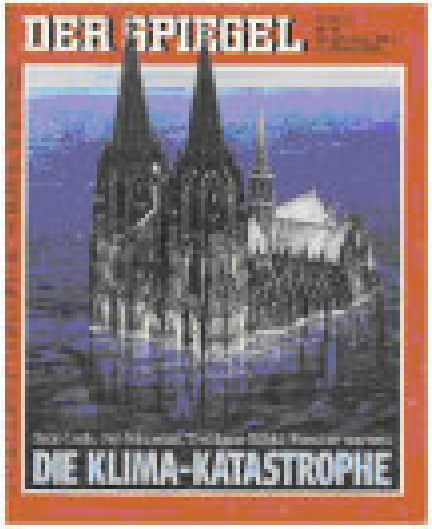
A World Transformed

The Consequences of Climate Change and Human Land Use

Wolfgang Lucht • Potsdam Institute for Climate Impact Research
Chair, Research Domain „Earth System Analysis“

THE DAY AFTER TOMORROW
IN THEATRES WORLDWIDE 28 MAY 2004
WHERE WILL YOU BE?

by far the most terrifying film
you will ever see.
aninconvenienttruth
A GLOBAL WARNING

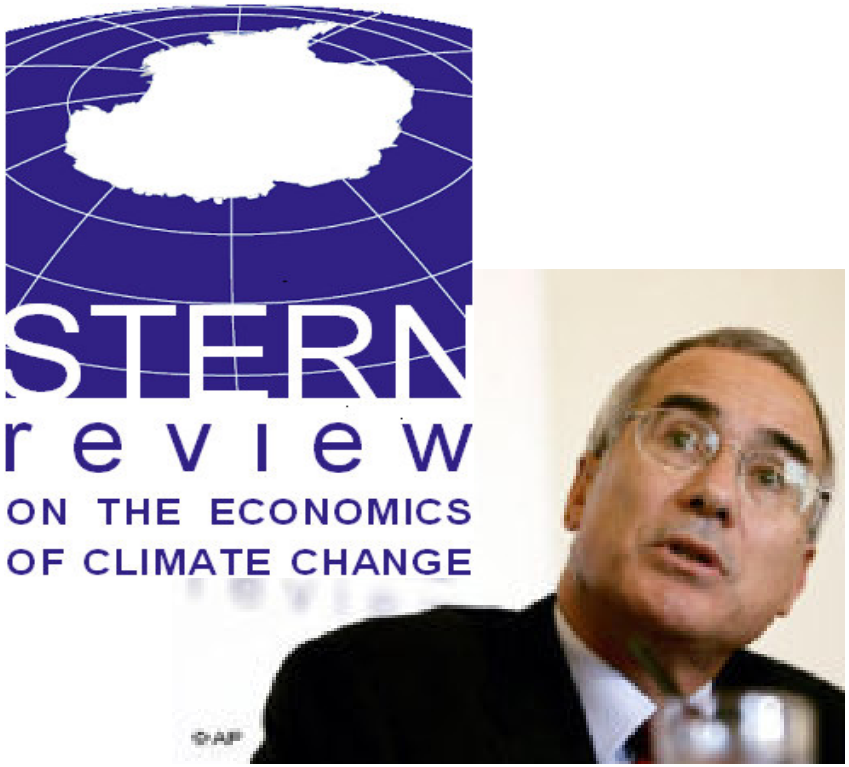


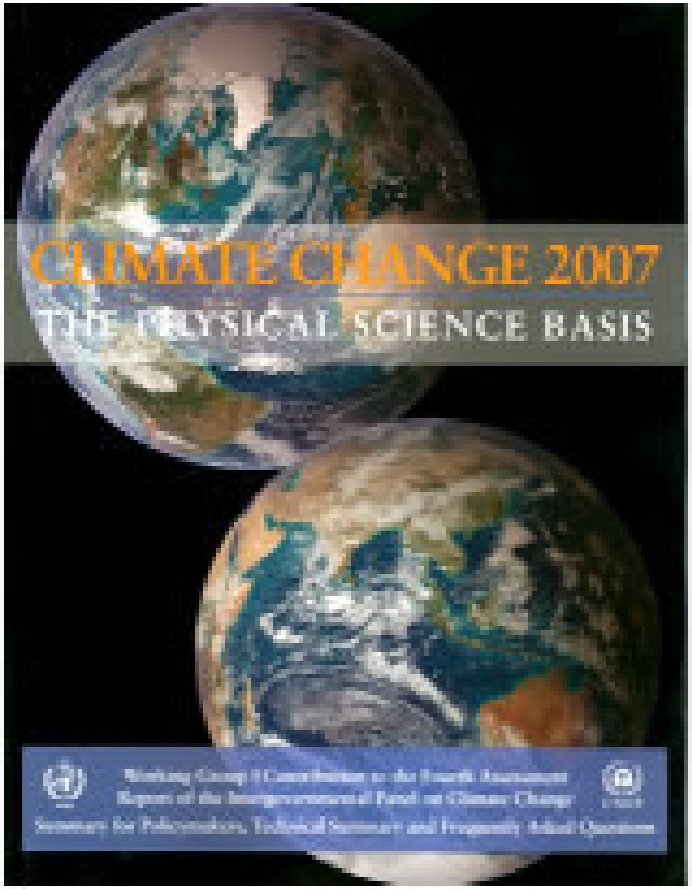
SPIEGEL
44/1986

SPIEGEL
14/2004

SPIEGEL
45/2006

SPIEGEL
19/2007





30 October 2006

Costs of Climate Change
Benefits of Avoidance

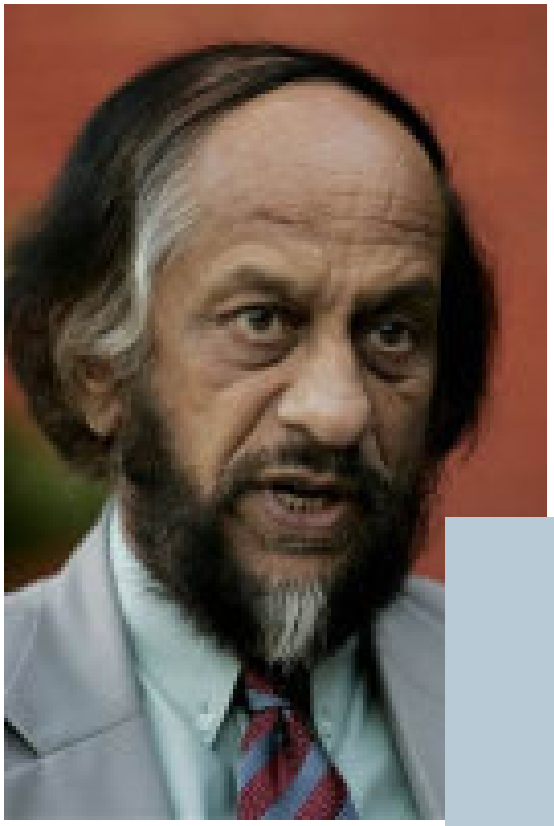
2 February 2007
6 April 2007
4 May 2007

UN IPCC Climate Report

Nobel Peace Prize
12 November 2007

Al Gore

IPCC
(Rajendra Pachauri)

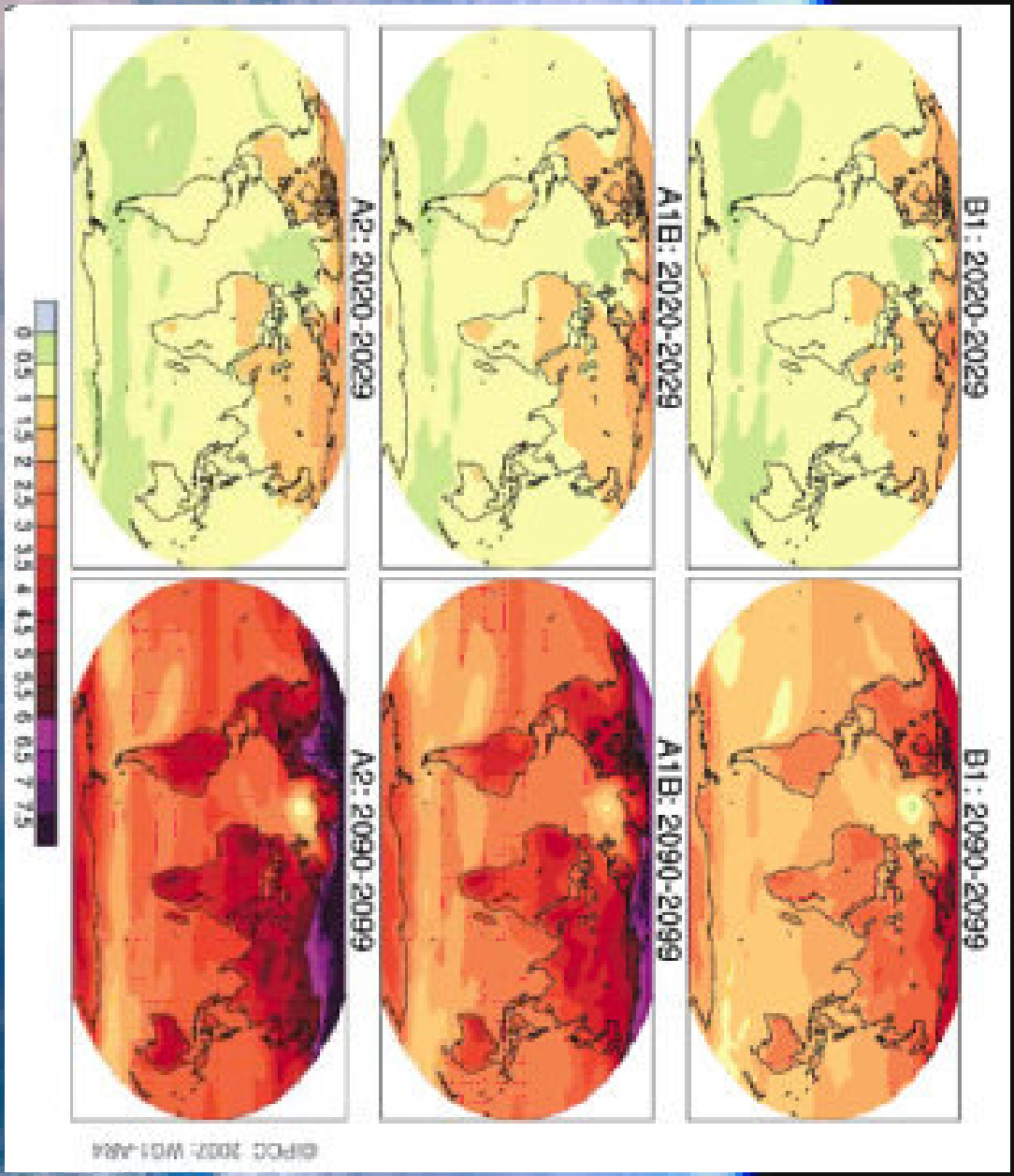


Global Temperature Increase

Three Scenarios (Different Emissions)

