CLOUDSAT: STATUS AND PROSPECTS

Steven J. Walter
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

ABSTRACT

CloudSat is a proposed space mission to measure the vertical structure of clouds. Current spaceborne observational systems only characterize the uppermost cloud layer. CloudSat will profile cloud properties with a 94 GHz radar, microwave radiometer, and spectral imager. Measurements of cloud structure provide a unique vantage point from which to investigate climate feedback mechanisms linking clouds, radiation, and atmospheric circulation. CloudSat will fill a critical gap in cloud measurement systems needed to validate the new generation of general circulation models (GCMs). This mission is being proposed in response to the NASA Earth System Science Pathfinder (ESSP) Announcement of Opportunity (A.O.) to be released in April 1998.

INTRODUCTION

CloudSat is being developed to profile cloud properties. The capability to sense the vertical structure of clouds will fill an important gap in existing observational systems. Current space surveillance systems routinely image clouds using visible, infrared and microwave sensors as shown in Figures 1 and 2. Although cloud images are standard weather forecasting and climate research data products, they provide an incomplete characterization of clouds. Optical imaging and spectroscopy are limited in their ability to retrieve bulk cloud properties for optically thick and multi-layer clouds. Passive microwave techniques are unable to retrieve cloud liquid content over land, nor are they sensitive to ice clouds.

Figure 1. *The NOAA GOES spacecraft maps daytime cloud cover with a visible imager.*

Figure 2. *The corresponding thermal IR GOES image is sensitive to cloud temperature and provides imaging capability during the night.*

CloudSat is designed to profile both ice and liquid clouds over a wide range of conditions.

MISSION OBJECTIVES

CloudSat is being proposed to elucidate feedbacks relating radiation, climate, and clouds. One of the mission goals is to generate a database of cloud measurements for process studies to identify and quantify fundamental climatic processes connecting the Earth energy balance to its hydrological cycle. The ultimate goal is improve the long-term predictive accuracy of climate models. CloudSat will also demonstrate key technologies for operational space-based cloud profiling and will facilitate assessment of the use of cloud profiles for weather forecasting.

Understanding and resolving climate feedback mechanisms is an important objective for the NASA Earth Science Enterprise. However, planned EOS, GOES, and NPOESS payloads are limited in their ability to detect radiatively important characteristics of optically thick and multi-layer clouds. It is this observational gap that CloudSat intends to fill. CloudSat will permit investigations into climatic processes by:

- Documenting the vertical distribution of clouds.
- Measuring the ice and liquid content of clouds.
- Determining optical depth.
- Making measurements concurrently with EOS to validate EOS cloud products.
- Providing a database to help assess the performance of climate models.

MISSION PAYLOAD

The mission payload includes a cloud profiling radar, spectral imagers and a microwave radiometer as is illustrated in Figure 3.

Cloud Profiling Radar

The CloudSat radar will profile clouds. It is a 94-GHz radar with 1.5 kW peak power. The choice of radar frequencies is a trade-off between sensitivity, technological limitations, and atmospheric attenuation. Radar backscatter from hydrometeors (ice crystals, cloud droplets, and precipitation) increases dramatically with increasing frequency. The sensitivity to cloud particles needs to be balanced against atmospheric transmittance and the performance of radar technology which both degrade at higher frequencies. A small percentage of the time, the 94-GHz radar will not be able to penetrate the cloud base. This will occur when very thick clouds or heavy precipitation are present. The mission objective dictates this choice. To derive radiative heating, it is more important to have the sensitivity to detect thin clouds at high altitudes than it is to determine cloud base for heavy cloud decks.

Spectral Imagers

A visible imager provides the context for CloudSat measurements. It will allow researchers to associate cloud profiles with mesoscale weather patterns. For example, it will be able to identify when a cloud profile is associated with a tropical storm, a cumulus column, or a uniform cloud deck. The data from the imager will be highly compressed to reduce its data requirements. The payload will also include a thermal imager to provide nighttime images and determine cloud temperature. High-resolution spectral measurements are being considered to improve retrieval of optical depth, photon path length, and various characteristics of the scattering particle.

