Retrievals from sunphotometer cloud mode observations and synergy with HSRL-KAZR during MAGIC

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Outline

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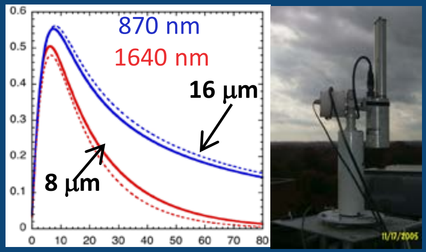
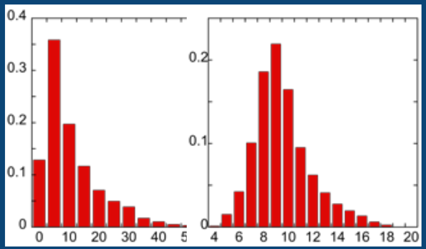
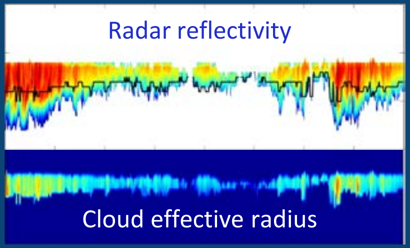


MAGIC sunphotometer cloud mode obs. and retrieval methods



Cloud statistics from cloud mode measurements



A showcase using synergy between cloud mode and active sensors

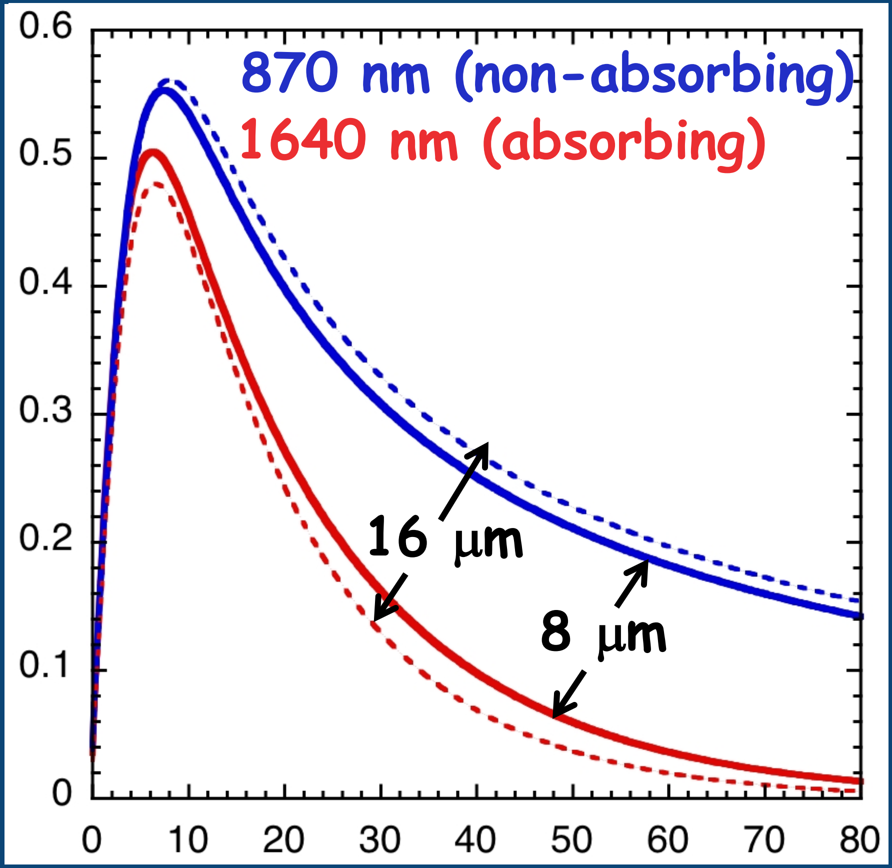
Cloud mode operations during MAGIC measure zenith radiance continuously every 10 s

- The old method requires vegetated surface
- 440, 870 and 1640 nm

Aerosol mode

Cloud mode

Zenith radiance



Cloud optical depth

Chiu et al. (JGR, 2010; ACP, 2012)

