Forecasting global climate change in the 21st century

You're Getting Warmer, You're Getting Colder...

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We discuss climate change and its potential outcomes for Poland and the world with the climatologist Prof. Mirosław Miętus - coordinator and member of projects studying global climate change

Academia: When do early scenarios talking about global warming date back to?

Mirosław Miętus: *The concept of global warming is well over a century old, although the first scientific papers discussing global warming - or global climate change - were published much later. Note that am deliberately talking about global "change," in the singular. In Polish the phrase "climate changes"* (zmiany klimatu) *is often used, in the plural, even though what we have is a single global climate affected by a single change, albeit including different elements such as temperature, precipitation, and even wind speed. When Prof. Maciej Sadowski and I co-translated the "Abstract for Decision Makers" from the most recent Intergovernmental Panel on Climate Change, it was the first time we used the term "climate change" in Polish, rather than "climate changes." This provoked widespread discussion across climatology circles.*

Today there are varying opinions being voiced in Poland by professionals working in meteorology, climatology, glaciology, hydrology, limnology and other Earth sciences questioning the phenomenon of contemporary global warming. For example, according to the PAS Committee on Geological Sciences, global warming does not exist. And yet the position of the PAS Committee for Geophysics, of which I used to be a member, and the statement from PAS, differ from the Committee on Geological Sciences.

What factors shape climate?

There are two main types. The first type includes natural processes, largely linked with the Earth's rotation around the Sun. This is to do with the shifting shape of our planet's orbit, since the ellipsis does not always follow the same curve. Also important is the changing tilt of the ecliptic and the precision of the Earth's rotational axis. These factors are responsible for long-term cycles, occurring over periods from tens to hundreds of thousands of years. They are known as the Milankovitch cycles, first described by the Serbian climatologist in the early 20th century. If they were to be considered alone, we would expect Earth's climate now to be entering a phase of global cooling. Another factor affecting climate that also tends towards cooling is volcanic eruptions. During the eruption process, volcanoes expel vast volumes of dust and aerosol high in the atmosphere; as a result, some of Sun's radiation is reflected and scattered beyond our planet's atmosphere, and the heat doesn't reach the Earth's surface. This is why major volcanic eruptions are always accompanied by slight drops in temperature. The internal dynamics of a climate system - interactions between the atmosphere and the oceans - also affect climate, although on a scale of hundreds or perhaps thousands of years. The final, equally important natural factor is the activity of our Sun, which happens to have increased recently. However, our information regarding how it changes and how much energy it emits is limited. In addition to natural factors, we have anthropogenic factors - those tied with human activity such as the release of human-made carbon dioxide, methane and other trace gases into the atmosphere, causing the greenhouse effect. Their increased concentrations change the climate system's heat capacity, which means that more heat is trapped within the atmosphere. There is also tropospheric ozone generated by human

Poland's climate is very sensitive to whether it rains or not. We see alternating floods and drought periods

activities, mainly pollution generated by combustion engines; its increasing concentration is another factor in rising temperatures. The Earth's surface also varies in its ability to absorb radiation as a result of changes of how land is used, such as deforestation and industrialization.

But there are also natural sources of carbon dioxide.

Of course! Carbon dioxide, just like other natural greenhouse gases, has always been present in the atmosphere regardless of human activity; it is the reason why our planet's temperature is around $32^{0}C$ higher than if CO_2 wasn't present. What happens to Sun's radiation when it reaches Earth's surface is described perfectly by the zero-dimensional energy balance model. Short-wave radiation reaching the upper layers of the atmosphere is partly reflected, although some penetrates further and heats the planet surface; as a result, Earth starts emitting long wave radiation according to the Stefan-Boltzmann law. If we write down such a balance equation and assume that the atmosphere is fully transparent - that its transmissivity is equal to 1 and it contains no greenhouse gases - we get an effective temperature of around 255K, or $-18^{0}C$. Meanwhile, Earth's mean temperature is around $14^{0}C$. This difference of $32^{0}C$ results from the fact that we have an atmosphere that comprises water vapor and gases such as carbon dioxide, methane and a few others. The system affords Earth thermal conditions amenable to human life. If $-18^{0}C$ were the actual mean, the temperature would be between $-60^{0}C$ and $-50^{0}C$ at the poles and just around 0oC near the equator; such conditions would support some primitive life, but not humans.

