AOS Climatepedia Info Session

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What would you say are the top three impacts of climate change that cause climate scientists the most worry, and why?

- It is difficult to pick just 3 top impacts. The earth system is very complex, and comprised of many parts, such as the oceans, atmosphere, land, ice, and each interact with, and influence, one another.

- But some examples of main concerns include:
  - Sea level rise
  - Extreme weather (e.g. heat waves, droughts, frequency and intensity of tornadoes and hurricanes)
    - Water and food resources

Sea level rise

→ The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (high confidence).
→ Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m.

- Main contributors:
  - Thermal expansion
  - Glacier melting
- Observations since 1971 indicate that thermal expansion and glaciers explain 75% of the observed rise (high confidence).
- There is high confidence in projections of **thermal expansion** and Greenland surface mass balance, and medium confidence in projections of **glacier mass loss** and Antarctic surface mass balance.

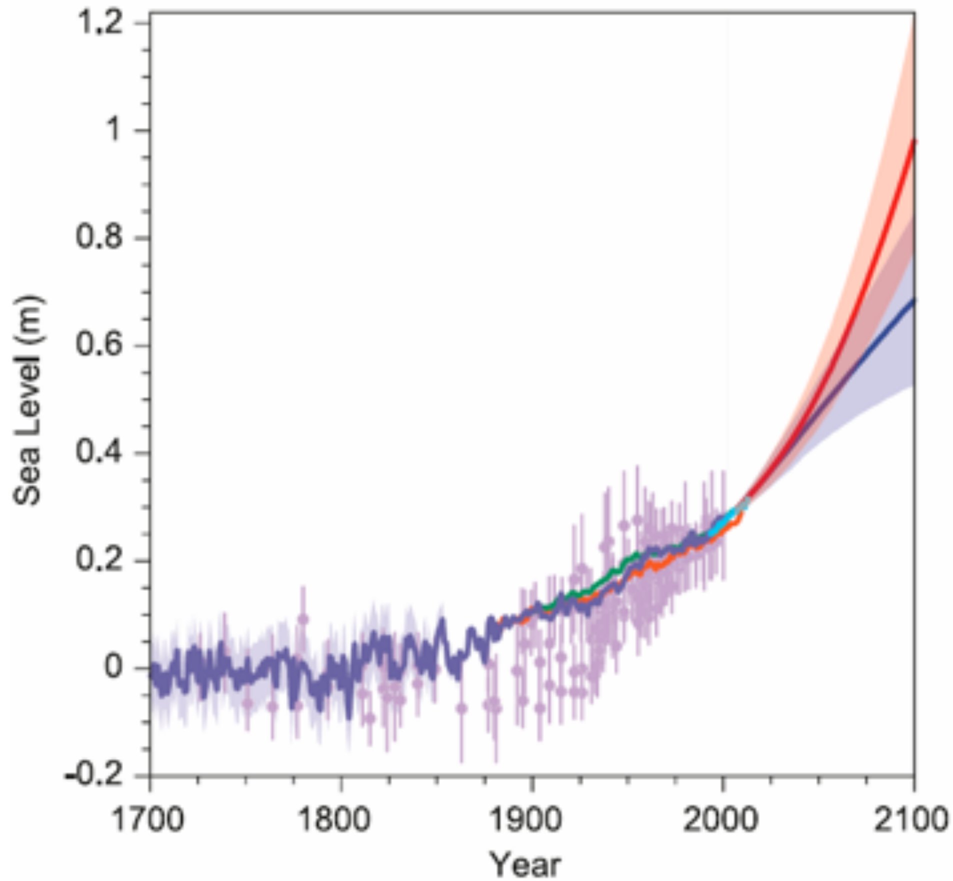

Fig. 1. Past and future sea-level rise. For the past, proxy data are shown in light purple and tide gauge data in blue. For the future, the IPCC projections for very high emissions (red, RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27. - See more at: http://www.realclimate.org/index.php/archives/2013/10/sea-level-in-the-5th-ipcc-report/#sthash.bioLrN76.dpuf

Source: IPCC AR5

Extreme Events

A **changing climate** leads to <u>changes in</u> the **frequency**, **intensity**, **spatial extent**, **duration**, and **timing <u>of extreme weather and climate events</u>**, and can result in unprecedented extreme weather and climate events.

Changes in extremes can be linked to changes in the mean, variance, or shape of probability distributions, or all of these (Figure SPM.3). Some climate extremes (e.g., droughts) may be the result of an accumulation of weather or climate events that are not extreme when considered independently.

Many extreme weather and climate events continue to be the result of natural climate variability. Natural variability will be an important factor in shaping future extremes in addition to the effect of anthropogenic changes in climate. [3.1]

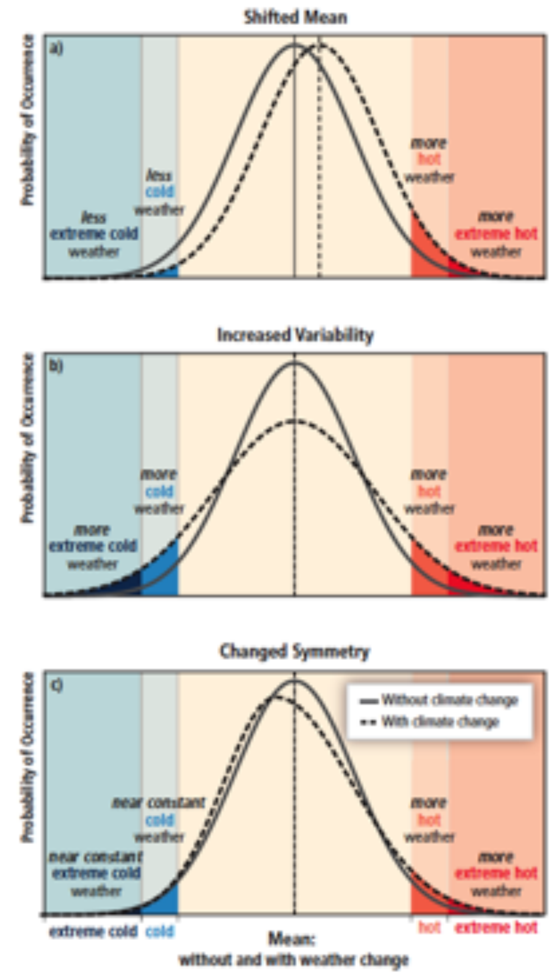

Figure SPM.3 | The effect of changes in temperature distribution on extremes. Different changes in temperature distributions between present and future climate and their effects on extreme values of the distributions: (a) effects of a simple shift of the entire distribution toward a warmer climate; (b) effects of an increase in temperature variability with no shift in the mean; (c) effects of an altered shape of the distribution, in this example a change in asymmetry toward the hotter part of the distribution. [Figure 1-2, 1.2.2]

Source: IPCC AR5
Summary for Policymakers
http://www.ipcc.ch/pdf/special-reports/srex/

Observed changes in Extremes

- **Extreme events are rare, which means there are few data available to make assessments regarding changes in their frequency or intensity. The more rare the event the more difficult it is to identify long-term changes.**
- There is evidence that some extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases.
- It is likely that anthropogenic influences have led to warming of **extreme daily minimum and maximum temperatures** at the global scale.
- There is medium confidence that anthropogenic influences have contributed to intensification of **extreme precipitation** at the global scale.
- It is likely that there has been an anthropogenic influence on increasing **extreme coastal high water** due to an increase in mean sea level.
- The uncertainties in the historical **tropical cyclone** records, the incomplete understanding of the physical mechanisms linking tropical cyclone metrics to climate change, and the degree of tropical cyclone variability provide only low confidence for the attribution of any detectable changes in tropical cyclone activity to anthropogenic influences.
- **Attribution of single extreme events to anthropogenic climate change is challenging.**

