Training Course

Climate Change and its Impact on Water Resources

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LECTURE - 5

KEY FINDINGS OF FOURTH ASSESSMENT REPORT (AR4) OF IPCC-2007

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1.0 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) was founded in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). It is open to all members of WMO and UNEP, and its findings are a basis for the international negotiations within the United Nations Framework Convention on Climate Change (UNFCCC). The first full IPCC assessment report was published in 1990. It stimulated the formation of the intergovernmental negotiation committee for the UNFCCC through the UN general assembly. The UNFCCC was signed in 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro and was enacted in March 1994. It provides a political framework in which climate change themes can be addressed. The second IPCC report in 1995 contained key information for the negotiations which then led to the adoption of the Kyoto Protocol through the UNFCCC in 1997. The IPCC also publishes special reports and technical reports on themes for which independent scientific information and advice are necessary, and supports the UNFCCC in its work for national greenhouse gas inventories.

Climate Change 2007, the Fourth Assessment Report (AR4) of IPCC, is the fourth in a series of reports intended to assess scientific, technical and socio-economic information concerning climate change, its potential effects, and options for adaptation and mitigation.

2.0 CLIMATE CHANGE 2007: REPORT OVERVIEW

The Fourth Assessment Report (Climate Change 2007) is released in four distinct sections:

- Working Group I Report (WGI): Climate Change 2007: The Physical Science Basis.

- Working Group II Report (WGII): Climate Change 2007: Impacts, Adaptation and Vulnerability.
- Working Group III Report (WGIII): Climate Change 2007: Mitigation of Climate Change (final version).
- The Synthesis Report (SYR): Summary for Policymakers (SPM)

2.1 Working Group I Report (WGI): Climate Change 2007: The Physical Science Basis

Climate Change 2007: The Physical Science Basis, the report of Working Group I, "assesses the current scientific knowledge of the natural and human drivers of climate change, observed changes in climate, the ability of science to attribute changes to different causes, and projections for future climate change".

The report was produced by 620 authors and editors from 40 countries, and reviewed by more than 620 experts and governments. Before being accepted, the summary was reviewed line-by-line by representatives from 113 governments during the 10th Session of Working Group I, which took place in Paris, France, between 29 January and 1 February 2007.

- "Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the timescales required for removal of this gas from the atmosphere."

2.2 Working Group II (WGII): Impacts, Adaptation and Vulnerability

The summary for policymakers for the Working Group II[16] report was released on April 6, 2007. The full report[17] was released September 18, 2007.

WGII states that "evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases."

Some observed changes have been associated with climate change at varying levels of confidence.

With a high confidence (about an 8 in 10 chance to be correct) WGII asserts that climate change has resulted in:

- More and larger glacial lakes.
- Increasing ground instability in permafrost regions.
- Increasing rock avalanches in mountain regions.
- Changes in some Arctic and Antarctic ecosystems.
- Increased run-off and earlier spring peak discharge in many glacier and snow-fed rivers.
- Changes affecting algae, plankton, fish and zooplankton because rising water temperatures and changes in:
    - ice cover
    - salinity
    - oxygen levels
    - water circulation

With a very high confidence (about a 9 in 10 chance to be correct) WGII asserts that climate change is affecting terrestrial biological systems in that:

- Spring events such as the unfolding of leaves, laying of eggs, and migration are happening earlier.
- There are poleward and upward (to higher altitude) shifts in ranges of plant and animal species.

WGII also states that the ocean has become more acidic because it has absorbed human-caused carbon dioxide. Ocean pH has dropped by 0.1, but how this affects marine life is not documented.

Attribution of changes

WGII acknowledges some of the difficulties of attributing specific changes to human-caused global warming, stating that "Limitations and gaps prevent more complete attribution of the causes of observed system responses to anthropogenic warming." but found that the agreement between observed and projected changes was "Nevertheless ... sufficient to conclude with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems."

Projections

WGII describes some of what might be expected in the coming century, based on studies and model projections.

Fresh water

It is projected with high confidence that:

- Dry regions are projected to get drier, and wet regions are projected to get wetter: "By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics..."
- Drought-affected areas will become larger.
- Heavy precipitation events are very likely to become more common and will increase flood risk.
- Water supplies stored in glaciers and snow cover will be reduced over the course of the century.

