MBL Cloud Properties and Surface CCN from Azores-AMF Observations

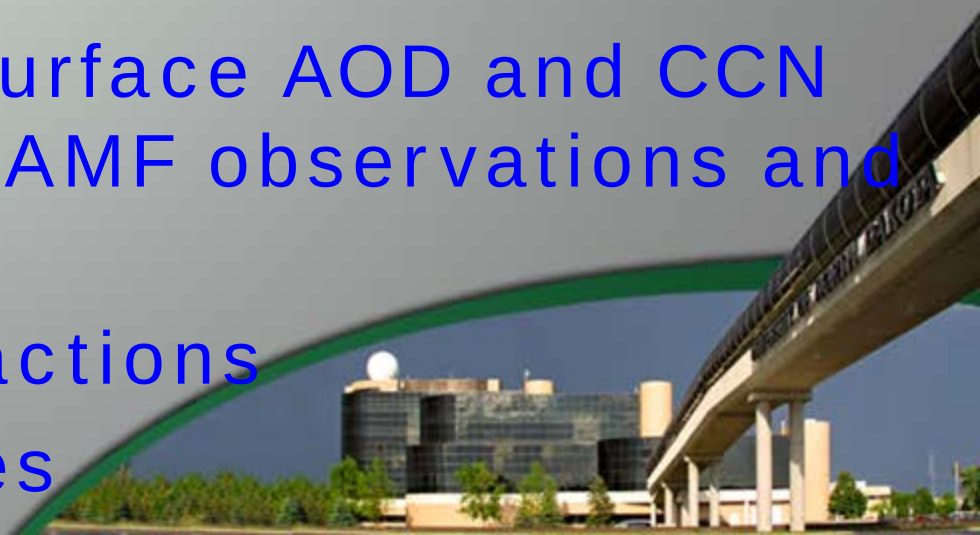
Xiquan Dong, University of North Dakota

With Contribution of Peng Wu, Adam Schwants, Tim Logan and Baike Xi, University of North Dakota

Goals:

1) Seasonal and diurnal variations of MBL cloud properties and surface AOD and CCN from 19-month Azores-AMF observations and retrievals

2) Aerosol-cloud Interactions from 7 selected cases



Location of DOE ARM Azores site

Dominated by clean airmasses but with periodic episodes of polluted air masses advected from the continents

Dong et al. 2014a
Logan et al. 2014

1) Seasonal and diurnal variations of MBL cloud properties and surface AOD and CCN from 19-month Azores-AMF observations and retrievals

Showing a few highlights we submitted

Aerosol Properties and Size Distribution over the Azores

Xiquan Dong / University of North Dakota

Science Question

What are the seasonal variations of aerosol properties over the Azores?

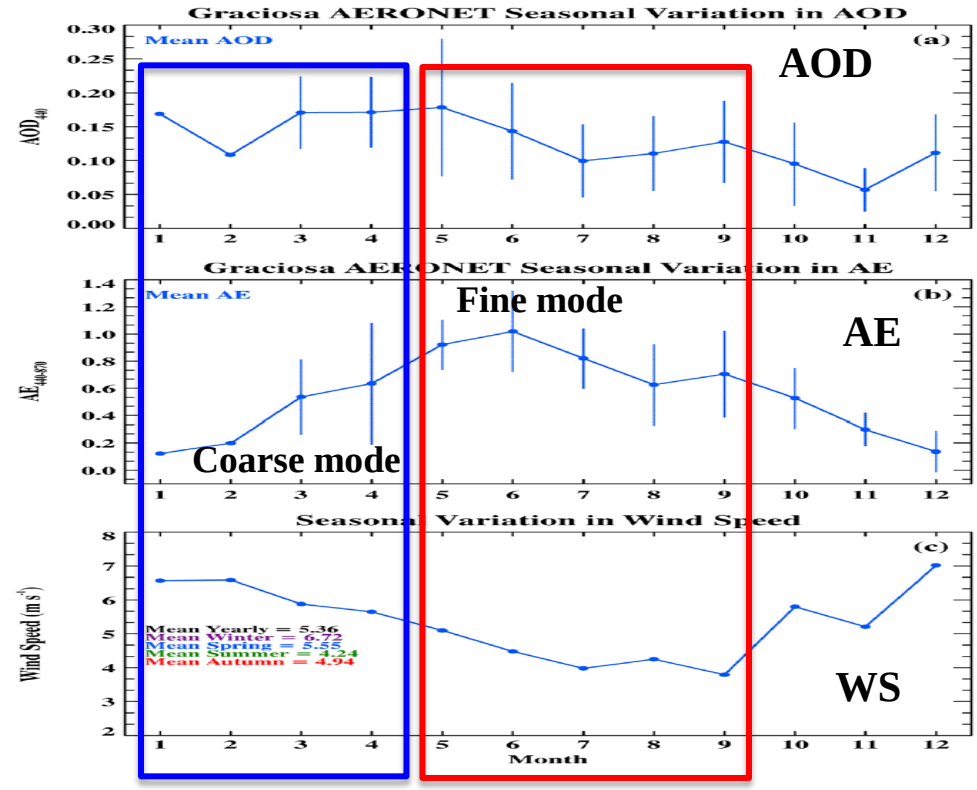
Are these aerosol properties impacted by the synoptic patterns?

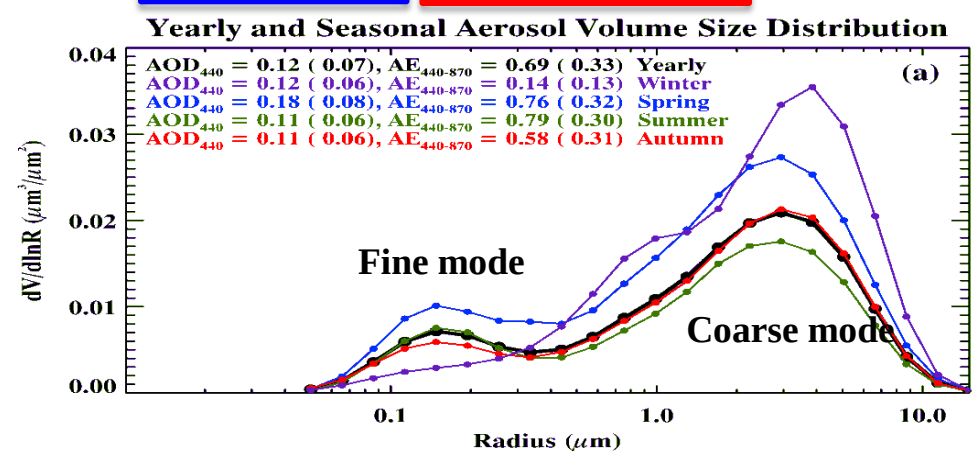
Key Accomplishment

1) The winter and early spring months had the highest surface wind speed (> 5 m s^{-1}) and greatest contribution of sea salt to AOD (coarse mode), while continental fine mode aerosols contribute more to AOD from May to September.
2) A bimodal aerosol size distribution with coarse mode (r ≥ 1 μm) dominated that of the fine mode (r < 1 μm) throughout the year.
3) The coarse mode aerosols (e.g., sea salt) dominated during the winter and spring months due to persistent low-pressure system. However, weather patterns begin to advect continental aerosols during the spring months over the Azores region as evidenced by the larger fine mode number concentrations and higher AE values.

Publication

Logan, T., B. Xi, and **X. Dong** (2014), Aerosol properties and their influences on marine boundary layer cloud condensation nuclei at the ARM mobile facility over the Azores, JGR, 119, doi:10.1002/2013JD021288.





Cloud fractions derived from the Azores-AMF deployment

Xiquan Dong / University of North Dakota

Science Question

What are the seasonal variations of cloud fractions at the Azores?

