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Technical Report 1: Characterization of the observing conditions of the Helmos Observatory

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Abstract

In this report we present an analysis of the environmental parameters which characterize the observational conditions of the Helmos Observatory. For this characterization we used data taken on the site, as well as satellite data, for the years 1998 - 2017. We measured and analyzed temperature, humidity, winds, cloudiness, night sky brightness, and seeing. The results show that the mountain of Helmos is a very good observatory site for Greece and mainland Europe.

1. Introduction

The Helmos Observatory is one of the largest contemporary research infrastructures in Greece. It hosts the ARISTARCHOS telescope, which is the largest optical telescope in the Balkans and the second largest optical telescope in continental Europe. This telescope, with a diameter of 2.3 meters, is located on the top of the mountain of Helmos in central Peloponnese (Longitude: E22^{h}11^{m}46^s, Latitude: N37^{o}59'04"), at an altitude of 2340 meters above sea level. This location is one of the darkest sites in Greece and continental Europe because it is under-populated. Due to its high altitude, the observatory very often lies above the top of the clouds and above the inversion layer of the atmosphere, yielding excellent seeing conditions. One additional important characteristic is the fact that the climate of southern Greece is mild and this translates to a large number of clear nights per year (the yearly average varies from 160 to 180 clear nights). Moreover, the mountain of Helmos has a low frequency of lightning. In addition, dust from Sahara is a very rare phenomenon.

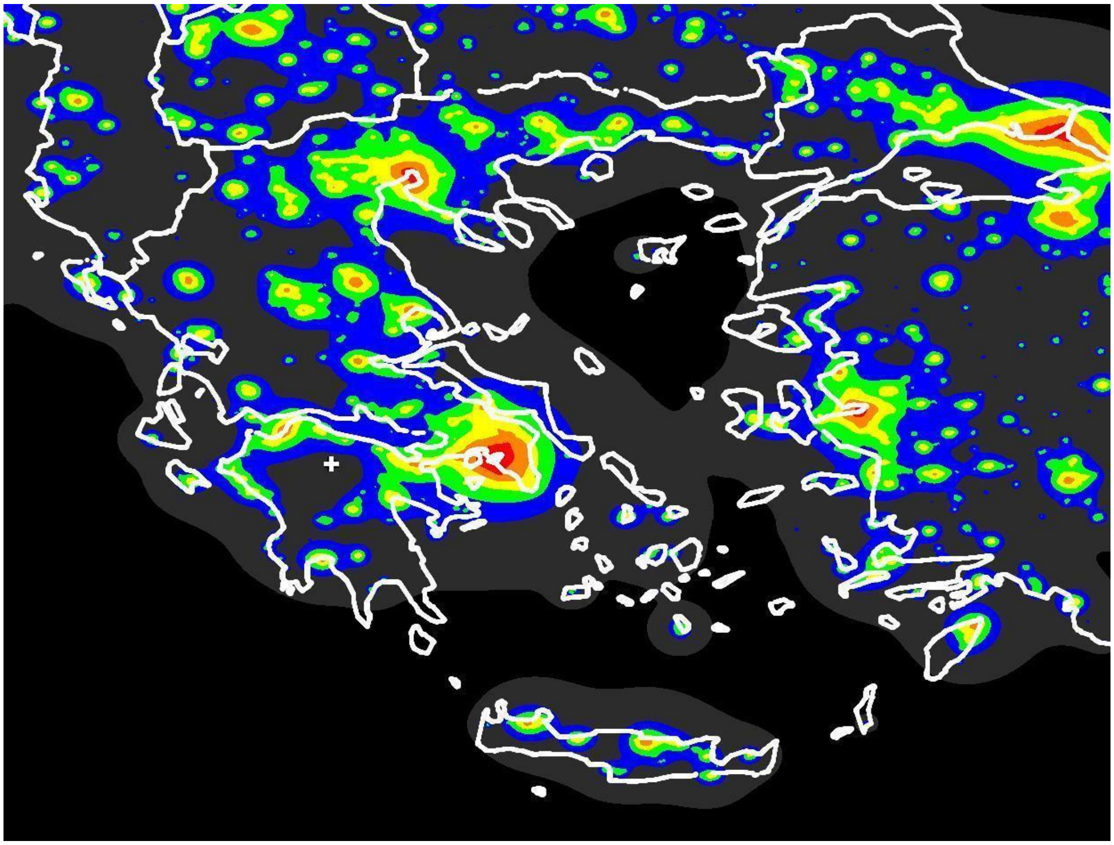


Figure 1. *Light pollution map of Greece. The location of the Helmos Observatory is marked with a white cross.*

The existence of the nearby Kalavryta Ski Center enabled the development of the basic infrastructure, which includes road and electric power to the Helmos Observatory. It also guaranties the access to the observatory during the winter time via the ski lifts and snow vehicles of the Ski Center. This combination of favorable factors makes the Helmos Observatory unique in continental Europe. In this report we will focus on the environmental conditions which characterize the site.