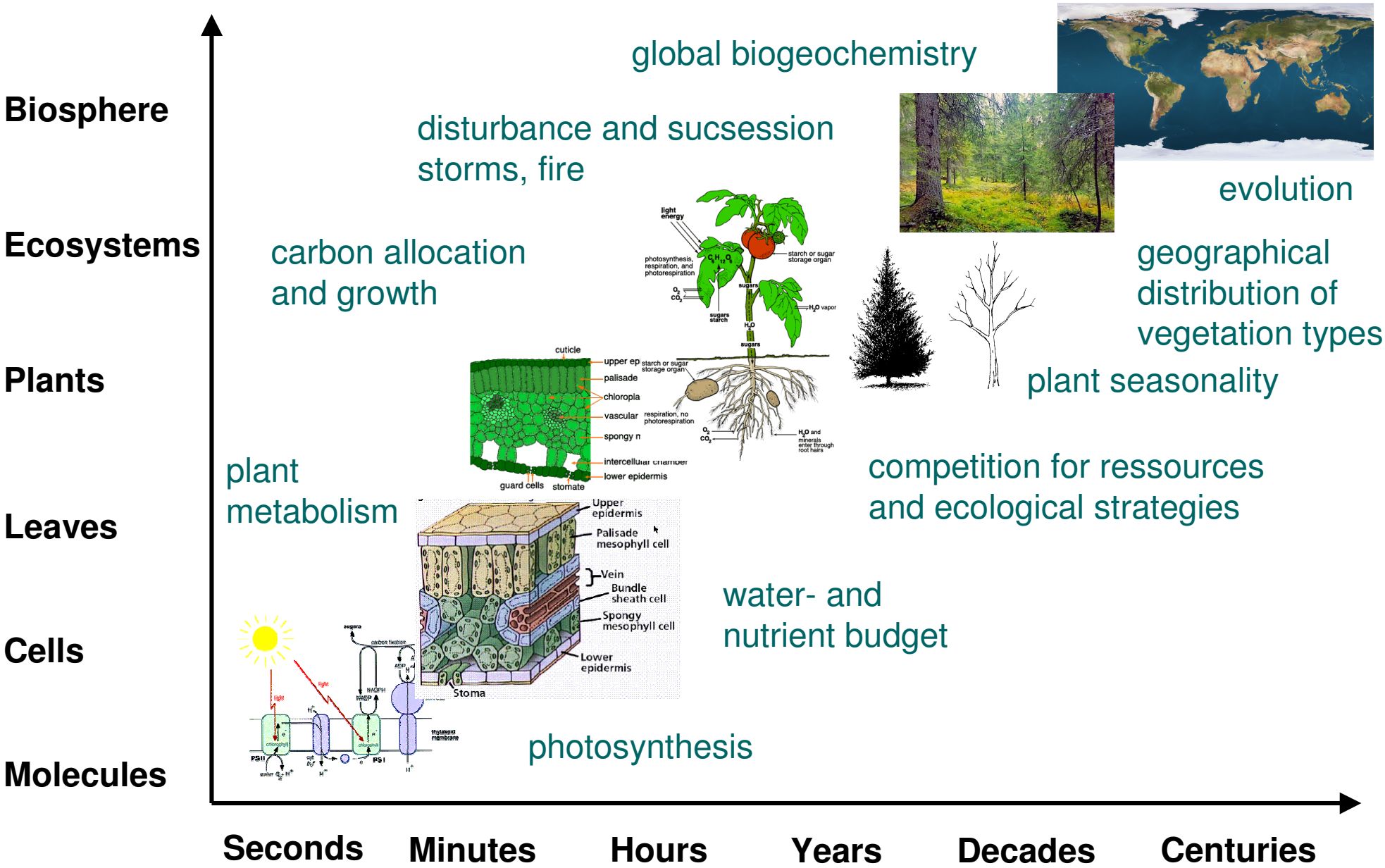
in 20 Years

in 90 Years



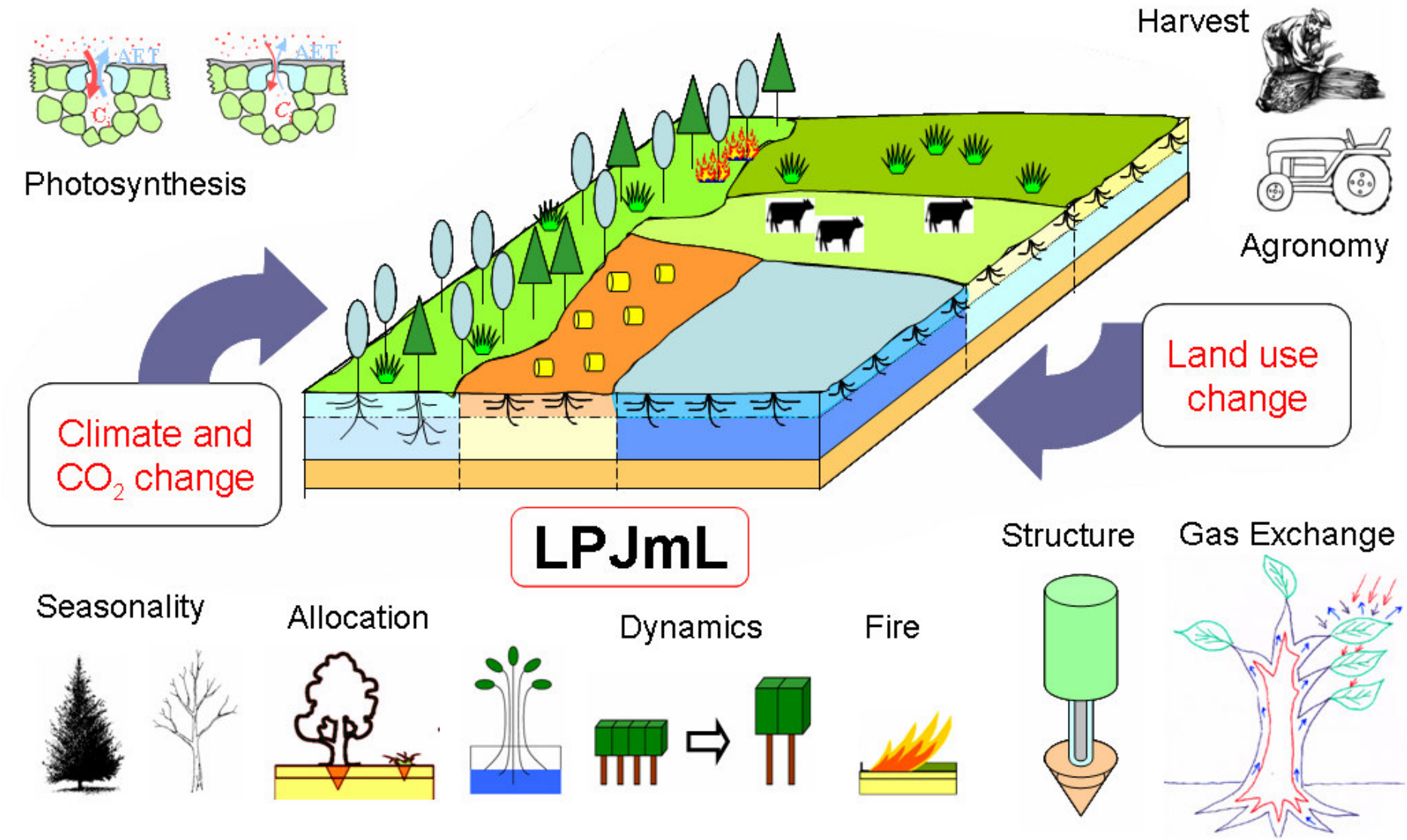
IPCC AR4 WG1 SPM

Scale Challenges in Global Vegetation Modelling

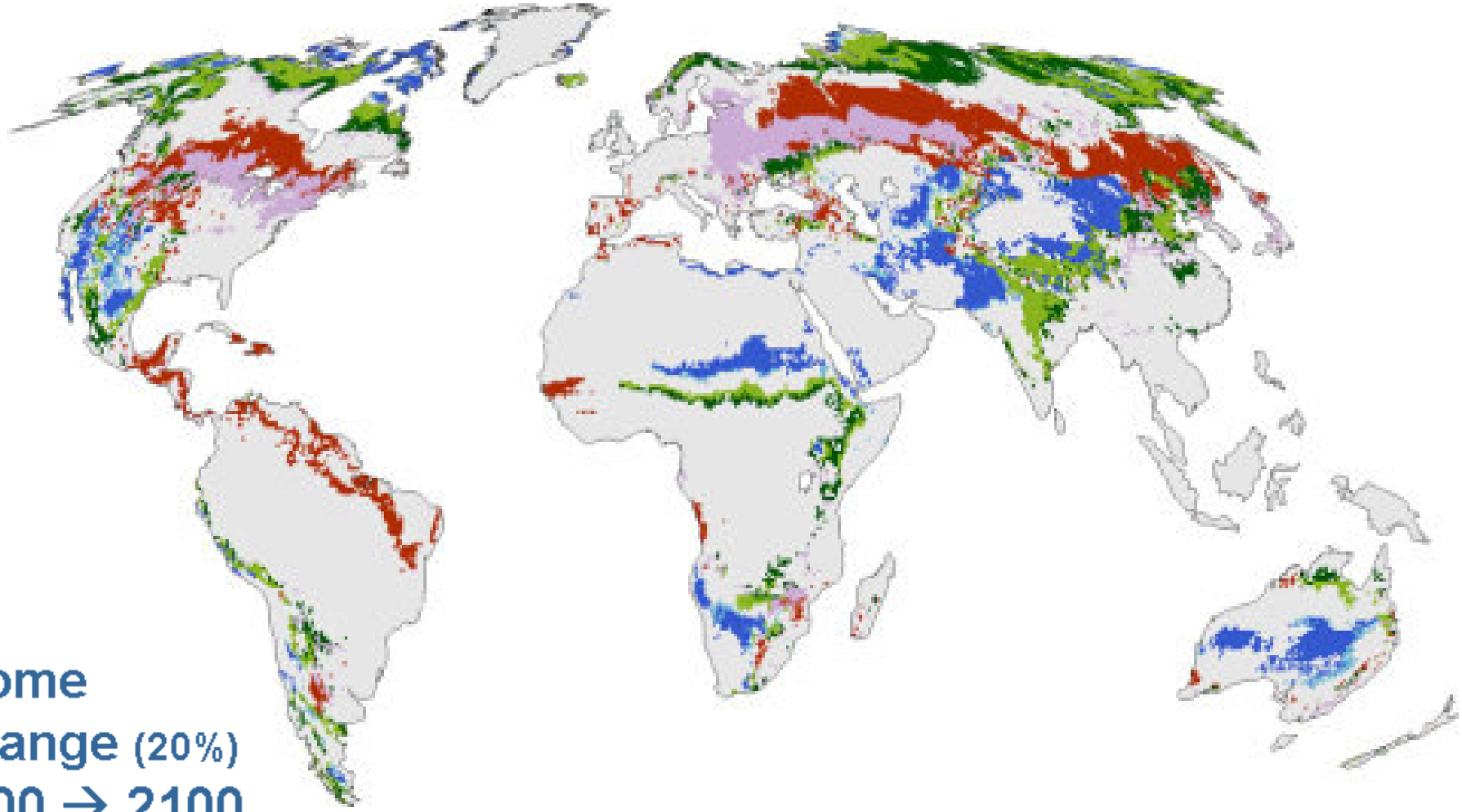


Source: W. Lucht, PIK

LPJmL Global Model of Natural Vegetation & Agriculture



Sitch et al., GCB, 2003; Gerten et al., J. Hydrol., 2004; Bondeau et al., GCB, 2007



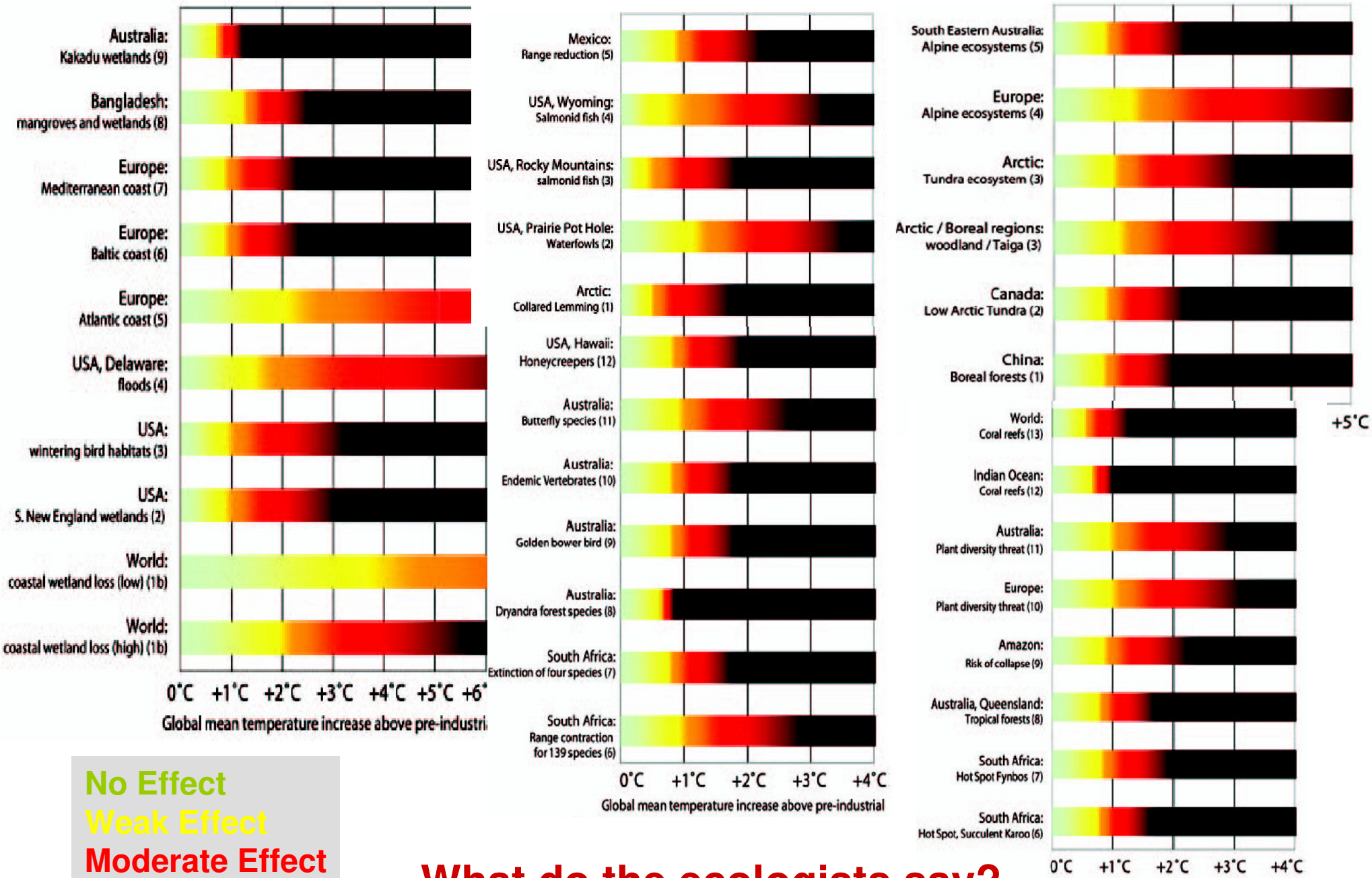
Lucht et al. 2007; IPCC 2007

Biome Change (20%) 2000 → 2100

- Forest cover gain
- Shrub/woodland cover gain
- Herbaceous cover gain
- Desert amelioration
- Forest type change
- Forest/woodland decline
- Grass/tree cover loss

$\Delta T_{Globe} = +3.6$ K, $\Delta T_{Land} = +5.3$ K

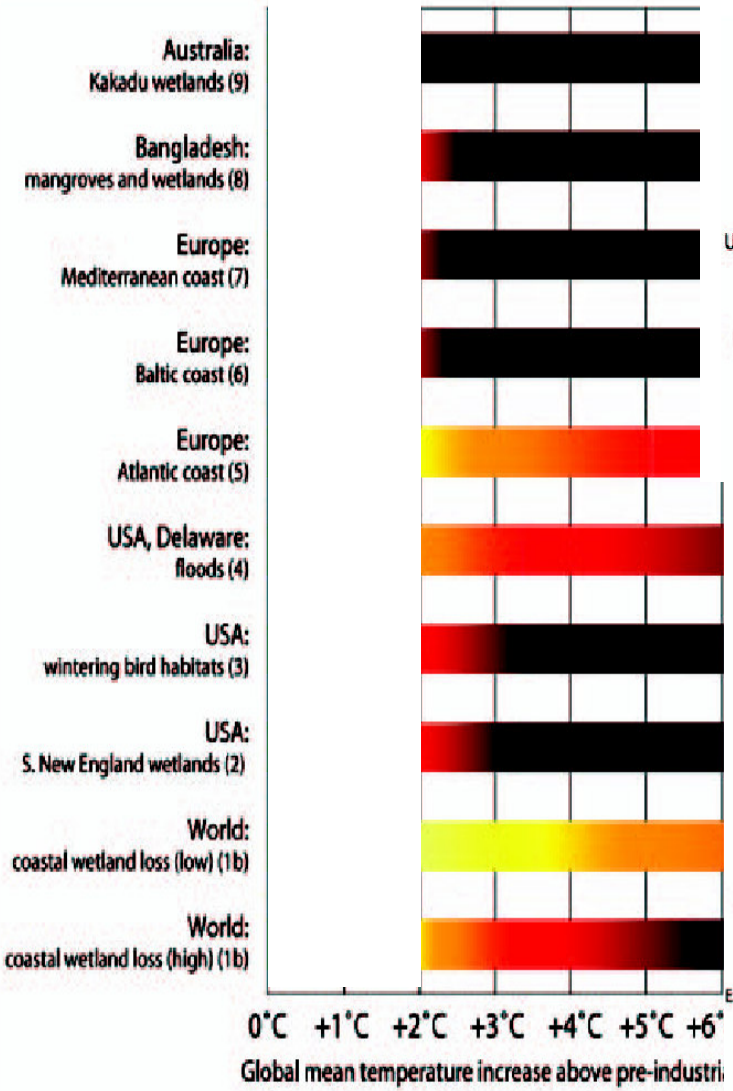
Emissions: SRES-A2
Climate: HadCM3/CRU
Biosphere: LPJv3-DGVM

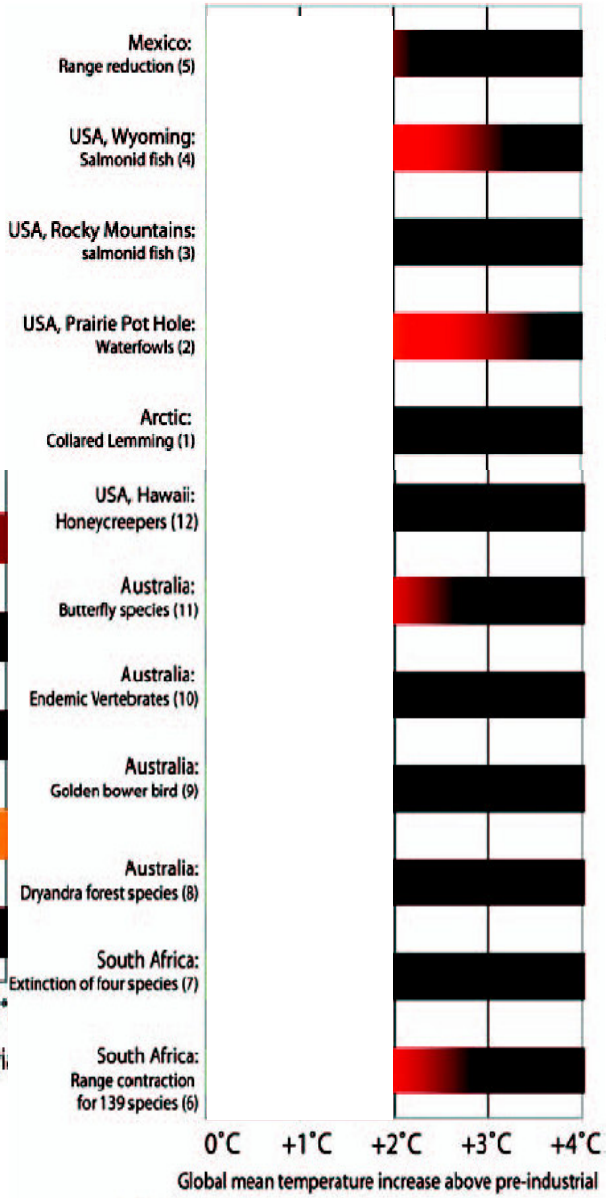


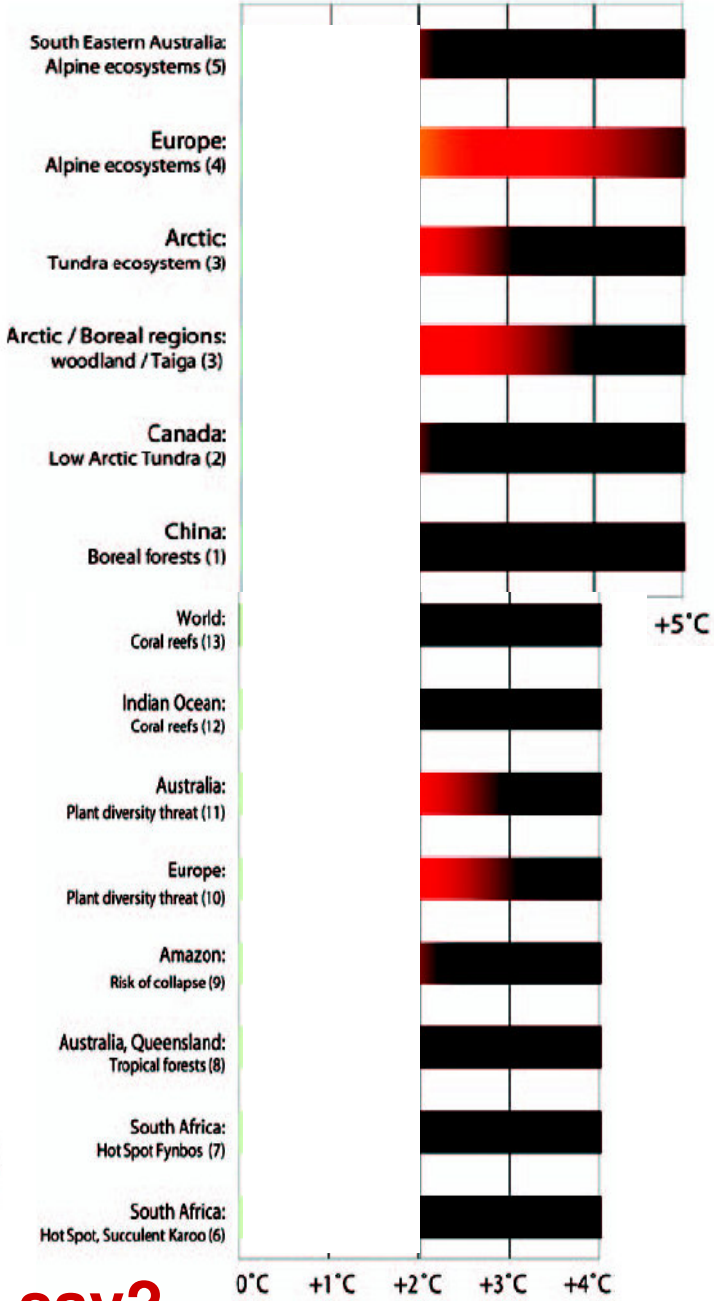
No Effect
Weak Effect
Moderate Effect
Strong Effect

What do the ecologists say?

Hare, Avoiding Dangerous Climate Change, 2006







No Effect
Weak Effect
Moderate Effect
Strong Effect

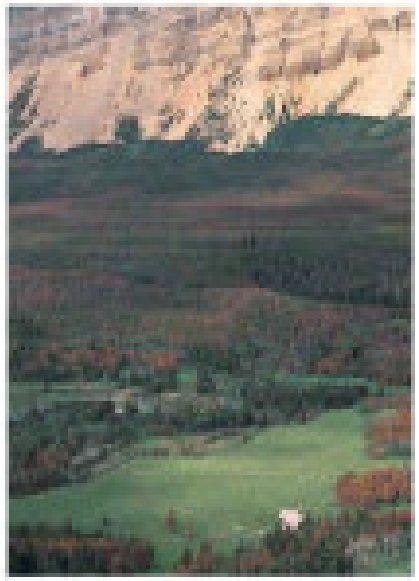
What do the ecologists say?

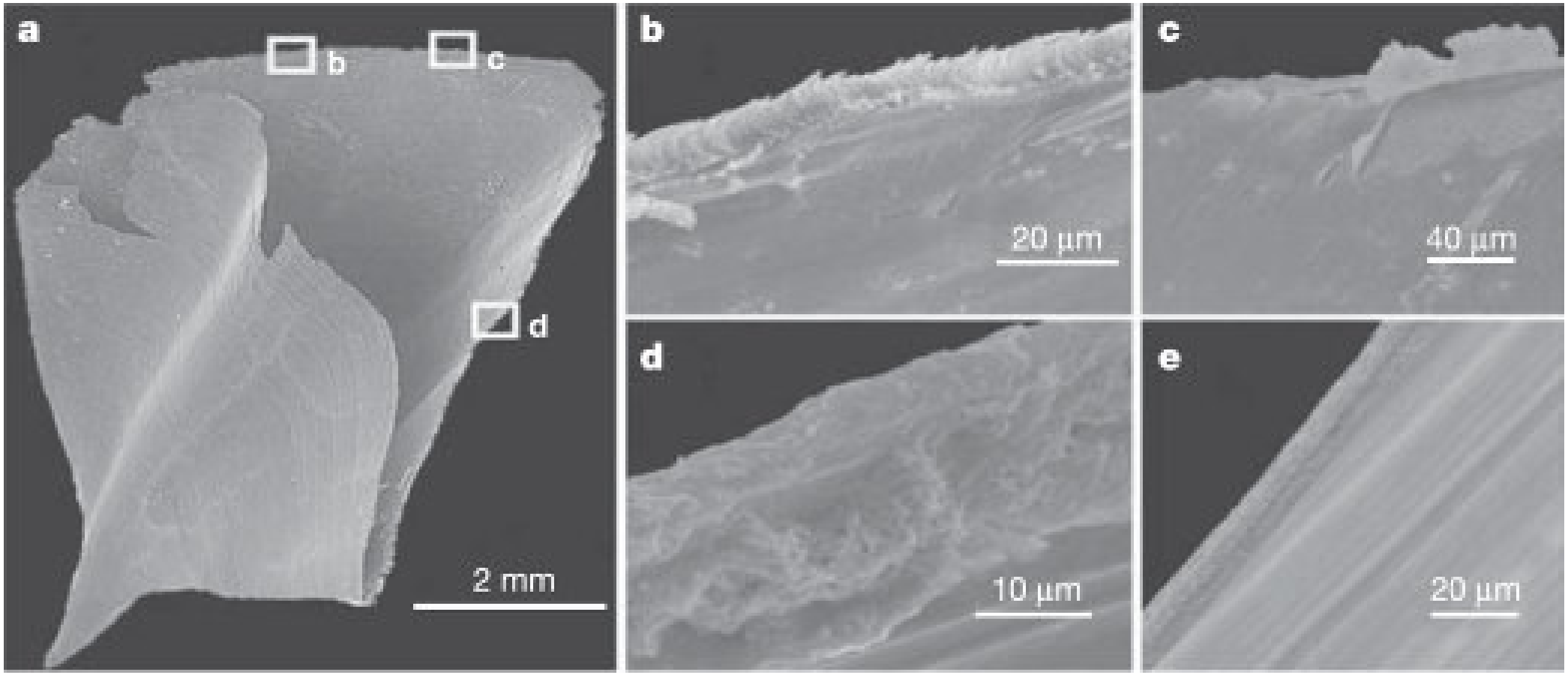
Hare, Avoiding Dangerous Climate Change, 2006

