Determination of Cloud Liquid Water Distribution with 3D Cloud Tomography

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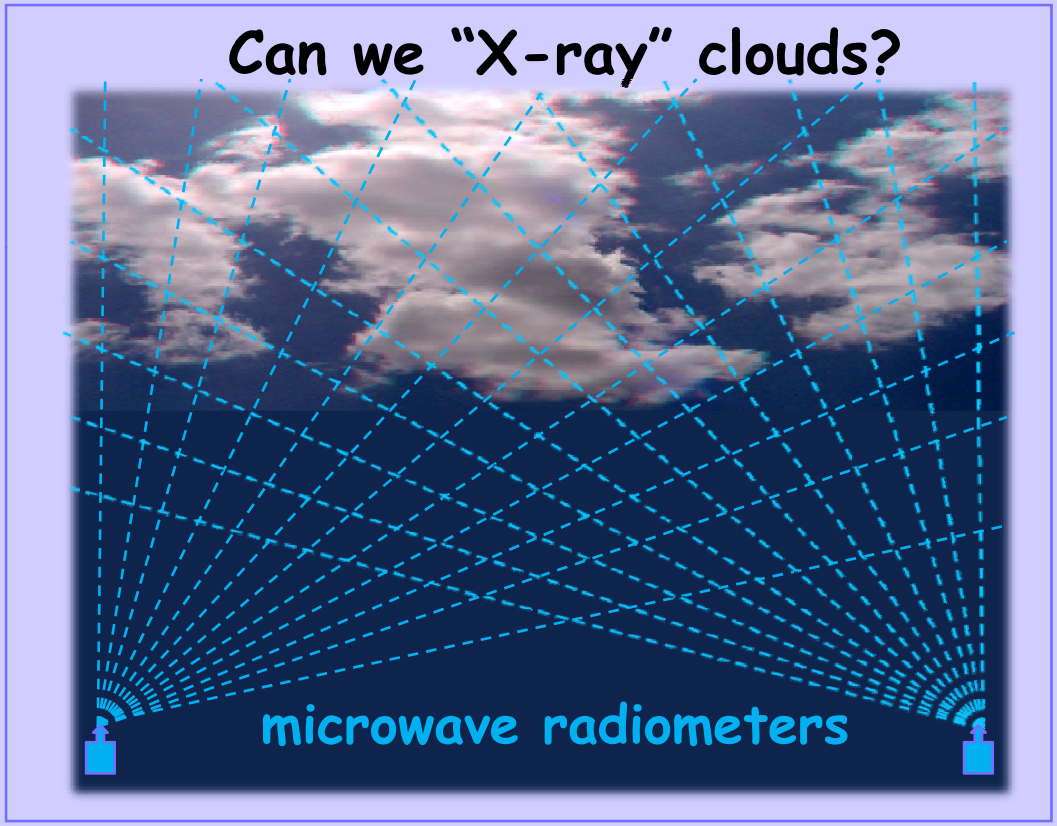

BROOKHAVEN NATIONAL LABORATORY

NASA

ARM Atmospheric Radiation Measurement

ARM science team meeting

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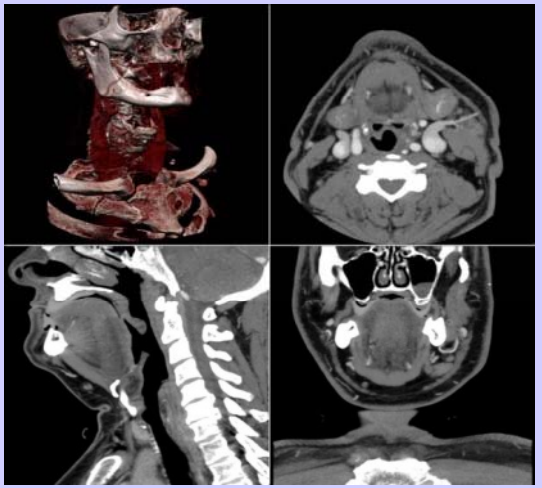
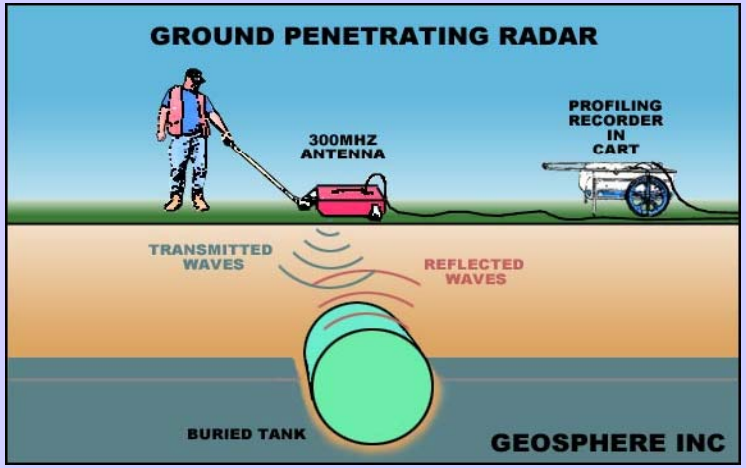
Tomography is a method for imaging the interior of an object from its projections

