P 4.31

STATISTICAL DEPENDENCE OF CLOUD FRACTION AS A FUNCTION OF VIEW ANGLE DERIVED FROM MISR DATA

G. Zhao * and L. Di Girolamo
Department of Atmospheric Sciences, University of Illinois, Urbana, IL, USA

1. INTRODUCTION

Cloud fraction as a primary product reported in cloud climatologies plays an important role in monitoring and modeling our climate. However, cloud climatologies derived from satellites always suffer from an increase of cloud fraction with satellite viewing obliquely, which is largely a consequence of an increase in the amount of cloud-sides observed with viewing obliquity and pixel expansion with viewing obliquity. These two effects cannot be decoupled until now.

The Multi-angle Imaging SpectroRadiometer (MISR) on-board EOS-Terra is the first high-resolution imager to make global, near-simultaneous, multi-spectral, multi-angle radiometric measurements of the Earth (Diner et al. (1998)). Nine separate cameras provide viewing zenith angles at the surface that range from ± 70.5°. Each camera is designed to collect data at 275 m resolution over a 360 km swath. With this unique multi-angle viewing capability, MISR, for the first time, minimizes the effects of pixel expansion with view angle.

Cloud fraction is calculated from MISR's Radiometric Camera-by-Camera Cloud Mask (RCCM), which uses two observables to determine clear vs. cloudy that depend on whether the observations are made over water or land (Diner et al. (1999)). Over water, the observables are the bi-directional reflectance factor (BRF) in the 865nm channel at 1.1 km resolution and the standard deviation of the 4×4 array of 275-m-resolution 670 nm BRF found within 1.1 km spatially averaged measurements. Each observable is tested against three thresholds in order to classify the pixel as cloud with high confidence, cloud with low confidence, clear with low confidence, and clear with high confidence. Only MISR data over ocean is used to examine the statistical relationships of cloud fractions vs. view angle, since it is this part of the world where the RCCM is working best in the early part of the MISR mission.

Snow et al. (1985) analyzed multiple-view photographs taken from the Space Shuttle of several cloud scenes. However, there is only a very limited set of data from which statistically stable results cannot be calculated. Minnis (1989) analyzed coincident GOES East and GOES west data over the tropical Pacific Ocean. However, these results need to be verified from an independent source in order to determine the impact of the GOES pixel expansion and global applicability of the results. With MISR data, it is now possible to examine cloud fraction vs. view angle globally and (in principle) more accurately.

*Corresponding author address: Guangyu Zhao, Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, IL 61801; email <gyzhao@atmos.uiuc.edu>

2. FEATURES SUMMARY

Figure 1 shows an ideal case in which cloud fractions smoothly increase as the view angle increases. But in reality, the function relating cloud fraction to view angle may become very complicated because of the following factors.

1) Sun-glint: Sun-glint causes the BRF to increase dramatically. As a result, the RCCM may overestimate clouds, if it is not working properly. If so, only one camera is contaminated by sun-glint at a time, which is shown as a spike on the curve of cloud fraction as a function of view angle.

2) Heavy Aerosols/thin clouds: In this situation the nadir RCCM may detect the scene as clear, but the oblique RCCM may detect it as cloudy, which leads to unrealistic behavior in cloud fraction vs. view angle.

3) Multi-layered clouds: It is possible that cloud fractions may decrease as view angle increases due to multi-layered clouds, as shown on Figure 2.

3. APPLICATION OF CLOUD FRACTION VS. VIEWING ANGLE

The importance of characterizing the cloud fraction dependence on view angle is embodied in its applications, which can be summarized as followings:

1) To validate the MISR cloud detection algorithm. If statistical results show that the changes of cloud fraction with view angle for a scene with fixed geometric parameters are not consistent with the ideal case, the RCCM threshold dataset is in need of improvement.

2) To identify heavy aerosols/thin clouds automatically. Whenever there is a big jump of cloud fractions between the nadir and 70.5° cameras (e.g. 50%), this scene will be marked as heavy aerosols/thin clouds. Further analysis of the scene can be performed to distinguish between heavy aerosols and thin clouds.

3) To calculate geometrical thickness of clouds. Statistical results may establish a function relating cloud geometrical thickness to the variation of cloud fractions with view angle.

4) To examine and reduce the biases in cloud climatologies derived from satellite radiometers that have large view angles (e.g., GOES, AVHRR, and MODIS)

5) To help reconcile the differences between surface-based cloud climatologies and satellite-based cloud climatologies.