2. Methodology

Until 2013, meteorological data were collected from the meteorological station of the telescope. For this reason, the yearly sampling of meteorological data was not very dense and concentrated mainly in the summer – autumn period. Currently, the telescope is in good operating condition and the data sampling has improved. Moreover, with the installation of the heavy duty meteorological station of the Helmos Observatory (October 2013), we now have continuous meteorological data monitoring and collection, independent of our presence on the mountain. As a result, the data statistics have improved significantly.

For the determination of the cloudiness statistics we used both satellite data and observations from the site. Until recently, the satellite images of the area were inspected visually. Currently (since June 2014), this process is being executed in a more coherent and automated fashion through the project BEYOND of our Institute. In addition, since December 2013, we are also employing the two cameras of the Helmos Observatory. The combination of cloudiness data from the BEYOND project with data obtained from the two cameras gives an excellent correlation with the on – site visual observations (correlation coefficient 0.94). The night sky brightness was measured with the Aristarchos telescope and the seeing parameter with the DIMM telescope of the Helmos Observatory. For the reasons mentioned above, and until we collect large samples of environmental data, we performed the analysis for the two markedly different seasons separately: the Summer period (including Autumn, from June to November) and the Winter period (including Spring, from December to May). Even the access to the observatory depends on the seasonal differences: from June to November we can access the Helmos Observatory with car, while during the winter – spring period access is possible only via the lifts of the Ski Center.

3. Observations

3.1 Meteorological conditions

As we mentioned earlier, until the middle of 2013 we did not have a dense sampling of the meteorological data. By July 2013, this picture changed dramatically. We had a regular presence on the observatory, collecting meteorological data among other works, and on November 2013 we installed the heavy duty meteorological station of the Helmos Observatory. The instruments are all electrically heated and this helps to reduce the "frozen" time intervals in the wintertime. The parameters examined here are temperature, relative humidity, wind speed, wind gust, and wind direction. Humidity and wind speed are of particular interest for our purposes, since they affect the observing conditions of the telescope. The allowed observing ranges for telescope operation are: Relative Humidity < 80% and Wind Speed < 54 km/hr.

3.2 Cloudiness statistics

The observations of the satellites span all the months of the year (for 8 years in the last decade), but they give only the picture of the general area and cannot resolve the mountaintop of the Helmos Observatory. However, the resolution of the satellites is not a problem for our purpose. A circle with a diameter of 7 pixels (and a corresponding area of 38.5 pixels) covers a cone on the sky with a solid angle of approximately 150 degrees on the average, depending on the altitude of the clouds, as seen by the observer on the ground. On the other hand, the observations from the site are precise, but they are taken mostly during the fulltime period of operations. Until 2012, 90% of the observations referred to the period from June to October and only 10% to the rest of the year. With the observatory now running in a regular mode and with the assistance of the Ski Center, we collected more visual data for the winter – spring time and the percentages currently are 78% and 22% respectively.

3.3 Night sky brightness.

The sky brightness was measured in the moonless night of 10 September 2013. We took observations in the standard Johnson pass-bands U, B, V, R, and I. However, even though the specific night was pretty dark, it turned out to be not really photometric because there were some very thin sparse clouds which affected the sky brightness and these measurements will have to be repeated.

3.4 Seeing.

In the autumn of 2012 we finished the installation of a Differential Image Motion Monitor (DIMM) to observe the seeing parameter, which is a measure of the atmospheric turbulence and affects the sharpness of the observed astronomical images. During the summer of 2013 we started taking seeing measurements. It must also be mentioned that the DIMM telescope was not equipped at the time with an autoguider to correct constantly the tracking of the telescope. This often adds artificial motion of the images. In 2014 we installed the autoguider and continued taking seeing measurements.