CAT scanner

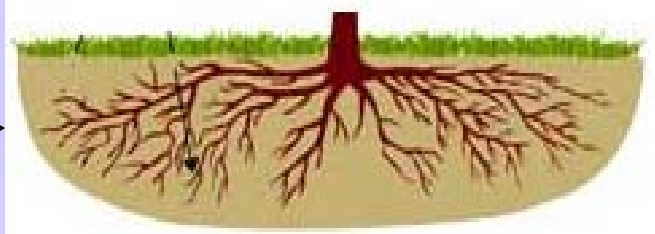
Computed Tomography





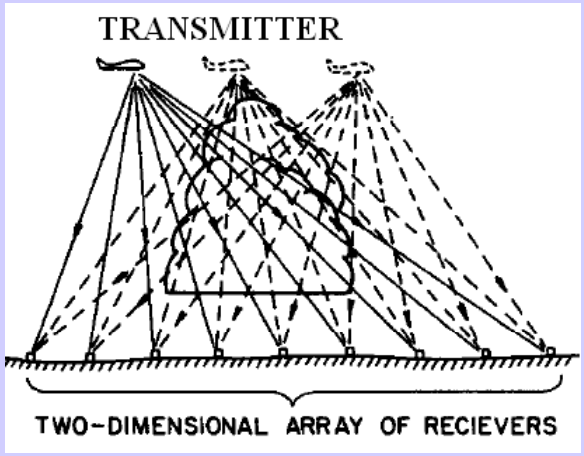
Tomography

Tree root distribution

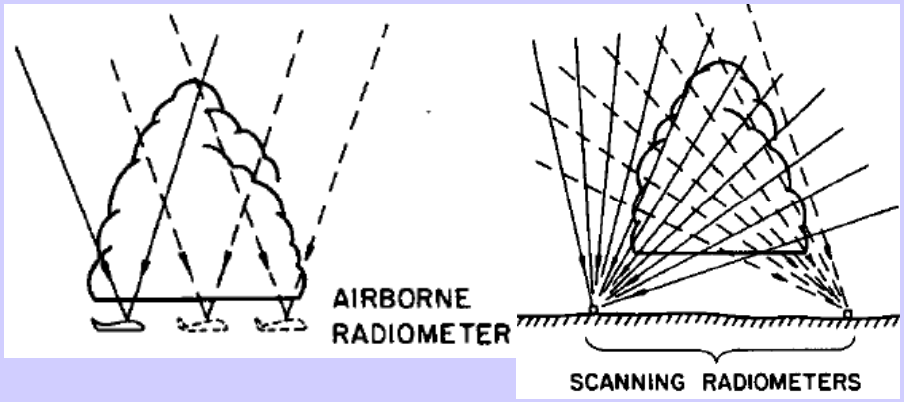


What if the patient is a cloud?

