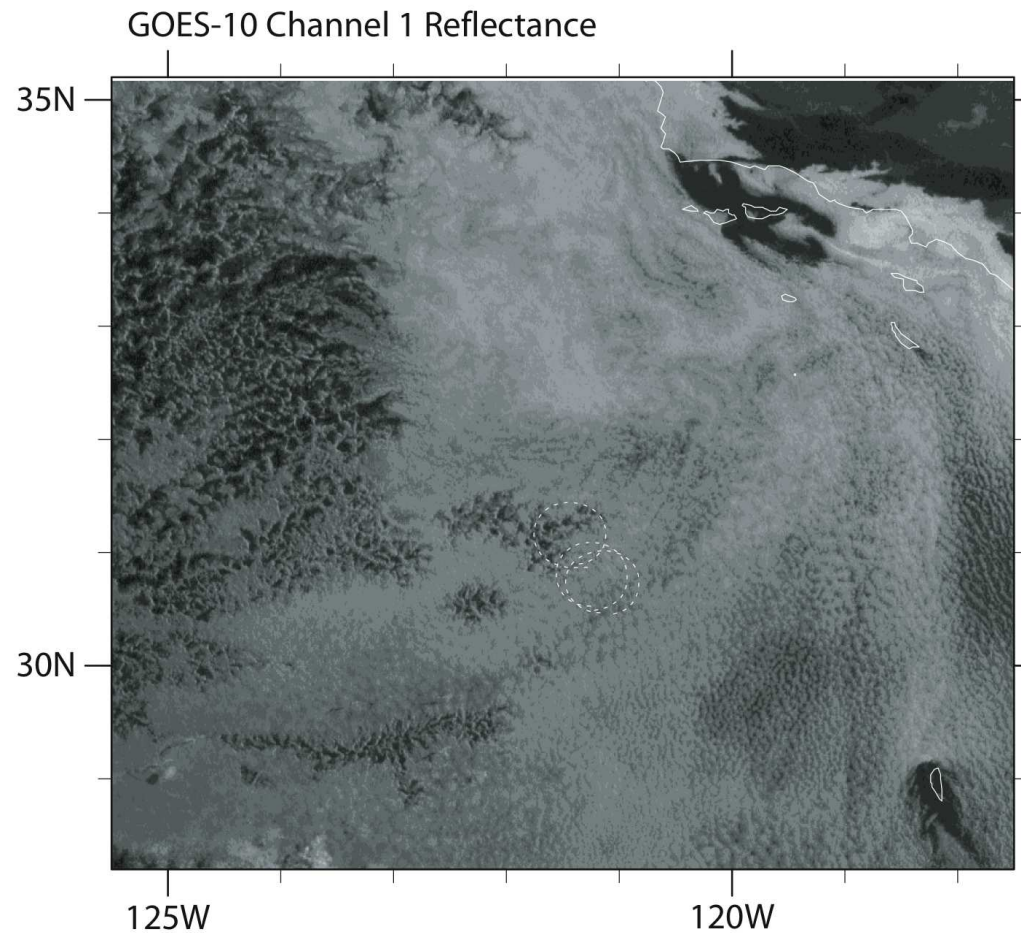


Model Intercomparisons of Drizzling Stratocumulus: DYCOMS-II RF02

Andy Ackerman, NASA Goddard Institute for Space Studies
Matt Wyant, University of Washington



(Figure from *van Zanten & Stevens 2005*)

