Global Change

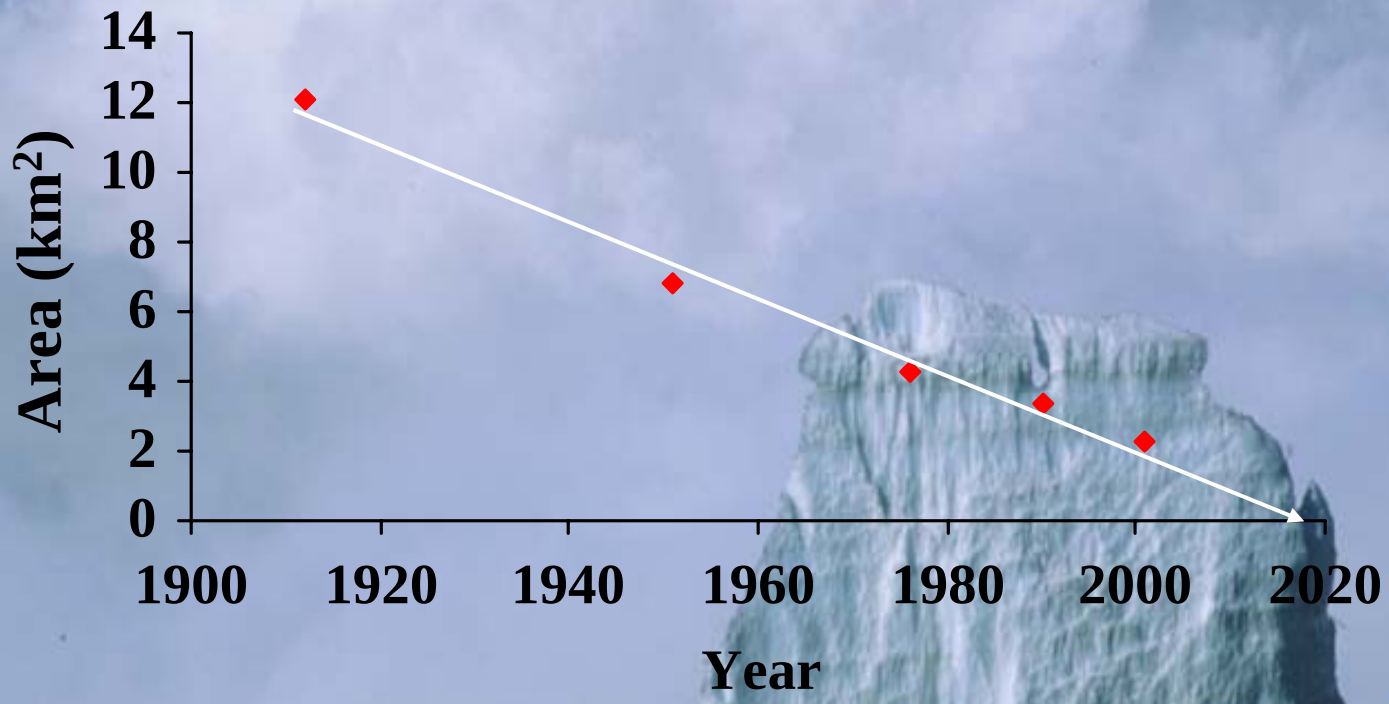
and the

Earth System

Kilimanjaro 1970


Kilimanjaro 2000
PAGES

Ice on Kilimanjaro



L.Thompson et al. 2002

Kilimanjaro 2020?

Land-based glaciers are retreating nearly everywhere around Earth: Triftgletscher Glacier, Switzerland. Since the 1850s ice cover in European alpine regions has decreased From 4,472 km^2 to 2,272 km^2.

Photos: Michael Hambrey; Data: World Glacier Monitoring Service 2006

Antarctica:
Disintegration of Larsen B Ice Shelf

Photo: British Antarctic Survey

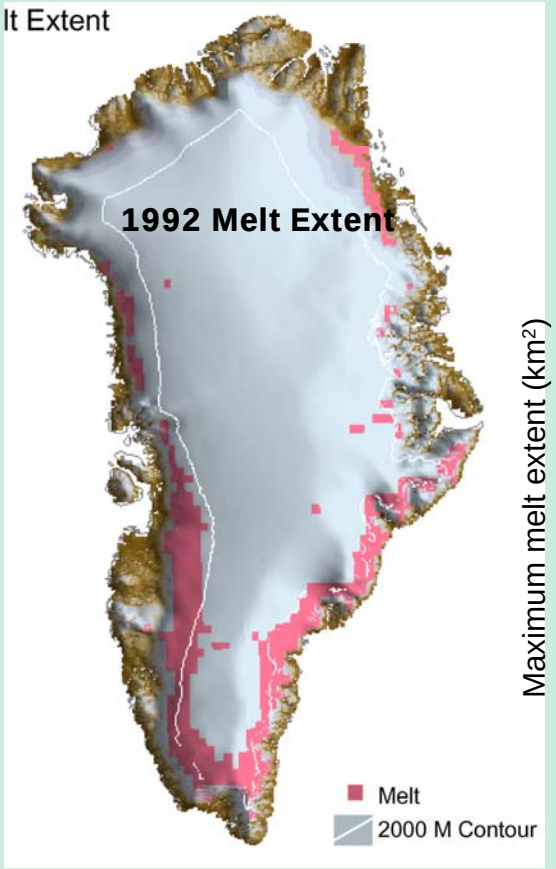
Observed sea ice September 1979

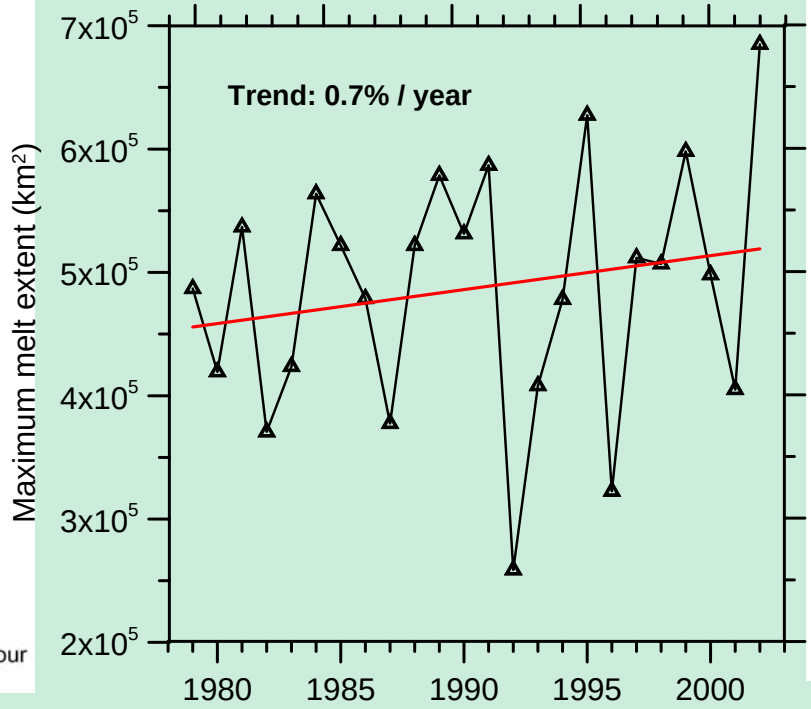
Observed sea ice September 2003

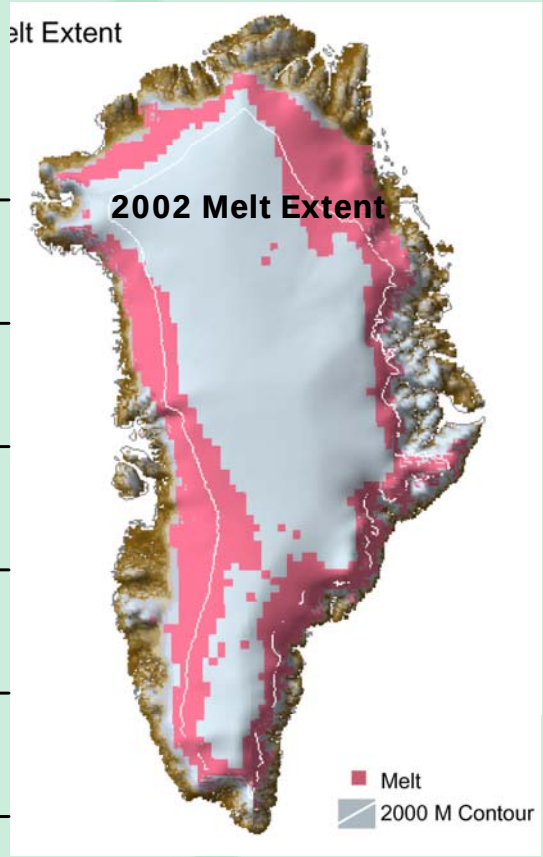
Source: Arctic Climate Impact Assessment (ACIA), 2004. Impacts of a Warming Arctic.

Melting of Ice over Greenland: 1992 - 2002

Passive Microwave derived maximum melt extent





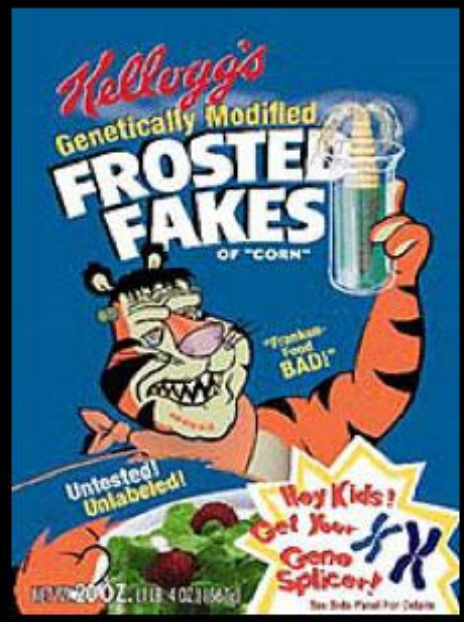


Greenland ice sheet melt area increased on average by 16% from 1979 to 2002.
The smallest melt extent was observed after the Mt. Pinatubo eruption in 1992

Data from Konrad Steffen and Russell Huff, University of Colorado

Human Imprint on the Terrestrial Biosphere

From landscapes to genes...



Southern China:
Loss of Biological Diversity

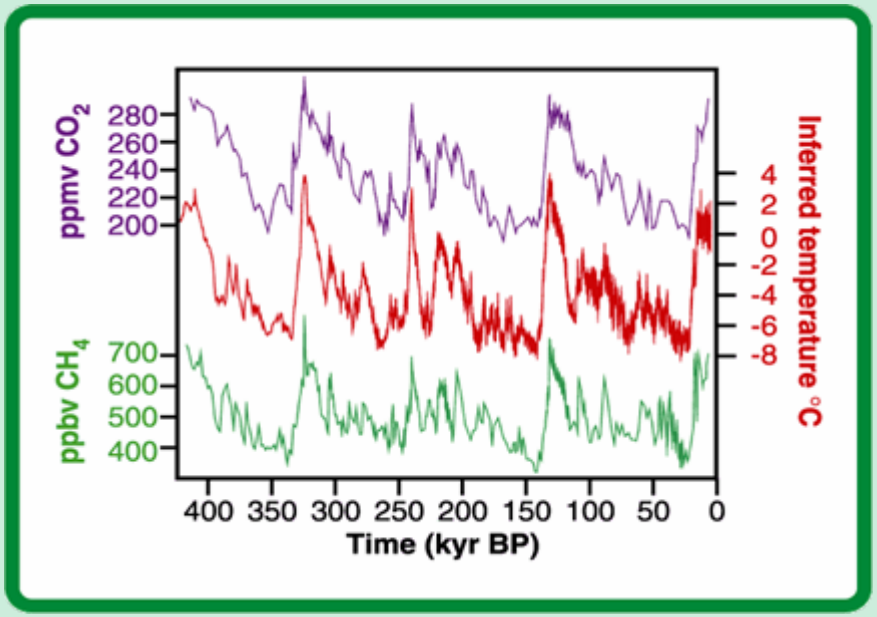
Photo: ICIMOD

The Earth as a System

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



Petit et al. 1999

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.

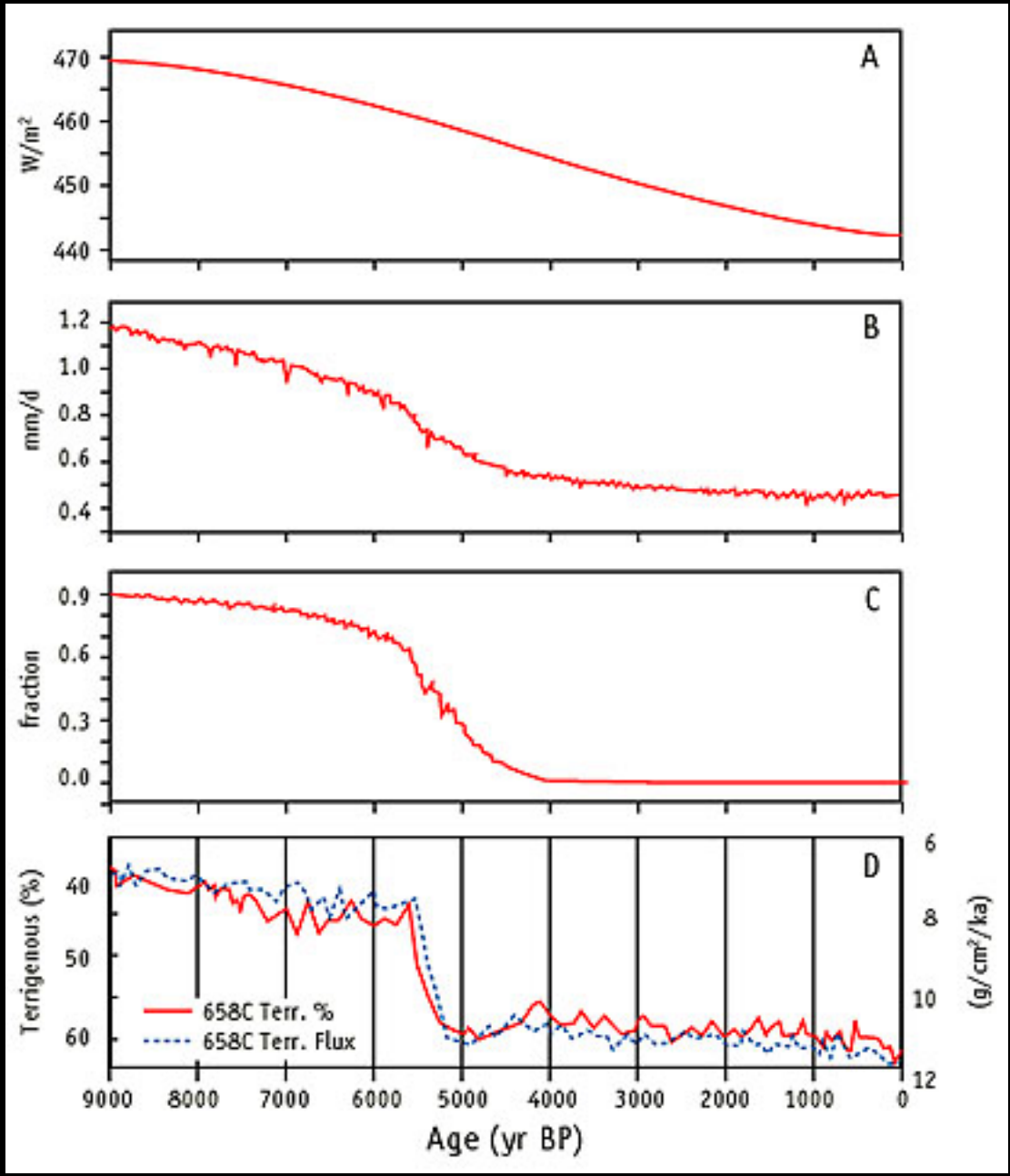
The ranges of CO_2, other gases and temperature are tightly constrained at both upper and lower levels.