Warner et al., 1985



Transmission Tomography

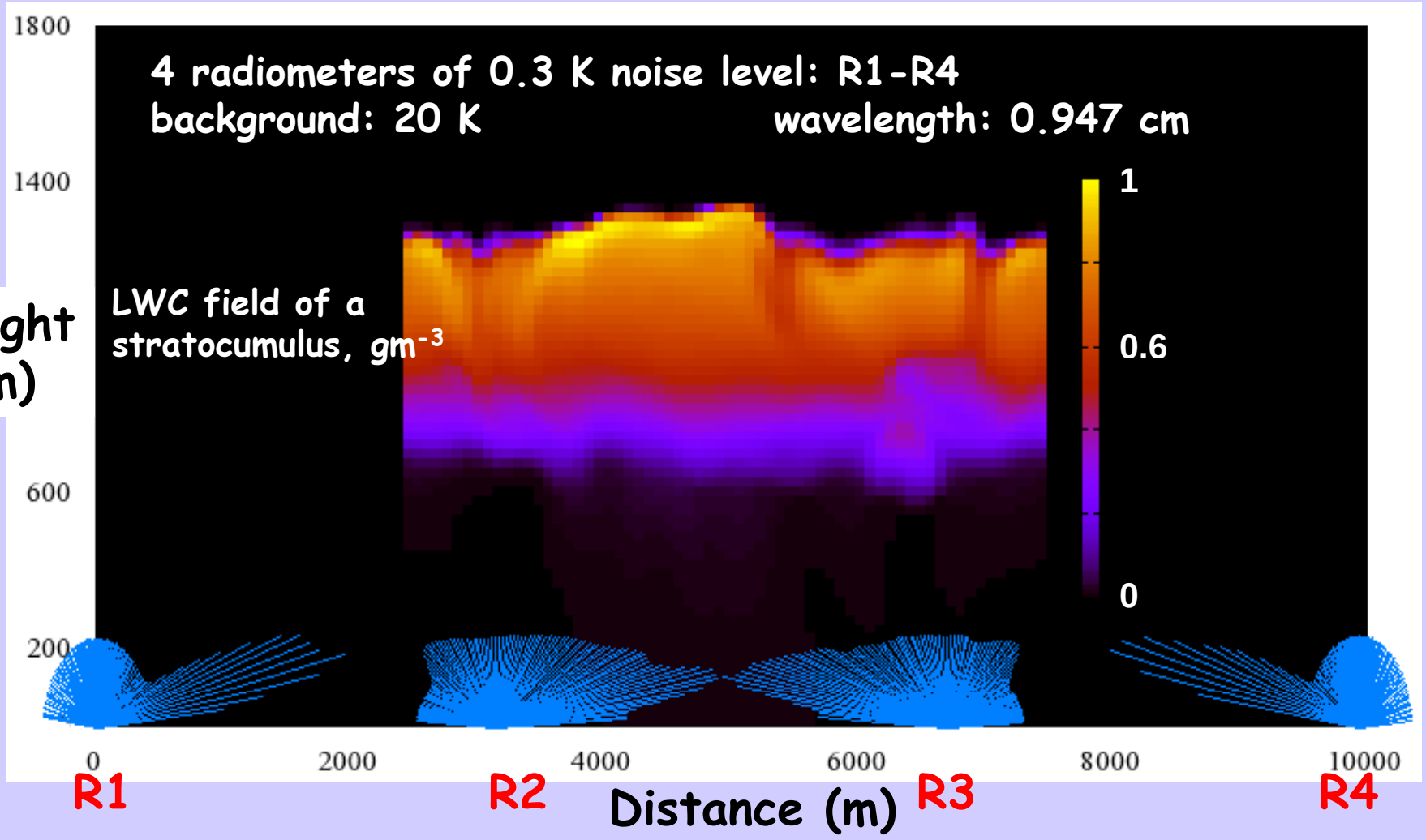


Emission Tomography

Forward model

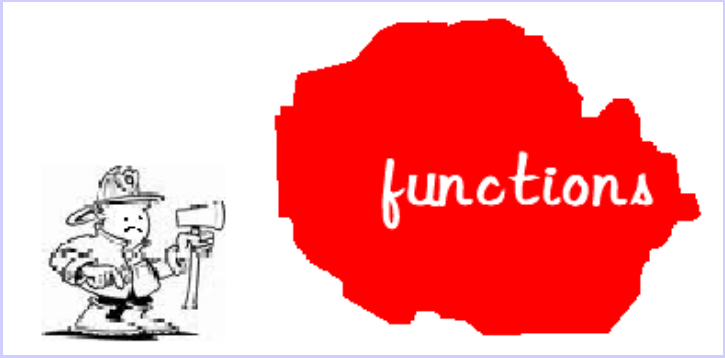
Inverse model

Simulated data (brightness temperature)



The simulated brightness temperatures are proportional to the length of the lines radiating from each radiometer.

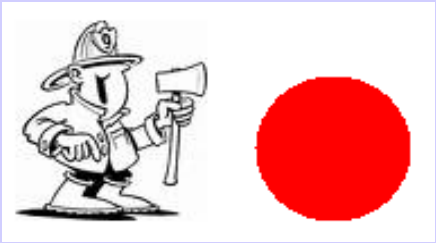
Regularization helps obtain optimal solution for ill-posed inverse problem



