Earth System Research for Global Sustainability

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

Prof. Johan Rockström
Stockholm Resilience Centre
Stockholm Environment Institute

Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

Stockholm University

A centre with: SEI Stockholm Environment Institute; The Beijer Institute of Ecological Economics

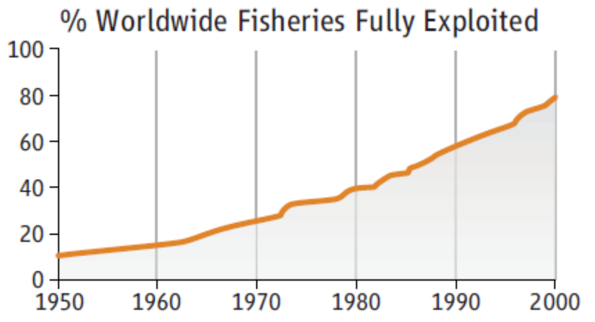
Article

Will Steffen, Paul J. Crutzen and John R. McNeill

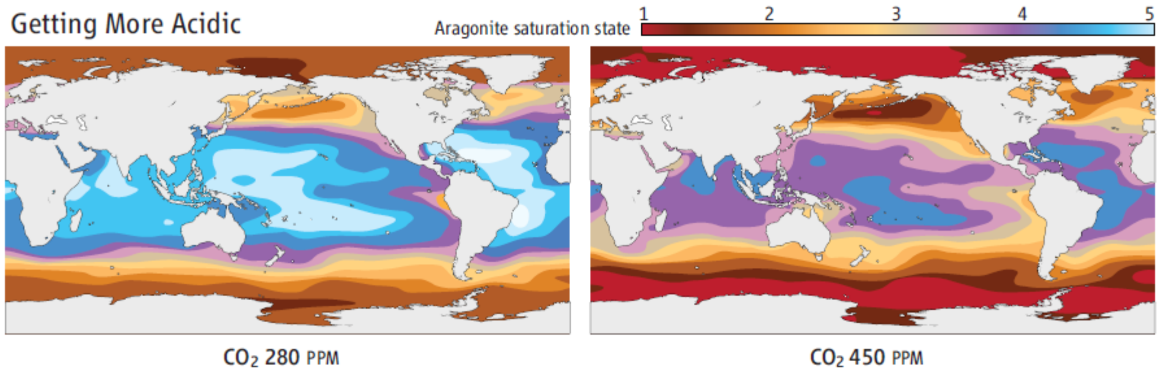
The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?

A Global Perspective on the Anthropocene

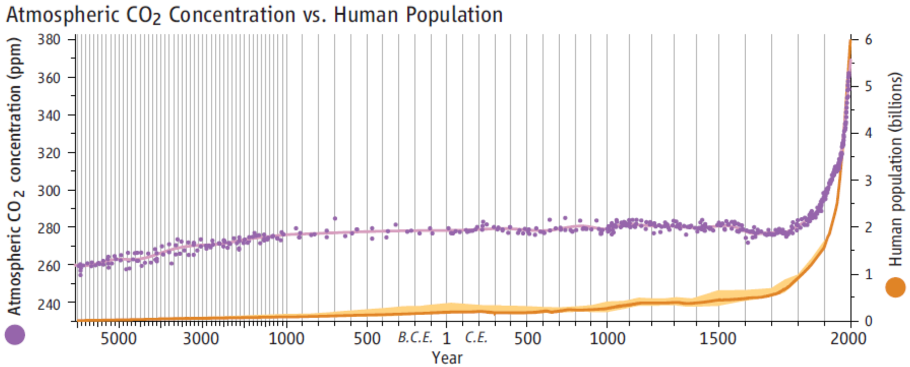
www.sciencemag.org SCIENCE VOL 334 7 OCTOBER 2011



SOURCE: WILL STEFFEN *ET AL., PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A* **369** (2011)



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



SOURCE: JED O. KAPLAN *ET AL., THE HOLOCENE* **21**, 5 (AUGUST 2011)

Humanity has reached a planetary saturation point

A resilient biosphere the basis for humen 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...”

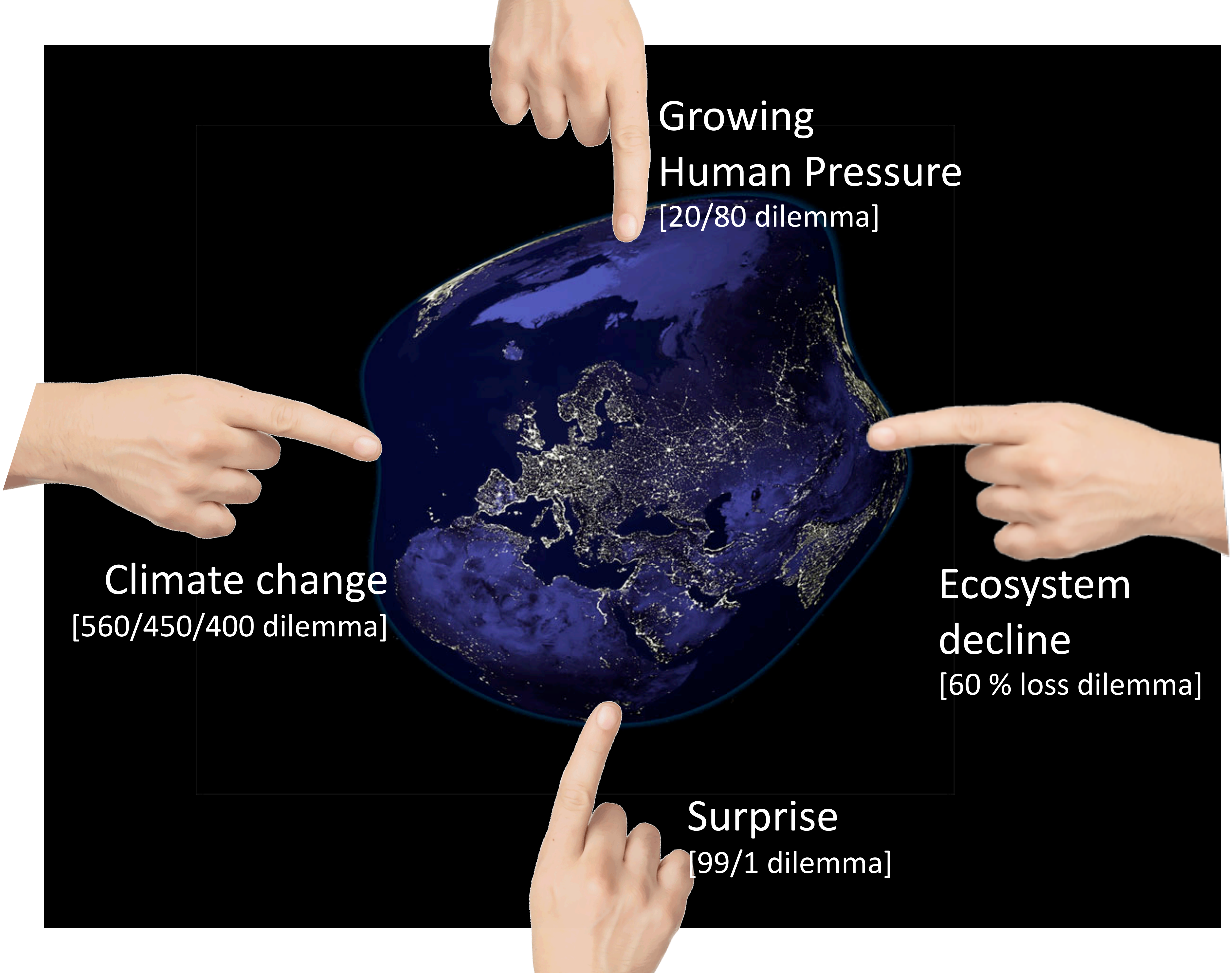
Ban Ki-moon Secretary General of the UN

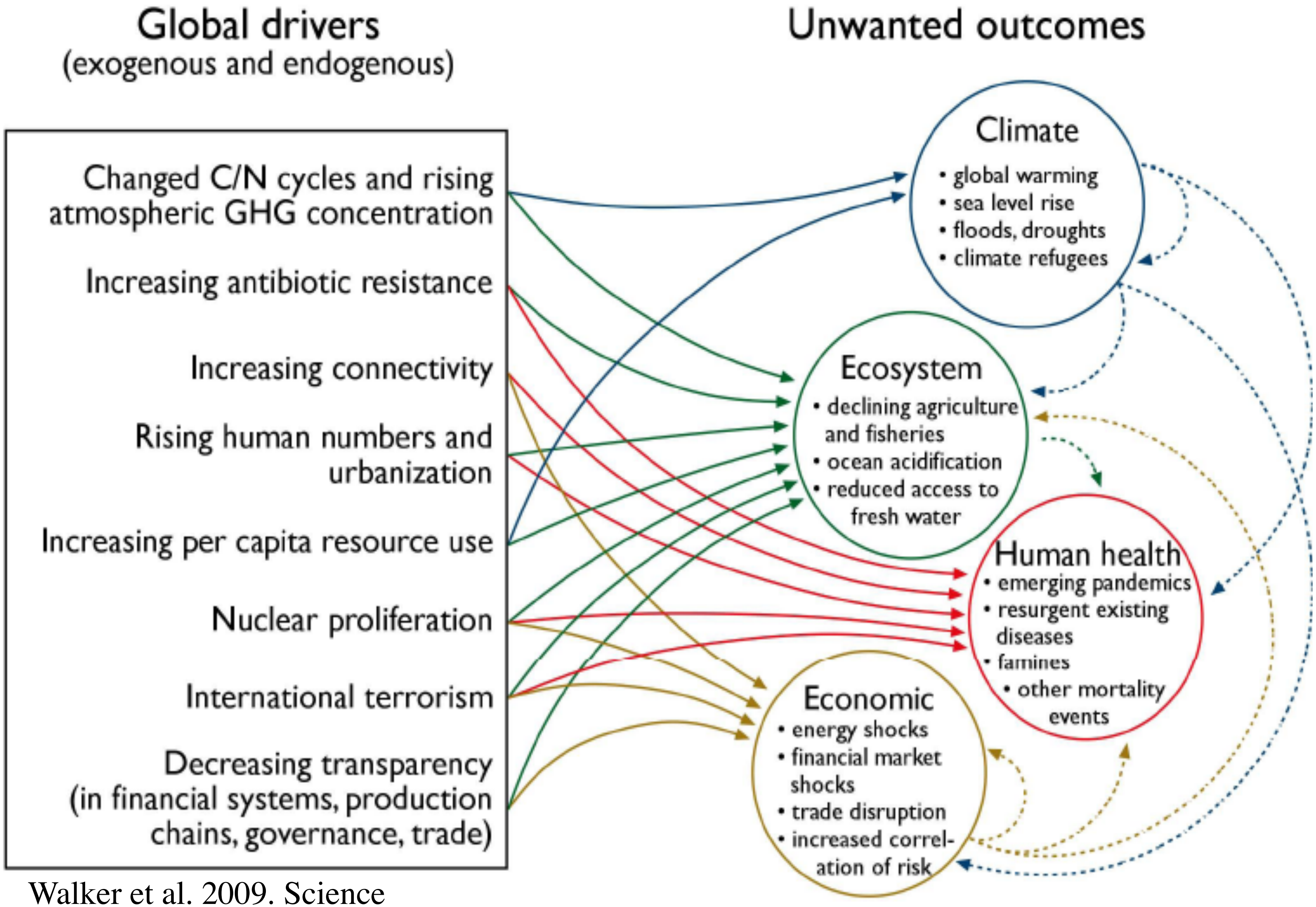
“We are destabilizing our climate *and* stretching planetary boundaries to a perilous degree”.

Rio+20 and a transition to Global Sustainability

UN Secretary General Ban Ki-Moon
High Level Panel on Global Sustainability

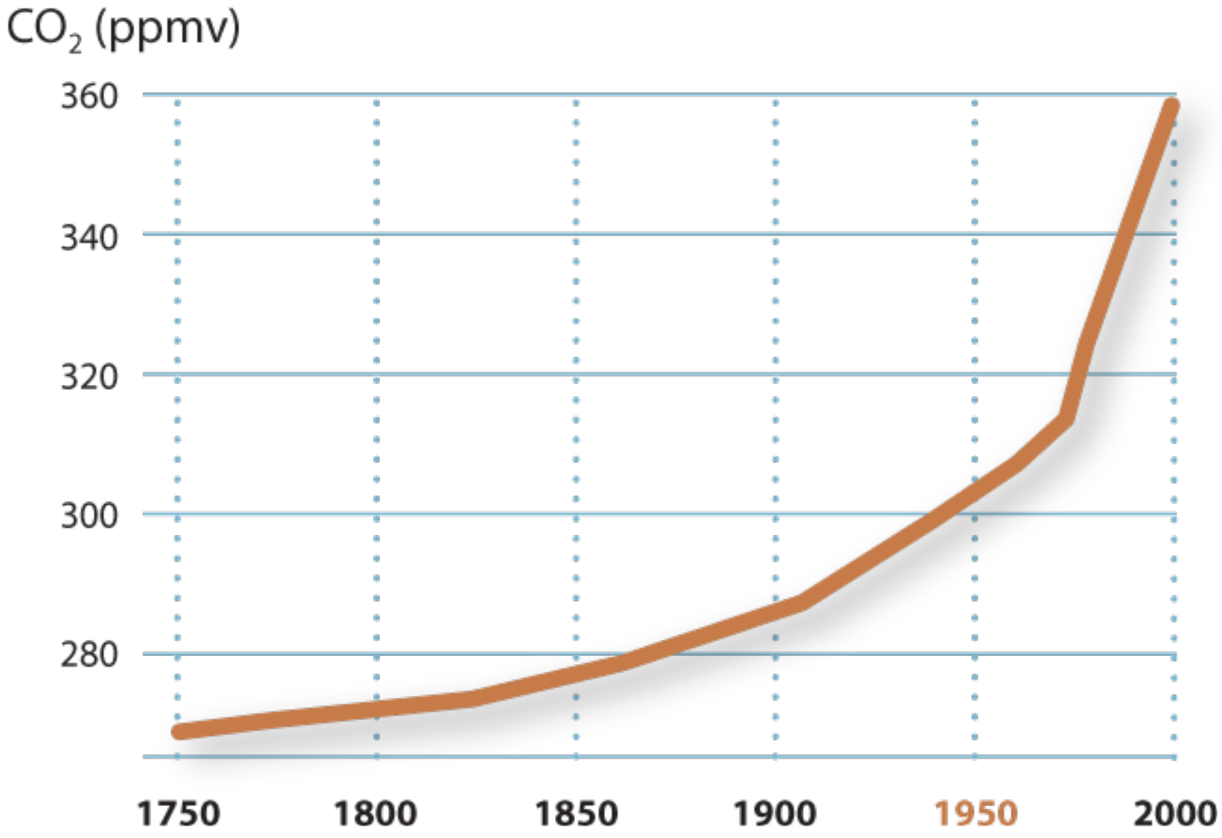
”When ***reality is changing faster than theory*** *suggests it should, a certain amount of nervousness is a reasonable response”*
The Economist


Growing
Human Pressure
[20/80 dilemma]
Climate change
[560/450/400 dilemma]
Ecosystem
decline
[60 % loss dilemma]
Surprise
[99/1 dilemma]



