Detection and attribution of impacts of climate change

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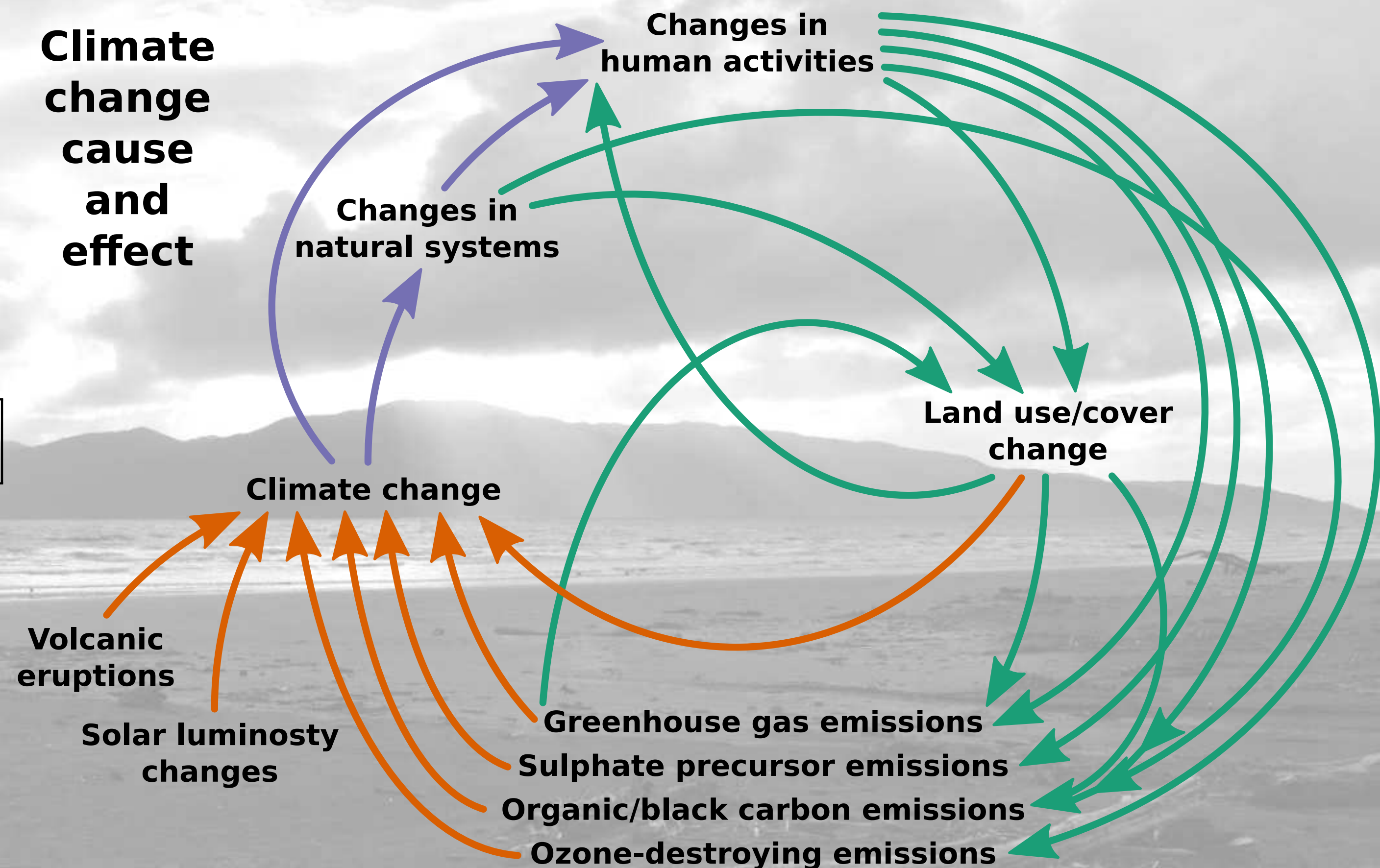
3.1. Why care about climate change?

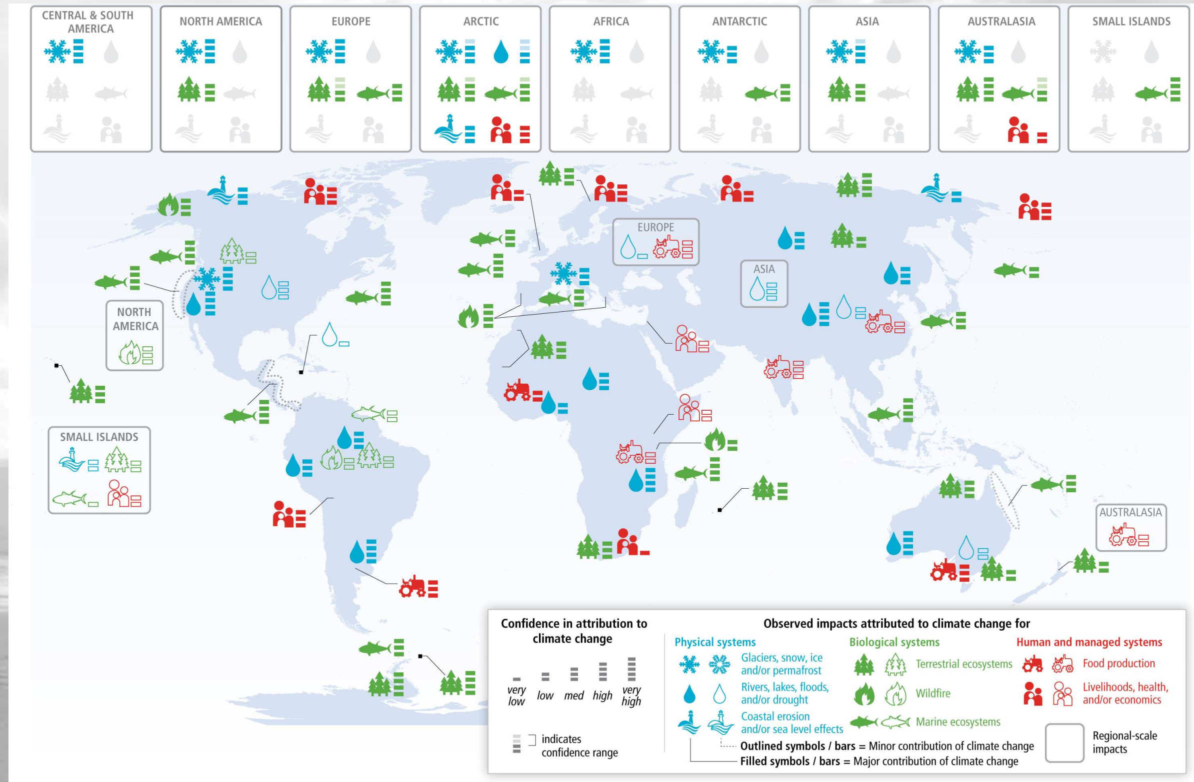
Climate change cause and effect



This lecture: Purple

3.2. Current (∼2013) state of understanding

Evidence of effects of observed climate change on other systems



IPCC (2014), from Cramer et alii (2014)

"Impacts of recent changes in climate on natural and human systems occur on all continents and across the oceans"

