Aerosol proxies and their co-variability with cloud microphysics during MAGIC

David Painemal[1,2] and Patrick Minnis[2]
[1]SSAI, [2]NASA Langley

Christine Chiu
University of Reading

Ernie Lewis
Brookhaven National Laboratory

Motivation

- Simple quantification of the aerosol-cloud interaction (ACI)

  $ACI=d\ln(C)/d\ln(a_i)$

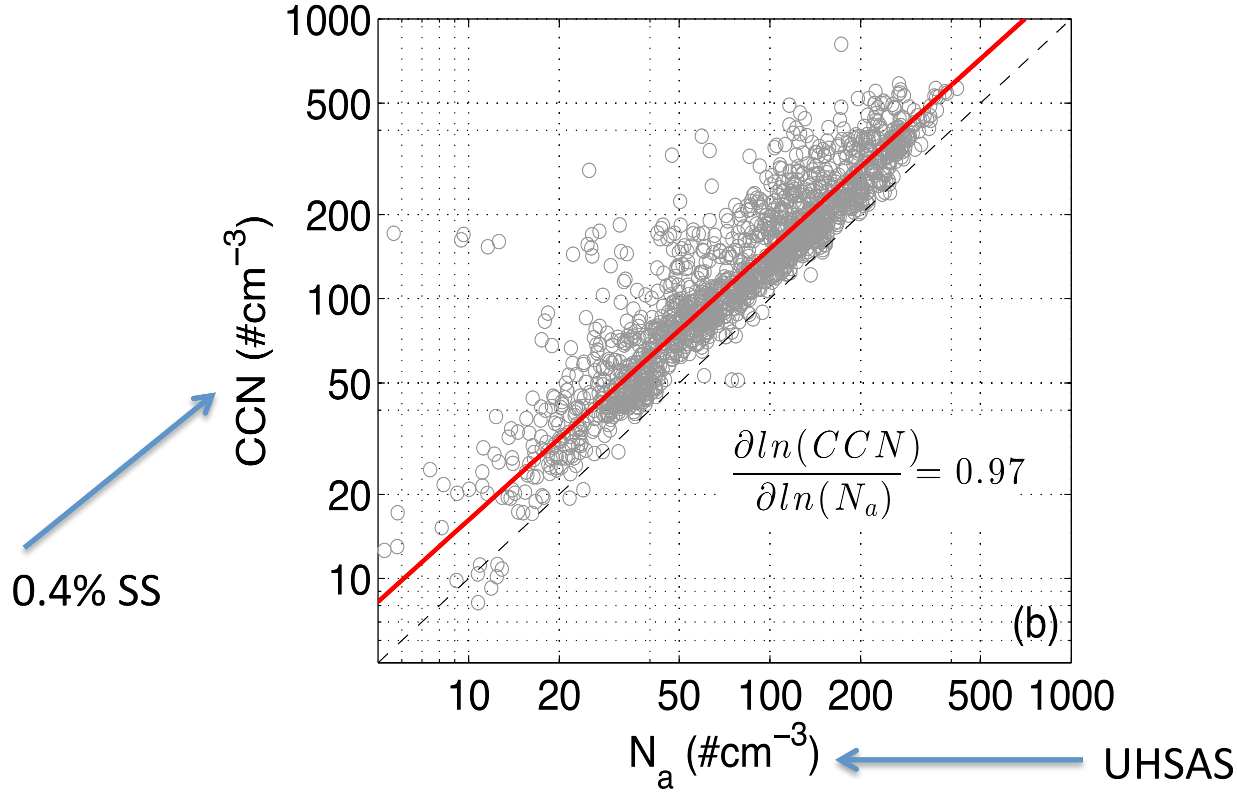
- C: cloud property, a_i: aerosol proxy
- Ideally, a_i=CCN
- Other aerosol measurements can also provide information about CCN but…
- They are not the same, i.e.:

- **$d\ln(C)/d\ln(a_1) \neq d\ln(C)/d\ln(a_2) \neq d\ln(C)/d\ln(a_3)$**

Dataset

- CCN probe: CCN at different supersaturation values
- Nephelometer: aerosol scattering coefficient
- Particle soot absorption photometer (PSAP): aerosol absorption coefficient
- Ultra-High sensitivity aerosol spectrometer (UHSAS): Dry aerosol size distribution (≤1 μm)
- High spectral resolution lidar: aerosol extinction and backscatter
- Probably we analyzed data from every single aerosol probe.

