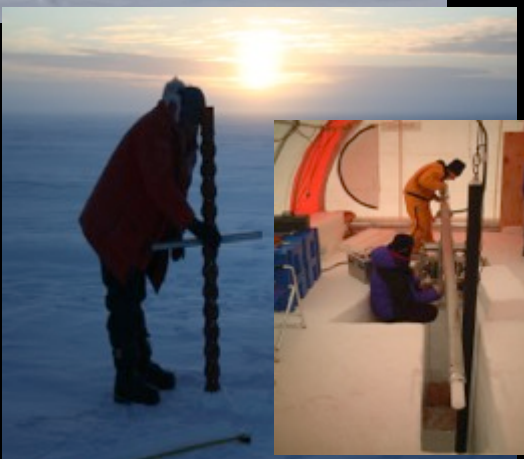


The Earth System, the Anthropocene and Planetary Boundaries

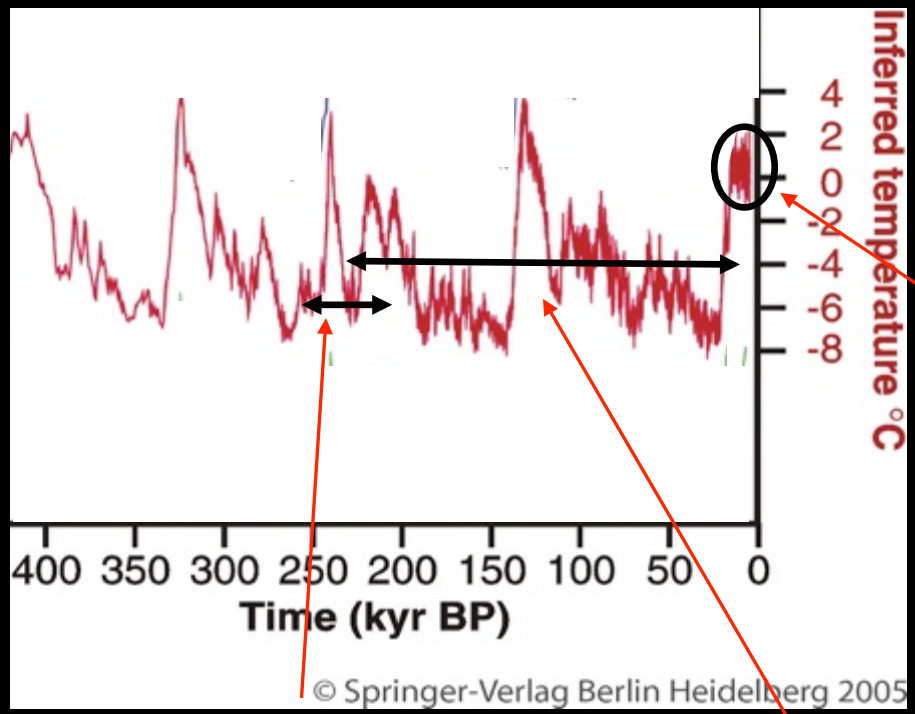


Will Steffen

Our planet is a single system – the Earth System



Human Development
and
the Earth System



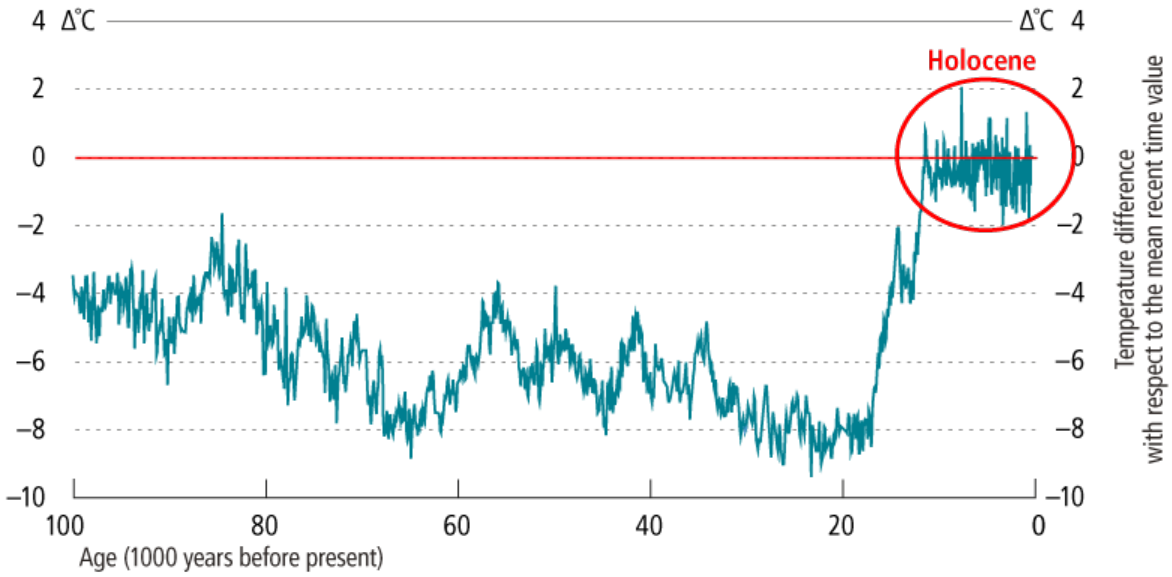
Beginning of agriculture

Evolution of fully modern humans in Africa

Hunter-gatherer societies only

Adapted from Steffen et al. 2004; ice core data from Petit et al. 1999

Human Development and Earth System Dynamics



Source: J. Rockström and N. Nakicenovic
Data from Petit et al. 1999 and Oppenheimer 2004

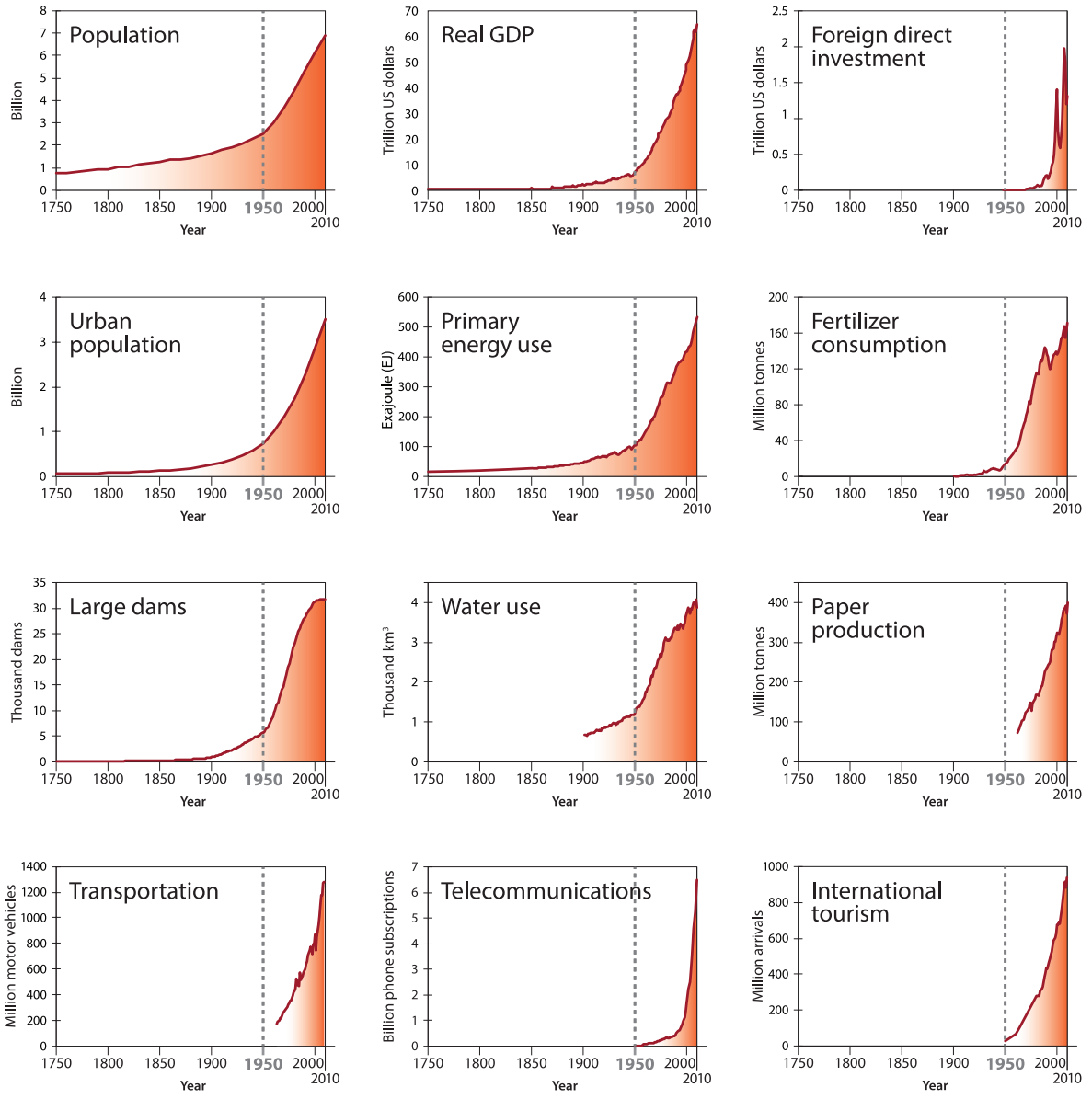
The Holocene and Human Development

- The Holocene is a warm, relatively stable state of the Earth System that has lasted about 11,700 years, following the most recent ice age (the Pleistocene)
- The Holocene is the only state of the Earth System that we know, for certain, can support contemporary human civilisation
- Without human interference, the Holocene is expected to last for another 20,000 or 30,000 years

The Human Enterprise

- **Population**
- **Economic Growth**
- **Freshwater use**
- **Energy use**
- **Urbanization**
- **Globalization**
- **Transport**
- **Communication**

