Global change scenarios

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Global change scenarios

- Some definitions
- Classifying global change scenarios
- Examples of global-scale scenarios
- Regional and local scenarios
- Dealing with uncertainties

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Some definitions

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What is global change?

- **Long-term changes in the environment affecting many or all areas of the globe**

and

- **Long-term changes in the driving factors of environmental change, which are also global in extent**

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Examples of global environmental change

- atmospheric composition changes
- eutrophication of waters
- stratospheric ozone depletion
- climate change
- sea-level rise
- land degradation and desertification

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Drivers of global change can be:

- **Natural - processes in the environment (e.g. climatic fluctuations, erosion and sedimentation, ice dynamics, volcanoes, solar variations, population dynamics)**
- **Anthropogenic - relating to human activity (e.g. demographic trends, economic development, land use change, fossil fuel combustion, industrial processes, agriculture)**

Examples of the global driving factors of environmental change

- demographic change (human population)
- socio-economic development
- technological change
- land cover/land use change

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Scenarios

- alternative images of how the future can unfold
- *not* forecasts/predictions
- important tools for assessing future developments in complex systems with high uncertainties

Not all impact/vulnerability assessments require scenarios

For example:

- **Assessing vulnerability to climate change by studying adaptive capacity under present-day climate variability**

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Who needs scenarios?

- ***Scientists*** **need projections of global change to assess impacts and adaptive capacity**
- ***Policy makers*** **need projections to assist in formulating appropriate responses to global change**
- **The *general public* needs to be informed about global change**

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Possible uses for scenarios in policy-oriented environmental assessments

- provide a picture of future alternative states of the environment
- raise awareness about the future connection between different environmental problems
- illustrate how alternative policy pathways can achieve an environmental target
- combine qualitative and quantitiative information about the future evolution of an environmental problem
- identify the robustness of environmental policies under different future conditions
- help stakeholders, policymakers and experts to account for the large time and space scales of a problem
- help raise awareness of new or intensifying environmental problems

Alcamo, 2001

Classifying global change scenarios

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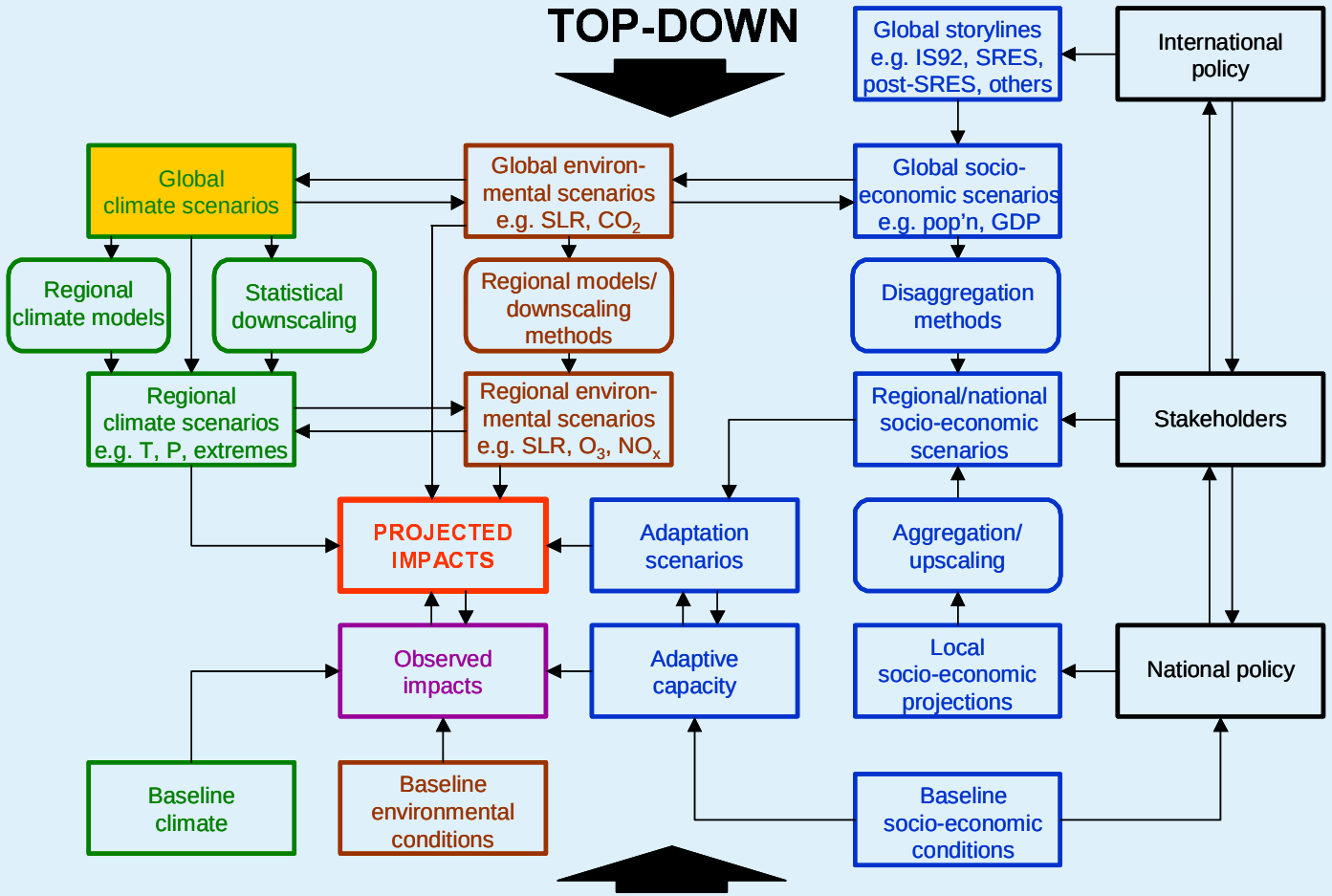
Organisation of data/scenarios in the IPCC DDC



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Approaches for organising data and treating scenarios

- Top down = impact assessment?
- Bottom up = vulnerability assessment?

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Broad scenario types

1. Exploratory (descriptive) scenarios

Describe how the future might unfold based on known processes of change and extrapolations of past trends

Include "business-as-usual" scenarios, but can also describe bifurcations or other assumptions about regulation or adaptation

2. Normative (prescriptive) scenarios

Describe a prespecified future; a world achievable (or avoidable) only through certain actions

Includes "worst case" scenarios and "target-based" scenarios, often requiring "back casting"

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Scenarios may be required for:

- **Illustrating global change (e.g. regional analogues of projected climate)**
- **Communicating potential consequences of global change (e.g. vegetation shift; species at risk)**
- **Strategic planning (e.g. design of coastal or river flood defences)**
- **Guiding emissions control policy (e.g. alternative options for achieving atmospheric composition targets)**
- **Methodological purposes (e.g. new scenario development techniques; impact model evaluation)**

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Classification of global change scenarios

- Qualitative scenarios/narrative storylines
- Incremental scenarios for sensitivity testing
- Analogue scenarios
- Model-based scenarios
- Scenarios based on expert judgement
- Composite scenarios

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Some general scenario requirements for integrated regional impact studies

- Constructed for a relevant set of climate and non-climate changes
- Internally consistent, mutually consistent and physically plausible
- Projected over an appropriate time horizon
- Of a sufficient spatial and temporal resolution
- Representative of the range of uncertainty in projections, including non-linear events
- Consider changes in variability as well as mean conditions

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Base case scenarios

Various roles:

- To provide a reference or benchmark against which to evaluate global changes
- To characterise the social, economic, technological and environmental conditions to which systems are exposed at the present-day
- To provide the initial conditions for modelling future changes

- Impact/vulnerability assessments can be very sensitive to the base case

Defining base case scenarios

Possible interpretations of the base case for a given state of an environmental variable:

- ***Point of departure*: observed state in a reference year**
- ***Current baseline*: observed present-day state in the present-day context**
- ***Future baseline*: observed present-day state in a projected context**
- ***Business-as-usual future*: projected state in a projected context without policy intervention**
- ***Policy reference*: projected state in a projected context assuming a given policy measure**

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Scenario time horizon

Choice is influenced by:

- Relevance to the system/sector under study
- Signal:noise considerations
- Importance of lags in response
- Availability of projections

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Examples of global-scale scenarios

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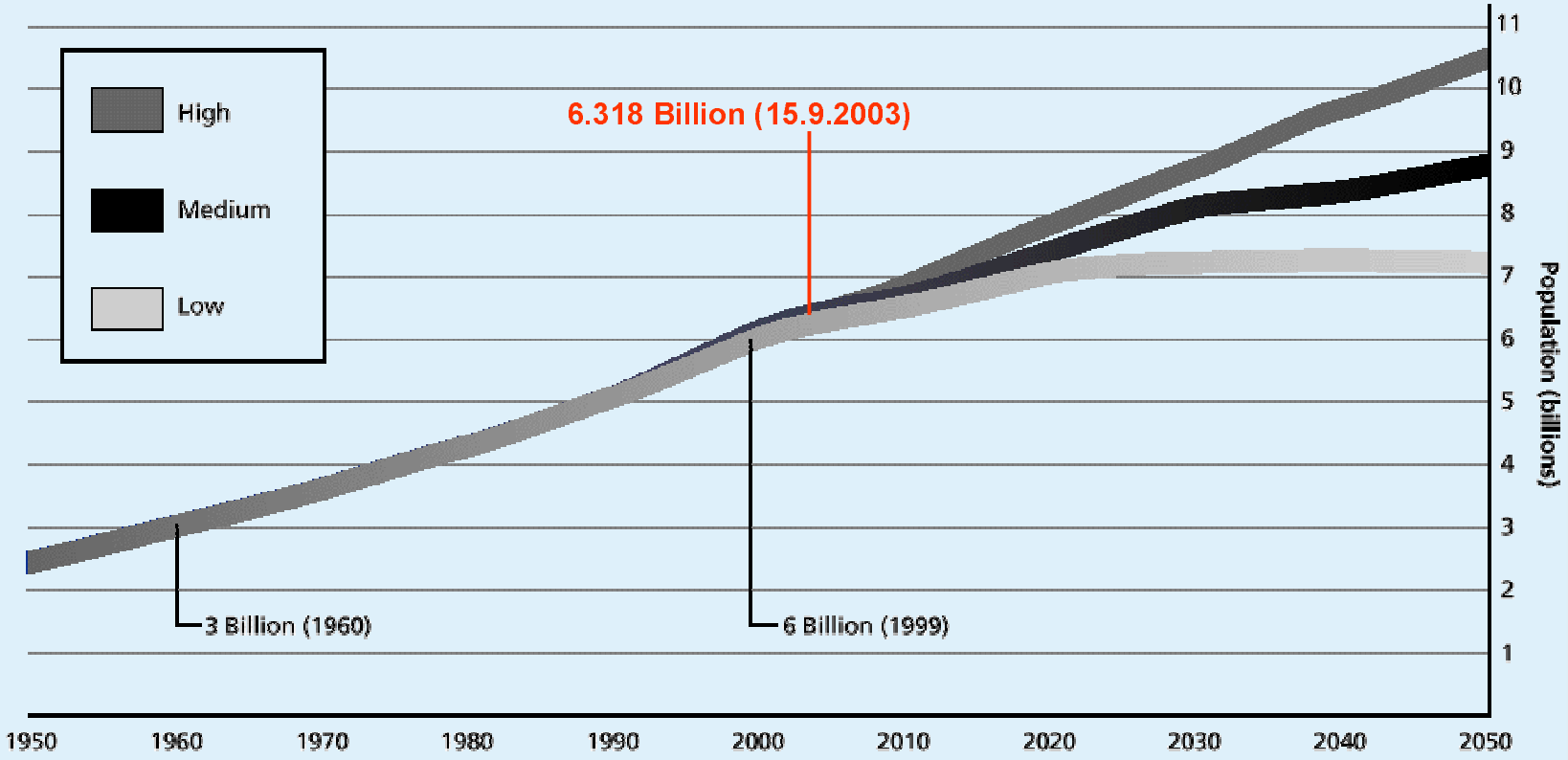
World population: observed and projected 1950-2050



United Nations, 1998;
World population clock

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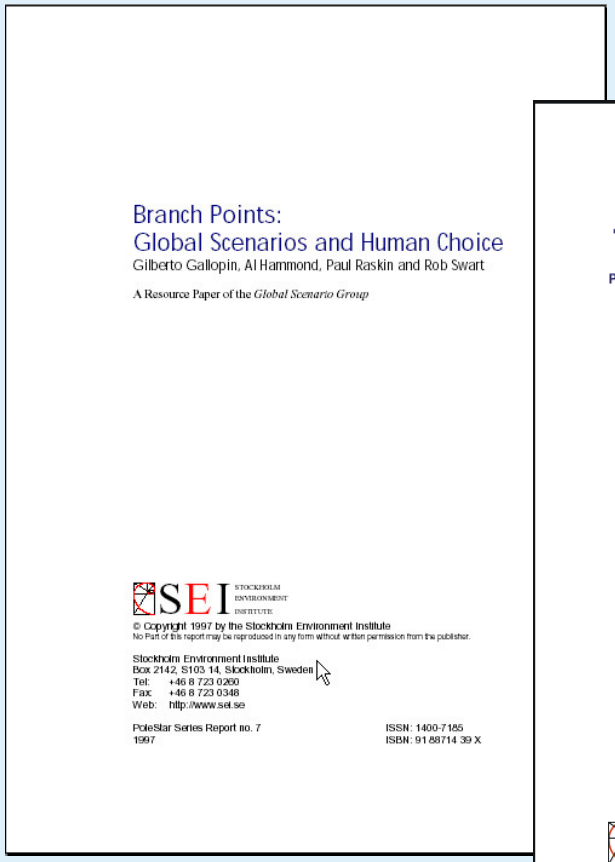
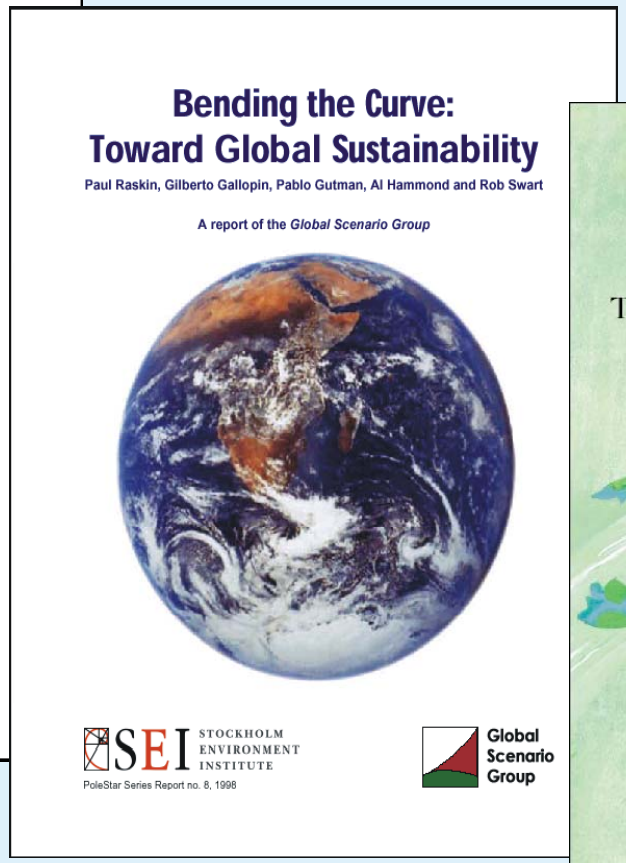
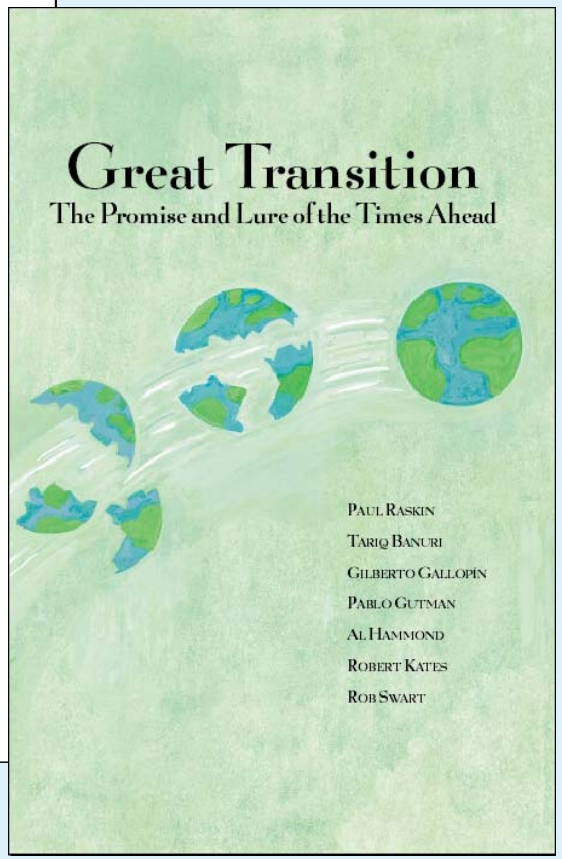
AVEC International Summer School, Peyresq / France, 2003



Gallopin *et al.*, 1997



Raskin *et al.*, 1998



Raskin *et al.*, 2002

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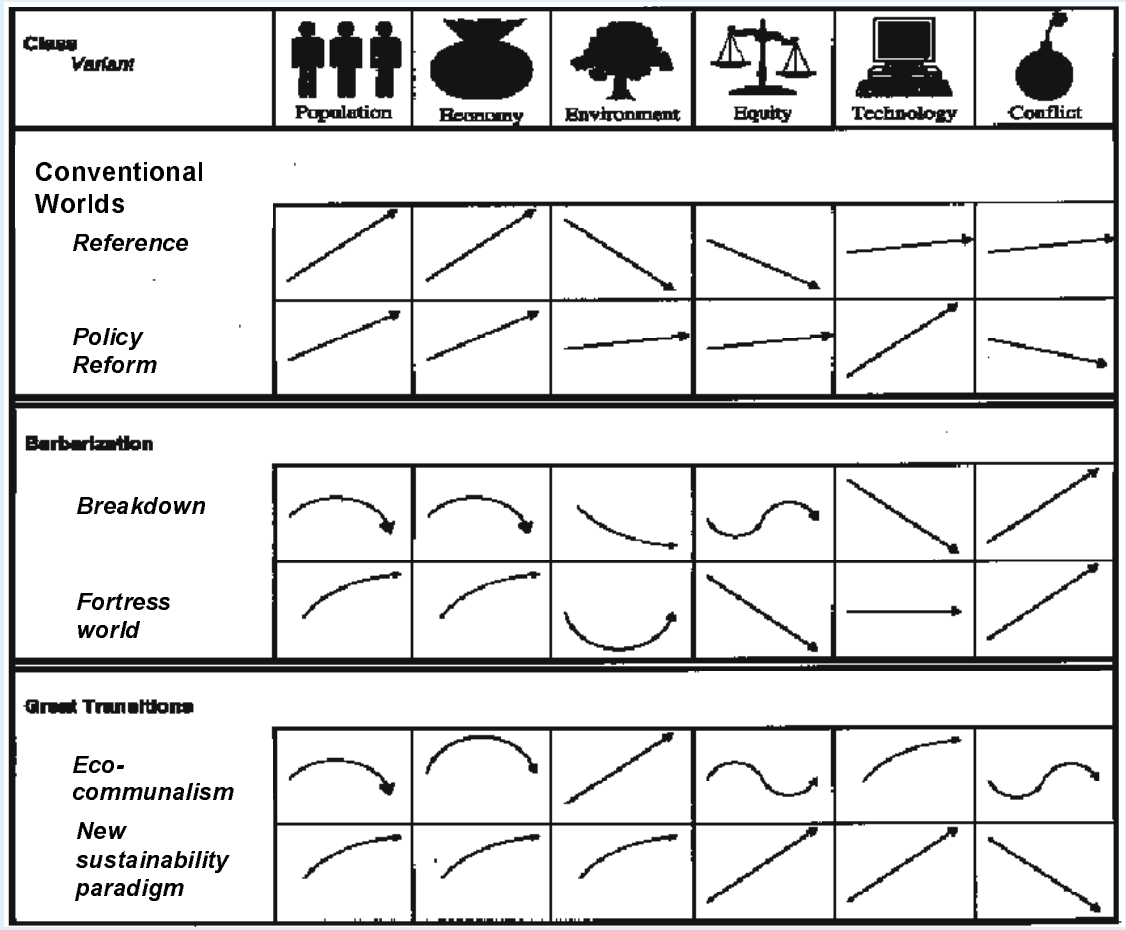
Three archetypal scenarios of the future

- **Conventional Worlds:** current trends play out without major discontinuity and surprise in the evolution of institutions, environmental systems and human values.
- **Barbarization:** fundamental social change occurs, but is unwelcome, bringing great human misery and collapse of civilized norms.
- **Great Transitions:** fundamental social transformation but to a new and arguably higher stage of human civilization.

