First astronomical preselecting site in the Beni Mellal region: On the use of satellite data

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Abstract: In this paper we use satellite meteorological and geophysical data to compare three new sites to the Oukaimeden Observatory (O43) located in the Atlas mountains (Morocco). The Three other sites are located in Beni Mellal mountains. The data are obtained from several satellites: MODIS (Moderate Resolution Imaging Spectroradiometer), AIRS (the Atmospheric Infrared Sounding System). These three sites, located on the middle Atlas Mountain, are not far from the University of Beni Mellal by good roads. As results, we find that these three sites are of good quality and can be qualified to house some astronomical instruments, but in situ data are required. We will install some astronomical instrumentation to measure the nocturnal extinction and the seeing.

Keywords: Astronomical site testing; satellite data.

1. Introduction

A major concern for the astronomical community is to find the best sites on Earth conducive to astronomical observations, where the sky is clear and the less turbulent atmosphere. The satellite measures and weather data, by scanning the whole earth, constitute an essential tool to aid in the decision-making process concerning the pre-selection of astronomical sites. This work fits into this framework here: it’s developing tools for the characterization of astronomical sites using satellite measurements and meteorological databases.

Aerosols play important roles in global climate change. They affect earth’s radiative budget by scattering or absorbing radiation and by altering cloud properties, so, they directly affect the astronomical observations. The Sahara and Sahel dust intrusions affect the southwestern Morocco, but many studies showed that it moves westward (https://www.nasa.gov/centers/goddard/images/content/93874main_DustStorm20000226TH1.jpg).

The first use of the aerosol index satellite data (Al) to deduce the astronomical atmospheric extinction (AE) was presented by Sihier et al. [1]. They present a correlation between the aerosol index and the atmospheric extinction. This study is based on the selection of data that Al>0.7 and AE>0.2 mag/airmass. This method was used by Aksaker et al. [2] and Laken et al, [3].

The main meteorological requirements for the best observing sites are: small daytime and nighttime air temperature gradients, high stability of the air temperature along the night, small relative humidity, and low wind speed and wind gusts [4],[5] et [6,7].

Three sites were sounded: Tassemit, Tazerkount and Ghnime, geographical coordinates, altitude and sites locations will be presented in the second section.

The data were provided by satellites equipped by standard meteorological sensors of air temperature, barometric pressure, relative humidity, wind speed and direction, aerosol optical depth and aerosol index.

The structure of this paper is as follows: in section 2, we present data and sites description. In section 3, we present the results and their discussions.

2. Data and sites description

The data used in this work were derived from measurement carried out by the Giovanni satellite. A more interactive access to the sampled data is provided by the WEB-based data customization and plotting interface.

The data used in this work pour for a period of six years (2009-2015) is given by the following satellites: MODIS (Moderate Resolution Imaging Spectroradiometer). The MODIS instrument is operating on both the Terra and Aqua spacecraft. It has a viewing swath width of 2,330 km and views the entire surface of the Earth every one to two days. Its detectors measure 36 spectral bands between 0.405 and 14.385 µm, and it acquires data at three spatial resolutions: 250m, 500m, and 1,000m.

(AIRS): The Atmospheric Infrared Sounder, or AIRS, instrument is a key tool for climate studies on greenhouse gases and carbon dioxide distribution, as well as weather forecasts. When it launched in 2002 along with five other instruments aboard NASA’s Aqua satellite, the Atmospheric Infrared Sounder became the
most advanced atmospheric sounding system ever deployed in space.

The instrument is designed to collect climate data and turn it into 3-D maps of air and surface temperature, water vapor, and cloud properties, helping improve researchers’ understanding of severe weather patterns and how they relate to global climate change.

MERRA (The Modern-Era Retrospective analysis for Research and Applications) was undertaken by NASA’s Global Modeling and Assimilation Office with two primary objectives: to place observations from NASA’s Earth Observing System satellites in a climate context, and to improve upon the hydrologic cycle represented in earlier generations of reanalyses.

In this study, we compare three sites in Beni Mellal city to the Oukaimeden observatory. Oukaimeden observatory is at 70 km of fairly good southward, from the city of Marrakech.

The geographic coordinates of the observatory are 7°52'52" West longitude and 31°12'32" North latitude.

The process of selecting the site as a potential site for observations was presented by Benkhaldoun et al. in [8]. Several experiments were installed of this observatory in order to enhance their knowledge for the astronomical observations quality.

A first weather study began with data analysis by Kadiri in [9]. Then both French and Moroccan researches have selected Oukaimeden as an astronomical observing site. Benkhaldoun in [8] and Siher in [10] has already presented the criteria for the choice of Oukaimeden. Weather so favorable conditions at Oukaimeden that several international and national astronomical groups has built their experiments.

These three sites are Ghnine (al 2358m, lat°: 32°13'12"N, long: 6°20'37"W), Tassemit (al 2204m, lat°: 32°18'0"N, long: 6°15'0"W) and Tazerkount (al 1697m, lat°: 32°9'53"N, long: 6°29'15"W). Fig.1 shows the locations map of these sites.

3. Results and discussion

3.1. Aerosol optical depth AOD (μa)

The data used in aerosol analysis derived from MODIS (the Moderate Resolution Imaging Spectroradiometer).

The MODIS aerosols product measures the aerosol optical depth and aerosol fraction having a fine mode (aerosol pollution and forest fire) over the continents and oceans.

The phenomena that contribute to the attenuation of solar radiation in a clear atmosphere are aerosol extinction, molecular diffusion and gas absorption. The spectral bands of the photometers are judiciously chosen to avoid strong gaseous absorption.