Walker et al. 2009. Science

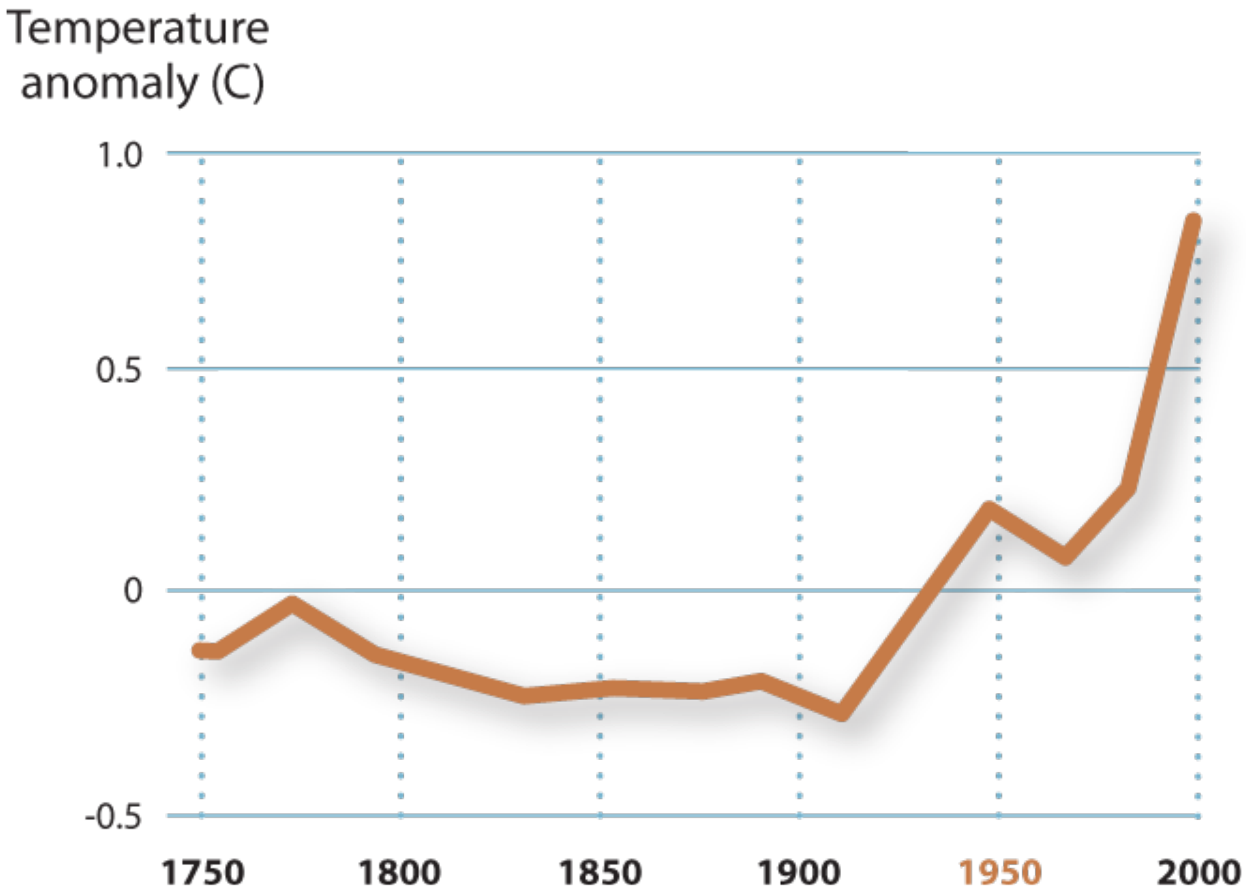
Atmospheric CO_2 concentration



Etheridge et al. Geophys Res 101: 4115-4128

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

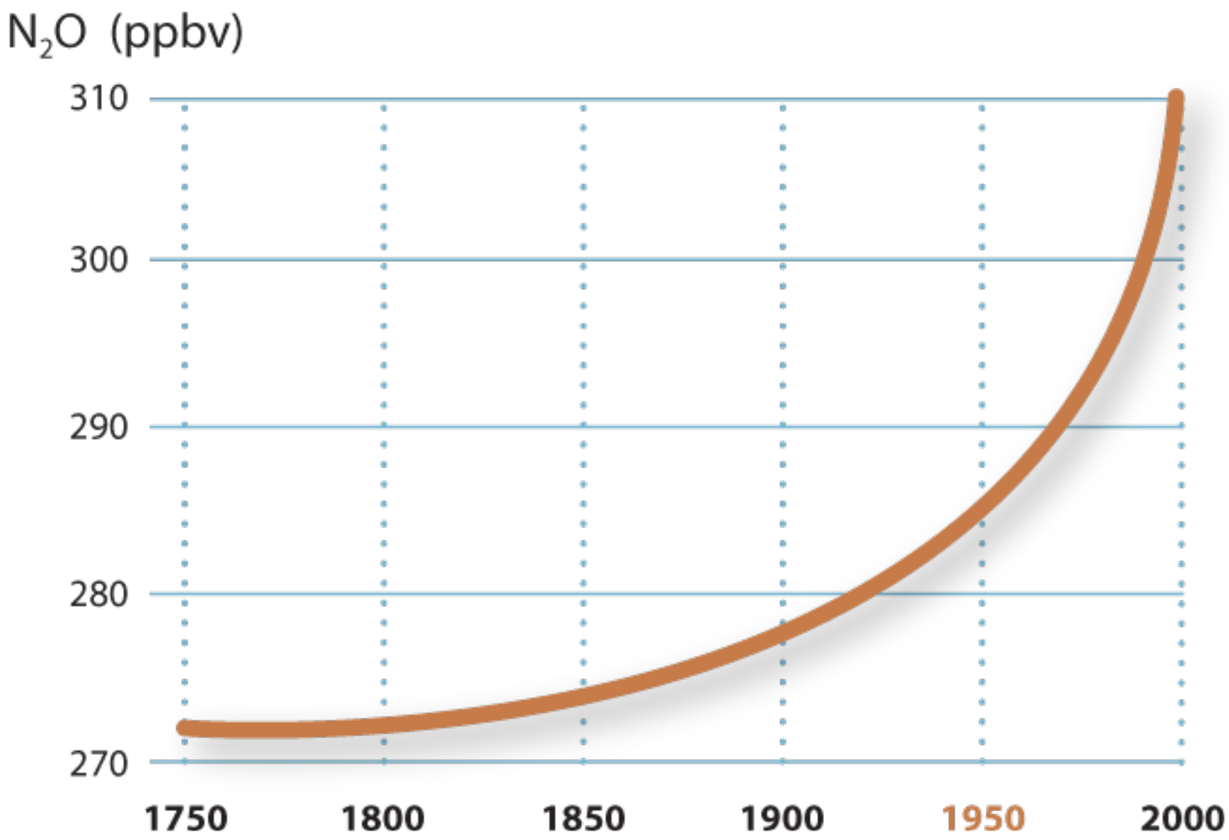
Northern hemisphere average surface temperature



