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CLIMATE CHANGE AND IMPACT ON TERRESTRIAL ECOSYSTEMS

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Abstract. *The main scientific knowledge regarding the climate change and its impact stored during the period 2001-2007, included in the report 3 and 4 of IPCC or in other published works, is presented in this paper. This knowledge particularly refers to new arguments in favour of the anthropogenic origin of the global warming observed in the last century, the corresponding changes induced in the terrestrial ecosystems, the prediction of the global temperature dynamics during the 21st century for different emission scenarios as well as the anticipation of the possible impacts on physical and biological systems. Also, the climate change issue and its potential impact in Romania are discussed.*

Keywords: Ecosystems, climate change, global warming

"In terms of complexity, next to human nature is climate"
Albert Einstein

1. Introduction

At the world meeting of the state leaders, which was held in Rio de Janeiro in January 1992, the United Nation Framework Convention on Climate Change (UNFCCC) was signed by more than 150 countries. This fact proves that the mankind becomes aware of the risk involved by the global warming for its sustainable development as well as of the necessity to take measures for diminishing the possible adverse effects on environment and society. The global warming phenomenon is accepted by all scientific community, being emphasized by the observational data of temperature at global level as well as by the physical and biological natural processes depending on surface air temperature. This phenomenon is attributed to the anthropogenic emissions of greenhouse gases which result in air temperature increase within the layer located between Earth surface and troposphere. In the last time, significant progress in understanding the mechanisms which determine the climate change and the corresponding impacts, have been made. Thus, the fourth IPCC-report published in 2007 presents new observations regarding the dynamics of greenhouse gas concentrations since pre-industrial period until 2005, the air and ocean temperature changes, the decrease tendency of snow cover and sea ice, the increase of the global sea level as well as the changes at continental, regional and ocean basin level. An important issue

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analyzed in the last IPCC report is the validation of the climate models on (temperature and precipitation) measured data as well as the use of these models to anticipate the temperature and precipitation temporal evolution during the 21st century (IPCC-Working Group I).

Also, in order to assess the vulnerability and adaptation options to the potential climate change, this report points out the observations and predictions regarding climate change impact on water resources, terrestrial ecosystems, economic sectors and human health (IPCC-Working Group II).The contribution of the Working Group III consists in the assessment of options and measures for reducing the greenhouse gas emissions.

The present paper deals with main scientific information on climate change and impact on terrestrial ecosystems acquired during the period 2001-2007 revealed by IPCC-AR 4 and other publications [3-7, 11].

2. Glossary for specific terms

Climate: This word comes from the Greek word <*klivo*> which means *"inclination"* and signifies the fact that weather is changing at the same time as the Sun astronomical inclination (during the day, seasonal or with latitude) [14].

Climate: Climate, in a narrow sense, is defined as the average state of current meteorological state, or more rigorously, as the statistical description in terms of the mean and variability of suitable meteorological parameters observed on relevant time intervals, usually, 30 years, as is recommended by World Meteorological Organization (WMO). The main quantities that define the climate are the Earth surface parameters: air temperature, precipitation, wind, solar radiation intensity. Climate, in a broader sense, is the state, including statistical characteristics, of the climate system, that is determined by global interactions of its components, having as origin the solar energy. The climate system components are: atmosphere, hydrosphere (particularly, the oceans), terrestrial and marine biosphere, cryosphere and land surface. They interact by continuous exchanges of energy (mechanical and thermal) and mass.

Climate change: Climate change can be defined as a change in the state of climate identified by changes in the mean and/or the variability of its characteristics, that persists for extended time intervals, usually decades or longer. Climate change can be induced by natural processes or external factors or by anthropogenic changes in the composition of atmosphere and land use. According to the UNFCCC [2, 3] the climate change is defined as *"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"*.

Forcing: Forcing is a physical constraint on the development of some specific processes from an ensemble of phenomena [12]. For example, the external forcing refers to an external factor that can induce a change of climate parameters. Such forcings are the volcanic eruptions, changes in solar radiation intensity and changes of anthropogenic origin of atmospheric composition and land use.

Radiative forcing: Radiative forcing is the change in the net, downward minus upward, energy flux (W m^{-2}) crossing a surface unit at the tropopause level due to a change in an external forcing, such as, for example a change in the concentration of a greenhouse gas or in the output of the Sun. A positive radiation forcing induces a climate warming while the negative one, the cooling of climate. The greenhouse gases have a positive radiative forcing and the aerosols a negative one. In IPCC-AR4 [3], the radiative forcings are given for the year 2005 relative to the year 1750 and refer to global and annual average values.

Climate feedback: Climate feedback describes an interaction mechanism in climate system when an initial process triggers changes in another process that in turn influences the initial one. A positive feedback intensifies the initial process, and a negative feedback diminishes it.

Albedo: Albedo is the fraction of solar radiation which is reflected by a surface or an object, usually expressed as percentage. For example, a surface covered by snow has a great albedo while the land cover with vegetation and ocean surface have a small albedo

ppm (ppb): 1 ppm (ppb) of greenhouse gas is a concentration which corresponds to one gas molecule for one million (billion) of dry air molecules

Residence time: global atmospheric residence lifetime is the ratio of the mass of a reservoir (e.g., a gaseous compound in the atmosphere) and the total rate of removal from the reservoir.

3. Climate change

3.1.Greenhouse gases and aerosols

The Earth climate is influenced by many factors such as, the quantity of energy coming from Sun, the properties of the land surface or the atmospheric concentrations of greenhouse gases (GHG) and aerosols. Climate change can be induced by:

- natural internal processes(e.g., ocean-atmosphere interaction),
- external forcings: solar radiation intensity, Earth orbital parameters(orbit eccentricity and obliquity and precession around the rotation axis),
- persistent changes of atmospheric composition and land use induced by human activities.

Each of the above mentioned factors has a positive or negative forcing, thus contributing to the planet warming or cooling due to the variations induced in the energy balance of the climate system. The atmospheric constituents that contribute to the climate change are greenhouse gases and aerosols. The greenhouse gases are of natural or anthropogenic origin or anthropogenic one only. They absorb and emit long wave radiation specific to the spectrum of infrared radiation emitted by Earth surface, atmosphere and clouds.

Water vapours are the most important natural constituent of atmosphere which causes the greenhouse effect, but they are not considered as being affected by human activity. The main greenhouse gases of natural and anthropogenic origin are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3). The greenhouse gases of pure anthropogenic origin are the halocarbons; these are carbon compounds containing fluorine, chlorine, bromine and iodine.

