Economics of Climate Adaptation (ECA) Methodology workshop for KfW

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Swiss Re

Agenda

- 8:30h coffee
- 9-10h: block 1
  - Brief introduction to probability, uncertainty and risk management 20'
  - Probabilistic risk assessment model: from concept to concrete application (risk today) 20'
  - Q&A 20' (well, part of above)
- 10-10:30h break (and a buffer for further Q&A)
- 10:30-11:45: block 2
  - Climate change and impacts, scenarios, use of scenarios 10'
  - Total climate risk 10'
  - Basics of economic evaluation and economic decision making in the context of total climate risk 20'
  - The cost of adaptation - application of economic decision making to climate adaptation --> adaptation cost curve 20'
  - Q&A 15' (well, part of above)
- 12-13:30h lunch
- 13:30-15h: Hands-on, climada: Shaping climate-resilient development
- 15-16h: wrap-up

Block 1

- Brief introduction to probability, uncertainty and risk management
  20’
- Probabilistic risk assessment model: from concept to concrete application (risk today)
  20’
- Q&A
  20’

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Most material taken from:

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

Reto Knutti, IAC ETH
David Bresch, Swiss Re

See www.iac.ethz.ch/edu/courses/master/modules/climate_risk

What this course aims to provide

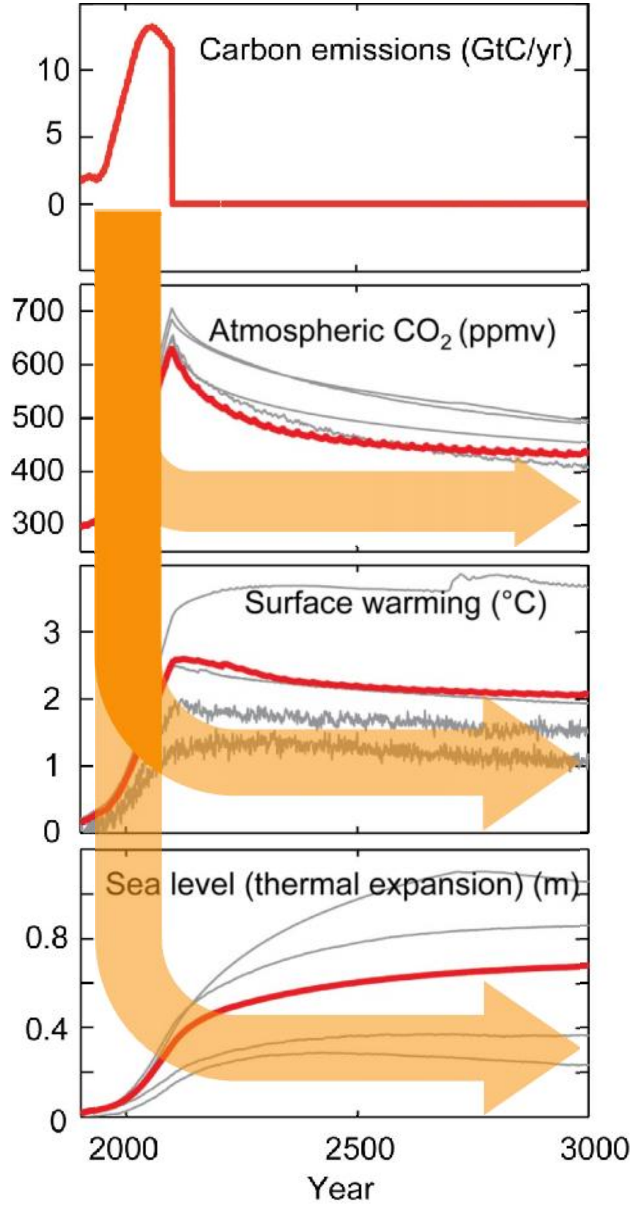
- Different perspectives on the problem of understanding, quantifying and communicating probability, uncertainty and risk, and how to make decisions in their presence
- Hands on experience with climada
- Opportunities for discussion

and

- Opportunities to think about a problem, rather than providing a recipe for a solution

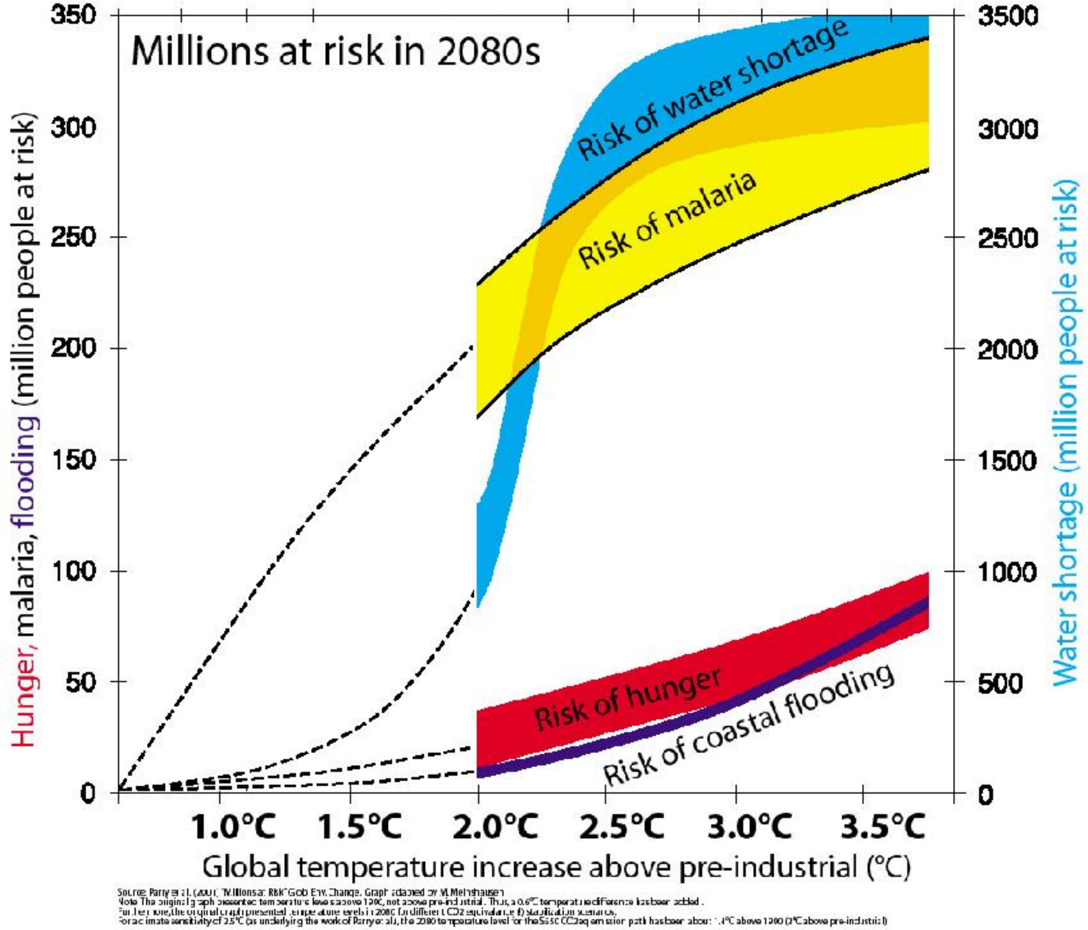
Irreversible climate change

- Both adaptation and mitigation cost money, but on different timescales and those bearing the costs may not be the same.
- Much of the warming, once realized, is irreversible for centuries.
- Today's emissions will be a legacy for many centuries.



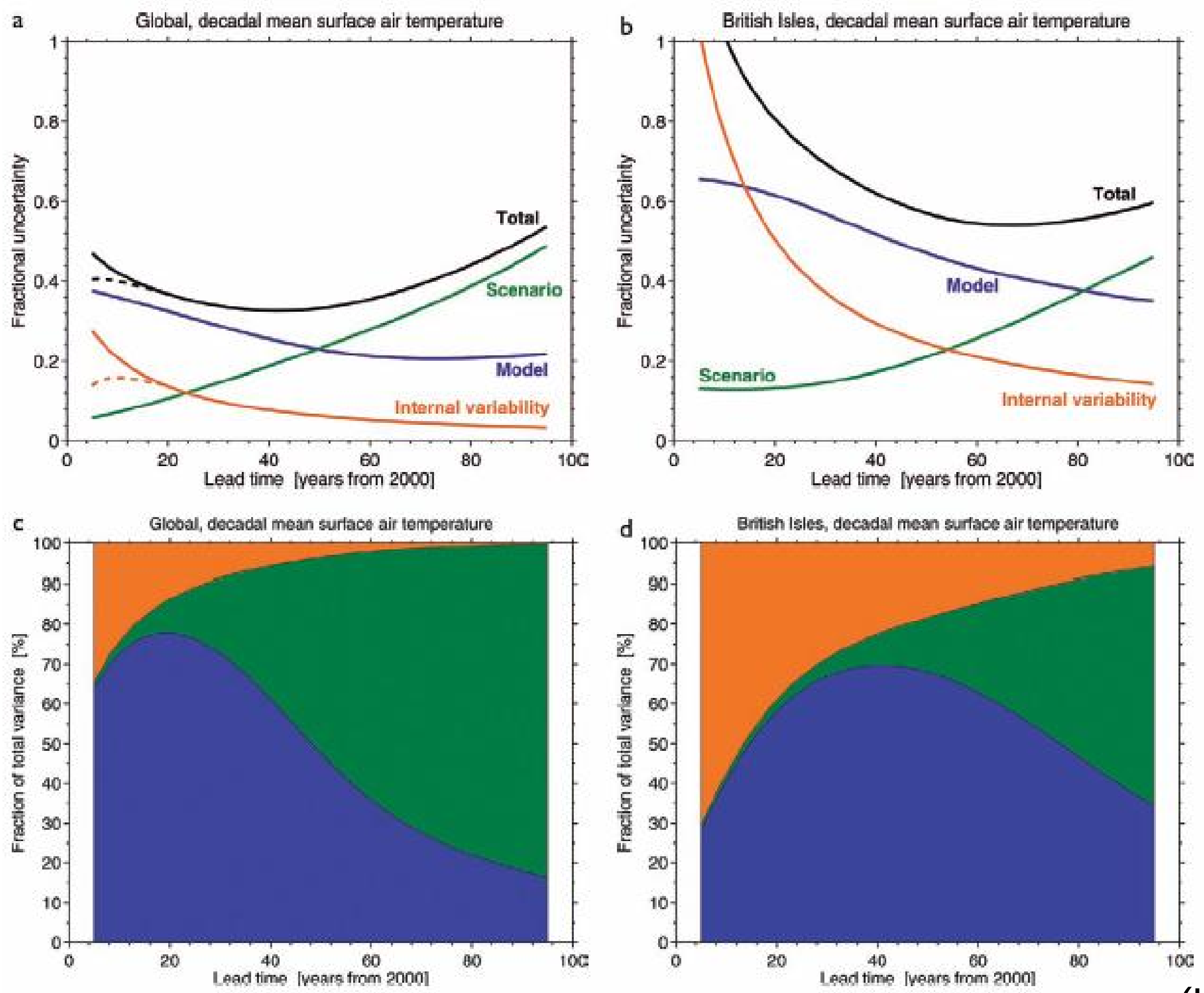
(IPCC 2007, Plattner et al. 2008, Solomon et al. 2009)

Three billion people at risk from water shortage



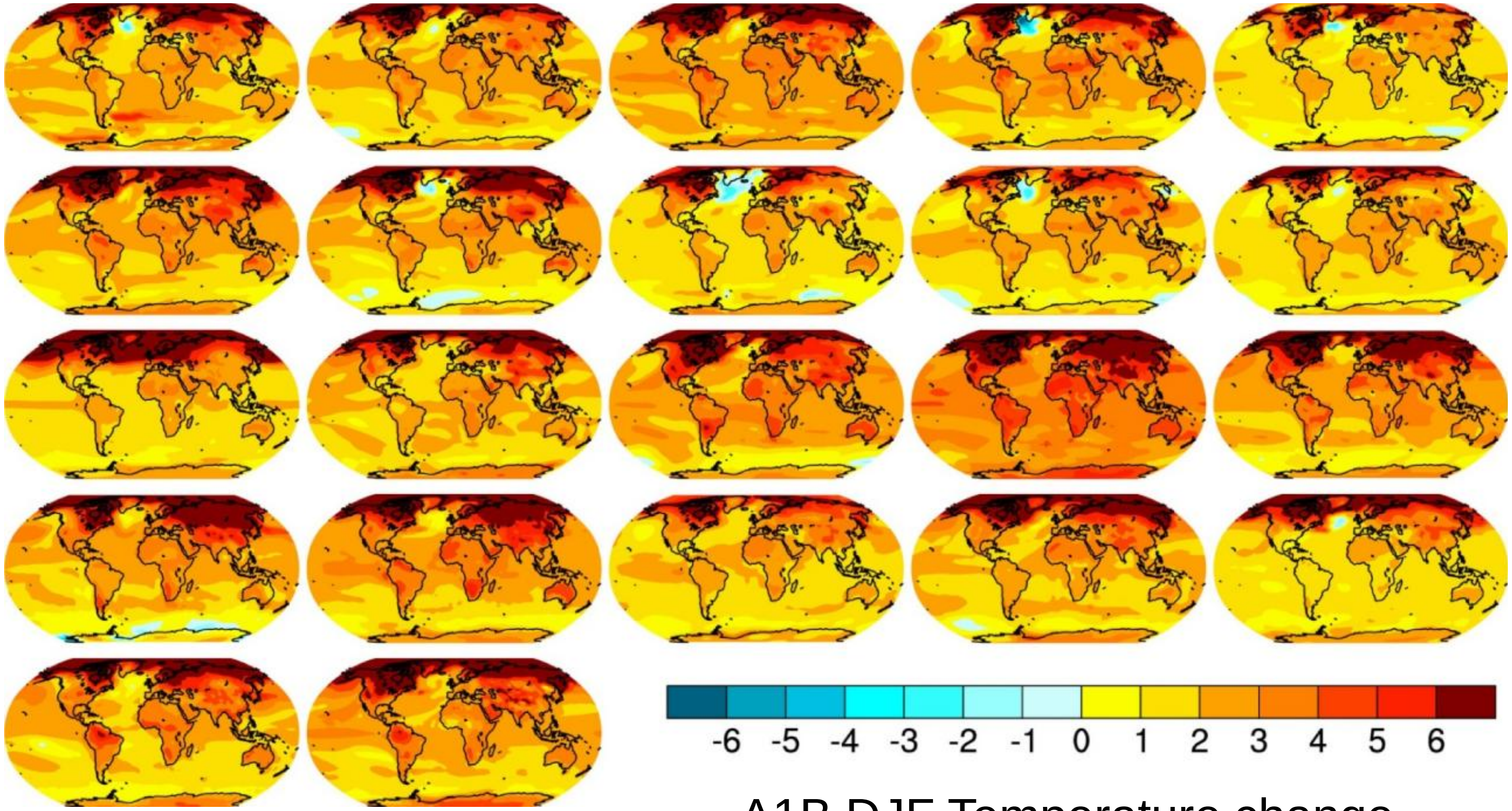
(Figure: M. Meinshausen, based on Parry et al. 2001)

Sources of uncertainty



(Hawkins and Sutton, 2009)

Which model should you believe?



A1B DJF Temperature change
2080-2099 minus 1980-1999 (K)

Do we trust a model?

- "All models are wrong, but some are useful." (Box 1979)
- "There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes." (IPCC AR4 FAQ 8.1)

Risk

- Risk concerns the expected value of one or more results of one or more future events.
- Risk = $\underbrace{\text{Probability}}_{\text{expected}} \otimes \underbrace{\text{Severity}}_{\text{value}}$
- Risk is defined in ISO 31000 as the effect of uncertainty on objectives (whether positive or negative).
- The term risk may be traced back to classical Greek rizikon (ριζα) meaning root, later used in Latin for "cliff". The term is used in Homer’s Odyssey: Odysseus tried to save himself from Charybdee at the cliffs of Scylla, where his ship was destroyed by heavy seas generated by Zeus as a punishment for his crew killing before the bulls of Helios (the god of the sun), by grapping the roots of a wild fig tree.