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

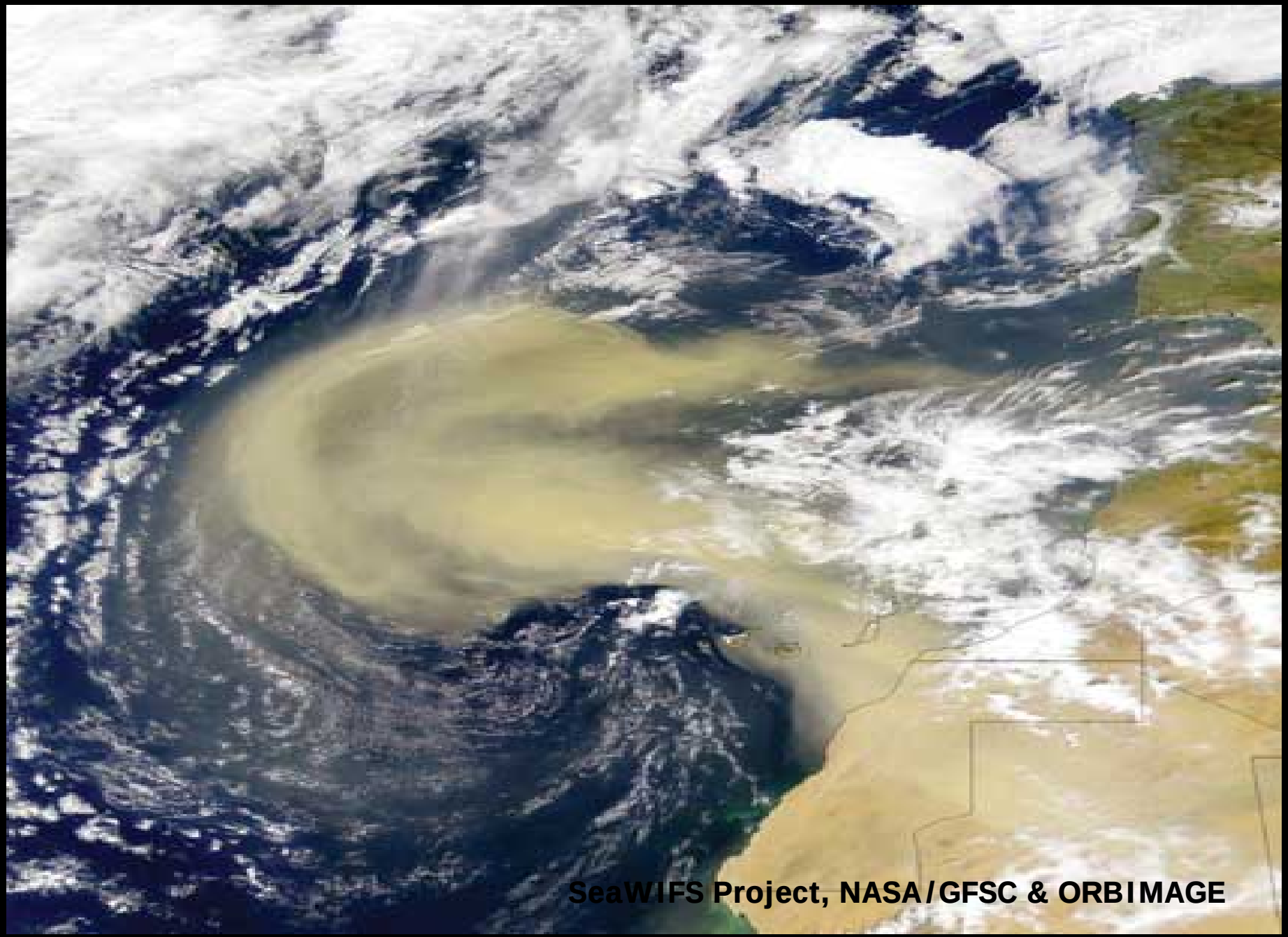
From Steffen et al. 2004

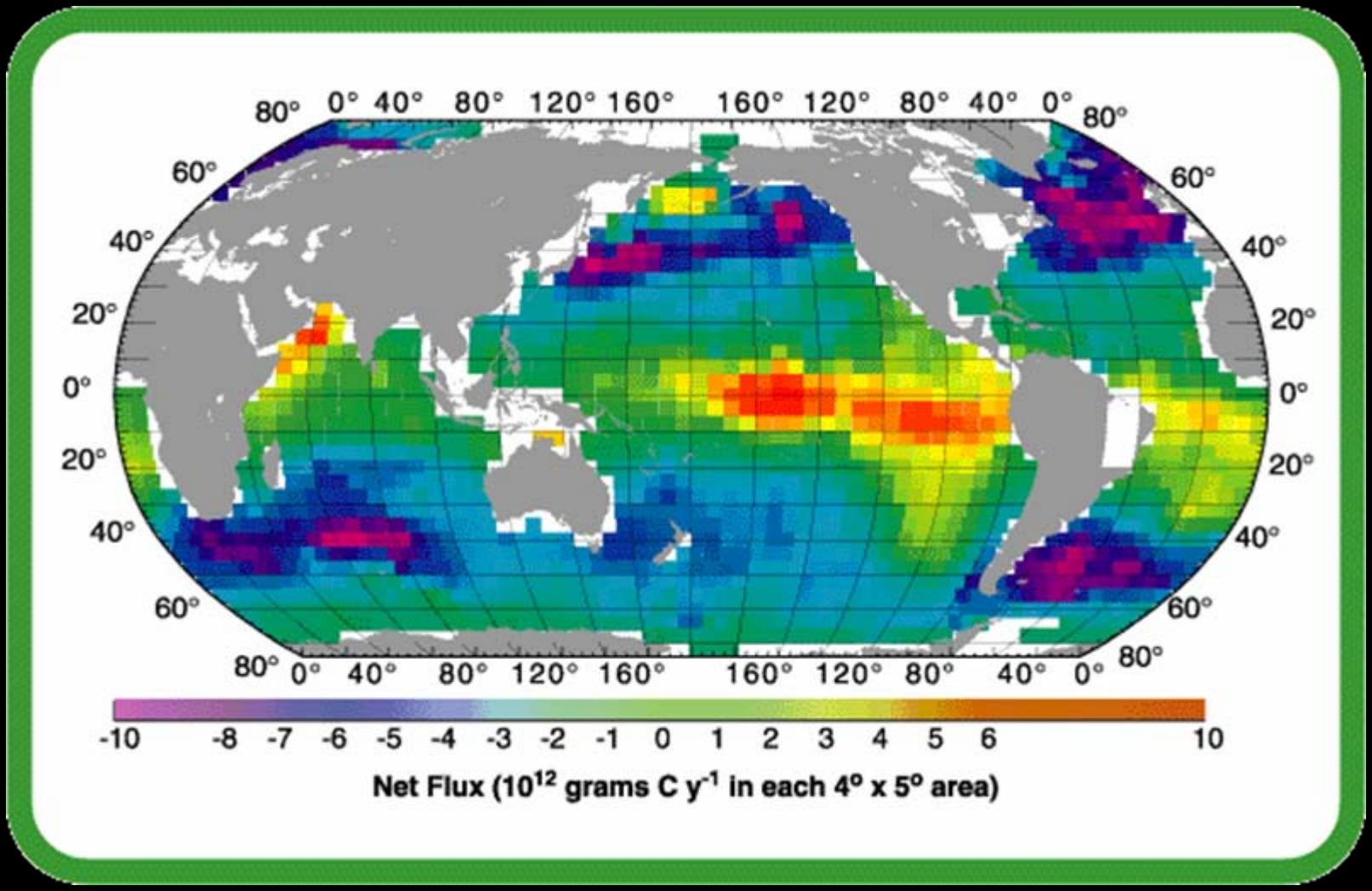
Earth System Dynamics…

…the ‘Browning’ of the Sahara

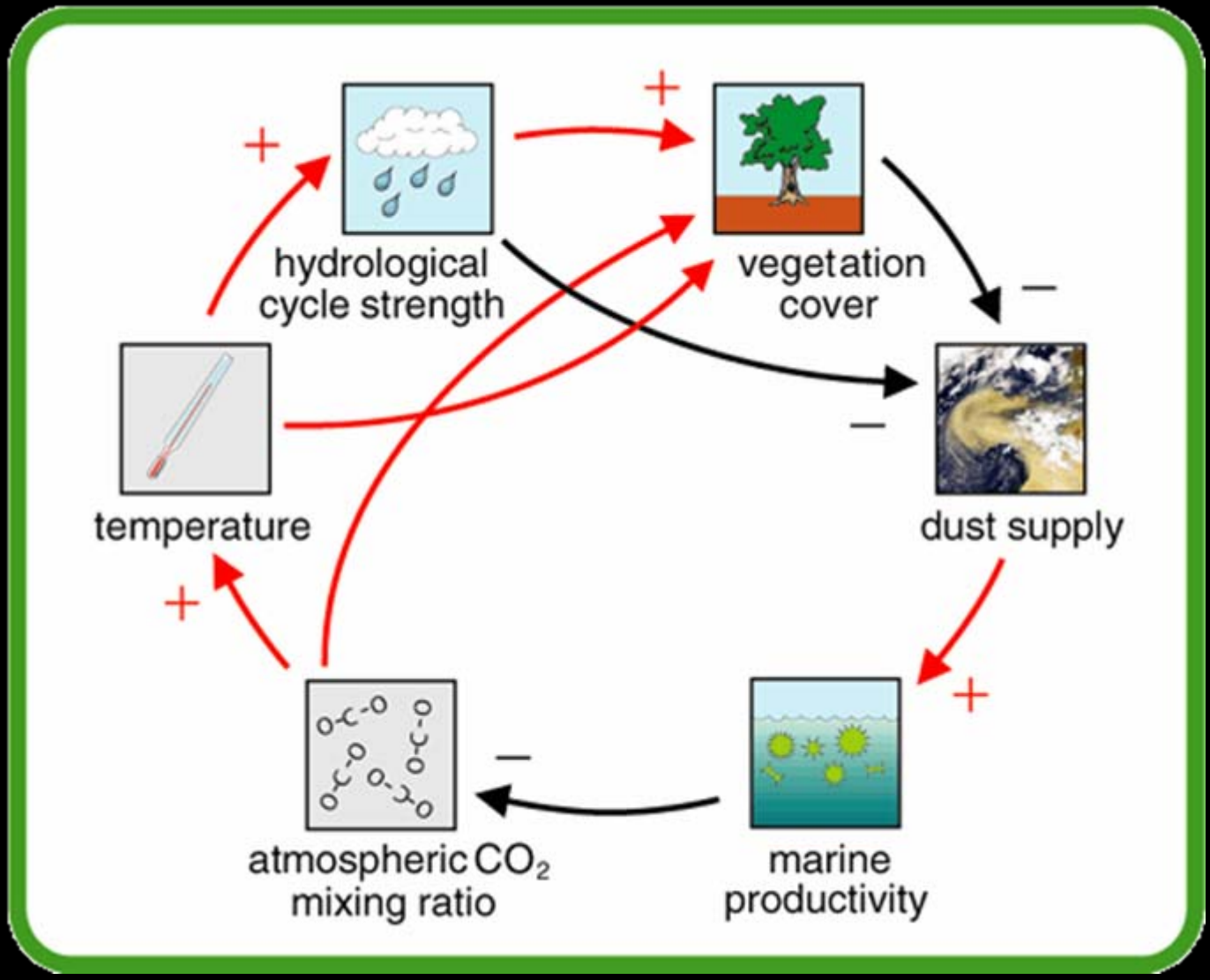


Claussen et al. 1999; deMenocal et al. 2000


SeaWIFS Project, NASA/GFSC & ORBIMAGE



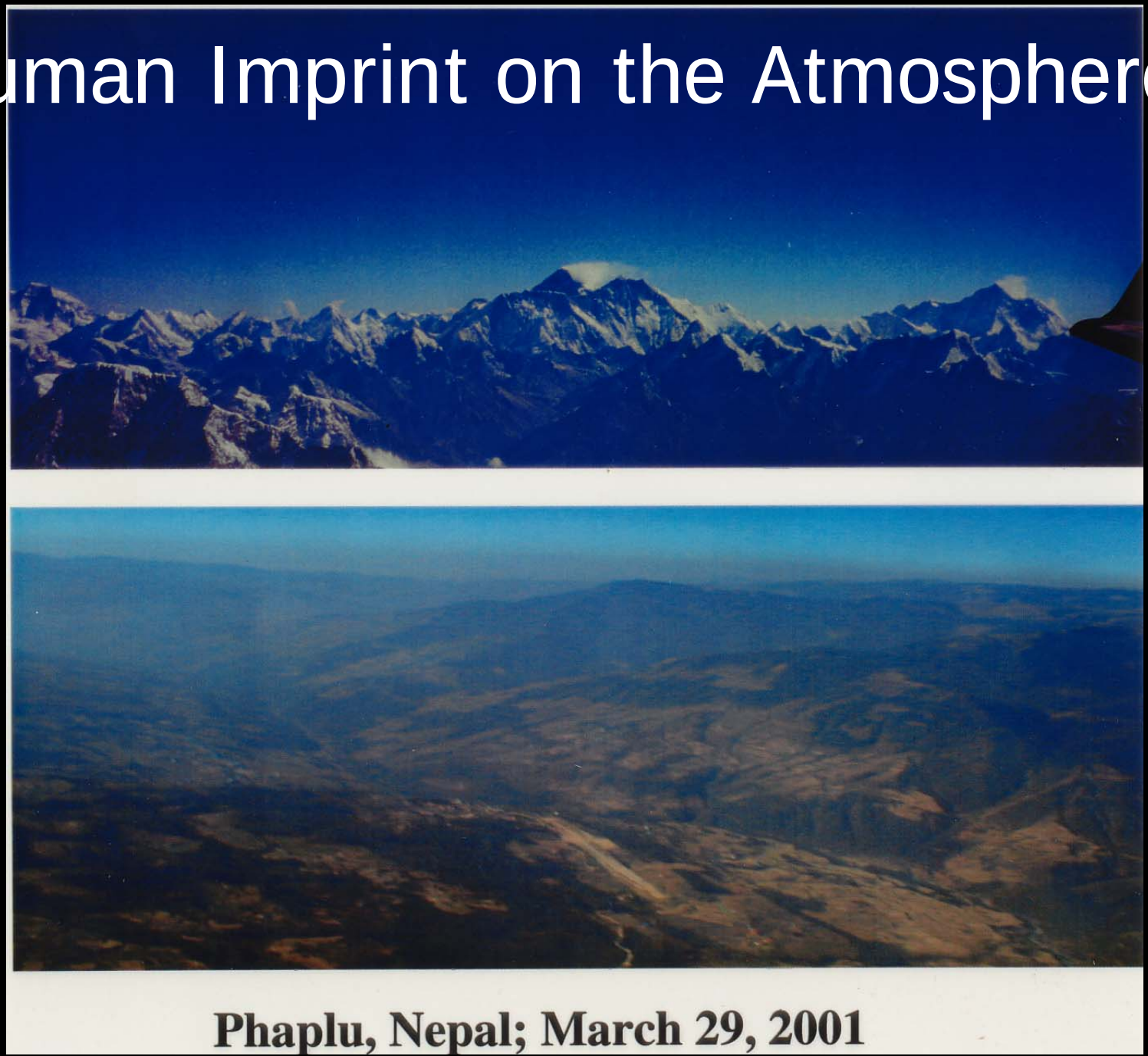
Takahashi et al. 1997



Ridgwell 2002

The Human Imprint on the Earth System

Human Imprint on the Atmosphere



Phaplu, Nepal; March 29, 2001

4x4s replace the desert camel and whip up a worldwide dust storm

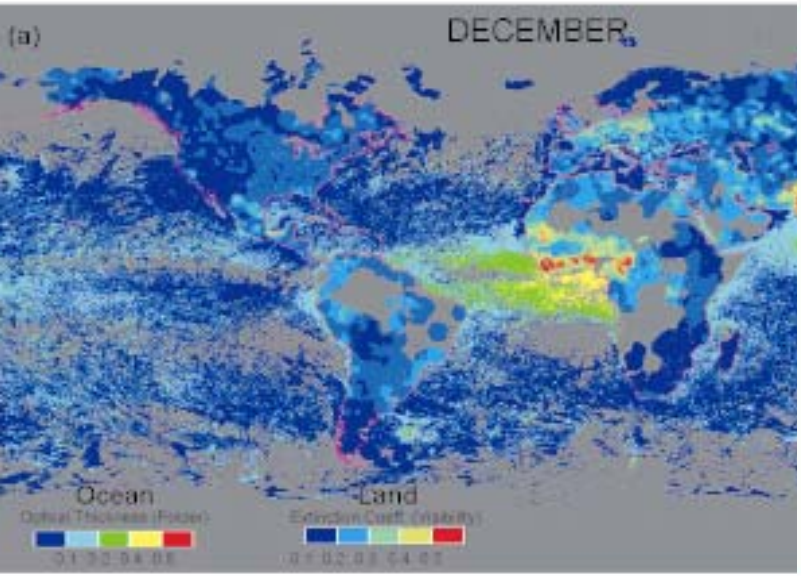
The Guardian Friday August 20 2004

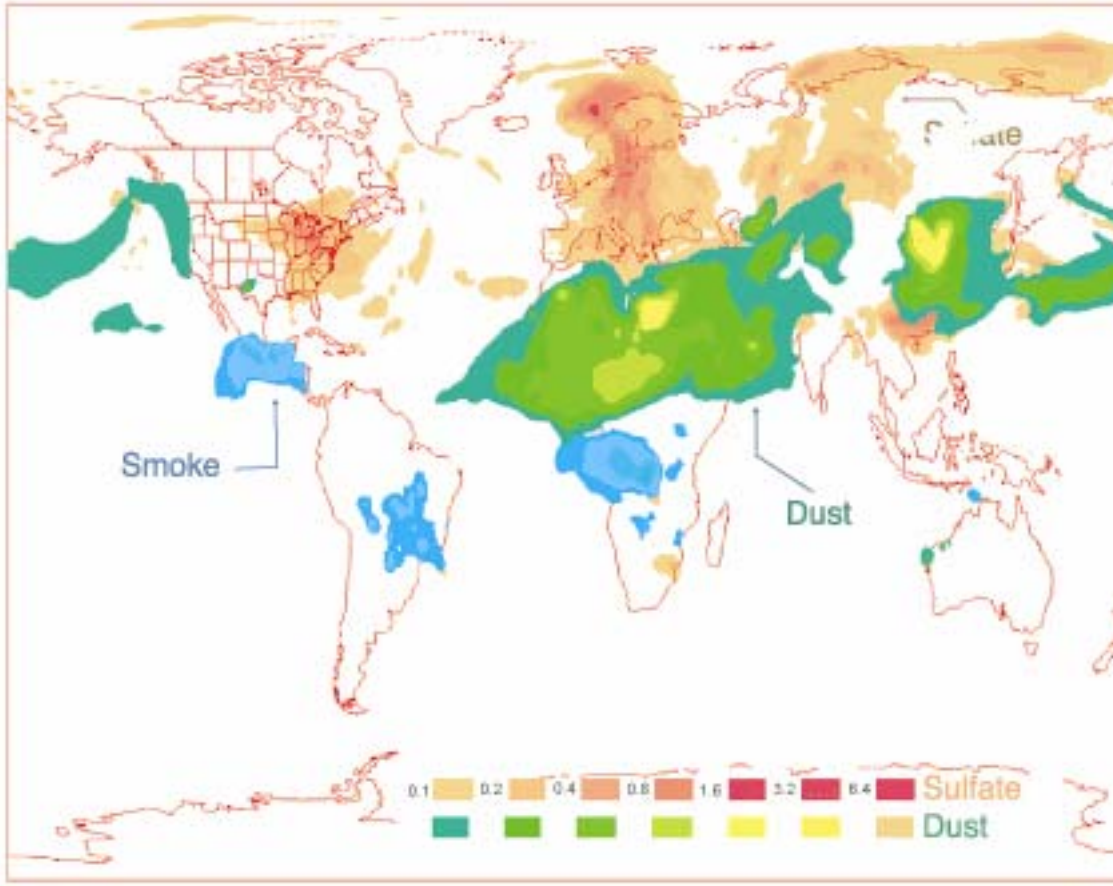
Dust storm MODIS image: NASA Goddard Space Flight Center, Jacques Descloitres. www.rednova.com/image_gallery.html

www.suedafrika

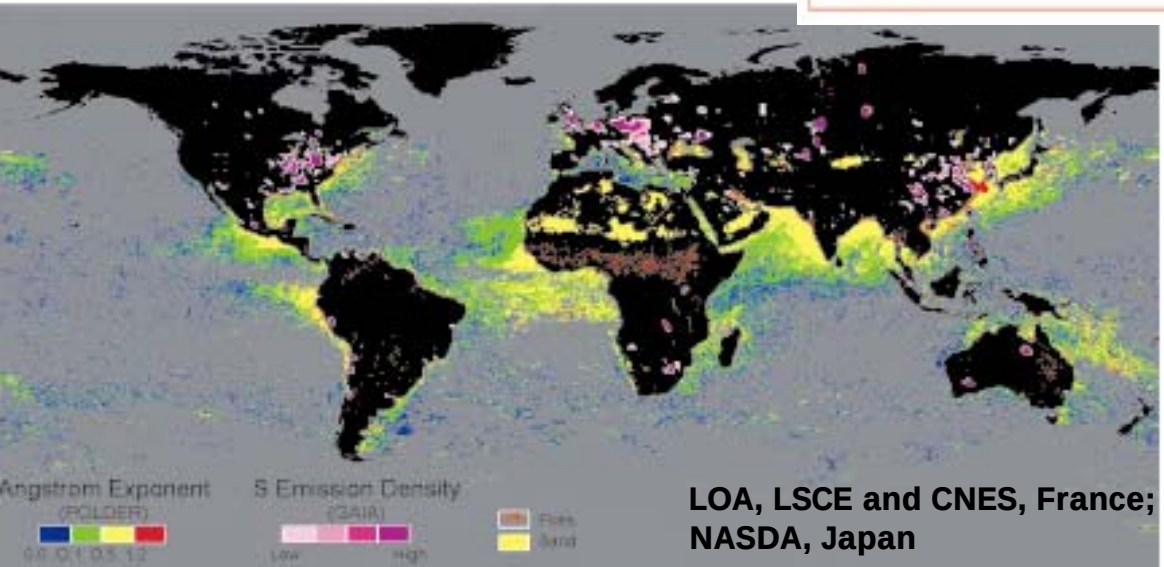
Aerosols

Aerosol optical thickness observed by satellite





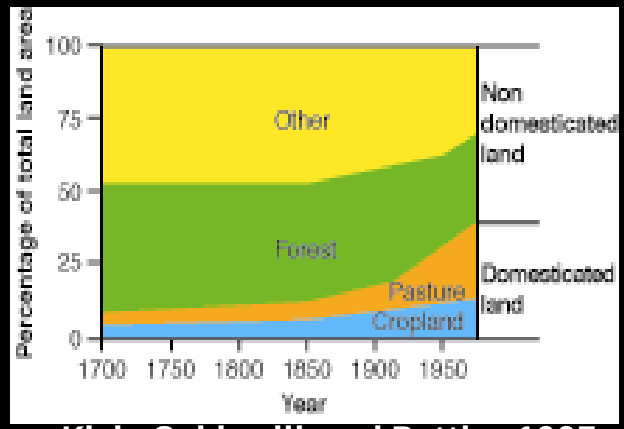
Heintzenberg et al. 2003



LOA, LSCE and CNES, France; NASDA, Japan

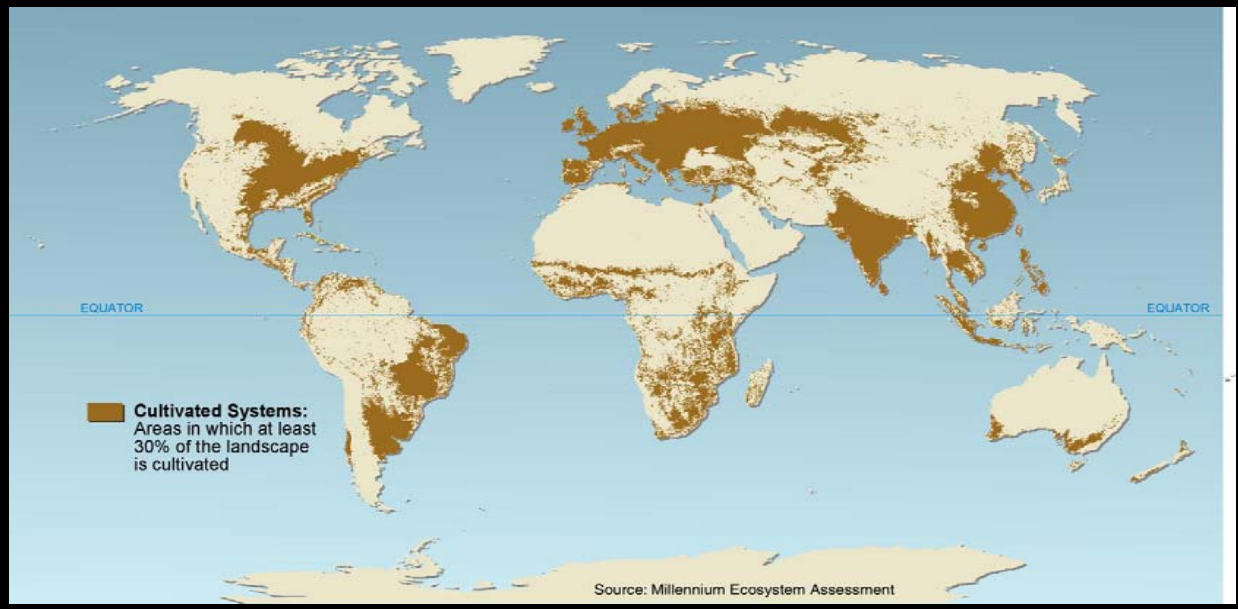
Model-calculated distribution of dust, sulphate and smoke aerosol particles

Human Imprint on Land



Klein Goldewijk and Battjes 1997

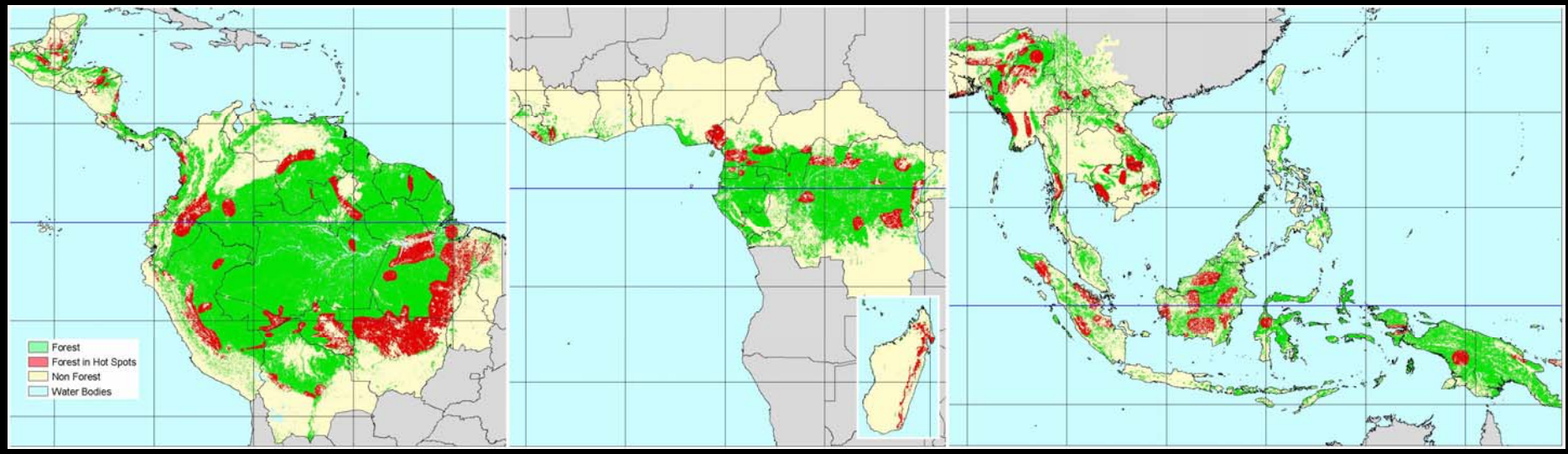
More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 & 1850



Cultivated Systems in 2000 cover 25% of Earth's terrestrial surface

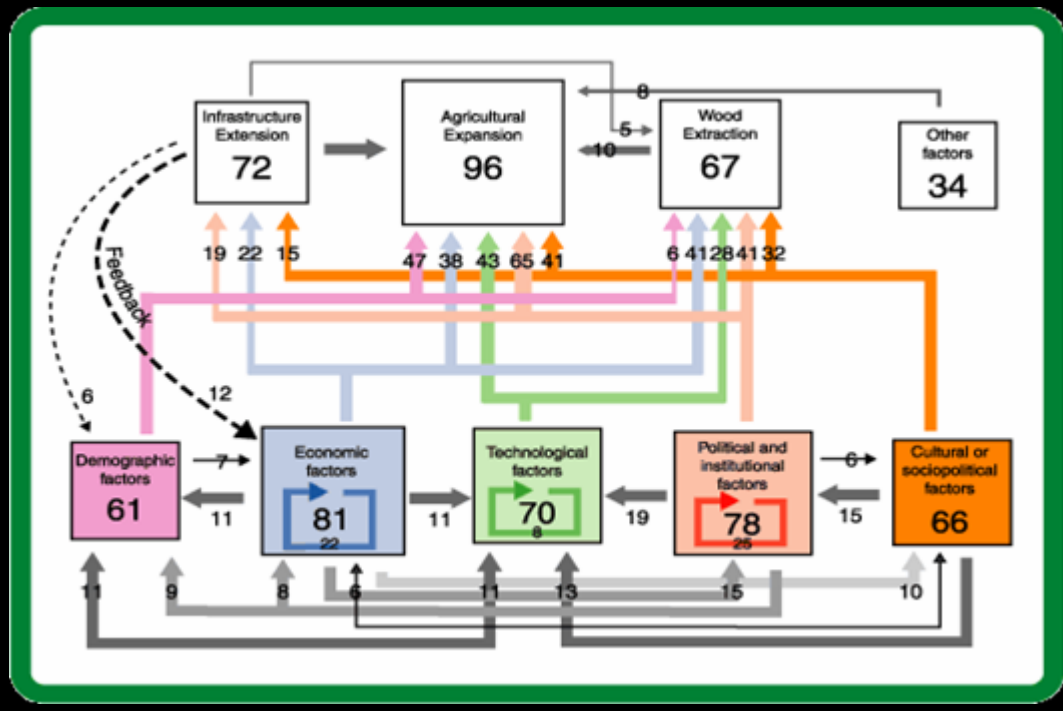
(Defined as areas where at least 30% of the landscape is in croplands, shifting cultivation, confined livestock production, or freshwater aquaculture)