Socio-economic trends

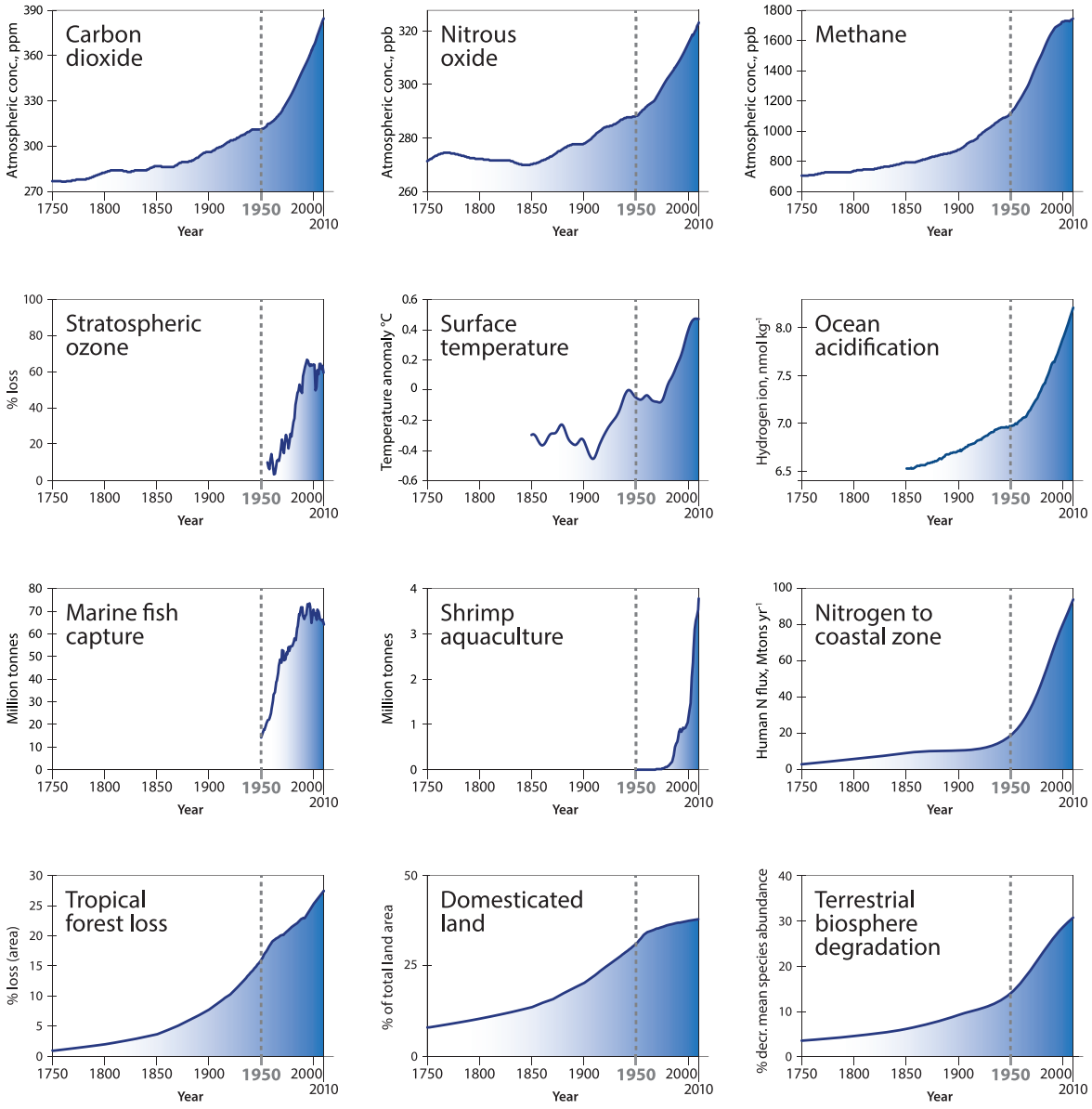


Steffen et al. 2015

Global Impact

- **Greenhouse gases**
- **Ozone depletion**
- **Climate**
- **Marine ecosystems**
- **Coastal zone**
- **Nitrogen cycle**
- **Tropical forests**
- **Land systems**
- **Biosphere integrity**

Earth system trends



Steffen et al. 2015

IGBP Newsletter 41: May 2000

The "Anthropocene"

by Paul J. Crutzen and Eugene F. Stoermer

The name Holocene ("Recent Whole") for the post-glacial geological epoch of the past ten to twelve thousand years seems to have been proposed for the first time by Sir Charles Lyell in 1833, and adopted by the International Geological Congress in Bologna in 1885. (1). During the

panied e.g. by a growth in cattle population to 1400 million (6) (about one cow per average size family). Urbanisation has even increased tenfold in the past century. In a few generations mankind is exhausting the fossil fuels that were generated over several hundred million

groves. Finally, mechanized human p
dation ("fisheries") removes more th
25% of the primary production of t
oceans in the upwelling regions and 3
in the temperate continental shelf
gions (10). Anthropogenic effects are a
well illustrated by the history of biotic

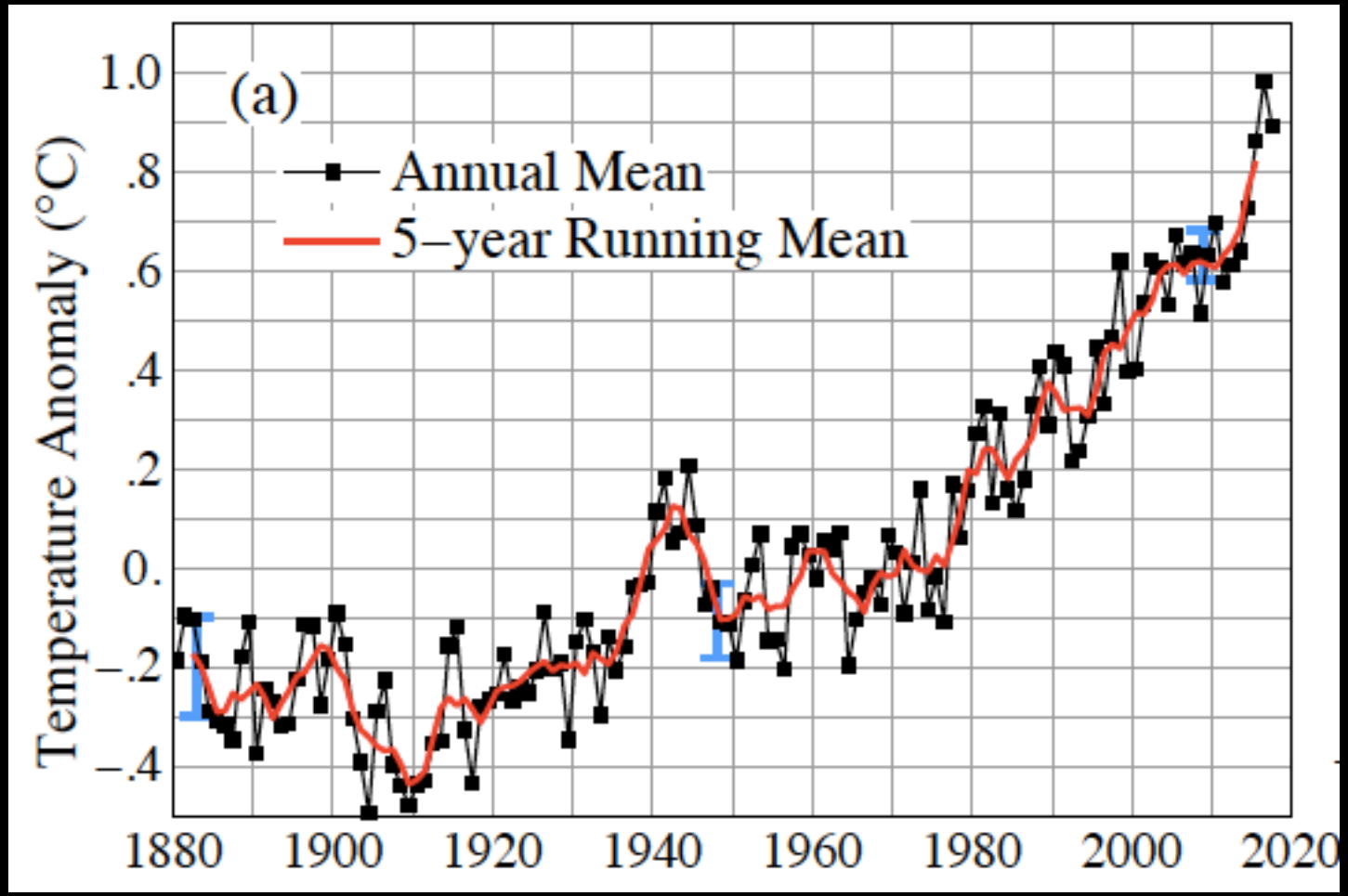
P.J. Crutzen, "The Geology of Mankind", Nature 2002

Explicitly proposed the Anthropocene as a new geological epoch.

Suggested that the start date be set at the beginning of the Industrial Revolution, late 1700s, or beginning of the Great Acceleration, ca. 1950

Climate Change

Global Average Temperature Anomaly, 1880-2017



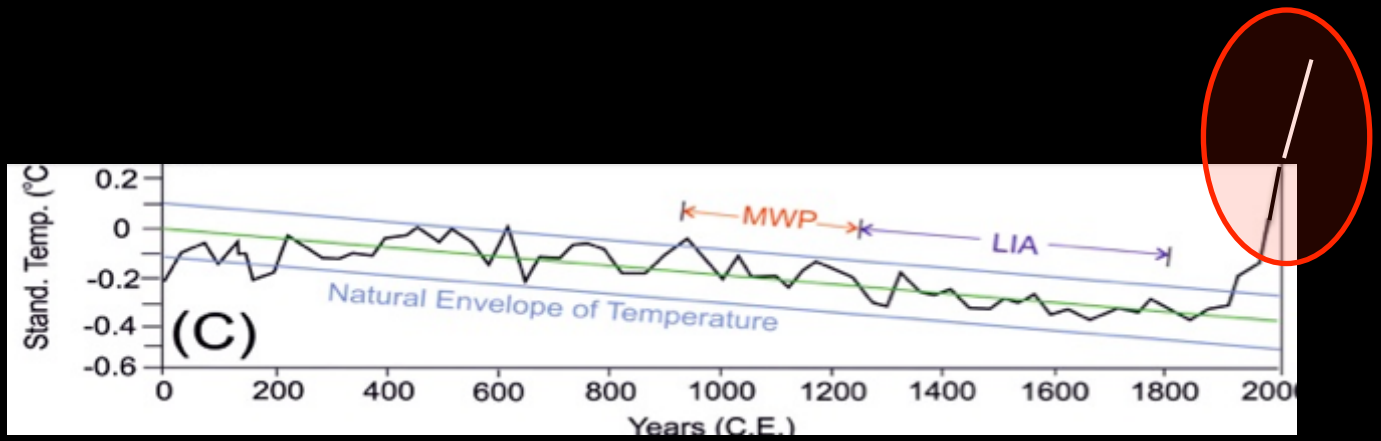
Baseline is 1951-1980

NASA 2018

An Earth System Perspective

Temperature rise:
Beyond the envelope of natural variability!

