Global change scenarios

Tim Carter

Finnish Environment Institute, SYKE

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Global change scenarios

- Some definitions
- Classifying global change scenarios
- Examples of global-scale scenarios
- Examples of regional scenarios
- Dealing with uncertainties

Some definitions

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

Examples of global environmental change

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

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

What are scenarios?

***"A scenario is a coherent, internally consistent and plausible description of a possible future state of the world"* (IPCC, 1994)**

Scenarios are:

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

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 (and see Alcamo, 2001)
- The *general public* needs to be informed about prospective global changes

Not all impact/vulnerability assessments require scenarios

For example:

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

Use of environmental information by impact/adaptation researchers?

Two alternative approaches:

- Prognostic approach
- Diagnostic approach

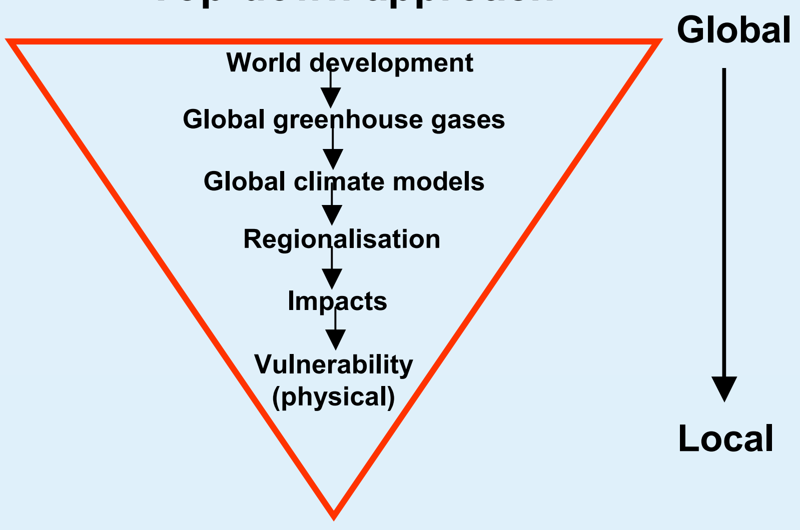
Prognostic approach

Select one or more projections of the future for assessing impacts

Question: *"If the environment changes like this, what will the impacts be?"*

Conventional "top-down" approach - results are highly dependent on the specific scenarios selected.

Top-down approach



"If you wanna know how vulnerable you are then tell me how the environment will change"

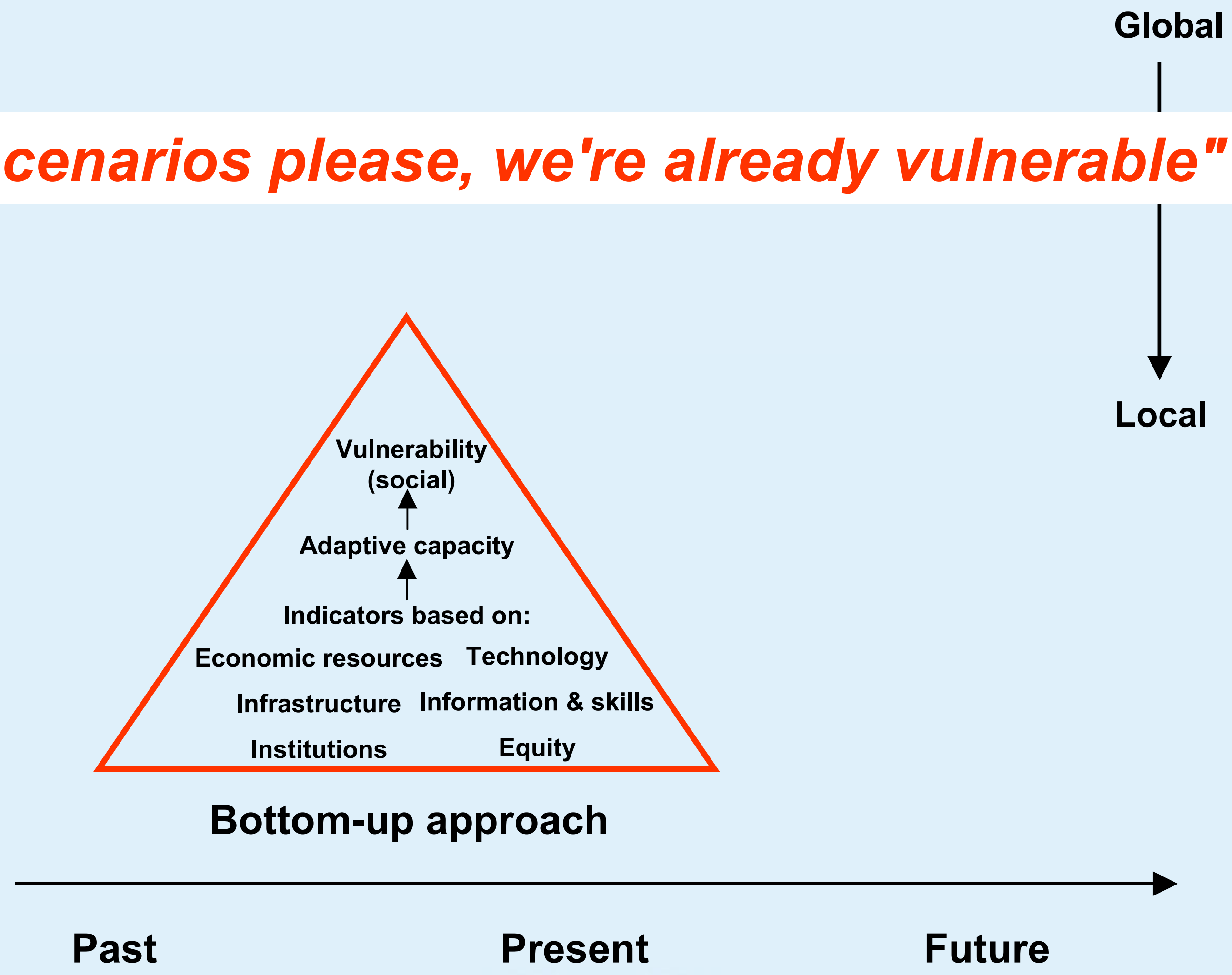
Diagnostic approach

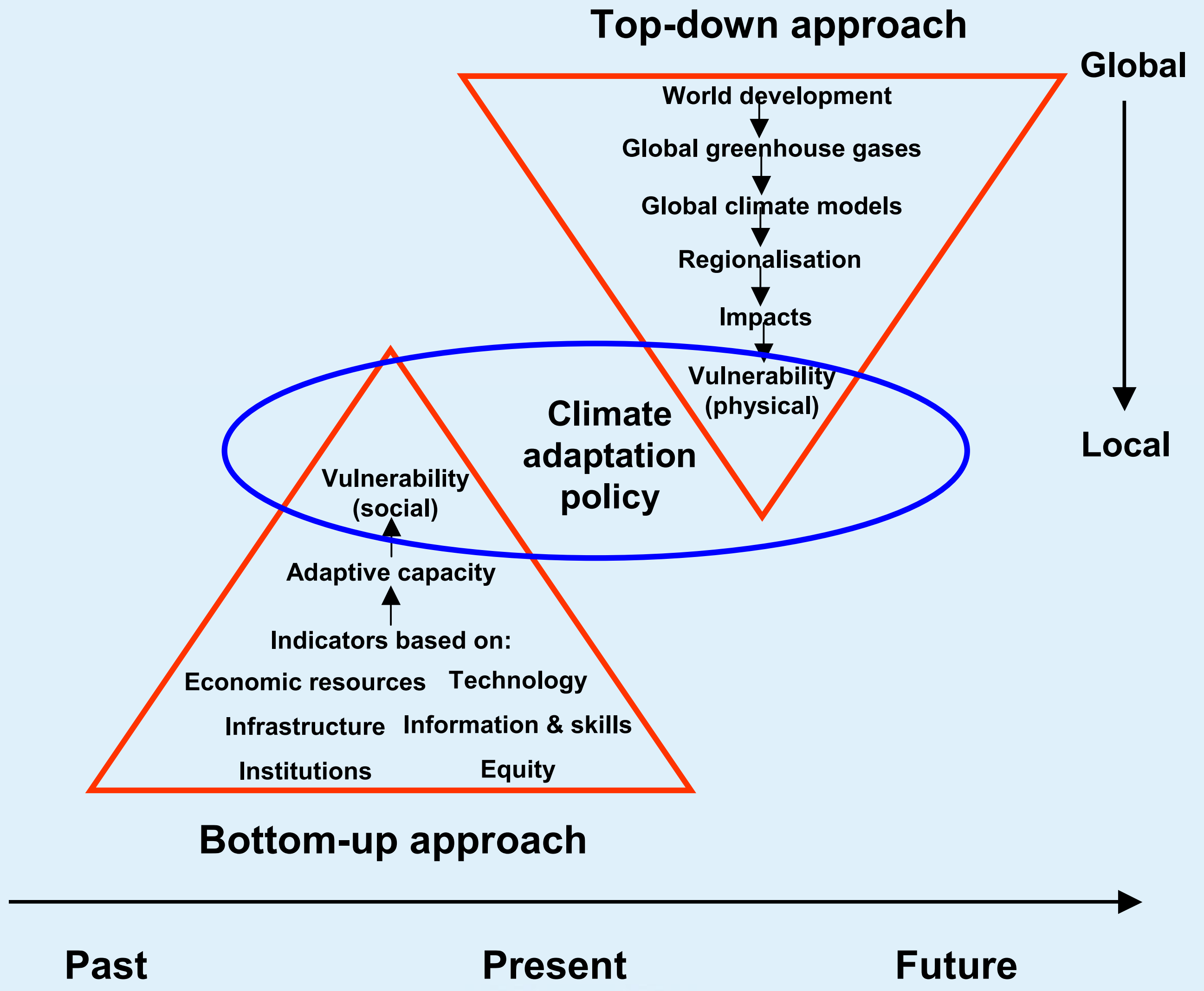
Select a wide range of projections for conducting sensitivity analyses

Question: *"What types of changes are needed to produce a given impact?"*

Less common, "bottom-up" approach - accounts for a range of uncertainties in projections; can provide insights into policy questions

"No scenarios please, we're already vulnerable"





Dessai and Hulme (2003)

Classifying global change scenarios

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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

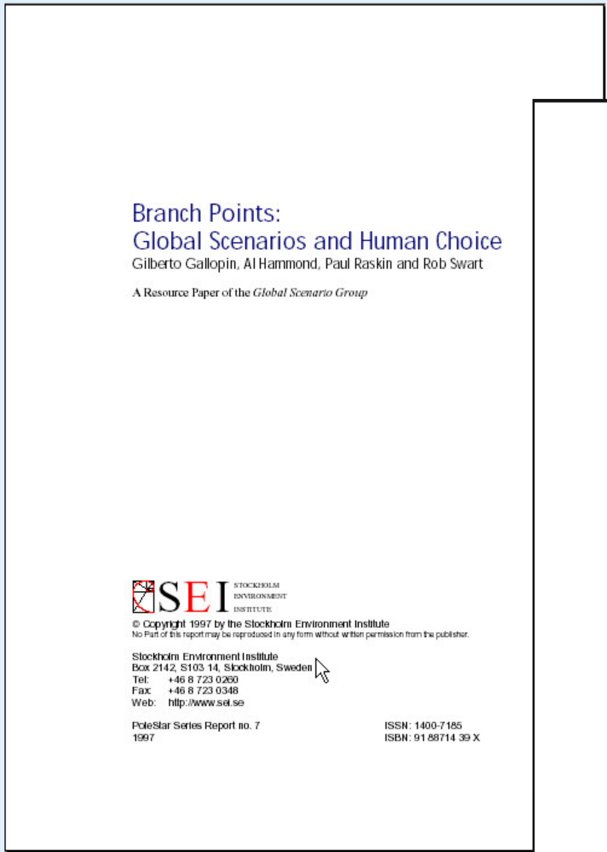
Describe a prespecified future; a world achievable (or avoidable) only through certain actions

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

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)

Examples of global-scale scenarios



Branch Points:
Global Scenarios and Human Choice
Gilberto Gallopin, Al Hammond, Paul Raskin and Rob Swart

A Resource Paper of the *Global Scenario Group*

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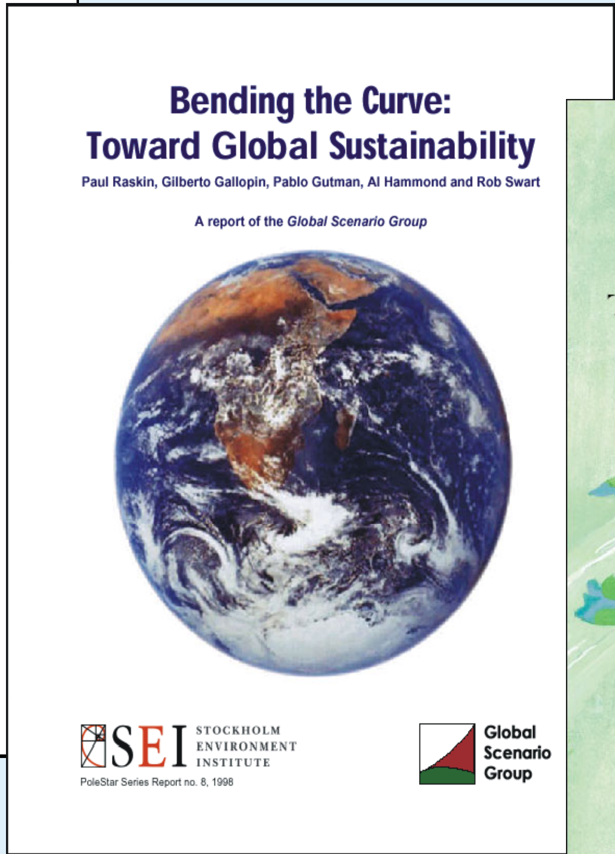
Stockholm Environment Institute
Box 2142, S103 14, Stockholm, Sweden
Tel: +46 8 723 0260
Fax: +46 8 723 0348
Web: http://www.sei.se

PoleStar Series Report no. 7
1997

ISSN: 1400-7185
ISBN: 91 88714 39 X

Gallopin *et al.*, 1997



Bending the Curve:
Toward Global Sustainability
Paul Raskin, Gilberto Gallopin, Pablo Gutman, Al Hammond and Rob Swart

A report of the *Global Scenario Group*

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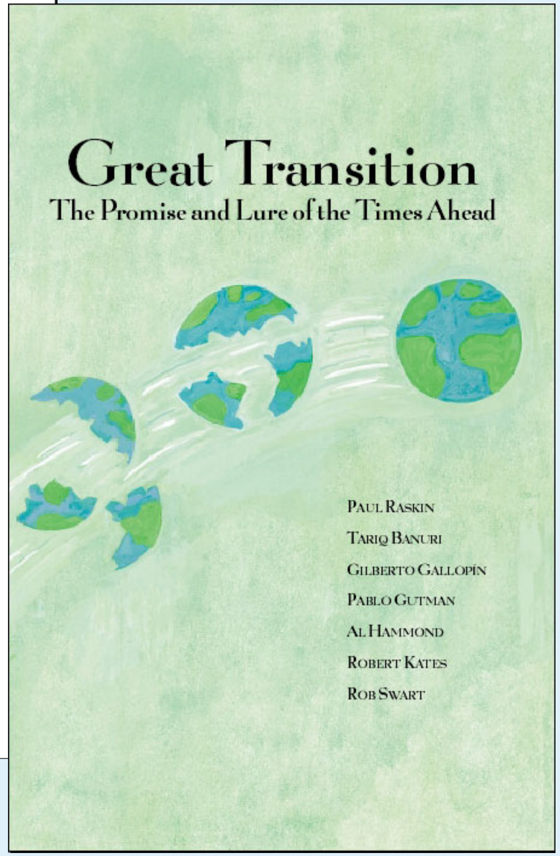
PoleStar Series Report no. 8, 1998

Global Scenario Group

Raskin *et al.*, 1998



Great Transition
The Promise and Lure of the Times Ahead

Paul Raskin
Tariq Banuri
Gilberto Gallopin
Pablo Gutman
Al Hammond
Robert Kates
Rob Swart

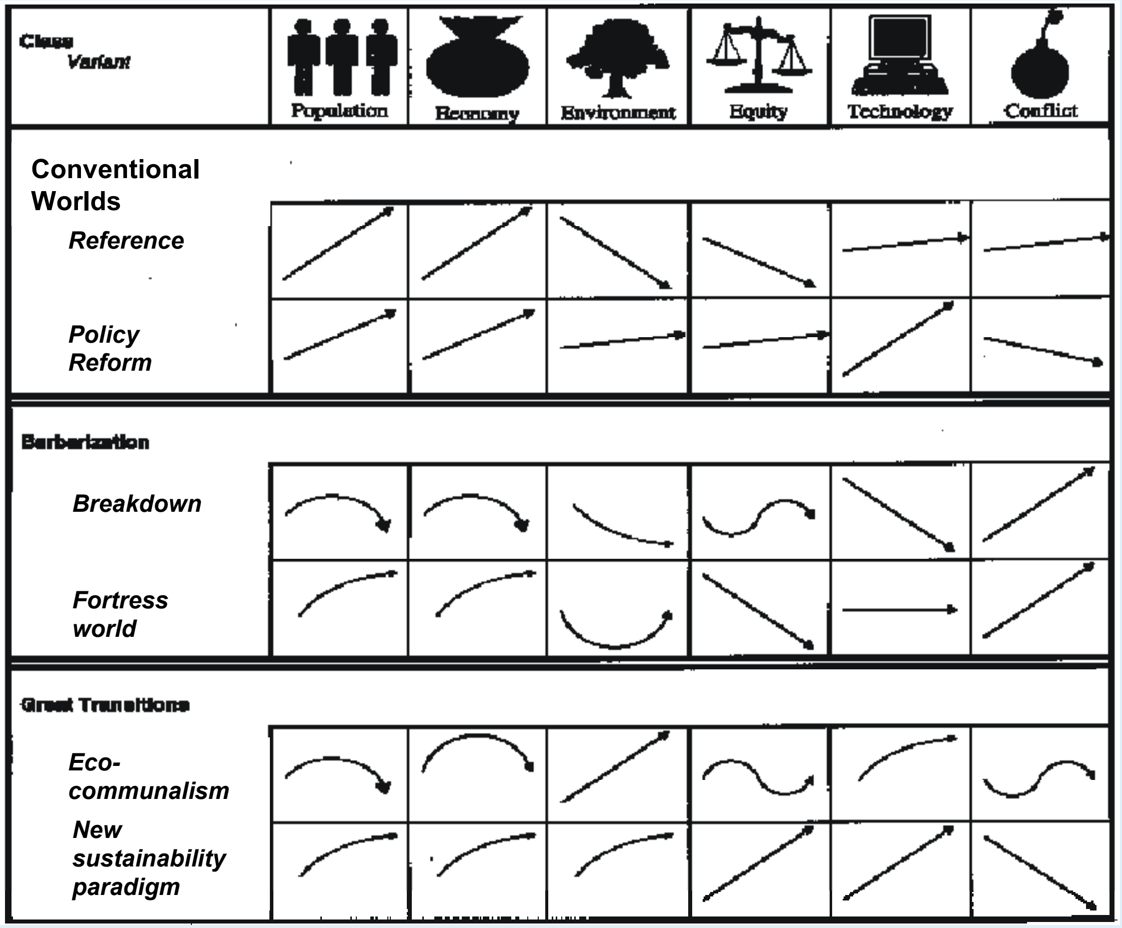
Raskin *et al.*, 2002

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

The IPCC Special Report on Emissions Scenarios (SRES)

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

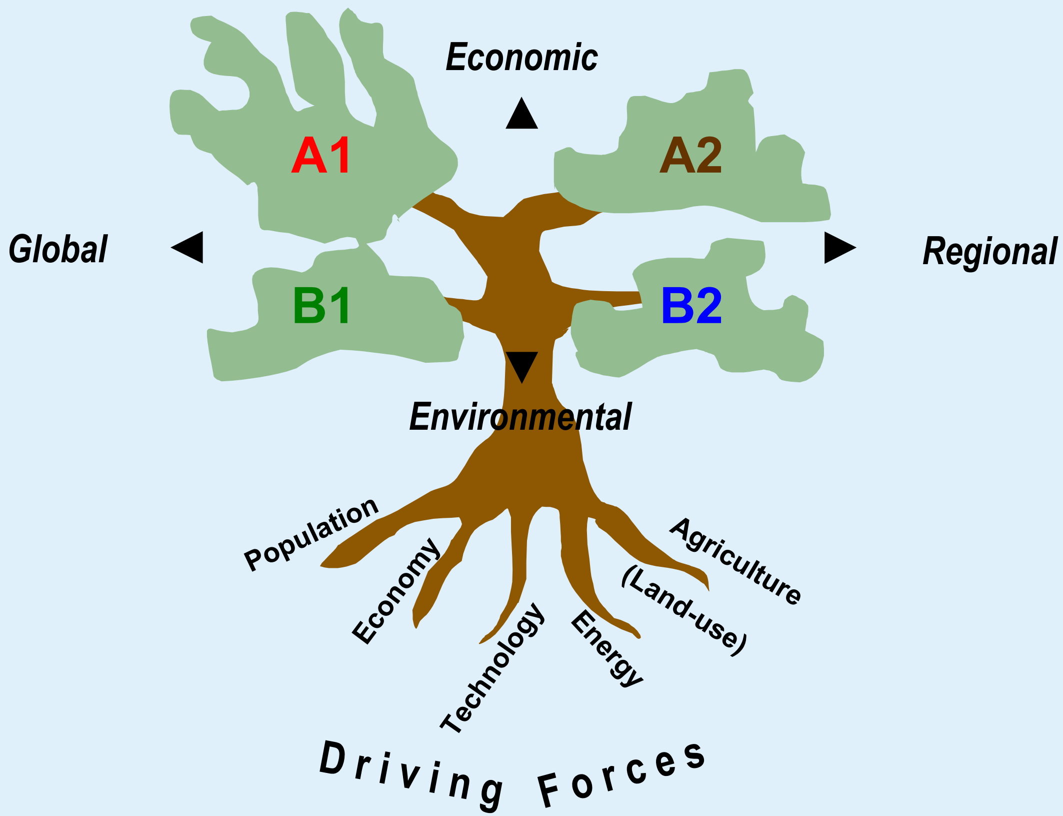
Four preliminary marker scenarios: no more or less likely than other scenarios

Exclude outlying "surprise" or "disaster" scenarios

Exclude additional climate policy initiatives (UNFCCC)

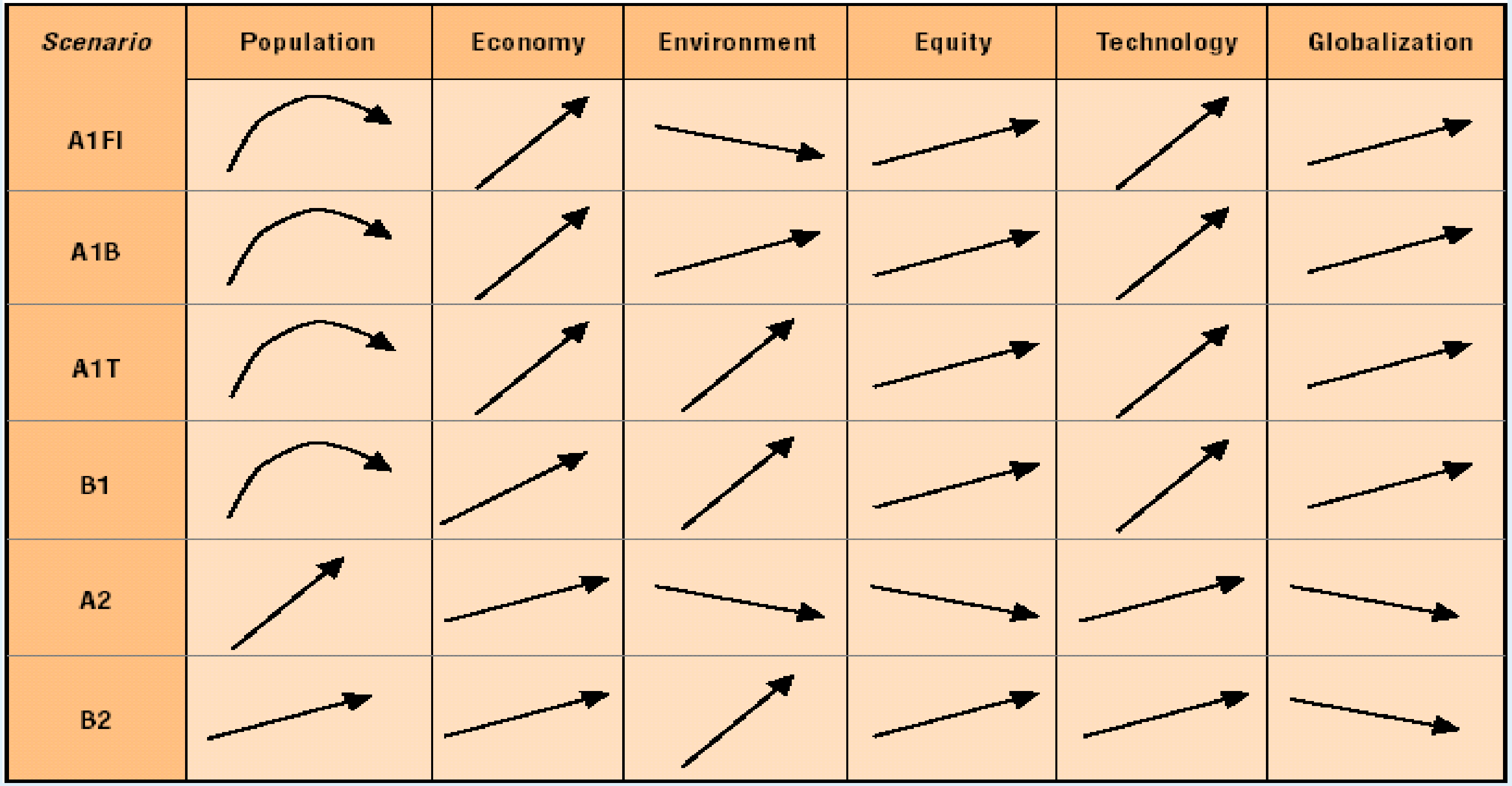
Six integrated assessment models employed

The SRES driving forces and storylines



Nakicenovic *et al.* (2000)