June 2002
and
4 months later

Jemenez Mountains

New Mexico





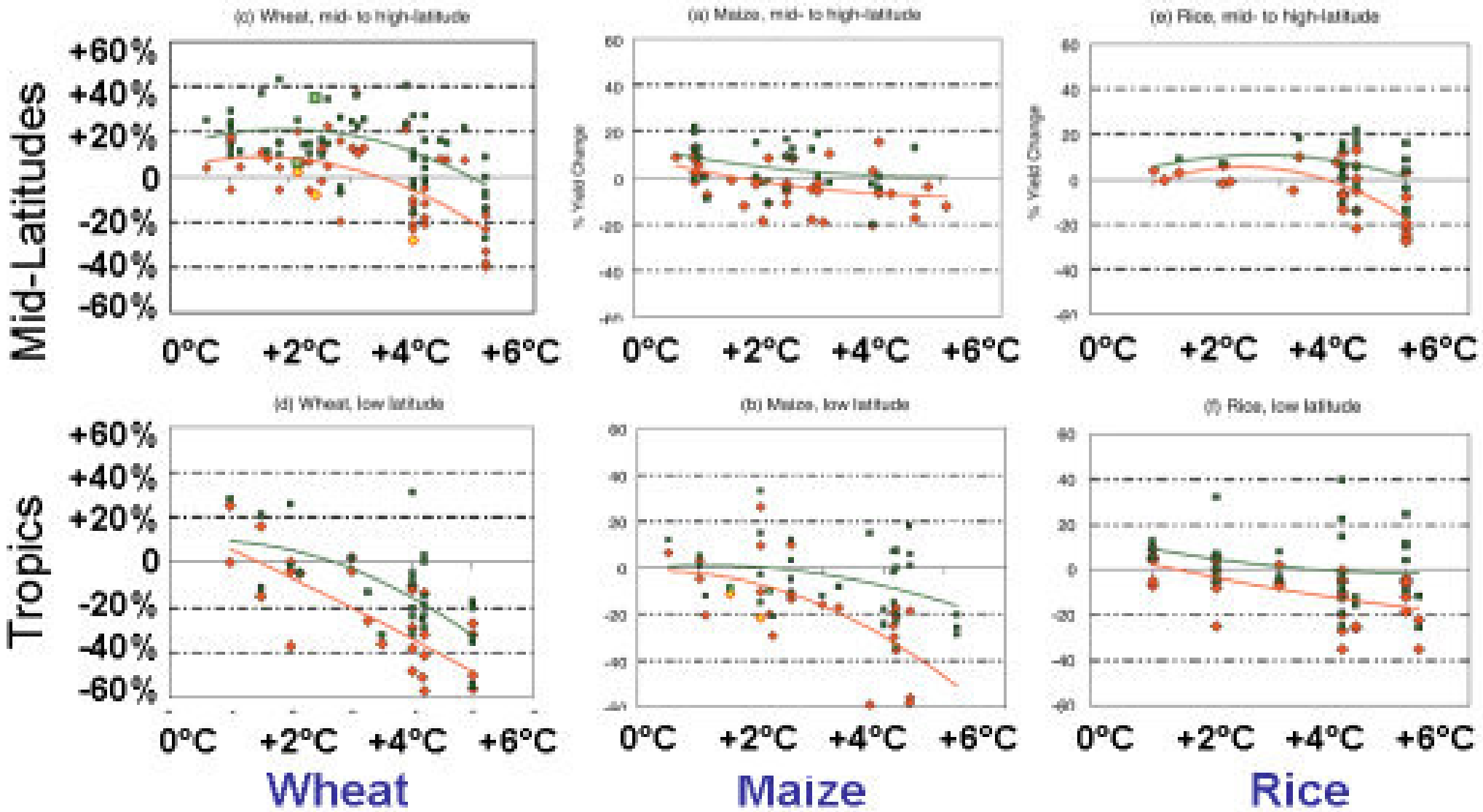
Shell of a South Pacific Pteropod under aragononite shortage.

Ocean acidification attacks the shells of organisms in the oceans.

Orr et al., Nature, 2005

Crop Yields under Climate Warming (69 Studies)

with Adaptation / without Adaptation



Source: IPCC WG2, 2007

Earth is under (at least) Double Pressure

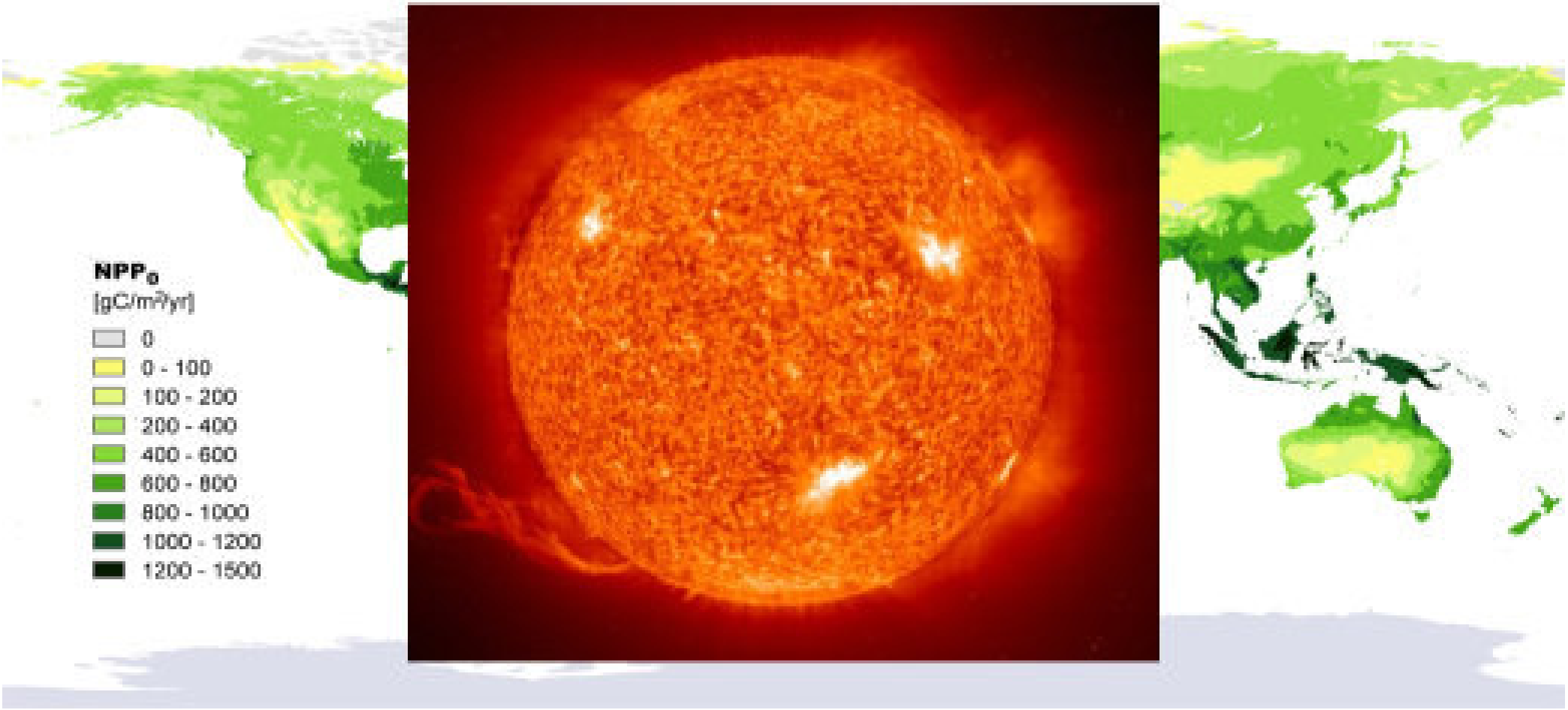
Accelerating Climate Change

Continued Land Use Expansion

Land Use
Land Misuse?

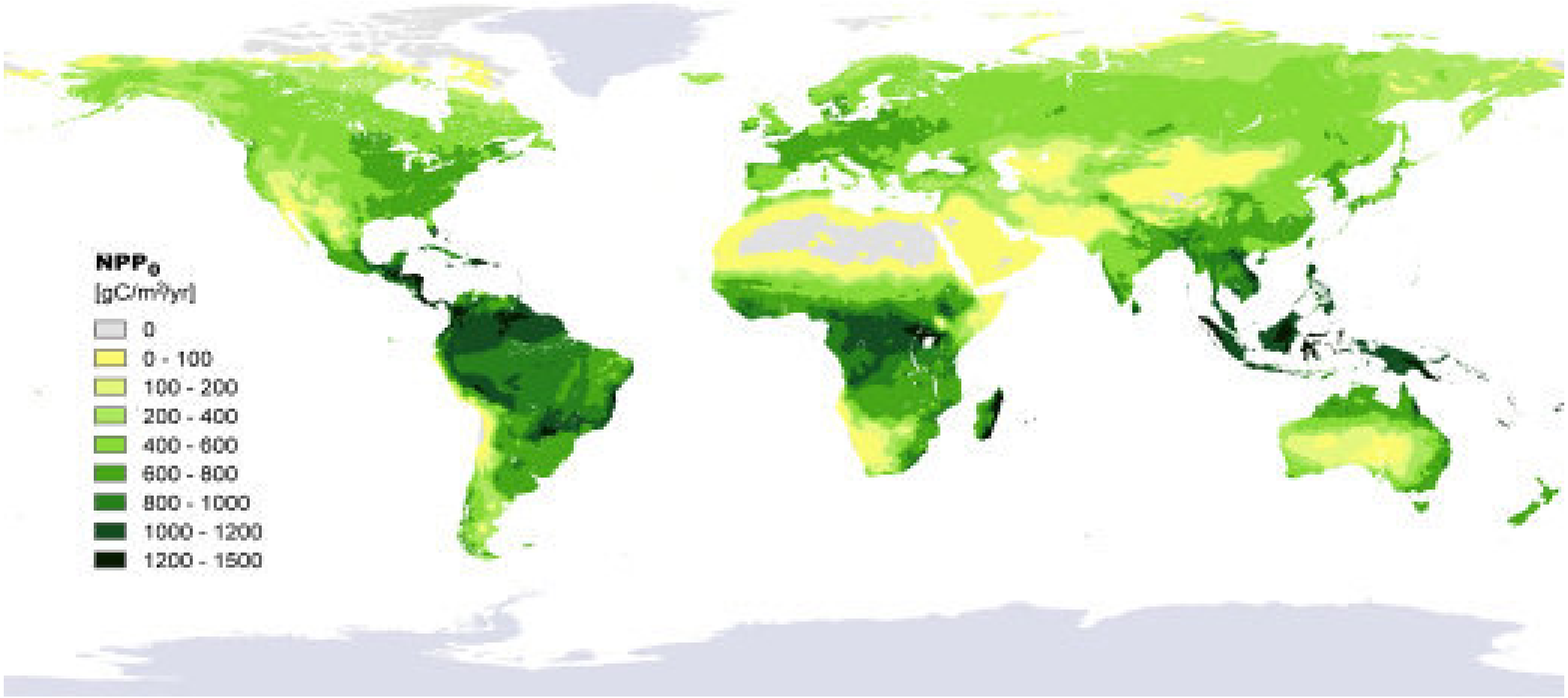
Images © Roman's Travel Website

Natural Productivity of the Land Biosphere



Haberl et al.,
PNAS 104, 2007

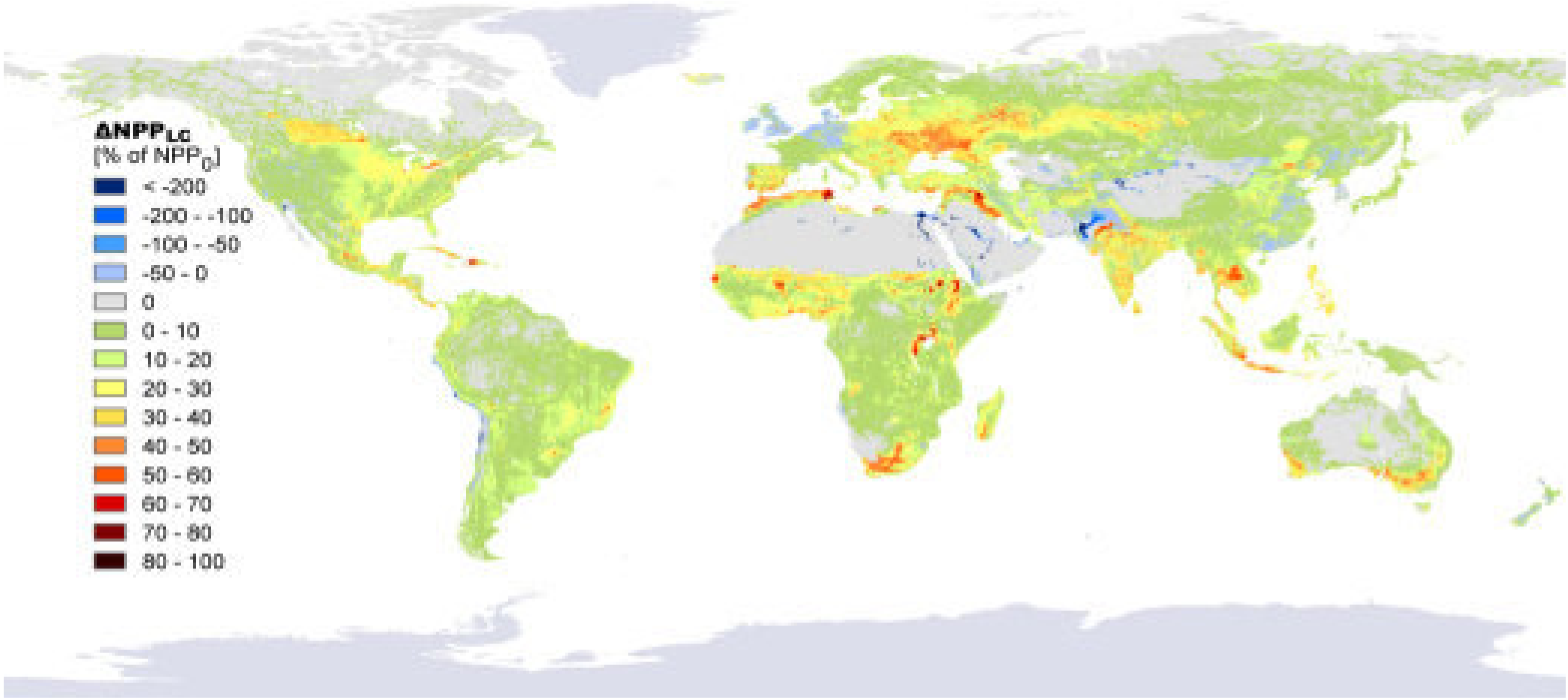
Natural Productivity of the Land Biosphere



Photosynthetic fixation (plant growth):
+ 65.5 billion tons of carbon / year

Haberl et al.,
PNAS 104, 2007

Changes in Land Productivity from Land Surface Alterations



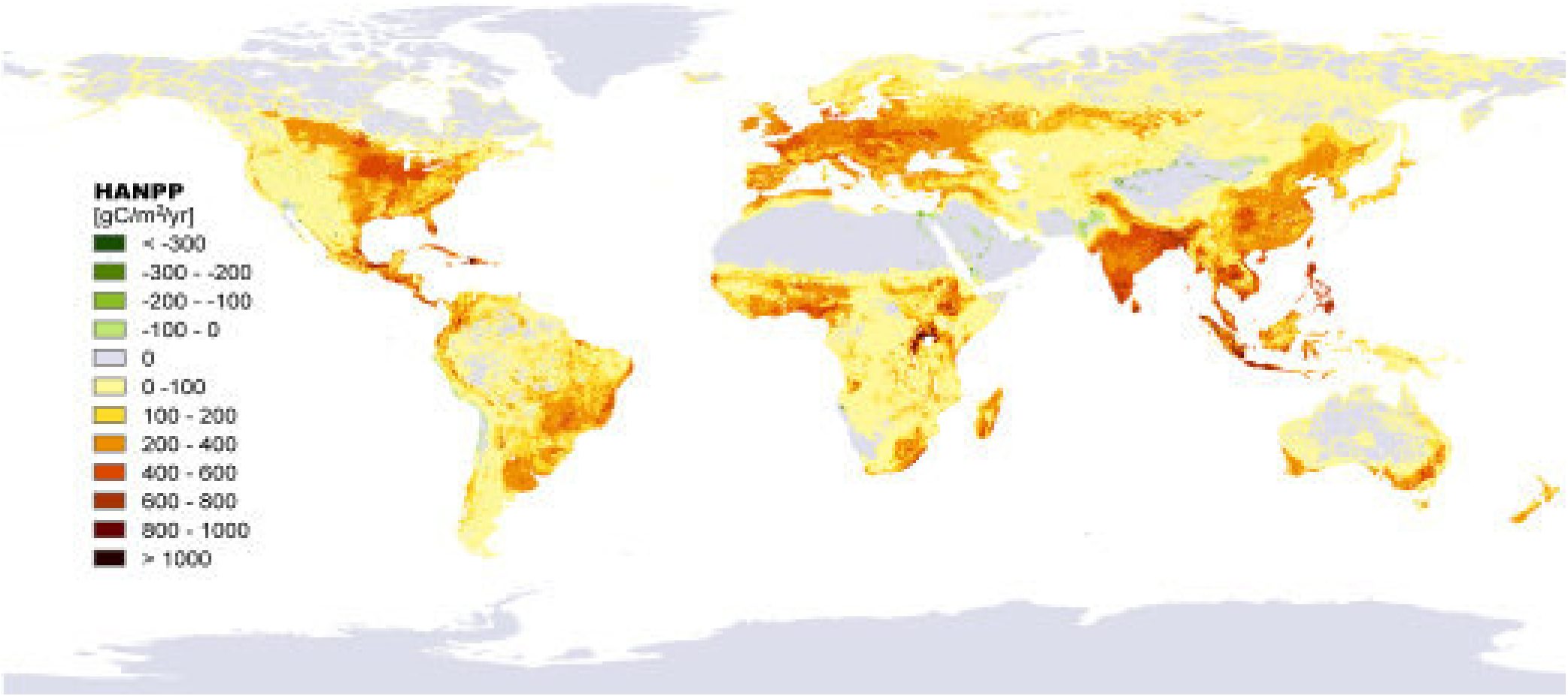
Human interference: altered land surfaces

–6.3 billion tons of carbon / year

Compare: Fossil fuel emissions ~ –7 bn tons C/year

Haberl et al.,
PNAS 104, 2007

Human Appropriation of Photosynthetic Production



Human interference and harvest:

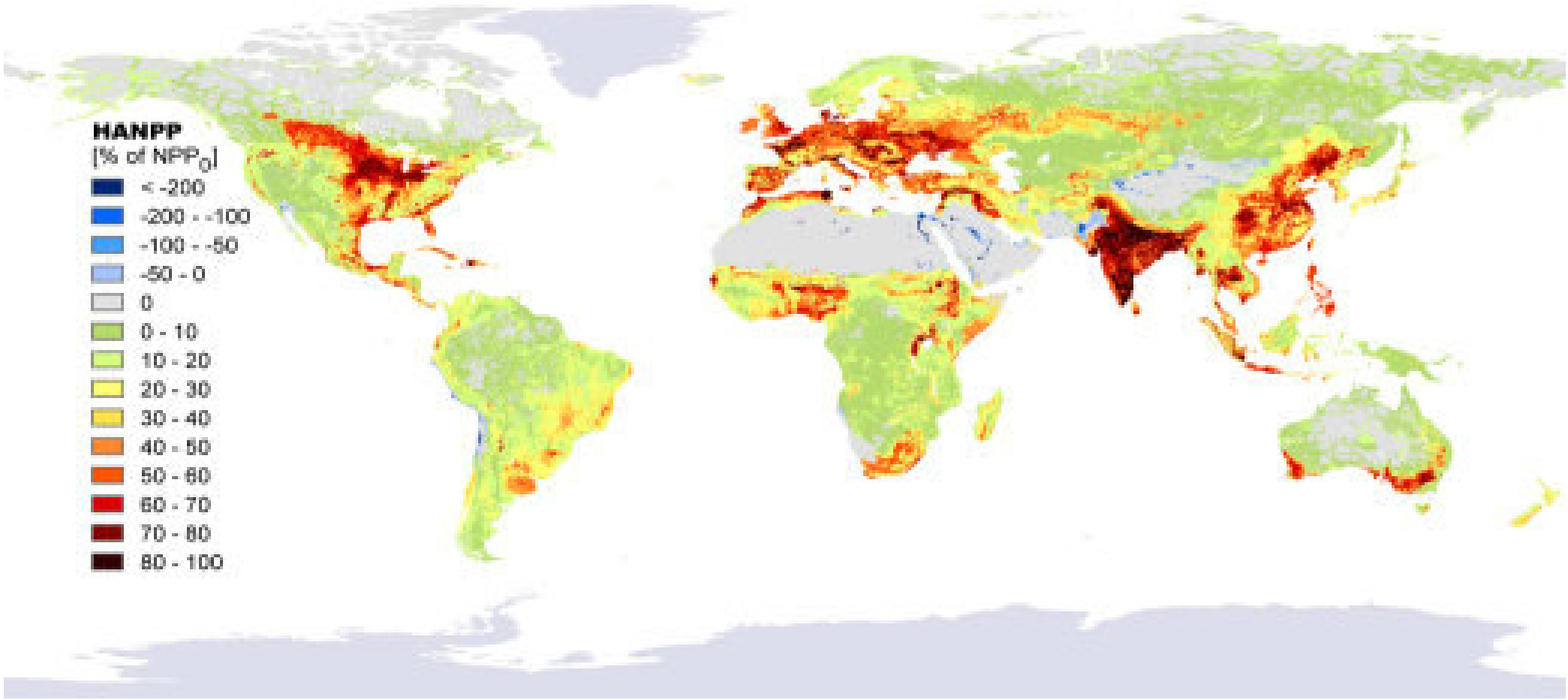
–15.6 billion tons of carbon / year

Compare: Fossil fuel emissions ~ –7 bn tons C/year

Haberl et al.,
PNAS 104, 2007

altered land surfaces – 6.3 GtC/yr
harvest – 8.2 GtC/yr
fires – 1.1 GtC/yr
backflows + 2.2 GtC/yr

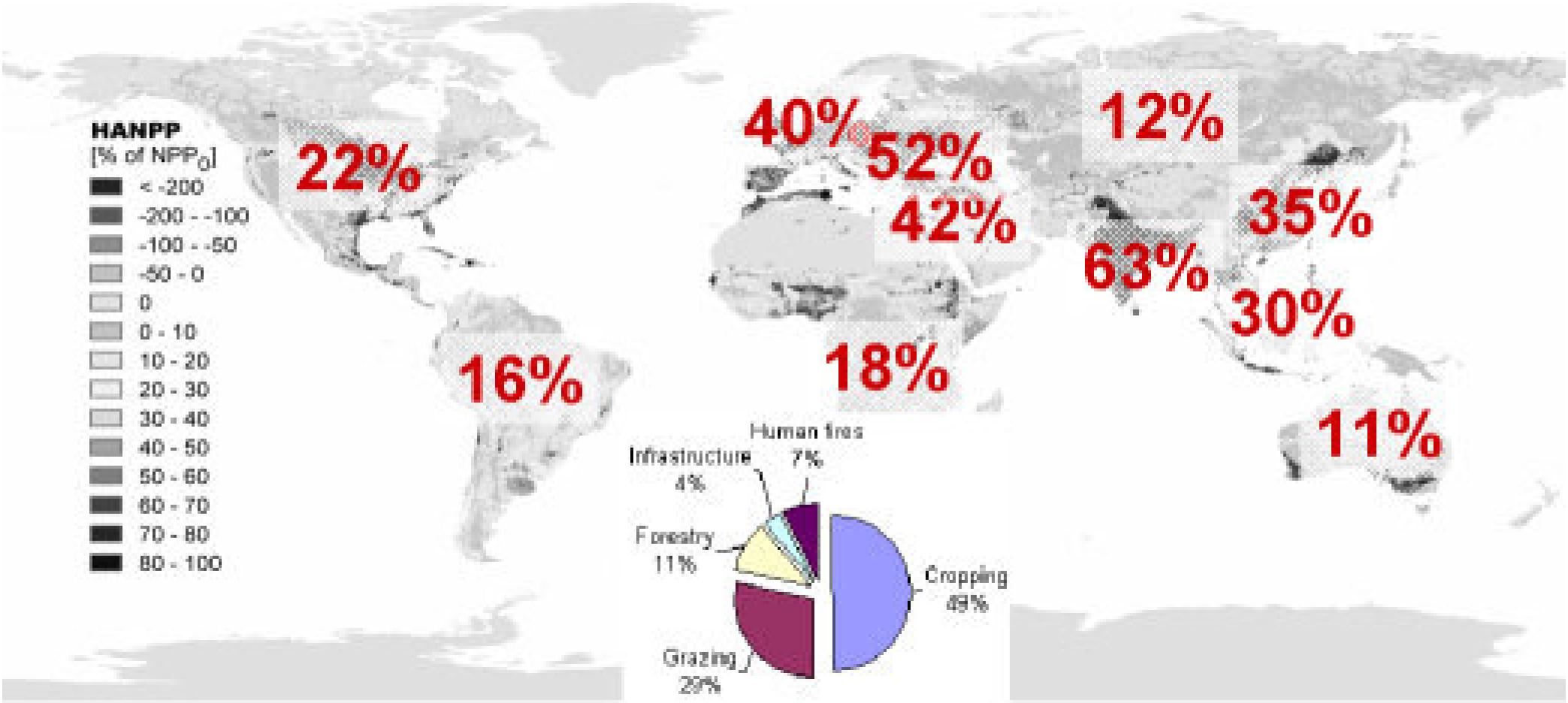
Human Appropriation of Photosynthetic Production



Human interference and harvest:
= 22% of Natural Net Primary Production

Haberl et al.,
PNAS 104, 2007

Human Appropriation of Photosynthetic Production



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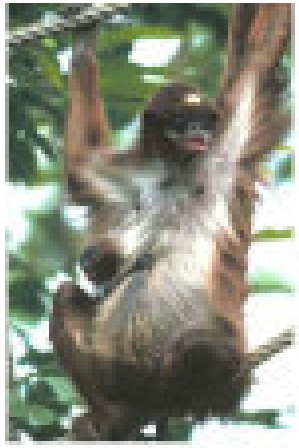
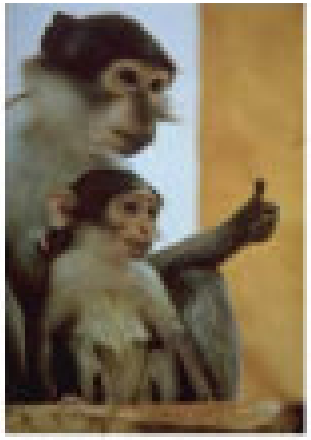
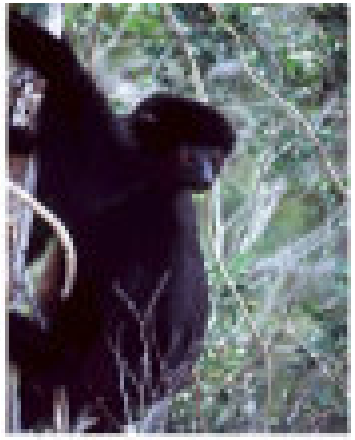
Haberl et al., PNAS 104, 2007

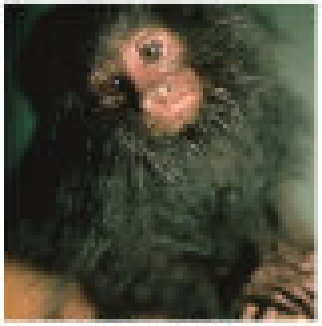


Critically Endangered or Endangered Primates:

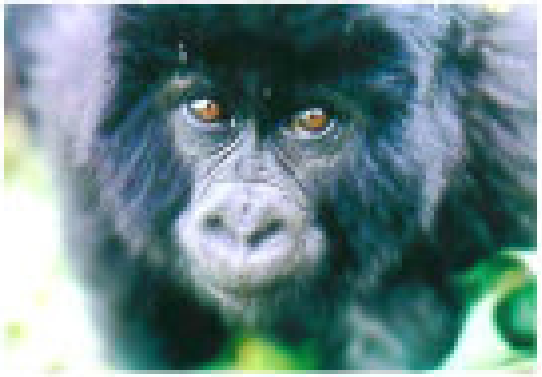
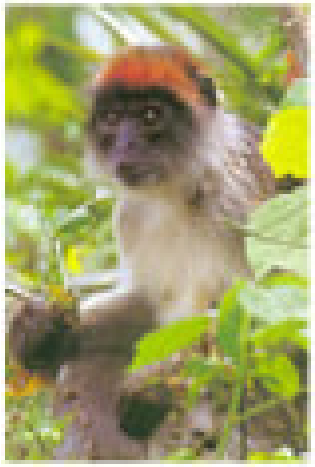
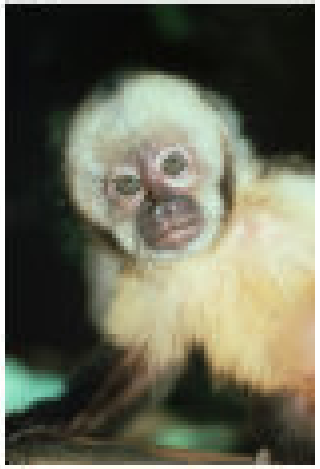
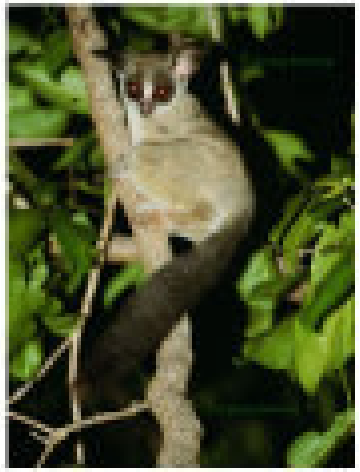
1996 15%
2000 20%
2005 26% (160 of 625)

Cause: Habitat Destruction and Fragmentation

Threated: New World 30%, Africa 30%, Madagascar 58%, Asia 42%



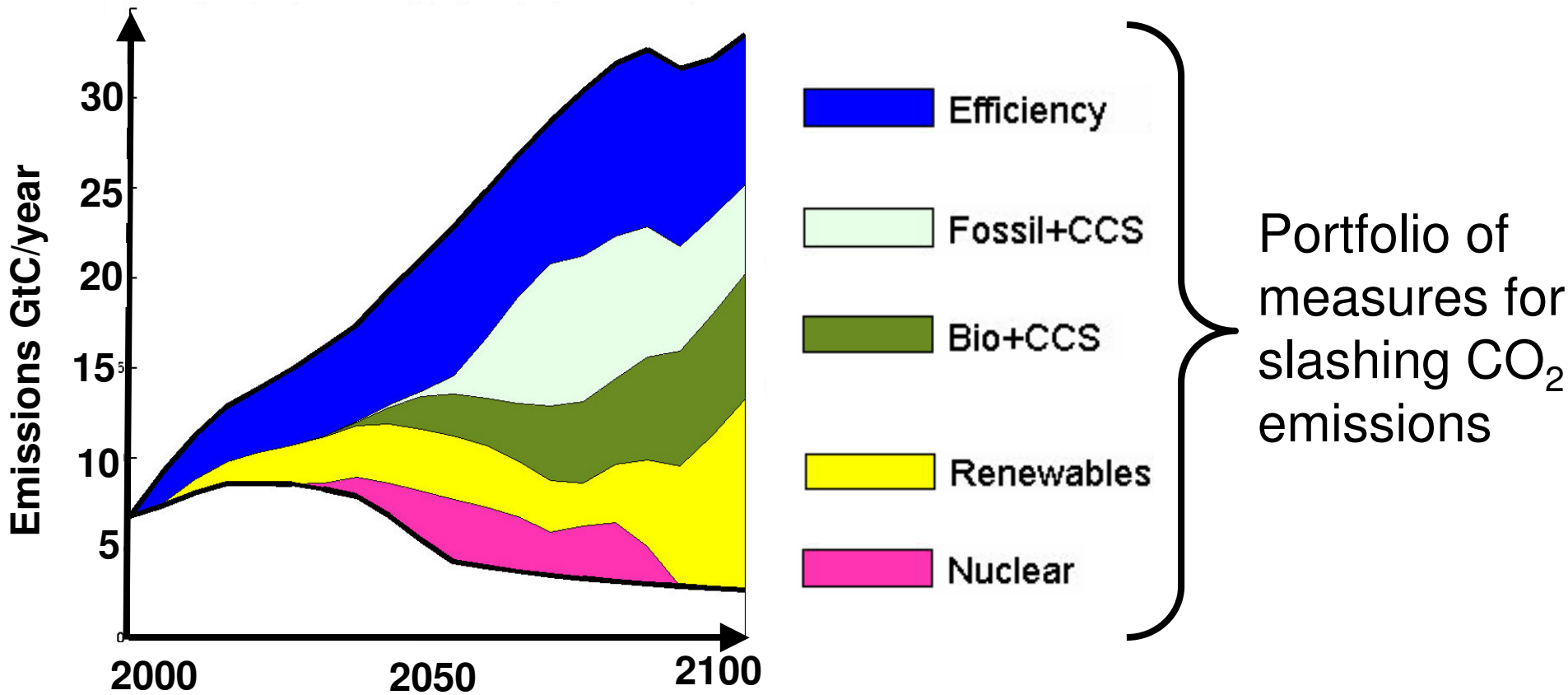
Mittermaier et al., IUCN/SSC, PSG, IPS, CI Report 2005

Landscapes very strongly form our cultures, social structures and identities – if they change, much will change

Images: top right by Morten Maegaard, top left by Amina Tariq, bottom left by Mutanga Mulambwa

Assumption: 200 EJ/Year of Bioenergy available



O. Edenhofer and team, PIK, 2007

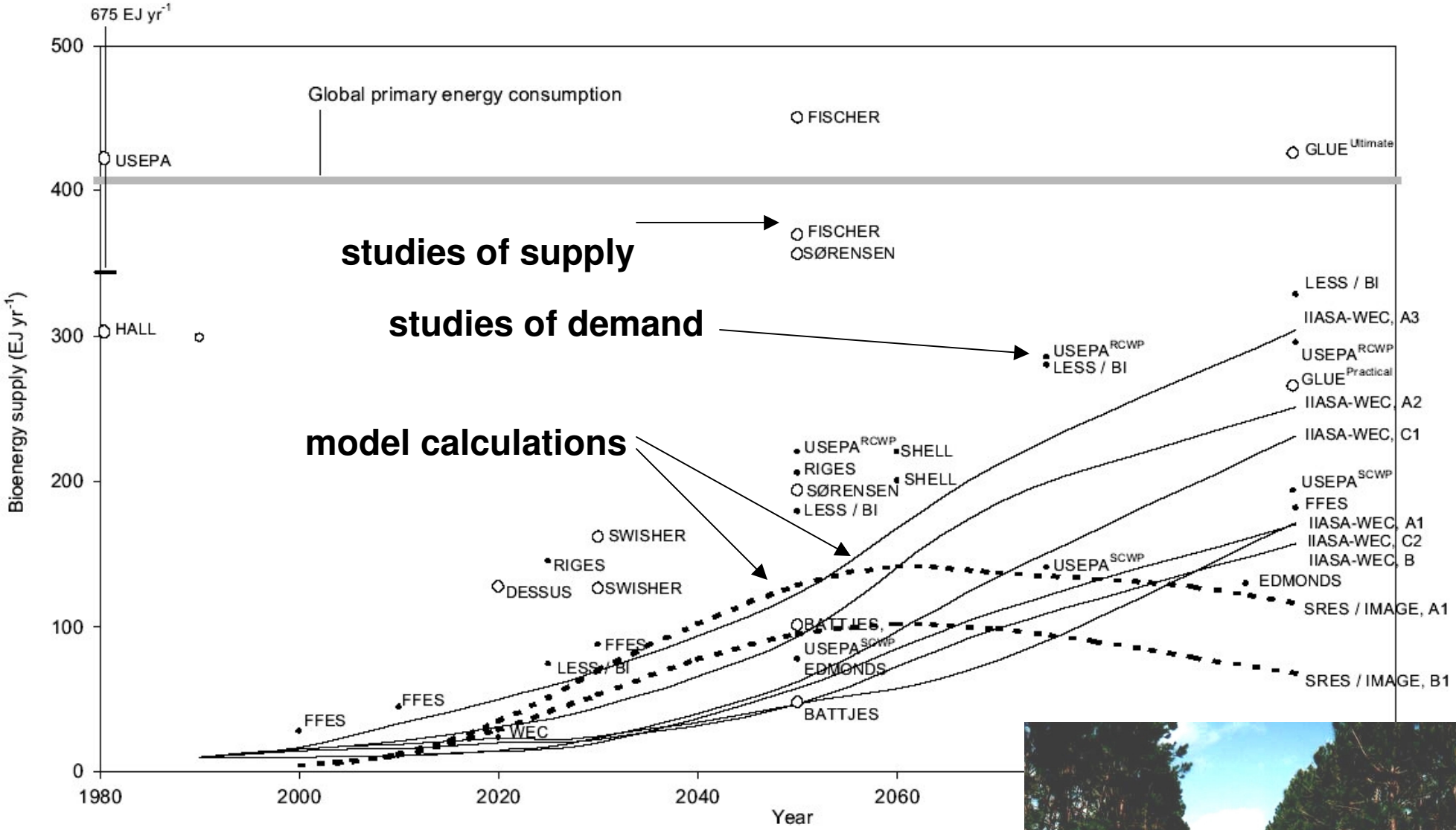


Fig. 2. Potential biomass supply for energy over time. Resource-focused studies are represented by hollow circles and
circles. USEPA and HALL, who do not refer to any specific time, are placed at the left side of the diagram. IIASA-WE
dashed lines respectively, with scenario variant names given without brackets at the right end of each line. The present a
included for comparison. (The global consumption of oil, natural gas, coal, nuclear energy and hydro electricity 1999–2
consumption for energy is estimated at 35–55 EJ yr^{-1} [44–46].)