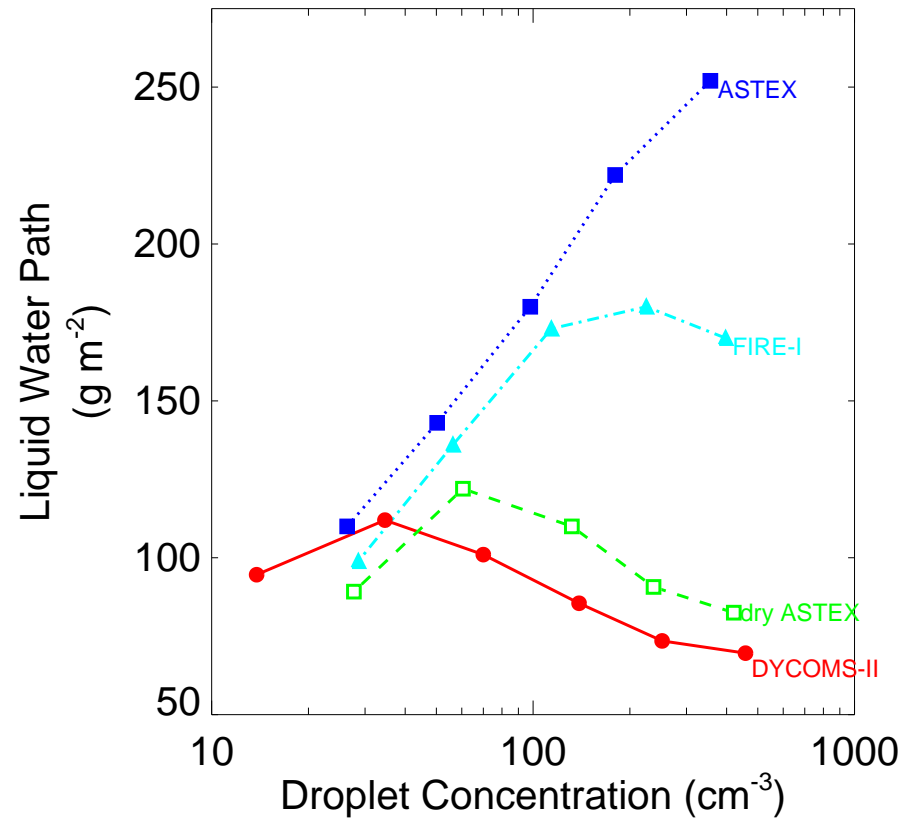
Motivation

- 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

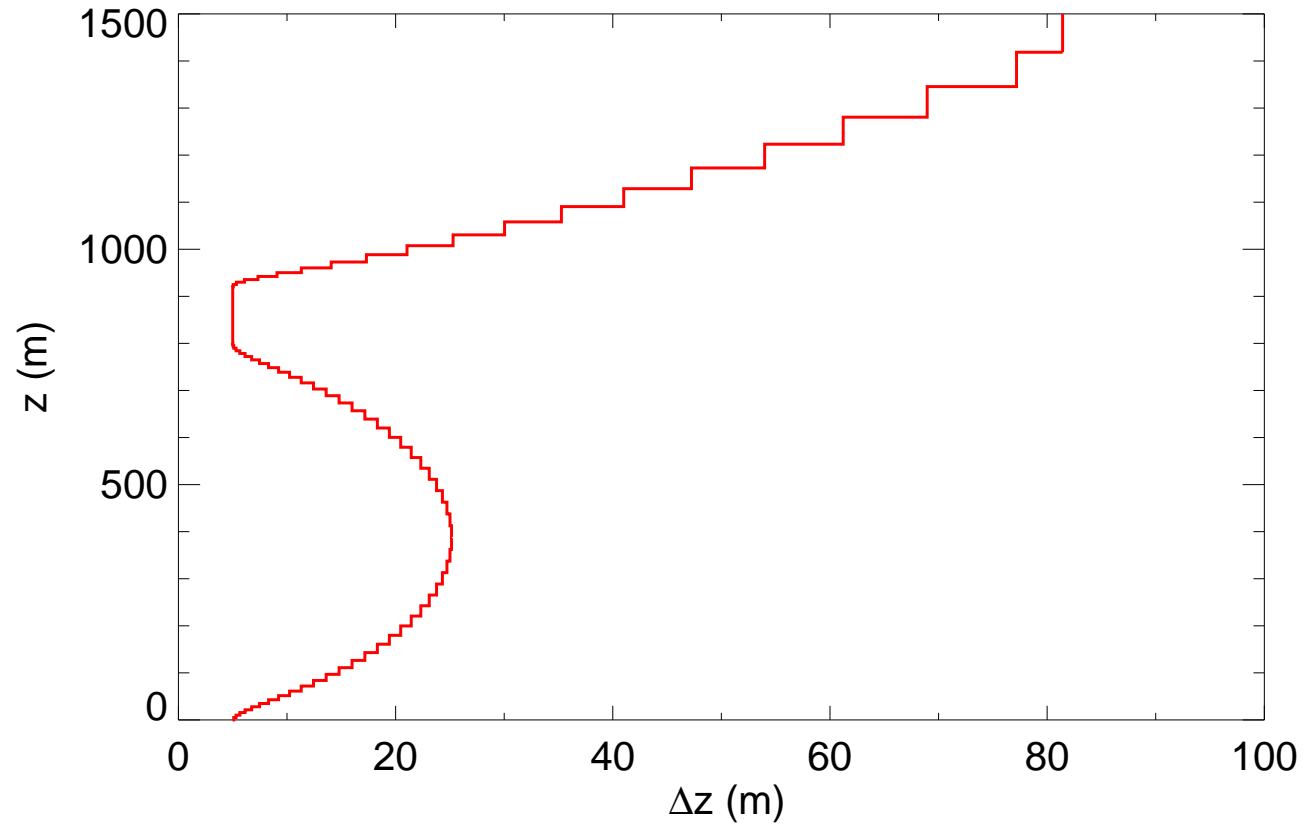


(Figure from *Ackerman et al. 2004*)