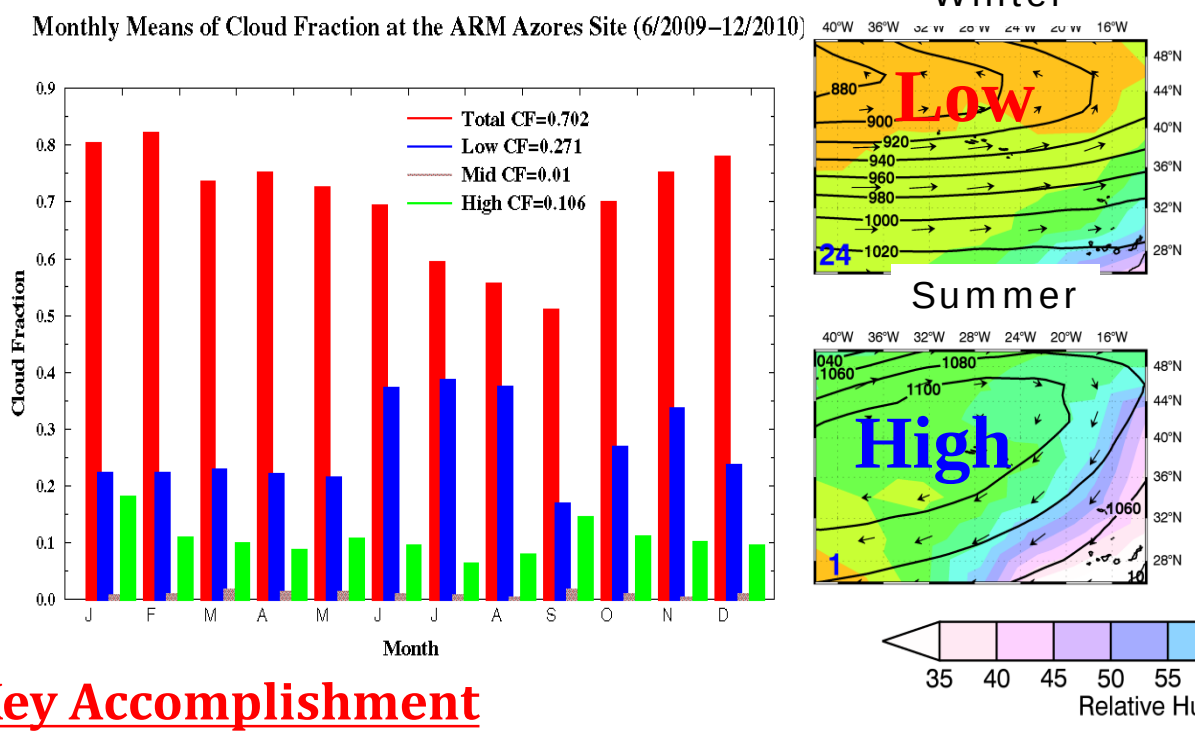
How do the seasonal variations of CFs associate with the synoptic patterns?

Approach

- **Using the ARM radar-lidar observations to derive total, high, middle and low cloud fractions.**
- **Using the NASA MERRA reanalysis to generate the synoptic patterns**

Publication

Dong, X., B. Xi, A. Kennedy, P. Minnis and R. Wood, 2014: A 19-month record of Marine Aerosol-Cloud-Radiation Properties derived from DOE ARM AMF deployment at the Azores: Part I: Cloud Fraction and Single-layered MBL cloud Properties. *J. Clim.*, 27, 3665-3682. DOI: 10.1175/JCLI-D-13-00553.1



Key Accomplishment

1) **Greater total and single-layered high (> 6 km) CFs occurred during the winter, while single-layered low (< 3 km) CFs were more prominent during summer.**
2) **Persistent high pressure and dry conditions produce more single-layered MBL clouds and fewer total clouds during summer, while the low pressure and moist air masses during winter generate more total and multilayered clouds, and deep frontal clouds associated with mid-latitude cyclones.**

Profiles of CFs derived from the Azores-AMF deployment

Xiquan Dong / University of North Dakota

Science Question

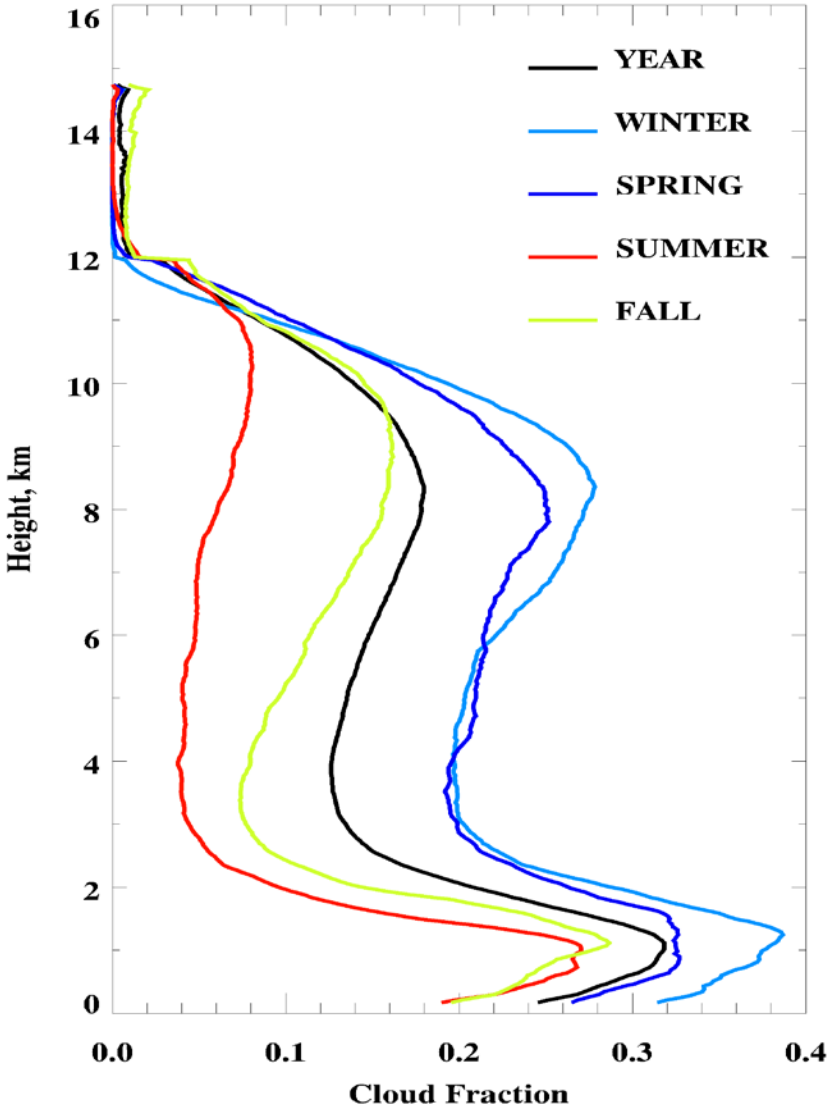
What are vertical distribution of Clouds (by season) over the Azores?

