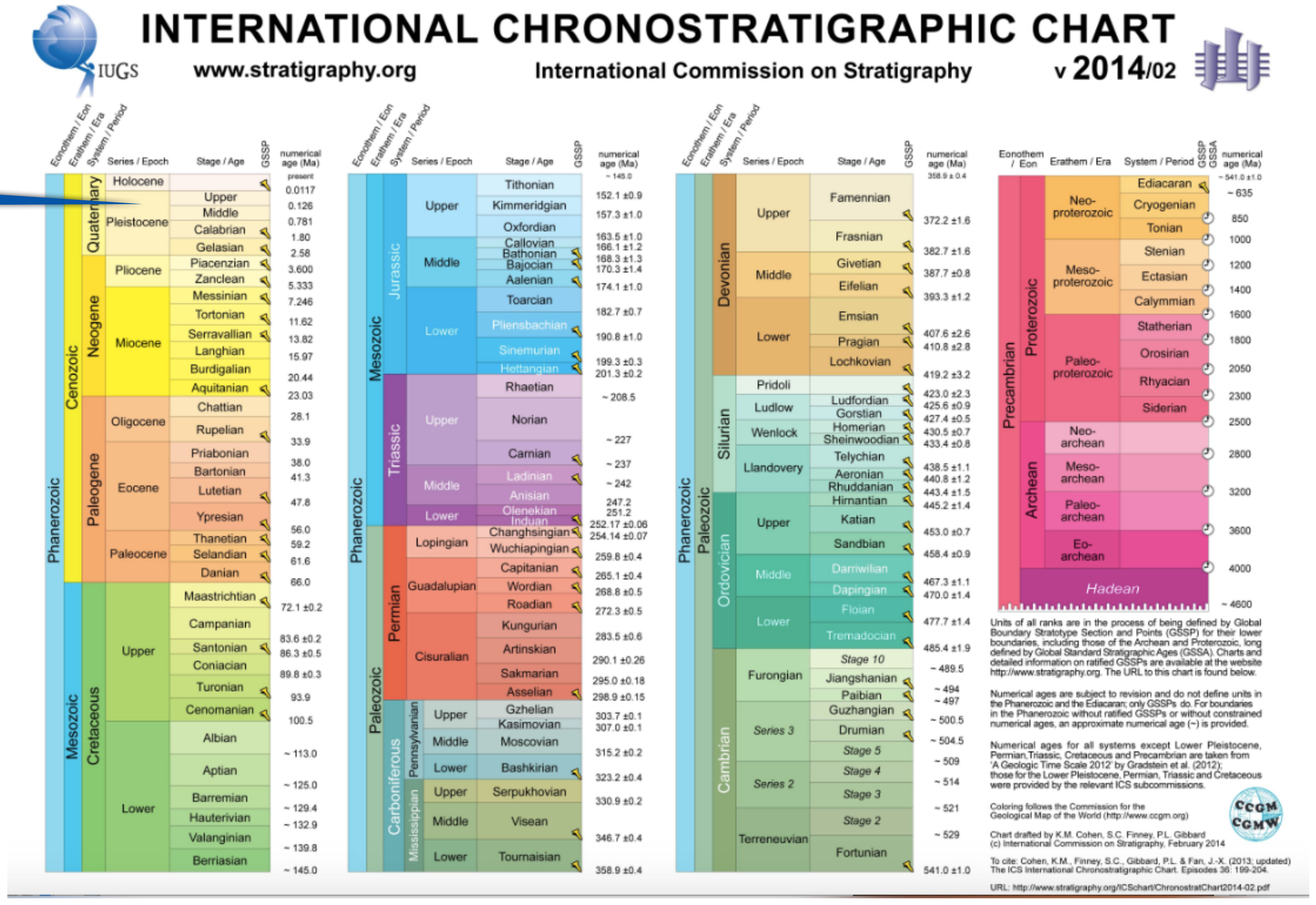


The Baseline: Past Climate and Global Change



The Baseline: Past Climate and Global Change

Subdivisions of the Quaternary System			
System/ Period	Series/ Epoch	Stage/ Age	Age (Ma)
Quaternary	Holocene		0.0117–0
	Pleistocene	Tarantian	0.126–0.0117
		Ionian	0.781–0.126
		Calabrian	1.80–0.781
		Gelasian	2.58–1.80
Neogene	Pliocene	Piacenzian	older



The Baseline: Past Climate and Global Change

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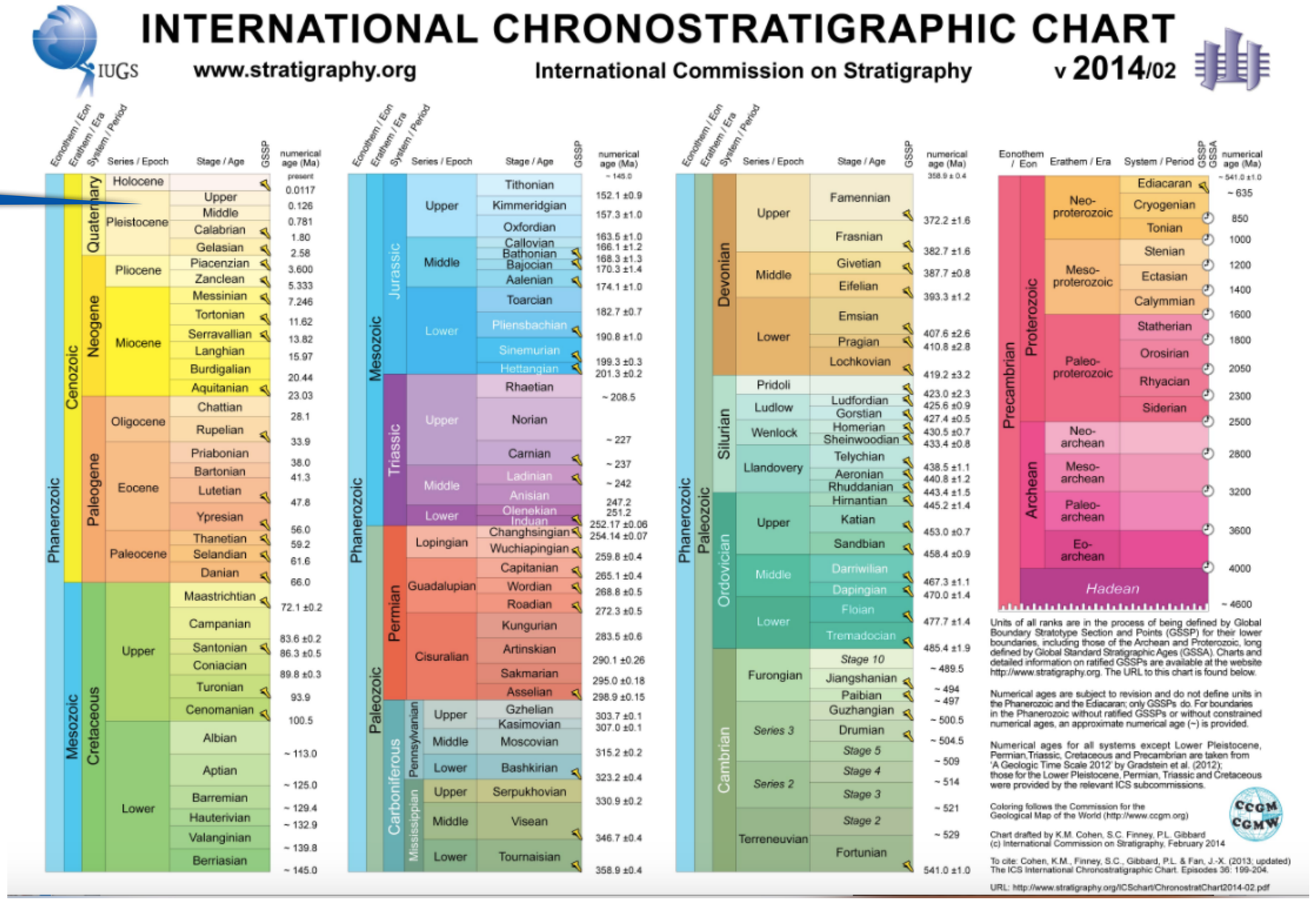

The Baseline: Past Climate and Global Change

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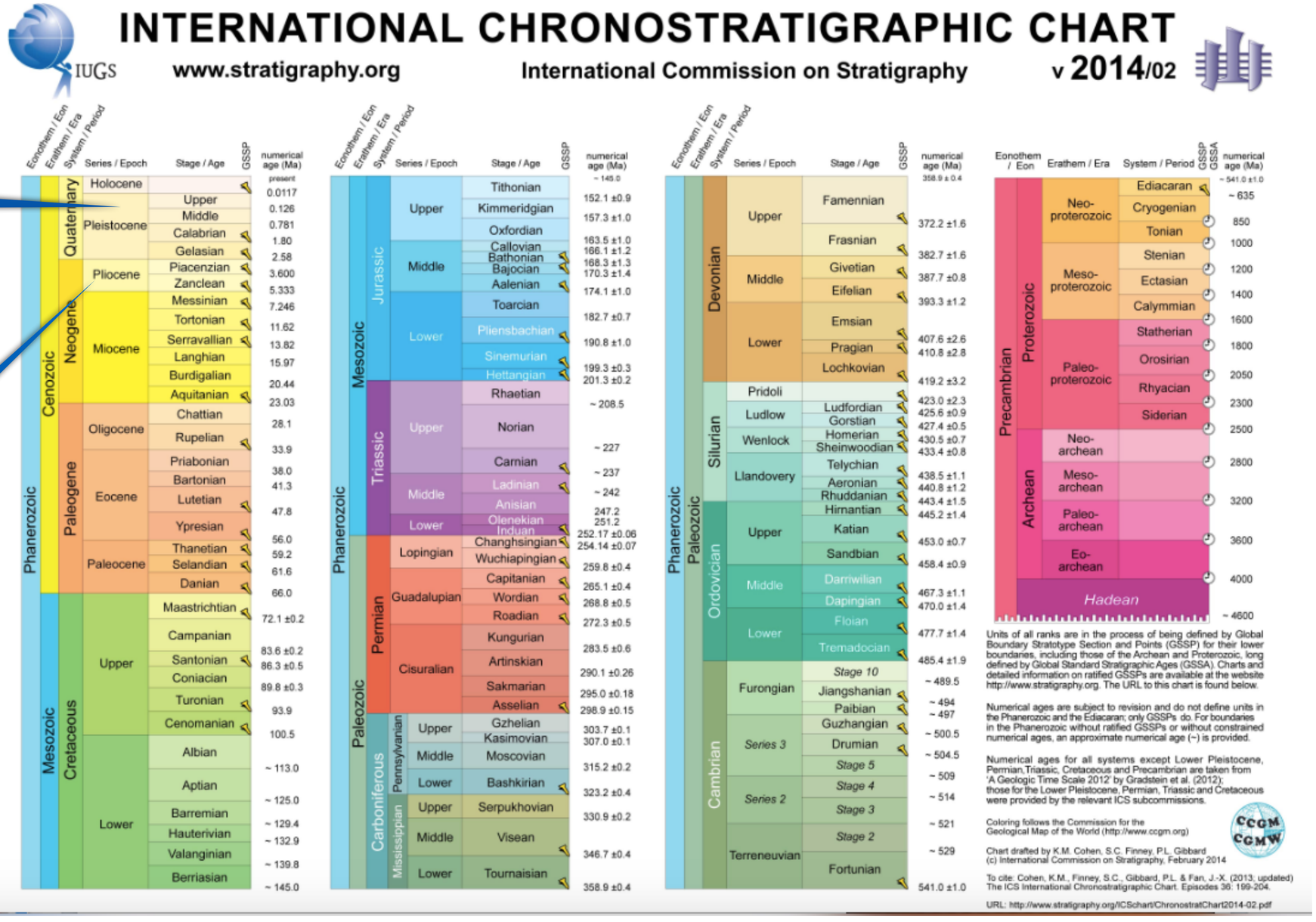
Neogene	**Pliocene**	Piacenzian	3.600–2.58
		Zanclean	5.333–3.600
	Miocene	Messinian	7.246–5.333
		Tortonian	11.62–7.246
		Serravallian	13.82–11.62
		Langhian	15.97–13.82
		Burdigalian	20.44–15.97
		Aquitanian	23.03–20.44
Paleogene	Oligocene	Chattian	**older**



The Baseline: Past Climate and Global Change

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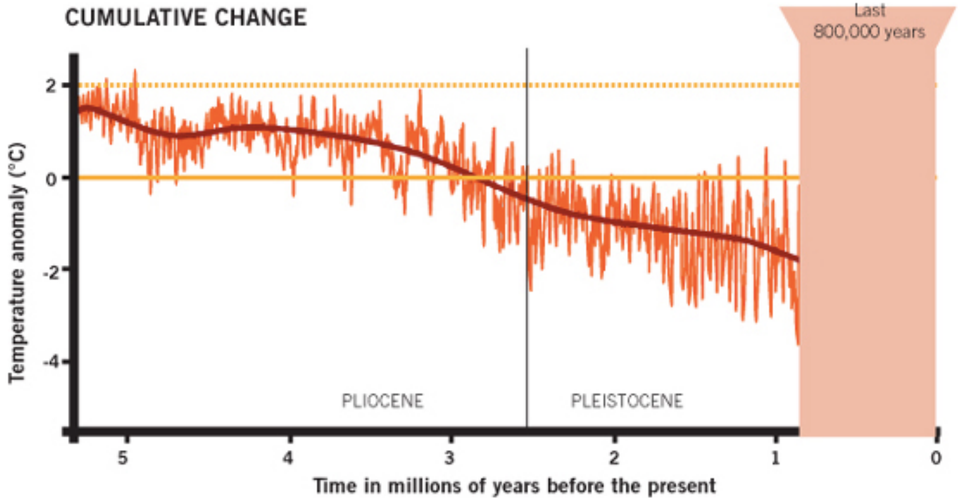
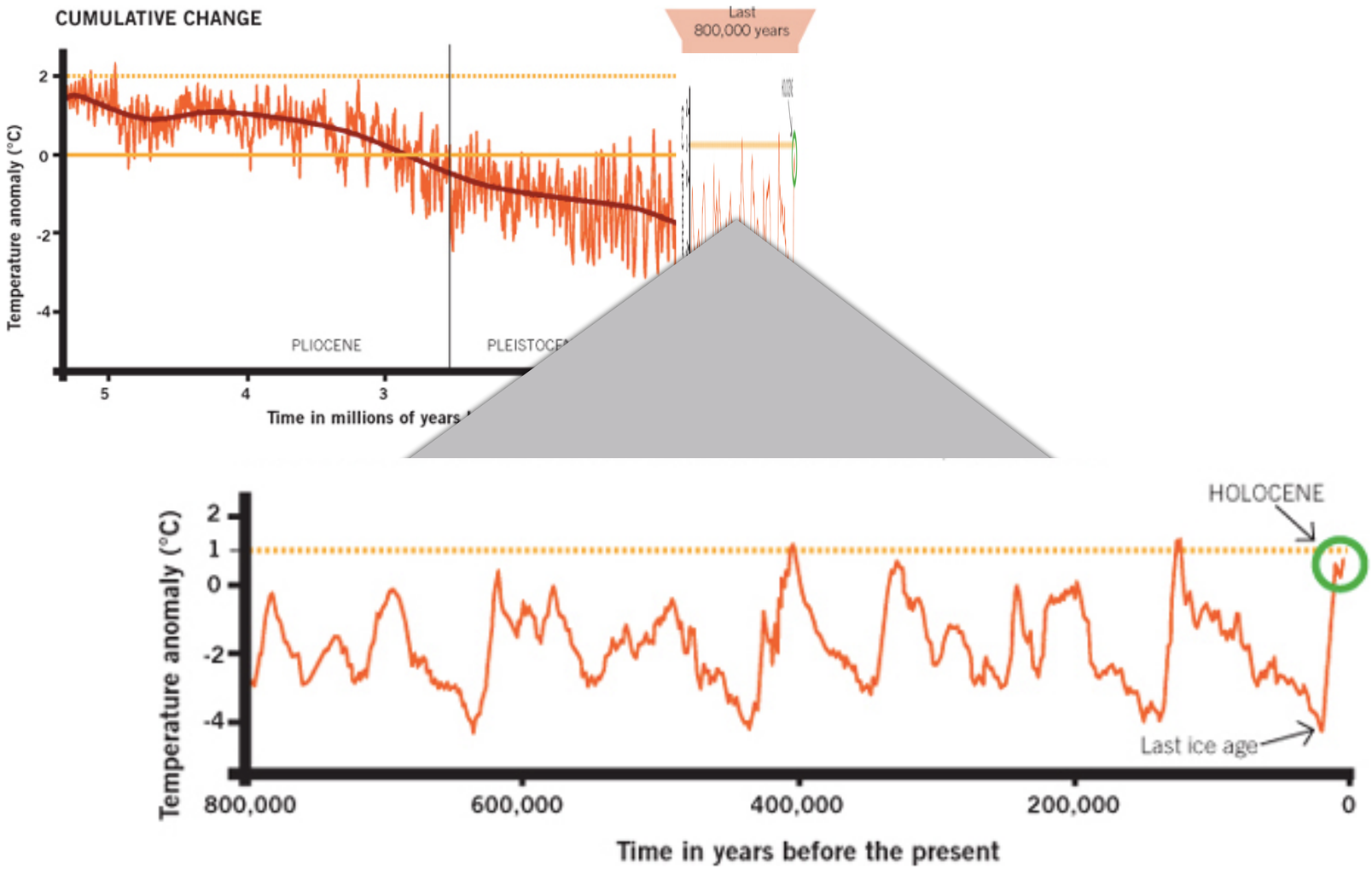


Rockstrom and Klum, 2015

The Baseline: Past Climate and Global Change



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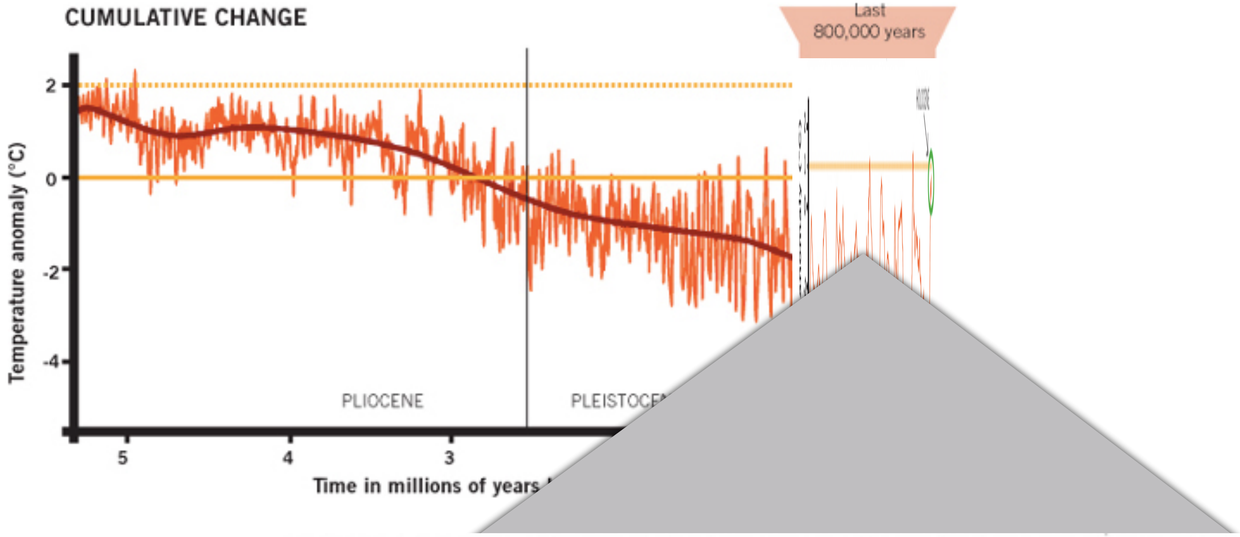

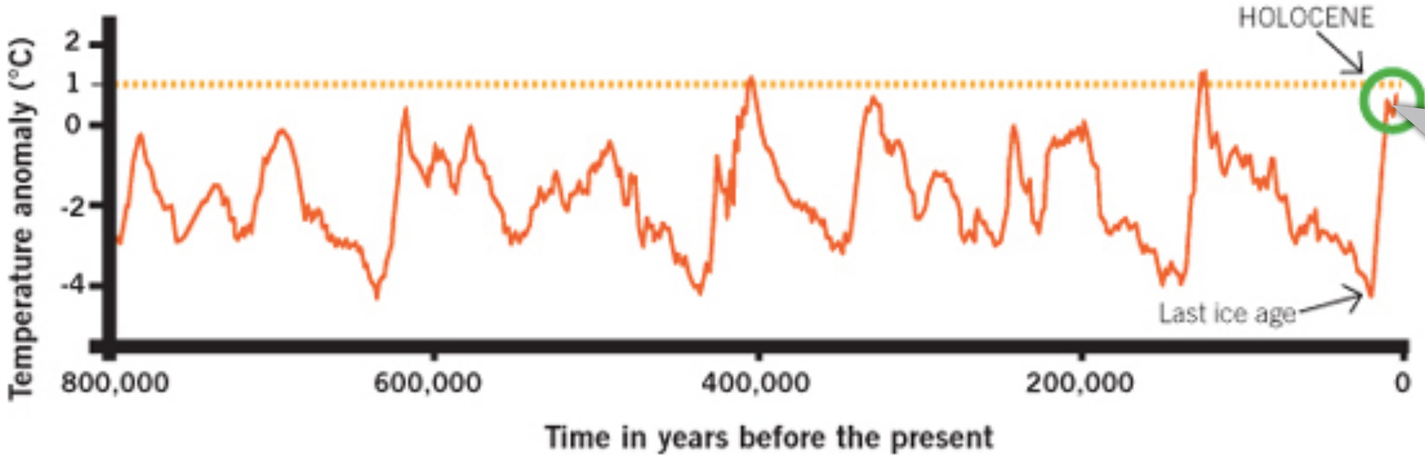

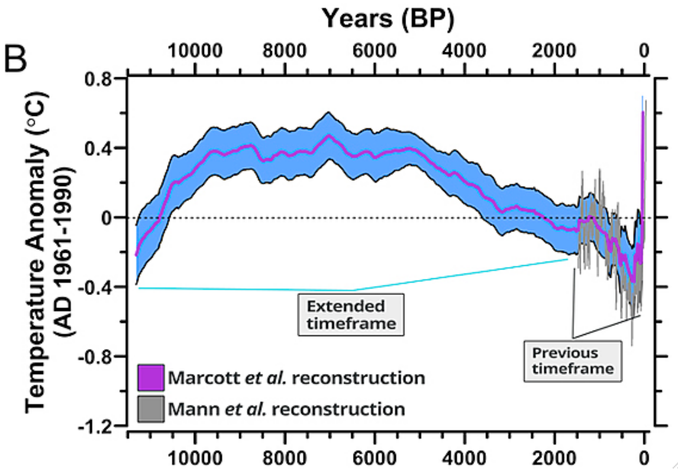

Rockstrom and Klum, 2015

Marcott et al., 2013

The Baseline: Past Climate and Global Change

Our Commitment: The “~400 ppm CO_2 World”:

The Baseline: Past Climate and Global Change

Our Commitment: The "~400 ppm CO_2 World":

Example: Mid-Pliocene, 3.3 to 3.0 Million Years ago
Temperature: ~1 - 2 ^oC higher
Sea level:

- global average on the order of 10 m higher than today
- regionally 5 to 40 m higher;
- most likely, much stronger storms due to larger temperature difference between tropics and polar regions

The Baseline: Past Climate and Global Change

Hansen et al., 2015:"… Evidence … that 2°C global warming is highly dangerous."

Example: A
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Atmos. Chem. Phys. Discuss., 15, 20059-20179, 2015
www.atmos-chem-phys-discuss.net/15/20059/2015/
doi:10.5194/acpd-15-20059-2015
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Research Article 23 Jul 2015

Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous

Review Status
This discussion paper is under review for the journal Atmospheric Chemistry and Physics (ACP).

