THE CERES S'COOL PROJECT

BY LIN H. CHAMBERS, DAVID F. YOUNG, P. KAY COSTULIS, PAULINE T. DETWEILER, JOYCE D. FISCHER, ROBERTO SEPULVEDA, DOUGLAS B. STODDARD, AND AMANDA FALCONE

The lessons learned during the development and operation of a NASA outreach program can benefit other educational efforts linked to scientific projects.

LESSON ONE: THINK GLOBALLY, ACT INCREMENTALLY. *A short-term project is probably best done with a small, local audience. For a longer-term, extensive project, start slowly, incorporate teacher feedback, and allow time for your project to become known and appreciated.*

The Students' Cloud Observations On-Line (S'COOL) Project was initiated in late 1996, before the launch of the three low Earth orbit satellites that now carry the Clouds and the Earth's Radiant Energy System (CERES) instruments. From the beginning, S'COOL was developed with input from teachers. Indeed, the idea for this project arose in a conversation between the first author and a sixth-grade science teacher. She was seeking a simple, safe, and cheap way to connect her students' in-class experiments to the National Aeronautics and Space Administration (NASA). CERES, which was designed to monitor the earth radiation budget and how it is impacted by cloud properties (Wielicki et al. 1996), needed to validate cloud retrievals on a global basis. Her class served as the first test site for S'COOL, confirming that students would be interested in the project. The scope of the S'COOL project was then expanded over the year leading up to the launch of the first CERES instrument [on the Tropical Rainfall Measuring Mission (TRMM) satellite on Thanksgiving Day, 1997, from Tanegashima, Japan]. Table 1 summarizes the development phases of S'COOL. After each phase, teacher comments were solicited and used to improve the project. Specific lessons learned are included in Table 1. S'COOL was declared operational in April 1998. It now involves the part-time efforts of two scientists, two Web and database specialists, and a full-time former classroom teacher (part of the team since October 1997). A part-time teacher consultant was added in 2000 to focus on interaction with the Spanish-speaking audience. (Bilingual team members cover French and German translation needs.) In 2001, a part-time administrative assistant was added to keep up with the growing S'COOL community.

AFFILIATIONS: CHAMBERS, YOUNG, AND COSTULIS—Radiation and Aerosols Branch, NASA Langley Research Center, Hampton, Virginia; DETWEILER, FISCHER, SEPULVEDA, AND STODDARD—Science Applications International Corporation, Hampton, Virginia; FALCONE—Trinity University, San Antonio, Texas
CORRESPONDING AUTHOR: Lin H. Chambers, Radiation and Aerosols Branch, NASA Langley Research Center, 21Langley Blvd., MS 420, Hampton, VA 23681-2199
E-mail: l.h.chambers@larc.nasa.gov
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LESSON TWO: KEEP IT SIMPLE. *For teachers: Teachers have many demands on their time, so keeping outreach as simple and flexible as possible is imperative.*

For students: What may seem trivial to scientists can be fascinating new knowledge to a young student.

To participate, interested teachers simply register. S'COOL needs a record of the location of each school in order to match their observations with the satel-

Table 1. The development phase of S'COOL.

Dates	Test	Participants: No.	Participants: Location	Participants: Grade	Observations*	Lessons learned
13–17 Jan 1997	Postal/ interface scientist visit	1	Peasley, MS Gloucester, VA	6th	Ground 5 Satellite 4	Importance of clear-sky observations. Need for a consistent cloud chart.
11–17 Mar 1997	E-mail interface/ remote site	1	Big Timber Grade school, Big Timber MT	6th	Ground 5 Satellite 0	Scientist visit is not necessary. Lots of multilayer clouds.
17–21 Mar 1997	Web interface	1	Poquoson Elementary Poquoson, VA	4th	Ground 5 Satellite 4	Potential of the Internet.
28 Apr–2 May 1997	National Test	9	AZ, GA, MT, NM NY, PA, SD, VA (2)	1–12	Ground 41 Satellite 17	System works for distributed sites and multiple grades.
Jul 1997	International test	0	No successful contacts in Southern Hemisphere		Ground 0 Satellite 0	Need time to make connections outside United States.
20–24 Oct 1997	Global test/ draft poster and brochure	26	AR (2), FL, IL, ME, MI (3), NM, NY, SC, VA (3), France (7), Switzerland (4), Sweden	1–Univ. (Educ.)	Ground 119 Satellite 12	Need to be flexible for teacher schedules.
9–13 Feb 1998	TRMM satellite test	31	AK, CO, DE, FL, IL, MI (2), NY (3), OH, OR (2), PA, TX (3), VA (3), France (6), Norway, Sweden, Switerland (3)	1–Univ. (Educ.)	Ground 168 Satellite 29	Teachers use S'COOL even outside test week (Nov–19 Feb 1998)

