# Integrating vulnerability indicators from natural and social science

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"What is simple is wrong;
What is complicated is useless." *Paul Valéry*

"Make things as simple as possible, but not any simpler." *Albert Einstein*

*Content:*

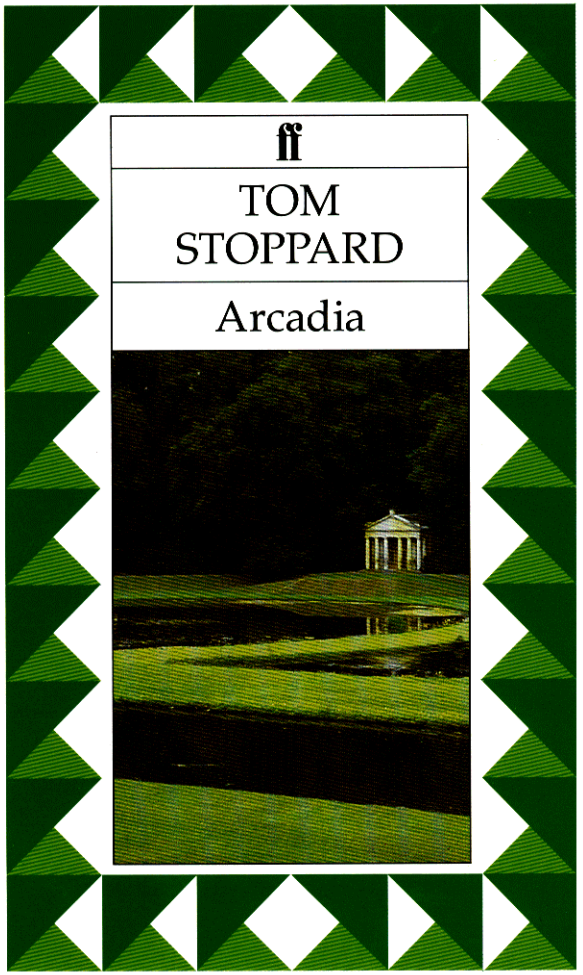
What are indicators?
The objectives of the conventions
"Safe landing" indicators
The IPCC TAR vulnerability synthesis
Aggregated indicators

# Distortions. Interference. **Real data is messy.**

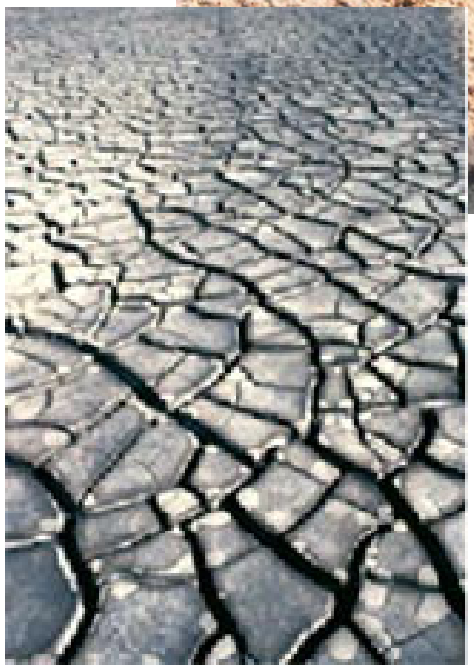
There's a thousand acres of moorland that had grouse on it, always did till 1930. But nobody counted the grouse. They shot them. So you count the grouse they shot. But burning the heather interferes, it improves the food supply. A good year for foxes interferes the other way, they eat the chicks. And then there's the weather.

It's all very, very noisy out there. **Very hared to spot the tune.**

Like a piano in the next room, it's playing your song, but unfortunately it's out of wack, some of the strings are missing, and the pianist is tone deaf and drunk- I mean, the noise! Impossible! **You start guessing what the tune might be.**




From: *Arcadia. Tom Stoppard, 1993.*



One third of the world's population is now subject to water scarcity

Population facing water scarcity will more than double over the next 30 years

1.6 billion people are without electricity today

Electricity demand in developing countries will increase 3-5 times over the next 30 years

Food production needs to double to meet the needs of an additional 3 billion people in the next 30 years

# The Millennium Development Goals

Goal 1: Eradicate extreme Poverty and Hunger
Goal 2: Achieve universal primary education
Goal 3: Promote gender equality and empower women
Goal 4: Reduce Child Mortality
Goal 5: Improve maternal health
Goal 6: Combat HIV/AIDS, malaria and other disease
Goal 7: Ensure environmental sustainability
Goal 8: Develop a global partnership for Development

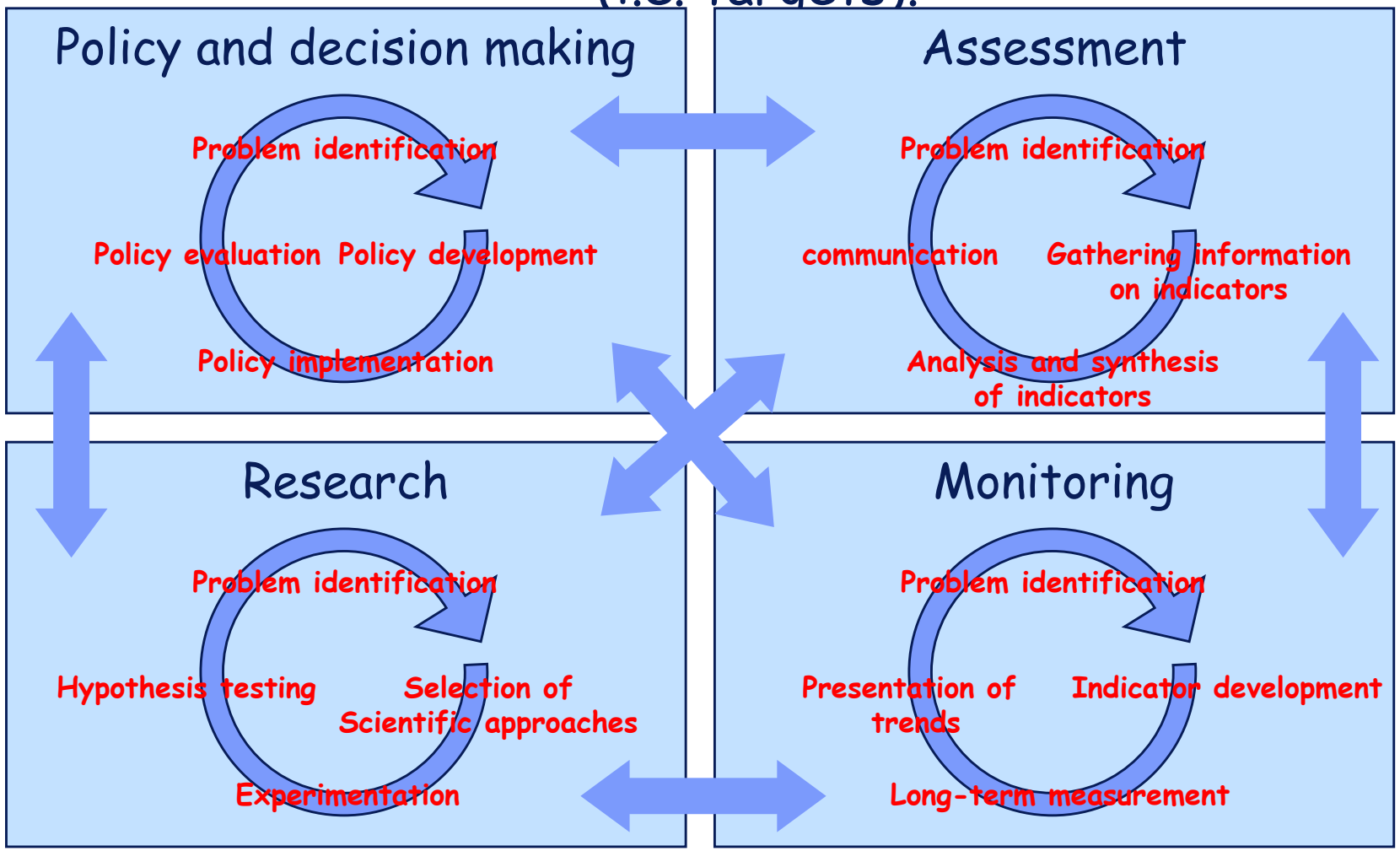
# The Millennium Developent Goals: Progress?

Of the world's 6 billion people, 1.2 billion live on less than $1 a day. About 10 million children under the age of five died in 1999, most from preventable diseases. More than 113 million primary school age children do not attend school—more of them girls than boys. More than 500,000 women die each year during pregnancy and childbirth—unnecessarily. And more than 14 million adolescents give birth each year.
**Cause for despair? Or hope?**

In 1990 there were 1.3 billion living on less than $1 a day. There were more than 11 million deaths among children under five. There were more children out of school and enrolment rates were also lower.
**So there has been progress.**

# Indicators

A indicator is a measure that quantifies systemic changes of one or more properties of a system, a community or a nation. Indicators are often used to evaluate progress towards planned/desired goals (i.e. targets).



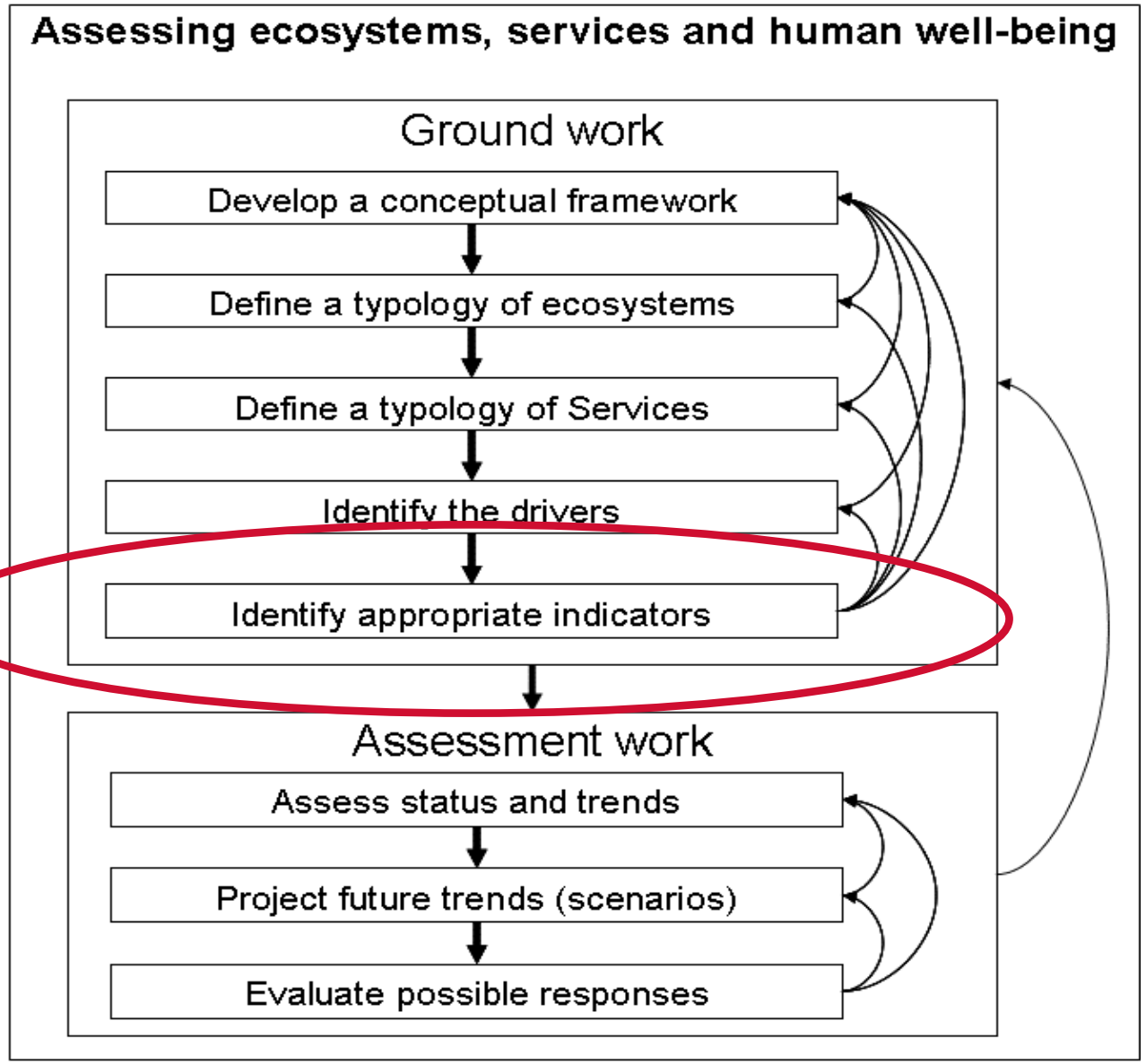
# Criteria for Indicators

The set of indicators must be designed in such a way that the behavior of major attributes of the human-environment systems are covered. But, many attributes are not well defined!

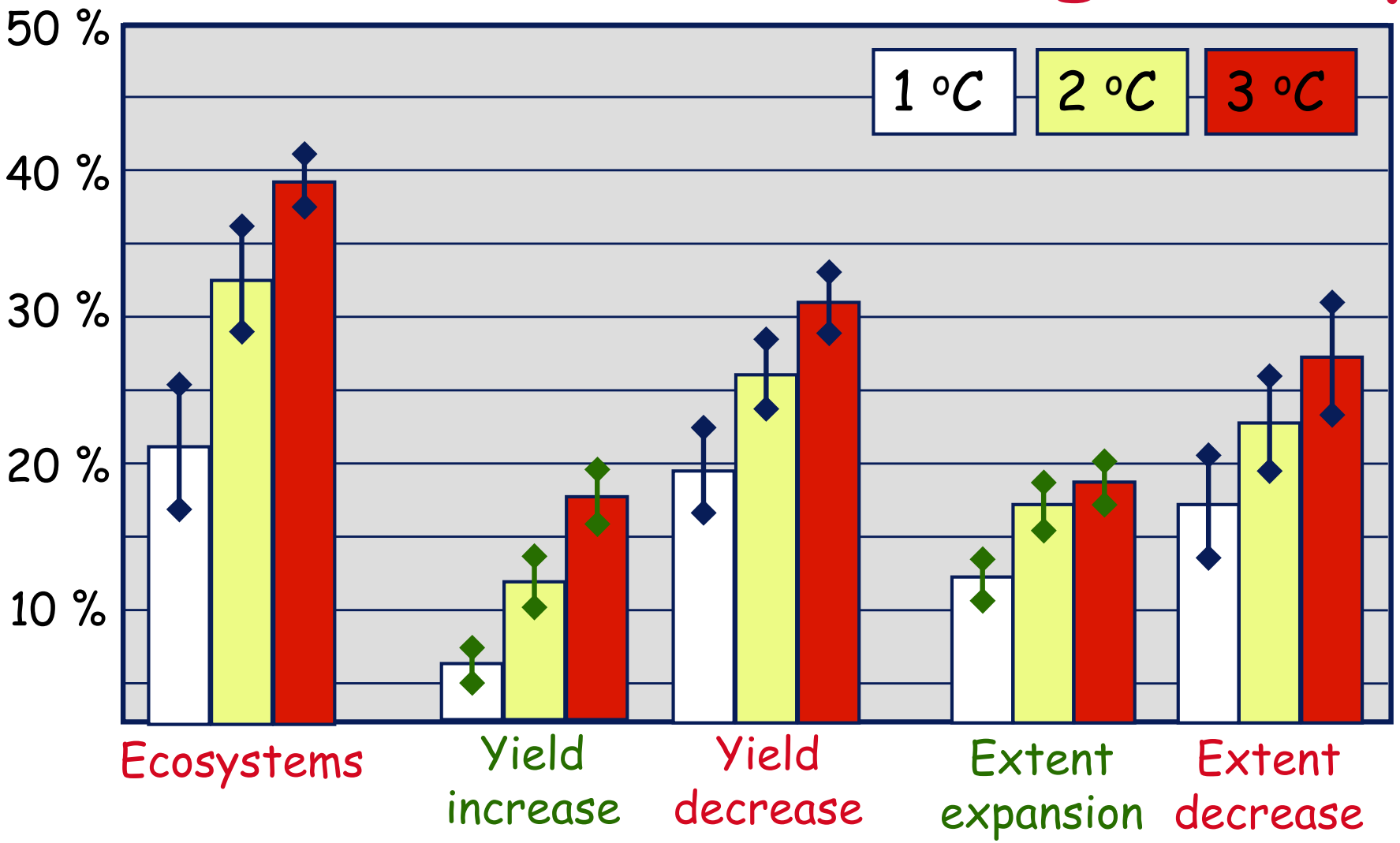
Indicators shouldbe:

- ✓ representative for the attribute that they characterize.
- ✓ easy to communicate
- ✓ acceptable for a broader audience.
- ✓ sensitive to change
- ✓ reliably track changes
- ✓ measurable an monitorable (i.e. data collection is not too difficult or expensive)
- ✓ testable and verifiable