Mann et al Geophys Res Lett 26(6): 759-762

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

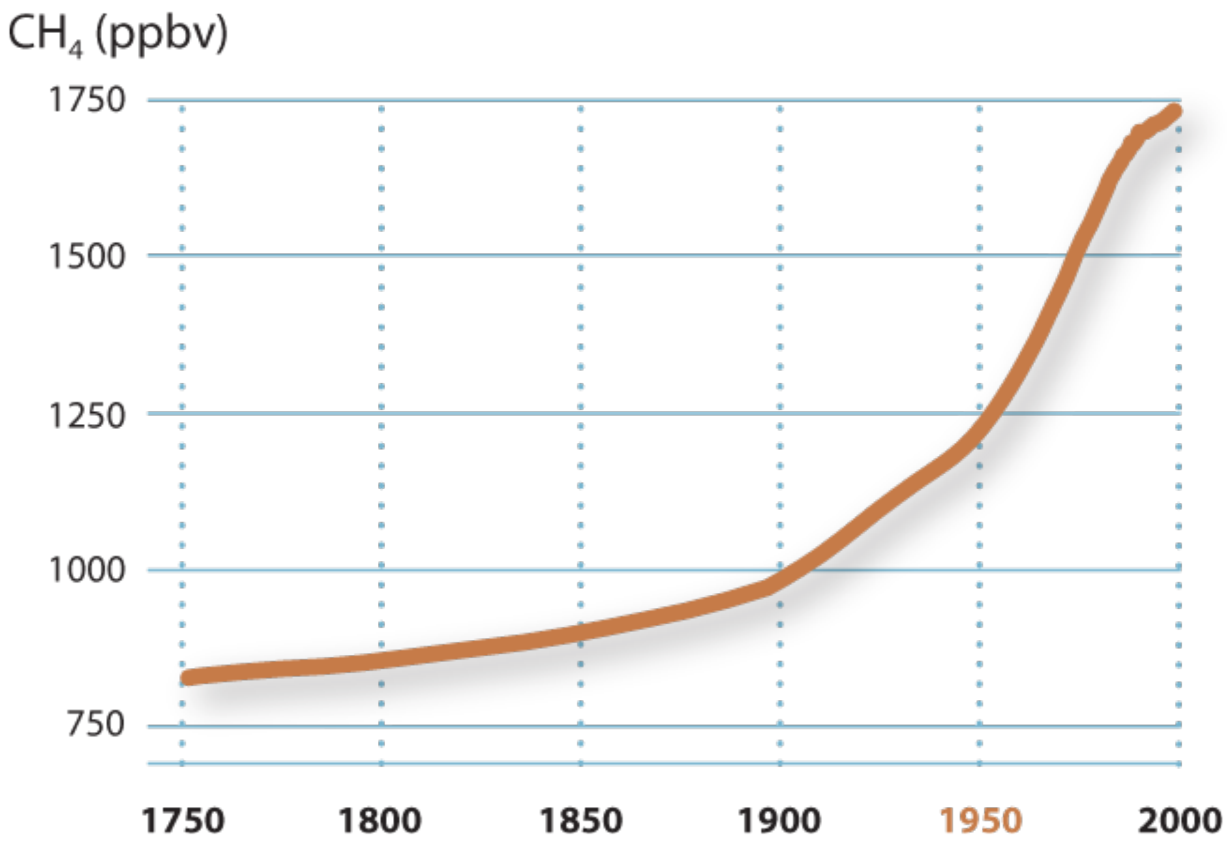
Atmospheric N_2O concentration



Machida et al Geophys Res Lett 22:2921-2925

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

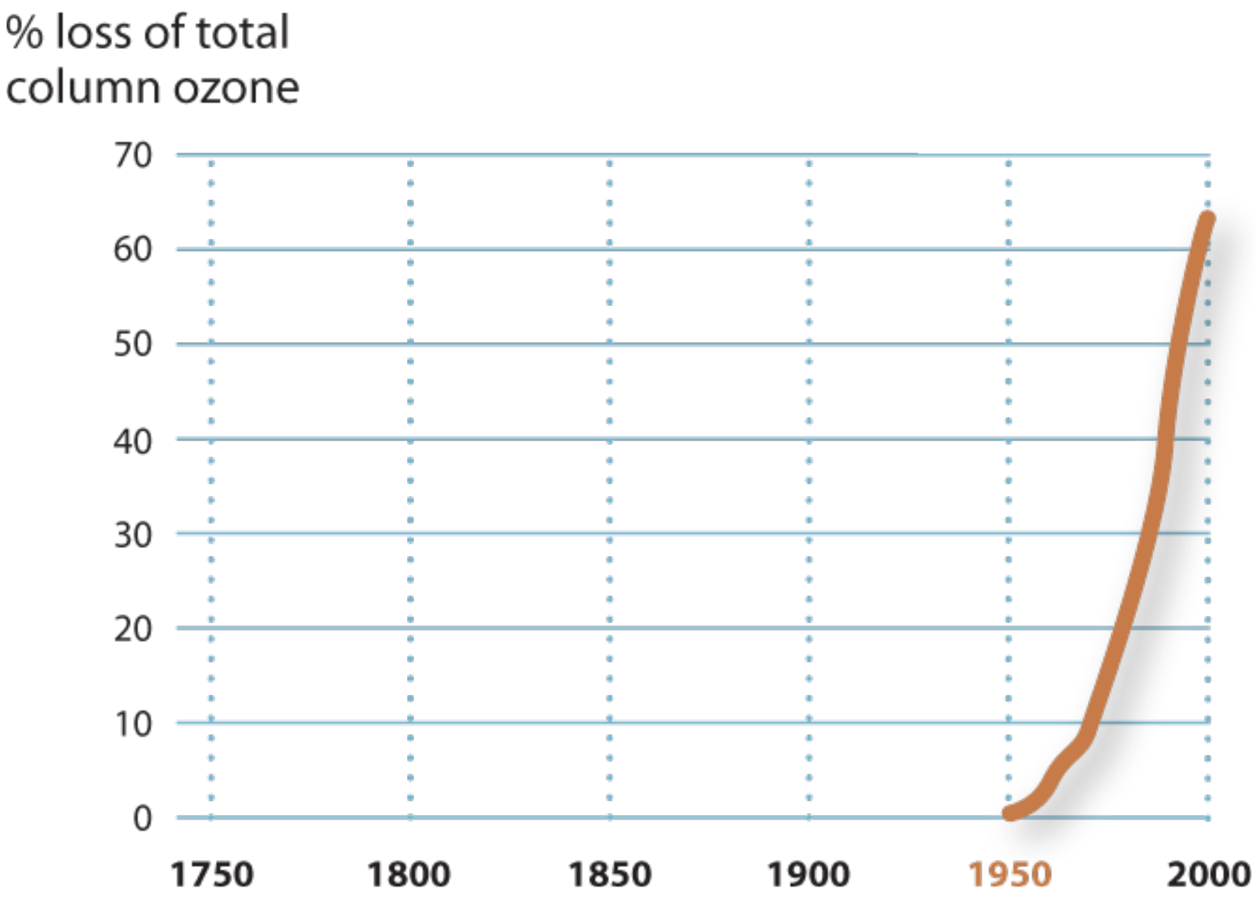
Atmospheric CH_4 concentration



Blunier et al J Geophy Res 20: 2219-2222

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

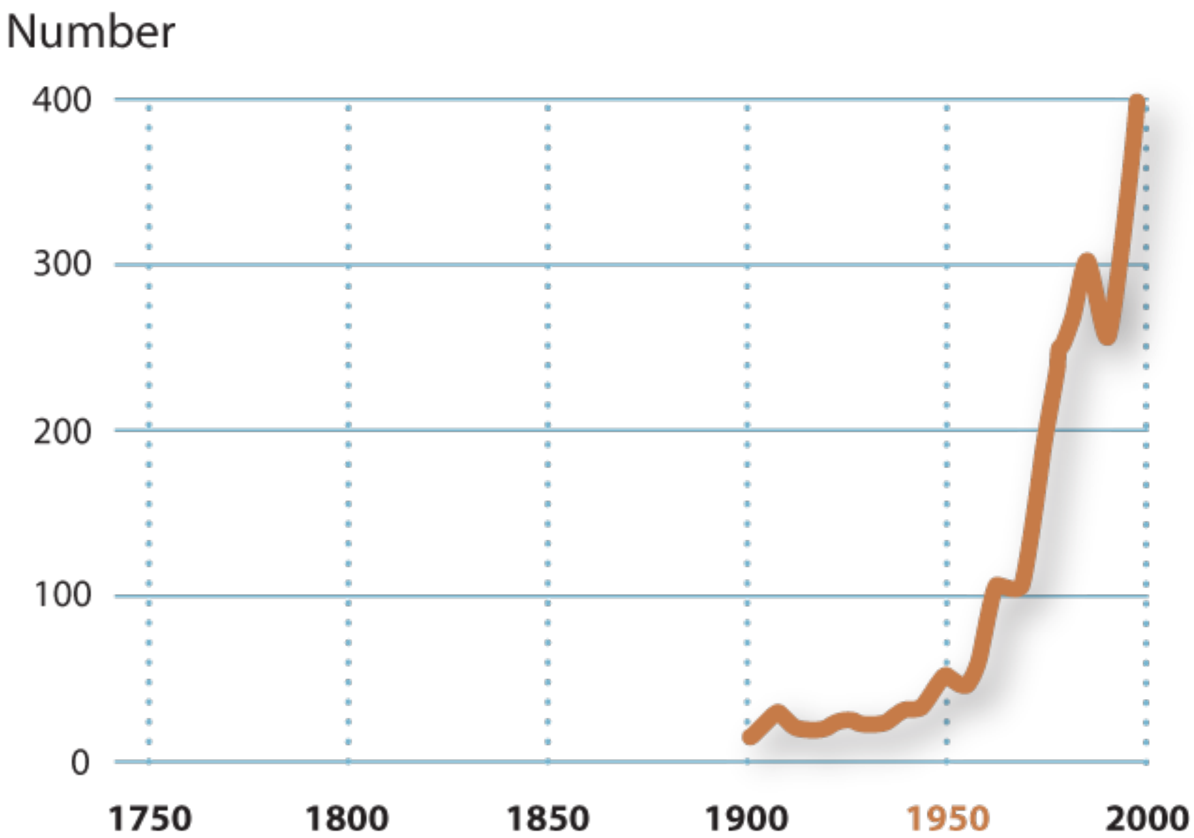
Ozone depletion



JD Shanklin British Antarctic Survey

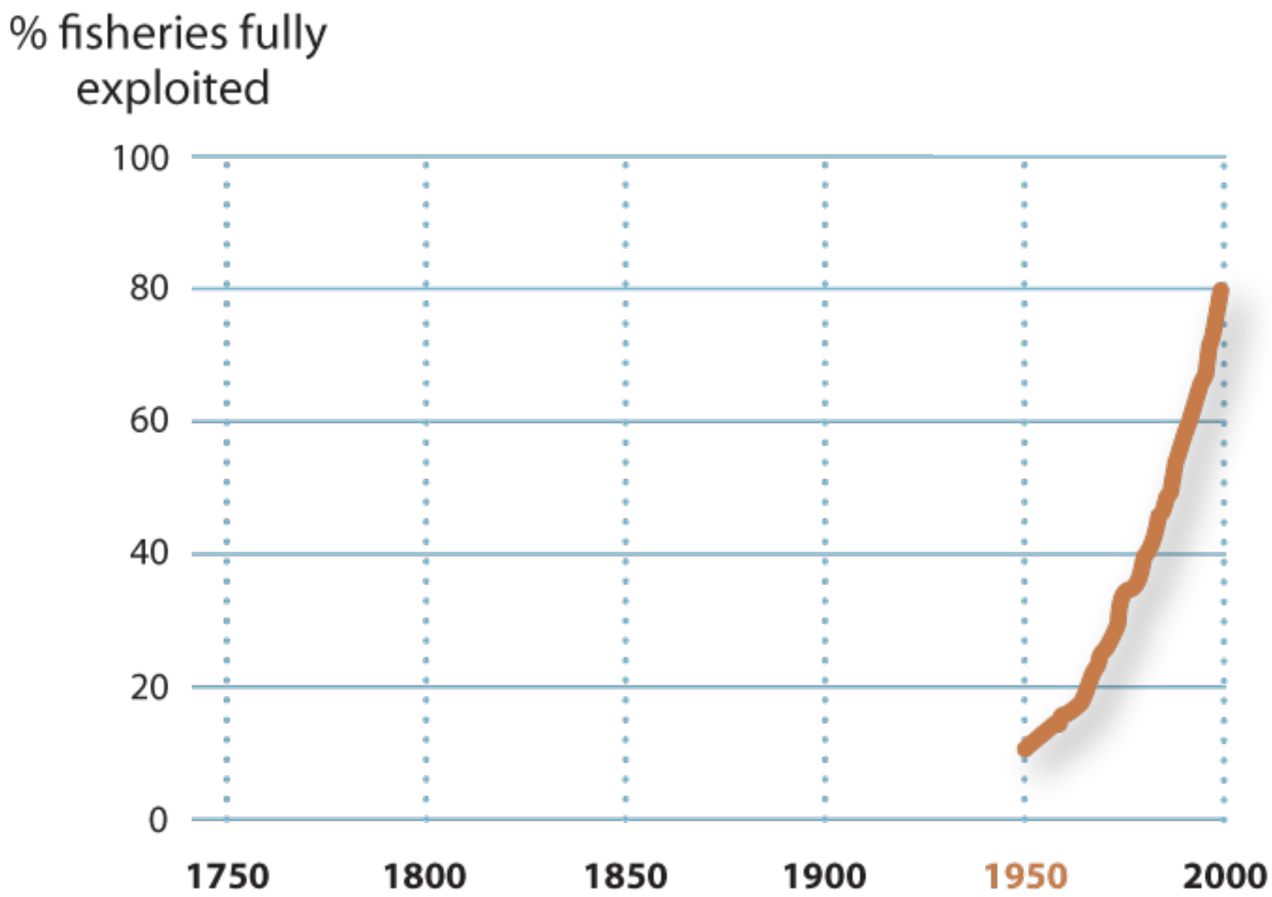
IGBP synthesis: Global Change and the Earth System, Steffen et al 2004

Natural climactic disasters



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

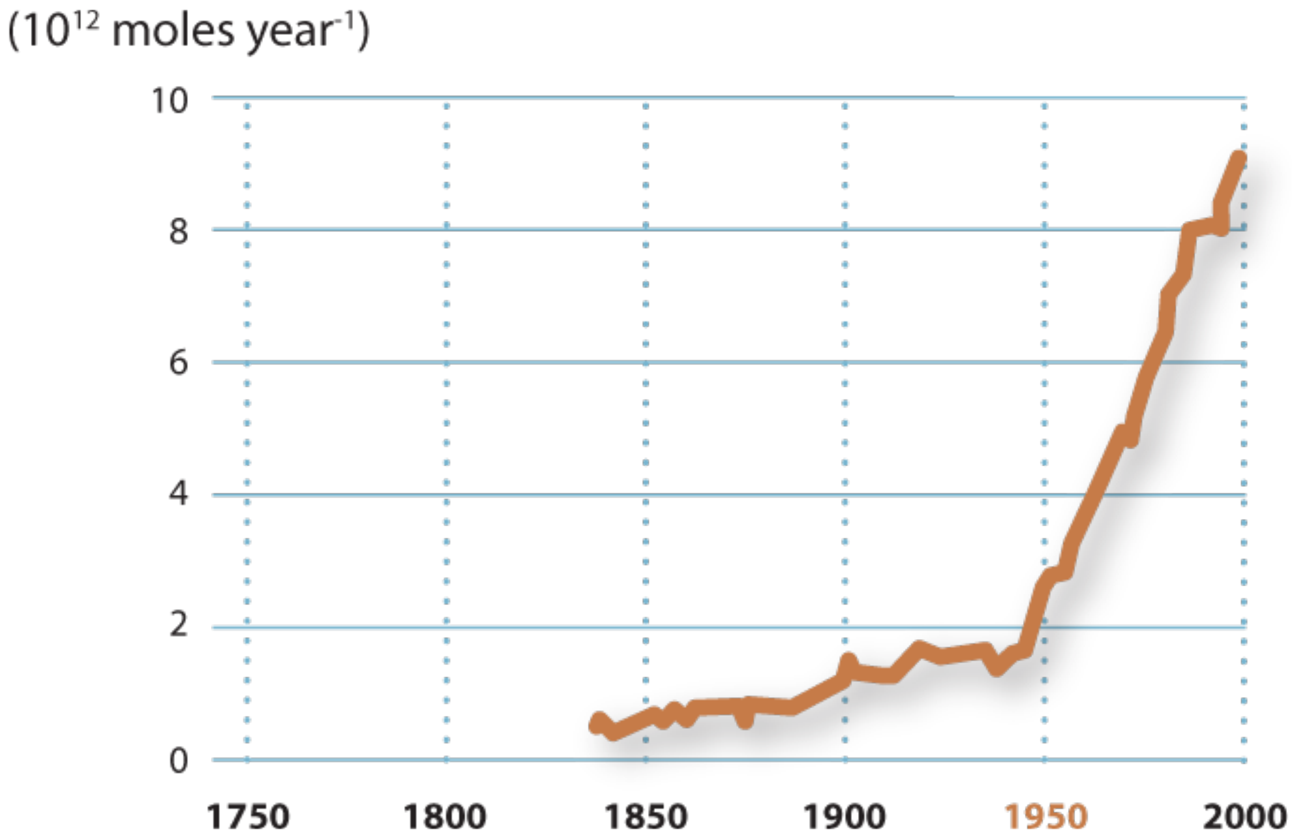
Ocean ecosystems



FAOSTAT 2002 Statistical database

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

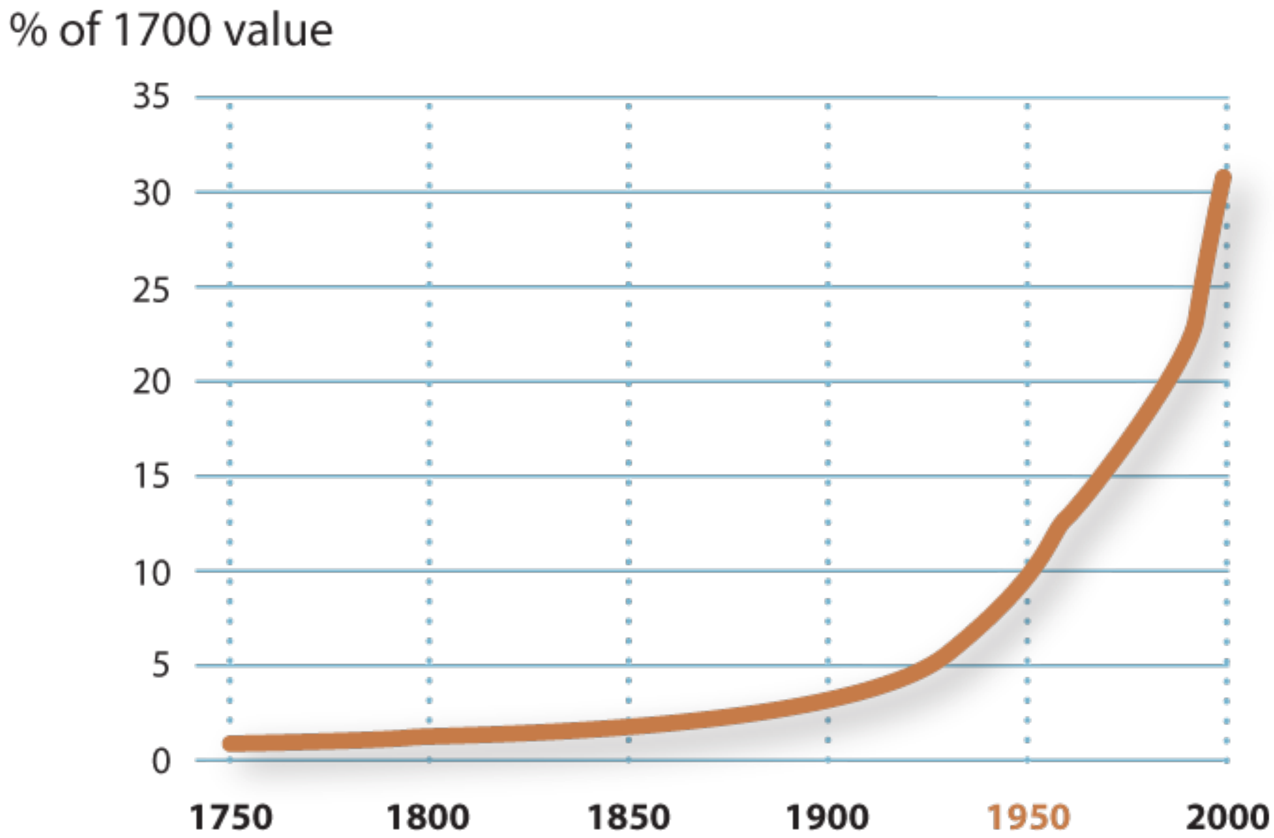
Coastal zone nitrogen flux



Mackenzie et al 2002.

