Global Change, the Earth System and the Anthropocene

Will Steffen
Executive Director, The ANU Climate Change Institute
The Australian National University
Global Change

The Human Imprint on the Earth System

The Earth is Warming

Global Annual Mean Surface Temperature Anomaly (base 1961-90)

Climate Research Unit (CRU), UK, 2007
Human Imprint on the Terrestrial Biosphere

From landscapes to genes...
Human Imprint on Marine Ecosystems

Fisheries collapse

- The Atlantic cod stocks off the east coast of Newfoundland collapsed in 1992, forcing the closure of the fishery.
- Depleted stocks may not recover even if harvesting is significantly reduced or eliminated entirely.
- About 50% of all fish stocks are fully exploited, 15-18% are overexploited, and 9-10% have been depleted or are recovering from depletion.

Source: Millennium Ecosystem Assessment 2005, Steffen et al. 2004
Significant and largely irreversible changes to species diversity

- Humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the planet’s history (medium certainty)

- 10–30% of mammal, bird, and amphibian species are currently threatened with extinction (medium to high certainty)

Source: Millennium Ecosystem Assessment 2005
Economic Globalization:
Virtual Water Flows
(Cereals only)

Oki, et al., 2002, IHE-UNESCO (Based on Statistics from FAO etc., for 2000)
The multi-faceted nature of global change

Global Annual Mean Surface Temperature Anomaly (base 1961-90)

Mean Surface Temperature Anomaly (°C)

Year

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Sea Surface Temperature

Aug 27 2005
Recent oil price rises

“High oil prices are fueling one of the biggest transfers of wealth in history. Oil consumers are paying $4 billion to $5 billion more for crude oil every day than they did just five years ago, pumping more than $2 trillion into the coffers of oil companies and oil-producing nations this year alone.” Steven Mufson, Washington Post, 10 Nov 2007.

The rising cost of food: Rising input prices

Nitrogen fertiliser
$ per metric tonne

Source: Reuters
International Cereal Prices

Selected international cereal prices

USD/tonne

The fate of the global economy hangs on this wedge of uncertainty. Where does the truth lie?
The Earth as a System
Understanding the dynamics of the Earth System requires understanding processes in the land, ocean, atmosphere, cryosphere and lithosphere and the interactions between them. It also requires considerations of scale from the molecular to the global. And now, it must explicitly include human activities.
Back to the Future:
Drilling Ice Cores in Antarctica
and Greenland
The Earth as a System

The Vostok Ice Core: Four Cycles of Glacial-Interglacial Cycling

Variations in climate and in the amount of gases in the atmosphere are tightly linked through time.

Earth’s metabolism shows a regular pattern with cycles of about 100,000 years.

The ranges of CO₂, other gases and temperature are tightly constrained at both upper and lower levels.

In summary, there is a high degree of self-regulation in the metabolism of the Earth System.

From Steffen et al. 2004
Earth System Dynamics...
Tipping Elements in the Earth System

Source: Schellnhuber, after Lenton et al, PNAS, 2008
Have we underestimated how fast the Earth System can change?
Impacts of Climate Change

Source: Munich Reinsurance Company
In August 2002, massive flooding in Bangladesh, India, Indonesia and Eastern Europe
In the past 30-50 years, fire frequency and extent have increased in Canada, western USA, Siberia, and the Mediterranean region.
'Night Lights' of Earth

Image: NASA
Outside the envelope of self-regulation?

Petit et al. 1999; Keeling and Whorf 2000
Northern Hemisphere Surface Temperature

Source: Mann et al. 2003 (EOS)
Simulated Night Lights

From: Nakicenovic 2002
Global Temperature (°C)

Earth System moves to a new state; modern civilisation collapses

Feedbacks push climate change higher; abrupt changes much more likely; massive impacts to humans

Loss of Greenland ice sheet

Large biodiversity loss; coral reefs disappear

“Committed” Climate Change

IPCC Projections 2100 AD

Now
Observed carbon emission trajectory compared to projections and stabilisation scenarios

Raupach et al. 2007
Projected and observed temperature and sea-level rise since 1970

From: Rahmstorf et al. 2007
Sustainability or Collapse:

Where on Earth are We Going?
The Anthropocene

From Hunter-Gathers to a Global Geophysical Force

Human Development and Earth System Dynamics

Evolution of fully modern humans in Africa

Hunter-gatherer societies only

Beginning of agriculture

Inferred temperature°C

ppmv CO₂

ppbv CH₄

Time (kyr BP)

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Human Development and Earth System Dynamics

First migration of fully modern humans out of Africa
Aborigines arrive in Australia
Migrations of fully modern humans from South Asia to Europe
Beginning of agriculture
Great European civilisations: Greek, Roman

Source: GRIP ice core data (Greenland)
And S. Oppenheimer, "Out of Eden", 2004
Before the Anthropocene: Pre-Anthropocene Events (Pre-1800)

• “Fire-Stick Farming” - use of fire as a tool to modify ecosystems to favour particular desired species and to aid in the hunt. Fire was most often used to convert dry forests and woodlands into savannas and grasslands, and to maintain ecosystems in those states.

