Ultra-clean Layers (UCLs) and Low albedo Clouds in the Marine Boundary Layer

- cloud parcel model simulation with bin microphysics scheme

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and all the other CSET members

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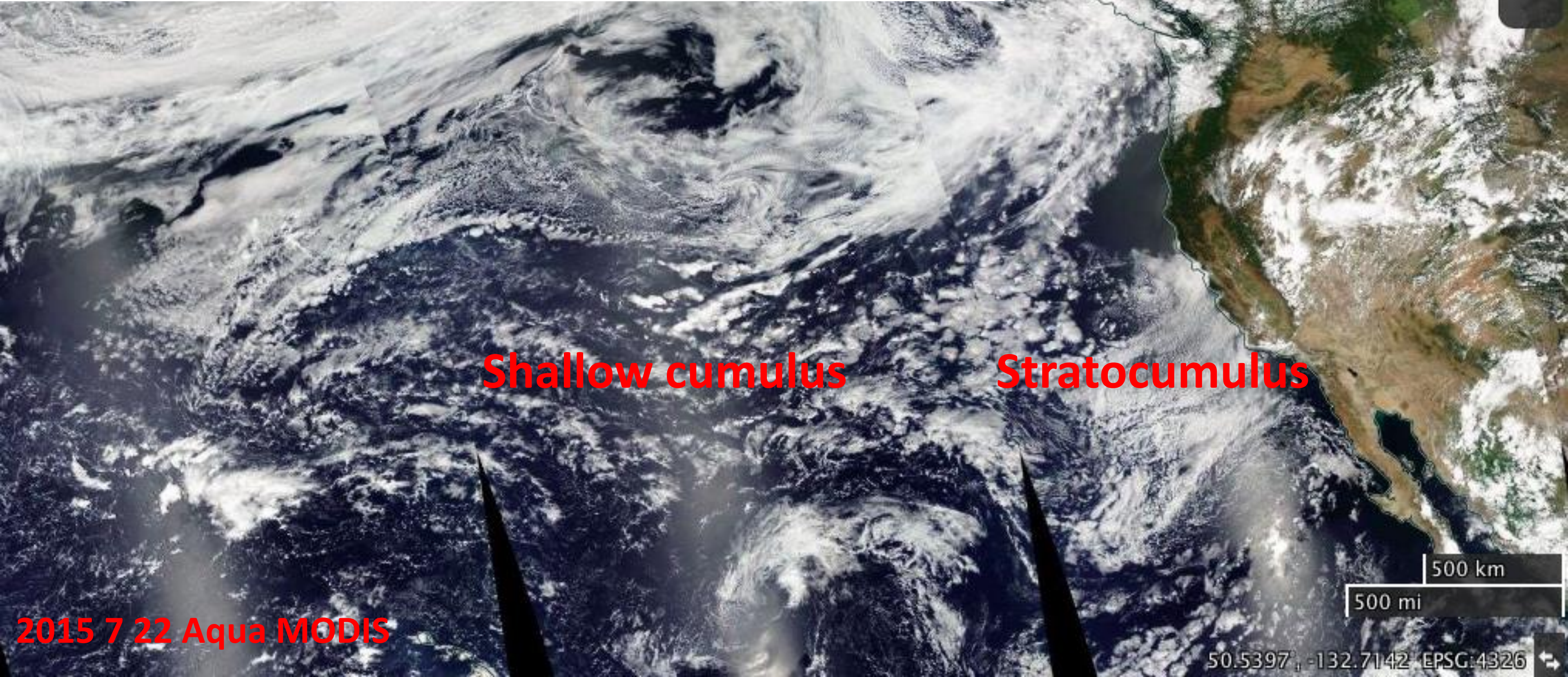
Short summary from the CSET observation of UCL clouds

- UCLs are most commonly found at height of 1.5-2 km
- UCLs coverage 0.4-0.6 between 135W and 155W
- UCL clouds is very quiescent (non-turbulent)



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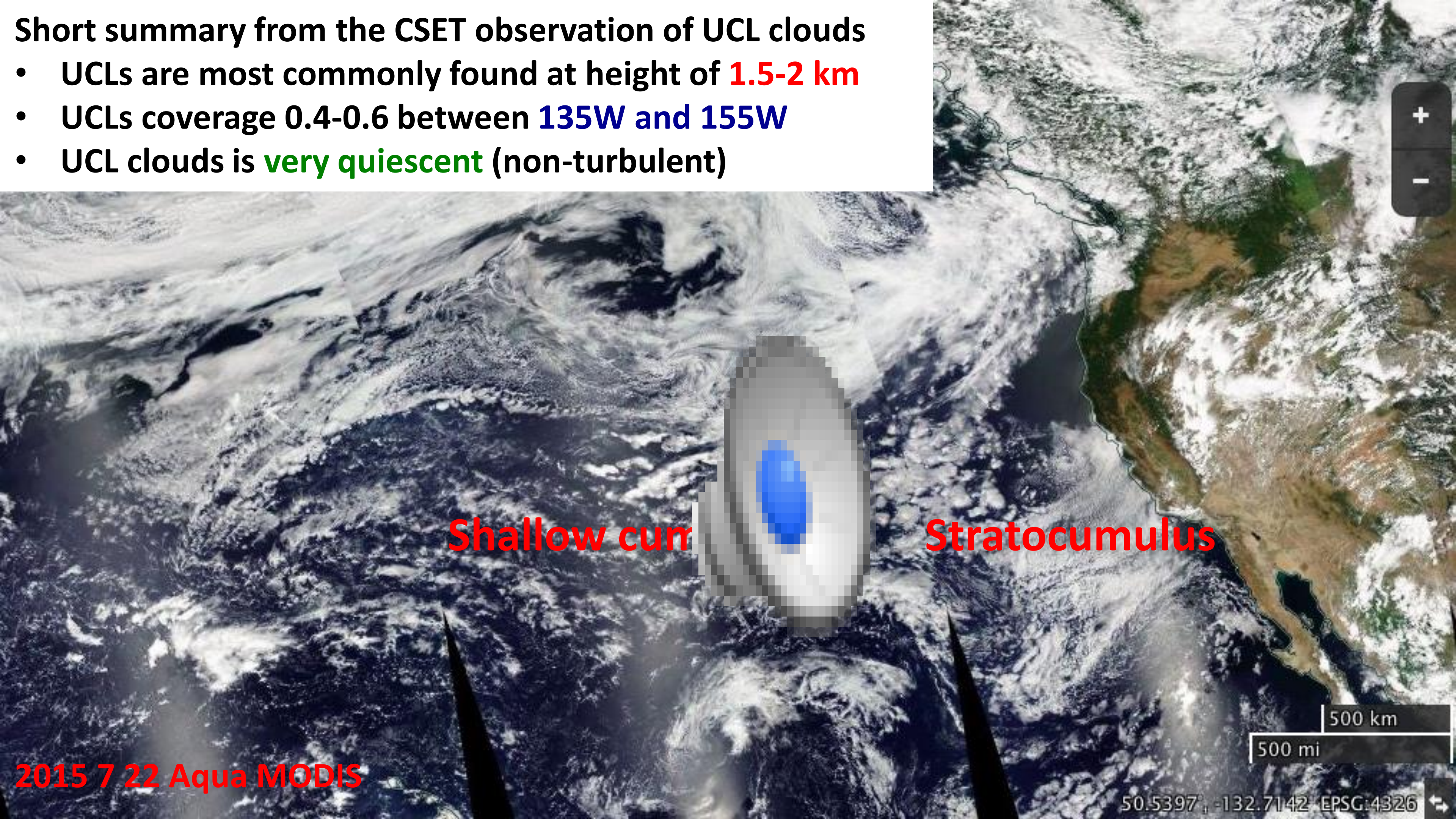

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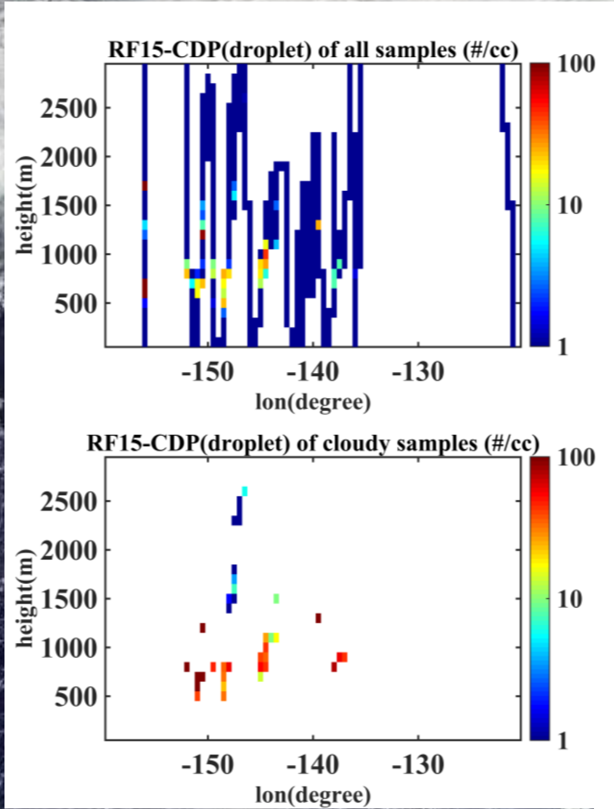

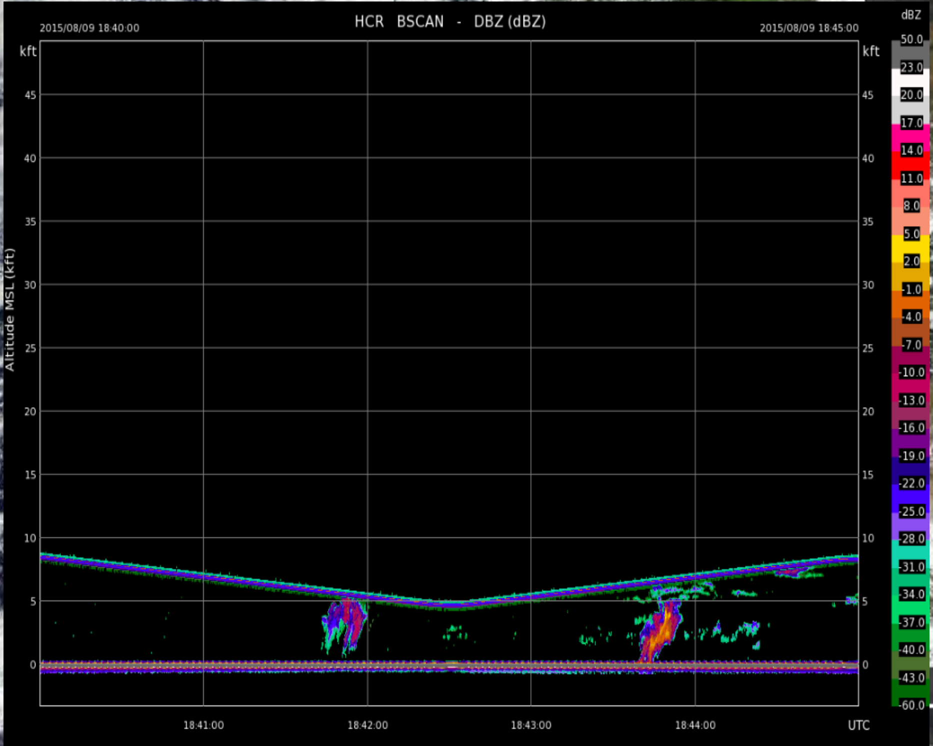

Cloudy sky: RH>95% and qc(cdp)>0.01 g m^{-3} or qd(2dc)>0.001 g m^{-3} or Ndd(2DC)>1/L

