# Model Intercomparisons of Drizzling Stratocumulus: DYCOMS-II RF02

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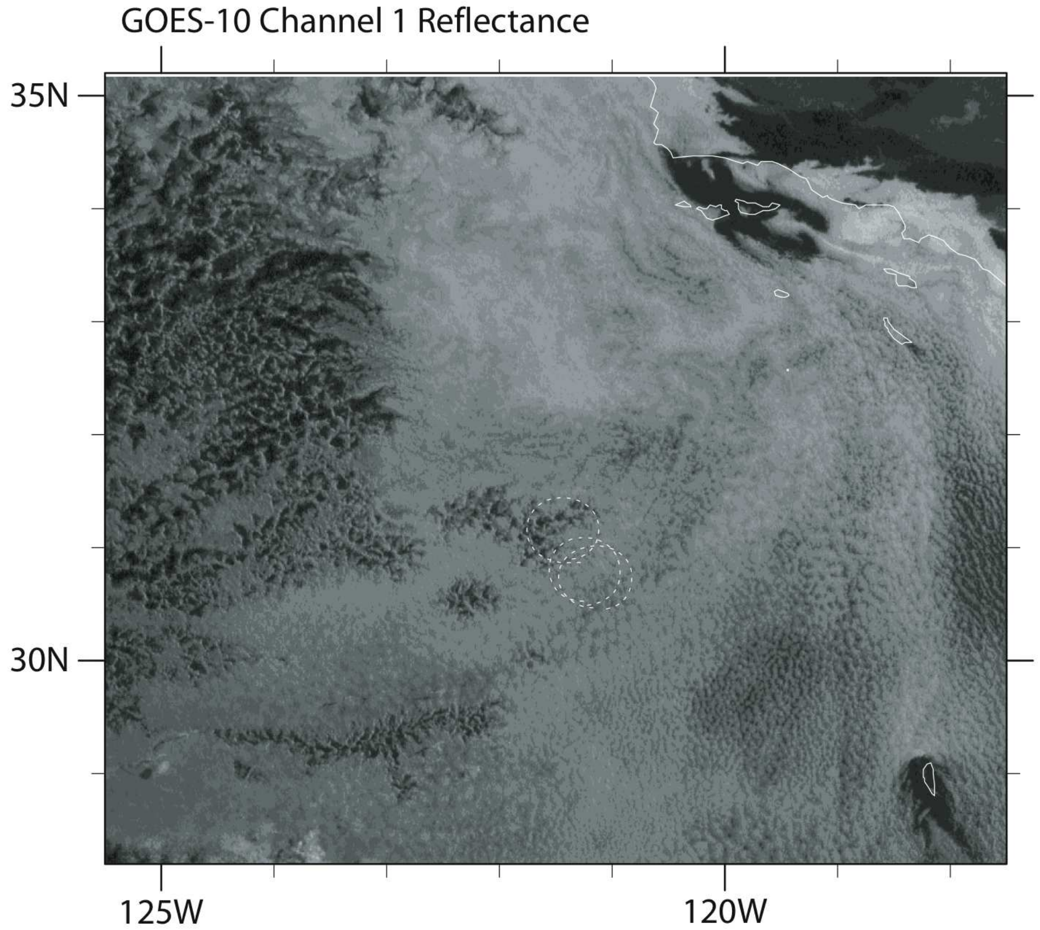



(Figure from *van Zanten & Stevens 2005*)

# Motivation

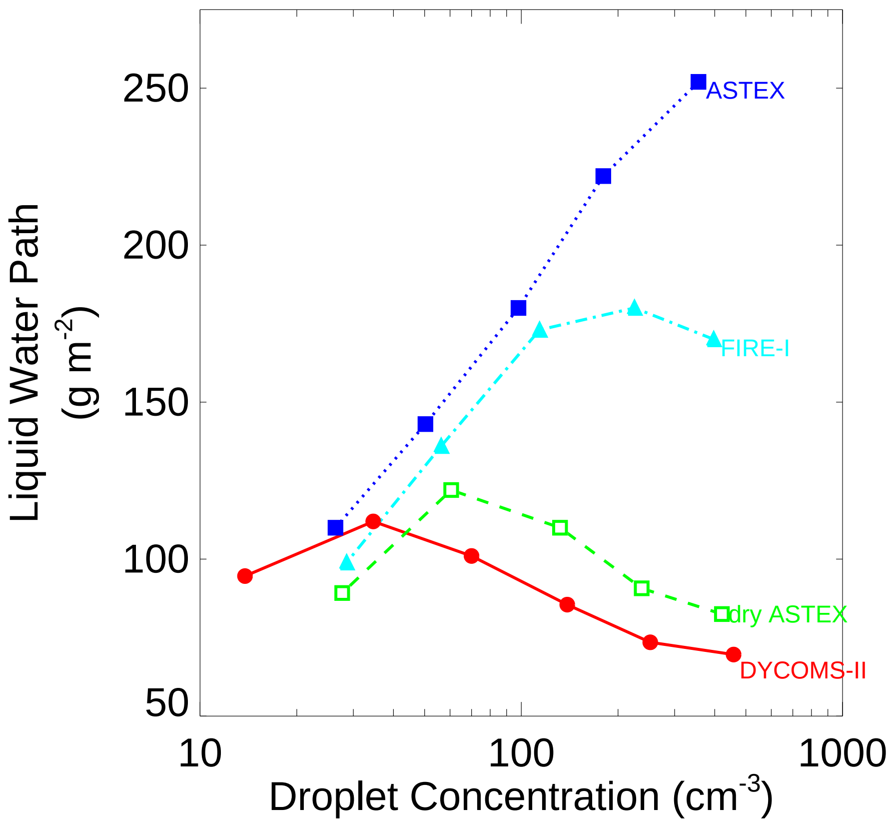
- How does drizzle affect
  - boundary layer dynamics, particularly entrainment
  - bulk cloud properties, particularly LWP
- How do predictions of drizzle in LES compare with observations?
- How does sedimentation of cloud droplets affect simulations?
- Outline:

  I. Large-eddy simulations (LES)
  II. Single-column models (SCM)

## Results from Previous Workshop (*Stevens et al. 2005*)

- Case: DYCOMS-II RF01, with very dry inversion, droplet concentrations about 100 $cm^{-3}$, and no precipitation below cloud base
- Most LES entrained overlying air faster than measurements indicated, resulting in a thin, cloud layer with LWP lower than observed
- Limiting subgrid-scale mixing at inversion reduces entrainment, resulting in well-mixed boundary layer with thick cloud layer

# LWP Response to Increasing Droplet Concentrations Depends on Overlying Humidity

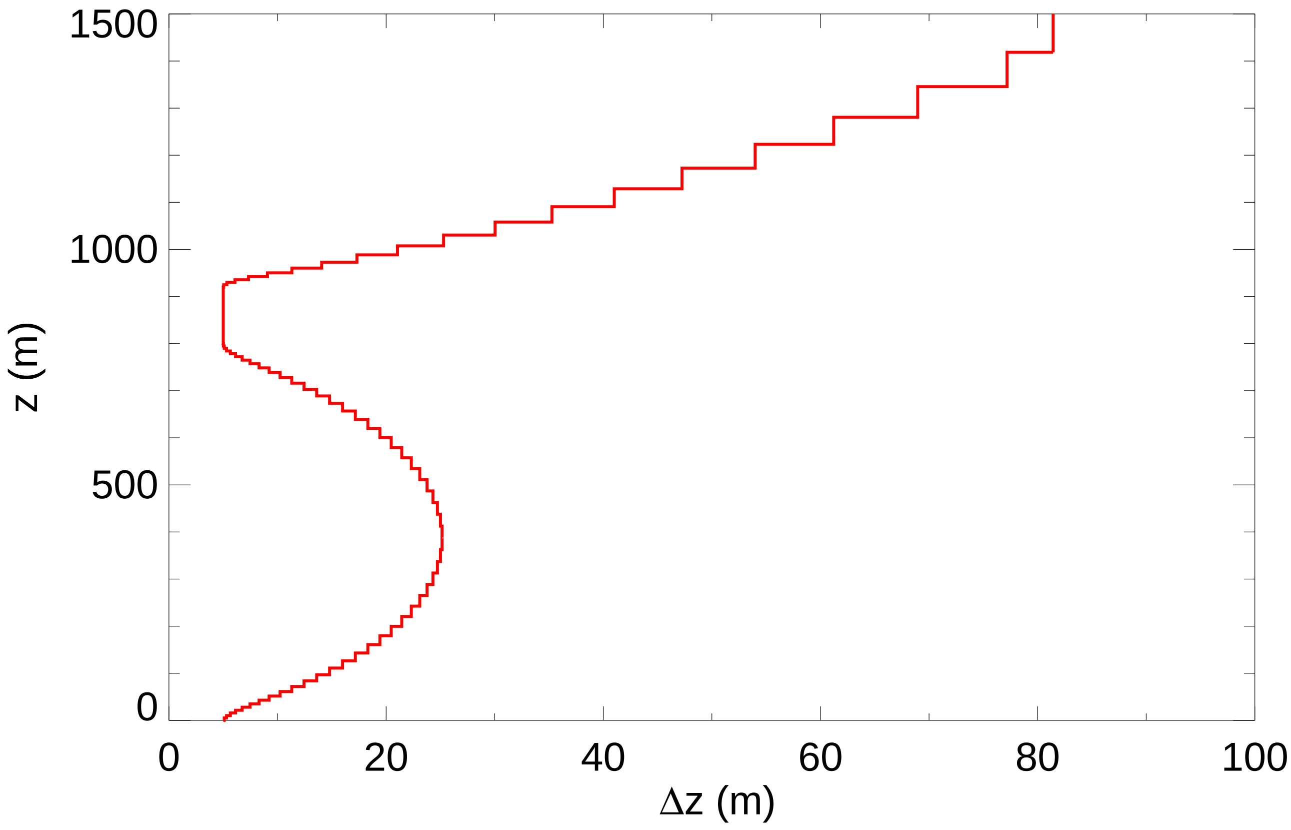



(Figure from *Ackerman et al. 2004*)