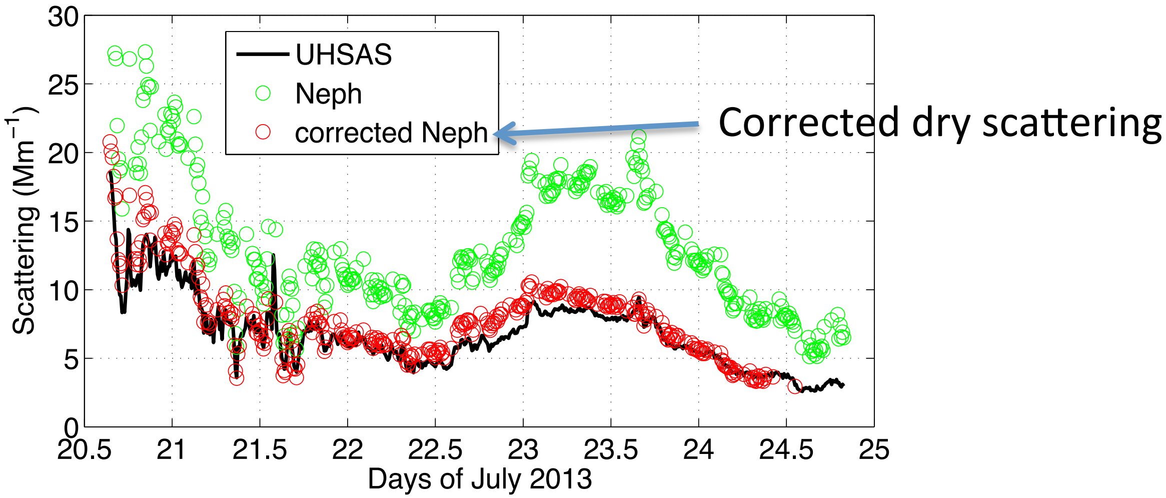
Accumulation mode (N_a) vs *CCN*



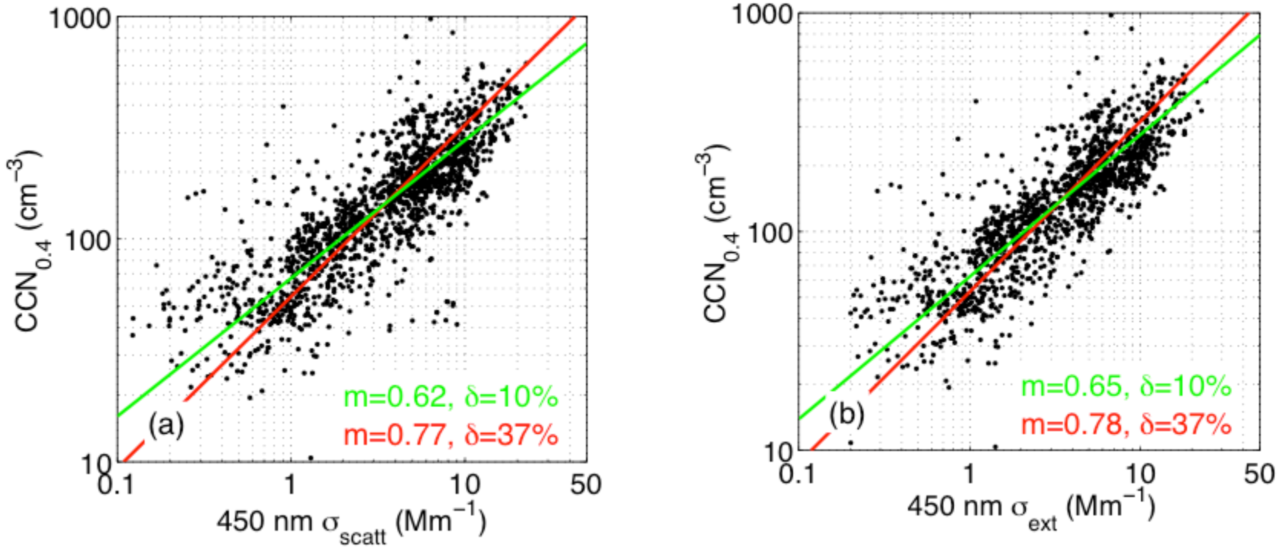
- Correlations near 1, slopes=0.97.
- Accumulation mode is a good CCN proxy.