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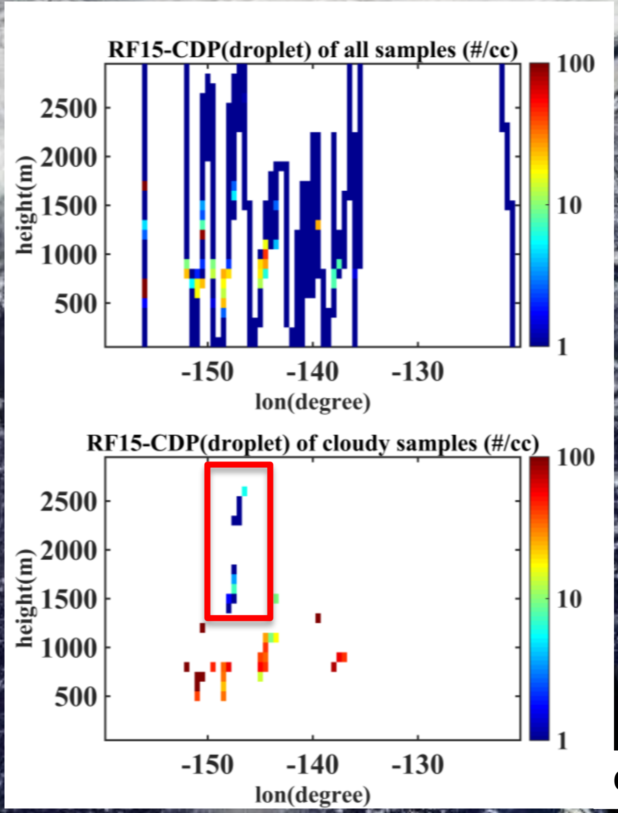

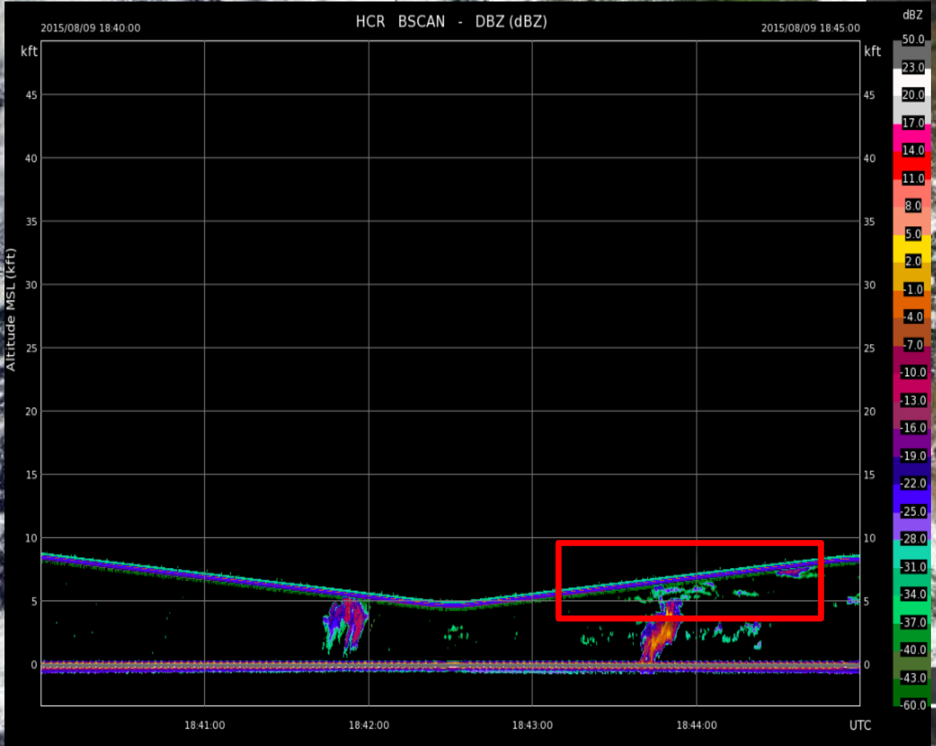

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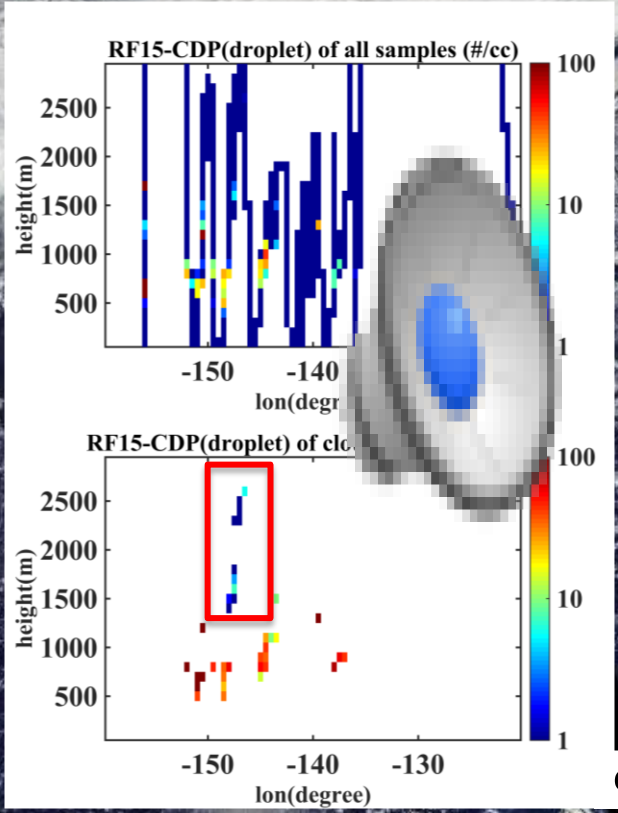

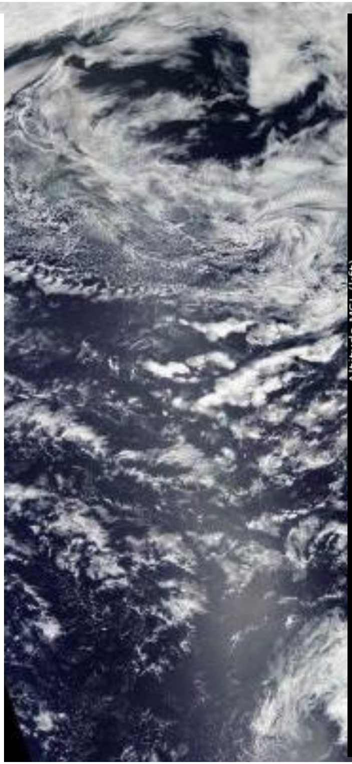

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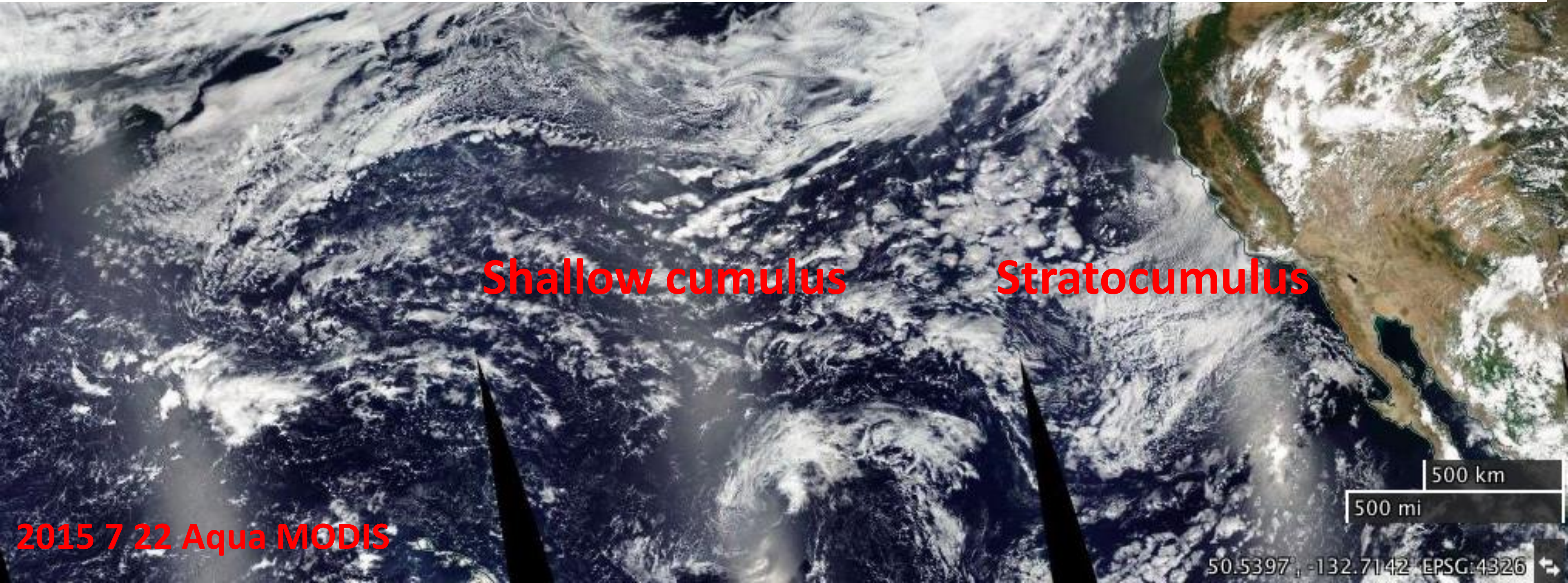

