WS3: Extremes and impacts: Design your own climate adaptation strategy – a practical application of open-source probabilistic damage modeling

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Inspired by/based on (explains the slide layout, too ;-)
"Climate Change Uncertainty and Risk: from Probabilistic Forecasts to Economics of Climate Adaptation", spring term lecture at ETH, by Reto Knutti, IAC ETH and David Bresch, Swiss Re.

All material available at https://github.com/davidnbresch/climada
Manual: https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf

About the workshop

Climate adaptation is an urgent priority for the custodians of national and local economies, such as finance ministers and mayors. Such decision makers ask: 1) What is the potential climate related damage to our economies and societies over the coming decades? 2) How much of that damage can we avert, with what measures? 3) What investment will be required to fund those measures - and will the benefits of that investment outweigh the costs?

Put yourself in the shoes of a local decision maker and gain hands-on experience with the economics of climate adaptation (ECA) methodology as implemented in the open-source climada tool (https://github.com/davidnbresch/climada). Working in small teams, this will enable you to understand the effect of weather and climate on an economy - and to identify actions to minimize that impact at lowest cost. It demonstrates how to integrate adaptation with economic development and sustainable growth.

Using state-of-the-art probabilistic modeling, we will estimate the expected economic damage as a measure of risk today, the incremental increase from economic growth and the further incremental increase due to climate change. We will then build a portfolio of adaptation measures, assessing the damage aversion potential and cost-benefit ratio for each measure. The resulting adaptation cost curve will help us compare results at the end of the workshop - which will conclude with a critique of the methodology.

Recommended reading

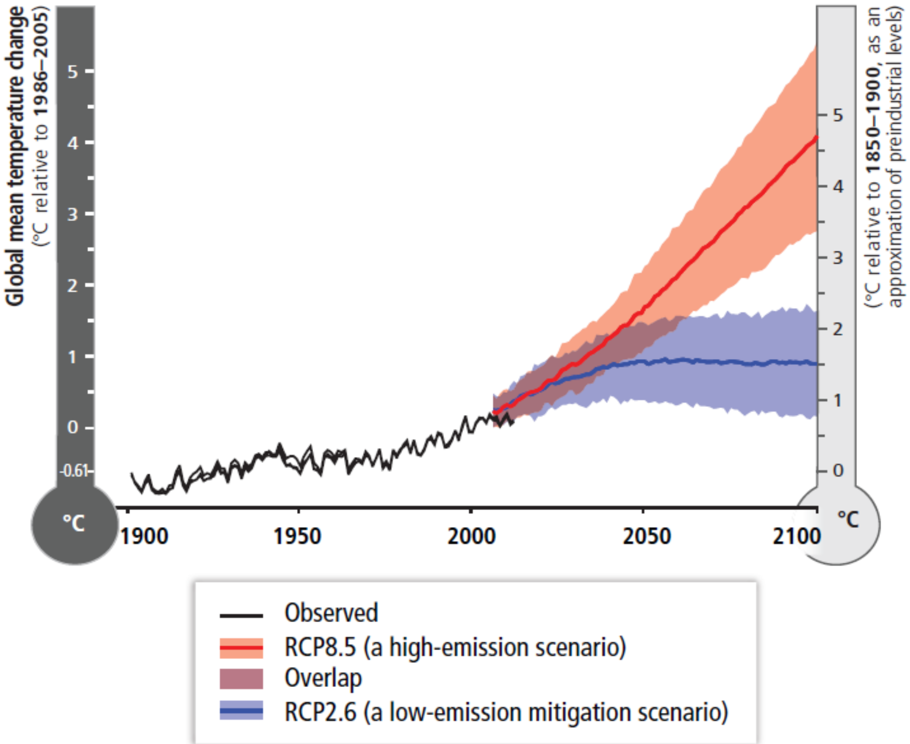
- The climate resilience story:
  http://media.swissre.com/documents/sigma1_2014_en.pdf#page=17
- Short introduction to the ECA methodology and global overview of case studies done so far:
  http://media.swissre.com/documents/Economics_of_Climate_Adaptation_focus_infrastructure.pdf
- Reference: the climada manual (and access to the full tool, ready to use with MATLAB or Octave): https://github.com/davidnbresch/climada/blob/master/docs/climada_manual.pdf

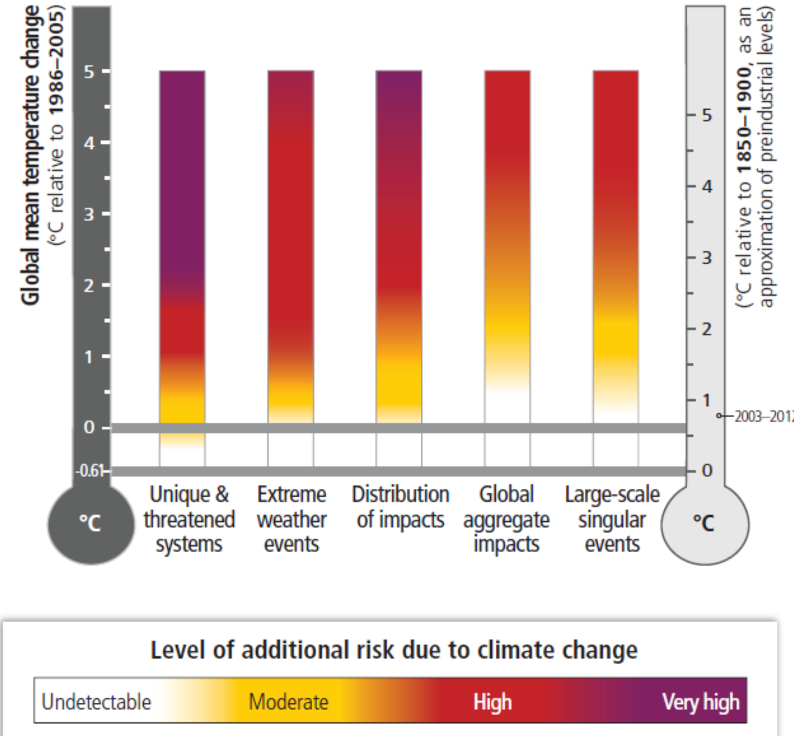
What this workshop aims to provide

- Climate adaptation: Different perspectives on the problem of understanding, quantifying and communicating probability, uncertainty and risk, and how to make decisions in their presence
- Opportunities to think about a problem, rather than providing a recipe for a solution
- Hands on experience with an operationally used open-source tool
- Opportunities for discussion

No worries, hands-on is less than 30 slides away

Global reasons for concerns



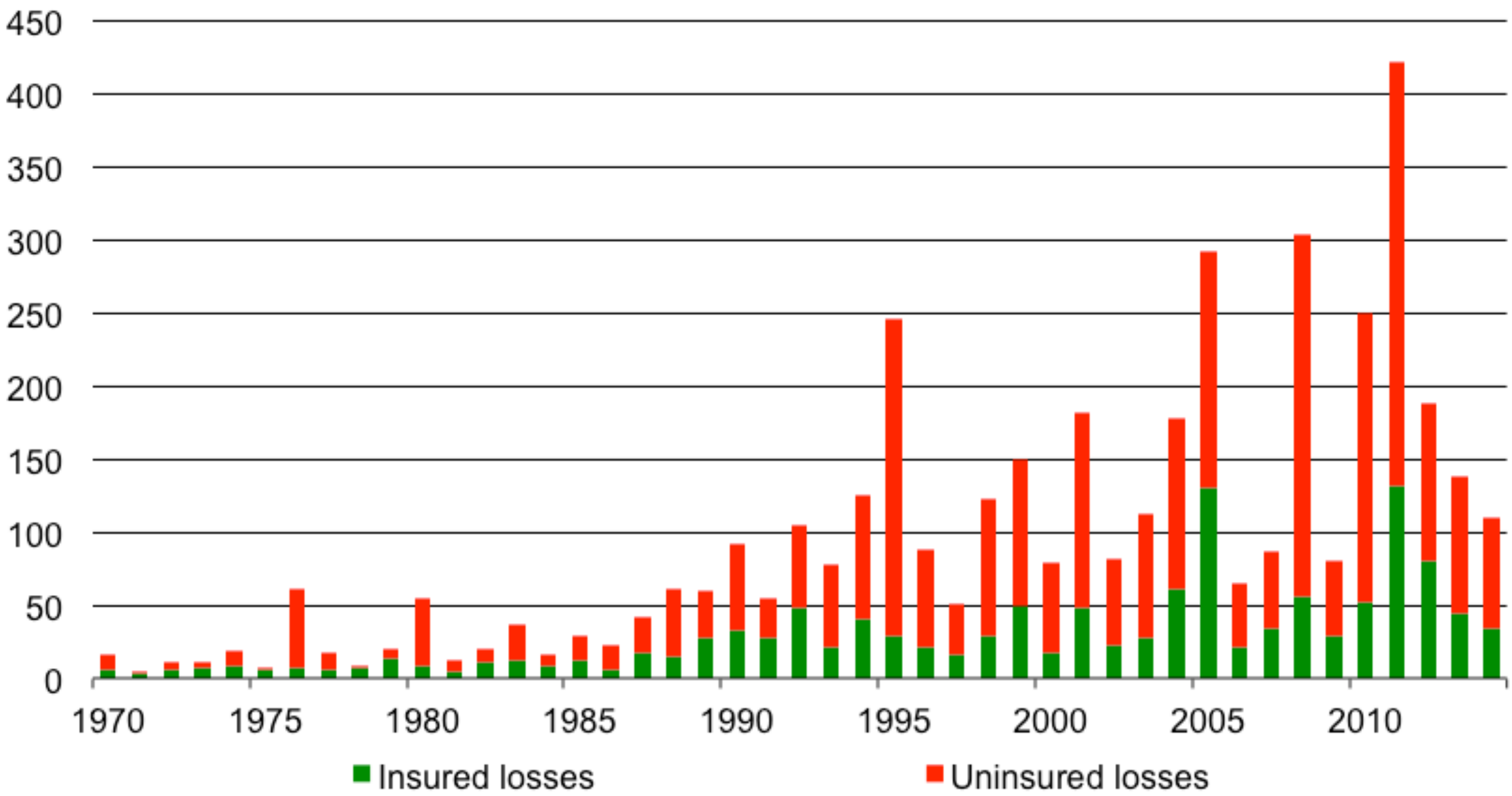


(Figure: IPCC AR5 WG2, 2014, Assessment Box SPM.1 Figure 1)

Natural catastrophe damages on the rise

and: Massive gap between economic and insured damage

Natural catastrophe damages 1970-2014, in USD billion



Note: Amounts indexed to 2014. Source: Swiss Re sigma catastrophe database, http://www.swissre.com/sigma/

Note on drivers

The upward trend in natural catastrophe damage is driven by:

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

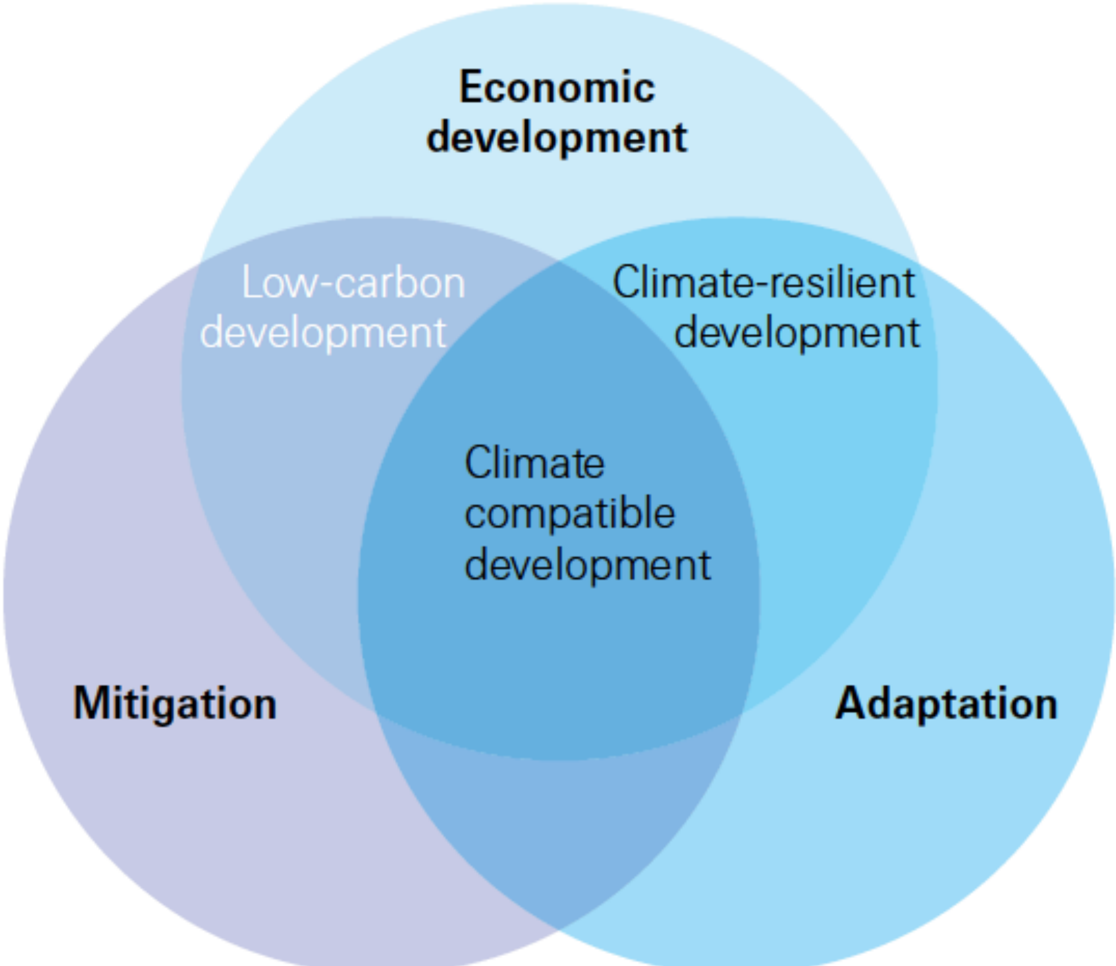
Trend decomposition going forward ?