J. Hansen[1], M. Sato[1], P. Hearty[2], R. Ruedy[3,4], M. Kelley[3,4], V. Masson-Delmotte[5], G. Russell[4], G. Tselioudis[4], J. Cao[6], E. Rignot[7,8], I. Velicogna[7,8], E. Kandiano[9], K. von Schuckmann[10], P. Kharecha[1,4], A. N. Legrande[4], M. Bauer[11], and K.-W. Lo[3,4]

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[2]Department of Environmental Studies, University of North Carolina at Wilmington, North Carolina 28403, USA
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[4]NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA
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[6]Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710075, China
[7]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 91109, USA
[8]Department of Earth System Science, University of California, Irvine, California, 92697, USA
[9]GEOMAR, Helmholtz Centre for Ocean Research, Wischhofstrasse 1–3, Kiel 24148, Germany
[10]Mediterranean Institute of Oceanography, University of Toulon, La Garde, France
[11]Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY, 10027, USA

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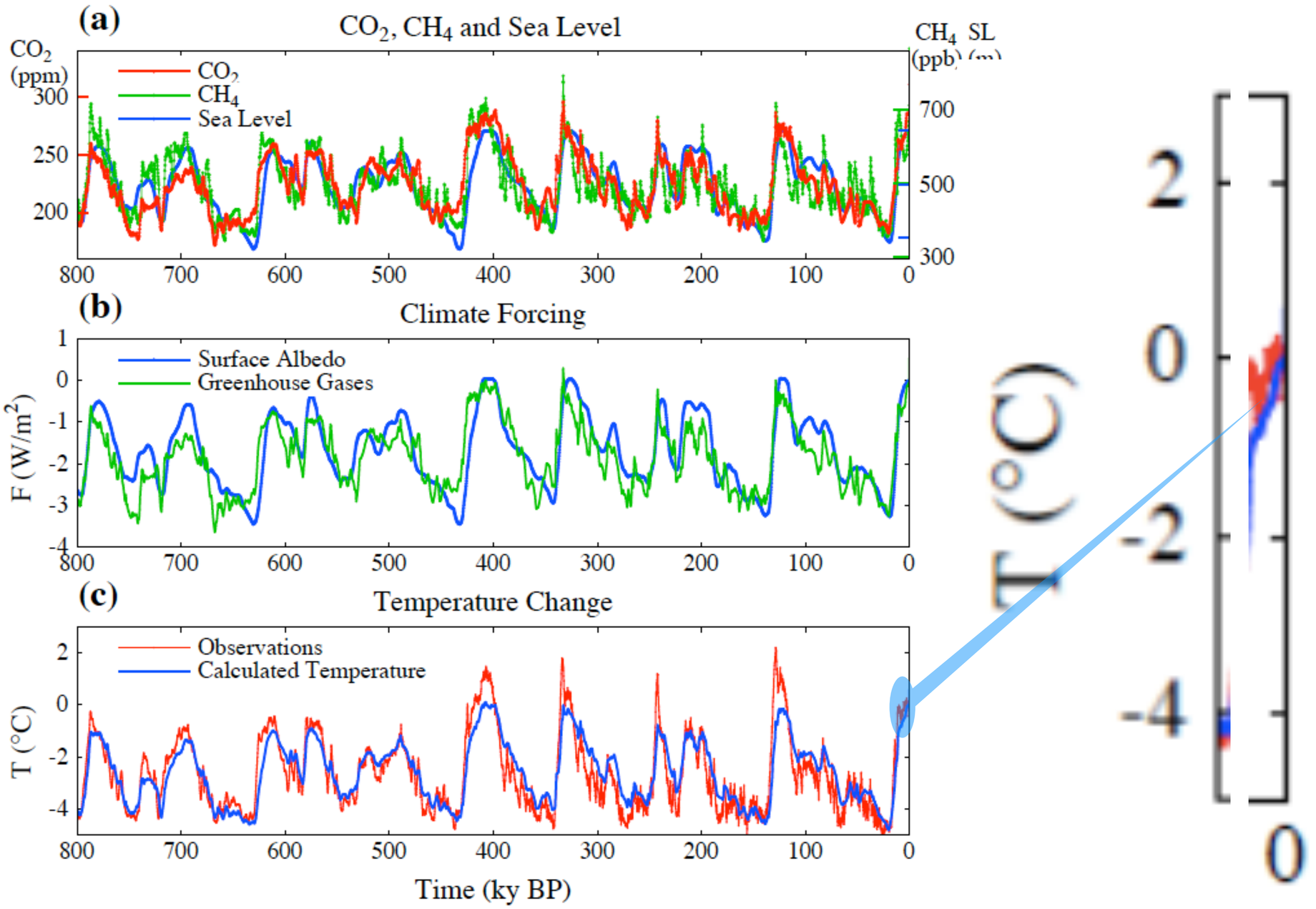
Abstract. There is evidence of ice melt, sea level rise to +5–9 m, and extreme storms in the prior interglacial period that was less than 1 °C warmer than today. Human-made climate forcing is stronger and more rapid than paleo forcings, but much can be learned by combining insights from

The Baseline: Past Climate and Global Change

The Baseline: Past Climate and Global Change



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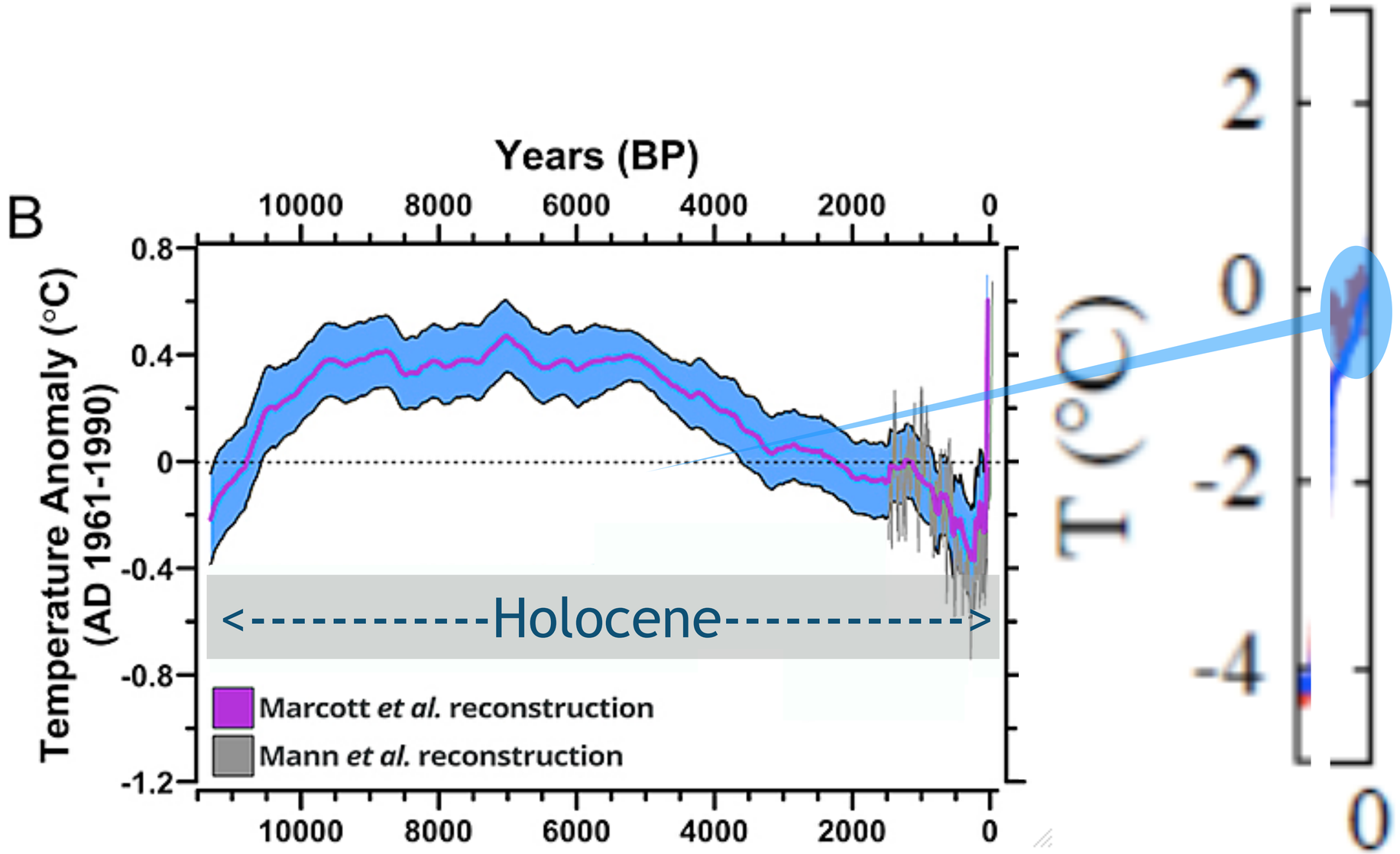
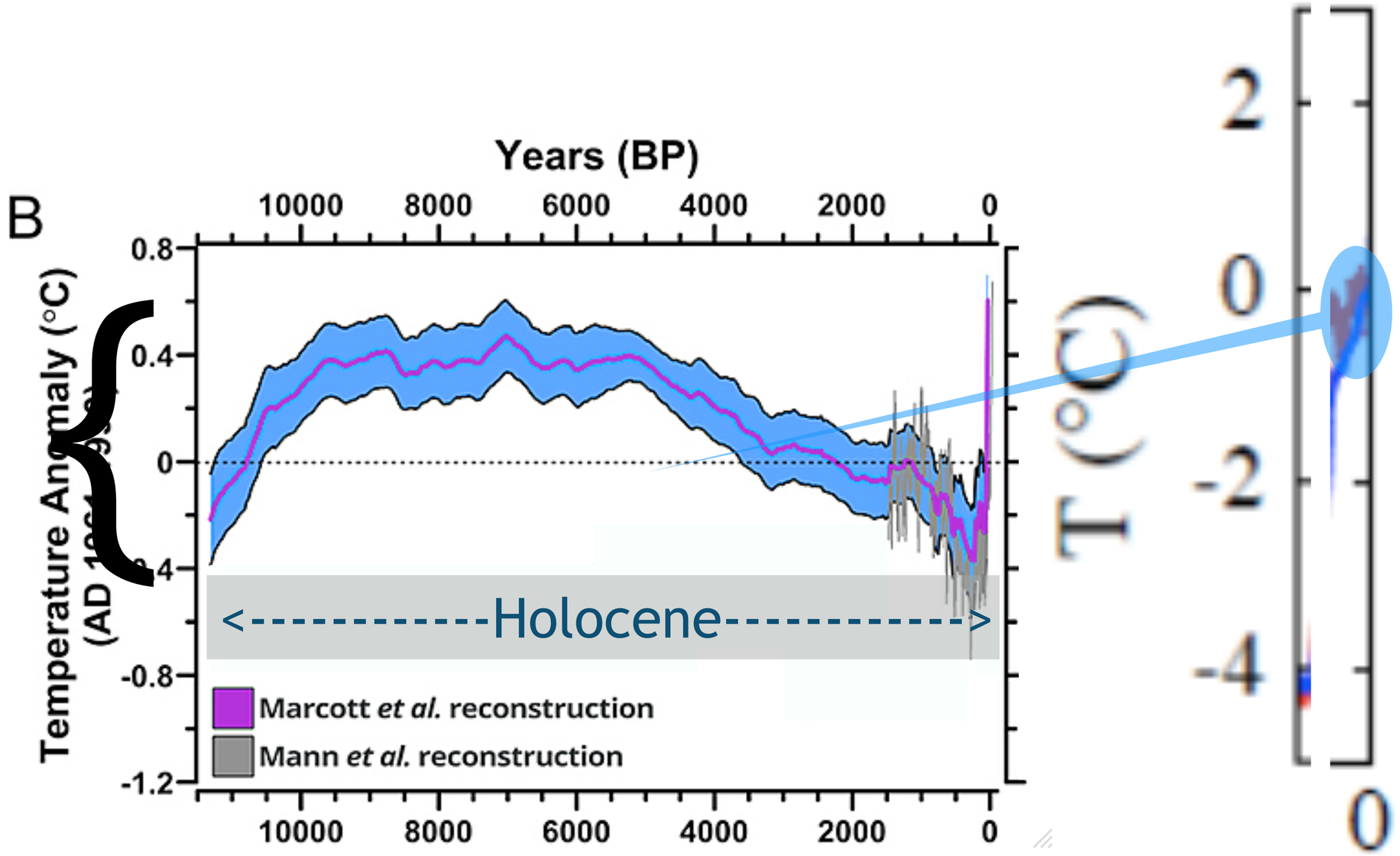


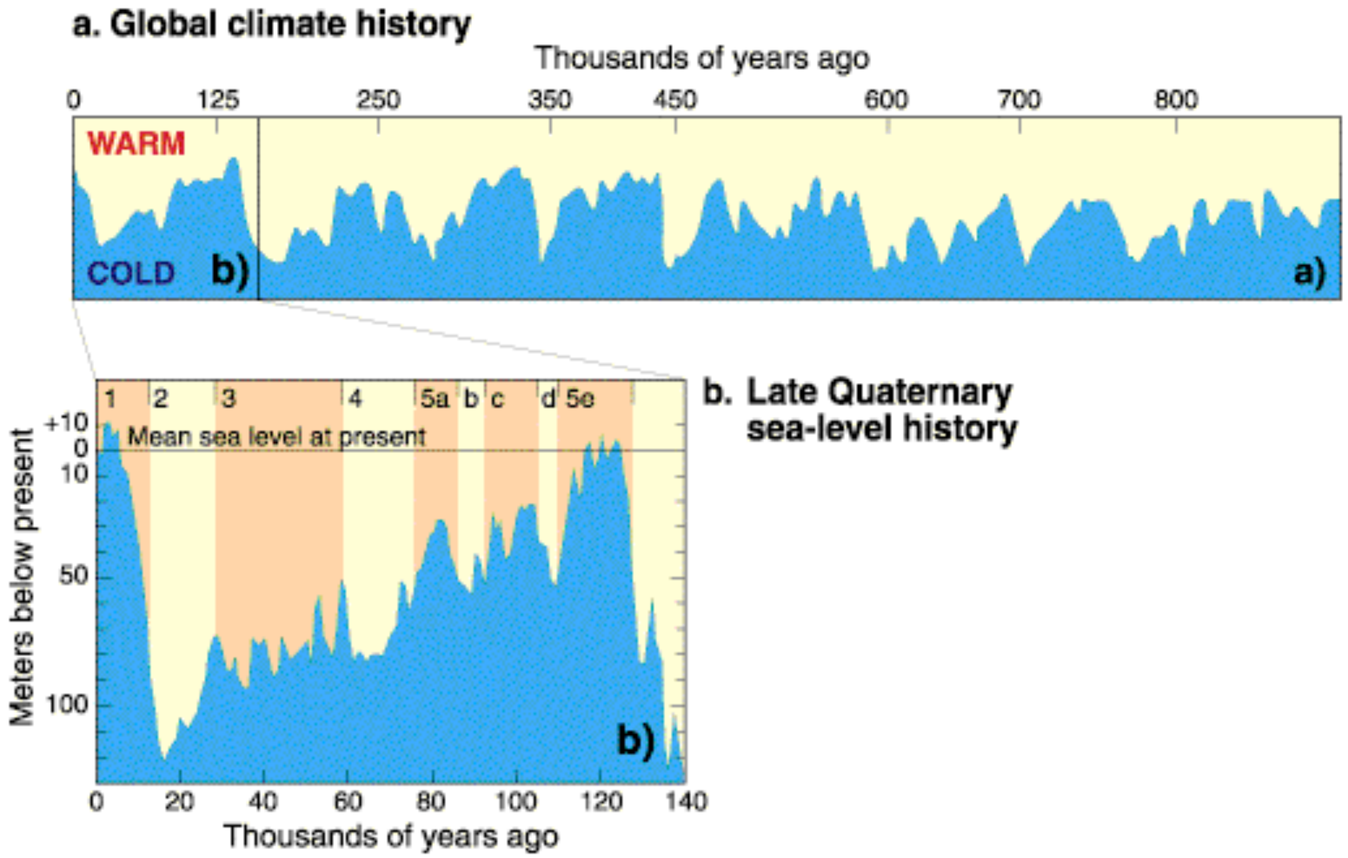
The Baseline: Past Climate and Global Change

Total range in Holocene: ~1°C



The Baseline: Past Climate and Global Change

Sea Level And Temperature



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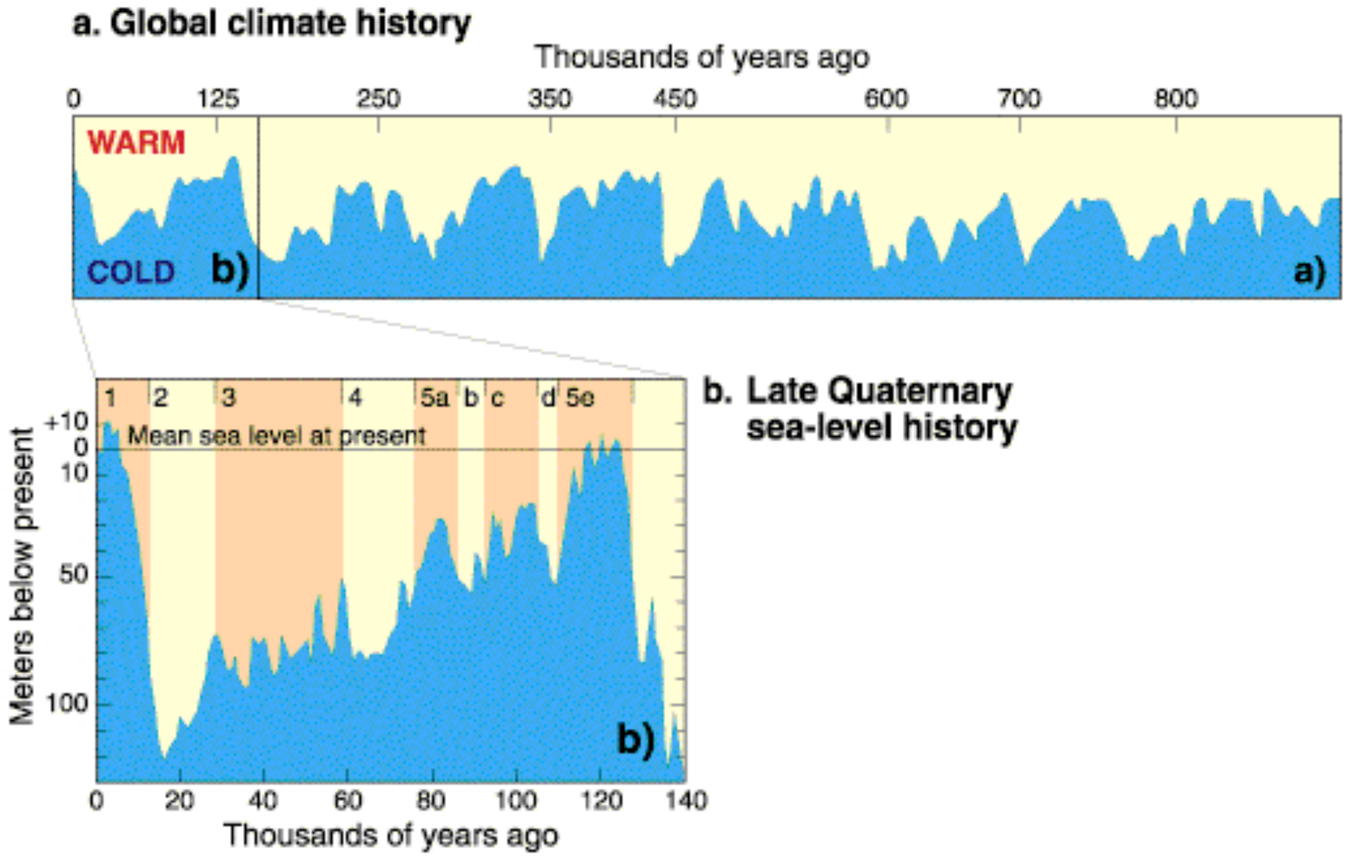
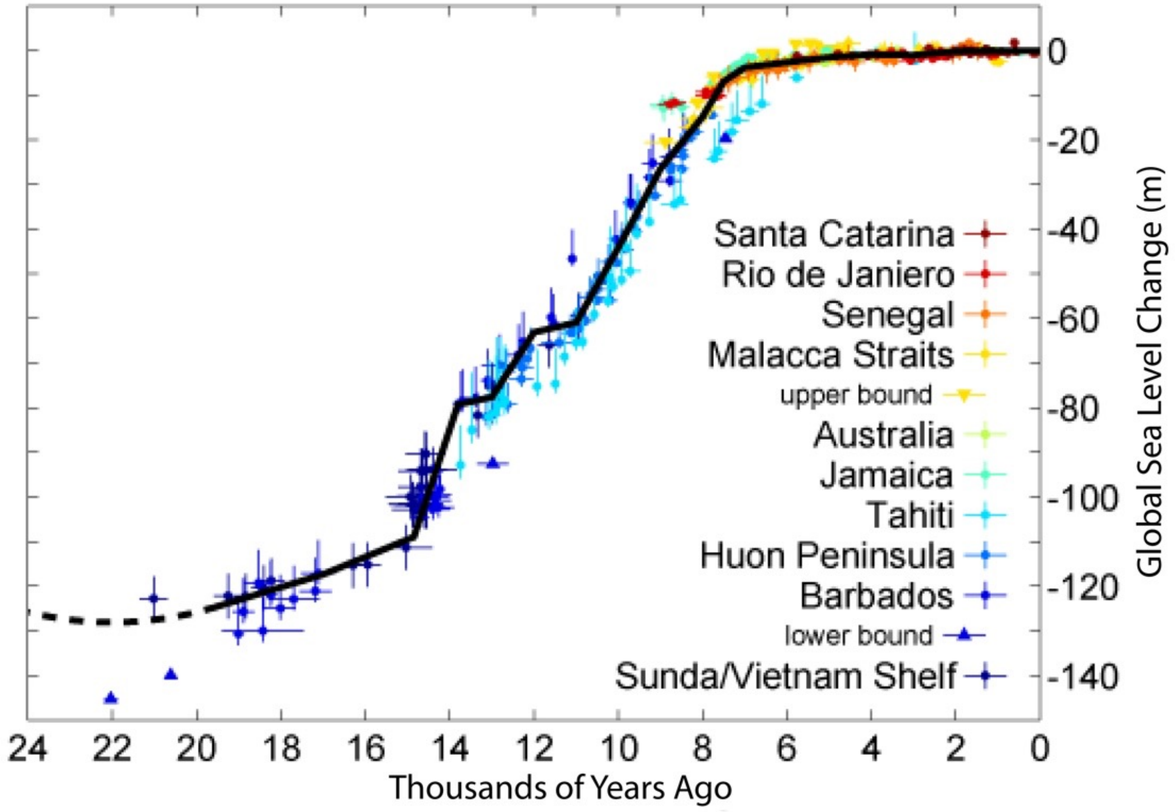


Warmer Climate means Higher Sea Level

Global and Local Sea Level Changes

The Baseline: Past Climate and Global Change

Global and Local Sea Level Changes



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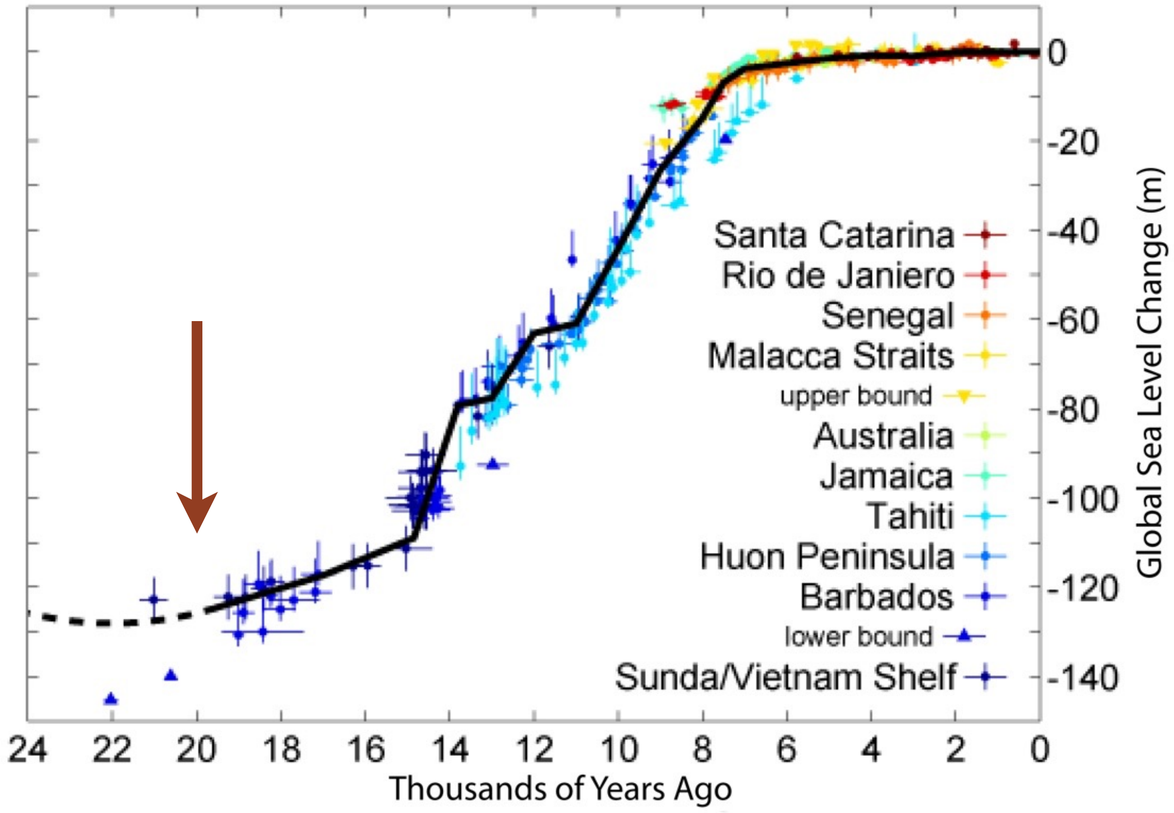
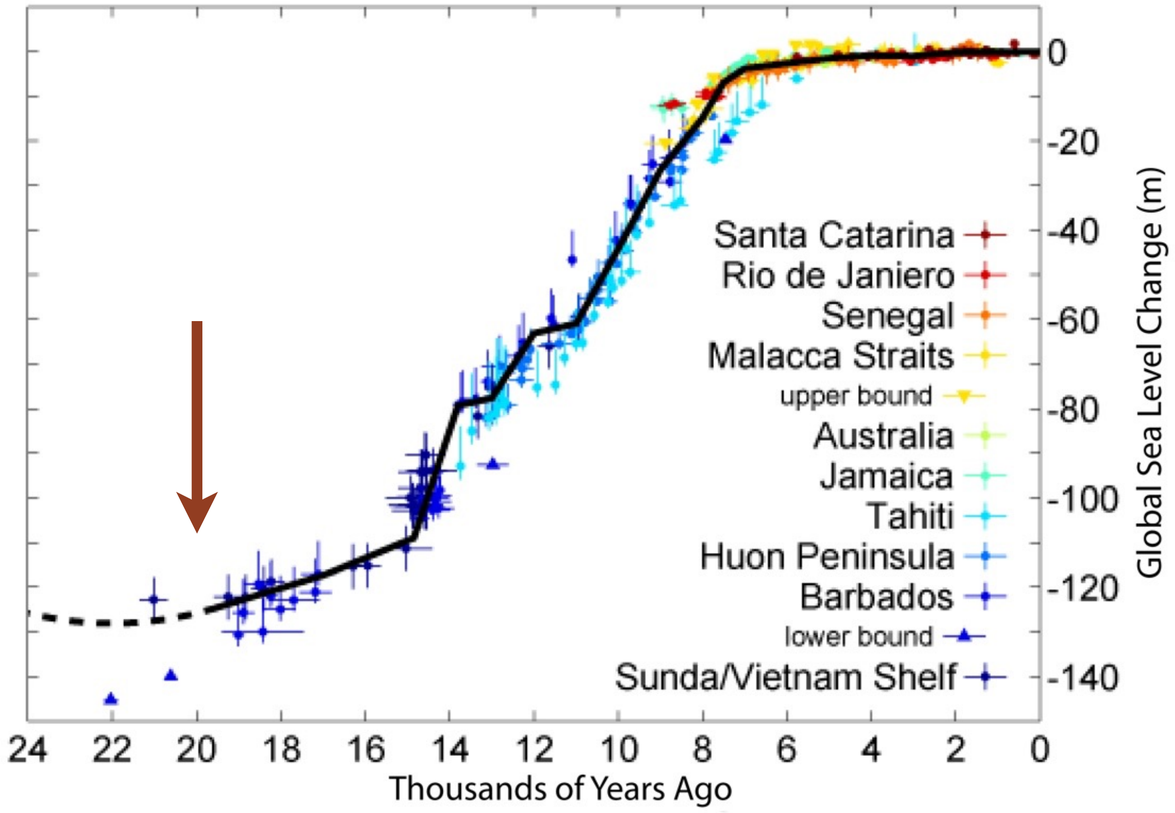


