Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Modeling damages, extremes and impacts: Design your own climate adaptation strategy – a practical application of open-source probabilistic damage modeling

David N. Bresch, ETH Zürich/MeteoSwiss
dbresch@ethz.ch , dbresch@meteoswiss.ch

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

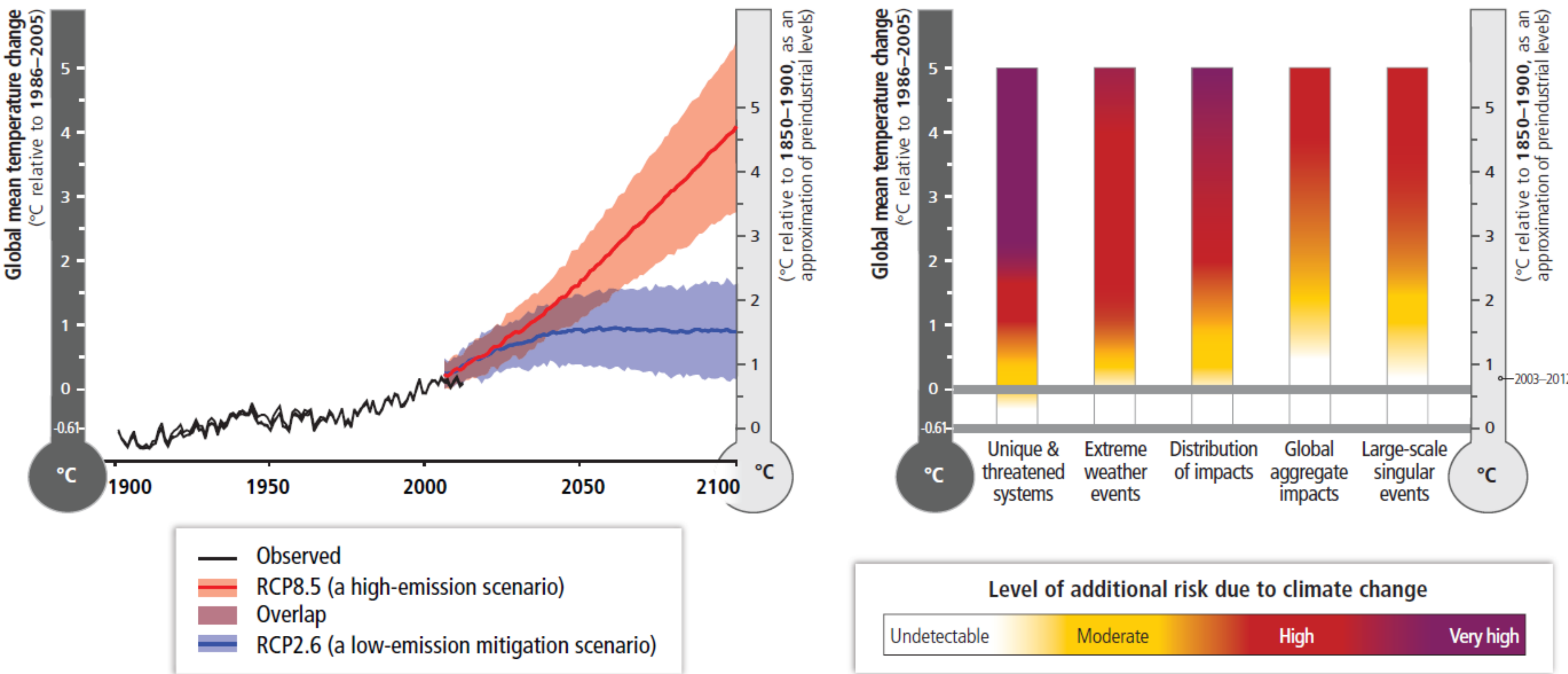
- The climate resilience story: http://media.swissre.com/documents/sigma1_2014_en.pdf#page=17
- Short introduction to the Economics of Climate Adaptation (ECA) methodology and global overview of case studies done so far: http://media.swissre.com/documents/Economics_of_Climate_Adaptation_focus_infrastructure.pdf
- 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

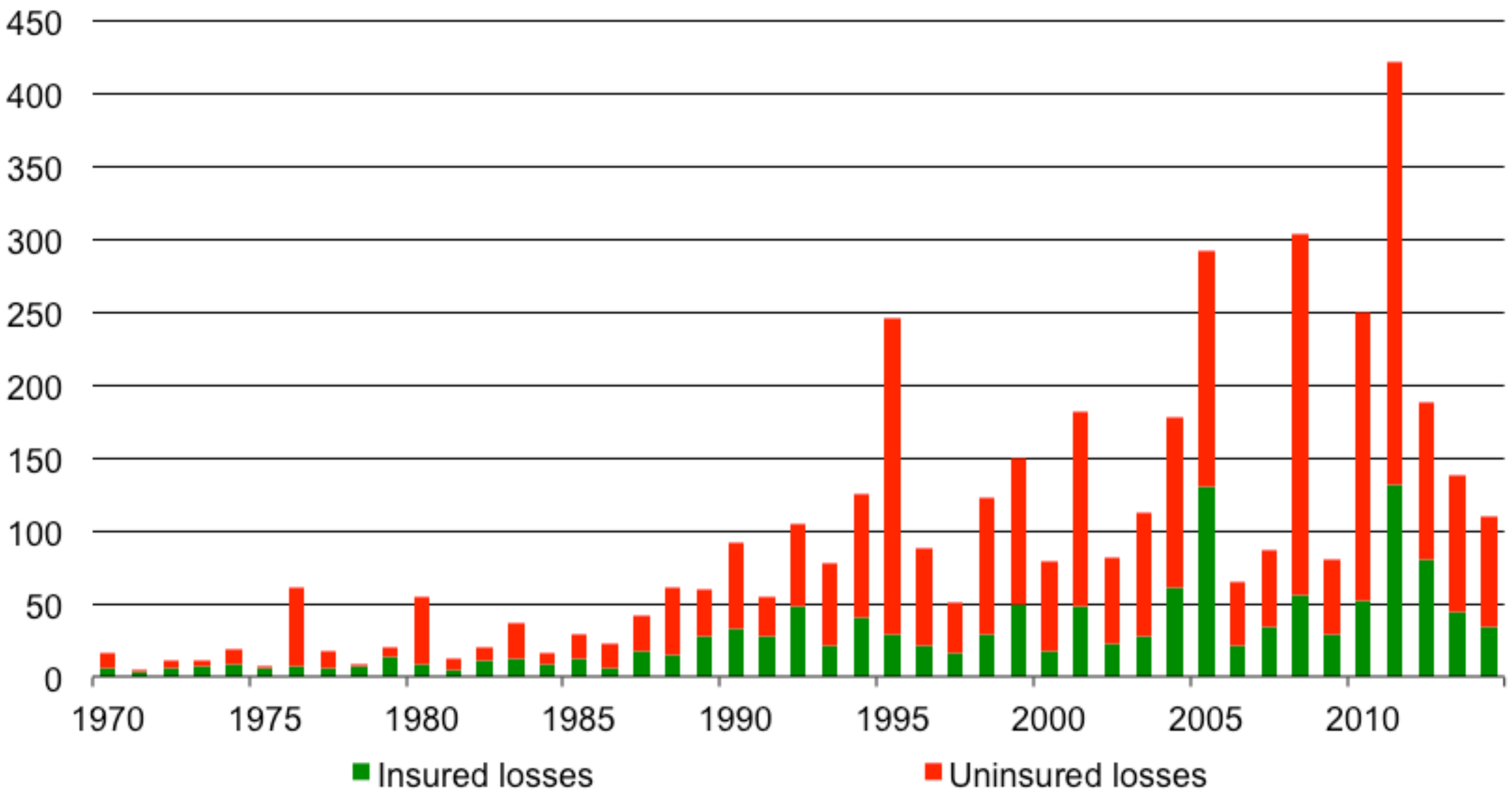


(Figure: IPCC AR5 WG2, 2014, Assessment Box SPM.1 Figure 1)