→ Need for climate resilient development

Ocean Drive, FL, 1926

Ocean Drive, FL, 2000

The need for climate-resilient development



→ How would you tackle this? Adaptation first, development second? Or vice versa?

Climate-resilient development
or: Economics of climate adaptation (ECA)

Objectives

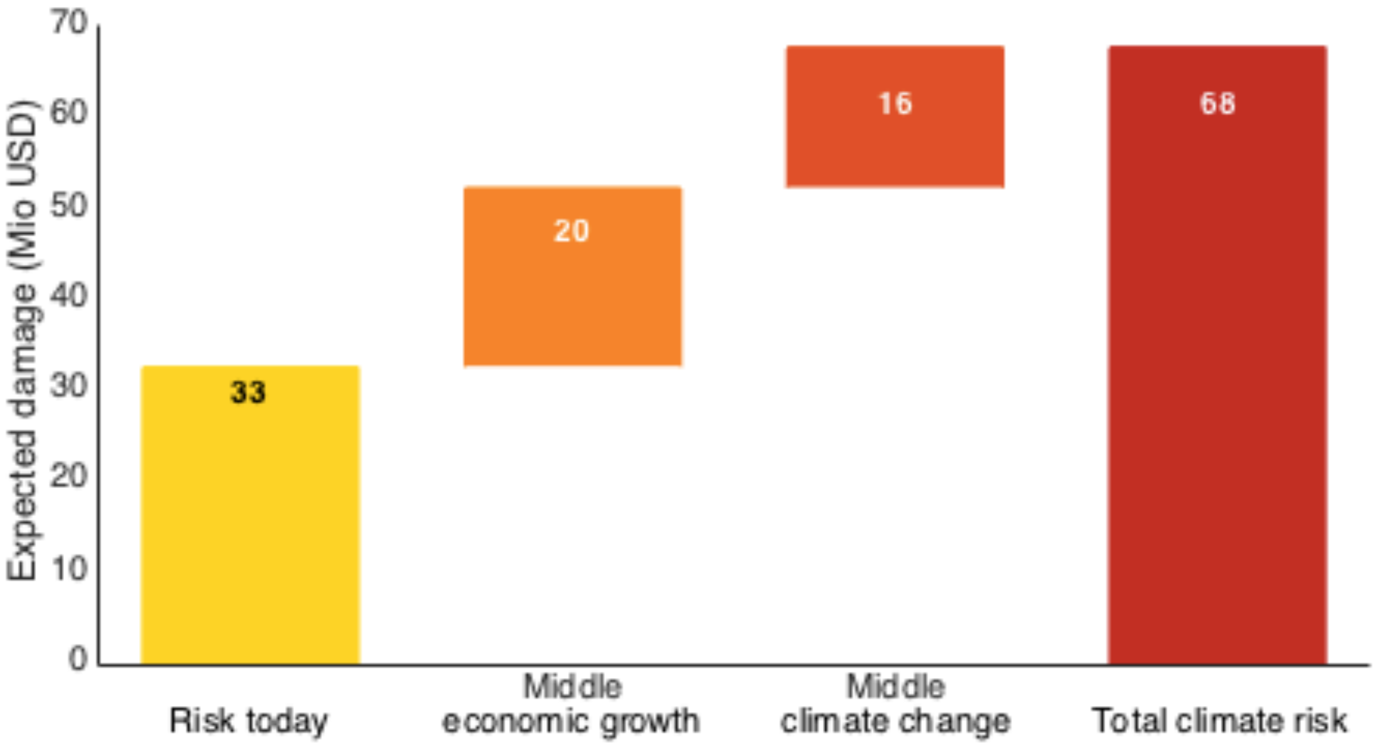
- Provide decision makers with the facts and methods necessary to design and execute a climate adaptation strategy
- Supply financial institutions, potential funders and insurers with the information required to unlock and deepen global adaptation finance and risk transfer markets

Key features of the methodology:

- Follow a rigorous risk management approach to <u>assess</u> ***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 <u>address</u> total climate risk on an economic basis

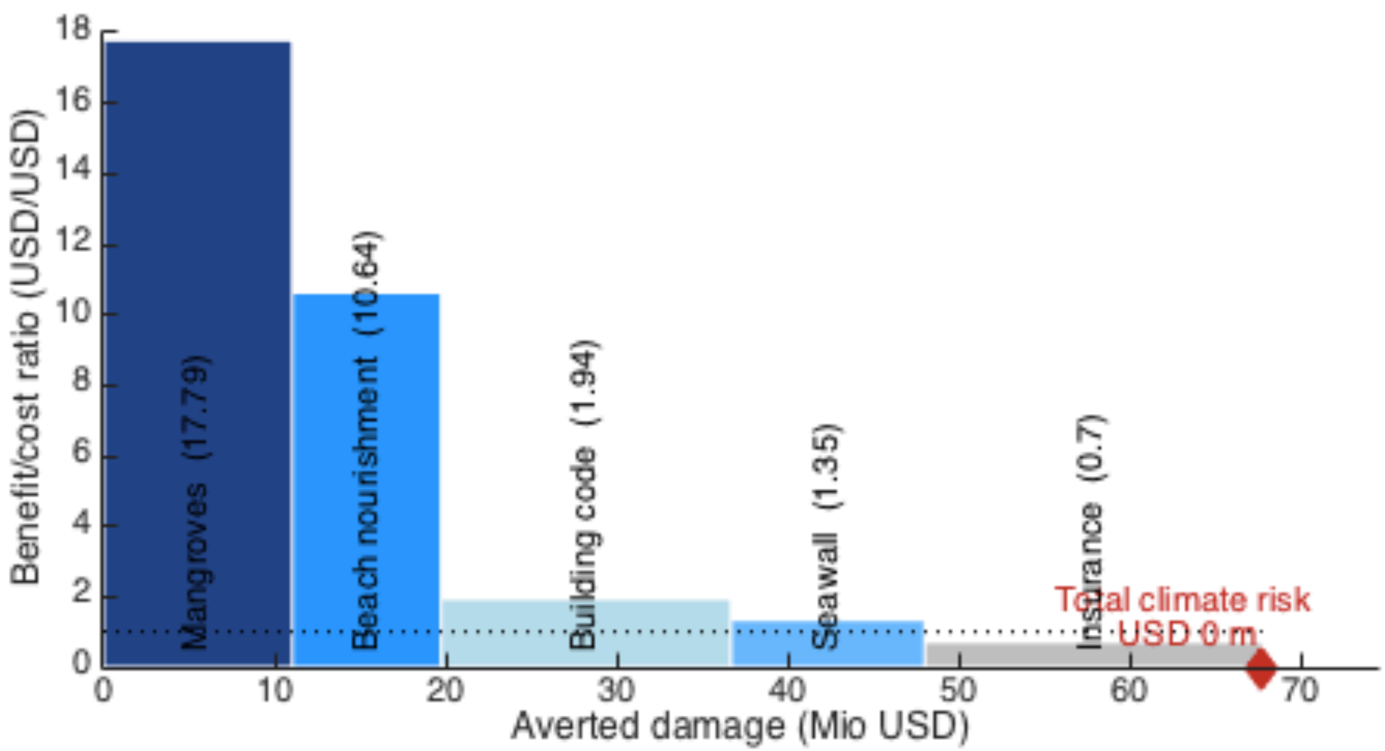
Economics of climate adaptation (ECA)
Key outputs of the methodology (1/2)

Risk today+economic growth+climate change: the ‘waterfall chart’



Economics of climate adaptation (ECA)
Key outputs of the methodology (2/2)

The adaptation cost curve: adaptation measures sorted by cost and benefit



Risk

- Risk concerns the expected value of one or more outcomes of one or more future events.
- $\text{Risk} = \underbrace{\text{Probability}}_{\text{expected}} \otimes \underbrace{\text{Severity}}_{\text{value}}$
- Risk is defined (e.g. ISO 31000) as the effect of uncertainty on objectives (whether positive or negative).

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

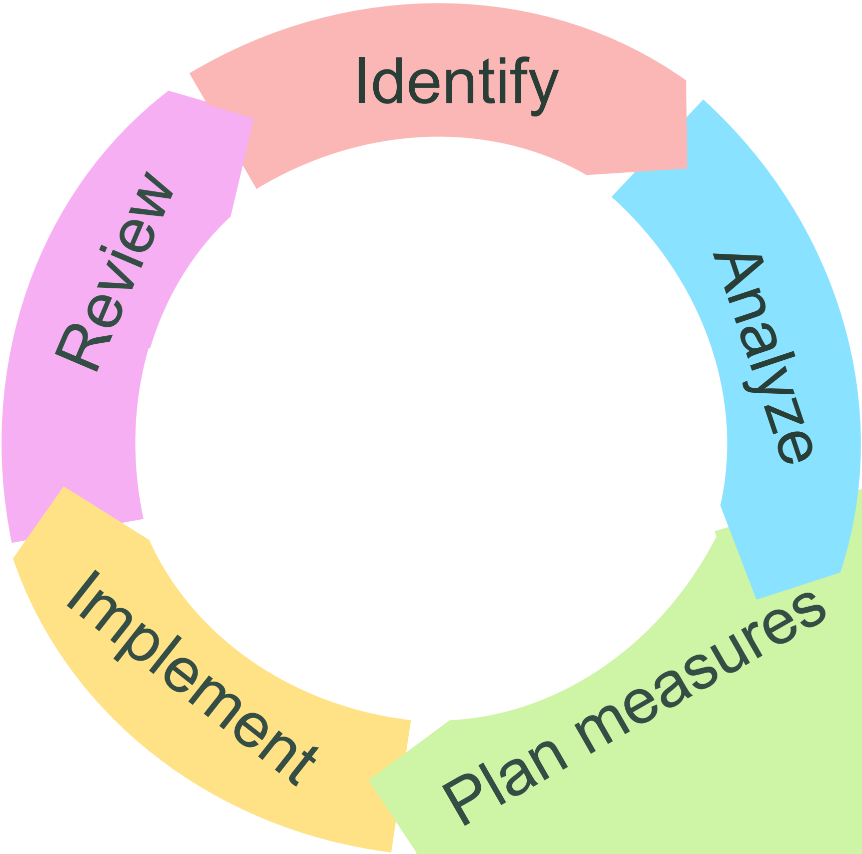
- Risk model: the quantitative expression of a shared mental model
  → allows to assess risk mitigation options

Risk mitigation: Prioritization based on metrics, options are to

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

[1] Risk = Probability $\otimes$ Severity

Risk Management Cycle



Options:

- Avoid
- Reduce
- Prevent
- Transfer
- Retain

ECA[1] – 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

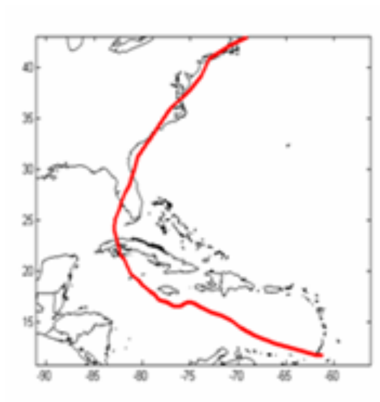
- Assess current progress against the measures
- Understand requirements to implementation
- Determine actions required to implement measures

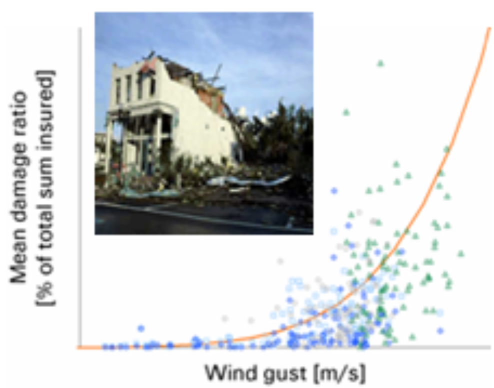
[1]Economics of Climate Adaptation

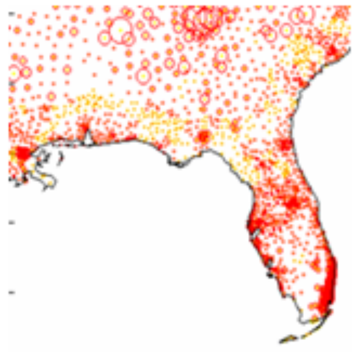
Natural catastrophe modelling

What is the magnitude of the expected loss?