- Entrainment increases as drizzle, or even just cloud droplet sedimentation decreases
- LWP increases with $N$ only when surface precipitation $>\sim$ 0.1 mm/d

# Intercomparison Setup: Grid

- 6.4 x 6.4 x 1.5 km, $\Delta x = \Delta y$ = 50 m
- If possible, use stretched grid with 96 layers:



# Intercomparison Setup: Forcings

- Radiation: Beer's Law parameterization from previous workshop, which includes heating at cloud base, cooling at and above cloud top
- Subsidence: fixed divergence of horizontal wind (3.75 x $10^{-6}$ $s^{-1}$)
- Coriolis: geostrophic wind profiles specified
- Fix surface heat fluxes and fix friction velocity at 0.25 m/s

# Intercomparison Setup: Microphysics

- Fix $N$ at 55 cm$^{-3}$, if possible

- If otherwise ignoring sedimentation of cloud water, use integral over log-normal size distribution assuming Stokes sedimentation:

  $$F = cN^{2/3} q_c^{5/3} \exp(\ln^2 \sigma_g)$$

  with $\sigma_g$ = 1.5 (1.2 would have been more appropriate)

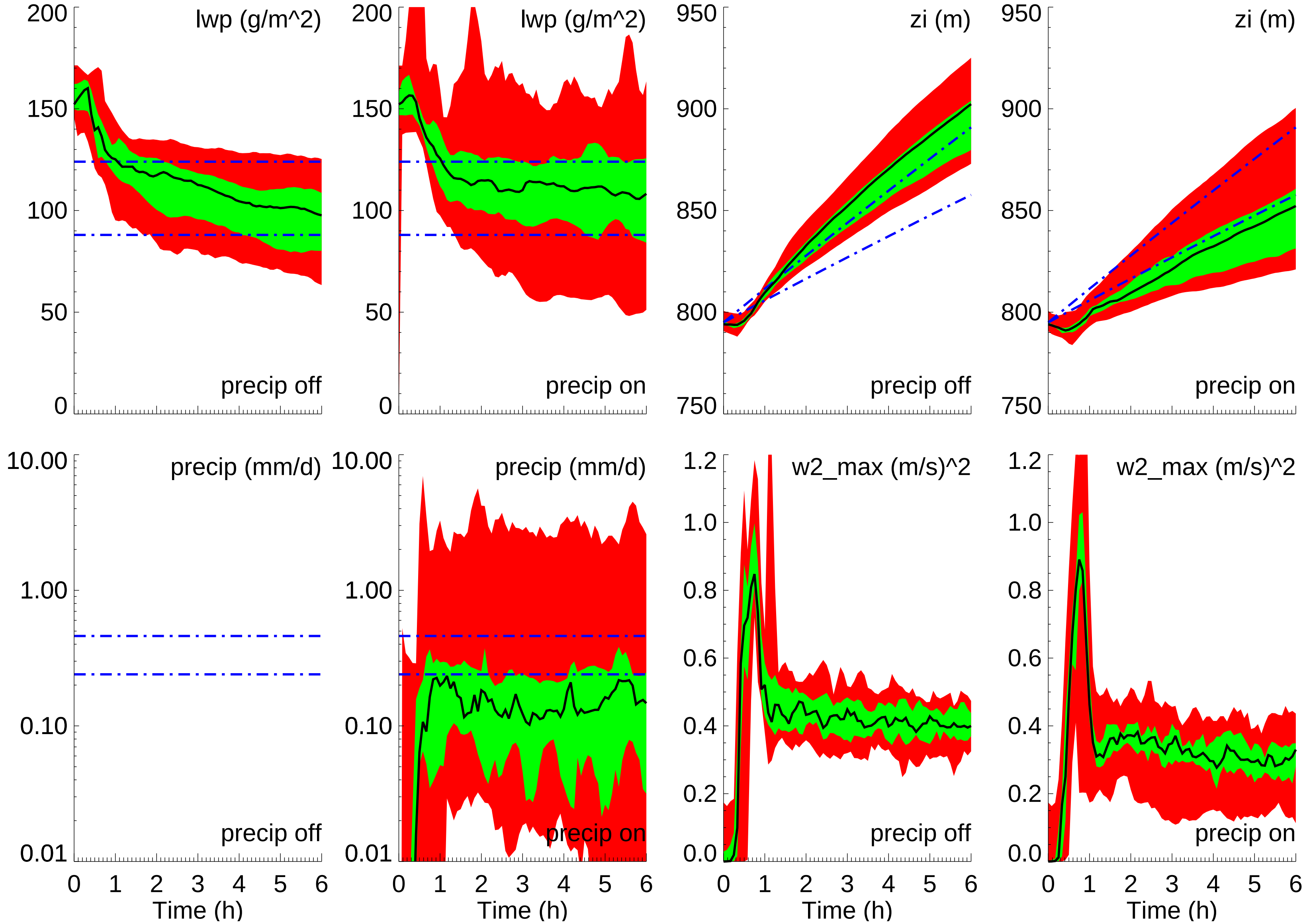
- If predicting $N$, adjust magnitude of measured CCN spectrum to get $N \simeq$ 55 cm$^{-3}$

- First LES, then SCM results...

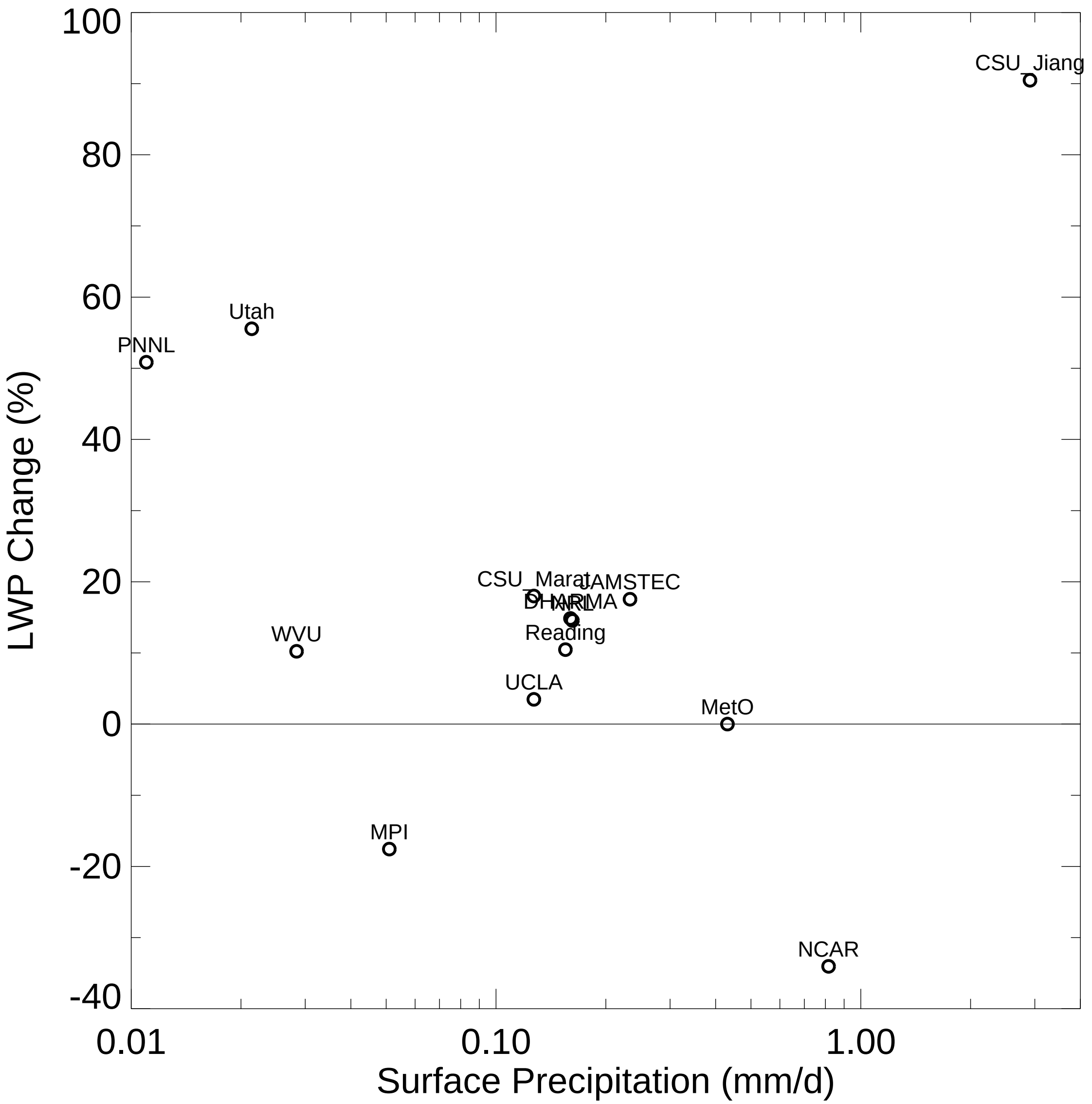
# LES Participants

| Group/Model<br>Team | Precipitation<br>Microphysics |
|---|---|
| CSU/RAMS<br>Jiang | bin |
| CSU/SAM<br>Khairoutdinov | parameterized (KK) |
| JAMSTEC<br>Nakamura | parameterized |
| MetO<br>Lock | parameterized |
| MPI<br>Chlond | parameterized |
| NASA/DHARMA<br>Ackerman | bin |
| NCAR<br>Moeng | parameterized |
| NRL/COAMPS<br>Golaz | parameterized (KK) |
| PNNL<br>Ovtchinnikov | parameterized |
| U Redding/LEM<br>Weinbrecht | parameterized |
| UCLA<br>Savic-Jovcic, Stevens | parameterized (KK) |
| U Utah<br>Zulauf, Krueger | parameterized |
| WVU<br>Lewellen | parameterized (KK) |

