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Measuring the Height of Clouds

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MEASURINGTHEHEIGHTOFCLOUDS

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Measuring the Height of Clouds

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I. Introduction

The International Atlas of Clouds was produced as a result of long observations and it lists 10 cloud species, 14 cloud types, 9 cloud subtypes, 9 accessory clouds and their possible varieties. The Cloud Atlas contains the characteristic features of clouds, their height measured from the Earth's surface, among others. The measured altitude values result from a great many instrumental measurements, so for the purposes of describing the height of a selected cloud species, the tables – due to the alterations of the volumes determining the atmosphere – contain not only one specific altitude value, but a series of values covering a wide range.

Altimetry can be carried out with balloons, using radar-technology or lasers. The altitude of the dew-point, which equals the altitude of the cloud base, can be determined with the help of the psychrometer lifted by the balloon.

Measuring with electromagnetic waves means that the reflection of a vertical beam is detected from a known distance (Figure 1). The plus angle can be determined from the position of the receiver; thus the altitude of the cloud can be calculated. [1].

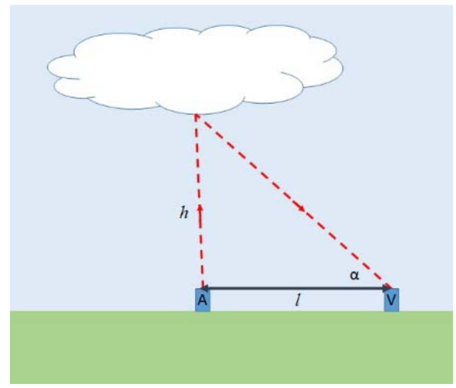

Figure 1 : The waves emitted by station „A" and reflected by the cloud are detected by receiver "V". The altitude of the cloud base can be determined from the data of the receiver. $(h = l \cdot tg\alpha)$

In the absence of expensive measuring appliances we can define the altitude of the observed clouds using the following method [2]:

After sunset the clouds are still sunlit for a while. This happens because the clouds are higher (h) than the observer located at P.

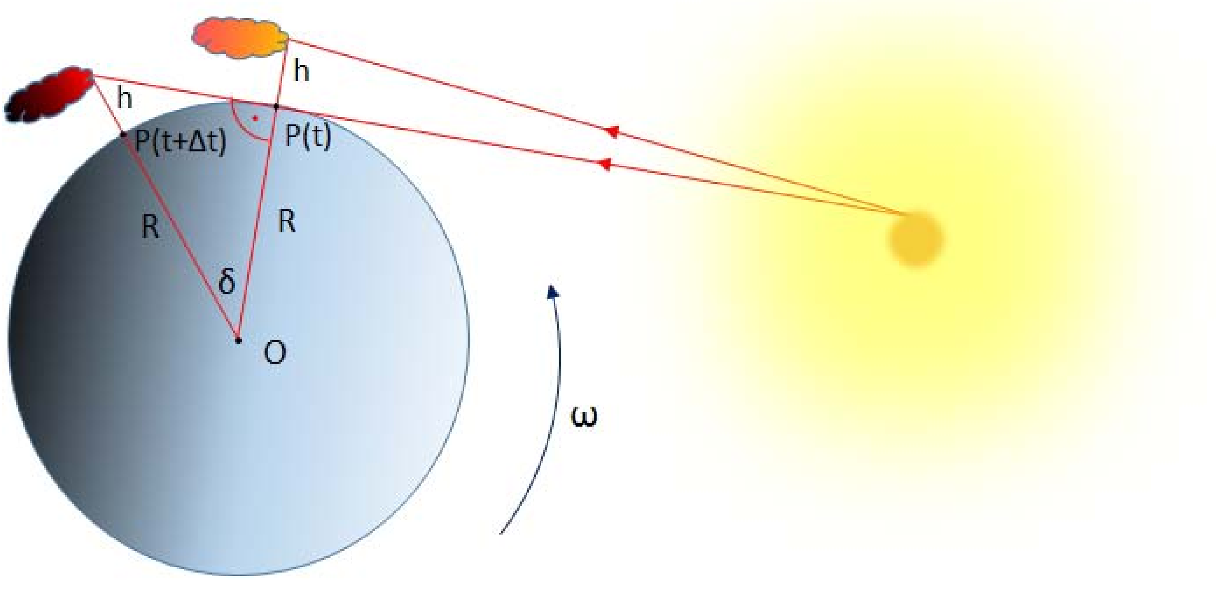

Figure 2 : After sunset the clouds above us are still sunlit for a while

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In order to successfully measure the altitude of the clouds above us, we need a clear sky above the horizon. Let's monitor the sunset, and start a stopwatch when the Sun sinks below the horizon. Let's stop the stop-watch when the light moves away from the cloud above us. During the elapsed Δt time the Earth rotated around its axis with angle δ, and point P(t) moved to point P(t+Δt). The angle δ can be calculated simply by using direct proportionality:

$$86400\ s\ \rightarrow 360°$$

$$\Delta t = 429{,}6\ s\ \rightarrow \delta$$

$$\delta = \frac{429{,}6s}{86400s} \cdot 360° = 1{,}79°$$

Then the altitude of the cloud (h) can be expressed from the right-angled triangle in Figure 2:

$$cos\delta = \frac{R}{R+h} \rightarrow h = \frac{R}{cos\delta} - R = \frac{6{,}37 \cdot 10^6 m}{cos1{,}79°} - 6{,}37 \cdot 10^6 m = 3109{,}9m$$

In the first place, for the success of the measuring, it was important to find a suitable location, one which gave a clear view of the horizon without landmarks covering the view. The second critical precondition was having few clouds above the horizon so that the last rays of the setting Sun could reach first the observer, then – after the sunset – the clouds above us, and then be reflected by the clouds back to the observer's eyes.

We found this suitable location on the 6th floor of the College of Nyíregyháza, but only after several attempts could we observe favourable conditions and carry out the measuring itself.

II. Ideas for a More Accurate Height Determination

During the measuring the students worded a number of ideas on how to make the calculations more accurate. The most relevant idea was to examine to what extent the degree of latitude and the altitude above sea level influence the end result of the measuring. The values measured above sea level might – under different terrain conditions – be different at different points on the Earth. Thus Figure 2 had to be altered (Figure 3).

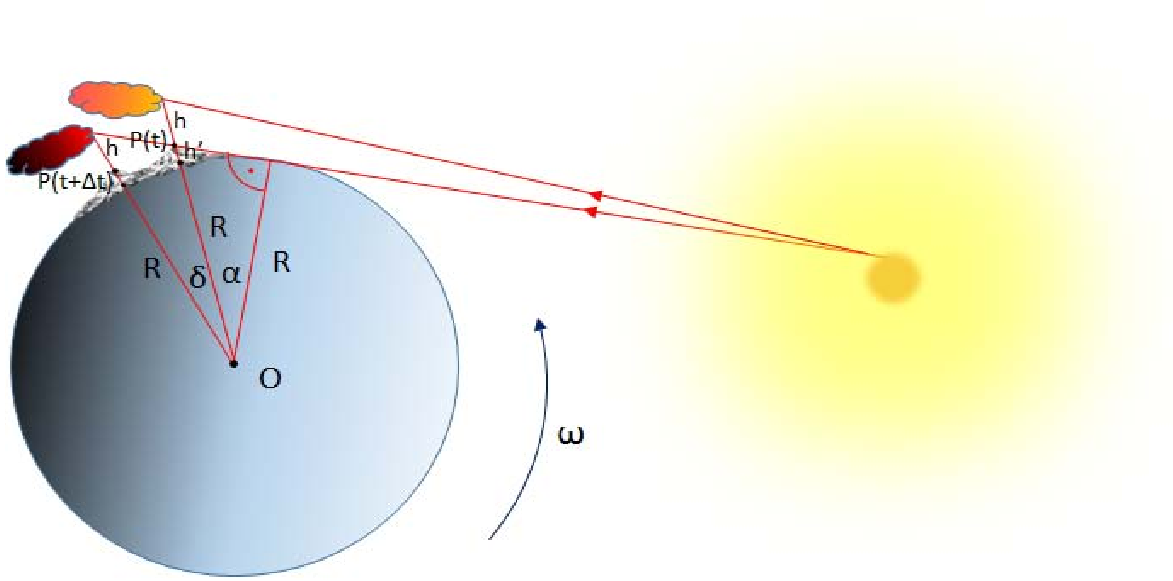

Figure 3 : If the measuring is carried out above sea level, Figure 2 alters. For the purposes of determining the altitude of the cloud we used the similarity relations of the two right-angled triangles. Letter h' means the altitude above sea level of the measuring location

