6.2 STUDENTS AS GROUND OBSERVERS FOR SATELLITE CLOUD RETRIEVAL VALIDATION

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1. INTRODUCTION

The Students' Cloud Observations On-Line (S'COOL) Project was initiated in 1997 to obtain student observations of clouds coinciding with the overpass of the Clouds and the Earth's Radiant Energy System (CERES) instruments on NASA's Earth Observing System satellites. Over the past seven years we have accumulated more than 9,000 cases worldwide where student observations are available within 15 minutes of a CERES observation.

This paper reports on comparisons between the student and satellite data as one facet of the validation of the CERES cloud retrievals. Available comparisons include cloud cover, cloud height, cloud layering, and cloud visual opacity. The large volume of comparisons allows some assessment of the impact of surface cover, such as snow and ice, reported by the students.

The S'COOL observation database, accessible via the Internet at http://scool.larc.nasa.gov, contains over 32,000 student observations and is growing by over 700 observations each month. Some of these observations may be useful for assessment of other satellite cloud products. In particular, some observing sites have been making hourly observations of clouds during the school day to learn about the diurnal cycle of cloudiness.

2. THE S'COOL OBSERVATION PROTOCOL

The observation protocol for the S'COOL project was designed to provide sufficient information to make it useful for CERES validation; while at the same time keeping it simple enough that even younger students could participate. The result is a one-page data sheet, shown in Fig. 1. The bulk of the observation concerns the cloud situation, with identification of cloud type (which specifies cloud level), cloud cover at each level, and a qualitative measure of cloud visual opacity. A count of the number of persistent and short-lived contrails is also requested. Information about surface cover follows. Of particular interest is the presence of snow or ice to create a bright reflecting surface. Finally, if instruments are available, measurements of temperature, pressure and relative humidity can be reported. Comments of all kinds are welcomed, and we have received some beautifully descriptive similes from classes where teachers integrate the observation with language arts. The final piece of the observation report is identification of the location and time of observation.

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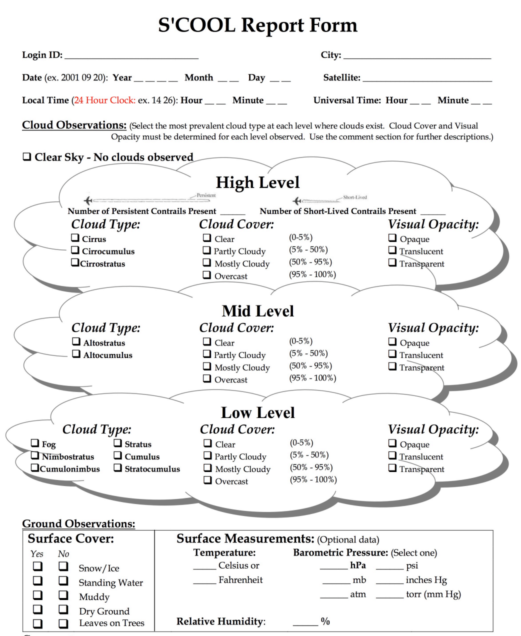
3. INITIAL COMPARISONS

Following the first year of operation (1998) of the first CERES instrument launched on the Tropical Rainfall Measuring Mission (TRMM) spacecraft, and the subsequent processing of the CERES data, an initial comparison of student to satellite data was performed. Because TRMM is a precessing satellite that allowed the CERES instrument to view only the Tropics (~35 S to 35 N), and because the initial network of S'COOL schools was primarily in North America and Europe, very few ground to satellite correspondences were available. A correspondence is defined as a ground observation that occurs within 15 minutes of a satellite observation, and it is compared in this study to the average properties obtained by the satellite for the 1-degree region containing the ground site. The 50 or so correspondences for CERES TRMM were augmented with about 50 geostationary satellites images that were manually processed through CERES-like cloud algorithms for some of the higher latitude observations. In these cases, a box was drawn somewhat subjectively around the school site. Tables 1 and 2 present the comparison of these 99 ground to satellite matches

Table 1 compares the cloud cover, observed on the


S'COOL Report Form

Login ID: ____ City: ____

Date (ex. 2001 09 20): Year _ _ _ _ Month _ _ Day _ _ Satellite: ____

Local Time (24 Hour Clock: ex. 14 26): Hour _ _ Minute _ _ Universal Time: Hour _ _ Minute _ _

Cloud Observations: (Select the most prevalent cloud type at each level where clouds exist. Cloud Cover and Visual Opacity must be determined for each level observed. Use the comment section for further descriptions.)

