Retrieving LWC from Zenith-Pointing Microwave Observations

(NOT)

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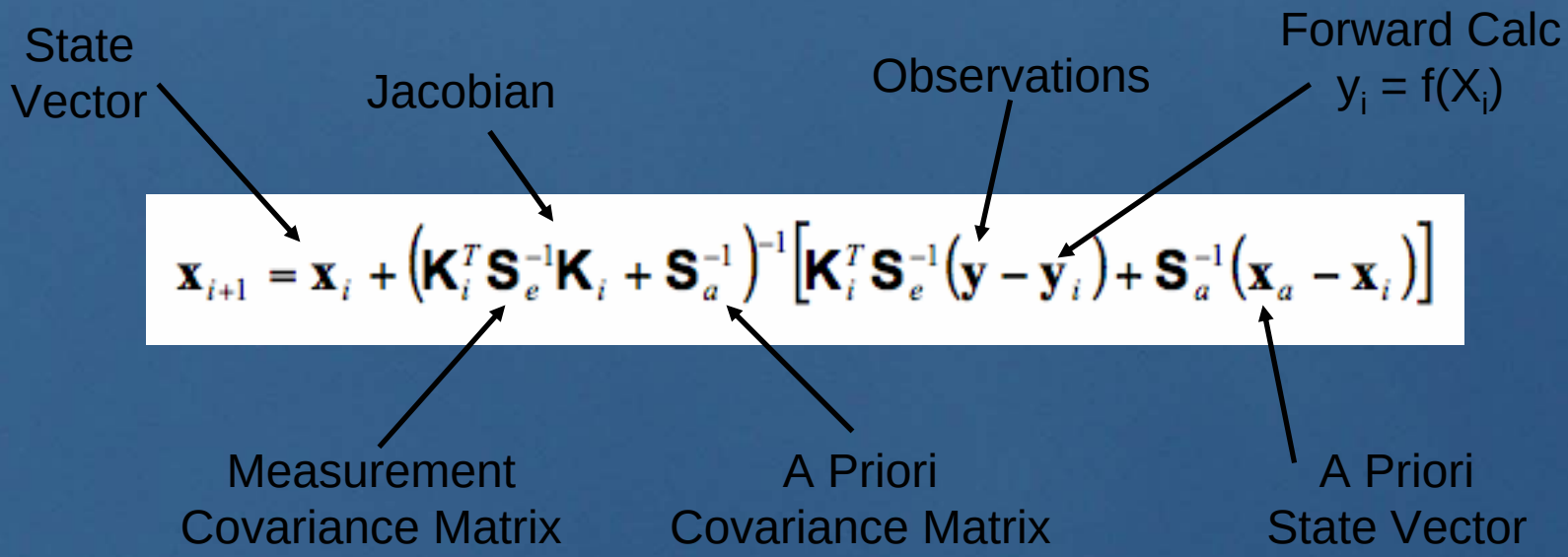
Information Content

- Most retrieval problems are ill-defined
- Retrieval technique must add information to constrain the retrieved state vector **X** (i.e., the solution)
- Important to know how much of the information in **X** is from the observations vs. from the retrieval technique
- Some methods, such as optimal estimation, allow this to be determined directly

Optimal Estimation



"Optimal" Solution Covariance Matrix →

$$\mathbf{S}_{op} = \left(\mathbf{K}_i^T \mathbf{S}_e^{-1} \mathbf{K}_i + \mathbf{S}_a^{-1}\right)^{-1}$$

Averaging Kernal →

$$\mathbf{A} = \mathbf{S}_{op} \cdot \left(\mathbf{K}_{op}^T \mathbf{S}_e^{-1} \mathbf{K}_{op}\right)$$