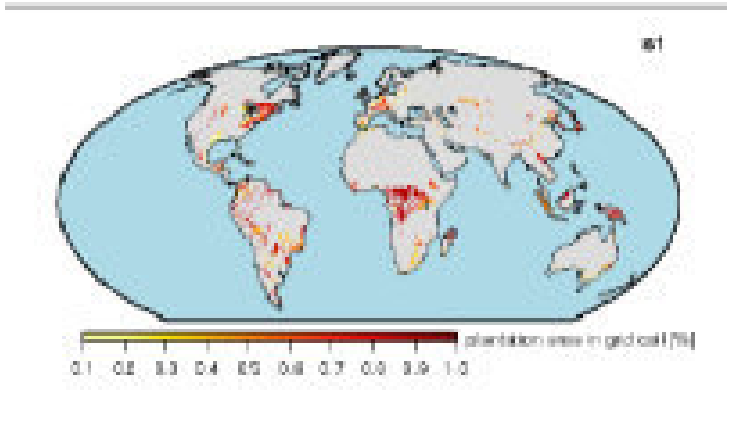
Berndes et al., 2003

LPJmL Pattern of Biomass Production on Deforested Land

IUCN areas and frontier forests protected

100% current cropland set aside

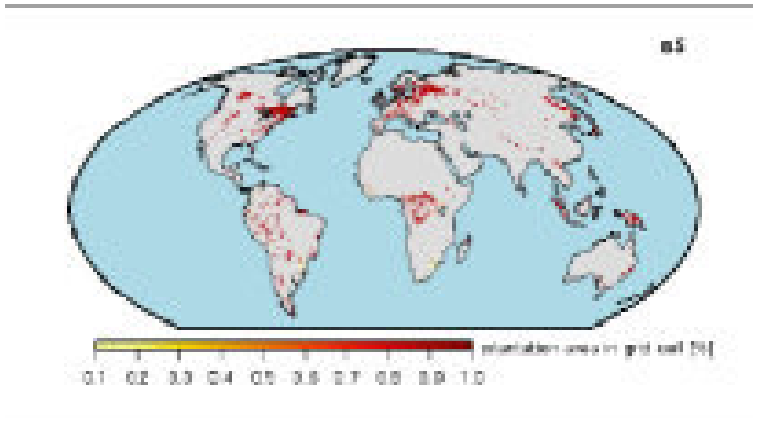
130% current cropland set aside

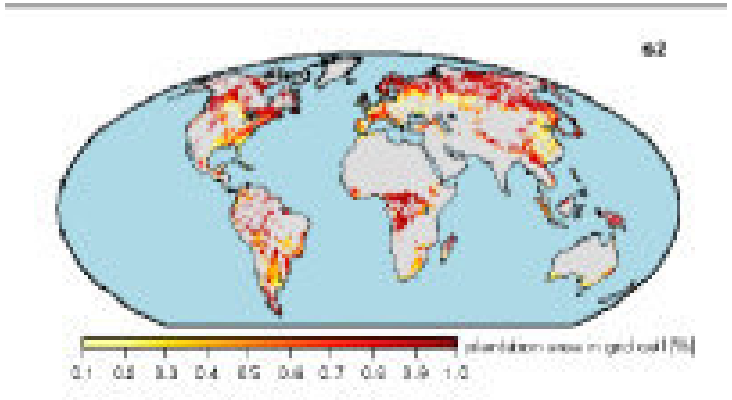


Energy:
150 EJ/yr

8 Mio km²
53 GtC C-loss

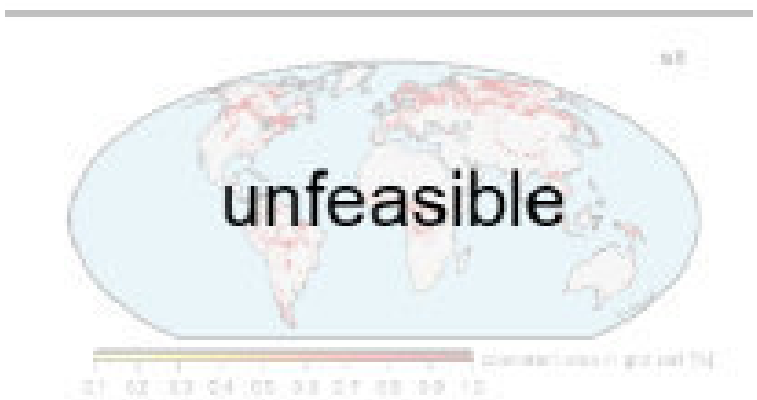
8.4 Mio km²
60 GtC C-loss





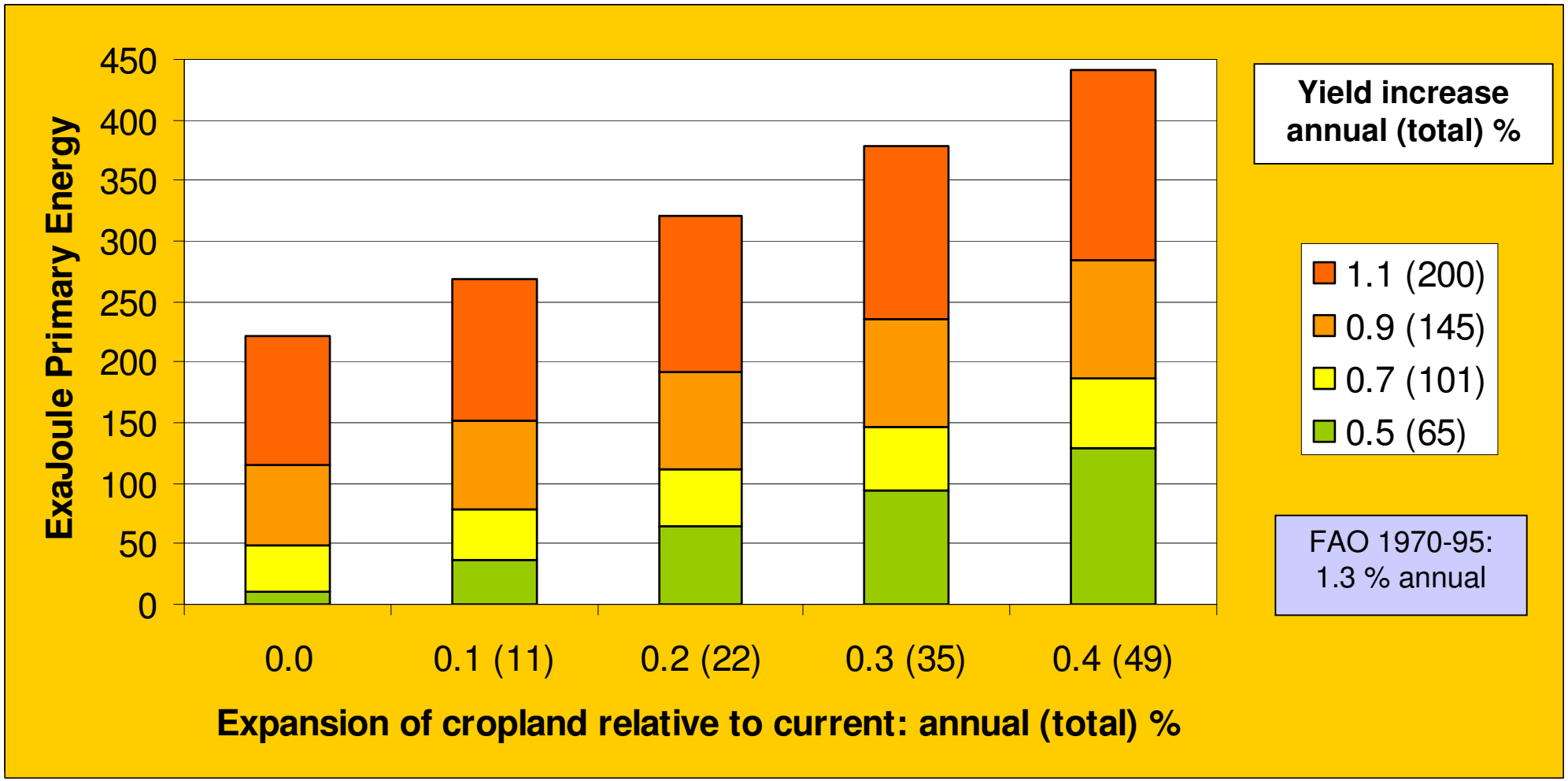
24 Mio km²
140 GtC C-loss

Energy:
400 EJ/yr



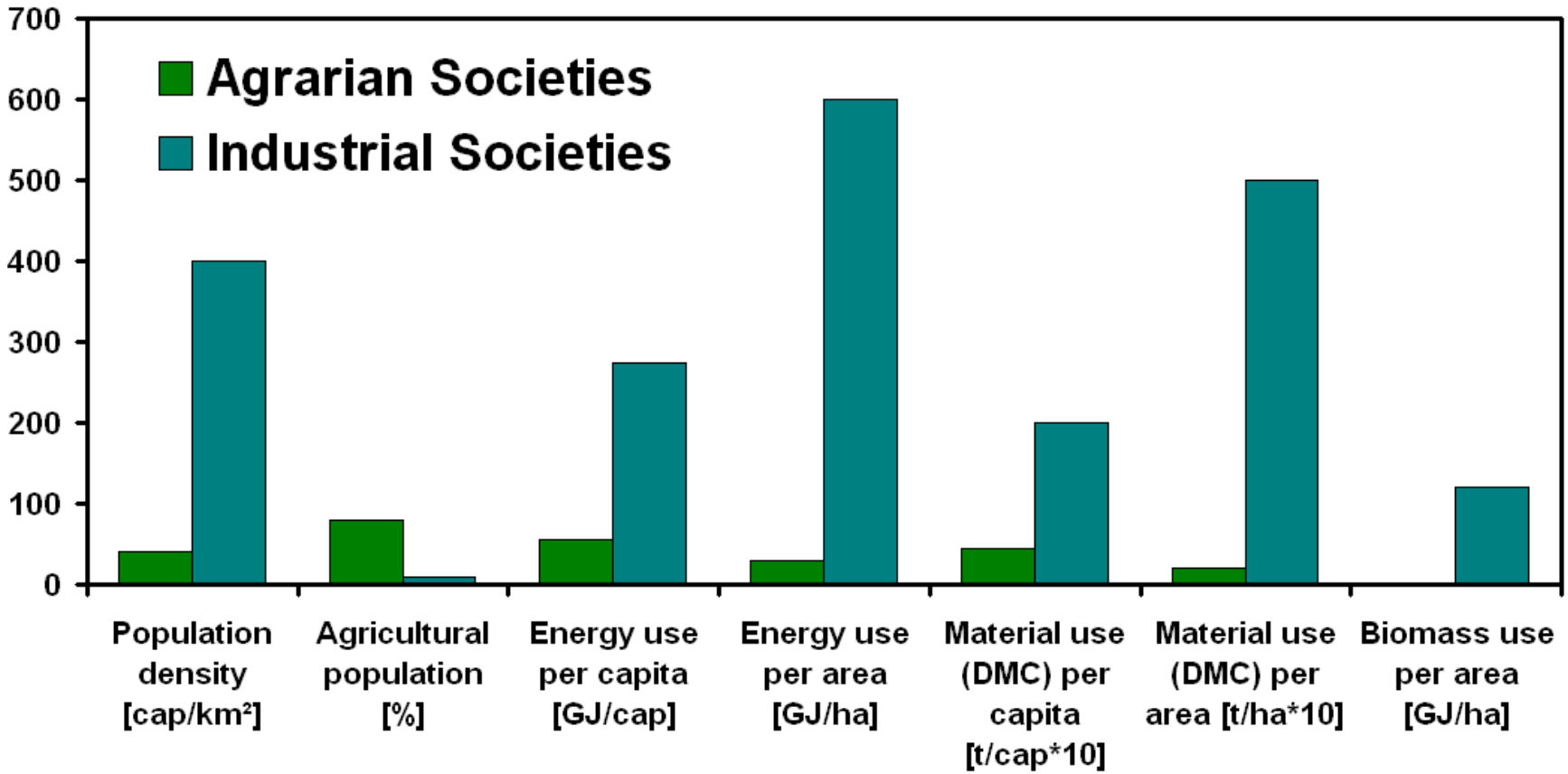
Erbrecht and Lucht, 2008

Global Bioenergy Potential
(2100, 9 bn people, increased cal/cap)



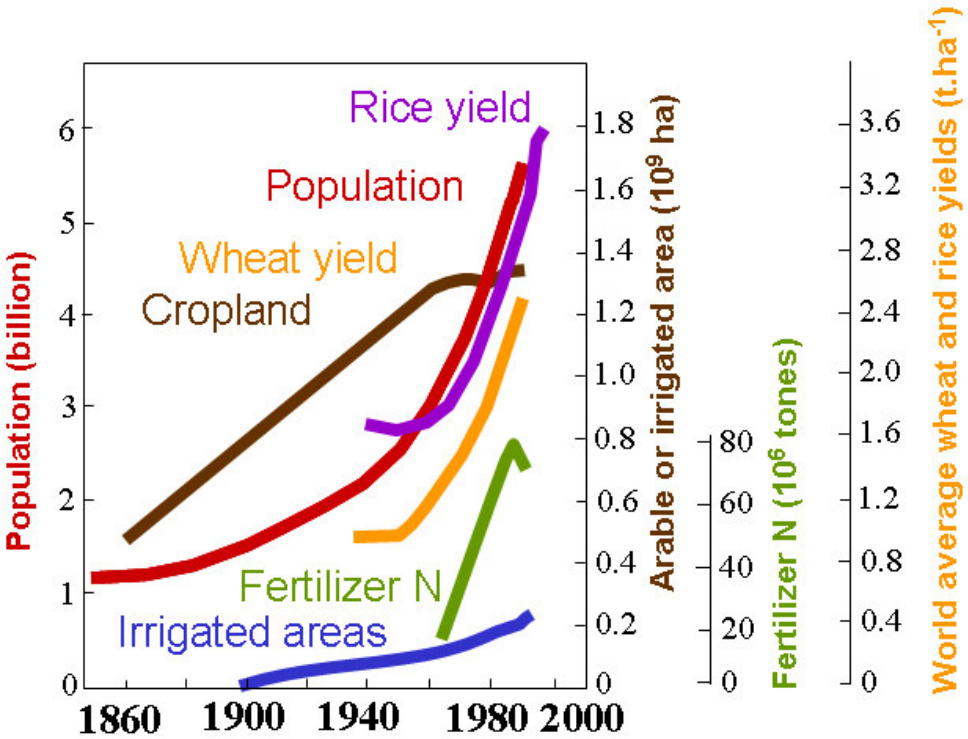
H. Lotze-Campen, PIK, 2008

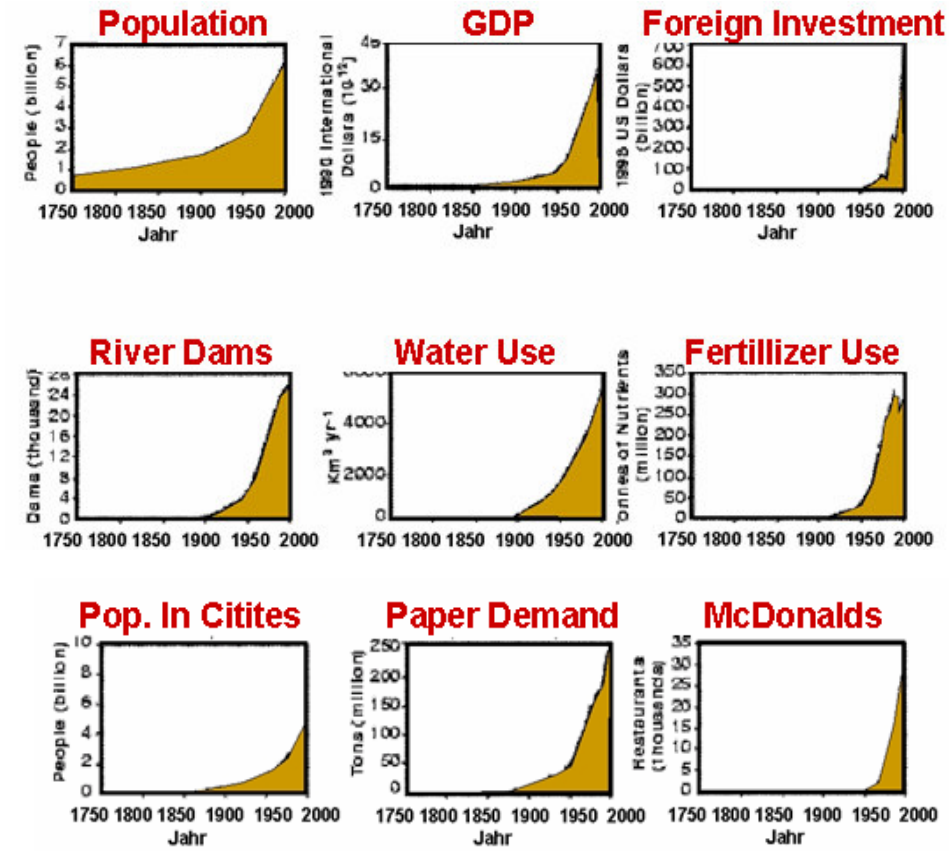
Metabolic Effects of Industrialisation



Industrialisation is a revolution in the socioeconomic metabolism and the structure of society.

