XII SIMPÓSIO DE RECURSOS HÍDRICOS DO NORDESTE

4 a 7 / novembro / 2014 ★ Natal ★ RN

Mudanças Climáticas

Susan Gaskin

McGill University, Canada

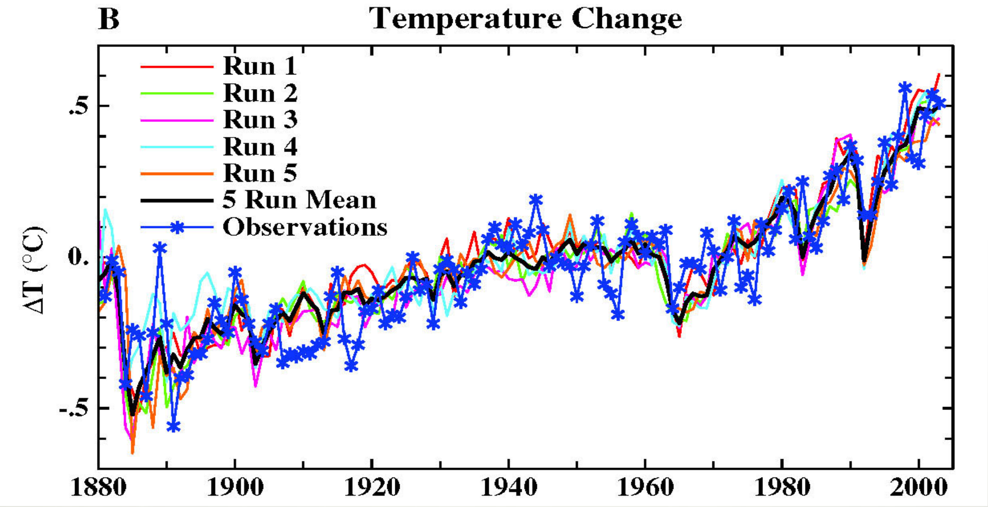
ABRH

ASSOCIAÇÃO BRASILEIRA DE RECURSOS HÍDRICOS

Climate Change

Although climate change is driven by many climate forcing agents and the climate system also exhibits unforced (chaotic) variability, it is now widely agreed that the strong global warming trend of recent decades is caused predominantly by human-made changes of atmospheric composition (IPCC, 2007, IPCC 2013).

Although climate change is driven by many climate forcing agents and the climate system also exhibits unforced (chaotic) variability, it is



Simulated and observed surface temperature change.

(Earth's energy imbalance: Confirmation and implications. *Science* **308**, 1431, 2005).

Climate change dynamics

XII SIMPÓSIO DE RECURSOS HÍDRICOS DO NORDESTE
4 a 7 / novembro / 2014 ★ Natal ★ RN

- The planetary energy imbalance caused by a change of atmospheric composition defines a climate forcing.
- Climate sensitivity, the eventual global temperature change per unit forcing, is known with good accuracy from Earth's paleoclimatic history.
- However, two fundamental uncertainties limit our ability to predict global temperature change on decadal time scales.

The image cannot be displayed. Your computer may not have enough memory to open the image, or the image may have been corrupted. Restart your computer, and then open the file again. If the red x still appears, you may have to delete the image and then insert it again.

Change of climate forcings in W/m^2 between 1750 and 2000.

[from Hansen *et al.* "Efficacy ... Geophys. Res.* (2005)]

Change of climate forcings in W/m^2 between 1750 and 2000.
[from Hansen *et al.* "Efficacy

ABRH

Human made aerosols

First, although climate forcing by human-made greenhouse gases (GHGs) is known accurately, climate forcing caused by changing human-made aerosols is practically unmeasured.

Aerosols are fine particles suspended in the air, such as dust, sulfates, and black soot (Ramanathan et al., 2001).