Trace(**A**) = Degrees of Freedom of Signal

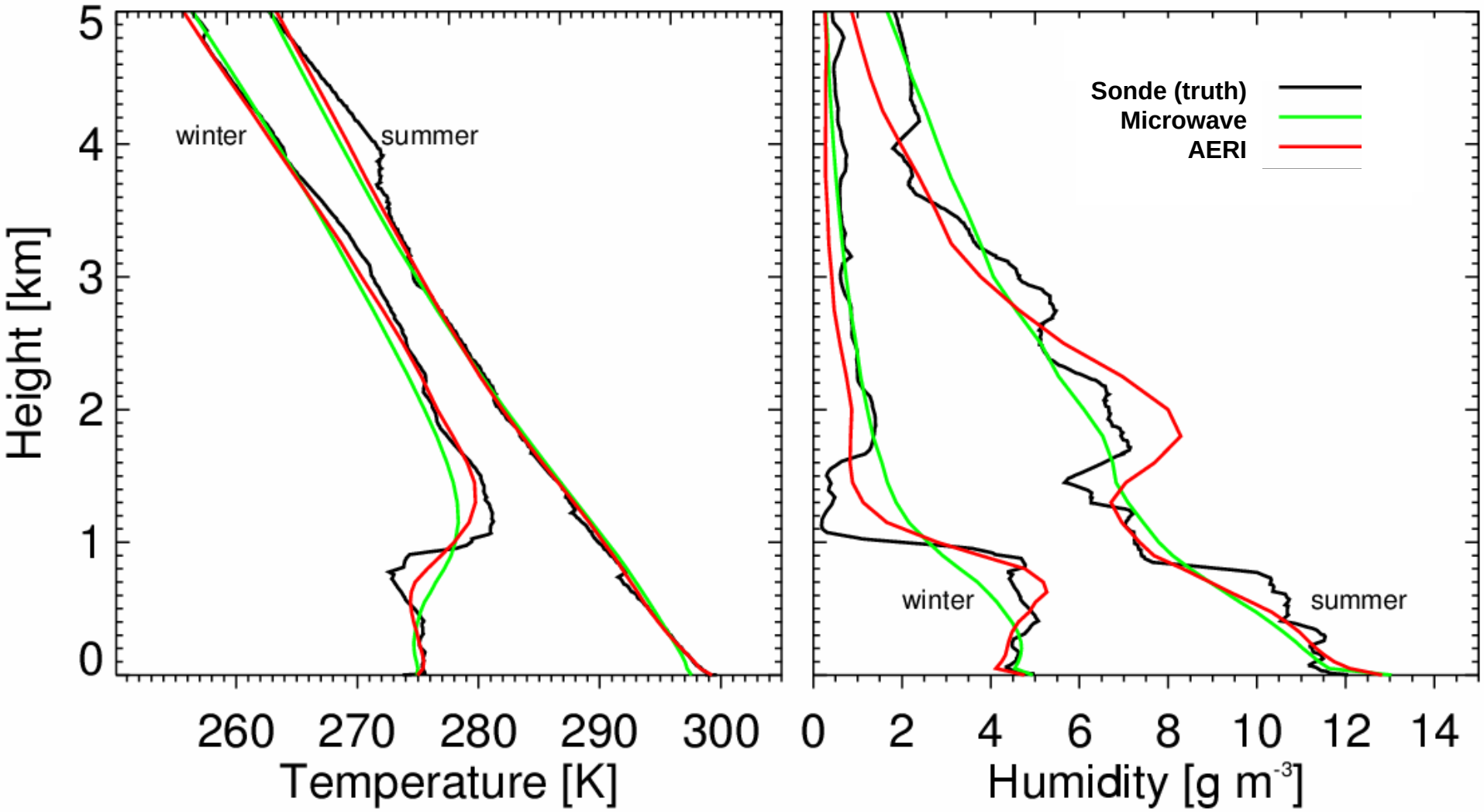
Rodgers 2000

Retrieving Water Vapor and Temperature Profiles

- Multi-channel microwave radiometers have been used to profile T and Q
- Typically use observations on side of 22.2 GHz H_2O line and 60 GHz O_2 complex
- Due to transparency of non-precipitating clouds in microwave, T/Q profiles can be retrieved the majority of the time
- Also able to retrieve T/Q profiles from AERI, but clouds can be very limiting

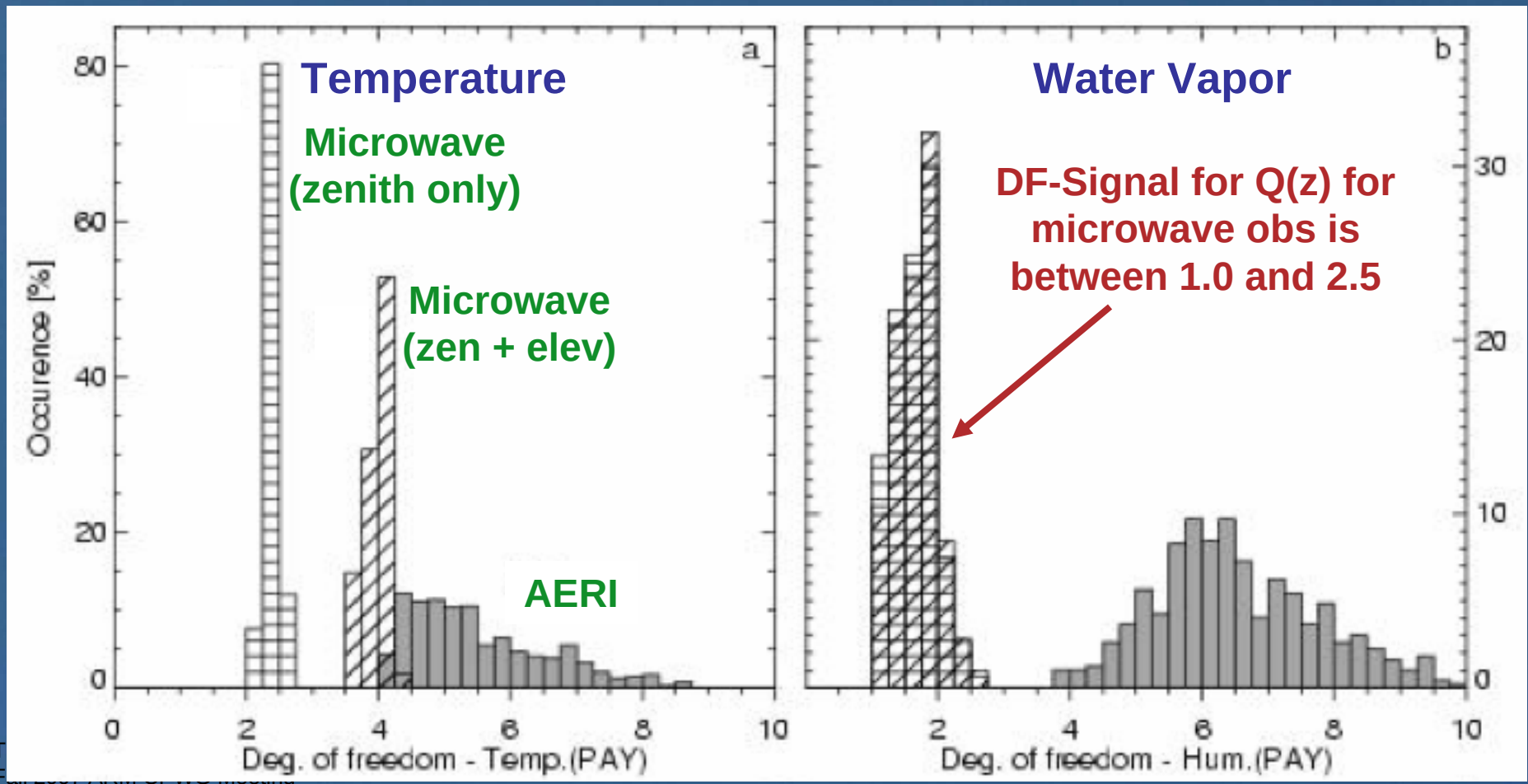
- What is the information content (i.e., number of pieces of independent information) for T/Q profiles in these observations?