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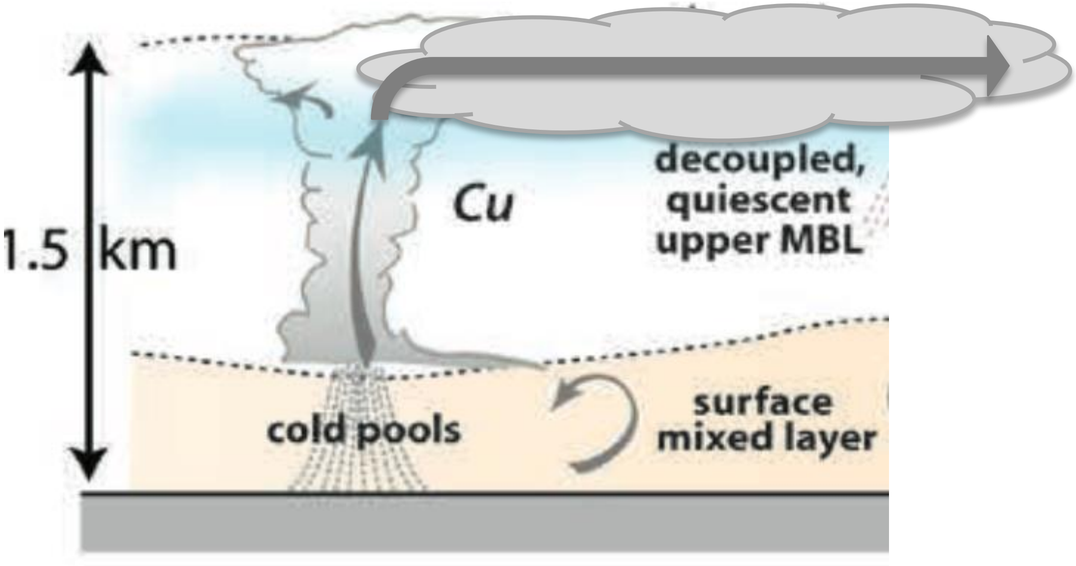

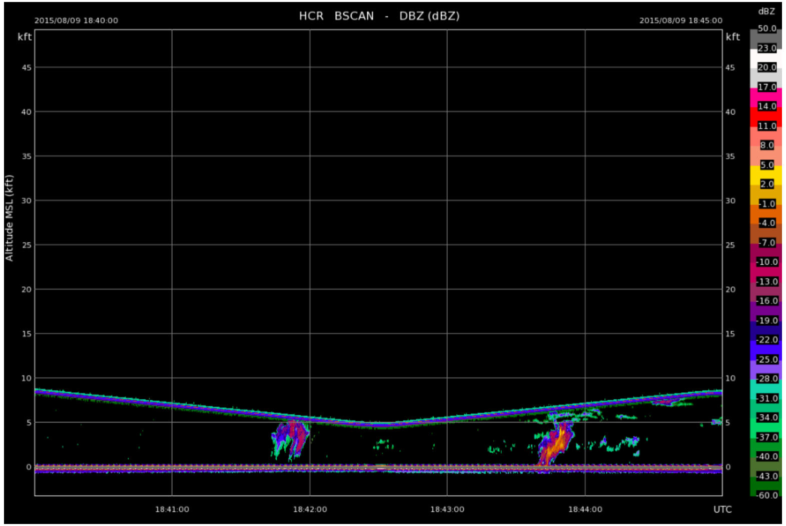

Revised figures from Mechoso et al. 2014

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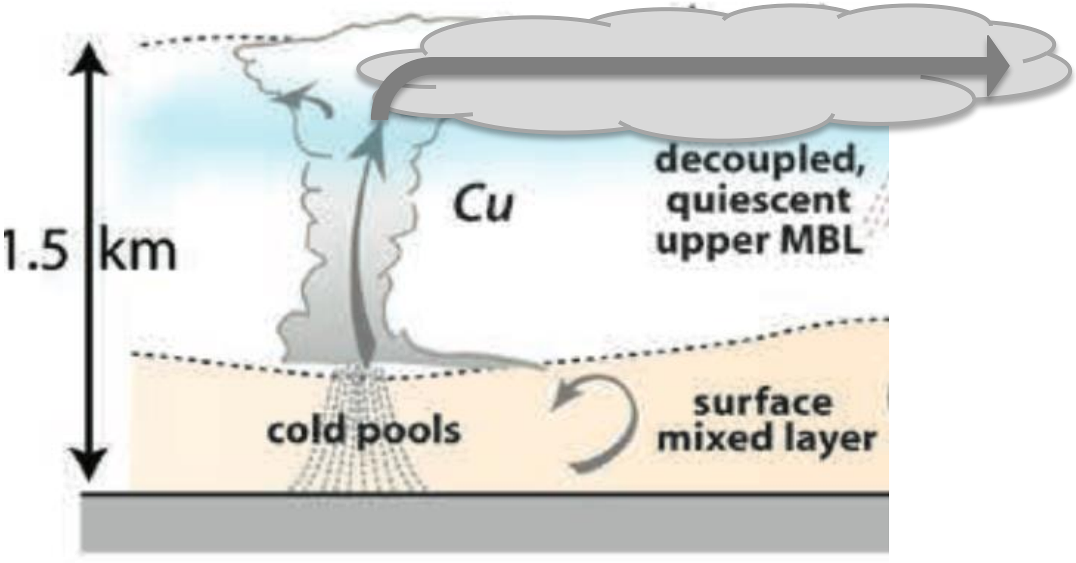
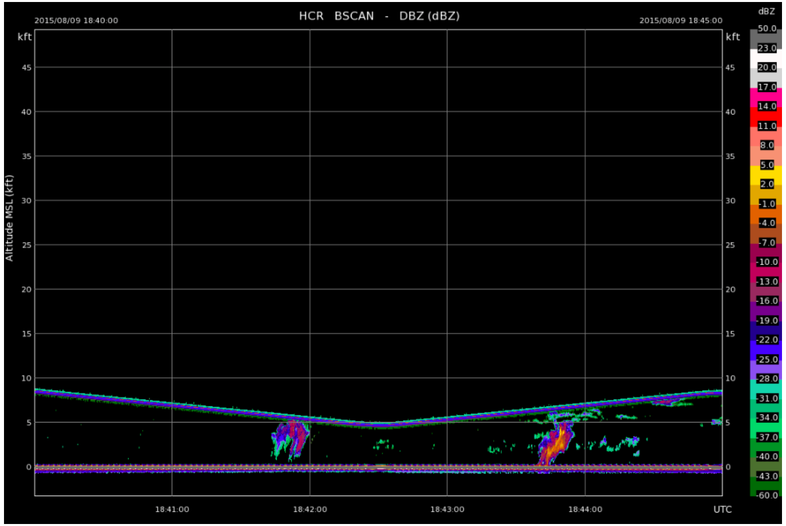
➔ **Can we prove it by cloud parcel model?**

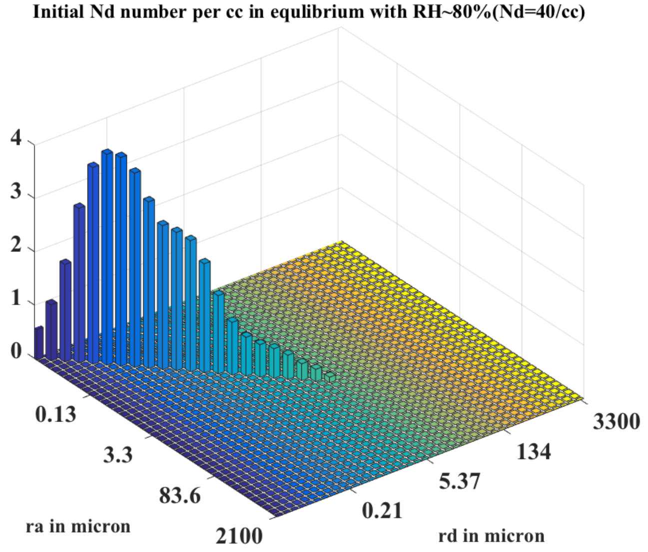


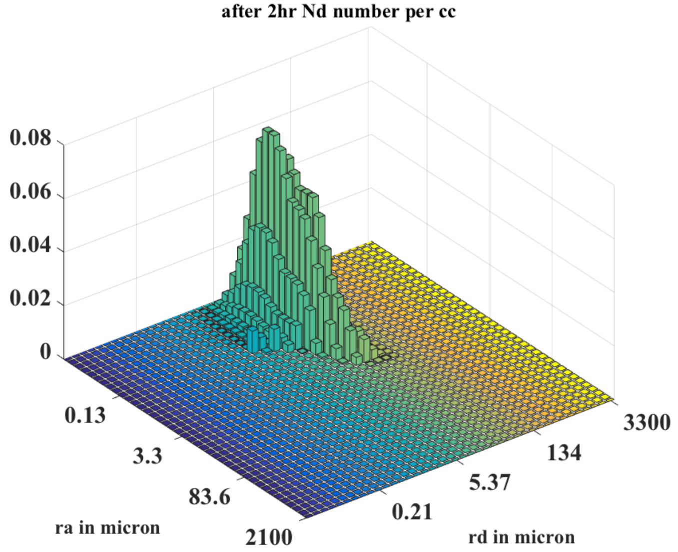


Revised figures from Mechoso et al. 2014

Cloud parcel model

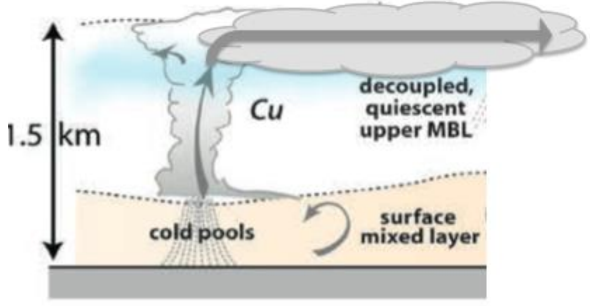
- bin microphysics scheme
- condensation/evaporation (bin shift by Chen and Lamb 1994 scheme)
- Collection coalescence (Bott 2000 Two-dimensional scheme)
- Sedimentation (i.e. flux method : $\frac{dN_{sedi}}{dt} = \frac{dN_d V_t}{dz}$, assuming parcel depth=300m)
- temperature/ saturation ratio is explicitly calculated (moist adiabatic)
- Including aerosol scavenging by droplet (collection kernel by Berner et al. 2013)

