

Going Beyond Conventional Aerosol-Cloud Interaction (ACI) Parameterization Paradigm: ACI Regime

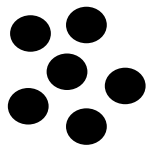
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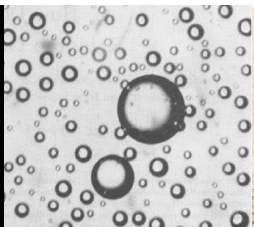
³NUIST, China



Molecule



Aerosol



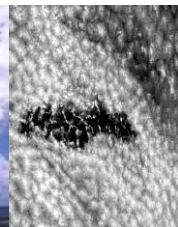
Droplet



Turbulent Eddies



S. Cu



Clusters



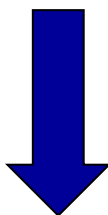
Global



Science Drivers from IPCC-AR5



Clouds may typically be less sensitive to aerosol perturbation in Nature than in large scale models due to buffering (compensating) factors/processes that are either poorly represented or not at all in models.

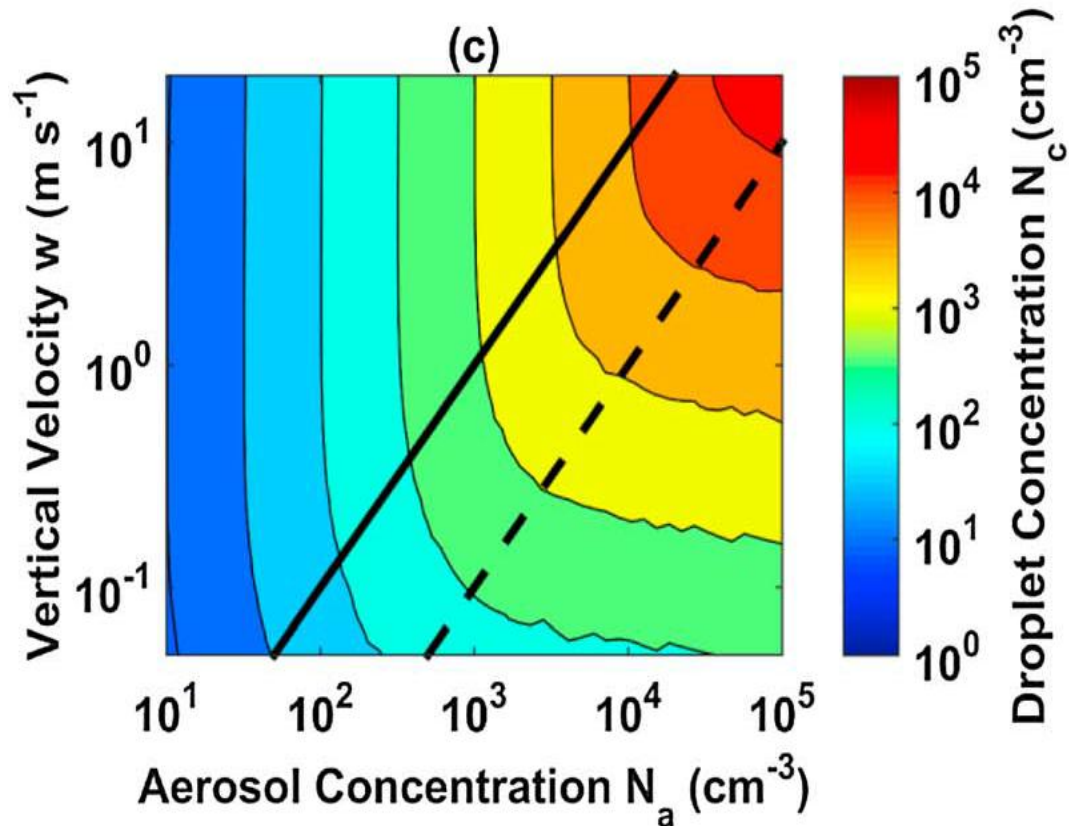


Going Beyond Conventional Aerosol-Cloud Interaction (ACI) Parameterization Paradigm:

Dispersion effect, entrainment-mixing effect, and couplings in context of ACI regime dependence.