Human influence



Summerhayes 2015

Rates of Change

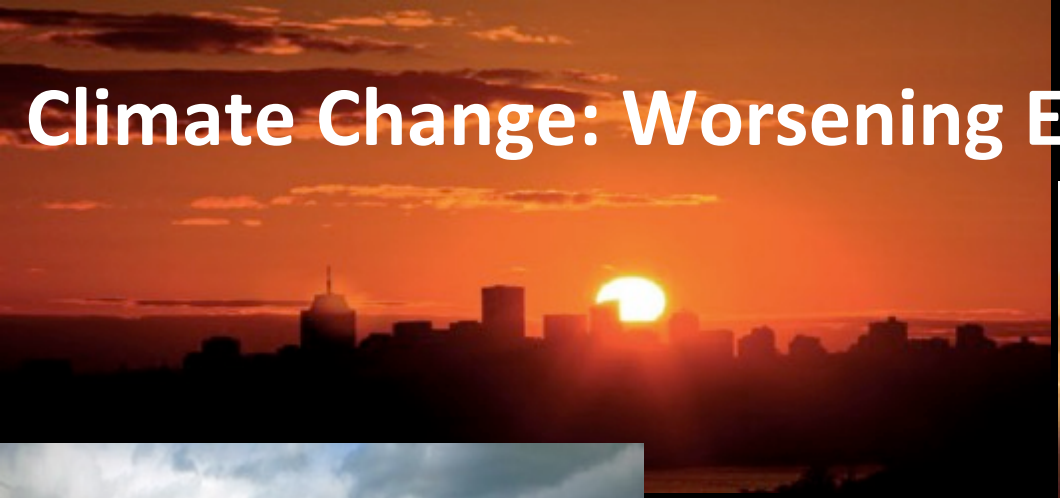
Since 1970 the global average temperature has risen at a rate about 170 times the background rate over the past 7,000 years of the Holocene, and in the opposite direction.

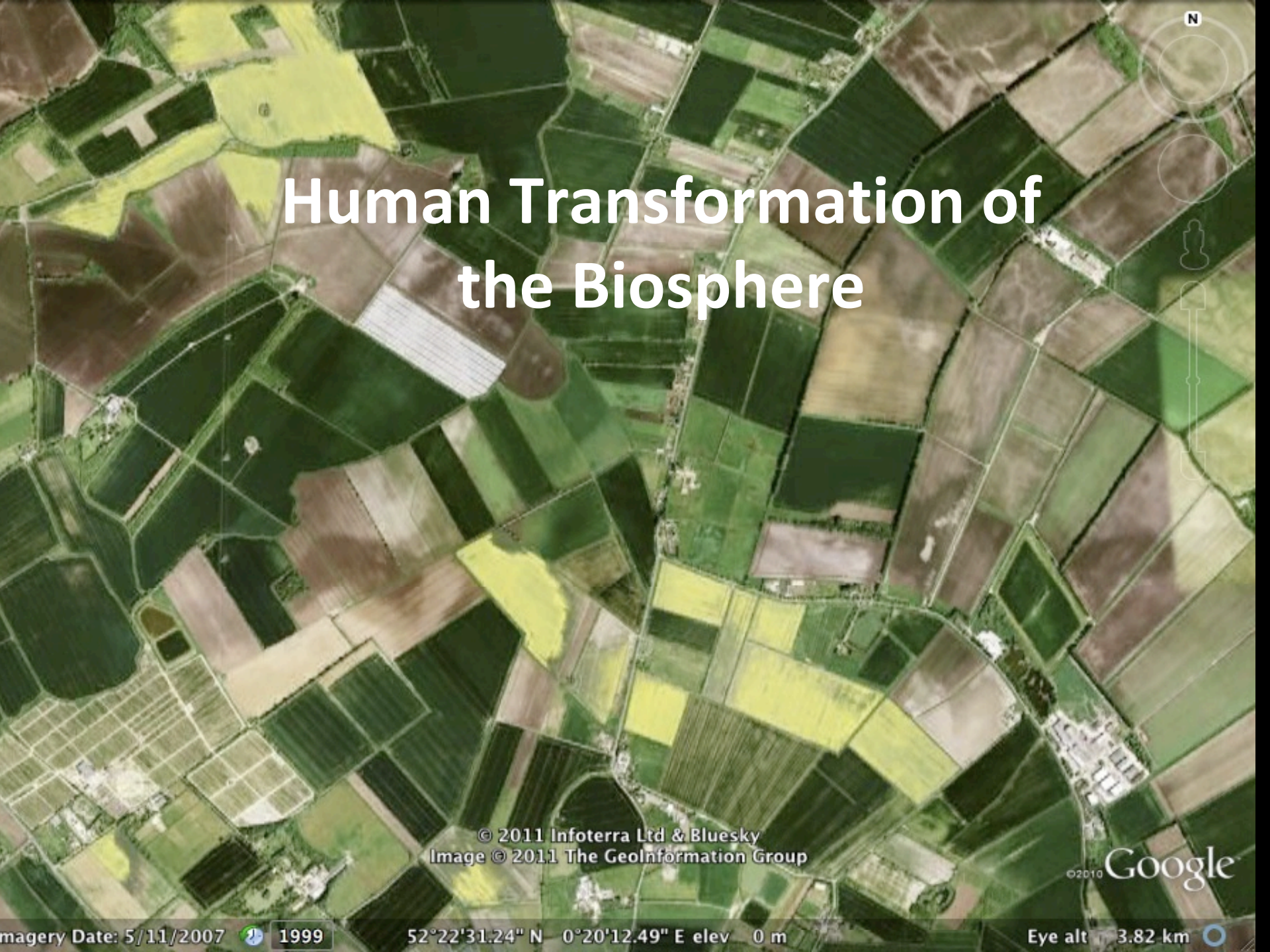
Rate of atmospheric CO_2 increase over the past two decades is about 100 times the maximum sustained rate during the last deglaciation.

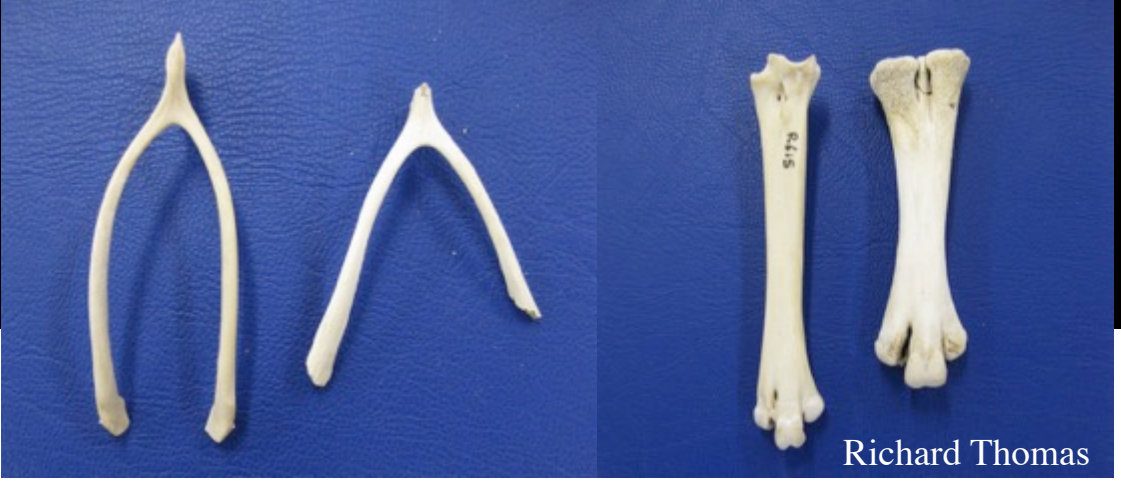
Rate of increase in ocean acidification is unparalleled for at least the last 300 million years.

De Vos et al. 2014; Wolff 2011; Marcott et al. 2013; NOAA 2016; Canfield et al. 2010