Approach

- **Using the ARM radar-lidar observations to derive vertical distributions of clouds.**

Key Accomplishment

Bimodal distributions with peaks of 1 km and 8 km, respectively. More clouds during winter and spring, less clouds during summer



Publication

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Seasonal Variation of MBL cloud properties and surface CCN over the Azores

Xiquan Dong / University of North Dakota

Approach

Daytime: Dong et al. 1998

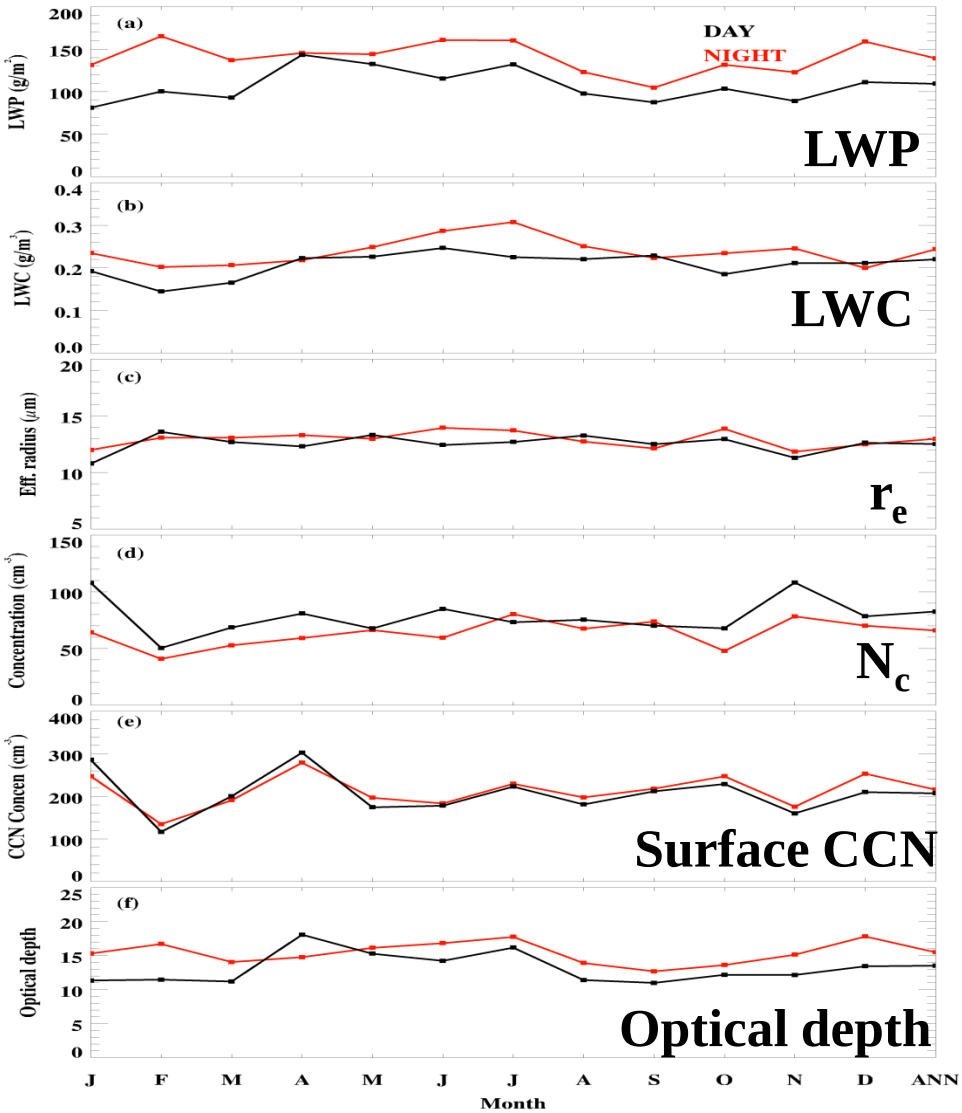
Nighttime: Dong et al. 2014b

Key Accomplishment

1) No strong seasonal variations in MBL cloud properties.

2) Nighttime monthly means of *LWP* are 31 gm^{-2} larger than the daytime means (109 gm^{-2}), which results in higher nighttime cloud *LWC* and optical depth.

3) Nighttime monthly means of r_e (12.9 um) are nearly identical to the daytime means with an annual difference of 0.4 µm. The day-night differences in monthly mean N_c (83 vs. 66 cm^{-3}) and N_{CCN} (207 vs. 216 cm^{-3}) are also small.



Publication

Dong, X., et al., 2014a: A 19-month record of Marine Aerosol-Cloud-Radiation Properties derived from DOE ARM AMF deployment at the Azores: Part I: Cloud Fraction and Single-layered MBL cloud Properties. *J. Clim.*, 27, 3665-3682. DOI: 10.1175/JCLI-D-13-00553.1.

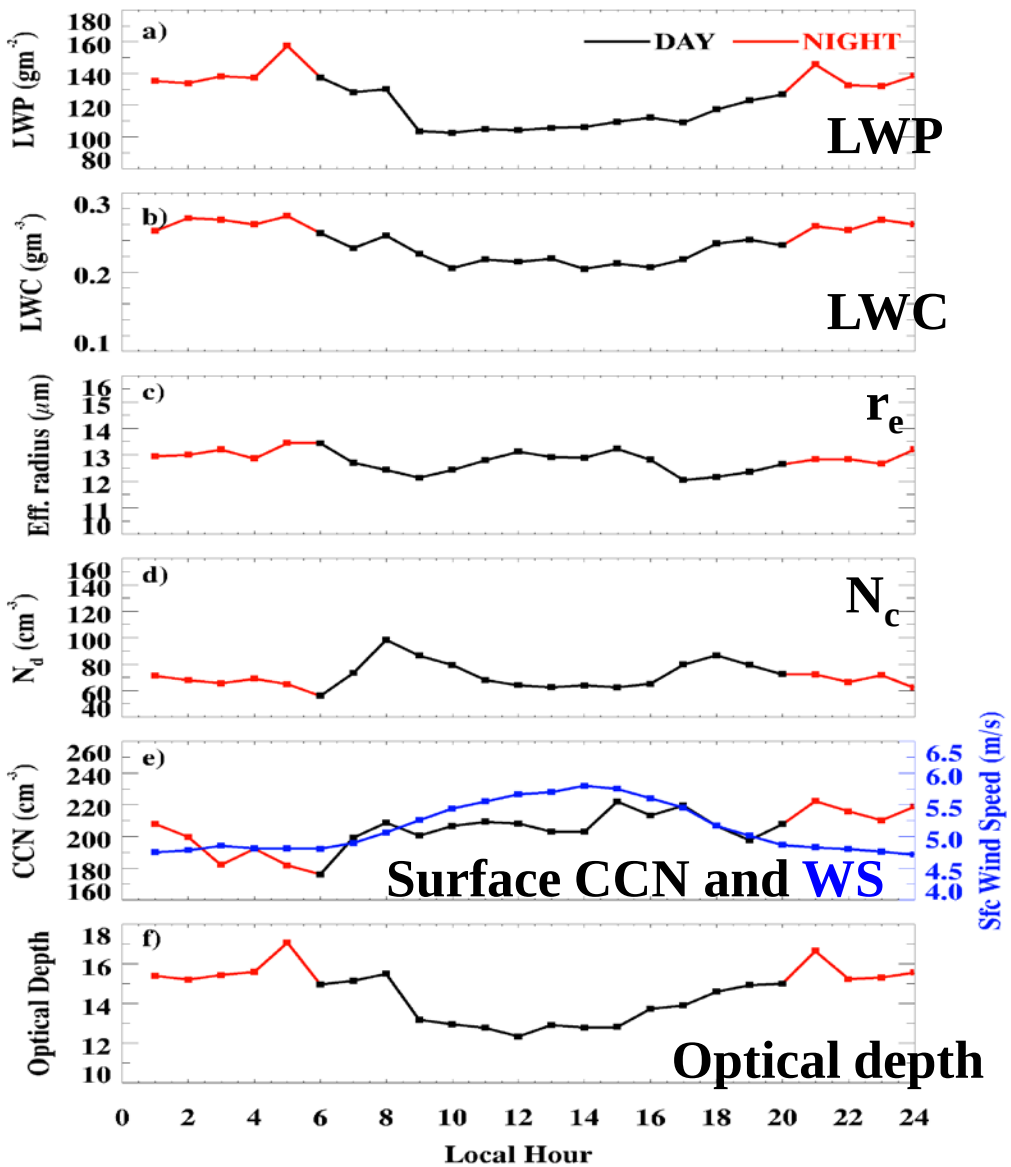
Dong et al. 2014b: Investigation of the diurnal variation of MBL cloud microphysical properties at the Azores. J. Clim, DOI: 10.1175/JCLI-D-14-00434.1