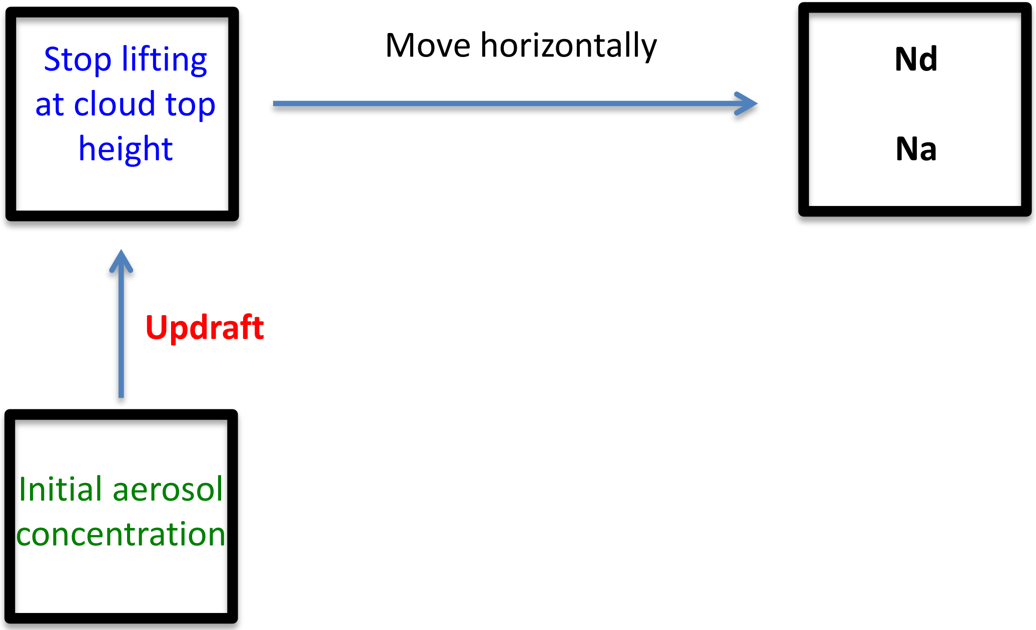




Cloud parcel model

- Three important parameters for cloud parcel model
  1. Initial aerosol concentration (#/cc)
  2. cloud top height (m)
  3. updraft (vertical velocity) (fixed Uz=1m/s for cumulus)





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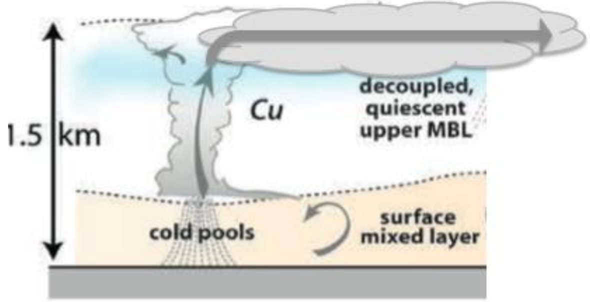


Stop lifting at cloud top height

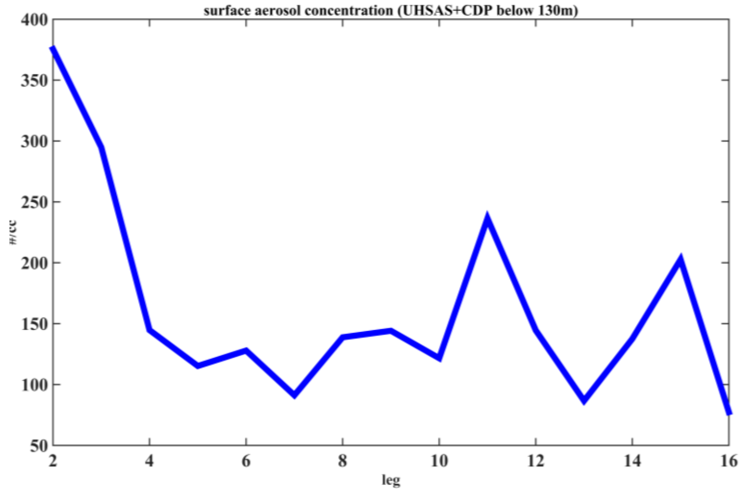
Move horizontally →

Nd

Na

↑ **Updraft**

Initial aerosol concentration



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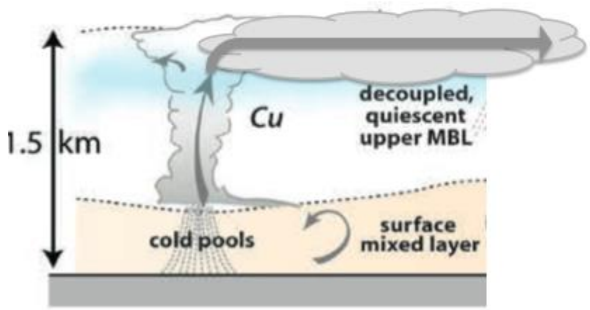

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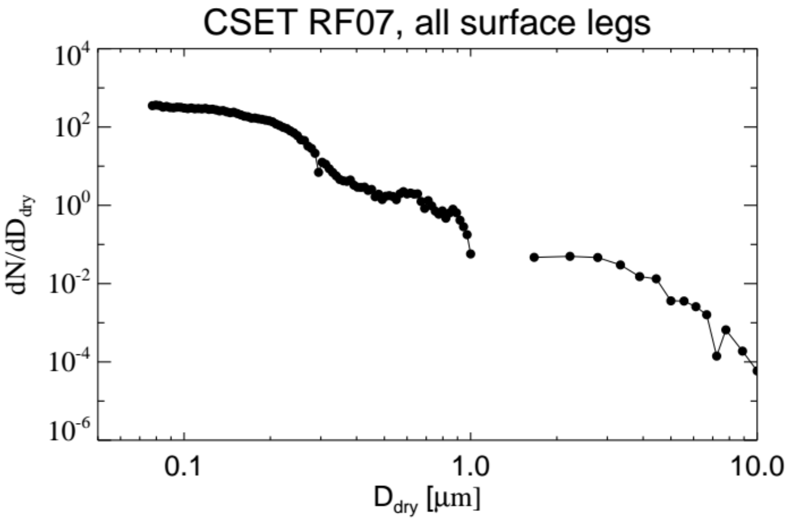

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  1. Initial aerosol concentration (#/cc) (50 #/cc to 200 #/cc)
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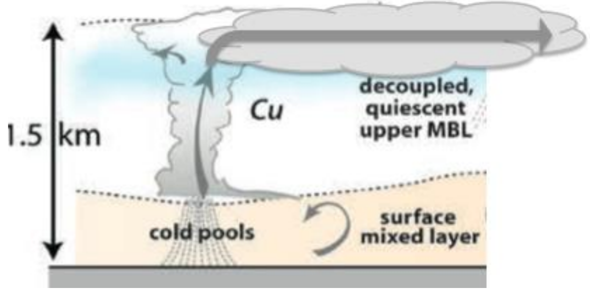

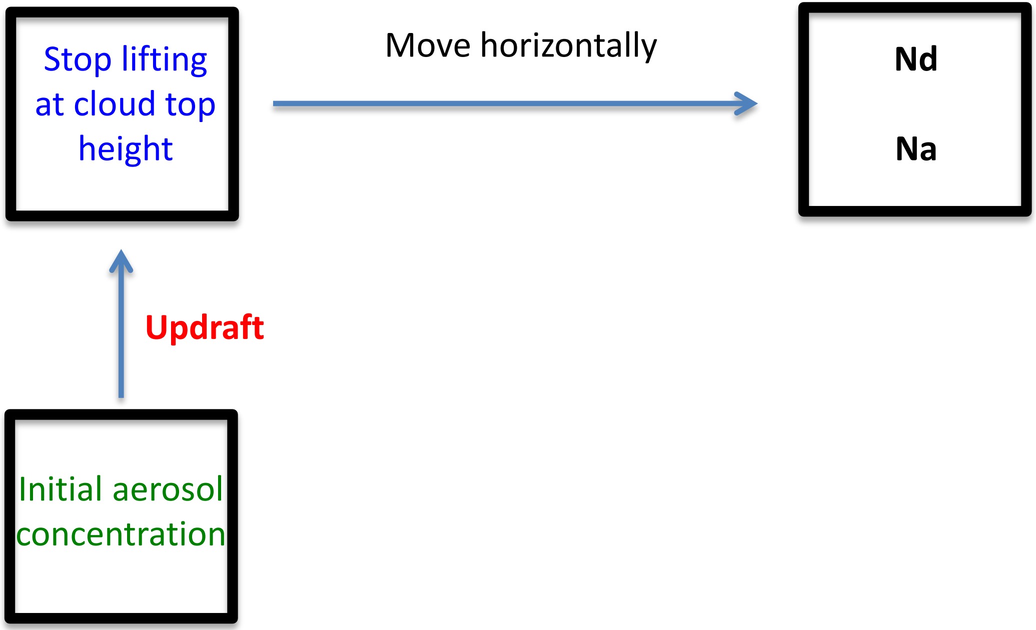

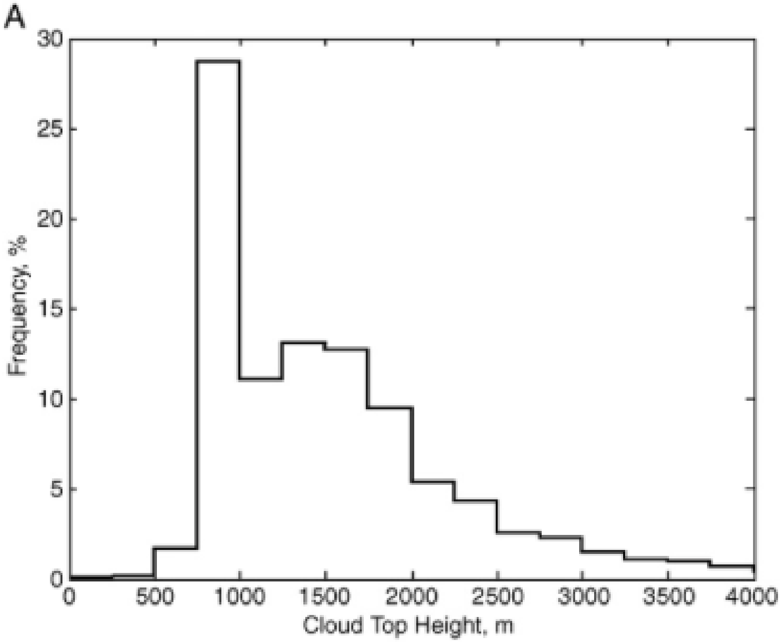

Trade cumulus cloud top height from Aster
Genkova et al. 2006

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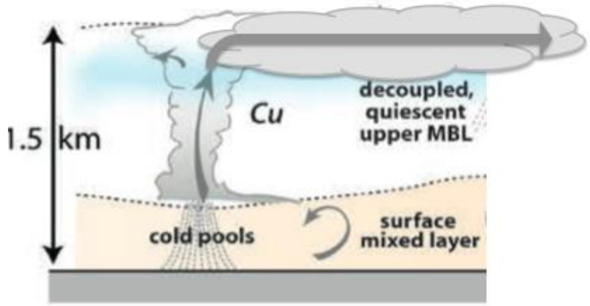

