Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Climate Change Uncertainty and Risk: from Probabilistic Forecasts to Economics of Climate Adaptation

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Schedule

29.02.16 (1) Logistics, Introduction to probability, uncertainty and risk management, introduction of toy model (RK, DB)

07.03.16 (2) Predictability of weather and climate, seasonal prediction, seamless prediction (RK)
Exercise 1 (toy model)

14.03.16 (3) Detection/attribution, forced changes, natural variability, signal/noise, ensembles (RK)
Exercise 2 (toy model)

21.03.16 (4) Probabilistic risk assessment model: from concept to concrete application - and some insurance basics (DB)

28.03.16 Ostermontag (no course)

04.04.16 (5) Model evaluation, multi model ensembles and structural error (RK)

11.04.16 (6) Climate change and impacts, scenarios, use of scenarios, scenario uncertainty vs response/impact uncertainty (RK, DB)
Exercise 3 (toy model), preparation of presentation

18.04.16 (7) Model calibration, Bayesian methods for probabilistic projections (RK)

25.04.16 (8) Presentations of toy model work, discussion (DB, RK)

Schedule

02.05.16 (9) Basics of economic evaluation and economic decision making in the presence of climate risk (DB)
Exercise 4 (introduction to climada)

09.05.16 (10) The cost of adaptation - application of economic decision making to climate adaptation in developing and developed region (DB)
Exercise 5 (impacts)

16.05.16 Pfingstmontag (no course)

23.05.16 (11) Shaping climate-resilient development – valuation of a basket of adaptation options (DB)
Exercises 6 (adaptation measures, preparation of presentation)

30.05.16 (12) Presentations of climada exercise, discussion (DB, RK)

Scenario

Definition: A scenario is a snapshot that describes a possible and plausible future. Scenario analysis is a systematic approach to anticipate a broad range of plausible future outcomes

Scenario analysis is used in general …

- as a risk management tool to assess the potential impact of an event or development to anticipate and understand risks
- as a tool to spot new business opportunities and to discover strategic options
- as foresight in contexts of accelerated change, greater complexity and interdependency
- for evaluation of highly uncertain events that could have a major impact
- to steer mitigation strategies, implementation and monitoring by reviewing and tracking different possible developments

Scenarios

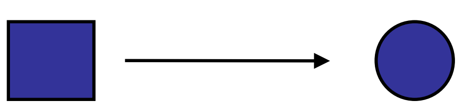
- Types of scenarios: hazard, impact, emissions,…
- 'Realistic scenarios' as opposed to sensitivity tests, physics tests, idealized scenarios
- Scenarios should be plausible, self consistent, broad. They can be used to explore response of system, identify important drivers
- Scenarios do not necessarily have probability attached
- For cost benefit and insurance, a probability is needed. For policy we may not need probabilities.

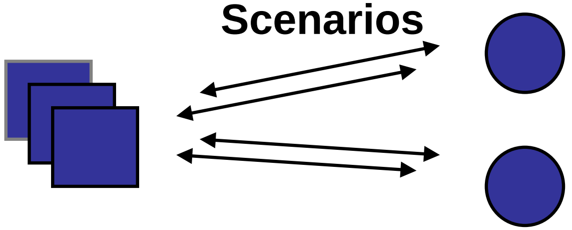
Forecast

- Focuses on certainties, disguises uncertainties
- Conceals risks
- Results in a single-point projections
- Sensitivity analysis
- Quantitative > qualitative

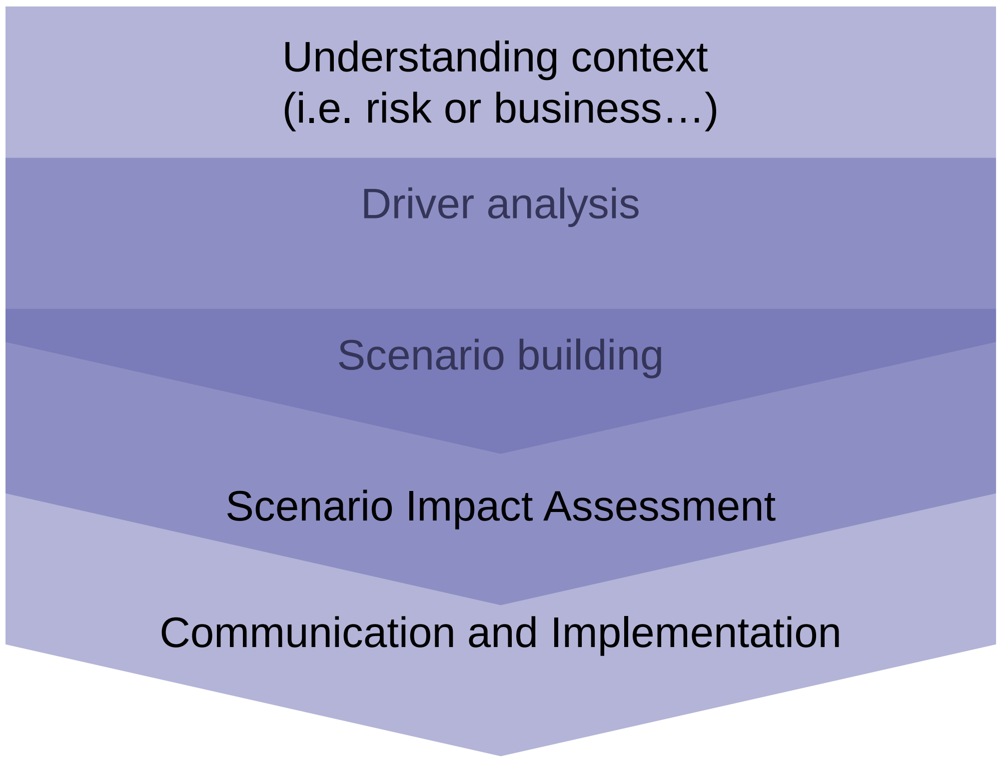
Scenario

- Focuses on uncertainties, legitimizes recognition of uncertainties
- Clarifies risk
- Results in adaptive understanding
- Diversity of interpretations
- Qualitative > quantitative





