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Gulmarg, Kashmir, India: Potential Site for Optical Astronomical Observations

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Abstract. The site characteristics of Gulmarg, Kashmir at an altitude of about 2743.2 m above sea level is based on analysis of meteorological conditions, cloud cover, temperature, wind speed, wind direction, relative humidity and atmospheric pressure, etc. Analysis and characterization of meteorological conditions suggest that Gulmarg, Kashmir is a potential site for carrying out photometric as well as spectroscopic observations of celestial objects.

Keywords. Astronomy—meteorological parameters—site survey—Gulmarg.

1. Introduction

Smaller telescopes equipped with modern detectors, if housed at high altitude observing sites can remarkably improve night sky observations (Pandey 2006). Before site selection for in-housing of a telescope, an objective assessment of atmospheric transparency variations is necessary as it profoundly influences the quality of observations. Gulmarg is located 56 km South-West of Srinagar, the capital city of Jammu & Kashmir, India and is in the Pir Panjals, one of the six mountain ranges which make up the Himalayas. Gulmarg, has been characterized as a mid-altitude site of 2743.2 m above sea level. The longitude and latitude of Gulmarg are 74°24′E and 34°03′N. Gulmarg is thinly populated and logistically well suited for establishing an optical astronomical observatory.

The essential requirements for good observing site are: (i) clear, dark and cloud free nights, (ii) low atmospheric extinction, (iii) good seeing, (iv) low precipitable water vapour content, and (v) small variation in night temperature (Sagar *et al.* 2000; HIROT team 1996). Due to its altitude, accessibility, infrastructure (new observatory building and 14″ telescope with all important accessories supported by University of Kashmir and DST, New Delhi), proximity to transportation and supplies, Gulmarg meets the basic requirements for setting up an optical astronomical observatory. In this paper, we analyse the feasibility of Gulmarg as a potential site for optical astronomical observations based on meteorological conditions like percentage cloud cover, relative humidity, wind speed, wind direction, atmospheric pressure etc. The results are encouraging.

2. Meteorological conditions

At Gulmarg, the Department of Physics, University of Kashmir and Indian Meteorological Department is having a well established atmospheric laboratory about 10 m from the site, which records meteorological parameters during day and night. The same data is used in this paper. At Gulmarg, the meteorological equipments installed are hygrograph, barograph, rain gauge, snow gauge, anemometer and wind vane, dry bulb and wet bulb thermometers etc. The cloudiness was recorded visually. Results of meteorological conditions at Gulmarg are discussed as follows: The night time is defined as the duration between end of evening astronomical twilight to the start of morning astronomical twilight (Sagar *et al.* 2000). At Gulmarg site, it varies from 8 h (in June–July) to about 12 h (in Jan.–Feb.) with a mean value of 10 h and this criterion is applicable to photometry only. However, optical spectroscopy and IR observations can be carried out beyond this limit as well

(HIROT team 1996). The analysis and characterization of photometric and spectroscopic nights is based on the following criteria:

(1) An observing night is said to be photometric night if the sky is clear and cloud free i.e. cloud cover is equal to 0 octa for 4 h or more (HIROT team 1996). Another way of defining photometric night is if the sky is having less than or equal to 15% cloud cover (Tapia 2003).
(2) An observing night is said to be spectroscopic night if the cloud cover is less than or equal to 3 octas for more than 4 consecutive hours or if the percentage of cloud cover is less than 65% (Tapia 2003).

