Site evaluations of the summit of Co. Chajnantor for infrared observations.

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ABSTRACT

Because of the high transparency in infrared wavelength, Co. Chajnantor (5,640m altitude) at Atacama, Chile, is one of the most promising sites for infrared astronomy in the world. For evaluating the site condition quantitatively we carried out weather and cloud emissivity monitoring campaign from April 2006 to April 2007. The ground-level condition such as wind direction, wind speed, air temperature, and humidity was monitored by a weather station installed at the summit. Cloud emissivity was estimated by mid-infrared sky images taken by a whole-sky infrared camera every five minutes for 24 hours a day, every day. Results are summarized as followings. 1) The weather condition at the summit is slightly harsher than the condition at the Pampa la Bola plateau. Maximum speed of the wind is 35m/s, and minimum temperature is about -10 degree. 2) Fraction of "clear+usable" weather (which is defined as the cloud emissivity < 10%)" is 82% in a year. The fraction decrease to 40-50% on Bolivian winter season, and increases to over 90% from April to July. This is comparable or even better than the other astronomical sites.

Keywords: Atacama, site survey, weather monitor, cloud monitor, infrared

1. INTRODUCTION

Co. Chajnantor is a mountain altitude of 5,640m located on the Pampa la Bola plateau in the Atacama desert, Chile. Thanks to the high altitude and dry weather condition Co. Chajnanotor is one of the most appropriate sites for infrared astronomical observations. Especially a continuous transmission from optical to the K-band and new windows in long mid infrared region (25-40 micron) will provide us a new tool for observing the Universe. We, Institue of Astronomy, University of Tokyo is promoting a project to build a 6.5-meter infrared telescope at the summit of Co. Chajnantor, the University of Tokyo Atacama Observatory (=TAO) project (P.I.: Yuzuru Yoshii)[1,2]. This will be the highest observatory in the world.

The weather condition is one of the most important factors to choose the observatory site. Northern Chile including the Atacama area is known to be ideal for astronomical sites, and many astronomical projects have studied the weather condition. The ALMA project located at the foot of Co. Chajnantor has investigated the Atacama area since the early 1990's, and elaborated the weather condition in many reports[3]. Next generation optical/infrared projects such as Giant Magellan Telescope (GMT), Thirty Meter Telescope (TMT), and European Extreme Large Telescope (E-ELT) have also investigated the northern Chile for their site selection[4]. They reported the high elevation sites around the Atacama desert are potentially good sites for infrared observations. The TAO project and Cerro Tololo Inter-American Observatory conducted a satellite survey monitoring cloud and water vapor over large areas. It concluded that the Chajnantor site is one of the best sites for infrared observations because of low water vapor (0.38mm at best 10%, 0.85mm at median) and fair sky (clear fraction of 70%)[5]. Although the satellite survey is useful for the comparison between sites, the spatial resolution of the satellite observation (~10km) is not enough for evaluating the weather condition especially for mountain sites since the weather of mountains is sometimes localized. In-situ measurements of the weather and the cloud are needed.

We have carried out the monitoring of the ground level weather conditions and the cloud emissivity at the summit of Co. Chajnantor from April 2006 to April 2007. In section 2 the instruments used for this monitor are described. In section 3 the results of the measurements are reported. We summarize the conclusion in section 4.

2. MONITORING INSTRUMENTS

2.1. Weather Station

For monitoring the ground level condition a stand-alone weather station is used. It monitored wind speed, wind direction, air temperature, and humidity every five minutes 24 hours. Data was acquired and stored in the data logger system manufactured by Campbell Scientific. Inc. The logger can store the data of 1.5 years long. The stored data was transferred into a laptop computer via serial connection, and brought to Japan.

The weather station was initially installed at the ridge point (altitude of ~5,00m) between Co. Chajnantor and Co. Chascon September 2001 for system tests and moved to the summit of Co. Chajantor in April 2006.

