Responds of Marine Boundary Layer Cloud Properties to Aerosol Perturbations under Different Meteorological Condition over the AMF-Azores Site

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1. Background

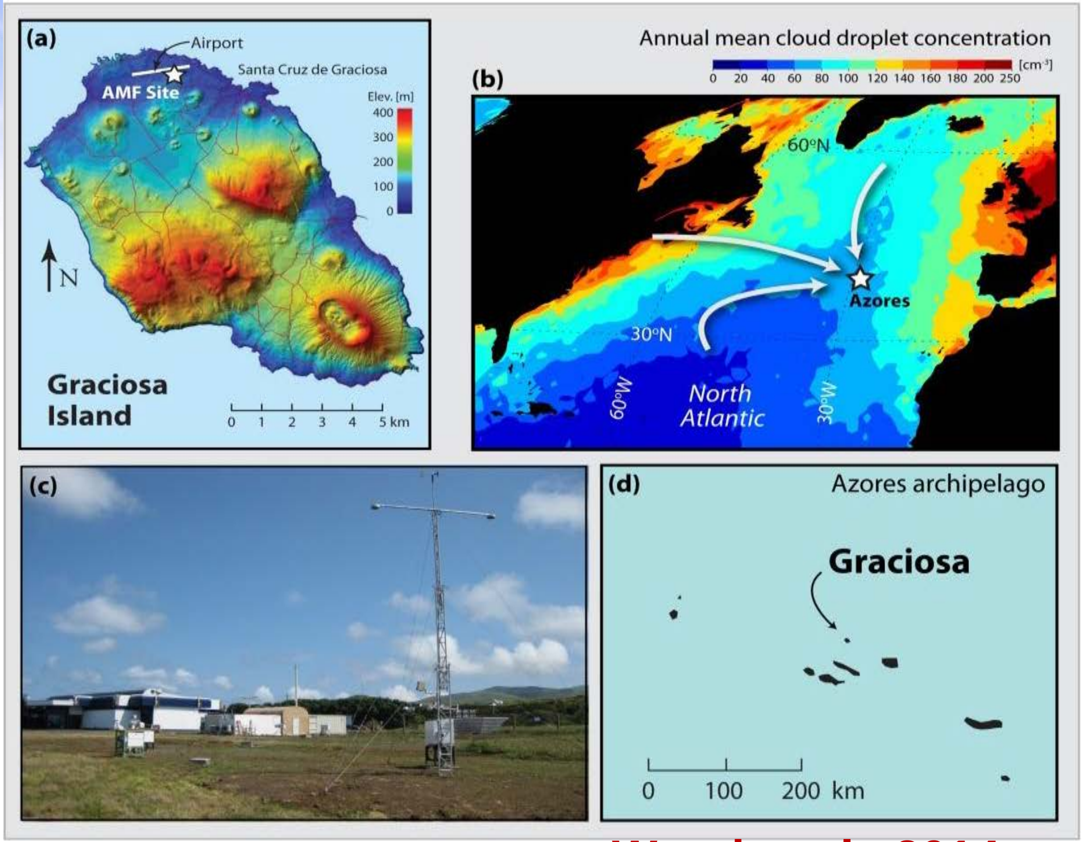
- The Microphysical, structural and dynamic properties of MBL clouds all show sensitivity to aerosol loading, but the responses are not uniform. ***What processes control diversity in the sensitivity of warm clouds to aerosol perturbations*** has been one of the important science questions in the studies of cloud-aerosol-precipitation interaction

Goal:

Investigate the responds of MBL clouds properties to the changing of aerosol loading and examine the contributions of meteorological parameters on the diversity in the sensitivity of MBL clouds to aerosol perturbations

2. Sites, Data and Methods

19 month from May, 2009 to Dec. 2010



Wood et al., 2014

Cloud base and top height (Clothiaux et al., 2000; Wang and Sassen, 2001; Mather and Voyles, 2013)

Aerosol condensation nuclei (CN) number concentrations

Retrieval LWP (Liljegren et al. 2001; Liljgren and Lesht, 2004)

Layer-mean DER, N_C and COD (Dong et al., 1998)

2. Sites, Data and Methods

Data analysis:

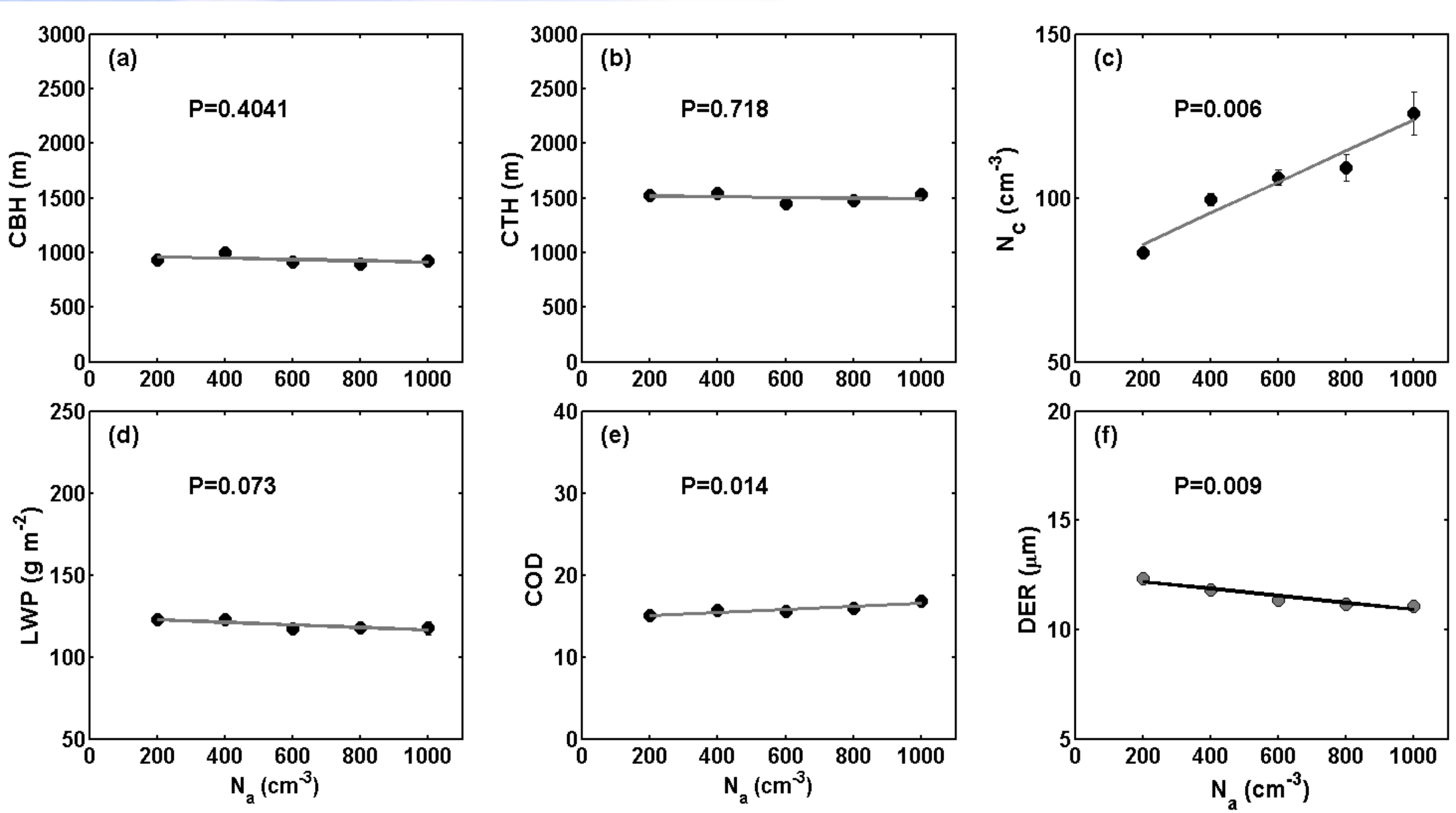
- MBL clouds, defined as the clouds with top height (CTH) are smaller than 3 km (*Dong et al., 2014*);
- LWP observations below 20 g m^{-2} and larger than 700 g m^{-2} were excluded to avoid very thin or broken cloud cover, as well as post-precipitation conditions (*McComiskey et al., 2009)* and the potential precipitation contamination (*Dong et al., 2008*).
- DER values above 25 μm, are unrealistic for low-level cloud have also been filtered from the data (*Bulgin et al., 2008; Dong et al., 2004*).

ECMWF reanalysis data with one hour average from ARM archive.

- Vertical velocity at 700 hPa (**ω**) is used as a proxy for large-scale ascending and descending motions to constrain the dynamic regimes (*Bony et al., 2004; Medeiros and Stevens, 2010; Sun et al., 2010*);
- Lower tropospheric stability (**LTS**) is used to constrain thermodynamic state (*Matsui et al., 2004; Lebsock et al., 2008*)