Retrieval method and performance using 3-channel zenith radiance

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- Retrieve cloud optical depth (τ) and effective radius (μm)
- Assuming constant cloud droplet # concentration and linearly increasing LWC with height (Wood and Hartmann, 2006); adiabatic assumption (McComiskey et al., 2009):

$$LWP = \frac{5}{9}\rho_w \cdot r_e \cdot \tau$$

$$N_d = C(T,P) \cdot \tau^3 \cdot LWP^{-2.5}$$

- RMSD: 2 optical depth; 1.5 μm; 20 g m^{-2}
- Take into account surface wind in ocean albedo calculations
- Correct pointing errors due to ship movements

Statistics of cloud optical depth and effective radius during May–July 2013

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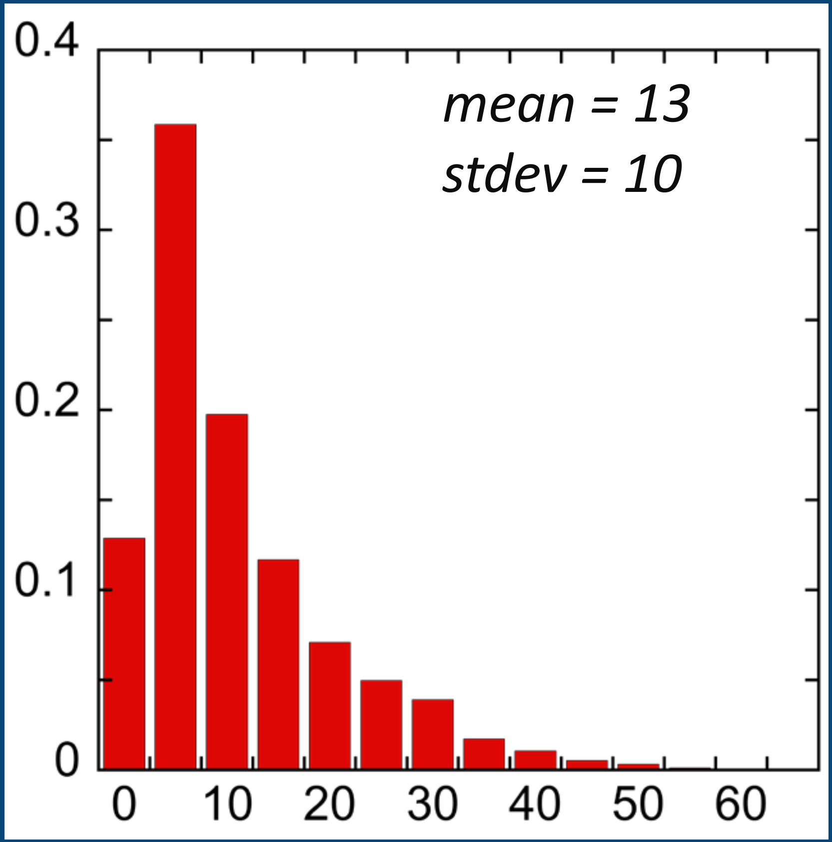
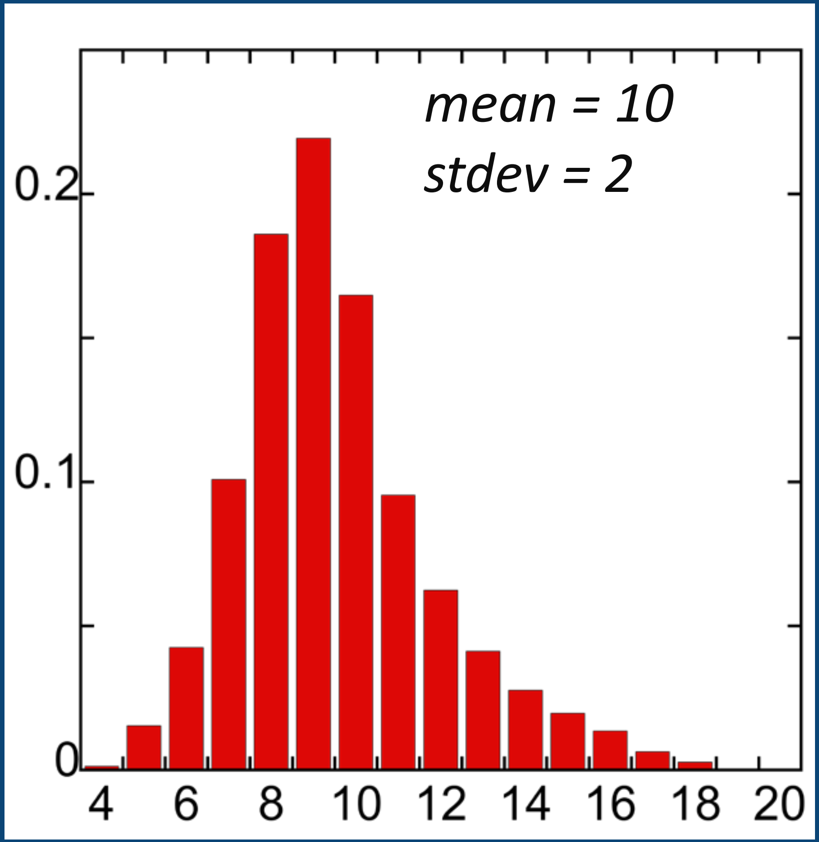
Frequency of occurrence