Conventional ACI Regime Paradigm

- Adiabatic, concentration-based
- Regime dependence is nonlinear but monotonic.
- Three regimes: aerosol-limited, updraft-limited, and transitional.
- Black lines represent Reuter's regime equations.



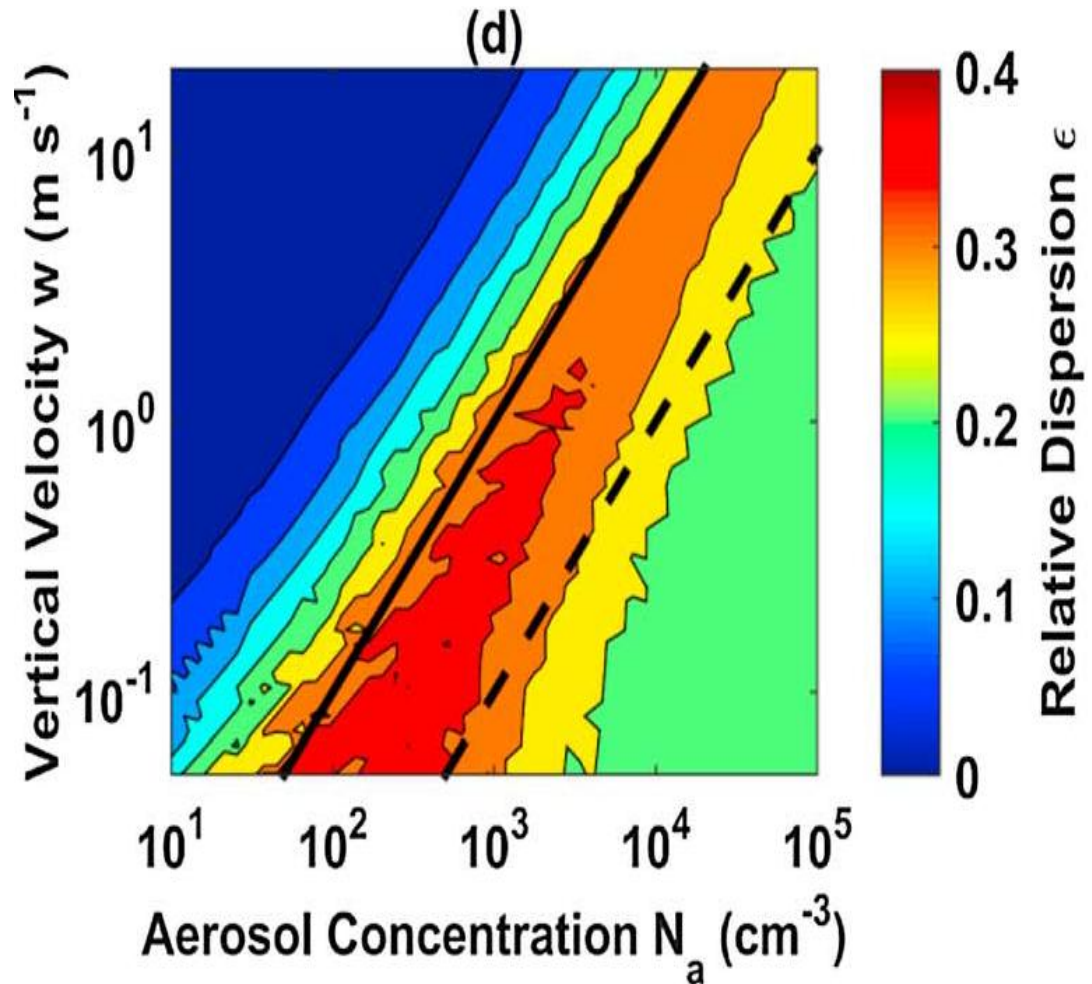
(Reutter et al. ACP, 2009)

