Krisztina Hegedüs

# 1. Scenarios and roots of climate change

There have been more and more words about climate change and global warming in the last few decades. But what do we really understand them? Is it logic that the climate change derived by human behaviour or is it an independent process of nature that occurs no matter how we try to stop it? Is the climate change a global warming or global cooling method? We know for sure that something is changing around us and we heard a million times that if we exhaust the resources of the Earth than we will cause permanent and irreversible damage.

In the first part of this chapter we will see the facts. There will be a few different perspectives from a few different institutions publication about the methodology of measurement on climate change. In the second part of the chapter we shall distinguish how big part of the changes may be the results of the human activities, or is it even possible to distinguish what causes the climate change. In the last part of this chapter the IPCC's scenario will be explained on the case if the process of the climate change can not be stopped, or if human kind does not do anything for mitigation.

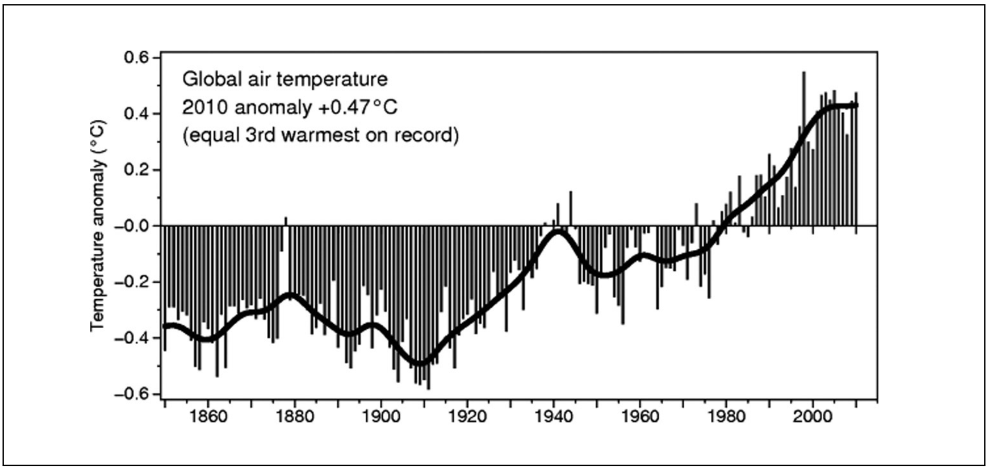
## 1.1 What are the facts?

Usually when we hear the term "climate change" global warming comes up first. But is it so obvious? Because some ones argue that it is even a global cooling method going on. The climate change is not only the change in the temperature of the air, but its side effects, too. For example with the increase of the average temperature, the ice caps melt which modifies the water temperature, which leads to oceans circulation upheaval. When volume and distribution of precipitation changes we have to face with an increasing number of extreme phenomena. Naturally, as the regions of the World have different climate, the climate change affects these regions differently. In this chapter there will be a look at statistical facts about how our climate changes and the methods of its measurement.

### *Air temperature*

According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report the global surface air temperature has been the highest in 1998 and 2005 since 1850 (we have reliable data since 1850). The surface temperature has increased from 1950 even faster. The total surface air temperature has increased from 1850-1899 to 2001-2005 is 0.76°C ± 0.19°C. The period 2001-2010 was 0.2°C warmer than the previous decade (1991-2000). Almost all years of this decade is in the 10 warmest years from 1850, the only exception is 2008, but still the 12$^{th}$ warmest from 1850. Figure 1 concludes these data. It seems obvious looking at this time series that it is a warming period since 1850. However the average temperature for the period 1901-2000 was 13.9°C, which means that the change was from 13.5°C to 14.3°C.

**Figure 1** Global air temperature for the period 1850-2010




The time series shows the combined global land and marine surface temperature record from 1850 to 2010.
*Source:* Climatic Research Unit (CRU) at the University of East Anglia
http://www.cru.uea.ac.uk/cru/info/warming/

For the whole picture, we have to add some different opinion about the size of the warming. Those who are sceptic about the climate change usually add that the temperature in the 1850s was the coldest in last 8000 years (http://www.climatecooling.org/). So if we compare the data to that period we might get false information about today's warming. Also there are other opinions claims that temperatures in the Bronze Age, the Roman Age and the Medieval Period were higher than today. Furthermore they say that the period between 1400-1800 called "The Little Ice