Recap: Risk[1] Management

Risk identification: Shared mental model, the prerequisite for awareness

- perception is based on a *shared mental model*
  → wider sharing builds awareness

Risk analysis: Quantification, the basis for decision-making

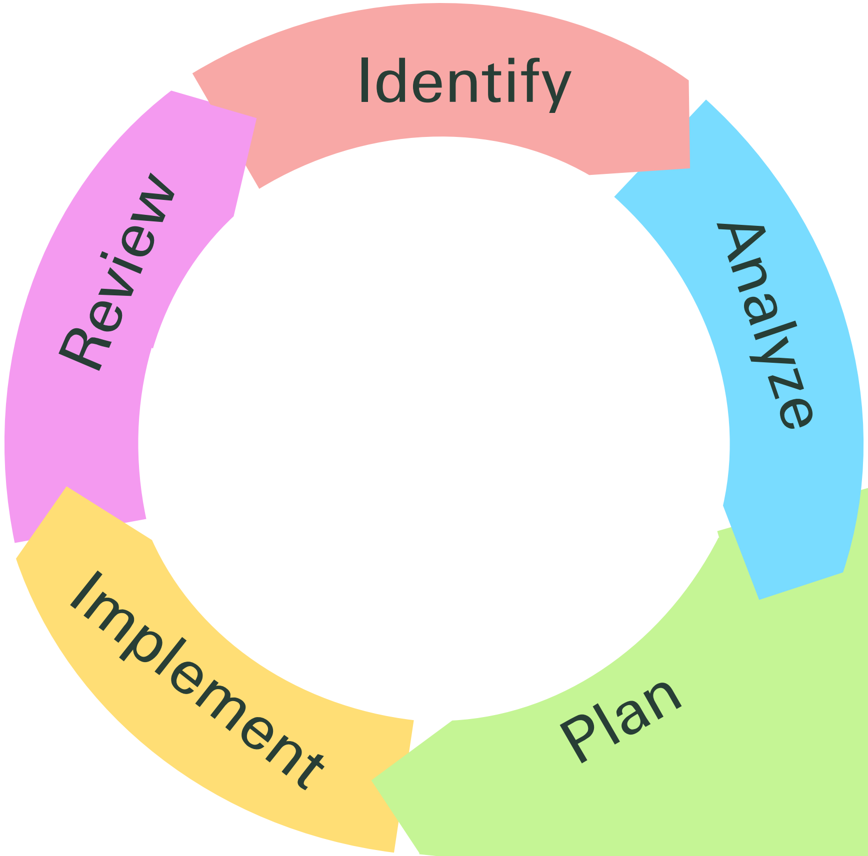
- Risk model: the quantitative expression of a shared mental model
  → allows to assess risk mitigation options

Risk mitigation: Prioritization based on metrics, options are to

- avoid
- prevent
- transfer : Insurance puts a rice tag on risks → incentive for prevention
- or retain the risk

[1] Risk = Probability ⊗ Severity

The Risk Management Cycle



Mitigation options:

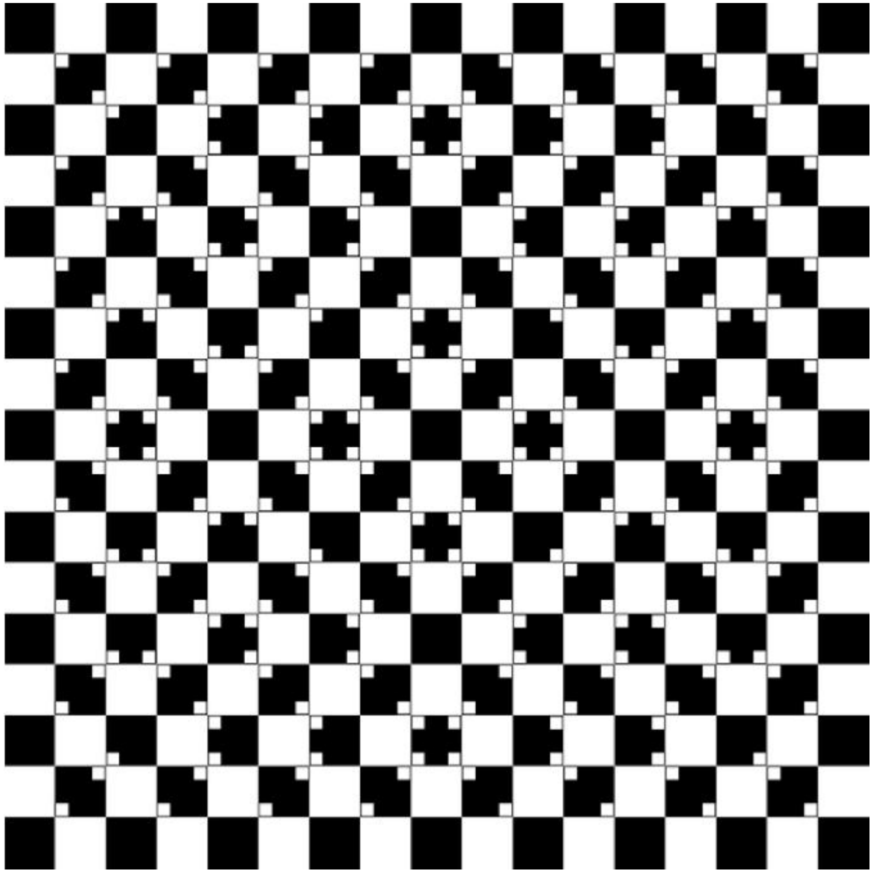
- Avoid
- Reduce
- **Prevent**
- Transfer
- Retain

Risk Management should

- create value
- be an integral part of organizational processes
- be part of decision making
- explicitly address uncertainty
- be systematic and structured
- be based on the best available information
- be tailored
- take into account human factors
- be transparent and inclusive
- be dynamic, iterative and responsive to change
- be capable of continual improvement and enhancement.

Source: ISO

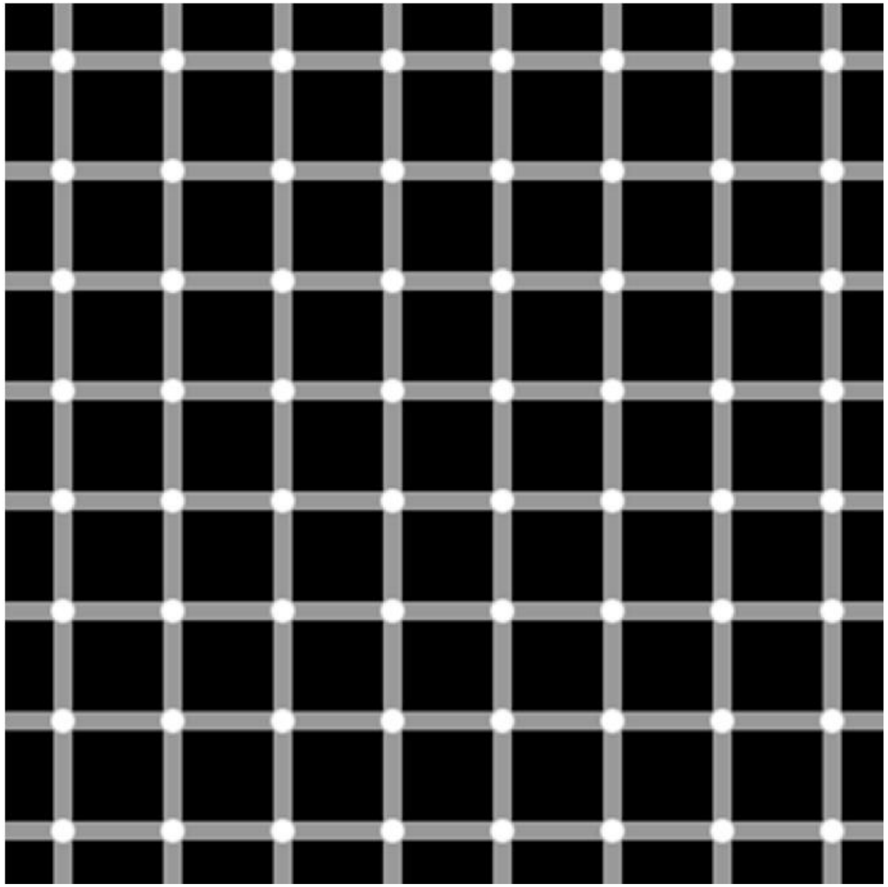
Notes on perception – an illustration (static)



All lines are straight ...

Figure by Bernard Ladenthin, 2008

Notes on perception – an illustration (dynamic)



There are no black dots (only large squares) ...

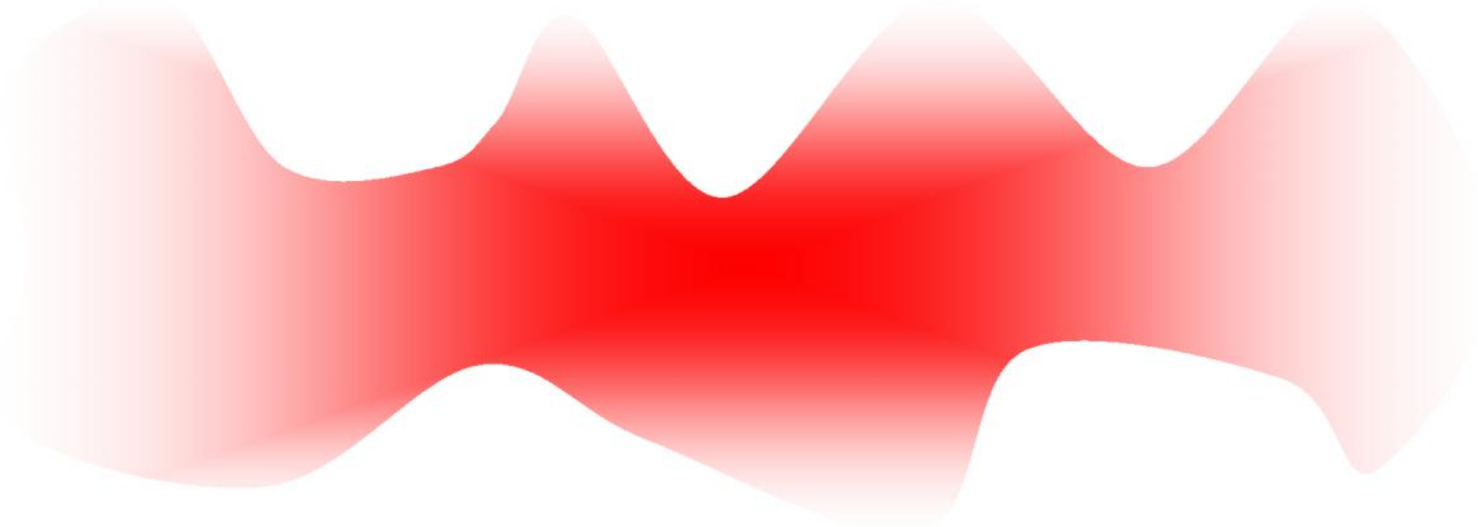
Hermann-Grid, figure by António Miguel de Campos, 2007

Notes on perception – a further illustration

Ideal model, de-constructed reality ...

photo by Roger Zenner, built by Shigeo Fukuda, 200x

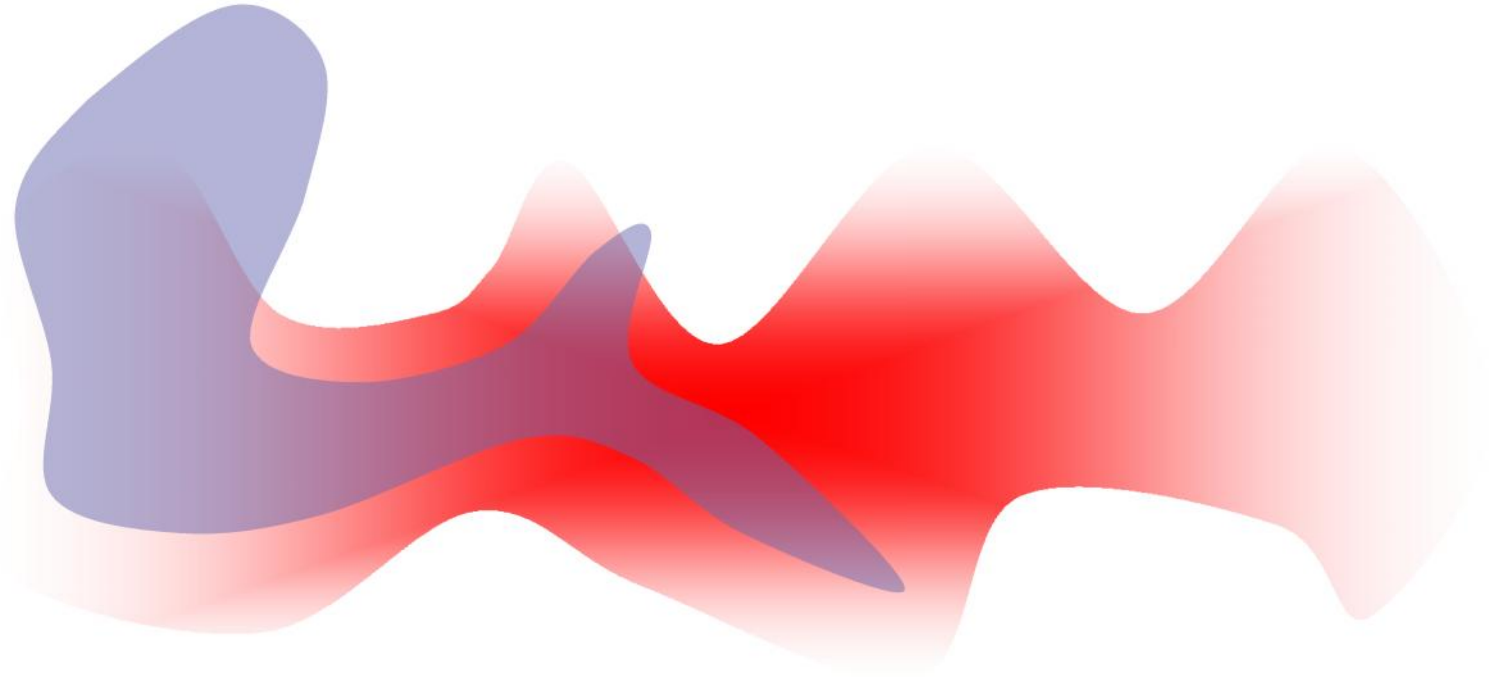
Notes on quantification and validity – reality