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

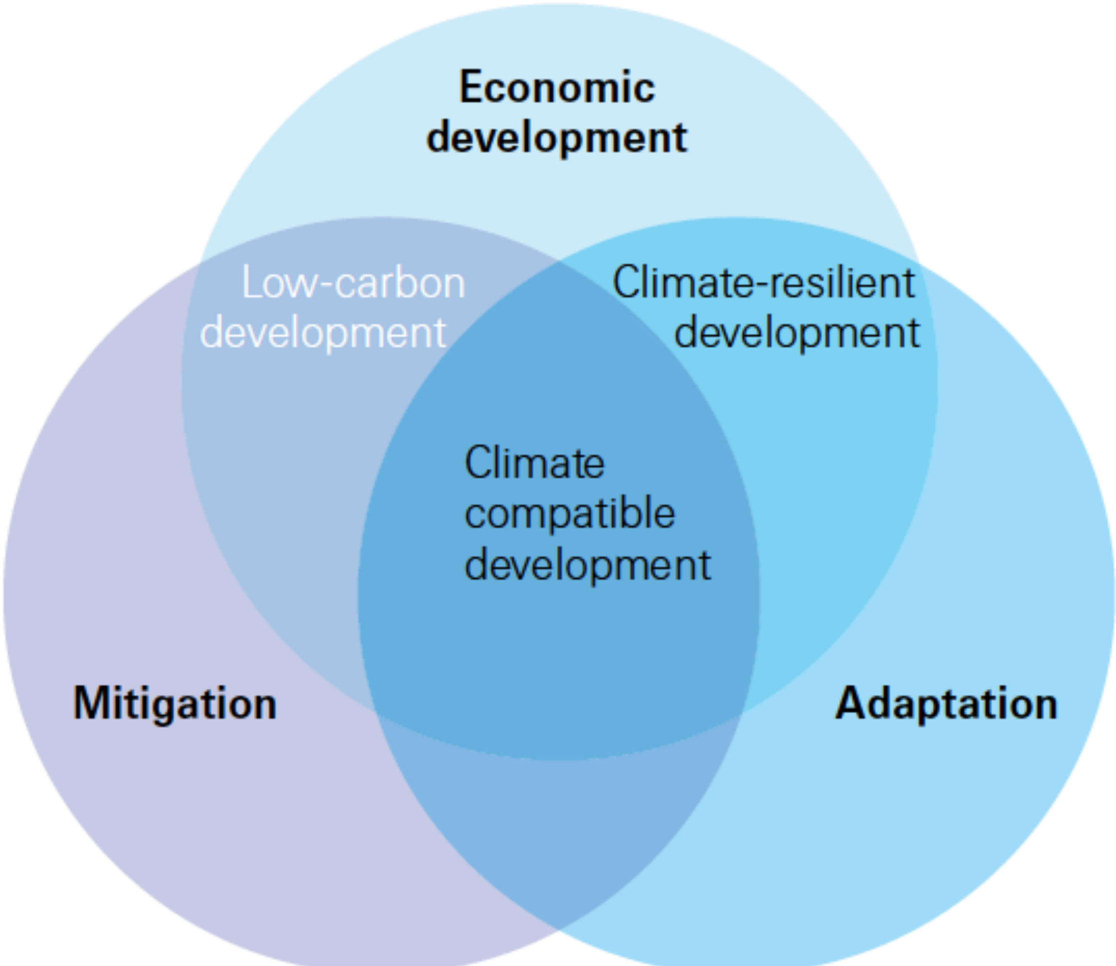
Trend decomposition going forward ?

→ 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

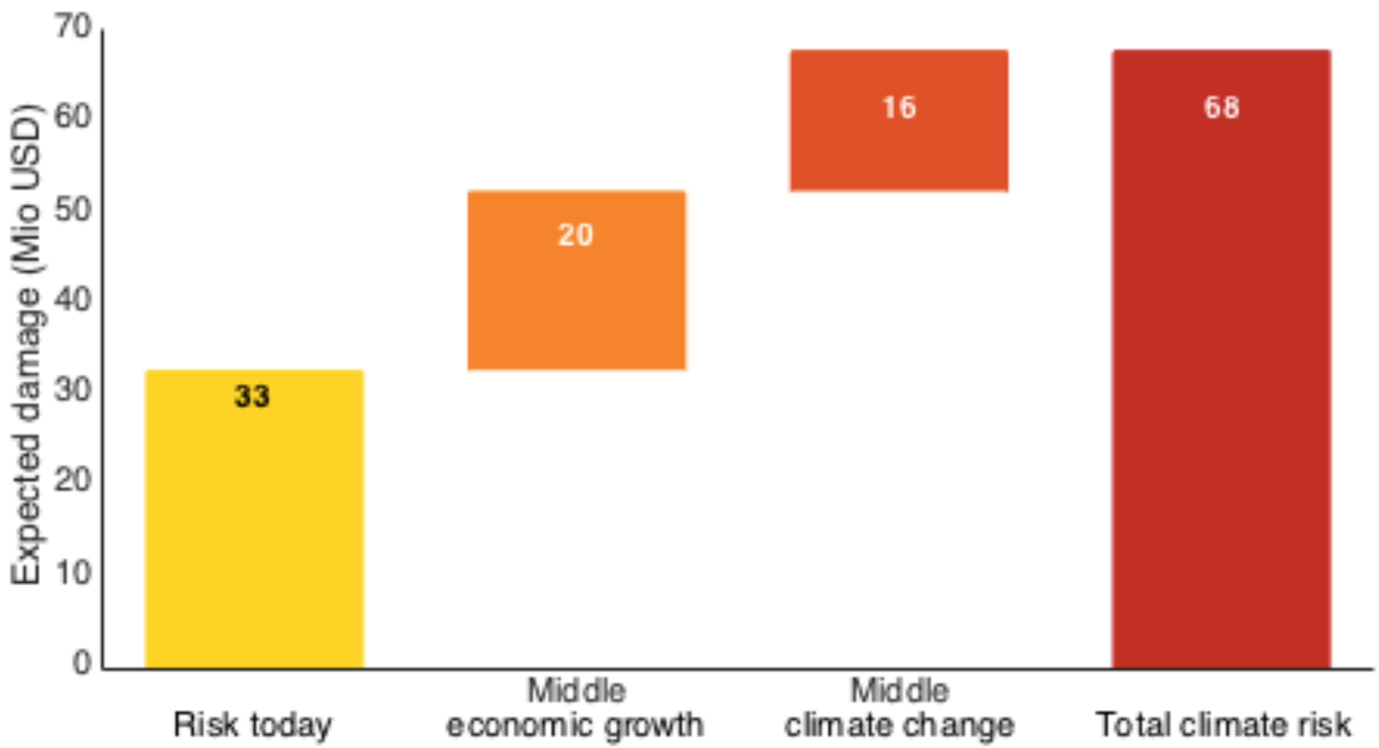
- Provide decision makers with the facts and methods necessary to design and execute a climate adaptation strategy
- Supply financial institutions, potential funders and insurers with the information required to unlock and deepen global adaptation finance and risk transfer markets