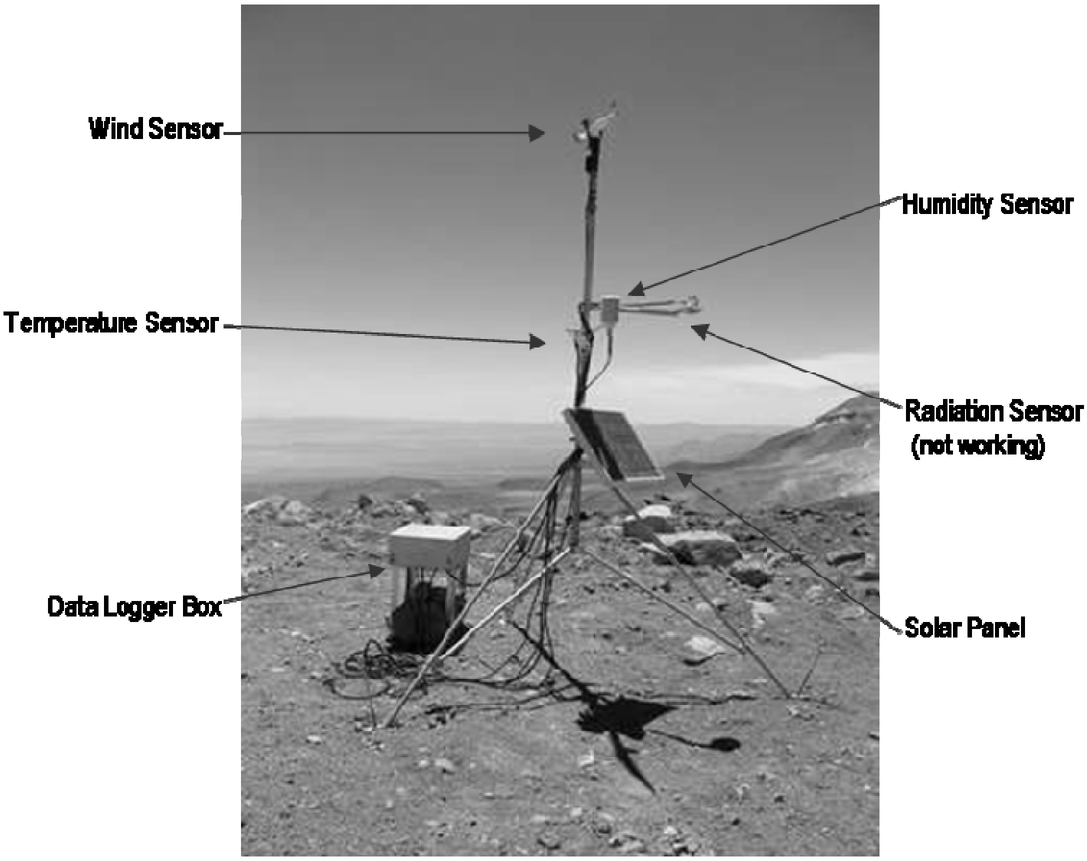

Fig. 1. The weather station installed at the summit of Co. Chajnantor (altitude 5,640m).

2.2. Cloud Monitor

For quantitative evaluation of the cloud condition, we developed an infrared cloud monitor. It monitors the whole sky area in mid-infrared wavelength every 5 minutes around the clock. Schematic drawing of the cloud monitor is shown in Figure 2. To cover wide area of the sky the whole-sky mirror system was employed. This is the Cassegrain-like reflecting optics which consists of two aspheric mirrors and covers the sky with the zenith angle < 70degree. This optics was originally designed for the MAGNUM telescope (P.I.: Yuzuru Yoshii) at Haleakala observatory[6], and made by the advanced technology center of the National Astronomical Observatory of Japan. Similar optics has been used in many observatories such as Subaru telescope (Mauna Kea, Hawaii), Kiso observatory (Nagano, Japan), Okayama observatory (Okayama, Japan), and ASTE (Atacama, Chile).

