Living in the Anthropocene:

Challenges for the next decades

Guy Brasseur

Max Planck Institute for Meteorology, Hambourg, Allemagne

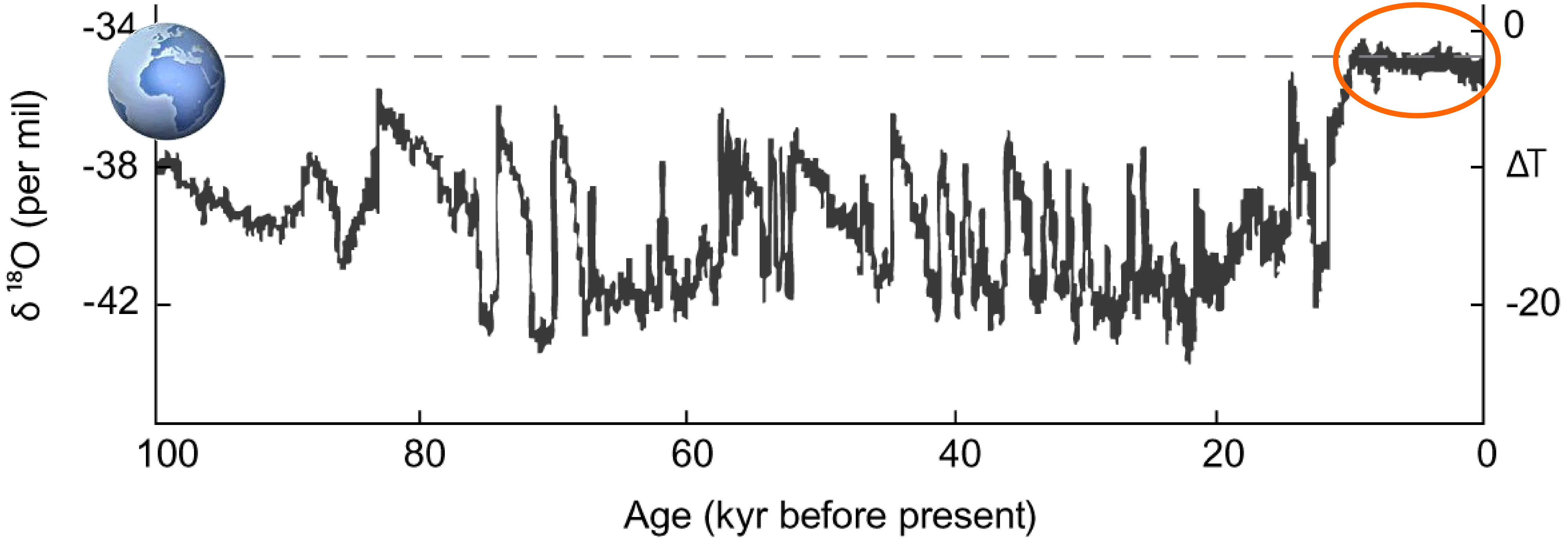
and

National Center for Atmospheric Research, Boulder, CO, USA

2022

The Earth: A Dynamical System

The evolution of the Earth has been very dynamic with different climatic modes, glacial and interglacial periods. Humanity has known a mild climate for 10,000 years.



An Earth System Perspective

The Earth System

- The Earth System is a single, planetary-level complex system composed the biosphere (defined as the sum of all biota living at any one time and their interactions), including interactions and feedbacks with the geosphere (defined as the atmosphere, the hydrosphere, the cryosphere and the upper part of the lithosphere) (Steffen, 2016)

The Earth System

- Earth is approximately 4.54 billion old, and the biosphere 3.7-4.1 billion years old
- Astronomical forces (changes in solar irradiance linked for example to orbital changes of the Earth) and geophysical forces (volcanic activity, weathering and tectonic movements) have been the dominant external drivers of the Earth System.

Equation of the Earth System at the highest level of abstraction

If *E* represents the state of the Earth system, its evolution is given by (Schellnhuber, 2001)

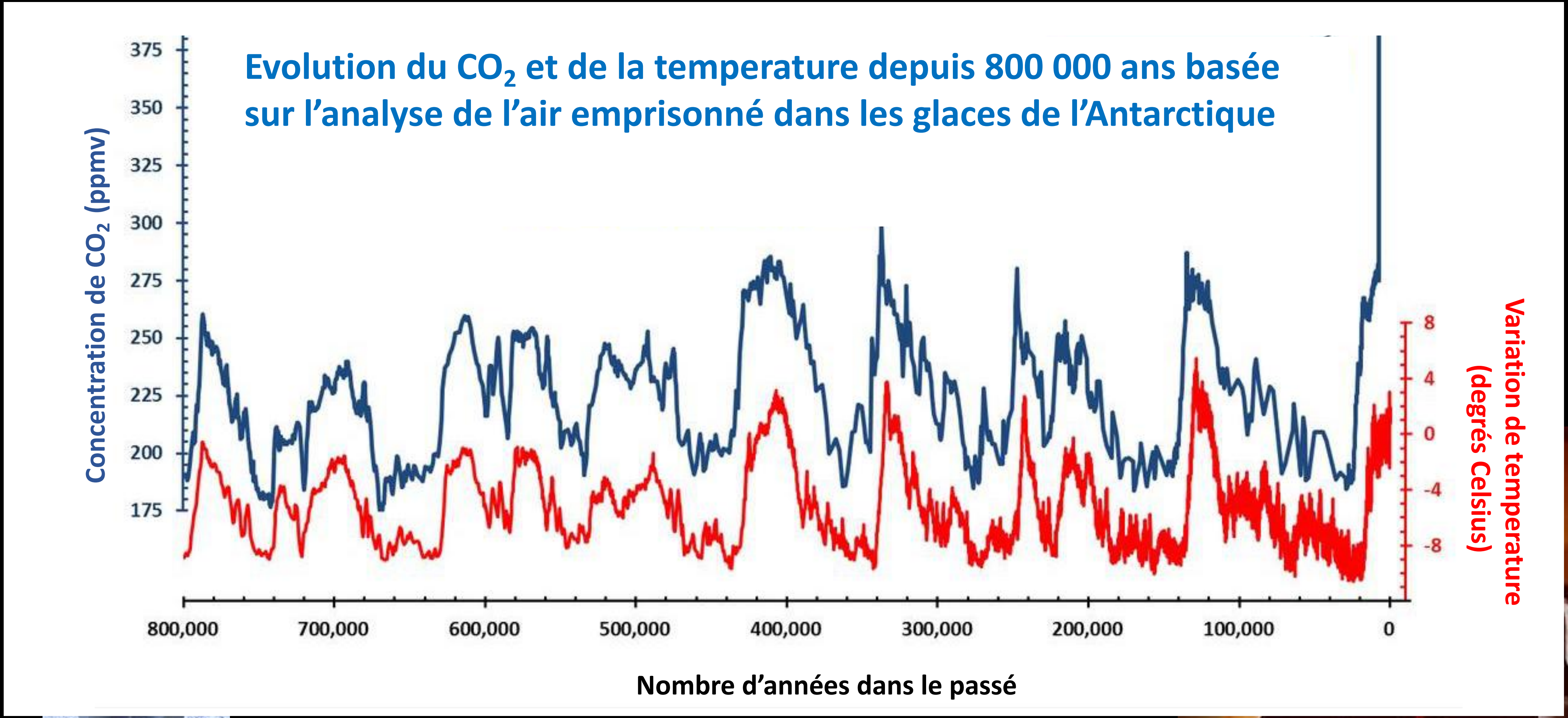
$$\frac{dE}{dt} = f(A, G, I)$$

where

- *A* is the Astronomical forcing
- *G* is the geophysical forcing
- *I* account for internal dynamics of the Earth system (positive and negative feedbacks

The Earth System

- During the quaternary, the evolution of the earth system has been dominated by cyclic variations in the earth’s orbit with changes in solar irradiance, and irregular events such as volcanic eruptions.
- A clear signal of the response of the Earth System has been provided by the long term oscillations between glacial and interglacial periods.


Evolution du CO2 et de la temperature depuis 800 000 ans basée sur l'analyse de l'air emprisonné dans les glaces de l'Antarctique
Concentration de CO2 (ppmv)
375
350
325
300
275
250
225
200
175
Variation de temperature (degrés Celsius)
8
4
0
-4
-8
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Nombre d'années dans le passé

Ed Lorenz

Earth System Regulation

- Support of life by biogeochemical cycles and related feedbacks
- Mechanisms responsible for Earth system regulation (nutrient regulation, oxygen regulation, carbon regulation, climate regulation).
- Possible shift shift of certain bio-geophysical feedback loops from negative (dampening) to positive (self-reinforcing) operations in response to human activities.

Earth System Regulation: The Gaia hypothesis by James Lovelock

The hypothesis states that living organisms interact with their inorganic surroundings on Earth to form a synergetic and self-regulating complex system that helps maintain and perpetuate the conditions for life on the planet.

Earth System Revolutions

- Evolution of the Earth as a system in which life has shaped the planet and changes in planetary environment has shaped life.
- At a few times in Earth history, the Earth system was radically transformed.
- Issues: Origin of the Earth, emergence of life, origin of recycling by the biosphere, origin of photosynthesis, the great oxidation event 2.4 billion years ago, climate disturbances (e.g., snowball Earth), glacial-interglacial transitions, etc.

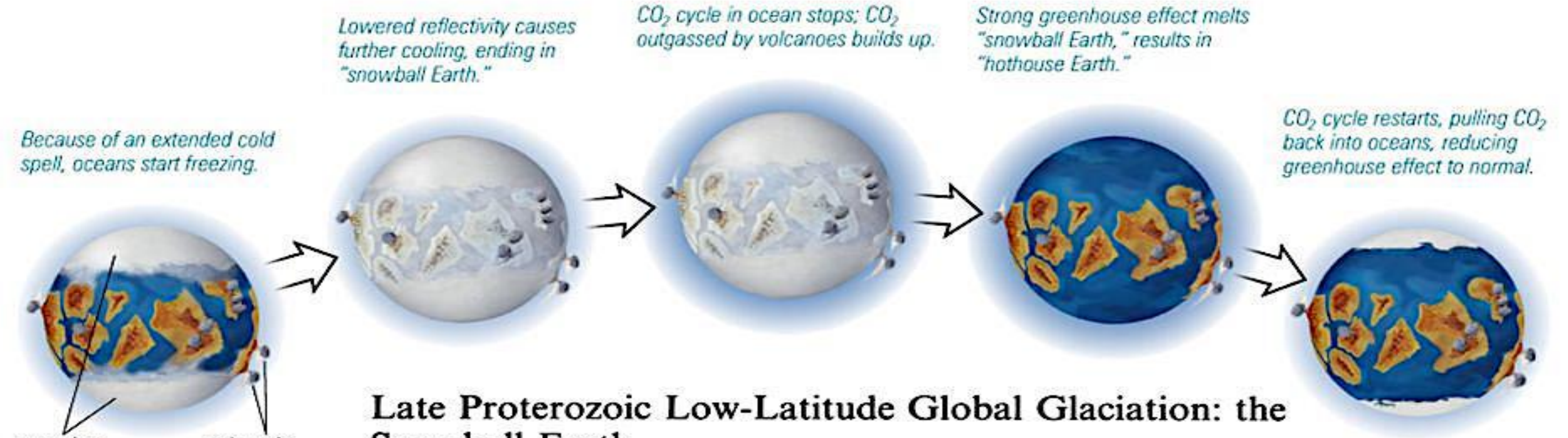
The Snowball Earth Hypothesis

- The Snowball Earth hypothesis proposes that, during one or more of Earth's icehouse climates (2220 Ma, circa 710 Ma and circa 640 Ma ago), the planet's surface became entirely or nearly entirely frozen.
- Snowball Earths arose from **a "runaway" effect involving an ice-albedo feedback**: As incoming sunlight was reduced by ice albedo, ice expanded from the poles to the equator.
- Explosive underwater volcanos injected high levels of CO_2 in the atmosphere, which lead to greenhouse warming and paved the way for life as we know it.

What is Snowball Earth?

Most extreme climate event in Earth history.
Characteristics:

- Occurred at least twice between 750-635 Ma.
- Global (or almost global) ice coverage.
- More than 1 km thick sea-glacier.
- Mean global temperature: -44°C.



Late Proterozoic Low-Latitude Global Glaciation: the Snowball Earth
JOSEPH L. KIRSCHIVINK (1992)

The Human Forcing

A profound transformation of the Earth system is underway.

During the last 50 years,

- the human population has increased from 2 to 7 billion,
- The economic activity has increased by a factor of 10,
- the connectivity of the human enterprise has increased considerably (globalization, globalization of the economy, flow of information, people, products and diseases).

Intensification and diversification of land use and advances in technology have introduced rapid changes in biogeochemical cycles, hydrological processes, air and water quality, and landscape dynamics.

The population started to grow rapidly

Live Earth Concert, London 2004

And the global economy expanded

NASA

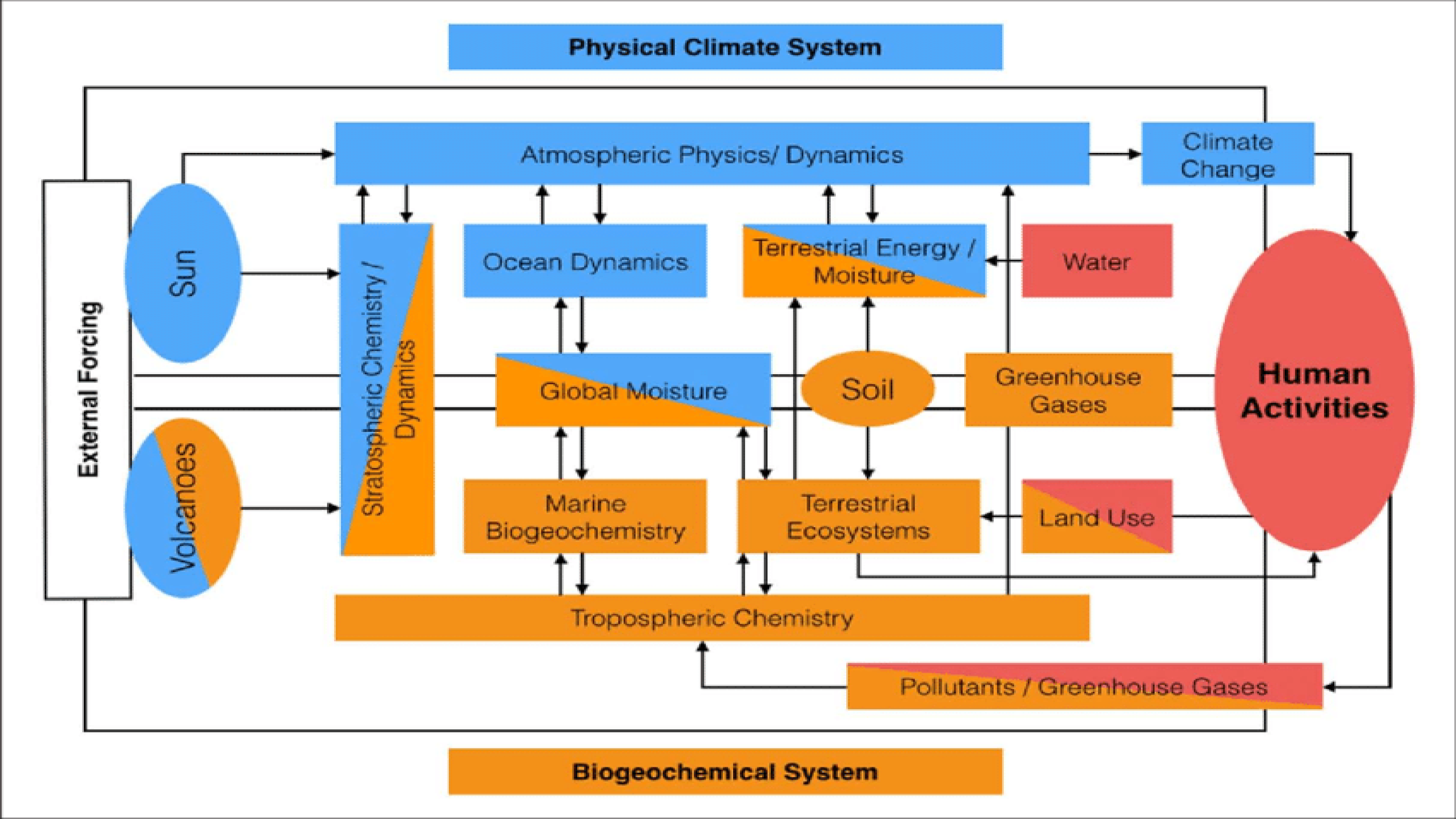
Equation of the Earth System at the highest level of abstraction

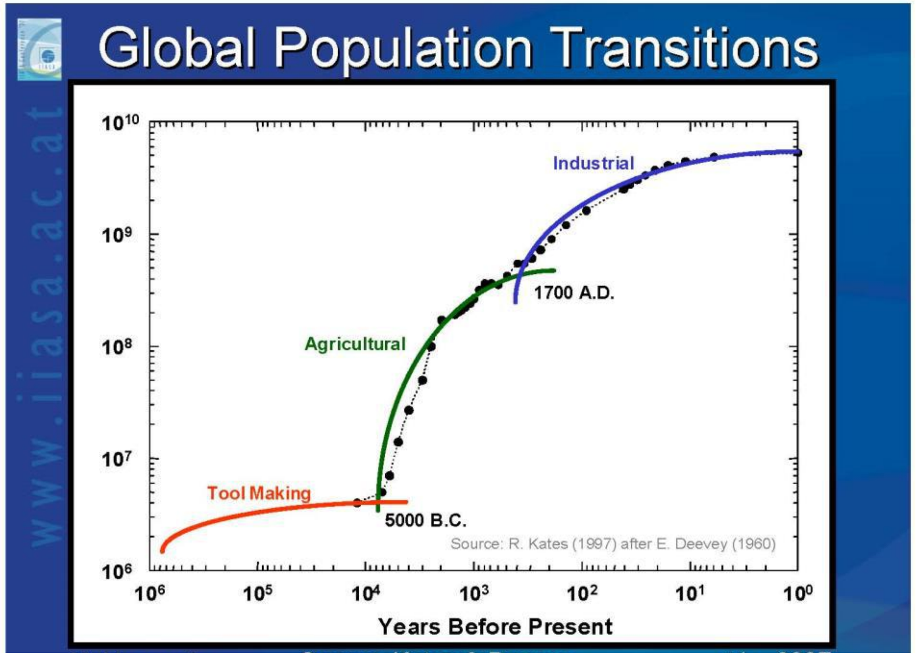
A entirely new forcing is now driving changes in the earth System: *H, which* represents the human forcing