The following relations can be formulated from the right-angled triangles of Figure 3:

$$cos\alpha = \frac{R}{R+h'}$$

$$\cos(\alpha+\delta) = \frac{R}{R+h'+h}$$

$$h = \frac{R}{\cos(\alpha+\delta)} - (R+h')$$

Considering the distance (R') measured from the rotation axis defined by the degree of latitude (φ):

$$R' = R \cdot cos\varphi$$

We can define the following function:

$$h(\Delta t) = \frac{R \cdot cos\varphi}{\cos(arccos\dfrac{R \cdot cos\varphi}{R \cdot cos\varphi + h'} + \dfrac{\Delta t}{86400s} \cdot 2\pi)} - (R \cdot cos\varphi + h')$$

For the purposes of defining the function domains and the function ranges we also used the data of the Cloud Atlas:

Table 4 : Illumination periods calculated with the altitude values of the Cloud Atlas at the Equator and at Nyíregyháza

Cloud Type	Altitude of Occurrence (Km)	Observation Period After Sunset (Min) $\Phi=0^0$	Observation Period After Sunset (Min) $\Phi=48^0$
Noctilucent Clouds	76-85	35-37	43-45
High Clouds	6-13	10-15	12-18
Middle Clouds	2-6	6-10	7-12
Low Clouds	0-2	0-6	0-7

When looking at the cloud classification we can see that there is a so called "forbidden zone", namely the stratosphere, where clouds can form only in extremely specific conditions (especially at the poles) (Table 4 and Figure 5), where "traditional" clouds cannot form (13-76 km), but above this – in the mesosphere – polar mesospheric clouds can be observed. It is evident from Table 4 that a cloud moving at a given altitude will illuminate in the dark for a longer period when observing it from a greater angle of latitude.