Reality

To be more precise: ***Perceived* reality**

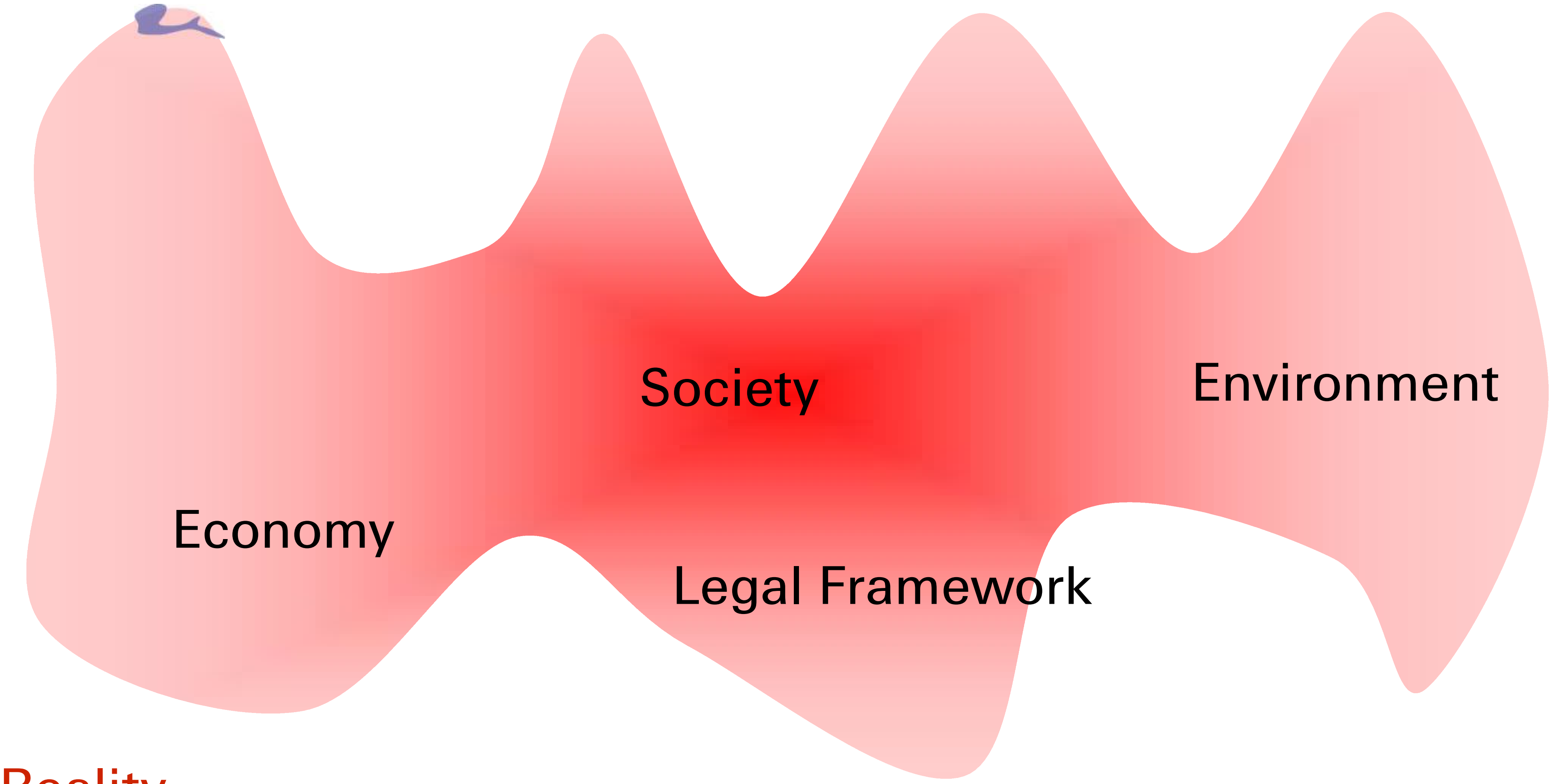
Notes on validity – model



Reality

Model

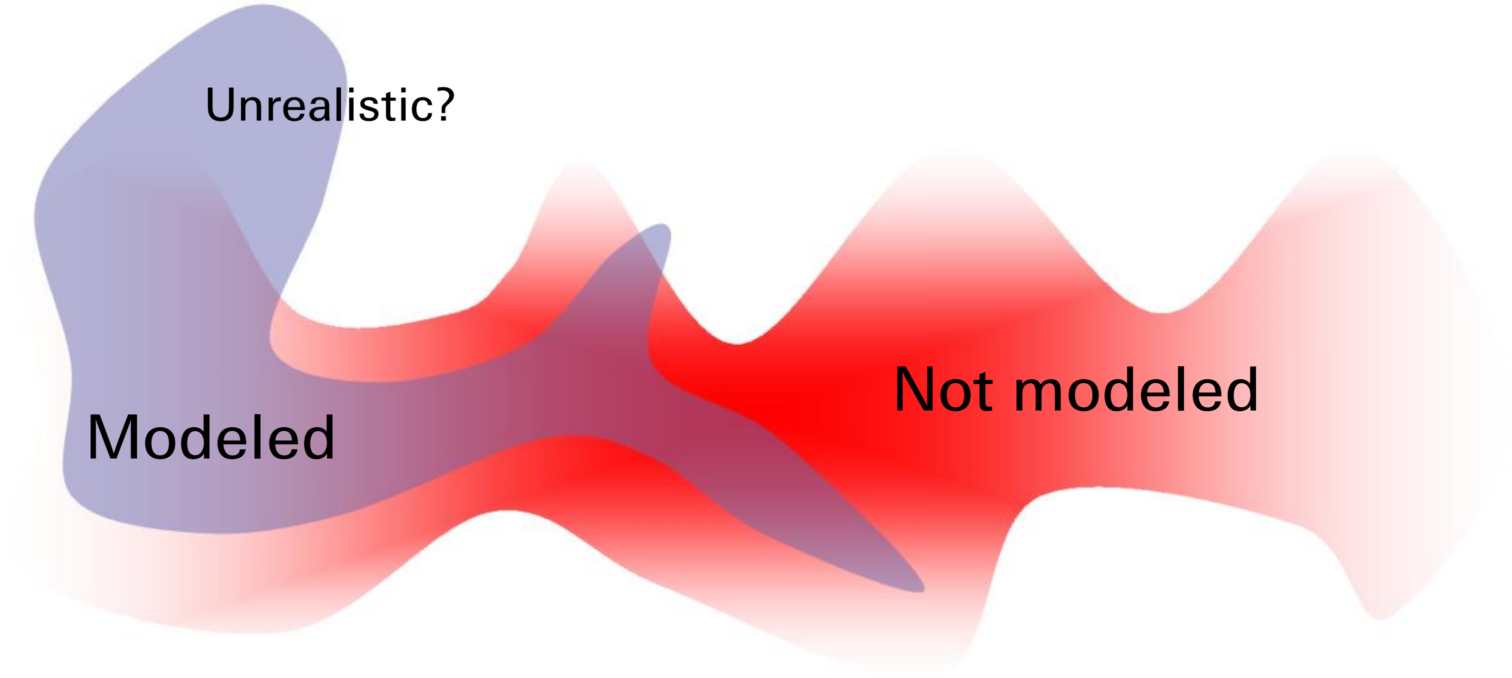
Notes on validity – proportions



Reality

Model

Notes on validity – application

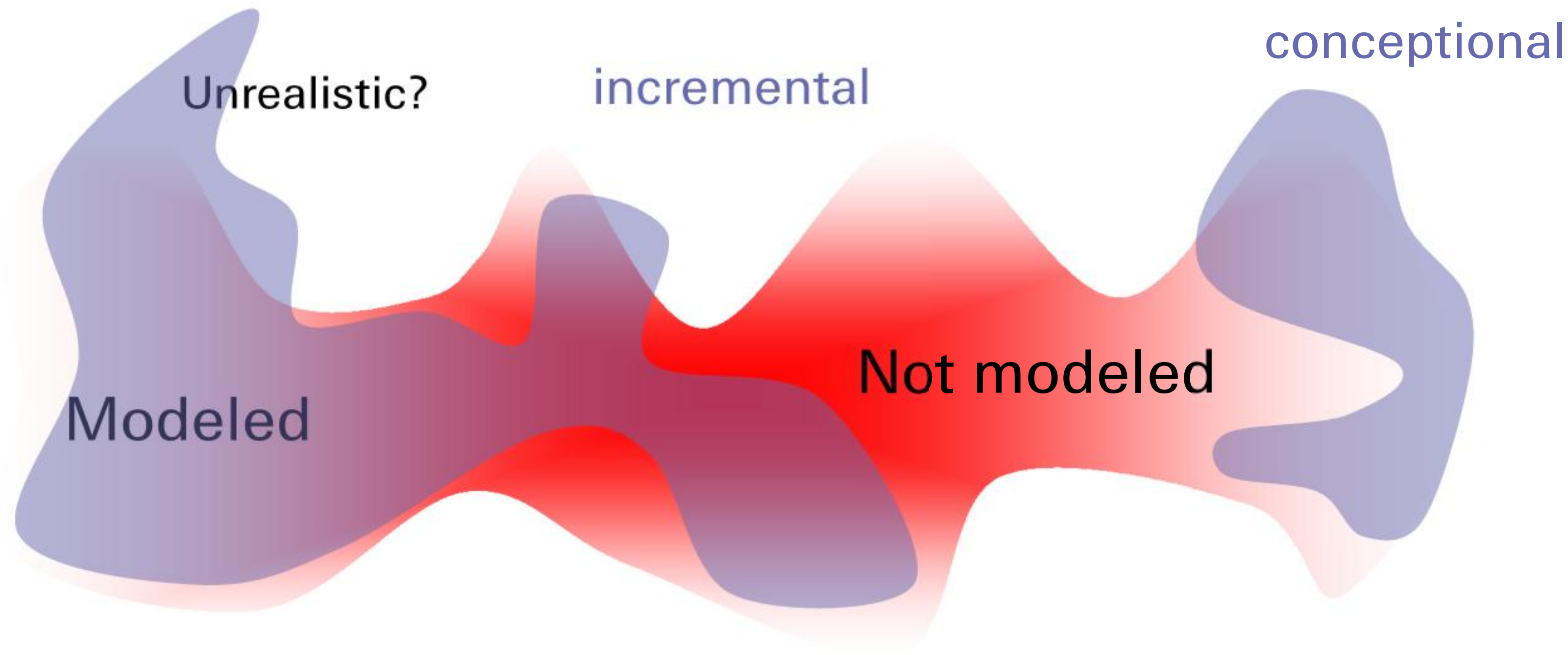


Reality → Model: Abstraction

Described in Model

Model → Reality : Interpretation (*Verification*/Falsification/Calibration)

Notes on validity – development

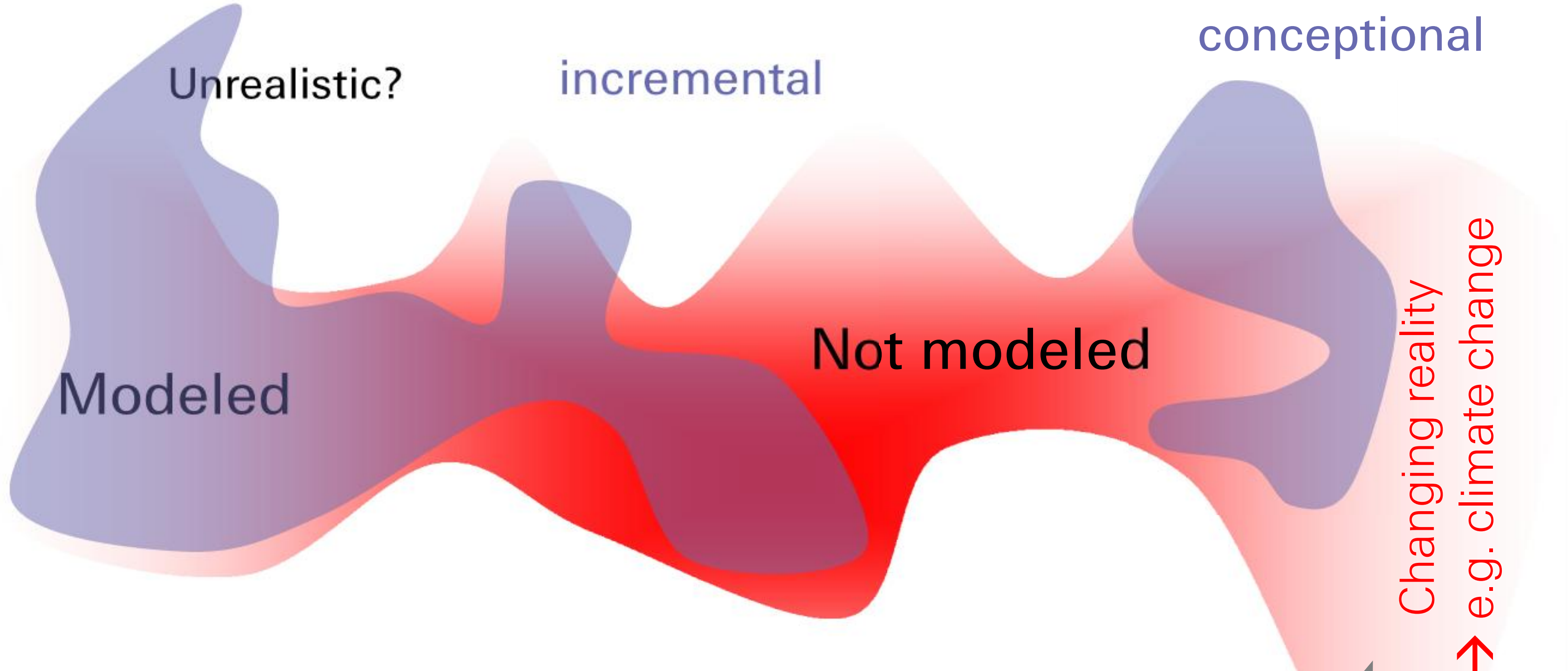


Reality → Model: Abstraction

Described in Model

Model → Reality : Interpretation (*Verification*/Falsification/Calibration)

Notes on validity – adaptation

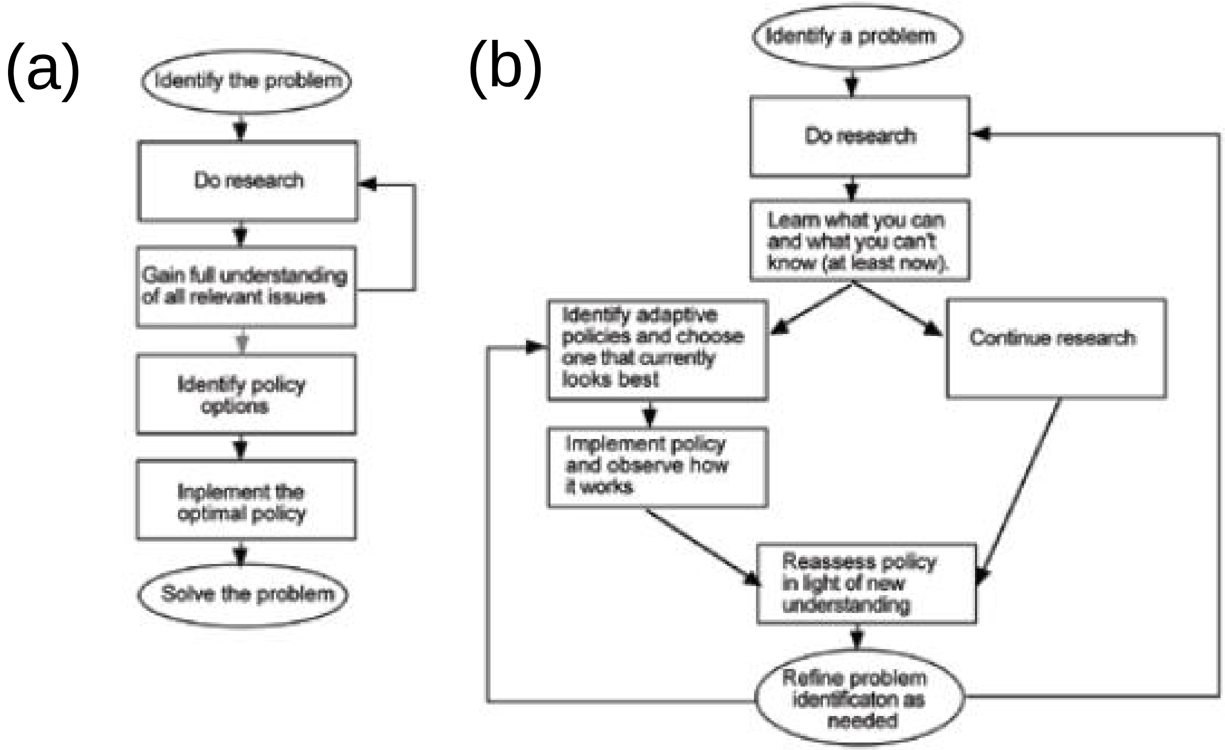


Reality → Model: Abstraction

Described in Model

Model → Reality : Interpretation (*Verification*/Falsification/Calibration)

Note on decision strategies



In the face of high levels of uncertainty, which may not be readily resolved through research, decision makers are best advised to not adopt a decision strategy in which (a) nothing is done until research resolves all key uncertainties, but rather (b) to adopt an iterative and adaptive strategy.

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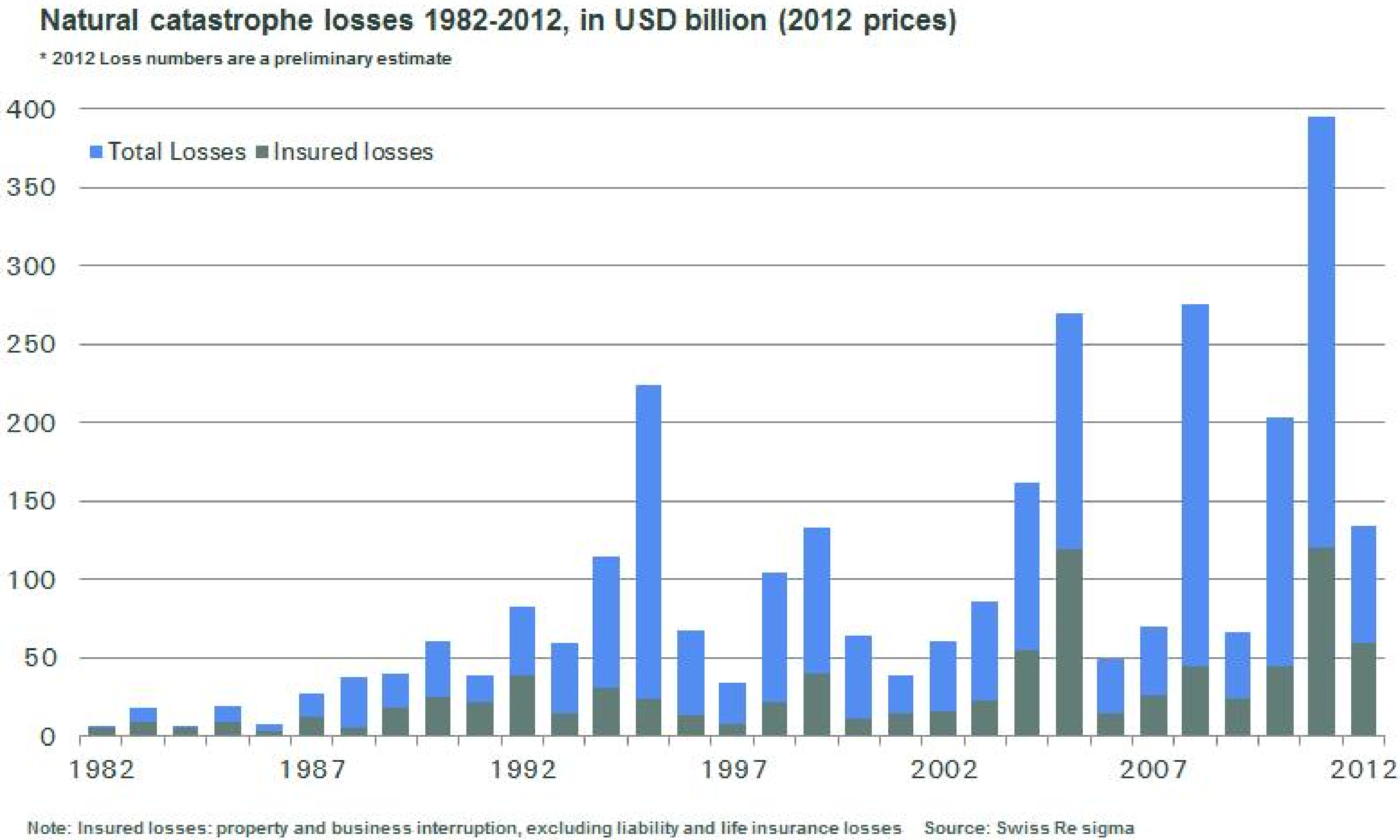
Natural Nat Cat damages on the rise

and: Massive gap between economic and insured damage



Note on trend drivers

The upward trend in natural catastrophe damage is driven by:

- Higher insurance penetration
- Growing property values
- Coastal value concentration
- Higher vulnerabilities
- Climate change

Trend decomposition going forward ?

