

Climate Change The Global Picture

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The human imprint on the planet is increasing. Global population has increased dramatically over the past few centuries to over 6 billion people and it is projected to rise several billion more. The number of species, which have been extinguished, continues to rise. Human activities have converted the domesticated land, from less than 10% about 150 years ago, to about 35% now. Use of fertilizers to increase agricultural productivity to feed the growing population now result in more nitrogen fixation due to human activities than due to natural processes, since about 1980. Further, over the past few centuries, human activities, initially due to land clearing and for the last century due to fossil fuel combustion, have increased the emissions of carbon dioxide and other greenhouse gases into the atmosphere. The result is that atmospheric CO₂ concentration has increased from about 280 ppm (the value for at least a 1000 years prior to industrialization) to a present value of near 370 ppm. Although climate change is the topic of this workshop, it is appropriate and necessary to consider climate change, loss of biodiversity, air pollution and other issues in a more integrated way.

There is a long history of scientific investigations on the role of greenhouse gases in the climate system. Through a series of scientific meetings in the 1970's and 1980's, there emerged a scientific consensus that changing climate was a matter in need of the attention of governments. At Villach in 1986, the conference statement included the view that the climate of the past was no longer acceptable as a basis for planning the future and that governments should work towards limiting emissions of greenhouse gases. In 1988, the World Meteorological Organization and the United Nations Environment Program jointly created the Intergovernmental Panel on Climate Change (IPCC) to assess the state of knowledge of climate science, impacts of climate change and potential response strategies. The IPCC completed its first assessment report in 1990. This report provided much of the analytical stimulus for the United Nations Framework Convention on Climate Change (UNFCCC), which was agreed to by governments at the Earth Summit in 1992. The IPCC Second Assessment Report was completed in 1995 and was the scientific basis for action, which governments took in Kyoto in 1997 (the Kyoto Protocol). The IPCC has now completed its Third Assessment Report (in 2001); many of the results quoted in this presentation are based on that report.

The UN Framework Convention on Climate Change has as its Article 2, the theme of:

“ ... *stabilization of greenhouse gas concentrations* in the atmosphere at a level that would prevent *dangerous anthropogenic interference* with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure food production is not threatened and to enable economic development to proceed in a sustainable manner.”

And hence the emphasis on the stabilization of concentrations through limitations on emissions. An important issue is: what is *dangerous anthropogenic interference*. Dangerous depends on the point of view and what is dangerous for one country may not be of significant concern for others. For example, 50 cm of sea level rise is clearly of concern and dangerous for many small island states and other countries with low coastal zones, while it is not directly dangerous to countries without coastlines.

There are other relevant articles of the UNFCCC, including: Article 4 on the scientific, technological, technical, socio- economic and other research; systematic observation; data archives; full, open and prompt exchange of information; and education, training and public awareness. Article 5 further elaborates on research and systematic observations, while Article 6 deals further with education, training and public awareness.

As noted, there has been about a 30% increase in the atmospheric concentration of carbon dioxide over the last 150 years. Has the climate changed? The IPCC analysis has concluded that there has been climate change and that it is attributable, mostly, to human activities (see Figure 1). Further, the IPCC also projected that there will be even large changes in global mean temperature over this century (up to 2100), the magnitude depending on the emissions scenario that becomes reality (Figure 1).

