3.8 THE CERES S'COOL PROJECT: TWO YEARS AFTER FIRST LAUNCH

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1. INTRODUCTION

The idea for the Students' Cloud Observations On-Line (S'COOL) project as an outreach and education element of NASA's Clouds and the Earth's Radiant Energy System (CERES) research program was conceived in late 1996 during a conversation with a middle school science teacher. S'COOL was implemented in a series of increasingly developed test phases during 1997, as the launch of the first CERES instrument approached. Even before launch, the reception of the project in schools far exceeded expectations. After several delays the first instrument, on the Tropical Rainfall Measuring Mission (TRMM) spacecraft, was launched on Thanksgiving Day, 1997.

Since the first launch, development and expansion of the project has continued with expectations for launch of Terra carrying two CERES instruments into a polar orbit in mid-1998. That launch is now expected in fall 1999, and will finally provide overflight of all participating schools. In two years, the project has grown from three initial test participants to over 300 schools now participating in 23 countries on five continents. Students from first grade through university level are involved (most participants are ages 10-15). S'COOL is also being used by a few education professors to teach about Internet use in the classroom. The project continues to grow through word of mouth, presentations at teacher workshops, and now increasingly through teachers who find it during web searches.

Participants in the S'COOL project are part of the CERES validation team. They provide ground truth measurements at the time the CERES instrument flies over their location, to be compared with the retrieval of cloud properties by remote sensing from CERES. Quantities reported include cloud type, height, fraction and opacity; information on contrails; surface temperature, pressure and relative humidity; and ground cover (snow/ice, wet, dry; leaves on trees or not). In addition, a comment field on the report form serves as a catch-all for all kinds of interesting observations, including similes written by some classes to describe more exactly the clouds they see.

Several not totally unexpected complications with the CERES instrument and processing software mean that the CERES team has not yet reached the point of computing the cloud properties, a high level product at the end of the processing stream. However, progress is being made and we anticipate that we will soon be populating the S'COOL database with a large number of satellite retrievals for comparison with the students' observations. Some satellite retrievals from the initial test phases are already available in the database.

The CERES instruments are planned to operate at least through 2006, and the S'COOL Project is planned to continue at least that long, providing motivational learning to as many students as possible.

This paper reports on the first several years of the S'COOL project. It further reports on some of the noteworthy observations and comparisons made possible by this project. Schools are often located in interesting places, in terms of the clouds found there and the satellite's ability to observe these clouds. The paper also reports on the learning opportunities delivered by this project, and on new questions about the planet and its climate which arise in the students' minds as a result of their active participation.

2. PROJECT DEVELOPMENT

The S'COOL Project was developed in a phased approach over the course of a calendar year. Periodic testing with schools provided important feedback to this development. Reports on the early phases are given in Chambers et al. (1998). Each phase encompassed an increasing number of participants and a wider geographic area. Phases 4 (global test) and 5 (TRMM satellite test) were held in October 1997 and February 1998, respectively, following local and national test phases. The first operational year is summarized in some detail in Chambers et al. (1999).

During the development phases, various existing satellites were used as stand-ins for the yet-unlaunched CERES instrument. This allowed teachers and students to practice making observations at specific overpass times. These satellites (NOAA and Meteosat weather satellites) allow us to retrieve information on cloud properties similar to that provided by CERES and its companion imager instruments, using essentially the same retrieval algorithms.

The TRMM satellite carrying the first CERES instrument, with its orbit inclined at 35 degrees, drifts in local time over a 46-day period. This means that at times it sees a given area only at night; and also that it can't see beyond about 40 degrees north or south latitude. For these reasons, participants are still given a choice of observing at the overpass times of either the TRMM or the NOAA-14 or -15 spacecraft. Upon launch

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of the Terra spacecraft into a 10:30 am local time sun-synchronous polar orbit in fall 1999, that spacecraft will replace the NOAA options.

3. PROJECT OPERATION

The operational phase of the S'COOL project began officially in April 1998 and will continue for a number of years. Teachers can participate at a time and for a duration which best fits their particular curriculum and the level and interest of their students. The S'COOL project will continue to be dynamic, with periodic additions of information to the website and continuing development of other materials.

There are six main elements of the Operational Configuration of the CERES S'COOL Project, described below. One key ground rule is that Internet access, while convenient, is not required.

3.1 *Registration*

Interested teachers can register to participate via e-mail, mail, fax, or telephone (contact information below). We request the teacher and school name, school address, grade level, postal and e-mail (if available) address, whether or not Internet access is available, and the location (city, state and country, as well as latitude and longitude, if known). We also like to know how a teacher heard about the project, to help us track the flow of information about S'COOL. Upon registration teachers are given a login ID (which serves to geolocate their observations) and sent a set of materials including a full-color classroom poster. There is no participation fee.