# Using indicators in an assessment

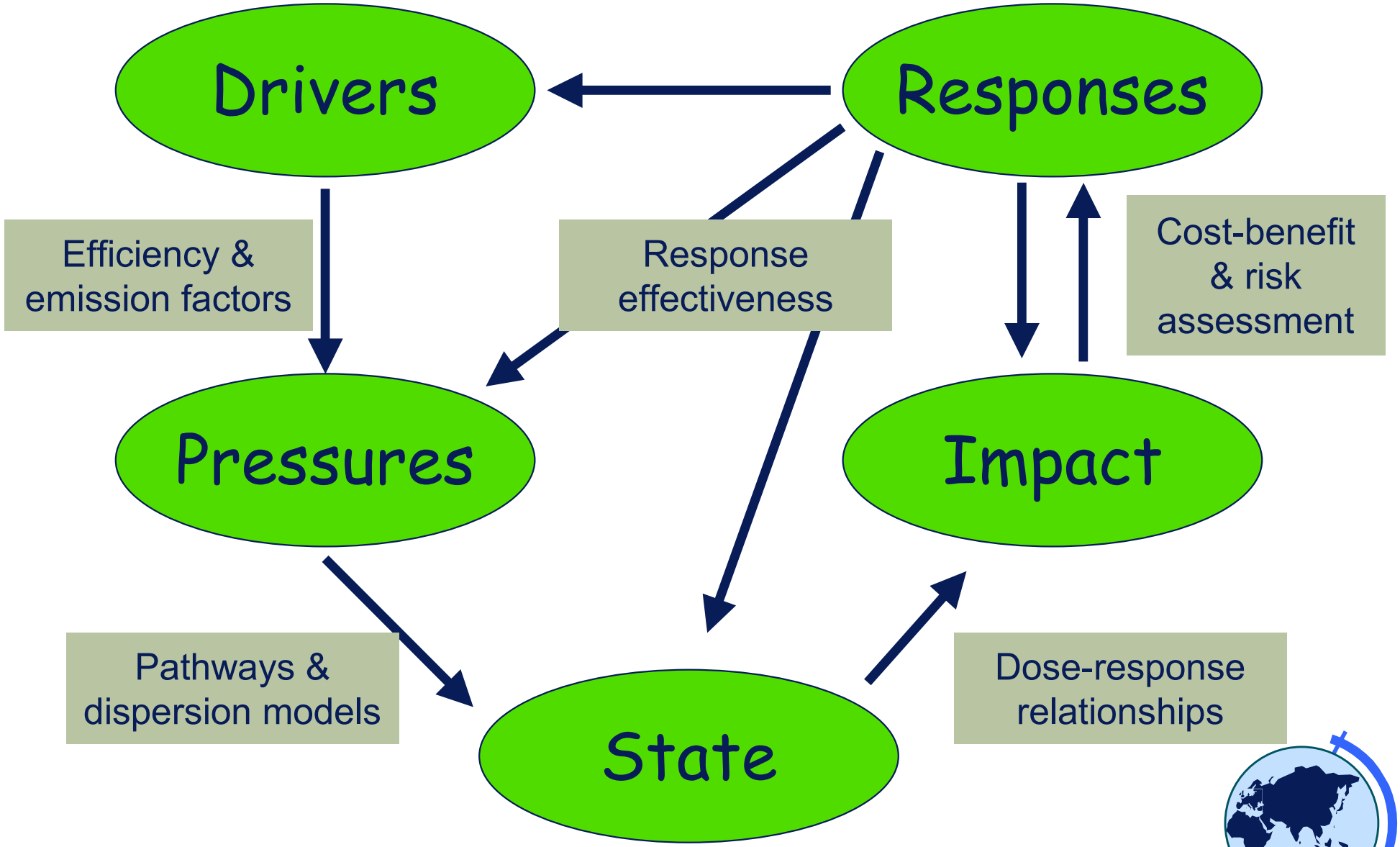


# How do risks evolve globally?




Impacts are expressed as the percentage area affected. The reference is the current area (crops) or the total amount of land (ecosystems).

# The causal chain: DPISR (OECD)



# Swedish Natural Capital Indicators

**The environmental quality goals of the Swedish Ministry of the Environment (1998):**

- ✓ Clean air
- ✓ High
- ✓ Sus
- ✓ Flou
- ✓ A b
- ✓ No

**The sustainability indicators of the Swedish Environmental Advisory Council (1998):**

- ✓ electricity usage and efficiency in relation to GDP
- ✓ materi
- ✓ usage
- ✓ Numbe

**The pressure indicators of the economic and environmental accounts of Statistics Sweden (1998)**

- ✓ Forest accounts
- ✓ Water accounts

Many pressure and state indicators but few that shed insight in dynamics, resilience and vulnerability of the whole human-environment system

Deutsch, L., C. Folke, and K. Skanberg. 2003. The critical natural capital of ecosystems perforance as insurance for human well-being. Ecological Economics **44**:205-217

# Partial indicators

# Partial indicators will hide systemic behaviour

# The objectives of the conventions

# The objective of the UN-FCCC

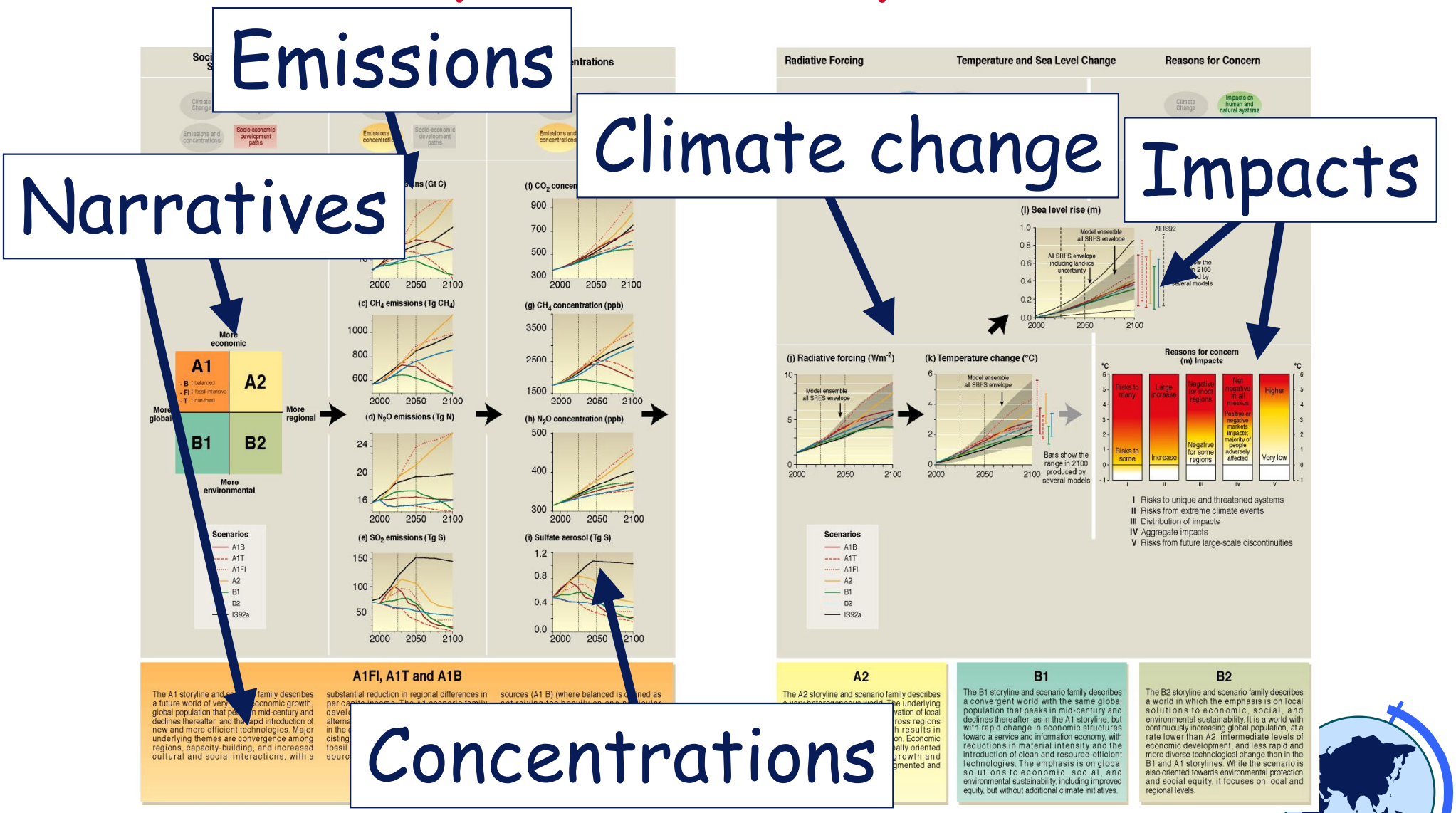
## (Article 2 of the Framework Convention on Climate Change)

.... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent **dangerous** anthropogenic interference with the climate system.

Such a level should be achieved within a time frame sufficient:

- To allow ecosystems to adapt naturally to climate change
- To ensure that food production is not threatened,
- To enable economic development to proceed in a sustainable manner.

# The summary indicators in IPCC's synthesis report



# The Objective of the Biodiversity Convention (Article 1)

… is to conserve biodiversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of its utilisation.

# Additional aspects of the CBD

**The convention further stimulates parties to:**

- develop national strategies for conservation and sustainable use, which are linked with other environmental and societal issues (Article 6);
- develop appropriate identification and monitoring systems (Article 7). These monitoring systems should identify and quantify the biodiversity threatening processes and activities.

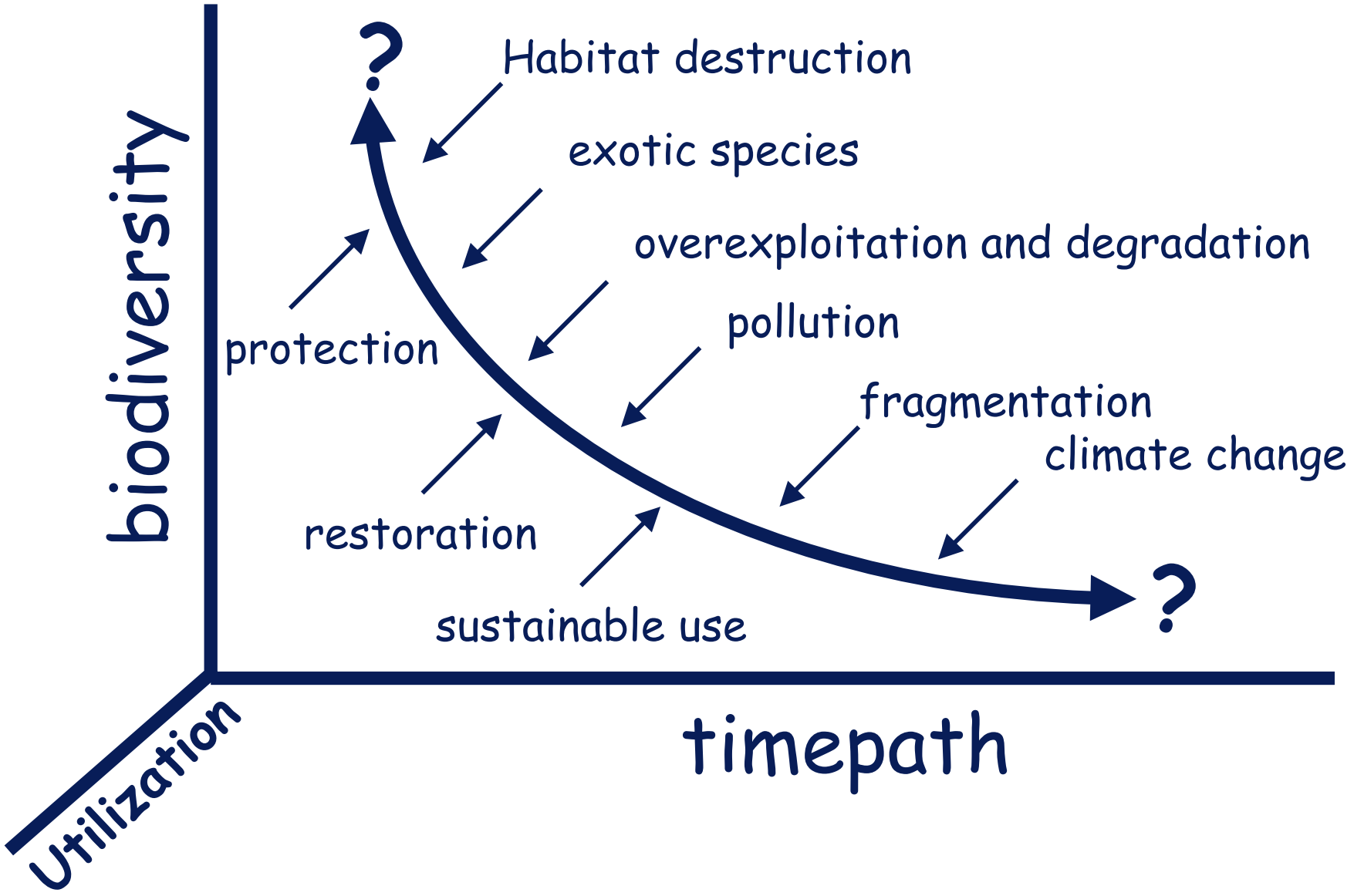
**The convention especially focuses on conservation by:**

- establishing protected areas, where natural habitats and viable populations can be maintained and the influence of humans and alien species is reduced (Article 8).
- the development of research, training, educational and awareness programs (Articles 12 and 13).

**And urges urges the parties to develop:**

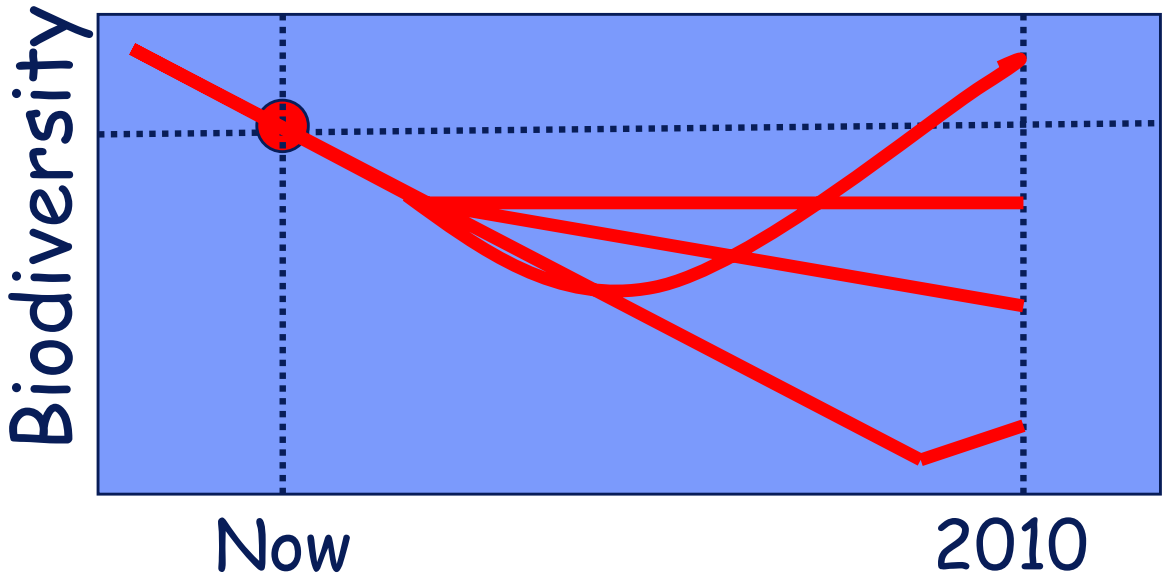
- the appropriate assessment capacity to evaluate processes and activities that potentially can have an adverse impact (Article 1

# Causes of changes in biodiversity



# One of the environmental goals of the World Summit on Sustainable Development (WSSD)

..... To significantly reduce the decline of biodiversity by 2010.



