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ADVANCES IN A STUDY OF SKY QUALITY FOR ASTRONOMICAL OBSERVATIONS IN COLOMBIA

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RESUMEN

El principal objetivo de este estudio es determinar la calidad del cielo en Colombia con fines astronómicos en el óptico. Se analizaron cerca de 10,000 imágenes en infrarrojo (6.7 μm y 10.7 μm) obtenidas de los satélites meteorológicos GOES en tres instantes de la noche sobre un período de 5 años (2008 hasta 2010). Seguimos una metodología innovadora con el fin de determinar si las noches eran claras o cubiertas. También fueron usados datos de la red de estaciones climáticas del Instituto Nacional de Meteorología, IDEAM. Se encontró una correlación entre la temperatura umbral y la altitud para la serie histórica de datos a 30 años. Los resultados de la fracción de cielo claro en la noche se validaron con los reportes del número de horas de las bitácoras de observación astronómica del Observatorio Llano del Hato, Mérida-Venezuela. Se obtuvo una diferencia porcentual acumulada durante los cinco años menor al 10%. Después de validar el método, se calculó el cubrimiento anual de nubes sobre todo el territorio colombiano y las noches se clasificaron como claras o utilizables basados en la definición de un factor de calidad.

ABSTRACT

The aim of this study is to determine the sky quality in Colombia for astronomical observations in the optic. About 10,000 images in infrared (6.7 μm and 10.7 μm) were analyzed from the GOES meteorological satellites in three night times taken during a period of five years (2008 to 2014). A novel methodology was followed to determine how clear or covered was the sky in a given image. Meteorological data also were used from the weather stations network of the national meteorological institute, IDEAM. A correlation between threshold temperature and altitude was found for a historical data series of about 30 years. The results of the average percentage of nights with clear skies per year or clear sky fraction (CSF) were validated with the reports on the number of hours of astronomical observation from the logbooks of Llano del Hato Observatory in Merida-Venezuela, obtaining a cumulative percentage difference during the five years less than 10%. Annual cloud covering was computed over the whole country and it was classified the nights as clear or usable based on the definition of a quality factor.

Key Words: atmospheric effects — methods: statistical — site testing

1. DATA ACQUISITION

The primary aim of this work is to derive the number of clear nights in Colombia using satellite images. To quantify the amount of clear sky over Colombia sites, we used different data sets collected at both, ground and satellite, facilities. The ground base data are available thanks to the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) of Colombia.

The number of clear nights is estimated by combining ground- and satellite-based data. In particular we used GOES[2] meteorological satellites that have geostationary orbits, because their very high stationary orbit (∼36000 km) provides extremely stable conditions and it is not influenced by phenomena in the high exosphere (Cavazzani at al. 2011). The geostationary satellites have orbits over the Earth Equator and provide a large coverage of the globe. The GOES weighting function for B3 and B4 are shown in a Fig. 1.

2. METHODOLOGY

Several authors (Erasmus & Sarazin 2002; Cavazzani at al. 2011; Hidayat et al. 2012), have proposed a methodology based in satellite images for night time site testing. They established a criterion to identify whether the measured values from satellite images correspond to clear or covered nights. The general relationship take the general form:

$$T_B > T_T \longrightarrow Clear \quad (1)$$

$$T_B < T_T \longrightarrow Covered \quad (2)$$

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[2]`www.class.noaa.gov/`

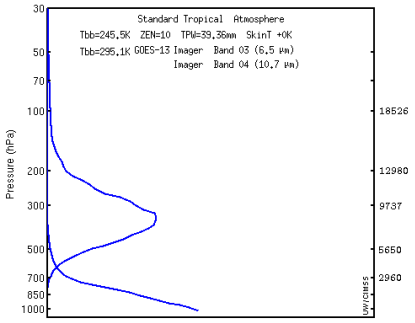

Fig. 1. Weighting function examples for bands B3 and B4 of GOES13 for an atmosphere standard tropical, a zenit angle of 10^o, a percentage column moisture of 100% and a skin temperature adjustment of 0^oK. Courtesy: `http://cimss.ssec.wisc.edu/goes/wf/`.

where T_B is the temperature value measured by the satellite at 10.7μm, and T_T is a threshold temperature yet to be defined. This threshold temperature is a reference temperature that can tell us whether the satellite has detected a cloud or not. A cloud will be detected if $T_B < T_T = T_S - 3\sigma$, where T_S is the surface mean temperature as measured by weather stations, averaged monthly for 30 year, and σ is its respective standard deviation.

3. CONCLUSIONS

We find that the threshold temperatures (T_T) have a linear correlation with altitude. This result is powerful, it means we do not need to know the surface temperature to find out if there is a cloud or not. It is enough to know the altitude of the place, then calculate the threshold temperature and use the relationship shown in equations 1 and 2.

In orden to compare the data from satellite images with ground data, a semivariogram model was fitted to data for the Colombian territory. An spatial intepolator Kringing was used to determine the altitude on each point. The threshold temperature map for Colombia can be seen in Figure 2.

We used about 10,000 images in the B3 and B4 infrared bands to determine the cloud coverage using both satellite and ground data in three night instants: early night, midnight and end of the night. Then, we defined the Quality Factor (Q) as a number between 0 and 100 that defines a night cloud covering quality. Q=100% is a night without clouds during all instants. Q=0% is a completely covered night. Nights with Q≥70% are called clear, i.e., with at least 3/4 of the night cloud-free.

The clear sky fraction (CSF) map is shown in Figure 3. At a given location, CSF is defined as the

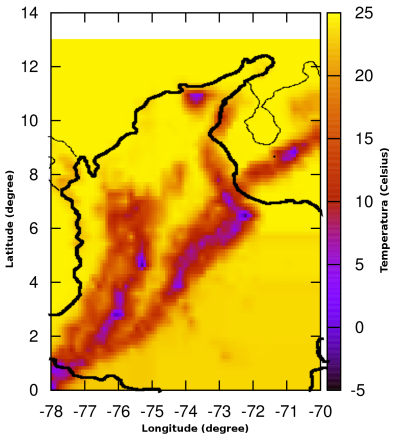

Fig. 2. Map of threshold temperature T_T for Colombia, during January. Temperatures measured by the satellite less than these threshold temperatures indicate the presence of clouds.

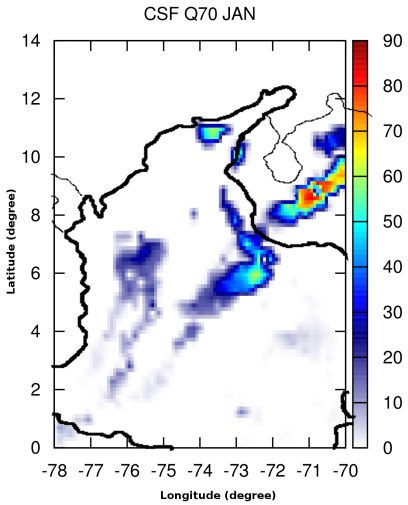

Fig. 3. Clear sky fraction (CSF) for the entire Colombian territory during the month of January. Computed with data from five years, this map provides information about the regions with at least 3/4 of the night cloud-free (Q≥70%), using the B3 and B4 bands of GOES satellites.

percentage of nights during a given period (a month) with Q≥70%. The best site in Colombia throughout the year is the Sierra Nevada de Santa Marta, with about 68 clear nights (Q≥70%) per year.

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