Diurnal Variation of MBL cloud properties and surface CCN over the Azores

Xiquan Dong / University of North Dakota

Key Accomplishment

1) **Nighttime cloud LWP, LWC and optical depth are higher than their daytime counterparts, while cloud-droplet effective radius re is nearly constant.**
2) **Surface N_{CCN} increases from around sunrise (~0600 LT) to late afternoon, which strongly correlates with surface wind speed (r=0.76).**
3) **The trend in hourly means of N_c is consistent with the N_{CCN} variation from 0000 to 1400 LT, but not for the late afternoon and evening due to decoupling.**
4) **An averaged ratio (N_c / N_{CCN}) is 0.35 during the entire study period.**



Publication

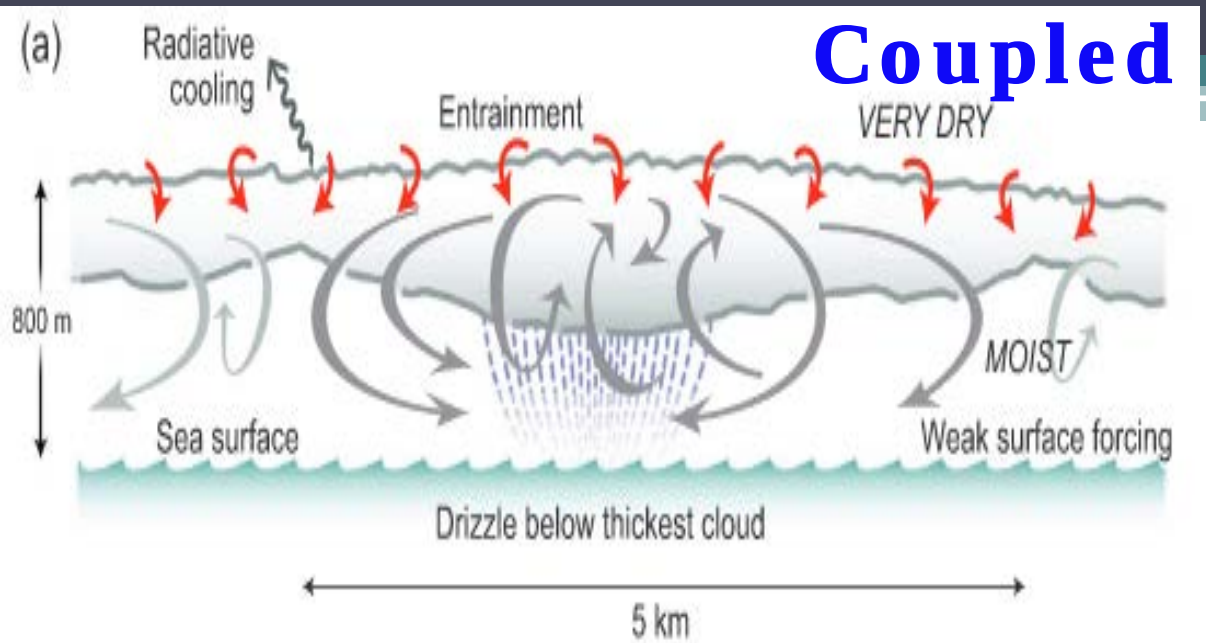
Dong, X., et al., 2014a: A 19-month record of Marine Aerosol-Cloud-Radiation Properties derived from DOE ARM AMF deployment at the Azores: Part I: Cloud Fraction and Single-layered MBL cloud Properties. *J. Clim.*, 27, 3665-3682. DOI: 10.1175/JCLI-D-13-00553.1.

Dong, X., et al. 2014b: Investigation of the diurnal variation of MBL cloud microphysical properties at the Azores. J. Clim, DOI: 10.1175/JCLI-D-14-00434.1

2) Aerosol-Cloud Interactions from 7 selected cases (217 hourly means) at the Azores

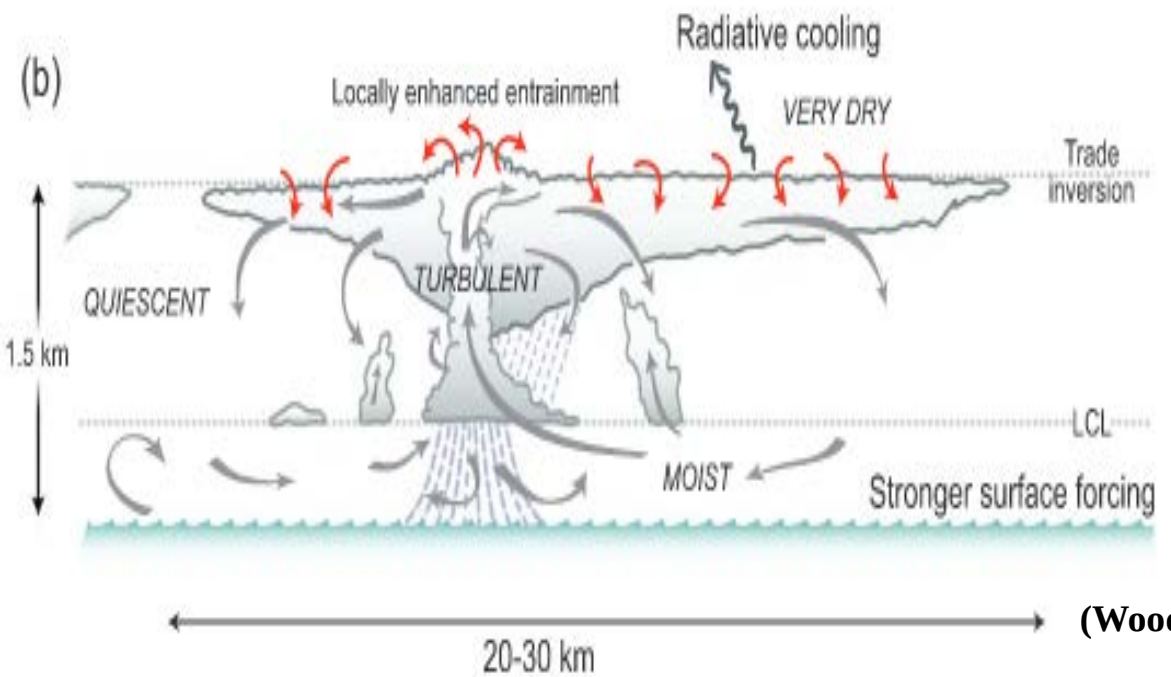
Dong, X., A. C. Schwantes and B. Xi (2014c): Investigation of the Marine Boundary Layer Cloud Properties under Coupled and Decoupled Conditions at the Azores. Will be submitted to JGR

Coupled



A well mixed cloud layer is turbulently mixed from top to down due to LW radiative cooling at cloud top (deeper during night).