4. Analysis

4.1 Temperatures

The lowest temperature measured is -18 degrees in December and the highest is 29 degrees in July. The average temperature variation through the year, as well as the highest and lowest values measured in 10 day intervals each month is shown in figure 2. A typical ΔT between day and night in a cloudless August day is 8 degrees. In the wintertime the typical ΔT between day and night is about 5 degrees.

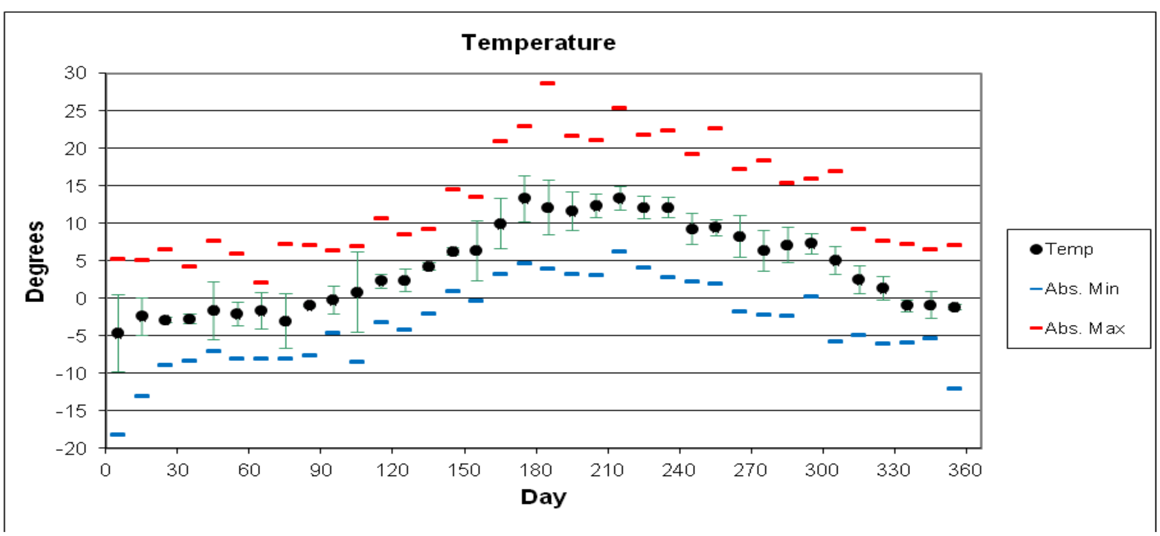
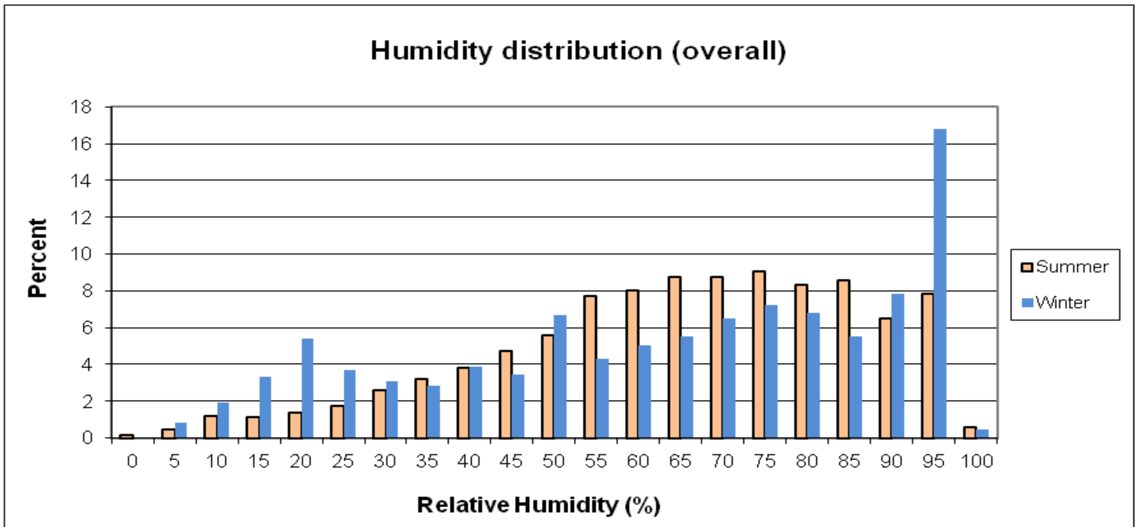