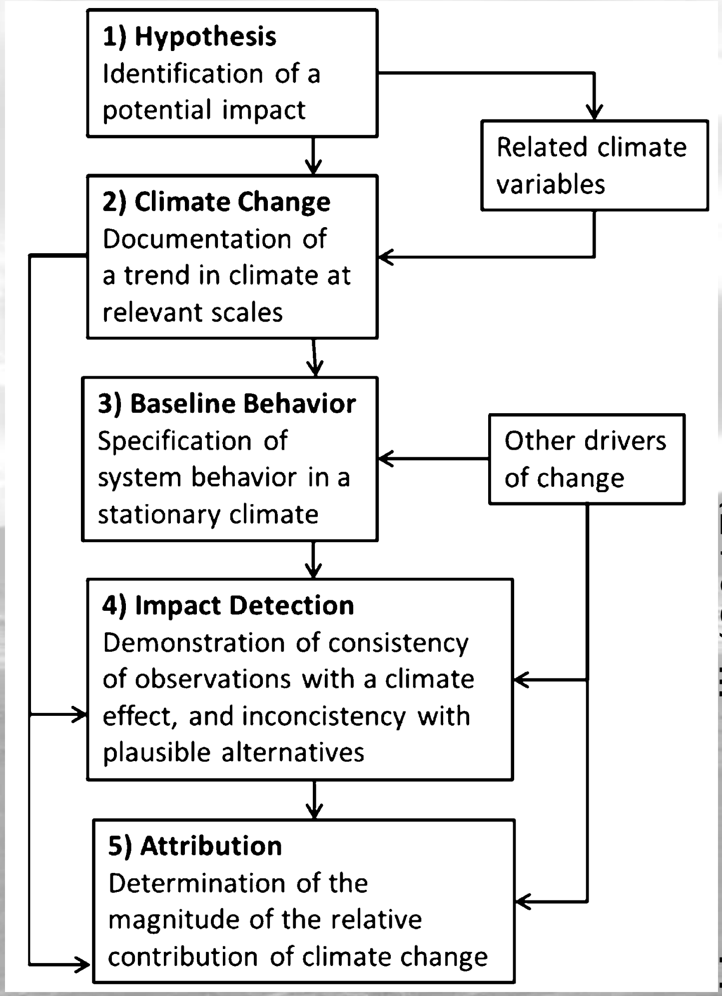
Today we will ask how those assessments were made

- This is still detection and attribution
- For simplicity, we will call it “impacts D&A”
- Differs from climate D&A (Lecture #1) in practical aspects
  - There are many more possible causes
  - Often requires very different types of analysis tools

    (e.g. linear regression not useful for non-linear economic system)
  - Can be extremely multi-disciplinary
  - Can be quite established research field

    (e.g. epidemiology has been around for centuries)
  - Often not called “detection” or “attribution”

3.3. Definitions and protocols



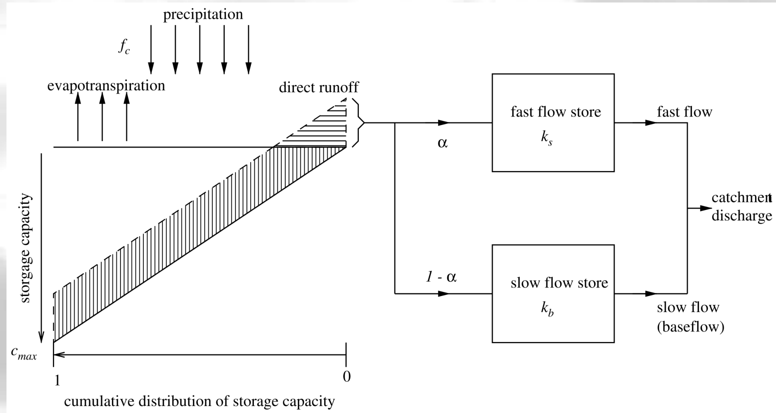
Hansen et alii (2015)

- Need a hypothesis
- Need climate observations
- Need observations of non-climate drivers
- Need observations of system
- Need to understand how system operates

3.4. Step #1: Develop a hypothesis

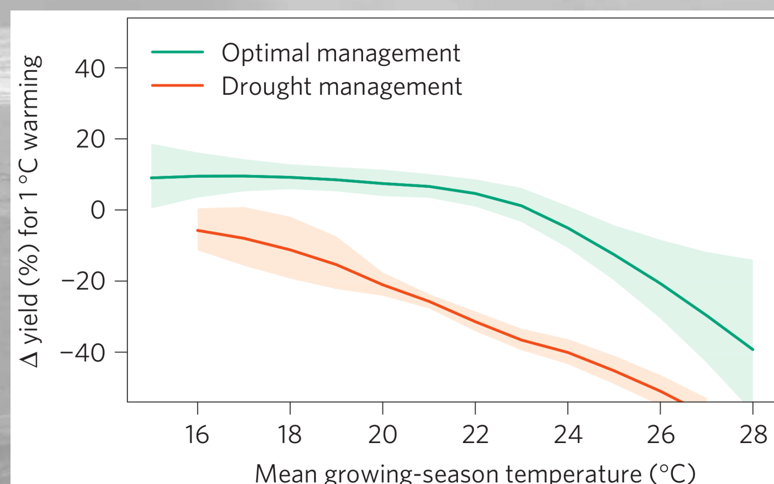
- Based on process understanding
- Could be from mechanistic model
- Could be from statistical model fit to year-to-year variations
- Does not necessarily have to be quantitative

Physics-based catchment model



Kay et alii (2006)

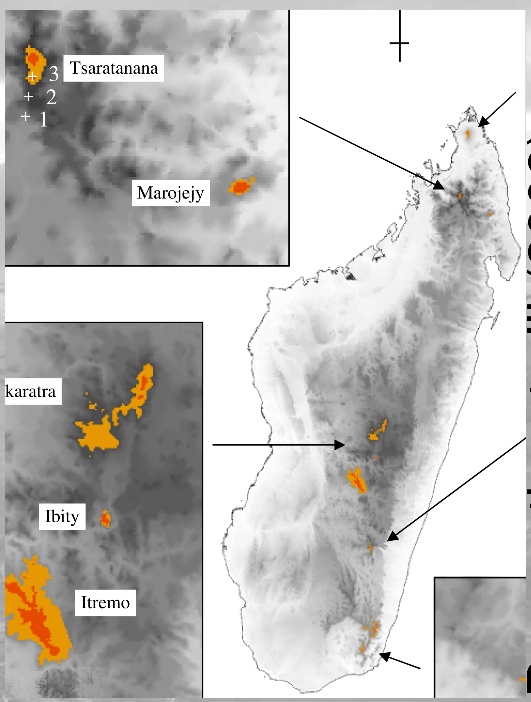
Regression fits to maize yield in field trials



Lobell et alii (2011)

A hypothesis for Madagascan montane ectotherms

- Example: amphibians and reptiles on Madagascar's highest mountain
  - They are ectothermic: their body temperature depends on ambient temperature
  - If mountain temperature is warming, we might expect them to move upslope with the warming
  - Lag effects, ecological effects unclear