Gallopin *et al.*, 1997

Scenarios structure with illustrative patterns of change



Gallopin *et al.*, 1997

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The IPCC Special Report on Emissions Scenarios (SRES)

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The SRES scenarios

Purpose: to represent the range of driving forces and emissions in the scenario literature

Scenario characteristics:

- **Extensive literature assessment and "open" process**
- **Four preliminary marker scenarios: no more or less likely than other scenarios**
- **Exclude outlying "surprise" or "disaster" scenarios**
- **Exclude additional climate policy initiatives (UNFCCC)**
- **Six integrated assessment models employed**

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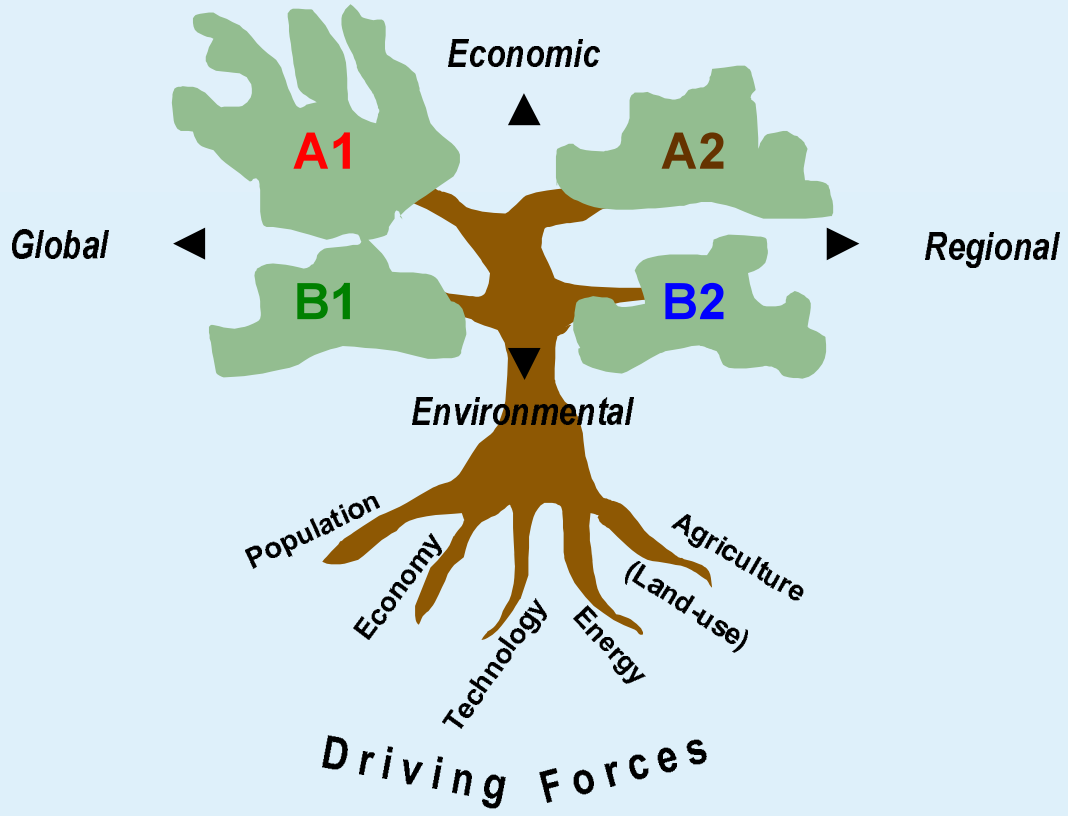
The SRES driving forces and storylines



Nakicenovic *et al*. (2000)

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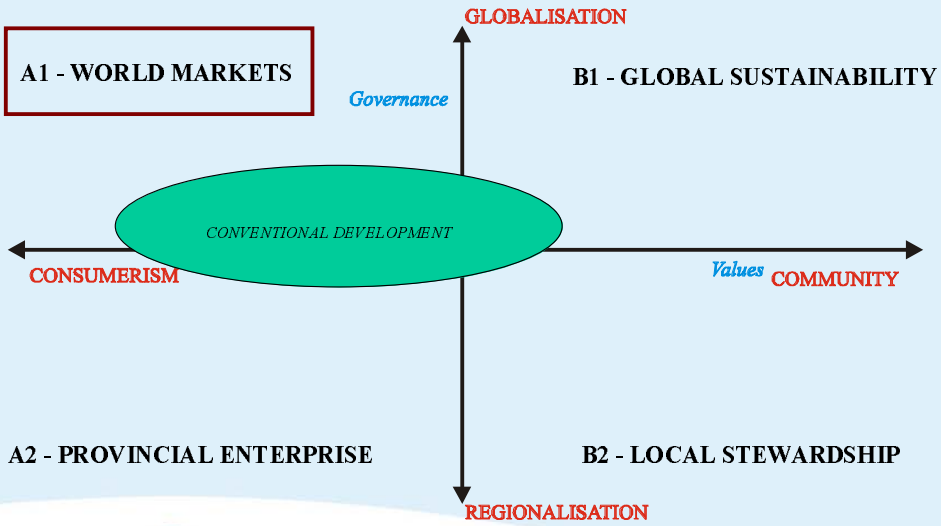
The four IPCC SRES storylines



SRES (2000)

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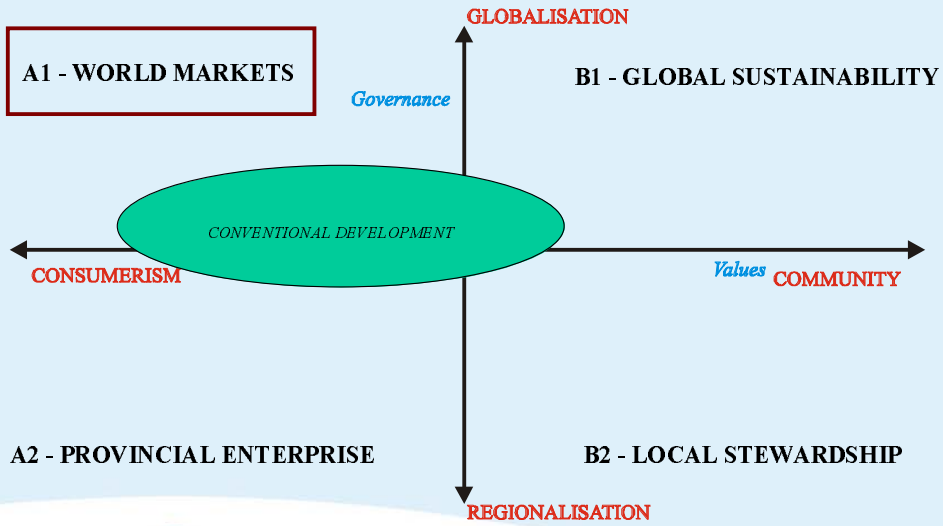
The four IPCC SRES storylines

A1 storyline and scenario family: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.

Major underlying themes are economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. In this world, people pursue personal wealth rather than environmental quality.

Three A1 groups:

- *fossil intensive (A1FI)*
- *non-fossil energy (A1T)*
- *balanced (A1B)*



SRES (2000)

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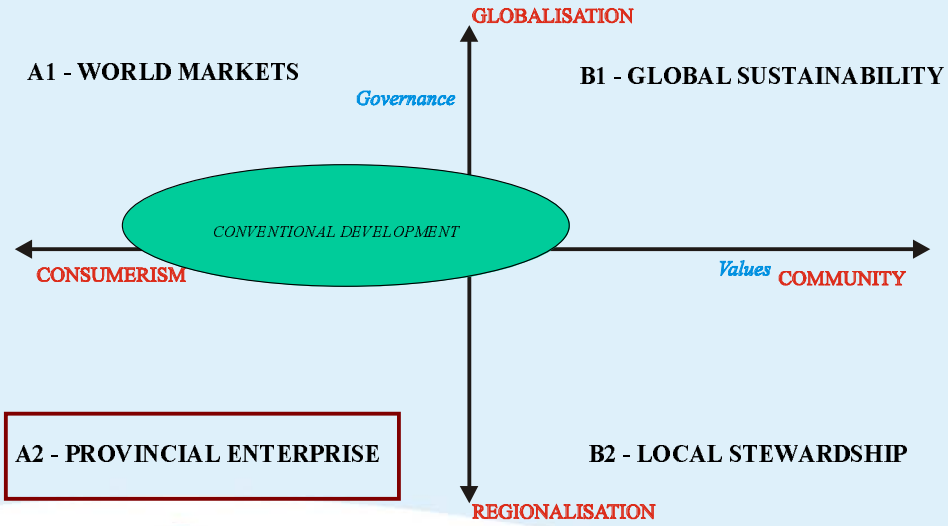
The four IPCC SRES storylines

A2 storyline and scenario family: a very heterogeneous world.

The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.



SRES (2000)

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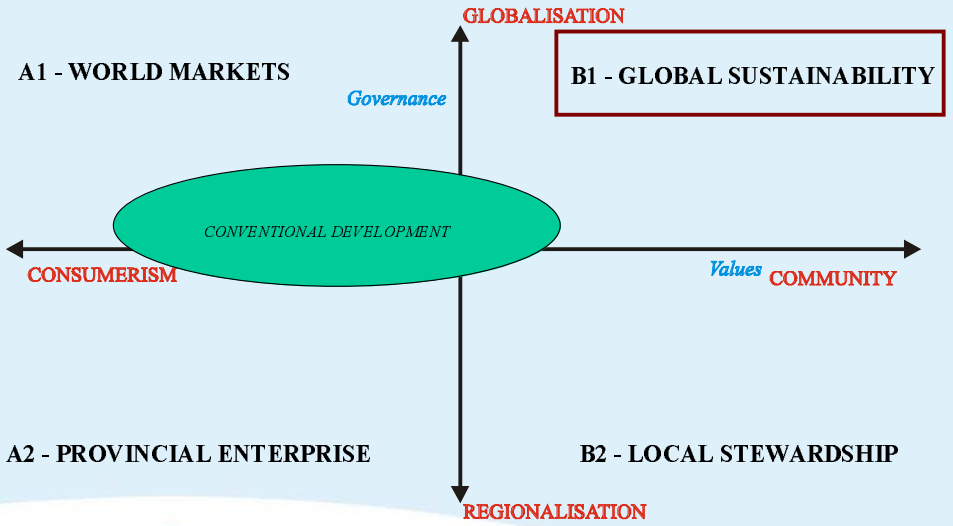
The four IPCC SRES storylines

B1 storyline and scenario family: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.



SRES (2000)

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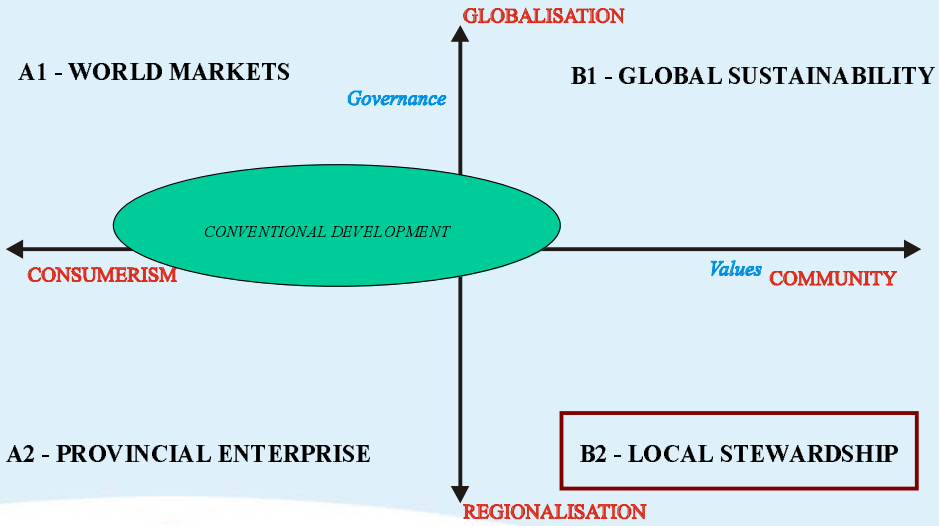
The four IPCC SRES storylines

B2 storyline and scenario family: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability.

It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.



SRES (2000)

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Relative direction of global driving forces for the SRES illustrative scenarios

Scenario	Population	Economy	Environment	Equity	Technology	Globalization
A1FI	↗	↗	→	→	↗	→
A1B	↗	↗	→	→	↗	→
A1T	↗	↗	↗	→	↗	→
B1	↗	→	↗	→	↗	→
A2	↗	→	→	→	→	→
B2	→	→	↗	→	→	→

IPCC (2000)

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The SRES illustrative scenarios: primary driving forces

Family			A1		A2	B1	B2
Scenario group	1990	A1FI	A1B	A1T	A2	B1	B2
Population (billion)	5.3						
2020		7.6	7.5	7.6	8.2	7.6	7.6
2050		8.7	8.7	8.7	11.3	8.7	9.3
2100		7.1	7.1	7.0	15.1	7.0	10.4
World GDP (10^{12} 1990 US$/yr)	21						
2020		53	56	57	41	53	51
2050		164	181	187	82	136	110
2100		525	529	550	243	328	235
Per capita income ratio	16.1						
2020		7.5	6.4	6.2	9.4	8.4	7.7
2050		2.8	2.8	2.8	3.6	3.6	4.0
2100		1.5	1.6	1.6	1.8	1.8	3.0

Nakicenovic *et al*. (2000)

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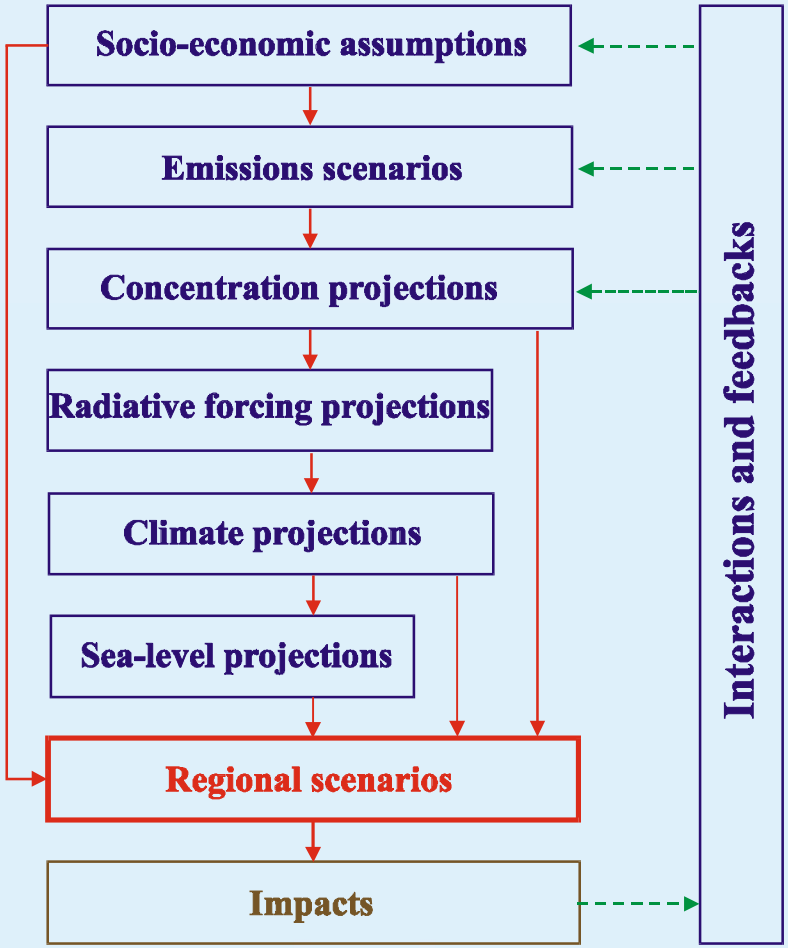
Cascade of dependencies in scenarios for impact assessment



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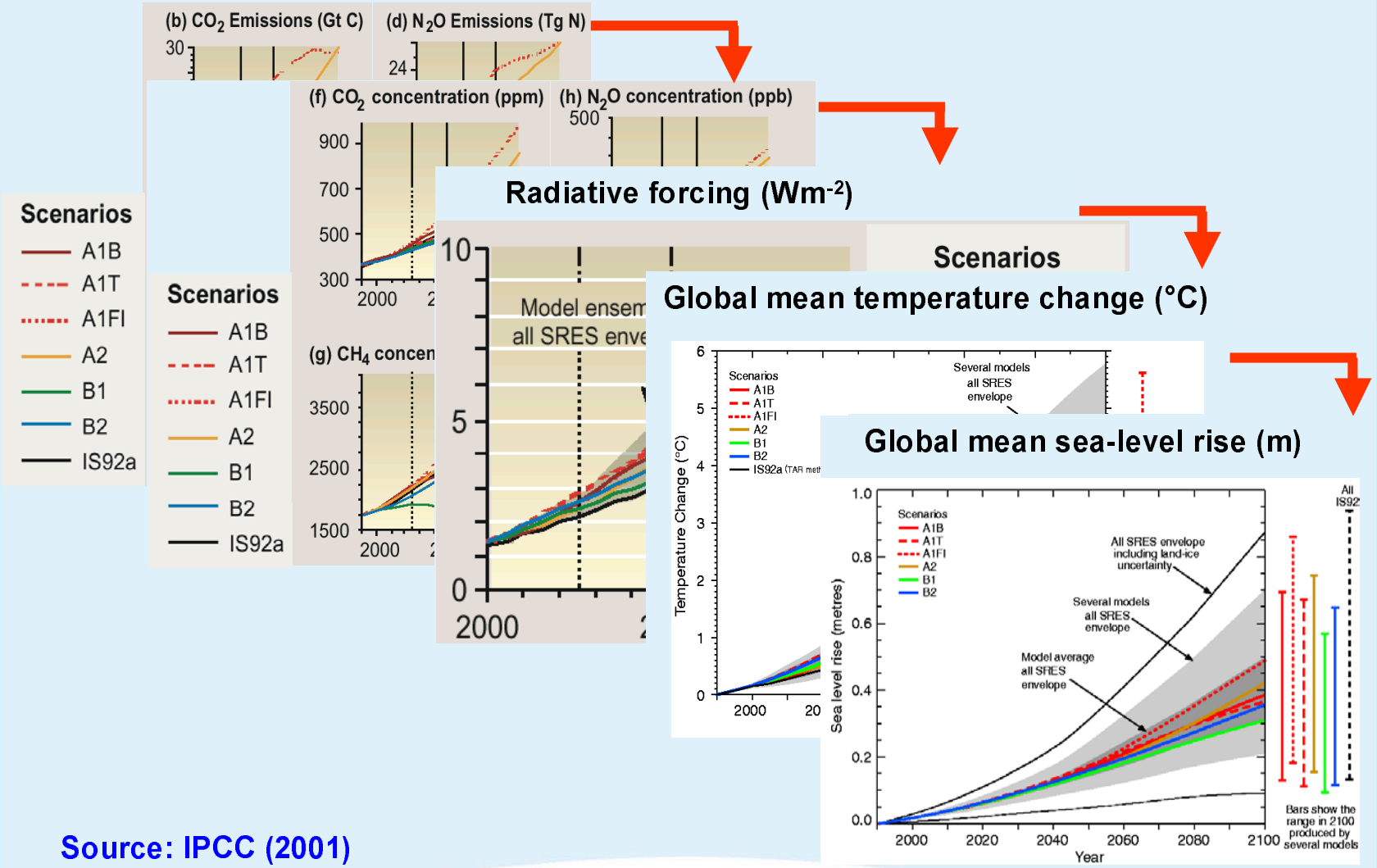