Aerosol scattering (σ_{scat}) and extinction (σ_{ext}) vs *CCN*

- Dry nephelometer was not dry: instrument relative humidity was not ambient RH either.
- Correction: Commonly used approximation: $\sigma_{wet}=\sigma_{dry}*F$
- *F*: humidification factor, Gassó et al. (2000): $F=0.76*(1-RH/100)^{-0.69}$
- Nephelometer was compared against Mie calculation using UHSAS aerosol distribution and refractive index at =1.54+0i (ammonium sulfate, salt).



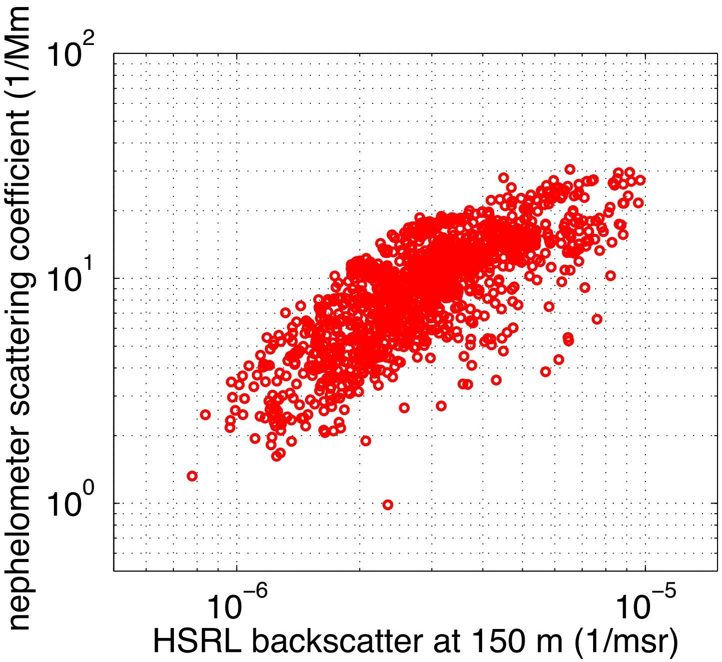
"Dry" scattering (σ_{scat}) and extinction (σ_{ext}) vs *CCN*



- σ-*CCN* slope 0.62-0.78 (York fit), depending on the error assumed in the measurements
- Contribution of absorption is modest. Mostly scattering.
- Results consistent with Shinozuka et al (2015, ACP)
- dln(Cloud)/dln(σ_{scat})<dln(Cloud)/dln(CCN)
- (1/0.77)*dln(Cloud)/dln(σ_{scat})=dln(Cloud)/dln(CCN)
- Lidar could offer suitable observations for aerosol indirect effect quantification.

