Science Report: Atmosphere

A Comparison of Satellite-Based Cloud Observations to GLOBE Cloud Observations using the MODIS Cloud Product

Matt Rogers and Graeme Stephens
Colorado State University, Department of Atmospheric Science
Campus Delivery, Fort Collins, Colorado 80523-1371, USA
Telephone: 970-491-8124 Fax: 970-491-8768
rogers@atmos.colostate.edu

Abstract

GLOBE student observations of cloud type are compared to coincident satellite-derived observations, using MODIS Cloud Product data from the EOS-PM satellite. Cloud type is computed using satellite observed cloud top pressure and cloud optical thickness in the framework of the ISCCP cloud classification scheme (Rossow and Schiffer, 1991.) Common errors and biases in the surface based observations are explored, with the goal of improving observation and training of observers.

Introduction

Surface-based observations from the GLOBE program are a welcome addition to the researcher. With schools participating around the planet, the opportunities to integrate student scientific observations into contemporary scientific research are many indeed. As with all datasets, it is of some value to examine how certain elements of the GLOBE data interface with other scientific observations. Besides providing an opportunity to evaluate the utility of the datasets involved, such examinations allow for greater understanding of how the observations relate to one another, and increase our understanding the physical systems involved therein.

As an example, we consider observations of cloud type from the GLOBE Atmosphere protocol, combined with a retrieval of the same based on satellite observations from the MODIS instrument flying on NASA's EOS-PM satellite. Although both datasets (theoretically) provide the same end results, the mechanisms for generating said results are very different indeed. The GLOBE dataset is reliant on daily observations made by trained student eyes, while the MODIS dataset is a combination of satellite retrievals of cloud physical properties made at different frequencies. In comparing the two datasets, it becomes possible to examine the relative strengths and weaknesses of each, and the insight gained allows for improvement of both datasets.

The GLOBE dataset used for this report consists of observations of cloud type made by students of five Colorado schools collected during the fall of 2003. The satellite dataset determines cloud type based on the MODIS cloud retrievals of cloud-top pressure and cloud optical depth. By co-locating (in both time and space) overpasses of the MODIS instrument with the GLOBE observations, it becomes possible to compare the two datasets. We will begin by describing the GLOBE dataset, followed by an overview of the MODIS retrieval, followed by our results and a brief discussion.

Globe Observations of Cloud Type

As is specified in the GLOBE Cloud protocol, observations of cloud type are made daily by student observers, typically within an hour of solar noon. In the GLOBE paradigm, cloud types are broken down into three, height-determined categories, with subcategories determined by cloud shape (e.g. cumuliform, stratiform, precipitation, etc.) Observations of ‘No Clouds’ and ‘Sky Obscured’ are also allowed as the situation dictates. The ten types of cloud types allowed are as follows: cirrus, cirrostratus, cirrocumulus, altostratus, altocumulus, stratus, stratocumulus, cumulus, nimbostratus, and cumulonimbus. At the prescribed observation time, students are responsible for estimating cloud height and shape, and then record all cloud types observed.

The mechanisms of the GLOBE observations closely parallel other surface-based observation of cloud type. Because of the close relationship with weather systems, observation of cloud type is also one of the more intuitive and educational of the atmosphere protocols. Certain elements of the observation are difficult, however; particularly hard to estimate is the altitude of the cloud. This is true both for students and for trained observers. Other elements, such as cloud shape and the presence of precipitation, are easier to observe.

The MODIS Cloud Product and Cloud Type Retrieval

The MODIS cloud product is described in detail by Platnick et al. (2003) and includes details of the retrieval algorithms used to create the cloud product. The MODIS cloud retrieval returns (among other variables) cloud top pressure (at 5km resolution) and cloud optical depth (at 1km resolution.) Co-locating satellite observations with GLOBE surface stations is accomplished by creating a 0.5 x 0.5 degree box centered on the reported latitude/longitude of the GLOBE station, and using the satellite pixels contained inside this bounding box to construct histograms of cloud type. This creates a bounding box of approximately 55 x 42 km centered on the school, sufficient to contain all clouds likely observed by the school. Incomplete boxes (where the bounding box is not completely contained in the satellite swath) are rejected.

Ensuring the satellite observations are coincident in time with the GLOBE observations is hampered by the lack of a definite observation time in the GLOBE observation; however, GLOBE observations by protocol occur within an hour of local solar noon. The MODIS data used here comes from the EOS-PM satellite, which is sun-synchronous with an equator-crossing ascending node at 1:30 pm local solar time (LST.) At the latitudes for this study, therefore, the satellite observations are approximately two hours past local solar noon, with an unknown separation in time between the satellite overpass and the GLOBE observation. This time separation should be no longer than three hours, assuming a satellite overpass at 2:00pm LST, and an 11:00am LST GLOBE observation. Except for rapidly-evolving weather systems, it is expected that the satellite observations will observe essentially the same conditions observed by the GLOBE schools, and may safely be considered coincident in time.