Climate Change: Worsening Extreme Weather

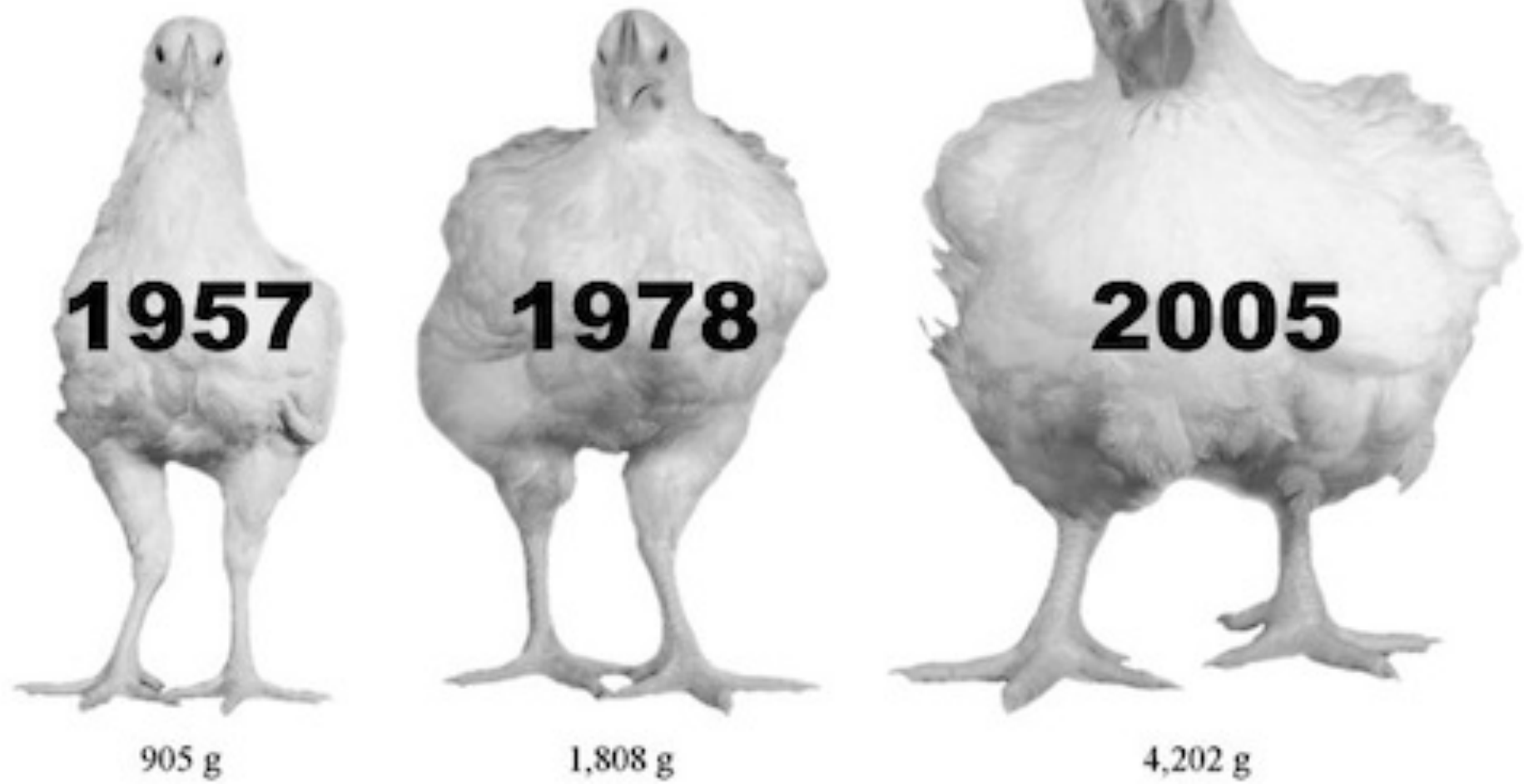



Human Transformation of the Biosphere
© 2011 Infoterra Ltd & Bluesky
Image © 2011 The GeoInformation Group
©2010 Google
magery Date: 5/11/2007
1999
52°22'31.24" N 0°20'12.49" E elev 0 m
Eye alt 3.82 km

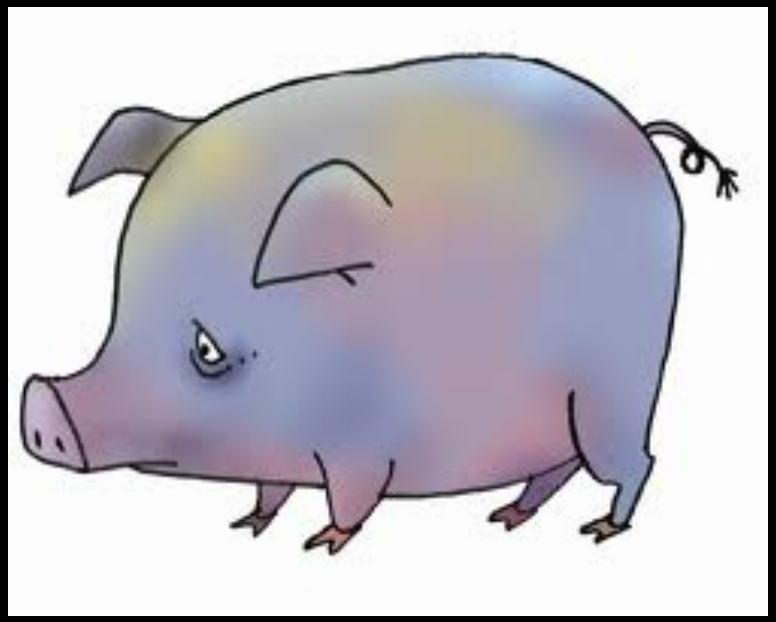


The Anthropocene chicken

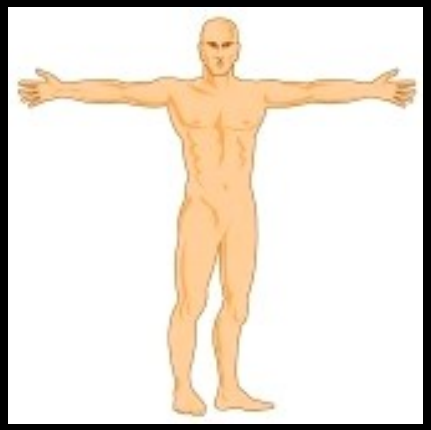
J. Zalasewicz 2015



Terrestrial vertebrate biomass



Domesticated animals
ca 65%

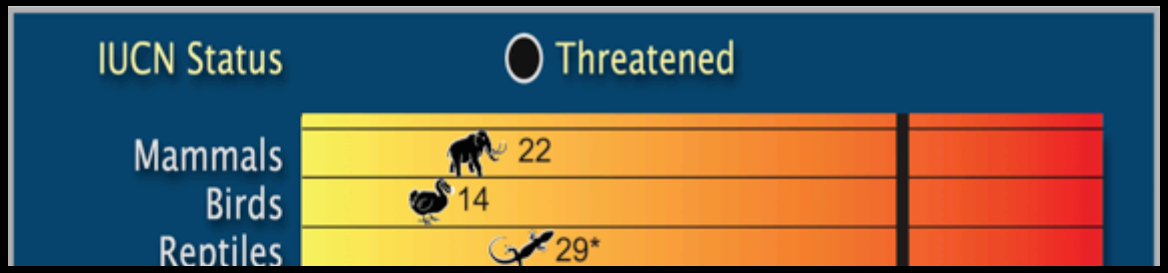


Humans
ca 32%

Vertebrate
wildlife
< 3%

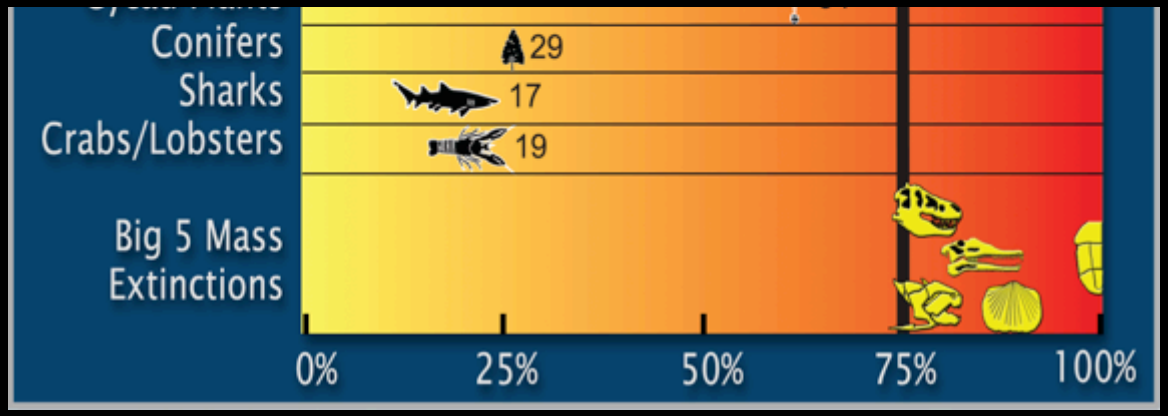
Smil 2002

Mass extinction plausible within two to three human lifetimes



Current extinction rates are 10s to 100s higher than the background level.

Ceballos et al. 2015



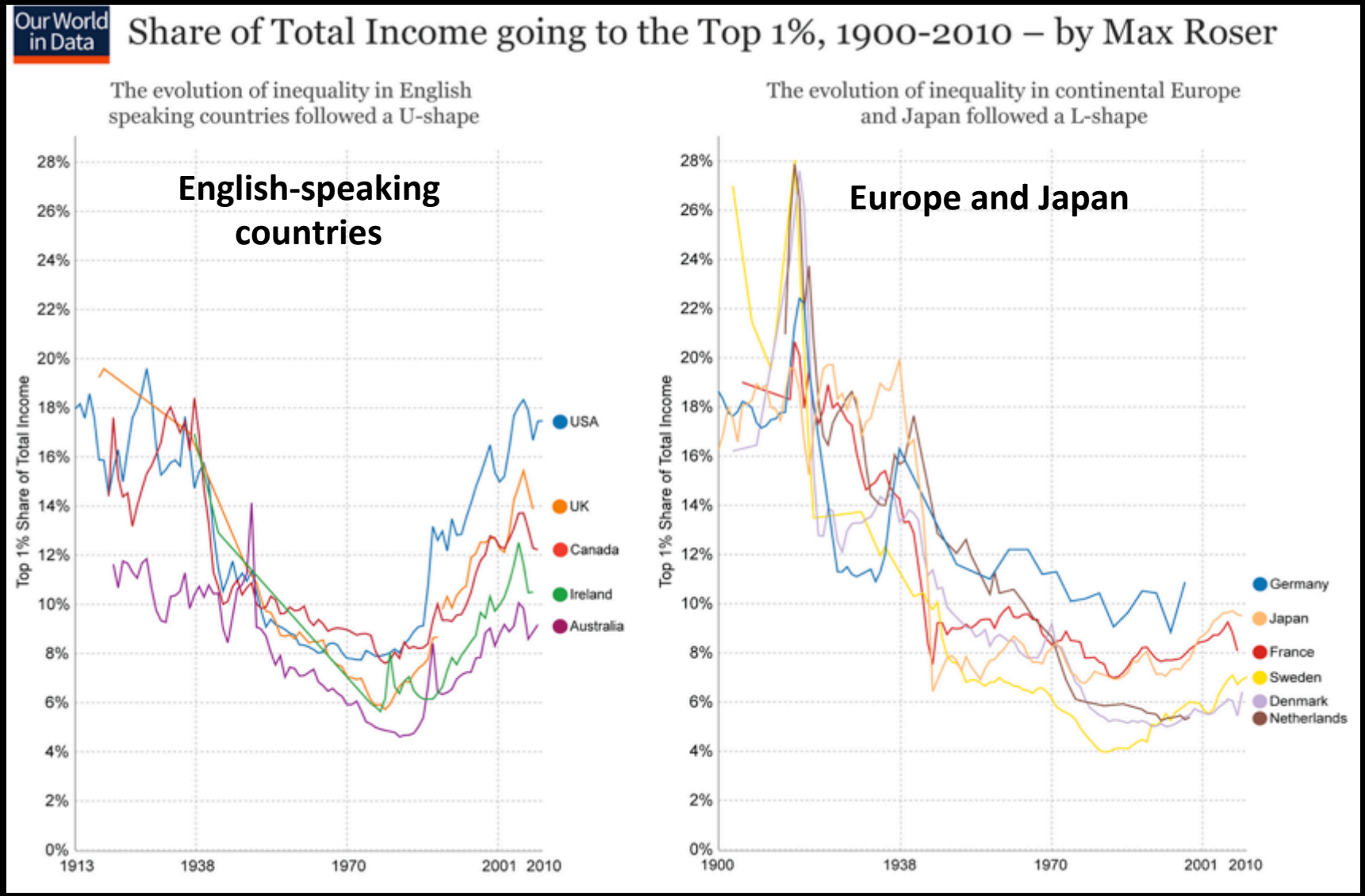
Source: A Barnosky

The climate system, the biosphere…

What about humans and our systems?