- 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 ($3.75 \times 10^{-6} \text{ s}^{-1}$)
- 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:

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

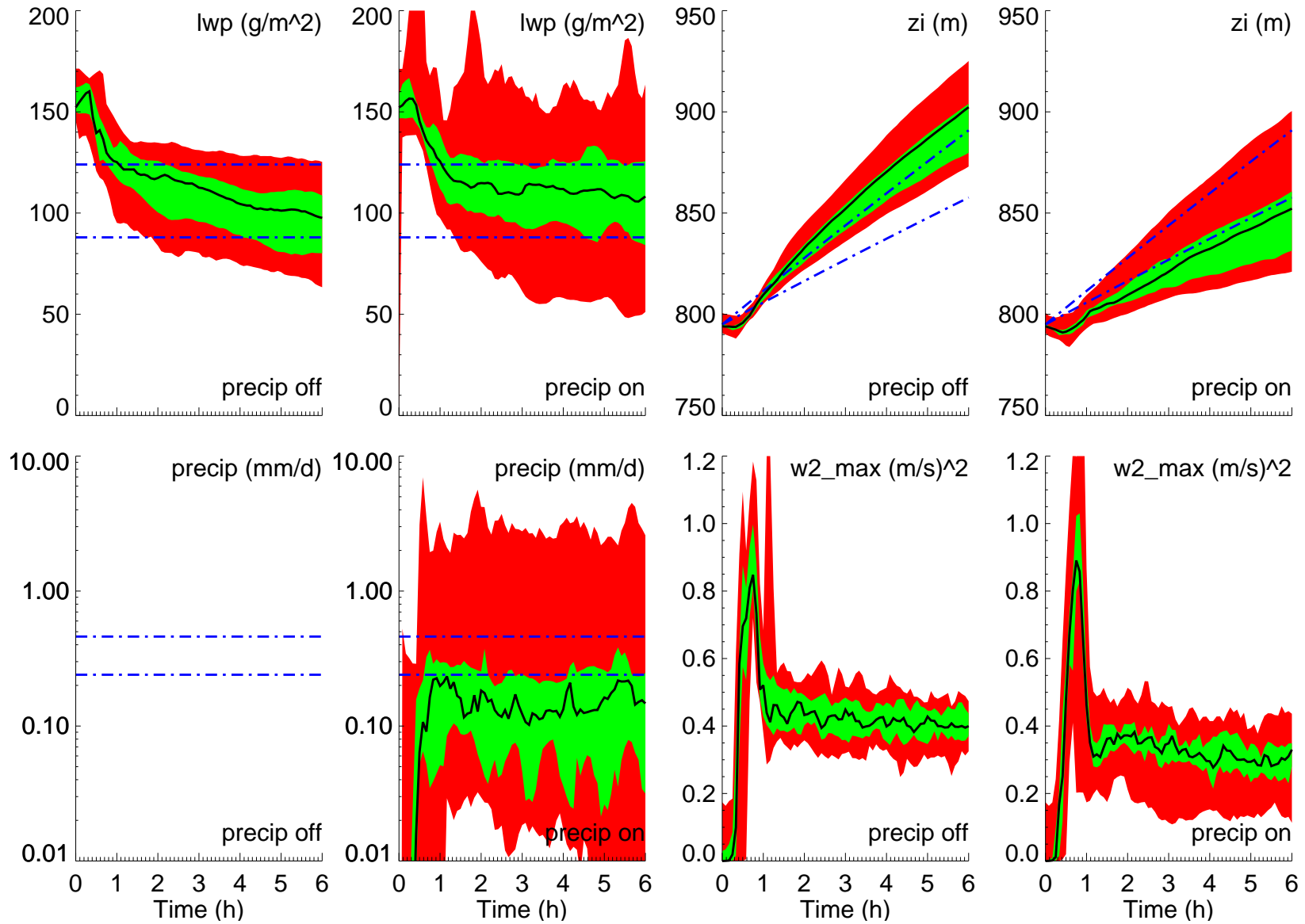
with $\sigma_g = 1.5$ (1.2 would have been more appropriate)

- If predicting N , adjust magnitude of measured CCN spectrum to get $N \simeq 55 \text{ cm}^{-3}$
- First LES, then SCM results...