• Megafauna extinctions - large-scale (continental) extinctions of large Pleistocene mammals by hunting, perhaps in combination with climatic changes - North America, northern Eurasia, Australia.

• No discernable effect on Earth System functioning at the global scale
Anthropocene Stage 1
(1800-1945)

- Evidence - increase in GHG concentrations, widespread deforestation of temperate forests, etc.

- Industrial Revolution - steam engine, fossil fuel energy systems, rapid and wide spread of these energy systems

- Flow-on effects - more efficient techniques for land clearing; synthetic fertiliser; more reliable water supply and better sanitation, leading to better public health. These developments, in turn, led to an increase in population AND their ability to consume.
Anthropocene
Stage 2
(1945 - 2010/2020)

The changing 'human enterprise’, from 1750 to 2000.

Note the start of the 'Great Acceleration' around 1950, when many activities began or accelerated sharply.
Responses of the biophysical Earth System to the accelerating ‘human enterprise’.

The biophysical responses of the Earth System show many of the same features as the Great Acceleration in the human enterprise.
Triggers of the Great Acceleration

• Globalisation: Global networks of communication & finance - crossed a threshold of connectivity

• Emergence of "armies of scientists & technologists" from WWII

• Dramatic shifts in political & economic structures/institutions

• Establishment of the Bretton Woods institutions

• World economy based on capitalist/neo-liberal economic principles

• Increasing commoditisation of public goods

• ‘Growth imperative’ - increasing consumption per capita
Knowledge $\leftrightarrow$ Science $\leftrightarrow$ Technology

Population $\rightarrow$ Energy

Production/Consumption $\rightarrow$ Institutions $\rightarrow$ Political Economy

From: Hibbard et al. 2006
The Changing Human-Environment Relationship under the Great Acceleration

Complex impacts of globalisation
- Mixed environmental impacts at local levels but homogenisation of the environment at the global level
- Loss of diversity of cultural values
- Negative environmental impacts of debt crisis

Urbanisation and the environment
- Different experiences and understanding of nature between urban and rural dwellers
- Increased wealth, rising consumption expectations
- Transformation of rural-urban linkages - ‘footprints’

Governance
- Shift to free-market economic systems
- Decentralisation & privatisation of environmental management
Global Footprint of the Human Enterprise

Source: Global Footprints Network 2005
Sustainable development quadrant

Global average available biocapacity per person with no area set aside for wild species.

Source: Moran et al., Ecological Economics, 64, 470-474, 2008
Anthropocene Stage 3
(2010/2020 - ?)

Sustainability or Collapse?
Collapse of Early Civilisations

Top: East African civilisation (from Verschuren et al. 2000)

Middle: Classic Mayan Civilisation (from Hodell et al. 2001)

Bottom: Akkadian civilisation (Syria) (from Cullen et al. 2000)
Possible Explanations for the Collapse of Early Civilisations

• Tainter - increasing complexity & decreasing resilience

• Friedman - waves of ‘globalisation’ to an upper limit of system compatibility

• Diamond - inflexibility of core societal values

• Scarborough (Maya) - self-organisation - networks of alliances and exchanges; adaptation to dynamics of natural ecosystems. Collapse due to centralisation of power around two super-cities and distortion of network flows.
Transformation instead of Collapse

Australian Aborigines: living for 65,000 years, through ice ages, drought, heat and storms.

SE Asian rice irrigation systems: a response to drought?
Scenarios: MA Storylines

- **Global Orchestration**: Globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education.

- **Order from Strength**: Regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems.

Millennium Ecosystem Assessment 2005
Scenarios: MA Storylines

- **Adapting Mosaic:** Regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems.

- **TechnoGarden:** Globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems.