Millennium Ecosystem Assessment 2005



Lepers et al. 2003, based on data from Archard et al. 2002, De Fries et al. 2002 and Landsat Pathfinder

Hot spots of tropical deforestation, and the causitive patterns of tropical deforestation from 1850 to 1997, showing the proximate and underlying drivers of change

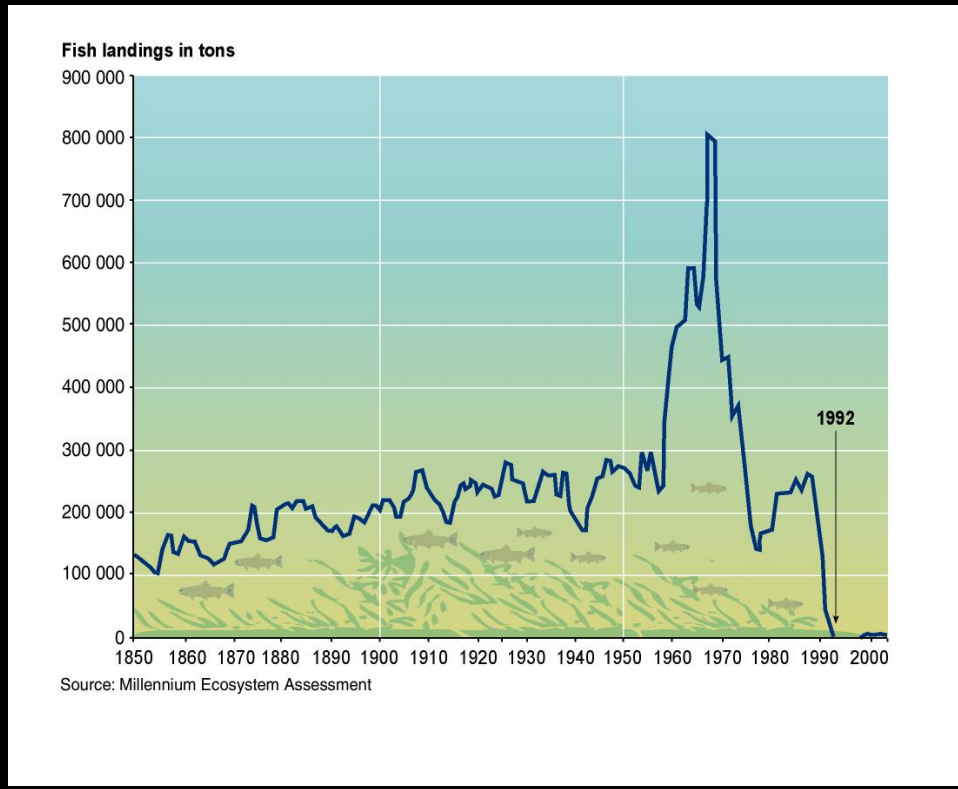


Geist and Lambin (2001)

Human Imprint on Marine Ecosystems

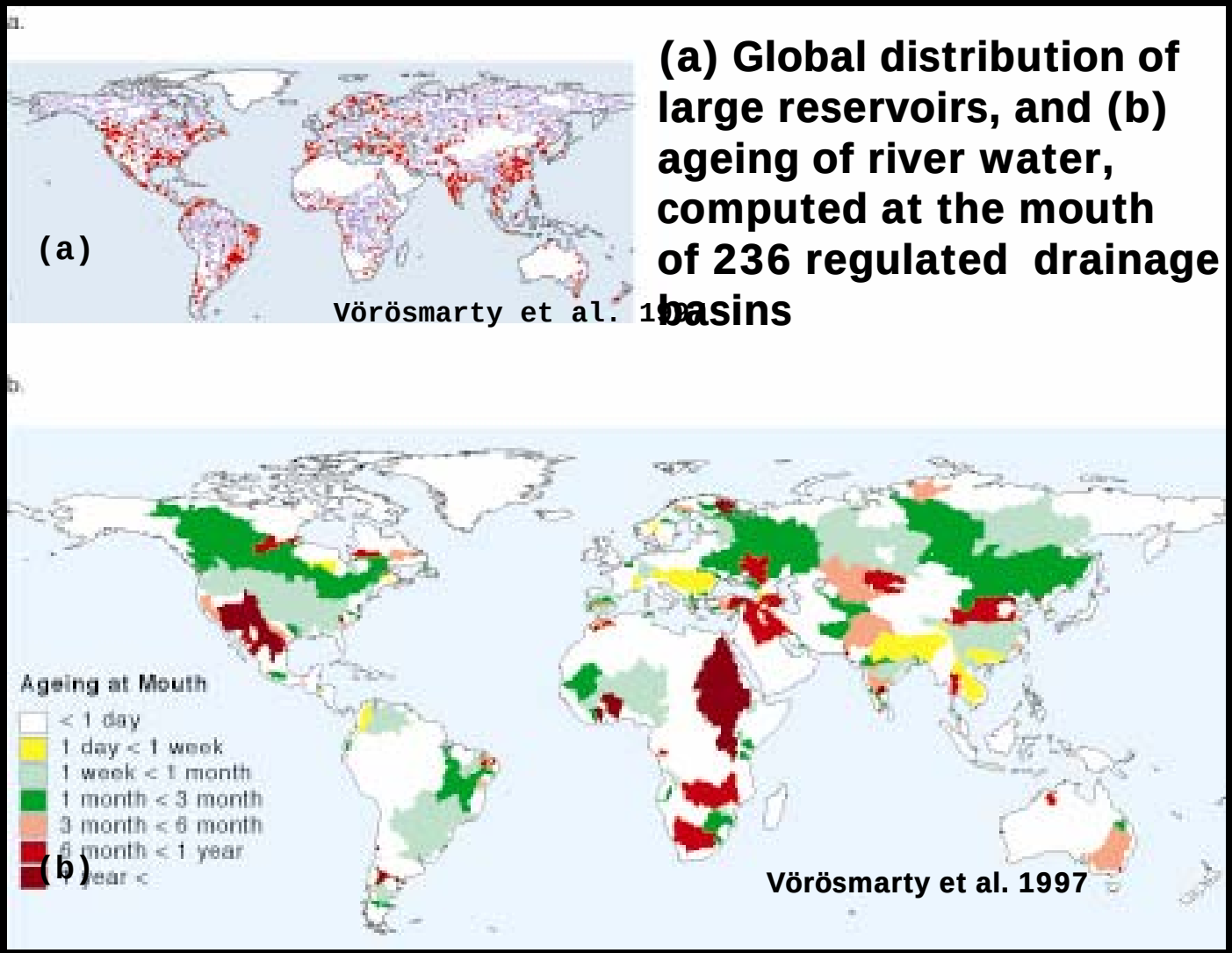
Fisheries collapse

- 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



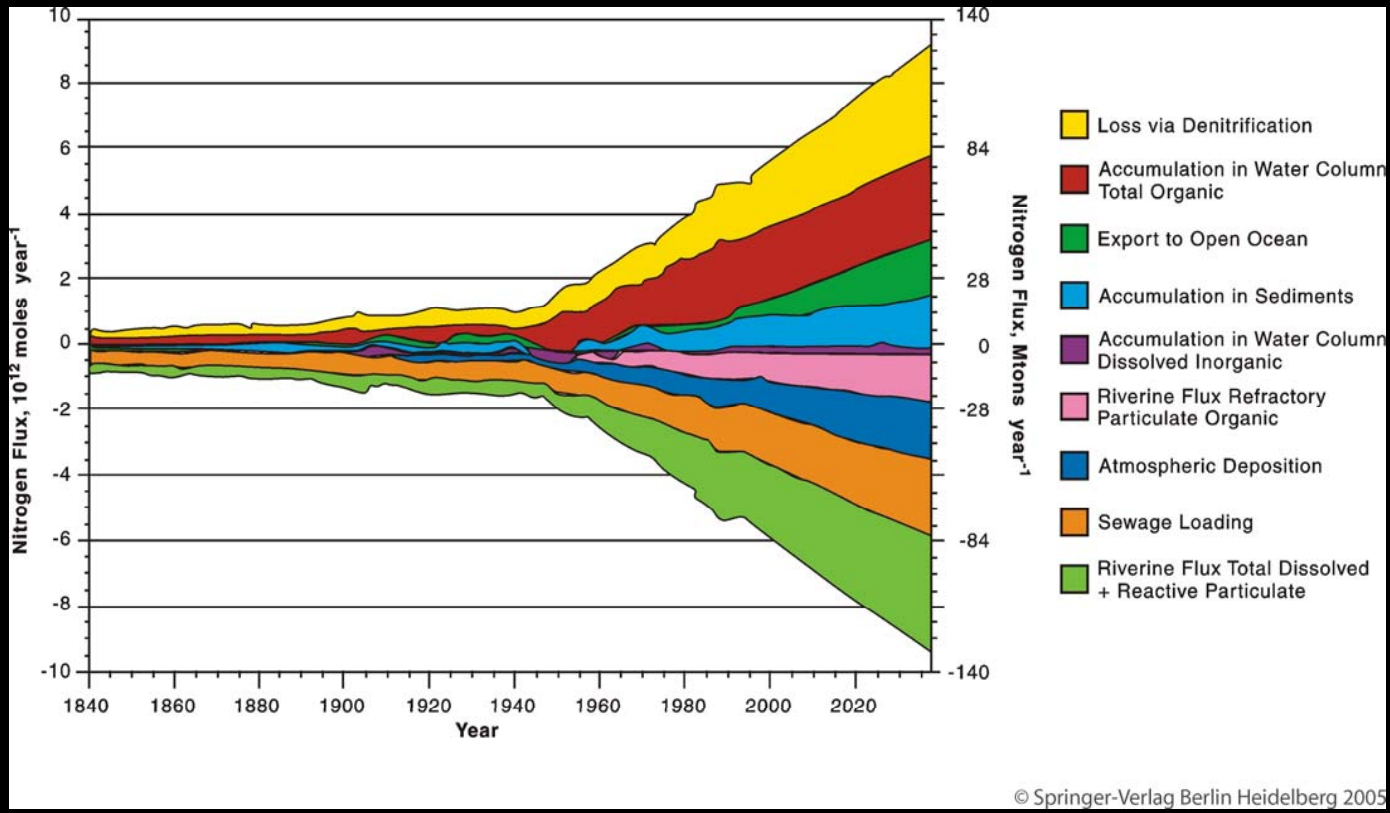
Millennium Ecosystem Assessment 2005, Steffen et al. 2004

Human Imprint on the Hydrological Cycle



(a) Global distribution of large reservoirs, and (b) ageing of river water, computed at the mouth of 236 regulated drainage basins

Human Imprint on the Nitrogen Cycle

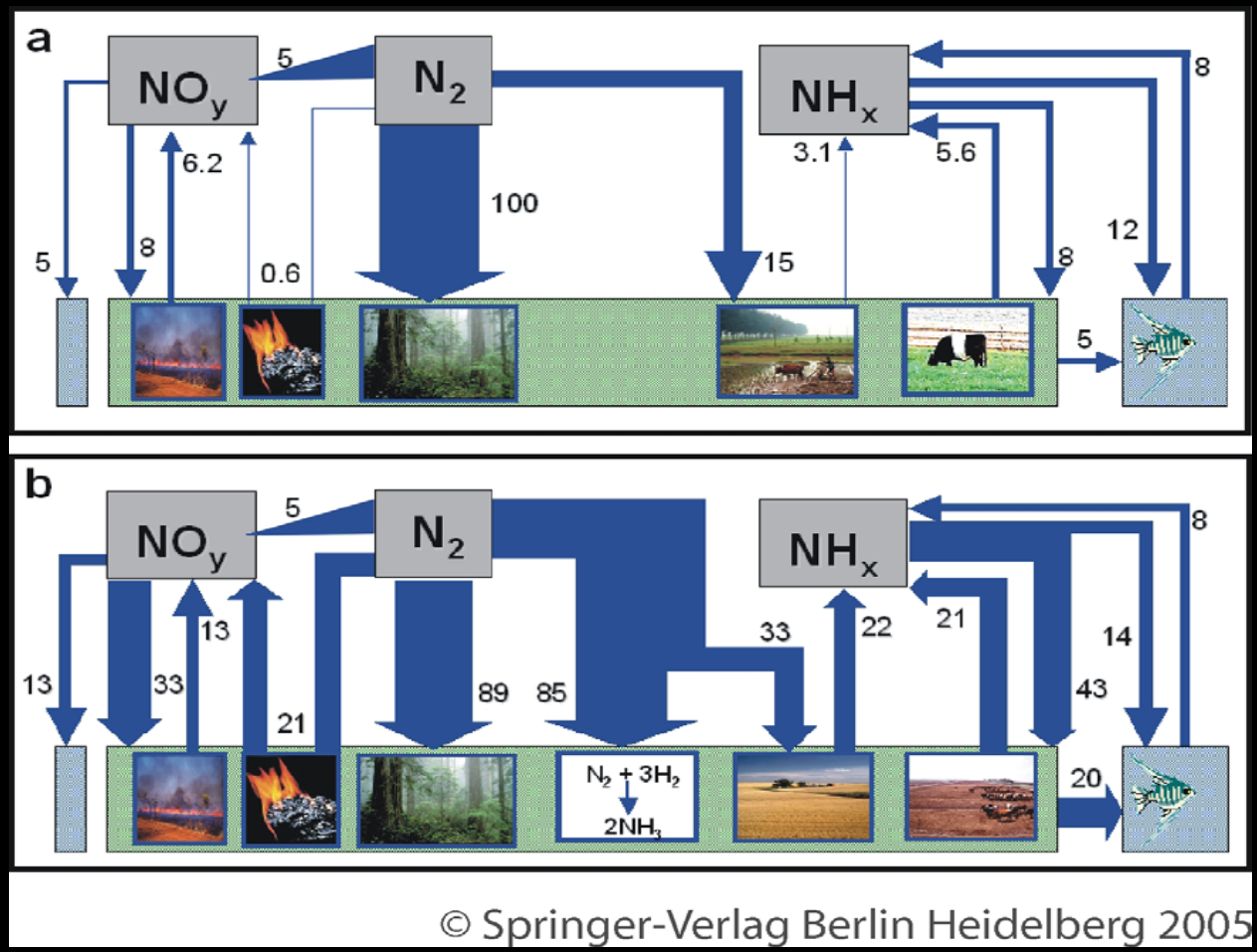


From: MacKenzie et al. 2002

Global Nitrogen Budget

1890

1990

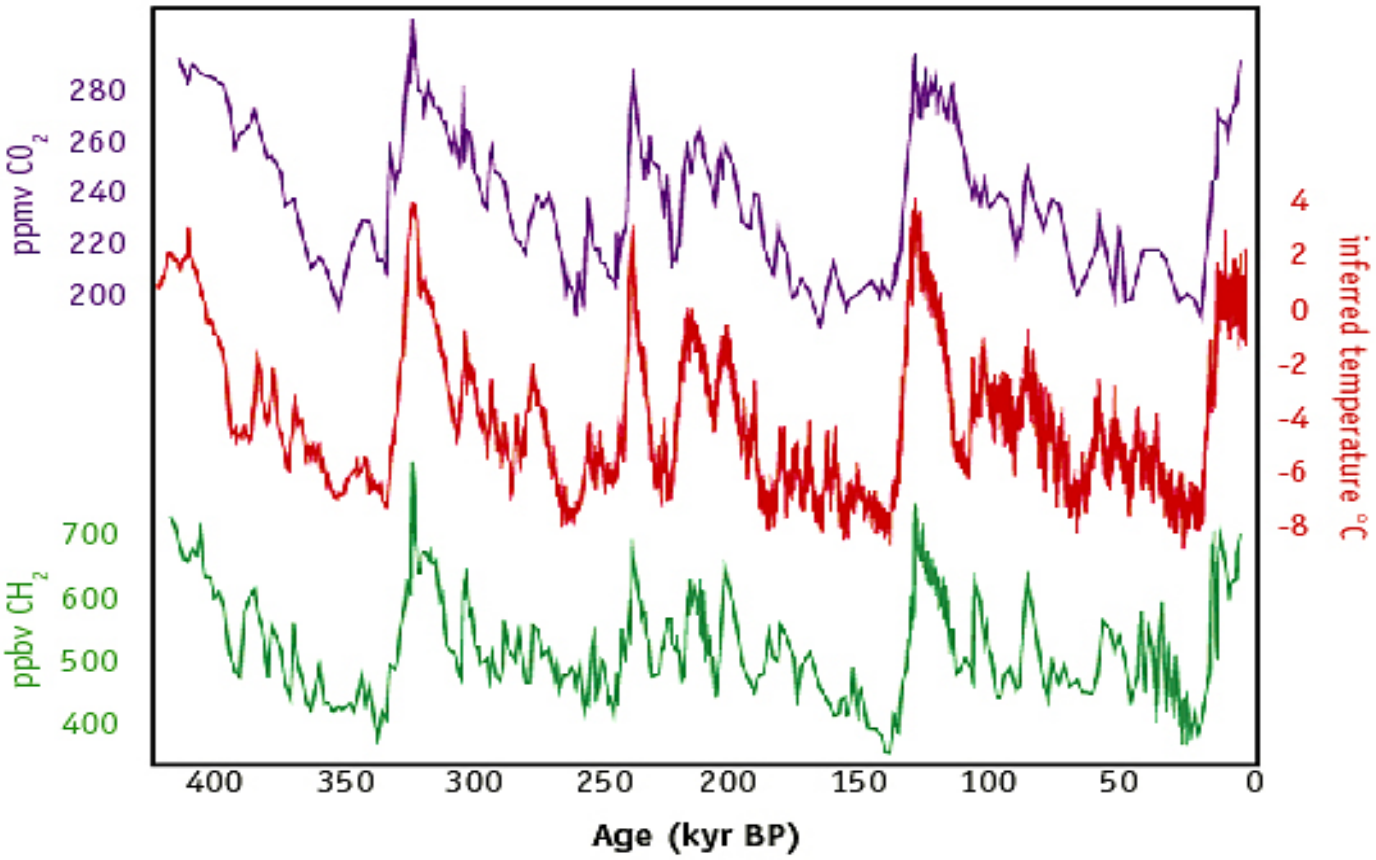


Galloway 2004

Night Lights of Earth: 2000

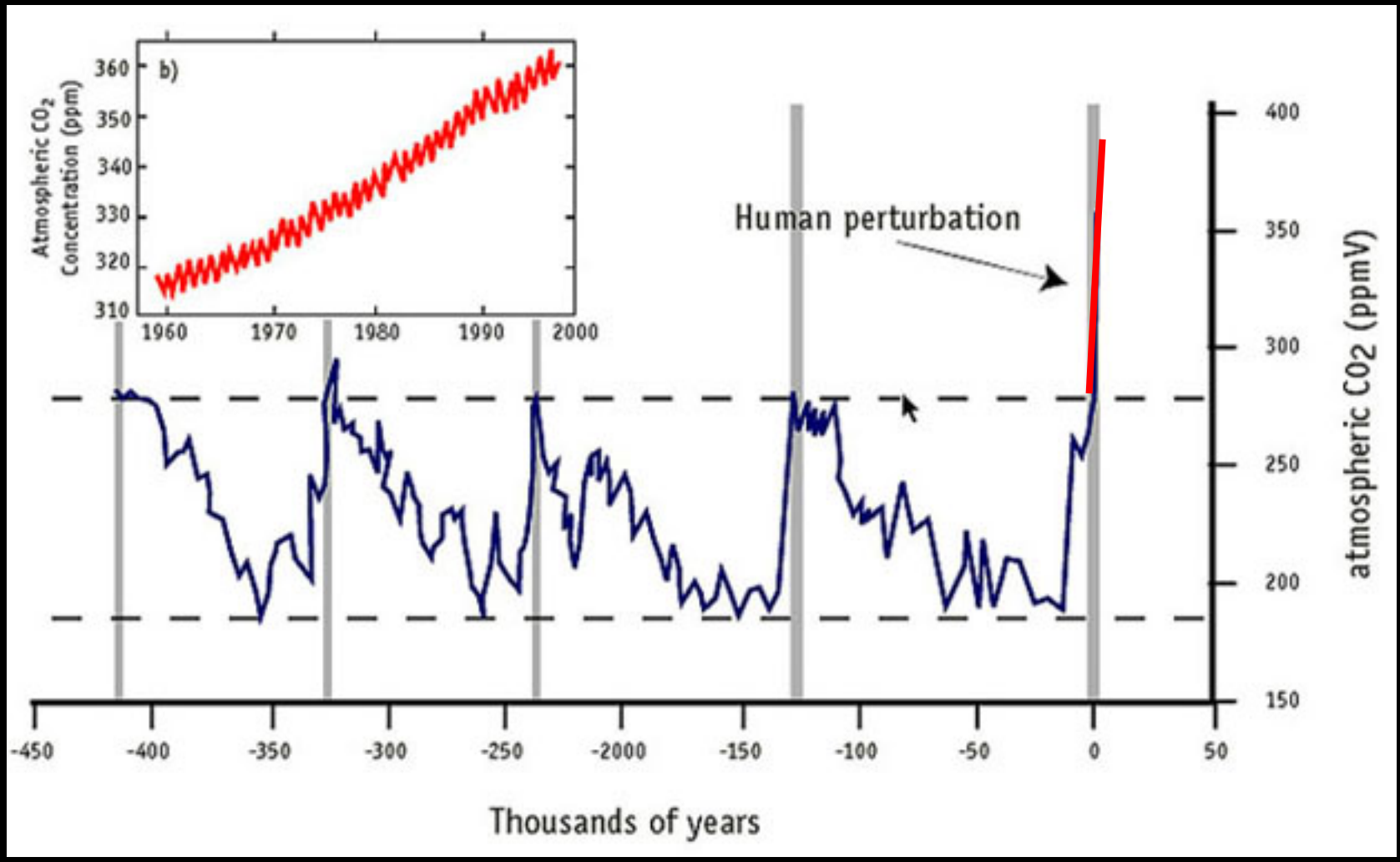
Source: NASA

4 glacial cycles recorded in the Vostok ice core



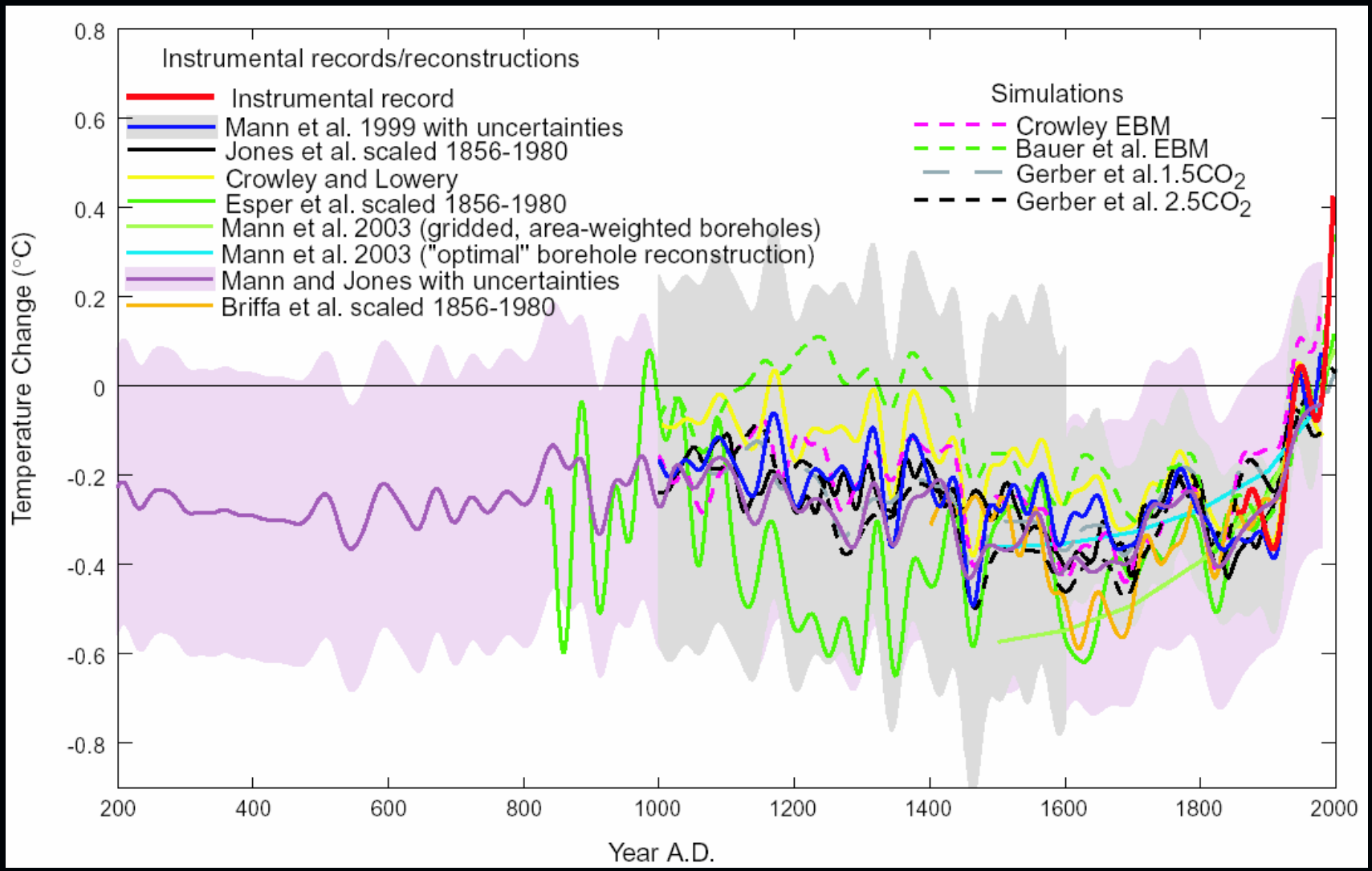
J.R. Petit et al., *Nature,* **399,** 429–36, 1999.