Virtually certain	99-100% probability
Very likely	***90-100% probability***
Likely	***66-100% probability***
About as likely as not	***33-66% probability***
Unlikely	***0-33% probability***
Very unlikely	***0-10% probability***
Exceptionally unlikely	***0-1% probability***

Source: IPCC AR5
Summary for Policymakers
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Extreme Events Projections

- Models project substantial warming in **temperature extremes** by the end of the 21st century.
- It is virtually certain that **increases** in the **frequency and magnitude of warm daily temperature extremes** and **decreases in cold extremes will occur** in the 21st century at the global scale.
- It is very likely that the length, frequency, and/or intensity of warm spells or **heat waves** will increase over most land areas.
- It is likely that the **frequency of heavy precipitation** or the proportion of total rainfall from heavy falls will **increase** in the 21st century over many areas of the globe. This is particularly the case in the high latitudes and tropical regions, and in winter in the northern mid-latitudes
- Average **tropical cyclone maximum wind speed** is likely to **increase**, although increases may not occur in all ocean basins. It is likely that the **global frequency of tropical cyclones will either decrease or remain essentially unchanged**
- Medium confidence in a projected **poleward shift of extratropical storm tracks**
- There is medium confidence that **droughts** will **intensify** in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration.
- Projected precipitation and temperature changes imply possible changes in **floods**, although overall there is low confidence in projections of changes in fluvial floods.
- There is high confidence that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as **slope instabilities, movements of mass, and glacial lake outburst floods.** There is also high confidence that changes in heavy precipitation will affect **landslides** in some regions.

- **Extreme events will have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry, health, and tourism.**

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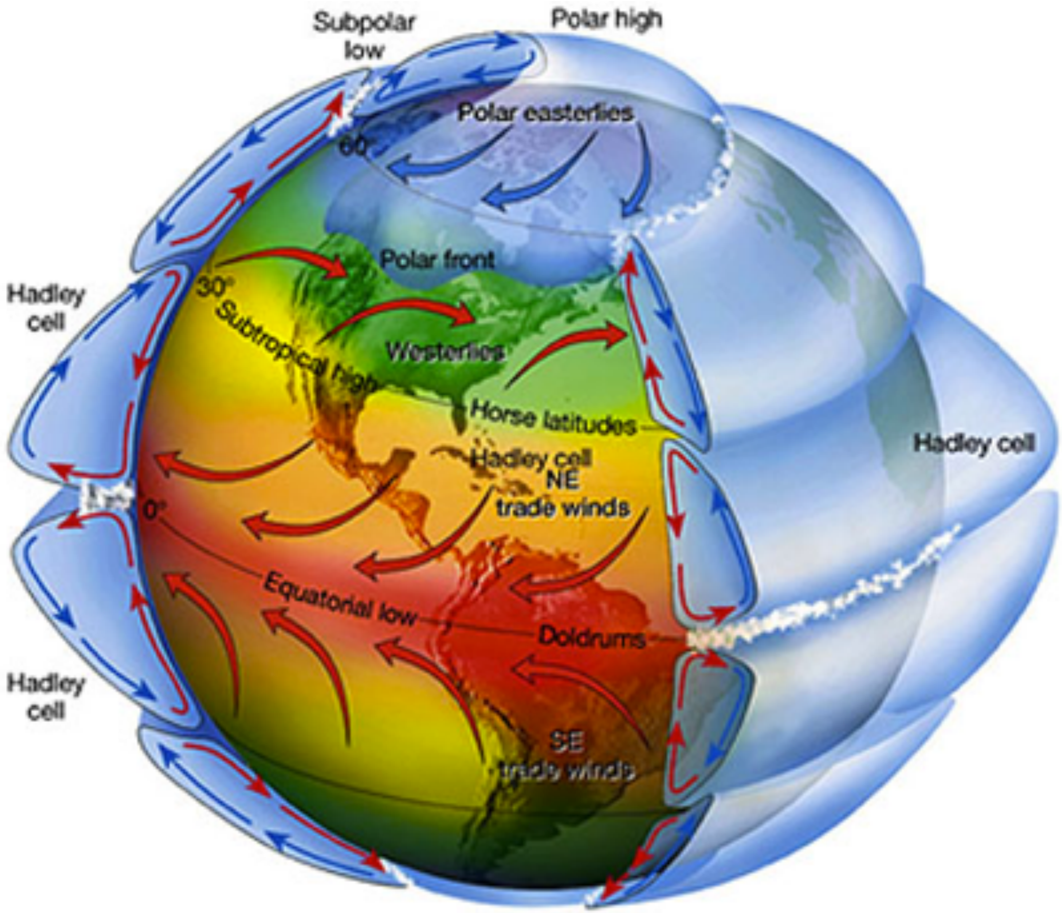
A **level of confidence** is expressed using five qualifiers: very low, low, medium, high, and very high

Source: IPCC AR5
Summary for Policymakers
http://www.ipcc.ch/pdf/special-reports/srex/

Regional Climate Impacts



What gives rise to generalized regional climates? →Large scale atmospheric circulation driven primarily by temperature gradients

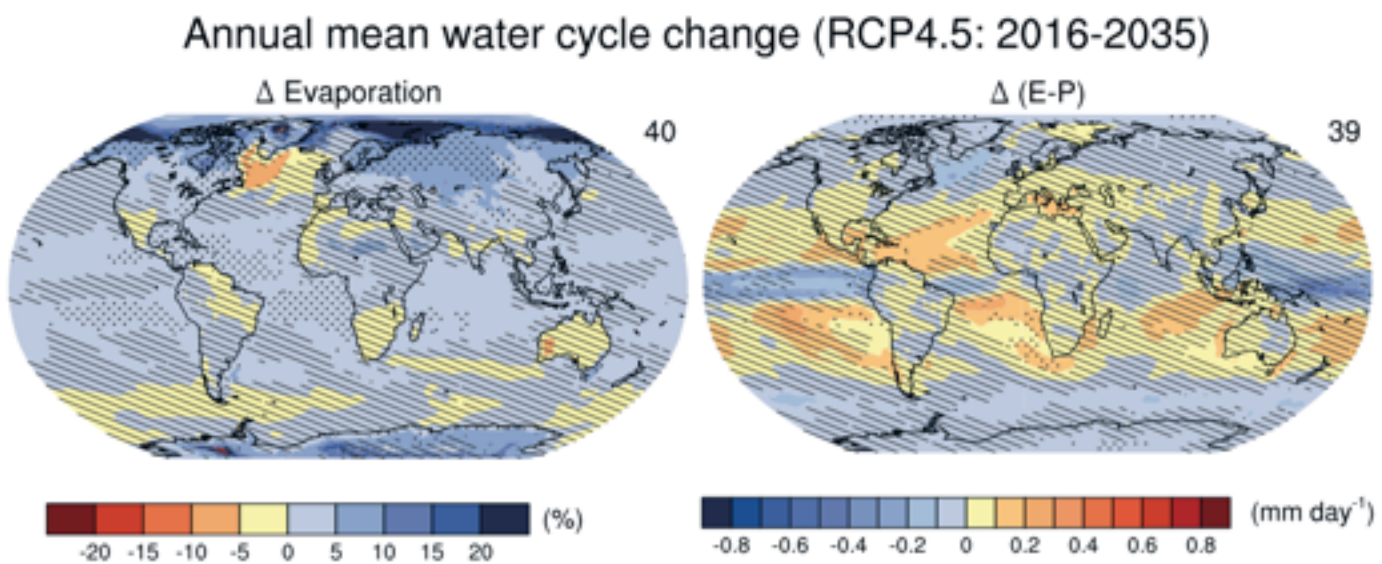
Dry subtropics, wet tropics and subpolar regions