Scenario building



Scenario

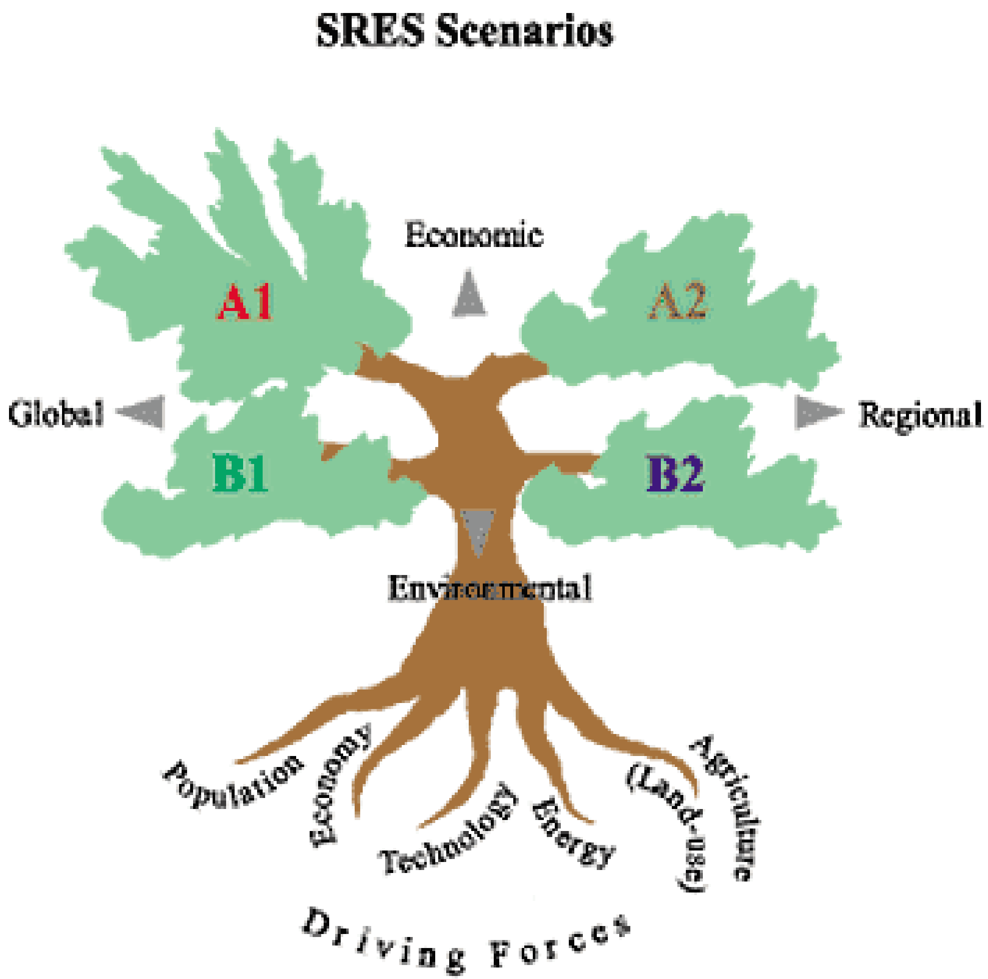
Scenario

Scenario for a nuclear power plant

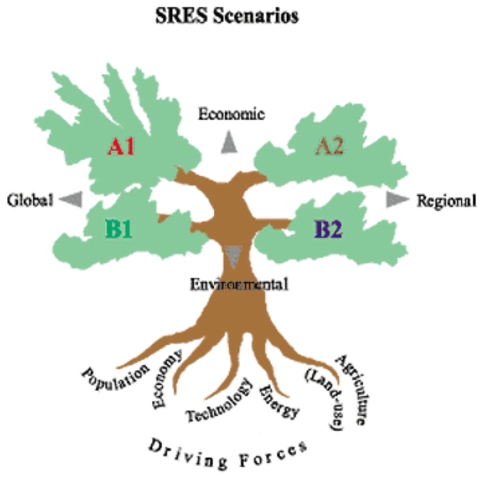
Bei der Standortwahl und den bautechnischen Vorgaben werden dort die erhöhte Erdbebengefahr und die allfällige Bedrohung durch Flutwellen (Tsunamis) eingerechnet. Die Normen werden laufend den zunehmenden Kenntnissen über Erdbeben angepasst und die Werke gegebenenfalls nachgerüstet. Bisher sind weltweit nach Erdbeben noch nie relevante Mengen radioaktiver Stoffe aus einer Kernanlage freigesetzt worden.
http://www.nuklearforum.ch/factsheets.php?id=de-127843742719--f-6_p-4

Hatte man bei den AKW-Betreibern ein solches Szenario, wie es in Japan eingetroffen ist, auf dem Radar?
Zusammen mit den Behörden werden regelmässig Notfallszenarien durchgespielt, und da werden auch Situationen simuliert, die über die zu erwartenden Naturereignisse hinausgehen.
Kurt Rohrbach, BKW
http://www.tagesanzeiger.ch/schweiz/standard/Muehleberg-und-Fukushima-sind-nur-bedingt-vergleichbar/story/31826773

