Natural Hazards and Disaster

Class 3: Global Threats and Extraterrestrial Hazards

- Extreme Natural Hazards
- Global Risk Assessments
- Modern Global Change
- Major (Global) Risks
- Global Risk Governance
- Extraterrestrial Hazards

Extreme Events:

- Extinction Level Events: more than a quarter of all life on Earth is killed and major species extinction takes place.
- Global Catastrophes: more than a quarter of the world human population dies and that place civilization in serious risk.
- Global Disasters: global-scale events in which a few percent of the population die.
- Major Disasters: disasters exceeding $100 Billion in damage and/or causing more than 10,000 fatalities.

From Plag et al. (2015)

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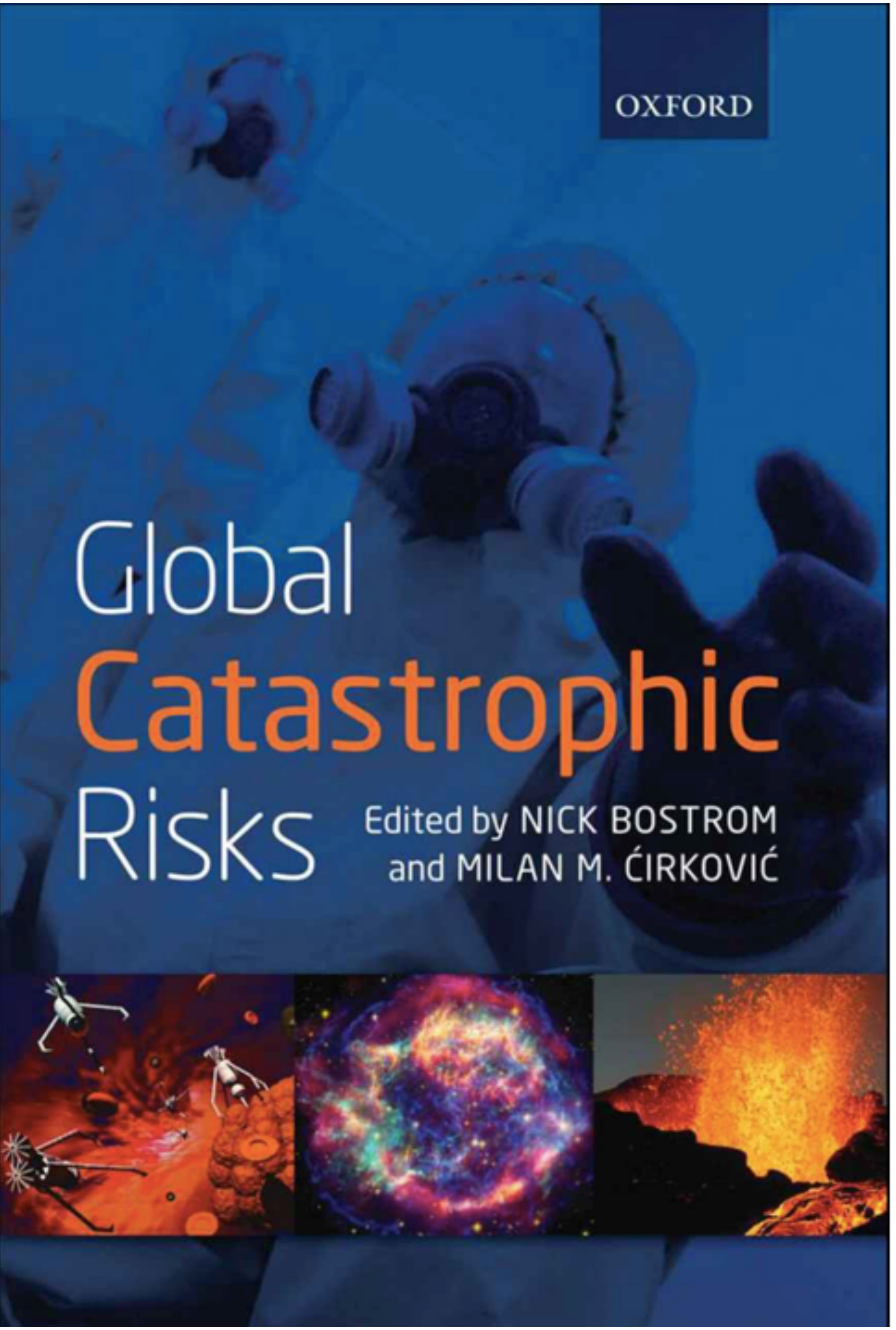
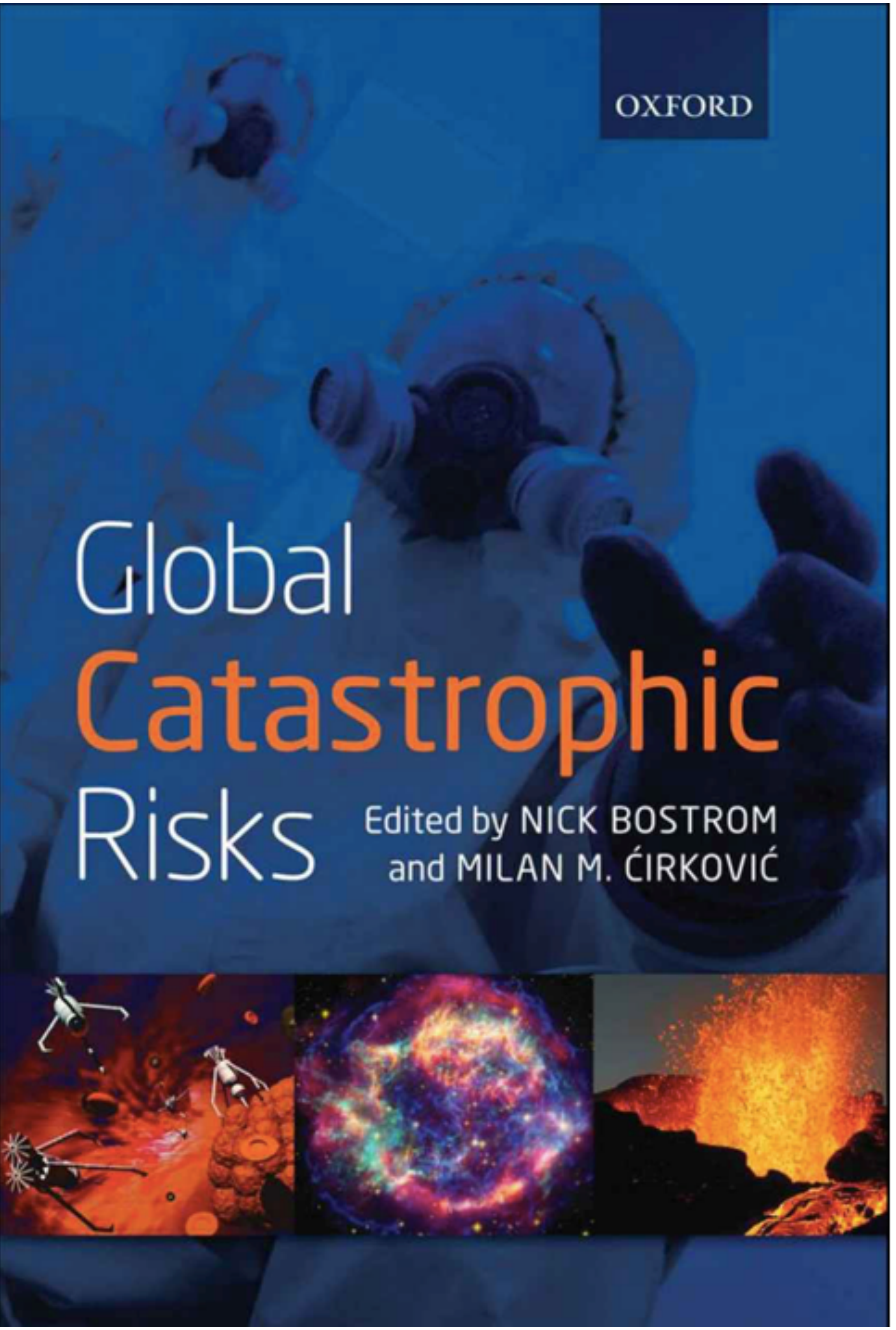
How can we assess risk for low-probability high-impact events?



"*To decide how to allocate effort and resources, we must make* ***comparative judgements****.* ***If we treat risks singly****, and never as part of an overall threat profile, we may become* ***unduly fixated on the one or two dangers that happen to have captured the public or expert imagination of the day****, while neglecting other risks that are more severe or more amenable to mitigation.*"

- Risks from Nature
- Risks from Unintended Consequences
- Risks from Hostile Acts

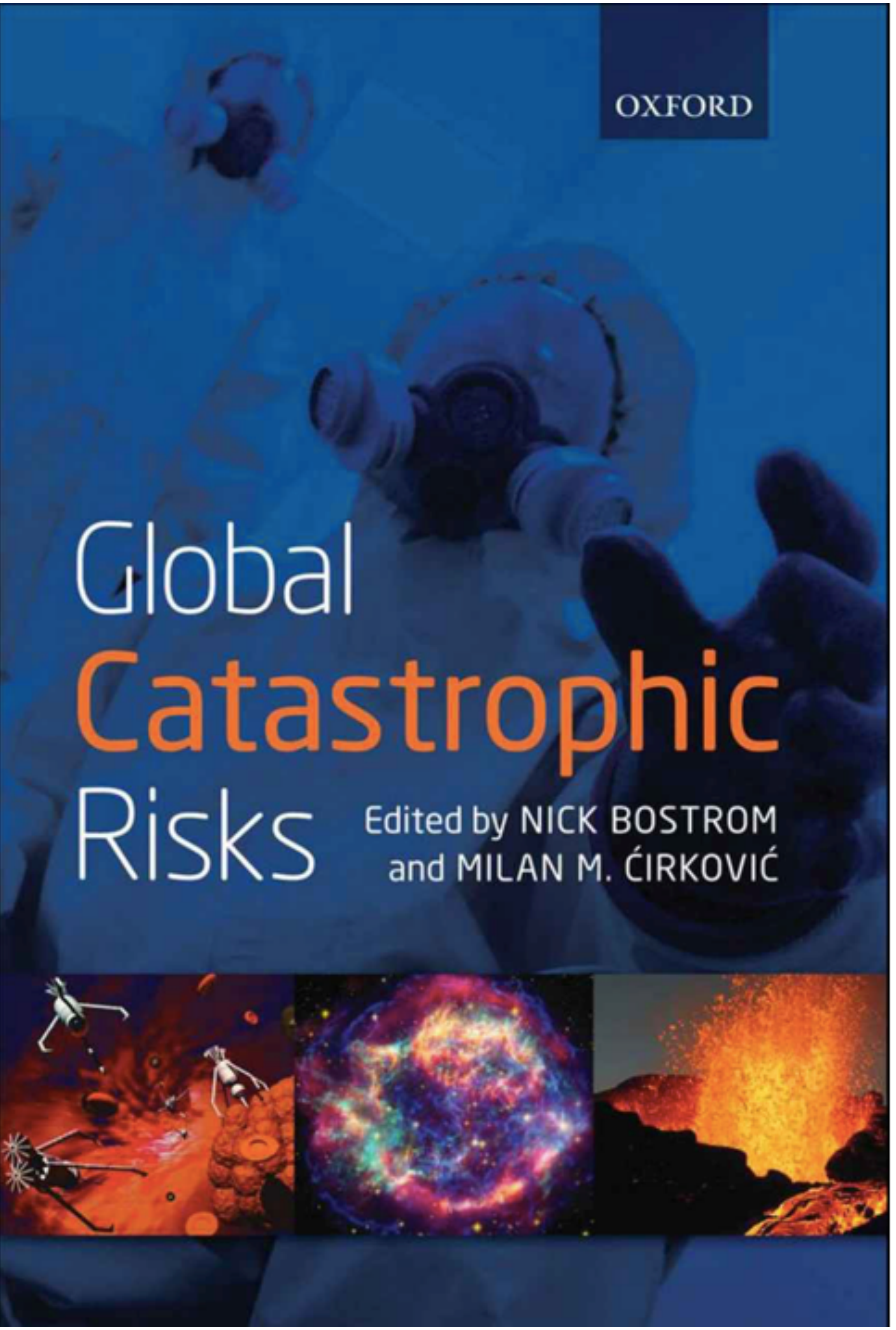


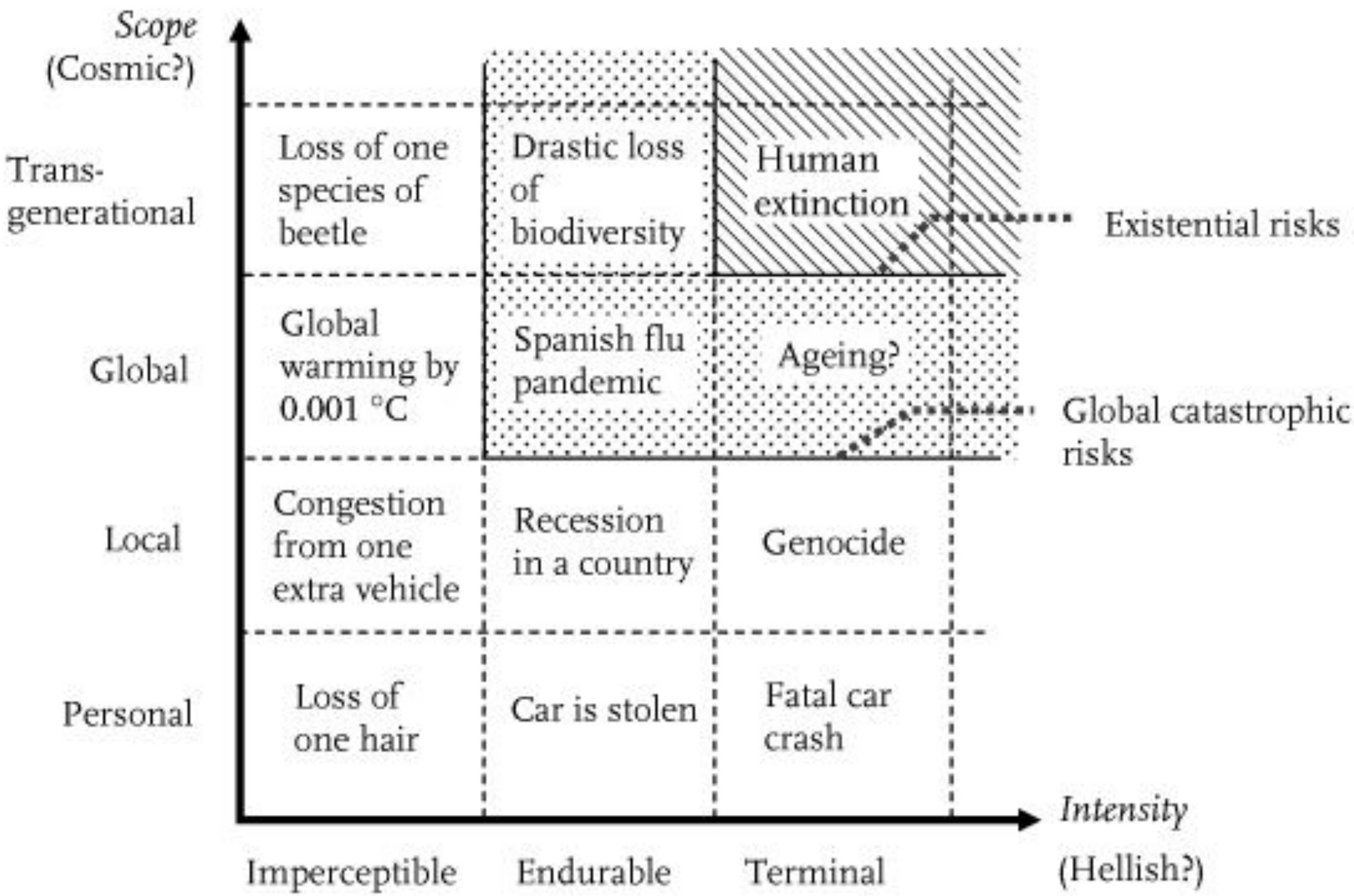
"*We can roughly characterize the severity of a risk by three variables: its scope (how many people – and other morally relevant beings – would be affected), its intensity (how badly these would be affected), and its probability (how likely the disaster is to occur, according to our best judgement, given currently available evidence).*"

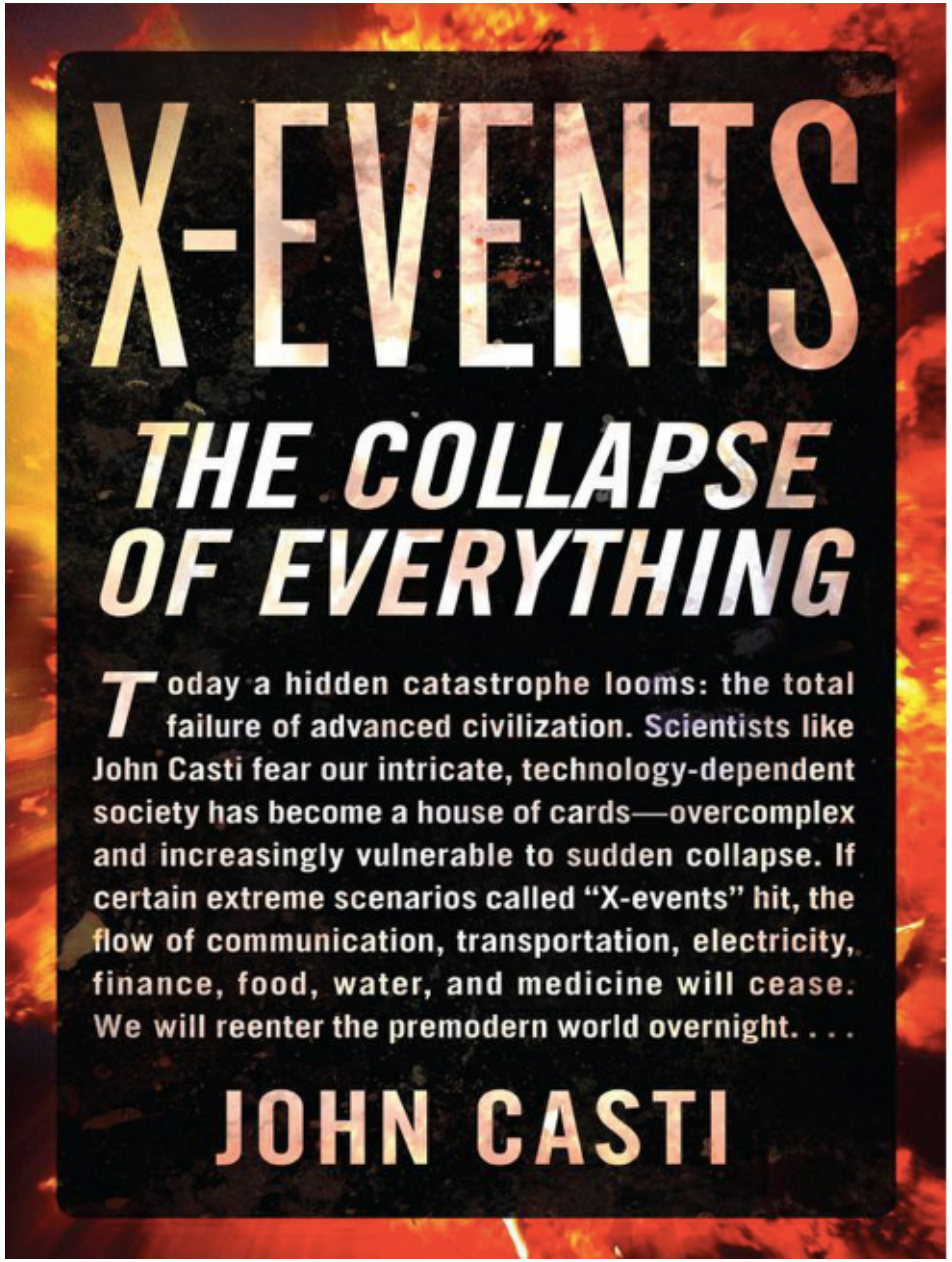
Severity of a risk:

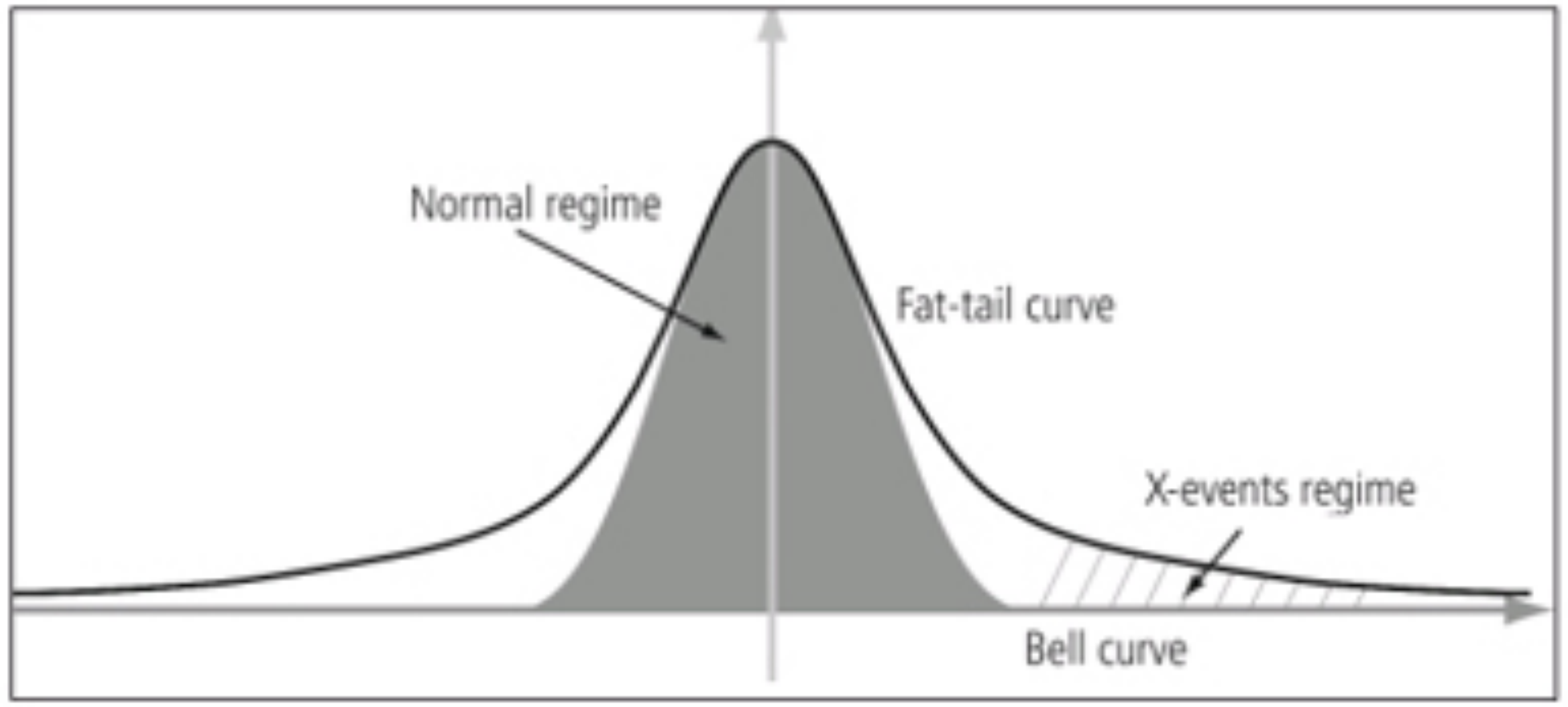
- its **scope** (how many people – and other morally relevant beings – would be affected),
- its **intensity** (how badly these would be affected),
- its **probability** (how likely is the disaster is to occur).

Extreme Natural Hazards



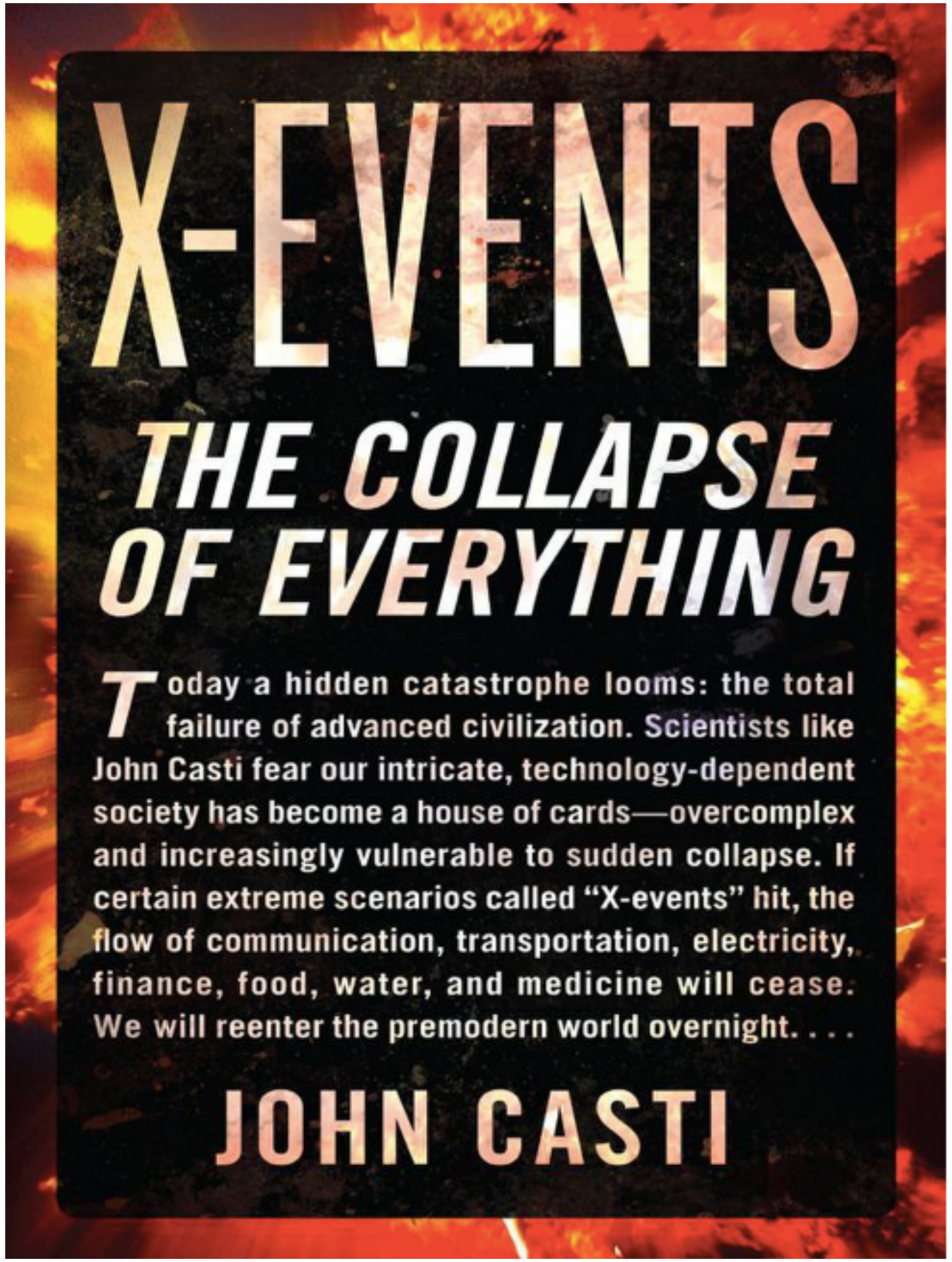




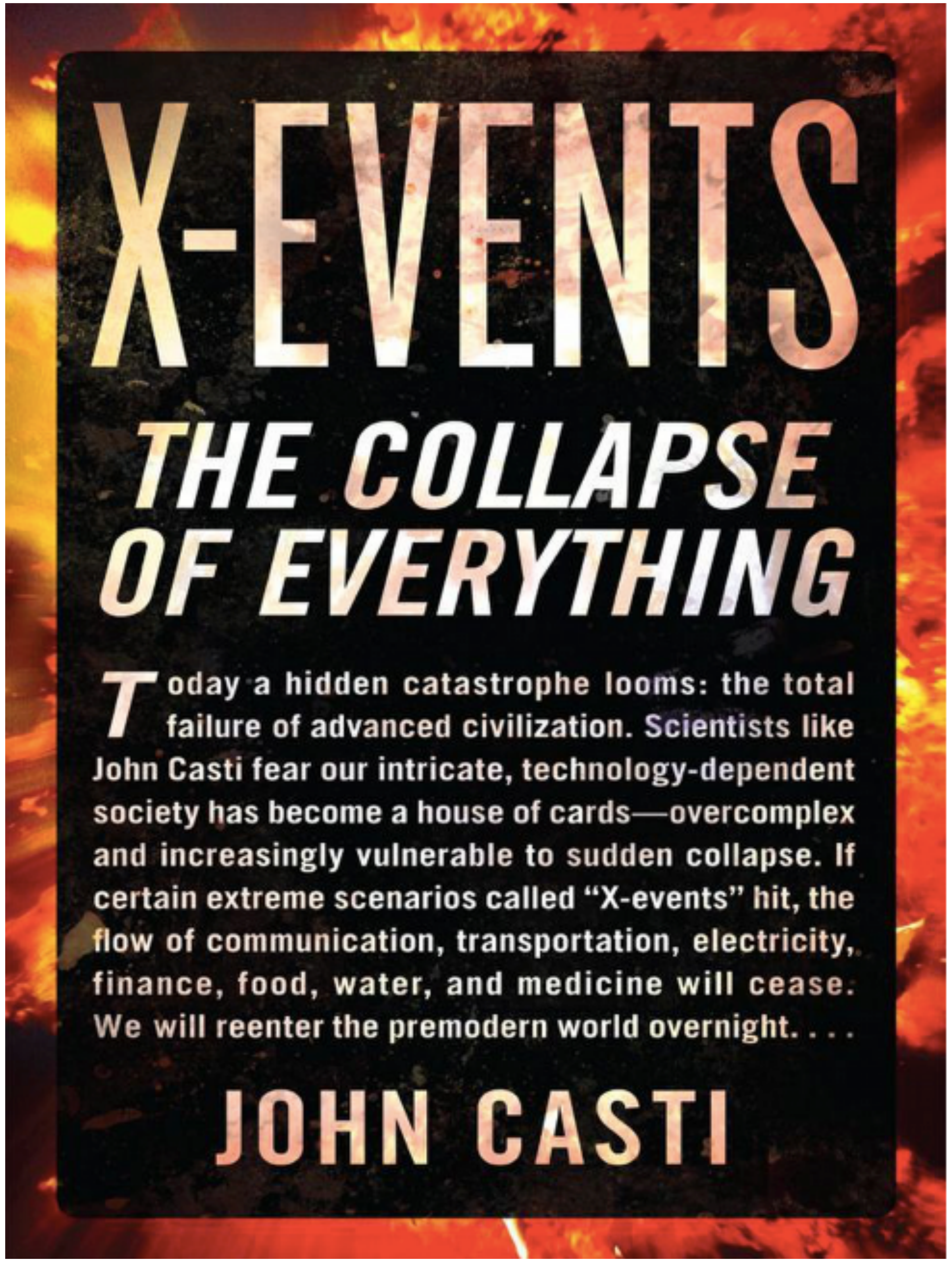


The bell-shaped vs. fat-tailed distributions

Casti (2012) defines 'X-events' as events that are rare, surprising, and have potentially huge impacts on human life. X-events are outliers that are found outside the 'normal' region and could lead to 'the collapse of everything'.



How do we characterize risk in situations where probability theory and statistics cannot be employed?



How do we characterize risk in situations where probability theory and statistics cannot be employed?

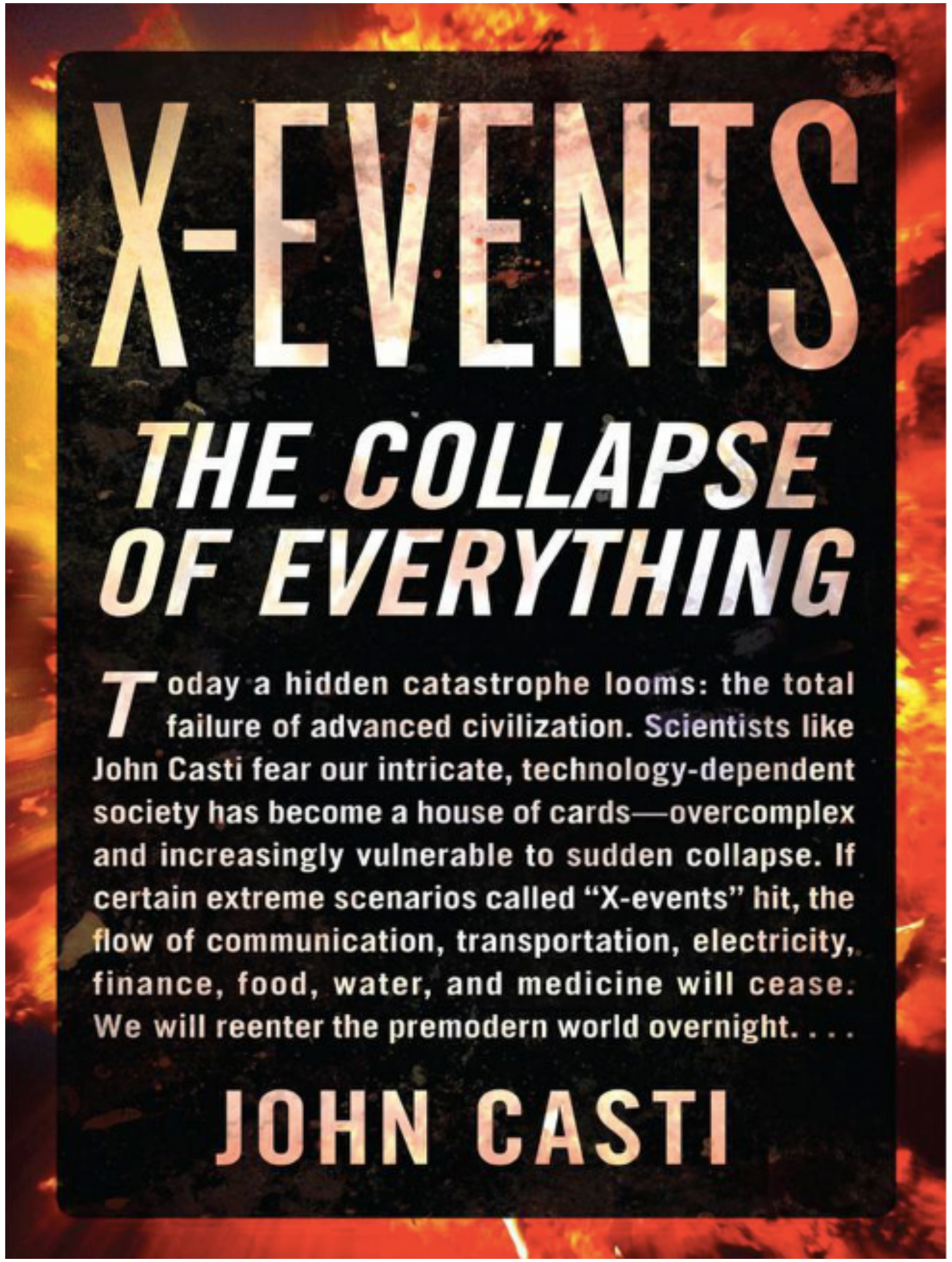
Casti (2012) defines:

$$X = \frac{\delta E}{E}\left(1 - \frac{U}{U + I}\right)$$

where:

- X is the X-ness of an event (a measure of the impact of the event),
- E the impacted ensemble (e.g. impact on the gross domestic product or the total annual deaths in the impacted region),
- δE the change in the ensemble due to the event,
- U the unfolding time of the event, and
- I the impact time.

Extreme Natural Hazards



X-Event 1: Digital Darkness: A Long-Term, Widespread Failure of the Internet

X-Event 2: When Do We Eat?: Breakdown of the Global Food-Supply System

X-Event 3: The Day the Electronics Died: A Continent-Wide Electromagnetic Pulse Destroys All Electronics

X-Event 4: A New World Disorder: The Collapse of Globalization

X-Event 5: Death by Physics: Destruction of the Earth Through the Creation of Exotic Particles

X-Event 6: Blown Away: Destabilization of the Nuclear Landscape

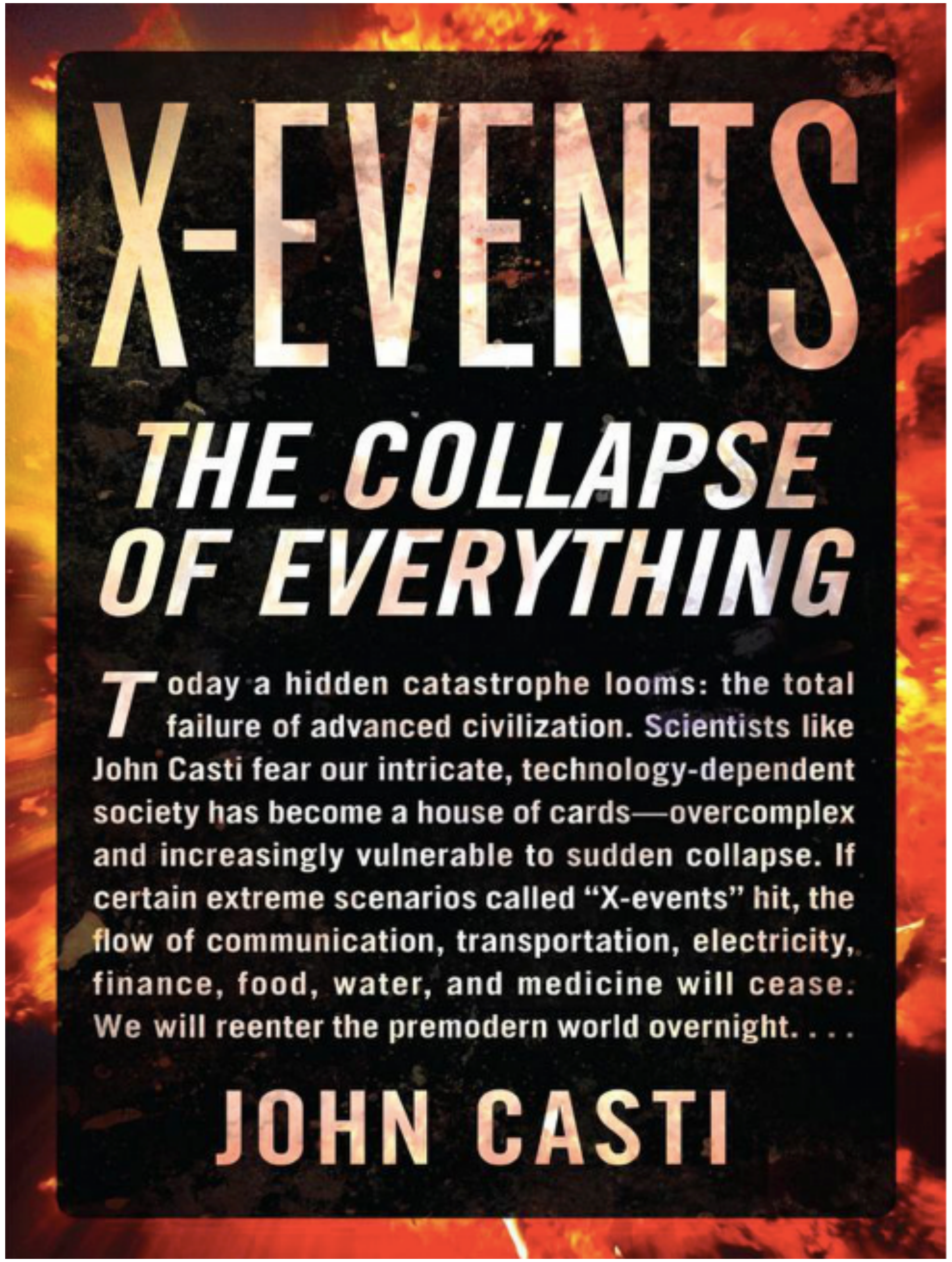
X-Event 7: Running on Empty: Drying Up of World Oil Supplies

X-Event 8: I'm Sick of It: A Global Pandemic

X-Event 9: Dark and Dry: Failure of the Electric Power Grid and Clean Water Supply

X-Event 10: Technology Run Amok: Intelligent Robots Overthrow Humanity

X-Event 11: The Great Unwinding: Global Deflation and the Collapse of World Financial Markets

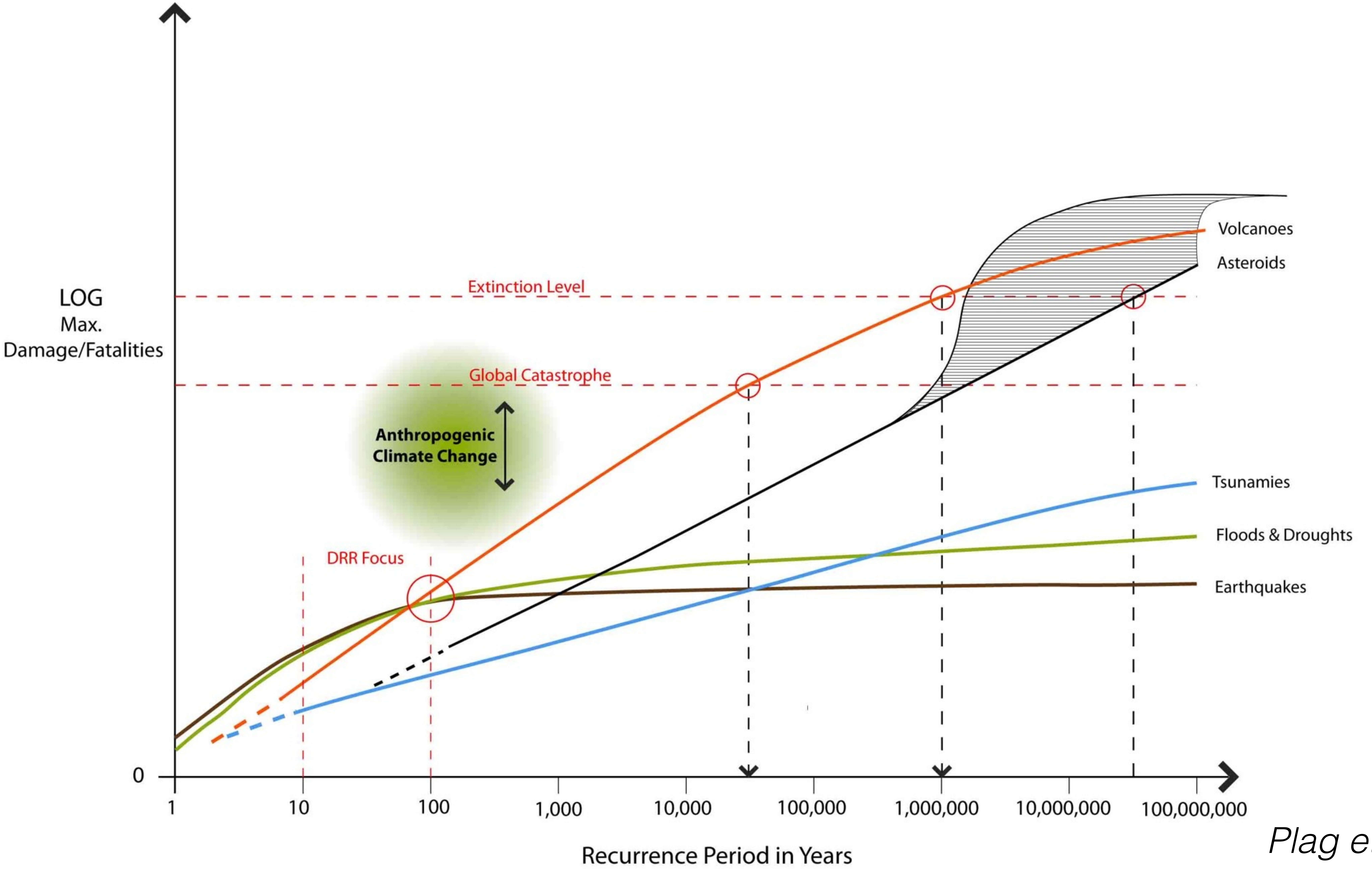


Five warning signs of impending system state shifts

- An increasing rate of fluctuations
- High-amplitude fluctuations
- Critical slow down
- Skewness in distribution of system states
- Rapid changes in spatial patterns

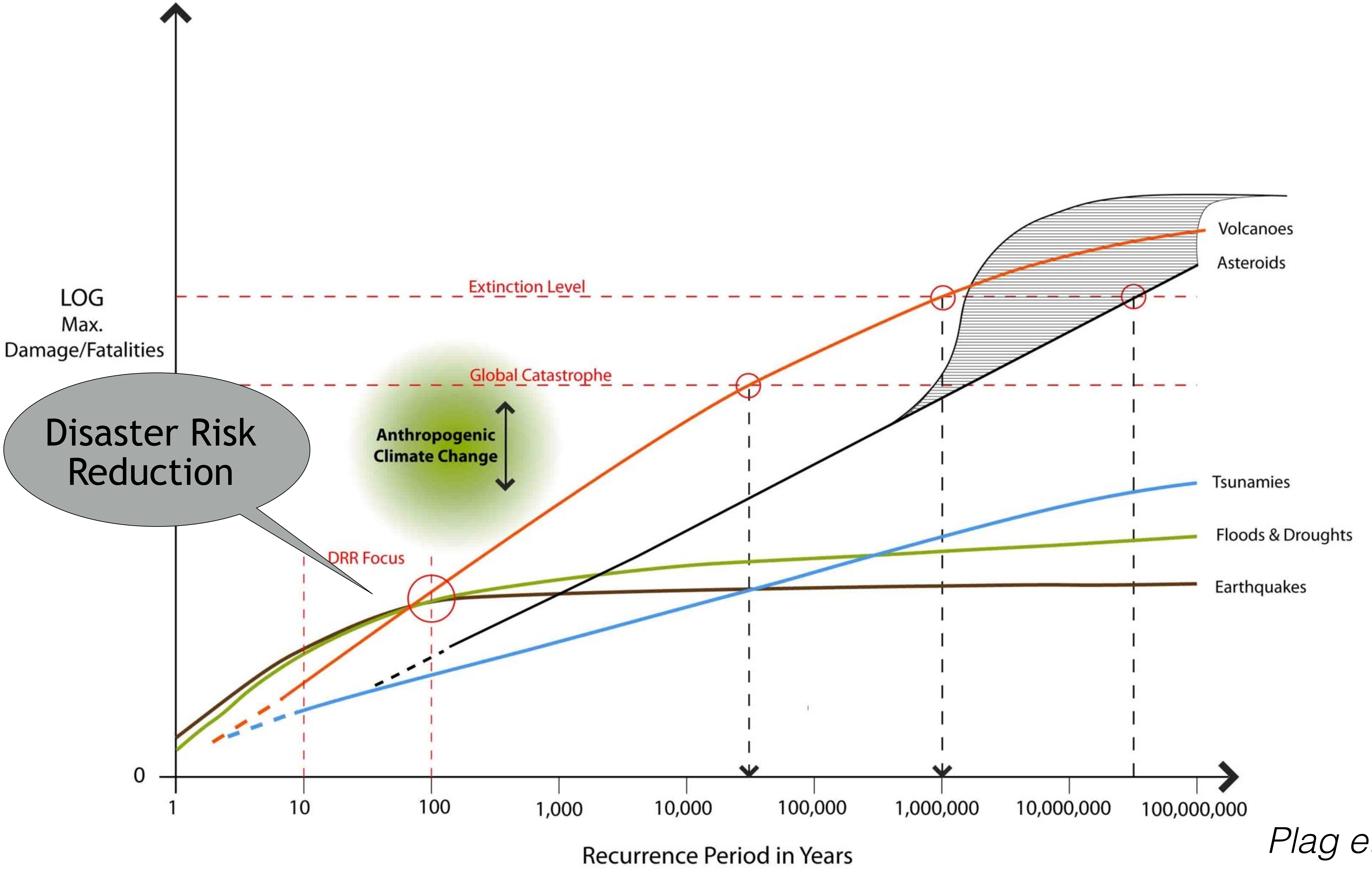
Plag et al., 2015

Extreme Natural Hazards



Plag et al., 2015

Extreme Natural Hazards



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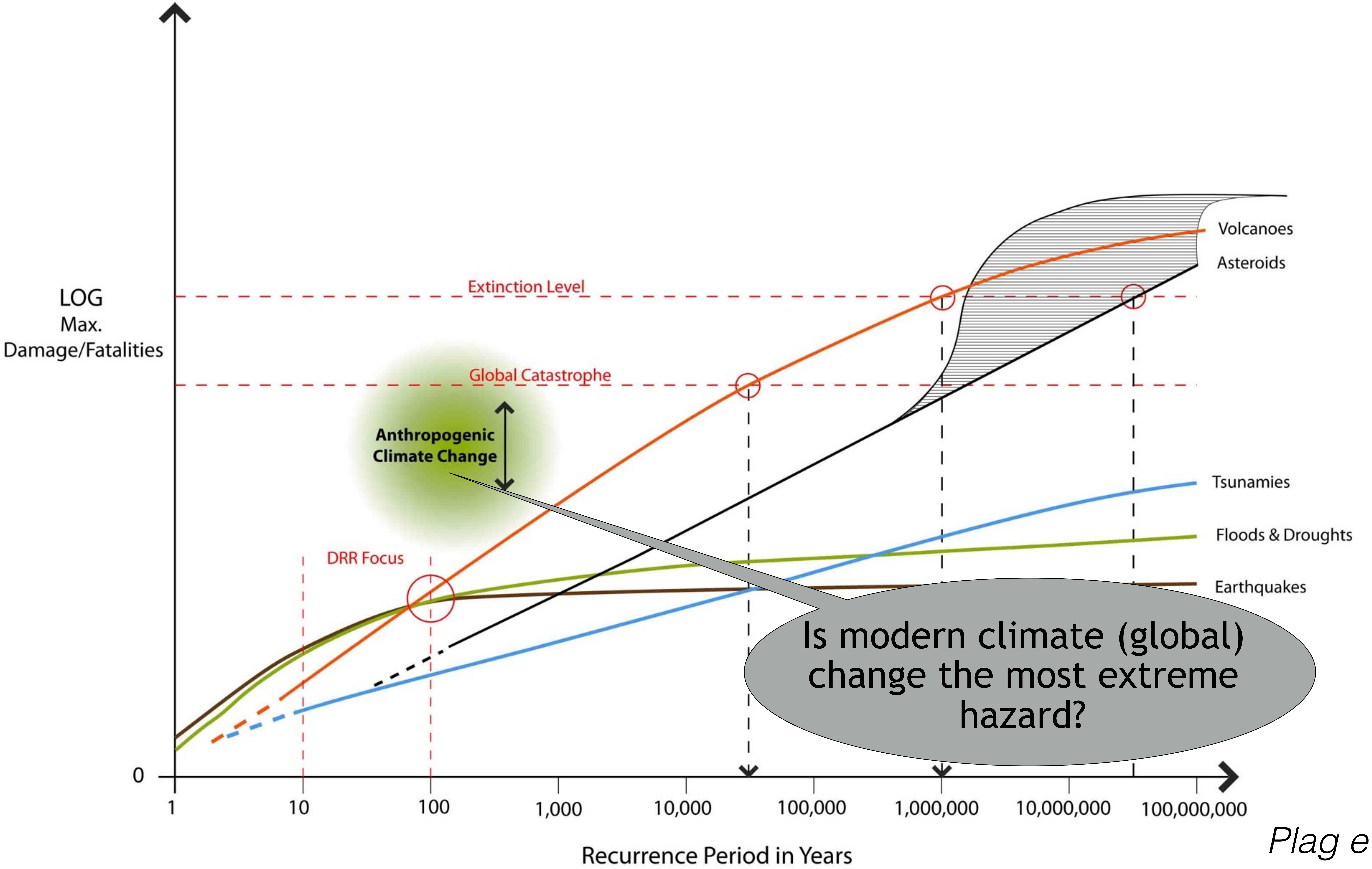
Extreme Natural Hazards



Plag et al., 2015

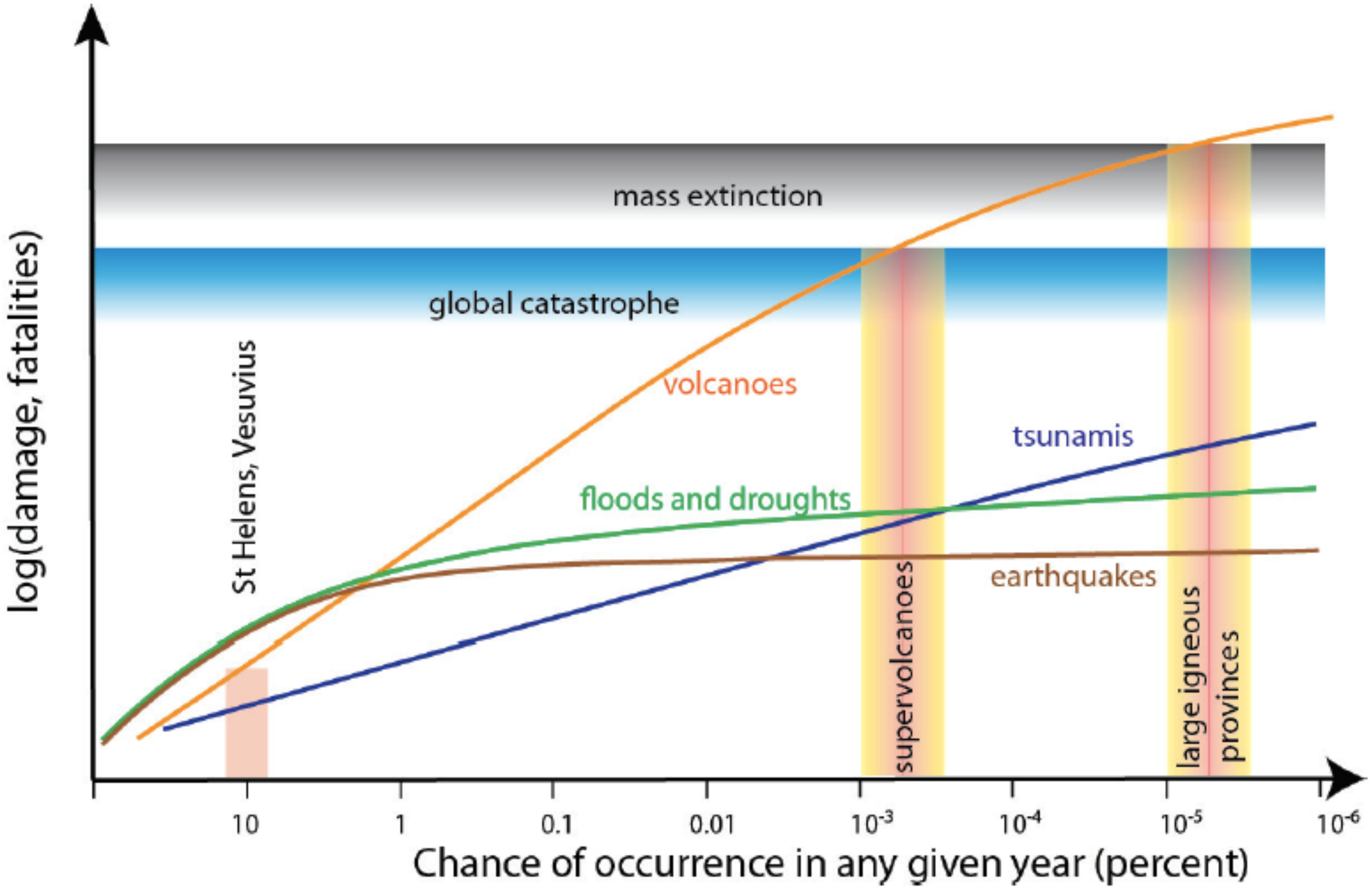
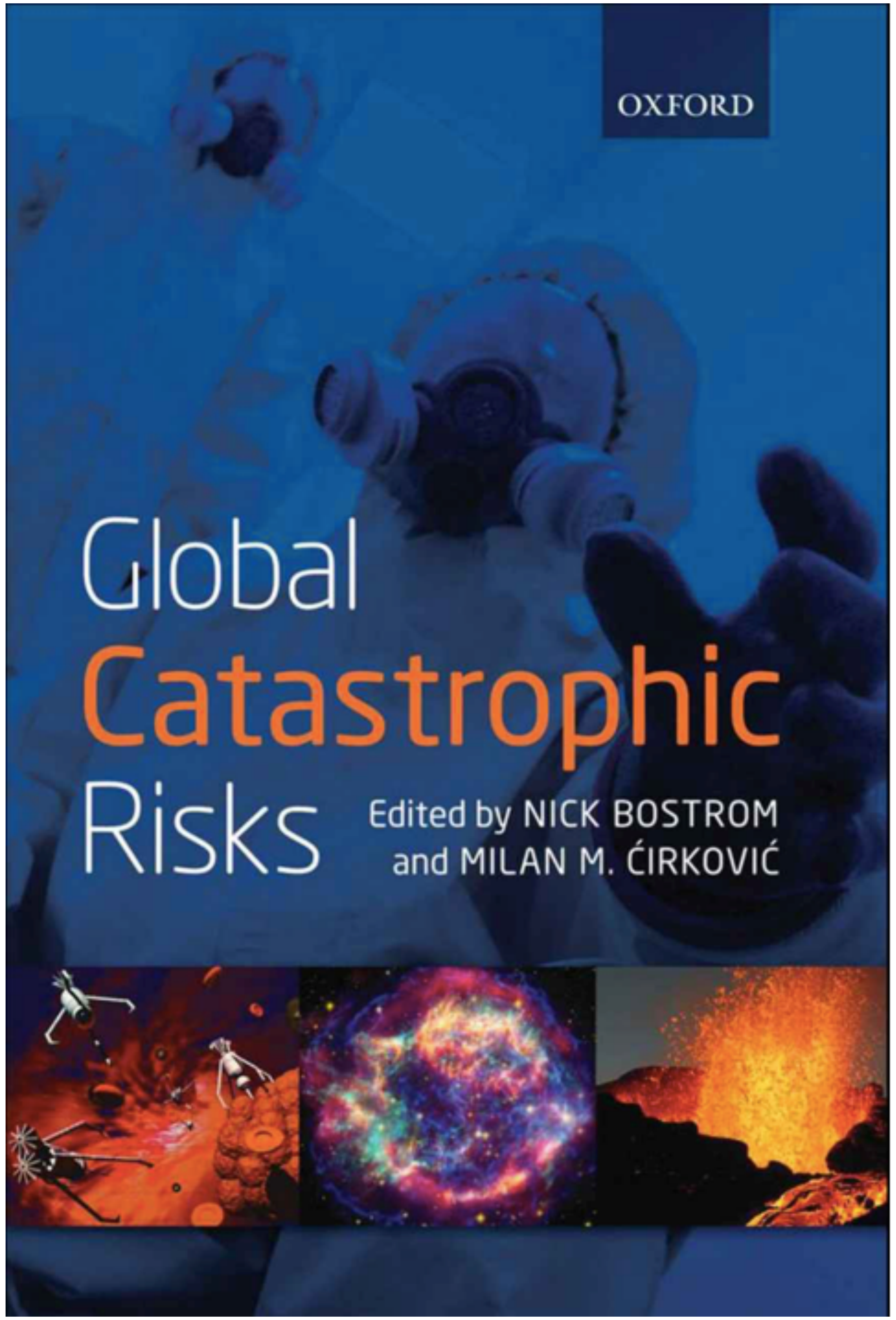


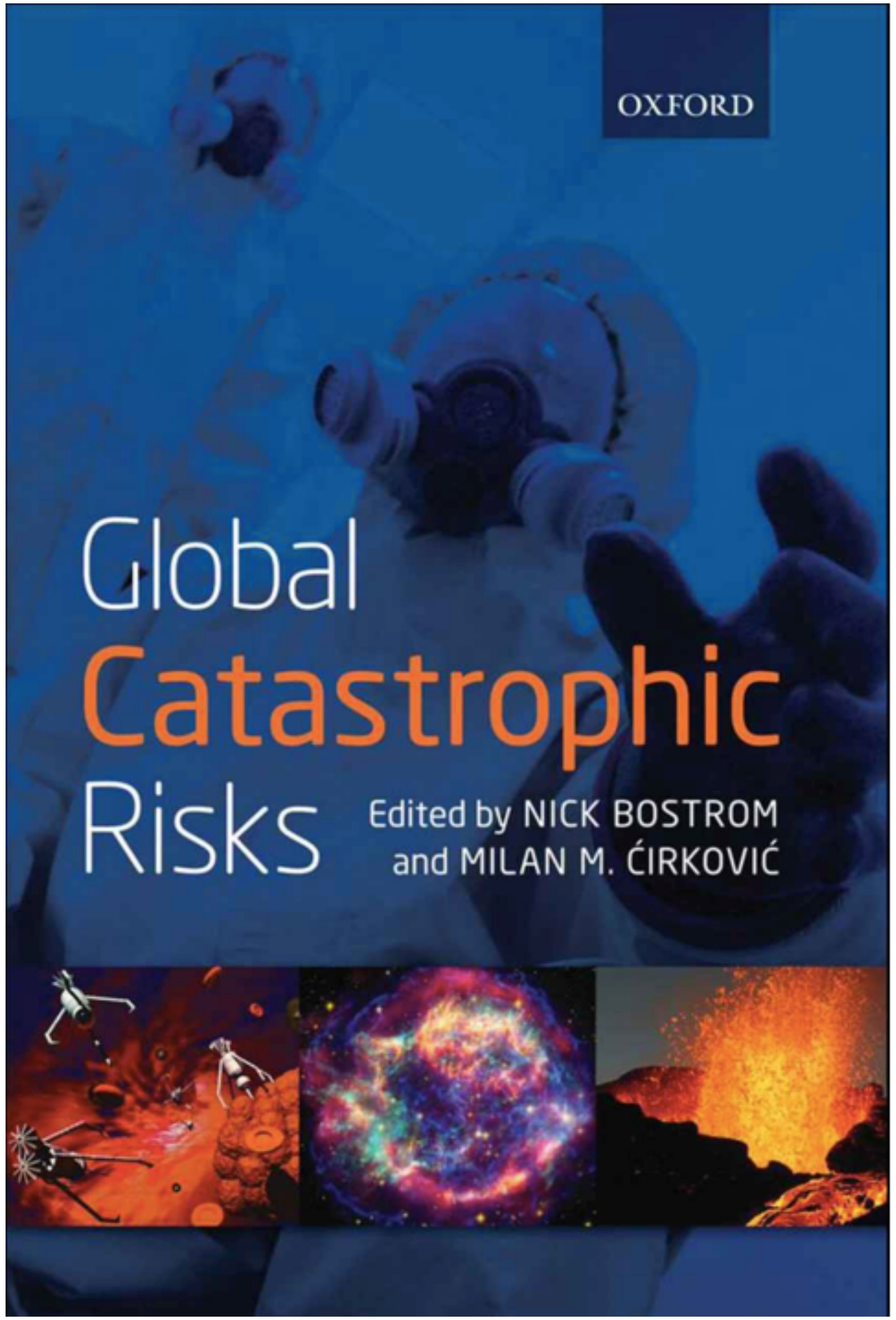
FIGURE 1.2 Qualitative comparison of consequences of selected natural hazards. Also shown are the frequency of events with magnitudes similar to Mount St. Helens (1980) and Vesuvius (79 AD), super-eruptions, and large igneous province eruptions. An exceptionally rare but very large supervolcano and large igneous province eruptions would have global consequences. In contrast, the maximum size of earthquakes limits their impacts. Tsunamis can be generated by earthquakes, landslides, volcanic eruptions, and asteroid impacts. The slope of the curves, while qualitative, reflects the relationship between event size and probability of occurrence: Earthquakes, and to a lesser extent floods and drought, saturate at a maximum size. SOURCE: Adapted from Plag et al. (2015).