# "Safe landing" indicators

# Targets for Climate Change

GMT > 0.2 °C/decade
sea level rise >0.05 m/decade

- Social & economic disruption
- Large risk of instabilities

*Max. GMT = 2°C*
*Max. sea level rise = 0.5 m*

0.1 °C/dec < GMT ≤ 0.2 °C/dec
0.02 m/dec < SLR ≤ 0.05

- Large damages to ecosystems
- Risk of instabilities

*Max. GMT = 1°C*
*Max. sea level rise = 0.2 m*

GMT ≤ 0.1°C/decade
sea level rise ≤ 0.02 m/decade

- Limited damages to ecosystems
- Limited risk of instabilities

From: Vellinga & Swart, 1991. The greenhouse marathon. Climatic Change 18: viii-xii

# Safe Landing Analysis

- **Science-policy dialogue**
  - development in "Delft-workshops" with FCCC-delegates
  - feedback from FCCC-delegates during AGBM/CoP meetings
- **Aim Safe Landing Analysis:**
  - to determine short-term emission targets compatible with-long term climate protection goals
  - use global indicators to define the long-term climate goals
- **Methodology provides insights, no answers**
  - focus on trade-offs (risks, timing, burden sharing)
  - results subject to scientific uncertainties
  - Selection of climate protection goals is a political choice

# Developing a parsimonious model

$$CO_2 = CO_2$$

$$CO_2 = POP/POP \cdot CO_2$$

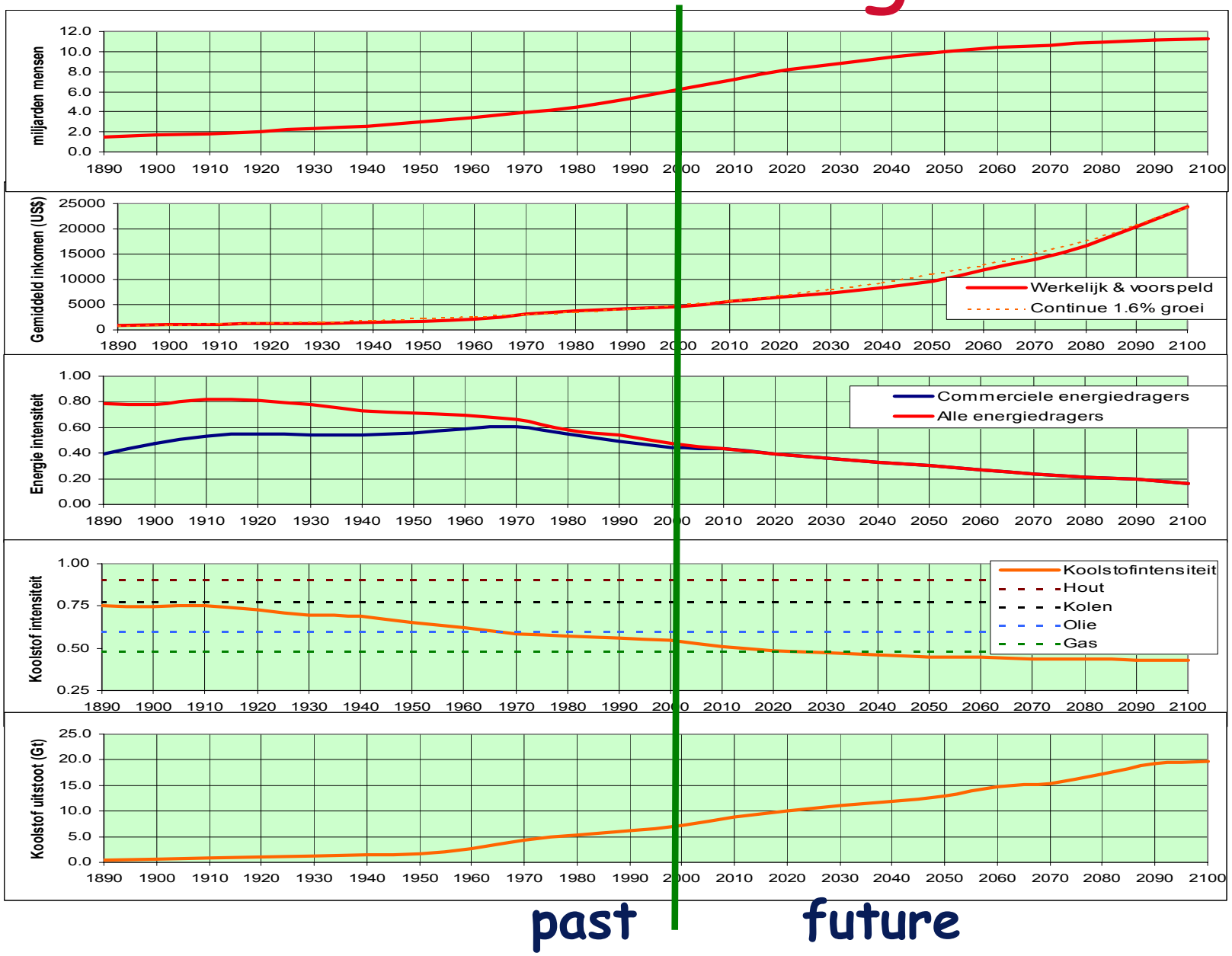
$$CO_2 = POP/POP \cdot GDP/GDP \cdot CO_2$$

$$CO_2 = POP/POP \cdot GDP/GDP \cdot EU/EU \cdot CO_2$$

$$CO_2 = \underbrace{POP}_{\text{Population}} \cdot \underbrace{POP/GDP}_{\text{Affluence}} \cdot \underbrace{GDP/EU}_{\text{Energy intensity}} \cdot \underbrace{EU/CO_2}_{\text{Carbon intensity}}$$

The KAYA identity

# KAYA through time




Population

Affluence

Energy intensity

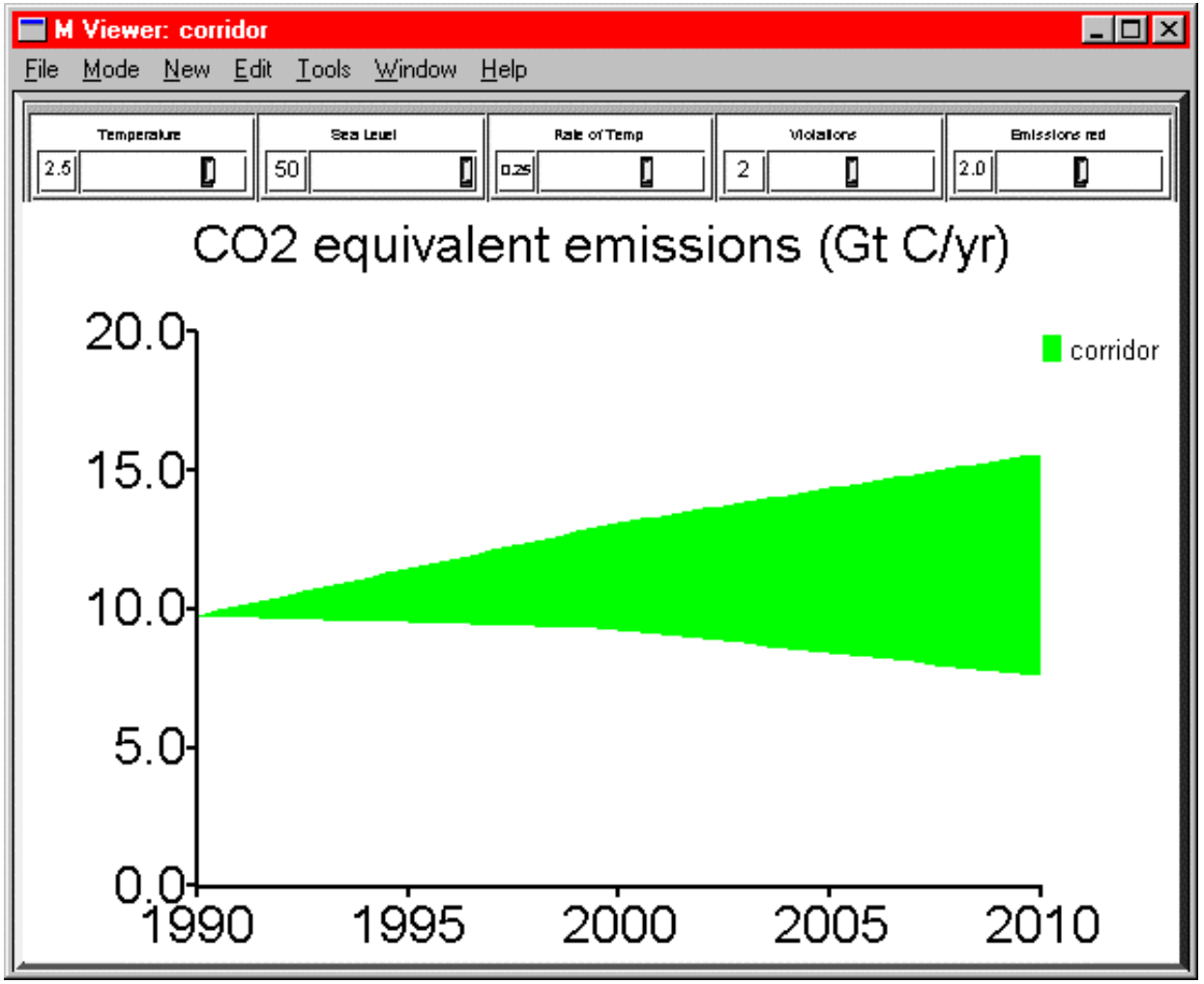
Carbon intensity

CO2 emissions

# What are emission profiles that comply with non-dangerous human interference?

- ✓ Cumulative temperature change – for example, the EU temperature goal of less than 2°C GMT
- ✓ Rate of temperature change - to account for limited adaptation capabilities
- ✓ Maximum sea level rise - relevant for e.g. AOSIS
- ✓ Maximum rate of emissions reduction - to account for technological/economic feasibility