(Ghan et al)

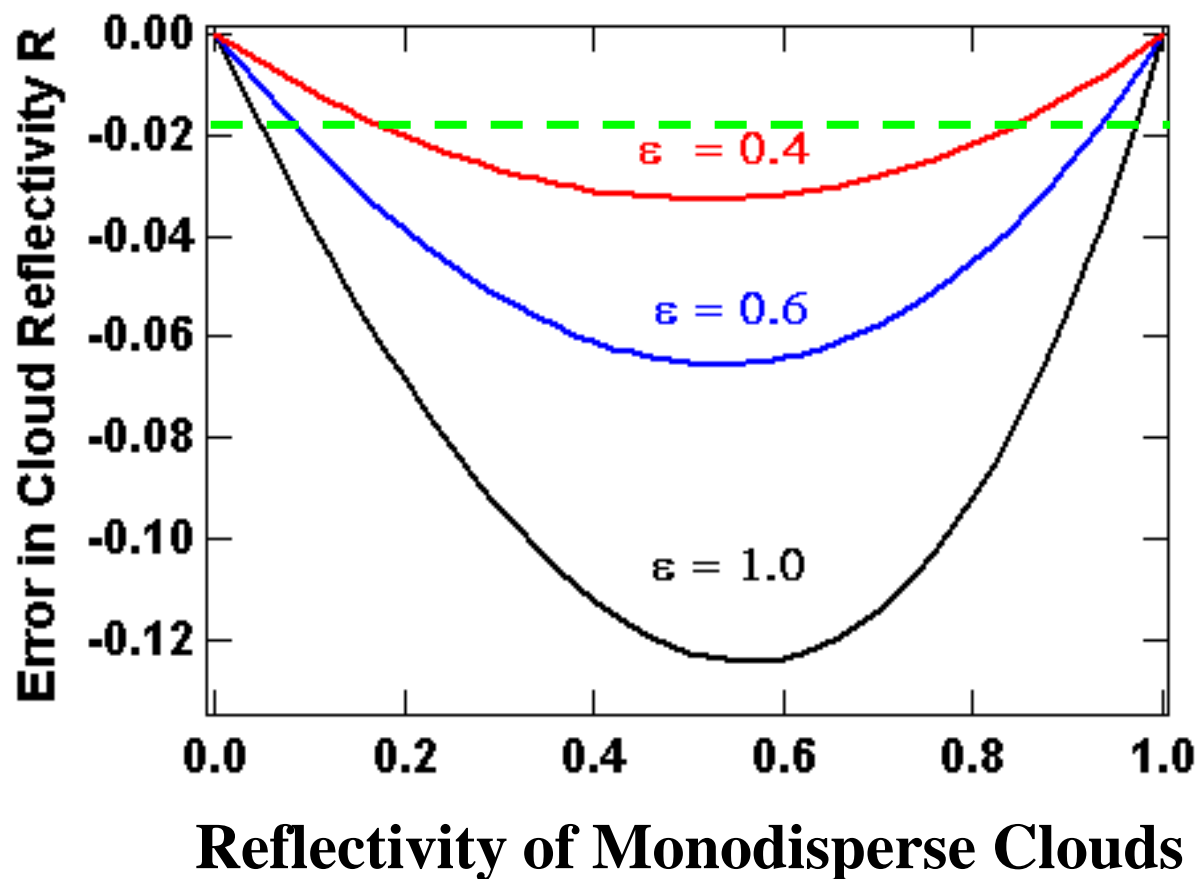
Outstanding AIE issues are likely due to this oversimplified ACI regime paradigm most ACI parameterizations are based on.

Stronger Dispersion Regime Dependence

- Dispersion regime dependence is nonlinear and non-monotonic: dispersion peaks at some (N_a, w) .
- New regime equation: $w^* = 5 \times 10^{-4} N_a^*$ falling between Reutter's.
- Buffering dispersion effect: Warming aerosol-limited regime but cooling in updraft-limited regime.