NASEM, 2017



"*To produce a civilization-disrupting event, an impactor would need a diameter of at least 1 or 2 km. A 10-km impactor would, it appears, have a good chance of causing the extinction of the human species. But even sub-kilometre impactors could produce damage reaching the level of global catastrophe, depending on their composition, velocity, angle, and impact site.*"

Extreme Natural Hazards



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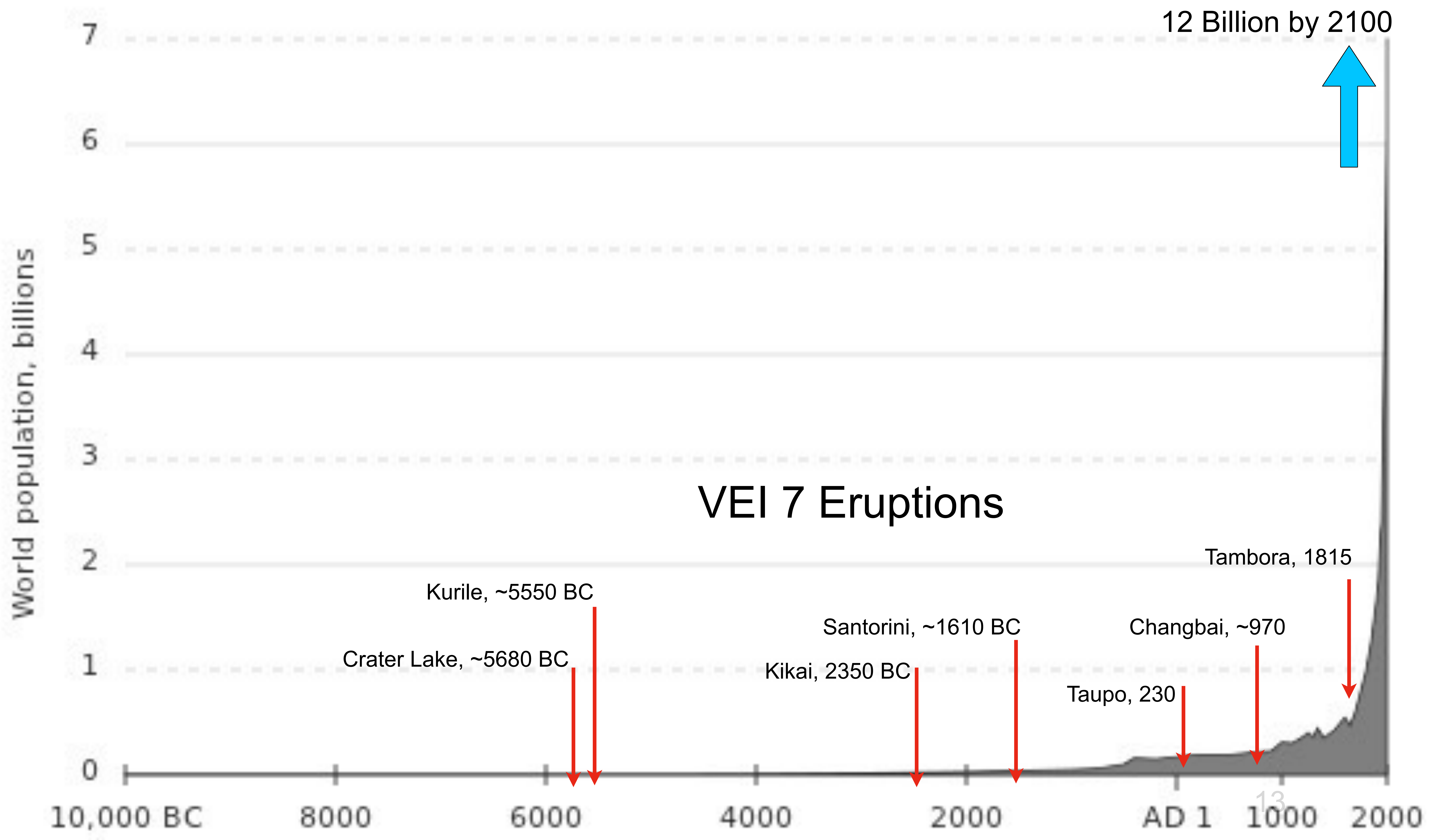
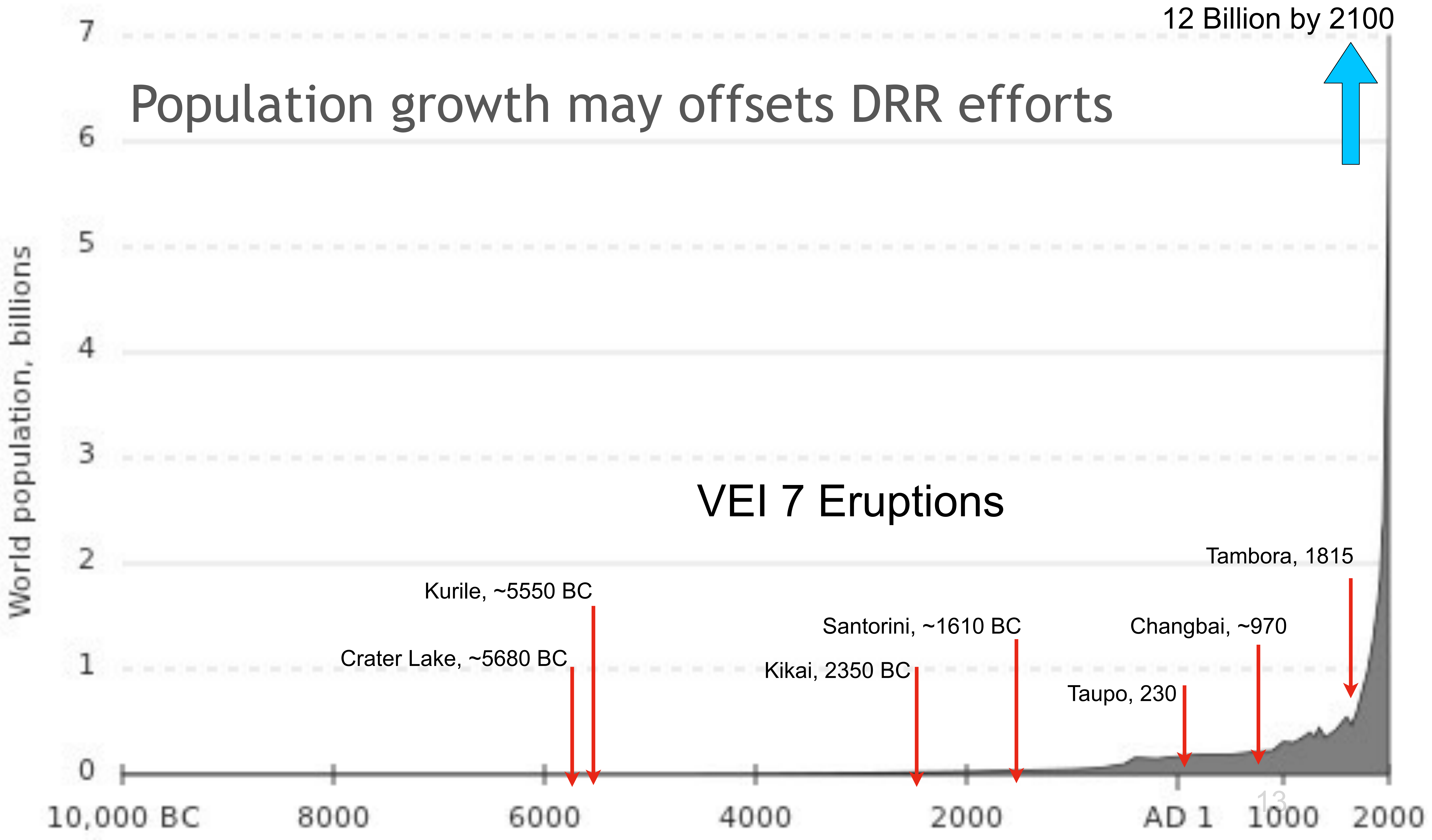
"More than 20 super-eruption sites for the last 2 million years have been identified. This would suggest that, on average, a super-eruption occurs at least once every 50,000 years. However, there may well have been additional super-eruptions that have not yet been identified in the geological record."


12 Billion by 2100
World population, billions
7
6
5
4
3
2
1
0
VEI 7 Eruptions
Kurile, ~5550 BC
Crater Lake, ~5680 BC
Santorini, ~1610 BC
Kikai, 2350 BC
Tambora, 1815
Changbai, ~970
Taupo, 230
10,000 BC
8000
6000
4000
2000
AD 1
1000
2000


12 Billion by 2100
Population growth may offsets DRR efforts
VEI 7 Eruptions
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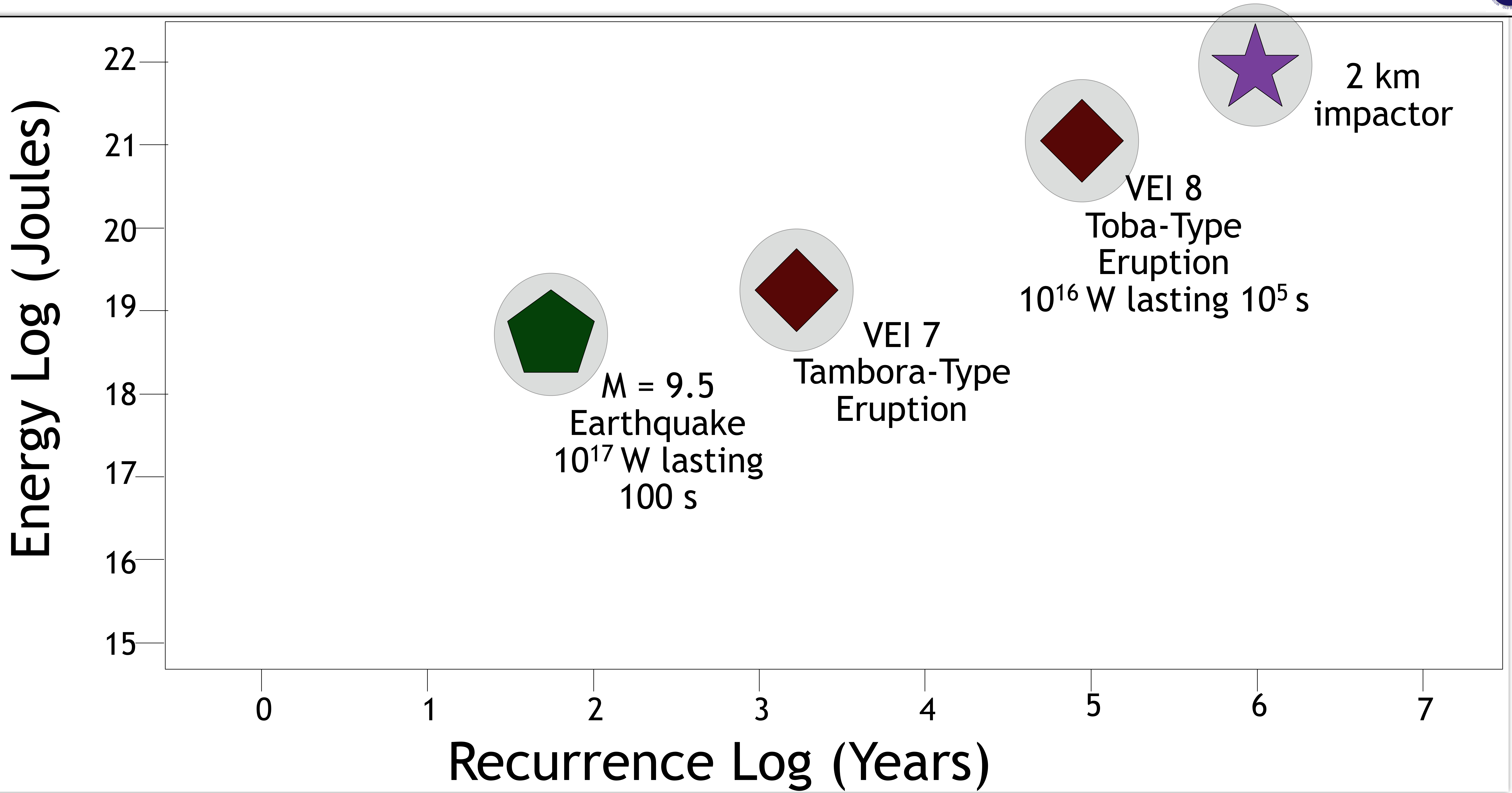
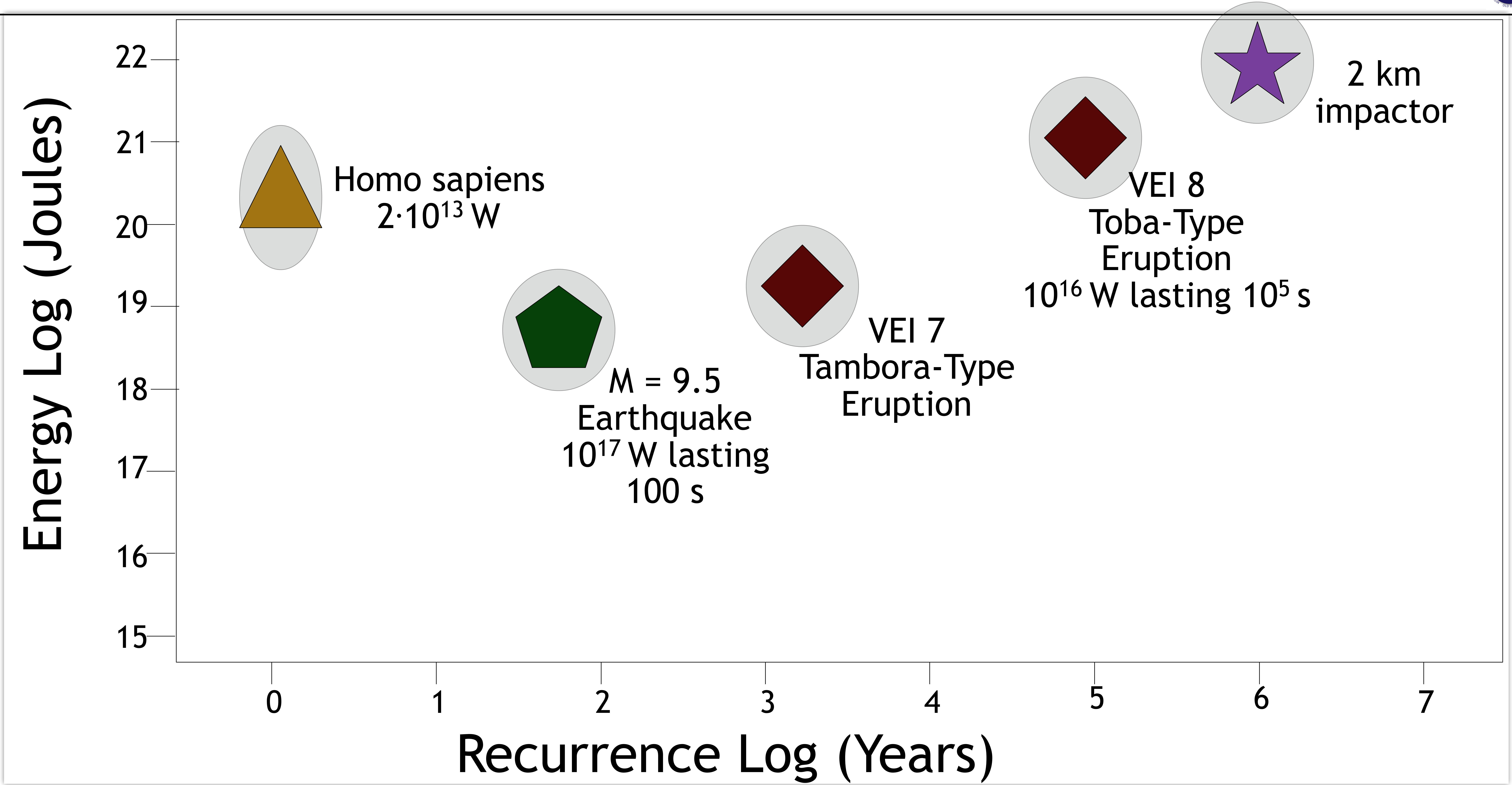
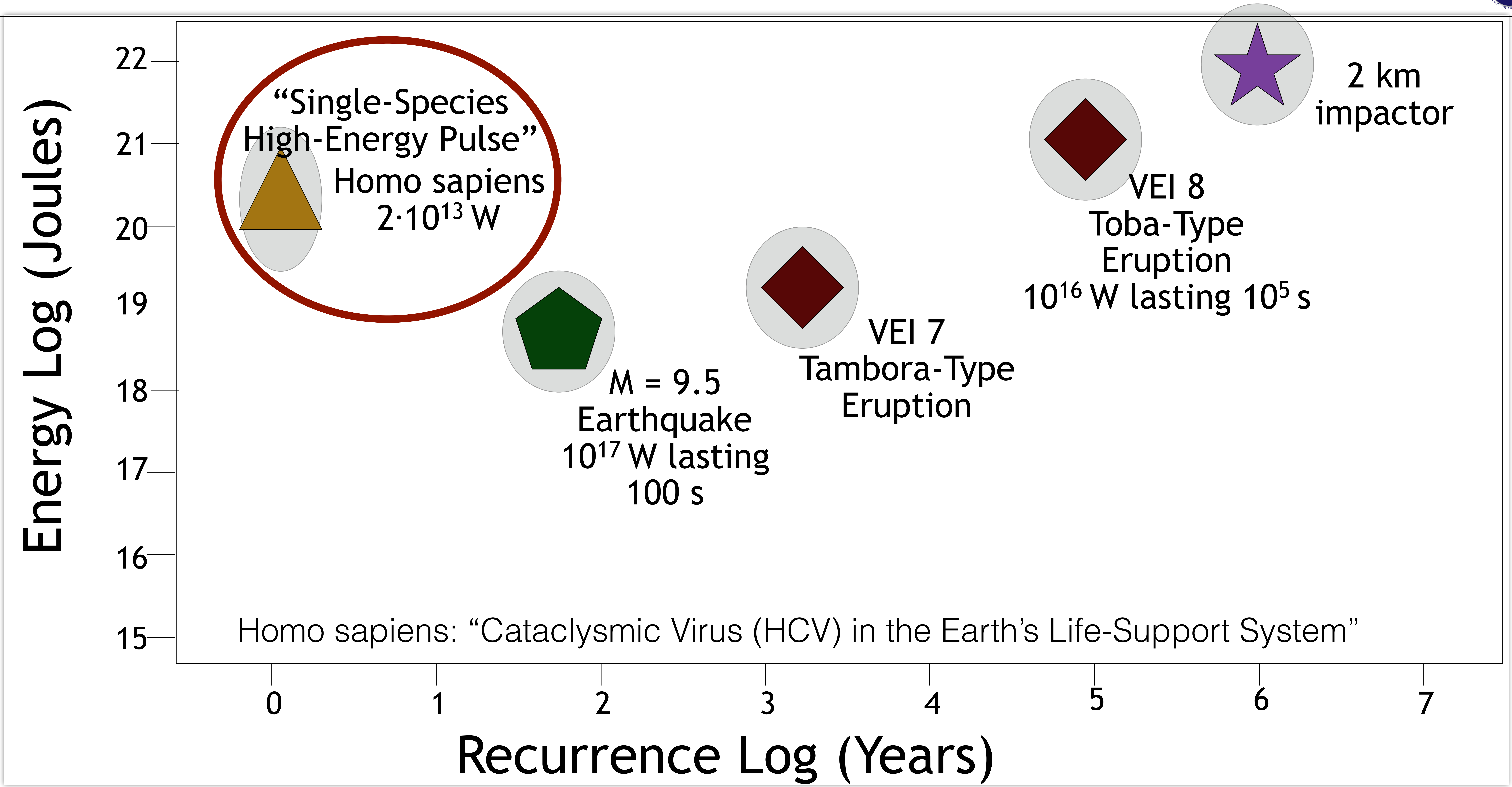
Extreme Natural Hazards

Extreme Natural Hazards





Energy Log (Joules)
22
21
20
19
18
17
16
15
Homo sapiens
2·10[13] W
M = 9.5
Earthquake
10[17] W lasting
100 s
VEI 7
Tambora-Type
Eruption
VEI 8
Toba-Type
Eruption
10[16] W lasting 10[5] s
2 km
impactor
0
1
2
3
4
5
6
7
Recurrence Log (Years)


Energy Log (Joules)
22
21
20
19
18
17
16
15
"Single-Species
High-Energy Pulse"
Homo sapiens
2·10^13 W
M = 9.5
Earthquake
10^17 W lasting
100 s
VEI 7
Tambora-Type
Eruption
VEI 8
Toba-Type
Eruption
10^16 W lasting 10^5 s
2 km
impactor
Homo sapiens: "Cataclysmic Virus (HCV) in the Earth's Life-Support System"
0
1
2
3
4
5
6
7
Recurrence Log (Years)

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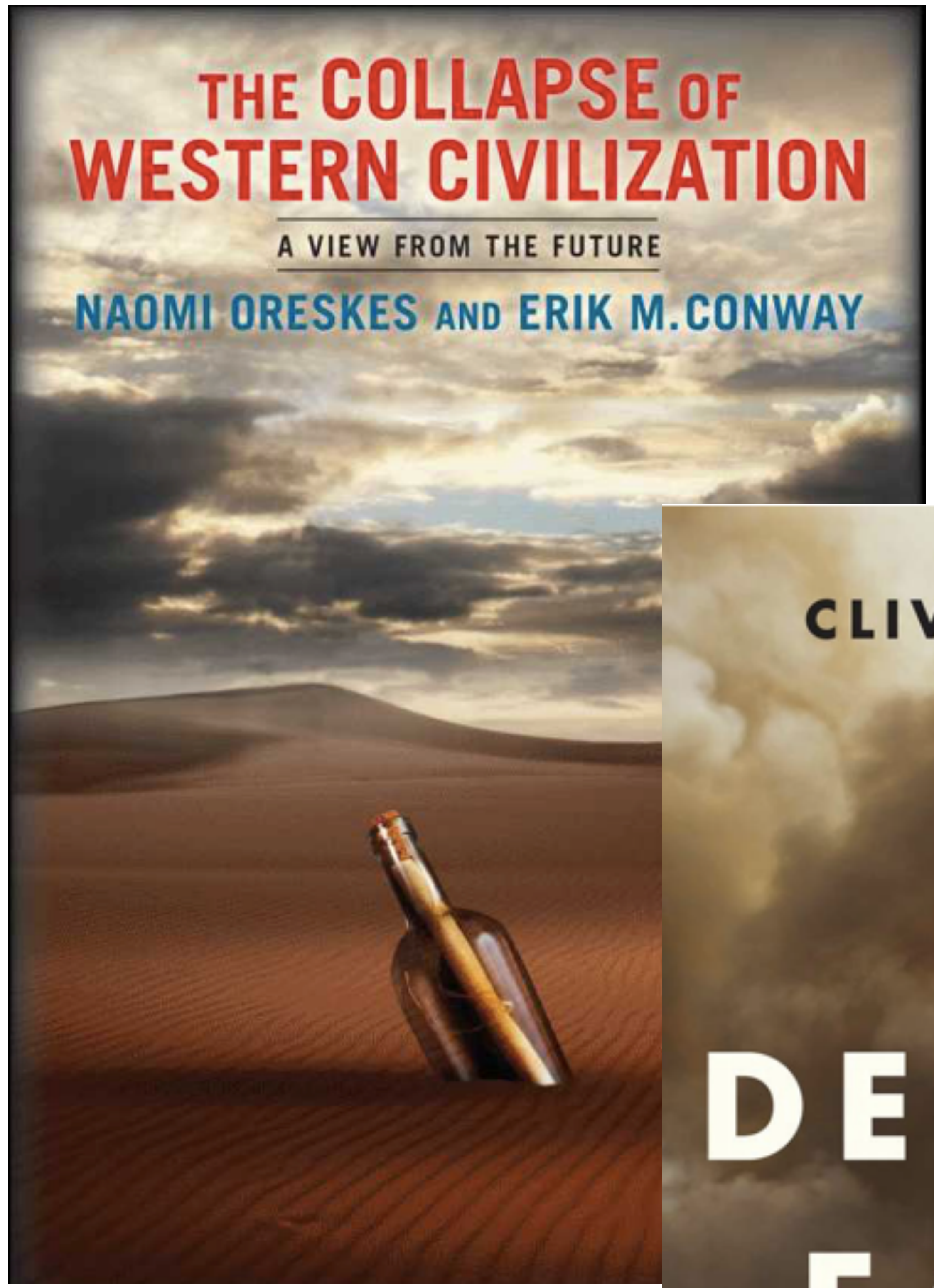
Global Risk Assessments

How to think and talk about possible futures, including worst cases?



The Uninhabitable Earth

Famine, economic collapse, a sun that cooks us: What climate change could wreak — sooner than you think.

By **David Wallace-Wells**

July 9, 2017
9:00 pm

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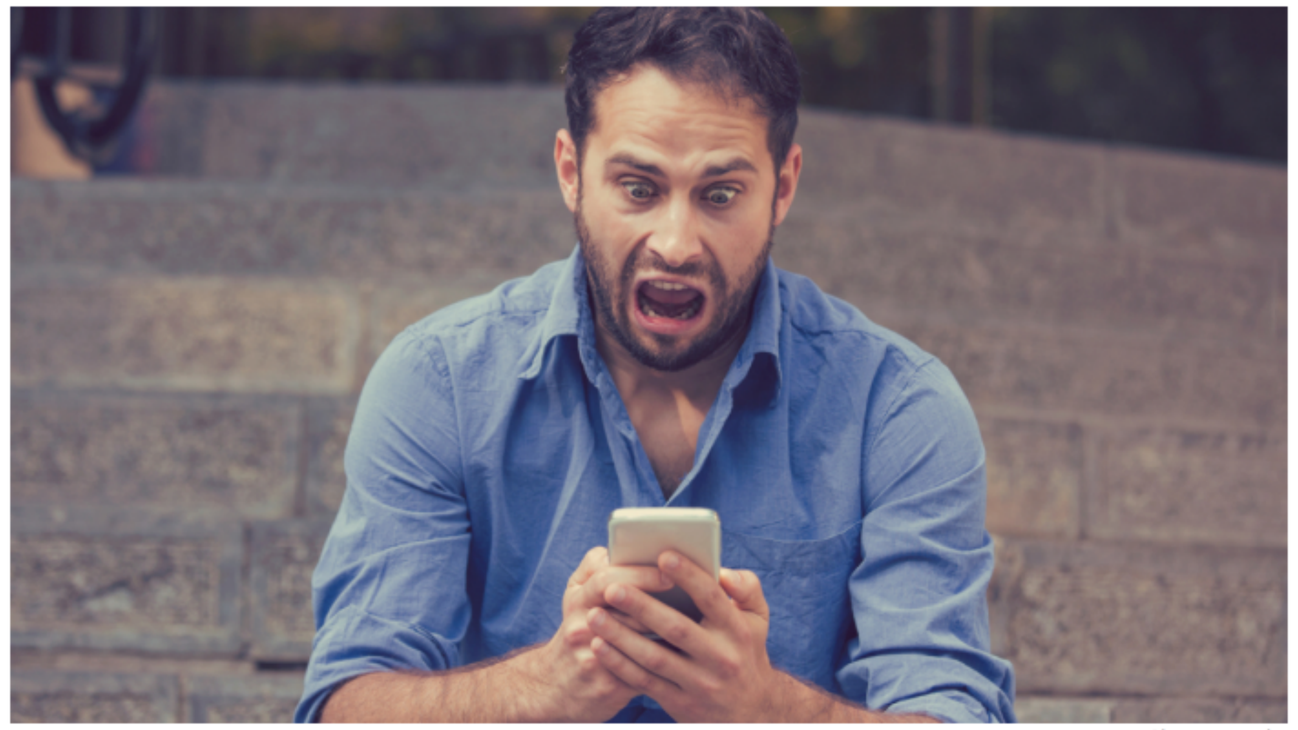
To read an annotated version of this article, complete with interviews with scientists and links to further reading, click here.

I. 'Doomsday'

Fossils by Heartles

In the jungles of C
tops 90 percent, si
over 105 degrees i
effect would be fas



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HIGH ANXIETY

Stop scaring people about climate change. It doesn't work.

By Eric Holthaus on Jul 10, 2017

Global Risk Assessments

Global Risk Assessments

What are the causes and consequences of unsustainability and how does this relate to our ethics?

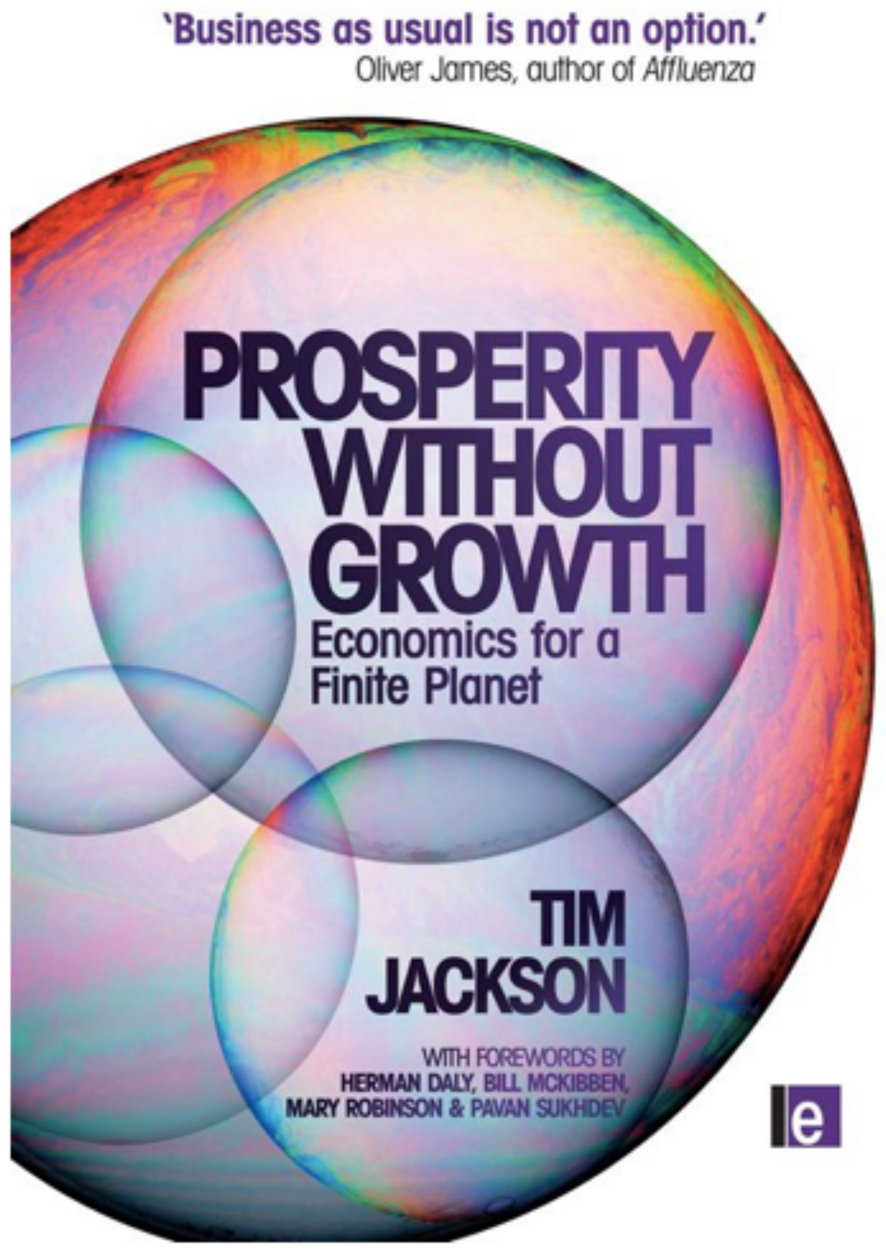



Image Credit: Niño Jose Heredia/©Gulf News

What's causing the sixth mass extinction?

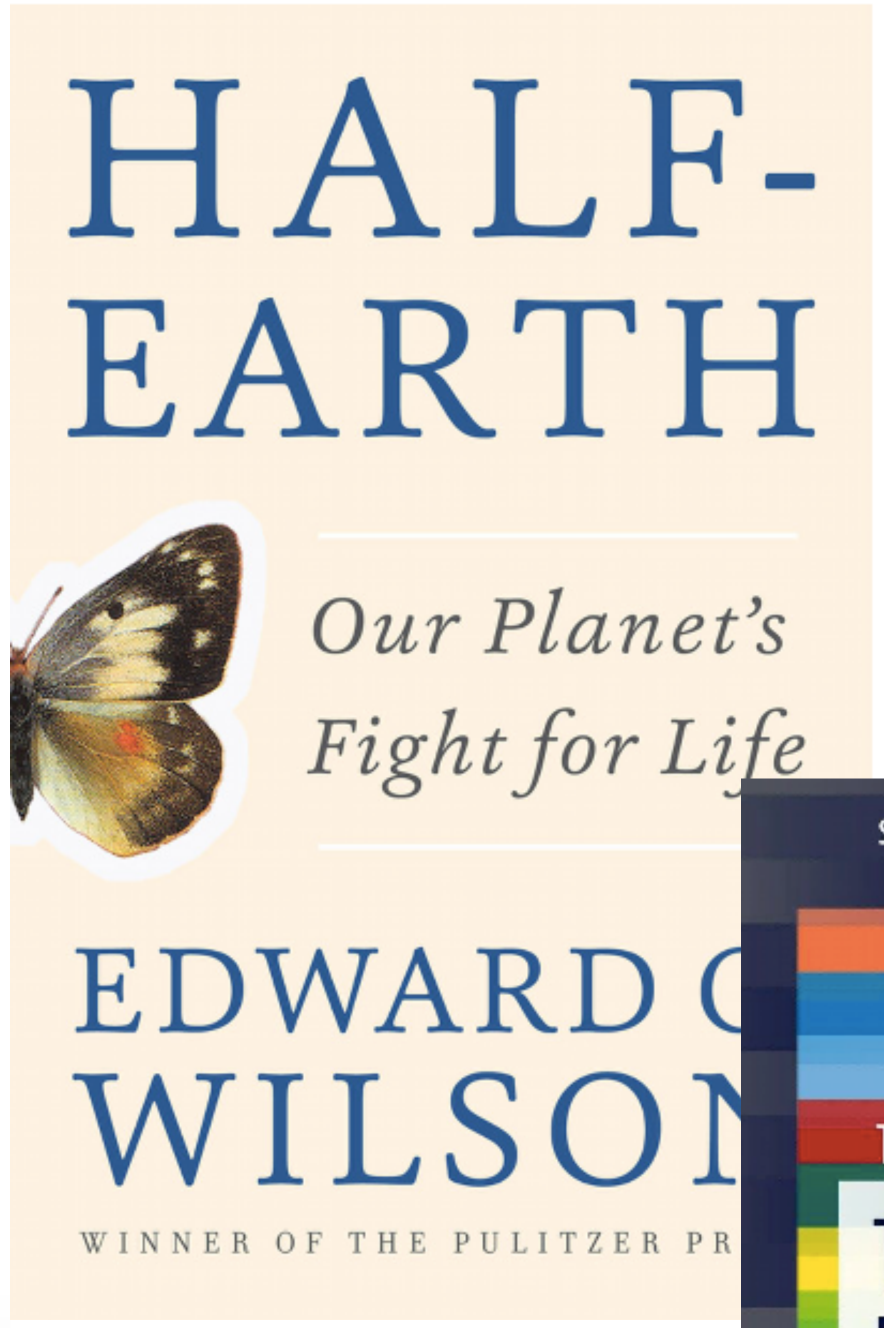
It's simple. It's us. The more people there are, the more habitats we destroy. Human civilisation can only survive if the population begins to shrink

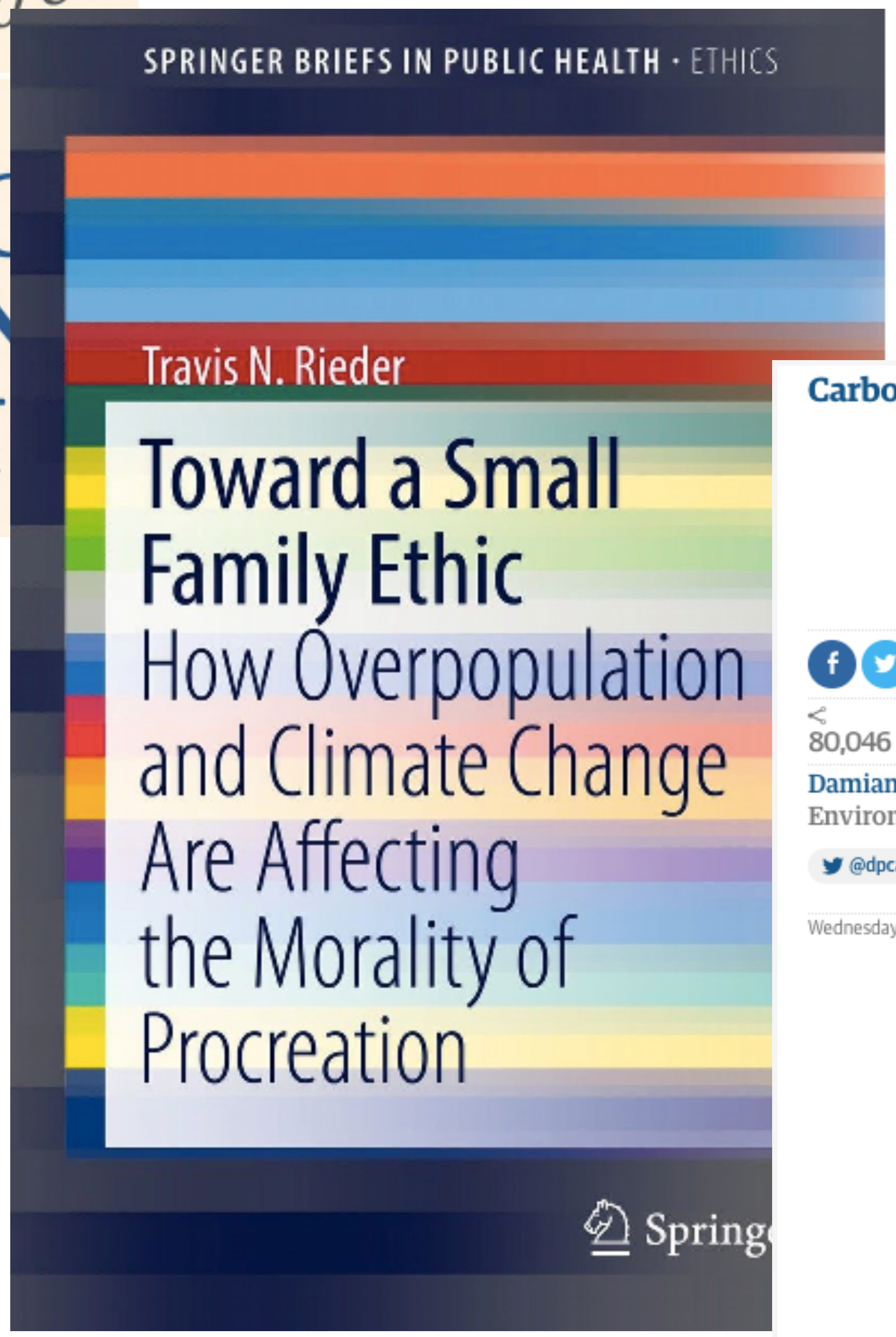
By Paul R. Ehrlich
Published: 16:36 July 13, 2017

GULF NEWS

+MGN AA+

By Paul R Ehrlich






Carbon footprints

Want to fight climate change? Have fewer children

Next best actions are selling your car, avoiding flights and going vegetarian, according to study into true impacts of different green lifestyle choices

80,046 1,415

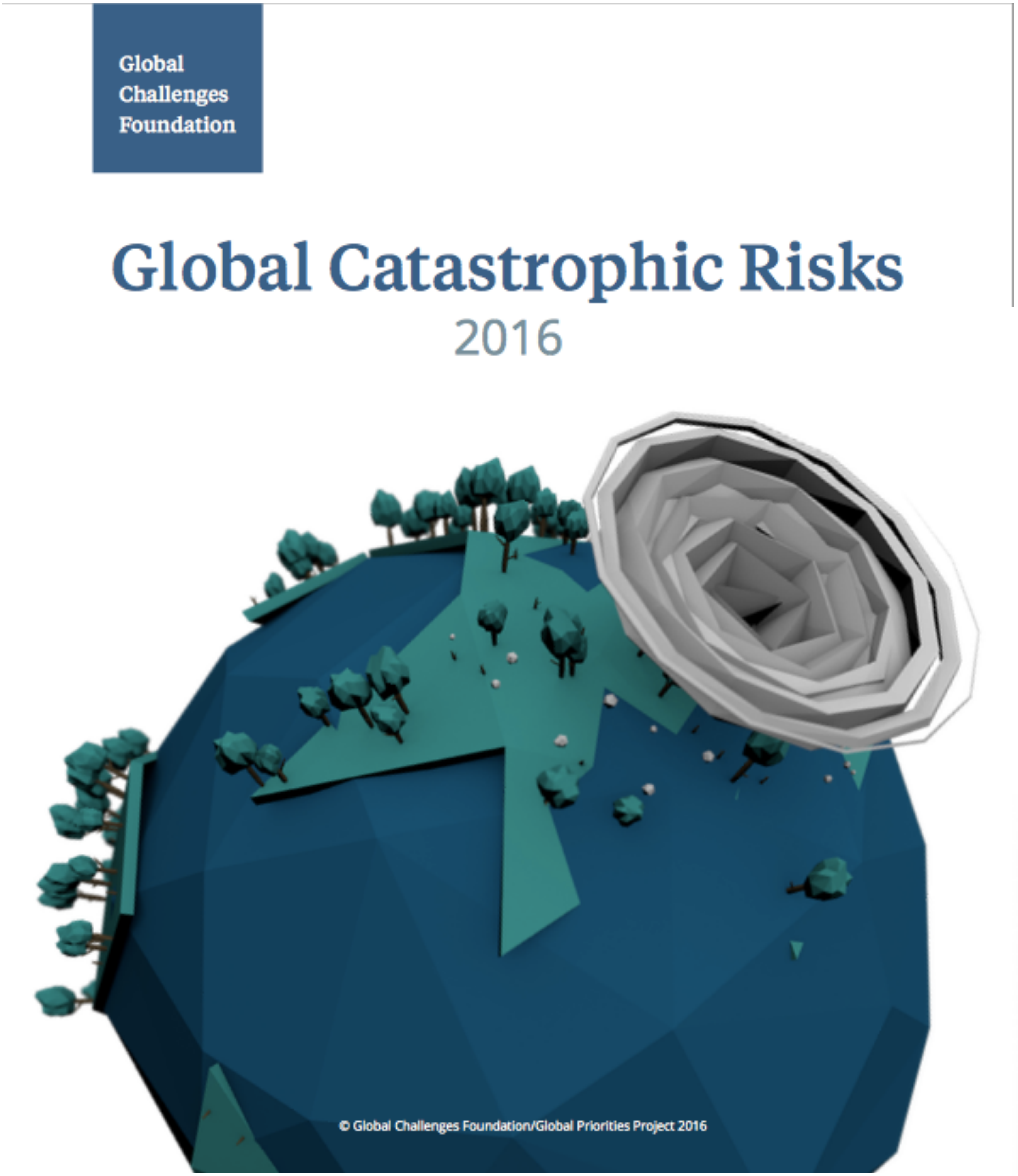
Damian Carrington
Environment editor
@dpcarrington

Wednesday 12 July 2017 00.45 EDT

Can you bring yourself to have one fewer of these? Photograph: fStop Images GmbH/Alamy

The greatest impact individuals can have in fighting climate change is to have one fewer child, according to a new study that identifies the most effective ways people can cut their carbon emissions.

Global Risk Assessments



Global Challenges Foundation

Global Priorities Project

in association with

Future of Humanity Institute
UNIVERSITY OF OXFORD

OXFORD MARTIN SCHOOL

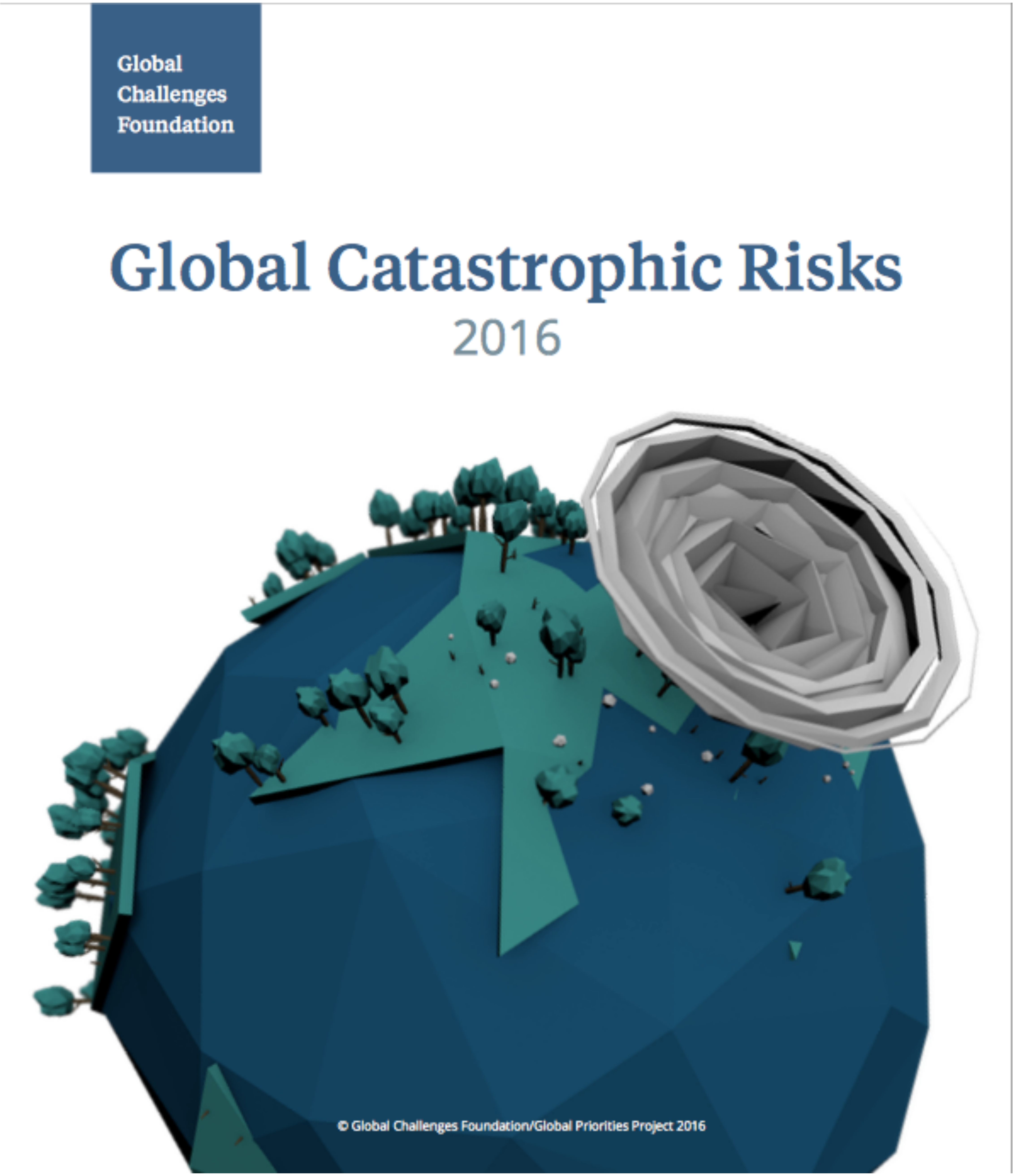
UNIVERSITY OF OXFORD

Global Risk Assessments

"*THE GLOBAL CHALLENGES FOUNDATION works to raise awareness of the Global Catastrophic Risks. Primarily focused on climate change, other environmental degradation and politically motivated violence as well as how these threats are linked to poverty and rapid population growth. Against this background, the Foundation also works to both identify and stimulate the development of good proposals for a management model – a global governance – able to decrease – and at best eliminate – these risks.*"

"*THE GLOBAL PRIORITIES PROJECT helps decision-makers effectively prioritise ways to do good. We achieve this both by advising decision-makers on programme evaluation methodology and by encouraging specific policies. We are a collaboration between the Centre for Effective Altruism and the Future of Humanity Institute, part of the University of Oxford.*"

Global Risk Assessments



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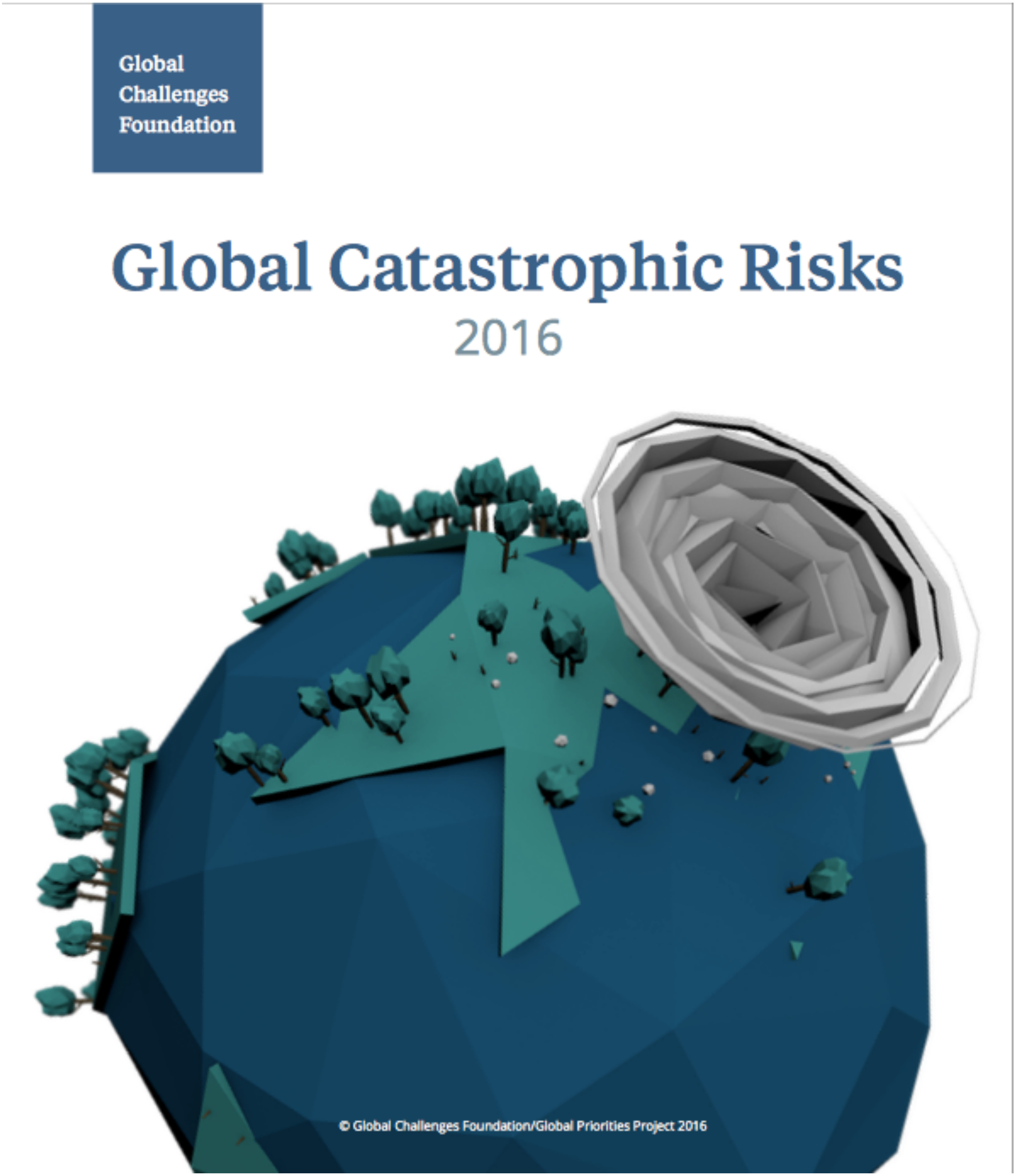
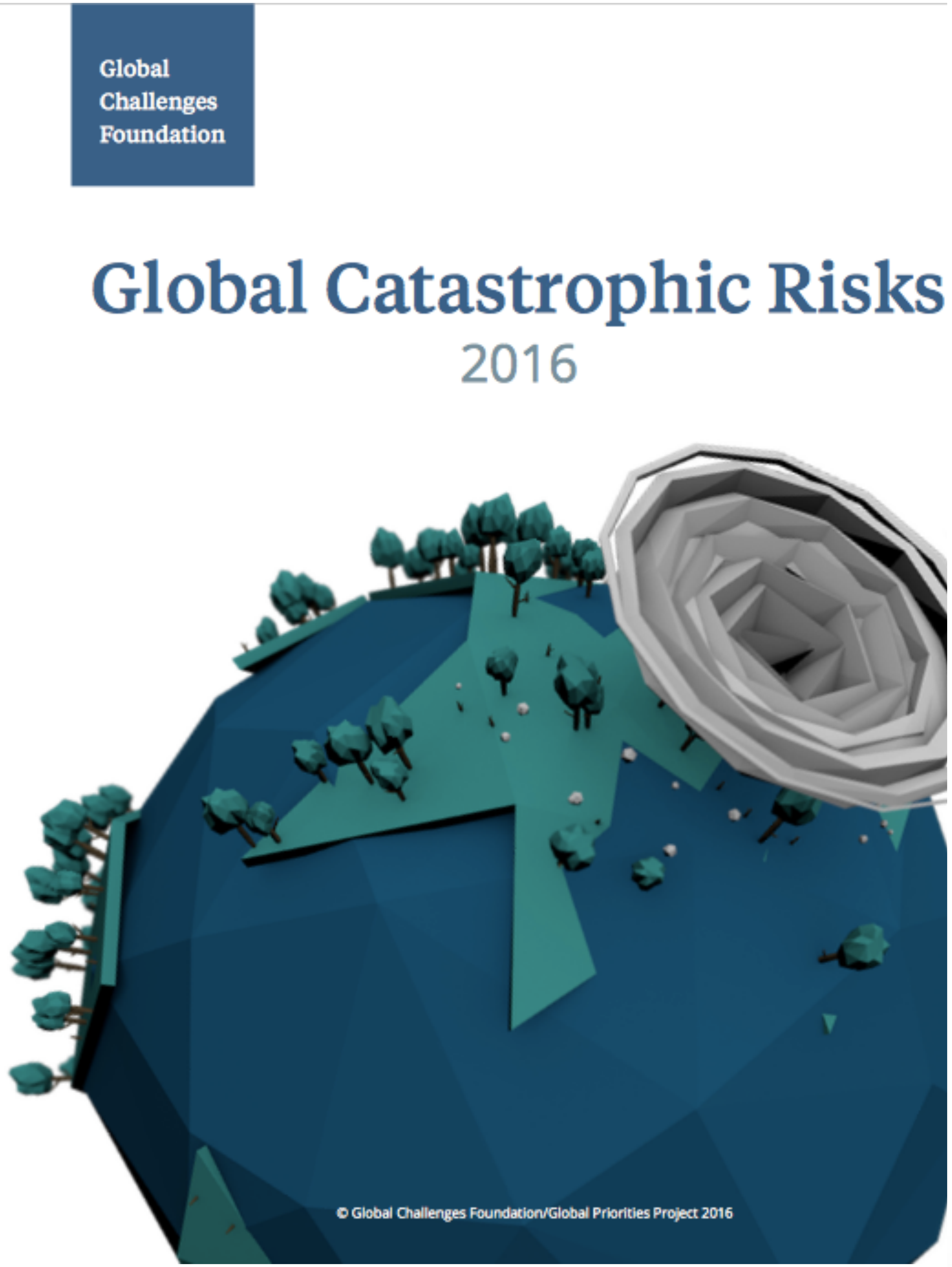
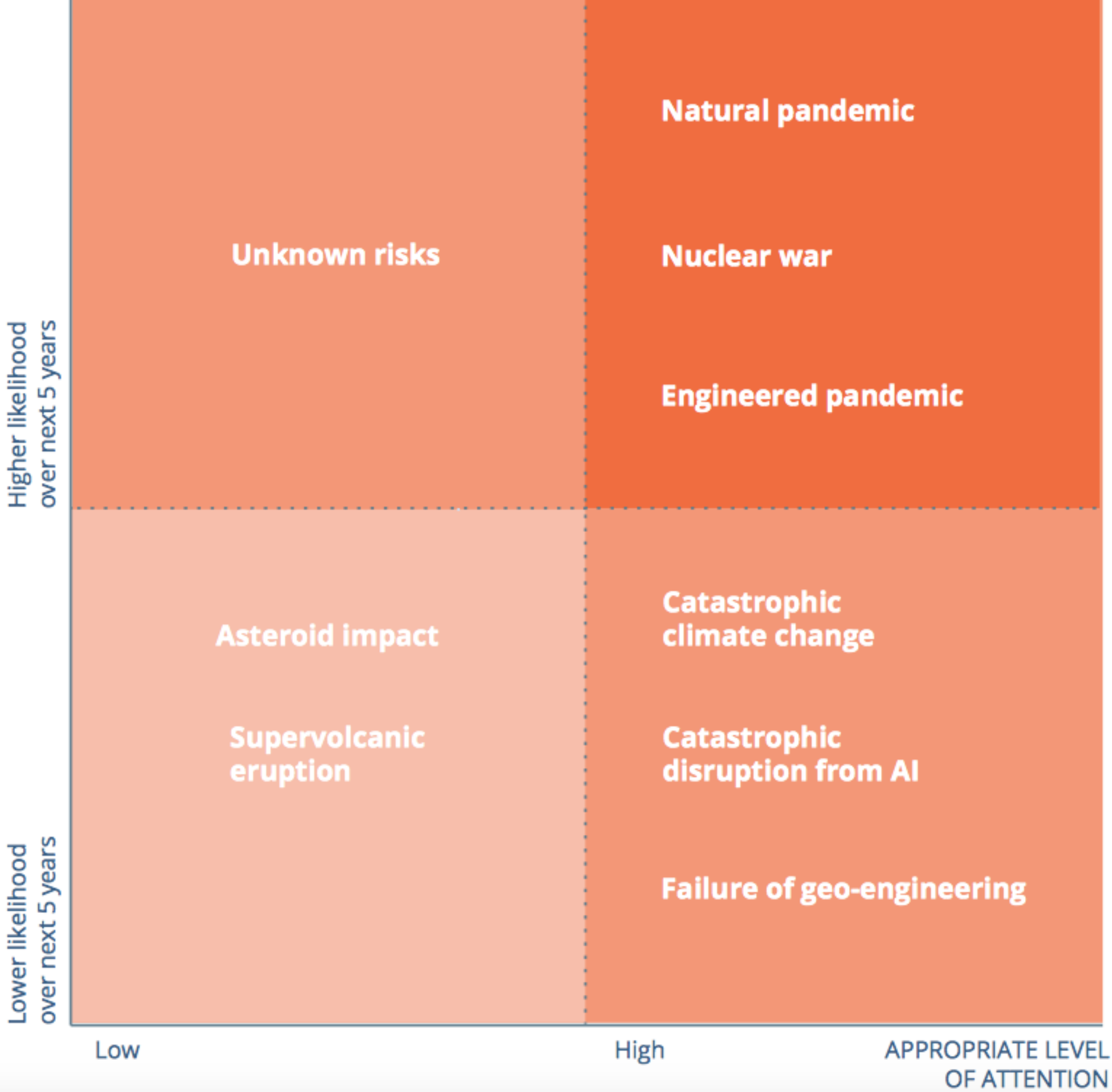