Cloud optical depth

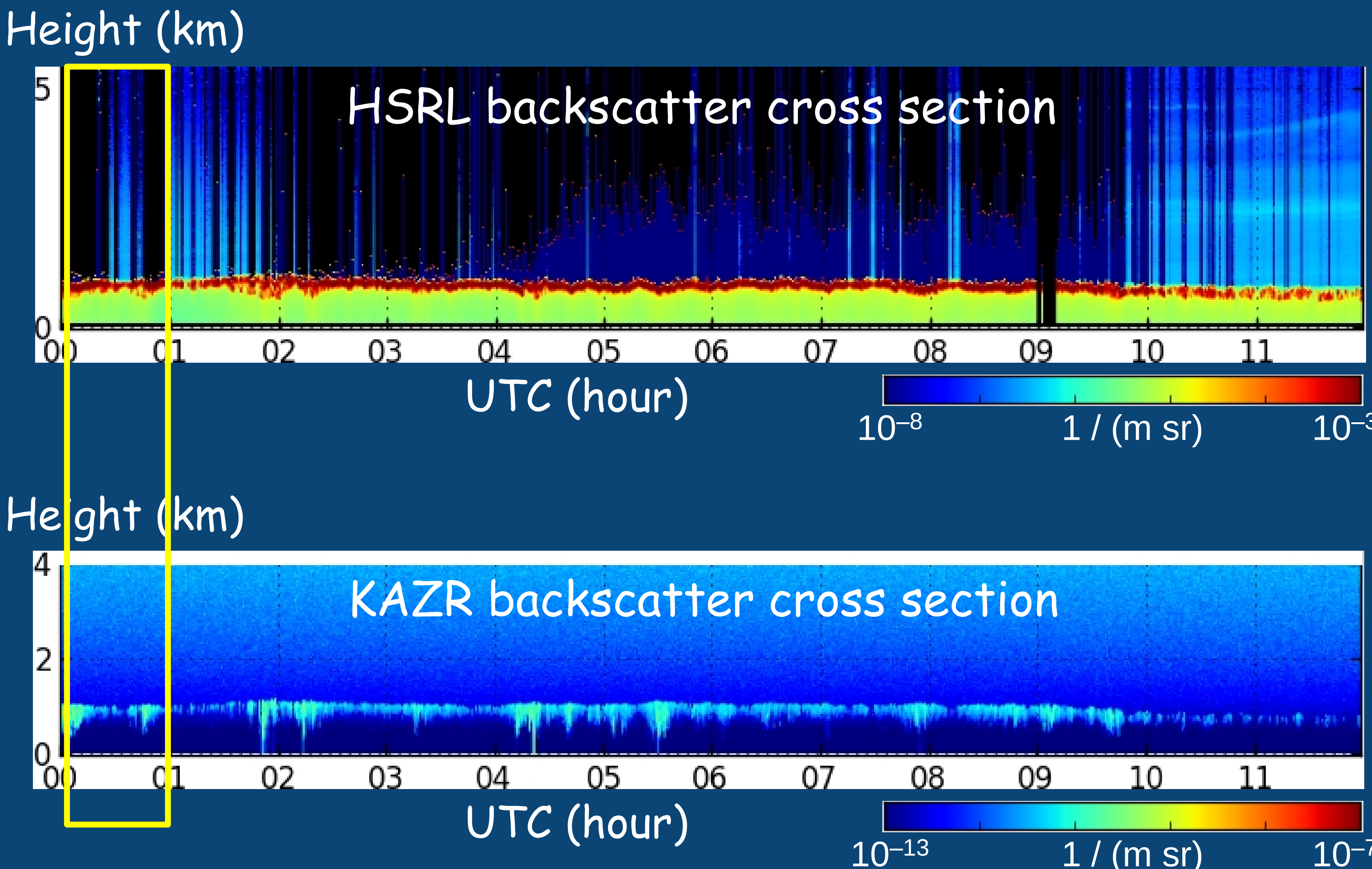


Cloud effective radius (μm)

