GLOBAL AND REGIONAL CLIMATE CHANGE:
NEW EVIDENCES BETWEEN TWO IPCC REPORTS

JÁNOS MIKA

ABSTRACT. – Even the economical crisis was not strong enough to deflect the anthropogenic greenhouse gas forcing for more than one year. It tends to develop at the upper edge of the IPCC (2007) projection band of uncertainties. The part of the emitted carbon dioxide remaining in the atmosphere is increasing due to weakening of both the biospheric- and the oceanic sinks of this greenhouse-gas. The new radiation balance estimations must admit the imbalance between the atmosphere and the oceans indicating the fact that the greenhouse warming definitely takes place. The year 2010 became most likely the warmest one on the global temperature record. The sea-level rise also follows the most rapid track among the foreseen scenarios. In the meantime modelling effort to better estimate regional features of the changes also develop in their full strength. The ENSEMBLES Project ended in December 2009 and published a lot of maps with 25 km model resolution. These results, however, do not show convergence in the estimations for many regions, including Central Europe, either.

Keywords: carbon-dioxide, radiation balance, sea-level, regional climate models

1. INTRODUCTION

Climate of our Planet has never been constant, but the recent changes are by two orders of magnitude faster than the natural changes since the appearance of anthropogenic effects. The discernable global warming started in the 19th century and after speeding up in the 20th century, it has reached about 0.8 K. This fact and the realization of the likely reasons for the changes, plus rapid development of computer technology have resulted in systematic investigations of climate science.

The Intergovernmental Panel on Climate Change (IPCC) finalised its Fourth Assessment Report in 2007. The present paper surveys some recent moments of global and regional climate change issued after the Report.

2. CHANGES IN THE GREENHOUSE GAS CONCENTRATIONS

The worldwide economical crisis led to -1.3% decrease in 2009’s annual fossil-fuel CO2-emission (Fig. 1.) comparing to 2008. One should note, however, that this 8.4±0.5 PgC emission is still larger by 37 % than that in 1990, considered as a reference in various mitigation policy calculations. The annual increase was as

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large as +3.2% in the 2000-2008 period and for 2010 a >3% increase had recently been projected. (Global Carbon Project, 2010).

The pace of the CO₂-emission indicated in Fig. 1 was steeper than any IPCC (2007) scenario, originated from the study by Nakicenovic and Swart (2000)!

![Fig. 1. Trends in the fossil fuel vs. land-use forms of anthropogenic CO₂-emission 1960-2009 (left - Global Carbon Project, 2010) and the fraction of the emission remaining in the atmosphere (right - Global Carbon Project, 2010)](image)

Natural land and ocean CO₂ sinks removed 57% of all CO₂ emitted from human activities during the 1958-2009, each sink in roughly equal proportion.

However, there is the possibility, however, that the efficiency of the natural sinks is declining. According to complex model calculations, the experienced decrease in both the biological and oceanic sources in the recent decades broadly explains this increase. If we can believe in the graph presented by the right panel of Fig. 1., then a dramatic increase of the airborne fraction is going on with a 5% increase, from 40% to 45% of CO₂ remaining in the atmosphere.

Both the steeper than expected increase of the emission and the increased fraction of the emitted CO₂ point at the possibility, that the present, post-IPCC (2007) estimate of the main greenhouse gas forcing is even more rapid than it was assumed by the Report in 2007! This increasing forcing is already seen in the global radiation balance, as presented in the next Section, below.

### 3. CHANGES IN THE RADIATION BALANCE

The state of climate system largely depends on the radiation process, and human activity can primarily modify the radiation processes, too. Hence it was inevitable to know the actual radiation balance of the Planet with high accuracy.

Recently, Trenberth et al. (2009) re-considered (Fig. 2) the earlier radiation balance estimations (Kiehl and Trenberth, 1997). The earlier study was based on observations from 1985-1989, while the recent estimates covered the March 2000 – May 2004 period. In some cases the difference between the two estimates is ca. 10 Wm⁻², or over 20% in relative terms. Majority of the changes are likely caused by uncertainties of the estimation, not by the climate change during this short period.
Climate change is seen not from these differences but from the 0.9 Wm$^{-2}$ unbalance between the atmosphere and the underlying surface, i.e. mainly the oceans. This heat is removed from the atmosphere and leads to slower warming at the surface. On the other hand, this heat would be given back to the atmosphere after stabilisation of the atmospheric composition at a certain time, afterwards.