2.1 *Cloud cover*

Night time cloud coverage visual observations at Gulmarg for the years 2014 and 2015 are summarized in Tables 1 and 2. Comparison of Tables 1 and 2 at Gulmarg and Leh (HIROT team 1996) show the number of photometric and spectroscopic nights at Gulmarg site is not as good as Hanle, Leh but far better than Vainu Bappu Observatory, Kavalur. At Kavalur, the number of clear nights recorded by Singh *et al.* (1990) for the period June to October, 1988 is only one. In comparison, Gulmarg shows a remarkable number of photometric clear nights with 0 octa cloud cover for more than 5 h. The percentage photometric nights and spectroscopic nights at Gulmarg for the year 2014 is 34.15 and 51.07 respectively. The year 2015 shows 35.61% photometric and 51.23% spectroscopic nights. The advantage lies in the fact that Kavalur receives monsoon rains due to which sky remains mostly cloudy making astronomical observations difficult. Gulmarg on the other hand, is not much effected by monsoon rains during the above mentioned period making plenty of clear nights available for astronomical observations. The South-West monsoon does not cause rainfall in Kashmir valley where local climate cycles lead to precipitation during summer. The rain bearing SW monsoon clouds shed their waters on the Southern slopes of the Pir Panjal range and are unable to cross them to cause rain in Kashmir valley (Negi 1998). The data recorded at IUCAA telescope site between November 1996 and April 1997 by Das *et al.* (1999) revealed that 50% of the nights are photometric and 80% are spectroscopic. As monsoon progresses, the number of photometric and spectroscopic nights goes on decreasing. At San Pedro Martir Sierra, Mexico site the data reveals that the periods between April to July, September and October are 63.1% photometric, in August it reaches 62%, in March it shows only 45% of photometric time and the remaining part of the year records decrease in percentage of photometric and spectroscopic hours (Echevarria 2003).

2.2 *Average rainfall and average snowfall*

Figure 1 shows the average monthly rainfall and Fig. 2 shows the average monthly snowfall (in mm/day) during the year 2014 and 2015. January, February and December receive less or no rainfall in comparison to average

Table 1. Photometric and spectroscopic nights at Gulmarg during the year 2014.

Months	Total nights	Photometric nights	%age of photometric nights	Spectroscopic nights	%age of spectroscopic nights
Jan.	31	11	35.48	12	38.70
Feb.	28	03	10.71	08	28.57
March	31	06	19.35	08	25.80
April	30	05	16.66	08	26.66
May	31	03	09.97	08	25.80
June	30	13	43.33	21	70.00
July	31	11	35.48	19	61.29
Aug.	31	13	41.93	18	58.06
Sept.	30	13	43.33	25	83.33
Oct.	31	14	45.16	20	64.51
Nov.	30	19	63.33	21	70.00
Dec.	31	14	45.16	21	67.74
Total	365	125	34.15	189	51.70

Table 2. Photometric and spectroscopic nights at Gulmarg during the year 2015.

Months	Total nights	Photometric nights	%age of photometric nights	Spectroscopic nights	%age of spectroscopic nights
Jan.	31	14	45.16	17	54.48
Feb.	28	03	10.71	08	28.57
March	31	05	16.12	06	19.35
April	30	11	36.66	14	46.66
May	31	09	29.03	13	41.93
June	30	14	46.66	17	56.66
July	31	05	16.12	16	51.61
Aug.	31	09	29.03	18	58.06
Sept.	30	14	46.66	23	76.66
Oct.	31	19	61.29	22	70.96
Nov.	30	12	40.00	14	46.66
Dec.	31	15	48.38	19	61.29
Total	365	130	35.61	187	51.23

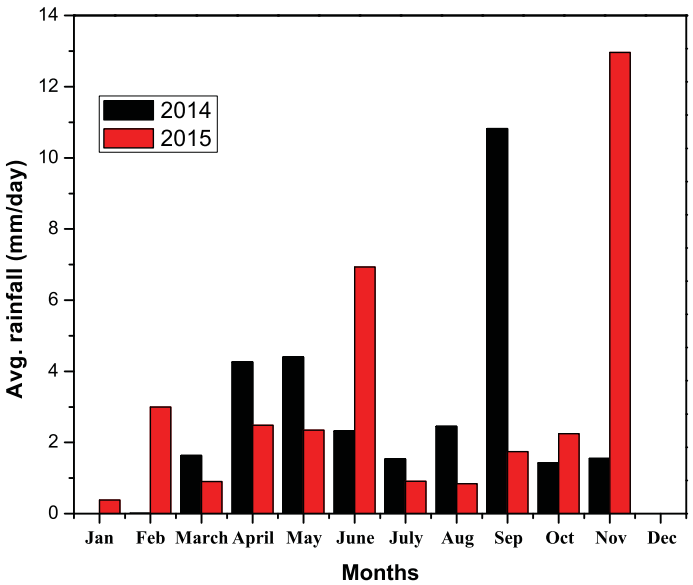

Figure 1. Daily rainfall averaged monthly for the years 2014 and 2015.