20,000 years ago, sea level in Northern America and Scandinavia was up to 600 m higher than today, and in some other location 200 m lower

Global and Local Sea Level Changes



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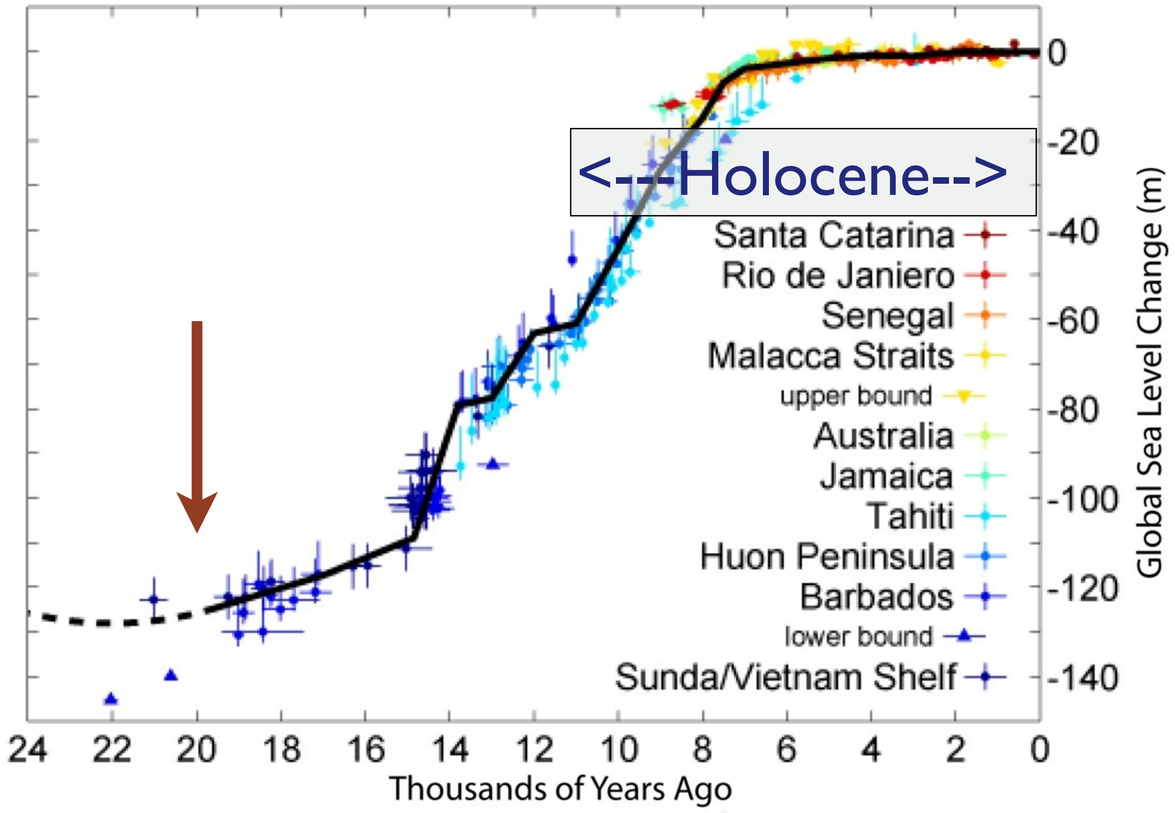
Local Sea Level changes can be much larger than the global average changes.

Global and Local Sea Level Changes



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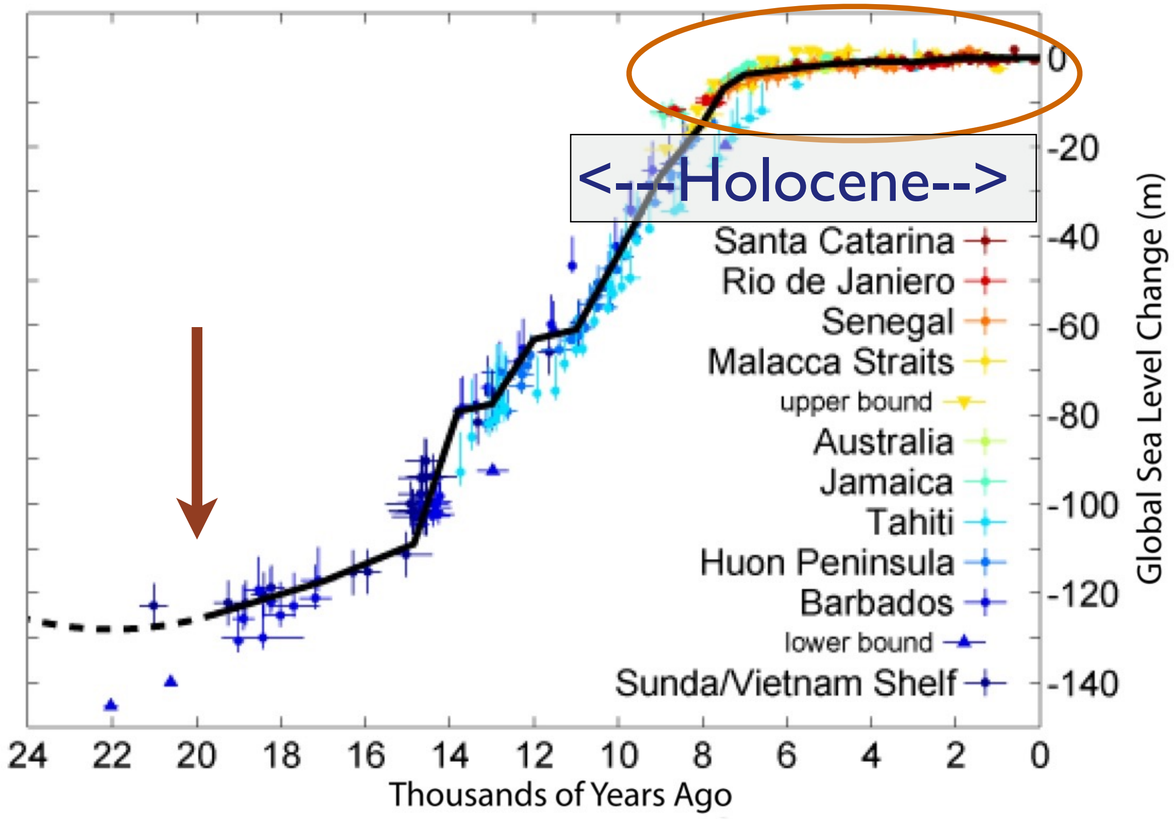

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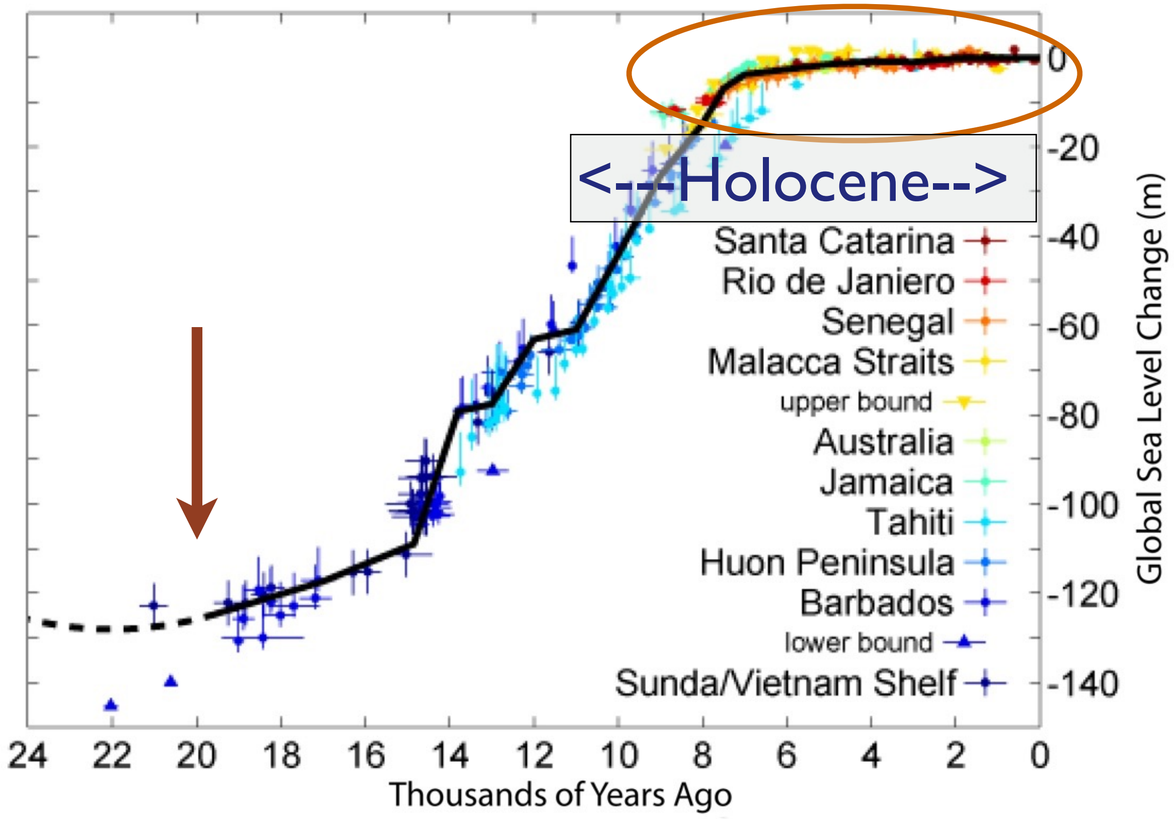
During the last 7,000 years, global (and local) sea level was exceptionally stable

Global and Local Sea Level Changes



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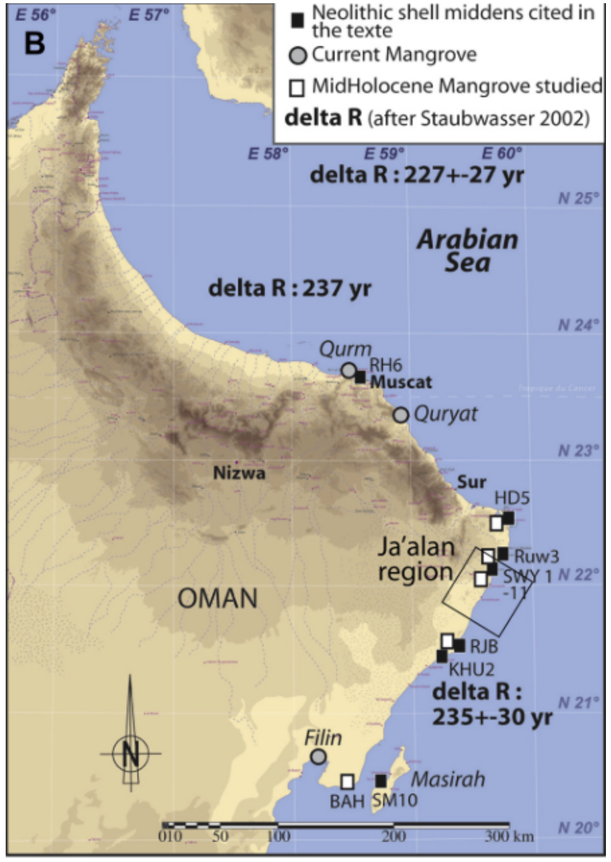
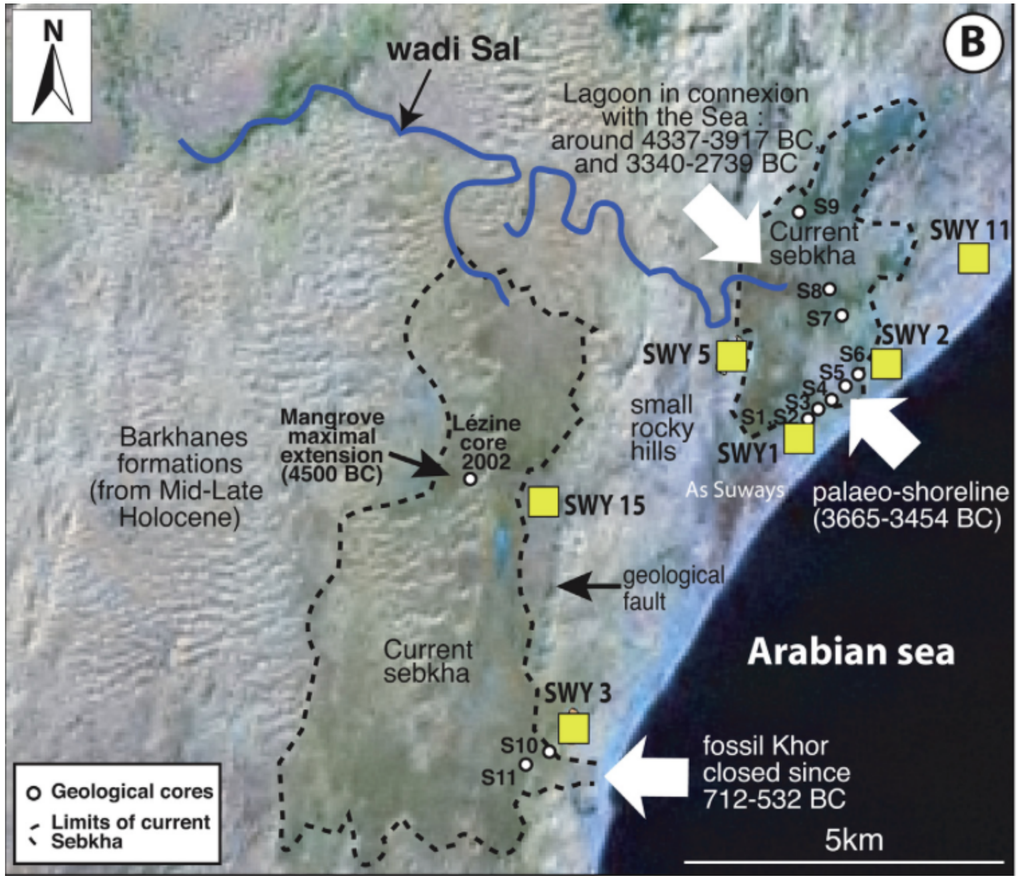
Sea Level changes can be much larger than what we know from our history.

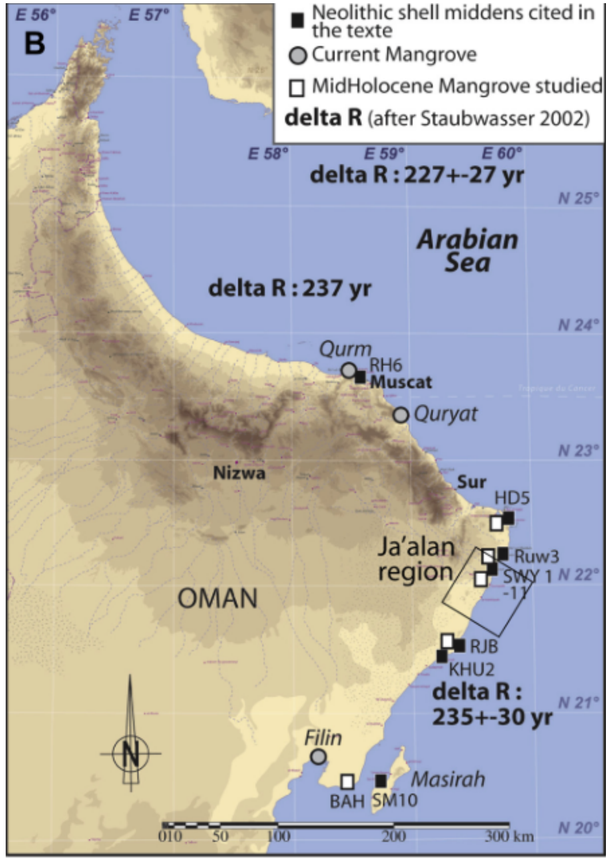
The Baseline: Past Climate and Global Change

