Tackling the climate challenge
A climate risk framework

Reinhard Mechler
IIASA

Institute of Advanced Studies in Climate Extremes and Risk Management
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Overview

1. Climate Change challenges
2. IPCC risk framework
3. Modelling and assessing risk
4. Risk assessment: Challenges
5. Example: Bangladesh
6. Conclusions
1. Climate Change Challenges
WIDESPREAD OBSERVED IMPACTS
A CHANGING WORLD
ADAPTATION IS ALREADY OCCURRING
RISKS OF CLIMATE CHANGE INCREASE WITH CONTINUED HIGH EMISSIONS
(a) Schematic effect of regional sea level rise on projected extreme sea level events (not to scale)

Historical Centennial extreme sea-level events (HCEs) become more common due to sea level rise.

1/century
1/decade
1/year
1/month

(b) Year when HCEs are projected to recur once per year on average

RCP8.5

RCP2.6

(c) Difference between RCP8.5 and RCP2.6

The difference map shows locations where the HCE becomes annual at least 10 years later under RCP2.6 than under RCP8.5.

IPCC, 2019
PLAN A
EFFECTIVE CLIMATE CHANGE MITIGATION AND CLIMATE RISK MANAGEMENT
A MORE VIBRANT WORLD
2. Perspective on risk
IPCC risk framework
Knight (1921): Uncertainty and risk

- Deep uncertainty
- Subjective uncertainty: subjective risk
- Quantified uncertainty: objective risk
- Certainty
1. **Idealized risk:** the conceptual framing of the problem at hand - dangerous anthropogenic interference with the climate system as dominant framing → informing mitigation

2. **Calculated risk:** the product of a model based on a mixture of historical (observed) and theoretical information → informing adaptation

3. **Perceived risk:** the subjective judgment people make about an idealized risk → informing adaptation

After Jones et al., 2014
IPCC AR5, chapter 2
Constructing of risk in the IPCC

• Historically focused on idealized and calculated risk—expert orientation

• Calculated risk: much stronger emphasis and embracing downside and upside risks

• Perceived risk: receiving more recognition also in terms of relevance for decision-making—towards more bottom-up decision-making

→ All are relevant and being taken up, integration by way of iterative risk management
Idealized risk

Responds to UNFCCC Article 2, 1992

Art. 2: “[...] prevent dangerous anthropogenic interference with the climate system.”

Art. 3: “[...] specific needs and special circumstances [...] especially those that are particularly vulnerable to the adverse effects of climate change [...].”

• Thresholds and tipping point perspective: 5 reasons for concern
• Also understanding of large and deep uncertainty key: halfway between risk-based and precautionary decision-support

IPCC, 1990
The 5 Reasons for Concern/burning embers diagram

IPCC, 2001

- Risks to Unique and Threatened Systems (I)
- Risks from Extreme Climate Events (II)
- Distribution of Impacts (III)
- Aggregate Impacts (IV)
- Risks from Future Large-Scale Discontinuities (V)
5 Reasons for Concern - the ‘Burning embers’

1. **Unique and threatened systems:** Some unique and threatened systems, including ecosystems and cultures, are already at risk from climate change (high confidence). Example: coral-reef systems.

2. **Extreme weather events:** Climate-change-related risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding, are already moderate (high confidence) and high with 1°C additional warming (medium confidence).

3. **Distribution of impacts:** Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development. Example: water availability.

4. **Global aggregate impacts:** Risks of global aggregate impacts are moderate for additional warming between 1-2°C, reflecting impacts to both Earth’s biodiversity and the overall global economy (medium confidence). Example: biodiversity loss.

5. **Large-scale singular events:** With increasing warming some physical systems or ecosystems may be at risk of abrupt and drastic changes. Example: Wet Antarctic Iceshield.
Approximation of pre-industrial levels)

- 2 degrees! COP16
- 1.5 degrees! COP21
- Current warming

Level of additional risk due to climate change

- Undetectable
- Moderate
- High
- Very high

IPCC, 2014
Message 5: The 2°C limit should be seen as a defence line. The ‘guardrail’ concept, in which up to 2 °C of warming is considered safe, is inadequate and would therefore be better seen as an upper limit, a defence line that needs to be stringently defended, while less warming would be preferable.
Calculated risk
From Climate Vulnerability...

Vulnerability to climate change is the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change.

EEA, 2012
Example
Economic Climate Vulnerability in Europe

Combined potential impacts of changes in annual mean evaporation, summer days, snow cover days, frost days, changes in inundation heights of a 100 year river flood event and a sea level rise adjusted 100 year coastal storm surge event on agriculture, forestry, summer and winter tourism, energy supply and demand.