Decoupled

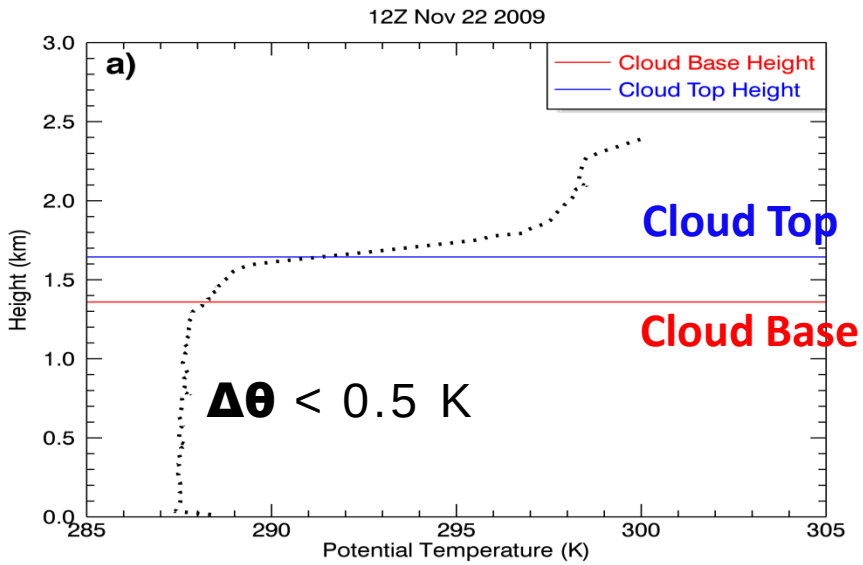


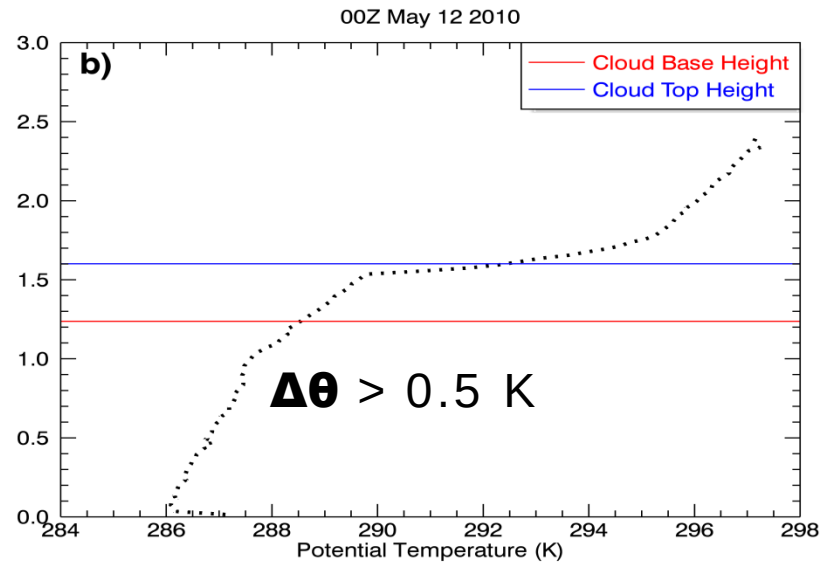
Solar absorption at cloud top supresses turbulence➔circulation weakened.

Two circulations now present, and upper cloud layer becomes decoupled from the surface moisture supply.

(Wood, 2012)

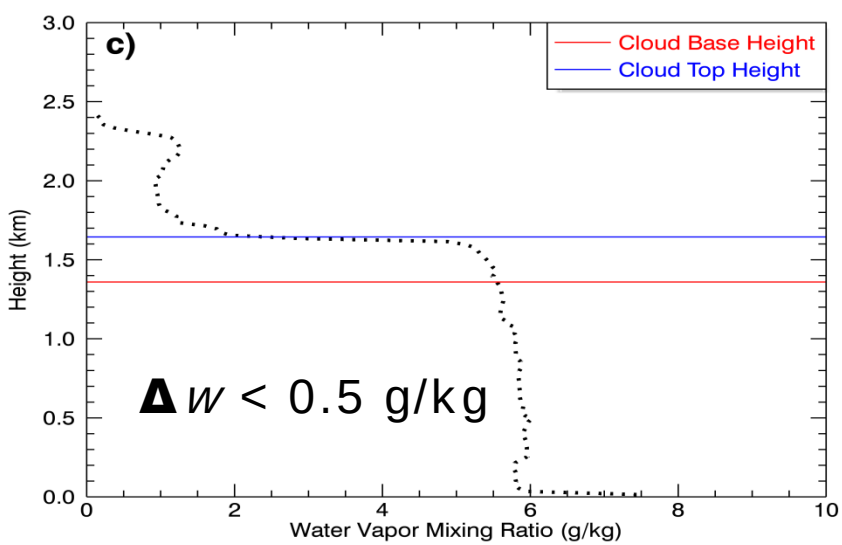
Vertical profiles of potential temp and water vapor mixing ratio

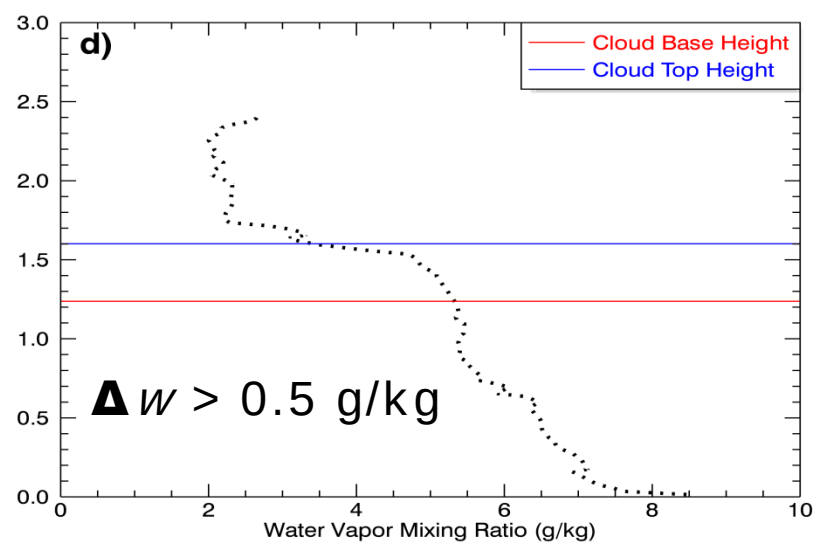




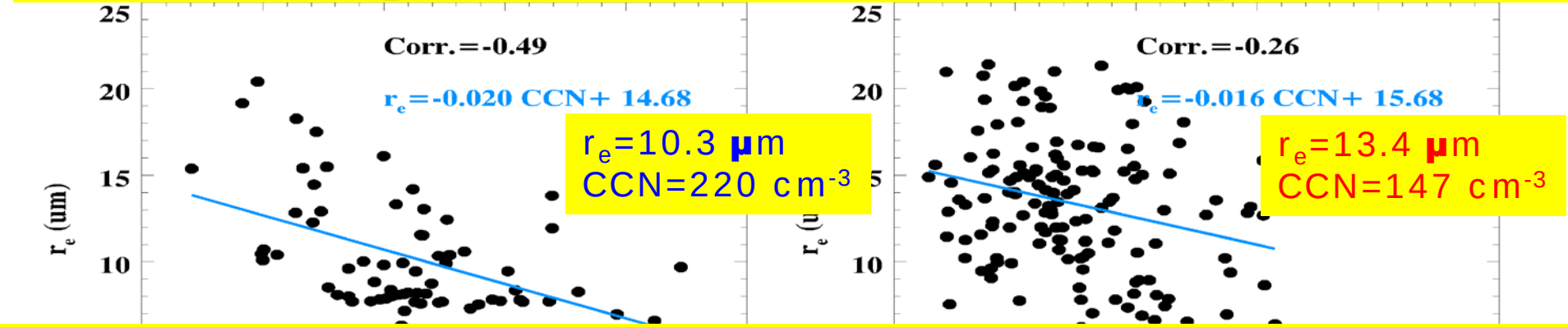
Coupled (68 hourly means)

Decoupled (149 hourly means)