Example: Retrieved T/Q Profiles in Clear Sky Mid-Latitude Conditions



Distribution of Degrees of Freedom of Signal for Retrieved T/Q Profiles

Mid-latitude site, several hundred clear-sky examples spanning range of PWV



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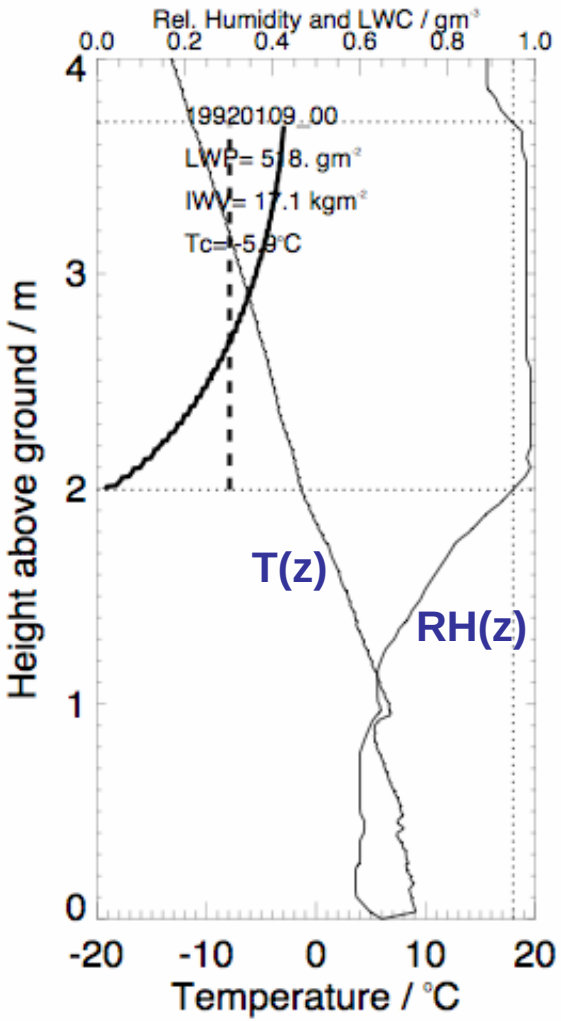
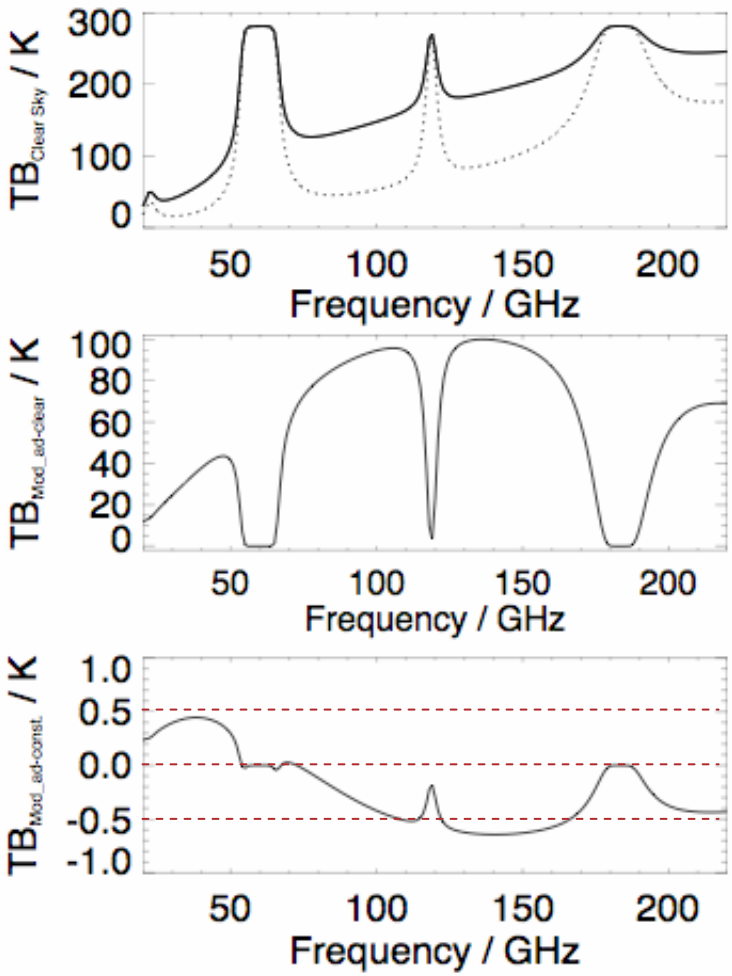
- Question: How much information content is there in passive zenith microwave radiometer observations to the profile of LWC?