*Before TRMM launch, NOAA AVHRR, GOES, and Meteosat data were used.

lite. Each registered teacher receives a packet of information, including a colorful cloud identification poster (Fig. 1). Upon registration, teachers are sent their first overpass schedule, telling them what time the satellite will pass over their school each day. Schedules are projected a maximum of two months into the future, since satellite orbit adjustments occur. Further schedules can be requested online at http://scool.larc.nasa.gov.

From the schedule, teachers select an overpass that fits their class situation. Students then go outside within 15 min of the satellite's passage to observe and record cloud and surface properties on a 1-page report form (Fig. 1). For an experienced class, this process takes only 5–10 min. Overpass schedules do not always mesh with school schedules, but solutions can be worked out. For example, a high school teacher reported the following: "Our overpass times are always while they are in classes other than science. We designed special S'COOL hall passes, and my colleagues who teach other disciplines have been very supportive and allow the students to leave class for five minutes to go outside and take their readings."

The observation is sent to NASA either by accessing an online form, or by sending an e-mail, a fax, or even a hard copy (a ground rule for S'COOL is that Internet access is not required, enabling us to reach students without computers). The S'COOL ground

FIG. 1. A variety of materials have been developed for S'COOL over the years. All the items pictured are now available on the Internet (http://scool.larc.nasa.gov).

observations are stored in a database at the NASA Langley Atmospheric Sciences Data Center (ASDC; online at http://eosweb.larc.nasa.gov). ASDC is responsible for processing and archiving CERES data along with many other atmospheric datasets. During operational processing, CERES data corresponding to S'COOL observations are extracted and placed in the S'COOL satellite database. For the TRMM satellite, data are only available between about 35°N and 35°S latitude. In December 1999, the launch of two CERES instruments on the *Terra* spacecraft provided a daily morning overpass of the entire globe. The *Aqua* launch, with two more CERES instruments and a daily afternoon overpass, was on 4 May 2002.

Figure 2 shows the history of participants and ground and satellite observations in the S'COOL database. Within a month of sending their first observation (and for each new school year), a class receives a "S'COOL Observer" decal (Fig. 1) for each student. Teachers can also print certificates for each student from the Web site to recognize their progress, which can be substantial. For example, one teacher reported ". . . my first graders got very good at identifying the cloud types. I was impressed with their knowledge at such a young age."

LESSON THREE: THE INTERNET ADVANTAGE. *The Internet is invaluable to facilitate communication with participants and to share information among them. There is also an increasing amount of useful information on the Web, which can be used for background and supplementary information.*

The S'COOL ground and satellite databases are available via a public Web interface, for use by teachers in educational applications (such as graphing, mapping, and comparing). Lesson plans describing data-use projects are available. Figure 3 shows a sample query result when ground and satellite data correspond. From this display that data can also be downloaded into spreadsheets for analysis.

From the beginning, S'COOL observations have been a useful complement to the satellite information. The very first S'COOL observation occurred on a beautifully clear January day. Reports from *cloud* observers on clear days may seem dull but are very important. Determination of a completely clear sky from the satellite can be a challenge in certain circumstances, given the inhomogeneous background of the earth's surface, but there is high confidence in the accuracy of students' report of clear sky. Other challenges to the satellite cloud retrieval algorithm include clouds over snow, subpixel-scale clouds, and very thin clouds—none of which pose problems for observers on the ground. When multiple cloud layers are present, the surface observation gives an additional data point from the bottom, while the satellite views the cloud top.