→ Economics of Climate Adaptation

Ocean Drive, FL, 1926

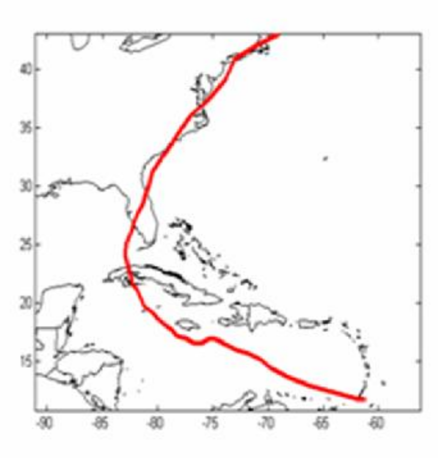
Ocean Drive, FL, 2000

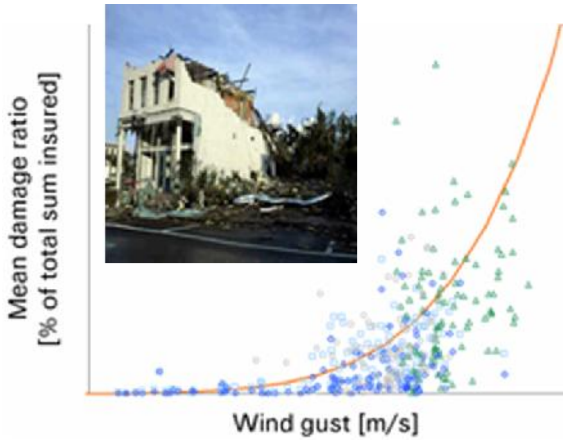
Natural Catastrophe Risk Assessment Model

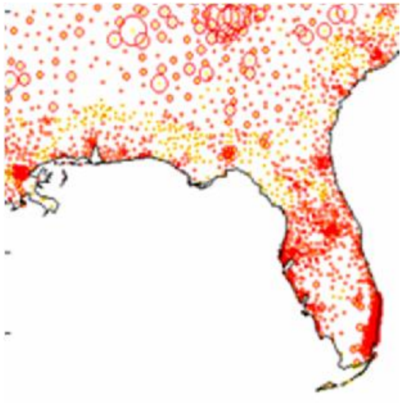
Hazard	...	...

Natural Catastrophe Risk Assessment Model

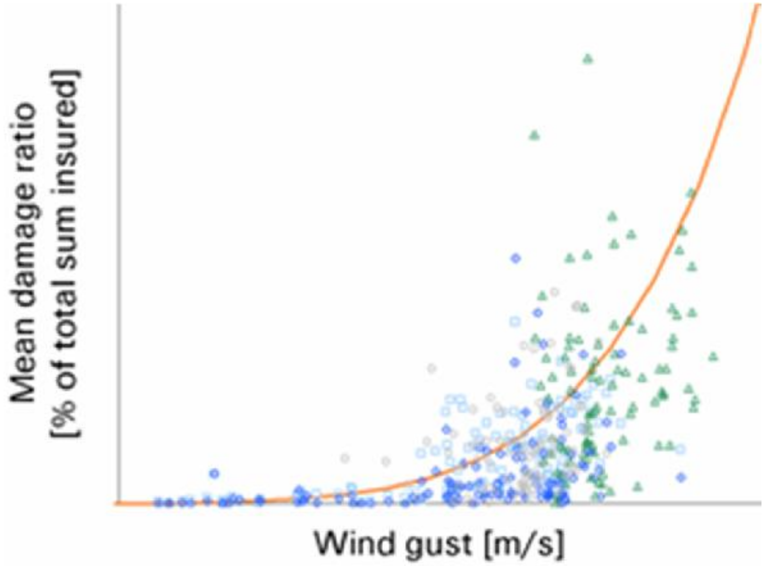
Hazard	Damage function	Assets
How strong? How frequent?	How well built?	Where? What?