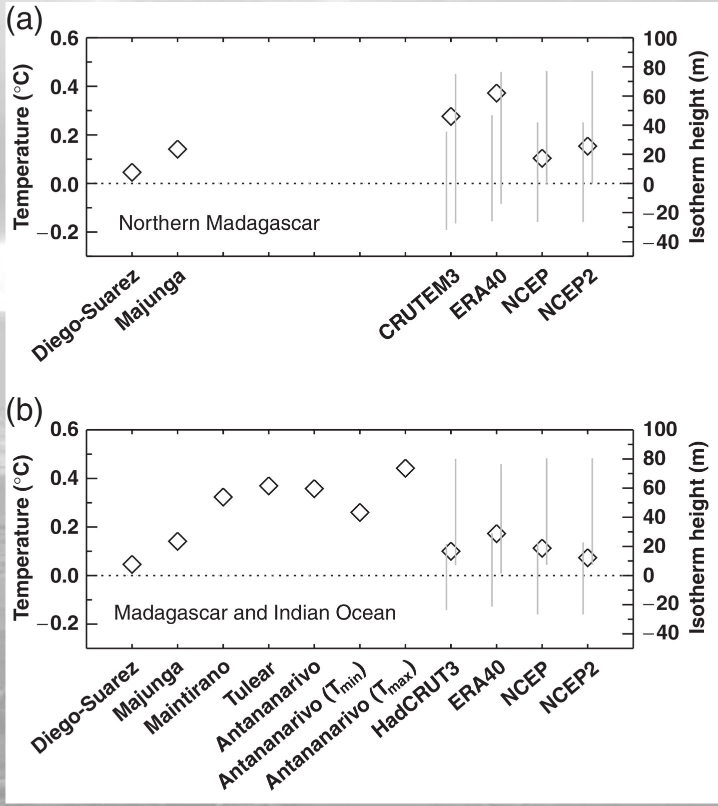


Raxworthy et alii (2008)

3.5. Step #2: Document climate trend(s)

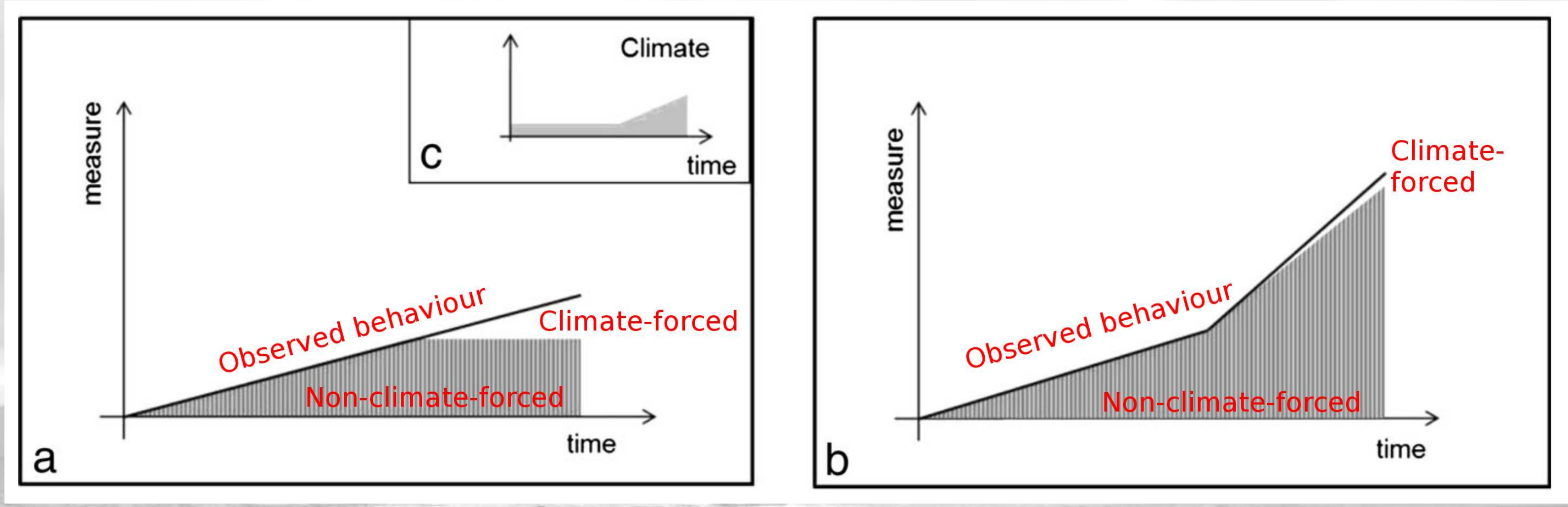
- What is the relevant climate trend(s)?
- For Madagascar case, assumed response to temperatures of previous 10 years
- We need to know if warming happened!
- In this case, no weather stations on mountain slope, so we need to infer
  - Madagascan stations recorded warming
  - Weather forecasts indicated warming
- Right axis: conversion of warming to upslope movement, assuming 6°C per 1000m

Changes in annual temperature, 1984–1993 and 1994–2003



Raxworthy et alii (2008)

3.6. Step #3: Determine baseline behaviour in the absence of climate change



Hansen et alii (2015)

- For Madagascan study, there has been a lot of deforestation around the base of the mountain
  - Would that push ecosystems upslope?
- Otherwise no reason to expect species-wide shifts

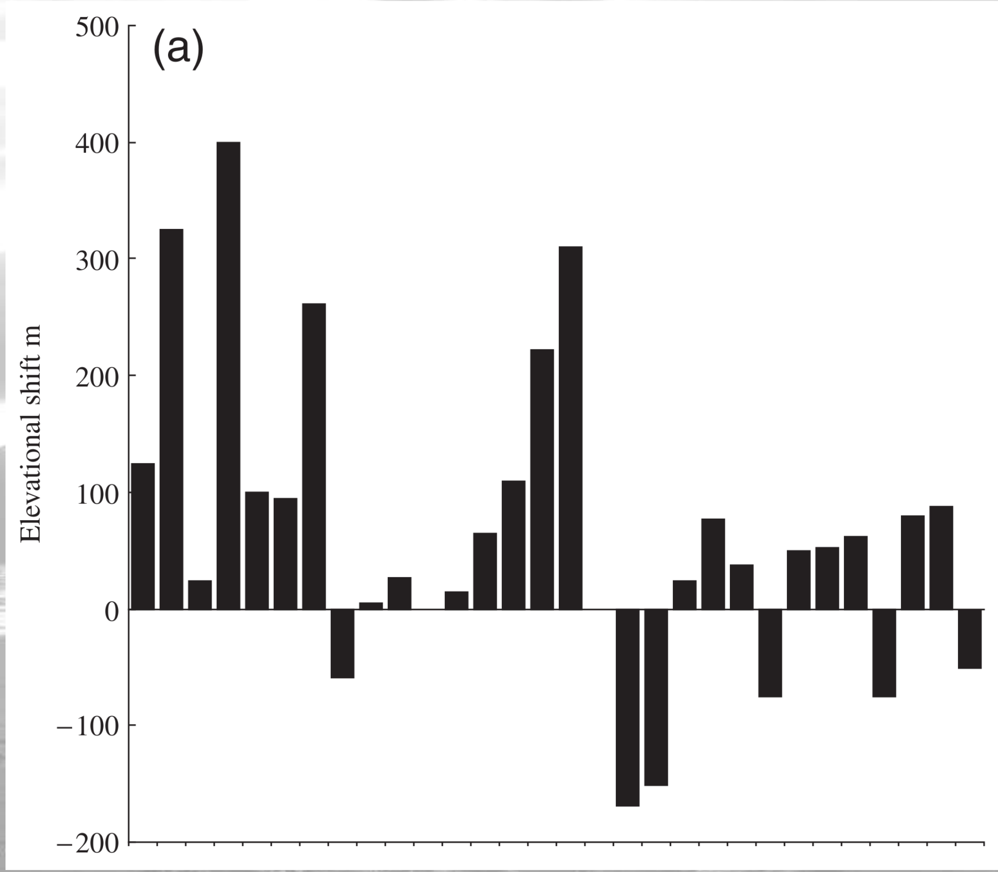
What is baseline behaviour of human systems?