High Spectral Resolution Lidar (HSRL): preliminary analysis

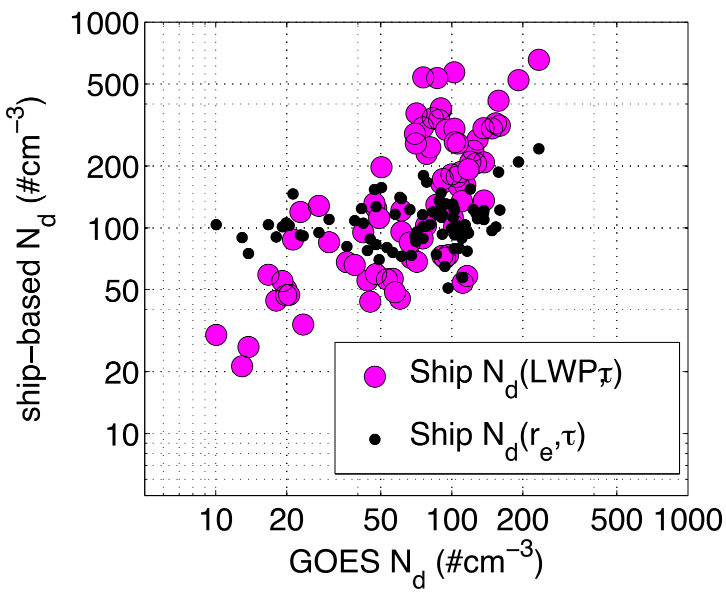
- Aerosol backscatter
- Preliminary comparison with nephelometer scattering (extinction) is promising.



Cloud droplet number concentration (N_d)

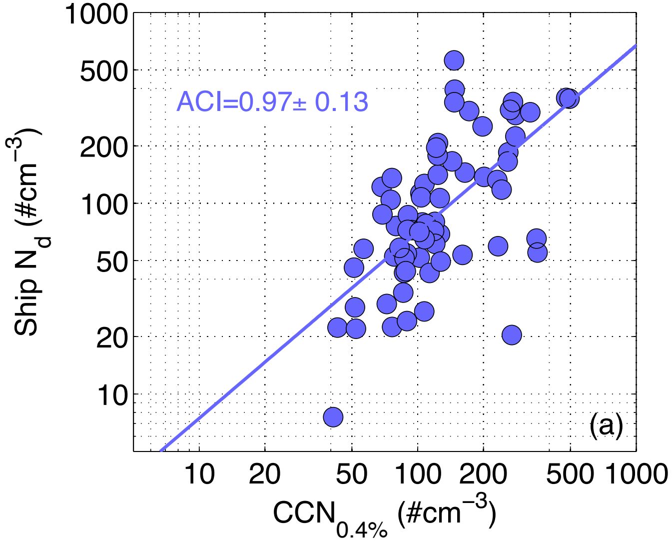
- $N_d = K^* \tau^3 * LWP^{5/2}$ or $N_d = K'^* \tau^{1/2} * r_e^{-3}$ (adiabatic-like)
- LWP: μ-wave radiometer (Cadeddu)
- τ and r_e: sun-photometer (Christine Chiu)

- We compared the data with GOES-15 satellite data (adiabatic-like), $N_d = K''^* \tau^{1/2} * r_e^{-3}$