An Earth System Perspective on CO_2 Rise



Petit et al. 1999; Keeling and Whorf 2000

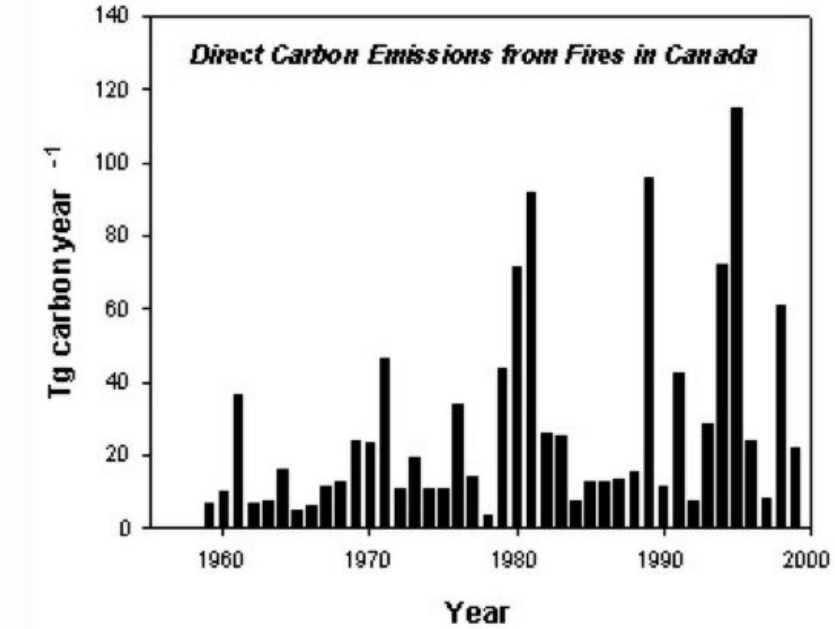
Northern Hemisphere Surface Temperature



Source: Mann et al. 2003 (EOS)

Impacts on People...
...Fires, Storms, Floods

In January 2003, violent wildfires devastated Canberra, Australia's capital city

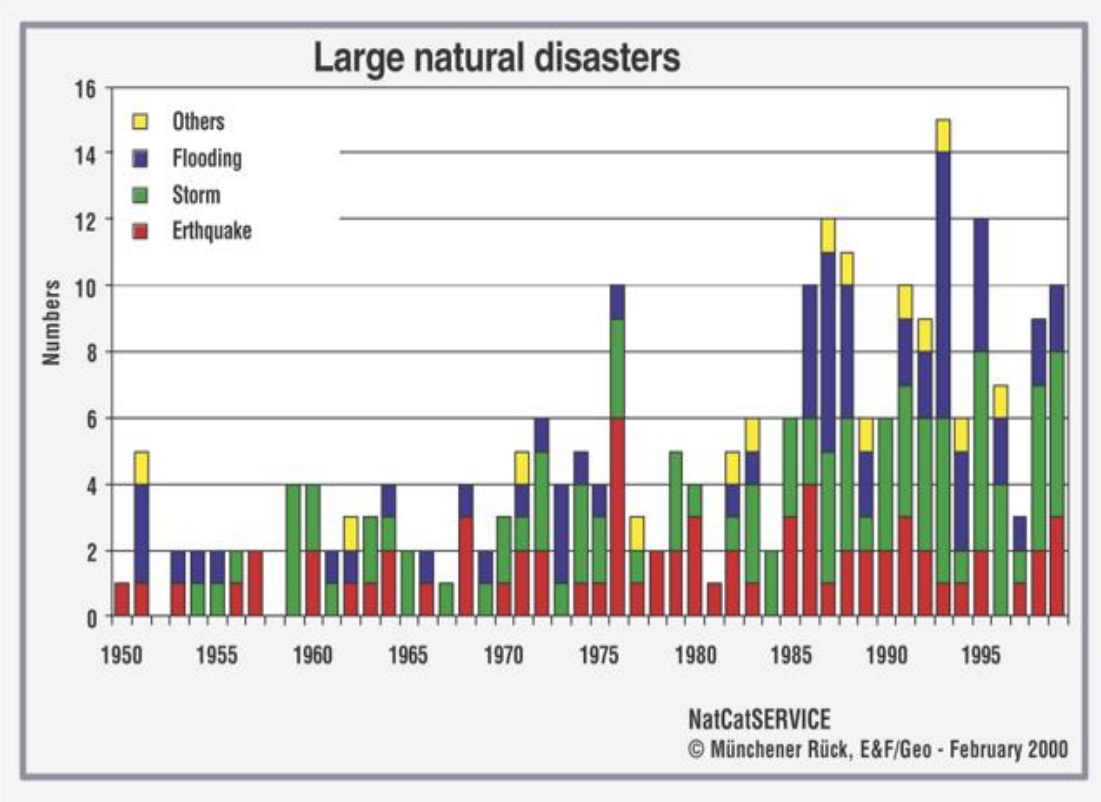


Kurz and Apps 1999

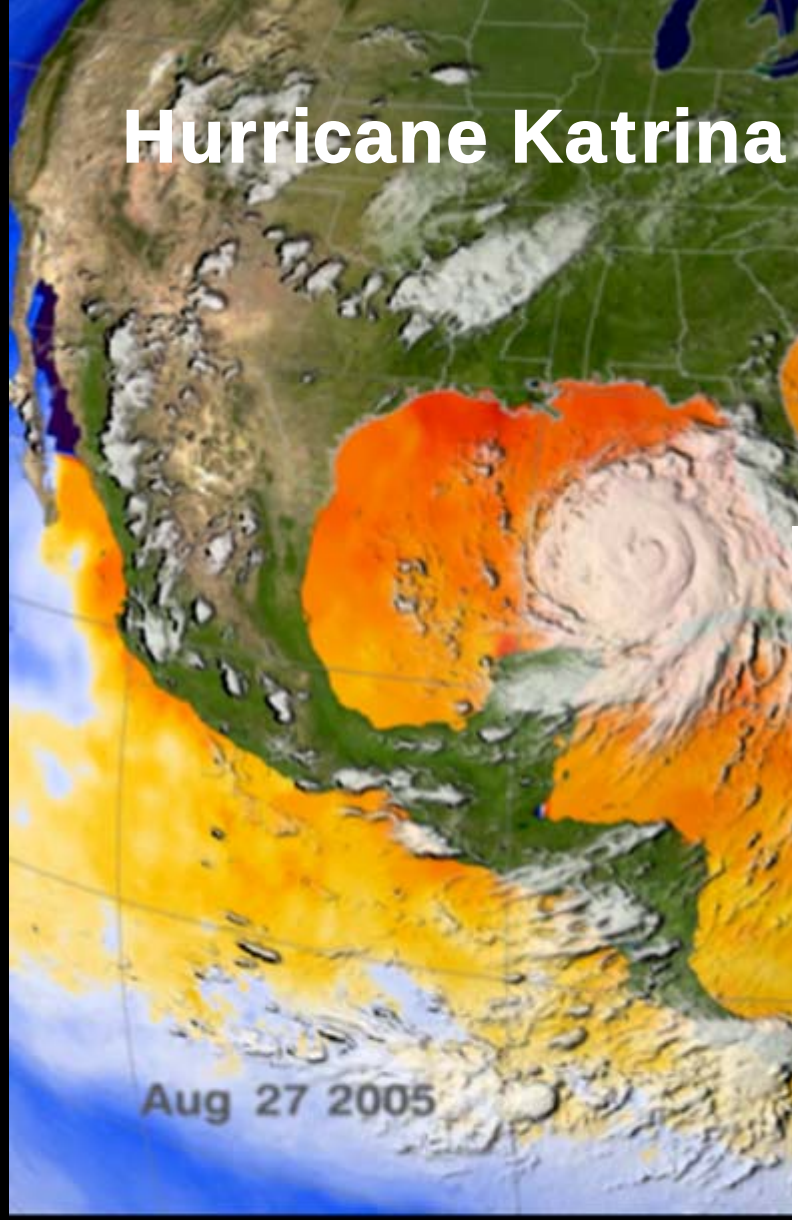
Over the past few decades, wildfires have increased in Canada, Siberia, western USA and the Mediterranean region of Europe. Bushfires have also increased in Australia, with an earlier start to the fire season.

In August 2002, massive flooding in Bangladesh, India, Indonesia and Eastern Europe

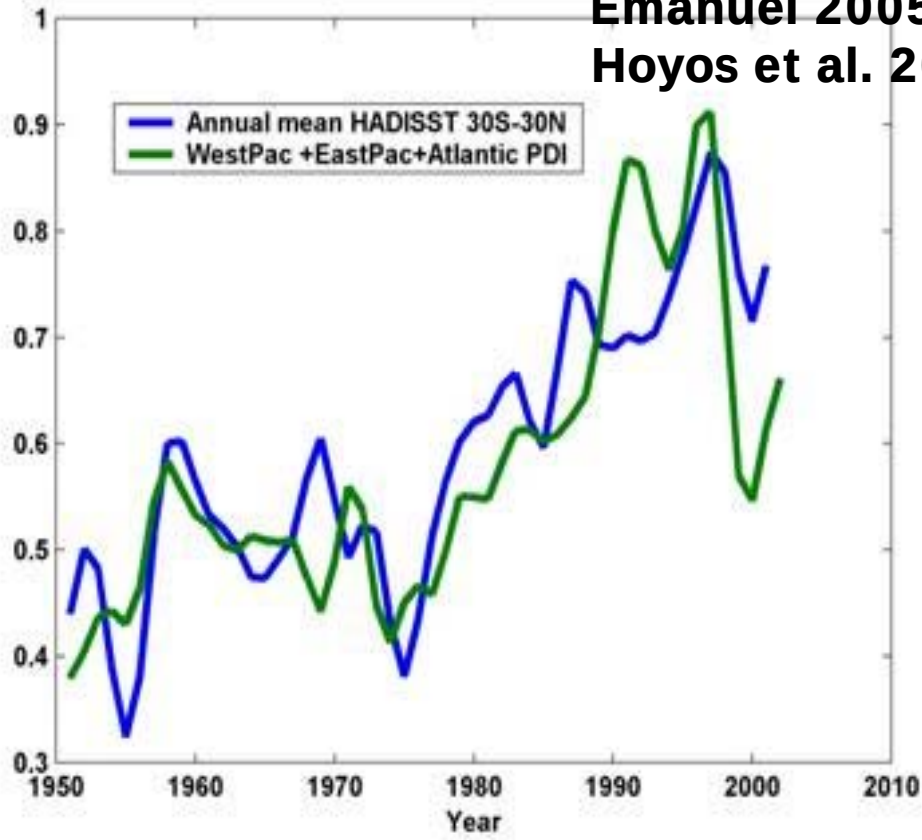
Source: Munich Reinsurance Company



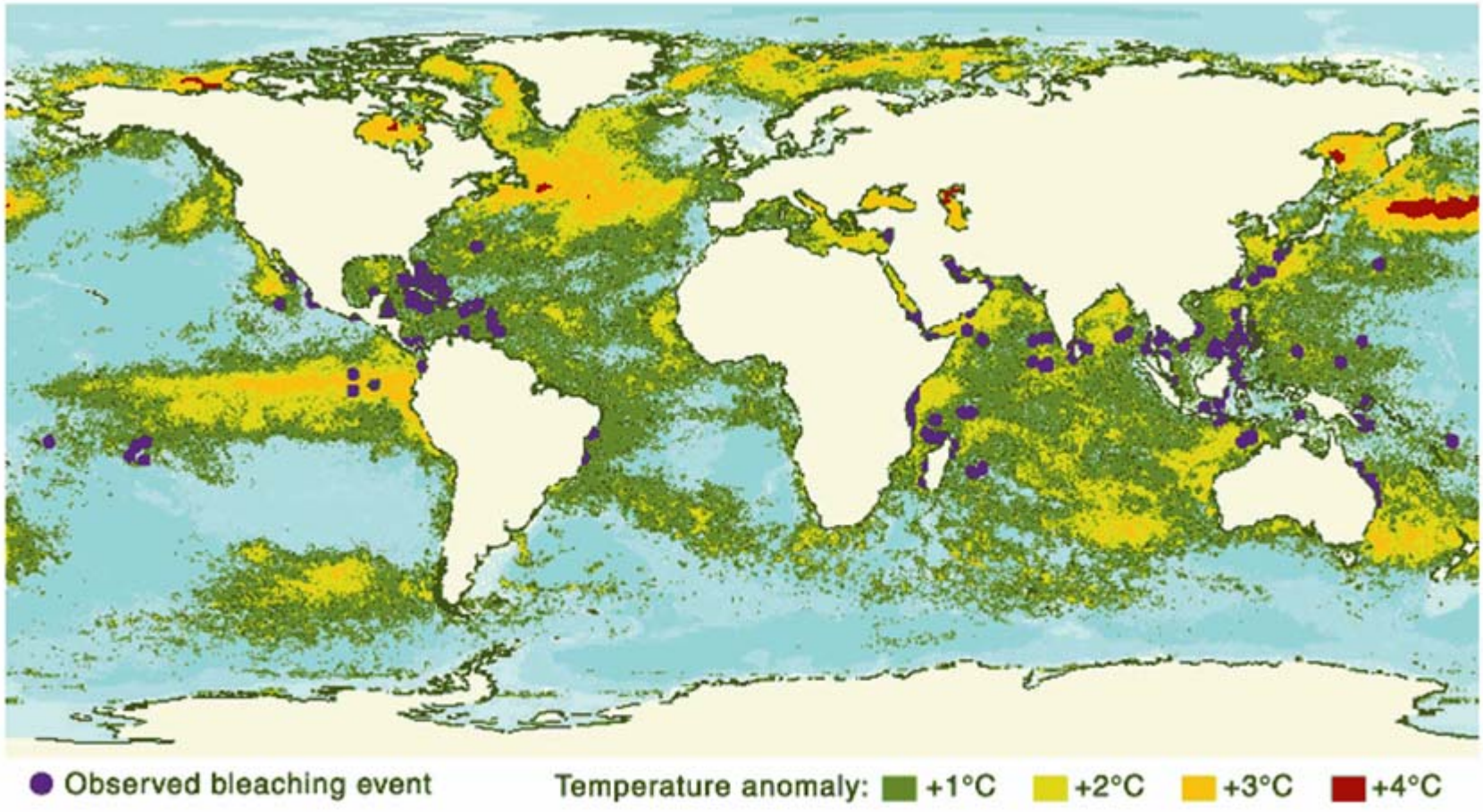
Hurricane Katrina



Emanuel 2005
Hoyos et al. 200



SST Anomalies & Coral Bleaching: 1997-98



WRI 2002

Coral Bleaching Events: 1870-1998

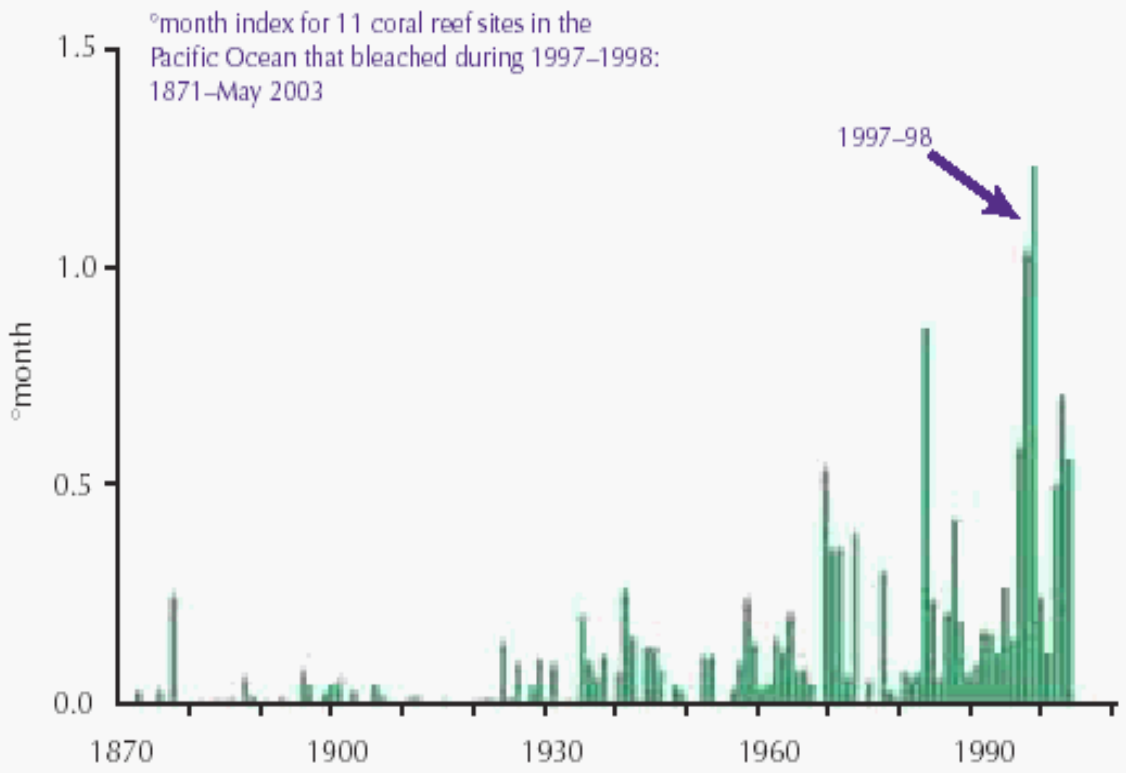
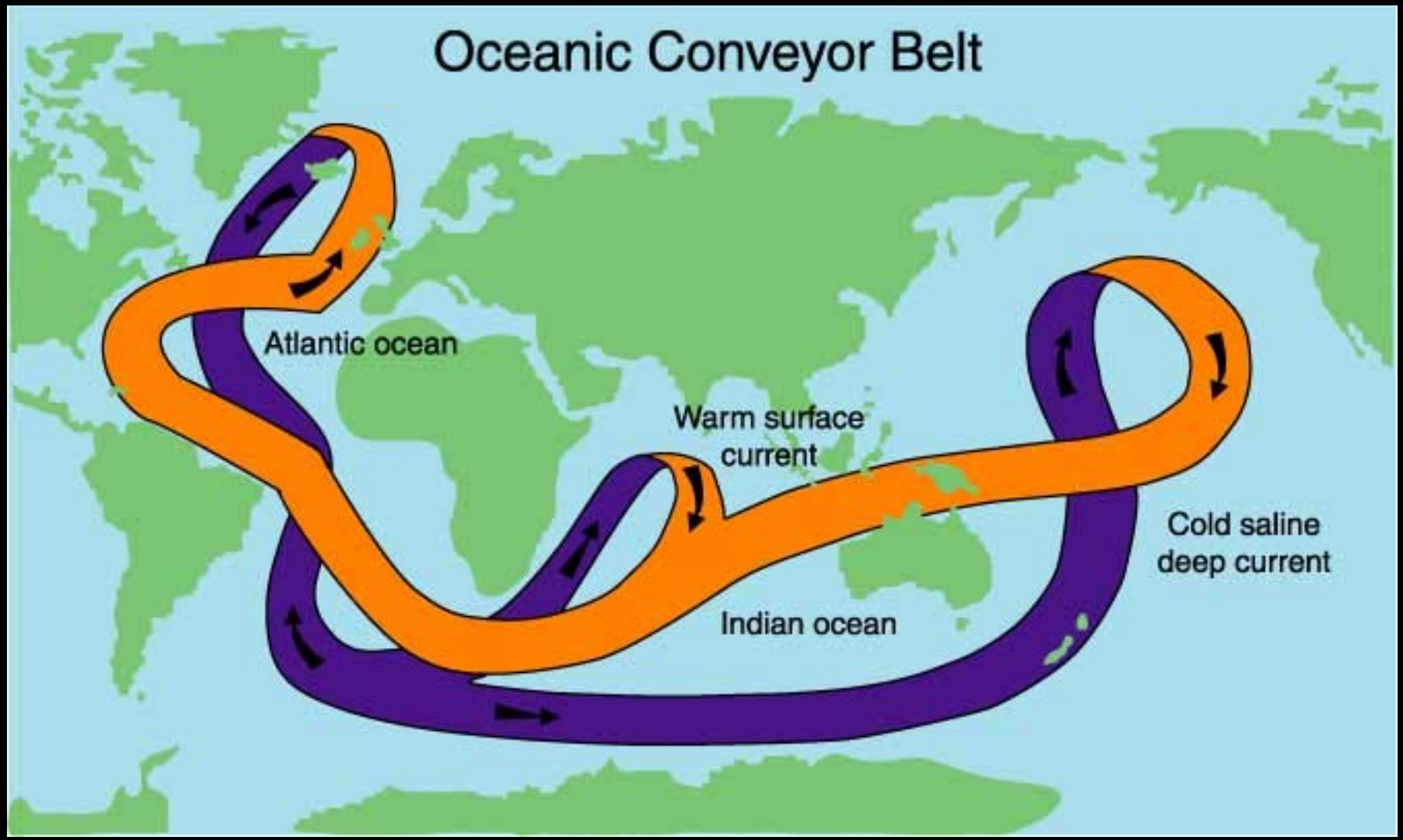
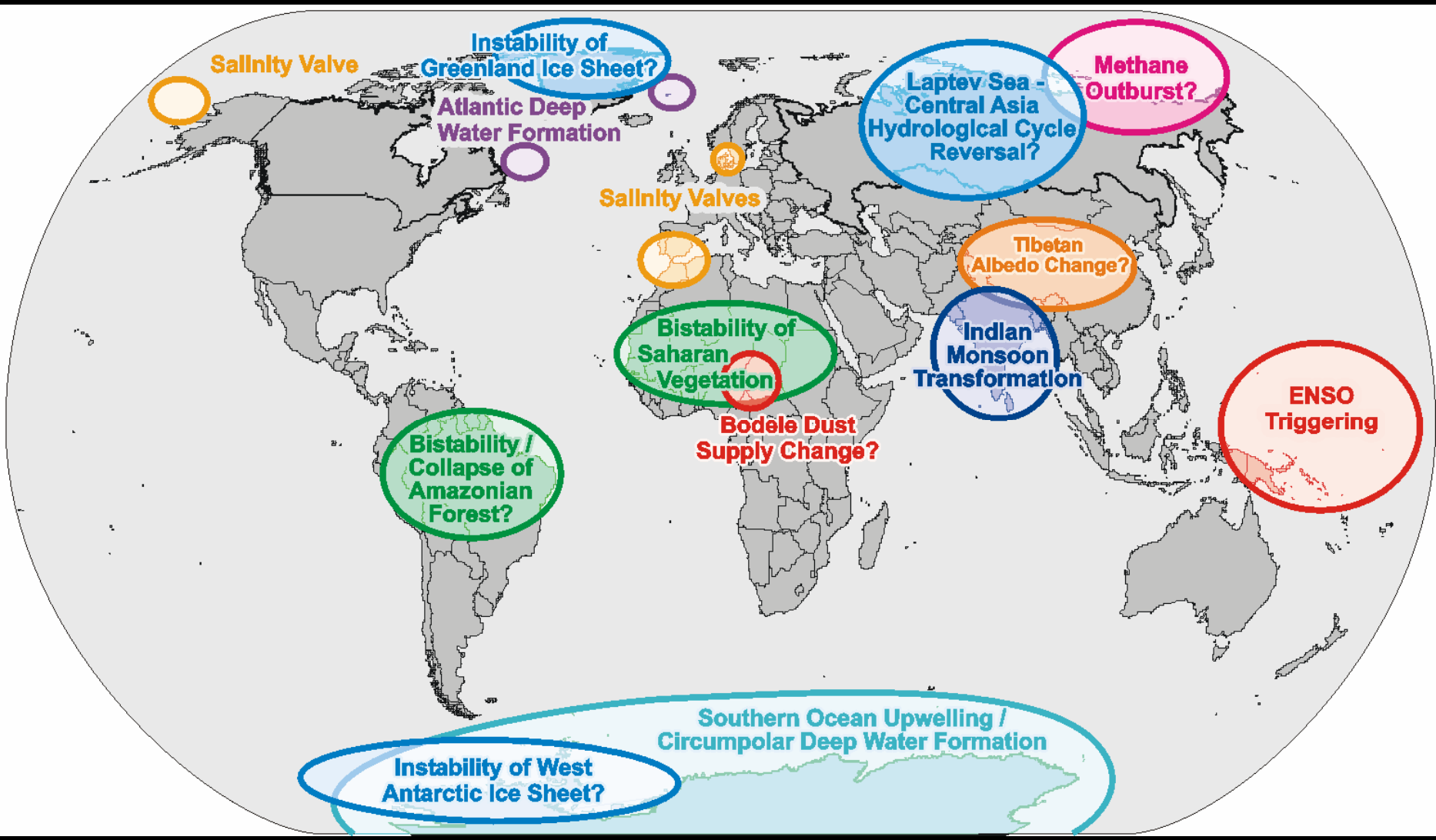