Relative direction of global driving forces for the SRES illustrative scenarios

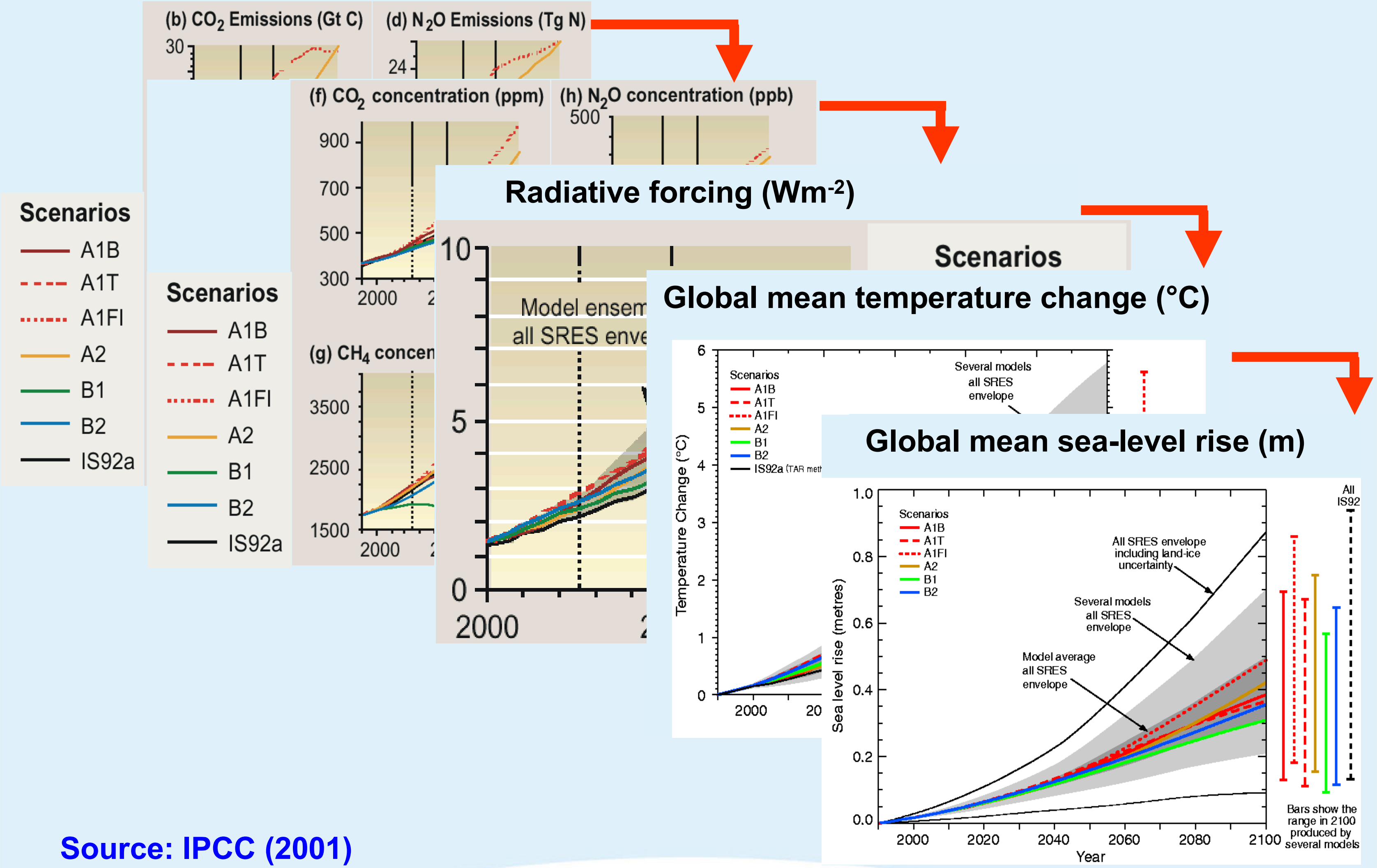


IPCC (2000)

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)



Source: IPCC (2001)

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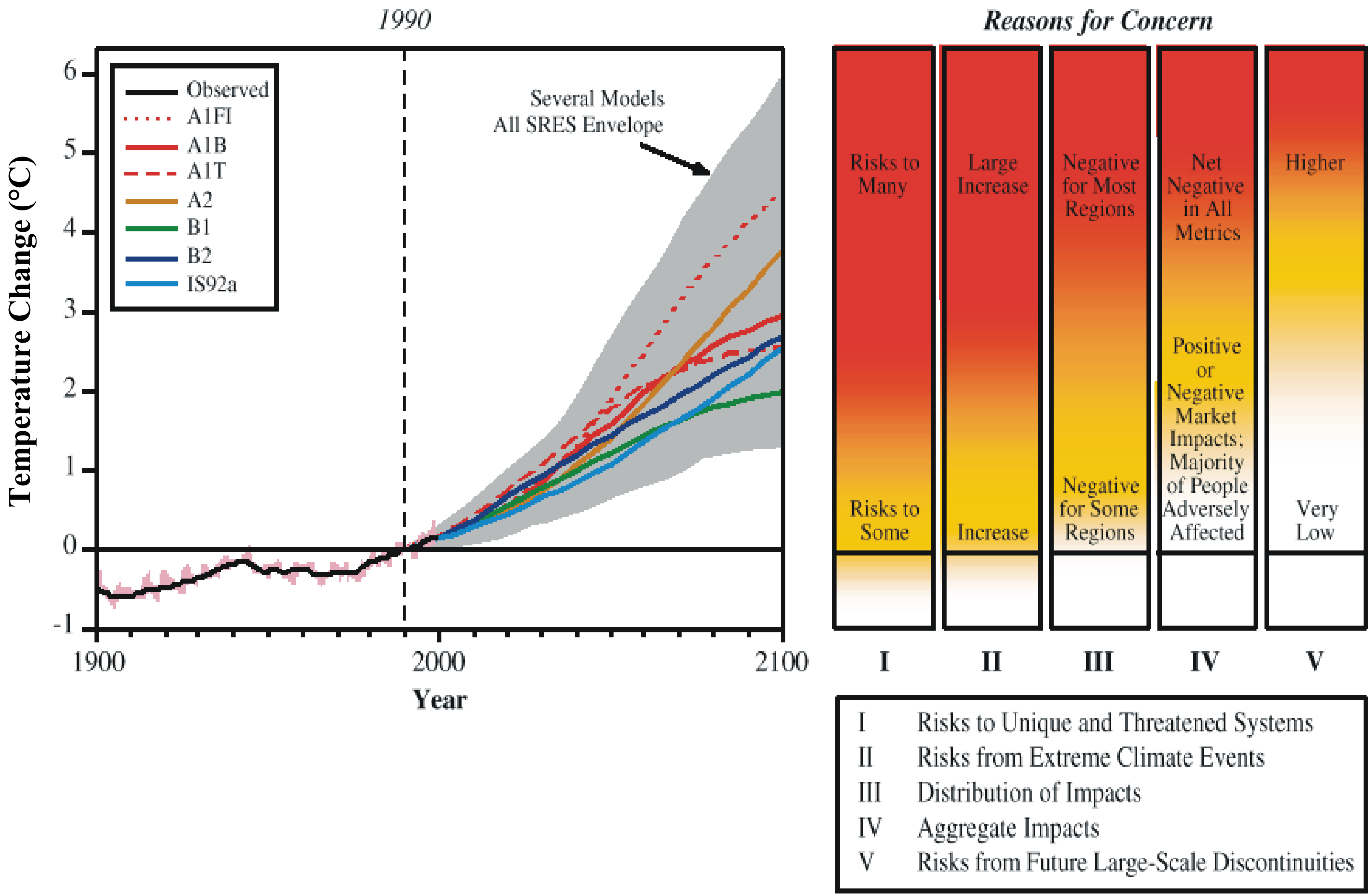

1990
Reasons for Concern
Temperature Change (°C)
Observed
A1FI
A1B
A1T
A2
B1
B2
IS92a
Several Models All SRES Envelope
Year
1900
2000
2100
Risks to Many
Risks to Some
Large Increase
Increase
Negative for Most Regions
Negative for Some Regions
Net Negative in All Metrics
Positive or Negative Market Impacts; Majority of People Adversely Affected
Higher
Very Low
I
II
III
IV
V
I Risks to Unique and Threatened Systems
II Risks from Extreme Climate Events
III Distribution of Impacts
IV Aggregate Impacts
V Risks from Future Large-Scale Discontinuities

IPCC, 2001

Other features of the SRES scenarios

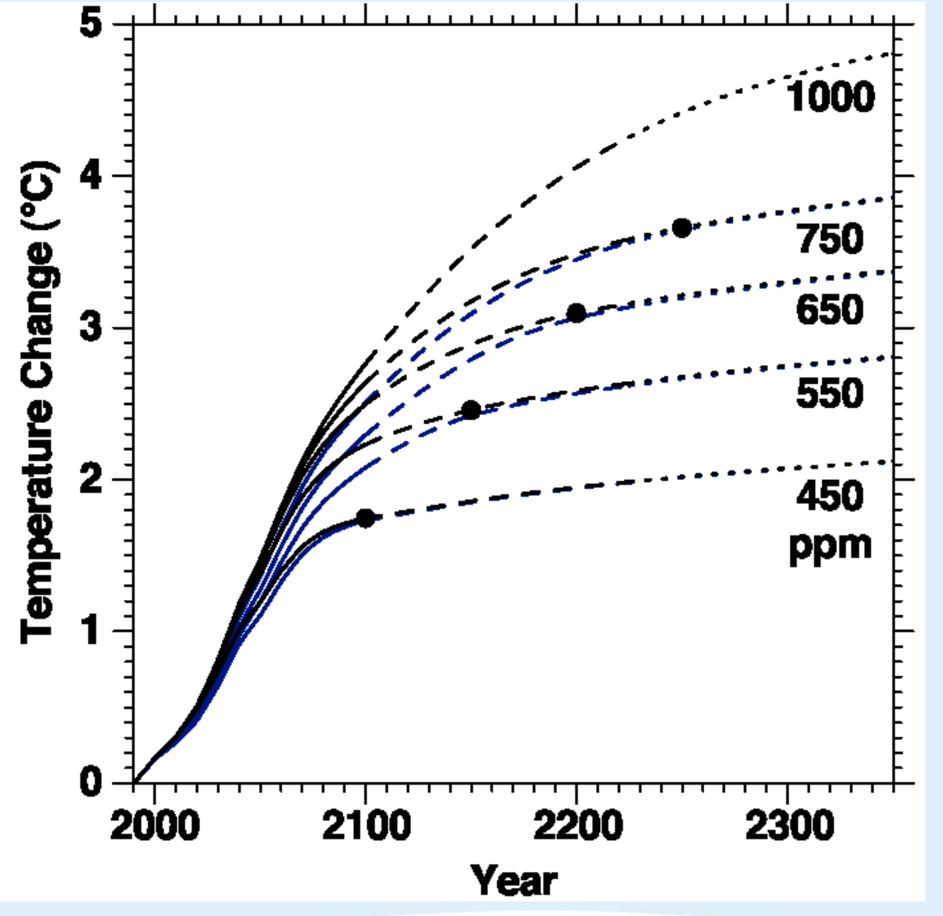
- Non-intervention, baseline scenarios, but …
- Some scenarios resemble mitigation scenarios

SRES "surrogate" stabilisation (CO_2 only) scenarios

- **B1 approximates 550 ppm stabilisation**
- **B2 and A1T approximate 650 ppm stabilisation**
- **A1B approximates 750 ppm stabilisation**

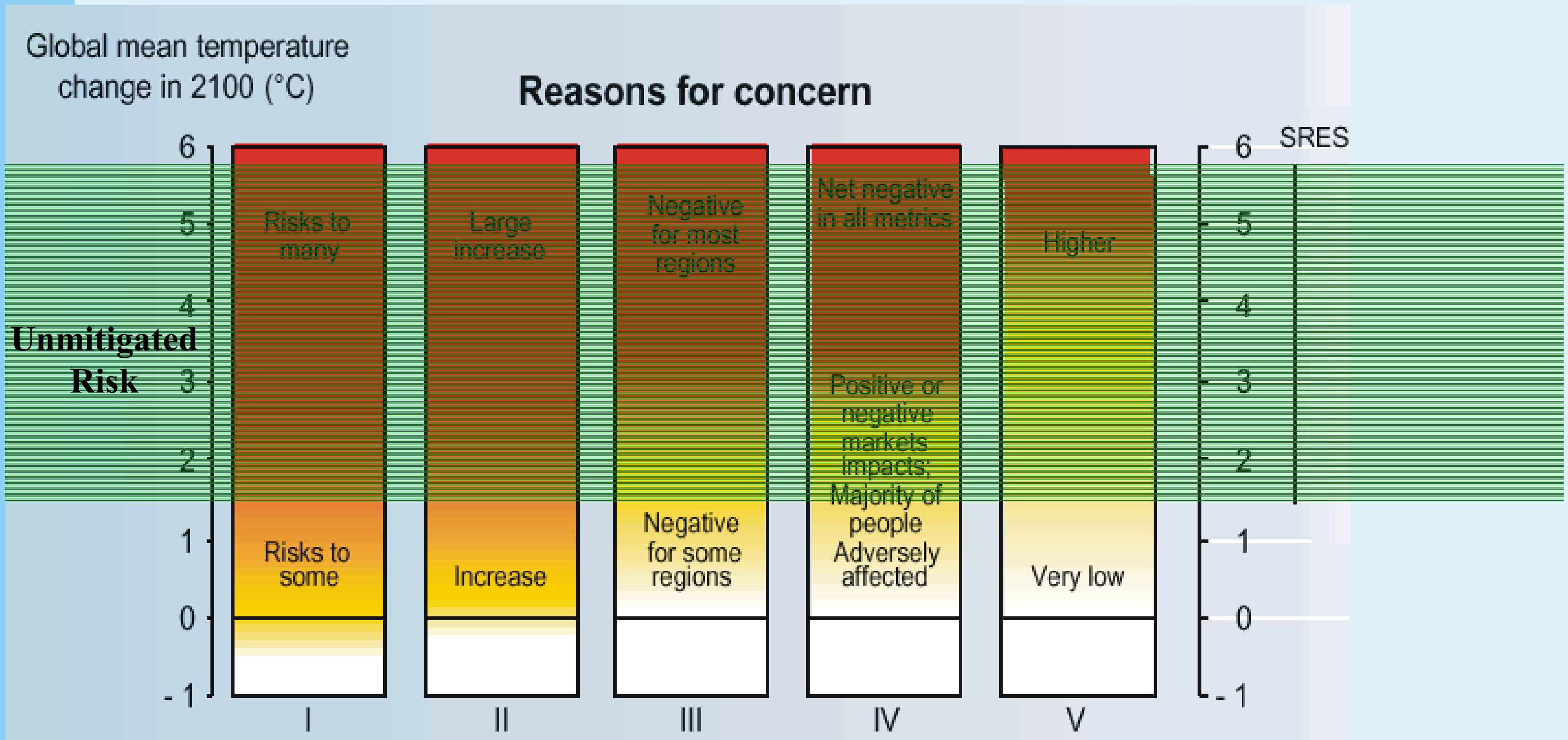
Swart et al. (2002)

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



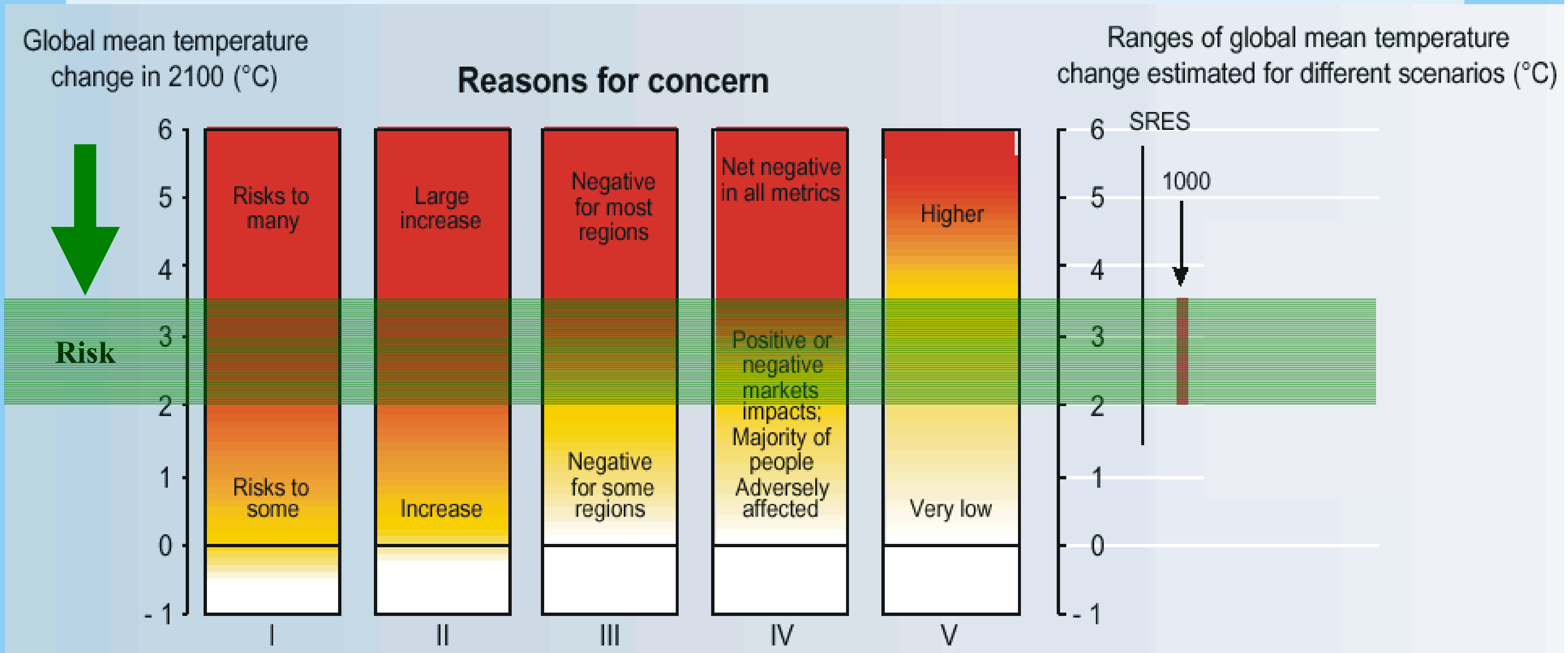
Cubasch *et al.* (2001)

Reducing risks: mitigation



IPCC, 2001

Reducing risks: mitigation



IPCC, 2001

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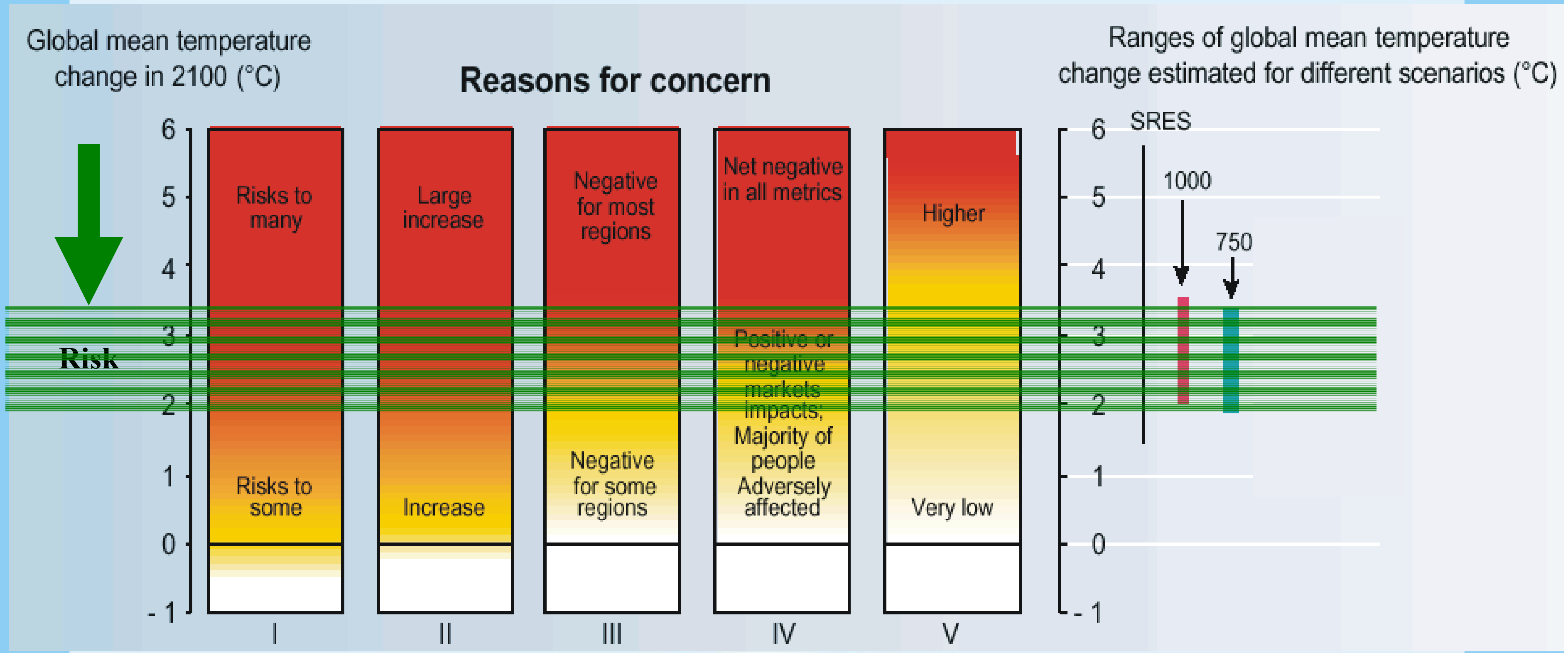
Reducing risks: mitigation



IPCC, 2001

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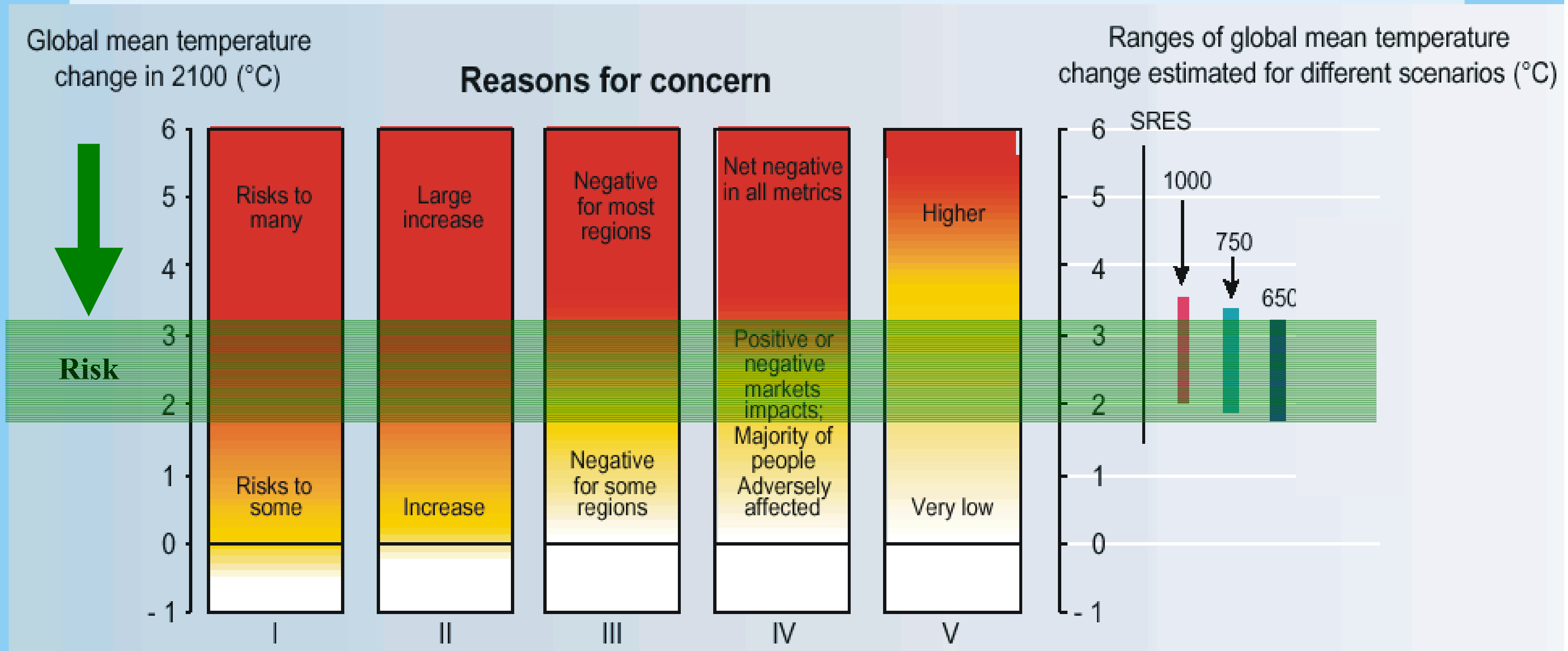
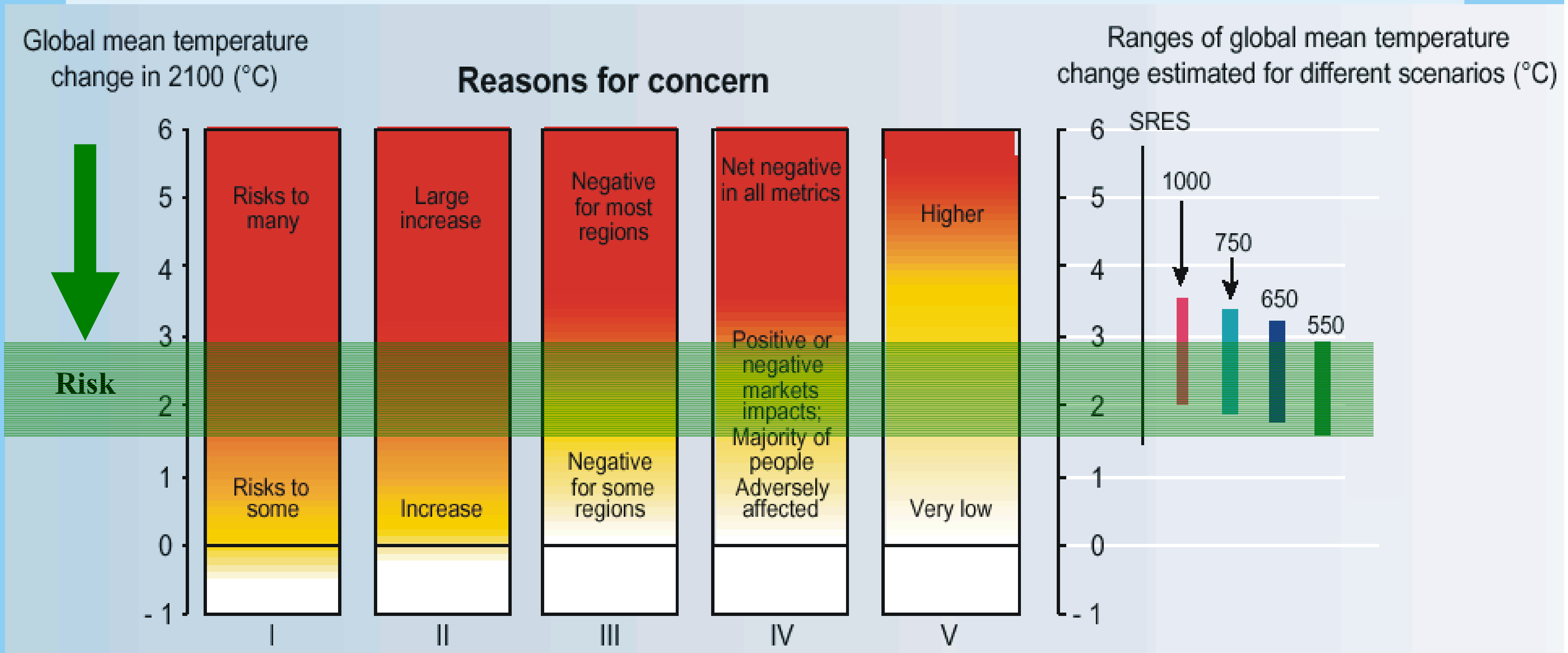
Reducing risks: mitigation