Regional Climate Impacts

"Wet get wetter, dry get drier" (Hydrologic Cycle Intensification)

More CO_2 in the atmosphere → increase in temperatures → increase in evaporation (more water vapor in atmosphere)→ areas of precip and evap as driven by large scale circulations are more amplified

Subtropics will become drier and subpolar regions will become wetter → this presents a water resource issue in already dry regions



Climate change impacts in the developing world

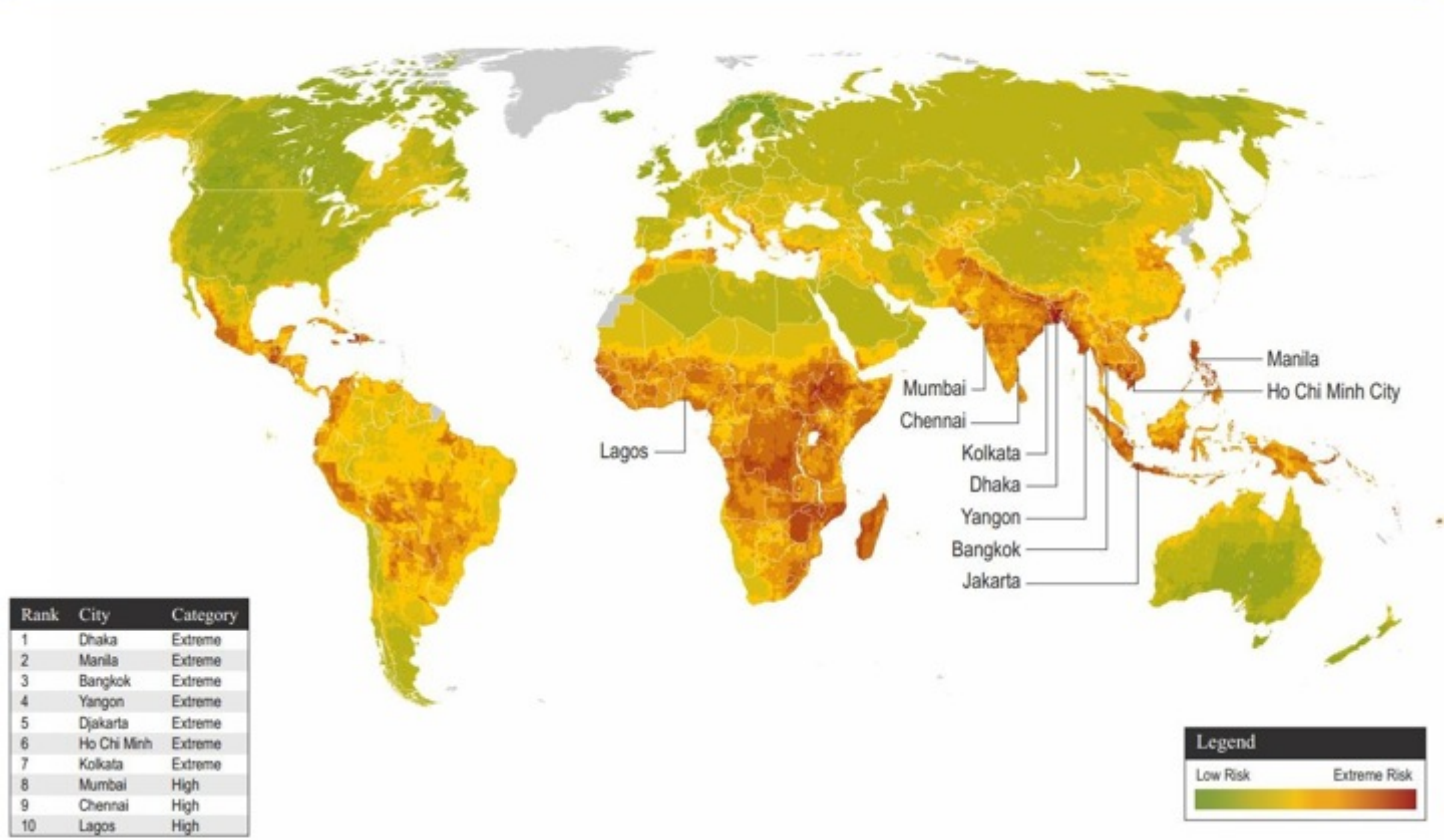
- Climate change will hit poor countries the hardest
- Dry regions will become drier, wet regions wetter
- Developing regions in Africa, Asia, Latin America, and small island developing states (SIDS) will be most vulnerable
- Extreme events (floods, droughts, heat waves, etc.) expected to rise in frequency and intensity; sea level rise will affect islands and coastal communities
- Many of these countries do no have the social, technological, or financial resources in place to adapt

Source: UNFCCC Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries

Climate change impacts in the developing world

- **Impacts:** temperature, precipitation, extreme events
- **Vulnerabilities:** water, agriculture and food security, health, ecosystems, coastal zones

Source: UNFCCC Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries

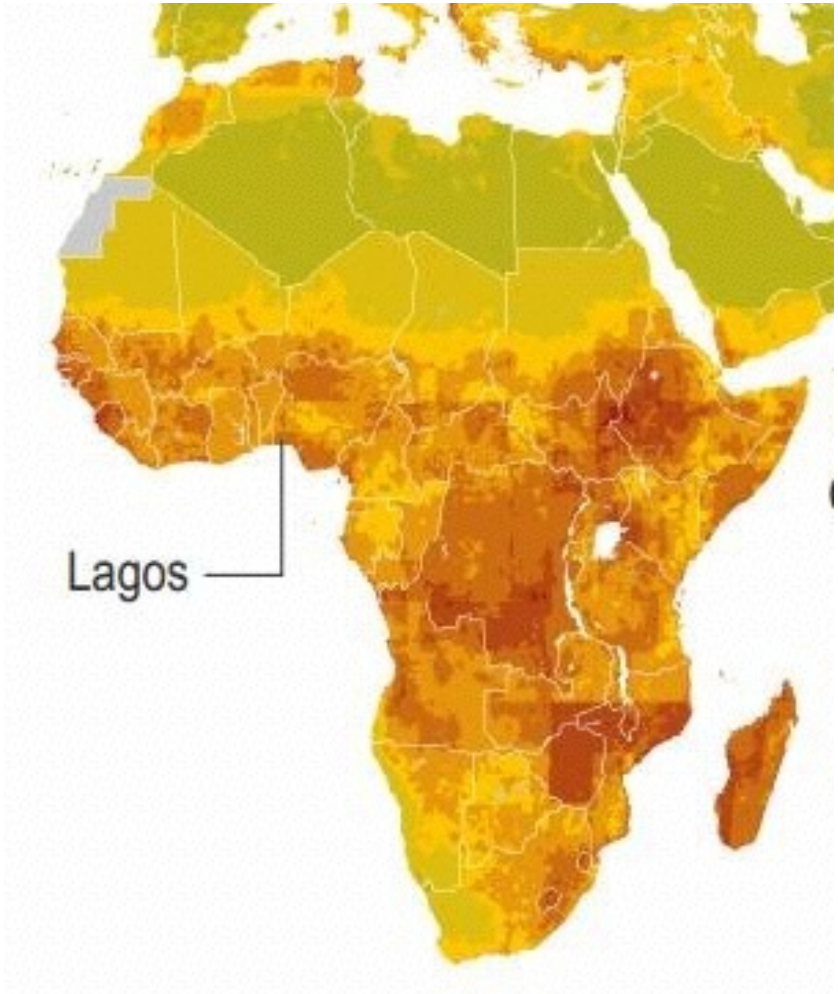


Rank	City	Category
1	Dhaka	Extreme
2	Manila	Extreme
3	Bangkok	Extreme
4	Yangon	Extreme
5	Djakarta	Extreme
6	Ho Chi Minh	Extreme
7	Kolkata	Extreme
8	Mumbai	High
9	Chennai	High
10	Lagos	High