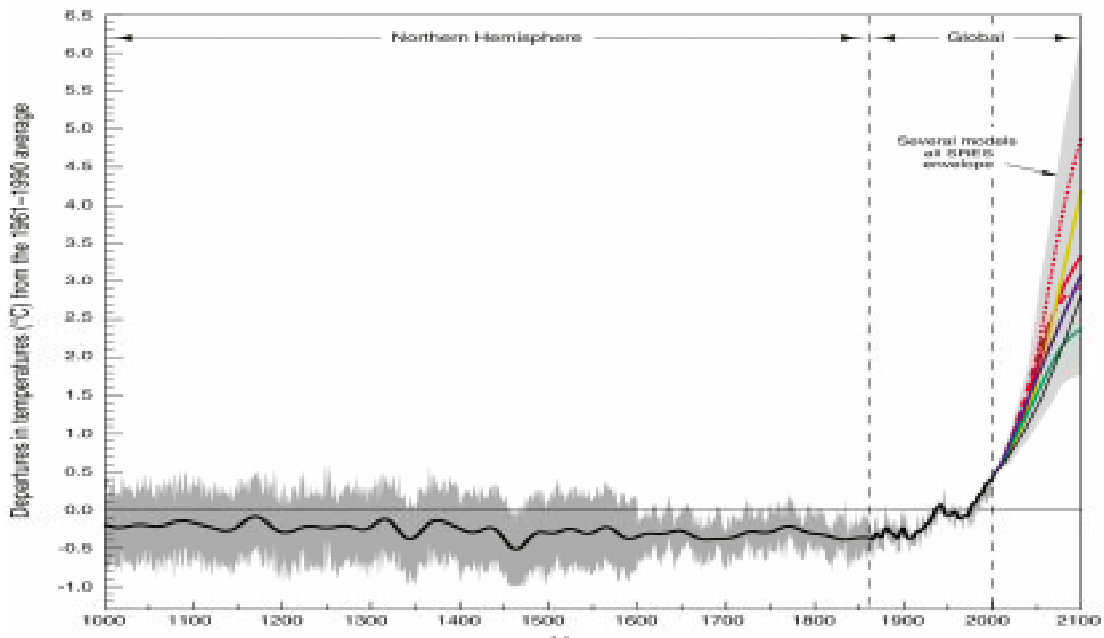


Figure 1. Northern hemispheric mean temperature from 1000 to about 1850, due to interpretations of paleoclimatic data and since about 1850, due to measurements. Based on the period from 1900 to present, the IPCC concluded that there is evidence of human-induced climate change. For the period, 2000 to 2100, the temperature changes are model simulations dependent on the emissions scenario chosen.

In a presentation to the Sixth Conference of the Parties under the UNFCCC, Dr. R. Watson, chair of the IPCC, said:

“The overwhelming majority of scientific experts, whilst recognizing that scientific uncertainties exist, nonetheless believe that human-induced climate change is inevitable.”

“One of the major challenges facing humankind is to provide an equitable standard of living for this and future generations: adequate food, water and energy, safe shelter and a healthy environment (e.g., clean air and water). Unfortunately, human-induced climate change, as well as other global environmental issues such as land degradation, loss of biological diversity and stratospheric ozone depletion, threatens our ability to meet these basic human needs.”

Part of the basis for the conclusions of the IPCC is simulations by climate research groups using global climate models. In Figure 2 is an example from the Canadian Climate Centre of the Meteorological Service of Canada. The control experiment is part of a 1000-year simulation with fixed greenhouse gas concentrations – the climate did not change. Then, with only changing the greenhouse gas (and aerosol) concentrations as have been observed since 1900 to present and using a simple scenario of 1% increase annually until 2100, the model was re-run. The dashed curve shows a dramatic increase in global mean temperature, reaching a warming of 4-5C by 2100. The correspondence with the heavy solid curve from the 20th century gives confidence in the validity of the projection.