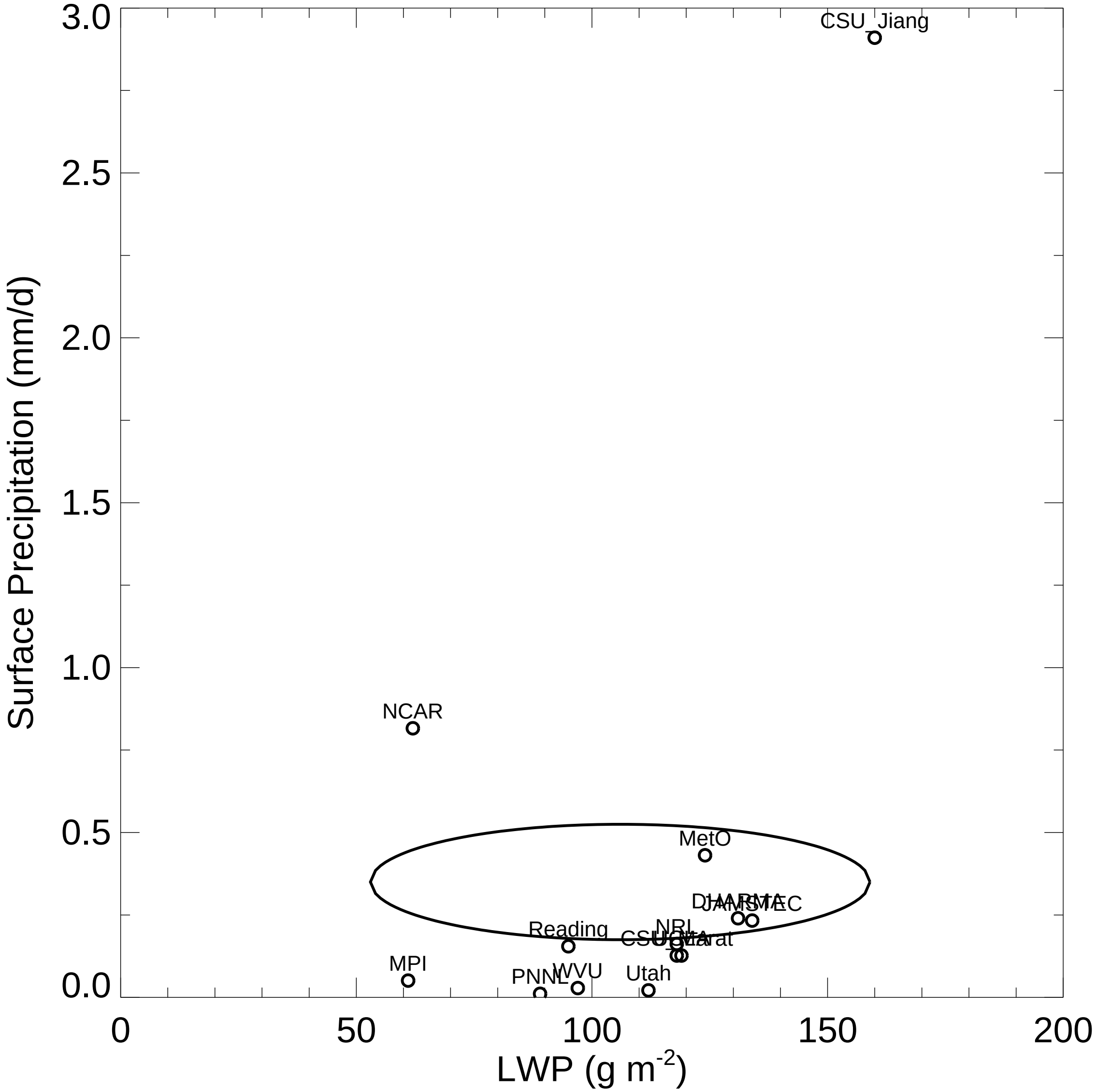
# Time Series (all models)



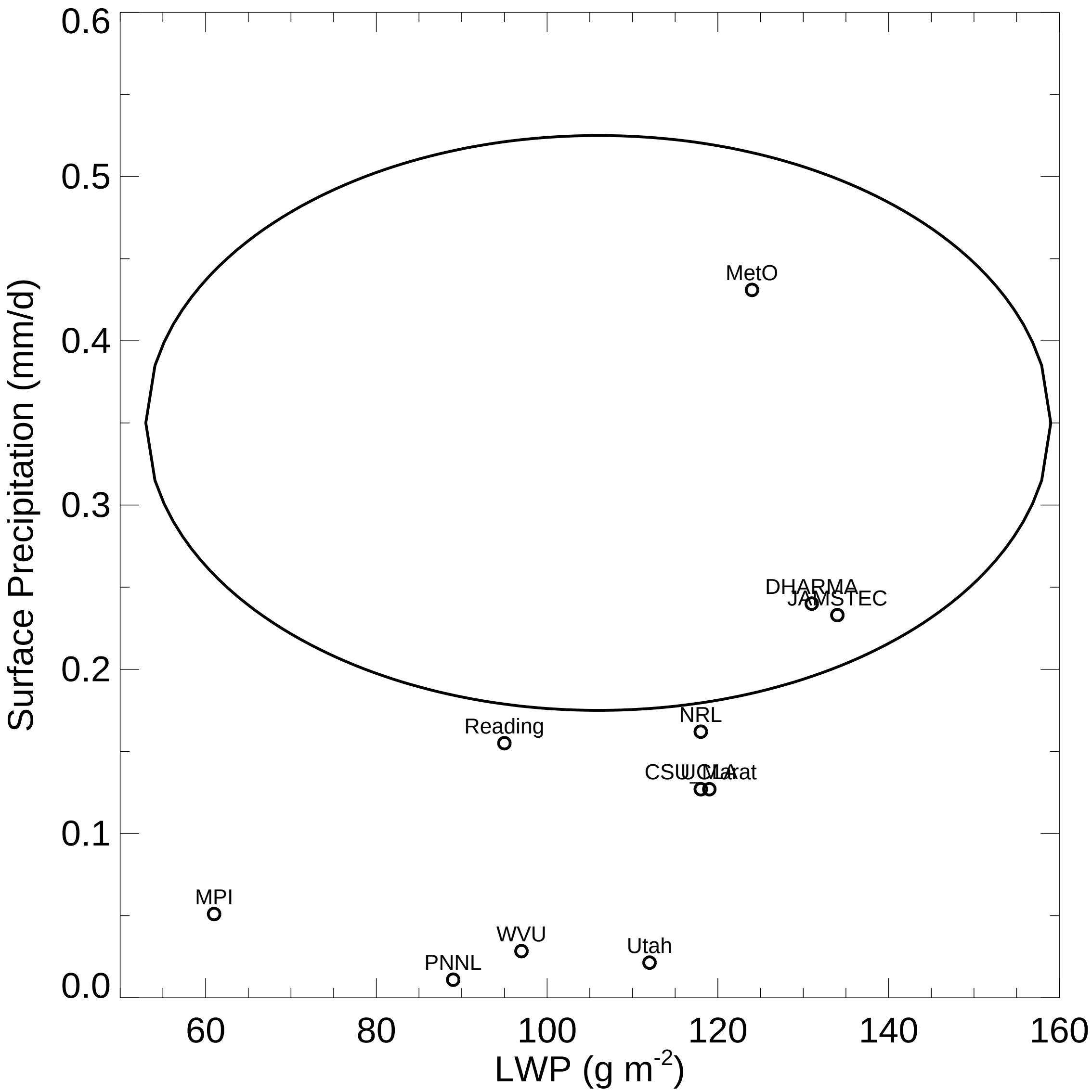
# Response of LWP to Drizzle (domain averages, 3-6 h)



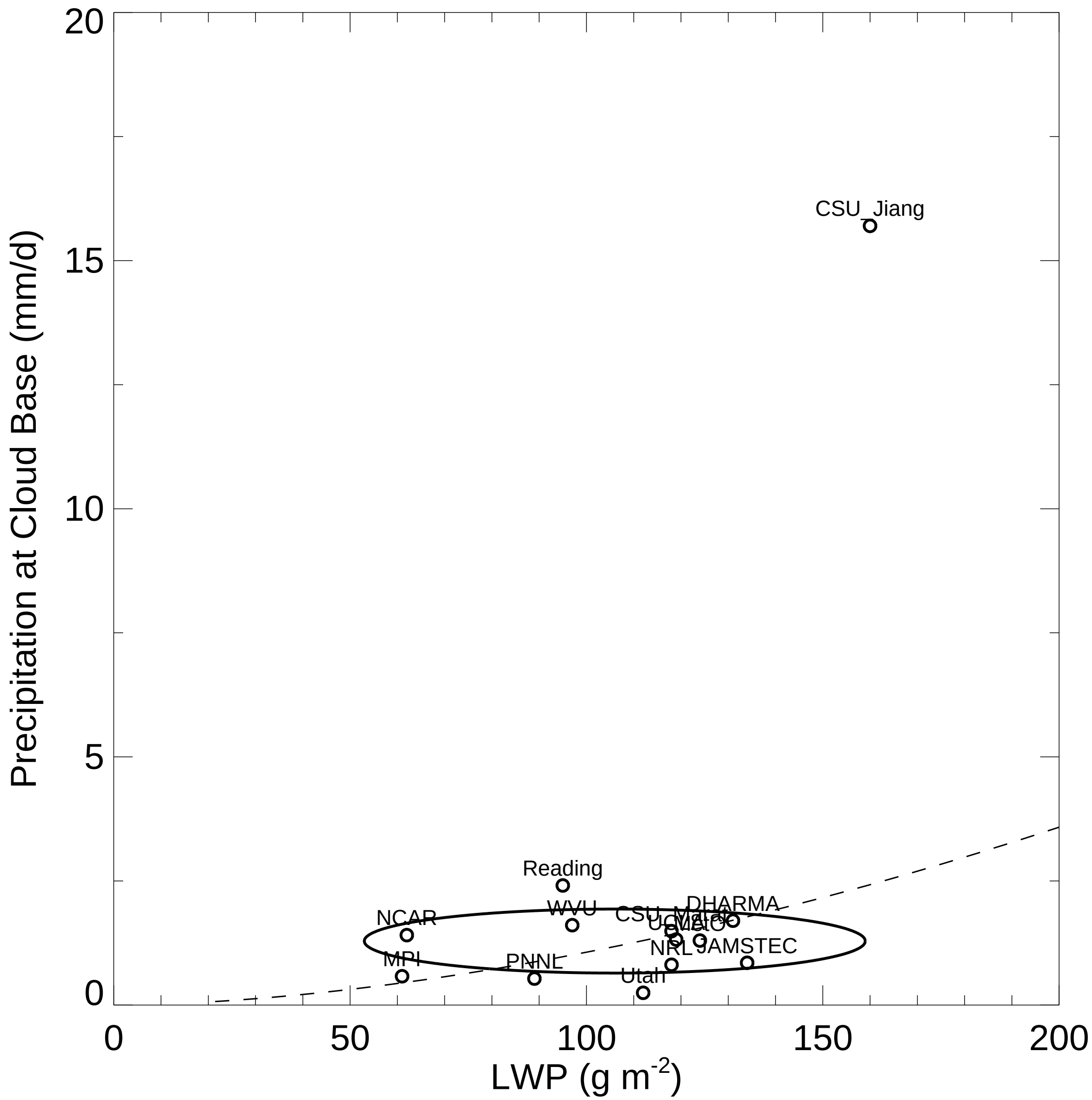
# Surface Precipitation
# (domain averages, 3-6 h)