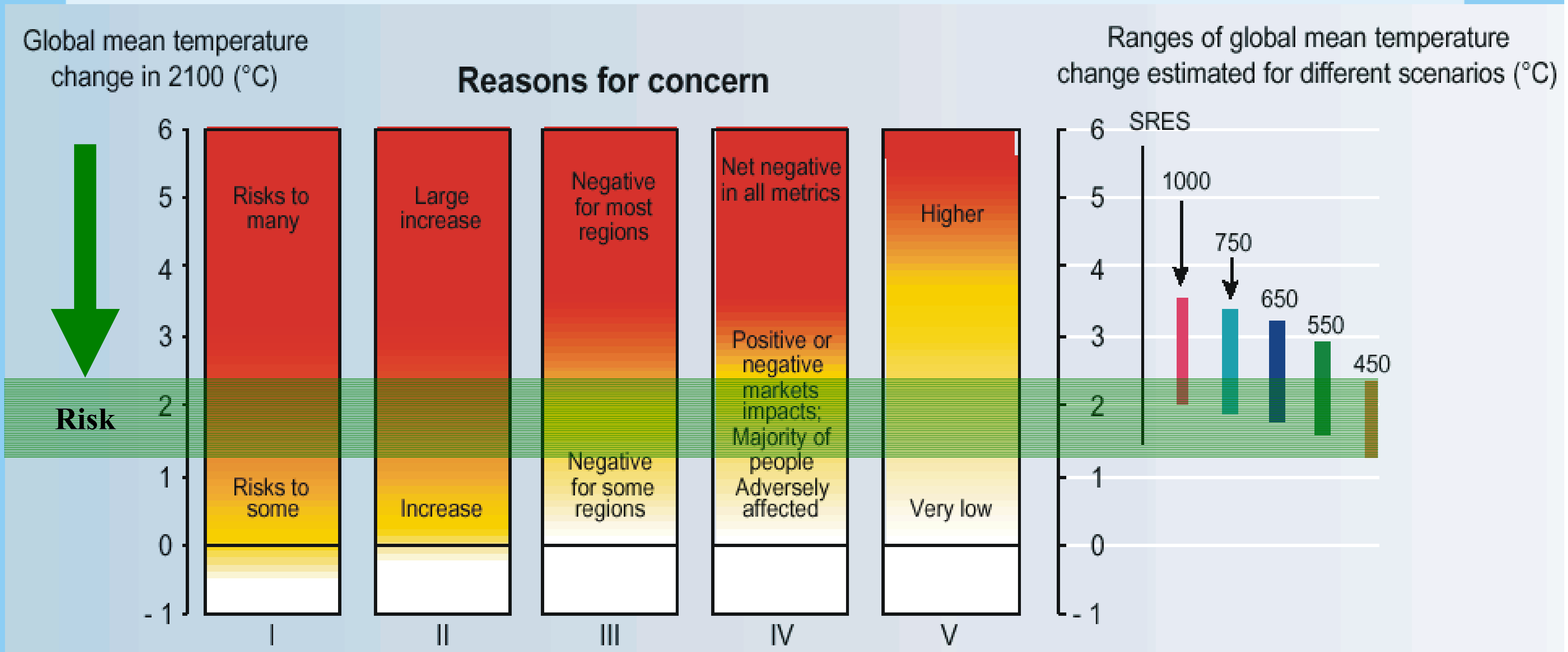
IPCC, 2001

Reducing risks: mitigation



IPCC, 2001

Reducing risks: mitigation



IPCC, 2001

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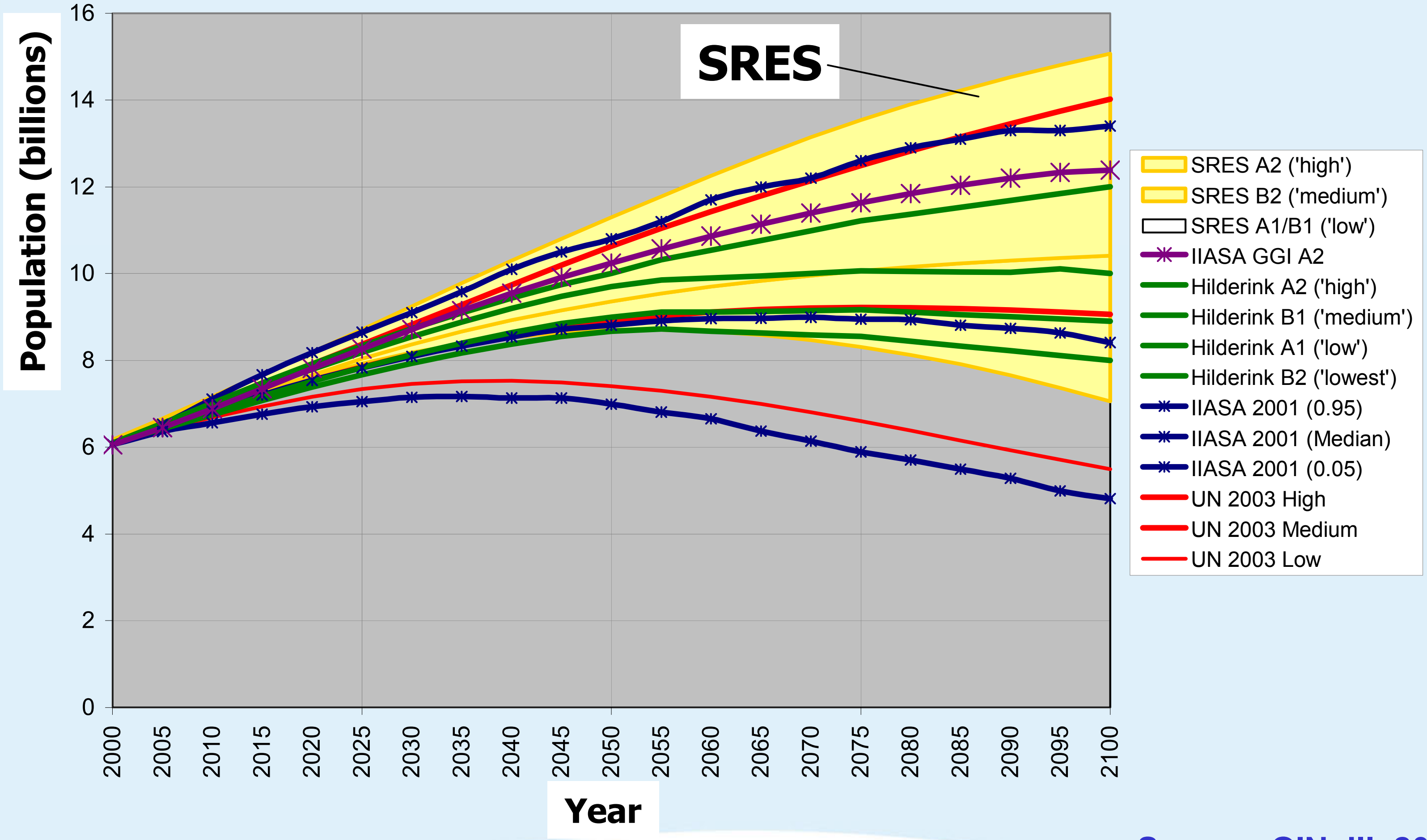
Some examples of global scale applications of the SRES scenarios

Population Size: Global



Source: O'Neill, 2005

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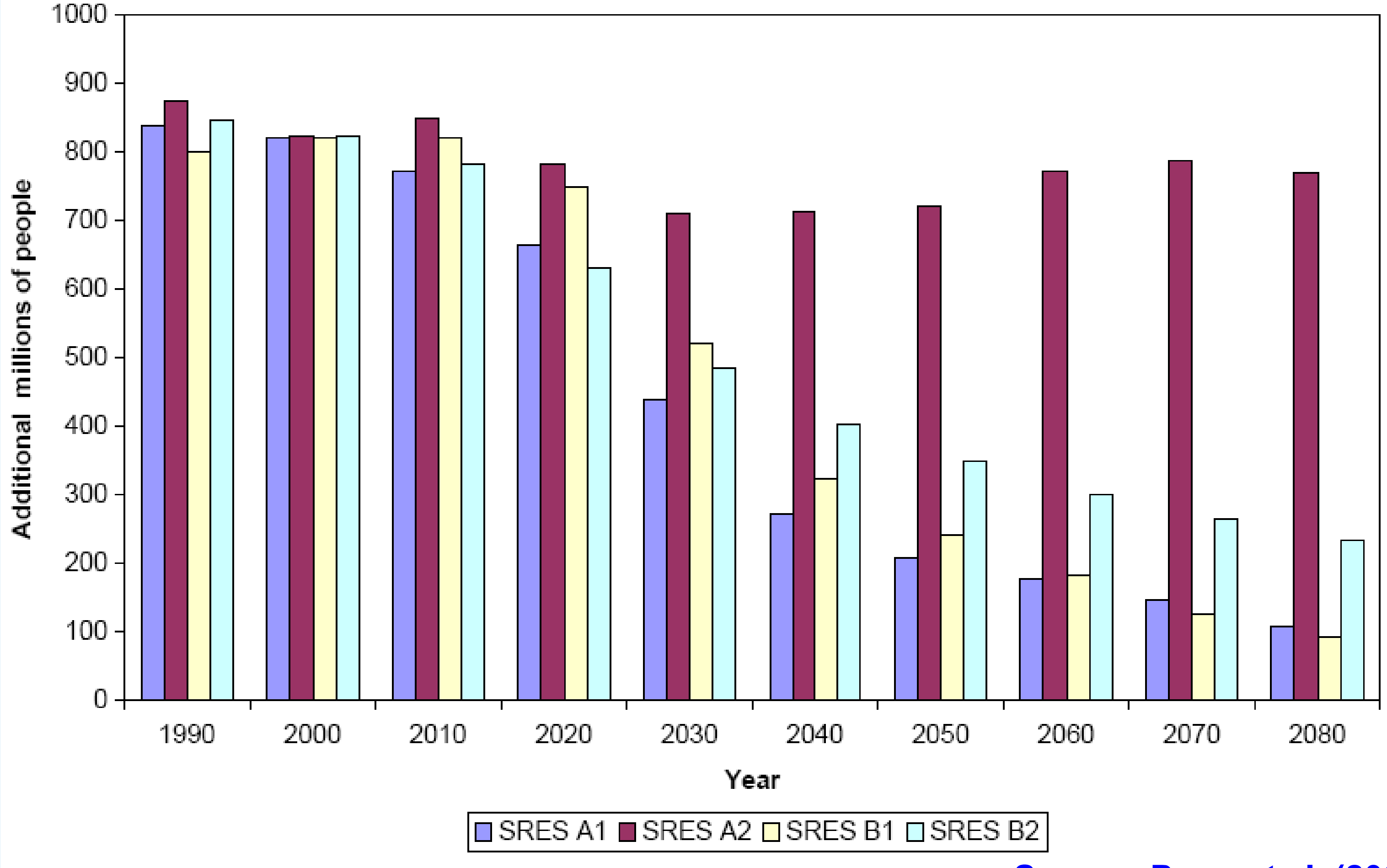
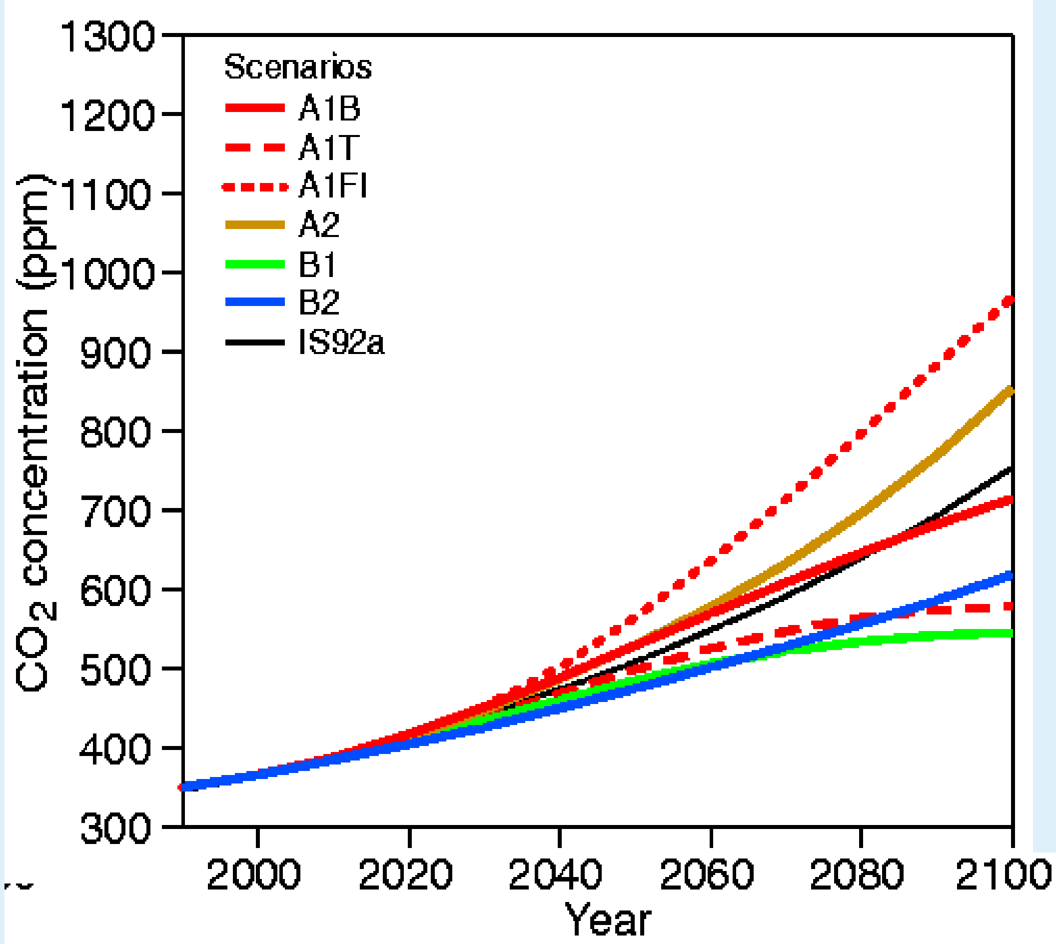
Numbers of people at risk of hunger for the four SRES marker scenarios assuming no climate change



Source: Parry et al. (2004)

SYKE

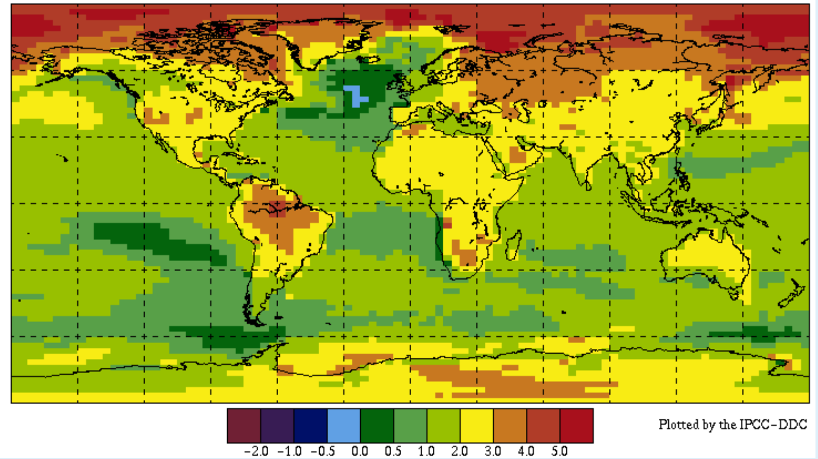
CO_2 concentrations projected for the 21st century



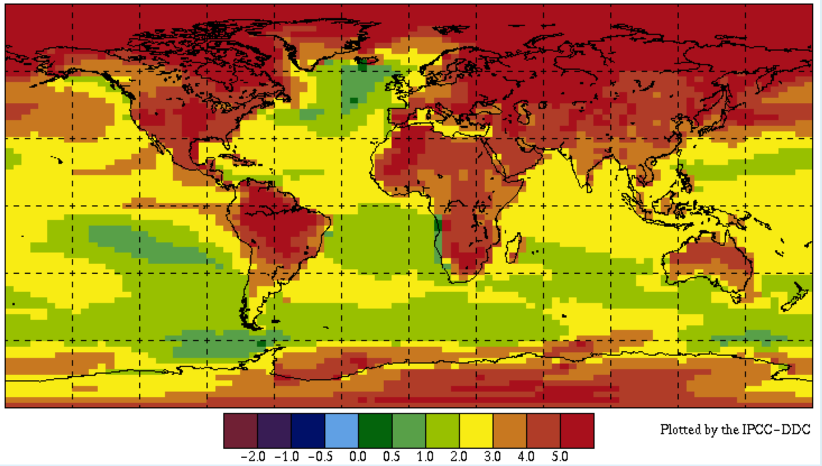
IPCC, 2001

HadCM3-derived mean annual temperature change (ºC) under A2-forcing

2041-2070



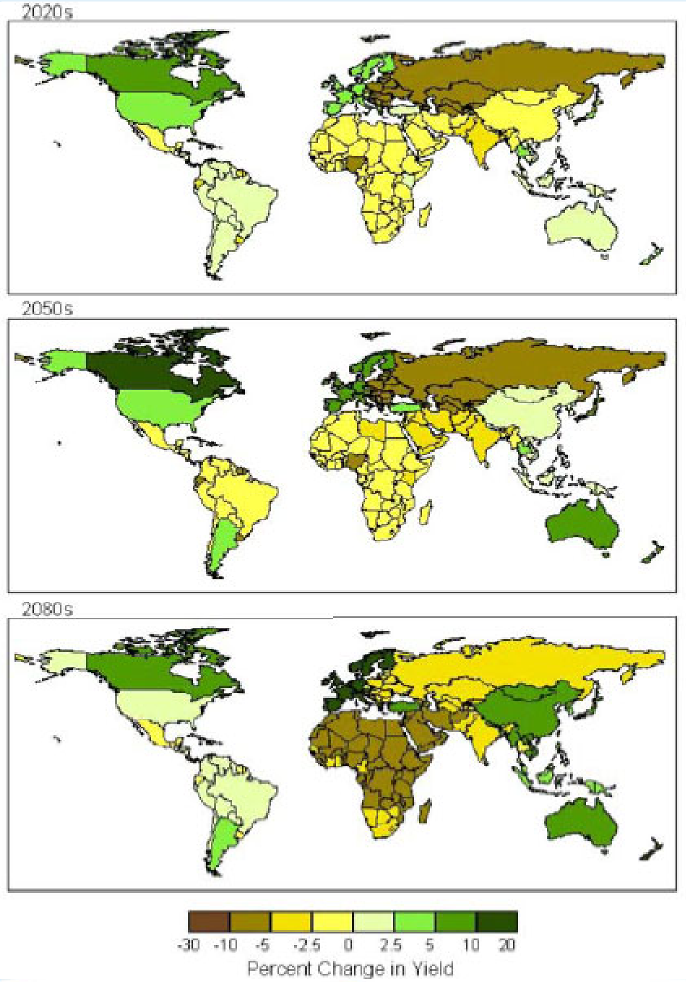
2071-2100



Source: IPCC Data Distribution Centre.

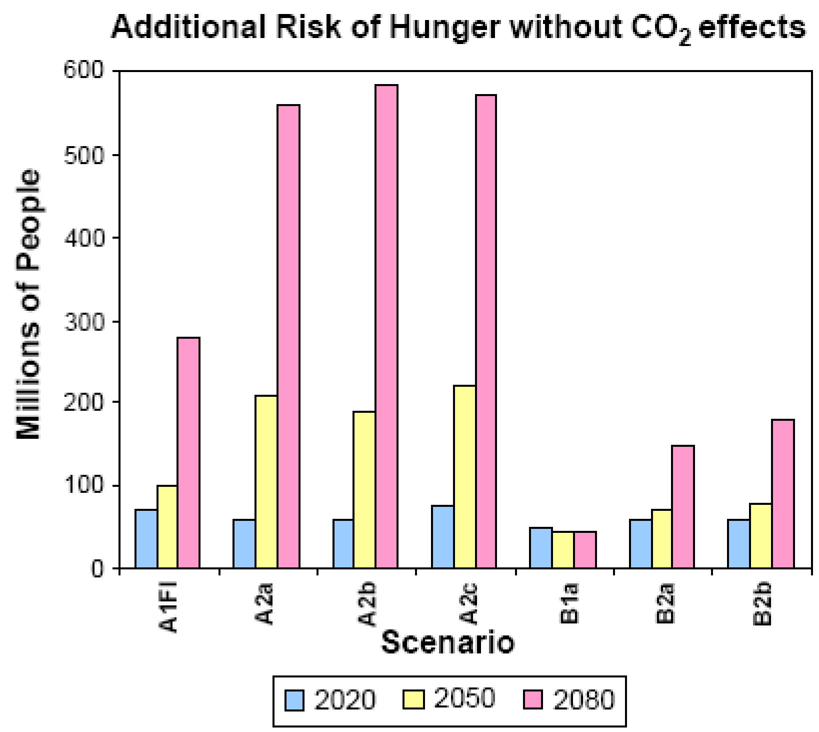
Potential changes (%) in cereal yields: 2020s, 2050s and 2080s (w.r.t. 1990) under the HadCM3 SRES A2a scenario

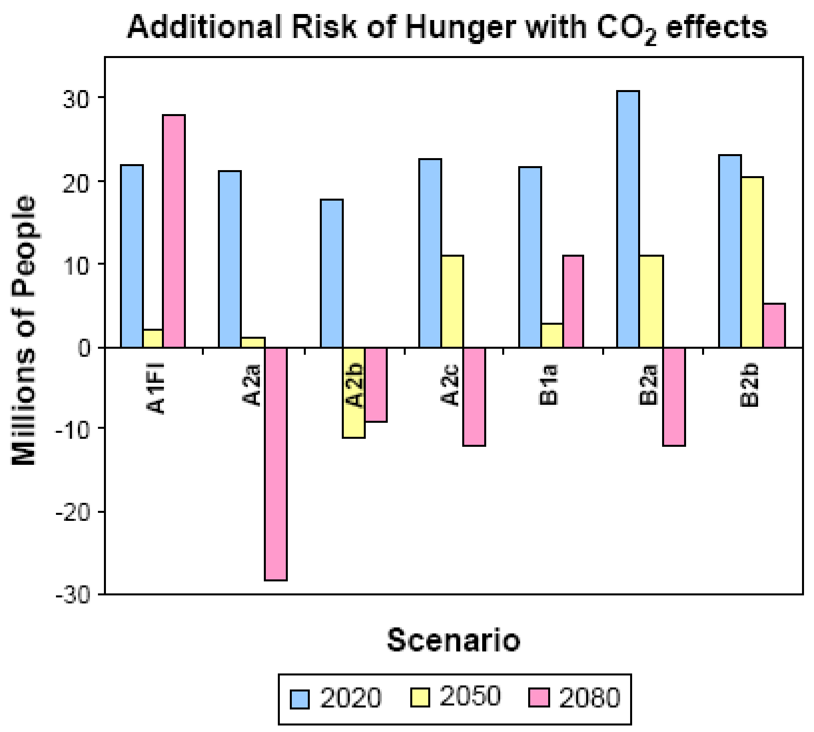
With direct CO_2 effects



Source: Parry et al. (2004)

Additional numbers of people at risk of hunger under seven SRES scenarios, relative to the reference (no climate change)





Source: Parry et al. (2004)

Abrupt global changes

Scenarios or thought experiments?

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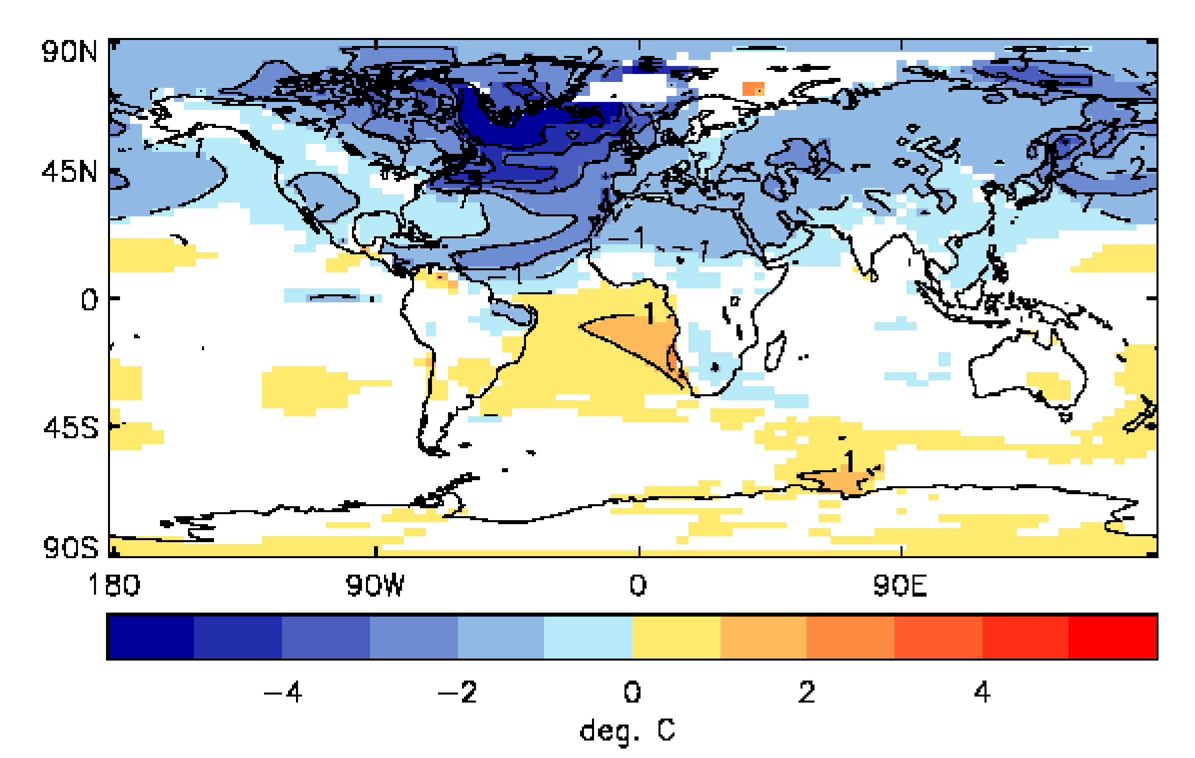
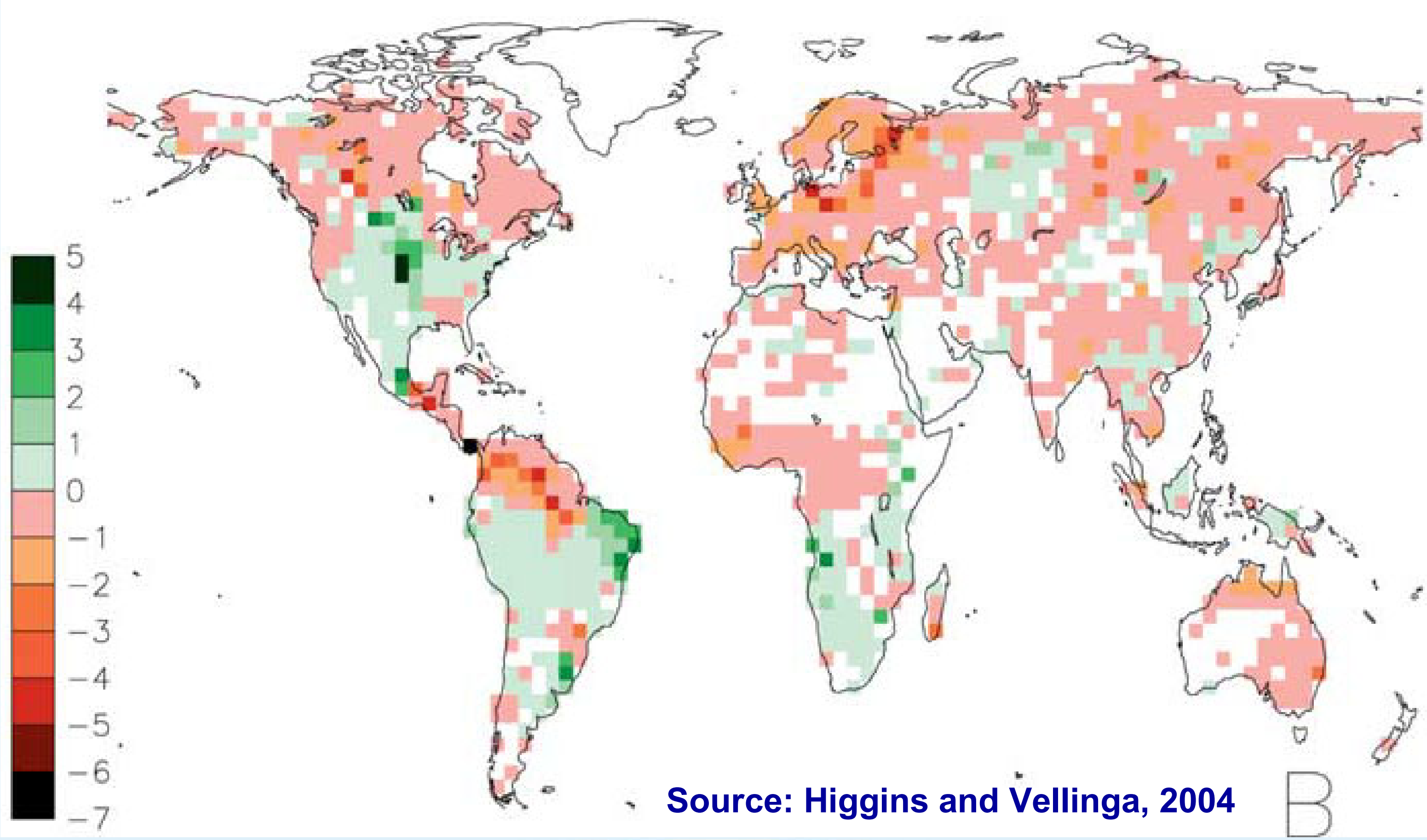
Modelled change in surface air temperature during years 20-30 after the collapse of the THC (HadCM3)