Microwave Radiometer

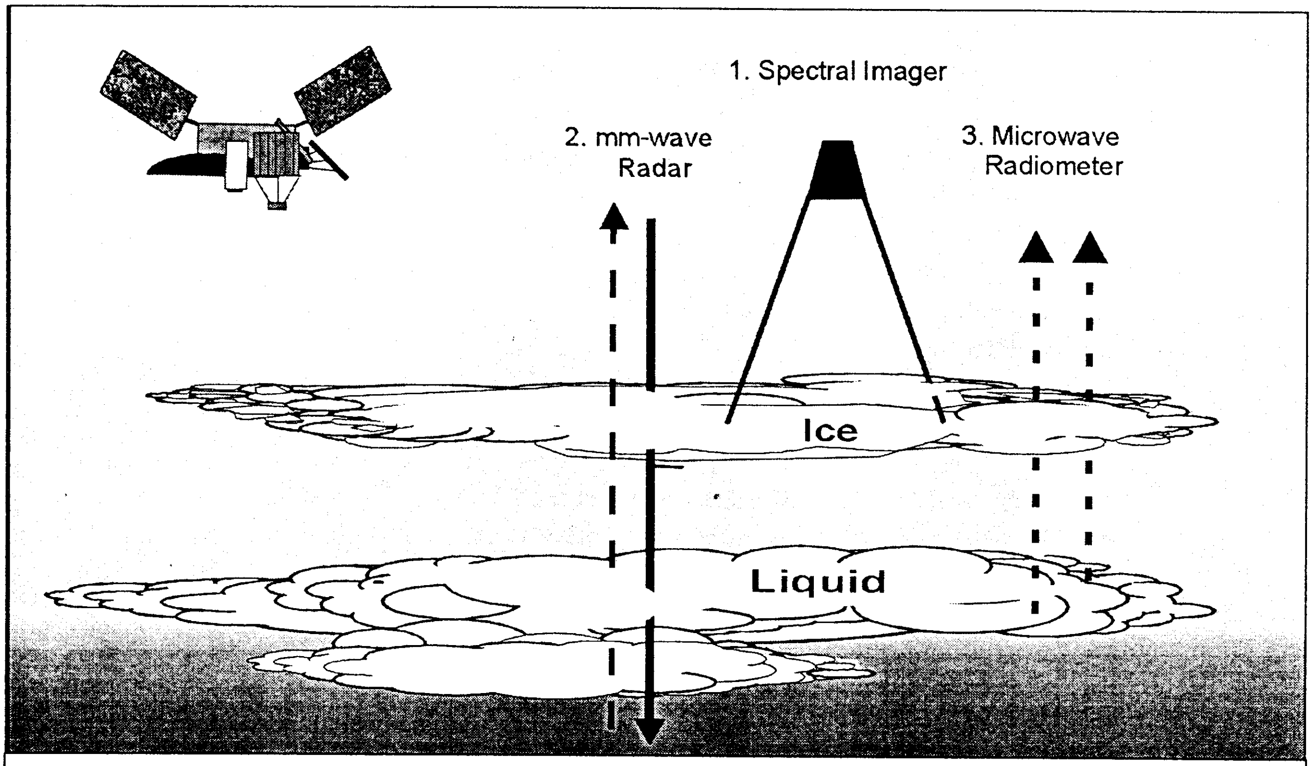

Figure 3. *CloudSat profiles cloud properties with a millimeter-wave radar, visible and infrared spectral imagers, and a microwave radiometer.*

Microwave radiometric measurement of clouds can be used to determine both cloud ice content and liquid content. Measurements at centimeter-wavelengths can be used to retrieve integrated cloud liquid over the oceans. Measurements at millimeter and submillimeter-wavelengths are able to constrain cloud ice content. The CloudSat radiometer will possibly include centimeter, millimeter, and submillimeter-wavelength channels.

NASA's ESSP PROGRAM

Two years ago NASA created the Earth Science Systems Pathfinder (ESSP) program. It was inaugurated to fund development of "better, cheaper, faster" earth observation missions. The program goal is to stimulate yearly launches of low-cost, rapidly developed spacecraft. NASA earth science priorities for ESSP are spaceborne measurements that improve the understanding of seasonal-to interannual climate variability, long-term climate variability and change, atmospheric ozone, land cover and land use change, and natural hazards. Preference is given to proposals that complement, not duplicate, existing flight programs such as the Earth Observing System, EOS. Principal investigators (PI) develop mission concepts and propose them during a competition held every two years. The proposals are judged on their scientific merit, technical readiness, management plan, and cost. Each competition selects two missions for development. Once funding begins, the PI has three years to construct and launch a spacecraft.

The first ESSP competition in 1996 capped NASA costs at $ 60 M for the first ESSP mission and $ 90 M for the second mission. These cost are inclusive and must cover the payload, spacecraft, launch vehicle, operations, science team, data processing, and validation. The 1998 ESSP competition begins in April 1998 and is capped at $ 90 M for the third ESSP mission and $ 120 M for the fourth mission. These cost limitations effectively restrict mission lifetimes to one to three years. These cost limitations apply only to NASA funds; additional support can be provided by both other government agencies such as the U.S. Department of Commerce and other nations.

CloudSat will be proposed to the 1998 ESSP competition. The NASA Announcement of Opportunity (A.O.) will be released next month, April 1998. The first step of the proposal process is a fifteen-page proposal that addresses the physics of the proposed measurement and the technical maturity of the instrumentation. This proposal is due in May 1998. In June, ten to fifteen proposals will be selected for further development. A complete proposal will then be requested detailing science, technical implementation, management, and costs. This proposal is due in September 1998. The winning missions will be announced in December 1998.

CONCLUSIONS

CloudSat is being developed to measure the vertical structure of clouds from space. It integrates a cloud profiling radar with spectral imagers and a microwave radiometer. This payload is designed to profile clouds, image the regional cloud field, retrieve cloud ice and liquid content, and assist in validating measurements made by the NASA Earth Observing System (EOS). CloudSat will also furnish an important technology demonstration for future scientific, civilian, and tactical forecast systems.

The CloudSat concept was originally proposed to the 1996 NASA ESSP mission opportunity. It was ranked very highly, but was not selected due to the ESSP program cost cap. We plan to propose this mission concept to the 1998 ESSP Announcement of Opportunity.

ACKNOWLEDGMENTS

This research was partially carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with National Aeronautics and Space Administration.