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University of Zurich[UZH]

Integrated climate impact assessment in mountains

Context, concepts and terms

Dr. Christian Huggel and Dr. Mario Rohrer

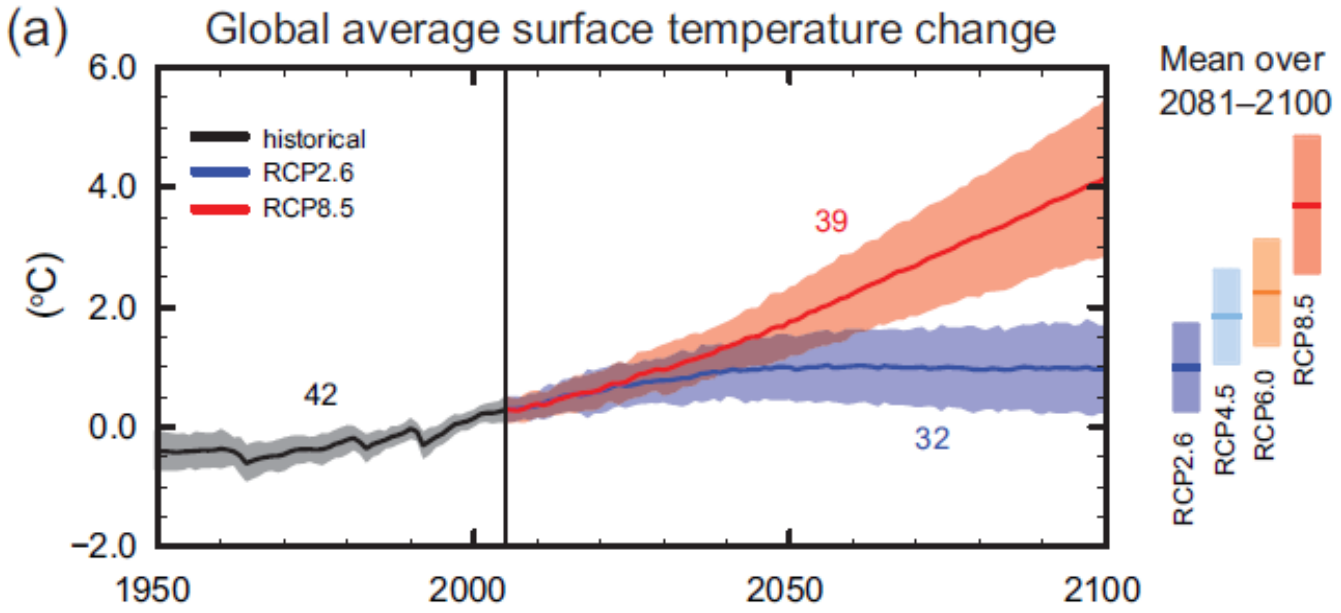
IHCAP – Indian Himalayas Climate Change Adaptation Programme
Capacity building programme “Cryosphere” Level-2, 2015

International context

International climate policy – 2015 is a decisive year

Global warming and carbon budgets

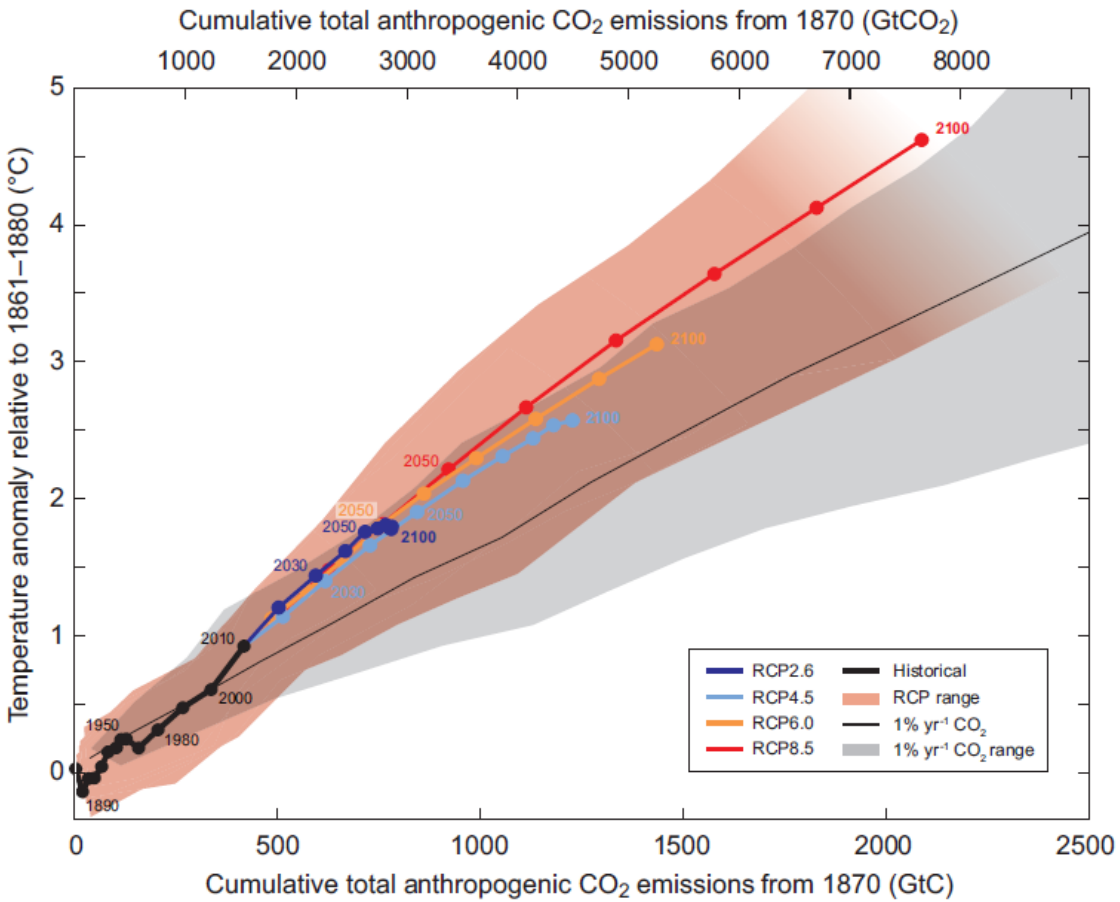
Projections of 21st century temperature increase



IPCC WGI AR5, 2013

Global warming and carbon budgets

The world's carbon budget

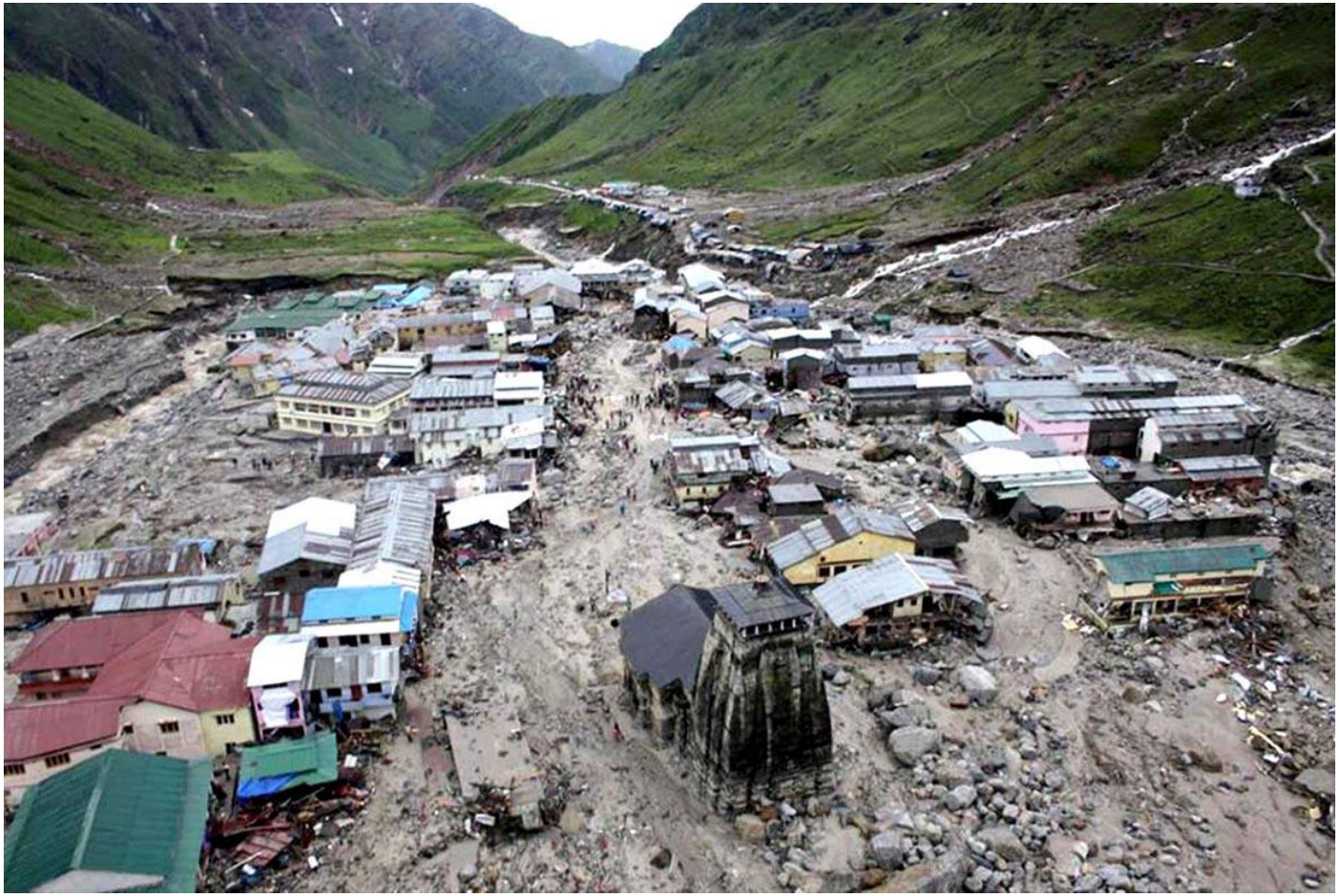


IPCC WGI AR5, 2013

Glacier lake outburst floods

Glacier lakes (Peru)