3. Preliminary Results

3.1 Variations in cloud properties with aerosol loading

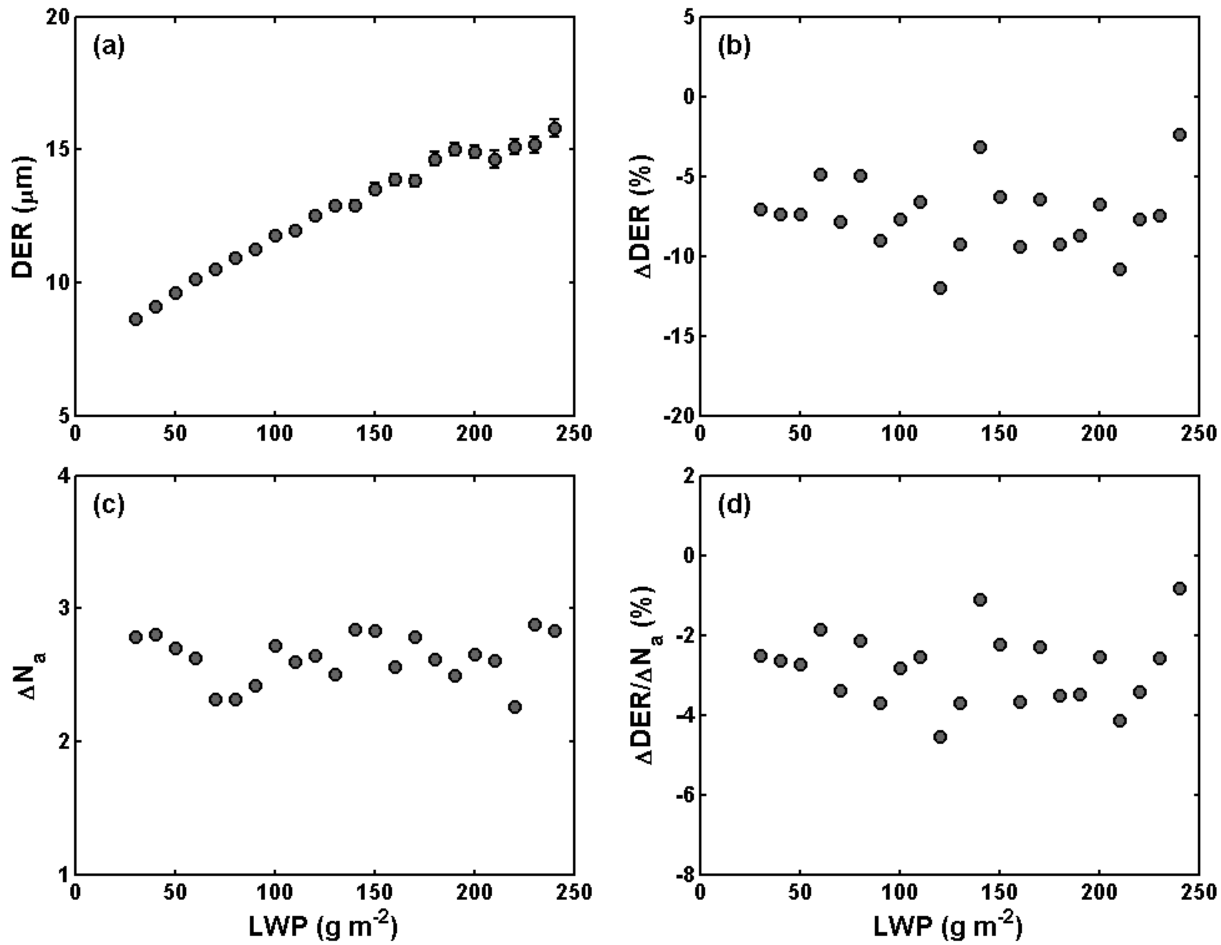


- **CBH and CTH are not sensitive to the aerosol loading;**
- **LWP doesn't show a significant relationship between N_a, but an observed decreases with increasing of Na are found;**
- **N_C and COD show a significant increase, DER shows a significantly decreasing;**