Sensitivity of Microwave Obs to LWC(z)

Thick Cloud – 518 g/m^2





Cloudy T_b

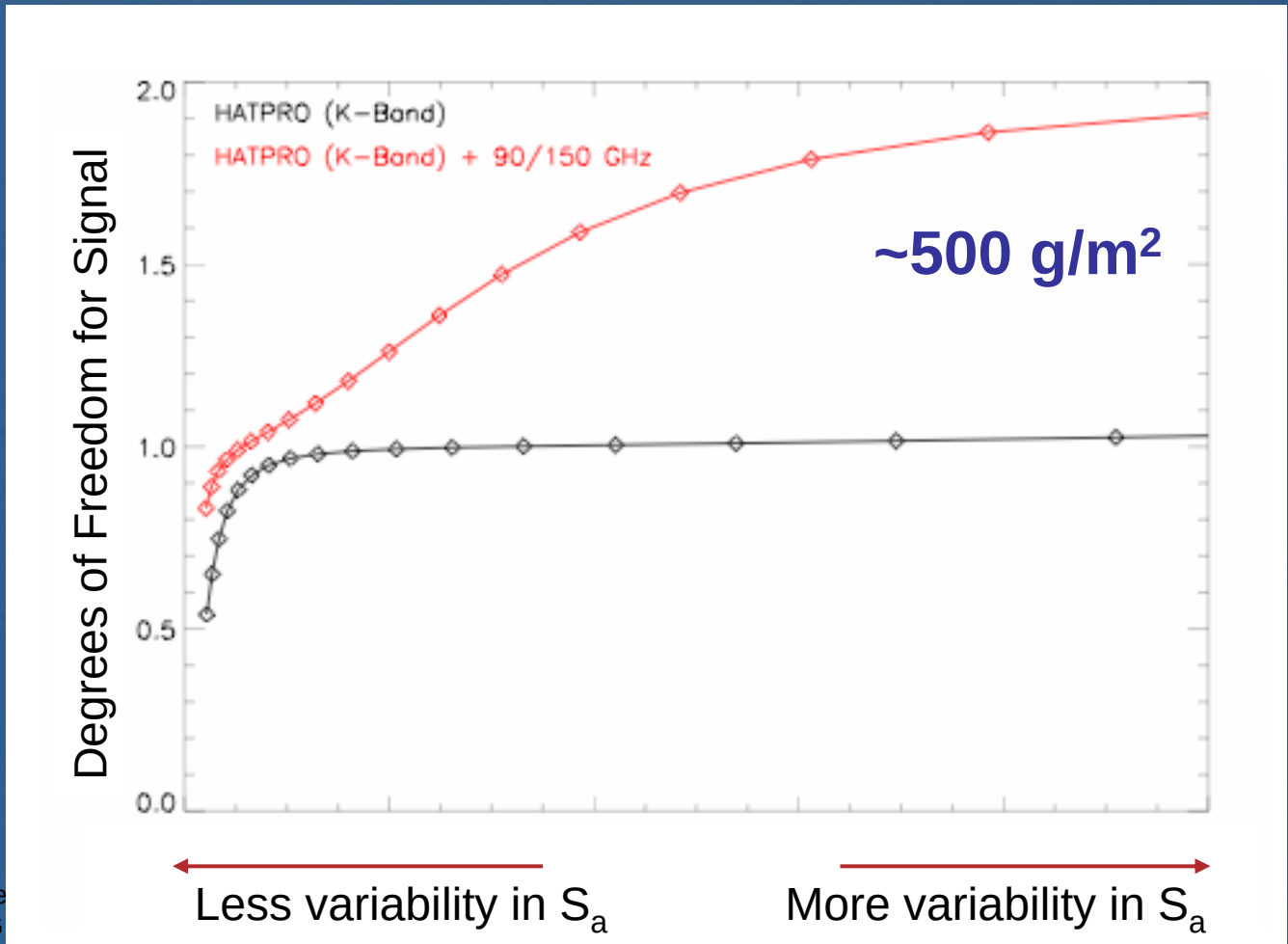
Clear T_b

Cloud minus Clear

Sub-adiabatic minus Constant LWC(z)

Sensitivity to A Priori Information

- Less variability in climatology covariance matrix ($\mathbf{S_a}$) will constrain the solution close to the a priori $\mathbf{X_a}$
  - Results in less degrees of freedom in signal