Source: Maplecroft (global risks advisory firm) Climate Change Vulnerability Index – uses social, economic, and environmental factors to assess vulnerabilities to natural disasters, sea-level rise,

Climate change impacts in the developing world

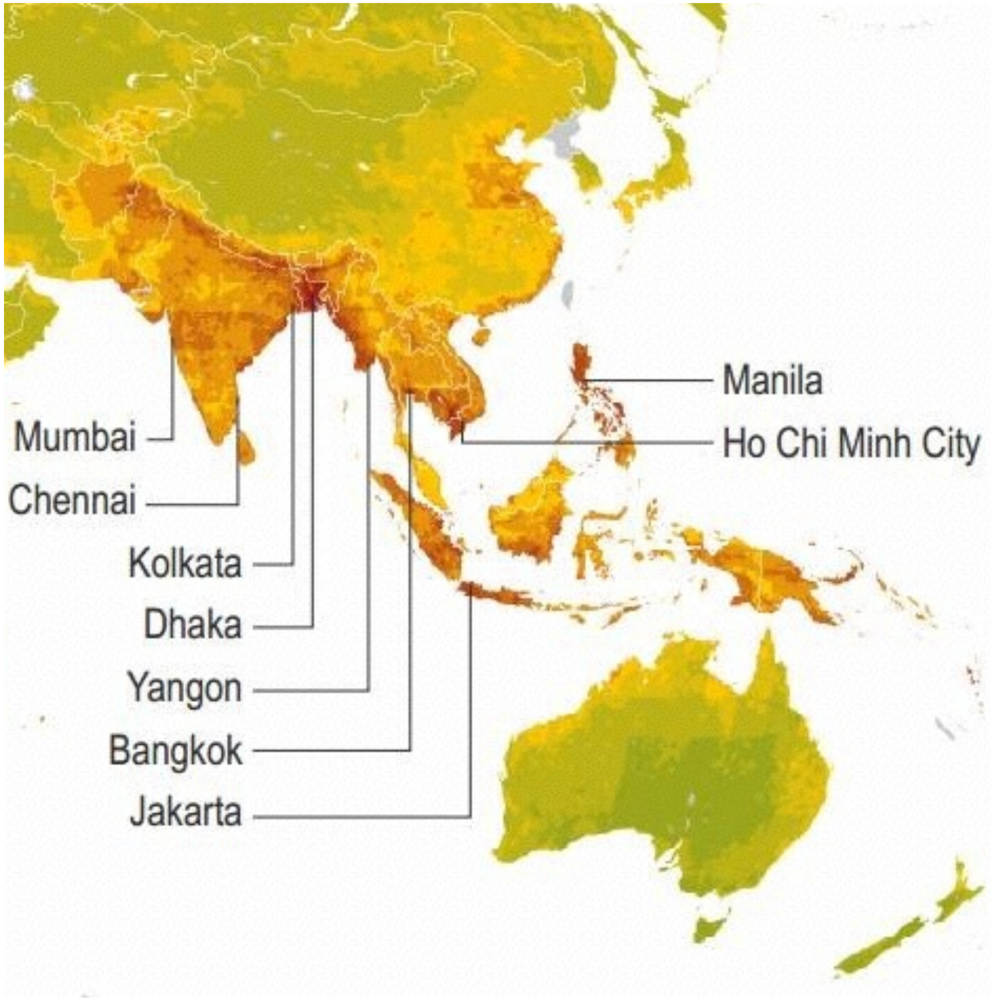
- Africa
  - Low adaptive capacity to climate variability and climate change
  - Continent is already under pressure: has one of the most variable climates in the world (seasonal and decadal timescales)



Source: UNFCCC Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries

Climate change impacts in the developing world

- Asia
  - Varied adaptive capacity
  - Southeast Asia already has largest burden of climate change-attributable malnutrition and diarrhea
  - Summer monsoon is slated to increase in intensity



Source: UNFCCC Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries

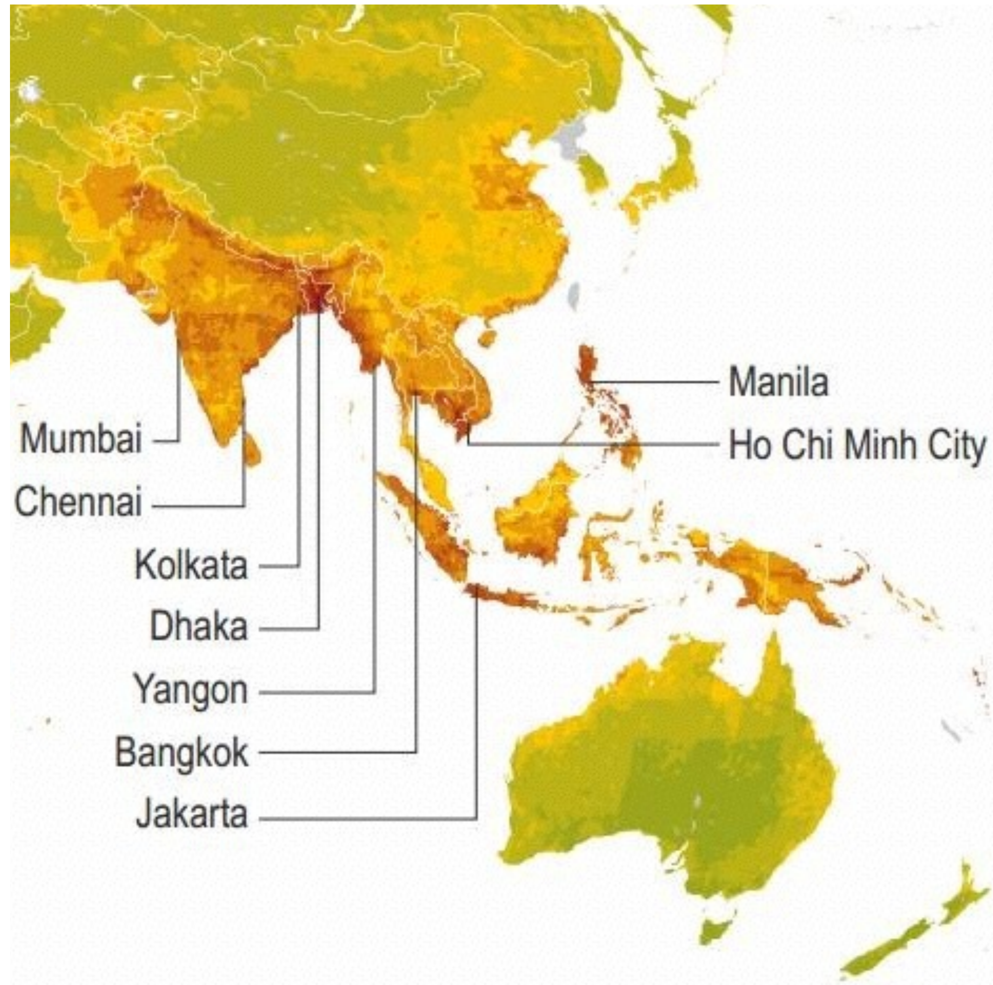
Climate change impacts in the developing world