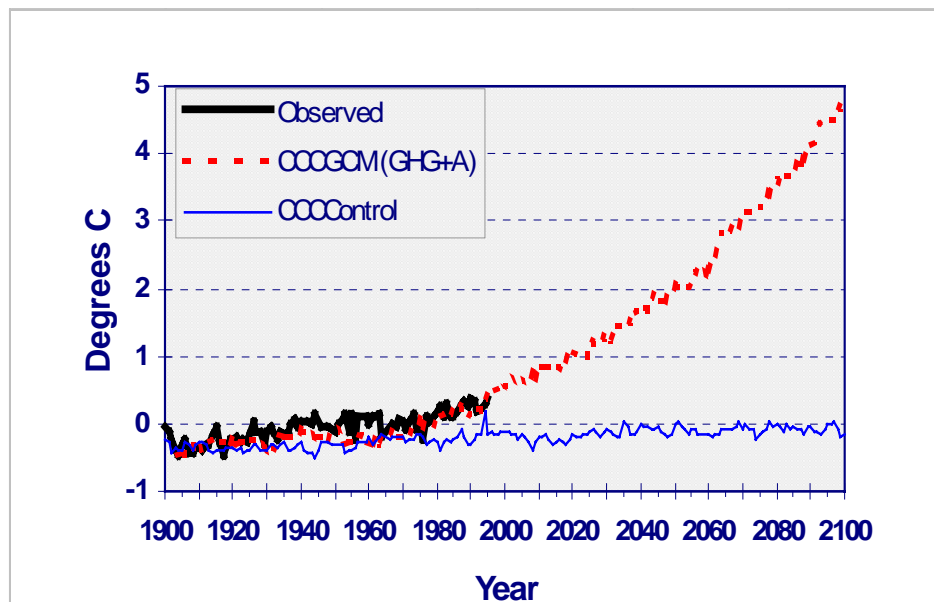


Figure 2. Simulations with the Canadian Climate Centre model of the climate over the past 100 years and for the next 100 years, assuming a 1% annual increase in greenhouse gas concentrations. The light curve is the control simulation with fixed greenhouse gas concentrations, while the heavy curve is the observed temperatures over the past 100 years.

A major uncertainty in projecting future climates is the actual emissions over the next 100 years. Figure 3 shows a range of emission scenarios and the resulting atmospheric concentrations of carbon dioxide. The scenarios range from ones where emissions continue to increase and result in atmospheric concentrations about 3 times the pre-industrial value by 2100, to a case where emissions start to fall about mid-century. Even in this latter case, the atmospheric concentration is increasing to the end of the century with a value of about 500 ppm reached. This and other analysis leads one to conclude that greenhouse concentrations will continue to increase for at least the next 100 years and values, at 2100, of between about twice and three times pre-industrial values are likely. Hence, we need to plan for climate change to at least twice carbon dioxide over 100 years.

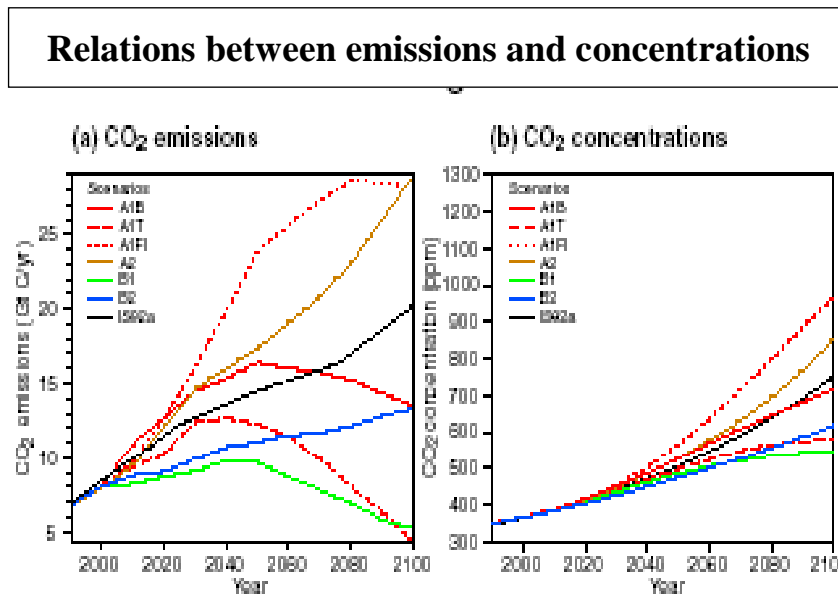


Figure 3: Scenarios of emissions and corresponding atmospheric concentrations of carbon dioxide over the next 100 years.

Note the wide range of emissions scenarios. A major element of the uncertainty in dealing with climate change projections has its origins in our lack of knowledge of which of these scenarios will people of the world chose to follow. We can note, however, that the difference between the scenarios for 2100 emissions (about a factor of 5) leads to a smaller difference in the resulting atmospheric concentrations (a little less than 2). When considering the information on uncertainty in subsequent parts of this presentation, keep in mind that the uncertainties, in a sense, cascade, starting with uncertainties in atmospheric concentrations (resulting from the different emission scenarios). To that is then added the uncertainties due to model simulations of the large-scale climate. Model uncertainties are both inherent within individual models and in differences between models. To reach a detailed assessment of impacts, we then need to scale down to local areas, adding another level of uncertainty. Finally, our understanding the relations between climate/weather and impacted systems is imperfect, as is our knowledge of how we might respond.

In view of the inevitability of climate change, it is appropriate to consider disaster management approaches in dealing with climate change. Usually disaster management approaches are considered to include: recovery (from the disaster); anticipate; mitigation; and adaptation. Although recovery is often necessary, it is preferable to be able to focus on the other approaches that can collectively called prevention.