Figure 2. *Mean yearly temperature variation (in 10 day intervals).*

4.2 Humidity

The average relative humidity is 68%. This value refers to the total number of days, clouded, partly clear, and clear. Excluding the clouded days, for the clear and partly clear days the average humidity is 61% in the summer – fall period, while for the winter – spring period it is 54%. The lowest relative humidity measured is 4% and the highest is 100%. From the humidity distribution it follows that for the summer – fall period, when the sky is clear or partly cloudy, 13% of the times the relative humidity is beyond the telescope operation limit (humidity > 80%). For the winter – spring period this percentage is 19%.



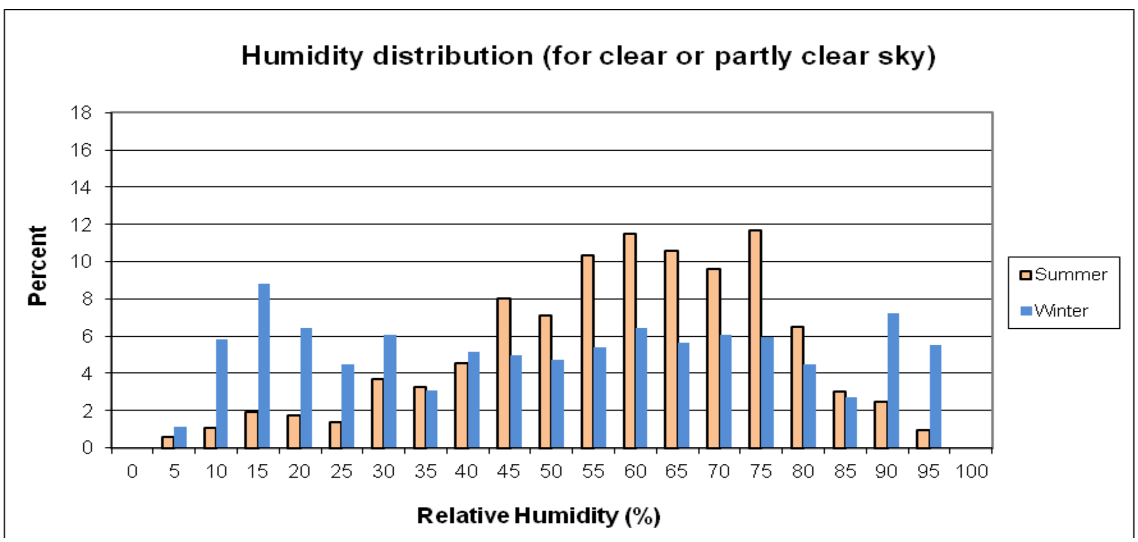


Figure 3. *Humidity range and distribution for the Summer and Winter periods. On the top is the overall distribution. On the bottom is the distribution for clear and partly clear days.*

In most cases during summer and autumn, the relative humidity is lower during the day and higher during the night. The opposite is observed mostly in the winter and springtime.

4.3 Winds

The two wind parameters that we measured are the direction and the speed. The wind speed is characterized by two values: the mean wind speed in a time interval and the peak wind speed value (gust) in that interval. The maximum mean wind speed measured is 103 km/hr and the maximum gust measured is 157 km/hr. From the wind speed distribution it was found that for 17% of the time there was practically no wind (speed < 10 km/hr, including the gusts). The percentage of times with winds stronger than the operating limits of the telescope (> 54 km/hr) is 8%. The strongest winds measured are coming from the south - southwest direction.