- We may be actively responding to signals by suppressing them
  - Health services are mandated to react at the first hint of a signal and ensure that the signal disappears
- We are now anticipating change, and may be taking precautionary adaptation measures
  - The disappearance of the “Phillips curve” behaviour in 1970s economies, after its discovery in the 1960s
- Difficult when drivers interact nonlinearly
  - For instance, threshold behaviour
- Sometimes just too complicated to understand!

3.7. Step #4: Detection

Is the observed change different from what would be expected in the absence of climate change?

- Change in species midpoint elevation for 30 species, between surveys in 1993 and 2003
- Notwithstanding possible lowland deforestation effect, we would expect no change in the absence of climate change



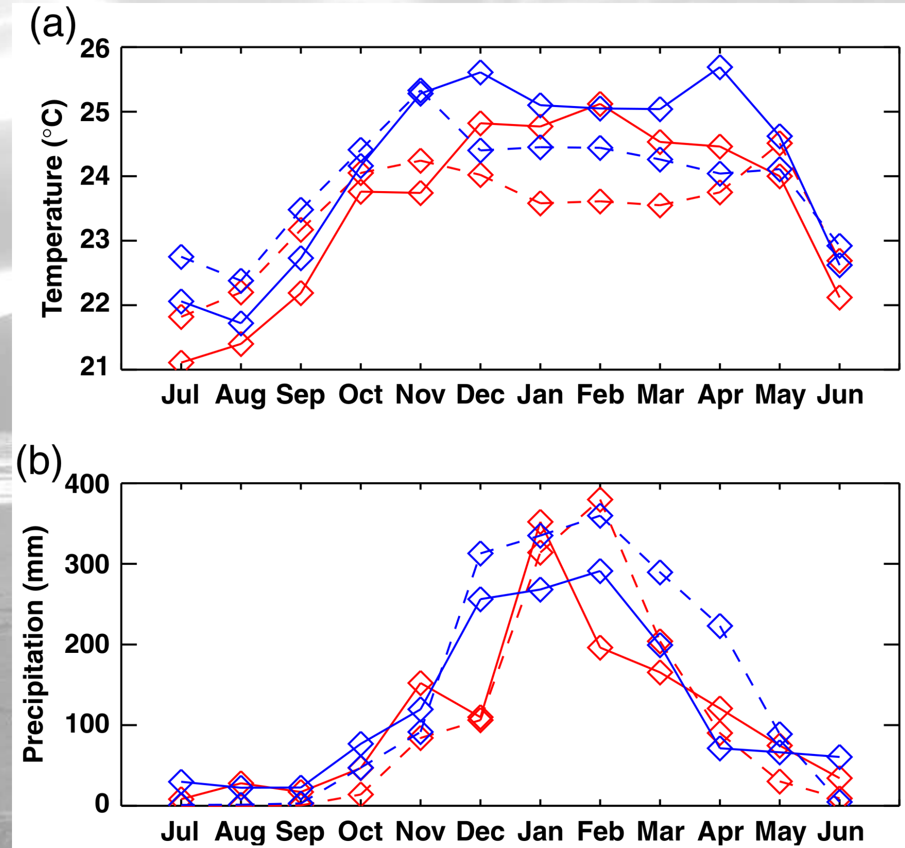
Raxworthy et alii (2008)

Is sampling a contributing factor?

- Species make themselves much more visible in mating season
- Surveys in 22 March–2 April 1993 and 1 Febuary–1 March 2003
- Mating season initiated by seasonal signals
- Both sampling periods in same season
- Wet season precipitation totals differed between years
- Conclusion that phenological factors probably not important

Red=1992–1993, blue=2002–2003

Solid/dashed: different data products



Raxworthy et alii (2008)

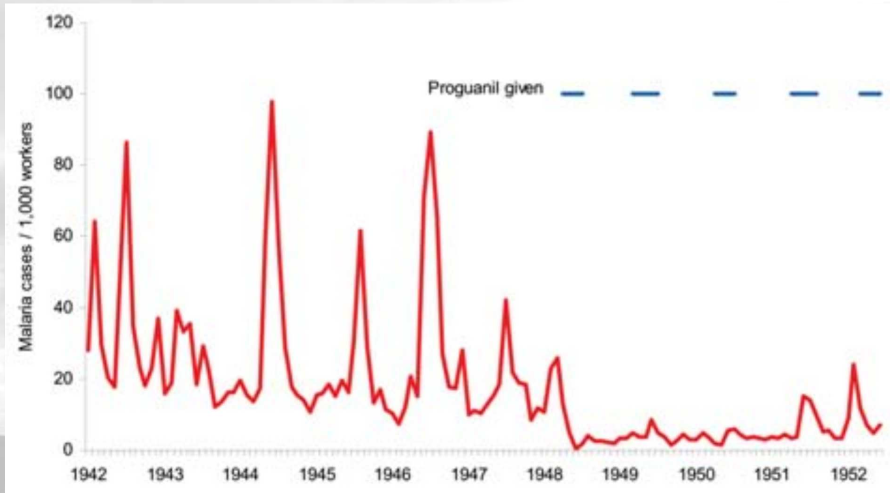
3.8. Step #5: Attribution

What was the role of climate change in relation to other factors?

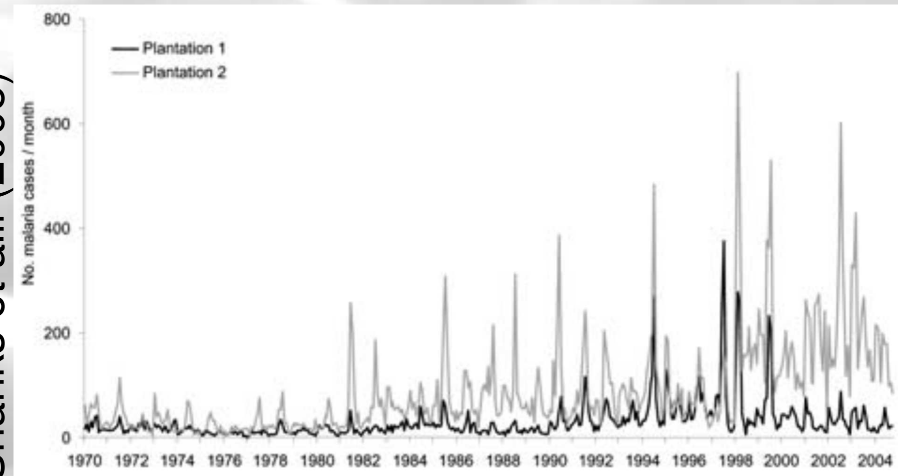
- Argument that surrounding deforestation unlikely to push species so far upslope
- Argument that phenological timing during survey periods not a major factor
- Only remaining option is warming effect
- Warming trends predict 17–74m upslope displacement
- Observed trends for five families (represented by 30 species): 19–51m
- Observations are consistent with warming effect
- Conclusion: observed warming has played a dominant role