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

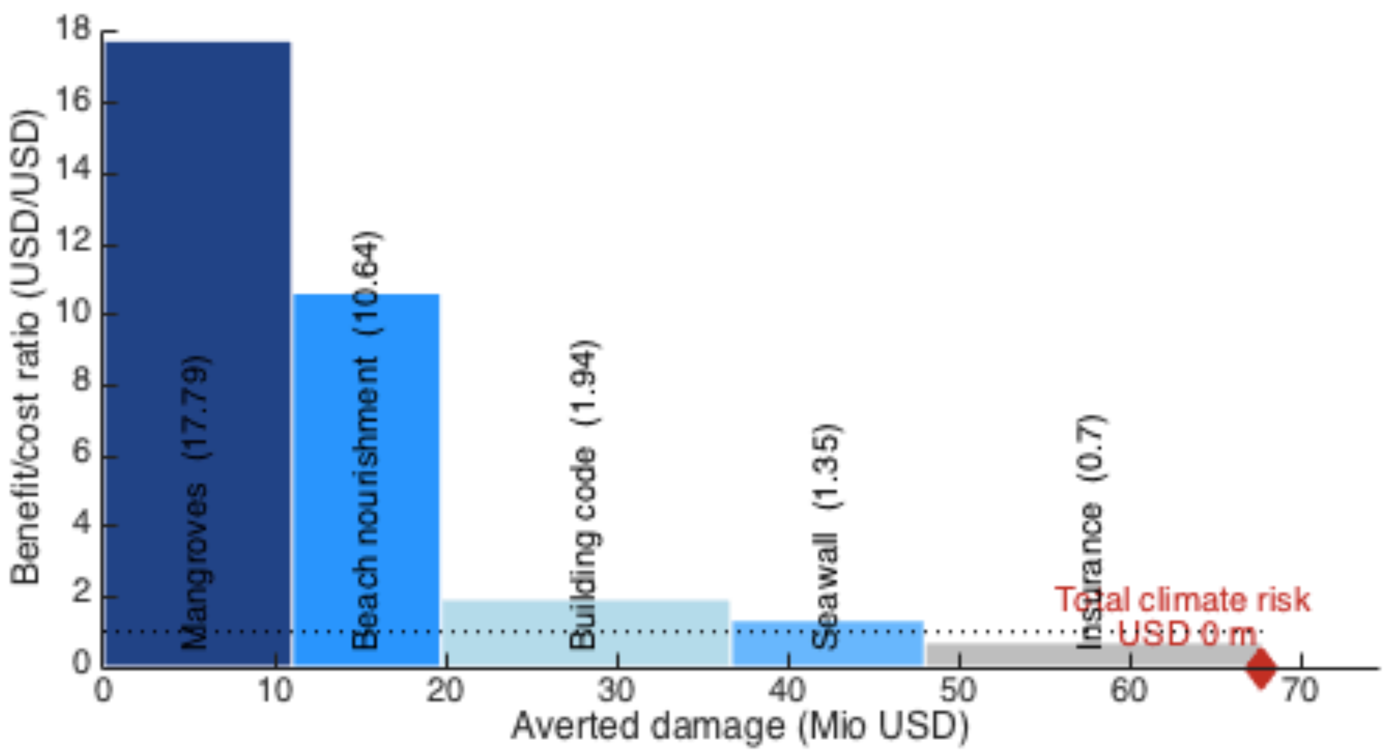
Economics of climate adaptation (ECA)
Key outputs of the methodology (1/2)

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

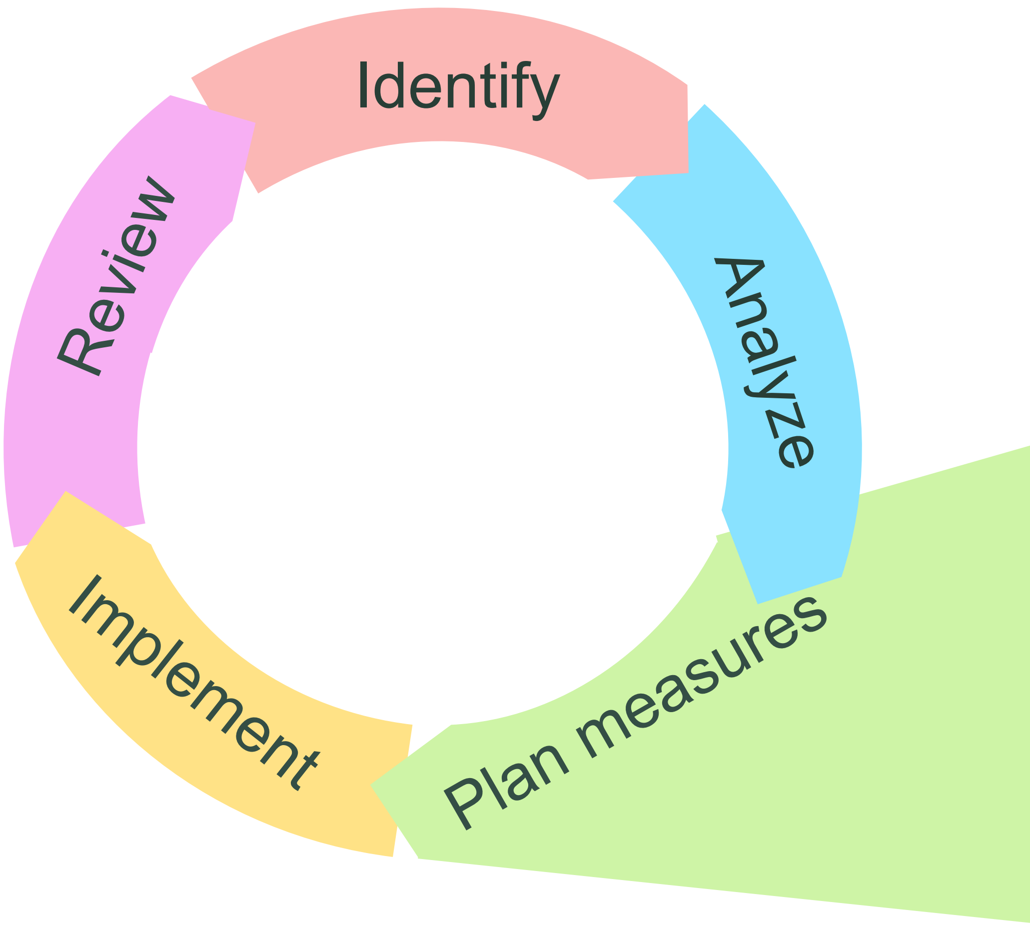
- Risk model: the quantitative expression of a shared mental model
  → allows to assess risk mitigation options