snowfall for the same period. Gulmarg receives heavy snowfall during this period ranging from 0.6 m to 3 m making accessibility to observatory difficult. Western part of Himalayas receives enormous amount of precipitation due to extratropical cyclones called western disturbances (Semwal & Dimri 2012). The Kashmir valley is enclosed with three prominent mountain ranges, named as Pir Panjal, the great Himalayan and broken mountain range known as Shamsabari range. On interaction with Pir Panjal and Shamsabari ranges the western disturbances generate orographic lifting and hence accelerates the precipitation forming mechanism. As a result the Pir Panjal and Shamsabari ranges receive maximum precipitation in winter as they are the first interacting barriers with western disturbances in the Kashmir valley (Dimri & Dash 2011). Gulmarg which is near to Srinagar but situated in complex topography records higher precipitation than other parts of Kashmir valley in the form of snow and rain during winter from December to March. Whereas, Hanle Leh, receives very less amount of snowfall of the order of few millimeters from December–March. The estimated amount of total rainfall is about 2 cm during the monsoon period (HIROT team 1996).

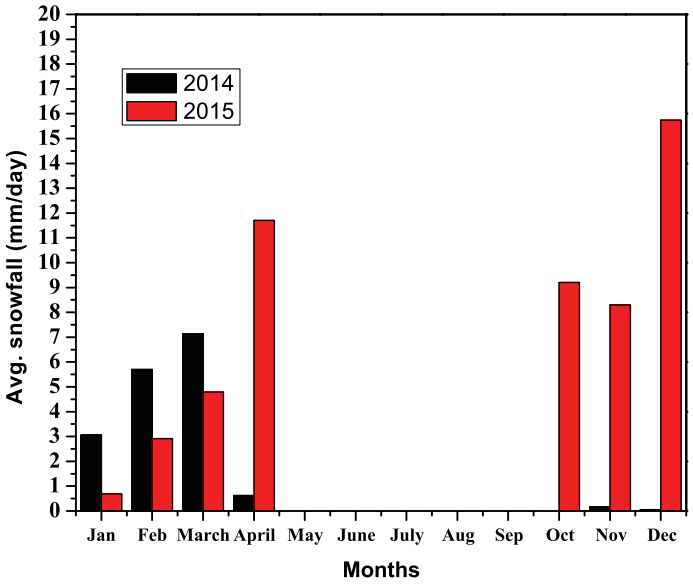

Figure 2. Daily snowfall averaged monthly for the years 2014 and 2015.

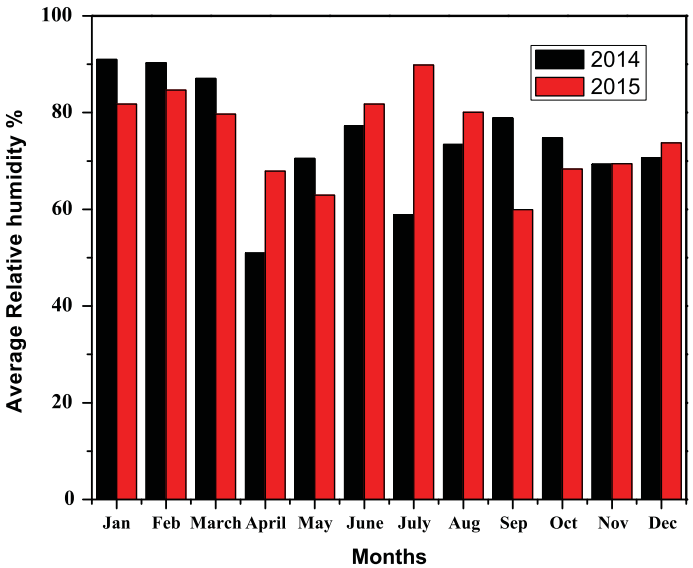

Figure 3. Average relative humidity during 2014 and 2015.