1D ENCORE (Ensemble Cloud Retrieval)

- Combine KAZR, HSRL and sunphotometer observations
- Retrievals (i.e., state vector) are cloud droplet number concentration (height-invariant) and vertical profiles of effective radius
- Obs. uncertainty: 5% in radiance, 2dB in radar, 5dB in lidar (*corrections made for radiance, but not others yet*)
- Forward models
  - a lognormal cloud droplet size distribution
  - 1D radiative transfer

Case on June 2, 2013



courtesy of http://hsrl.ssec.wisc.edu

Zenith radiance constrains cloud optical depth well in 1D ENCORE (not surprising)

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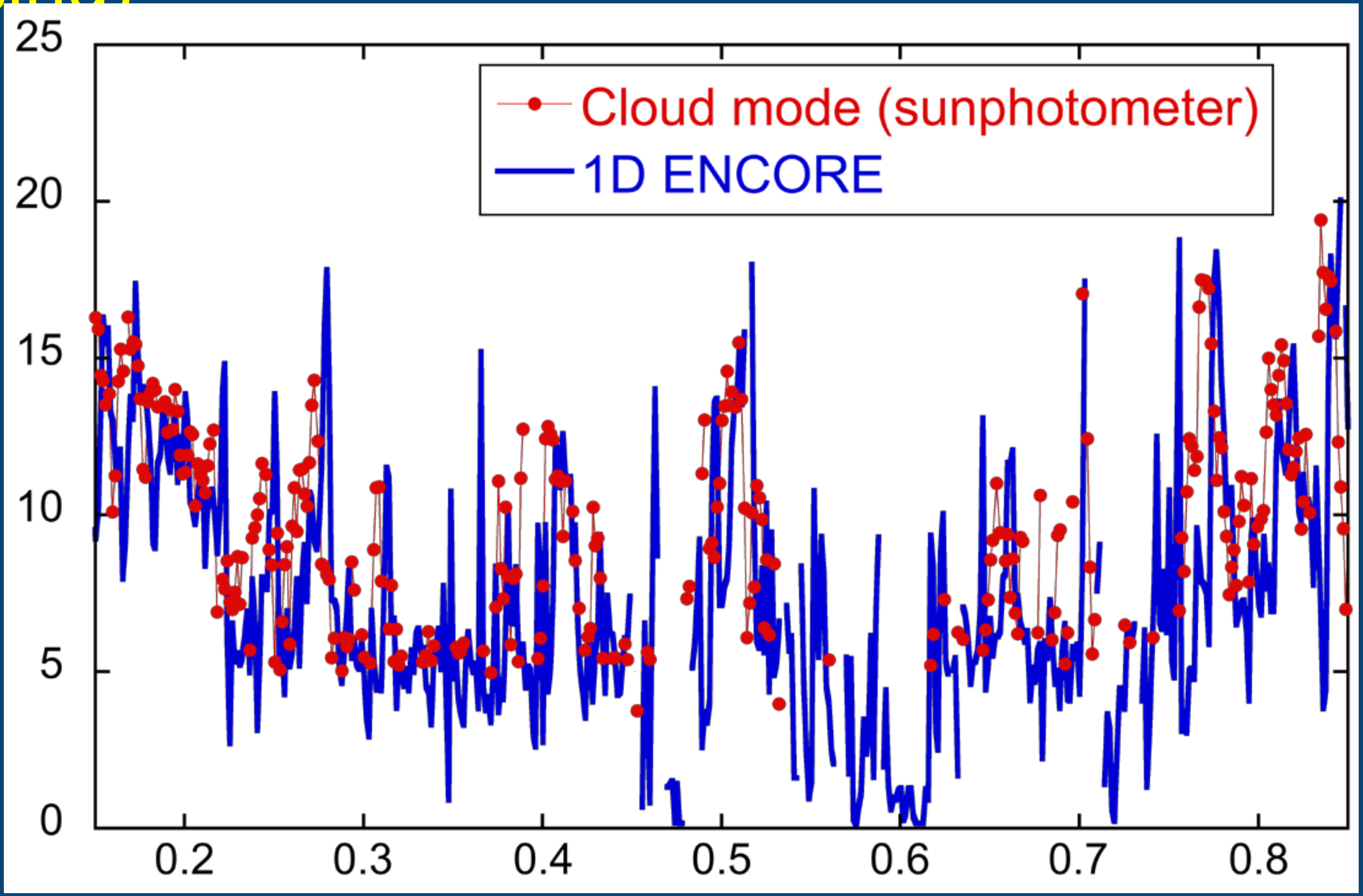
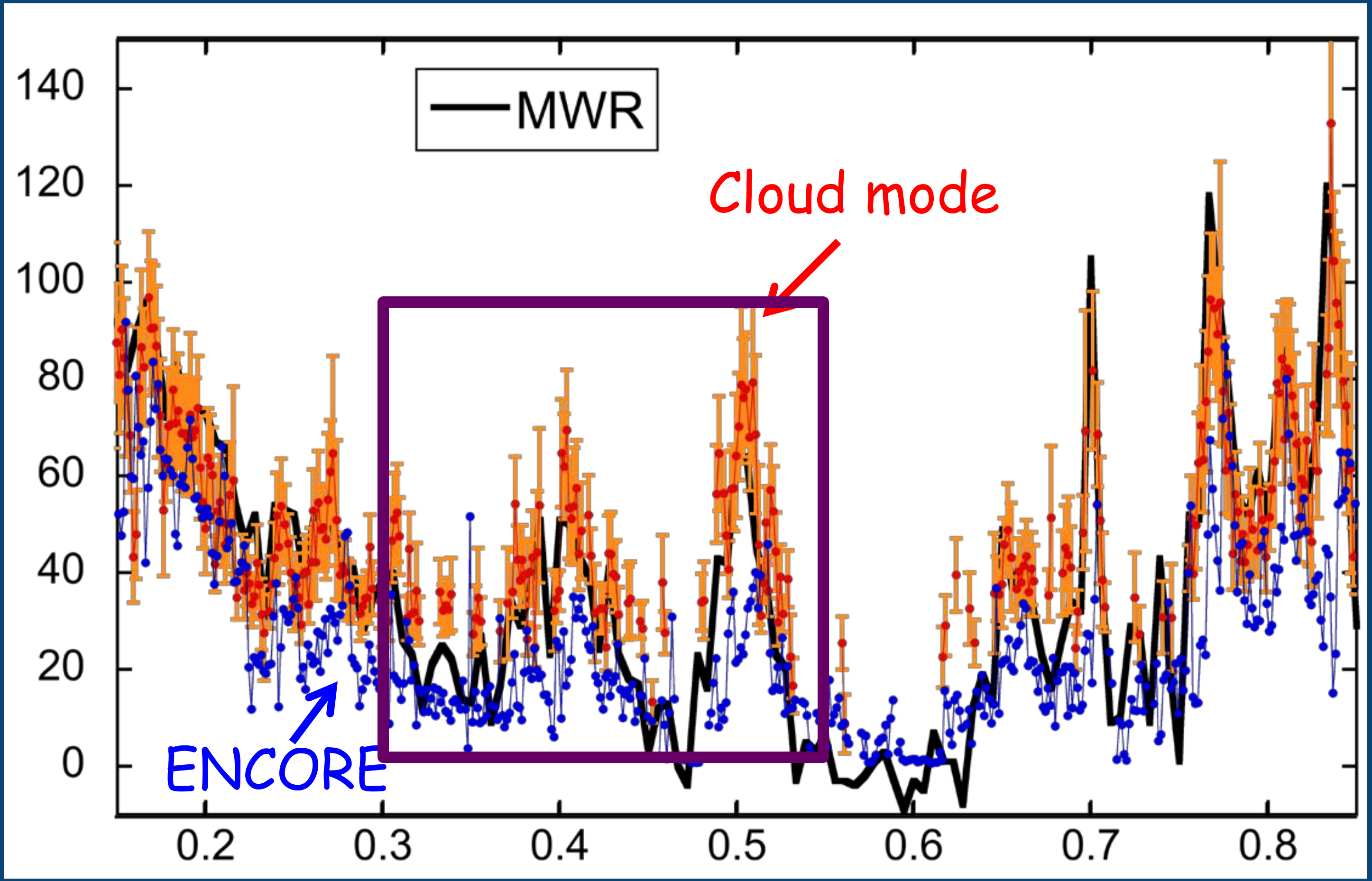
Cloud optical depth