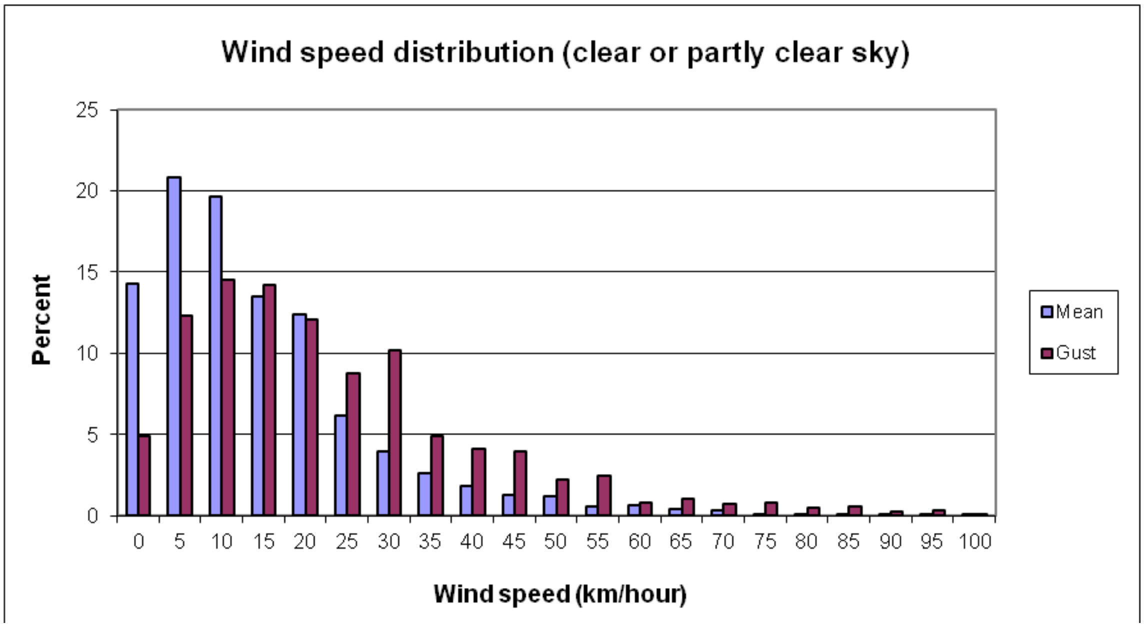
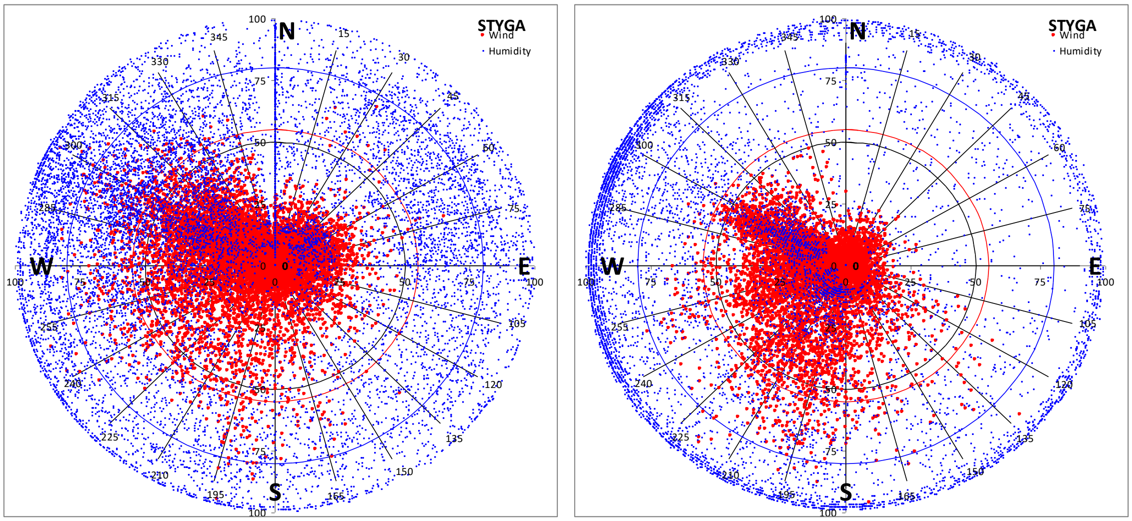


Figure 4. *Wind speed range and distribution for the Summer and Winter periods.*

The prevailing wind direction is the west, especially in the wintertime. In the summer we have also a significant percentage of east winds (17%). As with the case of humidity, the winds too exhibit opposite average daily variations between summer and winter. In the summer the wind speed increases during the night and in winter is higher during the day and decreases at night.

The general trends and distributions of the winds as a function of direction, are best visualized in the polar diagrams of figure5. In these diagrams the direction varies in the angular fashion and the wind speed increases radially. In the same diagrams we have also placed the corresponding humidities. Of course, humidity is not a vector quantity but it is associated with a wind direction in the sense that the wind coming from a direction carries with it the humidity that we measure each time. Since the mean wind speeds measured at the Helmos observatory vary from 0 to roughly 100 km/h and the relative humidity varies from 0 to 100% by definition, it is very convenient to place both quantities in the same radial scale and study their association with wind direction.