The need to consider all factors

Malaria incidence in tea plantations in Kenya’s western highlands

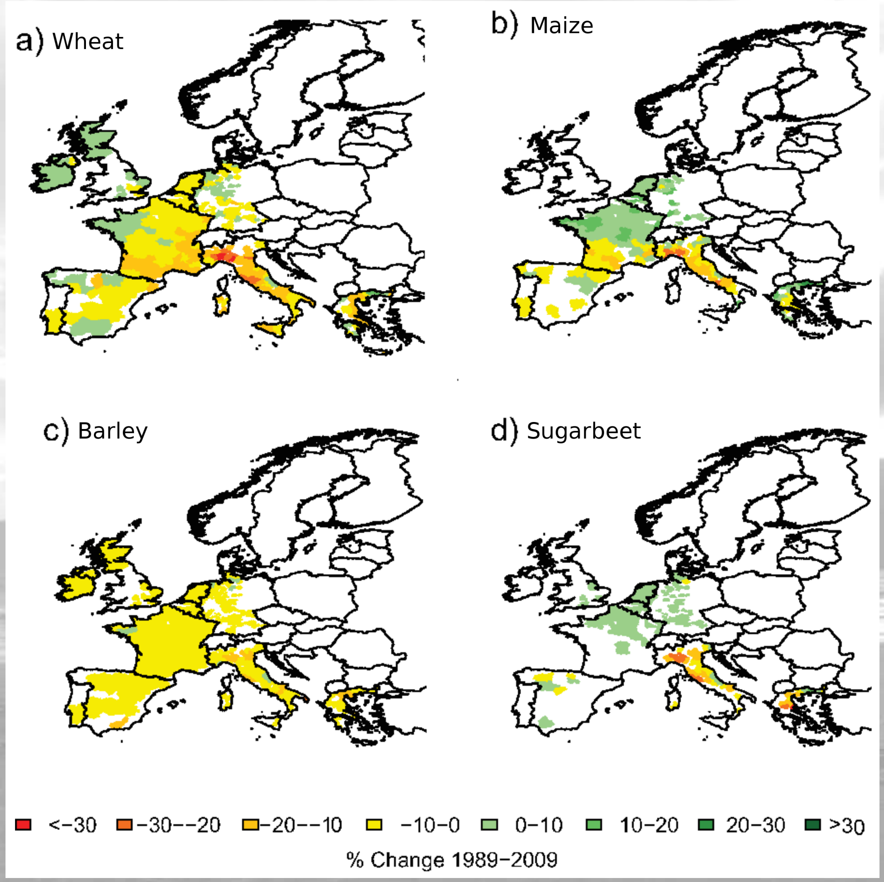


Shanks et alii (2005)



- Seasonal malaria was endemic
- Dramatically reduced in 1949 with the usage of proguanil
- Resistance to proguanil and chloroquine developed in 1980s
- Switch to SP and artemisinin in 2000s

3.9. Fingerprints can be useful here too



Moore and Lobell (2015)

- Observed climate trends expected to have spatially-varying impacts on yields of European staple crops
- These are "fingerprints" again
- At least one study claims to have identified the fingerprints in observed changes in yield

3.10. Quantitative synthesis assessment

- If you have many similar systems, where measures can be assembled into standardised indices, then you can look at the statistics across those systems
  - For instance, butterflies are expected to shift their ranges poleward with warming
  - If you have range estimates for 100 species of butterflies, did most of them shift poleward as expected?
- May be possible to include fingerprint
  - For our butterflies, was the shift larger in locations with larger warming?
  - Only works if you assume all butterfly species should respond identically.
  - If sampling across very different systems (e.g. butterflies and glacers), then how should they be weighted in the analysis

- Assumes systems are statistically independent
  - For our butterflies, they may be responding to warming but jointly through some ecological influence, rather than independently in direct response to warming
- Need to ensure hypothesis is independent of observed shift!

3.11. Assessments of risk to human systems

- These can be quite complicated
- Policy decisions, shifts in cultural norms become important
- Example risk of property damage associated with bushfire in Victoria, Australia

	Potential driver	Observed changes	Expected changes
Climate drivers of hazard	High summer temperatures	Positive trends in maximum temperature on the continental scale but less consistent for Victoria (Alexander et al. 2007; Alexander and Arblaster 2009)	Increasingly frequent, intense, and longer duration high temperatures with anthropogenic emissions (Reisinger et al. 2014)
	Precipitation	Some decrease in autumn totals over recent decades, but with background decadal variability (Alexander et al. 2007; Reisinger et al. 2014)	Probably decreases in annual totals with anthropogenic emissions (Reisinger et al. 2014)
	Relative humidity	Decrease over recent decades in all seasons but summer (Willett et al. 2008)	Probably decreases with anthropogenic emissions (Willett et al. 2007)
	Fire weather	Small increase in a commonly used fire weather index since 1973 (Clarke et al. 2013)	Increases in extreme fire weather (Hasson et al. 2009; Reisinger et al. 2014)
Non-climate drivers of hazard	CO_2 fertilisation	Unknown (Hovenden and Williams 2010)	May increase fuel load under anthropogenic emissions (Williams et al. 2009)
	Ignition	Unknown	Unknown
	Fire management	Improvements in fire-fighting equipment and techniques and weather forecasting (Nicholls 2011)	Prolonged fire season makes controlled burning difficult (Reisinger et al. 2014)
Exposure	Settlement patterns, land use, and land cover	Increased settlement in high-risk zones in urban suburbs, increased regulation on vegetation clearing around properties (VBRC 2009; Buxton et al. 2011)	Increased with population growth
	Fire response policies	Implementation of "prepare, stay and defend or leave early" policy may have exposed more lives (Whittaker et al. 2013)	Unknown
Vulnerability	Responses of homeowners	Less important for the large, most damaging fires (Crompton et al. 2011; Nicholls 2011)	Supposedly no change
	Awareness	High levels of bushfire awareness in high risk areas, but lower levels in more suburban locations (Whittaker and Handmer 2010)	Unknown

Huggel et alii (2015)

