Earth System Research for Global Sustainability

WCRP Open Science Conference
Denver, Colorado, 29th Oct 2011

Prof. Johan Rockström
Stockholm Resilience Centre
Stockholm Environment Institute
The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?
NEWSFOCUS

A Global Perspective on the Anthropocene

www.sciencemag.org  SCIENCE  VOL 334  7 OCTOBER 2011

% Worldwide Fisheries Fully Exploited


Getting More Acidic

Aragonite saturation state

CO₂ 280 PPM

CO₂ 450 PPM

SOURCE: O. HOIGH-GULDBERG ET AL., SCIENCE 318, 5857 (14 DECEMBER 2007)

Atmospheric CO₂ Concentration vs. Human Population


Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

A centre with:
Humanity has reached a planetary saturation point.

A resilient biosphere the basis for human development

Climate change one interacting component of global sustainability

A great transformation to global sustainability necessary, possible, and desirable
"We have our foot on the accelerator driving towards the abyss..."

Ban Ki-moon Secretary General of the UN

“We are destabilizing our climate and stretching planetary boundaries to a perilous degree”.
Rio+20 and a transition to Global Sustainability

UN Secretary General Ban Ki-Moon
High Level Panel on Global Sustainability
"When reality is changing faster than theory suggests it should, a certain amount of nervousness is a reasonable response”

The Economist
Growing Human Pressure [20/80 dilemma]

Climate change [560/450/400 dilemma]

Ecosystem decline [60 % loss dilemma]

Surprise [99/1 dilemma]
Atmospheric CO$_2$ concentration

Etheridge et al. Geophys Res 101: 4115-4128

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Northern hemisphere average surface temperature

Mann et al Geophys Res Lett 26(6): 759-762
IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Atmospheric $\text{N}_2\text{O}$ concentration

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Atmospheric CH$_4$ concentration

Blunier et al J Geophy Res 20: 2219-2222

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Ozone depletion

% loss of total column ozone

JD Shanklin British Antarctic Survey

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Natural climactic disasters

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Ocean ecosystems

% fisheries fully exploited

FAOSTAT 2002 Statistical database
IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Coastal zone nitrogen flux

(10^{12} \text{ moles year}^{-1})


IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Tropical rainforest and woodland loss

% of 1700 value

Richards, the Earth as transformed by human action, Cambridge University Press

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Domesticated land

% of total land area

Klein Goldewijk and Batties

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
Species extinctions

Wilson, the Diversity of Life.

IGBP synthesis: Global Change and the Earth System, Steffen et al 2004
The Planetary Response to the drivers of the Anthropocene

Professor Will Steffen

1900

1950

2000

1960

1970

1980

1990

2000

2010-2020

CO\textsubscript{2}, N\textsubscript{2}O, CH\textsubscript{4} concentrations

Overfishing

Land degradation

Loss Biodiversity

.....
20th Century

<table>
<thead>
<tr>
<th>Metric</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>4X</td>
</tr>
<tr>
<td>Economic Output</td>
<td>22X</td>
</tr>
<tr>
<td>Fossil fuel consumption</td>
<td>14X</td>
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</tbody>
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OECD Green Growth Report 2011

Human impact, which had been growing steadily since the Industrial Revolution, started to grow exponentially after World War II, a phase scientists call the “Great Acceleration.”
Critical transitions or regime shifts
(Meinsheuizen et al., in prep)
Valuable Ecosystem Services (Desirable) —— Loss of ecosystem services (Undesirable)

1. **Coral dominance**
   - Overfishing, coastal eutrophication
   - Phosphorous accumulation in soil and mud
   - Fire prevention

2. **Clear water**
   - Disease, hurricane
   - Flooding, warming, overexploitation of predators
   - Good rains, continuous heavy grazing

3. **Grassland**
   - State shift

4. **Algal dominance**
   - Turbid water
   - Shrub-bushland
Average Monthly Arctic Sea Ice Extent
September 1979 to 2011

Extent (million square kilometers)

Year


National Snow and Ice Data Center

Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

A centre with:

Stockholm University

SEI STOCKHOLM ENVIRONMENT INSTITUTE

Belyar Institute of Botanical Cosmetics
Reefs at risk revisited, 2011

- About 75% of coral reefs threatened by local and global pressures.
- Climate change, ocean acidification, overfishing, destructive fishing, coastal development, and pollution.
- Since first Reefs at Risk in 1997 threats have increased on 30% of reefs.
- Unless steps are taken threatened reefs will increase to more than 90 percent by 2030 and to nearly all reefs by 2050.
Trophic Downgrading of Planet Earth


www.sciencemag.org SCIENCE VOL 333 15 JULY 2011
Tipping elements in the Earth system –
PNAS Special Feature released December 2009

PNAS Special Feature:
Tipping elements in the Earth System, Jan 2010, vol 106 (49)
The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?

Catastrophic regime shifts in ecosystems: linking theory to observation

Marten Scheffer¹ and Stephen R. Carpenter²

¹Department of Aquatic Ecology and Water Quality Management, Wageningen University, PO Box 8080, 6700 DD Wageningen, The Netherlands
²Center for Limnology, University of Wisconsin, 680 North Park Street, Madison, WI 53706, USA
The Resilience of the Earth System
Humanity’s 10,000 years of grace
Transgressing safe boundaries

Biosphere interactions with the climate system

Adapted from Canadell et al., 2007
Global sustainability now a prerequisite for Poverty Alleviation

Predict risks of catastrophic thresholds in the Earth system

Innovation pathways for a Grand Transformation to global sustainability

Planetary Stewardship for human prosperity in the Anthropocene
What significant environmental changes are likely to result from human actions? How would those changes affect human well-being, and how are people likely to respond?