Glacier lake outburst floods



tibetsun.com

Kedarnath flood disasters 2013

Floods

Landslides

Snow avalanches

1997 Brenva rock-ice-snow avalanche (M. Fonte)

Snow avalanches

Kashmir, Photo AP

Rock and ice avalanches

Debris flows

Debris flow Swiss Alps, Transitgas AG / Kt. Bern

Debris flows

Debris flow Kazahstan, Kazhydromet

Debris flow Swiss Alps

Debris flows

Debris flow Swiss Alps, Kanton Graubünden

Heat wave

tldm.org

Inblive.in

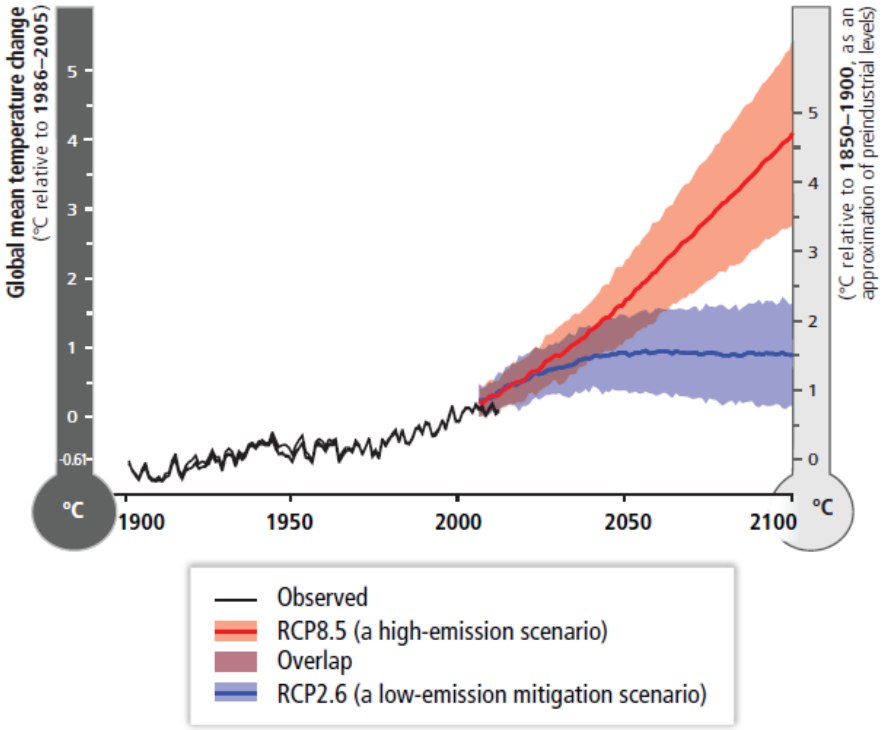
wxedge.com

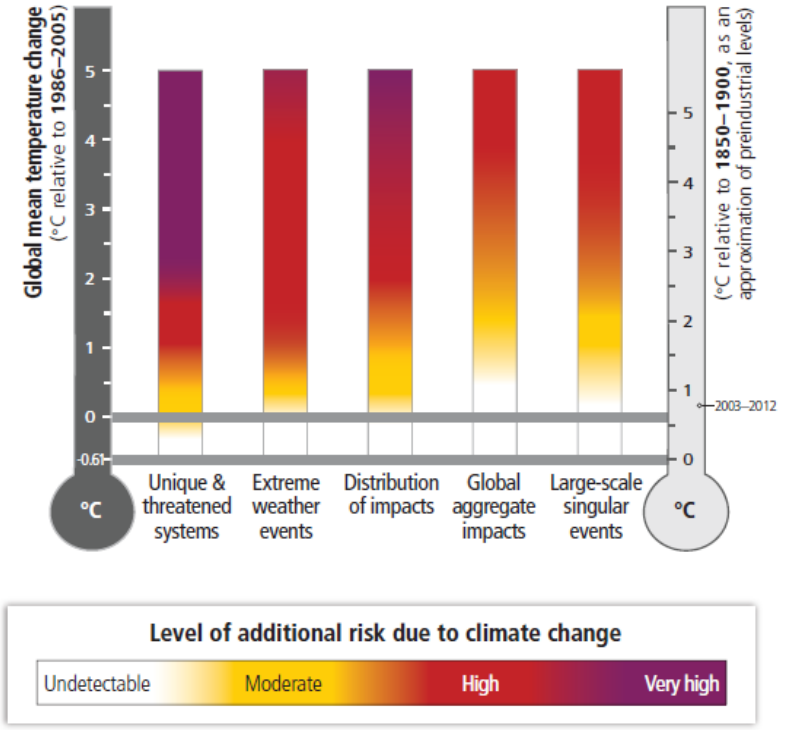
Droughts

Cold waves

Warming and risks

Increasing temperatures - increasing risks

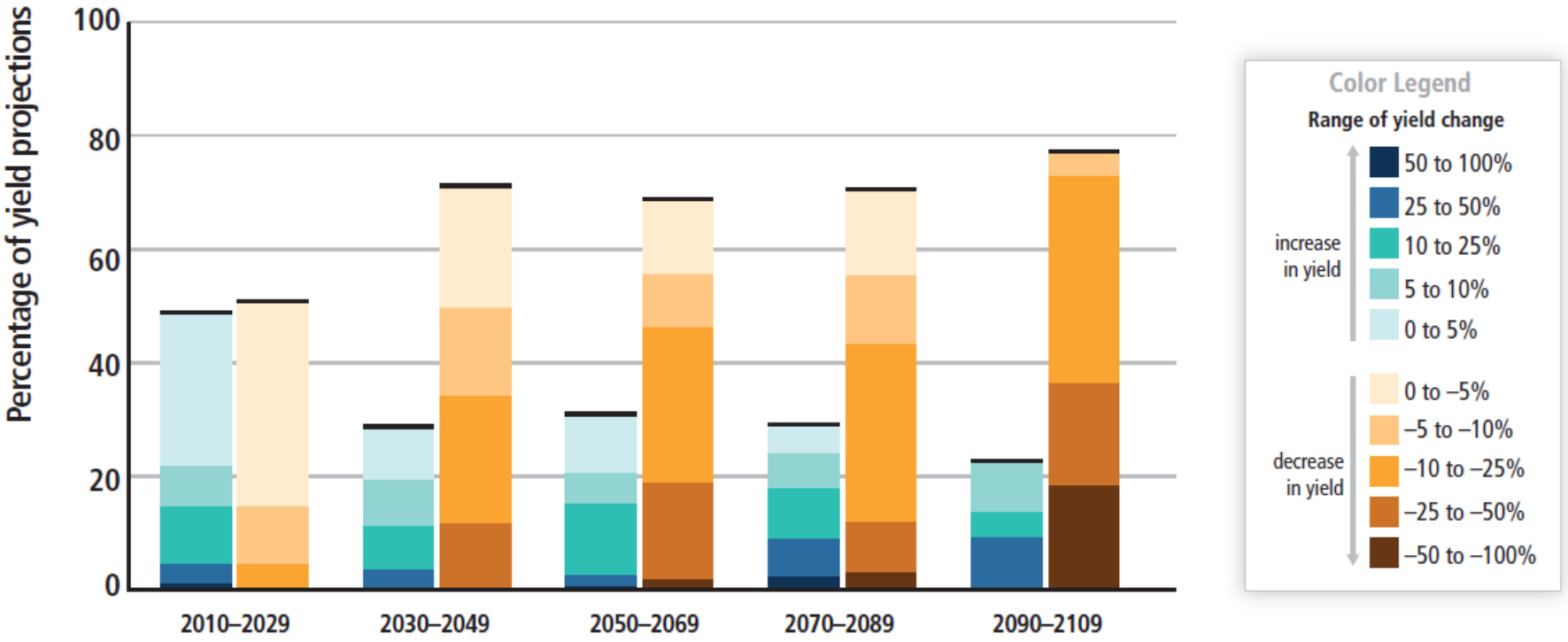




IPCC WGII AR5, 2014

Climate impacts

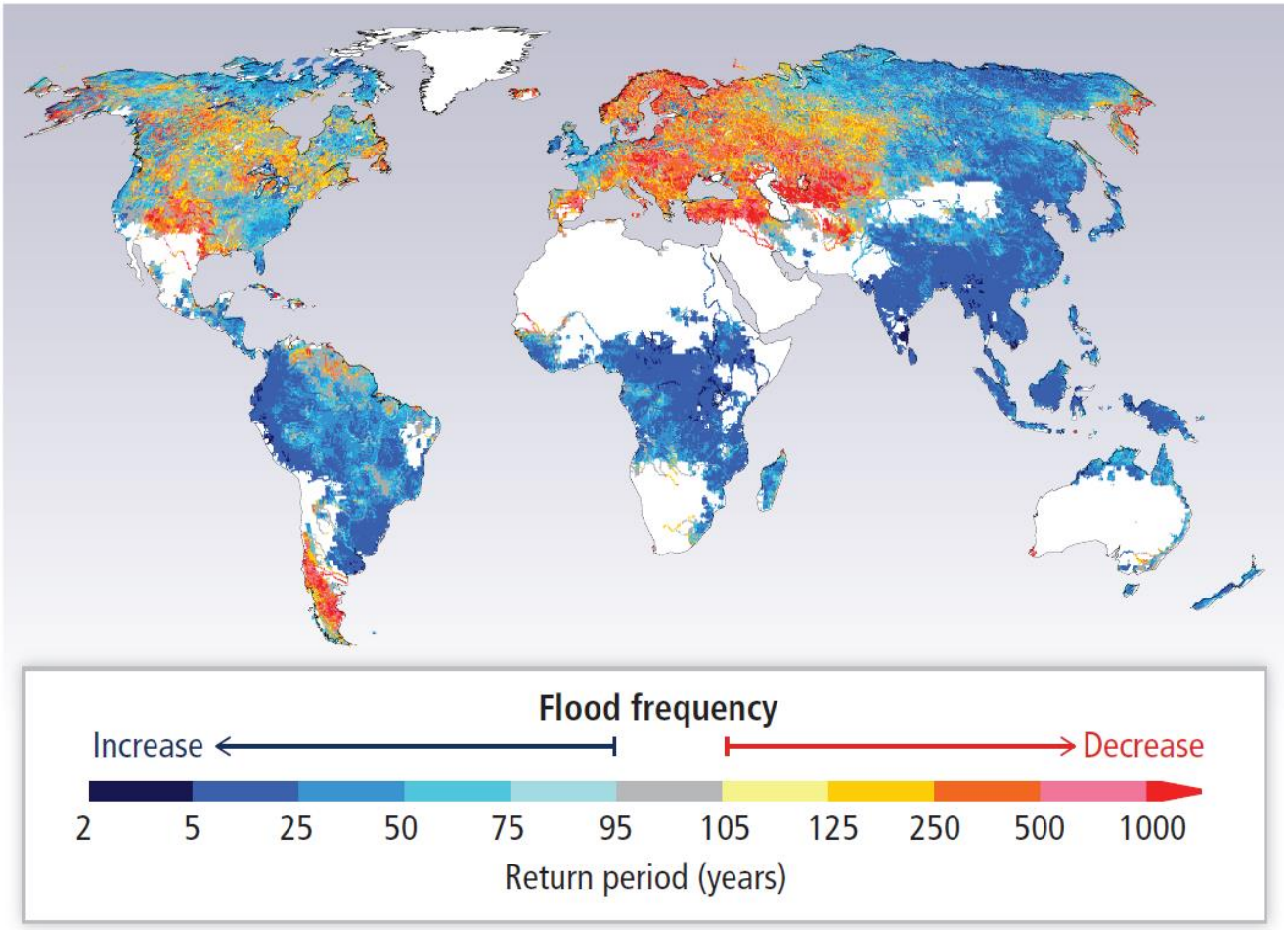
Effects on crop yields



IPCC WGII AR5, 2014

Climate impacts

Effects on flood frequency

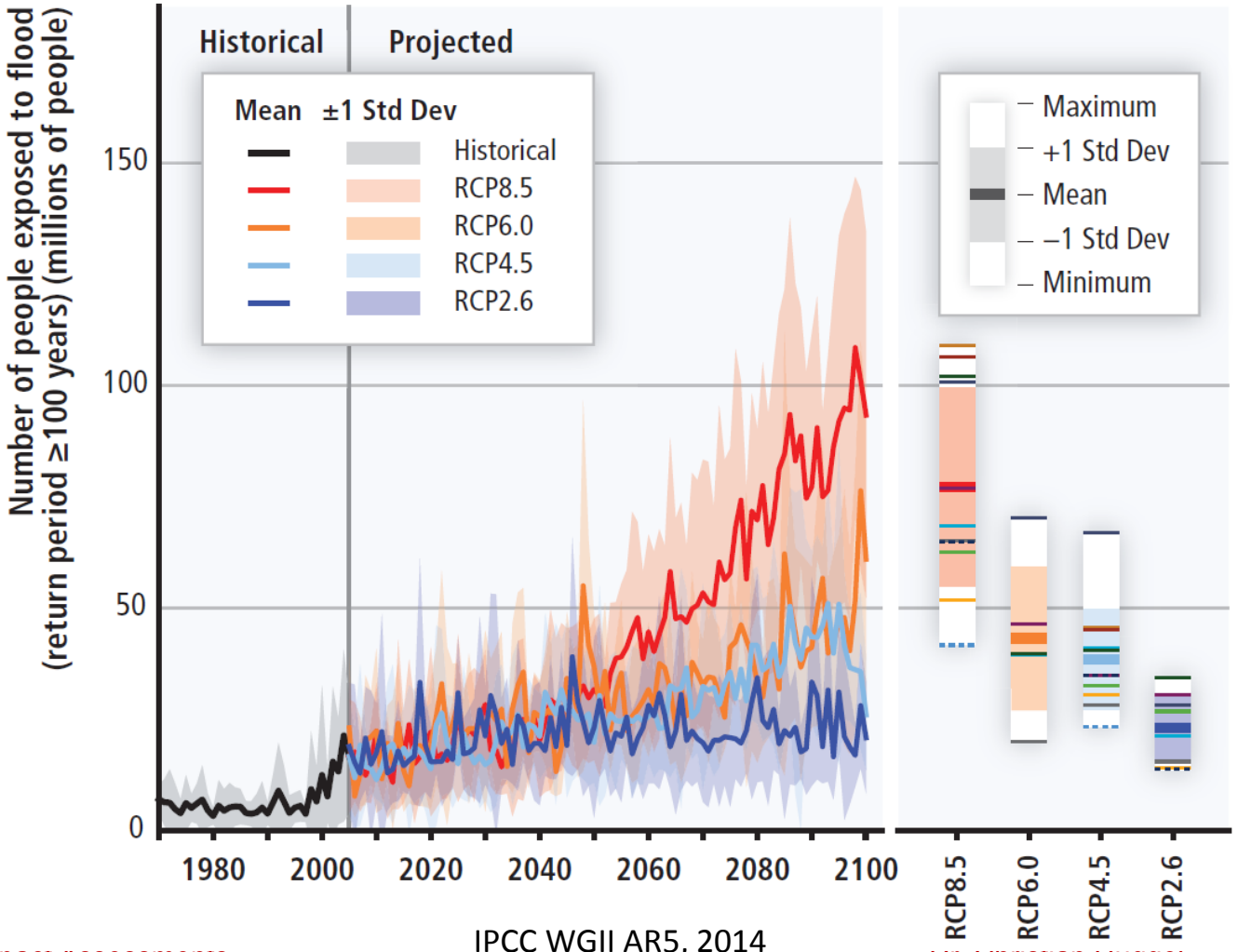


Flood frequency change in 2080's relative to 20th century return periods, under RCP8.5

IPCC WGII AR5, 2014

Climate impacts

People exposed to floods

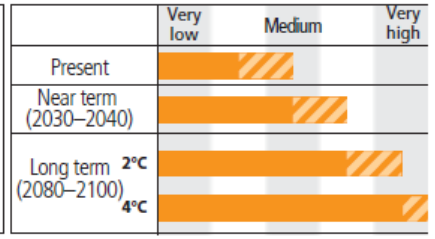
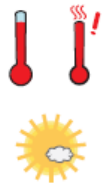
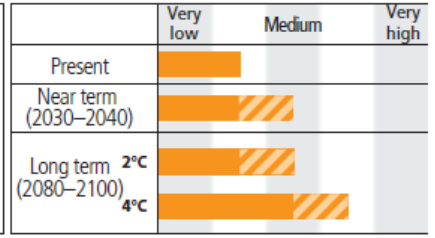


Global exposure to floods (to 20th century 100 year return period floods)