3. Preliminary Results

3.1 Variations in cloud properties with aerosol loading

$$\Delta DER = (DER_H - DER_L)/DER_L$$

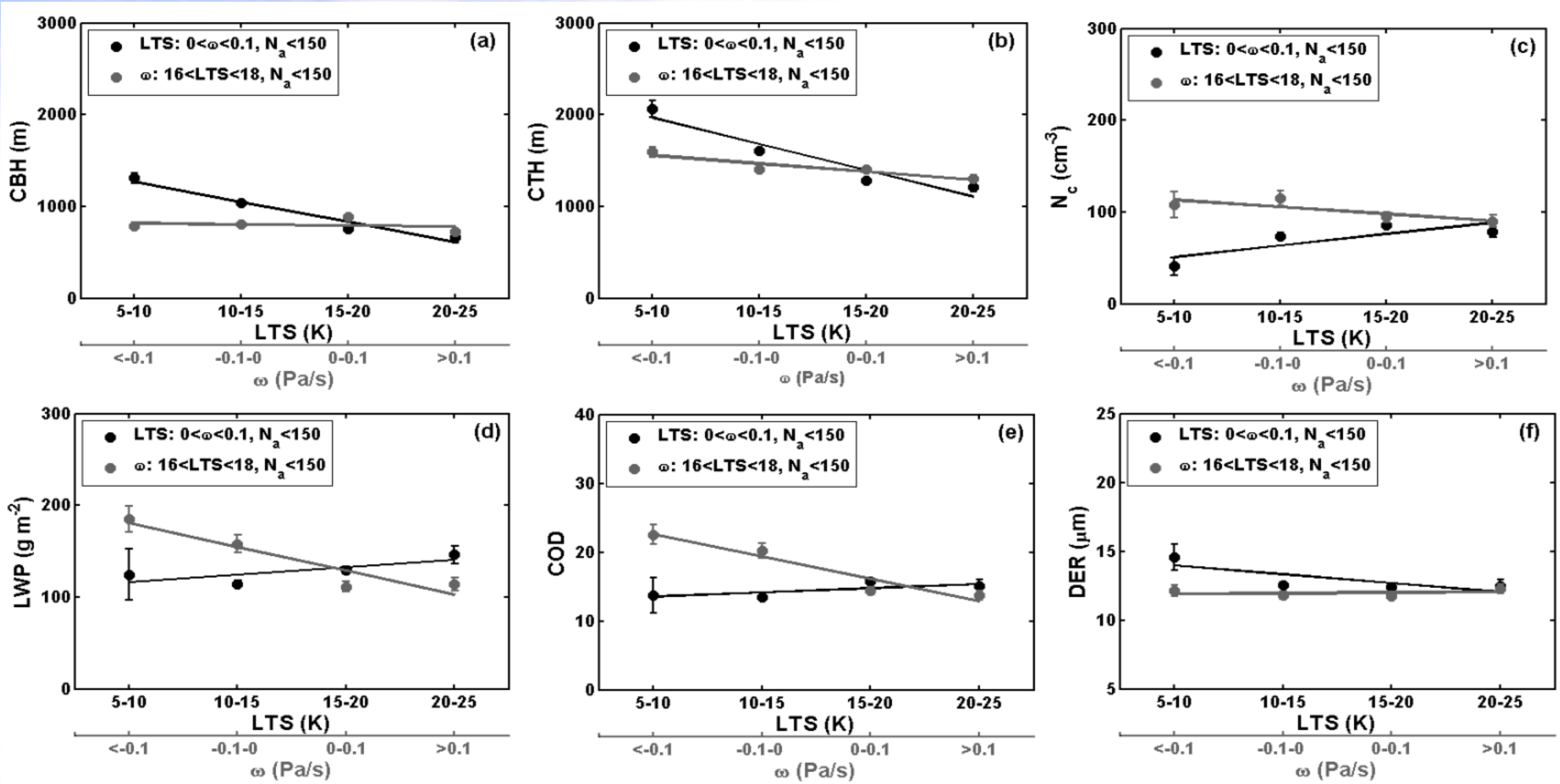


DER has significantly **increase** with increasing of LWP

ΔDER and $\Delta DER/\Delta N_a$ under low and high aerosol loading conditions **don't show** an obvious trend with increasing of LWP

3. Preliminary Results

3.2 Meteorological parameters on cloud properties



With increasing of LTS:

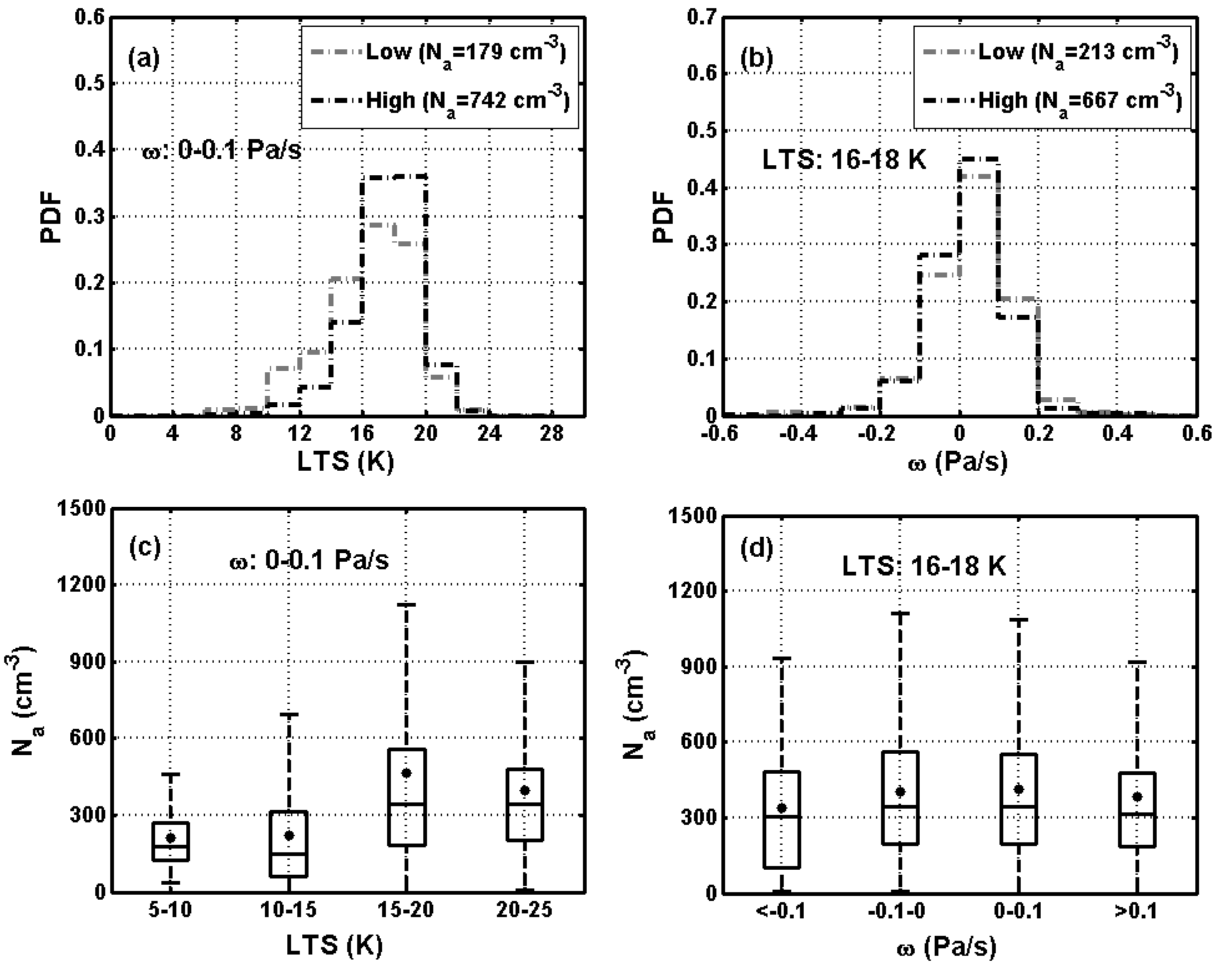
- CBH and CTH, significant decrease;
- Increase in N_C, LWP and COD
- DER is slightly lower under more stable conditions

With increasing of ω:

- CBH shows a constant;
- CTH tends to lower for downdraft cases;
- Decrease in N_C, LWP and COD;
- DER is consistent

3. Preliminary Results

3.2 Feedback between the meteorological condition and aerosol concentration



high aerosol loading

- more large values of LTS;
- more samples with weak vertical motion;

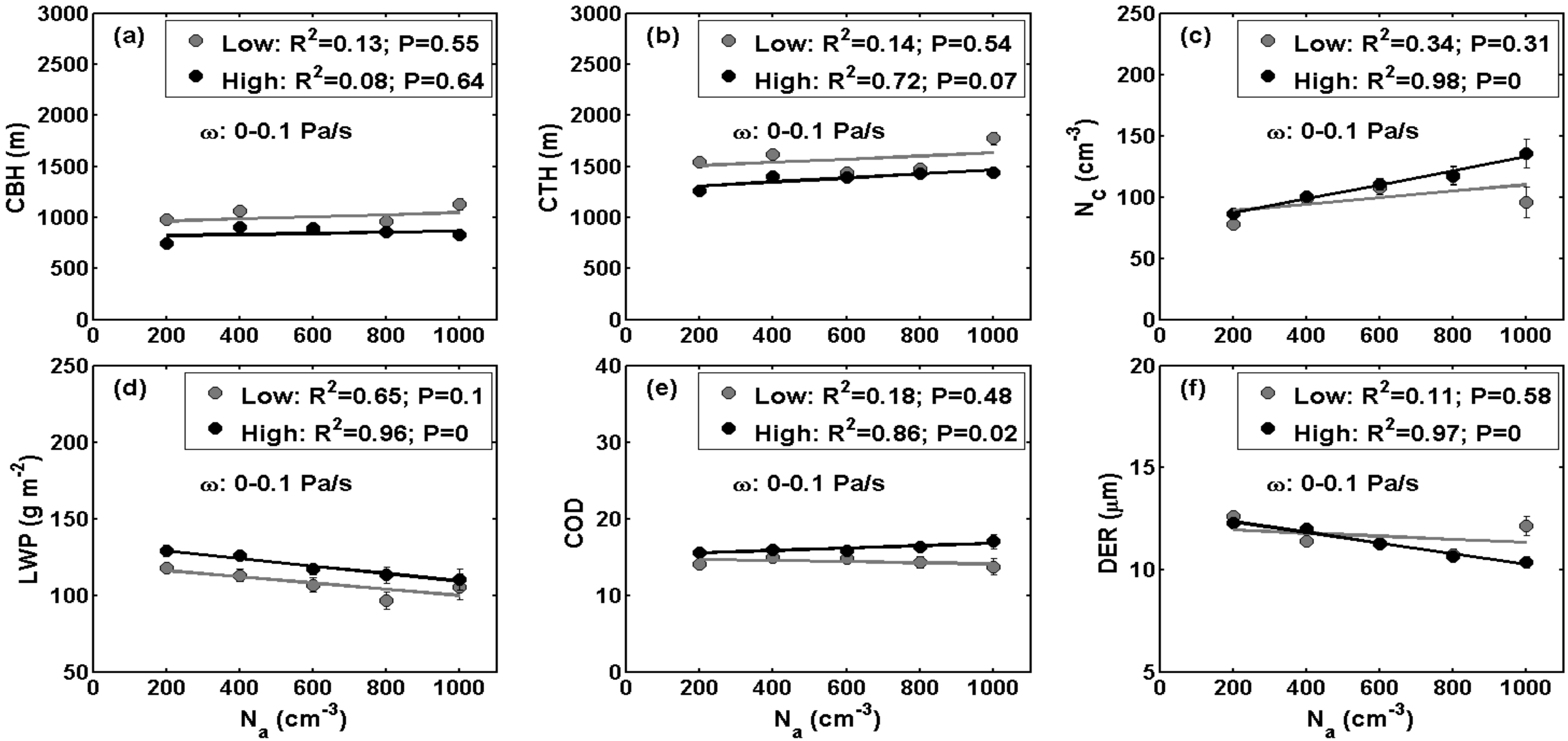
More stable condition and weak vertical motion

