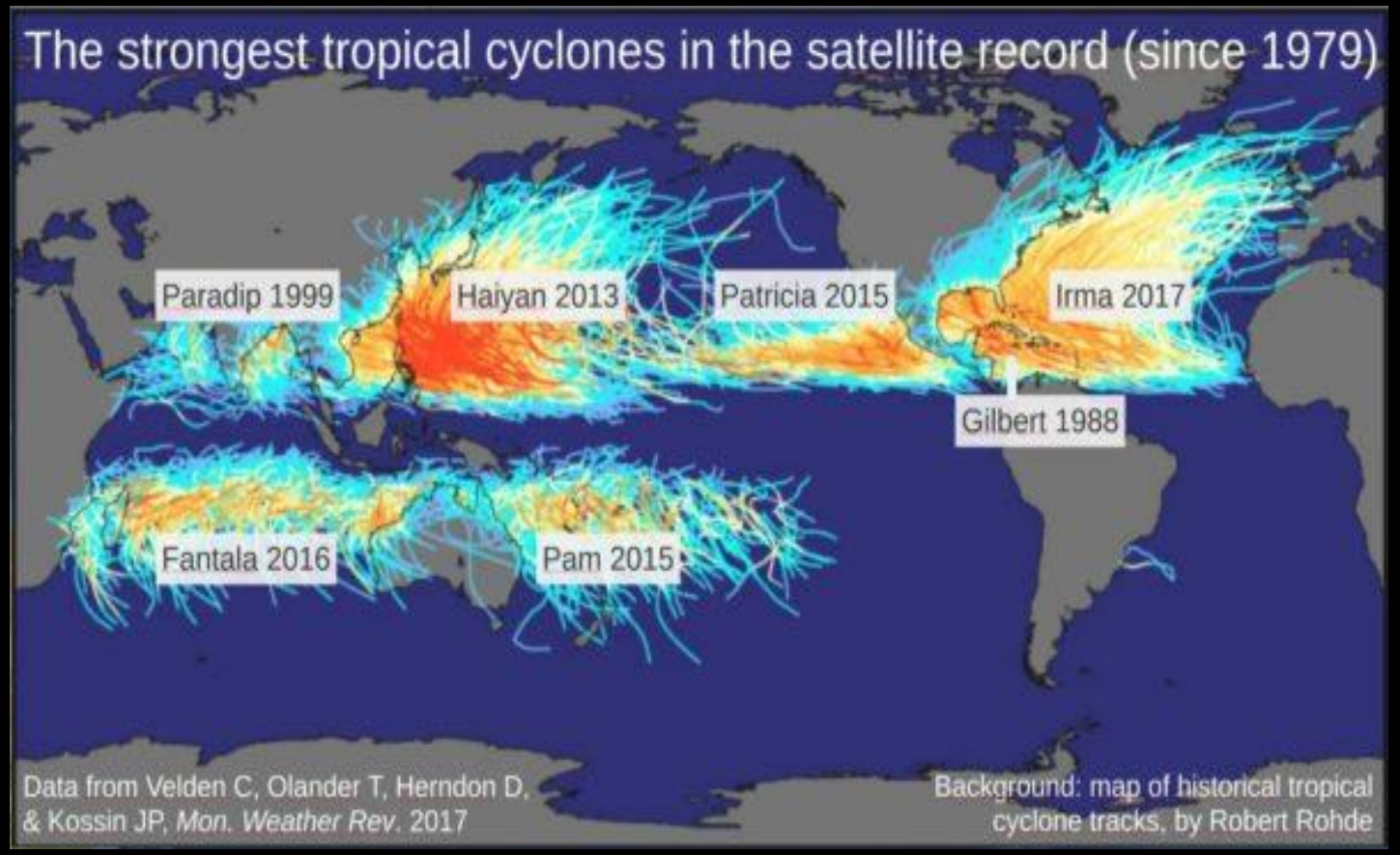
The Anthropocene:
Where on Earth are We Going?

Will Steffen
Emeritus Professor, Australian National University
Senior Fellow, Stockholm Resilience Centre

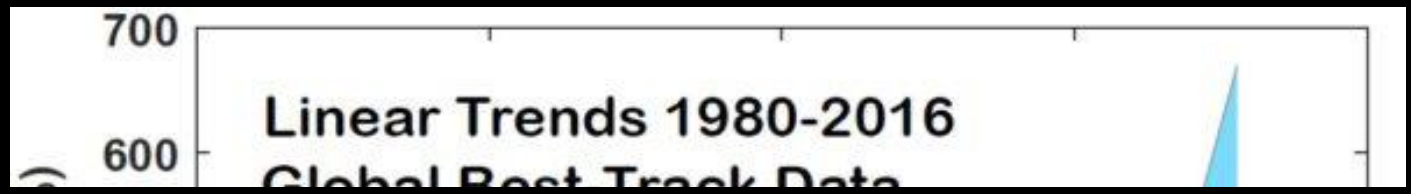
Climate Change: Worsening Extreme Weather

Increase in Intense Tropical Cyclones



Rahmstorf, Emanuel, Mann and Kossin 2018

Increase in Intense Tropical Cyclones

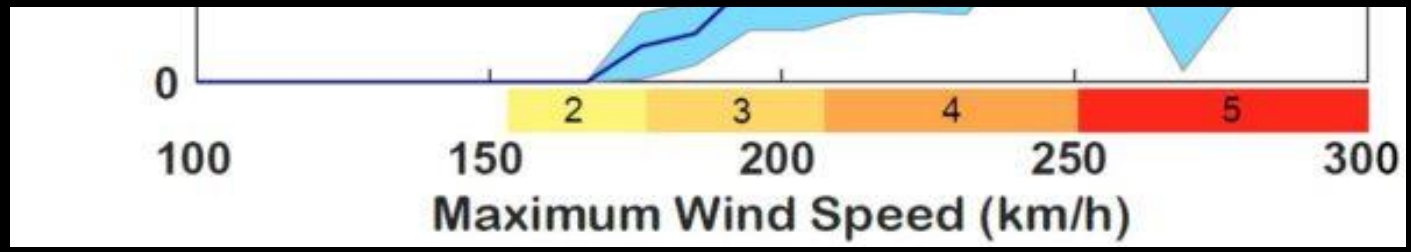


Significant global increase in cyclones with maximum wind speed of 175 km/h or higher.

Storms of 200 km/h and more have doubled in number.

Storms of 250 km/h and more have tripled in number.

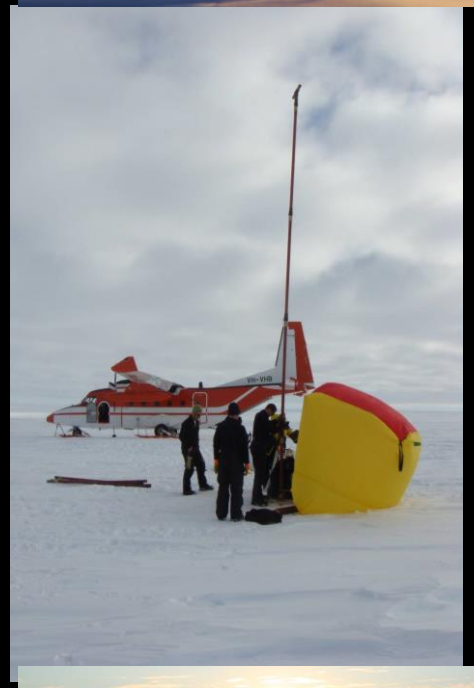
Proposal for a new Category 6 for most intense cyclones.



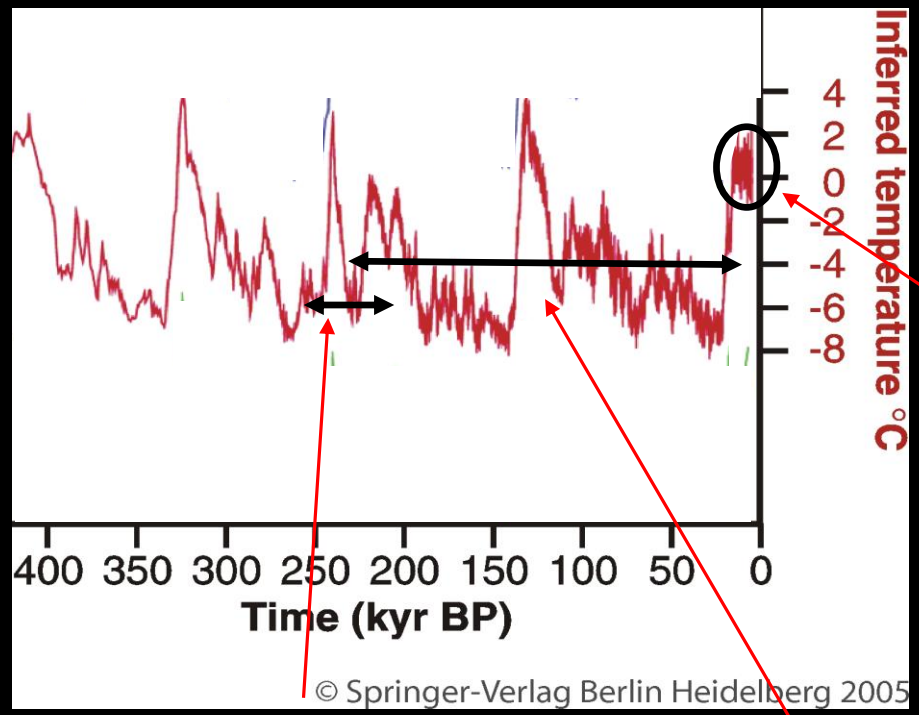
Rahmstorf, Emanuel, Mann and Kossin 2018