*Millennium Ecosystem Assessment 2005*
The Human Enterprise: Early Globalised

**GLOBALISING COMMUNITY**
- 1%
- USA
- Japan
- Singapore
- Hong Kong
- Western Europe
- Australia/NZ
- Taiwan
- South Korea
- China
- India
- Estonia
- Hungary
- Thailand

**MODERN STATES**
- 14%
- Brazil
- Egypt
- Russia
- Syria
- China
- India

**PREMODERN SOCIETIES**
- 5%
- Angola
- China
- India
- Rwanda
- Sudan
- Zaire

T. Ries, Swedish Institute of International Affairs
Let’s take our country back…

Barack Obama
US Democratic Party Convention
August 2008
Towards Solutions…

Technology

Economics

Institutions

….but is something missing?
A large number of energy sources, each with a much lower rate of CO$_2$ emissions than fossil fuels, are can contribute to the solution(s) to the climate change challenge...
...this “wedge approach” can bridge the emissions gap.
End of Pipe Solutions or the Renewables Transition

The ‘Base Case’ or ‘steady as she goes’

80% renewable electricity and liquid fuel from vast ‘woodscapes’ on replanted agricultural landscapes (methanol and di-methyl-ether or DME)

Source: B. Foran
End of Pipe Solutions or the Renewables Transition

**GDP Growth Rate**
- Base case: 2.2%
- Renewables: 1.8%

**Carbon Dioxide Emissions from the Energy Sector**
- Base case: 28.7 bn tonnes
- Renewables: 11.6 bn tonnes
- Achievement: -60%
Policy options: An economic analysis

- **Policy instruments**
  - emissions trading gives broad incentives for efficient abatement
  - other policies to address specific market failures or societal objectives

- **Policy analysis**
  - effectiveness of emissions abatement policies
  - design of emissions trading and post-Kyoto climate policy
Towards Earth System Governance?

United Nations Framework Convention On Climate Change

UN Millennium Development Goals

UN Convention on Biological Diversity
Integration: Internalising energy system externalities

• Reducing carbon emissions
  – at least economic cost
  – taking account of other externalities and of societal preferences

• Economics research needed
  – Identifying and valuing externalities
  – Dealing with uncertainty
  – Economics of public R&D funding
Integration:
Are we in a 21st century transport trap?
Europe’s growing fast train network...

...outcompeting short-haul flights.
Transport: Thinking Outside the Box

From motorcar, truck and aviation-dominated systems to integrated transport systems (note the transformation of some petroleum companies towards energy companies).

Emergence of an integrated European transport system - electrified fast rail for short-haul (ca. 1000 km and less), light rail/bus/electric cars in urban areas, and air travel for intercontinental transport.

Co-location of airports and train stations; integration of schedules across national rail systems and between rail and air travel.

High speed rail systems can be driven by non-CO$_2$ emitting energy sources.
Observed carbon emission trajectory compared to projections and stabilisation scenarios

Raupach et al. 2007
The Sustainability Gap

- Risk of collapse:
  - Degree of un-sustainability
- Time

Present

Short-term Pragmatism

Sustainability Target

Short-term policy actions

Long-term and foundational issues

Fischer, Manning et al. 2007
The “Sustainability Hierarchy”...
...rather than the “Triple Bottom Line”

After I. Lowe 2005
Research on the Earth System is usually carried out by different, specialised communities focusing on the land, ocean, atmosphere, cryosphere and lithosphere. Much less effort is spent on studying the interactions between them or on the Earth System as a whole.
Perspectives on the Human-Environment Relationship

Hurt not the earth, neither the sea, nor the trees.
Revelation 7:3, the Holy Bible

Most Gracious is Allah, Who reveals Himself
In the Qur'an, in man's Intelligence
And in the nature around man.
Balance and Justice, Goodness and Care,
Are the Laws of His Worlds....

Summary from Surah 55, the Holy Qur'an
Without the willow, how to know the beauty of the wind.
Lao She, Buddhist monk

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....

Vilma Webb, Noongar People, Australian Aborigines, from: 'Elders: Wisdom from Australia's Indigenous Leaders'
In the Enlightenment expertise in the arts, letters, history, languages, maths, religion, and science was embodied (and integrated!) in one person…

…the Renaissance Man…
...in the 21st century, we need “Renaissance Teams”
Towards Solutions...

Technology, economics and institutions are all important components of meeting the global change challenge...

...but integration within and across these components - and thinking “outside of the box” - will be even more important. Creativity and innovation are essential...

...but the most important feature of any solution is a critical examination of the core values of contemporary society. Do we need a comprehensive change in direction of society? A transformation? Is so, what are the new core values required for a sustainable solution?
Sustainability or Collapse?

...The future will depend on the nature of human aspirations, values, preferences and choices...