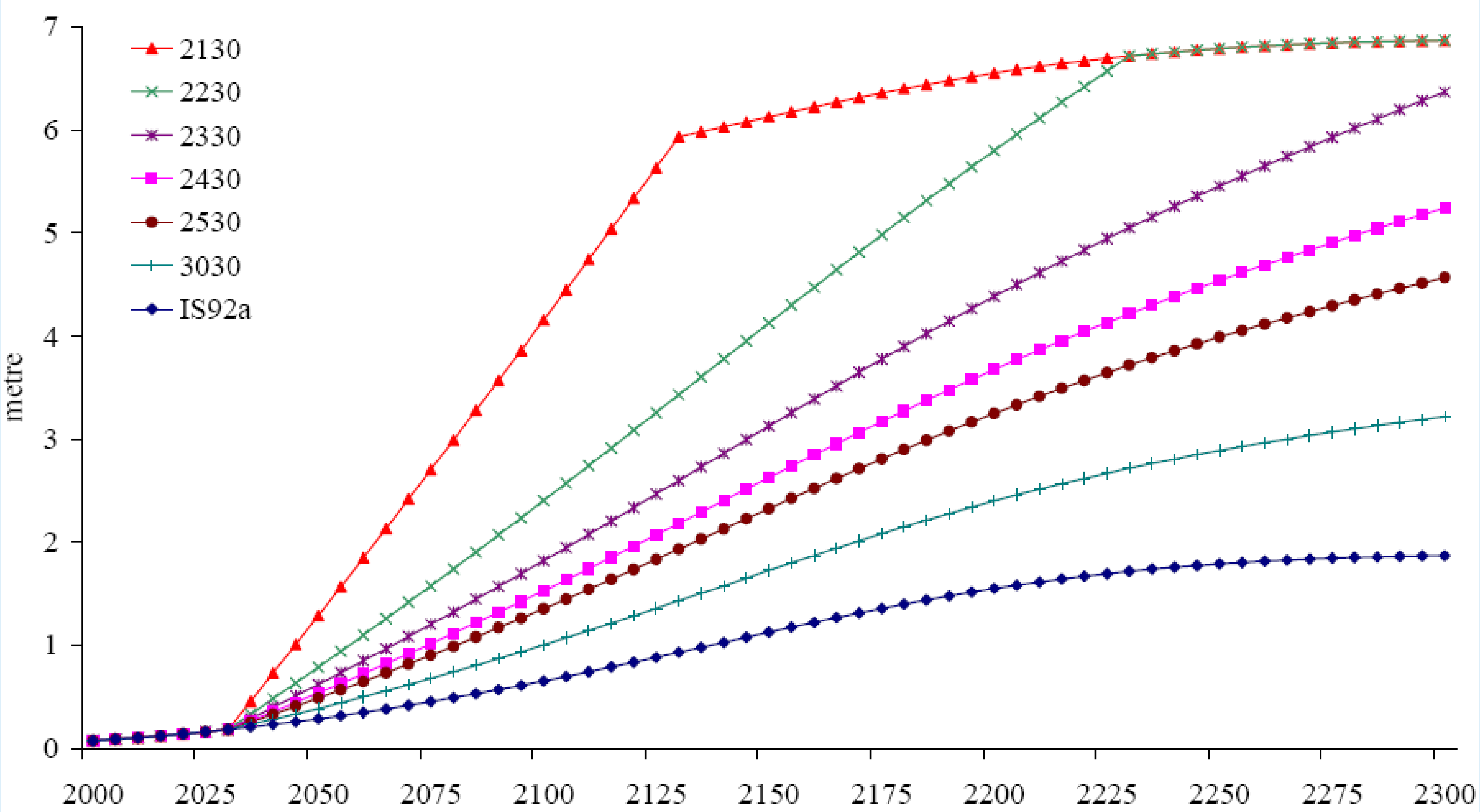
Vellinga and Wood, 2002

Change in biomass (kg/m^2) (mean of last 10 years) for a weakening THC "scenario" relative to the control.



Source: Higgins and Vellinga, 2004

Extreme sea-level rise scenarios: EU Atlantis project



Nicholls et al. (2005); Tol et al. (2005)

Regional and local scenarios

Why are regional scenarios needed?

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

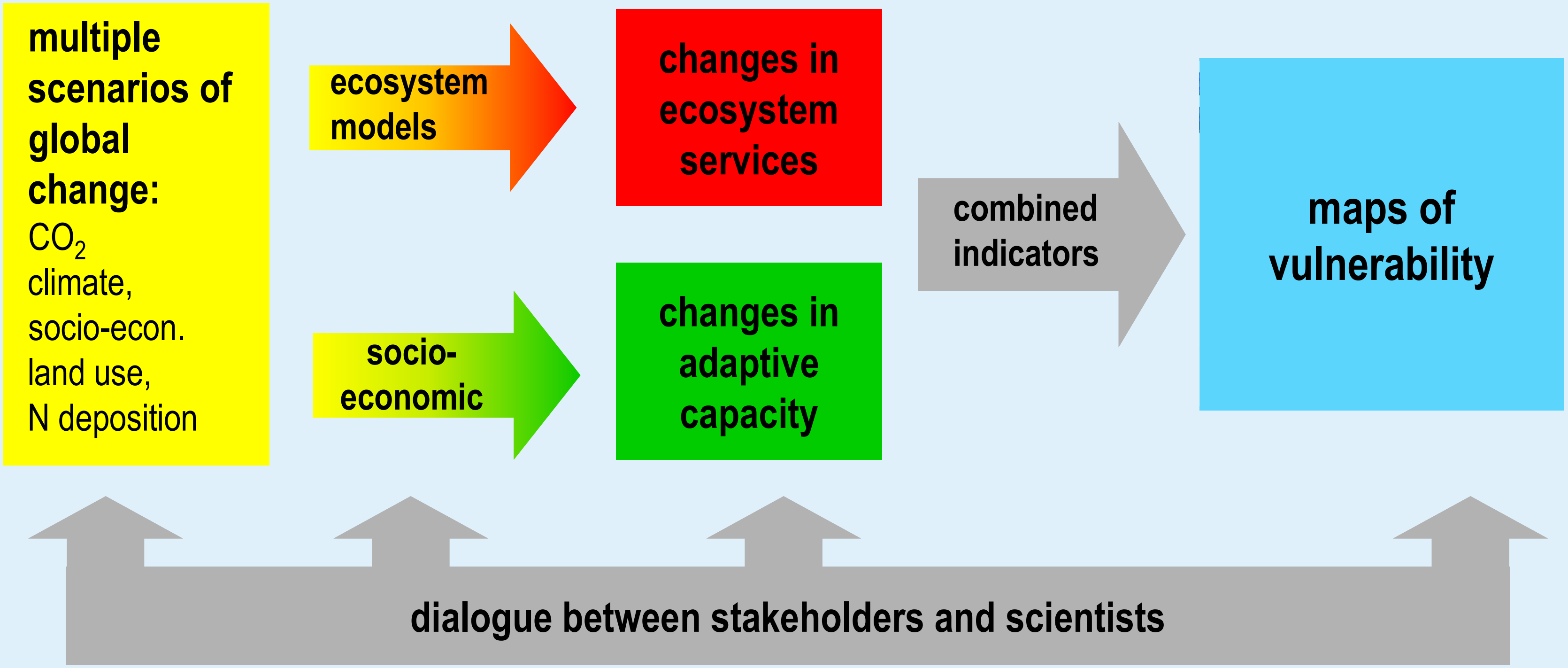
Some general scenario requirements for integrated regional impact studies

- 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

Some examples of integrated regional scenarios

Vulnerability assessment of ecosystem services for Europe

ATEAM **(Advanced Terrestrial Ecosystem Analysis and Modelling)**



Schröter et al. 2005 (submitted)

Ecosystem services and indicators

ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling)

Sectors	Services	Indicators
Agriculture	Food & fibre production Bioenergy production	▪ Agricultural land area (Farmer livelihood) ▪ Suitability of crops ▪ Biomass energy yield
Forestry	Wood production	▪ Tree productivity: growing stock & increment
Carbon storage	Climate protection	▪ Carbon storage in vegetation ▪ Carbon storage in soil
Water	Water supply (drinking, irrigation, hydropower) Drought & flood prevention	▪ Runoff quality and quantity ▪ Runoff seasonality
Biodiversity	Beauty Life support processes (e.g. pollination)	▪ Species richness and turnover (plants, mammals, birds, reptiles, amphibian) ▪ Shifts in suitable habitats
Mountains	Tourism (e.g. winter sports) Recreation	▪ Snow (elevation of snow line)

Schröter et el. 2005 (submitted)

European agricultural land use drivers

ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling)

Policy	Socio-economics	
	Demand	Supply
Market intervention (subsidies, quotas)	Population (consumption)	Resource competition (e.g. urban)
Rural development (LFAs[a])	Consumer preferences (meat, organic)	Climate change (temperature, precipitation, CO_2)
Environmental policy (NVZs[b], ESAs[c])	Market liberalisation (WTO[d])	Technology and management
	European Union enlargement	

[a] Less favoured areas.
[b] Nitrate vulnerable zones.
[c] Environmentally sensitive areas.
[d] World trade organisation.

Rounsevell et al. 2005

Estimated relative effect of different drivers on cropland in Europe

Demand for agricultural goods

Scenario	Cropland		
	2020	2050	2080
A1FI[a]	1.25	1.51	1.46
A2[b]	1.14	1.31	1.38
B1[c]	1.18	1.39	1.29
B2[d]	1.06	1.09	1.07

Assumed effects of technology (yield)

Scenario	Cropland		
	2020	2050	2080
A1FI[a]	1.37	1.87	2.34
A2[b]	1.36	1.81	2.16
B1[c]	1.29	1.62	1.86
B2[d]	1.19	1.27	1.27

Assumed effects of CO_2 (yield)

Scenario	2020	2050	2080
A1FI[a]	1.04	1.16	1.32
A2[b]	1.04	1.13	1.27
B1[c]	1.04	1.09	1.11
B2[d]	1.04	1.11	1.15

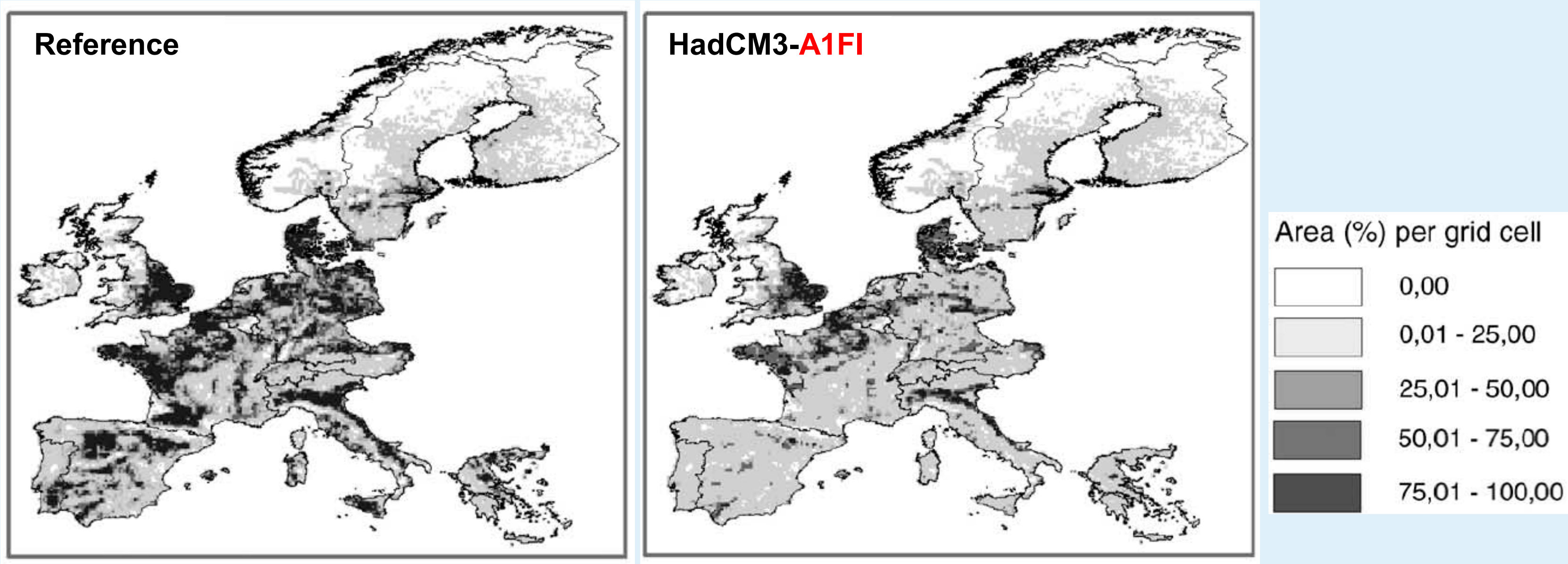
[a] Global economic and fossil fuel intensive world.
[b] Regional economic world.
[c] Global environmental world.
[d] Regional environmental world.

Estimated effects of climate change (yield)

Scenario	Cropland		
	2020	2050	2080
A1FI[a]	0.99	0.92	0.93
A2[b]	1.01	0.97	0.95
B1[c]	1.01	0.98	0.97
B2[d]	1.01	0.98	0.97

Rounsevell et al. 2005

Modelled cropland areas in Europe in 2080: alternative storyline assumptions, HadCM3 climate



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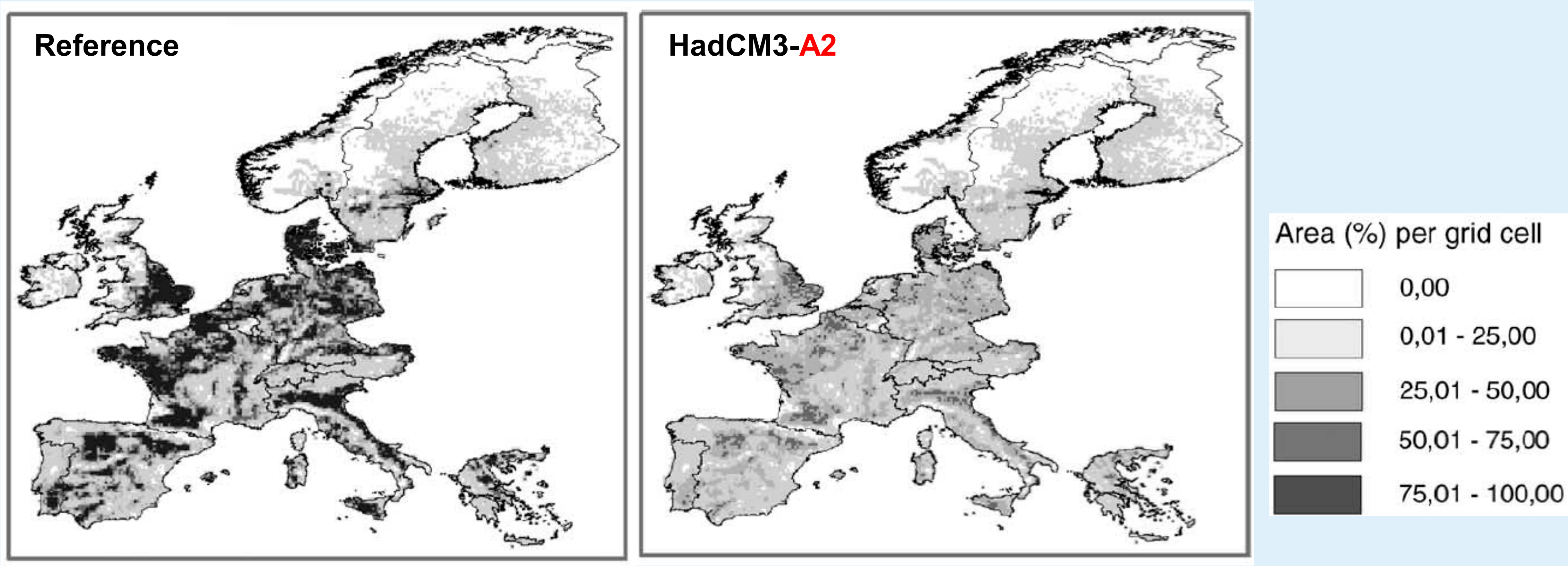

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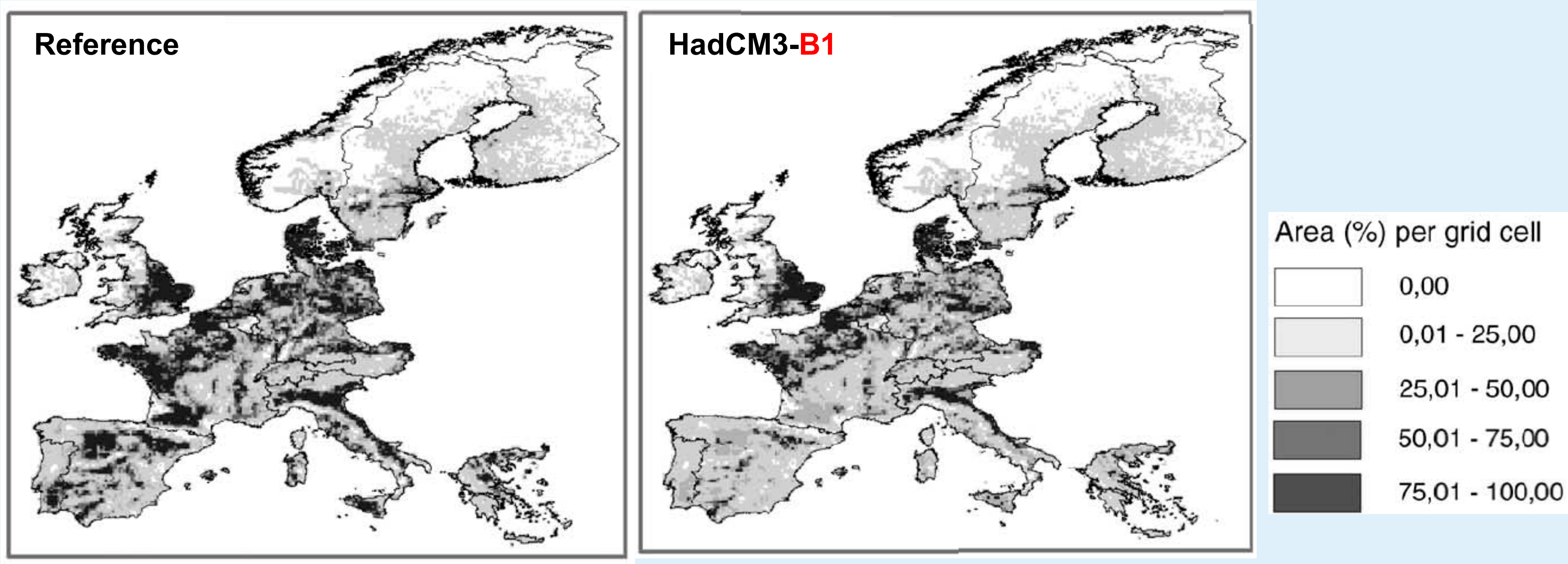

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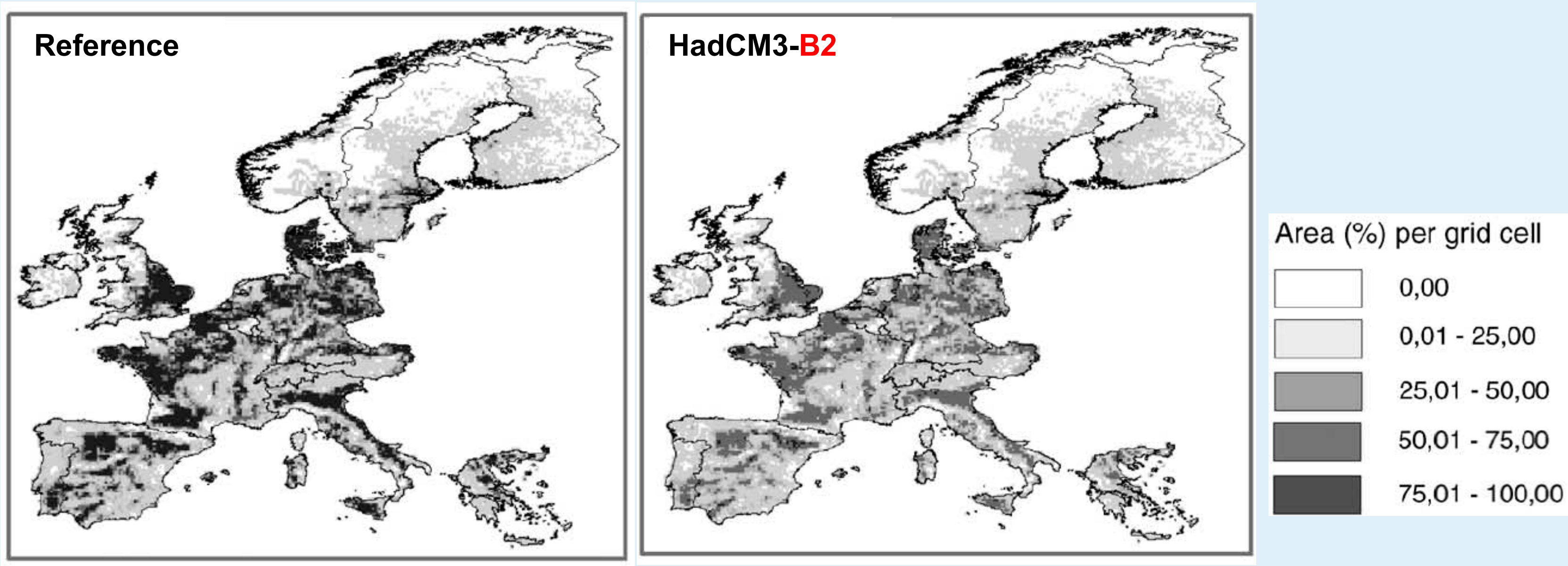

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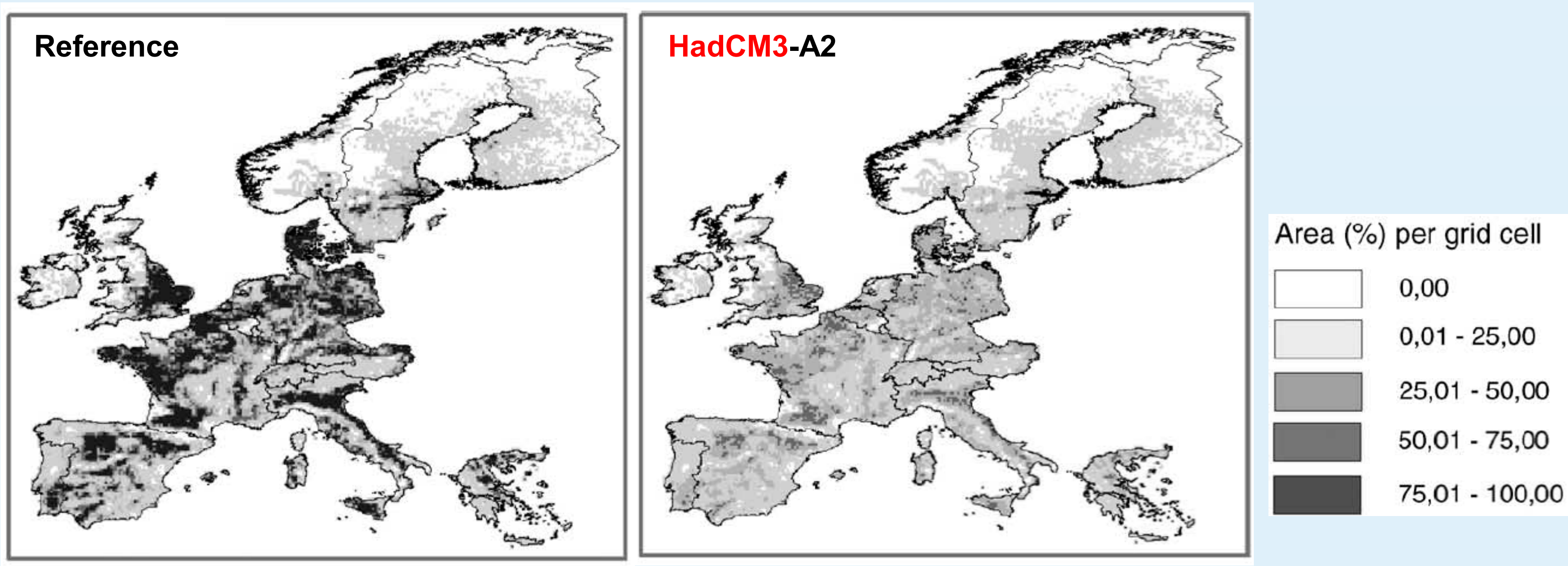
Rounsevell et al. 2005

Modelled cropland areas in Europe in 2080: alternative GCM-based climates, A2 storyline



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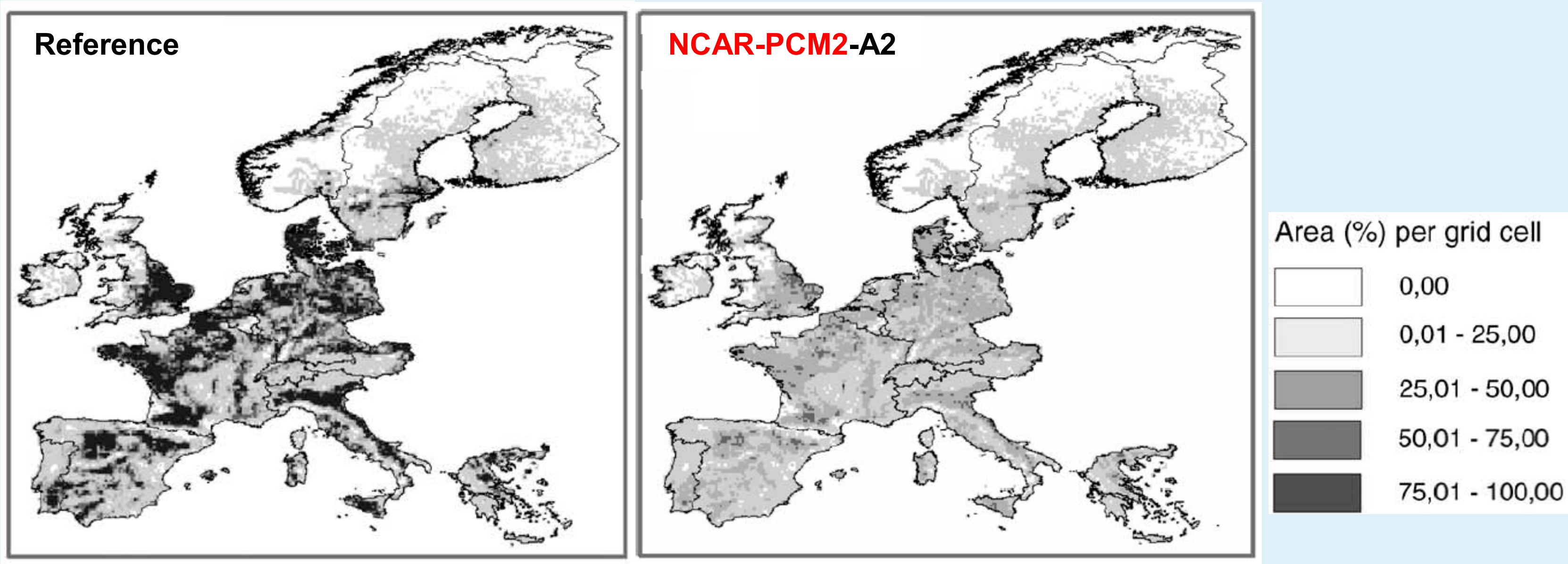