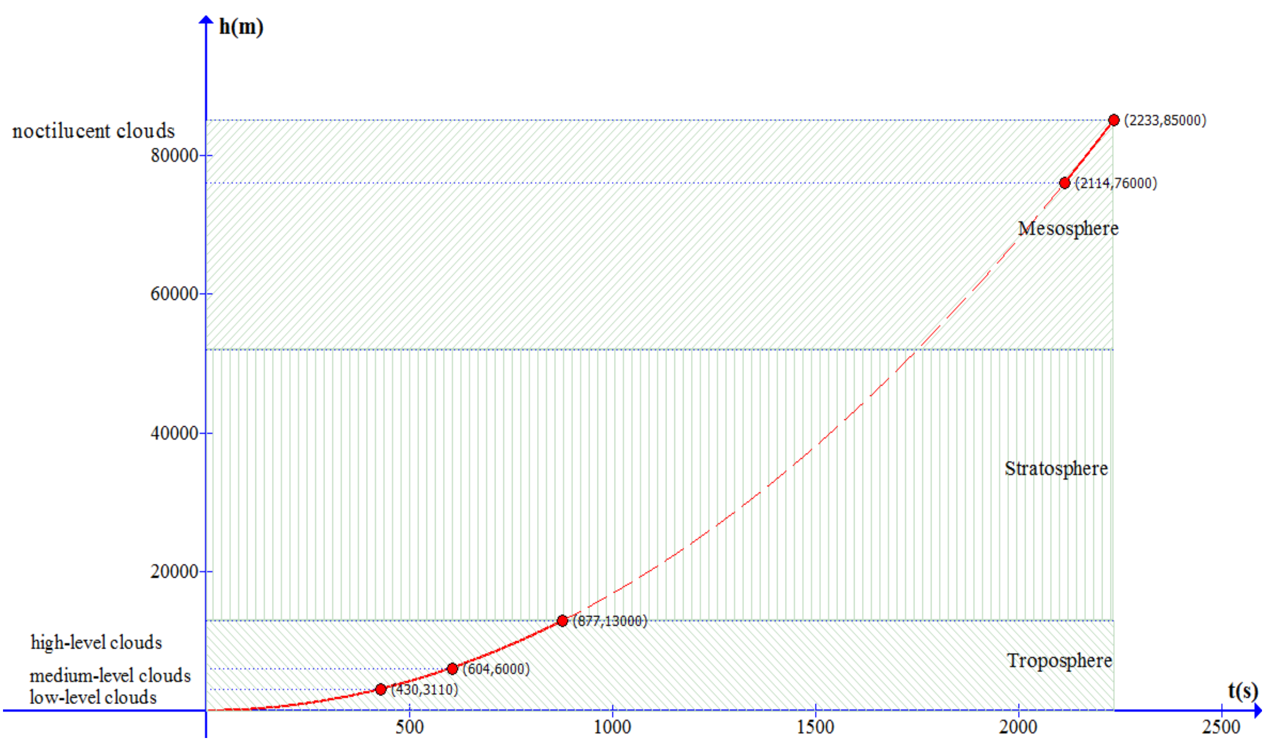

Figure 5 : The altitude of clouds above sea level as a function of illumination periods ($\varphi = 0,\ h' = 0$)*. The broken line on the figure indicates the forbidden zone*

Similarly, the altitude above sea level of the measuring location itself might significantly influence the calculations (calculated with 40% of time difference between the sea level and Mount Everest) (Figure 6).

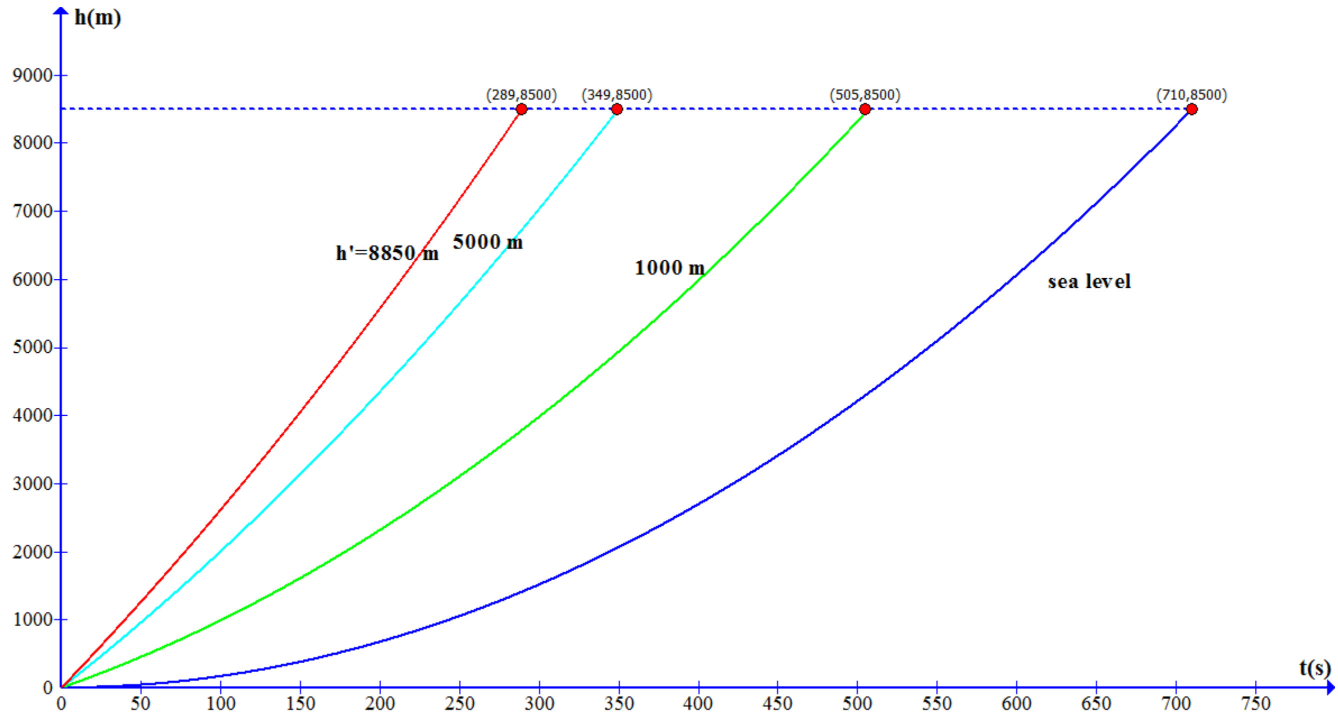

Figure 6 : *The altitude of clouds as a function of illumination periods using variable h' (altitude above sea level)*

The degree of latitude influences the measuring to an even greater extent: there might even be a 60% difference between the illumination periods of two clouds at the same altitude, one being at the Arctic Circle, the other at the Equator (Figure 7).

