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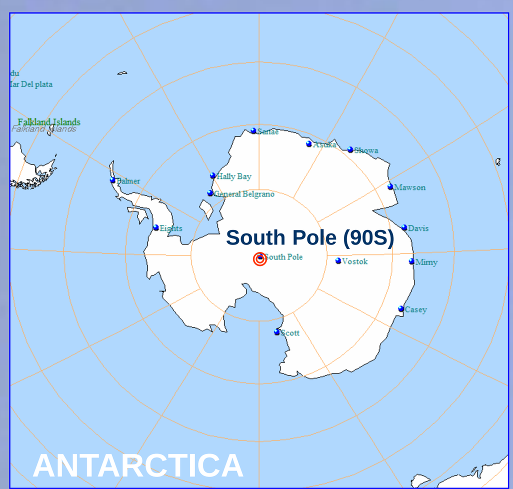
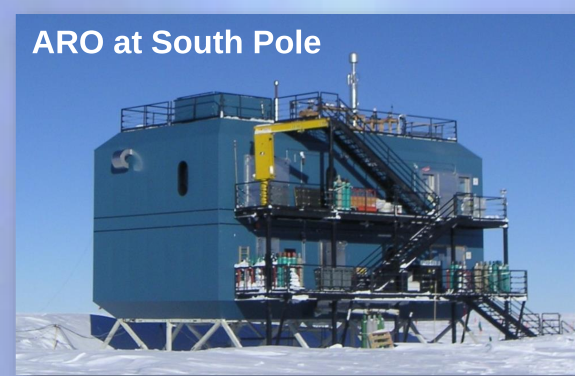
CLOUD MEASUREMENTS WITH AN ALL-SKY CAMERA SYSTEM FOR INVESTIGATING LONG-TERM VARIABILITY OF CLOUD PROPERTIES AT SOUTH POLE





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Abstract

Since December 2005, an all-sky camera system has been used to acquire images for monitoring cloud conditions at the Amundsen-Scott South Pole Station. The project has been conducted in collaboration with the NOAA Global Monitoring Division. The system is comprised of a Prede Model PSV-100 that includes a 3-color CCD camera with a fish-eye lens and a laptop computer for acquiring JPEG images. The camera was placed on the roof-top of the Atmospheric Research Observatory (ARO) and programmed to collect images at 10 minute intervals continuously each year during the sunlit period from October into March. Measurements were made from 18 December, 2005 until 24 March, 2017. For the purpose of this study, only the data collected during November through February were analyzed to avoid issues related to low sun angles and very cold temperatures. An analysis method proposed by Yabuki et al. (2014) was applied to obtain the cloud fraction from the all-sky images. In this paper, variability of the South Pole cloud fraction will be shown for the Antarctic summer season for the last decade. Figure 1 depicts monthly mean cloud fraction at South Pole derived from the all-sky camera measurements made from December 2005 to February 2017. The result shows large variation of cloud fractions for both month-to-month and from year-to-year. Consequently, no clear trend is manifested in the decade long time series.

Cloud Measurement at South Pole

Location: ARO (89.98S, 24.8W, 2810m)
Term: 18 December 2005 – 24 March 2017
Instrument: Prede PSV-100 All-Sky Camera

Objectives:

1. Climatology of total cloud fractions
2. Relationship between cloudiness and meteorological parameters

All-Sky Camera, Prede PSV-100

Specifications

Detector	3-color CCD
Data format	JPEG
Time interval	nominally 10 min
FOV	160 deg full
Operating Temp.	> -40 ℃

Result 1

Long-term variation of cloud fraction

From decade long cloud measurements at South Pole, temporal variation of cloud fraction was obtained as shown in **Figure 1**. The figure reveals large variability in cloud fraction from month-to-month and year-to-year.

Figure 2 shows monthly time series of the cloud fraction for each austral summer, 2005 to 2017. There is no significant trend in either monthly or yearly variations.

Further, trend analyses were performed by fitting each time series with linear and first order harmonic functions (**Figure 3**).While the regression shows a tendency towards slightly increased cloud fraction, no statistically significant linear trends were found. However, the monthly mean cloud fraction shows approximately a seven-year oscillation.