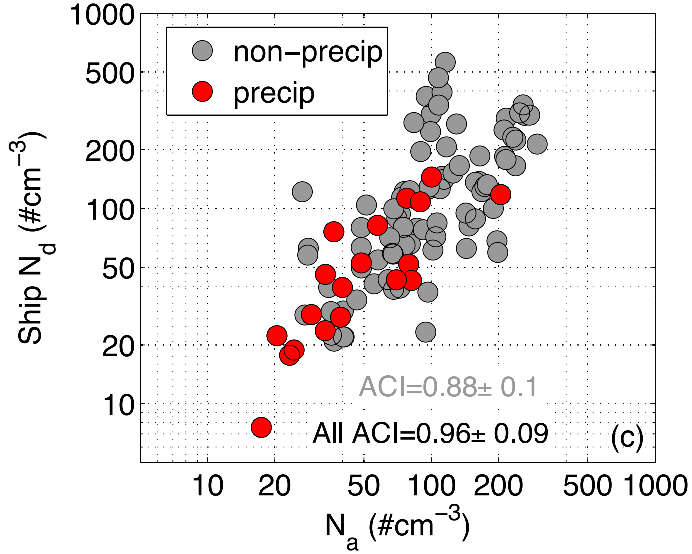


N_d vs aerosol concentration

CCN

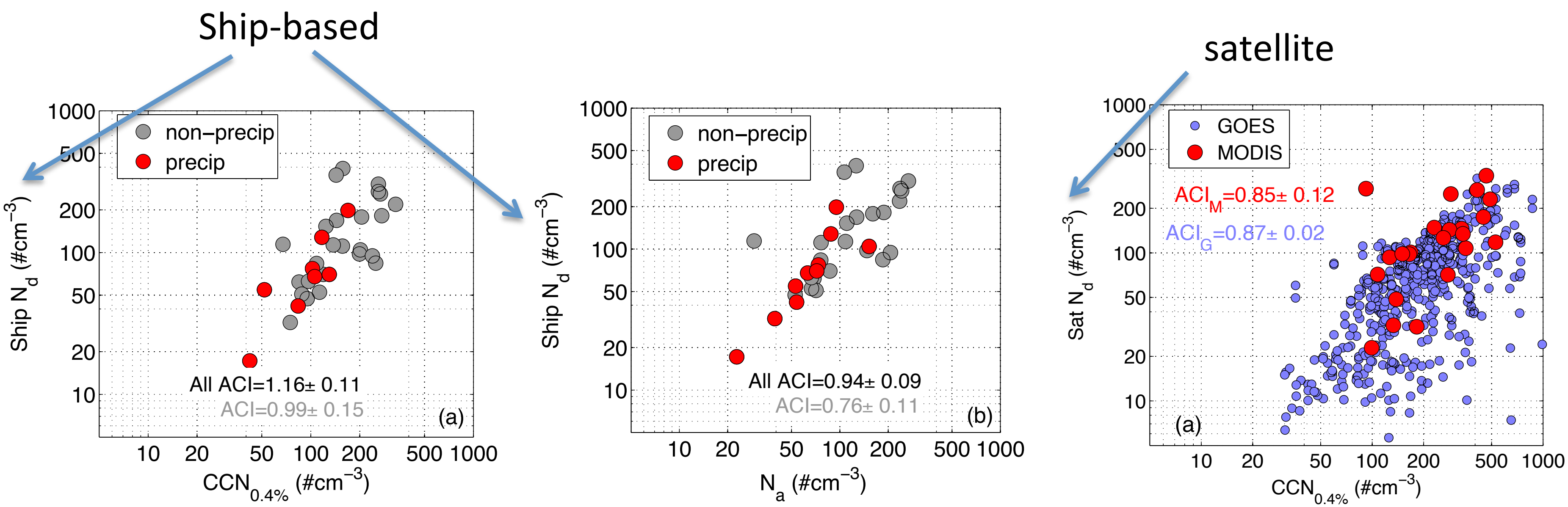


Accumulation mode



- Ship-based retrievals (10-min average)
- Linear correlation >0.9
- Slopes ACI=dln(N_d)/dln(*aerosol*)>0.88
- Low N_d consistent with precipitation (kazr)
- Precipitating samples tend to increase ACI.

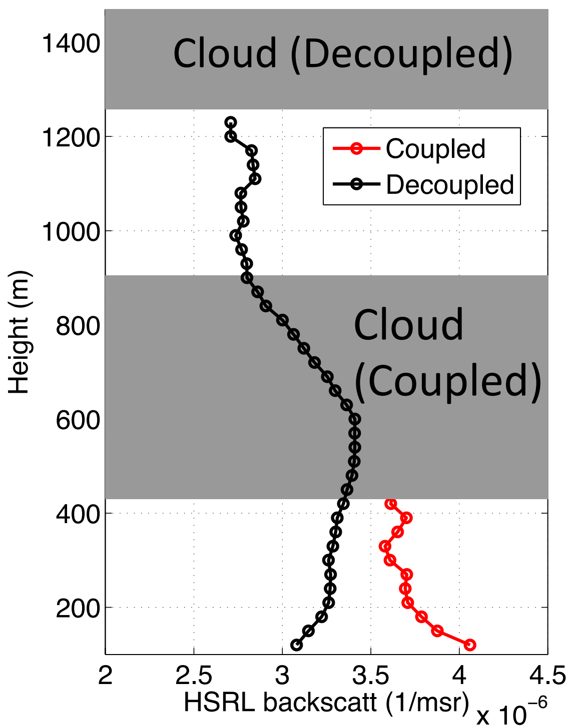
N_d vs aerosol concentration: One-hour average