The retrieved MODIS pixels of cloud-top pressure and cloud optical depth are analyzed in the framework of the ISCCP cloud classification scheme, described by Rossow and Schiffer (1991.) Essentially, the algorithm categorizes cloud type by cloud thickness (represented by cloud optical depth) and vertical extent (represented by cloud-top pressure.) As is described in Rossow and Schiffer (1991) this results in seven cloud type classifications: cumulus or stratocumulus, stratus, altocumulus or altostratus, nimbostratus, cirrus, cirrocumulus or cirrostratus, and cumulonimbus. An example of MODIS data and the computed histogram of cloud type is presented in Figure 1.

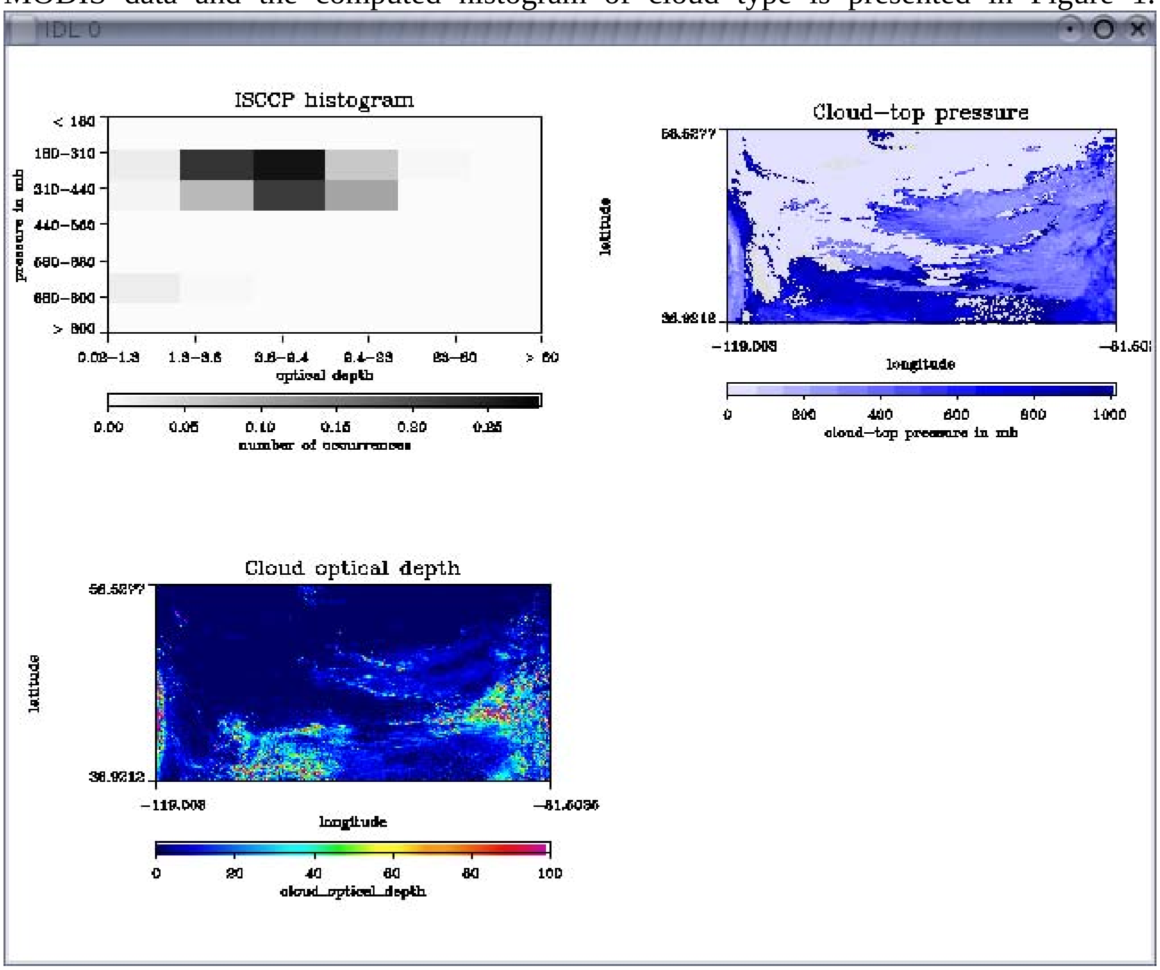

Figure 1. ISCCP histogram from MODIS observations of cloud top pressure and cloud optical depth.