Global Risk Assessments





Global Risk Assessments

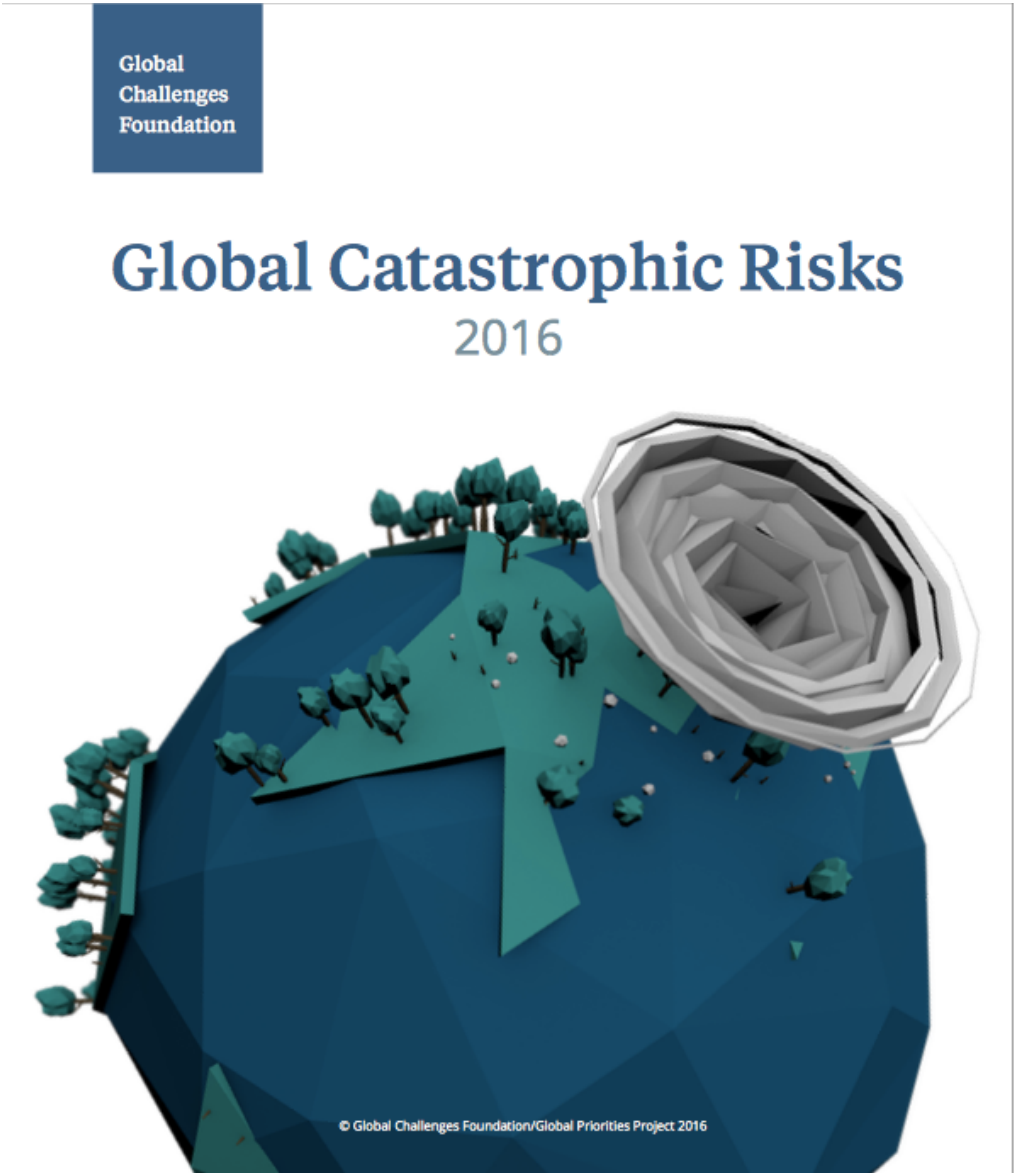
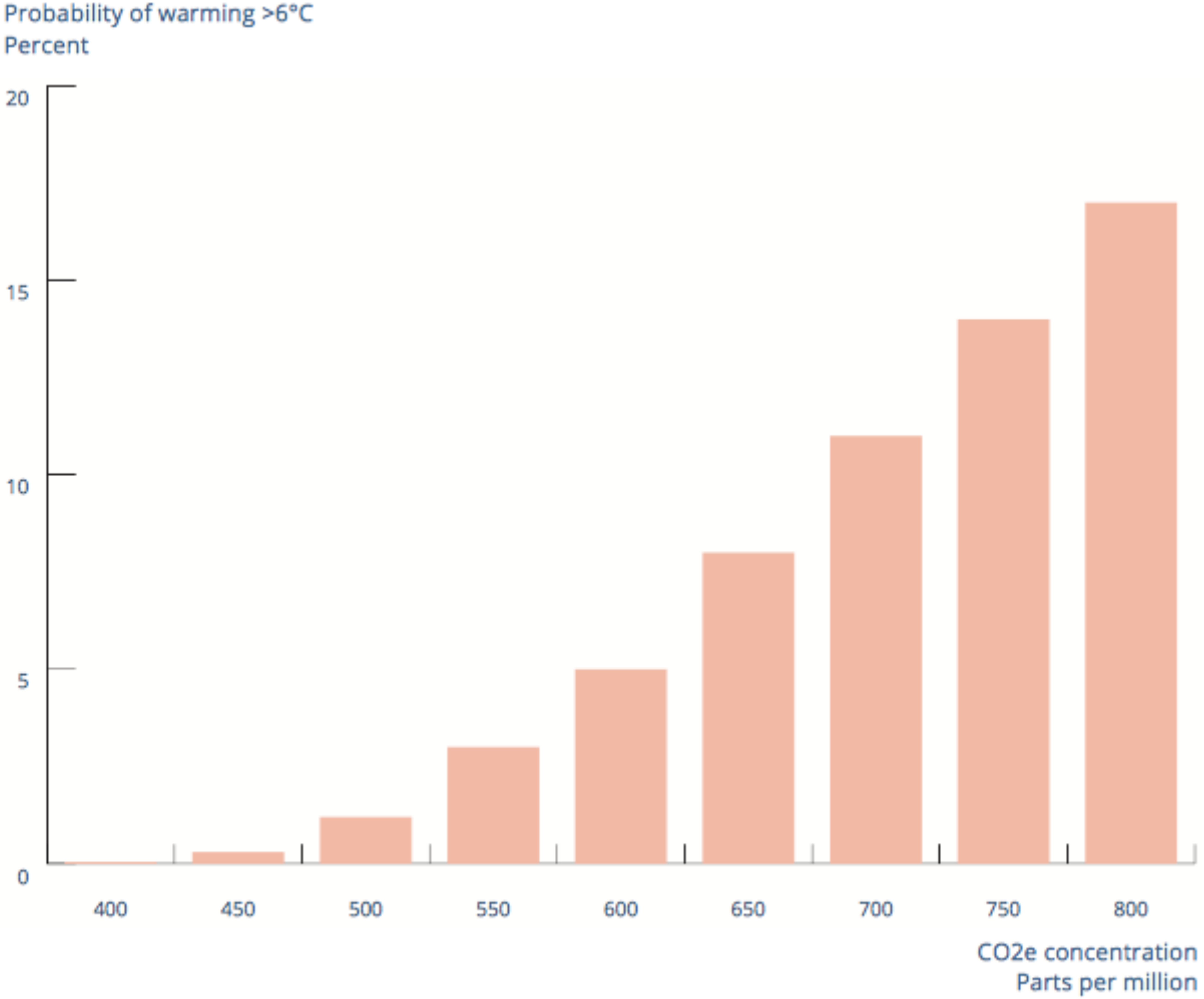


FIGURE 2.1. THE CHANCE OF EXTREME CLIMATE CHANGE

The probability of warming of 6°C for different atmospheric concentrations of greenhouse gases.[39]



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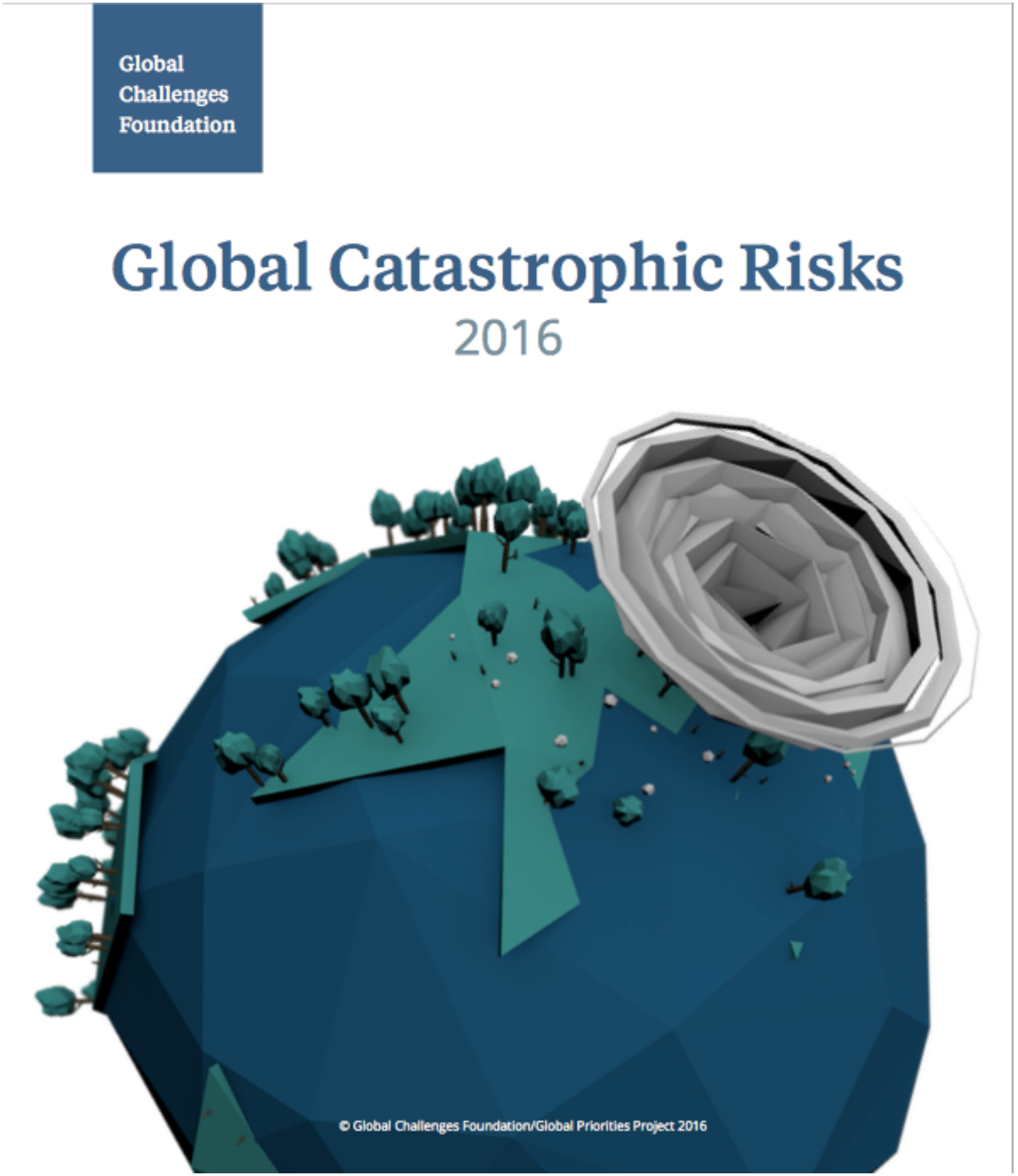
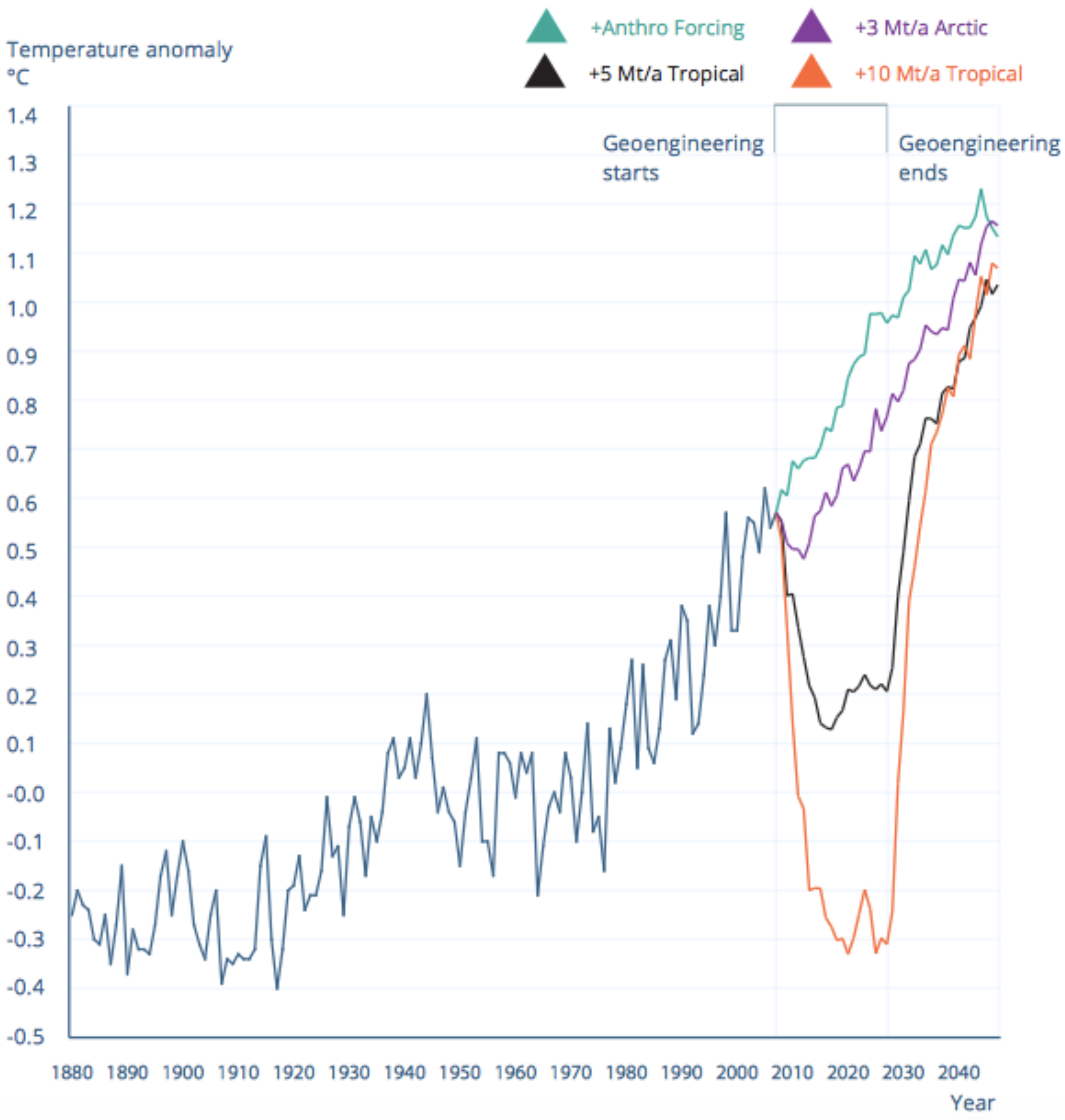
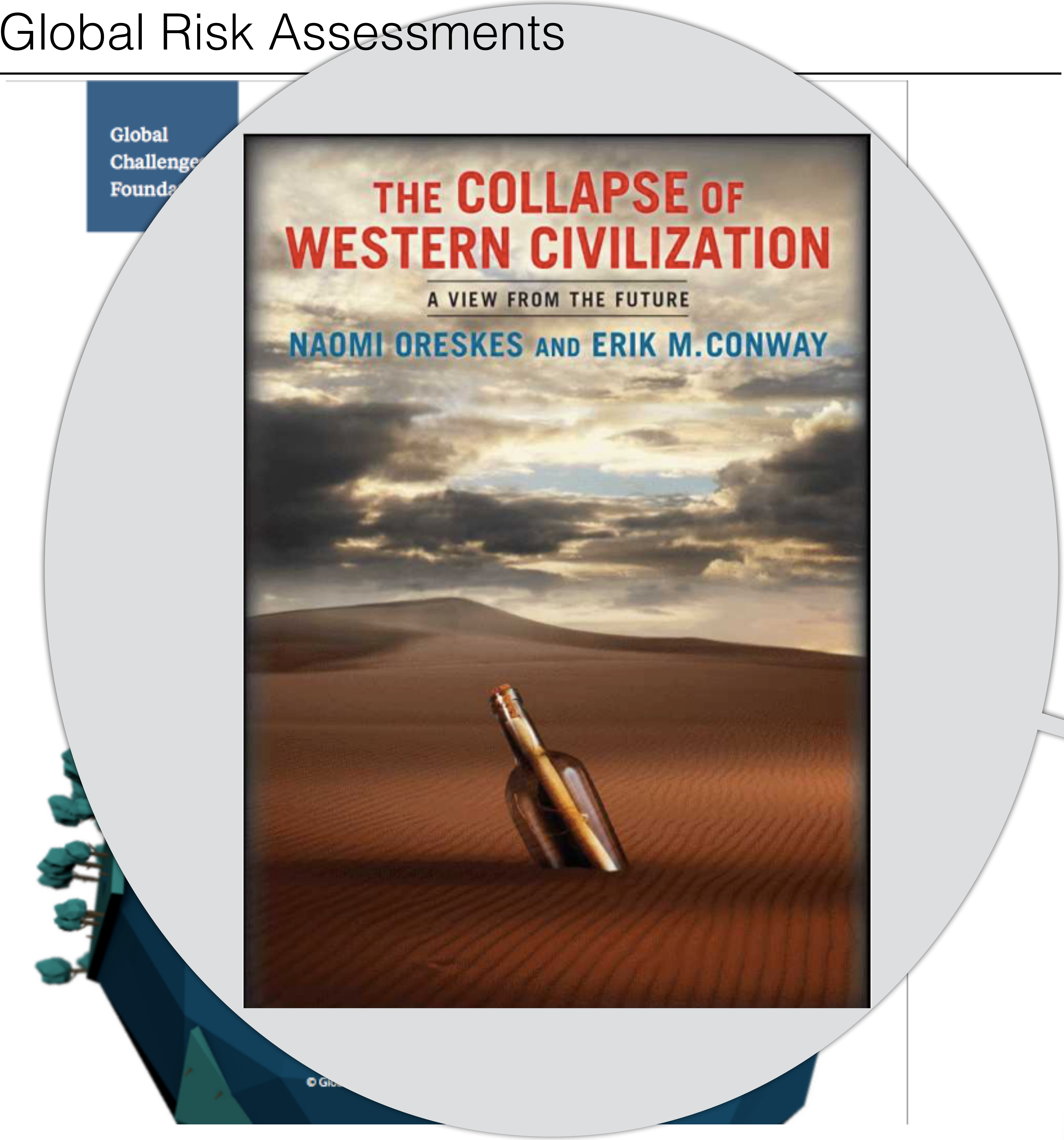


2.5.2. GLOBAL TEMPERATURE ANOMALY FROM GEO-ENGINEERING FOLLOWED BY TERMINATION

Global average surface air temperature change from business as usual emissions, injection of 3 megatons/annum (Mt/a) of SO2 in the Arctic, 5 Mt/a of SO2 in the tropics, and 10 Mt/a SO2 in the tropics.[130]



Global Risk Assessments



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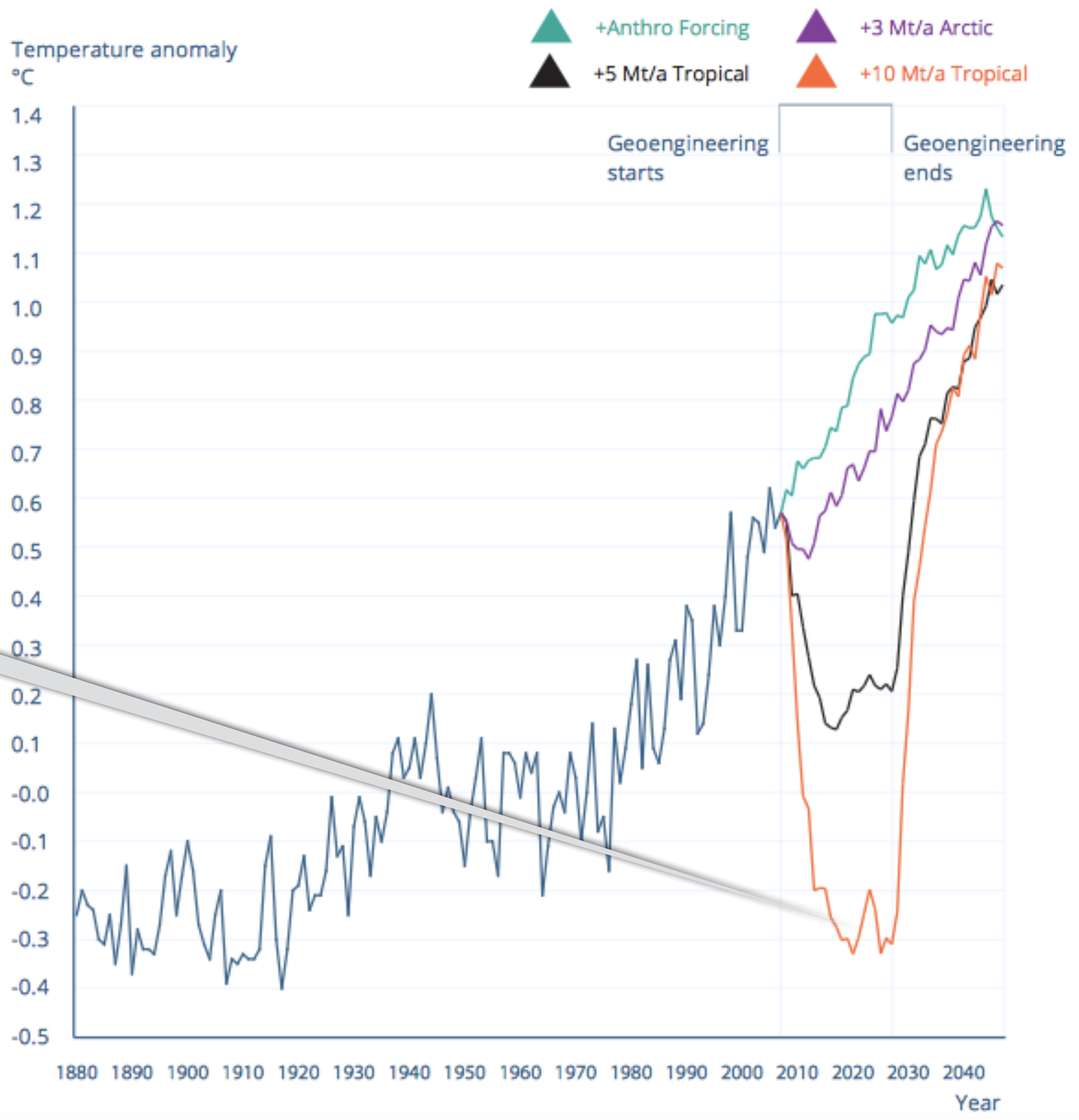
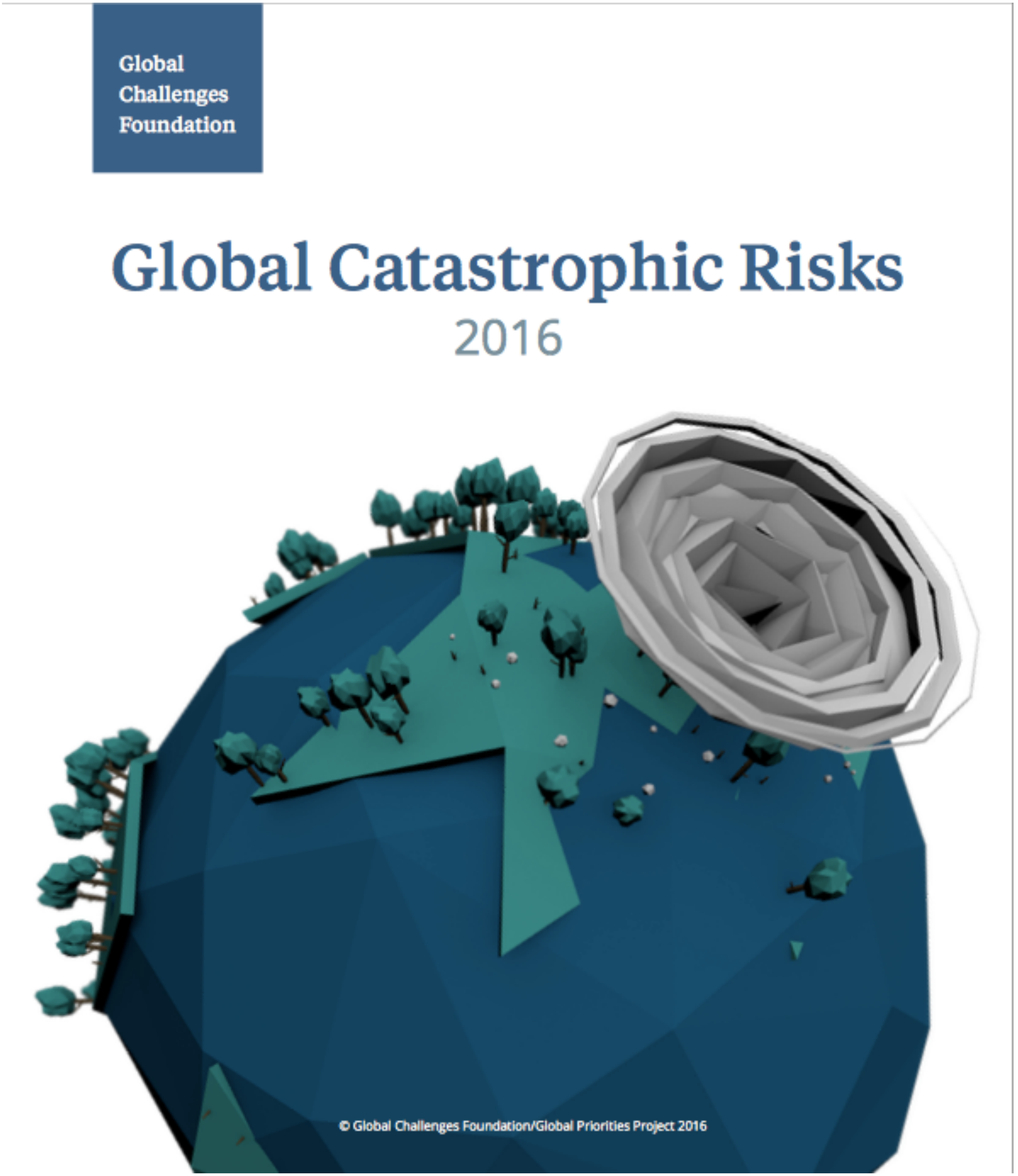


Global Risk Assessments



> Food stockpiles and the ability to rapidly increase production of alternate sources of food would increase resilience to a broad range of risks.

Global Risk Assessments

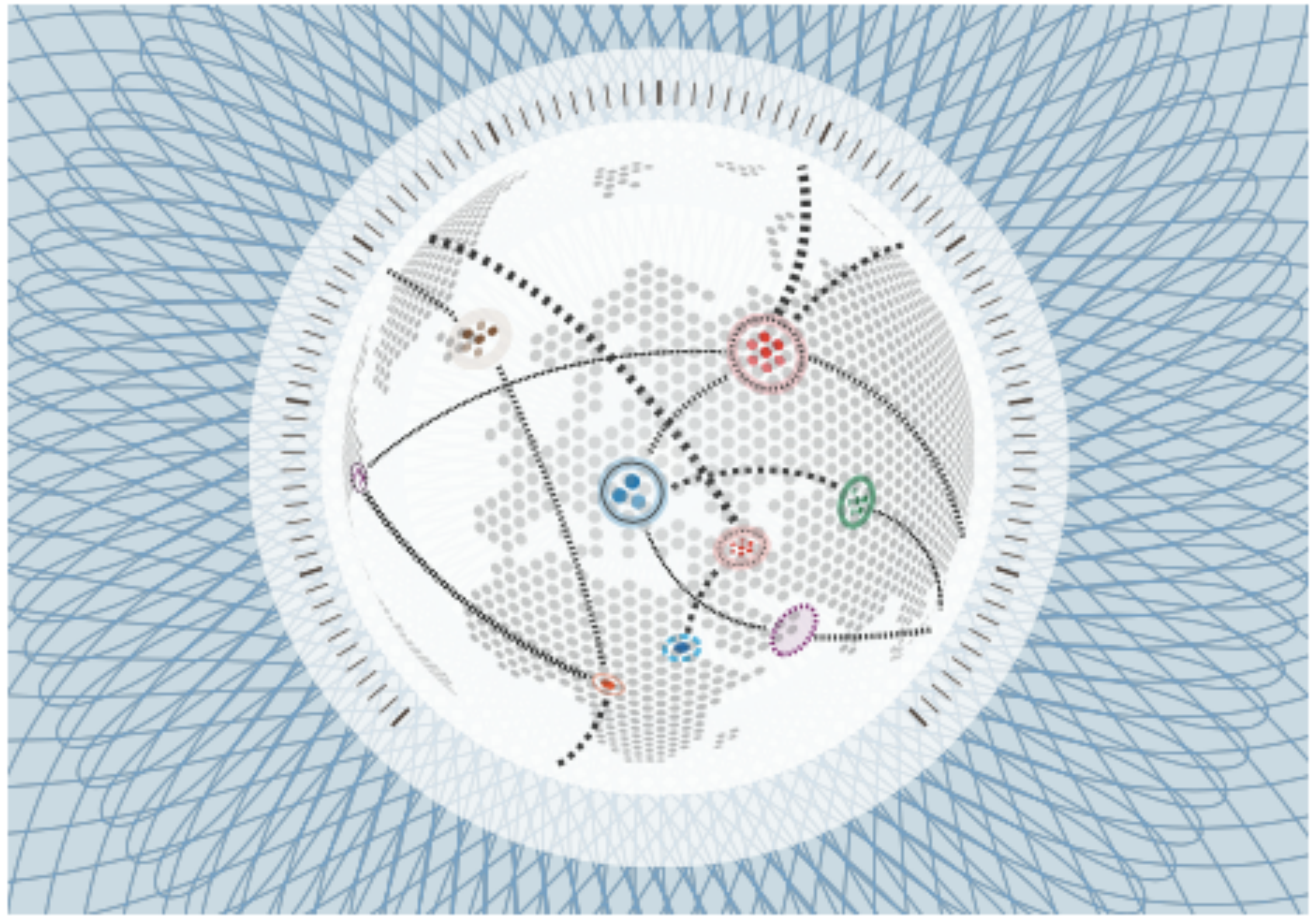
Global Risk Assessments

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

Insight Report

The Global Risks Report 2017
12th Edition



Global Risk Assessm

Insight Report

The Global Risks Report 2017
12th Edition

Figure 2: The Evolving Risks Landscape, 2007-2017

Top 5 Global Risks in Terms of Likelihood

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1st	Breakdown of critical information infrastructure	Asset price collapse	Asset price collapse	Asset price collapse	Storms and cyclones	Severe income disparity	Severe income disparity	Income disparity	Interstate conflict with regional consequences	Large-scale involuntary migration	Extreme weather events
2nd	Chronic disease in developed countries	Middle East instability	Slowing Chinese economy (<6%)	Slowing Chinese economy (<6%)	Flooding	Chronic fiscal imbalances	Chronic fiscal imbalances	Extreme weather events	Extreme weather events	Extreme weather events	Large-scale involuntary migration
3rd	Oil price shock	Failed and failing states	Chronic disease	Chronic disease	Corruption	Rising greenhouse gas emissions	Rising greenhouse gas emissions	Unemployment and underemployment	Failure of national governance	Failure of climate-change mitigation and adaptation	Major natural disasters
4th	China economic hard landing	Oil and gas price spike	Global governance gaps	Fiscal crises	Biodiversity loss	Cyber attacks	Water supply crises	Climate change	State collapse or crisis	Interstate conflict with regional consequences	Large-scale terrorist attacks
5th	Asset price collapse	Chronic disease, developed world	Retrenchment from globalization (emerging)	Global governance gaps	Climate change	Water supply crises	Mismanagement of population ageing	Cyber attacks	High structural unemployment or underemployment	Major natural catastrophes	Massive incident of data fraud/theft

Top 5 Global Risks in Terms of Impact

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1st	Asset price collapse	Asset price collapse	Asset price collapse	Asset price collapse	Fiscal crises	Major systemic financial failure	Major systemic financial failure	Fiscal crises	Water crises	Failure of climate-change mitigation and adaptation	Weapons of mass destruction
2nd	Retrenchment from globalization	Retrenchment from globalization (developed)	Retrenchment from globalization (developed)	Retrenchment from globalization (developed)	Climate change	Water supply crises	Water supply crises	Climate change	Rapid and massive spread of infectious diseases	Weapons of mass destruction	Extreme weather events
3rd	Interstate and civil wars	Slowing Chinese economy (<6%)	Oil and gas price spike	Oil price spikes	Geopolitical conflict	Food shortage crises	Chronic fiscal imbalances	Water crises	Weapons of mass destruction	Water crises	Water crises
4th	Pandemics	Oil and gas price spike	Chronic disease	Chronic disease	Asset price collapse	Chronic fiscal imbalances	Diffusion of weapons of mass destruction	Unemployment and underemployment	Interstate conflict with regional consequences	Large-scale involuntary migration	Major natural disasters
5th	Oil price shock	Pandemics	Fiscal crises	Fiscal crises	Extreme energy price volatility	Extreme volatility in energy and agriculture prices	Failure of climate-change mitigation and adaptation	Critical information infrastructure breakdown	Failure of climate-change mitigation and adaptation	Severe energy price shock	Failure of climate-change mitigation and adaptation

Economic · Environmental · Geopolitical · Societal · Technological

Source: World Economic Forum 2007-2017, Global Risks Reports

Note: Global risks may not be strictly comparable across years, as definitions and the set of global risks have evolved with new issues emerging on the 10-year horizon. For example, cyberattacks, income disparity and unemployment entered the set of global risks in 2012. Some global risks were reclassified: water crises and rising income disparity were re-categorized first as societal risks and then as a trend in the 2015 and 2016 Global Risks Reports, respectively. The 2008 edition of the Global Risks Report did not have a risks landscape

Global Risk Assessm

Insight Report

The Global Risks Report 2017
12th Edition

Figure 2: The Evolving Risks Landscape, 2007-2017

Top 5 Global Risks in Terms of Likelihood

	2007	2008	2009	2013	2014	2015	2016	2017
1st	Breakdown of critical information infrastructure	Asset price collapse	Asset price collapse	Severe income disparity	Income disparity	Interstate conflict with regional consequences	Large-scale involuntary migration	Extreme weather events
2nd	Chronic disease in developed countries	Middle East instability	Slowing Chinese economy (<6%)	Chronic fiscal imbalances	Extreme weather events	Extreme weather events	Extreme weather events	Large-scale involuntary migration
3rd	Oil price shock	Failed and failing states	Chronic disease	Rising greenhouse gas emissions	Unemployment and underemployment	Failure of national governance	Failure of climate-change mitigation and adaptation	Major natural disasters
4th	China economic hard landing	Oil and gas price spike	Global governance gaps	Water supply crises	Climate change	State collapse or crisis	Interstate conflict with regional consequences	Large-scale terrorist attacks
5th	Asset price collapse	Chronic disease, developed world	Retrenchment from globalization (emerging)	Mismanagement of population ageing	Cyber attacks	High structural unemployment or underemployment	Major natural catastrophes	Massive incident of data fraud/theft

Top 5 Global Risks in Terms of Impact

	2007	2008	2009	2013	2014	2015	2016	2017
1st	Asset price collapse	Asset price collapse	Asset price collapse	Major systemic financial failure	Fiscal crises	Water crises	Failure of climate-change mitigation and adaptation	Weapons of mass destruction
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Source: World Economic Forum 20017-2017, Global Risks Reports
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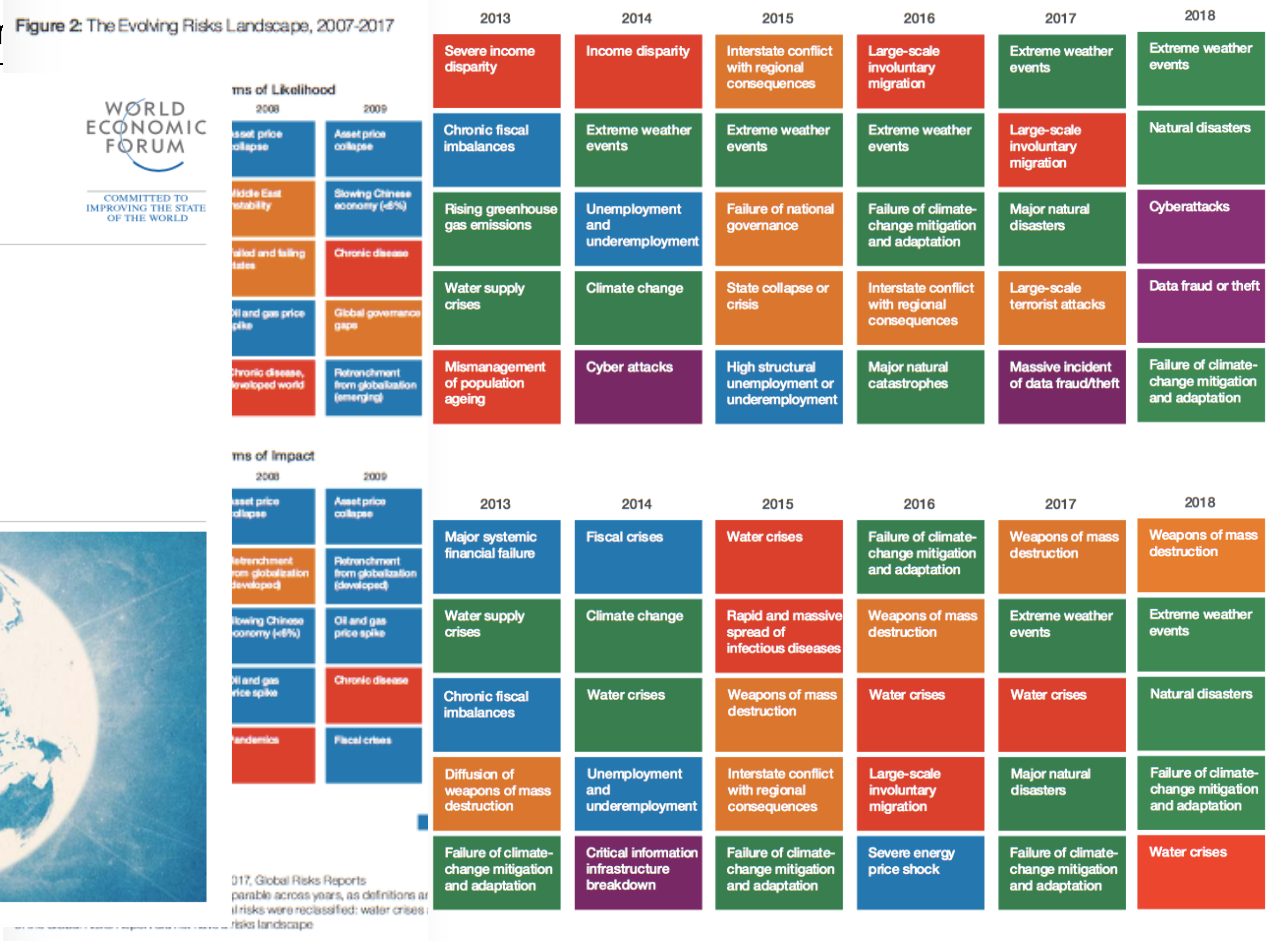
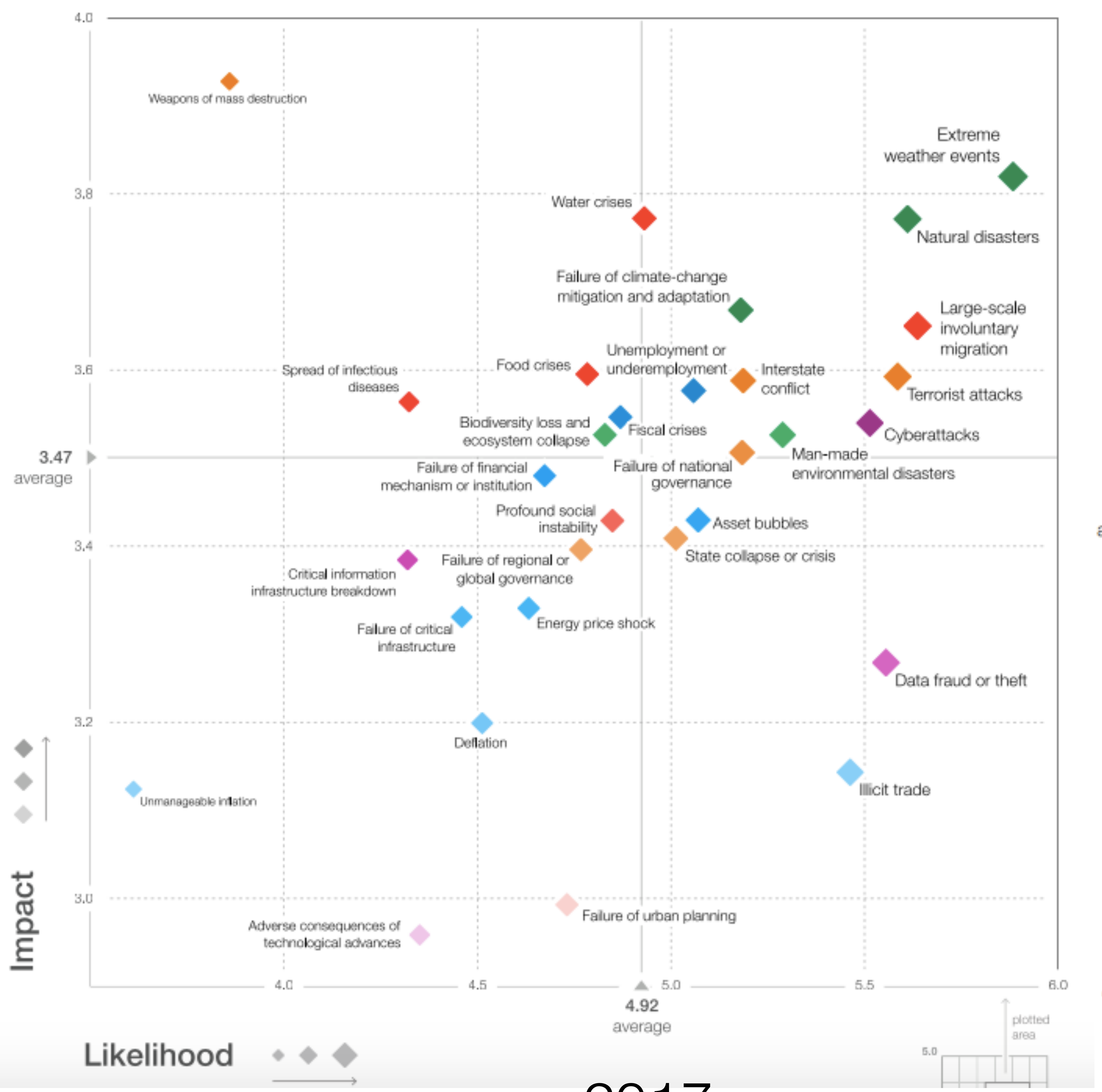
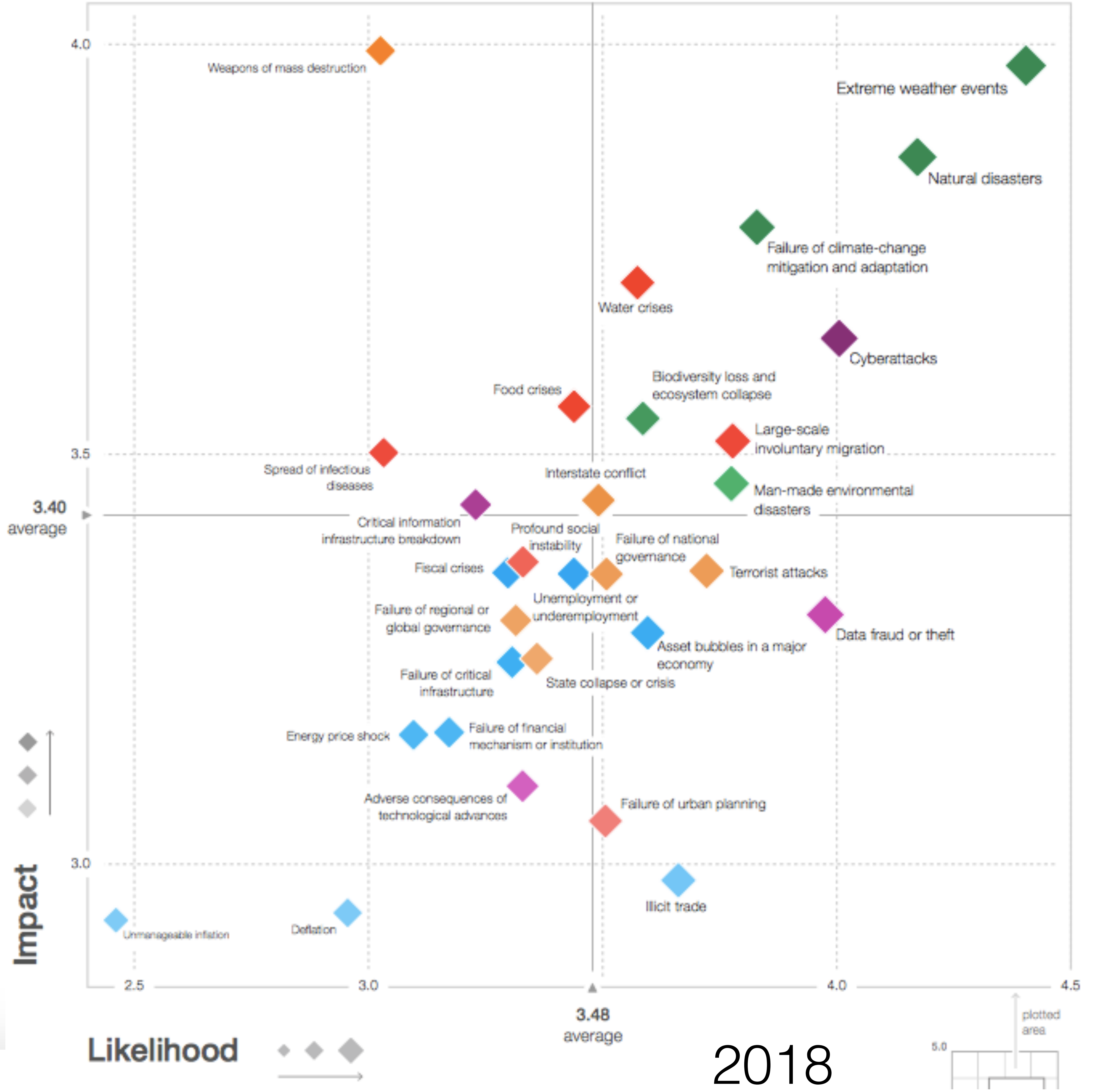
Global Risk Assessm



Global Risk Assessments



2017



2018

Bulletin
of the
Atomic
Scientists

It is two and a half minutes to midnight

2017 Doomsday Clock Statement

Science and Security Board
Bulletin of the Atomic Scientists

Editor, John Mecklin

IT IS TWO AND A HALF MINUTES TO MIDNIGHT©

Reducing risk: Expert advice and citizen action. Technology continues to outpace humanity's capacity to control it, even as many citizens lose faith in the institutions upon which they must rely to make scientific innovation work for rather than against them. Expert advice is crucial if governments are to effectively deal with complex global threats. The Science and Security Board is extremely concerned about the willingness of governments around the world—including the incoming US administration—to ignore or discount sound science and considered expertise during their decision-making processes.

Bulletin of the Atomic Scientists

Doomsday Clock Announcement, 2018

National Press Club, Washington, D.C.

January 25th, 2018, 10:00a.m. EST

By KATIE REILLY Updated: January 25, 2018 10:29 AM ET

The Bulletin of the Atomic Scientists moved the doomsday clock closer to midnight on Thursday morning, warning the world that it is as close to catastrophe in 2018 as it has ever been.

Scientists cited growing nuclear threats, climate change and a lack of trust in political institutions as they set the doomsday clock at two minutes to midnight — 30 seconds closer than it was last year.

“The world is not only more dangerous now than it was a year ago; it is as threatening as it has been since World War II,” Lawrence Krauss and Robert Rosner of the Bulletin of the Atomic Scientists wrote in a Washington Post column on Thursday, referencing President Trump’s repeated threats of war against North Korean leader Kim Jong Un, as well as his reversal of the Obama Administration’s efforts to stop climate change.

Time, January 25, 2018

https://clock.thebulletin.org

IT IS TWO AND A HALF MINUTES TO MIDNIGHT©

Two Minutes to Midnight Video

https://vimeo.com

Global Risk Assessments

Clock Changes

2018
IT IS 2 MINUTES TO MIDNIGHT

2017
IT IS TWO AND A HALF MINUTES TO MIDNIGHT

2016
IT IS STILL 3 MINUTES TO MIDNIGHT

2015
IT IS 3 MINUTES TO MIDNIGHT

2012
IT IS 5 MINUTES TO MIDNIGHT

2010
IT IS 6 MINUTES TO MIDNIGHT

2007
IT IS 5 MINUTES TO MIDNIGHT

2002
IT IS 7 MINUTES TO MIDNIGHT

1998
IT IS 9 MINUTES TO MIDNIGHT

1995
IT IS 14 MINUTES TO MIDNIGHT

Global Risk Assessments

2018
IT IS 2 MINUTES TO MIDNIGHT
View Full Statement

2017
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View Full Statement

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1981
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1980
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1974
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1972
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1968
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1963
IT IS 12 MINUTES TO MIDNIGHT
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1960
IT IS 7 MINUTES TO MIDNIGHT
View Full Statement

1953
IT IS 2 MINUTES TO MIDNIGHT
View Full Statement

1949
IT IS 3 MINUTES TO MIDNIGHT
View Full Statement

1947
IT IS 7 MINUTES TO MIDNIGHT

THINKING THE UNTHINKABLE

Successful risk management requires thinking "outside the box" to avoid a failure of imagination, but this is a skill rarely found at the senior levels of government and global corporations. (Spratt and Dunlop, 2018)

THE UNDERESTIMATION OF (MAJOR) RISKS

"When all the new knowledge that challenges the old is on the more worrying side, one worries about whether the asymmetry reflects some systematic bias… I have come to wonder whether the reason why most of the new knowledge confirms the established science or changes it for the worse is scholarly reticence."

Prof. Ross Garnaut, 2011

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Natural Hazards and Disaster

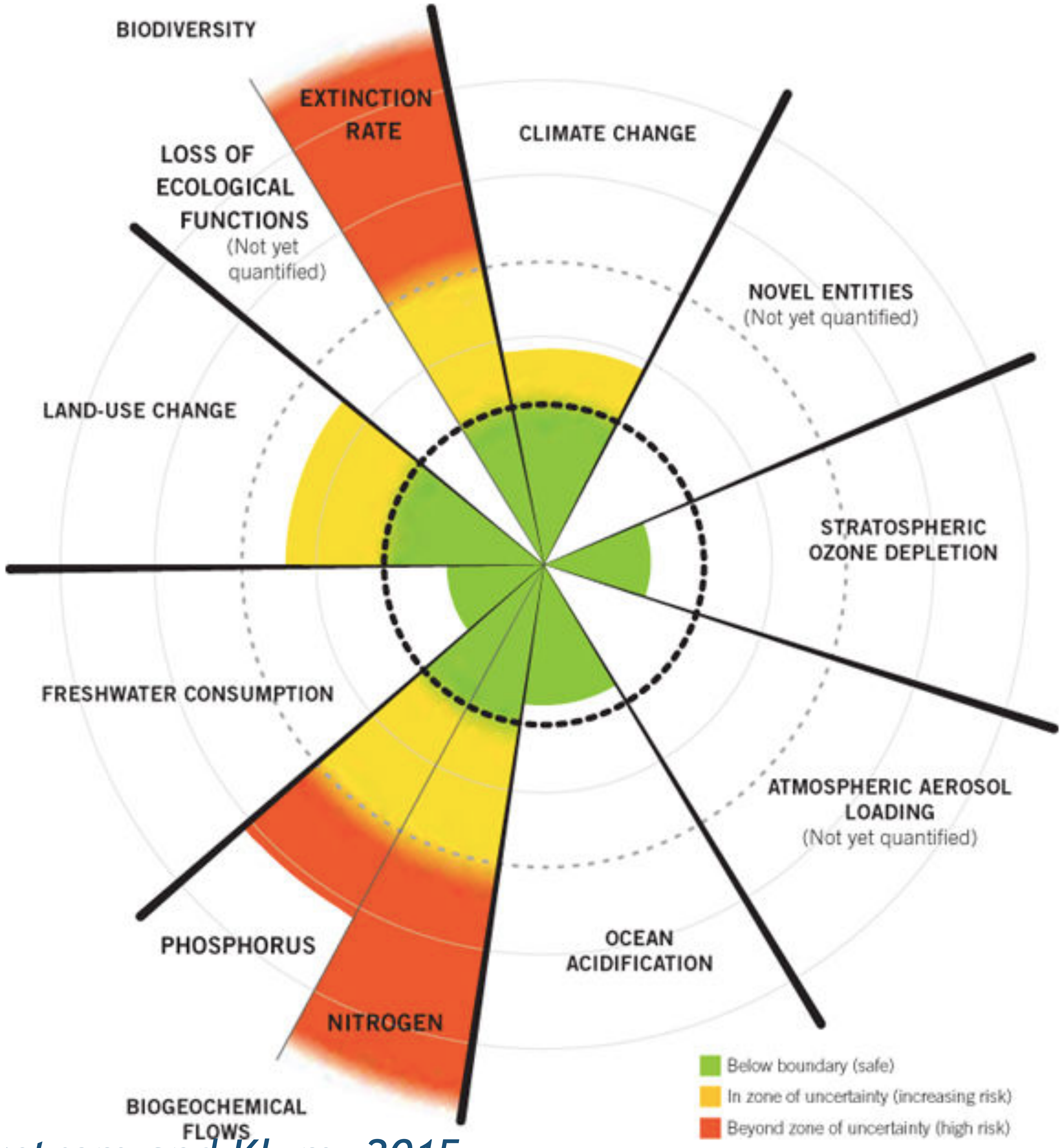
Class 3: Global Threats and Extraterrestrial Hazards

- Extreme Natural Hazards
- Global Risk Assessments
- Modern Global Change
- Major (Global) Risks
- Global Risk Governance
- Extraterrestrial Hazards

Modern Global Change

Modern Global Change

The Holocene was a “safe operating space for humanity”



Rockstrom and Klum, 2015

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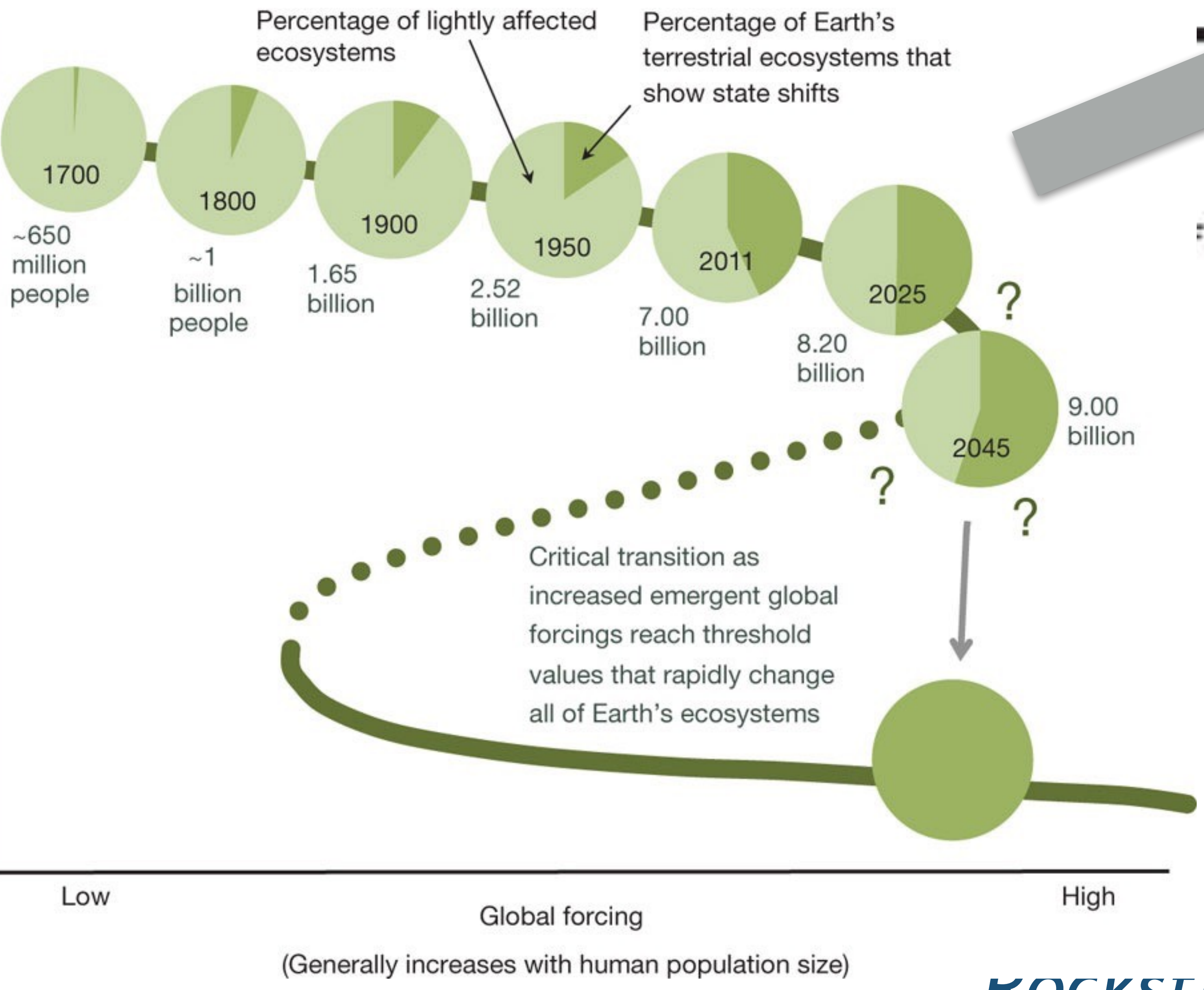

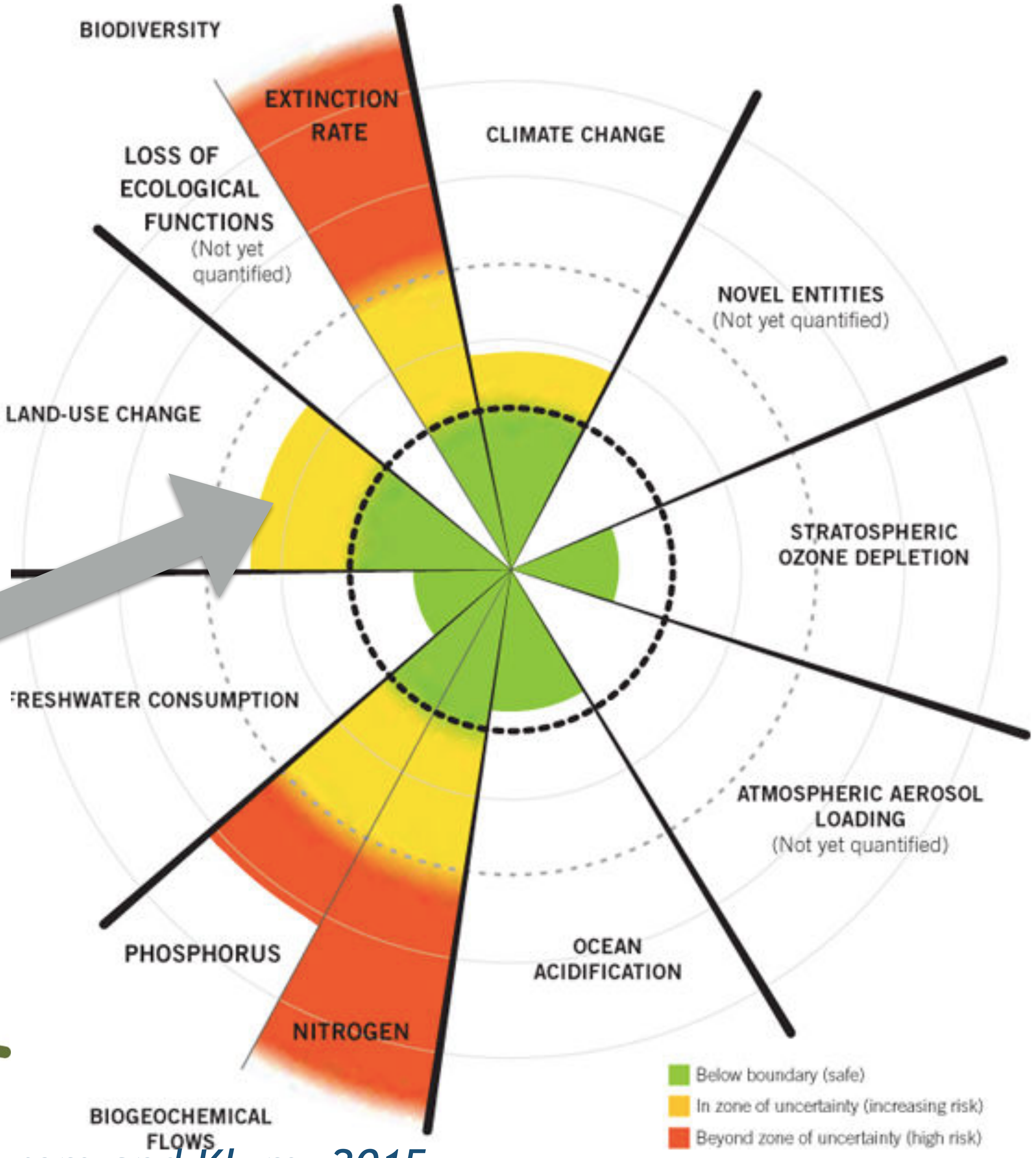

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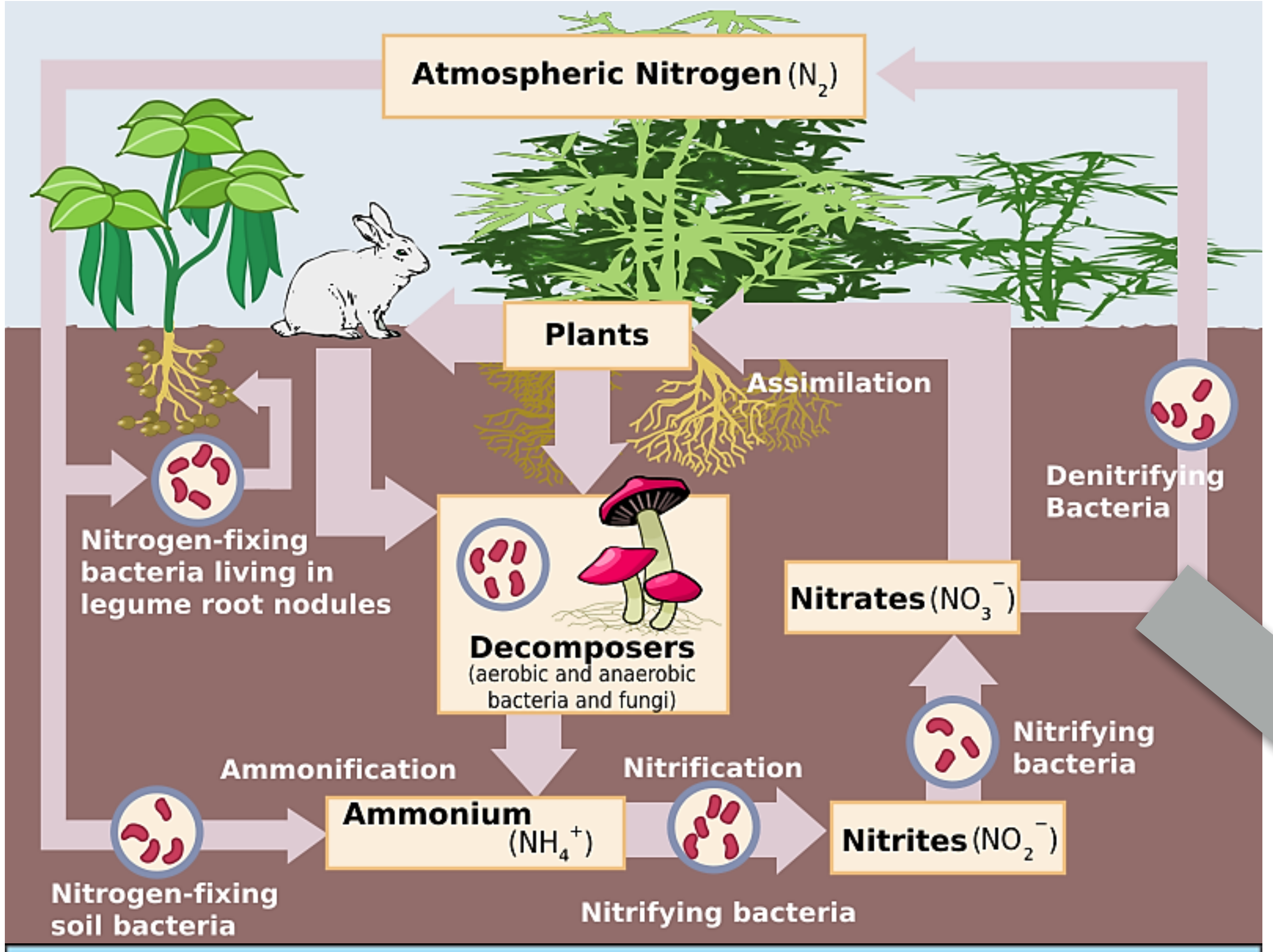