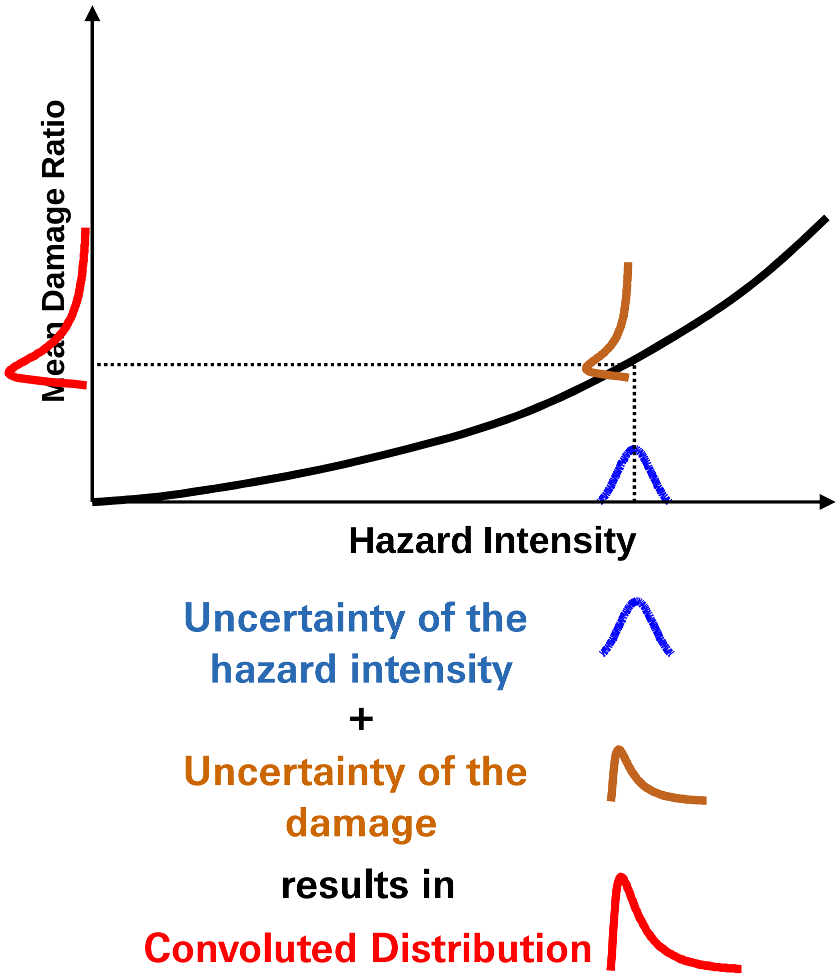






Notes on damage function





Uncertainty of the hazard intensity

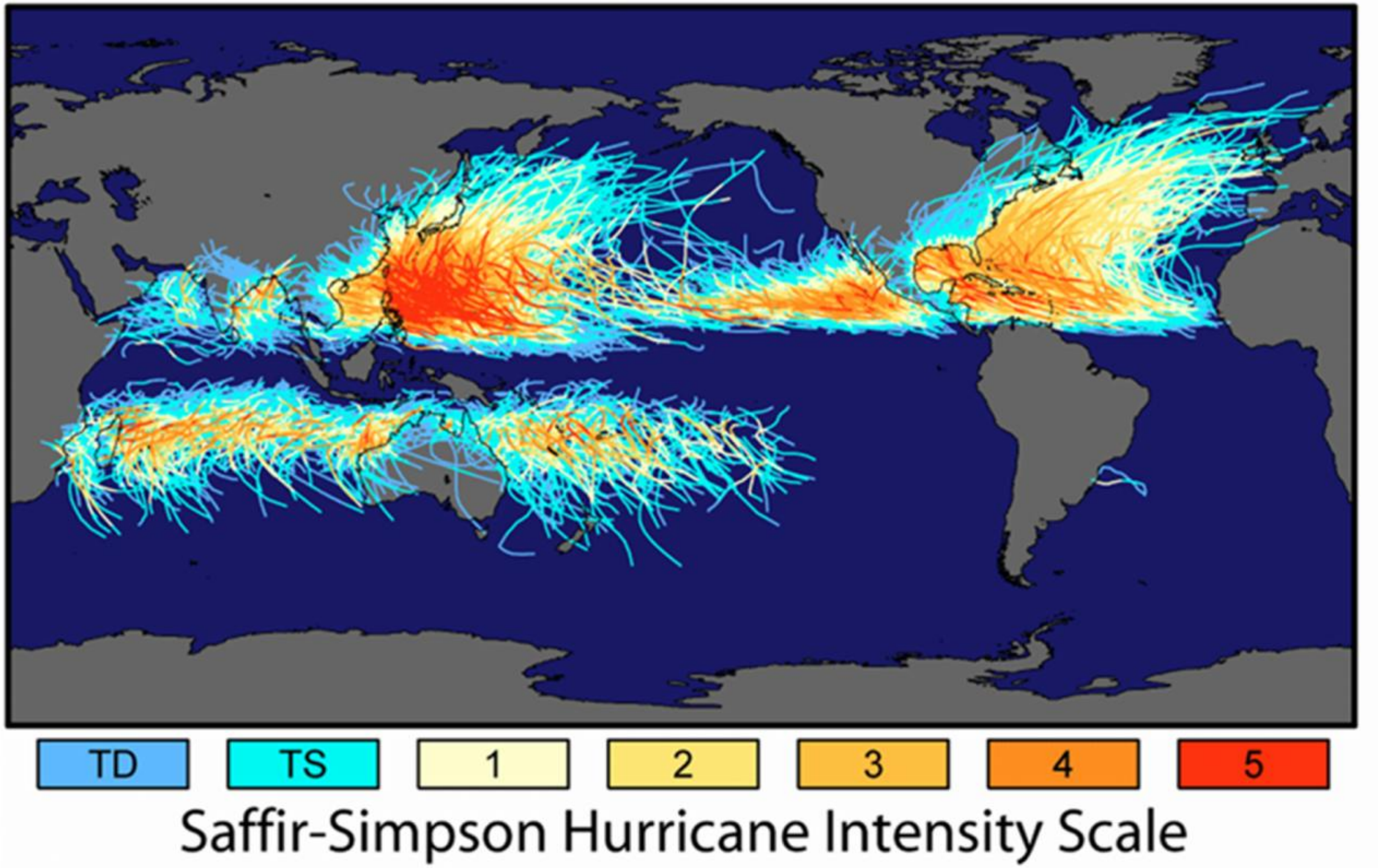
+

Uncertainty of the damage

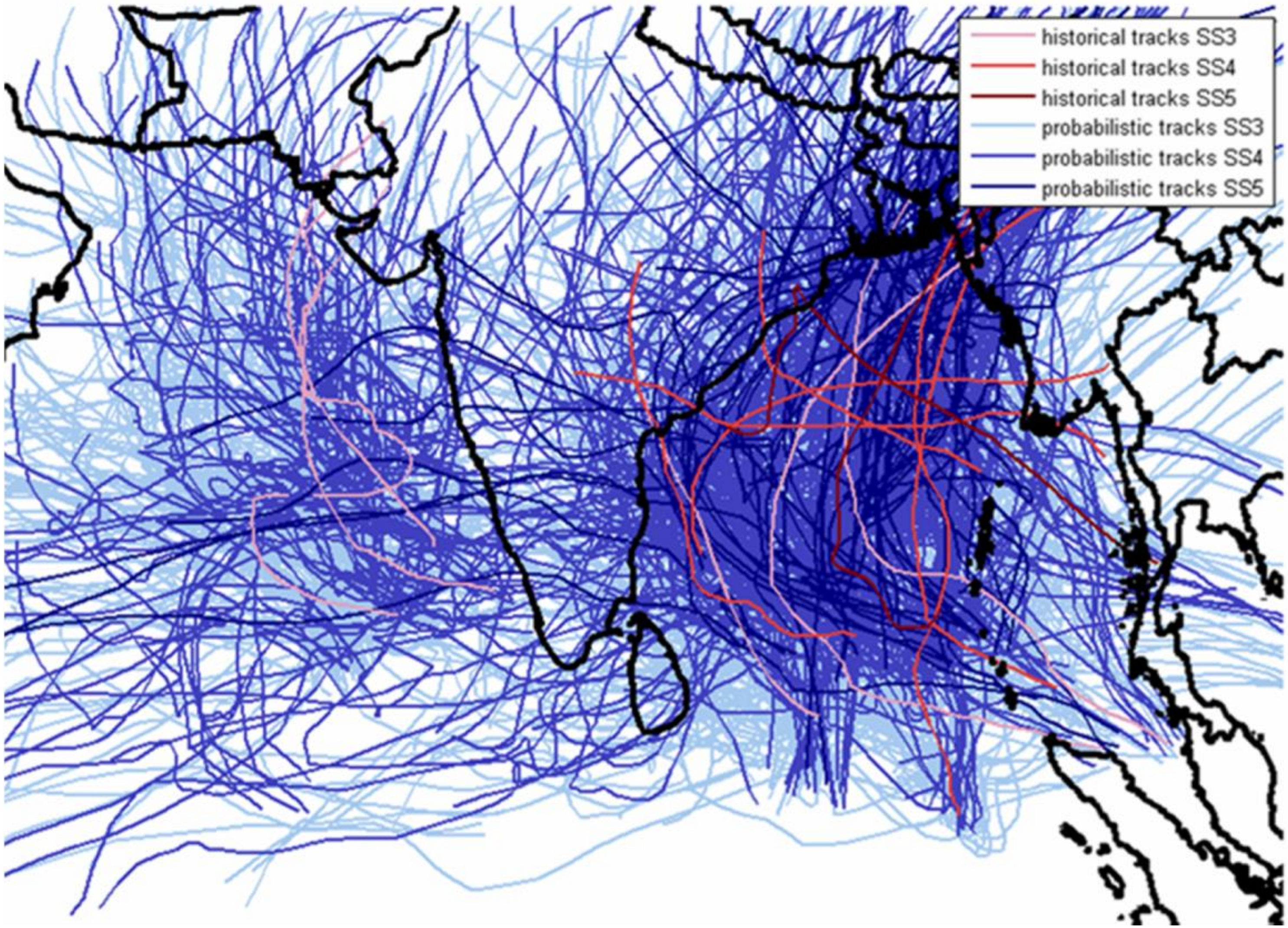
results in

Convoluted Distribution

Understanding the hazard – how strong



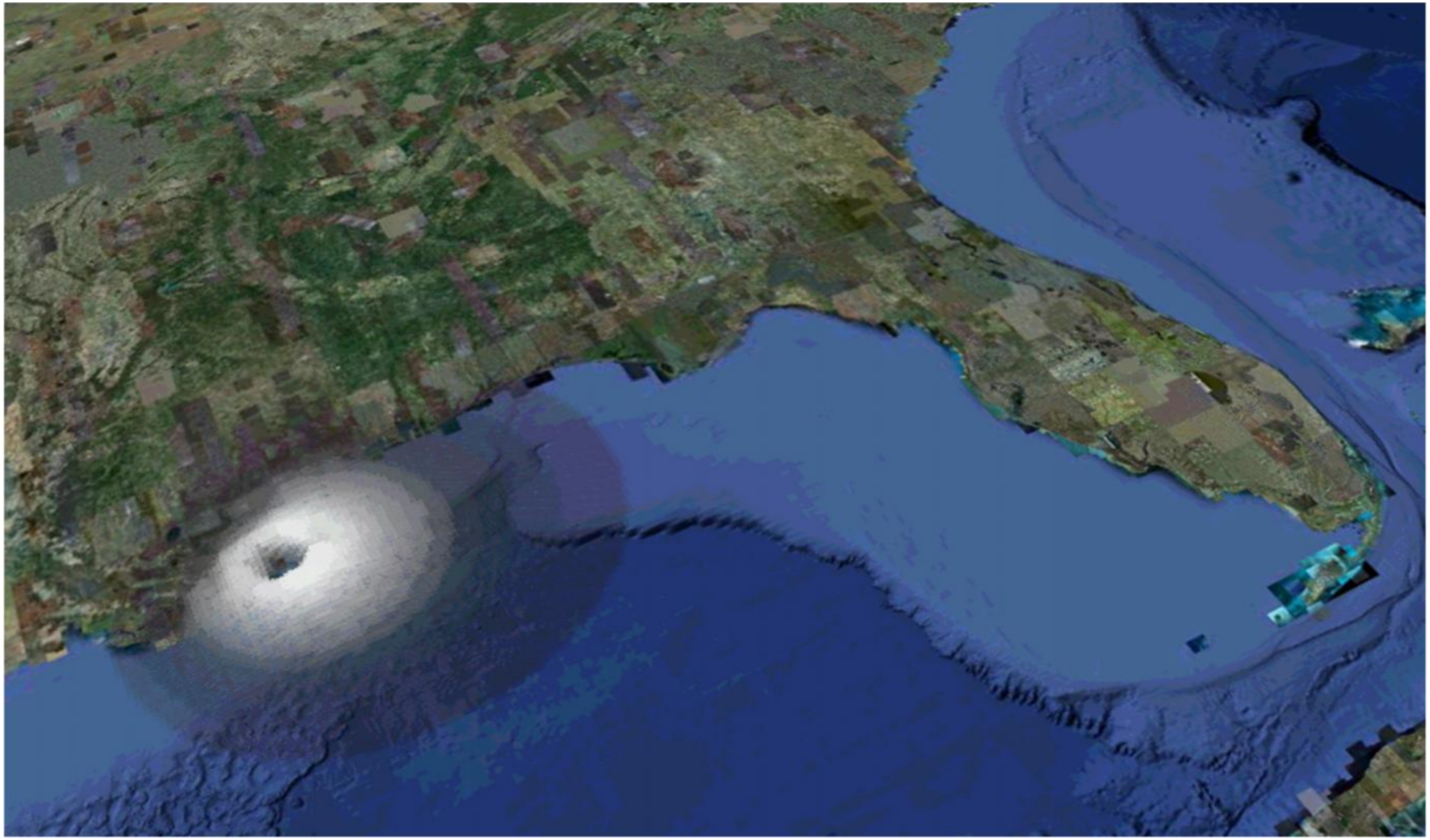
Tropical cyclones in the Indian ocean



historic
~ 25 years

probabilistic
~ 5'000 years

Windfield – a rendering



Damage calculation (1/2)

The damage is calculated for each single asset at each location for each scenario or *event*, so basically damage = value * damage function (see below), looped over assets and events

$$\text{damage} = \text{asset value} * \underbrace{\text{MDD} * \text{PAA}}_{\text{damage function}}$$

- damage is the damage 'from ground up', from the first dollar, so to speak
- asset value is the total value of the asset
- MDD is the **M**ean **D**amage **D**egree (the damage for a given intensity at an affected asset) - how strongly an asset is damaged. Range 0..1 (from none to total destruction)
- PAA is the **P**ercentage of **A**ssets **A**ffected (the percentage of assets affected for a given hazard intensity) - how many assets are affected. Range 0..1 (from none affected to all affected)

Damage calculation (2/2)

So far, the hazard intensity did not show up in the calculation, did we miss something? Well, the damage is a function of the hazard intensity, hence:

MDD = f(hazard intensity)

PAA = f(hazard intensity)

where hazard intensity is the hazard's intensity at each asset for each event. Since the damage also depends on the asset type, we have in fact:

MDD = f(hazard intensity, asset type)

PAA = f(hazard intensity, asset type)

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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

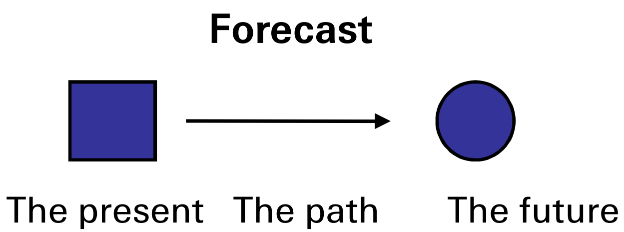
- Types of scenarios: hazard, impact, emissions,…
- ‘Realistic scenarios’ as opposed to sensitivity tests, physics tests, idealized scenarios
- Scenarios should be plausible, self consistent, broad. They can be used to explore response of system, identify important drivers
- Scenarios do not necessarily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

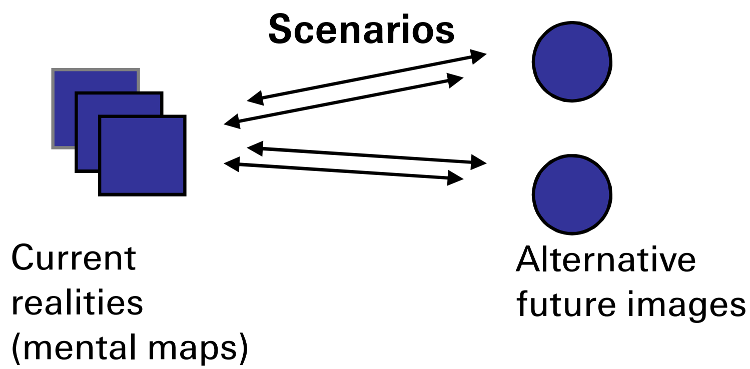
Forecast

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

Scenario

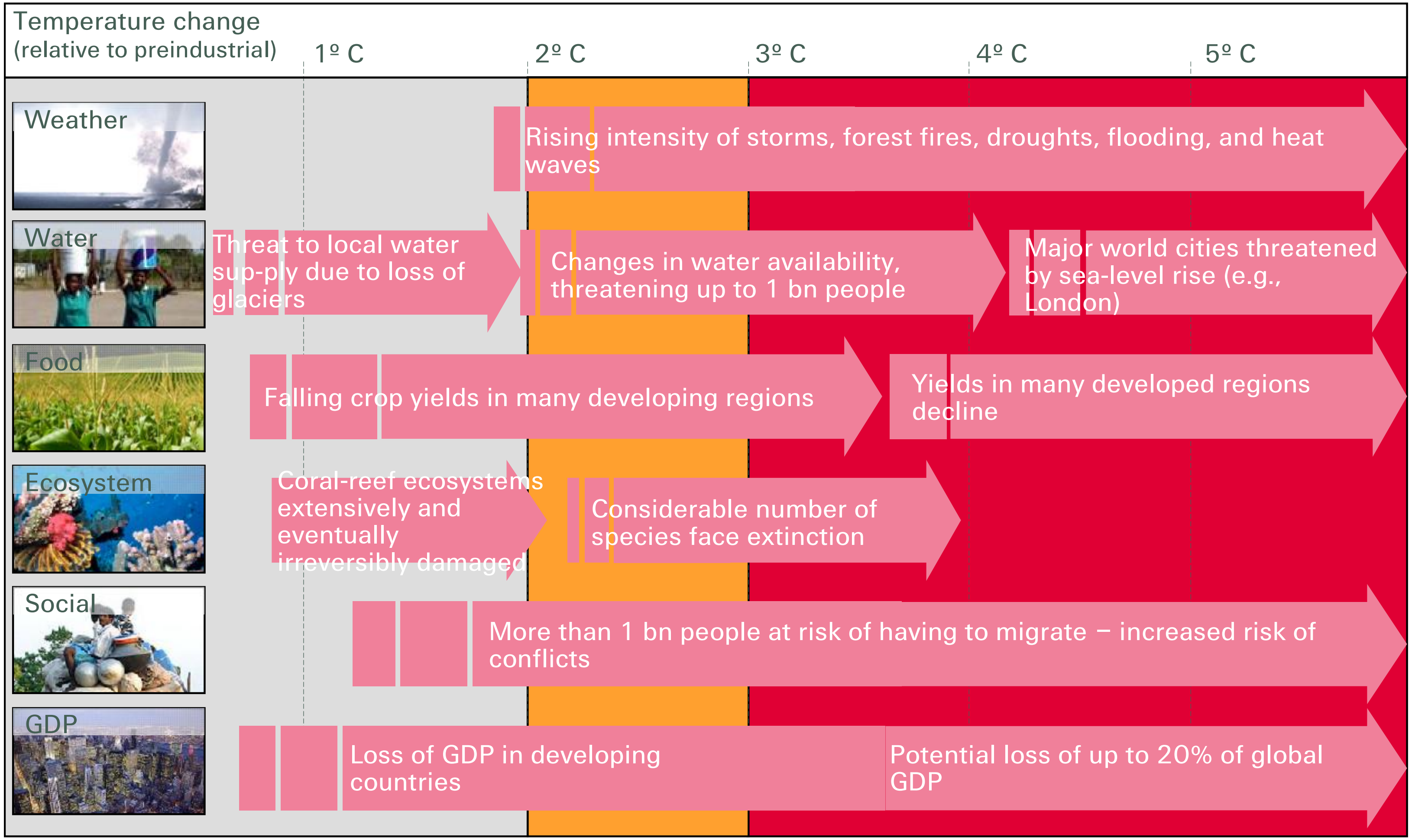
- Focuses on uncertainties, legitimizes recognition of uncertainties
- Clarifies risk
- Results in adaptive understanding
- Diversity of interpretations
- Qualitative > quantitative





Climate impacts

Scenario A1B
IPCC AR4 worst-case scenarios



Source: Stern Review; IPCC

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

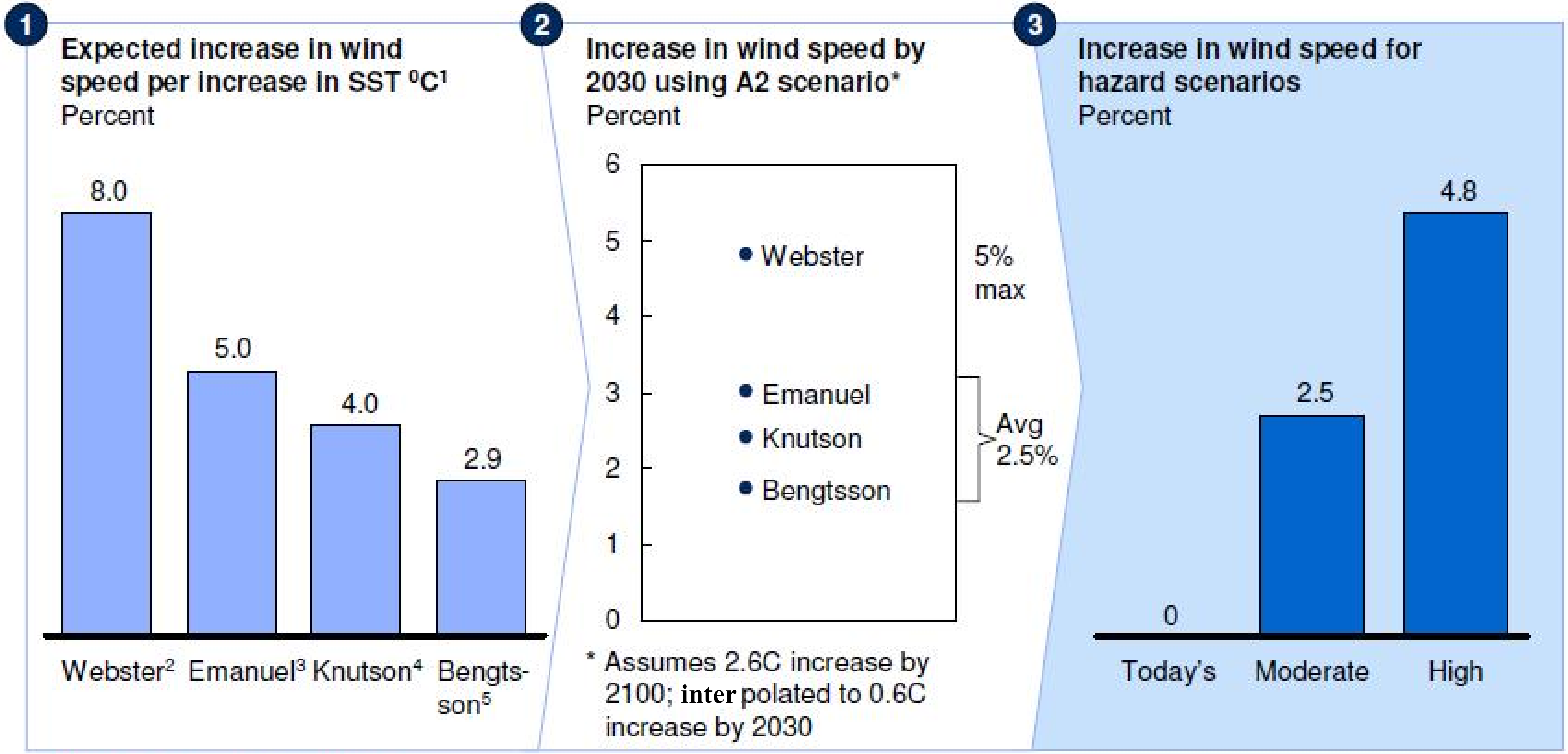
Parameterized impact: TC Florida case study (1/3)

Hazards	Impact	Comments
Hurricane		• Hurricane damage likely to increase with climate warming • Primary cause of flooding and responsible for the majority of hazard induced damages
Sea level rise		• 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		• 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)

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

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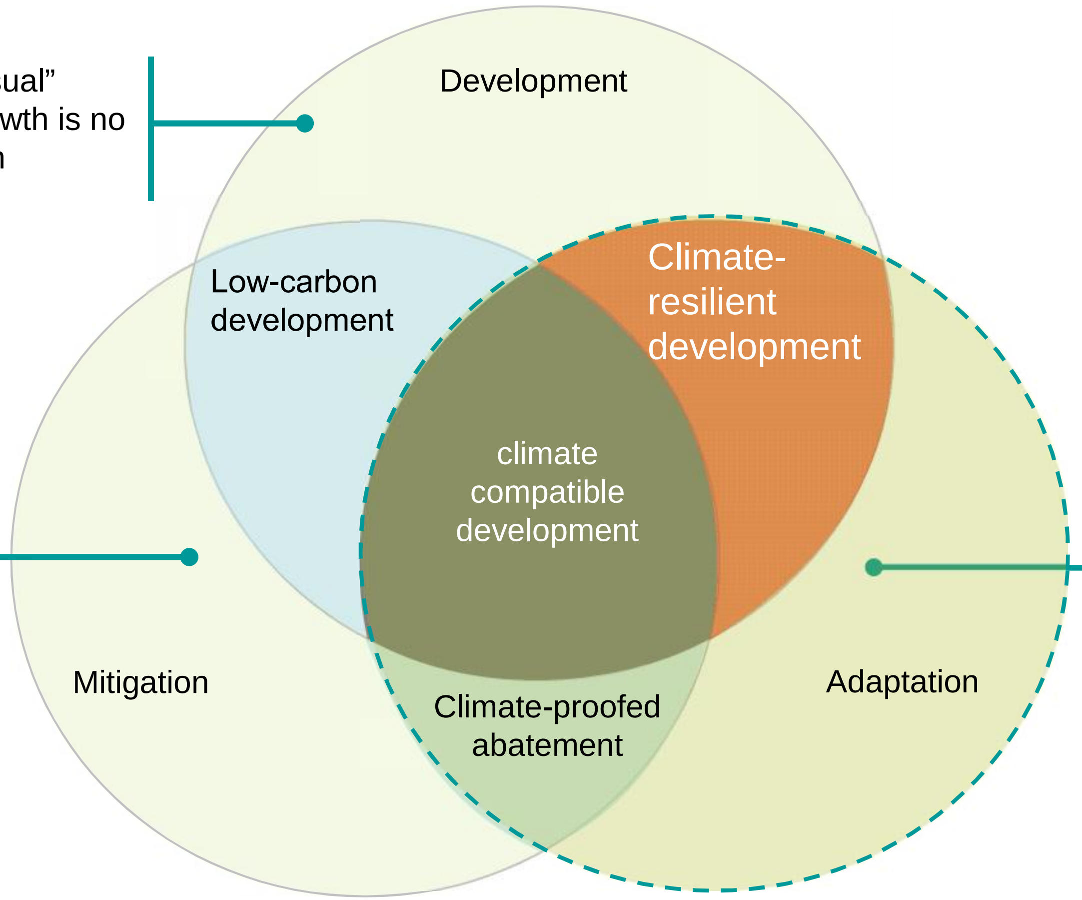
Climate-compatible development requires both mitigation and adaptation