# Emission corridor with broad settings




**Selected settings:**

Max. $\Delta T$ is 2.5 °C

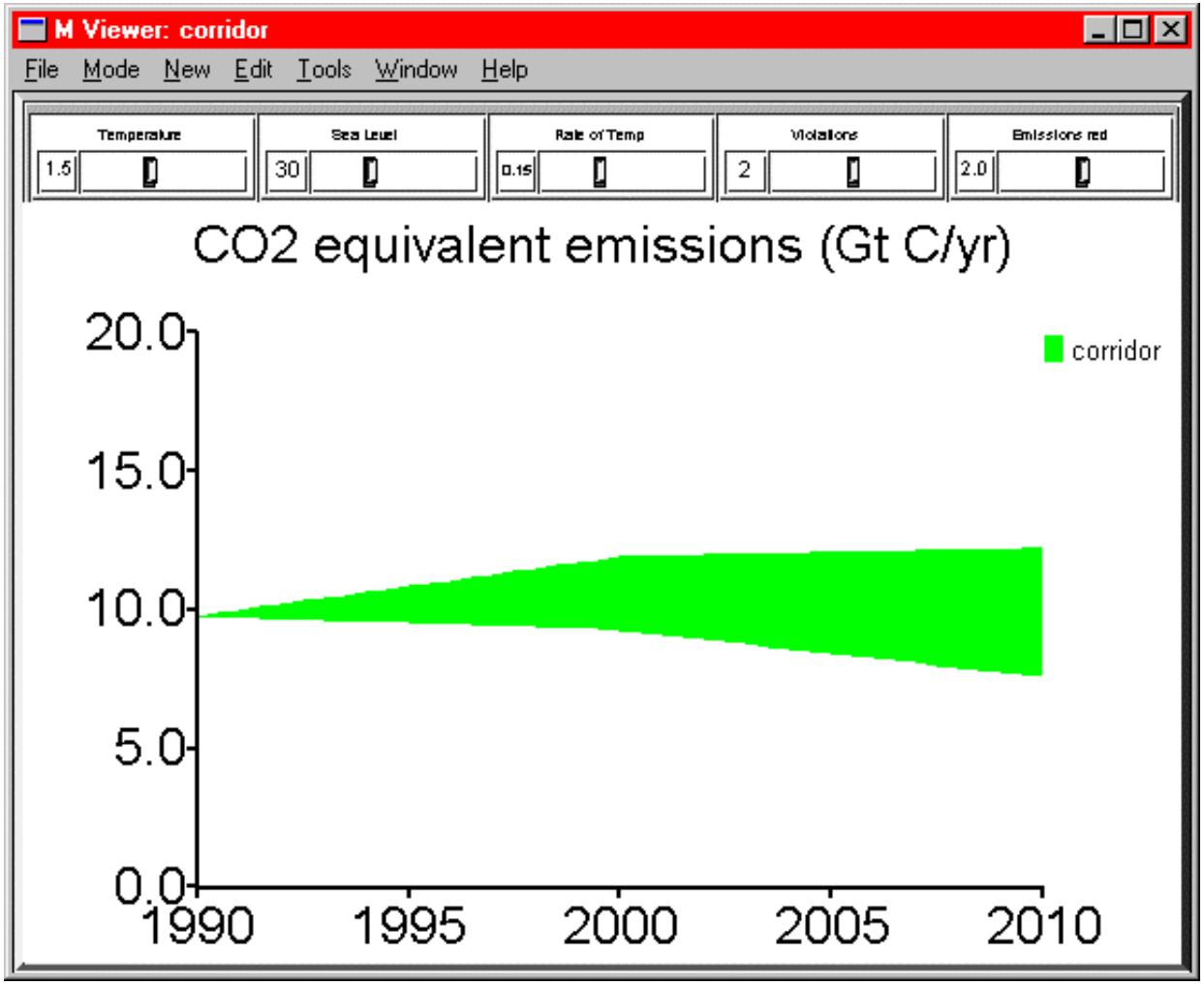
Max. sea-level rise is 50 cm

Max. $\Delta T$/decade is 0.25 °C

Number of violations is 2

Max. emission reduction is 2% year$^{-1}$

# Safe emission corridors with EU objectives




**Selected settings:**

Max. ΔT is 1.5 °C

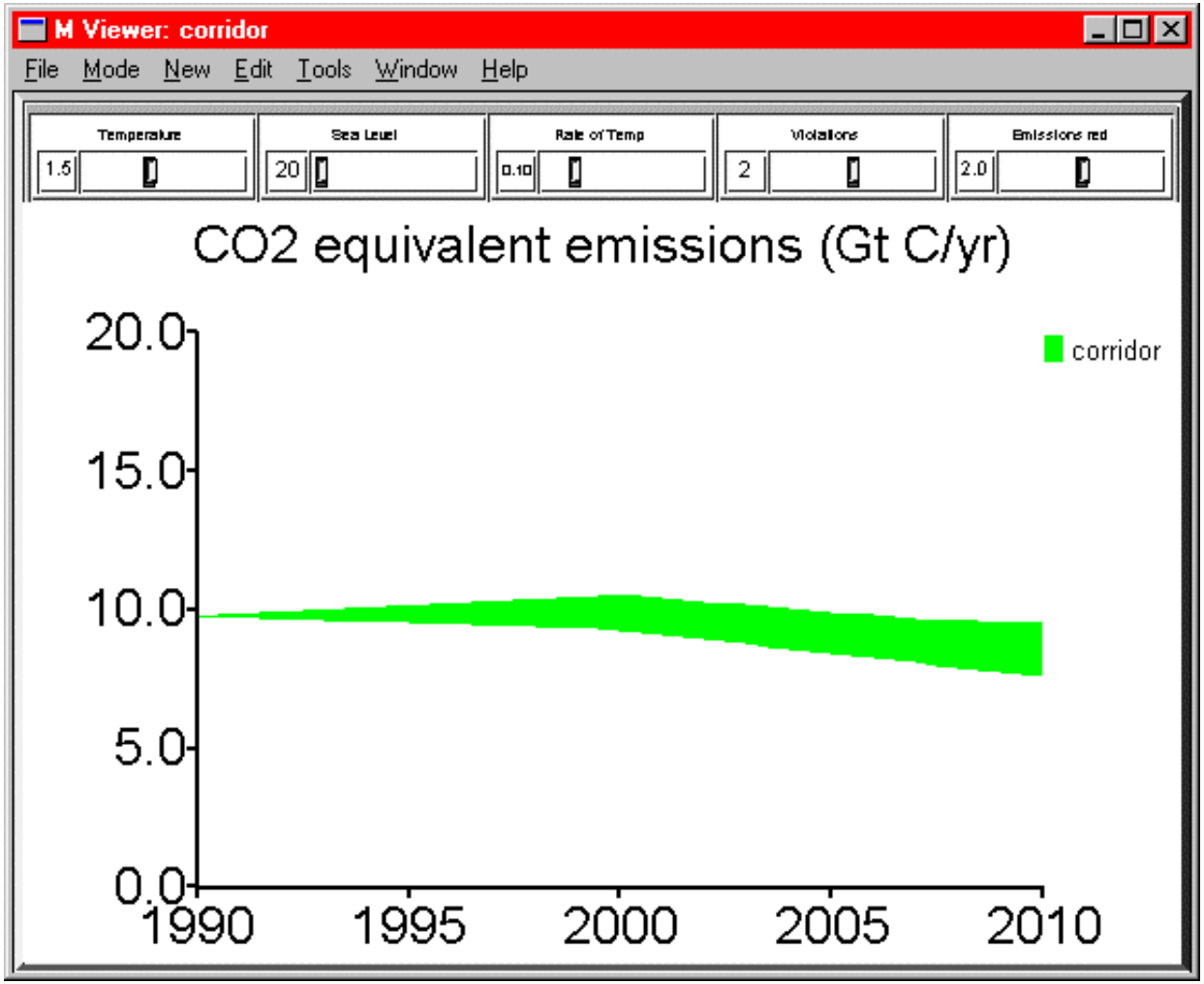
Max. sea-level rise is 30 cm

Max. ΔT/decade is 0.15 °C

Number of violations is 2

Max. emission reduction is 2% year$^{-1}$

# Emission corridor with stringent settings




**Selected settings:**

Max. ΔT is 1.5 °C

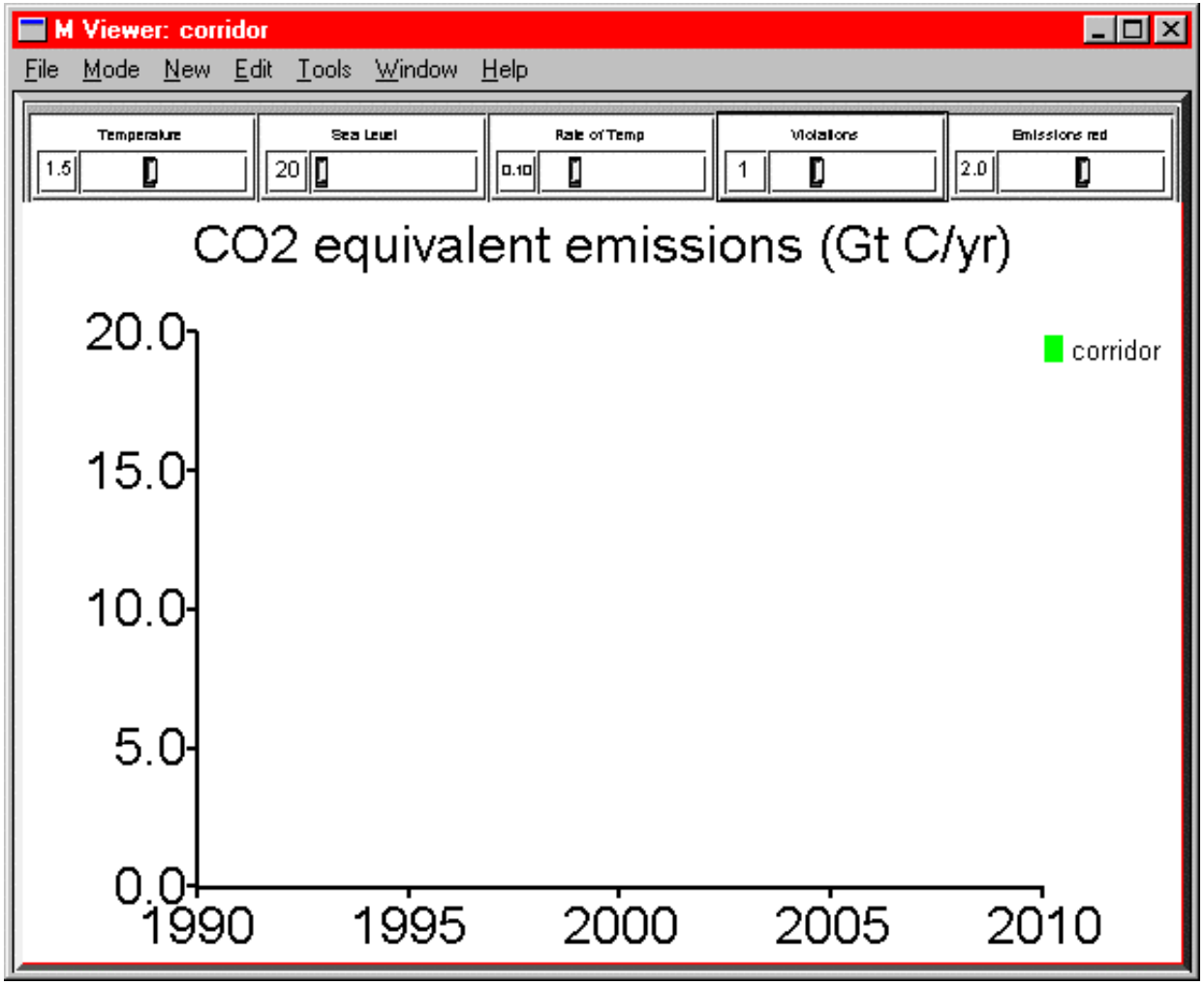
Max. sea-level rise is 20 cm

Max. ΔT/decade is 0.15 °C

Number of violations is 2

Max. emission reduction is 2% year$^{-1}$

# Emission corridor with very stringent settings




**Selected settings:**

Max. ΔT is 1.5 °C

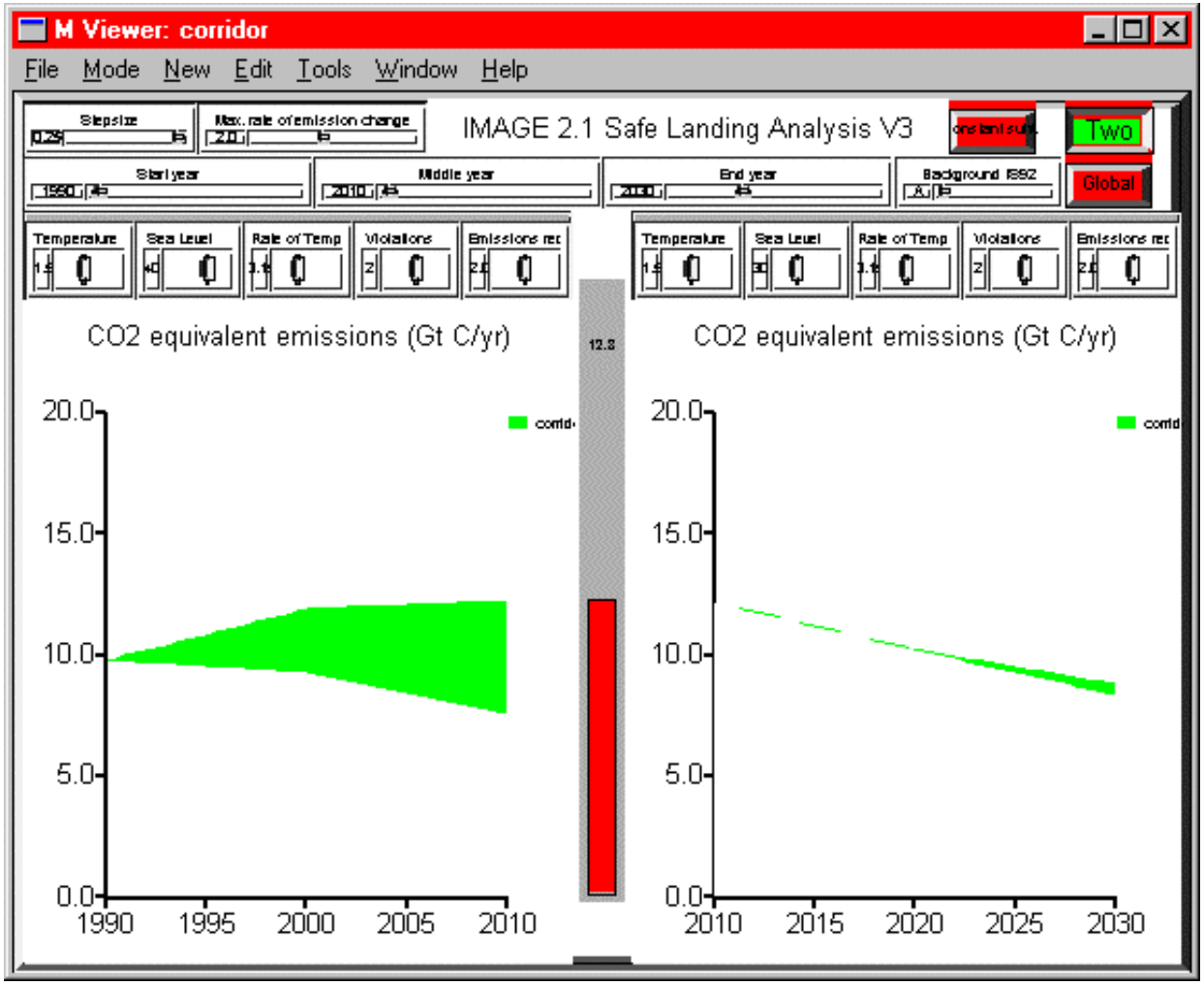
Max. sea-level rise is 20 cm

Max. ΔT/decade is 0.1 °C

Number of violations is 1

Max. emission reduction is 2% year$^{-1}$

# Safe emission corridors with EU objectives




**Selected settings:**

**Max ΔT is 1.5 °C**

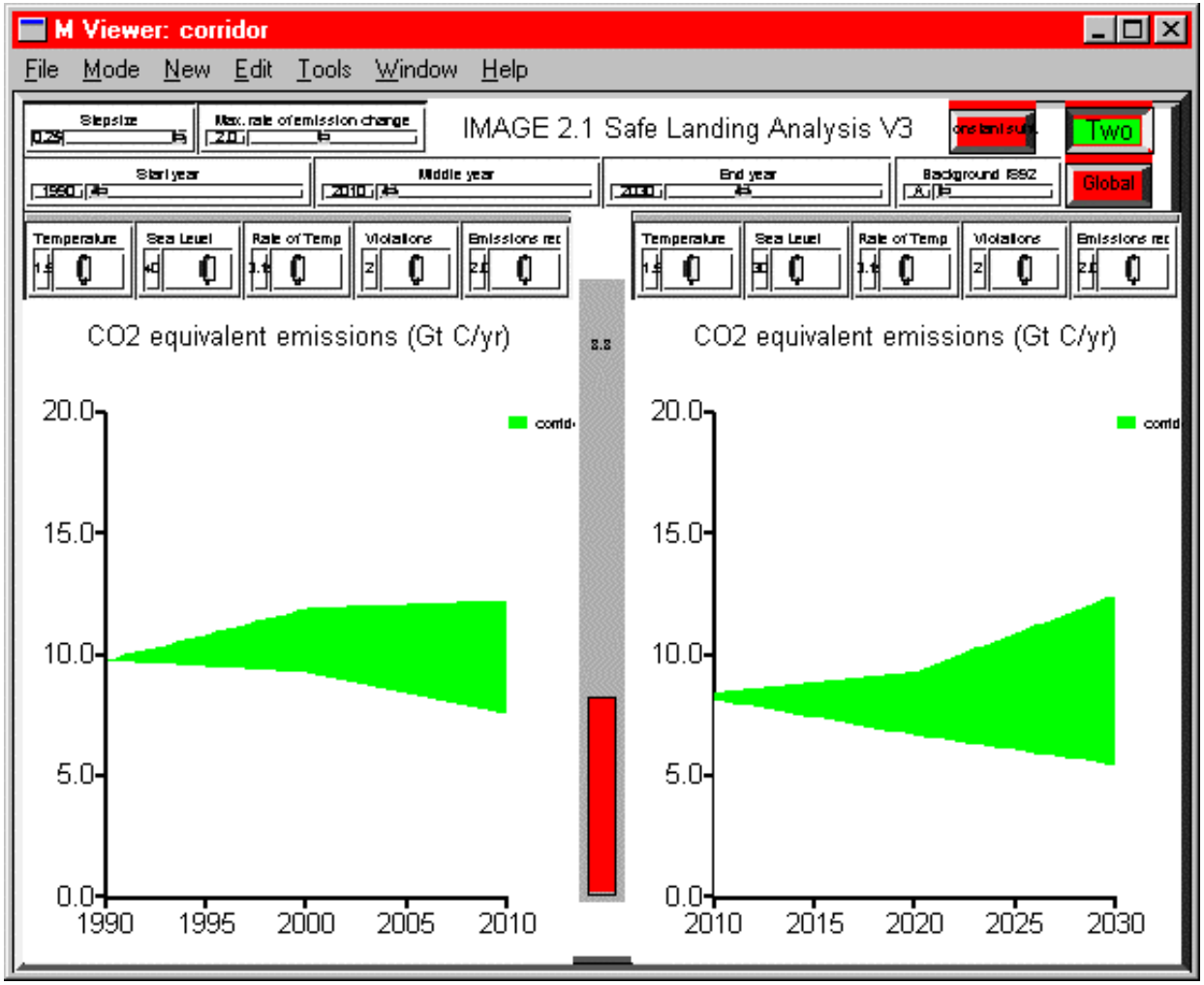
**Max sea-level rise is 30 cm**

**Max ΔT/decade is 0.15 °C**

**Number of violations is 2**

**Max emission reduction is 2% year$^{-1}$**

# Safe emission corridors with EU objectives




**Selected settings:**

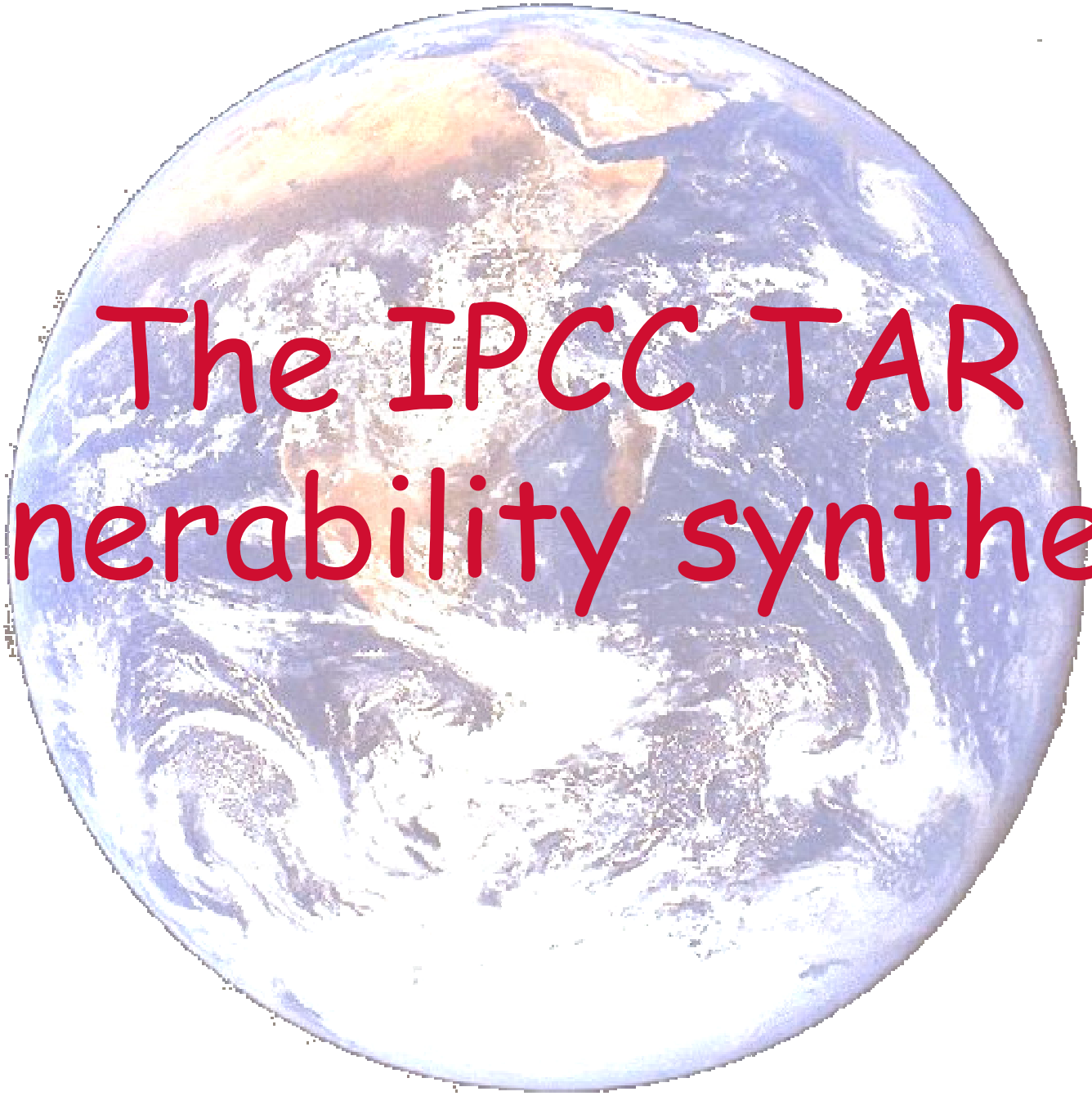
**Max ΔT is 1.5 °C**

**Max sea-level rise is 30 cm**

**Max ΔT/decade is 0.15 °C**

**Number of violations is 2**

**Max emission reduction is 2% year$^{-1}$**



# The IPCC TAR vulnerability synthesis

# How do we determine "What constitutes dangerous?"

- ✓ Dangerous is a value judgment and not appropriate for analysts to determine
- ✓ We can give information on impacts that may be considered to be dangerous
- ✓ Organized our work along "Reasons for concern" about what may be dangerous