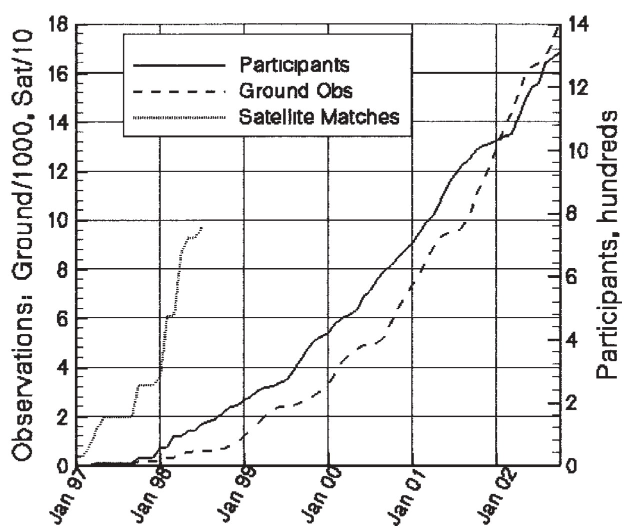

FIG. 2. Growth of S'COOL: The solid line denotes the number of participants, in hundreds. The dashed curve shows the number of S'COOL ground observations, in thousands. Note the plateau each summer, associated with summer vacation in the Northern Hemisphere. The dotted curve shows the number of matching satellite data, in tens. Only satellite data through 1998 have been processed so far.

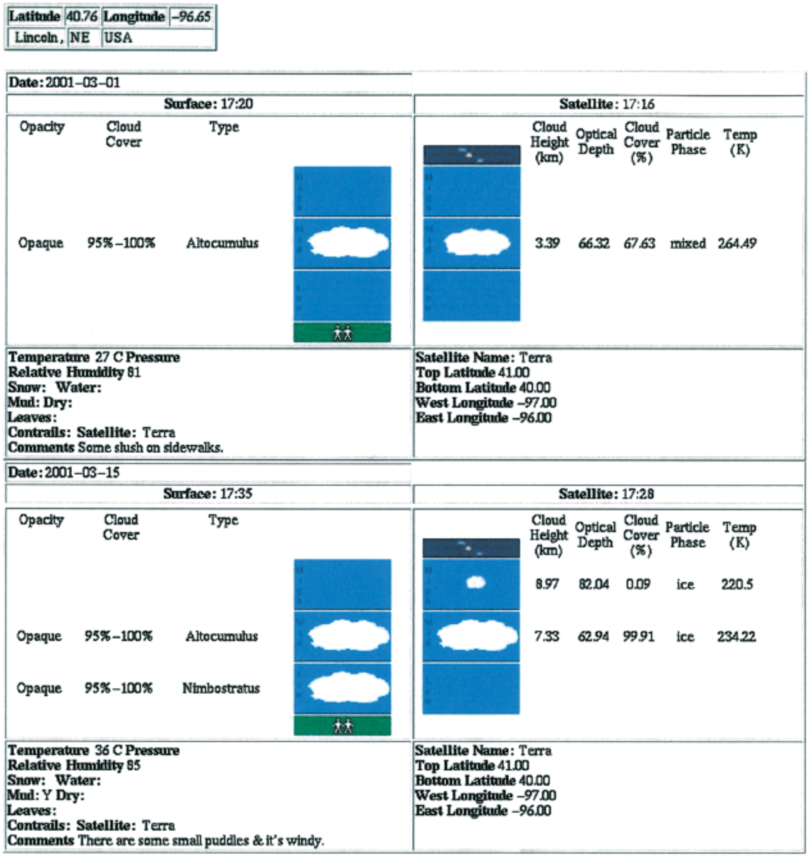

FIG. 3. Sample result for query of S'COOL database when both ground and satellite data are available. The top panel shows excellent agreement between the satellite retrieval and the surface observers. The bottom panel is an example where the satellite cannot see through a thick midlevel cloud to the low-level nimbostratus that is reported by the S'COOL observers.

Instrument problems and data delays have slowed the production of satellite data, so that timely comparison of ground and satellite results has been a major challenge. Nonetheless, a statistical comparison using the limited amount of satellite data now available is instructive. Table 2 summarizes the cloud cover observed from the two vantage points, while Table 3 summarizes the cloud layers observed. Note in the latter the nine cases where the satellite finds clear sky while ground observers report a single layer of cloud. In eight of these nine cases, surface observers reported 0%–5% translucent cirrus cloud cover, which was not detected by the satellite. Despite the delays with the satellite data, many participants have been very happy with the observational portion of S'COOL. Yet motivating all registered teachers to become active participants has been a challenge. Once routine processing of CERES data begins we hope to encourage additional teachers to become more active. S'COOL will, however, remain an elective project, used by teachers as time permits and interest dictates.

LESSON FOUR: TEACHERS ARE PROFESSIONALS, TOO.

The ways teachers use a simple project to enhance learning will surprise you.