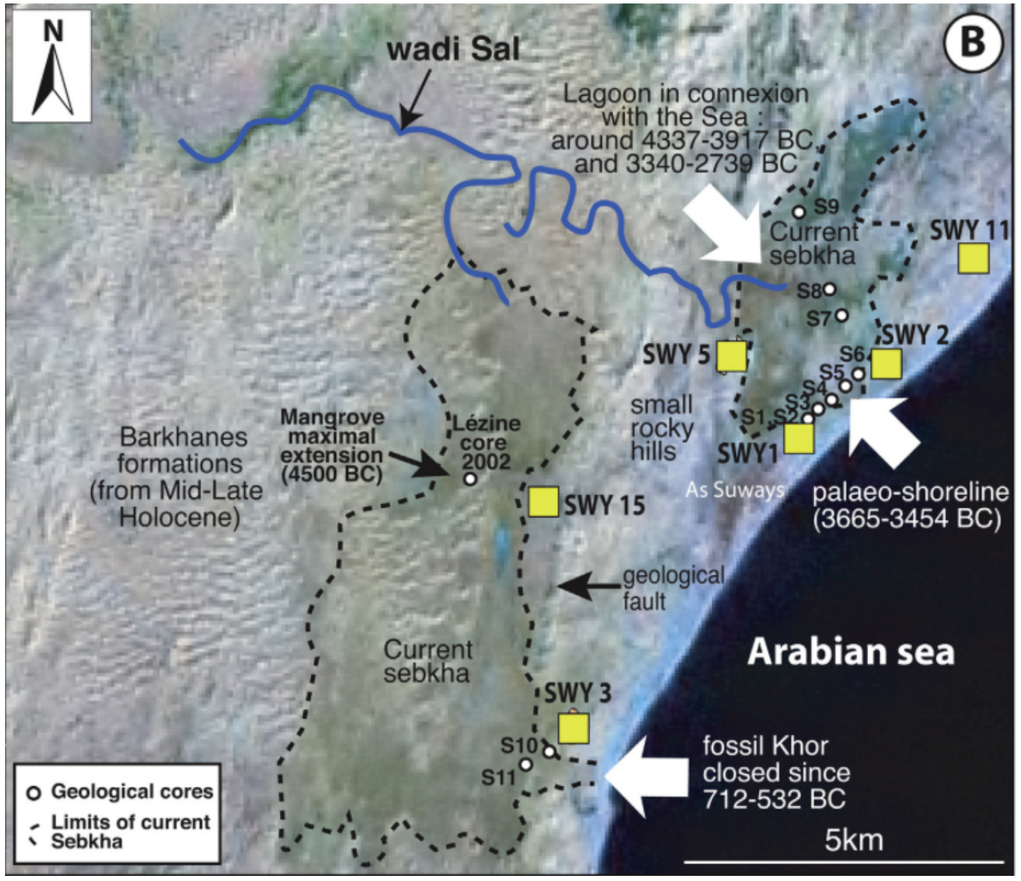




The Baseline: Past Climate and Global Change

Small changes in sea level caused large changes in coastal ecosystems





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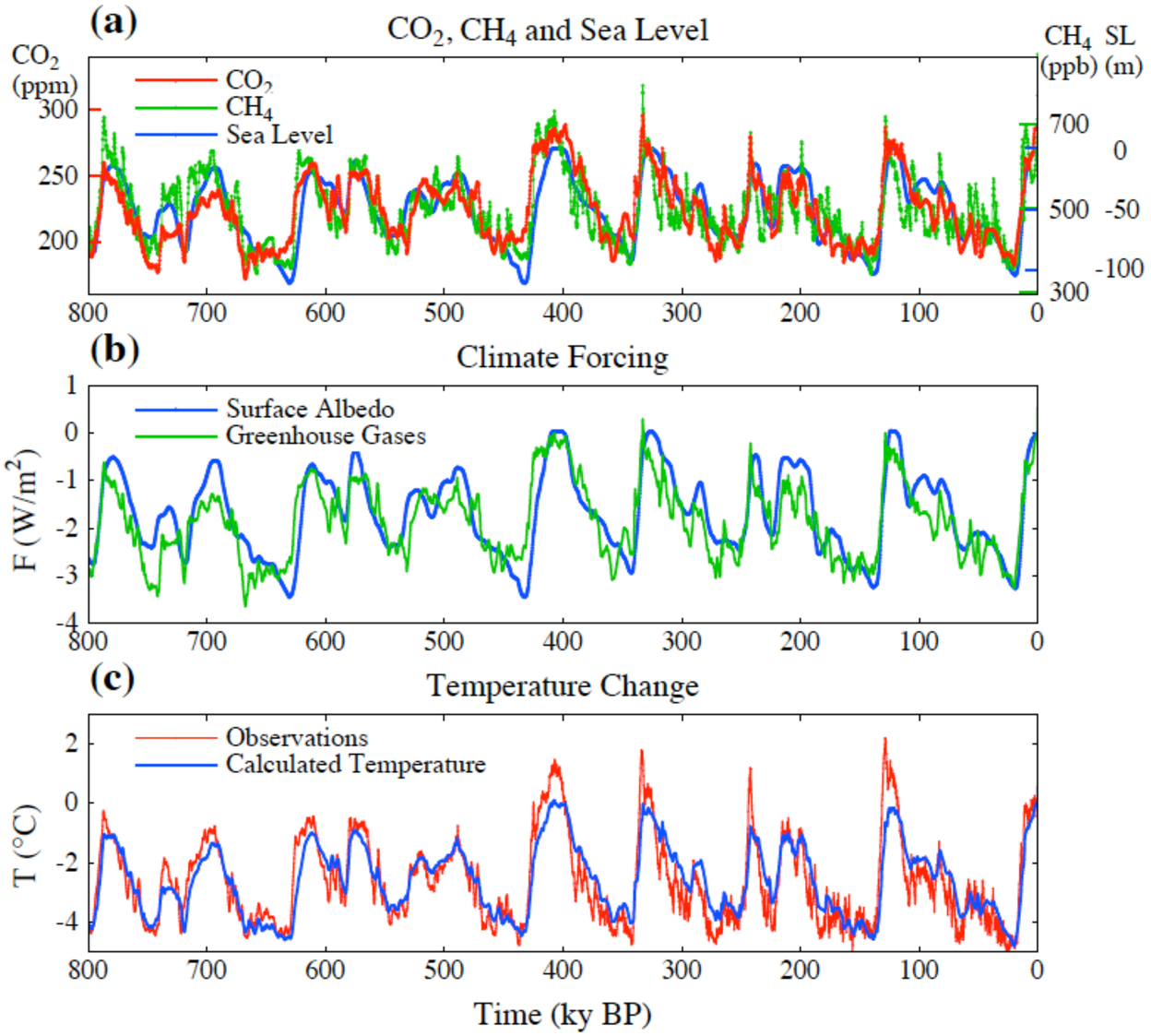
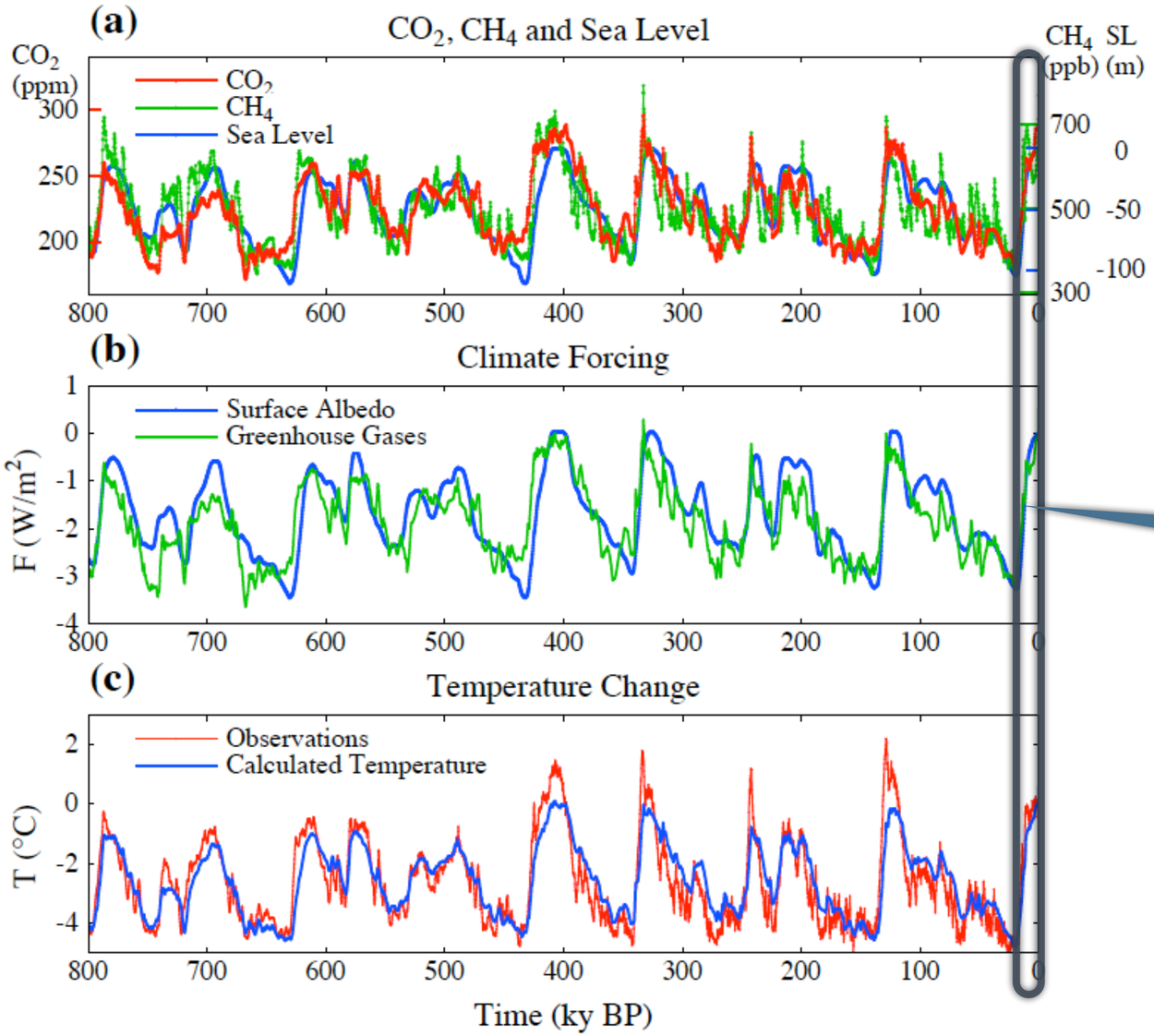
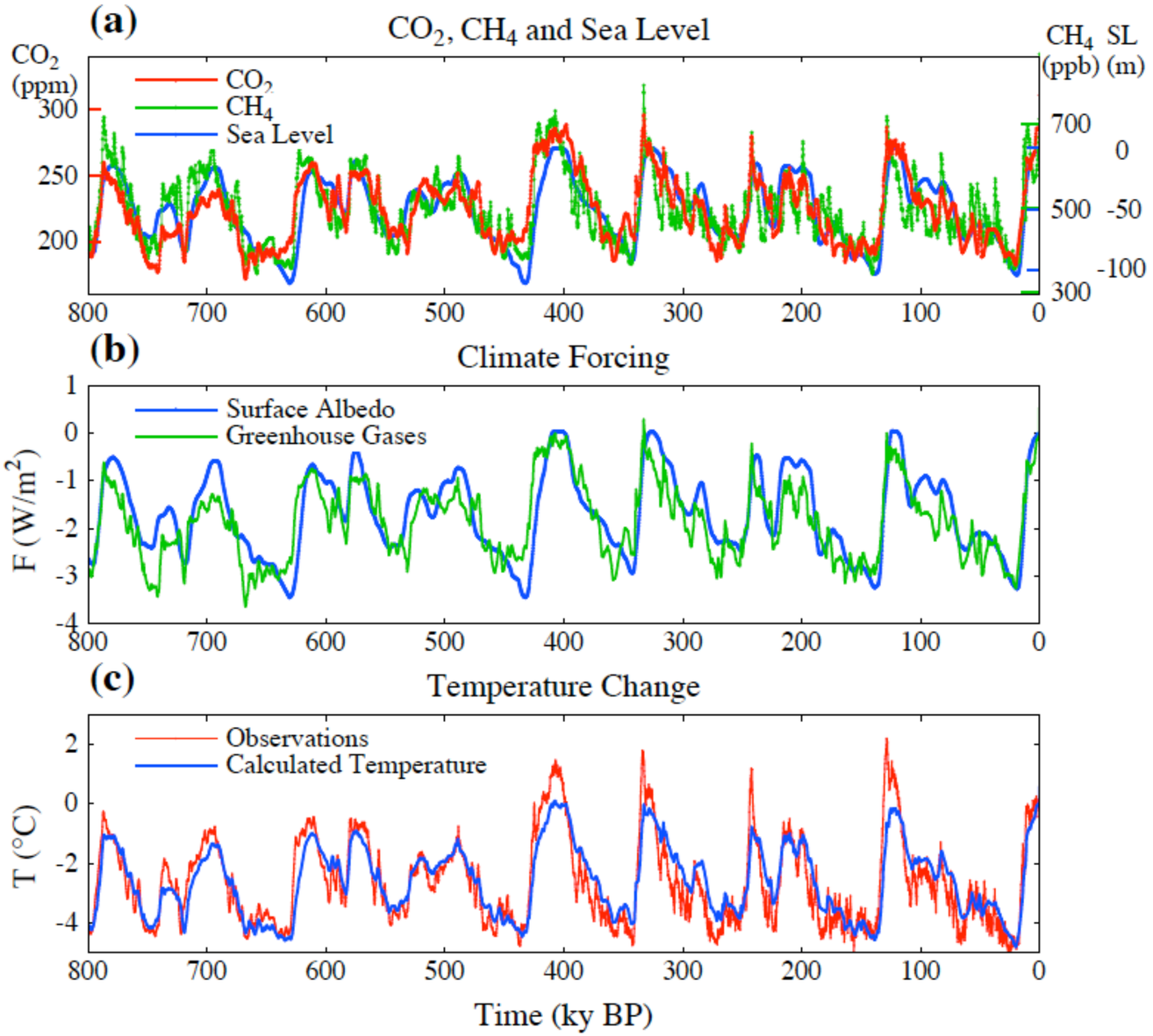


A “Safe Operating Space for Humanity”



The Holocene had unusually stable climate and sea levels; a perfect condition for the development of civilizations.

The Baseline: Past Climate and Global Change



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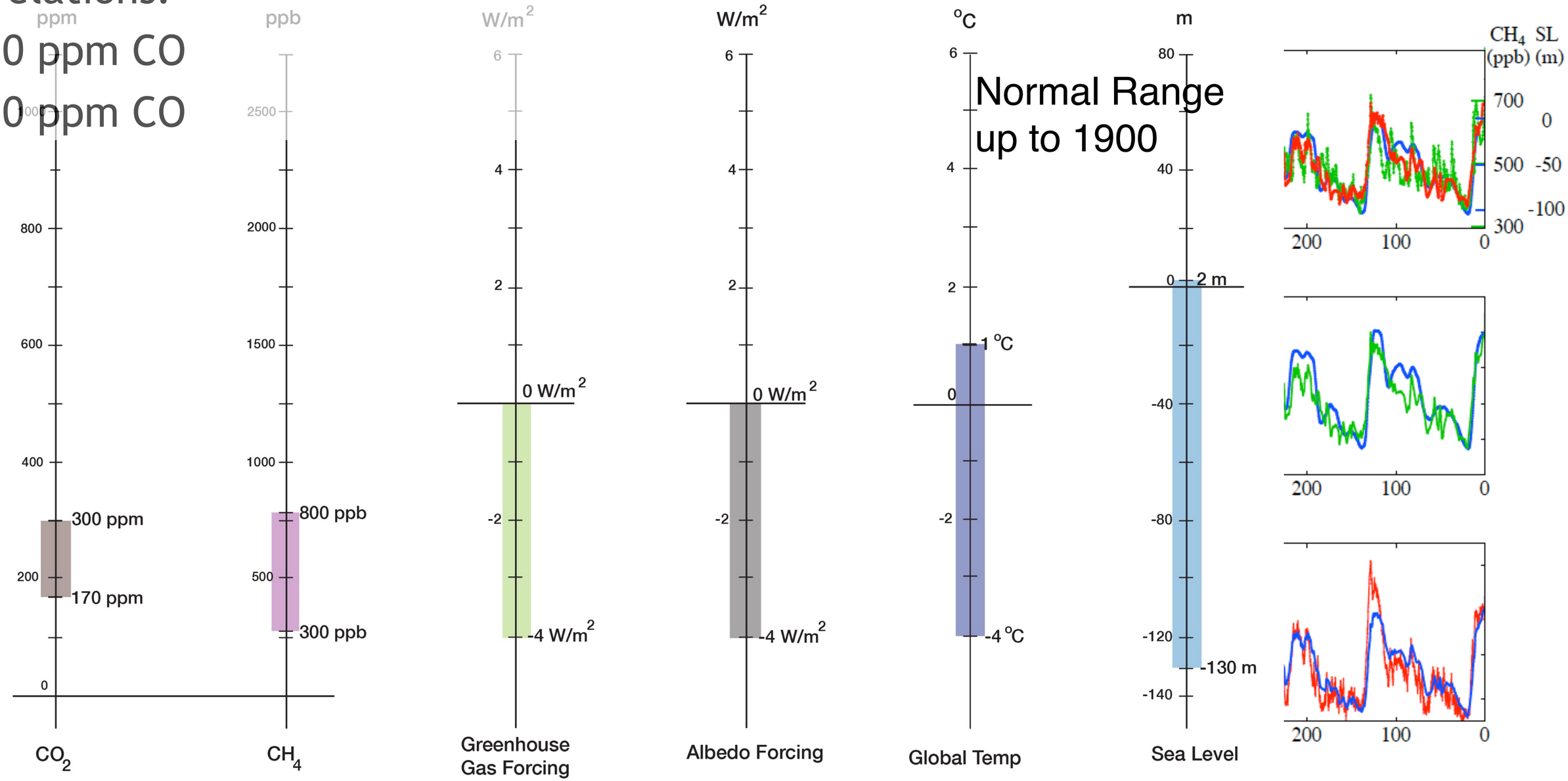

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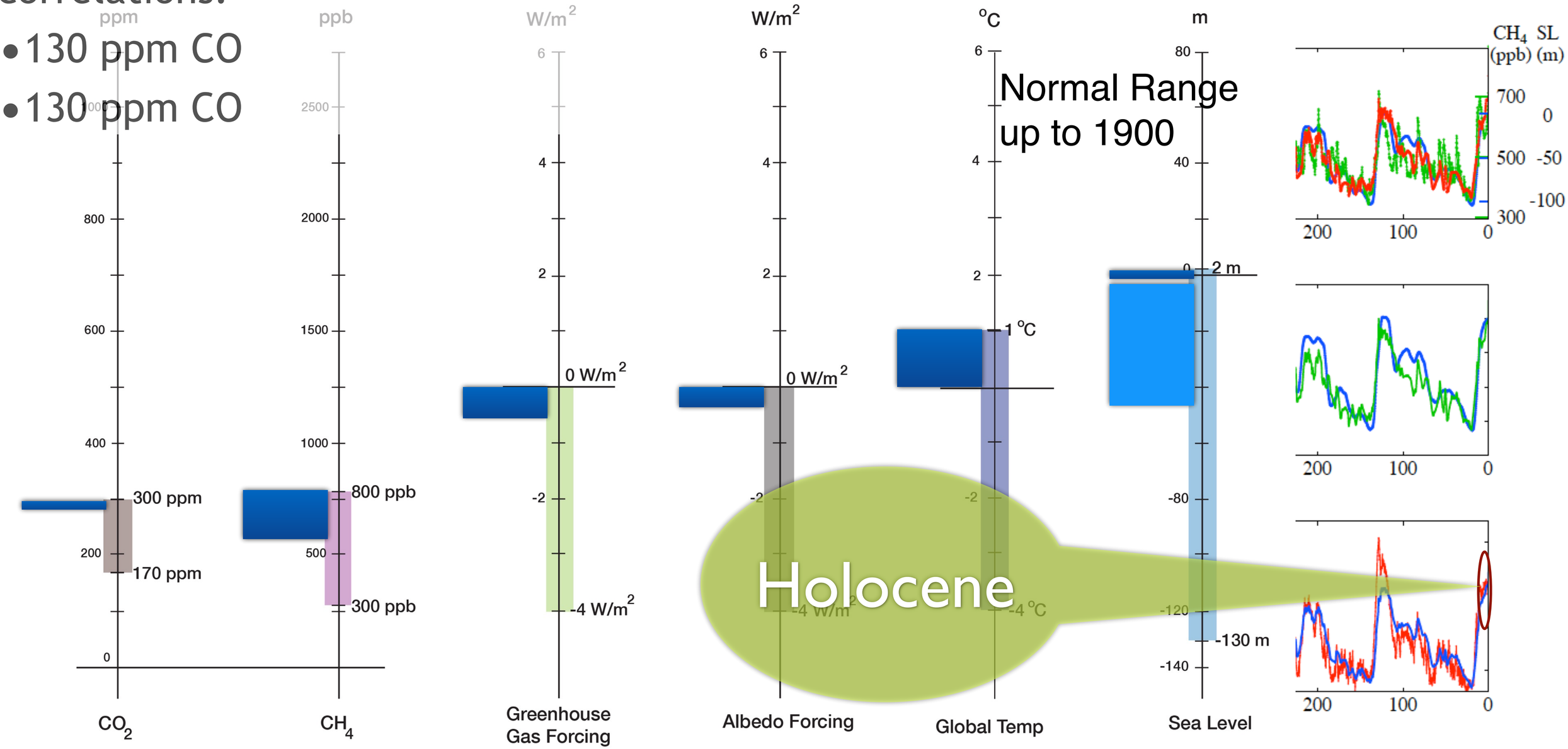

Humankind has grown

- in number …

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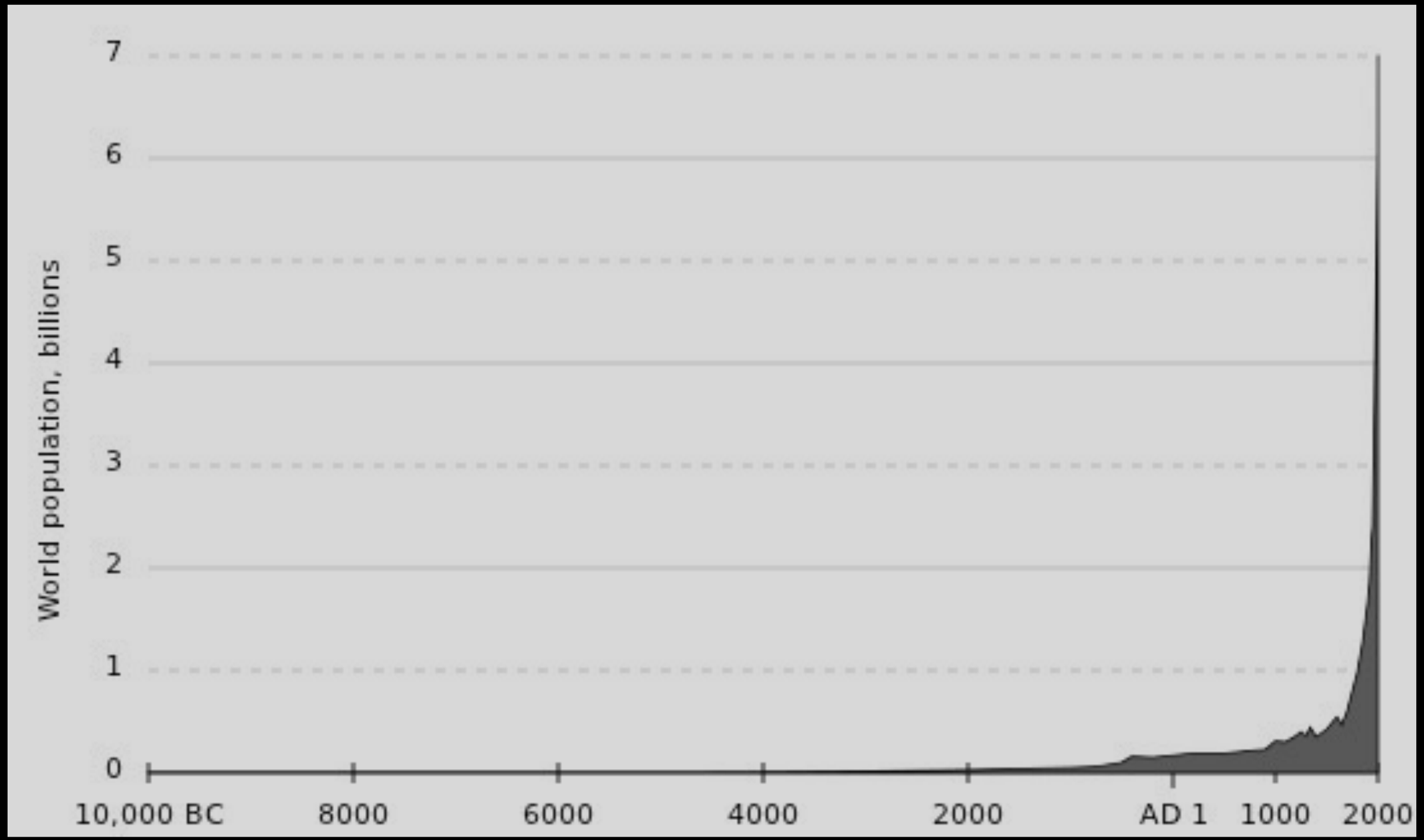

Humankind has grown

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- in activity: example deforestation…

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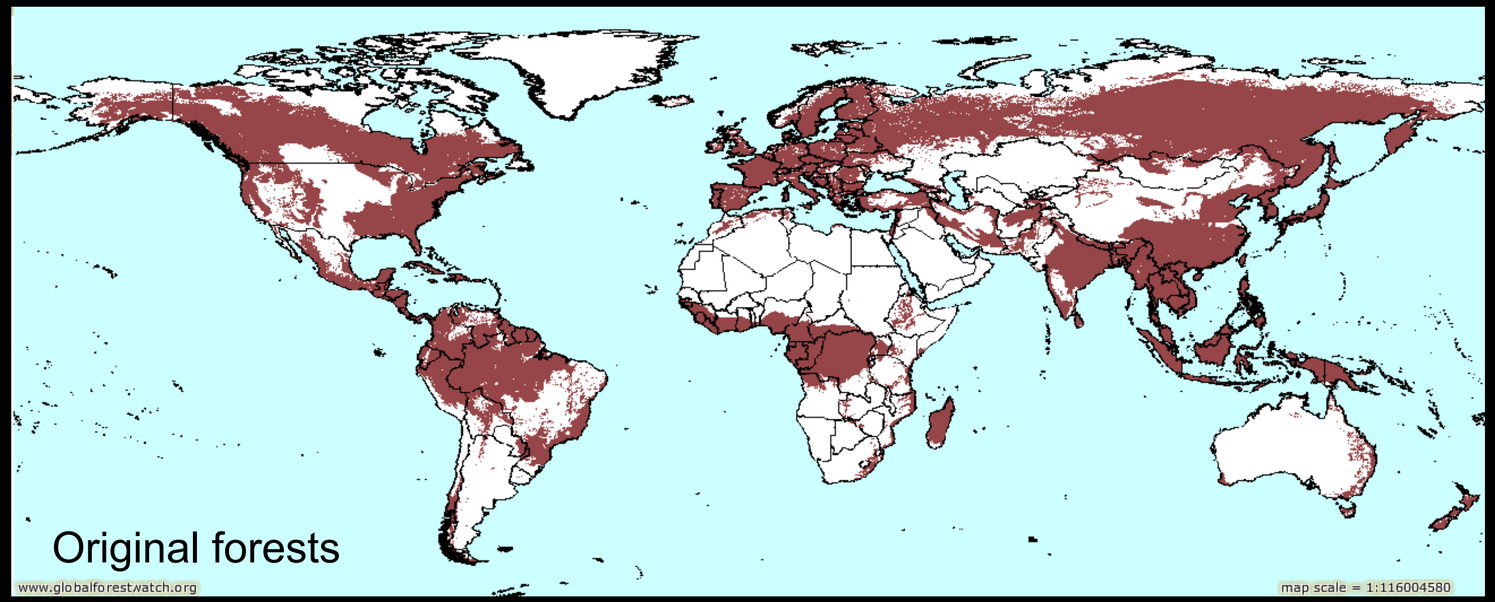

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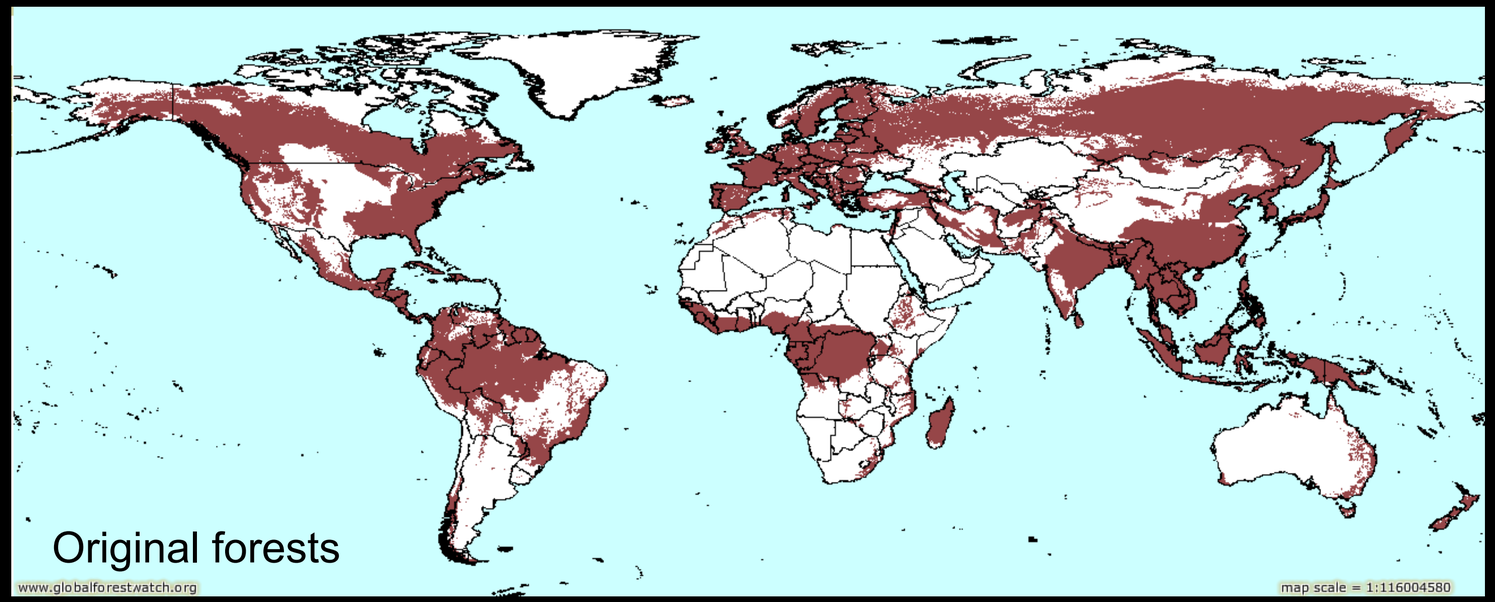
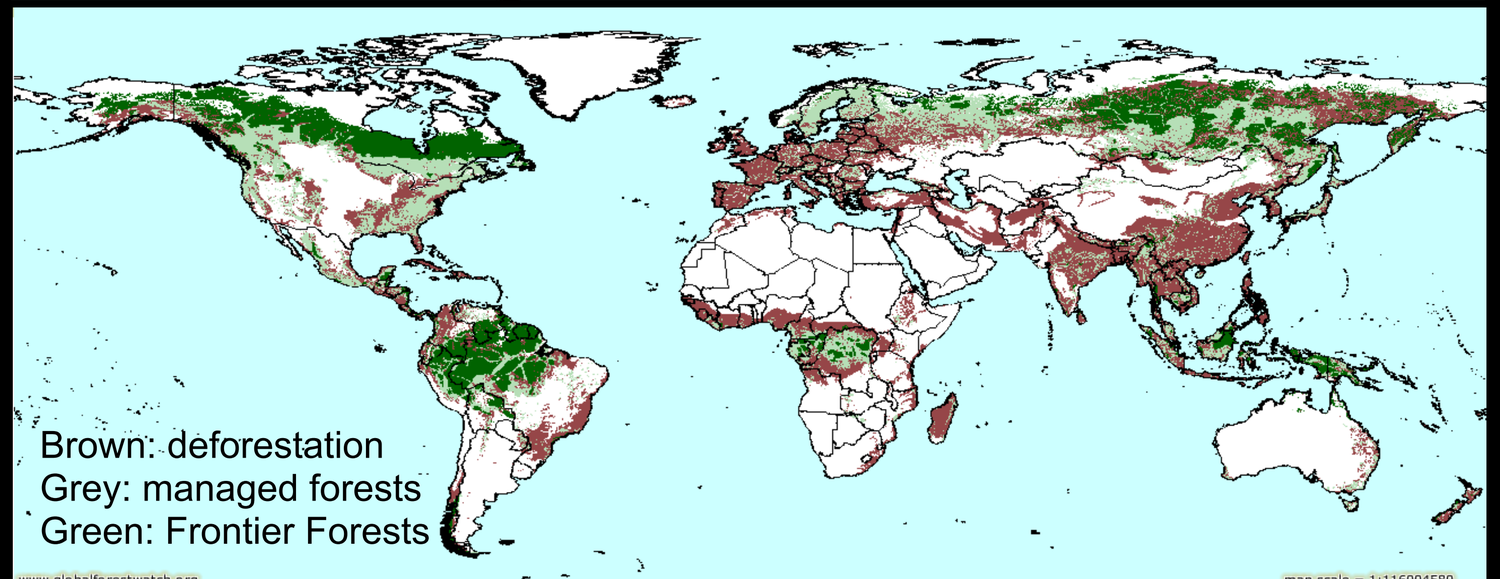
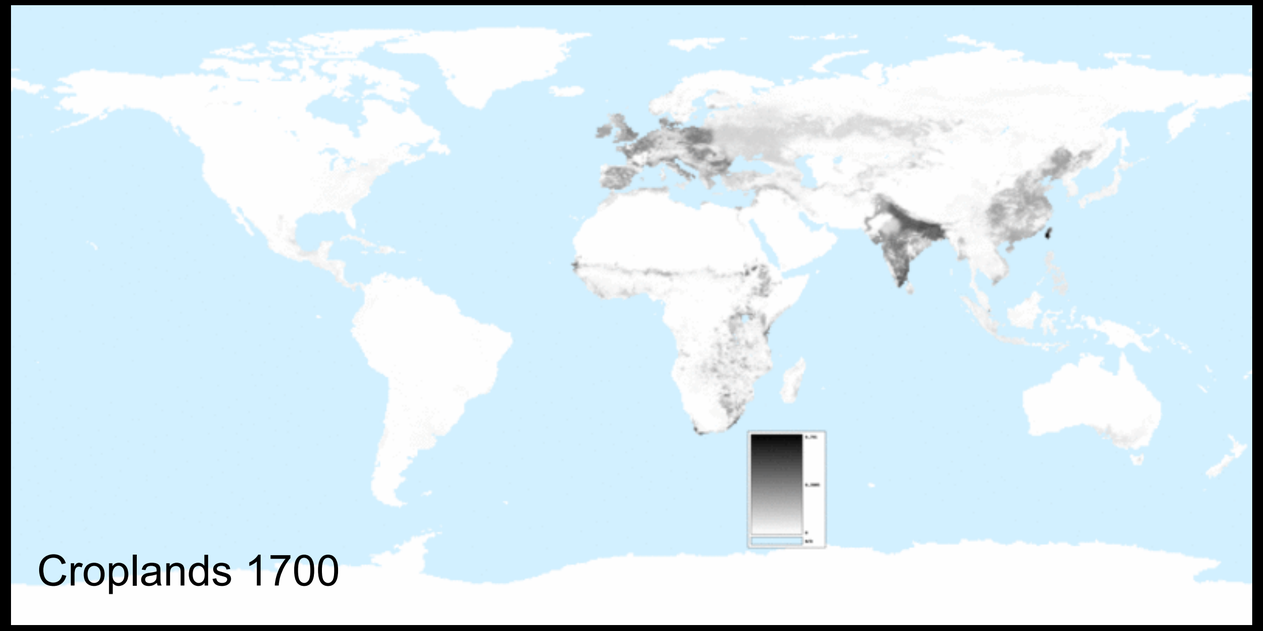