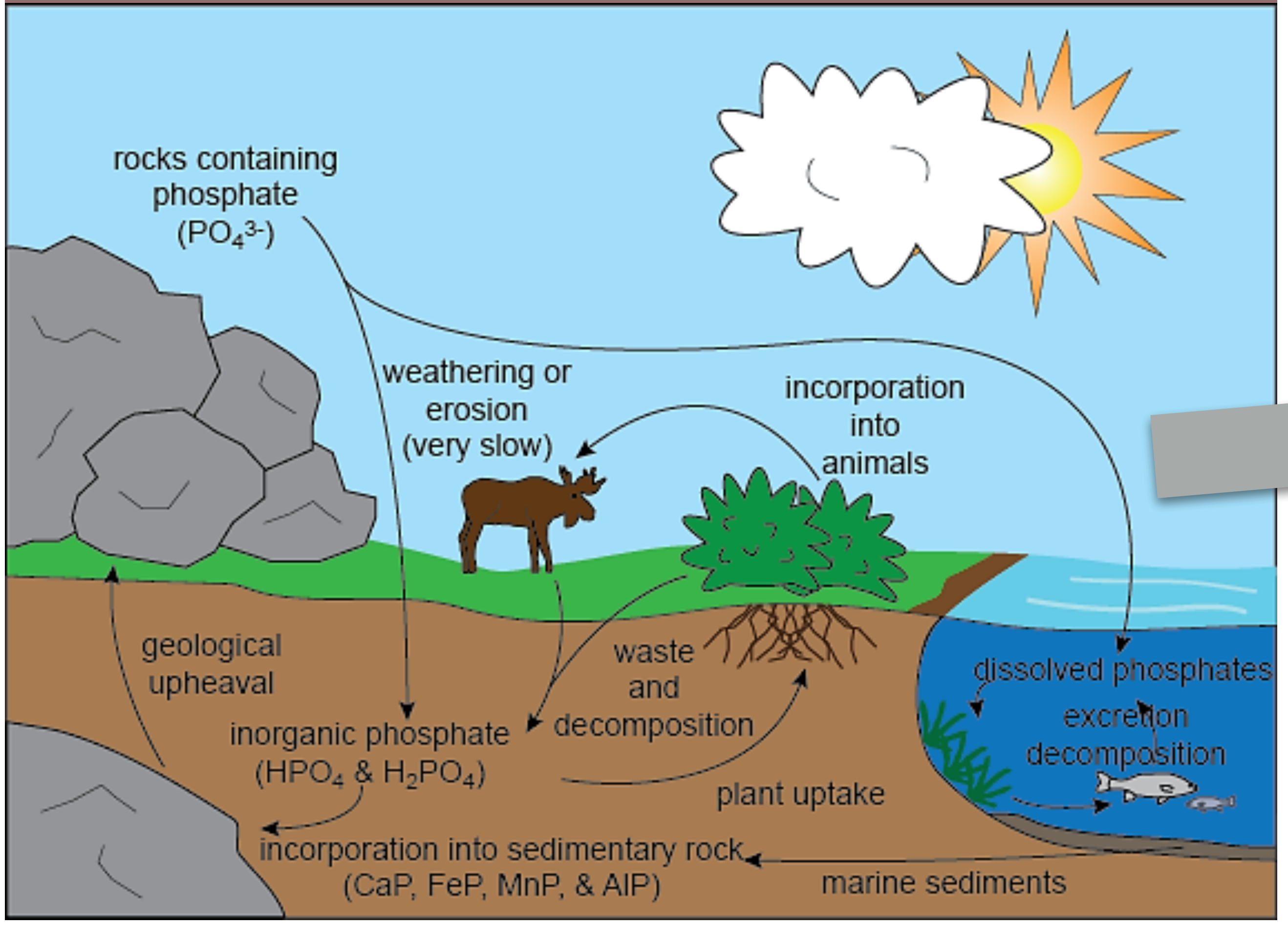

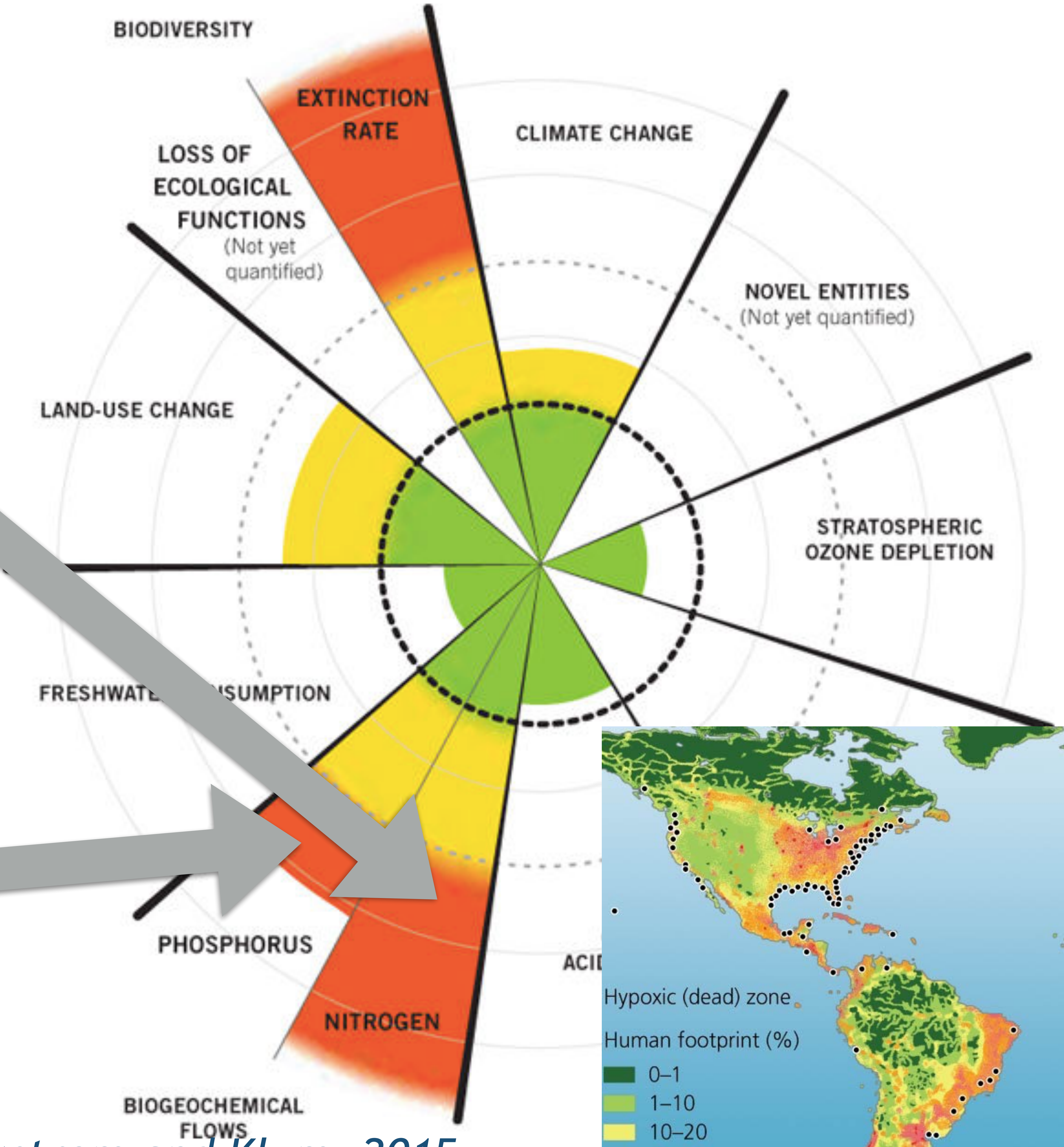

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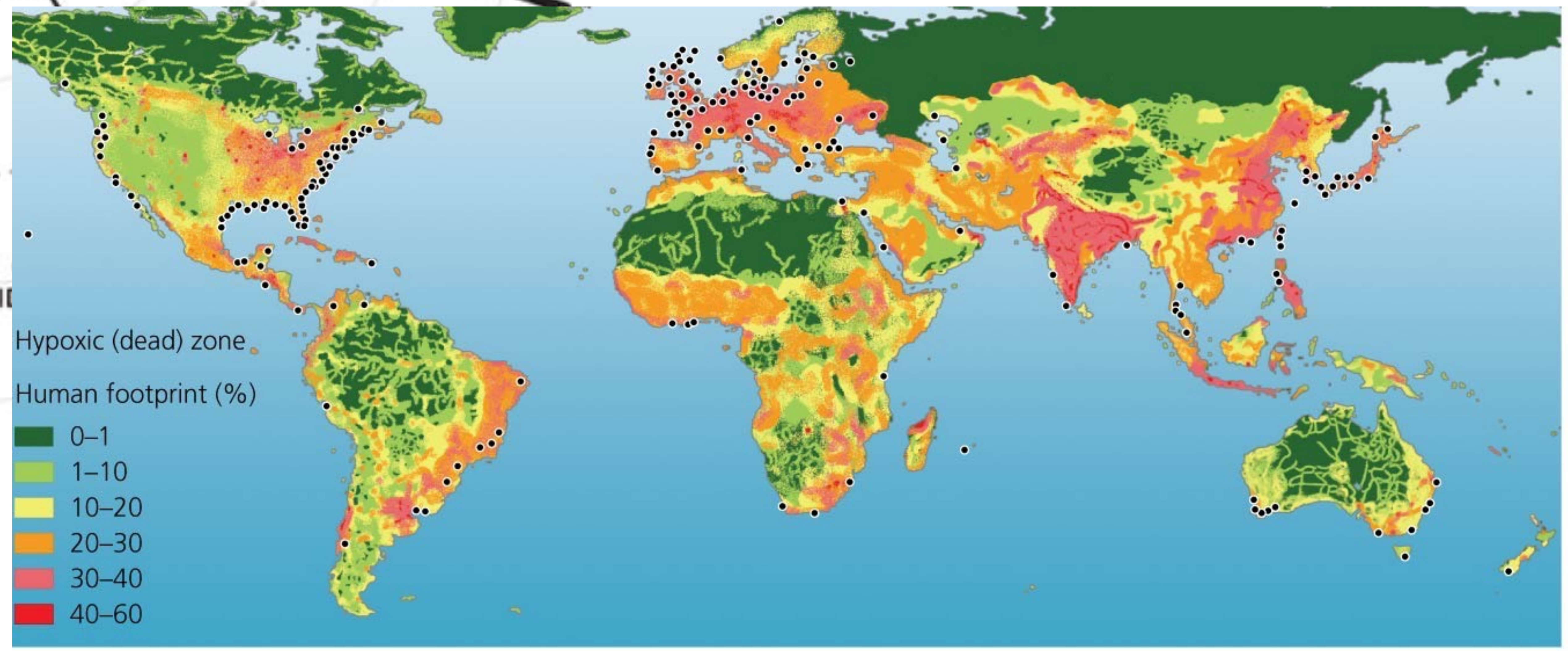
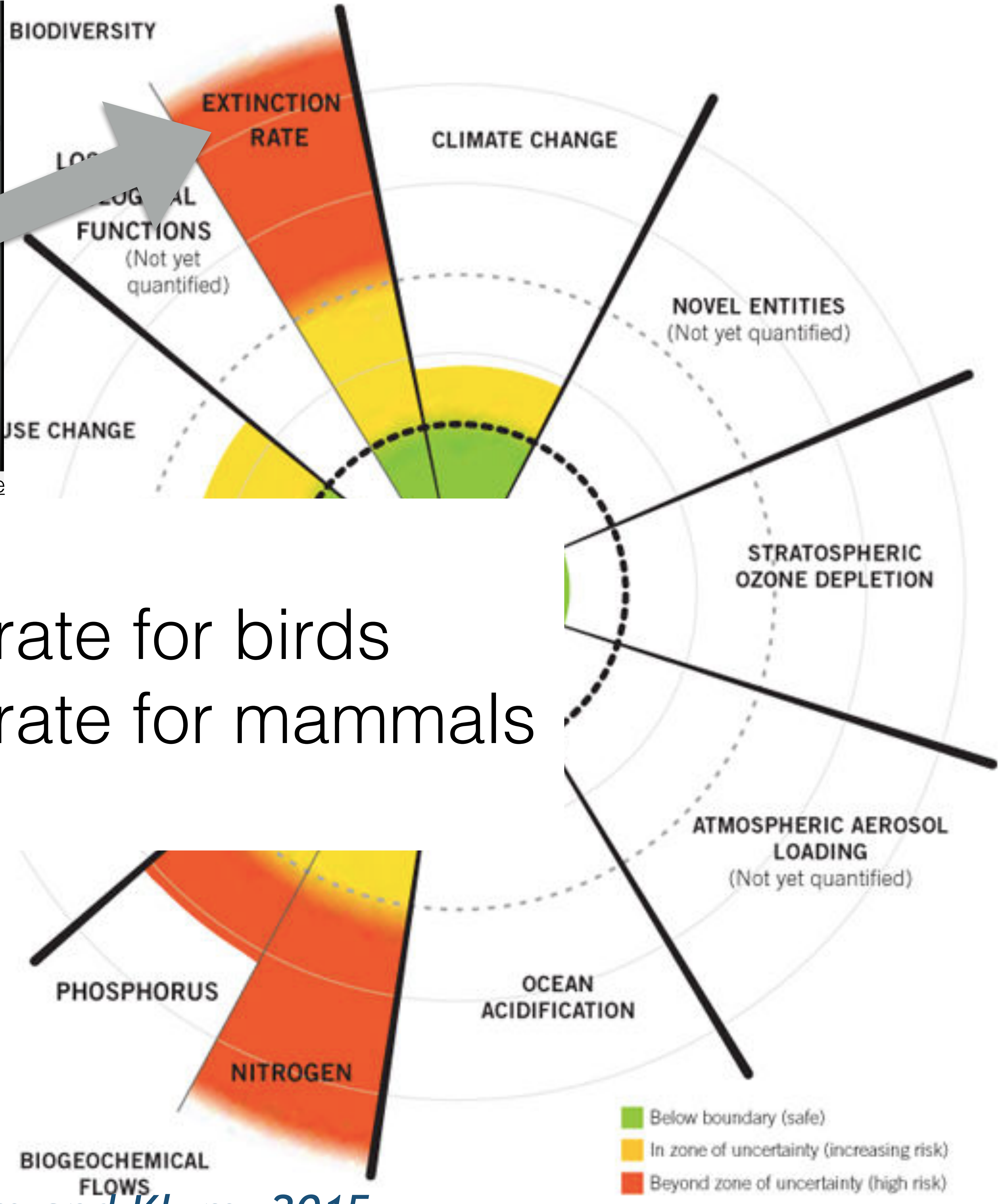


Modern Global Change

The Holocene was a “safe operating space for humanity”

https://www.youtube.com/watch?v=gPq9YAg9mfc&feature=youtu.be



Current extinction rates:

300 times background rate for birds

80,000 times background rate for mammals

Rockstrom and Klum, 2015

Modern Global Change

The Holocene was a “safe operating space for humanity”

“We are the asteroid …”

https://www.youtube.com/watch?v=gPq9YAg9mfc&feature=youtu.be

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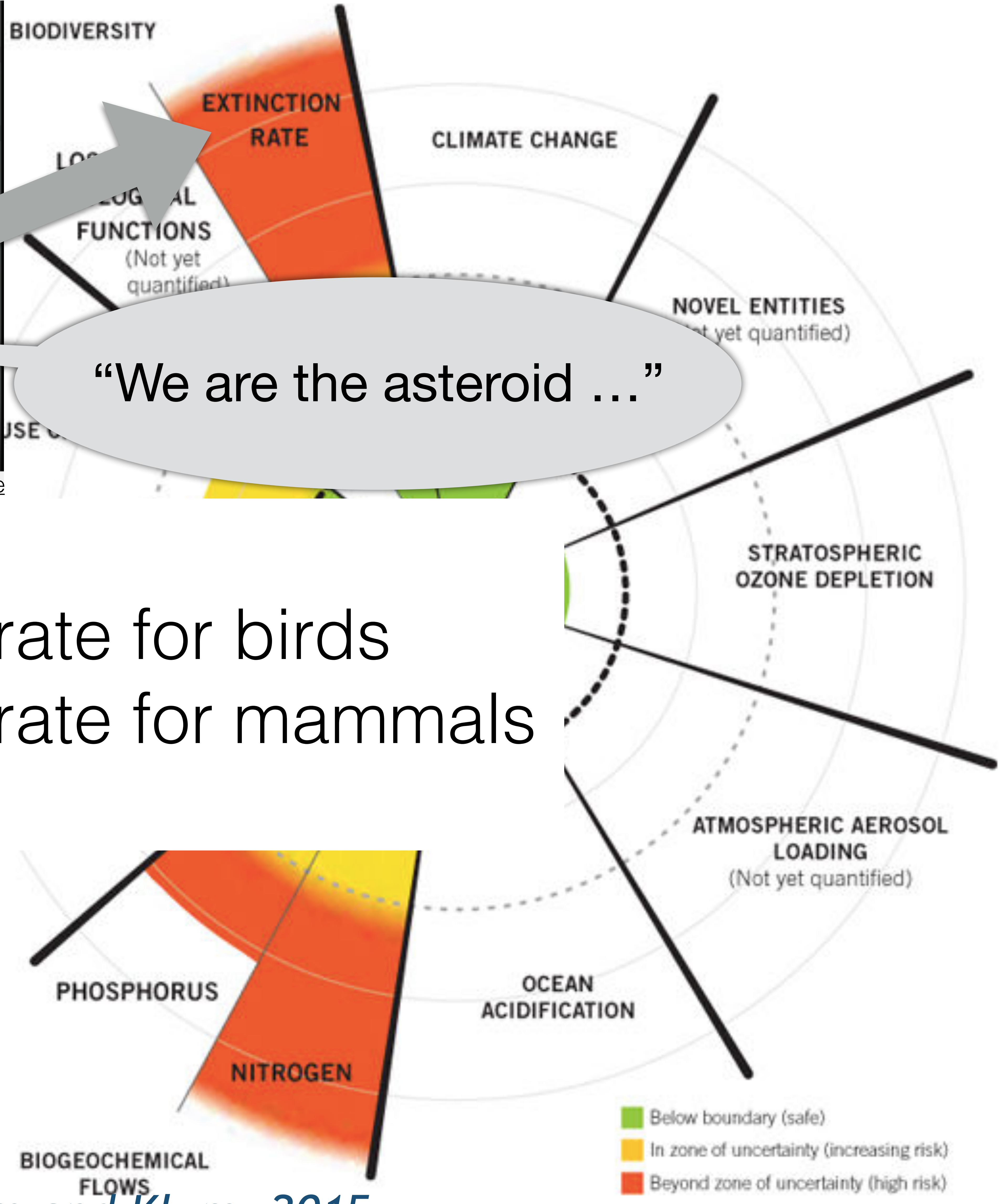

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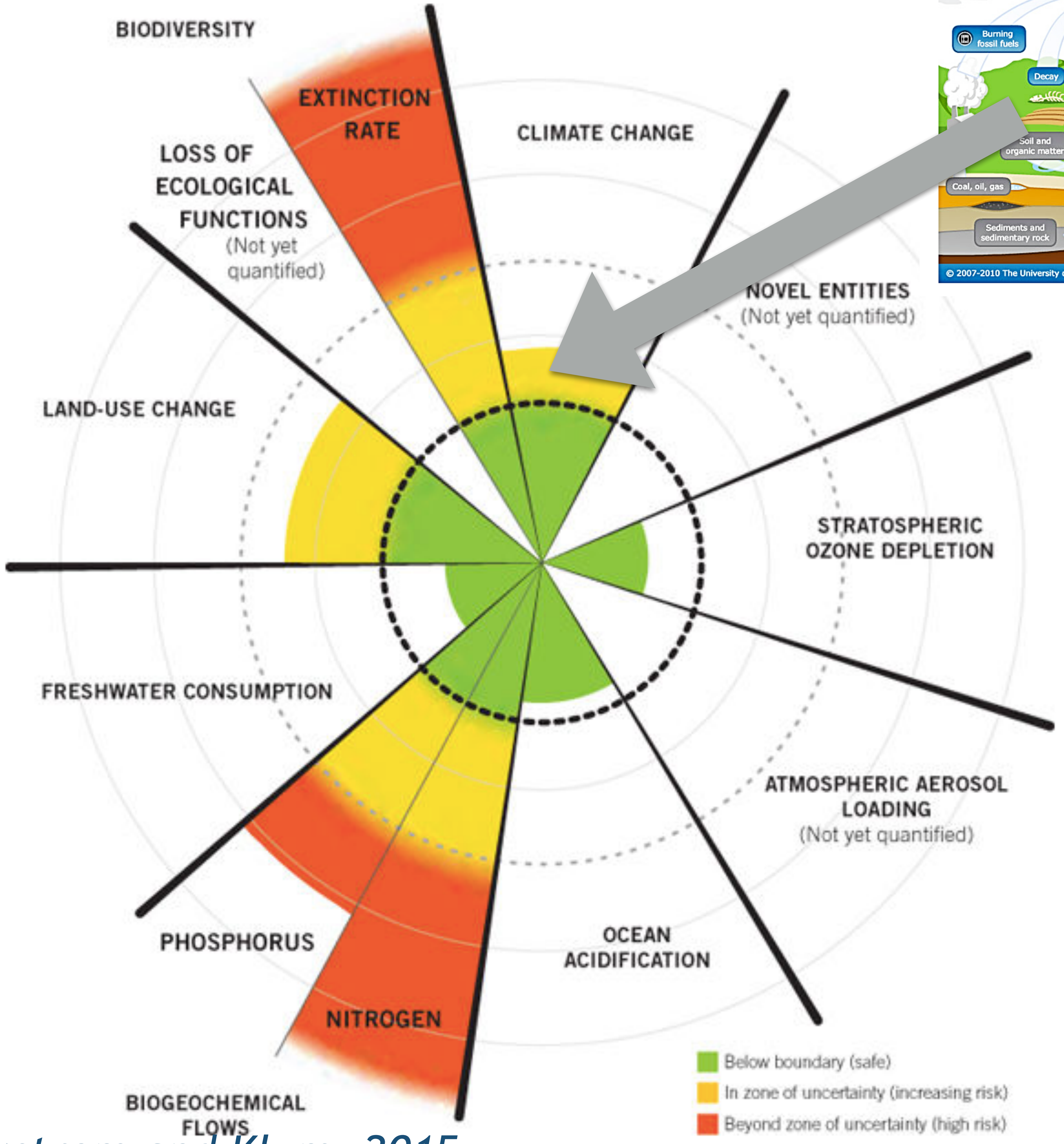

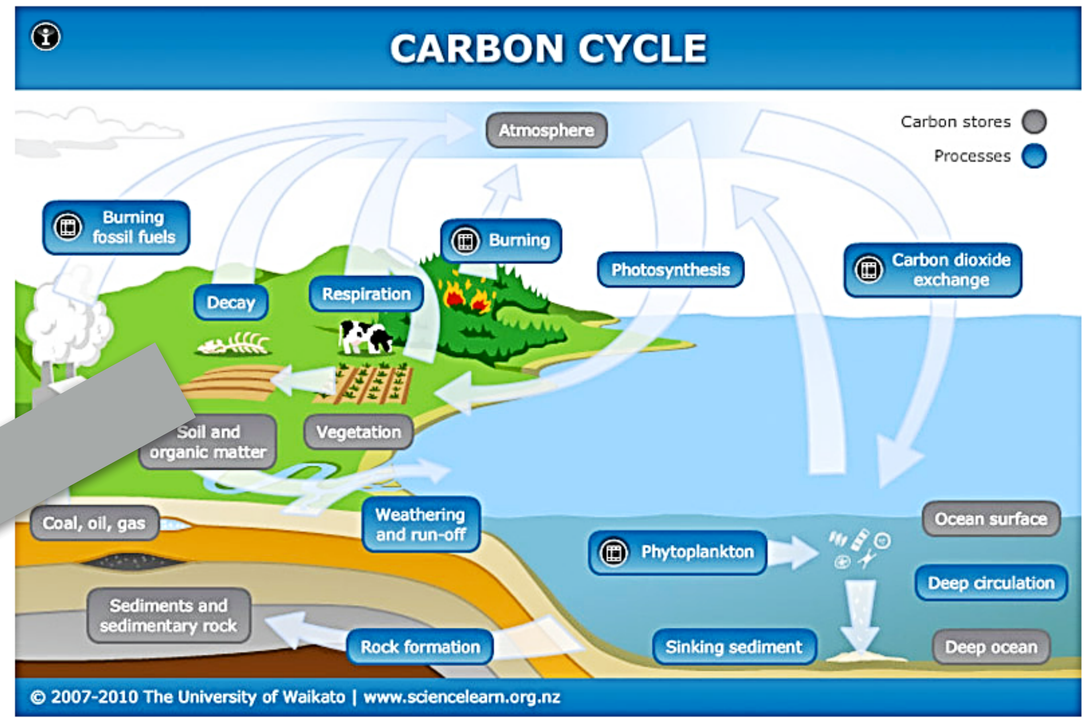

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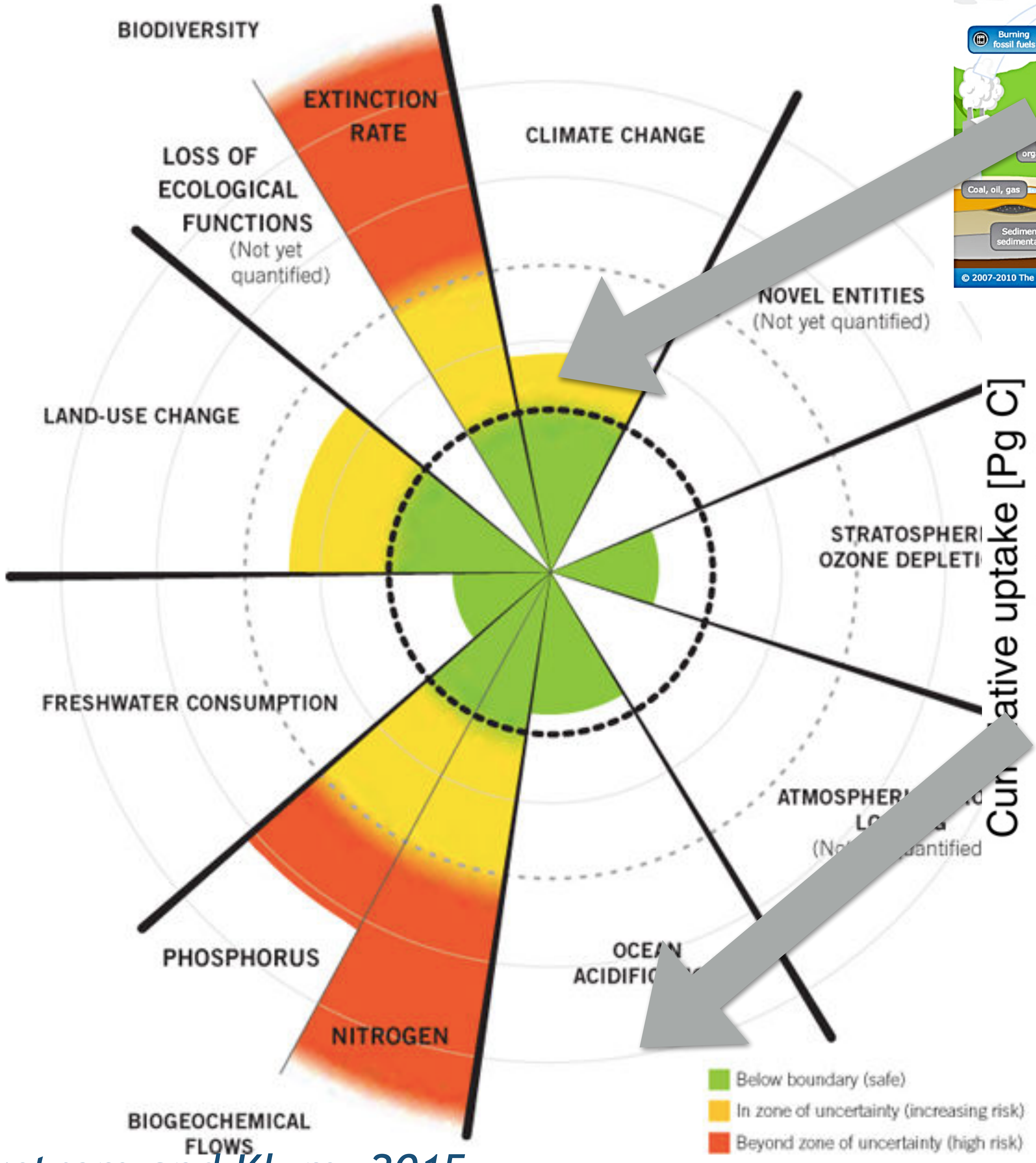

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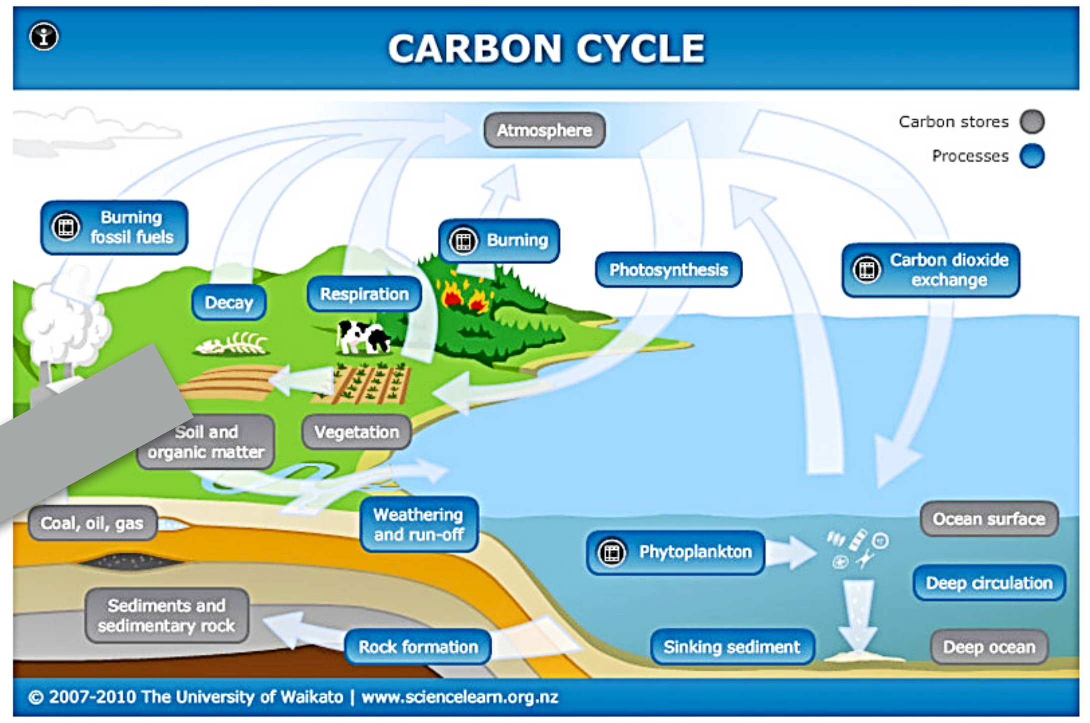

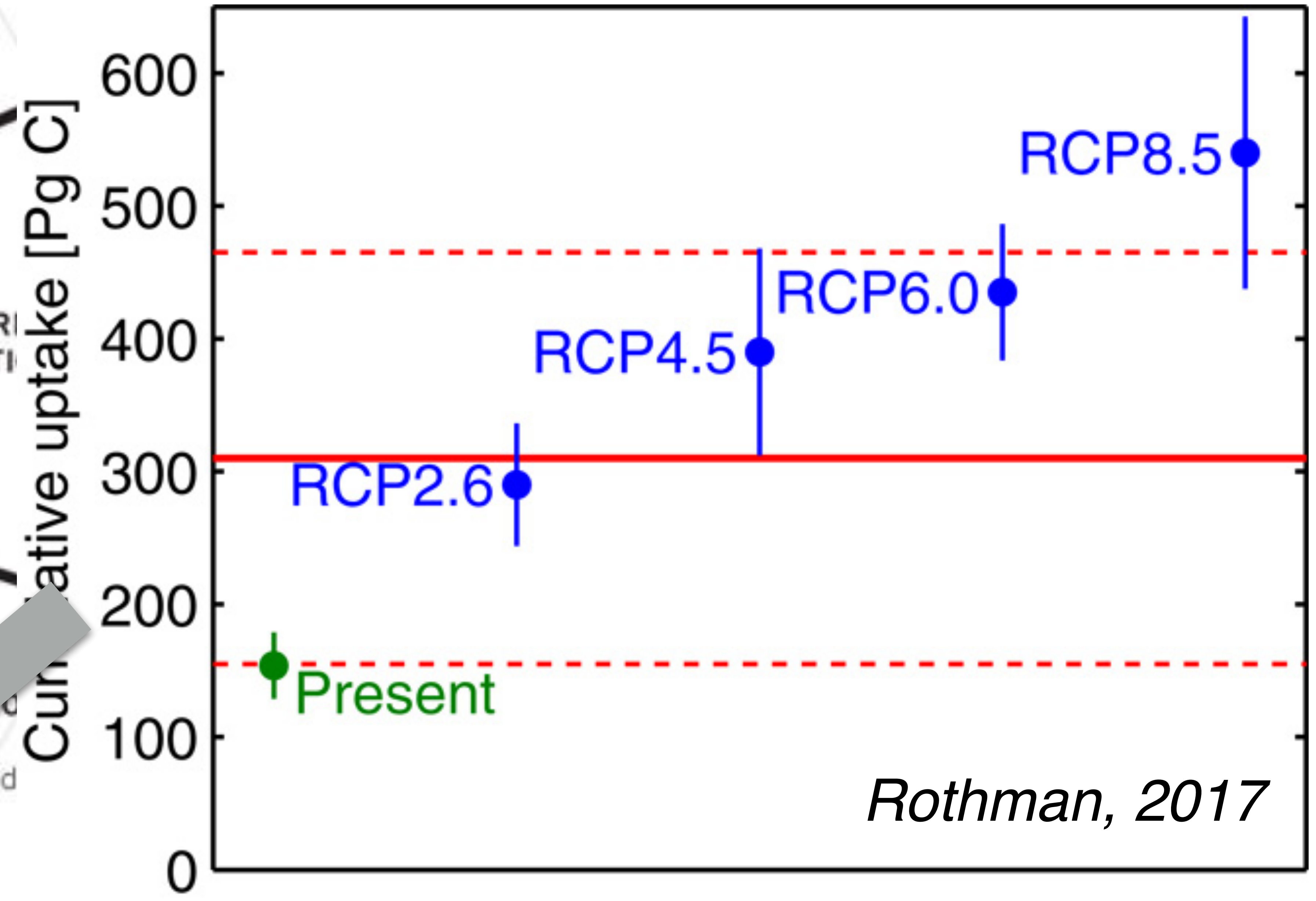

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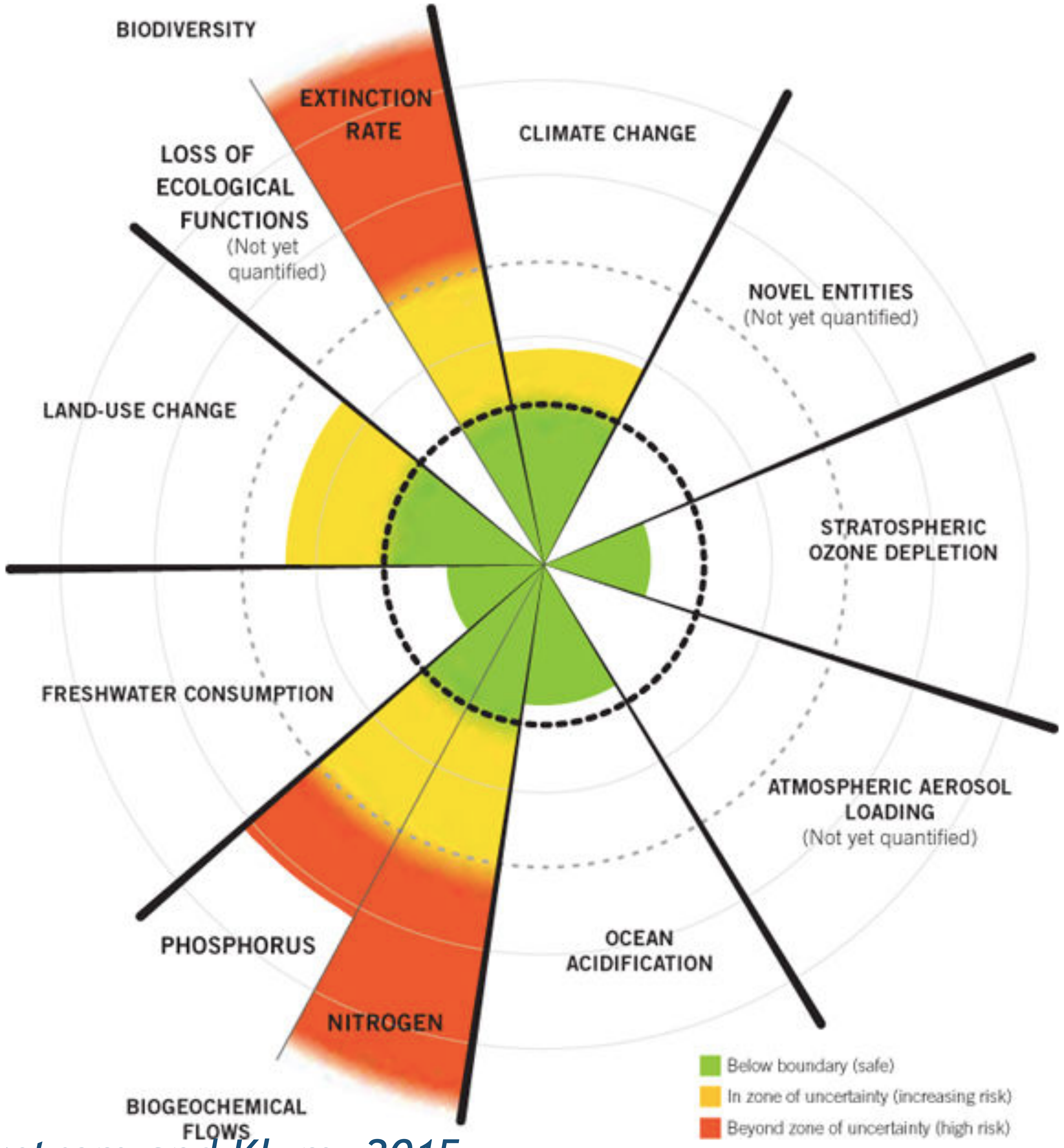

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Modern climate change is a symptom, not the cause, not the "sickness."
It is a symptom of a single-species, high-energy pulse.

Modern Global Change

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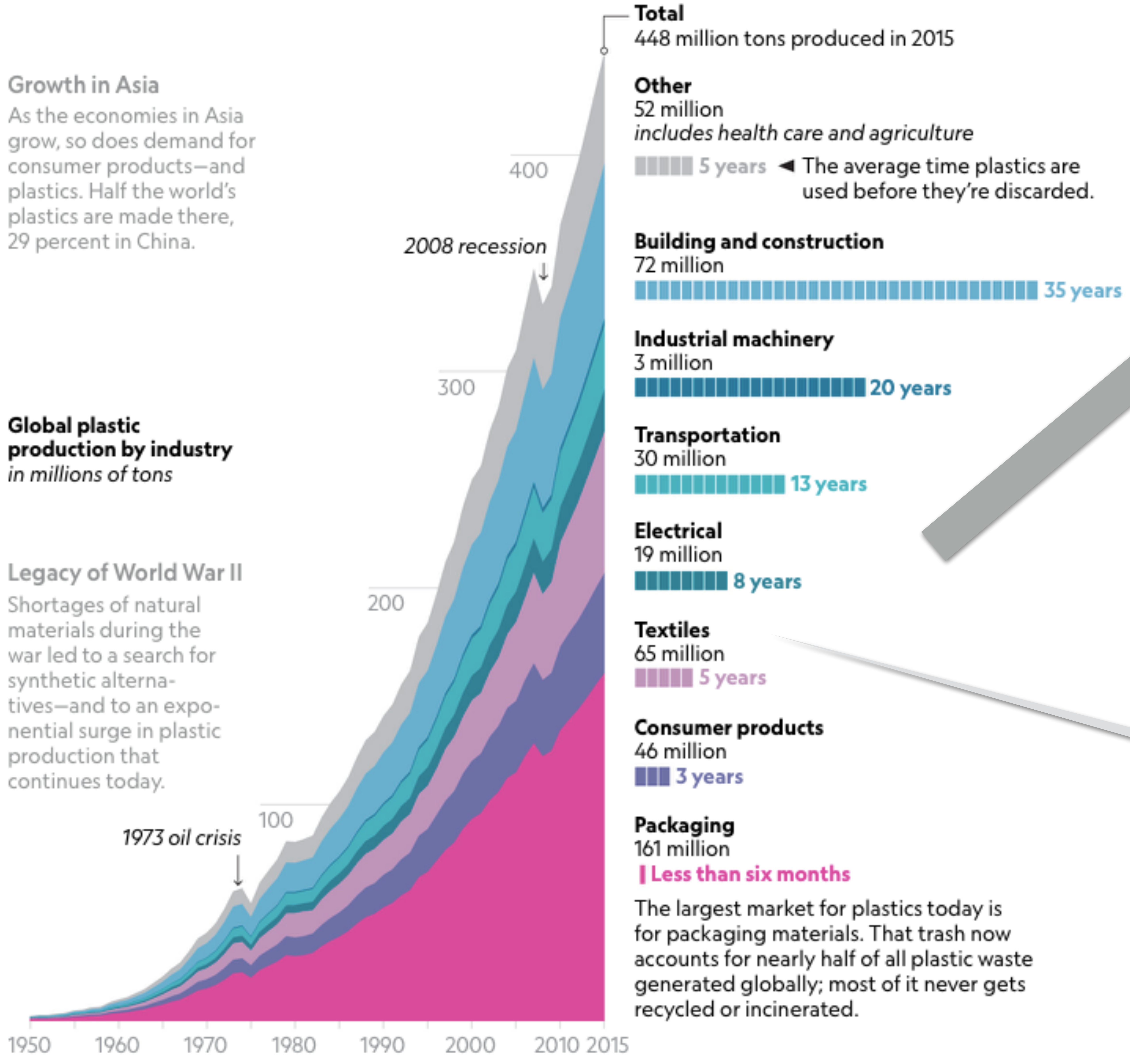
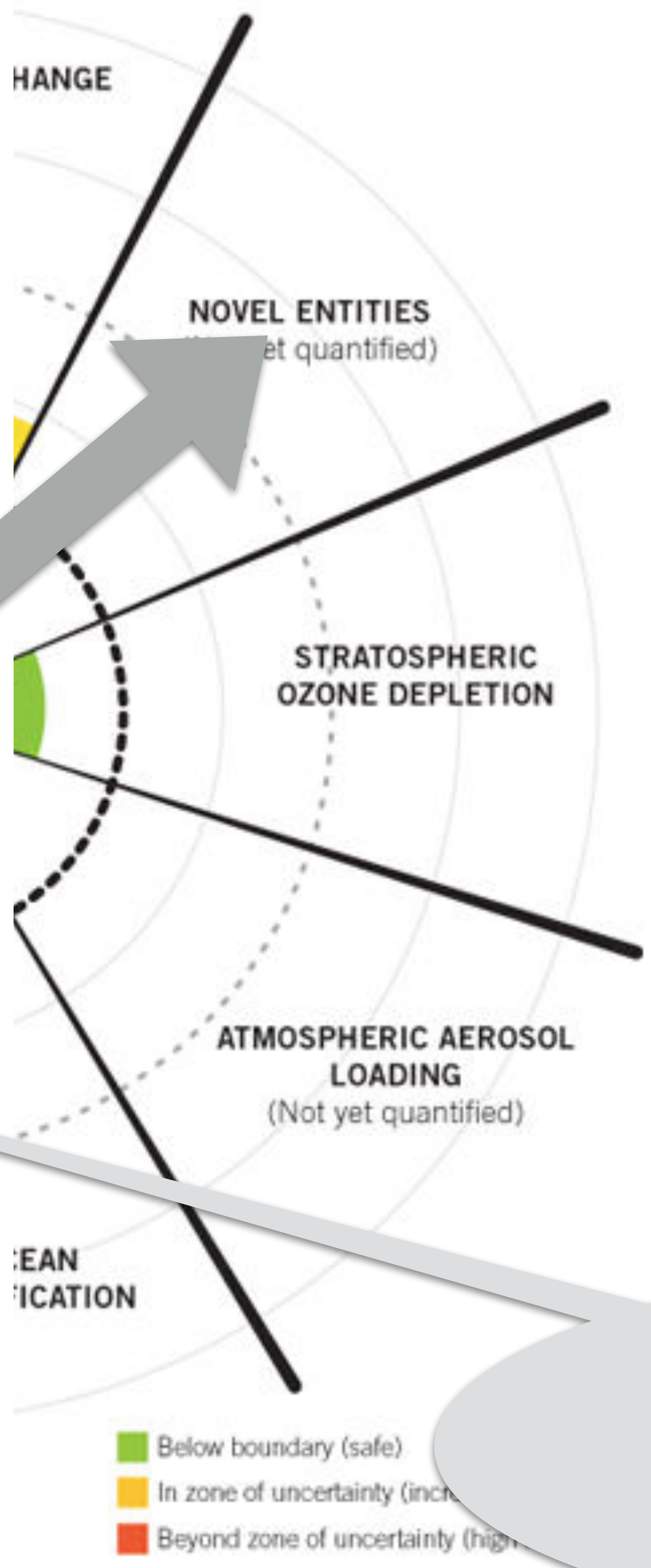
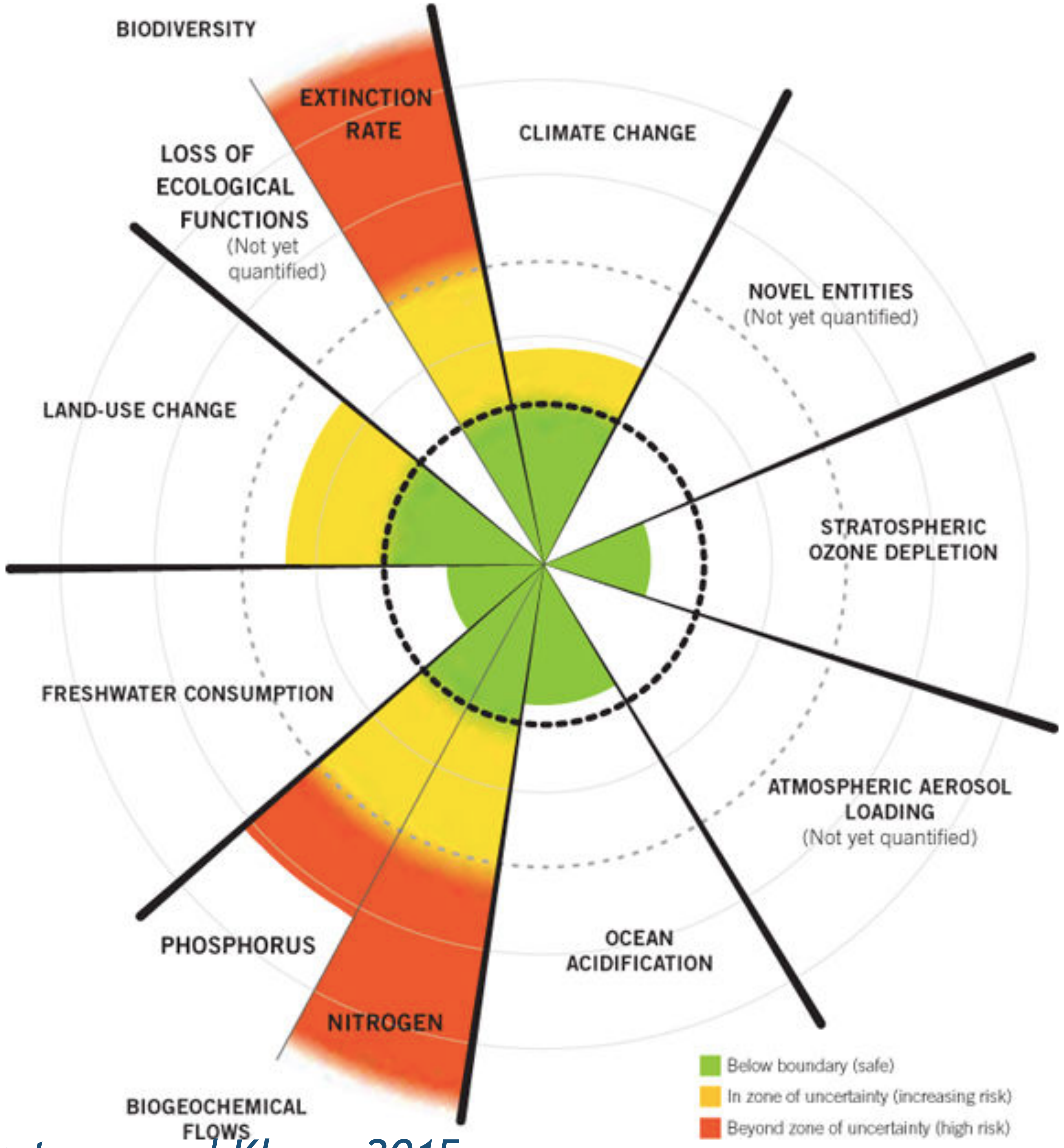




The urgent challenge of plastics

Modern Global Change

The Holocene was a “safe operating space for humanity”



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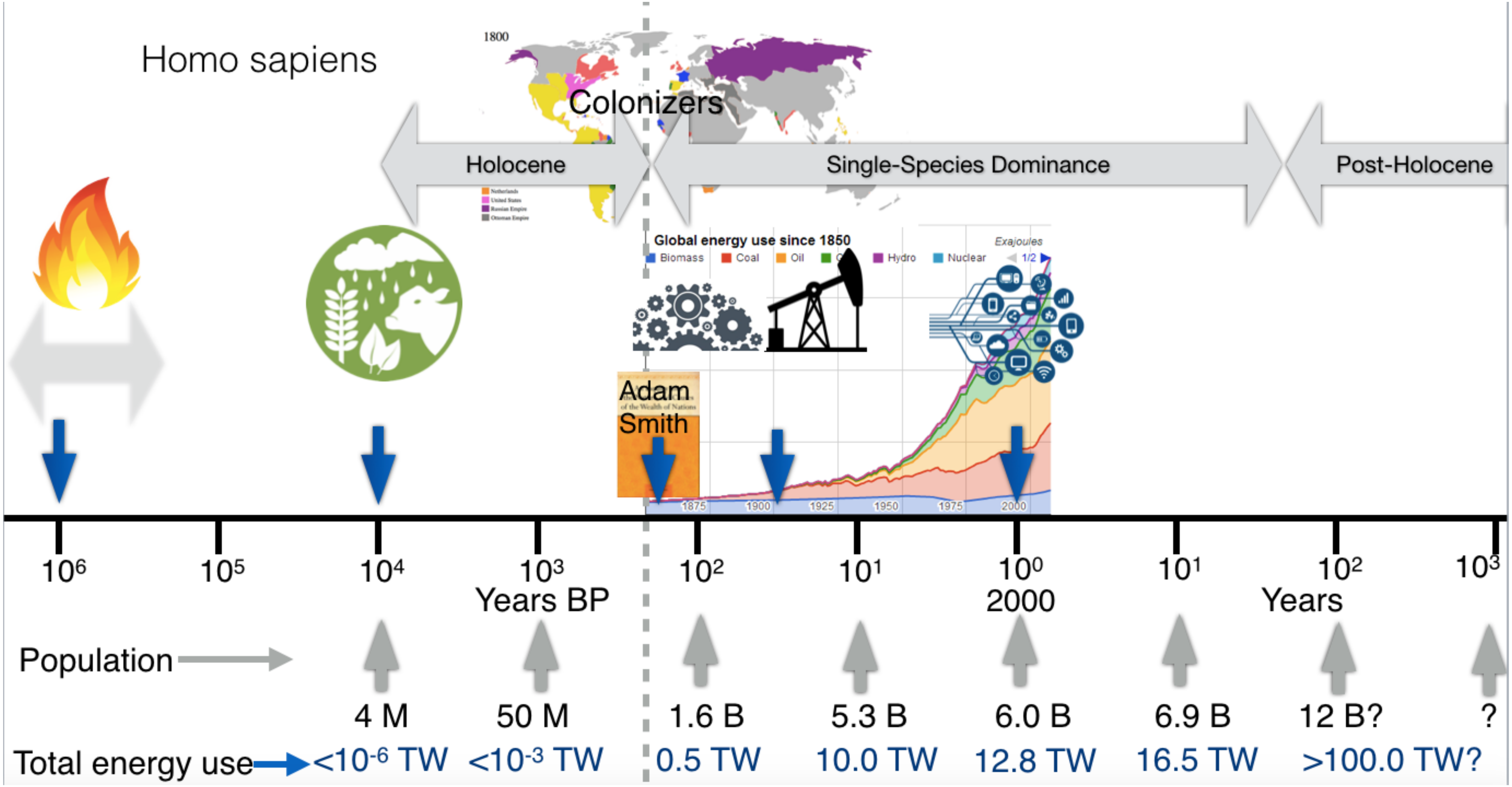
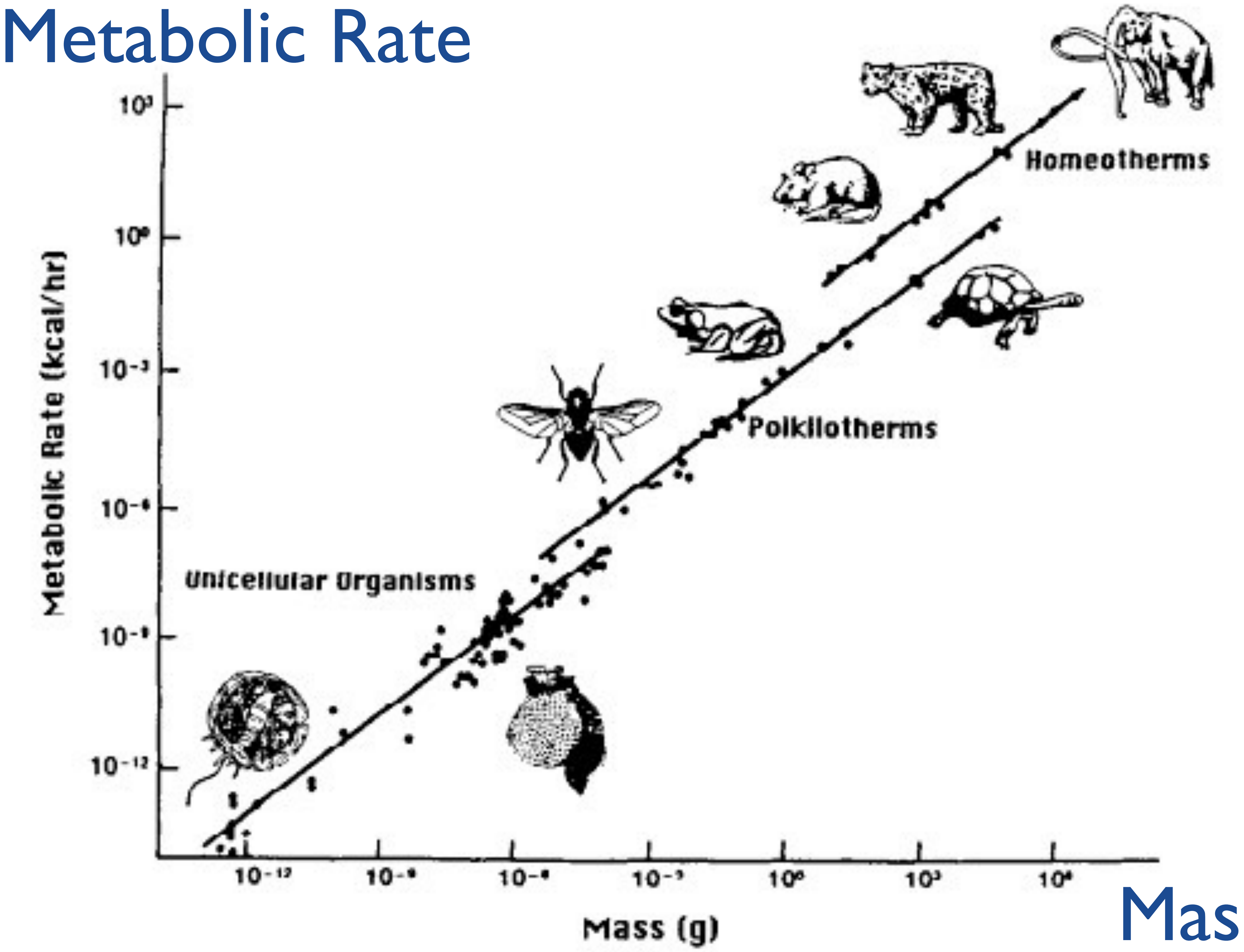