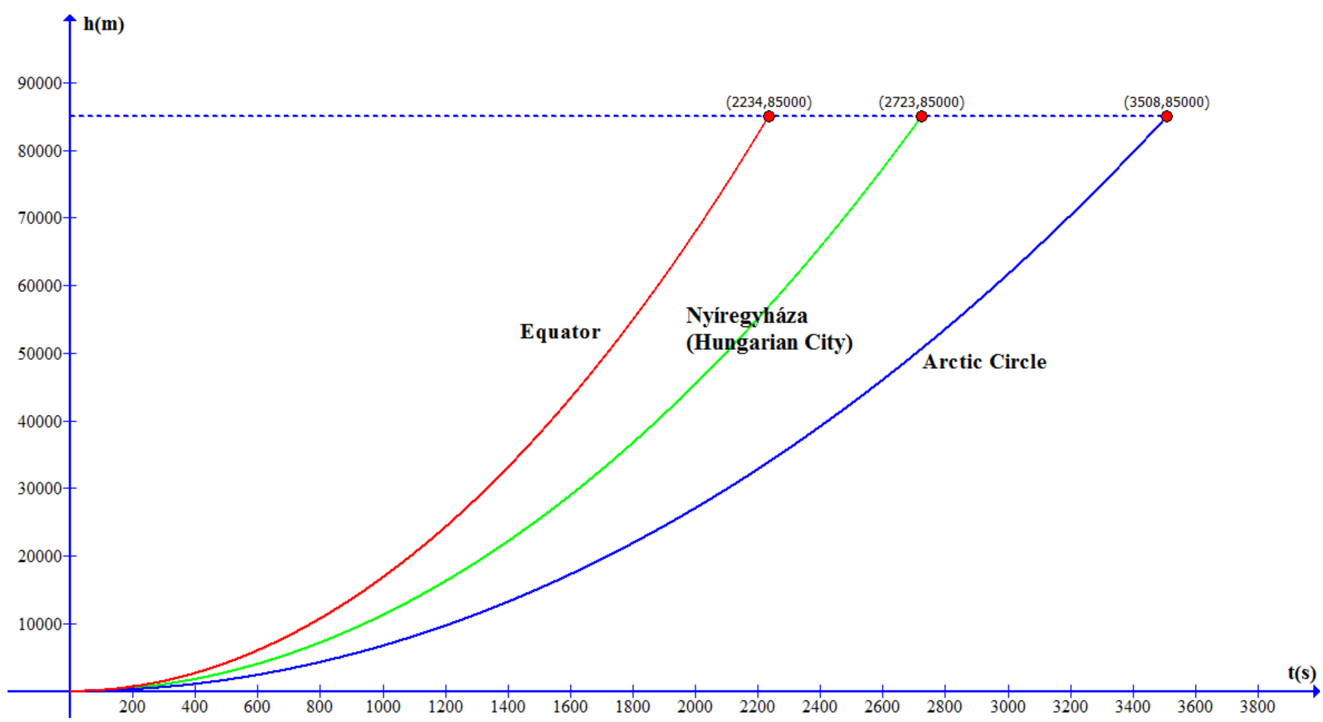

Figure 7 : The altitude of clouds as a function of illumination periods using the variable of the degree of latitude. The forbidden zone is not indicated in the figure

III. The Illumination of Landmarks

The illumination of clouds is a fascinating spectacle in the night and dawn sky. However, the taller landmarks, towers and mounts are also capable of illuminating; only for shorter periods than clouds (Figure 8).

Figure 8 : Illumination of a mountain-top on the Isle of Hvar. The towering white cliff top shines in gold against its dark surroundings

The obelisks and colossal pyramids of the Ancient Egypt might have also presented breathtaking spectacles before and after sunset when the brightly polished stones (which have almost completely disappeared by now) reflected the sunrays into the dark landscape. Prayers addressed to the Sun-God were carved on the obelisks the tips of which were covered in some intensely light-reflecting polished metal, mainly gold. These facts suggest that the 10-30 metre high monoliths were used for letting the first sunrays be seen, as well [3].