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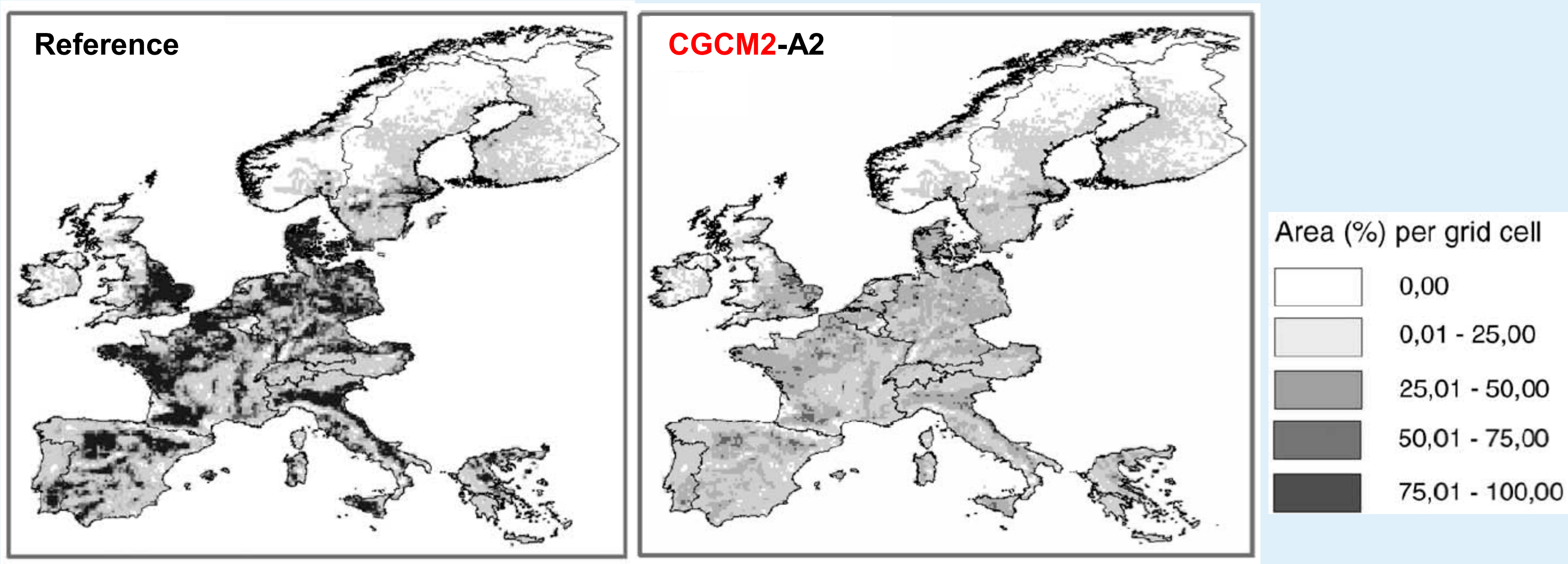

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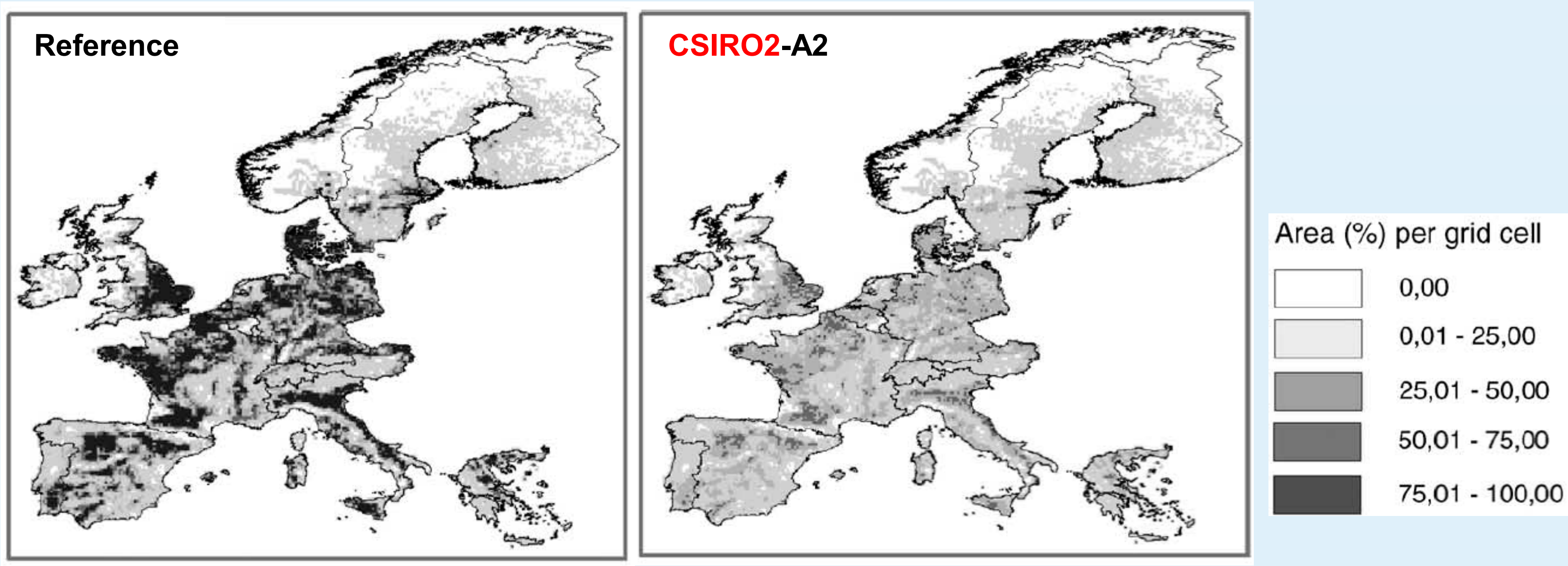

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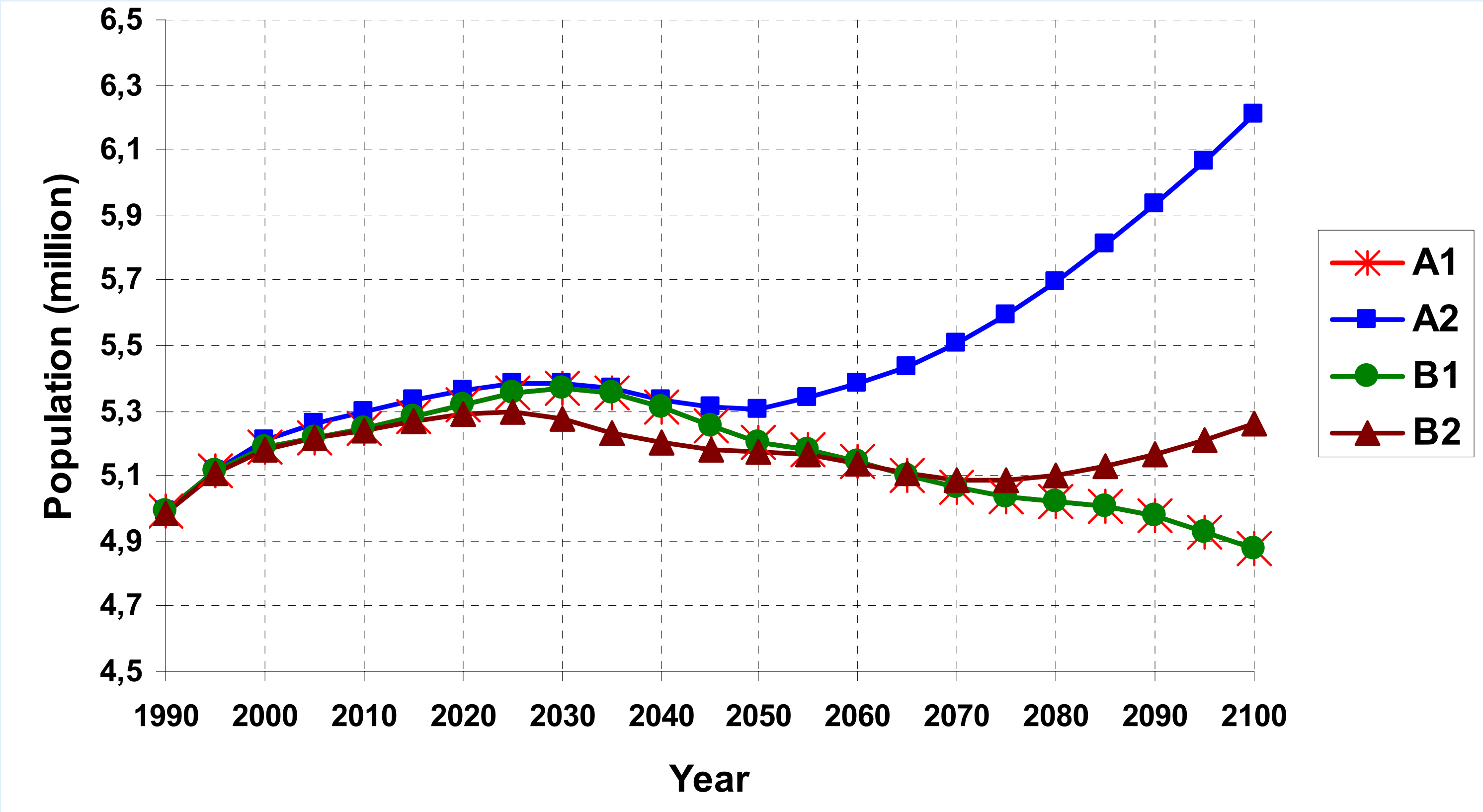
Rounsevell et al. 2005

National-scale example: FINSKEN scenarios

- Based on IPCC SRES global scenarios
- Use available models/information
- Use model results and expert judgement
- Combine elements of social and natural science
- Internally- and mutually-consistent
- Focus on the entire 21st century: 2001-2100
- Geographically explicit in Finland
- Consider uncertainties in projections

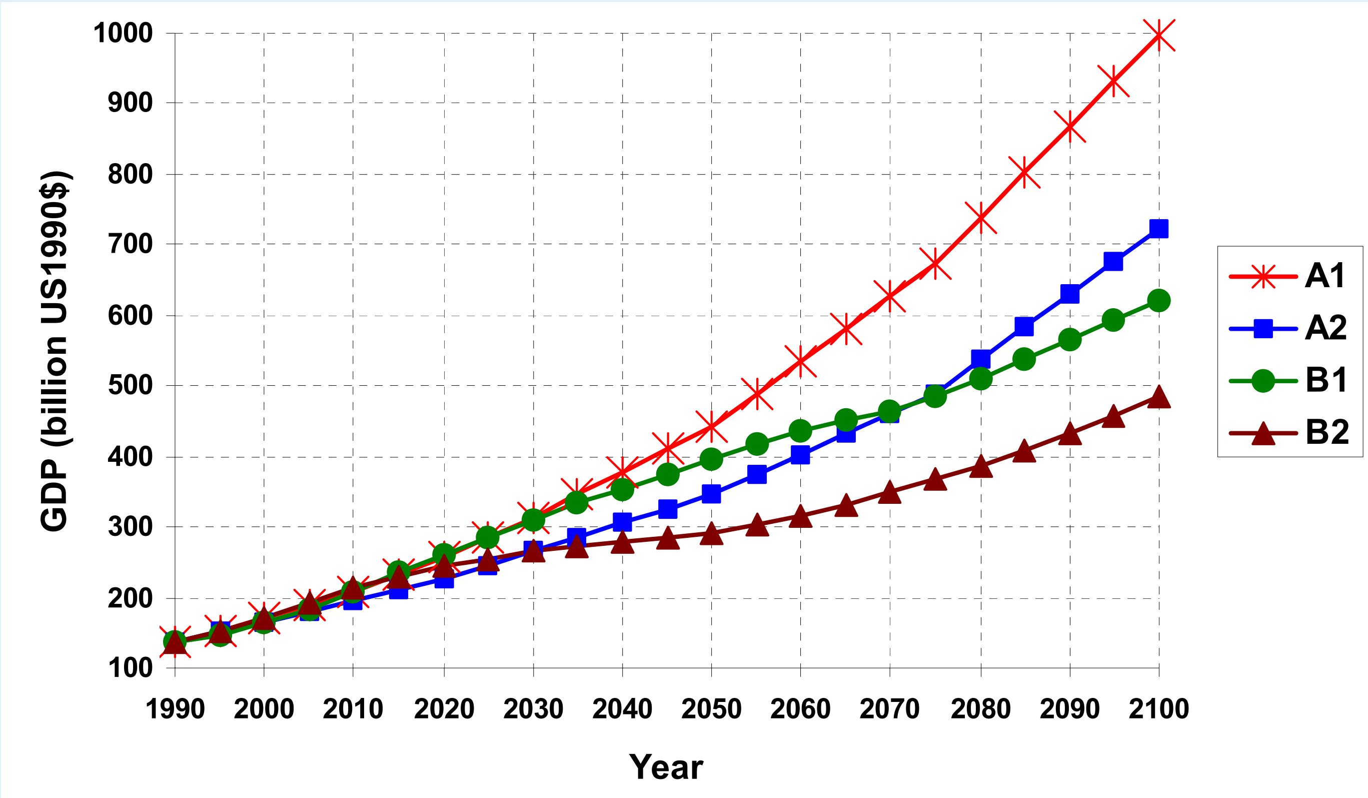
Carter et al., 2004

Population of Finland: 1990-2100
Downscaled from the SRES global scenarios



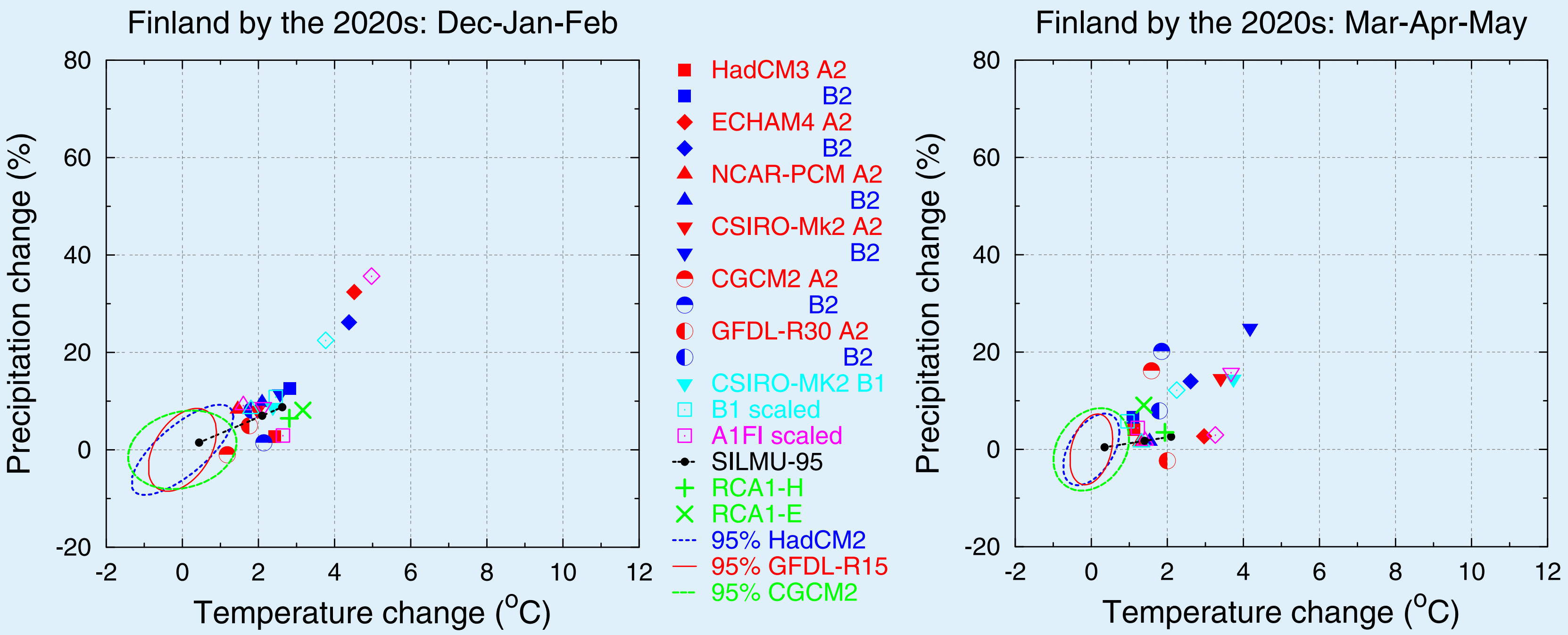
Source: CIESIN (2002)

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



Source: CIESIN (2002)

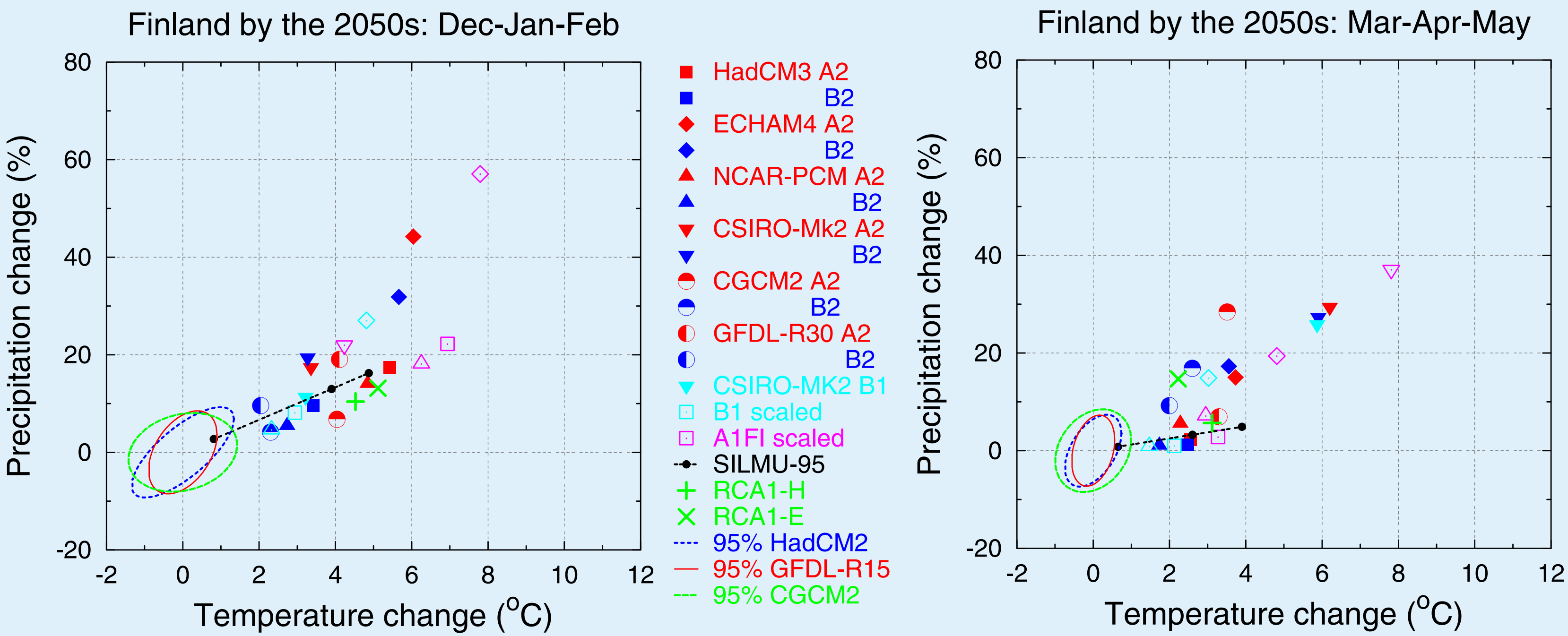
Projected temperature and precipitation change in Finland by the 2020s relative to 1961-1990: winter and spring



Jylhä et al., 2004

SYKE

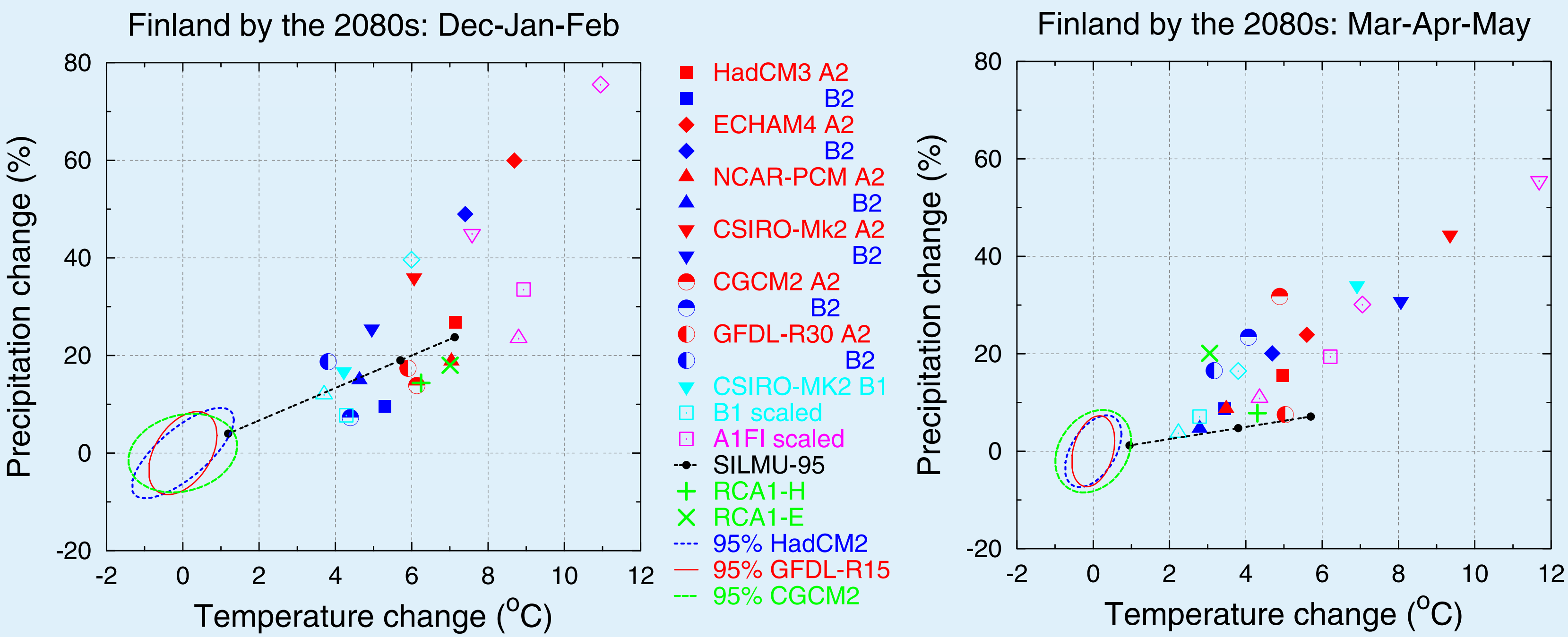
Projected temperature and precipitation change in Finland by the 2050s relative to 1961-1990: winter and spring



Jylhä et al., 2004

SYKE

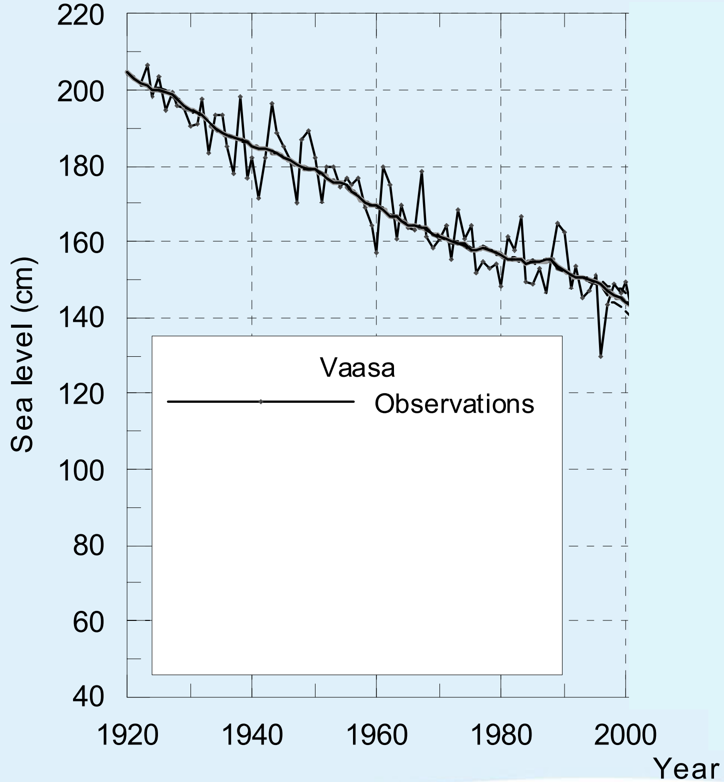
Projected temperature and precipitation change in Finland by the 2080s relative to 1961-1990: winter and spring



Jylhä et al., 2004

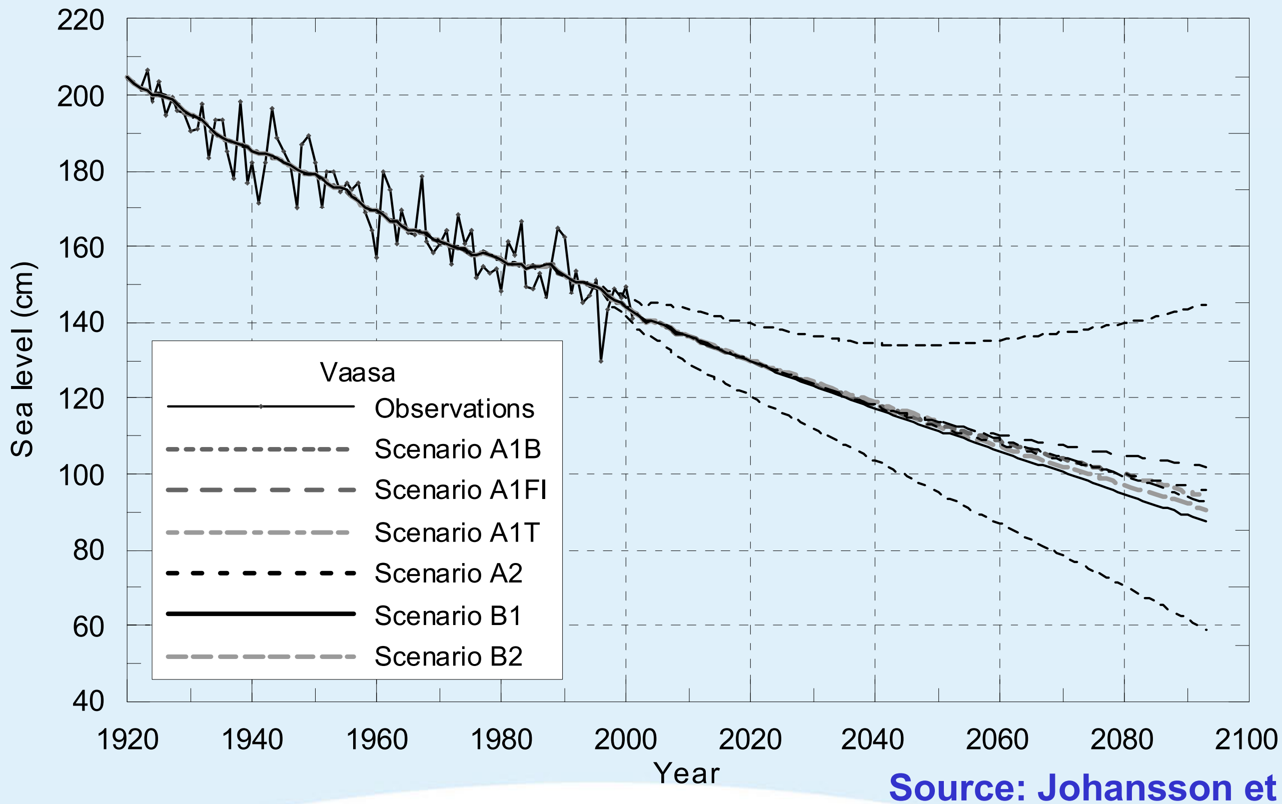
S Y K E

Mean sea level at Vaasa, C. Finland, 1920-2000
Observed: annual and 15-yr running means