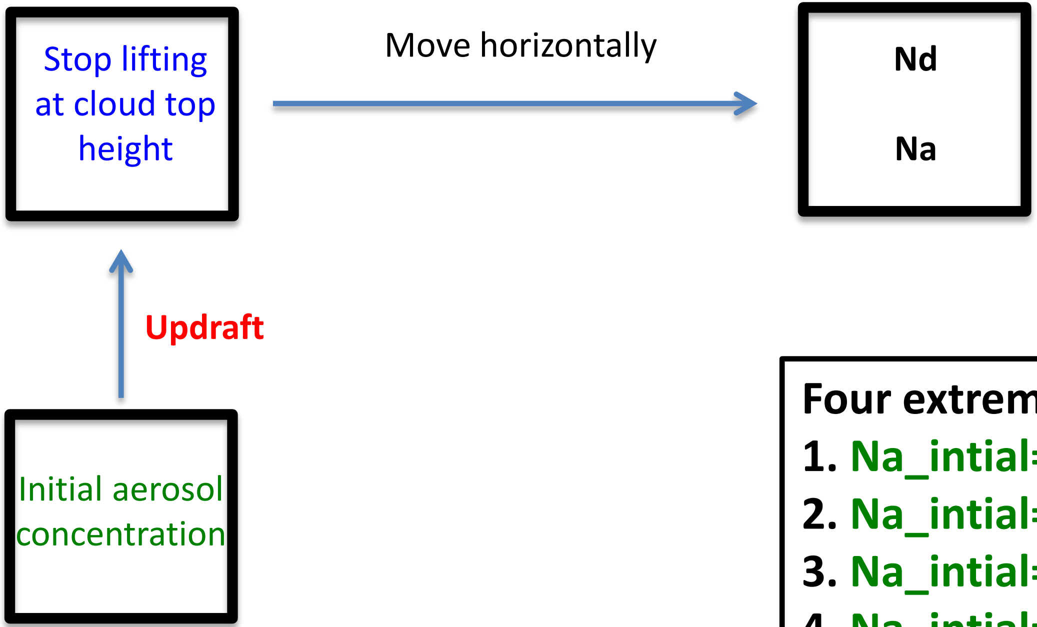

Four extreme cases are presented here (U_Z=1m/s)

1. Na_intial=50 #/cc cloud top height=800m

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3. Na_intial=200 #/cc cloud top height=800m

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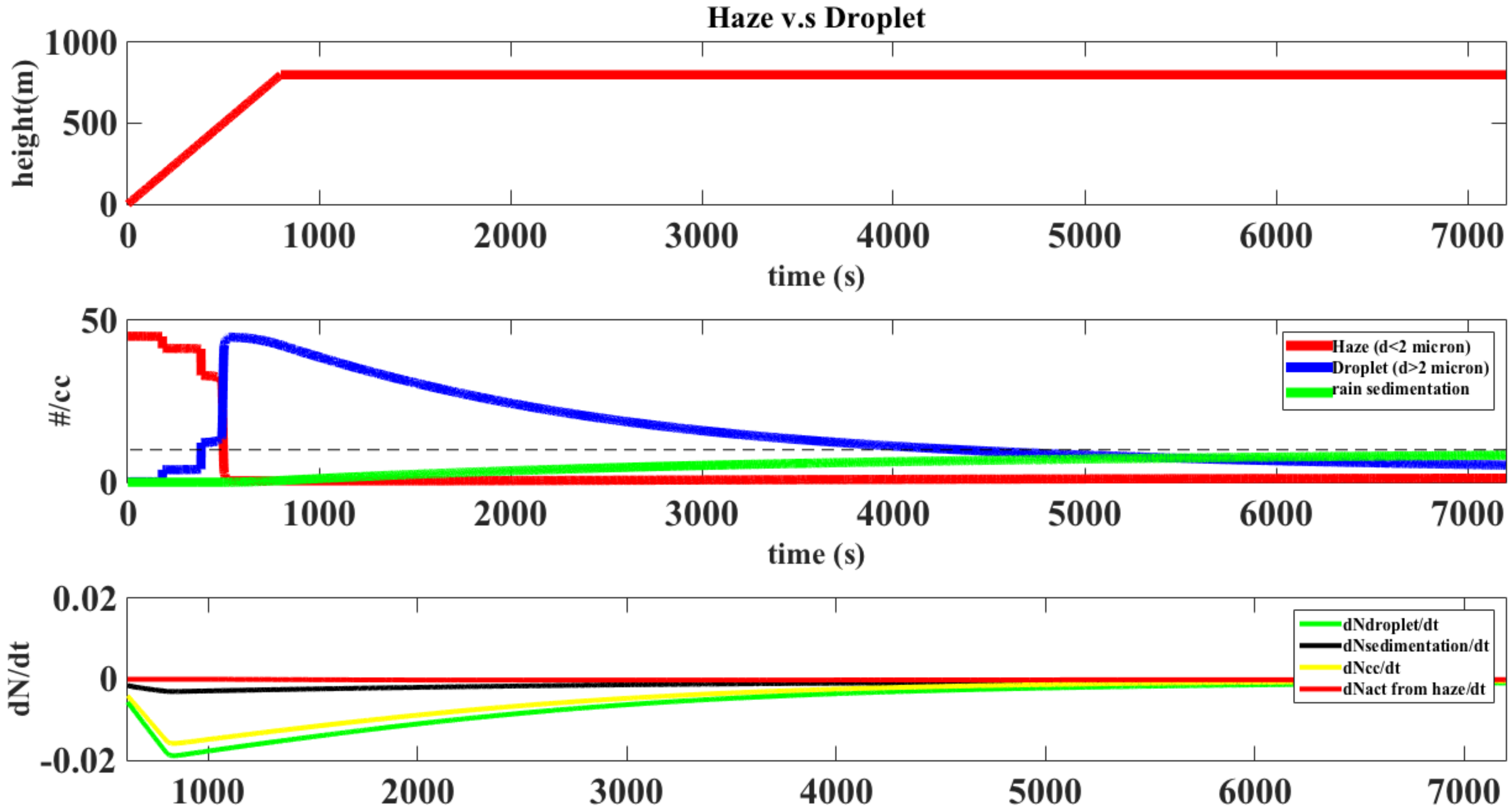
Na_intial=50 #/cc cloud top height=800m (low aerosol , low cloud top height)



$$\frac{dN_{droplet}}{dt} \sim \frac{dN_{cc}}{dt} + \frac{dN_{sedi}}{dt} + \frac{dN_{act}}{dt}$$

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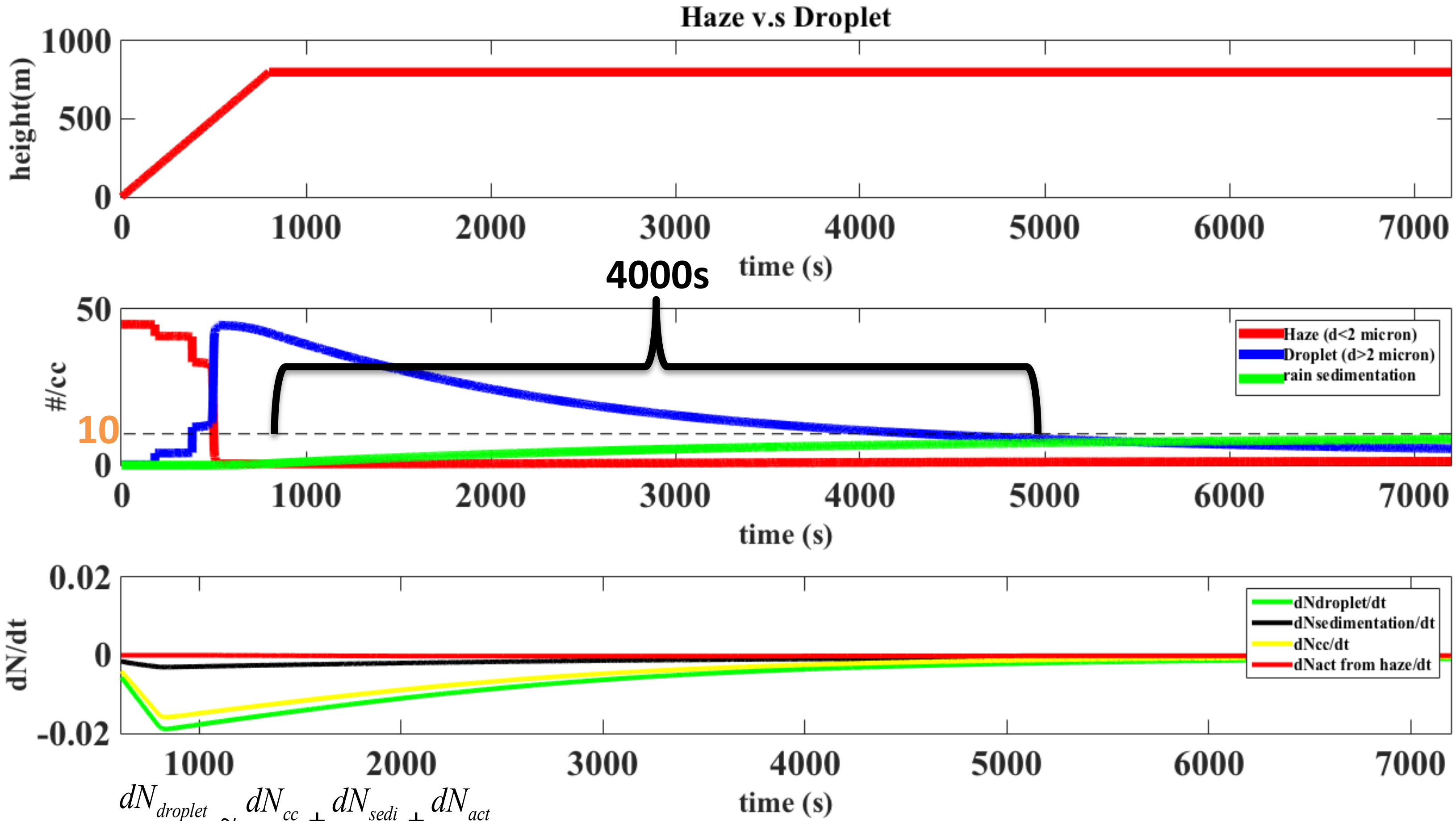