TIME
DECEMBER 9, 1985
$1.95
SPIES, SPIES EVERYWHERE
The U.S. Roundup Accelerates
Children Having Children
Teen Pregnancy In America
101
TIME
SPECIAL REPORT/SCHOOL VIOLENCE
Is Jeff Gordon good for NASCAR? JIM CRAMER on should you day trade
HOW TO SPOT A TROUBLED KID
DEPRESSION: Do pills help or hurt?
How bad is the copycat problem?
The tide turns on guns
SHATTERED LIVES
Portraits From America's Drug War
by Mikki Norris Chris Conrad & Virginia Resner
ANTI SOCIAL BEHAVIOUR
JOE KLEIN: HOW CONSULTANTS RUINED POLITICS
TIME
FLIGHT 93: THE MOVIE
EXCLUSIVE FIRST LOOK
SPECIAL REPORT
DROPOUT NATION
30% of America's high school students will leave without graduating. Here is what one town tells us about the crisis
BY NATHAN THORNBURGH

Evolution of Income Equality



Source: S. van der Leeuw

Health and Social Problems are Worse in More Unequal Countries

Index of:

- Life expectancy
- Math & Literacy
- Infant mortality
- Homicides
- Imprisonment
- Teenage births
- Trust
- Obesity
- Mental illness – incl. drug & alcohol addiction
- Social mobility

Source: Wilkinson & Pickett, The Spirit Level (2009)

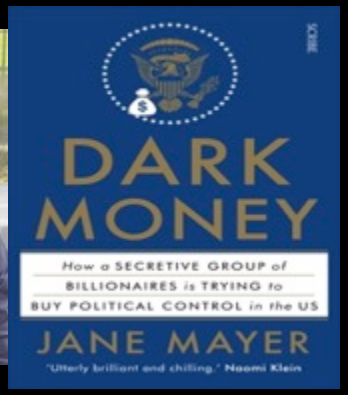
www.equalitytrust.org.uk

The Equality Trust

Pickett and Wilkinson 2015

Capitalism drives inequality in wealth

Capitalism drives climate disruption



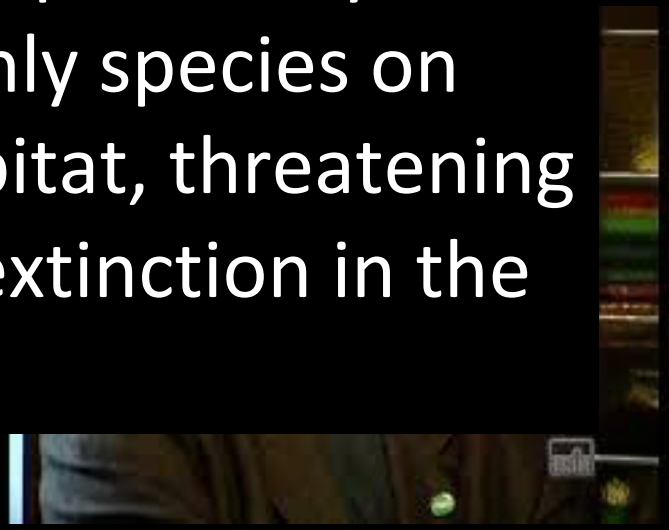
Extreme wealth corrupts political systems

“The astonishing force of consumer culture has swamped traditional customs, values, and aspirations, replacing them with a devotion to money, materialism and branded identities that has left tradition a smoking rubble.”

Fritjof Capra and Pier Luigi Luisi

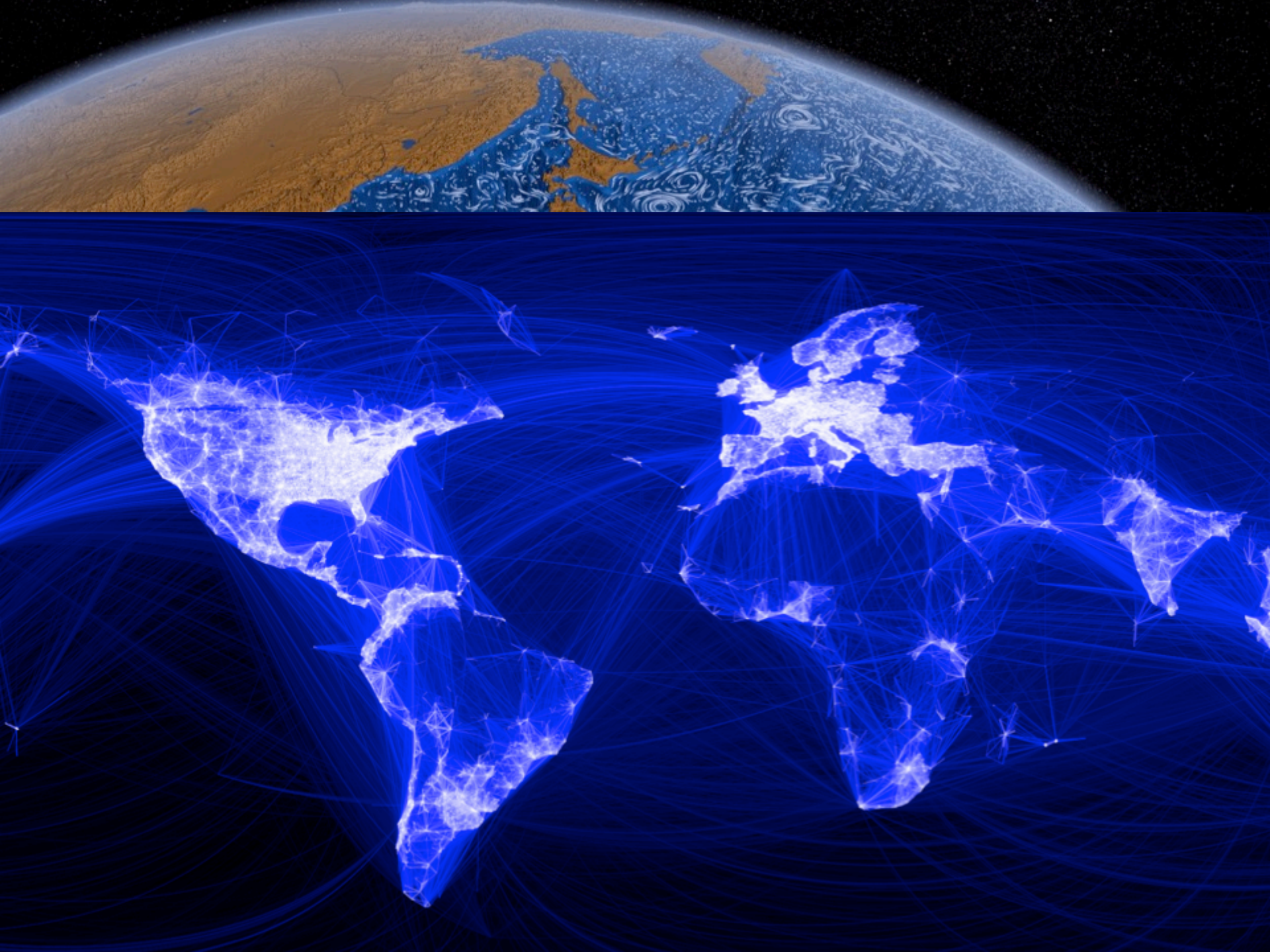
The Systems View of Life

…Our world today is dominated by a global economic system with disastrous social and environmental impacts – “predatory capitalism”.... We are the only species on Earth who destroys its own habitat, threatening countless other species with extinction in the process.



System Incompatibilities?