Source: IPCC (2001)

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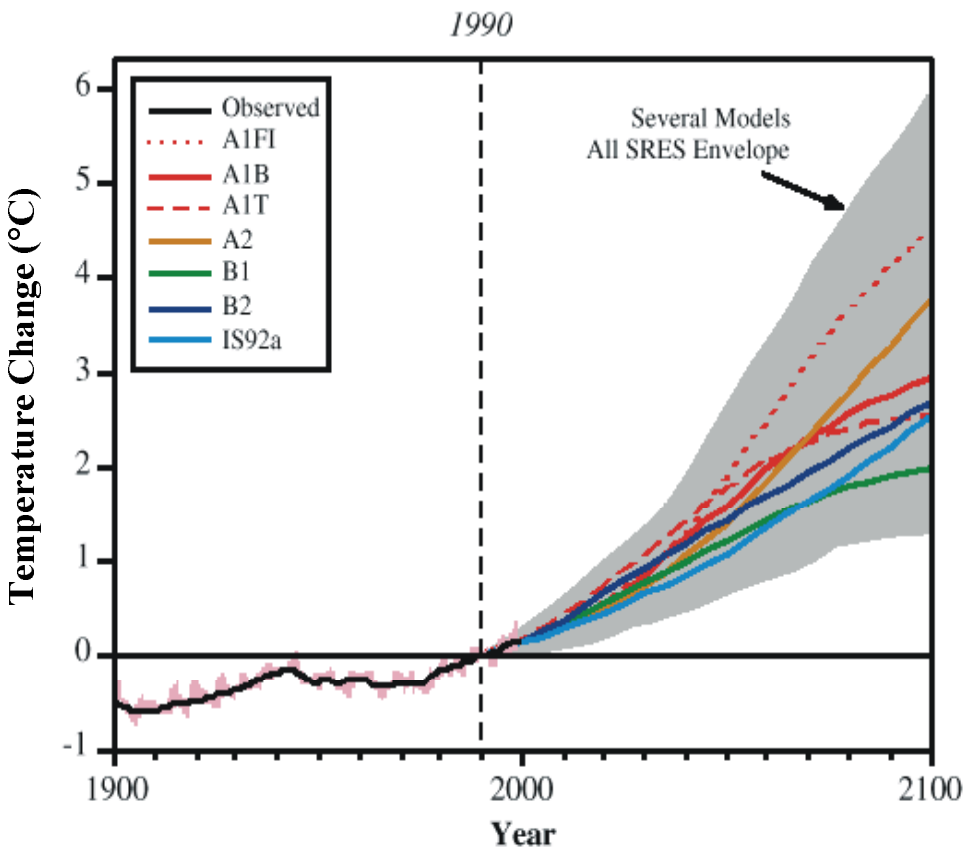

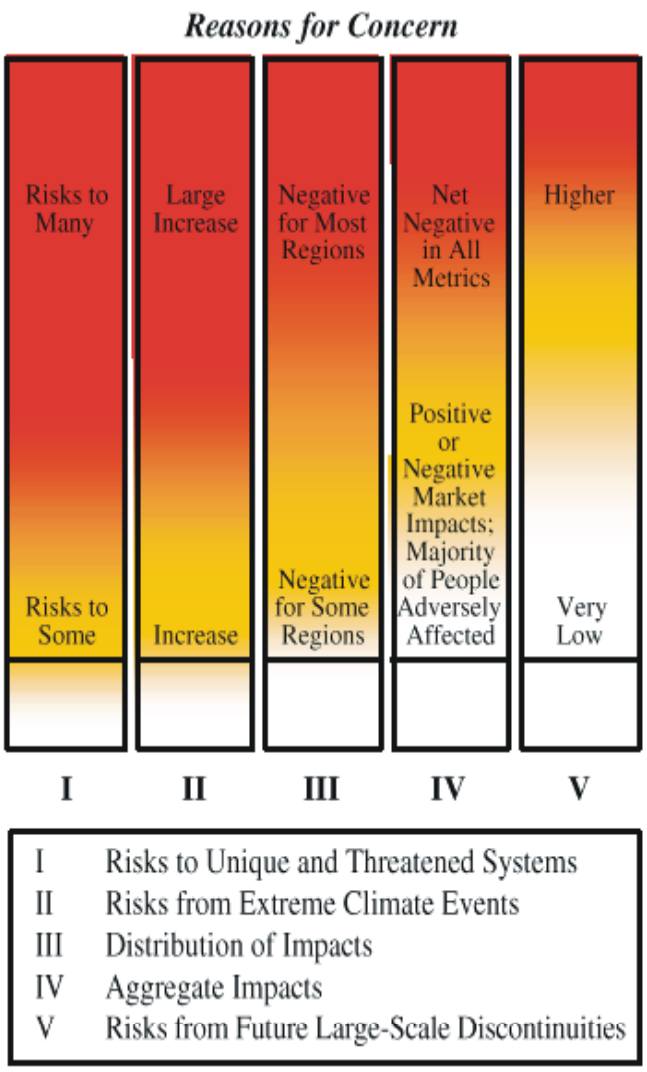

IPCC, 2001

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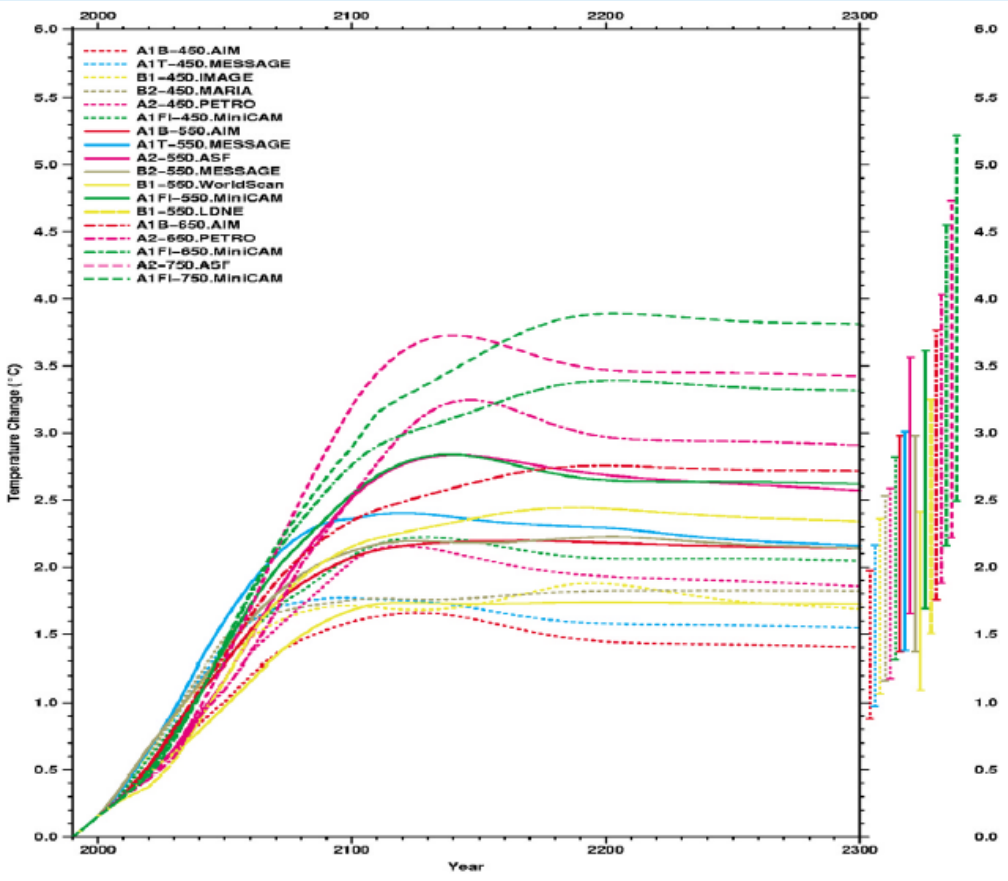
Other features of the SRES scenarios

- Non-intervention, baseline scenarios, but …
- Some scenarios resemble mitigation scenarios

Mean annual temperature change analysed with MAGICC for a range of post-SRES stabilisation scenarios



Swart et al. (2002)

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Resemblance of SRES non-intervention scenarios to stabilisation scenarios

- A1FI: extreme high emissions case
- A2: high emissions case
- A1B: similar to 750 ppm stabilisation
- B2/A1T: similar to 650 ppm stabilisation
- B1: similar to 550 ppm stabilisation

Swart *et al.*, 2002

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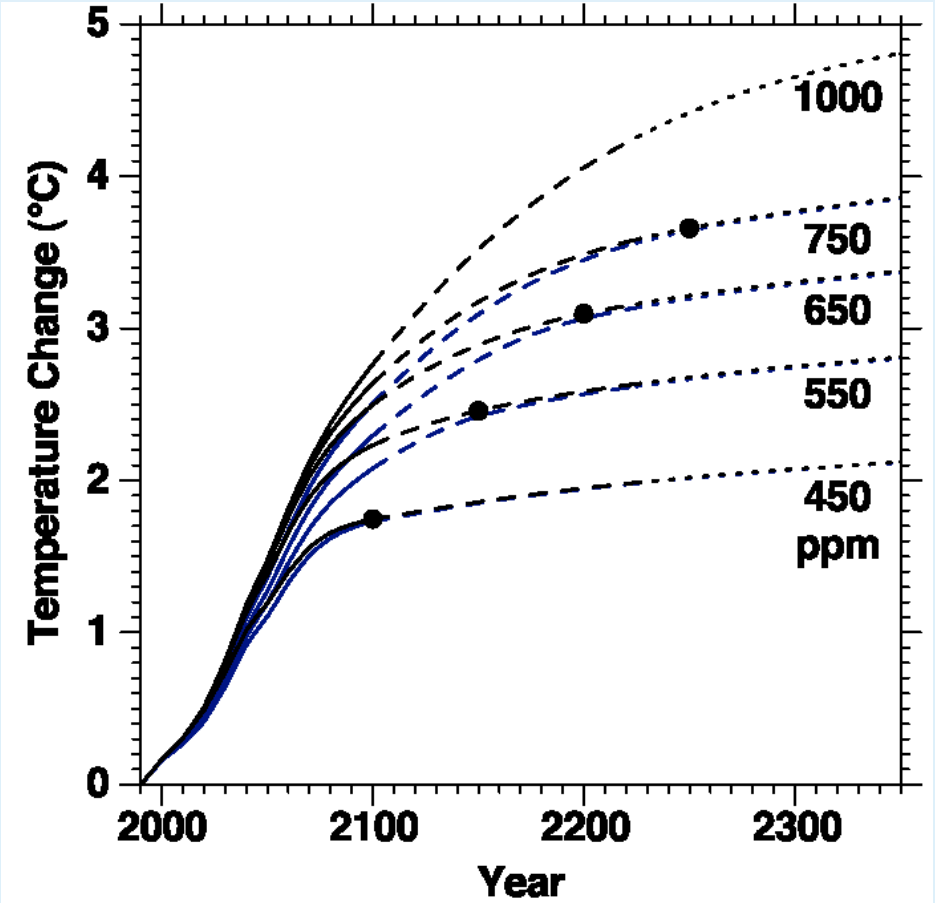
Global mean temperature changes for a stabilisation of CO_2 concentration at different levels from 450-1000 ppm



Cubasch *et al*. (2001)

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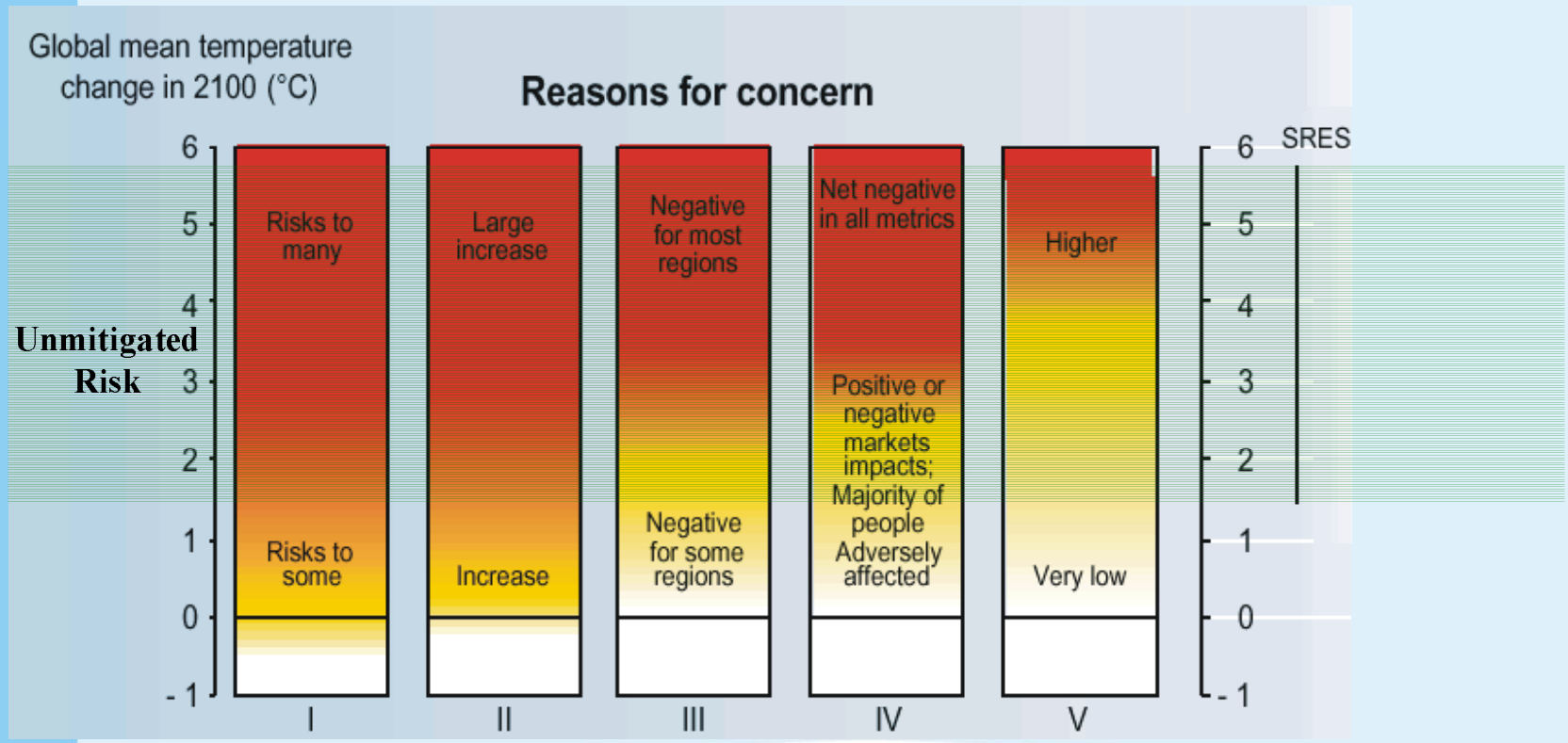
Reducing risks: mitigation



IPCC, 2001

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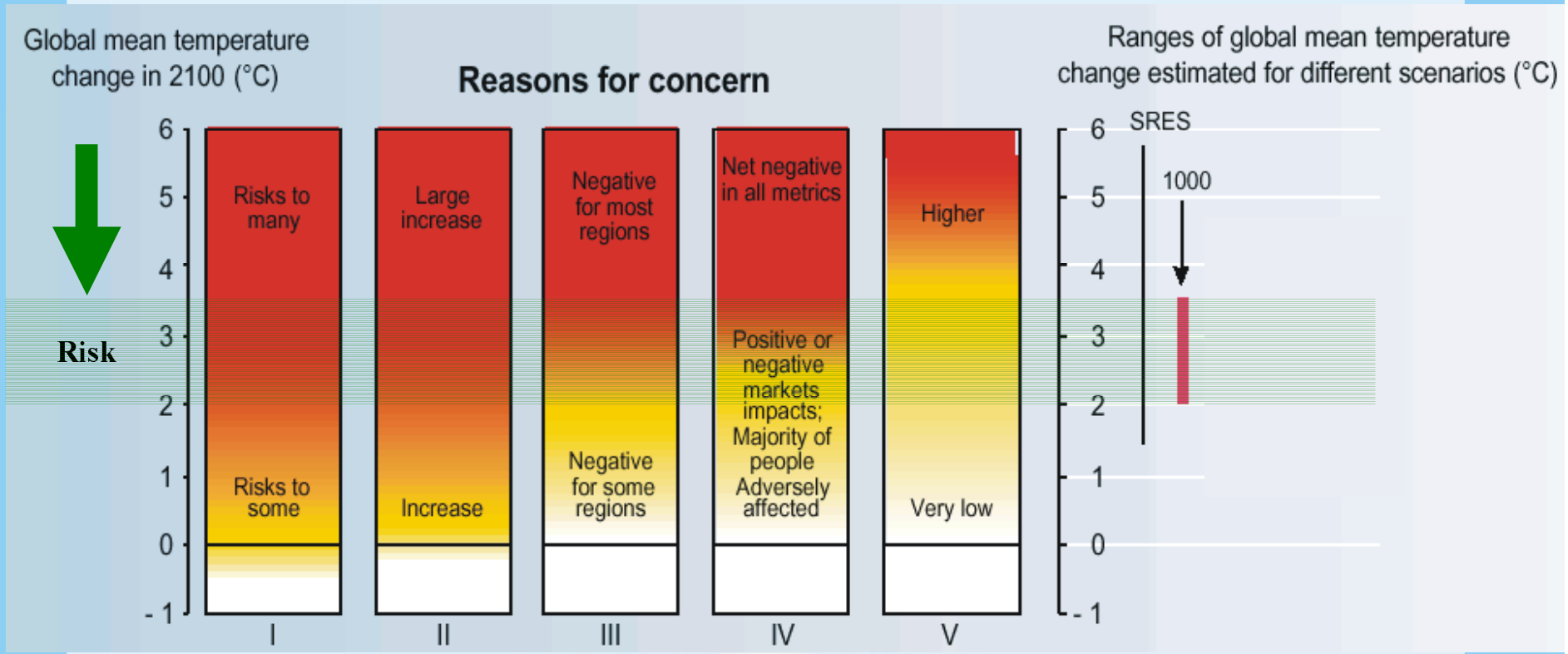