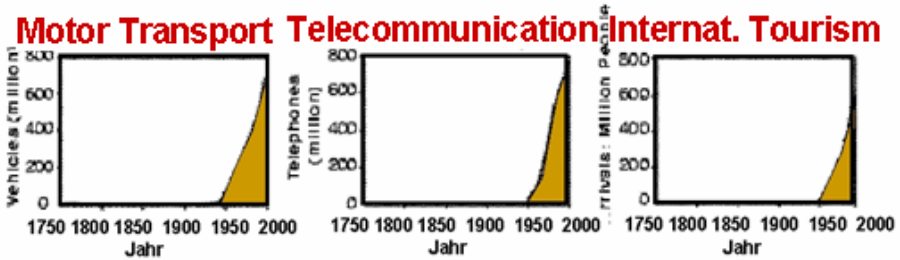
Source: M. Fischer-Kowalski, iff Vienna





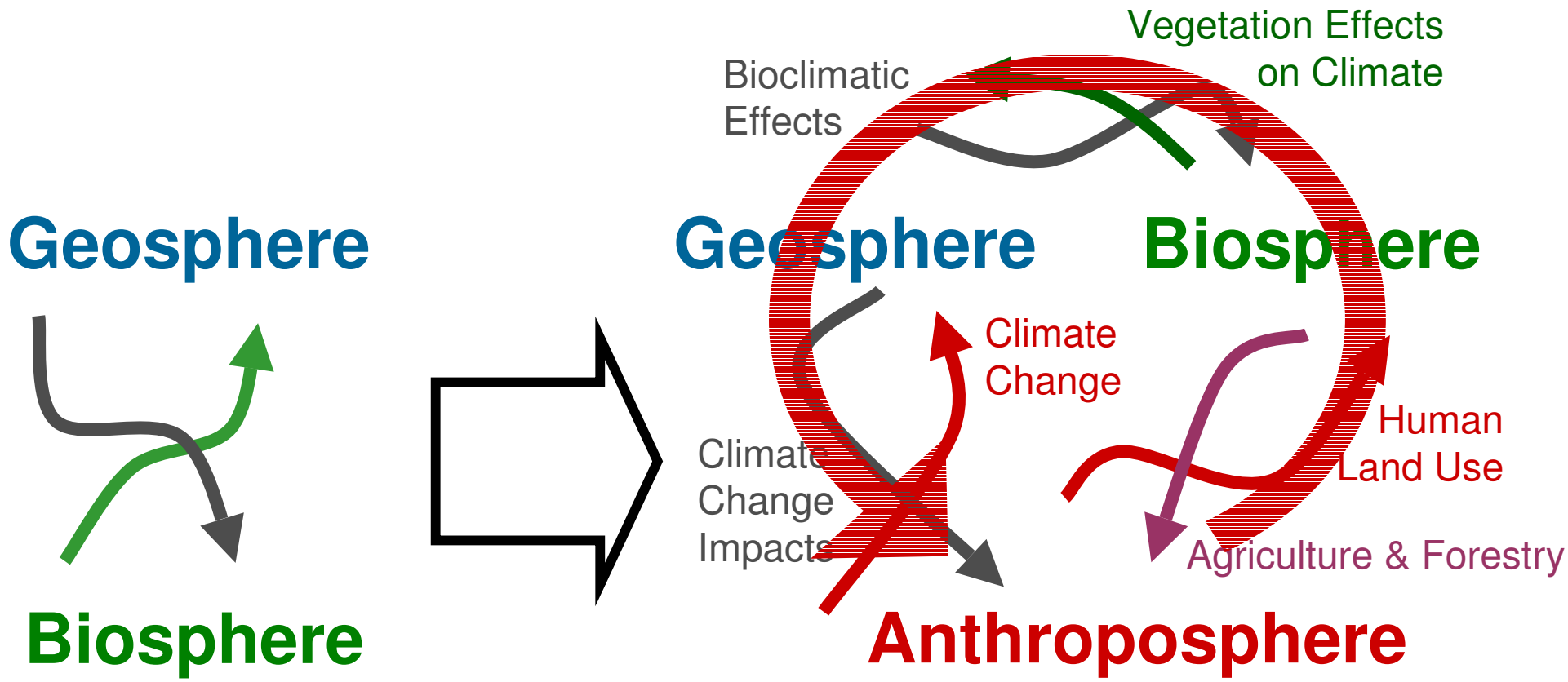
Currently ongoing:

Continued Industrialisation of Land Use



Crutzen and Steffen, 2004

From Co-Evolution … into the Anthropocene



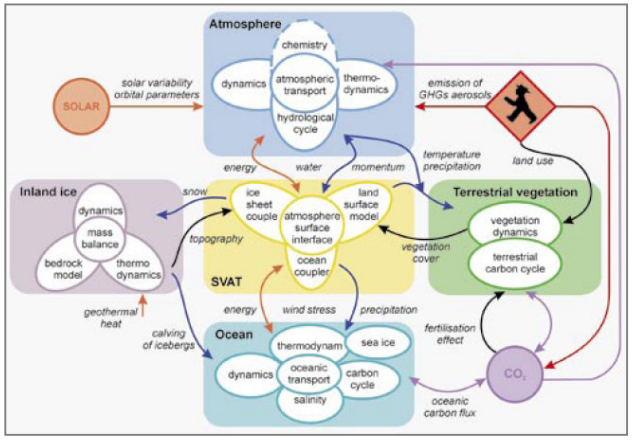
The Challenge:
Emergence of Conscious Global Action

W. Lucht, PIK

How can Earth be understood as a system?

1. Digital Mimicry Principle

Earth System Modelling of Intermediate Complexity



2. Bird‘s Eye Principle

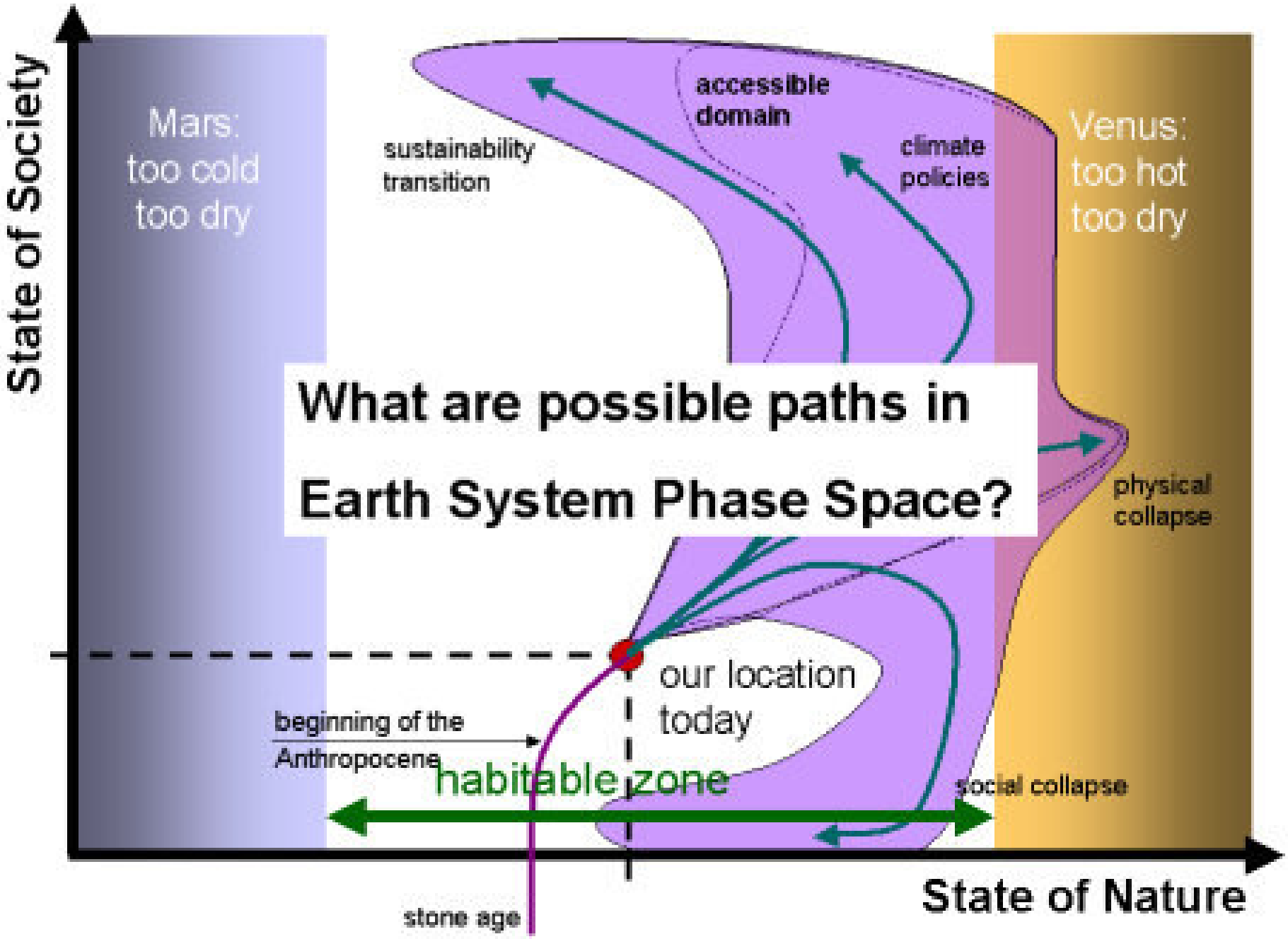
Earth Observation, Macroscopes

3. Lilliput Principle

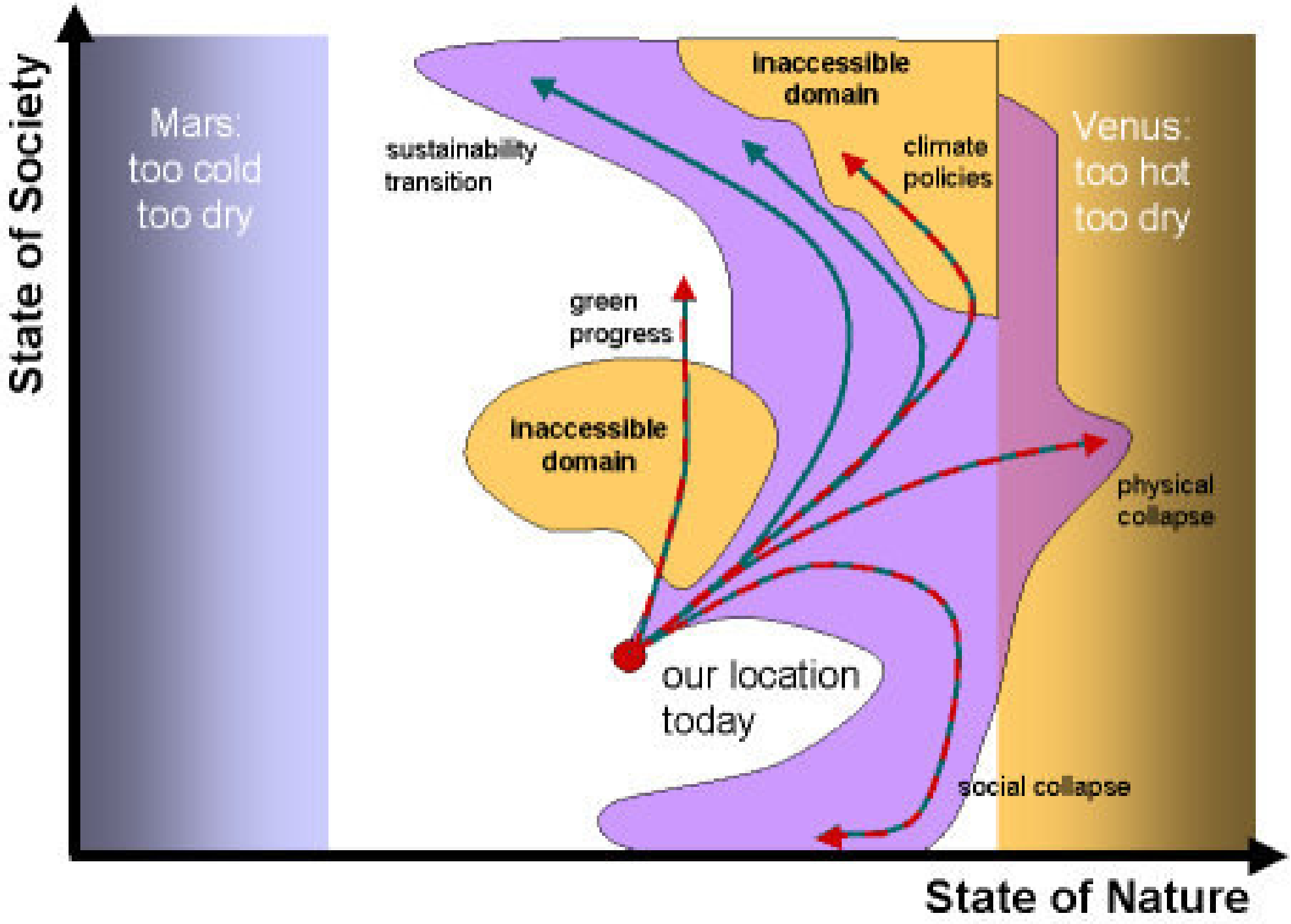
Environmental Experiments

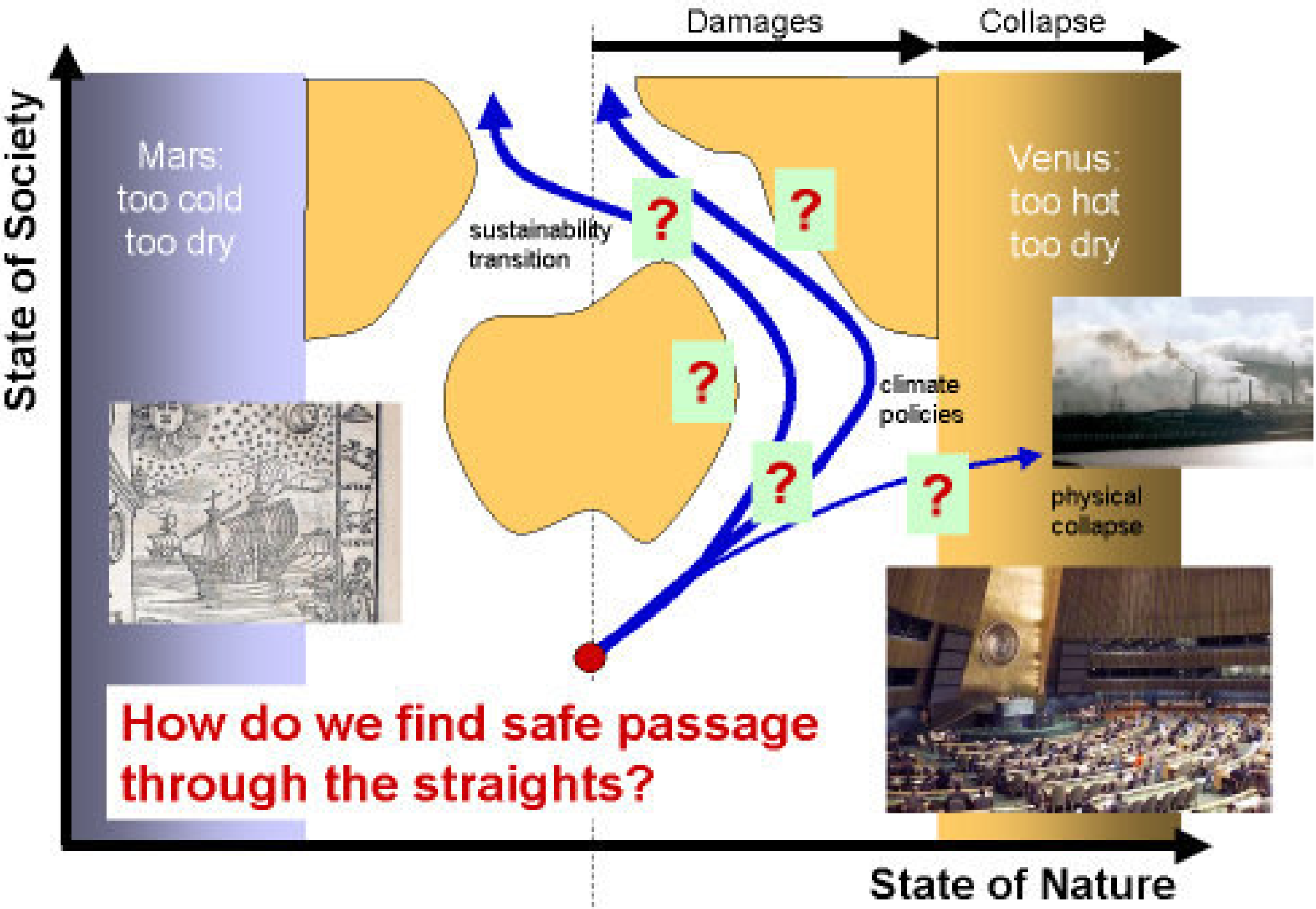
Schellnhuber, Nature, 1999

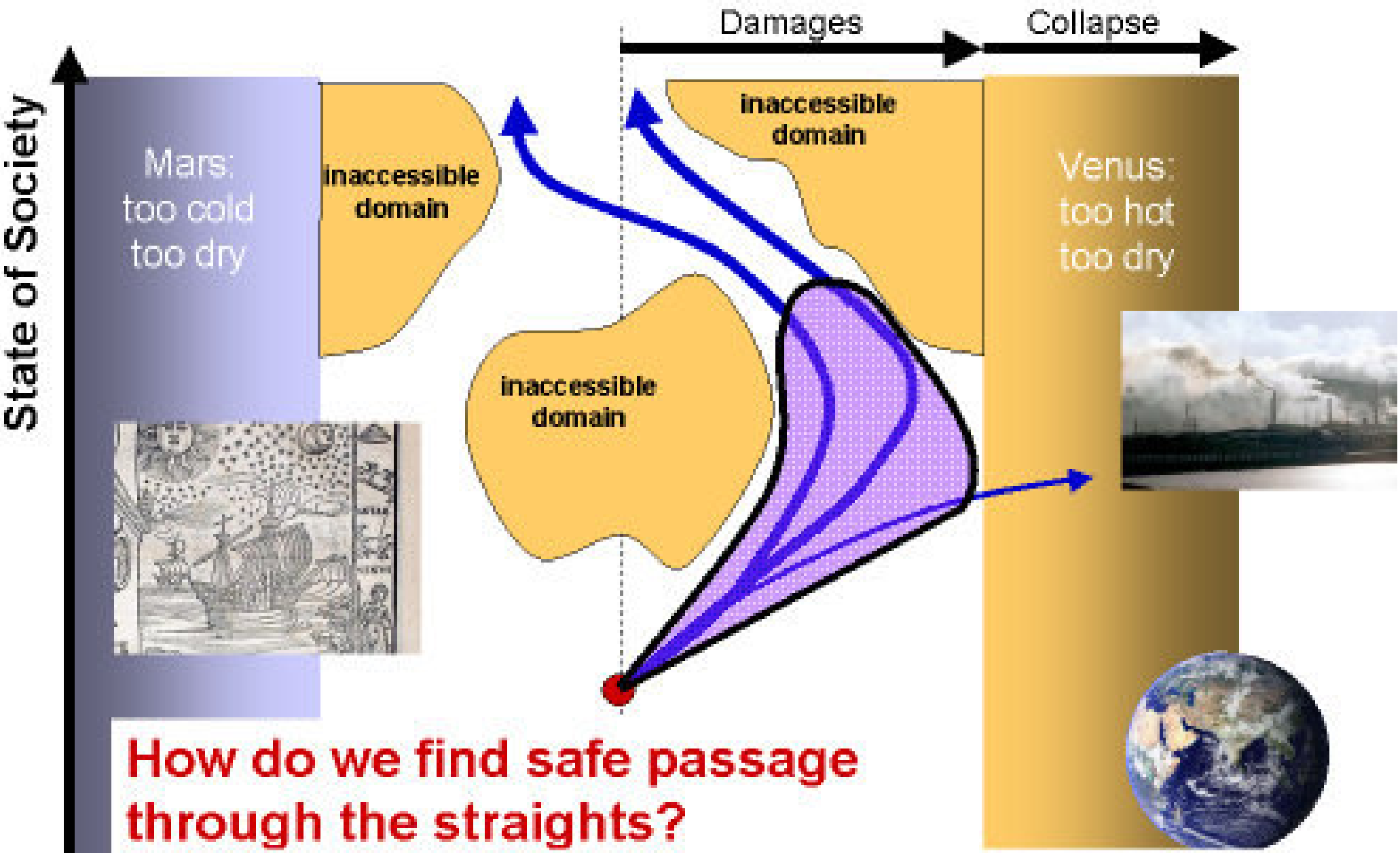
Building on HJ Schellnhuber, Nature, 1999



What are possible paths in Earth System Phase Space?