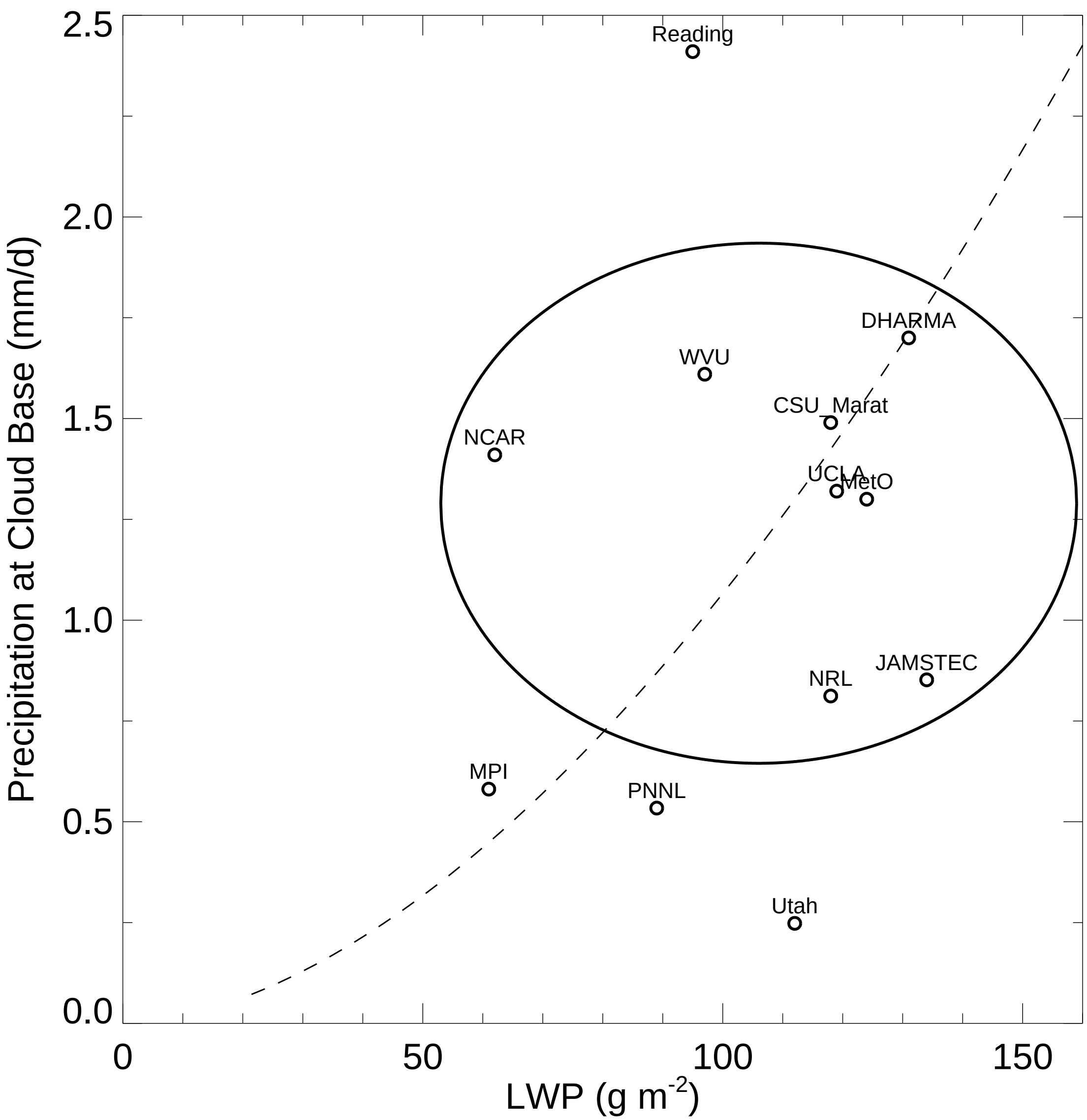
Surface Precipitation
(domain averages, 3-6 h)



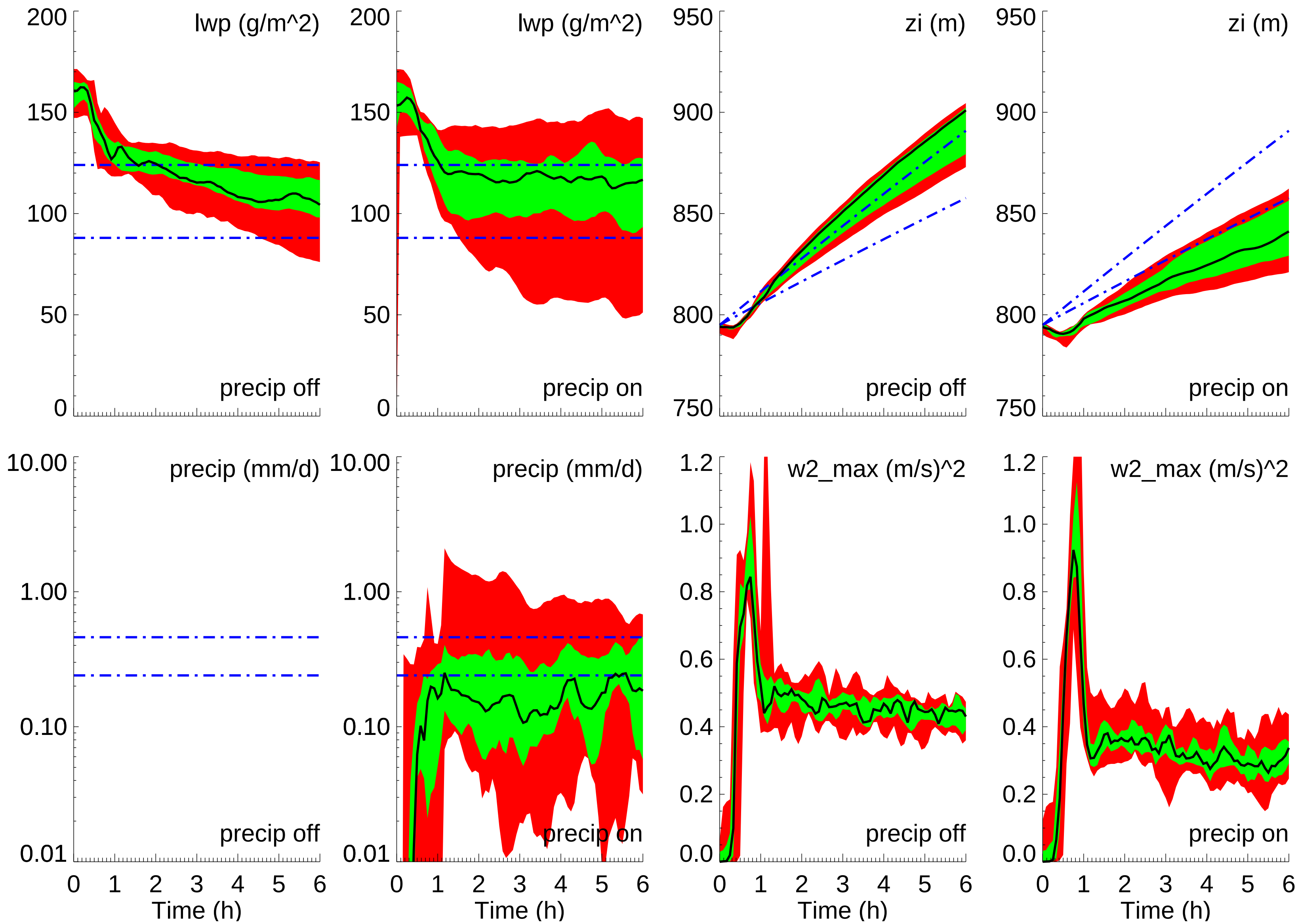
# Precipitation at Cloud Base
# (domain averages, 3-6 h)