Potential economic impact of climate change

- **Highest negative impact**
- **Medium negative impact**
- **Low negative impact**
- **No/marginal impact**
- **Low positive impact**
- **Medium positive impact**
- **High positive impact**
- **No data**
- **Reduced data**

Source: ESPON, 2011; EEA, 2012
Calculated risk …to Climate-related Risk

The potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the consequences if these events occur (IPCC, 2014)
Impacts from weather and climate events depend on:

- **nature and severity of event**
- **vulnerability**
- **exposure**
Socioeconomic development interacts with natural climate variations and human-caused climate change to influence risk.

Disaster Risk:
the likelihood of severe alterations in the normal functioning of a community or society due to weather or climate events interacting with vulnerable social conditions.

Vulnerability:
the predisposition of a person or group (exposure) to be adversely affected.
Increasing vulnerability, exposure, or severity and frequency of climate events increases **risk**.
Increasing vulnerability, exposure, or severity and frequency of climate events increases risk.
Entry points to the solution space

Vulnerability & Exposure
- Vulnerability & exposure reduction [C-1]
- Low-regrets strategies & actions [C-1]
- Addressing multidimensional inequalities [A-1, C-1]

Risk
- Risk assessment [B]
- Iterative risk management [A-3]
- Risk perception [A-3, C-1]

Anthropogenic Climate Change
- Mitigation [WGIII AR5]

Socioeconomic Pathways
- Diverse values & objectives [A-3]
- Climate-resilient pathways [C-2]
- Transformation [C-2]

Adaptation & Interactions with Mitigation
- Incremental & transformational adaptation [A-2, A-3, C-2]
- Co-benefits, synergies, & tradeoffs [A-2, C-1, C-2]
- Context-specific adaptation [C-1]
- Complementary actions [C-1]
- Limits to adaptation [C-2]

Governance
- Decision-making under uncertainty [A-3]
- Learning, monitoring, & flexibility [A-2, A-3, C-1]
- Coordination across scales [A-2, C-1]
3. Modelling and assessing risk
Risk appraisal

Hazard Assessment
- Flood Hazard
  - 10 and 100 years Return Period

Exposure Assessment
- Overlay with Sectors
  - Agriculture
  - Health
  - Education
  - Population

Vulnerability Assessment
- Define Damage Depth Ratio

Risk Assessment
- Agriculture at Risk
- Housing at Risk
- Health at Risk
- Education at Risk
From hazard to risk

Step 1: Hazard analysis
- Hazard intensity
- Eg water level

Step 2: Vulnerability analysis
- Damages

Step 3: Risk analysis: Probability * Damages
- Damages

Step 4: Analysis of benefits of risk reduction: Probability * Damages reduced

Exposure
People & Assets

Map showing infrastructure objects (symbols and lines) intersected with subsidence projections for 2013 for center of Semarang City, Central Java
Risk appraisal
Normal vs. extreme value distributions
Calculated risk

Figure 3: Example of Loss Exceedance Probability Curves

- 10 year (10%)
- 20 year (5%)
- 50 year (2%)
- 200 year (0.5%)
Calculated risk
Projecting riverine flood risk in Bangladesh

Exceedance probability

Baseline
2020 Const V
2050 Const V
2020 Dyn V

Asset loss in respective year as % GDP

Mechler & Bouwer, 2015
Benefits from reducing risk

Figure 3: Exceedance probability (EP) curve showing potential benefits of disaster risk reduction. Note: The EP curve represents the probability that losses will be a given amount, and flood risk reduction intervention shifts the EP curve to the left and therefore reduces the expected loss.

Mechler et al., 2014
Climate variability or change?
River gauge in Passau, Germany

Return period:
~ 100 years

Return period:
~ 50 years

Source: Zurich, 2014
Calculated risk

IPCC, 2014
Losses from coastal and riverine flooding - Europe

<table>
<thead>
<tr>
<th>Climatic drivers</th>
<th>Timeframe</th>
<th>Risk &amp; potential for adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Very low</td>
</tr>
<tr>
<td></td>
<td>Near-term (2030-2040)</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Long-term 2°C</td>
<td>Very high</td>
</tr>
</tbody>
</table>

Assessment Box SPM.2 Table 1.
**Coral reefs: Impact on biodiversity, fisheries, coastal protection**

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- Adaptation limits
Perceived risk

- Consider actors’ values, objectives, and planning horizons as they make decisions under uncertainty.
- Some risks may be routine and/or the consequences so minor that they are accepted.
- Other risks may be judged intolerable because they pose fundamental threats to actors’ objectives or the sustainability of natural systems.
- A key objective of adaptation is to avoid such intolerable risks. Yet, the capacity of societal actors and natural systems to adapt is finite, and thus there are limits to adaptation.
Perceived risk
Risk acceptance
4. Risk assessment: Challenges
Challenges with risk assessment