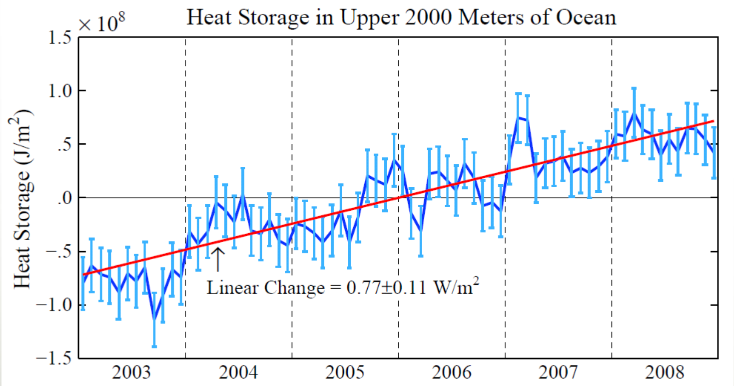
- Aerosol climate forcing is complex, because aerosols both reflect solar radiation to space (a cooling effect) and absorb solar radiation (a warming effect). In addition, atmospheric aerosols can alter cloud cover and cloud properties.

Therefore, precise composition-specific measurements of aerosols and their effects on clouds are needed to assess the aerosol role in climate change.

Mixing of heat into the deep ocean

Second, the rate at which Earth's surface temperature approaches a new equilibrium in response to a climate forcing depends on how efficiently heat perturbations are mixed into the deeper ocean.

- Ocean mixing is complex and not necessarily simulated well by climate models. Empirical data on ocean heat uptake are improving rapidly, but still suffer limitations.



Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data.

Data source: von Schuckmann *et al. J. Geophys. Res.* **114**, C09007, 2009.

IPCC 2014 report

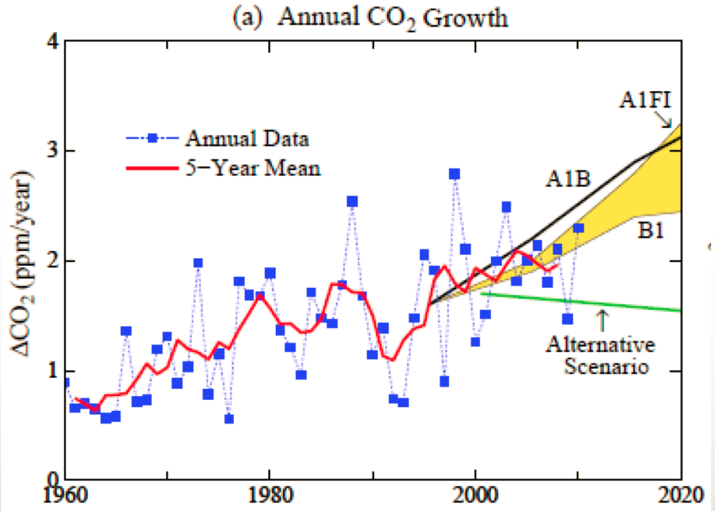
Observed Changes in the Climate System

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased (see Figures SPM.1, SPM.2, SPM.3 and SPM.4). {2.2, 2.4, 3.2, 3.7, 4.2–4.7, 5.2, 5.3, 5.5–5.6, 6.2, 13.2}
- i.e. warming of the atmosphere, oceans, melting of icesheets and glaciers, sea level rise, CO2 40% higher than pre-industrial times of which 30% is absorbed into the oceans causing acidification.

IPCC 2014 report

Drivers of Climate Change

- Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO2 since 1750 (see Figure SPM.5). {3.2, Box 3.1, 8.3, 8.5).



Source: Hansen et al (2011) Atmos.Chem.Phys. 11: 13421-13449

IPCC 2014 report

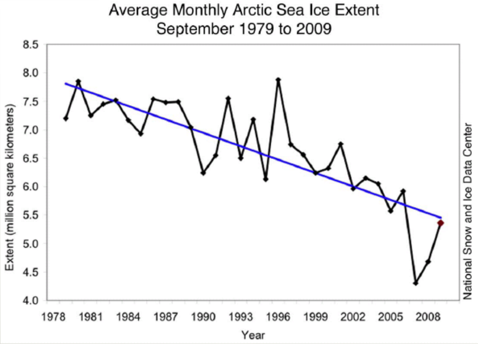
Understanding the Climate System and its Recent Changes

- Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system. {2–14}
- Observational and model studies of temperature change, climate feedbacks and changes in the Earth's energy budget together provide confidence in the magnitude of global warming in response to past and future forcing. {Box 12.2, Box 13.1}

IPCC 2014 report

Detection and Attribution of Climate Change

- Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes (see Figure SPM.6 and Table SPM.1). This evidence for human influence has grown since AR4. It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century. {10.3–10.6, 10.9}



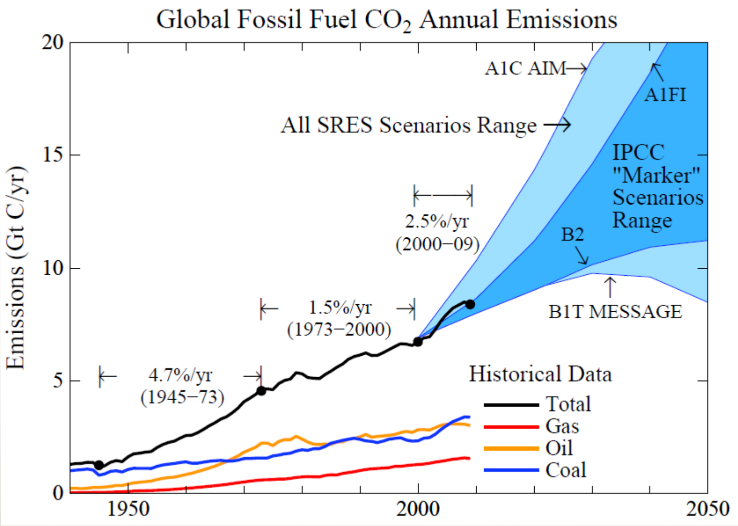
September sea ice extent based on satellite microwave observations.

Data source: National Snow and Ice Data Center

IPCC 2014 report

Future Global and Regional Climate Change

- Continued emissions of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and sustained impacts for people and ecosystems. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions. {6, 11–14}



Global fossil fuel carbon dioxide emissions accelerated after Kyoto Protocol.

Date sources: Marland et al. (U.S. Dept. Energy, Oak Ridge and extended with BP Statistical Review of World Energy.)

IPCC 2014 report

Implications

- Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed.
- Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts for people, species and ecosystems.
- Continued high emissions would lead to mostly negative impacts for biodiversity, ecosystem services, and economic development and amplify risks for livelihoods and for food and human security.
- Many aspects of climate change and its impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases are stop

IPCC 2014 report

Implications

- Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change.
- Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term, and contribute to climate-resilient pathways for sustainable development.{3.2, 3.3, 3.4}
- Effective decision making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgments, economic assessments and diverse perceptions and responses to risk and uncertainty. {3.1}

Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread, and irreversible impacts globally (high confidence)

Water management in a Variable and Changing Climate

- Climate variability and change impact water availability, safety and ecosystems.
- However, we are uncertain how it will affect water availability and extreme weather, particularly at the regional or local scale and over a range of time scales.
- Water demand will also change with climate change.

The question is how do we deal with the uncertainty and how do we integrate it into water management.