State of Society
Mars:
too cold
too dry
inaccessible
domain
sustainability
transition
climate
policies
Venus:
too hot
too dry
green
progress
inaccessible
domain
physical
collapse
our location
today
social collapse
State of Nature


Damages
Collapse
State of Society
Mars:
too cold
too dry
Venus:
too hot
too dry
sustainability
transition
?
?
?
?
?
climate
policies
physical
collapse
How do we find safe passage
through the straights?
State of Nature



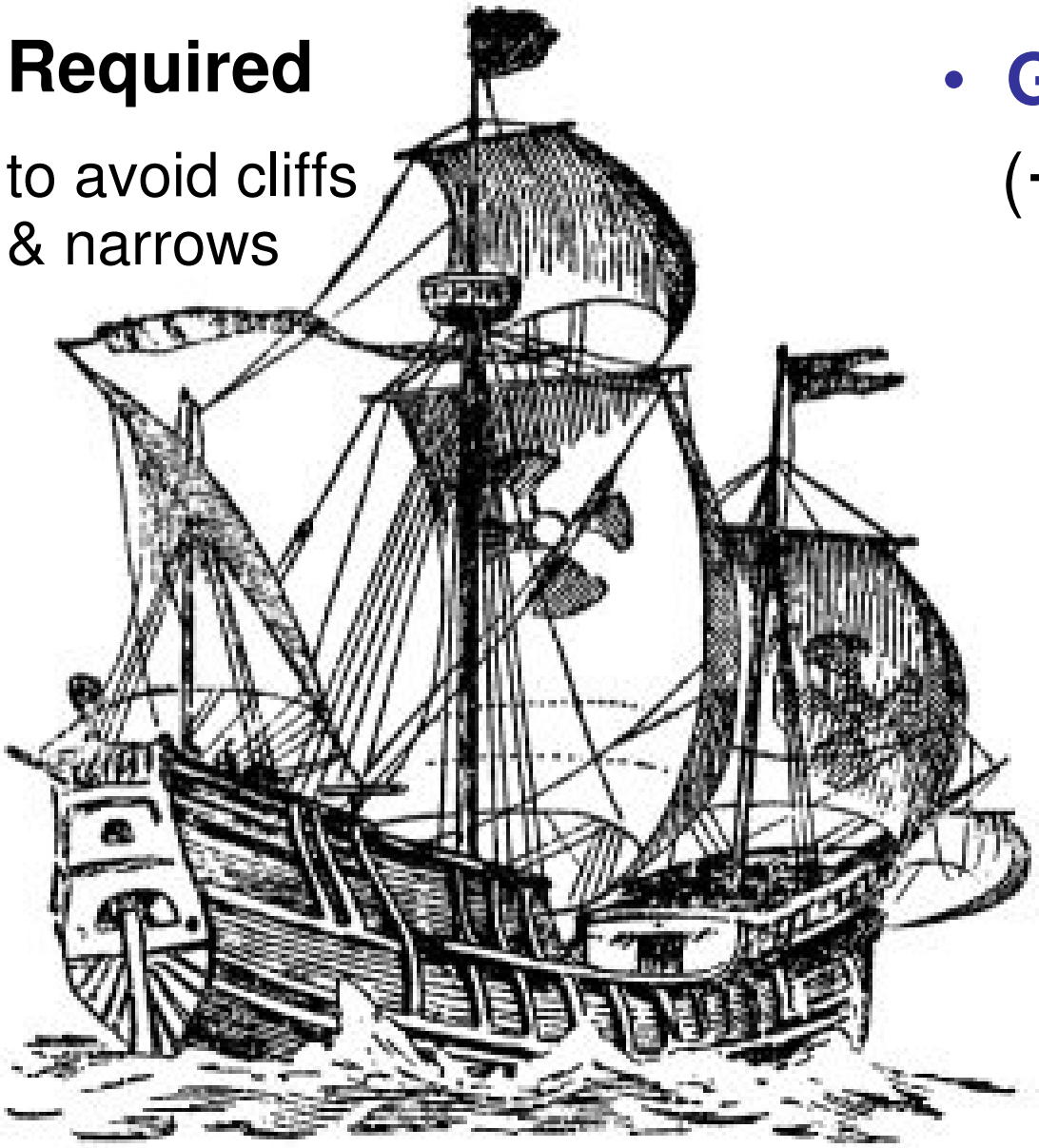
How do we find safe passage through the straights?

(1) Scanning what is ahead: Computer Modelling

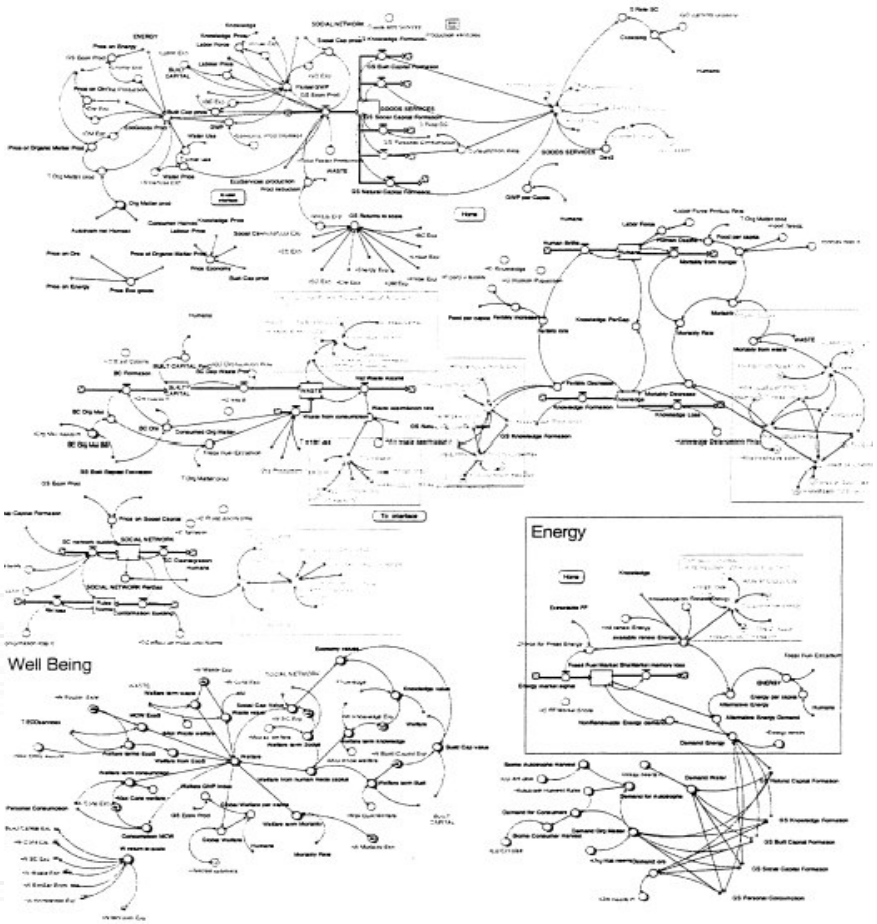
Plotting a future course for the Earth System

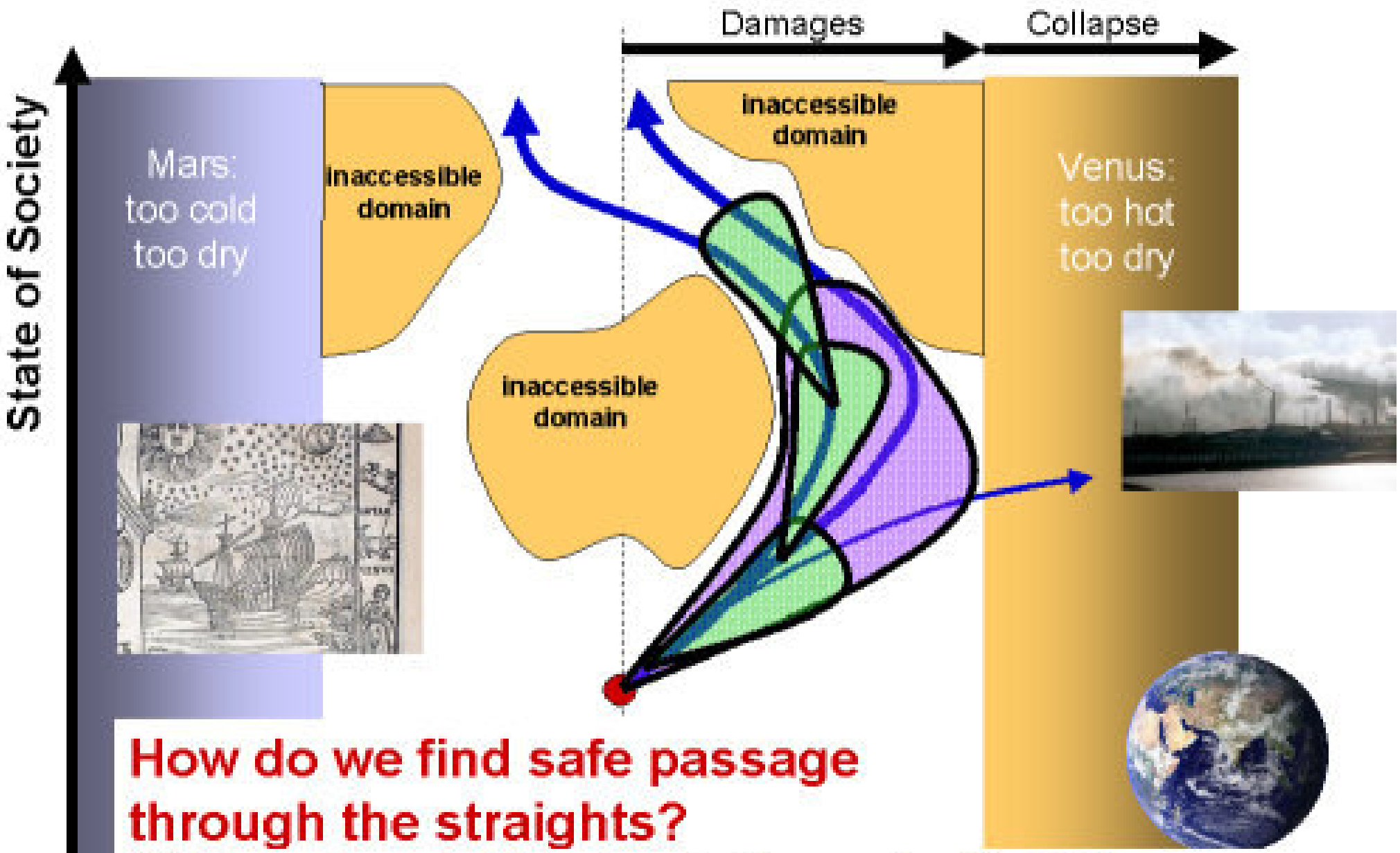
Required

to avoid cliffs
& narrows



- **Good Navigation Charts**
  (→ Computer Models)





How do we find safe passage through the straights?

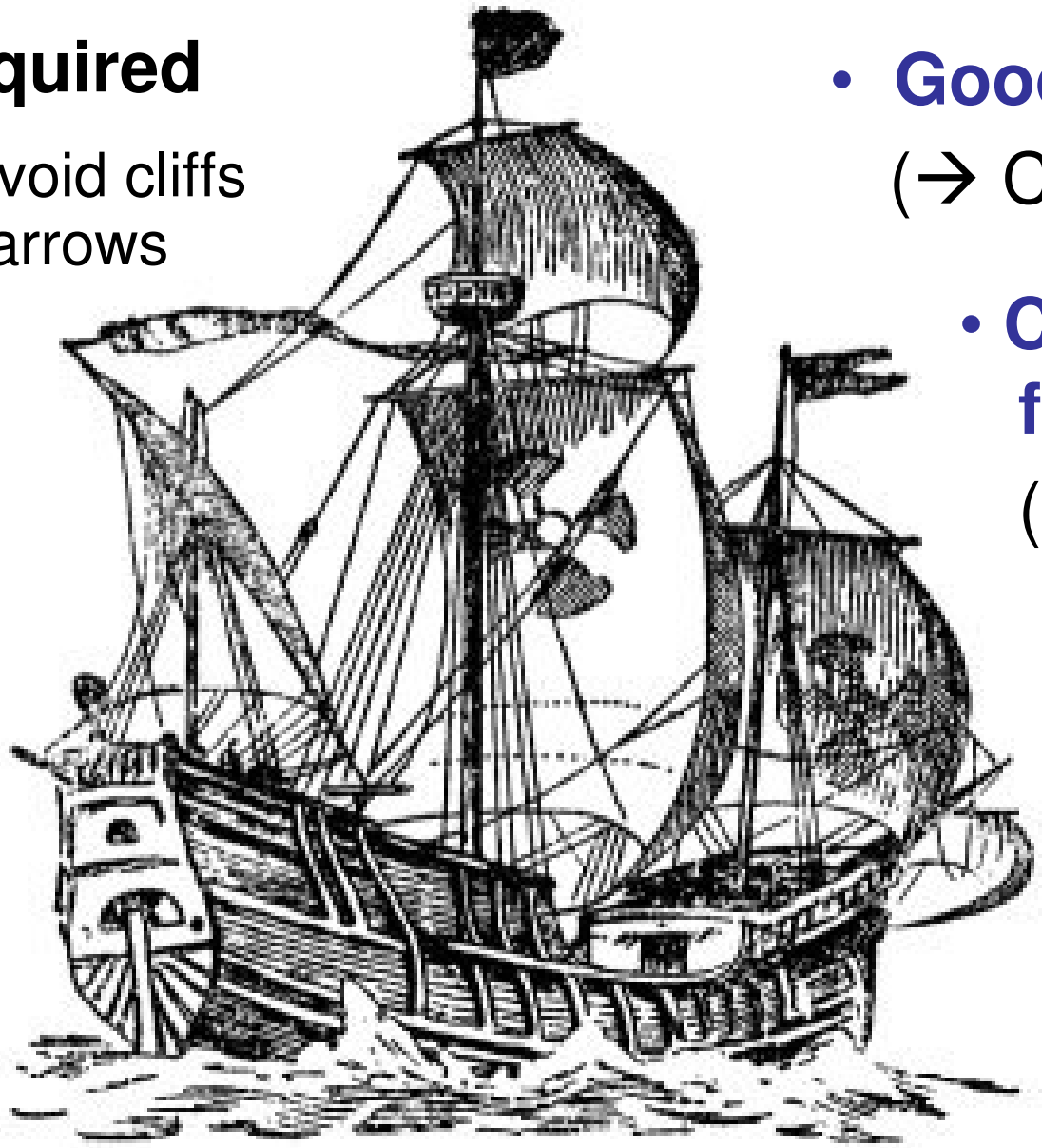
(1) Scanning what is ahead: Computer Modelling

(2) Checking on reality: Earth System Observation

Plotting a future course for the Earth System

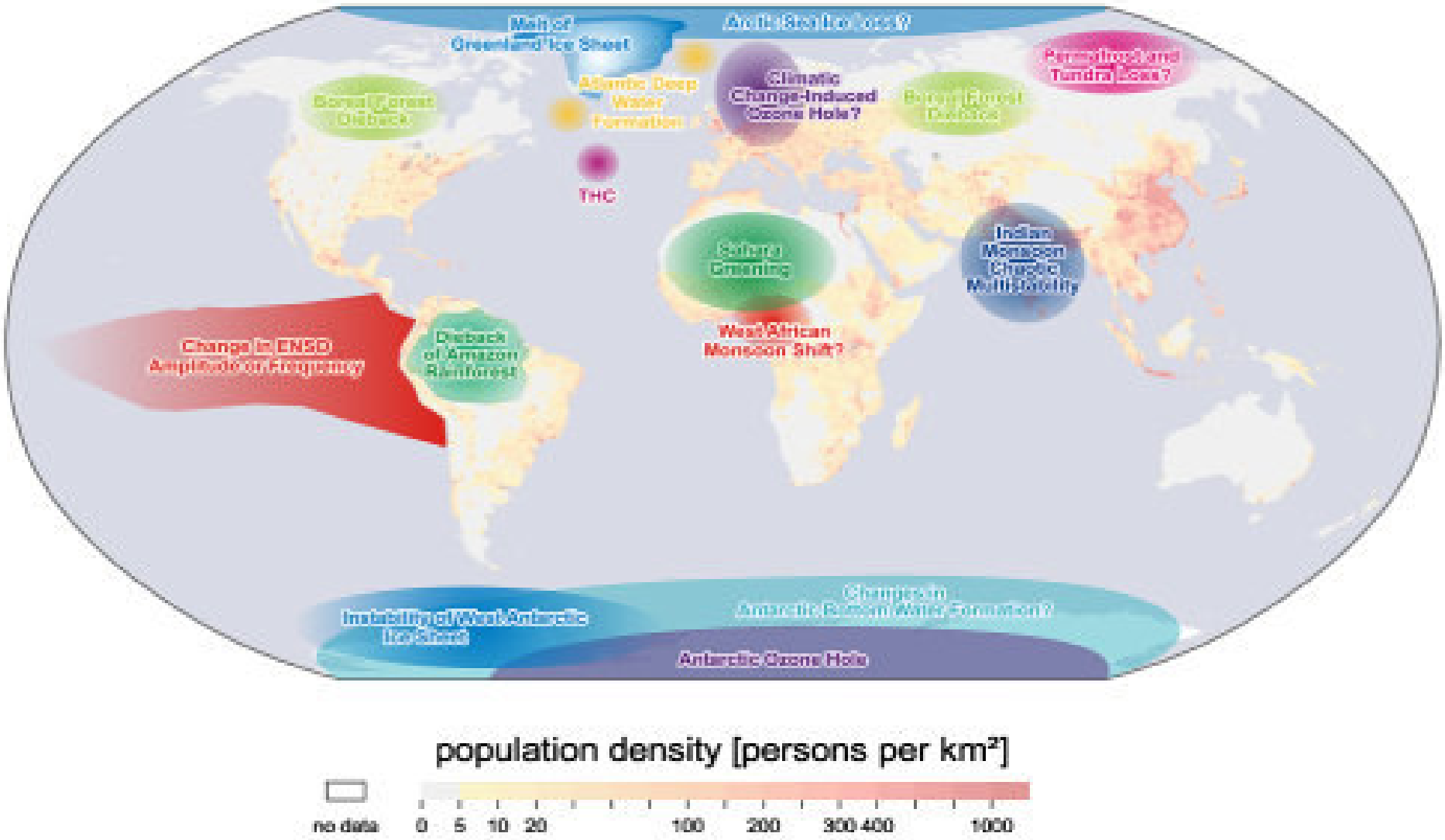
Required

to avoid cliffs
& narrows



- **Good Navigation Charts**
  (→ Computer Models)
- **Constant Observation from the Crow's Nest**
  (→ Earth Observations)