"Business as usual" high-carbon growth is no longer an option

Mitigation is aligning with the broader development agenda as people accept that high-carbon growth is unsustainable



Adaptation will require incremental funds beyond business as usual; adaptation and development are often indiscernible

Climate-resilient development
Economics of climate adaptation

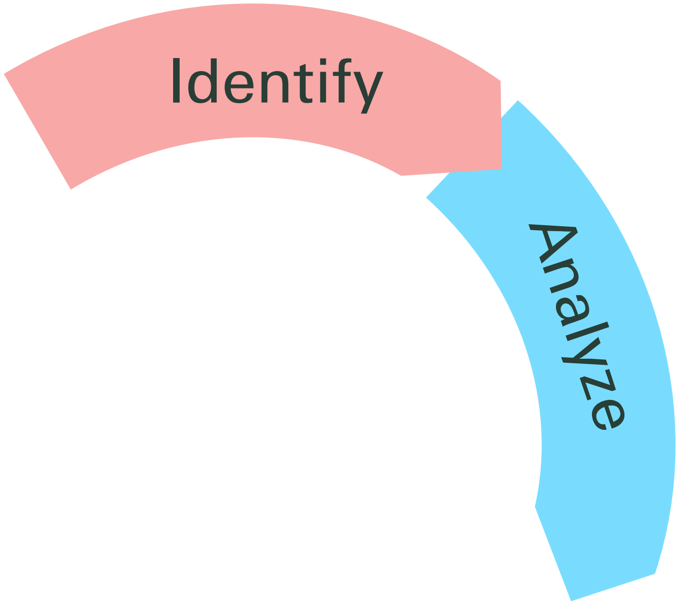
Objectives

- Provide decision makers with the facts and methods necessary to design and execute a climate adaptation strategy
- Supply financial institutions, potential funders and insurers with the information required to unlock and deepen global adaptation finance and risk transfer markets

Key features of the methodology:

- Follow a rigorous risk management approach to assess ***local* total climate risk**, the sum of
  - today's climate risk,
  - the economic development paths that might put greater population and value at risk (→ projection)
  - the additional risks presented by climate change (→ scenarios)
- Propose and prioritize a basket of adaptation measures to address total climate risk on an economic basis

Recap: Risk Management Cycle



Climate-resilient development – the methodology

Identify → Analyze

Where and from what is the region most at risk?

What is the magnitude of the expected loss?

Map of areas at risk

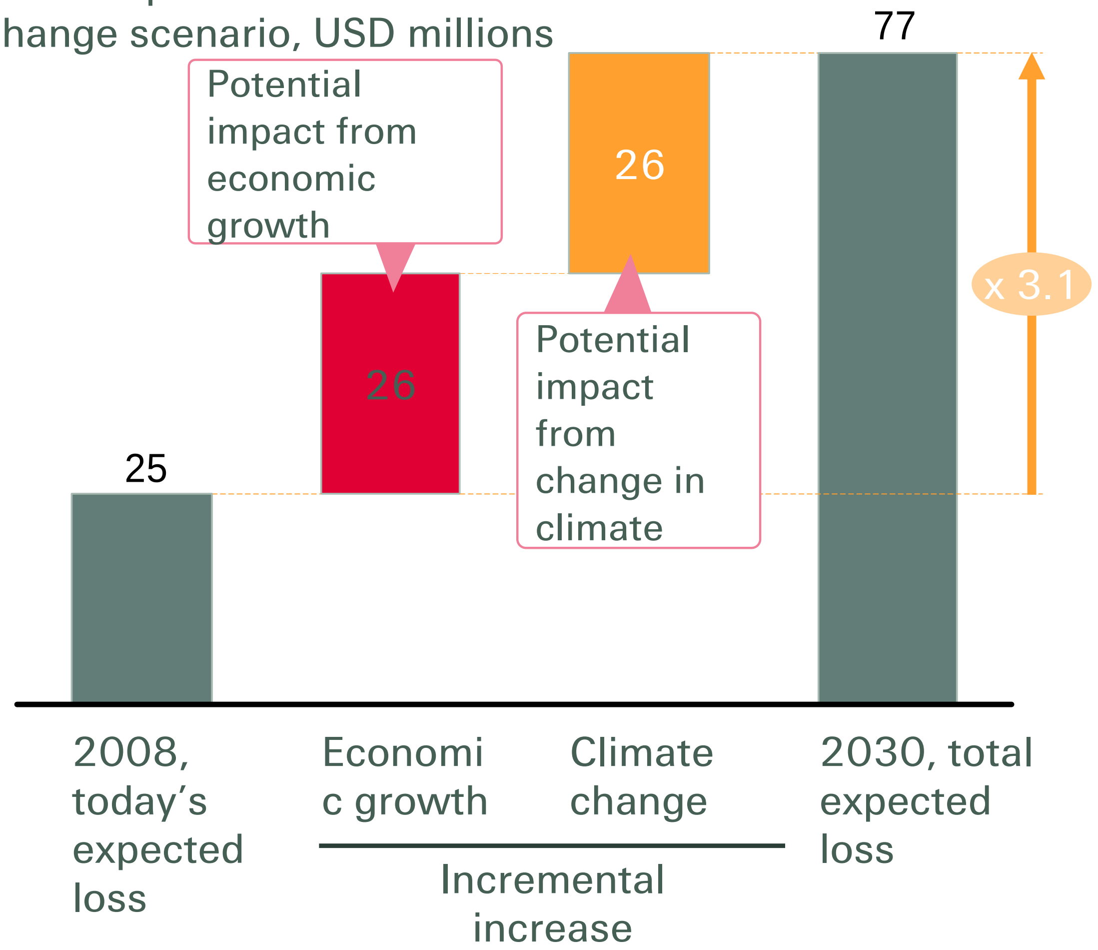
- Identify most relevant hazard(s) in case location
- Identify areas that are most at-risk, by overlaying hazard(s) on:
  - Population
  - Economic value (GDP)

Estimate of potential loss

- Hazard: Develop frequency and severity scenarios
- Assets: Quantify assets and income value in area at risk
- Vulnerability: Determine vulnerability of assets and incomes to the hazard

Total climate risk
Case study Samoa

Expected loss from exposure to climate
High climate change scenario, USD millions



Source: ECA group

Total climate risk – the recipe

1. Calculate risk today: run the model with today's hazard and today's assets
2. Calculate economic growth impact: run the model with today's hazard and future assets
   → difference 2) minus 1) gives you potential impact of economic growth
3. Calculate climate change impact: run the model with climate change scenario hazard and future assets
   → difference 3) minus 2) gives you potential impact of climate change

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Discounting – basics (1/2)

- All consideration are net of inflation, means all future costs and benefits expressed in terms of the amount they could purchase at today's prices. If we expect 3% inflation next year, then $103 at next year's prices has the same purchasing power as $100 at today's prices. So we can refer to it as $100 in 'real' or inflation-adjusted dollars (or any other currency).
- Is it better to receive $100 today or to receive $100 in the future?
→ clearly better to receive $100 today and to put it into a bank account. At say 2% interest, you will possess $122 [$=100*(1+0.02)^{10}$] in ten years from now. Or you only need to put $82 into the bank today to receive $100 in ten years [$=100/(1+0.02)^{10}$]. In the jargon of economics,
$82 today is the <u>present value</u> of 100$ to be received ten years from now, at a <u>discount rate</u> of 2%.
- The present value is the amount you would have to put in a bank account today, earning interest at discount rate, to end up with the target amount at the specified time in the future.

Discounting – present value (2/2)

- All compound interest and discounting examples in this course are based on annual compounding calculations. Compounding over different time periods or continuous-time calculations as in formal economic theory, produce different numbers, but support the same qualitative conclusions.
- Formally speaking: *FV* denotes the future value, *PV* the present value, *n* years at interest *i*:

$$FV = PV(1+i)^n \qquad PV = \frac{FV}{(1+i)^n}$$

- and hence:

$$i = \left(\frac{FV}{PV}\right)^{\frac{1}{n}} - 1 \qquad n = \frac{\log(FV) - \log(PV)}{\log(1+i)}$$

see e.g. http://en.wikipedia.org/wiki/Compound_interest

Discounting – continuous compounding (add)

- With *A(t)* denoting the initial amount A_0 after time *t* at annual interest *r* compounded *n* times per year (for *n*=1: same as before):

$$A(t) = A_0 \left(1 + \frac{r}{n}\right)^{nt}$$

- continuous compounding can be thought as making the compounding period infinitesimally small; therefore achieved by taking the limit of *n* to infinity (see definition of the exponential function for the mathematical proof of this limit):

$$a(t) = \lim_{n \to \infty} \left(1 + \frac{r}{n}\right)^{nt}$$

$$a(t) = e^{rt}$$

- and therefore $A(t)=A_0e^{rt}$ with the link to the effective interested rate (used in this course) as $i=e^r-1$, difference for $r<5\%$ smaller than errors in assumption of *r* (e.g. *r=10.00%, i=10.52%*)

see e.g. http://en.wikipedia.org/wiki/Compound_interest

Costs and benefits (1/5)

- Net present value calculations are used to compare amounts paid (costs) and received (benefits) in different years.
- A project is economically viable (attractive), if the net present value of benefits exceeds the net present value of costs, or cost-benefit ratio <1
- E.g. an investment of $100 in 2013, leading to a benefit of $123 in ten years time is perceived as attractive (cost-benefit ratio <1) if an interest rate of 2% is assumed (PV of $123 at 2% equals $101). Note that this is only true if you have no other option to invest at a better rate than 2% - and obviously crucially dependent on the assumption about the interest rate.
- In most cases, one deals with cost and benefit streams or patterns over years. Hence one needs to discount (complex) payment patterns – and often with a time-dependent yield curve (the key reason for the success of Excel)

Costs and benefits – example 1 (2/5)

A simple example shall illustrate this:

- Let's assume we expect a climate-related loss of 20 mio CHF by 2023 and hence evaluate the option to invest in prevention (the cost) starting 2013 in order to avert the loss (the *benefit*).
- Let's further assume the preventive measure be a dam to be built in 2013 (at a *cost* of 10 mio CHF) and recurring maintenance costs of 1 mio CHF every second year.
- Is it worth building the dam?
- No discounting, cost: dam, benefit: averted loss, in mio CHF:

interest	0%	year										
	NPV	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
cost	15	10		1		1		1		1		1
benefit	20											20
cost/benefit	0.75											

Costs and benefits – example 2 (3/5)

- at 2% discount rate:

interest	2%	year										
	NPV	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
cost	14.45	10		1		1		1		1		1
benefit	16.41											20
cost/benefit	0.88											

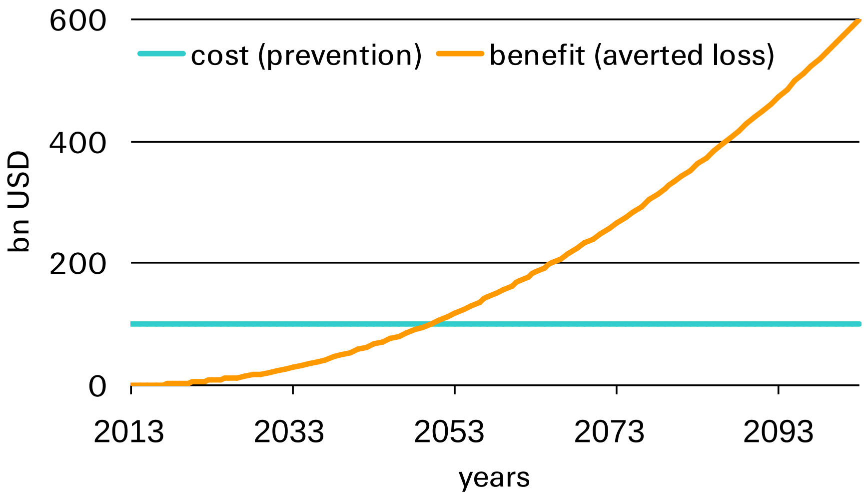
$$\text{cost}=10+\underbrace{0/(1+2\%)}_{2013}+\underbrace{1/(1+2\%)^2}_{2014}+\underbrace{0/(1+2\%)^3}_{2015}+\underbrace{1/(1+2\%)^4}_{2016}\ldots$$

- at 5% discount rate:

interest	5%	year										
	NPV	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
cost	13.77	10		1		1		1		1		1
benefit	12.28											20
cost/benefit	1.12											

Costs and benefits – climate policy example (4/5)

The benefits of climate policy (averted loss) start out small but grow faster and faster over time, while costs begin immediately but do not rise as rapidly, if at all (illustrative example):



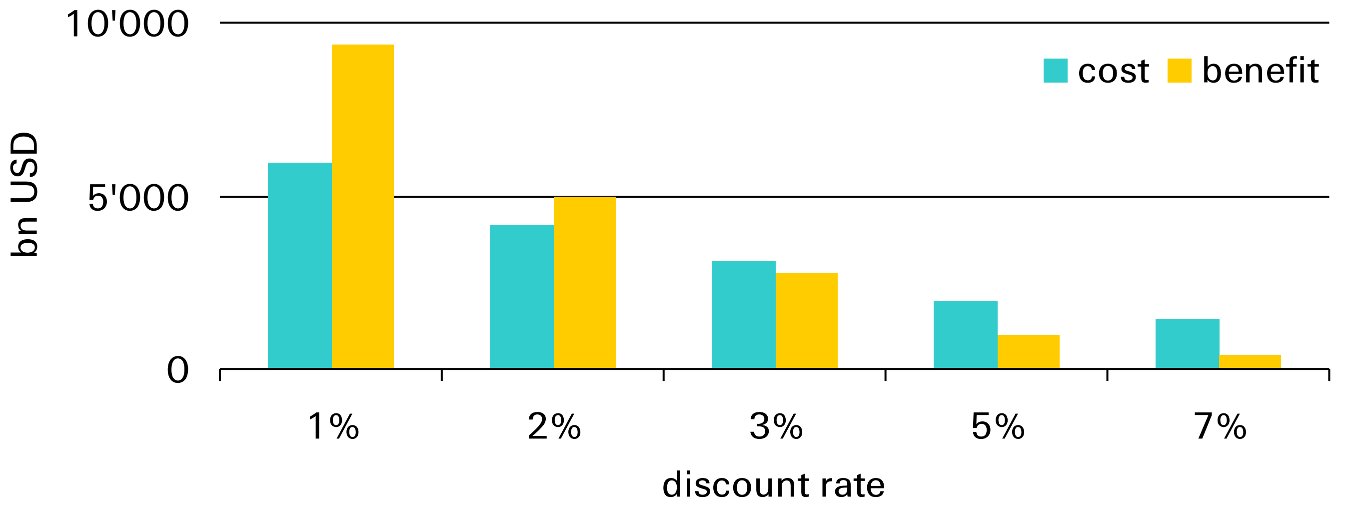
unbound losses
→ see exercise

Costs exceed benefits for the first 40 years, but benefits (averted losses) rise rapidly thereafter. In 60 years time, losses are already twice as big as prevention costs. Do the cumulative benefits (averted losses) exceed cumulative costs?

Source: F. Ackerman, 2009: Can we afford the future, ZED book, New York

Costs and benefits – climate policy example (5/5)

The balance between costs and benefits depends entirely on the discount rate. The policy (to finance prevention) is a bargain at a 1% discount rate, the present value of 90 years of benefits (averted costs) is about 50% greater than the present value of the corresponding costs.



At 3% discount rate, the balance has tipped in the opposite direction, present value of benefits being just a little less than the costs. And at 5%, the policy is not worth implementing, with benefits only half the costs. (but!)

Source: F. Ackerman, 2009: Can we afford the future, ZED book, New York

Discount rates (1/4)

There exist two broad families of theories about the discount rate:

- Descriptive approach
  - Discount rate should be equal to market interest rate, or the rate of return on financial investments
  - This approach advocates that climate investments should be made on the same basis as any other investments
- Prescriptive approach
  - Builds up the discount rate from first principles, based on two separate motives for discounting:
    - expected upward trend in income and wealth
    - pure time preference
  - This approach is more open to consideration of the complexity of climate investments

Source: F. Ackerman, 2009: Can we afford the future, ZED book, New York

Discount rates – descriptive approach (2/4)

There exist different version of descriptive approaches:

- Based on stock market long-term average return 5-7%
  → for climate policy the game is over before it starts
  (see previous example) – But: the stock market is only one market
- Based on government bonds: In order to achieve rates as high as 5-7%, one has to make risky investments. The rate of return on risk-free investments, such as government bonds, is much lower, averaging 1% or less above the rate of inflation.