The Anticipate function is through forecasts and warnings, to advise people about impending events and advise on response strategy. Examples would be forecasts and warnings of tsunamis, hurricane, seasonal drought and climate change. The response strategies would be different, depending on the event and the length of advance warning of the event. For a tsunami, where the warning may be only for about 10 minutes, the response is to run for cover. For a hurricane in next few days, the response is to prepare for and then undertake evacuation to more protected areas and to implement emergency responses.

The Mitigation and Adaptation functions are to adopt standards, codes and practices that protect people, infrastructure, economy, etc., from “reasonable” extremes. Examples would be building codes and agricultural practices. For example, if there is an increased likelihood of hurricanes, coastal storm surges or seasonal drought, the response is to modify codes and practices and prepare response strategies.

In both approaches there is a strong role for scientific predictions (see Figure 4), illustrating the case of responding to climate change.

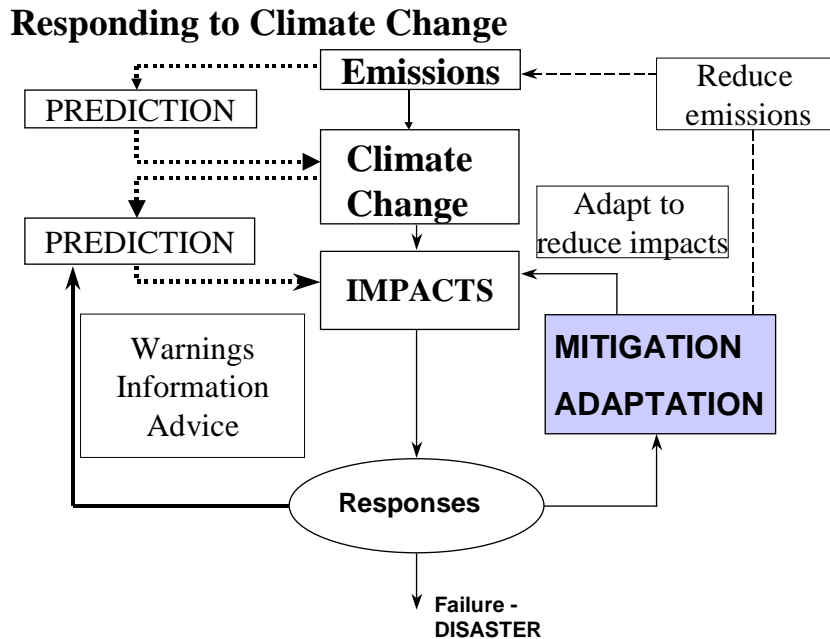


Figure 4. Schematic of responding to climate change, using prediction to provide the information and warnings and the responses being to mitigate (reduce the hazard by reducing emissions) and/or adaptation to reduce the impacts.

It is important to analyze the effect of the response by re-doing predictions with the response strategies included. Often the response of the climate system and the impacts is non-linear or not that which is immediately intuitively obvious so that simulations are recommended (Figure 4).

A risk management for climate change Must account for the reality that predictions of climate change are uncertain (especially on the time and space scales of local impacts) and there is need to account for, both:

- extreme events that are less likely (but may have very large impact if and when they occur); and
- less extreme events that are more likely.

This will be a probabilistic approach to reduce vulnerability. Further this kind of risk management approaches needs to include understanding of natural, social, engineering, health, and other sciences.

Our knowledge of the climate system varies from topics of high confidence, usually on the large scales (see Figure 5), such as increasing greenhouse gas concentrations and the general magnitude of global temperature change to topics where we have low confidence, such as detailed characteristics of local change and their local impacts.