Climate change and its effect on water resources

SIMPÓSIO DE RECURSOS HÍDRICOS DO NORDESTE
4 a 7 / novembro / 2014 ★ Natal ★ RN

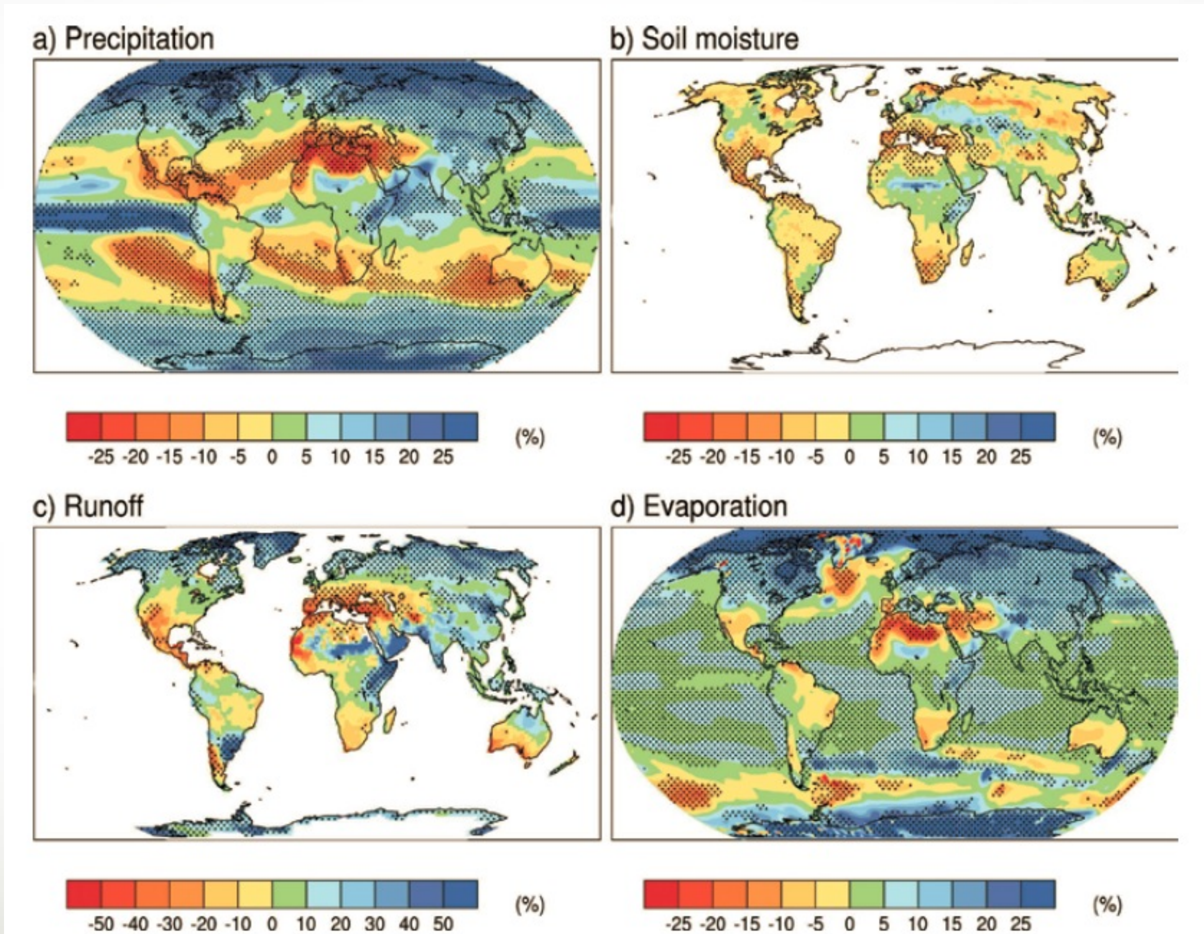
Phenomena	Likelihood of trend
Contraction of snow cover areas, increased thaw in permafrost regions, decrease in sea ice extent	Virtually certain
Increased frequency of hot extremes, heat waves and heavy precipitation	Very likely to occur
Increase in tropical cyclone intensity	Likely to occur
Precipitation increases in high latitudes	Very likely to occur
Precipitation decreases in subtropical land regions	Very likely to occur
Decreased water resources in many semi-arid areas, including western U.S. and Mediterranean basin	High confidence

Source: http://climate.nasa.gov/effects/
Accessed 2010

ABRH

15 model mean changes in a) precipitation (%), b) soil moisture content (%), c) runoff (%), and d) evaporation (%).

Stippled area indicate agreement by 80% of models. Changes are annual means for SRES A1B for 2080-2099 relative to 1980-1999. Soil moisture and runoff changes are shown at land points with valid data from at least 10 models.



Source: Bates ,B.C., Z.W. Kundzewicz, S. Wu and J.P Palutikof, Eds., 2008: Climate change and water. Technical Paper of the IPCC, IPCC Secretariat, Geneva, 210 pp.