- Downscaled climate projections with climate variability
- Understanding socio-economic vulnerability
- Spatially explicit or aggregated population and asset information

Diagram:
- DISASTER RISK
- Vulnerability
- Exposure
- Weather and Climate Events
Challenges
Hazard
Projections at 1.5°C and 2°C

Guldberg et al., 2019
Building on IPCC, 2018
Attribution

Confidence in capabilities for attribution of specific events to anthropogenic climate change

Understanding of the effect of climate change on event type

James et al., 2019
Challenges
Exposure
Exposure maps

Mapping the unmapped

Legend
- Drinking Water
- Villages
- High Risk Mud Houses
- Medium Risk Brick-Mud Houses
- Medium Risk Brick Houses
- Medium Risk Mud Houses
- Roads
- Agricultural Land
- Community Forest
- Waterways

Liu et al., 2018
Mapping the unmapped: Mapathons

Karnali river basin, Nepal

Rimac Valley, Peru
Challenges
Vulnerability
Vulnerability important

- Africa’s largest recorded cholera outbreak
- over 90,000 affected
- over 4,000 killed
- began following onset of seasonal rains
- vulnerability and exposure increased risk

Zimbabwe 2008
Vulnerability important

Danube flooding, June 2013
Risk Assessment (flood)

Conceptual framework for flood hazard and flood risk mapping (The matrix and curves are purely illustrative and based on a hypothetical case. In the matrix the yellow colour signifies low danger, the orange colour moderate danger and the red colour high danger) (de Moel, van Alphen and Aerts, 2009).
Risk assessment... in practice
Understanding risk and trends

- Area flooded ('000 km²)
  - Exceedance probability
  - Baseline, 2020, 2050

- Asset losses as share of GDP
  - Vulnerability baseline, Vulnerability 2020, Vulnerability 2050

- Weather and Climate Events
- Vulnerability
- Exposure
- DISASTER RISK

- GDP USD 2010 (1980 to 2060)
Case study Bangladesh

Climatic Change
DOI 10.1007/s10584-014-1141-0

Understanding trends and projections of disaster losses and climate change: is vulnerability the missing link?

Reinhard Mechler • Laurens M. Bouwer

Received: 22 April 2013 / Accepted: 27 April 2014 © Springer Science+Business Media Dordrecht 2014

Abstract  The recent IPCC-SREX report demonstrated for the first time comprehensively that anthropogenic climate change is modifying weather and climate extremes. The report also documents, what has been long known, that losses from natural disasters, including those linked to weather, have increased strongly over the last decades. Responding to the debate regarding a contribution of anthropogenic climate change to the increased burden from weather-related disasters, the IPCC-SREX finds that such a link cannot be made today, and identifies the key driver behind increases in losses as exposure changes in terms of rising
Case study Bangladesh

- Hotspot: Riverine flood risk dominating - 1 large riverbasin
- Good probabilistic data
- Good experience in reducing risk
- What can be said about dynamic risk at country levels - macro analysis?
- How to capture vulnerability?

Tanner et al., 2007
Case study Bangladesh-impacts from riverine flooding

![Graph showing losses in 100 million USD (Constant 2000 USD) and fatalities (1000's) over the years 1960 to 2000. The graph indicates significant peaks in both categories, especially in the 1970s and 1980s.]
Case study Bangladesh-impacts from major riverine flooding

Tanner et al., 2007

<table>
<thead>
<tr>
<th>Year</th>
<th>Probability</th>
<th>Flooded area (000 sq km)</th>
<th>Fatalities</th>
<th>Losses (million current $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>1%</td>
<td>100</td>
<td>1,050</td>
<td>2,128</td>
</tr>
<tr>
<td>1988</td>
<td>2%</td>
<td>90</td>
<td>2,440</td>
<td>1,424</td>
</tr>
<tr>
<td>2007</td>
<td>7%</td>
<td>62</td>
<td>405</td>
<td>1,100</td>
</tr>
<tr>
<td>1987</td>
<td>8%</td>
<td>57</td>
<td>2,280</td>
<td>1,167</td>
</tr>
<tr>
<td>2004</td>
<td>9%</td>
<td>58</td>
<td>761</td>
<td>1,860</td>
</tr>
<tr>
<td>1974</td>
<td>11%</td>
<td>53</td>
<td>28,700</td>
<td>936</td>
</tr>
<tr>
<td>1984</td>
<td>53%</td>
<td>28</td>
<td>1,200</td>
<td>378</td>
</tr>
</tbody>
</table>
Bangladesh- modelling risks from riverine flooding
# Bangladesh- modelling risks from riverine flooding