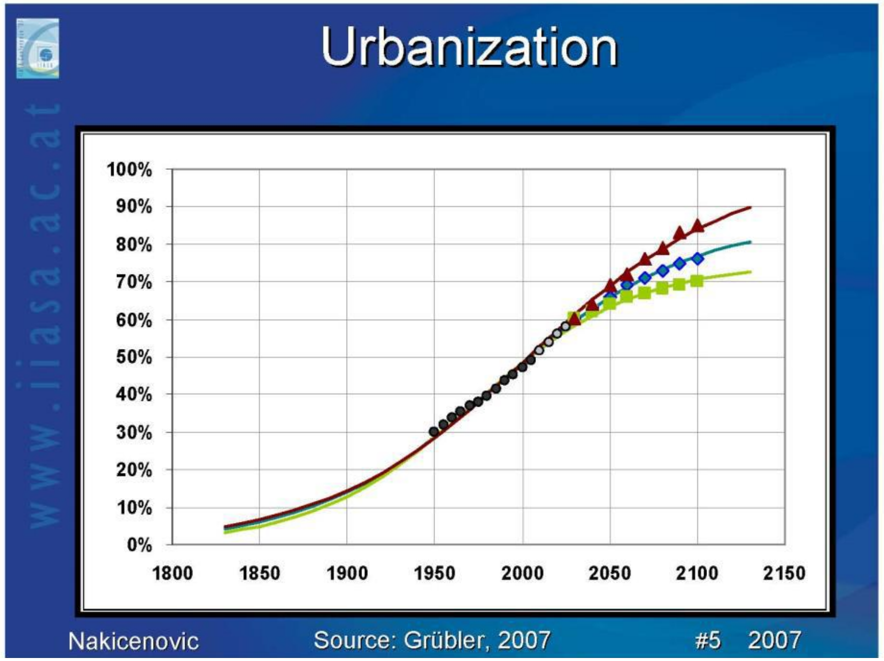
$$\frac{dE}{dt} = f(A, G, I, H)$$

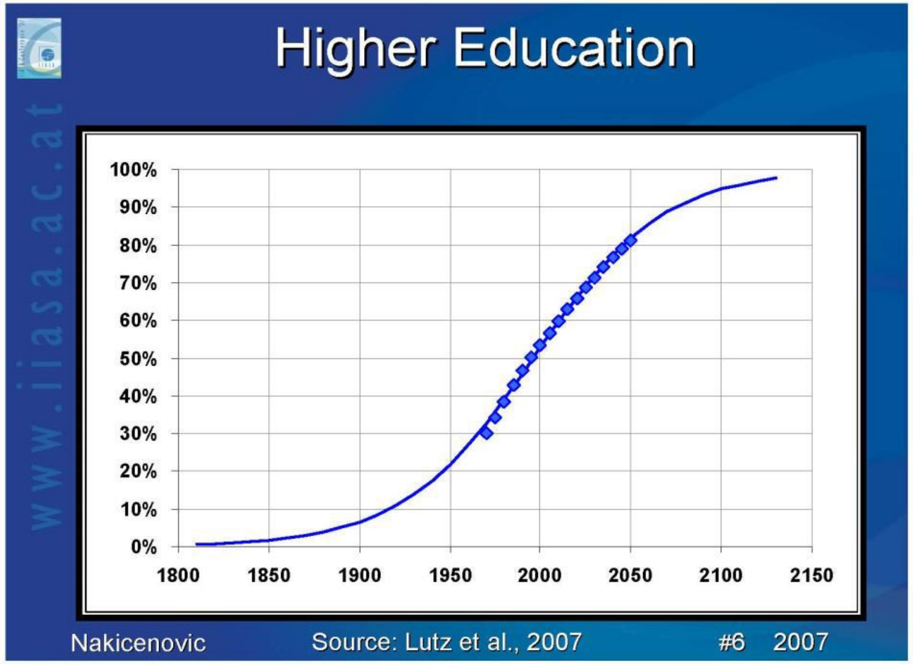
where

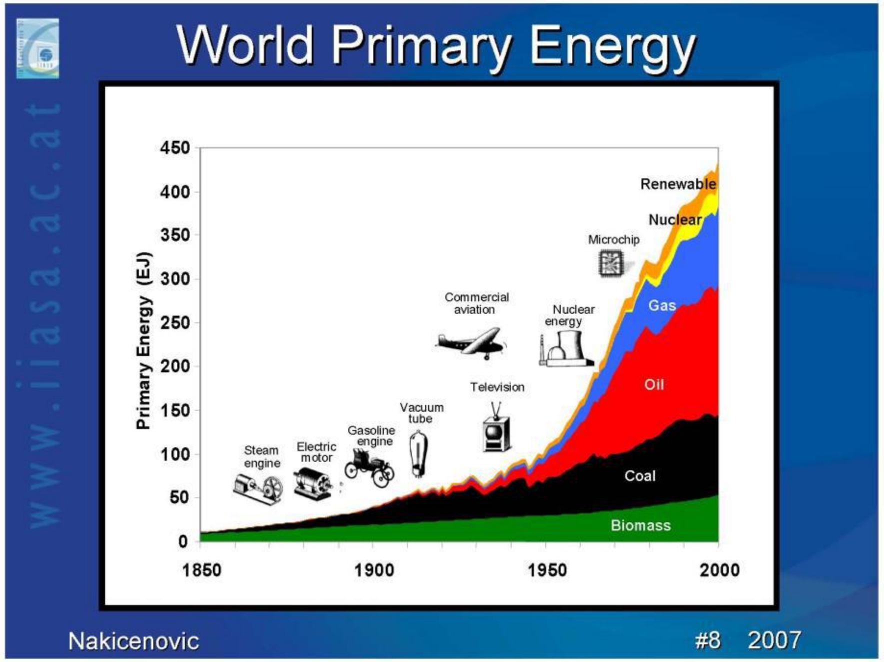
- *A* is the Astronomical forcing
- *G* is the geophysical forcing
- *I* account for internal dynamics of the Earth system (positive and negative feedbacks


Physical Climate System
External Forcing
Sun
Volcanoes
Atmospheric Physics/ Dynamics
Climate Change
Stratospheric Chemistry / Dynamics
Ocean Dynamics
Terrestrial Energy / Moisture
Water
Global Moisture
Soil
Greenhouse Gases
Human Activities
Marine Biogeochemistry
Terrestrial Ecosystems
Land Use
Tropospheric Chemistry
Pollutants / Greenhouse Gases
Biogeochemical System


Global Population Transitions
Industrial
1700 A.D.
Agricultural
Tool Making
5000 B.C.
Source: R. Kates (1997) after E. Deevey (1960)
Years Before Present
www.iiasa.ac.at


Urbanization
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1800 1850 1900 1950 2000 2050 2100 2150
Nakicenovic
Source: Grübler, 2007
#5 2007
www.iiasa.ac.at


Higher Education
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1800 1850 1900 1950 2000 2050 2100 2150
Nakicenovic
Source: Lutz et al., 2007
#6 2007
www.iiasa.ac.at


World Primary Energy
Primary Energy (EJ)
450
400
350
300
250
200
150
100
50
0
1850 1900 1950 2000
Renewable
Nuclear
Gas
Oil
Coal
Biomass
Microchip
Commercial aviation
Nuclear energy
Television
Vacuum tube
Gasoline engine
Electric motor
Steam engine
Nakicenovic
#8 2007
www.iiasa.ac.at

Factors of Growth: The Last 200 Years

	1800	2000	Factor
Population (billion)	1	6	x6
GDP PPP (trillion 1990 $)	0.5	36	~x70
Primary Energy (EJ)	12	440	~x35
CO_2 Emissions (GtC)	0.3	6.4	~x20

By 2100 80% of the world population will live in urban areas

An Urban Planet

Urbanisation:: 1 new city with 1 million inhabitants every10 days

- If the population increases by 3,2 billion until 2100 et lives in cities of 1 million people, we will have to create 3200 cities of 1 million people in 80 years

Karen Seto 2011

GLOBAL IGBP CHANGE International Geosphere-Biosphere Programme

Air pollution and health become very important problems

According to WHO, each year, 8 millions people in the world die prematurely due to the consequences of air pollution.

The New York Times

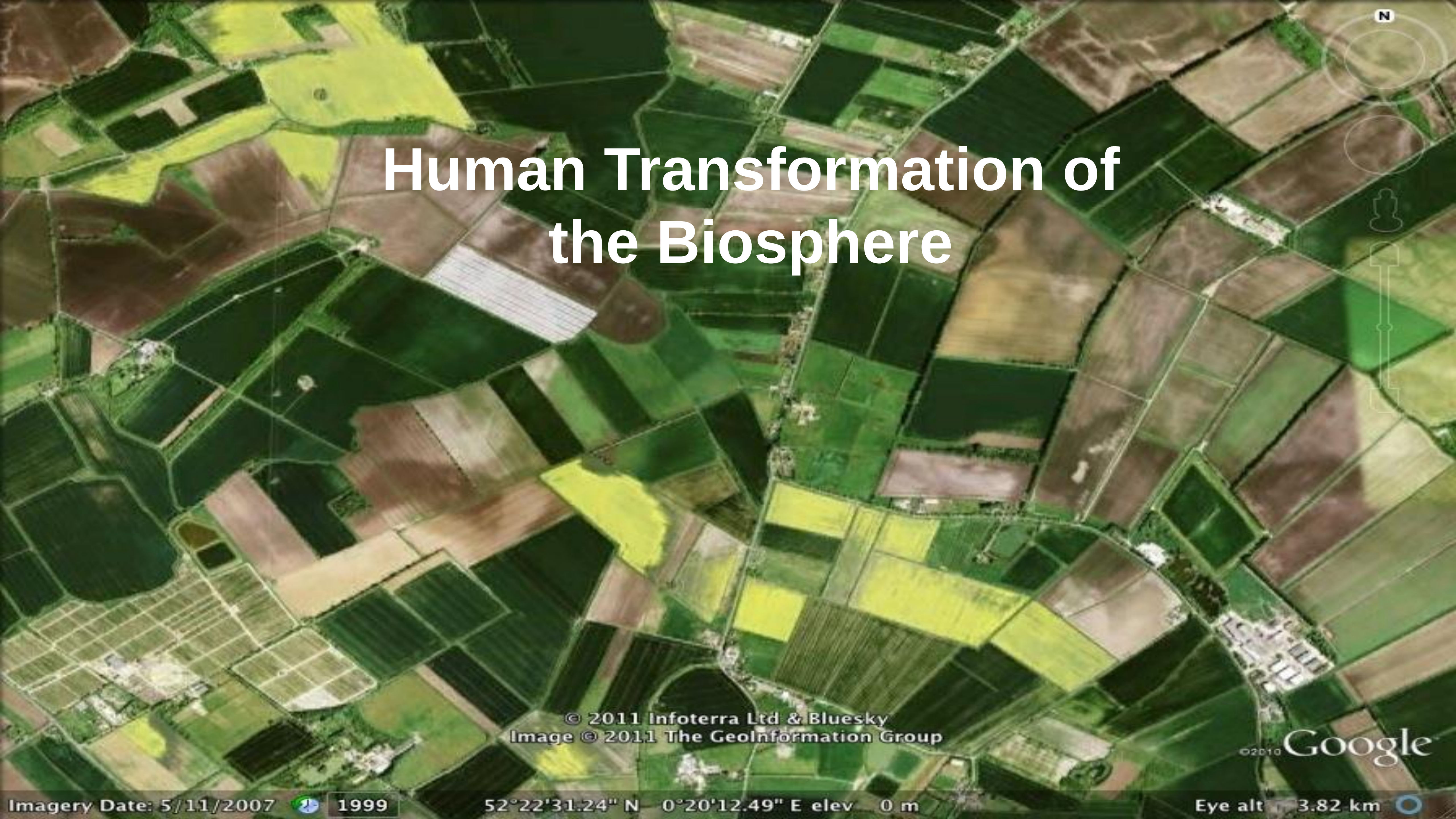
OPINION

DAVID WALLACE-WELLS

Air Pollution Kills 10 Million People a Year. Why Do We Accept That as Normal?

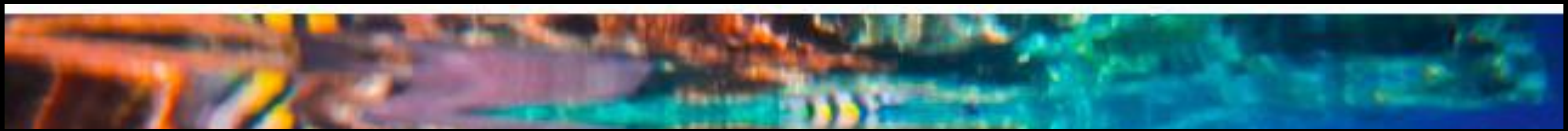
July 8, 2022

Human Transformation of the Biosphere




Access to water will become an acute problem in the 21st century

Nature’s Dangerous Decline



Nature is declining globally at rates unprecedented In human history

The rate of species extinctions is accelerating

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019

Nature’s Dangerous Decline

The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever.

We are eroding the very foundations of our economies, livelihoods, food security, health and qualify of life worldwide.

Around 1 million animal and plant species are now threatened with extinction, many within decades.

The essential, interconnected web of life on Earth is getting smaller and increasingly frayed.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019

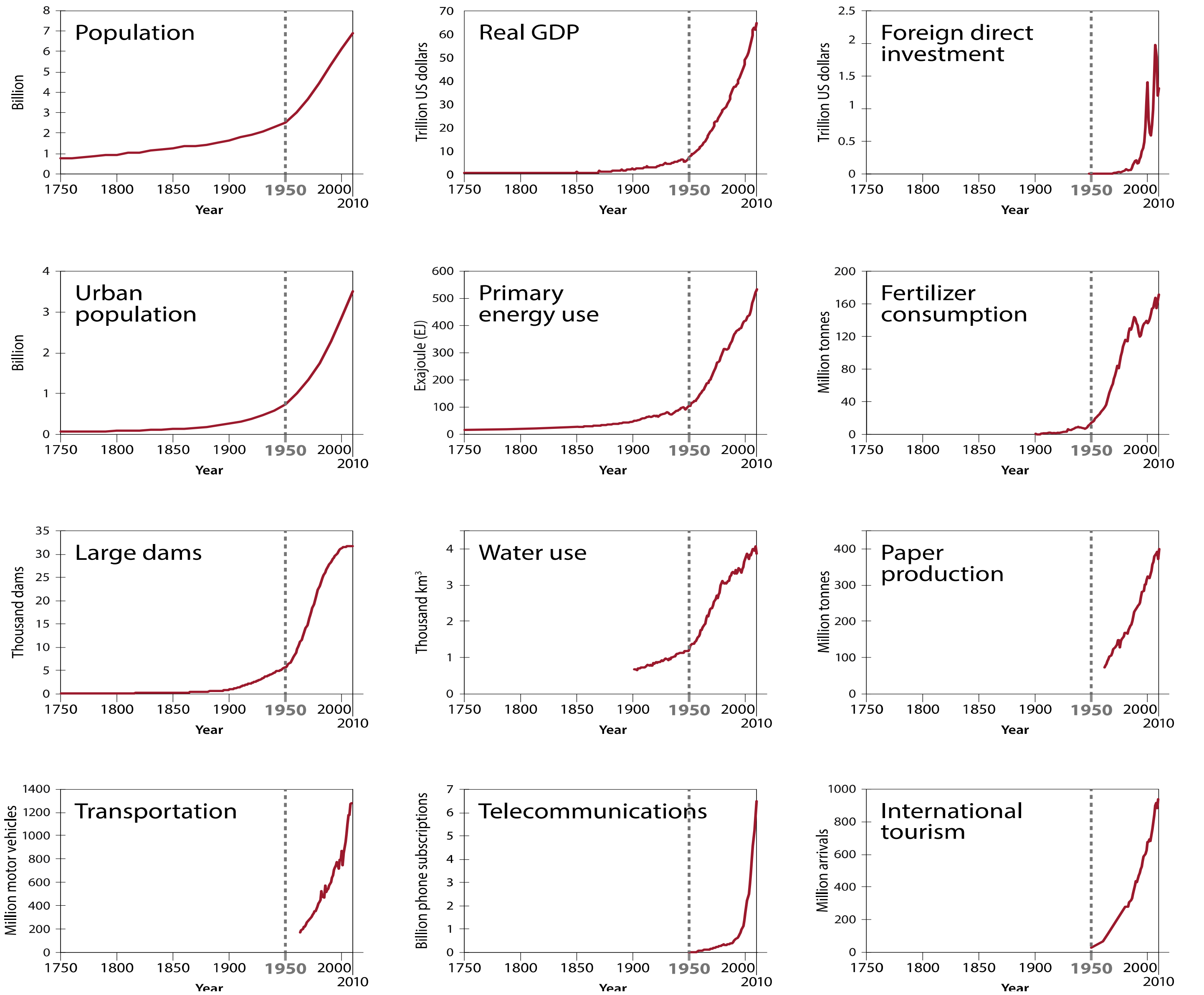
The Great Acceleration

The Great Acceleration

The Human Enterprise

- **Population**
- **Economic Growth**
- **Freshwater use**
- **Energy use**
- **Urbanization**
- **Globalization**
- **Transport**
- **Communication**

Socio-economic trends



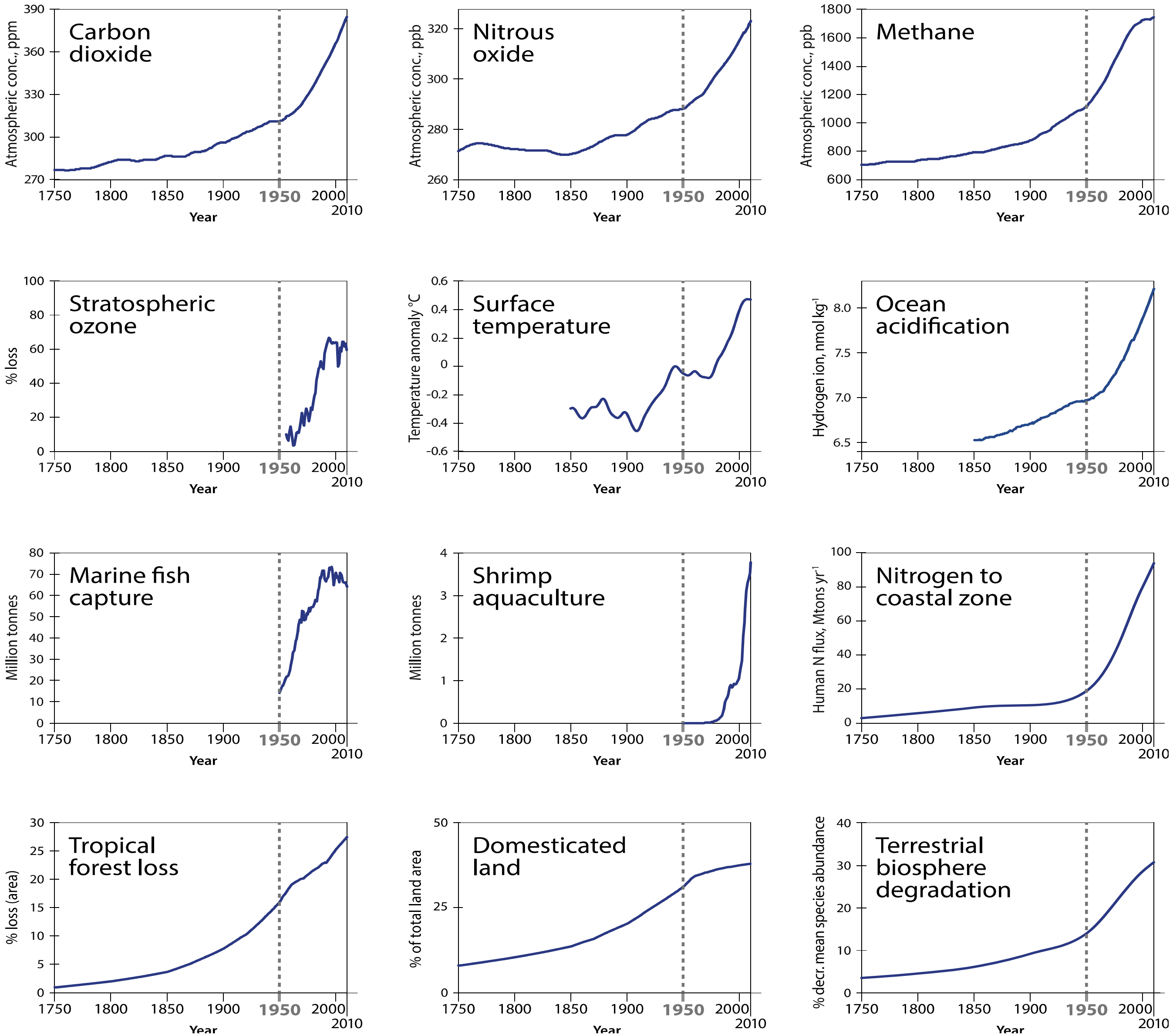
Steffen et al. 2015

The Great Acceleration

Global Impact

- Greenhouse gases
- Ozone depletion
- Climate
- Marine ecosystems
- Coastal zone
- Nitrogen cycle
- Tropical forests
- Land systems
- Biosphere integrity