- About 50% of the original forests are gone;
- Only 20% of frontier forests remain

Humankind has grown

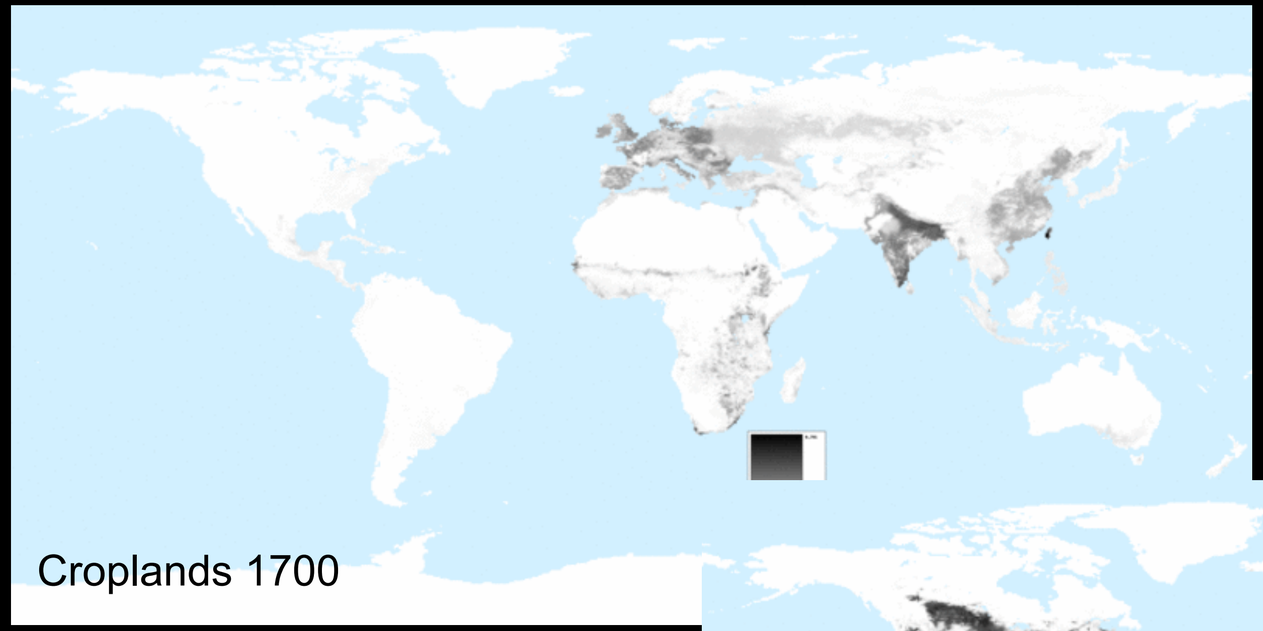
- in number …
- in activity: example land use…



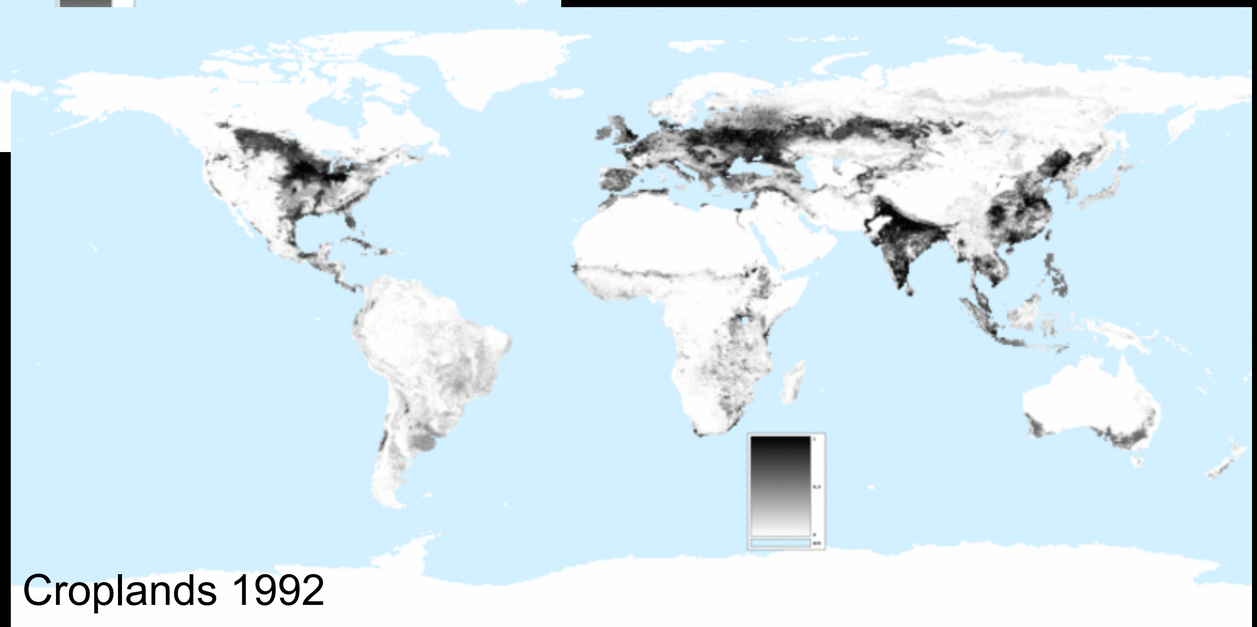
- More than 50% of the ice-free surface of the solid Earth is modified and managed by human activities

Humankind has grown

- in number …
- in activity: example land use…



Croplands 1700



Croplands 1992

- More than 50% of the ice-free surface of the solid Earth is modified and managed by human activities

Humankind has grown

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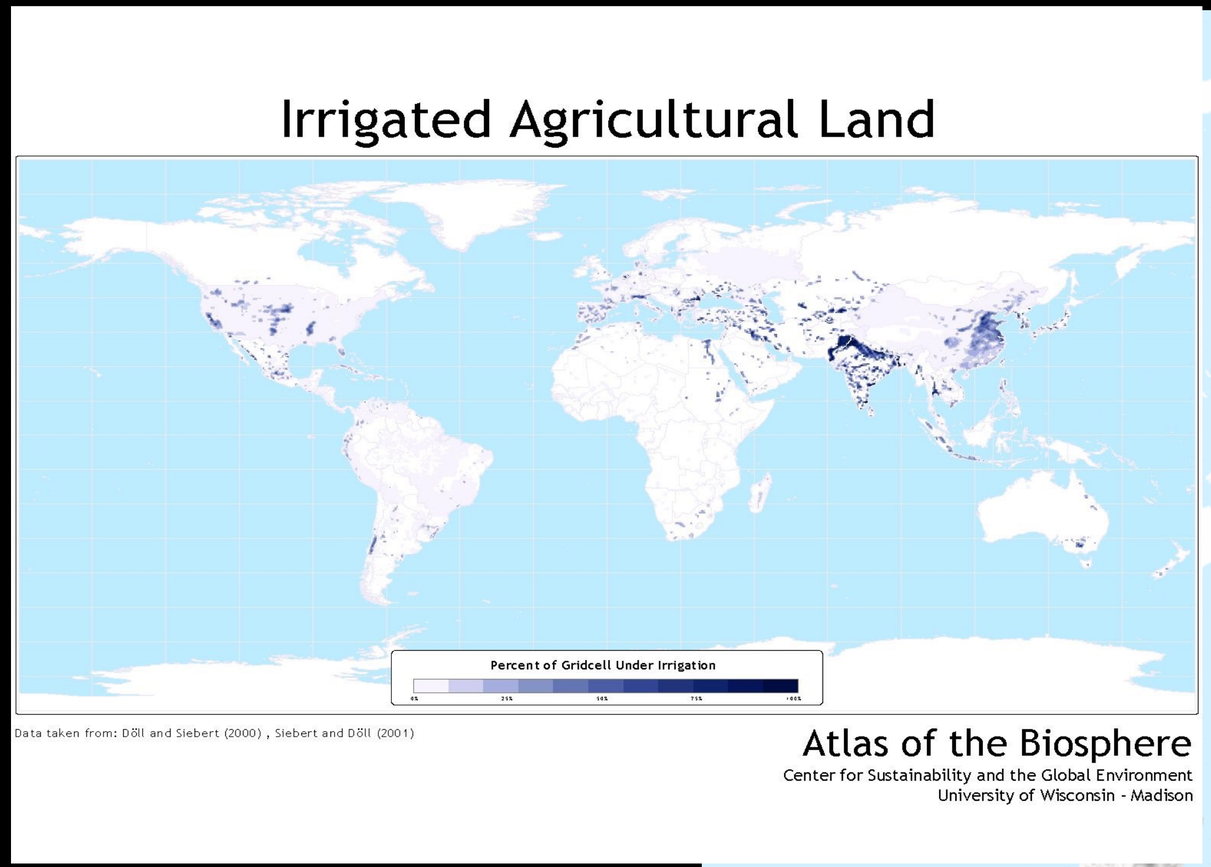
- in activity: example land use…



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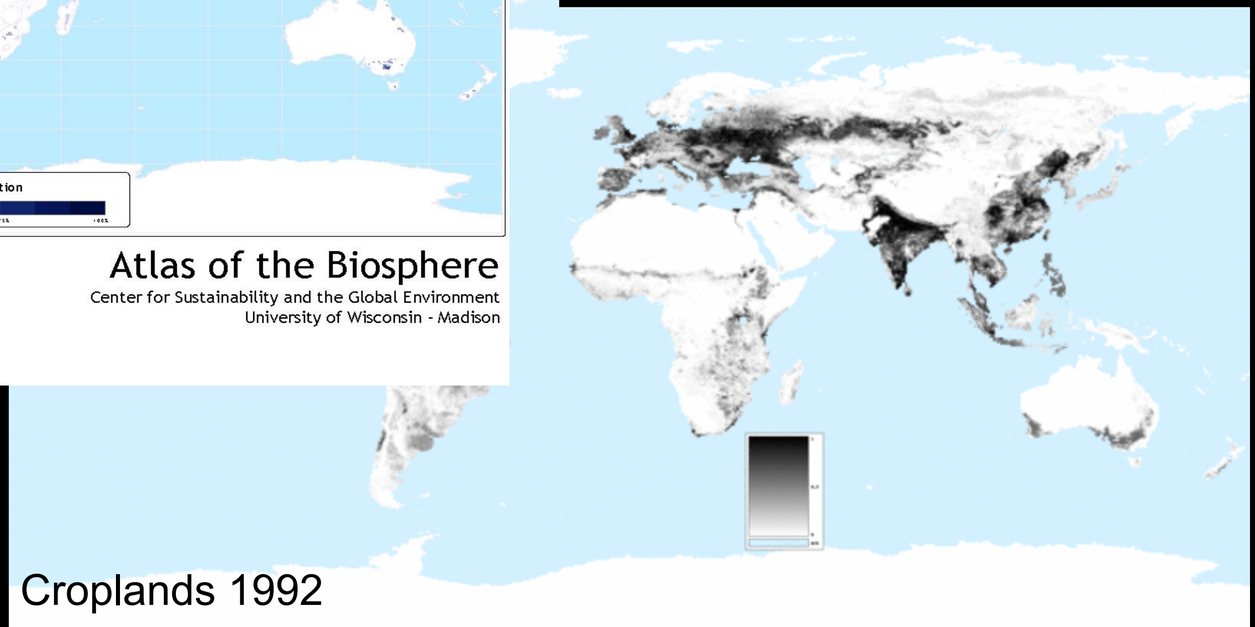
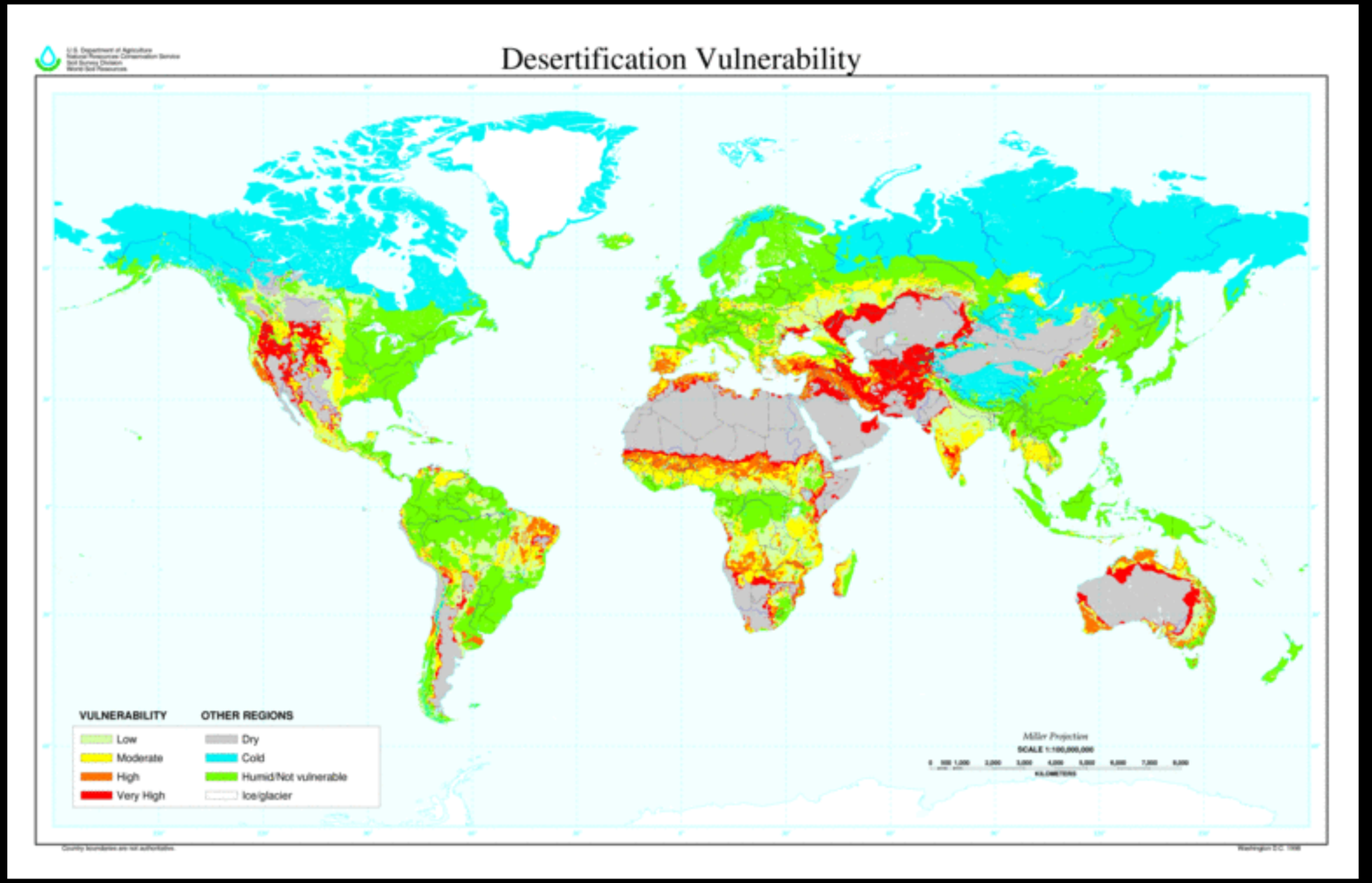


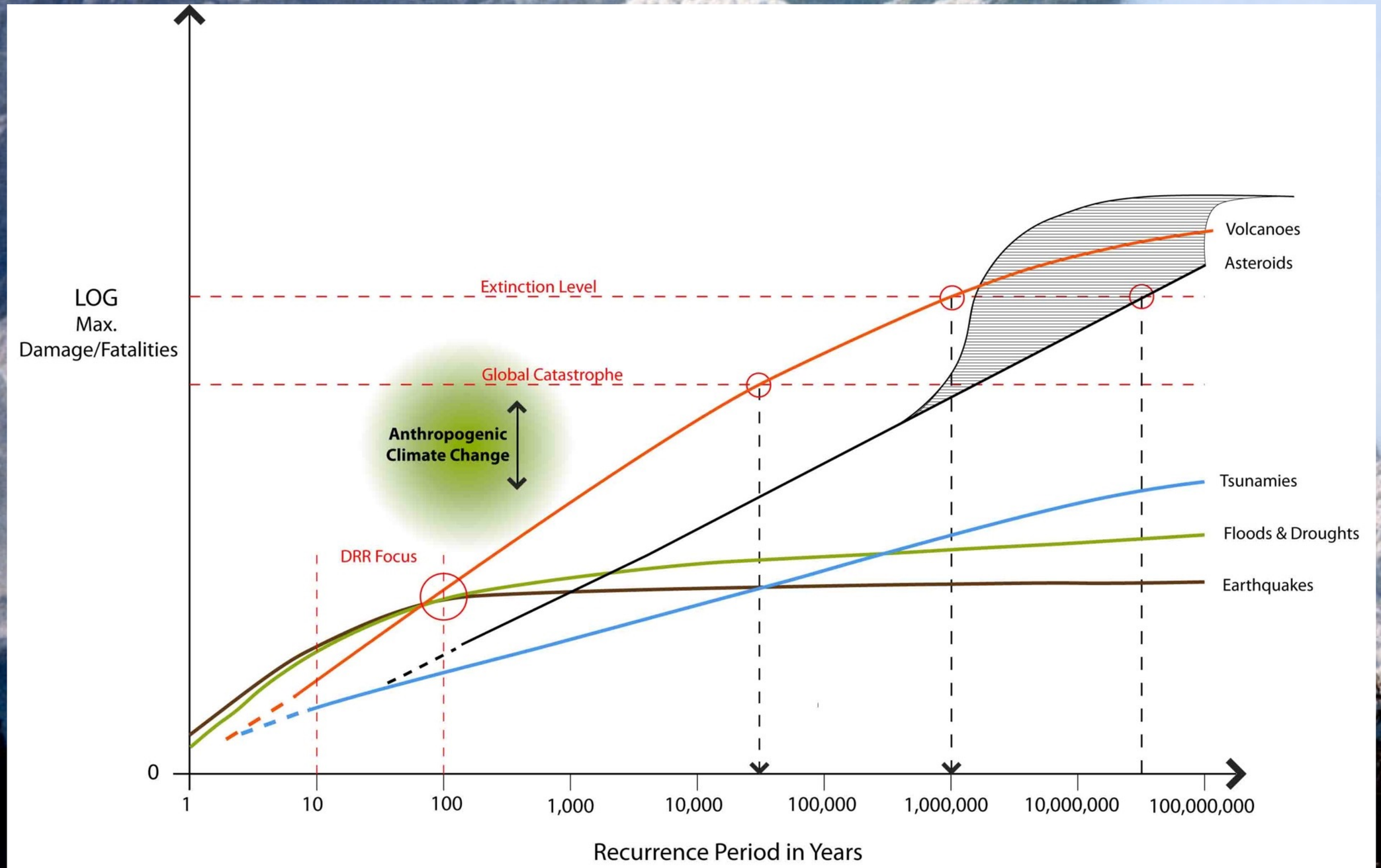
Croplands 1992

Humankind has grown

- *in number …*
- *in activity …*
- *in impact:* *example desertification*



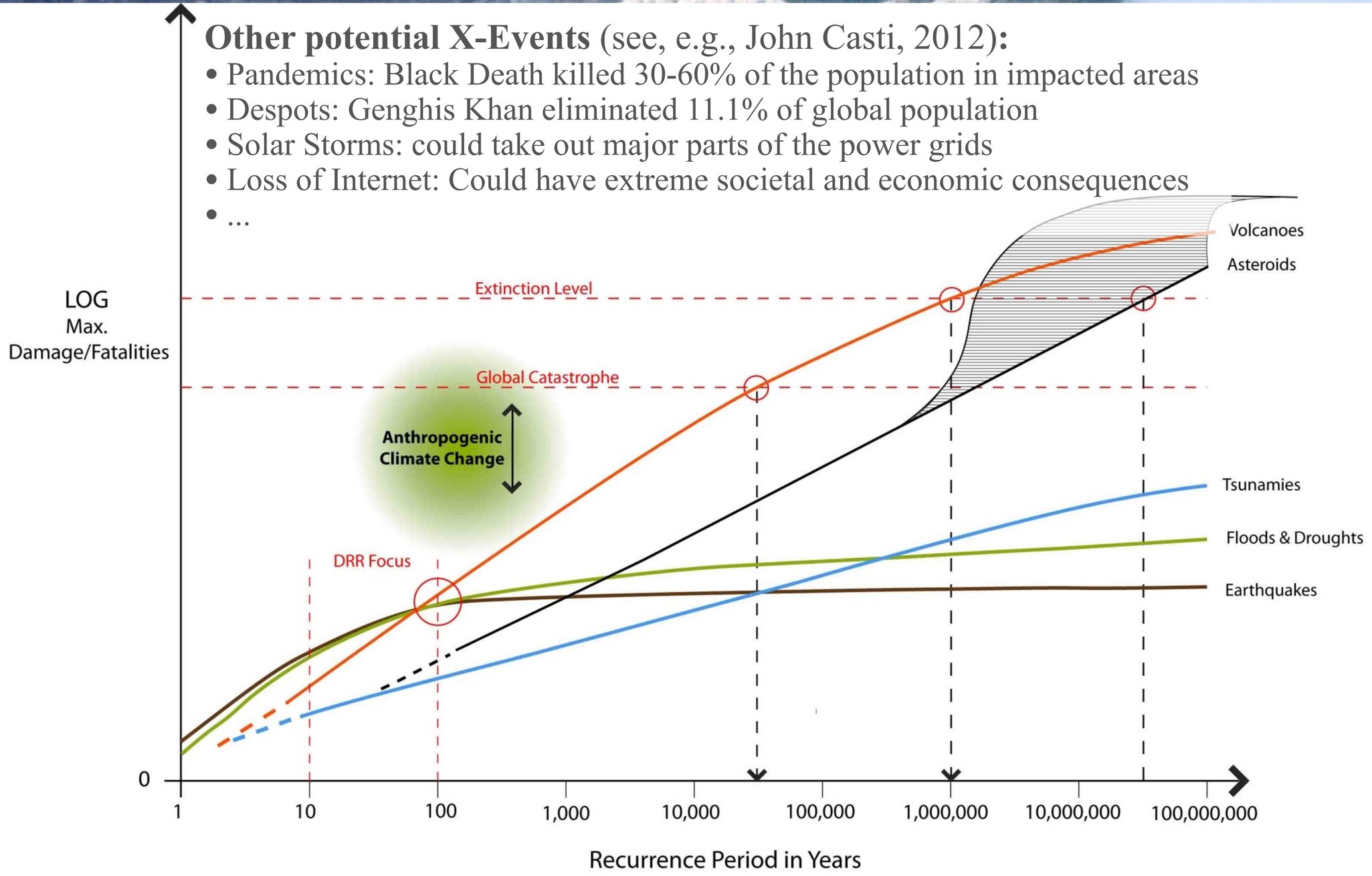
HAZARDS: The Big Picture



HAZARDS: The Big Picture

Other potential X-Events (see, e.g., John Casti, 2012)**:**

- Pandemics: Black Death killed 30-60% of the population in impacted areas
- Despots: Genghis Khan eliminated 11.1% of global population
- Solar Storms: could take out major parts of the power grids
- Loss of Internet: Could have extreme societal and economic consequences
- …