Dispersion Effect Peaks around Where Twomey Effect Is Most Sensitive.



Green dashed line indicates the reflectivity error where overestimated cooling is comparable to the warming by doubling CO₂.

New ACI Parameterization

Normalized variables virtually independent of w

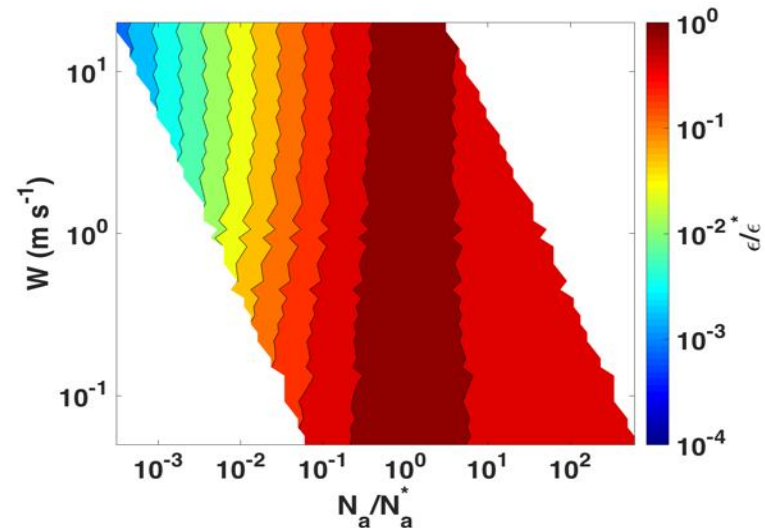
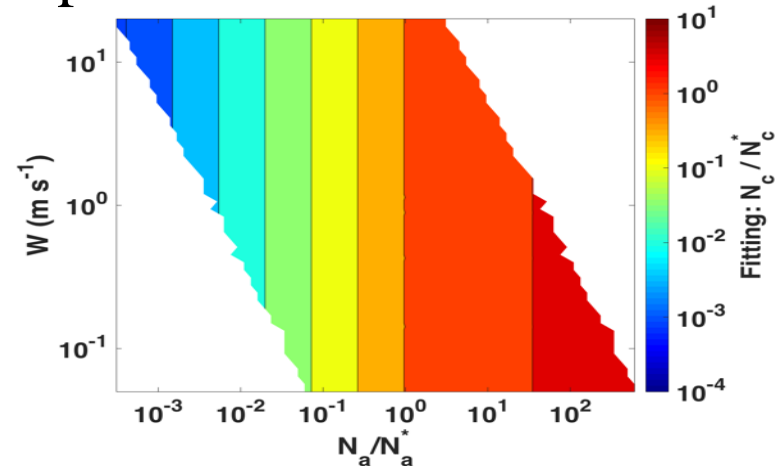
$$\frac{N_c}{N_c^*} = f1\left(\frac{N_a}{N_a^*}\right)$$