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

Identify

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)

Analyze

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

Plan measures

Set of adaptation measures

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

Implement

Implementation assessment

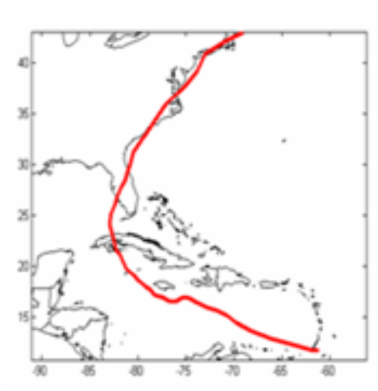
- Assess current progress against the measures
- Understand requirements to implementation
- Determine actions required to implement measures

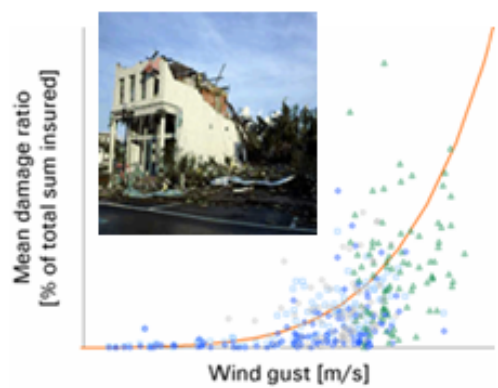
[1]Economics of Climate Adaptation

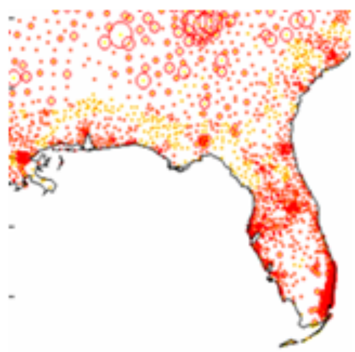
Natural catastrophe modelling

What is the magnitude of the expected loss?

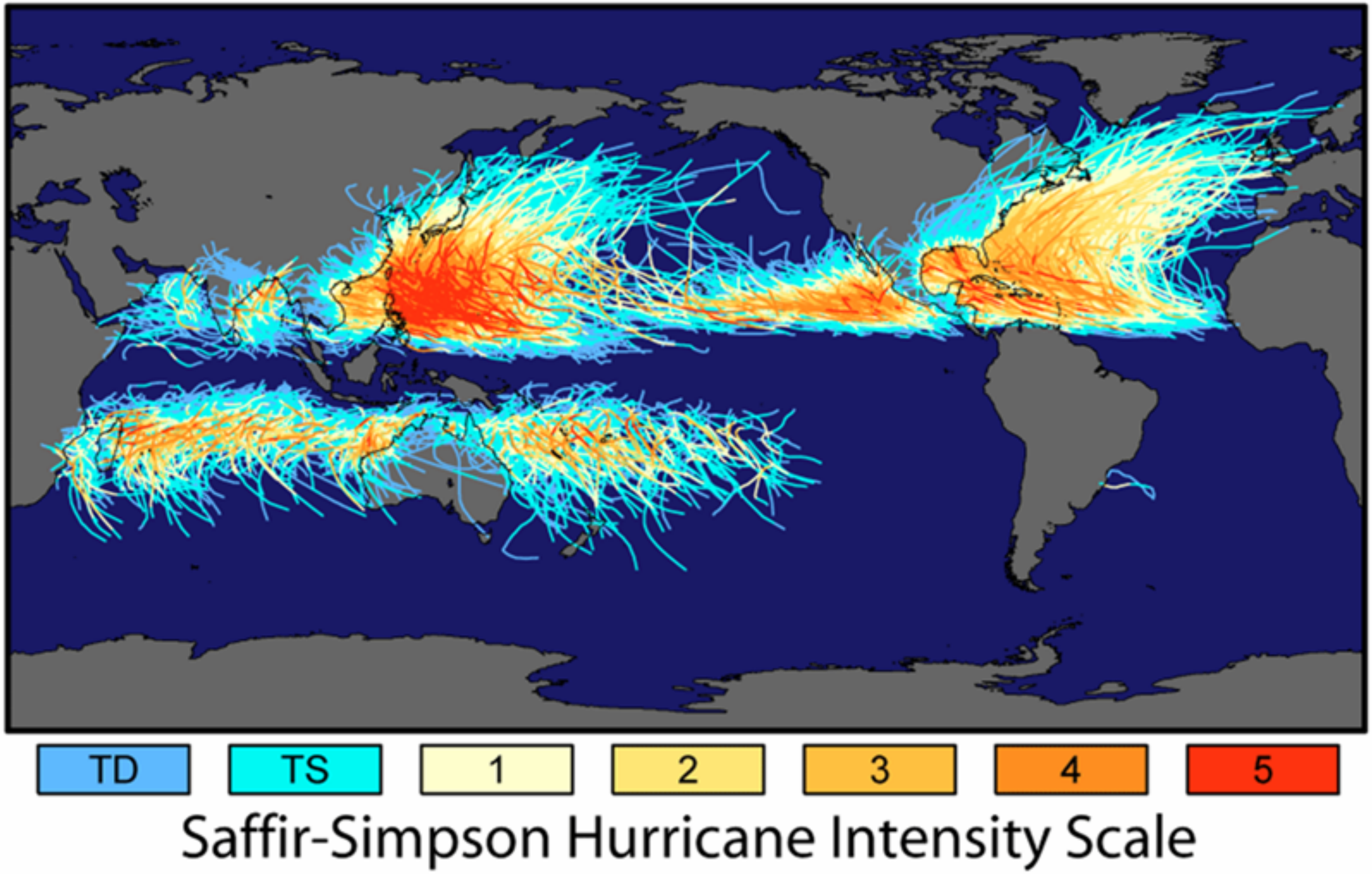
Hazard	Damage function	Assets
How strong? How frequent?	How well built?	Where? What?