Climate protection

- is most valuable (needed) when things turn badly (like insurance), and less in need when things go well, when one can deal with ups and downs of normal (stock-)market risk.
- is a risk-reducing investment, hence <u>the risk-free rate of return is more appropriate, of the order of 1%</u>

Source: F. Ackerman, 2009: Can we afford the future, ZED book, New York

Discount rates – prescriptive approach (3/4)

The prescriptive approach is based on two (separate) motives:

- expected upward trend in income and wealth: If future generations will be much richer then we are, they will need less help from us. So we can discount benefits that will flow to our wealthy descendants, on a rate based on expected growth of per capita incomes.
  - Note: If future generations turned out to be poorer, they would need more help from us, hence discount rate would be less than zero. Economic models and theories, however, almost always assume that incomes will grow – among economists, the income-related motive for discounting may be the least controversial part of the picture.
- pure time preference: the rate that would apply if all generations had the same per capita income. Time preference exists, since:
  - People prefer money now to money later, the psychological argument
  - The human race might not survive for ever. If there is a tiny probability of extinction (Stern's guess: 1‰), there should be a tiny contribution to the rate of pure time preference.

Source: F. Ackerman, 2009: Can we afford the future, ZED book, New York

Discount rates – Stern's approach (4/4)

Following the prescriptive approach

- expected upward trend in income and wealth:
  1.3% long-term average growth of per capita income.
- pure time preference:
  - Stern reviewed and endorsed the philosophical arguments for viewing all generations as people of equal worth, deserving equal rights and living conditions. As he states "if you care little about future generations you will care little about climate change. As we have argued that is not a position which has much foundation in ethics".
  - Stern observed that a natural or man-made disaster could destroy the human race. He arbitrarily assumed the probability of such a disaster to be 0.1% per year, and set pure time preference at that rate.
- <u>Stern's discount rate: 1.4%</u> (=1.3%+0.1%)
- Much lower than the rates used in traditional climate economics models

Source: Stern review, 2006

The (im)morality of discounting

- Investing 100$ now in a project that pays 300$ ten years from now is a financial success: it is equivalent to an annual rate of return of more than 11%.
- A policy that kills 100 people now in order to save 300 other lives ten years from now is not equally successful: there is no way to compensate the 100 people who paid the initial cost.
- The discussion of values without prices has a long history[1]: “Some things have a price, or relative worth, while other things have a dignity, or inner worth”.
- No price tag does justice to the dignity of human life or the natural world. Since some of the most important benefits of climate protection are priceless, any monetary value for total benefits will necessarily be incomplete.

Source: [1]Immanuel Kant, 1785: Grundlegung zur Metaphysik der Sitten. F. Ackerman, 2009: Can we afford the future, ZED book, New York

Block 2

- Climate change and impacts, scenarios, use of scenarios
  10'
- Total climate risk
  10'
- Basics of economic evaluation and economic decision making in the context of total climate risk
  20'
- The cost of adaptation - application of economic decision making to climate adaptation → adaptation cost curve
  20'
- Q&A
  15'

Climate-resilient development
Economics of climate adaptation

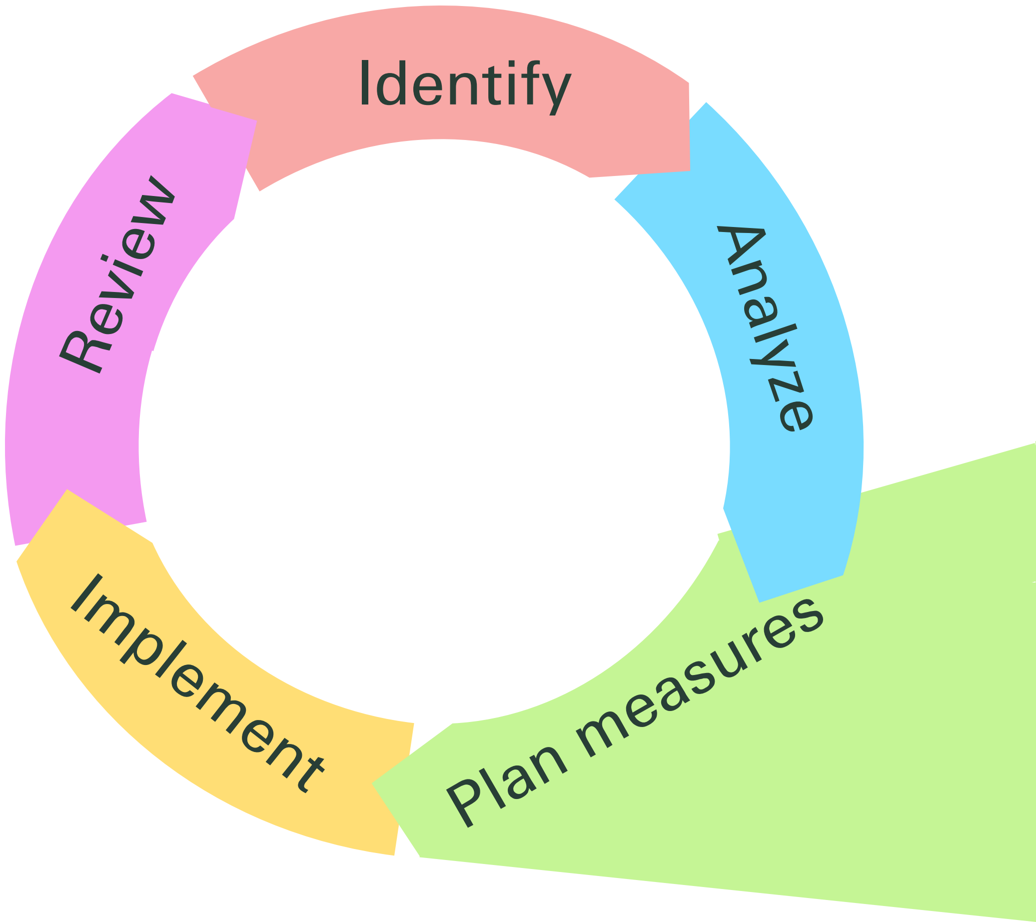
Objectives

- Provide decision makers with the facts and methods necessary to design and execute a climate adaptation strategy
- Supply financial institutions, potential funders and insurers with the information required to unlock and deepen global adaptation finance and risk transfer markets

Key features of the methodology:

- Follow a rigorous risk management approach to assess ***local* total climate risk**, the sum of
  - today's climate risk,
  - the economic development paths that might put greater population and value at risk (→ projection)
  - the additional risks presented by climate change (→ scenarios)
- Propose and prioritize a basket of adaptation measures to address total climate risk on an economic basis

Recap: Risk Management Cycle



Options:

- Avoid
- Reduce
- Prevent
- Transfer
- Retain

Climate-resilient development – the methodology

Identify → Analyze → Plan measures → Implement

Where and from what is the region most at risk?

What is the magnitude of the expected loss?

What measures should be considered?

How can measures be implemented?

Input into adaptation strategy

Map of areas at risk

- Identify most relevant hazard(s) in case location
- Identify areas that are most at-risk, by overlaying hazard(s) on:
  - Population
  - Economic value (GDP)

Estimate of potential loss

- Hazard: Develop frequency and severity scenarios
- Assets: Quantify assets and income value in area at risk
- Vulnerability: Determine vulnerability of assets and incomes to the hazard

Set of adaptation measures

- Identify potential adaptation measures
- Determine societal costs and benefits and basic feasibility
  - Interviews with experts
  - Economic analysis

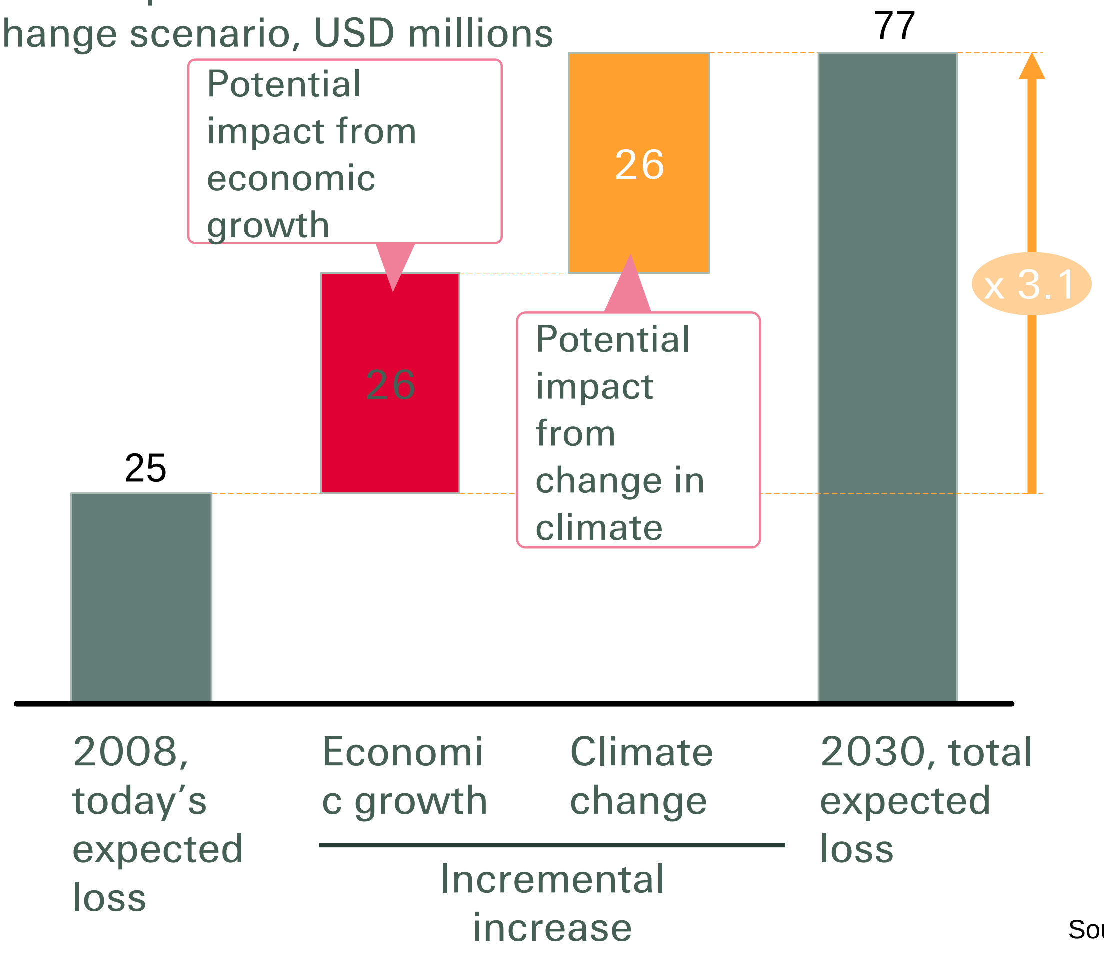
Implementation assessment

- Assess current progress against the measures
- Understand requirements to implementation
- Determine actions required to implement measures

Total climate risk

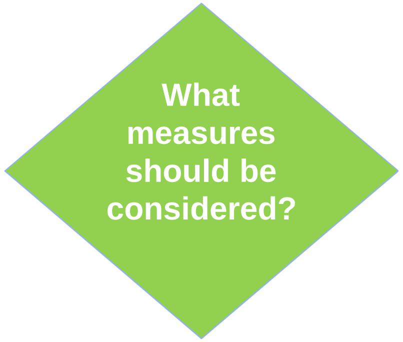
Case study Samoa

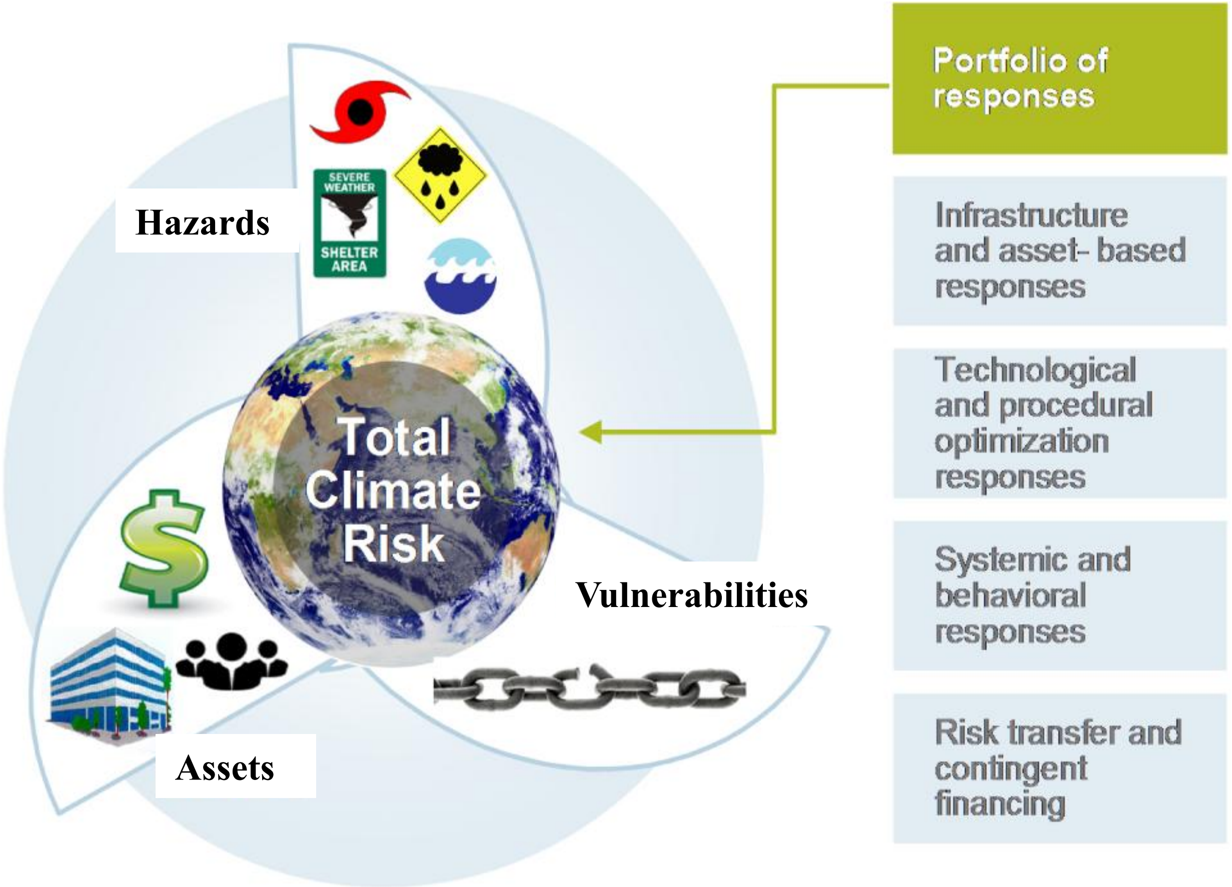
Expected loss from exposure to climate
High climate change scenario, USD millions



Source: ECA group

Basket of adaptation measures (or options)





Cost/benefit calculation of adaptation measures (1/3)

1. Determine the **discount rate**
   - local government infrastructure-related decision discount rates Given e.g. 2030 timeframe, the government investment discount rate usually is preferred to a more long-term social discount
2. Gather cost, benefit and expected useful lifetime **data on each measure**
   - to prepare the bottom-up calculation of the present value of costs and benefits of implementing the measure. This includes:
     - up-front expenditures, operating costs (for example, labour and maintenance)
     - asset growth, extent of coverage or penetration (for example, the number of houses to be protected)
     - value of location, assuming both current and future use.

Cost/benefit calculation of adaptation measures (2/3)

3. Define the **scope** of the measure by determining the maximum potential of implementing the measure in the local context.
   - total costs and averted loss will depend on the extent of the measure's implementation.
4. Calculate **costs** of each measure. Based on the bottom-up assessment, we calculate:
   - capital expenditures (CAPEX, basically the investment)
   - operating expenditures (OPEX)
   - operating expenditure savings (OPEX savings) compared to current approach. If OPEX savings are available for the measure, a negative bar may appear on the adaptation cost curve.