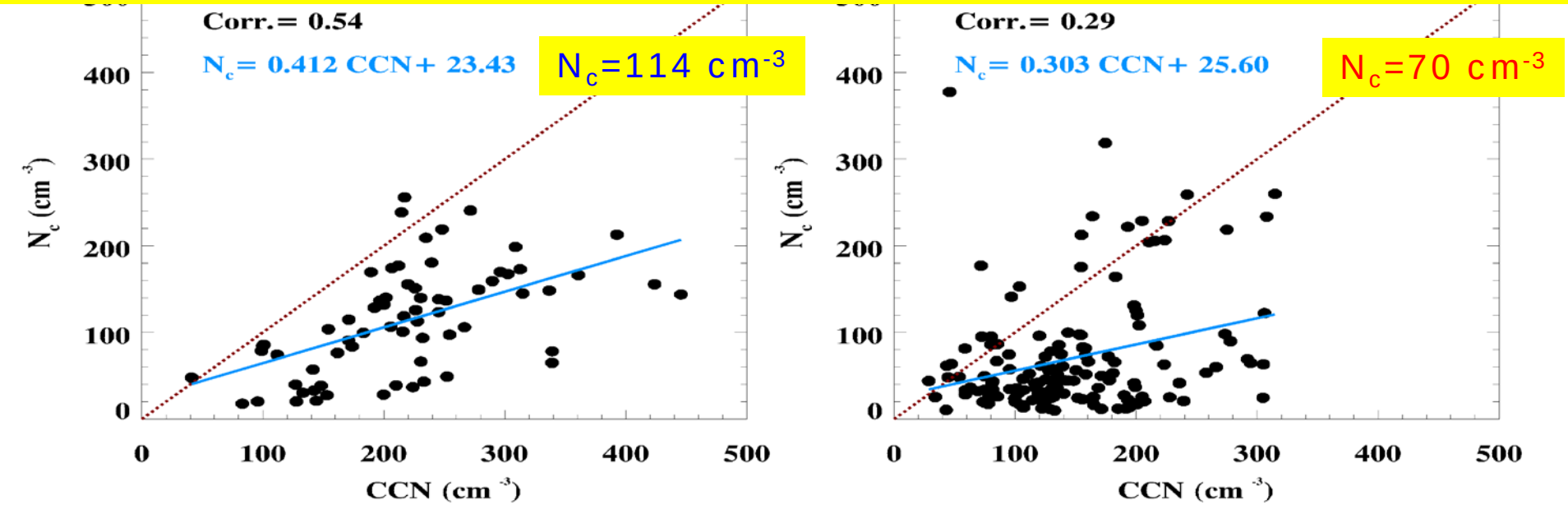




Coupled Decoupled

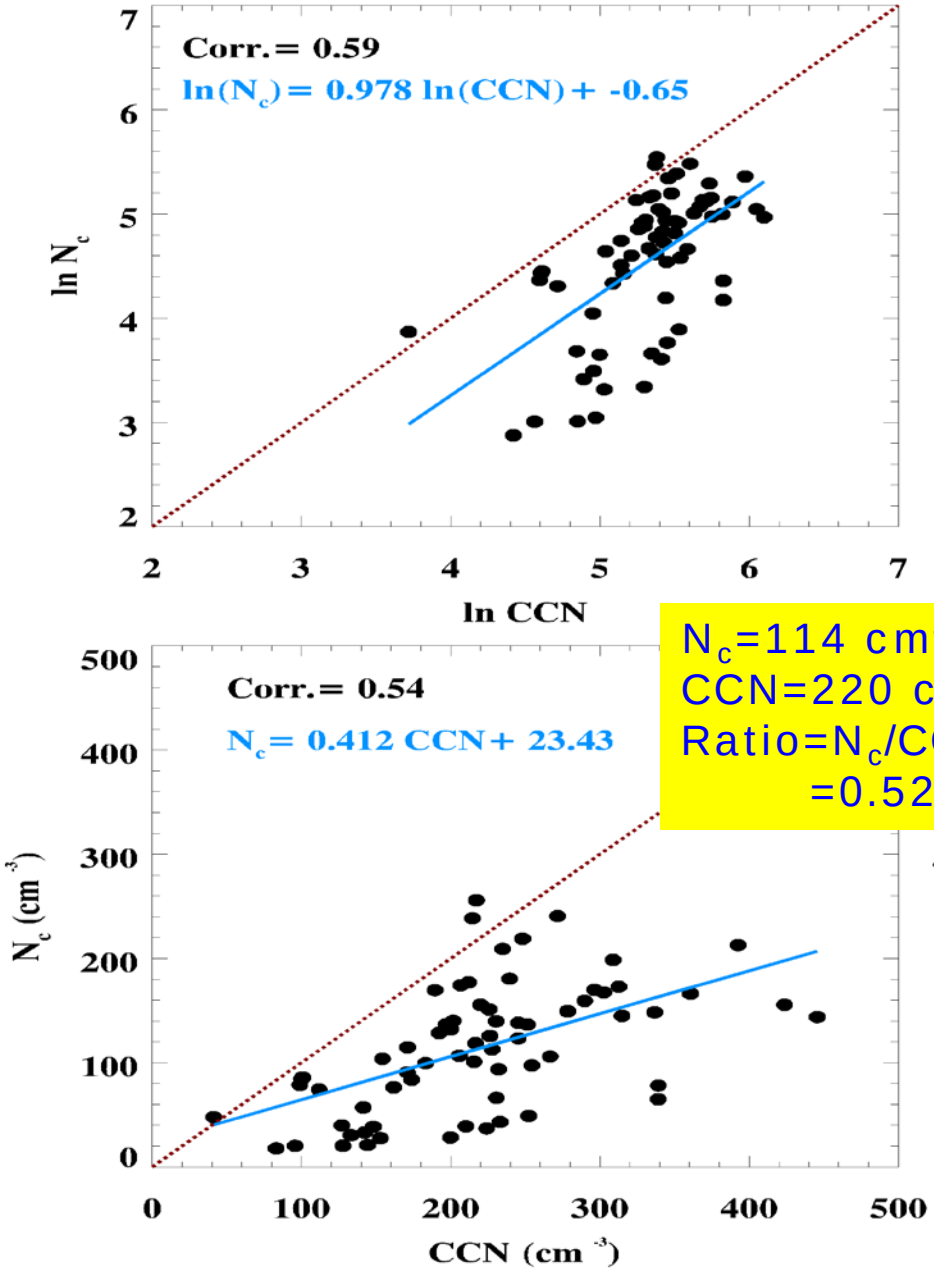


1) The coupled r_e is lower (10.3 μm) but N_c and CCN are higher than decoupled results.
2) The coupled correlations are higher, slopes are greater than decoupled ones.