# Reasons for Concern

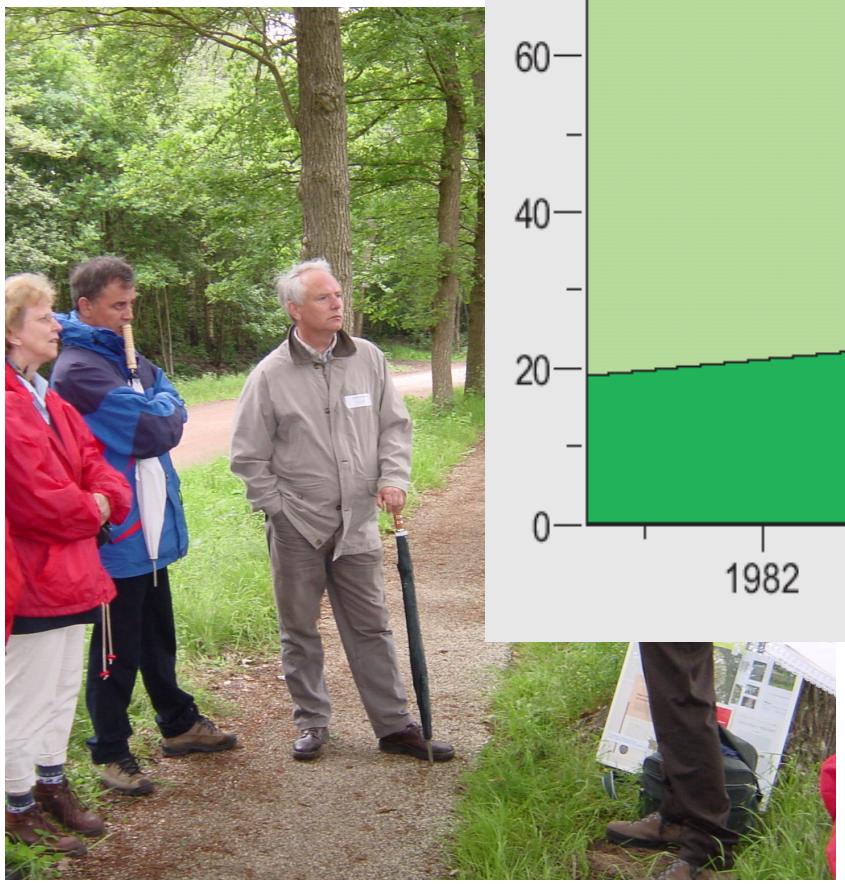
- ✓ Relationship between global mean temperature increase and:
  - o Unique and Threatened Systems (including observed change)
  - o Extreme Weather Events
  - o Distribution of Impacts
  - o Aggregate (total) Impacts
  - o Large Scale Singularities (e.g., NATHC; WAIS)
- ✓ Using global mean temperature increase because:
  - o It is a widely used indicator for climate change
  - o It can be regionalised with GCM-based scenarios for temperature, precipitation and other climate variables
  - o It is used by simple globally aggregated models and can be derived from the more complex models
  - o It is simple to communicate

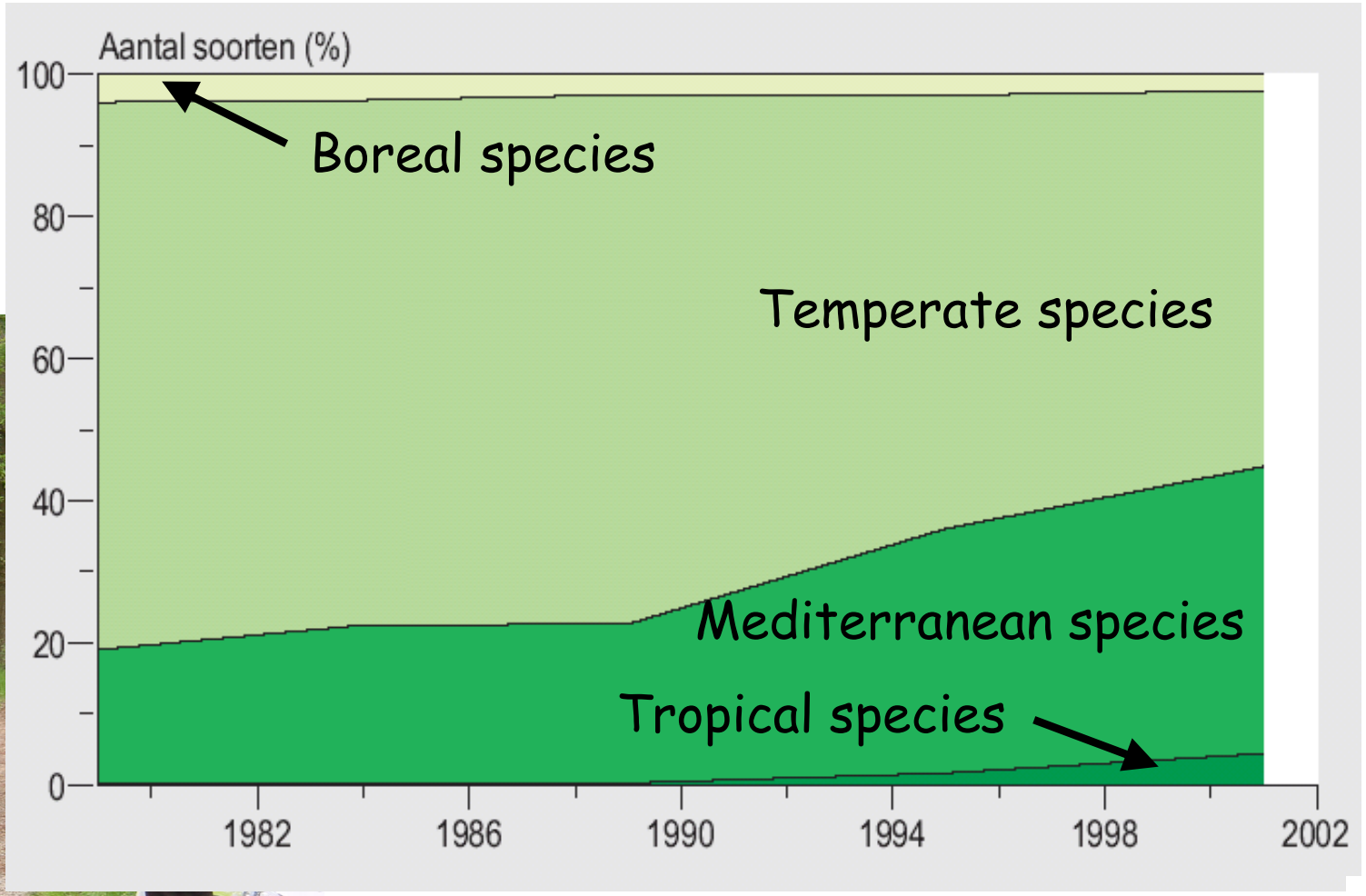
# Unique and Threatened Systems

Concern is about unique systems that may be lost or severly damaged, e.g.,

- Coral Reefs
- Polar Bears
- Alpine Ecosystems
- Glaciers
- Small Island States
- and many other ecosystems and species

# Changes in Dutch lichen communities







# Kilimanjaro: Ice free in 2015?

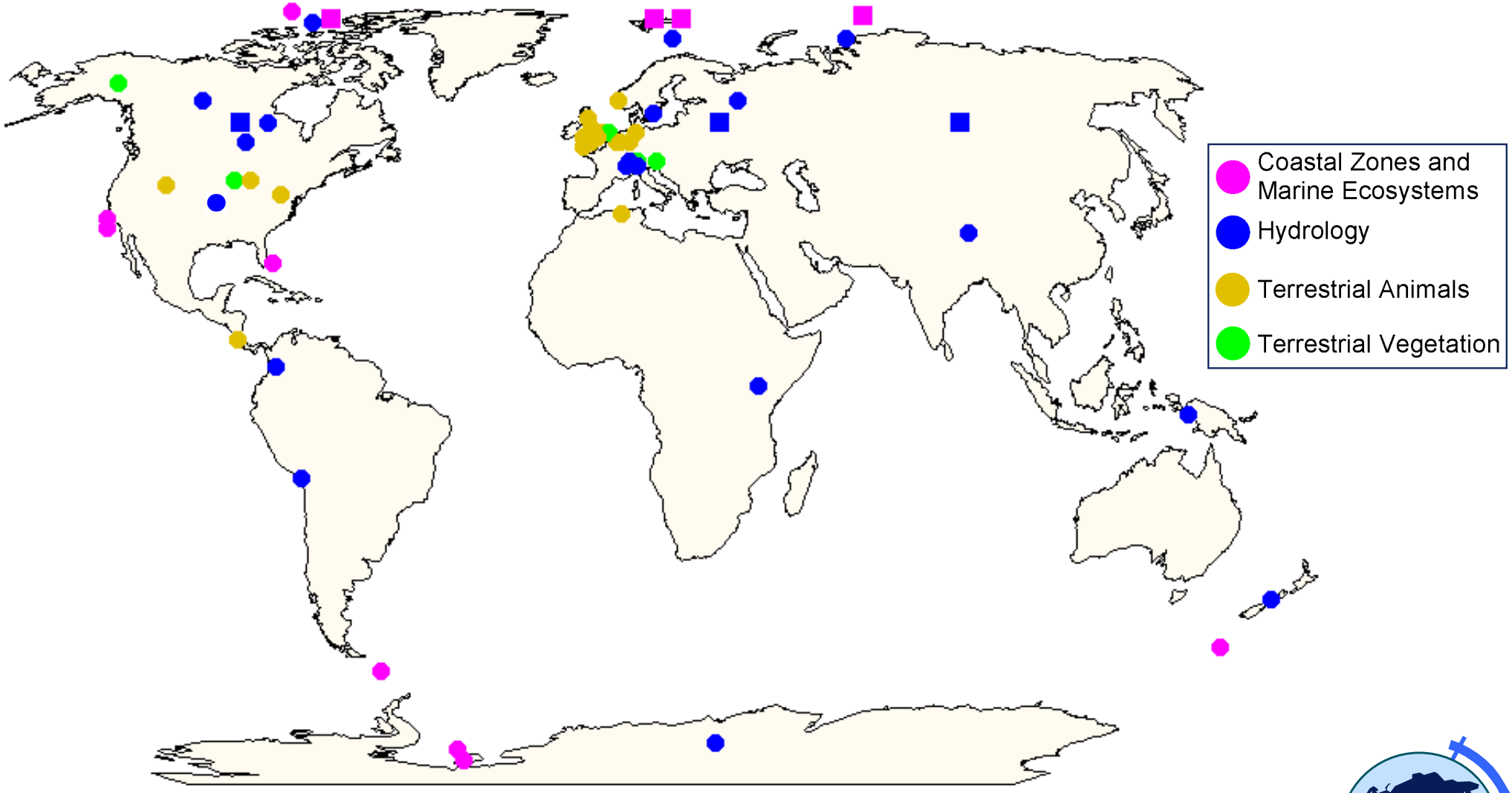
***Impacts on hydropower generation and agricultur***

**1978**

**2001**

*-- NASA space shuttle*

# Observed impacts of temperature-related regional climate change in the 20th century



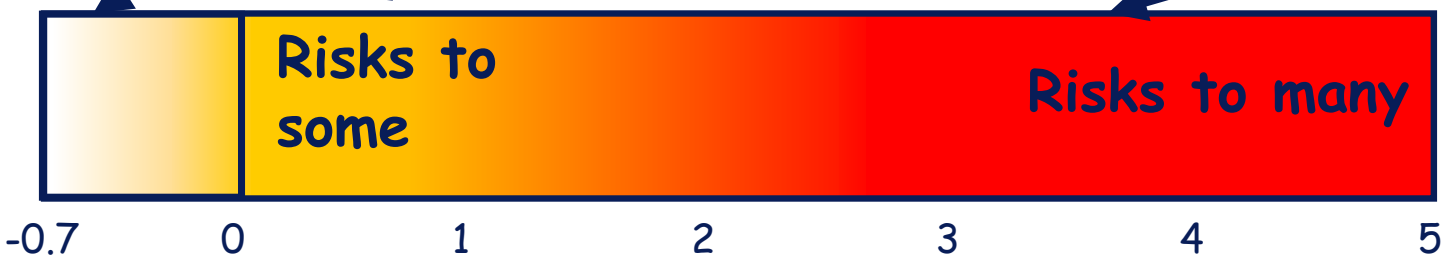

Observation period longer than 20 years

# The IPCC vulnerability synthesis: Reasons for Concern

White: no or little risk

Orange: Incresing risks

Red: Large (dangerous) risks



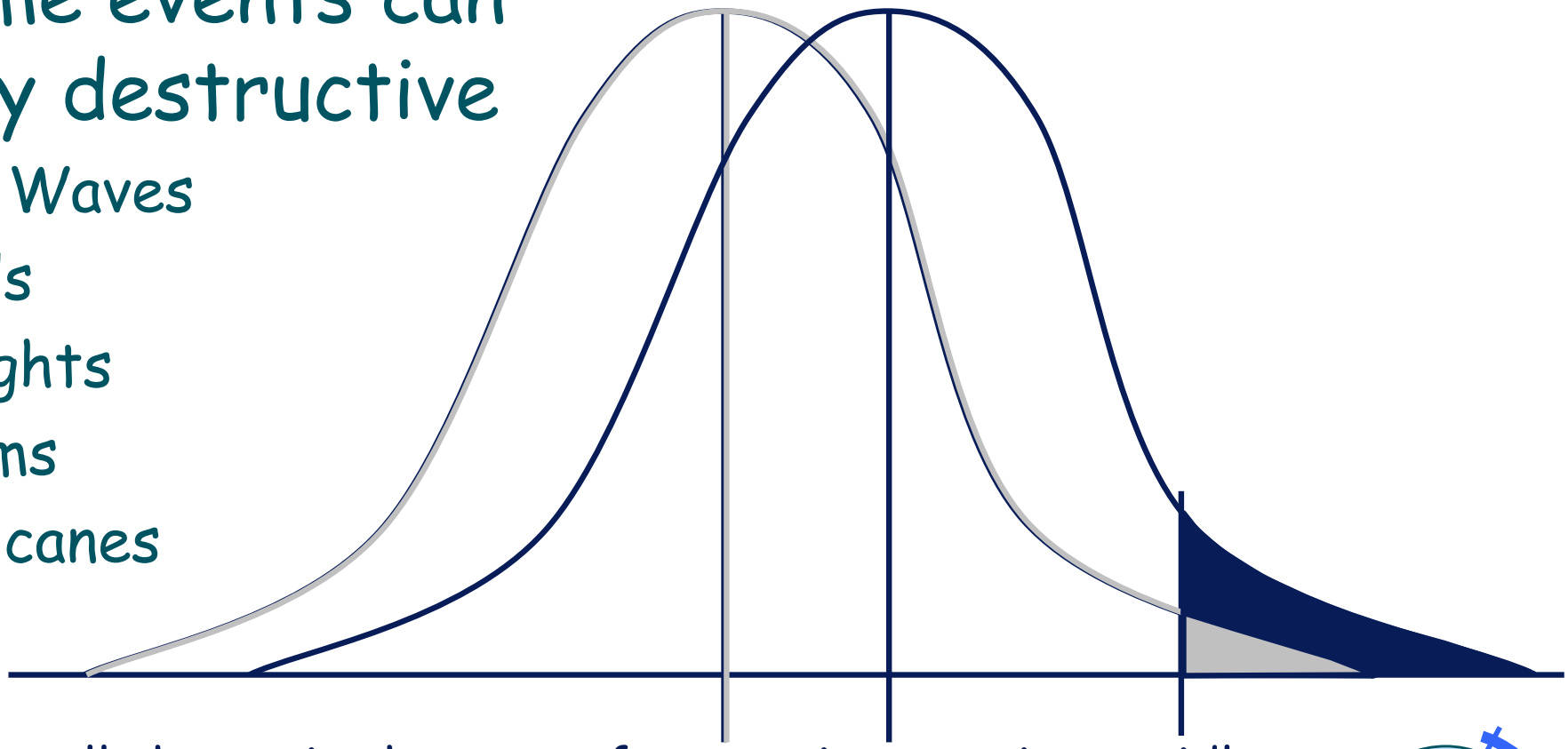

Risks to unique & threatened systems

Increase in global mean temperature after 1990 (°C)