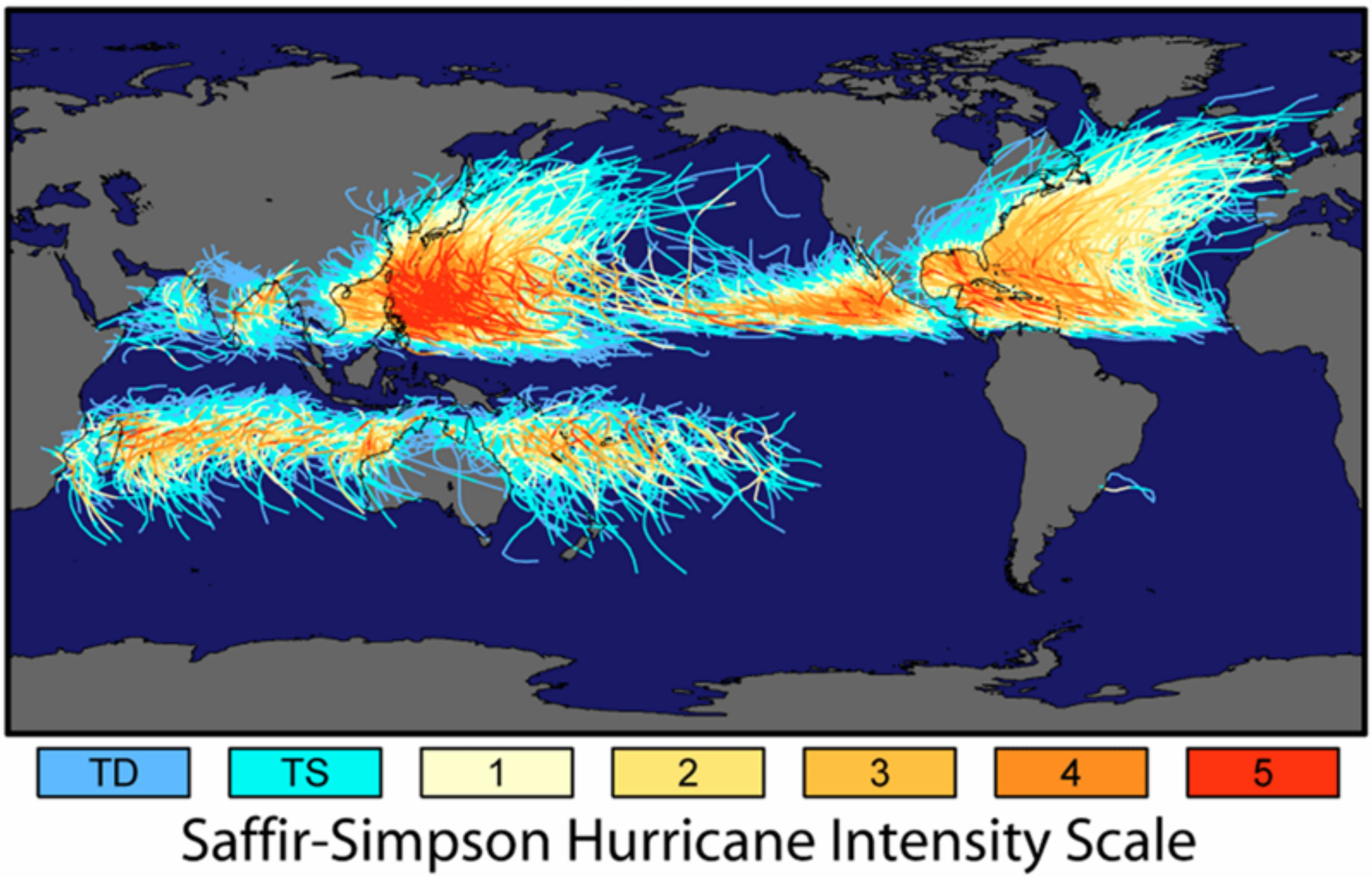
Hazard	Damage function	Assets
How strong? How frequent?	How well built?	Where? What?