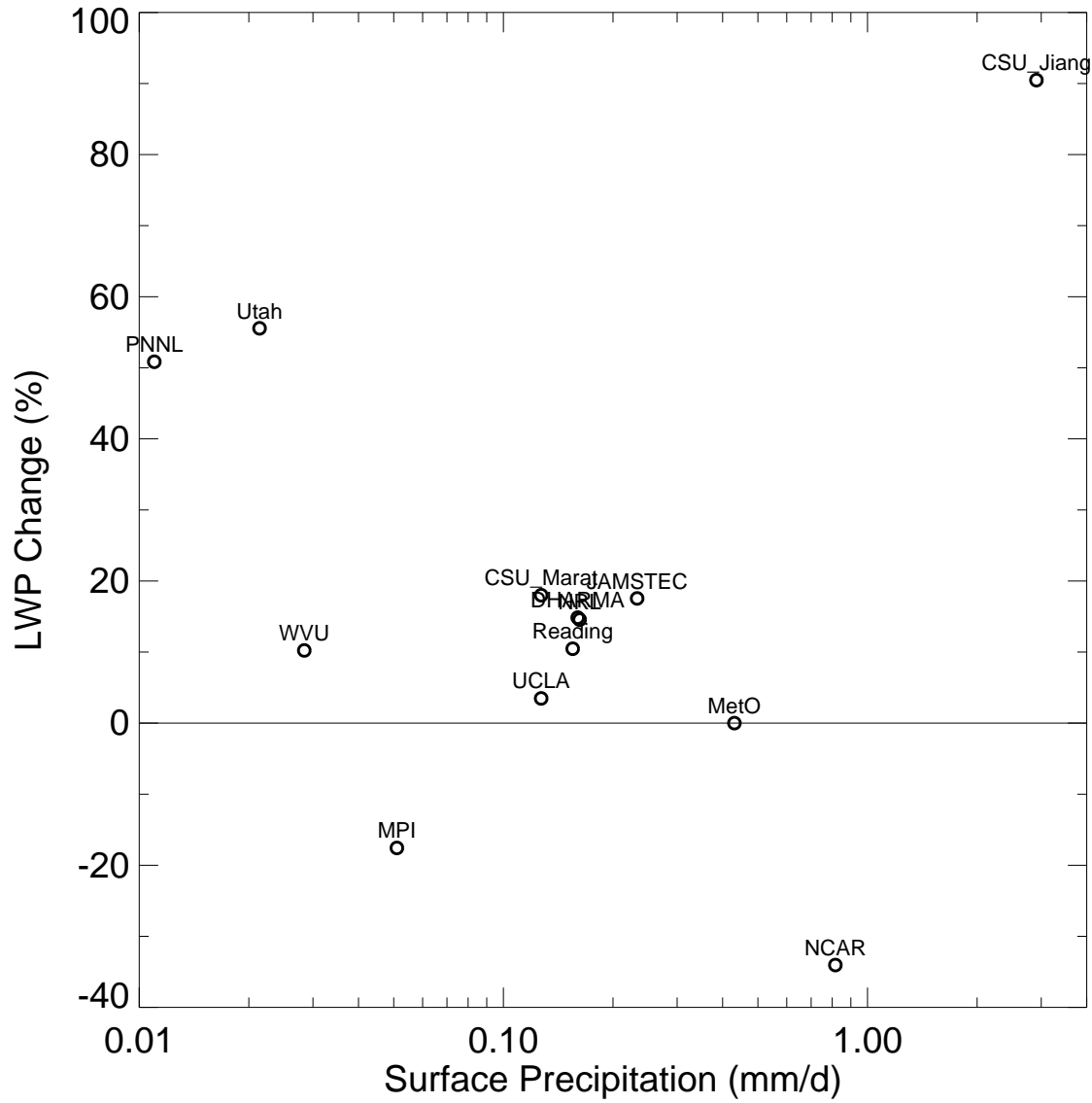
LES Participants

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

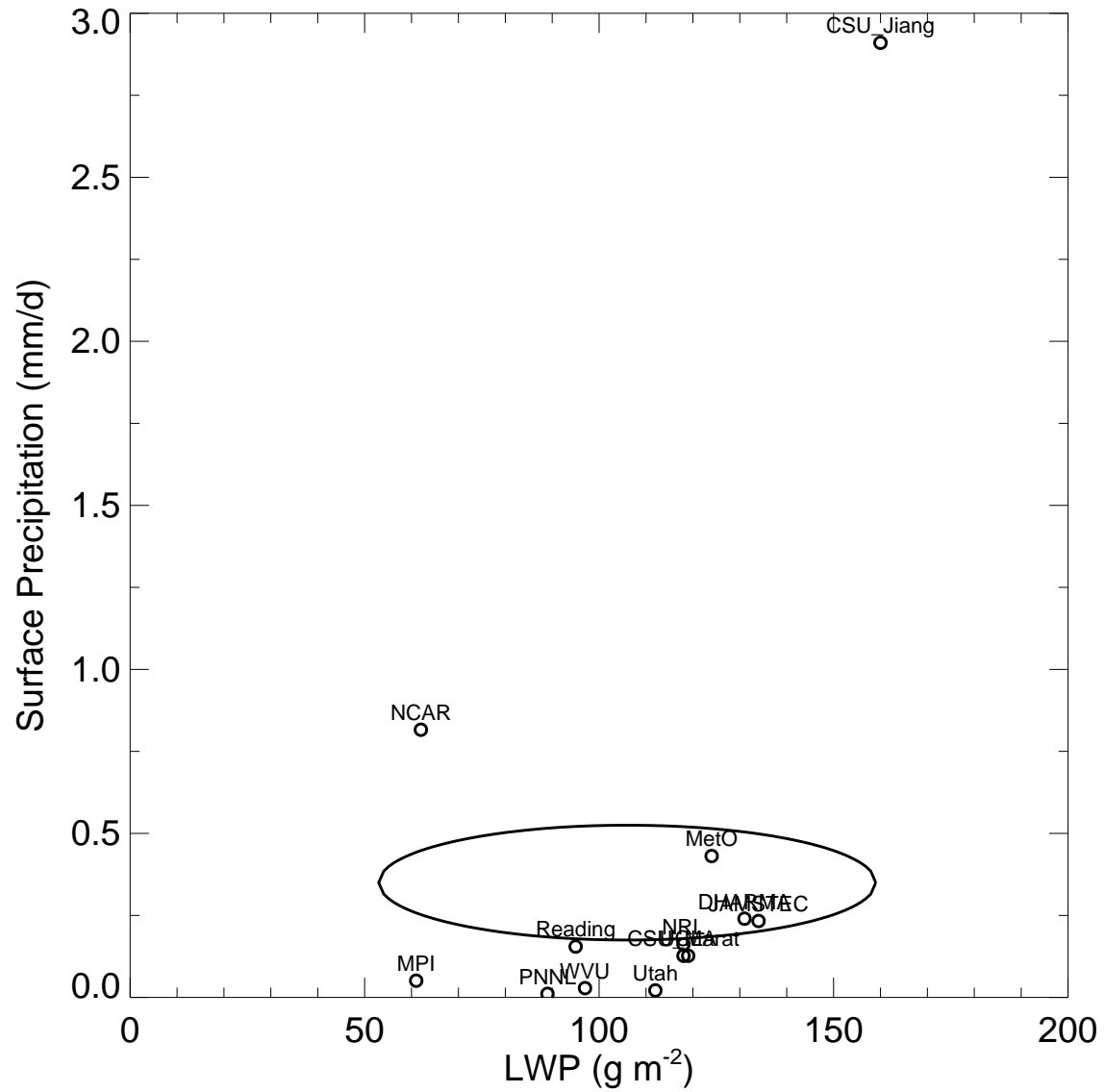
Time Series (all models)