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Why are we concerned about global warming?

The problem is that we are faced with threats brought by today's climate change, which is occurring too fast. The ability to adapt to these changes depends on how affluent a society is. According to UN data, at the turn of the 20th century Earth's population numbered around one billion; today it has reached around eight billion, and unfortunately the vast majority of our planet is not wealthy. Reports published by the World Meteorological Organization (WMO) and the reinsurance company Munich Re indicate that during most of the 20th century the number of natural disasters caused by geophysical factors remained relatively low and steady. However, since the early 1980s, we have been observing growing numbers of natural disasters with meteorological or climatic causes. Such disasters have so far claimed around two million lives, mainly in Asia, South America and Africa. In terms of material losses, however, the greatest damage has been inflicted on Asia, North America and Europe. Examining the data shows that many of the catastrophes occur in regions that are densely populated and steeped in poverty. The theory of global warming states that a warmer atmosphere is linked with an increased probability of adverse events; more frequent changes of conditions would also be more likely.

Is it possible to create a climate model serving to warn societies against the disastrous effects of its changes?

We know currently that any climate model must include at least a model of atmospheric and oceanic circulation, and an exchange of fluxes between the oceans and the atmosphere. We should also be aware that if the fluxes in the annual cycle are to balance, the equation must be almost equal to zero. If this is not achieved, we will experience what's known as concept drift. If the balance were negative, the models would tend towards cooling, while if it were positive, they would tend towards warming. A single model is insufficient; we really need to use several different ones, since some handle certain elements better than others. By averaging over a few models, we obtain what's known as a cluster. There are 42 models of global atmospheric and oceanic circulation available at present. They have been used to create numerous scenarios of how the climate system may evolve in the 21st century, including two extreme projections. The optimistic one assumes a reduction in emissions and gases affecting the rate of climate change; the pessimistic talks about an absence of changes in the economy whose growth means that we continue burning fossil fuels without any limitations. As such, models fall somewhere between these two extremes. Important changes concern the sea level - as we know it is rising for reasons including the melting of inland glaciers but mostly due to the heating of sea water and the thermal expansion of its volume. One of the results of this is the decreasing salinity of oceans and a disruption of thermohaline circulation (large-scale sea circulation driven by global density gradients created by surface heat and freshwater fluxes). According to the optimistic scenario, temperature may rise by just $2^{0}C$ and then stabilize. However, we will not be able to stabilize rising sea levels until the late 21st century, even if we were to implement recovery programs. Sea levels will continue to rise for the next two centuries, since the deciding factor is the thermal expansion of water. Considering that two thirds of the human population lives in coastal zones, it follows that vast numbers of people are under threat from rising sea levels.

Are there projections on how climate is likely to change in Poland?

Yes, there are numerous projections. Many have been developed on the basis of wider-reaching scenarios prepared for all of Europe. One of the projects I was in charge of for many years focused on developing projections on how Poland's climate is likely to change during two time periods: 2011-2030 (the coming two decades), and 2081-2100 (the turn of the 21st century). We used the period 1971-1990 for comparison. The results indicate that during the period 2011-2030, temperatures should increase at a slower rate. And it's true to say that in recent years we have observed a slight weakness in the rate of temperature increase, albeit a very tiny one. Generally speaking Poland's climate is warming faster than predicted by the model, meaning that the model underestimates the rate; comparing this to today's data, we can actually say that the model shows warming that has already occurred - warming that "has been consumed".

What about rainfall?

