CLOUDSAT TOTAL SKY IMAGING PROTOCOL

(Modified from 2003 GLOBE Teacher's Guide)

Purpose
Electronically record images of clouds

Overview
Students record images of the total sky with digital cameras after they observe and record which cloud and contrail types are visible and how much of the sky is covered by clouds.

Student Outcomes
Students learn the meteorological concepts of cloud heights, cloud types, and cloud cover and learn the ten basic cloud types and three contrail types.

Students improve their technological skills by learning how to use a digital camera with a tripod and how to submit photographs electronically as scientific data.

Science Concepts

Earth and Space Science

Weather can be described by qualitative observations.

Weather changes from day to day and over the seasons.

Weather varies on local, regional, and global spatial scales.

Clouds form by condensation of water vapor in the atmosphere.

Clouds affect weather and climate.

Different cloud types are often associated with different weather events.

The atmosphere has different properties at different altitudes.

Water vapor is added to the atmosphere by evaporation from Earth's surface and transpiration from plants.

The Sun is a major source of energy for Earth surface processes.

Solar isolation drives atmospheric and ocean circulation.

Physical Science

Materials exist in different states – solid, liquid, and gas.

Heat transfer occurs by radiation, conduction, and convection.

Heat moves from warmer to colder objects.

Geography

The nature and extent of cloud cover affects the characteristics of the physical geographic system.

The nature and extent of precipitation affects the characteristics of Earth's physical geographic system.

Scientific Inquiry Abilities

Use appropriate tools and techniques.

Identify answerable questions.

Design and conduct scientific investigations.

Develop descriptions and predictions using evidence.

Recognize and analyze alternative explanations.

Communicate procedures, descriptions and predictions.

Time
10 minutes

Level
All

Frequency
At the time of the NASA CloudSat satellite overpass approximately 2 to 6 times a month depending on latitude.

Materials and Tools
CloudSat Education Network Data Sheet

- Digital camera
- Tripod
- Convex unbreakable mirror (24 or 30 cm diameter) with ‘N’ (for north) label
- Compass
- Sunglasses (or other means of protecting the eyes)

Preparation

Confirm that camera batteries are fully charged.
Confirm that memory card is installed properly in camera.
Set photograph image size to 1600x1200 (or best size for submitting by e-mail)

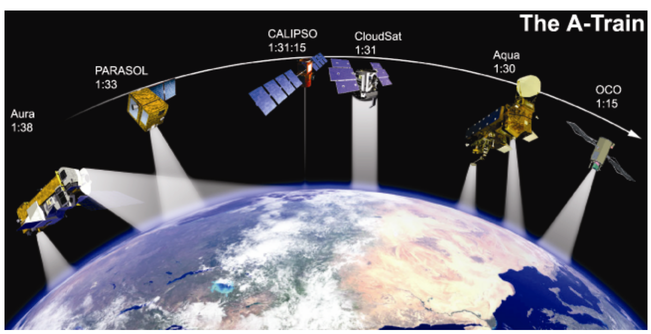
Prerequisites

GLOBE Cloud Protocols
GLOBE Precipitation Protocols modified for CloudSat
GLOBE Maximum, Minimum and Current Temperature Protocol
OR
GLOBE Digital Multi-Day Max/Min/Current Air and Soil Temperature Protocol
CloudSat Cloud Quadrant Protocol

CloudSat Total Sky Imaging Protocol

INTRODUCTION TO THE NASA CLOUDSAT SATELLITE MISSION

GLOBE students around the world have the opportunity to assist NASA scientists with their research on Earth’s atmosphere by participating in the CloudSat satellite mission. CloudSat is an experimental satellite that uses a unique 94 GHz radar to study clouds and precipitation from space. CloudSat flies in formation as part of the A-Train constellation of polar-orbiting satellites (Aqua, CloudSat, CALIPSO, PARASOL, and Aura) (Figure 1).



NASA Goddard

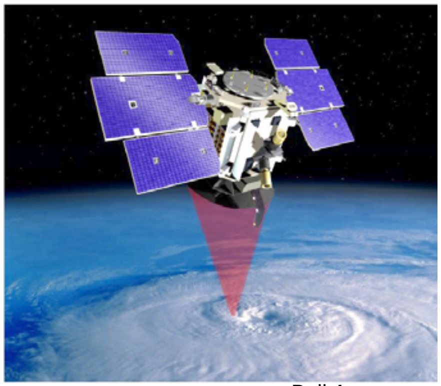
Figure 1. The “A-Train” consists of five satellites flying in formation for the purpose of studying Earth’s atmosphere. (A sixth satellite, OCO, is scheduled to join the A-Train in the near future.)