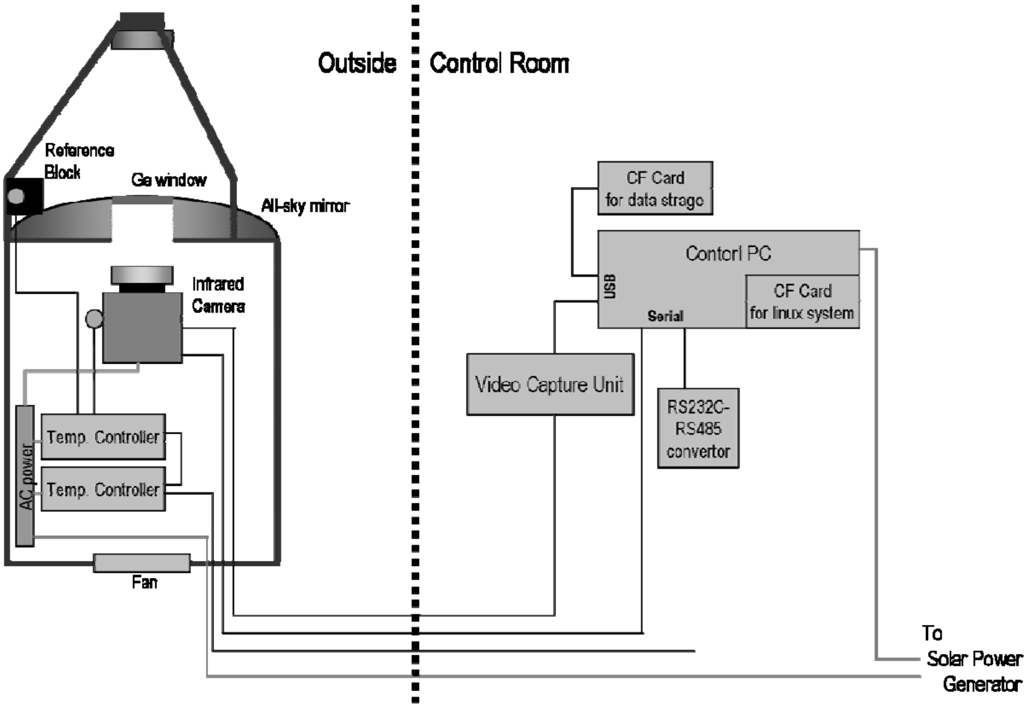

Fig. 2. Schematic drawing of the cloud monitor system. The infrared camera and the temperature controller are put in the rainproof tank (see Figure 3) . The mirrors and the Ge window are hard coated to resist water and the sun radiation. Wires between the camera tank and the control room are covered by the UV resist tube. All system is controlled by the control computer

We employed an uncooled infrared camera IR-30 manufactured by Nippon Avionics Co. Ltd. The spectra response is 7-12 micron. Sky images taken by the camera are output via composite video line, and captured as FITS file by the video capture unit on the control computer. To cancel out the drift of the output level, a black-painted block is put inside the field of view of the camera. The infrared radiation from the block can be estimated as a blackbody radiation with its temperature, so we can use it as a reference source. To measure the bright emission from the reference block simultaneously with the faint radiation from the cold sky/cloud, high dynamic range over 1000 is needed. Snap shot images with fixed camera parameters are inadequate. The cloud monitor continuously obtained five images with varying the camera gain parameter, and superimposed them into an image which has high dynamic range. The superimposed image is divided by the radiation count expected from the blackbody radiation of the air temperature, and converted to the emissivity image. Finally we subtracted the emissivity of the optics (the window and the mirrors) and clear sky. Since the emissivity of the optics changed with the dirtiness of the window/mirrors, the subtracted value would be varied. We estimated the value of 1st quartile of the measured emissivity in a month and subtracted it from the emissivity image. The reduced image is the “cloud emissivity” image. It is noteworthy that the “cloud emissivity” is underestimated because the sky/cloud temperature is expected lower than the air temperature measured on the ground.

However it is impossible to measure the sky/cloud temperature, so the “cloud emissivity” is used for the following discussion.

The acquisition and the reduction processes run in the control computer. Since hard disk drives cannot be used in such low pressure environment (~0.5 atm), two compact flash (CF) cards are employed; one is for linux operation system, and the other for data storage. Using CF cards also contributes saving electrical power. There are no power lines at the summit, and the power is generated by solar panels.