Knowledge of the Climate System

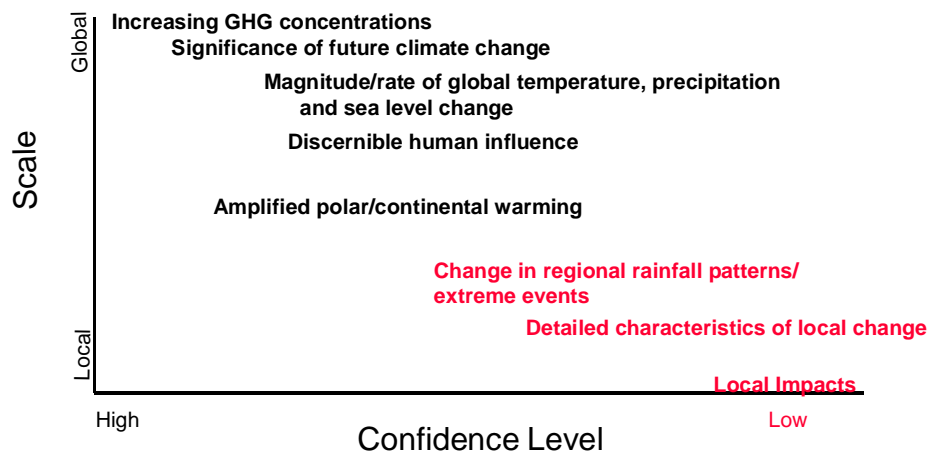
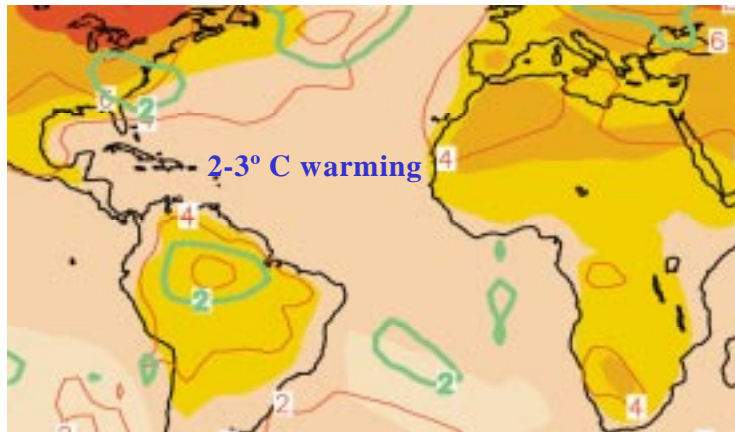


Figure 5: Schematic representation of knowledge of changes to the climate system. The scale is the physical scale of the change and the confidence level is given from low to high.

Using global climate models under several of the emissions scenarios shown in Figure 3, the IPCC presented the results for temperature and precipitation changes from the present to 2100. In Figures 6 and 7 are shown the results for scenario A2, a moderate emission scenario.

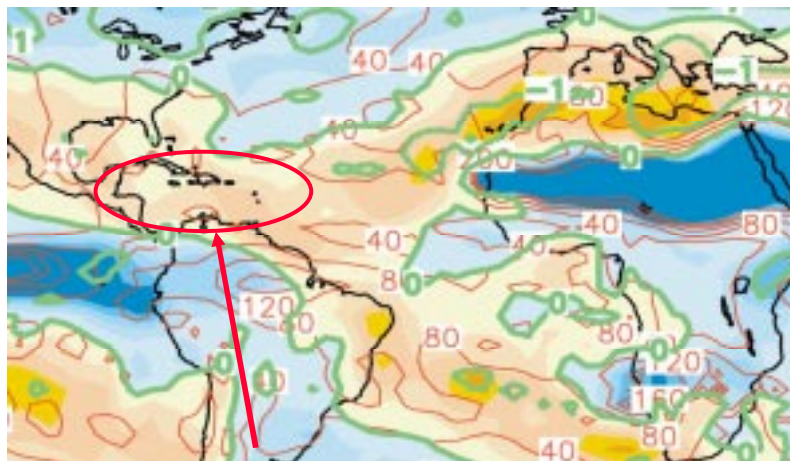
Ensemble of temperature responses (C) at 2100 under scenario A2



Cubasch et al, IPCC, 2001

Figure 6: The IPCC ensemble of temperature changes for 2100 under the A2 scenario. For the Caribbean, the annual average temperature change is 2-3 C warming.

Ensemble of precipitation responses (%) at 2100 under scenario A2



**5 to 15% decrease in precipitation (dominated by
summer decrease)**

Cubasch et al, IPCC, 2001

Figure 7: The IPCC ensemble of precipitation changes for 2100 under the A2 scenario. For the Caribbean, the annual average precipitation change is 5-15% reduction.

A further comment by the Chair of IPCC to CoP6 emphasized the importance of extreme events:

“Indeed, during the last few years, many parts of the world have suffered major heat waves, floods, droughts, fires and extreme weather events leading to significant economic losses and loss of life. While individual events cannot be directly linked to human-induced climate change, the frequency and magnitude of these types of events are predicted to increase in warmer world.”