THE A-TRAIN

For the first time, NASA will fly six satellites in a tight formation like the cars on a train. Officially known as the Afternoon Constellation, the formation was nicknamed the ‘A-Train’ after the famous jazz tune. The mission of the A-train is to study Earth’s energy balance and water cycle in order to better understand climate change among many other advances. The A-Train satellites travel around the poles (“polar-orbiting”) at an altitude of 705 kilometers above Earth’s surface in a sun-synchronous orbit. NASA fact sheet FS-2003-1-053-GSFC titled “Formation Flying: The Afternoon “A-Train” Satellite Constellation” contains descriptions of the six satellites (http://cloudsat.atmos.colostate.edu/education/cloudsat_resources).

NASA CLOUDSAT SATELLITE MISSION

As its name implies, CloudSat will collect data on clouds with an instrument known as a Cloud Profiling Radar (CPR). Clouds are one of the least understood elements of climate and the water cycle. Yet without an understanding of clouds, weather forecasting and climate modeling become nearly impossible. For millennia, humans have studied clouds from the ground. Over the last century, it has become possible to study clouds from above. Until now though, there was no good way to study the insides of clouds. CloudSat will use a special type of active microwave radar (94 GHz) to provide a global survey of cloud properties to aid in improving cloud models and the accuracy of weather forecasts, with a long-term goal of improving global climate models (Figure 2).



Ball Aerospace

Figure 2. NASA CloudSat satellite.

This cloud-profiling radar will provide vertical distribution of cloud physical properties such as liquid water and ice contents and other information. The CloudSat mission is a cooperative international effort that includes Colorado State University, Jet Propulsion Laboratory, Canadian Space Agency, Ball Aerospace, the United States Air Force, U.S. Department of Energy, Goddard Space Flight Center and scientists from France, United Kingdom, Germany, Japan, Australia and Canada. For additional information visit the CloudSat website at http://cloudsat.atmos.colostate.edu.

CLOUDSAT EDUCATION NETWORK

The CloudSat Education Network (CEN) consists of approximately 100 GLOBE schools and other educational organizations that work with CloudSat scientists by providing data from Earth's surface to compare to the satellite's radar data. Schools from around the world communicate with scientists, conduct research with satellite data, learn about other cultures and make genuine scientific contributions to the CloudSat satellite mission. The base level of participation in the CEN consists of reporting of cloud cover, cloud type, current temperature and precipitation data coinciding with the dates and times of CloudSat satellite overpasses. These observations are made following the corresponding GLOBE Program protocol and additional CloudSat protocol instructions. The advanced level of participation consists of the submission of digital photographs of the sky according to the *CloudSat Total Sky Imaging Protocol*.

The Network uses proven science and education programs to partner scientists, teachers, students and the communities where they live to give students meaningful, authentic and contemporary educational experiences. The main focus of the knowledge development component of the project is to help students better understand cloud formation and cloud associations with weather events, long-term climate change and the climatic processes that maintain Earth's energy balance.

Participation in the CloudSat Education Network can give teachers the tools to provide students with the opportunity to:

- Develop basic numeracy skills by gathering and processing environmental information that can be used by CloudSat scientists and students for research on the atmosphere.
- Stimulate their interests in science by observing the nature.
- Develop practical science skills by measuring, recording and analyzing local environmental measurements.
- Communicate with and learn from other students around the world using appropriate information and communications technologies.
- Interface with the CloudSat Education Network website which offers student friendly materials and ideas to support the educational goals of member schools.
- Interact with, ask questions of, and offer ideas to the CloudSat Science Team.

CLOUDSAT TOTAL SKY IMAGING PROTOCOL

As every teacher and student knows, clouds can be difficult to identify. The *CloudSat Total Sky Imaging Protocol* helps students improve their cloud identification skills and at the same time provides CloudSat scientists with valuable additional information on cloud types present during the satellite overpass. Students also improve their technological skills by learning how to use a digital camera with a tripod and how to submit photographs electronically as scientific data.

For a good introduction to clouds, their relation to weather and why it is important to know more about Earth's atmosphere study the *Cloud Protocols* section of the 2003 GLOBE Teacher's Guide (http://www.globe.gov/tctg/clouds.pdf?sectionId=8&rg=n&lang=en).

