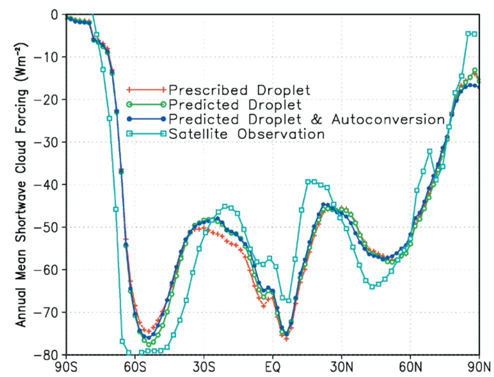
ARM Research Highlights

A "Little" Respect: Droplet Nucleation Finally Included in Global Climate Model

Aerosol particles interact directly and indirectly with the earth's radiation budget and climate. As a direct effect, aerosols scatter sunlight directly back into space. As an indirect effect, aerosols can influence the creation (or nucleation) of cloud droplets, leading to increased droplet surface area. This changes how the clouds reflect and absorb sunlight. Until recently, the treatment of droplet nucleation has been ignored by one of the most widely used computer models for simulating climate change. Without such a treatment, effects from aerosols on droplet number and hence, climate, cannot be determined.

Researchers funded by the Atmospheric Radiation Measurement (ARM) Program developed a treatment of droplet nucleation and applied it to the Community Atmosphere Model (CAM) from the National Center for Atmospheric Research. Findings from previous research in this area led to the current effort to fine tune the associated droplet nucleation parameters within CAM. Thus, CAM can now use the predicted droplet number to treat indirect effects of aerosols, an important climate forcing mechanism that has been neglected in all previous climate simulations by CAM.



Reflection of sunlight by clouds simulated with predicted droplet number agrees remarkably well with the reflection simulated with prescribed droplet number (red). Two calculations, with and without autoconversion feedback, are shown. Satellite observations (light blue) are shown for comparison.

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June 2005

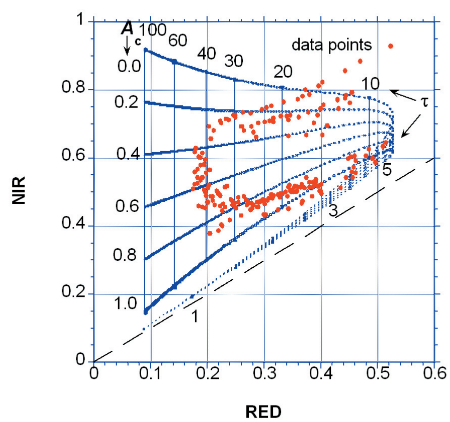
New Technique Successful for Measuring Thickness of Broken Clouds

Cloud optical depth (or thickness) is a fundamental property for calculating the amount of solar radiation entering and leaving the earth's atmosphere. Unfortunately, techniques used to measure this property work well for cloudy skies, but not for broken-cloud skies.

ARM Program researchers at NASA's Goddard Space Flight Center found that a spectral ratio approach used to calculate vegetation surface area could be modified for use in determining cloud optical depth.

The researchers measured the downwelling solar radiance in two narrow spectral bands in the near infrared (NIR, 0.87 um) and red (0.67 um) spectral regions. They then used these two radiances to construct a "normalized difference cloud index" (NDCI). To improve the solution of the NDCI equation for cloud optical depth, the researchers developed a "lookup table" approach by creating a graph using the normalized red and NIR wavelengths as the axes.

To test their approach, the researchers used radiance simulations and comparisons to satellite, aircraft, and surface data from the ARM Program's Southern Great Plains site. They found that in simulations where the true optical depth was known, 75% of the retrieved optical depths (out of about 10,000 pixels with a 25 m resolution) had absolute errors smaller than 3; averaging over 200 m substantially improved the retrieval.



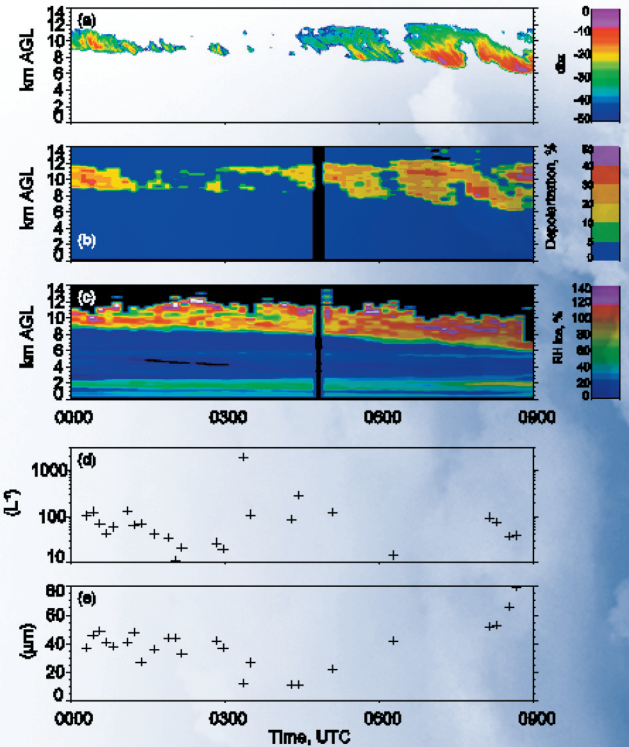
In the "lookup table," vertical lines within the curves show calculated values of cloud optical depth. Observed data points show actual red and NIR values; the cloud cover and optical depth are read from the overlaid lines.