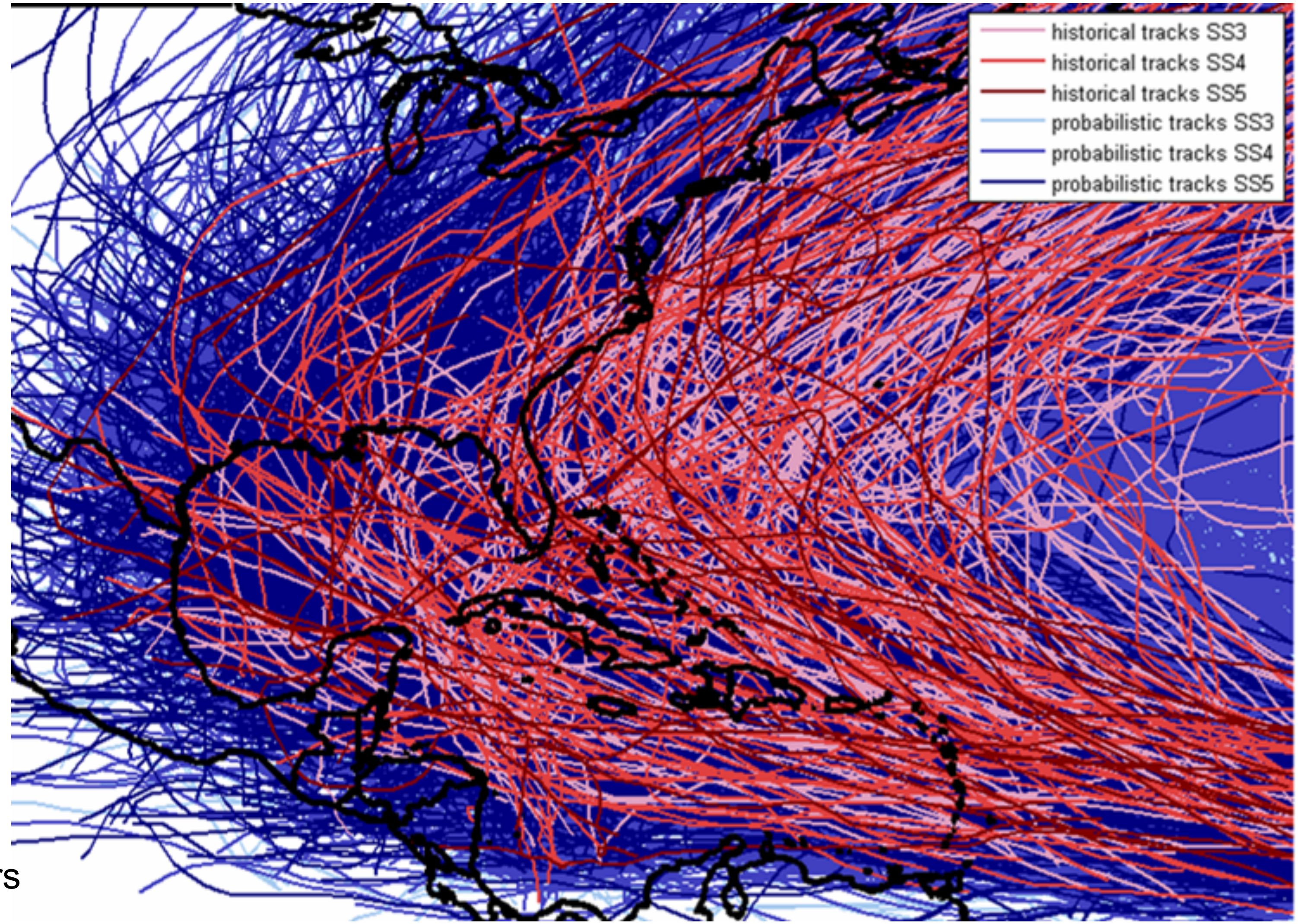




Tropical cyclones



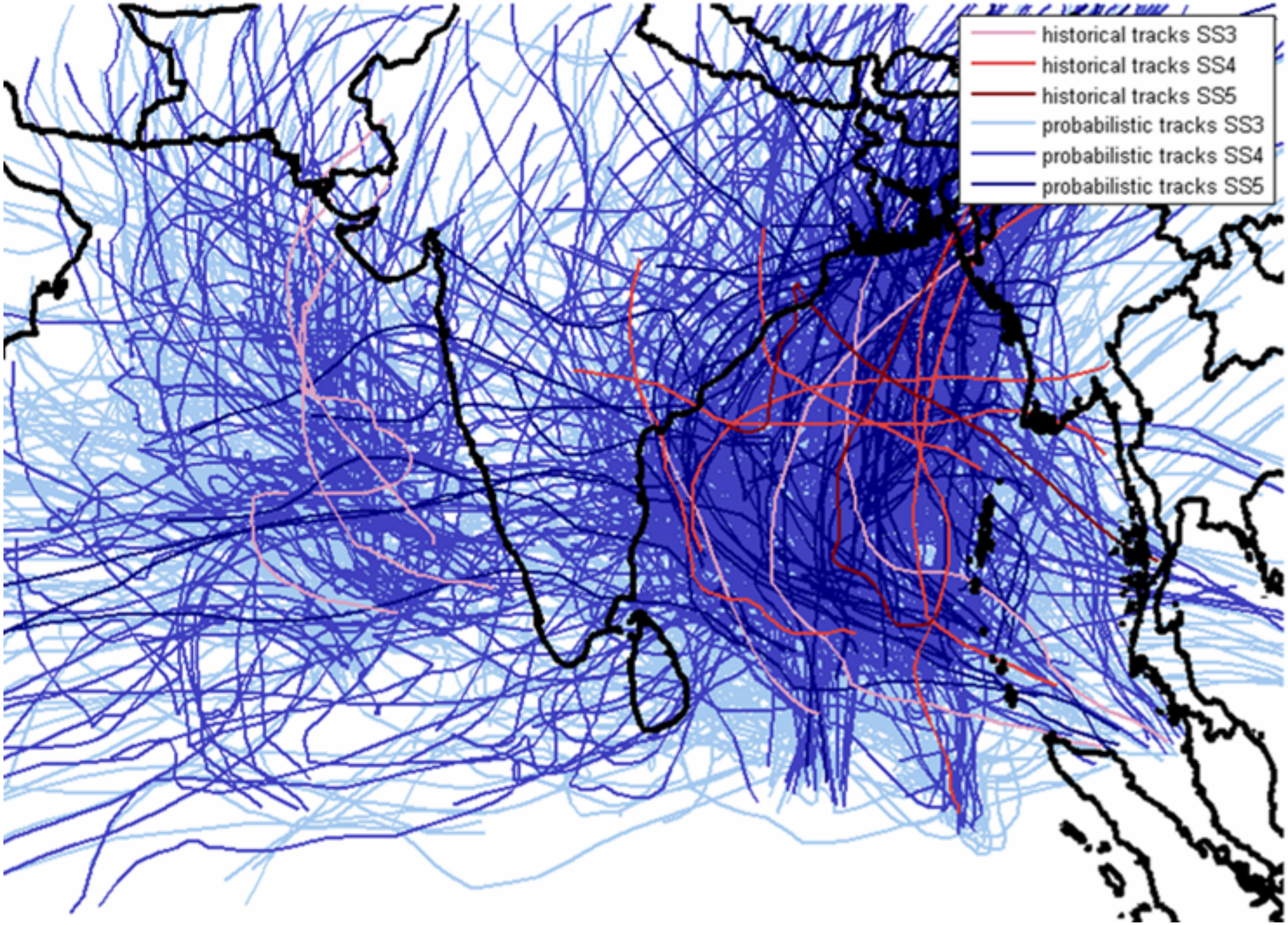
Tropical cyclones in the North Atlantic



historic
~100 years

probabilistic
~10‘000 years

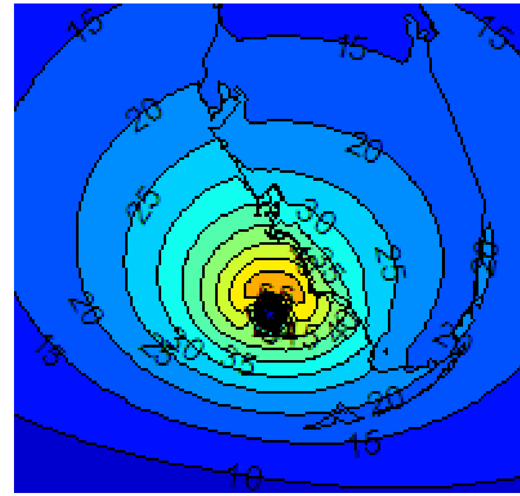
Tropical cyclones in the Indian ocean



historic
~ 25 years

probabilistic
~ 5‘000 years

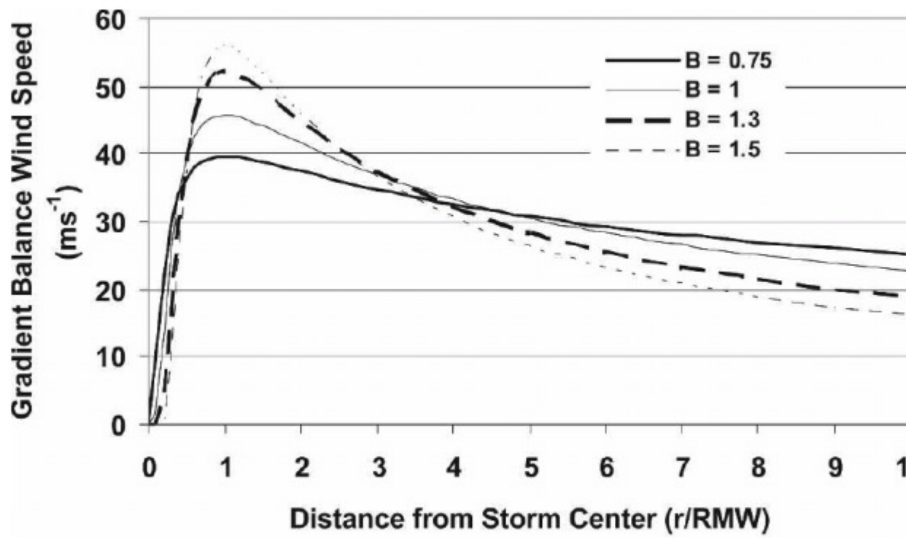
Tropical cyclone intensity – the wind field