Earth system trends



Steffen et al. 2015

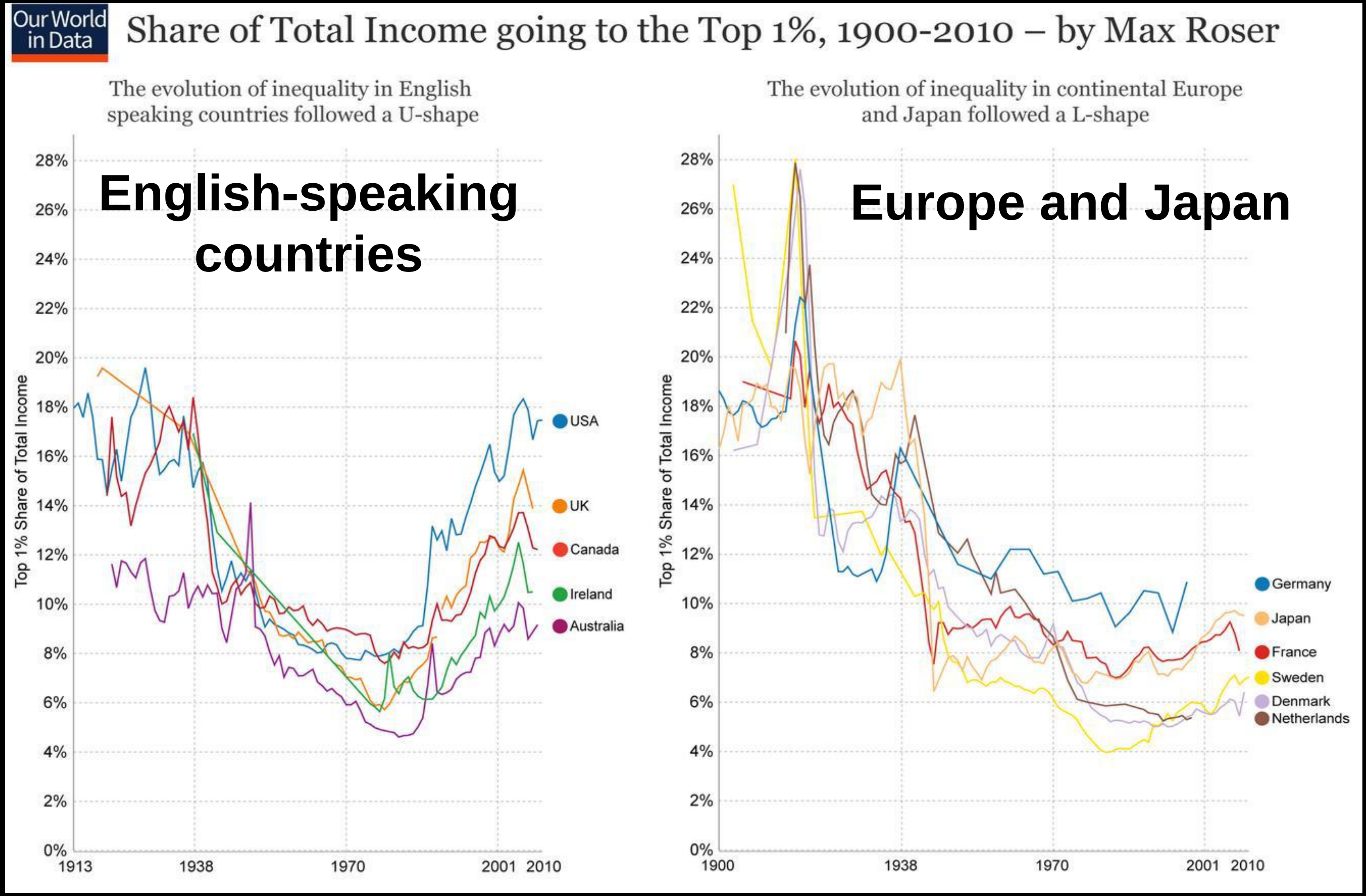
In year 2050

- The population will reach 9 billion: Per year, we will produce 6 billion tons of greenhouse gases and 60 million tons of polluting gases in urban centers.
- We will squander our natural resources: We will use 30% of fresh water and we will destroy a significant part of our forests
- We will encounter more risks to our health and we will often live in regions at risk: 80% of the population will live in urban areas, 25% in seismic zones, 2% in coastal regions less than 1 m above sea level. sea level.

Large unequalities in the world

Quelle: W. Cramer / Chr. Müller, P

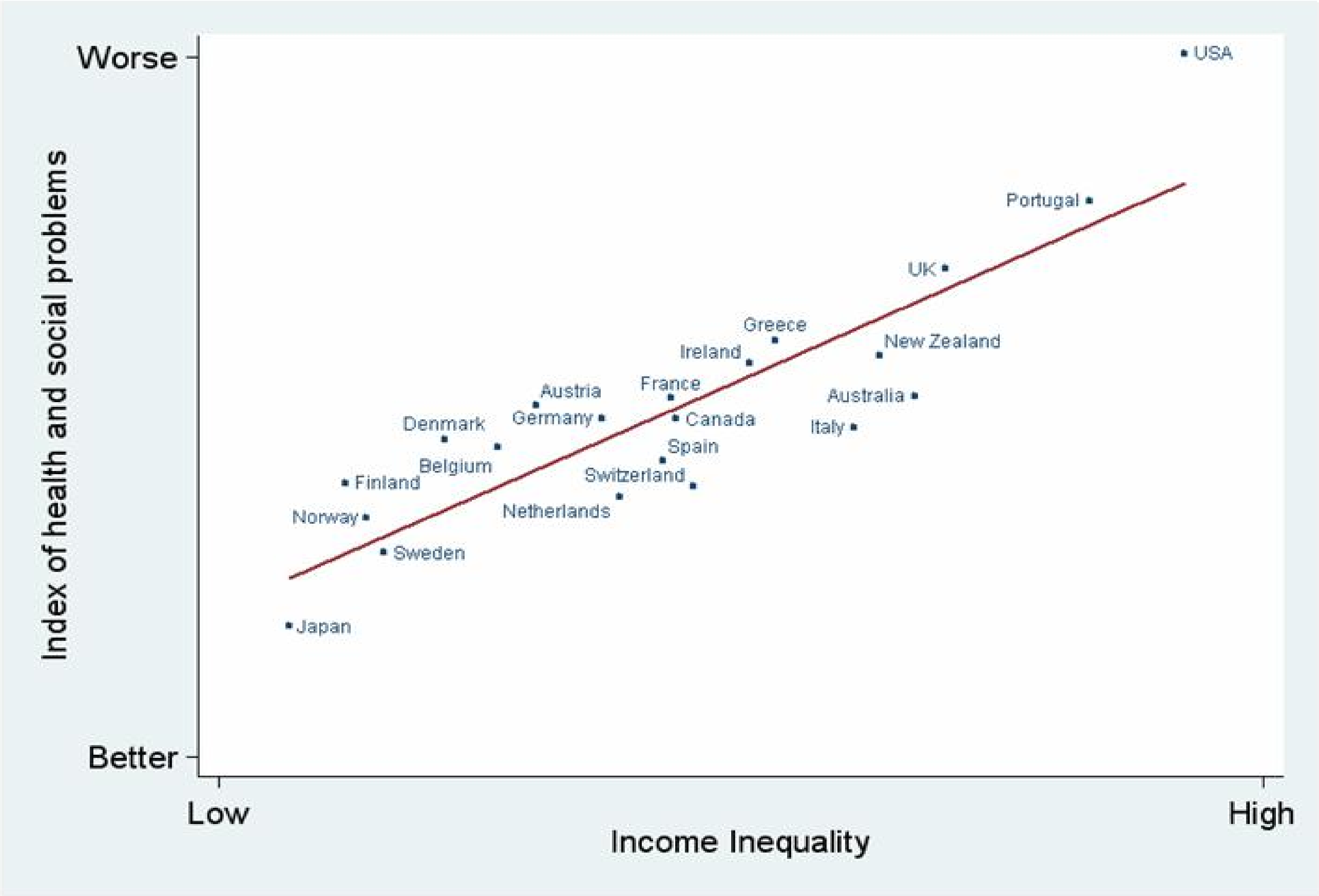
Evolution of Income Equality



Source: S. van der Leeuw

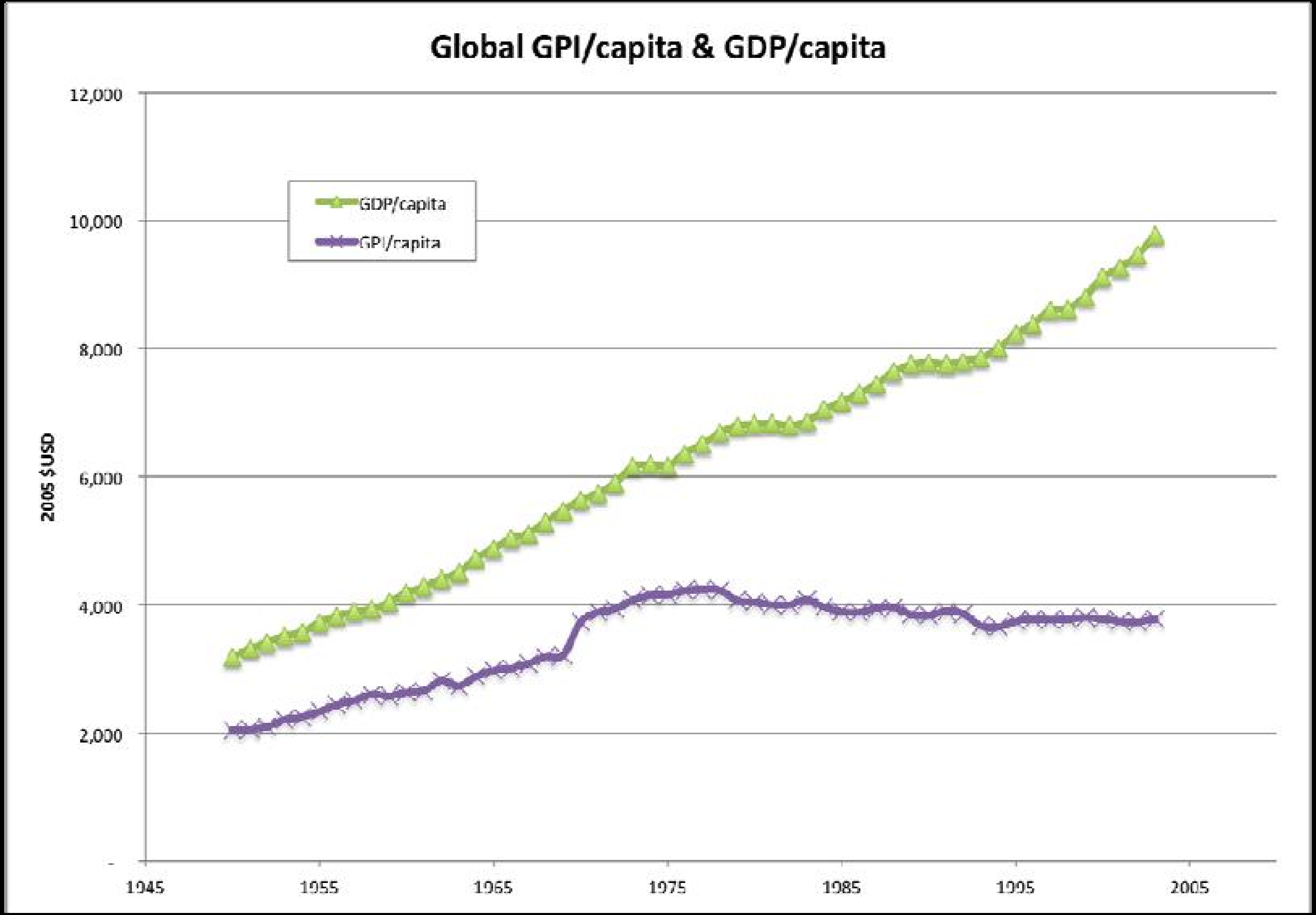
Health and Social Problems are Worse in More Unequal Countries

Index of:
- Life expectancy
- Math & Literacy
- Infant mortality
- Homicides
- Imprisonment
- Teenage births
- Trust
- Obesity
- Mental illness – incl. drug & alcohol addiction
- Social mobility



Source: Wilkinson & Pickett, The Spirit Level (2009)

Beyond GDP: Genuine Progress Indicator



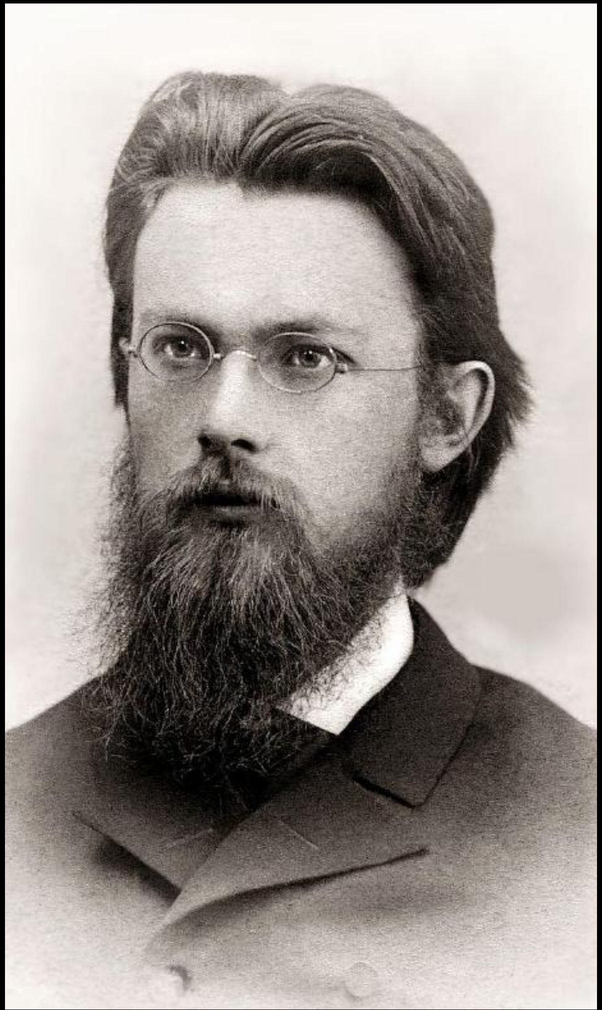
Kubiszewski et al. 2013

The Anthropocene

The Biosphere

In 1857, Austrian geologist Eduard Suess (1831-1914) introduces the concept of the biosphere, which was popularized in 1926 by Ukrainian/Russian scientist Vladimir I. Vernadskij (1863-1945).

Suess



Vernadsky

The realization that human activities affect the Earth system

In 1873, the Italian geologist and catholic priest Antonio Stoppani (1824-1891) was among the first to propose a geological epoch dominated by human activities that altered the shape of the land.

He referred to the 'anthropozoic era".

The realization that human activities affect the Earth system

In 1864, American philologist George Perkins Marsh (1801-1882) publishes a book entitled “Man and Nature, or physical geography as modified by human actions.

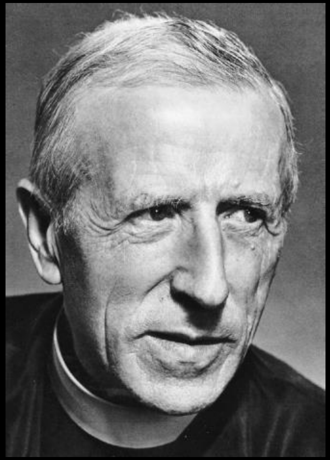
This Republican diplomat is often regarded as the first America’s environmentalist who recognized the irreversible impact of human activities on our planet.

The noosphere

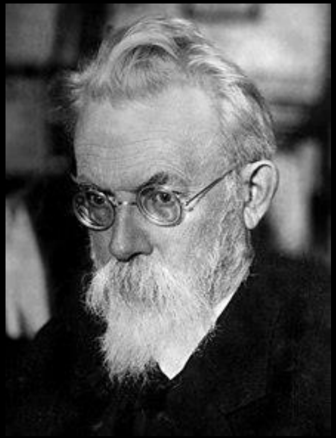
Planetary sphere of reason

Around 1925, two heterodox Catholic thinkers, the French mathematician and philosopher Edouard Le Roy (1870-1954) and the French philosopher, Jesuit Pierre Teilhard de Chardin (1881-1955) together with the Russian-Ukrainian geologist Vladimir Ivanovič Vernadskij (1863-1945), introduced the concept of the noosphere, a stage of evolutionary development dominated by consciousness, the mind and interpersonal relationships.

Le Roy



Teilhard de Chardin



Vernadskij

Evolution initiated by humans

- The Industrial revolution has initiated a profound change in our energy system.
- The rate of carbon emissions to the atmosphere (~10 Pg/yr) is probably the highest in the last ~66 Ma
- The rate of ocean acidification is unparalleled in the last ~300 Ma
- In one century, the Haber-Bosch process has doubled the amount of reactive nitrogen in the Earth System

Today, human activities rival the great forces of nature in driving changes to the Earth System.

Equation of the Earth System at the highest level of abstraction

During the Holocene, the astronomical and geological forcings have become considerably smaller than the human forcing, so that the 'Anthropocene equation' becomes

$$\frac{dE}{dt} = f(I, H)$$

where the human forcing H can be represented as

$$H = f(P, C, T)$$

if *P* is population, *C* is consumption and *T* technological development (energy system, knowledge development and political economy).

The "Anthropocene"

by Paul J. Crutzen and Eugene F. Stoermer

The name Holocene ("Recent Whole") for the post-glacial geological epoch of the past ten to twelve thousand years seems to have been proposed for the first time by Sir Charles Lyell in 1833, and adopted by the International Geological Congress in Bologna in 1885 (1). During the Holocene mankind's activities gradually grew into a significant geological, morphological force, as recognised early on by a number of scientists. Thus, G.P. Marsh already in 1864 published a book with the title "Man and Nature", more recently reprinted as "The Earth as Modified by Human Action" (2). Stoppani in 1873 rated mankind's activities as a "new telluric force which in power and universality may be compared to the greater forces of earth" [quoted from Clark (3)]. Stoppani already spoke of the anthropozoic era. Mankind has now inhabited or visited almost all places on Earth; he has even set foot on the moon.

The great Russian geologist V.I. Vernadsky (4) in 1926 recognized the increasing power of mankind as part of the biosphere with the following excerpt "... the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings". He, the French Jesuit P. Teilhard de Chardin and E. Le Roy in 1924 coined the term "noösphere", the world of thought, to mark the growing role played by mankind's brainpower and technological talents in shaping its own future and envi-

panied e.g. by a growth in cattle population to 1400 million (6) (about one cow per average size family). Urbanisation has even increased tenfold in the past century. In a few generations mankind is exhausting the fossil fuels that were generated over several hundred million years. The release of SO_2, globally about 160 Tg/year to the atmosphere by coal and oil burning, is at least two times larger than the sum of all natural emissions, occurring mainly as marine dimethyl-sulfide from the oceans (7); from Vitousek et al. (8) we learn that 30-50% of the land surface has been transformed by human action; more nitrogen is now fixed synthetically and applied as fertilizers in agriculture than fixed naturally in all terrestrial ecosystems; the escape into the atmosphere of NO from fossil fuel and biomass combustion likewise is larger than the natural inputs, giving rise to photochemical ozone ("smog") formation in extensive regions of the world; more than half of all accessible fresh water is used by mankind; human activity has increased the species extinction rate by thousand to ten thousand fold in the tropical rain forests (9) and several climatically important "greenhouse" gases have substantially increased in the atmosphere: CO_2 by more than 30% and CH_4 by even more than 100%. Furthermore, mankind releases many toxic substances in the environment and even some, the chlorofluorocarbon gases, which are not toxic at all, but which nevertheless have

groves. Finally, mechanized human predation ("fisheries") removes more than 25% of the primary production of the oceans in the upwelling regions and 35% in the temperate continental shelf regions (10). Anthropogenic effects are also well illustrated by the history of biotic communities that leave remains in lake sediments. The effects documented include modification of the geochemical cycle in large freshwater systems and occur in systems remote from primary sources (11-13).

Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "anthropocene" for the current geological epoch. The impacts of current human activities will continue over long periods. According to a study by Berger and Loutre (14), because of the anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour over the next 50,000 years.

