ATMOSPHERIC PHYSICS AS A TOOL FOR MAKING PHYSICS MORE INTERESTING FOR STUDENTS

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Abstract
The teaching of sciences such as physics and chemistry is in critical situation all over the world. Students think that the subjects are too difficult and boring. In reality, the textbooks are often very theoretical and their topics are far from the everyday life. Due to the rapidly increasing amount of scientific results and their modern technical applications textbooks are not up-to-date. Therefore it is crucial to find interesting tasks which are connected with real life in order to gain back the students' interest. In our opinion, atmospheric physics gives a lot of possibility to apply physical laws in real and exciting situations. In the present paper some questions of atmospheric physics are discussed in a relatively easy and understandable way which can even be understood by a secondary school student. Two topics, which can be illustrated with beautiful and amazing pictures, were chosen. One of them is the description of the birth and the development of thunderstorms. The other one is the phenomenon of halos. A lot of materials (beautiful photos and animations), connected to both topics, can be found on the internet, and it is relatively easy for anyone to take his or her own photos.

Motivation
A terrible decrease of the number of physics students can be experienced at the universities of Hungary. Together this the student's knowledge is also decreasing, they have not got even the basic understanding of the physical laws. Therefore university and secondary school teachers interested in didactics seek the way how to teach science more interestingly and more attractively that is how to foster scientific literacy of students. Seeking this, the role of the students' motivation has received increased attention. It is also well known, that the consequence of the poor motivation is very often low achievement. However, it is not clear which students are poorly motivated, and what is the reason of this? These are important questions for instructors of science who wish to improve their students' motivation. To answer these questions Glynn and Koballa (2006) developed a Science Motivation Questionnaire on he basis of which the dimensions (components) of the students motivation can be revealed and which can also be used as a tool to evaluate the effectiveness of instructional strategies and materials designed to increase students' motivation. Further investigation of Glynn at al. (2009) showed that one of the most important components of motivation is the intrinsic motivation, which involves learning science for its own sake. To improve the intrinsic motivation extended efforts were made both at the field of the reform of the curriculum and that of the teaching methods. Science teachers generally agree that subjects taught at secondary and college level should be closer to real life. Real life can be introduced into the schools through interdisciplinary projects which induce students to work creatively. Since pupils are not trained to look at the world from a physical point of view, might be they will not see the important features of the phenomena. So the first and probably the most difficult step is the creation of a model for the investigated phenomenon in the frame of which it can be explained or described with physical laws. In this problem students are often confronted with open questions or problems which would invite them to have a closer look or even to make further investigations. Therefore the physical approach of everyday life phenomena may be very stimulating and successful method for deep understanding of physical laws.

Why atmospheric physics?
Atmosphere and processes occurring in it are very interesting ones and our everyday life is highly influenced by them. Clouds, thunderstorms, lightning and rainbows are beautiful, sometimes frightening and exciting phenomena. There are lots of people who fanatically observe these phenomena and take photos and videos from them. In spite of this, mainly due to the complexity of the processes mentioned above, curriculums contain very modestly this field of physics. However, it is not difficult to excite the curiosity of the students by these admirable spectacles. Meteorological data, satellite and radar images of the atmosphere give wide possibility for teachers to set project work for students to do self sufficient research-work.

Without the demand of completeness we recite a list of field which is connected with atmospheric physics and give chance to construct interesting illustrations for basic physics: atmospheric electricity, optical phenomena of the atmosphere (rainbows, halos, lightning, etc.), properties of the gases, fluid dynamics, weather forecast, atmospheric radiations, green house effect and so on.. Most of these topics can be illustrated with beautiful pictures and videos from the internet (or with self made pictures) and the physical background of them can be treated at different level depending on the previous experiences of the students. This fits well to the concept of a spiral curriculum in which there is a reiteration of concepts and subjects throughout the course. Each time the concept is repeated, more in-depth knowledge is presented so that each successive encounter of the concept builds on the previous one.

1. Basic physics of thunderclouds

Fig. 1 shows. (http://jazzrock.wordpress.com), a beautiful well developed thundercloud a so called cumulonimbus. Other cloud pictures can be found on internet (http://www.atmos.washington.edu) A single cumulonimbus extends vertically from the ground to the troposphere, where it's top spread out and form an anvil which is generally consisting of ice needles, and is very characteristic part of the cloud. In these fascinating clouds vigorous convection and electric processes take place. During the development of the cloud the most characteristic process is the rapid turreting and bubbling. Exact properties of these clouds (velocities, water and ice content and the size distribution of the water and ice drops and so on.) are known only since the II. World War when in situ measurements could be made inside the clouds. Thundercloud physics cover a relative wide range of physical law from thermodynamics to electricity. The most important are the following.