Original space

Regularization

Impose constraints, e.g., smoothness, non-negativity

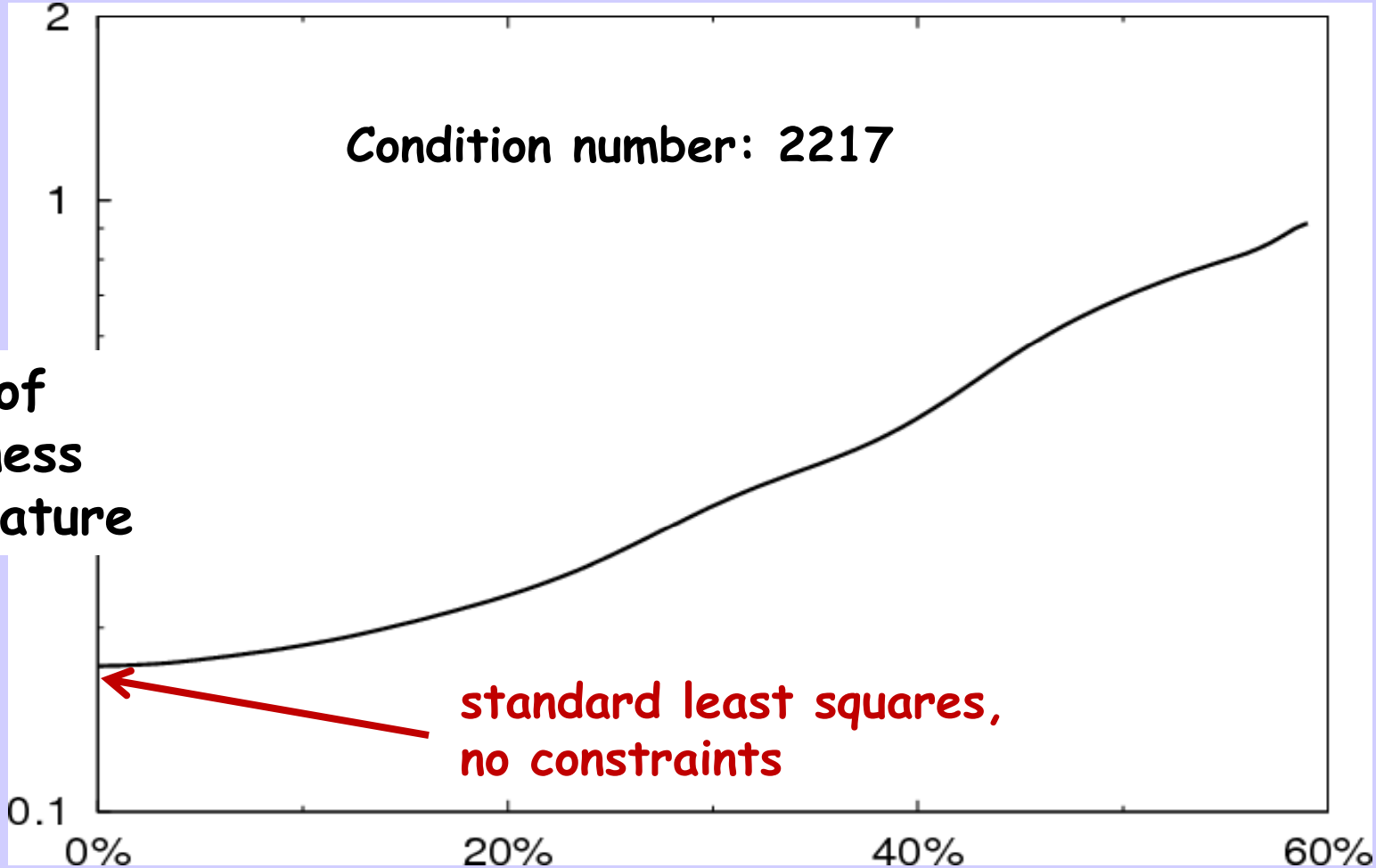


Reduced space

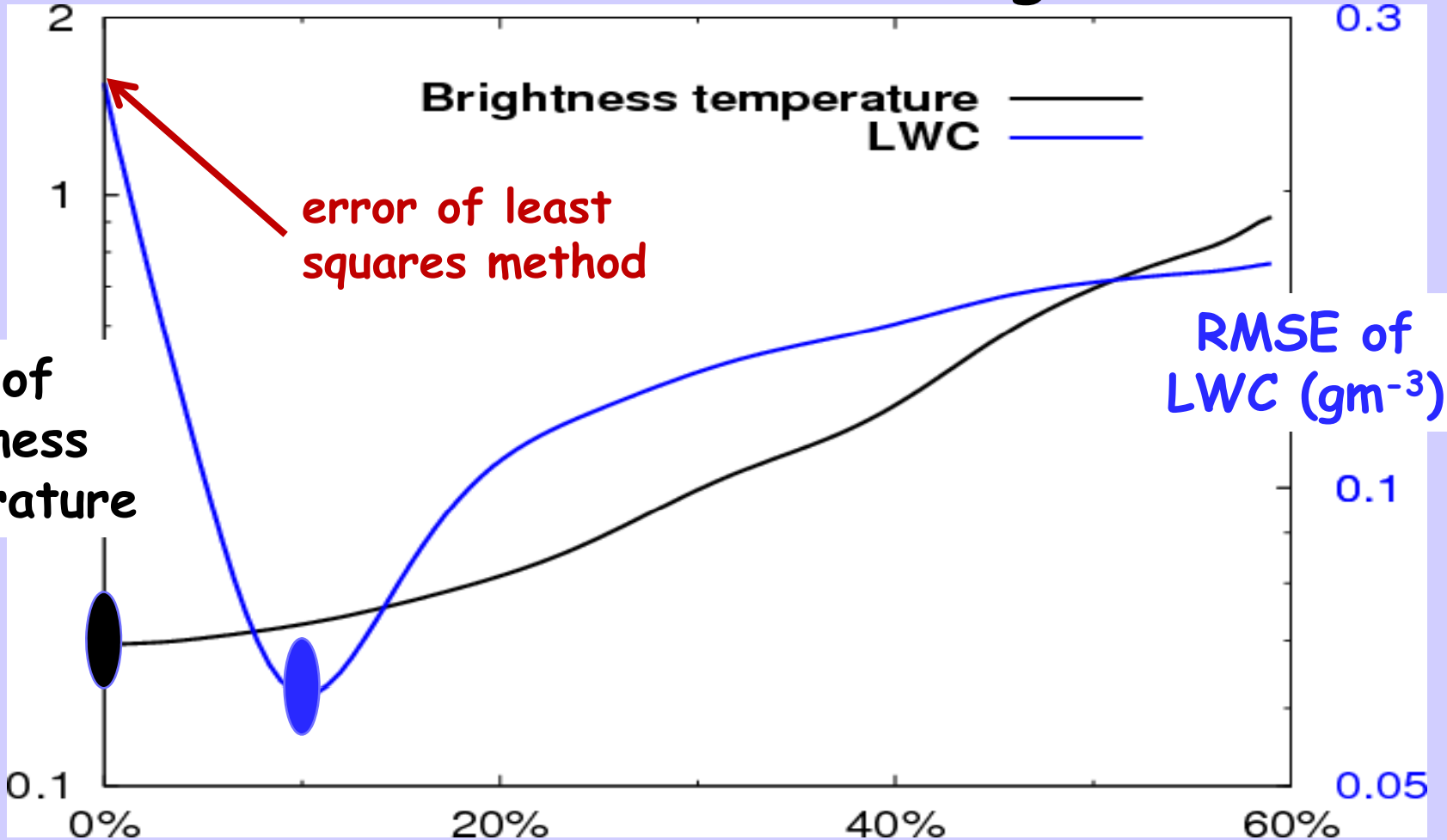
"Ill-posedness" is characterized by condition number; e.g.,
10000 → badly ill-posed, 10 → slightly ill-posed