$$\frac{\epsilon}{\epsilon^*} = f2\left(\frac{N_a}{N_a^*}\right)$$

$$N_c^* = f3(w)$$

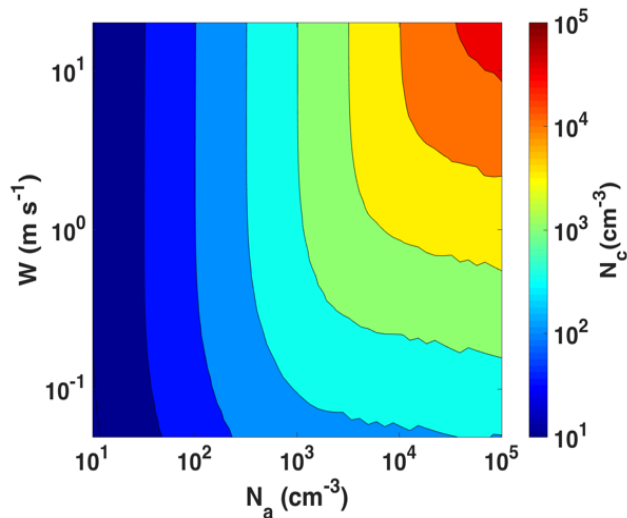
$$\epsilon^* = f4(w)$$

$$N_a^* = f5(w)$$

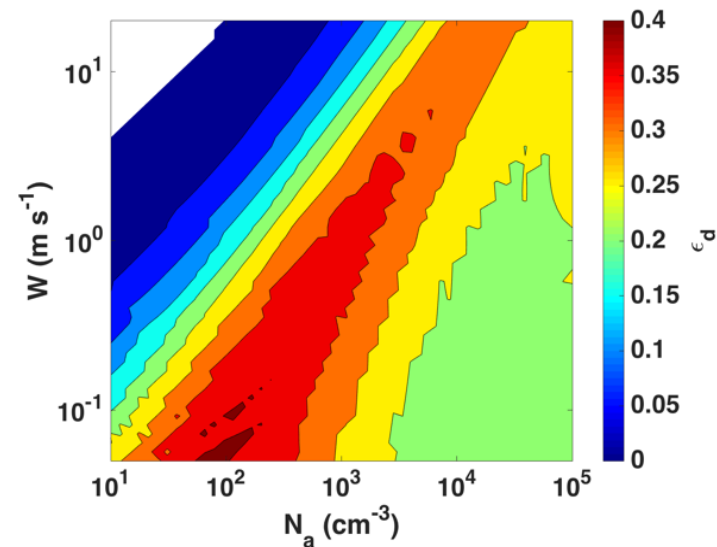
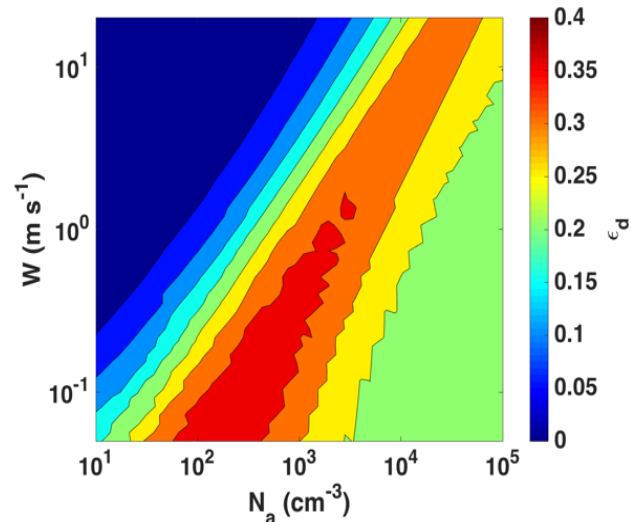
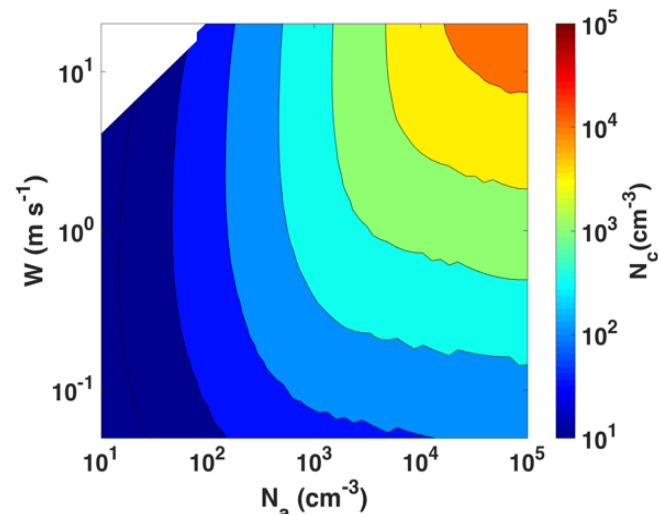