The IPCC undertook an analysis of these types of events, both as to whether there was evidence that there were already changes and, more importantly, how they would change in the future. To assist in the development of risk management strategies, the IPCC developed specific criteria for “Measures of Certainty“. IPCC Working Group 1 (Science) adopted:

- Virtually certain >99% chance result is true
- Very Likely 90-99%
- Likely 66-90%
- Medium likelihood 33-66%
- Unlikely 10-33%
- Very unlikely 1-10%

IPCC Working Group 2 (Impacts,...) adopted a similar approach. These results are an important advance over earlier analyses but will still need to be developed further as our understanding progresses. The IPCC applied this approach to significant changes, as shown in Figure 8.

IPCC –Quantification of % of Change

| Confidence in observed changes (latter half of the 20th century) | Changes in Phenomenon | Confidence in projected changes (during the 21st century) |
|--|--|--|
| Likely | Higher maximum temperatures and more hot days over nearly all land areas | Very likely |
| Very likely | Higher minimum temperatures, fewer cold days and frost days over nearly all land areas | Very likely |
| Very likely | Reduced diurnal temperature range over most land areas | Very likely |
| Likely, over many areas | Increase of heat index ⁵ over land areas | Very likely, over most areas |
| Likely, over many Northern Hemisphere mid- to high latitude land areas | More intense precipitation events ⁶ | Very likely, over many areas |
| Likely, in a few areas | Increased summer continental drying and associated risk of drought | Likely, over most mid-latitude continental interiors (Lack of consistent projections in other areas) |
| Not observed in the few analyses available | Increase in tropical cyclone peak wind intensities ⁷ | Likely, over some areas |
| Insufficient data for assessment | Increase in tropical cyclone mean and peak precipitation intensities ⁸ | Likely, over some areas |

Figure 8: The IPCC estimates of changes in significant events and an indication of the certainty of their conclusion.

Of particular interest to the Caribbean are the items shown in boxes on Figure 8. The likelihood of more intense precipitation events, potentially leading to flash floods or other damage, over

many areas was considered very likely (90-99% confidence that the result will be true). Increased summer continental drying is considered likely (66-90%). As shown in Figure 7, models indicate reductions in precipitation in the Caribbean.

Tropical cyclones or hurricanes are particularly important for the Caribbean since they continue to cause great loss of life and economic and environment damage. Changes in intensities of tropical cyclones are considered likely. In the IPCC, it was noted that:

“In Conclusion, there is some evidence that regional frequencies of tropical cyclones may change but none that their location will change. There is also evidence that the peak intensity may increase by 5% to 10% and precipitation rates may increase by 20% to 30%. There is need for much more work in this area to provide robust results.”

Concern about the occurrence of intense precipitation events, with associated flooding has been noted in the summaries of IPCC and other conferences. Sea level rise has been a particular concern.

“It (climate change) could even threaten survival in small island States and in low-lying coastal, arid and semi-arid areas” (Ministerial Declaration – Second World Climate Conference, Geneva, 1990)

“The most widespread direct risk to human settlements from climate change is flooding and landslides, driven by projected increases in rainfall intensity, and in coastal areas, sea-level rise” (IPCC 2001)

The IPCC analysis for sea level rise has found that there has been a global average increase of 1.0 to 2.0 mm/y or about 0.15m increase over 100y. By 2100, the combined climate, glacier and sea level models have projected an increase of:

- 0.09 to 0.88 m (for the full range of scenarios) (see Figure 9)

This rise is attributed to:

- | | |
|---------------------|-----------------|
| - Thermal expansion | 0.11 to 0.43 m |
| - Glaciers | 0.01 to 0.23 m |
| - Greenland | -0.02 to 0.09 m |
| - Antarctica | -0.17 to 0.02 m |

Note that although there has been much concern and debate of the possibility of the West Antarctic Ice Sheet sliding into the ocean, which would generate approximately 6m of sea level rise, the IPCC analysis concluded that this was very unlikely (1-10% chance) 21st century. The models generally have the West Antarctic Ice Sheet growing somewhat due to increased precipitation with a warmer climate (but still below freezing). The Greenland ice sheet is expected to slowly melt, contributing to sea level rise, and, with sustained warming over the next 1000 y, this would likely contribute a 3 m rise. The major contribution to the projected sea level rise is due to thermal expansion of the ocean waters. Sea level rise will not take place uniformly over the globe so that local analyses are necessary. Further, because of the slow response of the oceans and glaciers, once started, sea level rise will continue for a long time after the atmospheric

climate is stabilized. We have to deal with this “commitment” for centuries to come. Most of the coastal regions in the Caribbean are vulnerable to sea level rise.