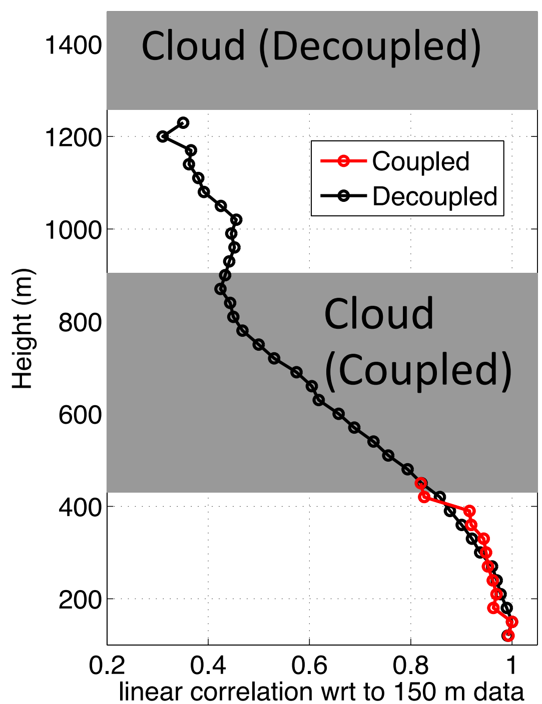


- Aerosol-N_d slopes remain high
- Consistency between ship-based and satellite N_d

HSRL: Aerosol vertical distribution

- Vertical structure under different boundary layer coupling
- Coupled: cloud base height-LCL<200 m
- Decoupled: cloud base height-LCL>400 m





Summary

- Close agreement among different aerosol measurements.
- Aerosol-cloud interactions are near the upper physical limit.
- HSRL provides relevant information about the aerosol vertical structure.
- Coupled vs decoupled boundary layers: BL deepening might influence the comparison between surface-based aerosol measurements and cloud properties

- *Acknowledgements: DOE-ARM Award # DE-SC0011675, CERES program*

Extra slide :Cloud adiabaticity

- Adiabatic liquid water path (LWP_{ad}) against the 3-ch microwave radiometer (MWR)

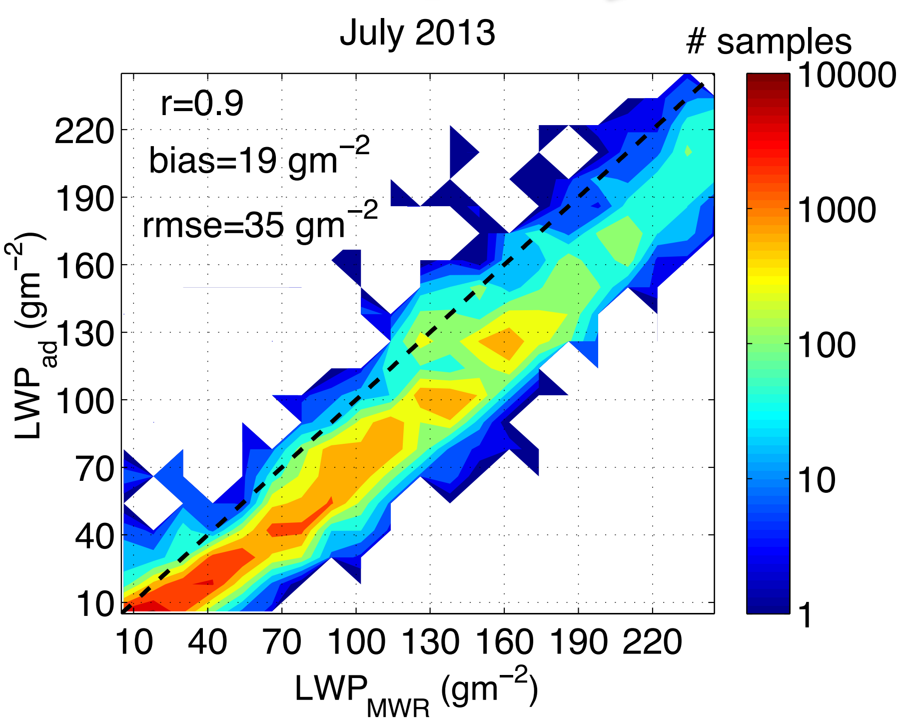
$$LWP_{ad} = K \cdot \frac{(Z_{top} - Z_{base})^2}{2}$$