Carbon dioxide

This is the most important greenhouse gas .Its atmospheric concentration increased from the pre-industrial value of ~ 280 ppm to 375 ppm in 2005. The naturally existing concentrations during the last 650.000 years varied within the interval (180÷300 ppm) as it follows from the ice cores.

The increase of CO_2 concentration is mainly due to burn-up of the fossil fuel and land use changes (deforestation, desertification).

The atmospheric residence time has values between 50-200 years. No single residence time can be defined because of the different rates of uptake by different sink processes.

Methane

The atmospheric concentration has increased from the pre-industrial value of ~ 715 ppb to 1732 ppb at the beginning of the year 1990 and to 1774 ppb in 2005. The concentration in 2005 is much greater than the values (320÷790 ppb) existing during the last 650,000 years, which have been determined from ice core samples.

The increase of methane concentrations in atmosphere is attributed to the agriculture and fossil fuel use. The atmospheric residence time is 12 years.

Nitrous oxide

The concentration of nitrous oxide has increased from the pre-industrial value of ~270 ppb to 319 ppb in 2005. The rate of increase was about constant beginning with 1980. More than one third of N_2O emissions is of anthropogenic origin, mainly, the agricultural activities. The atmospheric residence time is 120 years.

In Figure 1, the concentration dynamics of these three gases in the last 10,000 years, obtained from the present measurements and ice core samples, is presented.

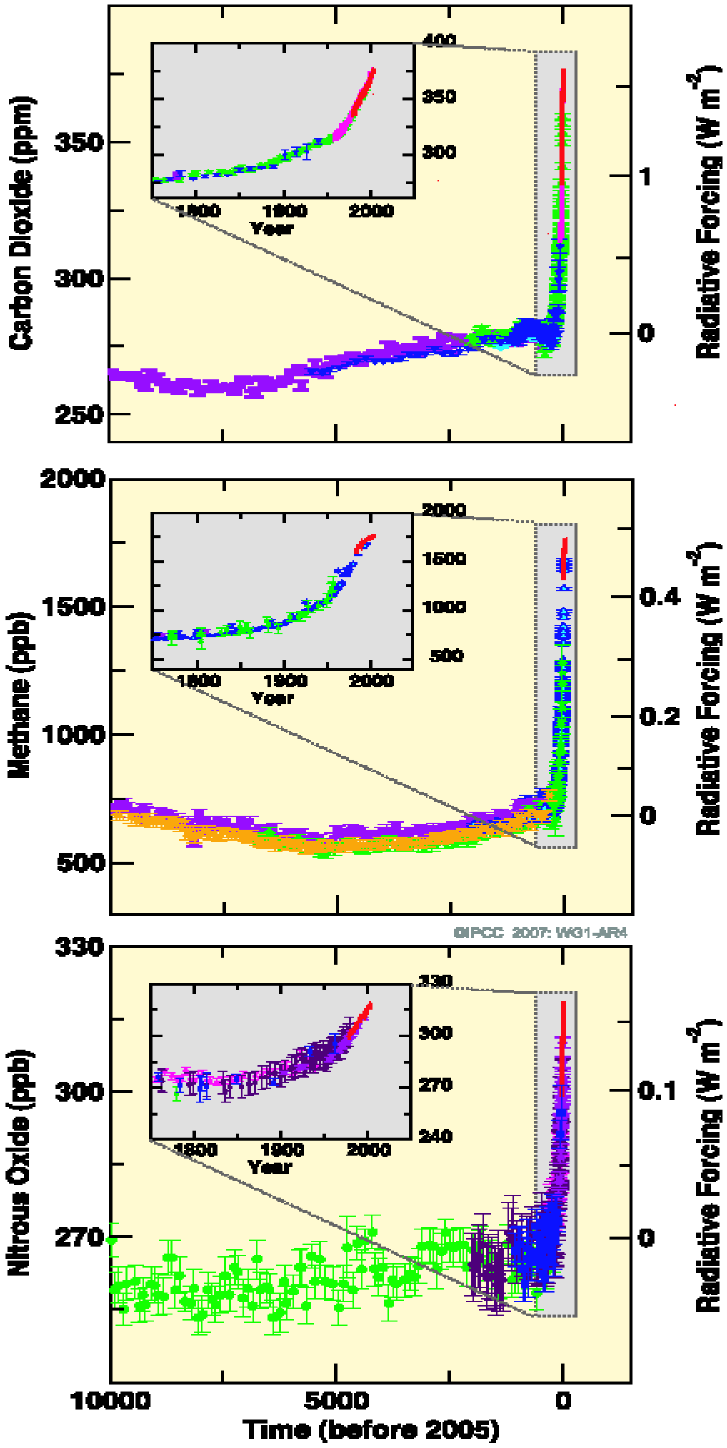

Fig. 1. Dynamics of CO_2 , CH_4 and N_2O concentrations on the last 10,000 years (present data and from ice core) [3].

Figure 2 shows the deuterium variation (δD) in the Antarctic sea cap, which is an indicator of the local temperature, and the concentrations of CO_2, CH_4 and N_2O from ice cores and present measurements. Data cover a period of 650,000 years and the shaded bands indicate current and previous interglacial warm periods.