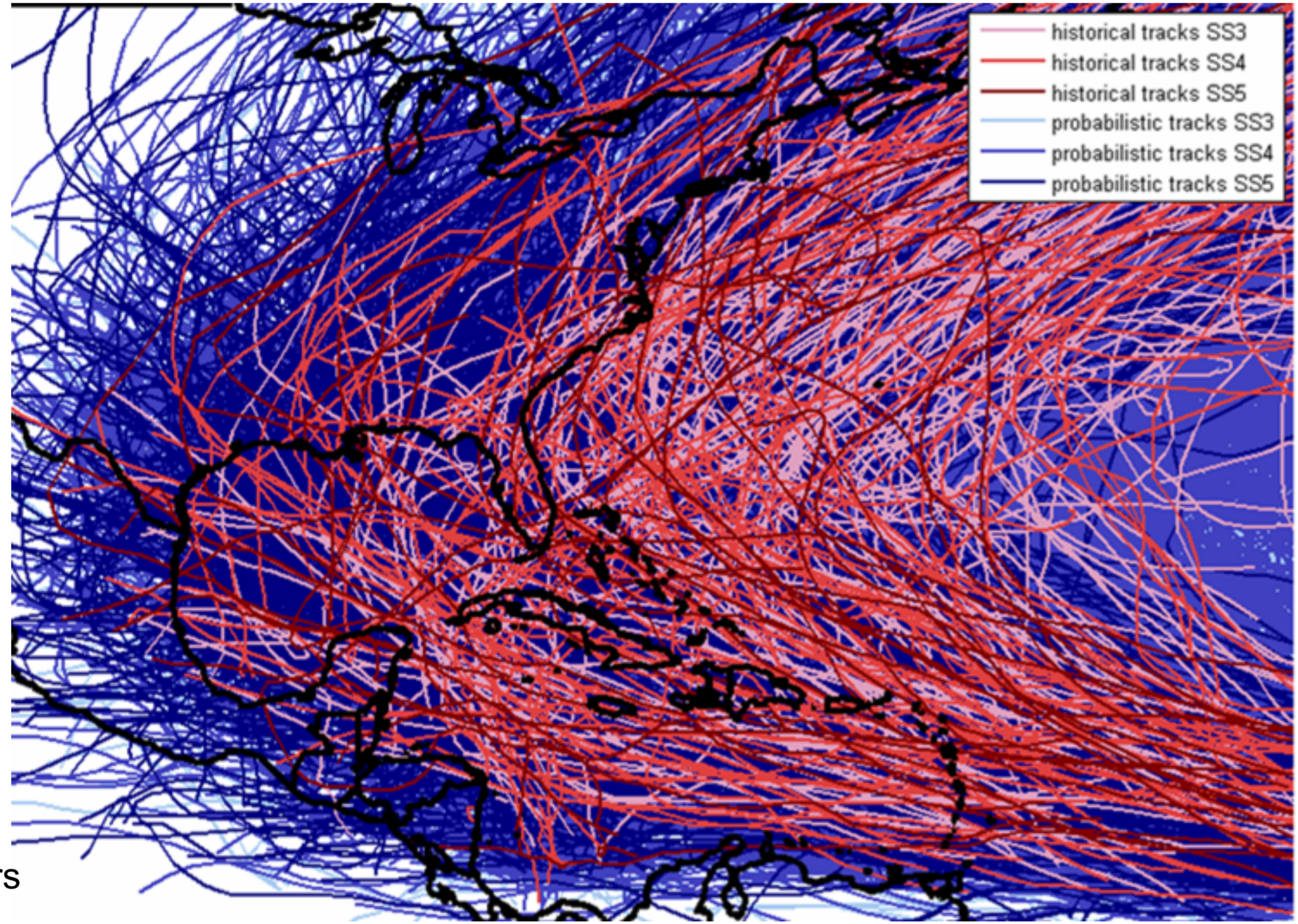




Tropical cyclones



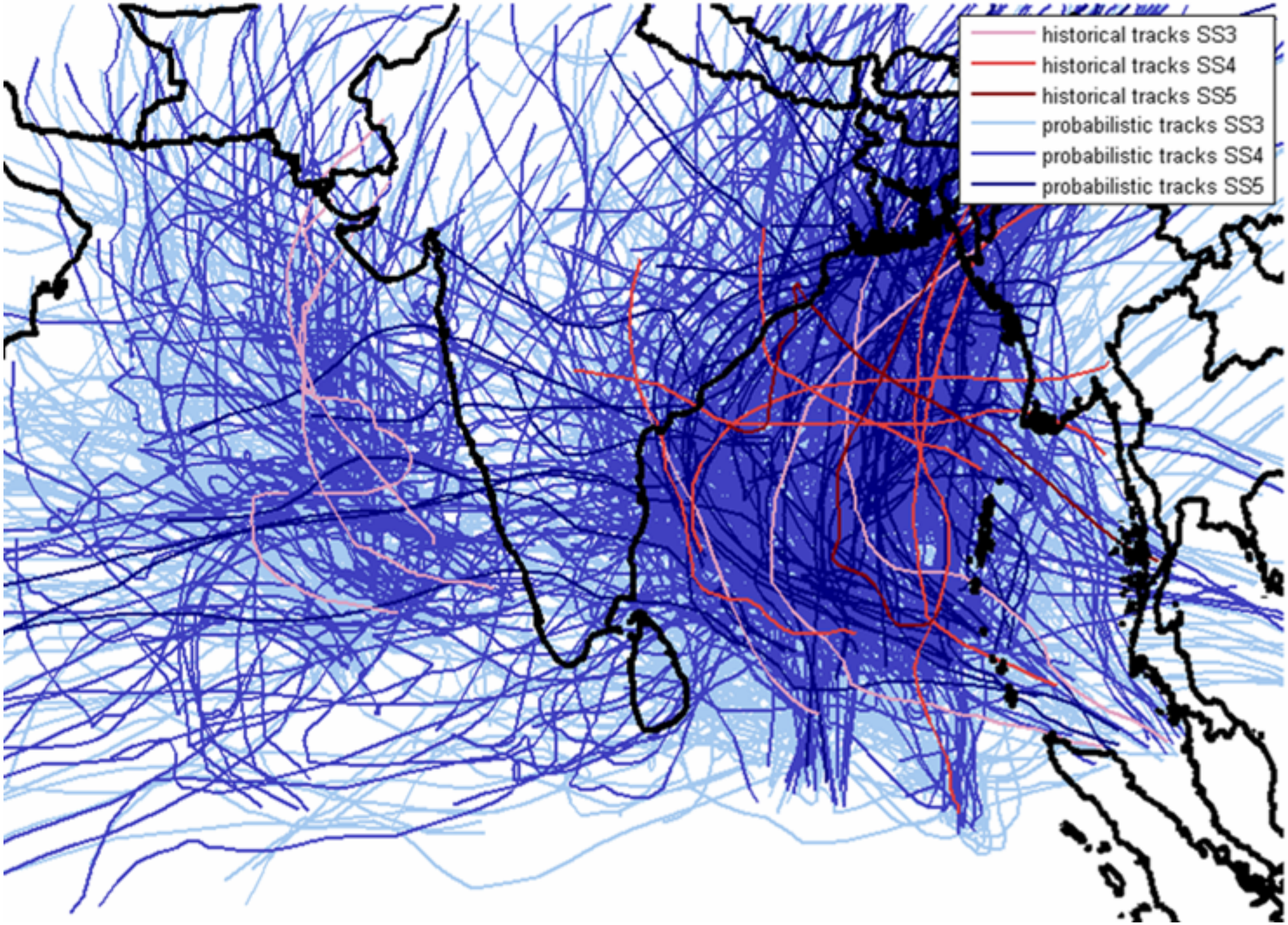
Tropical cyclones in the North Atlantic



historic
~100 years

probabilistic
~10‘000 years

Tropical cyclones in the Indian ocean

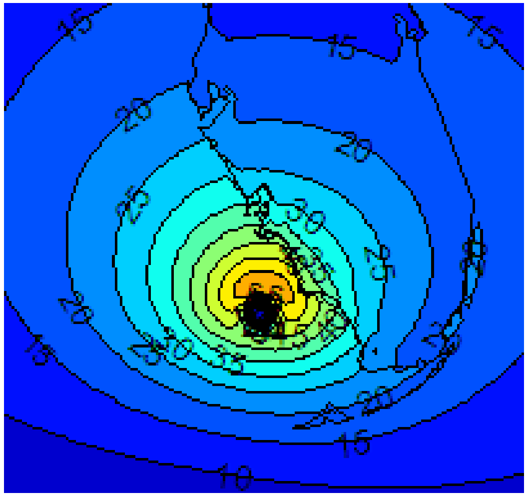


historic
~ 25 years

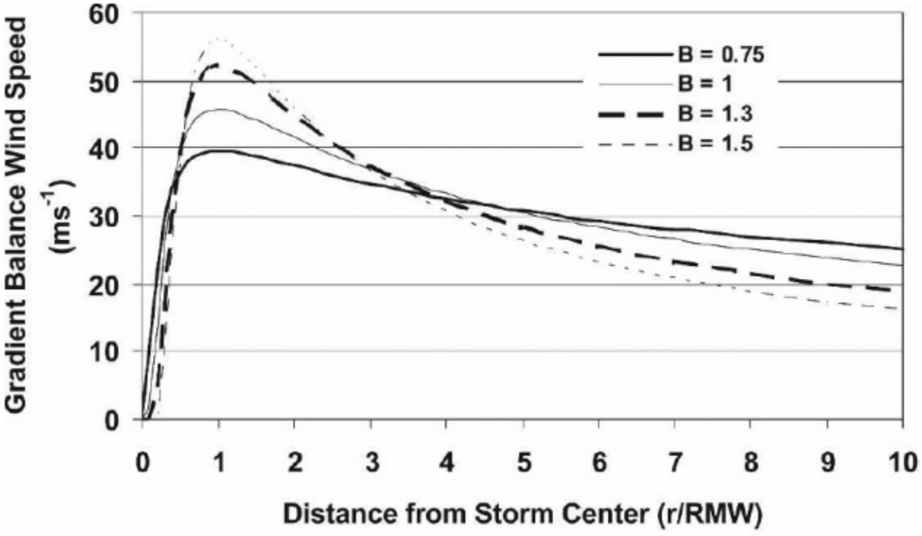
probabilistic
~ 5‘000 years

Tropical cyclone intensity – the wind field

We use the Holland wind field model

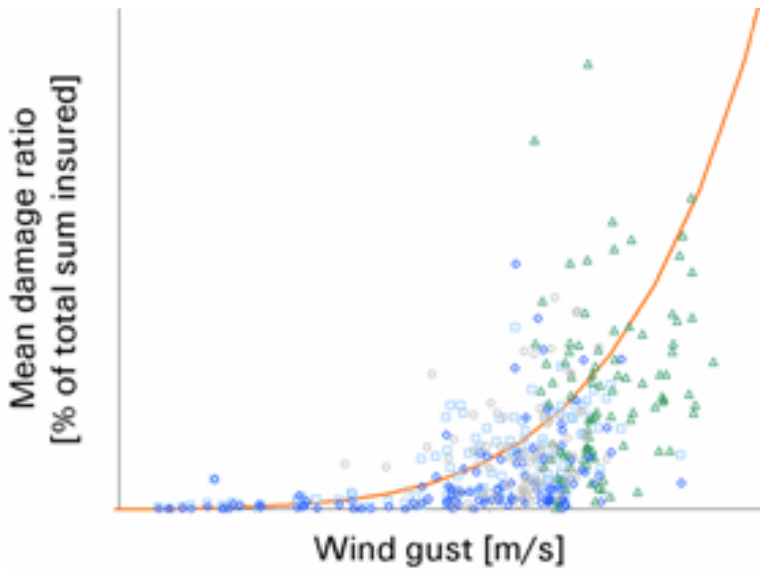


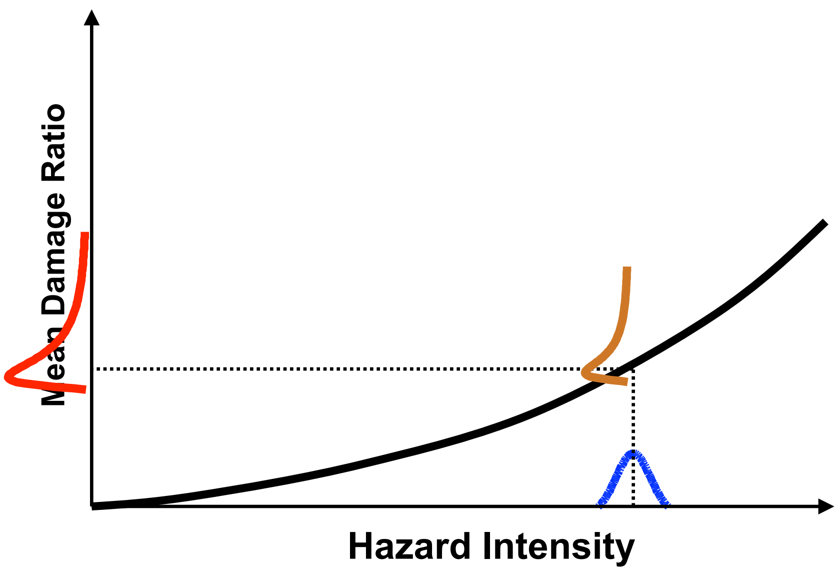
- The 1-min sustained wind at gradient wind level (boundary layer height & no surface effects) is modelled using the Holland 2008 approach. It models the first-order vortex of a tropical cyclone.
- The translational speed (also called celerity) is added geometrically.



- Holland, G. J., 1980: An analytic model of the wind and pressure profiles in hurricanes. Monthly Weather Review, 108, 1212-1218.
- Vickery, P.J. and D. Wadhera, 2008: Statistical models of Holland pressure profile parameter and radius to maximum winds of hurricanes from flight-level pressure and H*wind data. J. Appl. Meteor. Clim.

Notes on damage function





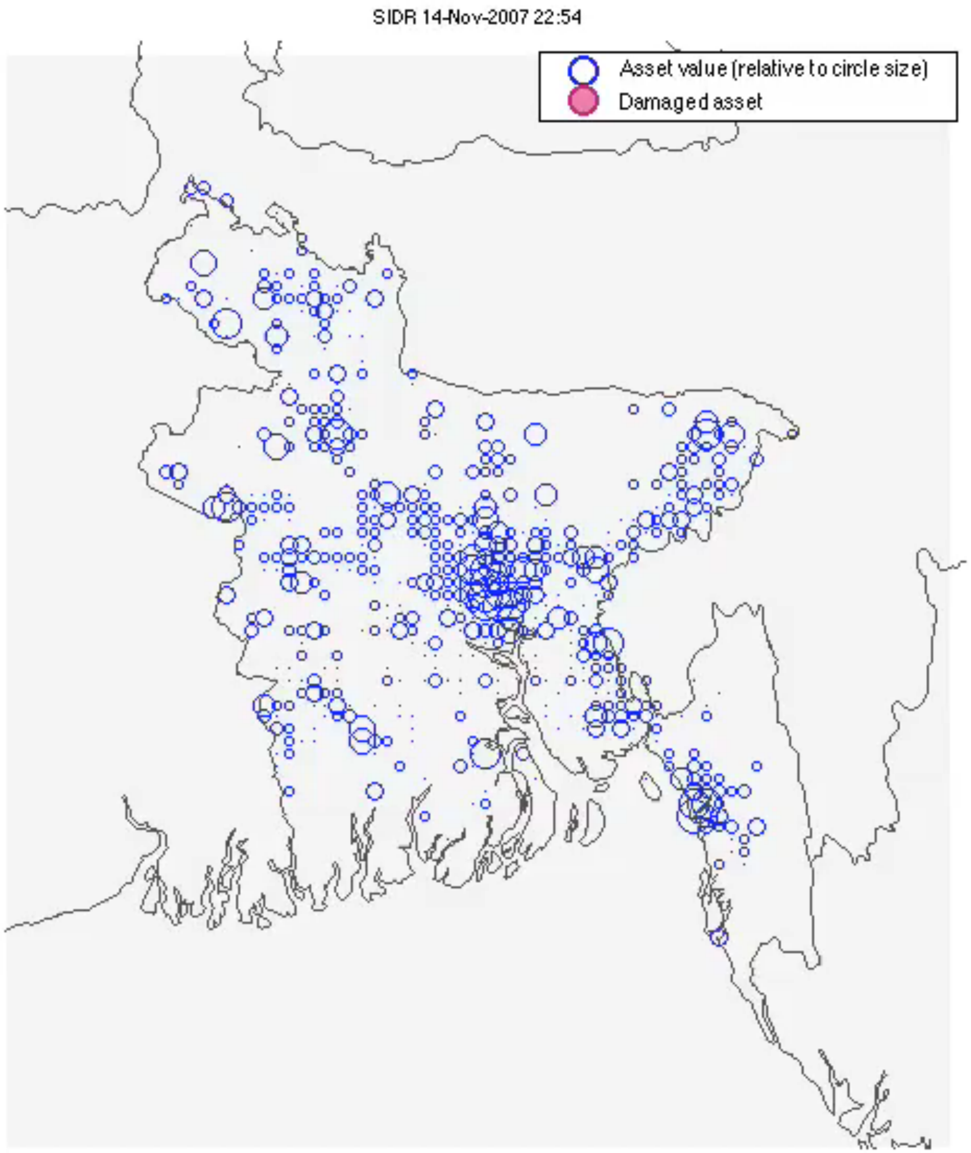
Uncertainty of the hazard intensity

+

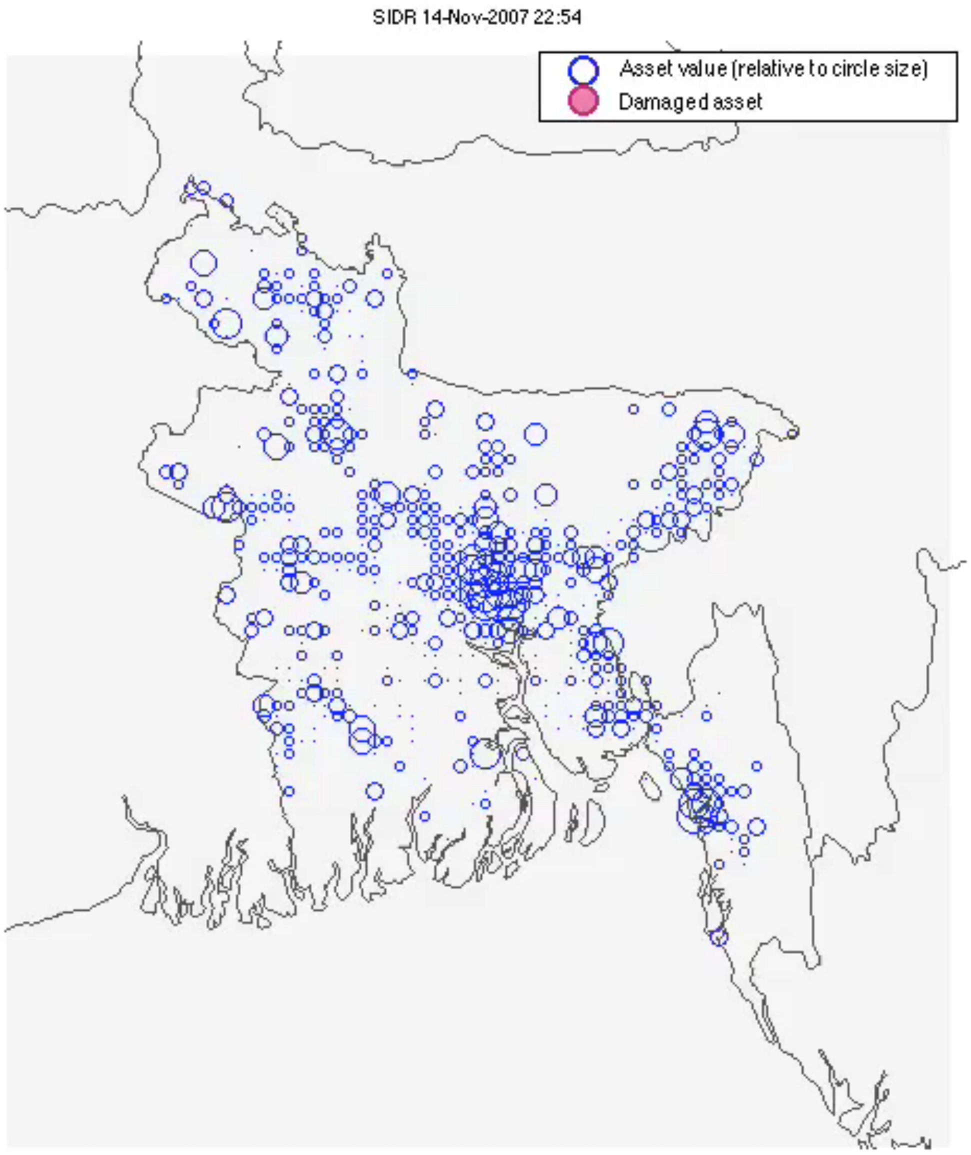
Uncertainty of the damage

results in

Convoluted Distribution



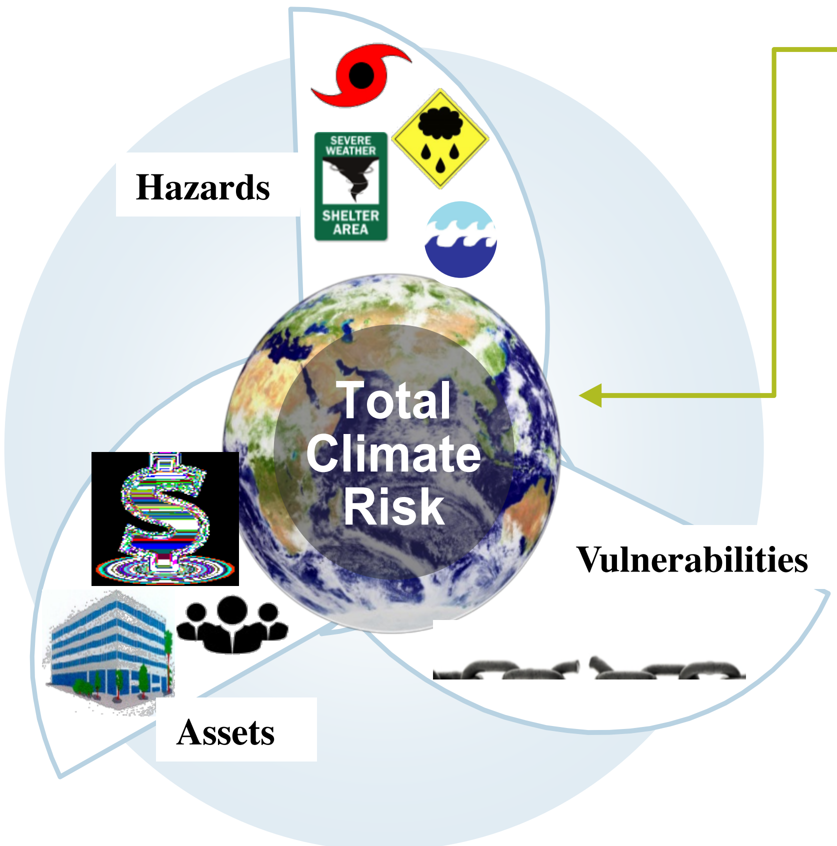
climada_event_damage_animation (time-stepping)



climada_event_damage_animation (footprint)

Basket of adaptation measures

What measures should be considered?



Portfolio of responses

- Infrastructure and asset- based responses
- Technological and procedural optimization responses
- Systemic and behavioral responses
- Risk transfer and contingent financing

→ adaptation measures for Miami, Florida, any ideas?

Excursion: Discounting – Present value calculation

- 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 (PV) 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.