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

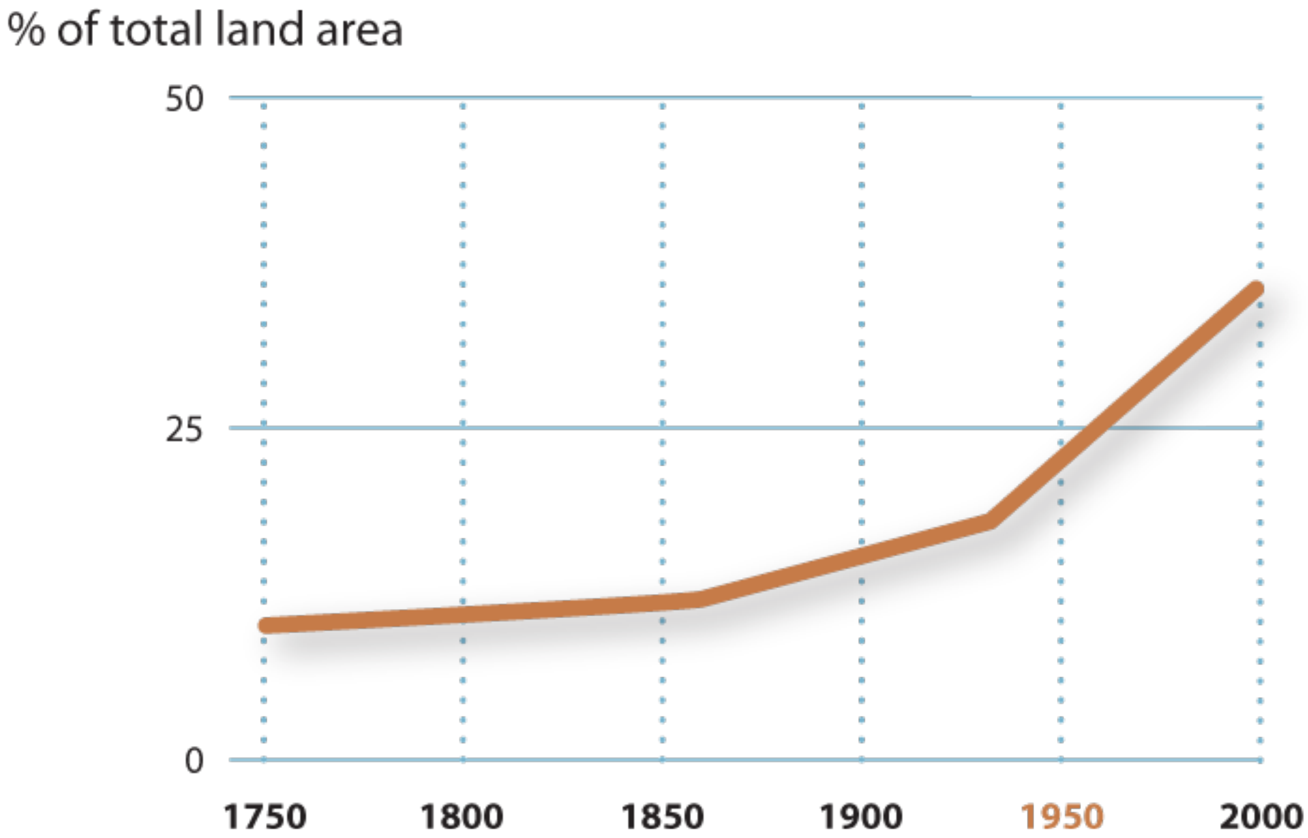
Tropical rainforest and woodland loss



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

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

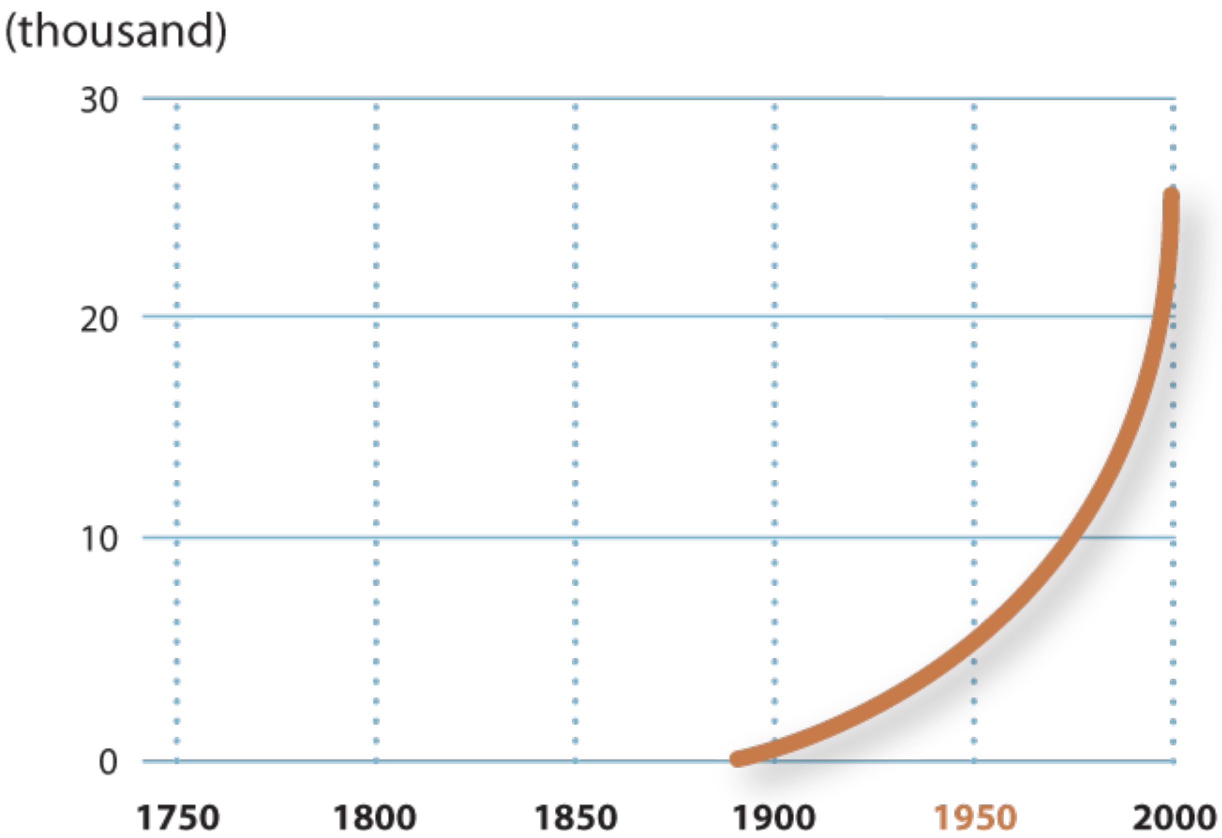
Domesticated land



Klein Goldewijk and Batties

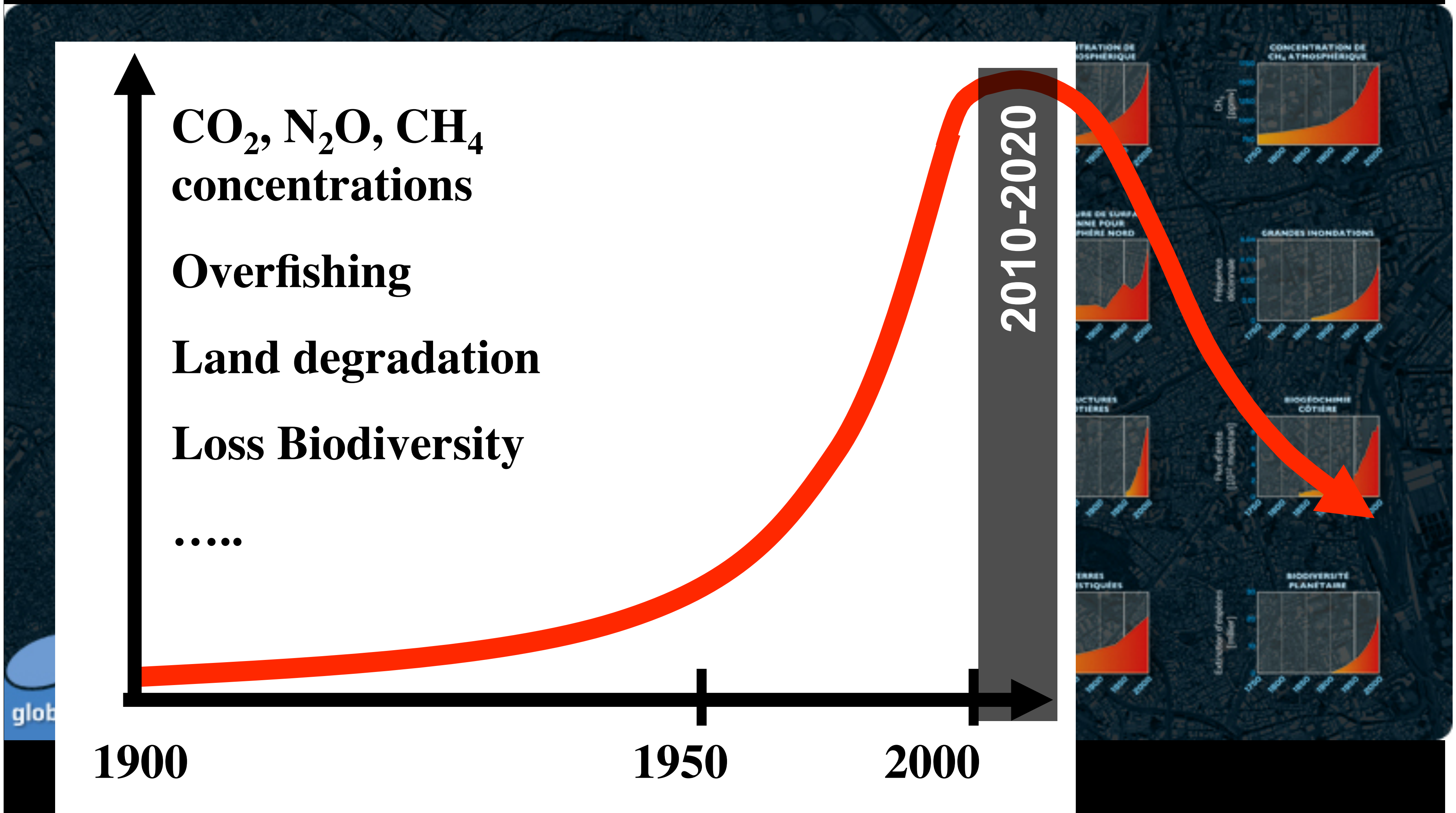
IGBP synthesis: Global Change and the Earth System, Steffen et al 2004

Species extinctions

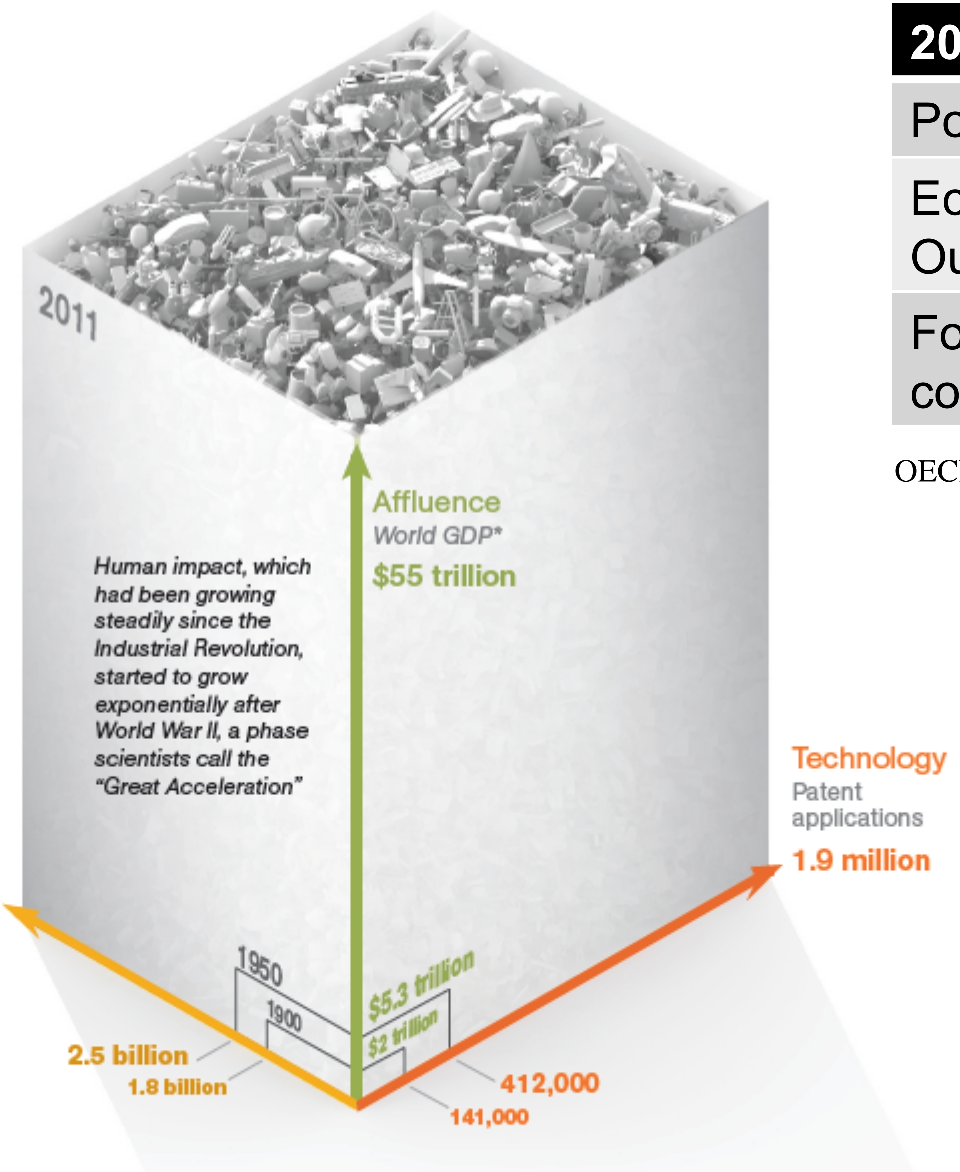


Wilson, the Diversity of Life.

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


CO_2, N_2O, CH_4 concentrations
Overfishing
Land degradation
Loss Biodiversity
…..
2010-2020
1900
1950
2000

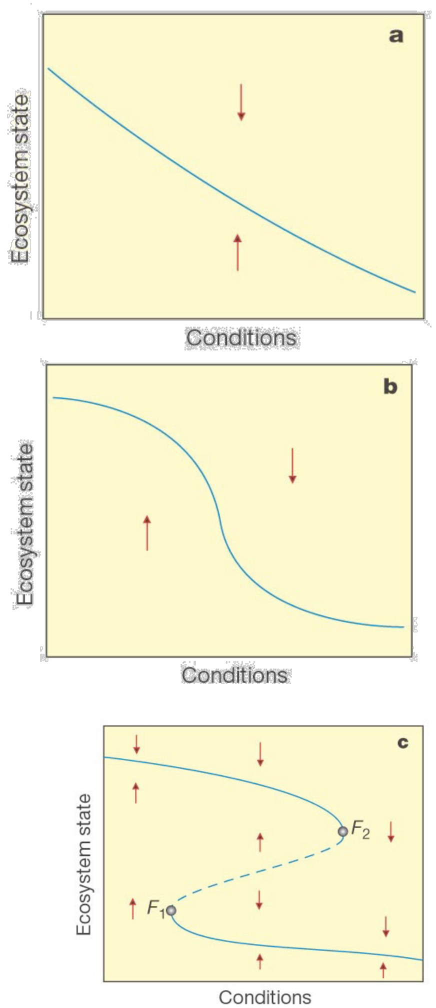
P x A x T = width times height times length of three boxes representing human impact in 1900, 1950 and 2011.

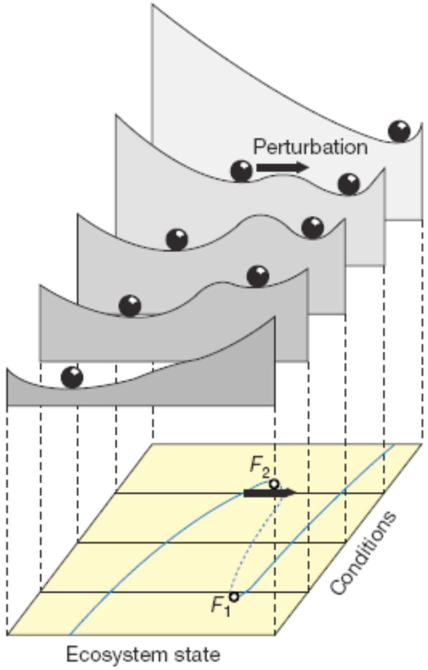


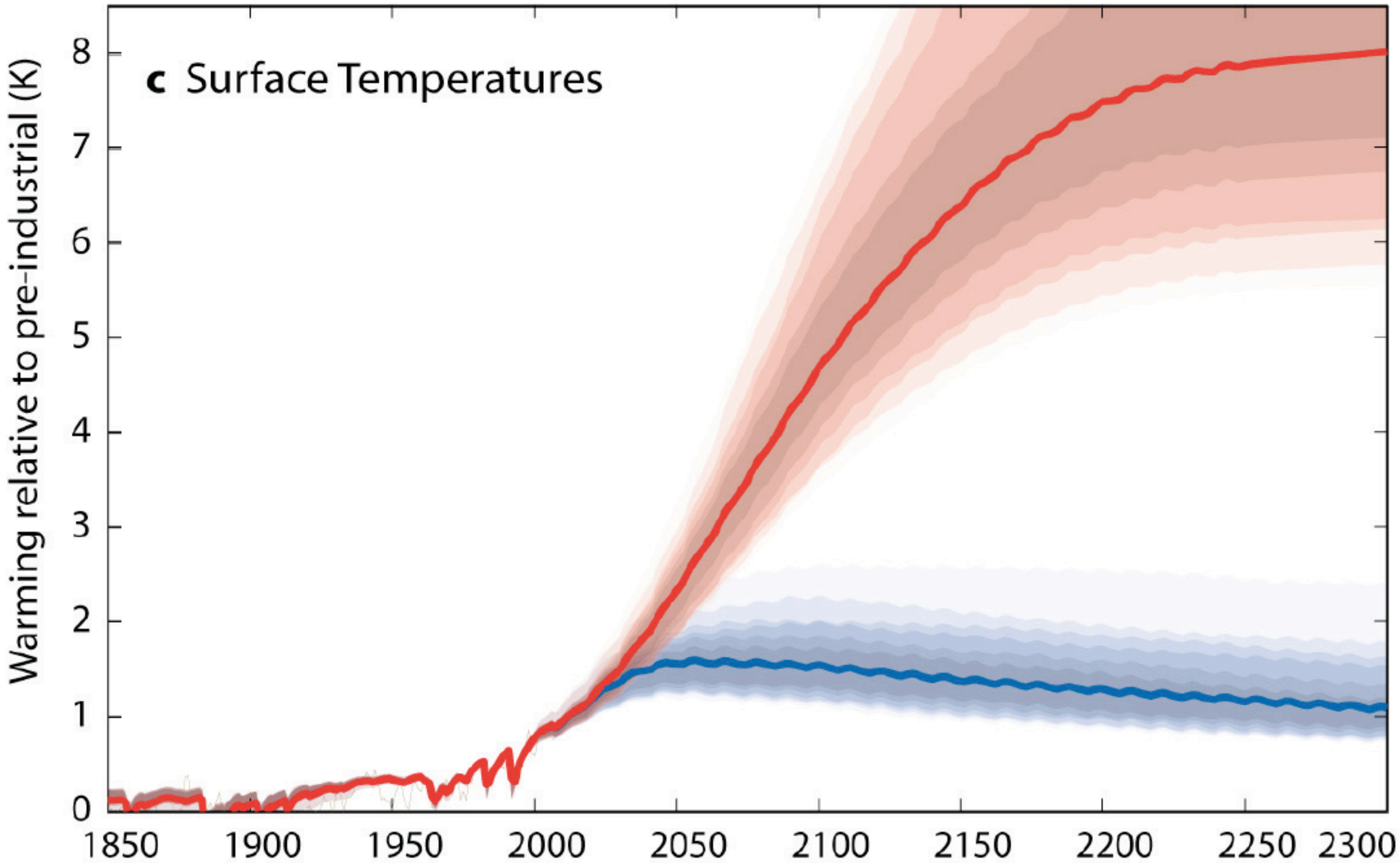
20th Century	
Population	4X
Economic Output	22X
Fossil fuel consumption	14X

OECD Green Growth Report 2011

Critical transitions or regime shifts

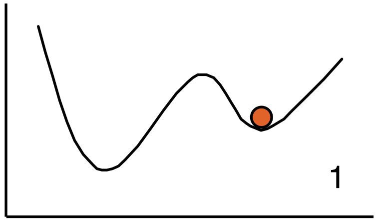


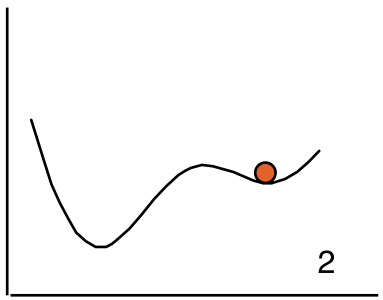


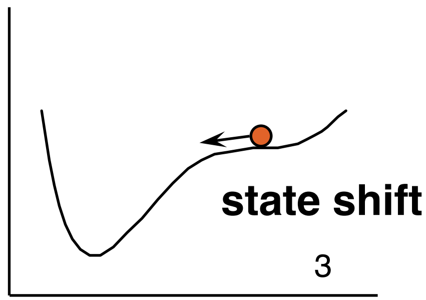


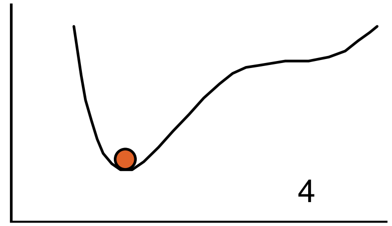
(Meinsheuzen et al., in prep)

Valuable Ecosystem Services (Desirable) → Loss of ecosystem services (Undesirable)