IPCC, 2001

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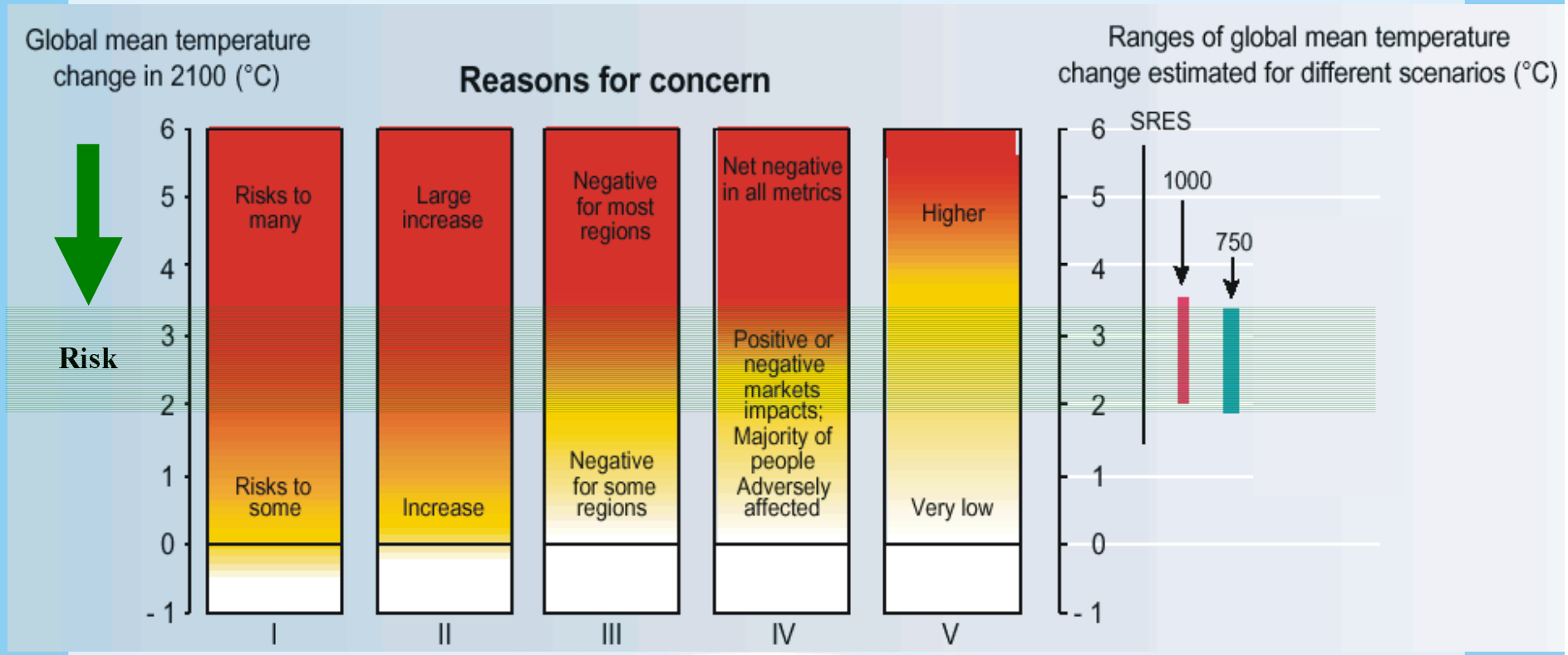
Reducing risks: mitigation



IPCC, 2001

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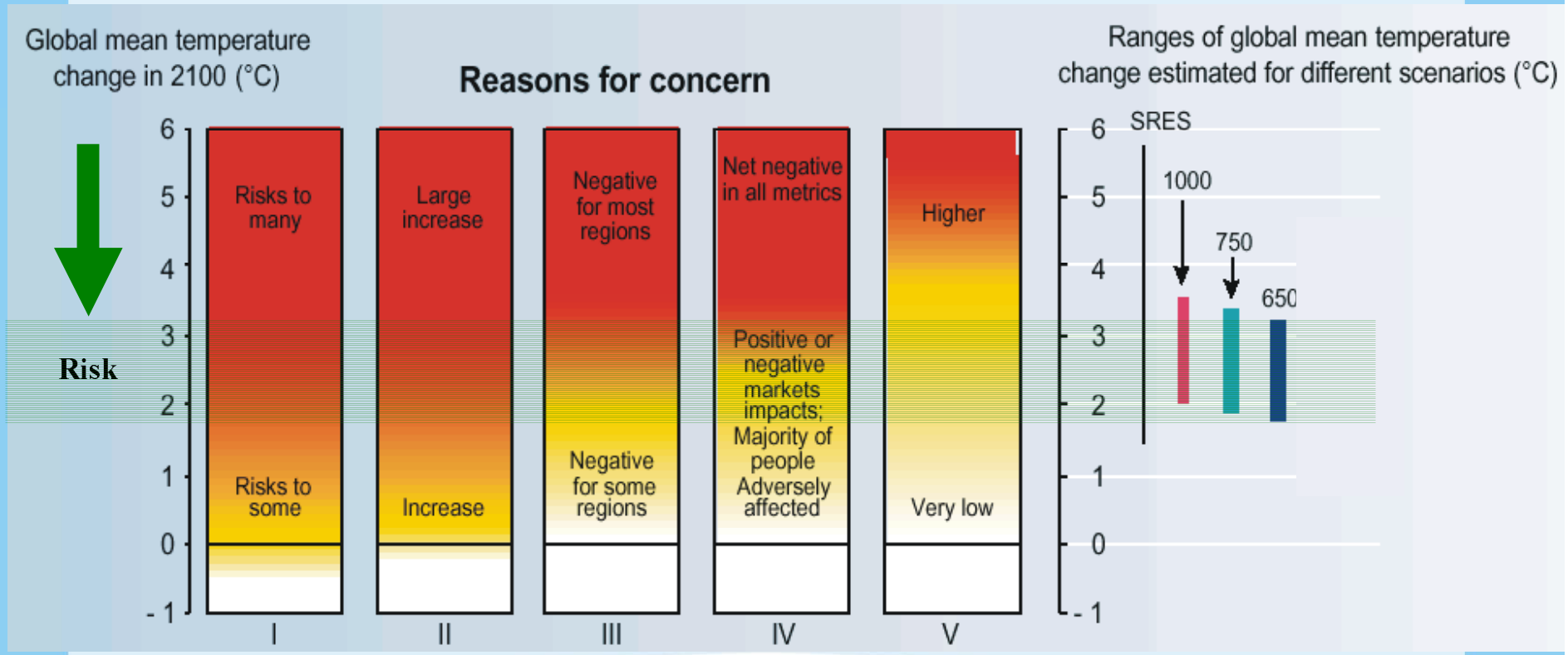
Reducing risks: mitigation



IPCC, 2001

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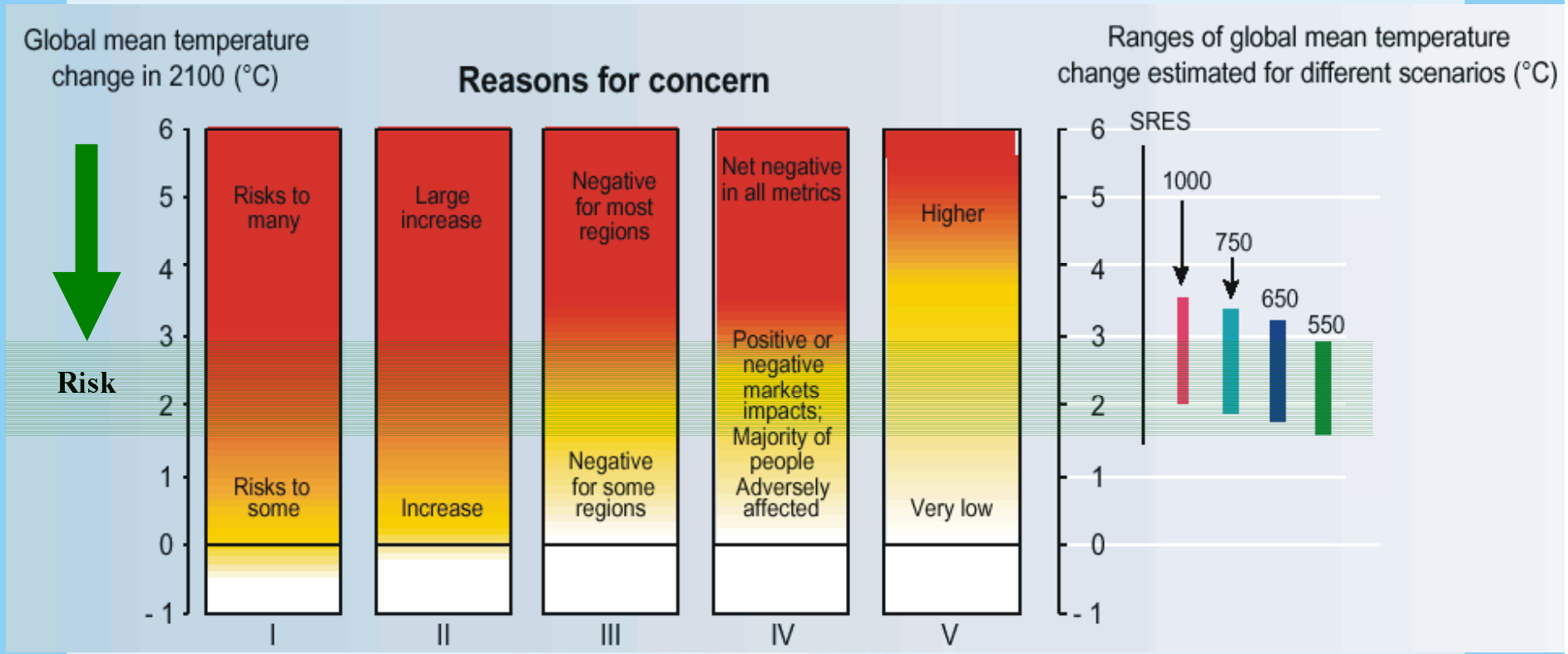
Reducing risks: mitigation



IPCC, 2001

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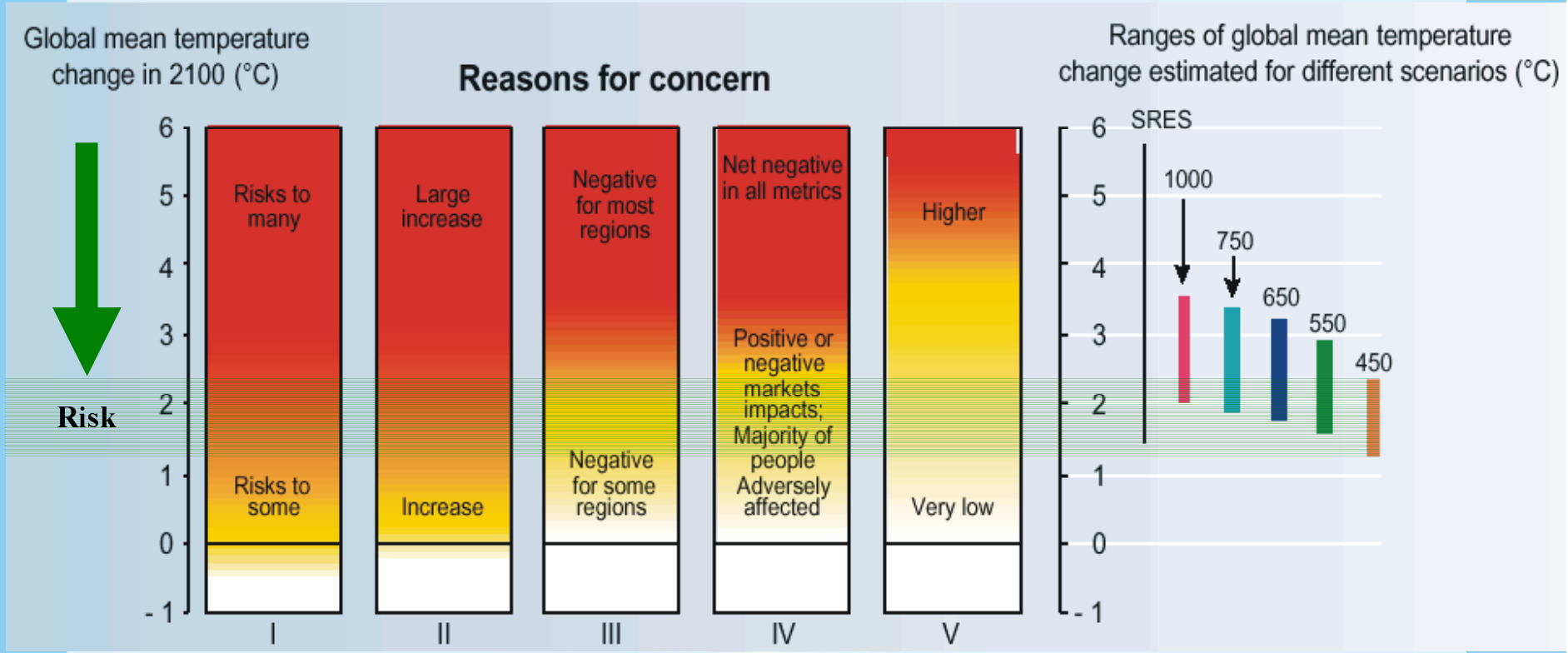
Reducing risks: mitigation



IPCC, 2001

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Selected reading

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How about some coffee?

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Regional and local scenarios

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Why are regional scenarios needed?

- To provide vital information not available from global scenarios
- To match the spatial scale of the vulnerability assessment (e.g. continental, national, river catchment, commune, site)
- To capture high temporal resolution information (e.g. flood peaks, storm surges, pollution episodes, urban effects

Regional socio-economic scenarios

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Why are socio-economic scenarios important in global change research?

- To represent the major driving forces influencing atmospheric emissions of greenhouse gases and aerosols and other environmental changes
- To provide a plausible and self-consistent set of socio-economic assumptions for assessing future global change impacts
- To evaluate future adaptation capacity and vulnerability to global change and to explore mitigation options
- To address uncertainties in future socio-economic and technological developments

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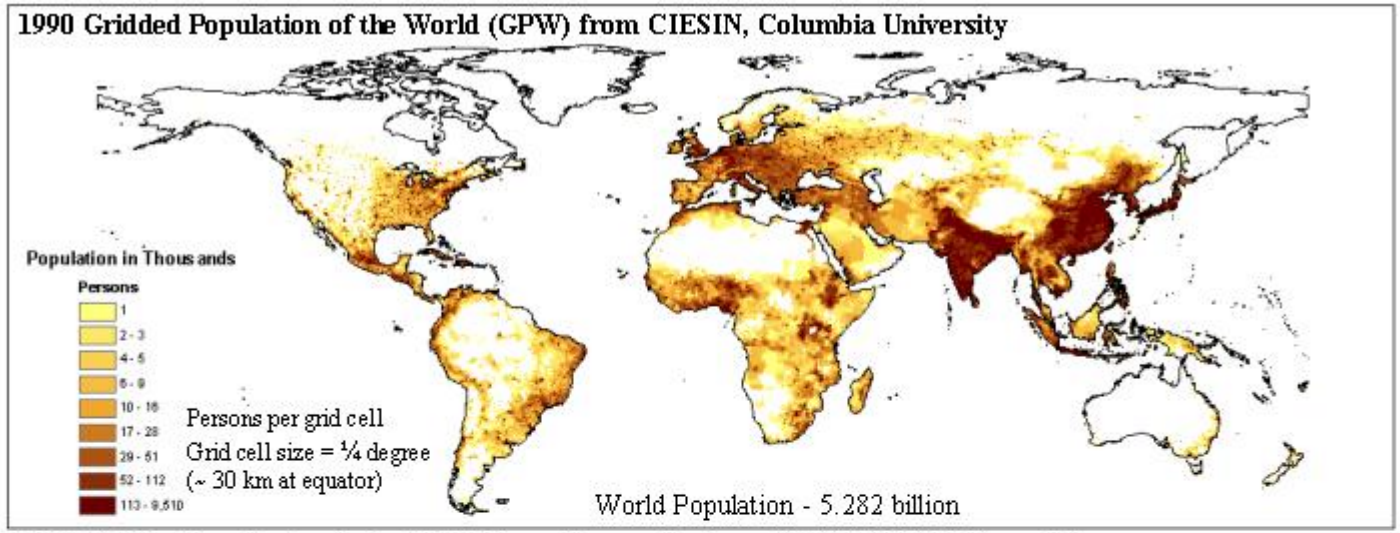

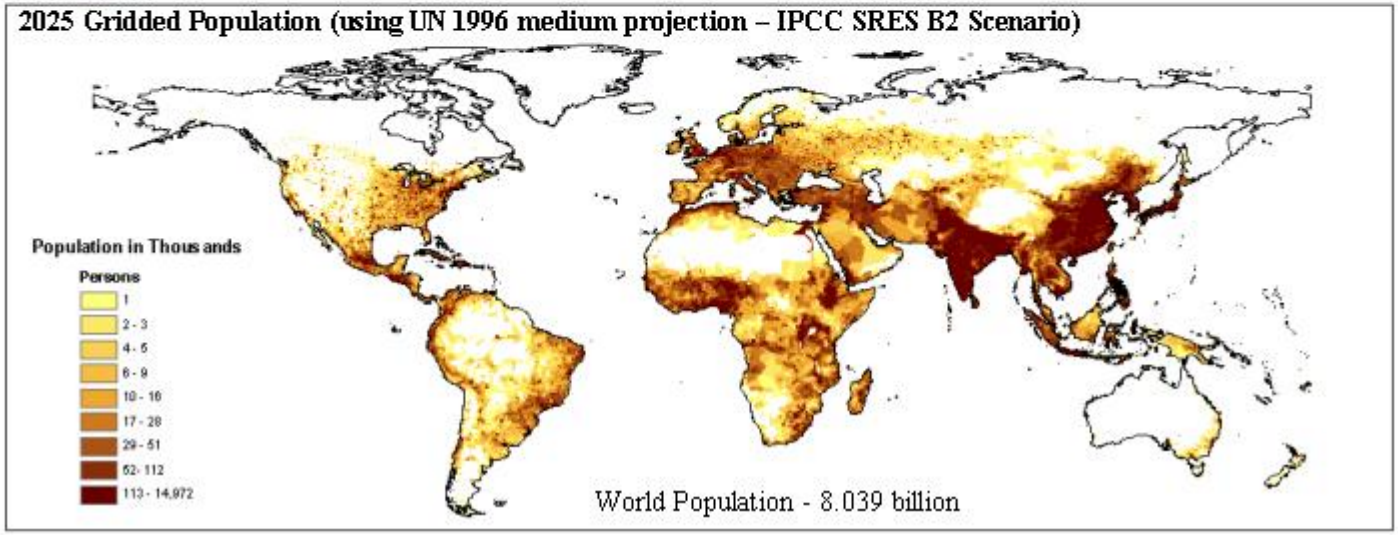

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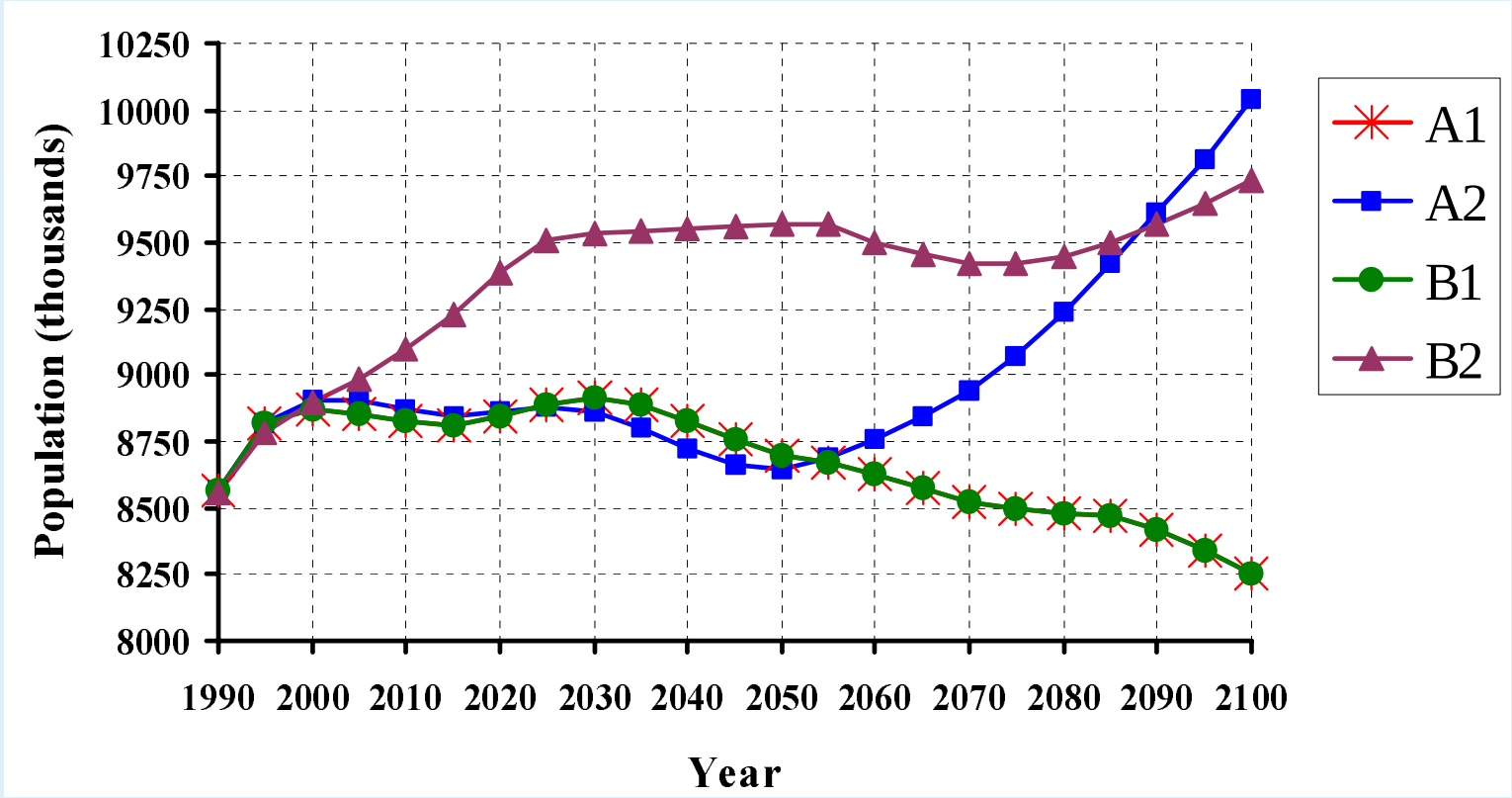
Population of Sweden: 1990-2100