IPCC SRES Scenarios

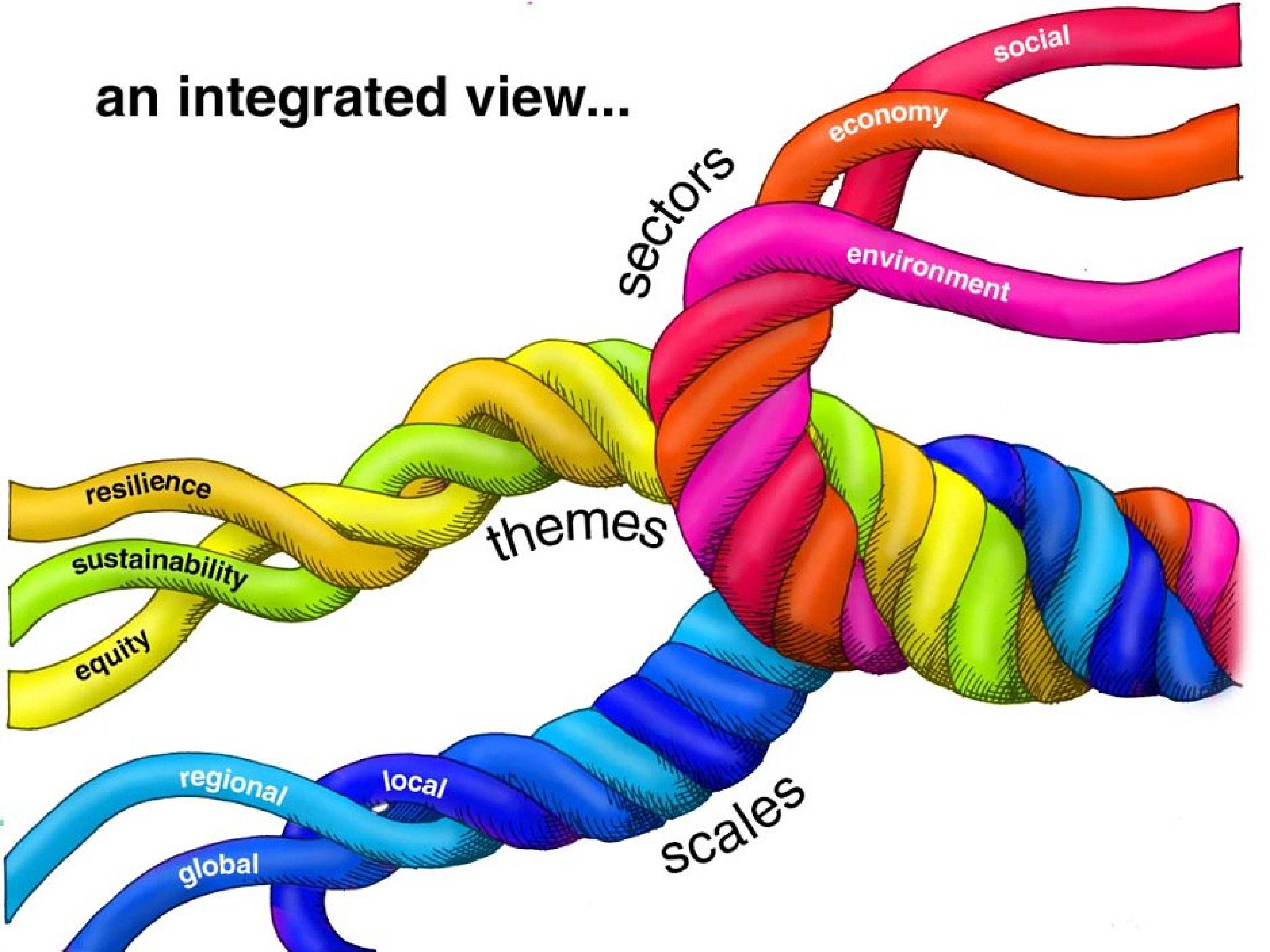


IPCC SRES Scenarios



- The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. []
- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. []
- The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, [] 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.
- The B2 …[]

an integrated view...



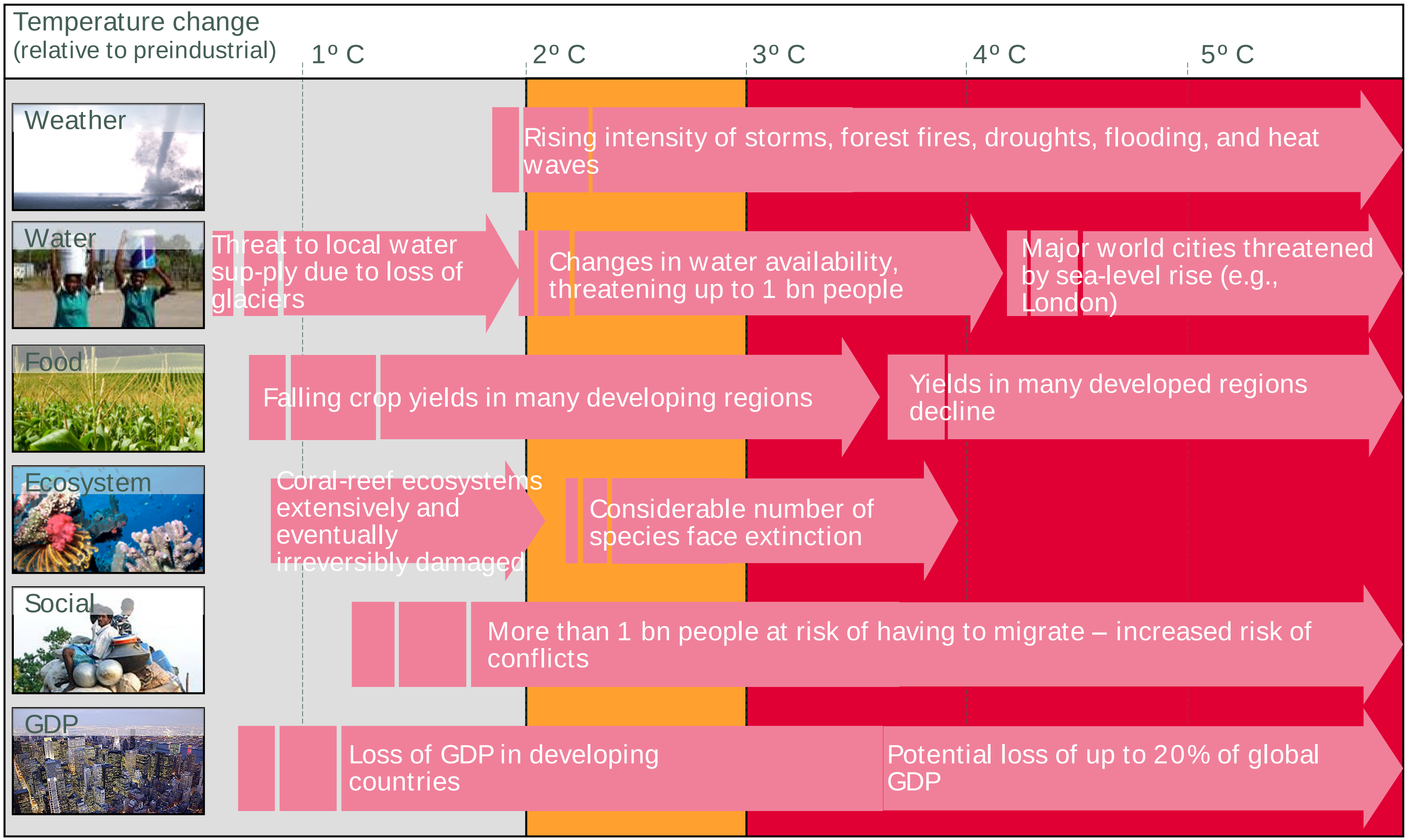
Scenario creation - 6 scenarios defined

1	2	3	4	5	6
GHG emission reductions not pursued	Late and dis-ruptive climate policy action	Slow greening of the economy	Clean technology breakthrough	High fossil fuel prices makes world go green	Policy con-sensus around climate change
In a long period of economic crisis, policy makers de-prioritize climate and in 2025 when real impact is seen adaptation becomes the only viable option	Following poor economic dev. no climate action is taken. A climate disaster wake-up-call in 2025 makes the world act drastically and very strong policies are implemented	Climate change is kept on the political agenda but only as a 2nd priority item as the economy and other issues are more important, sluggish implementation of climate policies with low reduction targets	Continued innovation and investments lead to a clean tech leap, making them competitive to today's fossil technology by 2020 and pick-up mainly through pure market forces	Investments in clean tech are continued at a moderate pace and by 2020 climate action becomes aligned with domestic economic interests for China and US	The economy is recovering very well and a common climate consensus makes the world come together to act on a global action plan and policies (starting 2015/2020)