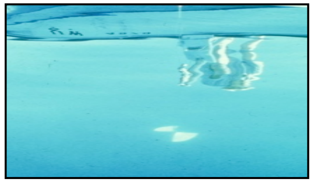


coral dominance

- overfishing, coastal eutrophication
- disease, hurricane

algal dominance

clear water



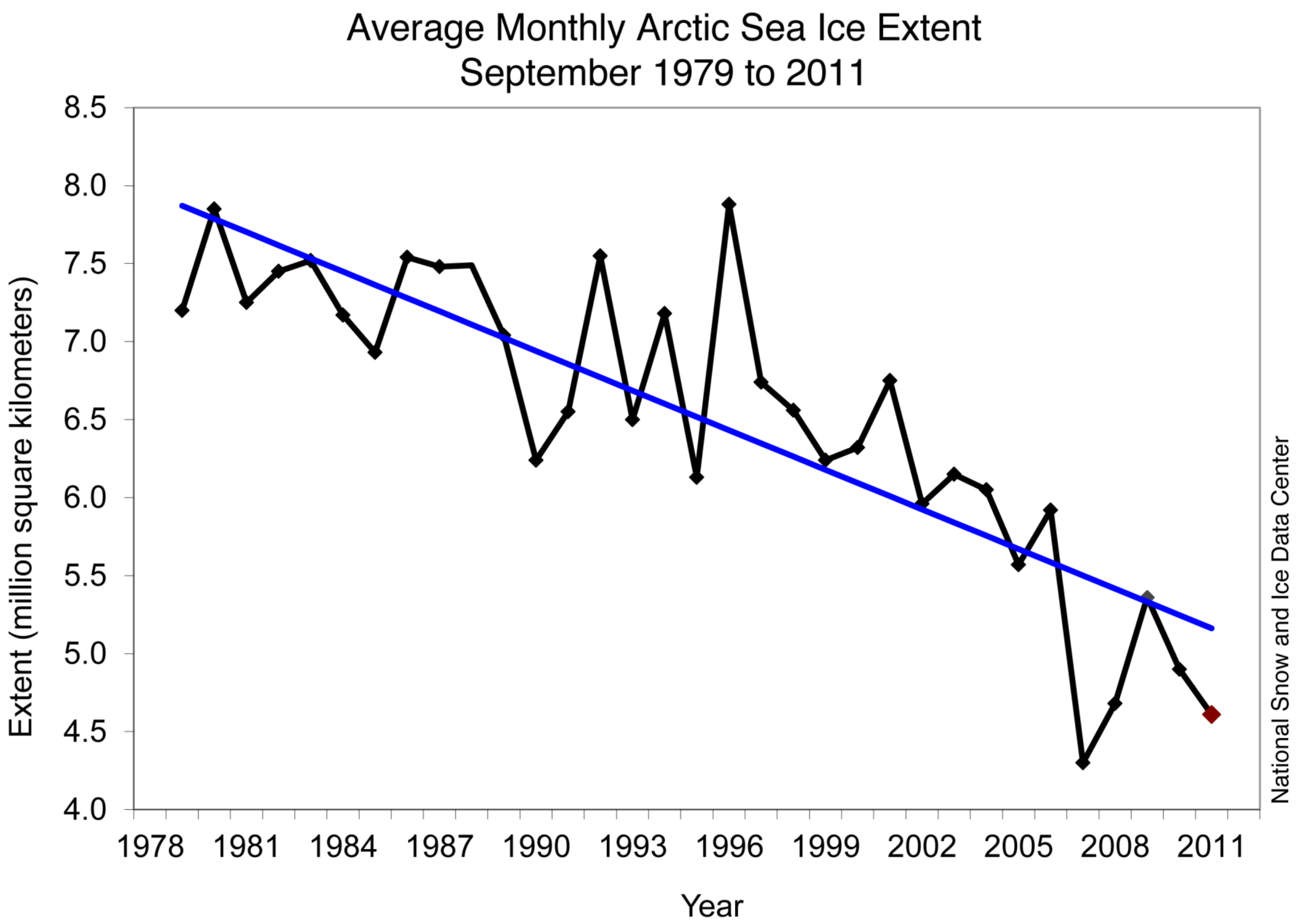
- phosphorous accumulation in soil and mud
- flooding, warming, overexploitation of predators

turbid water

grassland

- fire prevention
- good rains, continuous heavy grazing

shrub-bushland



Average Monthly Arctic Sea Ice Extent
September 1979 to 2011
Extent (million square kilometers)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Year
National Snow and Ice Data Center

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.

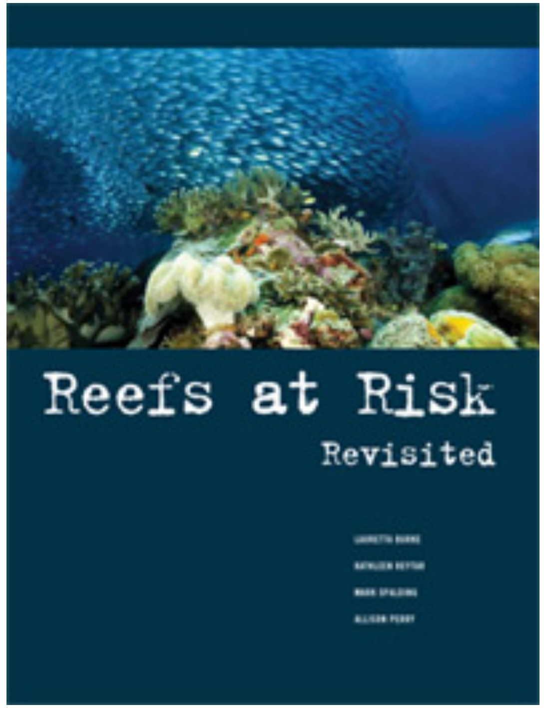


Photo: CC Jason Auch / Azote

Photo: S Zeff / Azote

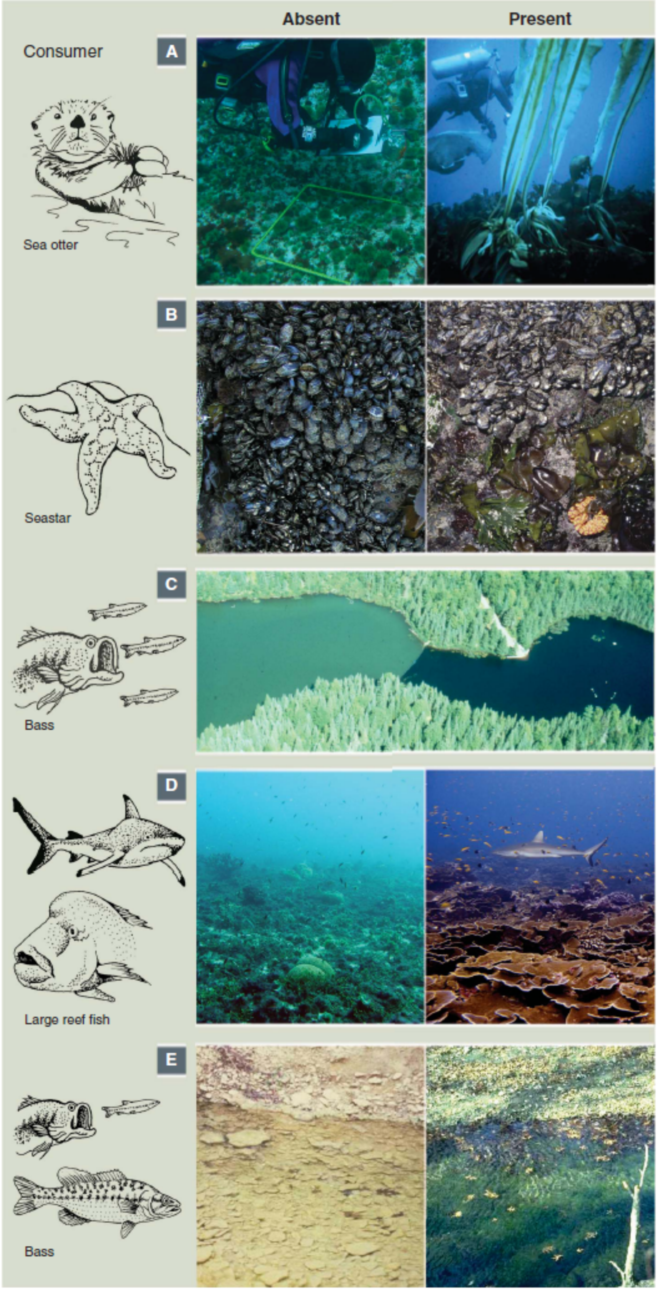
Photo: B Christensen / Azote

Photo: B Christensen / Azote

Trophic Downgrading of Planet Earth

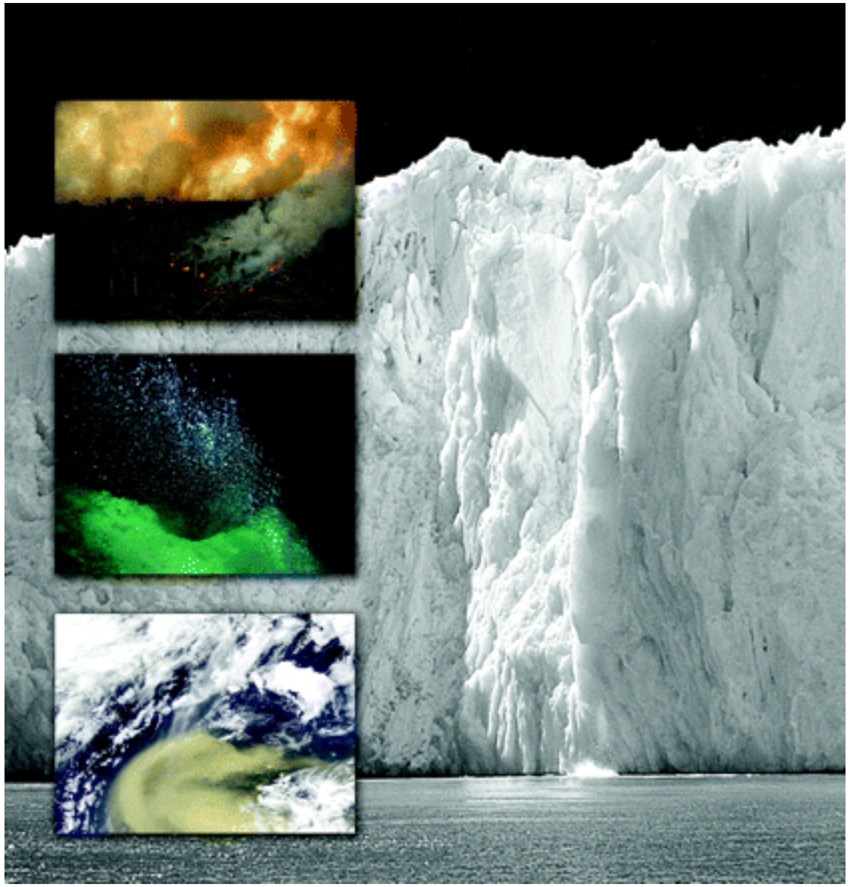
James A. Estes,[1*] John Terborgh,[2] Justin S. Brashares,[3] Mary E. Power,[4] Joel Berger,[5] William J. Bond,[6] Stephen R. Carpenter,[7] Timothy E. Essington,[8] Robert D. Holt,[9] Jeremy B. C. Jackson,[10] Robert J. Marquis,[11] Lauri Oksanen,[12] Tarja Oksanen,[13] Robert T. Paine,[14] Ellen K. Pikitch,[15] William J. Ripple,[16] Stuart A. Sandin,[10] Marten Scheffer,[17] Thomas W. Schoener,[18] Jonathan B. Shurin,[19] Anthony R. E. Sinclair,[20] Michael E. Soulé,[21] Risto Virtanen,[22] David A. Wardle[23]

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)

Article Will Steffen, Paul J. Crutzen and John R. McNeill

The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?

Ambio Vol. 36, No. 8, December 2007

+

648 Review TRENDS in Ecology and Evolution Vol.18 No.12 December 2003

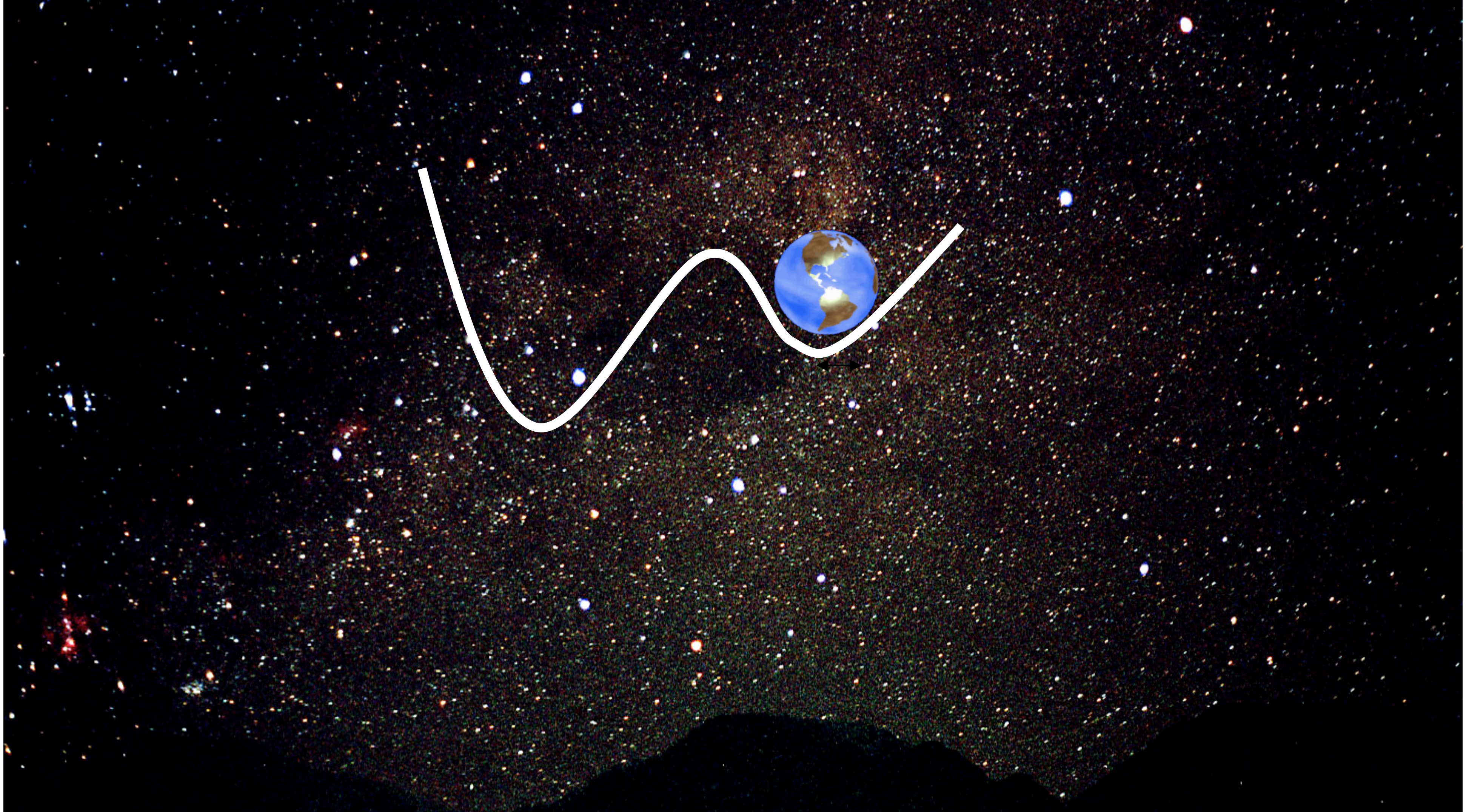
ELSEVIER

Catastrophic regime shifts in ecosystems: linking theory to observation

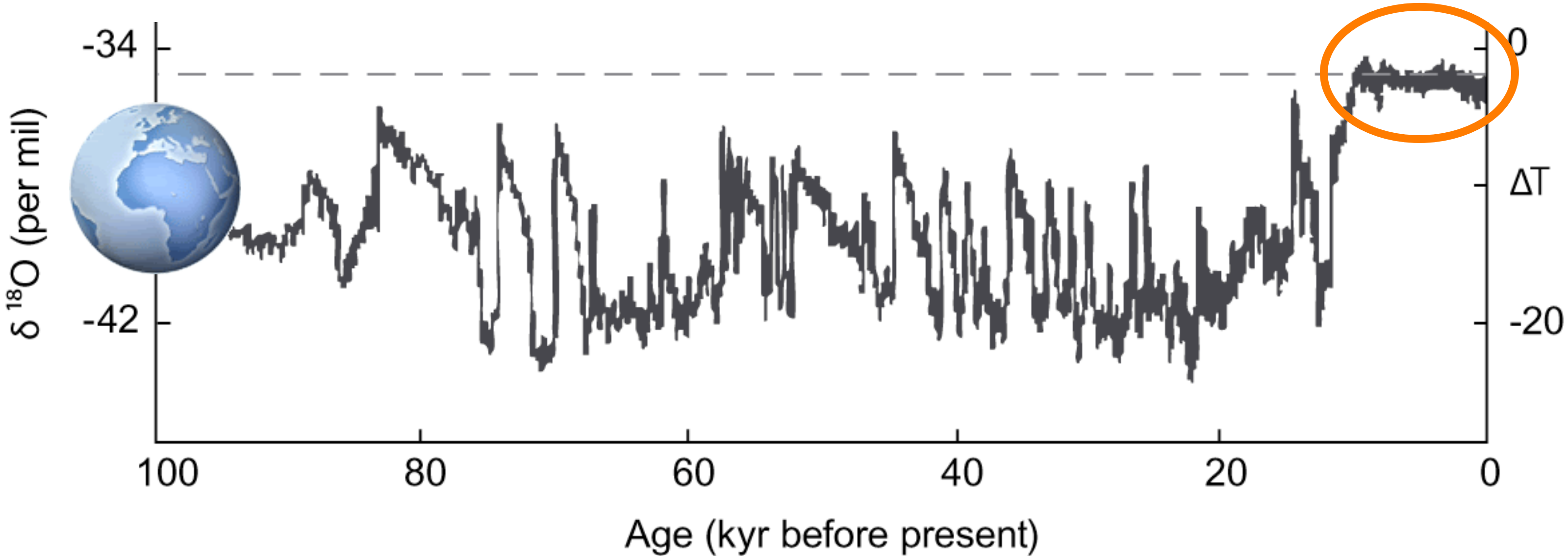
Marten Scheffer[1] and Stephen R. Carpenter[2]