To assign a more specific date to the onset of the "anthropocene" seems somewhat arbitrary, but we propose the latter part of the 18th century, although we are aware that alternative proposals can be made (some may even want to include the entire holocene). However, we choose this date because, during the past two centuries, the global effects of human activities have become clearly

Paul Crutzen

IGBP Newsletter 41: May 2000

The Anthropocene

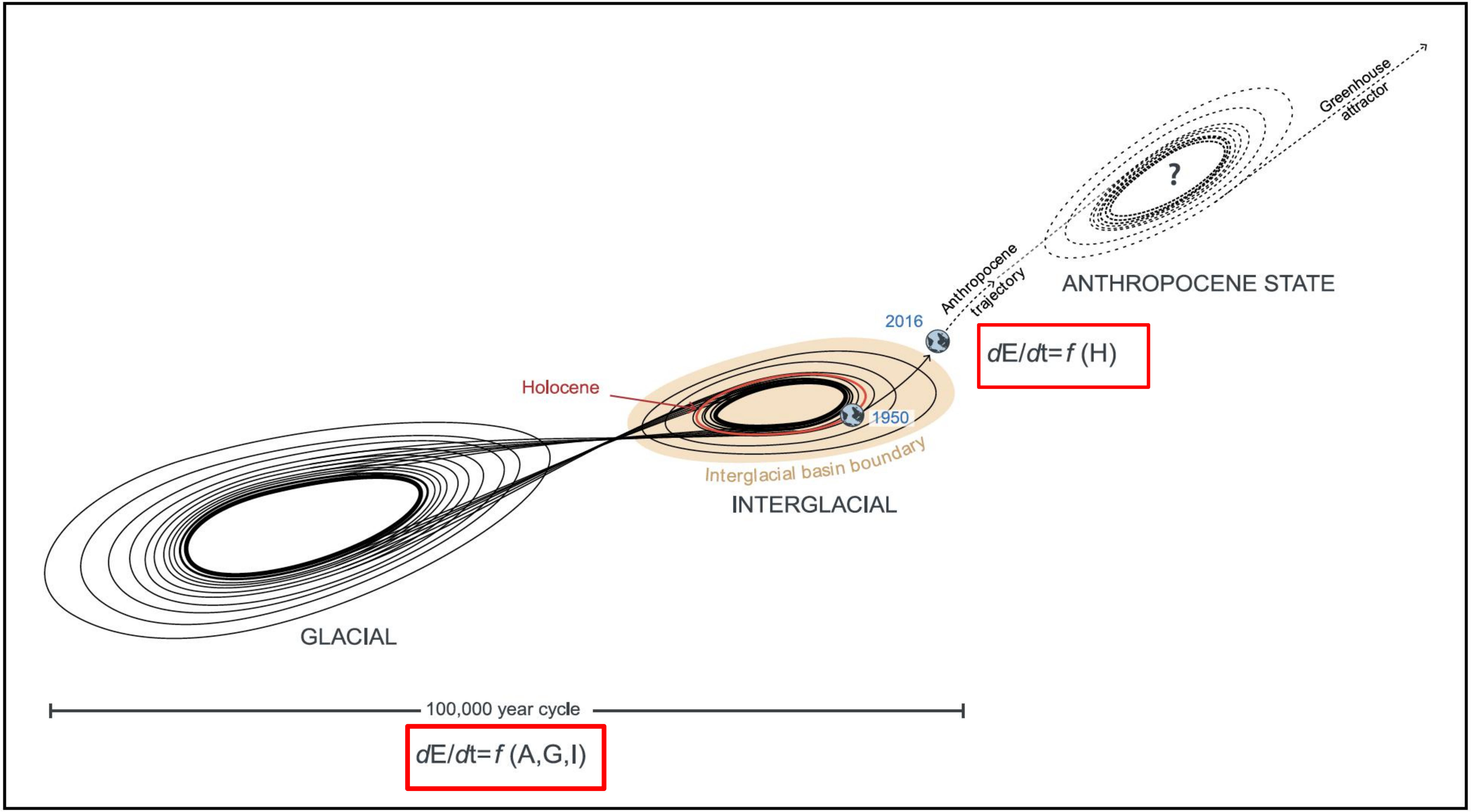
- The current geological age, viewed as the period during which human activity has been the dominant influence on climate and the environment.

- a proposed geological epoch dating from the commencement of significant human impact on Earth's geology and ecosystems including, but not limited to, anthropogenic climate change.

The Anthropocene

“The pressures we exert on the planet have become so great that scientists are considering whether the Earth has entered an entirely new geological epoch: the Anthropocene, or the age of humans. It means that we are the first people to live in an age defined by human choice, in which the dominant risk to our survival is ourselves.”

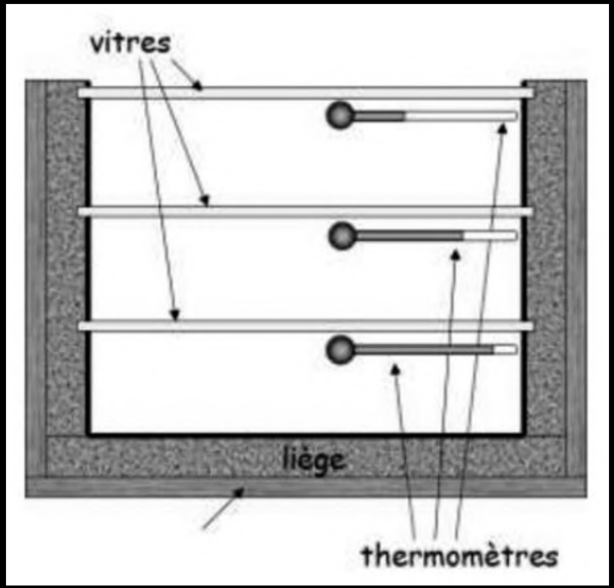
- *—Achim Steiner, UNDP Administrator*


Greenhouse attractor
?
Anthropocene trajectory
ANTHROPOCENE STATE
2016
$dE/dt = f\,(H)$
Holocene
1950
Interglacial basin boundary
INTERGLACIAL
GLACIAL
100,000 year cycle
$dE/dt = f\,(A,G,I)$

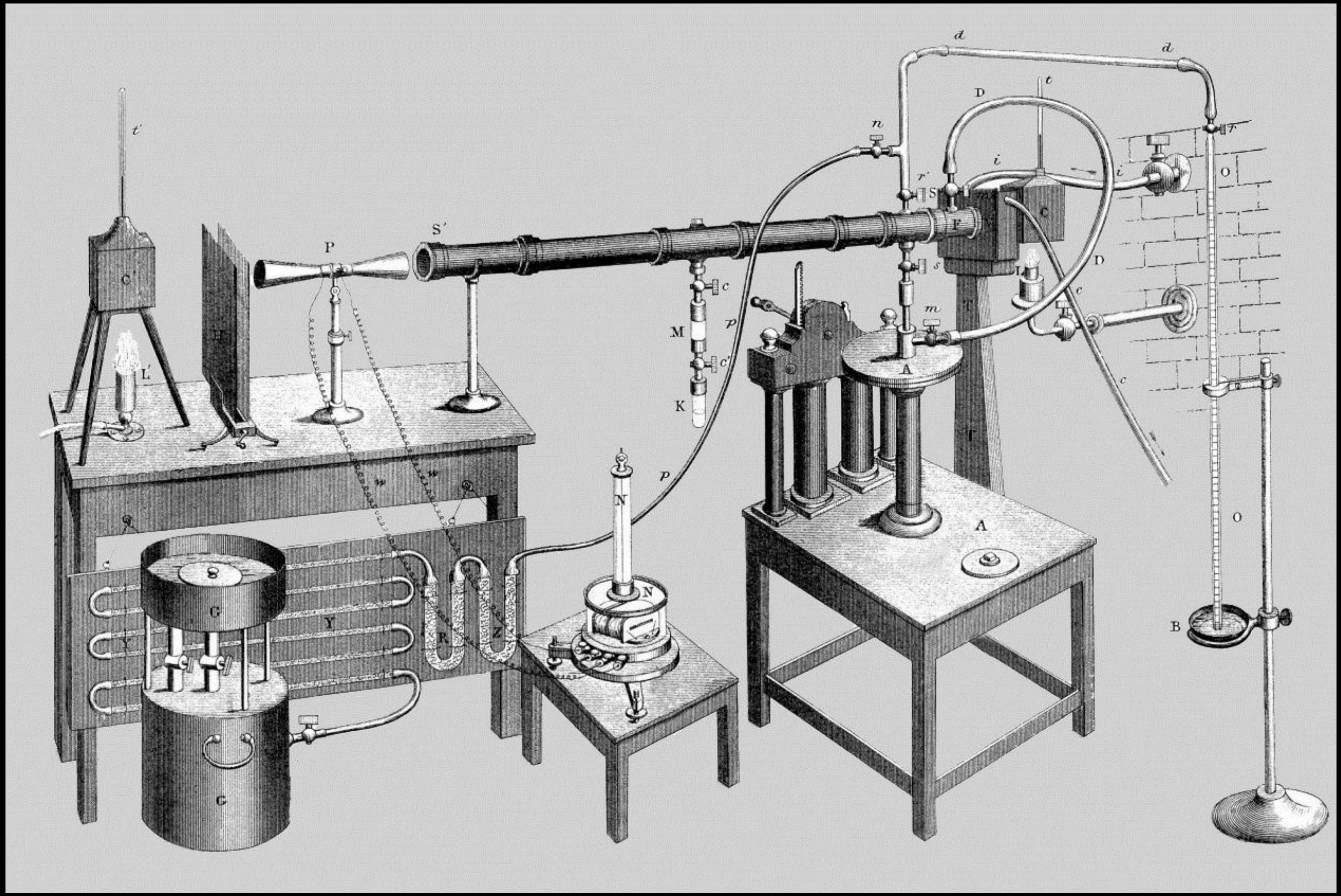
Climate Change

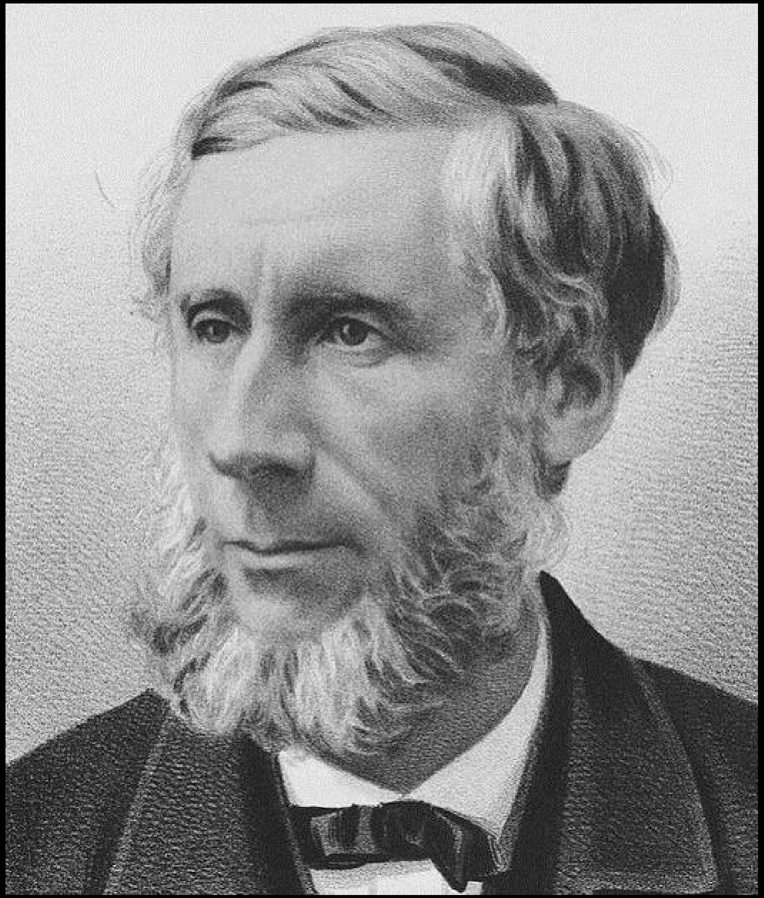
1788-1824: Discovery of the the Greenhouse Effect

In 1788, Horace Benedict de Saussure at the top of the Mont Blanc discovers that the temperature inside a glass bowl is higher than outside. Jean-Baptiste Fourier draws a parallel with the atmosphere: Solar light penetrates through the glass and is absorbed by the walls of the recipient. The energy is released as emission of some obscure heat released that warms the space and is trapped inside the glass bowl.

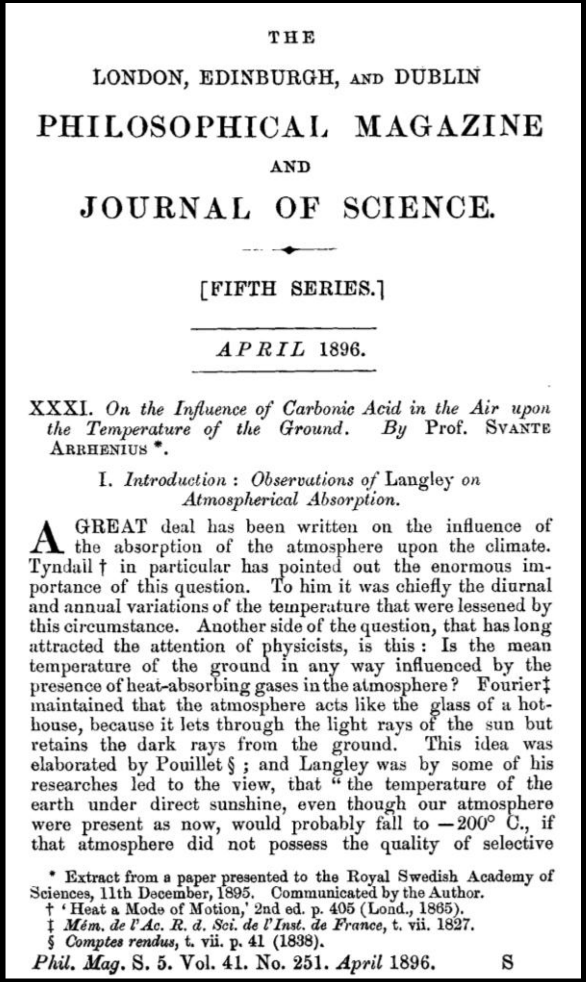


1859: John Tyndall measure the absorption of obscure radiation (IR) by CO_2 and H_2O





1896: The Greenhouse Effect and the role of CO_2



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* *By* Prof. SVANTE ARRHENIUS *.

I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.

† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).

‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.

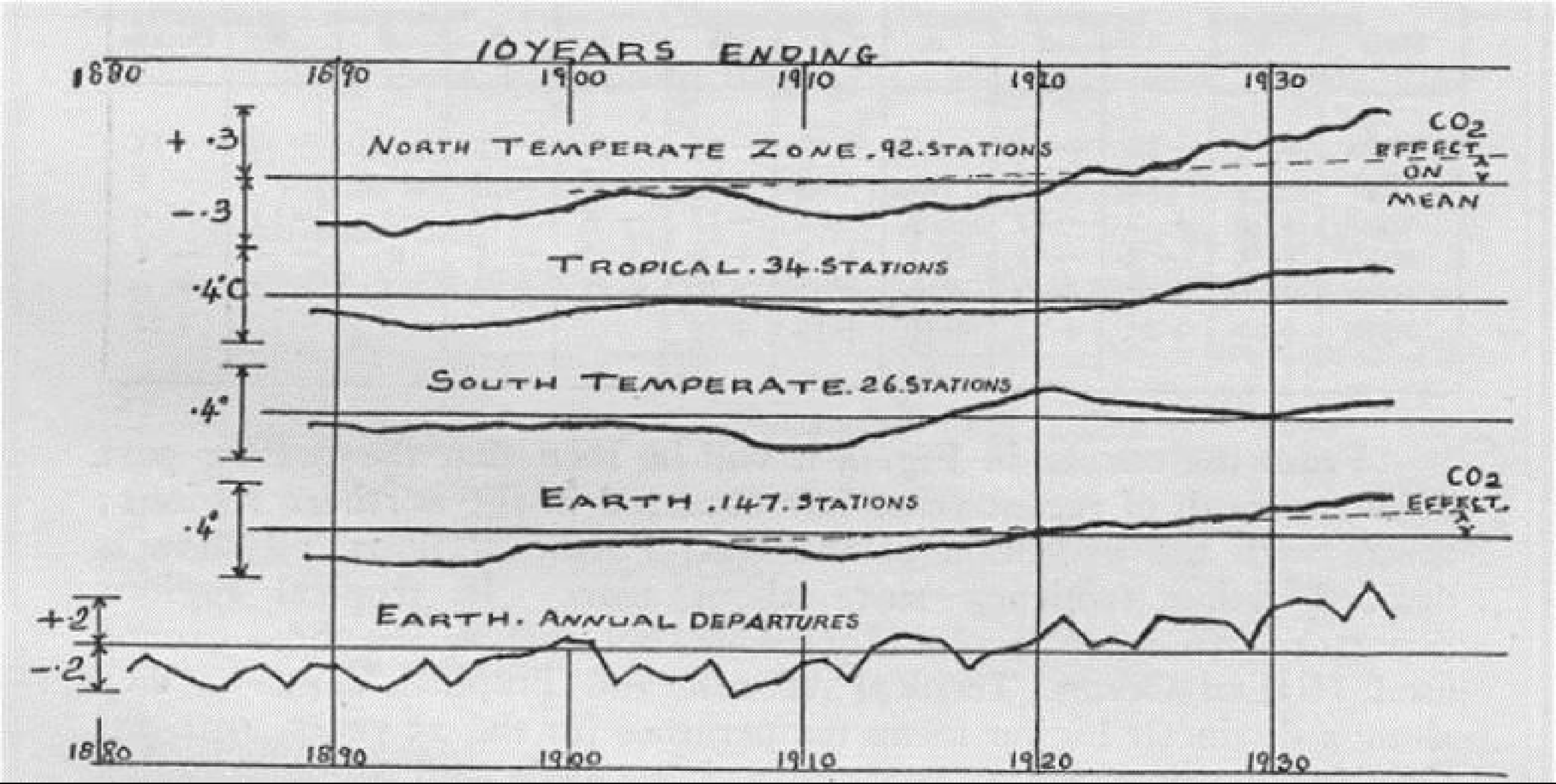
§ *Comptes rendus*, t. vii. p. 41 (1838).

Svante Arrhenius highlights the impact of increasing carbon monoxide on climate:

"If the level of carbonic acid increases geometrically, the temperature should increase quasi-linearly". A doubling of CO_2 would lead to a 5-6 C warming.