See http://media.swissre.com/documents/Scenarios_for_Climate_Change.pdf

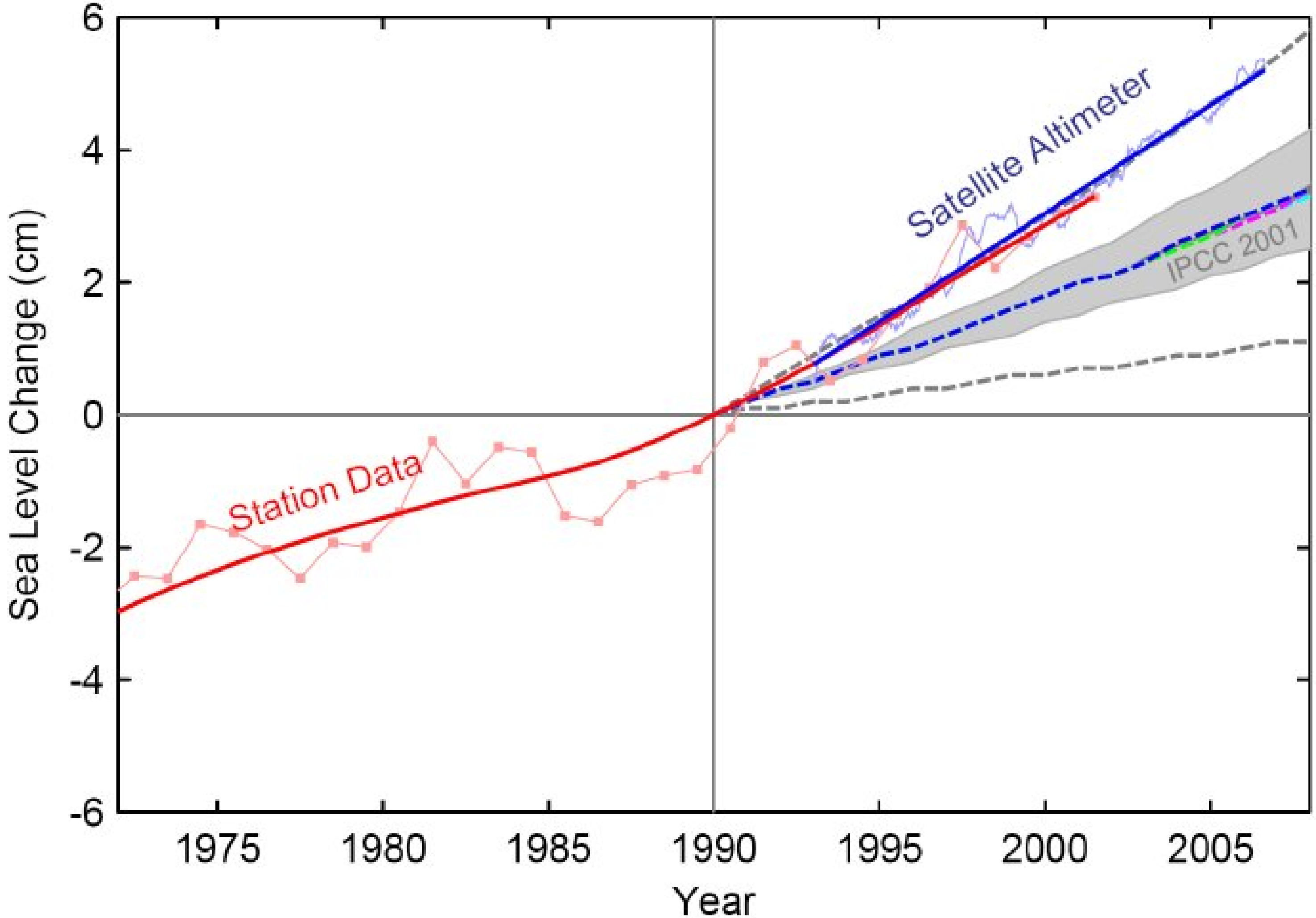
Climate impacts

Scenario A1B
IPCC AR4 worst-case scenarios



Source: Stern Review; IPCC

Note on sea level rise: measurements



Sources: Church, J.A. and N.J. White, 2006. Rahmstorf, S., 2008. Vellinga, P. et al. 2008

Climate impact scenarios

There are different ways to represent climate change scenarios in the model

Representation is possible via

- Parameterized impact (→ Tropical cyclone Florida case study): Estimate the climate change impact on key hazard parameters and represent those changes in the probabilistic event set, either by
  - re-generating the probabilistic event set based on these parameters
  - reflecting those changes by modification of the 'present climate' hazard event set (e.g. multiply the hazard intensity by a factor)
- Downscaled event set (→ Winterstorm European storm case study): Extract events from a downscaled GCM-driven model chain

Note that a changing climate might also have impacts on e.g. vulnerabilities

Parameterized impact: TC Florida case study (1/3)

Hazards	Impact	Comments
Hurricane	High impact	• Hurricane damage likely to increase with climate warming • Primary cause of flooding and responsible for the majority of hazard induced damages
Sea level rise	Half low / half high impact	• Expected to be a critical issue in long term; less potential for impact in 2030 timeframe • Storm surge and water supply are likely to be adversely impacted, particularly in southern Florida
Temperature increase	Mostly low impact	• Drought events may be exacerbated by an increase in global temperature. However, – Precipitation forecasts[1] not expected to change and impact on humidity unclear – Measures already in place to handle high temperatures