Downscaled from the SRES global scenarios



Source: CIESIN (2002)

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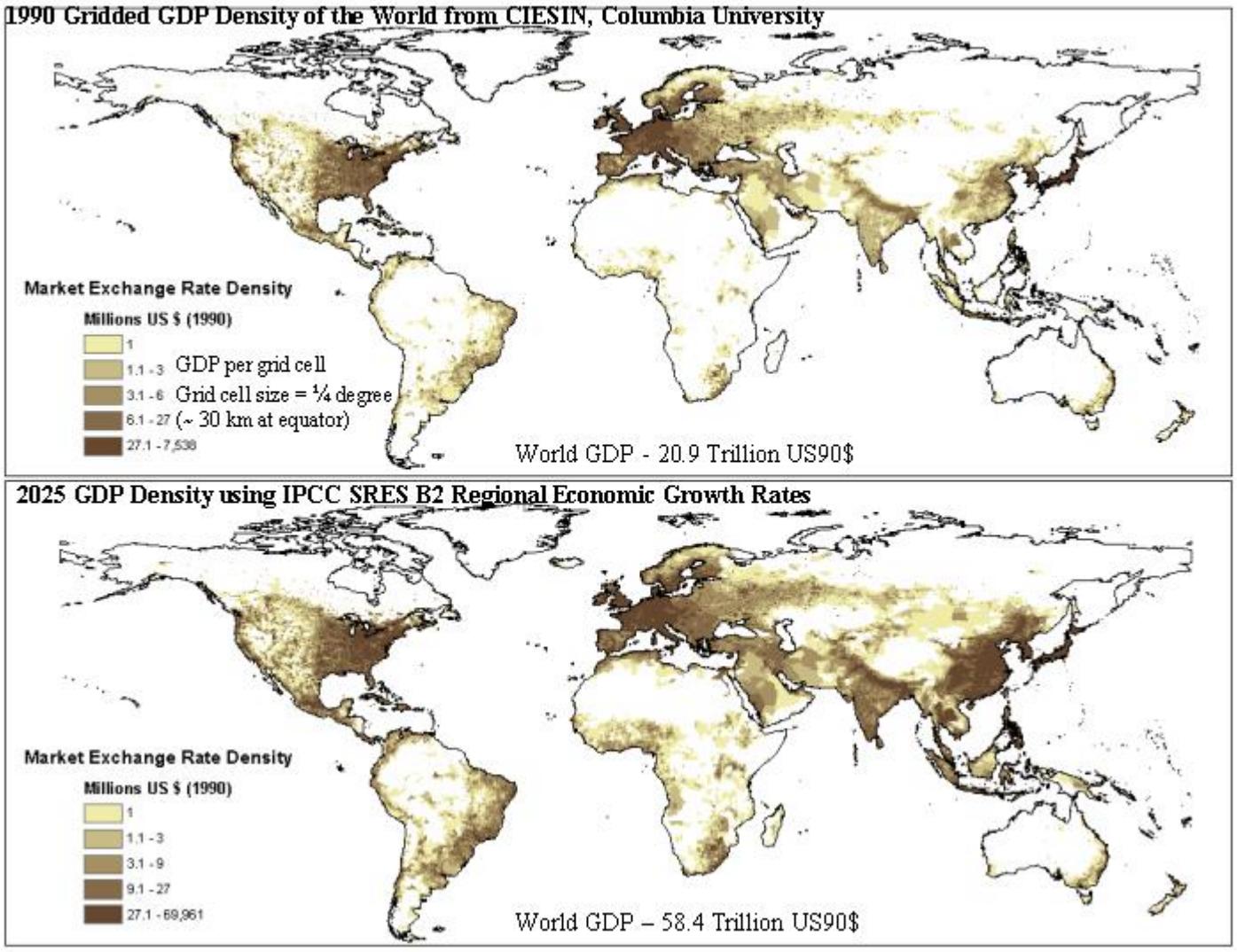

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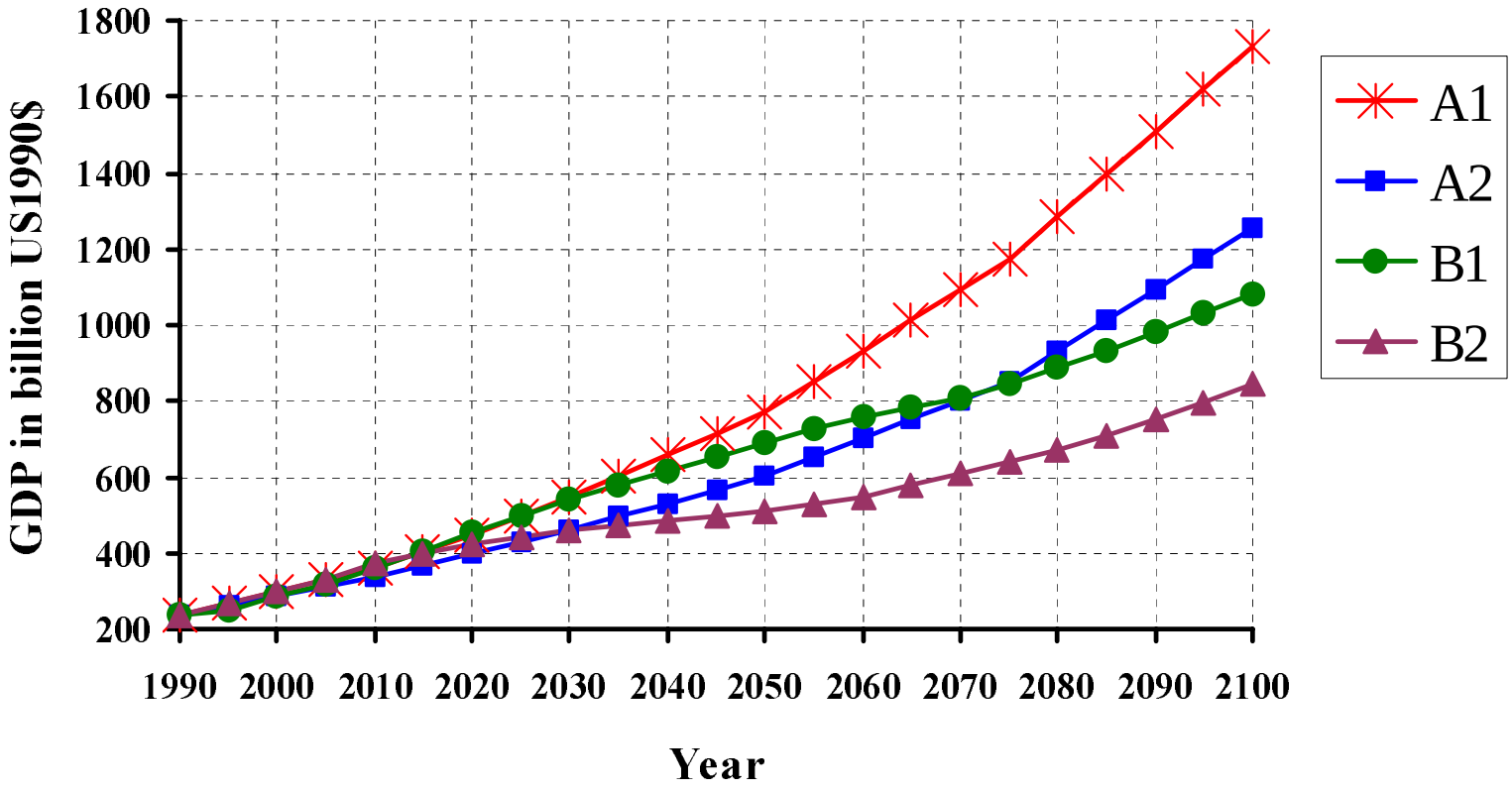
Gross Domestic Product of Sweden: 1990-2100
Downscaled from the SRES global scenarios



Source: CIESIN (2002)

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Example: UKCIP socio-economic scenarios

Purpose: to portray distinct pictures of the social, political and economic background in the UK against which adaptation to climate change might take place in the 2020s and 2050s.

Scenario characteristics:

- **Four scenario storylines (based on SRES)**
- **Stakeholder-driven**
- **Exclude "sideswipes"**
- **Distinguish "drivers" and "impact domains"**

Source: DETR, 1999

The UKCIP socio-economic scenarios

Drivers:

- Values and policy
- Economic development
- Settlement and planning

Impact domains:

- Agriculture
- Water
- Ecosystems
- Coastal zones
- Tourism
- The built environment

Source: DETR, 1999

The UKCIP national scenarios: selected indicators

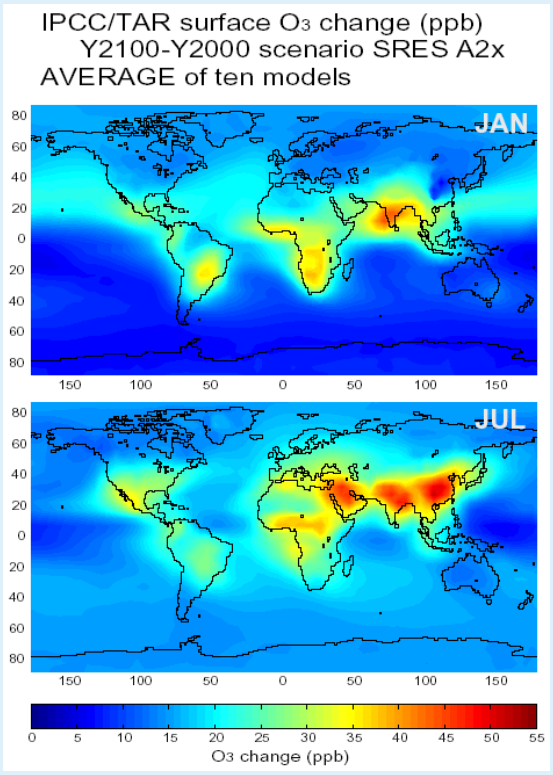
		UK in the 2050s				
	Today (mid 1990s)	2050s (linear)	"National" Enterprise	Local Stewardship	World Markets	Global Sustainability
Population (million)	58.5	61.5	57	55	59	57
GDP (average growth in % per annum)	+2	+2	+1.75	+1.25	+3	+2.25
GDP (factor cost, 1995 prices in billion £)	615	2000	1700	1300	3600	2300
GDP/capita (factor cost in £)	10,500	33,000	31,000	24,000	61,000	41,000
Land use (%)						
agricultural	75		70	75	60	70
urban	15		19	14	22	15
forest, woodland and other	10		11	11	18	15
UK passenger transport (%)						
air	1		1	0.5	3	1.5
rail	5.5		7	15	10	15
road (public)	6.5		7	14.5	2	19.5
road (individual)	87		85	70	85	64

Source: DETR, 1999

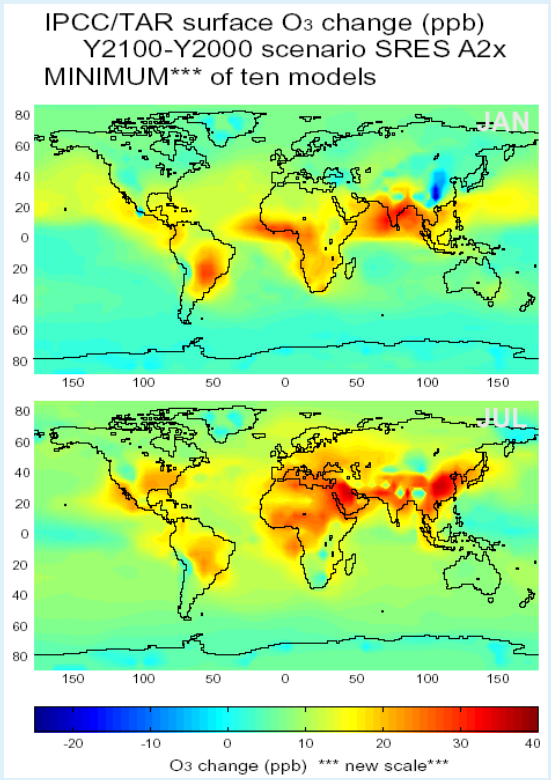
Regional scenarios of atmospheric composition

SYKE

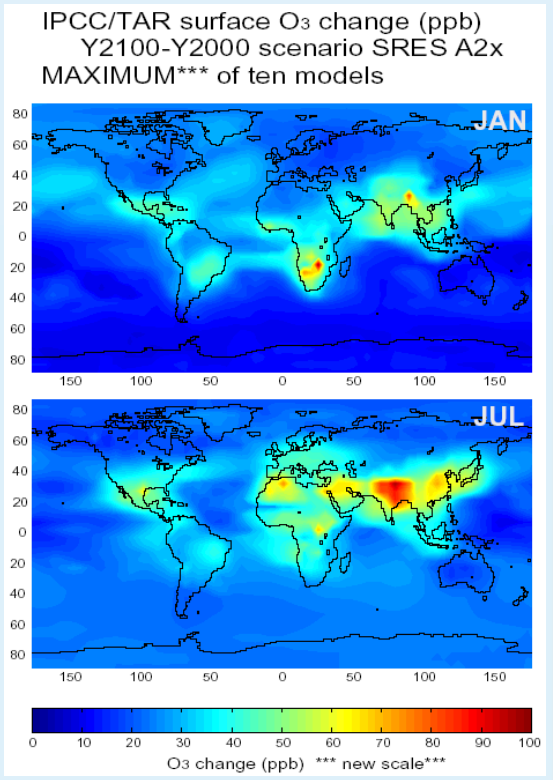
Model projected increases in near-surface O_3 (0-2 km) during 2000-2100 following SRES scenario A2x



10-model mean



10-model minimum

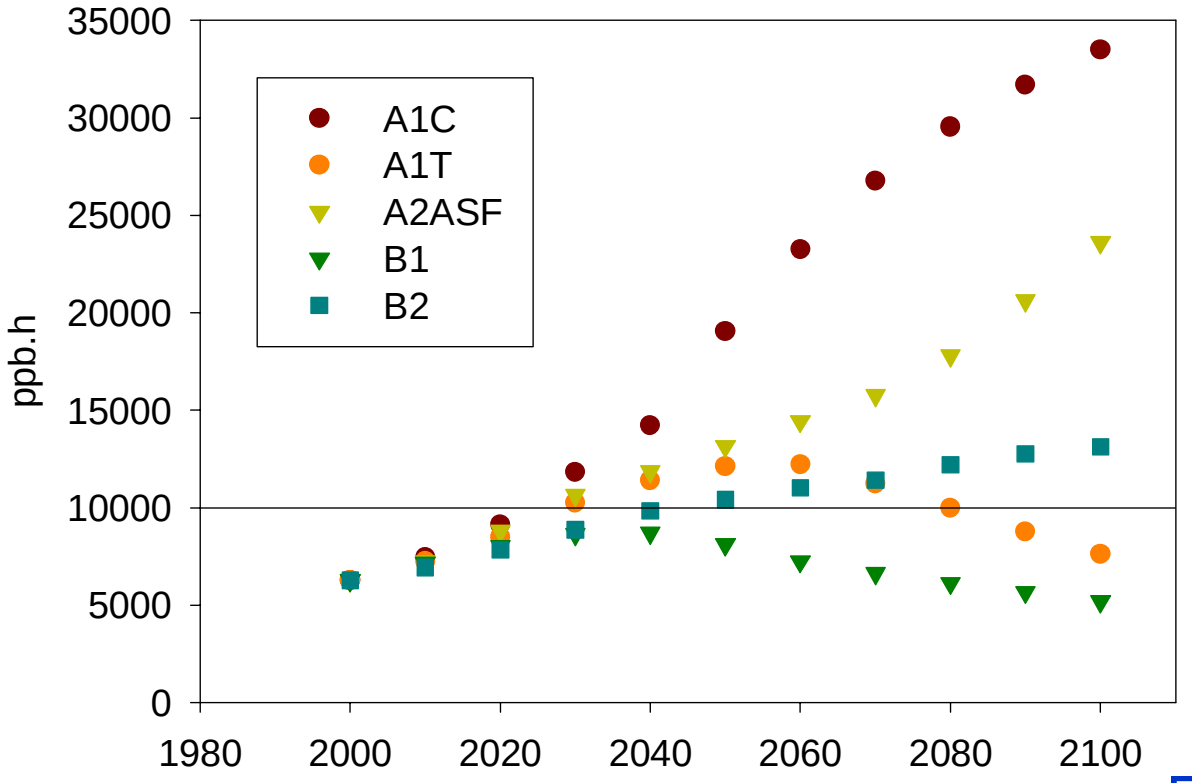


10-model maximum

Prather et al. (2001)

SYKE

Ozone exposure of forests at Ähtäri (AOT40 forest April-September)



FIN*SKEN* project, 2002

SYKE

Scenarios of regional climate change

SYKE

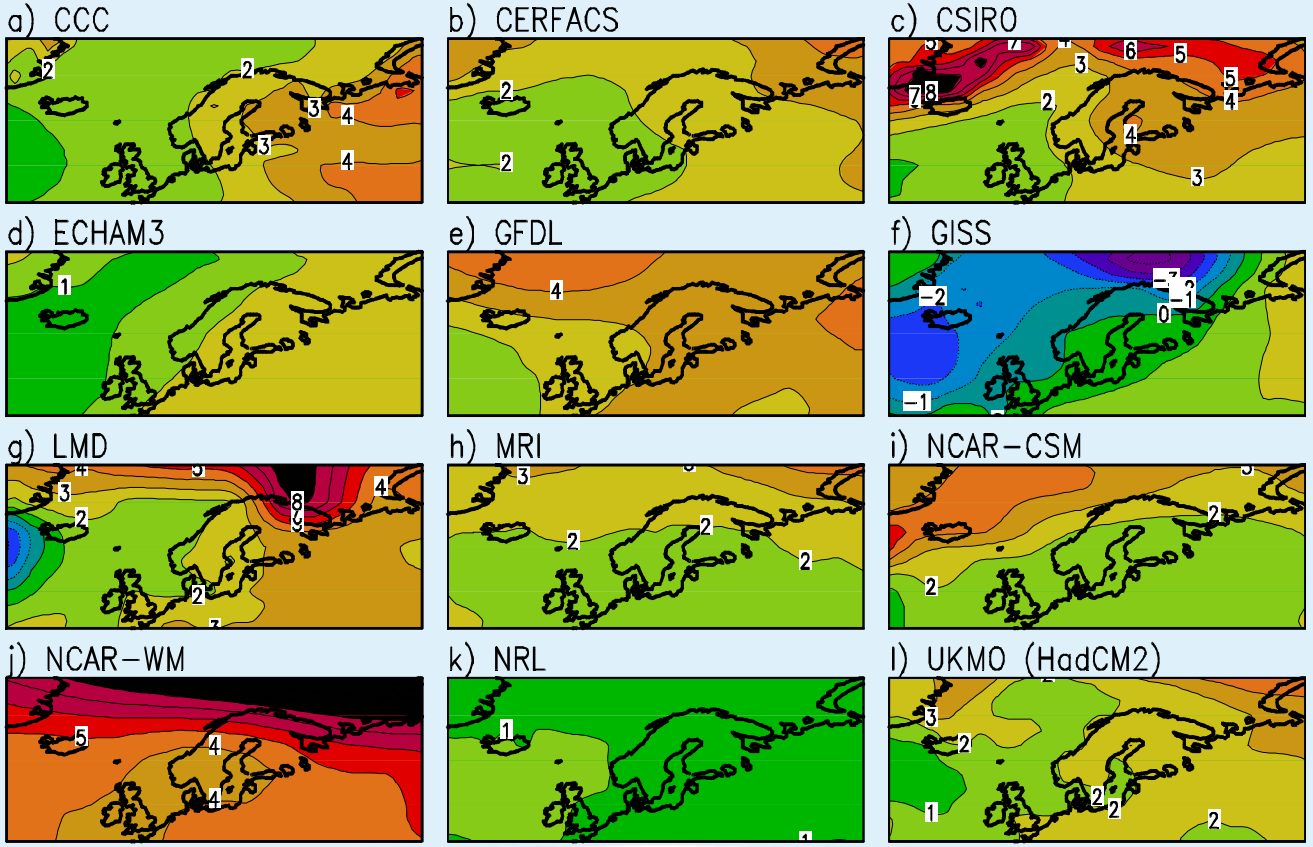
Regional climate:

Scenarios from global climate models

SYKE

Temperature change (°C): 1910-2090 (Hadley Centre model, UK)

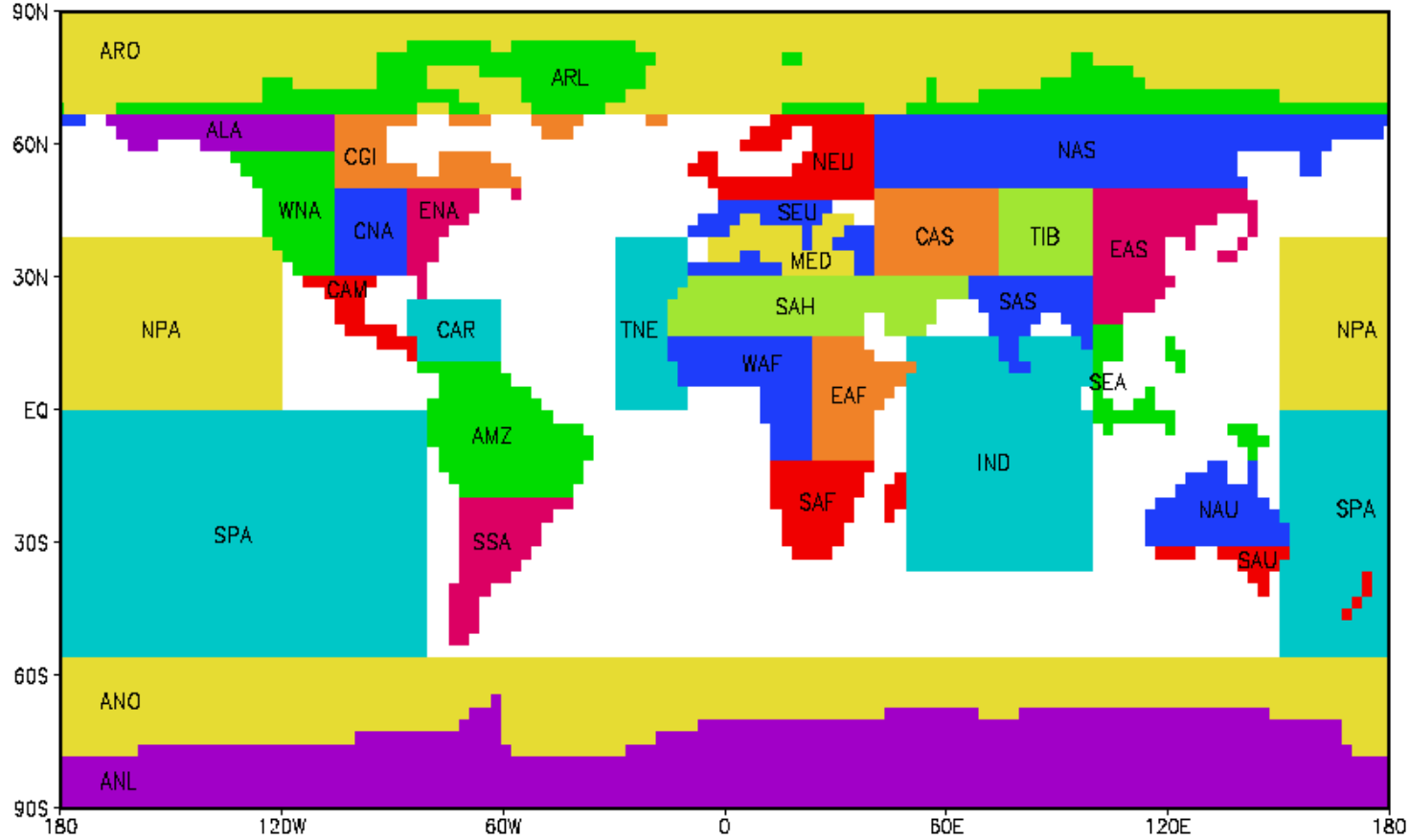
Changes in annual mean temperature (°C) by the time of CO_2 doubling in 12 CMIP experiments



Räisänen, 1999

SYKE

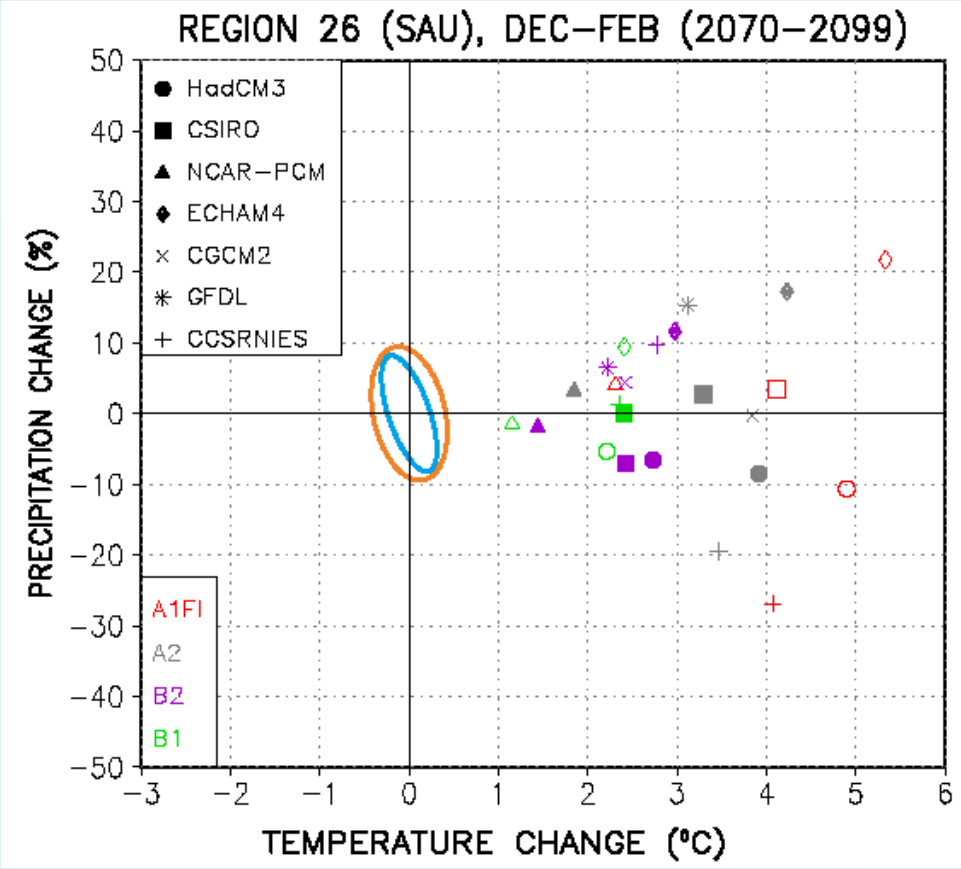
Regions for which intercomparisons conducted of modelled temperature and precipitation changes under the SRES scenarios



Source: Ruosteenoja *et al*. (2003)

SYKE

Projected changes in DJF temperature (°C) and precipitation (%) by 2070-2099 (relative to 1961-1990) in Southern Australia (Region 26) for different forcing scenarios (bottom left).



Solid: direct model outputs;

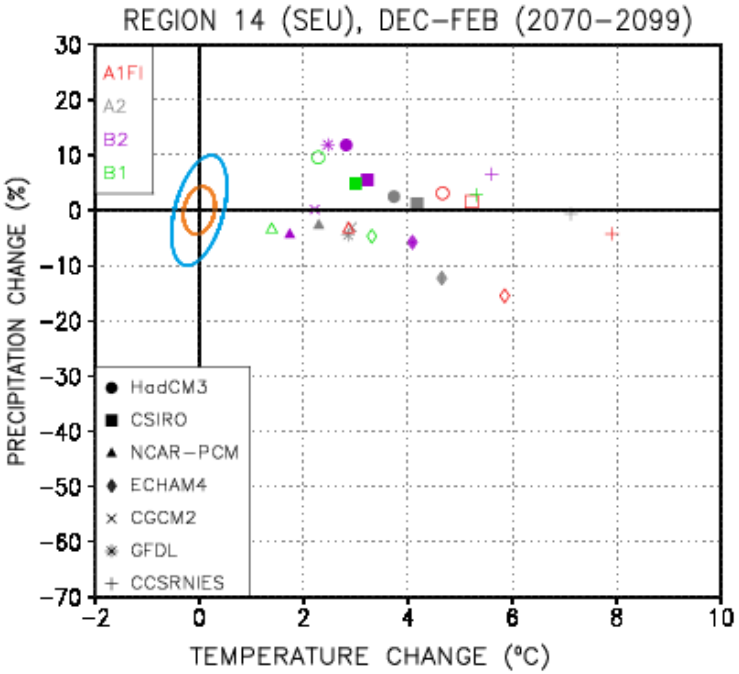
Open: pattern-scaled

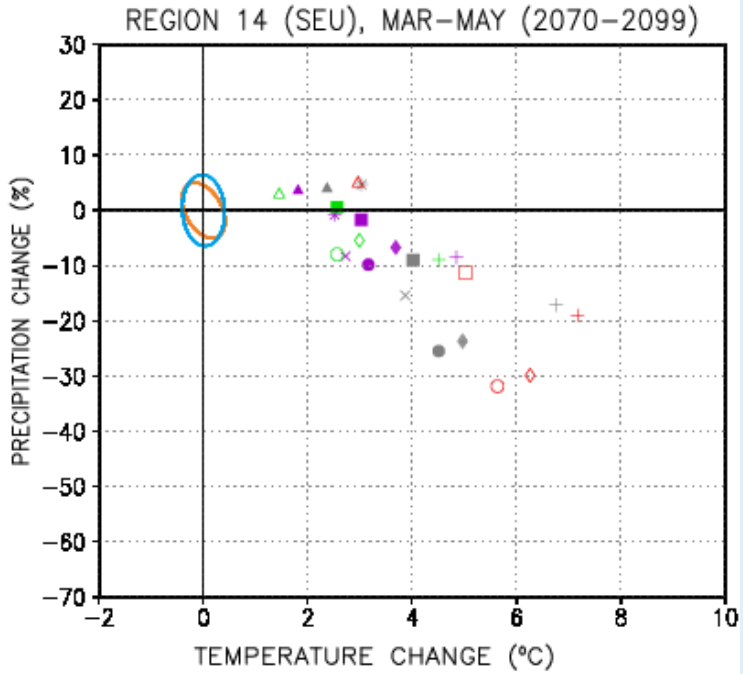
Ellipses: natural variability (95 percentile) from unforced 1000 year runs with the CGCM2 (orange) and HadCM3 (blue) models

Source: Ruosteenoja *et al.* (2003)

SYKE

Projected changes in seasonal temperature (°C) and precipitation (%) by 2070-2099 (relative to 1961-1990) in S Europe/N Africa (Region 14) for different forcing scenarios (bottom left).





Source: Ruosteenoja *et al.* (2003)

SYKE

Prioritizing the ATEAM climate scenarios

Emissions uncertainties

	CO_2 concentration					
	2050	2100	PCM	CGCM2	CSIRO2	HadCM3
A1FI	572	895	low	low	low	medium
A2	537	870	high	high	high	high
B2	506	607	low	low	low	medium
B1	485	516	medium	low	low	medium

Climate model uncertainties

Low end scenario

Mitchell and Carter, in prep.

SYKE

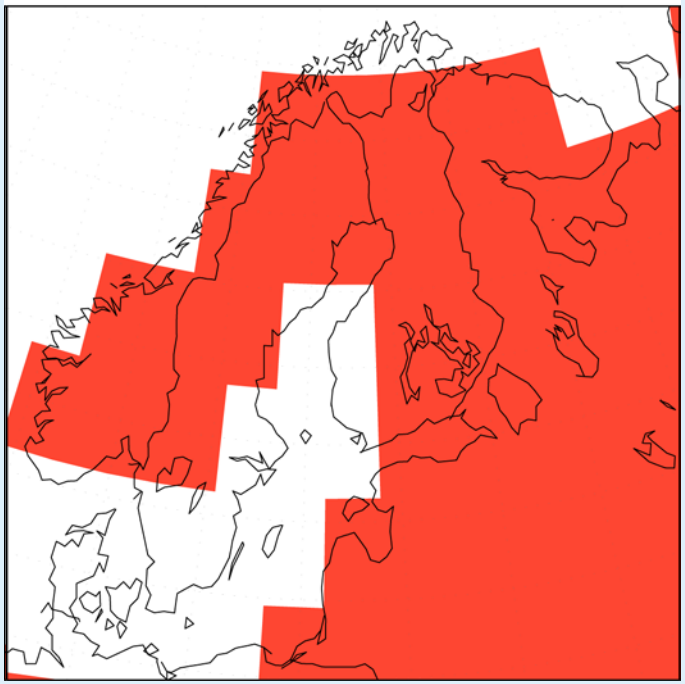
Regional climate:

Scenarios from regional climate models

SYKE

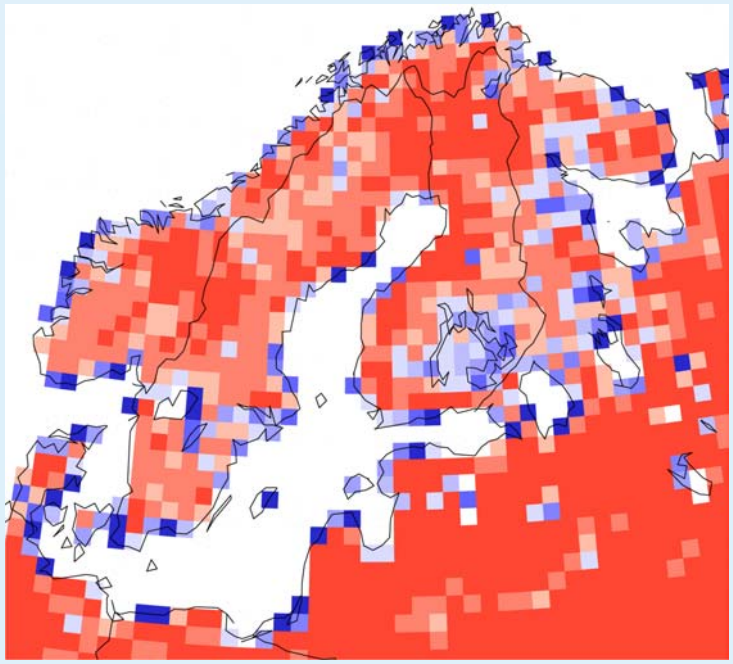
Resolution of the Rossby Centre regional climate model and of two global climate models in which it has been nested

echam4



Resolution: 2.8°x2.8°

Rossby

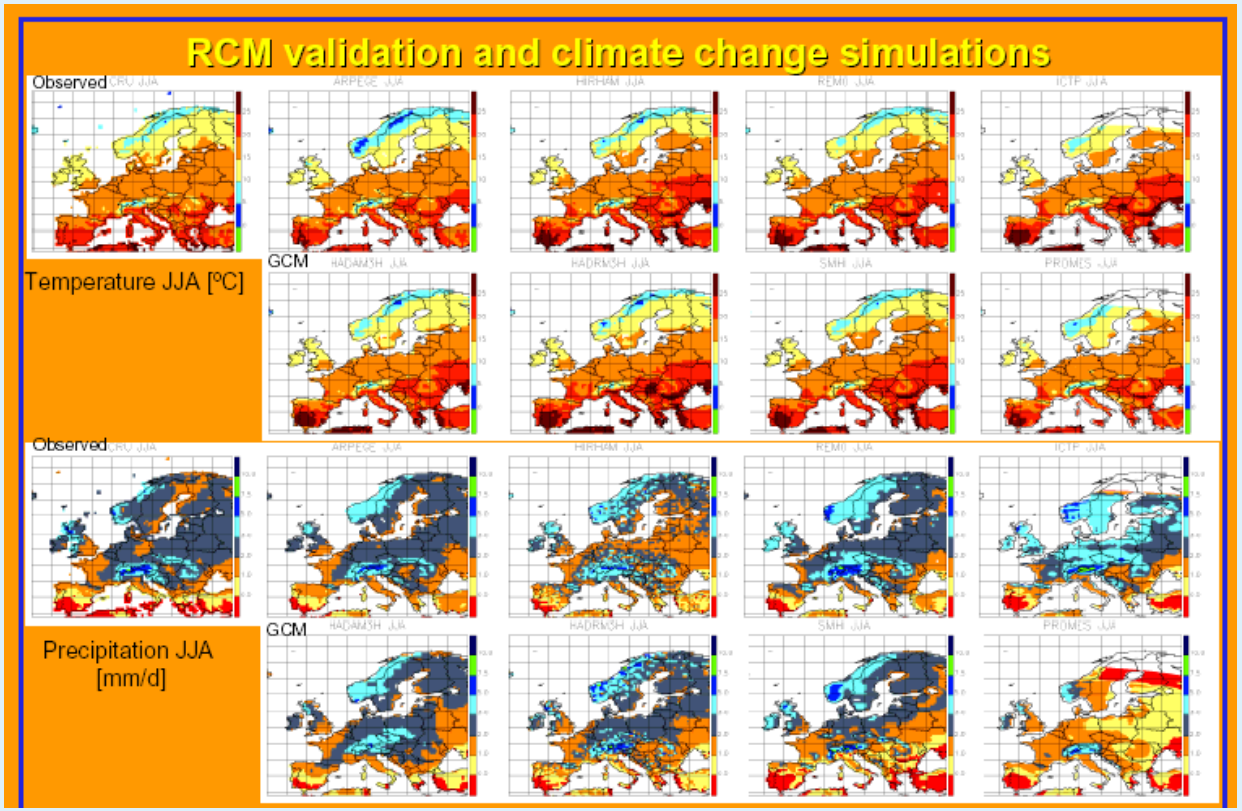


Resolution: 0.4°x0.4

Räisänen et al. (2001)

SYKE

(Prediction of regional scenarios and uncertainties for defining European climate change risks and effects)



Christensen et al. (2003)