❑ Clear Sky - No clouds observed

High Level

Persistent / Short-Lived

Number of Persistent Contrails Present ____ Number of Short-Lived Contrails Present ____

Cloud Type:	Cloud Cover:		Visual Opacity:
❑ Cirrus	❑ Clear	(0-5%)	❑ Opaque
❑ Cirrocumulus	❑ Partly Cloudy	(5% - 50%)	❑ Translucent
❑ Cirrostratus	❑ Mostly Cloudy	(50% - 95%)	❑ Transparent
	❑ Overcast	(95% - 100%)	

Mid Level

Cloud Type:	Cloud Cover:		Visual Opacity:
❑ Altostratus	❑ Clear	(0-5%)	❑ Opaque
❑ Altocumulus	❑ Partly Cloudy	(5% - 50%)	❑ Translucent
	❑ Mostly Cloudy	(50% - 95%)	❑ Transparent
	❑ Overcast	(95% - 100%)	

Low Level

Cloud Type:		Cloud Cover:		Visual Opacity:
❑ Fog	❑ Stratus	❑ Clear	(0-5%)	❑ Opaque
❑ Nimbostratus	❑ Cumulus	❑ Partly Cloudy	(5% - 50%)	❑ Translucent
❑ Cumulonimbus	❑ Stratocumulus	❑ Mostly Cloudy	(50% - 95%)	❑ Transparent
		❑ Overcast	(95% - 100%)	

Ground Observations:

Surface Cover:			Surface Measurements: (Optional data)		
Yes	No		Temperature:	Barometric Pressure: (Select one)	
❑	❑	Snow/Ice	____ Celsius or	____ hPa	____ psi
❑	❑	Standing Water	____ Fahrenheit	____ mb	____ inches Hg
❑	❑	Muddy		____ atm	____ torr (mm Hg)
❑	❑	Dry Ground			
❑	❑	Leaves on Trees	Relative Humidity:	____ %	

Comments:

Fig. 1. The S'COOL report form

ground in four broad categories developed from the Earth Radiation Budget Experiment (ERBE; Wielicki and Green, 1989) instrument algorithm: clear (0-5% cloud cover); partly cloudy (5-50%), mostly cloudy (50-95%) and overcast (95-100% cloud cover). Note first of all that there are no cases of complete disagreement, where the ground observers report overcast while the satellite reports clear sky or vice versa. Sixty-two percent of the cases show complete agreement between satellite and ground reported cloud cover. This level of agreement is comparable to what has been found in comparisons between satellites in different orbits, with differing fields of view (Green, personal communication).

Table 1. Cloud cover from satellite vs. ground observers

		Ground Observers			
		Clear	Partly	Mostly	Overcast
S	Clear	27	2	2	0
A	Partly	7	10	2	1
T	Mostly	5	3	12	7
	Overcast	0	1	8	12

Comparison of cloud layers is reported in Table 2. Here we find a very interesting result: 9 cases where the ground reports a single layer of cloud while the satellite reports clear sky. Further examination shows that in 8 of these 9 cases the ground observers reported 0-5% cover of thin cirrus. These cloud situations are beyond the detection limit of the CERES/Visible and InfraRed Scanner (VIRS) algorithm for the TRMM spacecraft. In addition, there are 29 cases where the ground observers report a single cloud layer while the satellite reports multiple layers. This reflects the complementary views of the ground observers and the satellite, where the satellite can see through some of the thin, high cloud layers while ground observers see only the thick, overcast lower layer. Some of the other mismatches are attributed to spatial mismatch in the two views, or to time mismatch. Early in the S'COOL project the conversion to universal time was a source of some confusion for participants.