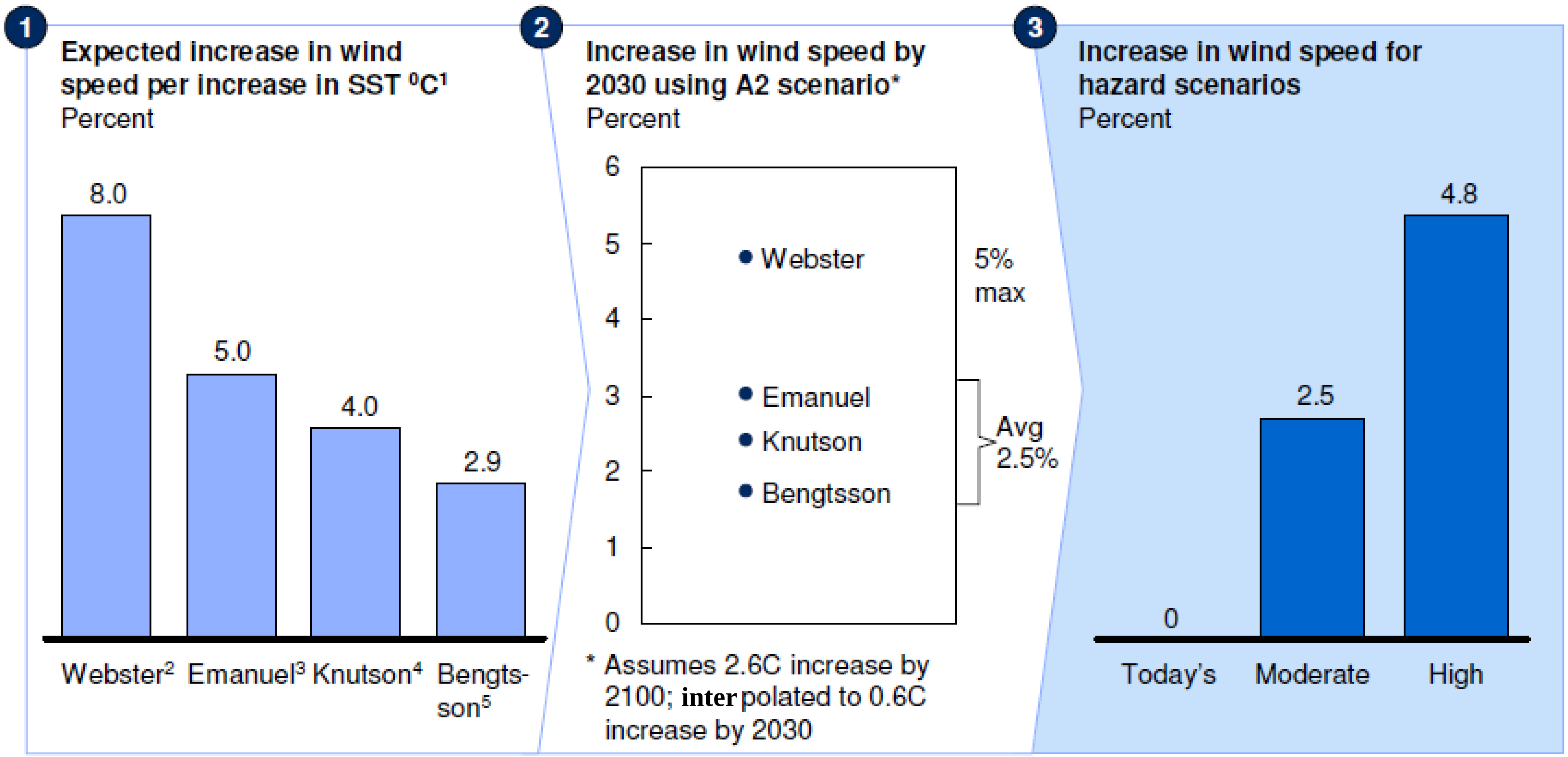
- While sea level rise and temperature increase are important risks to Florida, the focus of our work was on hurricanes
- More hurricanes hit Florida than any other State in the USA (30 between 1992-2005)

Low impact

High impact

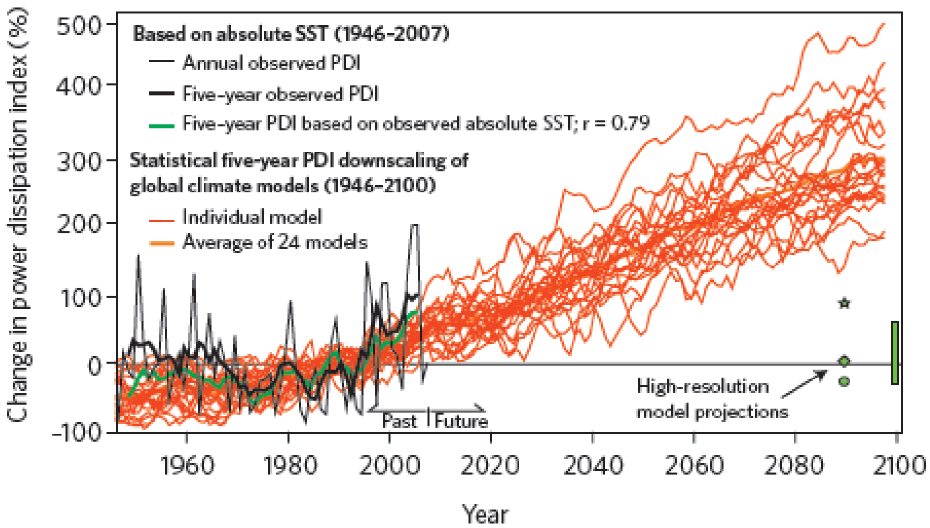
Examined further

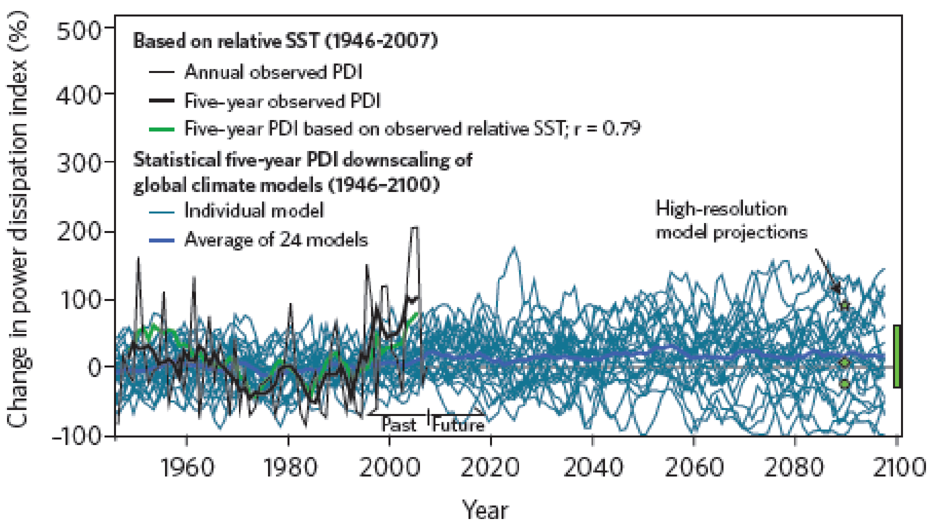
Parameterized impact: TC Florida case study (2/3)