3.2 *Overpass Determination*

When ready to start observing, the teacher or a student will access the S'COOL website and fill in a form selecting a spacecraft and their local time zone, along with start and stop dates for the overpass schedule. Overpass times for their location are returned by e-mail. From the list, which will typically include one or more choices each day, a teacher can select an overpass that best fits the class schedule. Those without Internet access can request overpass times by mail, fax or phone.

3.3 *Observe and Record*

Both the S'COOL poster and the website offer a concise explanation and description of the things the students need to observe and record, as well as instructions and tips for doing so. All observations can be made with materials on-hand in the classroom, though a set of weather instruments is useful.

3.4 *Transmit Results to NASA*

The results can be reported to NASA via the Internet form, e-mail (a template should be used to facilitate automatic processing), mail or fax. They are then placed in a database, which is accessible via the Internet.

3.5 *Compare to Satellite Observations*

Once CERES is providing cloud data on a routine basis, results matching participating S'COOL locations will be collected and placed in an Internet database. Some weather satellite data from the development phases are currently available. The satellite and surface databases are queried over the Internet via a single interface. Entries matching in latitude/longitude and/or a time interval can be retrieved, and searches can be done on a few other items. The results are displayed on a web page, and can be downloaded in a spreadsheet format for further examination by the students. For those who don't have Internet access, results can also be obtained by written request. It is hoped that creative students will learn many interesting things from these comparisons, and that they may bring new knowledge and ideas to the CERES scientists. Validation of a global dataset is limited by the data and the people available to study it. The S'COOL project contributes both ground truth data and people to study them.

S'COOL data are also available to the CERES Science Team and the atmospheric science research community as a whole. At a minimum, scientists may find the clear sky observations from S'COOL very valuable in their validation efforts. Other uses of the data, such as estimating cloud base, are also possible. Recently additional questions about contrails were added to the report form at the request of a CERES researcher. Such observational data on contrails are not available currently from any other source.

3.5.1 *Examples*

A few of the S'COOL observations have already been scrutinized. Even this small sample has produced some very interesting comparisons:

Clear-Sky: a number of school visits have occurred on perfectly clear days. While at first glance this may seem disappointing to the students, it allows us to make a very important point: determination of totally clear sky is trivial from the ground, but not from space. A report from the students of completely clear sky is invaluable for CERES validation efforts.

Clouds over snow: participating schools in the Alps and the Jura mountains have illuminated this problem. Since snow can be both as cold and as bright as clouds it can mask the presence of thin cirrus, for example.

Sub-pixel Clouds: a participating location in Bunnell, FL has provided some examples of this problem. It is quite typical in this area to see the development through the day of cumulus clouds. These start very small and grow through the afternoon, often turning into thunderstorms. Early in their life cycle, these clouds are smaller than the imager pixel size (a few km) and very hard to detect from space - but not from the ground.

Multi-layer clouds: these have been observed at a number of locations. In such situations the ground and

satellite observations may differ; but both can be correct. This results from the fact that cloud layers cannot be detected through an opaque lower or higher layer. Detection of multi-layer cloud systems is stretching the state-of-the-art for satellite instruments. Ground observations of the lower layers can be very helpful in determining progress in this area.

3.5.2 *Statistics*

An objective comparison of the satellite and ground-based data now in the S'COOL database has been performed. Over 2200 ground observations have been recorded, but only a little over 100 satellite retrievals have been done so far. Matches occur only for a subset of the database due to a number of factors; mainly the ever-present confusion in converting the observation's local time to universal time (UT). This has been an issue since the beginning of the project. We think we have finally solved it by having students record both their local time and the UT of observation. In cases where the UT is not computed correctly, this gives us a chance to fix it. Unfortunately this does not help with early entries to the database for which satellite matches are so far available.

For those cases where observation times matched within 15 minutes, Table 1 shows a comparison of cloud amount measured by the satellite and the ground observers. Entries along the diagonal indicate agreement between the two observations. Entries off the diagonal indicate disagreement. The disagreement may be caused by a difference in field of view, or when opaque low or high level clouds impede the view of another cloud layer.

Table 1. Ground versus Satellite Cloud Fraction, matched within 15 minutes. 45 observations.

Ground Satellite	Clear	Partly Cloudy	Mostly Cloudy	Overcast
Clear	13	1	0	0
Partly Cloudy	4	6	0	1
Mostly Cloudy	2	0	9	2
Overcast	0	1	0	6

As summarized in Table 2 below, the ground and satellite observations are in agreement in more than 75% of the cases, and there are fewer cases the farther one gets from the diagonal (1-, 2-, and 3-class errors). This level of agreement is fairly consistent with what we see when matching observations from 2 different satellites with differing resolutions. Furthermore, close analysis of those cases showing disagreement has the potential to give us greater understanding of the causes for the discrepancy.