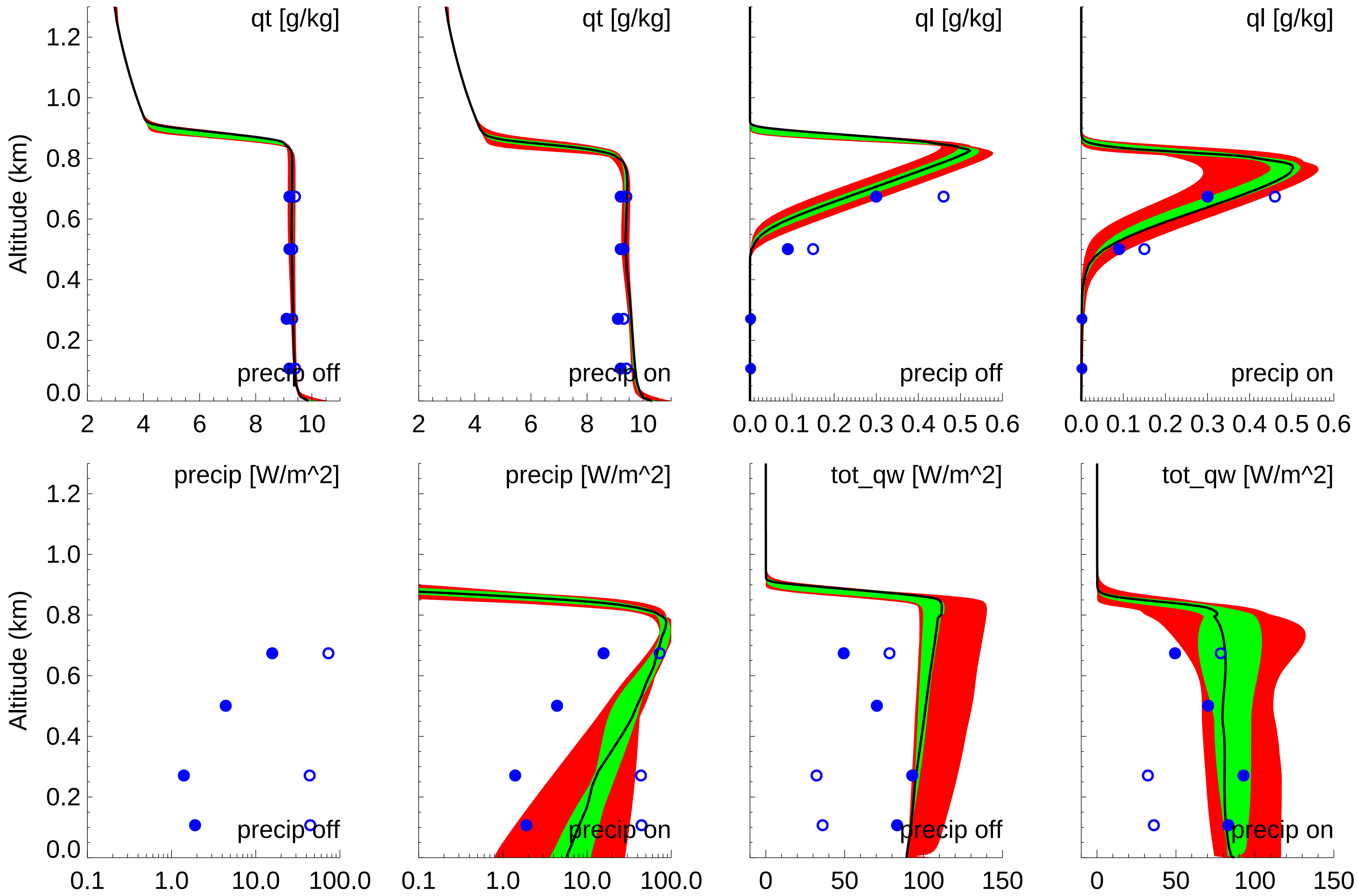
# Domain Averages (3-6 h)



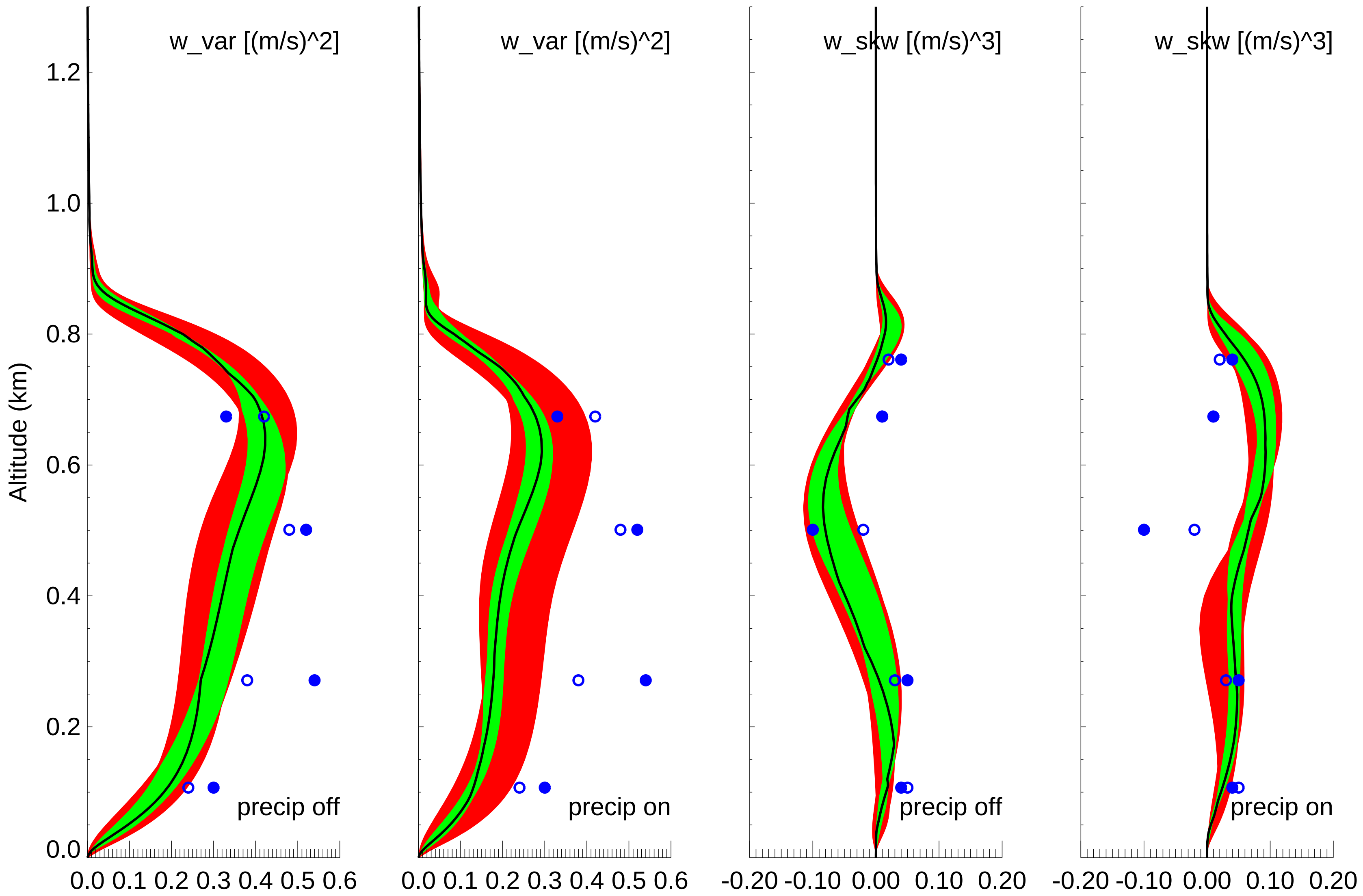
# Time Series (ensemble cut)