3.12. IPCC (2014) assessments concerning China

	Mountains, snow and ice	References	Confidence in detection	Role of climate	Climate driver	Reference behavior	Confidence in attribution
Asia	Permafrost degradation in Siberia, Central Asia, and the Tibetan Plateau	WGI AR5 Section 4.7.2; Section 24.4.2.2; Romanovsky et al. (2010); Yang et al. (2013)	*High*	Major	Warming	No change	*High*
	Shrinking mountain glaciers across most of Asia	WGI AR5 Section 4.3.3; Section 24.4.1.2; Box 3-1; Bolch et al. (2012); Cogley (2012); Gardelle et al. (2012); Kääb et al. (2012); Yao et al. (2012); Gardner et al. (2013); Stokes et al. (2013)	*High*	Major	Warming	No change	*Medium*
Asia	Changes in water availability in many Chinese rivers	Table SM24-4; Zhang et al. (2007); Zhang, S. et al. (2008)	*High*	Minor	Change in precipitation	Changes due to land use	*Low*
	Increased flow in several rivers in China due to shrinking glaciers	Casassa et al. (2009); Li et al. (2010); Zhang, Y. et al. (2008)	*High*	Major	Warming	No change	*High*
	Earlier timing of maximum spring flood in Russian rivers	Section 28.2.1.1; Shiklomanov et al. (2007); Tan et al. (2011)	*High*	Major	Warming	No change	*Medium*
	Reduced soil moisture in North Central and Northeast China 1950–2006	Sections 24.3.1 and 24.4.1.2; Sheffield and Wood (2007); Wang, A. et al. (2011); Seneviratne et al. (2012)	*Medium*	Major	Warming; change in precipitation	No change	*Medium*
	Surface water degradation in parts of Asia	Section 24.4.1.2; Prathumratana et al. (2008); Delpla et al. (2009); Huang et al. (2009)	*Medium*	Minor	Warming; change in precipitation	Changes due to land use	*Medium*
Asia	Changes in plant phenology and growth in many parts of Asia (earlier greening), particularly in the north and the east	Sections 4.3.2.1 and 24.4.2.2; Figure 4-4; Ma and Zhou (2012); Panday and Ghimire (2012); Shrestha et al. (2012); Ogawa-Onishi and Berry (2013)	*High*	Major	Warming	No change	*Medium*
	Distribution shifts in many plant and animal species, particularly in the north of Asia, upwards in elevation or polewards	Sections 4.3.2.5 and 24.4.2.2; Figure 4-4; Moiseev et al. (2010); Chen et al. (2011); Jump et al. (2012); Ogawa-Onishi and Berry (2013)	*High*	Major	Warming	No change	*Medium*
Asia	Decline in coral reefs in tropical Asian waters	Sections 24.4.3.2 and 30.5.1.4.3; McLeod et al. (2010); Krishnan et al. (2011); Coles and Riegl (2012)	*High*	Major	Ocean warming	Decline due to human impacts	*High*
	Northward range extension of coral in the East China Sea and western Pacific, and a predatory fish in the Sea of Japan	Section 24.4.3.2; Yamano et al. (2011); Tian et al. (2012); Ogawa-Onishi and Berry (2013)	*Medium*	Major	Ocean warming	No change	*Medium*
	Negative impacts on aggregate wheat and maize yields in China	Section 7.2.1; Figure 7-2; Tao et al. (2006, 2008, 2012); You et al. (2009); Chen et al. (2010)	*Low*	Minor	Warming	Increase due to improved technology	*Low*

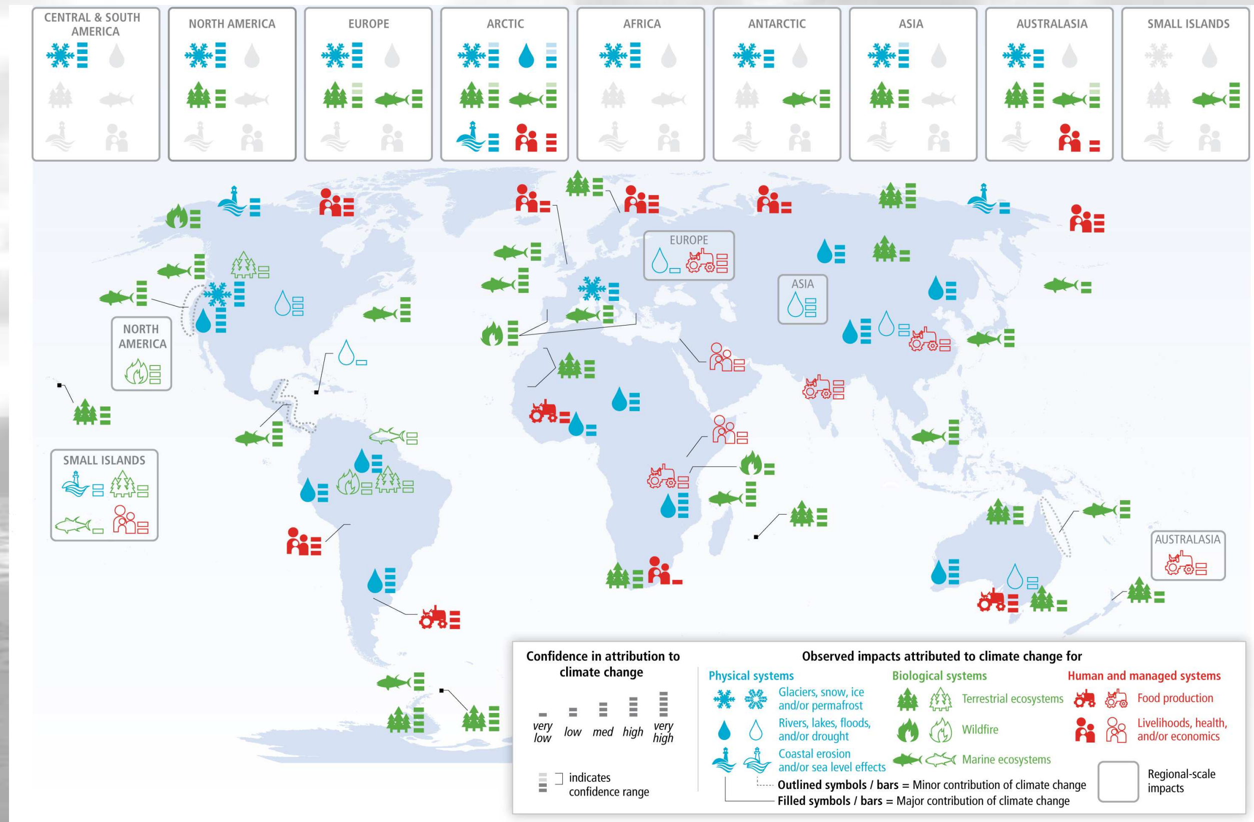
IPCC (2014) (Cramer et alii 2014)

3.13. Summary of 2013 assessments

More bars= higher confidence

Solid bars= attribution of "major" role

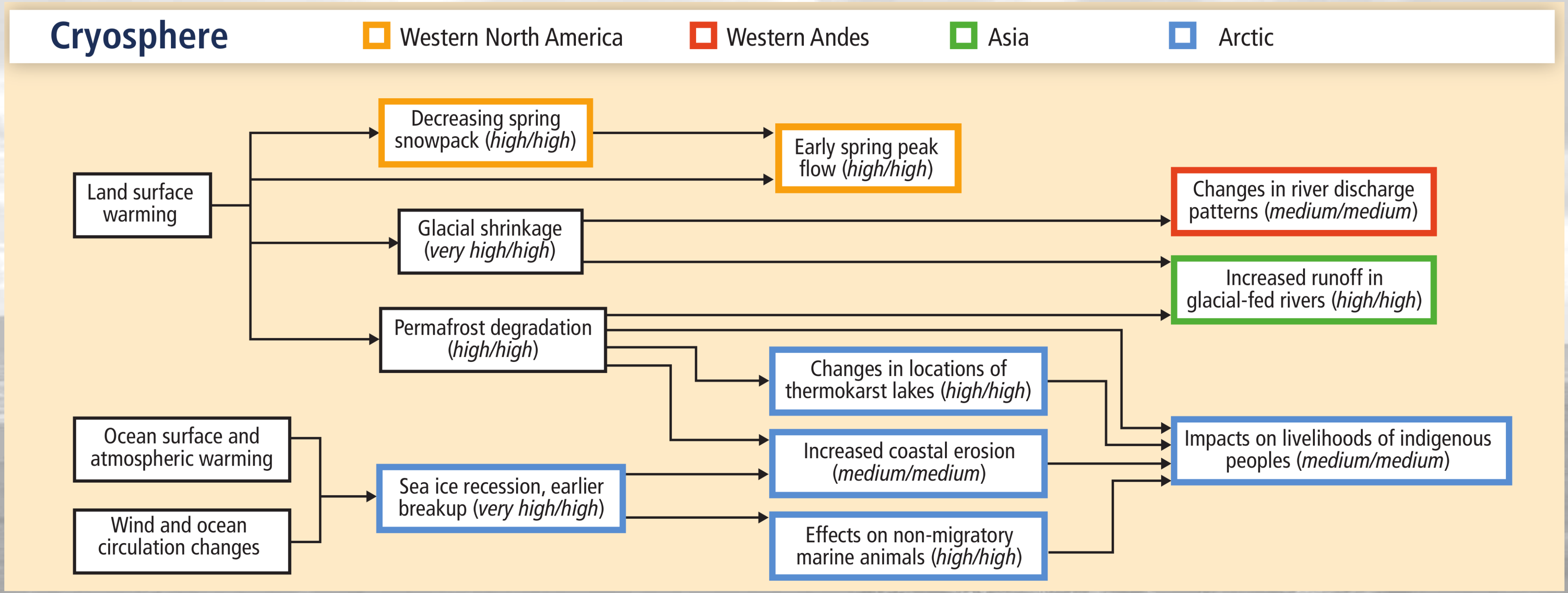
Empty bars= attribution of at least "minor" role