![Image of Earth's energy budget](image)

**Fig. 2.** The global annual mean Earth’s energy budget for the Mar 2000 to May 2004 period (Wm$^{-2}$). The broad arrows indicate the schematic flow of energy in proportion to their importance. Source: Trenberth et al (2009) Remark: The Fig. indicates global averages, independently from the type of the surface in the illustration.

It might be interesting to compare these figures of the energy balance with those changes summarised by the IPCC (2007: Fig. 2.20). The increase of greenhouse effect modified the balance by 2.3 Wm$^{-2}$ since the beginning of Industrial Revolution. The value is only 1% of the captured Sun originated energy but 1/5 of the changes happened in the last decade. (The energy balance remains zero at the top of the atmosphere, but it needs higher temperature near the surface!)

Among the important anthropogenic forcing factors, the greenhouse effect influences the backward atmospheric long-wave radiation to the surface. (Its present value is 333 Wm$^{-2}$, see above in Fig. 2.) The aerosol content modifies mainly the reflected short wave radiation (79 Wm$^{-2}$) and, to a smaller extent, the atmospheric long wave emission (239 Wm$^{-2}$).

The land use determines mainly the surface-reflected short-wave radiation and the sensible and latent heat exchange between the surface and the atmosphere. Among the natural forcing factors, decadal oscillations of solar activity directly modulate the incoming short wave solar radiation (341 Wm$^{-2}$), while the few big volcanic eruptions increase the reflected shortwave radiation 1-3 years.
The concentration of atmospheric carbon dioxide has grown from about 280 ppm before the Industrial Revolution to 385 ppm in 2008 (Copenhagen Diagnosis, 2009). The methane concentration has grown from 0.715 to 1.774 ppm in 2005. Both values are much higher than any time in the last 650,000 years! The atmospheric mass of nitrous oxide has reached 0.319 ppm in 2005 from 0.270.

The components of atmospheric aerosols have modified the atmospheric radiation balance in the opposite direction. The direct effect of aerosols, mainly the backscattering of solar radiation is about -0.5 Wm\(^{-2}\). Their indirect effect, through changes in cloud composition, is another -0.7 Wm\(^{-2}\) since the industrial revolution.

Further small effects, e.g. changes in land use, and increasing carbon content of snow leading to smaller reflectivity cause -0.1 – -0.2 Wm\(^{-2}\) in the radiation balance of the Planet. The Report also states that the influence of solar activity oscillations is +0.12 Wm\(^{-2}\) since 1750. This value is the half of the previous estimation (IPCC, 2001).

4. CHANGES OF GLOBAL TEMPERATURE AND SEA LEVEL

The global mean temperature is generally derived in comparison with its 1961-1990 average. This solution is explained by the fact that it is not easy to define the absolute value of the present, or any time’s global mean temperature. This is explained by the sparse distribution of the observing stations. Fig. 3 indicates long term tendencies of the global mean temperature between 1881 and 2010. As it is seen in Fig. 3, global mean temperature is gradually increasing since ca. 1960. The year 2010 is one of the warmest ones in tough competition with 1998 and 2005. The warmest decade on the record is the last ten years, for sure.

![Global Surface Temperatures](image)

Fig. 3. Global mean temperature as reconstructed by four international data centres: NASA Goddard Institute for Space Studies, NOAA National Climatic Data Centre, Meteorological Office Hadley Centre/Climate Research Unit and the Japanese Meteorological Agency. Credit: NASA Earth Observatory/Robert Simmon.
Another indicator of the thermal processes is the sea level, driven mainly by the thermal expansion and the water balance with the continental ice. Sea ice melting does not influence the sea level, in correspondence with the Archimedes’ principle on the floating objects.

_Fig. 4_ is an evidence of warming showing the sea level rise, combining the tide gauges and microwave satellite observations. They measure the sea level heights between 66°N and 66°S in ten-day averages since 1993. Accuracy of the individual ten-day mean sea-level anomalies, of satellite microwave measurement, is ±5 mm. According to the processing of the measurements, the rise of sea level is 3.1±0.7 mm per year which mainly happens in the Southern Hemisphere.