Being out of Scale

Scaling law for metabolic rate:
$Y = Y_0 * M^{(3/4)}$

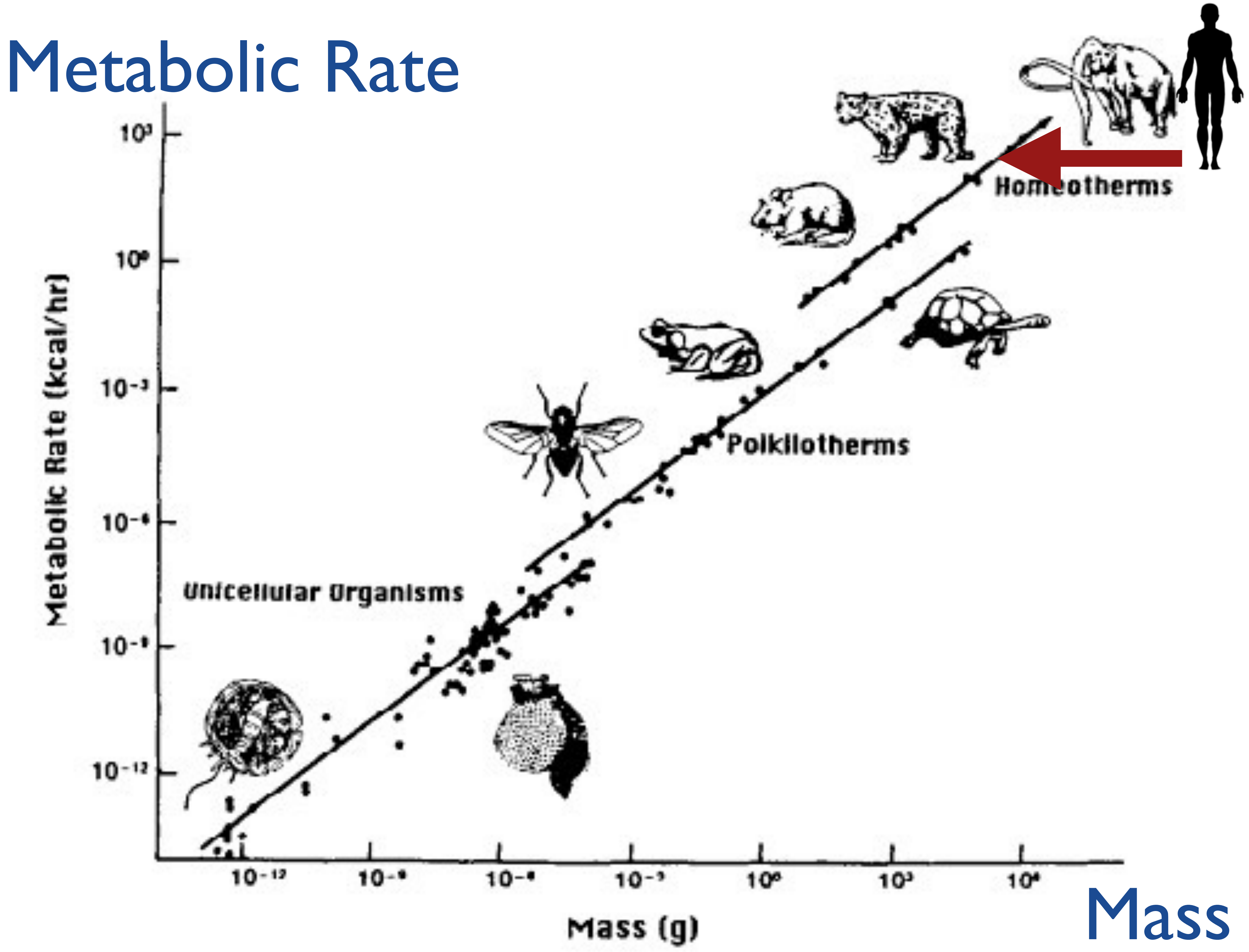
human: Y = 50 -100 Watt

Metabolic Rate



Mass

Being out of Scale



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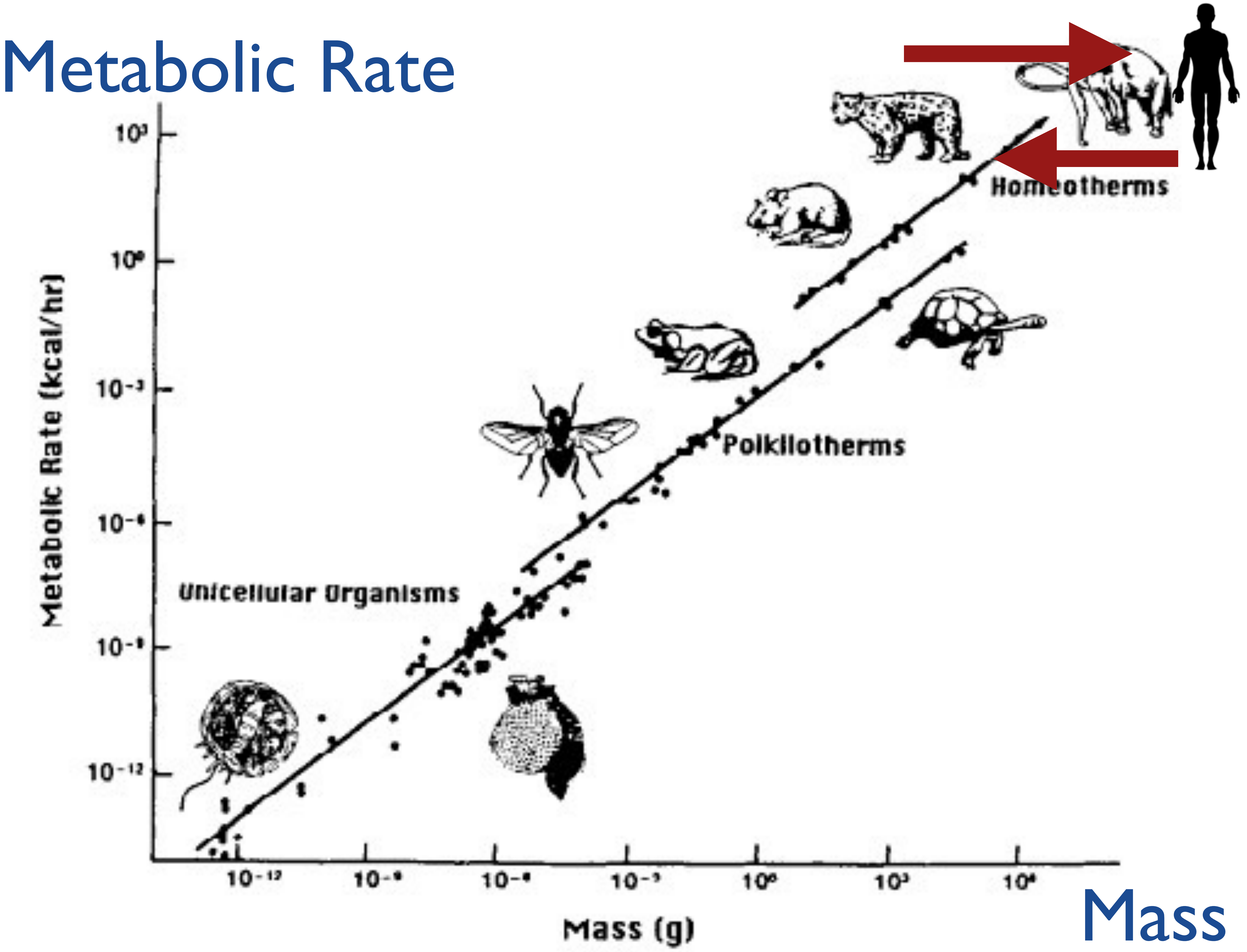


Mass

Scaling law for metabolic rate:
$Y = Y_0 * M^{(3/4)}$

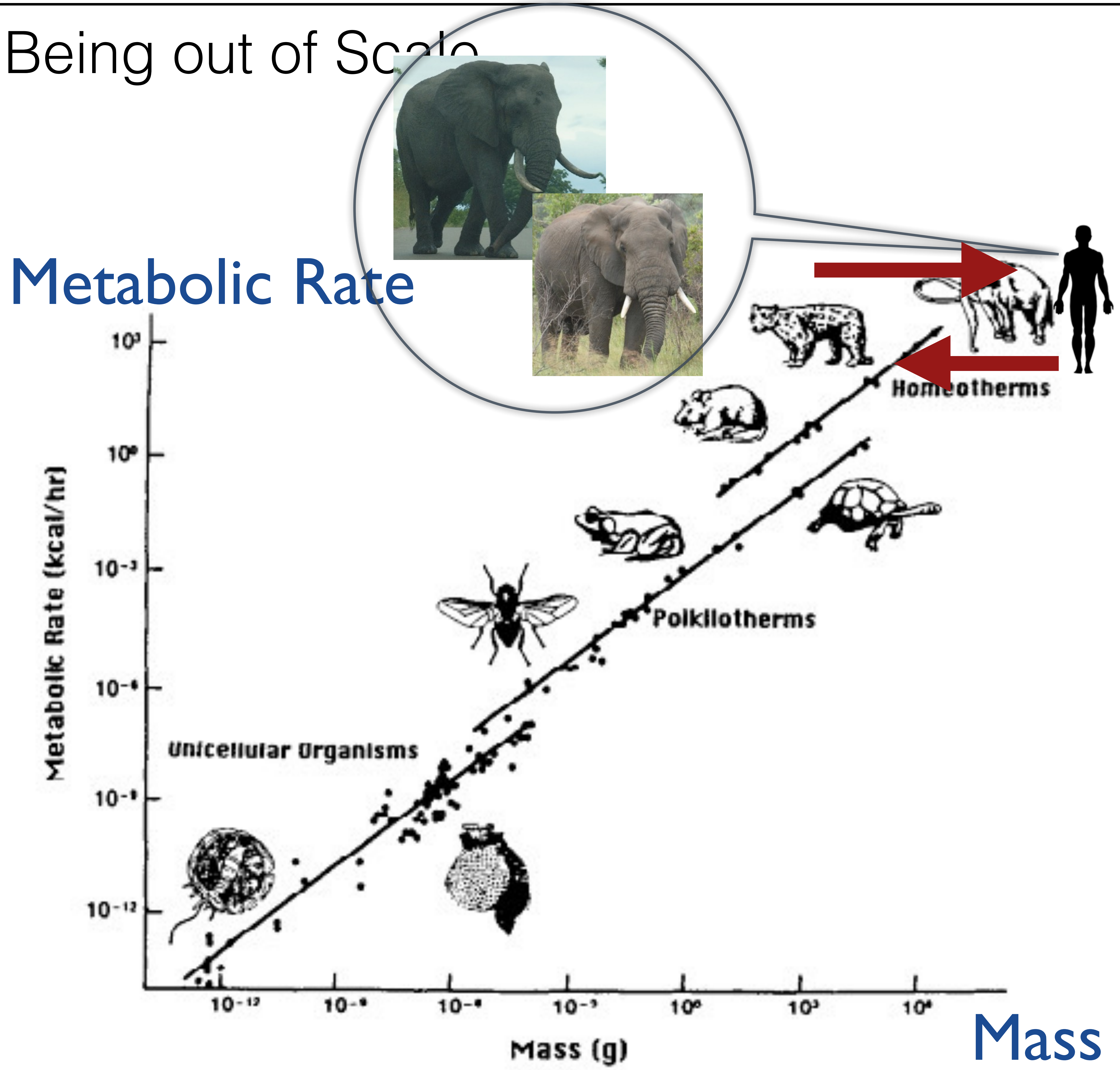
human: Y = 50 -100 Watt

Extended metabolic rate:
$Y_E = Y + C_E$
(C_E: total energy consumption)

Energy consumption per capita:
Global Average: Y_E = 2,735 Watt
M = 10 metric tons

Modern Global Change

Being out of Scale



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human: Y = 50 -100 Watt

14 Billion elephants: a heavy "load" for Earth

Modern Global Change

Changes in flows in the Earth's life-support system:

Modern Global Change

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- Energy flows from fossil fuels => humanity => life-support system.
- Impacts other flows in a "re-engineered" system
- Changes Earth's Energy Imbalance:

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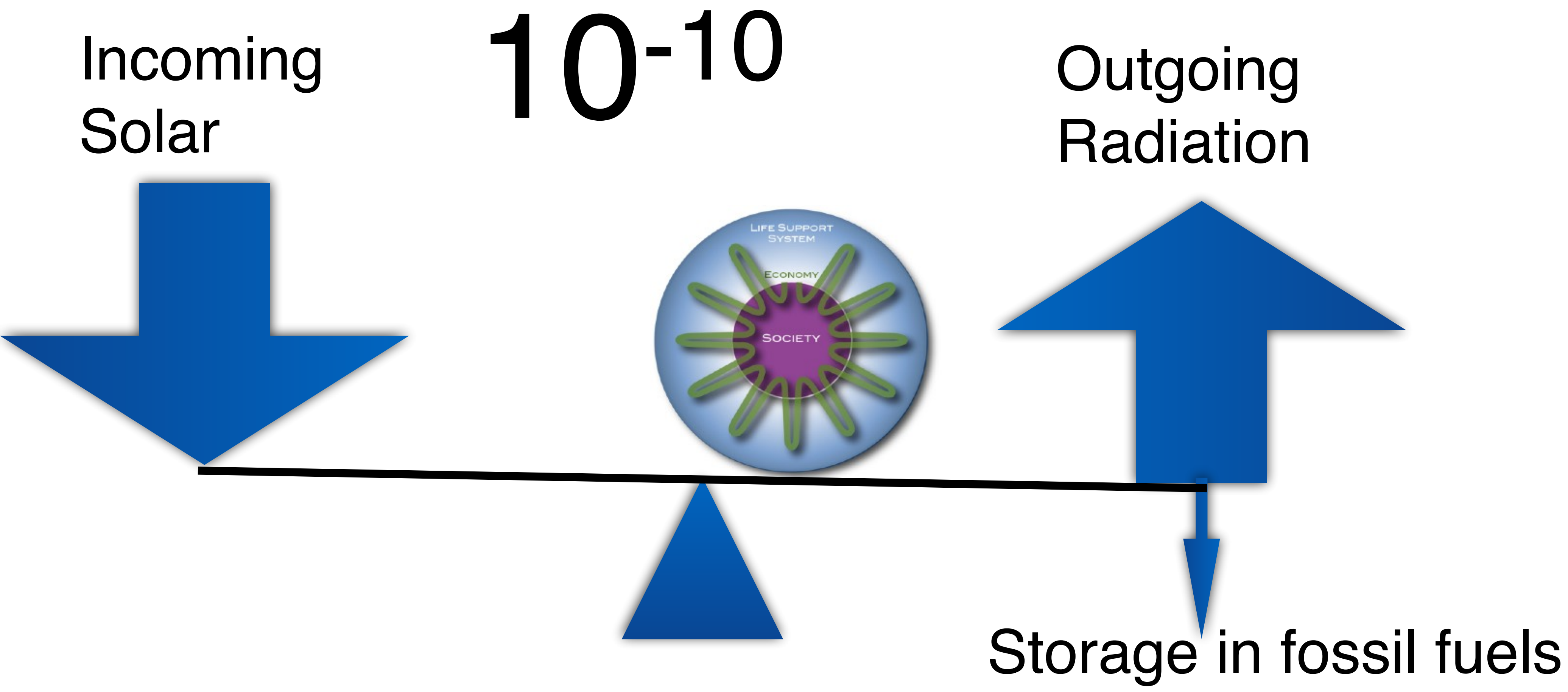

Imbalance on the order of 10^{-10}

Last 200 Million years

Modern Global Change

Changes in flows in the Earth's life-support system:

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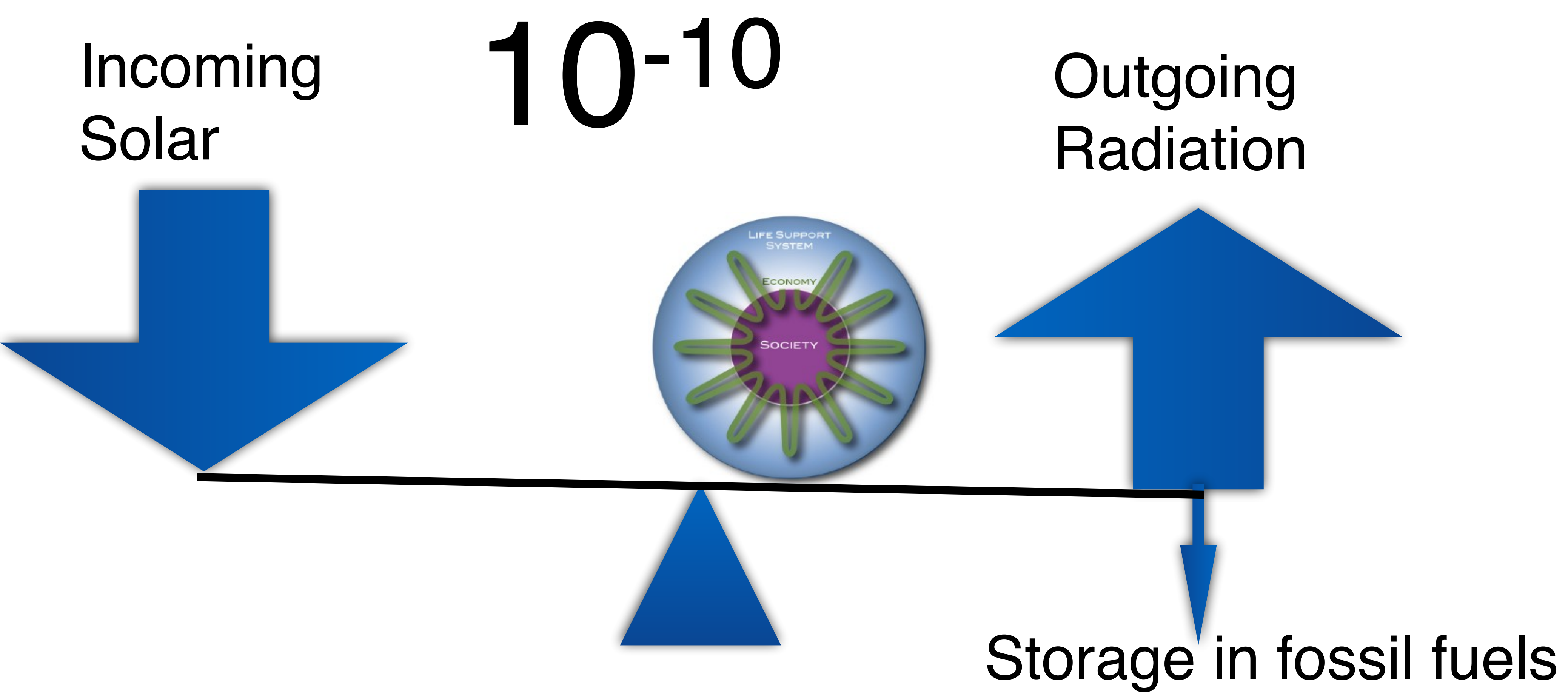

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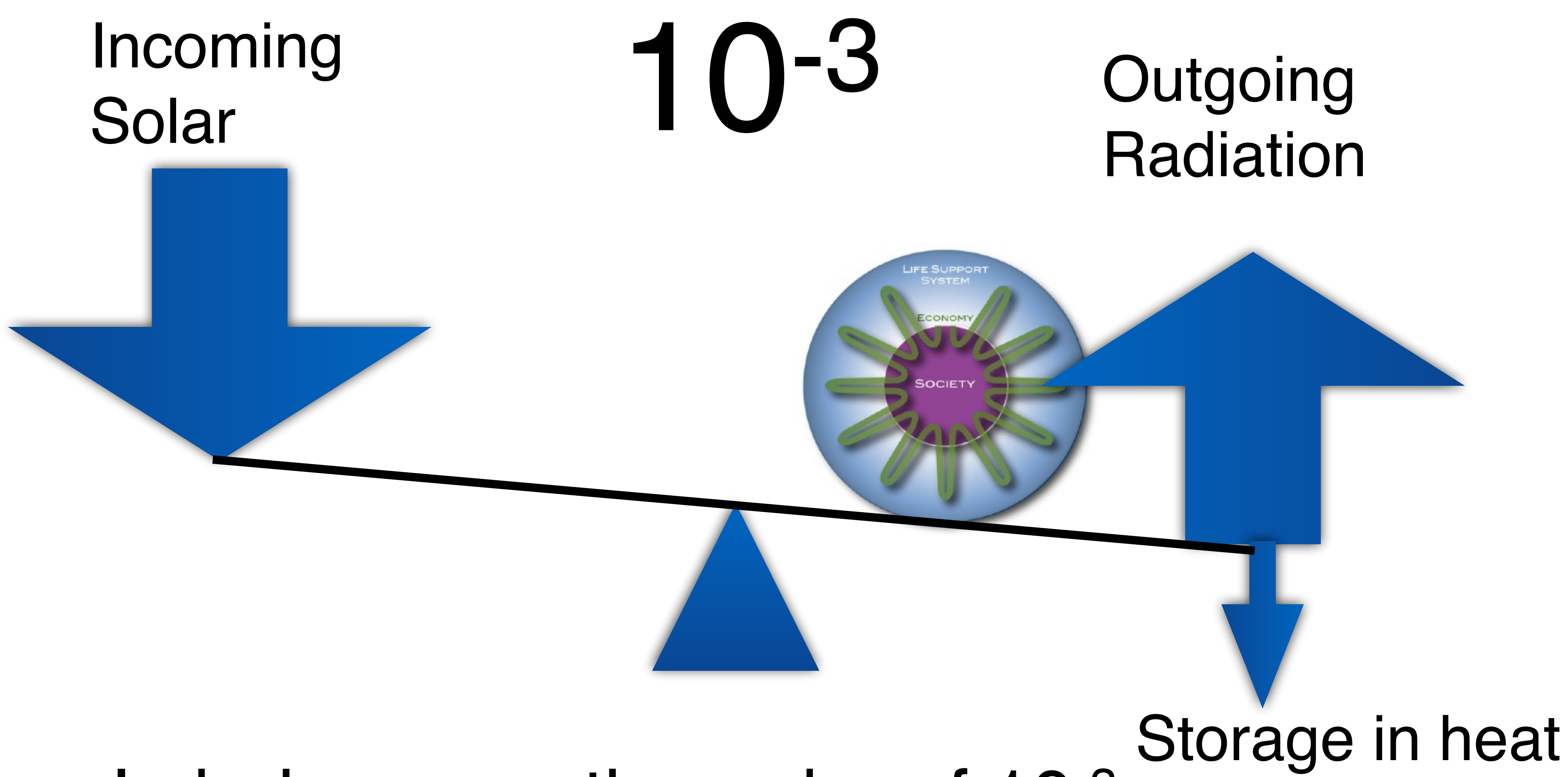
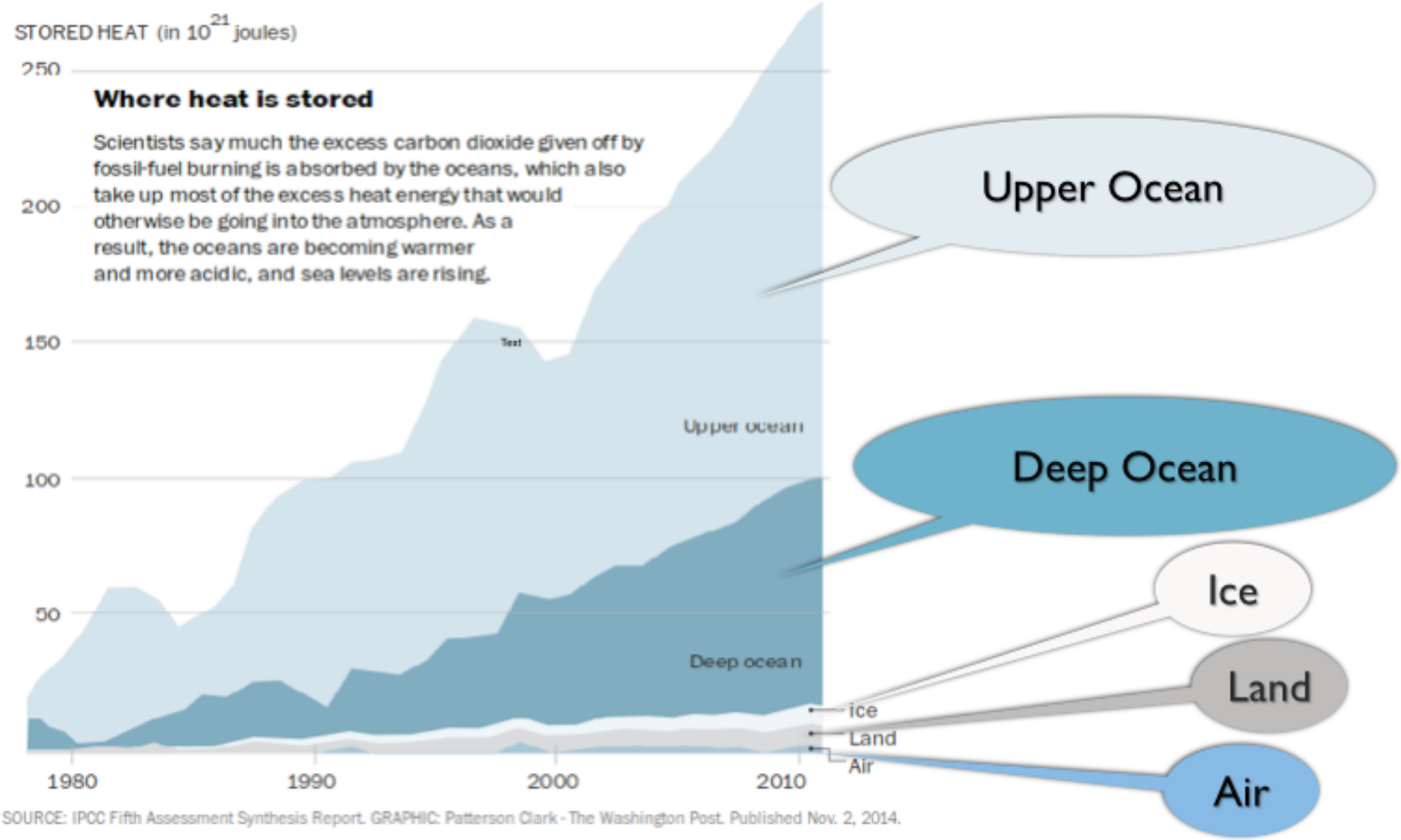
Last 200 Million years



Imbalance on the order of 10^{-3}

Last 70 years

Imbalance: 300-320 TW;



SOURCE: IPCC Fifth Assessment Synthesis Report. GRAPHIC: Patterson Clark - The Washington Post. Published Nov. 2, 2014.

Modern Global Change

Greenhouse

Modern Global Change

Greenhouse

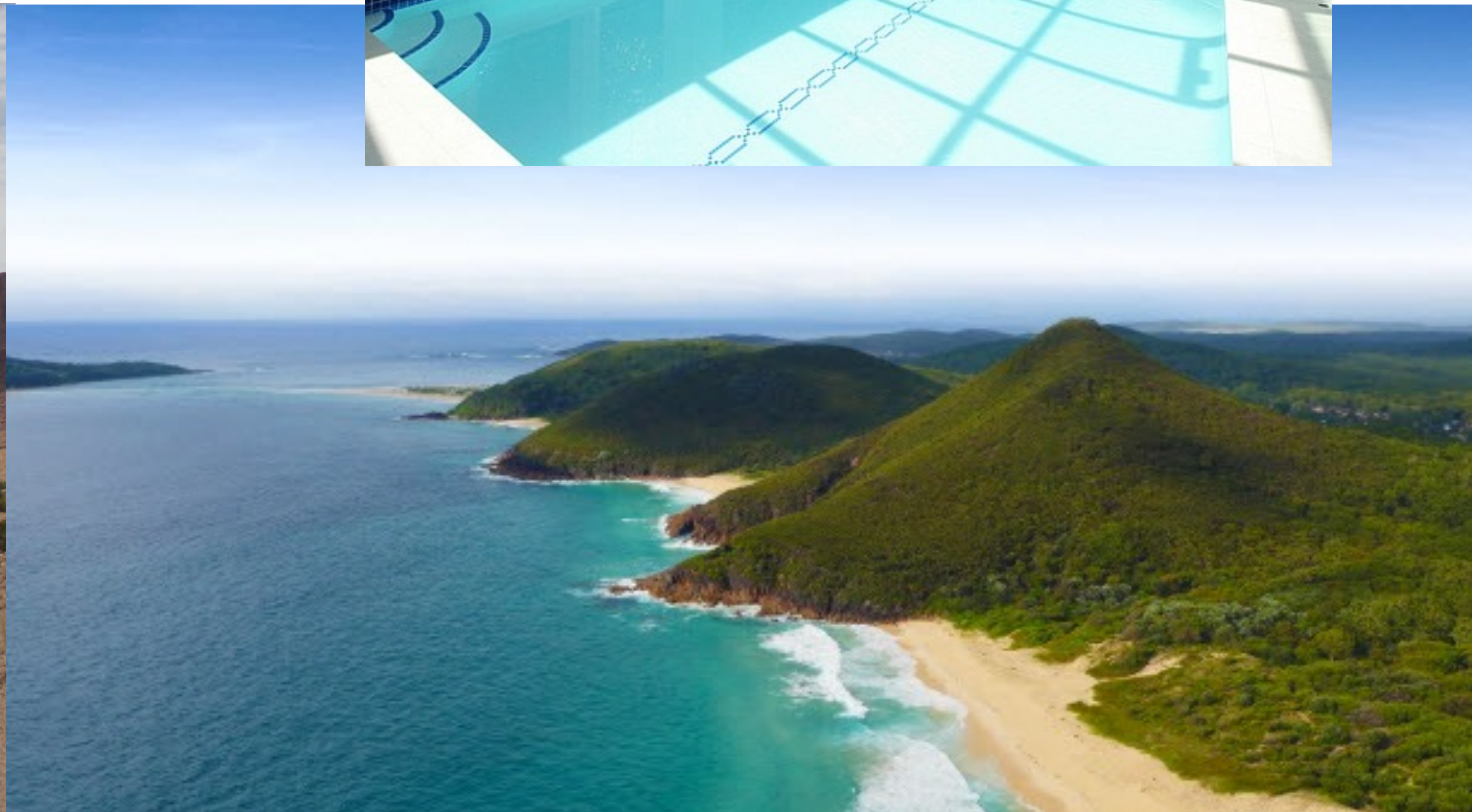
Modern Global Change

Greenhouse

Modern Global Change

Greenhouse

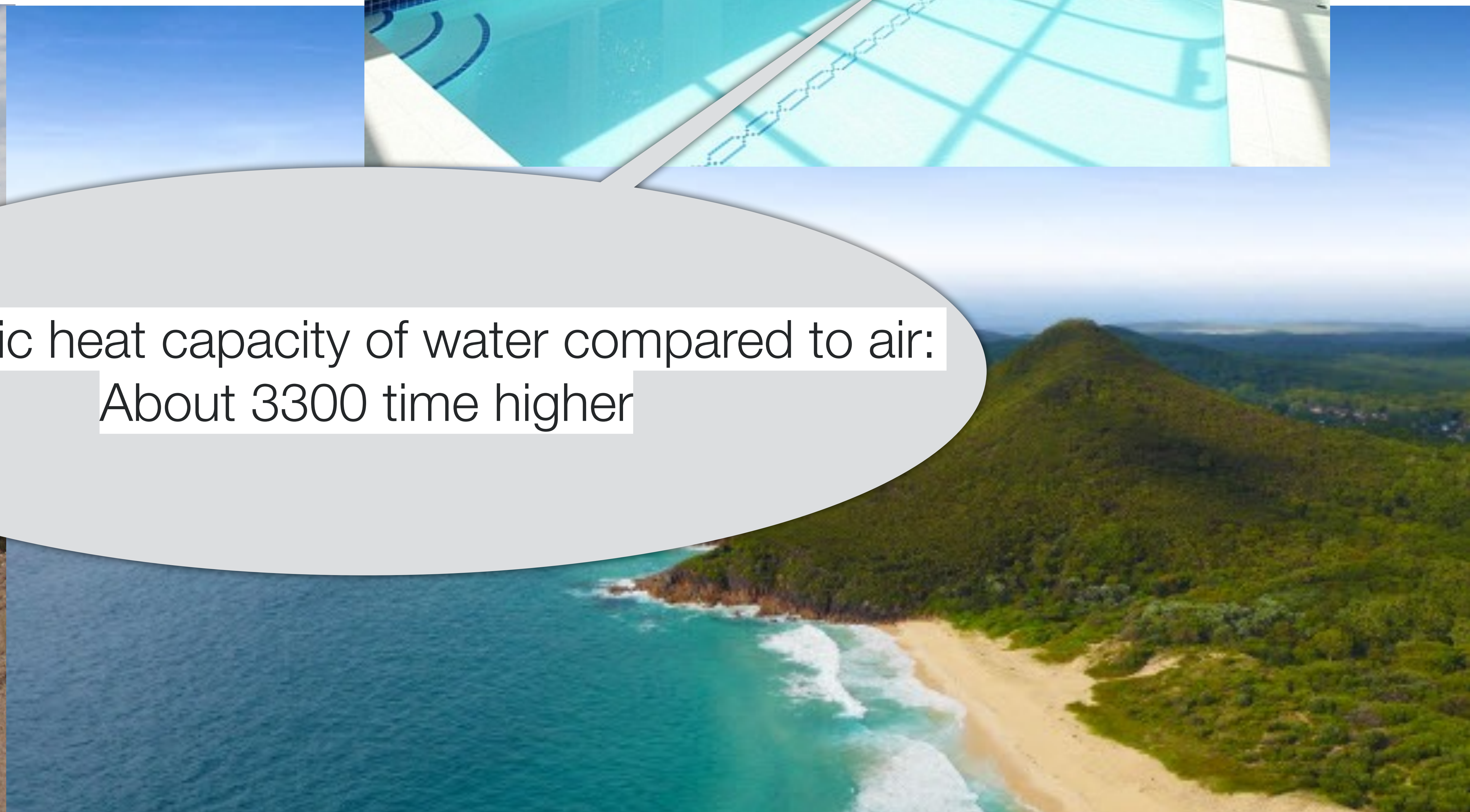
Poolhouse



Modern Global Change

Greenhouse

Poolhouse

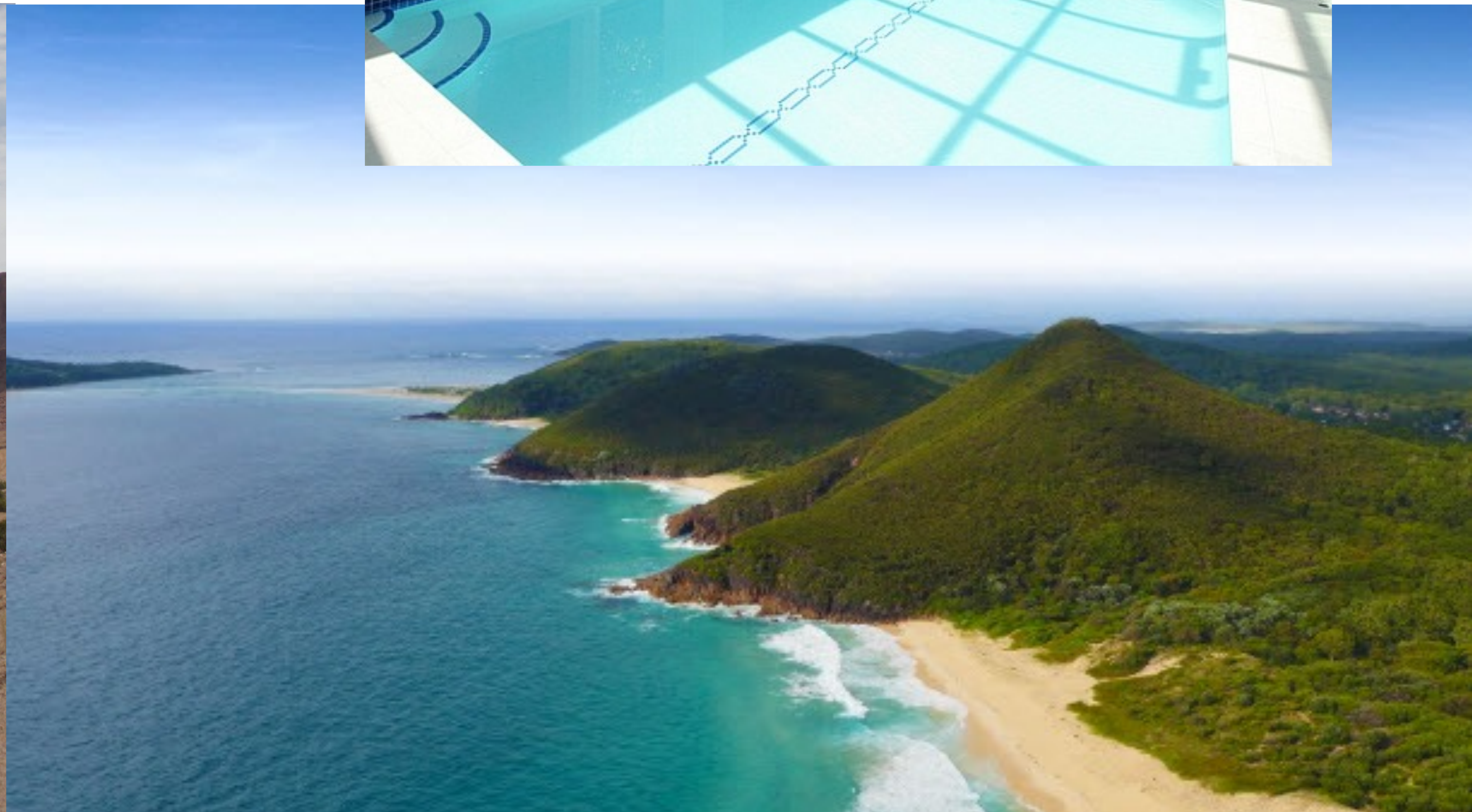


Volumetric heat capacity of water compared to air:
About 3300 time higher

Modern Global Change

Greenhouse

Poolhouse



ERIC HOLTHAUS SCIENCE 09.08.18 07:00 AM

WISCONSIN'S FLOODS ARE CATASTROPHIC—AND ONLY GETTING WORSE

Is there a connection to climate change? Well, a warmer atmosphere can hold more water vapor, and the region's main moisture source — the Gulf of Mexico — has reached record-warm levels in recent years, helping to spur an increase in precipitation intensity. Since the 1950s, the amount of rain falling in the heaviest storms has increased by 37 percent in the Midwest.

But there's more to it than that. Decades of development have also paved over land that used to soak up rainwater. Earlier this year, Wisconsin took controversial steps to loosen restrictions on lakeside development.

https://www.wired.com/story/wisconsins-floods-are-catastrophic-and-only-getting-worse

Modern Global Change

They also saw what could be a perilous future for low-lying airports around the world, increasingly vulnerable to the rising sea levels and more extreme storms brought about by climate change. A quarter of the world's 100 busiest airports are less than 10 meters, or 32 feet, above sea level, according to an analysis of data from Airports Council International and OpenFlights.

Twelve of those airports — including hubs in Shanghai, Rome, San Francisco and New York — are less than 5 meters above sea level.

https://www.nytimes.com/2018/09/07/climate/airport-global-warming-kansai.html

Modern Global Change

SCIENTIFIC REPORTS

Article | OPEN | Published: 06 September 2018

The 2015 landslide and tsunami in Taan Fiord, Alaska

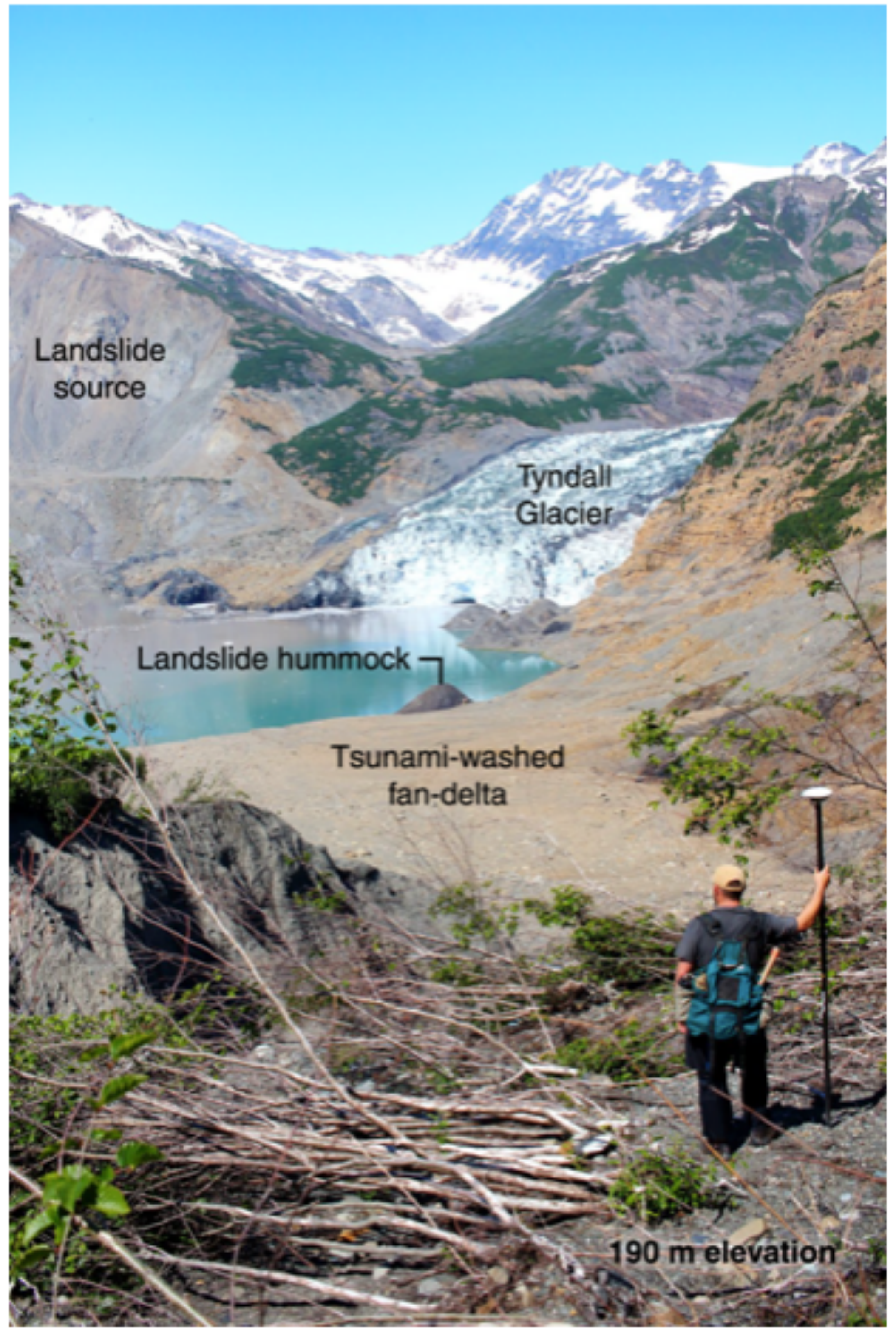
Bretwood Higman, Dan H. Shugar, […] Michael Loso

Scientific Reports 8, Article number: 12993 (2018) | Download Citation

Abstract

Glacial retreat in recent decades has exposed unstable slopes and allowed deep water to extend beneath some of those slopes. Slope failure at the terminus of Tyndall Glacier on 17 October 2015 sent 180 million tons of rock into Taan Fiord, Alaska. The resulting tsunami reached elevations as high as 193 m, one of the highest tsunami runups ever documented worldwide. Precursory deformation began decades before failure, and the event left a distinct sedimentary record, showing that geologic evidence can help understand past occurrences of similar events, and might provide forewarning. The event was detected within hours through automated seismological techniques, which also estimated the mass and direction of the slide - all of which were later confirmed by remote sensing. Our field observations provide a benchmark for modeling

Figure 1



Tsunami impacts near the landslide. The 2015 landslide and tsunami reshaped the landscape at the terminus of Tyndall Glacier. The person in the photo is standing about 190 m above the fjord level, just below the limit of inundation (near the point marked with 193 m runup in Fig. 2).

Table 1 Tsunamis with runup of 50 m or greater in the past century.

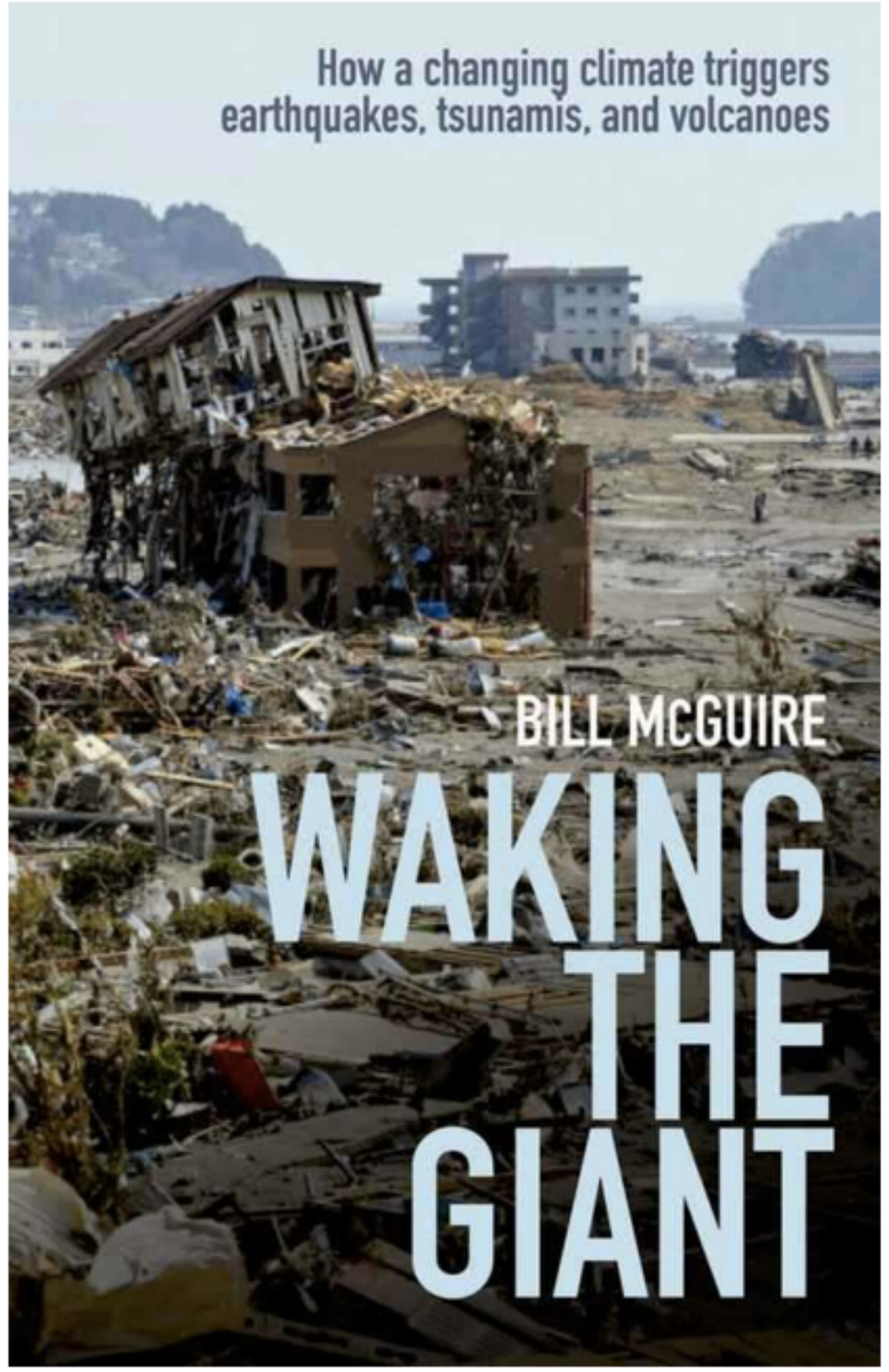
From: The 2015 landslide and tsunami in Taan Fiord, Alaska

Year	Location	Water body	Cause	Latitude	Longitude	Max runup (m)
1958	Lituya Bay, Alaska, USA	Fjord	Subaerial landslide	58.672	−137.526	524
1980	Spirit Lake, WA, USA	Lake	Volcanic landslide	46.273	−122.135	250
1963	Casso, Italy	Reservoir	Subaerial landslide	46.272	12.331	235
2015	**Taan Fiord, Alaska, USA**	**Fjord**	**Subaerial landslide**	**60.2**	**−141.1**	**193**
1936	Lituya Bay, Alaska, USA	Fjord	Subaerial landslide	58.64	−137.57	149
2017	Nuugaatsiaq, Greenland	Fjord	Subaerial landslide	71.8	−52.5	90
1936	Nesodden, Norway	Fjord	Subaerial landslide	61.87	6.851	74
1964	Cliff Mine, Alaska, USA	Fjord	Delta-front failure	61.125	−146.5	67
1934	Tafjord, Norway	Fjord	Subaerial landslide	62.27	7.39	62
1965	Lago Cabrera, Chile	Lake	Subaerial landslide	−41.8666	−72.4635	60
1967	Grewingk Lake, Alaska, USA	Lake	Subaerial landslide	59.6	−151.1	60
1946	Mt. Colonel Foster, BC, Canada	Lake	Subaerial landslide	49.758	−125.85	51
2004	Labuhan, Indonesia	Open coast	Earthquake displacement	5.429	95.234	51
2000	Paatuut, Greenland	Fjord	Subaerial landslide	70.25	−52.75	50

10 out of 14 tsunamis resulted from subaerial landslides into fjords or lakes in glaciated mountains. Other cases have diverse causes: volcanic eruption (1980), landslide into artificial reservoir (1963), subaqueous delta failure (1964), and earthquake displacement (2004). (Data modified from[53]).

Climate change is driving worldwide glacial retreat and thinning[1] that can expose unstable hillslopes. The removal of glacial ice supporting steep slopes combined with the thawing of permafrost in alpine regions[2] increases the likelihood of landslides

Modern Global Change



We know about the threat of modern climate change since more than 100 years, but …

“Humans, as individuals, as groups, and together as a society, seem to be hard-wired to respond quickly and effectively to a sudden threat, but not to a menace that makes itself known stealthily and over an extended period of time.”

We reacted in the past to extreme events, but …

“*Despite our increasingly desperate predicament, climate change has not prompted anything like this sort of response, and initiatives designed to cut carbon emissions, such as the Kyoto Protocol, have made no impression at all on the steadily rising concentrations of greenhouse gases in the atmosphere.*”

Natural Hazards and Disaster

Class 3: Global Threats and Extraterrestrial Hazards

- Extreme Natural Hazards
- Global Risk Assessments
- Modern Global Change
- Major (Global) Risks
- Global Risk Governance
- Extraterrestrial Hazards

Major Global Risks (My Assessment)

Even if carbon emissions are reduced, the ocean is still set for centuries or more of warming, acidification, deoxygenation, and sea level rise. Photo by Ethan Daniels/Alamy Stock Photo

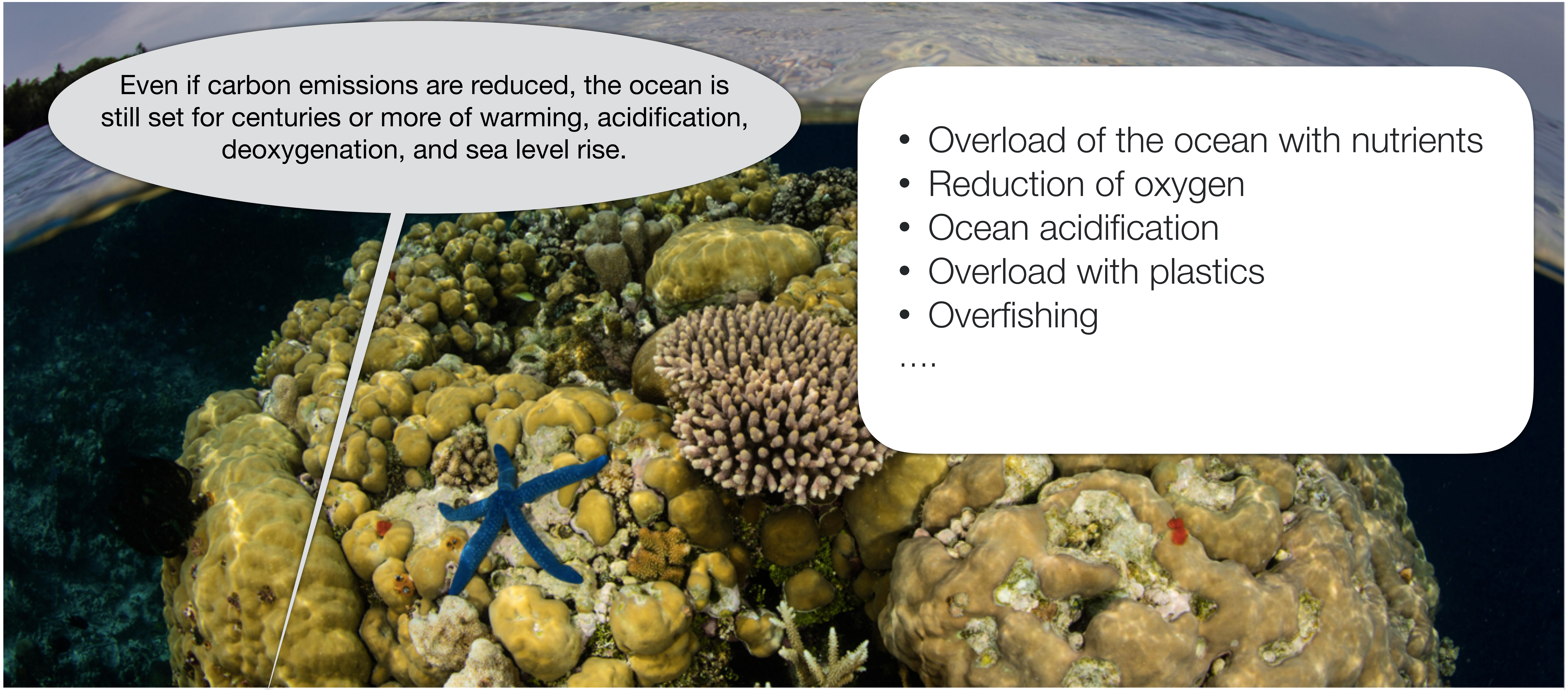
When It Comes to Climate Change, the Ocean Never Forgets

Major Global Risks (My Assessment)

Even if carbon emissions are reduced, the ocean is still set for centuries or more of warming, acidification, deoxygenation, and sea level rise. Photo by Ethan Daniels/Alamy Stock Photo

When It Comes to Climate Change, the Ocean Never Forgets

Major Global Risks (My Assessment)



Even if carbon emissions are reduced, the ocean is still set for centuries or more of warming, acidification, deoxygenation, and sea level rise.

- Overload of the ocean with nutrients
- Reduction of oxygen
- Ocean acidification
- Overload with plastics
- Overfishing

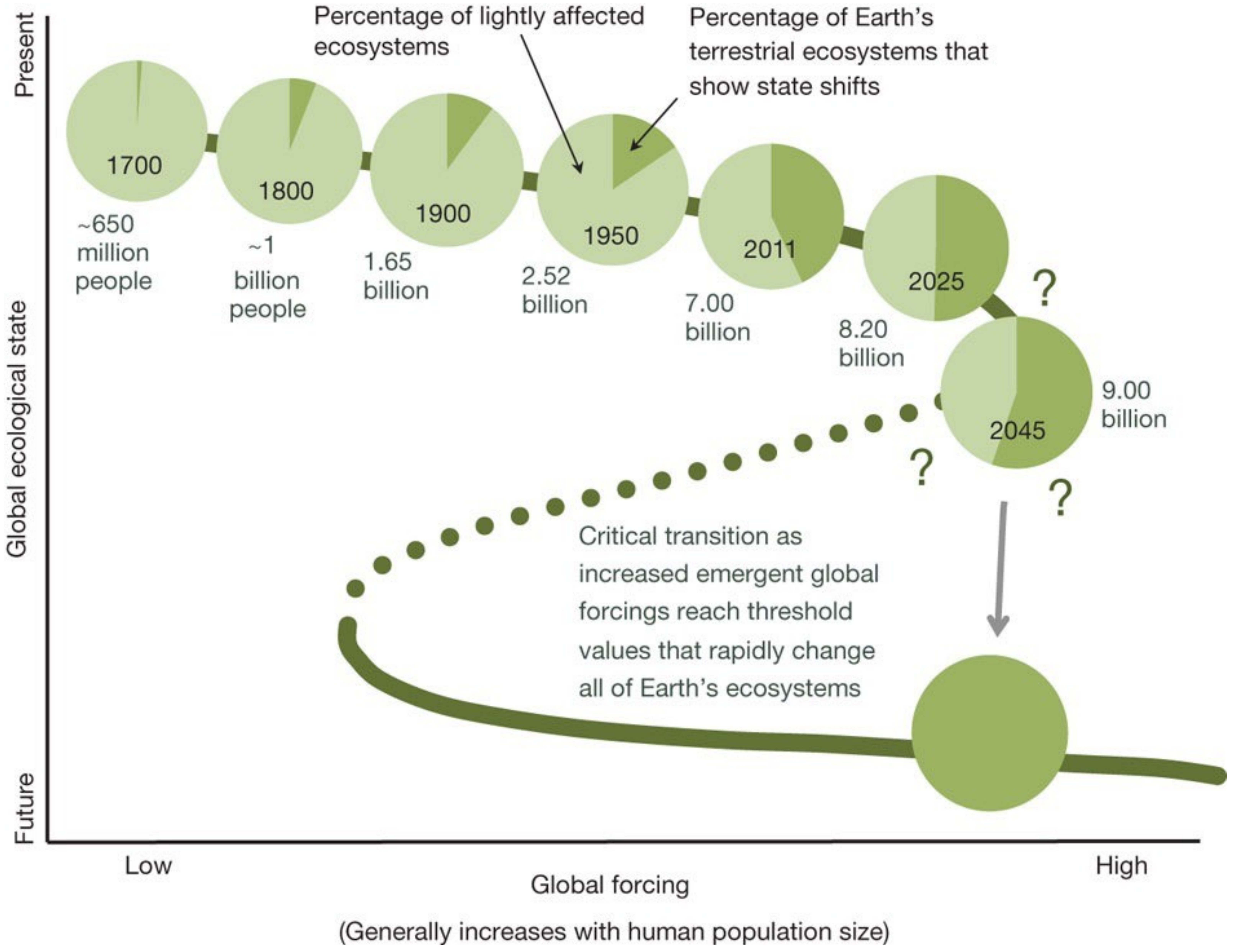
….