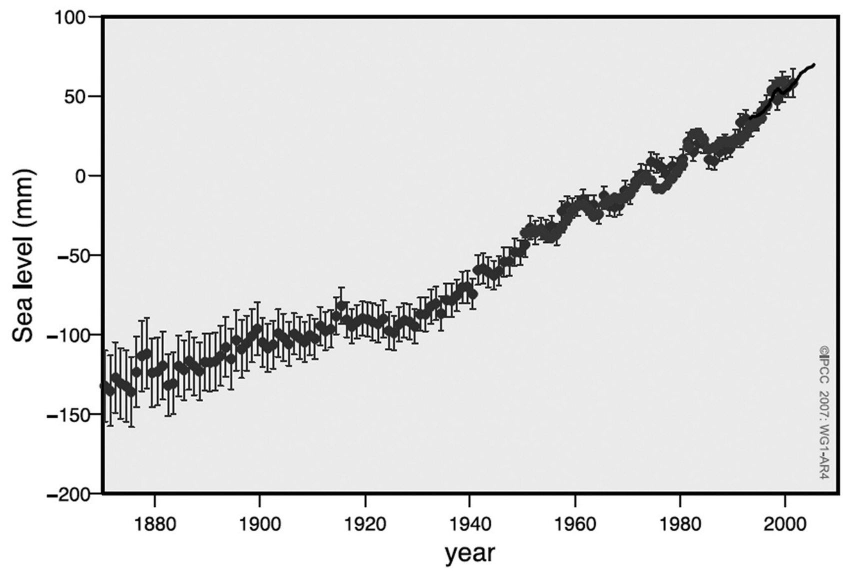
Age", the temperatures back than were several degrees cooler and the warming started in the 1700s, before the human contribution to the CO2 level started to grow (Pohanka; 2010)

However there are studies that declare, that a 0.76°C ± 0.19°C change may seems small, but it is sizeable, when we say that the average rate of warming in the last 10000 years (from the end of the last glaciations) was about 5°C, so 0.05°C per century, and this 5°C warming caused the huge transformation of the Earth surface, such as the disappearance of massive ice sheets and a sea level rise of about 120 meters (Pittock; 2009).

### *Sea level*

There are several problems with the estimation of the rise of sea level. Since about 1950 it has been estimated from tide gauge data, but these data shows the changes in the water level and vertical land movement also, therefore these two components have to be separated to estimate the sea level. Another problem with the measurement of the change of sea level is that there are much more tide gauges in the Northern Hemisphere (mainly near North America, Europe and Japan), so the measuring instruments are not equally distributed in the oceans, and this can affect the results. Since1992, data can be measured with satellite altimetry, which gives more reliable data (IPCC; 2007). Even together with those measurement problems, the fact that the global sea level have risen over the past 100 years is not questioned. The estimated change is about 10-20 cm rise during the last century (Raper; 2000). It is approximately the same volume as it was declared in another widely used study in 2009. In that study, the authors found 1.61 ± 0.19 mm/year sea level rise over the past 100 years (Wöppelmann et al.; 2009). Both studies are close to the IPCC estimates shown by Figure 2 Also there are some misunderstandings in the origin of the rising level. The main reason of the rise is the thermal expansion of the oceans, which changes the net mass balance of glaciers and ice sheets. However the melting of the sea ice and the floating ice shelves do not affect the sea level directly, because they already displace the water and the form of the water (solid or liquid) does not matter (Raper; 2000).

**Figure 2** Sea level rise[1]




*Source:* IPCC; 2007 p. 60

In case of sea level rise, we have to mention ice melting. The biggest land covered by ice is Antarctica in the South Pole, with about 90% of the world's ice. The ice cover in Antarctica is an average of 2,133 meters thick. The average temperature is about -37°C there, so worry on ice melting is unnecessary, but if the hole ice coverage from Antarctica would melt, the sea level would rise by approximately 61 meters (Brain; 2011).

On the other hand ice in the North Pole is not that thick as ice in the South Pole, but that ice land is floats on the Arctic Ocean, so it would not raise the sea level even if it would melt.

At last there is an important amount of ice covering Greenland. If all the ice would melt in Greenland, it would raise the sea level with 7 meters. The problem is with Greenland that it is nearer to the equator that Antarctica, therefore the temperature there is higher, so there is higher likelihood that the ice will melt (Brain; 2011).

[1] Annual averages of the global mean sea level are based on reconstructed sea level fields since 1870, tide gauge measurements since 1950 (thicker line) and satellite altimetry since 1992 (black line). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals.

So Antarctica and the Greenland ice melt is what IPCC defines as the very likely contribution to the higher sea level. However, measuring the actual level is not easy. There are some arguments about how it should be estimated. IPCC estimates that the Greenland ice melt contributed to the sea level rise by 0,14 - 0,28 mm/year between 1993-2003. The uncertainties are even bigger in the case of Antarctica, because there might be observed growth and shrinkage, too, in the ice thickness. Thus, Antarctica's contribution to the sea level is between -0,27 to +0,56 mm/year between 1961-2003 (IPCC; 2007).

According to the Arctic sea ice it has shrunk annually average by about 2,7 ± 0,6% per decade since 1978. Naturally the summer extent is larger. It is about 7,4 ± 2,4% per decade (IPCC; 2007). Table 1 concludes all the sources of the sea level rise and estimated contributions.

**Table 1** Observed rate of sea level rise and estimated contributions from different sources2

| Source of sea level rise | Rate of sea level rise | |
|---|---|---|
| | **1961-2003** | **1993-2003** |
| Thermal expansion | 0.42 ± 0.12 | 1.6 ± 0.5 |
| Glaciers and ice caps | 0.50 ± 0.18 | 0.77 ± 0.22 |
| Greenland Ice Sheet | 0.05 ± 0.12 | 0.21 ± 0.07 |
| Antarctic Ice Sheet | 0.14 ± 0.41 | 0.21 ± 0.35 |
| Sum of individual climate contribution to sea level | 1.1 ± 0.5 | 2.8 ± 0.7 |
| Observed total sea level rise | 1.8 ± 0.5? | 3.1 ± 0.7? |
| Difference (Observed minus sum of estimated climate contributions) | 0.7 ± 0.7 | 0.3 ± 1.0 |

*Source:* IPCC; 2007 p.7

## *Extreme weather events*

Extreme weather events are the phenomena that have the largest impacts on human life by causing a big amount of damage in economic cost and human life. We keep on feeling that there are more of these events now than it was in the past. But is it true perception? First of all we need to define what could be called extreme weather event. There is no generally accepted definition since extreme weather events are easy to recognize, but difficult to define. The concept of extremeness is highly

[2] 'a' data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry

depends on the circumstances and the terms "severe," "rare," and "extreme," are often used as synonyms is contexts of weather events. We call something a severe event if the phenomenon creates huge losses either in human life, financial capital or environmental disaster (loss of species). Rare events have low probability of occurrence. (Because of their rareness, humans can not well adapt to them. Because of the huge vulnerability these events usually accompanied with huge losses). Extreme events are events that have extreme values of certain important meteorological variables. Events like these are not necessarily causing high volume of damages, but still result measurable costs, usually, because of the extreme values of certain meteorological variables, like large amounts of precipitation (e.g., floods), high wind speeds (e.g., cyclones), high temperatures (e.g., heat waves), etc. Extreme is generally defined as taking maximum values above pre-existing high thresholds (Diaz-Murnane; 2008).

With these definitions we should try to collect the events that can classify as extreme weather event: Tropical cyclones and hurricanes, Extratropical cyclones (or windstorms), Convective phenomena like: tornadoes, waterspouts, and severe thunderstorms (these phenomena can described by extreme local wind speeds and precipitation amounts on horizontal scales of up to about 10 km), Mesoscale phenomena like polar lows, mesoscale convective systems, and sting jets (these features can described by extreme wind speeds and precipitation amounts on horizontal scales from 100 to 1,000 km), Floods of rivers, lakes, coasts, Drought (meteorological drought is defined usually on the basis of the degree of dryness in comparison to some "normal" or average amount and the duration of the dry period), Heat waves (periods of exceptionally warm temperatures can have profound impacts on human health and agriculture, duration is a key component determining the impact), Cold waves/spells (for example: extremely cold days or a succession of frost days with minimum temperatures below 0,8°C), Fog (extremely low visibility has major impacts on various sectors such as aviation and road transport) (Diaz-Murnane; 2008).

The frequency and the changes occurred from global warming is hard to measure when it comes to extreme weather event. Even IPCC gives us likelihoods[3] instead of concrete statistics. There are several uncertainties due to limited amount of data. Although there are strong likelihoods that there were significant changes after 1960 and according to IPCC the changes most likely going to grow during the twenty-first century.

[3] Likelihood terminology that IPCC uses: *Virtually certain* > 99% probability, *Extremely likely* > 95% probability, *Very likely* > 90% probability, *Likely* > 66% probability, *More likely than not* > 50% probability, *About as likely as not* 33 to 66% probability, *Unlikely* < 33% probability, *Very unlikely* < 10% probability, *Extremely unlikely* < 5% probability, *Exceptionally unlikely* < 1% probability

**Table 2** Changes in extreme events[4]

| Changes in phenomenon | Confidence in observed changes (post-1960) | Confidence in projected changes (during the twenty-first century) |
|---|---|---|
| Higher maximum temperatures and more hot days over nearly all land areas | Very likely | Virtually certain |
| Higher minimum temperatures, fewer cold days and frost days over nearly all land areas | Very likely | Virtually certain |
| Reduced diurnal temperature range over most land areas | Very likely | Virtually certain |
| Intense precipitation events, (frequency or proportion of total rainfall) | Likely | Very likely |
| Increased risk of drought in mid-latitude continental areas | Likely | Likely |
| Increase in tropical cyclone peak wind intensities and rainfall, with lower central pressures | Likely in some regions | Likely |
| Extreme extra-tropical storms: increased frequency/intensity and polewards shift | Likely | Likely |
| Coastal storm surges and flooding more severe (due to both highermean sea level and more intense storms) | Very likely due to sea-level rise last century | Virtually certain |

*Source:* Pittock; 2009 p

## 1.2 Regional differences

After we saw the aspects of the global climate change, it could be useful to see the differences between the regions. As the climate change does not affect the regions the same way, for example there could be regions where the increase of temperature is less observable than in other areas. Each area must face its own problem. The coastal areas can worry about the sea level, in some areas the precipitation will rise, while in other areas the desertification could be observed. How will the climate change affect in different regions, and what is the biggest individual problem of them? Let's see it region by region, but also in Figure 3 we can see all regions.

### *Europe*

In Europe the weather is warming above the global average. It was +0.90°C for the period between 1901 and 2005. The largest warming is the winter in north Europe and the summer in the south. The north became more like the south as it could have

[4] IPCC 2007 report estimates of confidence in observed changes during the twentieth century, and projected changes in the twenty-first century, for extreme weather and climate events

a Mediterranean climate, while in the south drought season is increasing (Hopkin; 2005). Thus, annual precipitation is increasing in the north and decreasing in the south, while in the central region precipitation is increasing in the winter, but decreasing in the summer. Heat-waves are likely to increase in the south. Snow season is likely to shorten and snow depth is likely to decrease in whole Europe (IPCC; 2007).

### *North America*

The annual mean warming in North America is likely to be above the global average. The largest warming is the winter time in the northern region and in the summer in the southwest. The winter temperature is increasing more that the global average in the northern part of North America. More precipitation expected in Canada and the northeast US, but less precipitation will occur in the south. Snow season and the depth of the snow is decreasing in most part of North America, except in Canada, where the snow depth is increasing (IPCC; 2007). In the northern part of the continent the melting Antarctica ice causing problems in the ecosystem.

### *South America*

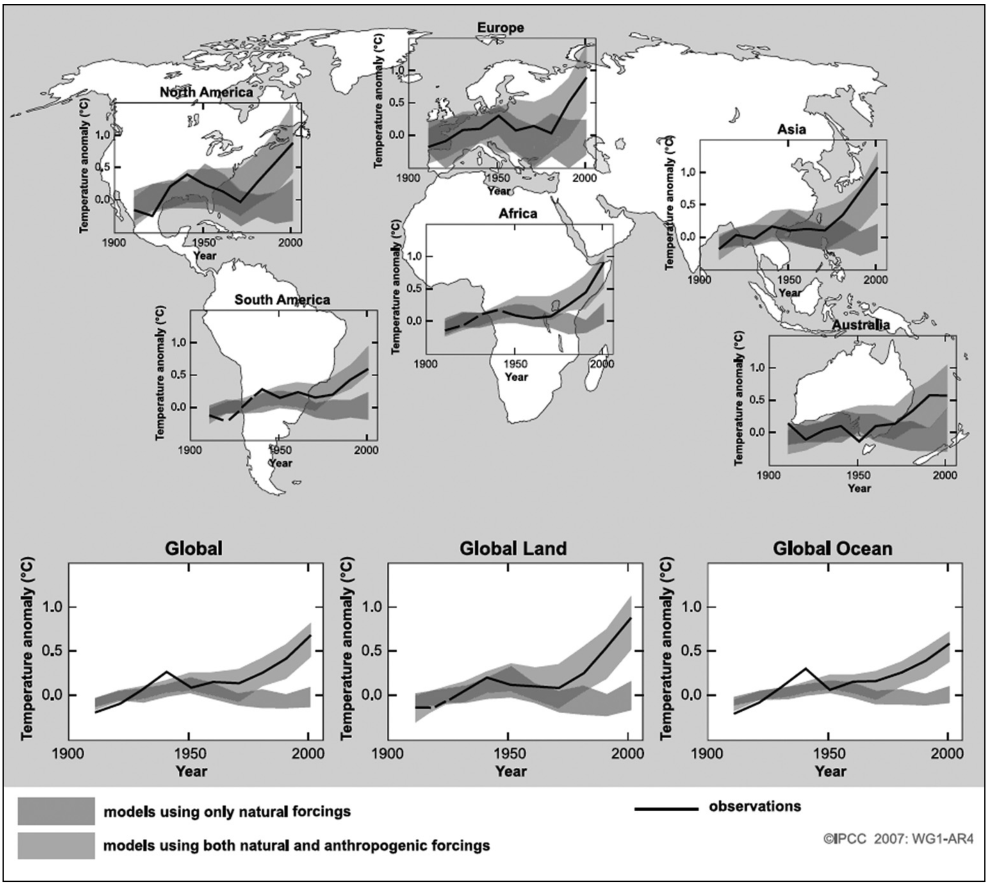
In this continent the global warming and the temperature growth is likely to be so much as the global average in the world. The warming will be the largest in the area of the Amazonia and Mexico. The annual precipitation will decrease in Central America and in the southern Andes, however it may vary highly locally, because of the atmospheric circulation in mountainous areas. Nevertheless, tropical storms can contribute a significant fraction of the rainfall in the hurricane season in this region. Thus, it might be modified by the possibility of increased rainfall in storms (IPCC; 2007).