- Latin America
  - Limited adaptive capacity
  - Low levels of education, high levels of inequality (income, access to fresh water)
  - Heat stress and transmissible disease prevalence will increase
  - Agricultural yields slated to decrease

Source: UNFCCC Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries

Climate change impacts in the developing world

- Small island developing states
  - Low adaptive capacity
  - Highly vulnerable to sea level rise and increase in extreme events



Source: UNFCCC Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries

Climate change impacts in the developing world

- **World Bank CIF** (Climate Investment Funds)
  - Established 5 years ago; aims “to trigger investments for immediate climate action” and promote “technologies and methods needed to mitigate and manage the effects of climate change in poorer regions of the world”
- Programs include:
  - Clean technology fund ($5.5 B)
  - Forest investment program ($639 M)
  - Program for climate resilience ($1.3 B)
  - Scaling up renewable energy ($551 M)

Source: https://www.climateinvestmentfunds.org/cif/content/cif-annual-report-2013

Emission Scenarios

“Business as Usual”

Mitigation

Mitigation

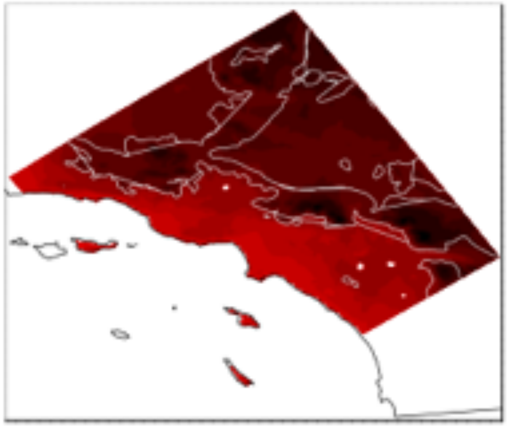
“Business as Usual”

Mid-century
(2041-2060)

Mitigation

“Business as Usual”

End-of-Century
(2081-2100)



Warming (°C)

Mitigation

“Business as Usual”

Mid-century
(2041-2060)

Mitigation

“Business as Usual”

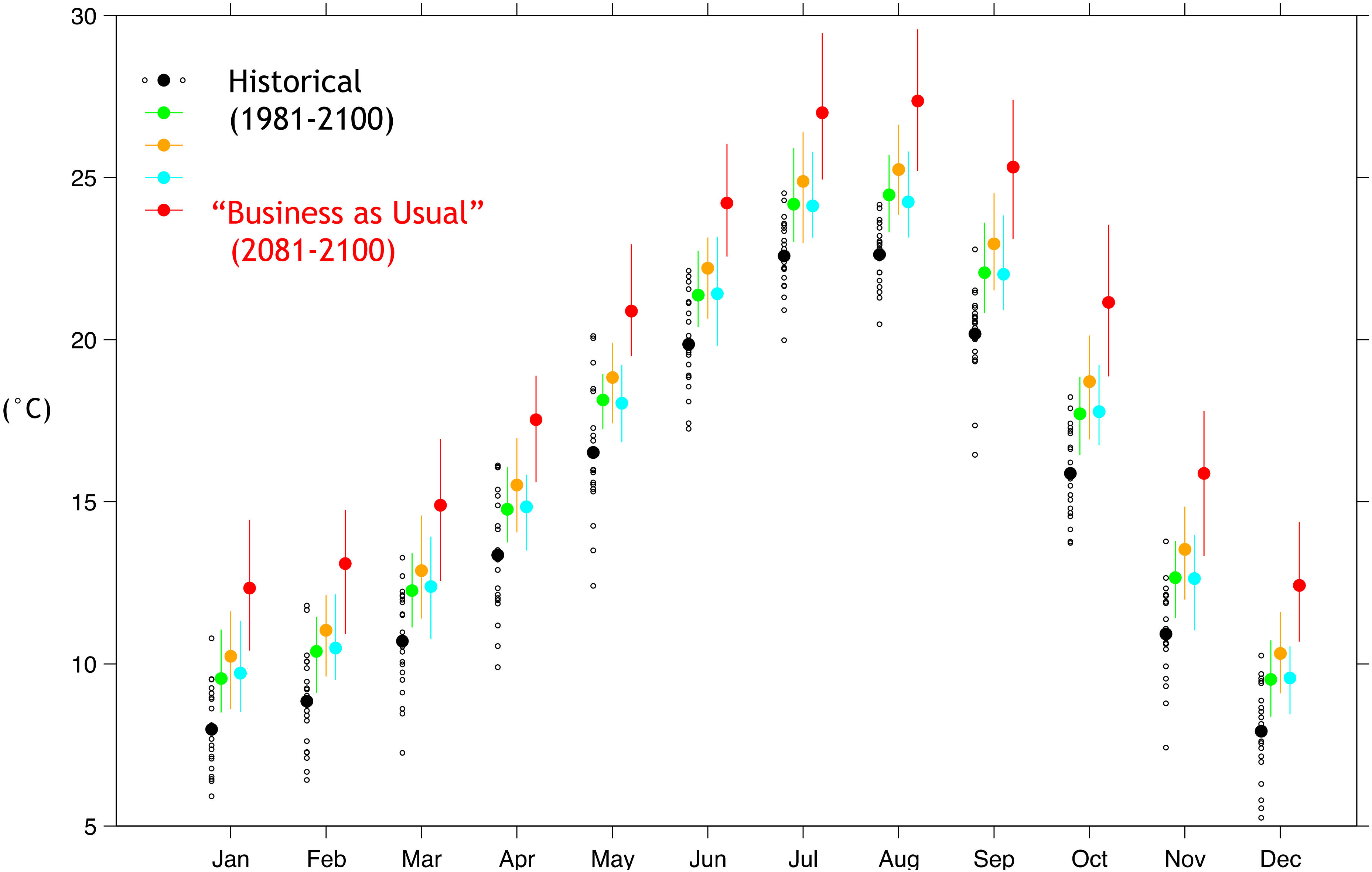
End-of-Century
(2081-2100)

+2.9 °F

+7.7 °F

Warming (°C)