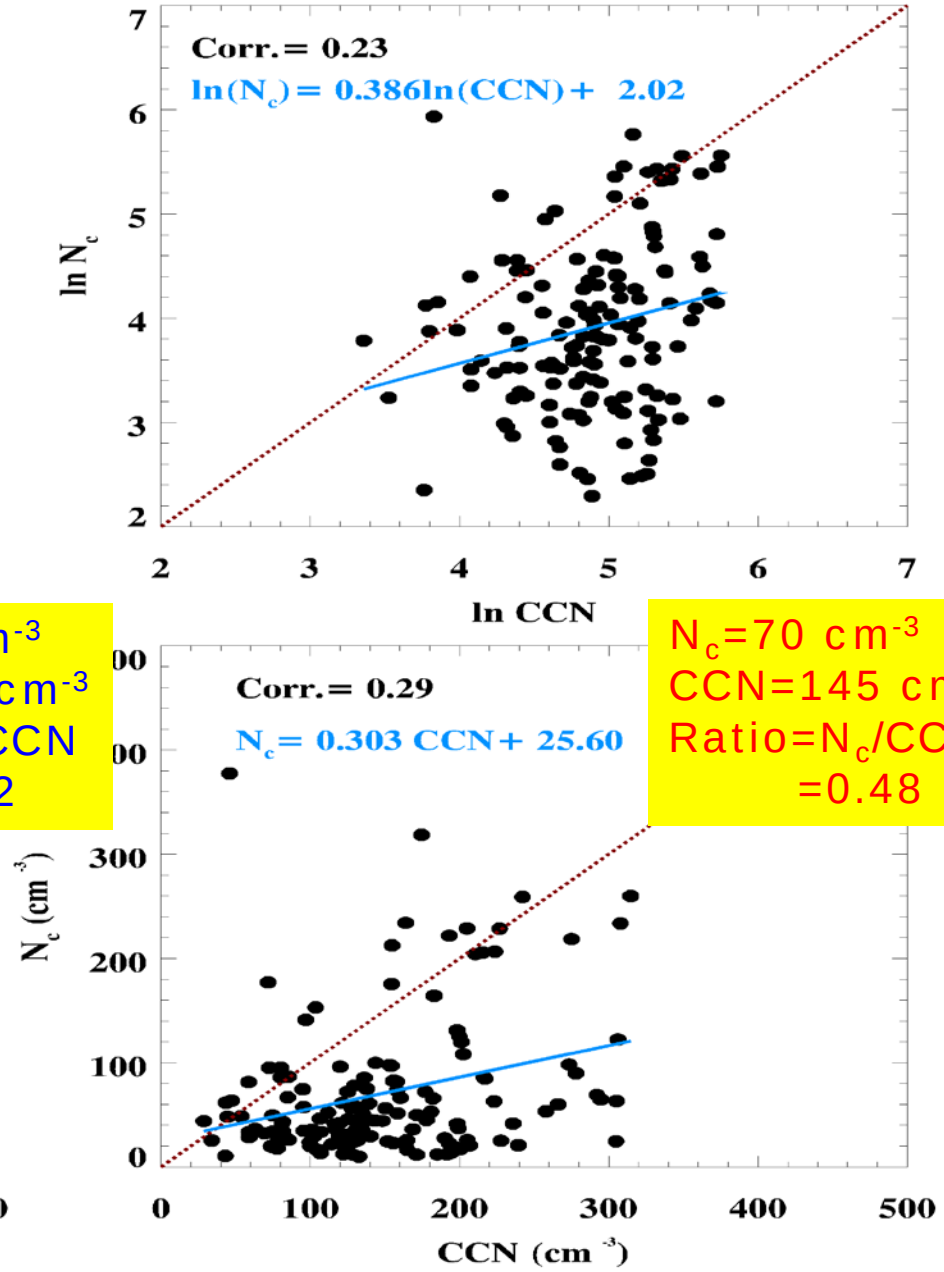


Coupled

Decoupled



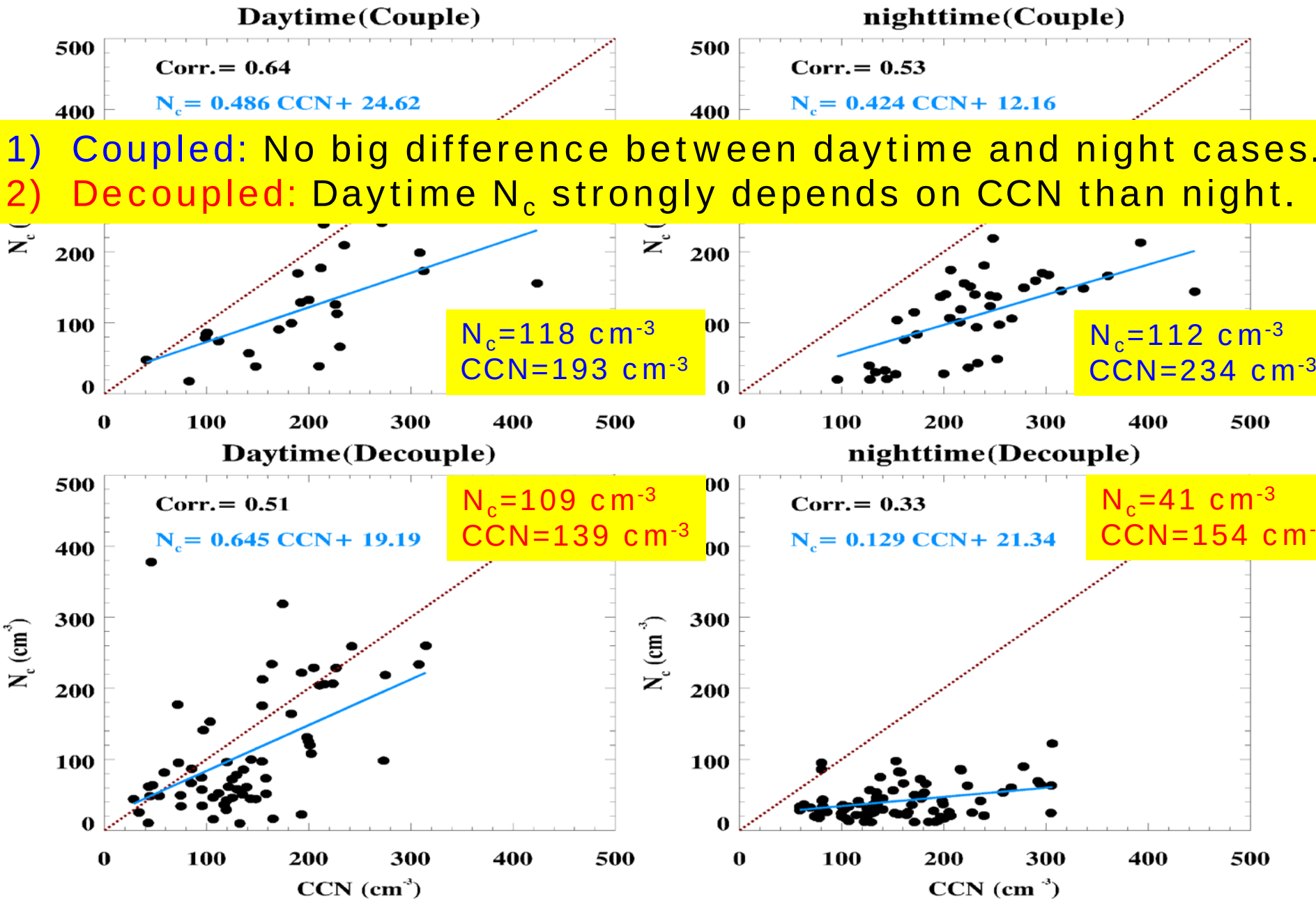
N_c=114 cm^{-3}
CCN=220 cm^{-3}
Ratio=N_c/CCN
=0.52



N_c=70 cm^{-3}
CCN=145 cm^{-3}
Ratio=N_c/CCN
=0.48

Daytime Nighttime

1) Coupled: No big difference between daytime and night cases.
2) Decoupled: Daytime N_c strongly depends on CCN than night.