Table 2. Cloud layers from satellite vs. ground observers

		Ground Observers		
		No Cloud	Single	Multi
S	No Cloud	14	9	0
	Single	3	29	3
	Multi	3	29	9

These initial comparisons were sufficiently interesting to encourage the continued operation of the S'COOL Project. They were reported, along with lessons learned from the operation of the project (Chambers et al., 2003).

4. EXTENSIVE COMPARISONS

In the last year, the first CERES reprocessing has occurred, using new angular distribution models derived from Terra. This processing included the first long time series of CERES Single Scanner Footprint (SSF) data products, from which the cloud information to compare to the student observations is obtained. As a result, there are now over 9000 correspondences between student-observed ground truth and satellite data for the

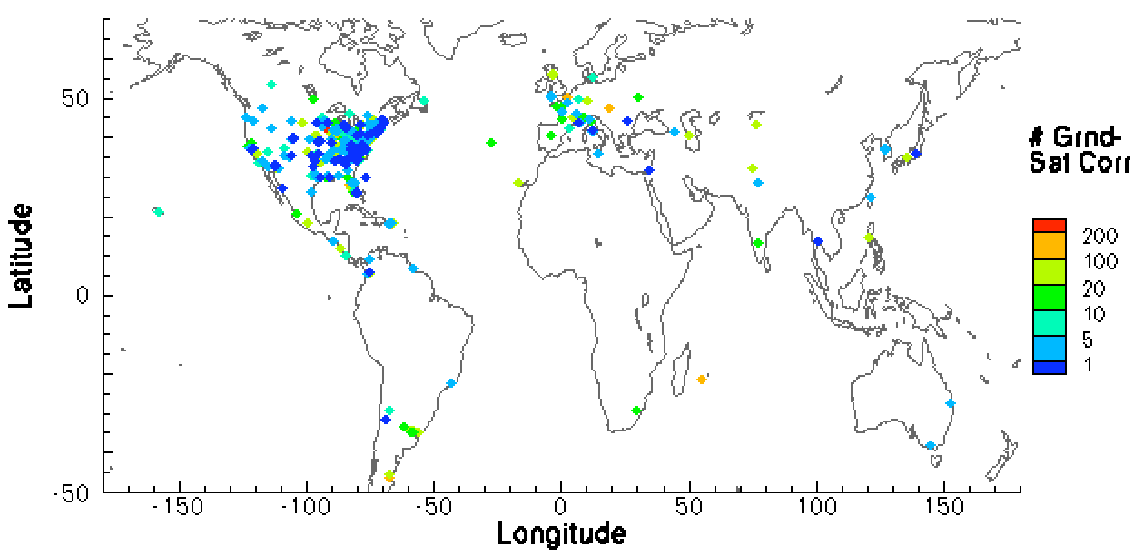


Fig. 2. Distribution of S'COOL student observations with corresponding CERES satellite data.

period between February 1998 and April 2004 (note that additional correspondences for this time period will be available when additional CERES data are processed). Figure 2 provides a summary of the locations for which ground truth observations are available. They are concentrated in North America, but a number of geographically distributed observations are also available. The S'COOL Project is on-going, so schools are invited to consider participation, especially if they are in a sparsely observed region. The maximum number of correspondences at a single observation site is 479. There are about 70 sites where only a single correspondence occurs so far.

Tables 3 and 4 summarize the cloud cover and cloud layers for this more extensive set of ground to satellite correspondences. These comparisons include ***only*** CERES data, with the average cloud properties for the 1-degree box compared to the student observation. In this case we have a somewhat lower proportion of direct matches, with a large number of 1-class errors. In some of these cases students report, for example, 0-5% cloud cover, while the satellite may report 7% cloud cover. Thus, 1-class errors can sometimes be near matches.

Table 3. Cloud cover from satellite vs. ground observers

		Ground Observers			
		Clear	Partly	Mostly	Overcast
S	Clear	1125	254	87	45
A	Partly	799	955	583	231
T	Mostly	297	585	700	681
	Overcast	154	193	490	1993

For this extensive, automated comparison, 4773 of 9172 cases agree (52%) with 3392 1-class errors, 808 2-class errors, and 199 3-class errors. The latter are of most immediate interest, as they reflect complete disagreement between the two data sources.