IPCC Technical Summary
Freshwater Resources

- In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (medium confidence).
- Glaciers continue to shrink almost worldwide due to climate change (high confidence) (e.g., Figure TS.2B), affecting runoff and water resources downstream (medium confidence).
- Climate change is causing permafrost warming and thawing in high-latitude regions and in high-elevation regions (high confidence).
- There is no evidence that surface water and groundwater drought frequency has changed over the last few decades, although impacts of drought have increased mostly due to increased water demand. [3.2, 4.3, 18.3, 18.5, 24.4, 25.5, 26.2, 28.2, Tables 3-1 and 25-1, Figures 18-2 and 26-1]

IPCC Technical Summary
Terrestrial and Freshwater Ecosystems

- Many terrestrial and freshwater plant and animal species have shifted their geographic ranges and seasonal activities and altered their abundance in response to observed climate change over recent decades, and they are doing so now in many regions (high confidence).
- Increased tree mortality, observed in many places worldwide, has been attributed to climate change in some regions (Figure TS.2C).
- Increases in the frequency or intensity of ecosystem disturbances such as droughts, wind storms, fires, and pest outbreaks have been detected in many parts of the world and in some cases are attributed to climate change (medium confidence).

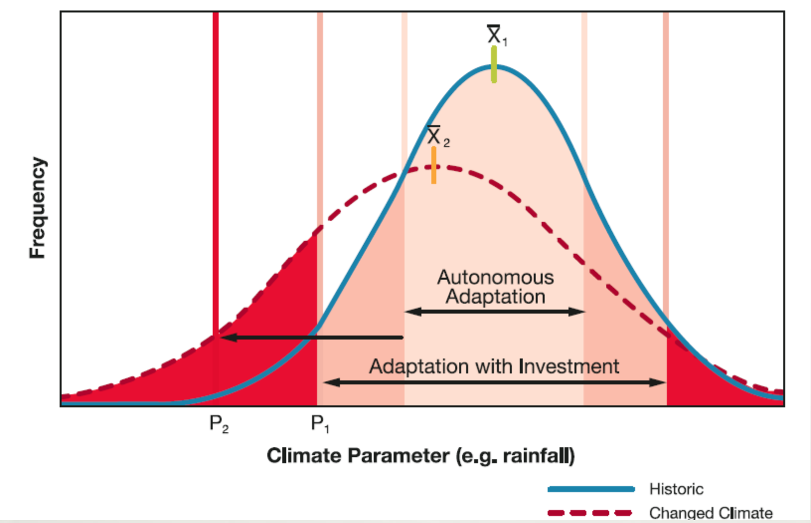
Understanding uncertainty in predictions

- Scenario development

- Global Climate Models :
  - data
  - resolution
  - description of physical processes
  - downscaling – statistical or dynamical
  - biases