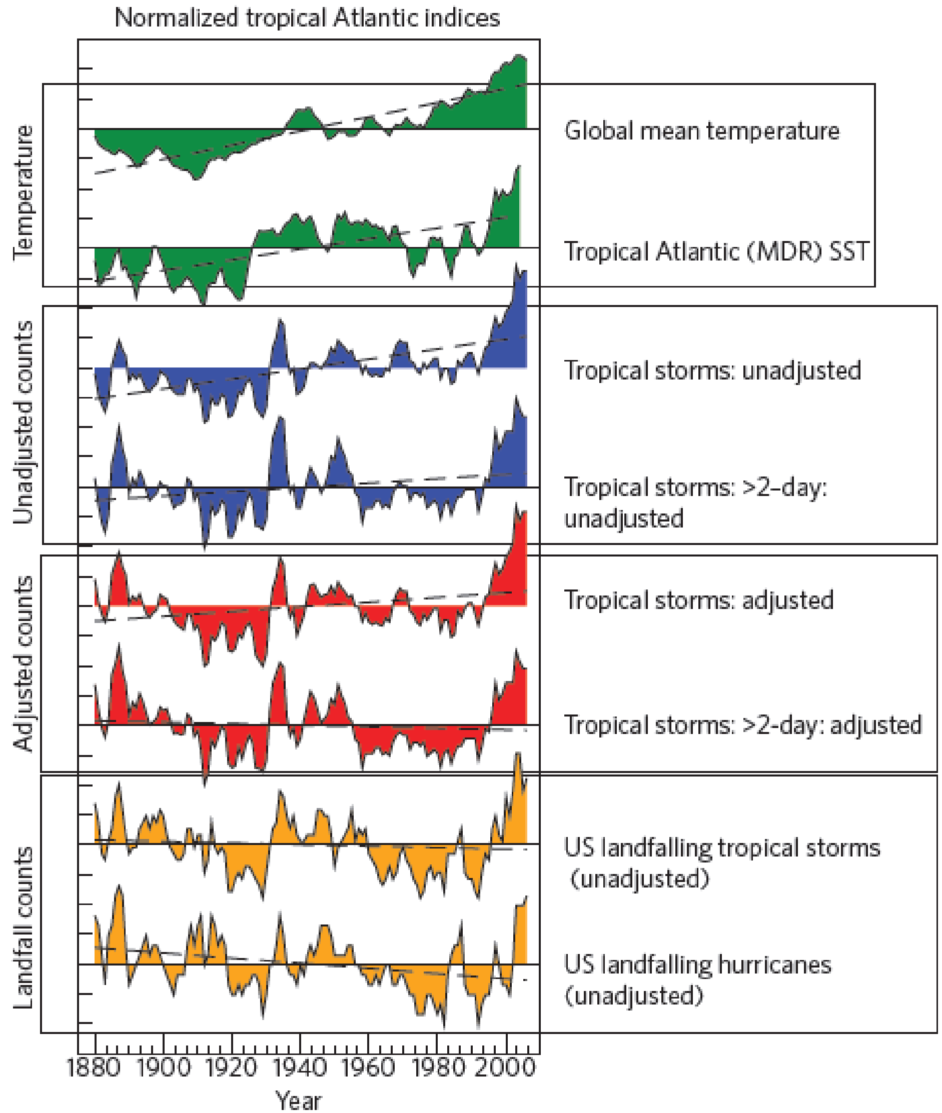


1 Holding all other variables constant
2 Webster et al. (2005) "Changes in tropical cyclone number, duration, and Intensity in a warming environment." *Science* **309**
3 Emanuel (2005) "Increasing destructiveness of tropical cyclones over the past 30 years." *Nature* **436**
4 Knutson and Tuleya (2004) "Impact of CO_2-induced warming on simulated hurricane intensity and precipitation: Sensitivity to the choice of climate model and convective parameterization". *J. Climate* **17**
5 Bengtsson et al (2007) "How may tropical cyclones change in a warmer climate?", *Tellus* **59**

Source: SOURCE: IPCC AR4 ECHAM5 model and average across models (Fig. 11.22)







Source: Knutson et al., Nature geoscience, Vol 3, March 2010

Parameterized impact: TC Florida case study (3/3)

- **High level of uncertainty around predicting hurricanes**
  - Many climate factors play a role in the development and strength of hurricanes
- Narrowed focus and scope to address only **hurricane intensity and height of sea level rise**
- Using expert input, **three climate scenarios were developed**
  - Intensity forecasts based on the link between sea surface temperature and wind speed
  - Sea level rise projections were based on projections across two ice flow outcomes
- Climate scenarios were later used to develop 3 hazard scenarios

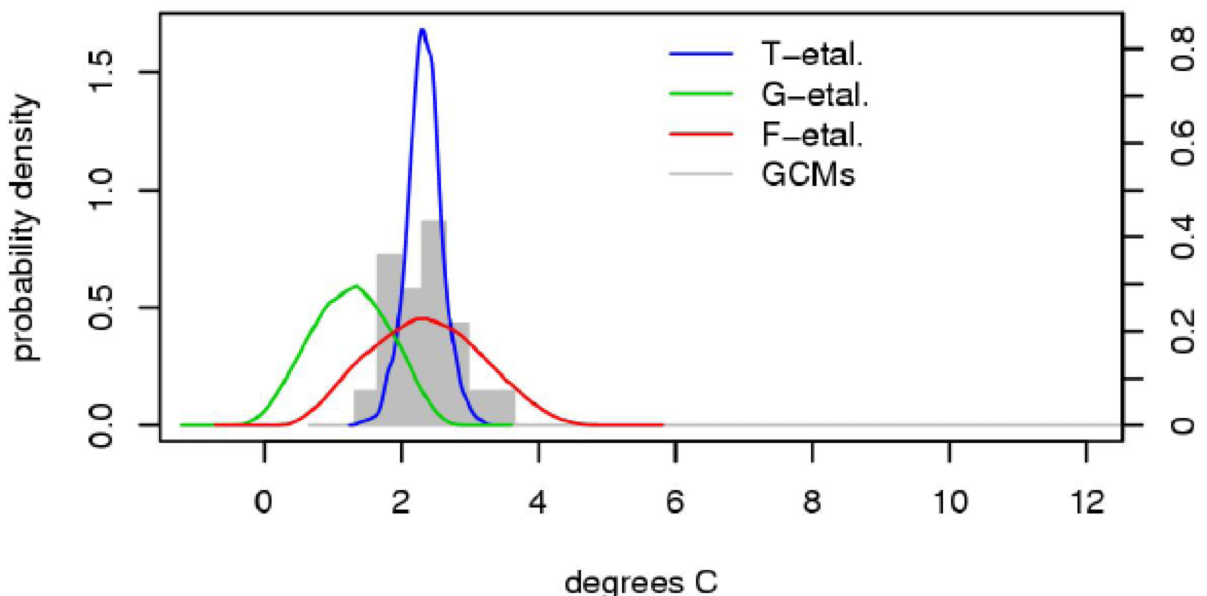
2030 scenarios	Description
1 **Today's climate**	▪ **Current climate data used** as the baseline for wind speed and sea level ▪ Frequency of hurricane events based on historical and is not varied
2 **"Moderate" Change**	▪ **Wind speed increase of 3% and sea level rise of 0.08m** ▪ Uses an average of various wind speed to sea surface temperature relationships ▪ Storm surge increases due to sea level rise
3 **"High" Change**	▪ **Wind speed increase of 5% and sea level rise of 0.24m** ▪ Uses a maximum wind speed to sea surface temperature relationship ▪ Storm surge increases further

SOURCE: IPCC, 2007; S.Rahmstorf; K, Emanuel; J. Kurry; L. Bengtsson; T. Knutson

Do we need probabilities?