Costs and benefits – example (1/2)

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. A simple example shall illustrate this:

- Let’s assume we expect a climate-related loss of 20 mio CHF by 2025 and hence evaluate the option to invest in prevention (the cost) starting 2015 in order to avert the loss (the *benefit*).
- Let’s further assume the preventive measure be a dam to be built in 2015 (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	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
cost	15	10		1		1		1		1		1
benefit	20											20
cost/benefit	0.75											

Costs and benefits – example (2/2)

- at 2% discount rate:

interest	2%	year										
	NPV	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
cost	14.45	10		1		1		1		1		1
benefit	16.41											20
cost/benefit	0.88											

$$\text{cost}=10+\underbrace{0/(1+2\%)}_{2016}+\underbrace{1/(1+2\%)^2}_{2017}+\underbrace{0/(1+2\%)^3}_{2018}+\underbrace{1/(1+2\%)^4}_{2019}\ldots$$

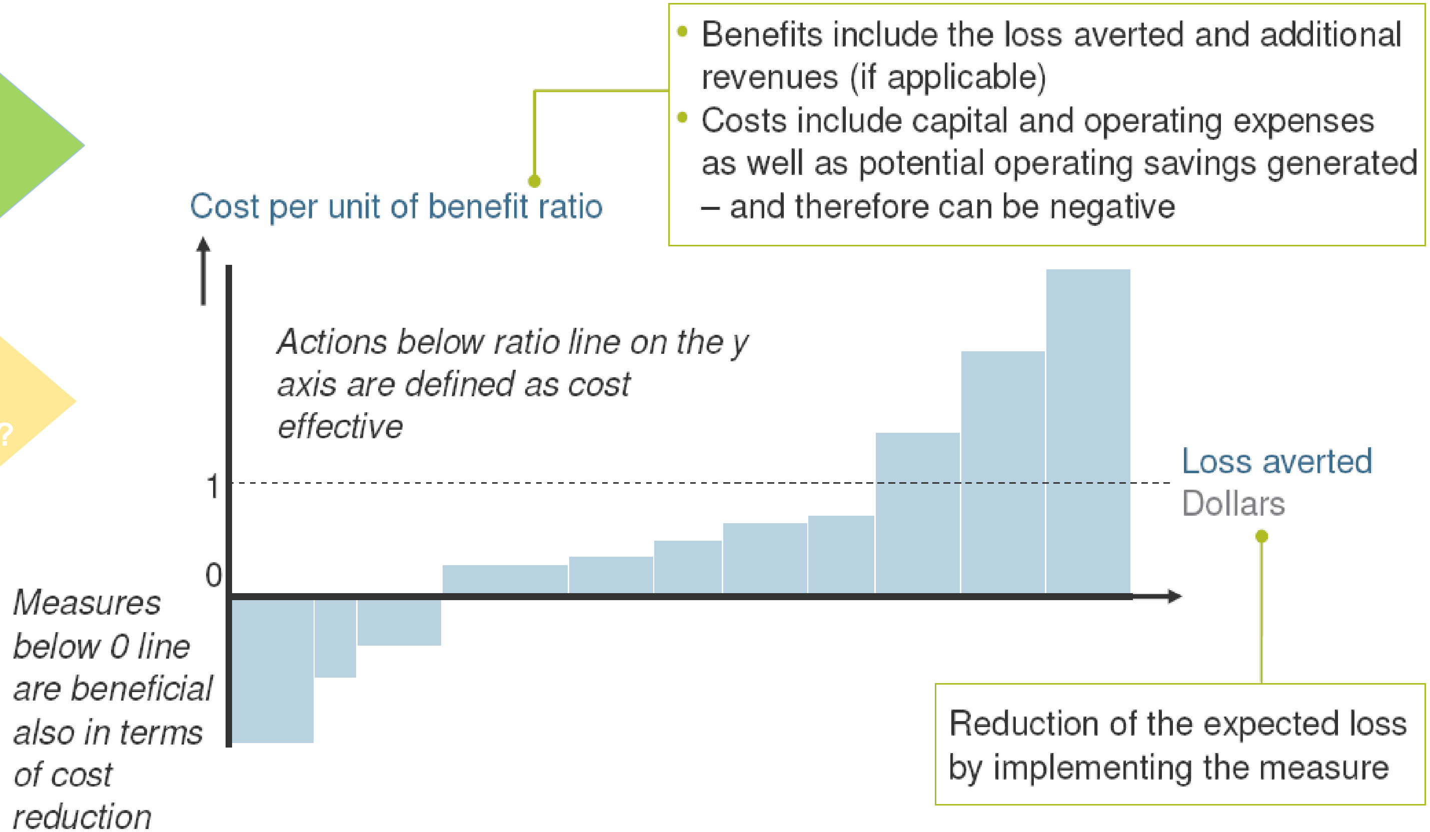
- at 5% discount rate:

interest	5%	year										
	NPV	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
cost	13.77	10		1		1		1		1		1
benefit	12.28											20
cost/benefit	1.12											

The adaptation cost curve

What measures should be considered?

How can measures be implemented[1] ?



- Costs and benefits calculated using existing practices and costs
- Cost per unit of benefit is a NPV calculation discounted at local rates

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

Adaptation cost curve – the recipe (one measure)

1. Calculate present value (PV) of costs of measure
2. Today (year 2015): assets, hazard as per today (probabilistic model)
    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 in the future (prob+scenario)
    1. calculate future annual expected loss with no measures
    2. calculate future 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

→ no worries, all implemented in climada, the open-source tool ;-)

WS3: Step-by-step (1/3)

Installation

- Create a folder named climada
- Download https://github.com/davidnbresch/climada into the climada folder
- Start MATLAB and browse to your local ../climada/climada-master folder, then enter*: `startup`

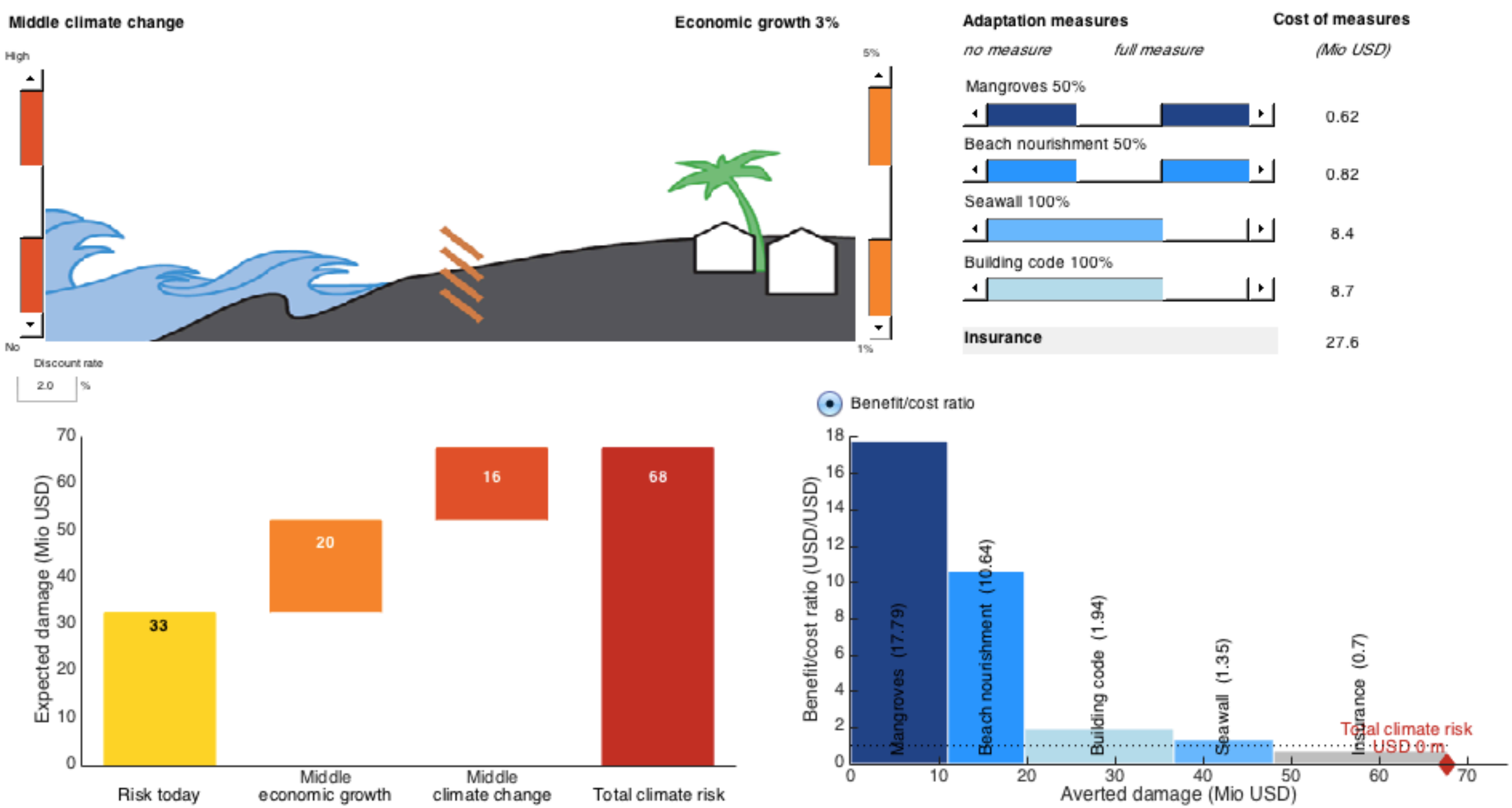
Getting started

- Enter **`climada_demo`** and play with the sliders etc. to get a feel (see climada manual, p. 4, “A visual primer”)
- Enter **`edit climada_demo_step_by_step`** (opens in the MATLAB editor) and play it trough using the MATLAB debugger (so you can run it step-by-step (consult the climada manual, p 13 ff, “From tropical cyclone hazard generation to the adaptation cost curve”, screenshot on next slide)

→ see the file WS3_step_by_step.pdf for further instructions.

* all MATLAB climada commands will be set in `courier`

A visual primer: `climada_demo`



On insurance …

Insurability

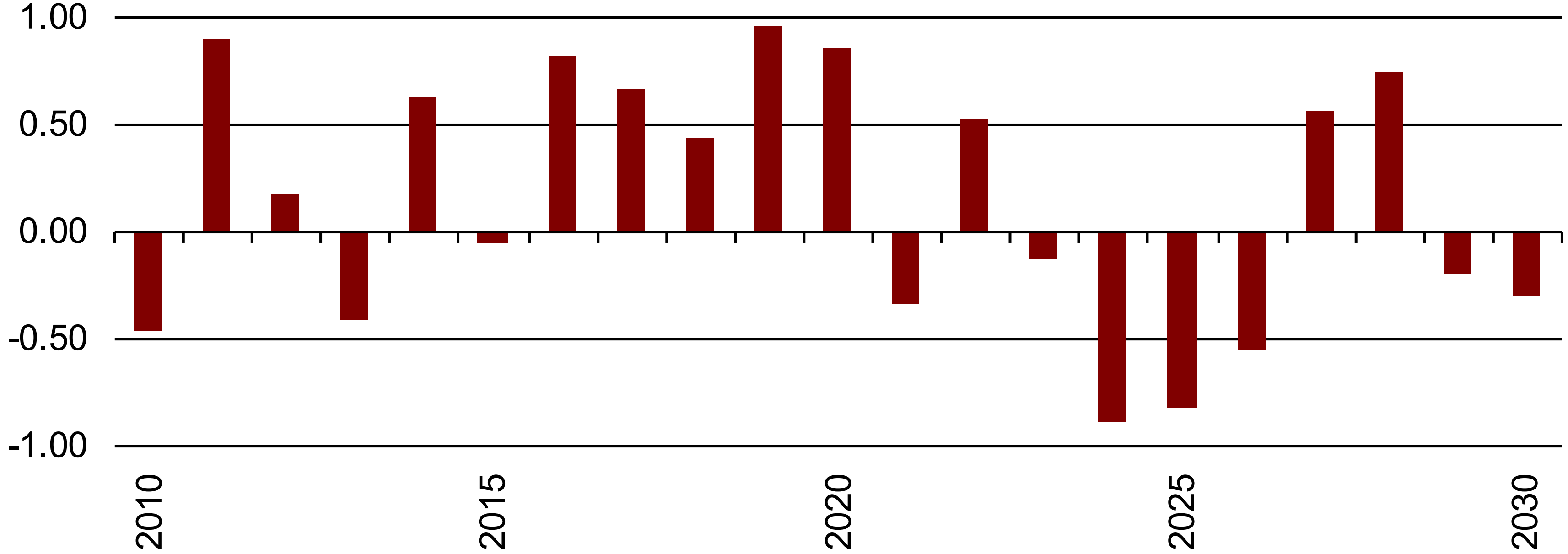
Insurance is the mutual cover of a fortuitous, assessable need of a large number of similarly exposed business

Alfred Manes, 1877-1963

- mutuality: numerous exposed parties must join together to form a risk community, to share and diversify the risk → large number
- fortuitous or randomness: time of occurrence must be unpredictable, occurrence itself must be independent of the will of the insured
- assessability: damage probability and severity must be quantifiable
- similarly exposed business → large number
- plus: economic viability: private insurers must be able to obtain a risk-adequate premium

Effect of insurance (1/4)

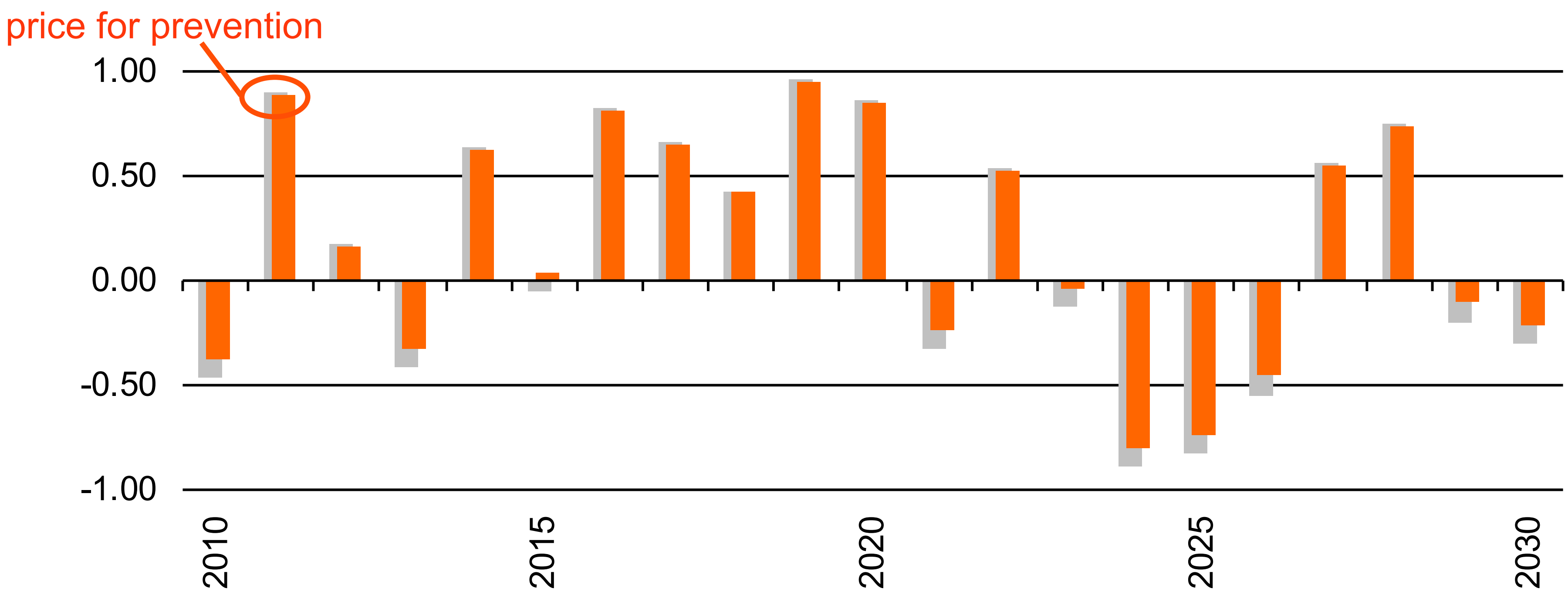
Time series of annual result



average result 0.15, stddev 0.60

Effect of insurance (2/4)