A smoothness constraint is added to Lawson and Hanson's non-negative least squares algorithm using the method of (Liu et al., 1998) .

Standard least squares method corresponds to the case in which no constraints is used

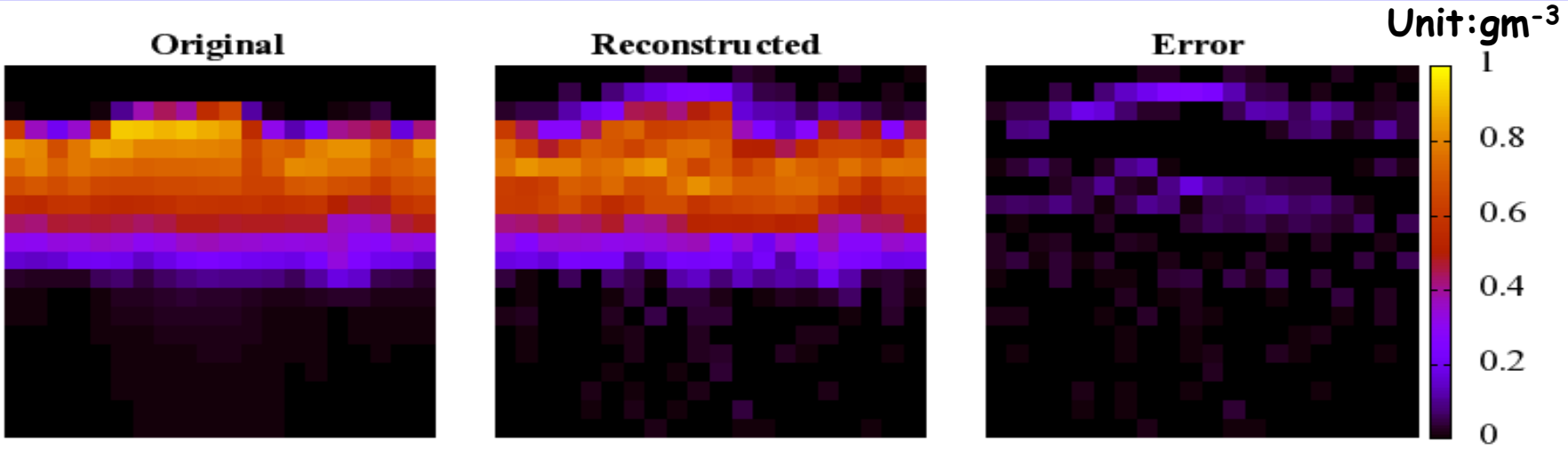


Error of least squares method is 5 times as large as smoothn's constrained regularizat'n