Figure 4.2.
Coral bleaching records showing the large number of events recorded in 1998. From Lough (2000), with permission.


Oceanic Conveyor Belt
Atlantic ocean
Warm surface current
Cold saline deep current
Indian ocean


Science
24 March 2006
Climate Change
Breaking the Ice
AAAS

Switch and Choke Points In the Earth System



After Schellnhuber 2002

Millennium Ecosystem Assessment

About 60% (15 out of 24) ecosystem services examined are being degraded or used unsustainably. Such pressure increases the risk of nonlinear, abrupt change in ecosystem functioning.

Over the past 50 years humans have changed ecosystems more rapidly and extensively than in any other period of human history. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.

Degradation of ecosystem services could become worse over the next 50 years. This projection can be averted only through significant changes in policies, institutions and practices not yet under way. Business-as-usual is not an option.

Source: MA Summary Report, 2005

GLOBAL CHANGE IGBP

The Earth is currently operating in a no-analogue state. In terms of key environmental parameters, the Earth System has recently moved well outside the range of natural variability exhibited over at least the last half million years. The ***nature*** of changes now occurring ***simultaneously*** in the Earth System, their ***magnitudes*** and ***rates of change*** are unprecedented.

From: Steffen et al. 2004

GLOBAL CHANGE IGBP

The Anthropocene

From Hunter-Gathers to a Global Geophysical Force

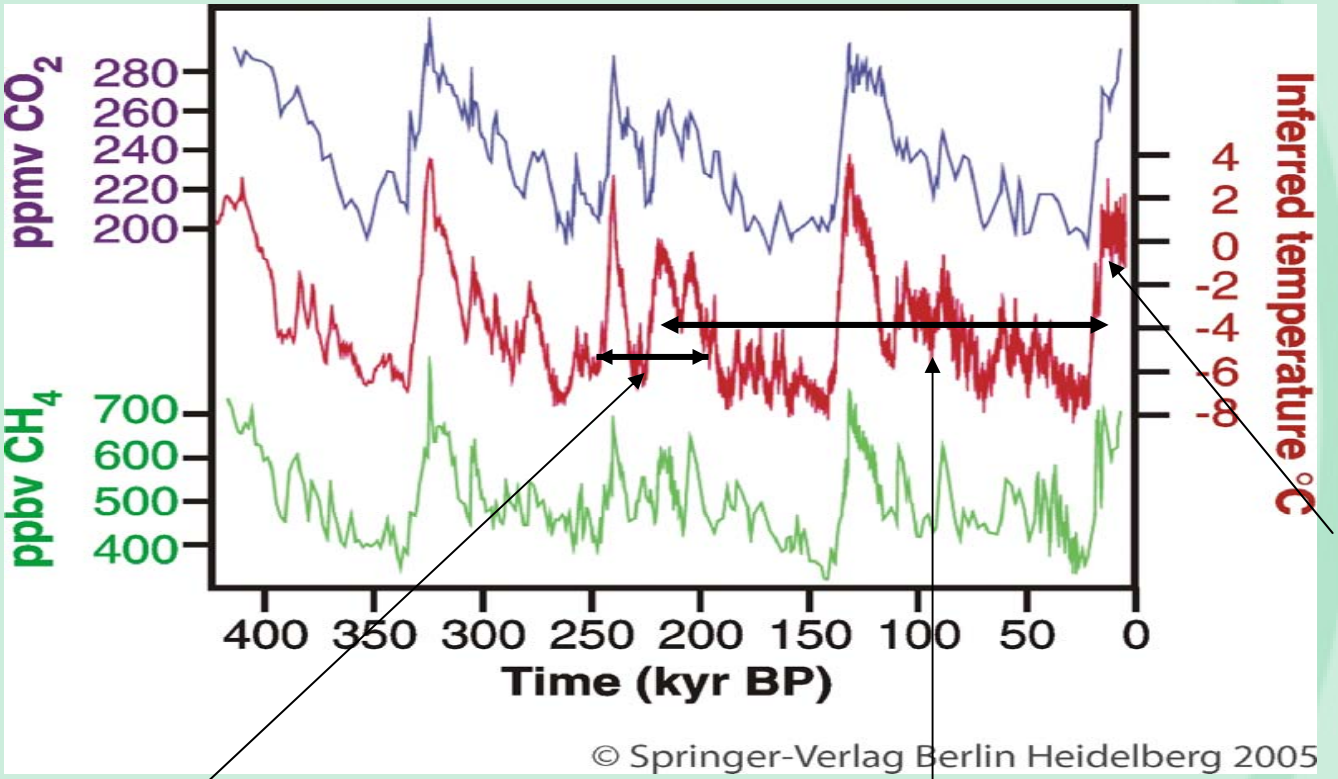
IHOPE: Integrated History and Future of People on Earth

Bob Costanza (Leader), Carole Crumley, John Dearing, Lisa Graumlich, Rik Leemans, Eric Lambin, John Schellnhuber, Will Steffen

Objective: To understand better the dynamic interactions between human societies and their environment by linking various forms of knowledge on human history and environmental change at multiple temporal scales (millennial, centennial, decadal, and future scenarios).

In short, a reconceptualisation of history - for us as a species and for Earth as a planet

Human Development and Earth System Dynamics



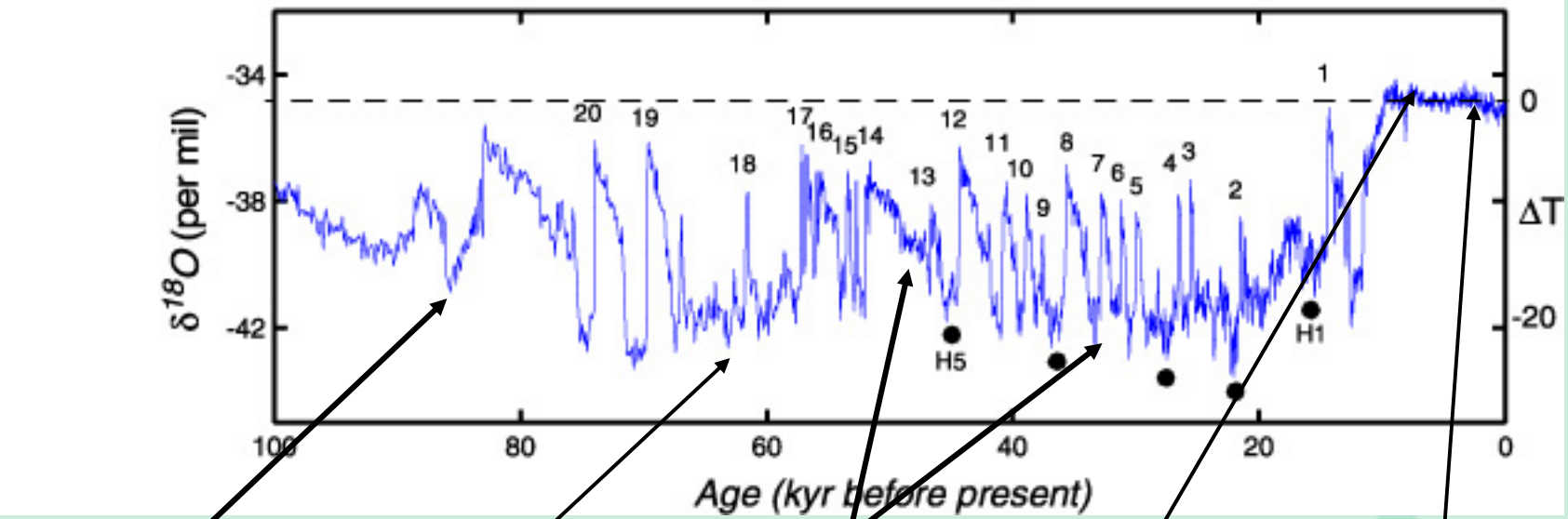
Beginning of agriculture

Hunter-gatherer societies only

Evolution of fully modern humans in Africa

GLOBAL CHANGE IGBP

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

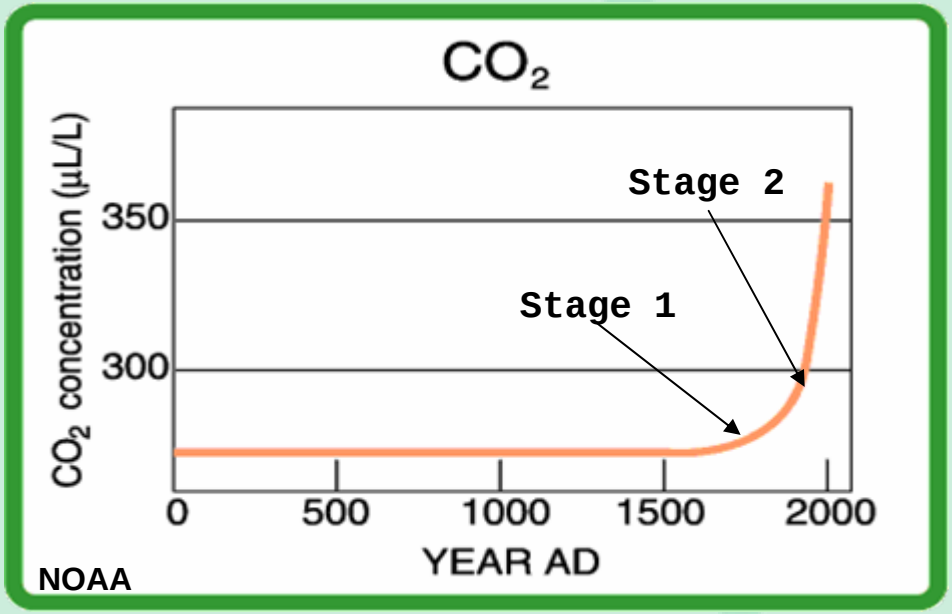
Source: GRIP ice core data (Greenland)
And S. Oppenheimer, "Out of Eden", 2004

The Anthropocene Era

The Stages of the Anthropocene

Pre-Anthropocene events: Fire-stick farming, megafauna extinctions, forest clearing

Anthropocene Stage 1 (ca. 1800 - 1945). Internal combusion engine, fossil fuel energy, sci & tech



Anthropocene Stage 2 (1945 - 2010 or 2020). The Great Acceleration, new institutions and vast global networks

Anthropocene Stage 3 (2010 or 2020 - ?). Sustainability or collapse?

From: Steffen, Crutzen & McNeill 2006

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.

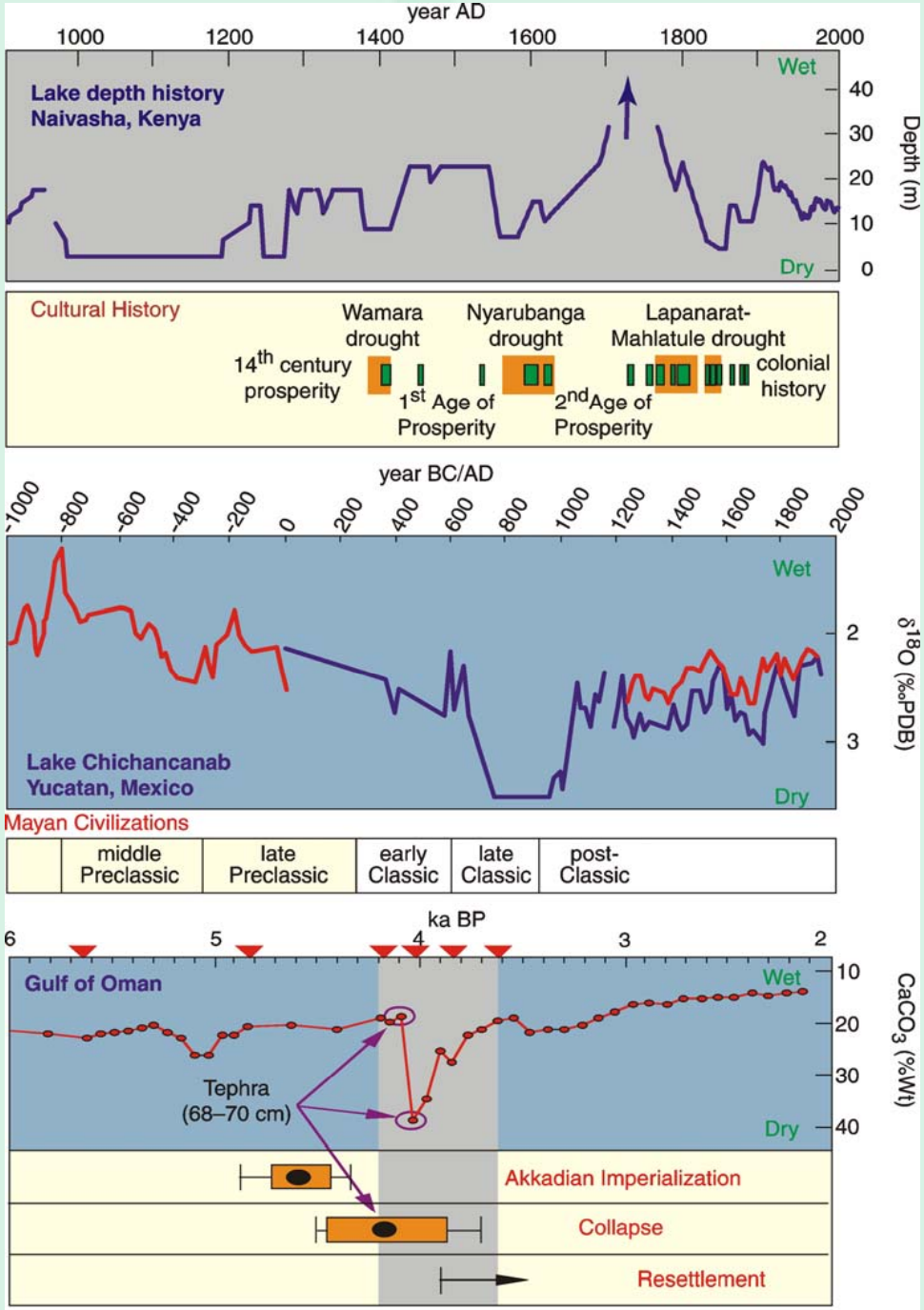
- No discernable effect on Earth System functioning at the global scale

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.

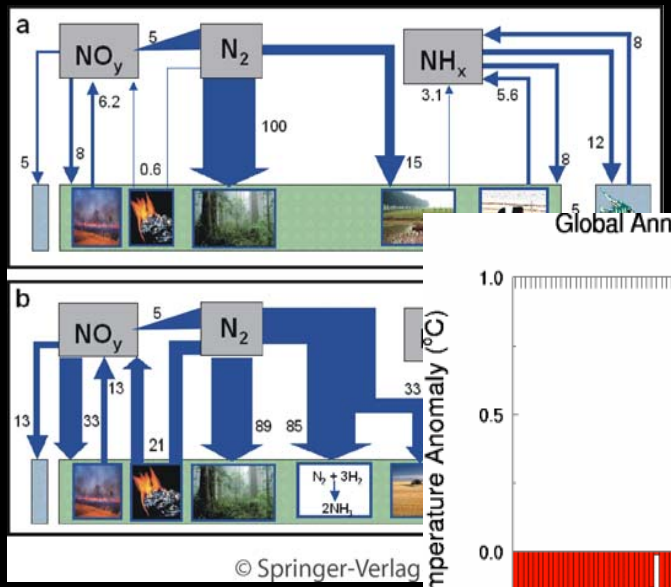
Anthropocene Stage 1 (1800-1945)

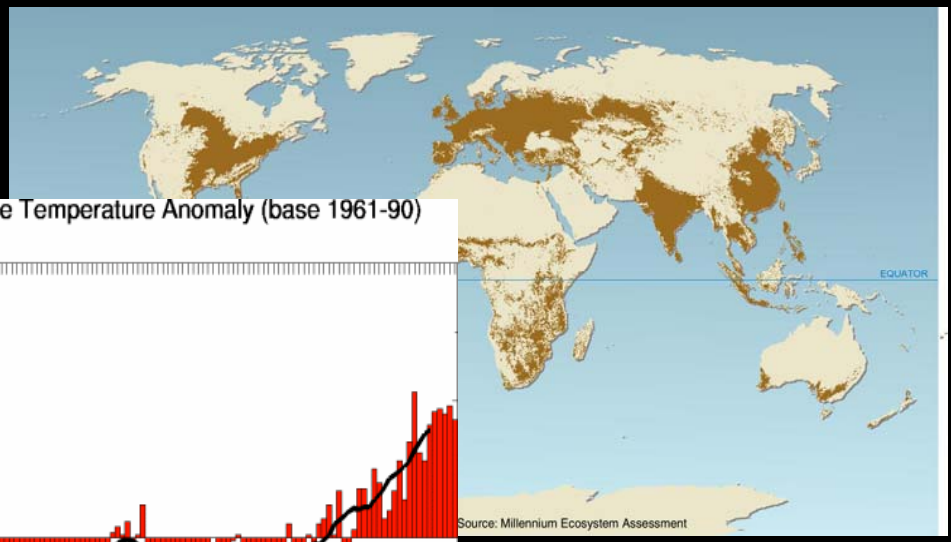
- Evidence - increase in GHG concentrations, widespread deforestation of temperate forests, etc.