- In the context of deep uncertainties, optimal decisions may not be possible. Robust decisions are those that perform well under a wide range of scenarios and are insensitive to uncertainties in models.

South East Asia temperature change Dec-Feb 2100 A1B



(Tebaldi and Knutti, Phil Trans Roy Soc 2007)

Do we need probabilities?

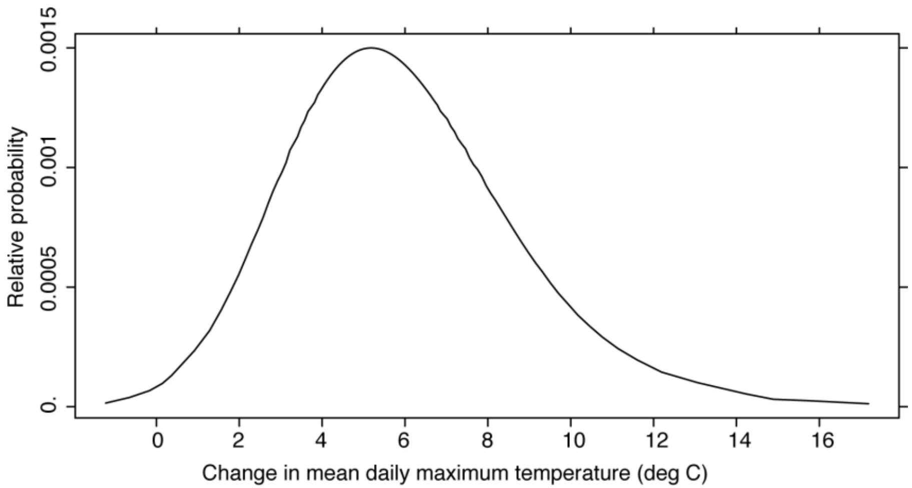
- Do we need a probability, e.g. for a nuclear power plant blowing up? This question is particularly relevant for low probability, high impact and/or irreversible events.
- “Likelihoods contain implicit confidence levels. When an event is said to be extremely likely (or extremely unlikely) it is implicit that we have high confidence. It would not make any sense to declare that an event was extremely likely and then turn around and say that we had low confidence in that statement. “
- “When faced with deep uncertainty, analysts should have the option of responding with statements such as “we just do not know” or “we can only assess the sign of this outcome/trend”, rather than producing a consistent response to communicating confidence across the entire assessment. From a policy perspective such statements might be more useful than introducing illusory precision […].”

(Kandlikar et al., 2005 C.R. Geo.)

Probabilistic projections UKCP09

- Clear formal quantification of uncertainties within a specified framework
- Sensitive to assumptions
- Implies high accuracy
- Value unclear for very high probabilities

UK CLIMATE PROJECTIONS



PDF of change in summer mean daily maximum temperature (ºC) over a particular 25 km square by the 2080s under the High emissions scenario.

“Keep it complex” (Stirling, Nature 2010)

«Expert advice is often thought most useful to policy when it is presented as a single ‘definitive’ interpretation. […] In this way, policy-makers are encouraged to pursue (and claim) ‘science-based’ decisions. […] After years researching — and participating in — science advisory processes, I have come to the conclusion that this practice is misguided.»

COMMENT

CONSERVATION Threats to Adélie penguins assessed p.1034

MATHEMATICS Roger Penrose reflects on 50 years and 6 volumes of work p.1039

REVIEWING Pool of peers grows to cope with submissions surge p.1041

OBITUARY Brian Marsden, keeper of comets, remembered p.1042

A UK crop circle, created by activists to signify uncertainty over where genetic contamination can occur.

G. GRAF/GREENPEACE

Keep it complex

When knowledge is uncertain, experts should avoid pressures to simplify their advice. Render decision-makers accountable for decisions, says **Andy Stirling**.

Worldwide and across many fields, there lurks a hidden assumption about how scientific expertise can best serve society. Expert advice is often thought most useful to policy when it is presented as a single ‘definitive’ interpretation. Even when experts acknowledge uncertainty, they tend to do so in ways that reduce unknowns to measurable ‘risk’. In this way, policy-makers are encouraged to pursue (and claim) ‘science-based’ decisions. It is also not uncommon for senior scientists to assert that there is no alternative to some scientifically contestable policy. After years researching — and participating in — science advisory processes, I have come to the conclusion that this practice is misguided.

An overly narrow focus on risk is an inadequate response to incomplete knowledge. It leaves science advice vulnerable to the social dynamics of groups — and to manipulation by political pressures seeking legitimacy, justification and blame management. When the intrinsically plural, conditional nature of knowledge is recognized, I believe that science advice can become more rigorous, robust and democratically accountable.

A rigorous definition of uncertainty can be traced back to the twentieth-century economist Frank Knight[1]. For Knight, “a measurable uncertainty, or ‘risk’ proper … is so far different from an unmeasurable one that it is not in effect an uncertainty at all”. This is not just a matter of words, or even methods. The stakes are potentially much higher. A preoccupation with assessing risk means that policy-makers are denied exposure to dissenting interpretations and the possibility of downright surprise.

Of course, no-one can reliably foresee the unpredictable, but there are lessons to be learned from past mistakes. For example, the belated recognition that seemingly inert and benign halogenated hydrocarbons were interfering with the ozone layer. Or the slowness to acknowledge the possibility of novel transmission mechanisms for spongiform encephalopathies, in animal breeding and in the food chain. In the early stages, these sources of harm were not formally characterized as possible risks — they were ‘early warnings’ offered by dissenting voices. Policy recommendations that miss such warnings court overconfidence and error.

The question is how to move away

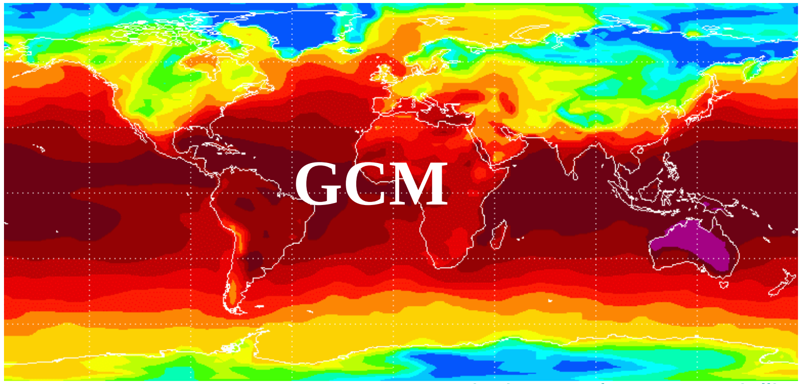
23/30 DECEMBER 2010 | VOL 468 | NATURE | 1029

Downscaled event set: WS Europe case study (1/3)

Example: Climate impact on European winter storms

Goal: Compare wind storm damage on a Europe-wide property insurance portfolio in current and future climate conditions.