Time series of annual result (after prevention)

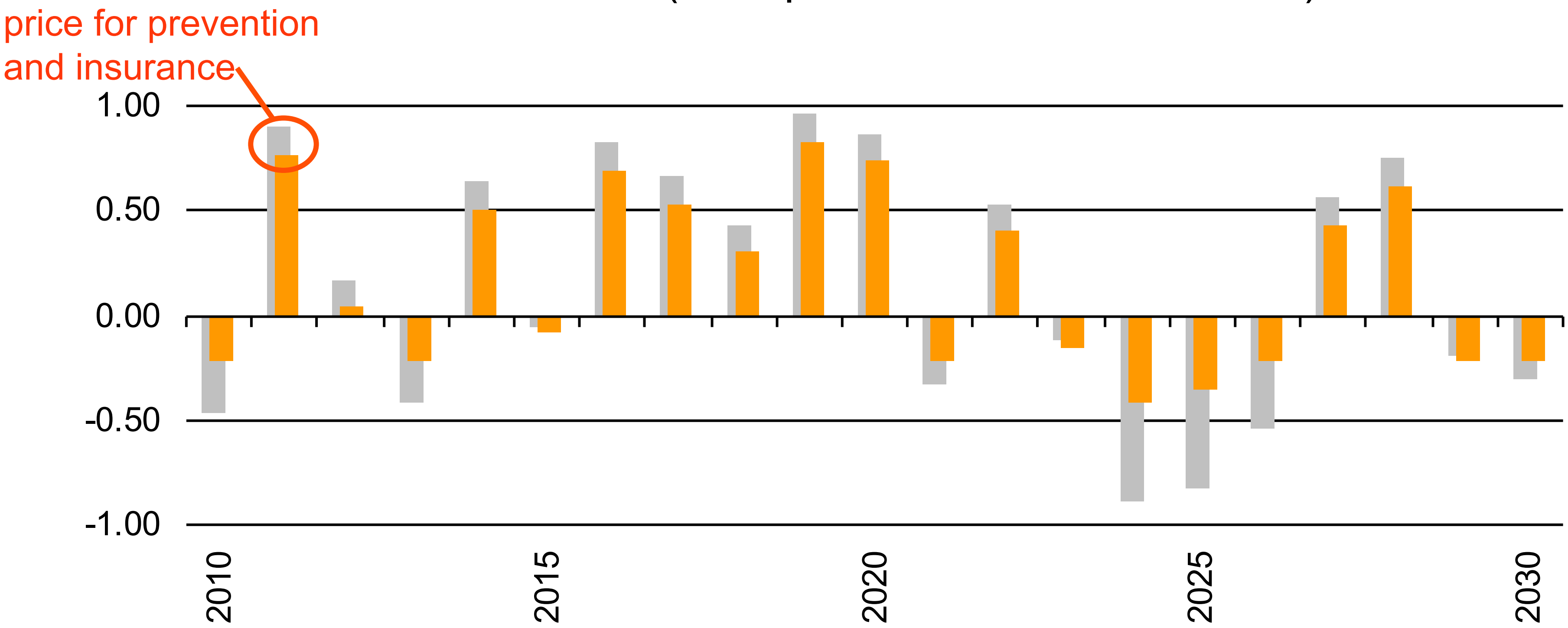


average result 0.19 (+25%), stddev 0.56 (-8%), prevention price 0.01

→ effect of prevention: stabilize result, reduce volatility

Effect of insurance (3/4)

Time series of annual result (after prevention and insurance)



average result 0.17 (+12%), stddev 0.43 (-29%), prev+ins price: 0.13

→ effect of insurance: reduce (extreme) volatility

Effect of insurance (4/4)

	result	stdev	*price**
raw	0.15	0.60	
+ prevention	0.19 (+25%)	0.56 (-8%)	*0.01*

→ cost-effective adaptation (net gain of 0.04 at cost of *0.01*)

	result	stdev	*price**
+ insurance	0.17 (+12%)	0.43 (-29%)	*0.01+0.12*

→ substantial reduction of volatility, result increase even after deduction of prevention cost and insurance premium → affordable!

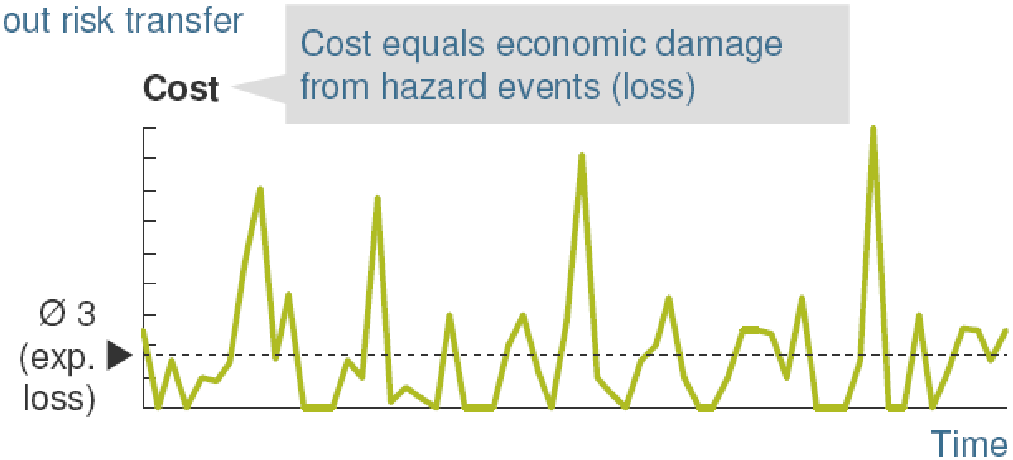
	result	stdev	*price**
insurance alone	0.12 (-17%)	0.45 (-25%)	*0.153*

→ prevention (strongly) incentivizes insurance

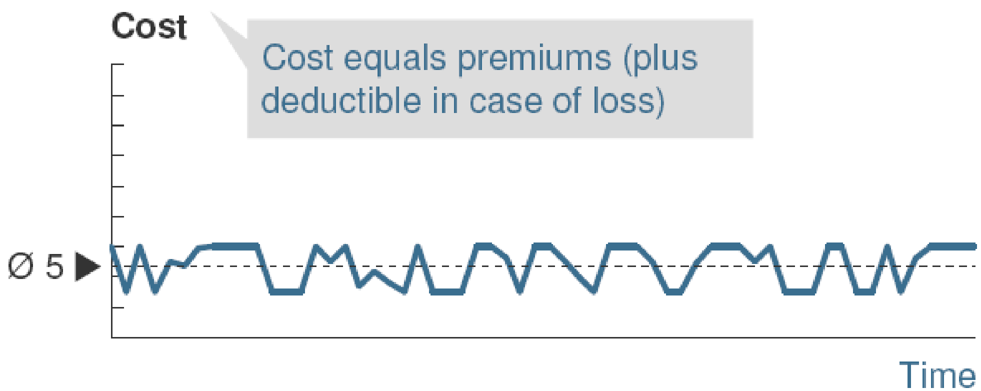
*price is already taken into account in result

The main function of risk transfer

Without risk transfer



With risk transfer



Risk transfer

Benefits

- Caps losses, protects livelihood from catastrophic events
- Smoothes costs, reduces volatility
- Increases willingness to invest
- Provides incentives ("price signals")

Costs

- Expected loss plus markup for production and distribution

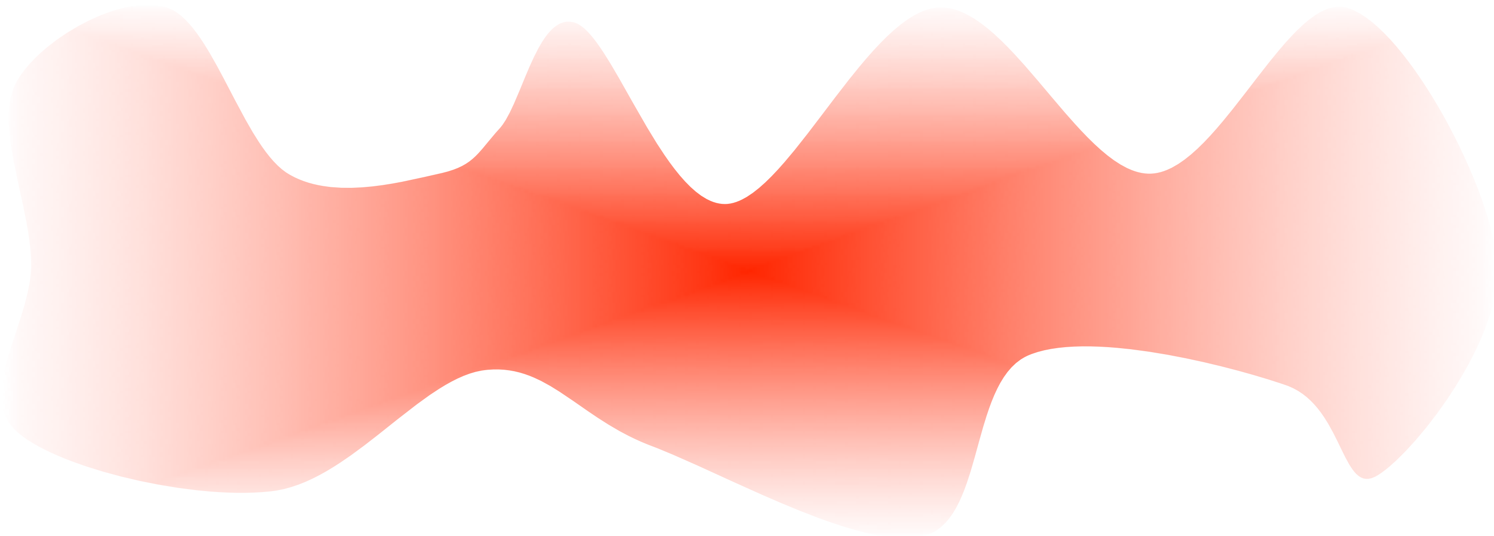
Forms of insurance

- Risk transfer can be agreed upon based on different triggers:
  - indemnity[1], also called incurred or occurred damage
  - parametric, also called index
  - modelled (well, a form of parametric)
- and with different partners, such as:
  - policyholders – from macro (e.g. large corporates in Texas) to micro (e.g. smallholder farmers in Ethiopia → Example)
  - insurers (reinsurers insure them)
  - other reinsurers, called retrocession
  - capital market, called insurance-linked security (ILS) or often also Cat Bond (→ Example)
  - public sector (PPP → Example)

[1] specific or market-share…

On models …

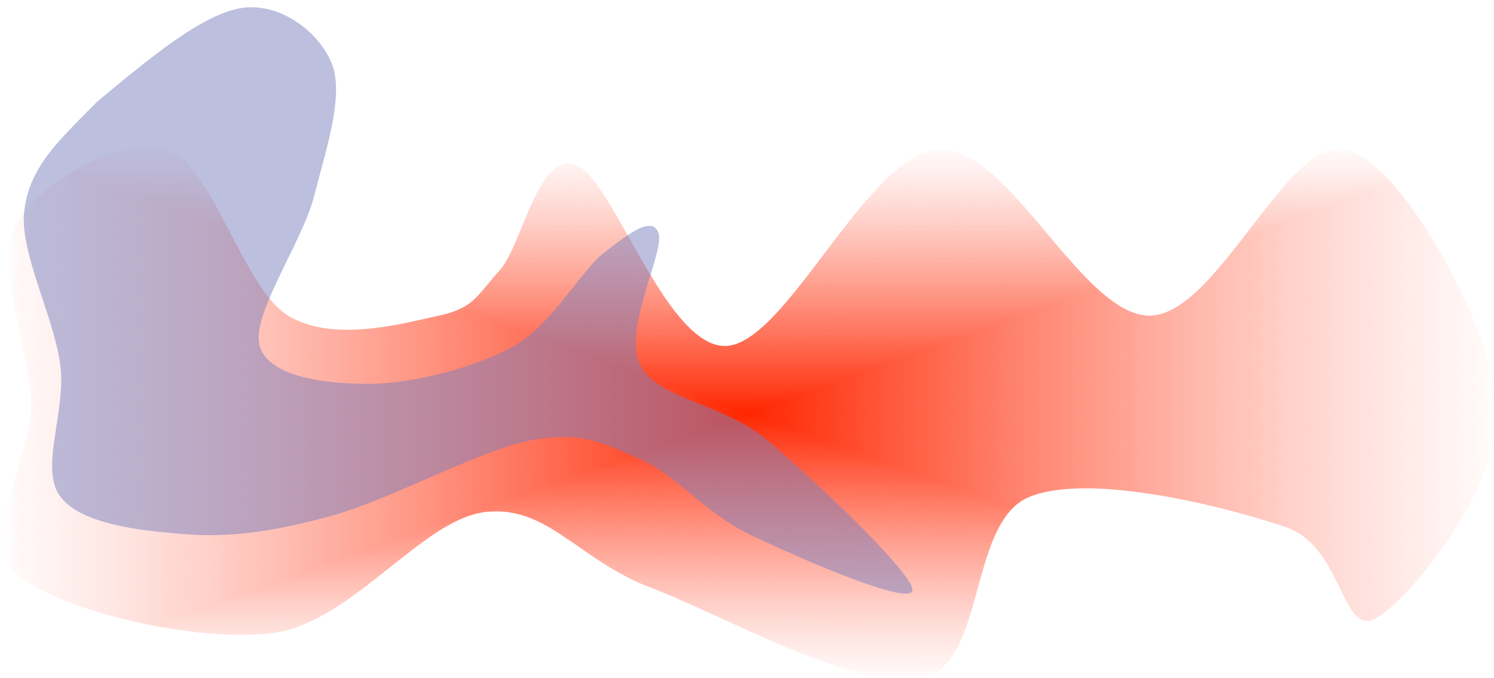
Notes on quantification and validity – reality