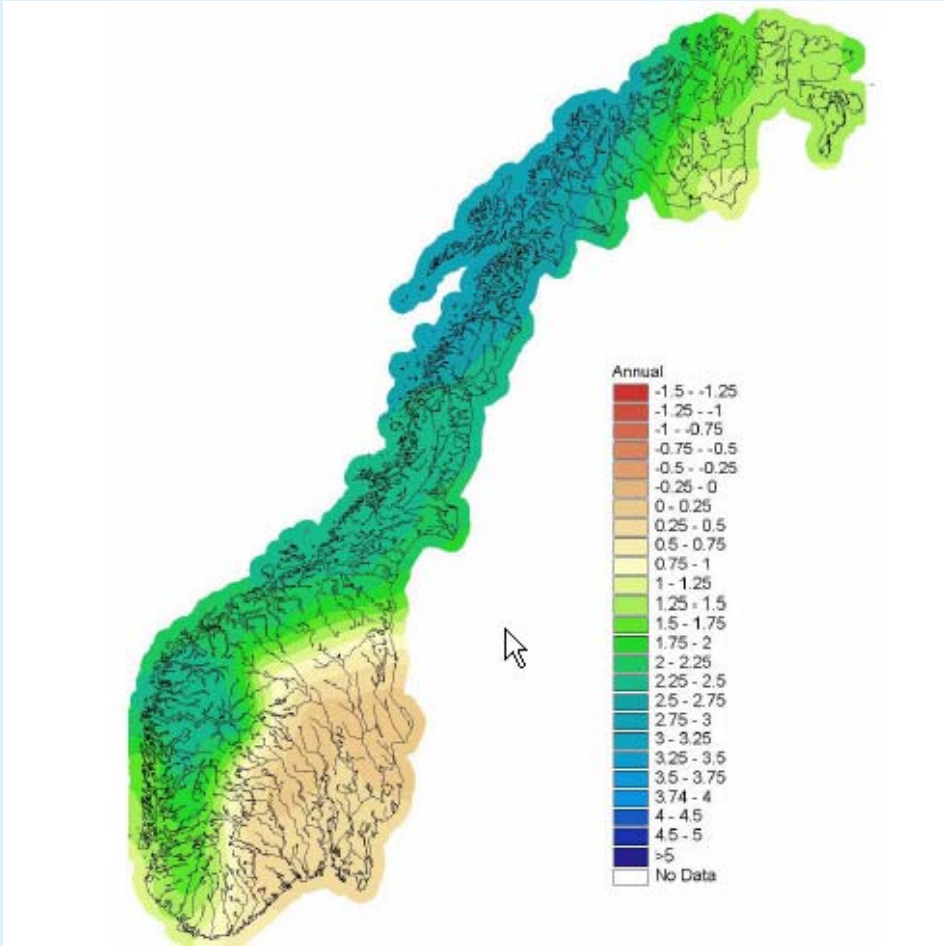
SYKE

Regional climate:

Local scenarios based on statistical downscaling

SYKE

Annual precipitation change in Norway (% per decade) relative to 1961-1990 statistically downscaled from the ECHAM4 model



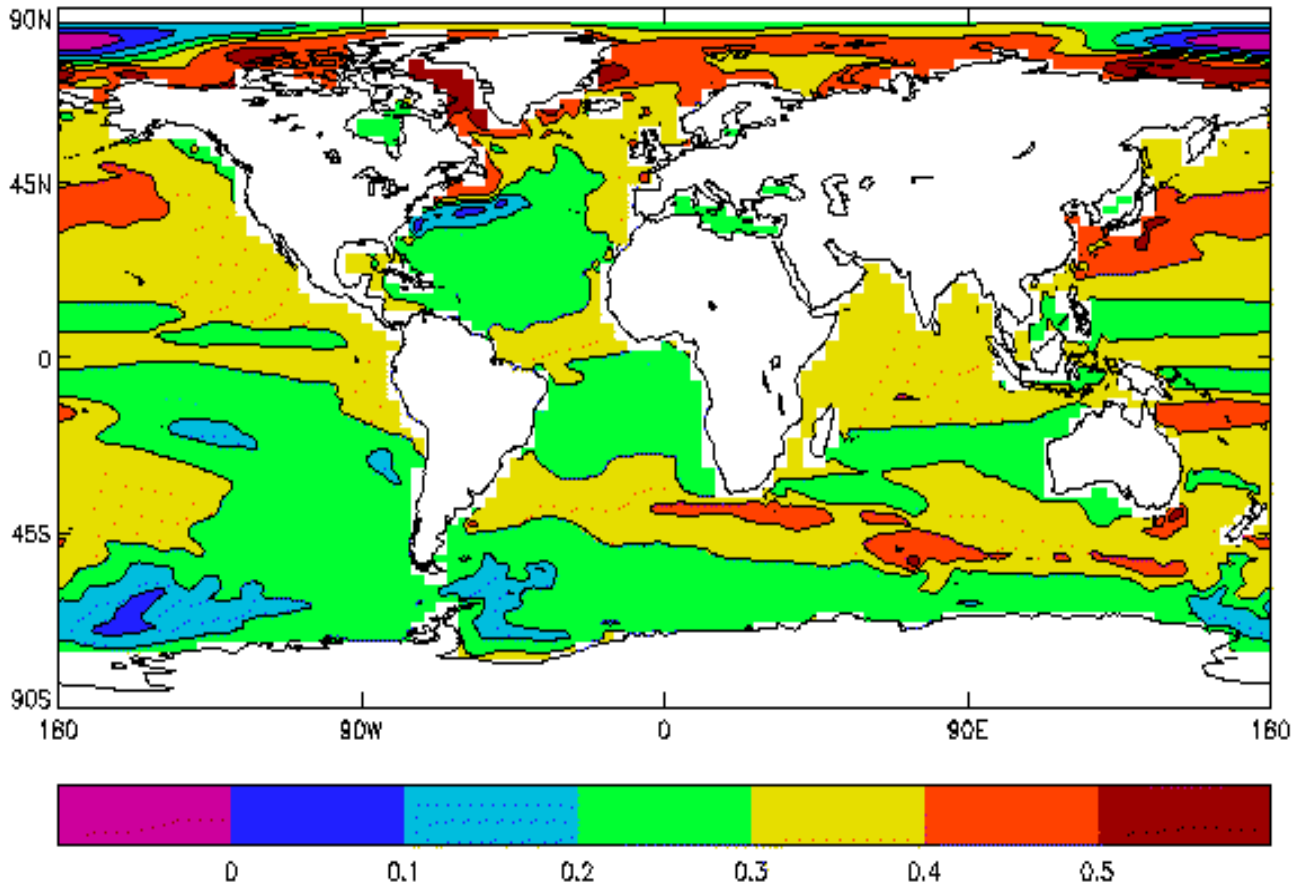
Hanssen-Bauer *et al.*, 2001

SYKE

Scenarios of regional sea-level change

SYKE

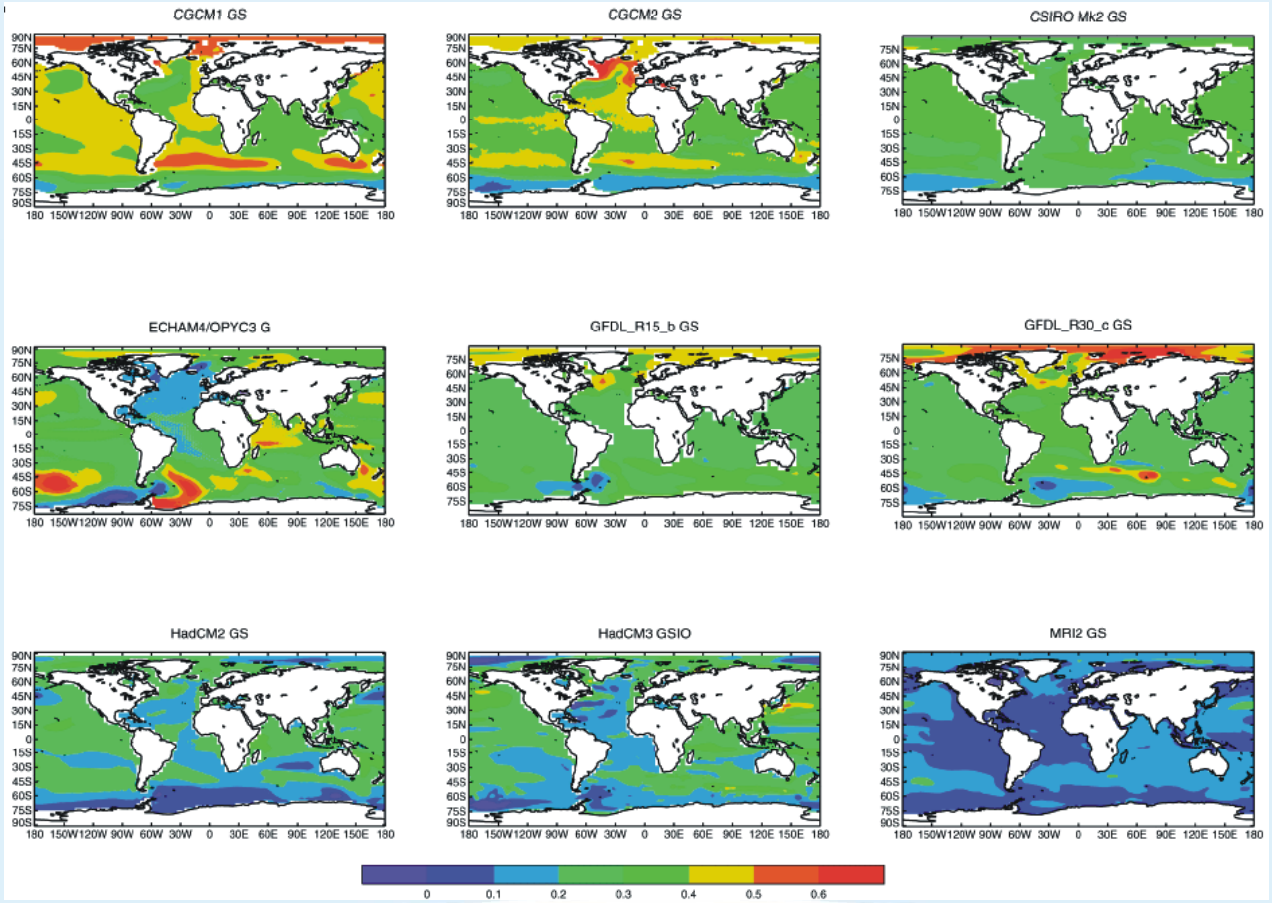
HadCM3 estimates of regional sea level rise (m) for the A2 scenario (2080s minus present day)



Source: Hadley Centre

SYKE

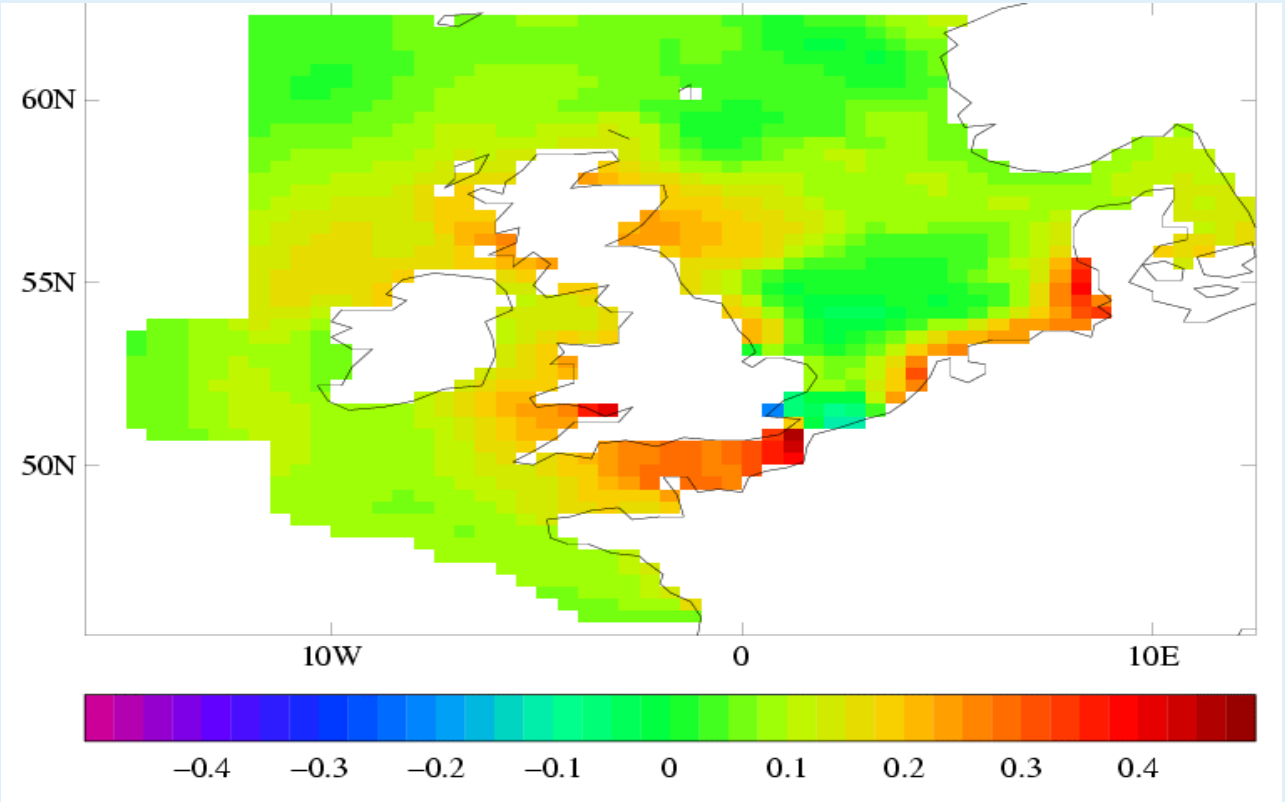
Uncertainties in model estimates of regional sea-level change (m) by 2100 for IS92a emissions



Source: IPCC (2001)

SYKE

Change in height of 50-year storm surge event due to changes in storminess estimated by HadCM2 (2080s minus present day)



Source: Hadley Centre

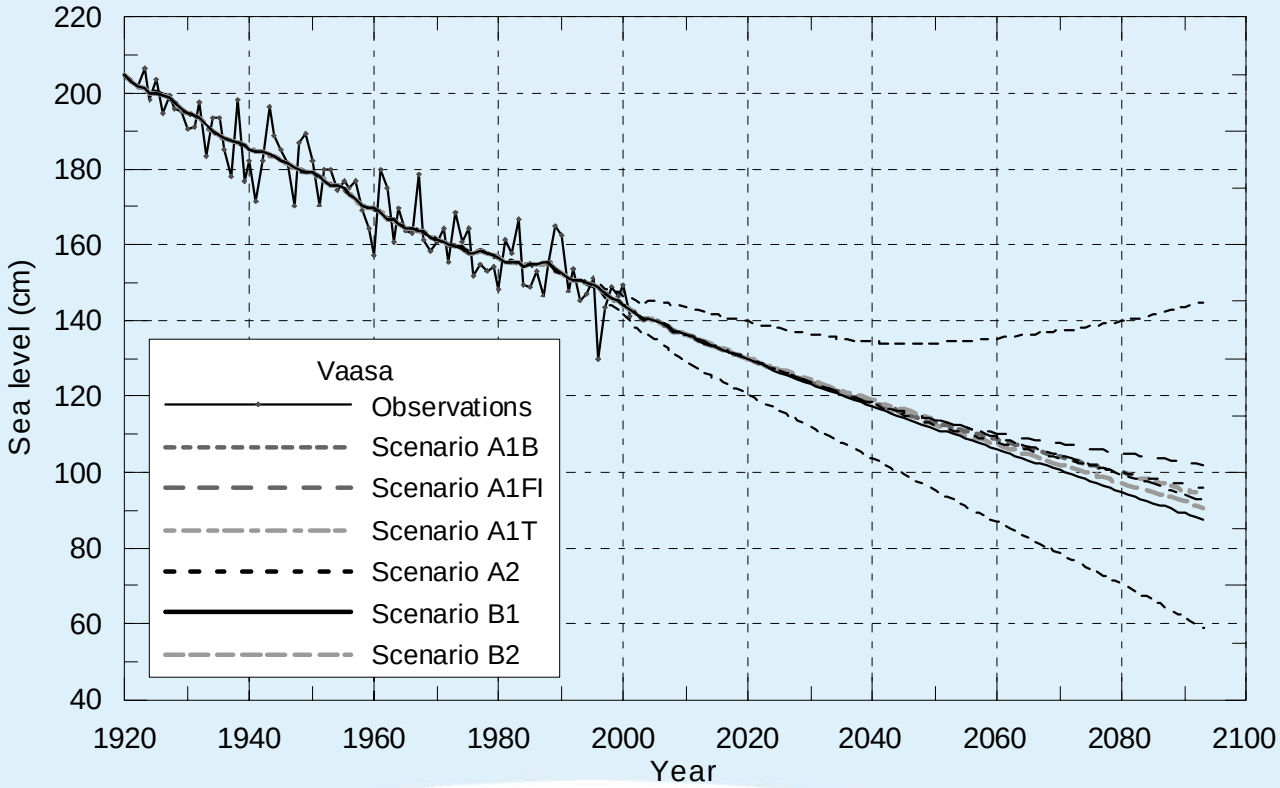
SYKE

Major factors affecting future mean sea level on the Finnish coast

- Postglacial land uplift (-)
- Global mean sea-level rise (+)
- Regional atmospheric circulation (NAO) (+/-)

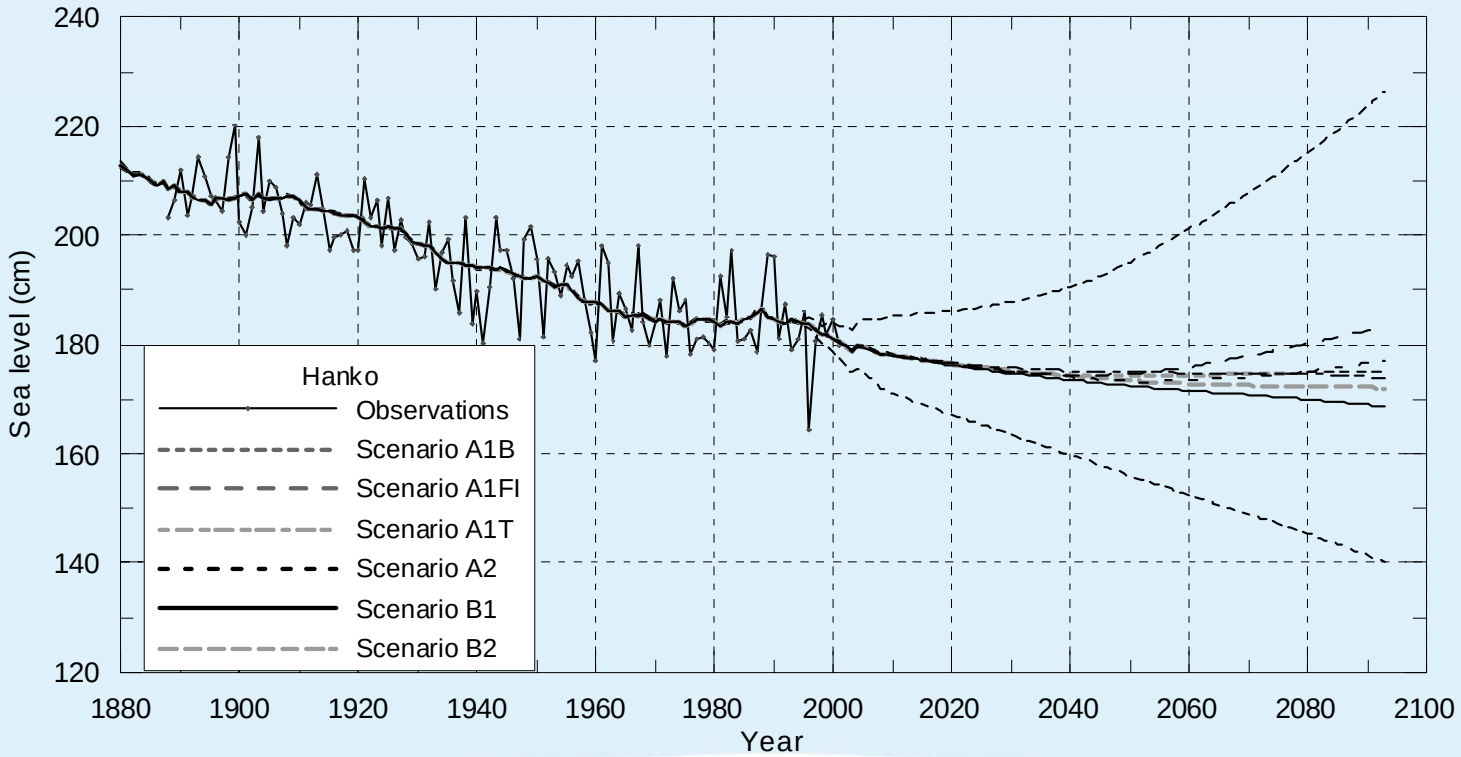
SYKE

Mean sea level at Vaasa, C. Finland, 1920-2100
Observed: annual and 15-yr running means
Projected: SRES scenarios and uncertainty bounds