[1]Department of Aquatic Ecology and Water Quality Management, Wageningen University, PO Box 8080, 6700 DD Wageningen, The Netherlands
[2]Center for Limnology, University of Wisconsin, 680 North Park Street, Madison, WI 53706, USA

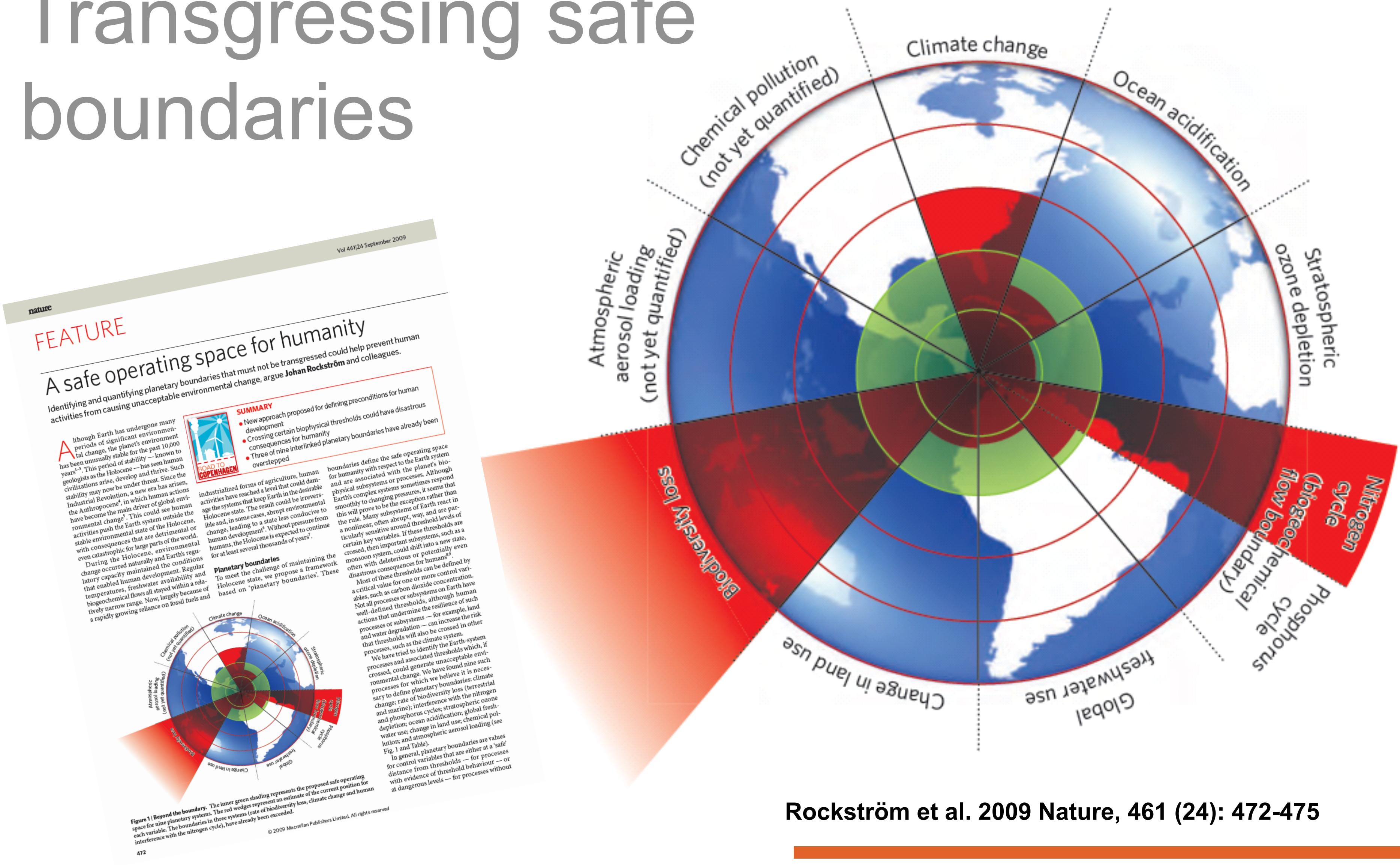
The Resilience of the Earth System



Humanity's 10,000 years of grace

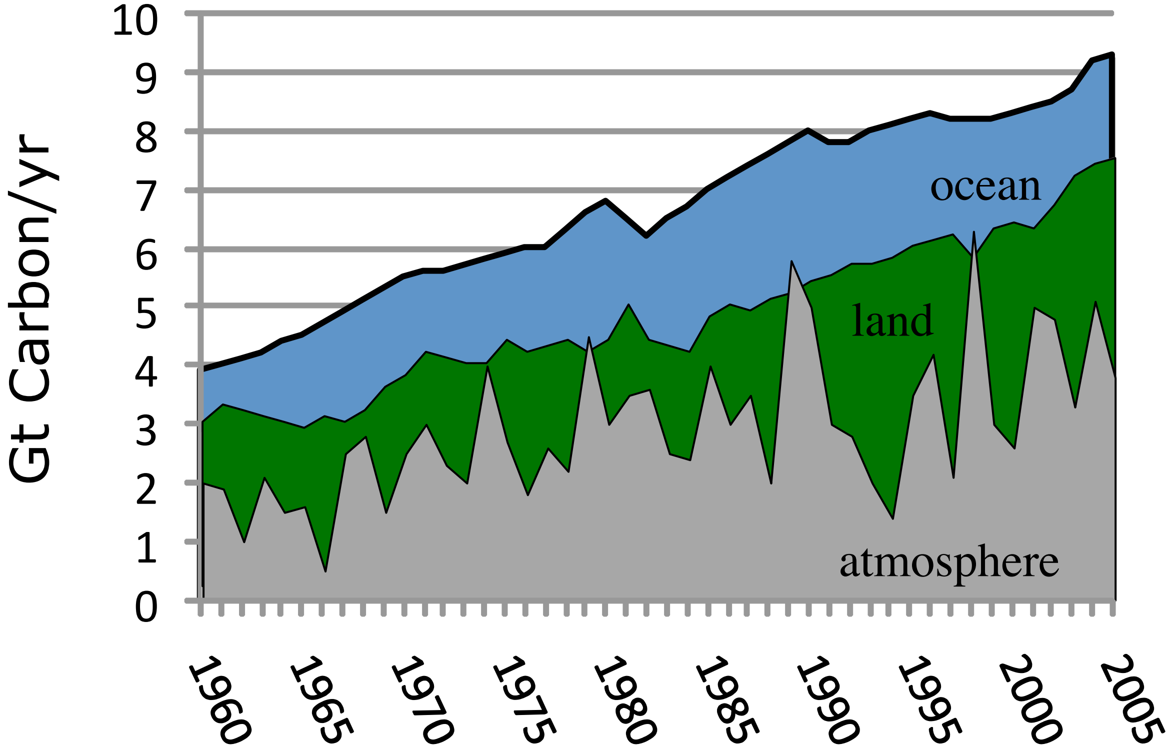


Transgressing safe boundaries



Rockström et al. 2009 Nature, 461 (24): 472-475

Biosphere interactions with the climate system



Adapted from Canadell et al., 2007

POLICYFORUM

ENVIRONMENT AND DEVELOPMENT

Earth System Science for Global Sustainability: Grand Challenges

Progress in understanding and addressing both global environmental change and sustainable development requires better integration of social science research.

W. V. Reid,[1*] D. Chen,[2] L. Goldfarb,[2] H. Hackmann,[3] Y. T. Lee,[2] K. Mokhele,[4] E. Ostrom,[5] K. Raivio,[2] J. Rockström,[6] H. J. Schellnhuber,[7] A. Whyte[8]

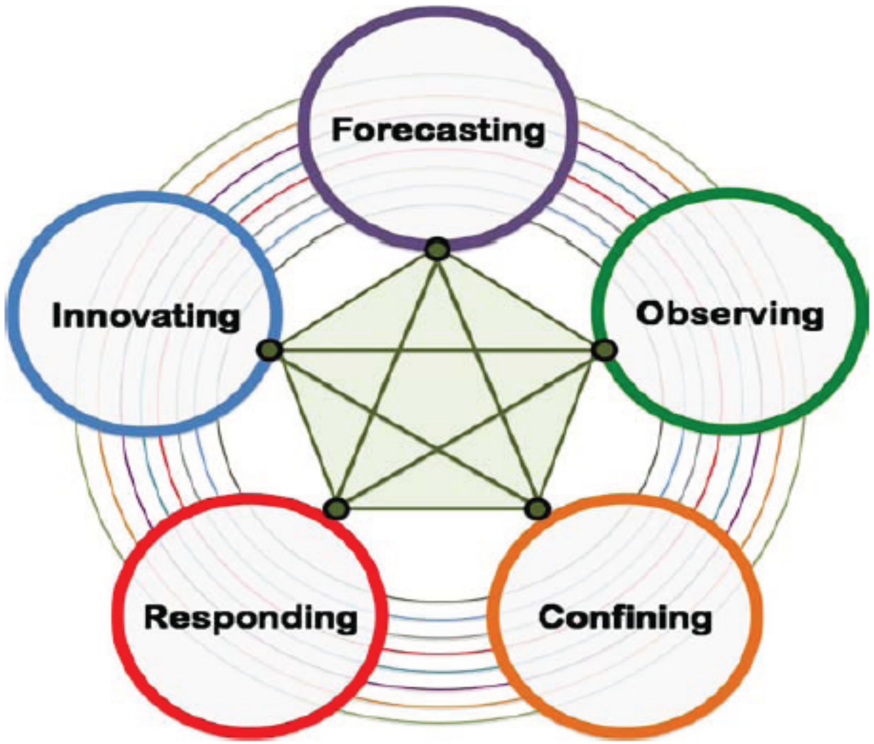
12 NOVEMBER 2010 VOL 330 SCIENCE www.sciencemag.org
Published by AAAS

Global sustainability now a prerequisite for Poverty Alleviation

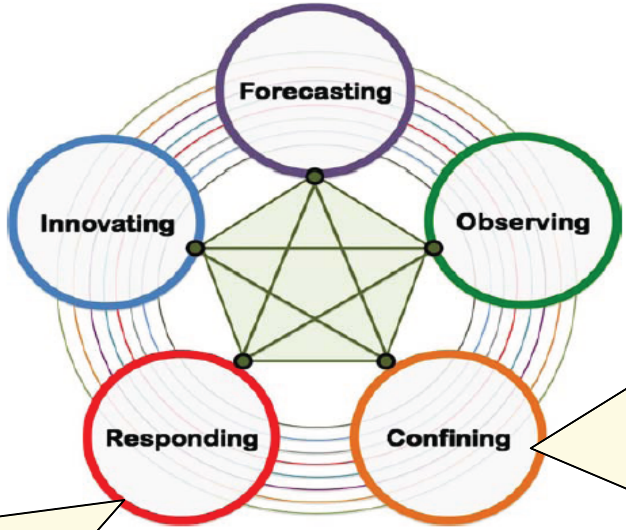
Predict risks of catastrophic thresholds in the Earth system

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

BELMONT FORUM

ICSU
International Council for Science

UNITED NATIONS UNIVERSITY

Earth System Sustainability Initiative (ESSI)

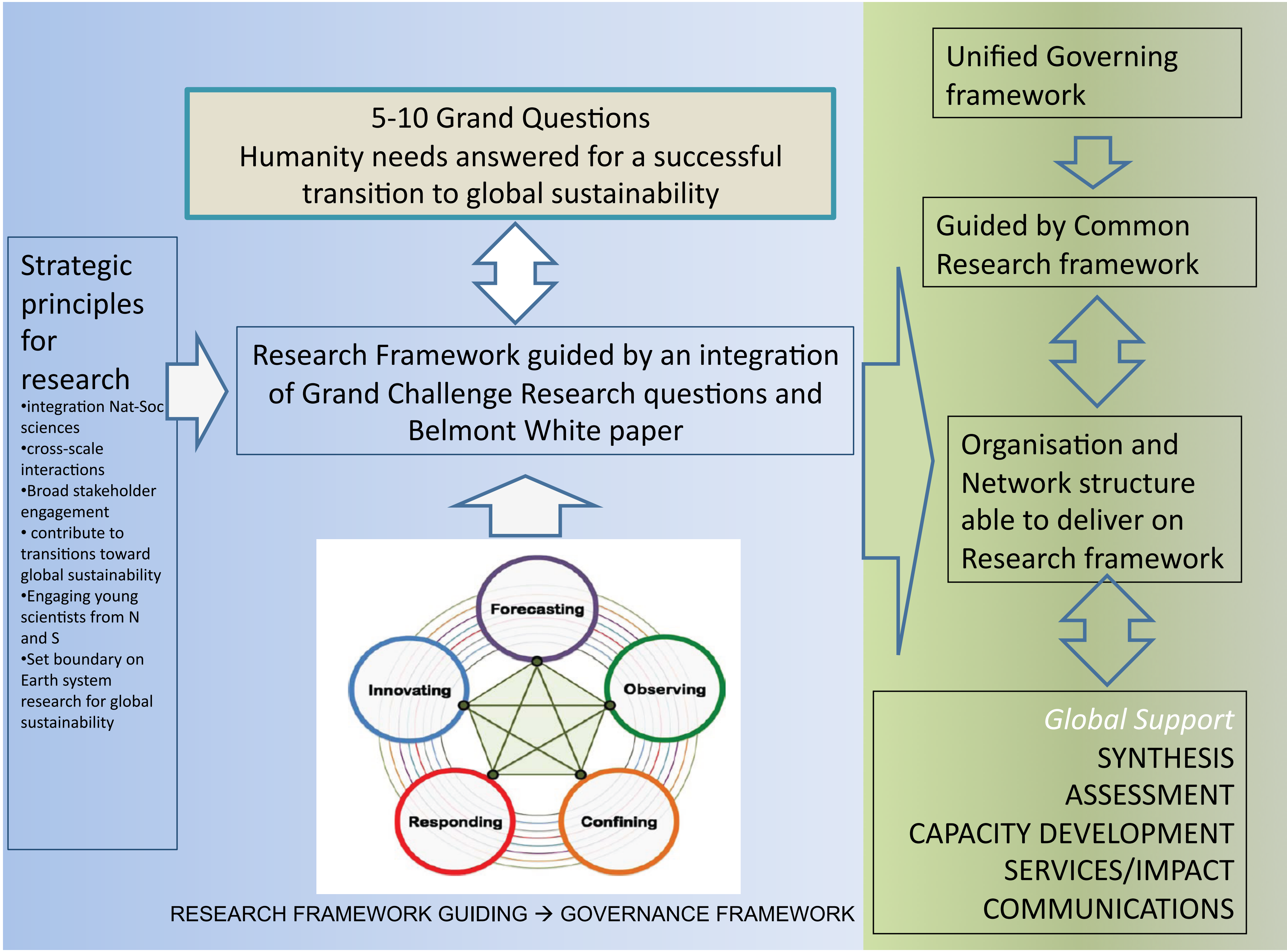
ISSC
international social science council

UNESCO
United Nations Educational, Scientific and Cultural Organization

IGFA
INTERNATIONAL GROUP OF FUNDING AGENCIES FOR GLOBAL CHANGE RESEARCH

UNEP

Note: WMO is an observer to ESSI


5-10 Grand Questions
Humanity needs answered for a successful transition to global sustainability
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
Research Framework guided by an integration of Grand Challenge Research questions and Belmont White paper
Forecasting
Innovating
Observing
Responding
Confining
RESEARCH FRAMEWORK GUIDING → GOVERNANCE FRAMEWORK
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)