Source: Johansson et al., 2004

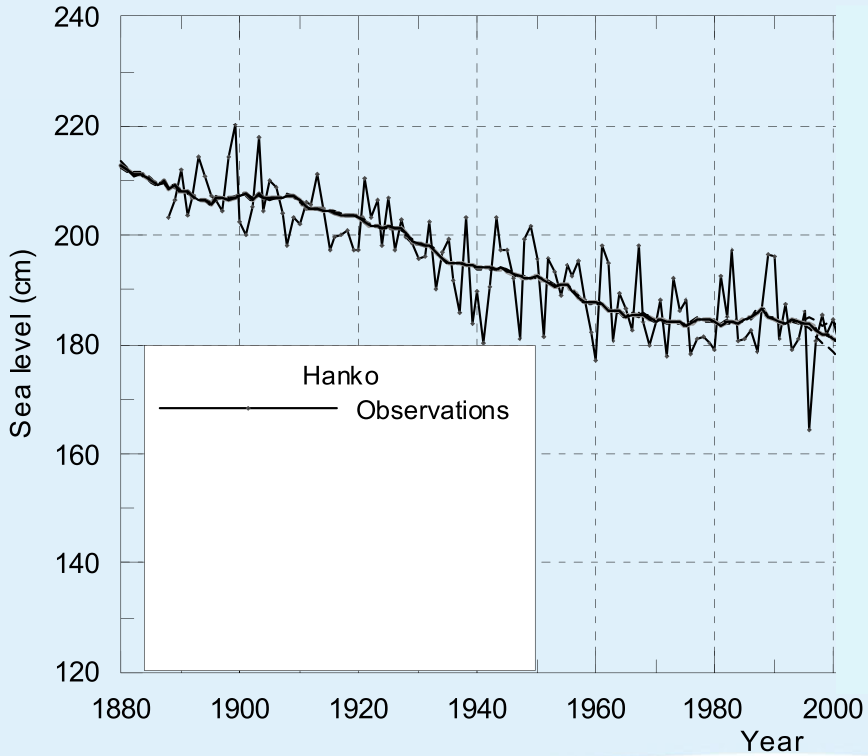
Mean sea level at Vaasa, C. Finland, 1920-2100
Observed: annual and 15-yr running means
Projected: SRES scenarios and uncertainty bounds



Source: Johansson et al., 2004

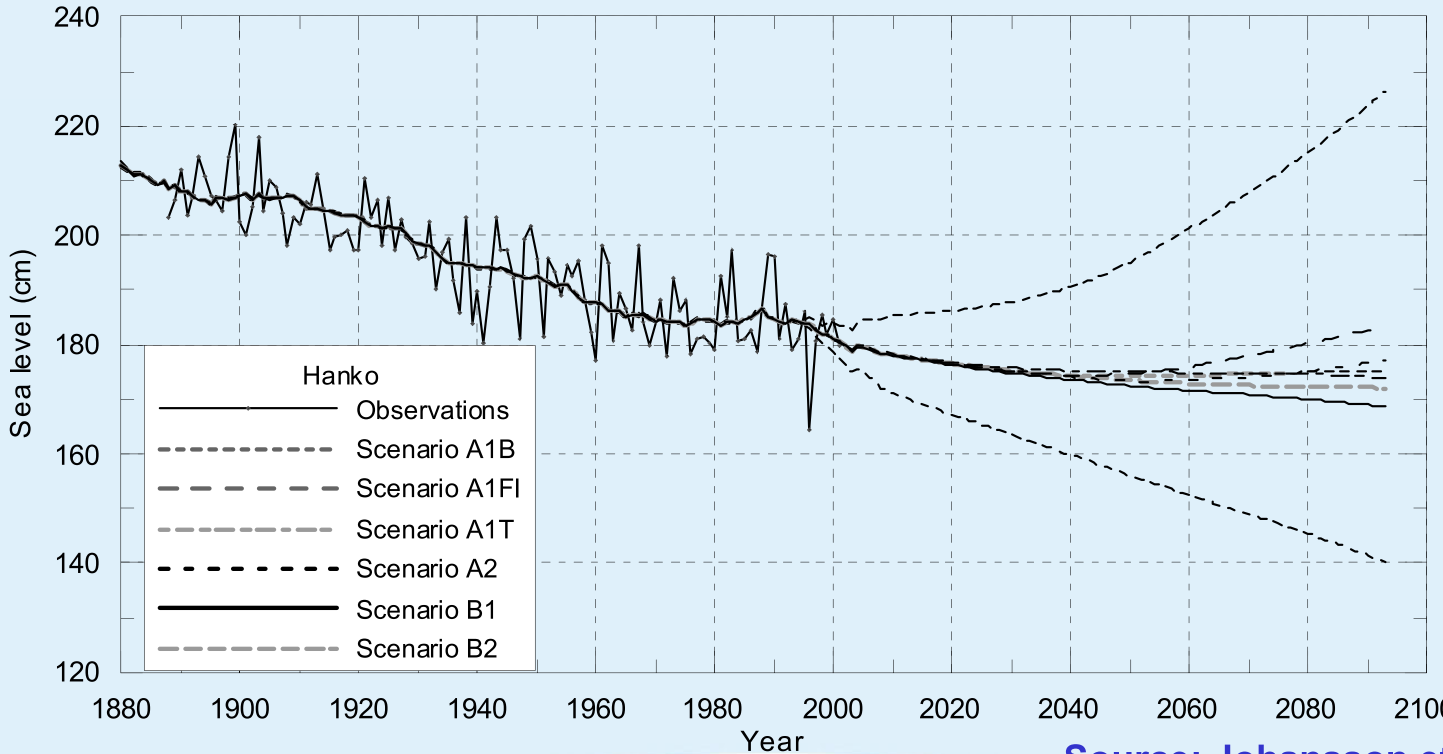
S Y K E

Mean sea level at Hanko, S. Finland, 1880-2000
Observed: annual and 15-yr running means



Source: Johansson et al., 2004

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



Source: Johansson et al., 2004

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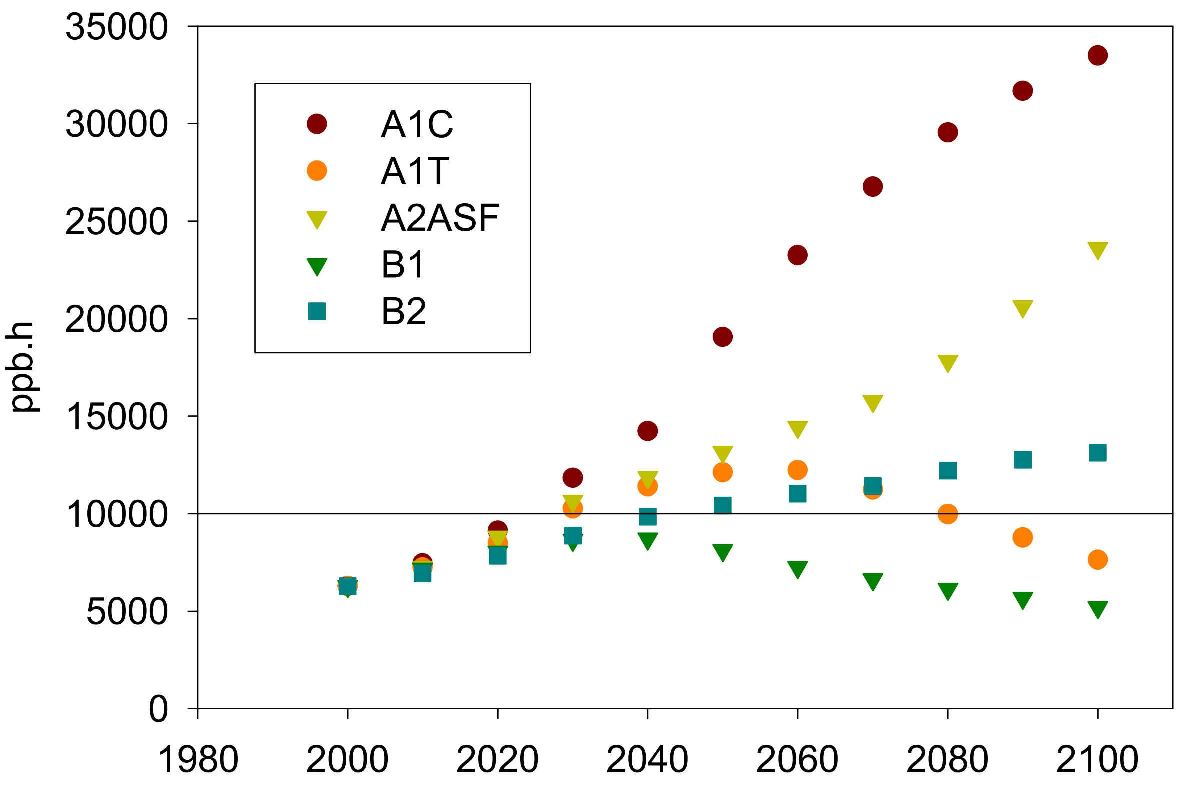
Ozone exposure of forests at Ähtäri (AOT40 forest April-September)

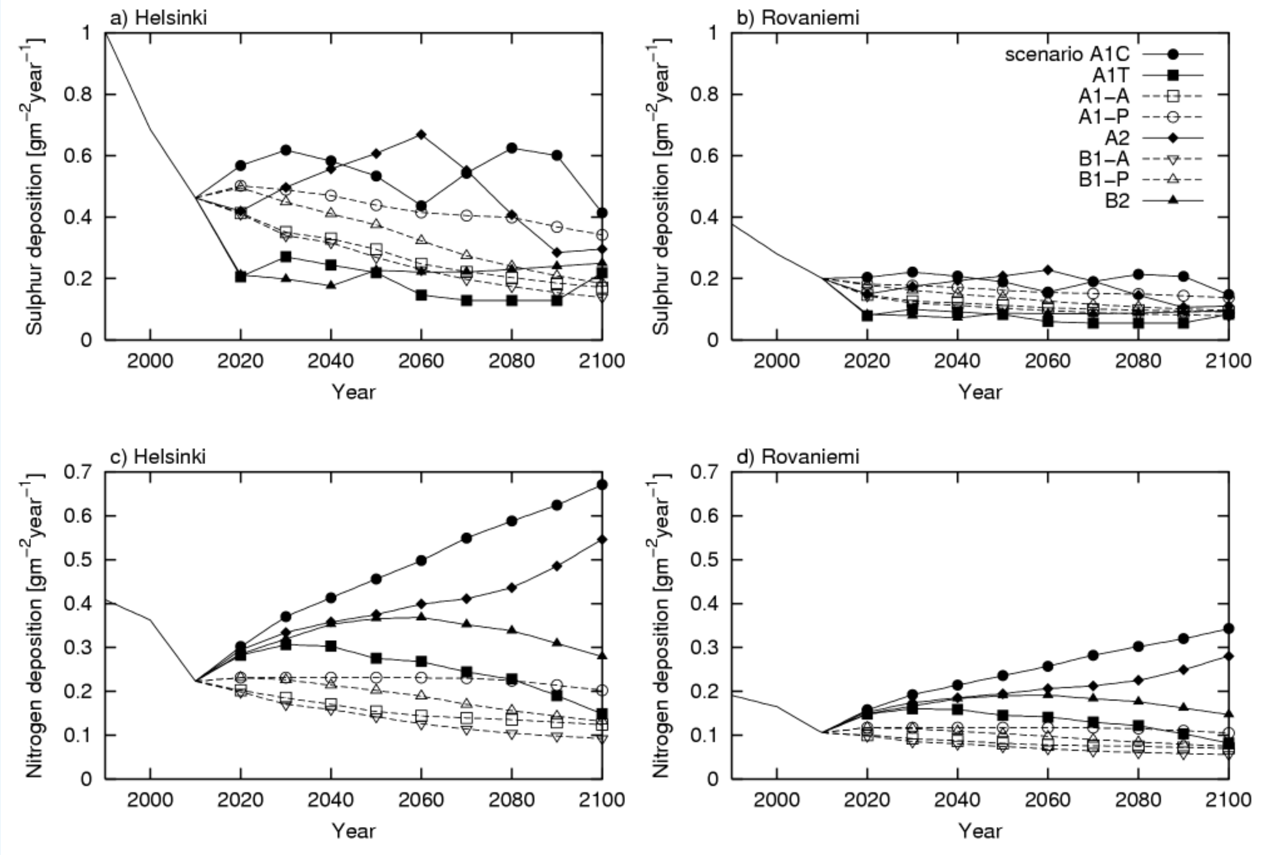


Laurila et al., 2004

Deposition plots for south and north Finland

Sulphur

Nitrogen



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FINSKEN 2020s | A1FI | A2 | B1 | B2

FINSKEN 2050s | A1FI | A2 | B1 | B2

FINSKEN 2080s		A1FI	A2	B1	B2
Population change (%) Present (2000): 5.2 million		–3.4	+11.5	–3.4	–0.9
Gross Domestic Product change (%) Present (2000): 170 billion US1990$		+370	+253	+228	+139
CO_2 concentration (ppm) Present (2000): 367 ppm		821	718	535	567
Mean annual temperature change (°C) Baseline (1961-1990)		5.6 – 7.4	4.4 – 5.9	2.4 – 4.4	3.0 – 5.0
Annual precipitation change (%) Baseline: 1961-1990		14 – 37	8 – 29	8 – 23	6 – 28
Sea level change (cm) Relative to 2000	**(S. Finland)**	+1	–3	–10	–8
Ozone exposure (ppb.h) 1996-2000: 2100 ppb.h	**(N. Finland)**	-	-	-	-
1996-2000: 4600 ppb.h	**(S. Finland)**	-	-	-	-
S deposition ($gm^{-2}a^{-1}$) 1998: 0.30 $gm^{-2}a^{-1}$	**(N. Finland)**	0.21	0.13	0.10	0.09
1998: 0.75 $gm^{-2}a^{-1}$	**(S. Finland)**	0.61	0.35	0.22	0.24
N deposition ($gm^{-2}a^{-1}$) 1998: 0.17 $gm^{-2}a^{-1}$	**(N. Finland)**	0.31	0.24	0.08	0.17
1998: 0.37 $gm^{-2}a^{-1}$	**(S. Finland)**	0.60	0.46	0.15	0.32

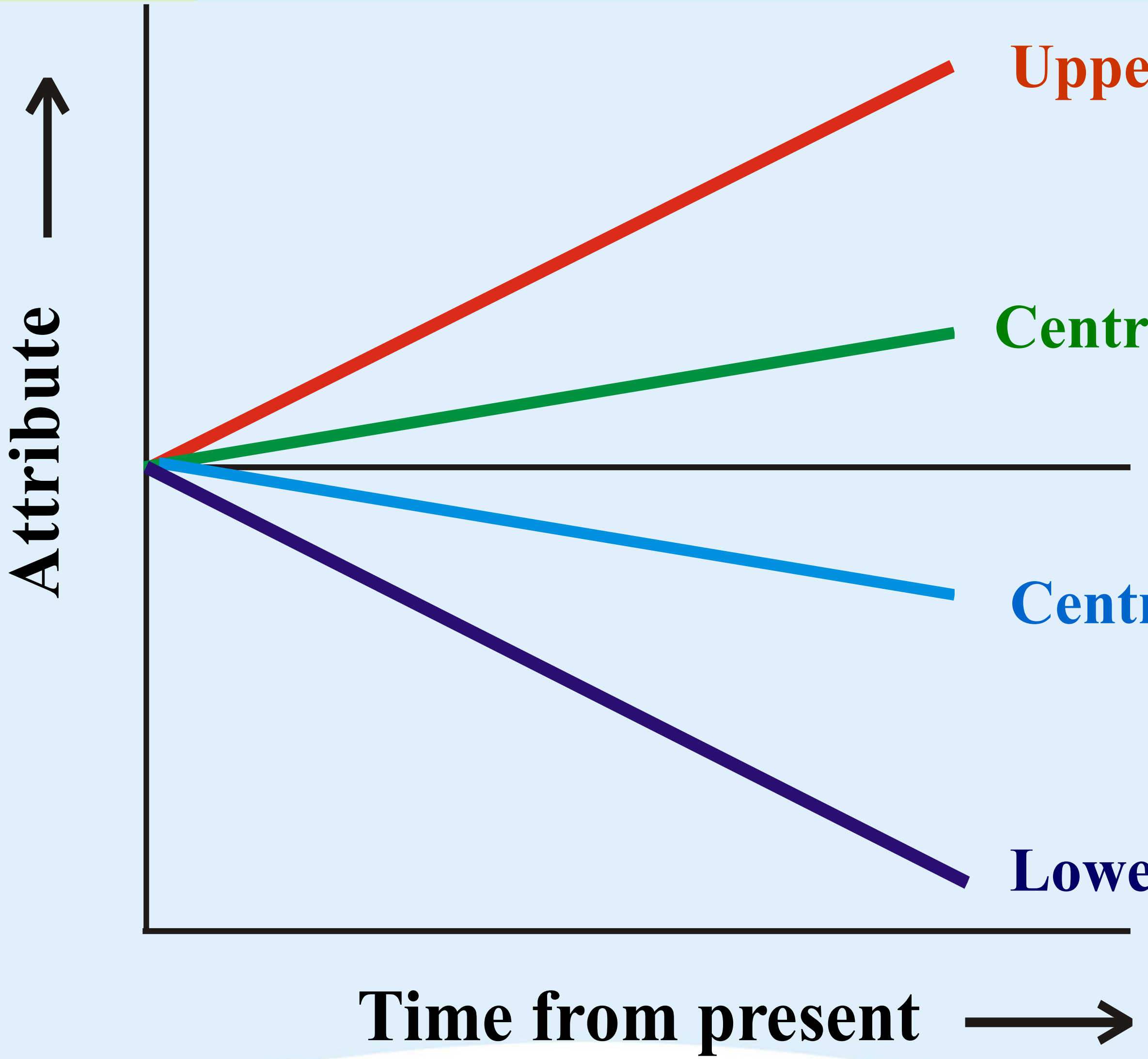
Carter et al., 2004

SYKE

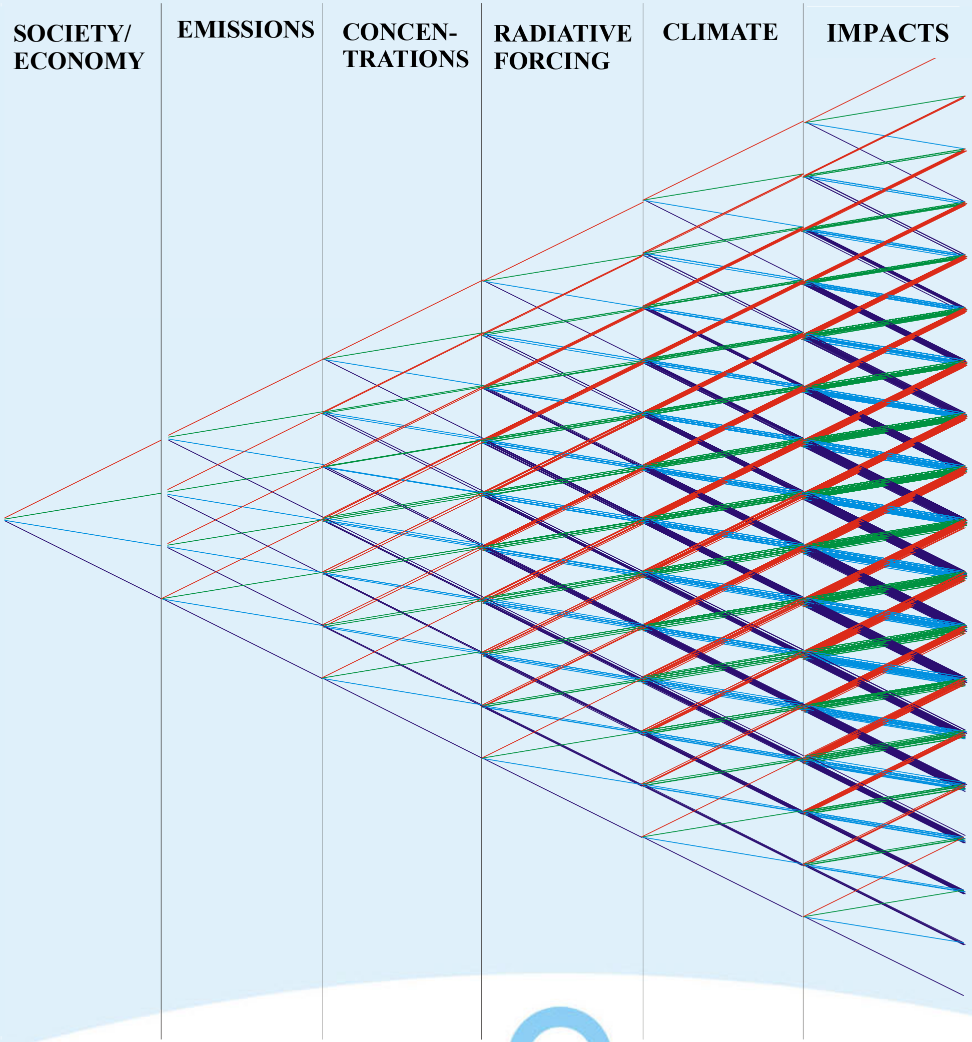
Regional scenarios: some issues

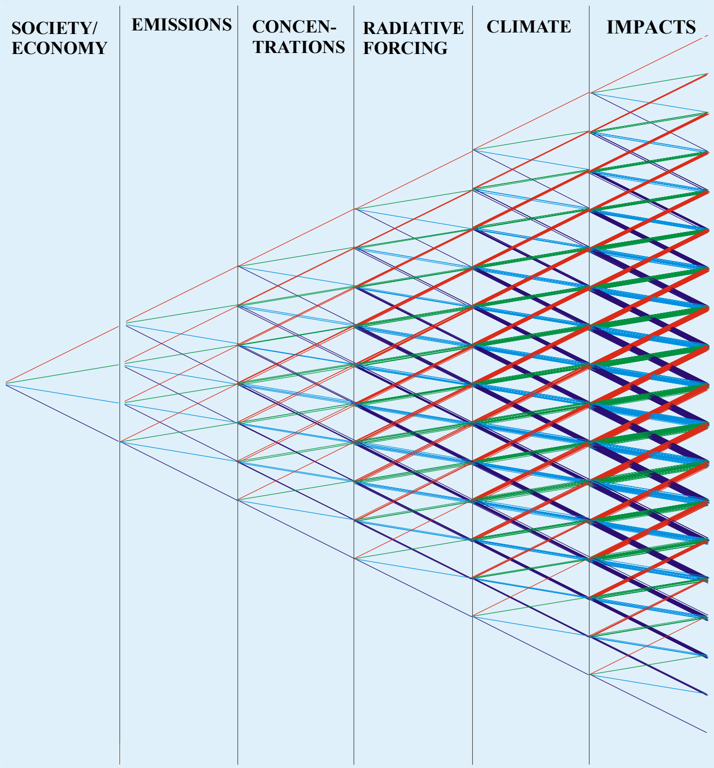
- "Top-down" or "bottom-up"?
- Relationships to global scenarios (downscaling)
- Storylines, their interpretation and quantification
- Scenario linkages, consistency and integration
- Regional relevance

Dealing with uncertainties


Upper
Central 1
Central 2
Lower
Attribute
Time from present

Propagation of uncertainties



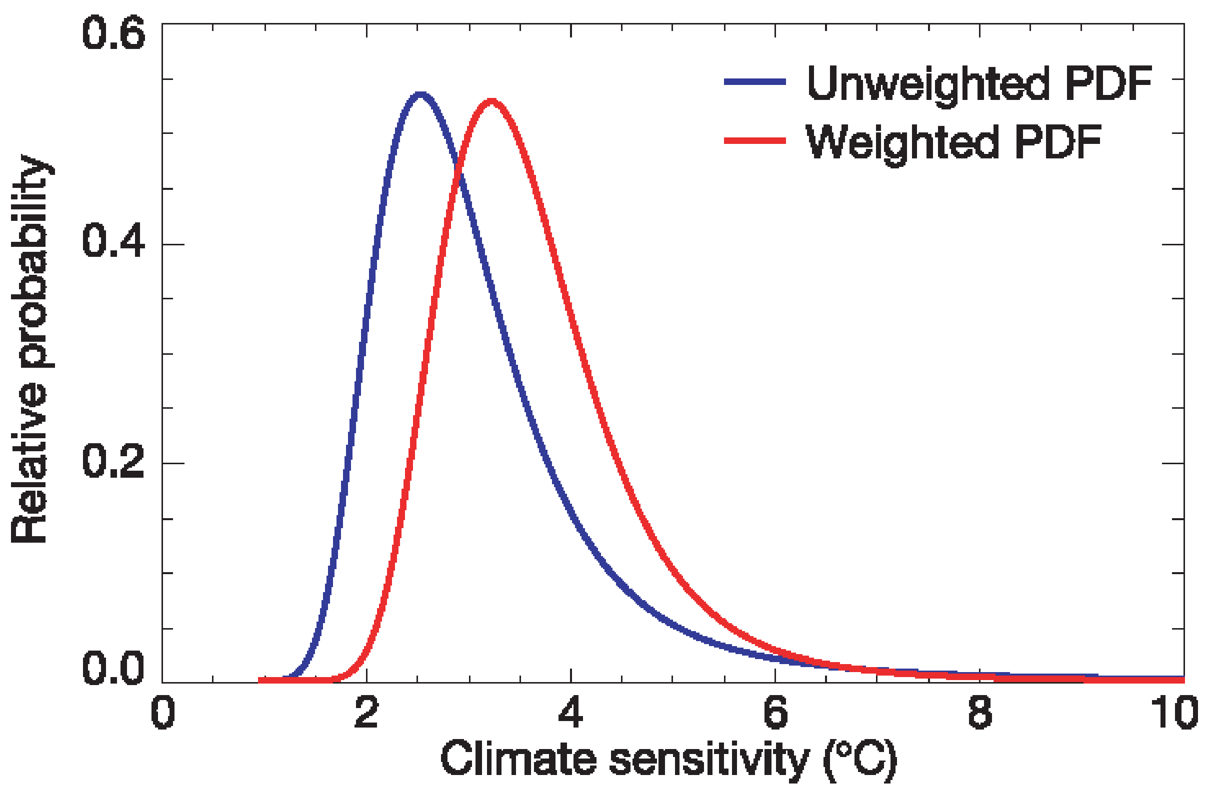


The "uncertainty cascade" (New and Hulme, 2000)

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

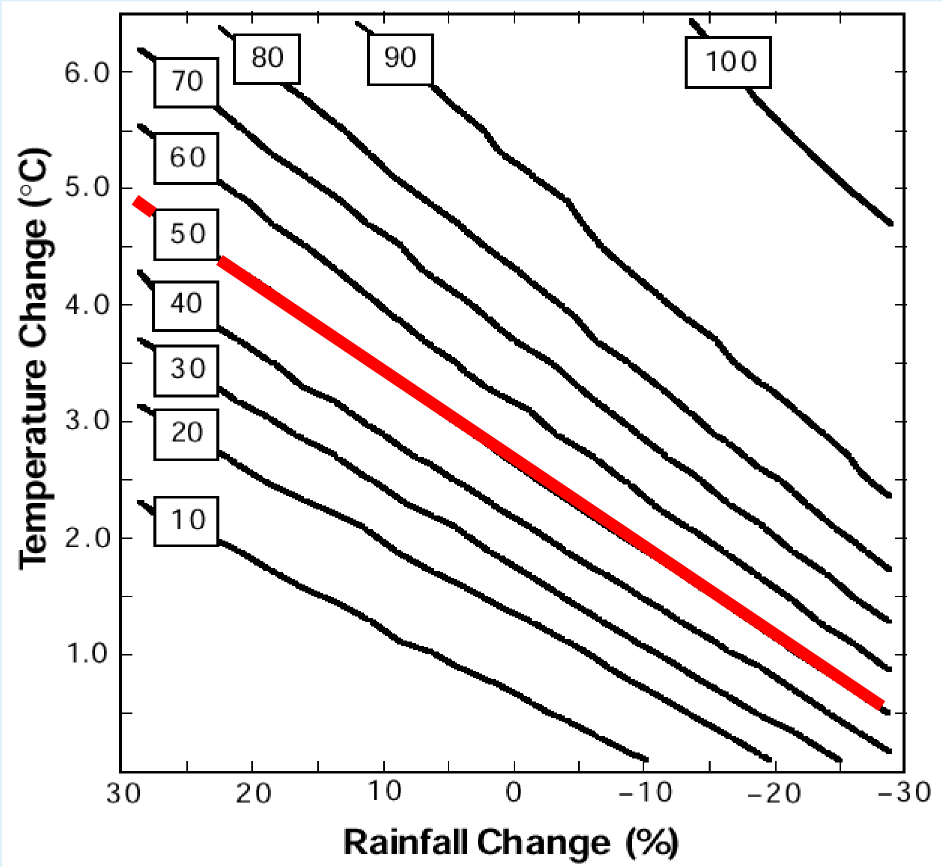
Can we express our projections of the future probabilistically?