The cloud monitor was delivered to Atacama in 2004, and tested at the ASTE site for two years. It was installed at the summit in April 2006. Unfortunately the monitor was stopped between July and September 2006 because of troubles in the solar power generator.

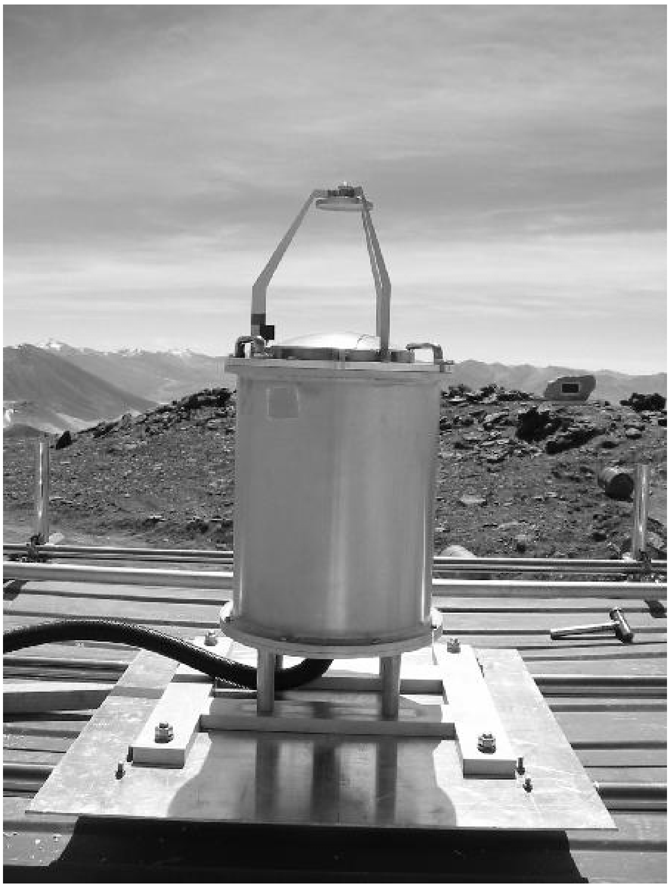

Fig. 3 The cloud monitor tank. This was installed on the rooftop of the container at the summit of Co. Chajnantor. A small block placed on the base of a left spider is the reference block.

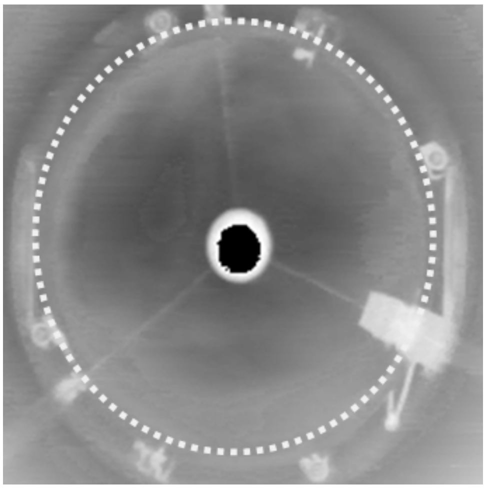

Fig. 4 A example of the superimposed sky image. The inner region of a dotted circle shows the sky. A bright rectangular at lower right of the circle is the image of the reference block.

3. RESULTS

3.1. Wind

The daily variation of the wind speed is plotted in Figure 5. The plotted wind speed was averaged over five minutes. Typically the wind speed increased around noon, had a peak at the evening, and decreased at the 1st half of the night. This trend was more remarkable in summer, although it almost disappeared in winter (from June to August). The wind always came from the west. This gives good agreements with the previous measurements on the Pampa la Bola plateau (~5,000m), but the wind speed was approximately 5 m/s higher than the Pampa la Bola[3]. The momentary maximum of the wind speed was recorded as 35 m/s.