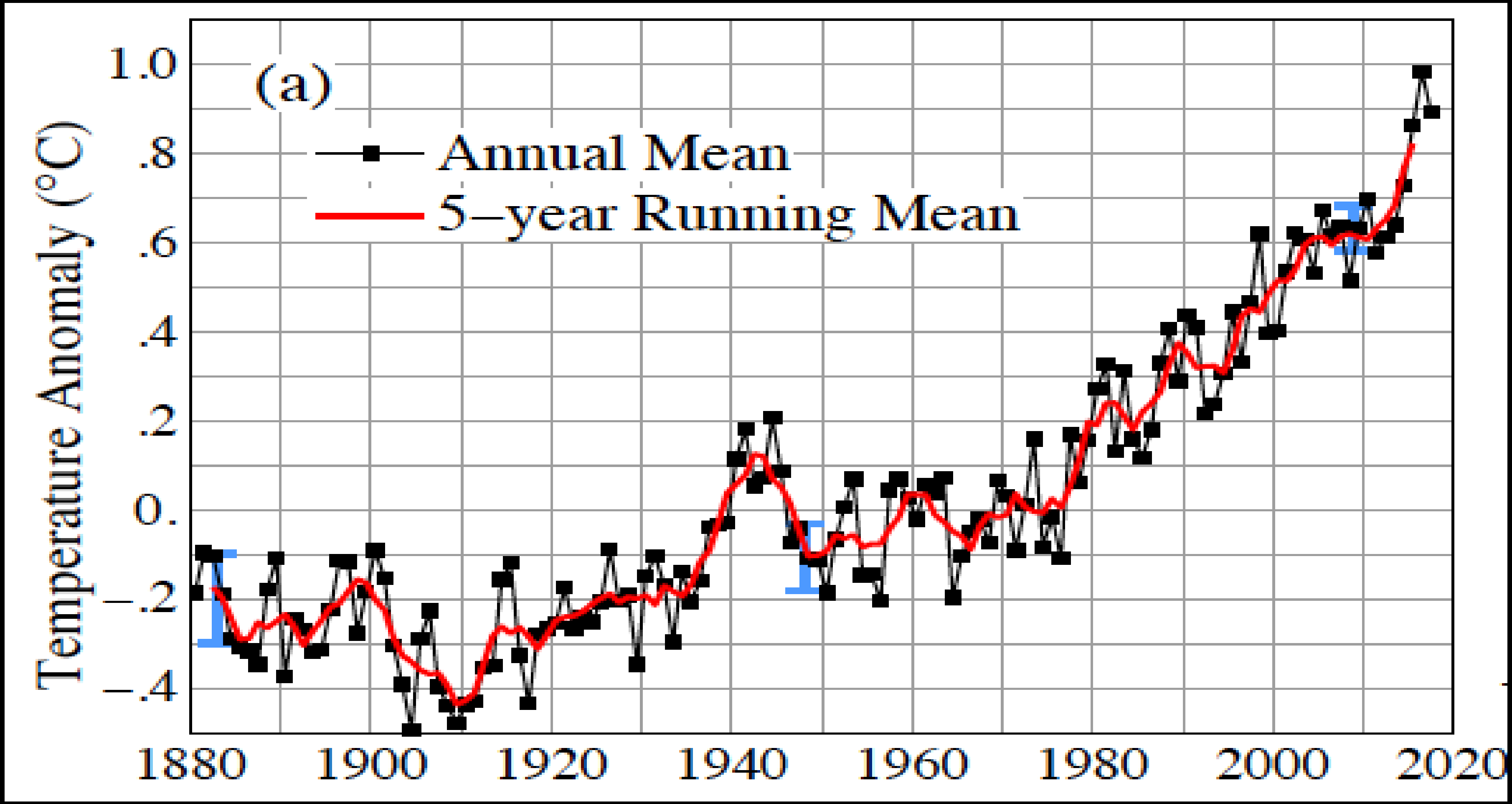
However, experimental measurements suggests that most of the greenhouse warming is provided by water vapor rather than CO_2 and the interest in the CO_2 problem vanishes…. For a while.

1938: Steam Engineer Guy calendar finds a relation between CO_2 increase and temperature trends



Climate Change

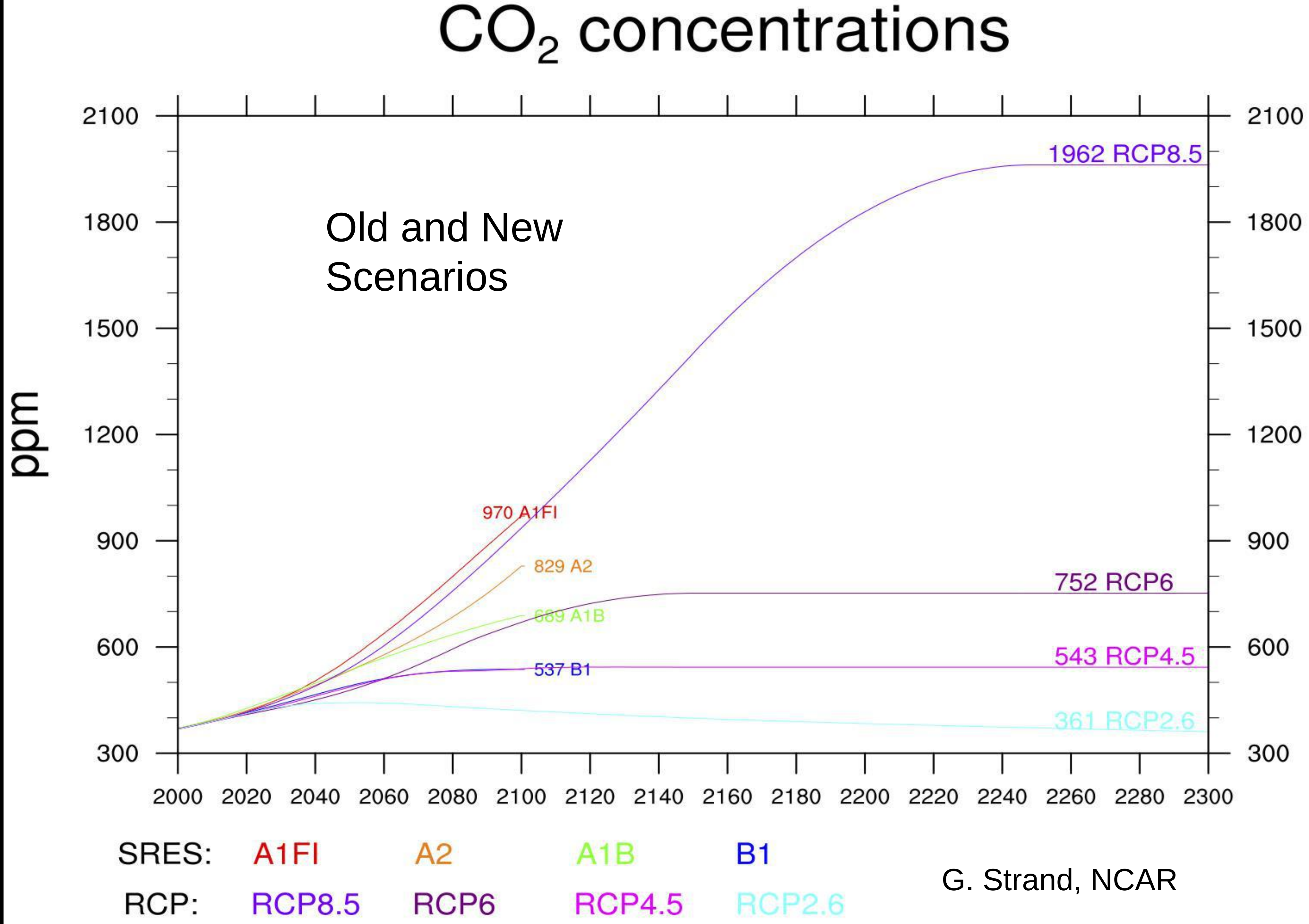
Global Average Temperature Anomaly, 1880-2017



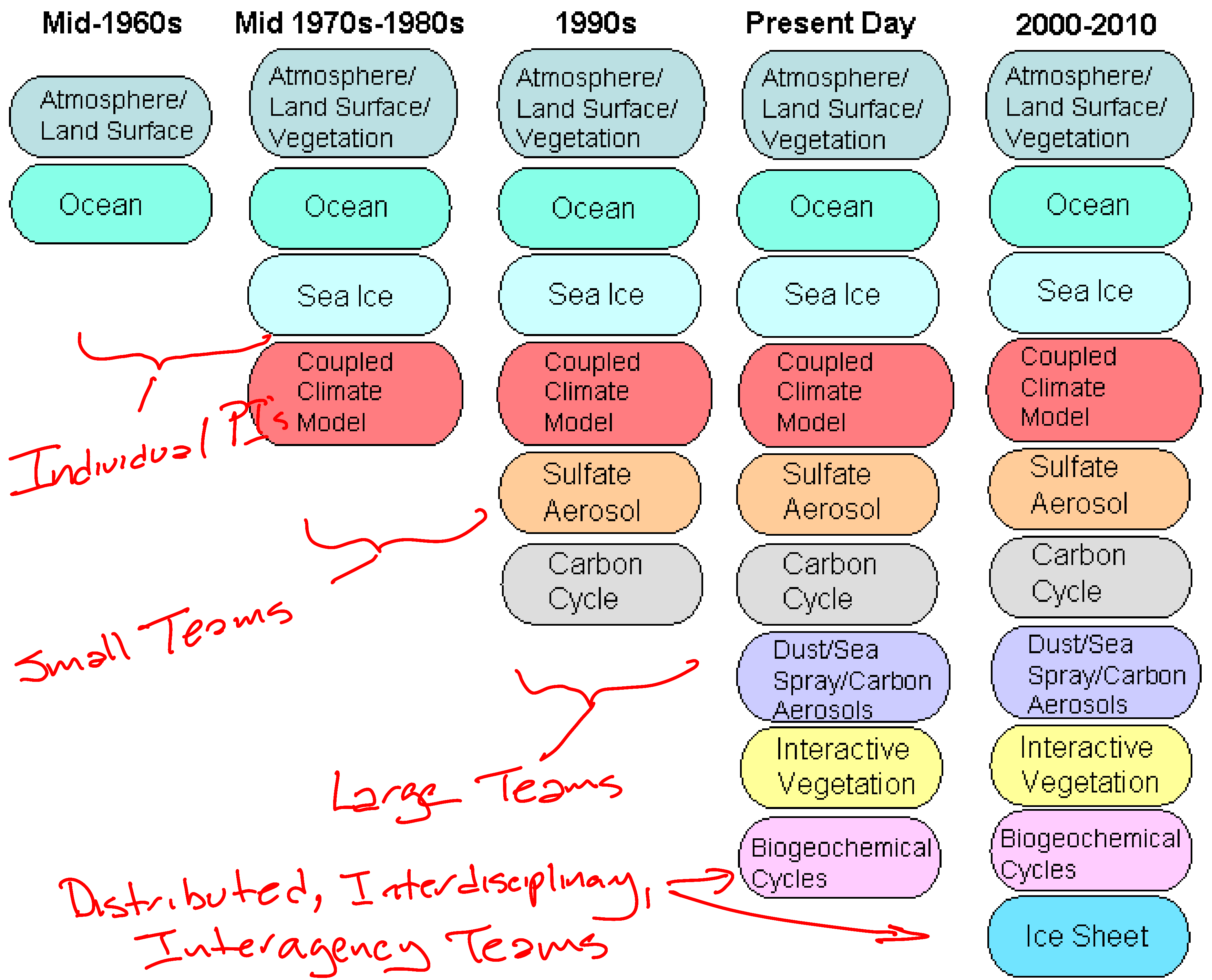
Baseline is 1951-1980

NASA 2018

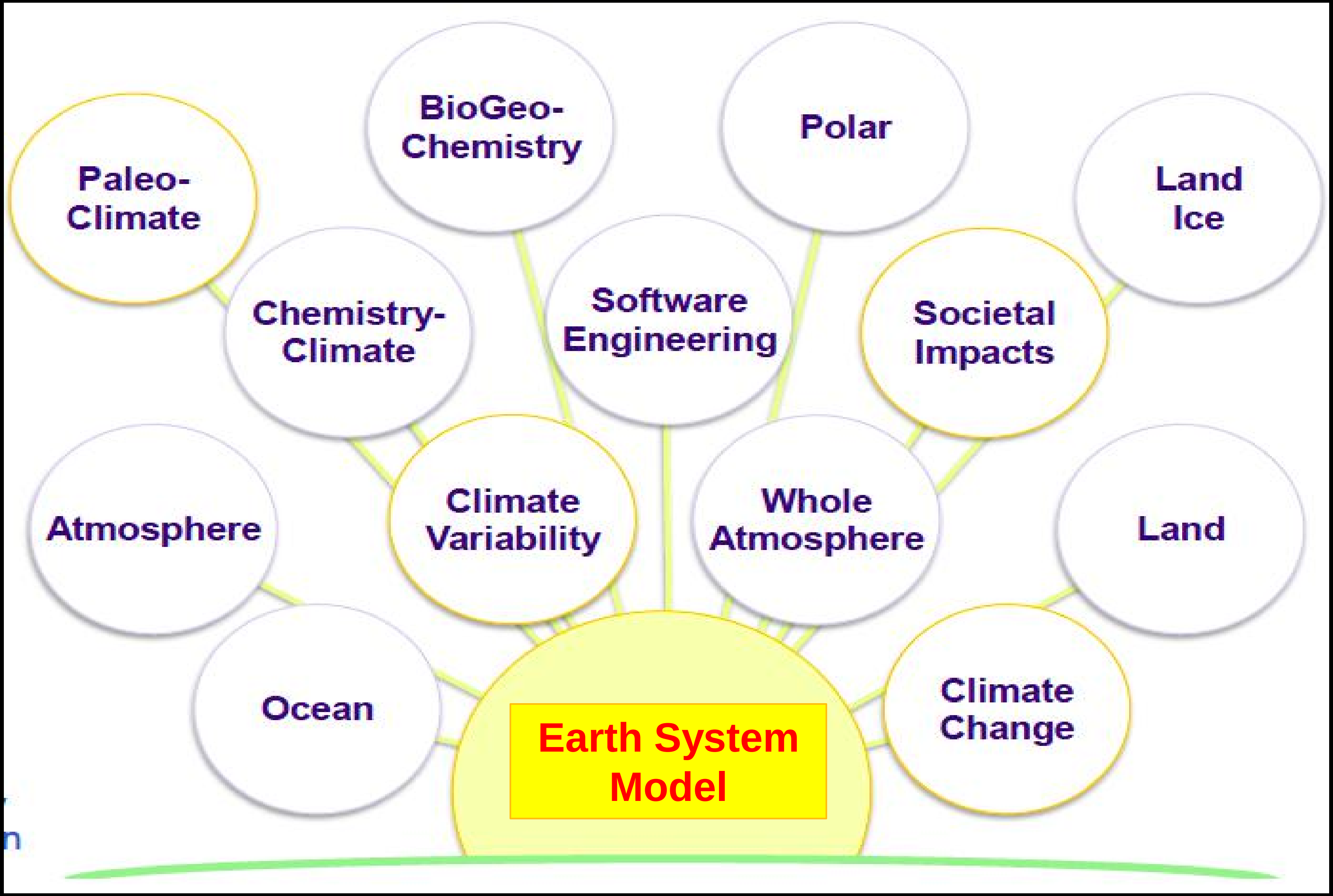
Future climate projections

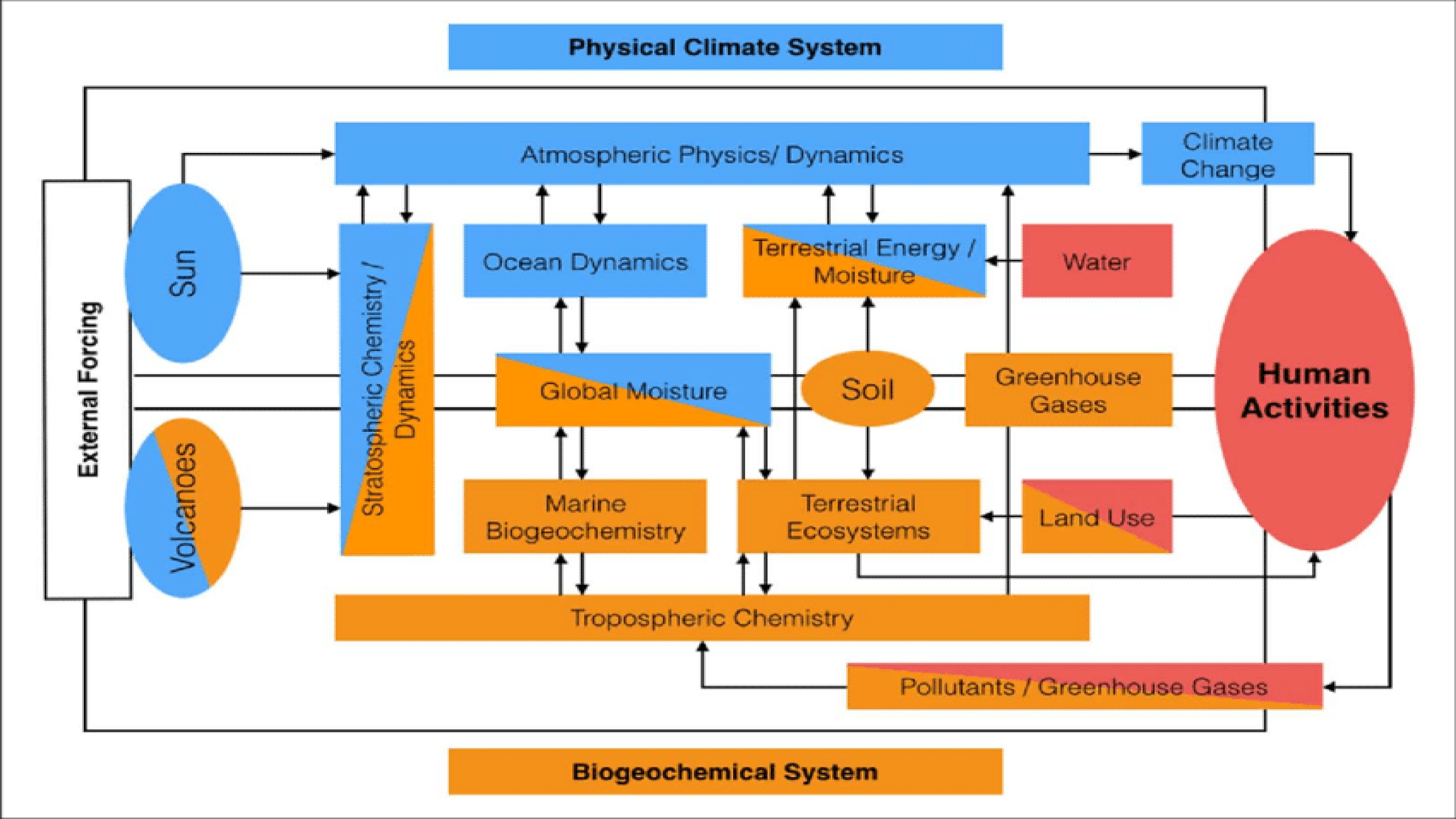


CO_2 concentrations
Old and New Scenarios
ppm
2100
1800
1500
1200
900
600
300
2000 2020 2040 2060 2080 2100 2120 2140 2160 2180 2200 2220 2240 2260 2280 2300
1962 RCP8.5
970 A1FI
829 A2
689 A1B
537 B1
752 RCP6
543 RCP4.5
361 RCP2.6
SRES: A1FI A2 A1B B1
RCP: RCP8.5 RCP6 RCP4.5 RCP2.6
G. Strand, NCAR