Warming vs Internal Variability

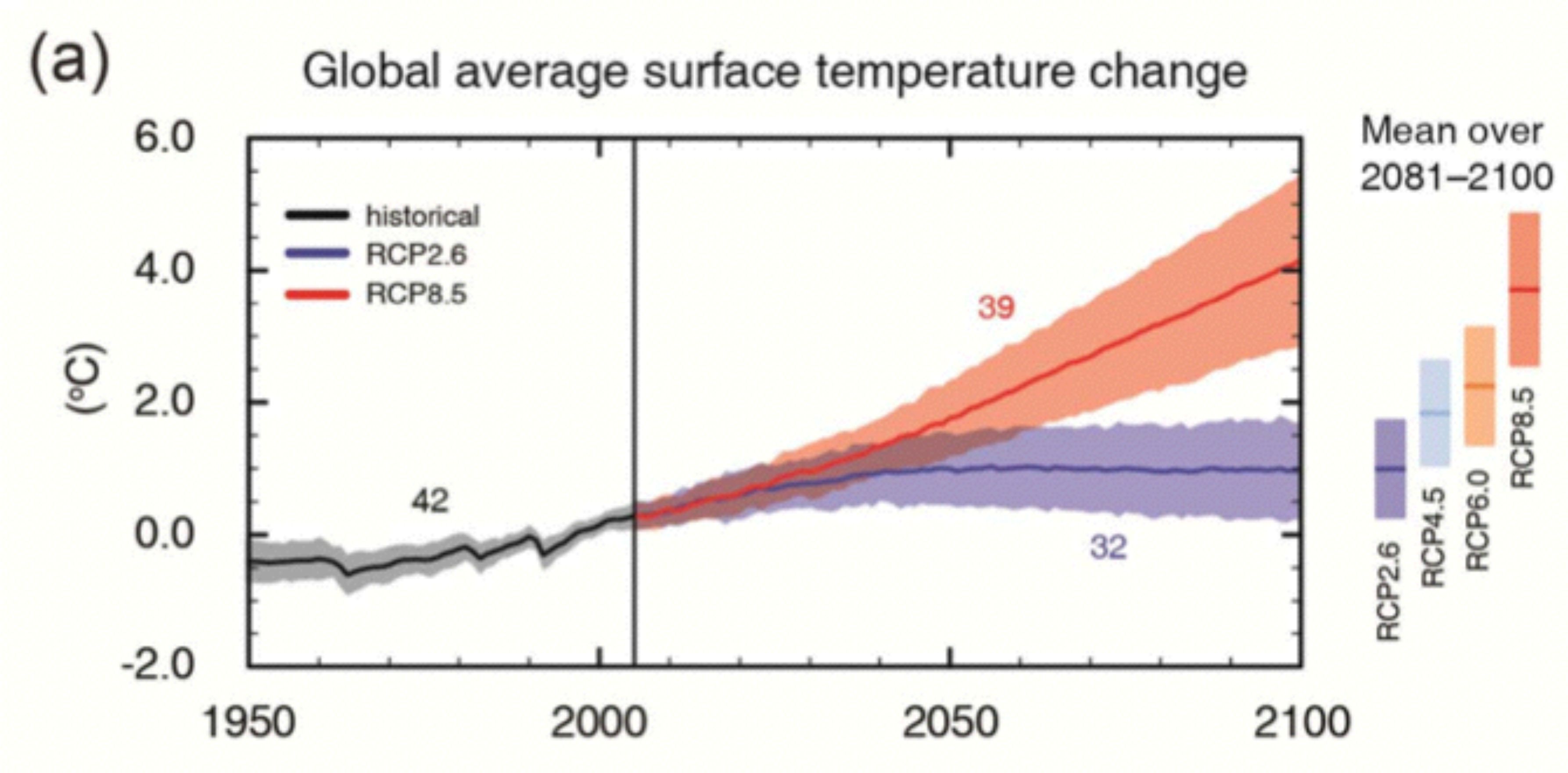


Tipping points

- We have already committed to ~1.5ºC of global mean surface warming by the end of the 21st century
- Many scientists say any warming above 2ºC would be
- Scientists have calculated that about 565 more gigatons of CO_2 can be released before we reach 2ºC
- But there are already about 2,795 gigatons of CO_2 already contained in the gas and oil reserves of fossil-fuel countries (and countries like Venezuela or Kuwait)
- Still unresolved whether a certain temperature increase can shift us into a new climate system

Source: Rolling Stone Magazine: *Global Warming's Terrifying New Math*

Tipping points



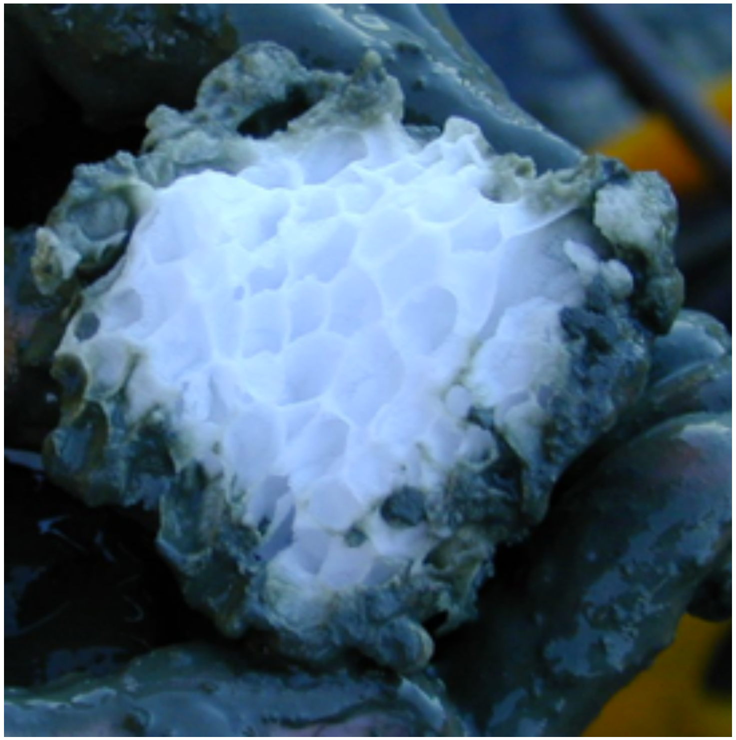
Source: IPCC Summary for Policymakers, 2013

Apocalypse!!!........?

- Irreversible change: "recovery time scale from this state due to natural processes is significantly longer than the time it takes for the system to reach this perturbed state"
- abrupt climate change: "a large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades, and causes substantial disruptions in human and natural systems"

Table 12.4 | Components in the Earth system that have been proposed in the literature as potentially being susceptible to abrupt or irreversible change. Column 2 defines whether or not a potential change can be considered to be abrupt under the AR5 definition. Column 3 states whether or not the process is irreversible in the context of abrupt change, and also gives the typical recovery time scales. Column 4 provides an assessment, if possible, of the likelihood of occurrence of abrupt change in the 21st century for the respective components or phenomena within the Earth system, for the scenarios considered in this chapter.