Our planet is a single system…

…the Earth System



Human Development
and
the Earth System



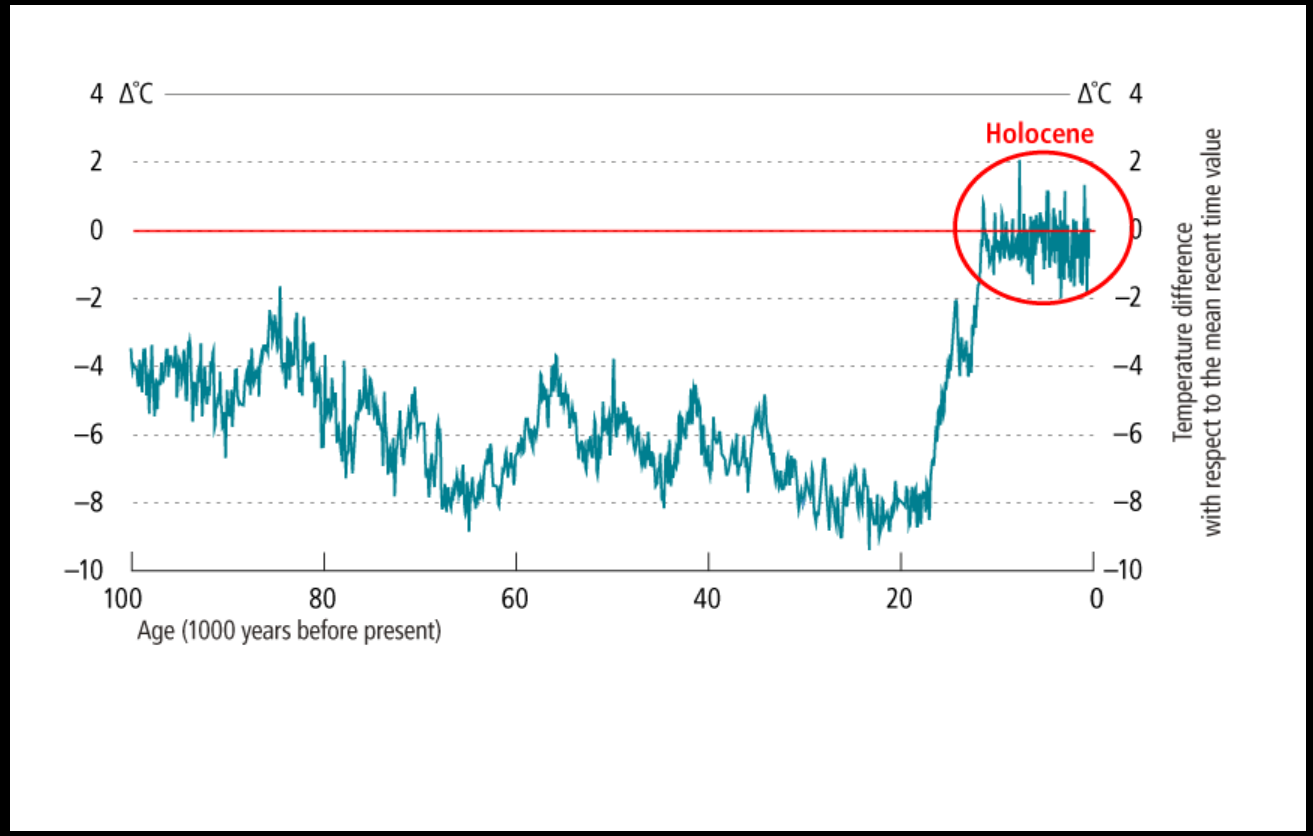
Beginning of agriculture

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



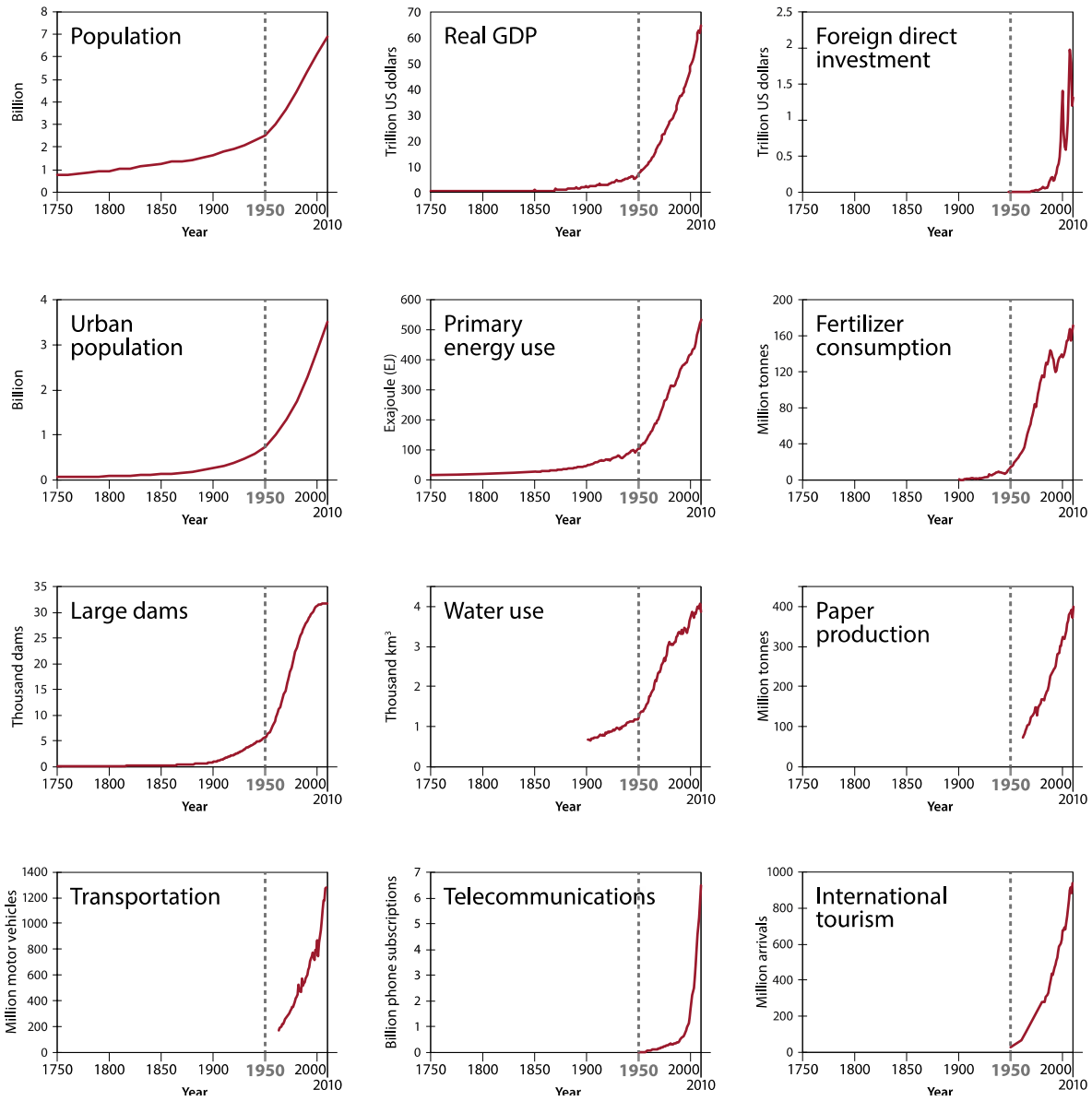
Source: J. Rockström and N. Nakicenovic
Data from Petit et al. 1999 and Oppenheimer 2004

The Great Acceleration

The Human Enterprise

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

Socio-economic trends



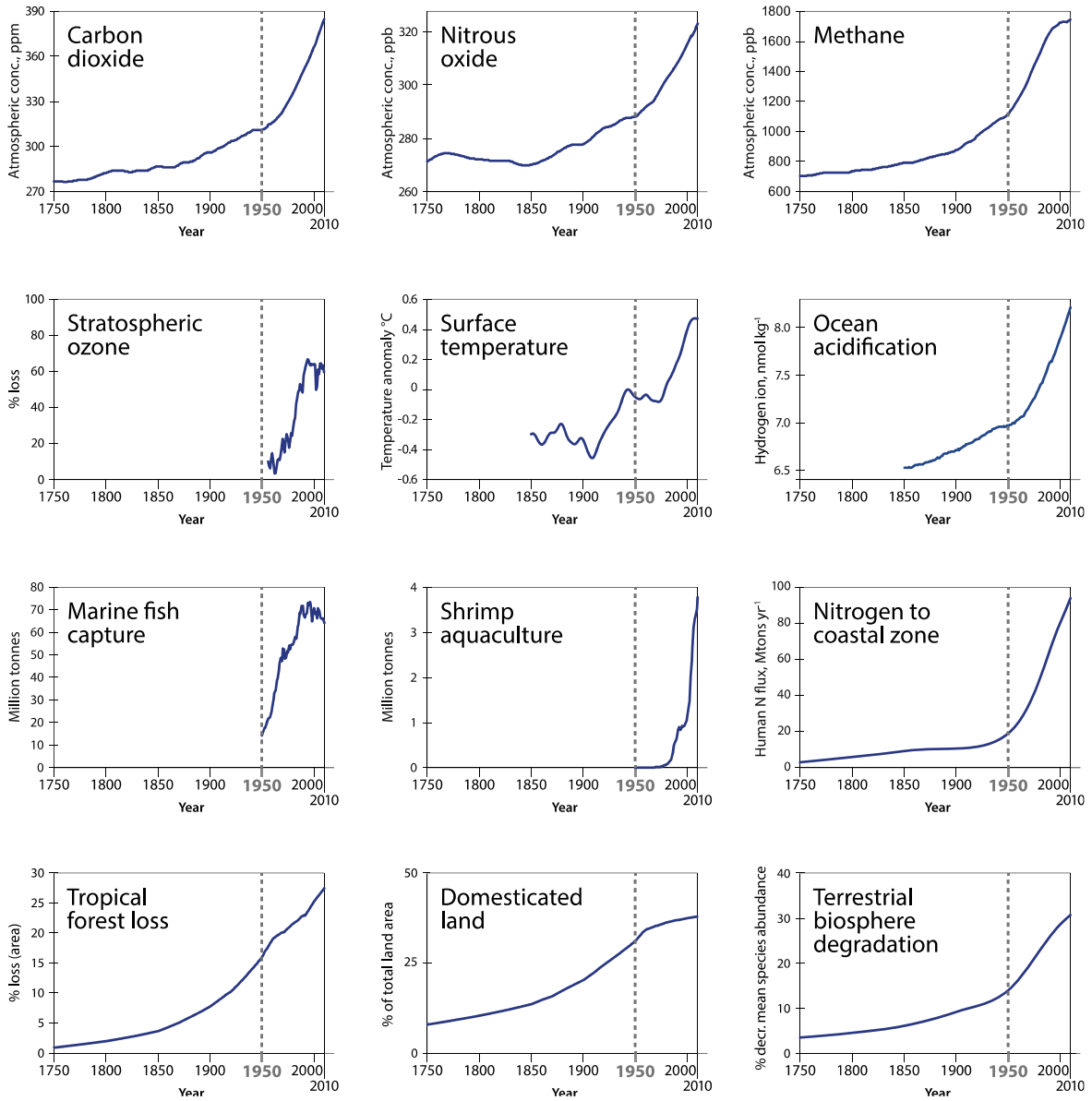
Steffen et al. 2015

The Great Acceleration

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 Holocene mankind's activities gradually grew into a significant geological, morphological force, as recognised early on by a number of scientists. Thus, G.P. Marsh already in 1864 published a book with the title "Man and Nature", more recently reprinted as "The Earth as Modified by Human Action" (2). Stoppani in 1873 rated mankind's activities as a "new telluric force which in power and universality may be compared to the greater forces of earth" [quoted from Clark (3)]. Stoppani already spoke of the anthropozoic era. Mankind has now inhabited or visited almost all places on Earth; he has even set foot on the moon.