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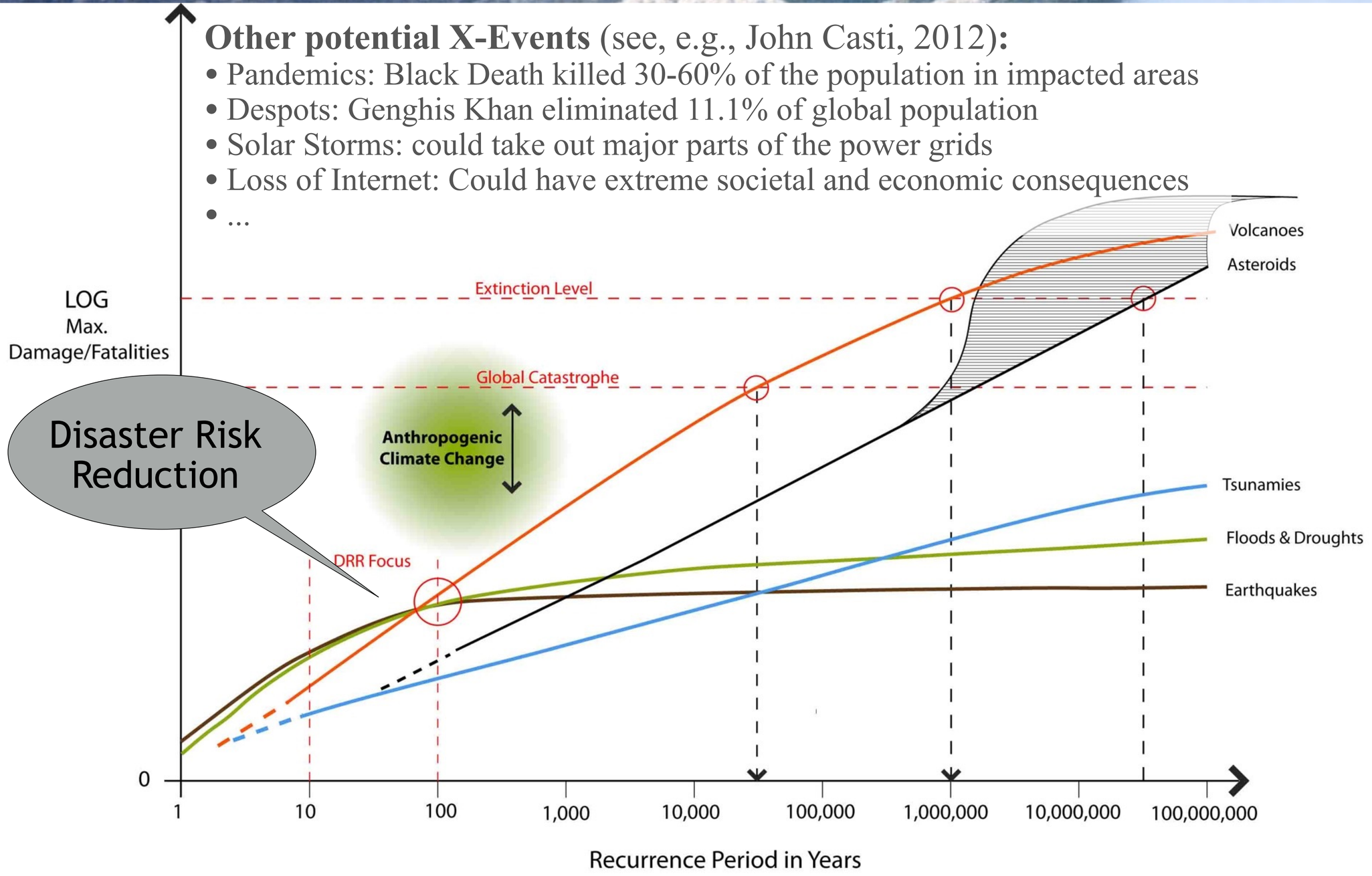

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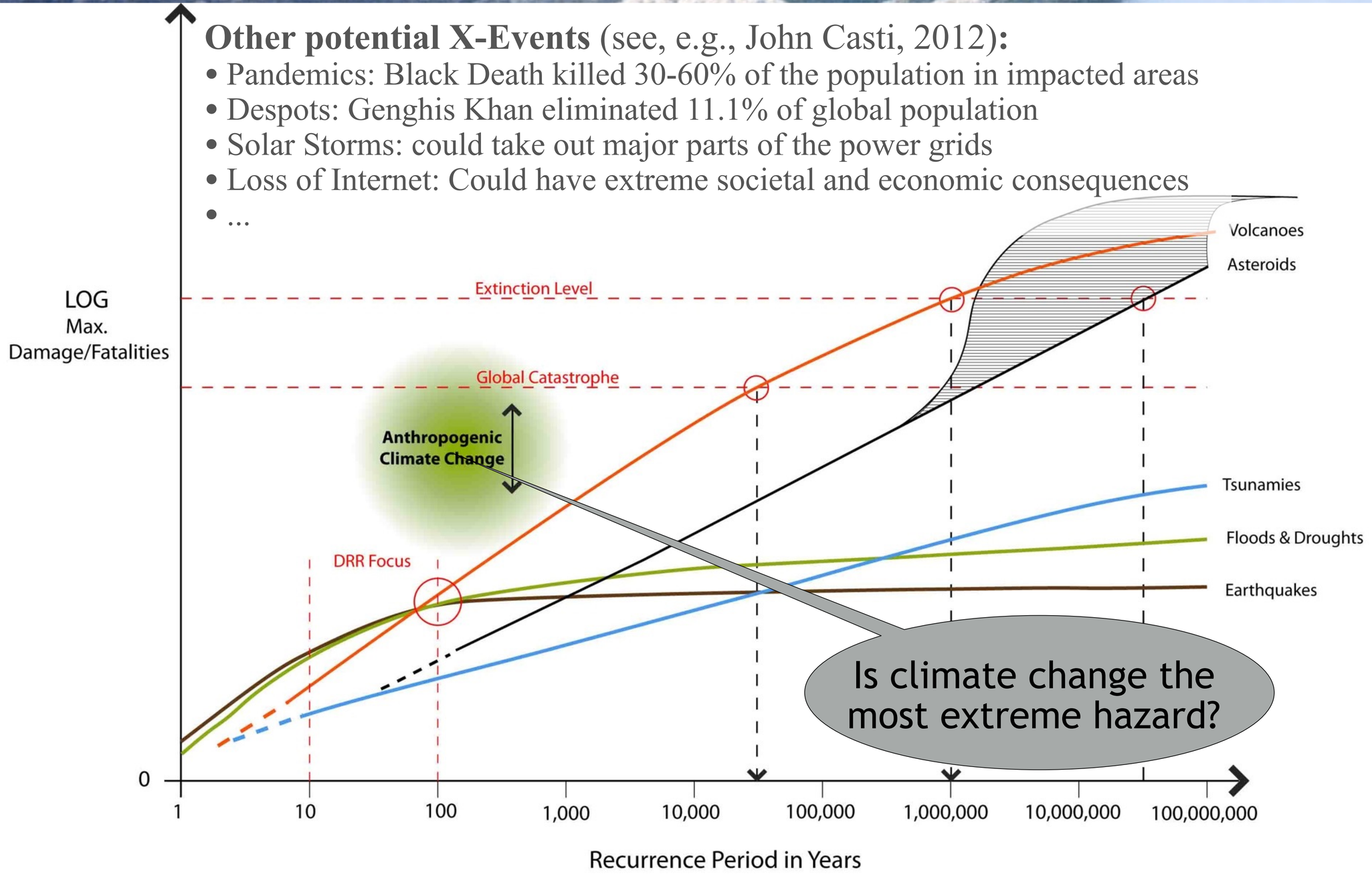

Volcanic Eruptions

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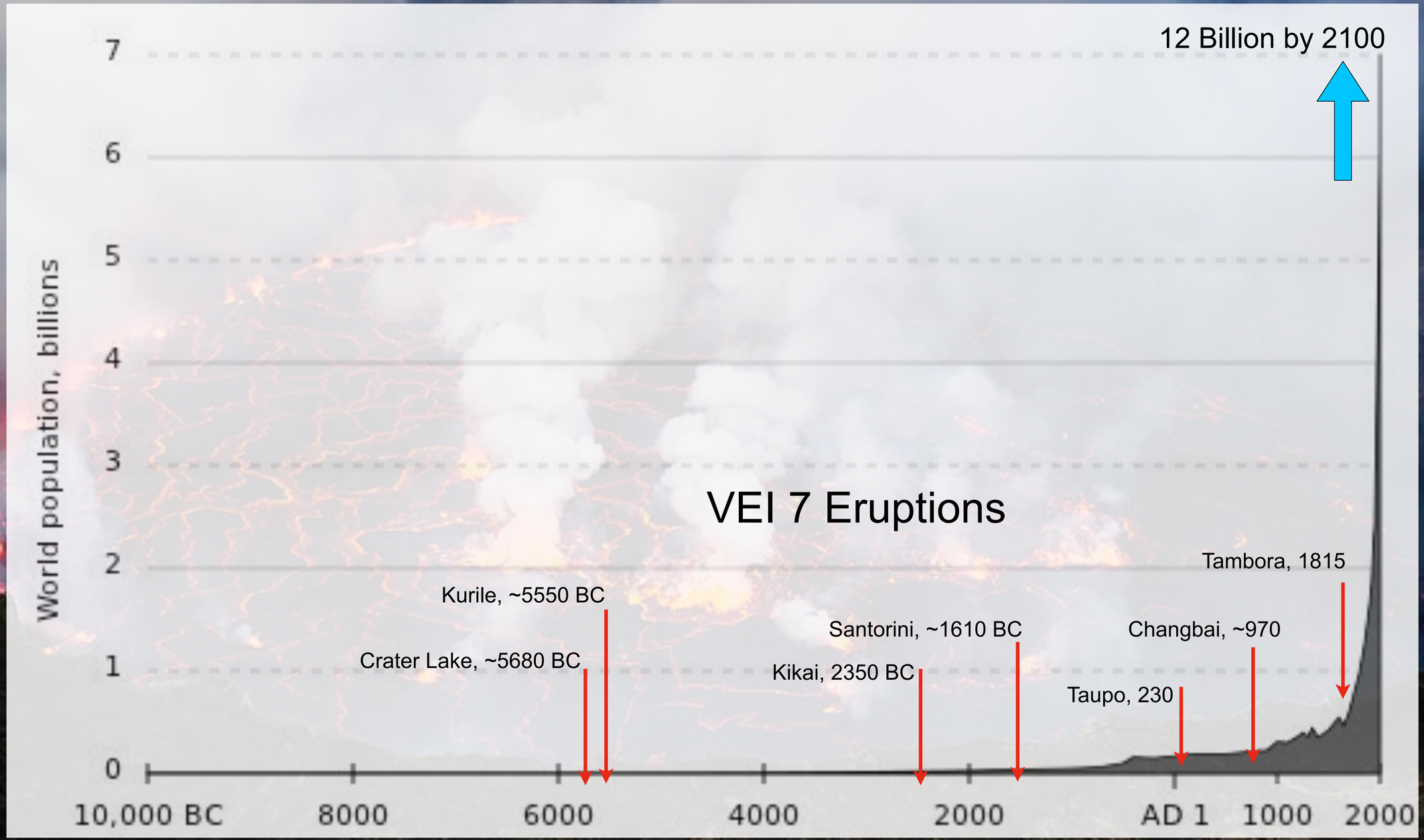
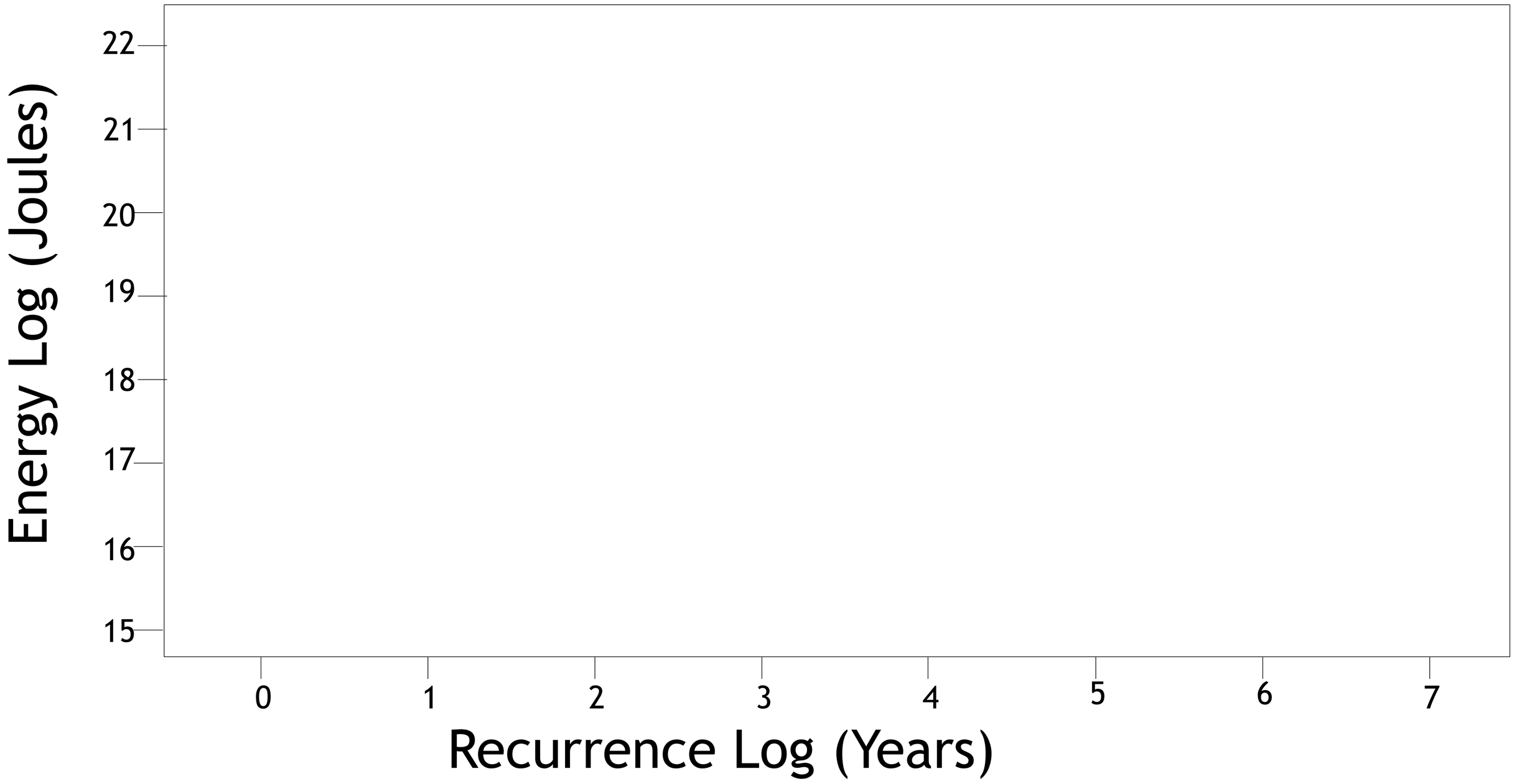
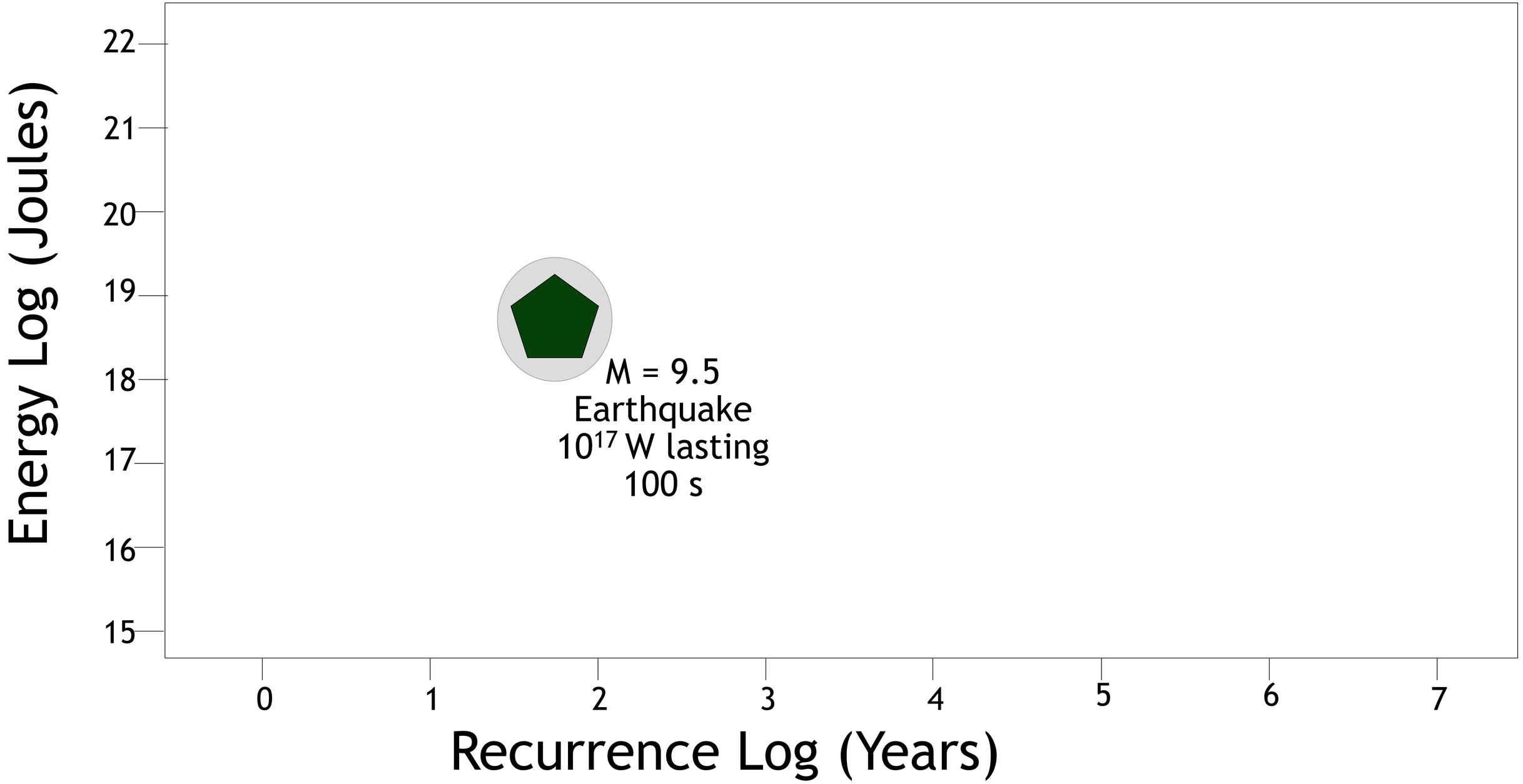



Energy Log (Joules)
22
21
20
19
18
17
16
15
0
1
2
3
4
5
6
7
Recurrence Log (Years)

Energy associated with natural hazards:



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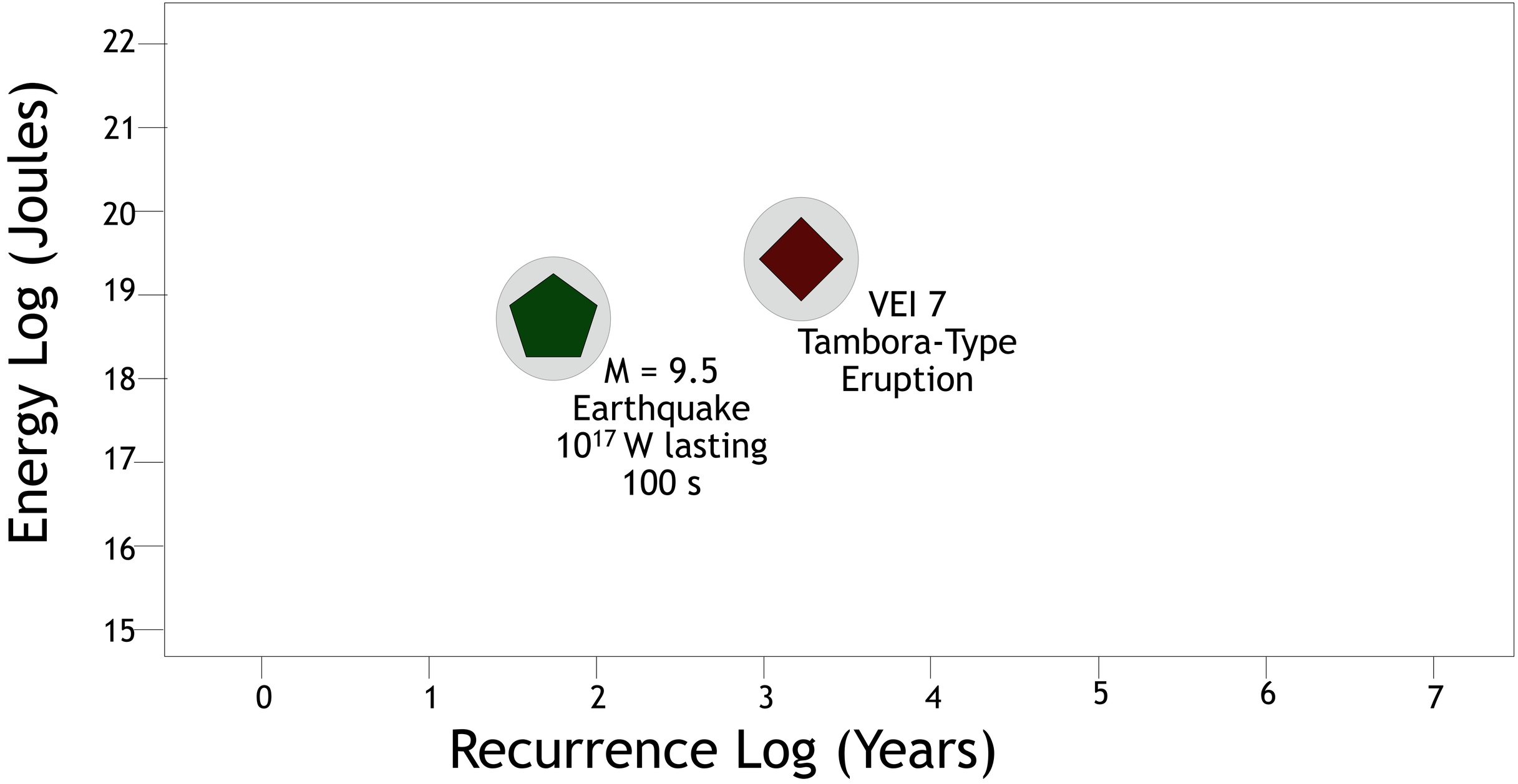

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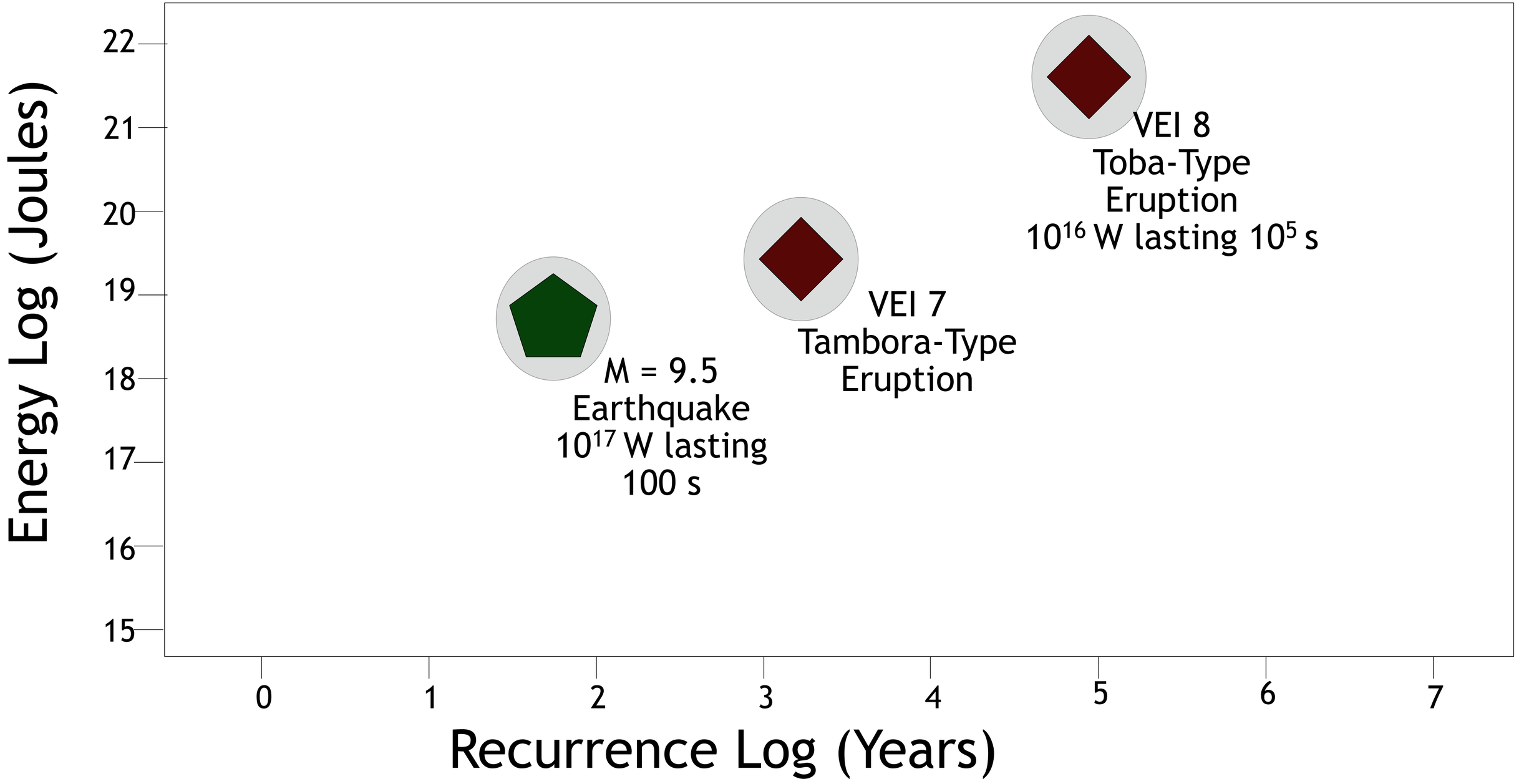