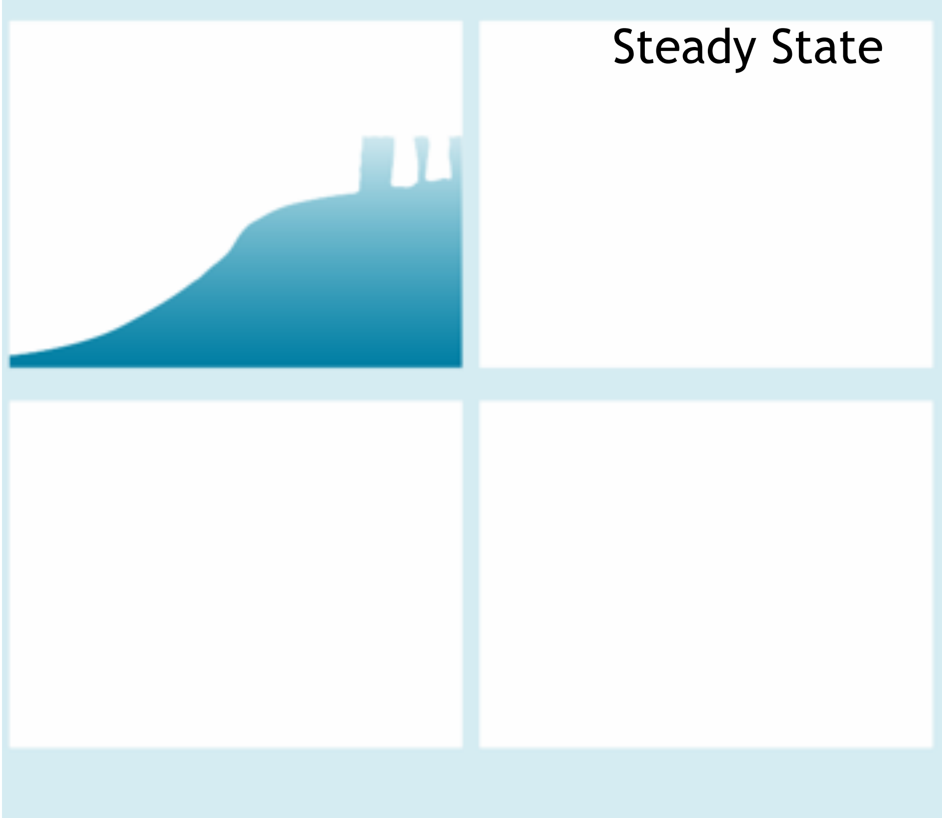
Change in climate system component	Potentially abrupt (AR5 definition)	Irreversibility if forcing reversed	Projected likelihood of 21st century change in scenarios considered
Atlantic MOC collapse	Yes	Unknown	*Very unlikely* that the AMOC will undergo a rapid transition (*high confidence*)
Ice sheet collapse	No	Irreversible for millennia	*Exceptionally unlikely* that either Greenland or West Antarctic Ice sheets will suffer near-complete disintegration (*high confidence*)
Permafrost carbon release	No	Irreversible for millennia	Possible that permafrost will become a net source of atmospheric greenhouse gases (*low confidence*)
Clathrate methane release	Yes	Irreversible for millennia	*Very unlikely* that methane from clathrates will undergo catastrophic release (*high confidence*)
Tropical forests dieback	Yes	Reversible within centuries	*Low confidence* in projections of the collapse of large areas of tropical forest
Boreal forests dieback	Yes	Reversible within centuries	*Low confidence* in projections of the collapse of large areas of boreal forest
Disappearance of summer Arctic sea ice	Yes	Reversible within years to decades	*Likely* that the Arctic Ocean becomes nearly ice-free in September before mid-century under high forcing scenarios such as RCP8.5 (*medium confidence*)
Long-term droughts	Yes	Reversible within years to decades	*Low confidence* in projections of changes in the frequency and duration of megadroughts
Monsoonal circulation	Yes	Reversible within years to decades	*Low confidence* in projections of a collapse in monsoon circulations



- Methane clathrate stability is dictated by relative contributions of pressure and temperature

- In the context of climate change, there is a battle between rising seafloor temperatures and rising sea levels (which increase pressure)

- Clathrate positive feedback (destabilization) acts on multi-millennial time scales



Marine Ice Sheet Instability Hypothesis

Grounding line (GL): location that separates ice sheet and floating ice shelf

If the grounding line retreats to a ridge where it is sloping down towards land, there can be increased outflow below the shelf→ self-sustaining retreat until a region of shallower, seaward sloping bedrock is reached

What triggers grounding line retreat?

1) Warmer ocean under ice shelves
2) Melt water ponds on surface of ice shelf

21st Century Outlook

Greenland Ice Sheet

-If increases in surface temperatures (2.5-4.5C) are maintained on **multi-millenial** time scales, then there will be full ice sheet collapse → this is not projected to happen in the next 100 years

Antarctic Ice Sheet:

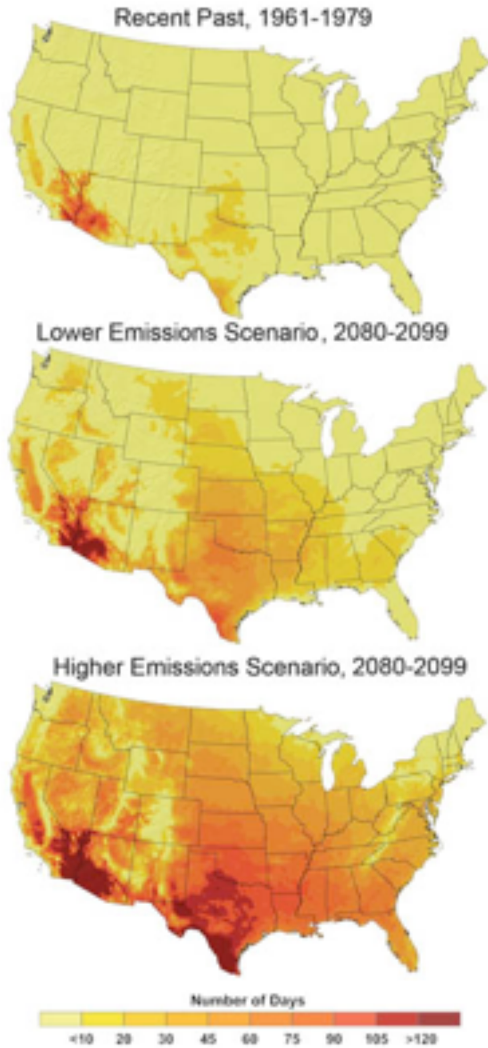
-Ablation(loss of ice) projected to remain small during 21st century because of relatively low increases in surface melting and increases in snowpack fall (increase in precip)

*This is still a very active topic of research and the dynamics of GL retreat are not fully understood

What public health issues do you foresee will arise from climate impacts in the future?

1. Impacts from heat wave

- Heat stroke and dehydration
- Could be especially severe in large metropolitan areas.
  - E.g. Los Angeles, annual heat-related deaths are projected to increase two- to seven-fold by the end of the 21st century,
- Stagnant air, leading to increases in air pollution and the associated health effects



The number of 100-degree days per year is projected to increase. Source: USGCRP (2009)

Source: http://www.epa.gov/climatechange/impacts-adaptation/health.html

Question 6: What public health issues do you foresee will arise from climate impacts in the future?

2. Impacts from extreme weather events

- E.g. extreme precipitation events:
  - Injuries and death
  - Reduce the availability of fresh food and water.
  - Interrupt communication, utility, and health care services.
  - Contribute to carbon monoxide poisoning from portable electric generators used during and after storms.
  - Increase stomach and intestinal illness among evacuees.
  - Contribute to mental health impacts such as depression and post-traumatic stress disorder (PTSD)

3. Impacts from reduced air quality

- Increases in frequency of days with unhealthy levels of ground-level ozone
- Changes in allergens
  - spring pollen season occurring earlier in the United States due to climate change.
  - length of the season may also have increased

Source: http://www.epa.gov/climatechange/impacts-adaptation/health.html

What public health issues do you foresee will arise from climate impacts in the future?

4. Impacts from climate-sensitive diseases

- Climate change may enhance the spread of disease by affecting the transmitters
  a) Food borne diseases
    - e.g. increase in T → salmonella and other bacteria-related food poisoning
    - Flooding and heavy rainfall → overflows from sewage treatment plants into fresh water sources → contamination of certain food crops with pathogen-containing feces
  b) Water-borne diseases
    - Heavy rainfall or flooding → increase water-borne parasites sometimes found in drinking water
    - Heavy rainfall → stormwater runoff → may contaminate water bodies used for recreation with bacteria

Source: http://www.epa.gov/climatechange/impacts-adaptation/health.html

What public health issues do you foresee will arise from climate impacts in the future?

4. Impacts from climate-sensitive diseases (cont.)

c) Animal-borne diseases
   - Temperature increase → range of ticks (lyme disease) likely to continue to expand northward
   - Higher temperatures favorable to the survival of new strains of viruses e.g. In 2002 a new strain of West Nile virus emerged in the United States.