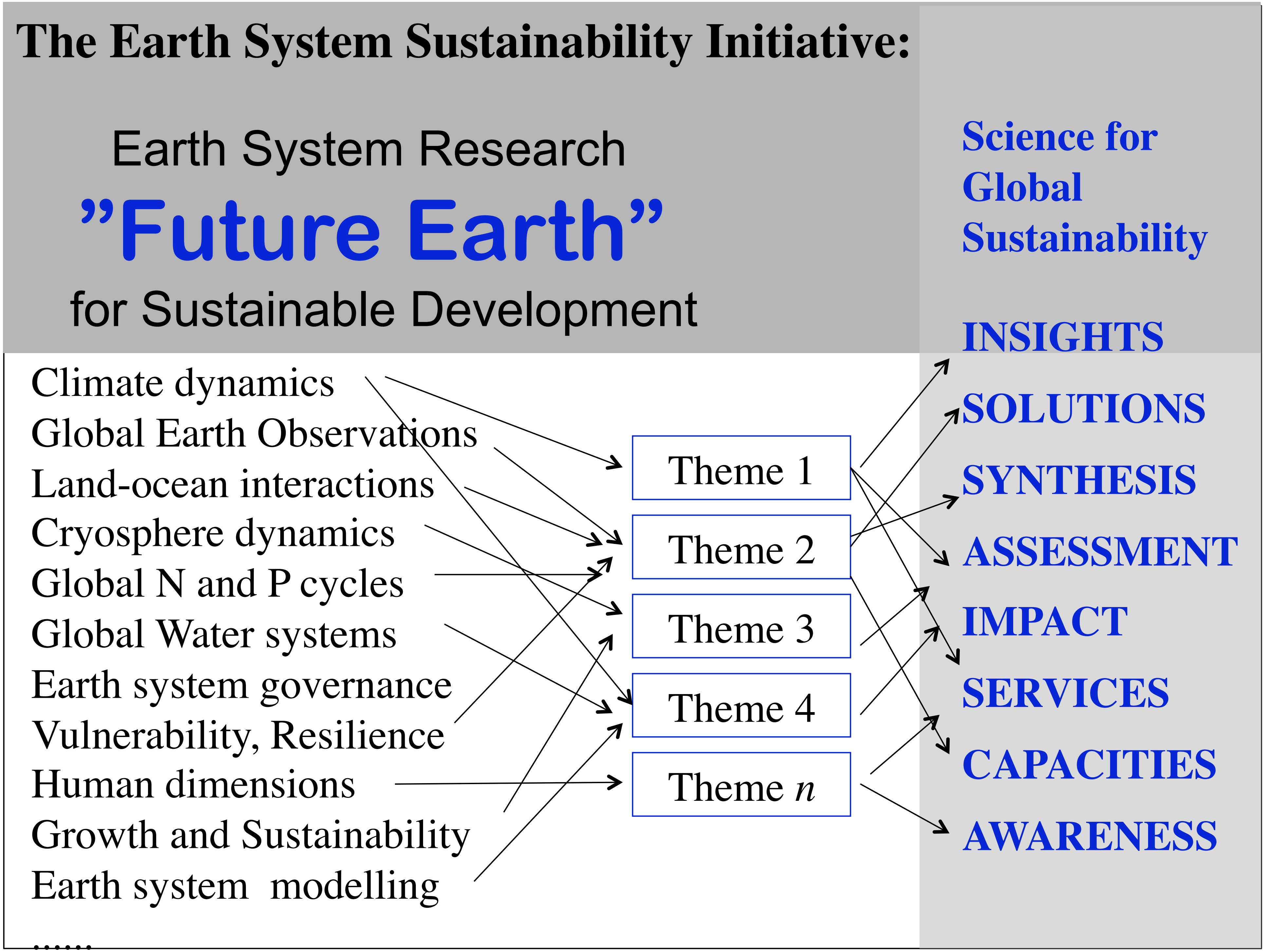
- Co-design and trans-disciplinary endeavour – integrating sciences, integrating science-policy-practice

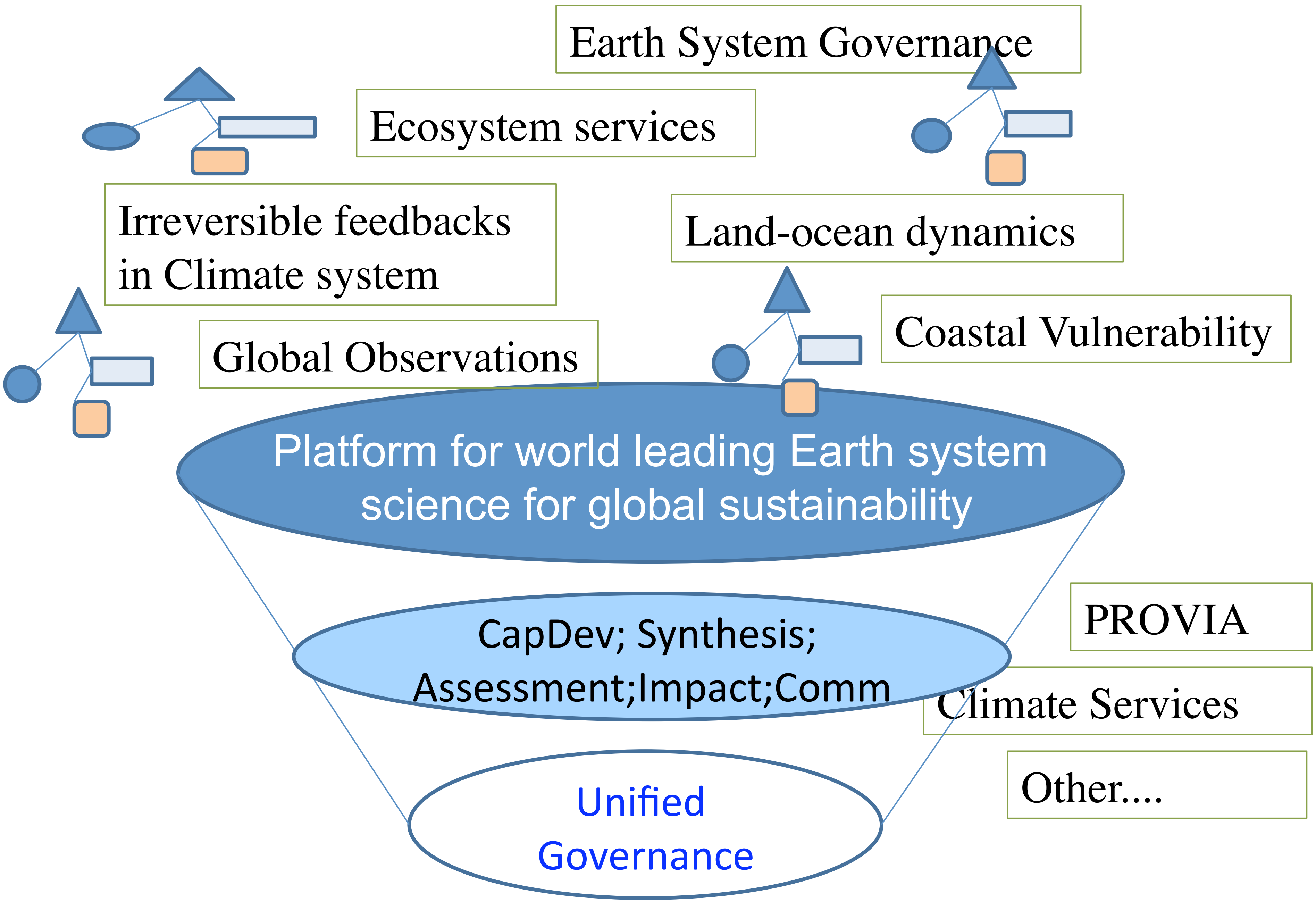
- Guided by common research strategy
- Governed by one unified governance framework

- 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
Science for Global Sustainability
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
INSIGHTS
SOLUTIONS
SYNTHESIS
ASSESSMENT
IMPACT
SERVICES
CAPACITIES
AWARENESS


Earth System Governance
Ecosystem services
Irreversible feedbacks in Climate system
Land-ocean dynamics
Coastal Vulnerability
Global Observations
Platform for world leading Earth system science for global sustainability
CapDev; Synthesis; Assessment;Impact;Comm
PROVIA
Climate Services
Other....
Unified Governance

RESPONSE: Climate science; global governance; innovation pathways;

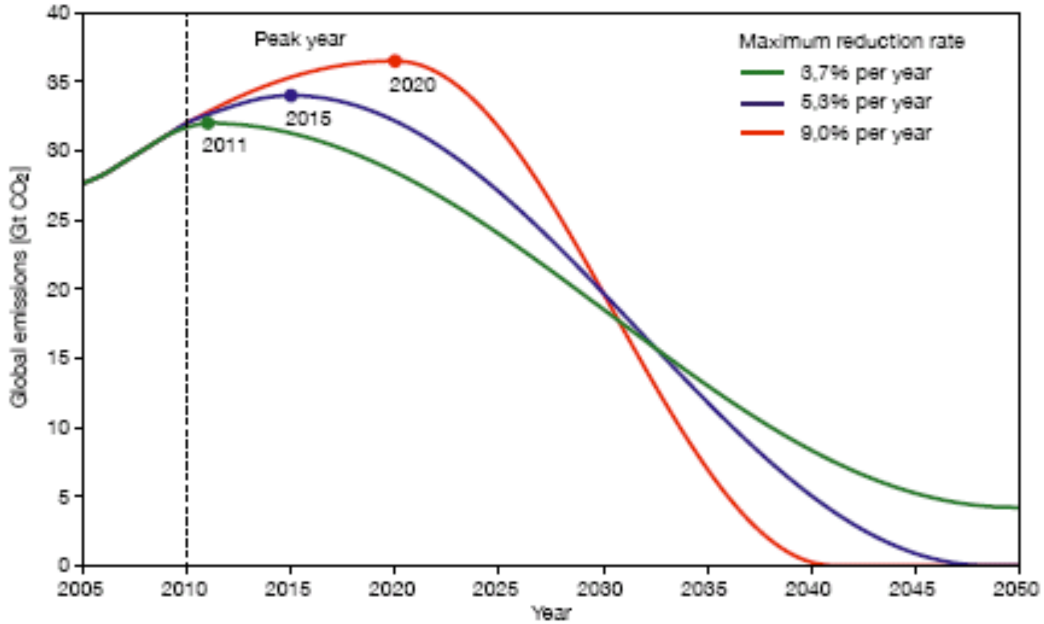


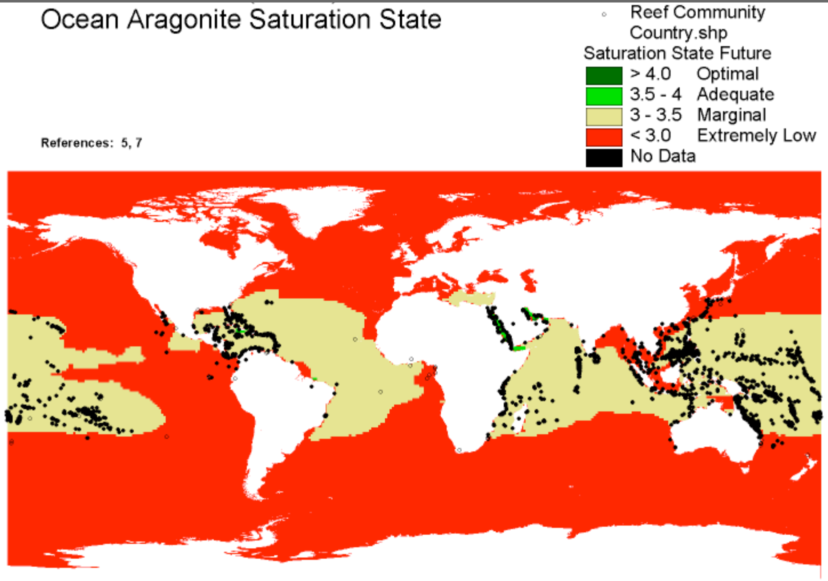
Figure 3.2-1
Examples of global emission pathways for the period 2010–2050 with global CO_2 emissions capped at 750 Gt during this period. At this level, there is a 67 % probability of achieving compliance with the 2°C guard rail (Chapter 5). The figure shows variants of a global emissions trend with 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

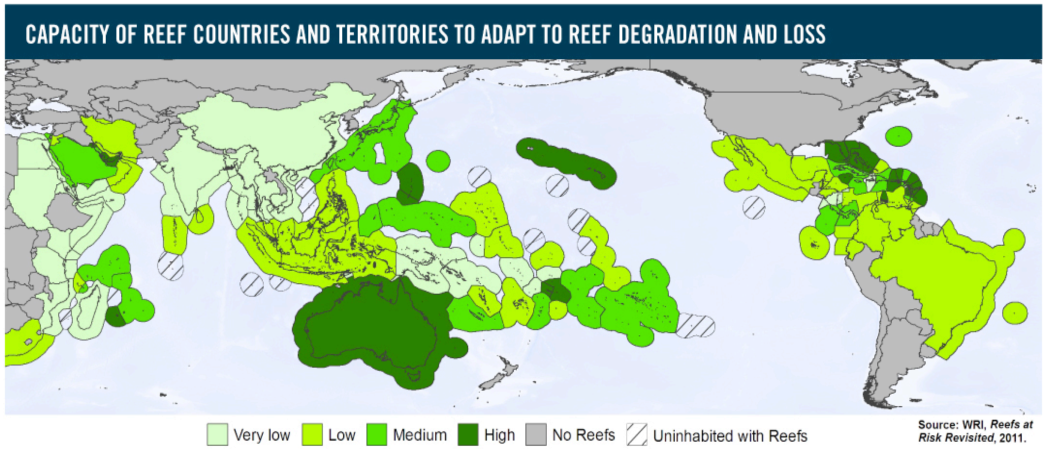
(WBGU 2009)

OBSERVATION + RESPONSE:

Ocean tipping points and marine stewardship

Coastal vulnerability – how far will adaptation take us?





Notes: Adaptive capacity is based on economic resources, education, health, governance, access to markets, and agricultural resources. Eighty-one countries, 21 island territories, and six subnational regions (Florida, Hawaii, Hong Kong SAR, Peninsular Malaysia, Sabah, and Sarawak) were assessed, and are categorized according to quartiles.

Ocean Acidification And capacity for adaptive Coral Reef management

CONFINING+OBSERVING+RESPONSE : Forest and Land use management to sustain global carbon sinks in the biosphere

A Large and Persistent Carbon Sink in the World's Forests

Yude Pan,[1]* Richard A. Birdsey,[1] Jingyun Fang,[2,3] Richard Houghton,[4] Pekka E. Kauppi,[5] Werner A. Kurz,[6] Oliver L. Phillips,[7] Anatoly Shvidenko,[8] Simon L. Lewis,[7] Josep G. Canadell,[9] Philippe Ciais,[10] Robert B. Jackson,[11] Stephen W. Pacala,[12] A. David McGuire,[13] Shilong Piao,[2] Aapo Rautiainen,[5] Stephen Sitch,[7] Daniel Hayes[14]