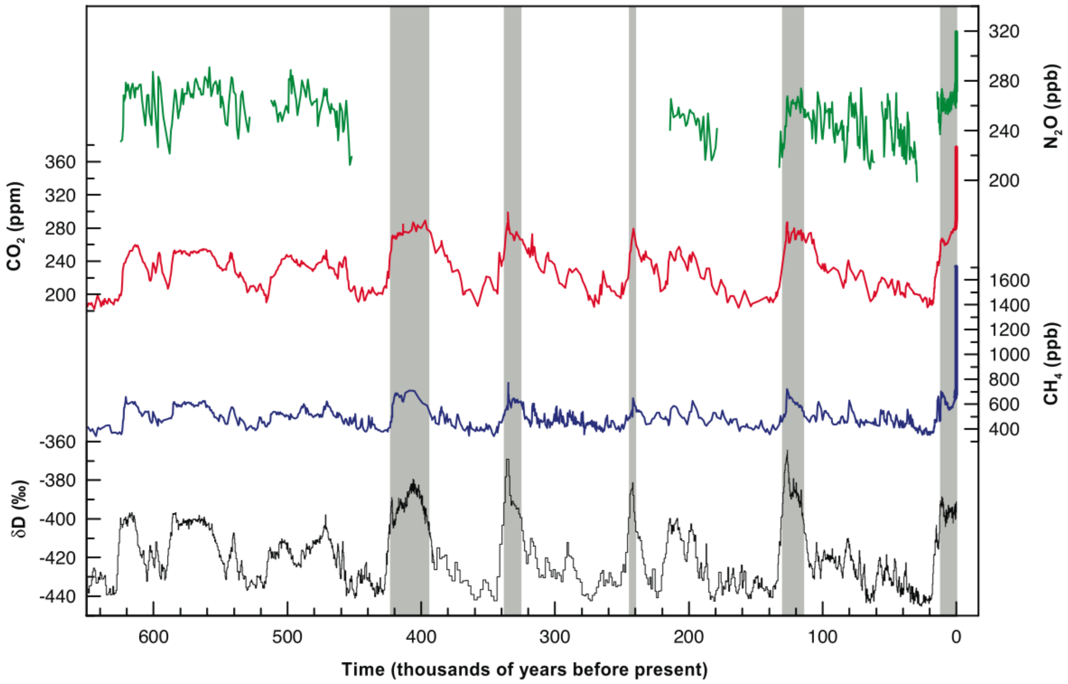

Fig. 2. Variation of GHG concentrations in the last 650,000 years. Shaded zones represent the warmed interglacial periods [3]

One may see that the present atmospheric concentrations of greenhouse gases are significantly greater than those existing during the last 650,000 years. This is a confirmation, on one hand, that the increase of these concentrations in the post-industrial period is not due to natural mechanisms and, on another hand, that these mechanisms are not able to counteract the respective increase. The increase rate of total radiative forcing of greenhouse gases ($\approx +1$ W m^{-2}) during the last 40 years, is at least 6 times greater than during any period from the last 2000 years before industrial era, such as it follows from the existing samples of ice cores with adequate time resolution.

Aerosols

Aerosols are liquid and solid airborne particles having a residence time of at least few hours, till 1-2 weeks. They can directly influence the climate by absorption and scattering of radiation and indirectly, by acting as condensation nuclei for clouds. The aerosol origin can be both natural (e.g., volcanic eruptions, wind carried dust) and anthropogenic (e.g., industry, transportations). Industrial aerosols mainly consisting in a mixture of sulphates, organic and black carbons, nitrates and industrial dust can be identified over many continental regions of the northern hemisphere. More accurate measurements in situ, from satellites and ground based specialized stations have enabled validation of global atmospheric aerosol models. These achievements provided, for the first time, the possibility to estimate the total radiative forcing of aerosols. Atmospheric aerosols result in a cooling effect of the climate.

3.2. Greenhouse effect

Greenhouse gases absorb the infrared radiation emitted by Earth surface, atmosphere (the same gases) and clouds. Thus, the molecules of these gases pass from the fundamental energetic states to the excited states and come back to fundamental states by emitting isotropically (therefore towards the Earth surface, too) the absorbed infrared radiation. The radiation emitted towards the Earth surface results in temperature increase of troposphere-Earth surface system. This is the greenhouse effect called in this way by analogy with the physical processes from a real greenhouse. Figure 3 shows that greenhouse effect has a significant contribution to Earth surface warming (324 W m^{-2}), as compared with the energy coming directly from the Sun (168 W m^{-2}).

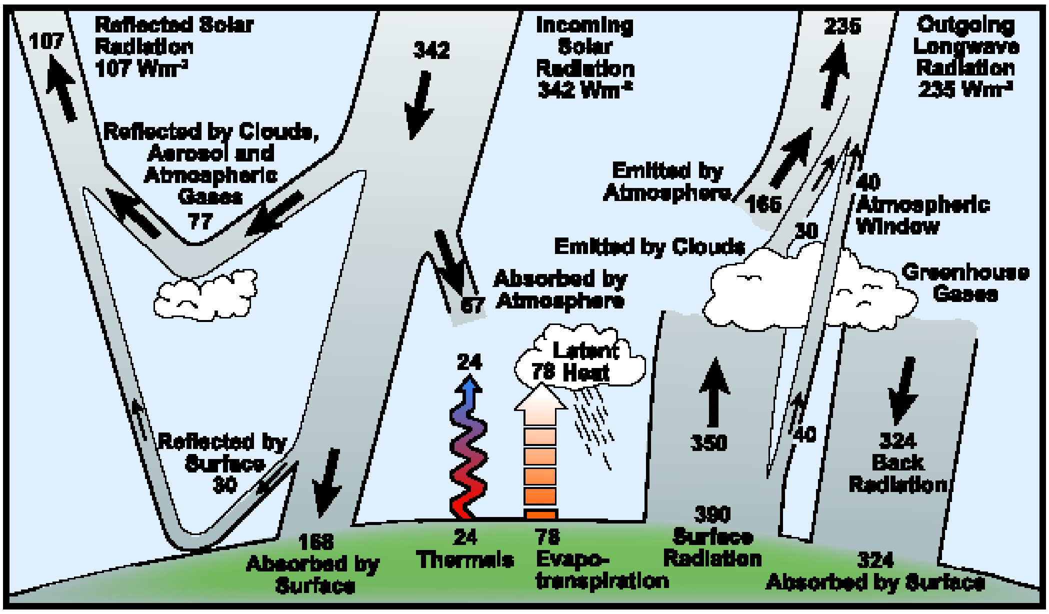

Fig. 3. Annual mean energy balance of the Earth [4].

The life exists due to the (natural) greenhouse effect because this one is warming Earth surface with 33°C. If this effect would not exist, the average temperature at the Earth surface would be –18°C, while due to this one is 15°C. The warming due to naturally occurring greenhouse effect is a condition for the presence of water under liquid state on Earth, which is the basis for biological life.

Anthropogenic component of the radiative forcing

In IPCC-2007 [3] is mentioned that the net effect (warming minus cooling) of human activities since 1750 was a warming one with a radiative forcing of +1.6 W m^{-2}. Cumulated radiative forcing due to the increase of CO_2, CH_4 and N_2O concentrations is +2.3 W m^{-2}. During the period 1995-2005, the CO_2 radiative forcing has increased with 20% being the greatest increase in a decade from last 200 years.