Cost/benefit calculation of adaptation measures (3/3)

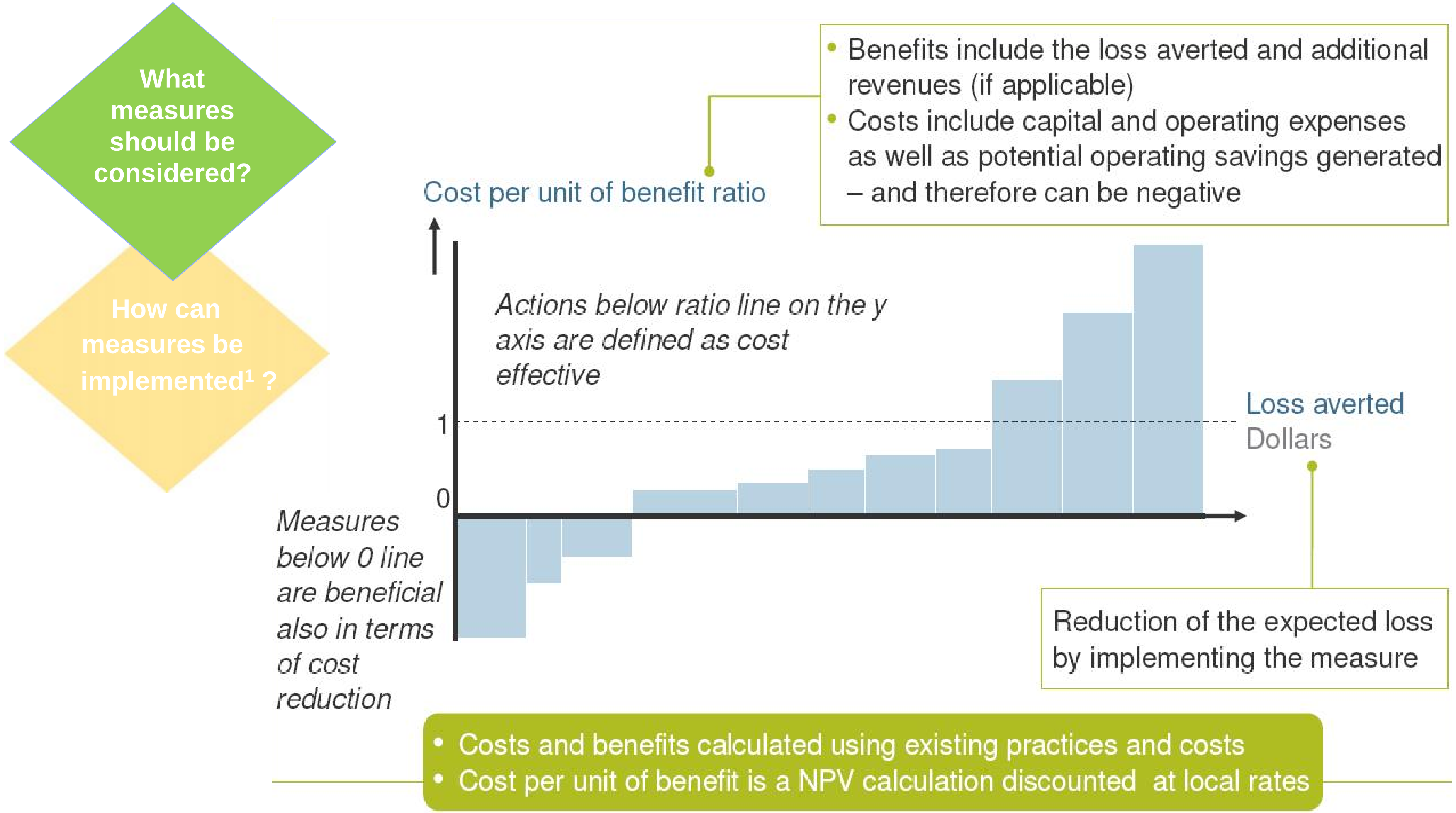
5. Calculate the benefits, i.e. the averted loss due to the specific measure

   - Perform **probabilistic total climate risk assessment** without and with measure → difference is averted loss

5. Determine if additional benefits from societal revenue upside is possible. In some cases, implementing an adaptation measure will have economic benefits in addition to reducing the loss from the climate risk.

6. Calculate cost-benefit ratio based on **net present value of the streams of costs and benefits over time** (including terminal value) in 2008 currency. This provides the y-axis location of the measure on the adaptation cost curve.

The adaptation cost curve

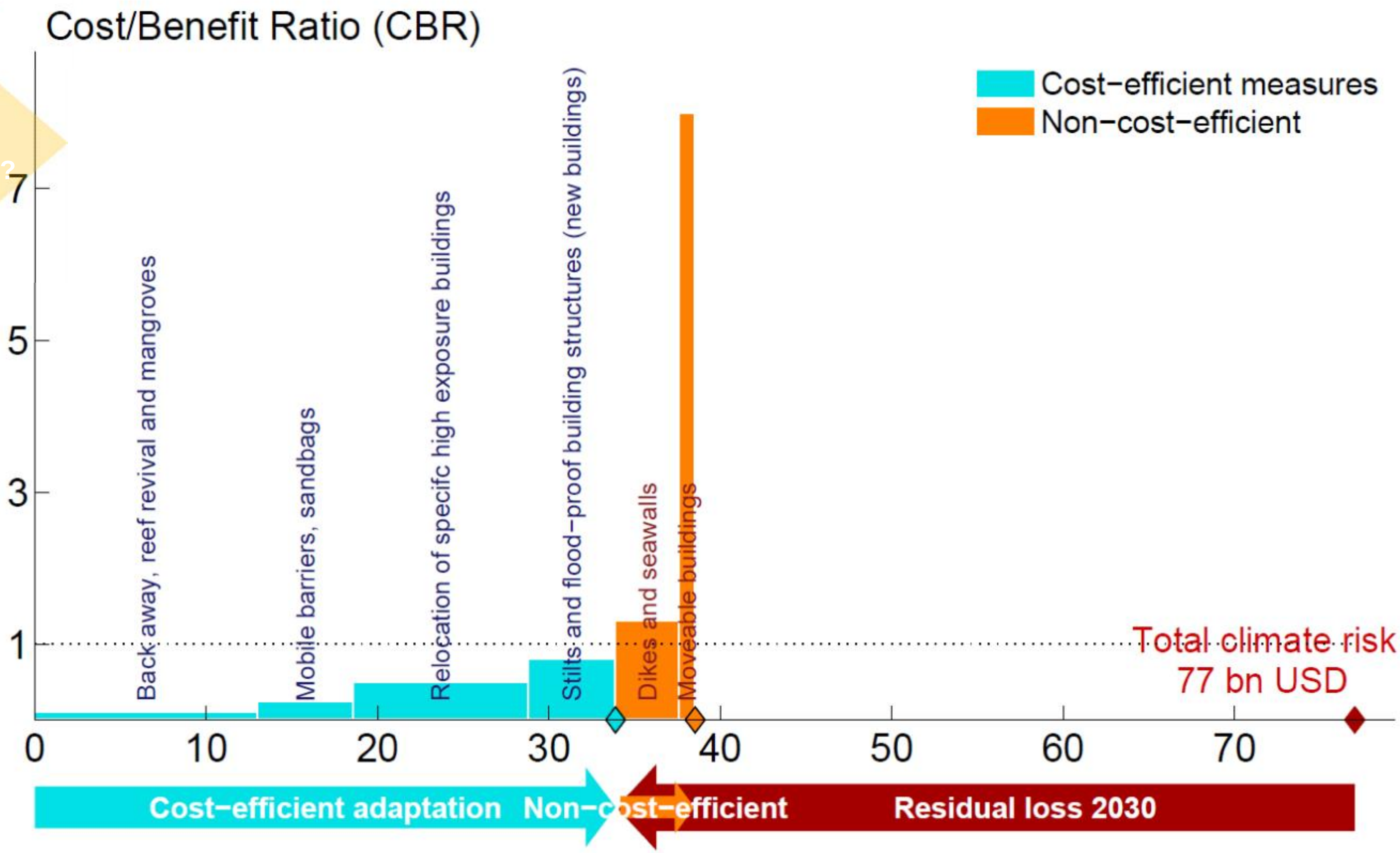


[1]The ‘how’ refers primarily to the sequence or priority and the financials, not the physical implementation

What measures should be considered?

How can measures be implemented[1] ?

Adaptation cost curve – Samoa case study

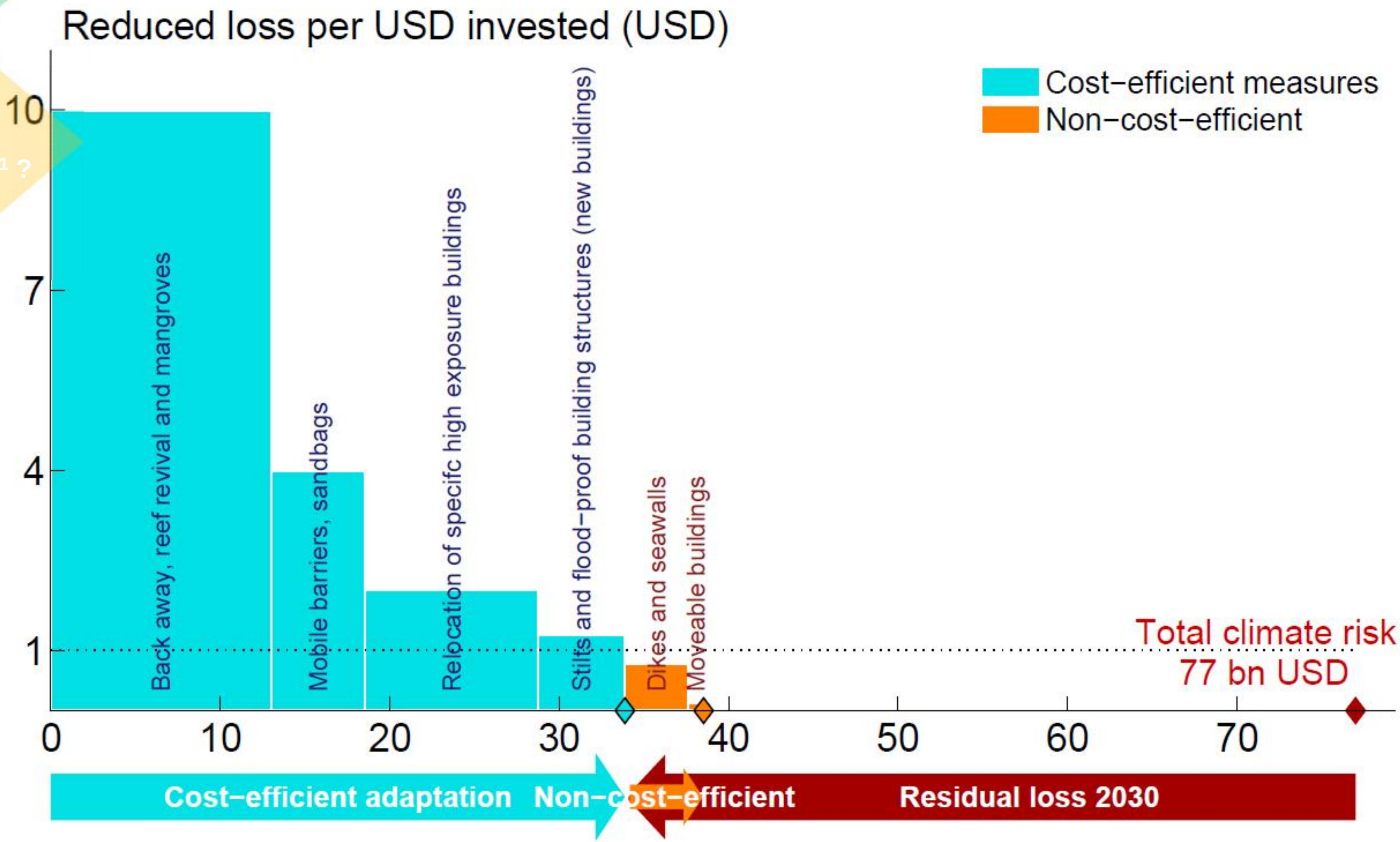


x-axis: Present value of averted loss (USD millions)

What measures should be considered?

How can measures be implemented[1] ?

Adaptation cost curve – Samoa case study



Adaptation cost curve – the recipe (one measure)

1. Calculate PV of costs of measure
2. Today (year 2013): assets, hazard as per 2013
    1. calculate annual expected loss with no measures
    2. calculate annual expected loss with measure applied

    → difference 2.1) minus 2.2) gives you benefit of measure today
3. Future (year 2030): assets, hazard as per 2030
    1. calculate annual expected loss with no measures
    2. calculate annual expected loss with measure applied

    → difference 3.1) minus 3.2) gives you future benefit of measure
4. Discount benefits → horizontal axis of adaptation cost curve
   compare with PV of costs → vertical axis of adaptation cost curve

See www.iac.ethz.ch/edu/courses/master/modules/climate_risk

For details, see: www.swissre.com/climatechange

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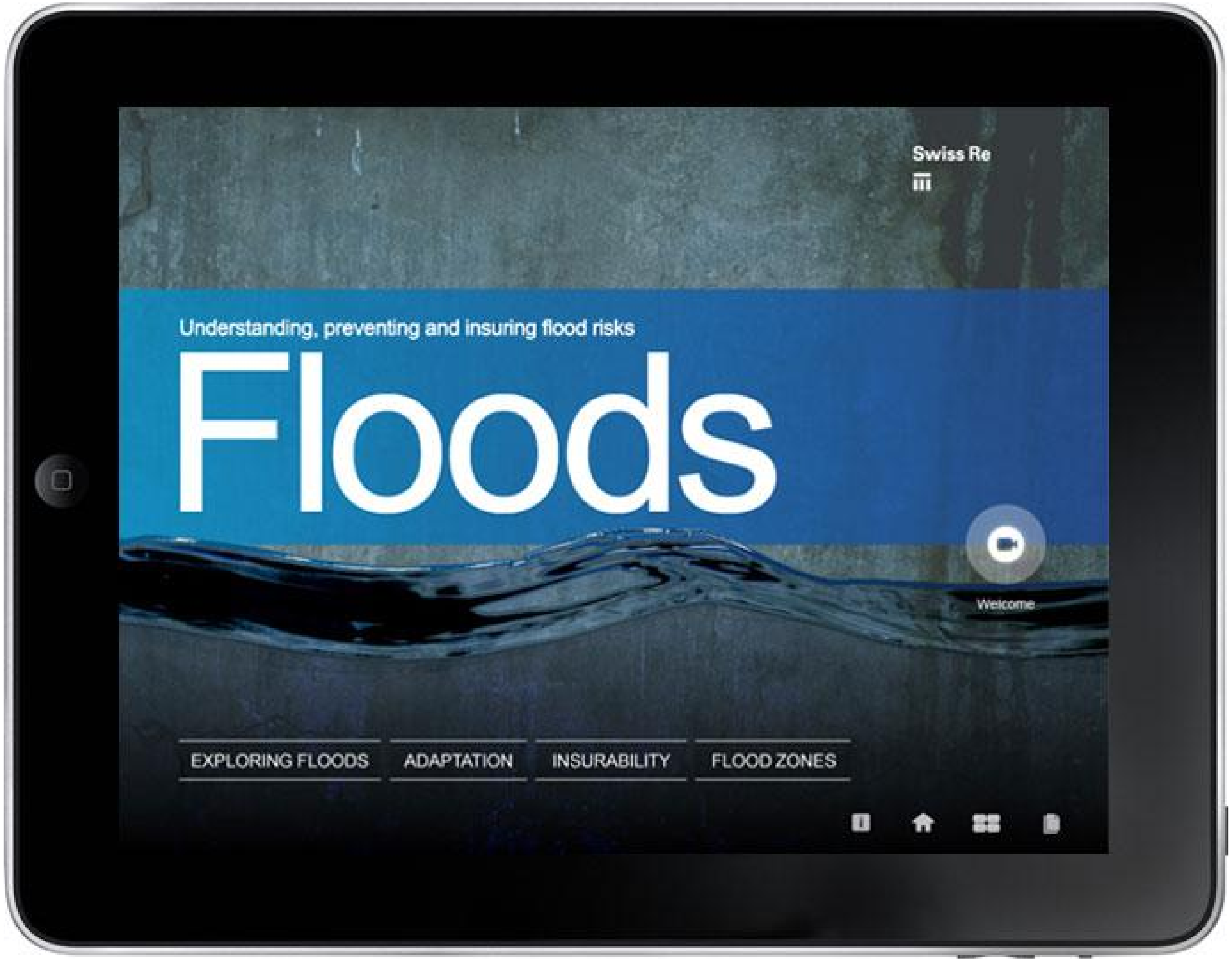

www.swissre.com/floodriskapp

50 out of 500 City Hotspots

Flood losses are on the rise and will become worse in the future. The lack of consistent flood hazard information in many countries is a blind spot that has led to bad surprises for the insurance industry. Closing the information gap is therefore key to strengthening flood preparedness and improving flood risk management.

Flooding exposure

Rotate the globe and tap a city for its info

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