Examination of the 45 cases where students report overcast cloud while the satellite reports clear sky reveals that almost half of these cases are for schools located very close to the edge (less than 0.1 degree) of a lat/long grid box. Thus, spatial mismatch may be an issue. Two cases appear to have an incorrect universal time. The remaining cases have no clear explanation and probably represent some sort of student error. Further investigation is needed. It is interesting to note that snow is reported in 10 of these cases, yet the satellite still reports clear sky.

About 30% of the 154 cases where the students report clear while the satellite reports overcast may be attributed to spatial mismatch error because the school is at the edge of a lat/long grid box. Another half dozen appear to have universal time errors, while in a dozen cases the students reported snow on the ground. The latter deserve additional scrutiny, as error in the satellite retrieval may be the cause. However, only one of the satellite retrievals appears to be suspect, with a low cloud temperature 2.5K below the surface temperature. This is good news for the CERES snow identification algorithm.

Recently, a comparison of MODIS cloud type (based on the ISCCP classification) with GLOBE (www.globe.gov) student data indicated the occurrence of some subvisual cirrus (Stephens and Rogers, 2004). In this S'COOL dataset, we find 19 cases where the total satellite optical depth is less than three, and five cases where it is less than one. None of the latter are high clouds, and none of the former are high cloud only. Thus, subvisual cirrus is not prevalent in the dataset. This may be due to the limited spatial sampling of the S'COOL student data, which is generally over land with few data points in the Tropics (Fig. 2).

Table 4 compares the number of cloud layers detected from the ground and from satellite. Similar to Table 2, the largest number of mismatches occurs when the ground observes a single layer while the satellite reports multiple layers. This is the situation with a low overcast cloud layer and the satellite seeing through thin cirrus or mid-level cloud layers from the top. In this case the ground and satellite views complement each other very well. The second largest number of mismatches occurs when the ground reports a single layer and the satellite reports clear. In more than half of these cases the ground reports a single cloud layer with 0-5% cloud cover (36% high, 5% mid-level and 14% low cloud). This provides a quantitative measure of how often the satellite instrument misses small amounts of cloud.

Table 4. Cloud layers from satellite vs. ground observers

		Ground Observers		
		No Cloud	Single	Multi
S	No Cloud	950	615	100
A	Single	306	2030	581
T	Multi	249	3306	1035

5. EFFECT OF BRIGHT SURFACE

Among the ground observations in the dataset are 1057 reports (~11%) that include snow or ice on the ground. The analysis was repeated for only these cases and is summarized in Tables 5 and 6.

Table 5. Cloud cover from satellite vs. ground observers when snow/ice is reported on the ground

		Ground Observers			
		Clear	Partly	Mostly	Overcast
S	Clear	115	20	8	10
A	Partly	87	77	35	19
T	Mostly	47	64	68	95
	Overcast	18	33	52	309

The agreement of the cloud cover observations is slightly better (54%) when the surface observers report snow or ice. There is little evidence of a bias toward excess cloud cover in the satellite data due to the presence of the bright surface.

The level of agreement for cloud layers is also quite similar in the presence of snow (Table 6). This is again very good news for the CERES cloud algorithm in terms of handling bright surfaces.

Table 6. Cloud layers from satellite vs. ground observers when snow/ice is reported on the ground

		Ground Observers		
		No Cloud	Single	Multi
S	No Cloud	92	73	5
A	Single	42	295	54
T	Multi	31	400	65

6. CONCLUDING REMARKS

This paper reports on initial comparisons using a surface observer ground truth dataset obtained for validation of the CERES cloud properties by globally distributed K-12 observers. While the dataset illustrates some of the pitfalls of using a student observer network, it also demonstrates that useful information can be obtained. This is just the beginning and additional comparisons will continue to be analyzed as new CERES data are processed and as new observations are received.

As another facet of this project, the students who made the observations can access the ground and satellite correspondences on the Internet for detailed analysis, particularly of their own reports. Data analysis has been shown to increase test scores (NCES 2000) at all grade levels tested, and analysis of their own data may increase motivation for both analysis and for increased care in observing and reporting clouds in the future.

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