We don't have a clear answer to this question. Analysis of data collected from hundreds of measurement stations over a period of decades at the same locations has allowed us to prepare mean levels of rainfall expected in individual regions and across the whole country. The average annual rainfall in Poland is just 624mm. We observe significant variation by region: the highest is seen in the Tatra Mountains (over 1020mm), and the lowest in the Polesie region (just 550mm). Our climate is very sensitive to whether it rains or not. This was particularly noticeable in 2010 when we had floods in the Vistula basin. In contrast, 2011 was marked by a great drought where Vistula levels fell to a record low. This shows that our rainfall varies greatly. In some regions, precipitation has been increasing over the last 60 years, and in others it has been decreasing. The variation can reach as much as +/-10% over a period of several years. We are already observing this today. Generally speaking, precipitation may increase by as much as 30% in winter months. This could manifest as wet snow, although at around 0oC we frequently observe sleet. Such weather is similar to that in Northern Germany - so we get a few days of snow, windy conditions and rain. But when rainfall is low in the summer, the risk of drought increases.

As part of the 7th Framework Programme known as THESEUS, a projection of extreme flood risk in the Puck Bay has been prepared, showing that the rising sea levels and wave heights 2.4m above average would leave the Hel Peninsula as a narrow strip of land broken up in several places. It's worth remembering that while the sea will reclaim beaches, they will be reformed a few years later further inland - it is an ongoing process. Sea cliffs are also under threat, since waves lap at their base; this may lead to their sliding into the sea at a faster and more frequent rate. There is also a risk that coastal lakes such as Poland's Łebsko will be reclaimed by the sea. Certain regions will cope with adverse conditions better than others. In the Wielkopolska province - one of the major food-producing regions - we are already seeing insufficient levels of rainfall, leading to drought in the soil. Projections show that in the summers the region may be affected by reduced precipitation, which will likely exacerbate the problem. ■

Interview by **Jolanta Iwańczuk**

Further reading:

The BACC Authors Team. (2008). *Assessment of the Climate Change for the Baltic Sea Basin.* Springer.

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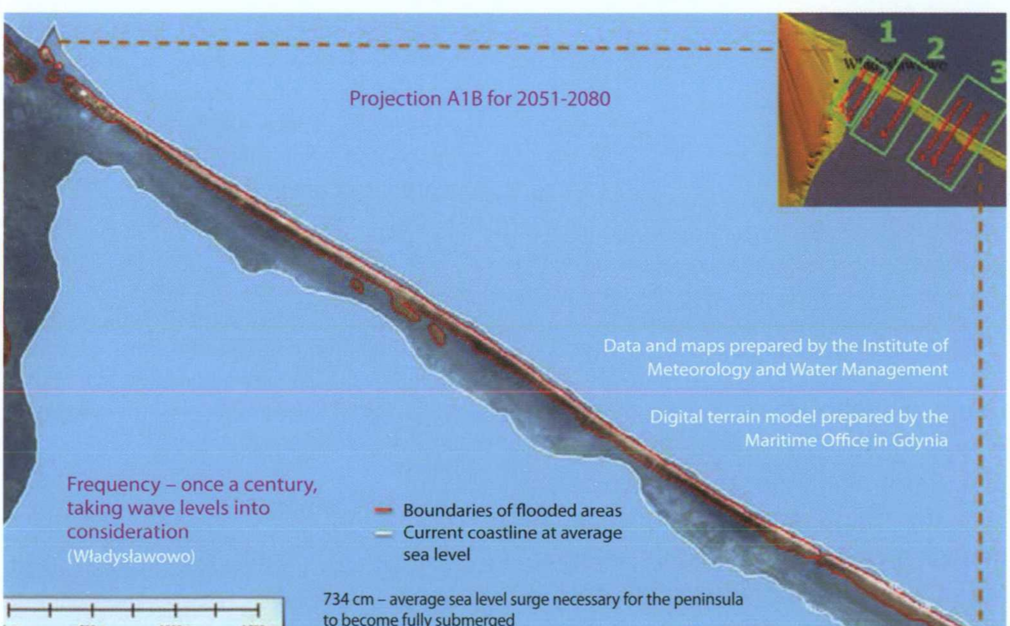

A map projection of extreme flood risk in the Puck Bay, showing that rising sea levels and wave heights 2.4m above average would leave the Hel Peninsula as a narrow strip of land broken up in several places