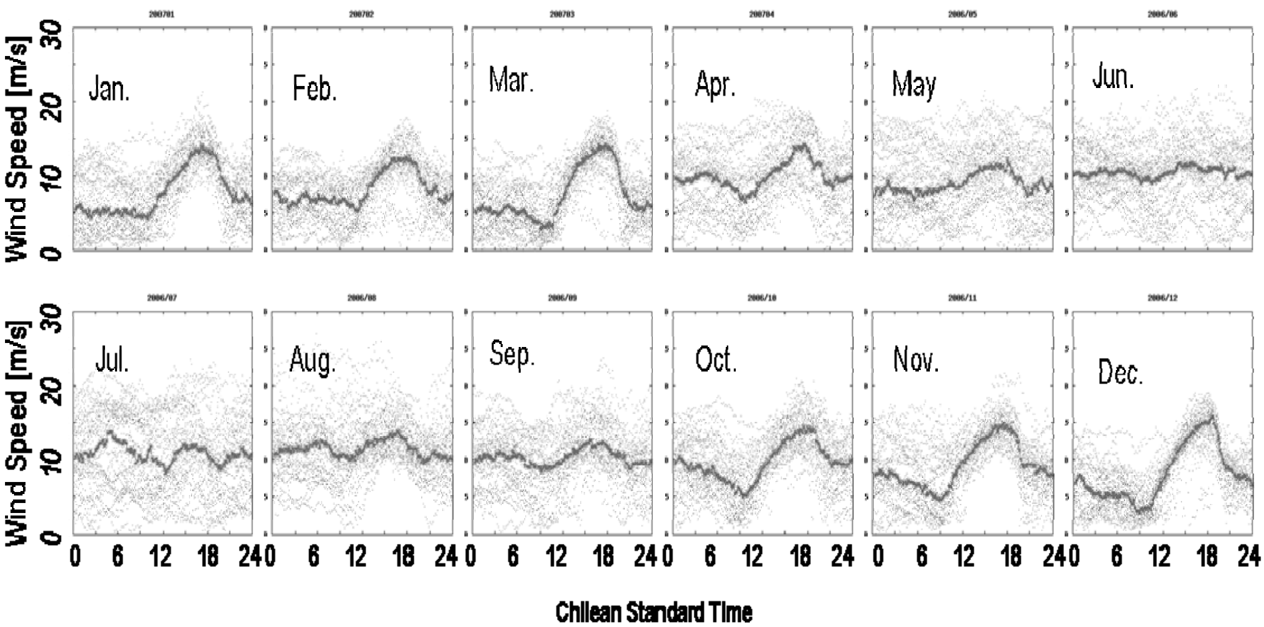

Fig. 5 Plots of the daily variation of the wind speed. The speed was averaged over data obtained in five minutes. Dots indicates all data, and thick lines show median of the data.

3.2. Temperature

The daily variation of the air temperature is plotted in Figure 6. Temperature in daytime was around zero degree, and sank to -3 degree (summer) or -10 degree (winter) at night. These were about 5 degree colder than the Pampa la Bola plateau[3].