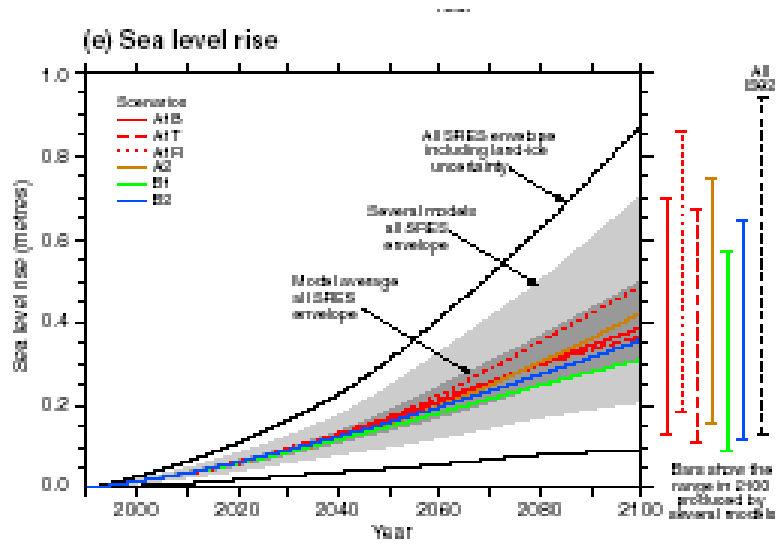


Figure 9: Global sea level rise for a full range of emissions scenarios (IPCC 2001).

Although sea level rise by itself is a major problem for many areas, the addition of storm surges will greatly compound the problem. Studies have shown that there are non-linear interactions of waves, water depth and bottom topography so that one cannot use linear addition of sea level rise plus knowledge of present storm surge levels. As an example, for Kingston, Jamaica, detailed, high-resolution model simulations were done by Watson and Johnson (2001). First, it was found that local sea level would rise to about 10 cm more than the value for the global mean. Then, assuming a 37 cm local sea level rise, they ran a storm surge model for a range of storm conditions. It was found that the increase in sea level due to the storm surge varied in the area around Kingston for a range of 23 to 68 cm, with the median value being 48 cm increase. Thus the median increase due to combined sea level rise and storm surge was large than the rise due to sea level (48 cm compared to 37 cm). This demonstrates the need for careful and systematic analysis of hazards due to sea level rise and storm surges.

El Nino is a natural climatic variation, which has major impacts on people, infrastructure and ecosystems in the tropical regions, in particular. Analyses by the IPCC lead them to conclude:

“Current projections show little or a small increase in amplitude of El Nino events over the next 100 years. However, ... global warming is likely to lead to greater extremes of drying and heavy rainfall and increase the risk of droughts and floods that occur with El Nino events in many regions.”

To provide people and their governments with advice and, when appropriate, warnings, there is need for integrated prediction systems, linking all events on time scales of minutes, to days to

seasons to decades (Figure 10). The prediction system should expand into related parameters such as air pollution and ozone levels.