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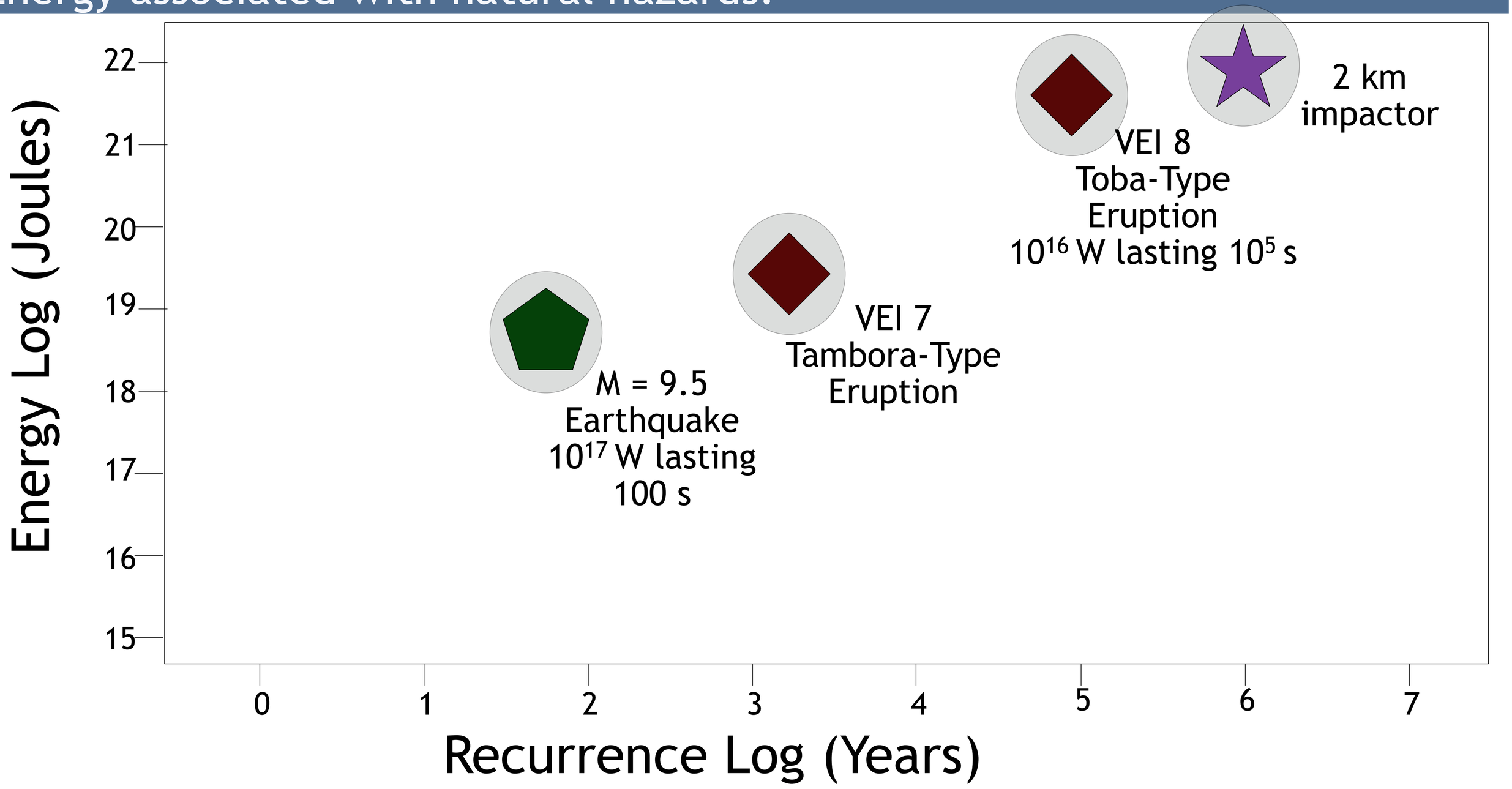

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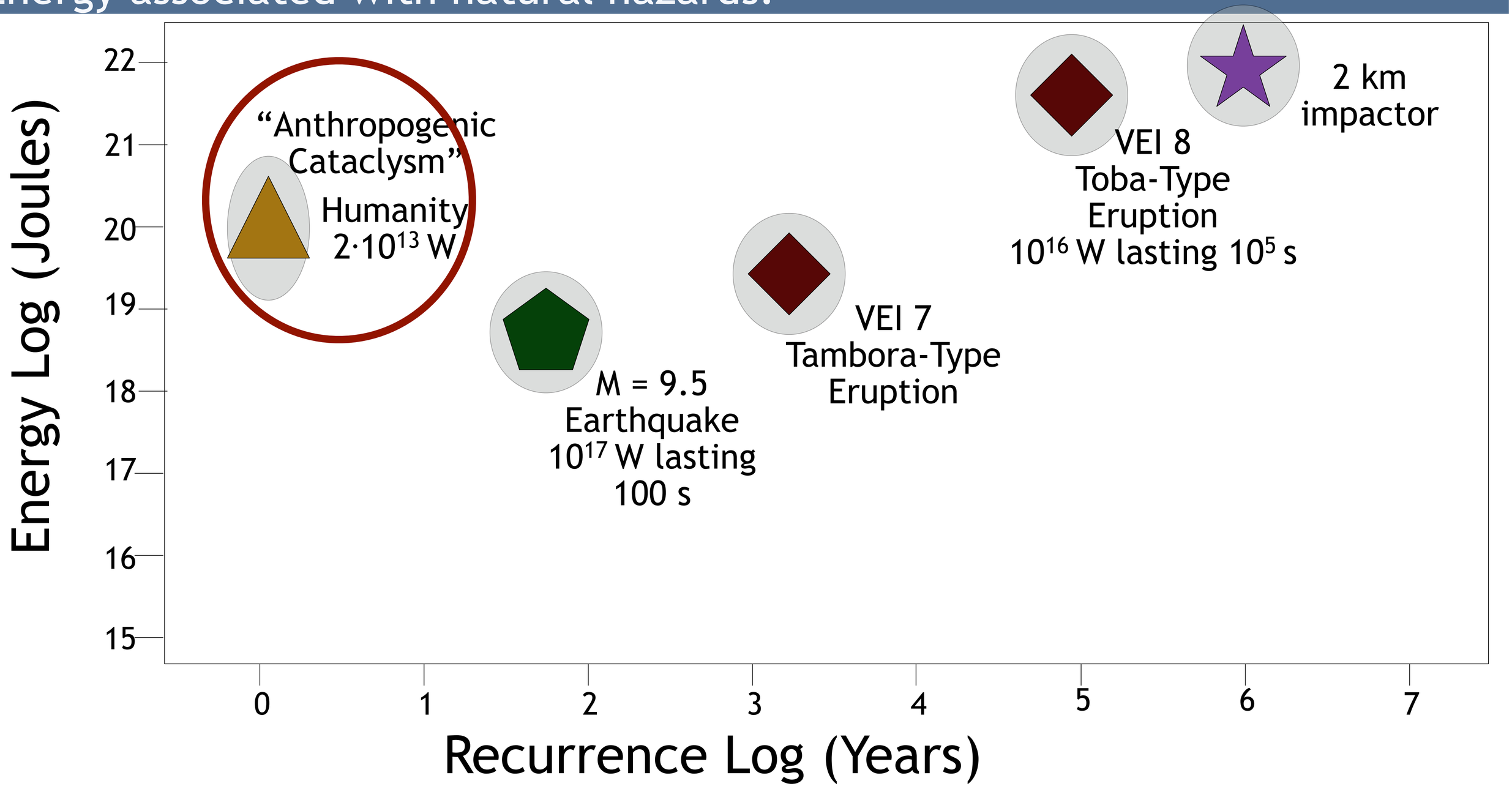


The New York Times

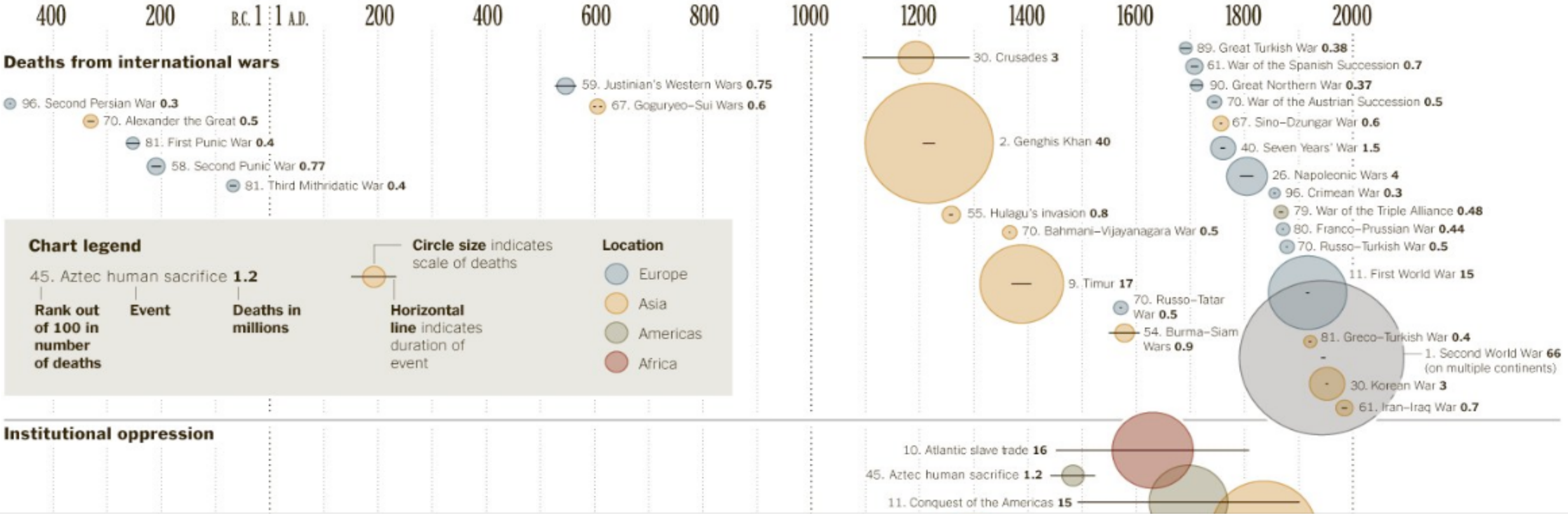
November 6, 2011

DATA POINTS

Population Control, Marauder Style

Last week, the United Nations announced that the world's population had reached seven billion, but there have been times when it headed in the opposite direction, and not in pleasant ways. The savagery of the Mongol conqueror Genghis Khan may have culled the global population by about 11 percent; two bloody upheavals in China — the An Lushan Rebellion and the collapse of the Xin Dynasty — each may have felled about 6 percent of humanity. Those are but 3 of the 100 worst atrocities in history, as cataloged by Matthew White in "The Great Big Book of Horrible Things," an amusing (really) account of the murderous ways of despots, slave traders, blundering royals, gladiators and assorted hordes. Estimating the tolls from such horrors is an inexact science, given war's nature and the mysteries of antiquity. The deadliest "multicides" are more plentiful in recent centuries, given that there were more people to kill and better ways to kill them on a grand scale. Even so, killings as a percentage of all humanity are probably declining. Below, the sweep of human brutality in a timeline.

BILL MARSH



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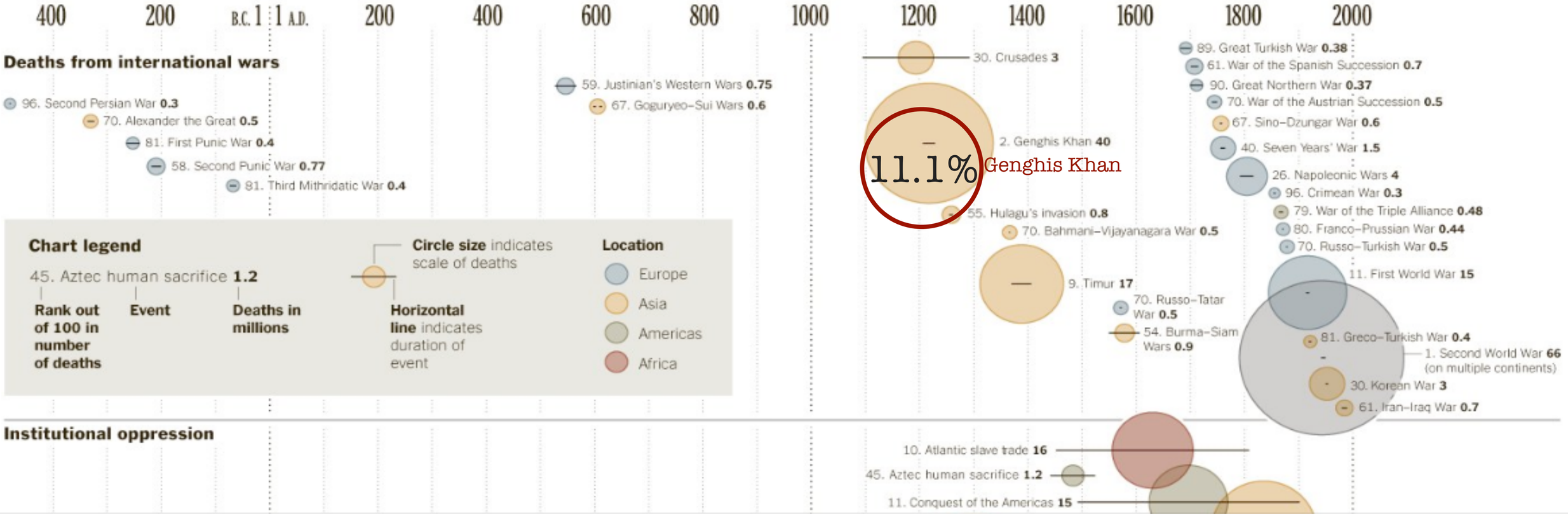
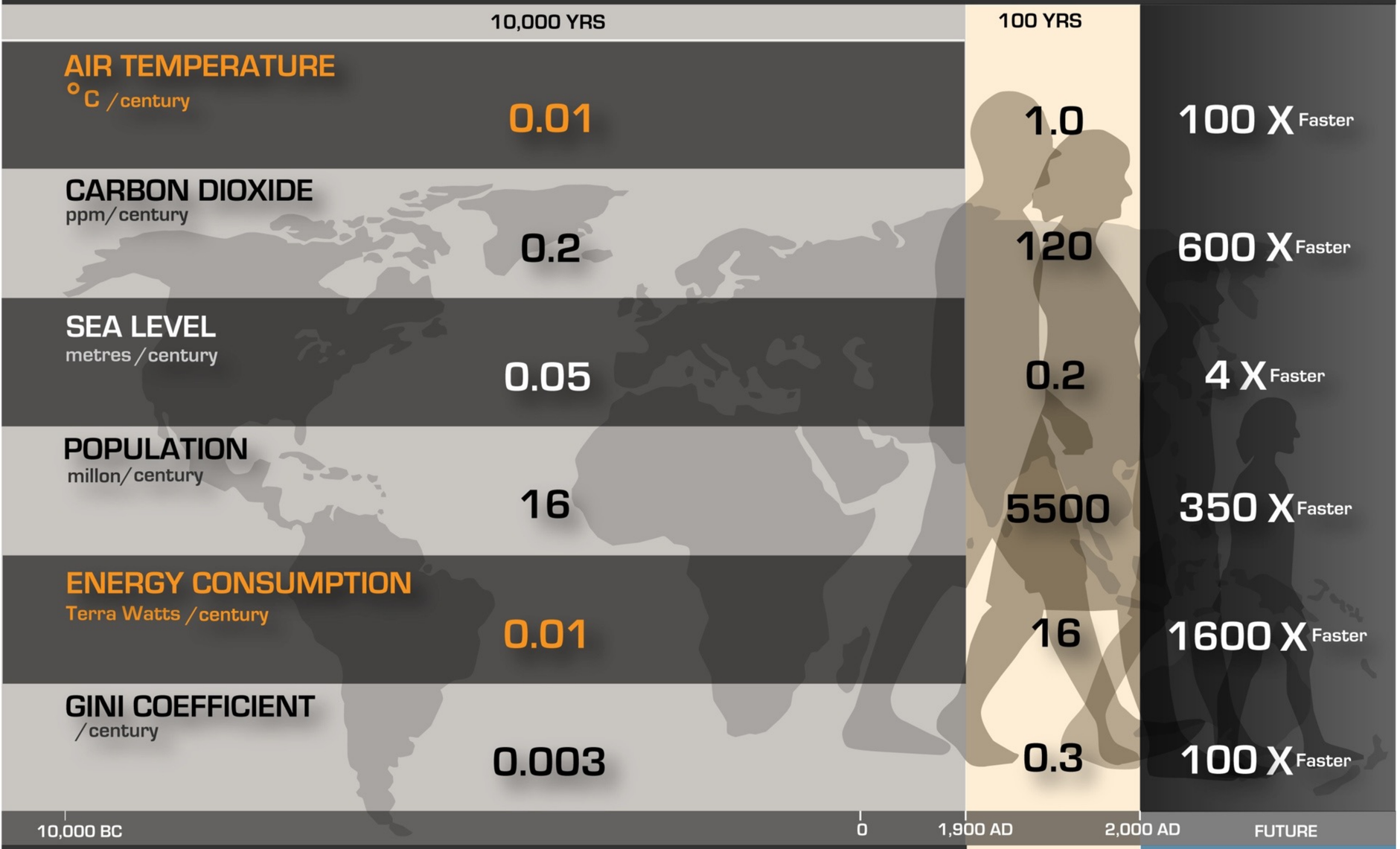


Humanity's Journey

The Evolution of Key Environmental Factors



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The Holocene:
"A Safe Operating Space For Humanity"

Johan Rockström-
Stockholm Resilience Centre

TED Talk, July 2010,
~600,000 views

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The Baseline: Past Climate and Global Change

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During the Holocene, climate and sea level were exceptionally stable

During the Holocene, global disasters caused by geohazards, asteroids, solar storms, etc. were very limited and not at the upper end of the scale

The Holocene was a “safe operating space for humanity”

Civilization could develop despite many anthropogenic conflicts and disasters

The Baseline: Past Climate and Global Change

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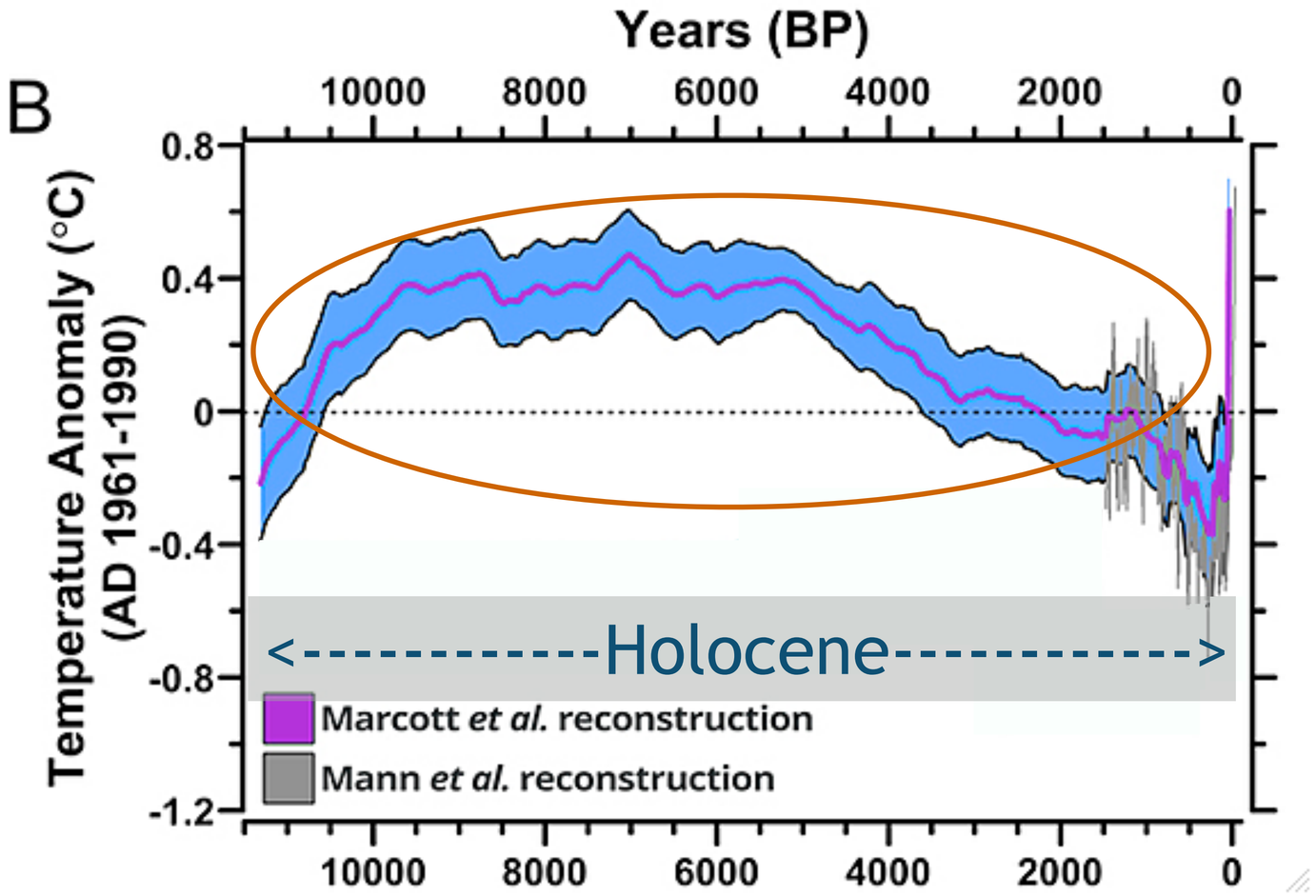
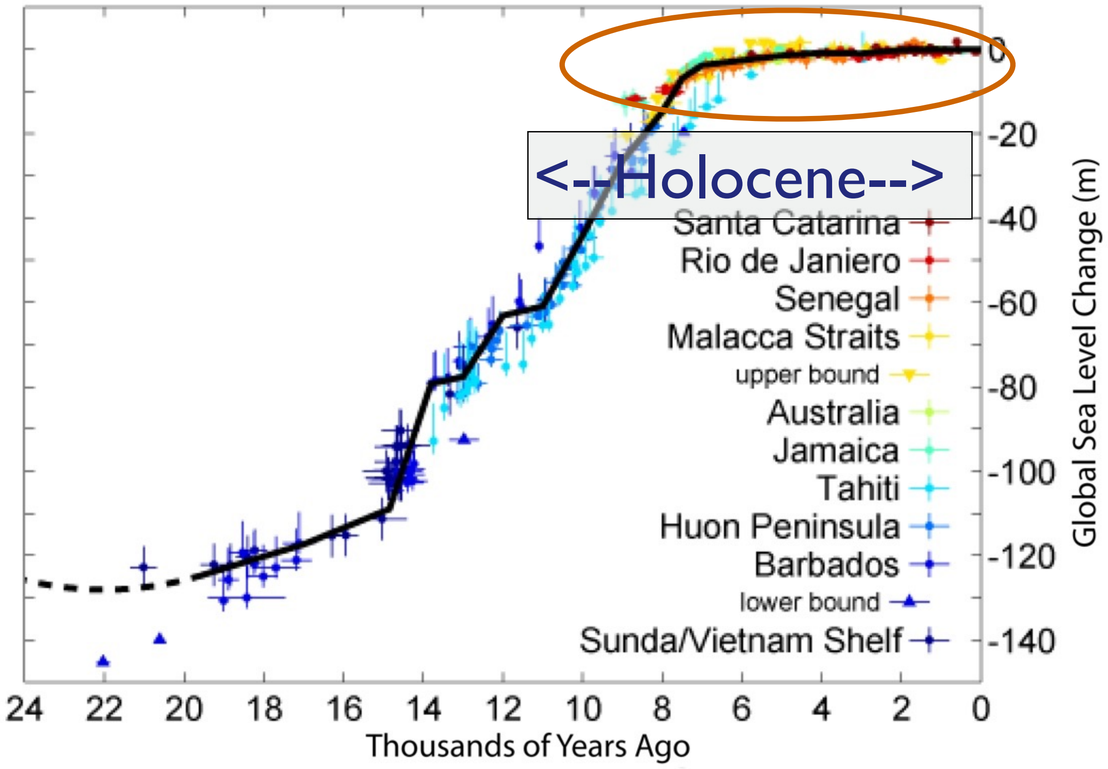
Global Temperature Changes