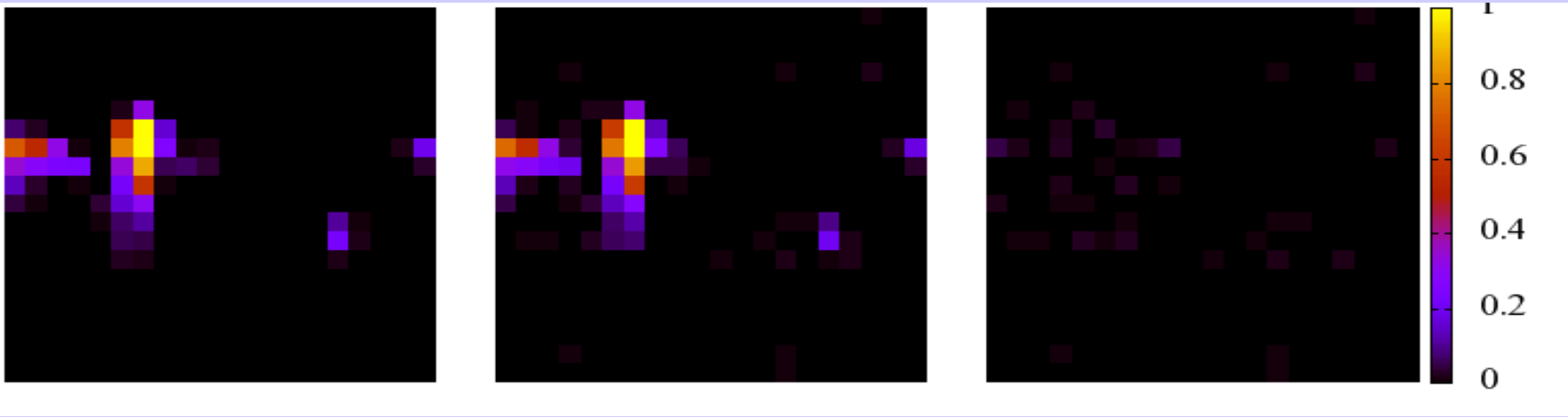


Min errors of LWC and T_B do not occur at same point.

8 radiometers well capture the spatial pattern of cloud liquid water at 20x20 resolution