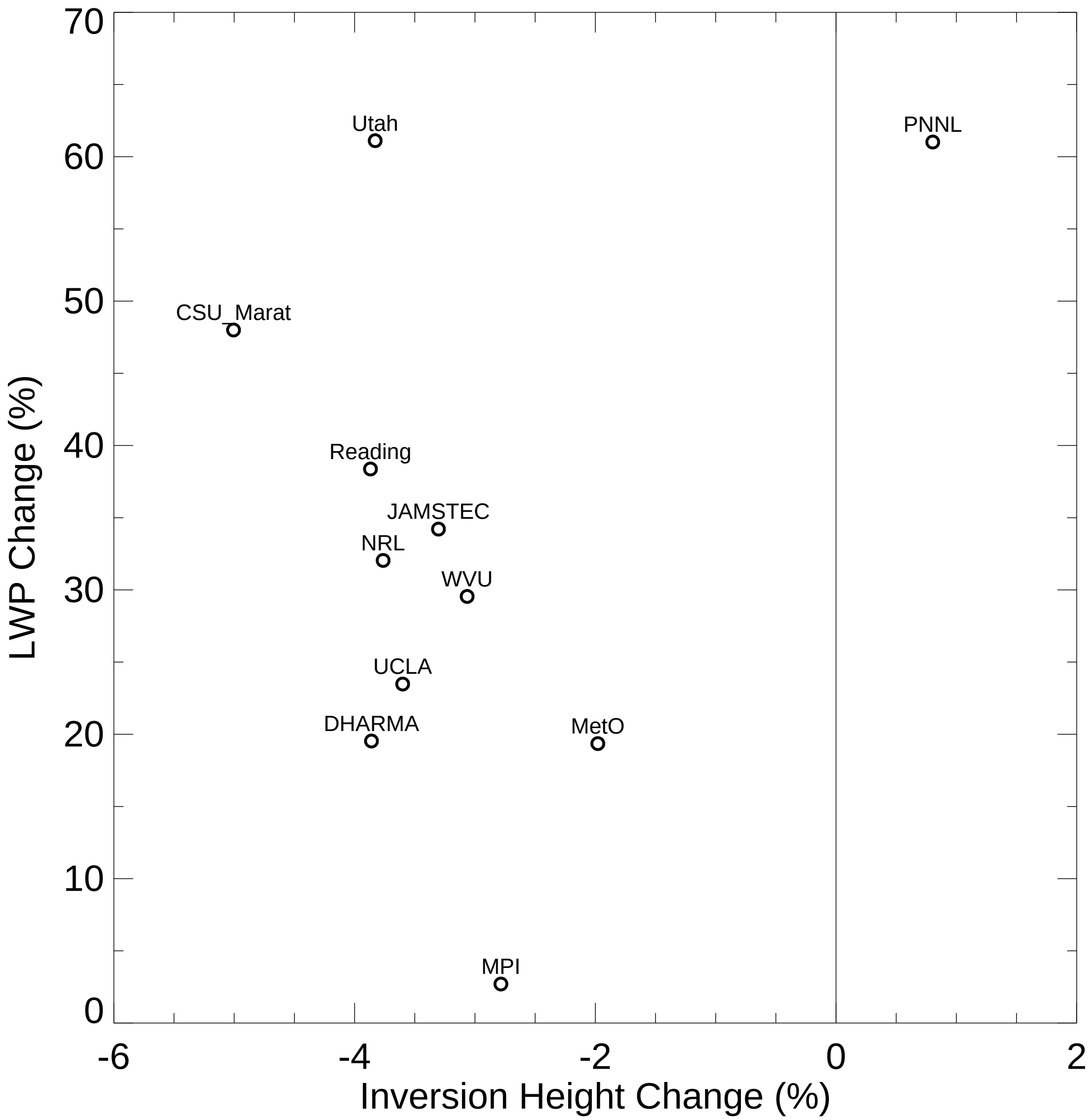
# Ensemble Profiles



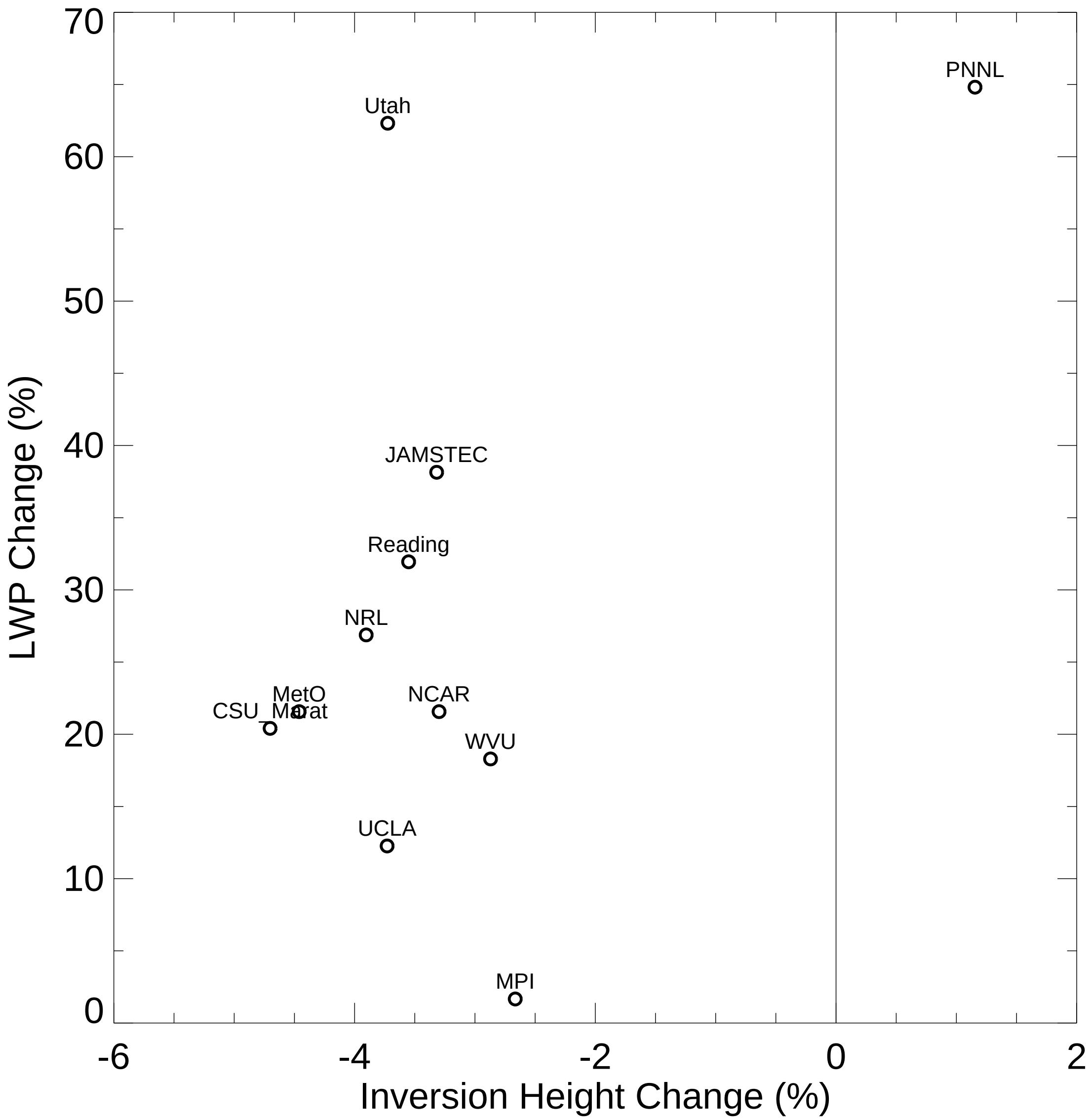
# Ensemble Profiles



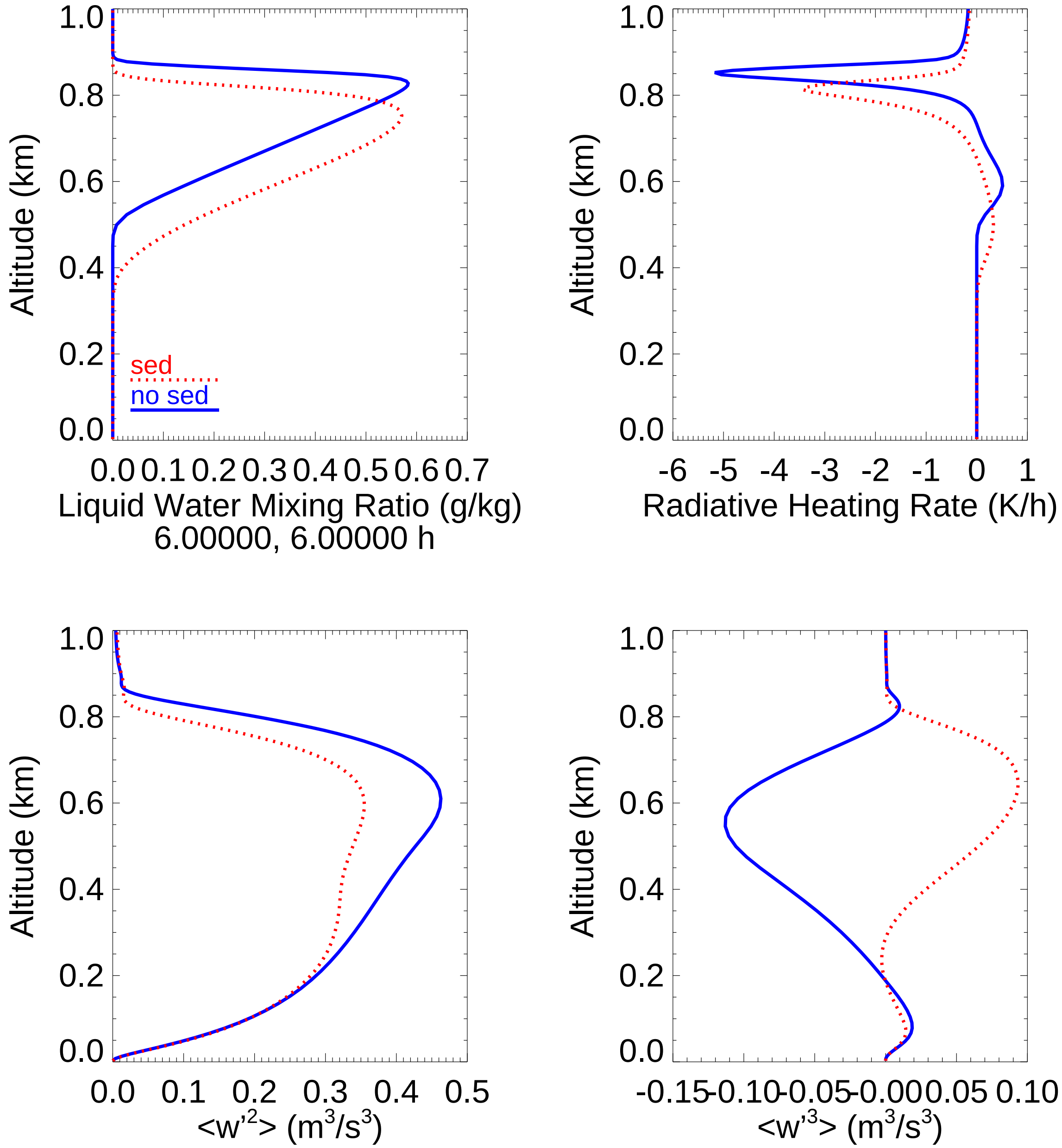
# Effects of Including Cloud Droplet Sedimentation (No Drizzle)



