The Impact of Explicit Cloud Boundary Information on Ice Cloud Microphysical Property Retrievals from Infrared Radiances

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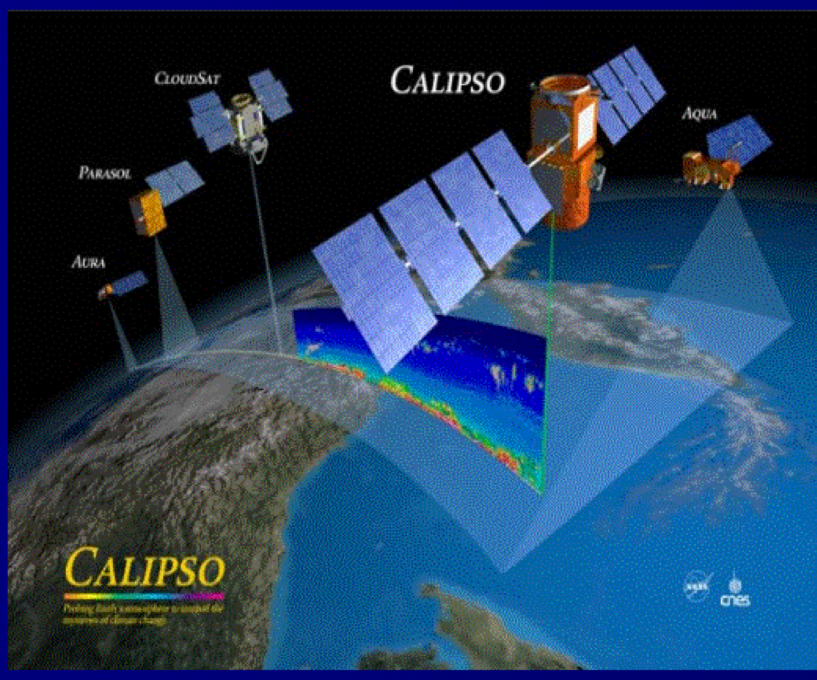
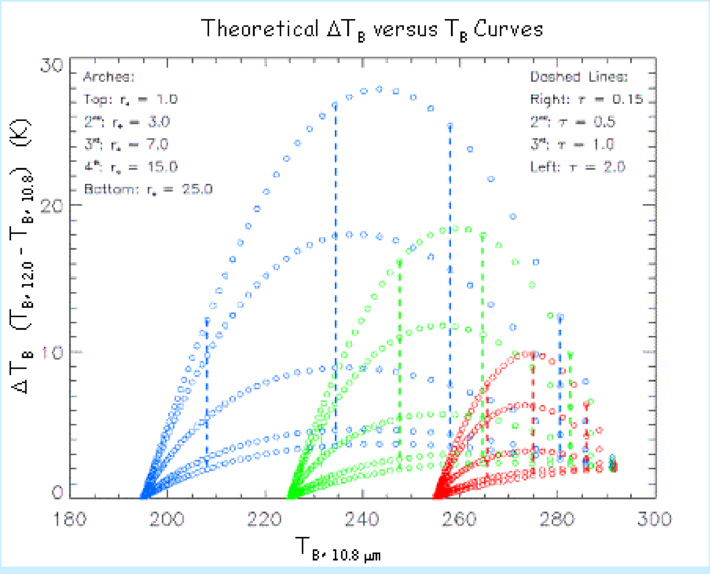


Motivation and Goals

Cirrus clouds play an important role in regulating climate through their impact on the Earth's radiation balance. Unfortunately, their exact influence is still poorly understood partly because the cirrus cloud properties themselves are poorly understood. The purpose of this work then is to to gain a better characterization of cirrus properties and global distribution through introduction of a new multiple- sensor cirrus retrieval.

Right: In the traditional split-window technique, cloud optical depth and effective radius can be retrieved from a simple plot of $T_{B,\ 10.8\ \mu m}$ versus ΔT_B (12.0-10.8 μm). Note that retrieved properties will be different for each cloud temperature, T_C. This ambiguity in cloud temperature used in the retrieval leads to large error and limits the usefulness of the technique.



This work introduces an optimal estimation based retrieval of cirrus properties that explicitly incorporates cloud boundary information into the retrieval as a constraint on cloud temperature. Inclusion of cloud boundaries is shown to significantly reduce error in retrieved optical depth and effective radius.

Retrieval Method

Our optimal estimation algorithm seeks the most likely estimate of cloud microphysical properties, **X**, by minimizing the following cost function, Φ,

forward model | **forward model and measurement error covariance matrix**

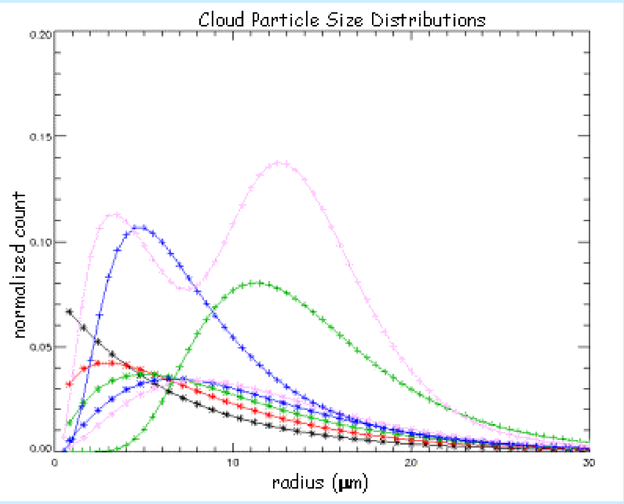
$$\Phi(X,X_a,Z) = (F(X)-Z)^T S_Z^{-1} (F(X)-Z) + (X-X_a)^T S_a^{-1} (X-X_a)$$

retrieval vector | **TRMM measurements** | ***A priori* guess**

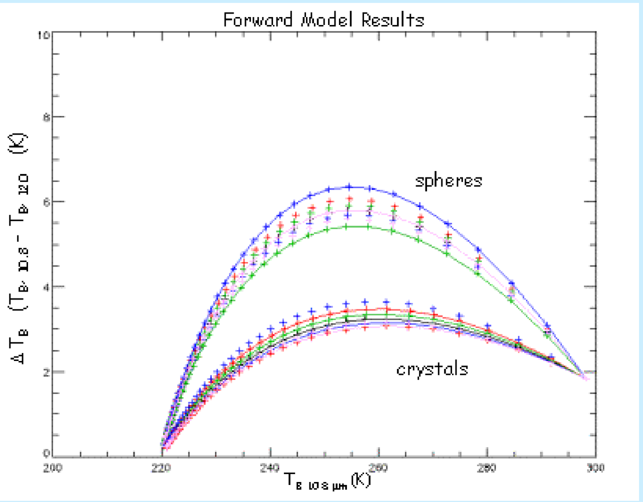
$$X = \begin{Bmatrix} \tau \\ R_{eff} \\ T_C \end{Bmatrix} \qquad Z = \begin{Bmatrix} T_{B,\ 10.8\ \mu m} \\ \Delta T_B \\ T_C \end{Bmatrix}$$

F $\equiv$ a simple, speedy two- layer infrared radiative transfer model based on anomalous diffraction theory that calculates simulated observations from **X**

S_Z Matrix Estimation

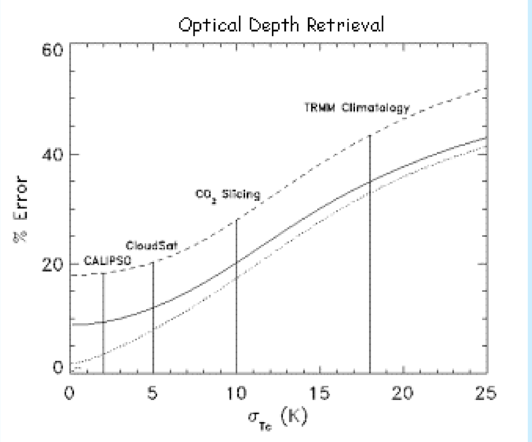


Error in $T_{B,\ 10.8\ \mu m}$ and ΔT_B were determined to be 1.5K and 2.5K, respectively, by determining the variance of the forward model to a variety of modified gamma and lognormal distributions of both ice spheres and hexagonal ice crystals. TRMM measurement error was consider negligible. Error in cloud temperature is variable by design.

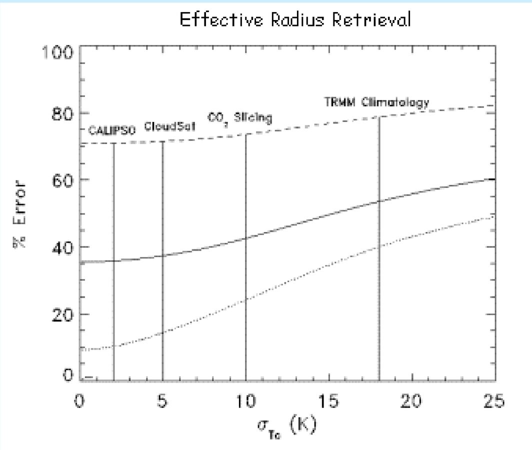


Synthetic Results

Simulated measurements with random, Gaussian error added were used in the algorithm to determine the accuracy of the operational.



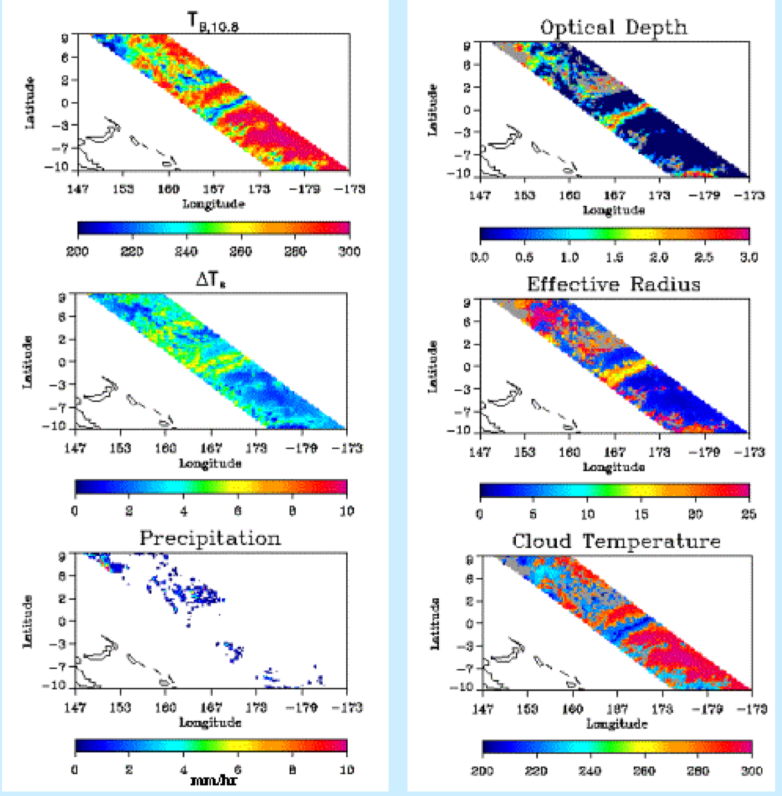
Percentage error in retrieved optical depth and effective radius as a function of error in cloud temperature measurement are shown at left and at bottom left, respectively. The three lines represent different assumptions used in the S_Z matrix; the middle line to our best estimate described in the S_Z matrix section above.



A more accurate estimate of cloud temperature in the retrieval significantly reduces error. Active sensors such as space-borne lidar or radar provide an ideal complementary measurement to infrared radiances to reduce the inherent error in the retrieval.

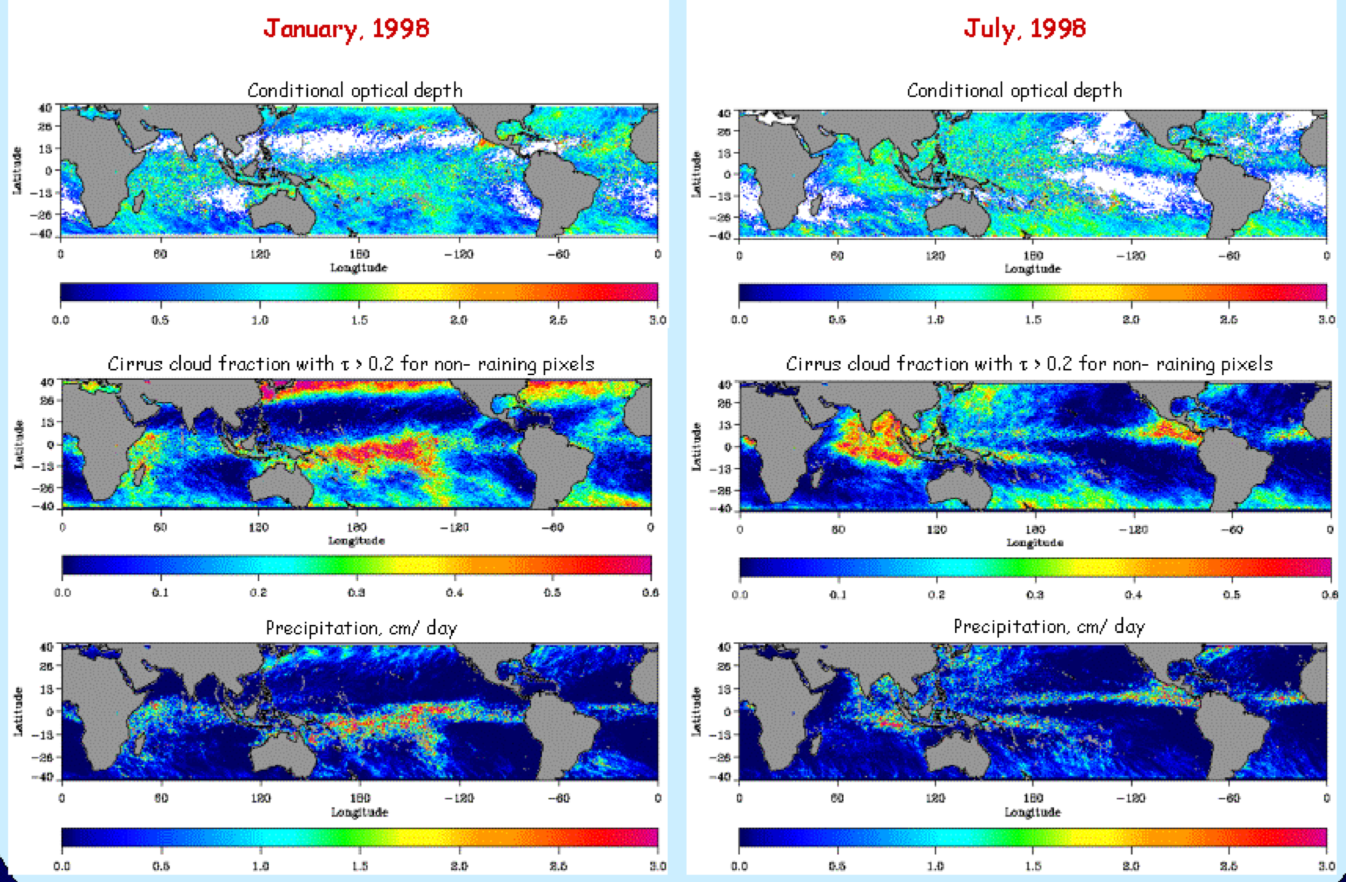
TRMM Example

Below is an example of our retrieval using VIRS data for infrared radiances and TRMM precipitation product 2A12 for an estimate of cloud temperature. Gray areas indicate regions of precipitating cloud.



Global Applications

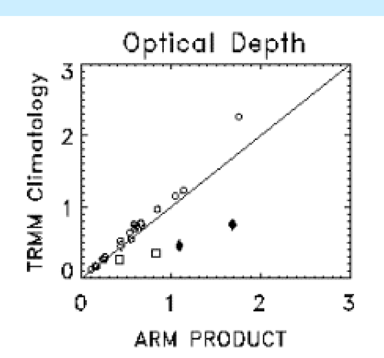
With the launch of CloudSat and CALIPSO in the near future, active measurements of cloud boundary information can be combined with infrared radiances from the MODIS instrument aboard AQUA to perform our retrieval on a global scale. Example applications using the less accurate TRMM climatology for cloud boundary information are shown below



Nauru Data

Retrievals were run for TRMM overpasses of Nauru ARM site using both ARM site active sensors and TRMM climatology as estimates of cloud boundary information.

Use of ARM cloud boundary information can result in significantly different results than techniques with less accurate estimates of cloud temperature



Summary and Future Work

We introduce an optimal estimation- based retrieval of thin cirrus clouds that combines explicit cloud temperature information with infrared radiances to reduce the error inherent to the original split- window approach.

The upcoming launches of CALIPSO and CloudSat in conjunction with the MODIS instrument aboard AQUA provide the ideal combination of sensors to implement this algorithm on a global scale.

The optimal estimation framework will allow for additional information to be easily incorporated into the retrieval to improve estimates of cirrus cloud properties.

Reference

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