Summer – Autumn Winter – Spring

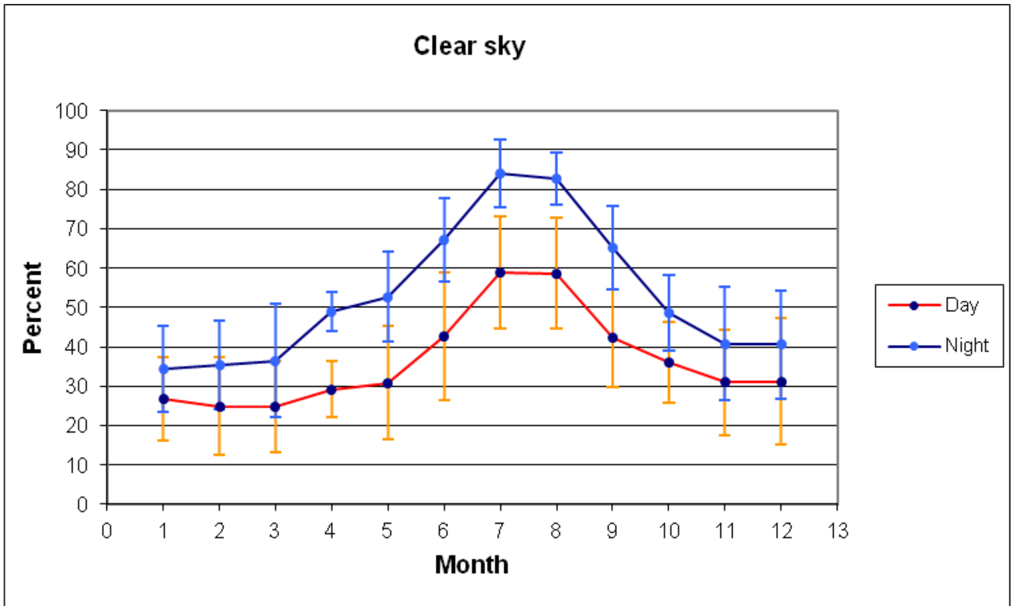
Figure 5*. Angular distribution of wind speed and humidity, for the two seasons of the Helmos Observatory. Wind directions are marked angularly every 15*^{o}*. The scale for wind speed and humidity is marked in units of 25, along the horizontal and vertical axes. The orange circle represents the operating limit of the telescope for wind speed (54km/h) and the blue circle the operating limit for relative humidity (80%).*

As seen in the above diagrams, the prevailing wind direction is the west, all year long. The main difference between summer and winter is that in the summer – autumn season the density of the points is moved towards the north direction, due to the increased frequency of northeast and northwest winds of this period. On the other hand, during the winter – spring season the density of the points is moved southwest because this is the prevailing wind direction at this period. In both cases the higher wind speeds are observed mainly in the west and southwest directions. We rarely observe high wind speeds from the east and northeast directions.

As far as humidity concerns, during the summer season the points in the northwest direction are mostly concentrated within the permitted limit (blue circle), while in the northeast direction the main concentration is around or close to the limit. In the wintertime the situation is very different. We have two main concentrations, one close to the center (low humidities) and another one along the perimeter (humidities between 95% and 100%) which is associated to the cloudy weather of the wintertime, leaving the intermediate space relatively empty. Overall, the wind speed points are mostly concentrated within their limiting circle, while the humidity points distribution is more extended relative to their limit, making humidity the main cause for losing clear or partly clear nights.

4.4 Cloudiness

The cloudiness data span 18 years. The methodology used for the measurement of the cloudiness, distinguishes the cloud coverage of the area into three categories: 1) clear sky, 2) partly cloudy, and 3) fully clouded. With this notation, the cloudiness was measured both through satellite images and on-site observations. The results are consistent and the accumulated data allows for studying the cloudiness on a monthly basis. As expected, the percentage of clear skies peaks around July and August and shows a minimum from January to March (figure6).