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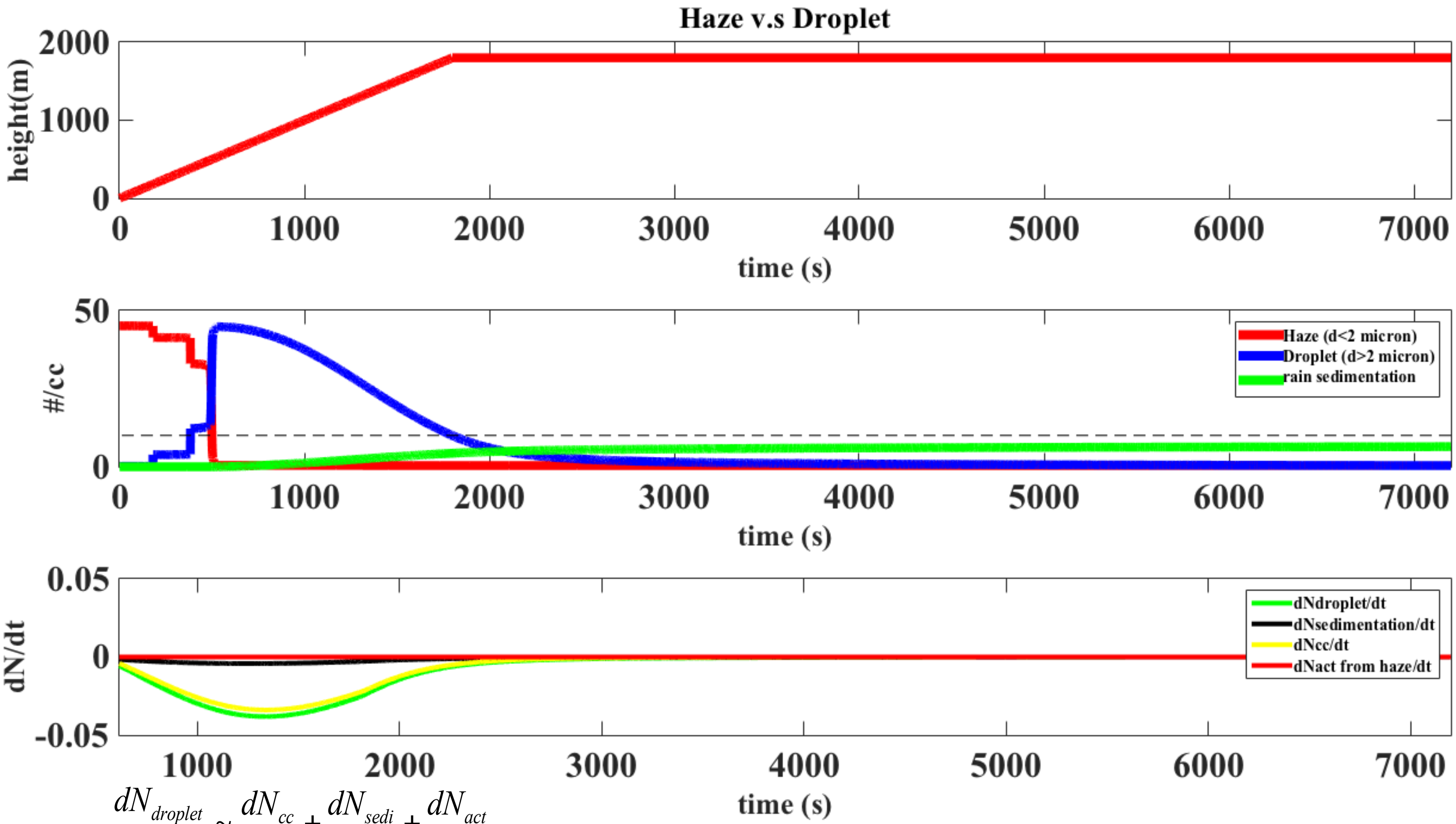
Na_intial=50 #/cc   cloud top height=1800m (low aerosol , high cloud top height)



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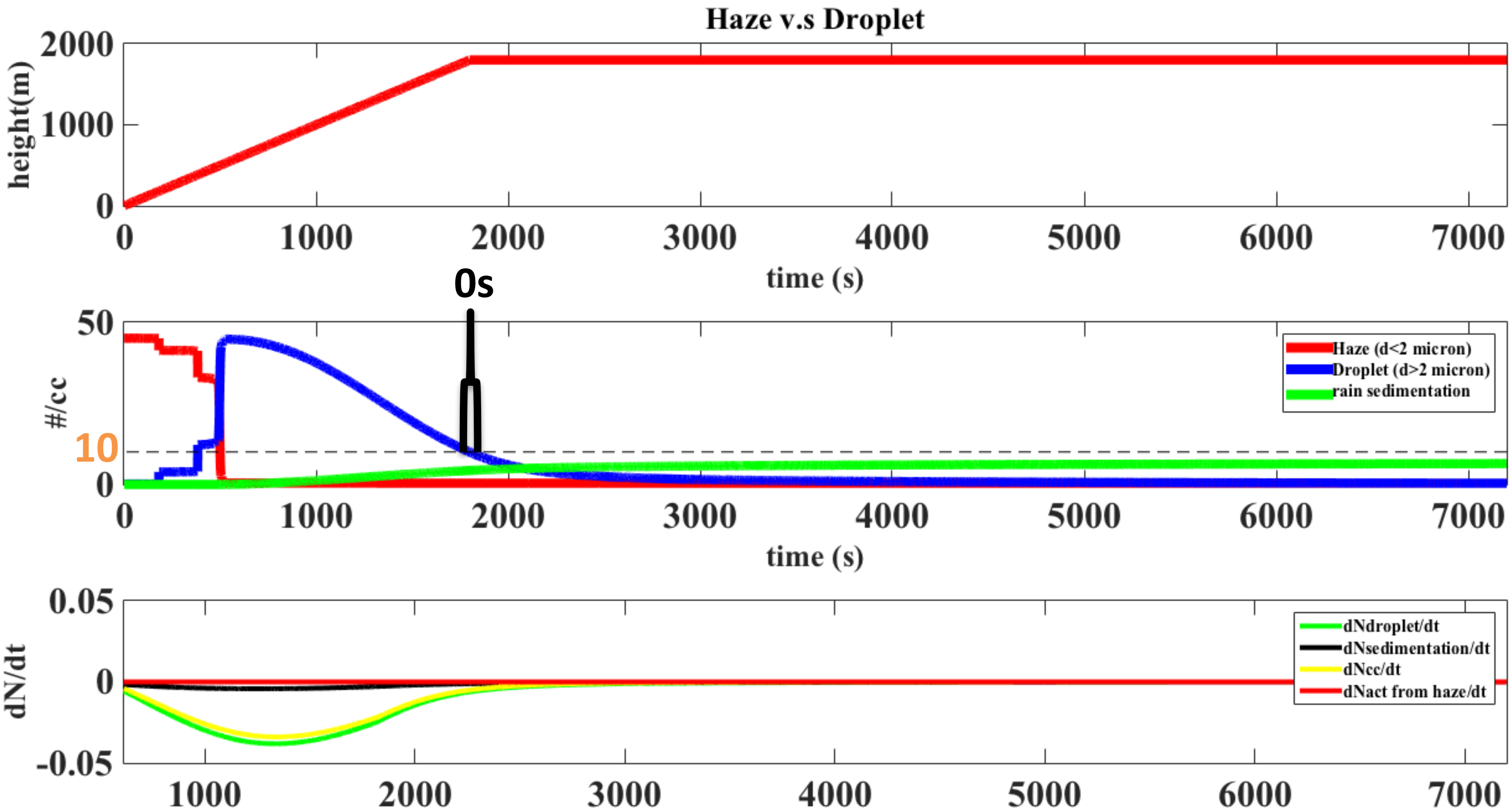

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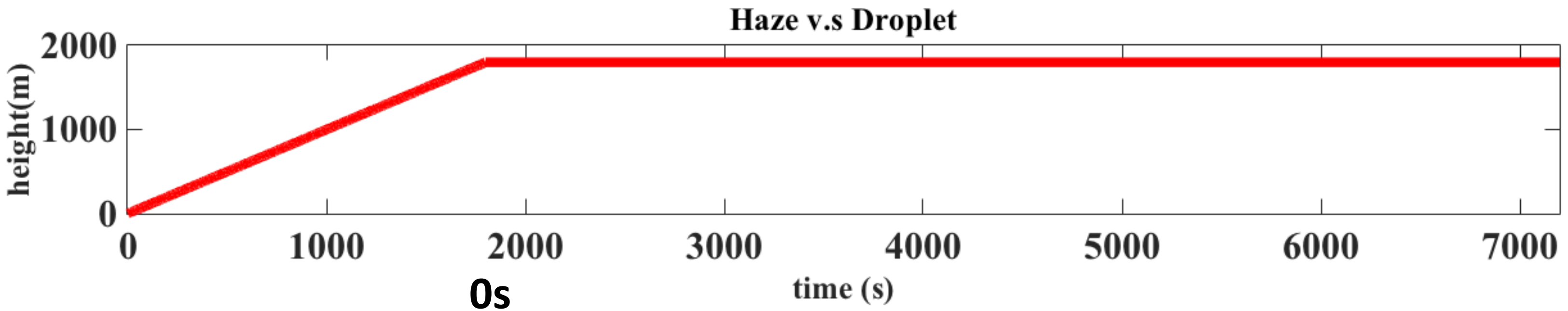