MODIS (aboard Terra (1999) and Aqua (2002) [11,12] uses a wide spectral range (0.55 μm -2.1 μm) to separate the anthropogenic components of aerosols (fine mode) from those of natural aerosols (coarse mode) [13].

In our study, we will only consider the monthly averages as the instrument MODIS Terra provides a value every two days. The optical depth measured by MODIS is at the wavelength $\lambda = 550$ nm MODIS Terra.
provides a value every two days. The optical thickness measured by MODIS is at the wavelength \( \lambda = 550 \text{ nm} \). We used monthly average of aerosol optical depth for six years (2010-2016) of Oukaimeden in Marrakech and three others sites in Beni Mellal.

Fig.2 represents the variation of the monthly average of AOD at 0.55 \( \mu \text{m} \) for seven years (2010-2016) depending on the time for the three sites and that Oukaimeden.

The purpose of our graphical representation is not aerosol interpretation but the graphic resemblance existing between the selected sites and the Oukaimeden site, which characterizes a site of excellent quality. From the Fig.2, we notice there is a good agreement between the three sites and Oukaimeden.

For the next study, in addition to photometric data such aerosol optical depth, we will use meteorological data such as temperature, relative humidity, air pressure and wind speed for the same period of data (2010-2016) but this time from the AIRS instrument (The Atmospheric Infrared Sounding System) not MODIS.

**Fig.2. Variation of the monthly average of AOD at 0.55 \( \mu \text{m} \) depending on the time, (2009-2016).**

### 3.2. Meteorological Results

#### 3.2.1. Temperature

We used monthly average of temperature for seven years (2010/2016).

The process of temperature is performed in the same way as the AOD. We represent the variation of the temperature as a function of time, using the same measurement period (Fig.3). We conclude that the three sites and Oukaimeden have the same appearance.

**Fig.3. Monthly average of temperature in Kelvin**
3.2.2. Relative humidity

The relative humidity is defined as the ratio of the partial pressure of water vapor in the air to the saturated vapor pressure of water at a given temperature.

For this data we have considered the same study made before; the graphical representation of the relative humidity as a function of time.

Fig.4 shows this study. We notice the three sites have the same graph as that of Oukaimeden with a small change.

The peaks shown in the Fig.4 correspond to the non-availability of the measure for this time of the year

3.2.3. Pressure of air

For this data, we have considered the same study made before; the graphical representation of the pressure as a function of time (Fig.5). On this figure, we show the same results as before: the sites of Beni Mellal approaching potential site Oukaimeden.

![Fig.4. Monthly average of relative humidity.](image)

![Fig.5. Monthly average of pressure.](image)
3.2.4. Wind speed

For this graphical representation, we have represented the variation of the monthly mean wind speed east (Fig.6) and north (Fig.7) as a function of time.

We note that the wind speed at Oukaimeden exceed 2m/s generally oriented to the east (negative values), and we also see the same thing for our three sites tested with a speed slightly higher than 2m/s visualized twice on the graph (see Fig.6), they are generally oriented towards the west (positive values).

The wind speed shows seasonal behavior at all the sites. The graphical representations of the wind speed and wind roses show the great concordance between the Beni Mellal sites and the potential Oukaimeden site.

The obtained results are very satisfactory. It is therefore concluded that the sites tested have the same climate profile as Oukaimeden site.

The three sites studied show that they are very close to the Oukaimeden site. This result is very satisfying.

In Fig.8, we present the wind rose over Oukaimeden, and our three sites. we note that the direction of the wind is predominant between west and north east. These directions are important in astronomy since these winds will be wet on the one hand and do not wear aerosols on the other hand.

![Fig.6. Monthly average of wind speed east.](image)

![Fig.7. Monthly average of wind speed north.](image)
3.3. Astronomical extinction study

For more accuracy, we will use the relationship between the atmospheric extinction and the aerosol index [14] to extract astronomical extinction (AE) from aerosol index (AI) over the three studied sites and Oukaimeden.

The used data of aerosol index were compiled from Giovanni satellite.

The study of astronomical extinction with the aerosol index is only a beginning (Siher et al, 2004). It is reliable for the environment of the study site (ORM) (Observatorio del Roque de los Muchachos) for which the equation: $AE = AI \times 0.16 + 0.14$ is defined in an area of $(97*111) \text{ km}^2$.

To generalize this hypothesis, it is necessary to apply it on several sites and we made the test for the three sites of Beni Mellal (see Fig.9).

Figs 9-11 presents the variation of the astronomical extinction as a function of the modified Julian Day (MJD) over Tazerkount (Fig.9), Ghnime (Fig.10) and Tassemit (Fig.11) compared to Oukaimeden Observatory.

The results obtained were very satisfactory and we notice very well that there is a great and concordance between the three sites of Beni Mellal and Oukaimeden observatory. In the all sites, the extinction coefficient does not exceed 0.4 mag/airmass

![Fig.8. Wind rose over the four sites](image)

![Fig.9. Astronomical extinction over Tazerkount](image)
4. Conclusion

Over seven years of meteorological and geophysical data have been acquired by NASA satellite. In this paper we have made innovative use of these data to derive measurements of atmospheric extinction over four sites and meteorological parameters, and we have presented the atmospheric extinction coefficients from each site over the years 2000 to 2016. This is an important contribution to the site testing. Beni Mellal sites can be qualified to install some astronomical instruments like Oukaimeden observatory.

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References