Ecosystems

It is projected with high confidence that:

- The resilience of many ecosystems is likely to be exceeded this century by a combination of climate change and other stressors.
- Carbon removal by terrestrial ecosystems is likely to peak before mid-century and then weaken or reverse. This would amplify climate change.

Food

It is projected with medium confidence (about 5 in 10 chances to be correct) that globally; potential food production will increase for temperature rises of 1-3° C, but decrease for higher temperature ranges.

Coastal systems

It is projected with very high confidence that:

- Coasts will be exposed to increasing risks such as coastal erosion due to climate change and sea-level rise.
- "Increases in sea-surface temperature of about 1-3° C are projected to result in more frequent coral bleaching events and widespread mortality unless there is thermal adaptation or acclimatisation by corals."
- "Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s."

2.3 Working Group III (WGIII): Mitigation of Climate Change

The Working Group III Summary for Policymakers (SPM) was published on 4 May 2007 at the 26th session of the IPCC. The full WG III report was published online in September, 2007.

The IPCC convened in Bangkok on April 30 to start discussions on the draft Summary, with the participation of over 400 scientists and experts from about 120 countries. At the full IPCC meeting on May 4, agreement was reached by the larger gathering of some 2,000 delegates. One of the key debates concerned a proposal to limit concentrations of greenhouse gases in the atmosphere to between 445 parts per million and 650 parts per million to avoid dangerous climate change, with pressure from developing countries to raise the lower limit. Despite this, the figures from the original proposal were incorporated into the Summary for Policymakers. The Summary concludes that stabilization of greenhouse gas concentrations is possible at a reasonable cost, with stabilization between 445ppm and 535ppm costing less than 3% of global GDP.

The WG III report analyses mitigation options for the main sectors in the near-term, addressing also cross-sectorial matters such as synergies, co-benefits, and trade-offs. It also provides information on long-term mitigation strategies for various stabilization levels, paying special attention to implications of different short-term strategies for achieving long-term goals.

Mitigation in the short and medium term (until 2030)

The Summary for Policymakers concludes that there was a high level of agreement and much evidence that 'there is substantial economic potential for the mitigation of global greenhouse gas emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels', taking into account financial and social costs and benefits.

The IPCC estimates that stabilizing atmospheric greenhouse gases at between 445-535ppm CO_2 equivalent would result in a reduction of average annual GDP growth rates of less than 0.12%. Stabilizing at 535 to 590ppm would reduce average annual GDP growth rates by 0.1%, while stabilization at 590 to 710ppm would reduce rates by 0.06%.[30] There was high agreement and much evidence that a substantial fraction of these mitigation costs may be offset by benefits to health as a result of reduced air pollution, and that there would be further cost savings from other benefits such as increased energy security, increased agricultural production, and reduced pressure on natural ecosystems as well as, in certain countries, balance of trade improvements, provision of modern energy services to rural areas and employment.

Mitigation in the long term (after 2030)

The IPCC reported that the effectiveness of mitigation efforts over the next two or three decades would have a large impact on the ability to stabilize atmospheric greenhouse gases at lower levels, and that the lower the ultimate stabilization levels, the more quickly emissions would need to peak and decline. For example, to stabilize at between 445 and 490ppm (resulting in an estimate global temperature 2 to 2.4°C above the pre-industrial average) emissions would need to peak before 2015, with 50 to 85% reductions on 2000 levels by 2050.

There was high agreement and much evidence that stabilization could be achieved by 2050 using currently available technologies, provided appropriate and effective incentives were put in place for their development, acquisition, deployment and diffusion, and that barriers were removed.[38] For stabilization at lower levels the IPCC agreed that improvements of carbon intensity need to be made much faster than has been the case in the past, and that there would be a greater need for efficient public and private research, development & demonstration efforts and investment in new technologies during the next few decades. The IPCC points out that government funding in real absolute terms for most energy research programmes has been flat or declining for nearly 20 years, and is now about half the 1980 level. Delays in cutting emissions would lead to higher stabilization levels and increase the risk of more severe climate change impacts, as more of the current high-emission technologies would have been deployed.

2.4 AR4 Synthesis Report

A draft version of the AR4 Synthesis Report, Summary for Policymakers (SPM) was published on 16 November 2007. The Synthesis Report goes one step further [than the first three Climate Change 2007 Working Group Reports]: it is the decisive effort to integrate and compact this wealth of information into a readable and concise document explicitly targeted to the policymakers. The Synthesis Report also brings in relevant parts some material contained in the full Working Group Reports over and above what is included in the Summary for Policymakers in these three Reports. It is designed to be a powerful, scientifically authoritative document of high policy relevance, which will be a major contribution to the discussions at the 13th Conference of the Parties in Bali during December 2007. In fact, this Conference was postponed to December to allow the IPCC Synthesis Report to come out first.