Continuous Dataset of Water Vapor Measurements Throws Water on Assumptions of Cirrus Cloud Formation

To study the link between water vapor, cirrus cloud formation mechanisms, and their potential climatic impacts, researchers sponsored by the ARM Program analyzed a 1-year dataset of water vapor measurements obtained by a Raman lidar at ARM's Southern Great Plains site in Oklahoma. As reported in *Geophysical Research Letters* in June 2004, the long-term continuous dataset allowed the researchers to provide the first analysis of reliable upper tropospheric water vapor profiles measured from a single location.

Their study showed that ice supersaturation occurred about 31% of the time in cirrus clouds, confirming assumptions regarding the frequency of homogeneous (non-aerosol related) cirrus formation. However, they also found that ice supersaturation often occurred at temperatures warmer than -40C, when heterogeneous (aerosol-related) cirrus formation typically occurs. This type of ice formation results in smaller ice particles, thereby increasing the resulting reflectivity of the cloud. This implies that heterogeneous formation may play a larger role in the impact of cirrus clouds on the earth's radiative energy budget than previously thought.

These findings, and the dataset used to reach them, represent an important link between the measurement and modeling communities as they continue to improve scientific understanding of the effect of cirrus clouds on the earth's global climate.



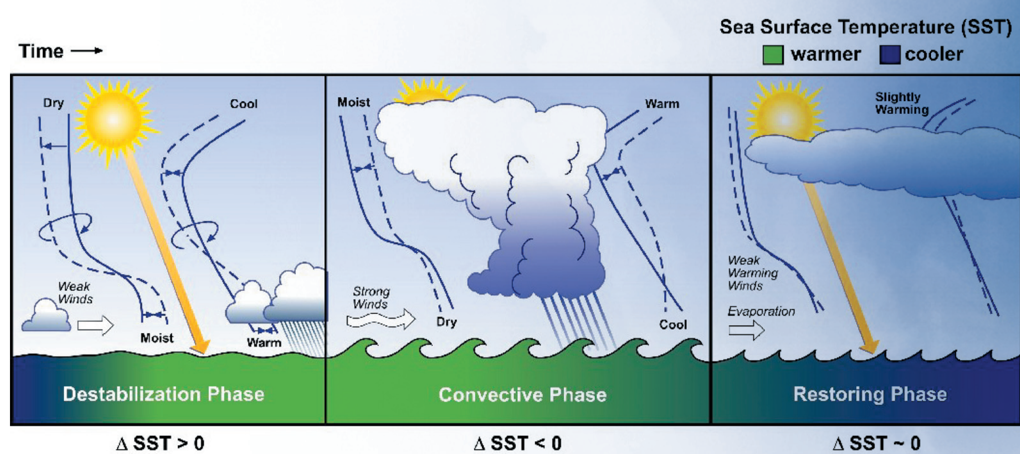
Height vs. time display of 35 GHz radar reflectivity (a), lidar depolarization radio (b), and relative humidity with respect to ice (c) derived from ARM measurements on 15 November 2000 at the Southern Great Plains site. Also shown are time series of mean layer number concentration (d) and effective radius (e).

Self-Regulation Strikes a Balance Between Hydrological Cycle, Radiation Processes, and Intraseasonal Dynamic Variations

A major obstacle in simulating climate variability and climate change is the lack of scientific understanding of cloud related feedbacks. In one way or another, clouds play a role in the processes that affect the hydrological cycle and all relevant feedback mechanisms that alter its response to external climate forcing. As described in the *Journal of Climate* in June 2004, research supported by the ARM Program suggests that for tropical regions, interactions between the ocean, moist atmospheric thermodynamics, and radiation establish a phased, self-regulating feedback mechanism.

The researchers demonstrate a mutually regulating feedback mechanism - termed a "humidistat" - that evolves in three phases: destabilization, convection, and restoring. They analyzed changes in atmospheric structure during several Madden-Julian oscillations and over longer periods to demonstrate their hypothesis.

According to the humidistat hypothesis, radiative cooling in the tropical atmosphere is largely balanced by latent heating associated with precipitation. A global observing system designed to measure not only precipitation, but also the related hydrological parameters, such as vertical distributions of clouds and the water and ice contents of these clouds, should reduce model-to-model uncertainties and increase scientific understanding of the parameters that alter the radiation balance of the atmosphere.



The "humidistat" feedback mechanism suggests that the hydrological cycle and sea surface temperatures mutually regulate each other in phases: the destabilization phase, the convective phase, and the restoring phase. These phases connect clouds and precipitation, radiative transfer, surface flux exchanges, and sea surface temperatures.

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