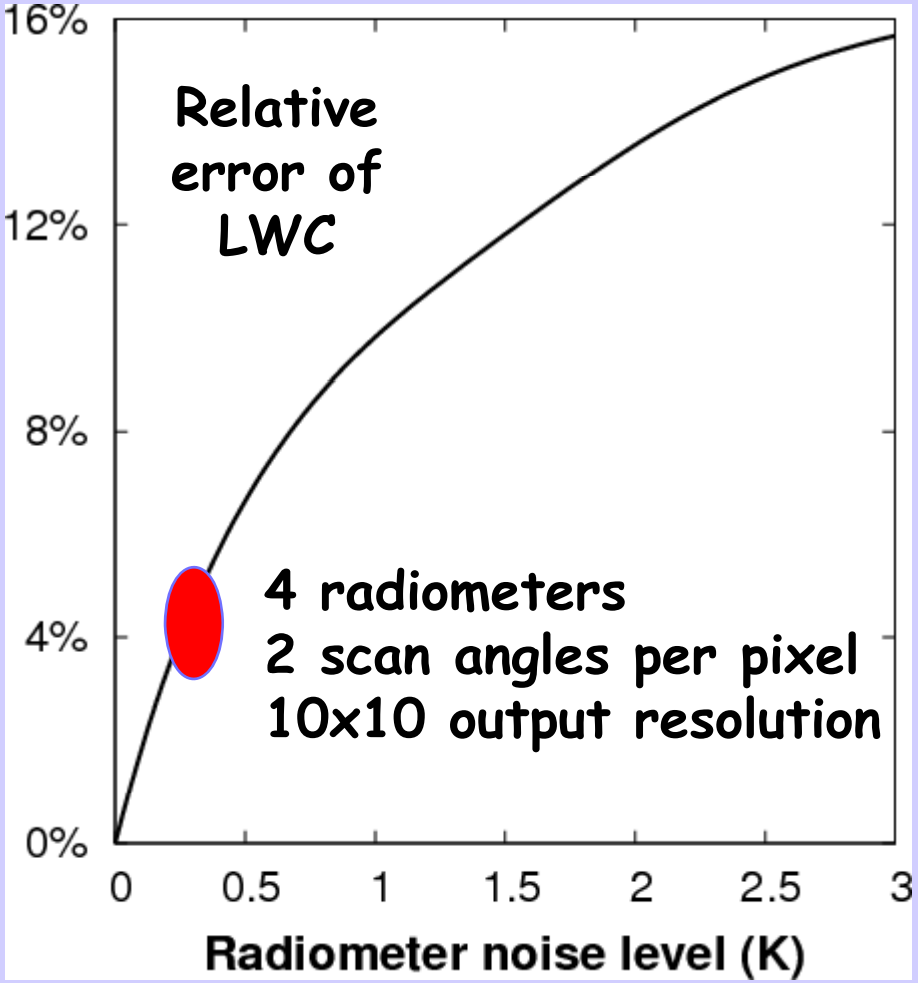


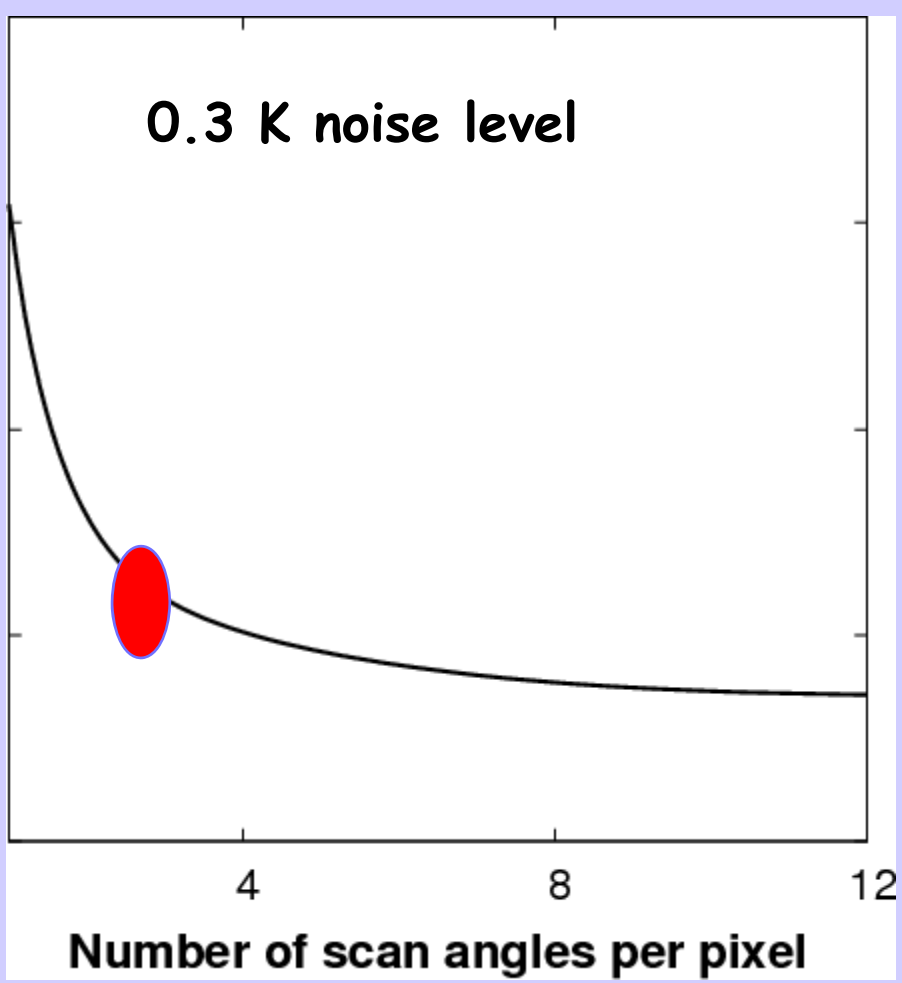
Stratocumulus, max(LWC)=0.97, mean(LWC) =0.31, RMSE=0.06