The great Russian geologist V.I. Vernadsky (4) in 1926 recognized the increasing power of mankind as part of the biosphere with the following excerpt "... the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings". He, the French Jesuit P. Teilhard de

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 years. The release of SO_2, globally about 160 Tg/year to the atmosphere by coal and oil burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine dimethyl-sulfide from the oceans (7); from Vitousek et al. (8) we learn that 30-50% of the land surface has been transformed by human action; more nitrogen is now fixed synthetically and applied as fertilizers in agriculture than fixed naturally in all terrestrial ecosystems; the escape into the atmosphere of NO from fossil fuel and biomass combustion likewise is larger than the natural inputs, giving rise to photochemical ozone ("smog") formation in extensive regions of the world; more than half of all accessible fresh water is used by mankind; human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain forests (9) and several climatically important "greenhouse" gases have substantially increased in the atmosphere: CO_2 by more

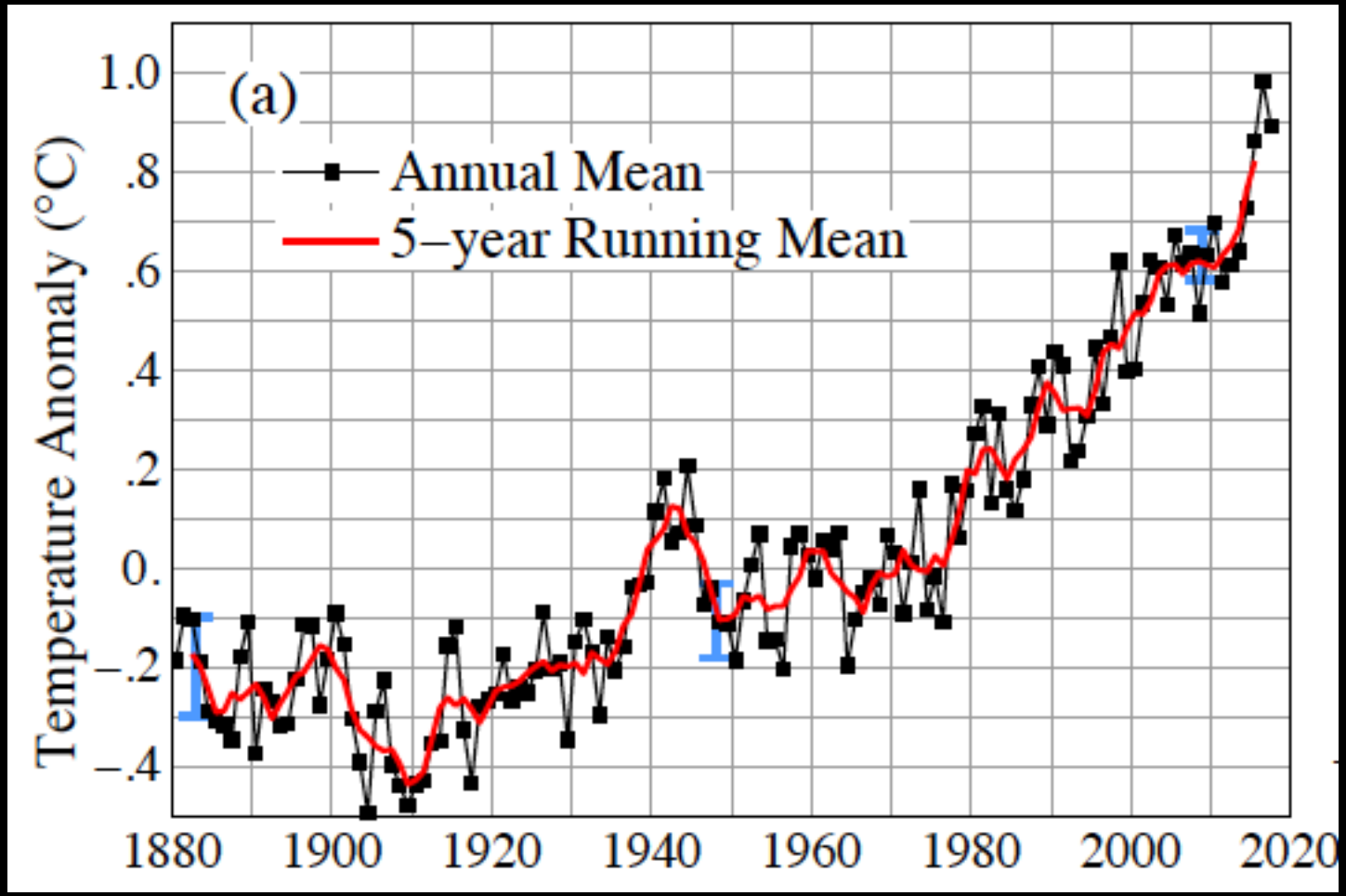
groves. Finally, mechanized human p
dation ("fisheries") removes more th
25% of the primary production of t
oceans in the upwelling regions and 3
in the temperate continental shelf
gions (10). Anthropogenic effects are a
well illustrated by the history of biotic communities that leave remains in lake sediments. The effects documented include modification of the geochemical cyde in large freshwater systems and occur in systems remote from primary sources (11-13).

Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "anthropocene" for the current geological epoch. The impacts of current human activities will continue over long periods. According to a study by Berger and Loutre (14), because of the anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour over the next 50,000 years.

To assign a more specific date to the onset of the "anthropocene" seems somewhat arbitrary, but we propose the latter part of the 18th century, although

Climate Change

Global Average Temperature Anomaly, 1880-2017

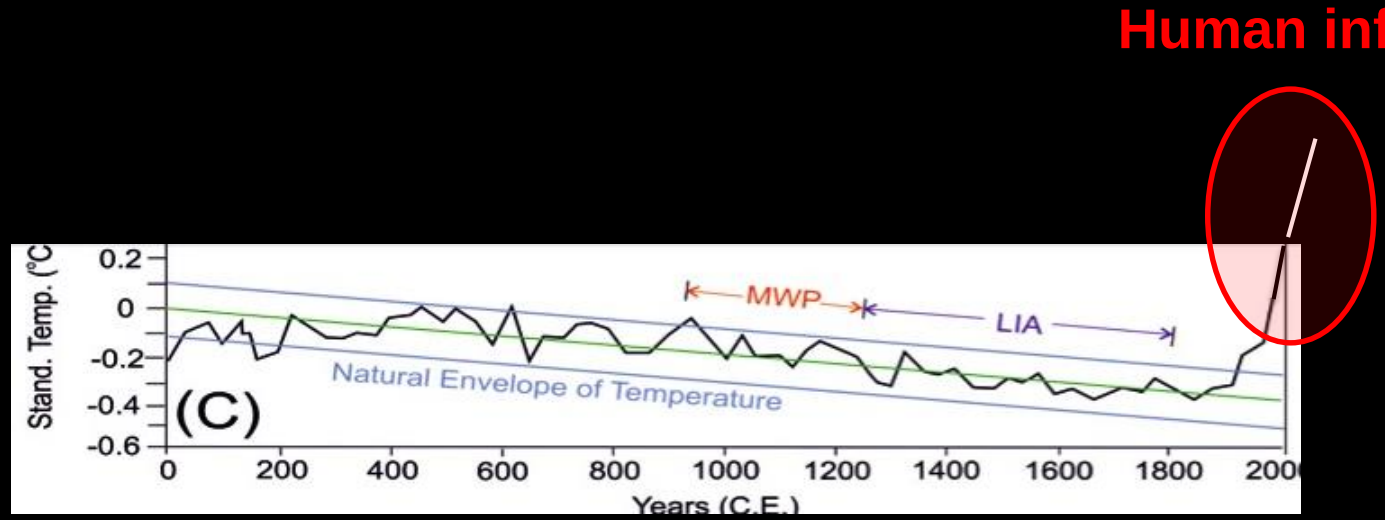


Baseline is 1951-1980

NASA 2018

An Earth System Perspective

Temperature rise:
Beyond the envelope of natural variability!



Summerhayes 2015

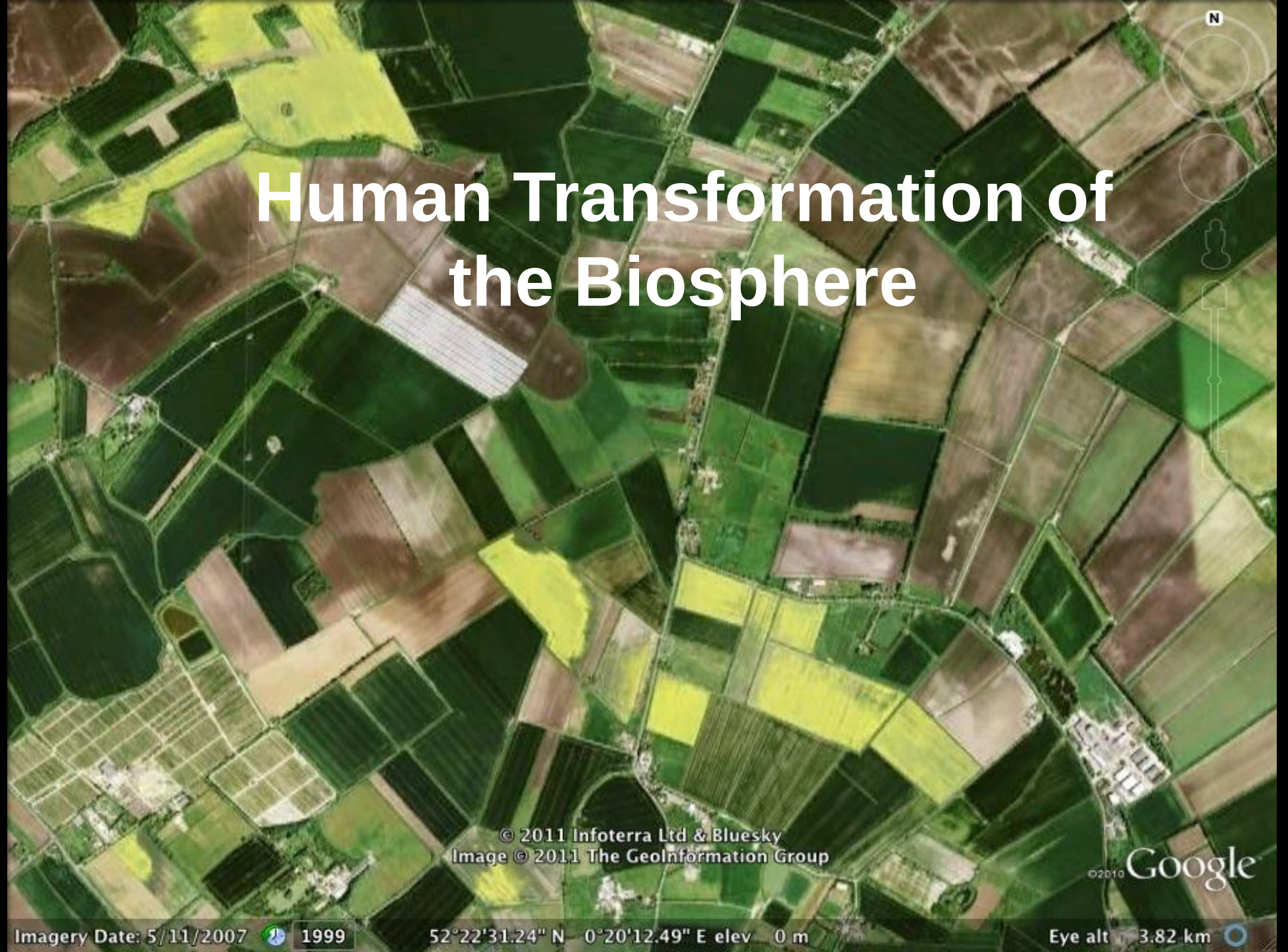
Rates of Change

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.