Figure 1. Cumulonimbus

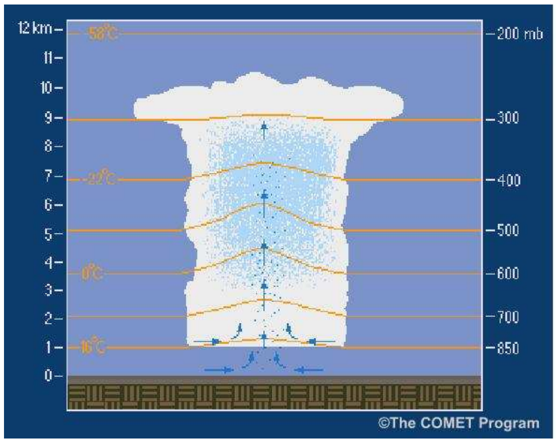

Figure 2.Schematic picture of a cumulonimbus

Buoyancy

Behind the most important process taking place in the clouds lays simply the buoyancy, which is upward force acting on an air parcel due to the density difference between that parcel and the surrounding air. This force causes the air parcel to accelerate vertically, so convective updraft is the consequence of this force. The increase or decrease of the buoyancy of air parcels are influenced by several factors. Increasing water vapour content increases buoyancy, while cloud water and precipitation act to decrease buoyancy. If a parcel is less dense than the surrounding air, it rises freely with increasing speed until it becomes as cool (as dense) as the surrounding air. At this level it stops accelerating, but since the parcel has upward momentum, some additional ascent occurs. This additional rise forms the overshooting top above the anvil. Finally, the parcel oscillates vertically about the equilibrium level, but its motion is quickly damped. This process can be illustrated beautifully with the free animation published at http://www.meted.ucar.edu/. Fig. 2 shows a characteristic picture from the buoyancy driven updraft.

Buoyancy and thermodynamics

Clouds are formations of condensed water vapour. Therefore they consist of air, some water vapour and aerosol particles. Their main component is the air which can be considered to be an ideal gas. The development of the cloud is essentially is the adiabatic ascent of an enormous air

bubble. The ascending air bubble is expanding and cooling and clouds appear when the temperature reaches the dew point.
Till this point the vapour content of the ascending air bubble is negligible and the temperature of the bubble can be approached as if the gas were pure air. When the water vapour is condensing the effect of the condensation heat must be taken into account.
While the air of the developing cloud is lifting up, its moisture is condensing. Although the acceleration of the air parcel increases due to the releasing latent heat, the weight of the condensed water drops will eventually be too much for the updraft to hold aloft. Therefore, precipitation will begin to fall back down through the updraft. Precipitation drags air with it and initially, this is the most significant effect influencing the strength of a downdraft. When the downdraft reaches the surface it spreads out and constitutes a cold pool. This is the last stage of the development of a cumulonimbus.

Advanced physics of thunderclouds

In the previous discussion the effect of the wind and the rotation of the air masses were not tacitly taken into account, although they cause important changes in the development of the thunderstorms. Vortices can interact with each other and influence the updraft of the air (Fig. 3).