2.3 *Average relative humidity*

At the site the relative humidity is recorded with hygrometer. The monthly average relative humidity at Gulmarg, shown in Fig. 3, from April to December is less than the rest of the year. The relative humidity ranges on day to day basis from 34 to 100 during the said period providing ample nights for observations. The average relative humidity increases from January to March owing to heavy snowfall during this period resulting in higher moisture content in air. Moisture and water condensation from higher relative humidity adversely effect the astronomical observations and facilities. Condensation is a serious issue for astronomical observations on at least two counts. One that it damages the sensors and electronic equipment and two that it degrades the quality of observed astronomical data (Radu *et al.* 2012). Relative humidity at ground level provides a useful value in determining conditions in which astronomical observations can be made. Humidity higher than, say, 90% makes observing unfeasible (Murdin 1985). The optical surfaces become wet and can be damaged. The percentage of hours with humidity less than 90% sets an upper limit on observable time (Jabiri *et al.* 2000). This brief period from January to March is unstable for observations because

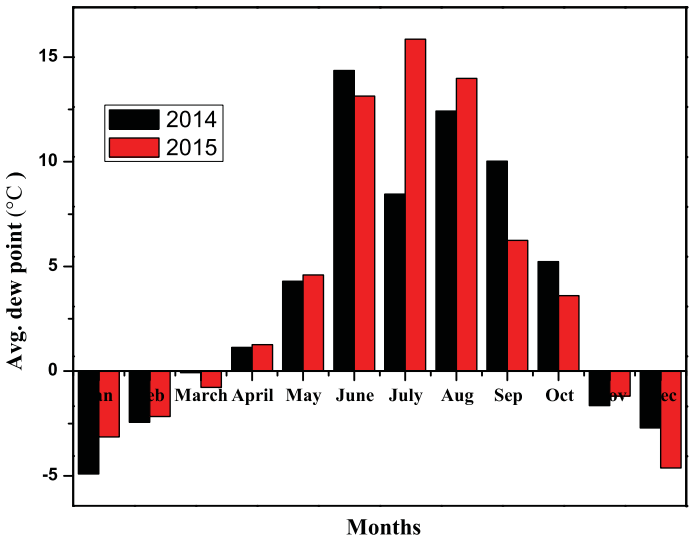

Figure 4. Average dew point temperature for the years 2014 and 2015.

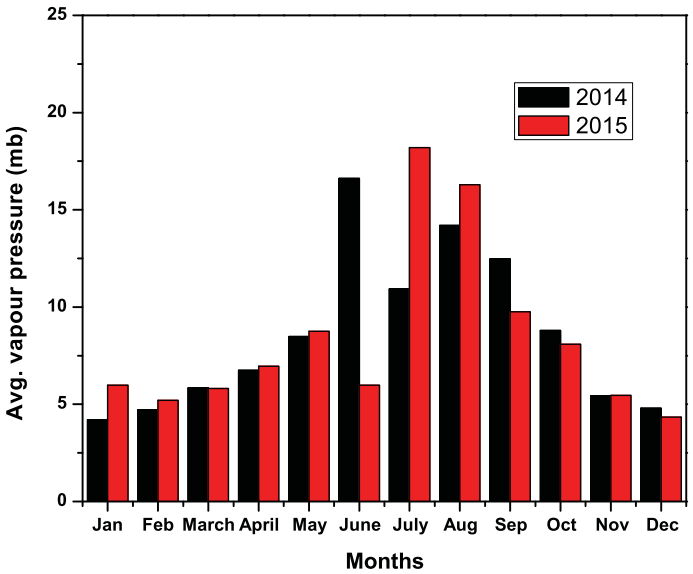

Figure 5. Average vapour pressure for the years 2014 and 2015.

of high relative humidity. On the other hand, the average night-time humidity over the year recorded by HIROT team (1996) was $65 \pm 9\%$. Dew point measurements in Fig. 4, show precipitation anomaly at Gulmarg. Average vapour pressure at the site is depicted in Fig. 5.

2.4 *Atmospheric pressure, wind speed and wind direction*

Measurements of atmospheric pressure have been recorded with barograph at the site. The data studied reveals that pressure variations at Gulmarg is within 1 mb. The wind speed and wind direction is measured with anemometer and wind vane stationed at Gulmarg. Data reveals that month by month average wind speed ranges between 0 m/s to occasionally 1.02 m/s during 2014 and 0 m/s to occasionally 1.543 m/s for the year 2015, which is either completely in agreement with some observatories in India and even lower than the value at Mauna Kea (4.5 m/s) or Chajnantor (5.5 m/s) (Bhat *et al.* 2000; Holdaway *et al.* 1996).