Even if carbon emissions are reduced, the ocean is still set for centuries or more of warming, acidification, deoxygenation, and sea level rise. Photo by Ethan Daniels/Alamy Stock Photo

When It Comes to Climate Change, the Ocean Never Forgets

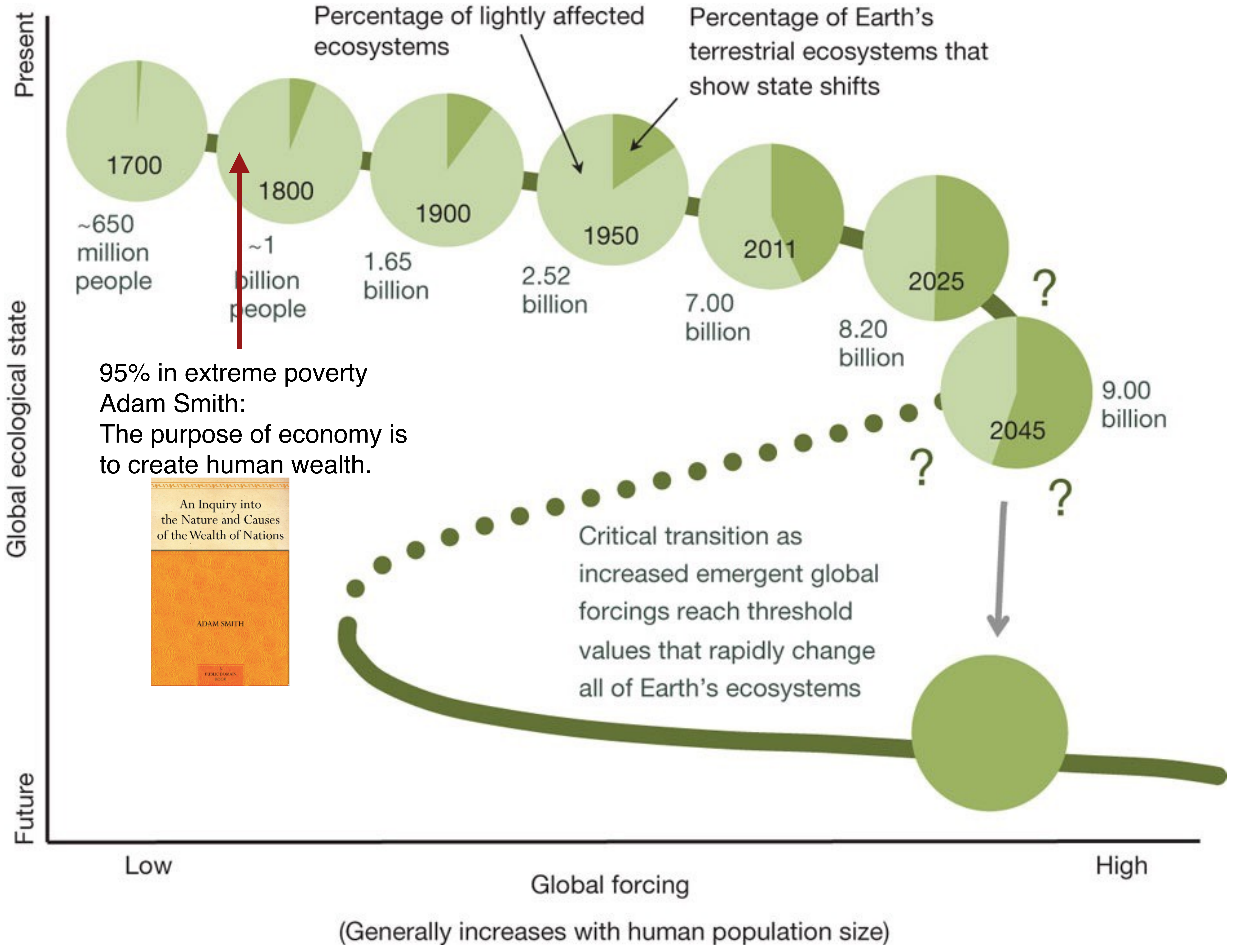
Major Global Risks (My Assessment)

Land use



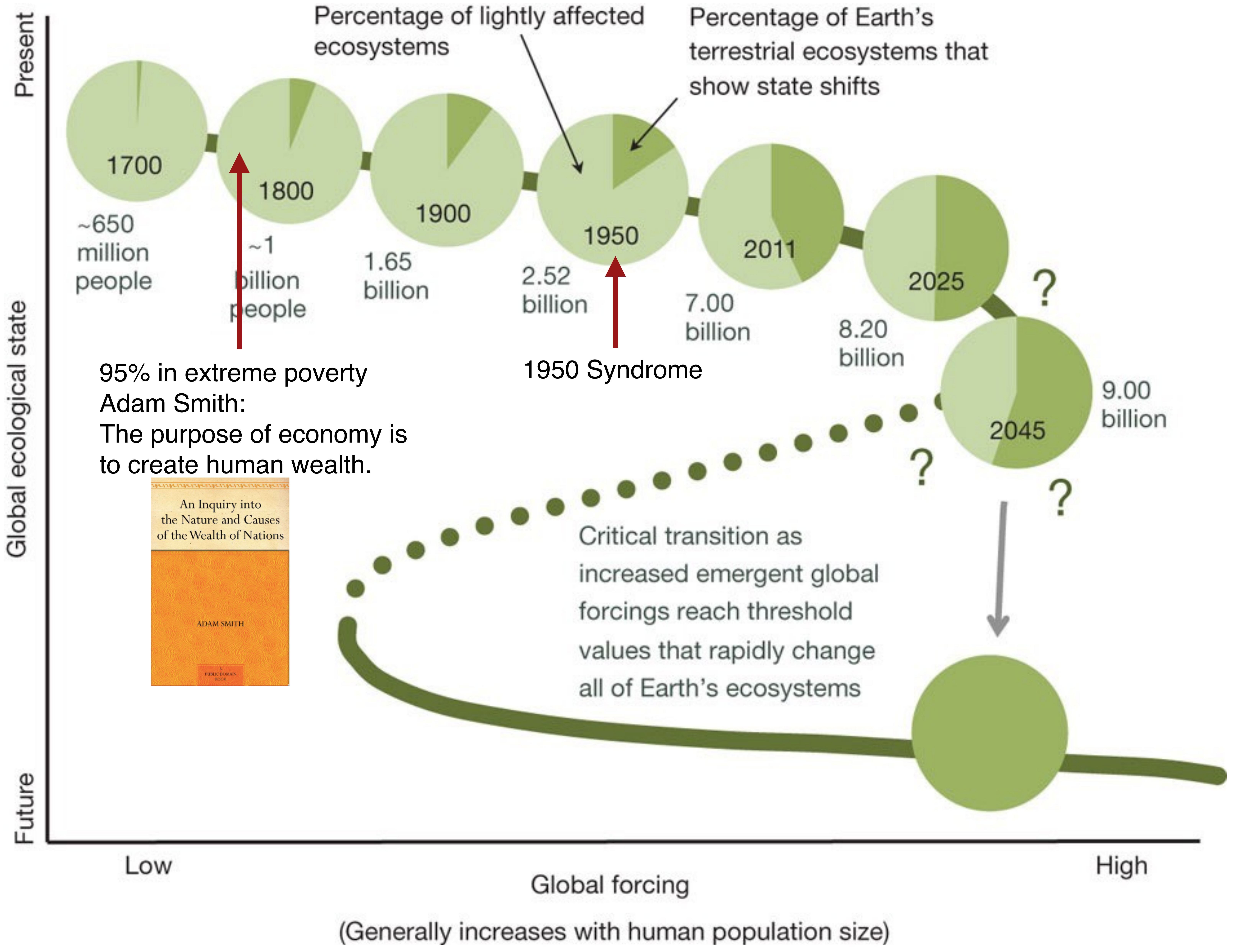
Major Global Risks (My Assessment)

Land use



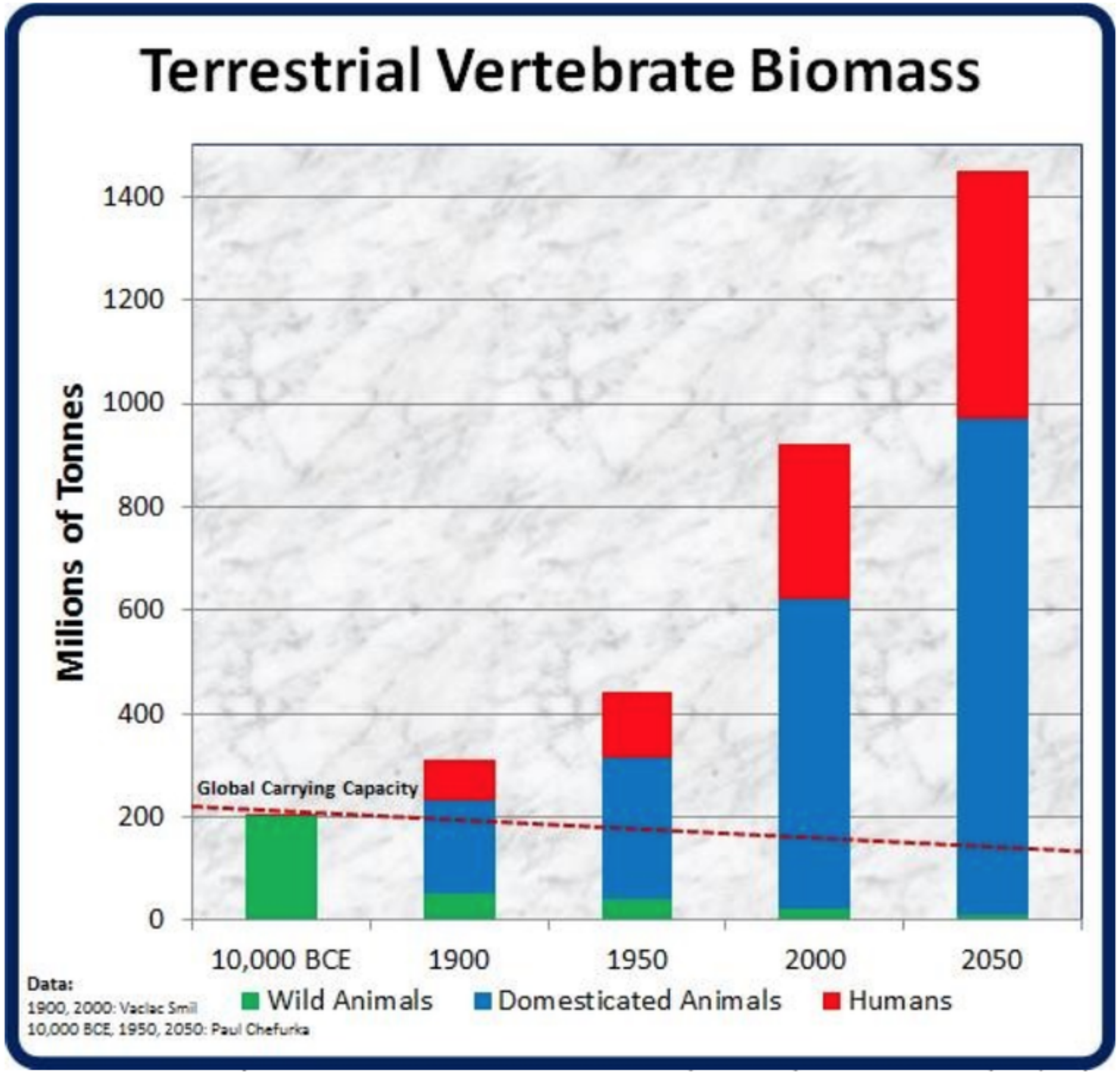
Major Global Risks (My Assessment)

Land use



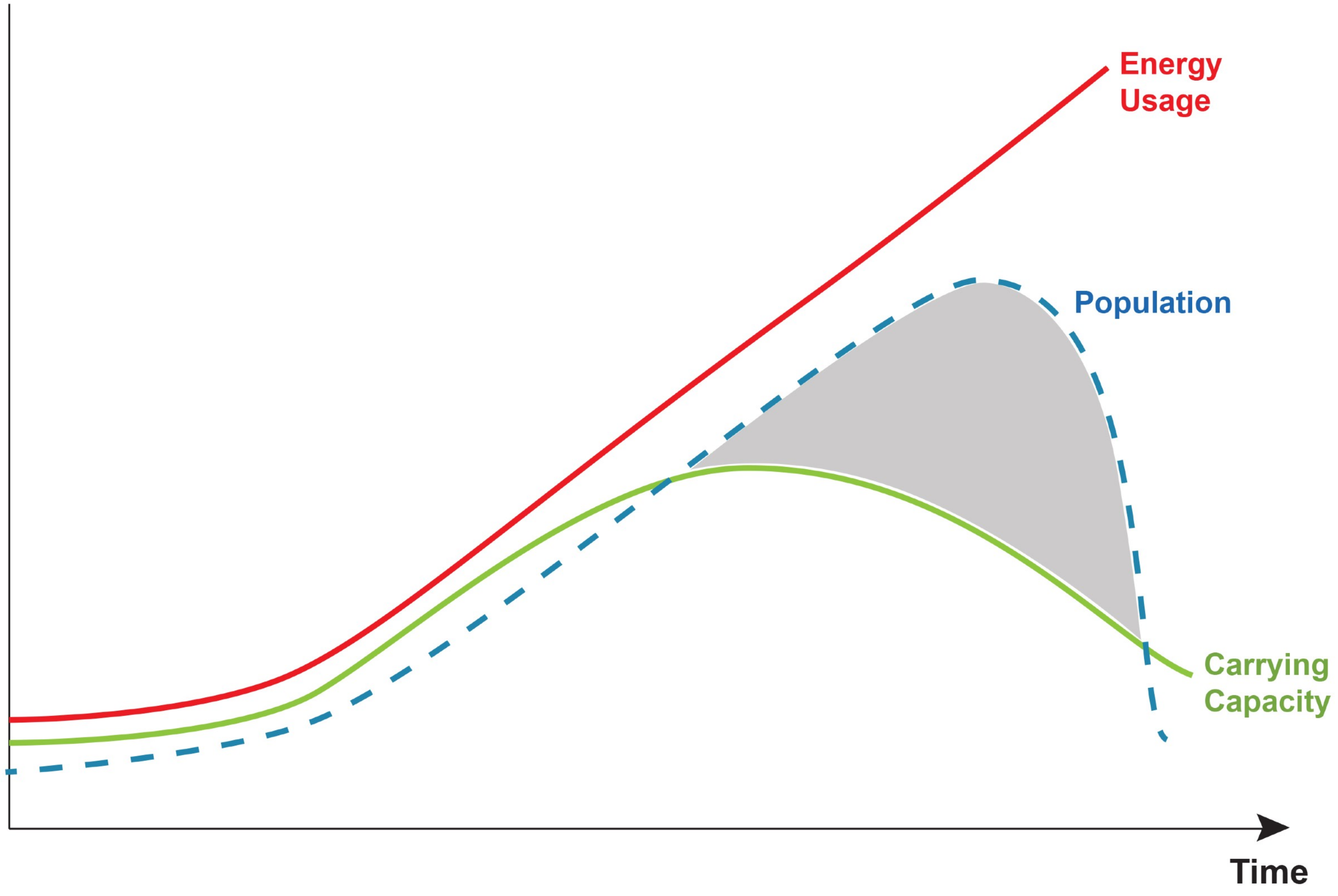
Major Global Risks (My Assessment)

Extinction



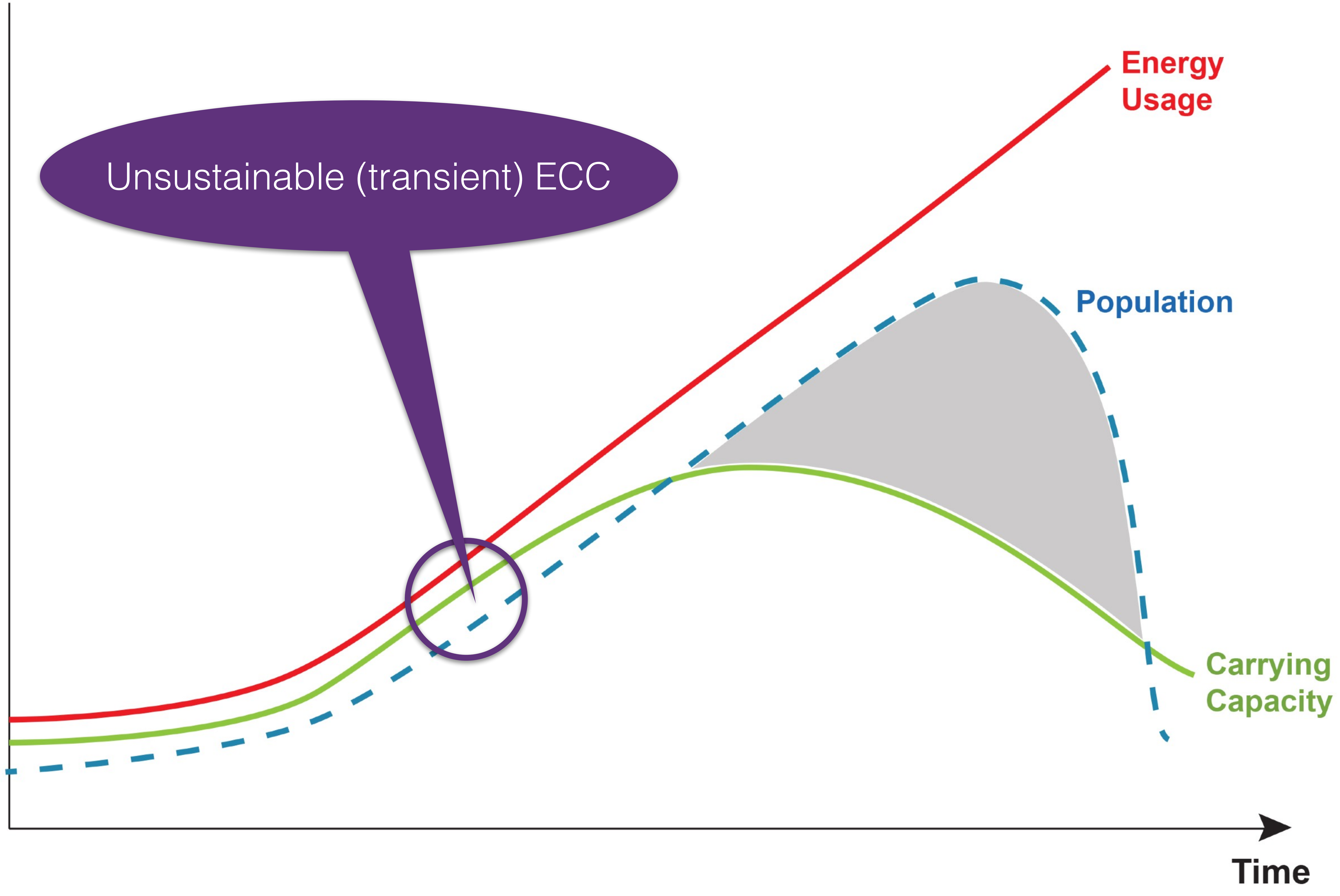
Major Global Risks (My Assessment)

Exceeding Earth's Carrying Capacity (ECC)



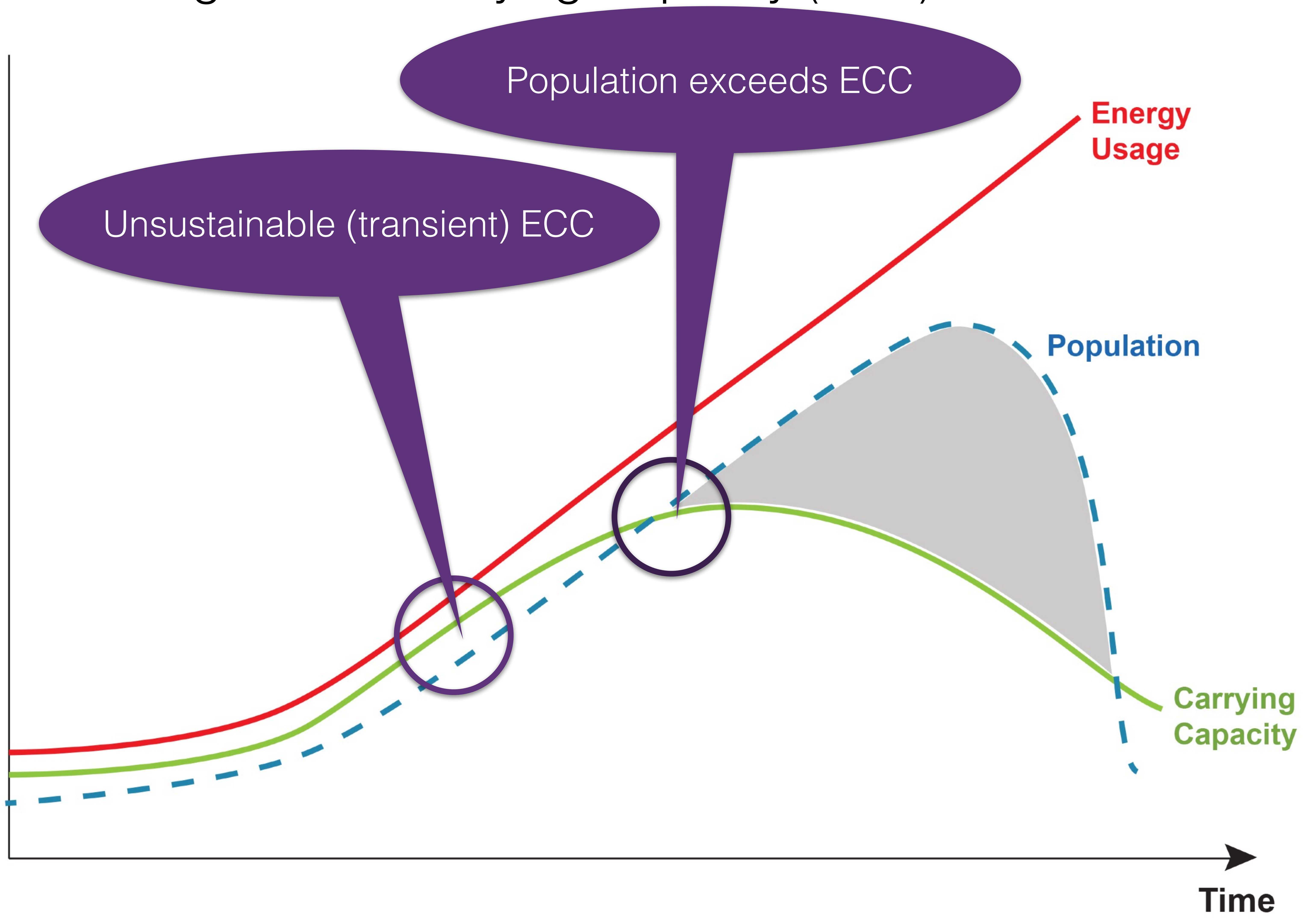
Major Global Risks (My Assessment)

Exceeding Earth's Carrying Capacity (ECC)



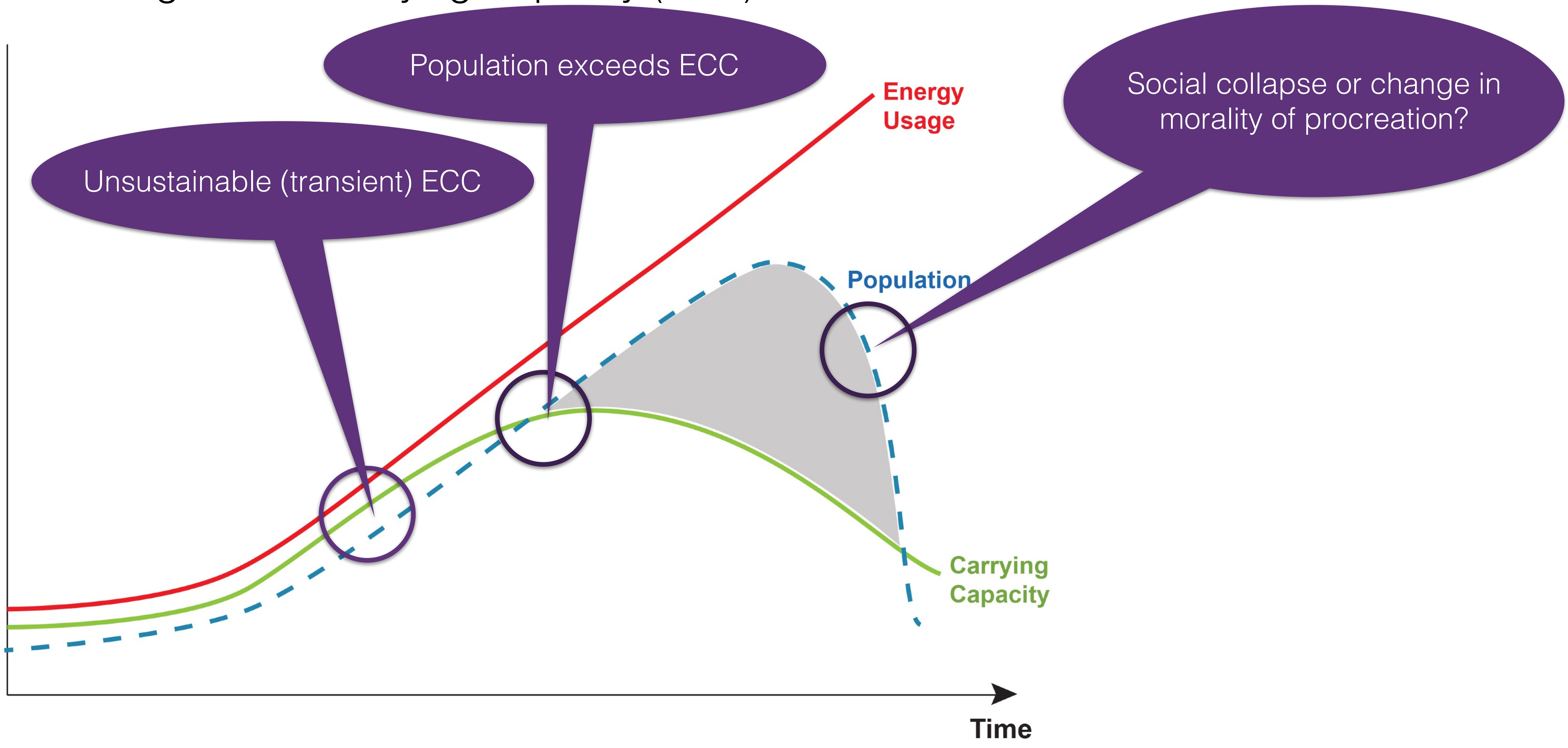
Major Global Risks (My Assessment)

Exceeding Earth's Carrying Capacity (ECC)



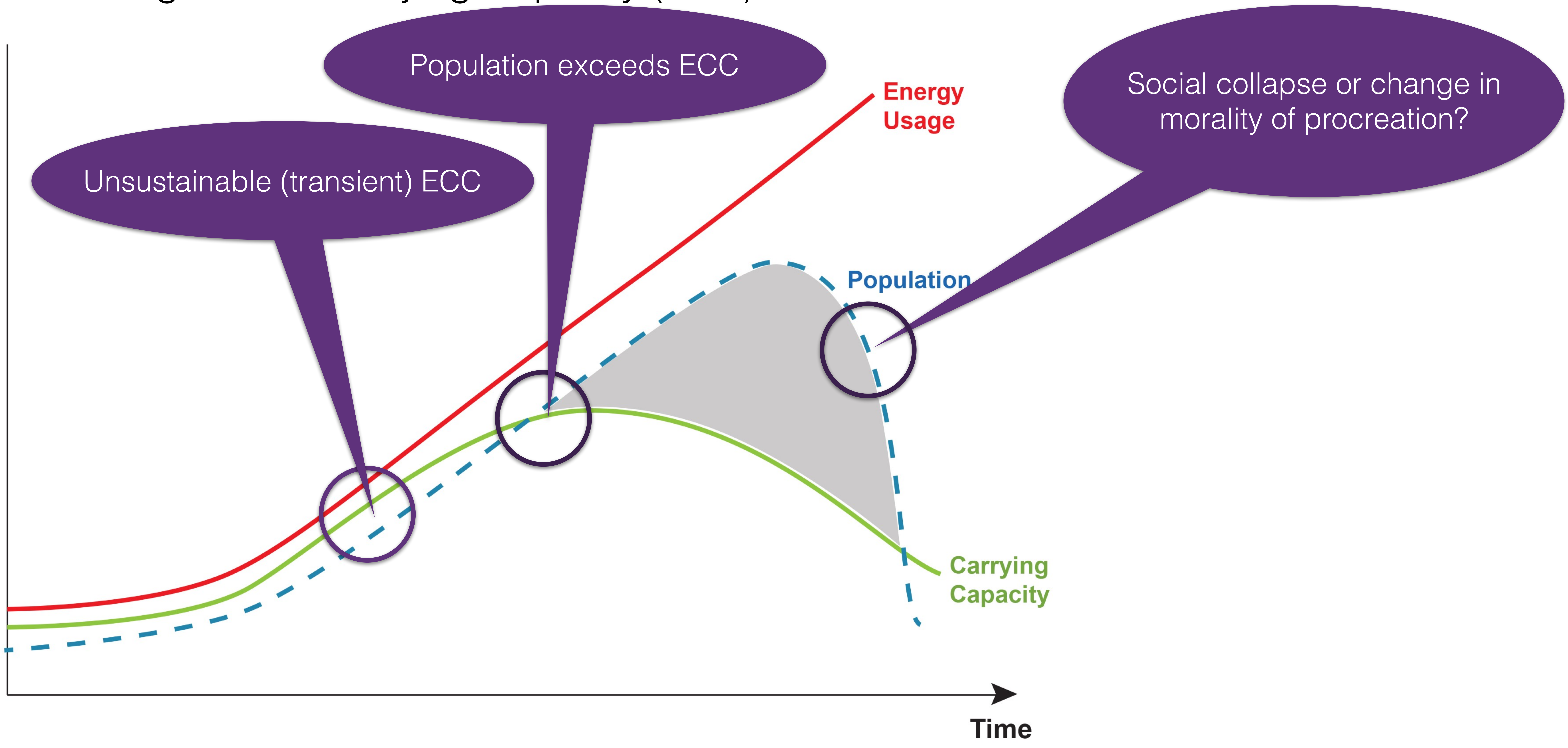
Major Global Risks (My Assessment)

Exceeding Earth's Carrying Capacity (ECC)



Major Global Risks (My Assessment)

Exceeding Earth's Carrying Capacity (ECC)



Lovelock: Carrying Capacity will be down to 1 Billion in 2050

Natural Hazards and Disaster

Class 3: Global Threats and Extraterrestrial Hazards

- Extreme Natural Hazards
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- (Global Risk Governance)
- Extraterrestrial Hazards

Natural Hazards and Disaster

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Natural Hazards and Disaster

Class 3: … Extraterrestrial Hazards

- Threats from Space
- Near-Earth Objects (NEOS)
- Meteoroids and Asteroids
- Comets
- Bolides
- Space Weather, Solar Storms, Gamma Rays

Threats from Space

- Near-Earth Objects: Meteoroids, asteroids and comets with orbits that intersect Earth’s orbit.
- Meteoroids and asteroids: Fragments of rock and/or metal in space. The smaller fragments generate light as meteors as they pass through Earth’s atmosphere. Larger fragments land as meteorites.
- Comets: Balls of ice, dust, and rock that normally reside beyond the orbit of Neptune.
- Bollides: Meteoroids and cometary fragments that explode on entering Earth’s atmosphere.
- Solar storms and space weather: Solar flares and coronal mass ejections occur frequently and can disrupt telecommunications or have more severe consequences for electrical and electronically infrastructure.
- Gamma Ray bursts: Extremely energetic explosions that have been observed in distant galaxies
- Extraterrestrial intelligence:
- Human space debris: debris of satellites and rockets

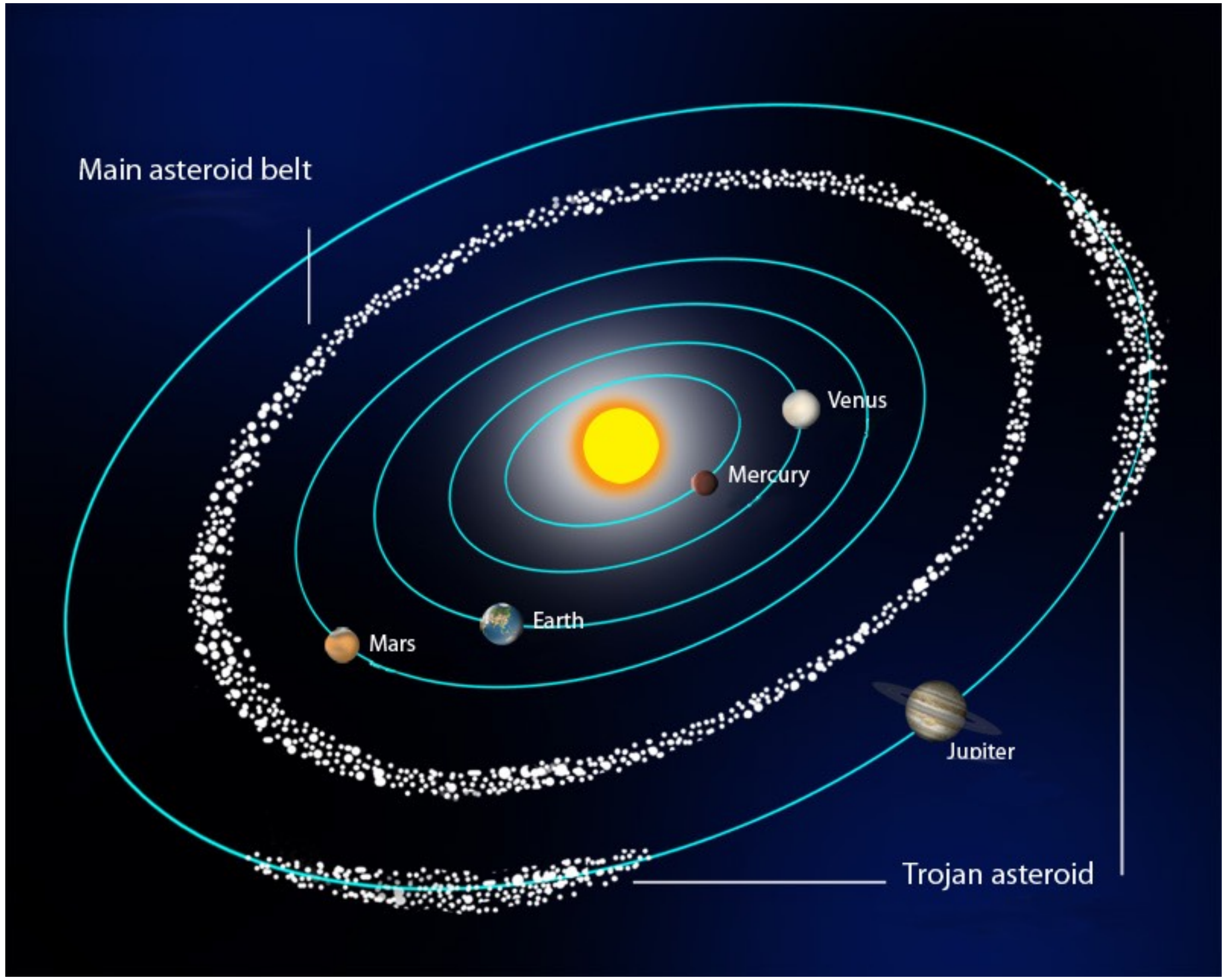
Natural Hazards and Disaster

Class 3: Extraterrestrial Hazards

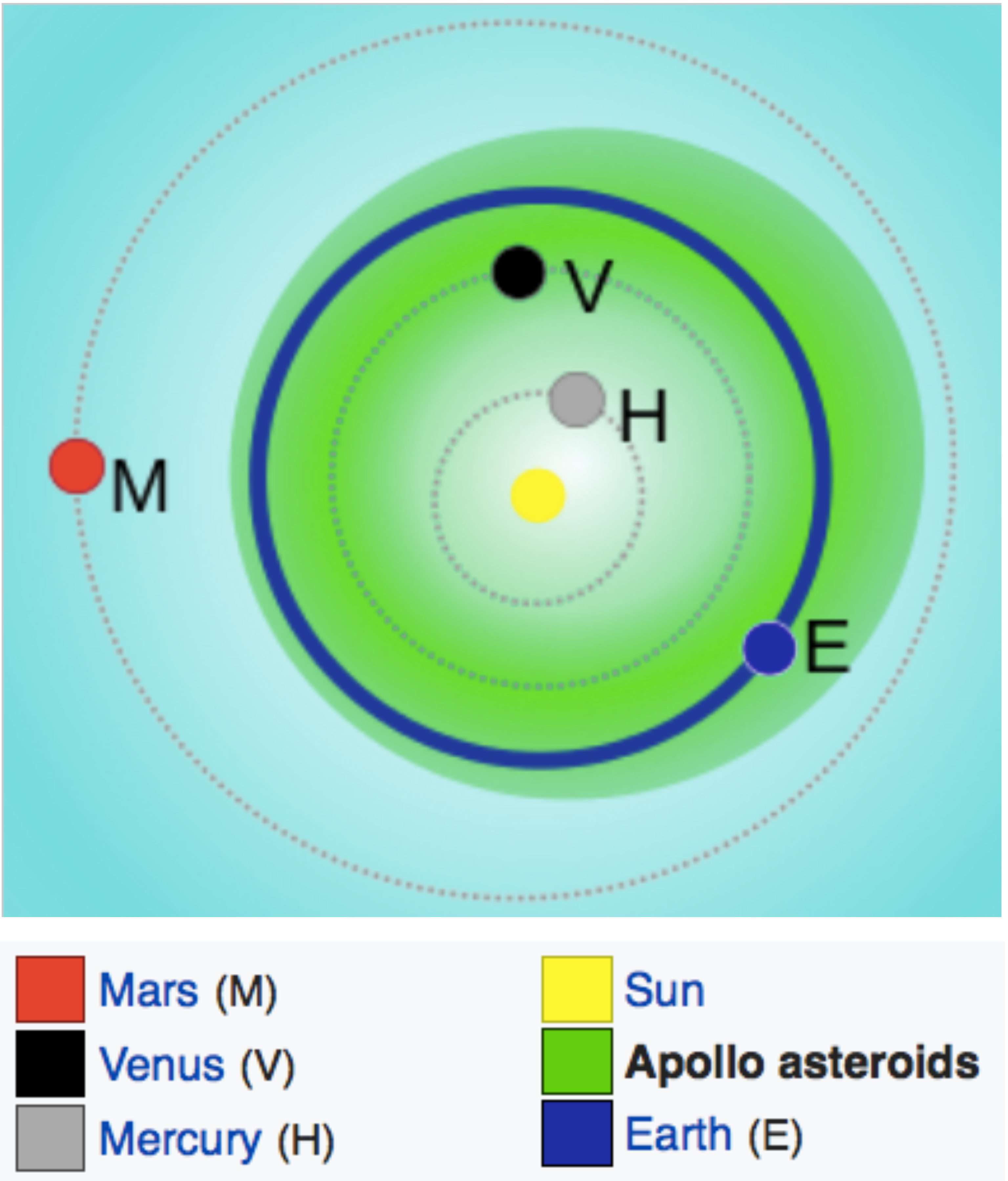
- Threats from Space
- Near-Earth Objects (NEOS)
- Meteorides and Asteroids
- Comets
- Bolides
- Space Weather, Solar Storms, Gamma Rays

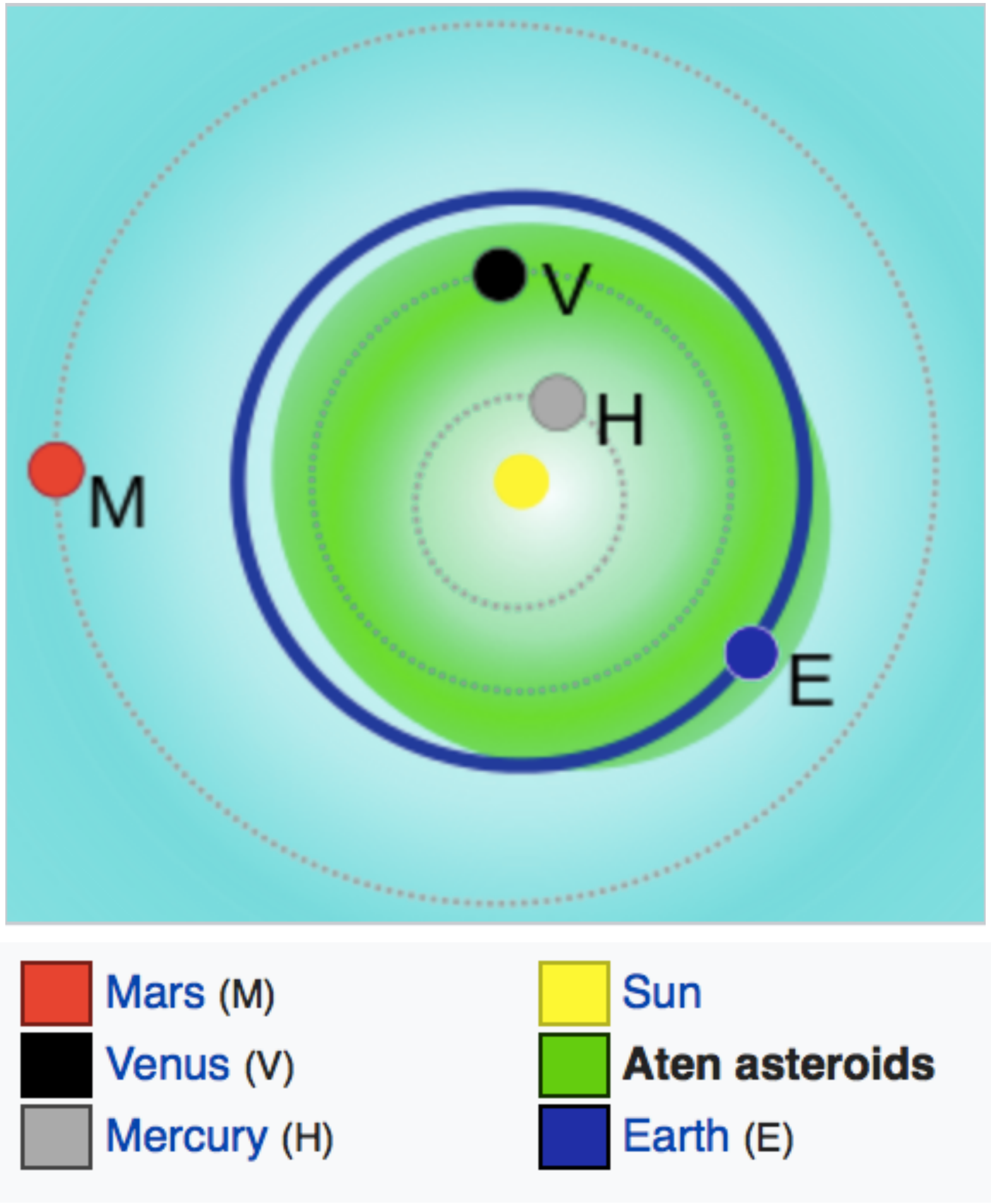
Near-Earth Objects (NEOS)

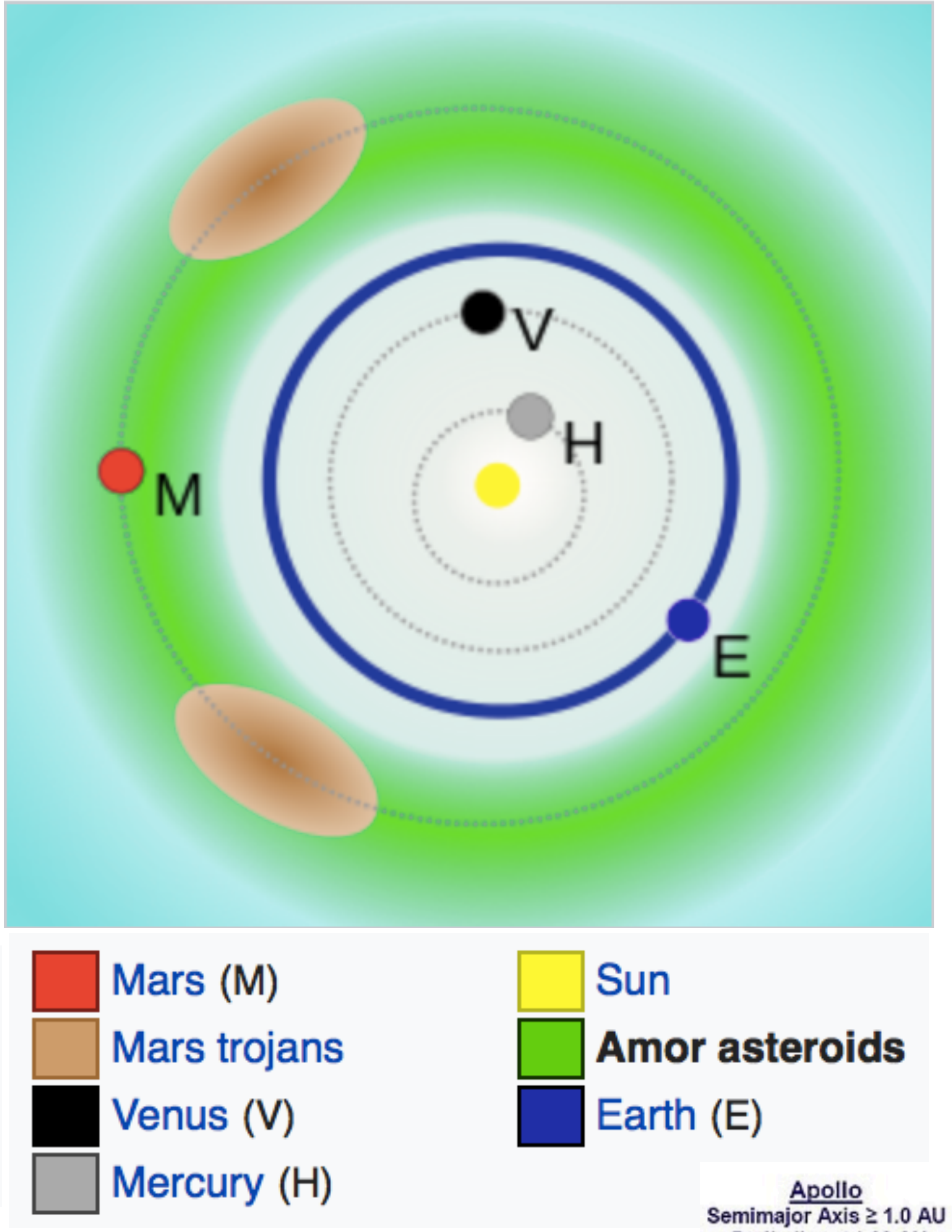
- Near Earth Objects (NEOs) are meteoroids, asteroids or comets that pass close to the Earth.
- Potentially hazardous NEOs are estimated to be greater than 20 m in diameter.
- Asteroids reside in the asteroid belt within the inner solar system.
- Comets originate from the Kuiper belt in the outer solar system.
- NEOs greater than 1 km in diameter have the potential to severely disrupt and destroy life.

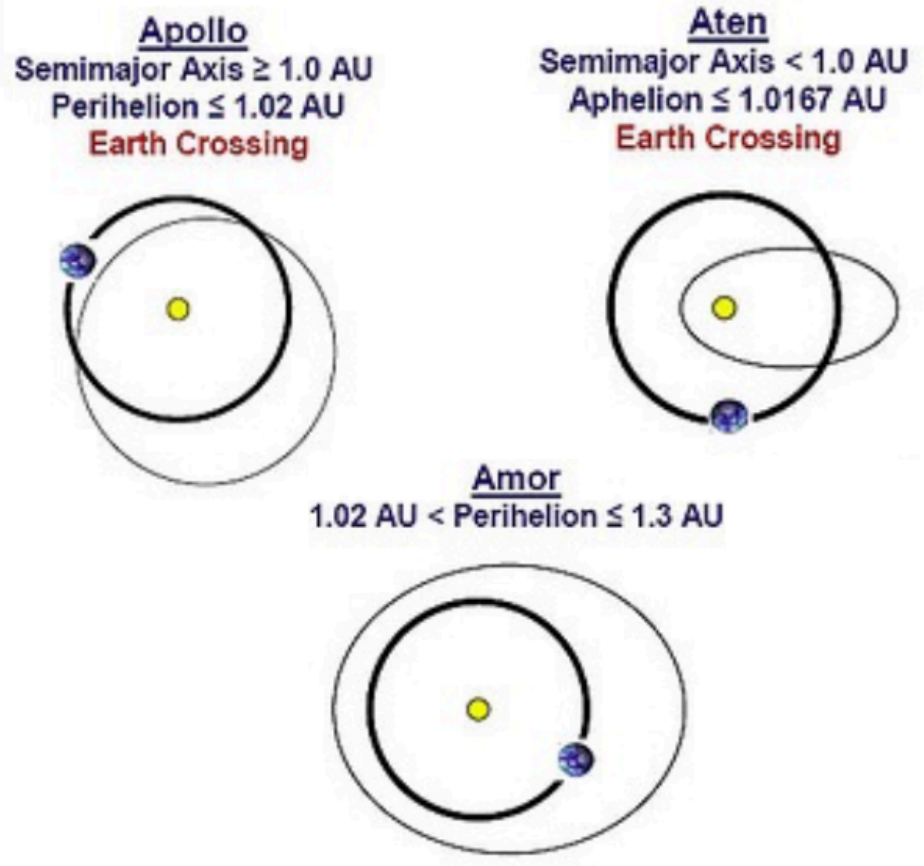


Near-Earth Objects (NEOS)

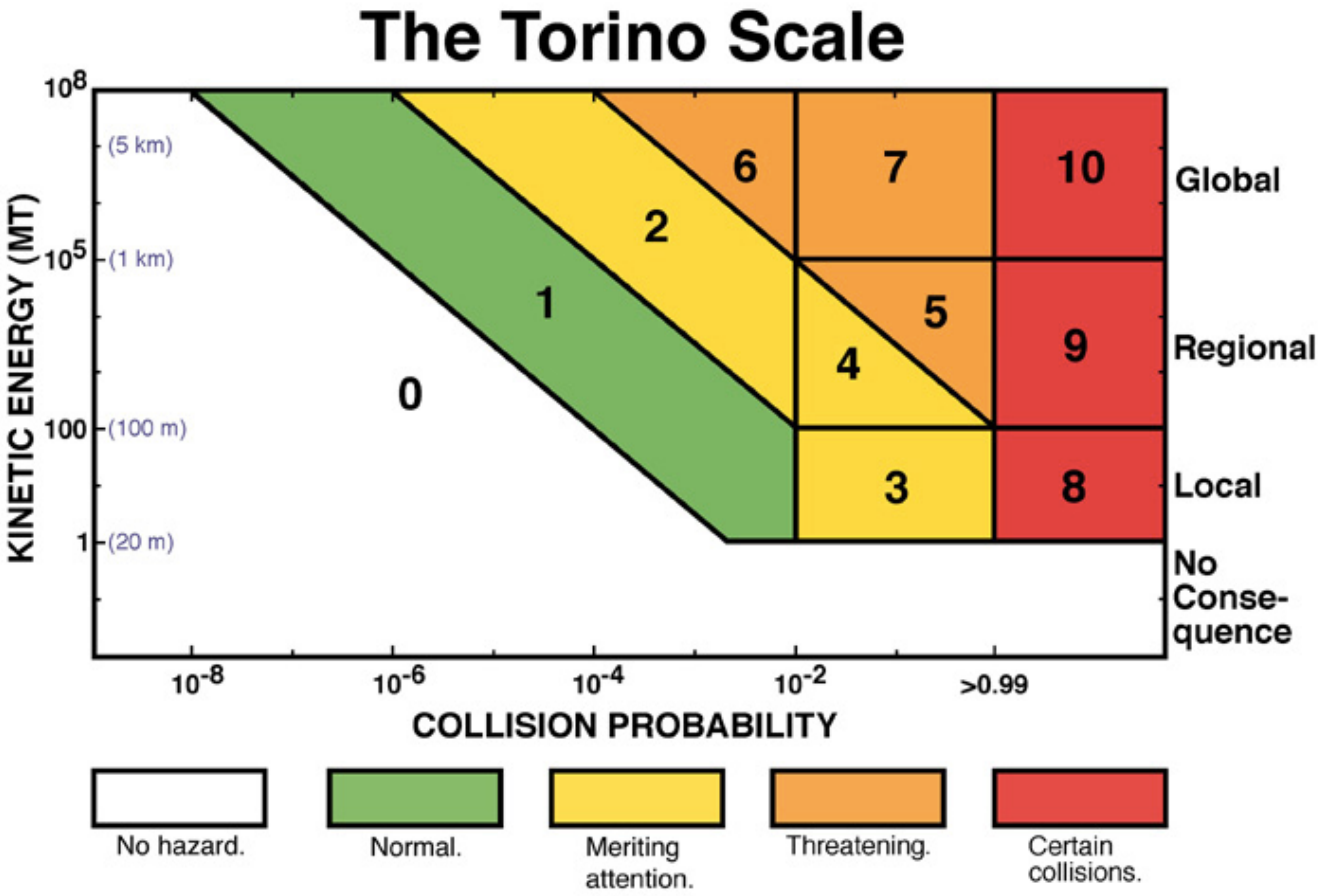








Near-Earth Objects (NEOS)



Binzel, 2000

Near-Earth Objects (NEOS)

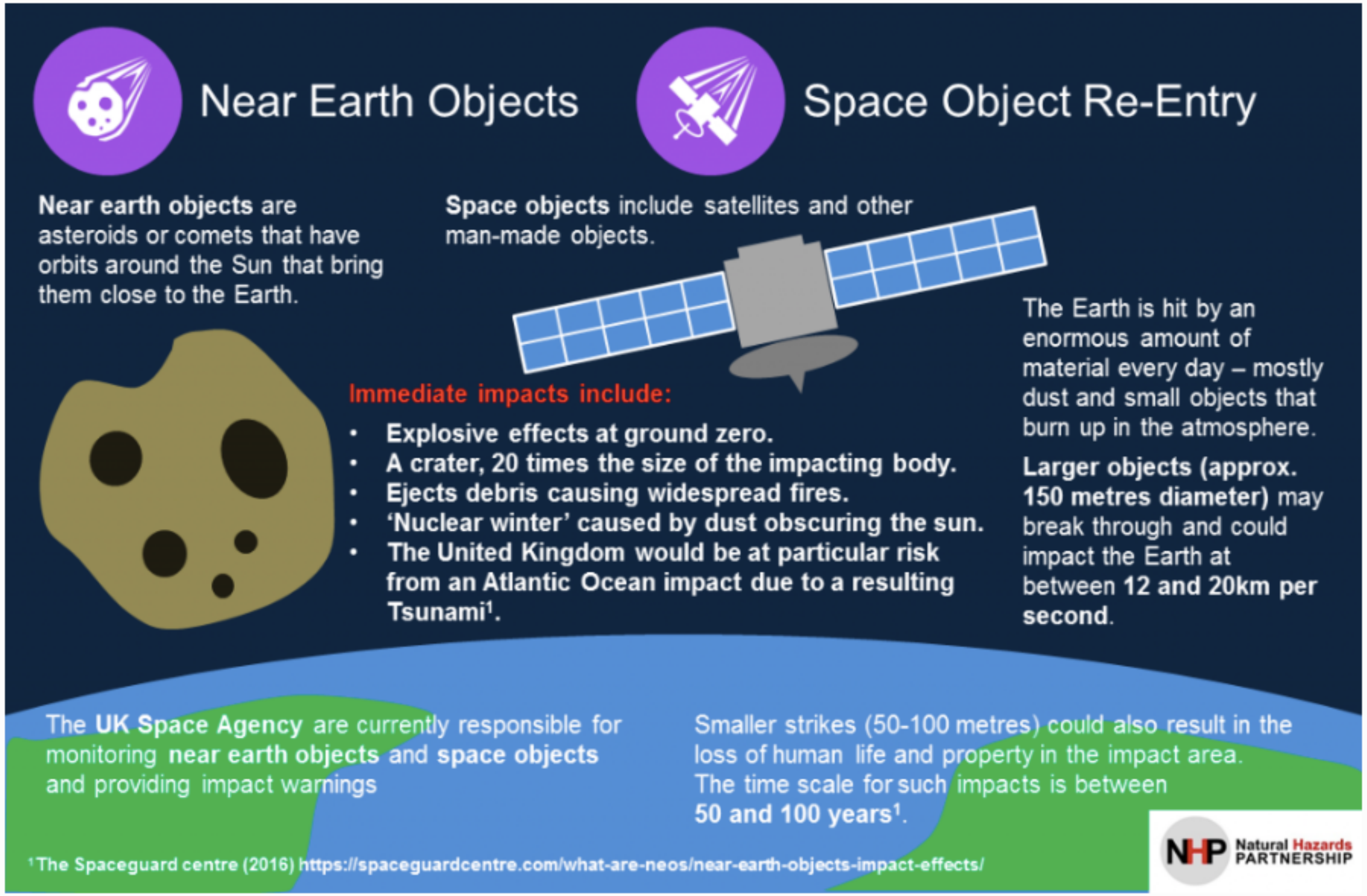
NO HAZARD (white)	
0.	The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.
NORMAL (green)	
1.	A routine discovery in which a pass near Earth is predicted, that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to reassignment to Level 0.
MERITING ATTENTION BY ASTRONOMERS (yellow)	
2.	A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to reassignment to Level 0.
3.	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of *localized destruction*. Most likely, new telescopic observations will lead to reassignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.
4.	A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of *regional devastation*. Most likely, new telescopic observations will lead to reassignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

THREATENING (orange)	
5.	A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.
6.	A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.
7.	A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether a collision will occur.
CERTAIN COLLISIONS (red)	
8.	A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several thousand years.
9.	A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.
10.	A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

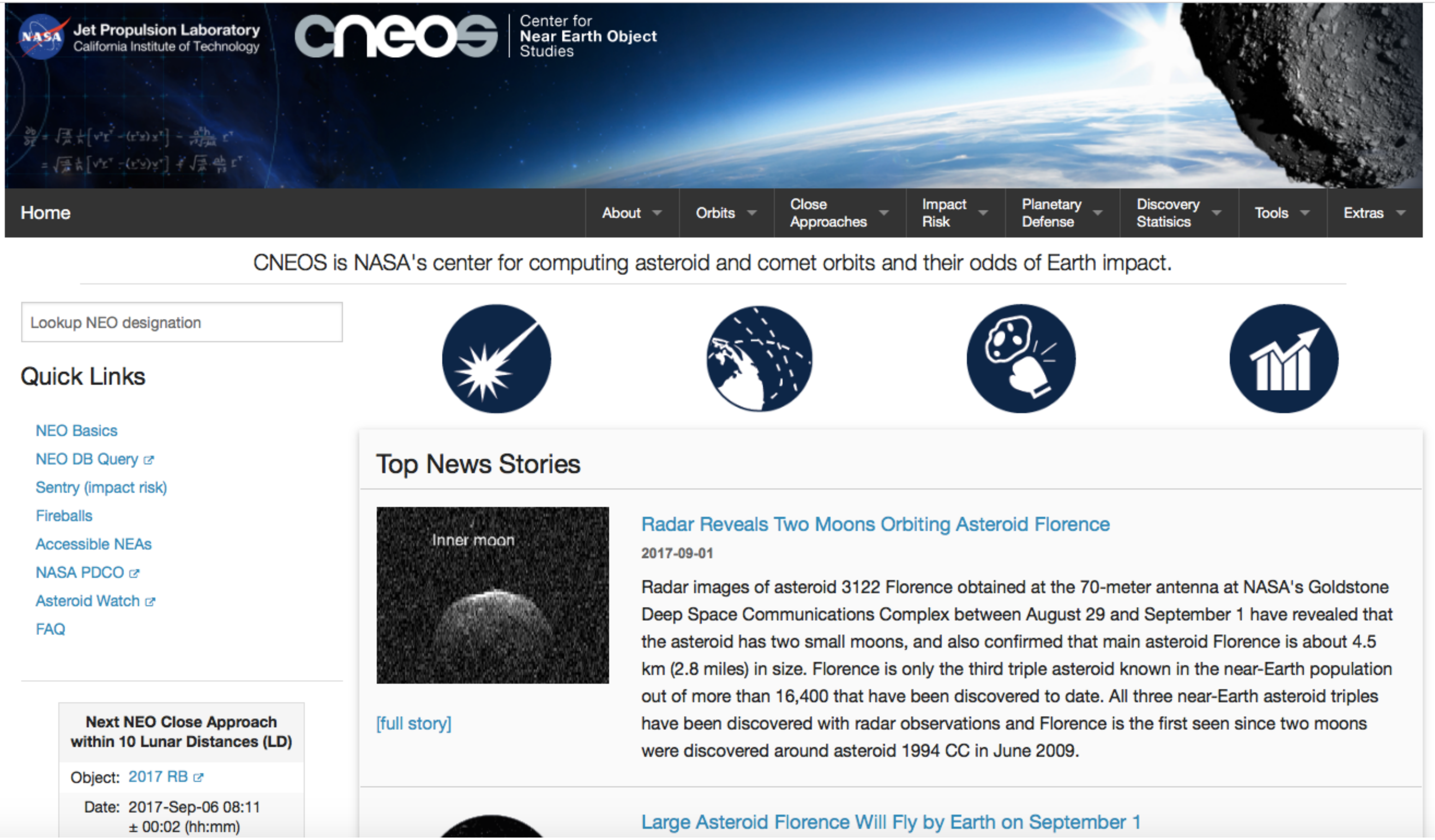
Binzel, 2000

Near-Earth Objects (NEOS)

The United States of America leads discovery and tracking survey programs using optical telescopes. NASA and the European Space Agency determine the likelihood of an impact with the Earth.