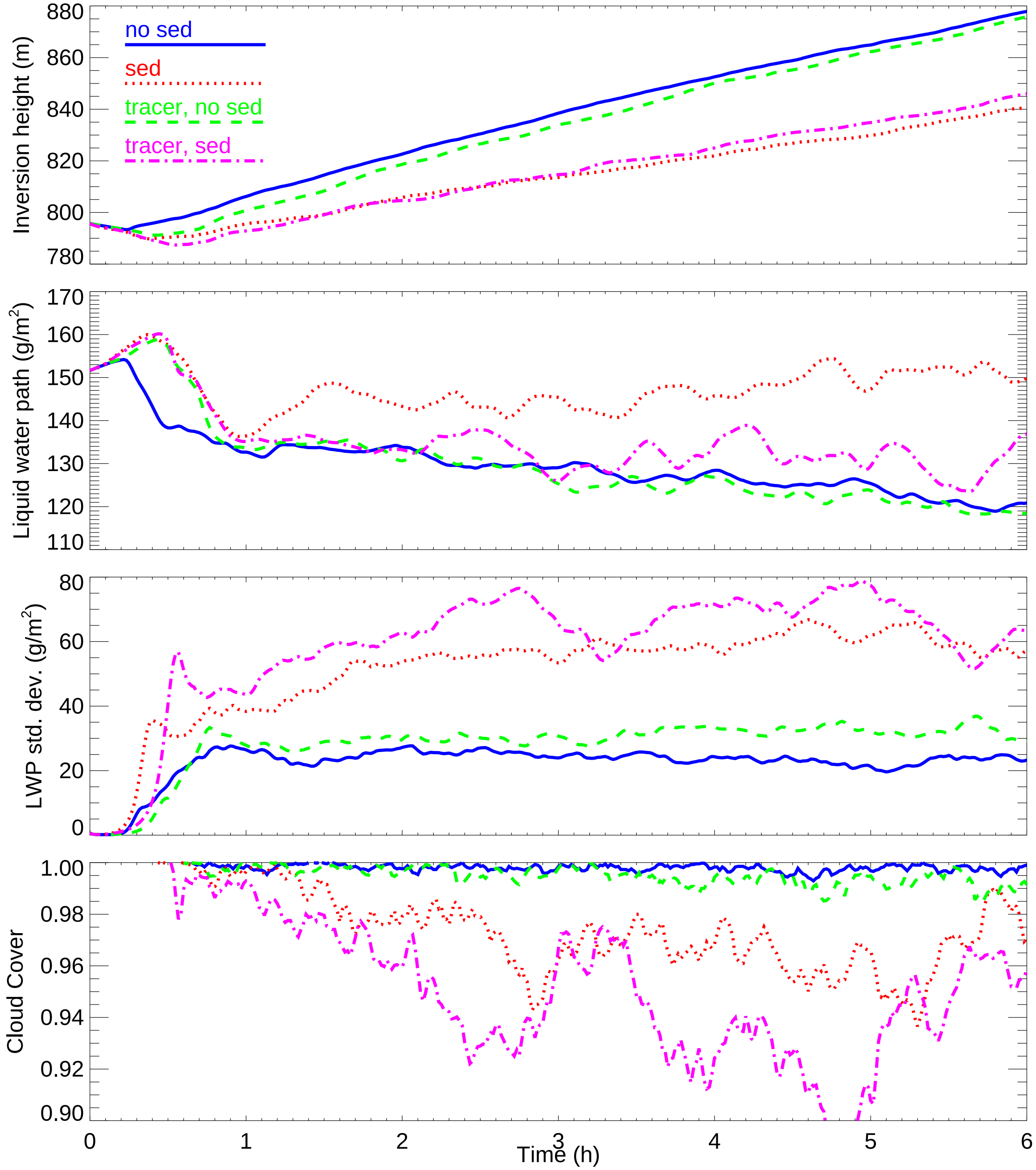
# Effects of Including Cloud Droplet Sedimentation (With Drizzle)



# Effects of Including Cloud Droplet Sedimentation
# (No Drizzle)



# Non-Radiative Impact of Cloud Droplet Sedimentation (No Drizzle)



# Summary of LES Intercomparison

- Drizzle generally reduces $\overline{w'^2}$ and entrainment, and increases $\overline{w'^3}$
- Drizzle leads to increased LWP on average and in majority of simulations
- Cloud droplet sedimentation decreases entrainment in nearly all cases and increases LWP in all cases
- A case study of a more uniform (less bimodal) cloud deck might serve as a better constraint (DCYOMS-II RF07)
- Thanks to Magreet van Zanten, Bjorn Stevens, Markus Petters, Chris Bretherton, and participants

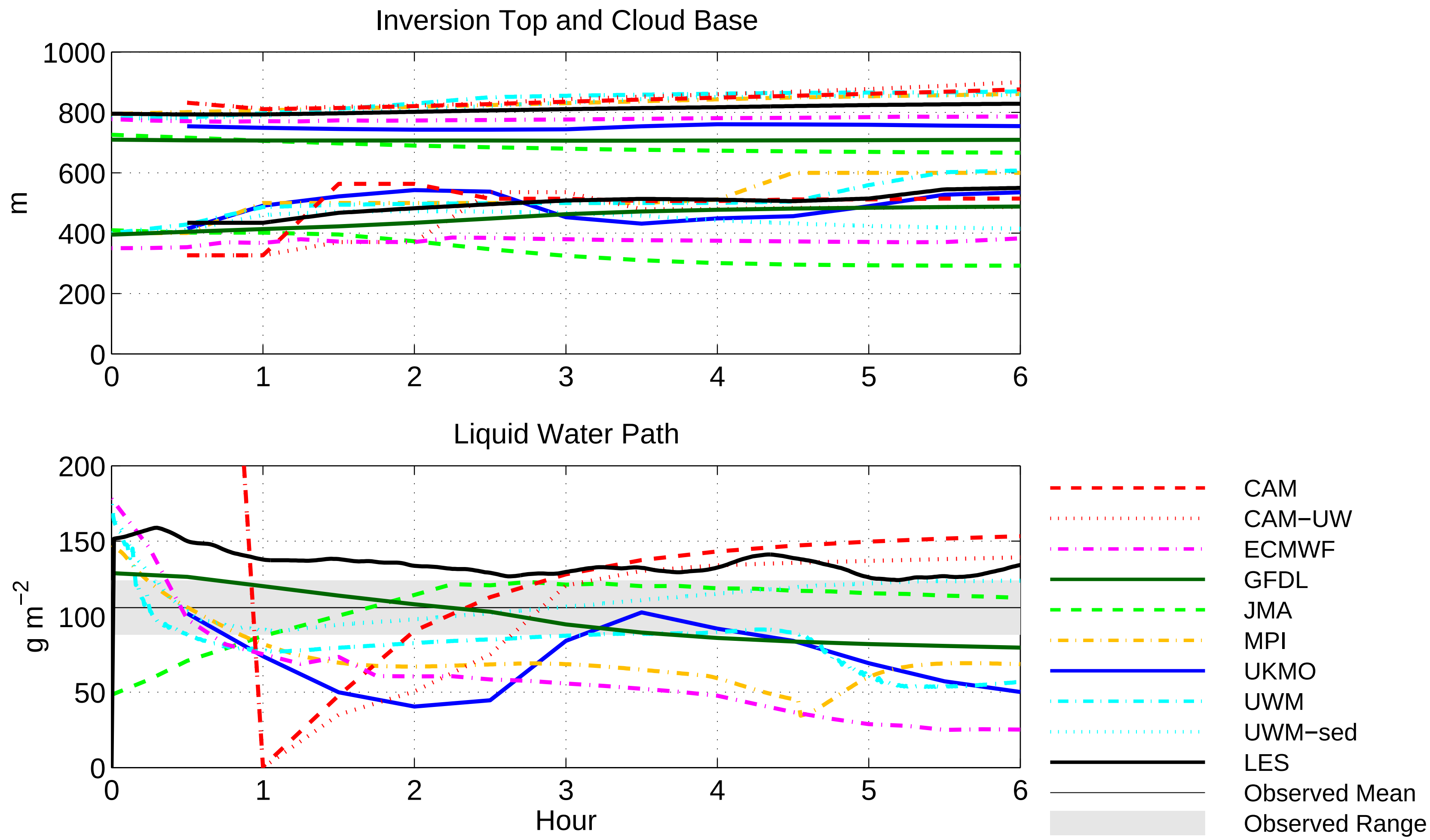
# SCM Intercomparison

- Eight SCMs and the one LES are compared. For the UWM run, there is an additional run with a cloud-droplet-sedimintation paramterization.
- Standard resolution of most SCMs is coarse: between 5 and 11 levels below 1 km.
- SCM Models all use bulk microphysics schemes; a few use Sundqvist microphysics and are unable to incorporate the specified cloud droplet concentration.
- Most models have explicit formulations for entrainment rate.