It is important to note that the histogram in the upper-left corner of Figure 1. contains only pixels contained in the bounding box around a GLOBE school, while the other images of cloud-top pressure and cloud optical depth contain pixels from the full data granule. As is seen in the histogram, the pixels inside the bounding box generally contain cloud top pressures of between 180-440 mb, and have optical depths between 1.3 and 9.4. According to the ISCCP classification, the pixels would represent either cirrocumulus or cirrostratus clouds. The MODIS/ISCCP method described here returns the single most prevalent cloud type, while GLOBE will return all cloud types observed. Thus, it is possible to have more observations in the GLOBE dataset than in the MODIS dataset. For purposes of comparison, an occurrence of the MODIS-determined cloud type in the GLOBE dataset will be considered agreement between the two datasets.

Results

The results presented here are from September of 2003. Results from additional months are currently undergoing analysis, and will be presented in a later publication. During the thirty days of September, there were approximately sixty GLOBE reports of cloud type, seventeen of which were sufficiently close to a MODIS overpass to compare observations. The comparisons are presented in Table 1.

Julian Date	*MODIS observation*	*GLOBE observation*	*Agreement*	*Possible cause of discrepency*
2003 245	AlCu/AlSt	Ci, Cu	Partial	Height estimation error
2003 246	Ns	Ns, St	Yes	None
2003 247	AlCu/AlSt	Cu	Partial	Height estimation error
2003 248	Ci	CiSt, Cu	Partial	Cirrus misidentification
2003 252	CiCu/CiSt	Sc	No	Unknown
2003 252	Ci	Cu	Partial	Blocking of satellite
2003 252	CiCu/CiSt	No Clouds	Partial	Subvisual cirrus
2003 254	St	Cu, Sc, Cb	Partial	St/Sc misidentification
2003 259	Cu/Sc	Ci, Cu	Yes	None
2003 259	CiCu/CiSt	Cu, Cb	Partial	Height estimation error (Cu)
2003 259	CiCu/CiSt	AlCu, Cb	Partial	Height estimation error (AlCu)
2003 259	Ci	Ci, Cu	Yes	None
2003 259	Cu/Sc	Cu	Yes	None
2003 261	Cu/Sc	CiCu, CiSt, Cu, Sc	Yes	None
2003 273	St	Cu, St	Yes	None
2003 273	Cu/Sc	AlCu	Partial	Height estimation error
2003 273	Cu/Sc	Ci, Cu	Partial	Height estimation error

Table 1. Summary of co-located GLOBE and MODIS observations during Sept. 2003.

Of the 17 co-located observations, seven of the MODIS observations agreed with one or more of the GLOBE observations. An additional six observations were of the same general cloud type, but of varying cloud-base height (e.g. cumulus versus altocumulus.)

Given the inability of the satellite to definitively measure cloud base, combined with the somewhat subjective estimation of cloud base as seen from the surface observer's standpoint, these cases are labeled as partially agreeing, due to errors in height estimation. Other cases where agreement is deemed as partial are cases where a thick cirrus deck shielded the MODIS instrument from observing lower-level clouds (as in the second observation from Julian day 252, confirmed by reanalysis of the satellite data), and an interesting case of sub-visual cirrus as seen in the third observation from the same Julian day. The MODIS retrieval from that date reveals a very thin layer of cirrus, which would be transparent to the ground-based observer. Other cases of near-agreement consist of misidentification of similar cloud structures, namely cirrus versus cirrostratus, and stratus versus stratocumulus. In only one case is the MODIS observation radically different from the GLOBE observation; the reason for this discrepancy is unknown.

Discussion

Further analysis of the dataset, spanning the entire calendar year of 2003, is currently being produced. The initial results are promising for researchers, however, and demonstrate the validity of this particular GLOBE dataset. As is seen in the preliminary results, the greatest source of error is the relative inability to estimate the altitude of cloud base. With the feedback provided by satellite studies, it should be possible to improve surface-based estimation of cloud height. Additional care in discriminating between similar cloud types cloud possibly eliminate the other errors seen in this study, although the subjective nature of what exactly constitutes a unique cloud type makes this a difficult task to achieve with great precision.

In summary, we demonstrate the utility of GLOBE observations to cloud research, especially for applications that are less sensitive to cloud base height. Further research to expand the dataset and analyze cloud cover observations as well is currently underway.

References

Platnick, S., M. D. King, S. A. Ackerman, W. P. Menzel, B. A. Baum, J. C. Riédi, and R. A. Frey, 2003: The MODIS Cloud Products: Algorithms and Examples from Terra. IEEE Transactions on Geoscience and Remote Sensing, *41, 459-473.*

Rossow, W.B., and R.A. Schiffer 1991. ISCCP cloud data products. *Bull. Amer. Meteor. Soc.* **71**, 2-20.