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

Evolution of fully modern humans in Africa

Hunter-gatherer societies only

Beginning of agriculture

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

- Carbon dioxide
- Nitrous oxide
- Methane
- Stratospheric ozone
- Surface temperature
- Ocean acidification
- Marine fish capture
- Shrimp aquaculture
- Nitrogen to coastal zone
- Tropical forest loss
- Domesticated land
- Terrestrial biosphere degradation

Steffen et al. 2015

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
The Anthropocene chicken

J. Zalasewicz 2015

Richard Thomas
Terrestrial vertebrate biomass

Domesticated animals ca 65%

Vertebrate wildlife < 3%

Humans ca 32%

Smil 2002
Mass extinction plausible within two to three human lifetimes

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

Source: A Barnosky

Ceballos et al. 2015
The climate system, the biosphere...

What about humans and our systems?
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

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.”
...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?
An Earth System Perspective

Temperature rise:
Beyond the envelope of natural variability!

Human influence

Summerhayes 2015
IPCC temperature projections

Model mean global mean temperature change for high emission scenario RCP8.5

Model mean global mean temperature change for low emission scenario RCP2.6

Global surface temperature change (°C)

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

Tipping Points?

Committed

IPCC Projections 2100 AD

Summerhayes 2015
Tipping Elements in the Earth System

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

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

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
HYPOTHESIS 1
Intrinsic biosphere dynamics shift earth system to “hot” ice-free state

HYPOTHESIS 2
Nonlinear social transformations can maintain earth in a manageable interglacial state

Task 1 – Earth system dynamics of the anthropocene
Task 2 – Biosphere tipping points in WEM

~1955 – Onset of great acceleration

10,000 CE 1000 CE Present 2025 2040 2090 3000
(Early holocene)
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

- Legal Framework
- Accounting Framework
- Scientific Framework
- Governance Framework
- Legally Recognised Safe Operating Space (SOS)
- Earth System Accounting Framework (ESAF)
- Planetary Boundaries (PBs)
- Condominium Framework (COND)
- Scientific Commission (SC)
- Quantifying Body