Reality

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

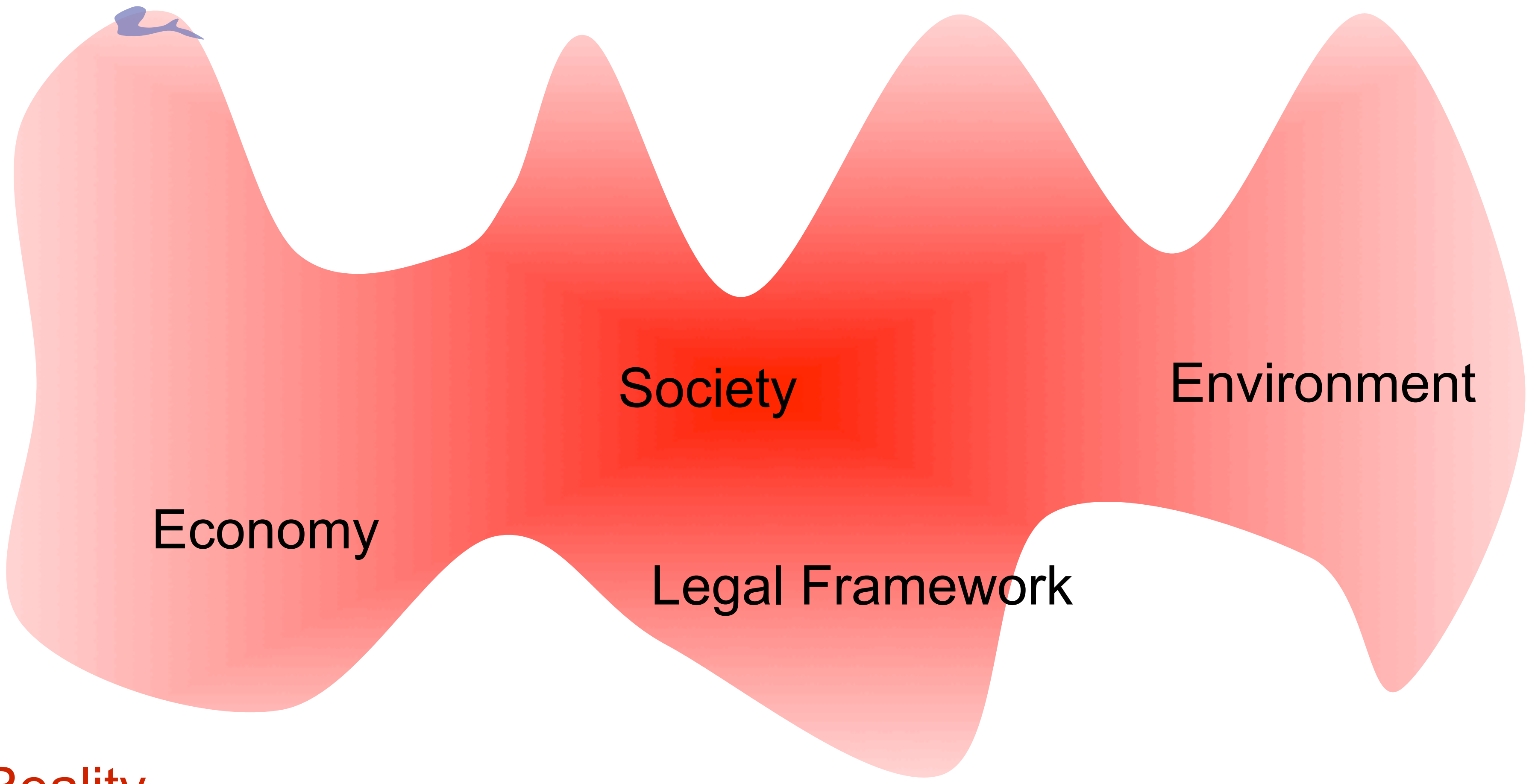
Notes on validity – model



Reality

Model

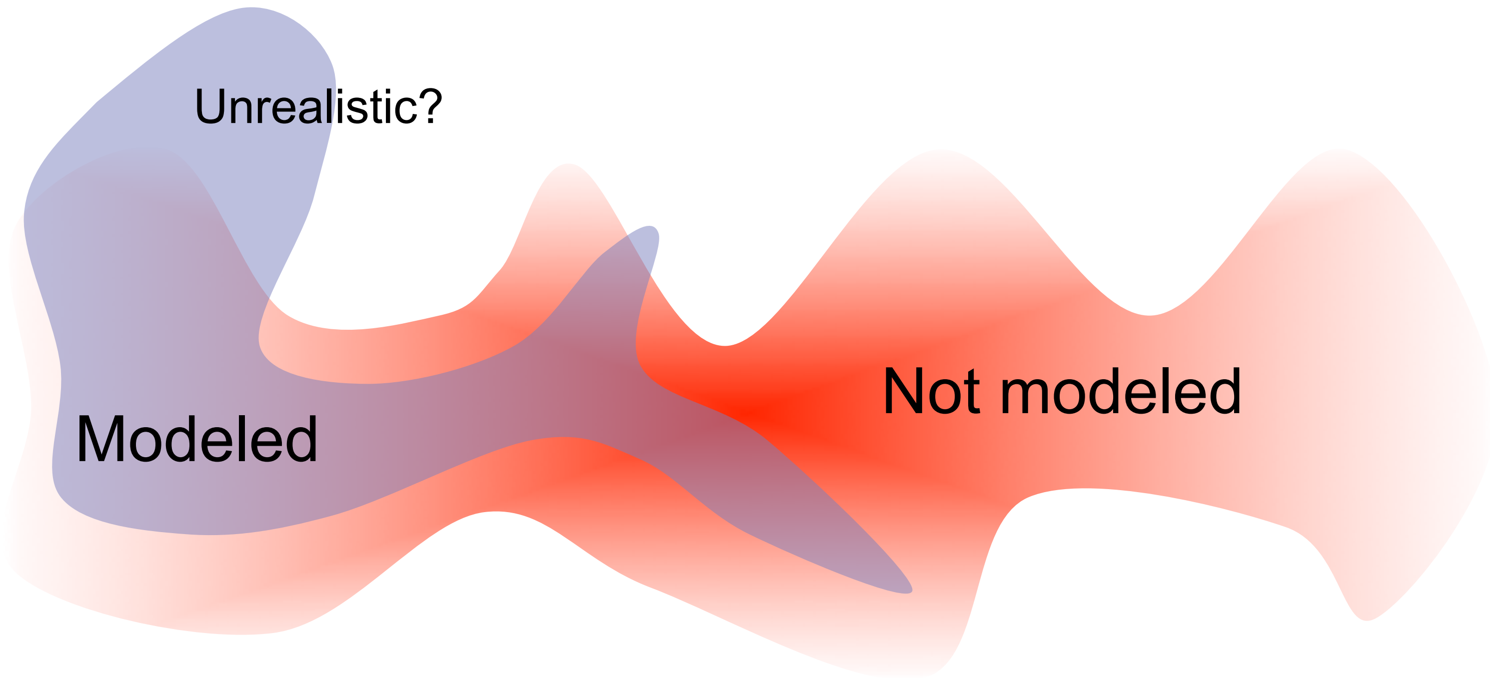
Notes on validity – proportions



Reality

Model

Notes on validity – application

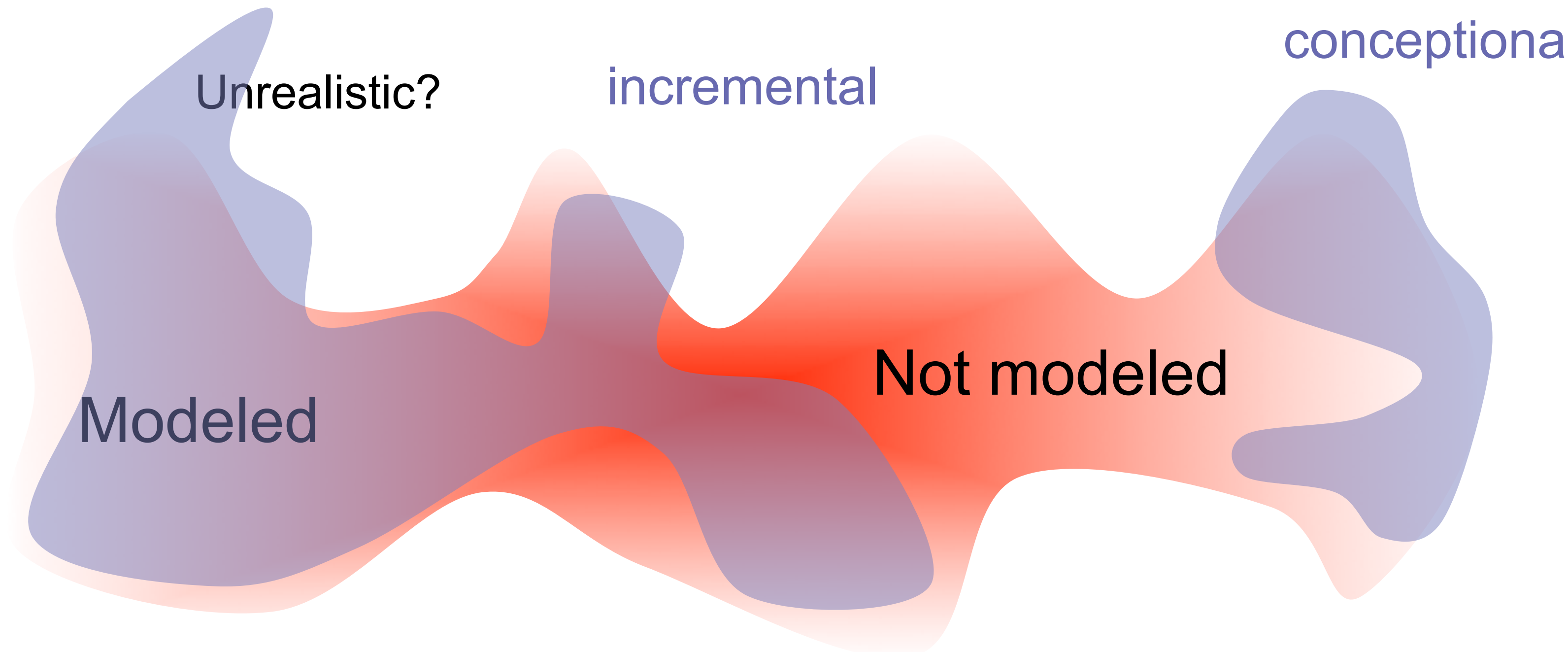


Reality → Model: Abstraction

Described in Model

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

Notes on validity – development

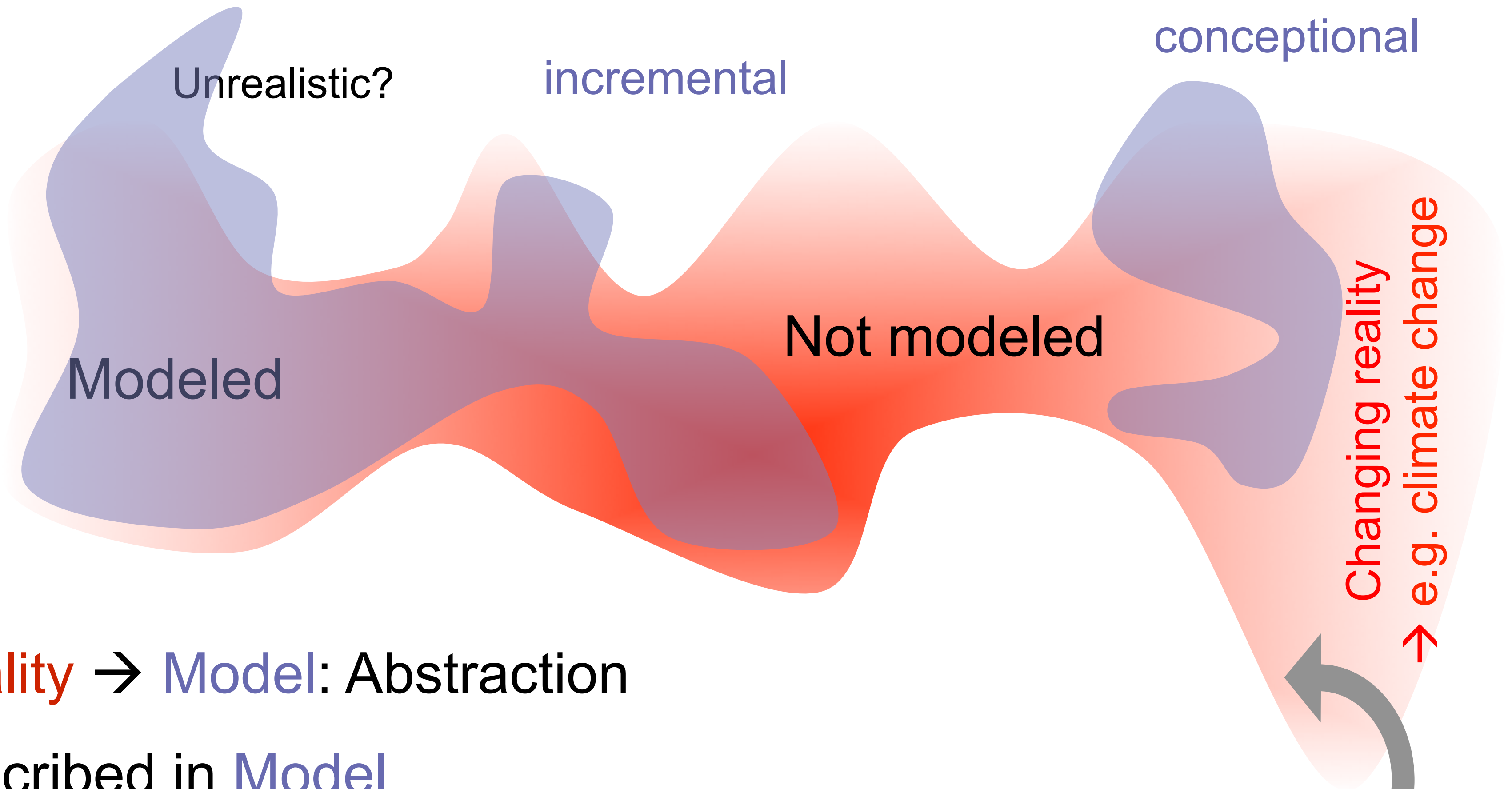


Reality → Model: Abstraction

Described in Model

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

Notes on validity – adaptation



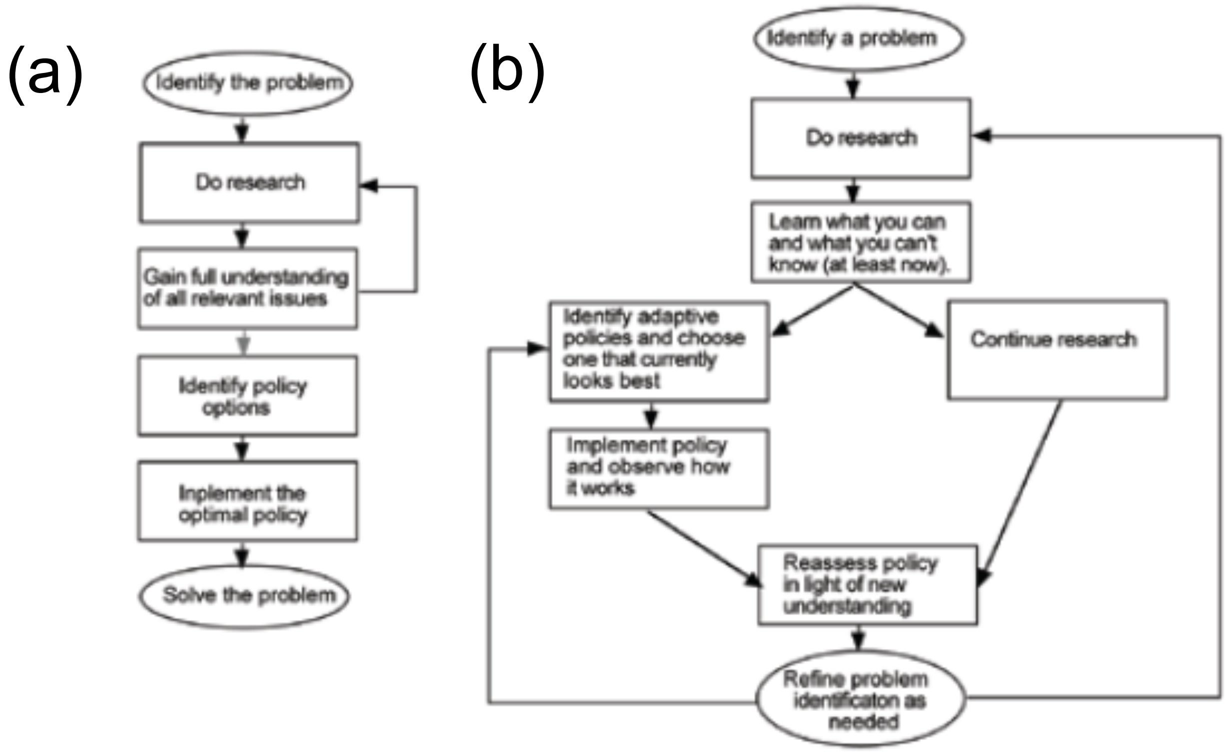
Reality → Model: Abstraction

Described in Model

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

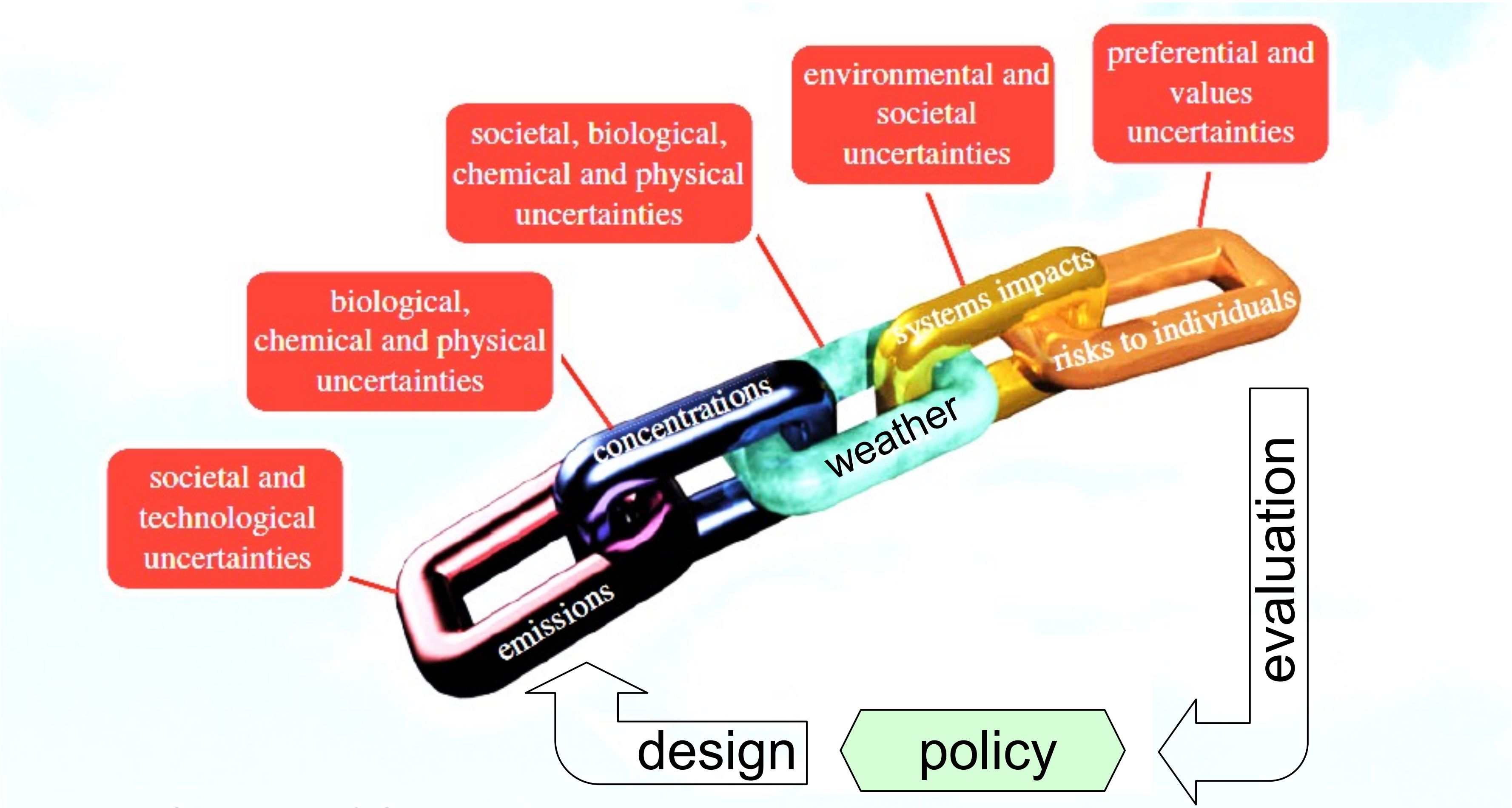
On decision-making …

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.

Causal chain of climate change from actions by people to impacts on people



From: Smith, L. A., & Stern, N., 2011: Uncertainty in science and its role in climate Policy

Do we trust a model?

- “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)
- “A vigorous Climate Prediction Project [ ] would ensure that the goal of accurate climate predictions at the regional scale could begin to aid the global society in coping with the consequences of climate change.” (http://wcrp.wmo.int/documents/WCRP_WorldModellingSummit_Jan2009.pdf)
- “New models that exploit extreme scale computing could determine the future frequency, duration, intensity, and spatial distribution of droughts, deluges, heat waves, and tropical cyclones.” (http://www.sc.doe.gov/ober/ClimateReport.pdf)

Do we trust a model?

- "All models are wrong, but some are useful." (Box 1979).
- "Verification and validation of numerical models of natural systems is impossible. This is because natural systems are never closed and because model results are always nonunique." (Oreskes et al. 1994)
- "…what these instances of fit [between their output and observational data] might confirm are not climate models themselves, but rather hypotheses about the adequacy of climate models for particular purposes." (Parker 2009)

On scenarios…

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

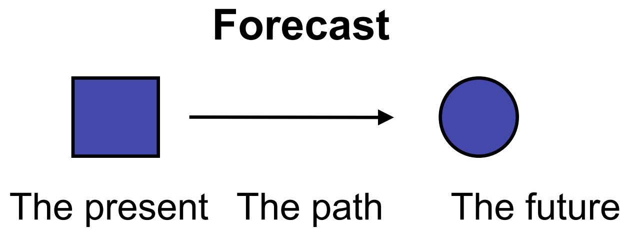
- Types of scenarios: hazard, impact, emissions,…
- ‘Realistic scenarios’ as opposed to sensitivity tests, physics tests, idealized scenarios