UTC (hour)

OK agreement in liquid water path (puzzling)

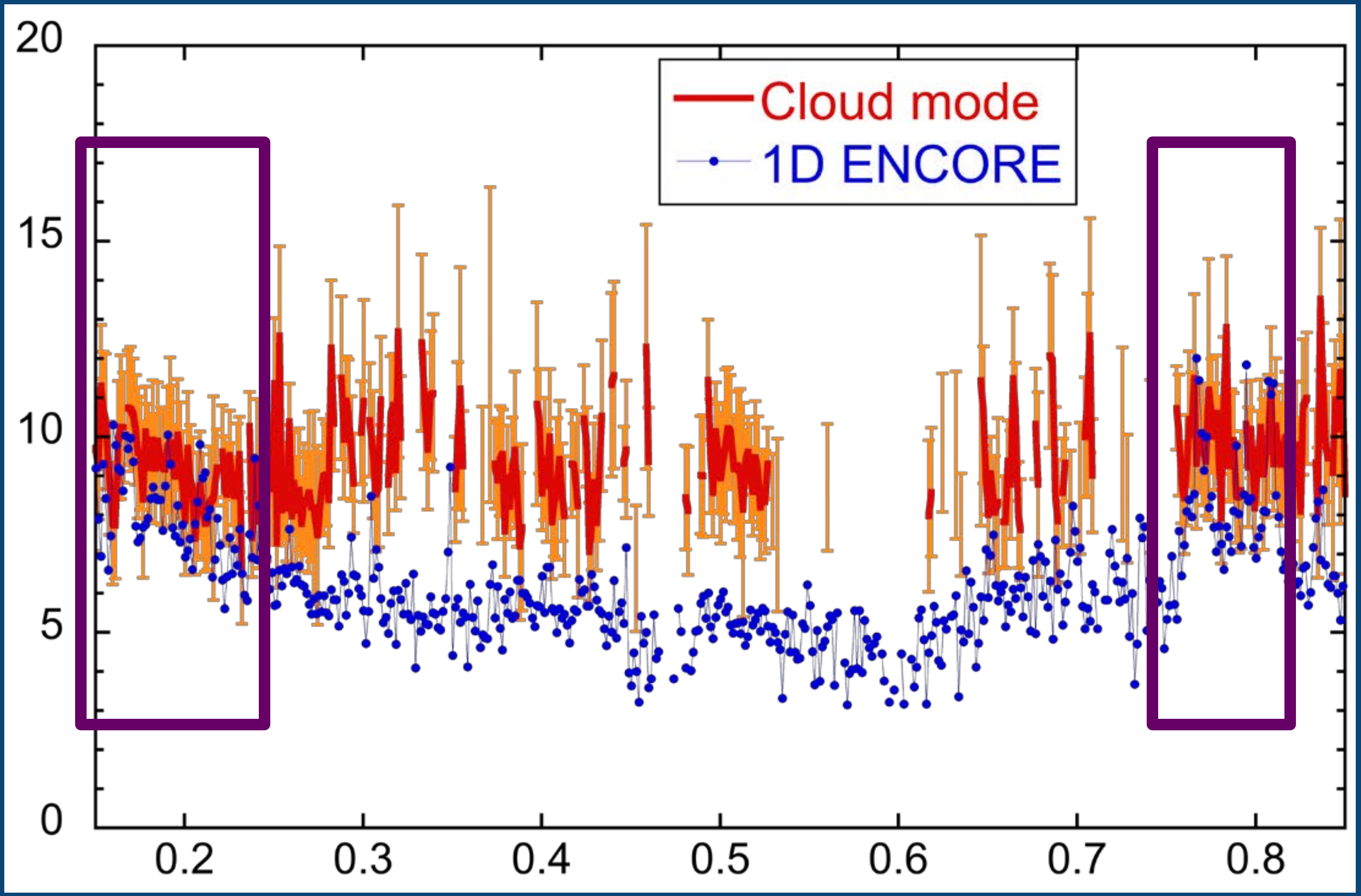
$$LWP = \frac{5}{9}\rho_w \cdot r_e \cdot \tau$$