- The spread of climate-sensitive diseases will depend on both climate and non-climate factors. The United States has **public health infrastructure** and programs to monitor, manage, and prevent the spread of many diseases. **The risks for climate-sensitive diseases can be much higher in poorer countries that have less capacity to prevent and treat illness.**

5. Other health linkages

- Changes in T and precip → droughts/floods → food security → malnutrition, spread of infections diseases, food poisoning

Source: http://www.epa.gov/climatechange/impacts-adaptation/health.html

Positive Impacts – Public Health

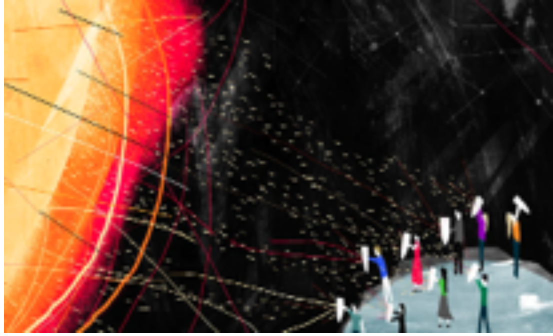
- Public health can (must) be improved at a city/ state/country planning level (not individual case by case)
- Climate change has definitely inspired building "green" and an appreciation of green space and nature within urban landscapes (for environmental and mental health reasons)
- Increased awareness and implementations of 'greened' urban landscape have the potential to lead to a healthier general population through encouragement of exercise and improvements in mental health

LA River Revitalization

Figure 2: Rendering of revitalized river: note the non-steep, vegetated banks and basin, and recreation and infrastructure along the edges

© Iwan Baan, 2011 - High Line Park Photos

Geoengineering



- Climate scientists are on either side of the issue
- Concerns of invoking geoengineering includes
  - Unknowns in climate system response
    - Perturbations to earth system (complex)
    - Don't know full, long term effects/repercussions
  - Effects on human quality of life
  - Political, ethical, and moral issues raised
- (Temporarily) fixing one part of the system could worsen another component
  - Changes very likely not confined to one region
  - E.g. Cloud seeding to brighten low level clouds
    - Pros:
      - increase cloud reflectivity, less sunlight reaches Earth
      - Slow down warming for about 25 years (one study suggests)
    - Cons:
      - Slow down of warming is only temporary
      - altering cloud composition → decrease in rainfall (e.g. over Amazon → ecosystems dry → reduce natural carbon sink)

sources: http://climate.envsci.rutgers.edu/pdf/20Reasons.pdf
http://www.metoffice.gov.uk/news/releases/archive/2009/geoengineering-pros-cons

Geoengineering

- Examples of geoengineering:
  - Injecting sulfate aerosols into the stratosphere as a means to block sunlight and cool Earth
  - Ocean fertilization, where iron dust is dumped into the open ocean to trigger algal blooms
  - Genetic modification of crops to increase biotic carbon uptake
  - Carbon capture and storage techniques such as those proposed to outfit coal plants
  - Planting forests
  - Other schemes involve blocking or reflecting incoming solar radiation, for example by spraying seawater hundreds of meters into the air to seed the formation of stratocumulus clouds over the subtropical ocean

http://climate.envsci.rutgers.edu/pdf/20Reasons.pdf

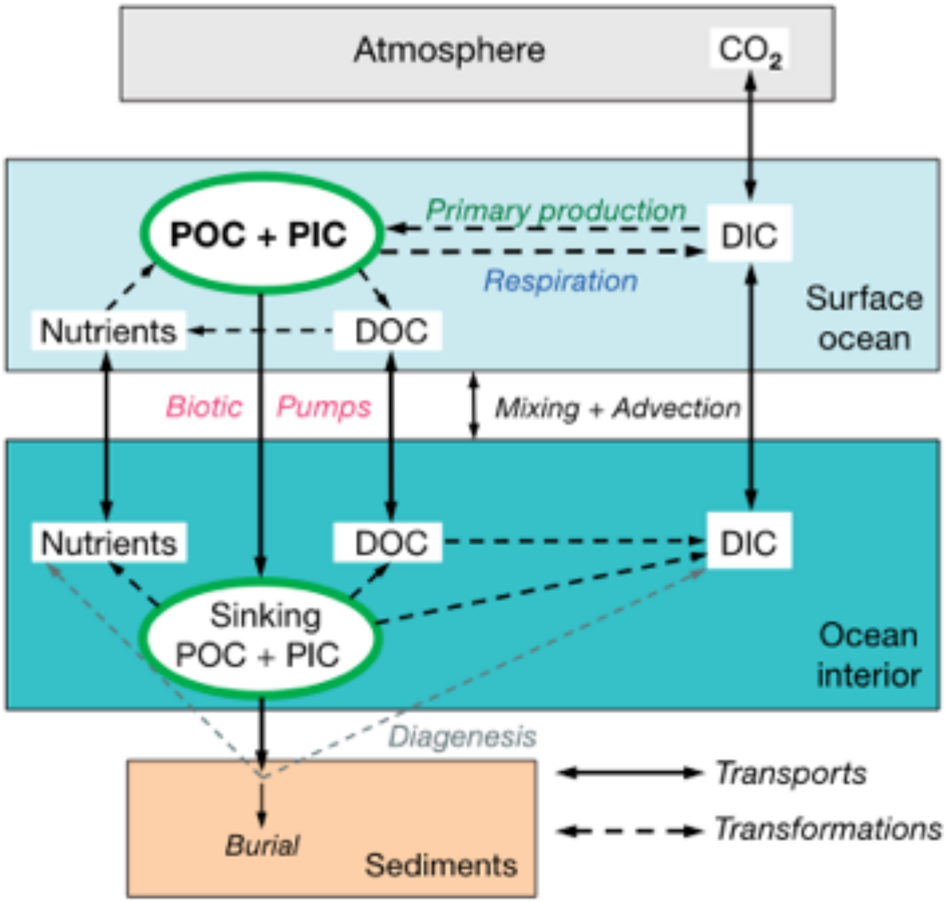
Geoengineering

More on Cons:

- large hydrological responses, including reduced precipitation, soil moisture, and river flow in many regions
- atm circulation: weaken monsoons, less precip
- increase ozone depletion
- direct vs diffuse effects on plant productivity
- more acid deposition (ocean acidification) (human health)
- less sunlight for solar power
- rapid warming if deployment/geoengineering feat stops
- there's no going back
- commercial control of technology
- military use of technology
- controlling the thermostat: how do you agree on optimal global climate

http://climate.envsci.rutgers.edu/pdf/20Reasons.pdf

Ocean Iron Fertilization: Feasible?



Carbon dioxide is absorbed into the ocean when there exists a concentration gradient between the surface ocean and atmosphere

Phytoplankton blooms are one way of creating this concentration gradient and thus a way of driving carbon into the ocean

In some areas around the globe, iron is a limiting micronutrient for phytoplankton (small amount of iron leads to a large amount of phytoplankton)

- Even if global scale fertilization were possible, it would not be enough to make a real dent in reducing anthropogenic carbon dioxide emissions
  - 2100 low estimate of atmospheric CO2: 770 Pg
  - Model estimated maximum carbon sequestration after 100 years continuous global fertilization: 152 Pg
  - The areas in which it is feasible to fertilize with iron are highly regionalized and thus global scale fertilization is not plausible.
- Stimulating the bottom of the marine food chain.
  - This stimulation can increase fisheries but also cause toxic algal blooms
- The mid-water depths can be subject to anoxia via remineralization.
- Increased CO_2 dissolution into sea water will increase ocean acidity.
- Remineralization can lead to outgassing of N_2O (a very potent GHG).