CERES personnel (scientists and engineers) expected S'COOL to apply mainly to science and math education. In practice, teachers have used it for other lessons as well, and over an extremely broad grade level from kindergarten to graduate school. A teacher in phase 1 reported the following: "It was a perfect addition to our science weather unit and covered the standards of learning as well as spilling into other curriculum areas and getting the class out of the traditional classroom."

Observation skills. An elementary school teacher in Michigan uses S'COOL as an opportunity to foster observation skills in her students. Every day before class, they sit out in the courtyard and quietly observe their surroundings: seasonal and weather changes, animal life, vegetation, etc. As she says, "A significant part of science education is to help students sharpen their observation skills . . . S'COOL is highly motivating to the children." S'COOL provides students with a motivation to learn cloud identification, something that is required in most curricula. It also makes learning fun, as indicated in this comment: "The kids have been enjoying collecting their data. They feel very important since they are working with NASA."

Math skills. An elementary school teacher in Virginia reported that her students are so excited about S'COOL that they want to perform calculations of unit conversions themselves rather than relying on the Internet calculator page. Addition and division are reinforced while obtaining a class consensus for the value of fractional cloud cover and temperature.

Writing/descriptive skills. An elementary school teacher in Virginia has her students writing similes and descriptions of what they see while outside observing clouds (i.e., "the clouds look like moldy bread"). These are reported with their observations in the comments section of the report form, and complement the more objective report of cloud type.

Foreign language skills. A school in Canada registered with S'COOL for the express purpose of using it to practice a second language. Several schools in Puerto Rico use S'COOL to practice English. An elementary school in Virginia used S'COOL as a focal point for supplementary language instruction offered by a bilingual parent. Recently the Foreign Language Association of Virginia embraced S'COOL as a real-world application of language skills.

Technology skills. An elementary school teacher in South Carolina reported that this project was a good way to begin introducing the Internet and computer technologies to her students. In a number of elementary schools S'COOL becomes a multiage project. For example, "I worked with a fourth grade class and that helped with the computer aspect. You might encourage other schools to combine a lower elementary room with an upper elementary room for increased participation and learning." Several college education professors use S'COOL to teach how to manage a class of students in a Web-based curriculum unit. Their motivation is expressed by this comment: "This project [is] a really nice connection to data collection/measurement and many other aspects of what I hope these 'becoming' teachers will do with kids when they get into the classroom.

Life skills. An elementary school teacher in France reported that he uses S'COOL to help teach his students about responsibility and being punctual. A high school teacher in Pennsylvania reports: "It's really a shot in the arm for us to have our kids eager to do anything. They go outside with instruments in hand, subtracting wet-bulb/dry-bulb readings to figure out humidity, and trying to read our ancient barometer, which has four scales on it. [. . . A learning disabled] science class is joining my . . . class when we go out. It's good for both sets of kids to see each other doing similar type of work. They take their "job" a little more seriously than most of my class; which serves as a motivational tool."

Scientific curiosity. While visiting a middle school in Paris, the first author watched students make relative humidity measurements following the simple directions on the S'COOL poster. The students were rather uninterested until they got to the last step and observed the change in temperature for the wet-bulb reading. This first-hand experience provided a teachable moment: why did this happen? During the snowy winter of 2000/01, a sixth-grade class in Illinois became curious about whether relative humidity affects the ability of snow to pack into snowballs. The began keeping records (Fig. 4) and tentatively concluded that it does.

LESSON FIVE: TWO-WAY STREET. *Outreach efforts are more valuable if they incorporate teacher feedback. Scientists know science; teachers know teaching.*

Table 2. 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

Table 3. Cloud layers from satellite vs ground observers.

		Ground observers		
		Clear	Single	Multi
S	Clear	14	9	0
A	Single	3	29	3
T	Multi	3	29	9

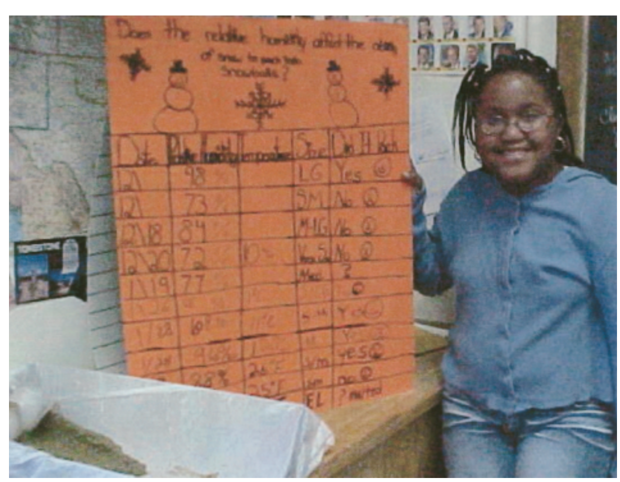

Fig. 4. Summary of the study by a sixth-grade class on the relation between relative humidity and the quality of snowballs.

