Determination of Cloud Liquid Water Distribution with 3D Cloud Tomography

Dong Huang, Yangang Liu, and Warren Wiscombe

BROOKHAVEN NATIONAL LABORATORY

Tomography is a technique for imaging an object's interior from its projections

Warner et al. proposed using tomography to determine cloud liquid water distribution in 1980s. Now is a good time to revisit this method because of advances in microwave scanning technology.

Can we "X-ray" clouds?

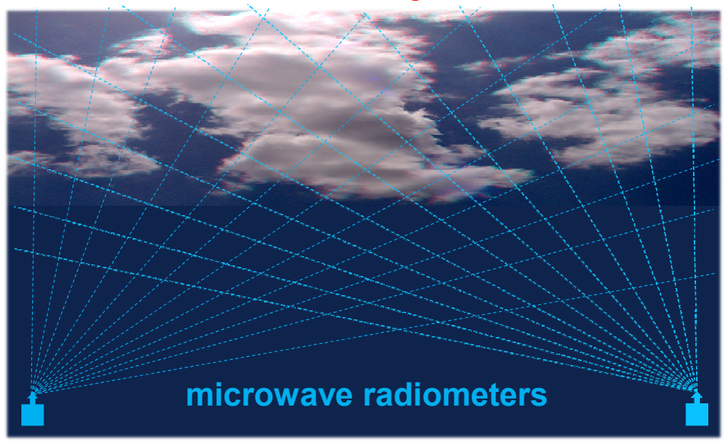

Figure 1. Warner's tomography setup based on cloud microwave emission.

Cloud tomography includes a forward and an inverse problem

The forward problem simulates microwave radiances knowing the liquid water field. The inverse problem reconstructs the cloud liquid water field from microwave emission data.

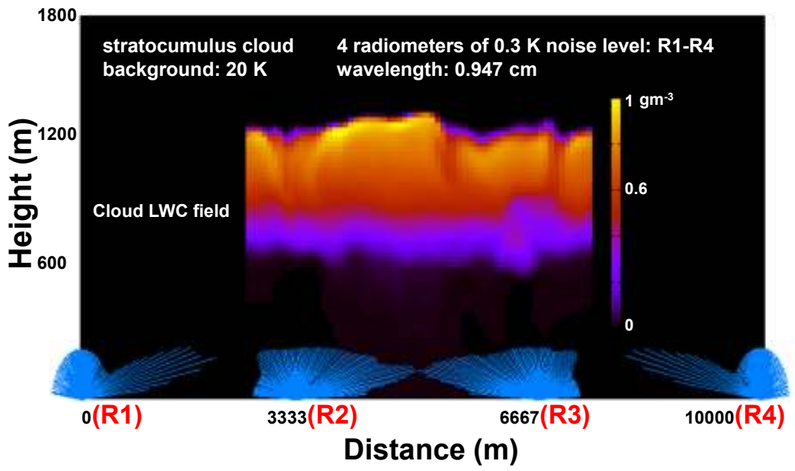

Figure 2. The simulated signals are proportional to the length of the lines radiating from each radiometer.

The inverse problem is ill-posed, but regularization methods can be used to obtain the optimal solution

The error of standard least squares method is 5 times as large as that of regularization method.

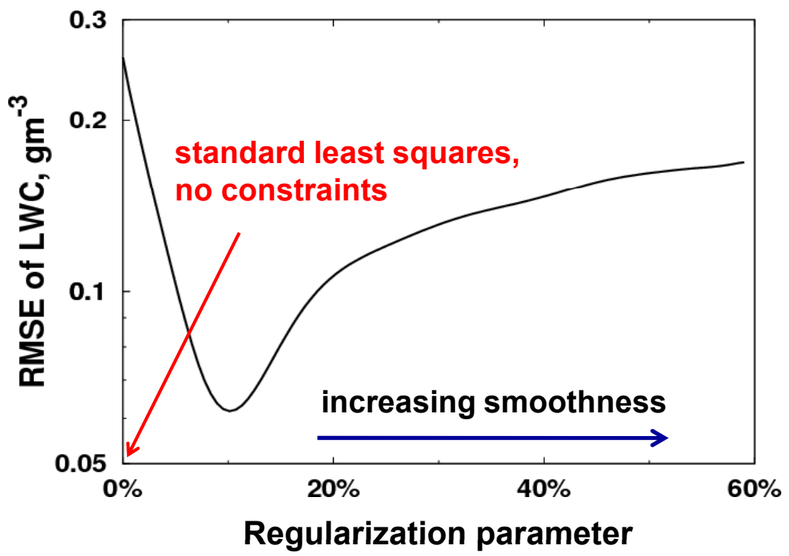

Figure 3. Demonstration of ill-posedness.

Spatial pattern of cloud liquid water is well captured by 8 radiometers

The error of the reconstruction at 20x20 output resolution is about 5% of the max LWC in clouds.

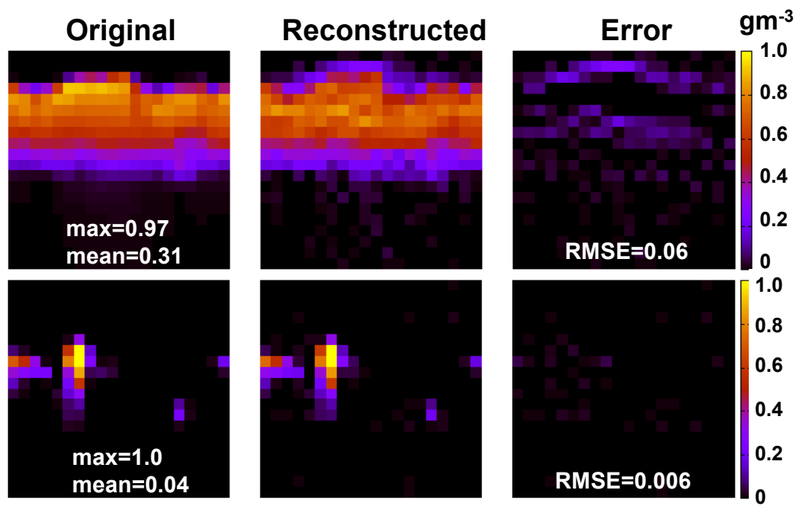

Figure 4. Original, reconstructed, and error fields of cloud liquid water (0.3 K noise). Pixel size: Δx=250 m, Δz=75 m.

Summary

With 4 radiometers having 0.3 K noise level, tomography can yield LWC within 5% of the max LWC with a resolution of a few hundred meters.

Reconstruction of cloud liquid water fields with cloud tomography is ill-posed. Non-negativity and smoothness constraints can be used to obtain the optimal solution.

Future directions: (1) couple radiometer data with radar and other measurements to improve retrieval, (2) retrieve vapor and ice water content with dual-frequency radiometers, (3) field trial.

Reconstruction accuracy depends on noise level, number of scan angles, number of radiometers, and output resolution

Some of these factors interact with others. E.g., noise level and number of scan angles trade off against each other. Optimal choice can be made through sensitivity studies.

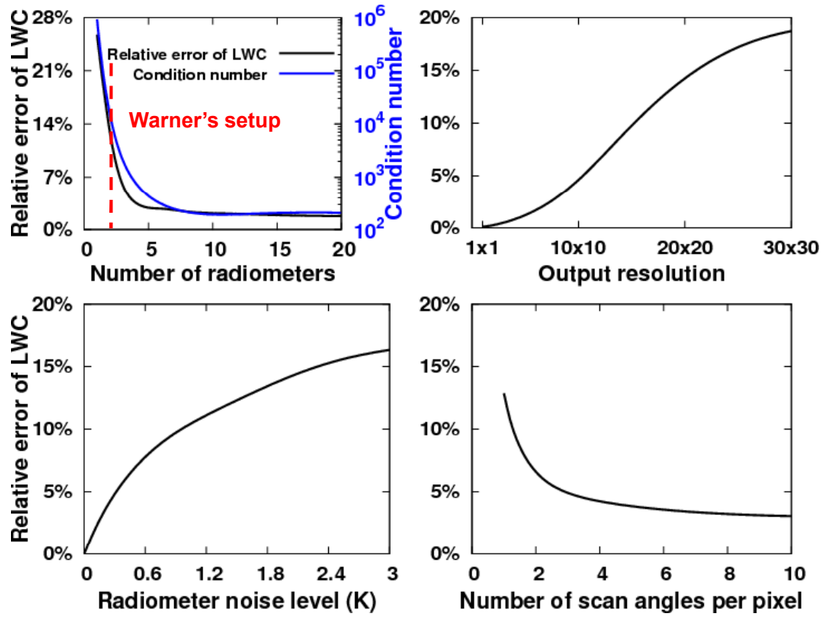

Figure 5. Impacts of number of radiometers, output resolution , noise level, and number of scan angles on reconstruction error.

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Reference

Warner, J., J.F. Drake, and P.R. Krehbiel (1985), J. Atmos. Sci. Ocean. Tech., 2, 293-303.

Email: dhuang@bnl.gov
Tel: (631) 344-5818