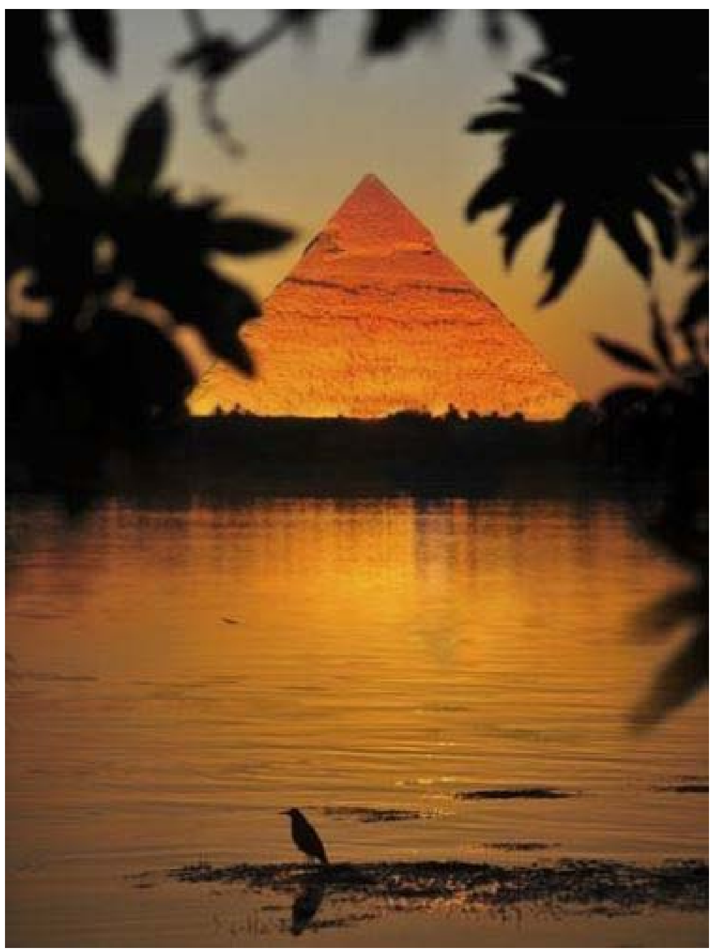

Figure 9 : The Great Pyramid of Giza [4]

Egyptian ethereal faith presumes that our souls are eternal and can migrate. According to this faith the spirit can again and again move into the mummified bodies buried in the deep of the pyramids. The shining of the pyramids at dawn and at dusk might also have symbolised the moving into and out of the body of the Pharaoh's returning soul.

If we create a Δt(h) function from the h(Δt) function, by using it, we can calculate the illumination periods of well-known tall buildings. However, the calculations are too lengthy, so we have written short software [5] in C# programming language for the purposes of calculating the altitude of the clouds and the illumination periods of the landmarks (Figure 10).