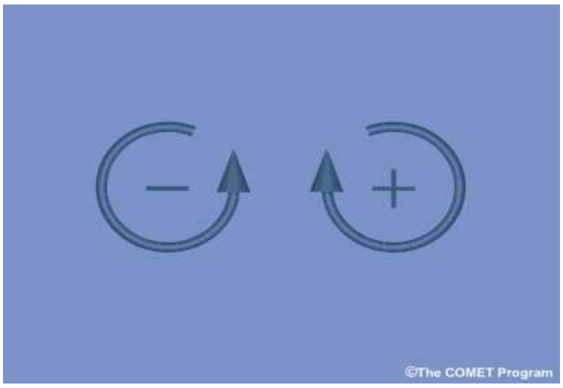

Figure. 3 inversely revolving vortices

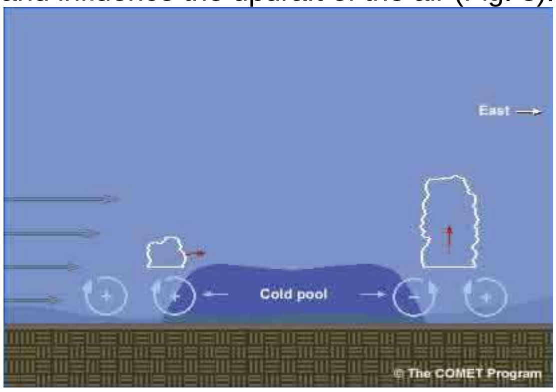

Fig. 4. Cold pool with interacting vortices

Vertical component of the wind generally increases with the height therefore there is a vertical wind shear in the wind field. A sheared vertical wind profile causes horizontal vorticity in the atmosphere. Vorticity can be demonstrated by the rotation of an imagined paddle wheel put into the wind field. It must be remarked, that the mathematical description of the vorticity needs the knowledge of basic elements of the tensor calculus and differential operators. However, the animation visualising the motion of the air gives a preliminary picture of this ideas. Similarly to the vertical wind shear horizontal vorticity is also generated by the formation of the cold pool. (Fig. 4.).
As the animation show the interaction of these vortices can generate new updraft and hereby initiate the development of a new cumulonimbus cloud (Houze, 1993).

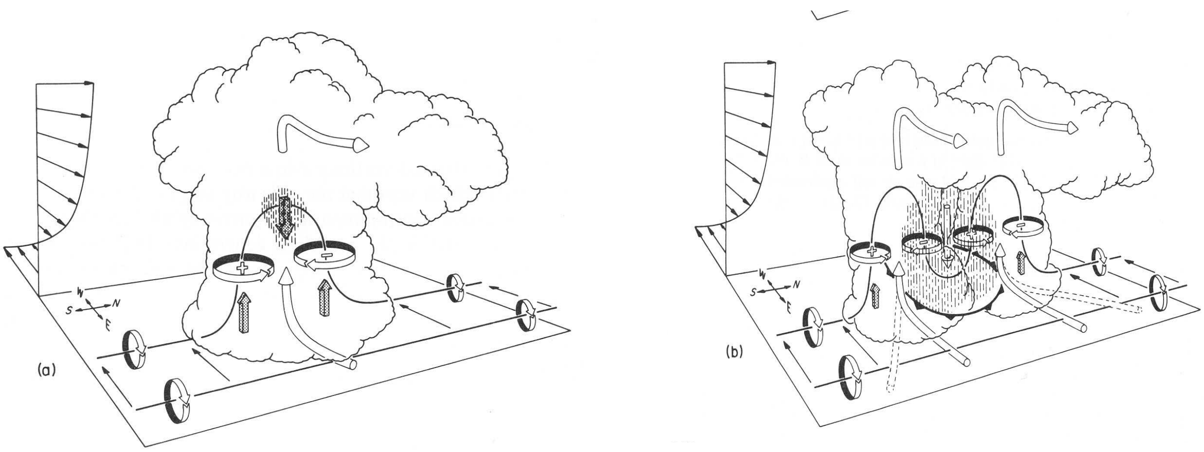

Figure 5. Transformation of the horizontal vorticity into vertical one

It is well known that the great storms rotate rapidly about its vertical axis. The development of this quick motion can be the result of the interaction of the horizontal vorticity existing due to the strong vertical wind shear and the ascending motion of the highly buoyant air parcel. Then the updraft conveys the vortex line with it and the horizontal vorticity is transformed into vertical one. This is the first step of the development of the high vertical rotation of a thunderstorm (Fig.4.) (Klemp, 1987).

Electrification of the clouds

Atmospheric electricity as a scientific discipline began when Benjamin Franklin in 1752 proved that thunderstorms are electrical phenomena. This field of science became very complex and broad one since Franklin's findings. So to give a survey about it is far beyond of this article. However, we try to show some interesting fragments of this field which can be attractive for students.

Most spectacular manifestation of cloud electrification is lightning (Fig. 6.). Lightning occurs when the electric field in some region exceeds the breakdown value. In a dry atmosphere an electric field of 3000 kV/m is needed to produce a spark between electrodes. However, observation shows that in thunderclouds breakdown values were of an order of smaller magnitude (Marshall and Rust, 1991) It is mysterious how lightning initiates! Recently Gurevich and Zybin (2005) proposed an supported experimentally an explanation according to which cosmic radiation triggers the lightning.