- Scenarios should be plausible, self consistent, broad. They can be used to explore response of system, identify important drivers
- Scenarios do not necessarily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

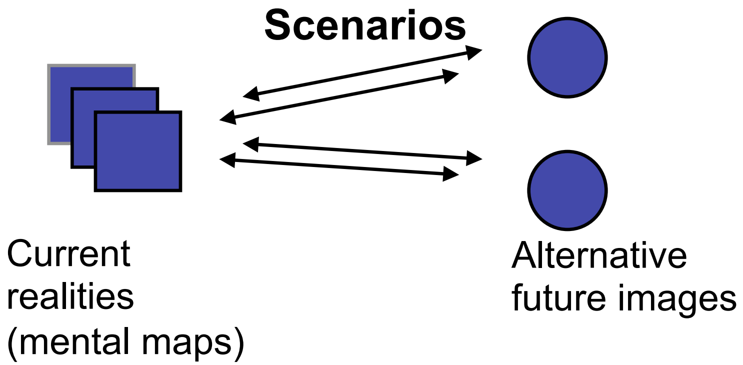
Forecast

- 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





On ECAs…

A global overview of ECA studies with a focus coastal communities
http://media.swissre.com/documents/Economics_of_Climate_Adaptation_focus_coastal_communities.pdf
Swiss Re
A global overview of case studies with a focus on fast growing coastal communities
Economics of Climate Adaptation – Shaping climate-resilient development
New York: Tropical cyclones and storm surge risk to a metropolis
http://media.swissre.com/documents/ECA_New_York_Gov_Factsheet.pdf
Economics of Climate Adaptation (ECA) – Shaping climate-resilient development
A framework for decision-making
Hull, UK: Flood and storm risk to urban property
http://media.swissre.com/documents/Economics_of_Climate_Adaption_UK_Factsheet.pdf
Economics of Climate Adaptation (ECA) – Shaping climate-resilient development
A framework for decision-making
ECA full report featuring the first 8 case studies, 164 pages
http://media.swissre.com/documents/ECA+Brochure-Final.pdf
SHAPING CLIMATE-RESILIENT DEVELOPMENT
a framework for decision-making
eca
China: Drought risk to agriculture
http://media.swissre.com/documents/rethinking_shaping_climate_resilent_development_en.pdf#page=74
8%
US Gulf Coast: Hurricane risk to the energy system
http://media.swissre.com/documents/Entergy_study_exec_report_20101014.pdf
Building a Resilient Energy Gulf Coast:
Executive Report
Caribbean: Hurricane risk to small islands
http://media.swissre.com/documents/ECA+Brochure-Final.pdf
CCRIF
Enhancing the climate risk and adaptation fact base for the Caribbean
CCRIF's Economics of Climate Adaptation (ECA) Initiative
Guayana: Flash flood risk to a developing urban area
http://media.swissre.com/documents/Economics_of_Climate_Adaption_Guyana_Factsheet.pdf
Economics of Climate Adaptation (ECA) – Shaping climate-resilient development
A framework for decision-making
Mali: Risk of climate zone shift to agriculture
http://media.swissre.com/documents/Economics_of_Climate_Adaptation_Factsheet_Mali.pdf
Economics of Climate Adaptation (ECA) – Shaping climate-resilient development
A framework for decision-making
India: Drought risk to agriculture
http://media.swissre.com/documents/Economics_of_Climate_Adaptation_India_Factsheet.pdf
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