IPCC WGII AR5, 2014

Impacts, risks and adaptation

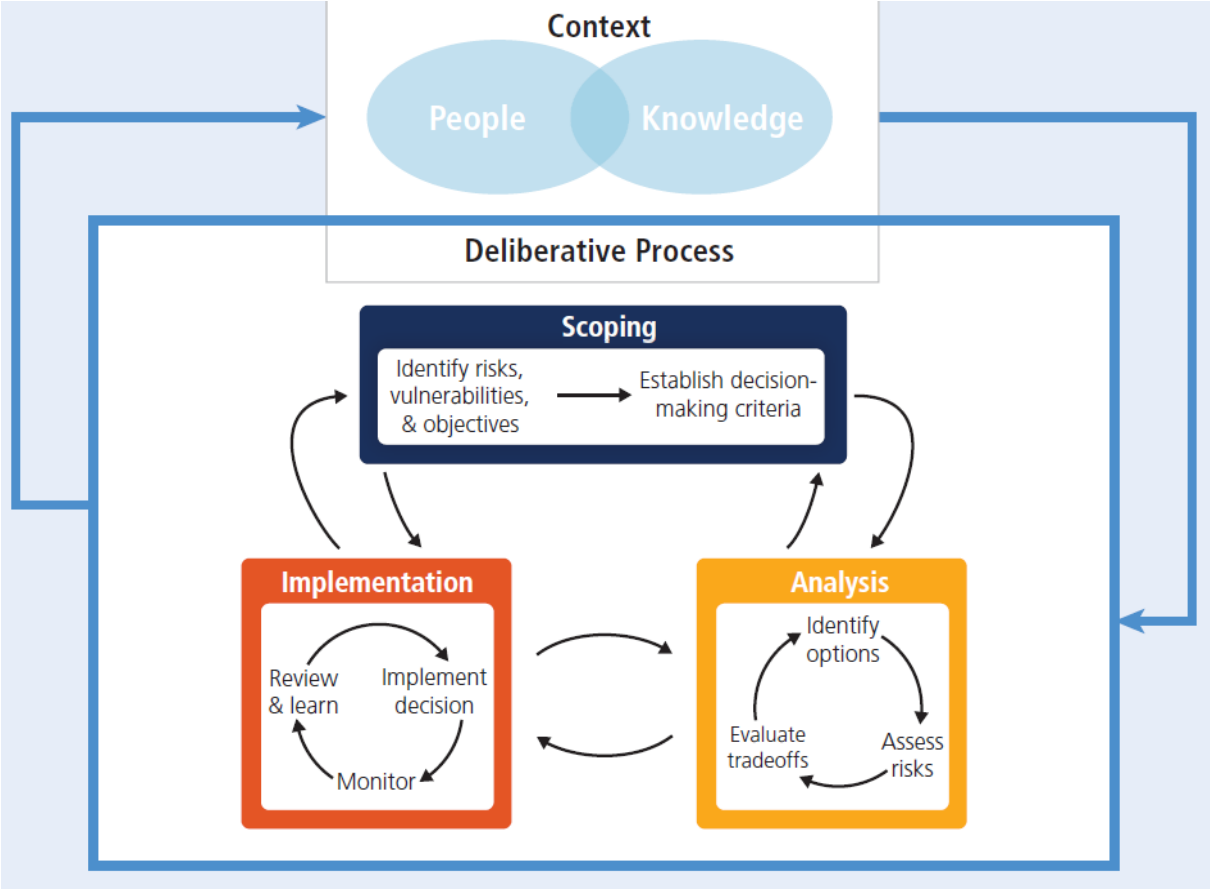
The risk – adaptation nexus

Asia				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation**
Increased risk of heat-related mortality (*high confidence*) [24.4]	• Heat health warning systems • Urban planning to reduce heat islands; Improvement of the built environment; Development of sustainable cities • New work practices to avoid heat stress among outdoor workers			
Increased risk of drought-related water and food shortage causing malnutrition (*high confidence*) [24.4]	• Disaster preparedness including early-warning systems and local coping strategies • Adaptive/integrated water resource management • Water infrastructure and reservoir development • Diversification of water sources including water re-use • More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture)			

IPCC WGII AR5, 2014

Adaptation

Framing processes for adaptation



IPCC WGII AR5, 2014

Adaptation

Institutional setting in India

1. How to adapt to climate change
2. How to make a transition to a low carbon growth path

National Level

National Action Plan on Climate Change (NAPCC)

8 National Missions

National Mission on Sustaining Himalayan Ecosystem (NMSHE)

Assessment of the **impacts of climate change in 2030s** on key sectors of the economy.

Sub-National (State) Level

State Action Plan on Climate Change (SAPCC)

Indian Network of Climate Change Assessment" (INCCA) provides input to NATCOM

Indian Himalayas Climate Adaptation Programme (IHCAP)

Impacts, vulnerability and risk

IPCC SREX 2012 / AR5 2014

Impacts
Effects on natural and human systems. Impacts refer to the effects on natural and human systems of extreme weather and climate events, and of climate change.

Hazard
The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources.

Vulnerability
The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity, or susceptibility to harm, lack of capacity to cope and adapt.

Impacts, vulnerability and risk

IPCC AR5 2014

Vulnerability index

A metric characterizing the vulnerability of a system to a change in climate. A vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent hazards or physical impacts, exposure, sensitivity, resilience, or adaptive capacity.

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 a hazardous event(s) multiplied by the consequences if the event(s) occurs.

Vulnerability definitions

IPCC (2007) defined vulnerability according to 3 dimensions:

Exposure
Physical exposure of a system to character, frequency, magnitude and rate of climate effect, climate change and variability.

Sensitivity
Sensitivity is the degree to which a system is affected, either adversely or beneficially, by *climate variability* or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to *sea-level rise*).

Adaptive capacity
The ability of a system to adjust to *climate change (including climate variability and extremes) to moderate potential damages,* to take advantage of opportunities, or to cope with the consequences.

Vulnerability definitions

IPCC (2007):

Vulnerability
Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is ***exposed***, its ***sensitivity***, and its ***adaptive capacity***.

Adaptation definitions

IPCC (2012, 2014):

Adaptation
In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate.

Schools of vulnerability

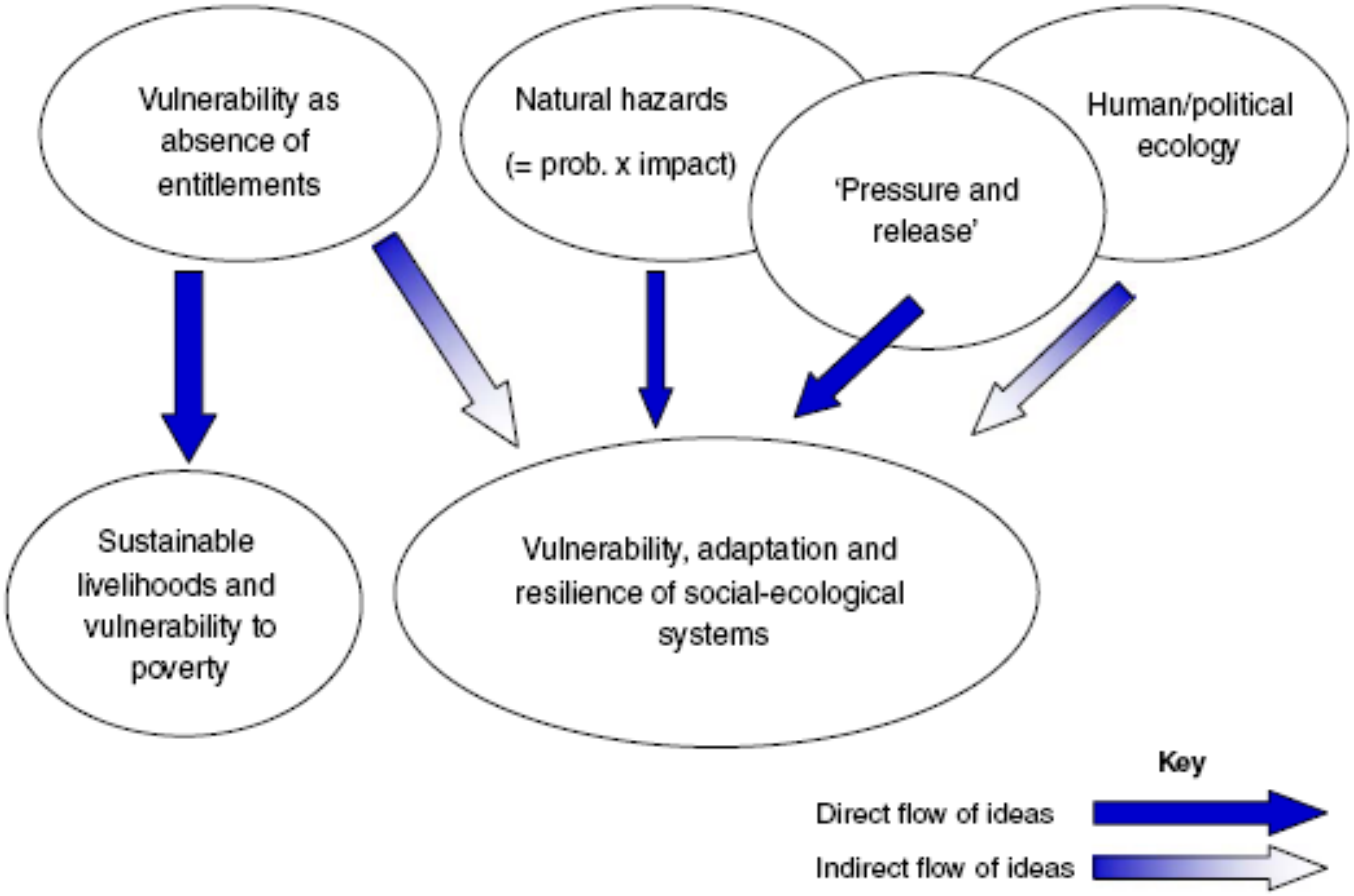


Fig. 1. Traditions in vulnerability research and their evolution.

Adger, 2006

Schools of vulnerability

Antecedent and successor traditions in vulnerability research

Vulnerability approach	Objectives	Sources
Antecedents		
Vulnerability to famine and food insecurity	Developed to explain vulnerability to famine in the absence of shortages of food or production failures. Described vulnerability as a failure of entitlements and shortage of capabilities.	Sen (1981); Swift (1989); Watts and Bohle (1993)
Vulnerability to hazards	Identification and prediction of vulnerable groups, critical regions through likelihood and consequence of hazard. Applications in climate change impacts.	Burton et al. (1978, 1993); Smith (1996); Anderson and Woodrow (1998); Parry and Carter (1994)
Human ecology	Structural analysis of underlying causes of vulnerability to natural hazards.	Hewitt (1983); O'Keefe et al. (1976); Mustafa (1998)
Pressure and Release	Further developed human ecology model to link discrete risks with political economy of resources and normative disaster management and intervention.	Blaikie et al. (1994); Winchester (1992); Pelling (2003)
Successors		
Vulnerability to climate change and variability	Explaining present social, physical or ecological system vulnerability to (primarily) future risks, using wide range of methods and research traditions.	Klein and Nicholls (1999); Smit and Pilifosova (2001); Smith et al. (2001); Ford and Smit (2004); O'Brien et al. (2004)
Sustainable livelihoods and vulnerability to poverty	Explains why populations become or stay poor based on analysis of economic factors and social relations.	Morduch (1994); Bebbington (1999); Ellis (2000); Dercon (2004); Ligon and Schechter (2003); Dercon and Krishnan (2000)
Vulnerability of social-ecological systems	Explaining the vulnerability of coupled human-environment systems.	Turner et al. (2003a, b); Luers et al. (2003); Luers (2005); O'Brien et al. (2004)

Adger, 2006

Vulnerability definitions

$$V_\alpha = \frac{1}{n}\left[\sum_{i=1}^{q}(W_0 - W_i/W_0)^\alpha\right]$$

where V_α is the vulnerability indicator, W_i the well-being of individual i; W_0 the threshold level of well-being representing danger or vulnerability; n the total number of individuals (whether households, farms, settlements or whatever); q the number of individuals above the vulnerability threshold; α the sensitivity parameter and individuals are ordered from bottom to top (W_1 is more vulnerable than W_2 and so on).

Adger, 2006

Schools of vulnerability

Community: Disaster risk reduction	Community: Adaptation to climate change
Vulnerability	
Conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards (UN/ISDR 2004). Vulnerability is characterized by a double structure and encompasses an internal and an external side (see in detail Bohle 2001). Vulnerability is multi-dimensional, scale dependent and dynamic (Vogel/O'Brien 2004, Birkmann 2006, Cutter 2003, Downing et al. 2006).	The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC 4th Assessment Report, Working Group II, Appendix I)

Birkmann et al., 2009

Schools of vulnerability

Similarities / differences	Recommendations for the use of terminology
The CCA school mainly views vulnerability as an end-point, while DRR focuses vulnerability more as a starting point. Vulnerability in the DRR community is clearly separated from the hazard part, while the vulnerability definition in the CCA community also encompasses the character, magnitude and rate of climate change. Exposure could be a bridge between vulnerability and the hazard or extreme event, but the magnitude and rate of climate change are not really a core characteristic of vulnerability and should therefore be treated separately.	Establishment of a process oriented view of vulnerability. Identification of generic elements of vulnerability. Improvement of the separation between vulnerability and characteristics of the climate change phenomena. A generic framework should be developed that outlines the main characteristics of vulnerability to climate change in a dynamic way.