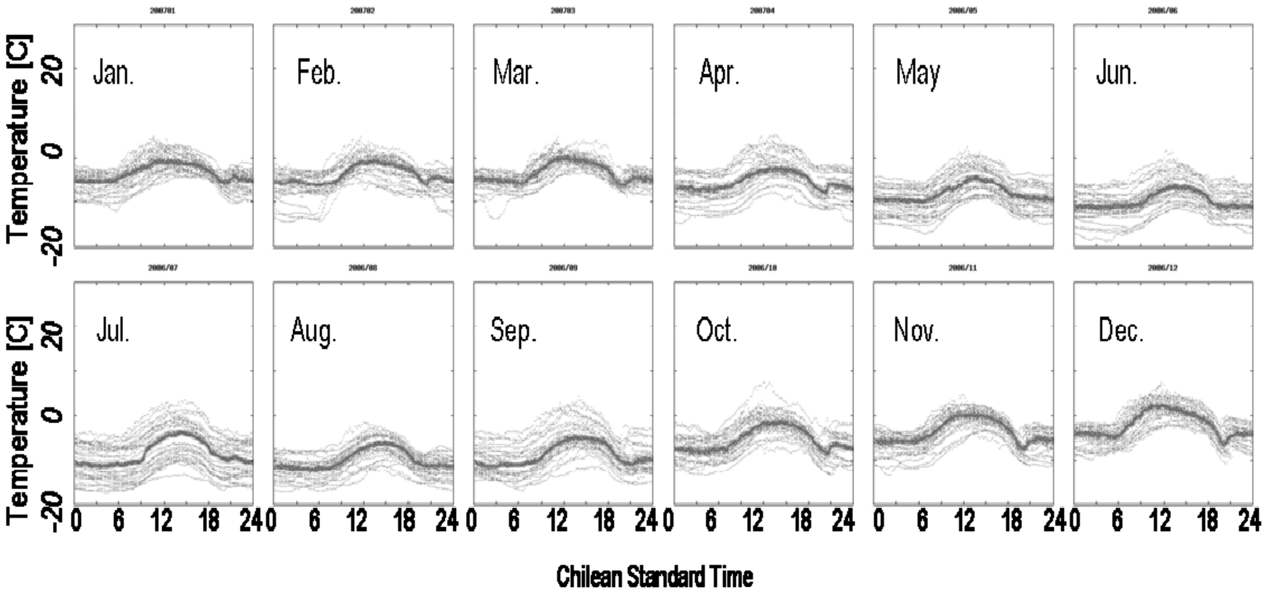

Fig. 6 Same as Figure 5 but the air temperature

3.3. Cloud

We empirically classified the cloud status as “clear” when the cloud emissivity (see section 2.2) at the zenith was under 5%, and as “usable” when under 10%. When the cloud emissivity was over 10%, the status was classified as “cloudy”. Figure 7 is a histogram of the classified cloud status. In summer season the fraction of the “clear” was approximately 40-50%. That is so-called the Bolivian winter season. On the other hand, the cloud condition was excellent in autumn. In May over 90% is classified as clear. The total fractions of the “clear” and the “clear+usable” were evaluated as 63% and 82%, respectively. It gives a good agreement with the fraction clear (70%) and the usable (79%) estimated by the satellite observation, indicating that the cloud condition is not localized at the summit of Co. Chajnantor.

Figure 8 shows the comparison of the fractions of clear nights of the other astronomical sites[7] with the present result. We supposed that the “photometric” corresponds to the “clear” in our classification, and the “spectroscopic” corresponds to the “usable”. This clearly demonstrates that the cloud condition at the Co. Chajnantor site is comparable or even better than the other astronomical sites.