Marcott et al., 2013

Global Sea Level Changes



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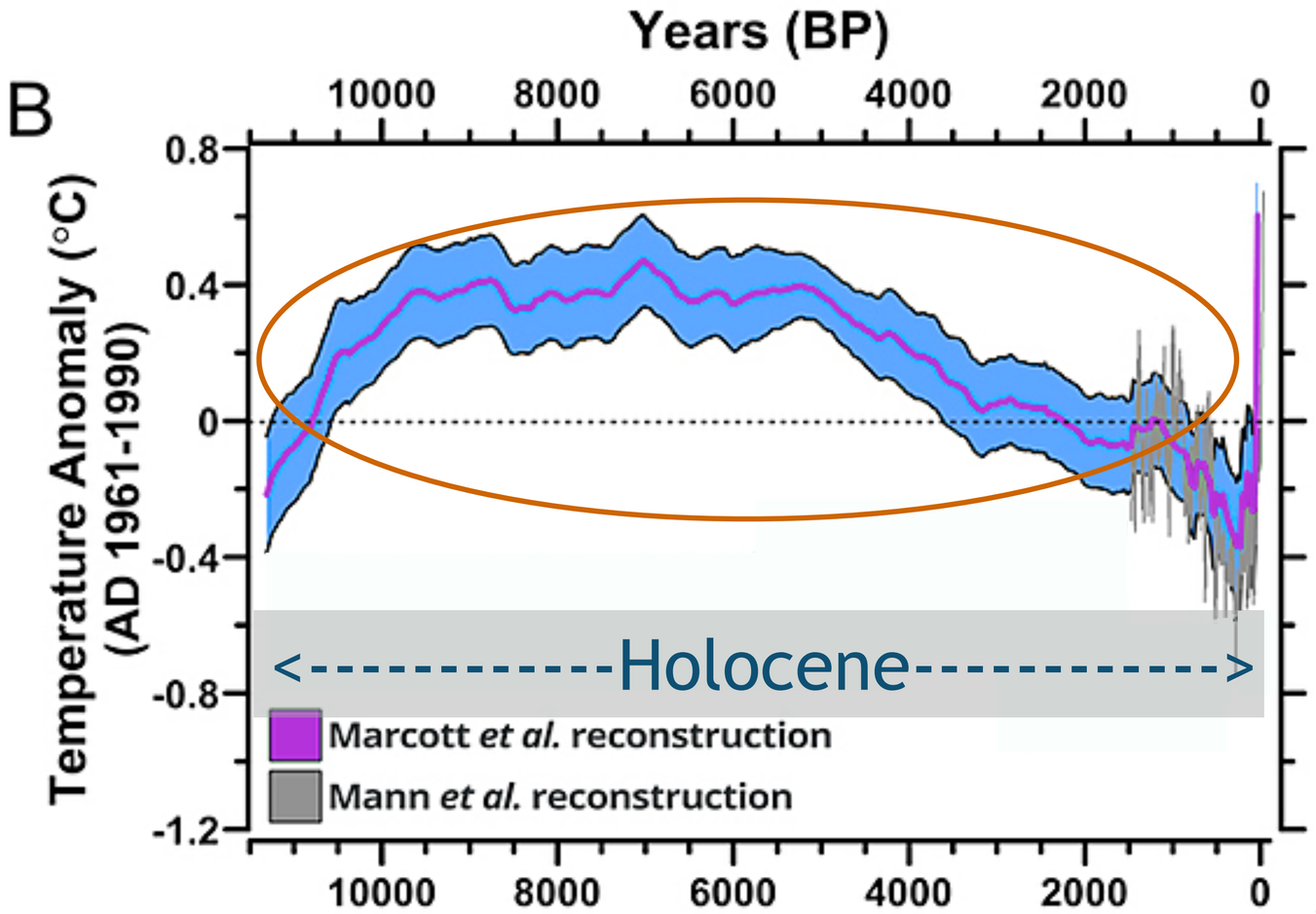

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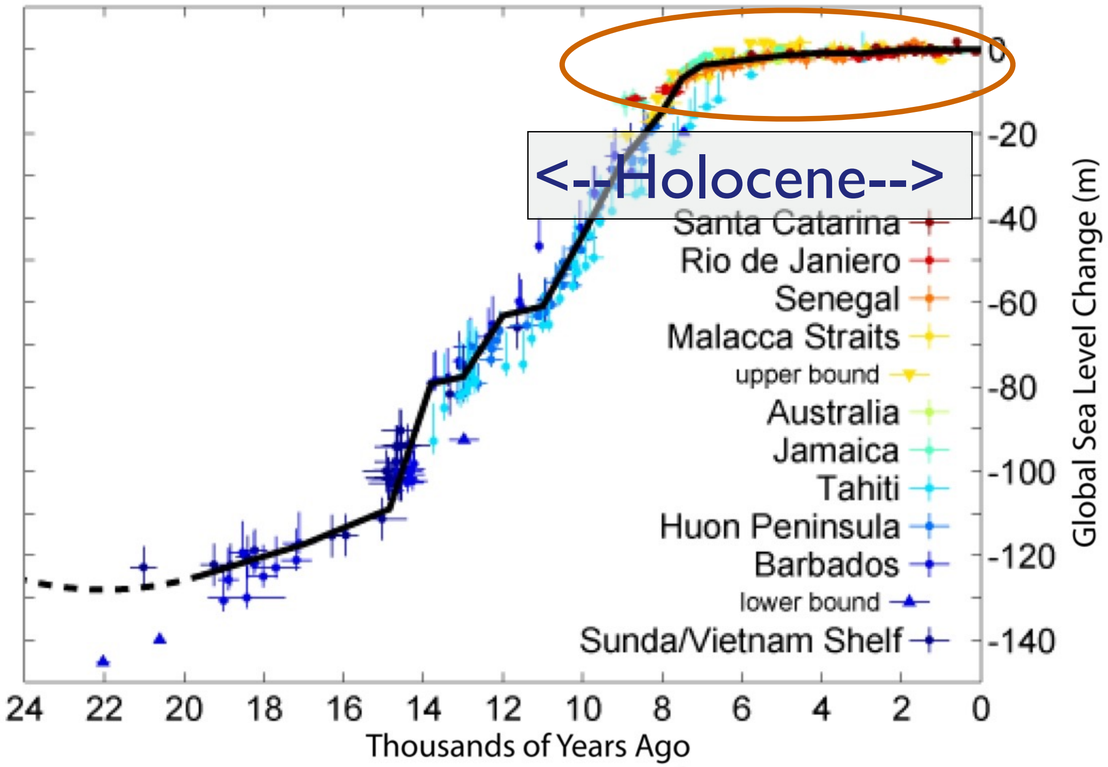

The Baseline for Civilization:
During the Holocene, climate, global temperature, and sea level were exceptionally stable; a perfect condition for the development of civilization.

The Baseline: Past Climate and Global Change

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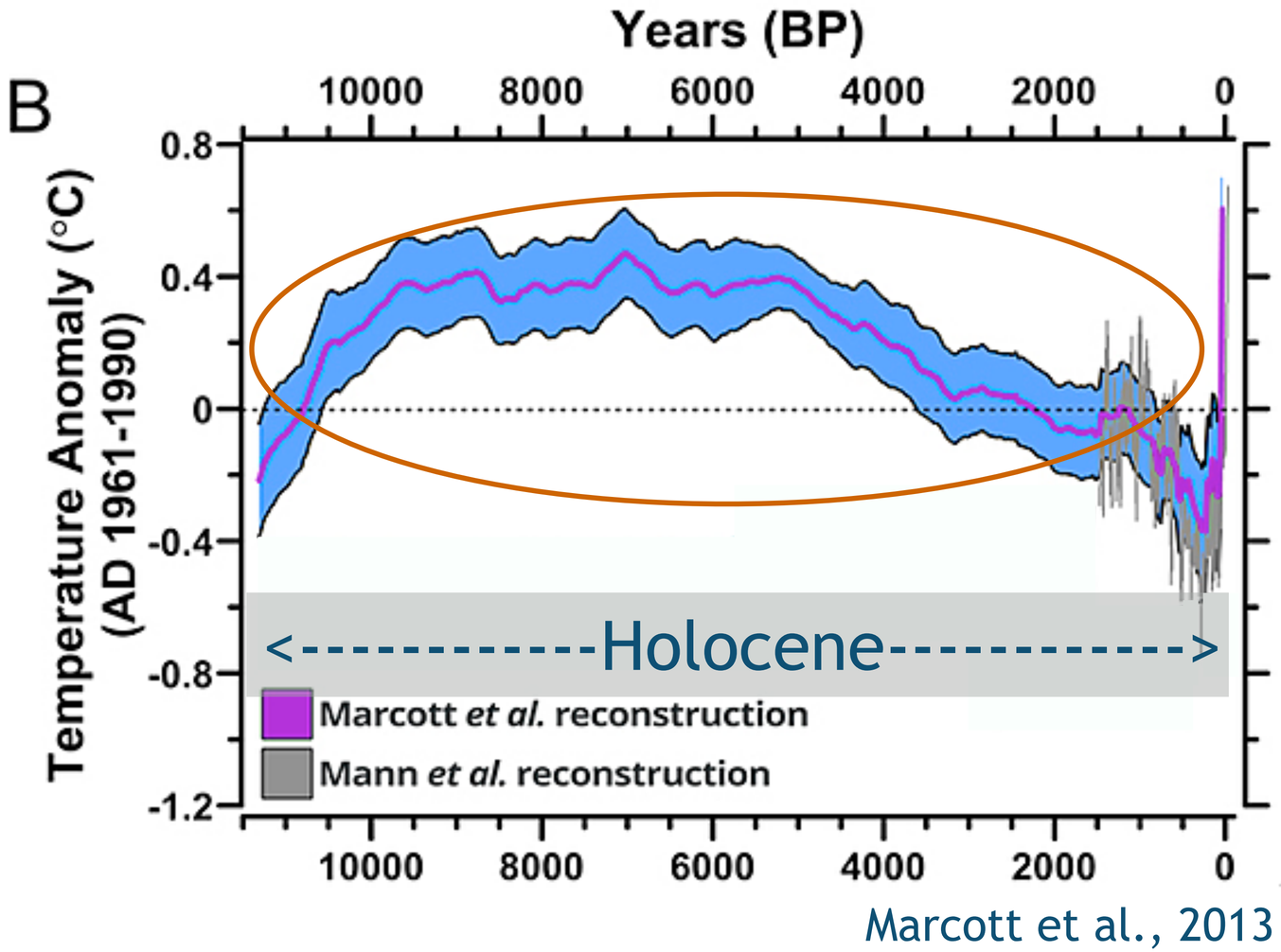

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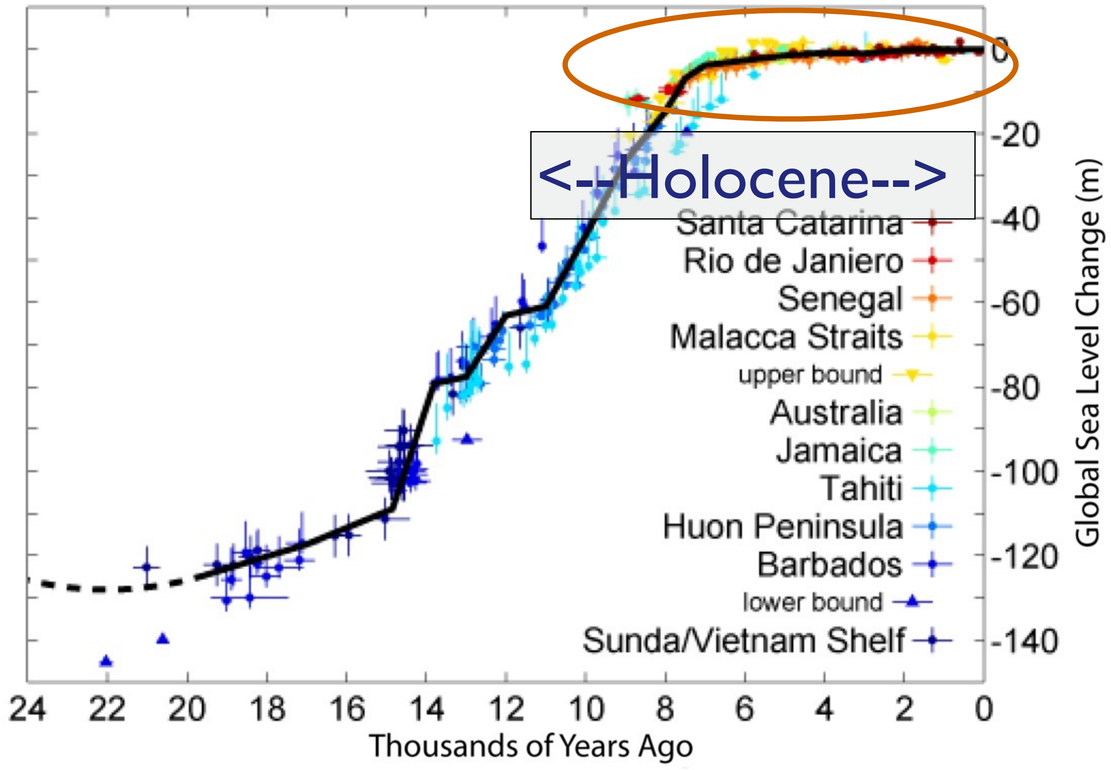

The Holocene was a "safe operating space for humanity"

The Baseline: Past Climate and Global Change

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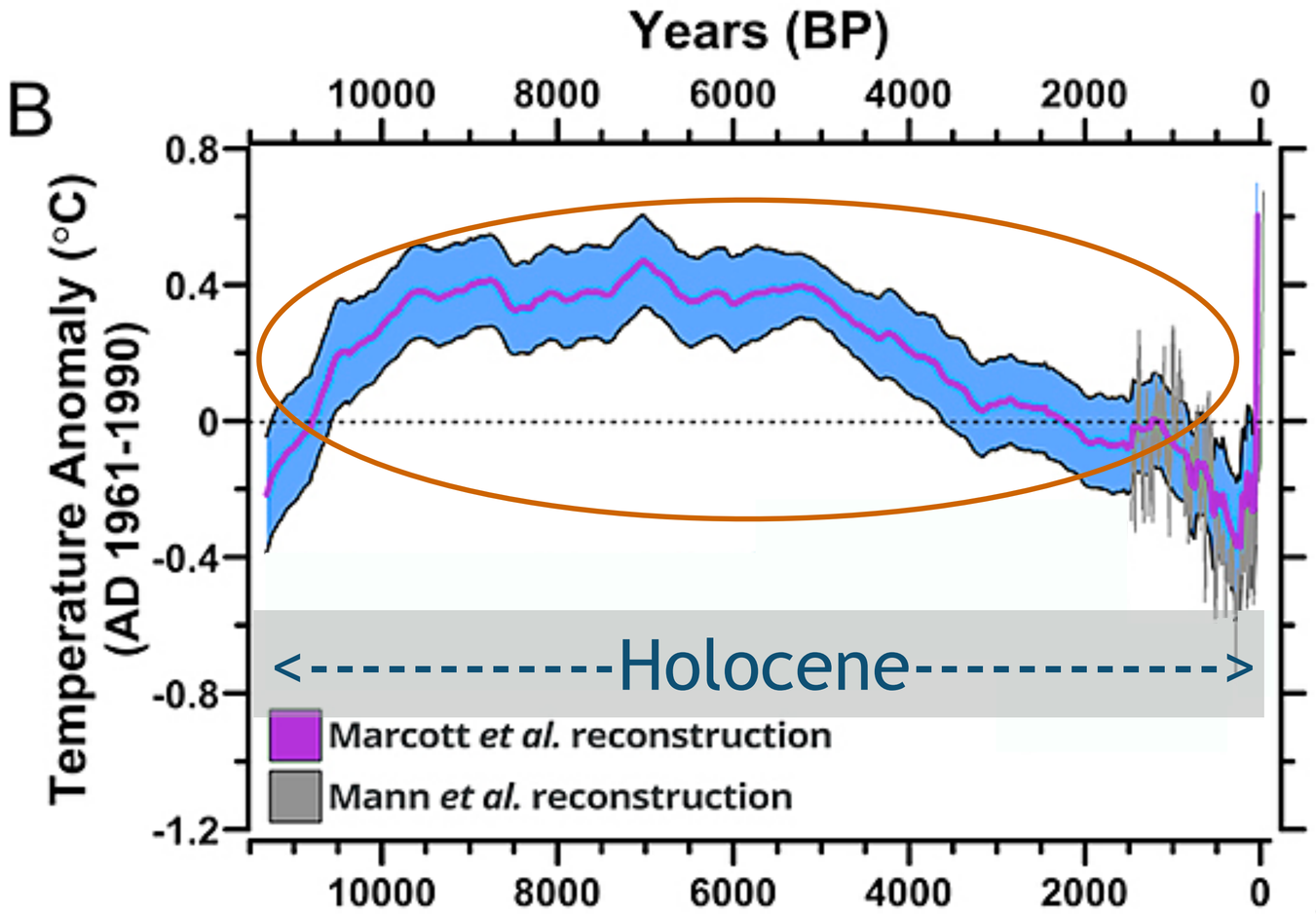

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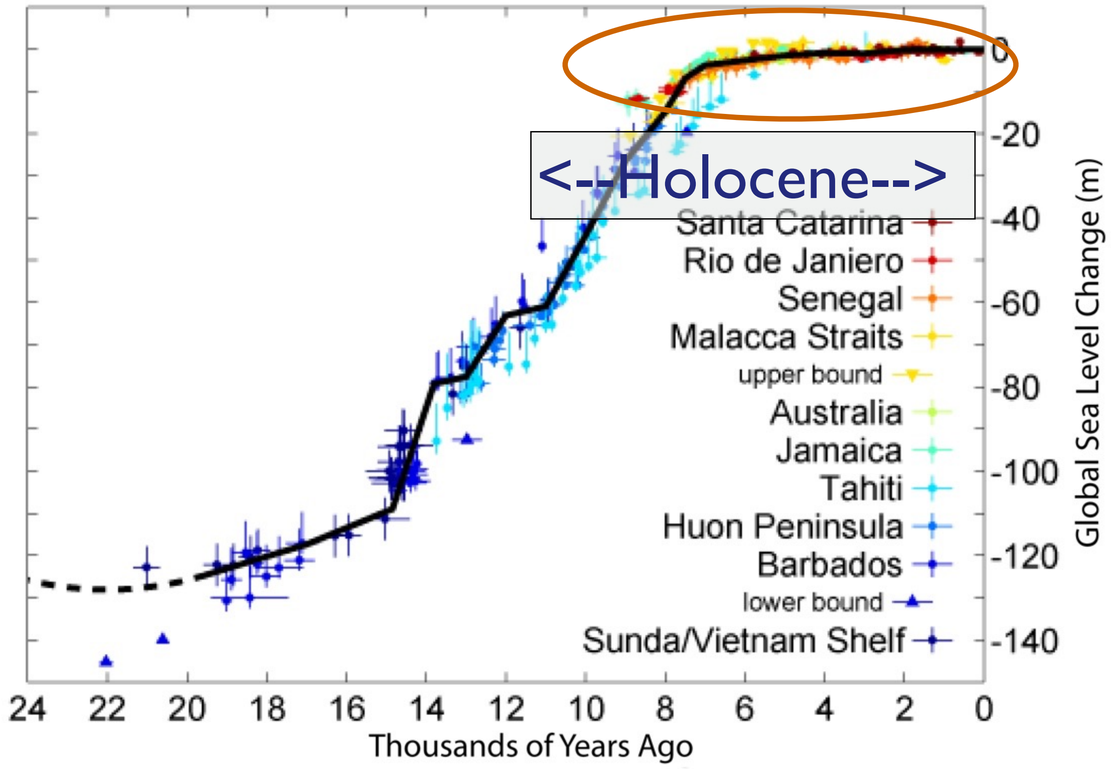

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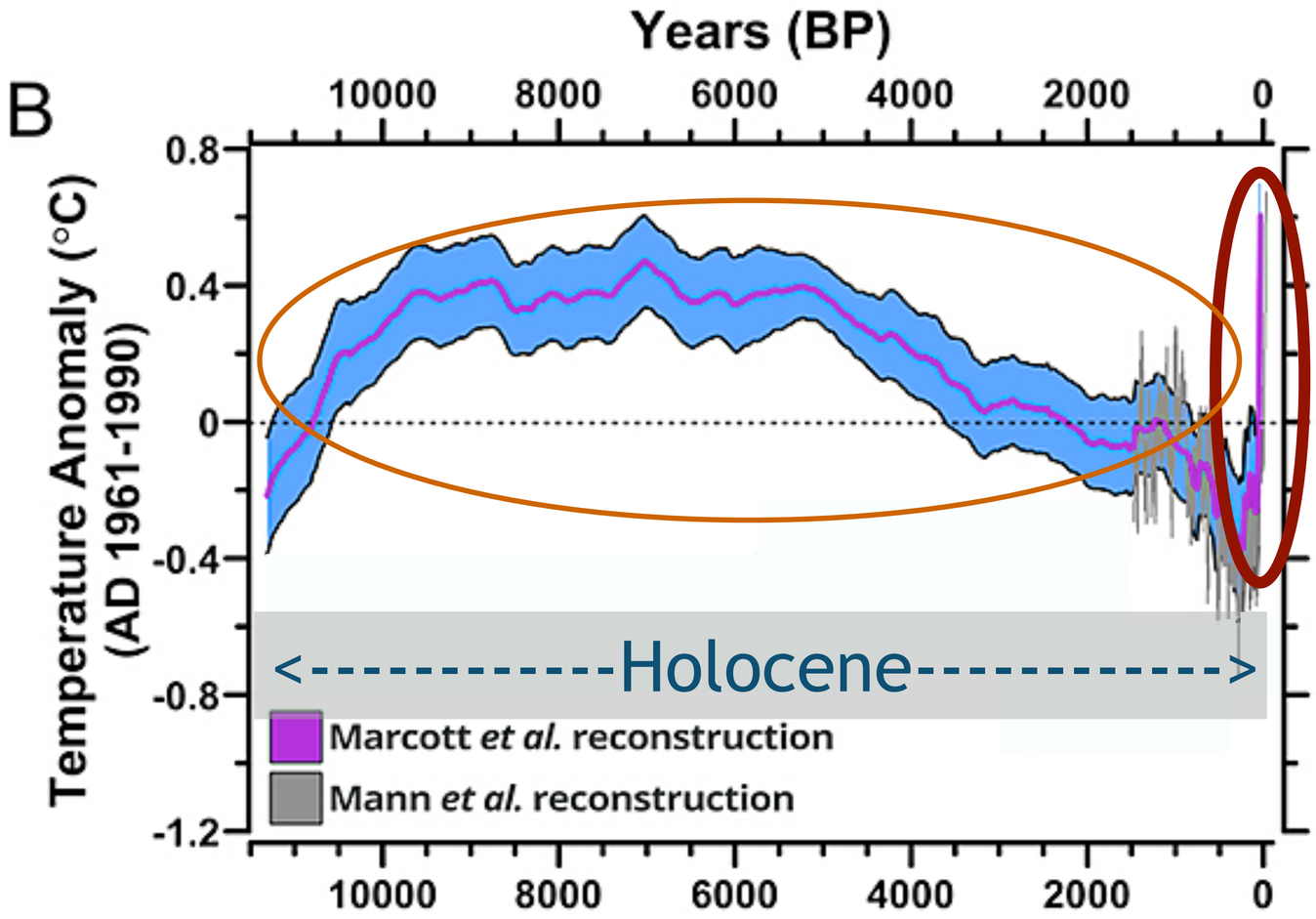

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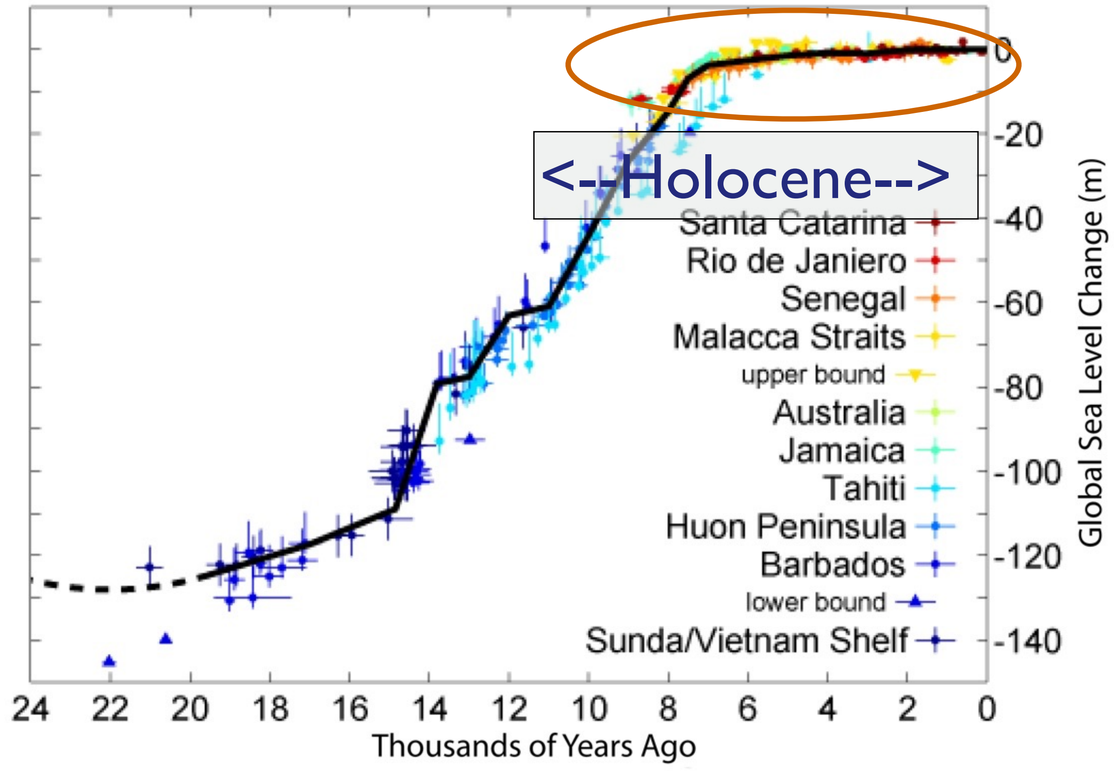

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Oluwakemi Izomo