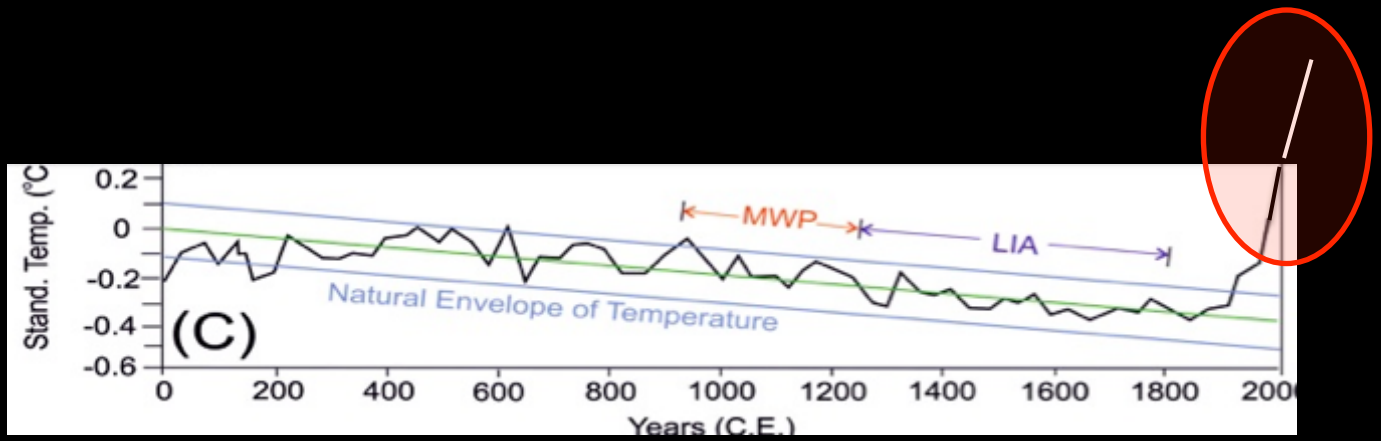
Photo: O.Henriksson/Azote



An Earth System Perspective

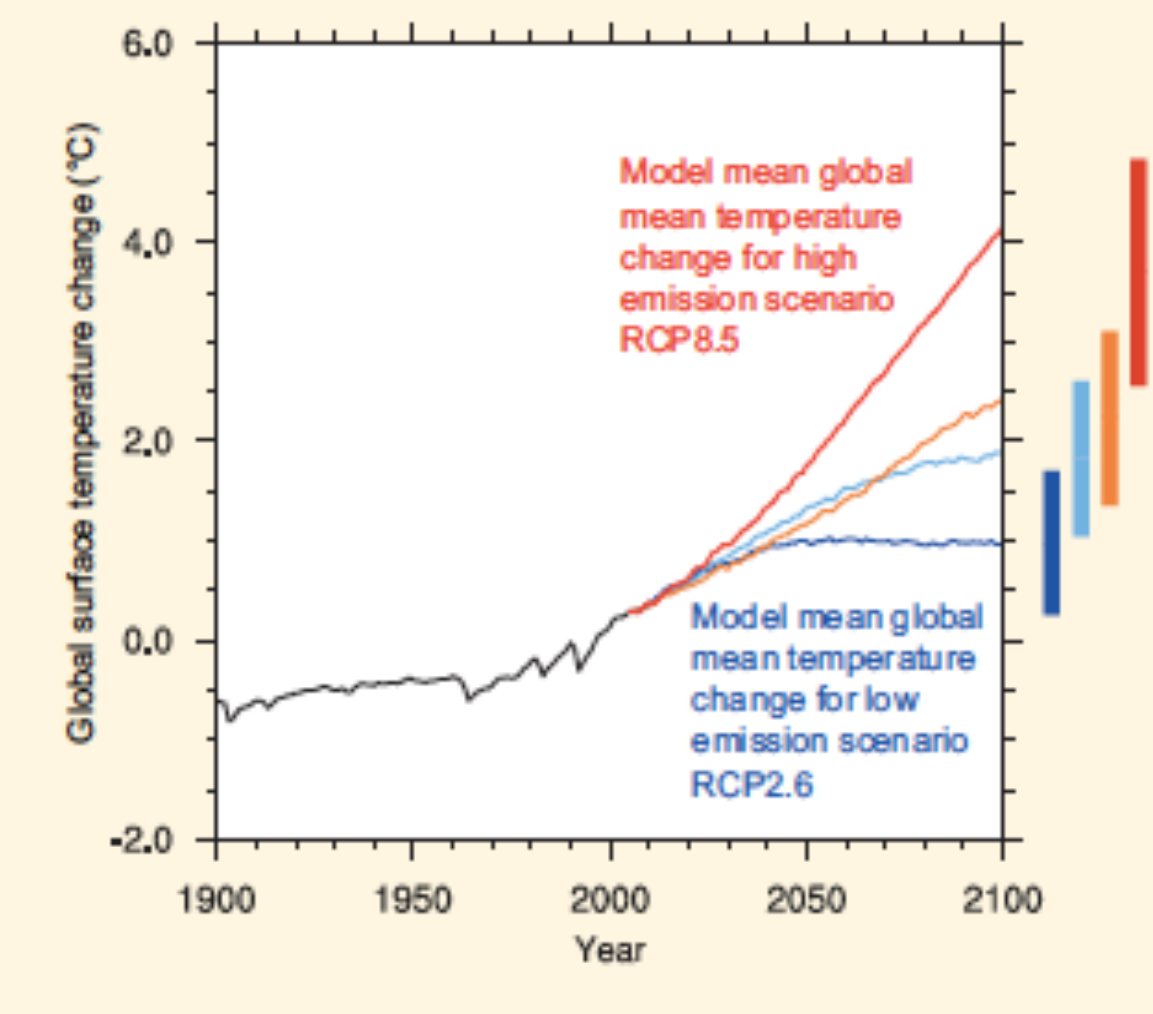
Temperature rise:
Beyond the envelope of natural variability!

Human influence



Summerhayes 2015

IPCC temperature projections



IPCC 2013

Earth System moves to a new state? Severe challenge to contemporary civilisation. Possible collapse?

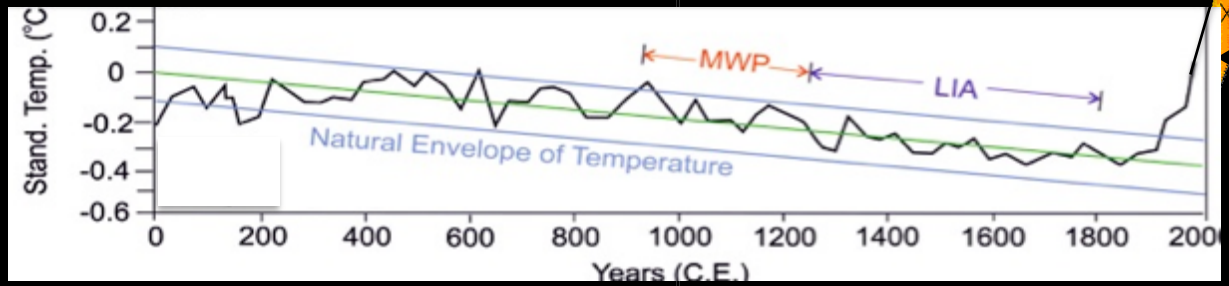
Tipping Points?

Committed

IPCC Projections 2100 AD

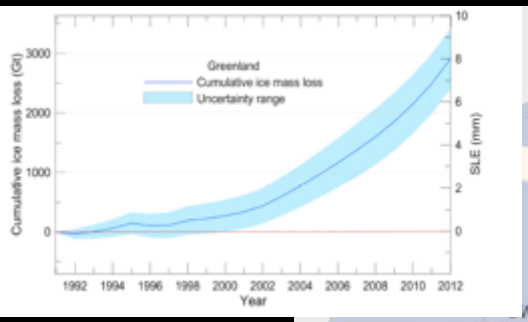
Global Temperature (°C)