How can the need to curb global environmental change be integrated with the demands of other inter-connected global policy challenges, particularly those related to poverty, conflict, justice and human security?

What strategies for avoidance, adaptation and transformation are effective for coping with abrupt changes, including massive cascading environmental shocks?
A global Alliance for a new 10-year initiative

Earth System Sustainability Initiative (ESSI)

Note: WMO is an observer to ESSI
5-10 Grand Questions
Humanity needs answered for a successful transition to global sustainability

Research Framework guided by an integration of Grand Challenge Research questions and Belmont White paper

Strategic principles for research
• Integration Nat-Soc sciences
• Cross-scale interactions
• Broad stakeholder engagement
• Contribute to transitions toward global sustainability
• Engaging young scientists from N and S
• Set boundary on Earth system research for global sustainability

Unified Governing framework
Guided by Common Research framework
Organisation and Network structure able to deliver on Research framework

Global Support
SYNTHESIS
ASSESSMENT
CAPACITY DEVELOPMENT
SERVICES/IMPACT
COMMUNICATIONS
• Alliance of science, funders with one common research framework (Grand Challenges and Belmont Challenge)

• Co-design and trans-disciplinary endeavour – integrating sciences, integrating science-policy-practice

• Guided by common research strategy
• Governed by one unified governance framework

• Invest in global network and knowledge nodes

• Generate global scientific enthusiasm – a common global challenge

• Major investment in joint "business plan" for IMPACT, SYNTHESIS, ASSESSMENT, CAPACITY DEVELOPMENT, COMMUNICATIONS, AND RESOURCES
The Earth System Sustainability Initiative:
Earth System Research
"Future Earth"
for Sustainable Development

Climate dynamics
Global Earth Observations
Land-ocean interactions
Cryosphere dynamics
Global N and P cycles
Global Water systems
Earth system governance
Vulnerability, Resilience
Human dimensions
Growth and Sustainability
Earth system modelling

Theme 1
Theme 2
Theme 3
Theme 4
Theme n

Science for
Global Sustainability
INSIGHTS
SOLUTIONS
SYNTHESIS
ASSESSMENT
IMPACT
SERVICES
CAPACITIES
AWARENESS
Platform for world leading Earth system science for global sustainability

Irreversible feedbacks in Climate system

Global Observations

Ecosystem services

Land-ocean dynamics

Coastal Vulnerability

Earth System Governance

CapDev; Synthesis; Assessment; Impact; Comm

Unified Governance

PROVIA

Climate Services

Other....
RESPONSE: Climate science; global governance; innovation pathways;

Figure 3.2-1: Examples of global emission pathways for the period 2010-2050 with global CO₂ emissions capped at 750 Gt during this period. At this level, there is a 67% probability of achieving compliance with the 2°C guard rail (Chapter 5). The figure shows variants of a global emissions trend with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, annual reduction rates of 3.7% (green), 5.3% (blue) or 9.0% (red) would be required in the early 2030s (relative to 2008).

Source: WBGU

(WBGU 2009)
OBSERVATION + RESPONSE: Ocean tipping points and marine stewardship
Coastal vulnerability – how far will adaptation take us?

Ocean Acidification
And capacity for adaptive Coral Reef management
Total Forest Sink $2.4 \pm 0.4$ Pg C yr$^{-1}$

Total Forest Source $1.3 \pm 0.5$ Pg C yr$^{-1}$

Net Forest Sink $1.1 \pm 0.8$ Pg C yr$^{-1}$
-changing the face of water scarcity

FORECAST + CONFINE: Global freshwater security and moisture feedback over continents under climate change scenarios

Rockström et al., 2009. Water Resources Research
RESPONSE AND INNOVATION: Turning crisis into opportunity
A shift in mindset for transformation

Latin America’s agricultural revolution
Australia’s Great Barrier Reef
Sweden’s urban landscapes

Preparing the system for change
Navigating the transition
Building resilience of the new direction
FORECAST & RESPONSE
Tipping toward global sustainability

Tellus, 2011, draft for Ban Ki-moon high level panel
RESPONDING: Integrating planetary efforts for human development
Great integrated Assessment capacity for global sustainability
Earth System Sustainability Initiative: towards a new architecture building on existing strengths
Thematic Challenges......

• A new generation of integrated Earth system models
• Predict risks of catastrophic regimes in the Earth system; in interlinked social-ecological systems
• Adaptability, transformability and innovation pathways
• Planetary stewardship and governance in the Anthropocene
• A global transition to sustainable food production within safe operating space
• A global energy transition that meets social needs and global sustainability criteria
• Economics in the Anthropocene (growth, wealth, equity, in a planetary saturation point)
• Global freshwater security
FORECAST + CONFINE : Global freshwater security and moisture feedback over continents under climate change scenarios

Figure 3. Average continental precipitation recycling ratio \( \rho_c \) (1999–2008).