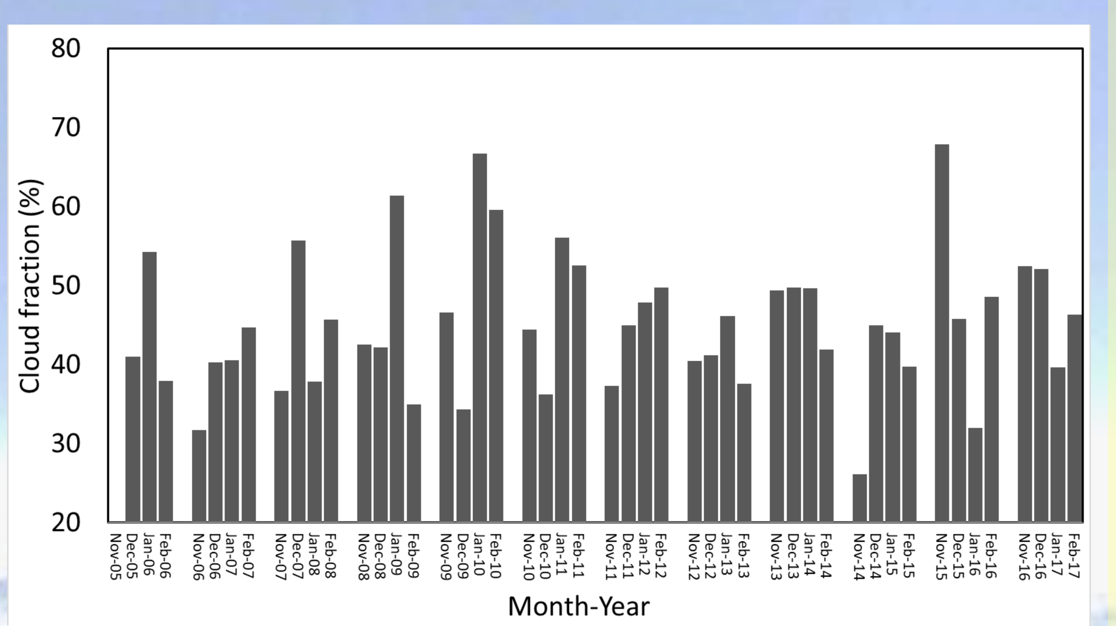


Fig. 1. Time series of monthly mean cloud fraction for December 2005 – February 2017.

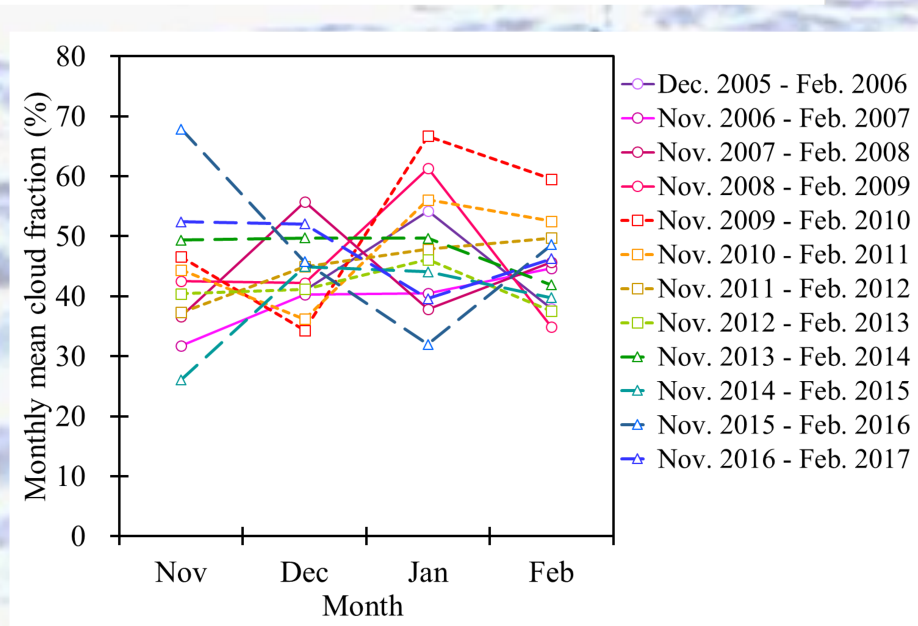


Fig. 2. Monthly variation of cloud fraction for each year since 2005 to 2017.