# SCM Participants

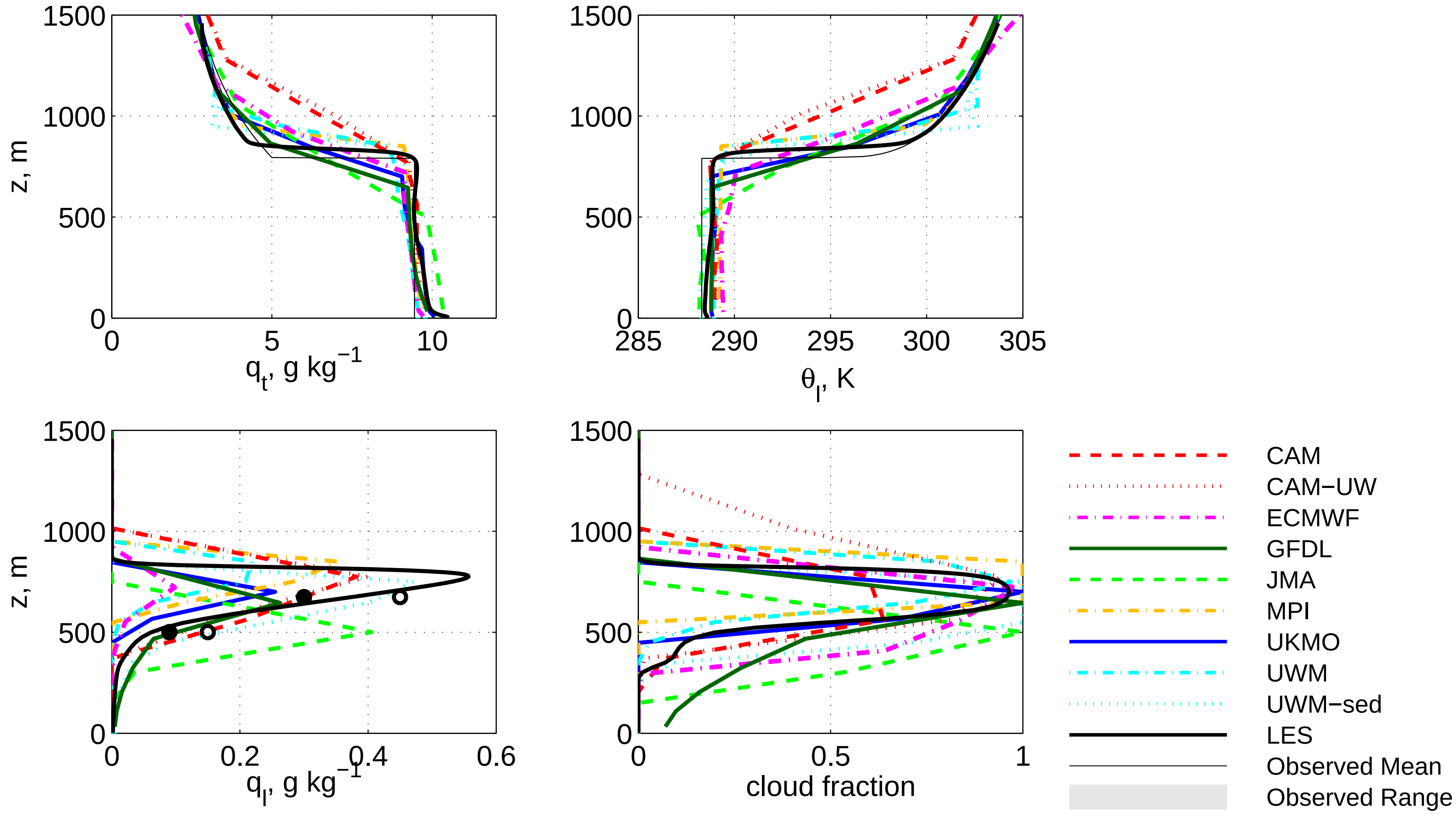
| Model/Team | Microphysics | Turbulence |
|---|---|---|
| CAM 3<br>Lappen | autoconversion,<br>collection | non-local,<br>sfc-based |
| CAM 3-UW<br>Lappen | same as CAM 3 | K-profile,<br>explicit $w_e$ |
| ECMWF<br>de Roode | Sundqvist | K-profile,<br>explicit $w_e$ |
| GFDL AM2.12b<br>Zhao | autoconversion,<br>collection | non-local, K-profile,<br>explicit $w_e$ |
| JMA<br>Kitagawa | Sundqvist | non-local, K-profile,<br>explicit $w_e$ |
| MPI ECHAM4/5<br>Chlond | autoconversion,<br>collection | moist TKE,<br>explicit $w_e$ |
| UKMO<br>Lock | autoconversion,<br>collection | non-local, K-profile,<br>explicit $w_e$ |
| UWM 2GPDF-HOC<br>Larson<br>Griffin | autoconversion,<br>collection,<br>w/ joint PDF | prognostic $\overline{w'^2}$,<br>$\overline{w'^3}$, $\overline{w'\theta_l'}$, $\overline{w'q_t'}$,<br>explicit $w_e$ |
| UWM-sed<br>Larson<br>Griffin | same as UWM,<br>plus cloud droplet<br>sedimentation | same as UWM |
| DHARMA LES<br>Ackerman | bin | Dynamic<br>Smagorinsky |

# Time Series



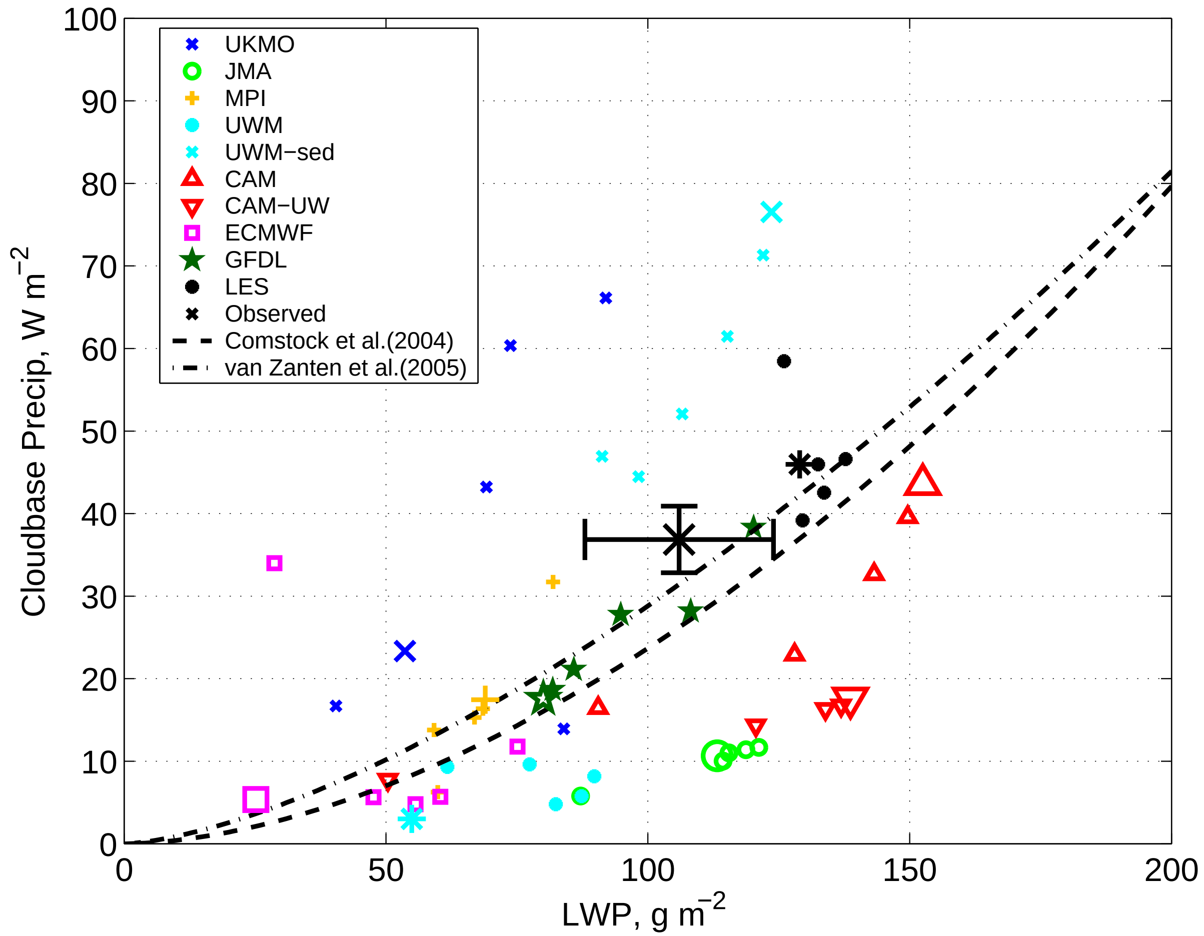

- After startup transients, most models appear to be approaching a quasi-steady state by the simulation end (though continuing to deepen).
- Liquid water paths and entrainment rates are quite diverse.

# Profiles



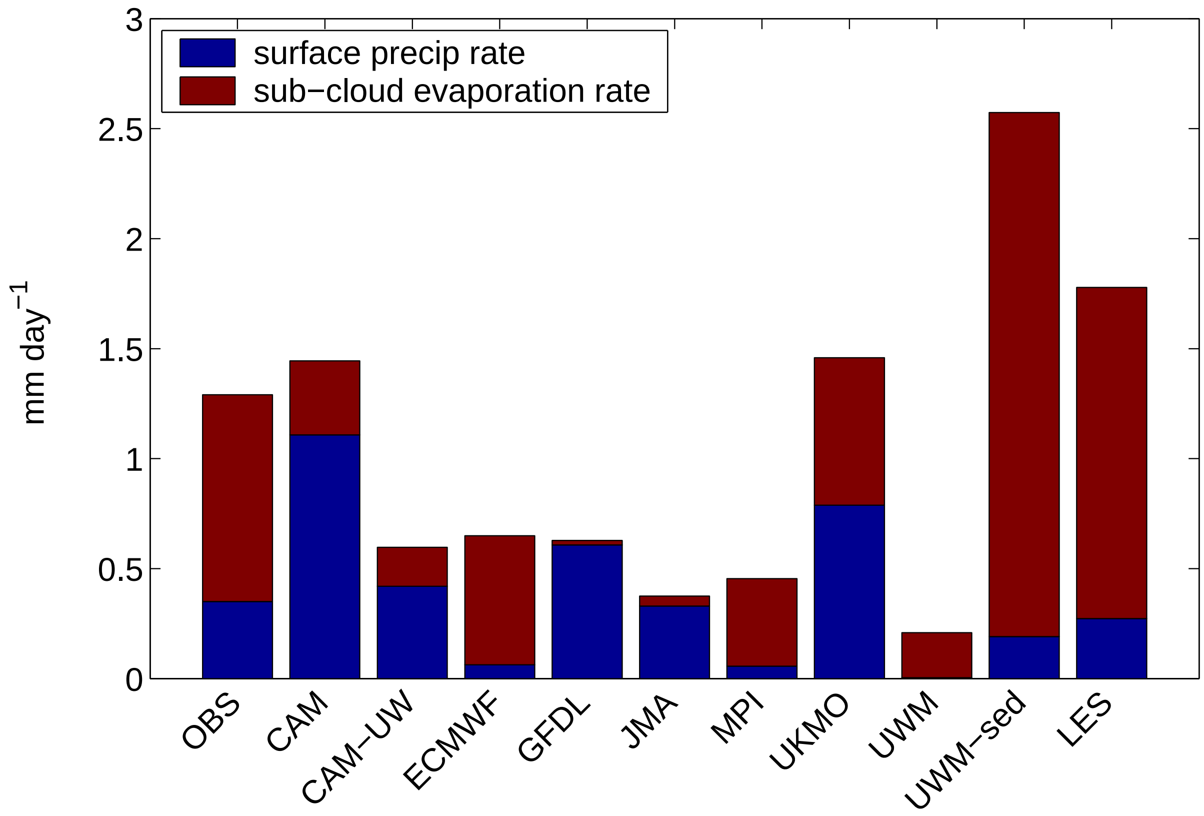

- Inversion not as well resolved as in LES.
- Profiles of $q_l$ are diverse.
- All of the models except CAM maintain large cloud fraction.

# Precipitation at Cloud Base




- Many models agree well with the empirical fits.

# Evaporation of Precipitation below Cloud Base




- Precipitation rates are quite diverse due to differences in LWP.
- Many models apparently underestimate drizzle evaporation substantially.