TOTAL SKY IMAGERS

The protocol is designed to model the operation of a professional scientific instrument called a Total Sky Imager or TSI. Below is a photograph of a Total Sky Imager used by the Atmospheric Radiation Measurement (ARM) Program around the world (Figure 3). For more information on this instrument and how it is used by the ARM Program visit the ARM website at: http://www.arm.gov/instruments/instrument.php?id=tsi. Students can view a user's manual (TSI Handbook) and learn about locations around the world where these instruments are currently collecting data. One of these locations is Darwin, Australia. Darwin is also the location of one of the field tracking stations that monitors CloudSat's orbits. For more information on the TSI at Darwin (and for some fun Aussie trivia) visit http://www.arm.gov/sites/twp/darwin.stm.

http://www.arm.gov/

Figure 3. Atmospheric Radiation Measurement (ARM) Total Sky Imager.

For another student example of studying the sky through the use of convex mirrors go to: http://mynasadata.larc.nasa.gov/P5.html.

CLOUDSAT TOTAL SKY IMAGING PROTOCOL - OVERVIEW

The purpose of the *CloudSat Total Sky Imaging Protocol* is to obtain data on clouds present in the sky at the time of a CloudSat satellite overpass. Students record cloud and atmospheric observations and take a digital photograph of the sky as reflected in a convex mirror placed on the ground. These unique digital images will provide researchers with an overhead view of the clouds. Additionally, students take photographs of the sky in the four cardinal directions – north, east, south, and west. These photographs are taken as the students make observations according to the CloudSat Cloud Quadrant Protocol (instructions available on the CloudSat website after logging in at http://cloudsat.atmos.colostate.edu/cen/login.html). The five photographs together provide a complete record of clouds during the satellite overpass. Student and scientific researchers can compare this record to CloudSat's radar data recorded at the same date, time, and location.

CLOUDSAT TOTAL SKY IMAGING PROTOCOL – TEACHER SUPPORT

Before starting to collect data for the *CloudSat Total Sky Imaging Protocol*, students should be familiar with the GLOBE *cloud type*, *cloud cover*, *precipitation* and *current temperature* protocols (http://www.globe.gov/tctg/tgchapter.jsp?sectionId=1), as well as the *CloudSat Cloud Quadrant Protocol* and data entry procedures located on the CloudSat website after logging in (http://cloudsat.atmos.colostate.edu/education). Access to these CEN web pages requires the school's GLOBE ID and special CloudSat CEN password.

EQUIPMENT

Equipment requirements for the *Total Sky Imaging Protocol* include a digital camera, a tripod and a convex mirror (Figure 4). For safety and durability reasons, the mirror should be composed of material that does not break easily such as plastic or metal. Either write or glue on the letter 'N' to one side of the mirror (for 'north). The mirror should be at least 24cm in diameter but not more than 30cm in diameter. Students should consider wearing sunglasses to protect their eyes from sun glare on the mirror. If the four cardinal directions have not already been determined for previous protocols then a compass will also be needed.

D. Krumm

Figure 4. Digital photograph of overhead clouds as viewed in a convex mirror.

PREPARATION

Familiarize students with the use of the digital camera including the use of the zoom lens and timer features using the camera's instruction manual. Before going outside to make observations, a student or teacher should check the charge level of the camera battery and confirm that the memory card is in the camera. Also confirm that the camera image size is set to the 1600x1200 setting. [NOTE: if you have trouble submitting the photographs over the internet because of their large size, refer to the camera instructions on how to select a smaller image size.]

PROCEDURE [Refer also to ***CloudSat Total Sky Imaging Protocol Field Guide.***]
Determine the date and time of the CloudSat overpass for your location by either 1) going to the CloudSat Education web pages (http://cloudsat.atmos.colostate.edu/cen/login.html), logging on with your school's GLOBE ID and CloudSat password, and running the automatic overpass predictor, or 2) accessing the NASA Langley CloudSat Orbital Prediction Tool from the CloudSat home page (http://www-angler.larc.nasa.gov/cgi-bin/predict/cloudsat.cgi) and entering your location's latitude and longitude to determine the overpass dates. During the overpass date and time, students should first make the standard CloudSat observations of cloud type, cloud cover, precipitation (rain and/or snow) and current temperature, following GLOBE and CloudSat protocols, before taking the *CloudSat Total Sky Imaging* photographs.