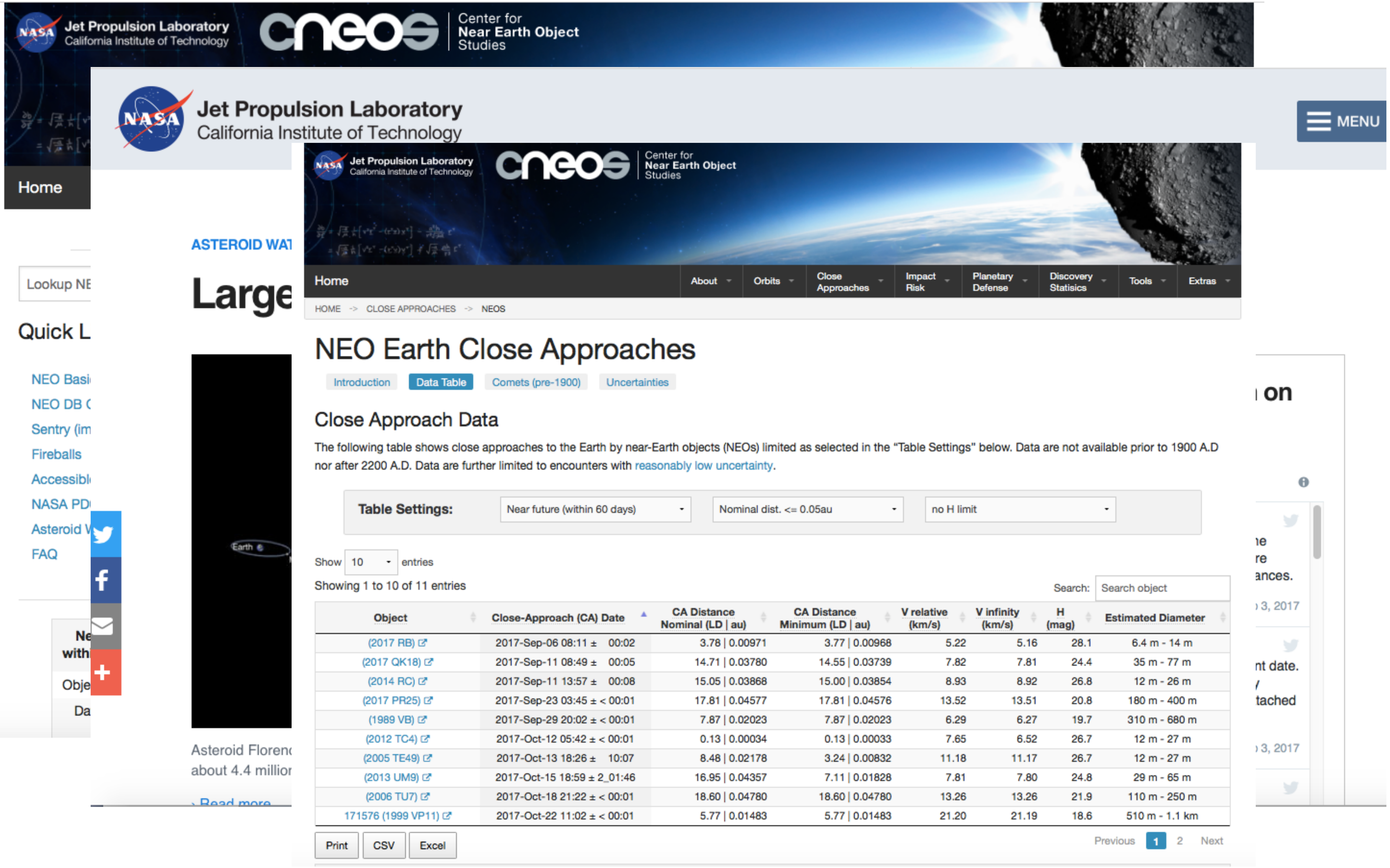


Near-Earth Objects (NEOS)

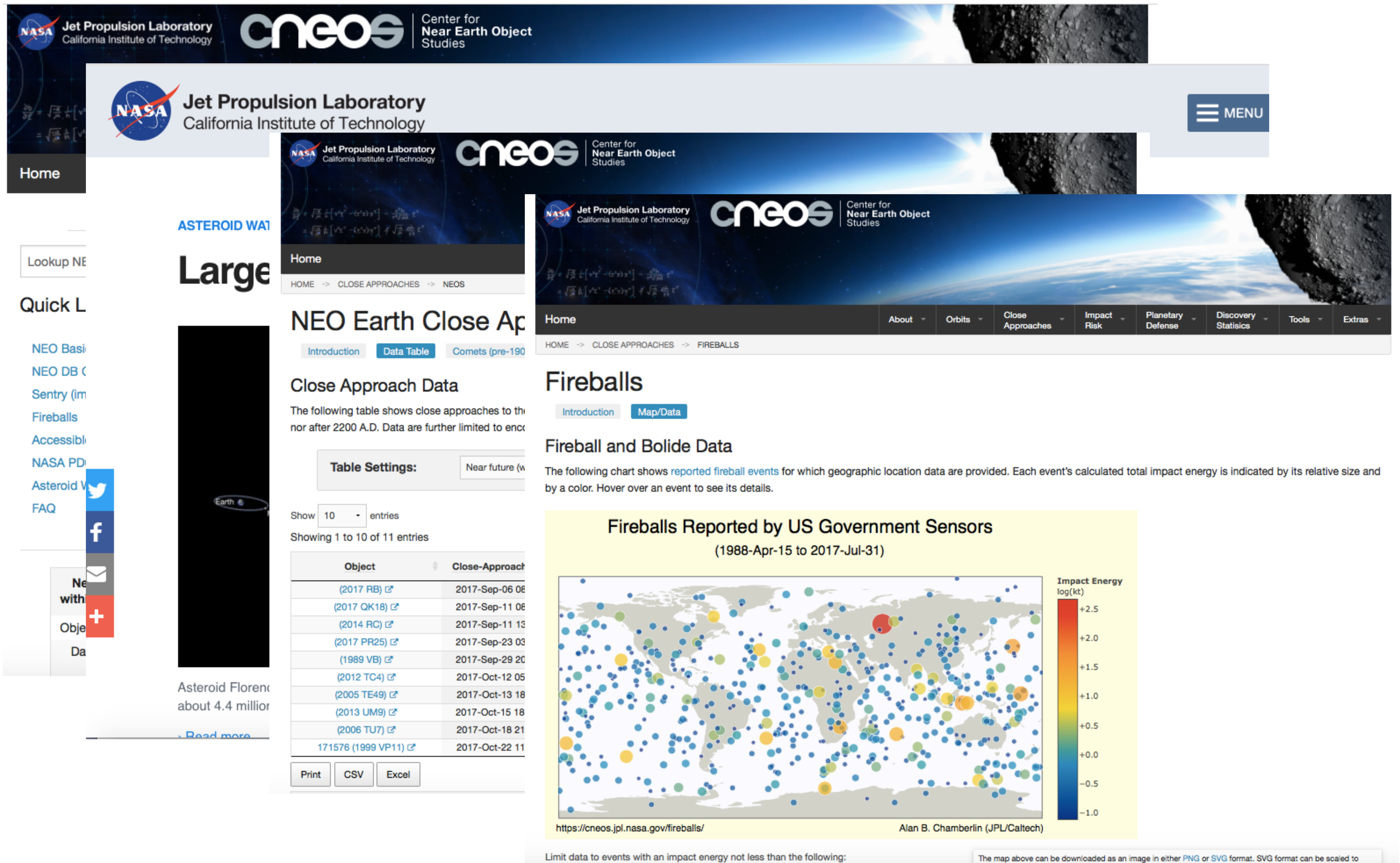


Near-Earth Objects (NEOS)

Near-Earth Objects (NEOS)



Near-Earth Objects (NEOS)



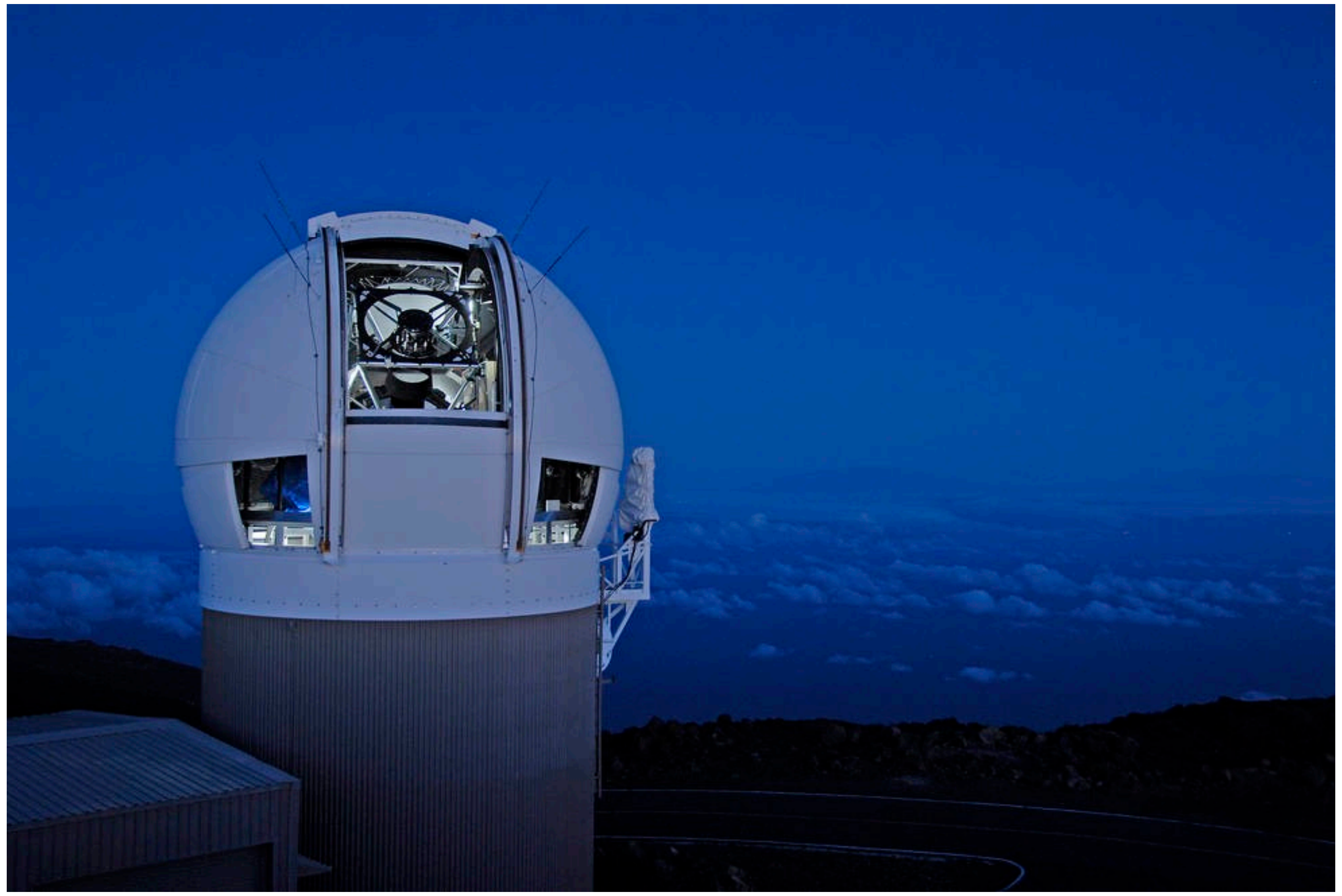
Near-Earth Objects (NEOS)

Near-Earth Objects (NEOS)

In 1998, NASA established a goal to discover 90% of the NEOs larger than one kilometer in diameter and in 2005, Congress extended that goal to include 90% of the NEOs larger than 140 meters. There are thought to be about 1000 NEAs larger than one kilometer and **roughly 15,000 larger than 140 meters**. T

All of the NEO discovery teams currently use so-called **charged couple devices (CCDs)** rather than photographic images. These **CCD cameras are similar in design to those used in cell phones** and they record images digitally in many electronic picture elements (pixels).

Catalina Sky Survey, University of Arizona



Pan-STARRS1 Telescope, IFA University of Hawaii

https://cneos.jpl.nasa.gov/about/search_program.html

Near-Earth Objects (NEOS)

Jet Propulsion Laboratory
California Institute of Technology

MENU

ASTEROID WATCH | AUGUST 17, 2017

Large Asteroid to Safely Pass Earth on Sept. 1

Asteroid Florence, a large near-Earth asteroid, will pass safely by Earth on Sept. 1, 2017, at a distance of about 4.4 million miles.

› Read more

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Tweets by @AsteroidWatch

Asteroid Watch @AsteroidWatch
@slashingaverage Asteroids with one moon are not unusual; two moons are more rare but we know of a few instances.
Sep 3, 2017

Asteroid Watch @AsteroidWatch
@adamere2012 Same hoax, different date. This particular hoax reappears every couple of months with a new date attached to it. All fake.
Sep 3, 2017

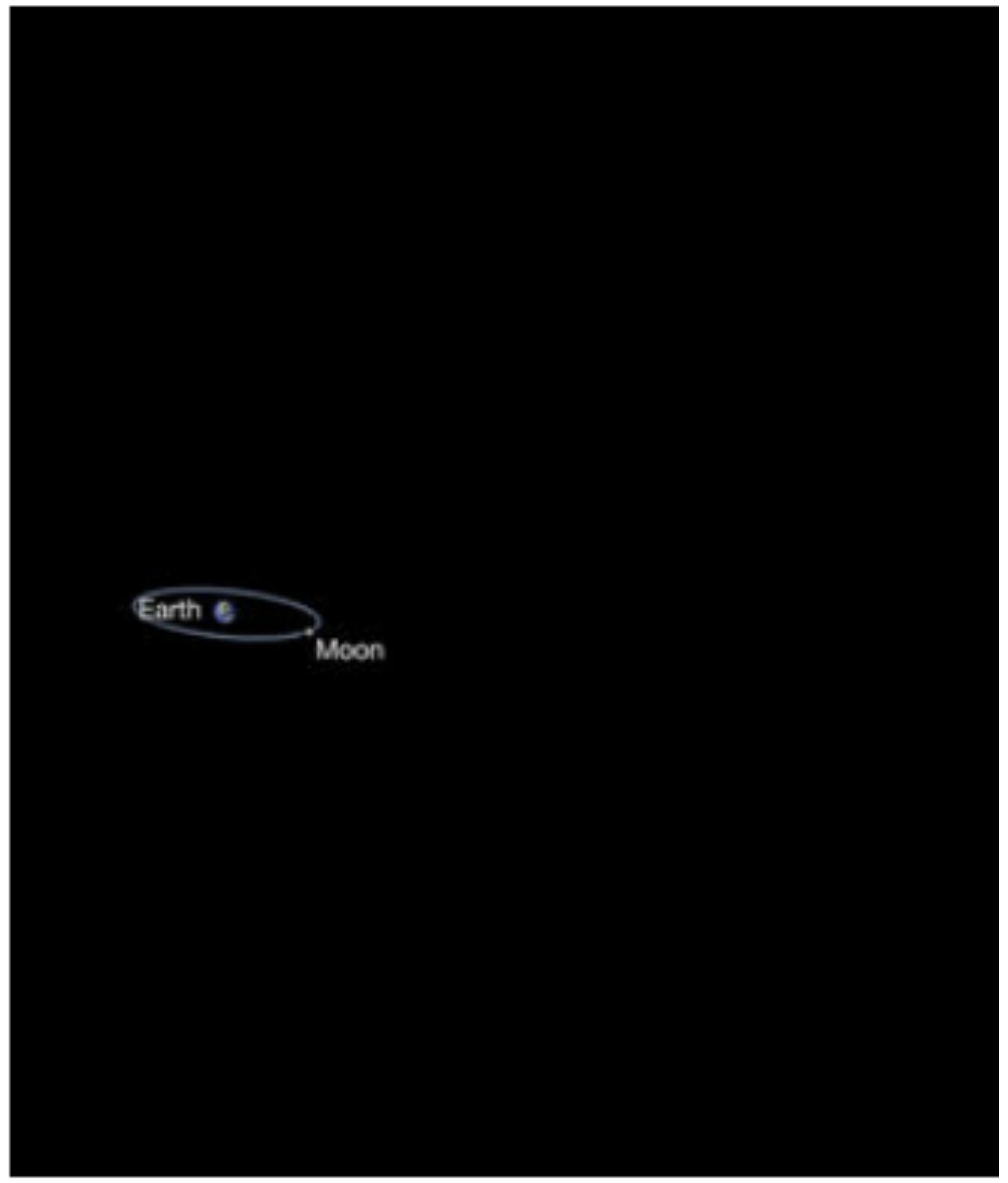
Asteroid Watch @AsteroidWatch

Near-Earth Objects (NEOS)

Jet Propulsion Laboratory
California Institute of Technology

ASTEROID WATCH | **AUGUST 17, 2017**

Large Asteroid to



Asteroid Florence, a large near-Earth asteroid, wil
about 4.4 million miles.

› Read more

Jet Propulsion Laboratory
California Institute of Technology

cneos Center for Near Earth Object Studies

Home | About | Orbits | Close Approaches | Impact Risk | Planetary Defense | Discovery Statisics | Tools | Extras

HOME -> CLOSE APPROACHES -> NEOS

NEO Earth Close Approaches

Introduction | Data Table | Comets (pre-1900) | Uncertainties

Close Approach Data

The following table shows close approaches to the Earth by near-Earth objects (NEOs) limited as selected in the "Table Settings" below. Data are not available prior to 1900 A.D nor after 2200 A.D. Data are further limited to encounters with reasonably low uncertainty.

Table Settings: Near future (within 60 days) | Nominal dist. <= 0.05au | no H limit

Show 10 entries

Showing 1 to 10 of 11 entries

Search: Search object

Object	Close-Approach (CA) Date	CA Distance Nominal (LD | au)	CA Distance Minimum (LD | au)	V relative (km/s)	V infinity (km/s)	H (mag)	Estimated Diameter
(2017 RB)	2017-Sep-06 08:11 ± 00:02	3.78 | 0.00971	3.77 | 0.00968	5.22	5.16	28.1	6.4 m - 14 m
(2017 QK18)	2017-Sep-11 08:49 ± 00:05	14.71 | 0.03780	14.55 | 0.03739	7.82	7.81	24.4	35 m - 77 m
(2014 RC)	2017-Sep-11 13:57 ± 00:08	15.05 | 0.03868	15.00 | 0.03854	8.93	8.92	26.8	12 m - 26 m
(2017 PR25)	2017-Sep-23 03:45 ± < 00:01	17.81 | 0.04577	17.81 | 0.04576	13.52	13.51	20.8	180 m - 400 m
(1989 VB)	2017-Sep-29 20:02 ± < 00:01	7.87 | 0.02023	7.87 | 0.02023	6.29	6.27	19.7	310 m - 680 m
(2012 TC4)	2017-Oct-12 05:42 ± < 00:01	0.13 | 0.00034	0.13 | 0.00033	7.65	6.52	26.7	12 m - 27 m
(2005 TE49)	2017-Oct-13 18:26 ± 10:07	8.48 | 0.02178	3.24 | 0.00832	11.18	11.17	26.7	12 m - 27 m
(2013 UM9)	2017-Oct-15 18:59 ± 2_01:46	16.95 | 0.04357	7.11 | 0.01828	7.81	7.80	24.8	29 m - 65 m
(2006 TU7)	2017-Oct-18 21:22 ± < 00:01	18.60 | 0.04780	18.60 | 0.04780	13.26	13.26	21.9	110 m - 250 m
171576 (1999 VP11)	2017-Oct-22 11:02 ± < 00:01	5.77 | 0.01483	5.77 | 0.01483	21.20	21.19	18.6	510 m - 1.1 km

Print | CSV | Excel

Previous 1 2 Next

Natural Hazards and Disaster

Class 5: Extraterrestrial Hazards

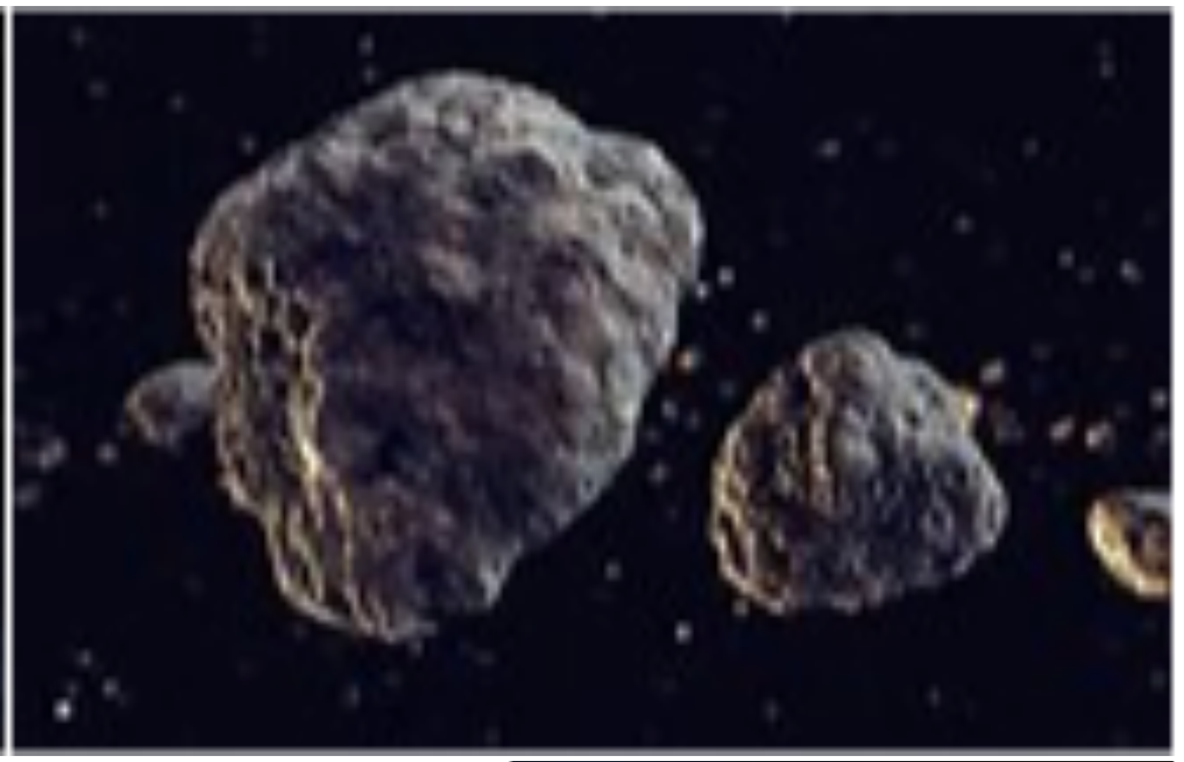
- Threats from Space
- Near-Earth Objects (NEOS)
- Meteoroids and Asteroids
- Comets
- Bolides
- Space Weather, Solar Storms, Gamma Rays

Meteoroids and Asteroids

A **meteoroid** is a small rocky or metallic body traveling through outer space. Meteoroids are significantly smaller than asteroids, and range in size from small grains to 1 meter-wide objects. Most are fragments from comets or asteroids, whereas others are collision impact debris ejected from bodies such as the Moon or Mars.

Asteroids are small, airless rocky worlds revolving around the sun too small to be called planets. They are also known as planetoids or minor planets. In total, the mass of all the asteroids is less than that of Earth's moon. Many asteroids have hit Earth in the past, and more will crash into our planet in the future.
If an asteroid is headed our way, we want to know that.

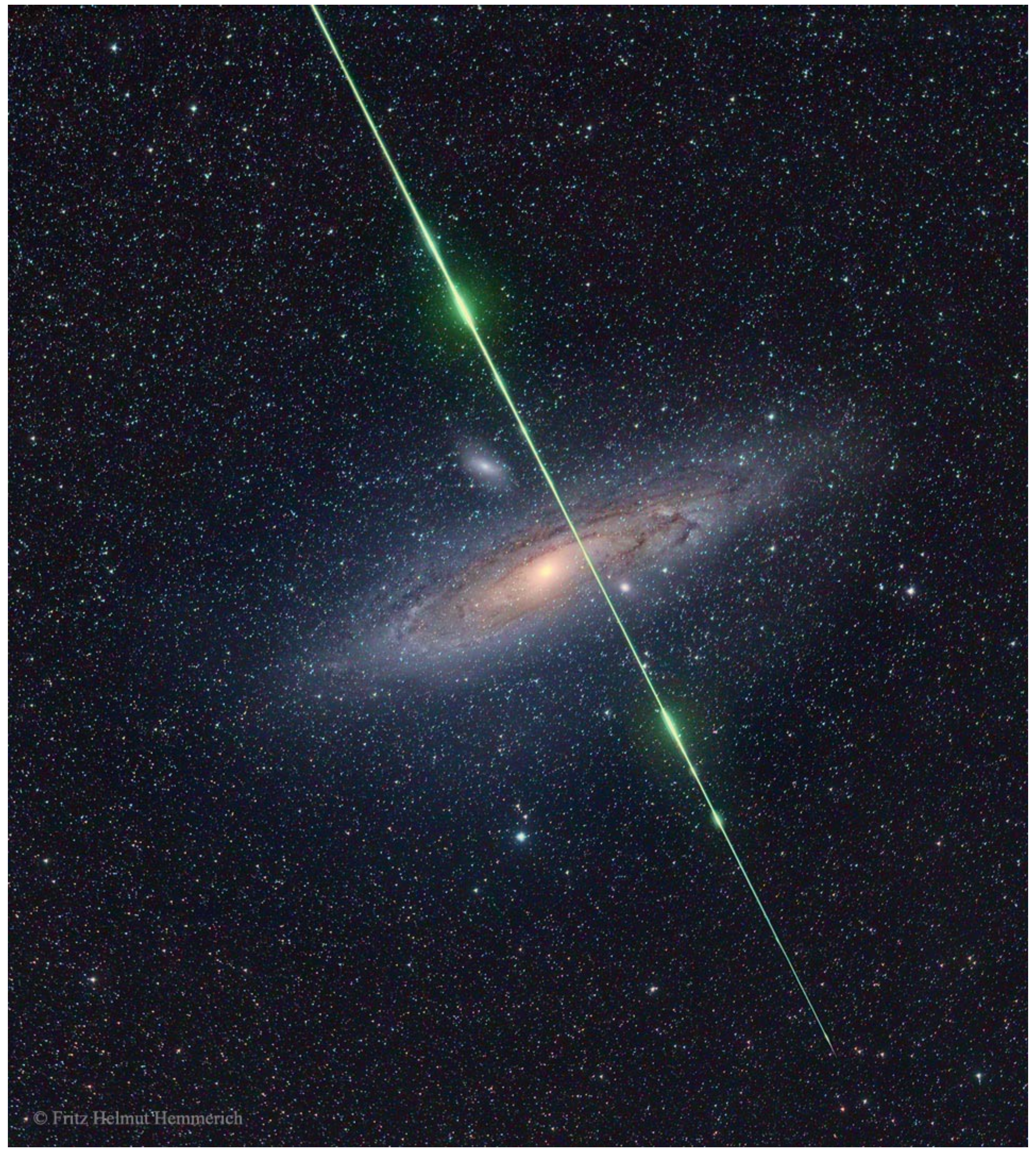


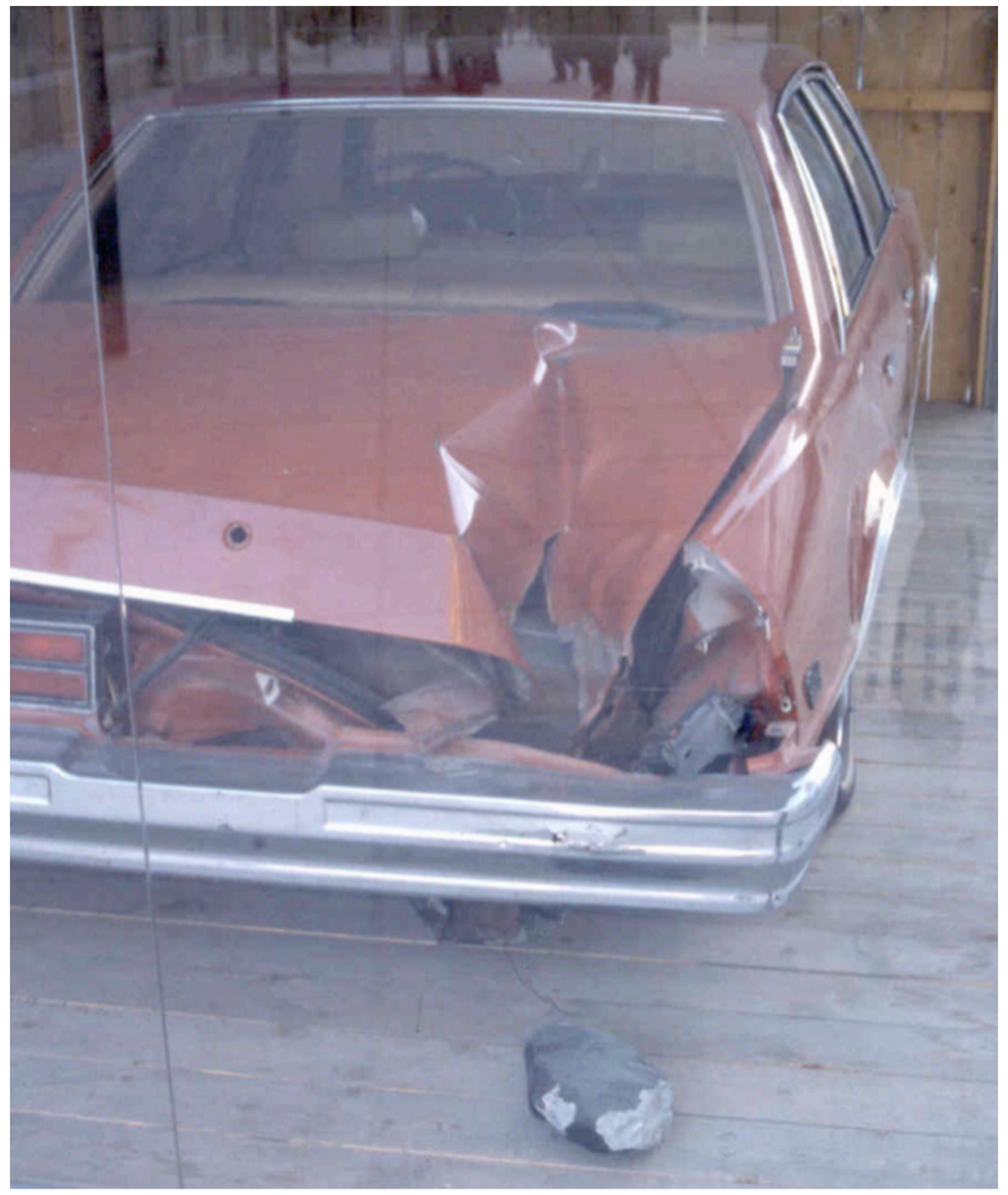

A **comet** is a very small solar system body made mostly of ices mixed with smaller amounts of dust and rock. The main body of the comet is the nucleus, which can contain water, methane, nitrogen and other ices. Most comets are smaller than a few kilometres in diameter. When passing close to the Sun, a comet warms and its ices begin to release gas (outgasing). The mixture of ice crystals and dust blows away from the comet nucleus in the solar wind, creating a pair of tails.


Meteoroids and Asteroids

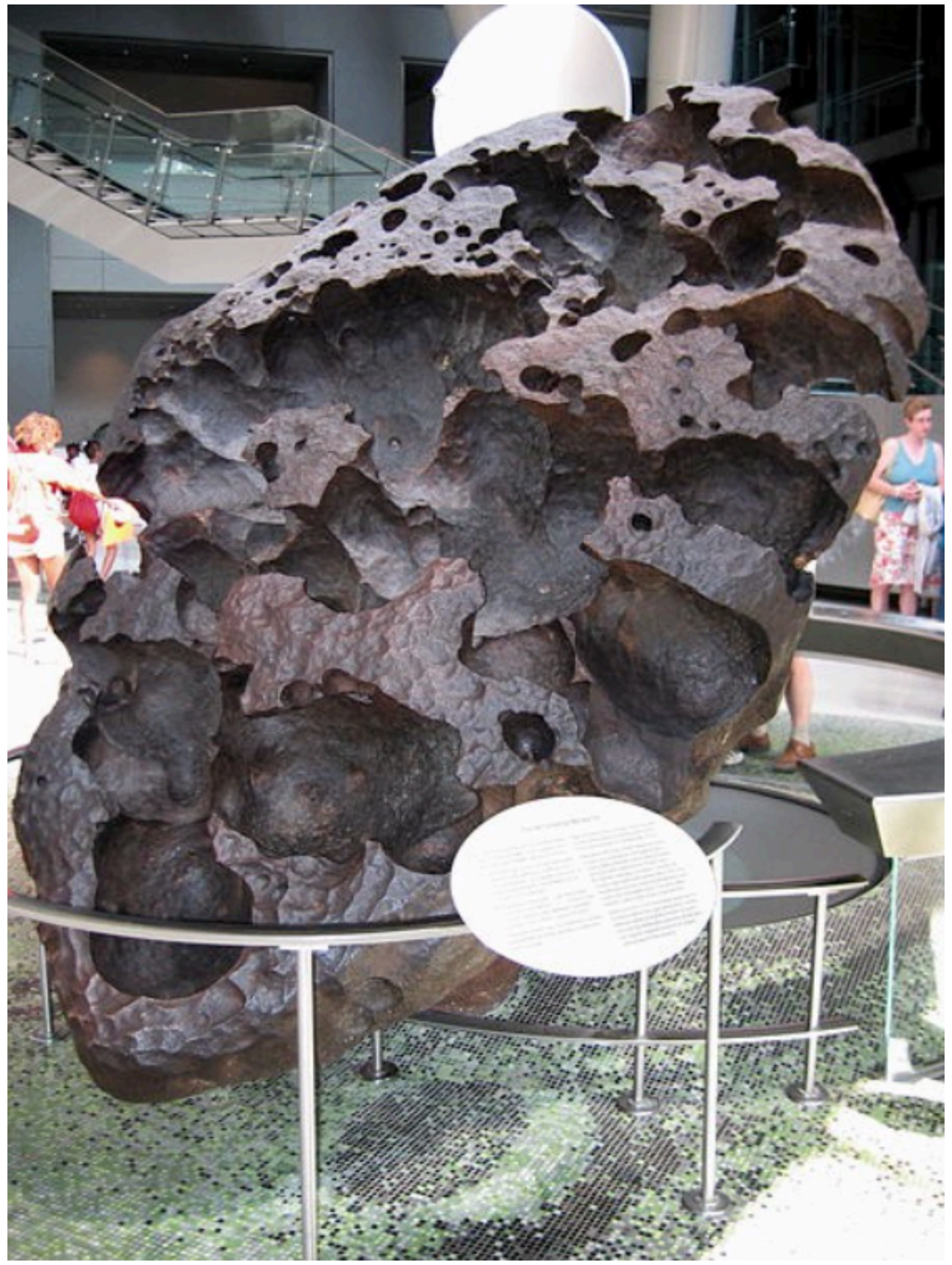
- Meteorites are rock and/or metal fragments that land on Earth after entering the Earth’s atmosphere at an average speed of about 64,000 km/h.
- Roughly 44,000 kg of meteoritic material falls onto Earth each day, almost all as fragments a millimeter or smaller in diameter.
- Larger pieces do fall, including a few in North America in recent times.
- Very large meteoroids and asteroids are extremely rare, but have caused catastrophic damage in the geological past.



Meteor streak photographed on August 12, 2016, with the Andromeda Galaxy in background. Green color is from vaporized meteor gas flares.



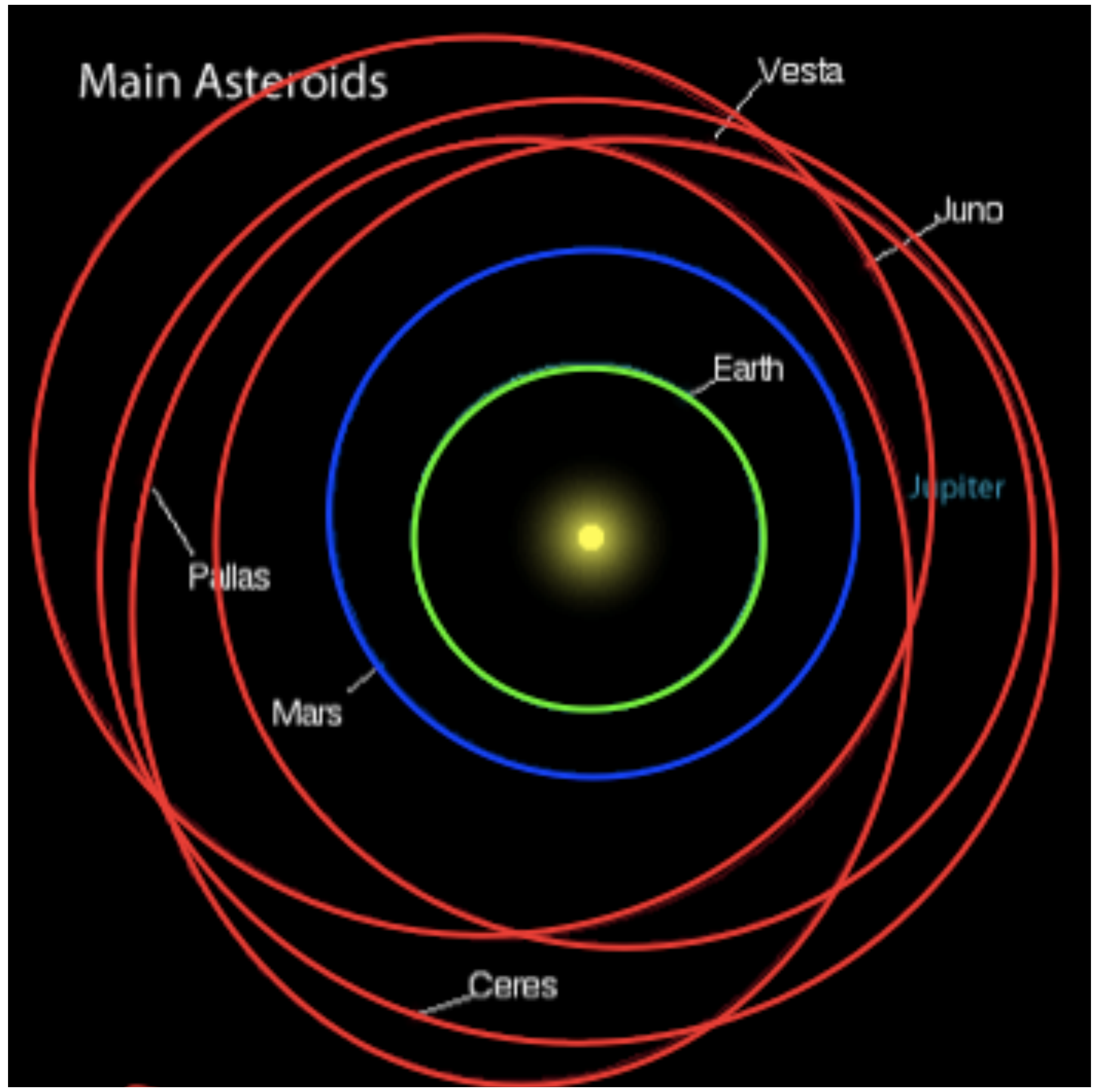
A 12 kg stony-iron meteorite (seen on floor), estimated as 4.4 billion years old, landed on this car in Peekskill, NY on October 9, 1992.



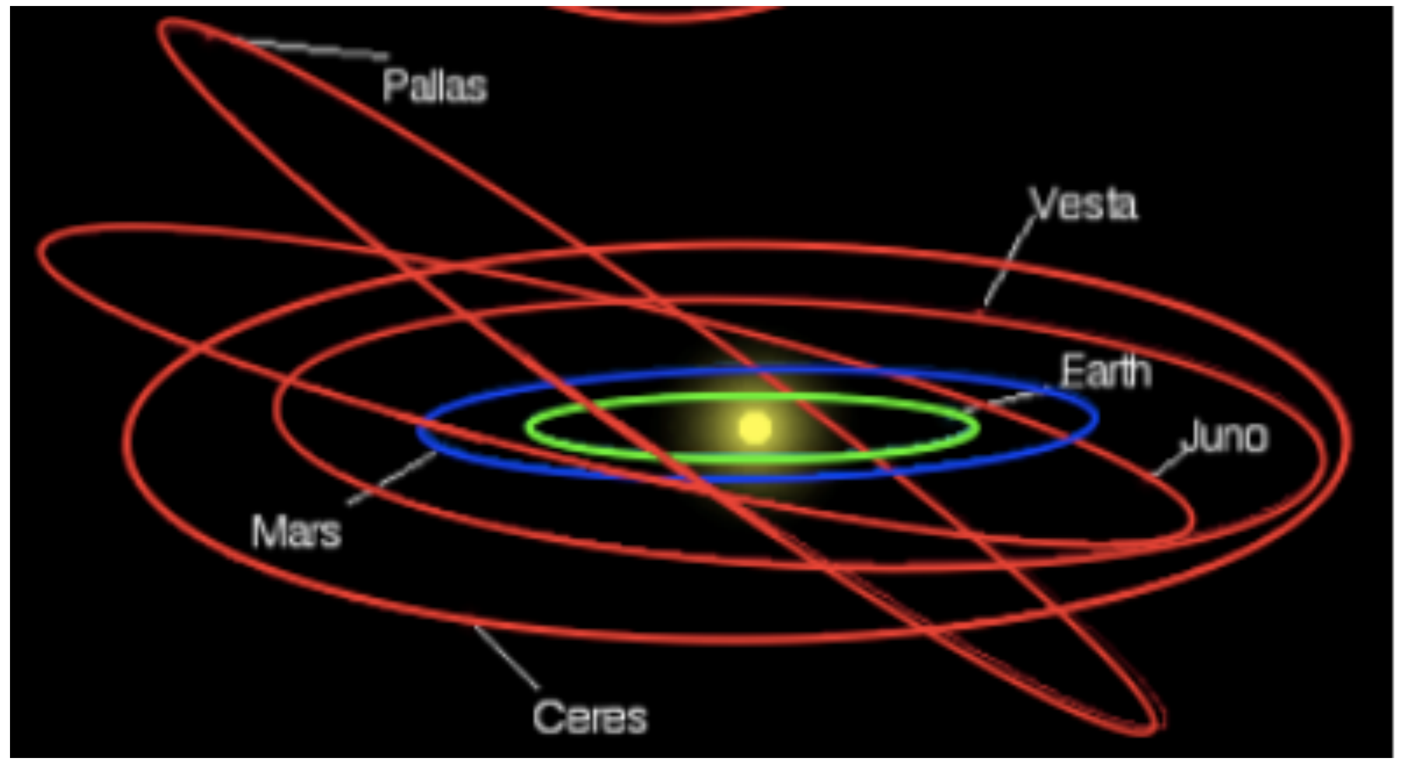
The Willamette iron (+nickel) meteorite found in Oregon, is the largest ever found in the U.S.A. at 14,000 kg.

More than 8,000 asteroids and meteoroids orbit in the asteroid belt, between Jupiter and Mars.

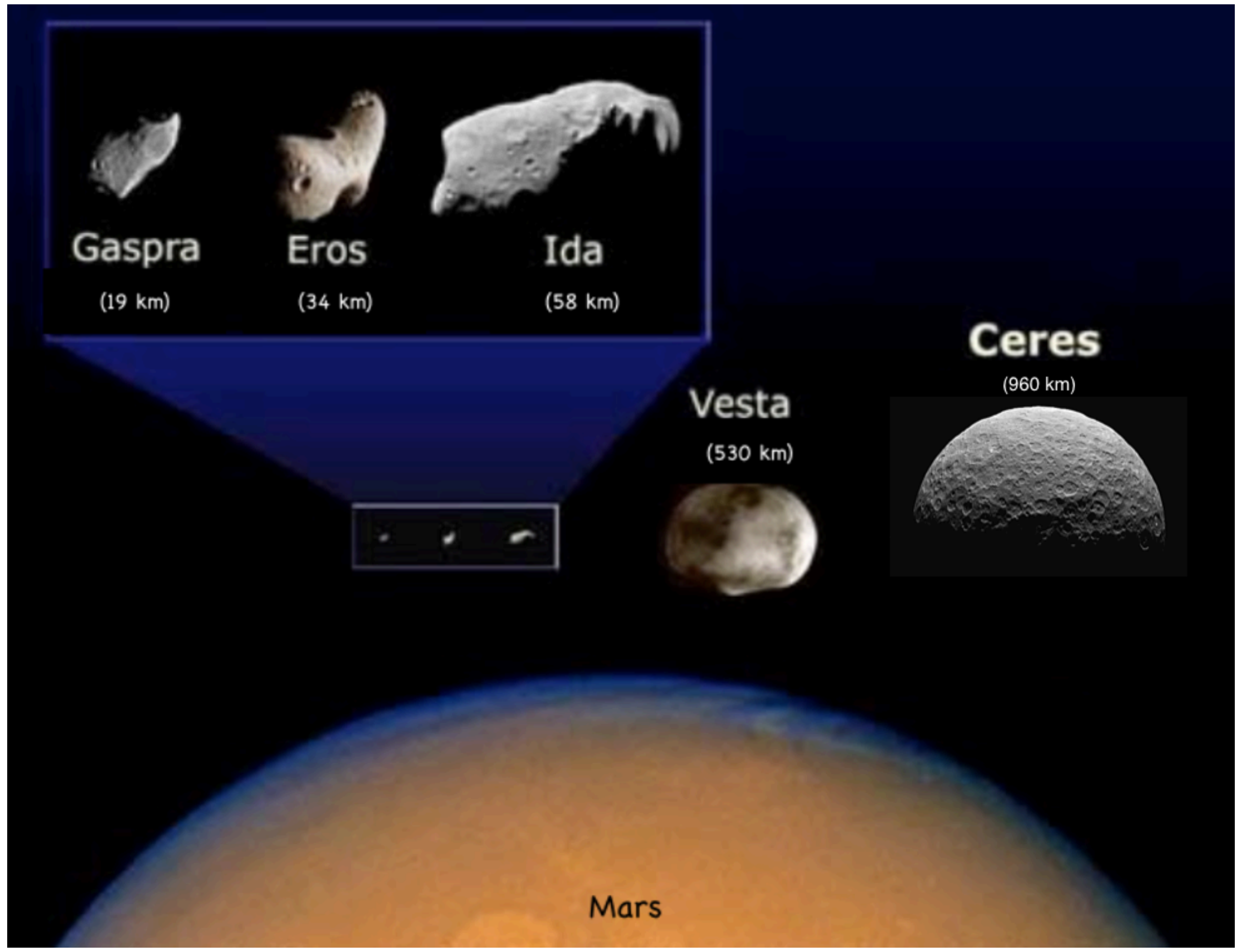
- The asteroid belt, located in the orbital plane between Jupiter and Mars, contains at least 8,000 asteroids that are 10 to 20 km in diameter and millions of smaller ones.
- The orbits of asteroid belt objects are generally stable, although they are often much more elliptical than those of Earth or Mars.
- Not all of the asteroids are in the same orbital plane, which can lead to asteroid-asteroid collisions.
- A few dozen of the objects in the asteroid belt are over 100 km across.
- Ceres is the largest at 960 km diameter, a little less than 1/4 the size of the Moon.



View looking down onto Earth's orbital plane shows the elliptical orbits of 4 of the main asteroids in the asteroid belt.



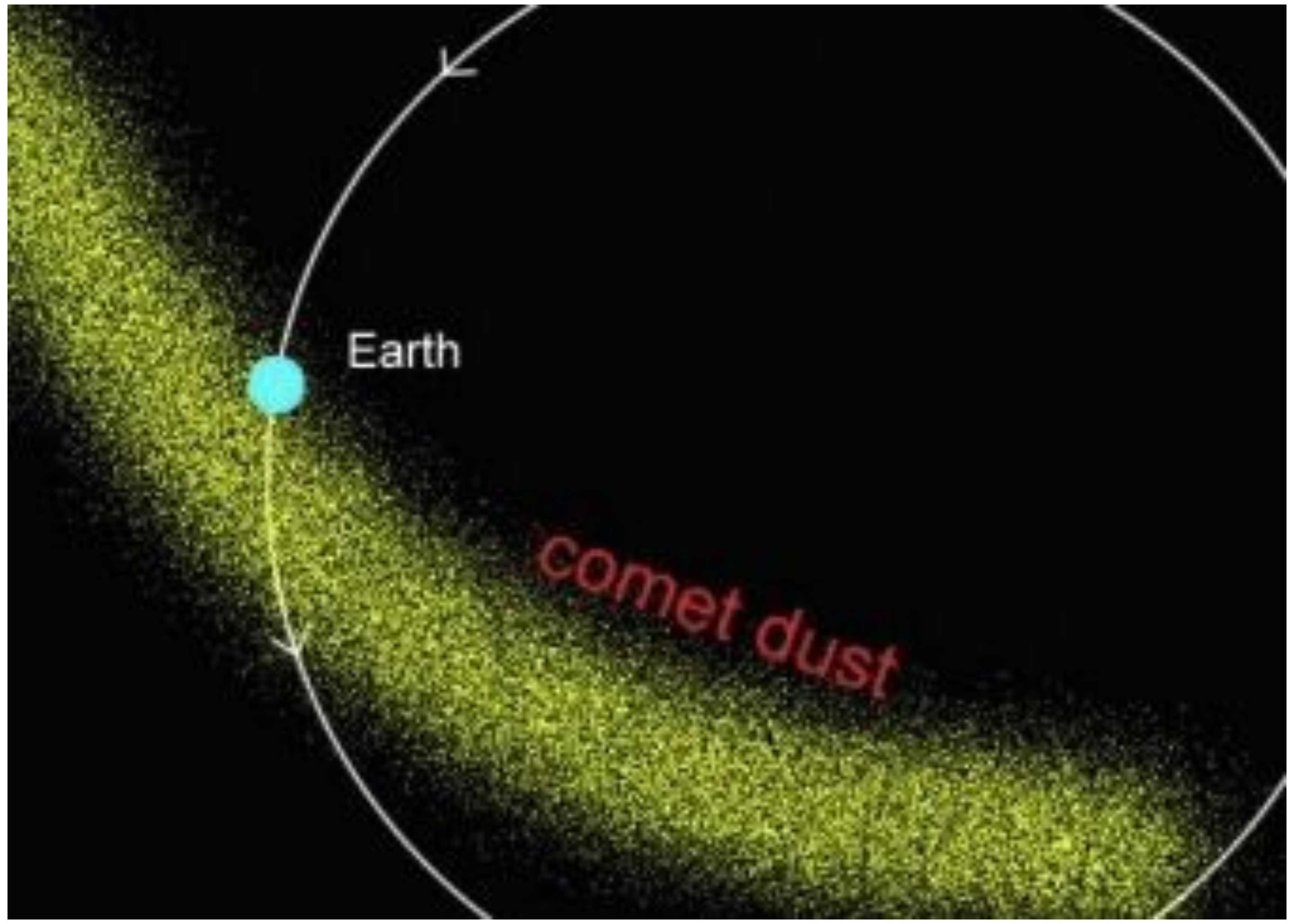
Oblique view shows the orbits of Pallas and Juno are at a significant angle to those of Earth and Mars.



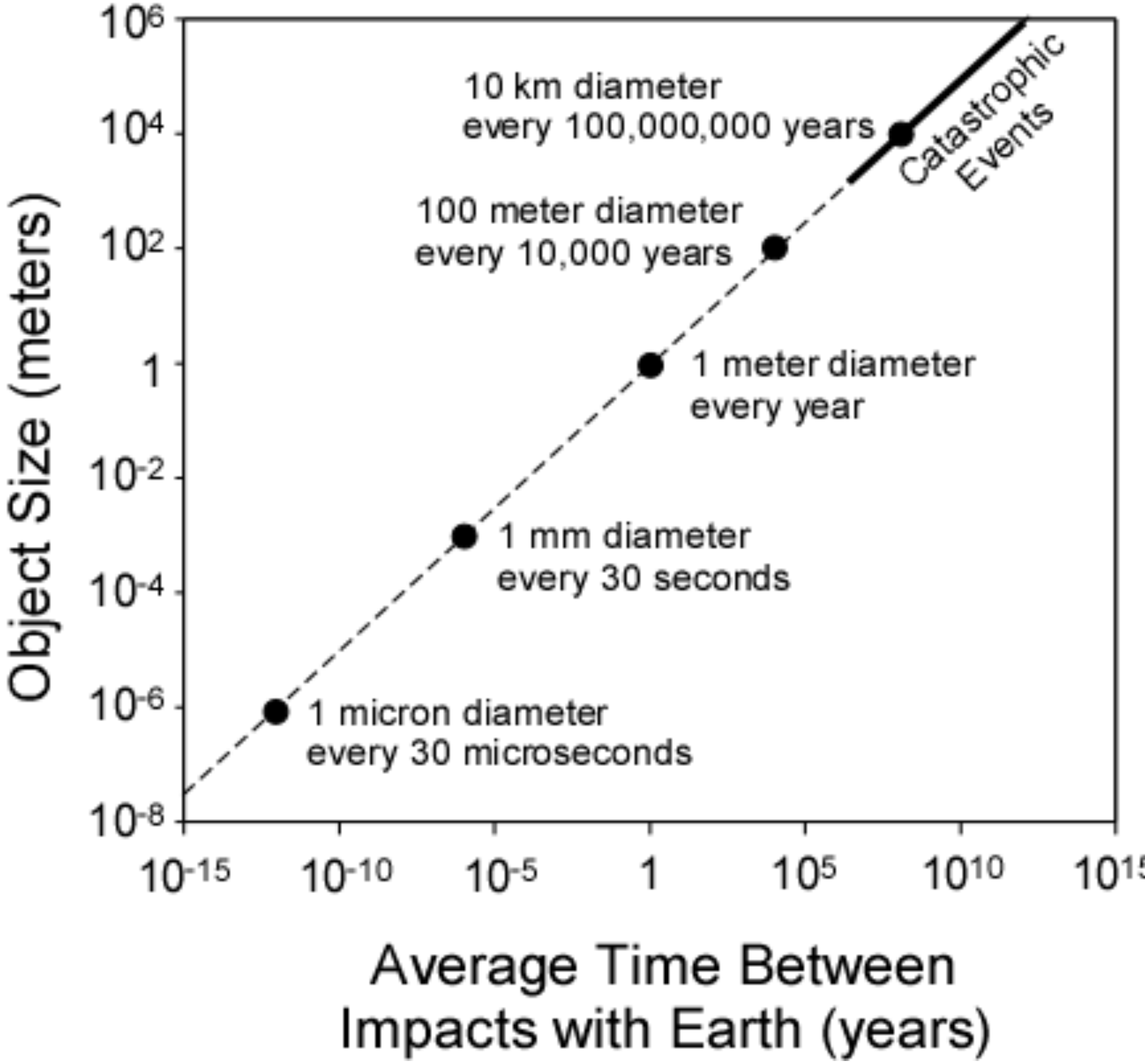
Small asteroids in the asteroid belt, shown to scale with Mars. Most are irregular in shape, but Ceres is large enough to have self-gravitated into a roughly spherical shape. Besides impact craters on its surface, Ceres shows evidence of geological activity, including landslides and cryovolcanoes (ice volcanoes) up to 4 km in height.

Meteorite Impact Frequency

- Meteor showers occur frequently, but large meteorite falls are very rare.
- Today, at least one meteorite of several cm to a meter in size, with velocities of 15 km/s or more, lands on Earth each year, but larger meteorite falls are rare.
- Meteor showers occur when Earth passes through locally high concentrations of space, e.g. mid-August Perseid Shower.
- Meteor showers are usually harmless events, although in 2003 a meteoroid impact that occurred during a meteor shower destroyed two houses and injured several people in India.



Meteor showers occur when Earth's orbit enters the dust and debris left behind by a comet.

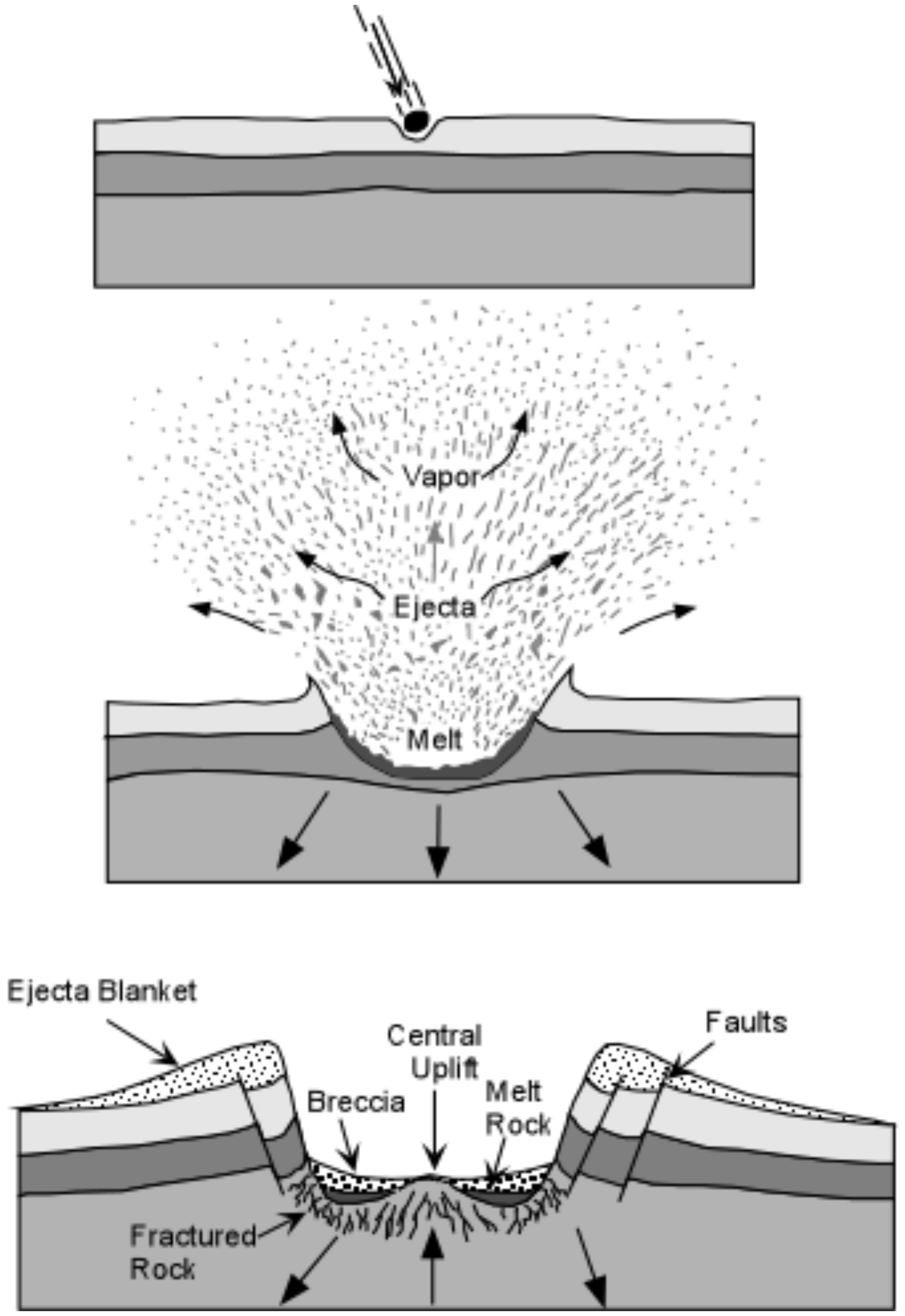


Meteorite fragments of 1 mm or less in diameter fall all the time onto Earth. Larger pieces fall less often, but are potentially very dangerous. A meteorite tens of meters in diameter, although rare, would cause a tsunami if it landed in an ocean and would devastate the region around a landfall.

Meteoroids and Asteroids

Impact Crater Formation

- Impact bodies release energy as a shock wave.
- The kinetic energy E_k of the impact shock depends upon the mass m and velocity v of the impactor.
- The shock wave radiates outward and fractures the surrounding rock into pieces, called breccia.
- The shock also melts rock at the impact site and blasts tiny globules of molten rock, along with pulverized rock fragments and meteoritic material, high into the atmosphere.
- The blasted-away material is called ejecta and it leaves behind a circular crater.
- Rock in the crater's center rebounds almost instantaneously, creating a central uplift in the crater.
- The molten ejecta globules can be carried far in the atmosphere before they are strewn as glassy objects, called tektites, over a very wide region around impact sites.



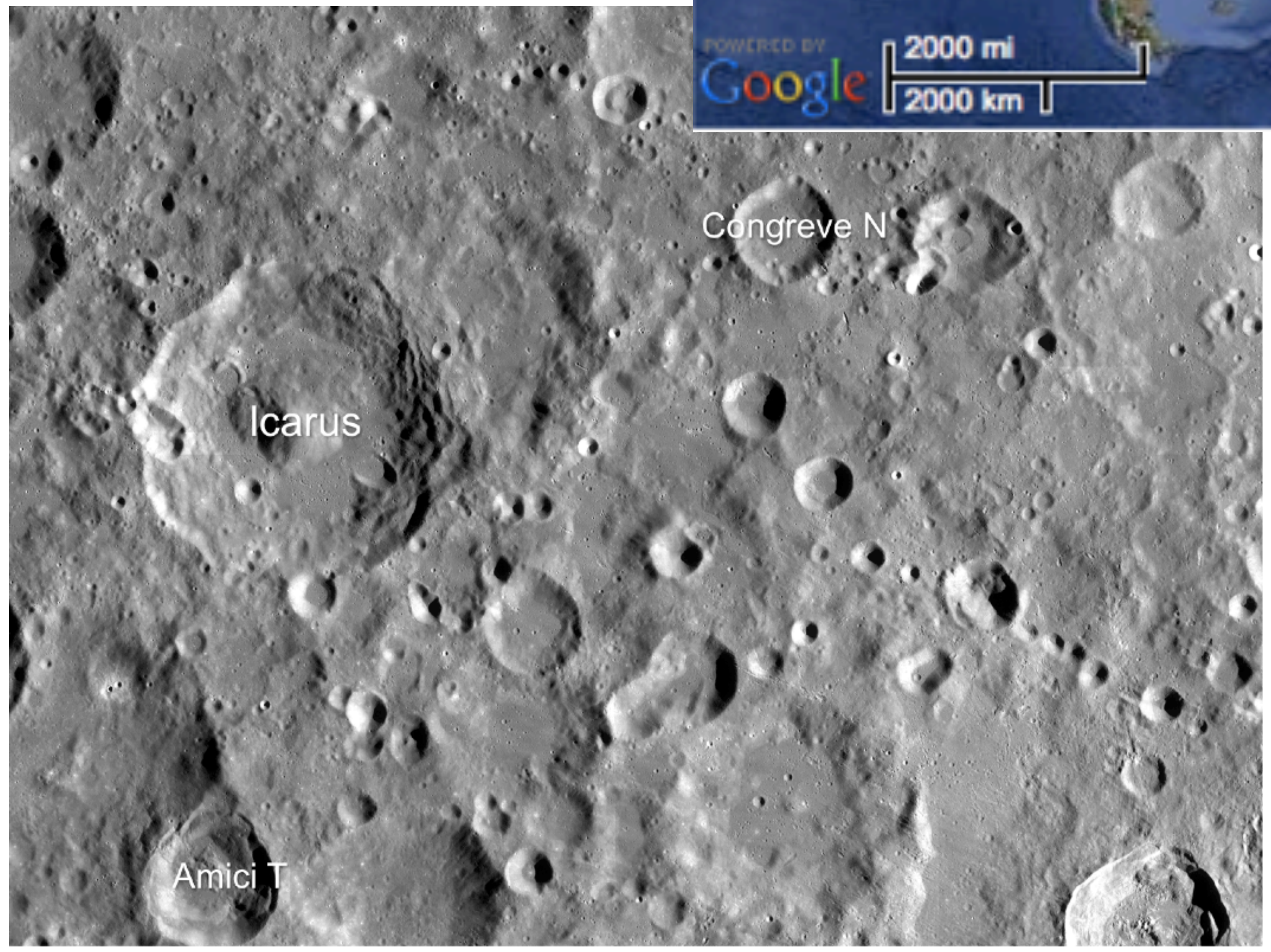
A meteorite impact releases kinetic energy E_k as a shock wave according to $E_k = m \cdot v^2$. Top: The shock wave creates a crater by pulverizing and melting rock strata, which is ejected high into the atmosphere. Bottom: Rebounded rock beneath the crater's center forms a central uplift, surrounded by an inner ring of breccia and an outer rim of upturned rock and ejecta.

Two tektites that originated from a 35.5 million year old impact in Chesapeake Bay, eastern U.S.A. Each specimen is just a few cm long. Left: Tektite found in Georgia, U.S.A. Right: Tektite found in east Texas, U.S.A.

Earth's Impact Craters

- Earth's erosional and tectonic forces have removed much of the evidence for asteroid impact craters.
- There are presently 190 confirmed impact craters on Earth, ranging from about 50 m to 300 km in diameter.
- This is a tiny number compared to the thousands of craters, large and small, that are visible on the Moon.
- Reasons for the lack of impact craters on Earth include: (i) tectonic processes;
  (ii) there is no oceanic crust older > 270 million years;
  (iii) erosion by wind, water and/or ice;
  (iv) younger sediment and volcanic rock cover;
  (v) the friction of passing through Earth's atmosphere.

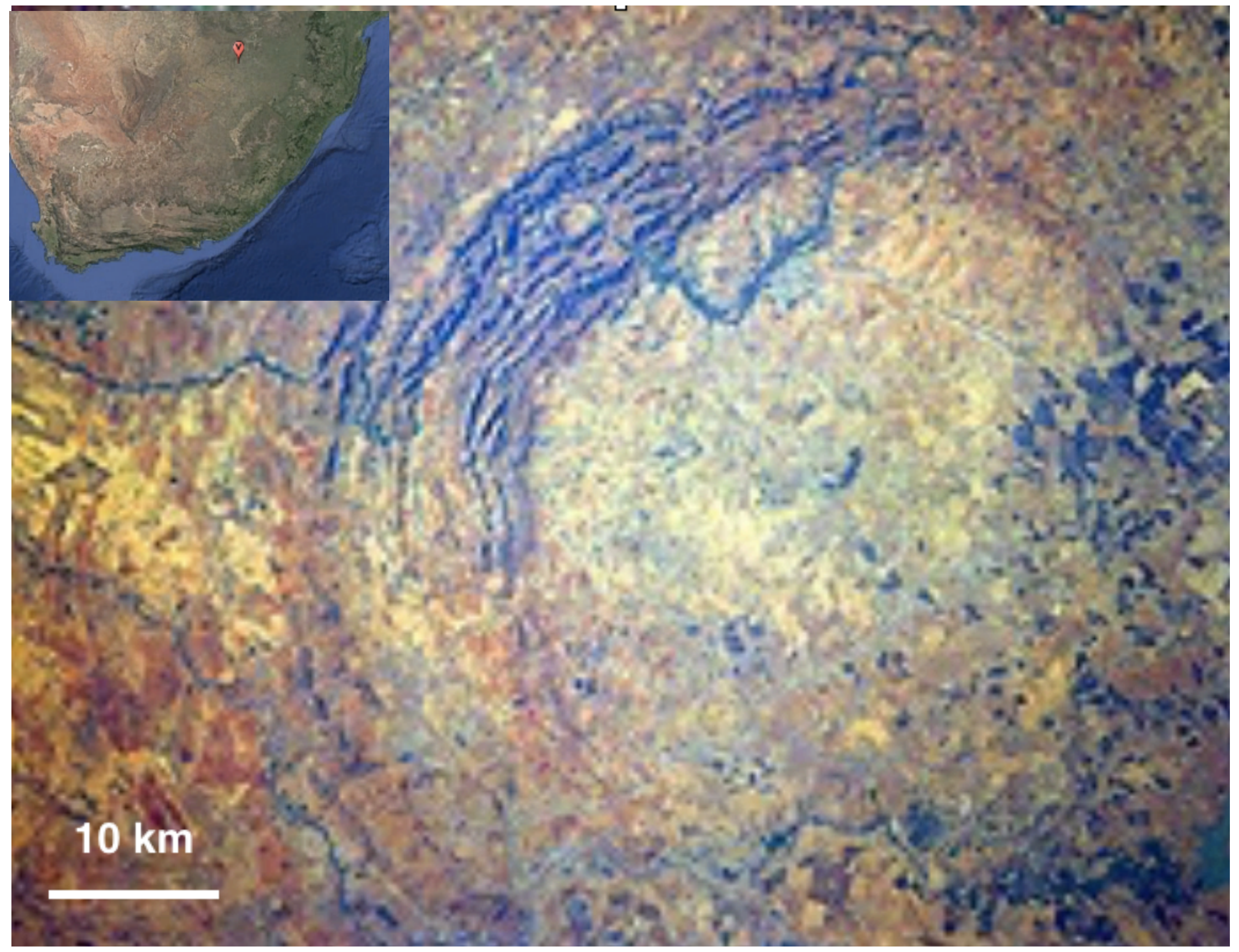
Localities of 50 of the 190 confirmed meteorite impact craters on Earth. At least 40 of the craters are over 20 km in diameter.