- More aerosol number concentration

A positive feedback loop between the aerosol loading and atmospheric stability

3. Preliminary Results

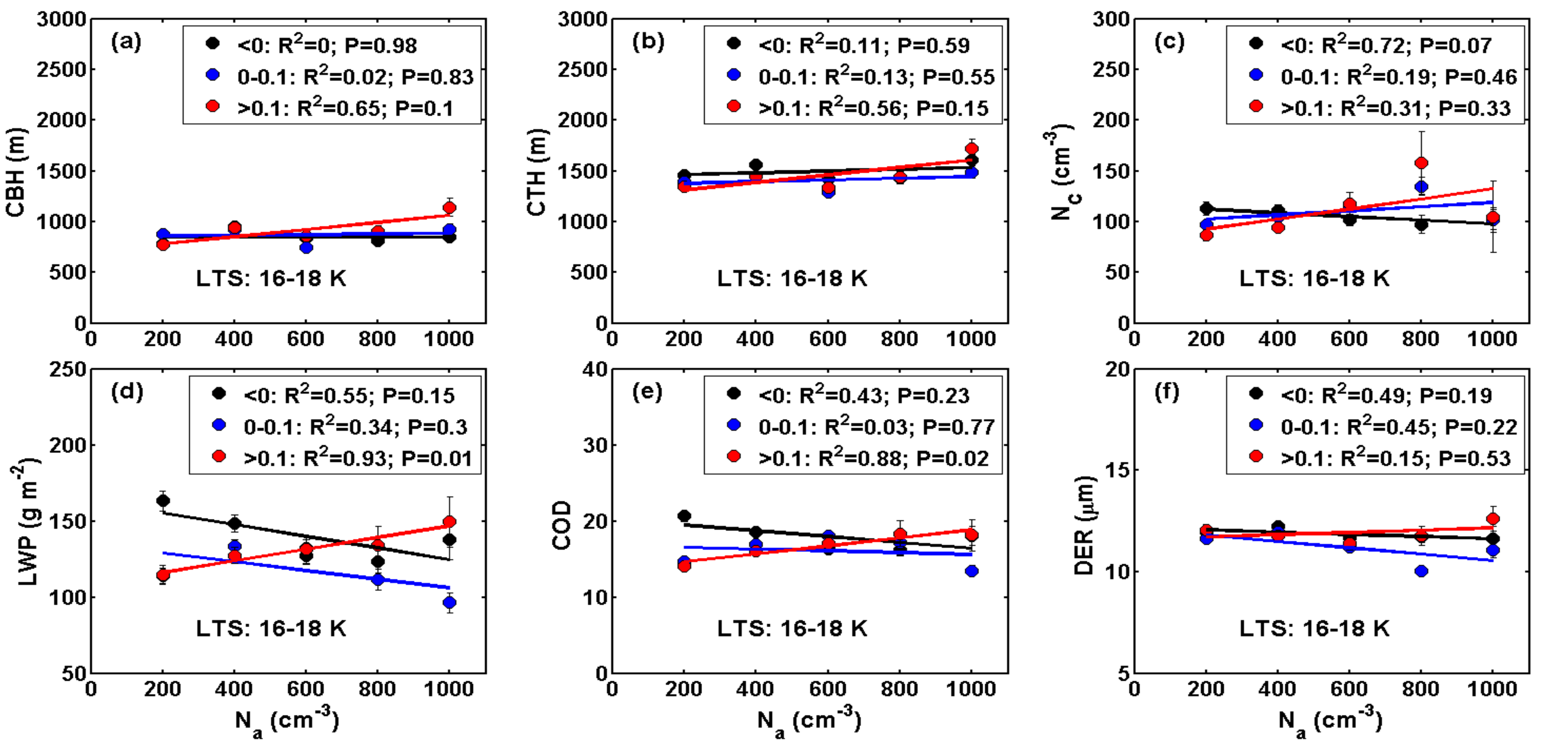
3.3 Meteorological conditions on responses of clouds properties to aerosol loading