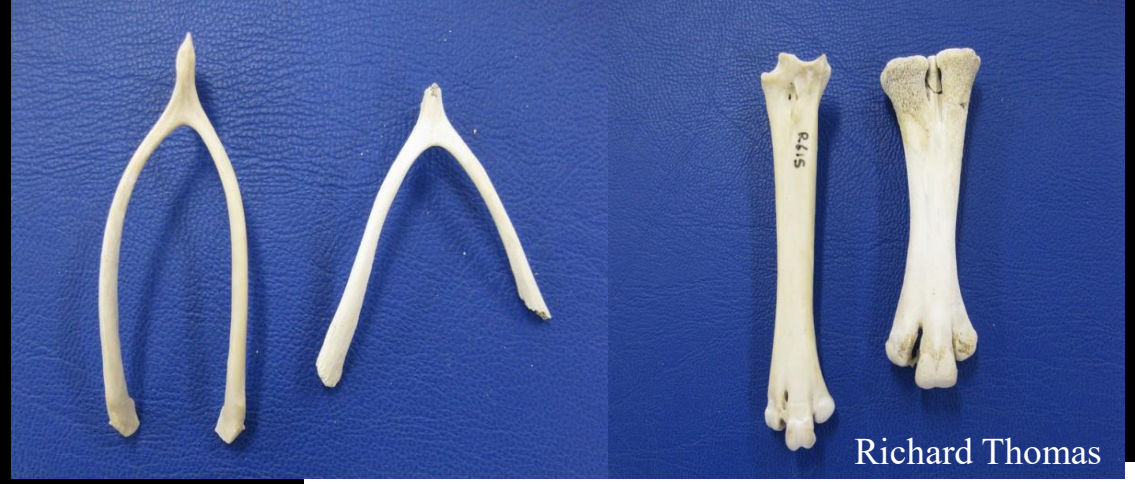
Rate of atmospheric CO_2 increase over the past two decades is about 100 times the maximum sustained rate during the last deglaciation.

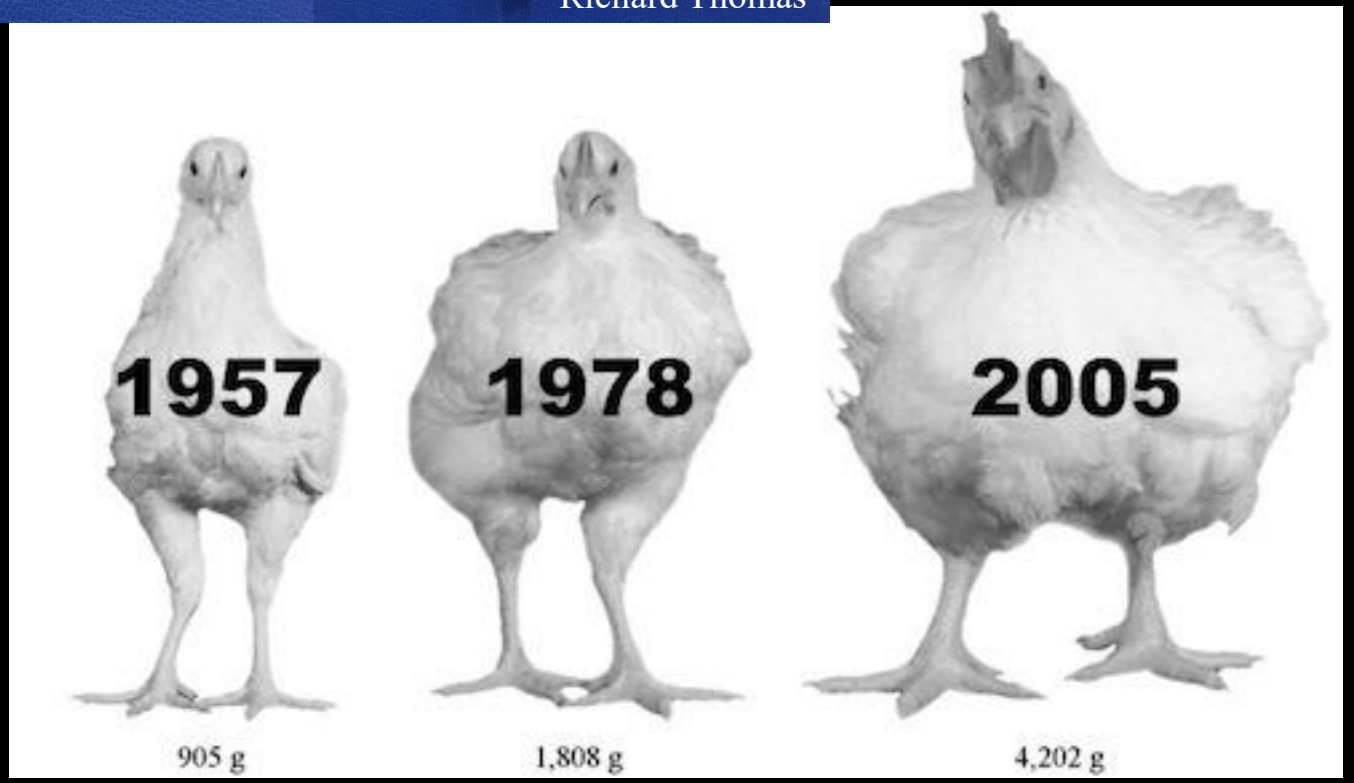
Rate of increase in ocean acidification is unparalleled for at least the last 300 million years.

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

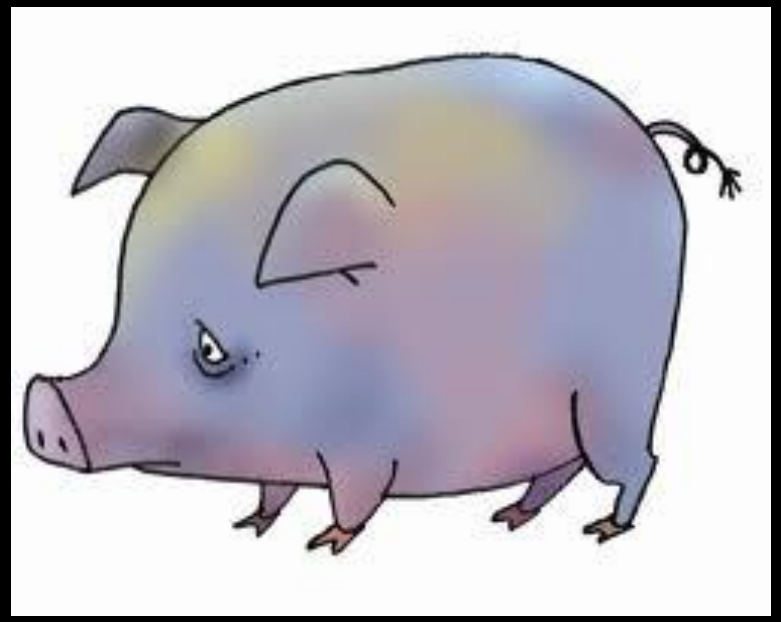

Human Transformation of the Biosphere
© 2011 Infoterra Ltd & Bluesky
Image © 2011 The GeoInformation Group
©2010 Google
Imagery Date: 5/11/2007
1999
52°22'31.24" N 0°20'12.49" E elev 0 m
Eye alt 3.82 km

The Anthropocene chicken

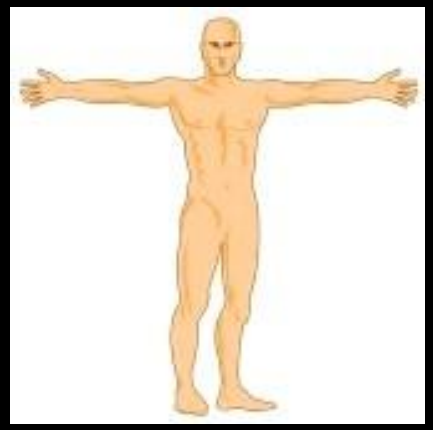




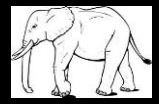
Terrestrial vertebrate biomass



Domesticated animals
ca 65%



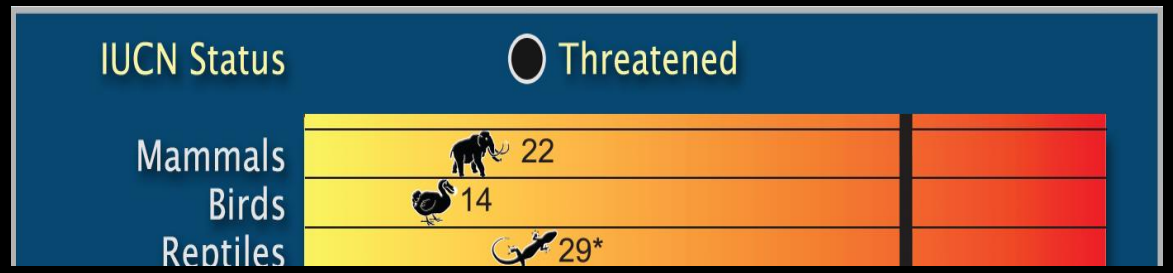
Humans
ca 32%



Vertebrate
wildlife
< 3%

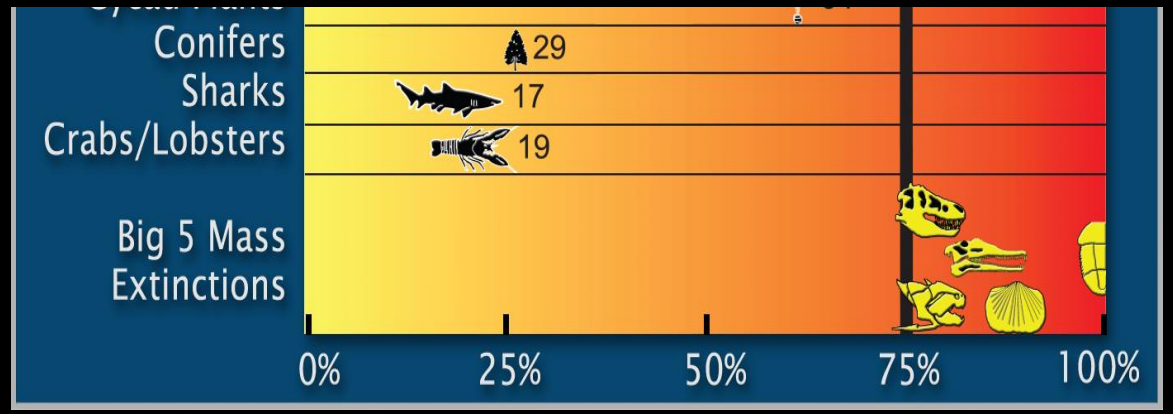
Smil 2002

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

Stratigraphic Definition of the Anthropocene

Have humans changed the Earth System such that geological deposits forming now and in the recent past include a fingerprint distinct from that of the Holocene Epoch?

If so, when has the change become recognizable worldwide?