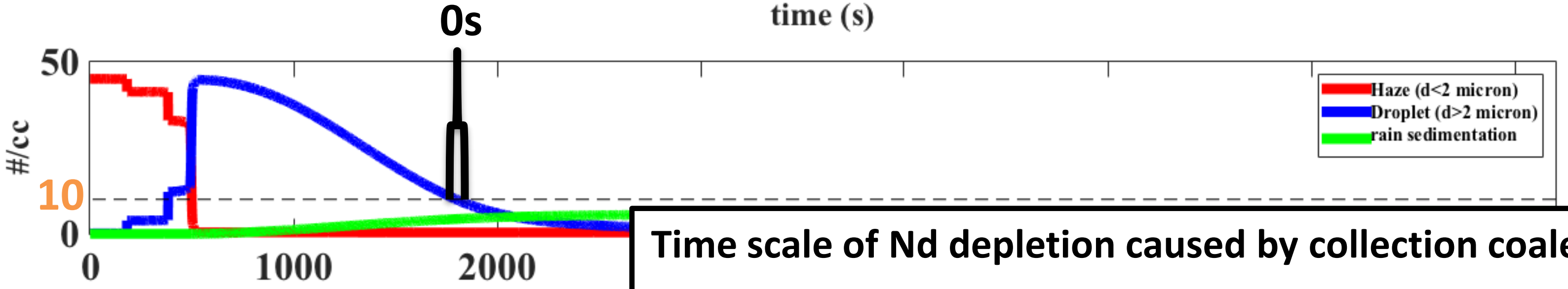

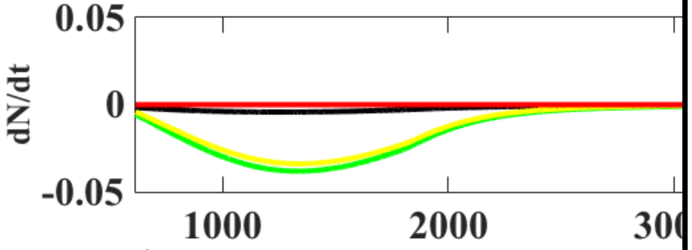

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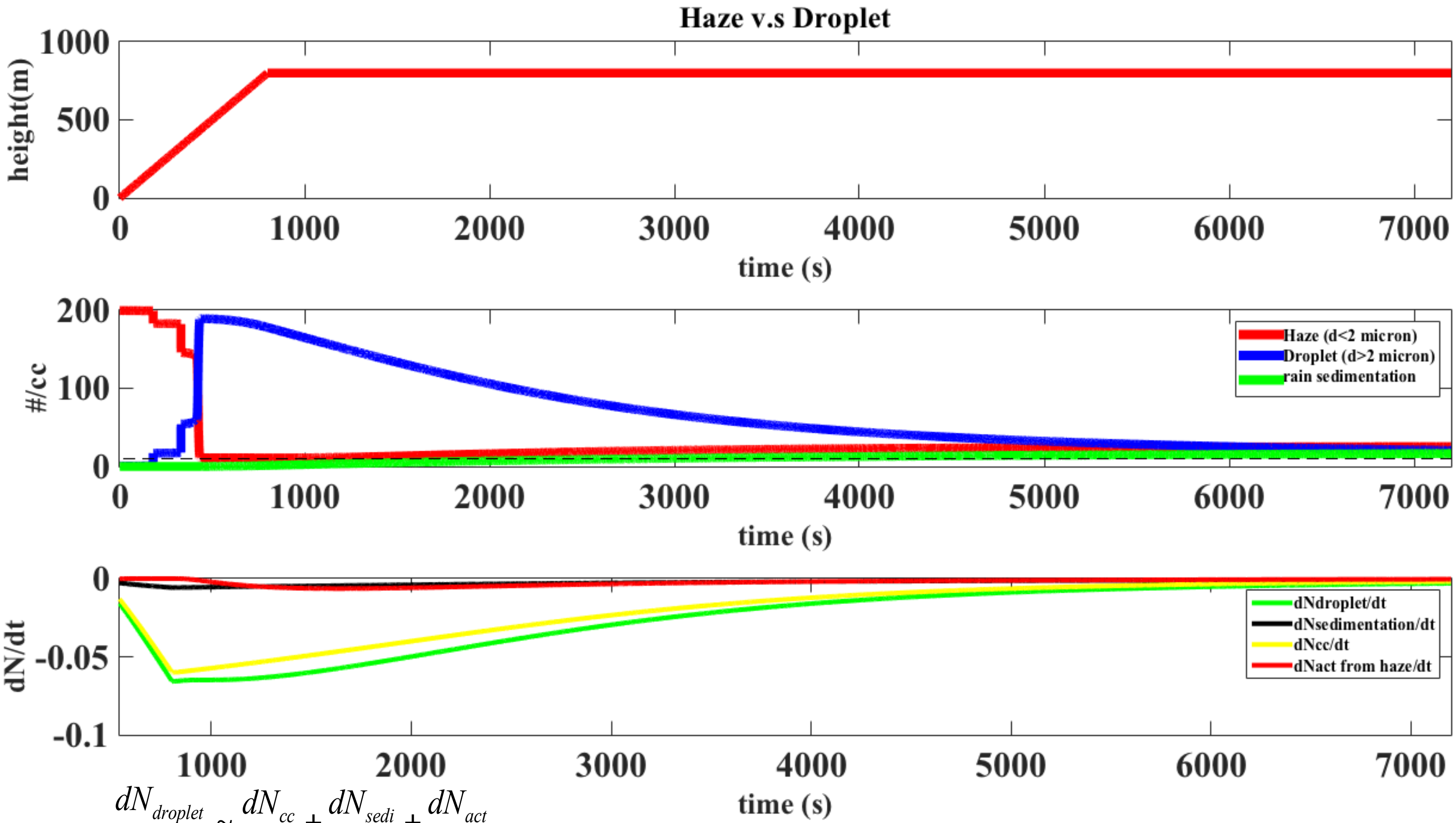
Time scale of Nd depletion caused by collection coalescence

$$\frac{dN_d}{dt} = -K_{kernal} \times N_d^2 = -K_{kernal} \times N_d \times N_d = -\frac{1}{t_{cc}} \times N_d$$

$K_{kernal} = 10^{-10}(\frac{m^3}{s})$, **for r=10 micron droplet**

$$t_{cc} = \frac{1}{K_{kernal} \times N_d} = \frac{1}{10^{-10}(\frac{m^3}{s}) \times 5 \times 10^7(\frac{\#}{m^3})} = 200s!!!$$

Na_intial=200 #/cc cloud top height=800m (high aerosol , low cloud top height)



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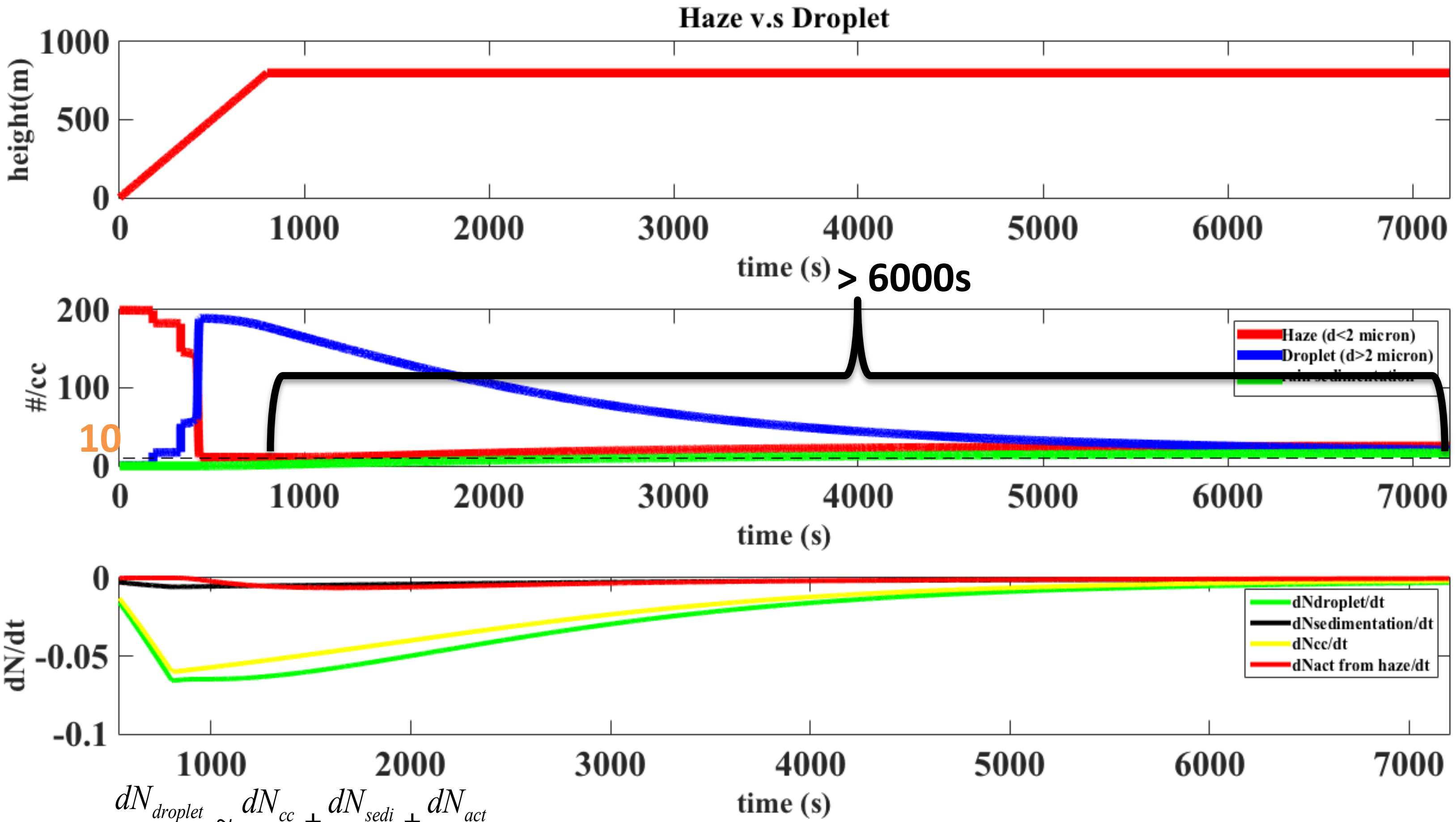

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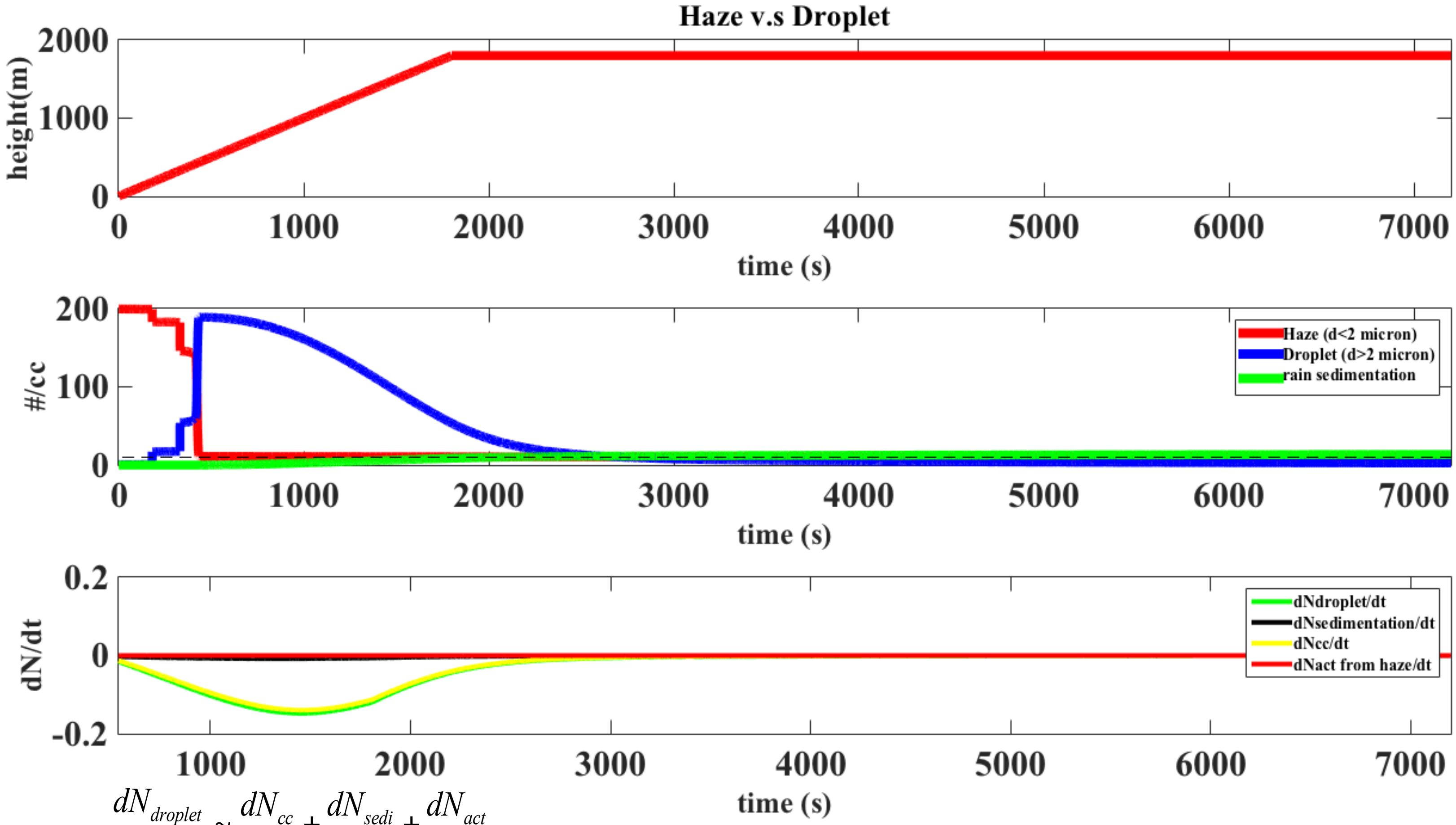