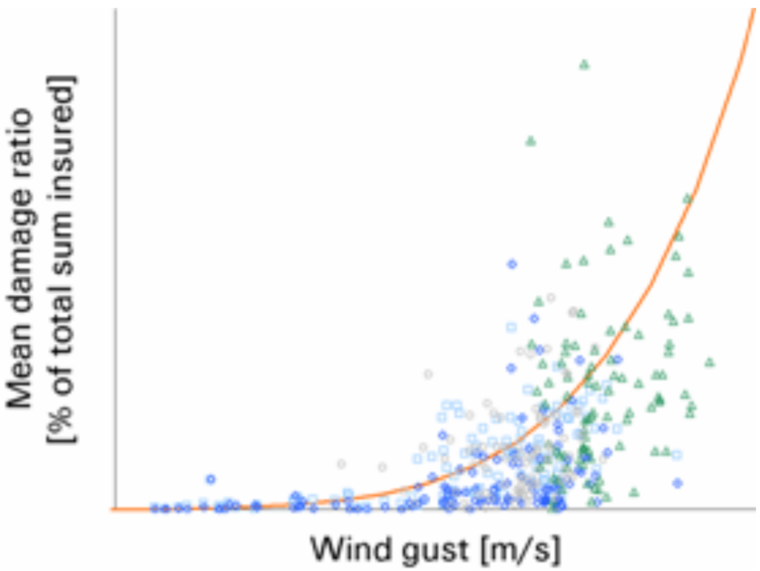
We use the Holland wind field model

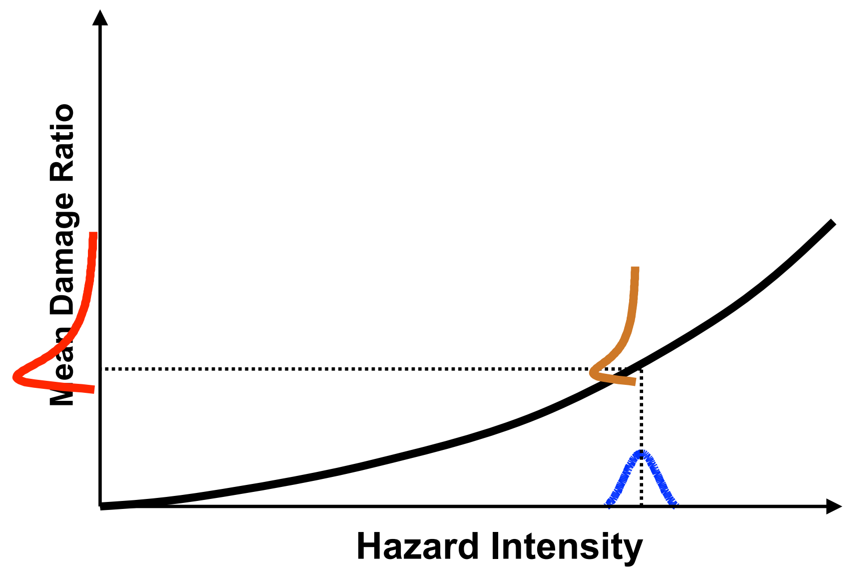
- The 1-min sustained wind at gradient wind level (boundary layer height & no surface effects) is modelled using the Holland 2008 approach. It models the first-order vortex of a tropical cyclone.
- The translational speed (also called celerity) is added geometrically.