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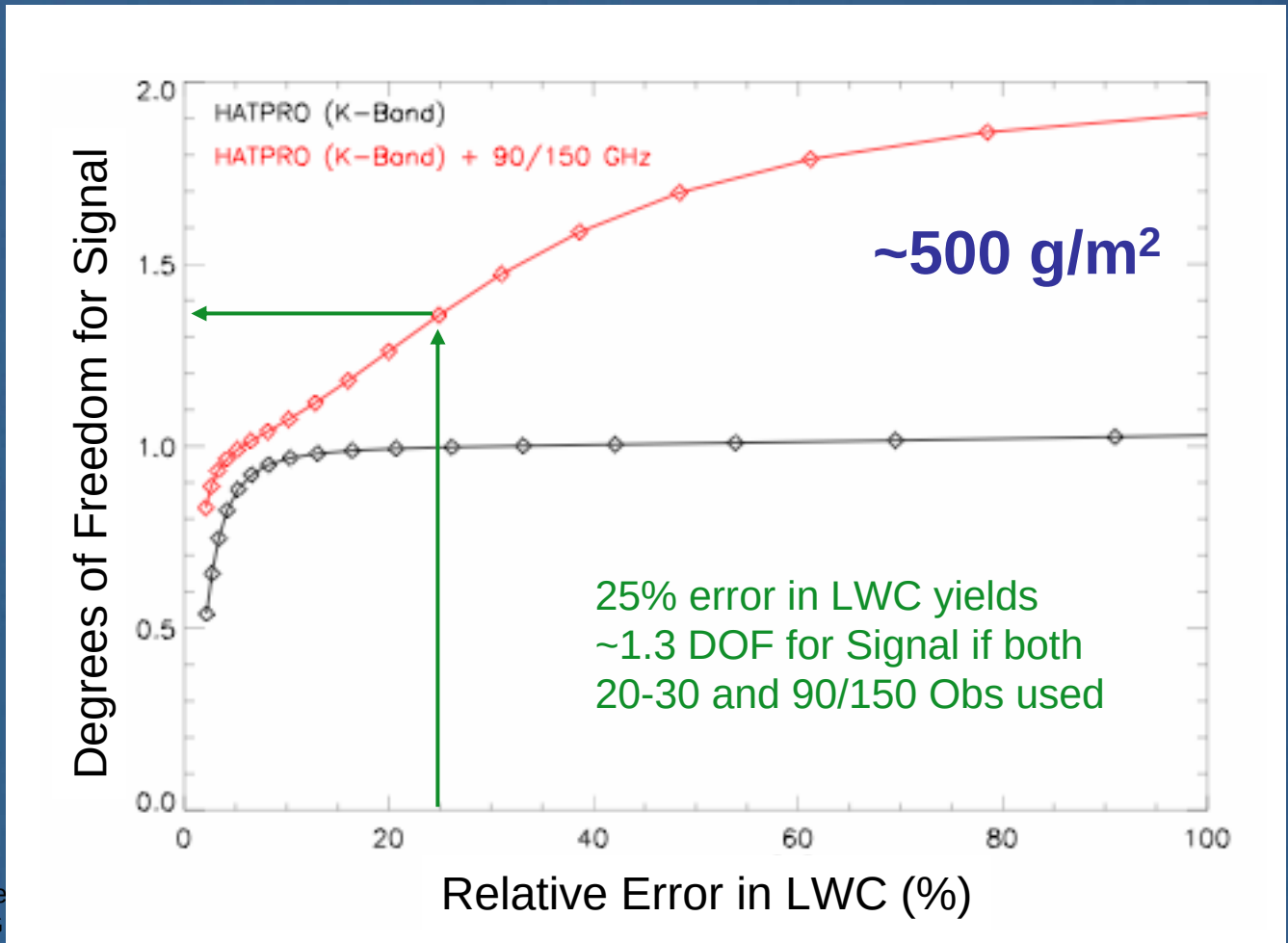
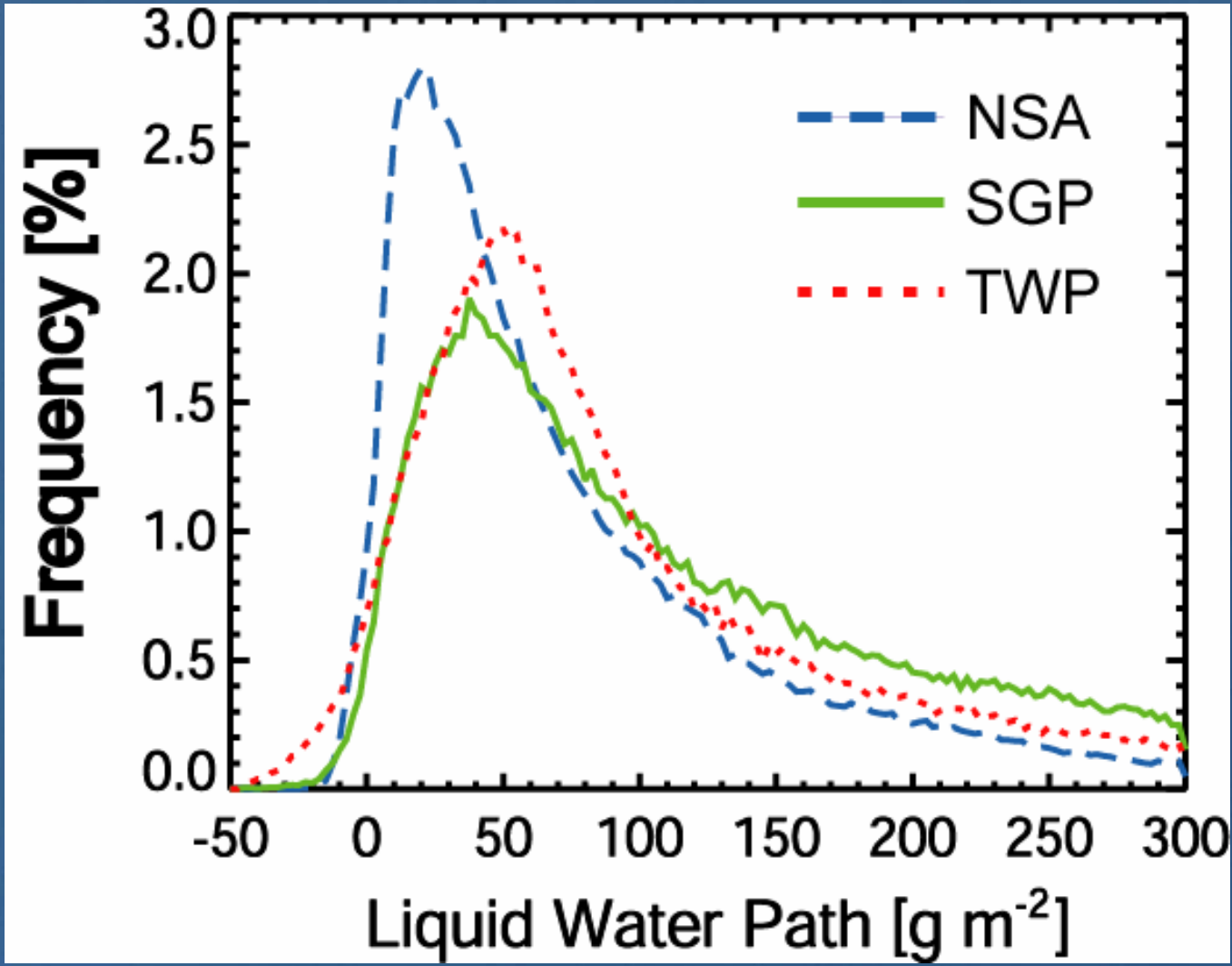