<table>
<thead>
<tr>
<th>Module</th>
<th>Functional relationship or drivers</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Function of mean temperature change</td>
<td>PRECIS RCM for A2 and B1 (Data taken from Tanner et al. 2007)</td>
</tr>
<tr>
<td>Maximum discharge</td>
<td>Function of precipitation</td>
<td>Based on Conway et al. 2007</td>
</tr>
<tr>
<td>Flooded area</td>
<td>Function of max discharge</td>
<td>Statistical model (based on Mirza 2002)</td>
</tr>
<tr>
<td>Economic Vulnerability</td>
<td>Observed losses and vulnerability</td>
<td>Bangladesh statistics (Based on CRED 2010-1)</td>
</tr>
<tr>
<td>Exposure</td>
<td>GDP, assets</td>
<td>World Bank, 2012, SRES</td>
</tr>
<tr>
<td>Risk</td>
<td>Function of hazard, exposure and vulnerability</td>
<td></td>
</tr>
</tbody>
</table>
Bangladesh- modelling risks from riverine flooding

\[ D_{Max \_ G} = 603.48\Delta P + 52623 \]  
\[ D_{Max \_ B} = 535.59\Delta P + 65271 \]  
\[ D_{Max \_ M} = 227.73\Delta P + 14084 \]  
\[ D_t = D_{Max \_ G} + D_{Max \_ B} + D_{Max \_ M} \]  
\[ F(x) = \exp(-\exp(-x)) \]  
\[ F_{\mu,\sigma}(x) = \exp(-\exp(-\left(\frac{x - \mu}{\sigma} + \gamma\right)\pi / \sqrt{6})) \]  
with \( \gamma = \lim_n \left[ \frac{1}{\sum_k k} - \log n \right] = 0.5772 \)  
\[ F(t) = 1.2621\left(\frac{D_t}{10000}\right)^{3.778} \]  
\[ V(F_t) = v_0 * F_t * V_t \]  
\[ V(t) = 5E + 25*e^{(-0.0308*t)} \]  
\[ L(t) = V_t * E_t \]
Projecting flooding
Change in frequency of area flooded

Tanner et al., 2007
Measuring economic vulnerability concept of stage-damage curves

Fig. 2  a,b: Observed changes in economic vulnerability and vulnerability of loss of life (left panel), and derived economic vulnerability functions (right panel) for riverine flooding in Bangladesh. Source: Extended from Tanner et al. 2007

Mechler and Bouwer, 2015
Projecting riverine flood risk in Bangladesh
Projecting riverine flood risk in Bangladesh

Asset loss in respective year as % GDP

Exceedance probability

Baseline

2020 Const V
Projecting riverine flood risk in Bangladesh

Exceedance probability

Baseline
2020 Const V
2050 Const V

Asset loss in respective year as % GDP

0% 10% 20% 30% 40% 50% 6% 8% 10%
0% 10% 20% 30% 40% 50%
Projecting riverine flood risk in Bangladesh

[Graph showing exceedance probability as a percentage of GDP]
Projecting riverine flood risk in Bangladesh

![Graph showing exceedance probability and asset loss in respective year as % GDP. The graph includes baseline and specific year scenarios.]
Projections: average losses

Recorded annual average losses
Projections: average losses

Recorded annual average losses
Projections: average losses

Billion constant 2010 USD

Year


Recorded annual average losses

Modelled decadal average losses

Vulnerability constant - B1

Vulnerability constant - A2
Projections: average losses

Recorded annual average losses
Putting things into perspective…
Observed vulnerability, exposure and risk

Fig. 4 Observed changes in economic vulnerability, exposure and risk for disaster risk in Bangladesh, South Asia, and the OECD (normalized to different years). Note: Hazard for Bangladesh and the OECD is flooding (marked in blue); for South Asia tropical cyclones (marked in red). Data sources: Tanner et al. 2007; UNISDR 2011

Mechler and Bouwer, 2015
Implications

• Absent quantifications of vulnerability, studies on future losses under climatic change are not robust
  → important for risk planning questions

• Analysis suggests substantial benefits to supporting vulnerability-reducing measures
  → important for tailoring support for risk management

• Need for taking a truly risk-based perspective on modelling extremes: Drivers and outcomes
Conclusions

• As climate change has become real, real action required

• Risk perspective useful to consider
  – Question of ‘danger’: idealized risk
  – Calculated risk: actionable metric
  – Perceived risk: perceptions of those at risk

• IPCC impactful with climate risk analytics: *Reasons for Concern and Key Risks*
Conclusions

- Climate risk assessment with challenges
- Hazard: projections and attribution
- Exposure: what about the unmapped
- Vulnerability: how to operationalize at relevant scale (as input to risk)?