Probability distributions of climate sensitivity (weighted PDFs based on a model reliability index)



Source: Murphy et al., 2004

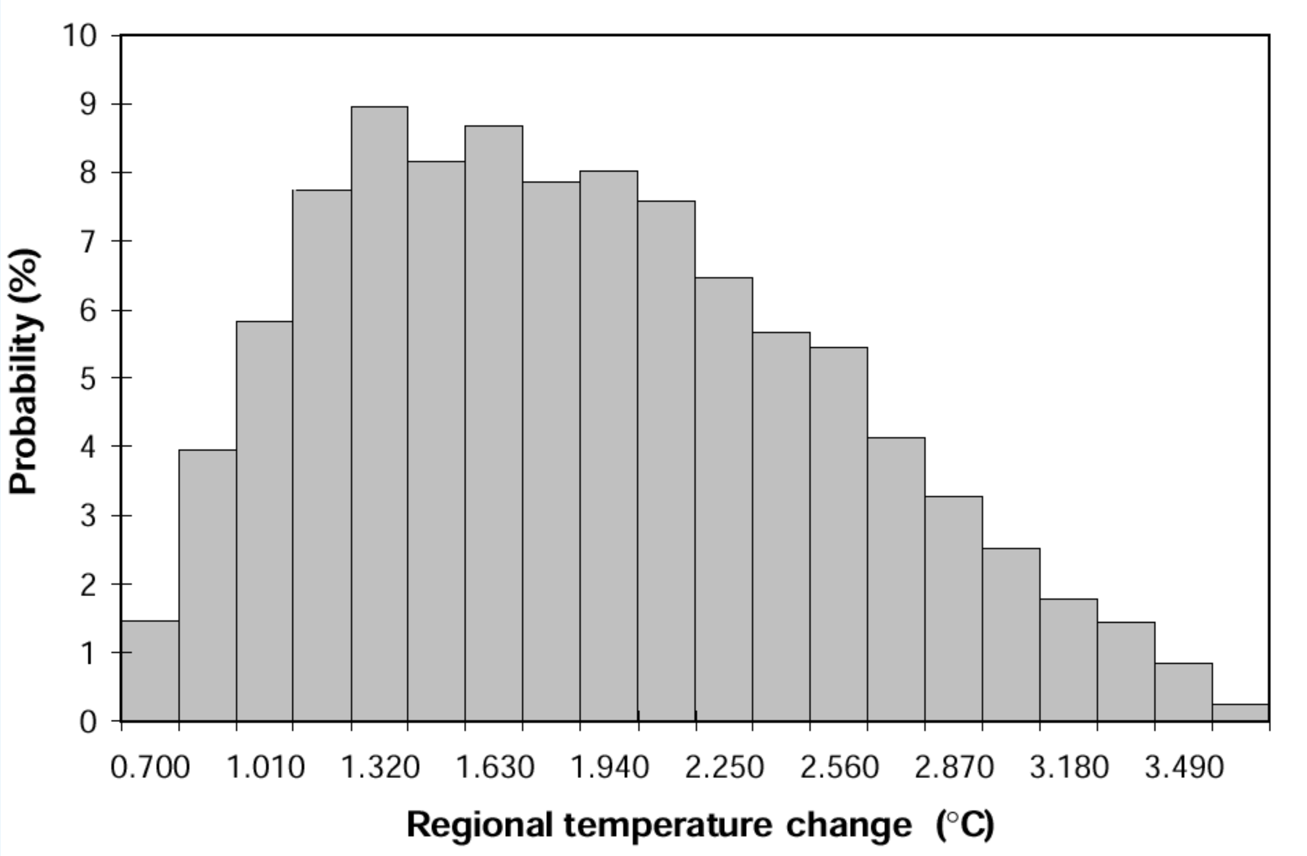
Sensitivity matrix showing probability of exceeding threshold irrigation level for pasture in northern Victoria



Jones, 2000

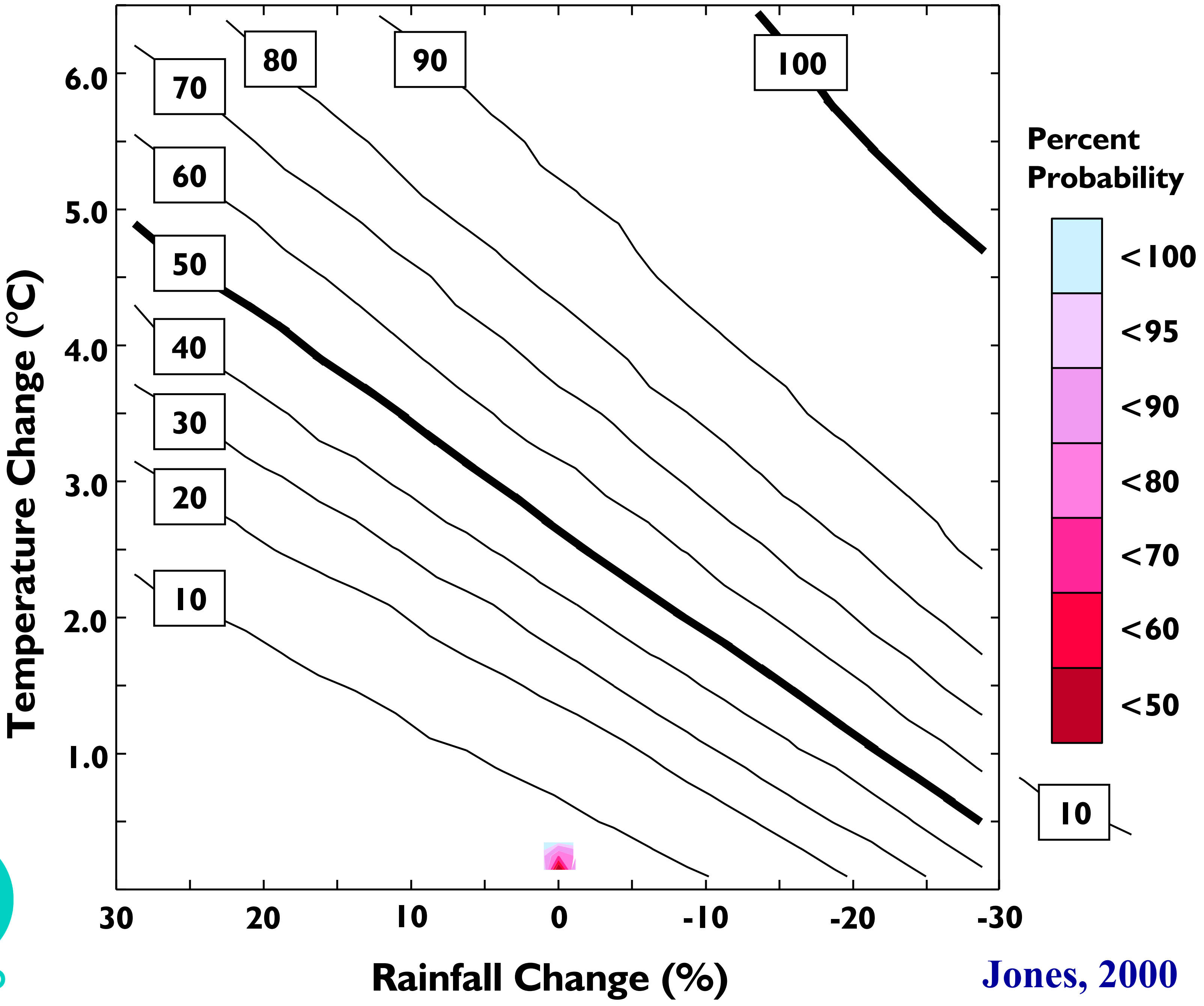
SYKE

Probability distribution of expected regional warming by 2070 in inland Australia based on Monte Carlo sampling of 5 GCM outputs



Source: Jones, 2000

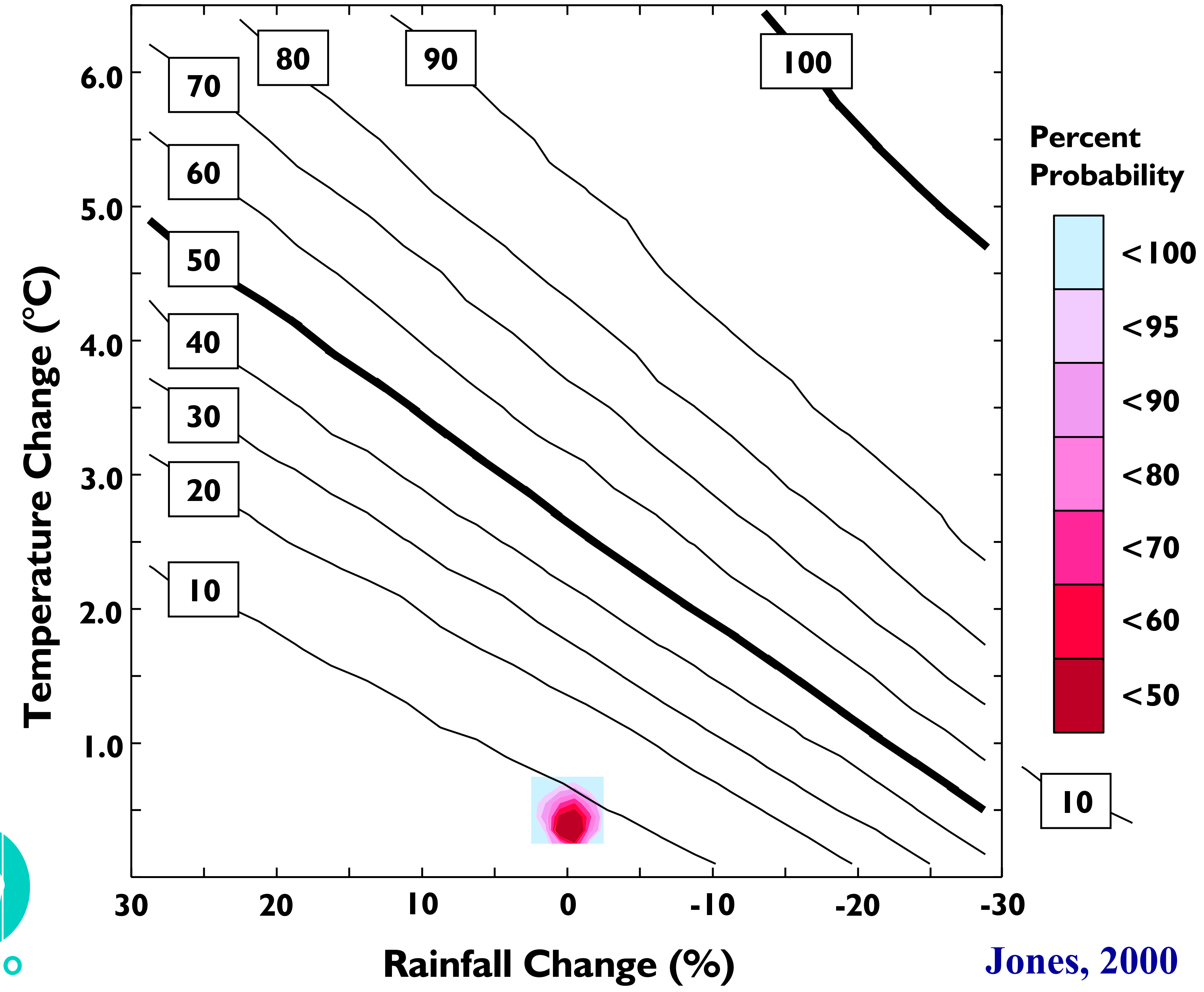
2000



CSIRO

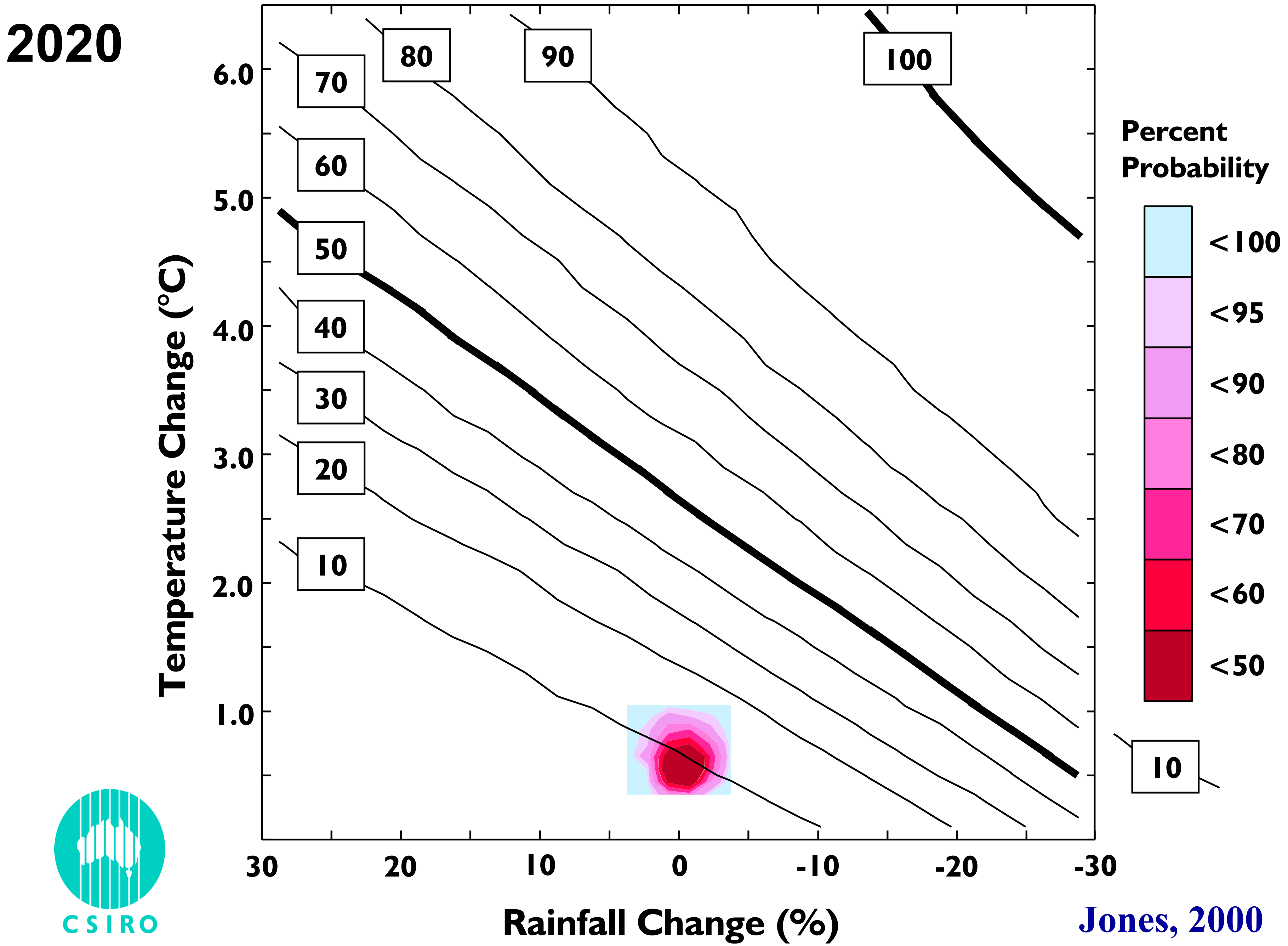
Jones, 2000

2010

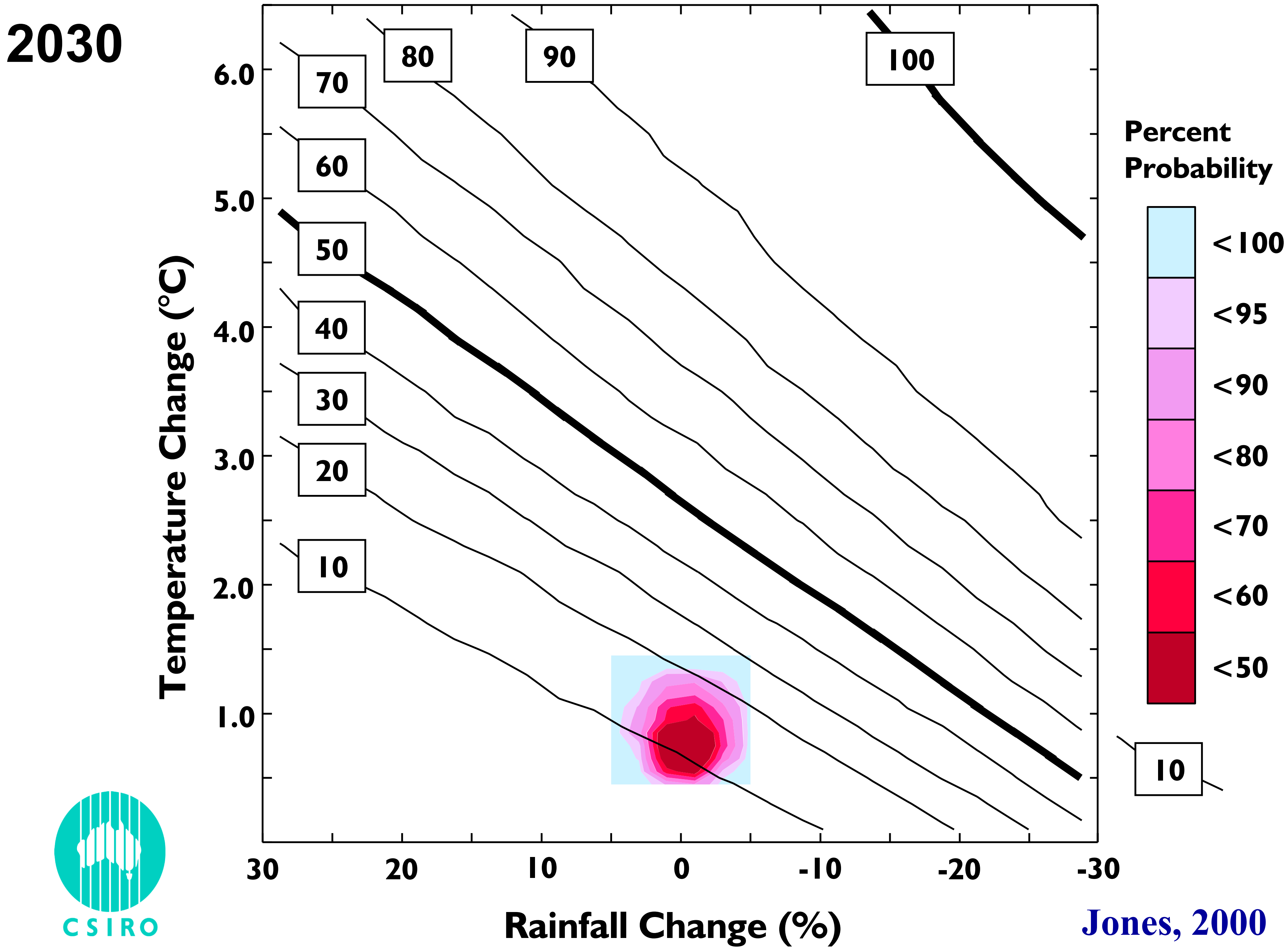


CSIRO

Jones, 2000

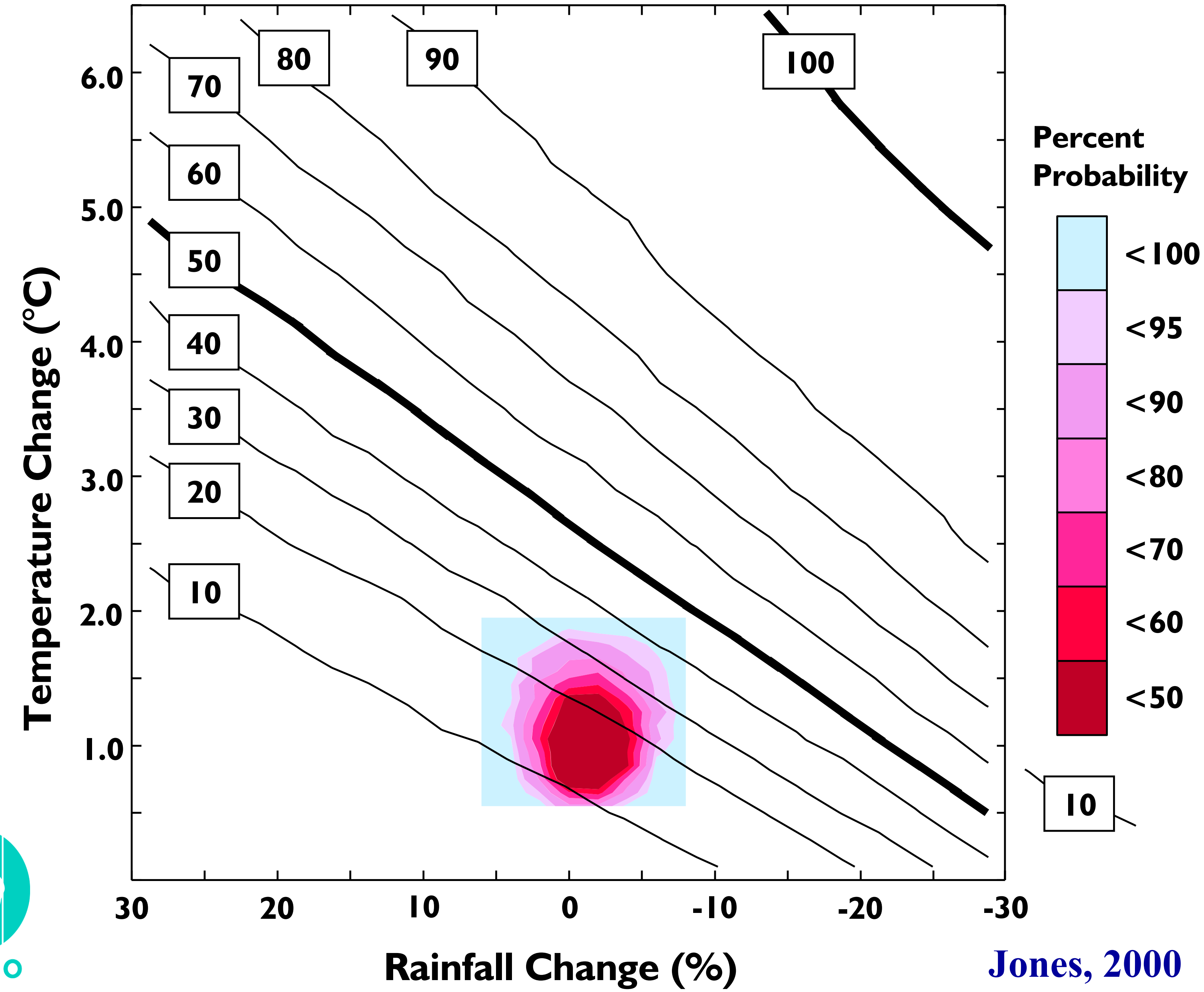


2020
Percent Probability
<100
<95
<90
<80
<70
<60
<50
70
80
90
100
60
50
40
30
20
10
10
6.0
5.0
4.0
3.0
2.0
1.0
Temperature Change (°C)
30
20
10
0
-10
-20
-30
Rainfall Change (%)
CSIRO
Jones, 2000



2030
Temperature Change (°C)
6.0
5.0
4.0
3.0
2.0
1.0
70
80
90
100
60
50
40
30
20
10
30
20
10
0
-10
-20
-30
Rainfall Change (%)
Percent Probability
<100
<95
<90
<80
<70
<60
<50
10
CSIRO
Jones, 2000