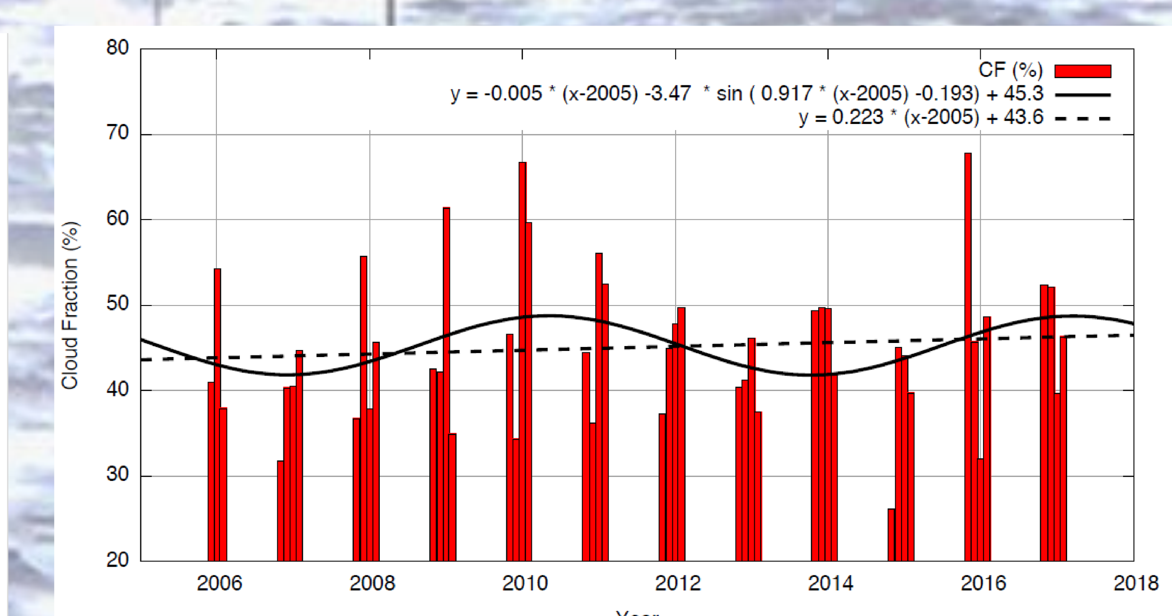
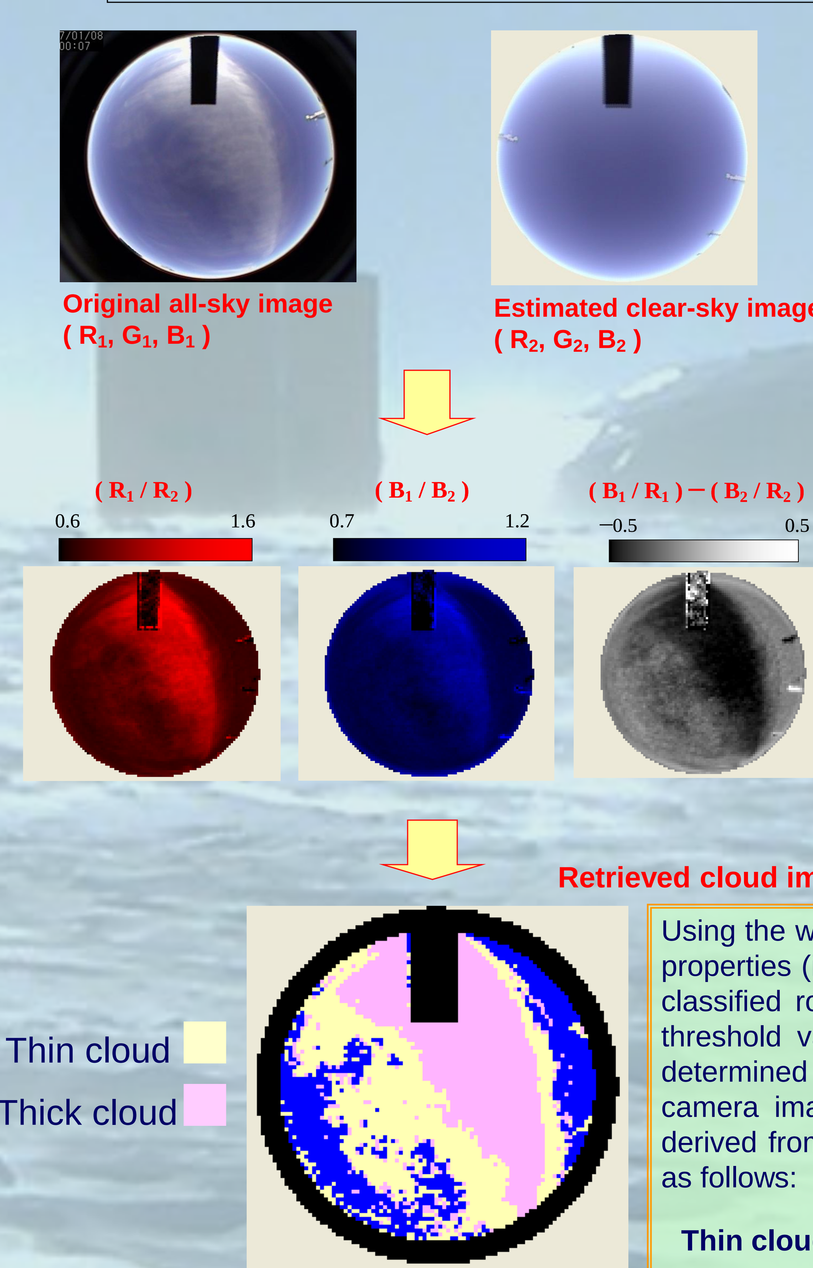