Variations of the tropospheric ozone determined by chemical anthropogenic substances has a contribution of +0.35 W m^{-2} and the direct radiative forcing due to the increase of the halocarbon concentrations is +0.34 W m^{-2}.

Aerosols of anthropogenic origin (sulphates, organic and black carbons, nitrates, industrial dust and soot particles) induce a total direct radiative forcing (radiation absorption and diffusion) of –0.5 W m^{-2} and an indirect forcing of –0.7 W m^{-2}, through the albedo of clouds (produced by aerosols like condensation nuclei).

Variations of terrestrial surface albedo due to land use changes (e.g., deforestation) and the deposition of black aerosols (coal burn-up residues) on snow generates a forcing of –0.2 W m^{-2} and +0.1 W m^{-2}, respectively.

Natural component of the radiative forcing

Solar radiation intensity has induced since 1750 a forcing of +0.12 W m^{-2}. Volcanic eruption determines a significant increase of the sulphate aerosol concentrations. A single such eruption can cool the climate at global level for a period of few years. The aerosols of volcanic origin disturb the energy balance in both stratosphere and troposphere in an episodic way, and many such events are revealed by the aerosol samples from ice cores and by air temperature time series. The last volcanic eruption which has caused a temporary cooling of climate at the global level, took place in 1991 (Mt. Pinatubo).

3.3. Observational data on climate change

Global warming is emphasized by following recent findings: (i) increase of the air and ocean average temperatures; (ii) decrease of the snow cover and ice on extended areas; (iii) increase of the average sea level. Figure 4 illustrates the variations of global average air temperature at the Earth surface, of sea level at the planetary scale as well as of snow cover in the Northern Hemisphere, during the period 1850-2005. The sea level is measured by means of tide gauge and satellites. The snow cover from the northern hemisphere refers to the state existing in March-April. All variations are relative to the averages corresponding to the period 1961-1990. Smoothed curves stand for decadal average values while circles show yearly values. The shaded areas represent uncertainty intervals estimated from the measurement uncertainties.

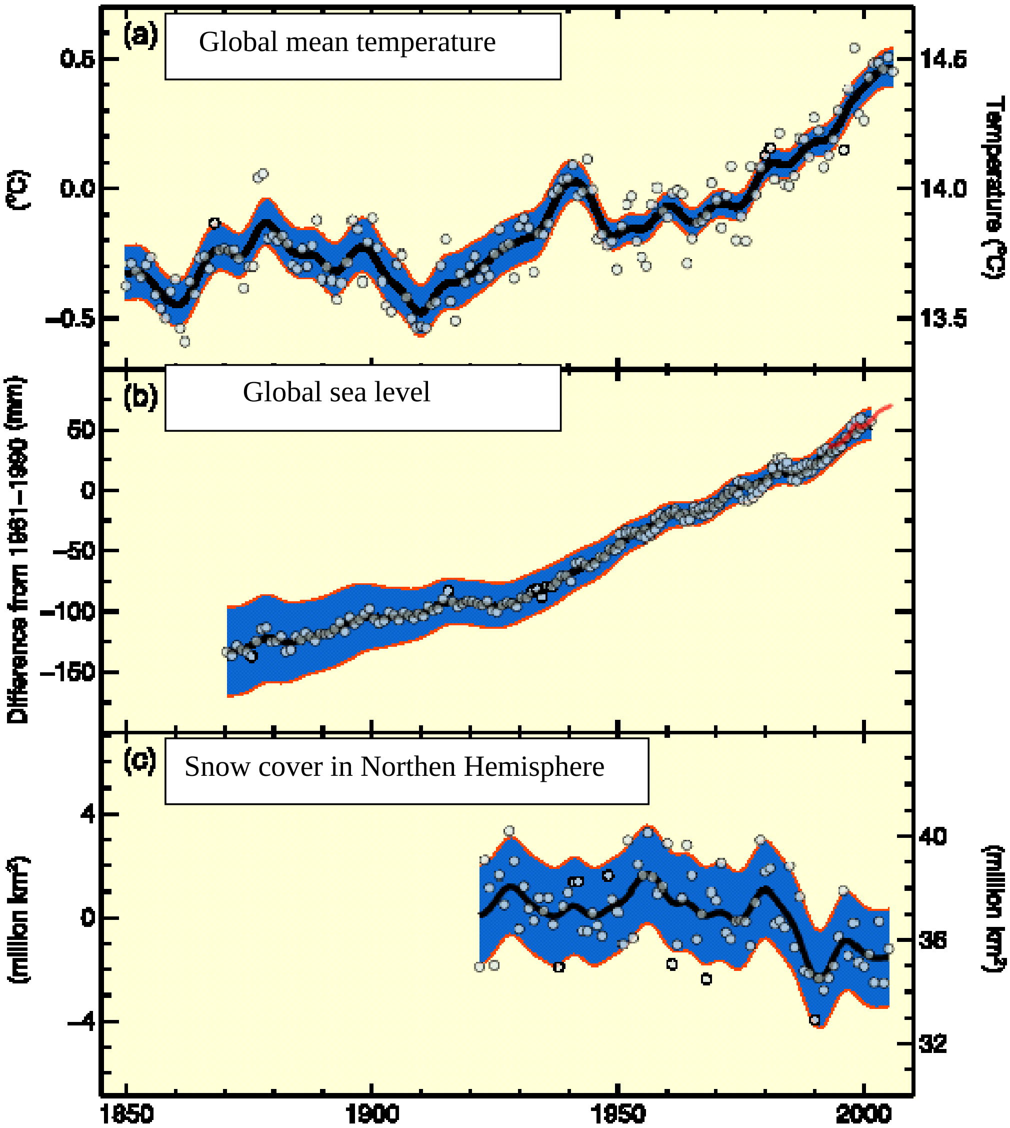

Fig. 4. Variations of temperature, sea level and snow cover in Northern Hemisphere [3].

Temperature increase

- 11 from the last 12 years (1995-2006) belong to the warmest 12 years from the history of air temperature measurements beginning of 1850: 1995, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006;
- in the last 100 years (1906-2005), the global air temperature has increased with 0.74°C;
- radiosounding and satellite data have indicated that the temperature of mean troposphere is characterized by warming rates similar to those of air temperature at the Earth surface;

- main part of the global temperature increase observed during the last 50 years is considered to be due to the anthropogenic emissions of greenhouse gases;
- according to paleoclimatic indicators, the warming from the last half of century is an unusual one for at least previous 1300 years;
- observations performed since 1961 prove that ocean average temperature has increased up to the depth of at least 3000 m and that ocean has absorbed more than 80% from the warm added to the climate system.