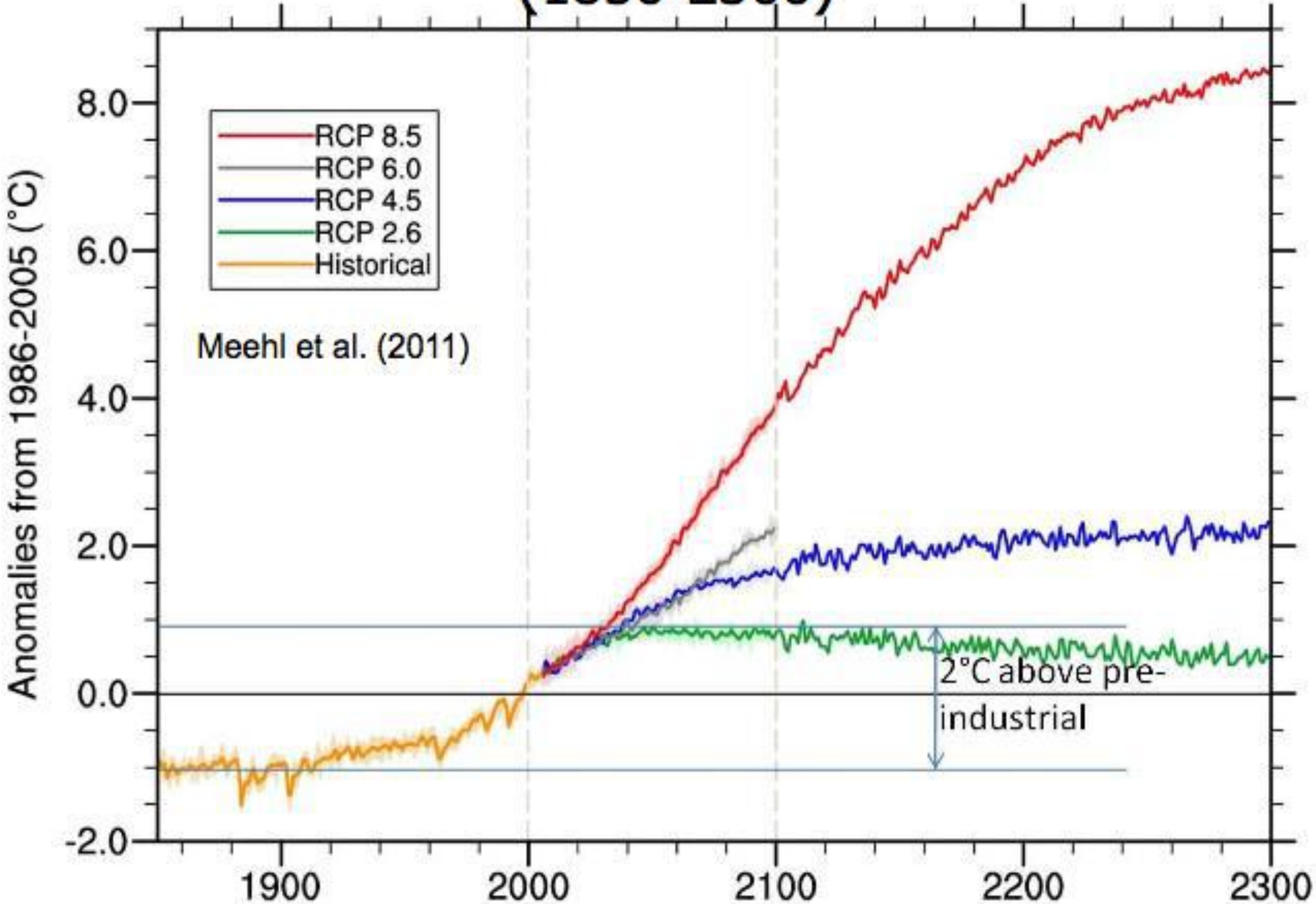

Mid-1960s
Mid 1970s-1980s
1990s
Present Day
2000-2010
Atmosphere/ Land Surface
Ocean
Atmosphere/ Land Surface/ Vegetation
Ocean
Sea Ice
Coupled Climate Model
Atmosphere/ Land Surface/ Vegetation
Ocean
Sea Ice
Coupled Climate Model
Sulfate Aerosol
Carbon Cycle
Atmosphere/ Land Surface/ Vegetation
Ocean
Sea Ice
Coupled Climate Model
Sulfate Aerosol
Carbon Cycle
Dust/Sea Spray/Carbon Aerosols
Interactive Vegetation
Biogeochemical Cycles
Atmosphere/ Land Surface/ Vegetation
Ocean
Sea Ice
Coupled Climate Model
Sulfate Aerosol
Carbon Cycle
Dust/Sea Spray/Carbon Aerosols
Interactive Vegetation
Biogeochemical Cycles
Ice Sheet
Individual PI's
Small Teams
Large Teams
Distributed, Interdisciplinary, Interagency Teams

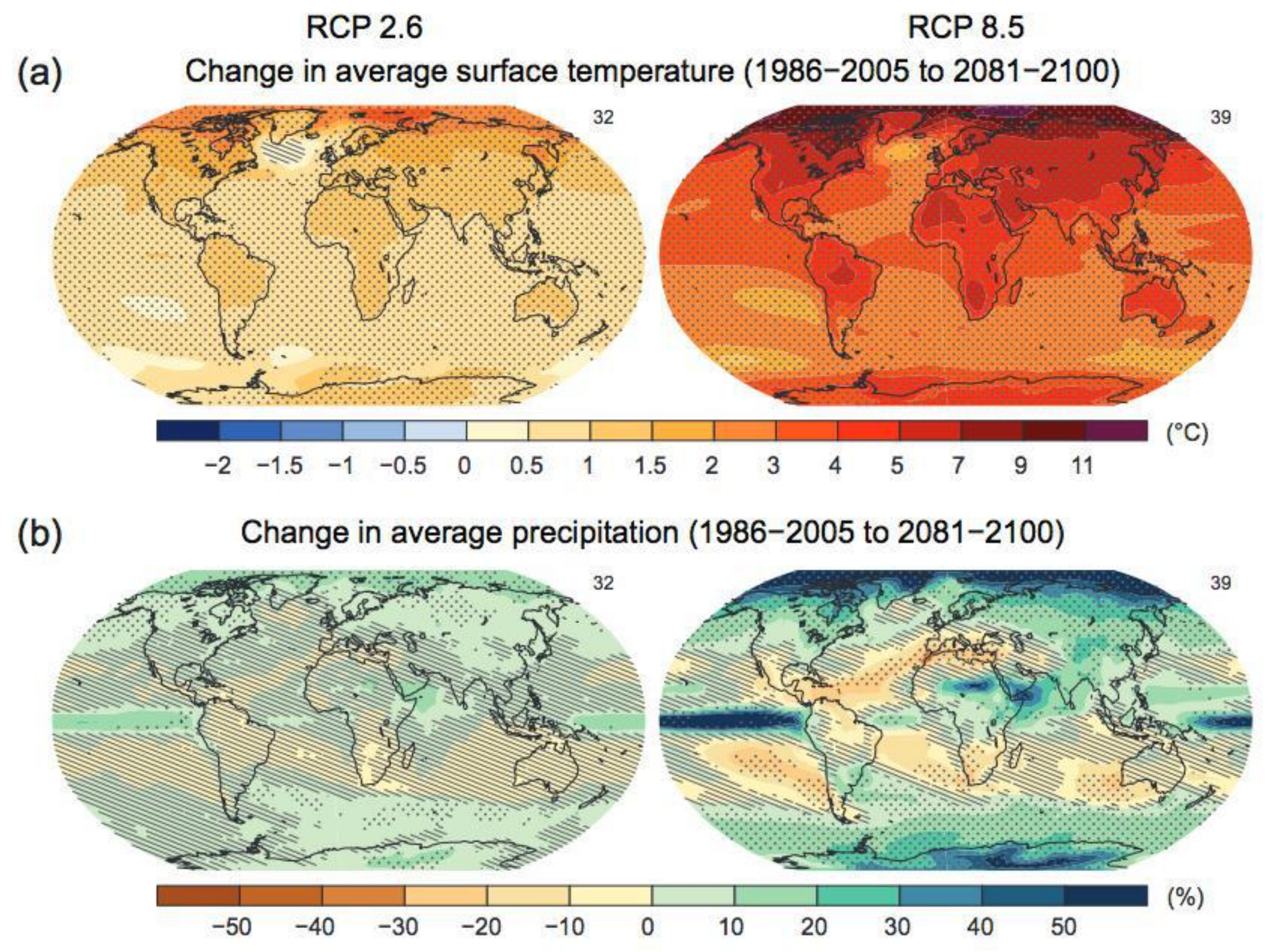
Earth System Model




Physical Climate System
Atmospheric Physics/ Dynamics
Climate Change
External Forcing
Sun
Volcanoes
Stratospheric Chemistry / Dynamics
Ocean Dynamics
Terrestrial Energy / Moisture
Water
Global Moisture
Soil
Greenhouse Gases
Human Activities
Marine Biogeochemistry
Terrestrial Ecosystems
Land Use
Tropospheric Chemistry
Pollutants / Greenhouse Gases
Biogeochemical System

Global Surface Temperature
(1850-2300)

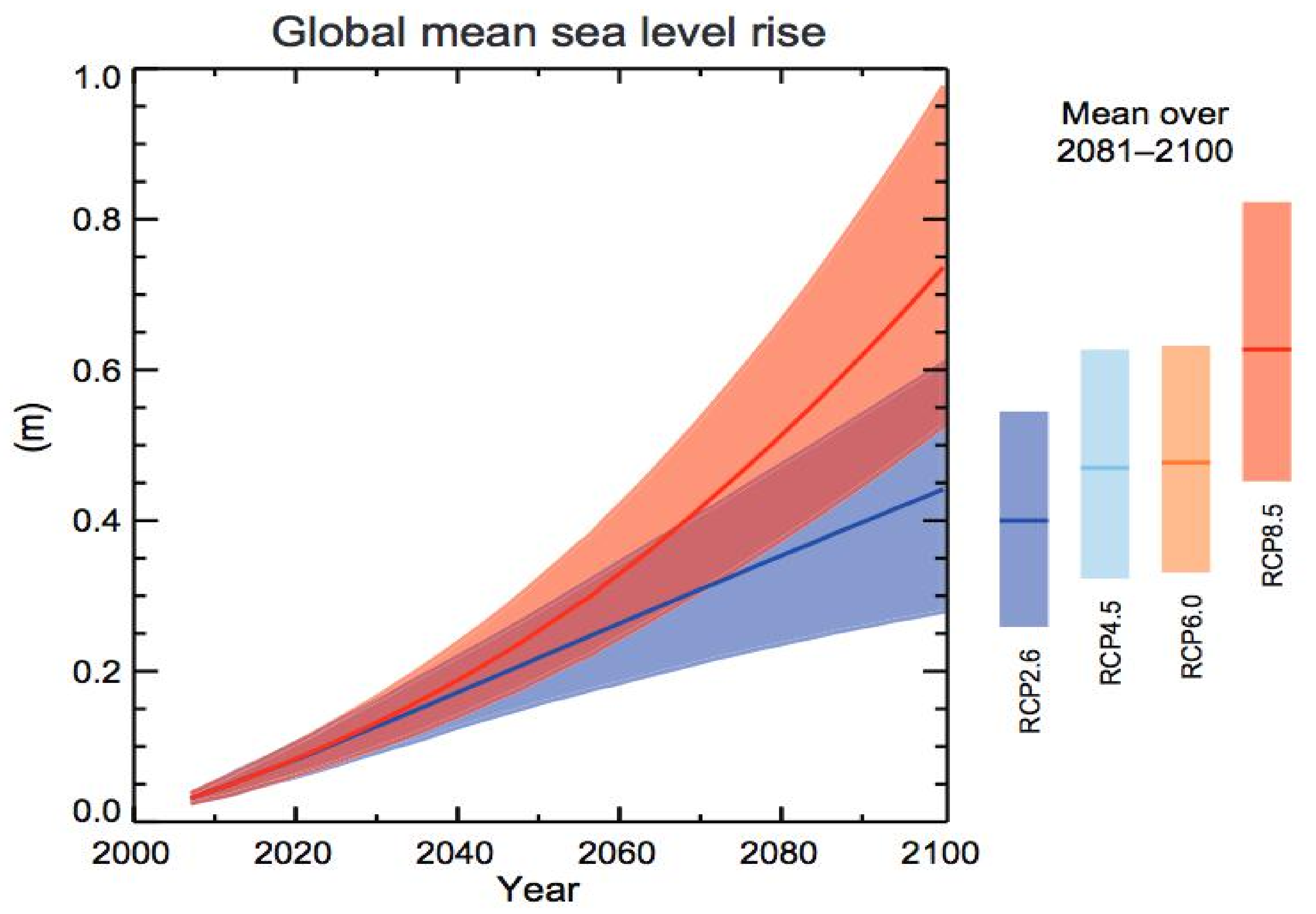



RCP 2.6
RCP 8.5
(a)
Change in average surface temperature (1986−2005 to 2081−2100)
32
39
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)
(b)
Change in average precipitation (1986−2005 to 2081−2100)
32
39
−50 −40 −30 −20 −10 0 10 20 30 40 50
(%)

The role of the ocean in the climate system

Sea Level Rise

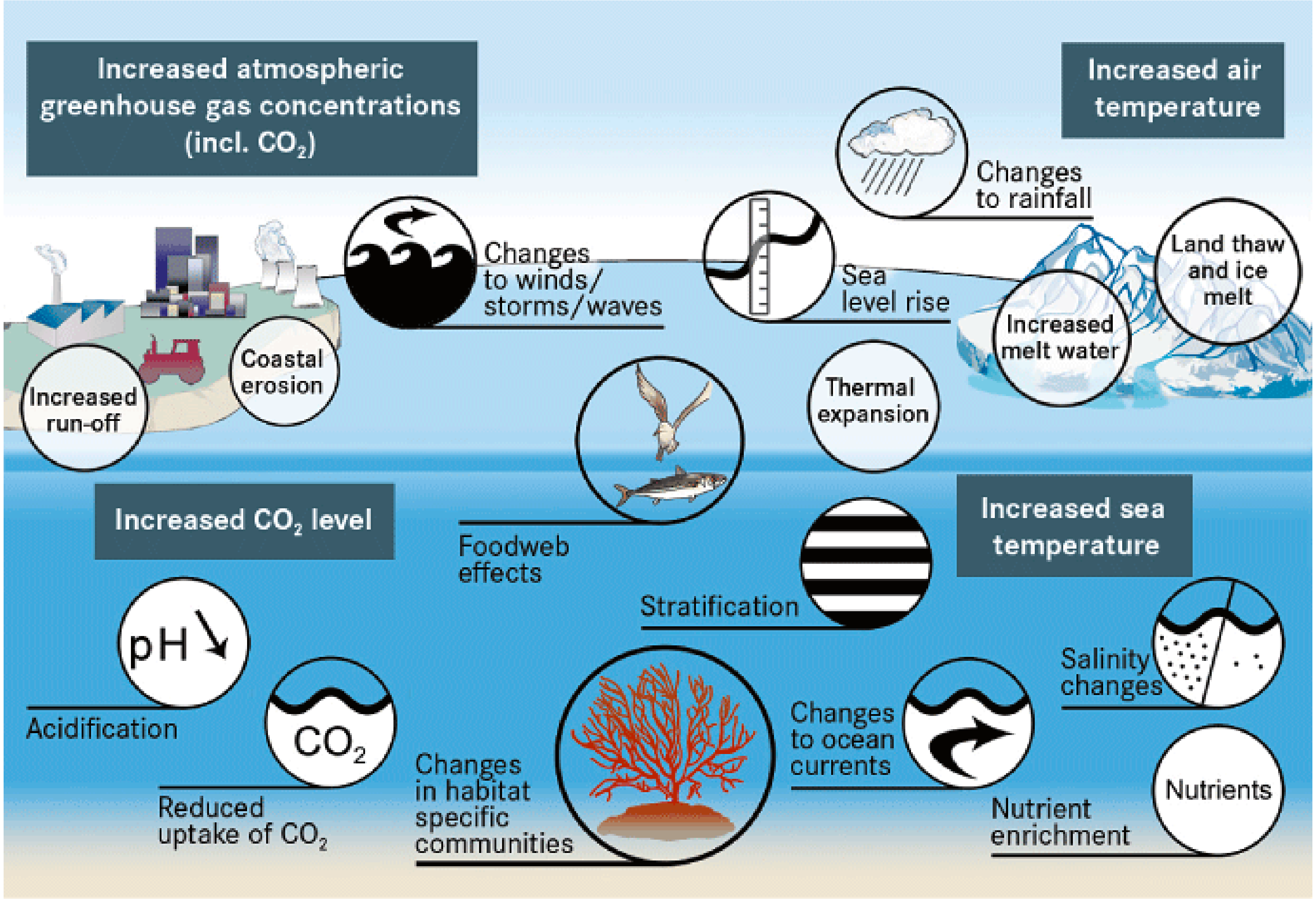
- The sea has risen globally with a speed of 1.7 mm per year during the 20th century. **(3.6 millimeters per year** for 2006–2015).
- This increase is linked to two phenomena:
  - The expansion of sea water due to the increase in ocean temperature
  - The melting of continental ice, glaciers, and polar caps with the supply of fresh water to the ocean
- Sea level rise will reach between 25 and 80 cm in 2100.



Global mean sea level will continue to rise during the 21st century (see Figure SPM.9). Under all RCP scenarios, the rate of sea level rise will *very likely* exceed that observed during 1971 to 2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets. {13.3–13.5}

Ocean Acidification

- The oceans absorb 30% of anthropogenic CO_2, which leads to acidification of seawater.
- The acidity of the oceans has increased by 30% in 250 years, and this acidity continues to increase.
- Acidification threatens species such as oysters and mussels and impacts marine food chains.