Use the compass to determine the four cardinal directions for collecting data for the *CloudSat Cloud Quadrant Protocol*. As students make observations on cloud type and cloud cover for each fourth of the sky, they also take a photograph of the clouds in their quadrant. (Caution: **NEVER** allow students to look directly at the sun. If the sun is too bright in a quadrant, do not take the photograph.) It is extremely important to **record the order** in which the photographs were taken (for example – "We took the first photograph facing north, the second facing east…") in the ***Comments*** section of the *CloudSat Education Network Data Sheet* (available on the CloudSat website after logging in with your school's GLOBE ID and special CloudSat CEN password). Students should record anything else that will help distinguish the photographs from one another after returning to the classroom. The photographs MUST be labeled correctly for the students and the CloudSat scientists to be able to compare them to CloudSat satellite radar data.

Place the convex mirror on the ground or on a flat surface close to the ground. Use the compass again to determine which way is north. Indicate which direction is north by writing or gluing the letter 'N' on the mirror. [NOTE: It is extremely important to return to the same place each time observations are made. If it becomes necessary to move to a different place, notify CloudSat at cloudsatoutreach@atmos.colostate.edu.] Position the tripod at the north point of the mirror and attach the digital camera. The cameras are equipped with a zoom feature so the height of the tripod is not critical. Raise it to a height that is comfortable for the students. To protect your eyes from sun glare, use sunglasses as a precaution or have other students stand with their backs toward the sun, blocking the reflection of the sun on the mirror. The student should tilt the camera down until he/she has a good view of the whole mirror including the 'N' for 'north'. Use the zoom feature on the camera to fill the camera's field of view with the image of the mirror. Try setting the timer and having the student step away so as not to be included in the photograph (not required). More sky will be visible in the mirror without the photographer's reflection. While only one image is required for submission to CloudSat, you may want to have different students take photographs of the mirror with its overhead view of clouds. Taking several photographs in the field will improve the chances for at least one high-quality image. When you are finished with this activity, place the mirror back into its plastic bag to prevent scratching and store it in a safe place. Leaving the mirror exposed to changing weather conditions may result in loss or damage to the mirror.

In the classroom, choose the best photograph of the reflection of the sky. Have the students label the five photographs that they will send to CloudSat. To do this, either refer to the camera's instruction manual or download the photographs to a computer. Right-click on the photograph number assigned by the camera underneath the image, select ‘Rename’, and type in the following information. Include their school’s GLOBE ID, the date (ddmmmyy) and the letter representing the direction of the photograph or “M” for the mirror image (i.e. “N” = North, “S” = South, “E” = East, “W” = West, and “M” = image from the mirror). For example, a photograph taken to the north by a fictional Colorado school on December 10, 2006, would have this label: USCOXYZ7_10Dec06N.

Photographs may submitted on-line on the CloudSat data entry page (best option) or e-mailed to cloudsatoutreach@atmos.colostate.edu. For on-line submissions, log in and go to the bottom of the data entry page where there are five input boxes (one for each photo). Use the 'Browse' buttons located next to each input field to locate the photograph files on your hard drive. When you click on 'submit', the files are uploaded, automatically renamed and resized, and stored on the server in each school's folder. If e-mailing is preferable, have the subject of the e-mail message be “CloudSat Cloud Photos” and include the following information in the body of the e-mail message to ensure that CloudSat is able to match the photographs to your school: GLOBE ID, school name, atmospheric site (for example, ATM-01 or the site’s name such as “Playground”), date and time (UT) and any additional information that you want CloudSat scientists to know.

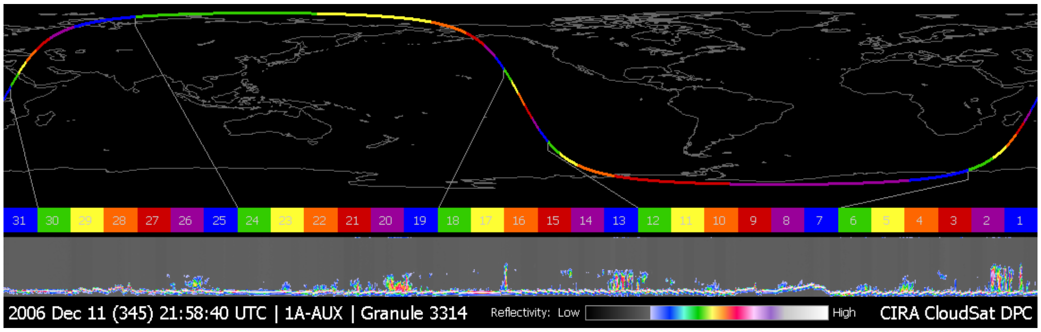
LOOKING AT THE DATA

Just like the CloudSat scientists, students can compare their data to data from the Cloud Profiling Radar (CPR) on board the satellite. Students use the CloudSat Quicklook tool to find graphs of cloud radar data from specific dates, times and locations.