Fig. 3. Same as Fig. 1, but with trend analyses. Annual trend is fitted with the solid curve of a harmonic function indicated at the top. Dashed line indicates only a linear trend.

Cloud detection algorithm developed by Yabuki et al. (2014)



A background clear-sky image is produced by a linear interpolation of image intensity between two cloud-free images as a function of the solar zenith angle (SZA).

Threshold parameters for cloud detection:

$\mathrm{Abs}\,(1 - (R_1 / R_2)) > \delta_1$

$\mathrm{Abs}\,(1 - (B_1 / B_2)) > \delta_2$

$(B_1 / R_1) < (B_2 / R_2)$

Using the wavelength dependence of cloud optical properties (i.e., (B_1 / R_1)), the cloud type can be classified roughly into thick and thin clouds. The threshold value used for classification has been determined from the examination of Arctic all-sky camera images through comparisons with those derived from a Micro-Pulse LIDAR (MPL) system, as follows:

Thin cloud: $0.5 < \tau\ (\lambda = 500\ \mathrm{nm}) < 1.0$

Thick cloud: $1.0 < \tau\ (\lambda = 500\ \mathrm{nm})$

Result 2

Relationship between cloud fraction and near-surface air temperature

Following the analyses by Stone et al. (1989) and Dutton et al. (2004), the relationship between cloud and air temperature measured nominally at 2 m was investigated. Using monthly mean cloud fraction and 2m temperature as shown in **Figure 4**, correlation coefficients (R) for November, December, January and February were obtained, shown in **Figure 5**. Positive correlations were found for the summer months, except for December.