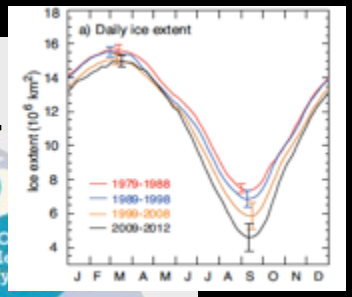
6
5
4
3
2
1
0

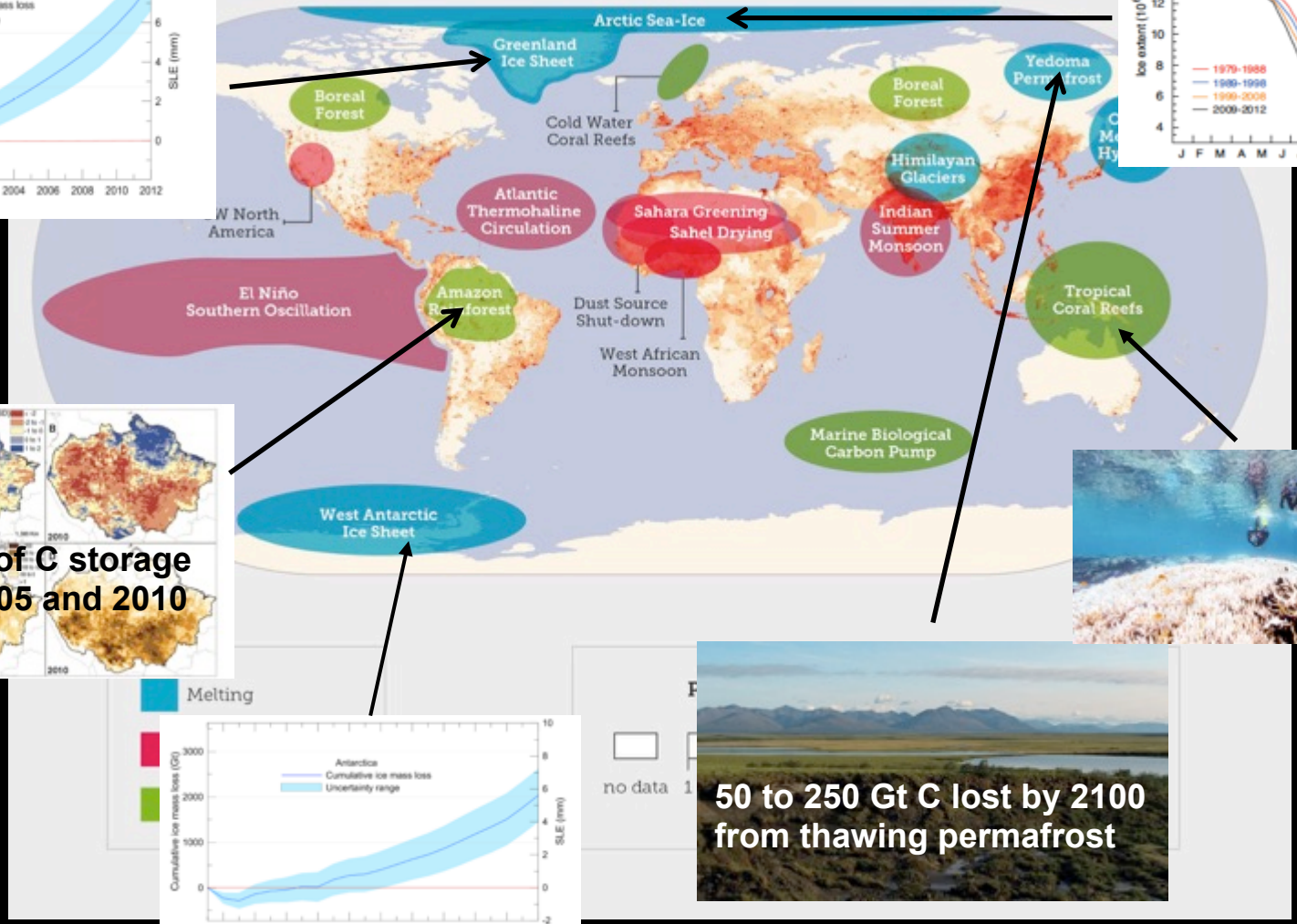


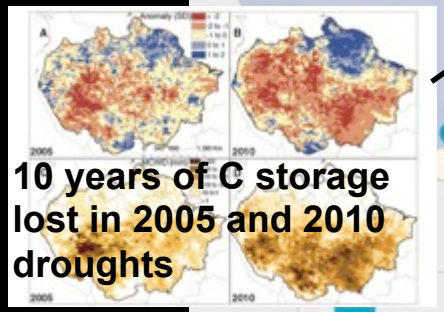
Summerhayes 2015

Tipping Elements in the Earth System

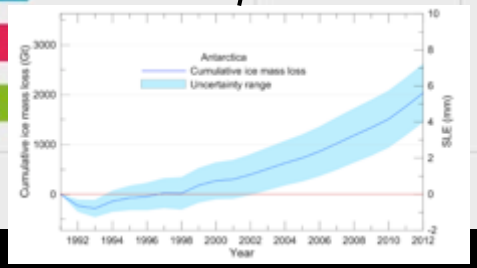








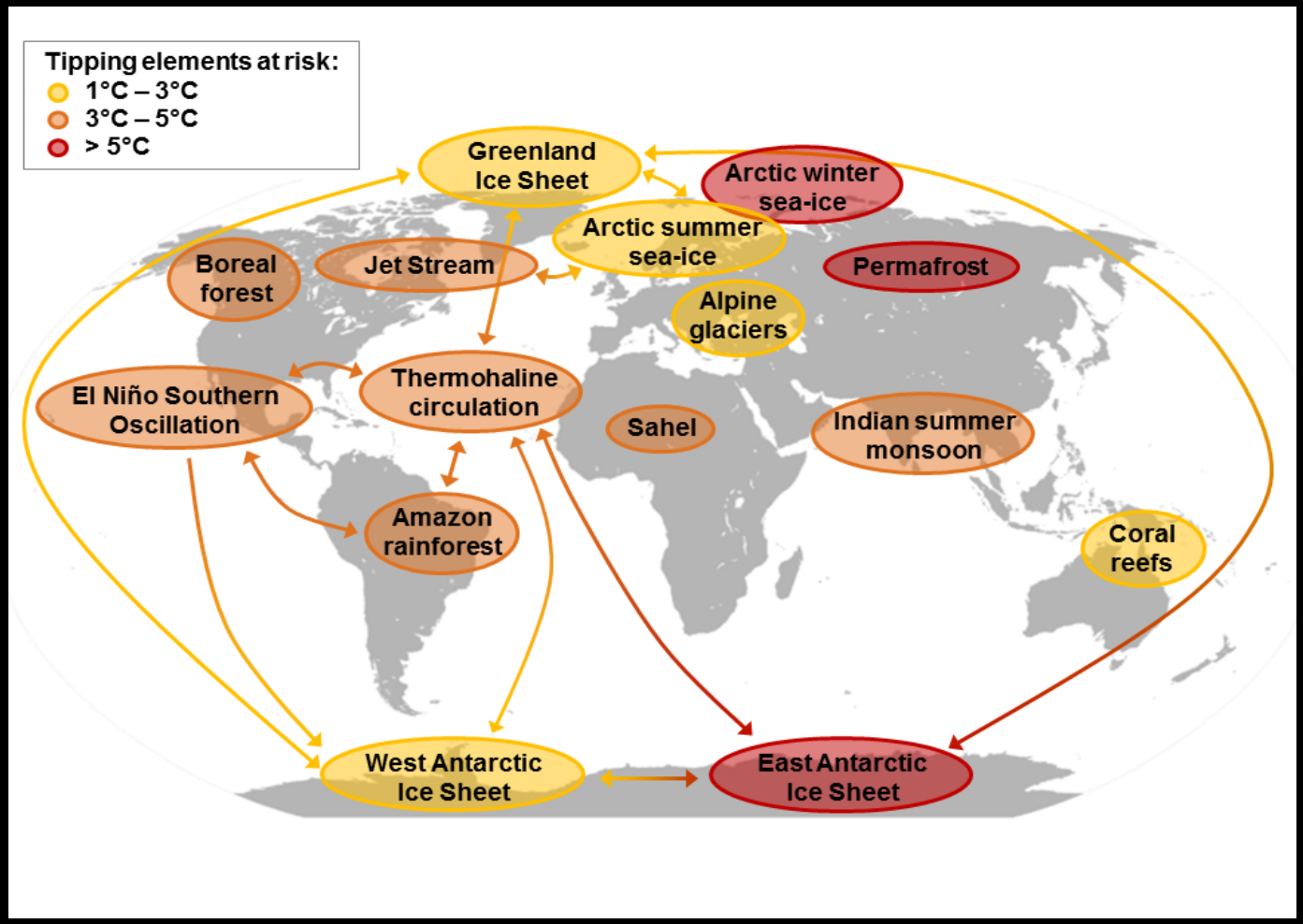
10 years of C storage lost in 2005 and 2010 droughts



50 to 250 Gt C lost by 2100 from thawing permafrost

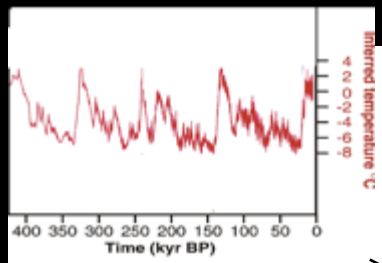
Huber, Lenton, and Schellnhuber, in Richardson et al. 2011

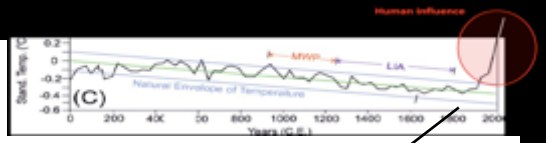
Tipping Cascades



Source: J. Donges and R. Winkelmann
in Steffen et al. 2018

Earth System Trajectories





Time

Glacial-interglacial limit cycle

Holocene

Anthropocene

Earth System stewardship

Human emissions

Biosphere degradation

Planetary threshold

Intrinsic feedbacks

'Stabilized Earth'

Hothouse Earth'

Stability

Temperature

Cold

Hot

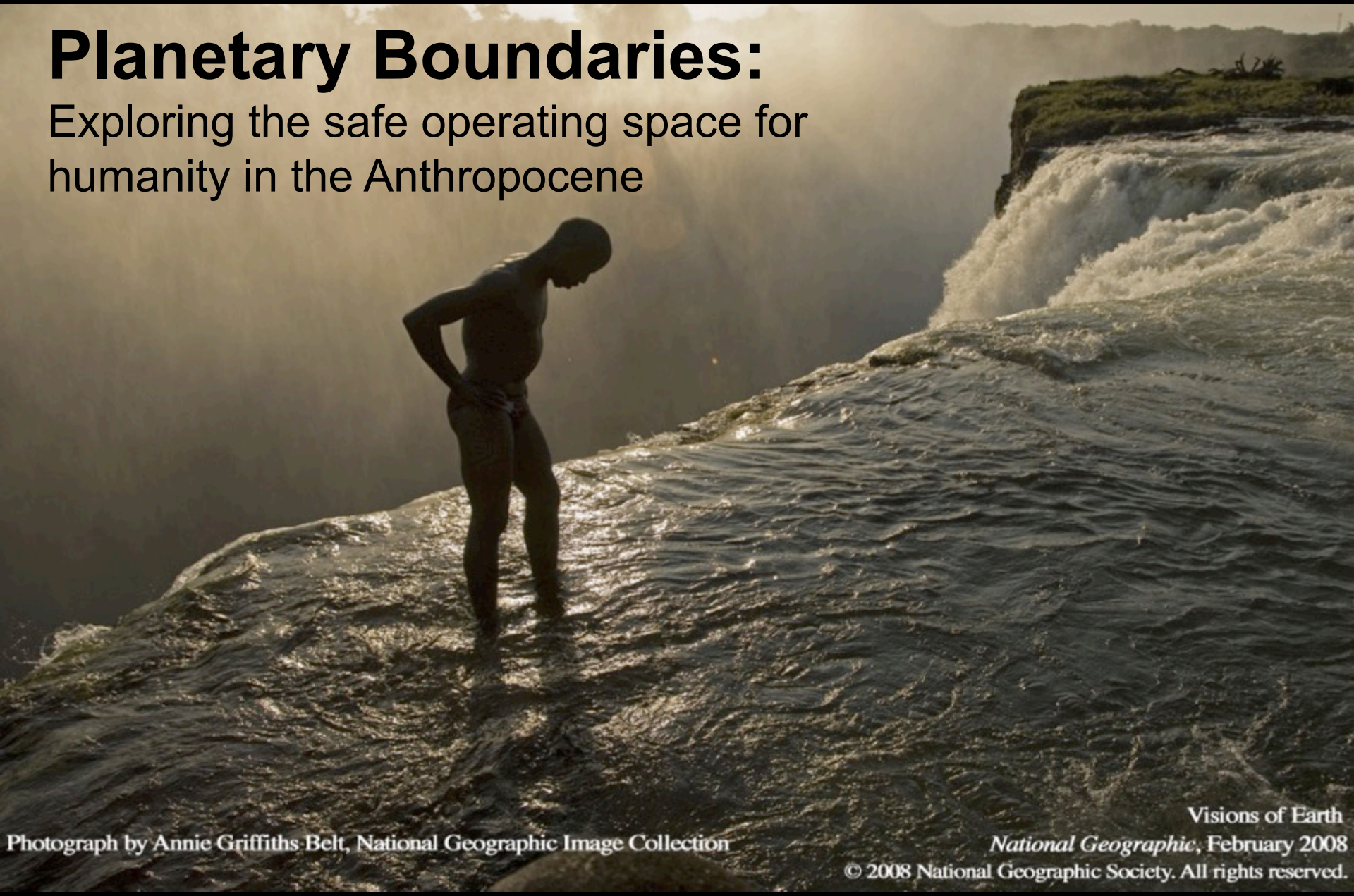
Steffen et al. 2018

Is ‘Hothouse Earth’ inhabitable?