Source: C.N. Waters et al., *Science*, 2016, (synthesis paper by the Anthropocene Working Group)

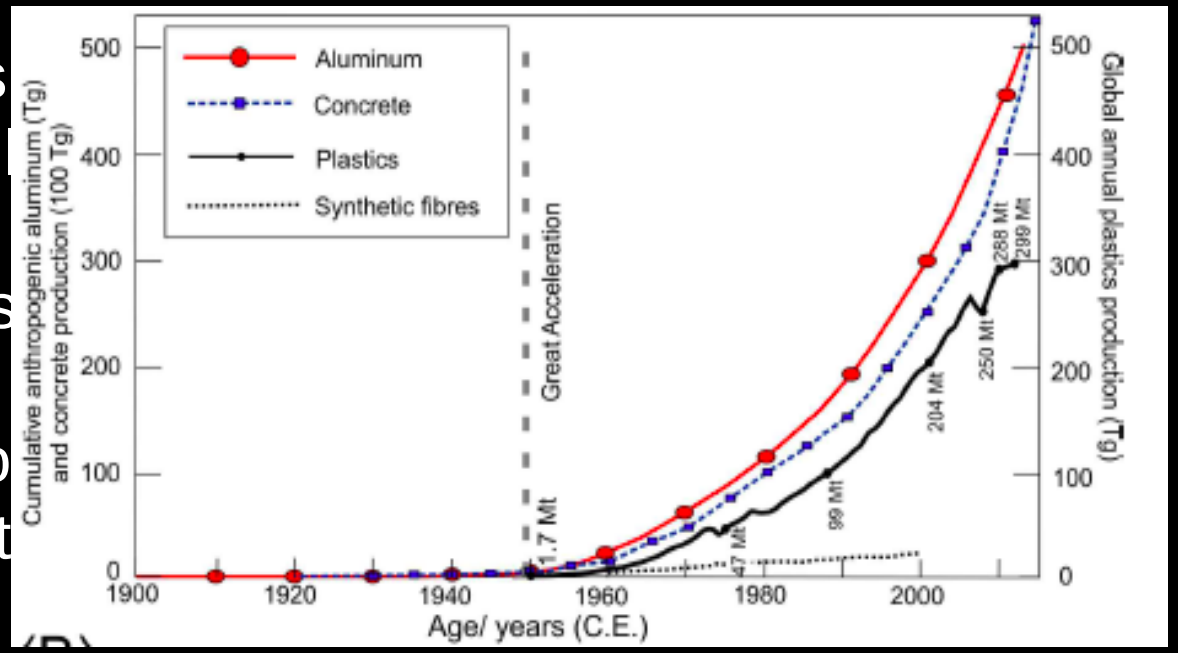
Formalization of the Anthropocene: Current Status

Jan Zalasiewicz, Convenor
Anthropocene Working Group
University of Leicester, UK

Stratigraphic signatures
Holocene norms and wi

Evidence is most consis

Specific stratigraphic co
proposal to the Internat



Waters et al. 2016

The climate system, the biosphere…

What about humans and our systems?

Perspectives and controversies

THE ANTHROPOCENE REVIEW

The geology of mankind? A critique of the Anthropocene narrative

The Anthropocene Review
201X, Vol XX(X) 1–8
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DOI: 10.1177/2053019613516291
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SAGE

Andreas Malm and Alf Hornborg

Abstract

The Anthropocene narrative portrays humanity as a species ascending to power over the rest of the Earth System. In the crucial field of climate change, this entails the attribution of fossil fuel combustion to properties acquired during human evolution, notably the ability to manipulate fire. But the fossil economy was not created nor is it upheld by humankind in general. This

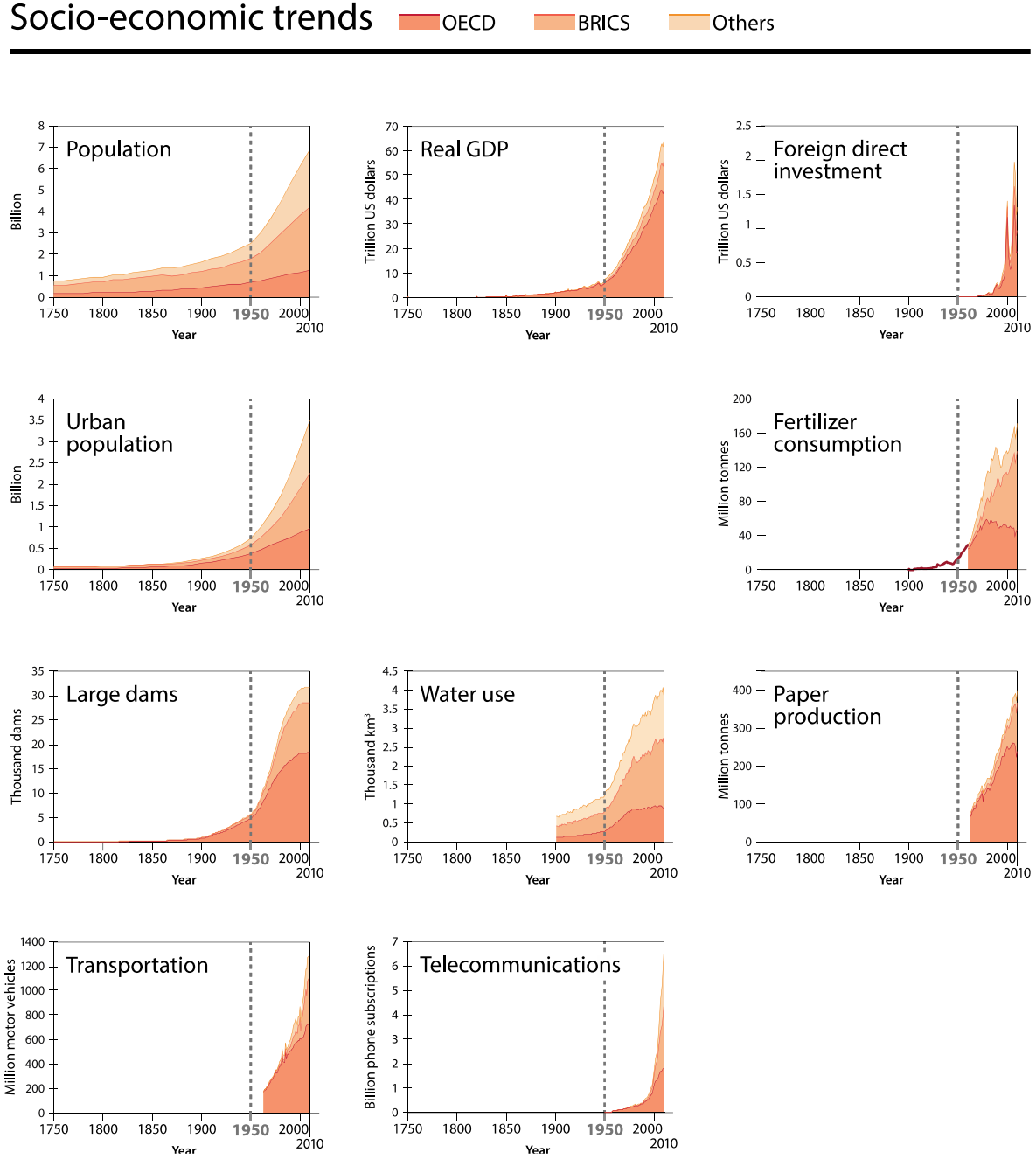
It is not correct to consider “mankind” or “humankind” in general

The fossil fuel-driven, consumption oriented, globalised economy was not created by humankind **in general**.

“Intra-species inequalities are part ….of the current ecological crisis and cannot be ignored in attempts to understand it.

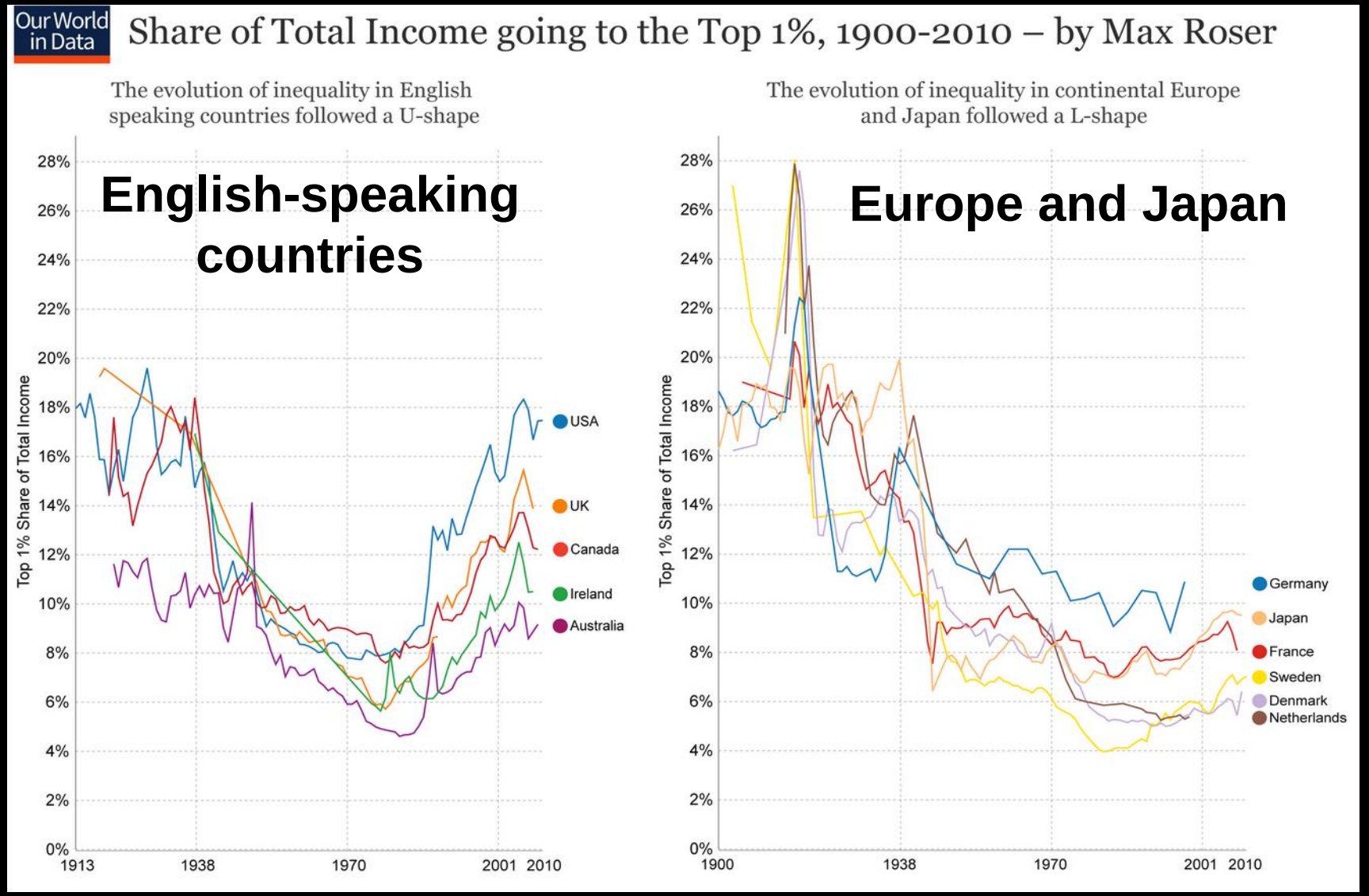
Equity Issues

- Population
- Economic growth
- Fertilizer use
- Urbanization
- Globalization
- Transport
- Communication



