Topic 6 – Robust findings, key uncertainties
(15 May 2007)

As in the Third Assessment Report, a robust finding for climate change is defined as one that holds under a variety of approaches, methods, models, and assumptions and one that is expected to be relatively unaffected by uncertainties. Key uncertainties in this context are those that, if reduced, could lead to new robust findings in relation to the issues discussed in this report. {TAR SYR Q.9}

Robust findings, as defined above, are only a part of the key findings of the AR4. Some key findings may be policy-relevant even though, or in some cases because, they are associated with large uncertainties or depend on assumptions and possible futures. Robust findings provide important cornerstones for climate change decision-making, but they do not summarise all scientific knowledge that may be relevant for prudent risk management. {WGII 20.9}

Compared with earlier assessments, the AR4 includes a greater number and detail of robust findings. Nonetheless, some key uncertainties identified earlier continue to exist. In some areas, there is now greater recognition of the sources and magnitude of uncertainties that limit our current ability to produce more quantitative robust findings. {WGI TS.6; WGII TS.6; WGIII TS.14}

6.1 Observed changes in climate and their effects, and their causes

Robust findings

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 mean sea level. {WGI 3.9, SPM}

The patterns of warming on land, on and in the ocean, as well as from the surface to higher altitudes are now more robust. {WGI 3.2, 3.4, SPM}

Many natural systems, on all continents and in some oceans, are being affected by regional climate changes. Observed changes in many physical and biological systems are consistent with a warming world. {WGII 1.3}

Anthropogenic greenhouse gas emissions have increased by 70% during the 1970-2004 period. The effect on global emissions of the decrease in the global energy intensity (-33%) during 1970 to 2004 has been smaller than the combined effect of global income growth (77%) and global population growth (69%); both drivers of increasing energy-related CO_2 emissions. As a result of anthropogenic emissions, concentrations of CO_2, CH_4 and N_2O are now at levels unprecedented in at least 10,000 years. {WGI SPM; WGIII 1.3}

Most of global average warming over the past 50 years is *very likely* due to anthropogenic greenhouse gas increases and it is *likely* there is a discernible human induced warming averaged over every inhabited continent. {WGI 9.4, SPM}

At the global scale, anthropogenic warming over the last three decades has *likely* had a discernible influence on observed changes in many physical and biological systems. {WGII 1.4, SPM}

Key uncertainties

Uncertainties arise from gaps and geographical imbalance in data and literature on observed climate changes and their effects in natural, managed and human systems, especially in the tropics and the Southern Hemisphere. {WGI SPM; WGII 1.5, SPM}

Methods to analyze and monitor extremes including drought, tropical cyclones, extreme temperatures, and the frequency and intensity of precipitation are less well-developed than methods for climatic averages. {WGI 3.8, SPM}

Responses to climate changes in human systems are difficult to detect because of multiple non-climate driving forces and the presence of adaptations. {WGII 1.3}

Difficulties remain in reliably simulating and attributing observed temperature changes to natural or human causes at smaller than continental scales. At these scales, other factors such as land-use change and pollution also complicate the detection of anthropogenic warming influence on physical and biological systems. {WGI 8.3, 9.4, SPM; WGII 1.4, SPM}

Key uncertainties in anthropogenic greenhouse emissions are CO_2 emissions from land-use change and individual methane sources. {WGI 2.3, 7.3, 7.4; WGIII 1.3, TS.14}

6.2 Drivers and projections of future climate changes and their impacts

Robust findings

With current climate change mitigation and related sustainable development policies, global greenhouse gas emissions will continue to grow over the next few decades. {WGIII 3.2, SPM}

For the next two decades a warming of about 0.2°C per decade is projected for a range of plausible emission scenarios. {WGI 10.3, 10.7, SPM}

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* be larger than those observed during the 20th century. The pattern of future warming where land warms more than the adjacent oceans and more in northern high latitudes is seen in all future scenarios. {WGI 10.3, 11.1, SPM}

Warming tends to reduce land and ocean uptake of atmospheric carbon dioxide, increasing the fraction of anthropogenic emissions that remains in the atmosphere. {WGI 7.3, 10.4, 10.5, SPM}

Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas emissions were to be reduced sufficiently for greenhouse gas concentrations to stabilise. {WGI 10.7}

Many recent studies, particularly in previously little researched regions, have enabled a more systematic understanding of how the timing and magnitude of impacts are projected to be affected by changes in climate and sea level associated with differing amounts and rates of change in global average temperature. However, effects on managed and human systems depend on climatic and non-climatic drivers and adaptation. {WGII SPM, TS.4.1, TS.4.2}

Impacts due to altered frequencies and intensities of extreme weather, climate and sea-level events are *very likely* to change. Confidence has increased that some weather events and extremes will become more frequent, more widespread or more intense during the 21st century; and more is known about the potential effects of such changes. {WGII Table SPM-2}

Events since the Third Assessment Report have demonstrated the vulnerability of some sectors and regions to extreme events like heat waves and tropical cyclones, providing stronger reasons for concern as compared to the findings of the Third Assessment Report. {WGII 19.3}

Widespread deglaciation of the Greenland ice sheet over a very long time frame (millennia) has the potential to cause very large impacts, including major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas. Uncertain processes relating to ice flow could potentially add contributions from parts of Antarctica or accelerate the melting, but there is no consensus on their magnitude. {WGI 10.7; WGII 19.3}

