REGIONAL AND GLOBAL CLIMATIC CHANGE PREDICTION[1]

Carlos Nobre[2]

I will talk about the physics of the greenhouse warming global climate change, the uncertainties to predict the global or the regional climate change. There is a long way to go from the better known physical aspects of climatic change to the state we would like to reach, which is to be able to predict the climate change due to greenhouse warming and its impact on environment and on society.

Initially, let us go back to the global energy balance. This is a relatively well unterstood subject. But one thing, that has not been mentioned yet in this seminar, and it is necessary to point out, is the fact that the atmosphere is threedimensional. We have been talking very much on the radiation balance, which happens mostly in the vertical direction. Indeed, aproximately 52% of the solar energy reaching the top of the atmosphere gets to the earth surface. But it is necesary to take into account that the surface heats up the atmosphere. This produces an unstable situation with warm fluids below and relativaly colder fluids above which have to adjust to obey the gravitational law in order to have colder heavy air below and the warmer light air above. Besides, at the surface level, we have continents and oceans which absorb heat at a different rate. Furthermore the equator receives more heat than the polar regions. These contrasts in heating drive atmospheric circulation, which is the way to redistribute energy.

This tridimensional picture with winds, ocean currents and the natural processes of adjustment are very much different from the unidimensional

[1] Condensed version based on the lecture given by the author

[2] Brazil, consultor OMM.

representation of the radiation equilibrium. We have a heterogeneous distribution of the temperature and the polar regions are much warmer than they would be without radiation adjustment. These are the threedimensional aspects of the planetary climatic system.

It is necessary to emphasize the complexity of the physical, chemical and biochemical aspects of the climate system and the processes that take place in the atmosphere, the ocean and the continental surface. All those processes are tightly coupled, sometimes, in very strange no-linear ways. Everything I said before was just to point out the difficulties to understand the climate system as a whole.

Now, after this introduction, let us see what it is going on in predicting the effects of changes in the composition of the atmosphere.

Let us review some of the better known aspects of this subject. First, there are evidences on the increasing of atmospheric concentrations of greenhouse gasses (CO_2, CH_4 and N_2O), although there are some doubts about the magnitude of the rate at which they are increasing. Now, the radiative power of each greenhouse gas is also more or less known. In the other hand, we have some knowledge on past climate. So, it is known that through the last 160.000 years there were changes in temperature, greater than the ones predicted for the future, associated with changes in atmospheric composition. Particulary, it has been stablished that colder conditions were related to less carbondioxide and warmer conditions to more carbondioxide. However, it is not known if an increase in temperature produced an increment in carbondioxide or if the increment in carbondioxide was the cause of higher temperatures. We know past climate has experienced long-time variations in temperature. If we look at the recent records, the last one hundred and twenty years (the period of instrumental observations), we see trends of increasing temperature. There is a lot of debate about the reality of these trends, but in a curve representing annual average temperatures at hemispheric or global scales, we see kind of a flat ending for the XIX century, a sharp rise for the early part of the XX century, then flat in the middle of this century and then again a sharp rise in the 1980's. This global increas of the surface temperature is about 0.5°C. Is this caused by the greenhouse warming? Of course, the CO_2 concentrations have increased from 270 ppm in the XVIII century to about 330-340 today, so this warming could be atribued to the greenhouse efect but it could also be a product of the natural variability of this very complex climate system. It is impossible to affirm that this rise of 0.5°C of the global mean air temperature of the surface is due to the observed increase in the CO_2 and other greenhouse gasses in the atmosphere. At the same time, it is impossible to issolate the natural global trends. Even though it is said that without long term natural cooling the warming would be of the order of 1°C, it is not possible to detect the greenhouse warming.

When we analyse the actual trends in the time secuences of the mean annual temperatures the 80s appear as a very warm decade, however we can not assure this is caused by greenhouse warming. This is one decade that was very warm but still is within the range of the natural inter-annual climate variability.