- Use 3-dimensional global climate models (GCM)
- Drive regional climate models (RCM) over Europe with initial and boundary conditions from global models
- Extract storm events from regional climate model
- Based on these events, build the probabilistic event set (for solid stats)



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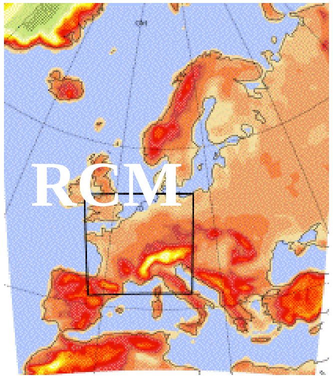


→ Damage Model

Schwierz et al, 2006: Modelling European winter windstorm losses in current and future climate, Climatic Change.

Downscaled event set: WS Europe case study (2/3)

Example: Climate impact on European winter storms (contd.)

For 3 climate models (ETHC, GKSS and ECHA) compute

- a control simulation (CTL 1961-1990) and
- a greenhouse gas scenario simulation (A2 2071-2100).

ETHC 30 yrs CTL, 10 CPU months on a super-computer, 200 GB of data

ETHC 30 yrs A2, 10 CPU months on a super-computer, 200 GB of data

GKSS 30 yrs CTL, 10 CPU months on a super-computer, 200 GB of data

GKSS 30 yrs A2, 10 CPU months on a super-computer, 200 GB of data

ECHAM 30 yrs A2, 10 CPU months on a super-computer, 200 GB of data

ECHAM 30 yrs CTL, 10 CPU months on a super-computer, 200 GB of data

→ Total 5 CPU years for 1.2 TB of data used in this study !!!

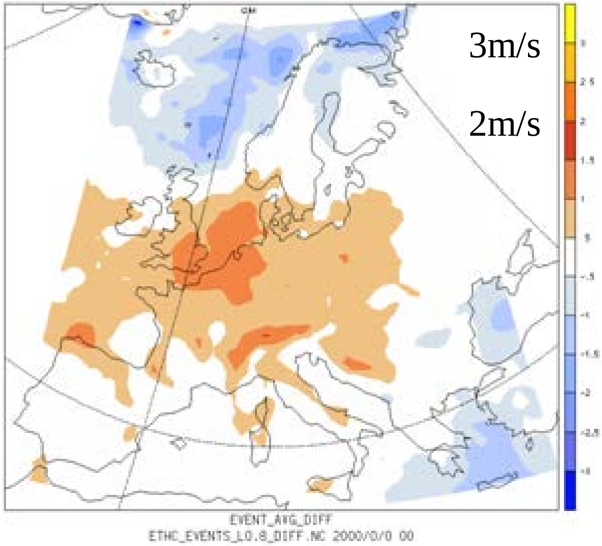
Schwierz et al, 2006: Modelling European winter windstorm losses in current and future climate, Climatic Change.

Downscaled event set: WS Europe case study (3/3)

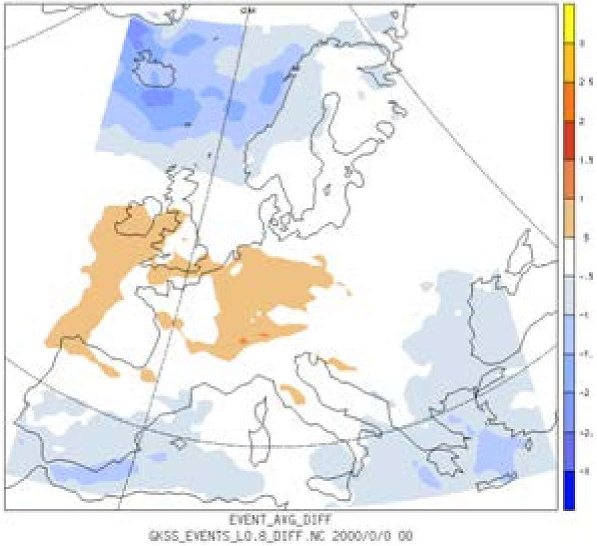
Example: Climate impact on European winter storms (contd.)

Difference in average wind gusts [m/s]

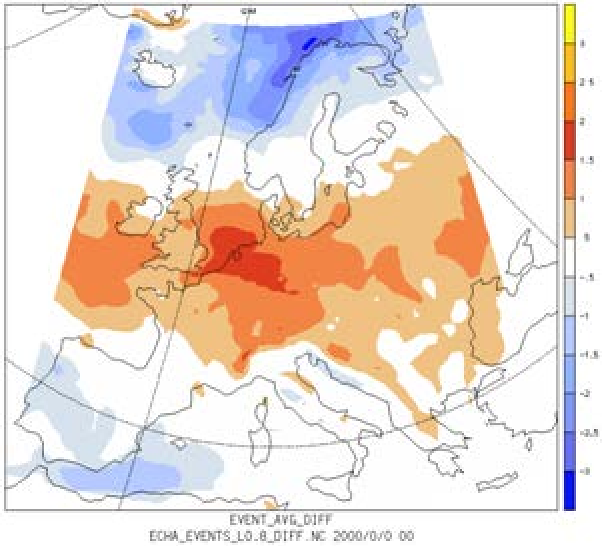
ETHC, A2 – CTL



GKSS, A2 – CTL



ECHAM, A2 - CTL



Schwierz et al, 2006: Modelling European winter windstorm losses in current and future climate, Climatic Change.

Downscaled event set: Results and Matlab hints

- Results (A2 for 2071-2100 compared with CTRL 1961-1990):

	ETHC	GKSS	ECHA
Climate impact	68%	48%	16%
per annum	1.0%	0.7%	0.2%
TruncatedAED calibration precision	1.9%	-6.1%	0.2%
gust adjustment factor[1]	1.22	1.17	1.09

- But: climate impact ONLY (assets fixed at today's values) and time slice difference A2 compared to CTRL (today's climate)

- The different scenario hazard events set are named WS_{Model}_{Scenario}, e.g. WS_ECHAM_A2 for the ECHAM A2 run

[1] CTRL runs have been calibrated to operational model using a gust adjustment factor (iteratively)
AED: Annual Expected Damage

Schwierz et al, 2006: Modelling European winter windstorm losses in current and future climate, Climatic Change.

Economics survey – please participate!

https://services.iac.ethz.ch/survey/index.php/239445/lang-en

A few questions to be answered (anonymous) to gather some data iro time preference etc. Takes about 2 min.

Results will be presented in next lecture.