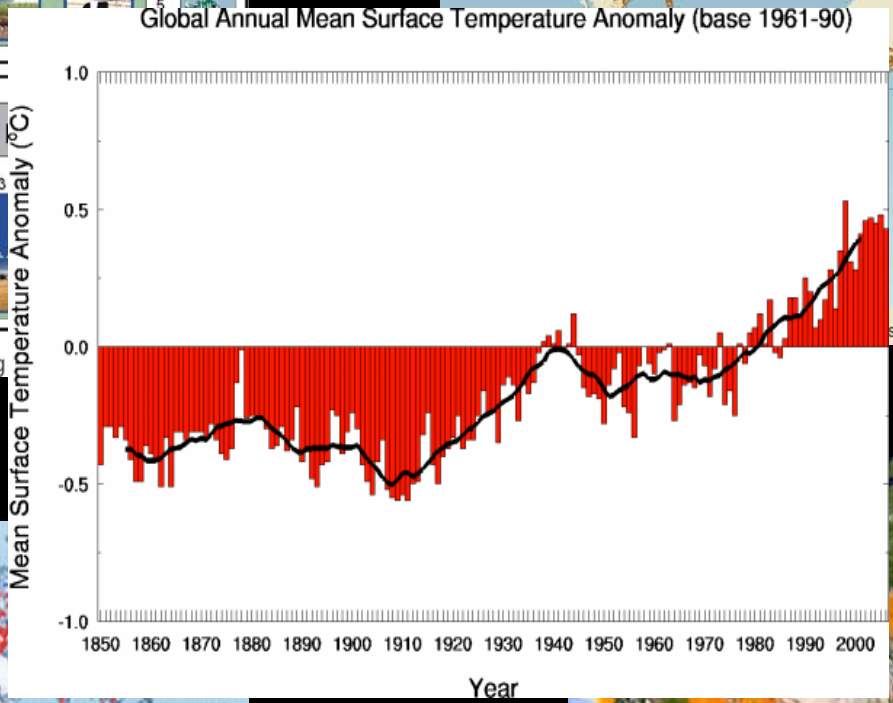
- Industrial Revolution - steam engine, fossil fuel energy systems, rapid and wide spread of these energy systems

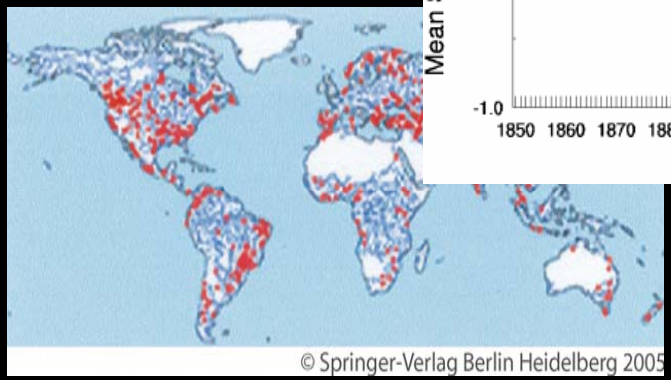
- Flow-on effects - more efficient techniques for land clearing; synthetic fertiliser; more reliable water supply and better sanitation, leading to better public health. These developments, in turn, led to an increase in population AND their ability to consume.

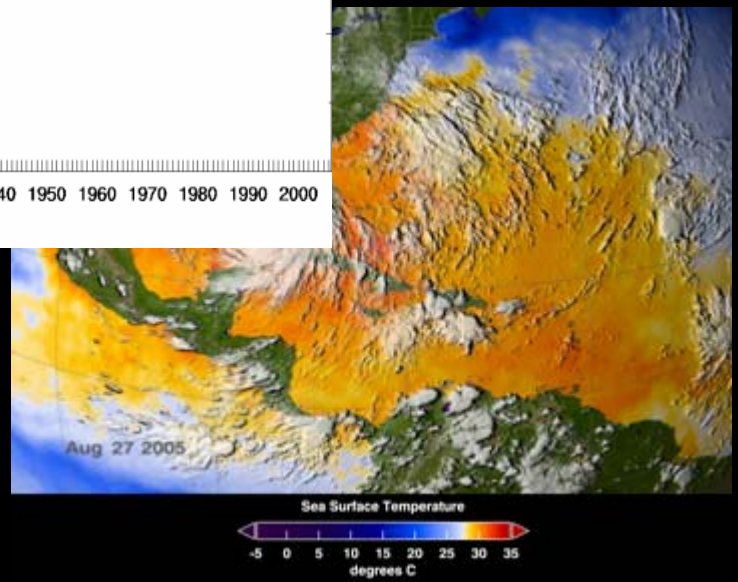
The multi-faceted nature of global change







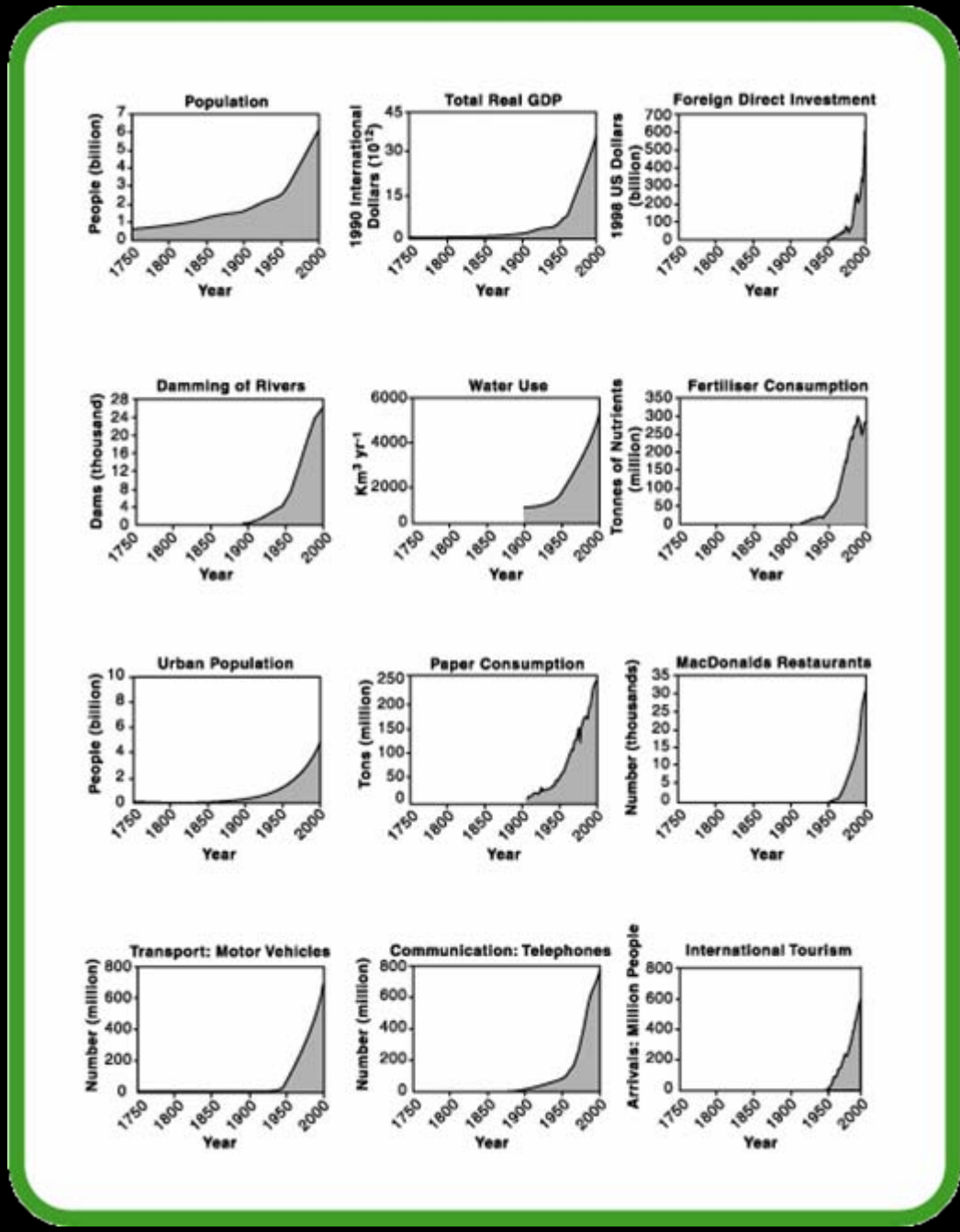




Anthropocene Stage 2
(1945 - 2010/2020)

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

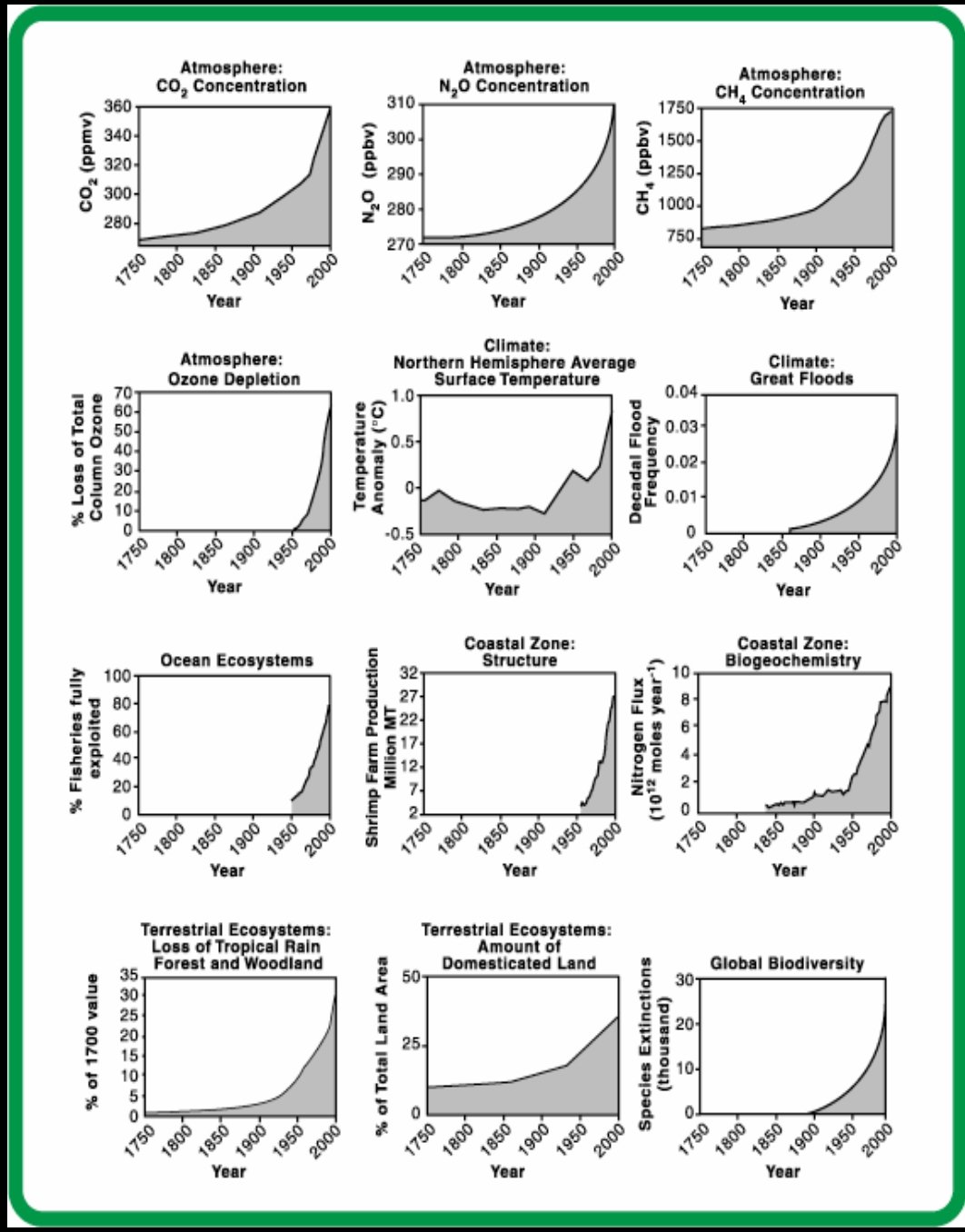
Note the start of the 'Great Acceleration' around 1950, when many activities began or accelerated sharply.



From Steffen et al. 2004

Responses of the biophysical Earth System to the accelerating 'human enterprise'.

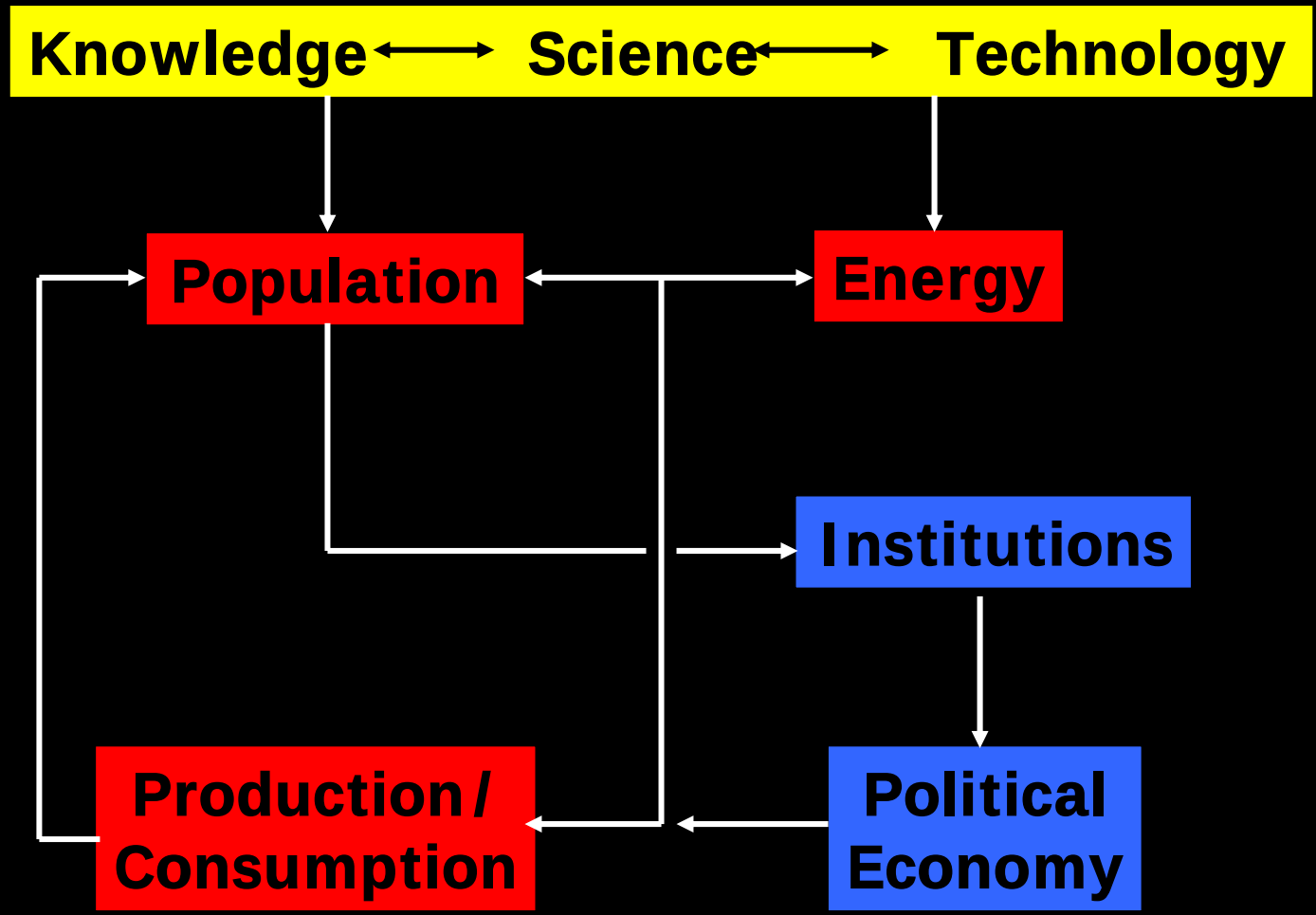
The biophysical responses of the Earth System show many of the same features as the Great Acceleration in the human enterprise.



From: Steffen et al. 2004

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



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

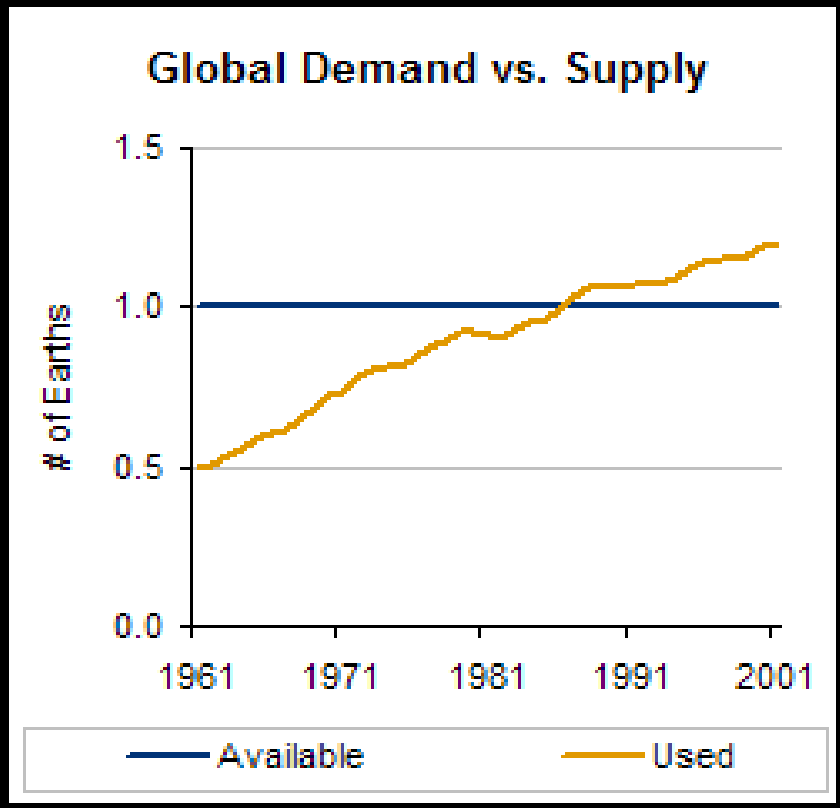
Urbanisation and the environment

- Different experiences and understanding of nature between urban and rural dwellers
- Increased wealth, rising consumption expectations
- Transformation of rural-urban linkages - 'footprints'

Governance

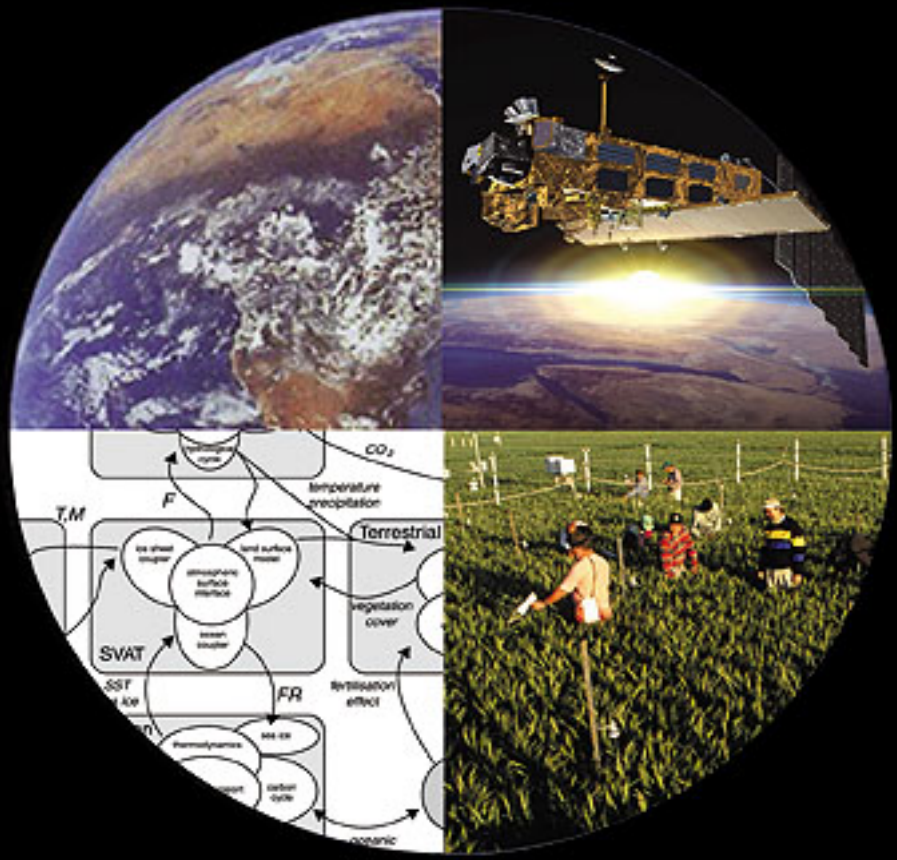
- Shift to free-market economic systems
- Decentralisation & privatisation of environmental management

Global Footprint of the Human Enterprise

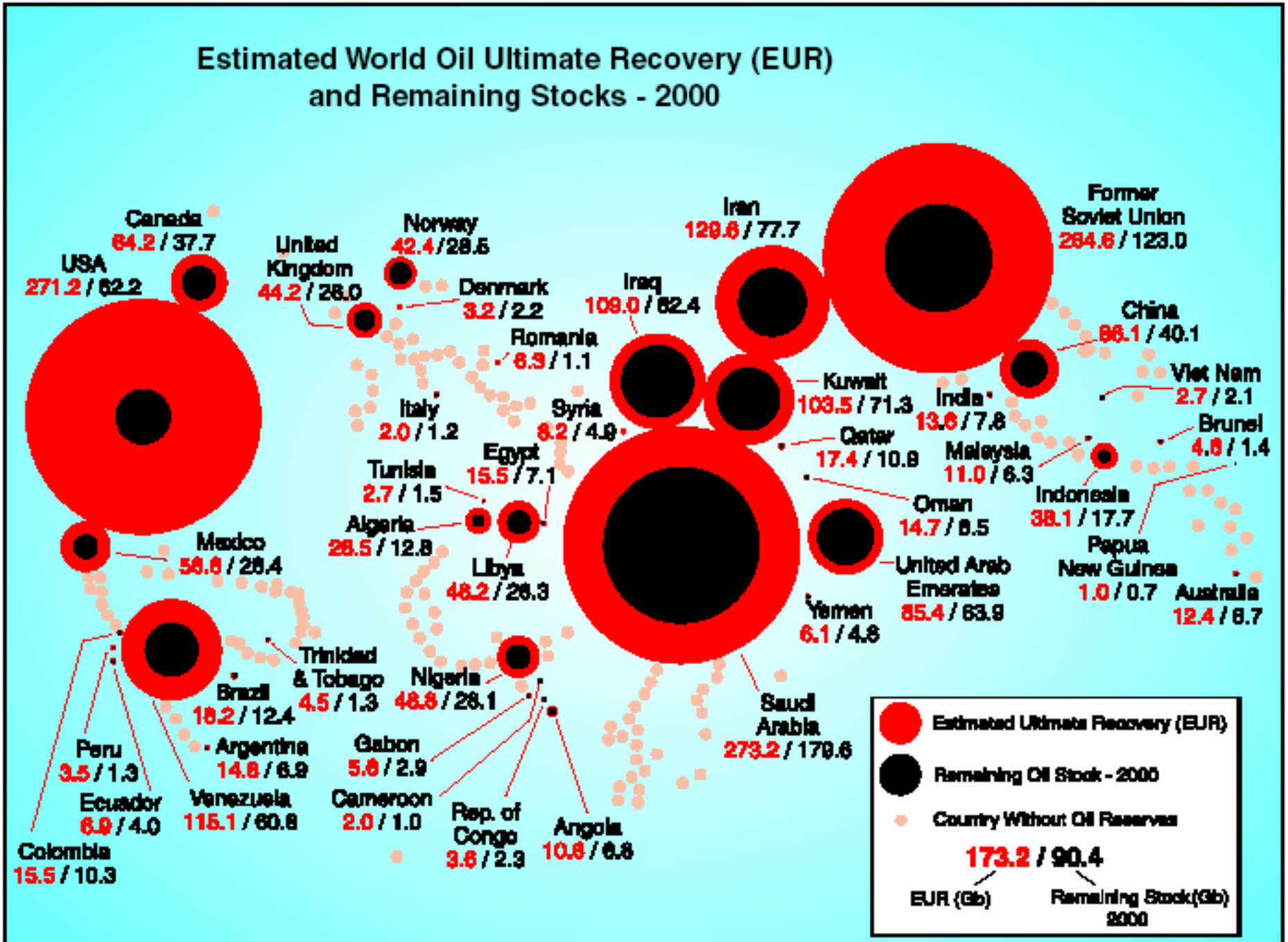


Source: Global Footprints Network 2005

Anthropocene Stage 3 (2010/2020 - ?)