Broken cumulus, max(LWC)=1.0, mean(LWC) =0.04, RMSE=0.006

Radiometer noise and number of scan angles trade off against each other

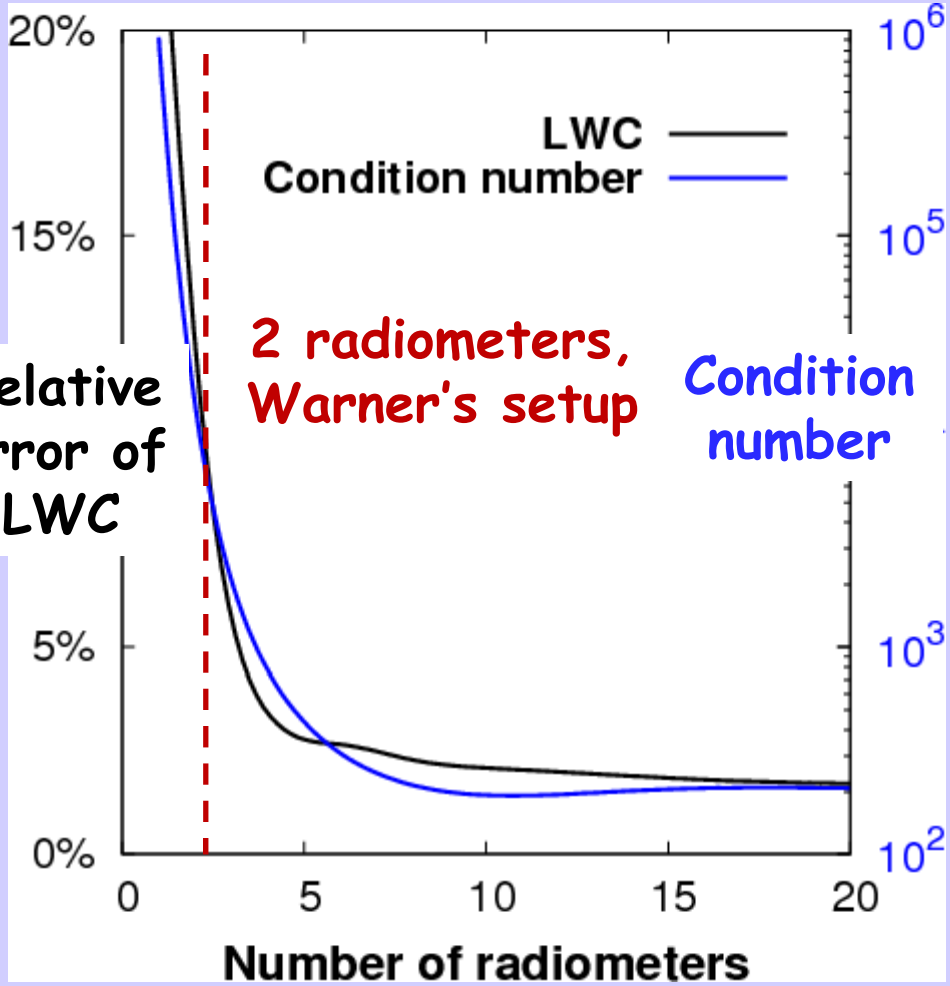




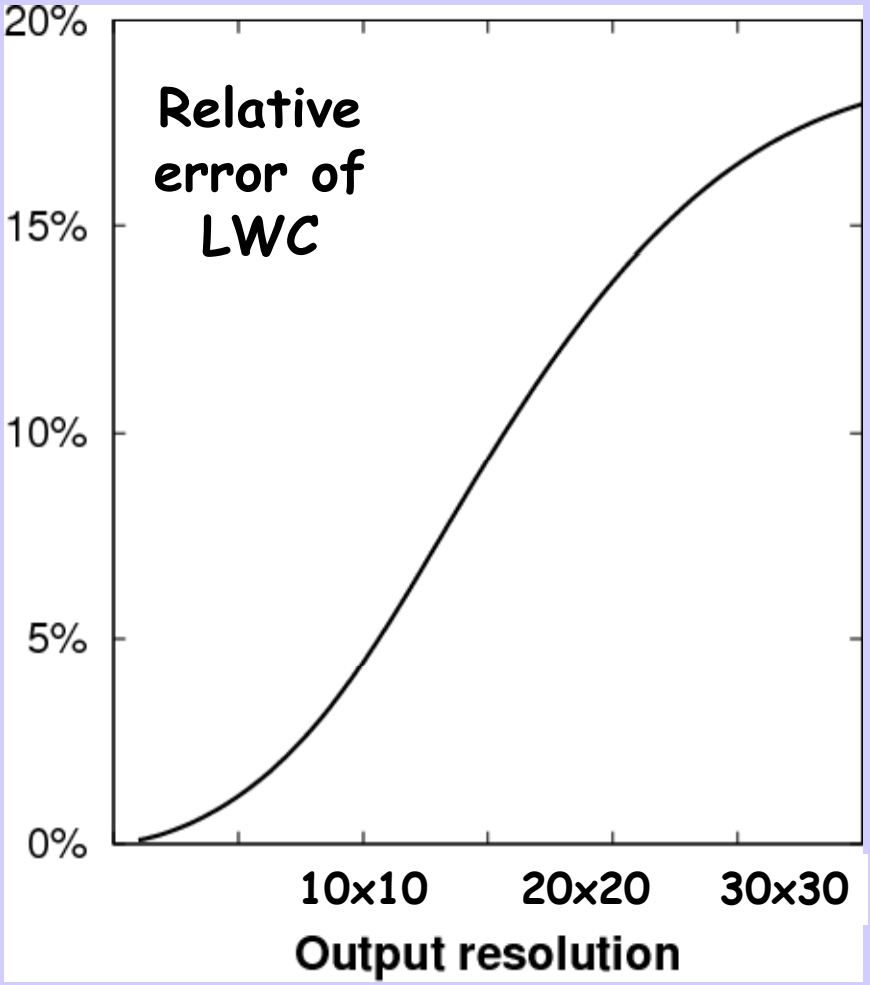
More scan angles means less dwell time and hence higher noise at each angle.

Reconstruction error declines when ...

Number of radiometers increases

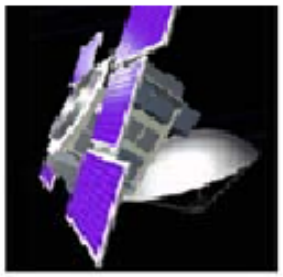


Output resolution decreases



Future: improve reconstruction through data fusion, retrieve vapor and ice water

MWR



Satellite

Small UAV

We need to talk!

IRT

TSI

radar

Summary: cloud tomography is able to retrieve LWC within 5% of the max LWC

... at resolution of a few hundred meters with a 4-radiometer setup.

The passive microwave tomographic reconstruction of cloud liquid water is ill-posed.

Regularization with non-negativity and smoothness constraints helps obtain the optimal solution.

Reconstruction accuracy depends on:

- Radiometer noise level
- Total number of scan directions
- Output resolution
- Number of radiometers