CloudSat uses the CPR to measure signals scattered backed by cloud particles at 94 GHz frequency. The signals are then calibrated and saved as water equivalent radar reflectivity. The satellite orbits Earth approximately once every 1 1/2 hours. During its orbit, it passes over ground stations belonging to the United States Air Force Satellite Control Network (AFSCN) where the data are downloaded on each overpass. The data are then sent to Albuquerque, New Mexico, USA, where data quality checks are performed. After the quality checks are performed, the data are transmitted via the internet to the NASA CloudSat Data Processing Center (DPC) at Colorado State University in Fort Collins, Colorado, USA, where they are sent through the data processing system to create a number of data products such as cloud type, cloud optical thickness, liquid water content of the cloud and others. For more information on the DPC including a diagram of the pathway that the data take, visit http://www.cloudsat.cira.colostate.edu/aboutInfo.php.

After processing, the data are made available on the CloudSat website. Students can use the CloudSat Quicklook tool to access the data. To access Quicklook, go to the CloudSat website: http://cloudsat.atmos.colostate.edu/. In the menu on the right side, select “Quicklook Images (DPC)” (http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php).

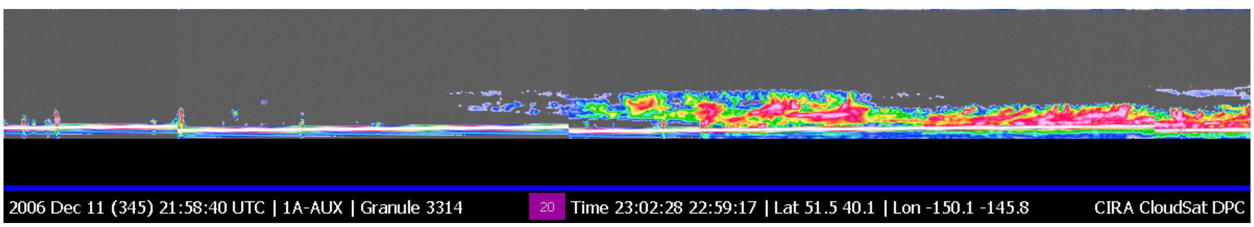
Next, select a date and time from the table labeled ‘Granule Quicklooks’ by looking in the “Starting Date (UTC)” column. (Notice that you must go over to the “Granule” column for the actual link.) Once you click, you will see a map of the world with a bright multi-colored band running across it (as an example, see Figure 5). This was CloudSat’s orbit on the date and time that you chose. Below the map, you will see a graph of CloudSat’s radar data. Below the bright colors from the radar, you will see that the surface appears uneven. This corresponds to the actual topography (highs and lows) of Earth’s surface.



CIRA CloudSat DPC

Figure 5. Graph of the radar data from one orbit of CloudSat on 11 December, 2006.

Quicklook allows you to zoom in and view the data from segments of the orbit track. To do this, click on any of the numbered colored boxes below the map that corresponds to matching colored segments on the orbit track. This gives you an enlargement of the graph of radar data. Each enlarged graph of radar data represents a distance of approximately 1200 km along the x-axis (surface of Earth) and a height of 30 km on the y-axis. The y-axis for the topographic window extends just beyond the height of Mount Everest (8850 m). This expanded view gives you an additional x-axis below the graph of the radar that shows topographic differences on land's surface in brown. Water is represented in blue (but is assumed to be sea level at all locations).



CIRA CloudSat DPC

Figure 6. Graph of the radar data for Box 20 from CloudSat's 11 December, 2006, orbit.

[NOTE**:** CloudSat data will always follow the direction of the orbit so that the scan that Quicklook images are created from moves from right to left in time.]

For more information, please go to these valuable links at the bottom of the Quicklook page: ***Quicklook Image Features*** and ***Quicklook Images FAQ – Frequently Asked Questions*** (http://www.cloudsat.cira.colostate.edu/images/QuicklookFAQ.pdf).

Have your students compare their photographs to the satellite radar data for the date and time of the CloudSat overpass. Before viewing the data, ask your students to list questions that they will try to answer using the photographs and the CPR data.

EXAMPLES OF QUESTIONS:
Did we see clouds that the CPR missed?
Did the CPR detect clouds that we could not see with our eyes?
If so, what types of clouds might these have been?
Was the CPR able to detect rain or snow that we reported?
Around the world, where were the most clouds on our overpass date?
Can we see a correlation between topographic features and the locations of the clouds?