Figure 6. Lightning

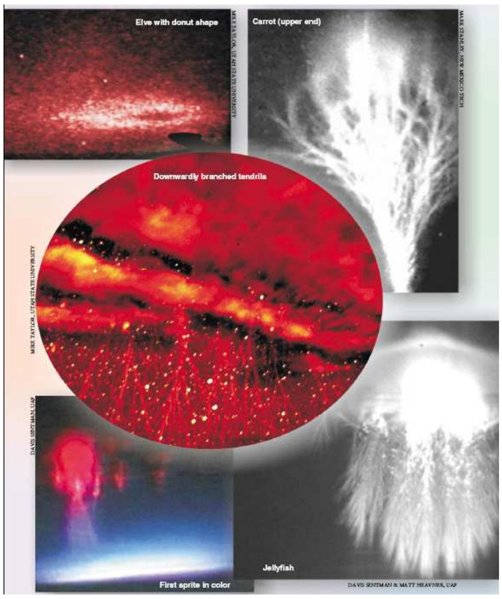

Figure 7. Sprites and elves

It was also a highly debated question of the charge structure of the clouds. Two very famous British scientists, Simpson and Wilson, debated on the electrical polarity of thunderclouds for nearly half of the 20th century. The history of their debate provides an interesting example of how different emphasis placed on different aspects of an incomplete picture by competent scientists can still lead to divergent interpretations.

A current topic of the cloud physics is how the charges are separating in clouds. (Sounders, 2008) Recently scientists agree that in various clouds various mechanisms are controlling the charge separation. Highly accepted mechanisms of it are particle interactive charge transfer, for example, the collisions of hydrometeors. It was shown that freezing of supercooled cloud drops on the hail and graupel particles surface is accompanied by exhalation of a great number of microscopic bubbles. The bubbles exhaled carry away a great amount of positive charge to the surrounding space while the compensating negative charge remains on the solid particles of hydrometeors. Zhekamukhov at al. (2006) in a current paper suggest this as the most powerful mechanism of thunderstorm electricity generation which explain all characteristic features of thunderstorm electricity. Finally, it is worth showing some picture of the mysterious elves and sprites appearing above the thunderstorms in the stratosphere (Fig.7). (Williams, 2001)

2. The halos

Notes about halos are known from the Middle Ages (Fig. 8). Halos are strange arcs on the sky situating mainly around the sun. Their origin is similar to that of the rainbows, but while rainbows are caused by the refraction of light on water droplets halos are the results of refraction on small ice crystals. Therefore it is understandable that the most beautiful halos can be observed in the Antarctic where the air is very cold and dry so ice crystals are growing quickly. In contrast with the uniform shape of the water drops the form of ice crystals (and their orientation to the sun) can be very various and it diversifies the form of halos. Explanation of the development of various halos is well documented in the literature and on the internet. Fig. 9. shows a beautiful picture taken from the internet which illustrate well the complexity of the haloes.

Simple forms of halos can be observed relatively often. However, taking photos from it is a challenge because photos should generally take against the sun and should use a fisheye lens. In spite of this there are halo “hunters” all over the world and students often are very keen on photographing these phenomena. Moreover the observation of the halos can be joined with nice simulations of the ”halosim” program available on the internet (http://www.atoptics.co.uk/halo/). One of the authors of this paper (Döményné) leads a group of enthusiastic students who studies the phenomena of the sky in a secondary school of Hungary.

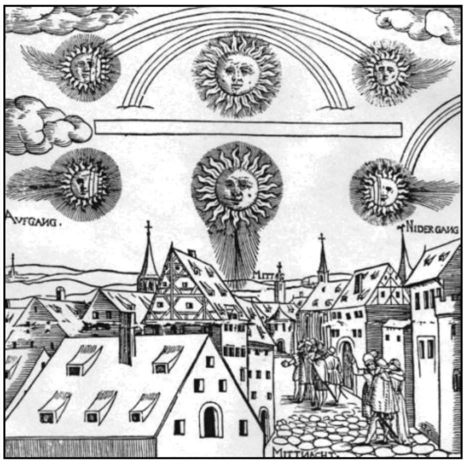

Figure 8 Halo (Nürnberg 1554)

Figure 9. Complex halo photographed at Antarctic

Summary

To foster the students’ internal motivation for learning physics is a basic goal of teachers. Present paper suggests for this the discussion of a collection of phenomena taken from the field of atmospheric physics. These phenomena can be introduced into the curriculum very different ways. They might be illustrations of the basic laws of physics, but some topic of it could serve as a project work.

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