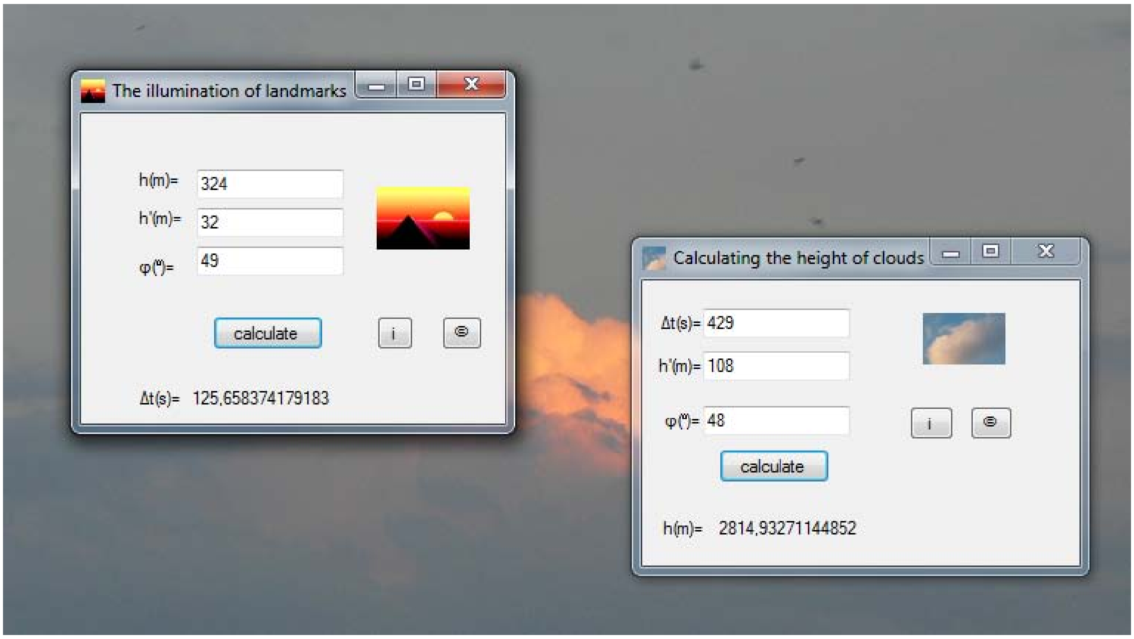

Figure 10 : *Software with informative tabs written in C# language assisted our calculations.*

Using these software and Google Earth [6] we have calculated the illumination periods of several well-known tall buildings (Figure 11).

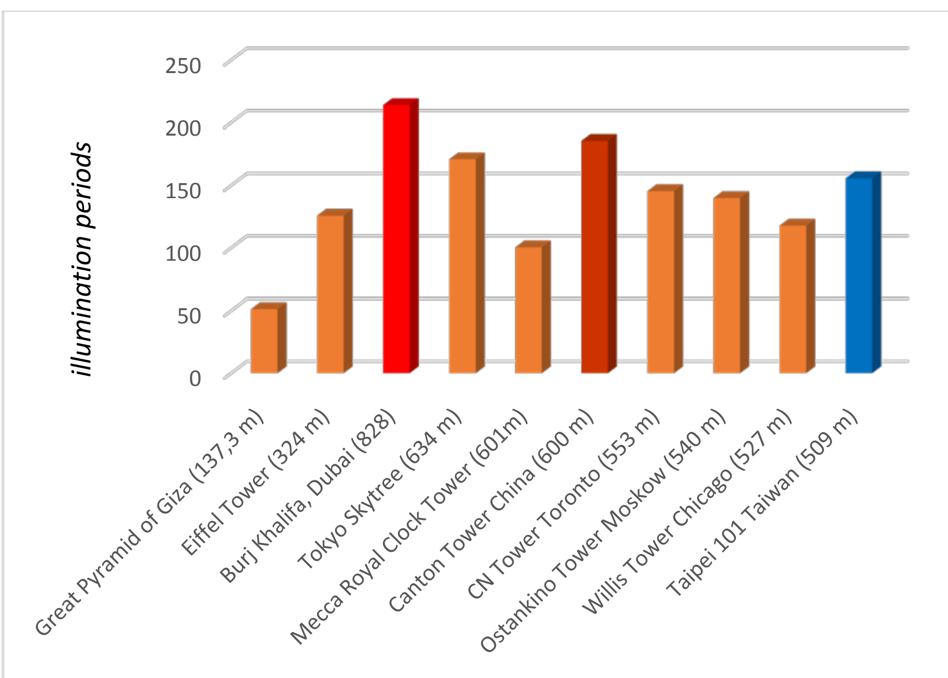

Figure 11 : The illumination periods of certain tall buildings. Besides the height of the building, the illumination periods depend also on the altitude above sea level and the degree of latitude

Contrary to the fact, that the Eiffel Tower is relatively not that tall, it has quite a long illumination period owing to its favourable location.

Of course, assigning illumination periods to various buildings would only make sense if they stood alone in the middle of a desert, without neighbouring landmarks, similarly to the pyramids. Otherwise the calculated results cannot be compared to the measured values.

IV. Conclusions

Besides the rotation of the Earth, the cloud was also moving during time measuring, and so was the Earth on its elliptical orbit. However, we ignored these movements in our measuring. The most significant inaccuracy of the measuring resulted from the temporal defining of the observations.

In spite of its inaccuracy, I do consider this measuring useful, because it approaches a specific Earth-related movement from a general point of view. The physical facts, that the Earth rotates (and to what extent could the atmosphere follow the Earth's surface?), and whether the clouds perform a uniform linear motion on short sections, and what data are necessary for measuring the speed of clouds, and what conditions influence the measuring and what conditions are negligible; all these realizations brought the students to a certain complex thinking as opposed to the exercises in the Physics books, which only favour problems relating to one specific topic. The above complex and at the same time general measuring, however, brought the Physics classroom sessions closer to everyday occurrences for my students.

V. Acknowledgements

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