4. STATISTICAL RESULTS

In the experiment presented here, 179 MISR orbits taken between April and May 2001 and limited to oceanic regions between 50°N and 50°S are examined. Total cloud fractions (including low confidence and high confidence clouds) for all the nine cameras are sorted into bins defined by the nadir cloud fraction over 5 MISR blocks (~$360\times640km^2$). Two quality assessment criteria are applied to filter the data. One is that cloud fractions over 10 MISR blocks must increase with view angle, and the other is that abnormal behavior in cloud fraction vs. view angle is rejected. These two QA criteria totally filter out seventy percent of the data, which may be affected by those factors such as sun-glint and multi-layered clouds as mentioned before.

The final statistical results are shown on Figure 3. As expected, the larger the nadir cloud fraction is, the smaller the difference of cloud fractions between two adjacent cameras. Most importantly, cloud fraction vs. view angles is consistent with the ideal case.

Minnis (1989) also presented cloud fraction increases with view angle based on a substantial amount of GOES data. However, the variation of cloud fraction with view angle is smaller and less smooth in his results than the results shown on Figure 3. Furthermore, the maximum difference of cloud fraction with view angle in the Minnis resuts doesn't vary too much between different cloud fraction bins when compared to the results presented here.

5. CONCLUSION/FUTURE WORK

This study presents preliminary statistical relationships of cloud fraction vs. viewing zenith angle and its application. The accuracy of calculating the cloud fraction highly depends on the quality of the MISR cloud detection algorithm, which has not undergone validation yet. However, the validation of RCCM over ocean is nearly in maturity. The cloud fraction vs. view angle criteria are now taken as important quality assessment parameters to validate the MISR cloud detection algorithm.

In the future, statistical relationships between cloud fraction and view angle will be stratified by cloud type and geographic parameters (e.g., longitude, latitude). Studies on how to use cloud fraction vs. view angle to determine cloud geometrical thickness are underway.

6. REFERENCE

Diner, D. J., and co-authors, 1998: Multiangle Imaging SpectroRadiometer (MISR) description and experiment overview. *IEEE Trans. Geosci. Rem. Sens.* 36, 1072-1087.

Diner, D. J., Di Girolamo, L., and Clothiaux, E.E., 1999: MISR Level 1 cloud detection algorithm theoretical basis. *JPL* D-13397, *Rev*. B, Jet Propulsion Laboratory, Pasadena, CA, 38pp.

Minnis, P., 1989: Viewing zenith angle dependence of cloudiness determined from coincident GOES East and GOES West Data. *J. Geophys. Res.*, 94(D2), 2303-2320.

Snow, J. W. and co-authors, 1985: Space shuttle cloud photographs assist in correcting meteorological satellite data. *Eos Trans.* AGU, 66, 489-490.

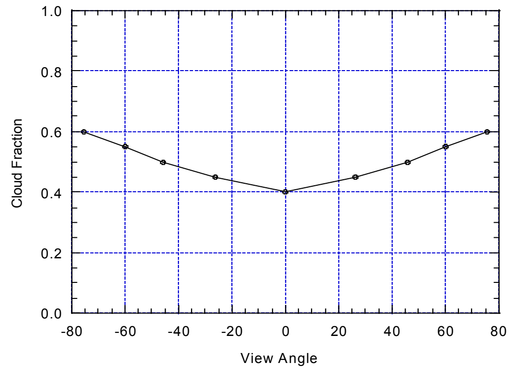

Fig. 1. Cloud fraction vs. view angle in an ideal case. The dots represent the 9 MISR view angles.

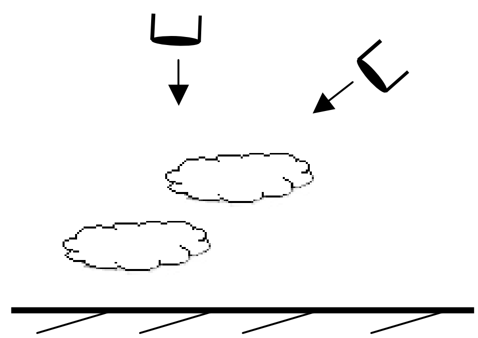

Fig. 2. An example of a scene in which cloud fraction decreases as view angle increases.

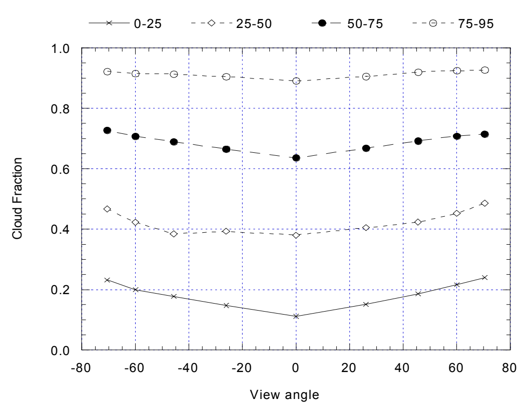

Fig. 3. The statistical relationship of cloud fraction vs. view angle is binned by the nadir cloud fraction.