2.5 *Night temperature*

Continuous observations of night time temperature indicates that the variation is within 4°C for more than 60% of the time. Moreover, the low ambient temperature implies an ease of operating photometric detectors

Table 3. Gulmarg site.

Year	% of nights having pressure variation ≤1 mb	% of nights having wind speed ≤3 (m/s)	Wind direction
2014–2015	97.5	98.3	Calm and West

Table 4. Devasthal site (Sagar *et al.* 2000).

Year	% of nights having pressure variation ≤1 mb	% of nights having wind speed ≤3 m/s	Wind direction
1986–1991	89	77	NW

like thermoelectrically cooled (peltier junction) CCDs (Sagar *et al.* 2000; Howell 2006) (Tables 3 and 4).

2.6 *Light pollution*

Light pollution can either be assessed visually or through satellite images (Hajjar 2012). The Gulmarg site is a natural conservation area protected by State Government far from populated area with low light pollution though there are hotels below the observatory site for visitors but these do not contribute much to the light pollution. The satellite images show the whole state of Jammu and Kashmir as less light polluted region (NASA Earthstar Geographics 2015). This provides enough evidence that Gulmarg qualifies for establishing an optical astronomical observatory.

3. Discussion and conclusion

From our analysis of meteorological records, it is amply clear that Gulmarg offers a promising site for establishing an astronomical observatory. The main advantages that the site offers are: (i) high altitude, (ii) low light pollution, (iii) higher available clear nights, (iv) lower relative humidity, (v) very small pressure variations during night. (vii) favourable wind speed and direction, and (viii) less night time temperature variation. Further, while it is monsoon time in the rest of India, Kashmir valley remains mostly dry and offers the advantage of increased clear nights during that period. Besides, the identified site is under the control of University of Kashmir and has all the basic facilities like water, electricity, metallic road, internet etc. However, the main disadvantage is heavy snowfall during winter (Nov.–March) which can range from 0.6 m to 3 m almost every year making accessibility to observatory site a bit difficult and also increasing the humidity. Seeing and atmospheric extinction at the site is yet to be carried out. Department of Physics, University of Kashmir is in the process of installing 14″ Celestron Telescope coupled with CCD and DIMM (Differential Image Motion Monitor) at the site.

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References

Bhat, B. C., Prabhu, T. P., Anupama, G. C. 2000, *BASI*, **28**, 441–443.
Das, H. K. *et al*. 1999, *BASI*, **27**, 609–626.
Dimri, A. P., Dash, S. K. 2011, Wintertime climatic trends in the western Himalayas, *Clim. Change,* doi:10.1007/s10584-011-0201-y
Echevarria, J. 2003, *RexMexAA (SC)*, **19**, 41–43.
Hajjar, R. 2012, African Skies/CIEUX AFRICANS, **16**.
HIROT team, 1996, *BASI*, **24**, 859–869.
Holdaway, M. A. *et al*. 1996, *MMA Memo*, **159**.
Howell, S. B. 2006, *Handbook of CCD Astronomy*, (Cambridge University Press, Cambridge).
Jabiri, A. *et al*. 2000, *Astron. Astrophys. Suppl. Ser.* **147**, 271284.
Murdin, P. 1985, *Vistas in Astronomy*, **28**, 449.
NASA Earthstar geo-graphics 2015, www.lightpoullutionmap.info.
Negi, S. S. 1998, Discovery of Himalaya, vol. 1, (Indus Publishing Company, New Delhi).
Pandey, S. 2006, *IAU special session*, No. 5.
Radu, A. A. *et al.* 2012, *Mon. Not. R. Astron. Soc.,* **422**, 2262.
Sagar, R. *et al*. 2000, *Astron. Astrophys. Suppl. Ser.*, **144**, 349–362.
Semwal, G, Dimri, A. P. 2012, *Nat Hazards* **64**, 1405–1424, doi:10.1007/s11069-012-0304-4.
Singh, J. *et al*. 1990, *BASI*, **18**, 7–15.
Tapia, M. 2003, *RexMexAA (SC)*, **19**, 75.