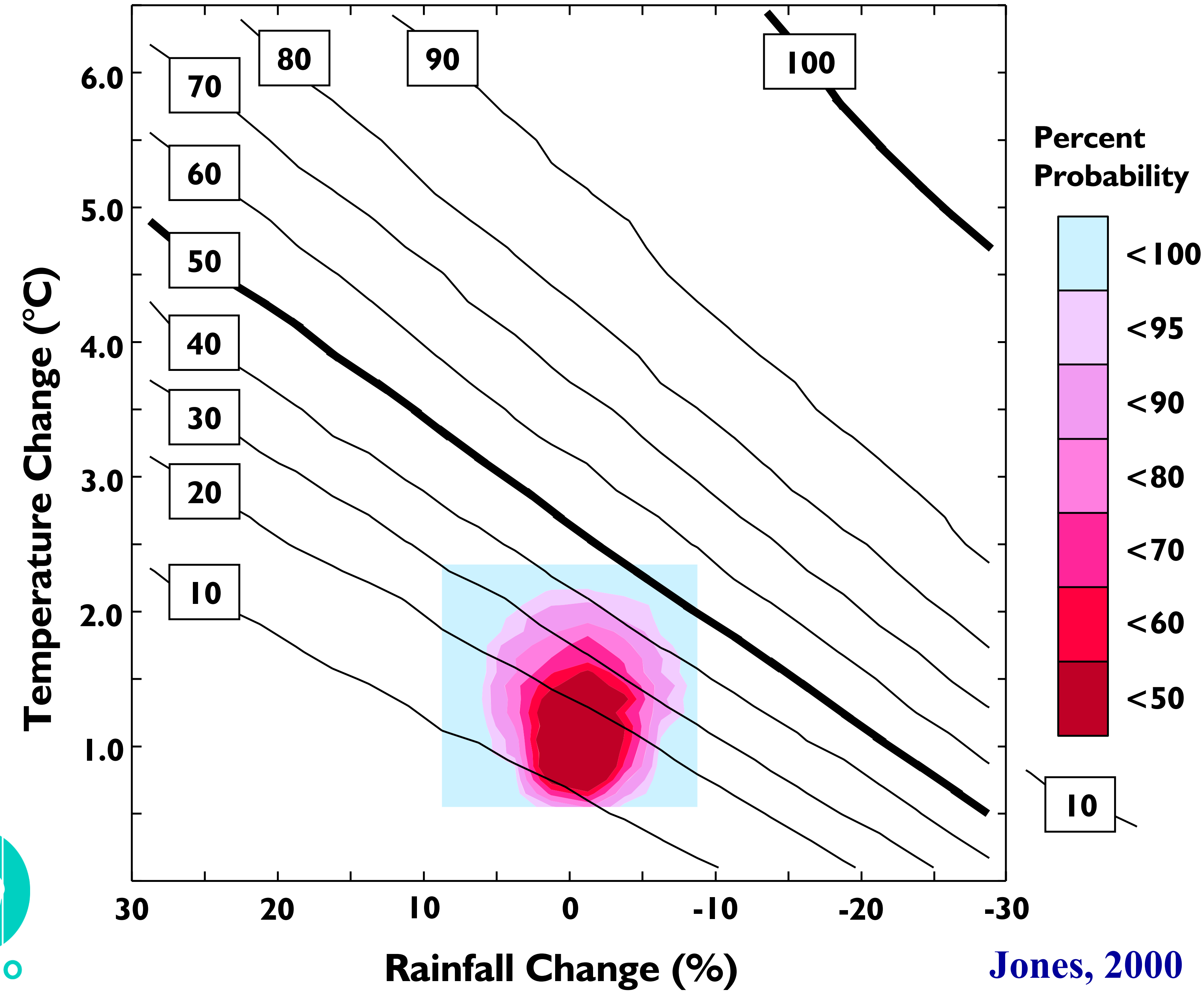
2040



CSIRO

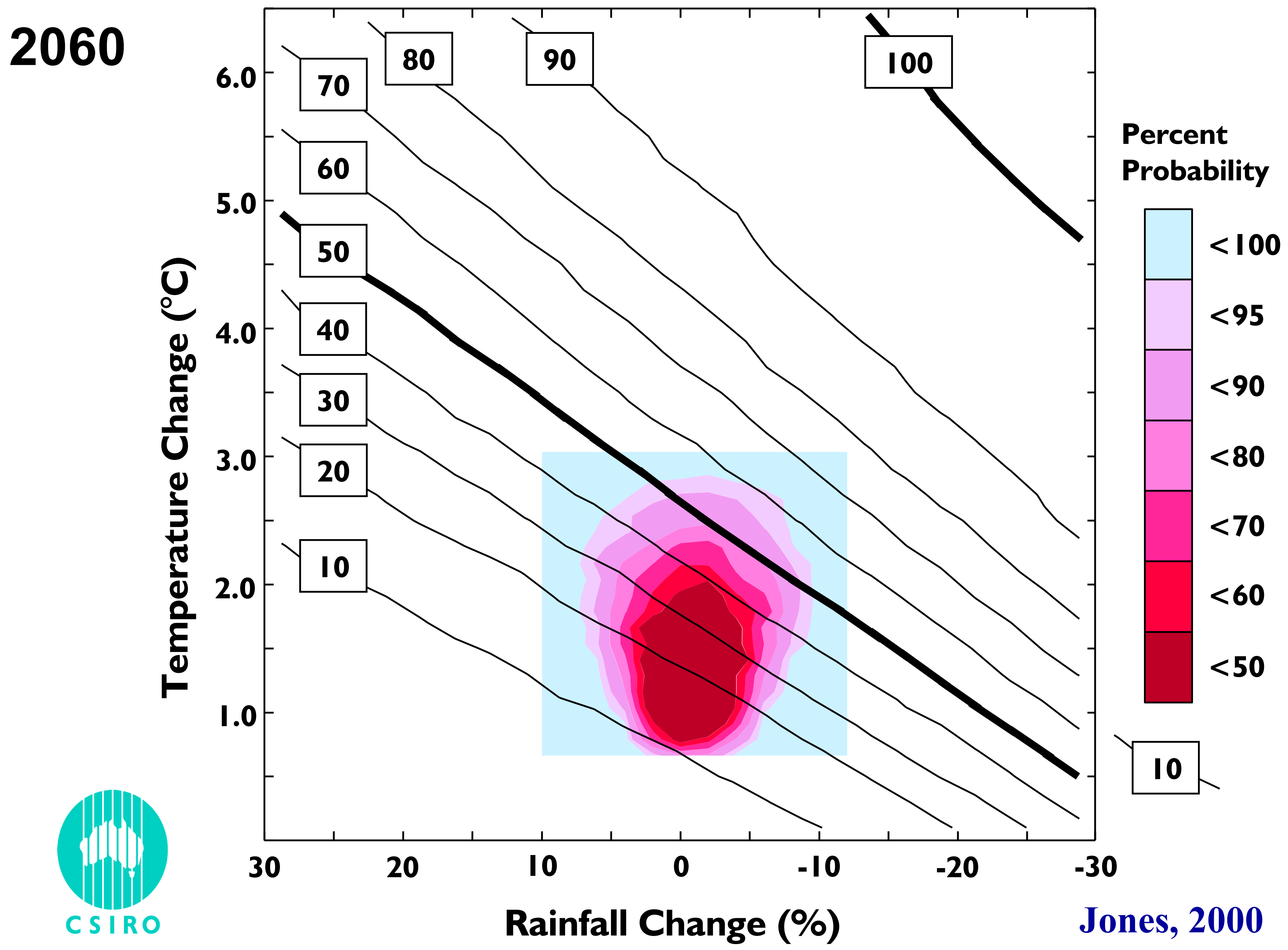
Jones, 2000

2050

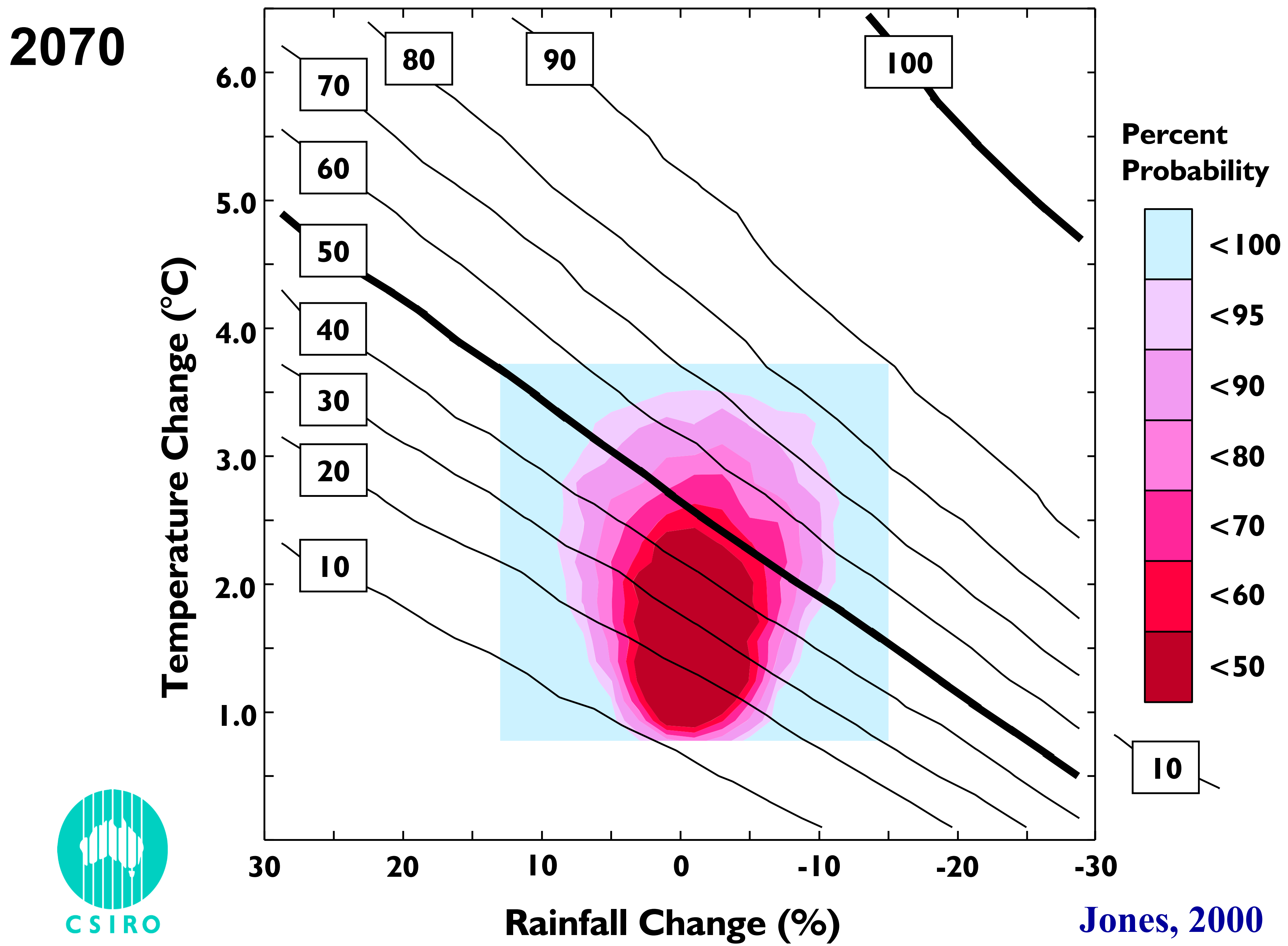


Jones, 2000

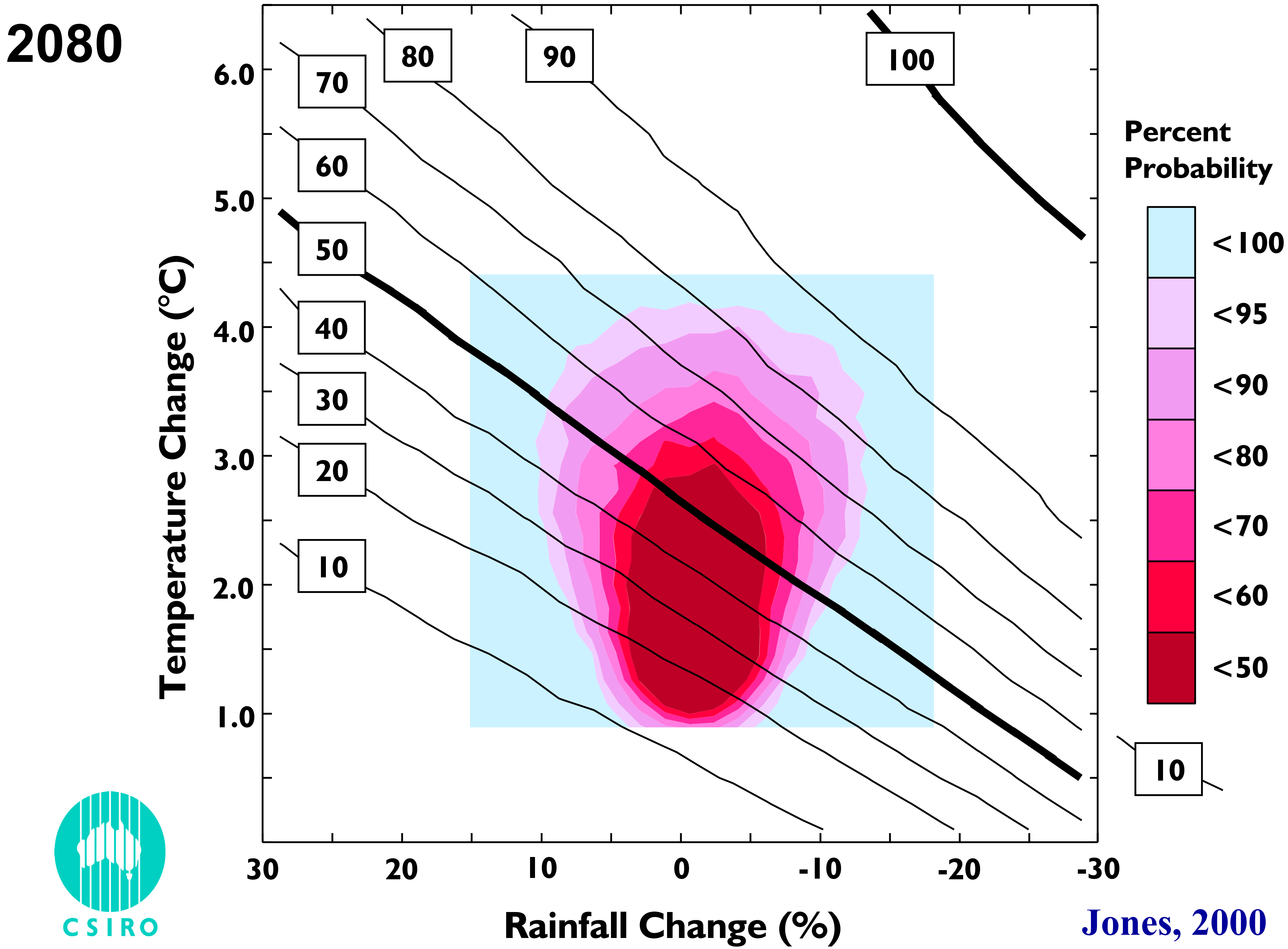
CSIRO



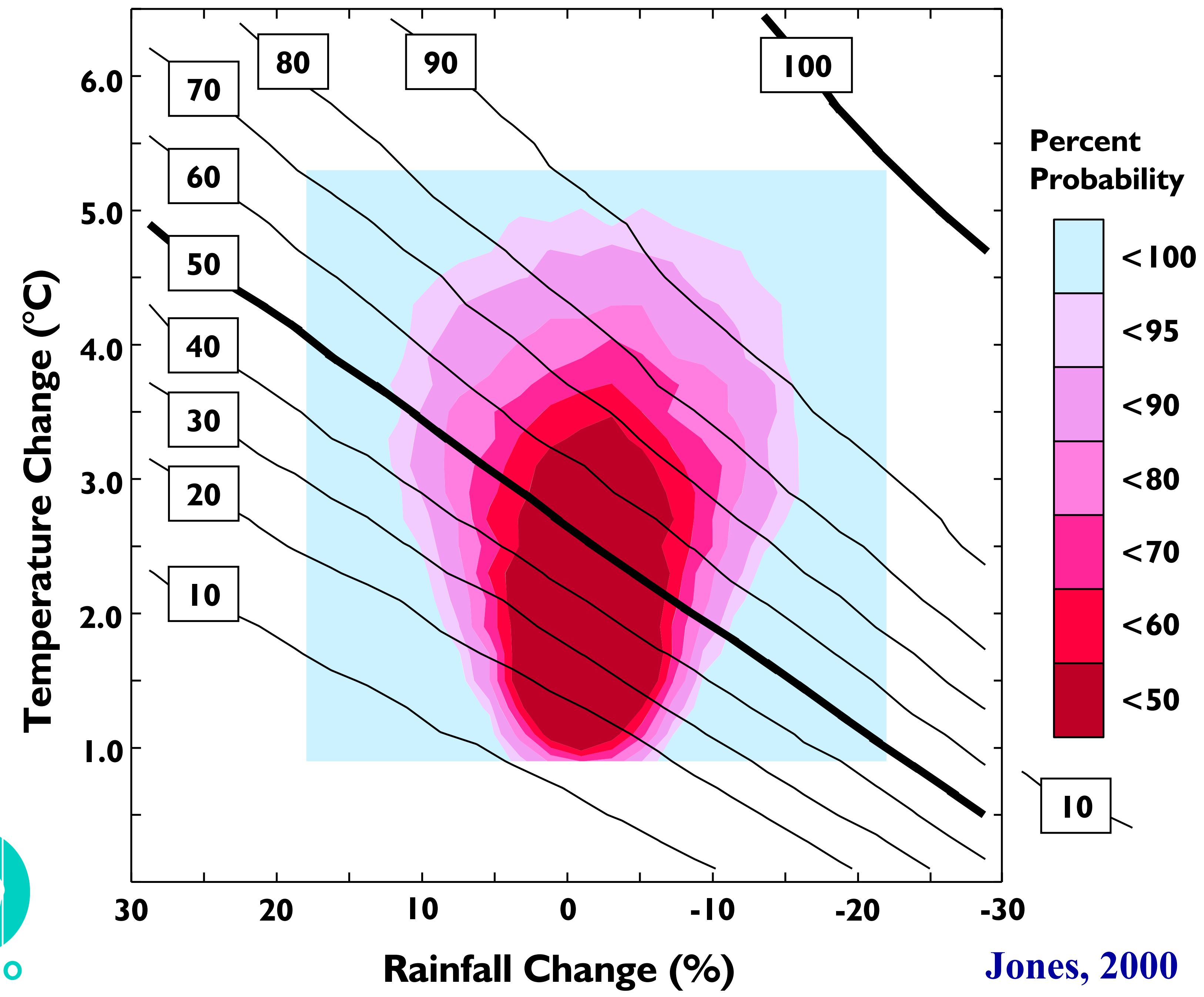
2060
6.0
5.0
4.0
3.0
2.0
1.0
Temperature Change (°C)
70
80
90
100
60
50
40
30
20
10
10
30
20
10
0
-10
-20
-30
Rainfall Change (%)
Percent Probability
<100
<95
<90
<80
<70
<60
<50
CSIRO
Jones, 2000



2070
Percent Probability
<100
<95
<90
<80
<70
<60
<50
Temperature Change (°C)
6.0
5.0
4.0
3.0
2.0
1.0
70
80
90
100
60
50
40
30
20
10
10
30
20
10
0
-10
-20
-30
Rainfall Change (%)
CSIRO
Jones, 2000


2080
6.0
5.0
4.0
3.0
2.0
1.0
Temperature Change (°C)
70
80
90
100
60
50
40
30
20
10
10
30
20
10
0
-10
-20
-30
Rainfall Change (%)
Percent Probability
<100
<95
<90
<80
<70
<60
<50
CSIRO
Jones, 2000

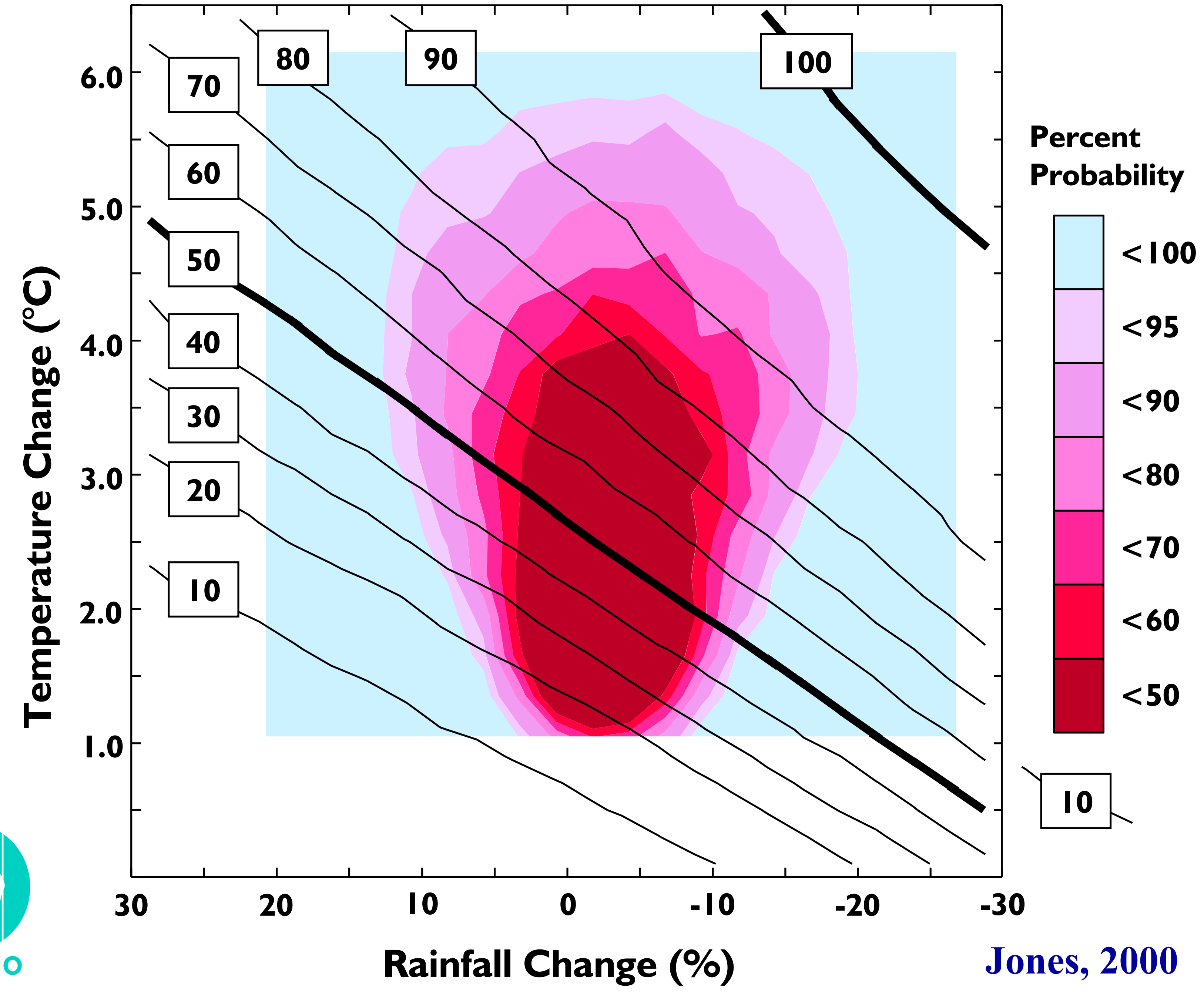
2090



CSIRO

Jones, 2000

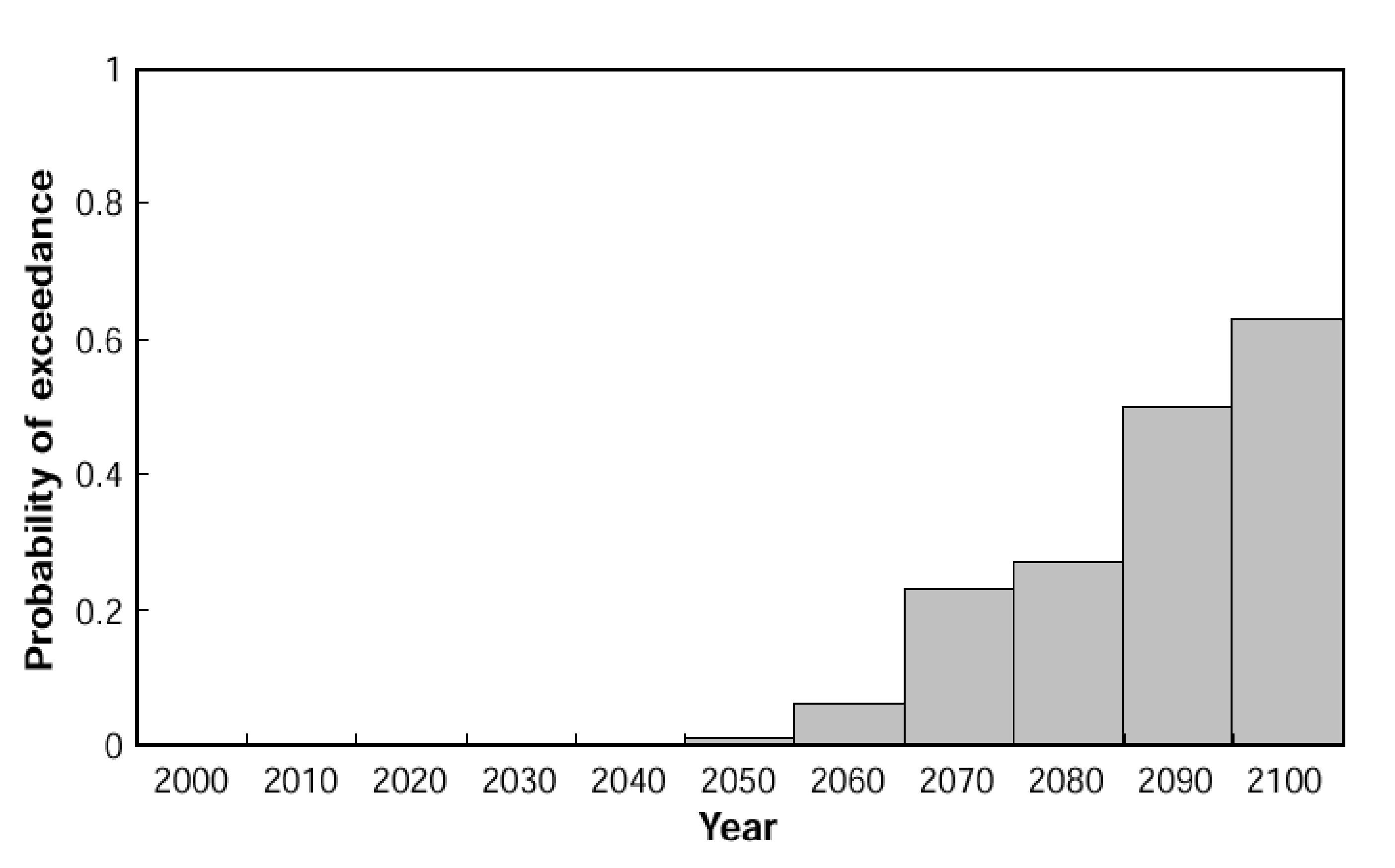
2100



CSIRO

Jones, 2000

Probability of exceeding irrigation threshold in > 50% years



Source: Jones, 2000

Probabilistic representations

- **Numerous recent examples for projected climate, however …**
  - **Usually conditional on the driving emissions scenario**
  - **Many alternative methods; all have subjective elements**
- **Recent examples for population projections**
- **Alternative views for socio-economic futures**
- **Useful for expressing impacts in terms of risk, but note ….**

- **No longer scenarios!**

ENSEMBLES

(Ensemble-based Predictions of Climate Changes and their Impacts)

FP6 Integrated Project began 1 Sep 2004

Some conclusions

- Scenarios can be used prescriptively or diagnostically
- 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 projections in terms of probability and risk

Selected reading

Alcamo J. 2001. Scenarios as tools for international environmental assessment. *Environmental issue report No 24*, European Environment Agency, Luxembourg, 2001, 31 pp. http://reports.eea.eu.int/environmental_issue_report_2001_24/en/issue_report_no_24.pdf

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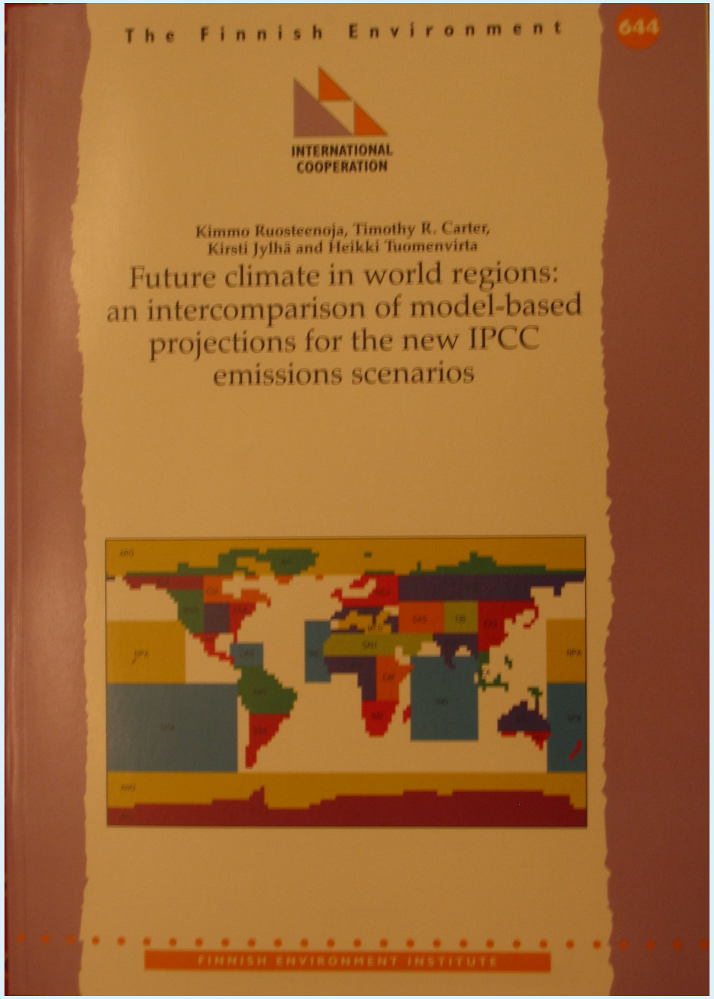
Raskin, P., Banuri, T., Gallopin, G., Gutman, P., Hammond, A., Kates, R. and Swart, R. 2002. *Great Transition: The Promise and Lure of the Times Ahead*. SEI PoleStar Series Report no. 10, Global Scenario Group, Stockholm Environment Institute, Stockholm, 99 pp. http://www.sei.se/pubs/dpubs.html




BOREAL ENVIRONMENT RESEARCH

VOLUME 9 No. 2 2004

An International Interdisciplinary Journal
http://www.borenv.net/

FINSKEN: Global change scenarios for Finland in the 21st century

Contents

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Final thought

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

Bertrand Russell (philosopher)