Sea level increase

- average global sea level has increased with a rate of 1.8 mm/an during the period 1961-2003. Increasing rate was greater, about 3.1 mm/year, during the period 1993-2003;
- Global sea level has increased with 17 cm in the century 20, partially due to snow and ice melting from many mountain zones and polar regions

Reduction of snow cover extent

- glaciers of mountainous regions and snow cover have diminished in both hemispheres. Melting of snow cover and glaciers has contributed to the sea level increase;
- ice cover from Greenland and Antarctic has contributed to sea level increase during the period 1993-2003, too.

Changes at continental, regional and ocean basin scales

- temperature in arctic zone has increased about two times more than the global average rate, in the last 100 years;
- satellite data since 1978 indicate that arctic sea ice extent diminished with 2.7% per decade, more pronounced rates being during the summer, 7.4% per decade;
- temperature at the upper part of permafrost from the arctic zone has increased with about 3°C since 1980;
- changes on extended areas of the precipitation amounts, ocean salinity(increase at the low latitude) and wind pattern;
- increase of the occurrence frequency of extreme events including heavy precipitations, warm waves and intense tropical cyclones;
- beginning with 1970 more severe droughts with longer durations on more extended areas have been observed;
- at middle latitude the western winds became more intense since 1960 in both hemispheres;
- extreme temperatures have been observed on extended areas during the last 50 years. Very warm days and nights became more frequent.

Paleoclimatic indicators

- Paleoclimatic indicators show that 120,000 years ago, the temperature in the polar regions was significantly greater (3÷5%) that the present one. The effect of this warming was the reduction of polar ice volume and the increase of sea level with 4÷6 m. This warming was determined by Earth orbit variations.

3.4. Climate modelling

A climate model describes from mathematical point of view the interactions among the climate system components taking into account the laws of mass, energy and momentum conservation. The most complex actual models are atmospheric general circulation three dimensional models coupled with planetary ocean.

The equations describing the space-time dynamics of climate system are non-linear (chaotic-deterministic system).

Climate models were validated on observational data existing from the beginning of instrumental measurements as well as on paleoclimatic data. An actual complex model includes following main components: atmosphere, earth crust, ocean and sea ice, sulfate aerosols, other aerosols, carbon cycle in climate system and atmospheric chemistry.

Figure 5 illustrates the time evolutions of measured and model simulated air temperature taking into account natural forcings (solar activity and volcanoes) and anthropogenic ones.

Measured data (black line) are decadal averages for the period 1906-2005 and are represented at the middle of each decade relative to average values for the period 1901-1950. Blue shaded bands indicates the 5-95% range for 19 calculations performed with five climate models using only natural forcings due to solar activity and volcanoes.

Red shaded bands indicates the 5-95% range for 58 calculations performed with 14 climate models making use of both natural and anthropogenic forcings. One may see that a significant warming of anthropogenic origin emerged in the last 50 years on all continents except for Antarctic.

The patterns of observed data including more pronounced warming on land than on ocean, are more accurately simulated only if the models take into account the anthropogenic forcing. Proper simulations of the temperature dynamics observed on each of six continents can be considered as credible arguments in favour of both the existence of anthropogenic influence on climate and the capacity of climate models to describe the climate dynamics [3].

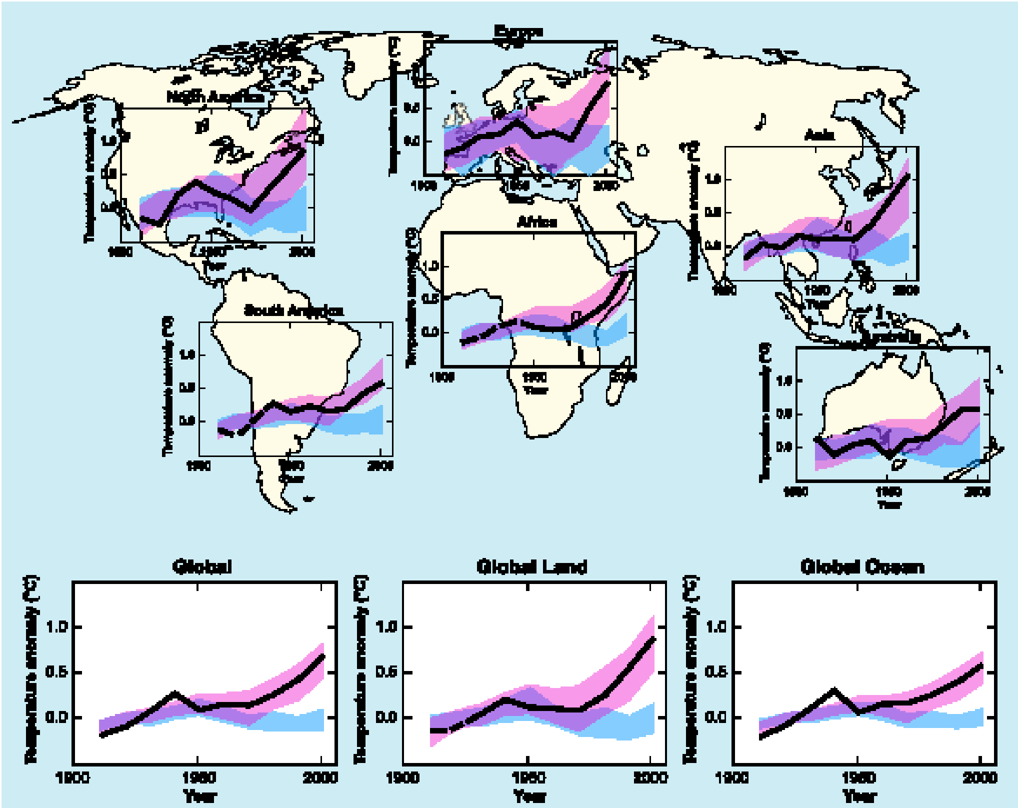

Fig. 5. Air temperature variation measured and simulated by climate models taking into account natural and anthropogenic forcings, in different geographical areas and at global level [3]

3.5. Future dynamics of climate

A climate model and scenarios of greenhouse gas emissions underlay the prediction of future dynamics of the Earth climate.

The climate models validated on the past and present climate parameters allow for a plausible anticipation of the future time evolution of the climate for various scenarios of the society development which result in different patterns of greenhouse gas emissions.

The main scenarios of society development used in the climate prediction studies are known as A1B, A2, B1 and are based on following assumptions:

- A1B
  - rapid economic development,
  - increase of population until 2050 and afterwards it decreases,
  - introduction of new and efficient technologies,

- B1
  - global economic development,
  - increase of population until 2050 and afterwards it decreases,
  - introduction of efficient technologies which protect the environment, too,
- A2
  - economic development only at regional level,
  - continuous increase of population,
  - much more slow introduction of technologies.

CO_2 emissions (in Pg C/y; 1 Pg $=10^{15}$ g) corresponding to the development scenarios, at the level of 2100, are: 13.4 (A1B); 29.09(A2); 4.23(B1) [2].

Figure 6 illustrates the possible evolution of mean surface air temperature at the global level, for the three mentioned scenarios.

It is expected that that mean air temperature to increase at a rate equals to 0.2°C per decade during the next two decades.

The continuation of the greenhouse gas emissions at the present rate or greater will result in an intensification of the global temperature increase during the 21^{st} century.

The most credible estimate of the temperature increase beginning with 1980 until the end of the 21^{st} century varies between 1.8°C (1.1°C–2.9°C) and 4°C (2.4°C–6.4°C) for the scenarios analyzed by IPCC.

The increase of 1.8°C is associated with the B1 scenario and the increase of 4°C with A1FI scenario which differs of A1B by an intensive use of the fossil fuel producing significant emissions of greenhouse gases.

It is expected that the greatest warming be above land and at high northern latitude and the lowest warming above the southern ocean and in the northern part of the Atlantic Ocean.

As regards the sea level, the models anticipate an increase varying between 18 and 59 cm until the end of the 21^{st} century.

The climate modeling experiments indicate that the limitation of the greenhouse gas emissions at the level of the year 2000 would reduce the increase tendency of the mean air temperature at a rate of $0,1^{0}$C per decade, mainly , due to the slow response of the ocean.

The warming results in a reduction of the CO_2 absorption capacity of the ocean, thus increasing the CO_2 fraction remaining in the atmosphere.

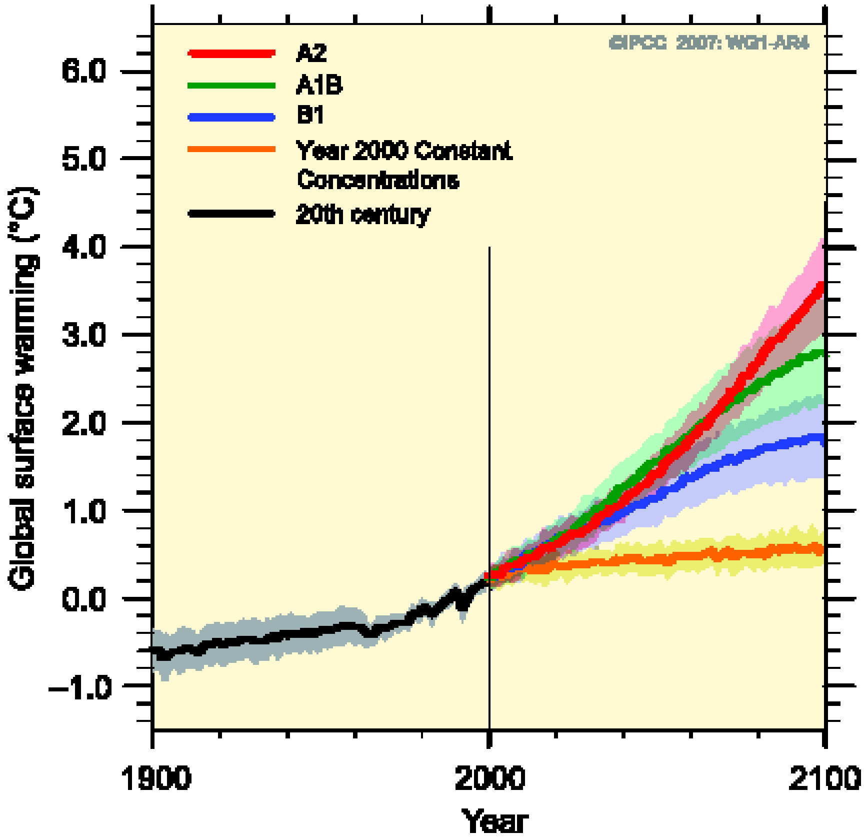

Fig. 6. Multi-model simulation of the mean temperature increase at the global level for the scenarios A1B, A2, B1 [3].

4. Impacts on terrestrial ecosystems

4.1. Observed impact at the global level

The global observations since 1970 show that the warming of anthropogenic origin has had a discernable influence on many physical systems(snow layer, ice, permafrost coastal zones, hydrological basins) and biological ones (terrestrial, marine). From about 29.000 time series of observational data which make evident significant modifications in many physical and biological systems, more than 89% are consistent with the climate change impact due to the global warming. The modelling studies of climate change impacts on certain physical and biological systems emphasize the fact that observed data are in a significantly better agreement with modelling results when both forcings, natural (sun activity and volcanic eruptions) and anthropogenic (greenhouse gases and aerosols) are taken into account, as compared with the case when only the natural forcing is considered. In what follows, examples of changes induced by the climate change will be presented:

- increase of soil instability in the regions with permafrost (possible abrupt climate change);
- increase of dimensions and number of the glacial lakes;
- changes in certain ecosystems in Arctic and Antarctic zones (e.g. changes in plant and animals on polar sea ice);
- loss of land and plantations in coastal zones due to sea level rise;
- the warming of lakes and rivers worsens water quality;
- events specific to the spring take place more early: leaf appearance (with 2 days per decade), bird migration;
- shifting of plant and animal species towards the pole and higher altitude: the analysis of data on last 45 years for 99 species existing in North America and Europe has shown that the living territory for birds, butterfly and alpine grass has shifted towards north in average with 6.1 km/decade or at higher altitude with 6 m/decade, [5].

4.2. Impact prediction at the planetary level

The impact prediction requires:

- a climate scenario (monthly mean temperatures and precipitations, solar radiation intensities) generated by a climate model for a given scenario of greenhouse gas emissions;
- a prediction model for the ecosystem specific quantities(e.g. cereal crop yield, tree species and biomass, water resources in the hydrological basins) using as input data the physical parameters of the climate scenario.

The following impacts on different sectors have been anticipated:

- *Water resources* : the available water resources will increase at tropics and high latitude and will diminish at mean and low latitude where the droughts will be more severe;
- *Ecosystems*: about 20÷30% of plant and animal species have a high risk to disappear if the global mean air temperature will increase with 1.5÷2.5°C. If the temperature increase will be about 4°C the biosphere tends to become a clear CO_2 source;
- *Coastal zones*: for a temperature increase of ~5°C the coastal zones at the global level will diminish with about 30% as compared with the present area;
- *Agricultural ecosystems*: at low latitude the crop yield will decrease even for small temperature increases (1÷2°C); at mean and high latitude the crop yield will increase for a temperature rise of 1÷3°C and decrease if the temperature rise will exceed this interval;

- *Human health*: the increase of the number of causes which could induce human diseases. Amongst these causes could be the more pronounced radiological impact of increased air radioactivity due to greenhouse effect [8], the greater number of victims due to extreme events (heat waves, floods, droughts).

5. Climate change in Romania during the 20th century

Variation of temperature and precipitations

The study of the annual mean temperature at the country level (14 meteorological stations) makes evident an increase of about 0.3°C during the period 1901-2000 (Figure 7).

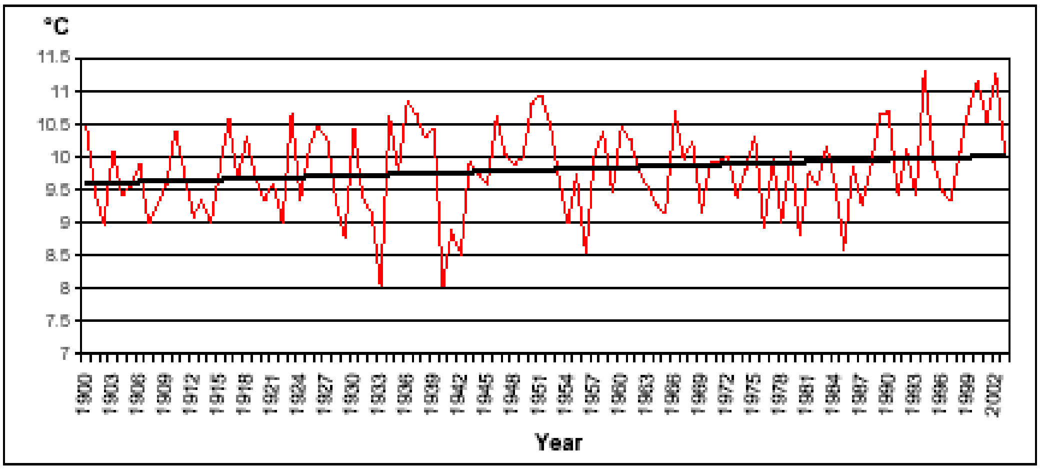

Fig. 7. Trend of the annual mean air temperature at the country level over the 20th century[7].

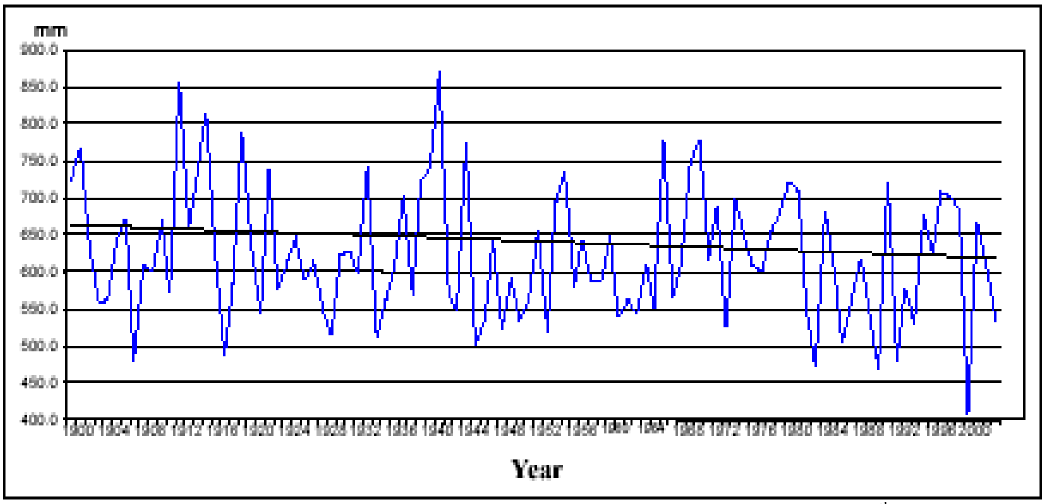

Fig. 8. Trend of the annual precipitation amount at the country level over the 20th century [7].

At the local level, the variations of annual mean temperature have positive (in extra-carpathian zones reaching 0.8°C) and negative values (Figure 9).

Fig. 9. Linear trend of the annual mean air temperature (°C) at the local level over the 20th century [6].

The seasonal means render evident a significant warming during the winter season (1.9°C at Filaret station), but in the western part of the country a slight tendency of cooling during the autumn season has been observed [7].

During the 20th century, the annual precipitation quantities at the level of whole country had a decreasing tendency (Figure 8), but at the local level both tendencies, increasing and decreasing, have been emphasized (Figure 10), [6, 7].

6. Possible impacts of climate change in Romania during the 21st century

Detailed scientific information regarding this subject is contained in the work *"National Country Study on climate change in Romania. Element 2: Vulnerability Assessment and Adaptation Options"* [9] worked out with assistance of USA government in the frame of the "*Country Study Program*".

The expert reviewers of the study have been scientific personalities from universities and research centres from USA and Romania. The study results are presented in different publications [6, 10]. Also, a part of information presented below was taken from [7, 11].

Fig. 10. Linear trend of the annual precipitation amount (mm) at local level over the 20th century [6].

Working out of climate scenarios

For this purpose the results of the following climate models with present CO_2 concentration ($1\times CO_2$) and a double one ($2\times CO_2$) were used: GISS (Godard Institute for Space Studies, USA); GFDL (Geophysical Fluid Dynamics Laboratory, USA); UK89 (United Kingdom); CCCM (Canadian Climate Center Model); HadCM3 (Hadley Center, UK).