- 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

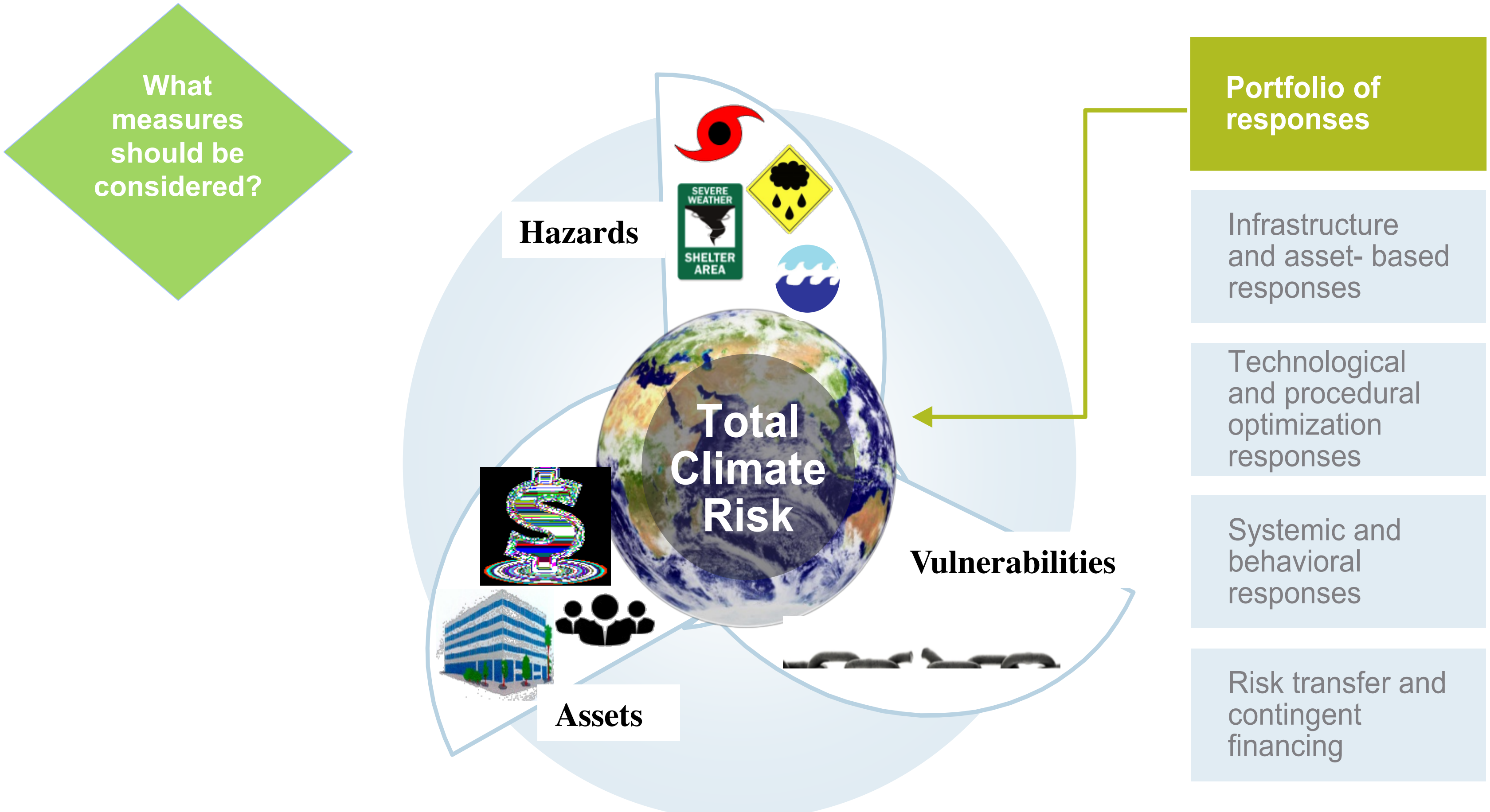
+

Uncertainty of the damage

results in

Convoluted Distribution

Basket of adaptation measures



→ 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:

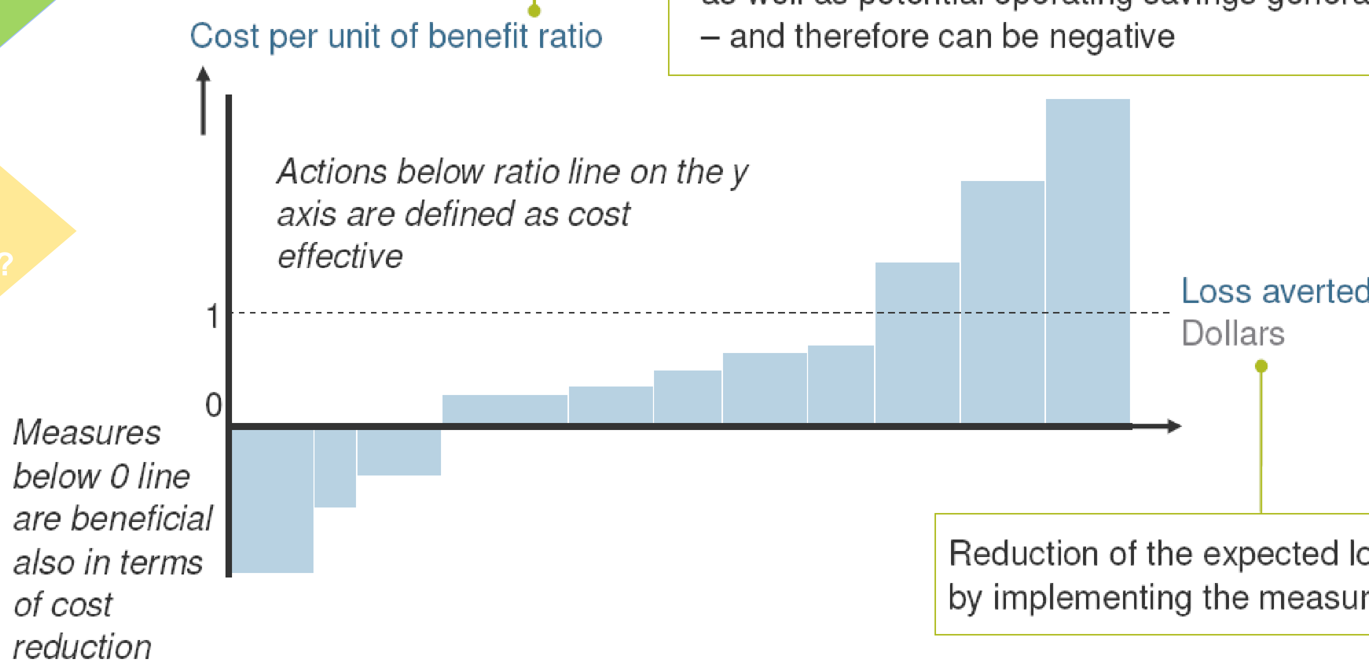
interest	5%	year										
	NPV	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
cost	13.77	10		1		1		1		1		1
benefit	12.28											20
cost/benefit	1.12											

The adaptation cost curve

What measures should be considered?

How can measures be implemented[1] ?

- Benefits include the loss averted and additional revenues (if applicable)
- Costs include capital and operating expenses as well as potential operating savings generated – and therefore can be negative



Reduction of the expected loss by implementing the measure

- 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

What measures should be considered?

How can measures be implemented[1] ?