Liquid water path (g m^{-2})

UTC (hour)

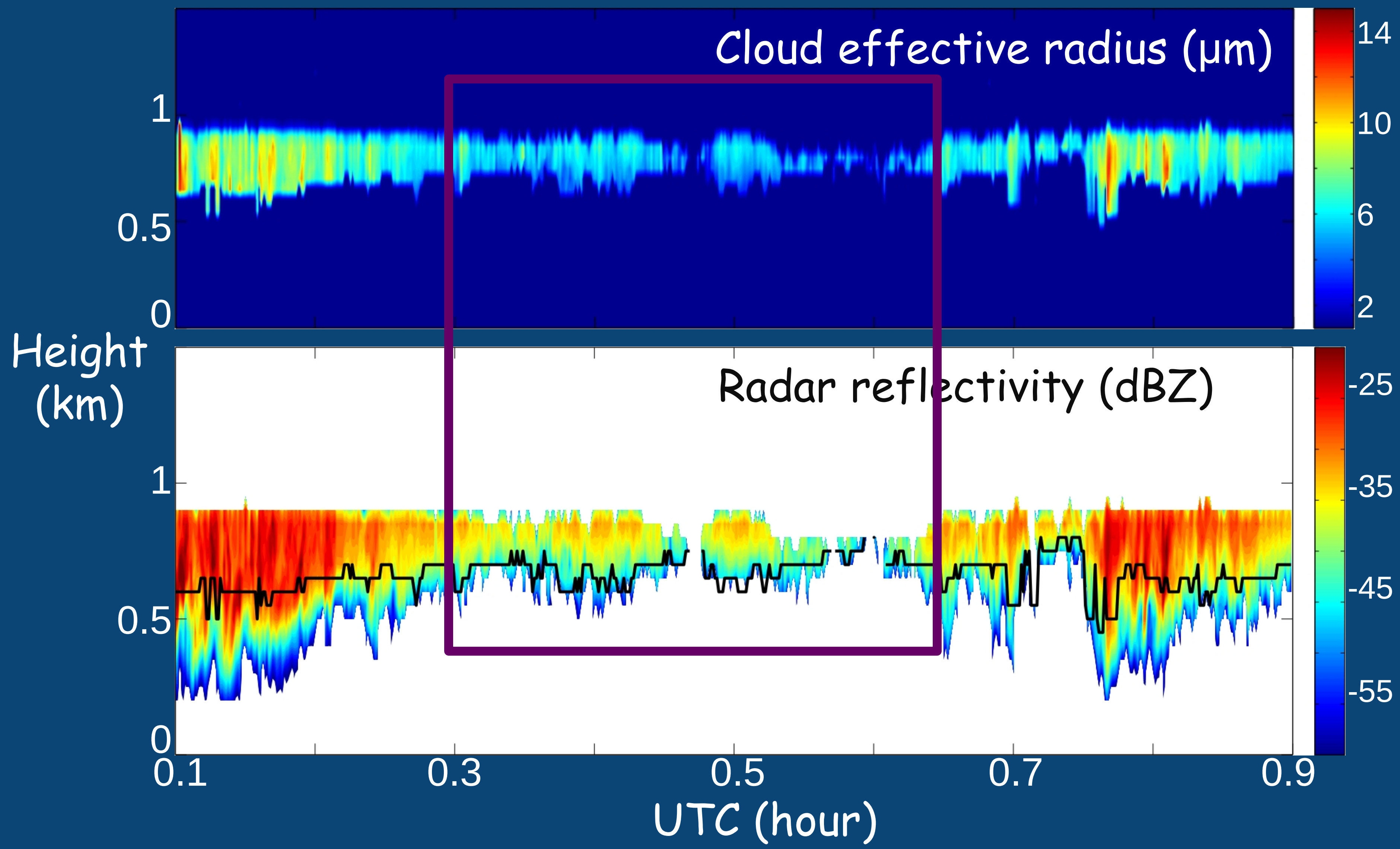
Difference in cloud effective radius retrievals between cloud mode and ENCORE is about 3 μm