Effect of Entrainment

Adiabatic

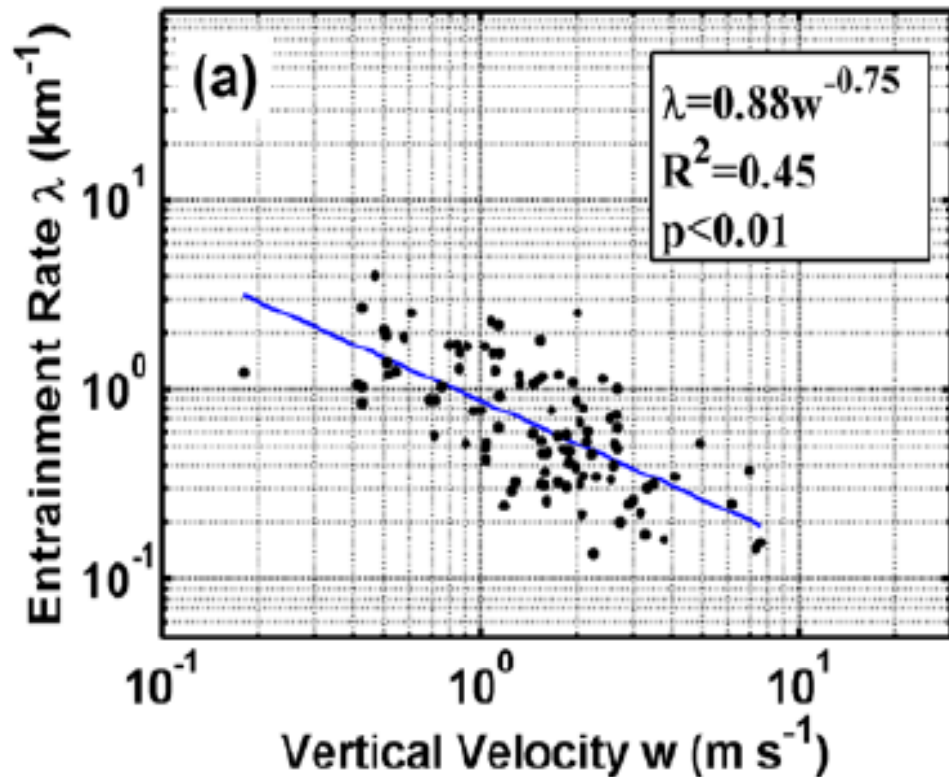


$\lambda = 1.0 \text{ km}^{-1}$; $\text{RH}_e = 0.6$



Relationship between Entrainment Rate and Vertical Velocity

- 102 cumuli at SGP
- Aircraft measurement
- Method for estimating entrainment rate (Lu et al., GRL, 2012)

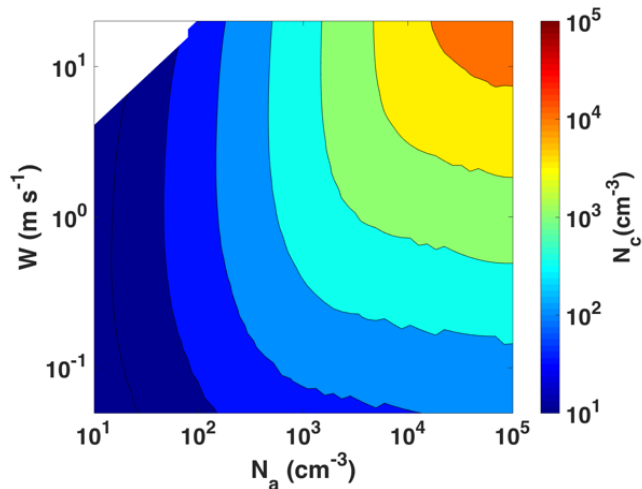


Clouds are weakly coupled due to entrainment and mixing processes >> effect of coupling on ACI regime using