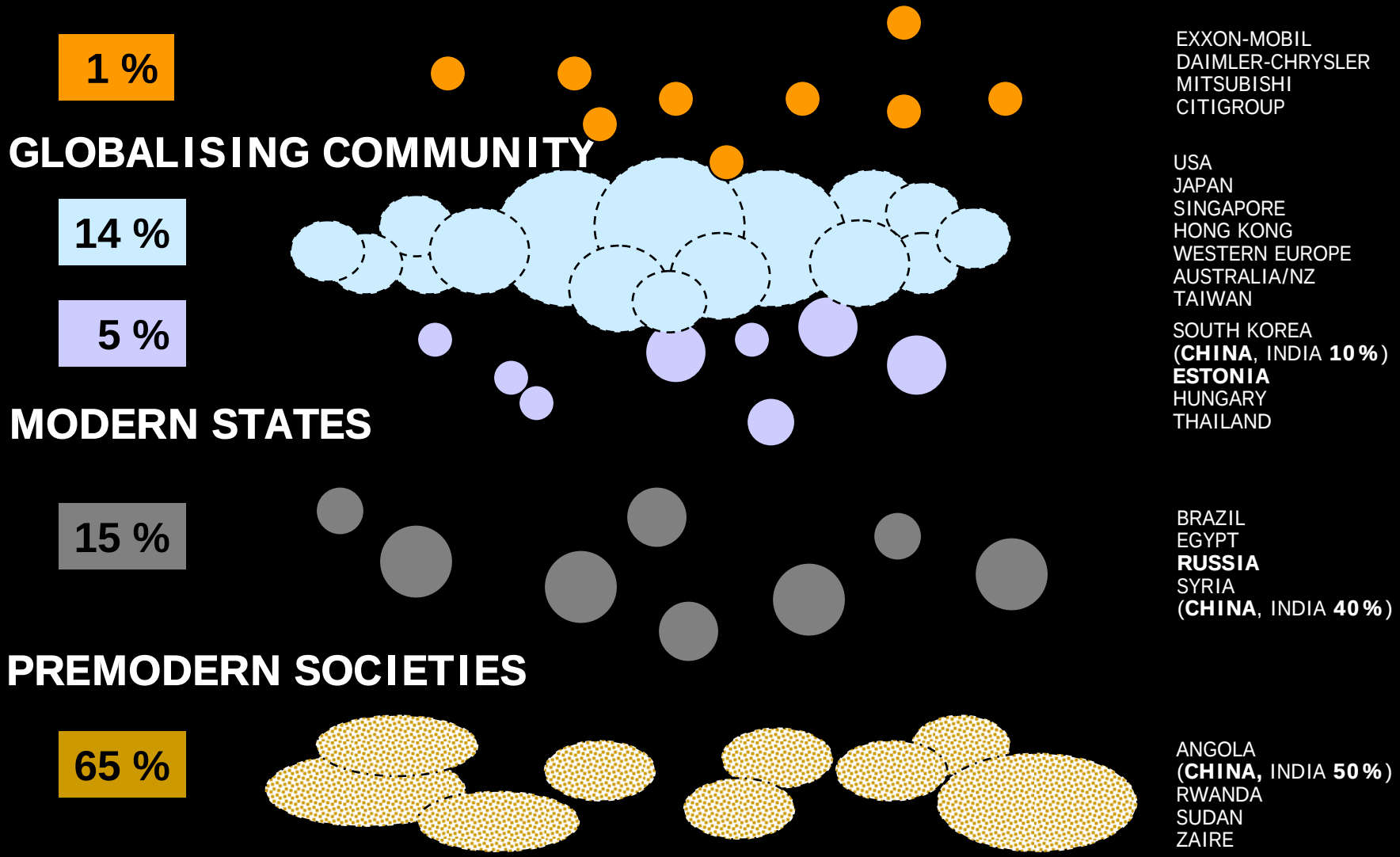


Estimated World Oil Ultimate Recovery (EUR) and Remaining Stocks - 2000



From: *The World Petroleum Life-Cycle*, Richard C. Duncan and Walter Youngquist, 1998

The Human Enterprise: Early Globalised



T. Ries, Swedish Institute of International Affairs

Photo: Brian Stocks

A1

B1

Hyper individualism

Business class

Markets first

Creative societies

Global sustainability

Market World

Changing course

‘The end of history’

New global age

‘Our Common Future ‘

Cybertopia

Policy first

Just do it

Shared responsabilities

The hundred flowers

Ecologically driven

Have & have- nots

Over the edge

Sustainability first

New Empires

Regional stewardship

Security first

Prism

Provincial enterprise

Transformed World

‘Clash of civilizations’

Cultural pluralism

Great transitions

‘No Logo’

Turbulent neighbourhoods

Change without progress

B2

Fortress World

Battlefield

Voluntary simplicity

A2

Barbarization

Local stewardship

Tribal society

INSIDE CHECHNYA: EXCLUSIVE PHOTOS • MICROSOFT'S STRATEGY

Newsweek

THE INTERNATIONAL NEWSMAGAZINE

November 22, 1999

Whose World?

Seattle Braces for Trade Talks— And Noisy Protests Over Food, Workers' Rights and the Environment

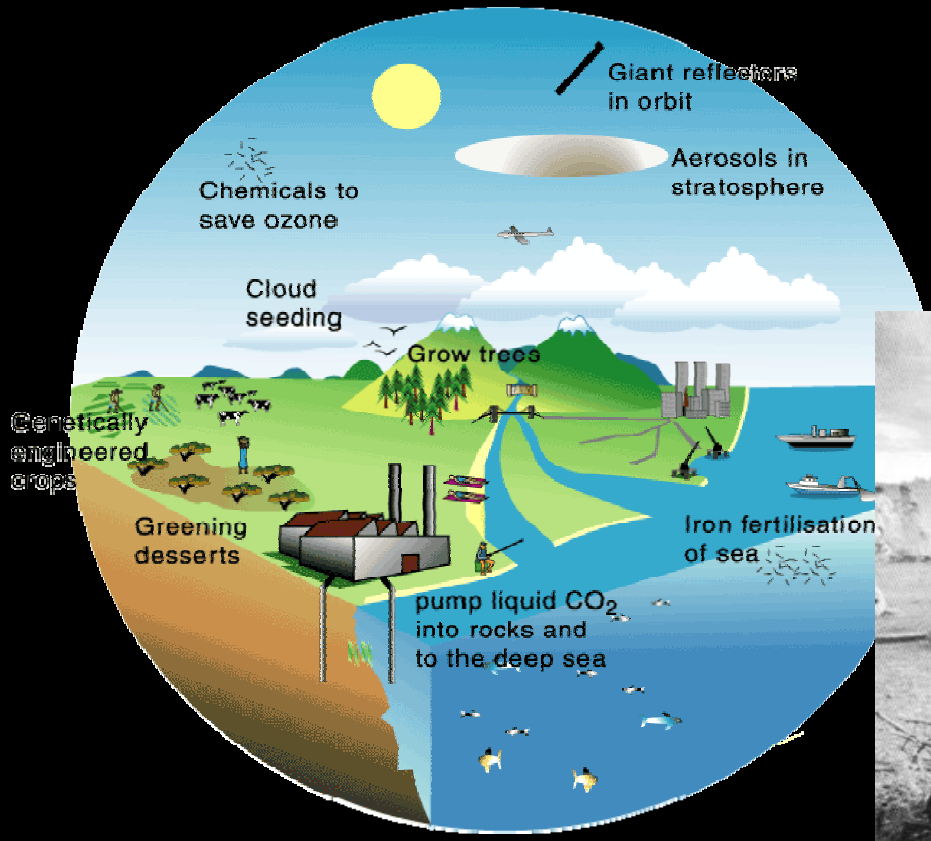
Albania Lek 500 Finland Mk 22.00 Israel NIS 14.00 Norway Kr 30.00 Sweden SKr 30.00

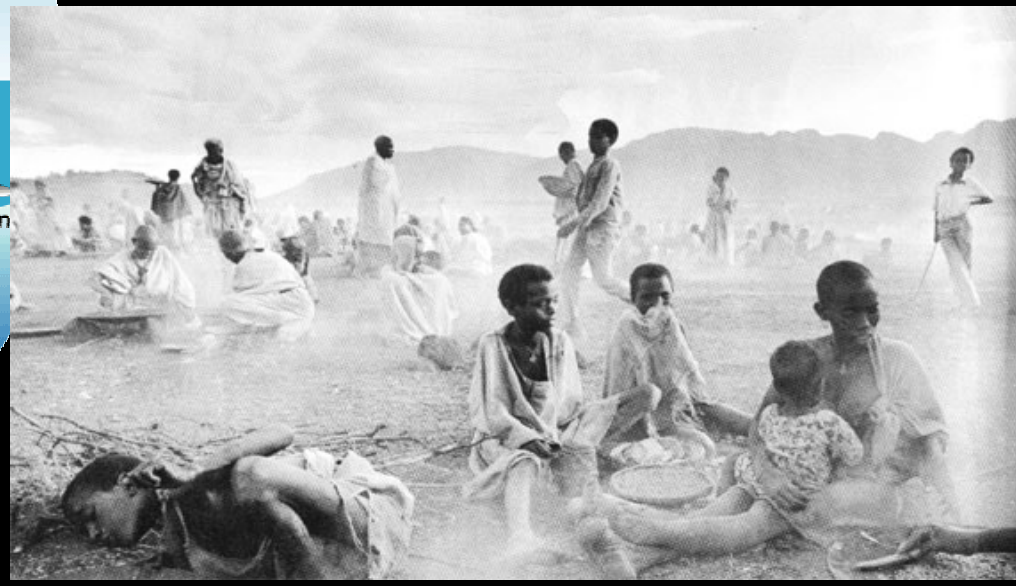
We begin the 21st century in a very volatile world

IHOPE Dahlem Conference, June 2005

GLOBAL CHANGE
IGBP

The Anthropocene Stage 3: Sustainability or Collapse

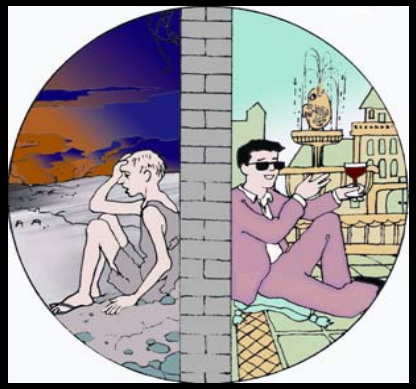




Where on Earth are We Going?

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

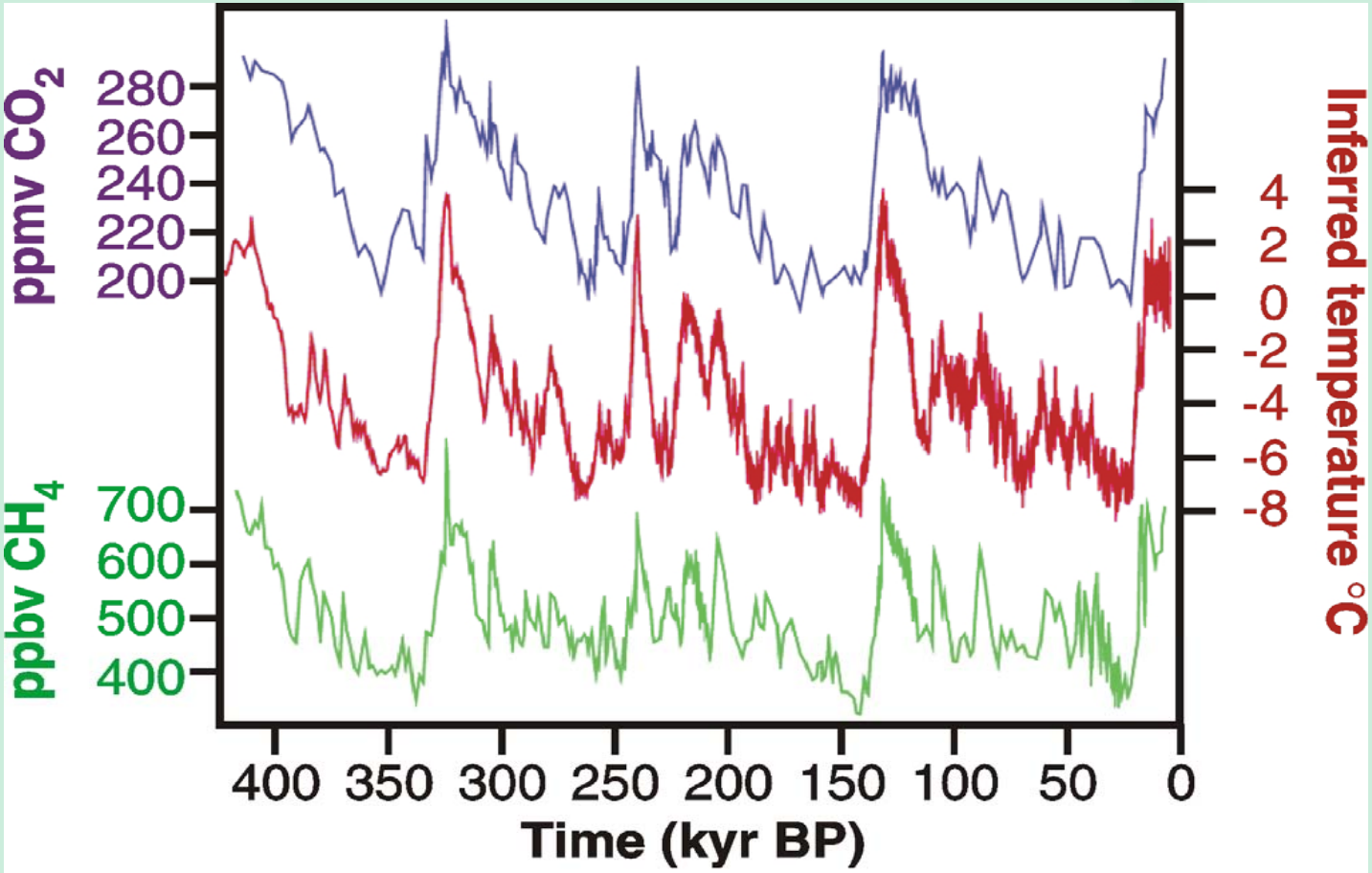
- **Adapting Mosaic:** Regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems.

- **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

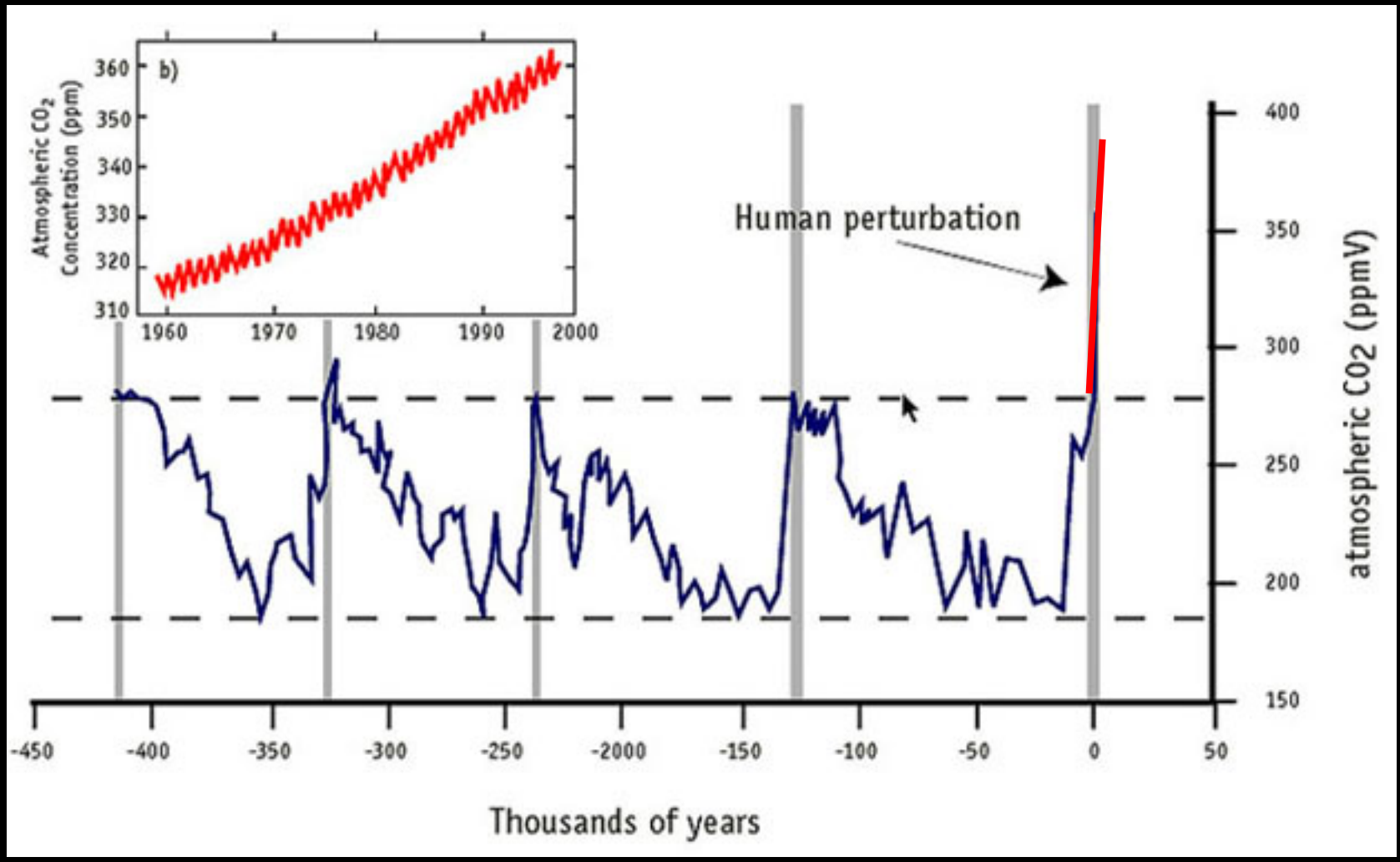
’Night Lights’ of Earth

Image: NASA



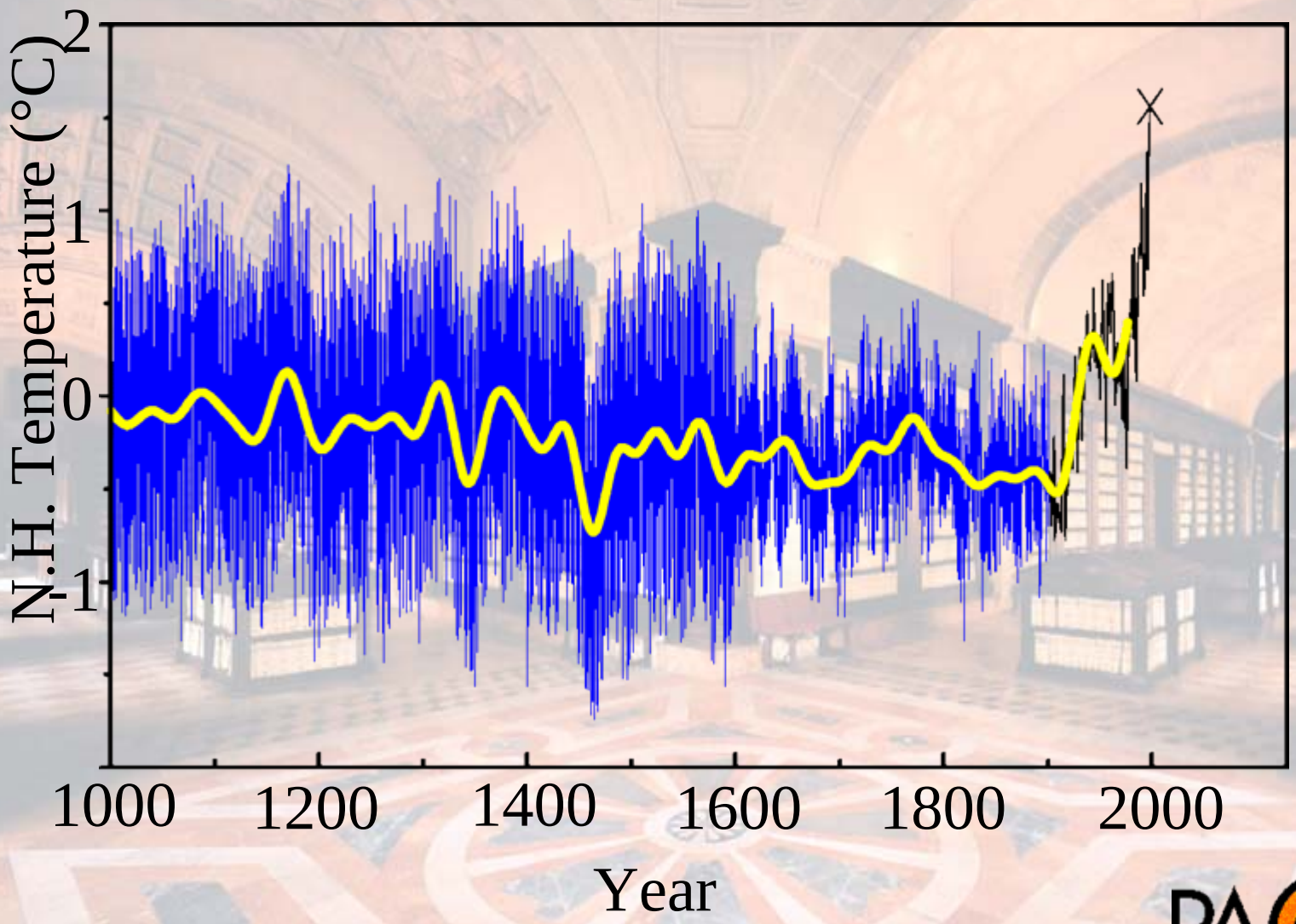
GLOBAL CHANGE
I G B P

Outside the envelope of self-regulation?