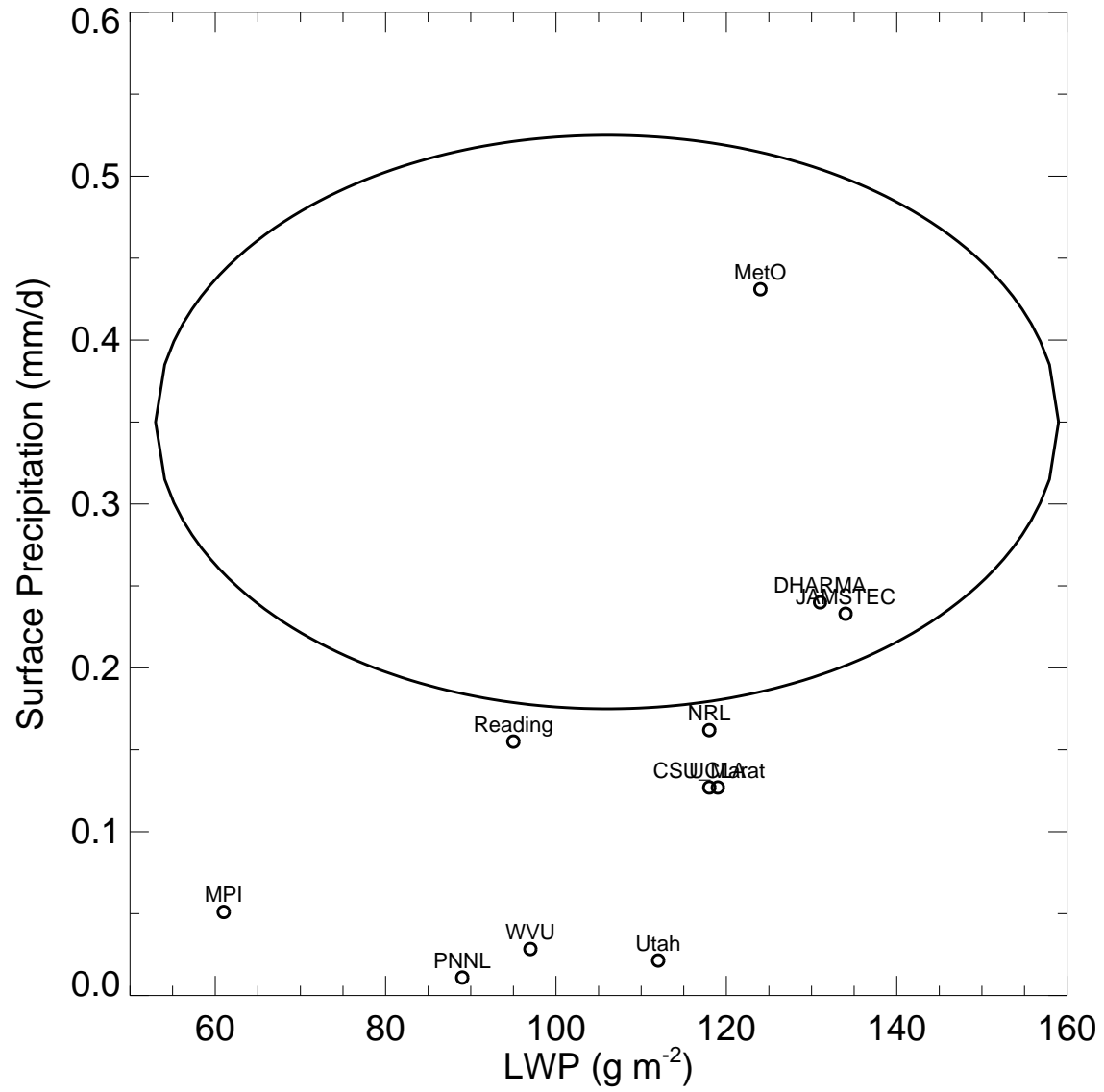
Response of LWP to Drizzle (domain averages, 3-6 h)