- Correlation between CBH and Na is not sensitive to LTS, CTH shows a slight sensitive;
- Remarkable differences in the correlation between cloud properties (N_C, LWP, COD, and DER) and N_a

3. Preliminary Results

3.3 Meteorological conditions on responses of clouds properties to aerosol loading

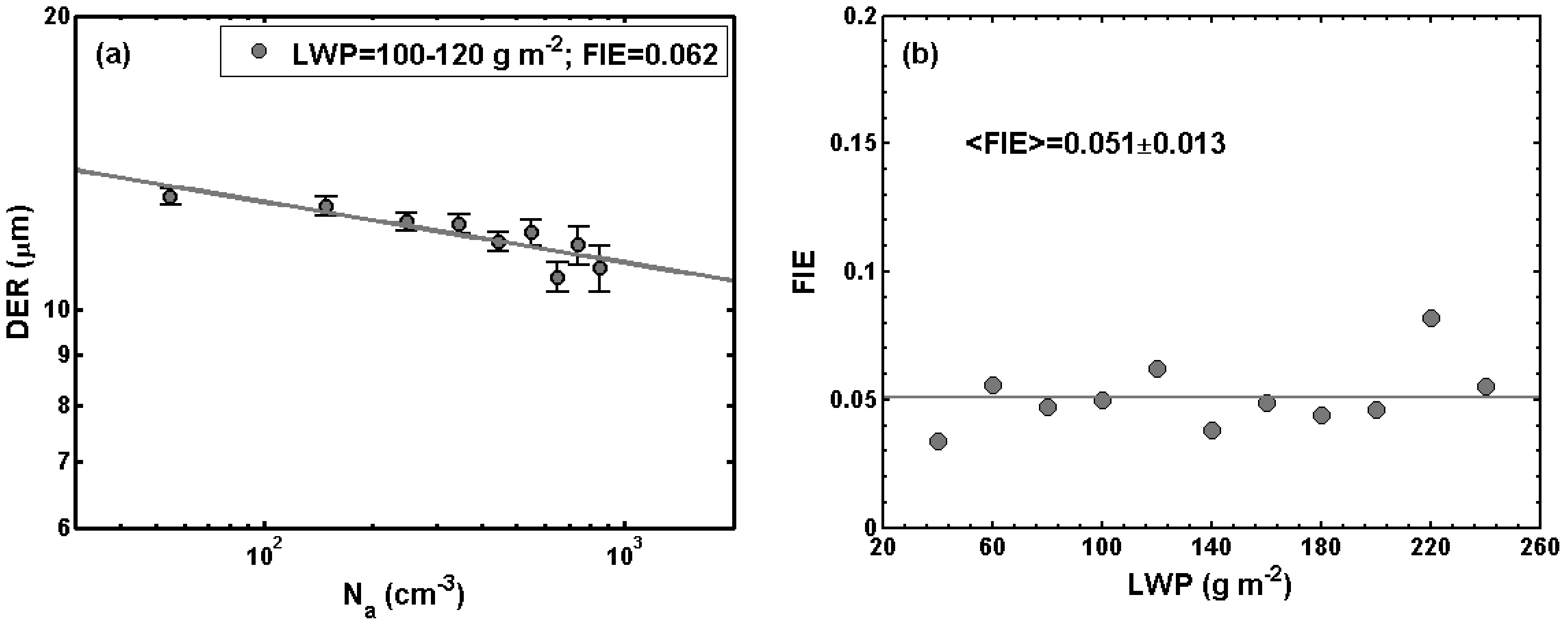


- The correlation between CBH/CTH and Na is not sensitive to ω;
- Correlation between Nc/LWP/COD and Na shows a sensitive to ω;
- no significantly differences in correlation between DER and Na;