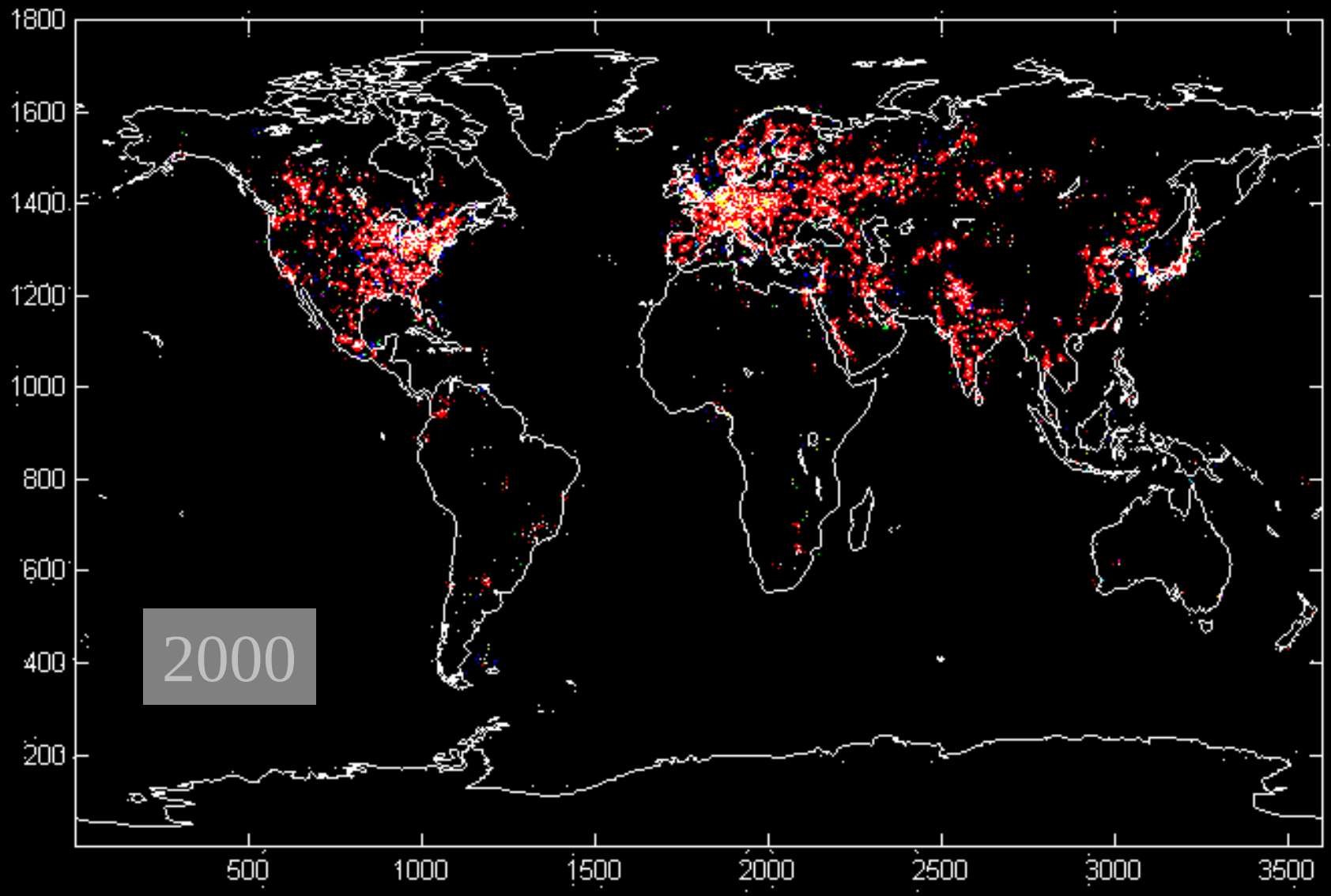
Petit et al. 1999; Keeling and Whorf 2000

A Millennium Scale Perspective …



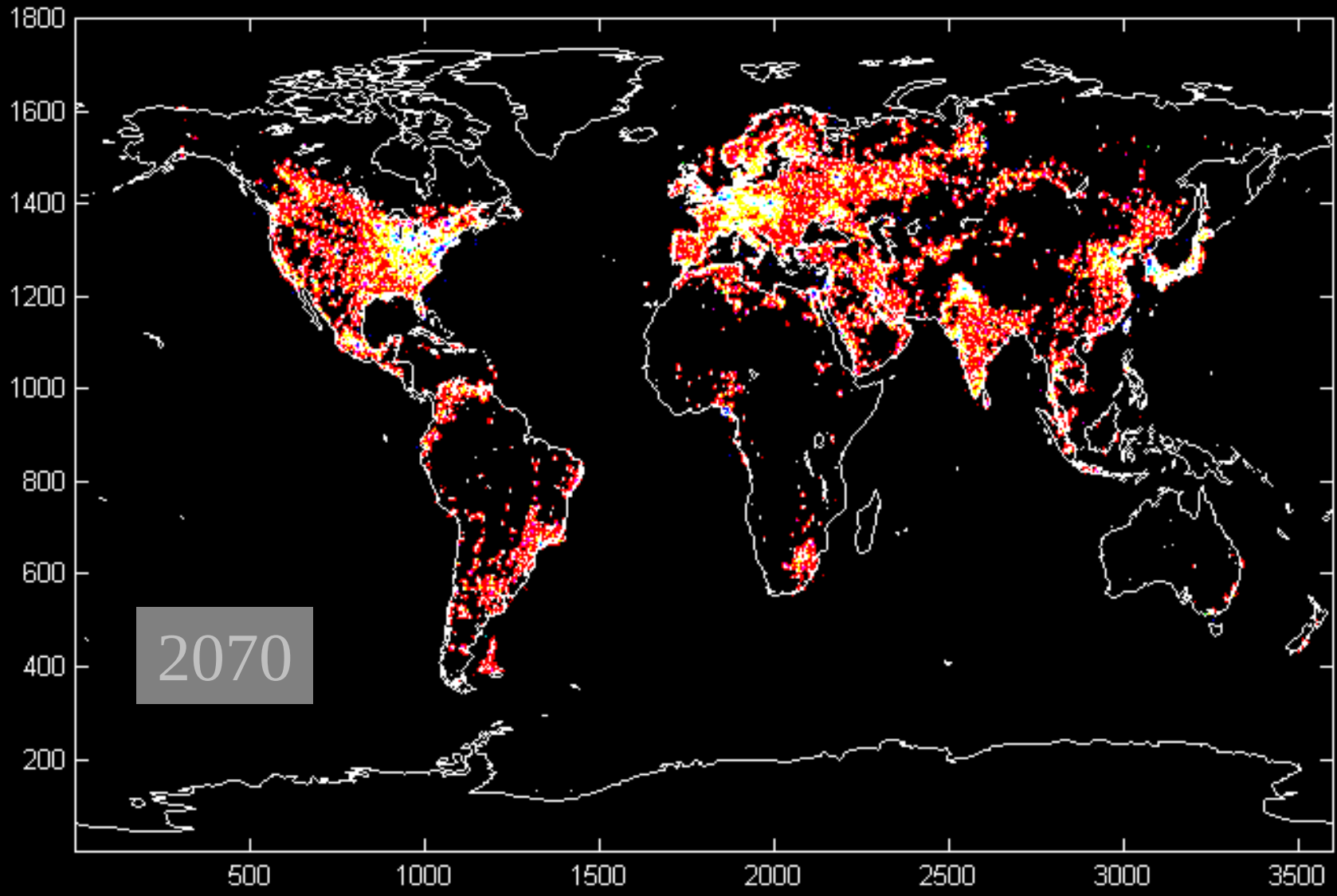
Mann et al. (1999) GRL 26:759-762

Simulated Night Lights



From: Nakicenovic 2002

Simulated Night Lights



From: Nakicenovic 2002

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

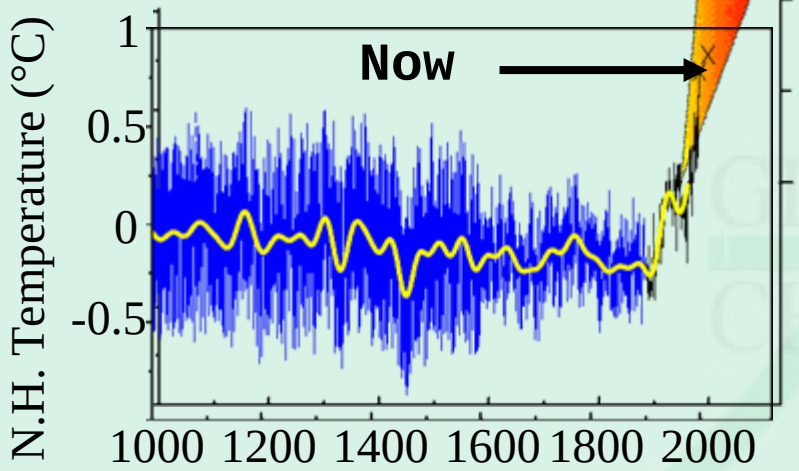
Large biodiversity loss; coral reefs disappear

"Committed" Climate Change

IPCC Projections
2100 AD

Global Temperature (°C)

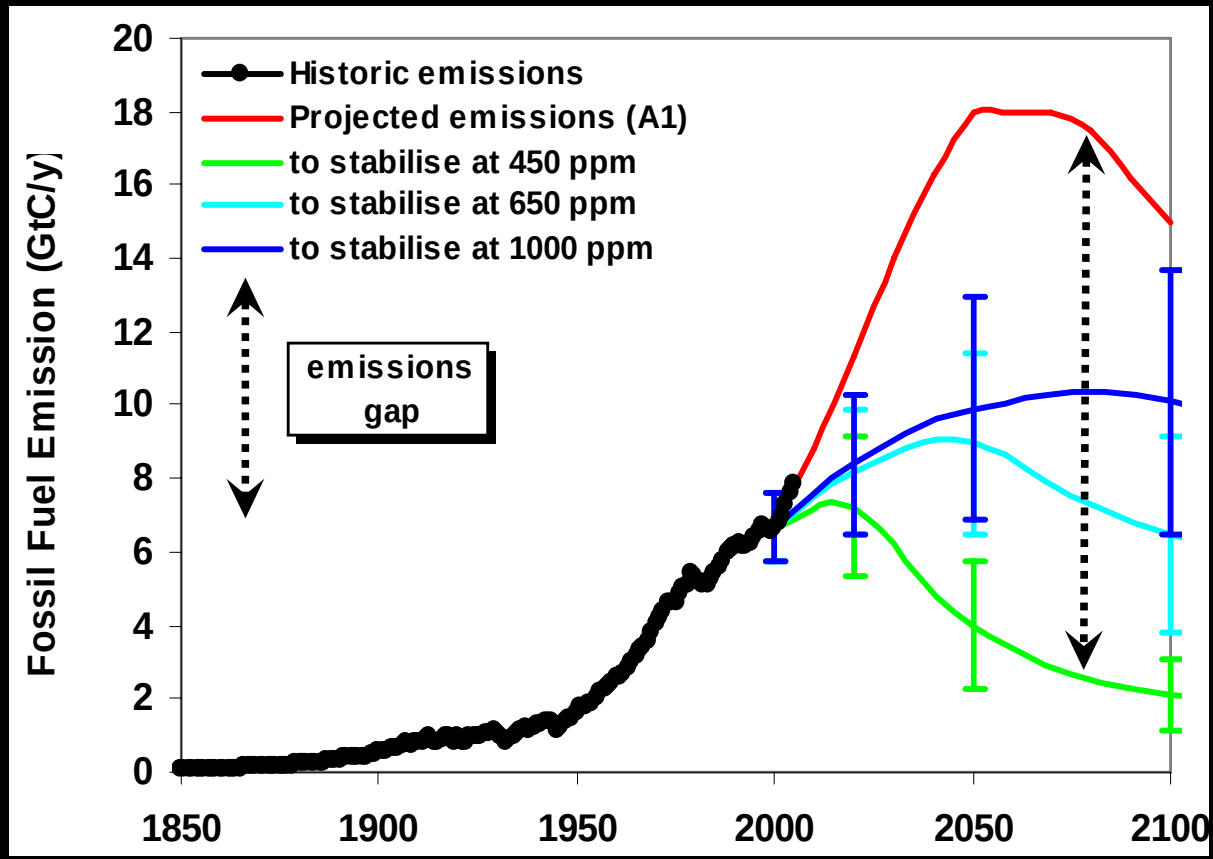
6
5
4
3
2
1
0

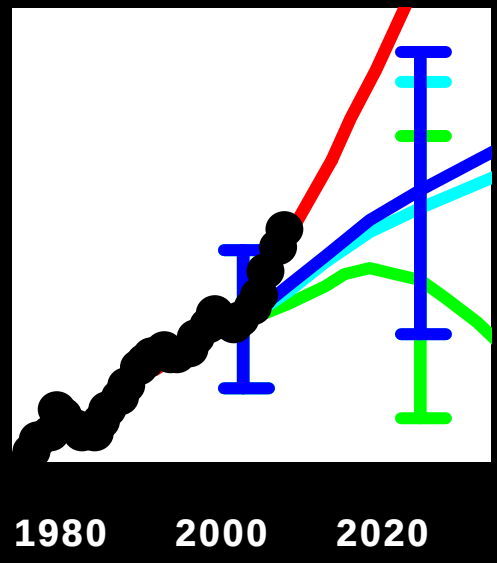


GLOBAL CHANGE

PAGES

Observed carbon emission trajectory compared to projections and stabilisation scenarios





Raupach et al. 2007

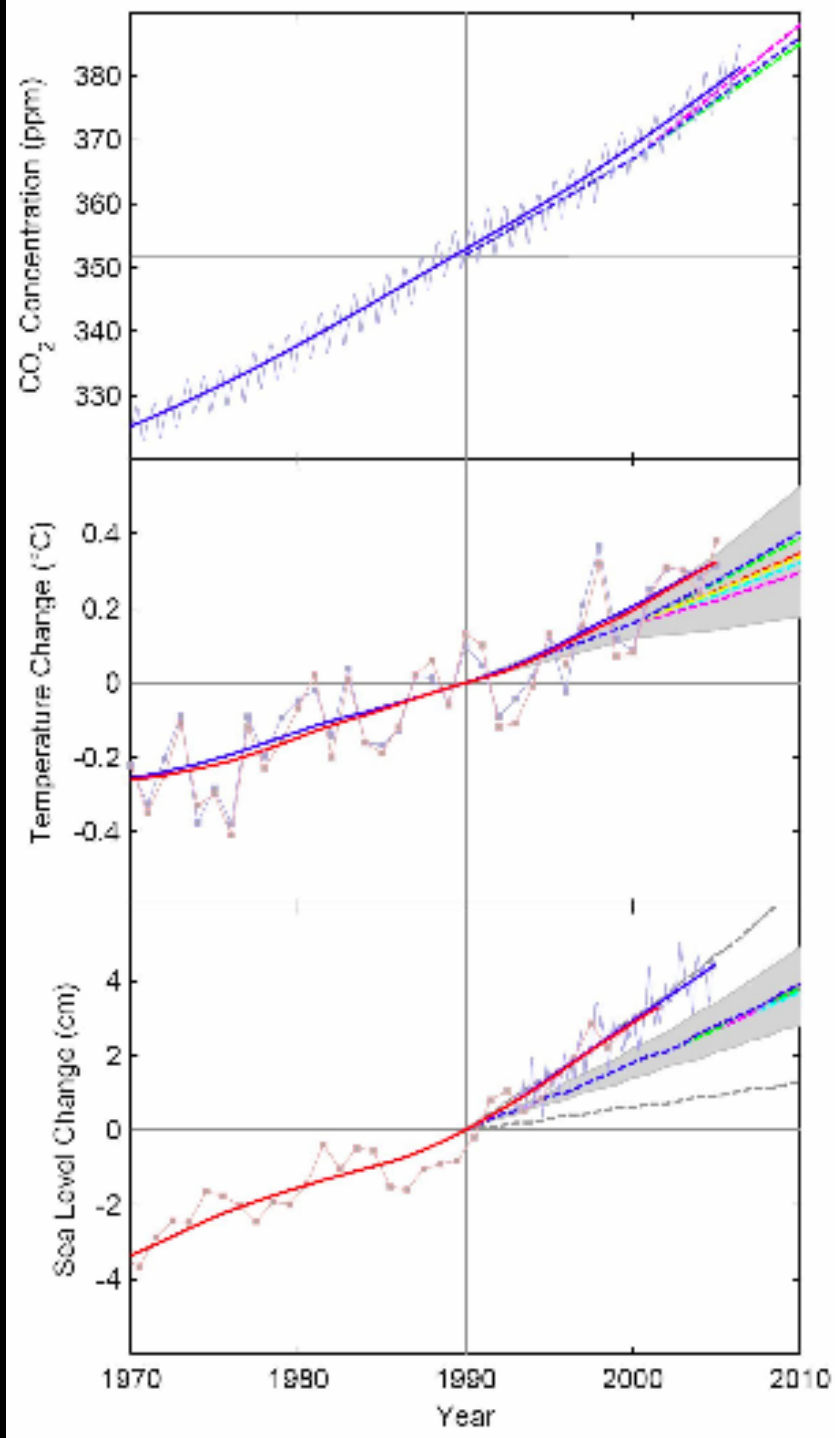
Observed changes in global climate parameters since 1970, (solid lines), compared to IPCC projections (broken lines with grey ranges):

(a) Atmospheric CO_2 concentration

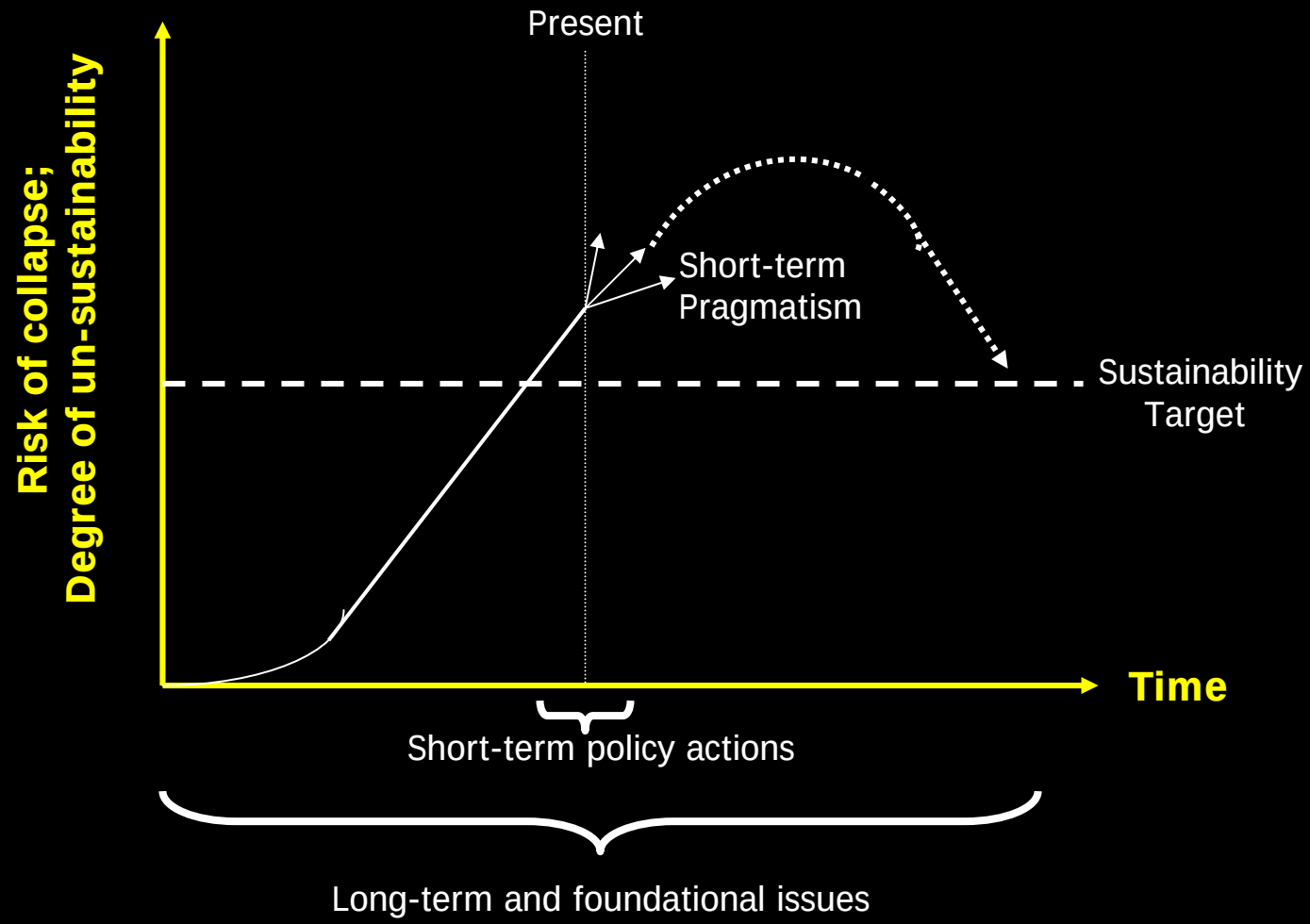
(b) Annual global mean surface temperature (land + oceans)

(c) Sea level data from tide gauges (red line) and satellite altimeters (blue line)

From: Rahmstorf et al. 2007



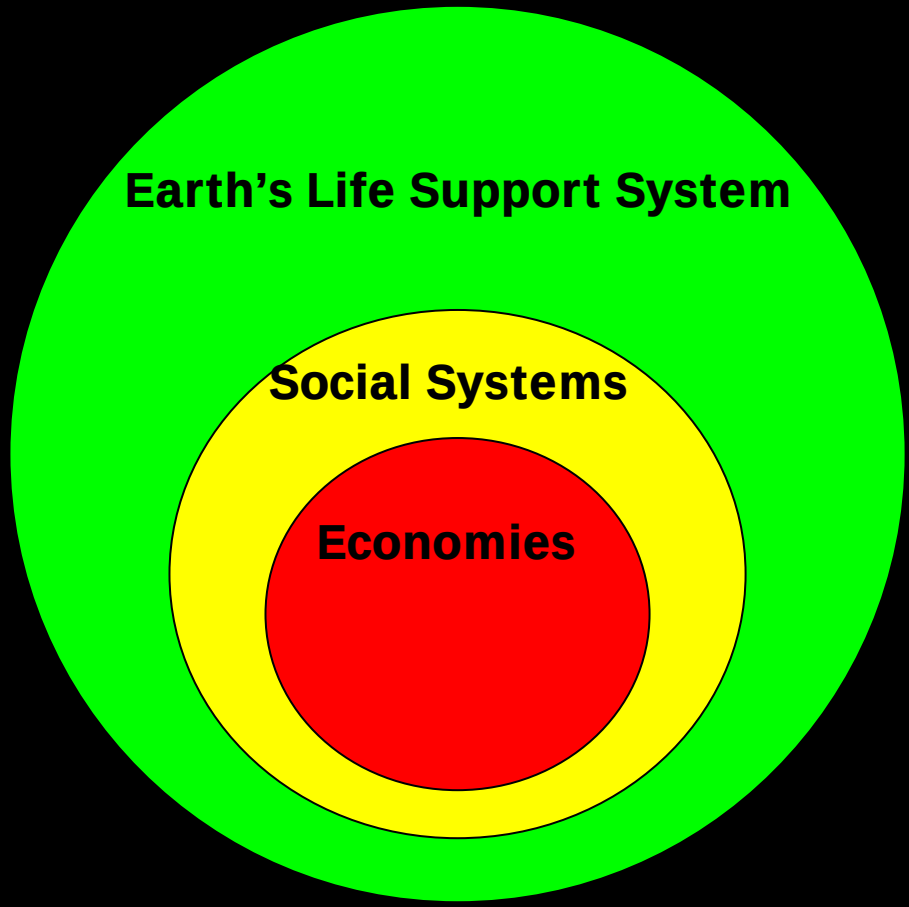
The Sustainability Gap



Fischer, Manning et al. 2007

The “Sustainability Hierarchy”…

…rather than the “Triple Bottom Line”



After I. Lowe 2005

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

GLOBAL IGBP CHANGE

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'

GLOBAL CHANGE IGBP

Sustainability or Collapse?

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