Birkmann et al., 2009

Schools of adaptation

Community: disaster risk reduction	Community: adaptation to climate change
Adaptation	
Interestingly, key publications of UN/ISDR, such as "Living with Risk" (2004) do not employ the term adaptation in the core glossary at the end on basic terms of disaster risk reduction (see UN/ISDR 2004). In current documents adaptation is linked to three activities in DRR such as: a) Risk Assessment, b) Early warning systems and c) Sector-specific risk reduction plans (see UN/ISDR; Submission to the UNFCCC; Status of Implementation of Article 4, Paragraph 8 of the Convention, Decision 5/CP.7 and Decision 1/CP.10). However, a more in-depth definition is not provided. Summarizing definitions of adaptation in DRR research, adaptation can be understood as e.g. the change or adjustment of livelihoods to the altered conditions in order to maintain major activities during extreme events without losing assets and capital. In contrast to coping adaptation is determined by medium- and long-term adjustments (Vogel/O'Brien 2004) and correspond with the notion of change (Birkmann 2009).	Adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC 4th Assessment Report, Working Group II; Appendix I)

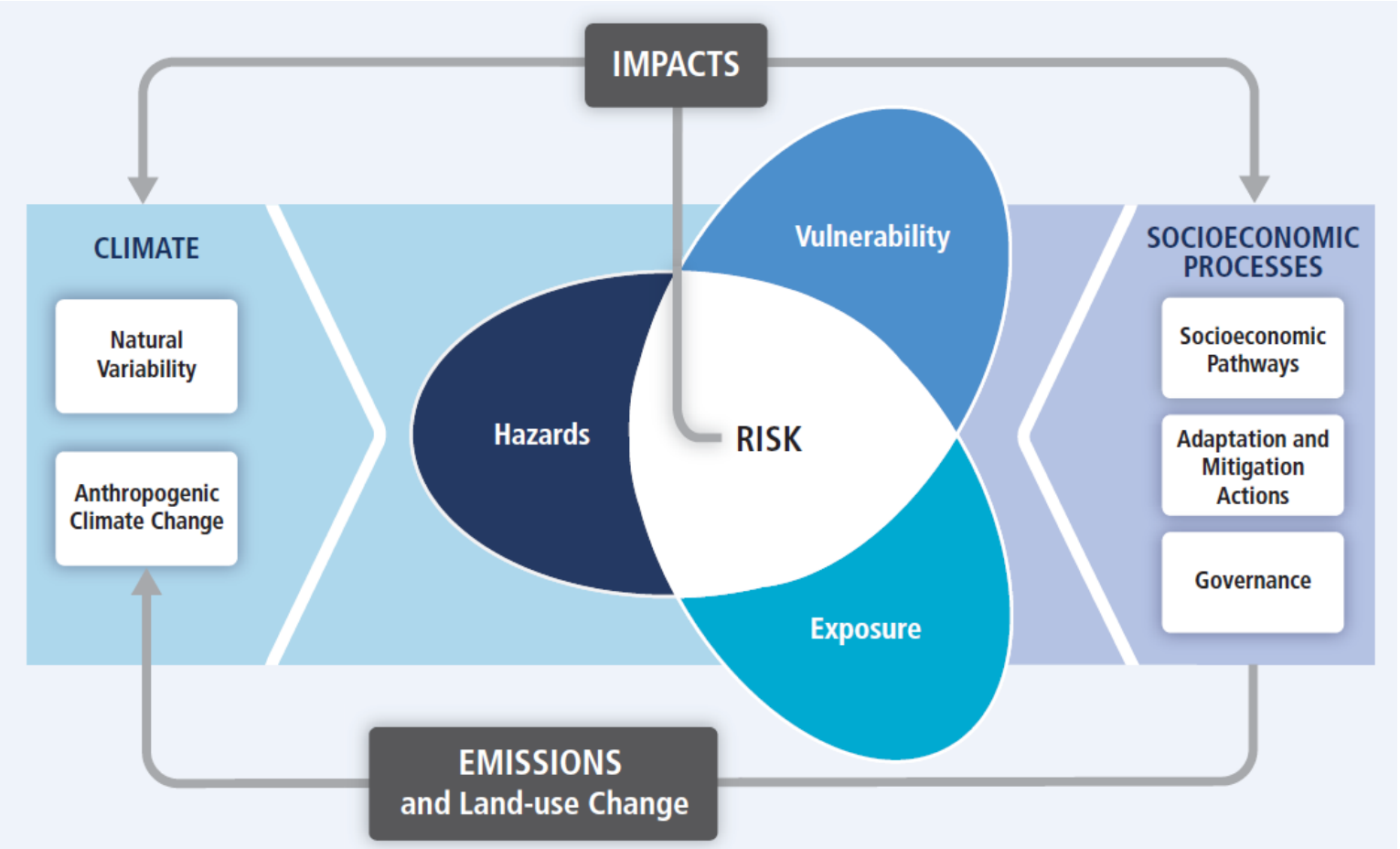
Birkmann et al., 2009

Schools of adaptation

Similarities / differences	Recommendations for the use of terminology
The disaster risk community has not sufficiently defined adaptation in terms of extreme events and disaster risk yet. The IPCC definition would also be a good starting point for the DRR community.	Differences between adaptation and coping should be made clear. The areas where adaptation should be considered in DRR need to be extended, e.g. also disaster aid and reconstruction (water, sanitation, shelter) should consider aspects of climate change adaptation in the future.

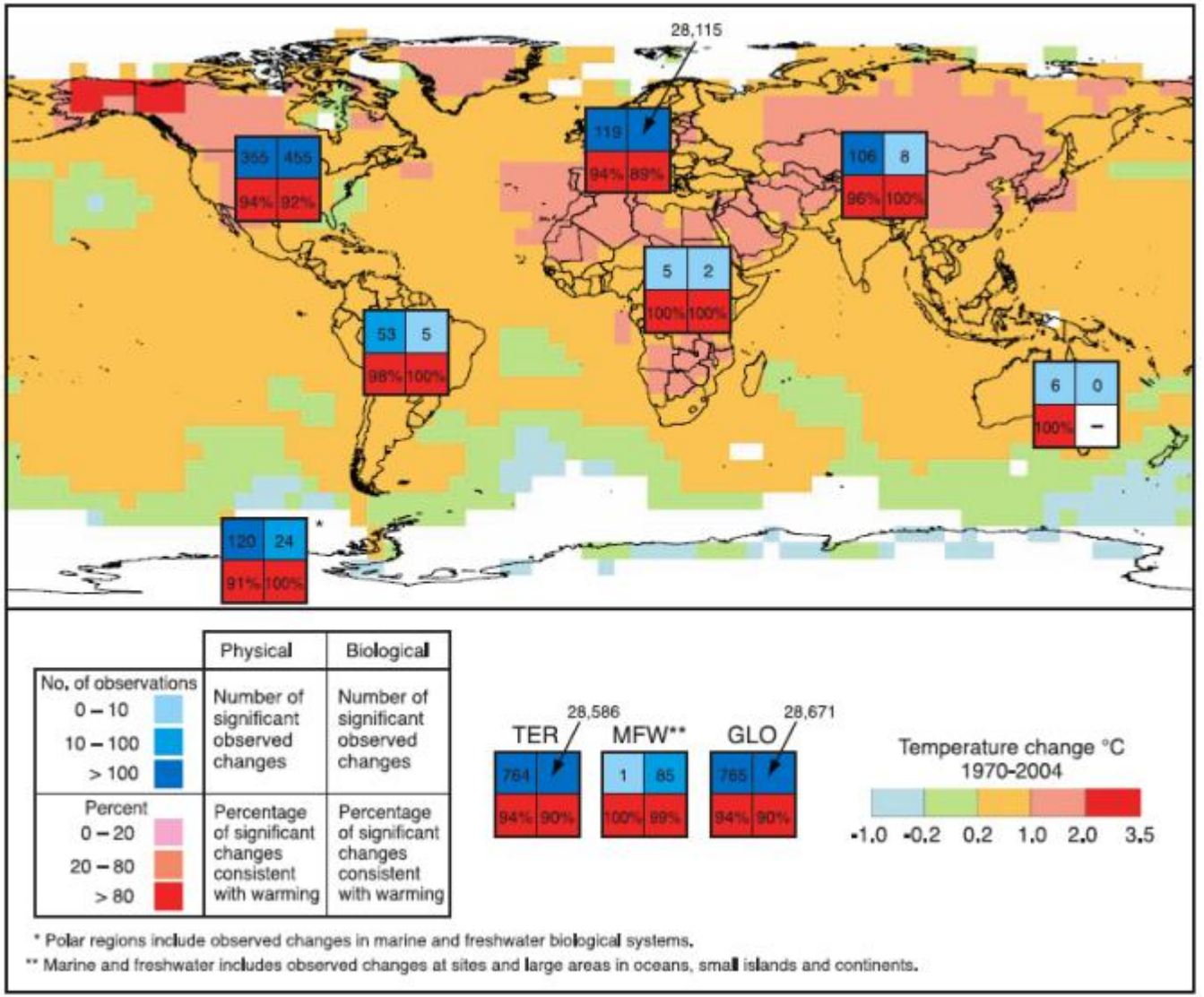
Birkmann et al., 2009

Integrated risk concepts



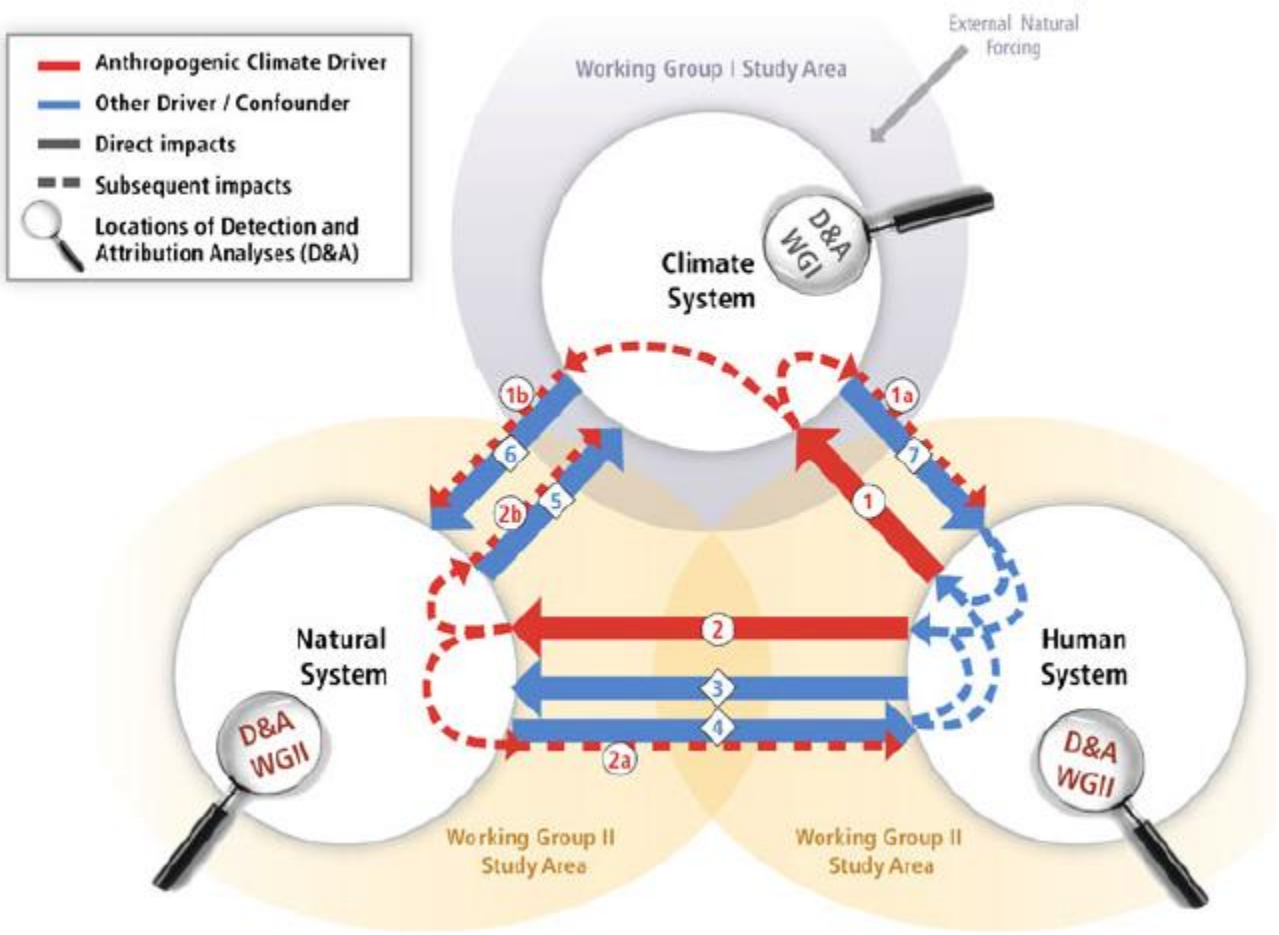
IPCC WGII AR5, 2014

Detection and Attribution of Climate Impacts



Rosenzweig et al., 2007 (IPCC AR4)