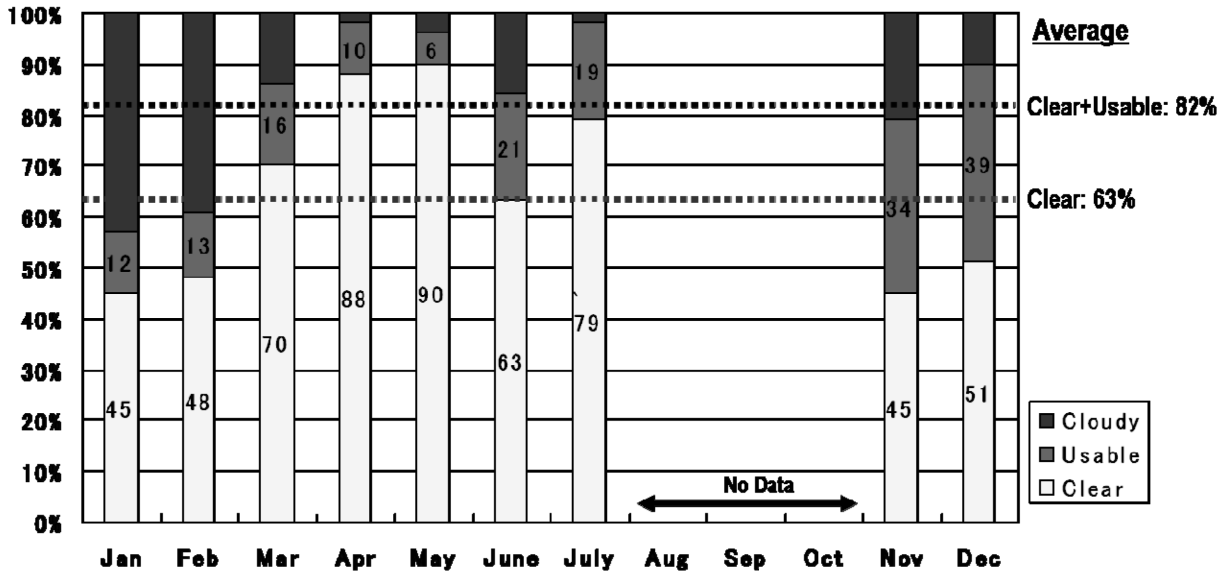

Fig. 7 Monthly fraction of the cloud status classified by the cloud monitor observation. We classified the cloud status as "Clear", "Usable" and "Cloudy" when the cloud emissivity is below 5%, between 5-10%, and above 10%, respectively.

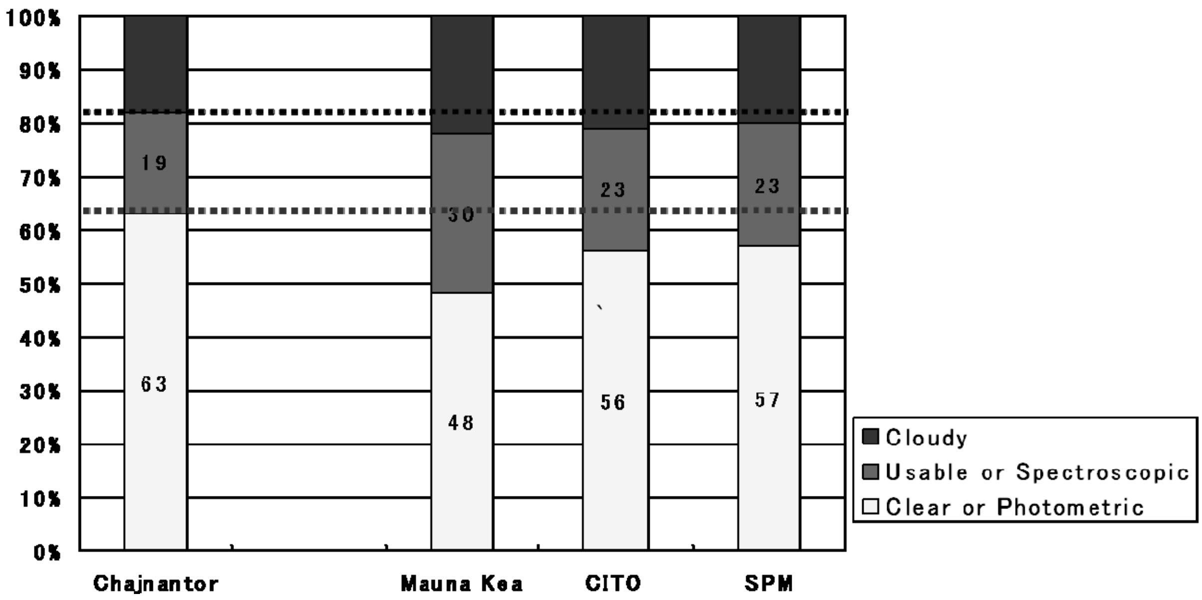

Fig. 8 Comparison of the clear fraction with those at the Mauna Kea Observatory, Cerro Tololo Inter-American Observatory (CITO), and San Pedro Martia (SPM).

4. Summary

We carried out weather and cloud emissivity monitoring campaign from April 2006 to April 2007 to evaluate the site condition at the Co. Chajnantor 5,640m site for the TAO project. Followings are the summary of the results.

1) The weather condition at the summit is slightly harsher than the condition at the Pampa la Bola plateau (~5,000m). Wind speed is approximately 5 m/s higher and the temperature is 5 degree cooler than the Pampa la Bola site. The maximum speed of the wind was recorded as 35m/s, and minimum temperature was about -10 degree.

2) Fraction of "clear+usable" weather (which is defined as the cloud emissivity < 10%)" is 82% in a year. The fraction decrease to 40-50% on Bolivian winter season, and increases to over 90% from April to July. These results give complete agreements with the previous satellite studies, indicating that the cloud is not localized at the summit. The cloud condition at the Co. Chajnantor site is comparable or even better than the other astronomical sites.

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