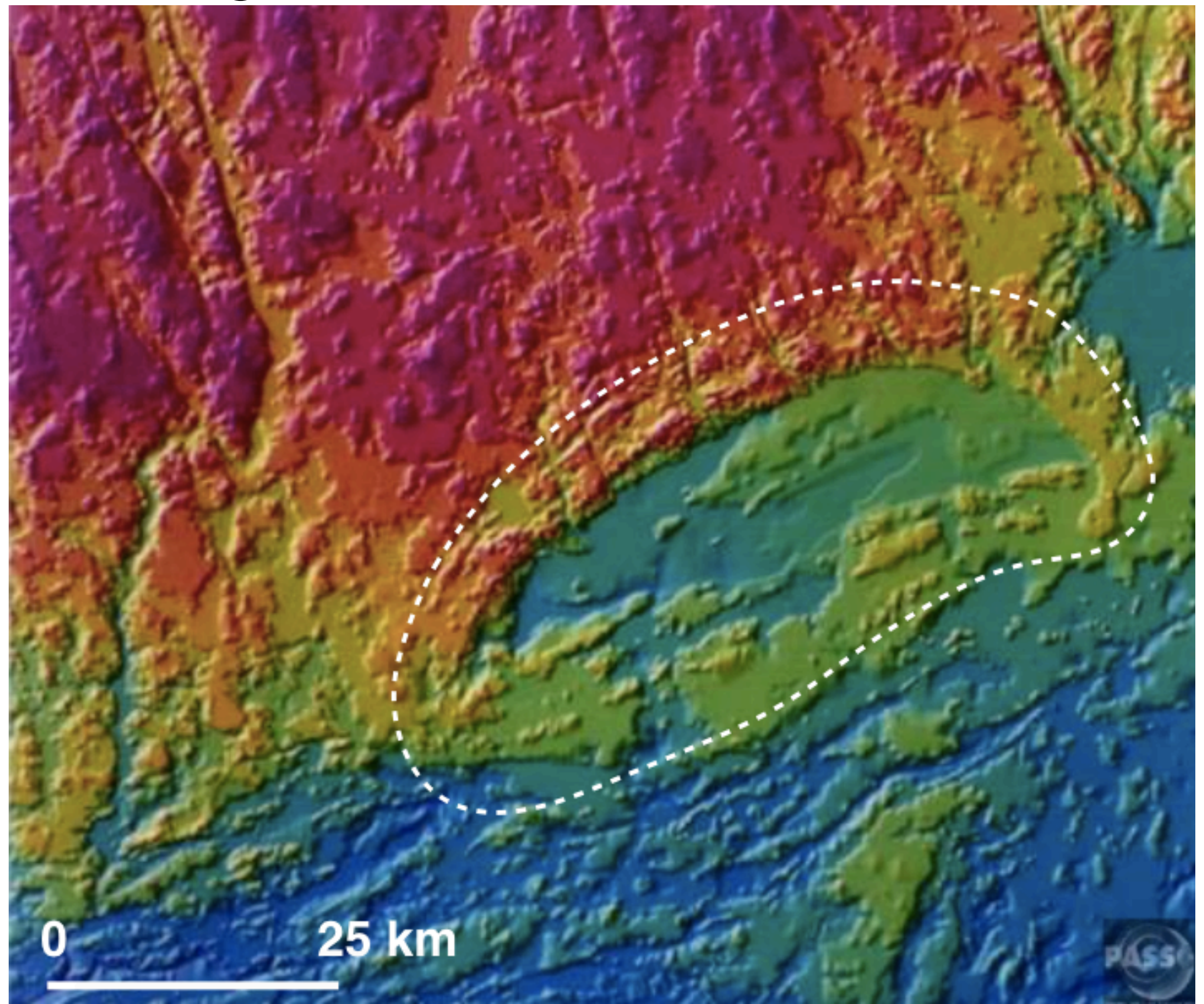
NASA's Lunar Reconnaissance Orbiter image of lunar craters. Image width 365 km.

Large Terrestrial Impacts

- The largest confirmed meteorite impact on Earth is the Vredefort Dome in South Africa, which was formed 2.02 billion years ago by a 10 km diameter impactor.
- The Vredefort crater is at least 120 km-in diameter now, although some estimates put the crater's original diameter at 300 km.
- Rocks from Earth's lower crust are exposed in its center along with a large volume of impact-generated melt rock called pseudotachylyte.
- Earth's second-largest impact crater formed near Sudbury, Canada. The originally circular, 1.85 billion year-old crater has been deformed into a roughly elliptical shape by younger tectonic events, but still contains shatter cones and other shock features, as well as high amounts of nickel, platinum, copper, and gold.



Left: The 2.02 billion year-old Vredefort impact crater in South Africa is at least 120 km in diameter and now partly covered by younger sedimentary rock. Right: A 4 m-high quarry face in the crater's inner ring shows shock-generated pseudotachylyte rock (black) containing large, rounded blocks of partially melted granite (pink).

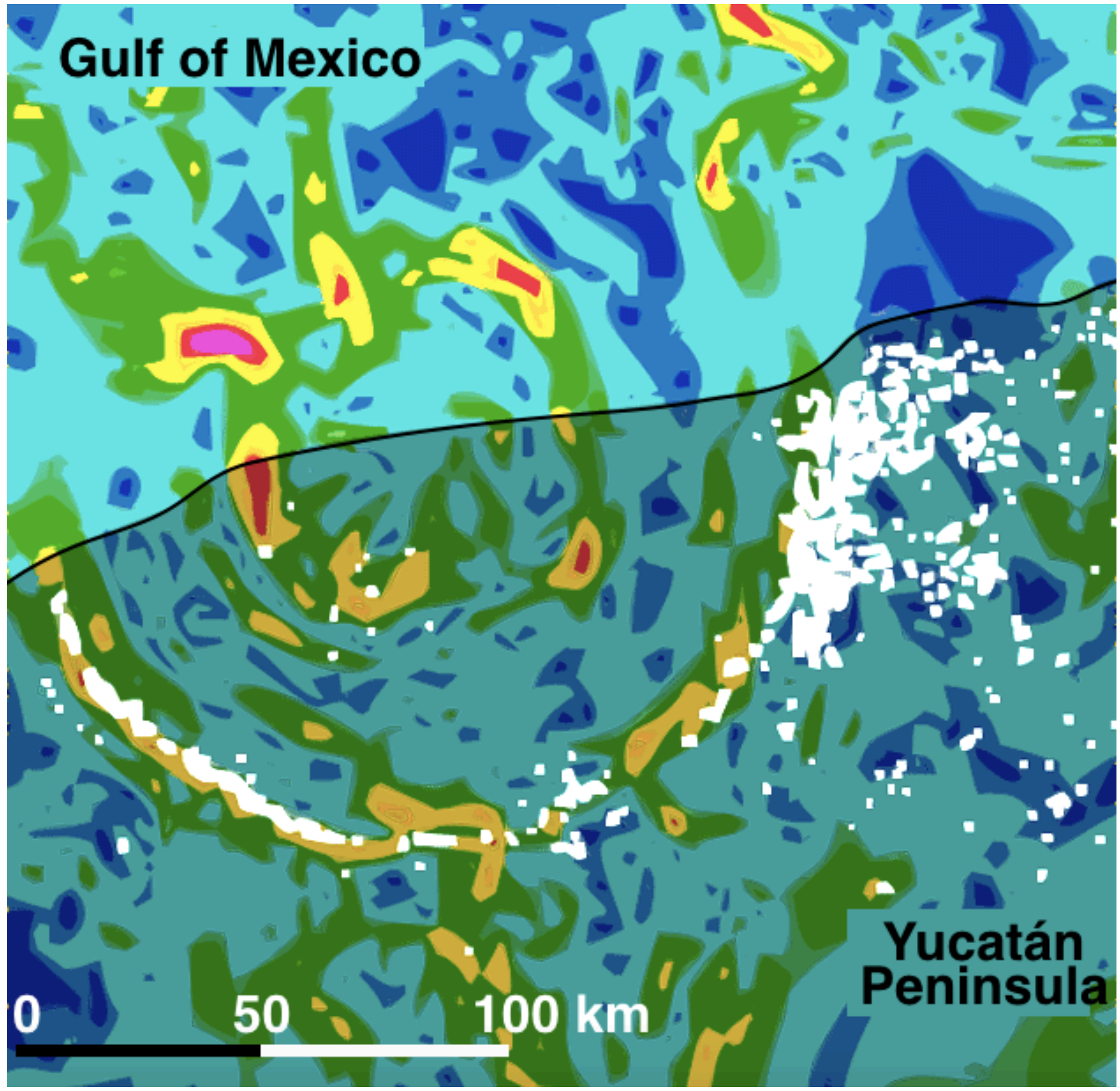


Aerial radar image of the Sudbury, Ontario, Canada impact crater, formed 1.85 billion years ago by a cometary impactor 10–15 km diameter. The crater's rim is outlined by dashed white line.

Chicxulub Impact And The End-Cretaceous Mass Extinction

- Several mass extinctions of biota on Earth may have been caused by asteroid impacts.
- The most famous is the demise of dinosaurs at the end of the Cretaceous Period, 65.5 million years ago.
- The Chicxulub asteroid, estimated as 12–14 km in diameter, made a crater 170–180 km across on the edge of the Yucatán Peninsula. The estimated energy released was equivalent to $5 \cdot 10^{23}$ J (about 100 times the energy released during the last eruption of the Yellowstone super volcano).
- Enormous tsunami waves would have been generated.
- The timing of the Chicxulub impact coincides with the extinction of 85% of Earth's animal and plant species, including almost all species of dinosaurs.
- However, the concept of an impact origin for this mass extinction event is still controversial.

Location of the Chicxulub impact crater.



Anomalies in Earth's gravity field outline the crater. Red and yellow colors indicate a higher than normal gravity signal. Lower half of image (darker) is over land; upper half with brighter colors is under water. White dots are locations of collapsed and broken limestone rocks around the crater's rim.

Natural Hazards and Disaster

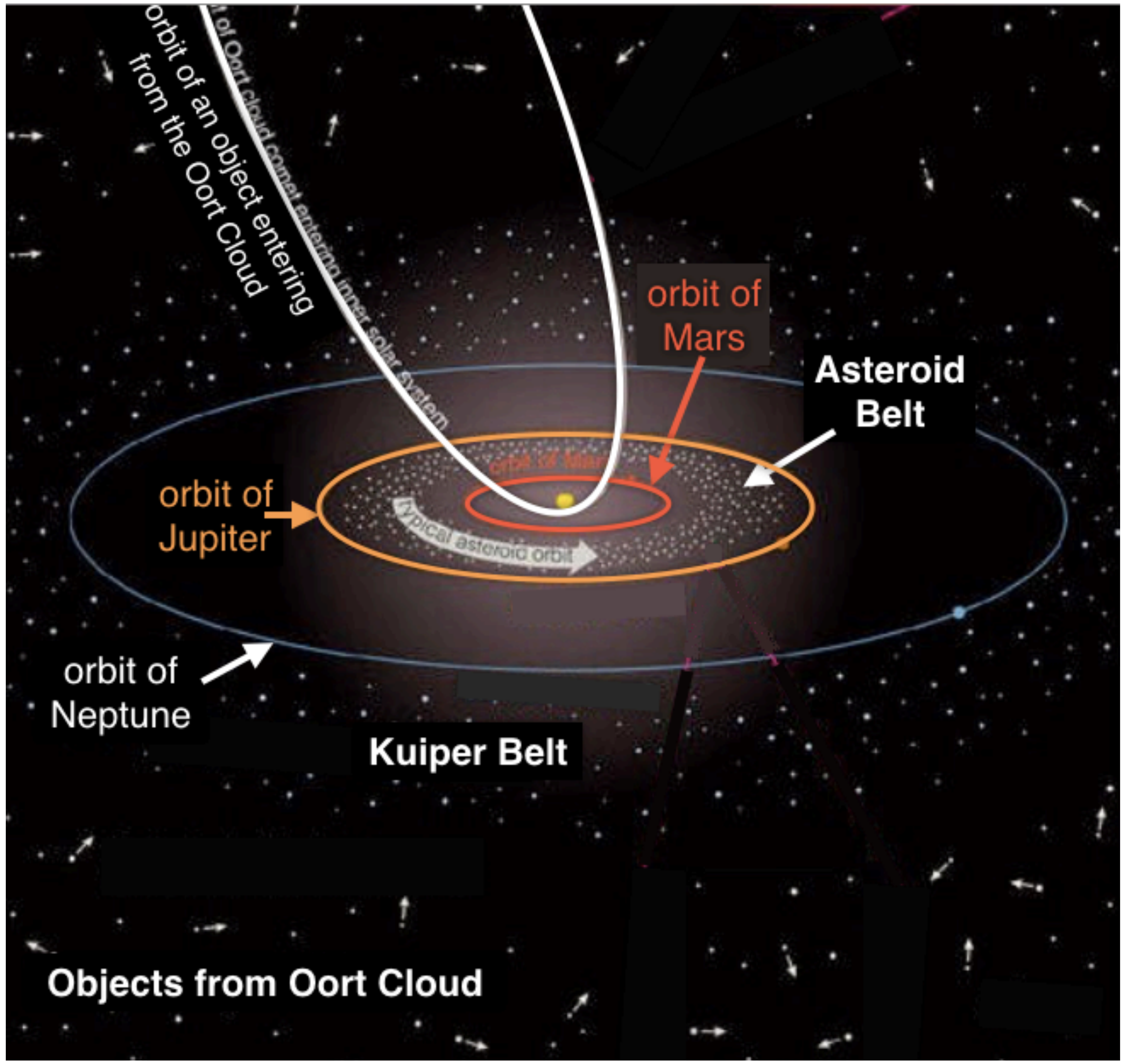
Class 5: Extraterrestrial Hazards

- Threats from Space
- Near-Earth Objects (NEOS)
- Meteoroids and Asteroids
- Comets
- Bolides
- Space Weather, Solar Storms, Gamma Rays

Comets

Comets are balls of ice, dust, and rock that normally reside beyond the orbit of Neptune.

- Some comets have a rocky center and many also contain small amounts of CO_2, CO, ammonia, and methane.
- They only become visible when, as they approach the Sun, their frozen surfaces emit gas that streams behind them as they travel.
- Some comets reside in the Kuiper Belt, beyond the orbit of Neptune, but most are in the Oort Cloud, well beyond Pluto.
- Some are occasionally perturbed into eccentric orbits.
- Comets that take less than 200 Earth-years to orbit the Sun have well-documented orbits, such as Halley's Comet.
- Others take much longer to complete one orbit, are less well mapped.



The Kuiper Belt, at 30 to 50 AU from the Sun (1 AU = 149,597,870,700 m), contains icy debris that orbits the Sun in a disc-shaped zone beyond the orbit of Neptune. The Oort Cloud is at 50,000 to 200,000 AU; its objects have random orbits. Image not to scale.

Halley's Comet as photographed on March 12, 1986 from Australia. The bright 'head,' also called 'coma,' of the comet is caused by expanding gases that are swept into a 'tail' by solar radiation pressure. Comet Halley's next appearance will be in 2062.

Natural Hazards and Disaster

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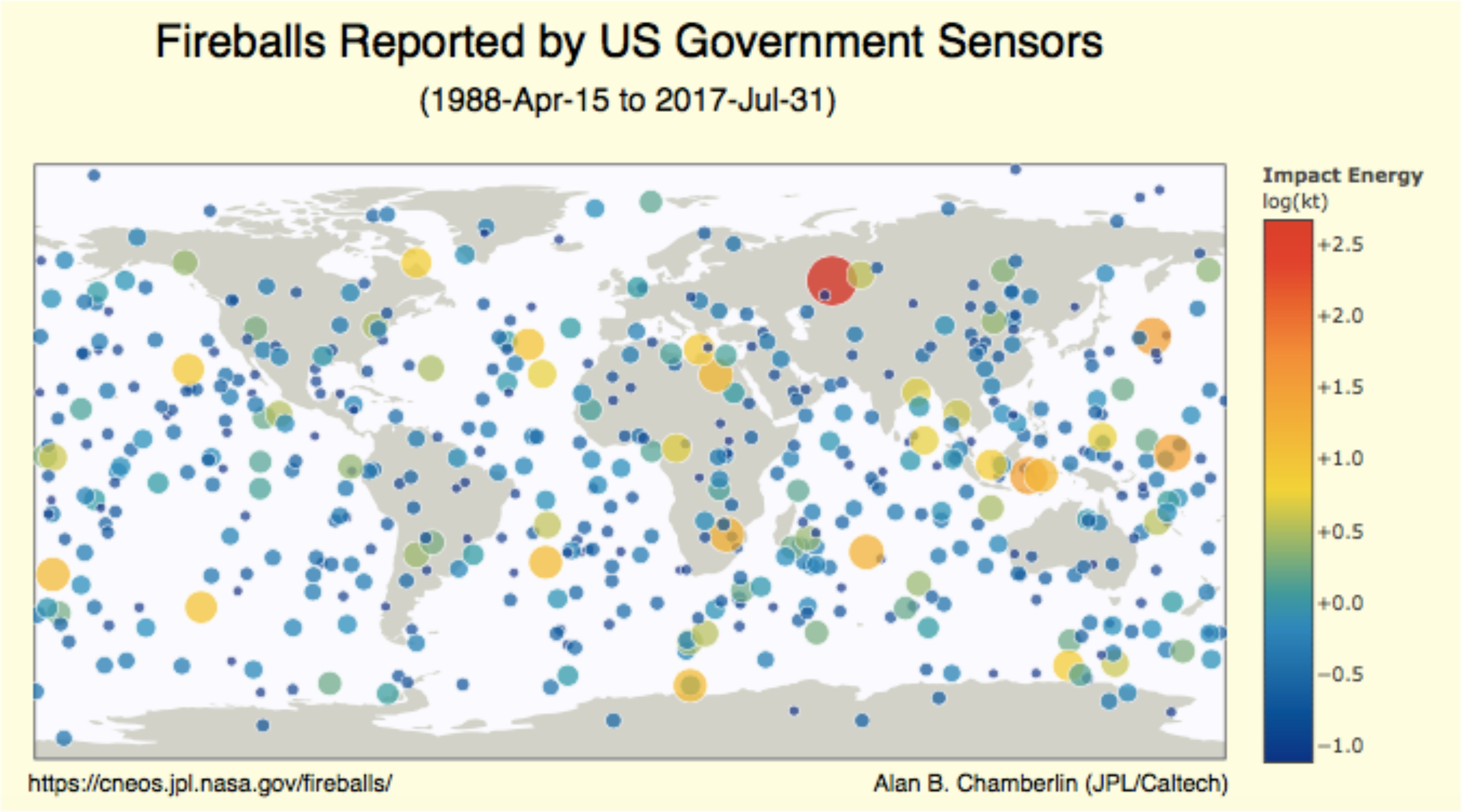
Bolides

Bolides are meteoroids and cometary fragments
that explode on entering Earth's atmosphere.

- Asteroids, meteoroids, and fragments of comets that explode in Earth's atmosphere before reaching the surface are called bolides.
- The explosions are seen as very bright meteors, sometimes called 'fireballs.'
- In a 20-year period, more than 500 bolides with diameters > 1 m are typical.
- Tunguska Bolide: An object thought to be at least 60 m in diameter and weighing 10^8 kg exploded in Earth's atmosphere on June 30, 1908, high above a remote forested region of the Tunguska River in Siberia. Roughly 80 million trees were flatted by the blast. Energy estimates are between 1.3 and $2.1 \cdot 10^{16}$ J.

https://en.wikipedia.org/wiki/Tunguska_event



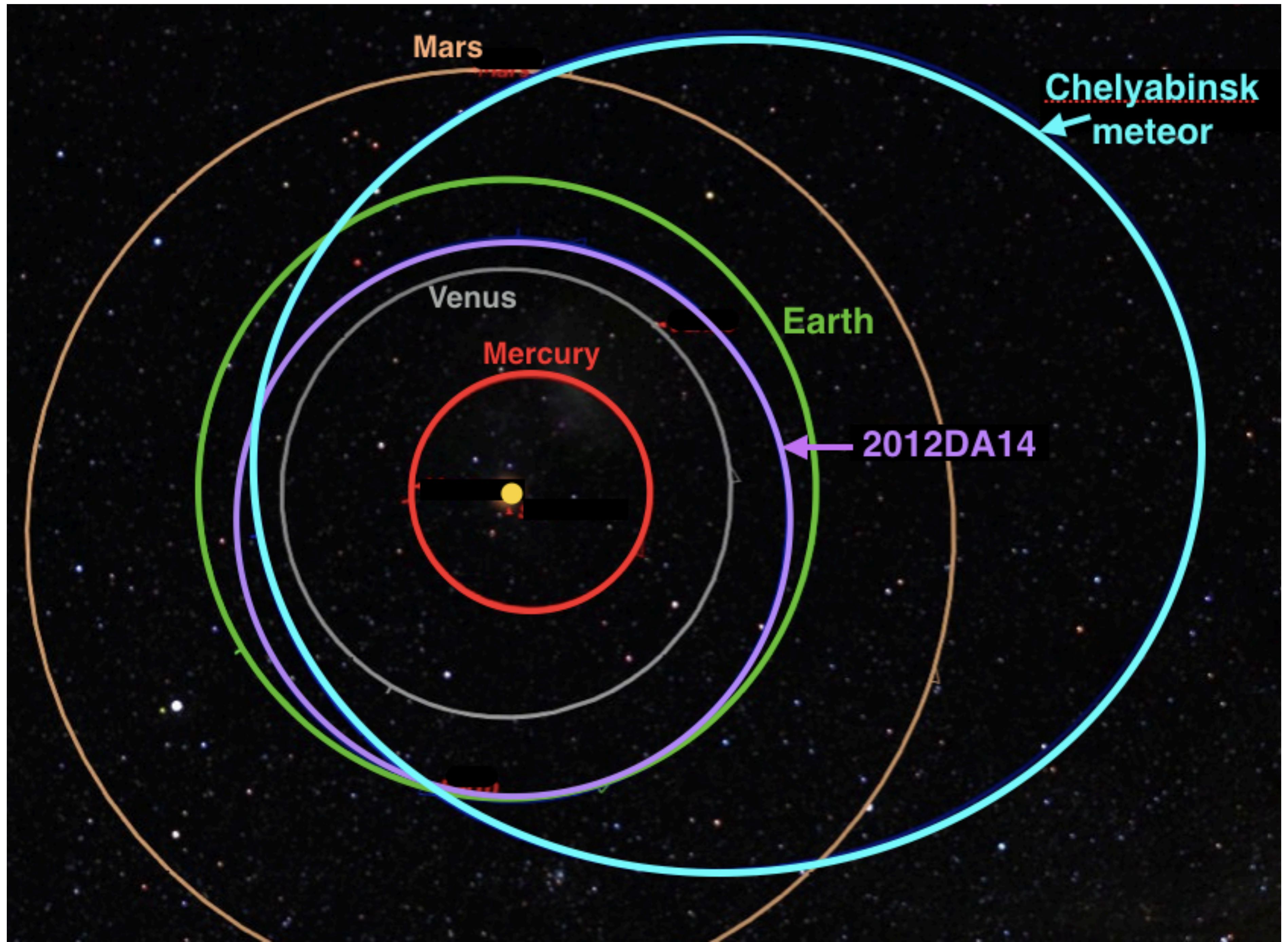
Each bolide on the map was visible as a meteor; circle sizes represent their optical radiated energy in GJ.

Flattened trees in Tunguska, Siberia, after a bolide blast on June 30, 1908. Trees over an area of about 2,000 km^2 were downed in a radial pattern, pointing inward toward the blast source.

Chelyabinsk, Russia, 2013

- An unexpected bolide blast over southern Russia shattered windows and caused multiple injuries.
- On February 15, 2013, an object at least 17 m in diameter exploded at a height of about 20 km in the atmosphere above Chelyabinsk, Russia.
- The bolide had an estimated energy release equivalent to over $2 \cdot 10^{15}$ J.
- The blast was recorded by seismic stations around the world.
- There were no direct fatalities from the bolide, but 1,500 people were injured, some seriously, by flying glass and debris.
- By coincidence, NASA had predicted that a different asteroid, they had named 2012DA14, would make a close approach to Earth on about the same day, however they were unaware of the Chelyabinsk asteroid; the two were on completely different and unconnected orbits.

The Chelyabinsk bolide explosion in 2013, as seen by a Russian driver's Dash Cam.



Orbits of the inner planets and those of the Chelyabinsk asteroid & 201DA14. Both asteroids crossed Earth's orbit within hours of each other. Only the Chelyabinsk object came close enough to become a bolide.

Natural Hazards and Disaster

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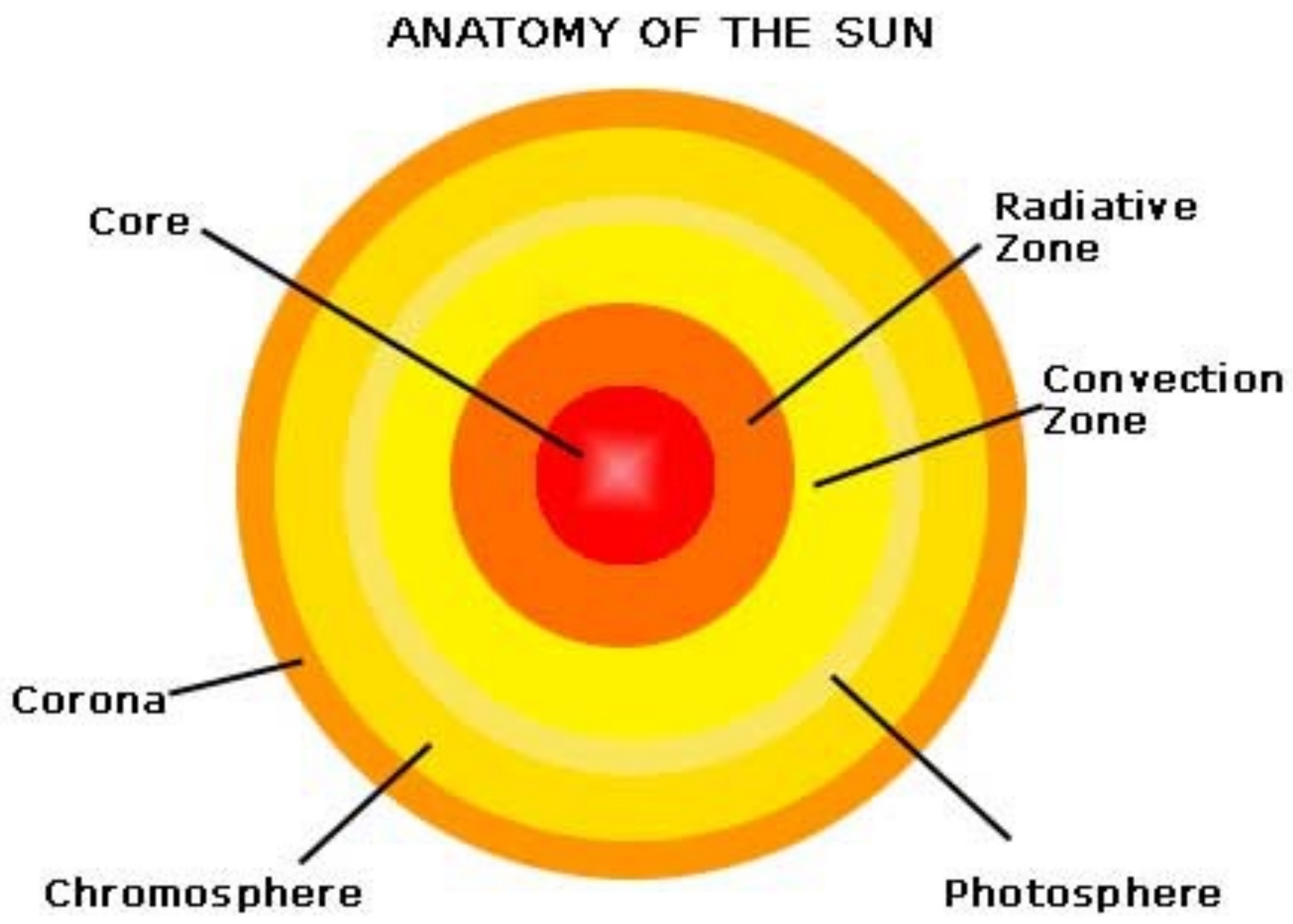
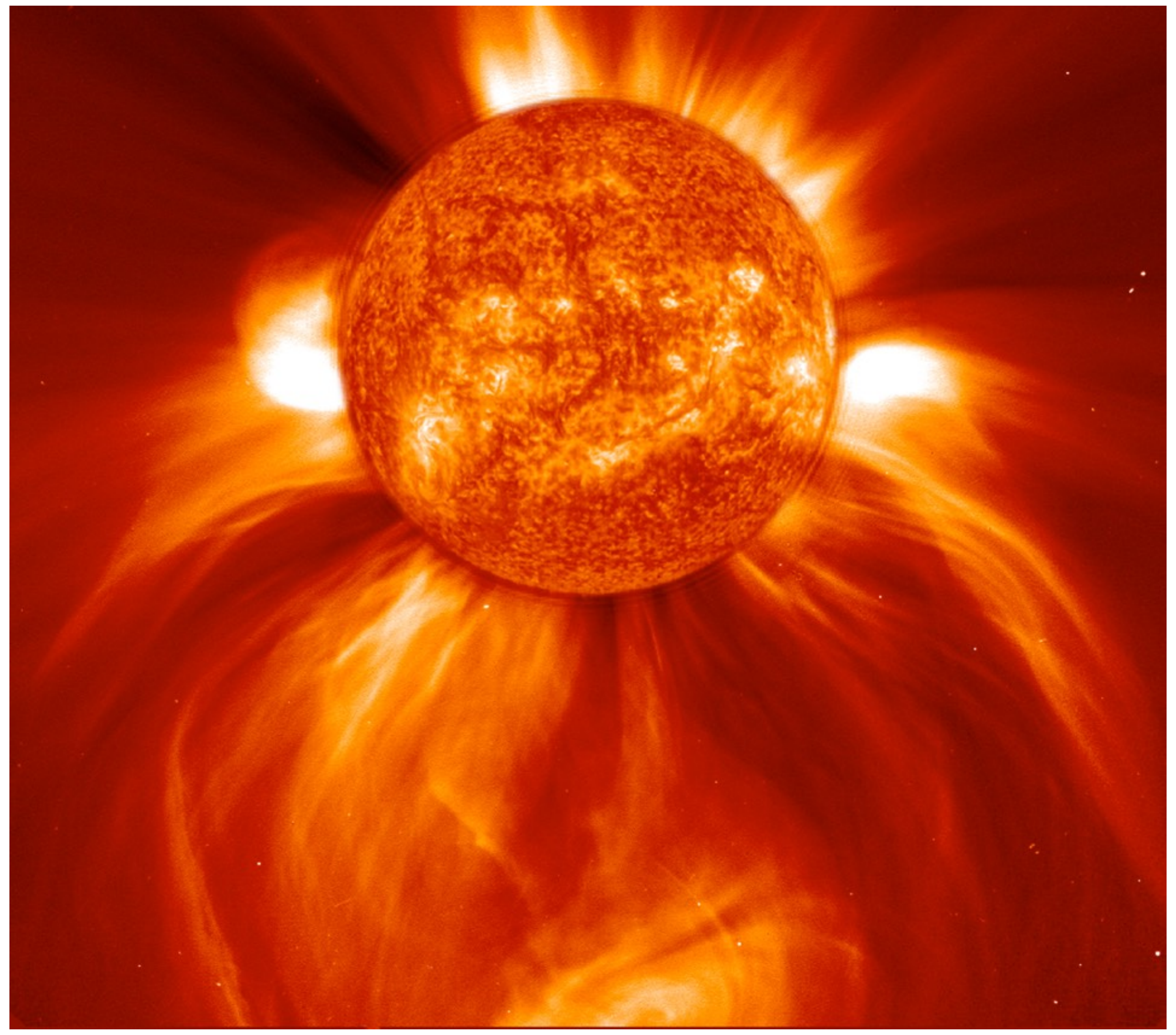
Space Weather and Solar Storms

Space Weather

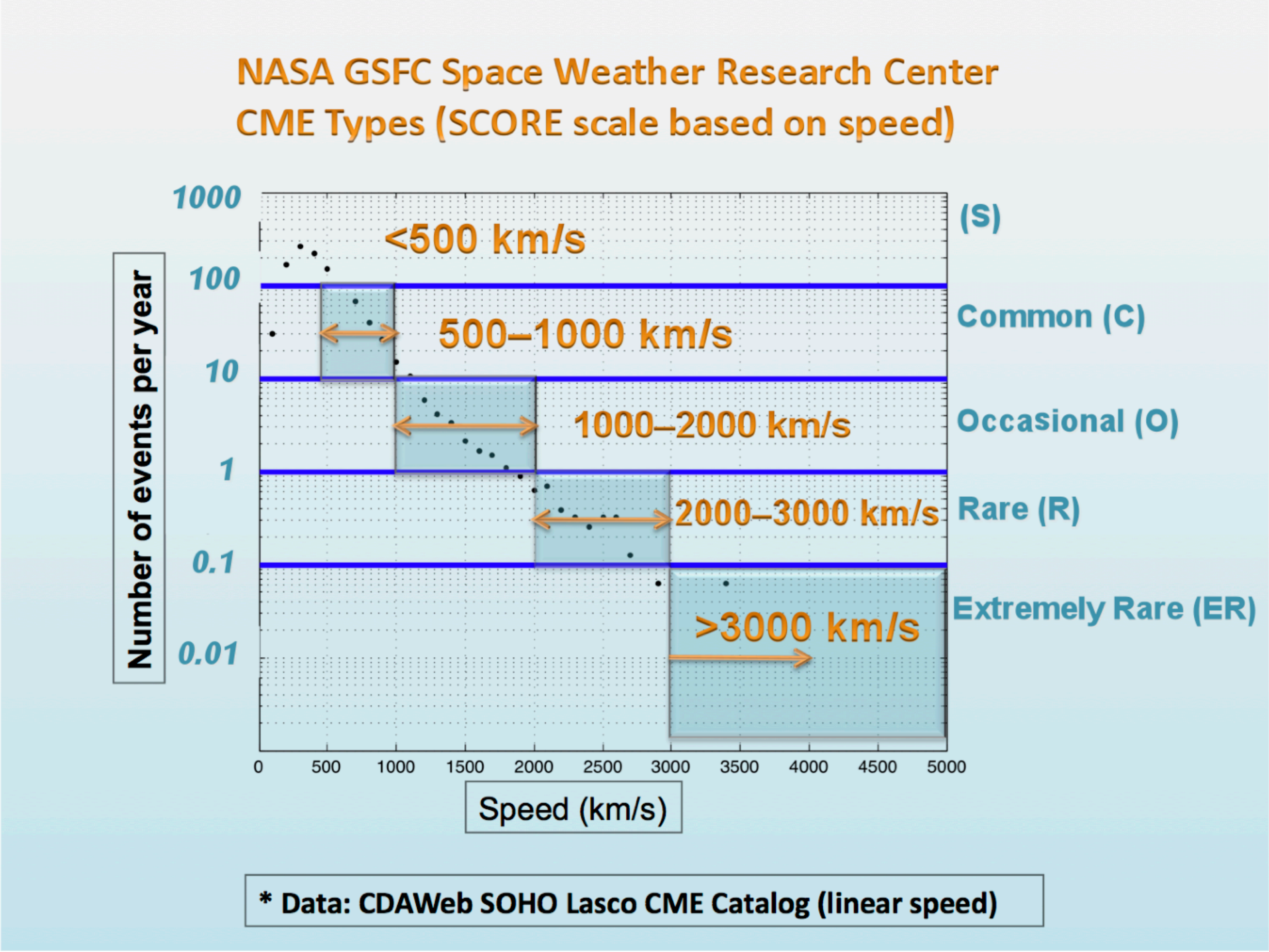
- Solar flares and coronal mass ejections occur frequently and can disrupt telecommunications.
- Streams of electrically charged particles are constantly emitted by the Sun as a 'solar wind.'
- Effects on the upper atmosphere cause Aurora Borealis.
- Variations in the Sun's magnetic field produce intense, localized solar X-ray and proton flares; frequency and strength are often correlated with sunspot activity.
- A solar X-ray burst disturbs the ionosphere and can jam both high- and low-frequency radio signals.
- Many solar flares trigger coronal mass ejections (CMEs), which blast billions of tons of charged gas into space at speeds of hundreds to thousands of km/s.
- A CME can take from one to four days to reach Earth, where it can cause serous disruption to telecommunications and power grids.
- CME's are monitored as part of NASA's Space Weather program.



Internal structure of the Sun.



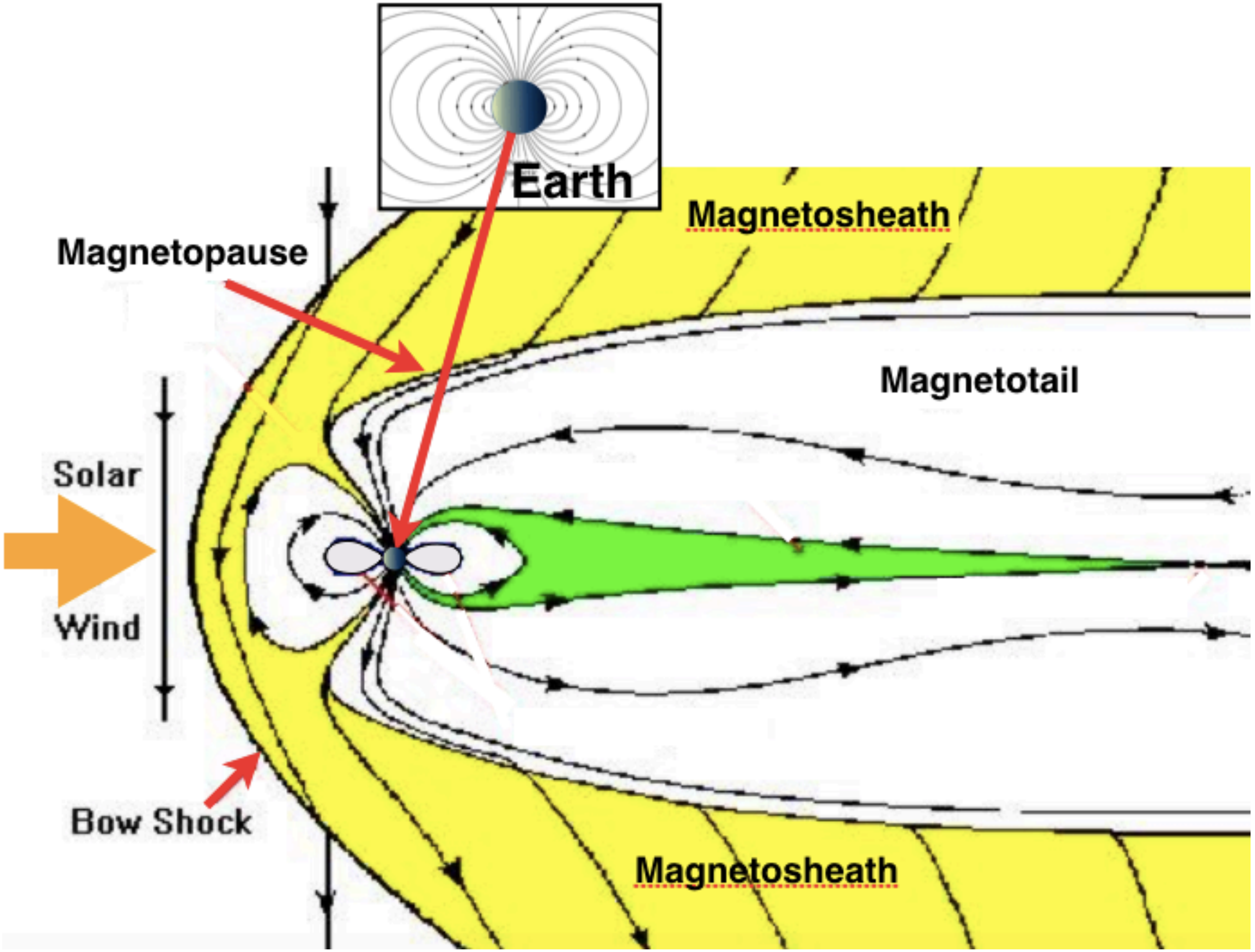
Composite image of the Sun's coronal surface and CMEs on January 8, 2002, imaged by NASA's Solar and Heliospheric Observatory.



Classification of CME's based on their frequency of occurrence and the speed at which the charged gases move through space. The fastest CMEs are most rare.

Earth's Safety Shield

- Earth's magnetic field deflects the solar wind, shielding the planet from harmful ions.
- Earth is protected from much of the ionized solar wind and from most solar emissions by its magnetosheath, which is the result of the magnetic field generated by electrical currents in Earth's core.
- The magnetosheath is not symmetrical, but is compressed on the daylight side of Earth (the side facing the solar wind) and extended on the dark, night-time side into a long tail, called the magnetotail.
- Large solar flares and very fast-moving CMEs further distort Earth's magnetosheath and cause geomagnetic storms that can seriously disrupt satellites and telecommunications.



Where the solar wind interacts with Earth's magnetic field, at a distance of about 90,000 km, a bowshaped boundary forms, called a 'bow shock' because of the abrupt reduction in the solar wind's speed. The approximate symmetry of Earth's local magnetic field (inset) is distorted, becoming compressed on the side facing the Sun and stretched on the night side of Earth.

Space Weather and Solar Storms

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Tuesday, September 05, 2017 07:43:58 UTC

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SPACE WEATHER CONDITIONS on NOAA Scales

24-Hour Observed Maximums

R2	S2	G1
moderate	moderate	minor

Latest Observed

R	S1	G
none	minor	none

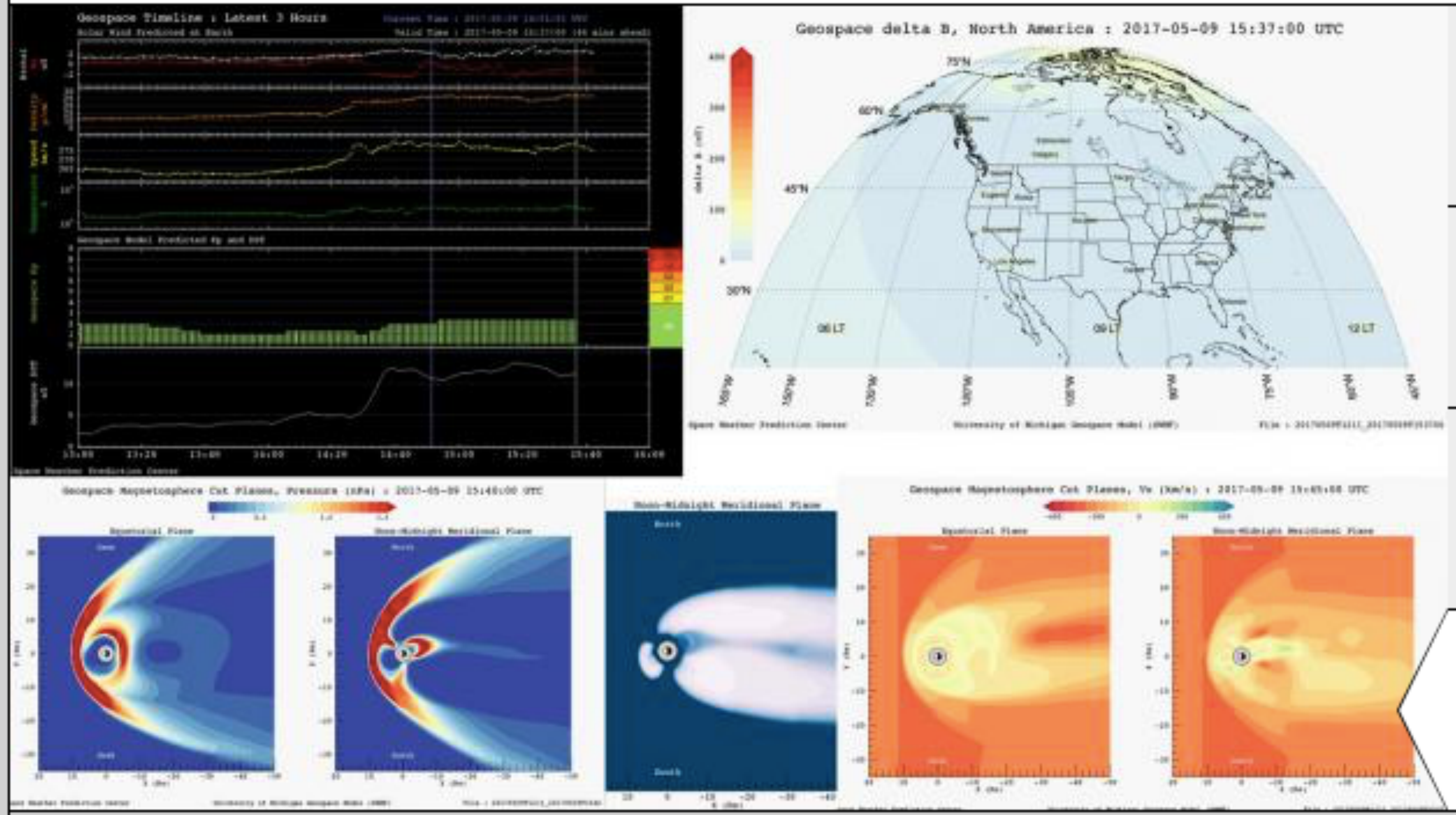
Predicted 2017-09-05 UTC

R1-R2	71%	S1 or greater	10%	G
R3-R5	25%			none

Solar Wind Speed: **542** km/sec

Solar Wind Magnetic Fields: Bt **4** nT, Bz **1** nT

Noon 10.7cm Radio Flux: **183** sfu



CME analysis in progress

published: Tuesday, September 05, 2017 02:59 UTC

Forecasters are in the process of analyzing a coronal mass ejection that could reach Earth within the next two days.

2018 Space Weather Workshop - 16-20 April, 2018

published: Monday, August 21, 2017 13:16 UTC

The date and location for the 2018 Space Weather Workshop have now been determined by UCAR. In 2018 we will be gathering from 16-20 April at the W

New Space Weather Model, the Geoelectric Field Model, Announced Today

published: Tuesday, June 27, 2017 19:08 UTC

The NWS Director, Dr. Louis W. Uccellini, announced a new space weather model, the Geoelectric Field model, today.

Regional Geomagnetic Model Products now Fully Operational

published: Tuesday, May 09, 2017 15:03 UTC

SWPC is pleased to announce that we have transitioned the entire set of Geospace model derived products from experimental to fully operational in o

SERVING ESSENTIAL SPACE WEATHER COMMUNITIES

- Aviation
- Radio Communications
- Electric Power
- Satellites
- Emergency Management
- Space Weather Enthusiasts
- Global Positioning System (GPS)

THE SUN'S X-RAYS | CORONAL MASS EJECTIONS | THE AURORA

Space Weather and Solar Storms

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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CURRENT SPACE WEATHER CONDITIONS on NOAA Scales

R none | S2 moderate | G none

OBSERVATIONS

SWPC utilizes an array of observed data sets in their Space Weather forecast operations and related research. Many of these data sets are available in near-real-time, and come from a variety of sources, ranging from solar imaging satellites to ground magnetometer stations. SWPC also provides these data sources to the external community.

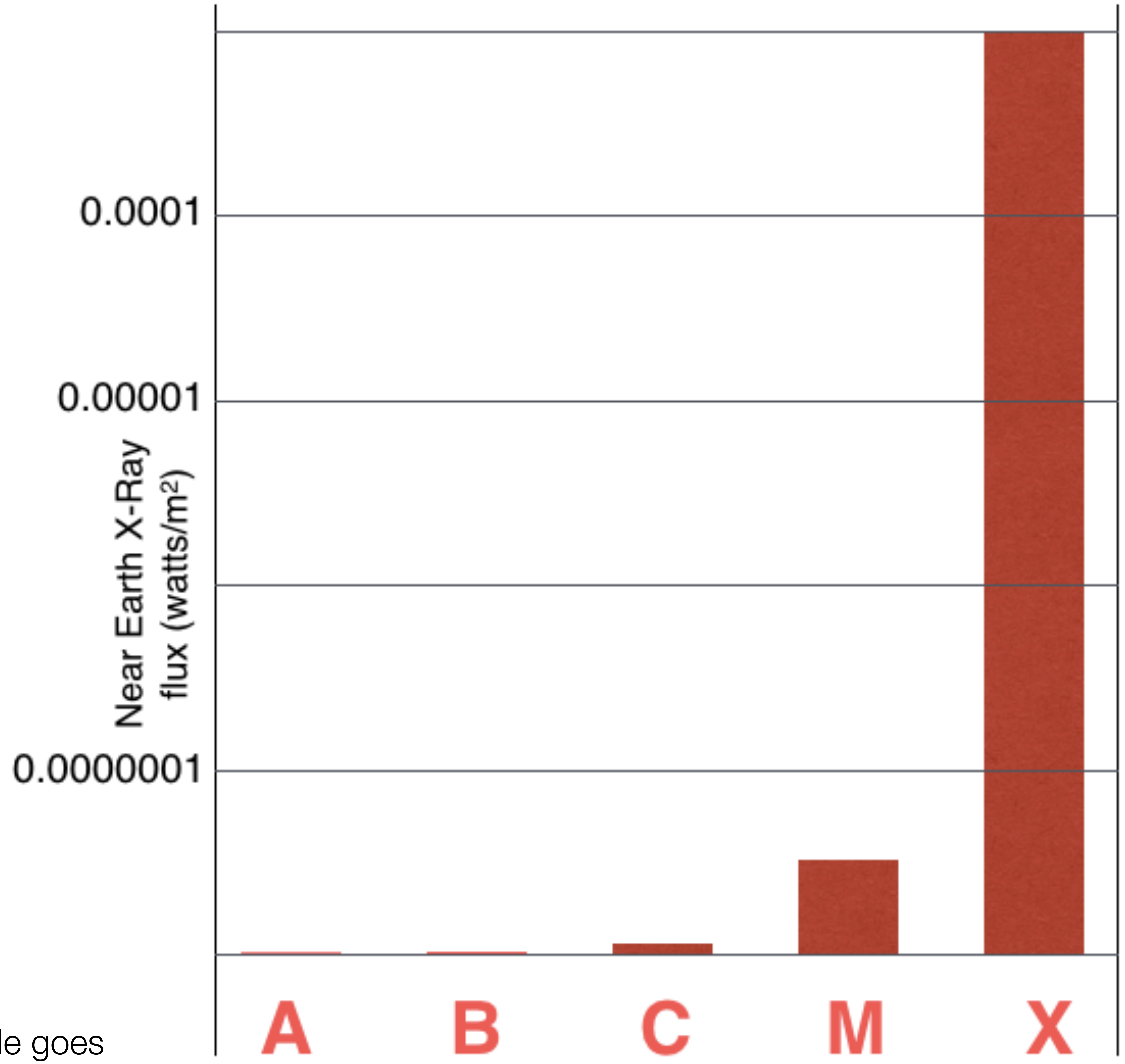
- Boulder Magnetometer
- GOES Electron Flux
- GOES Magnetometer
- GOES Proton Flux
- GOES Solar X-ray Imager
- GOES X-ray Flux
- LASCO Coronagraph
- Planetary K-index
- Real Time Solar Wind
- Satellite Environment
- Solar Synoptic Map
- Space Weather Overview
- Station K and A Indices

Aviation | Electric Power | Emergency Management | Global Positioning System (GPS)
Radio Communications | Satellites | Space Weather Enthusiasts

THE SUN'S X-RAYS | CORONAL MASS EJECTIONS | THE AURORA

Solar Flares

- Records of major solar flares and their associated coronal mass ejections first began in 1859.
- Solar flares are classified today according to their strength in watts per square meter reaching Earth, using a lettered scale in which each level is 10 times greater than the next lower rating.
- For example, an M0 flare is ten times greater than a C9, and an M3 is ten times greater than an M2.
- The strongest, most damaging flares are given X values, with no upper limit.



NASA's letter-scale rating of solar flare strength. The logarithmic scale goes from 1 to 9 within each letter, and extends beyond 20 for X-level flares.

Space Weather and Solar Storms

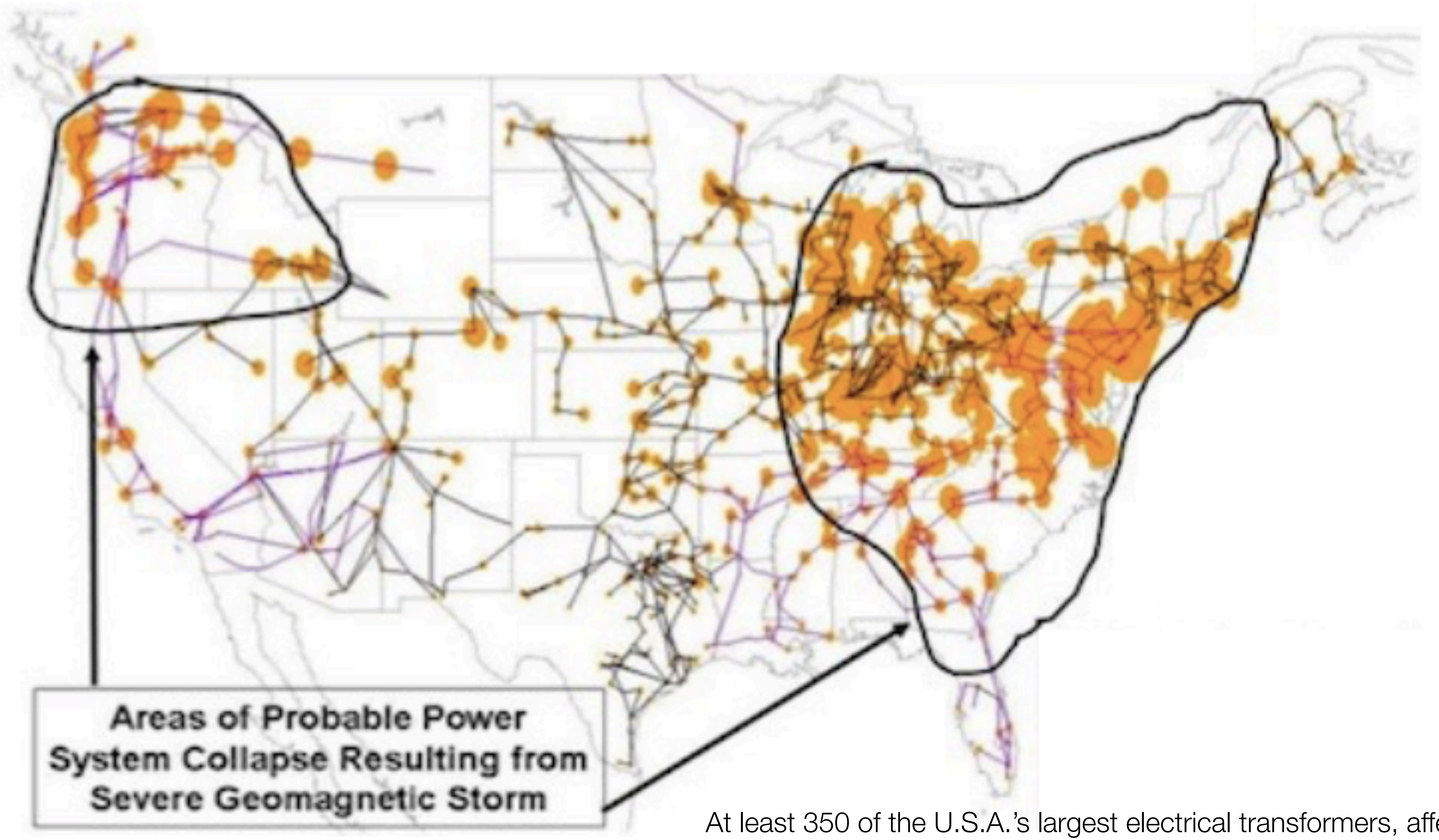
The Carrington Superstorm

- On September 1, 1859, an intense white-light solar flare was observed by British astronomer Richard Carrington.
- This was the first recorded observation of a solar flare, which lasted for about 5 minutes and is now classified as an X15 Super Geomagnetic Storm.
- When the intense burst of energy reached Earth it caused aurora-induced electrical currents in telegraph wires that were sufficient to give electric shocks to telegraph operators.
- In the hours before dawn next morning, bright auroras were visible as far south as Cuba.

Other Solar Flares

- A powerful geomagnetic storm occurred in May 1921, burning out telephone and telegraph wires across Europe and North America.
- On March 10, 1989, an X15 solar flare and CME caused a geomagnetic storm three days later that disrupted weather satellites and shut down the power grid of Quebec province, Canada, for over 9 hours.

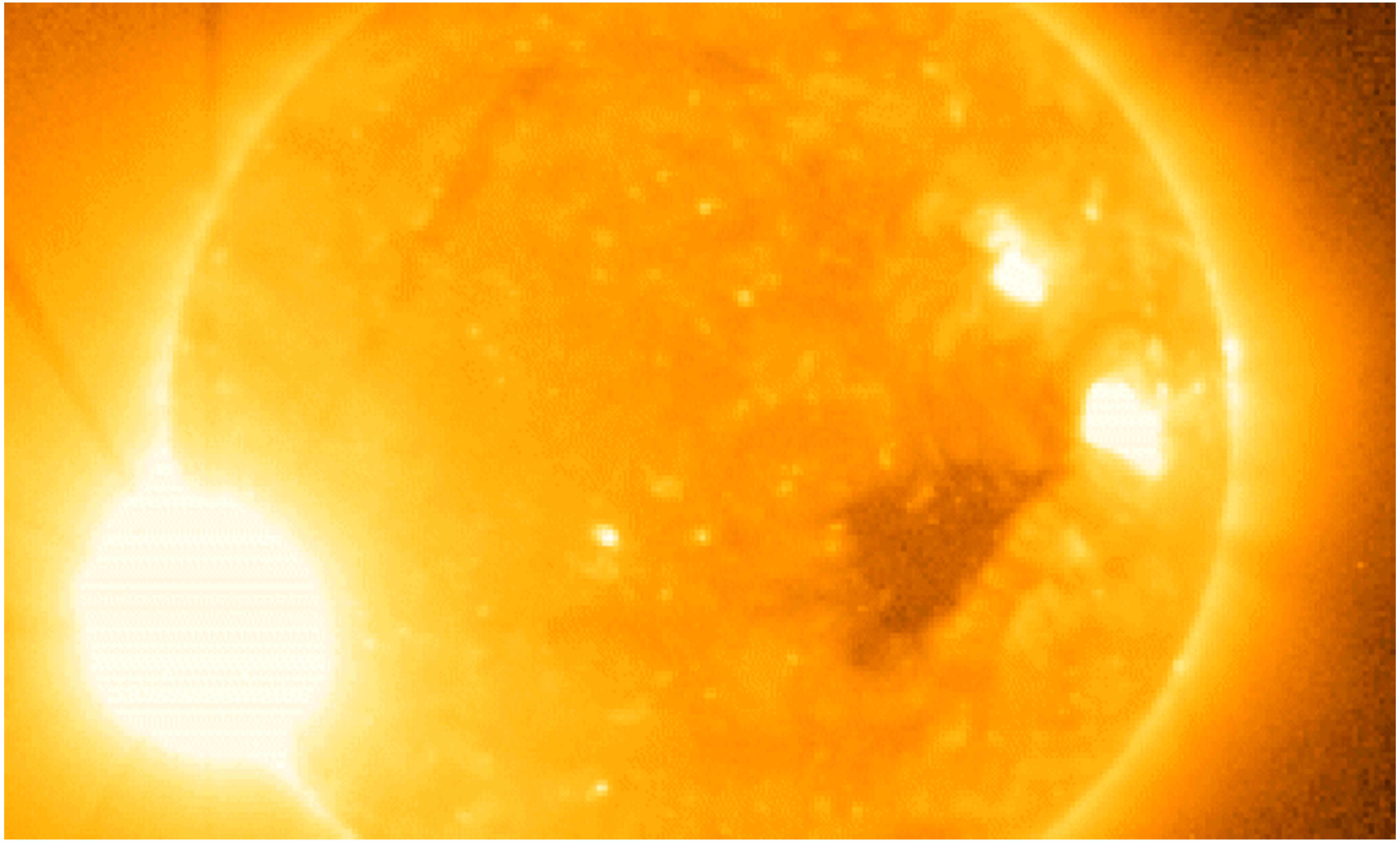
Space Weather and Solar Storms



At least 350 of the U.S.A.'s largest electrical transformers, affecting over 130 million people, could be damaged by a geomagnetic storm of the same magnitude as that of May 1921.

More Recent Solar Flares

- A large solar flare on August 4, 1972, disrupted telephone communication across the state of Illinois and caused AT&T to redesign its power system for transatlantic cable.
- On April 2, 2001, an X20 flare became the largest so far on record; it generated a 2,000 km/s CME blast that, fortunately, was not directed toward Earth.



NOAA's GOES-13 satellite recorded this Xray image of a solar flare on December 5, 2006. The flare was not as intense as the Carrington flare, but it still damaged the satellite's imaging instruments.