Key uncertainties

Uncertainty in the equilibrium climate sensitivity creates uncertainty in the expected temperature response for a given CO_2-eq stabilisation scenario. Uncertainty in the carbon cycle feedback creates uncertainty for emissions trajectories required for achieving a particular stabilisation scenario. {WGI 7.3, 10.4, 10.5, SPM}

Models differ considerably in their estimates of the strength of different feedbacks in the climate system, particularly cloud feedbacks, oceanic heat uptake, and carbon cycle feedbacks, although progress has been made in these areas. Also, the confidence in projections is higher for some variables (e.g. temperature) than for others (e.g. precipitation), and is higher for larger spatial scales and longer time averaging periods. {WGI 7.3, 8.1-8.7, 9.6, 10.2, 10.7, SPM}

Aerosol impacts on the magnitude of the temperature response and the hydrological cycle remain uncertain. {WGI 2.9, 7.5, 9.2, 9.4, 9.5}

Future changes in the Greenland and Antarctic ice sheets mass, particularly due to changes in ice flow, are a major source of uncertainty in sea level rise projections. The uncertainty in the penetration of the heat into the oceans also contributes to the future sea level rise uncertainty. {WGI 4.6, 6.4, 10.3, 10.7, SPM}

Large scale ocean circulation changes beyond the 21st century cannot be assessed because uncertainties in the meltwater supply from Greenland ice sheet and model response to the warming make the assessment of level of confidence difficult. {WGI 6.4, 10.3, 10.7, SPM}

Projections beyond about 2050 are strongly scenario- and model-dependent, and improved projections would require improved understanding of sources of uncertainty. Projections of climate change and its impacts would benefit from enhancements in networks of systematic observations of key elements of physical, biological, managed and human systems particularly in regions where such networks have been identified as insufficient. {WGII TS.6}

Some climate events have the potential to cause very large impacts and irreversible changes, but there remain large uncertainties in assessing these. {SYR 3.4, 5.7; WGI 8.7, 10.3, 10.7; WGII 19.4, TS.6}

Risk-based approaches to decision-making require thorough understandings of the full range of potential impacts, including events of lower probability, their associated consequences, and their sources and/or drivers. However, understanding of low-probability events is generally limited, representing a key uncertainty for decision-making. {WGII 19.4, 20.2, 20.4, 20.9, TS.6}

6.3 Responses to climate change

Robust findings

Some limited adaptation is occurring now, and more is projected as response to future climate change. More extensive adaptation is required to reduce vulnerability to higher levels and rates of warming, but there are barriers, limits and costs. Moreover, future vulnerability depends strongly on development pathway. {WGII 17.ES, Table 20.6, SPM}

Adaptation is necessary. However, adaptation will be infeasible in some cases and less feasible or very costly in most cases for the projected climate change beyond the next several decades. {WGII 17.ES, 19.3, 20.7, SPM}

Climate change could impede nations' abilities to achieve sustainable development pathways. {WGII 20.3, 20.7, SPM}

A wide range of mitigation options are currently available or projected to be available by 2030 in all sectors, with the economic potential at costs from net negative up to 100 US$/t$CO_2$-equivalent, sufficient to offset the projected growth of global emissions or to reduce emissions to below current levels over the coming decades. {WGIII 11.3, SPM}

The range of stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are currently available and those that are expected to be commercialised in coming decades. This assumes that appropriate and effective incentives are in place for development, acquisition, deployment and diffusion of technologies and for addressing related barriers. The lower the stabilisation levels, especially those of 550 ppm CO_2-eq or lower, the greater the need for more efficient RD&D efforts and investment in new technologies during the next few decades. {WGIII 3.3, 3.4}

The lowest stabilisation scenarios (445-490 ppm; best estimate equilibrium temperature increase of 2-2.4°C above pre-industrial) could over the longer term significantly reduce the risks of many major impacts on vulnerable systems. In these stabilisation scenarios, emissions would need to peak over the next few decades and to be reduced below 50% of current levels by 2050. {WGII Table 20.6; WGIII 3.3}

A wide variety of national policies, including non-climate policies, are available to governments to create incentives for adaptation and mitigation actions. Making development more sustainable by changing development paths can make a major contribution to climate change mitigation and adaptation and to reducing vulnerability to climate change. {WGII 18.7, 20.3, SPM; WGIII 13.2, SPM}

Decisions about macroeconomic policy, multilateral development, and other policies that seem unrelated to climate change can significantly affect emissions. {WGIII 12.2}

Key uncertainties

Understanding of how development planners will incorporate information about climate change into their decisions is limited, which represents a key uncertainty in local vulnerability assessments and in aggregated integrated vulnerability assessments. {WGII 18.8, 20.9}

Evolution of adaptive capacity and its realisation, and the dependence of these on underlying socio-economic development pathways over the long term, is a key uncertainty. {WGII 17.3, 17.4, 18.6, 19.4, 20.9}

Estimates of mitigation costs and potentials depend on assumptions about future socio-economic growth, technological change and consumption patterns. Uncertainty arises in particular from assumptions regarding the drivers of technology diffusion and the potential of long-term technology performance and cost improvements. {WGIII 3.3, 3.4}

Valuations of the co-benefits of mitigation and adaptation depend on assumed and realised development pathways, choices regarding multiple metrics of climate risk[1], and depend on spatial and temporal scales. {WGII 17.2, 18.6; WGIII 11.8}

The effects of non-climate policies on emissions are poorly quantified. {WGIII 12.2}

[1] For example, goods and services traded in markets, human lives, species lost, inequities altered etc.