D&A: a system perspective



Stone et al., 2013 / IPCC WGII AR5, 2014

Cascading impacts

Climate

Glacier shrinkage

Water resources

Agriculture

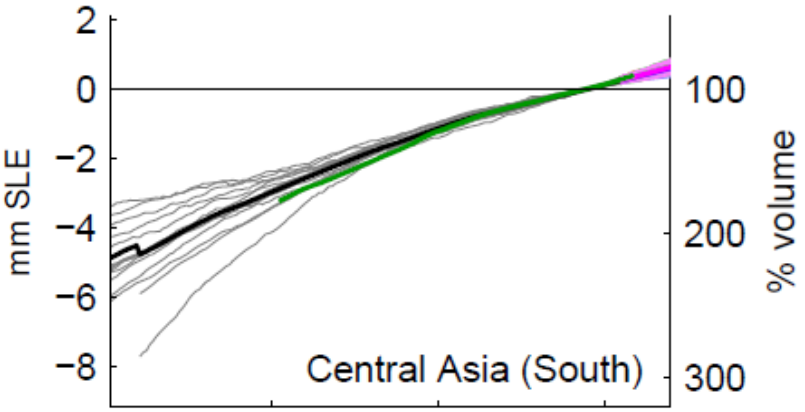
Local livelihoods

Decreasing climate signal

Increasing number of confounders

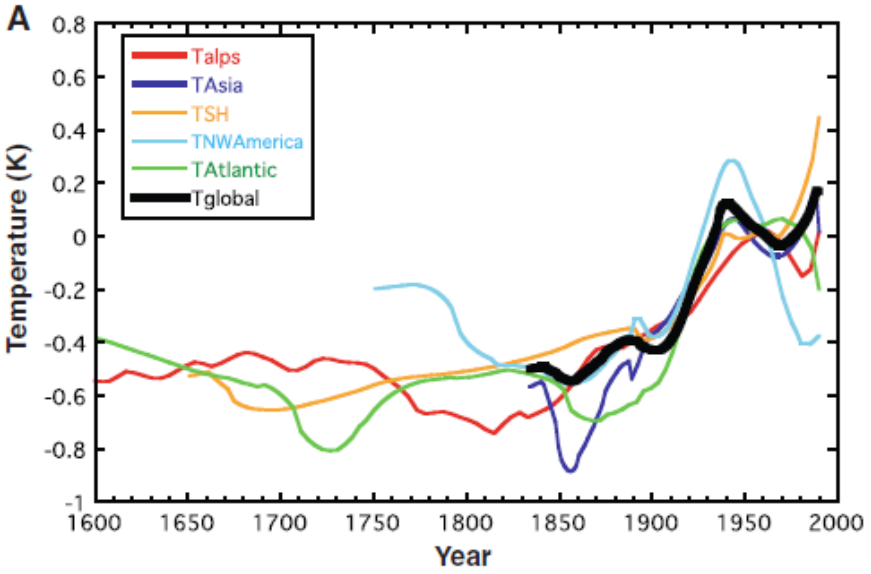
D&A: water resources

Global glacier volume / sea level equivalent change



Marzeion et al., 2012

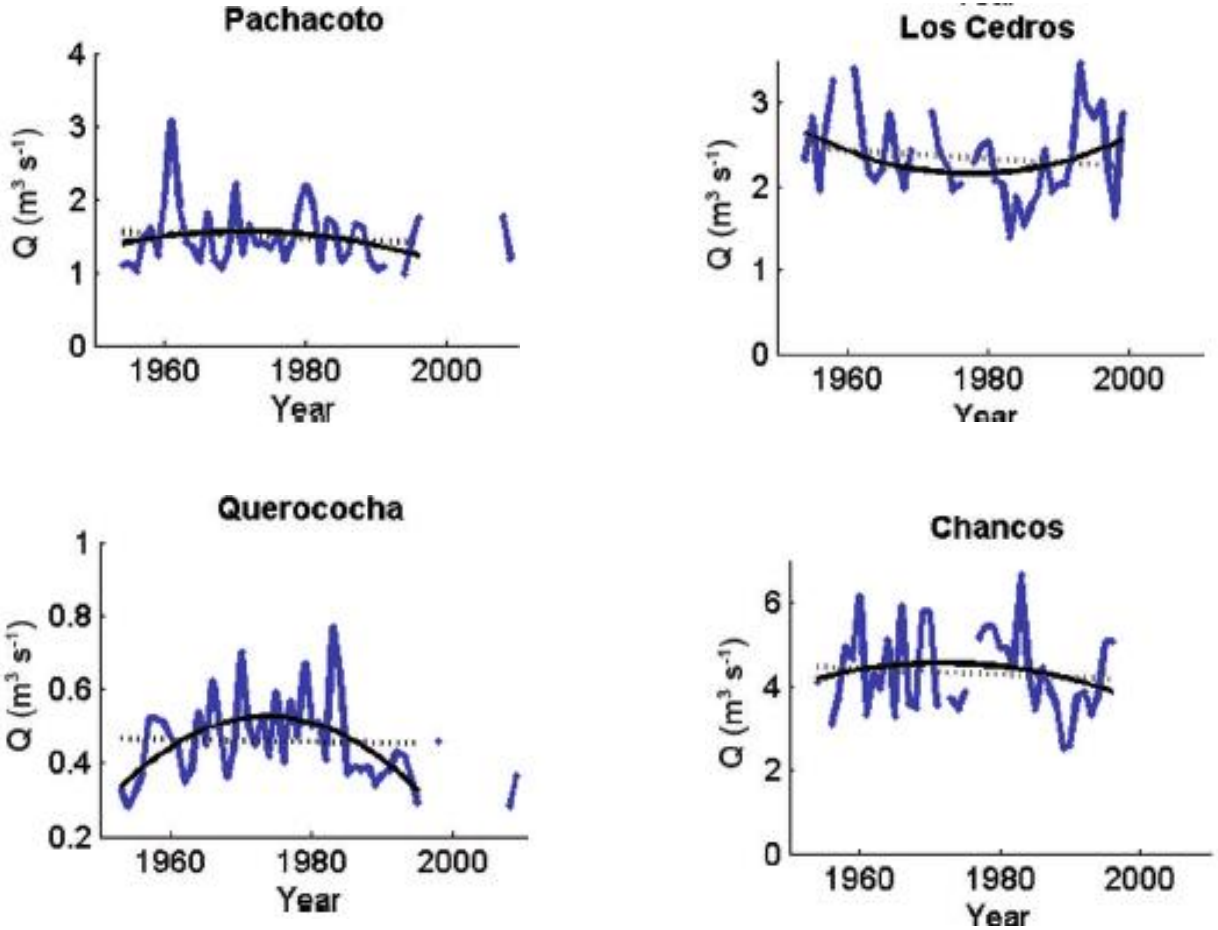
Temperature reconstruction based on observed glacier changes



Oerlemans, 2005

D&A: water resources

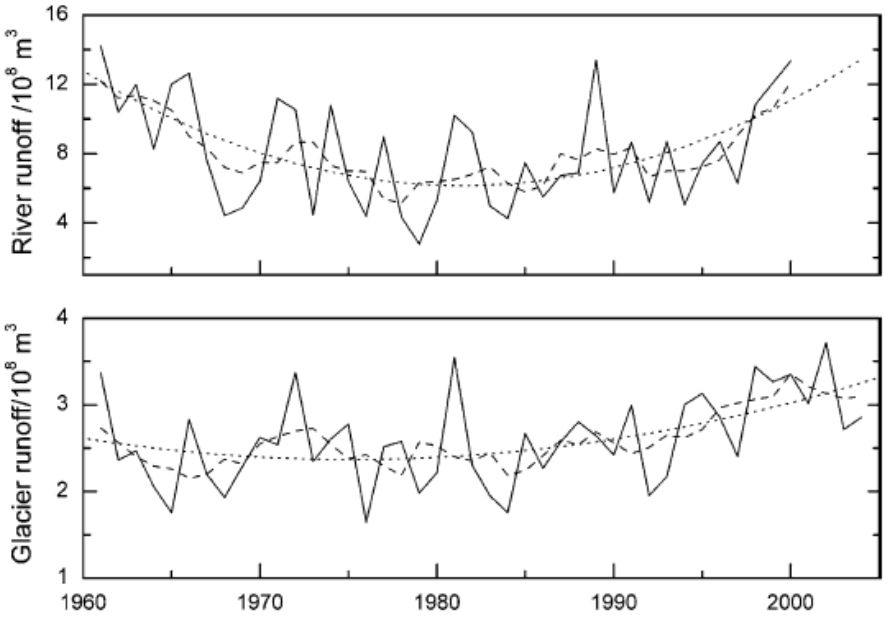
In 7 out of 9 catchments ‚peak water' has likely been passed in Peru