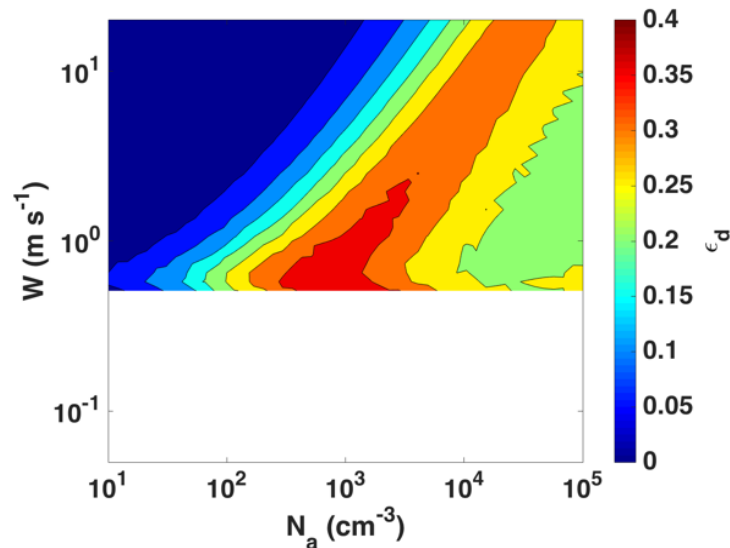
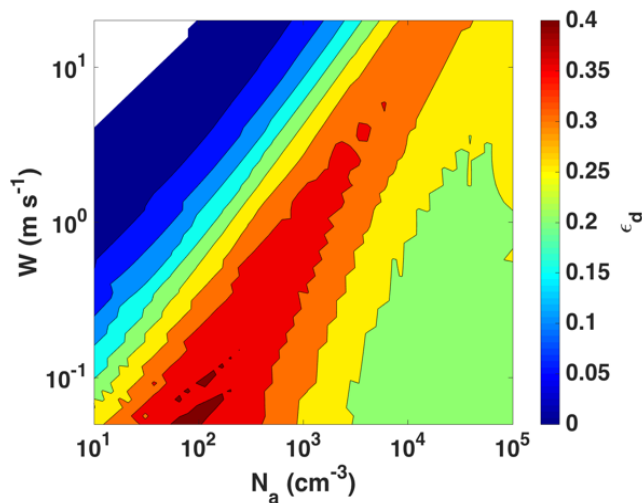
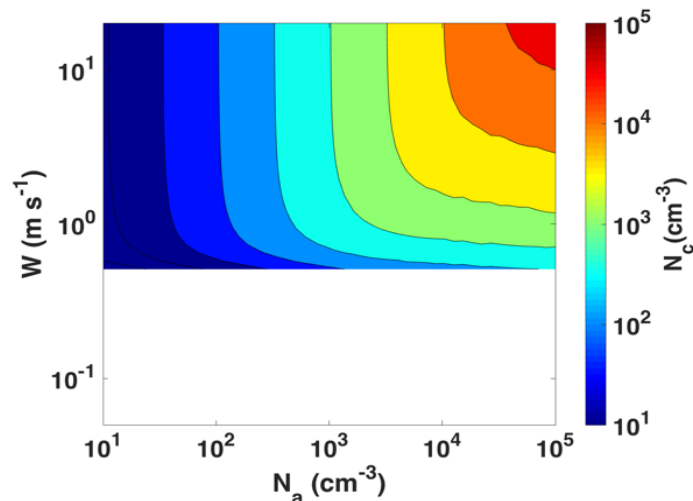
$$\lambda = 0.88 w^{-0.75}$$

Effect of w - λ Coupling

$\lambda = 1.0 \text{ km}^{-1}$; $\text{RH}_e = 0.6$



Coupled; $\text{RH}_e = 0.6$



Summary

- **Dispersion has non-monotonic regime dependence.**
- **Dispersion effect mitigates cooling in aerosol-limited regime, but enhances cooling in updraft-limited regime.**
- **The unique dispersion regime provides a new ACI parameterization considering both droplet concentration and relative dispersion.**
- **Entrainment and couplings alter the regime behavior, lead to height dependence of ACI regime (in progress)**