- Most of the tropics and subtropics will be too hot for human habitation.
- Changing temperature & rainfall patterns will likely make current large agricultural zones unproductive.
- Sea-level rise of 20-40 m ultimately likely, drowning coastal cities, agricultural areas and infrastructure.
- Maximum carrying capacity of ~1 billion humans (today’s population is 7.5 billion)

Planetary Boundaries:

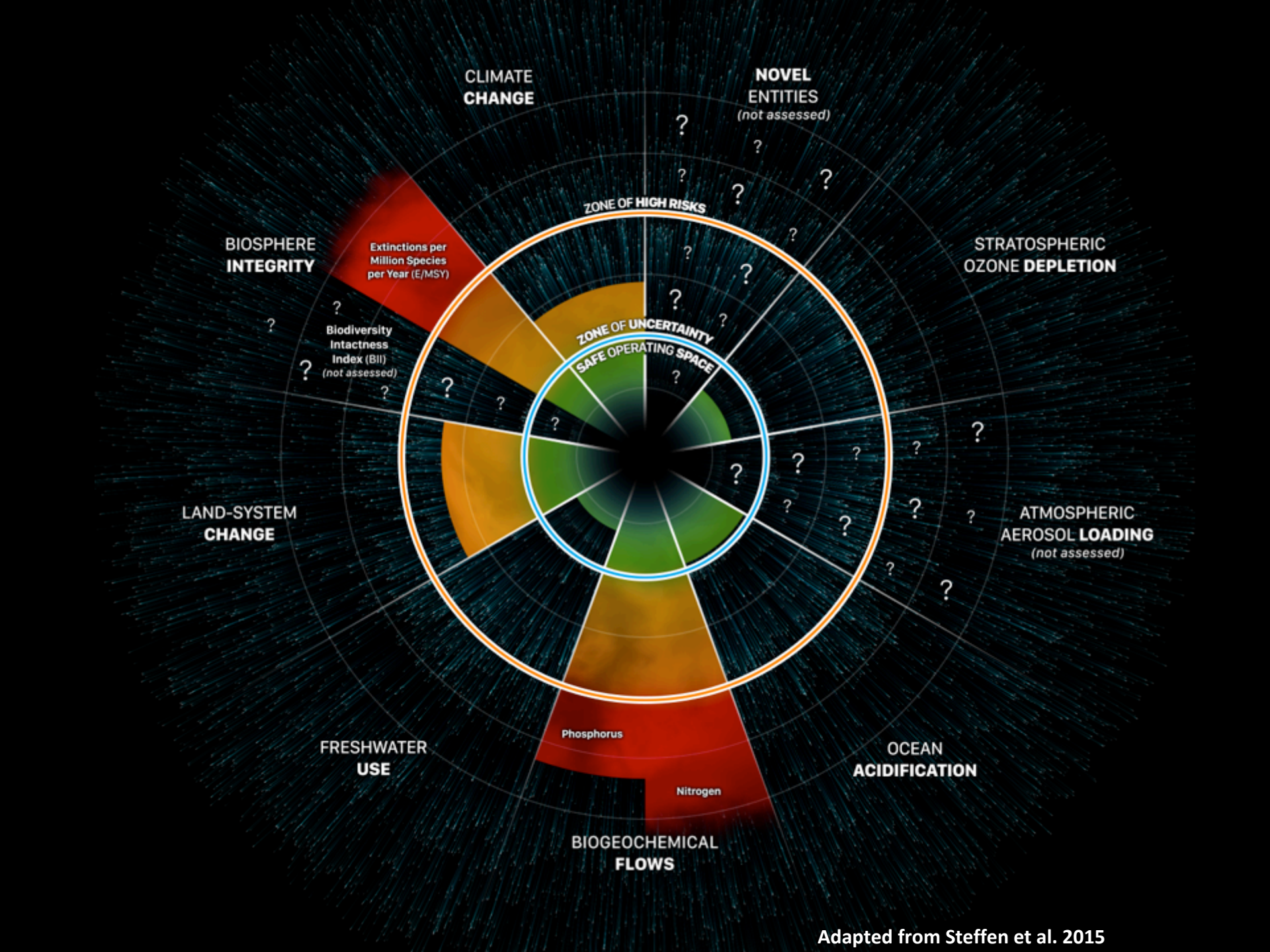
Exploring the safe operating space for humanity in the Anthropocene



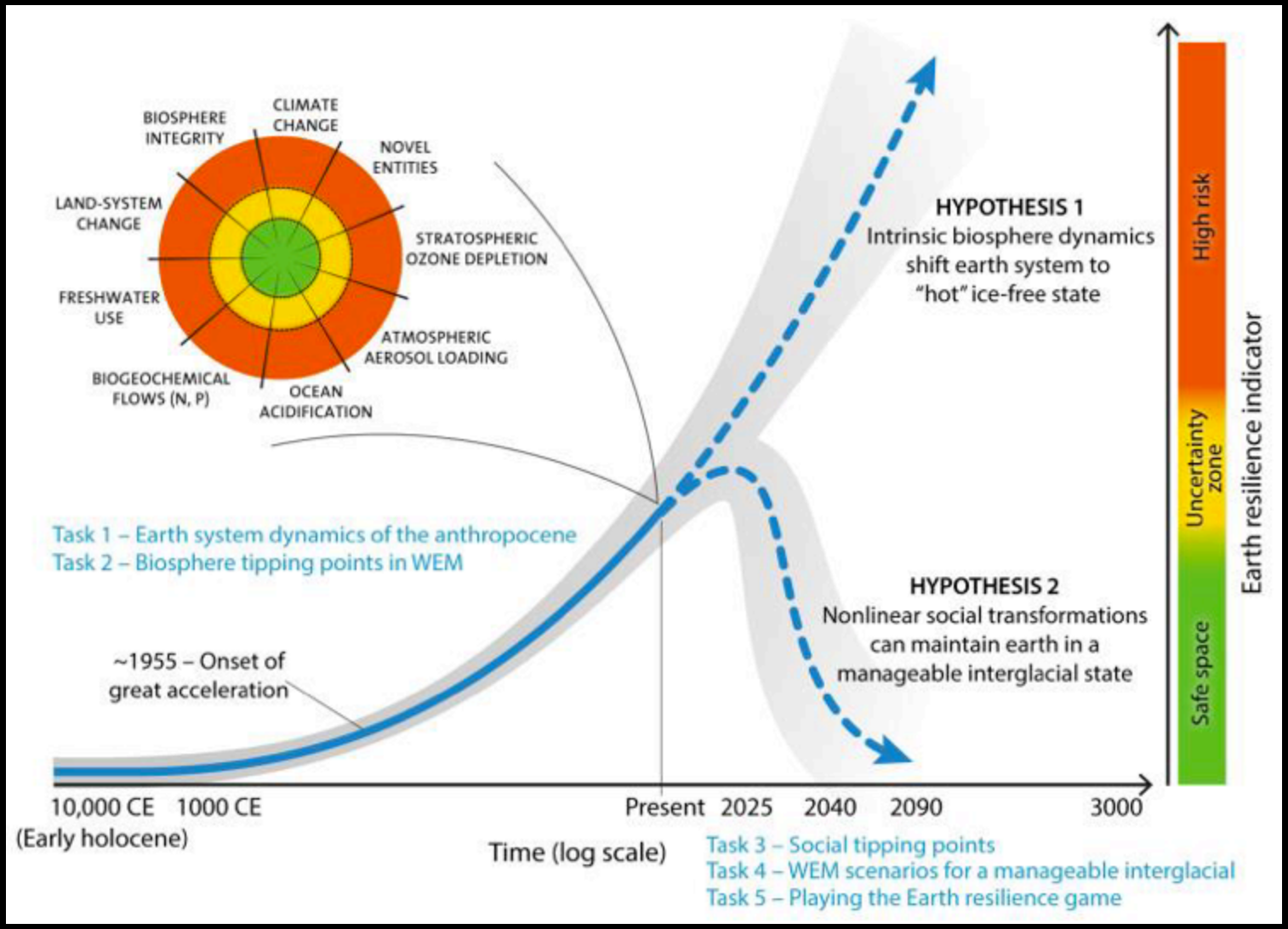
Photograph by Annie Griffiths Belt, National Geographic Image Collection

Visions of Earth

National Geographic, February 2008



Adapted from Steffen et al. 2015


BIOSPHERE INTEGRITY
CLIMATE CHANGE
NOVEL ENTITIES
LAND-SYSTEM CHANGE
STRATOSPHERIC OZONE DEPLETION
FRESHWATER USE
ATMOSPHERIC AEROSOL LOADING
BIOGEOCHEMICAL FLOWS (N, P)
OCEAN ACIDIFICATION
HYPOTHESIS 1
Intrinsic biosphere dynamics shift earth system to "hot" ice-free state
Task 1 – Earth system dynamics of the anthropocene
Task 2 – Biosphere tipping points in WEM
HYPOTHESIS 2
Nonlinear social transformations can maintain earth in a manageable interglacial state
~1955 – Onset of great acceleration
High risk
Uncertainty zone
Safe space
Earth resilience indicator
10,000 CE
(Early holocene)
1000 CE
Present
2025
2040
2090
3000
Time (log scale)
Task 3 – Social tipping points
Task 4 – WEM scenarios for a manageable interglacial
Task 5 – Playing the Earth resilience game

Planetary Boundaries:

a potentially valuable framework for guiding policy directed at achieving sustainable development

- **OECD Environmental Outlook 2012**
- **Global Energy Assessment 2012**
- **UNEP 2012**
- **UN High-level Panel on Global Sustainability (GSP) 2012**
- **UN Sustainable Development Solutions Network**
- **World Economic Forum 2013**
- **World Economic Forum 2015**
- **…**

Common Home of Humanity

A blueprint for global governance

What if we thought of the Earth as an immense condominium?

The CHH Architecture