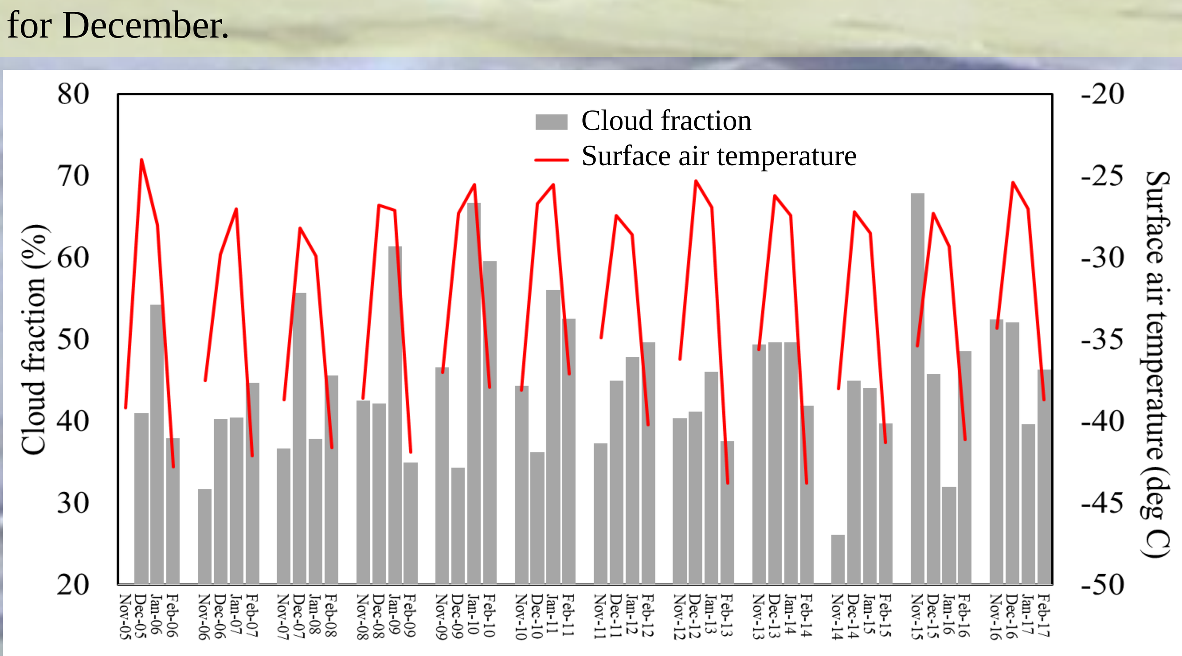


Fig. 4. Same as Fig. 1, but with the temporal variation of monthly mean surface air temperature (red).

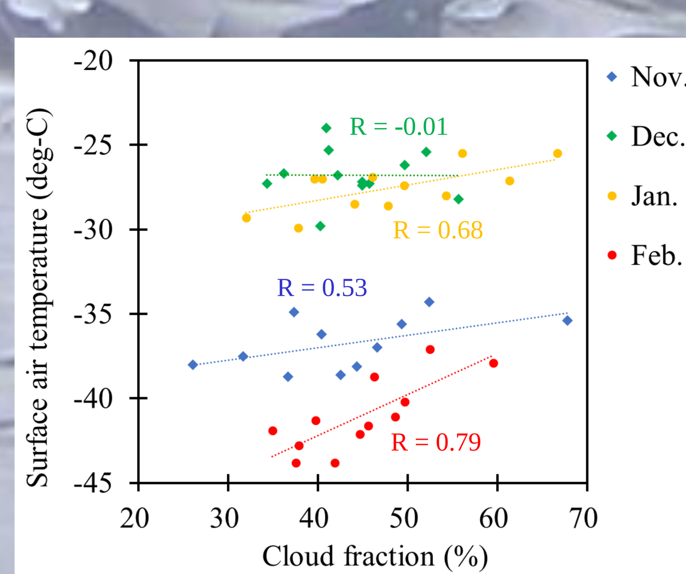


Fig. 5. Correlation between cloud fraction and surface air temperature for November (blue), December (green), January (orange) and February (red), respectively.