### *Asia*

According to IPCC all around Asia, it is very likely to warm much above the global average during this century. Only Southeast Asia will likely to warm as much as the global average, so less than other Asian regions. Together with warming, more and longer lasting heat-waves appear mainly in East Asia. It is also likely to have fewer cold days. Precipitation is very likely to increase in the winter season, in almost all parts of Asia, while summer precipitation increases everywhere in Asia except the Central Asia. The intensity of rain will likely to change. Extreme rainfalls and winds associated with tropical cyclones are expected more frequently in East, Southeast and South Asia (IPCC; 2007). In Siberia the permafrost zone melting could cause problems. The Asian landmass has a huge impact on the climate cycle through ocean circulation. The huge rivers in Asia supply fresh water to the Arctic

Ocean, which is the main source of the cold heavy water that sinks down and drives currents around the world (Hopkin; 2005). So if these sources warm up that would be a problem not just for Asia, but the whole planet.

**Figure 3** Global and Continental Temperature Change[5]




Source: IPCC; 2007 p.11

[5] Comparison of observed continental- and global-scale changes in surface temperature with results are simulated by climate models using natural and anthropogenic forcing. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901 to 1950. Lines are dashed where spatial coverage is less than 50%. Deeper grey shaded bands show the 5% to 95% range for 19 simulations from 5 climate models using only the natural forcing due to solar activity and volcanoes. Lighter grey shaded bands show the 5% to 95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcing.

### *Africa*

The African continent is very likely to warm during the next century with higher intensity than the global average. The drier subtropical regions warm above the moister tropic. Precipitation is likely to decrease in northern Sahara, Mediterranean Africa, but it is likely to increase in East Africa. That means that the world's largest desert, the Sahara can widen and the desertification of that region can go further. Meanwhile the increase of tropical rainfall can amplify the problem of malaria, as the mosquitoes that carry the disease likes rainy weather. So, more rain means more mosquitoes (Hopkin; 2005).

### *Australia and New Zealand*

In Australia the warming is likely to be similar to the global average. There is less warming expected in the south, especially in winter. In New Zealand, the rise of global temperature is likely to be under the global average. However the frequency of extreme high daily temperature increases both in Australia and New Zealand, and lower frequency of cold extreme temperature predicted. Precipitation decrease is expected in South Australia, on the other hand increase in precipitation is likely in South New Zealand. Extreme intensity of daily precipitation increasing in most areas, excluding the areas where significant decrease of rainfall predicted. In southern areas of Australia there are likely to be more drought season (IPCC; 2007).

### *Polar Regions*

Both the Arctic and the Antarctica are likely to warm in this century.

The Arctic is very likely to warm above the global average mainly in winter and the smallest warming expected during summer. Precipitation in the Arctic is very likely to increase mainly in winter. The Arctic ice is also very likely to decrease. However it may not affect the sea level, but it is uncertain how it is going to change the circulation of the Arctic Ocean (IPCC; 2007).

The Antarctica is very likely to warm during this century. The Antarctica is in the center of the scientist attention, it has a protected wilderness status, and it could influence the world's climate both positively and negatively. With the warming researchers fear that the West Antarctic ice sheet will break up and fell into the ocean, which would raise the sea level with several meters. However with the precipitation and snowfall increase it is possible that the frozen land growing in size, which would mean that it locks up water what otherwise, would end up in the ocean (Hopkin; 2005). Also growing number of extreme weather events is possible, but the frequency is uncertain (IPCC; 2007).

## 1.3 Human caused changes in the climate

After the statistical facts we have seen, in this sub-chapter we try to get some answers. The most important question whether the climate change seen in the previous sub-chapter has been happening because of the human intervention on the nature or these changes would happen anyway, because it is in the Earth long-run cycle and we reached a warming period? To answer this question we shall know about the history of these cycles and a few necessary things about the process of the warming and how humans can contribute to this process. Also we will see some different opinion about whether human kind is responsible for the changes or not.