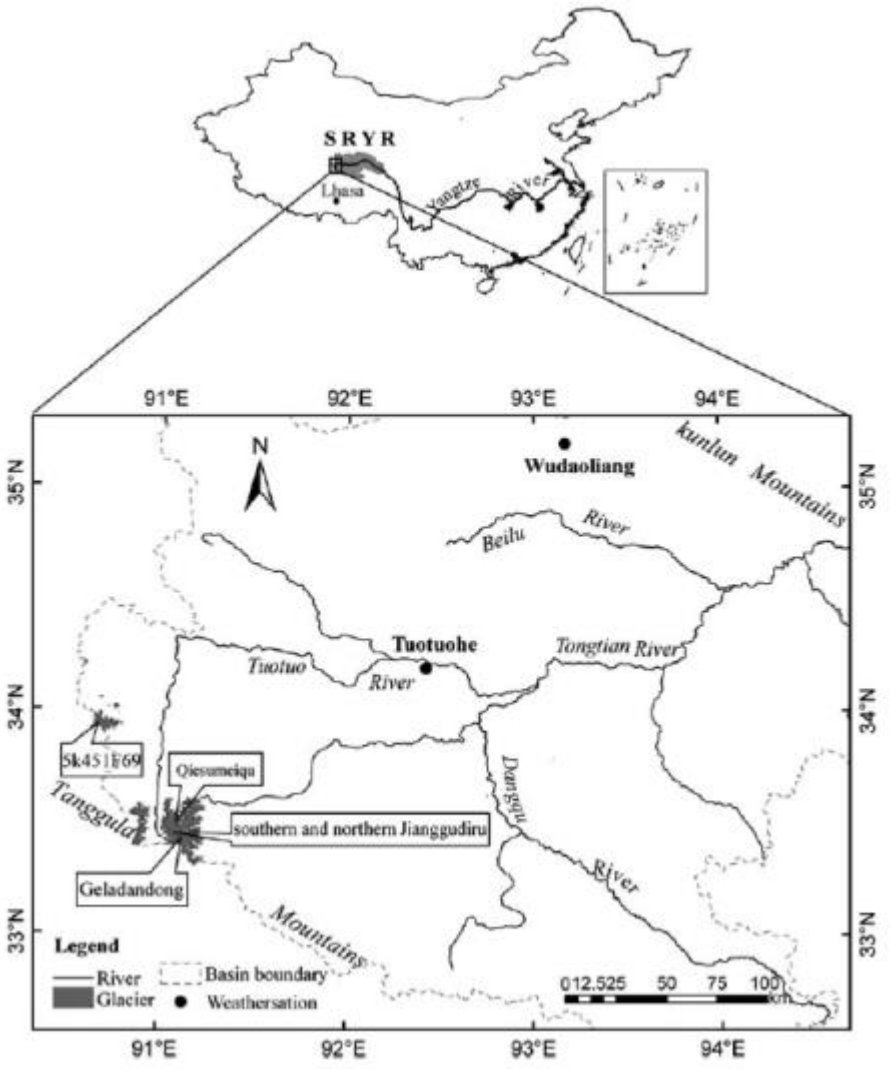
Barear et al., 2012

D&A: water resources

River runoff changes in Yangtze catchment

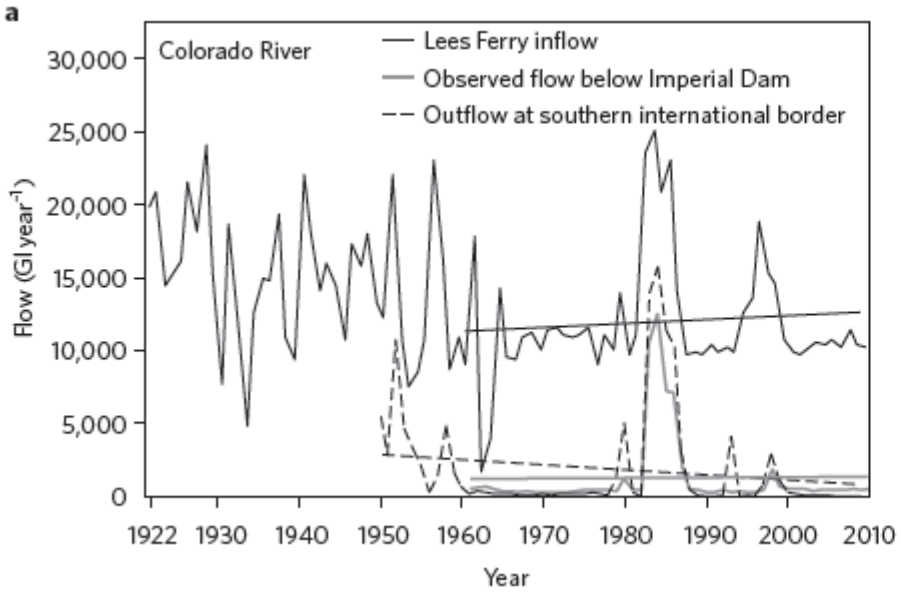


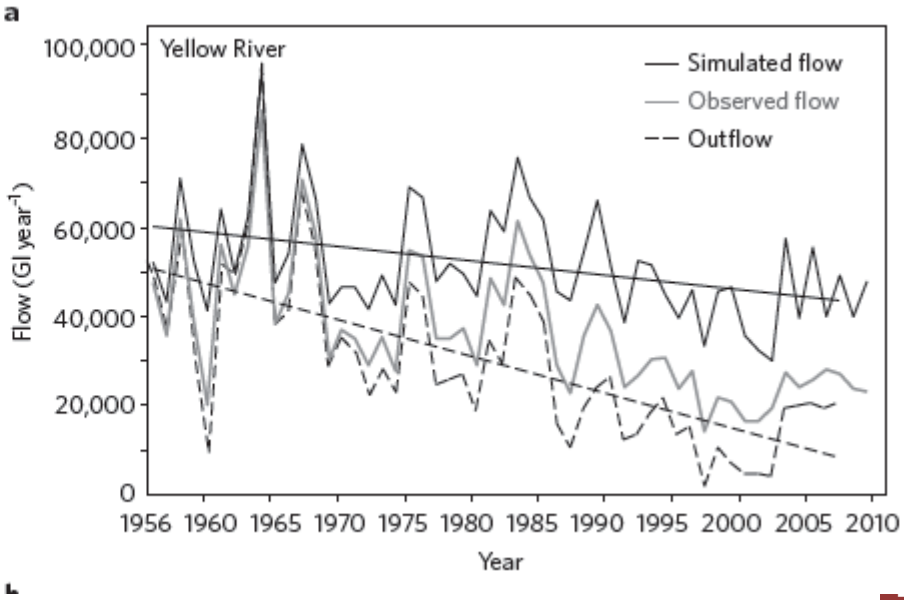
Zhang et al., 2008



D&A: water resources

Runoff changes in the Colorado and Yellow River





Grafton et al., 2013

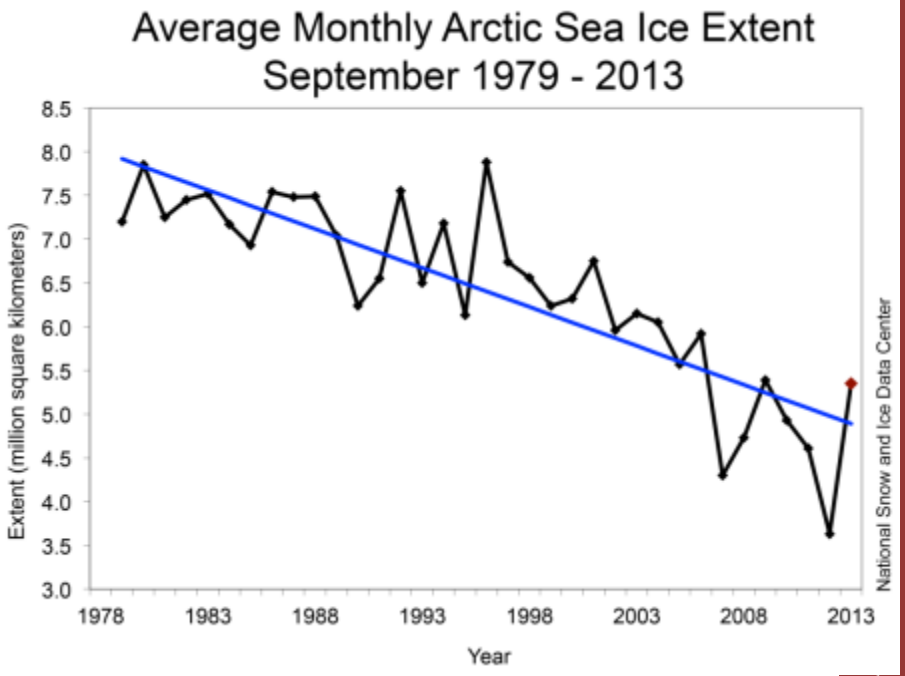
Influence of humen interventions and river management on runoff

D&A: socio-environmental impacts (Arctic)

Decline in Arctic Sea ice

Summer Arctic Sea Ice Decline

Source: NASA & Natural Resources Defense Council

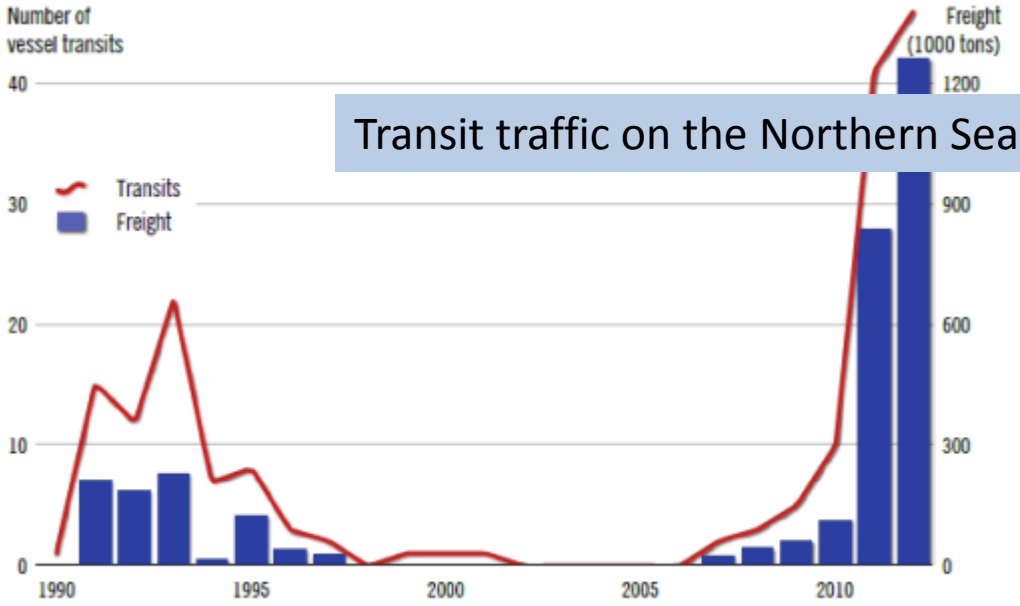


NSIDC

D&A: socio-environmental impacts (Arctic

Shipping in the Bering Strait

- Reduction in sea ice
- Increase of shipping
- Affects a large no. of species and their habitats
- Affects indigenous subsistence communities

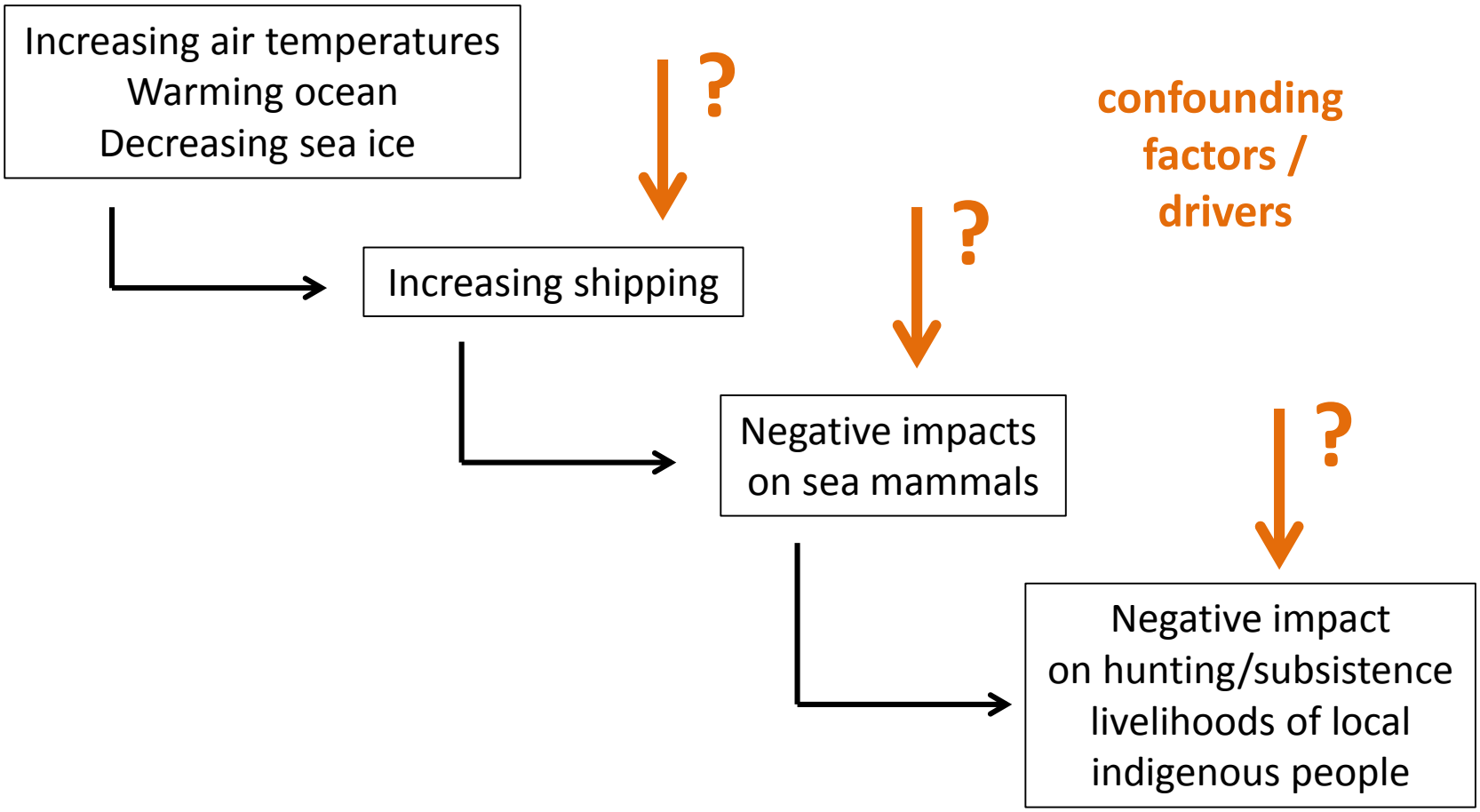


Transit traffic on the Northern Sea Route 1990-2012

Arctic Council, 2013

D&A: socio-environmental impacts (Arctic

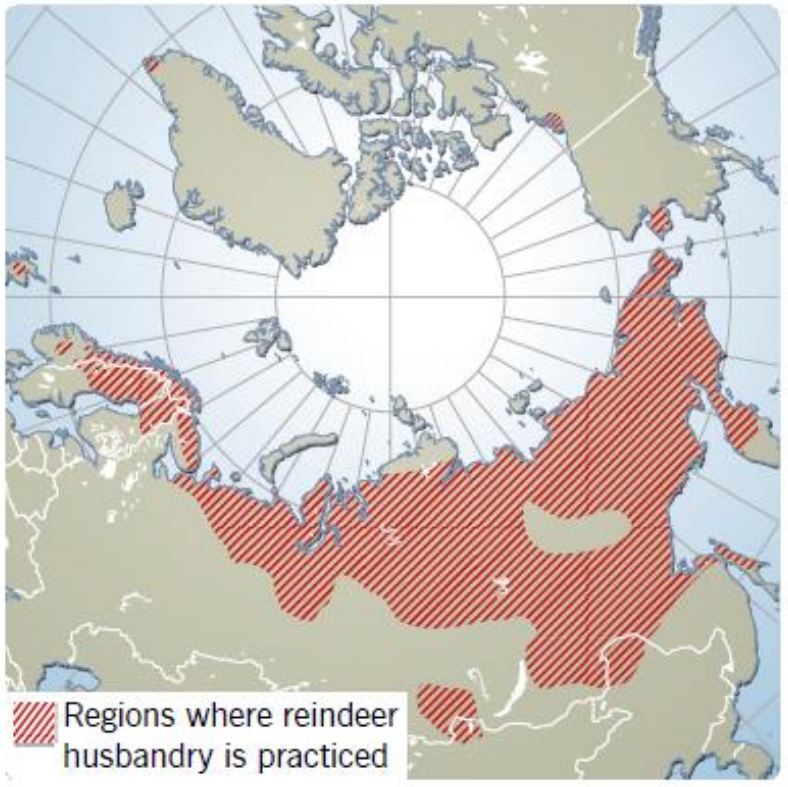
Shipping in the Bering Strait



D&A: socio-environmental impacts (Arctic

Reindeer herding

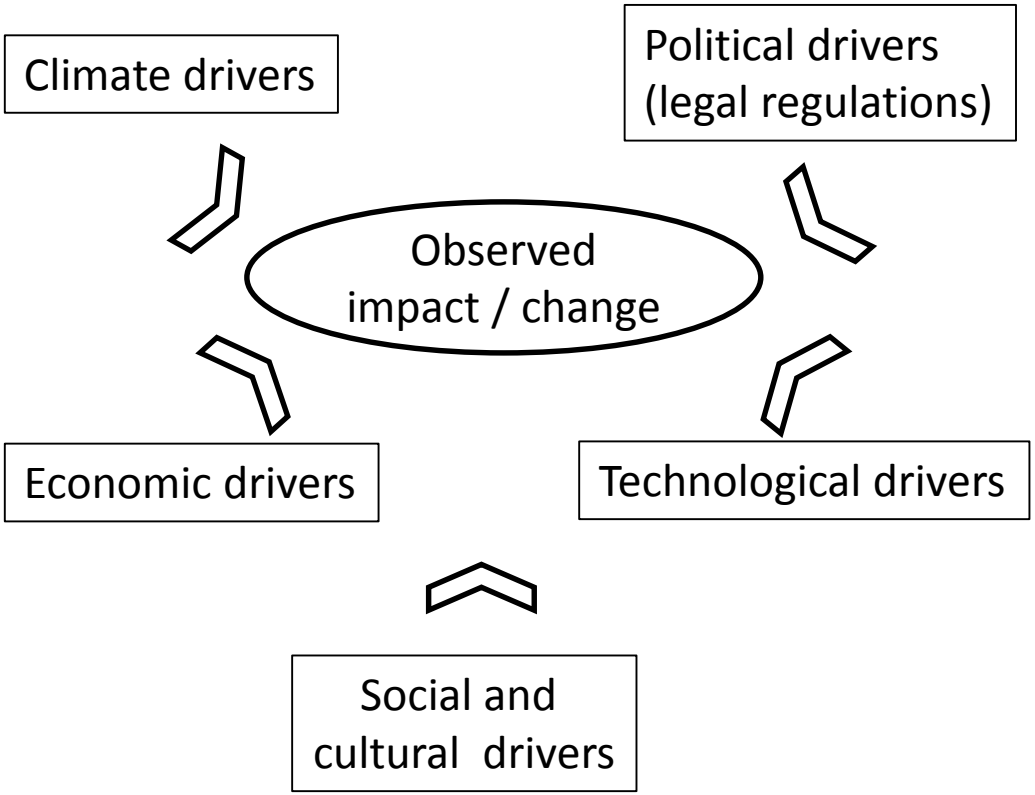
- Sami and other reindeer herding indigenous people heavily rely on snow conditions
- Over past 30 years increasing frequency of weather events causing negative impacts on reindeer feeding (ice layers due to rain on snow), and thus on herders‘ economy