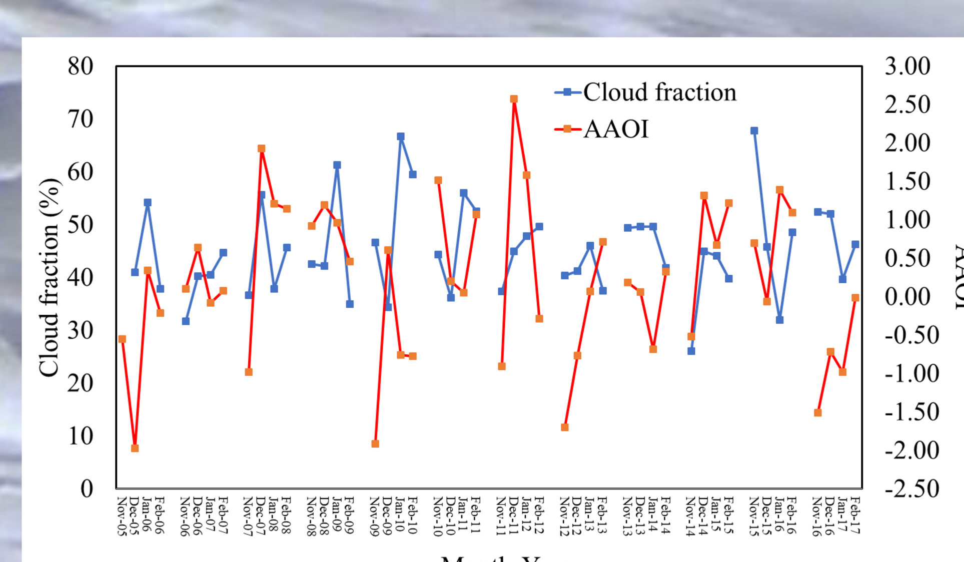


Fig. 6. Temporal variation of monthly mean cloud fraction (blue) and AAOI (red).

Result 3

Relationship between cloud fraction and AAOI

The Antarctic Oscillation Index (AAOI) is one of the best indicators of the general atmospheric circulation around Antarctica. Therefore, a relationship between monthly mean cloud fraction and AAOI (http://www.cpc.ncep.noaa.gov) was investigated.

Figure 6 and **Figure 7** show time series of monthly mean cloud fraction versus AAOI and a scatter plot of them, respectively. No significant correlation was found during the period of observation.

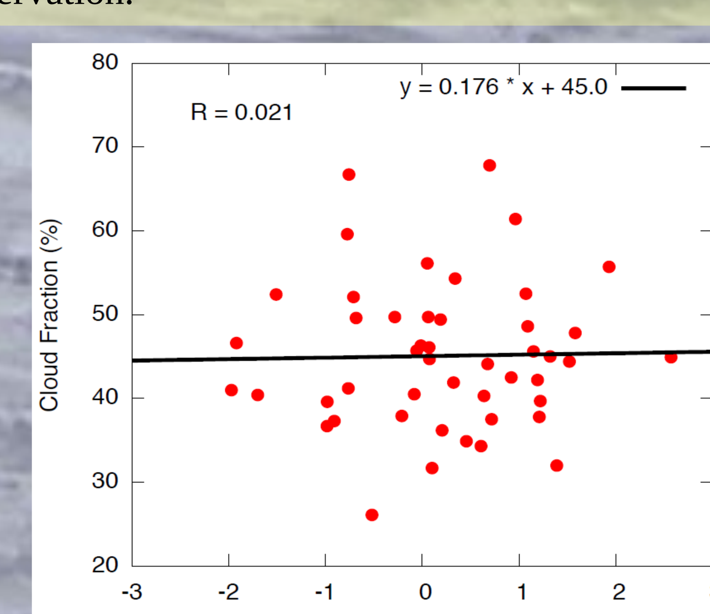


Fig. 7. Relationship between monthly mean cloud fraction and AAOI. The solid line is a linear regression, and the correlation coefficient R was 0.021.

Summary

The cloud measurements at South Pole, using an all-sky camera system, have revealed the following:

1. Long-term variation of cloud fraction showed no statistically significant trend, but an approximate, seven-year oscillation was observed.
2. Positive correlation between cloud fraction and surface air temperature was found for the summer months, except for December.
3. A relationship between cloud fraction and the Antarctic Oscillation index was not manifested for the period of observation.

From these preliminary results, the monthly mean cloud fraction appears to be influenced by the local atmospheric environment rather than the atmospheric circulation on a regional scale.

References

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NiPR National Institute of Polar Research

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE