Cloud Tomography: a Novel Method for Determining 3D Cloud Liquid Water Distribution

Contributors
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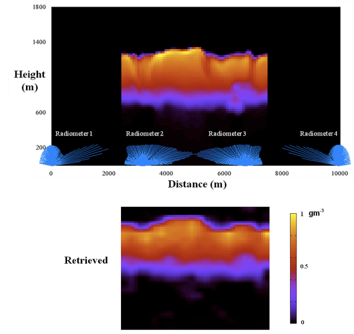
Research Highlight

Three-dimensional distributions of cloud water are needed for studying cloud physics/microphysics and atmospheric radiation, and for validating cloud-resolving and large-eddy-simulation models. Cloud tomography offers the promise of retrieving 3D cloud water distributions using multi-angular microwave emission measurements. The method was proposed in the 1980s, but neither the technology nor the cloud models were mature enough to make much headway. Now, the time is ripe for a renewed push. We have created a Tomography Simulator with simulated clouds and simulated microwave radiometers to show the feasibility of the cloud tomography method.

An ideal tomographic retrieval would require the clouds to be measured from all directions in a hemisphere. Because we will always fall far short of this ideal, we must use stringent physical constraints and modern numerical methods to reduce the resulting ill-conditioning and get a sufficiently accurate (10% or better) solution of the tomography problem with a reasonable number of microwave radiometers (2, 4, or 8).

Discretizing the continuous cloud field into little boxes (pixels) introduces further errors, which in conjunction with the ill-conditioning make the tomographic retrieval sensitive to both the measurement/numerical errors and the discretization scheme. We have partially circumvented the discretization problem by using a functional representation instead of the conventional pixel scheme to approximate the continuous field.

With the aforementioned problems addressed, we demonstrate that four state-of-the-art microwave sensors can reasonably capture the spatial variation of cloud water at a resolution of a few tens of meters in the vertical and a few hundred meters in the horizontal. The rms error is within 5% of the maximum cloud water content. Planned work will show how the addition of radar data can improve the retrieval even further, and allow the use of fewer radiometers.



Cloud tomography is a novel method for determining cloud water distribution by measuring cloud microwave emission from multiple directions. The upper plot shows a 2D cross-sectional snapshot of the liquid water structure of a stratocumulus cloud simulated by a large-eddy model. It also shows the four scanning microwave radiometers used to retrieve the cloud liquid water structure shown in the lower plot. (The cloud is assumed frozen while the radiometers scan it.) Note the fidelity of the retrieval. We greatly improve the tomographic retrieval methods proposed in the 1980s by: (1) using an iterative constrained algorithm; and (2) replacing the conventional pixel scheme with a functional representation. With four microwave radiometers, our tomographic method captures the spatial variation of cloud water at a resolution of 10s of meters in the vertical and 100s of meters in the horizontal. The difference between the true and retrieved liquid water fields is within 5% of its maximum water content.

Reference(s)

Huang, D., Y. Liu, and W. Wiscombe, 2007a: Determination of cloud liquid water distribution using 3D cloud tomography. J. Geophys. Res., submitted.

Working Group(s)
Cloud Properties