3. Preliminary Results

3.4 Quantify aerosol first indirect effects

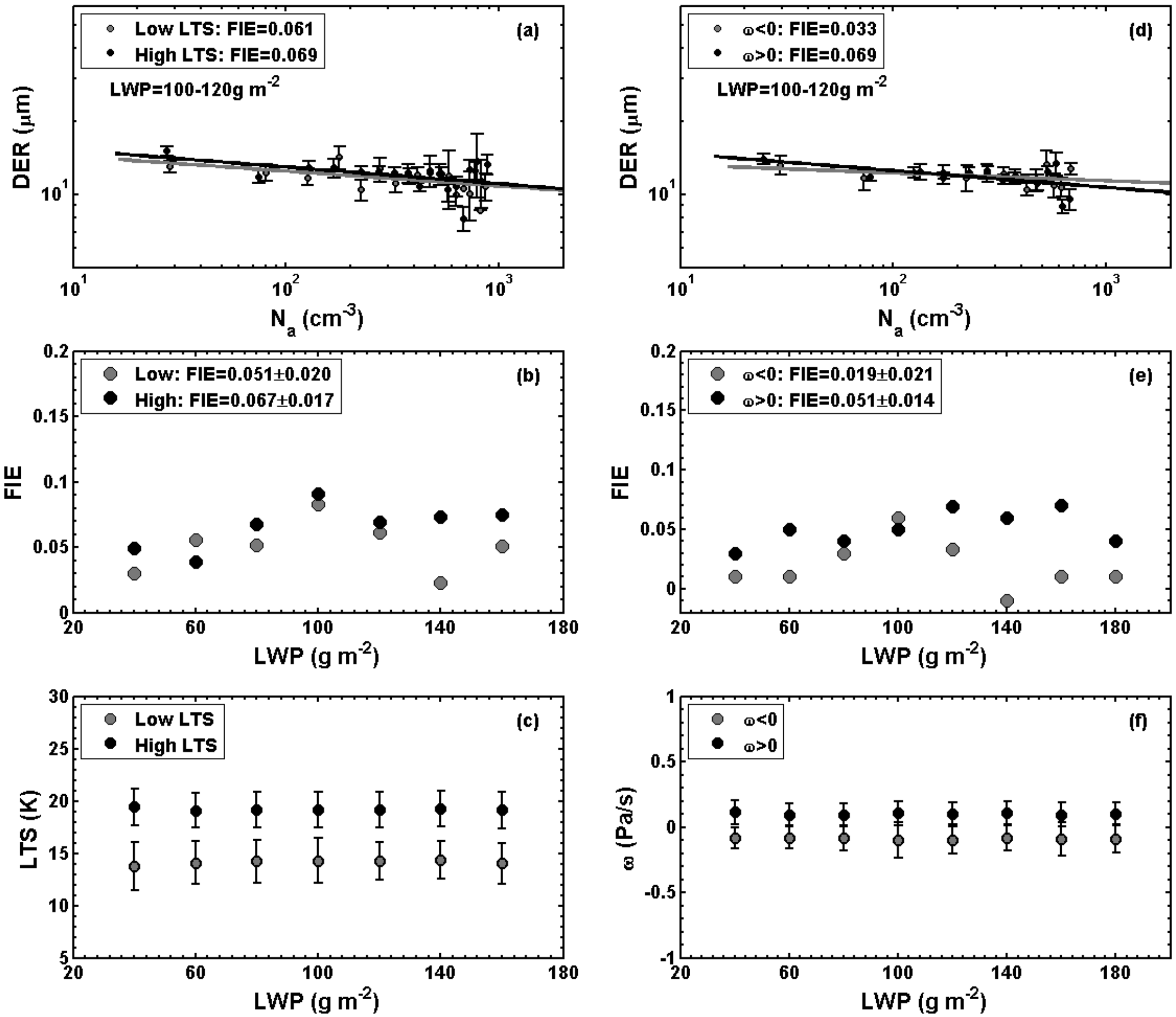
$$FIE = -\frac{d\ln(DER)}{d\ln(\alpha)}$$



FIE ranges from 0.034 to 0.082 in different LWP bins with no obvious trend with increasing LWP

3. Preliminary Results

3.4 Quantify aerosol first indirect effects



Larger values tend to exist in more stable and downdraft conditions with mean increase for all LWP bins by 31.4% from low to high stability and by 168.4% from updraft to downdraft conditions.

Statistical relationship between Cloud droplet effective radius (DER) and aerosol number concentration (Na) with constant LWP under less and more stability conditions as well as updraft (gray) and downdraft (black) cases.

4. Conclusion

1. The cloud base height (CBH) and cloud top height (CTH) are not sensitive to the aerosol loading, but cloud droplet number concentrations (N_C) and cloud optical depth (COD) significantly increase, and cloud droplet effective radius (DER) significantly decrease with increasing of aerosol number concentrations (N_a).
2. The correlation between CBH (CTH) and N_a are not significantly sensitive to both dynamic and thermodynamic condition, but more significant correlations between cloud microphysical properties (N_C, liquid water path (LWP), COD and DER) and N_a are found under more stable atmosphere conditions.
3. the magnitude of FIE ranges from 0.034 to 0.082 depending on the different LWP values.
4. The larger values of FIE associate with more stable and downdraft conditions, with mean increase for all LWP bins by 31.4% from low to high stability and by 168.4% from updraft to downdraft conditions.

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Thank you for your attention