Steffen et al. 2015

Evolution of Income Equality

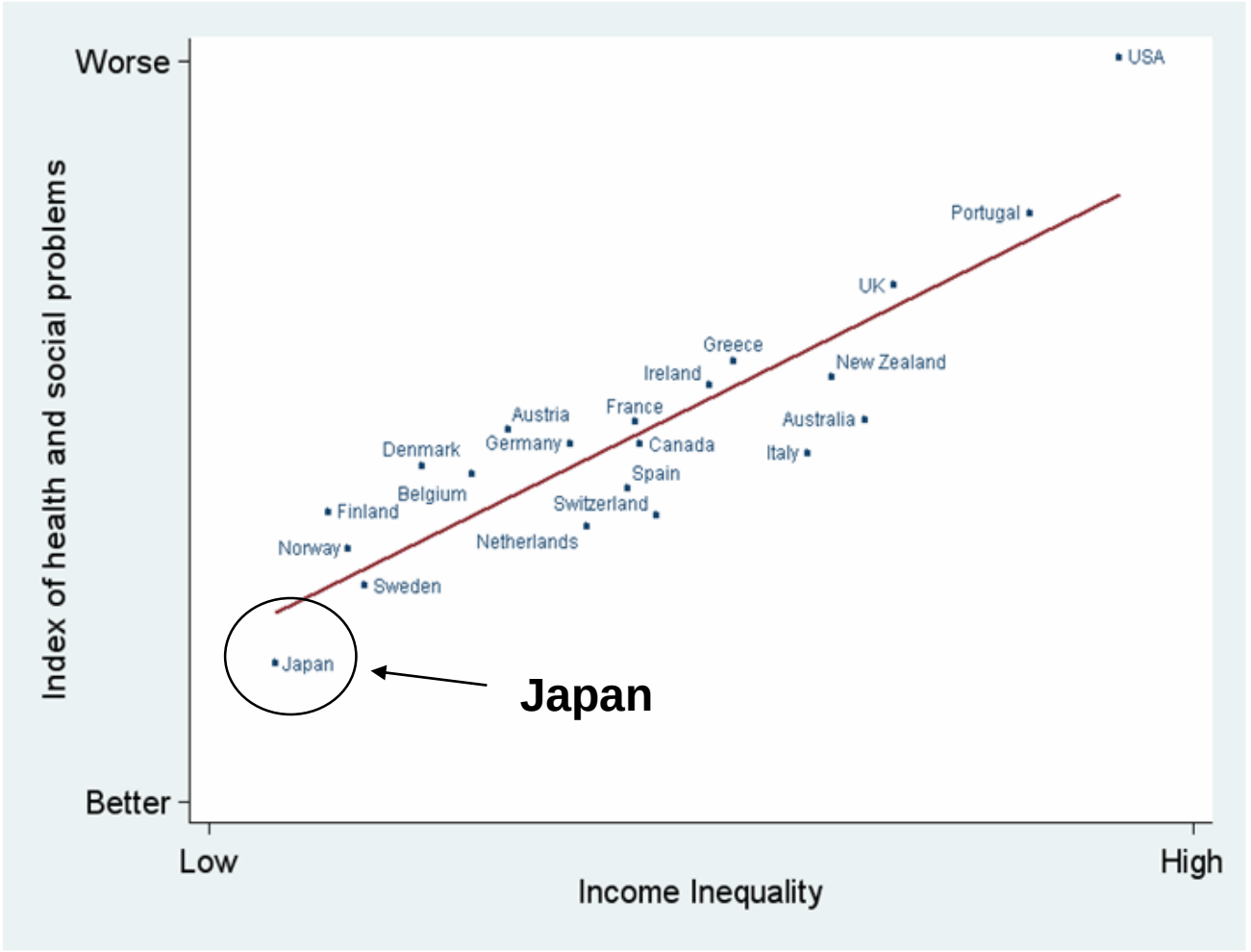


Source: S. van der Leeuw

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

System Incompatibilities?

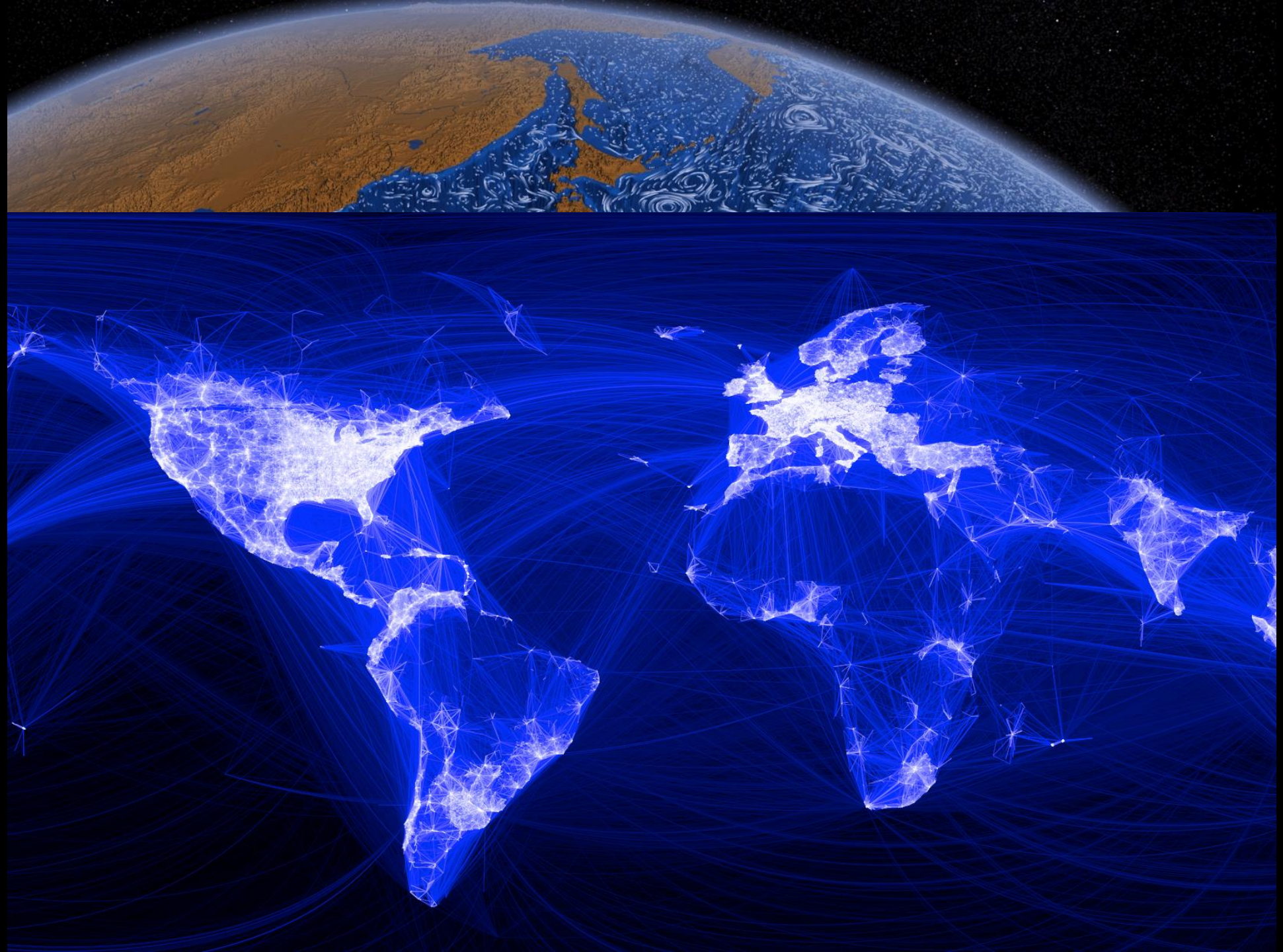


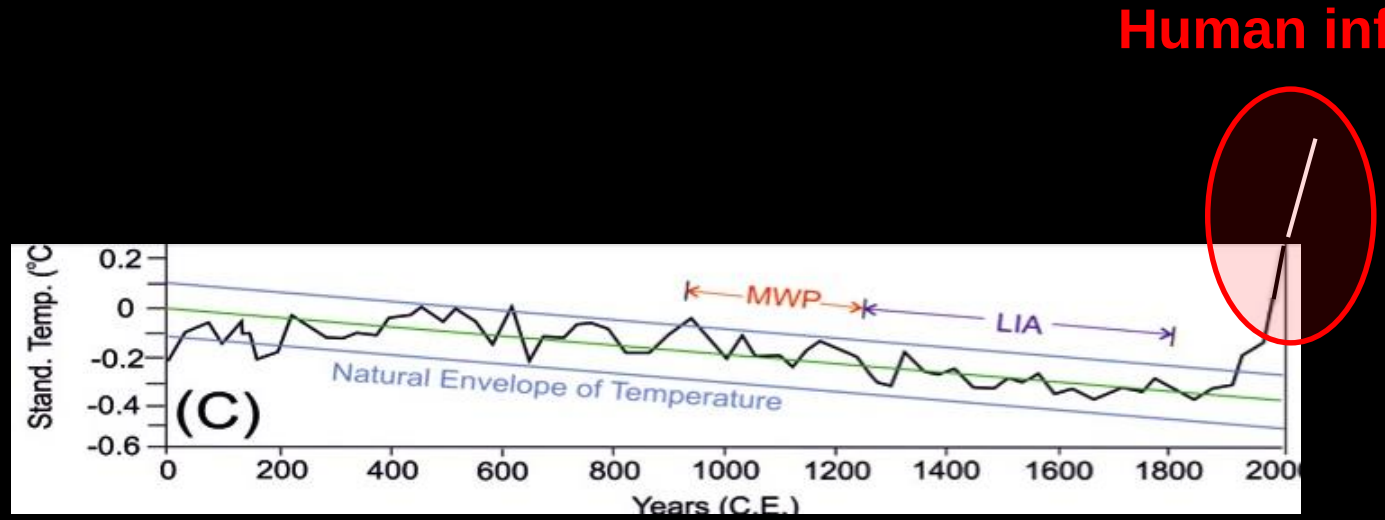
Photo: O.Henriksson/Azote

© Springer-Verlag Berlin Heidelberg 2005

Where is the Earth System going?