Now let us discuss a bit about predictions. What tools do we have to predict future climate? There are two options. The first one is to look at the paleoclimate, to try to find an analogue of the current conditions, to see what happened in the past when the Earth had about the same climatic conditions of today. This is rather difficult for many reasons: first, because we do not have a good record and, second, because the present time rate of change of the atmospheric composition of those gasses is imprecedent. In the past those changes took place over thousand of years and now we are talking about changes in decades. So, it is not easy to use paleoclimate records to find analogues.

The second tool is climate modelling. There is a consensus that the most valuable and best tools are mathematical models of the climate system and they have been used extensively. Basically, those models are simply one way of solving the equations to find out what happens under induced conditions. You represent all the atmosphere in small boxes, which are actually very big (200x200 kms horizontally and 1 km in height) but considering the whole planet they are relatively small. Then, it is calculated what happens in each box, and how it interacts with its neighboring boxes. Basically this is how a climatic general circulation model works.

The numerical models are used to predict the climate change when the model concentration of CO_2 is increased. There are a number of such studies based on doubling CO_2 concentration. This is a standar figure used by several scientist with models in Canada, USA and UK. The results of these experiments have shown that for the northern hemisphere winter there is a large warming in the high latitudes and some warming (about 2°C) in the tropics. This is the same for the southern hemisphere. However, for other variables, perhaps even more important as precipitation and soil moistiure, the models do not agree and are not ready to produce useful predictions.

Regionally, there are large uncertainties for most of these variables. Globally, the models usually agree for precipitation: all predict a small increase of about 10%. That is not difficult to understand: if the temperature increases the air is able to hold more water vapor, so you would expect a little bit more precipitation.

But the models do not agree at all at the regional level and so they are not yet reliable enough to take political actions. But then you can make use of the scenarios. They give you the range of change and based on them you can predict the possible regional impacts.

You can be more confident about predictions in some aspects of the regional climate than others. For instance, is easy to predict that due to temperature increase the middlatitudes will be slightly warmer and the growing season will be longer. But to predict things related to regional rainfall is much more difficult.

Another interesting aspect of the numerical climate simulation is the so called equilibrium runs of climate models, in the sense that you instantaneously change the concentration of the atmosphere and you assume the ocean adjusts instantaneously. Of course, this is not true in nature. The ocean takes a lot of time to adjust to a change in the atmosphere. So basically the more correct way of making a prediction is coupling the atmosphere model with the ocean model and that has been done. When you increase the CO_2 atmosphere concentration in a coupled model the warming takes longer than you would expect because it takes a long time for the ocean to adjust.

By the time the atmosphere has double the concentration of greenhouse gases, the warming is about 78% of the equilibrium value. Anyway this do not change dramatically the results that show a higher increase in temperature in the high latitudes than in the tropics.

There is very little doubt that concentrations of CO_2 keep increasing, the temperature will rise. It may take 50, 100 years or more. It depends on exactly how the oceans will behave. But not anybody would say that if greenhouse gases keep increasing there would be a cooling.

The most important question in the climate change issue is to know what will happen to the variability in the atmosphere, and the variability in climate. We would like to know more about the extrems. This is a very important question for many practical purposes. But is very difficult to make interences about this with the aid of the numerical models results, because the models do not agree in telling us what would happen to the variability. Maybe the climate will be more variable, but we do not have much basis to say so. But there could be a general warming and yet there could also be cold spells within. The importance of the variability is that extremes have a lot to do with the impacts. I give an example: probably one of the reasons which determines the southern boundaries of the tropical forest in South America (southern Bolivia and Brazil) is the ocurrence of cold spells. The tropical forest would not survive if there were cold spells with temperatures of 5°C ó 6°C once or twice a year.

I am not going to talk about the impacts. professor Izrael, the chairman of Group II of the IPCC, give a talk on the impacts and extensively deals with this subject. Thank you.