Summary

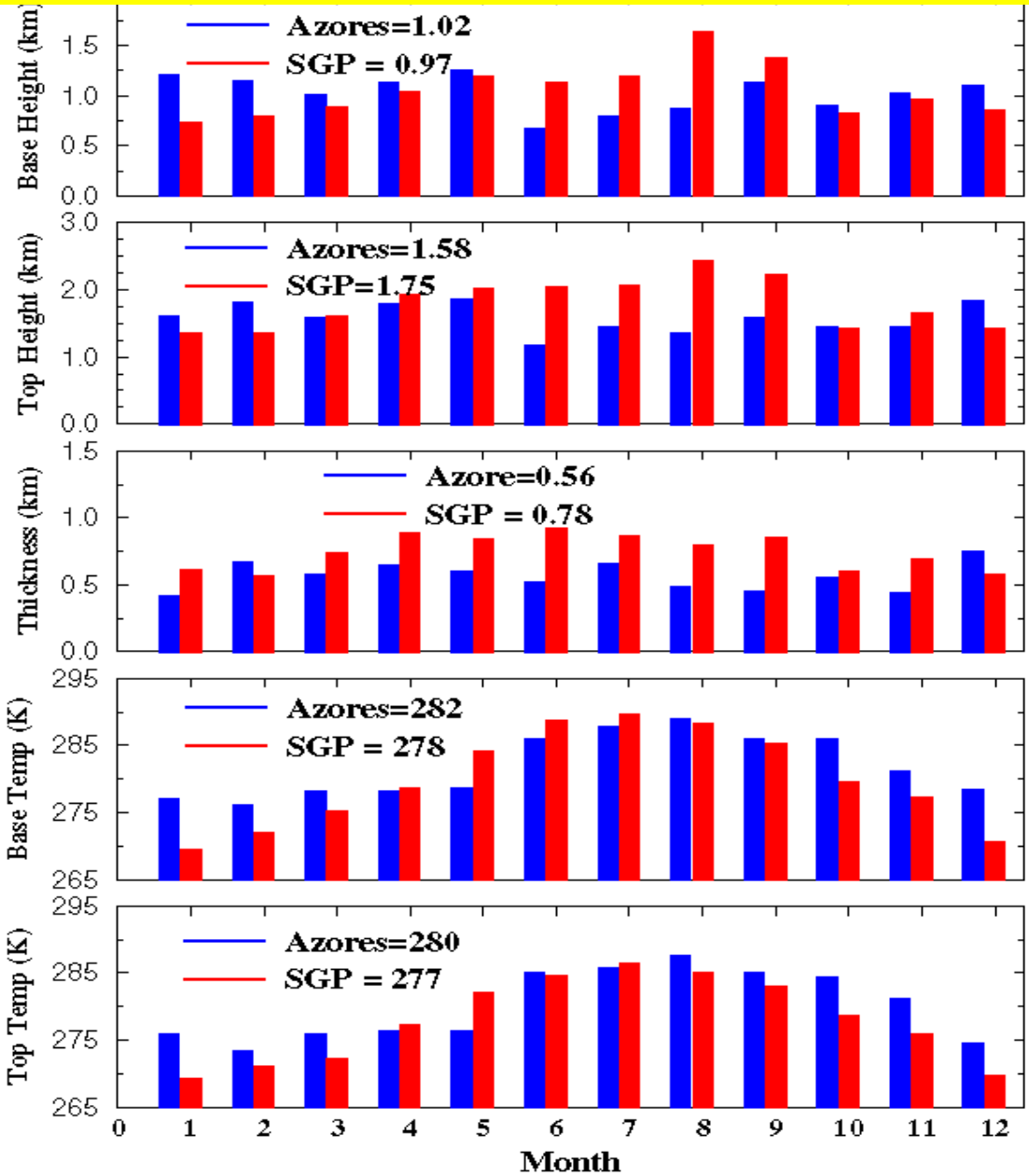
1) AOD values are low (0.12) with coarse mode dominant during winter and spring seasons due to persistent low-pressure system. The...\

2) Persistent high pressure and dry conditions produce more single-layered MBL clouds during summer, while low pressure during winter generates more total and high clouds.

3) No strong seasonal and diurnal variations in re/Nc/CCN.

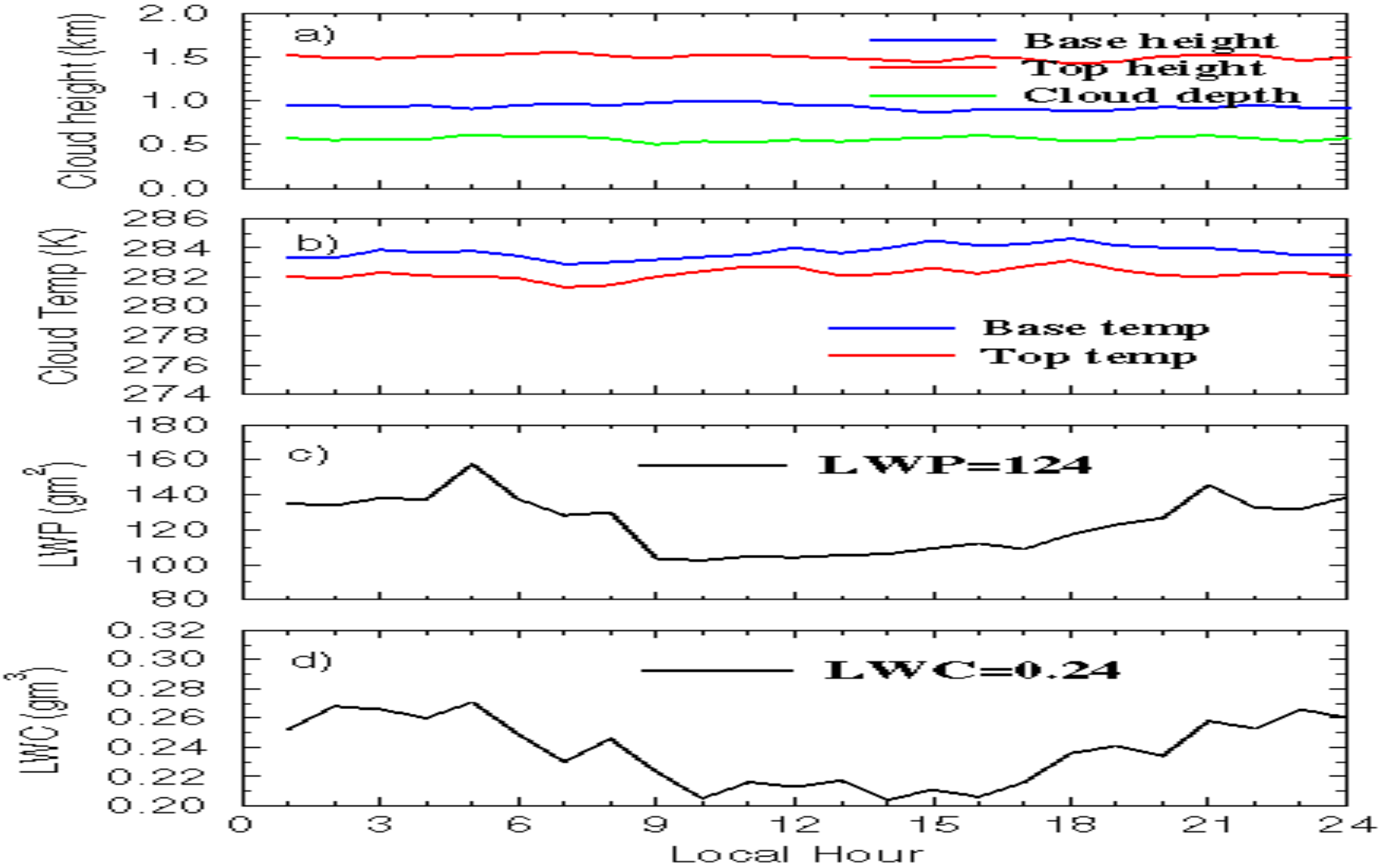
4) The coupled re (10.3 um) is lower, but N_c and CCN (N_c=114 cm^{-3}, CCN=220 cm^{-3}) are higher than decoupled results (re=13.4 um, N_c=70 cm^{-3}, CCN=145 cm^{-3}). The coupled correlations are higher, slopes are greater than decoupled ones.

Seasonal Variations of height/temp



a-b) Cloud layer:
Azores: Winter/spring is deeper than summer/fall due to low-pressure systems
SGP is opposite due to strong solar radiation in summer
c) Cloud thickness:
SGP is thicker than Azores
d-e) Cloud Temps.
Strong seasonal variation at SGP than at Azores.

Diurnal Cycle of cloud properties



Cloud heights, depth, and temps are nearly constant with higher LWP/LWC during night than during daytime.