Tipping Points in the Earth System

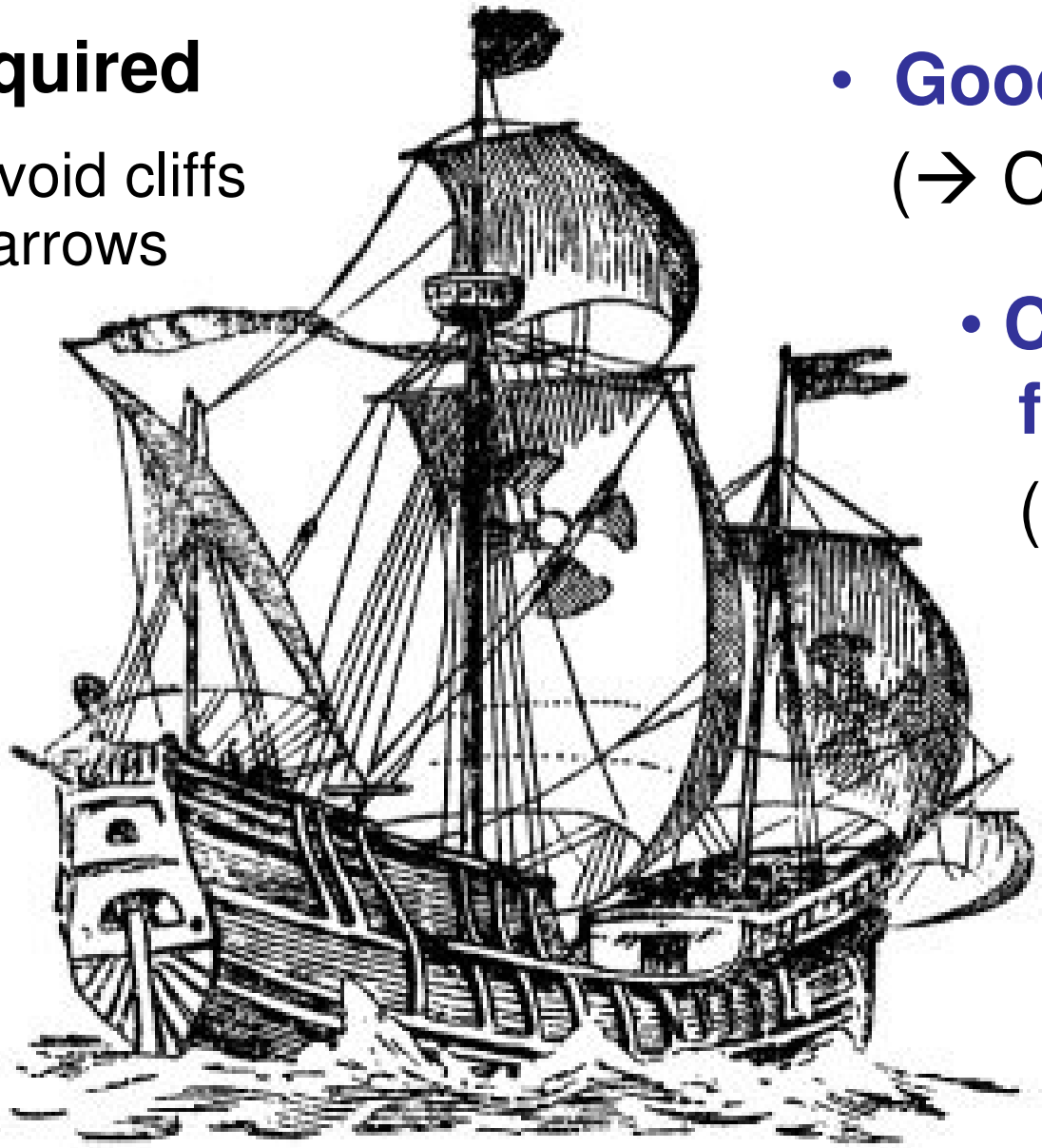


Lenton et al., PNAS, 2008

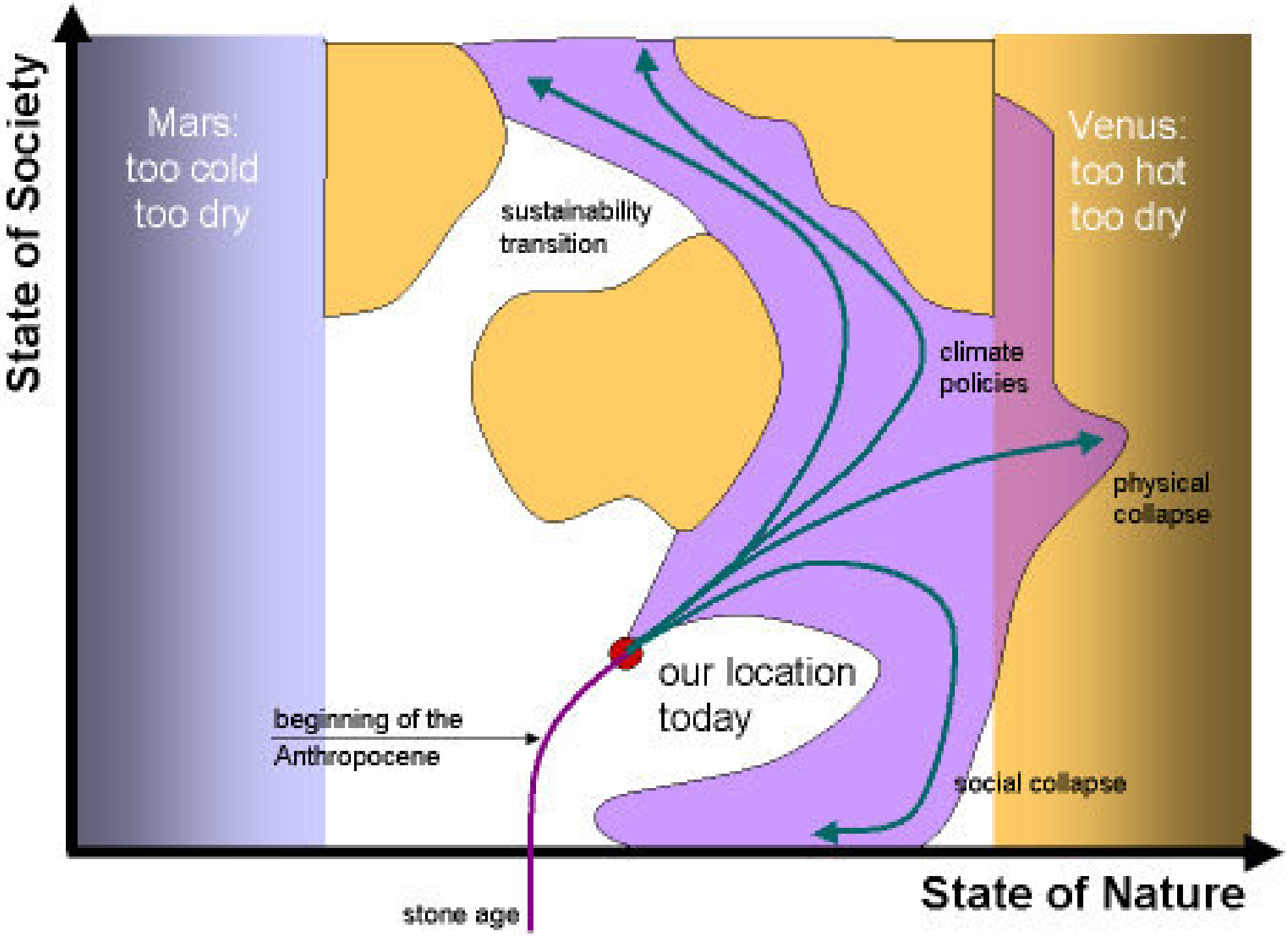
Plotting a future course for the Earth System

Required

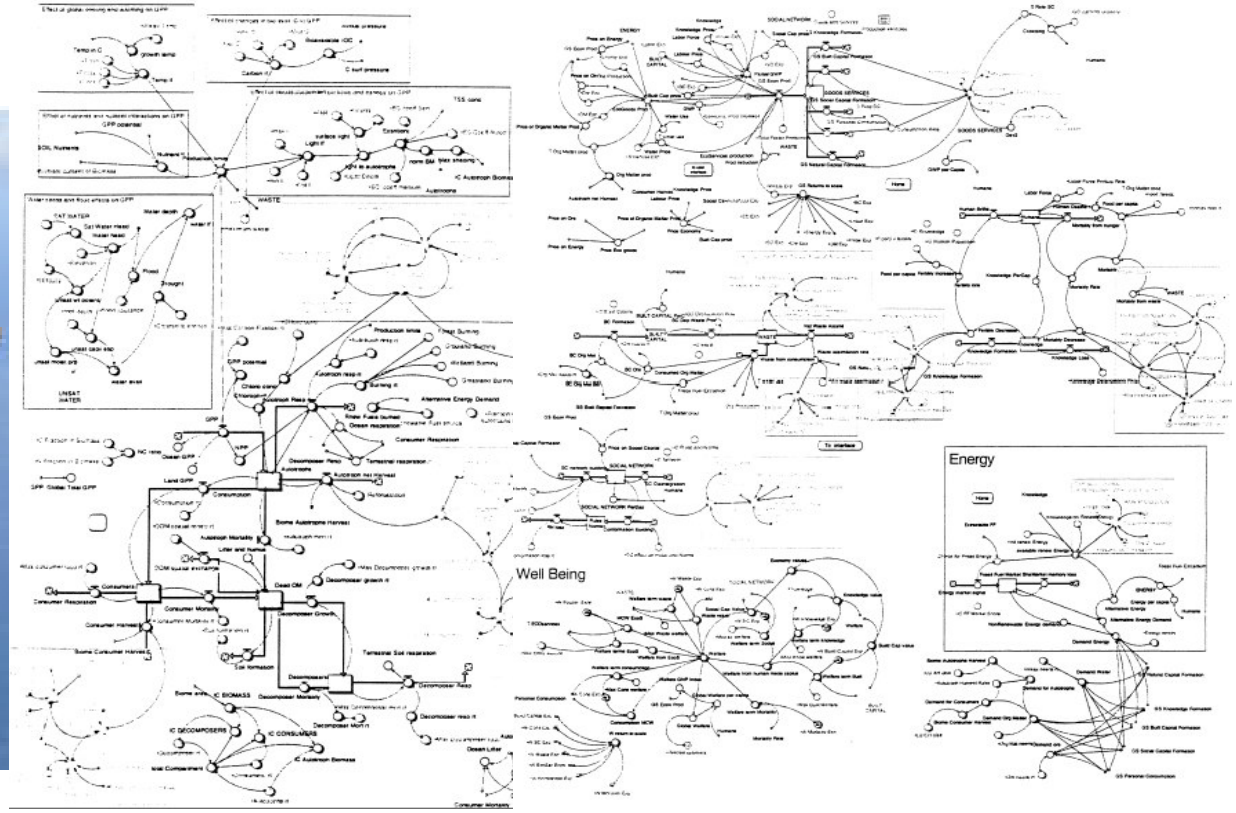
to avoid cliffs
& narrows

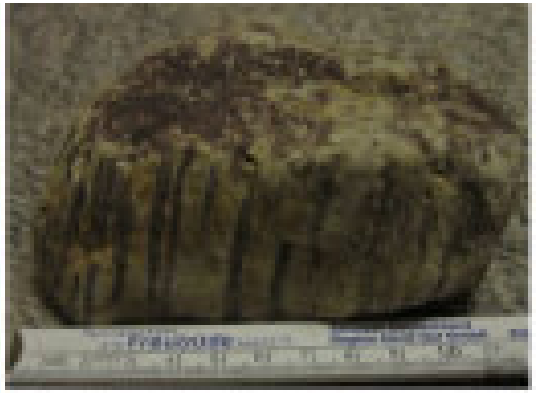


- **Good Navigation Charts**
  (→ Computer Models)
- **Constant Observation from the Crow's Nest**
  (→ Earth Observations)
- **Be prepared!**
  (→ Expect Surprises)


State of Society
Mars:
too cold
too dry
Venus:
too hot
too dry
sustainability
transition
climate
policies
physical
collapse
our location
today
beginning of the
Anthropocene
social collapse
stone age
State of Nature

EOS
TERRA
MODIS
MISR
CERES
ASTER


Well Being
Energy



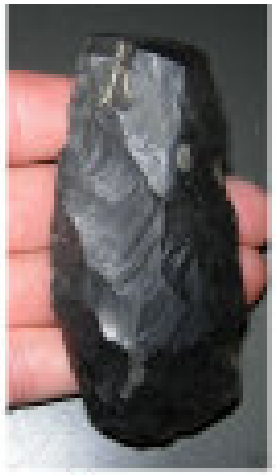
Unicellular soup
to first
soft-bodied animals.

Then the plant came
and invaded that land.

And the
vertebrates
appeared,
some of them
got really big!

Life has not always been what it is today.

W. Lucht, PIK



12.000 Years

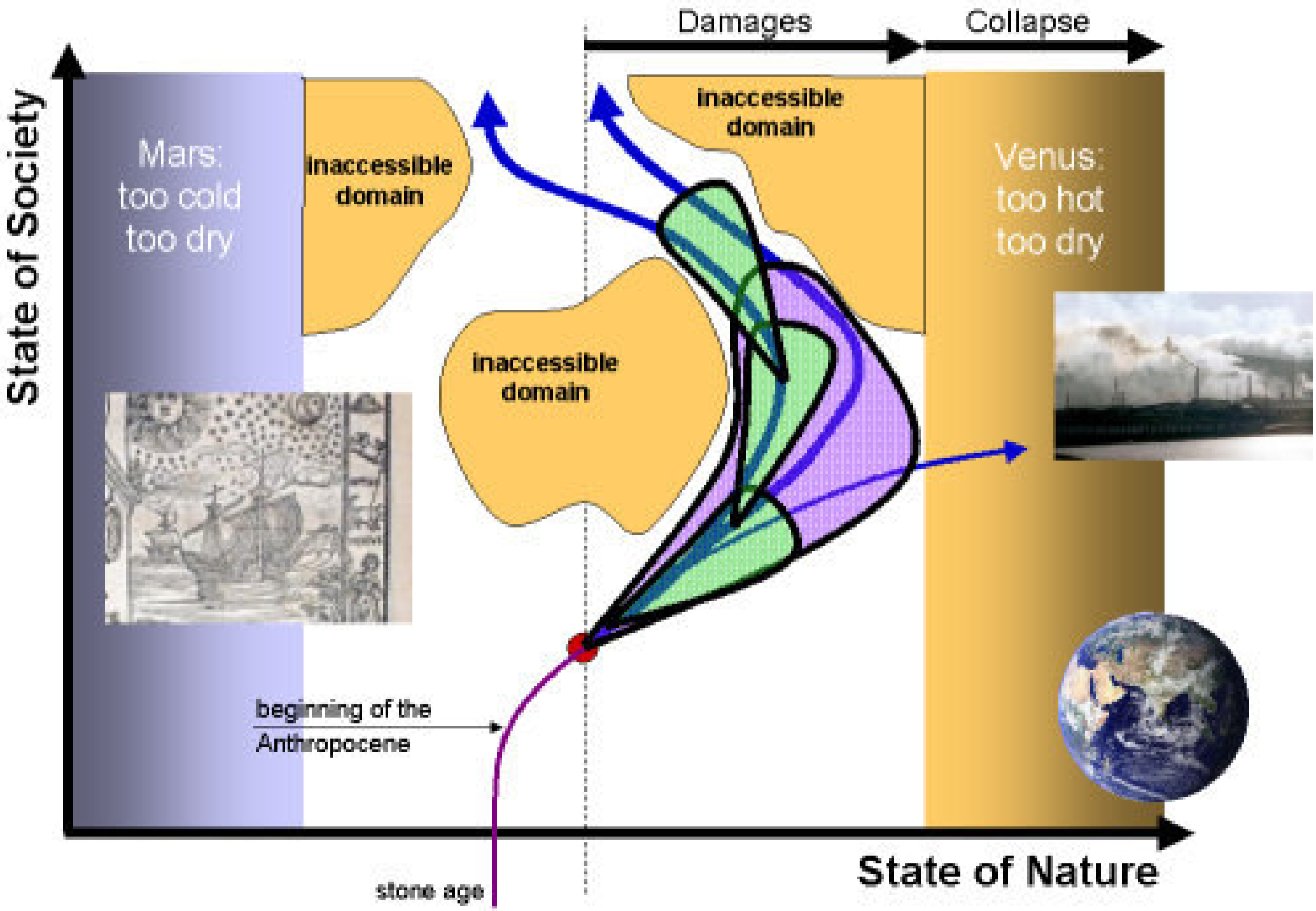
1.000.000 Years

… and then something happened

… and then something really happened

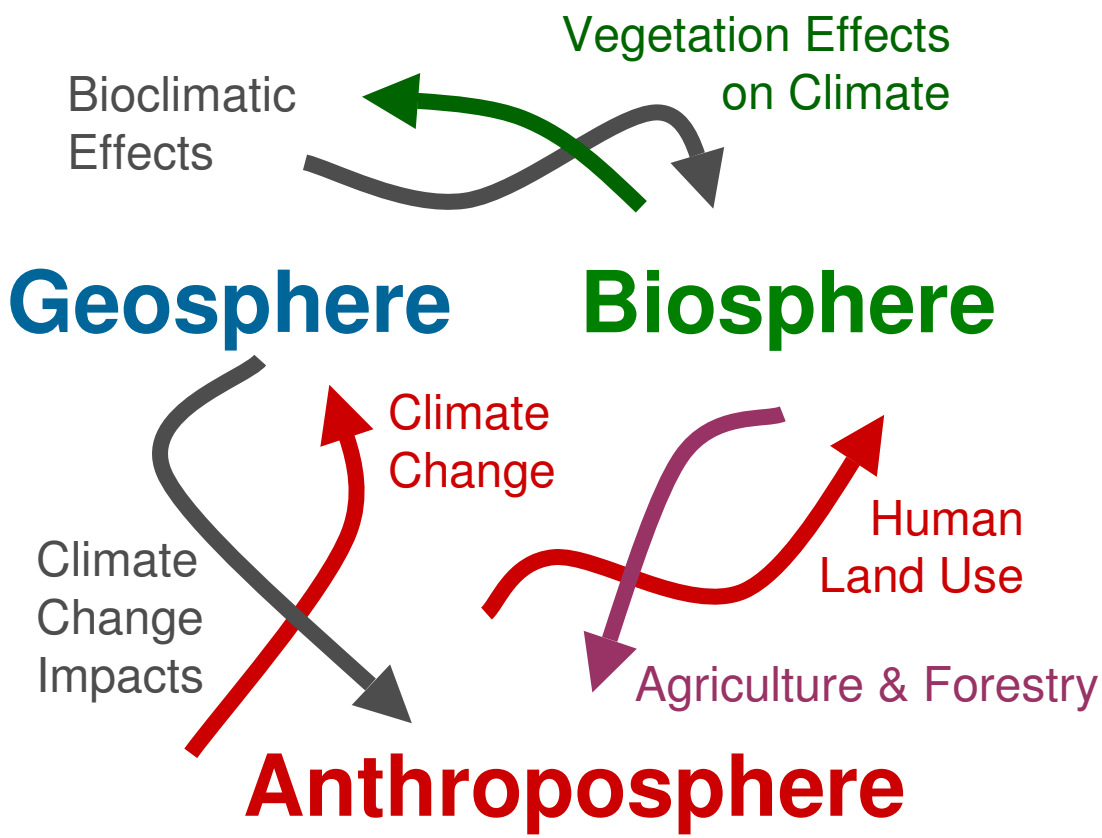
W. Lucht, PIK

Now we are facing a challenge:
Keeping the world a livable, exciting experience … with humans.


Damages
Collapse
State of Society
Mars:
too cold
too dry
inaccessible domain
inaccessible domain
inaccessible domain
Venus:
too hot
too dry
beginning of the Anthropocene
stone age
State of Nature

The Anthropocene

The Challenge: Emergence of Conscious Global Action



W. Lucht, PIK

A World Transformed

The Consequences of Climate Change and Human Land Use

Wolfgang Lucht • Potsdam Institute for Climate Impact Research
Chair, Research Domain „Earth System Analysis“