Validation of the models (for $1\times CO_2$) has been performed on the present climate of the geographical area where Romanian is situated as well as at the level of Romania's territory. CCCM and GISS describe the best the climatic parameters in Romania.

Referring to the temperature the models point out the following variations under the double CO2 concentration:

- CCCM, an increase between 2.8°C (December) and 4.9°C (March);
- GISS, an increase between 2.4°C (June) and 5.8°C(February);
- HadCM3, an increase of 2°C during the winter and a more pronounced one during the summer (3.5°C in the northern part of country and 4.3°C in southern part).

With regard to precipitations, the results are different from one model to another one:

- CCCM indicates o slight decrease of precipitations during the warm months and an increase during the cold ones (October- February);
- GISS anticipates an increase of precipitations in all months (except for September), the greatest being in October (40%);
- HadCM3 predicts an increase of precipitations during the summer and non-significant variations during the winter.

Impact on agricultural ecosystems

As regards the wheat crops, the crop growth simulation models predict an yield increase of 21% for CCCM climate scenario and 15% for GISS climate scenario; the negative effect of temperature rise determining the shortness of the vegetation period is counterbalanced by the positive effect of the CO_2 doubling on photosynthesis process.

As far as the maize crop is concerns, the results depend on model, in case of CCCM climate scenario the production decreases with 4÷15%, depending on the considered place, and in case of GISS climate scenario the yield increases up to 18%. The climate scenario generated by HadCM3 results in a reduction of wheat yield with 5÷20 % at the level of the year 2020 and with 10÷39% in 2050 [7].

Impact on forest ecosystems

Under the climate conditions anticipated by the climate models, the present forest zones will shift toward higher altitude and in low zone will grow a vegetation specific at present to the regions situated beyond the southern boundary of Romania. GFDL scenario anticipates for the plain and hill zones a sensible growing of the basal area and total biomass up to 2040 and a significant decrease as compared with the present state, till 2070, caused by the temperature rise and precipitation diminishing. For the mountain regions the scenarios indicate non-significant changes as against the present vegetation.

Impact on water resources

The climate change can cause the following modifications in the hydrological cycle components:

- reduction of thickness and duration of the snow cover;
- decrease of the river flow rate due to precipitation diminishing;
- earlier appearance of the high floods and reduction of mixed spring floods (snow and precipitation).

The analysis based on climate scenarios indicates that Siret and Tarnave basins are not vulnerable to climate change. As far as the Arges river is concerned, the assessments anticipate a vulnerability since 2020 because of the flow rate reduction of the supplying rivers for all irrigation standards.

7. International agreements regarding climate change

- *United Nations Framework Convention on Climate Change (UNFCCC)*

This international agreement was signed during the world meeting held in Rio de Janeiro (June 1992). Romania has ratified the Convention in 1994.

The main commitments of the parties in Convention are the presentation of periodic National Communications which have to contain:

- a national inventory of anthropogenic emissions by source and removed by sinks of all greenhouse gases not controlled by the Montreal Protocol;
- detailed description of the measures and policies adopted to reduce the anthropogenic emissions;
- assessment of climate change impacts, vulnerabilities and adaptation measures;
- research and systematic observations;
- education, training and public awareness.

Until now Romania has presented 4 national Communications [6, 7].

- *Kyoto Protocol (1997)*

This protocol makes provision for the reduction of the greenhouse gas emissions with at least 50%, as compared with the level of year 1990, during the period 2008-2012. For Romania a reduction of 8% as against the 1989 is stipulated.

- *International Panel on Climate Change (IPCC)*

This scientific body has been established in 1988, together by WMO and UNEP (United Nations Environmental Program), both UN (United Nations) organizations, with the following scientific tasks:

- assessment of the scientific, technique and socio-economic knowledge in order to understand the scientific basis of the climate change due to human activities;
- potential effects resulting from climate change;
- adaptation and mitigation options.

IPCC has 3 Working Groups: the WG I is dealing with the state of scientific knowledge regarding the climate change, the WG II, with impact assessment, vulnerability and adaptation of natural systems and socio-economic ones and the WG III, with the reduction measures of the greenhouse gas emissions. Till now, 4 scientific reports have been carried out by IPCC: in 1990, 1995, 2001, 2007 [1].

Nobel Prize as an international recognition for IPCC

In 2007 IPCC was honored with Nobel Peace Prize with the following justification: *”for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundation for the measures that are needed to counteract such change”* [13].

Conclusions

Present atmospheric concentration of carbon dioxide and methane exceed by far the concentrations of the respective gases existing during the last 650.000 years, which have been determined from ice cap samples. Use of fossil fuel, agriculture and changes in land use were the main causes of the increase of greenhouse gas concentrations during the last 250 years. The contribution of the solar radiation to the global warming is significantly less than that of greenhouse gas effect intensification during the industrial period. Land surface air temperature is continuously increasing during the last period, thus, 11 of the last 12 years are the warmest since the temperature observations started (1850). The direct consequences of the global warming are discernible at planetary level: reduction of the ice caps and snow cover, temperature increase of the high part of permafrost, sea level rise at global level. The warming from the last half of century cannot be explained by the radiation forcings due to external natural factors. The climate models have reproduced with adequate precision the temperature time series measured on the six continents. For the end of the 21st century, the models anticipate a temperature increase varying between 1.8°C and 4°C and a precipitation increase at tropics and high latitudes. The impact on different ecosystems show that there is the disappearance risk for many plant and animal species, the lost of a significant percent of the coastal zones, the increase at certain latitudes and decrease at others, of agricultural crop yield, the increase of causes which may affect the human health. In Romania the annual mean temperature, at the country level, has increased with 0.3°C during the 20th century, but at local level there were the increases up to 0.8°C, and decreases as well. In what concerns the precipitations, at the country level there was a decreasing tendency, but at the local level there were both increasing and decreasing tendencies. In the 21st century, in Romania, the following potential impacts of climate change are anticipated by models: an increase of the wheat crop yield and contrary tendencies, depending on model, for maize crop yield; change of distribution of the present forest zones by migration towards higher altitudes and replacement of the low zone forests with vegetation that is at present specific to the geographical zones located beyond the southern boundary of Romania; vulnerability of some water resources, as it is the case of Arges river basin, particularly, beginning with 2020, due to flow rate decrease of the river courses.

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