IPCC (2014) (Cramer et ali 2014)

3.14. Cascading impacts

- With that sample of impacts, we can explore pathways of cascading impacts

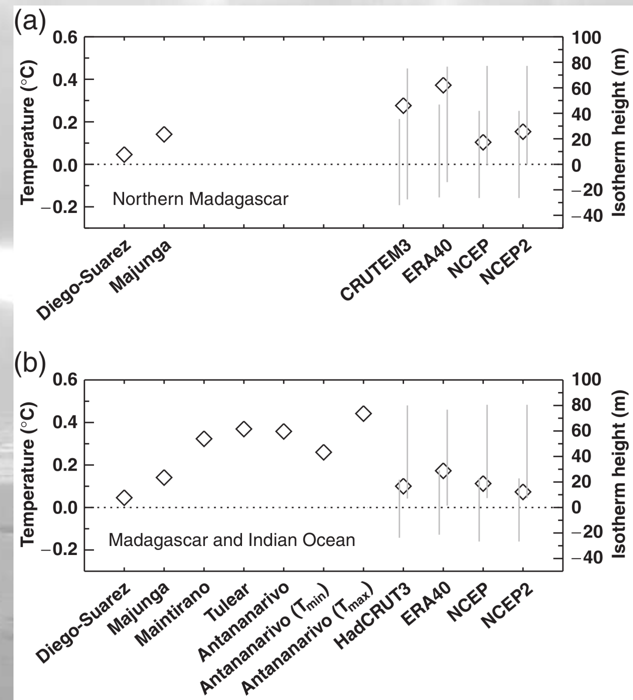


IPCC (2014) (Cramer et alii 2014)

3.15. What about *anthropogenic* climate change

- For Madagascar case, bars in plot indicate sampling uncertainties based on various climate model sources
  - Left bars: no forcing
  - Right bars: with anthropogenic and natural forcing
- Short period for local trend estimation
  - Observed trend consistent with anthropogenic climate change
  - But also with no change

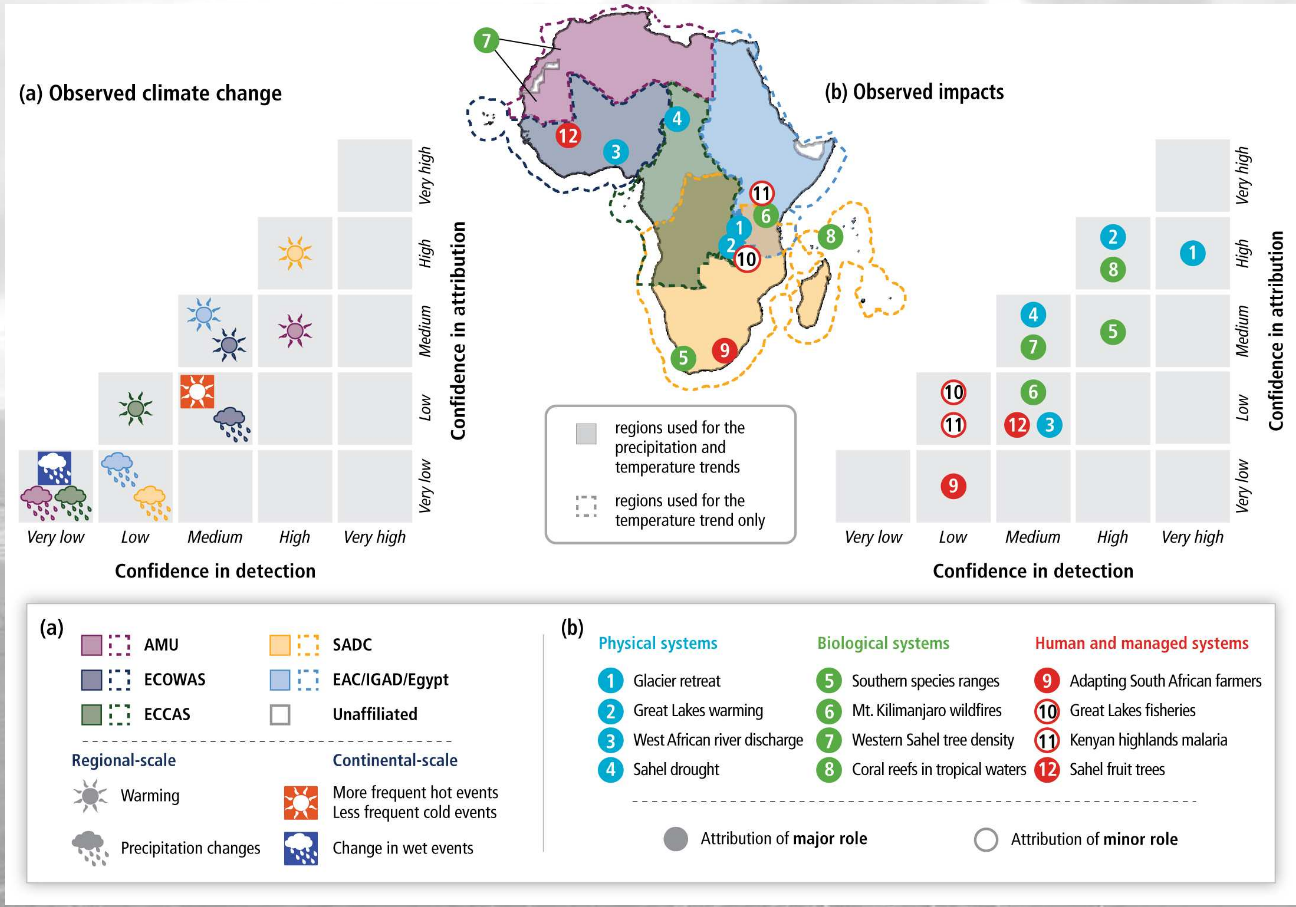
Changes in annual temperature, 1984–1993 and 1994–2003



Raxworthy et alii (2008)