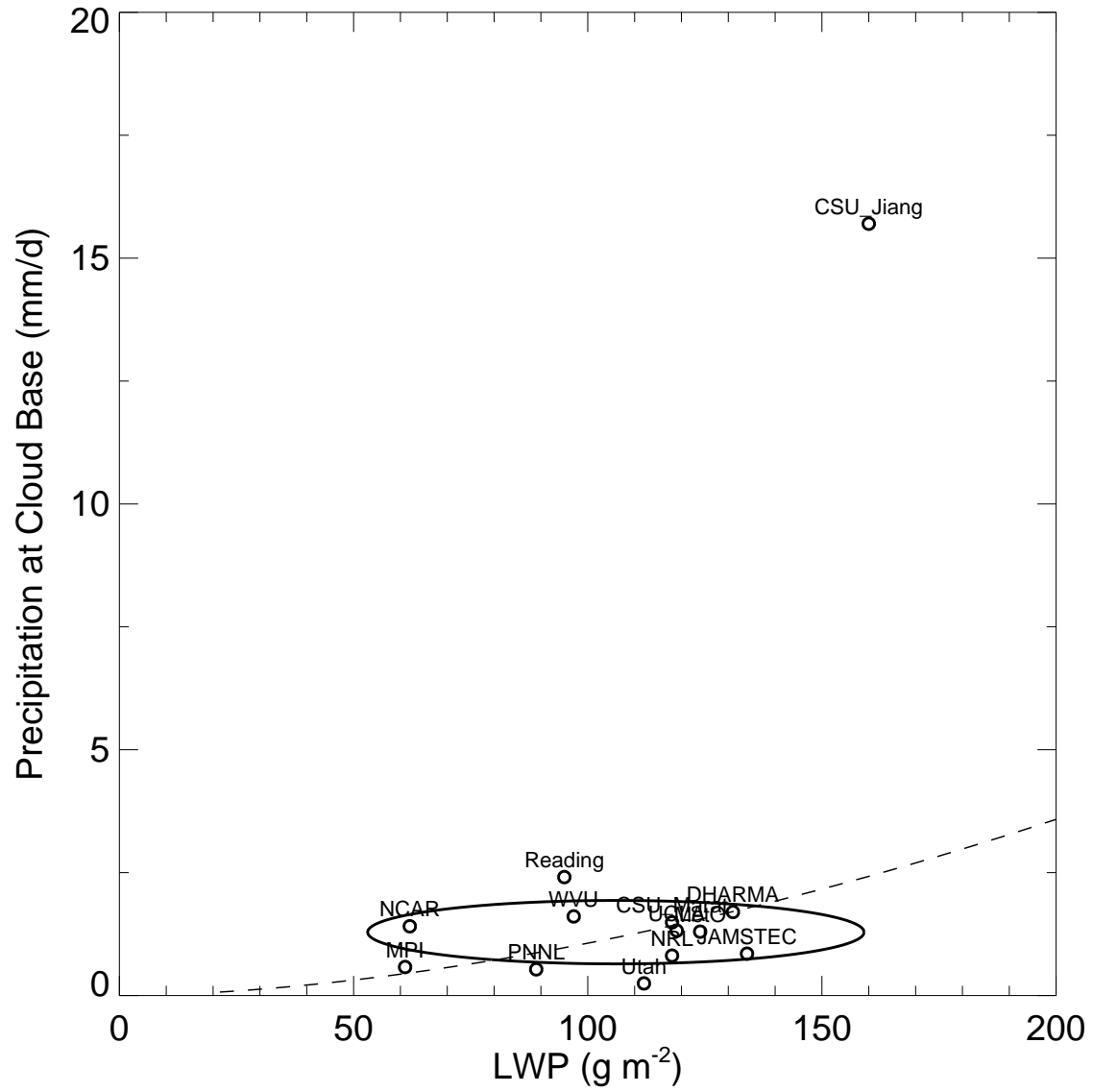
Surface Precipitation (domain averages, 3-6 h)