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

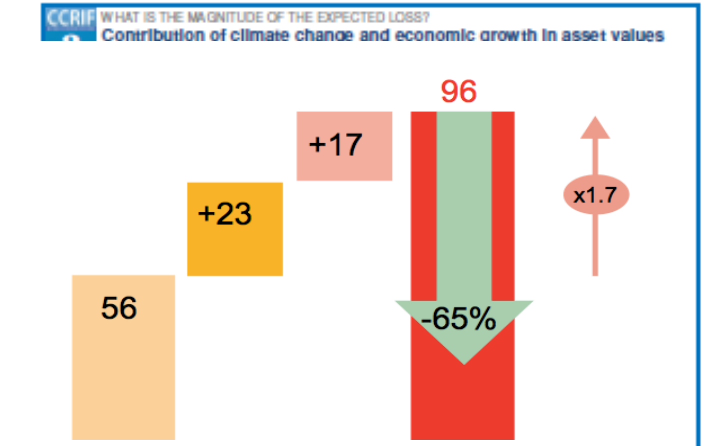
   → difference 2.1) minus 2.2) gives you benefit of measure today
3. Future (year 2030): assets, hazard as in the future (prob+scenario)
   1. calculate future annual expected loss with no measures
   2. calculate future annual expected loss with measure applied

   → 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

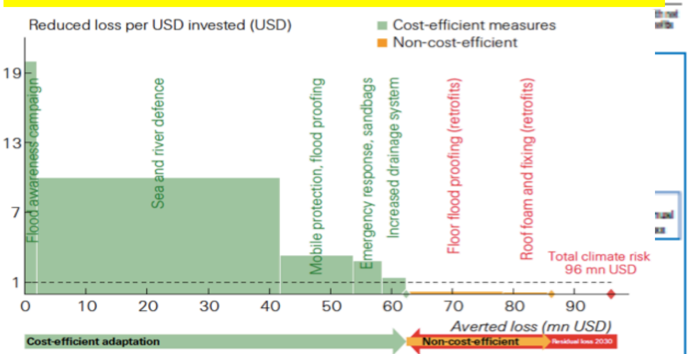
→ no worries, all implemented in climada, the open-source tool ;-)

Roadmap and business case for adaptation funding

Output of ECA analyses



Loss assessment



Cost/benefit analysis

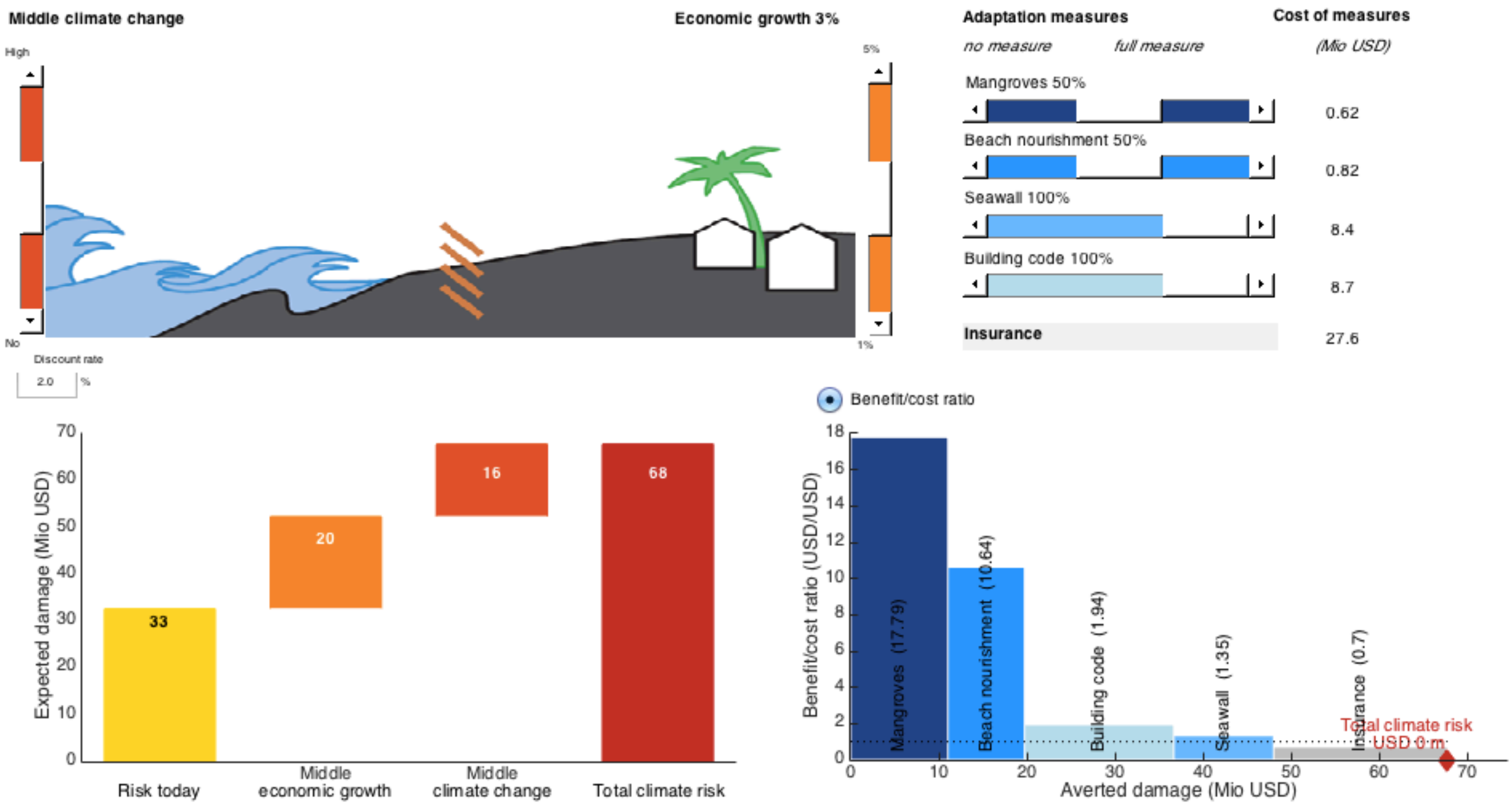
What if we …

- … **specify our 'risk appetite'** in line with our development priorities
- … **incorporate further criteria** relevant to us in addition to cost-benefit ratio
- … **(re-)prioritise** risk mitigation and transfer **measures** based on our priorities
- … calculate an **adaptation business case** incl. **investment plan**
- … develop a **roadmap** incl. **priority initiatives**
- … use **roadmap** and **business case for funding discussions**
- … **speed-up implementation** with the additional funding and further **increase resilience**

Workshop step-by-step

→ see the file climada_workshop_step_by_step.pdf for further instructions.

A visual primer in MATLAB: `climada_demo`



A global overview of ECA studies with a focus coastal communities
http://media.swissre.com/documents/Economics_of_Climate_Adaptation_focus_coastal_communities.pdf
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
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
Mali: Risk of climate zone shift to agriculture
http://media.swissre.com/documents/Economics_of_Climate_Adaptation_Factsheet_Mali.pdf
India: Drought risk to agriculture
http://media.swissre.com/documents/Economics_of_Climate_Adaptation_India_Factsheet.pdf