The CERES S'COOL project started from a conversation between a teacher and a researcher. The idea was developed with continuous feedback from teachers. As a result, the project has been very successful in the classroom and has provided learning and motivation to increasing numbers of students. S'COOL is available to all interested teachers for participation at their convenience, when it best fits their curriculum and schedule. The S'COOL materials and data are available for use by all.

S'COOL participants are part of the CERES validation team. We expect that they will pick up some interesting trends once matching satellite data become plentiful. Whenever possible, CERES researchers and S'COOL personnel visit participating schools. A S'COOL "Wall of Fame" (Fig. 5) marks the location of each participating school. It is on display near CERES researchers' workplace, enabling them to make S'COOL visits a part of any trip they take. These visits are a very important element of S'COOL, allowing us to take the scientific message behind the project directly to the children, and to show them science's human face. As a Swiss elementary school teacher said, "Continue thus and persuade your colleagues to do the same. It is the truest way to 'germinate' vocations."

Since 1999 there has been a weeklong summer S'COOL workshop for teachers at NASA Langley Research Center. The week includes in-depth work with elements of the S'COOL Project, introduction to CERES science and scientists, and tours of interesting facilities around NASA. Said one participate, "I can never get enough of these guys explaining the science behind the experiments." This direct interaction between scientists and teachers, some of whom are experienced S'COOL teachers, never fails to result in ideas for new ways to help students learn. Lesson plans and other materials developed in these workshops are made available online for all participants.

A participant survey during fall 2000 had a 20% response rate (134 respondents, which is about half of the then-active participants), and provided objective data as well as room for comments. A large majority of teachers rated the educational impact of S'COOL highly (Fig. 6). Thirty-three teachers reported a total of 557 students showing increased interest in science as a career after being involved with S'COOL. The remainder of responding teachers said it was "too soon to tell." While this is a qualitative assessment, it is encouraging news for the S'COOL team.

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Fig. 5. The S'COOL "Wall of Fame" in the hallway near many CERES researchers' offices allows the team to consider school visits whenever travel is necessary.

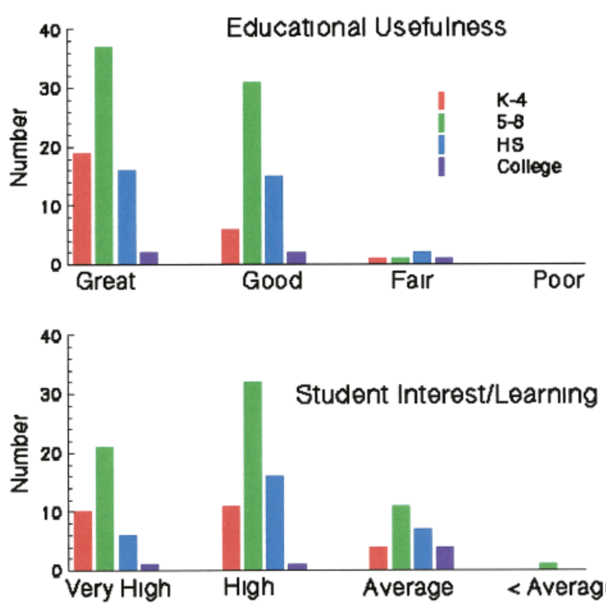

Fig. 6. Teacher Rating of Educational Usefulness of and Student Interest/Learning during the S'COOL Project, as recorded in a participant survey during fall 2000.

teacher; to Anne M. Racel and Susan J. Haberer of the ASDC, the first and second Web gurus of the S'COOL Project, without whom we could not reach so many schools in so many places; to Ian McGlynn, Gretchen Blauvelt, and Allan Armenta, student interns; to Christine York, teacher intern, who contributed to the S'COOL Project; to all the teacher graduates of our summer workshops, and to all S'COOL teachers around the world, without whom this project would remain only an idea.

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