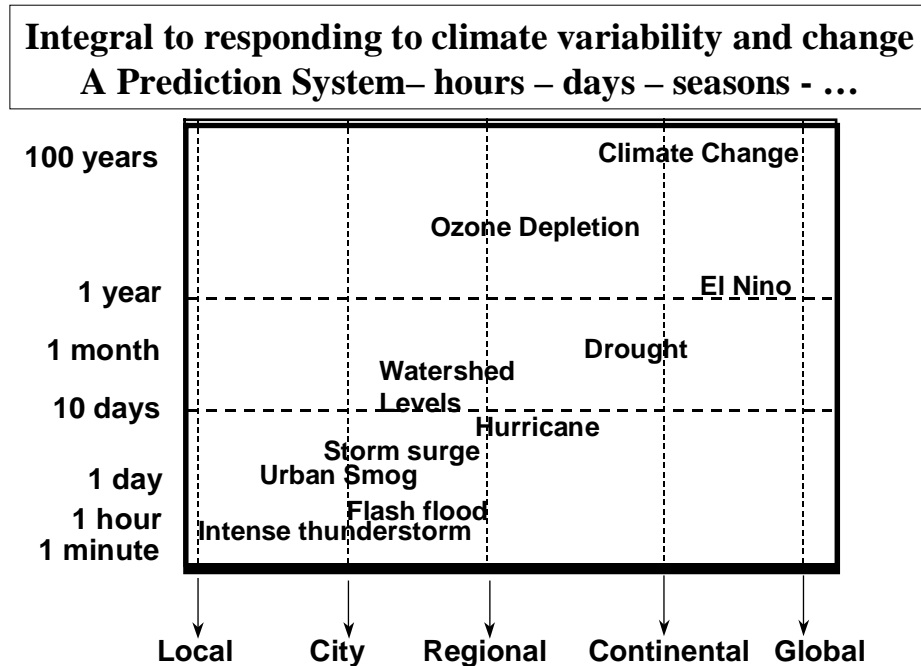


Figure 10: Schematic of integrated prediction system on time and space scales of minutes to years and local to global. An integrated system has scientific and public awareness efficiencies.

It is necessary to frame our response strategies to climate change in a way that will reduce our vulnerability, increase our resilience and gain any benefits. As the magnitude of climate change increases, the impacts increase in a non-linear way. For example, (see Figure 11), for small amounts (say 1-2C over 100 years) we will have impacts on unique and threatened ecosystems. Initially those impacted will be those most vulnerable; however, for larger amounts of climate change, say 3-4C over 100 years, we will see essentially all threatened ecosystems being impacted. As we move to larger amounts of climate change, the impacts will include those due to extreme events, again initially for the most vulnerable and the most extreme events, but shifting to broader impacts as we move up the chart. The distribution of impacts, by regions and sectors, will progress from some to all as we move from 1-2 C warming to 4-6 C warming, over 100 years. As we approach those highest rates of warming, we need to consider the greatly increased likelihood of triggering large-scale discontinuities.

The thermohaline circulation, that plays a critical role in maintaining our present climate and cycles of greenhouse gases, is expected to slow down as the climate warms. Some models show that the thermohaline circulation will recover after the climate stabilizes, on time scales of centuries. However, if we exceed certain thresholds of change, there is an increased probability that the thermohaline circulation will not recover. The IPCC concluded that a shutdown of the thermohaline circulation after 2100 could not be excluded.

Global mean temperature changes

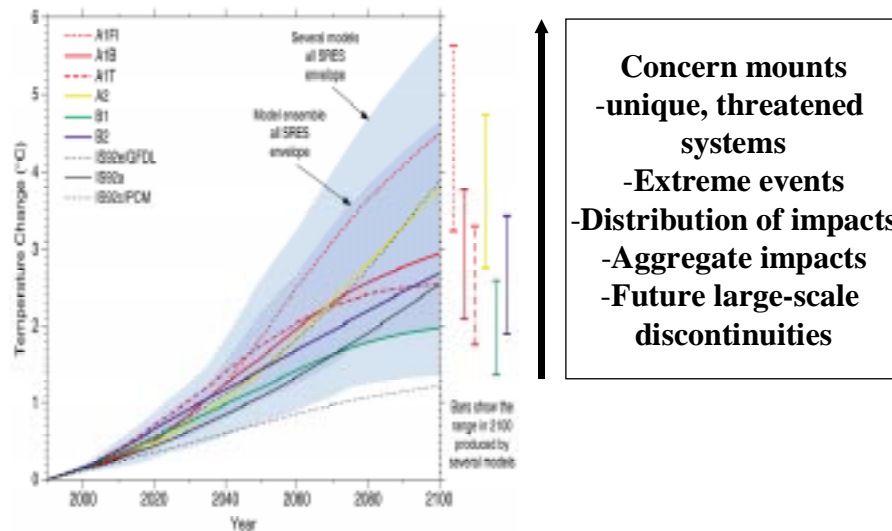


Figure 11: Global temperature change for a full range of emissions scenarios. The box on the right illustrates the increasing concern in issues as the amount for warming increases. (from IPCC, 2001)

Climate change is really a long time scale issue. Although climate changes are already impacting us, it is really about children and grandchildren who will bear the major brunt of the impacts. It is also about us being part of a global community, including the natural ecosystems and all peoples. We need to take actions now for the benefit of all.