# Changes in Extreme Weather Events

Extreme events can be very destructive

- Heat Waves
- Floods
- Droughts
- Storms
- Hurricanes



With a small change in the mean, frequencies can rise rapidly

# Increased Flooding is Likely

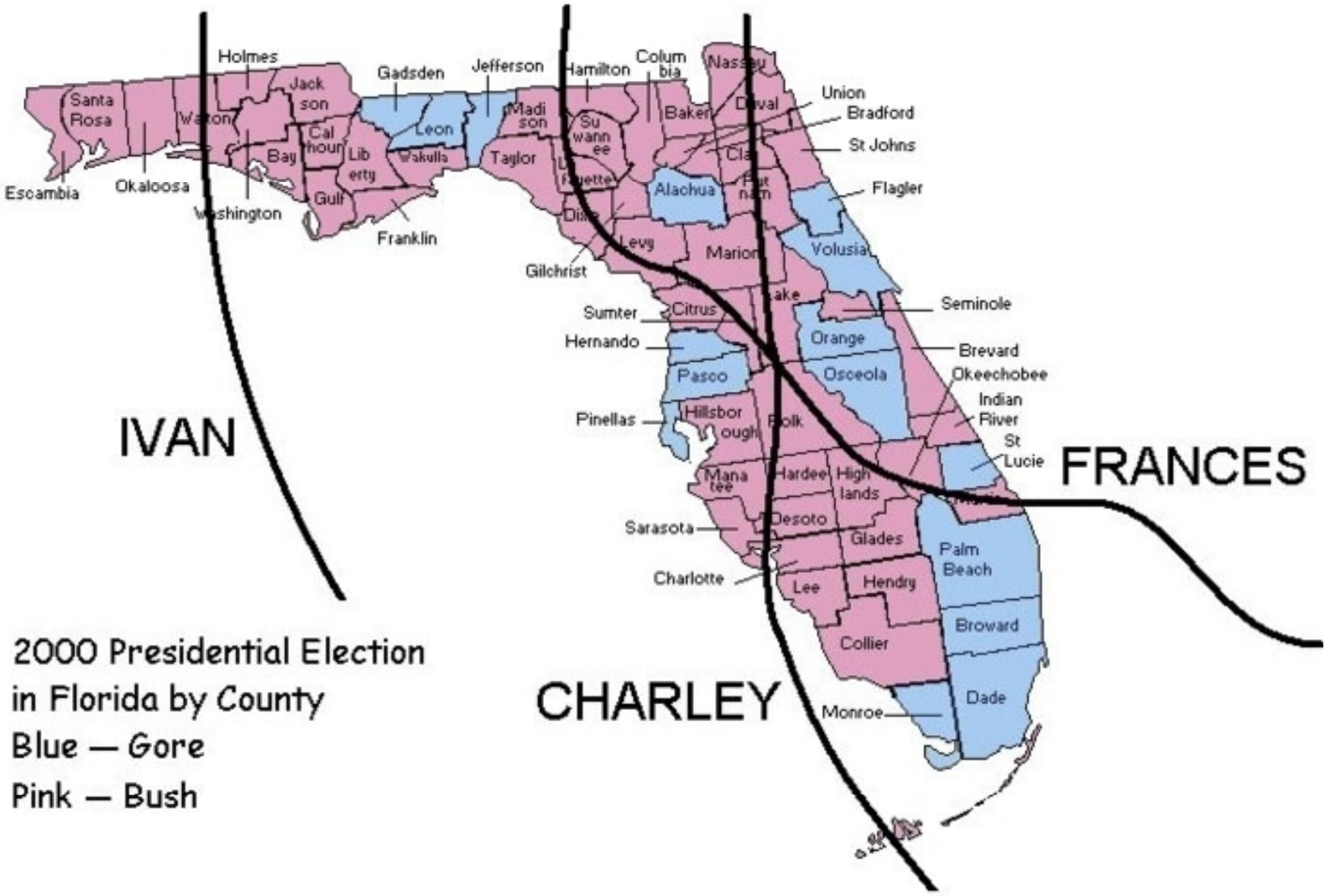
# Seasonal moisture actually may increase in springtime

# Changing drought frequencies affect soil stability

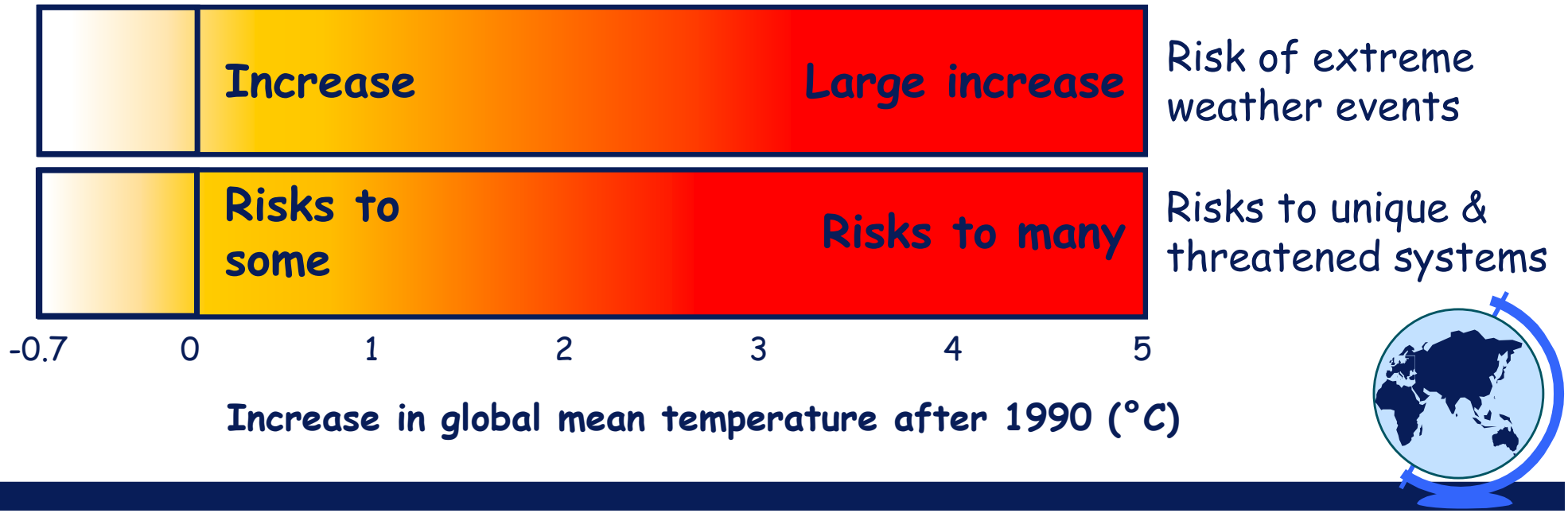
# Changing climatic extremes may be unwelcome

# Hurricane tracks 2002

## Coupling of the Human and Biophysical Dimensions



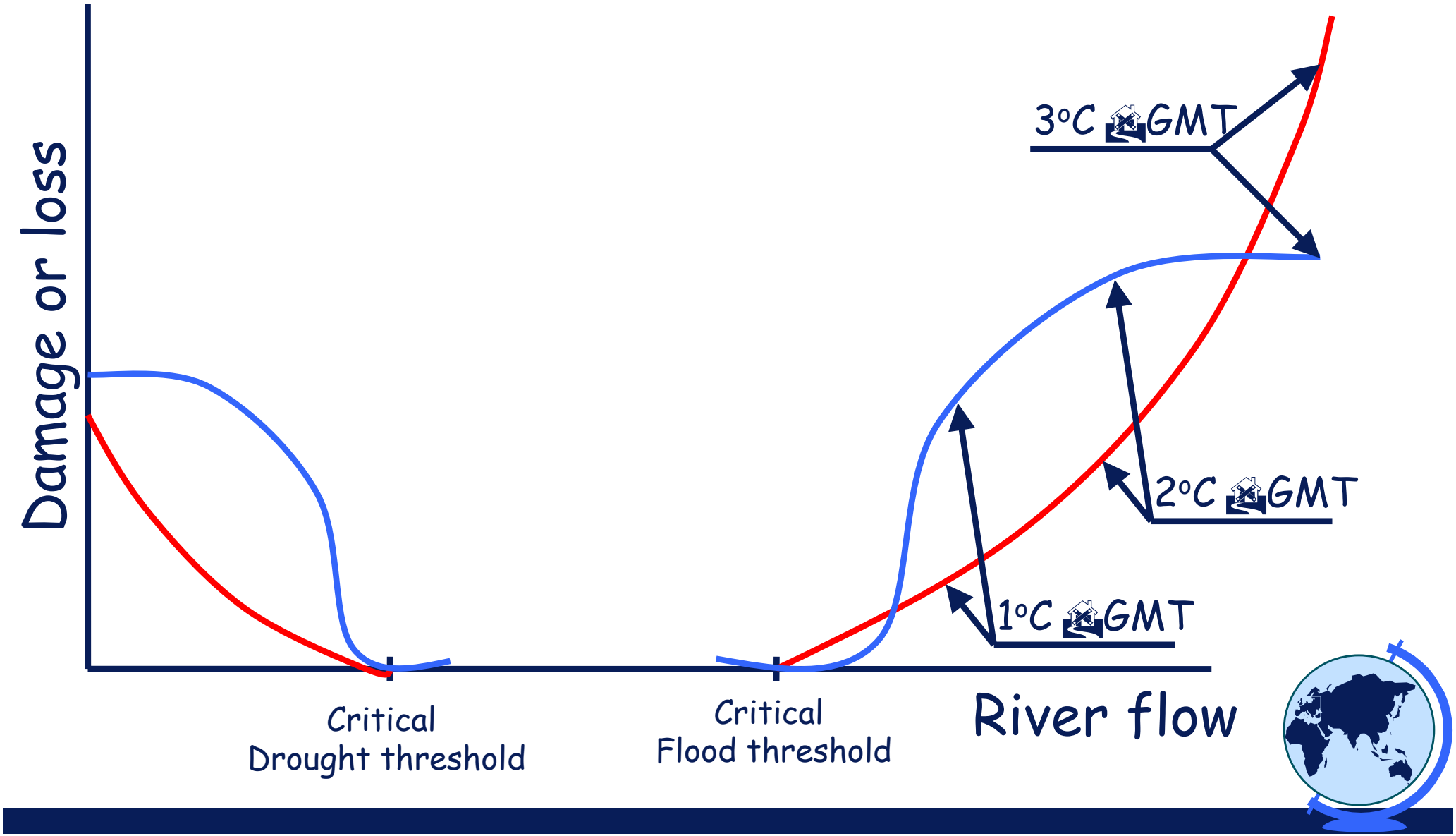
# The IPCC vulnerability synthesis: Reasons for Concern



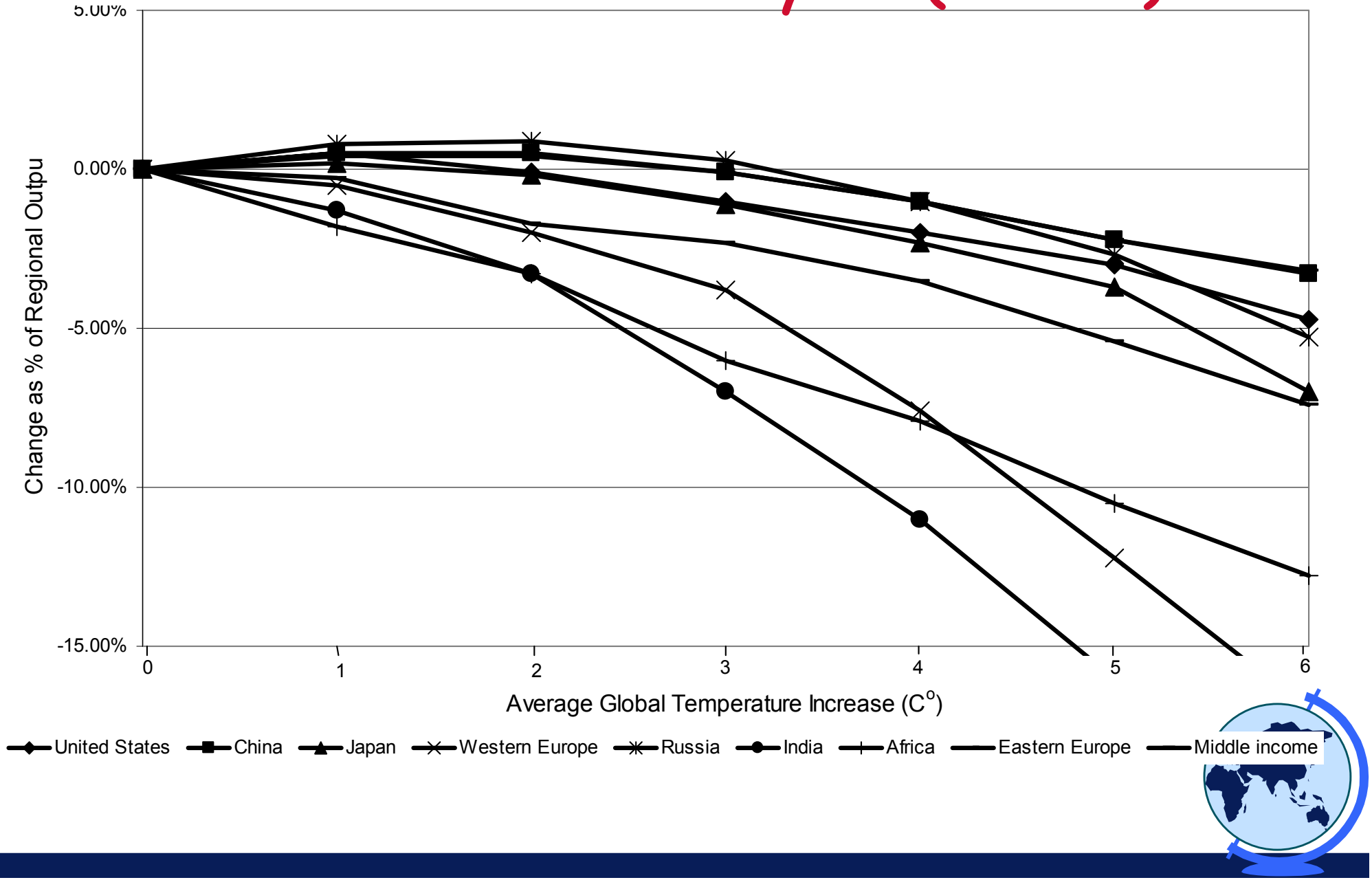
# Distribution of Impacts

- ✓ Are Some Regions, Peoples, Systems, More Adversely Affected Than Others?
- ✓ Is it Equitable?