19 AUGUST 2011 VOL 333 SCIENCE www.sciencemag.org

Total Forest Sink 2,4 ± 0,4 Pg C yr^{-1}

Total Forest Source 1,3 ± 0,5 Pg C yr^{-1}

Net Forest Sink 1,1 ± 0,8 Pg C yr^{-1}

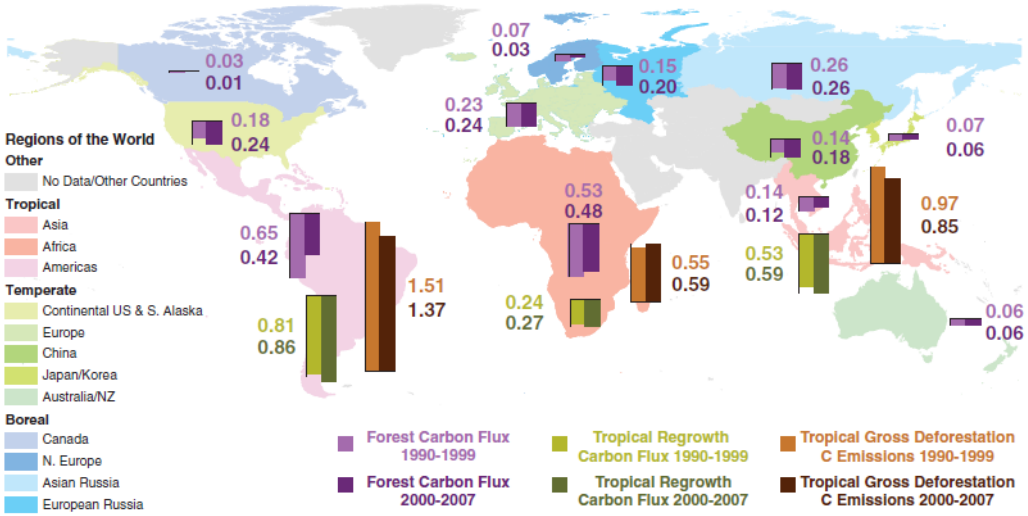
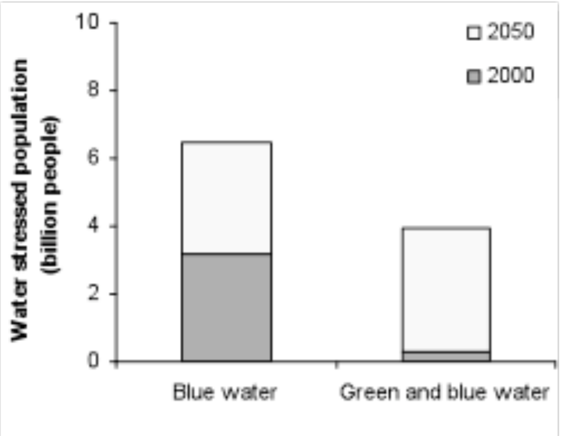
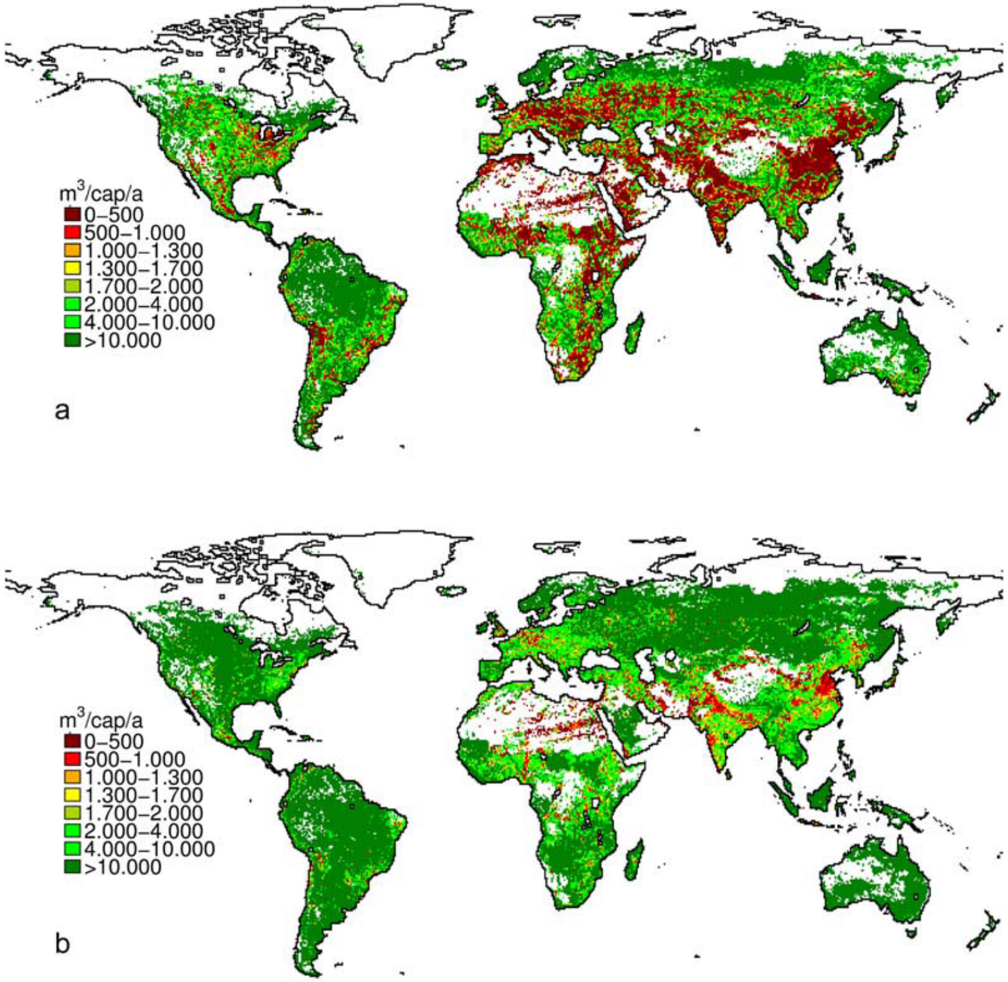


Fig. 1. Carbon sinks and sources (Pg C $year^{-1}$) in the world's forests. Colored bars in the down-facing direction represent C sinks, whereas bars in the upward-facing direction represent C sources. Light and dark purple, global established forests (boreal, temperate, and intact tropical forests); light and dark green, tropical regrowth forests after anthropogenic disturbances; and light and dark brown, tropical gross deforestation emissions.

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

Changing the Face of Water Scarcity

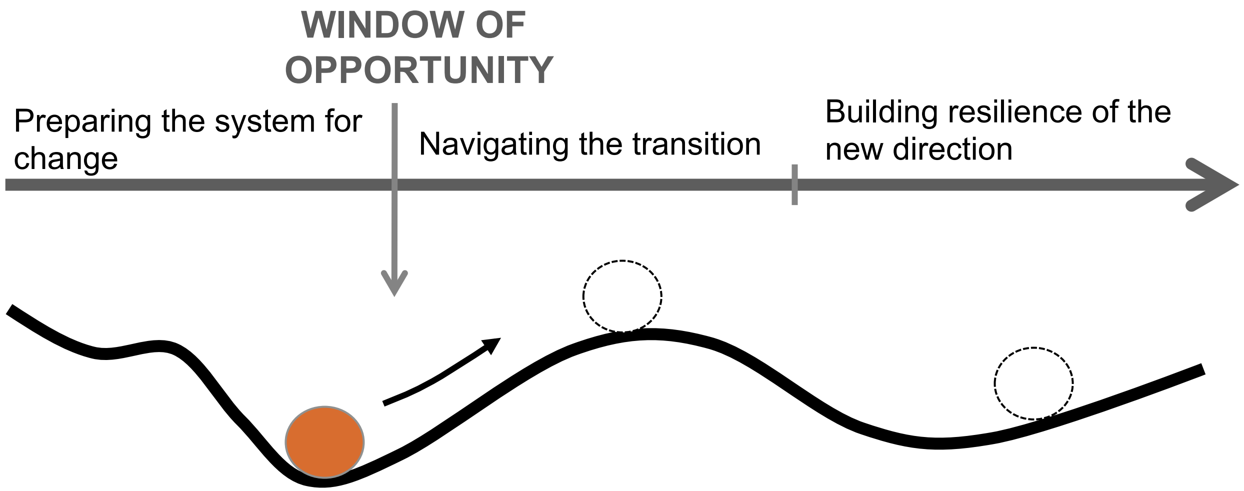




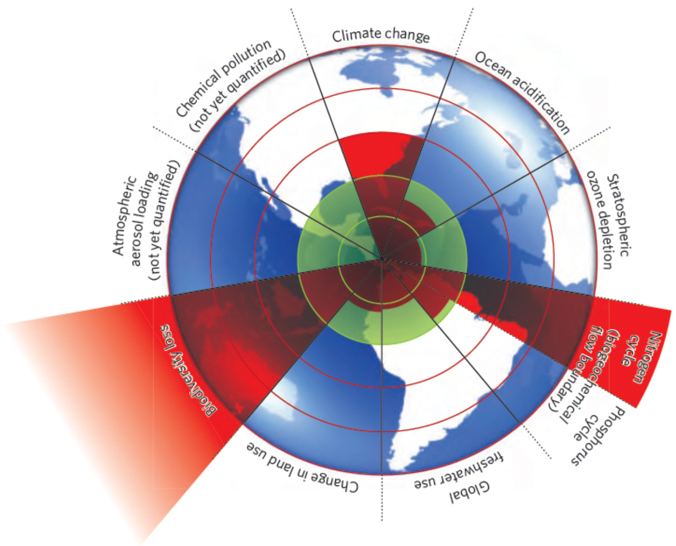
Rockström et al., 2009. Water Resources Research

RESPONSE AND INNOVATION: Turning crisis into opportunity

A shift in mindset for transformation



FORECAST & RESPONSE
Tipping toward global sustainability



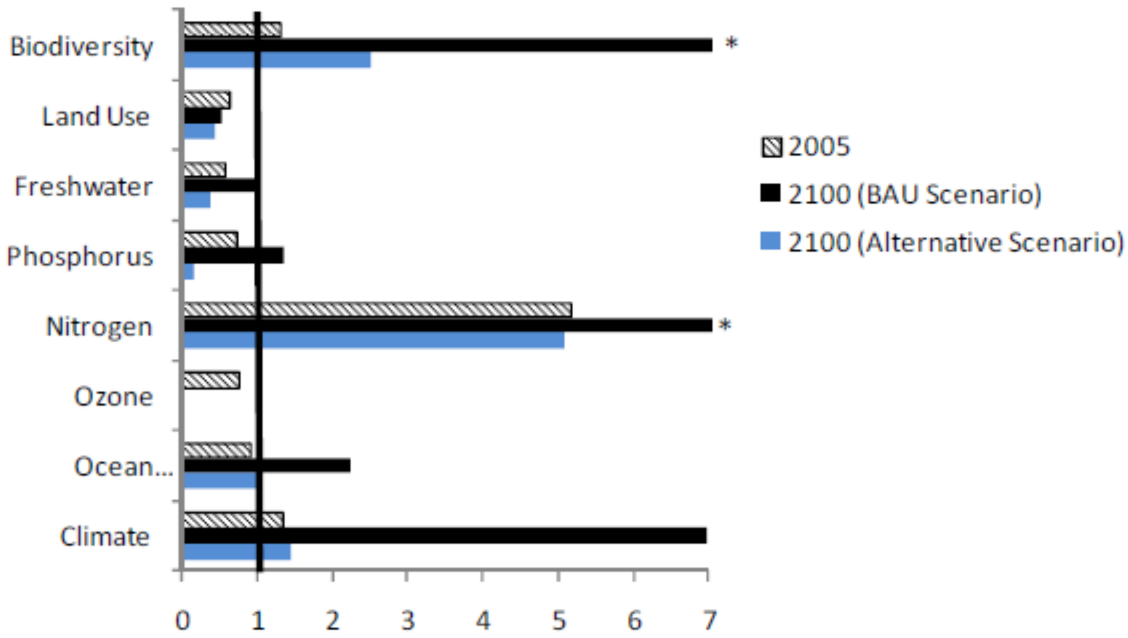
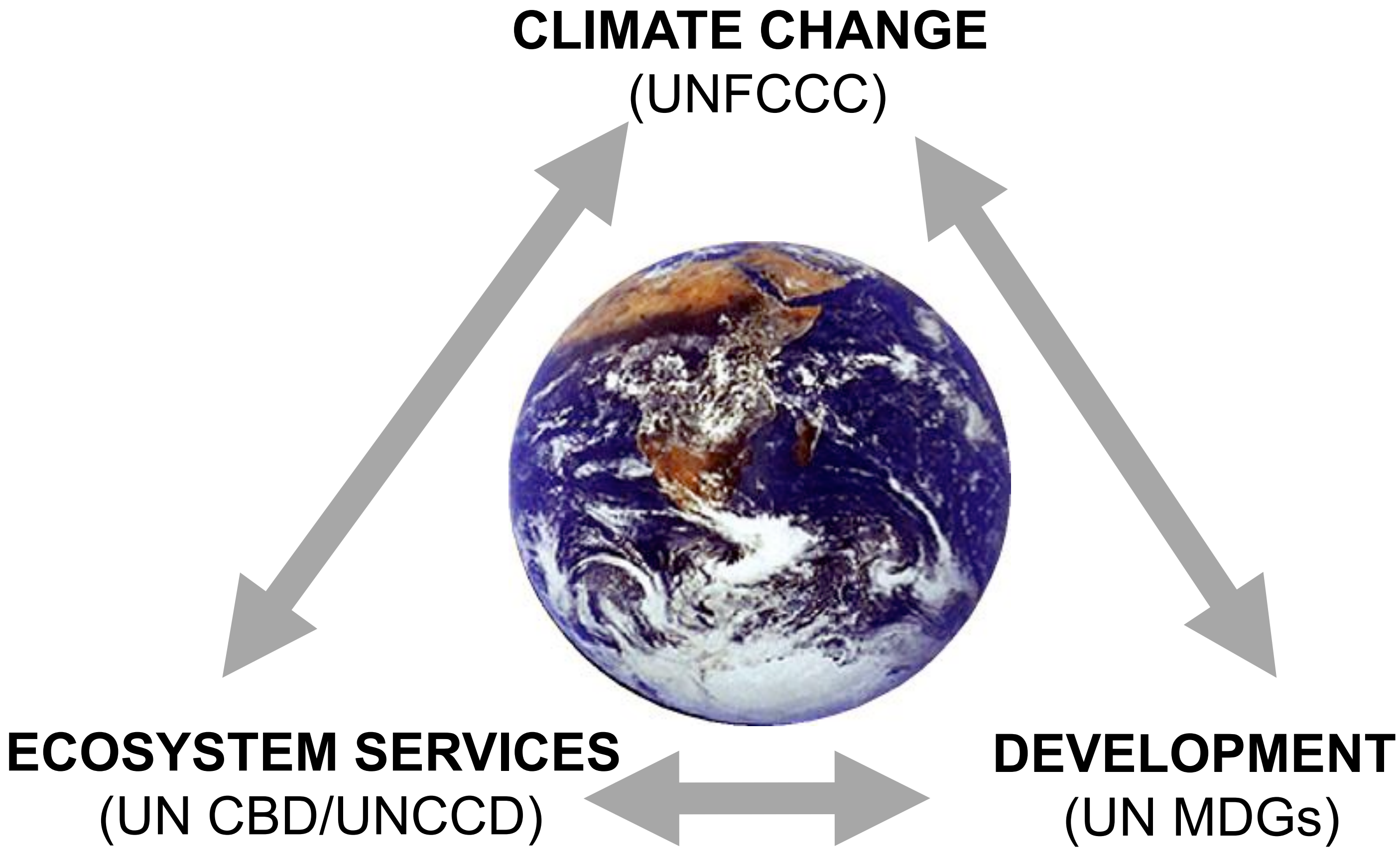


Figure 13. Planetary Boundaries. Horizontal axis is normalized so that a value below one indicates operation within Earth's safe operating space. * indicates values too large to display on chart (Biodiversity = 14 and Nitrogen = 11.5).

Tellus, 2011, draft for Ban Ki-moon high level panel

RESPONDING: Integrating planetary efforts for human development



POLICYFORUM

ECOLOGY

The Biodiversity and Ecosystem Services Science-Policy Interface

Assessments must provide conditional predictions of the consequences of specific policy options, at well-defined spatial and temporal scales.

Charles Perrings,[1*] Anantha Duraiappah,[2] Anne Larigauderie,[3] Harold Mooney[4]

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INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

= 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

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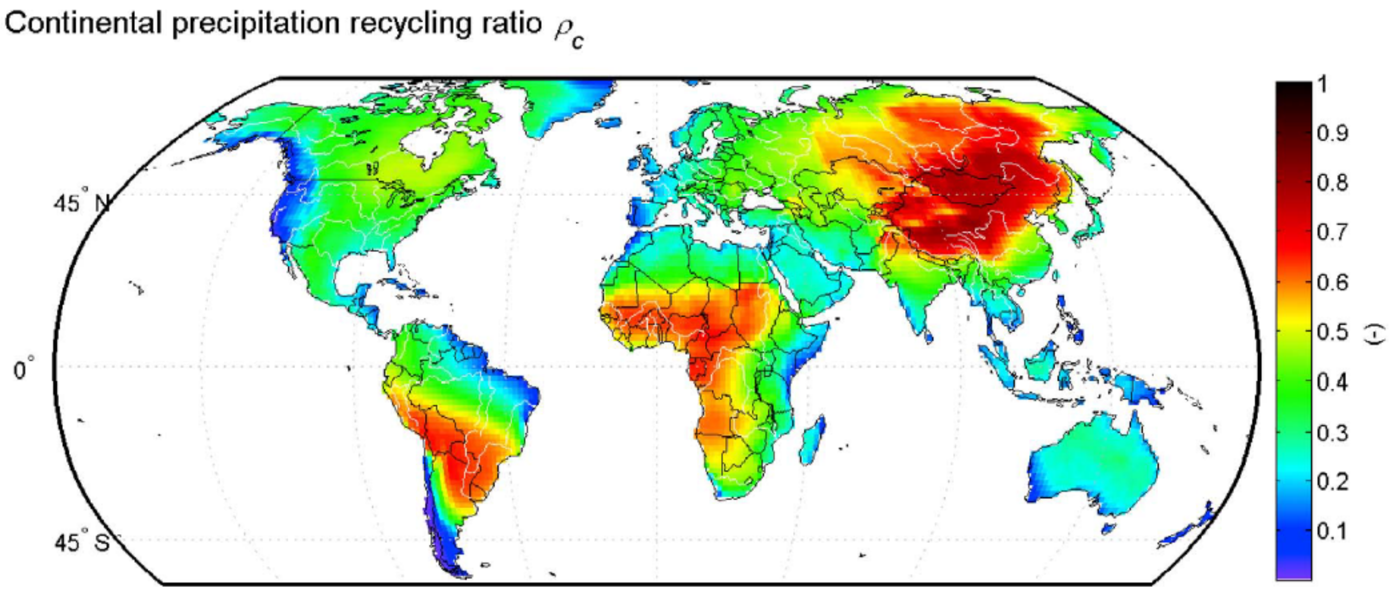

Figure 3. Average continental precipitation recycling ratio ρ_c (1999–2008).