The six topics addressed in the Synthesis Report are:

1. Observed changes in climate and its effects (Working Groups 1-2).
2. Causes of change (WGs 1, 3).
3. Climate change and its impacts in the near and long term under different scenarios (WGs 1-3).
4. Adaptation and mitigation options and responses, and the inter-relationship with sustainable development, at global and regional levels (WGs 2-3).
5. The long term perspective: scientific and socio-economic aspects relevant to adaptation and mitigation, consistent with the objectives and provisions of the Convention [sic], and in the context of sustainable development (WGs 1-3).
6. Robust findings, key uncertainties (WGs 1-3).

3.0 SUMMARY

This document summarizes, in plain language, progress that has been made in understanding human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future climate change. The AR4 provides the strongest statement to date on the extent and causes of climate change. This report expresses much greater confidence than past assessments that most of the observed warming over the past half-century is caused by human activities (greater than 90% certainty). It notes that the rates of warming and sea level rise accelerated during the 20^{th} century, the latter representing a major new finding. It also notes other important changes such as more intense precipitation, drought, and to some extent tropical cyclones. Because real-world observations have been greatly bolstered in this report, a particular strength of the AR4 over past reports is the overlap of nearly two decades between observational data and model projections. For certain aspects of climate change, such as the global temperature trends and rise in CO_2, the models reflect the observed changes reasonably well. In other cases, such as observed sea level rise, the models undershoot the actual observed change. Another strength of the AR4 is enhanced detection of human influence on climate at the regional scale, such as increases in precipitation in the Eastern U.S. and decreased precipitation in the Southwestern U.S. The following materials are drawn from the report either verbatim or in summary.]Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests)by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

Following are summary statements covering the report's main findings.

3.1 Human and natural drivers of climate change

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture.

The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report (TAR), leading to very high confidence that the globally averaged net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W/m^2.

3.2 Direct observations of recent climate change

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.

At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy rainfall and snowfall, heat waves, and the intensity of hurricanes.

Observed impacts include, but are not limited to:

- Eleven of the last twelve years rank among the twelve hottest on record.
- The ocean has warmed to at least 9750 feet depth and is absorbing more than 80% of the heat added to the climate system.
- Global sea level rise has accelerated.
- Mountain glaciers and snow cover have declined on average in both the northern and southern hemispheres.
- Average Arctic sea extent ice has shrunk by 20% at its summertime minimum since satellite observations began in 1978.
- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Some aspects of climate have not been observed to change. For example, there are is no clear trend in Antarctic sea ice extent or the flow rate of the Gulf Stream.

3.3 A paleoclimatic perspective

Paleo climate information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1300 years. The last time the Polar Regions were significantly warmer than present for an extended period was about 125,000 years ago, at which time reductions in polar ice volume led to 13-20 feet of sea level rise.

3.4 Understanding and attributing climate change

Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* (greater than 90% probability) due to the observed increase in anthropogenic greenhouse gas concentrations. This is an advance since the 2001 IPCC report, which concluded that "most of the observed warming over the last 50 years is *likely* [greater than 66% probability] to have been due to the increase in greenhouse gas concentrations".

Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes, and wind patterns. Analysis of climate models together with constraints from observations enables an assessed likely range to be given for climate sensitivity for the first time, and provides increased confidence in the understanding of the climate system response to radiative forcing.

3.5 Projections (model results) of future changes in climate

For the next two decades, warming of about 0.2°C per decade is projected for the range of emission scenarios considered. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* (greater than 90% probability) be larger than those observed during the 20th century.

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and of ice. Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized today.

Models indicate:

- It is *very likely* (greater than 90% probability) that hot extremes, heat waves and heavy precipitation events will become more frequent.

- If global average temperatures were to exceed 1.9 to 4.6 degrees C (3.4 to 8.3 degrees F) compared to pre-industrial temperatures, the Greenland ice sheet would lose mass faster than it gains, producing a net contribution to sea level rise. If sustained for thousands of years, the loss of ice would eventually lead to complete elimination of the Greenland ice sheet and contribute an additional 23 feet to sea level rise.