Arctic Council, 2013

D&A: socio-environmental impacts (Arctic

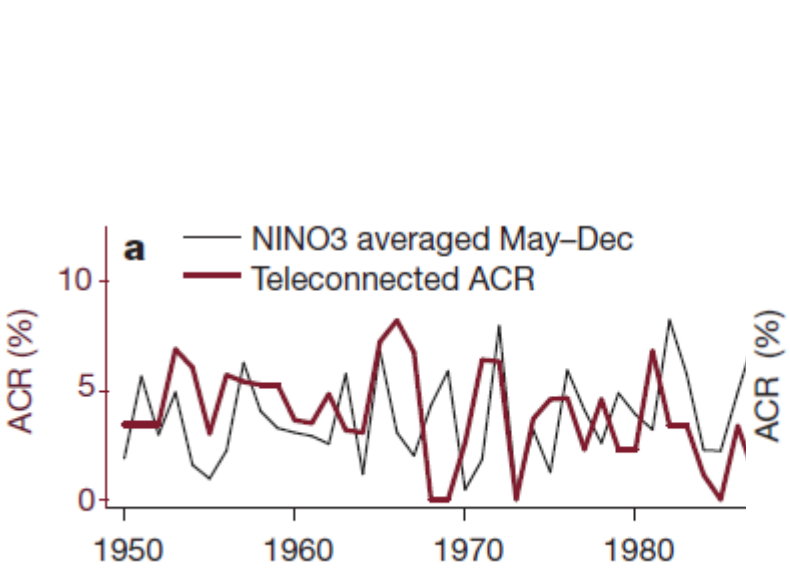
Reindeer herding

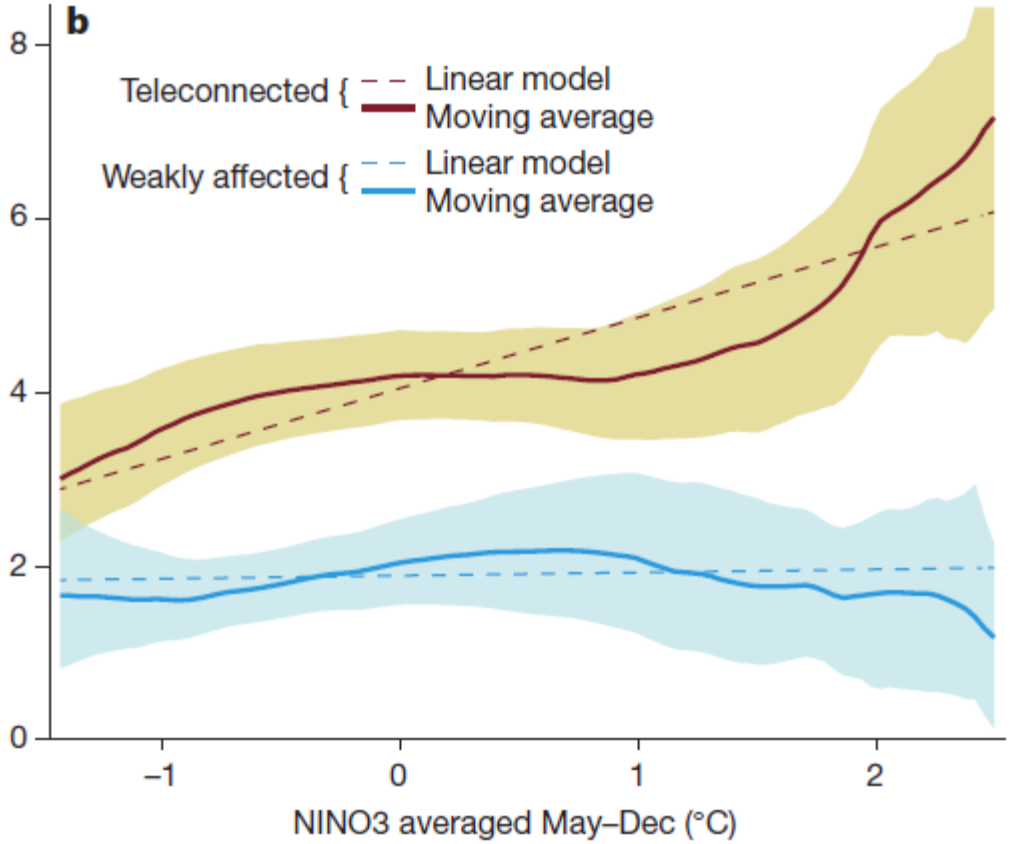


Galdu

D&A: social conflicts

Annual conflict riks (ACR) in relation with El Niño Southern Oscillation (ENSO, index: NINO3)

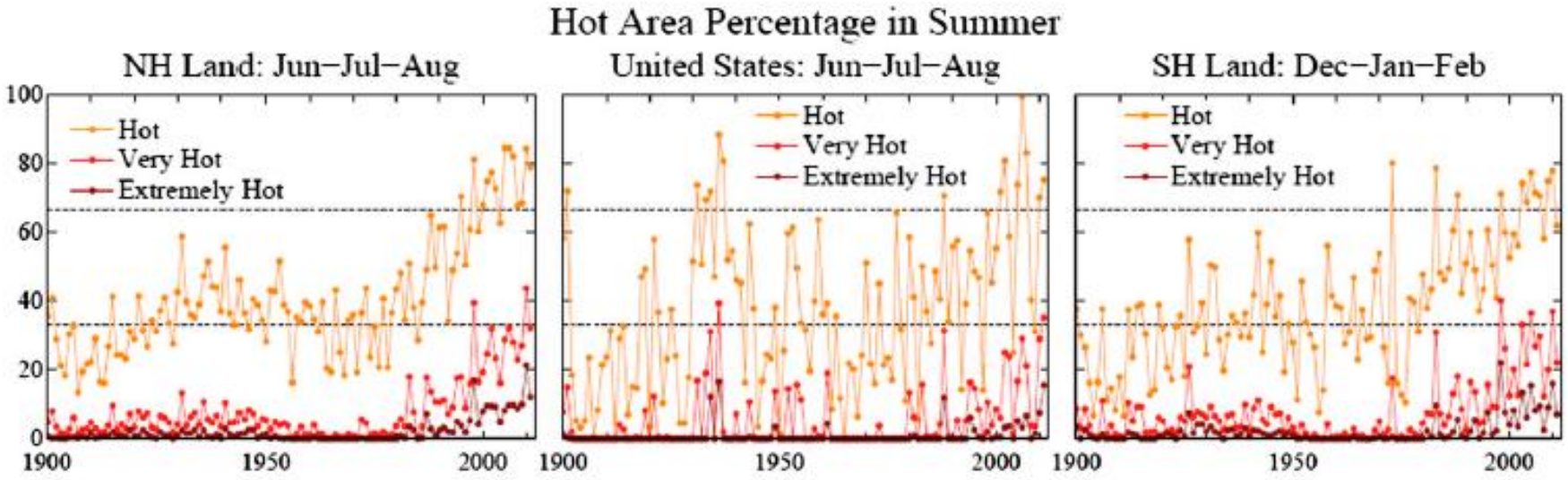




Hsiang et al., 2011

D&A: extreme events

Climate observations on temperature extremes

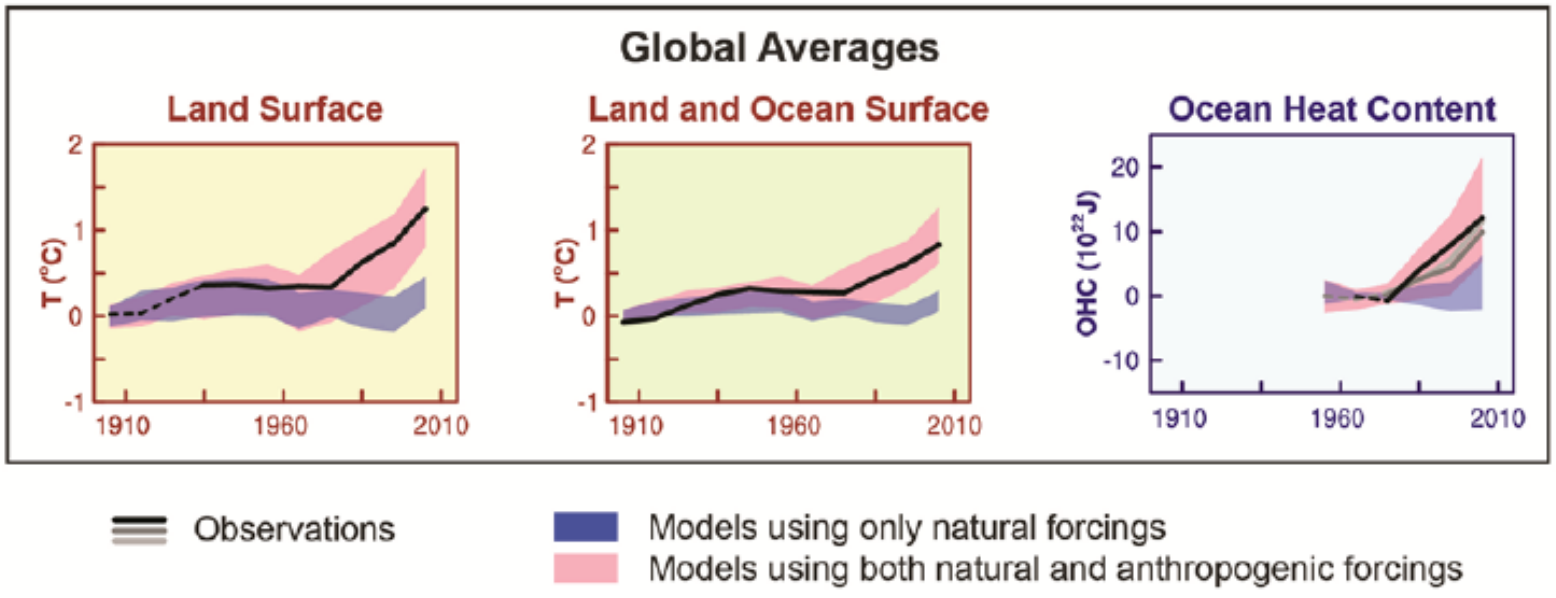


Percent area covered by temperature anomalies in categories defined as hot (>0.43σ), very hot (>2σ), and extremely hot (>3σ). Anomalies are relative to 1951–1980 base period; σ is from 1951–1980 data.

Hansen et al., 2012

D&A: extreme events and disasters

Observations vs. climate model runs with different forcings



IPCC, WGI AR5 SPM, 2013

D&A: extreme events and disasters

D&A approaches in physical climate science

• Due to their rarety, it is difficult to establish trends for extreme weather events with sufficient statistical power

• Approaches to circumvent attribution of unmonitored changes in extreme events to climate change:

  • Analyze another variable that is linked to the extreme event but better sampled in the observational record. Comparison of observed trends in this variable vs simulations (with and without anthropogenic forcing) (Stott et al., 2004; Pall et al., 2011)

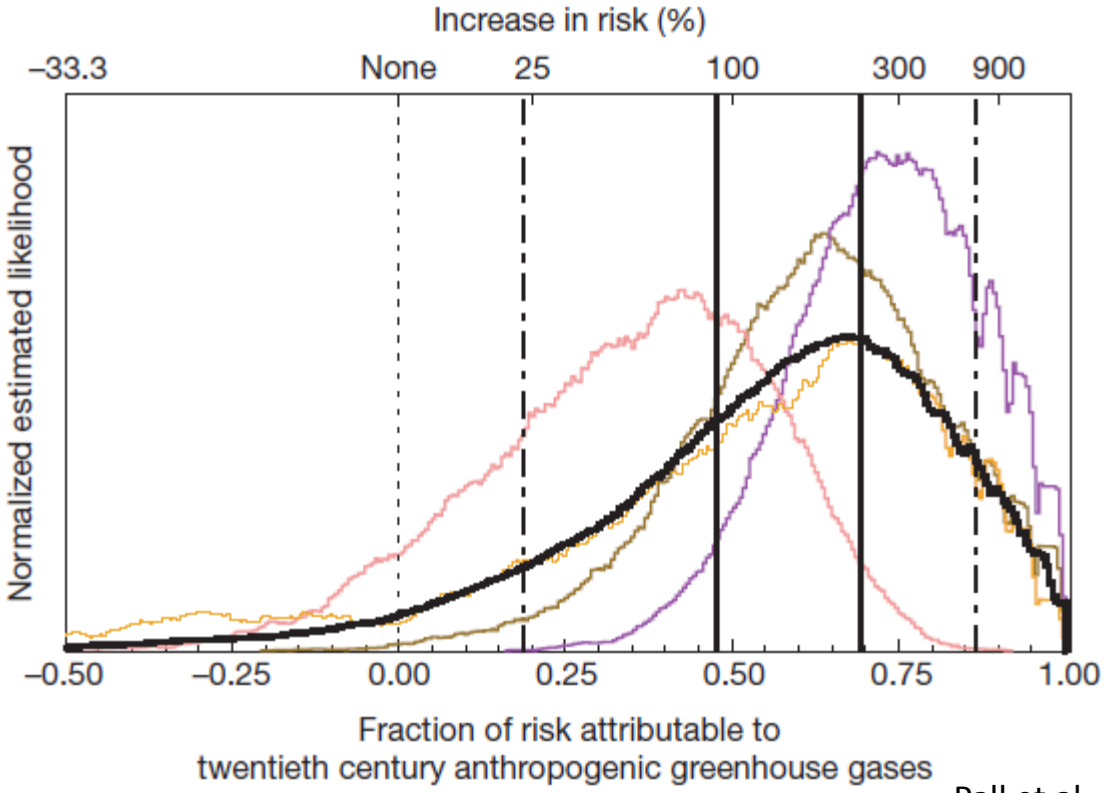
  • Global data pooled to provide statistical power for local analysis how the chance of the event has changed (caution if local and global trends are inconsistent) (Hansen et al., 2012).