# Damage of drought and floods (After Zbyscek Kundzewicz)



# Regional damage functions by Nordhaus and Boyer (2000)



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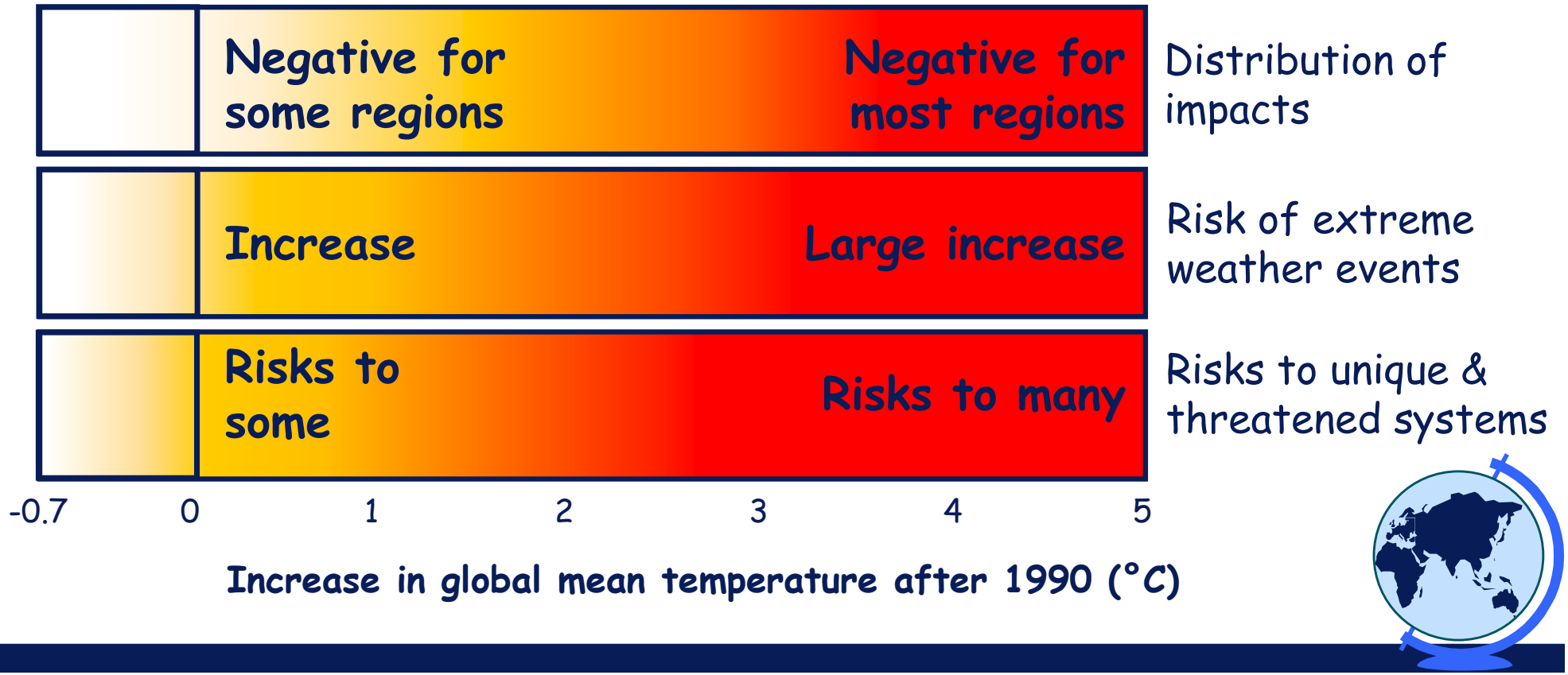
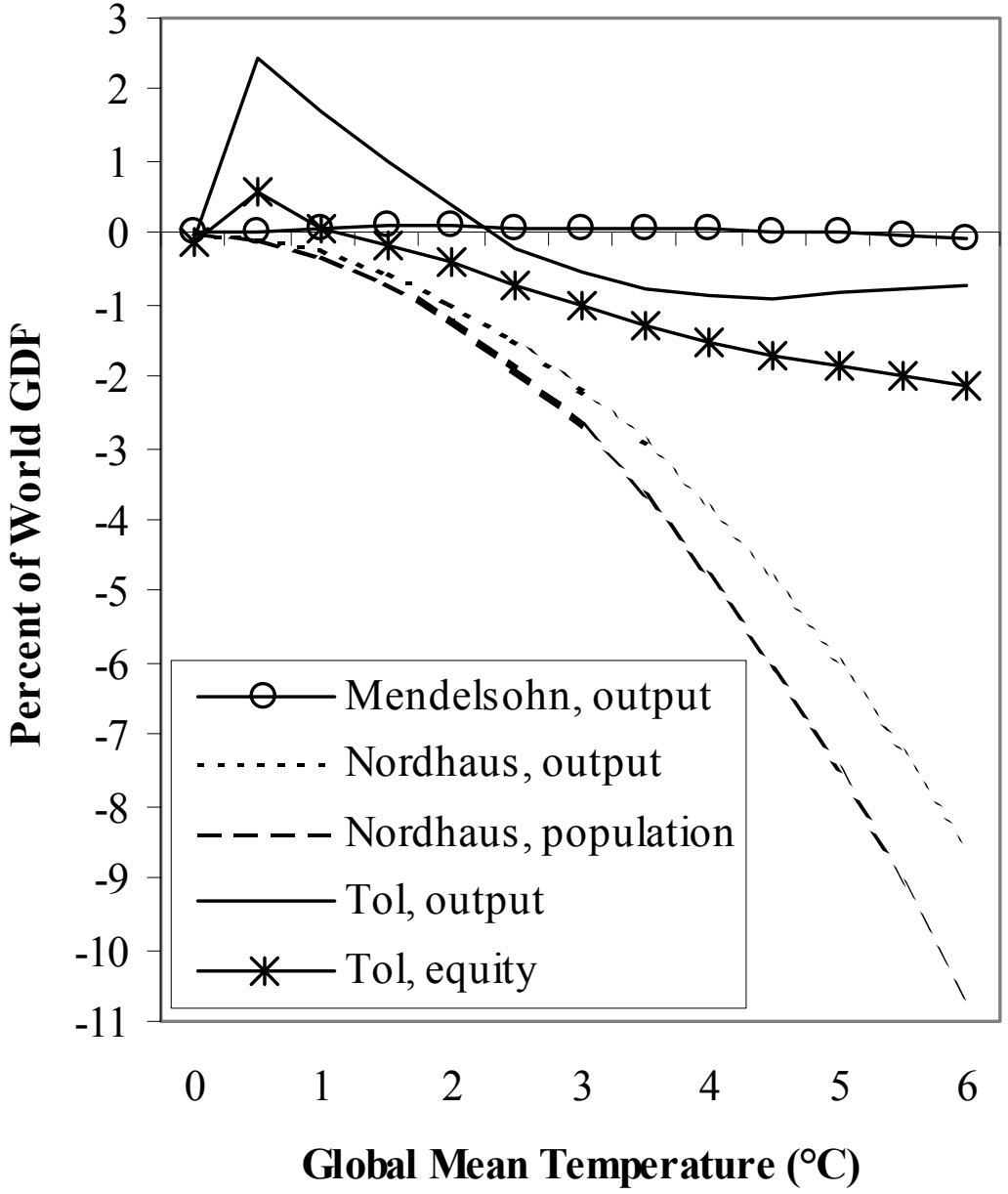


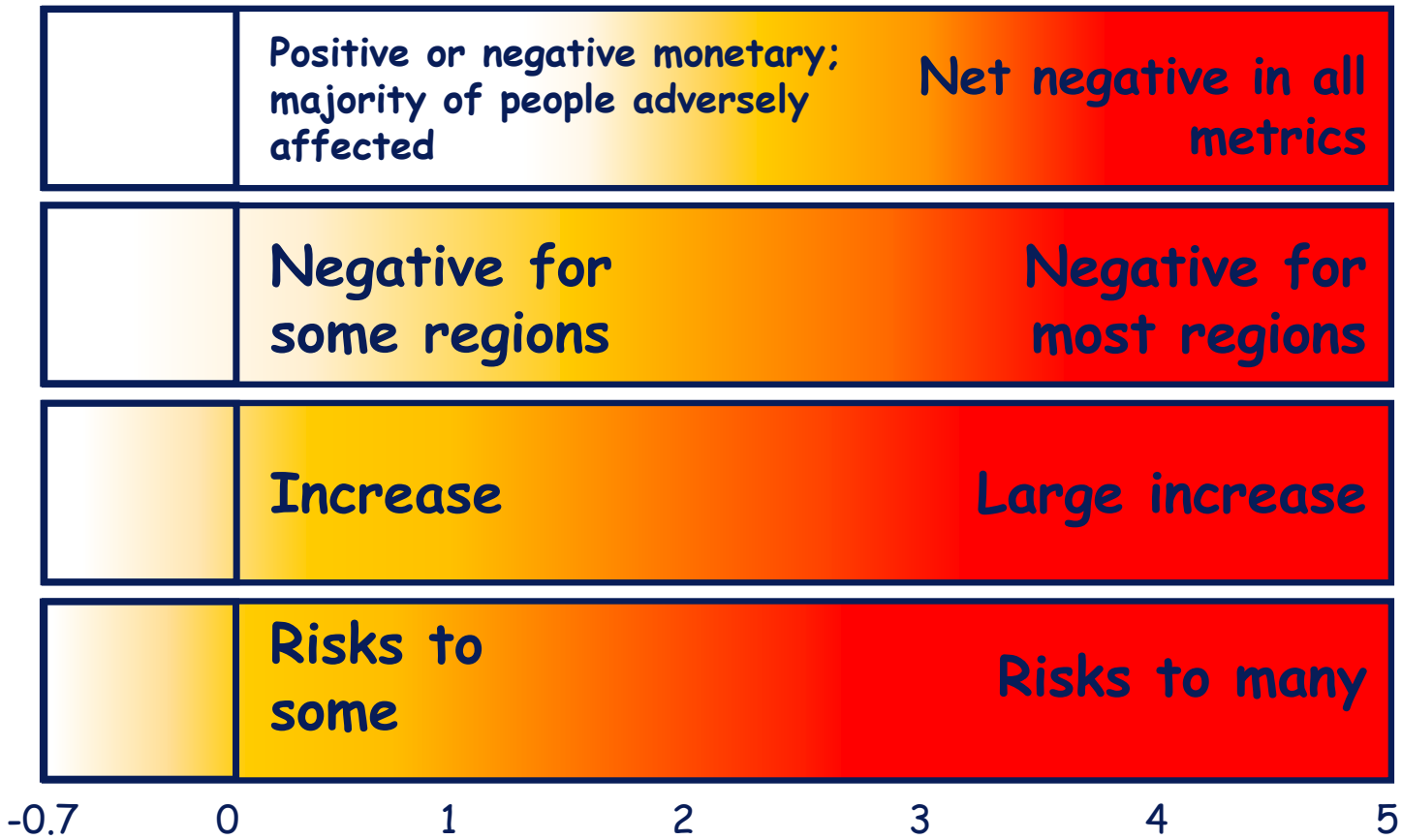
# Aggregate Impacts

- ✓ Examines totality of impacts, using a common metric
- ✓ Monetization is most often used
- ✓ Monetization is controversial because:
  - o Emphasizes wealthy at expense of poor
  - o Hides inequalities

# Global Monetary Impacts



# The IPCC vulnerability synthesis: Reasons for Concern

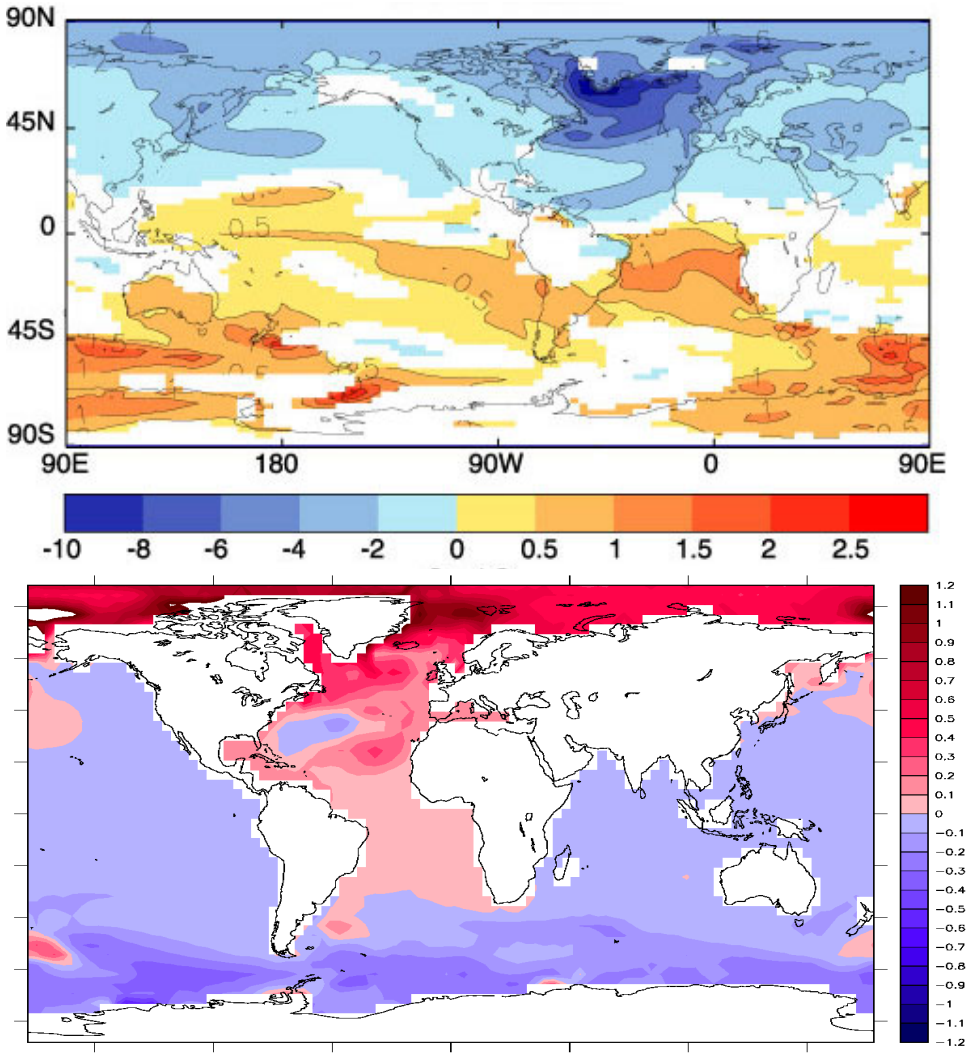


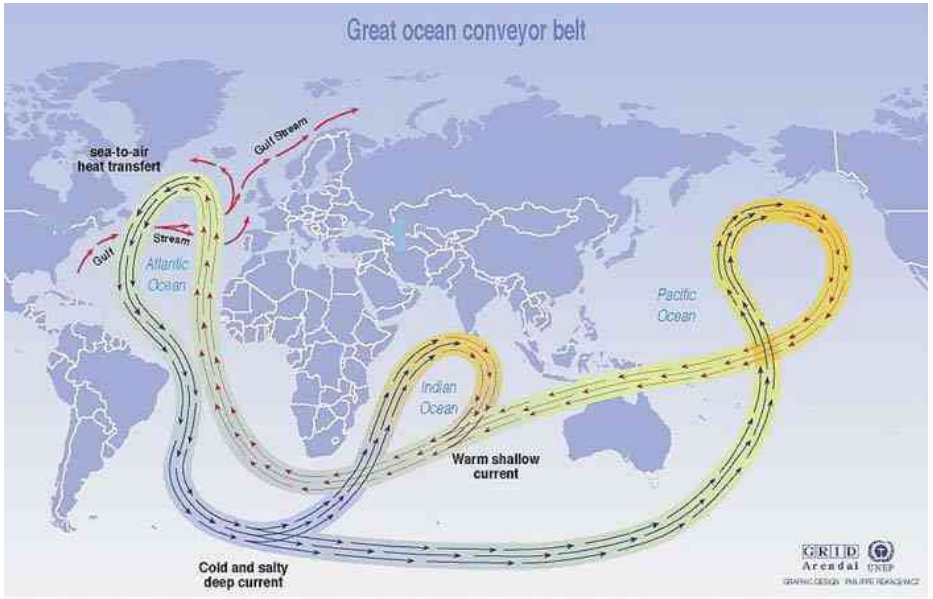
# Large Scale Singularities (surprises)

System Changes; Low likelihood but potentially large consequences

- West Antartic Ice Sheet disintegration: 4-6 meter sea level rise:
- ThermoHaline Circulation Collapse: Cooling of North Atlantic
- Runaway Greenhouse Effect: Positive feedbacks in the carbon cycle