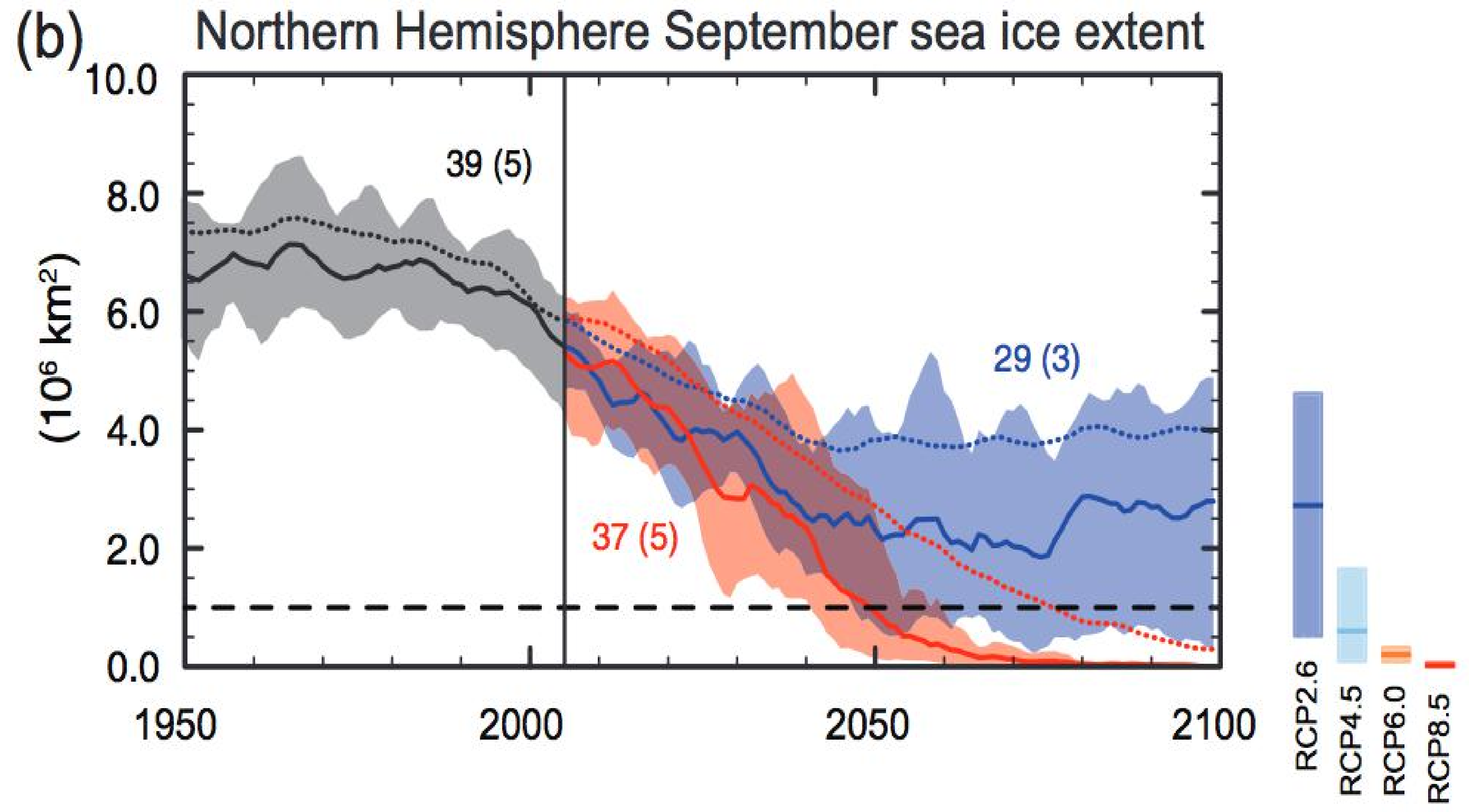


Impact of climate change on the ocean

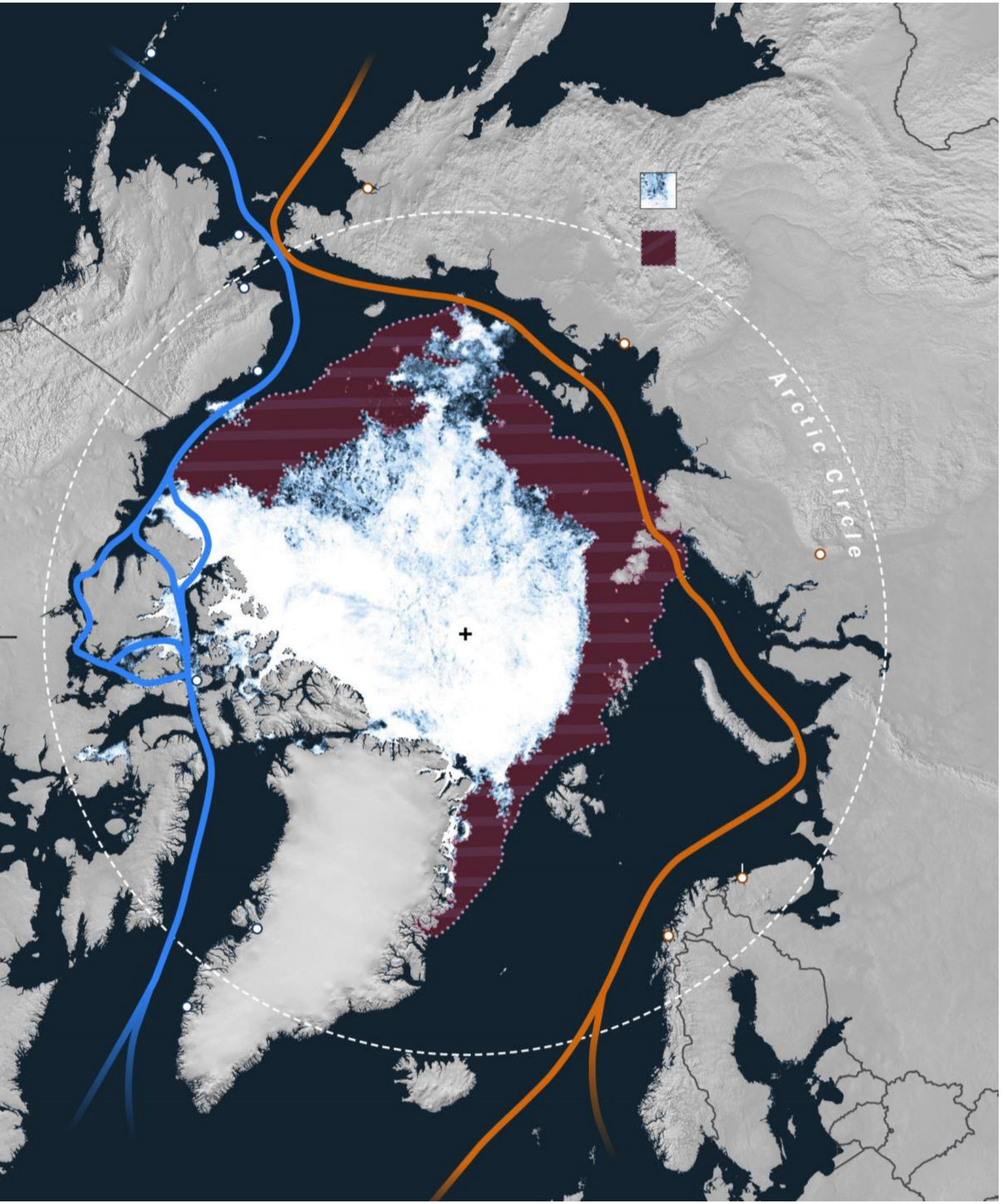
The Arctic: Challenges and Risks

The melting of sea ice induced by climate change opens access to natural resources, maritime routes and polar tourism areas.

These new opportunities for economic development in the Arctic are very attractive with high payoffs (“cold rush”) but with very high financial, environmental and social costs.



It is *very likely* that the Arctic sea ice cover will continue to shrink and thin and that Northern Hemisphere spring snow cover will decrease during the 21st century as global mean surface temperature rises. Global glacier volume will further decrease. {12.4, 13.4}



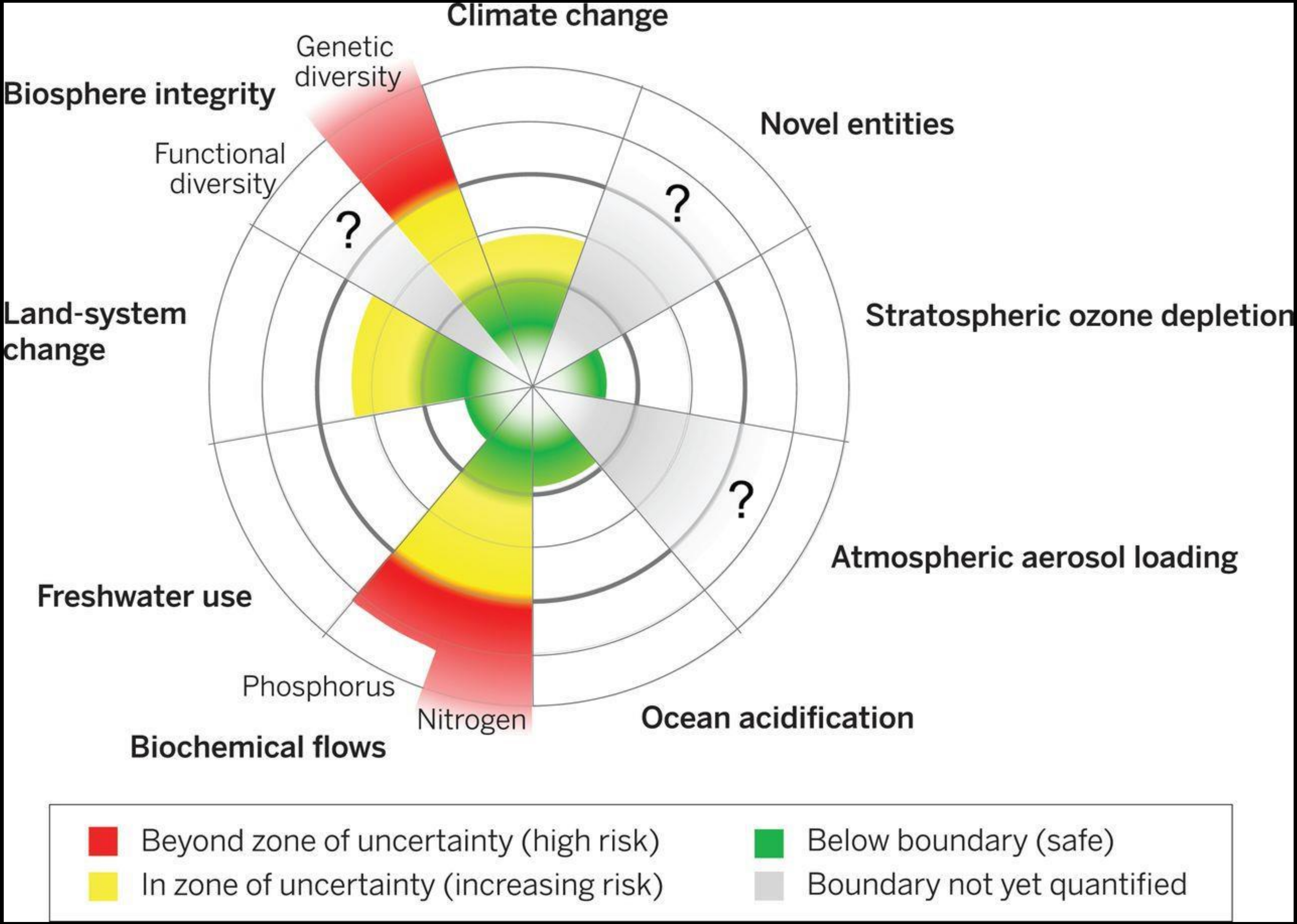
New maritime routes for navigation

In blue : Northwest passage

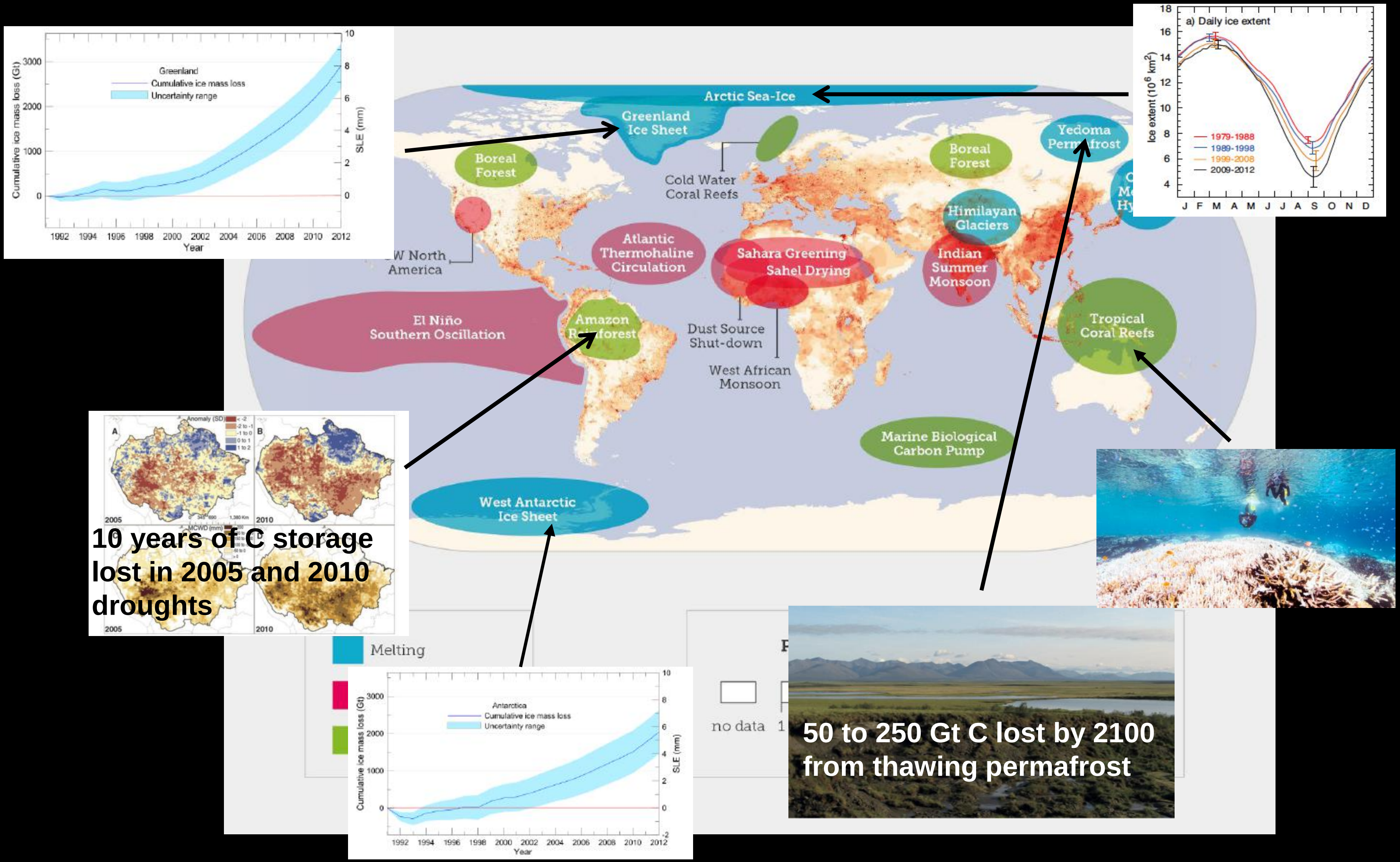
In orange: Northeast passage

Planetary Boundaries
and
Tipping Points

Planetary Boundaries

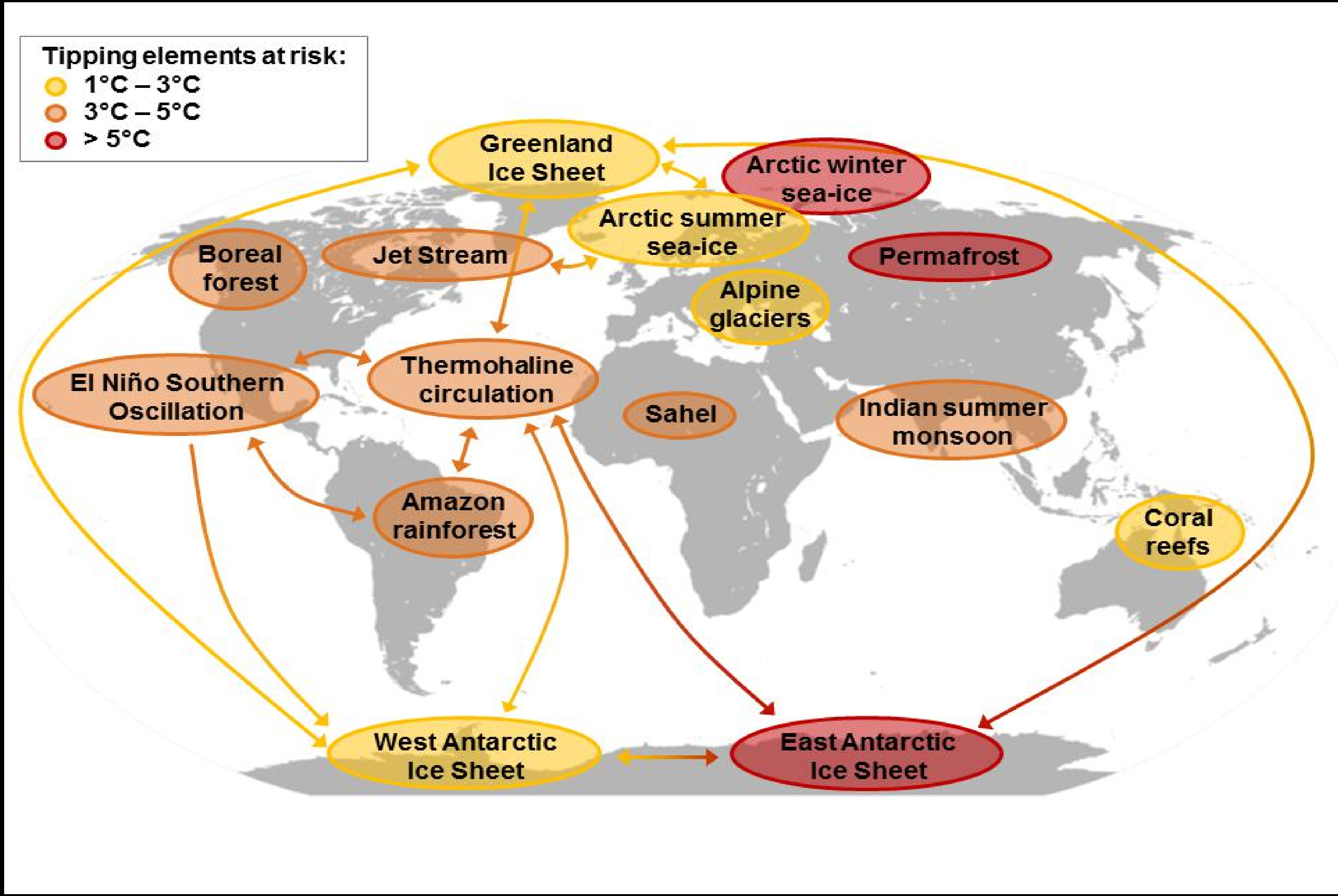


Tipping Elements in the Earth System



Huber, Lenton, and Schellnhuber, in Richardson et al. 2011

Tipping Cascades

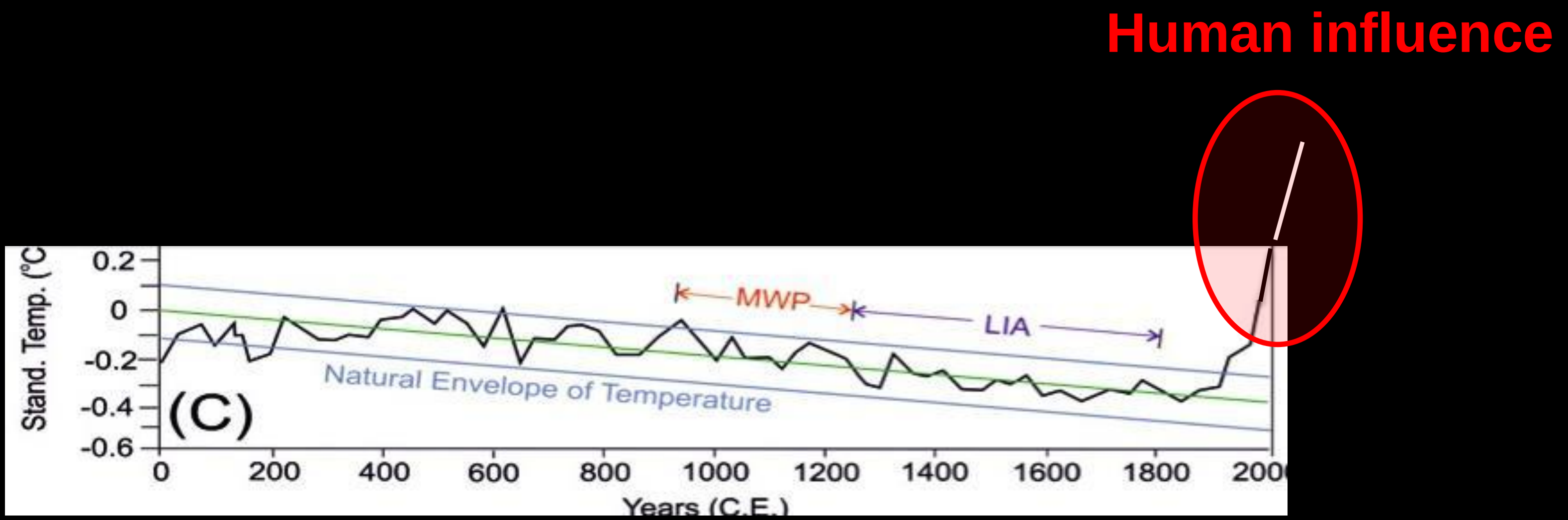


Source: J. Donges and R. Winkelmann in Steffen et al. 2018

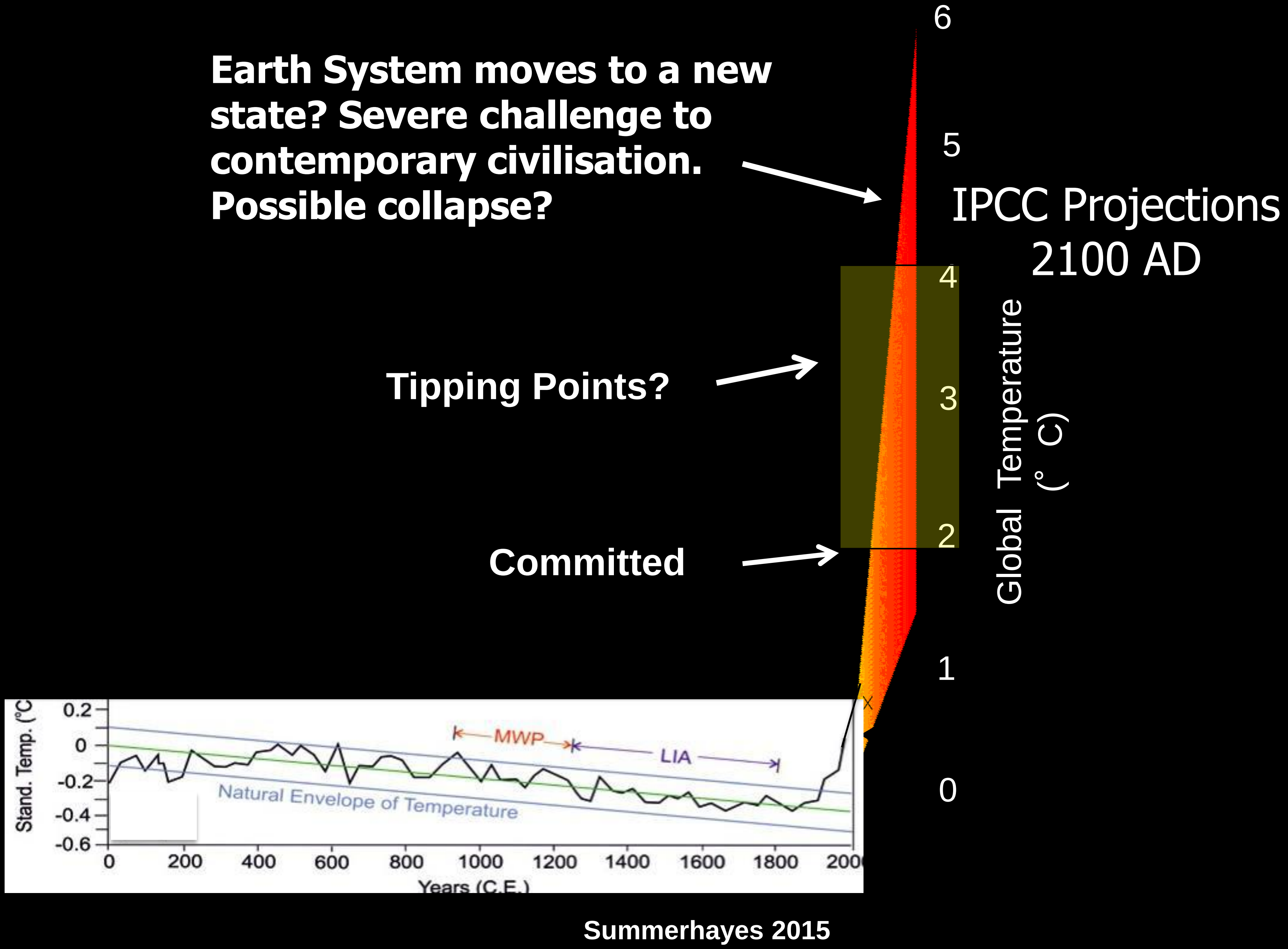
Where on Earth are we going?