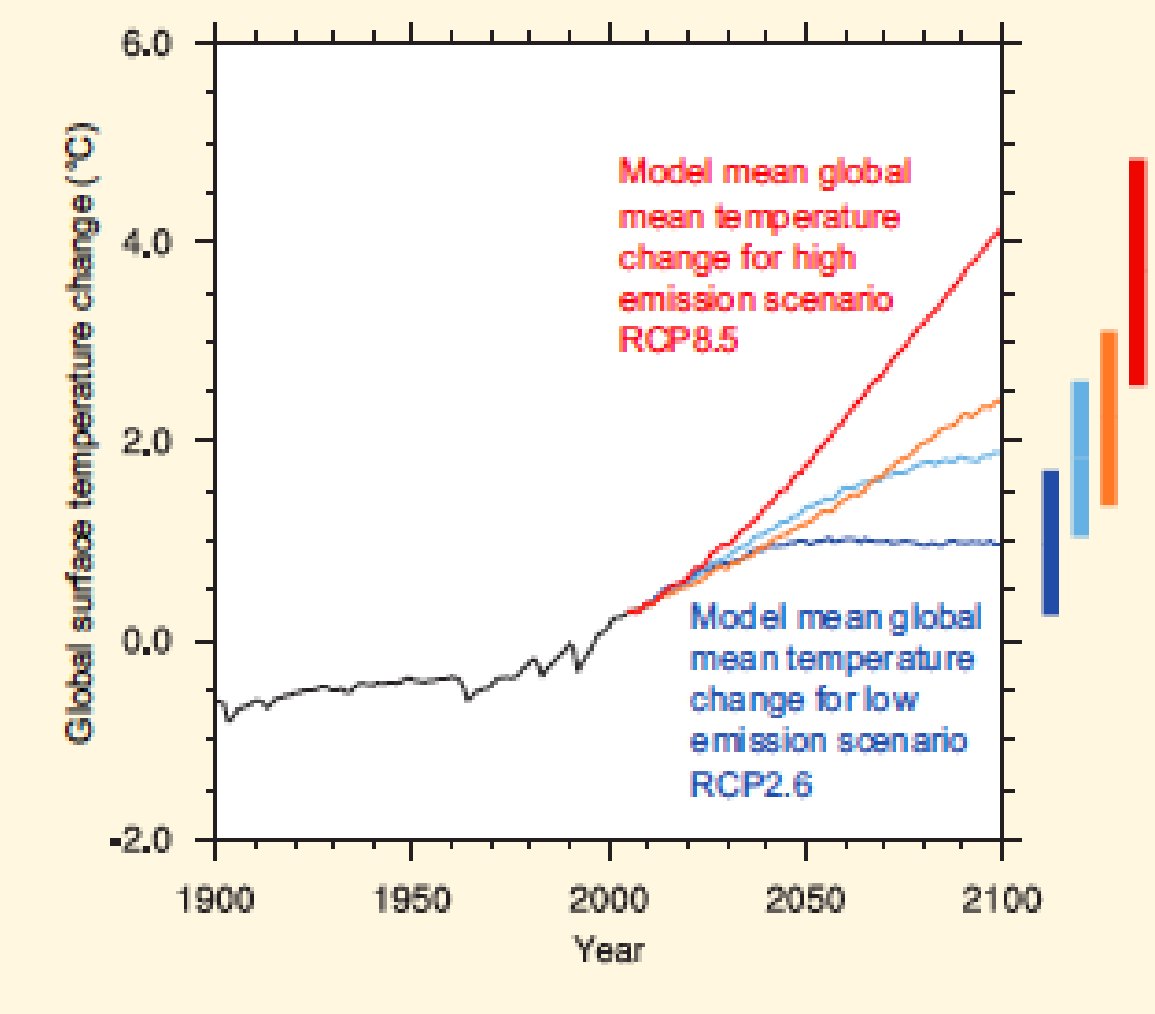
An Earth System Perspective

Temperature rise:
Beyond the envelope of natural variability!



Summerhayes 2015

IPCC temperature projections



IPCC 2013

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

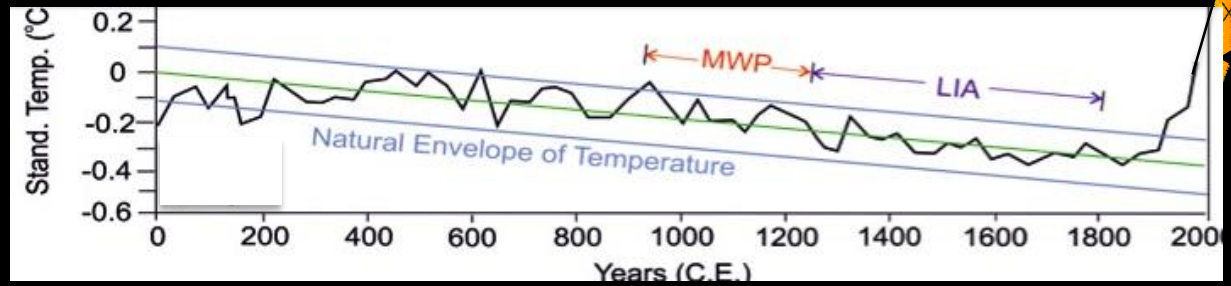
Tipping Points?

Committed

IPCC Projections 2100 AD

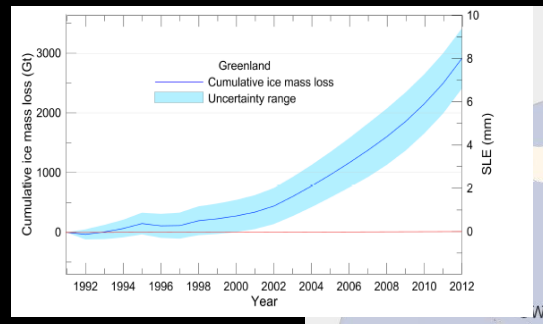
Global Temperature (° C)