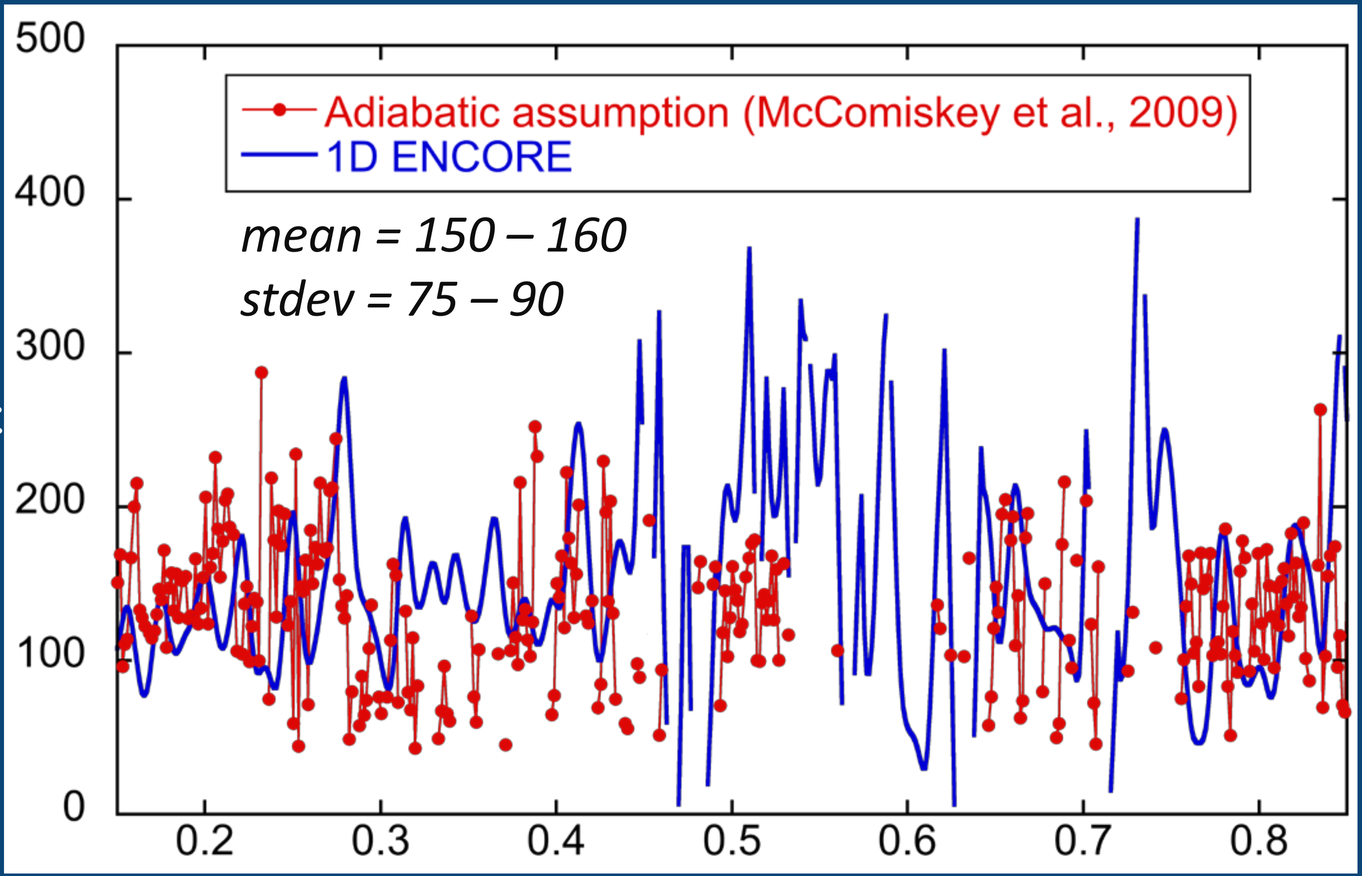
Cloud effective radius (μm)

UTC (hour)

Cloud effective radius is largely constrained by radar reflectivity



Cloud droplet number concentrations between two have similar means and standard deviaiton



$$N_d = C(T,P) \cdot \tau^3 \cdot LWP^{-2.5}$$

Summary

- Cloud mode observations during MAGIC show a mean optical depth of 13 and effective radius of 10 microns.
- 1D ENCORE that combines active/passive sensors show good agreements in optical depth and to some extent, in effective radius
- Compared to retrievals from cloud mode (only), the similar magnitude of number concentration and the relatively smaller droplet size in 1D ENCORE lead to smaller LWP