Future Trajectories

Temperature rise:
Beyond the envelope of natural variability!

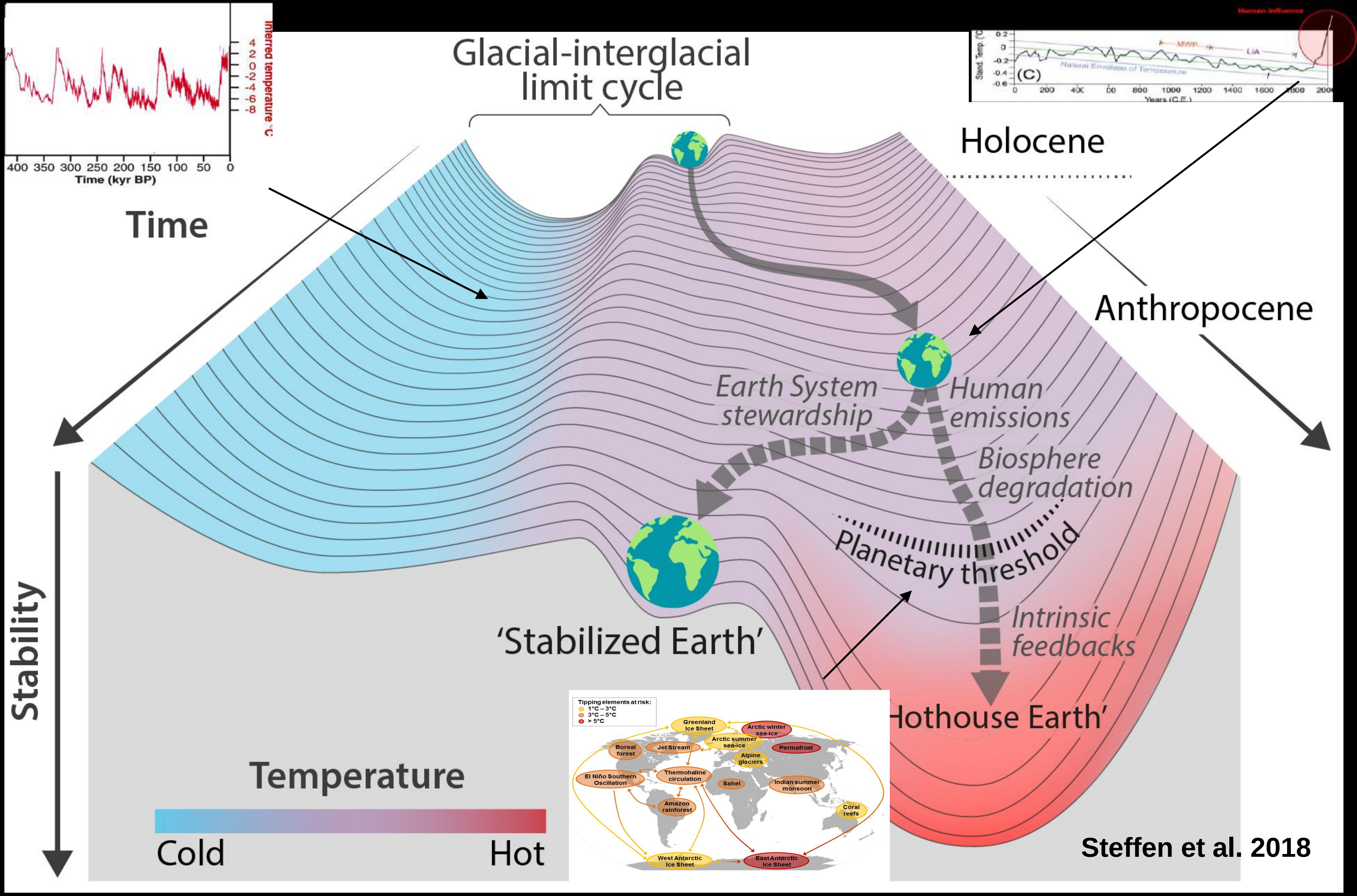


Summerhayes 2015



Earth System moves to a new state? Severe challenge to contemporary civilisation. Possible collapse?
Tipping Points?
Committed
IPCC Projections 2100 AD
Global Temperature (° C)
6
5
4
3
2
1
0
Stand. Temp. (°C
0.2
0
-0.2
-0.4
-0.6
MWP
LIA
Natural Envelope of Temperature
0
200
400
600
800
1000
1200
1400
1600
1800
Years (C.E.)
Summerhayes 2015

Earth System Trajectories



Steffen et al. 2018

Towards Solutions:

Mitigation or Adaptation ?

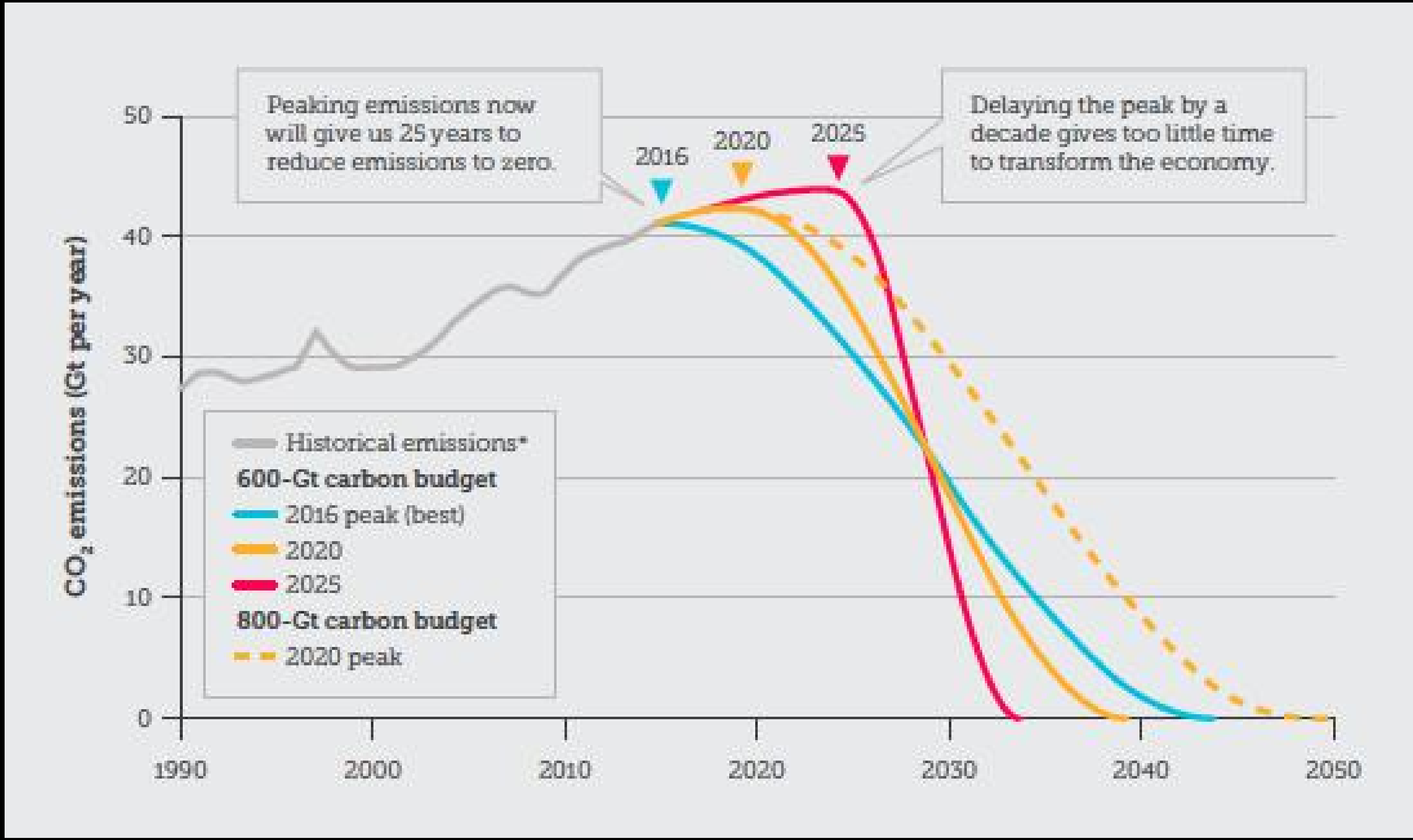
Towards Solutions (1)

We know that

- The planet is warming, that warming is accelerating and that warming will continue for decades.
- Sea level will rise and probably reach meters.
- Ice will be melting with large consequences
- Weather patterns will change
- Water scarcity and excess will amplify
- Parts of the Earth will become unlivable

Climate change is irreversible. We will not return to pre-industrial climate.

Emission Reduction Pathways for Meeting the Paris Target



Figueres et al. 2017

Towards Solutions (2)

The question is therefore:

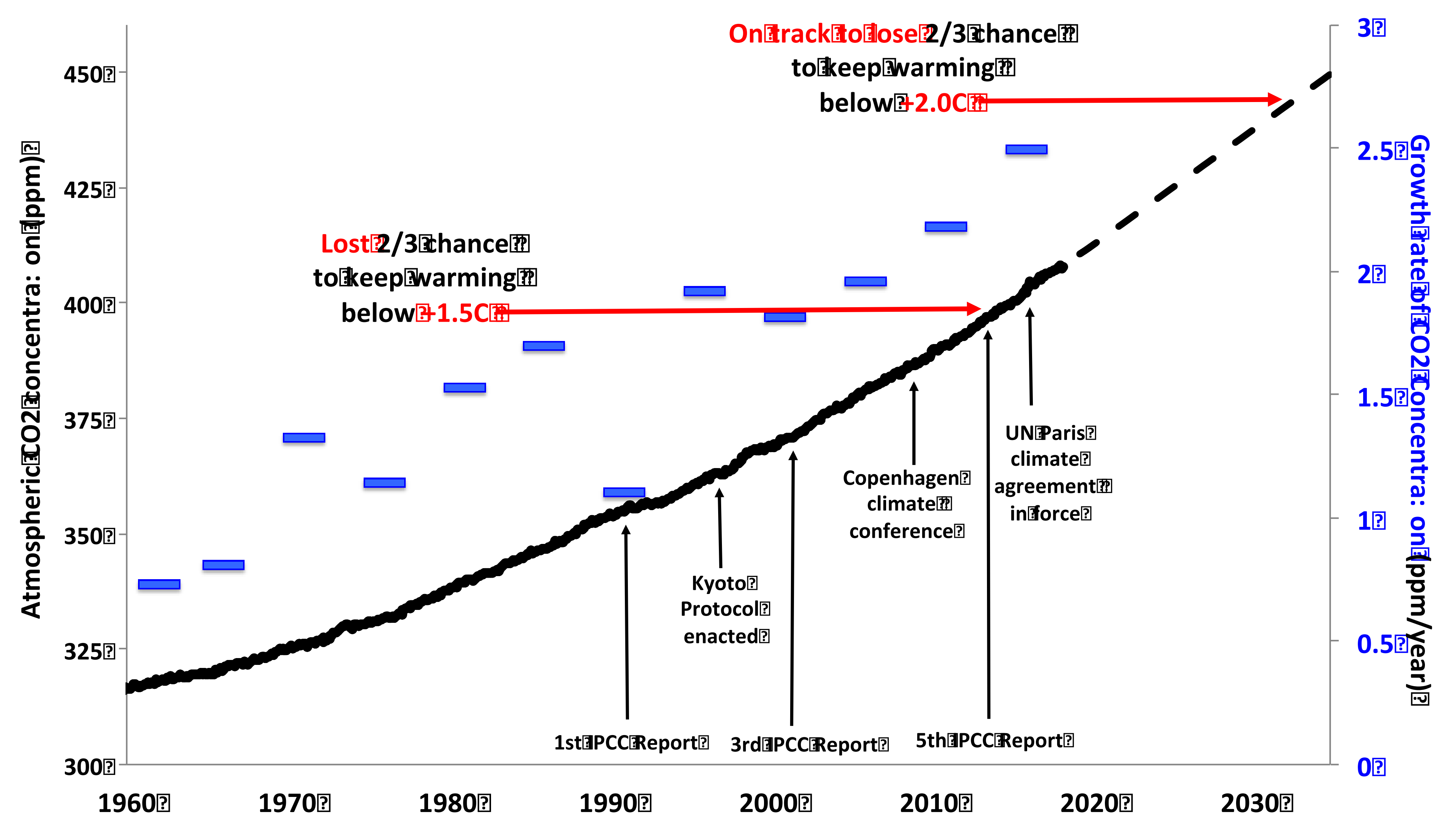
How to accelerate the incorporation of climate change knowledge into design, engineering and management?

It is probably more realistic to talk about 3 to 5 degrees C warming and to hight extreme events.

Two advantages:

- We know what is coming
- We have the technology

Failure of the Climate Science-Policy System



Source: P. Sackett and W. Steffen

Towards Solutions (3)

- Reducing emissions is not in our nature. (we never did)
- Adapting to changes is in our nature (we always did)

Therefore:

1. We need to reduce the emissions of GHG as much as possible and remove carbon from the atmosphere in order to limit the warming.
2. We need also to adapt to a warming planet.

Towards Solutions (4)

We need to change

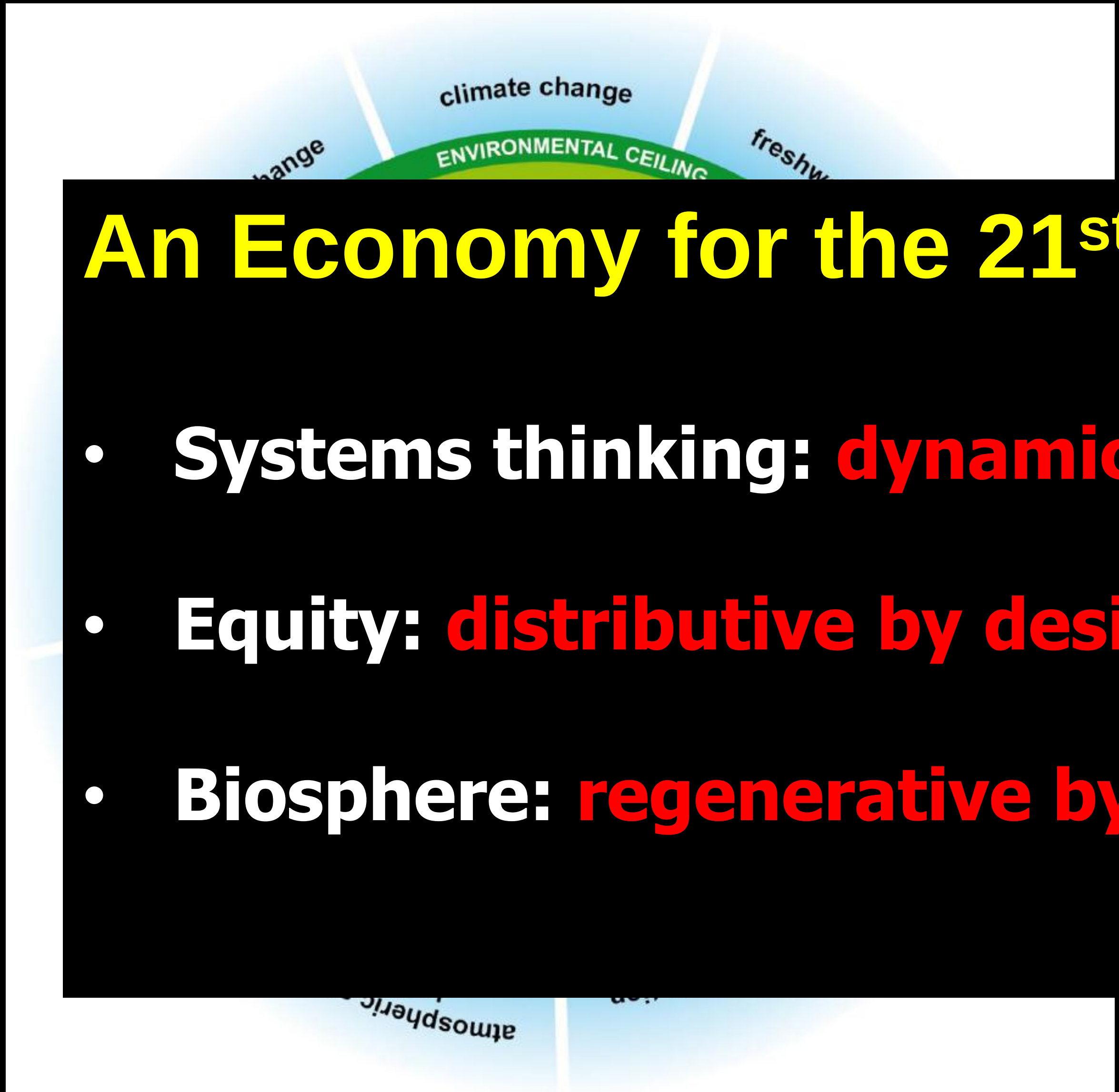
- Power structure
- Human behavior

We need to develop a culture that is prepared for climate changes and its societal impacts.

We need to identify barriers: political, societal and cultural barriers stronger than scientific and technological uncertainties.

The Way Forward

The ‘Doughnut’: a safe and just space for humanity



An Economy for the 21st Century

- **Systems thinking: dynamic complexity**
- **Equity: distributive by design**
- **Biosphere: regenerative by design**

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ty


ENVIRONMENTAL JUSTICE
fair treatment
quality of life
involvement
policy
SOCIAL MOVEMENT
high-poverty
political ecology
environmental laws
EJ
involvement
health hazards
SOCIAL MOVEMENT
EJ
high-poverty
political ecology
fair treatment
policy
quality of life
ENVIRONMENTAL BENEFITS
natural resources
ENVIRONMENTAL JUSTICE
policy
ENVIRONMENTAL JUSTICE
EJ
high-poverty
ENVIRONMENTAL BENEFITS
high-poverty
policy
policy
health hazards
EJ
fair treatment
political ecology
quality of life
health hazards
policy
high-poverty
EJ
fair treatment
health hazards
natural resources
involvement
environmental laws

Thanks to

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Thank You