There are several and popular opinions whether the human activity is what is responsible for the climate change by the growing amount of the greenhouse gas emission. There are scientist who claims that rapid warming started after the industrialization and current changes occur because of the changes in the Earth's atmosphere from waste gases due to industry, farm animals and land clearing, cropping and irrigation (Pittock; 2009). About between one-third and one-half of the land surface has changed due to human lifestyle and the carbon dioxide concentration emerged by 30% since the Industrial Revolution. Also more than half of the surface fresh water is under human use in several ways (Hill; 2004). Studies identifing human impact on current climate change and tring to separate it from inevitable changes of natural climate variability usually consist two parts: First, they identify an unusual change that would not have occurred without human contribution. Second, they try to put together the outcomes and its roots.

The most common 'unusual change' is the increasing amount of greenhouse gas emission as the result of the human contribution to the climate change since the Industrial Revolution human kind started to burn fossil reserves of the Earth. But how greenhouse gas emission leads to global warming and which forms of gases goes under the term of greenhouse gases?

To have life on Earth, there is need for the energy from the Sun. This energy is electromagnetic radiation in the form of visible light, with small amount of infrared and ultraviolet radiation. The visible energy is passes right through the atmosphere. About 30% of the sunlight is deflected by the outer atmosphere and scattered back into space (West; a). The rest reaches the Earth's surface and our planet's surface absorbs the solar energy and releases it back to the atmosphere as a type of slow-moving energy called infrared radiation. But some of the infrared radiation absorbed by greenhouse gases in the atmosphere and sent back towards the Earth's surface. This way the Earth's surface warms. So the greenhouse gases regulate our climate as they keep the Earth warm by trapping heat and holding it in. Without it the average temperature on Earth would be colder by about 30°C. So to maintain the present ecosystem we need the greenhouse gases. The problem is that, by the human activity, there could be easily more greenhouse gases in the atmosphere than needed to provide an ideal temperature. It seems that more greenhouse gases means more infrared radiation trapped and held which leads to a warmer surface temperature (West; a).

What are the greenhouse gases and how humans contribute the growing greenhouse gas emission? There are natural greenhouse gases, such as water vapour, carbon dioxide, methane, nitrous oxide, and ozone. Others like hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) result exclusively from human industrial processes (West; b). The Kyoto Protocol specifies six greenhouse gases to be regulated. These are: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) (Pittock 2009).

Human contribution to the greenhouse gas emission could come from many different sources. First, burning fossil fuels – just like natural gas, coal and oil – increases the level of carbon dioxide in the atmosphere (Pittock 2009). Burning solid waste, wood and wood products increases the carbon dioxide level, too. Second, some agricultural and industrial processes lead to nitrous oxide emission. Third, some farming practices and organic waste decomposes raise the emission of methane. Fourth, factories produce long lasting industrial gases, which do not occur naturally. Hydrofluorocarbons (HFCs) once were used in refrigerants and other industries, but nowadays they got phase out of use because of their potential to destroy atmospheric ozone. Perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) both are industrial gases used in the electronic and electrical industries, fire fighting, solvents and other industries (Pittock 2009). Deforestation is the fifth kind of way how human activity adds the increased value of greenhouse gas emission. As trees use carbon dioxide and emit oxygen, the fewer the trees are, the less oxygen they can perform. But it would be important for the optimal balance of gases. The last, but not least the human population growth contributes to the global warming. The more we are the more energy is needed, namely more fossil fuels, more farming etc. (West; a).

So what changes have occurred in the greenhouse gas emission since the Industrial Revolution, why IPCC convinced that it is very likely that the current warming is due to human activity?

Before the Industrial Revolution, the levels of carbon dioxide in the atmosphere were about 280 parts per million by volume (ppmv). Recent levels are about 370 ppmv. This number shows an extremely high level of concentration, as the concentration of carbon dioxide and other key greenhouse gases is higher than at any time in the past 650,000 years in the atmosphere today, and probably higher than in the past 20 million years (West; c). The situation with the other greenhouse gases is pretty similar. The emission of other greenhouse gases has jumped, too, after the industrialization. The atmospheric concentration of methane grew from the pre-industrialization level of 715 parts per billion (ppb) up to 1774 ppb to 2005. The concentration of nitrous oxide increased from 270 ppb (pre-industrial level) to 319 ppb to 2005. "*Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered.*" (IPCC; 2007 p. 101) Radiative: because these factors change the balance between incoming solar radiation and outgoing infrared radiation within the Earth's atmosphere. Forcing: because it indicates that the radiative balance has been upset. "*Radiative forcing is usually quantified as the 'rate of energy change per unit area of the globe as measured at the top of the atmosphere', and is expressed in units of 'Watts per square meter'*" (IPCC; 2007 p. 101). CO2 has the biggest radiative forcing by far, so carbon dioxide changes the climate the most.