$$K = K(P_c, T_c)$$

Z_{top}, Z_{base} → Ka-band radar, courtesy of X. Zhou/ P. Kollias (McGill U./BNL)

Z_{base} → ceilometer

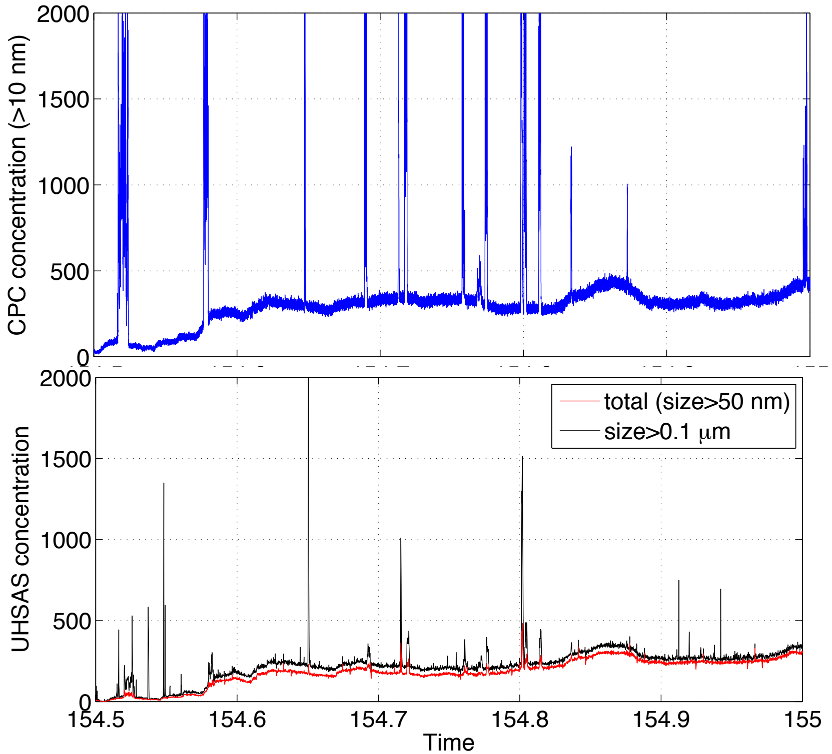
P_c, T_c → radiosondes



- High linear correlation between adiabatic and MWR estimates.
- Constant positive bias of MWR needs further investigation
- Degree of adiabaticity is difficult to address due to retrievals uncertainties
- **Adiabatic assumption appears to be appropriate**

Extra slide: Aerosol measurements during MAGIC

- CCN, CN probes, and aerosol concentration from the UHSAS are qualitatively consistent but….
- Frequent peaks of very high aerosol concentration. UHSAS data reveal that peaks are explained by very large concentrations of small particles (<0.1 μm)



Several methods to filter out CCN data:

- Simple method: Average data and remove samples with high standard deviation (e.g. 100/ cc)
- More sophisticated method: use UHSAS data to remove samples with small aerosol effective radius, but some high values might remain.