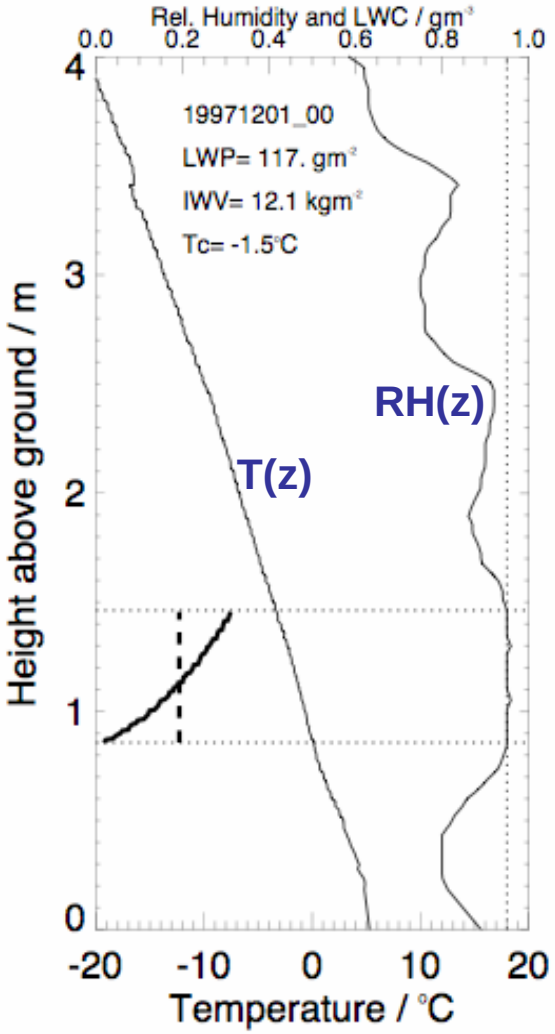
Distribution of LWP at ARM Sites

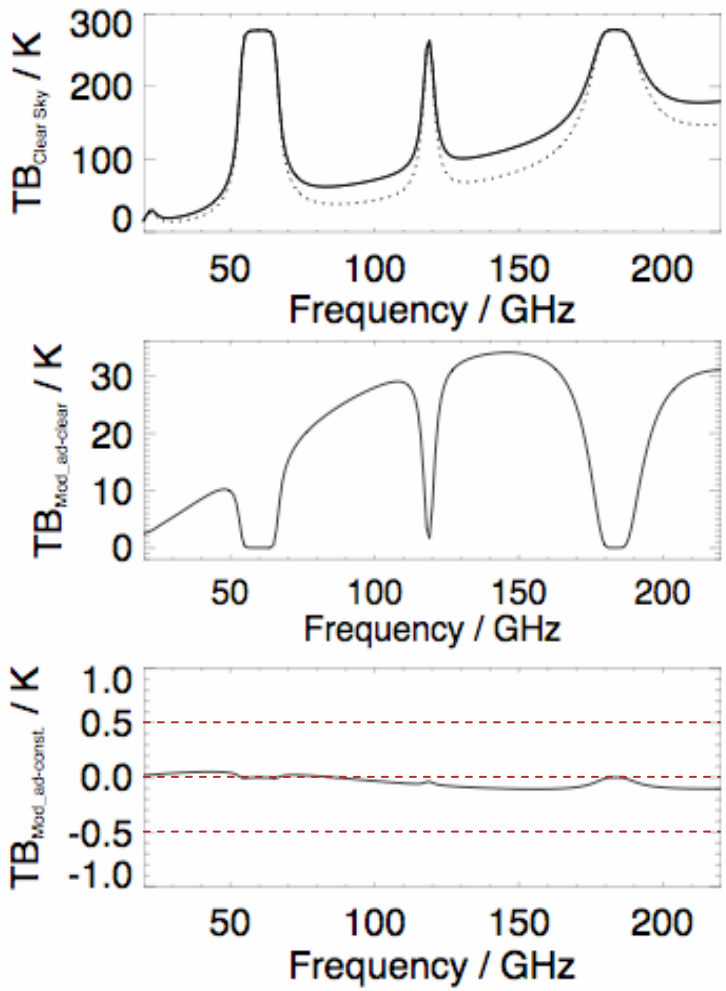


Most clouds have LWP << 200 g/m^2

Sensitivity of Microwave Obs to LWC(z)