=> Generally, slowly accumulating evidence and increasing confidence that anthropogenic climate change was a contributor to some, but certainly not all, major recent extreme weather events (e.g. 2003 European heat wave, 2000 UK floods).

D&A: extreme events and disasters

Attribution of 2000 UK floods

to antrhopogenic greenhouse gas emissions



Pall et al., 2011

=> Anthropogenic greenhouse gas emission increased the risk of flooding (UK 2000) in two out of three cases (model runs) by 90%

D&A: extreme events and disasters

Repeated heavy floods in Bolivia

Affected are often areas of recent uncontrolled urbanization:

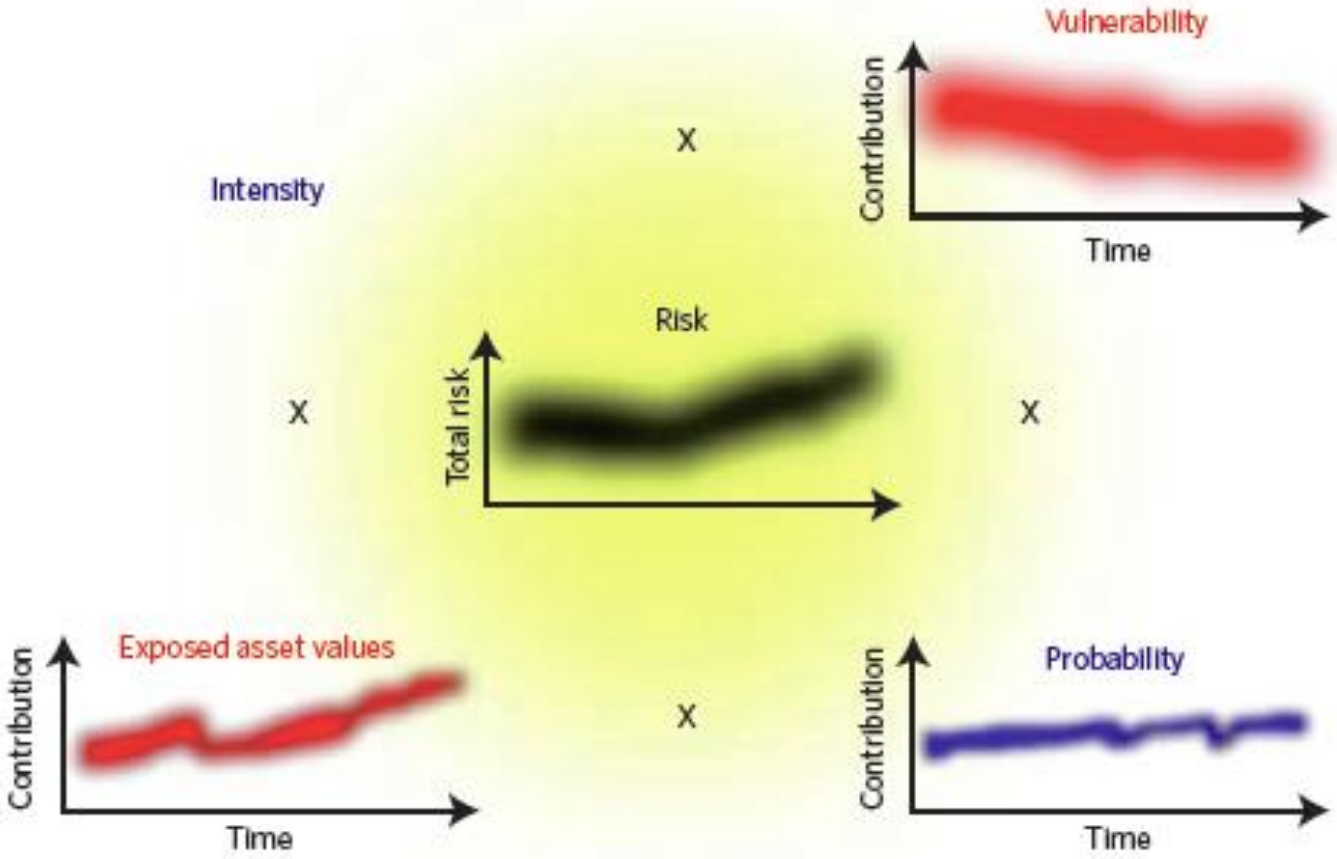
⇒ Can climate change be blamed ? (in case the event could be reliably attributed to climate change)

⇒ Are Annex 1 countries responsible for the losses in Bolivia?

2007 Floods, AFP/BBC

D&A: extreme events and disasters

An attribution framework



Huggel et al., 2013

D&A: extreme events and disasters

Superstorm Sandy in New York City (2012):

Largest Atlantic Hurricane on record
Damage and loss: ~300 people killed in total, ~65 billions of USD damage in the US

Attribution:

Intensity & frequency: complex interactions of the climate system involving sea surface temperature, atmospheric pressure systems, and related northern jet stream
Exposed asset values: very high concentration of high values
Vulnerability: complex and vulnerable urban infrastructure, but heavy investment in reducing vulnerability over the past years

Reuters

Nydailynews.com

D&A: extreme events and disasters

Example Typhoon Haiyan, Philippines (2013)

D&A: extreme events and disasters

Example Typhoon Haiyan, Philippines

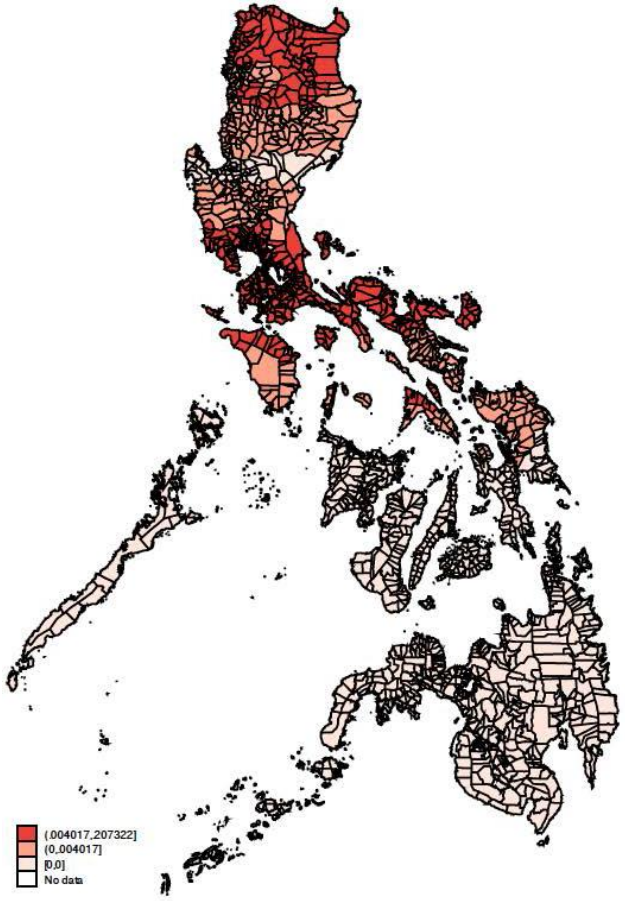
Before and after the typhoon assessment:

http://www.washingtonpost.com/blogs/worldviews/wp/2013/11/15/8-maps-that-explain-why-typhoon-haiyan-hit-the-philippines-so-hard/

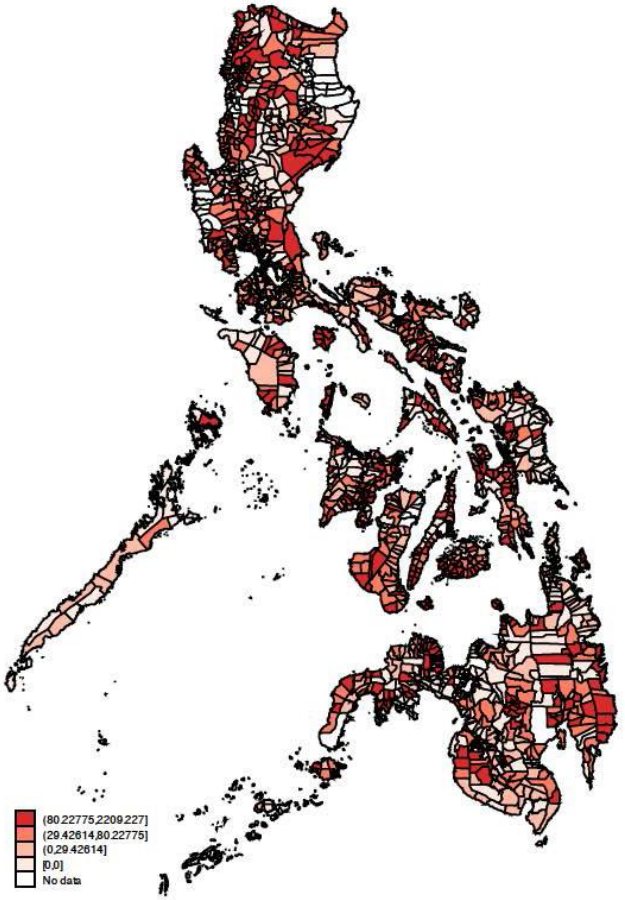
D&A: extreme events and disasters

Example Typhoon Haiyan, Philippines

Affected by storms 2001-2010



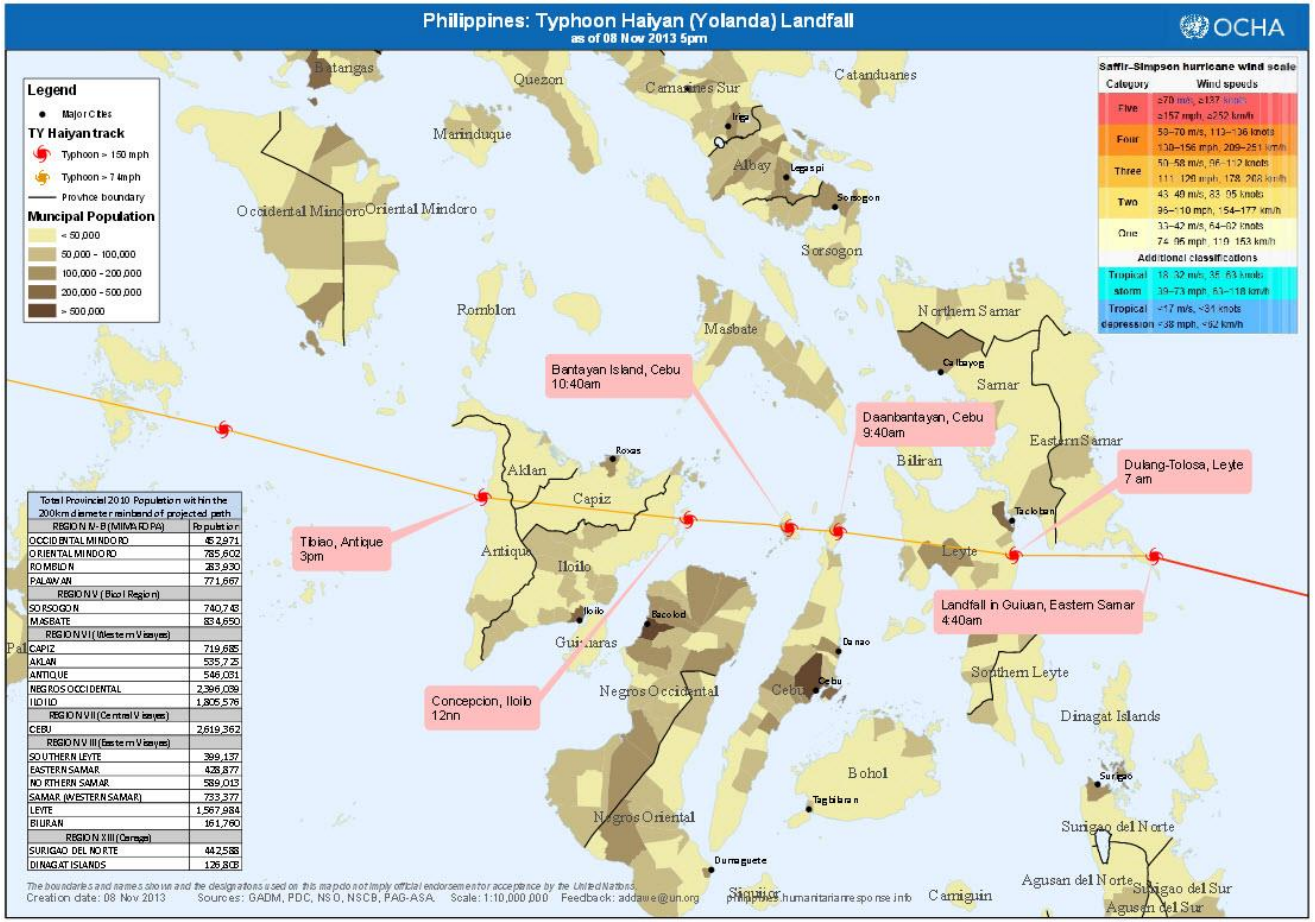
Distribution of money for disaster preparedeness



Atkinson et al.

D&A: extreme events and disasters

Example Typhoon Haiyan, Philippines



UNOCHA

Wrap-up

Climate (change) impacts --- vulnerability --- risks --- adaptation

Terms and definitions: risk is now (IPCC AR5) the dominant concept

Mitigation --- risks --- adaptation

Strong mitigation efforts can contain risk. Adaptation can reduce risks but there are limits of adaptation

Climate impact cascades

The sequence of impacts needs to be reasonably understood, as a basis for adaptation/risk reduction