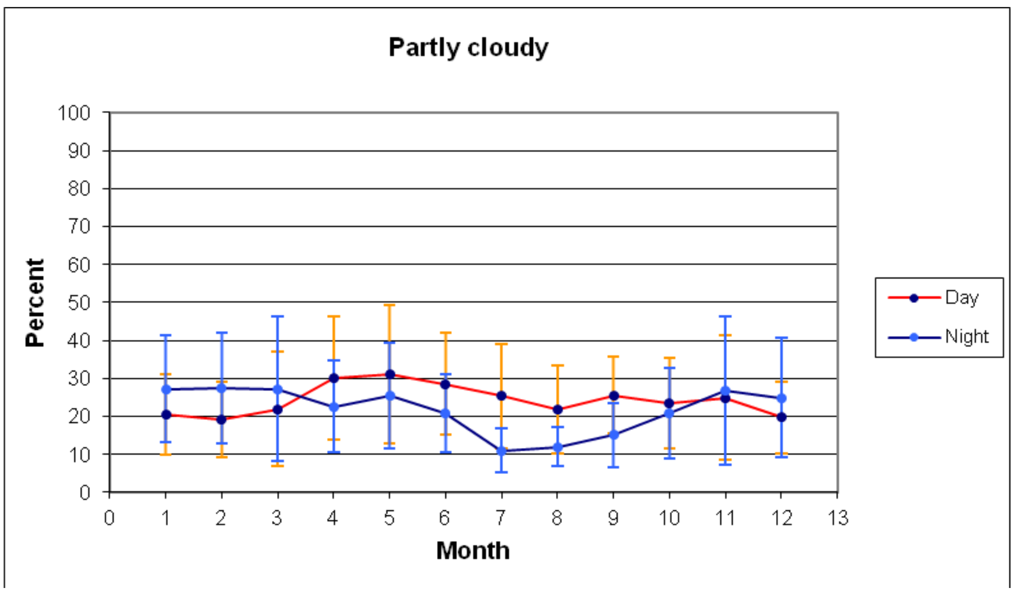


Figure 6. *Average monthly percentages of clear skies (top) and partly cloudy skies (bottom). Red color is for the day-time and blue for the night-time.*

In general, the cloudiness is higher in the day-time and lower in the night-time. The daily variation is twice as large in the summertime compared to the wintertime. For an observatory though, the cloudiness alone does not tell the whole story. What is more important is the percentage of the observable nights, which takes into account the losses due to wind – humidity. From these data we found that during the summer – autumn period 23.9% of the clear and partly clear nights are not observable because the wind speed exceeds 50 km/hr or the relative humidity is higher than 80%. For the same reason, during the winter – spring period this percentage increases to 32.1%. Excluding these nights, the percentage of observable nights is given in table 1:

Table 1
Direct measurement of fully or partly observable nights at Mt Helmos

Season	Fully observable	Partly observable	Non observable
Summer - Autumn	43.1 %	11.8 %	45.1 %
Winter - Spring	25.2 %	15.7 %	59.1 %
Yearly	34.2 %	13.7 %	52.1 %

During the period between June and November we can expect on the average 90 – 110 clear or partly clear observable nights and during the winter spring period we can expect approximately 70 - 80 clear or partly clear observable nights. From the observable nights, 19% are photometric for the summer – autumn period. For the winter – spring period, this percentage rises to 23%. In terms of observing hours, 53.3% of the summer season total hours are observable, and for the winter season 24.6% of the total hours are observable. The losses of clear or partly clear nights are 70.1% of the time due to humidity, 24.4% due to wind, and 5.5% due to both.

4.5 Night sky brightness

The observations of the night sky brightness that we took in the dark but not very photometric night of 10 September 2013, yielded the following values in the U, B, V, R, I photometric bands:

U filter: 20.2 mag/arcsec^2
B filter: 21.6 mag/arcsec^2
V filter: 20.7 mag/arcsec^2
R filter: 20.0 mag/arcsec^2
I filter: 18.3 mag/arcsec^2

For technical reasons, the U and I passband measurements must be considered with great caution and we should rather focus on the B, V, and R measurements. Due to the medium quality of the night, the observed magnitudes cannot be considered as limiting magnitudes. For instance, on other astronomical images taken with the R and I filters in July 2013, during nights without thin clouds, it was found that the sky brightness was 20.2 and 18.6 magnitudes/arcsec^2 respectively. So, in order to find the actual values we plan to repeat these measurements in summer 2019. In any case, the above first values already show that the site is very dark.