Table 2. Summary of Errors in Table 1

Agree	1 Class	2 Class	3 Class
34	7	4	0

3.6 *Reward and Evaluate*

Rewards have been developed for participating students: S'COOL Cloud Observer logos have been made in decal form. This decal is given only to students who have actually been involved in making cloud observations. A downloadable certificate of participation is also available on-line, for use at the discretion of each teacher.

Although the project is now in an operational phase, we continue to adjust and add to it. To this end, a teacher survey is available on-line to facilitate feedback on the project from participating teachers. Feedback via e-mail is also welcome at any time as teachers notice things needing improvement or explanation.

4. SPECIAL EVENTS

4.1 *NASA/CNES Demonstration*

In conjunction with the beginning of the operational phase in April 1998, the S'COOL project was put forward as a possible demonstration project for a NASA/CNES educational program. This cooperation was launched on May 13, 1998, with a trans-Atlantic demonstration featuring US First Lady Hillary Clinton in Paris, NASA Administrator Dan Goldin in Washington, DC, and a variety of other American and French dignitaries at these two sites and in Brooklyn, NY. The demonstration featured an Internet-based presentation of cloud observations carried out by students at each site, and a comparison with NOAA or Meteosat satellite data taken over the same area at the same time. Even this limited set of observations (3 sites on a single day) illustrated some key reasons why the S'COOL project was developed: multi-layer clouds, contrails, etc.

This event gave S'COOL access to additional resources and technology options, which continue to be used for the project. These include Internet-based presentations and a message board which allows more interaction among S'COOL participants. The event also enabled us to prepare and print a French-language version of the S'COOL poster, which is now available to participants in French-speaking areas. The poster was recently translated into Spanish as well, and will be available on-line later this year.

4.2 *School Visits*

Whenever possible, CERES researchers and S'COOL personnel visit participating schools. A S'COOL "Wall of Fame" marking the location of each school is on display in the hallway outside CERES researchers' offices, enabling them to make S'COOL visits a part of any trip they may take. These classroom visits are a very important element of S'COOL, allowing us to take the scientific message behind the project directly to the children. 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".

4.3 *Teacher Workshops*

Two teacher workshops have so far been organized solely on the topics of CERES and S'COOL. These workshops provide teachers with a more in-depth look at the science of CERES, while allowing them to practice cloud observation skills and to ask questions of researchers. So far, these have targeted teachers within commuting distance of NASA Langley. In summer 2000 we hope to hold the first workshop open to teachers from outside the area. In addition, S'COOL has become a regular feature of several NASA Educator Workshops, which are held each summer at the NASA Langley Research Center for teachers from around the country. It is now also being featured in teacher training by NASA Aerospace Education Specialists who conduct workshops in various locations throughout the year.

5. LEARNING OPPORTUNITIES

This section summarizes a few of the learning opportunities that the authors have observed while visiting classes or corresponding with teachers.

5.1 *Observation skills*

An elementary school teacher in Michigan has used this project 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. The project also provides students with a motivation to actually learn how to identify clouds.

5.2 *Math skills*

An elementary school teacher in Virginia reports that her students are so excited about this project that they want to perform some of the calculations of unit conversions themselves rather than relying on an Internet calculator page. Addition and division are routinely exercised in preparing a class consensus for the value of fractional cloud cover, temperature, etc.

5.3 *Writing/descriptive skills*

The same elementary school teacher in Virginia has her students writing similes and descriptions of what they see while outside making the cloud observations (i.e., "the clouds look like moldy bread"). These are reported with their observations in the comment section of the report form, and always result in close attention when their reports come in to NASA.

5.4 *Technology Skills*

An elementary school teacher in South Carolina, among others, reported that this project was a good way to begin introducing the Internet and computer technologies to her students.

5.5 *Life Skills*

An elementary school teacher in France reports that he uses this project to help teach his students about responsibility and being punctual. We rely on them to make the observations correctly and at the right time.

5.6 *Scientific curiosity*

Middle school students in Paris were observed making relative humidity measurements following the simple directions on the S'COOL poster. They 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 an entry for learning: why did this happen?

During visits to classrooms, all sorts of questions are raised: the ozone hole, El Niño, and global warming are typical, reflecting the students' awareness of current weather news; but also questions about tornadoes, the phases of the moon, the correlation between dew and rain, how satellites stay in orbit, and many other topics. These reflect young minds full of curiosity, and willing to ask questions about things they don't understand.

6. CONCLUDING REMARKS

The CERES S'COOL project started from an idea developed in a conversation between a teacher and a researcher. It was developed with continuous feedback from teachers. As a result, it has been very successful in the classroom and has provided learning and motivation to increasing numbers of students. S'COOL is now available to all interested teachers. Registration information should be sent to NASA Langley (see contact information below). Teachers can participate at their convenience, when it best fits into their curriculum

7. REFERENCES

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