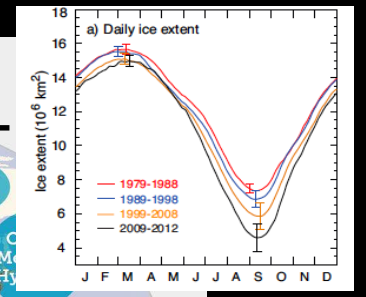
6
5
4
3
2
1
0

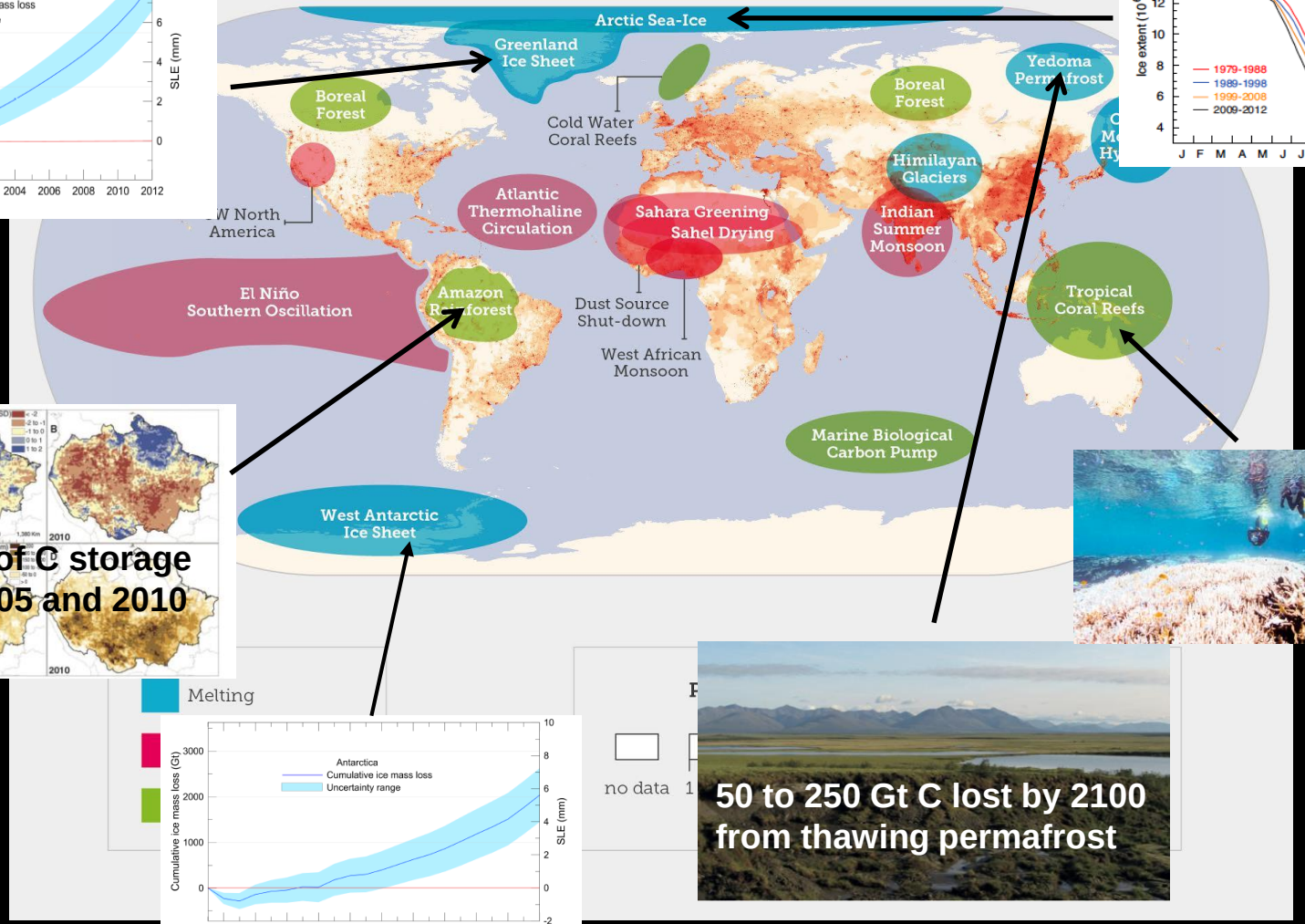


Summerhayes 2015

Tipping Elements in the Earth System





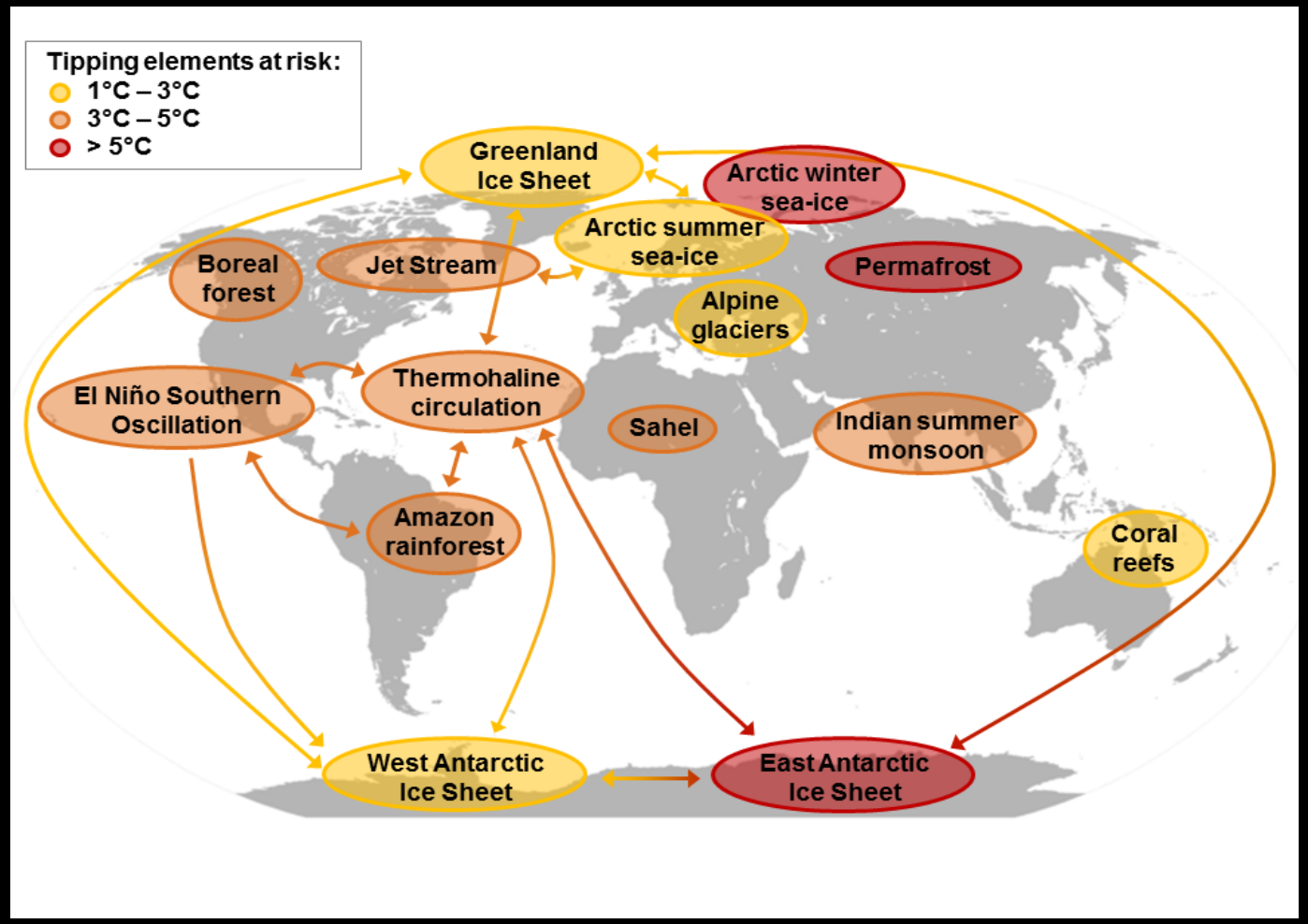


10 years of C storage lost in 2005 and 2010 droughts

50 to 250 Gt C lost by 2100 from thawing permafrost

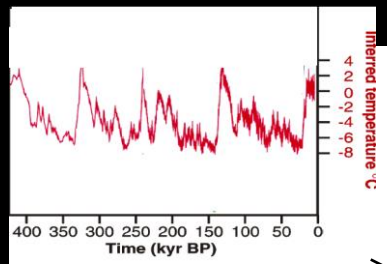
Huber, Lenton, and Schellnhuber, in Richardson et al. 2011

Tipping Cascades



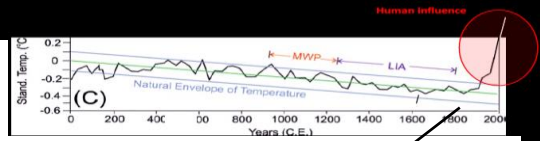
Source: J. Donges and R. Winkelmann in Steffen et al. 2018

Earth System Trajectories



Time

Glacial-interglacial limit cycle



Holocene

Anthropocene

Earth System stewardship

Human emissions

Biosphere degradation

Planetary threshold

Intrinsic feedbacks

'Stabilized Earth'

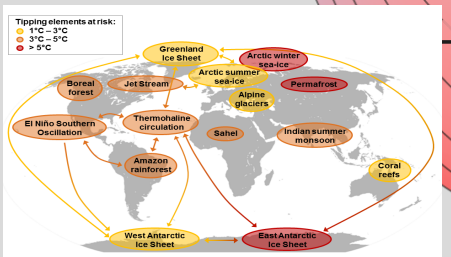
'Hothouse Earth'

Stability

Temperature

Cold

Hot



Steffen et al. 2018

The Hothouse Earth Trajectory

Climate state	Time BP	Atmos CO_2 conc.	Global surface T, ºC	Sea-level rise, m
Current (2017)	0	400	1.1-1.2	N/A
Mid-Holocene	~6-7 ka	260	0.6-0.9	N/A
Eemian	~125 ka	280-300	1.0-1.5	6-9
Mid-Pliocene	~3-4 Ma	up to 400-450	2-3	10-22
Mid-Miocene	~15-17 Ma	up to 300-500	4-5	10-60

Reference: Pre-industrial

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)

How Plausible is this Scenario?

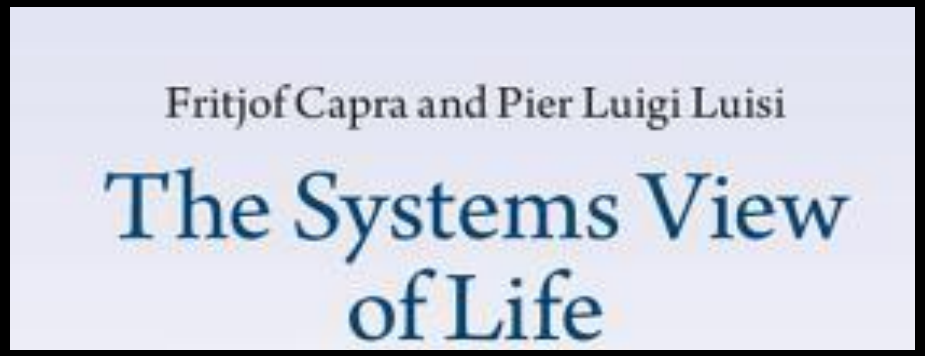
- **Complex system behaviour of the Earth System in the late Quaternary**
- **Hothouse Earth conditions accessible with projected CO_2 concentration and temperature**
- **Some feedback processes are the same as those in glacial-interglacial cycling**
- **Observations show some tipping elements vulnerable at 1-3ºC temperature rise**

Steffen et al. 2018

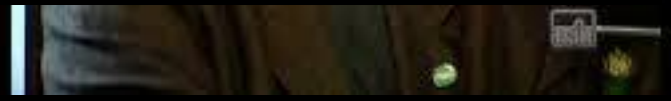
Human Feedbacks in the Earth System: Fundamental Changes in Societies

- Slow or reverse population growth
- Change consumption behaviour
- Improved governance - Earth System level
- **Value changes towards stewardship**
- Technological innovation
- Build resilience for transformations

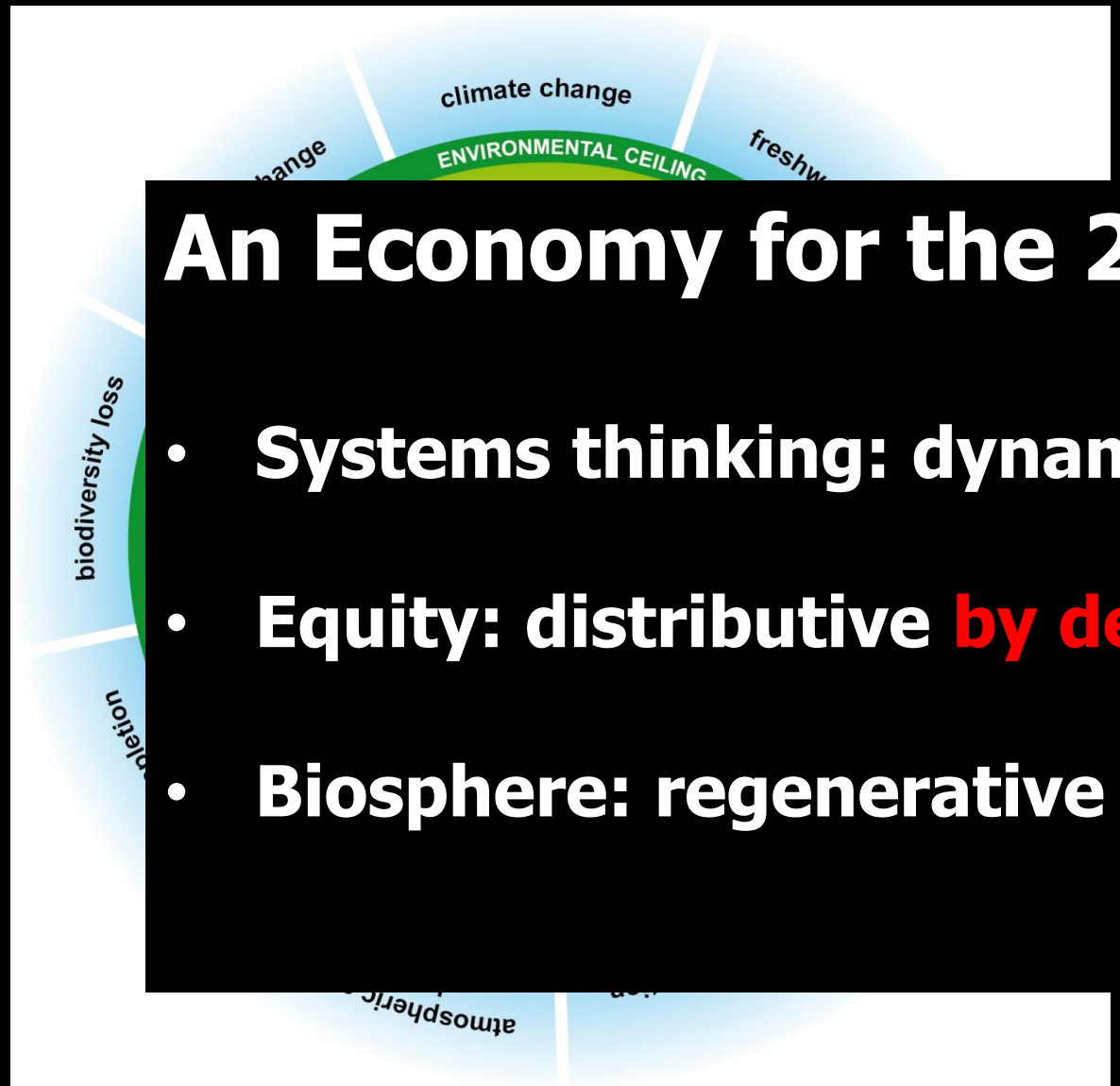
Steffen et al. 2018



…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.



The ‘Doughnut’: a safe and just space for humanity



An Economy for the 21st Century

- **Systems thinking: dynamic complexity**
- **Equity: distributive by design**
- **Biosphere: regenerative by design**

Prof Dipash Chakrabarty
University of Chicago

Homo-centric v. Zoe-centric
(human-centric v. life-centric)

Contemporary society is based on a homo-centric approach, but the Anthropocene demands a zoe-centric approach.

“epochal consciousness” v. “departmental thinking”

Tanner Lectures in Human Values, Yale University, 2015

We're only here for a short amount of time to do what we've been put here to do, which is to look after the country. We're only a tool in the cycle of things. …(we) go out into the world and help keep the balance of nature. It's a big cycle of living with the land, and then eventually going back to it....

An Elder, Noongar People. From: 'Elders: Wisdom from Australia's Indigenous Leaders’