However there is another point of view among many scientists. According to their researches *(see for example: Pohanka, Archibald and various website exist in the topic like: http://www.isthereglobalcooling.com/, http://www.climatecooling.org/, www.geocraft.com etc.)* there is no strong evidence for the global warming, even less evidence that it is caused by human activity. They state that the Earth has started to warm up somewhat 18 000 years ago after the 100 000 year long Ice Age. Back then the oceans where more than 90 meter lower than today. Only about 15 000 years ago, the temperature was so warm that glaciers melted and established the current environment. Since the last Ice Age, average global temperature has risen about 5°C. If we see that in perspective, the global warming is what allowed us to live like we live today.

These studies states, too, that global warming and global cooling are controlled primarily by 4 factors (geocraft.com; 1998):

- Cyclical variations in the sun's energy output
- Eccentricities in Earth's orbit
- The influence of plate tectonics on the distribution of continents and oceans
- The so-called "greenhouse effect," caused by atmospheric gases such as gaseous water vapor (not droplets), carbon dioxide, methane, and nitrous oxides, which help to trap radiant heat which might otherwise escape into space.

The greenhouse effect is not even the most important factor, more importantly human could not cause it, because 95% of the greenhouse gases come from natural water vapour. The other 5% is like: 4,72% comes from ocean biologic activity, volcanoes, decaying plants, animal activity, etc. and only 0,28% comes from human activity (Pohanka; 2010).

Greenhouse gases make up 2% of the total atmosphere. As for carbon dioxide, it only makes up 3,62% of the greenhouse gases. And only 3,4% of atmospheric CO2 comes from human sources. Additionally CO2's ability to absorb heat is logarithmical, therefore the more CO2 there is, the less heat it can absorv. So with these numbers we can see how minimal the human contribution is. So, why to bother to reduce it with such high costs, when we can hardly influence the Earth's cyclical periods (Pohanka; 2010).

## 1.4 Scenarios

In the previous sub-chapters we examined how the climate has changed, also we provided a bit of the future in the regional changes and we outlined a few possible reasons why the current climate change occurs. In this chapter we will show the most popular scenarios about the future of the climate change. As it is sure to state that our climate is changing whether it is caused by human kind or not, we should prepare the future changes. So far the IPCC scenario is the standard and most referenced scenario. In Figure 4 we can see the different options of the different possible events and in the box there are the refered explanations of the option. As Figure 4 shows the temperature change ranging from 1,4 to 5,8°C by 2100. This is a really wide range. As we saw in the previous sub-chapter, in the past 18 000 years from the latest Ice Age, the temperature increased about 5°C and it changed the entire living conditions of the planet. Therefore warming might not our biggest problem yet, but it could be if the scenario redeems its promises.

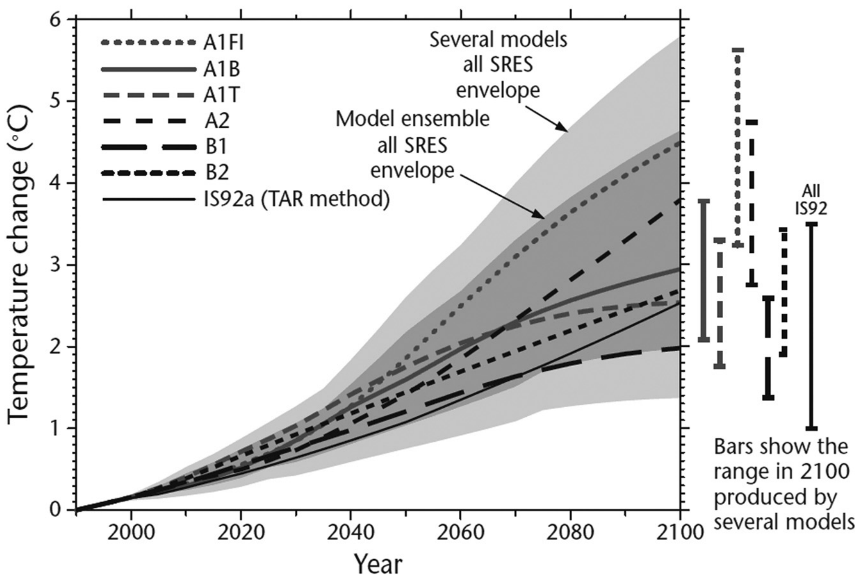
SRES also covers greenhouse gas emission scenarios. The scenarios also predict increase in the emission of the greenhouse gases. Almost all kind of greenhouse gas concentration in the atmosphere is likely to doubles, what indicates the temperature warming. Also with warming there comes the sea level rise, which according to the IPCC's fourth assessment report could range from 18 to 59 cm growth. This prediction includes thermal expansion of the oceans and water that melted from mountain glaciers and a contribution due to increased ice flow from Greenland and Antarctica.