Thinner Cloud – 117 g/m^2





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Cloud minus Clear

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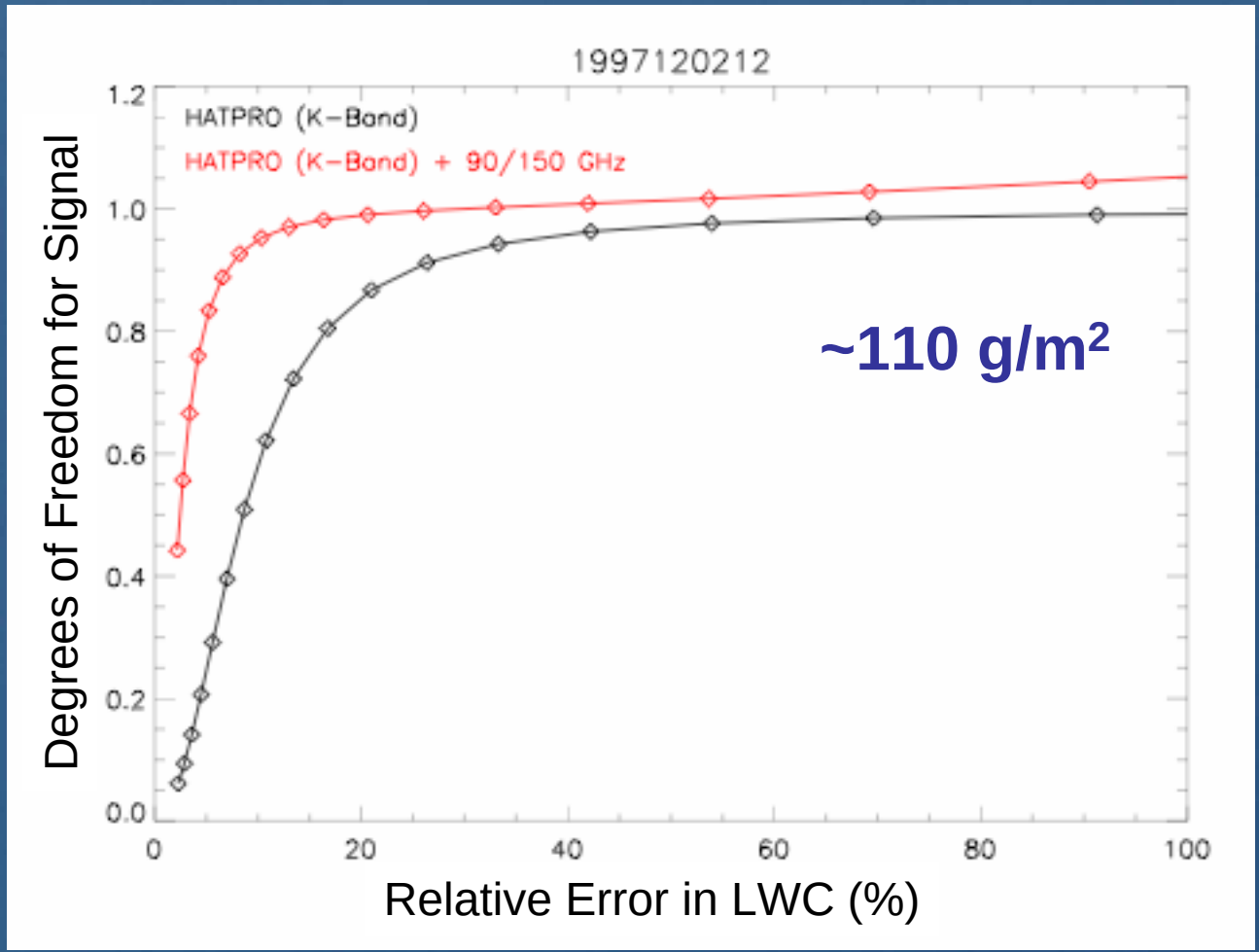
DoF Signal for LWC(z) in Thin Cld

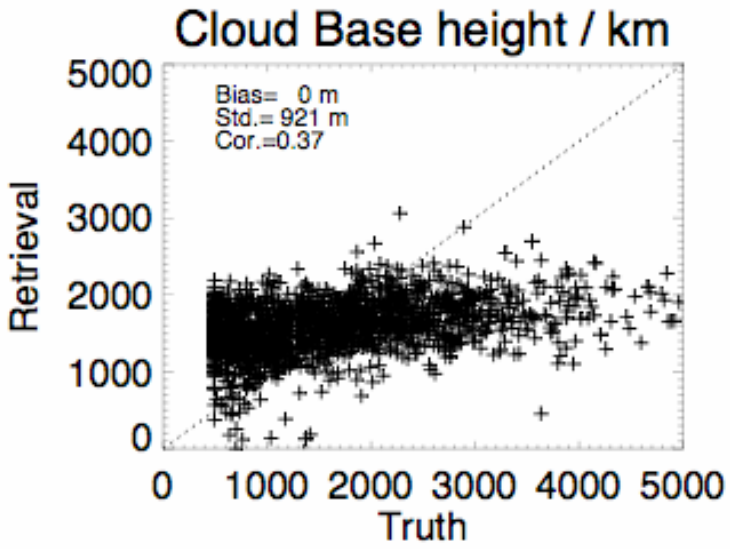


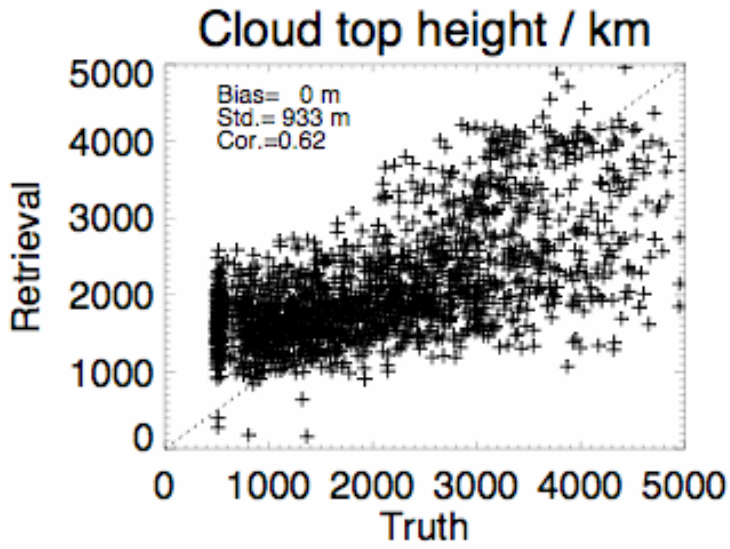
Number of independent pieces of info on LWC(z) is ~1.0 on this more typical cloud; even 90/150 obs don't really help