SYKE

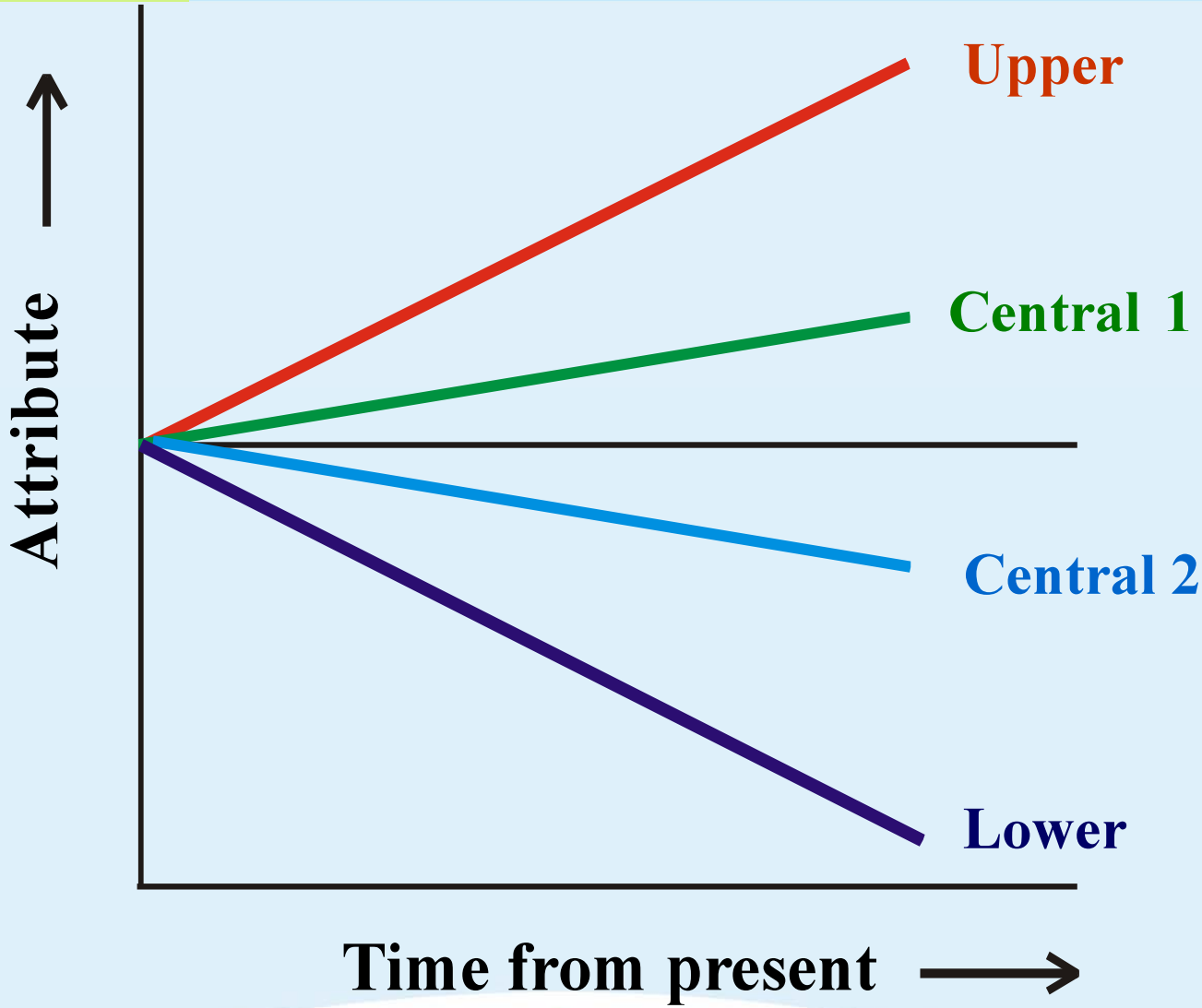
Mean sea level at Hanko, S. Finland, 1880-2100
Observed: annual and 15-yr running means
Projected: SRES scenarios and uncertainty bounds



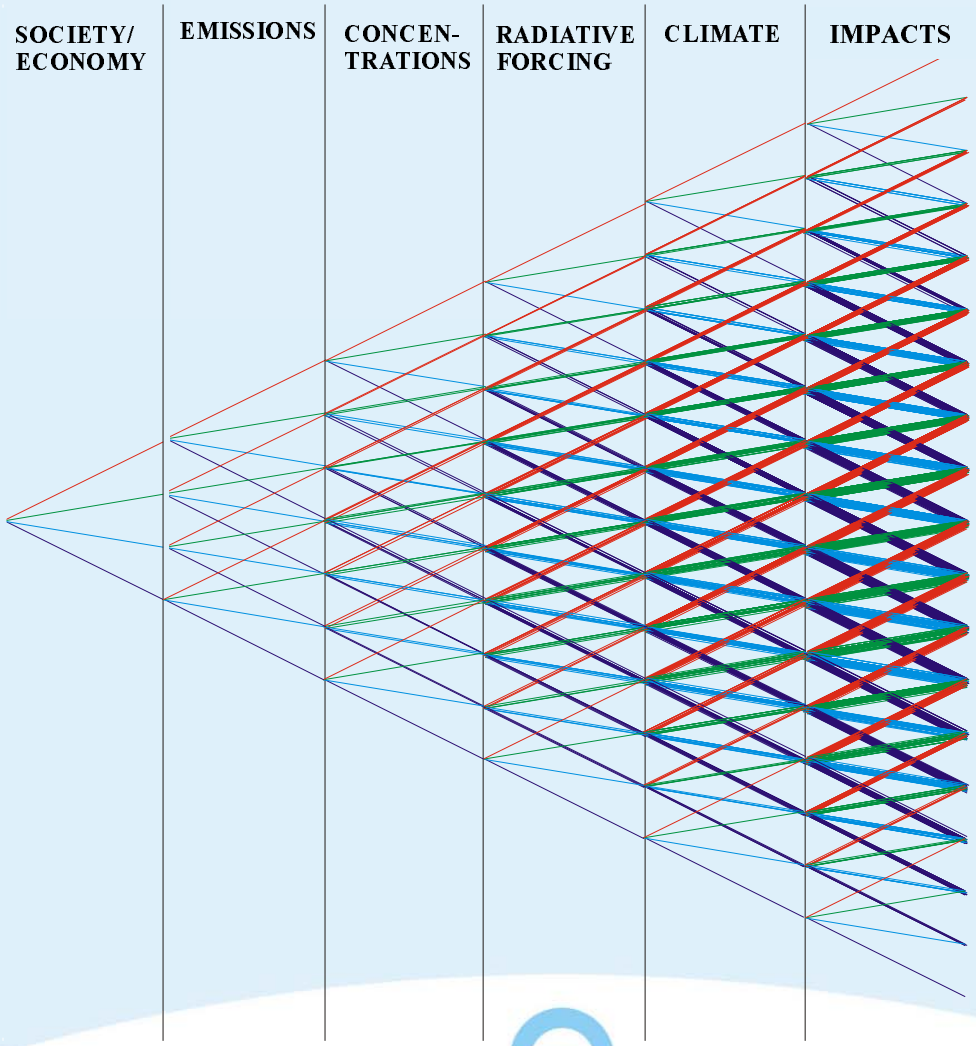
SYKE

Dealing with uncertainties

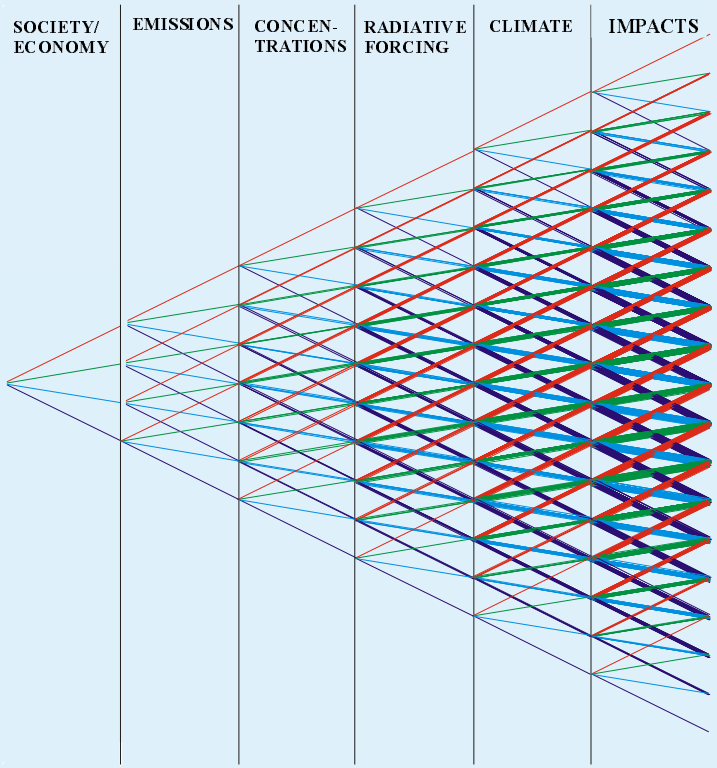
SYKE


Upper
Central 1
Central 2
Lower
Attribute
Time from present

Propagation of uncertainties



SYKE

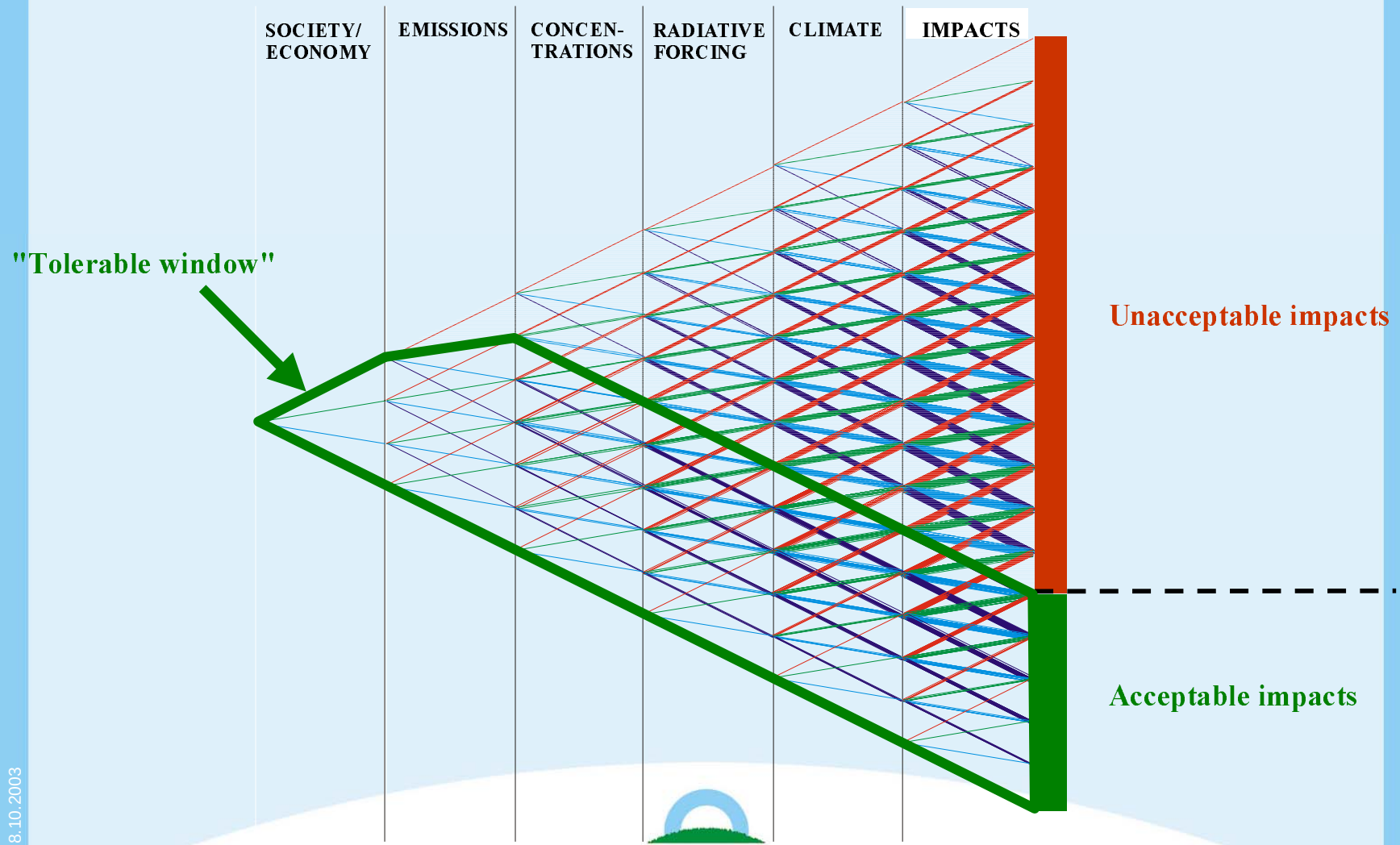


The "uncertainty cascade" (New and Hulme, 2000)

The "uncertainty explosion" (Henderson-Sellers, 1993)

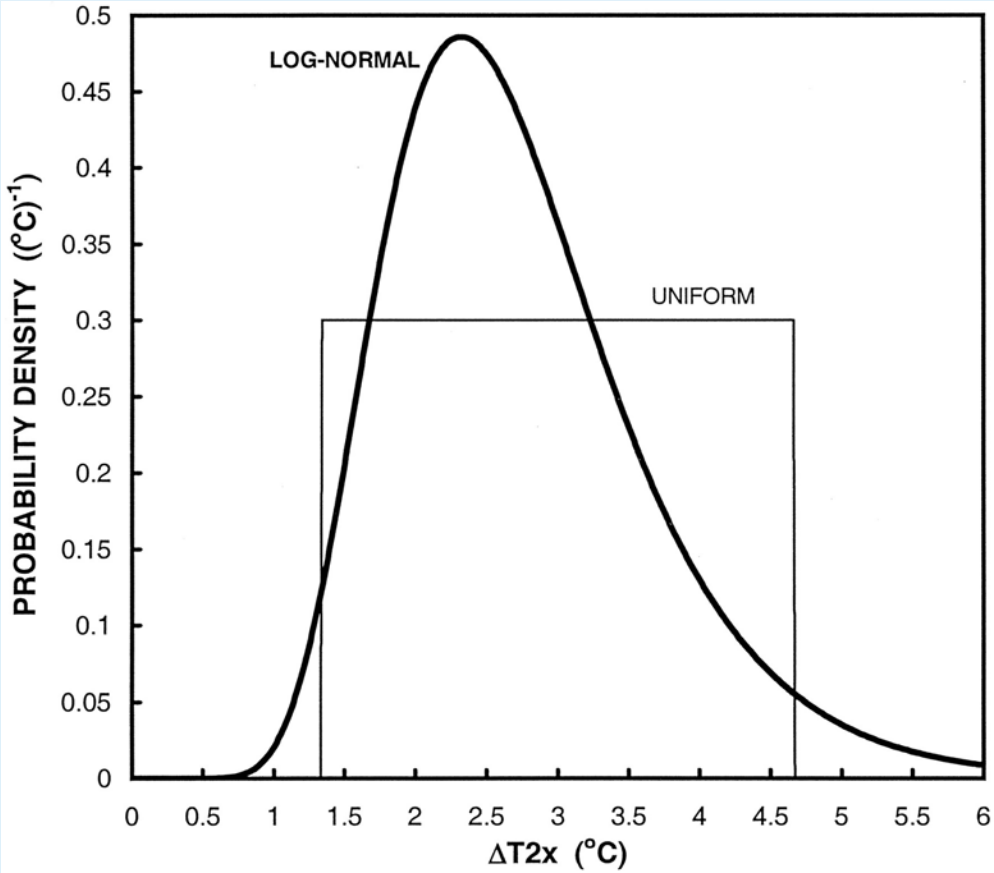
SYKE

Normative "back casting" scenarios



SYKE

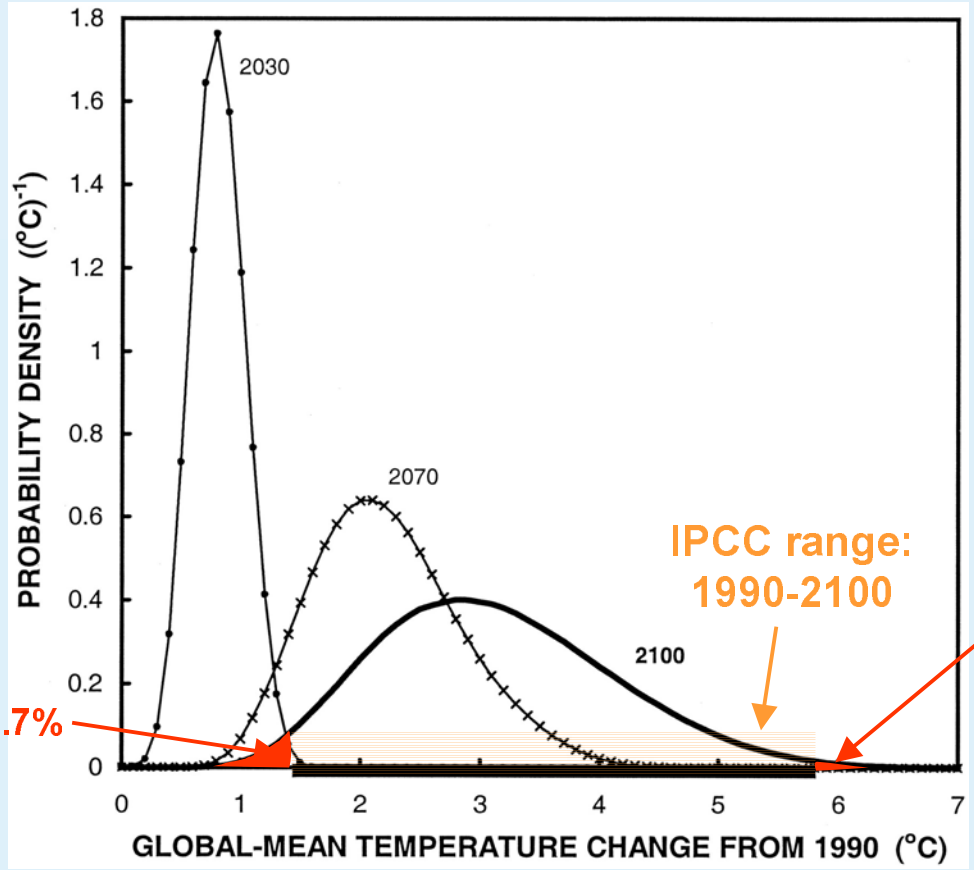
Alternative probability density functions for the climate sensitivity



Wigley and Raper, 2001

SYKE

Uncertainties in global-mean warming for the periods 1990-2030 (dotted), 1990-2070 (crosses) and 1990-2100 (bold)



Wigley and Raper, 2001

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"The only certainty is uncertainty"

Pliny the Elder

SYKE

Some conclusions

- Scenarios can be used prescriptively or diagnostically
- Impact/vulnerability assessments can be highly sensitive to base case scenarios
- A major role of scenarios is to illuminate uncertainties; they are NOT predictions
- The adoption of common driving factors is a prerequisite for ensuring consistency between global change scenarios
- Techniques to improve the spatial and temporal resolution of scenario information should be adopted only if they are truly appropriate in addressing the goals of the study
- Promising techniques are emerging for expressing scenarios in terms of probability and risk

Final thought

"Everything is vague to a degree you do not realize till you have tried to make it precise."

Bertrand Russell (philosopher)

SYKE