According to IPCC there will be several irreversible changes by 2100. These are changes such as the slowdown of the Atlantic Meridional Overturning Circulation (MOC)[6], the fast disappearance of the Arctic sea ice, the rapid disappearance of the glaciers or ice caps, increased melting of Greenland and the Antarctic ice cover,

[6] Atlantic Meridional Overturning Circulation (MOC) transports heat northward throughout the Atlantic Ocean

desertification in many area. These events could indicate changes the ecosystem and could cause many economic damage. Therefore if it is a slightest chance that we can do anything to avoid these changes than we should do everything that we could.

**Figure 4** Emission Scenarios by IPCC[7]




*Source:* Pittock 2009 p.79

[7] Global average temperature projections for six illustrative SRES scenarios, as depicted in the 2001 IPCC report. The darker shading represents the envelope of the full set of 35 SRES scenarios used as input to the climate models, using the accepted average climate sensitivity of 2.8°C. The lighter shading is the envelope based on a range of climate sensitivities in the range 1.7 to 4.2°C. The bars show, for each of the six illustrative SRES scenarios, the range of model results in 2100. For comparison, the IPCC IS92 range of warming's in 2100 is also shown.

**THE EMISSION SCENARIOS OF THE IPCC SPECIAL REPORT ON EMISSION SCENARIOS (SRES)**

- **A1.** The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereaf-ter, and the rapid introduction of new and more efficient technologies. Major under-lying themes are convergence among regions, capacity building and increased cul-tural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.
- The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).
- **A2.** The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increas-ing population. Economic development is primarily regionally oriented and per cap-ita economic growth and technological change more fragmented and slower than other storylines.
- **B1.** The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and in-formation economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
- **B2.** The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermedi-ate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.
The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

*Source:* IPCC 2007 p. 18

**References**

Burroughs, William James (2005): Climate Change in Prehistory - The End of the Reign of Chaos IPCC Cambridge University Press, 2005

Diaz, Henry F, - Murnane, Richard J. (2008): *Climate extremes and society,* Cambridge University Press, 2008

Hill, Marquita K. (2004): Understanding Environmental Pollution, Cambridge University Press, 2004

Hopkin, Michael (2005): Climate change: world round-up, *Nature* published online: November 2005 http://www.nature.com/news/2005/051114/full/news051114-10.html downloaded: 2011-10-28

Houghton, John (2009): *Global Warming The Complete Briefing* Cambridge University Press, 2009

IPCC (2007):*Climate Change 2007 - The Physical Science Basis* Contribution of Working GroupI to the Fourth Assessment Report of the IPCC Cambridge University Press, 2007

Nicholas Stern: *The Economics of Climate Change*

Pittock, A. Barrie (2009): Climate Change - The Science, Impacts and Solutions Csiro Publishing Australia

Pohanka, Geoffrey (2010): Anthropogenic Global Warming, Is Earth at the tipping point? Presentation from webpage: http://www.isthereglobalcooling.com/ downloaded: 2011-09-03

Wöppelmann, G., C. Letetrel, A. Santamaria, M.-N. Bouin, X. Collilieux, Z. Altamimi, S. D. P. Williams, and B. M. Miguez (2009): Rates of sea-level change over the past century in a geocentric reference frame, *Geophyical. Researche Letters*, *36*, L12607, doi:10.1029/2009GL038720.

**Internet sources:**

IPCC Intergovernmental Panel on Climate Changes

UN Framework Convention on CC

US Global Change Research Program

ClimateCooling.Org

http://www.globalwarming.org

Brain, Marshall (2011): If the polar ice caps melted, how much would the oceans rise?
http://science.howstuffworks.com/environmental/earth/geophysics/question473.htm downloaded: 2011-10-30

Jonas, Phil (2011): Global Temperature Record;
http://www.cru.uea.ac.uk/cru/info/warming/

Raper, Sarah (2000): Sea level rise; http://www.cru.uea.ac.uk/cru/info/warming/

West, Larry a) (*): What is the Greenhouse Effect?
http://environment.about.com/od/globalwarming/a/greenhouse.htm

West, Larry b) (*): What are Greenhouse Gases?
http://environment.about.com/od/faqglobalwarming/f/greengases.htm

West, Larry c) (*): Are Levels of Greenhouse Gases Increasing?
http://environment.about.com/od/faqglobalwarming/f/greenhousegases.htm