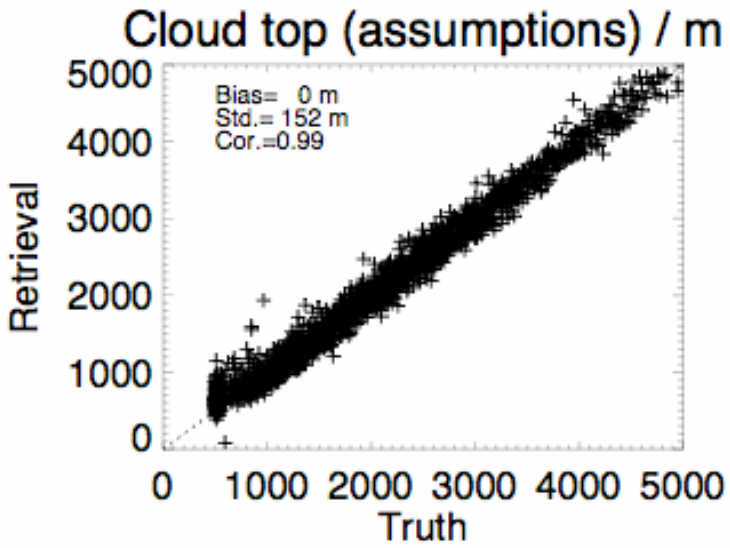
Conclusions

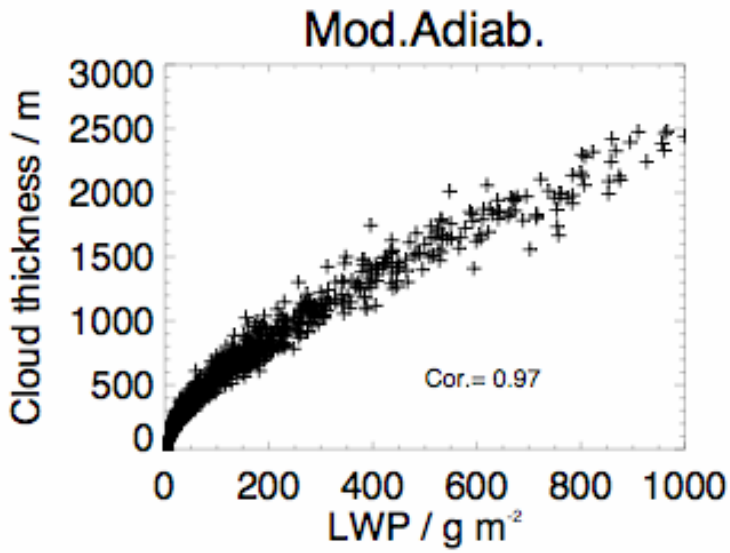
- Results assumed CBH and CTH of a single layer cloud is known, forward model is perfect, radiometer uncertainties are uncorrelated and are 0.5 K / channel
- Only under very ideal situations of thick cloud with large LWP are there more than ~1.1 DoF for signal
  - These clouds don't exist very often
  - These clouds are often precipitating
- In general, there is only **~1 piece** of information in passive zenith microwave observations between 20-31 GHz on LWC(z)
  - Addition of higher frequencies provides a little more information, but not significant improvement
  - Need to add additional information via scanning with multiple radiometers or with active remote sensors to get LWC(z)

Aside: Retrieving CBH and CTH

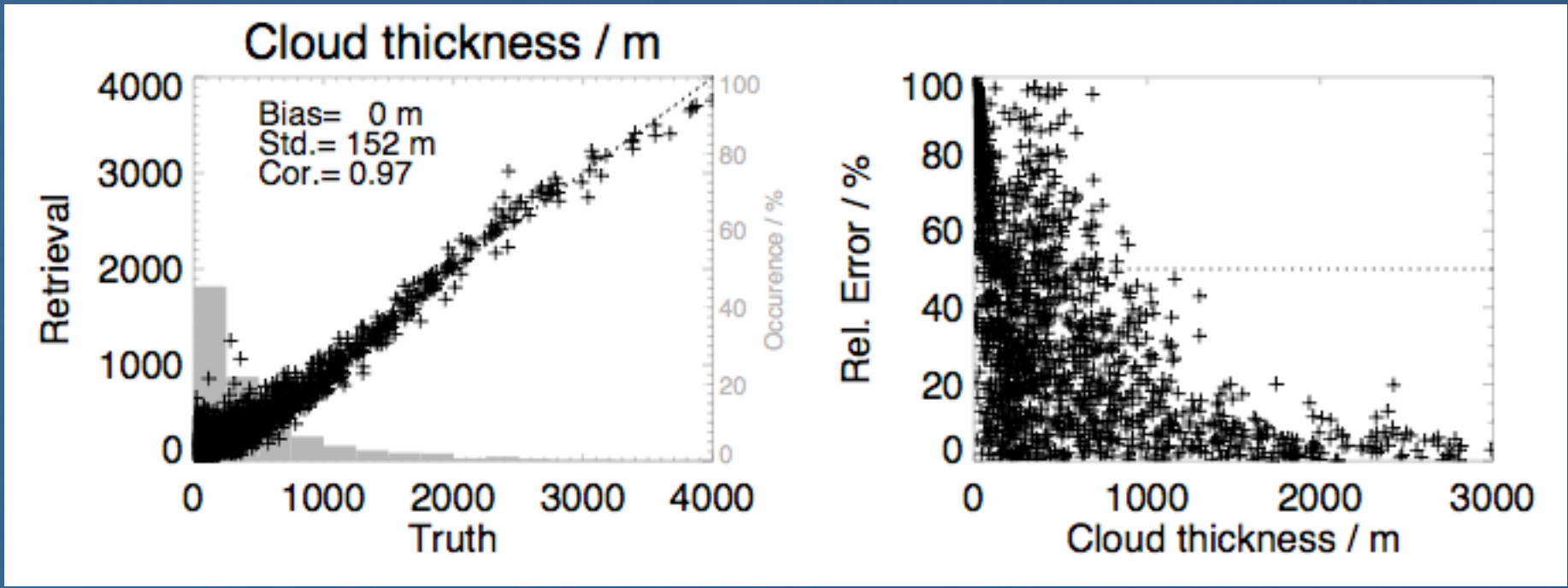








Large Uncertainties in Retrieved Cloud Thickness



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