- It is *very likely* (greater than 90% probability) that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent.

The Earth's global mean climate is determined by incoming energy from the Sun and by the properties of the Earth and its atmosphere, namely the reflection, absorption and emission of energy within the atmosphere and at the surface. Although changes in received solar energy (e.g., caused by variations in the Earth's orbit around the Sun) inevitably affect the Earth's energy budget, the properties of the atmosphere and surface are also important and these may be affected by climate feedbacks. The importance of climate feedbacks is evident in the nature of past climate. Changes as recorded in ice cores up to 650,000 years old.

4.0 TREATMENT OF UNCERTAINTIES IN THE WORKING GROUP I ASSESSMENT

The importance of consistent and transparent treatment of uncertainties is clearly recognized by the IPCC in preparing its assessments of climate change. Uncertainties can be classified in several different ways according to their origin. Two primary types are 'value uncertainties' and 'structural uncertainties'. Value uncertainties arise from the incomplete determination of particular values or results, for example, when data are inaccurate or not fully representative of the phenomenon of interest. Structural uncertainties arise from an incomplete understanding of the processes that control particular values or results, for example, when the conceptual framework or model used for analysis does not include all the relevant processes or relationships. Value uncertainties are generally estimated using statistical techniques and expressed probabilistically. Structural uncertainties are generally described by giving the authors' collective judgment of their confidence in the correctness of a result. In both cases, estimating uncertainties is intrinsically about describing the limits to knowledge and for this reason involves expert judgment about the state of that knowledge. A different type of uncertainty arises in systems that are either chaotic or not fully deterministic in nature and this also limits our ability to project all aspects of climate change.

The uncertainty guidance provided for the Fourth Assessment Report draws, for the first time, a careful distinction between levels of confidence in scientific understanding and the likelihoods of specific results. This allows authors to express high confidence that an event is extremely unlikely (e.g., rolling a dice twice and getting a six both times), as well as high confidence that an event is about as likely as not (e.g., a tossed coin coming up heads). Confidence and likelihood as used here are distinct concepts but are often linked in practice.

4.1 Greenhouse Gases

The dominant factor in the radiative forcing of climate in the industrial era is the increasing concentration of various greenhouse gases in the atmosphere. Several of the major greenhouse gases occur naturally but increases in their atmospheric concentrations over the last 250 years are due largely to human activities. Other green house gases are entirely the result of human activities. The contribution of each greenhouse gas to radiative forcing over a particular period of time is determined by the change in its concentration in the atmosphere over that period and the effectiveness of the gas in perturbing the radiative balance. Current atmospheric concentrations of the different greenhouse gases considered in this report vary by more than eight orders of magnitude (factor of 108), and their radiative efficiencies vary by more than four orders of magnitude (factor of 104), reflecting the enormous diversity in their properties and origins.

The impacts of land use change on climate are expected to be locally significant in some regions, but are small at the global scale in comparison with greenhouse gas warming. Changes in the land surface (vegetation, soils, water) resulting from human activities can significantly affect local climate through shifts in radiation, cloudiness, surface roughness and surface temperatures. Changes in vegetation cover can also have a substantial effect on surface energy and water balance at the regional scale. These effects involve non-radiative processes (implying that they cannot be quantified by a radiative forcing) and have a very low level of scientific understanding.

The warming in the last 30 years is widespread over the globe, and is greatest at higher northern latitudes. The greatest warming has occurred in the NH winter (DJF) and spring (MAM). Average arctic temperatures have been increasing at almost twice the rate of the rest of the World in the past 100 years. However, arctic temperatures are highly variable. A slightly longer arctic warm period, almost as warm as the present, was observed from 1925 to 1945, but its geographical distribution appears to have been different from the recent warming since its extent was not global.

4.2 SRES scenarios

SRES refers to the scenarios described in the IPCC Special Report on Emissions Scenarios (SRES, 2000). The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demo graphic, economic and technological driving forces and resulting GHG emissions. The SRES scenarios do not include additional climate policies above current ones. The emissions projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socio-economic, demographic and technological change serve as inputs to many recent climate change vulnerability and impact assessments. The A1 storyline assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies. A1 is divided into three groups that describe alternative directions of technological change: fossil intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B). B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy.B2 describes a world with intermediate population and economic growth, emphasizing local solutions to economic, social, and environmental sustainability. A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change. No likelihood has been attached to any of the SRES scenarios. For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios. Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emission scenarios.

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