

Global climatic change from the point of view of theoretical physics

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We know the forecast of the weather from news. We usually see that the forecast is reliable for 3 days. But why 3? Will we have the forecast for more than 3 days when we will have more powerful computers in the future?

We collect data from meteorological stations from the whole world when we are doing the forecast. We measure pressure, temperature and velocity of wind. The trouble is that the models are very sensitive to initial conditions. It means that a little change of the data at the beginning could cause a dramatic effect in the predictions of the model soon after. We should study the theoretical mechanics to illustrate this effect.

Look at the Figure 1 in [1]. There is a double pendulum. Simple pendulum is normally doing oscillations around the equilibrium position. Harmonic motion is described by the function $\sin(t)$. The situation with double pendulum is more complicated. We need to find the correct generalized coordinates first. The suitable coordinates are the two angles α_1 and α_2 . We compute the Lagrangian and we construct the equations. The final set of equations describing the motion of double pendulum is this system of 2 ordinary differential equations:

$$(m_1 + m_2)l_1^2\ddot{\alpha}_1 + m_2l_1l_2\ddot{\alpha}_2 + (m_1 + m_2)gl_1\alpha_1 = 0, \quad (1)$$

$$m_2l_1l_2\ddot{\alpha}_1 + m_2l_2^2\ddot{\alpha}_2 + m_2gl_2\alpha_2 = 0, \quad (2)$$

where l_1 and l_2 are the lengths of the pendulums, m_1 and m_2 are masses and g is the gravitational acceleration. We could watch the video in [1] now. There is a big qualitative change when we compare normal pendulum and double pendulum. When we deviate the double pendulum from equilibrium position just infinitesimally, there is almost no qualitative change of behavior. But there is a limiting deviation of the double pendulum, when it began to behave chaotically. It means that incredibly small change of the initial conditions (perturbation at the beginning) could cause a completely unexpected behavior. But why is this interesting for the weather forecast?

Figure 1: Swedish activist Greta Thunberg.



It seems to be the case that weather must be modeled by a chaotic system. A little change in the initial conditions how we measure temperature could cause an unpredictable behaviour of the model already in few days. What we want to stress that the limit of three days to forecast of the weather is a fundamental restriction, when we want to predict weather by supercomputers.

But what about climate? We need to say that we have climatic models. But we obtained trustworthy experimental data only in last 2 centuries. Climate is changing in very long periods of thousands of years. For example, the axis of Earth is doing two separate motions: precession and nutation; The period of nutation is approximately 18 years, but the period of precession 26 000 years. We know that climate is influenced by these two motions. For example, there were ice ages in the past and there is some correlation between ice age and precession. But again, we need to use deterministic chaos ¹ to model the climatic changes. And we need the precise initial conditions.

Are humans influencing the climate? Yes, they are for sure. How serious it is? The raising of temperature on big parts of Earth began around 1920. Is it correlated with the beginning of industrial revolution at this time? Or is it by accident? The ozone hole was caused by humans (it disappeared when people stopped to use freons), but we don't have reliable models concerning climate. There are 3 basic scenarios:

- The climatic change is not substantially caused by people. After some period of warming will follow global cooling with ice age. These are natural cycles and people could influence this only with difficulty.
- People are influencing climate heavily. The raise of temperature is caused by humans substantially. But still when people will start to do necessary changes in reducing pollution, the climate will return back to natural cycles.
- The climate was influenced by humans already irreversibly. The natural cycles were destroyed. And chaotic behavior could be expected. The temperature

¹Deterministic chaos is a branch of science, which is studying generation of random, unpredictable behaviour from a simple, but nonlinear rule.

could raise 20 degrees in next century, or maybe decades, for instance, and the Earth would be inhabitable.

Therefore we appreciate the effort of Swedish activist Greta Thunberg, although she should have more reliable informants how to interpret the meteorological data. The main activity should be different, because of these three variants, which we mentioned before. The planting of trees is important, but the key thing will be to know, what is happening. We need to find a better climatic model, how seriously we are influencing the climate. And it means more finances for meteorological sector.

References

- [1] <https://www.math24.net/double-pendelum>