3.16. This has not been covered in IPCC reports

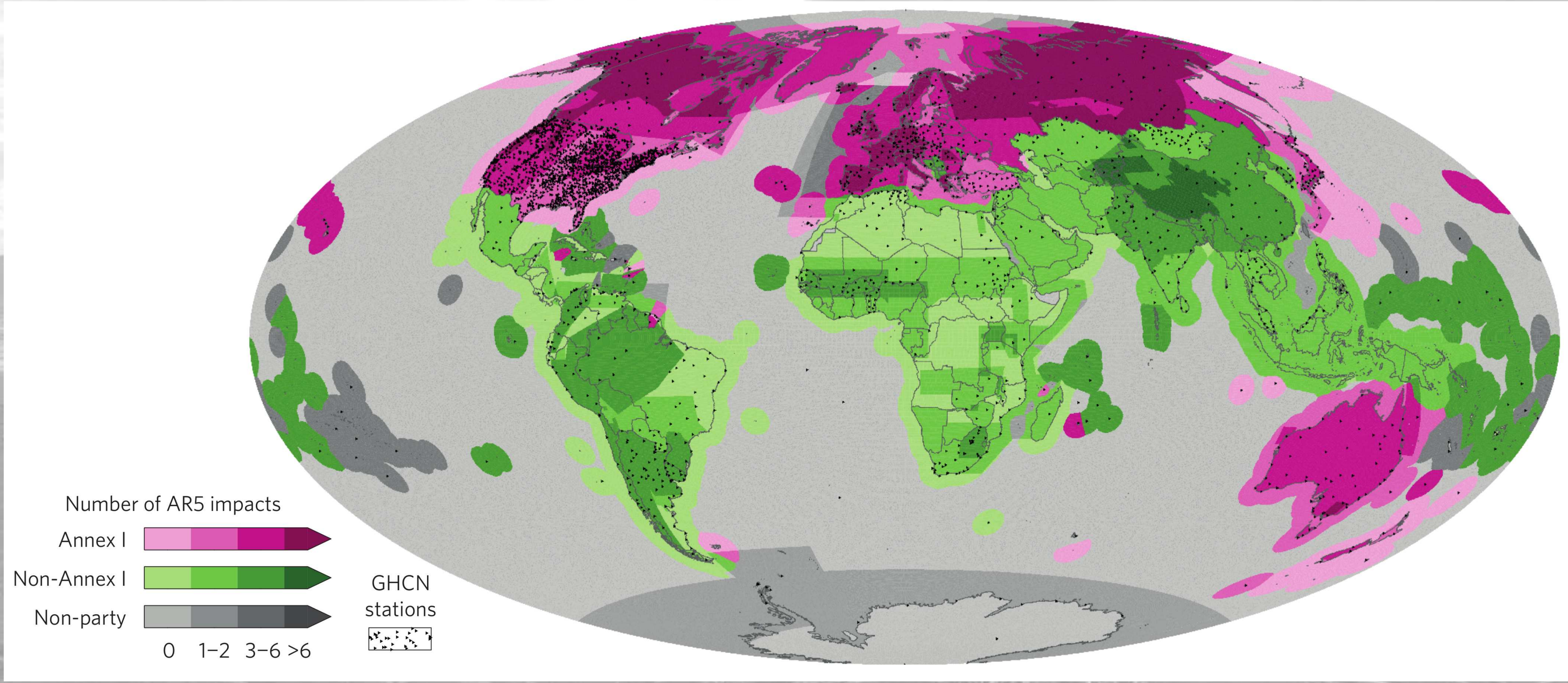
- Climate D&A and impact D&A assessment do not connect



IPCC (2014) (Niang et alii 2014)

Relevant climate change related to IPCC impact D&A assessments

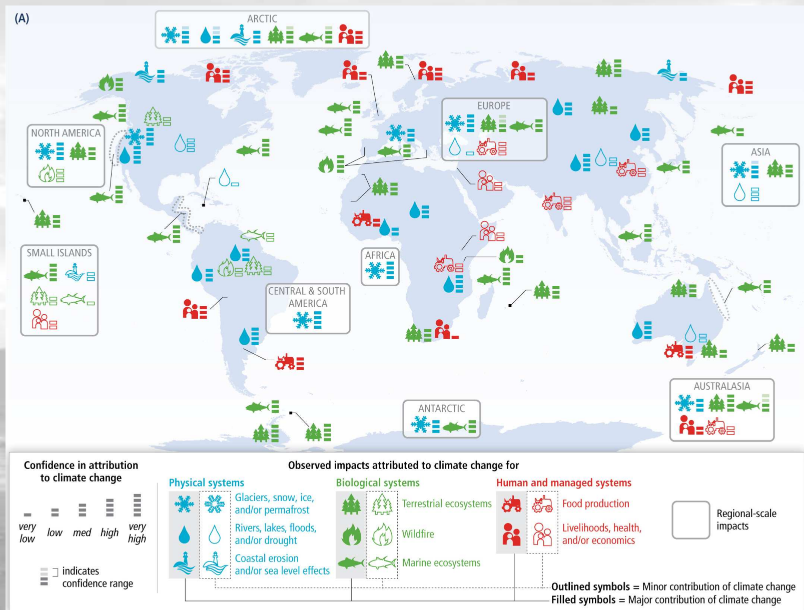
- Documented in tables in the IPCC report



Huggel et alii (2016)

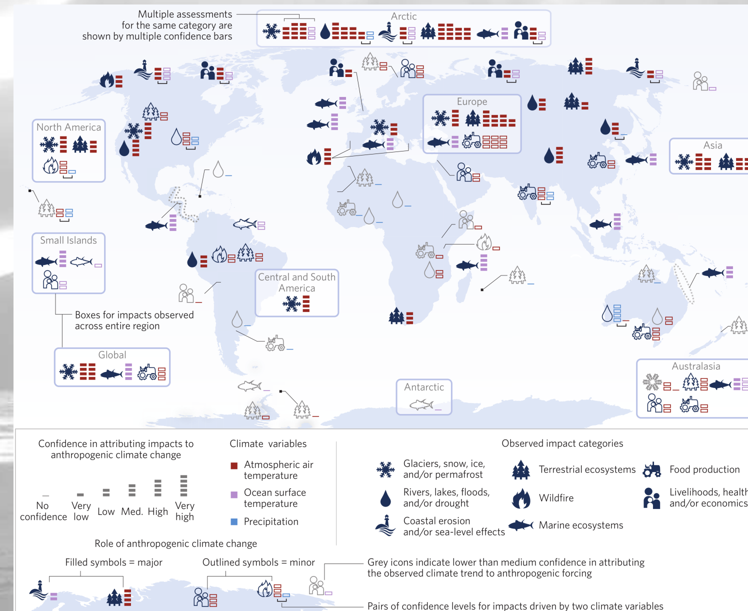
The effect of anthropogenic climate change on natural, managed, and humans systems

D&A to observed climate trends



IPCC (2014)

D&A to anthropogenic climate change



Hansen and Stone (2016)

- What happened in Africa?

3.17. Main messages

- Analysis of cause and effect in non-climate systems must consider a variety of possible causes, not just climate change
- There are many studies out there, often not focusing on the climate change component, usually under different terminology
  - Simple web search for “detection and attribution” may not find it
- Diversity of systems, situations, drivers, etc. requires a diversity of approaches
  - And expertise!
- Confidence in overall assessment depends on various factors, including trust in analysis approach
- D&A of influence of observed climate change not the same as D&A of influence of anthropogenic climate change