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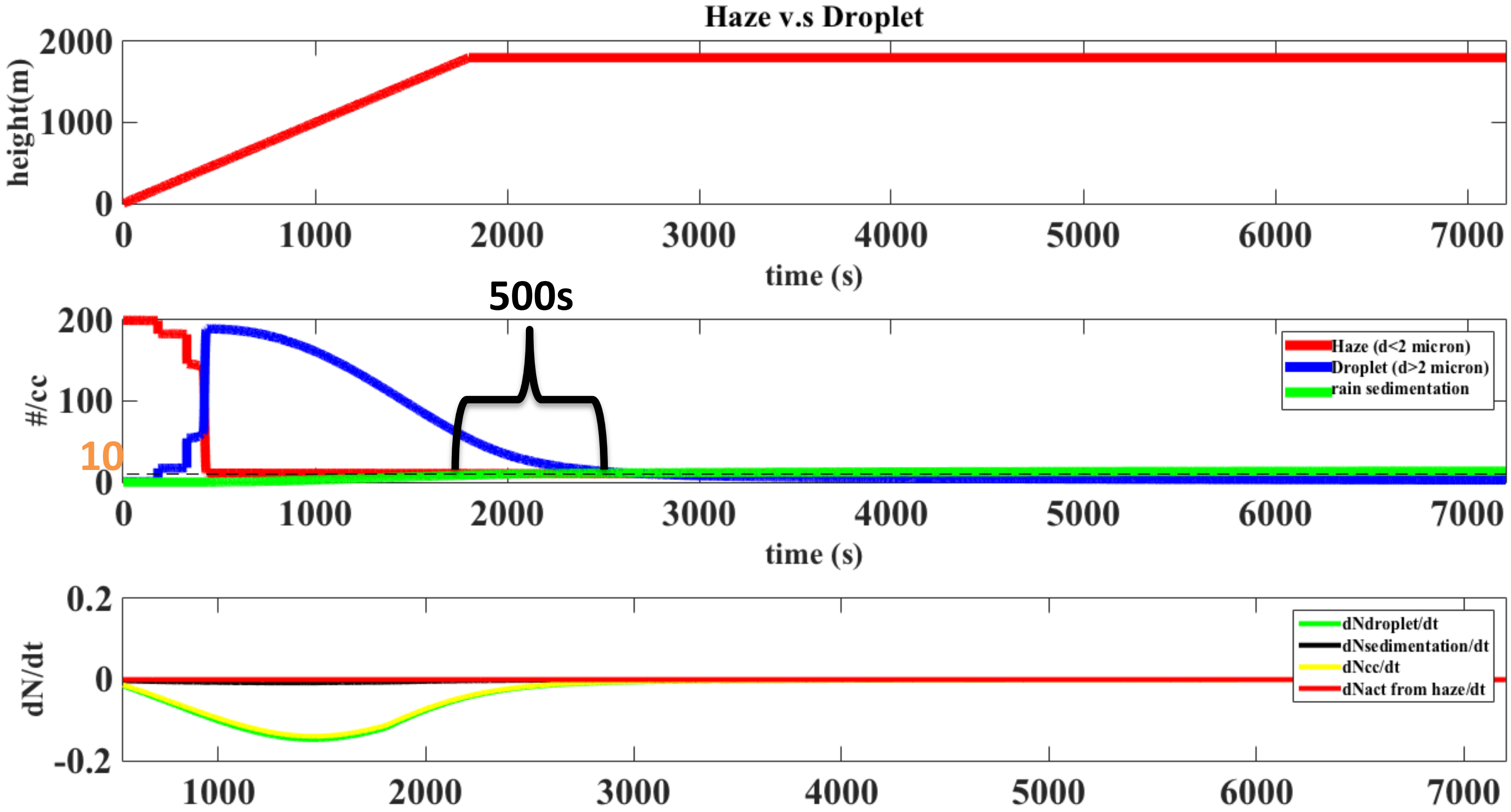

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1. **Low aerosol low cloud top height** : UCL clouds after 4Ks after reaching cloud top
2. **Low aerosol high cloud top height :** UCL clouds after 0s after reaching cloud top
3. **high aerosol low cloud top height : no** UCL clouds after 6Ks after reaching cloud top
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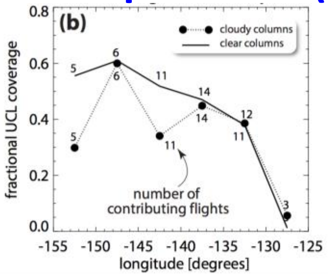
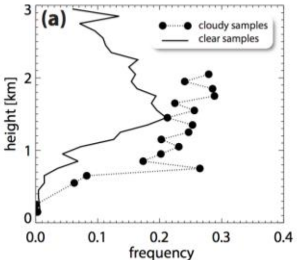
Summary (observation/parcel model)

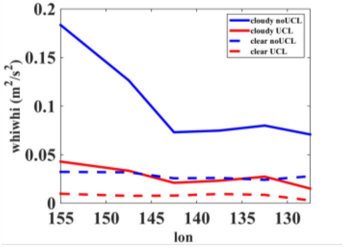
- **UCLs coverage 0.4-0.6 between 135W and 155W (trade cumulus regime favors UCLs)**
  UCLs occur very infrequently east of 130W (stratocumulus regime not favors UCLs)

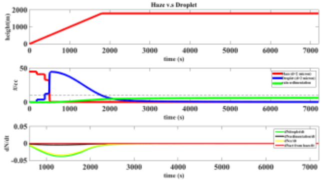
- **UCLs are commonly found at height of 1.5-2 km (UCL clouds can easily form at outspread layers at top of cumulus dominated by *collection coalescence* process)**

- **UCL clouds are quiescent (non-turbulent) (Outspread layers are supposed to be quiescent)**









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Summ

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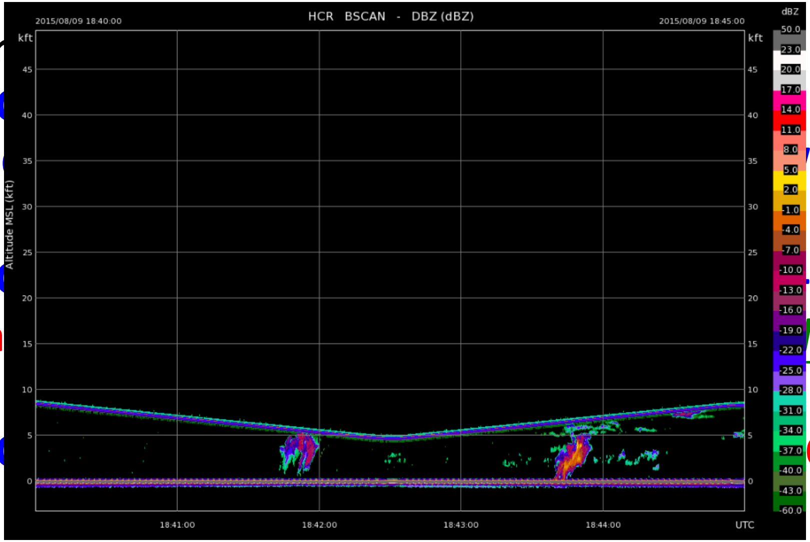
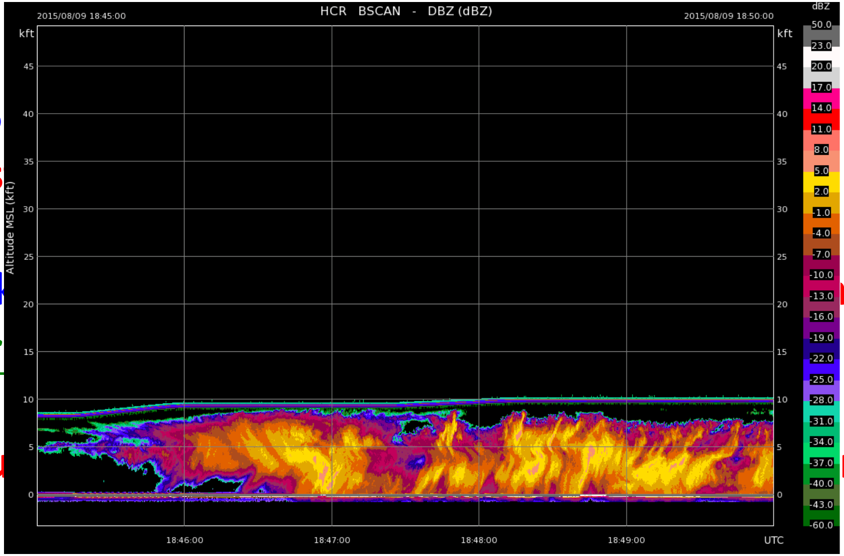
  U(... **(s**
- **UC** ... **2 k** ... **nd**
  la ... ***lec***
- **UC** ... **Ou** ... **nt)**





Future works (what does not consider so far?)

- **Entrainment/lateral mixing….**
- **Distance between cumulus/convective cell….** ➔ **LES model next step**