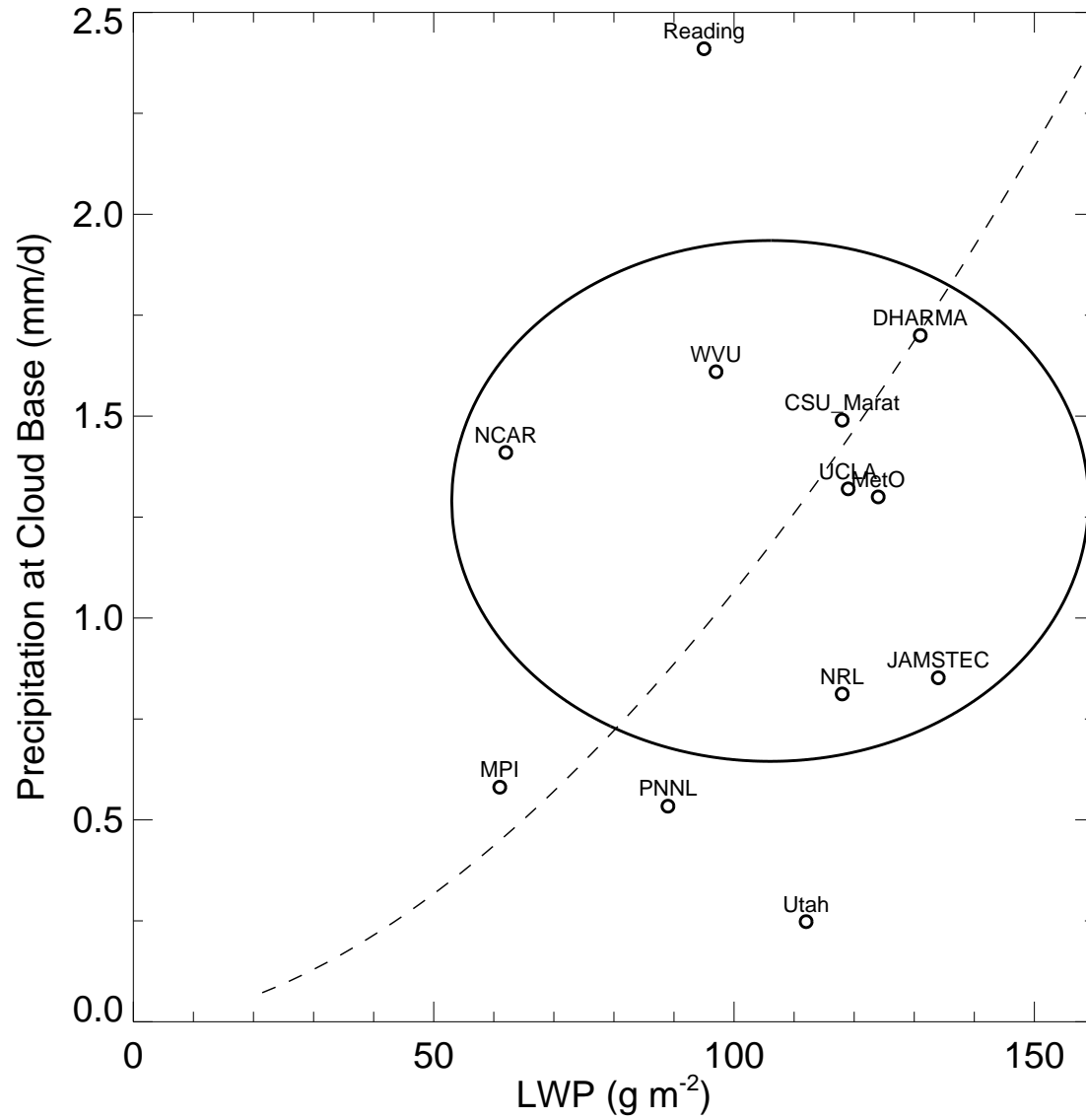
Surface Precipitation (domain averages, 3-6 h)