4.6 Seeing

Due to the lack of an autoguider that we mentioned earlier and a problem with the mask of the DIMM telescope, the data collected in 2013 give values artificially higher than the actual seeing values of these 19 nights. Hence, the values determined from the 2013 data can only serve as higher limits. The median value of the seeing measurements taken during these nights, grouped together, is 0.78 arcsec and the sample contains values as low as 0.25 arcsec in the low tail of the distribution. On the other hand, the seeing data of 2014 give a median seeing of 0.57 arcsec. This is an excellent value for the Helmos site. The difference with the 2013 data is mainly due to the technical improvements mentioned earlier and part of it is also due to the weather condition differences between the two years. The distribution of the values for the years 2013 and 2014 is shown in figure 7. We must keep in mind that the data sample is small and therefore these values can serve only as a first indication of a very stable atmosphere. We plan to continue taking measurements during the winter time in order to improve our sampling and study possible seasonal variations as well.

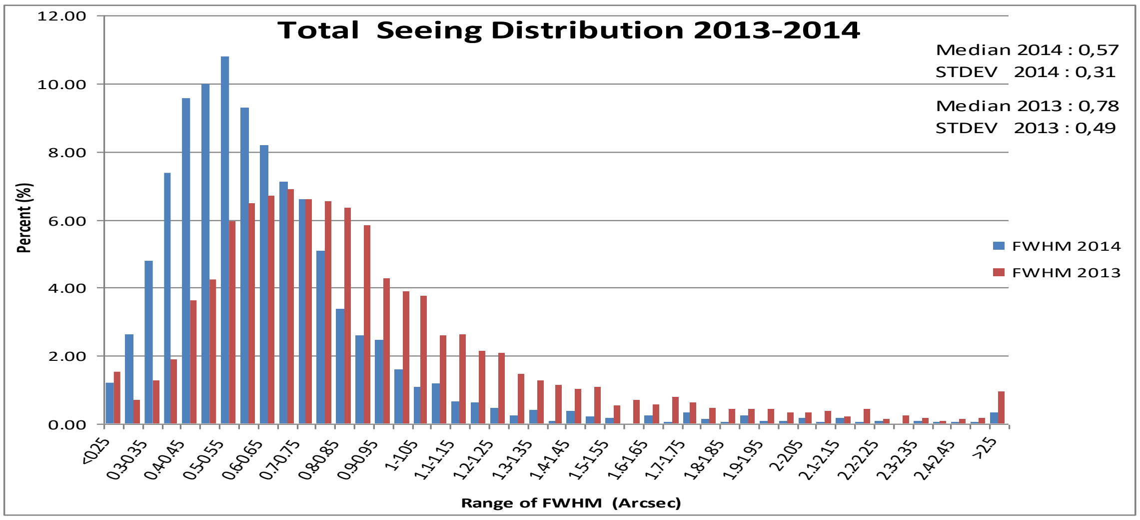


Figure 7. *The distribution of the median seeing values for 2013 and 2014.*

5. Conclusions

The environmental measurements at the top of the mountain of Helmos have so far yielded very good results. The data show that we have two main seasons: the summer - autumn and the winter – spring seasons. They are characterized by markedly different conditions. In general, in the summertime we have low cloudiness, higher humidity during the night as compared to the day time, as well as higher wind speeds than in the daytime. We also have relatively frequent east and northeast winds which are associated with high humidity. The increased night time humidity is compensated by the significantly reduced cloudiness. The average humidity and wind speed are no much different between summer and winter. On the other hand, in the wintertime we have increased cloudiness, lower humidity in the night time as compared to the day time, and lower winds in the night time as well. In addition, we have smaller cloudiness variation between day and night, as compared to the summertime. Clearly, the main observing period is the summer – autumn season as far as cloudiness concerns. It has twice as many observable nights, compared to the winter. On the other hand, this is partly compensated by the fact that the winter nights are much longer than the summer nights. In addition to that, the good winter nights are probably the best of the year, combining low humidity and wind speeds, and a cool stable atmosphere.

Concluding this report, we must say that the Helmos Observatory is the first high altitude observatory in Greece operating all year round. The site combines high altitude, dark sky, stable atmosphere, and good observing conditions which yield an expected number of 160 - 180 observable nights per year. It is accessible all year round through the road in the summer and via the ski lifts in the winter. These factors, together with the fact that it is located at driving distance from all major universities of Greece and 3 hours distance from the airport of Athens, make it a great location to observe the universe.

Acknowledgements

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