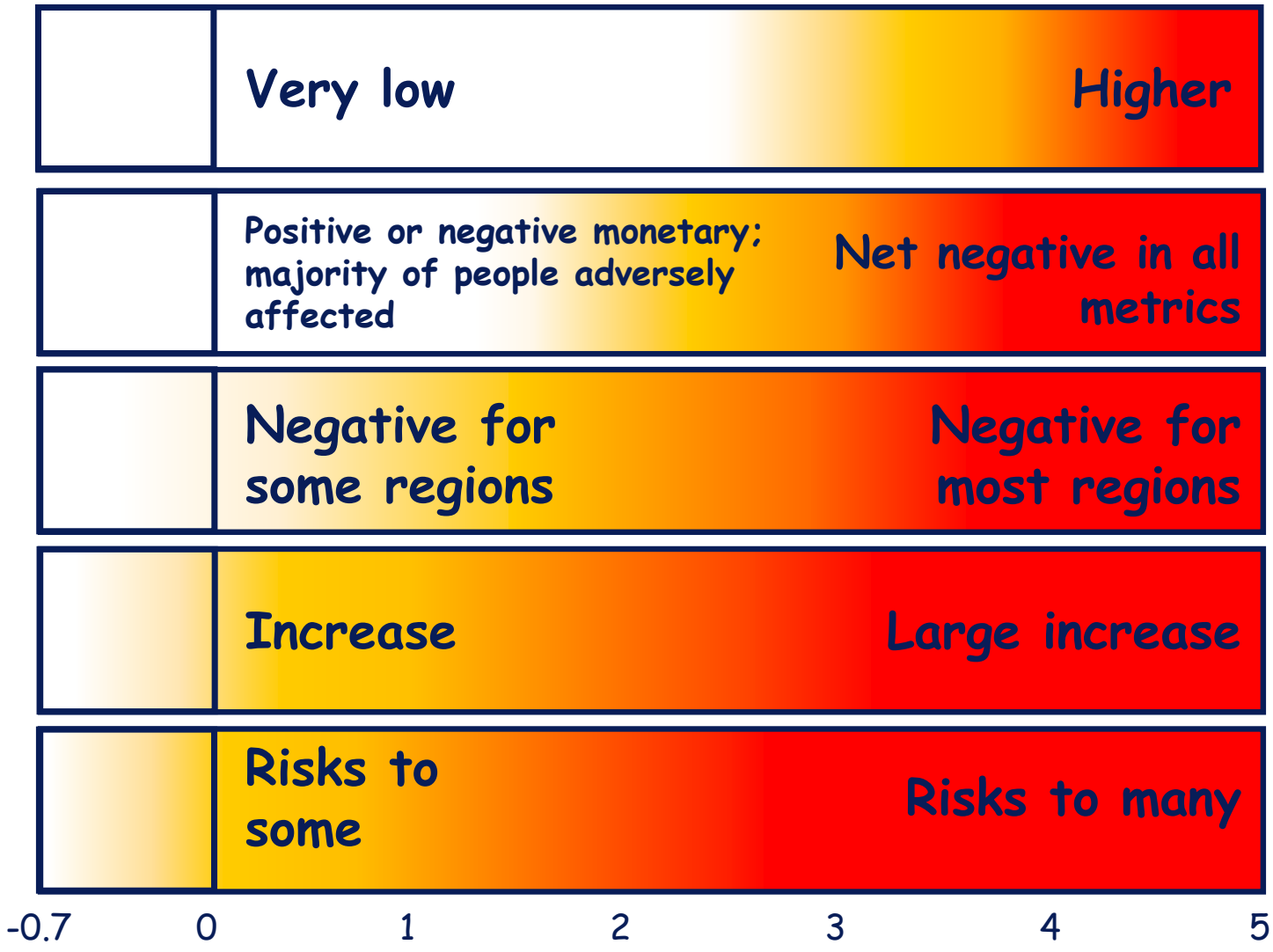
# Thermohaline Circulation



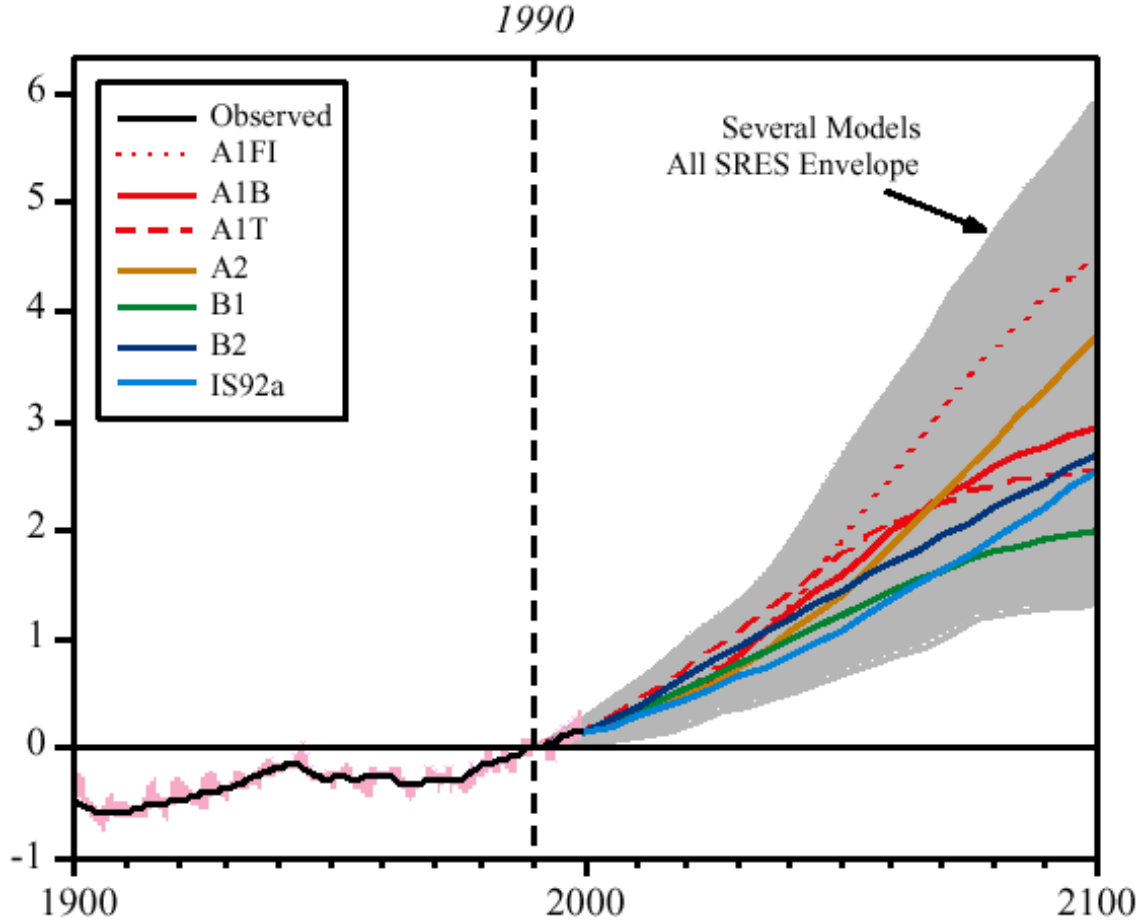



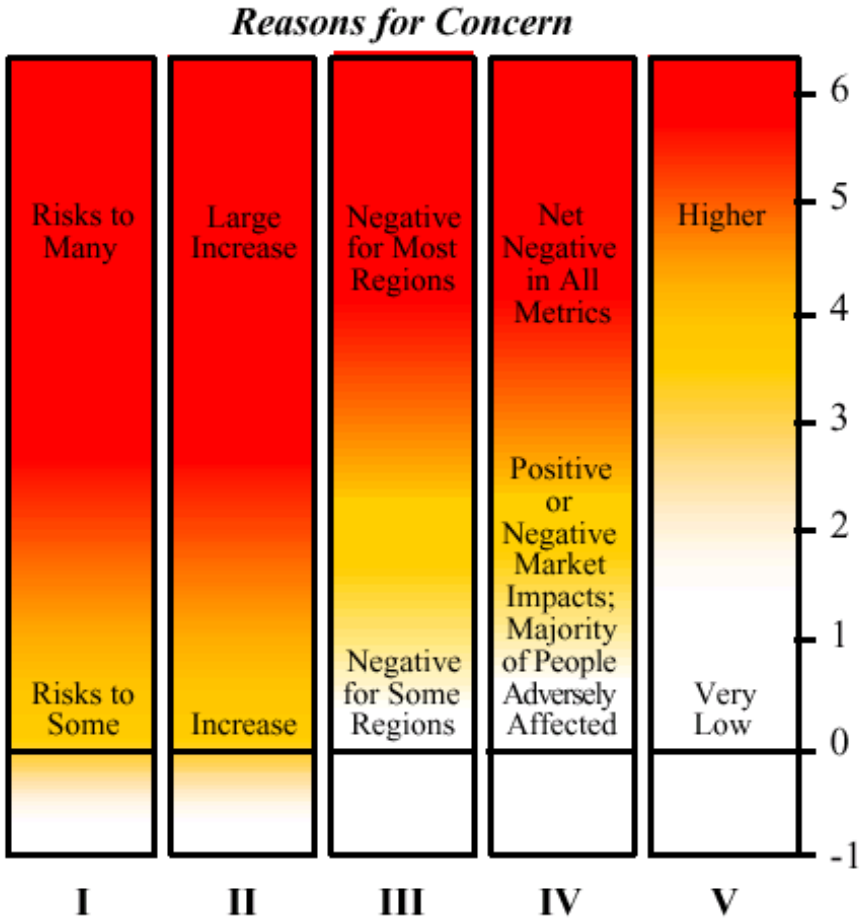

Response is a function of the absolute increase in temperature and the rate of temperature increase.

# The IPCC vulnerability synthesis: Reasons for Concern



# IPCC SRES scenarios and reason for concerns for dangerous impacts



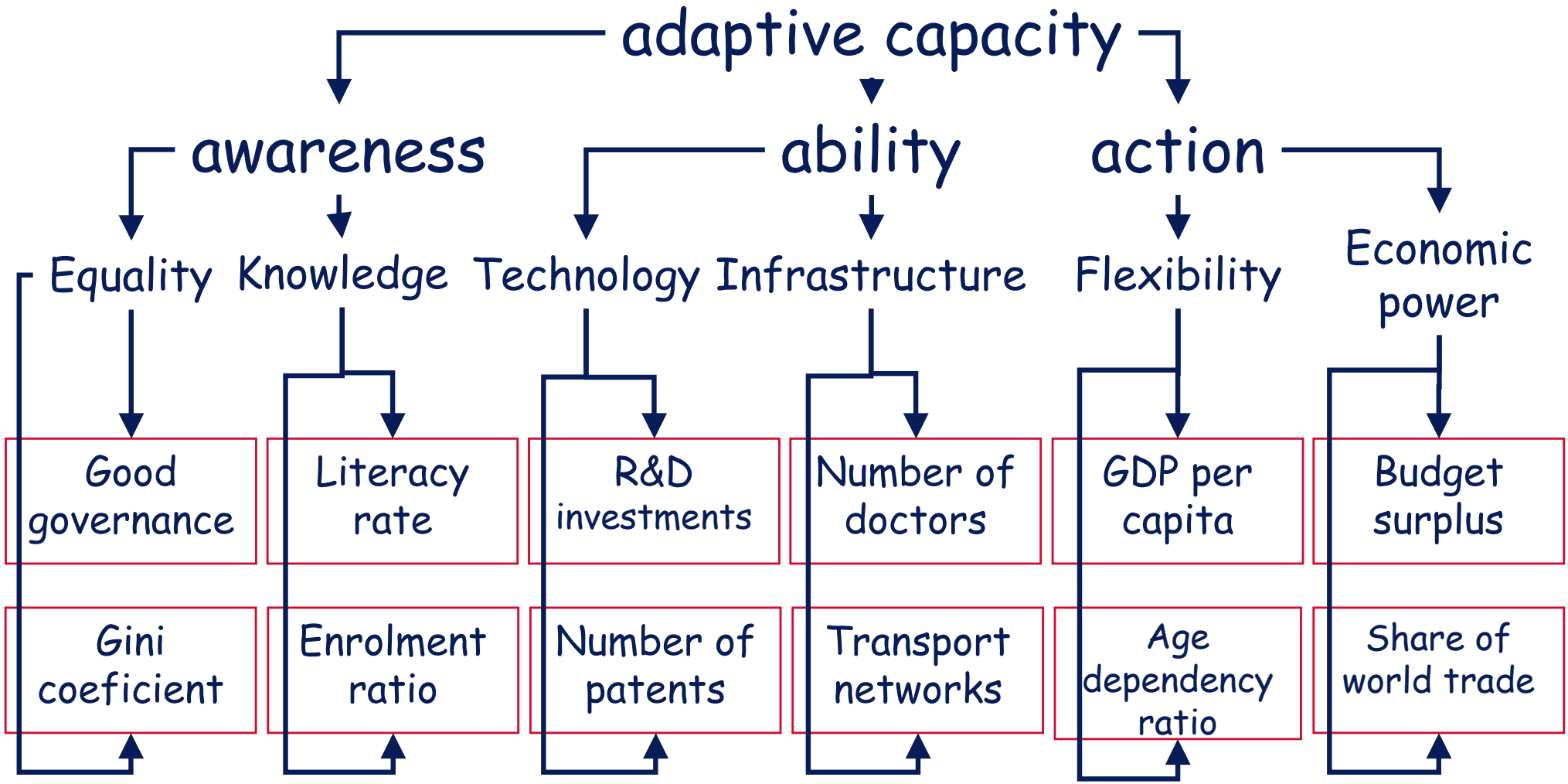



# Aggregated indicators

# Adaptive capacity

Vulnerability = f(exposure, sensitivity, adaptive capacity)

adaptive capacity = f(awareness, ability, action)



# Adaptive Capacity

adaptive capacity

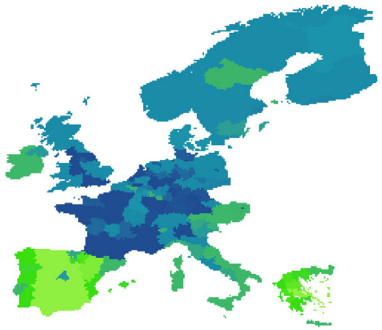
Freedom index
Gini coefficient
Literacy rate
Enrolment ratio
R & D investment
Number of patents
Transport network
Number of doctors
GDP per capita
Age dependency ratio
Budget surplus
Share to world trade

Equality
Knowledge
Technology
Infrastructure
Flexibility
Economic Power

Awareness
Ability
Action

Adaptive Capacity

1990



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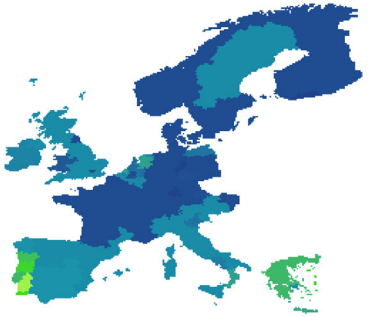


# Key indicators of vulnerabilty

Potential proxies for

| Category |
|---|
| Economy |
| Health & nutrition |
| Educatior |
| Infrastru |
| Governan |
| Geograph demograp |
| Agricultu |
| Ecology |
| Technolo |

| Most vulnerable countries | | Moderately to highly vulnerable | |
|---|---|---|---|
| Afghanistan | 13 | *Cote d'Ivoire* | 10 |
| *Angola* | 13 | Qatar | 10 |
| *Burundi* | 13 | *Kenya* | 9 |
| *Central African Rep.* | 13 | Laos | 9 |
| *Democratic Republic of Congo* | 13 | North Korea | 8 |
| | | Yugoslavia | 7 |
| *Eritrea* | 13 | *Nigeria* | 7 |
| *Ethiopia* | 13 | *Benin* | 6 |
| *Equatorial Guinea* | 13 | **Turks and Caicos Islands** | 6 |
| *Gambia* | 13 | Bosnia Herzegovina | 5 |
| *Guinea Bissau* | 13 | *Congo* | 5 |
| **Haiti** | 13 | *Mali* | 5 |
| *Mauritania* | 13 | **Guadeloupe** | 5 |
| *Mozambique* | 13 | *Senegal* | 5 |
| *Niger* | 13 | **Tonga** | 5 |
| Pakistan | 13 | Nepal | 4 |
| *Rwanda* | 13 | *Djibouti* | 3 |
| *Sierra Leone* | 13 | *Zimbabwe* | 3 |
| *Somalia* | 13 | Azerbaijan | 2 |
| *Sudan* | 13 | Puerto Rico | 2 |
| *Togo* | 13 | Bangladesh | 1 |
| Turkmenistan | 12 | Bhutan | 1 |
| *Chad* | 12 | Estonia | 1 |
| *Gabon* | 12 | Cambodia | 1 |
| Iraq | 12 | *Uganda* | 1 |
| *Liberia* | 12 | United Arab Emirates | 1 |
| *Malawi* | 11 | French Guiana | 1 |
| Brunei Darussalam | 11 | Morocco | 1 |
| *Burkina Faso* | 11 | **Wallis and Futuna Islands** | 1 |
| *Guinea* | 11 | | |
| Yemen | | | |

- Population with access to sanitation
- Literacy rate, 15-24 years olds
- Maternal mortality
- Literacy rate, over 15 years
- Caloric intake
- Voice and accountability
- Civil liberties
- Political rights
- Government effectiveness
- Literacy rate, female to male ratio
- Life expectancy at birth

Brooks, N., W. N. Adger, and P. M. Kelly. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change **15**:151-163.

# Hierarchical indicators framework

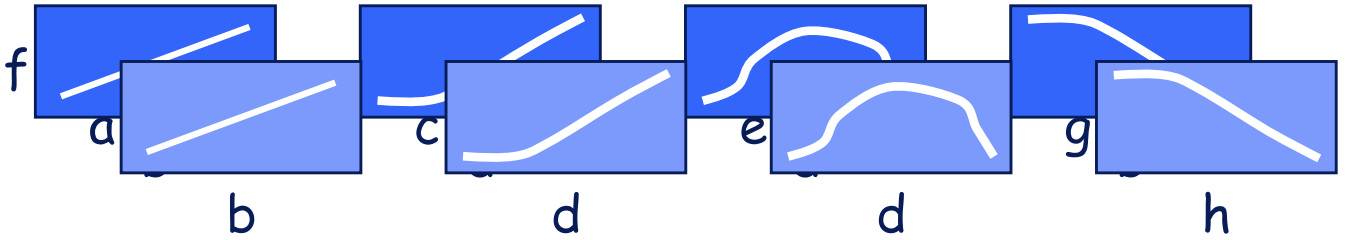
Ultimate indicator


Summary indicators

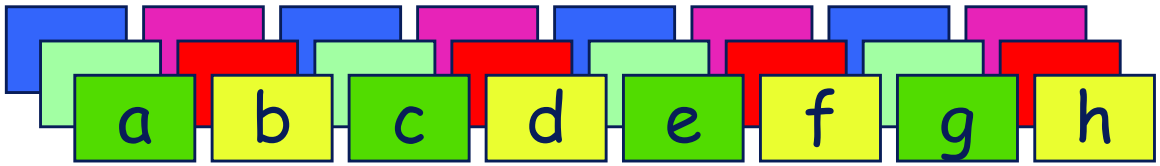

Aggregated indicators


Sectoral, issue oriented or regional indicators


Emperical correlations



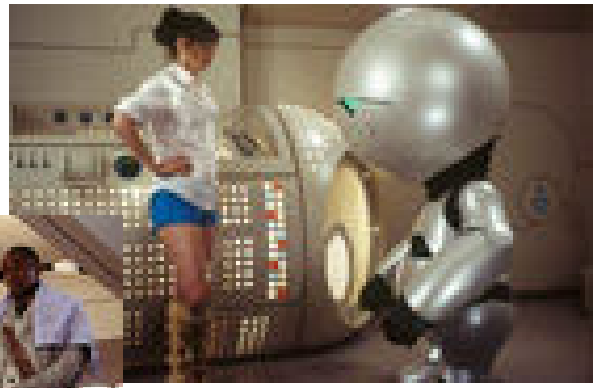

Direct observations & measurements





A race of hyper-intelligent pan-dimensional beings built themselves a gigantic supercomputer called **Deep Thought** to calculate once and for all the Answer to the **Ultimate Question of Life, the Universe and Everything**.

For seven and a half million years, Deep Thought computed and calculated, and in the end announced that the Answer was, in fact, **forty-two**.



From: Douglas Adams. The Hitch-hikers Guide to the Galaxy. Guild Publishing, London. (1986).

# Thanks for your attention