![Sea level change during 1970-2010. The tide gauge data are indicated in red (Church and White 2006) and satellite data in blue (Cazenave et al. 2009). The grey band shows the projections of the IPCC Report (2007). The graphs show the difference from the 1993-2001 period’s average in mm unit. The satellite data till 2002 are based on TOPEX/Poseidon, later on Jason satellites. (Copenhagen Diagnosis, 2009: Fig. 16)](image)

Hence, the temperature increase has already been detected in the upper 3 km layer of the oceans. The reason is that 80% of the radiation balance surplus is absorbed by the oceans. (This is the 0.9 Wm⁻² deviation of the total balance in _Fig. 2_) This warming together with the thawing of land ice has already caused 17 cm elevation of sea level (IPCC, 2007).

According to the Copenhagen Diagnosis (2009), the contribution of glaciers and ice-caps to global sea-level has increased from 0.8 mm/year year in the 1990s to be 1.2 mm/year today. The adjustment of glaciers and ice caps to present climate alone is expected to raise sea level by ~18 cm, (i.e. by 1 cm more after three years from 2005, than the IPCC AR4 estimation).

The area of the Greenland ice sheet, experiencing summer melt, has already been increasing by 30% since 1979, parallel to the increasing air temperatures. The net ice loss from Greenland accelerated since the mid-1990s and is now contributing as much as 0.7 mm/year to sea level rise due to both increased melting and accelerated ice flow.
5. RESULTS OF REGIONAL CLIMATE MODELLING

Nowadays the regional features of climate change are mainly based on finer resolution models imbedded into the mainframe GCMs, providing the boundary conditions for the partial derivatives of the fine-mash computations. However, diversity of these results sometimes even in signs, e.g. for precipitation is several seasons (Christensen et al., 2007; van der Linden, P. and J.F.B. Mitchell, 2009, see on the next page, as well) is a challenge to solve before finally neglecting the other sources of information applied in the impact and adaptation studies.

One reason of the diversity of regional model results may be the difference between boundary conditions taken from the mainframe models. This problem is presented by Fig. 11.6 of the IPCC (2007) Report, where two different mainframe models led to different responses in the same regional model, even in the sign of precipitation change in many sectors of Europe.

Table 2 indicate how the ENSEMBLES Project wanted to limit the effects of the boundary conditions and the variety of the results among the regional models. But, since far not all combinations of GCM + RCM can be performed for several (not only practical) reasons, one can calculate that the average number with which a regional model is combined is only 1.7!

Table 1. ENSEMBLES regional climate model experiments with 25 km horizontal resolution. The lines indicate the 15 regional models and the columns represent the 8 global mainframe GCMs, applied in the Project. These 25 combinations from the 120 ideally possible combinations mean a rather low proportion.

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The results differ fairly much even among the regional models (Fig. 5). This indicates the “large ensemble” where the regional models and the parameterizations were varied. For temperature this uncertainty involves just the measure of warming between tolerable to dangerous degrees in many regions of Europe. For precipitation, however, even the sign of the change is questionable comparing the two deciles.
Fig. 5. The 10 % and 90 % deciles of the distribution derived from the forecasts for 2080-2099 comparing to 1961-1990, summarized in Table 1 and further diversified by a set of different parameterizations (“large ensembles” see: van der Linden, P. and J.F.B. Mitchell, 2009). The first columns always show the temperature changes (K), the second columns indicate the precipitation changes (%). The upper two pairs of figures indicate the changes in winter (DJF) whereas the third and fourth pairs correspond to the summer changes (JJA).
6. CONCLUSION

Two main conclusions can be compiled from the presented recent results:

(i.) Both the anthropogenic global radiation forcing and its temperature and sea-level consequences have been developing according to the IPCC (2007) assumptions or even worse after 2005. Hence its mitigation remains one of the most important long-term challenges of our era.

(ii.) On the other hand, even the fast development of the coupled global and regional models could not really decrease the quantitative uncertainty. Hence, no single GCM output can be applied for adaptation-related consequences, and the embedded regional climate models aimed to overcome the insufficiency of the GCM-resolution are strongly influenced by the boundary conditions.

REFERENCES