Adapting to uncertainty in management

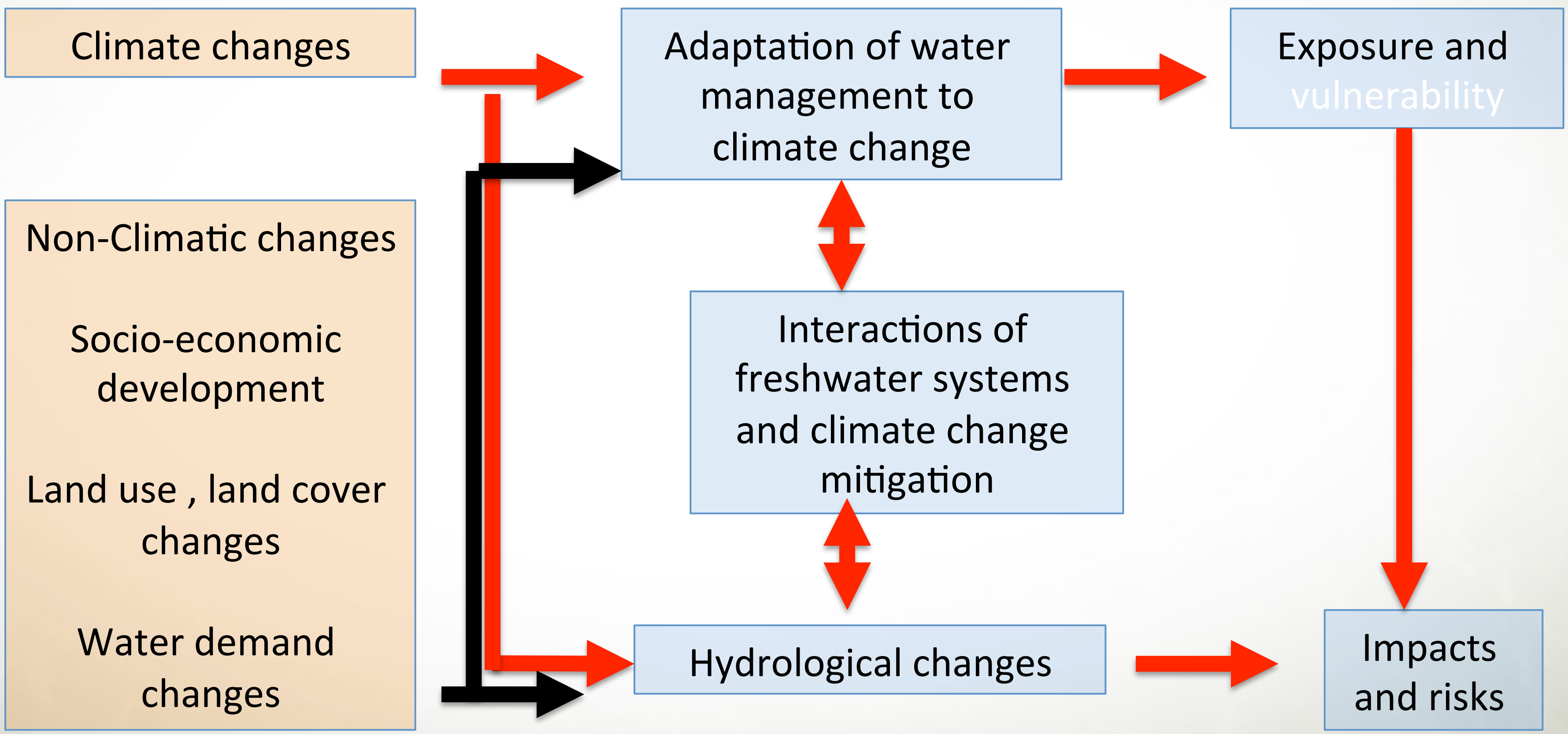
In light of the uncertainty and large variability in future predictions, more robust and flexible solutions need to be designed and management needs to also be more flexible.



Change in the probability function of a climate variable.

Source:The Gulbenkian Think Tank on Water and the Future of Humanity (2014) Water and the Future of Humanity: Revisiting Water Security, Springer, 236 pp.

Framework and linkages for considering impacts of climatic and social changes on freshwater systems



IPCC 2014

IPCC 5 Adaptation

- **Of the global cost of water sector adaptation, most is necessary in developing countries where there are many opportunities for anticipatory adaptation (*medium evidence, high agreement*).**
- **An adaptive approach to water management can address uncertainty due to climate change (*limited evidence, high agreement*).** Adaptive techniques include scenario planning, experimental approaches that involve learning from experience, and the development of flexible and low-regret solutions that are resilient to uncertainty. Barriers to progress include lack of human and institutional capacity, financial resources, awareness, and communication. {3.6.1, 3.6.2, 3.6.4}
- **Reliability of water supply, which is expected to suffer from increased variability of surface water availability, may be enhanced by increased groundwater abstractions (*limited evidence, high agreement*).**

Knowledge and Education

- Knowledge gap between general public and scientists/engineers
- Need to educate the general public – best method is through school curriculums, discussions in the media
- An educated public can understand and support the recommendations of the experts and demand change from the political system.

Current Political Context

In Quebec

- good progress in discussions
- target emissions of 20% below 1990 levels by 2020
- action plan addressing all sectors, includes incentives, regulatory measures and education

In Canada

- disastrous
- pulled out of Kyoto, obstructs global agreements
- priority of current government is to maximize oil revenue and pursue non-conventional fossil fuel development
- gutting of environmental regulations
- silences discussion

Thank you