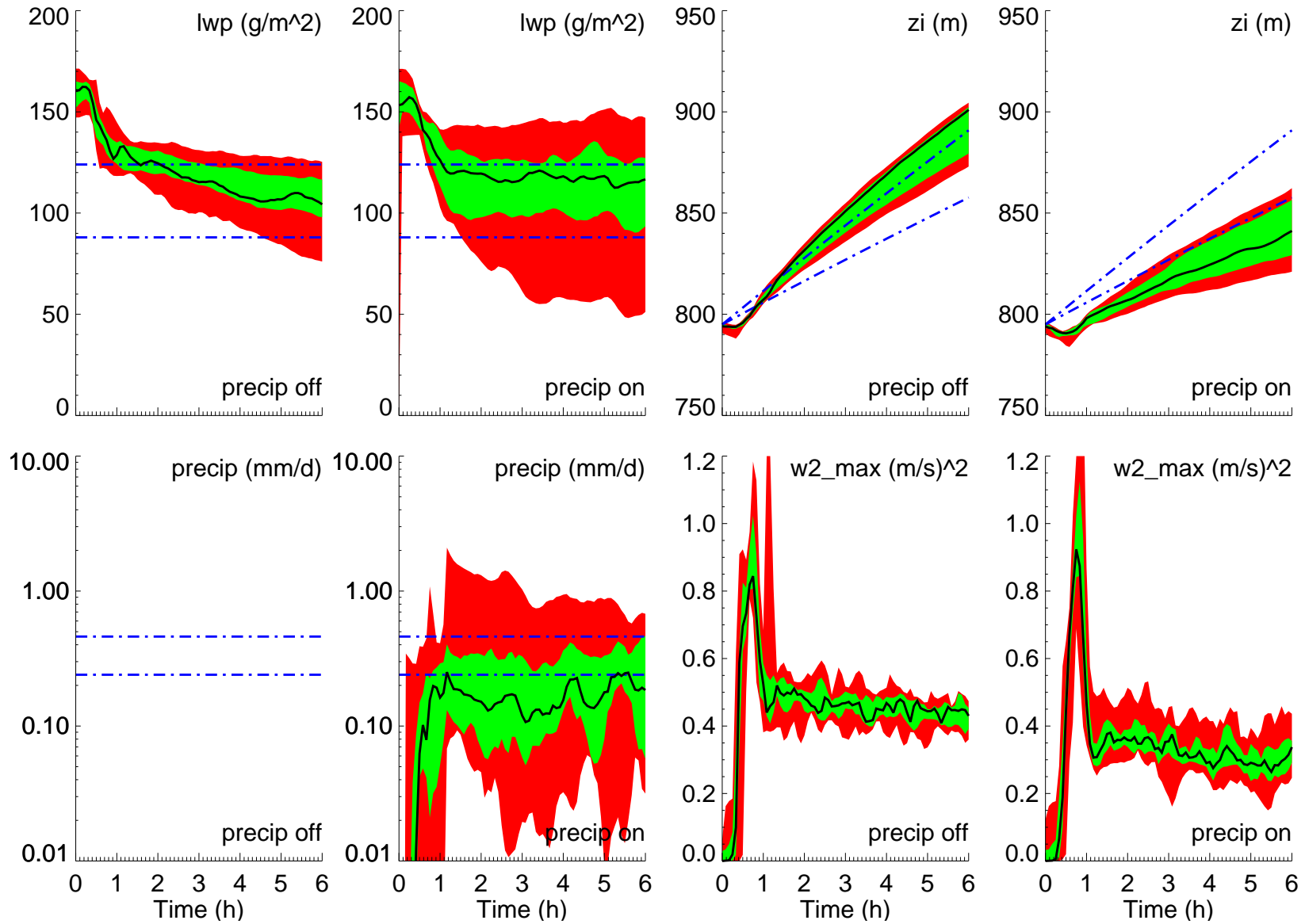
Precipitation at Cloud Base (domain averages, 3-6 h)



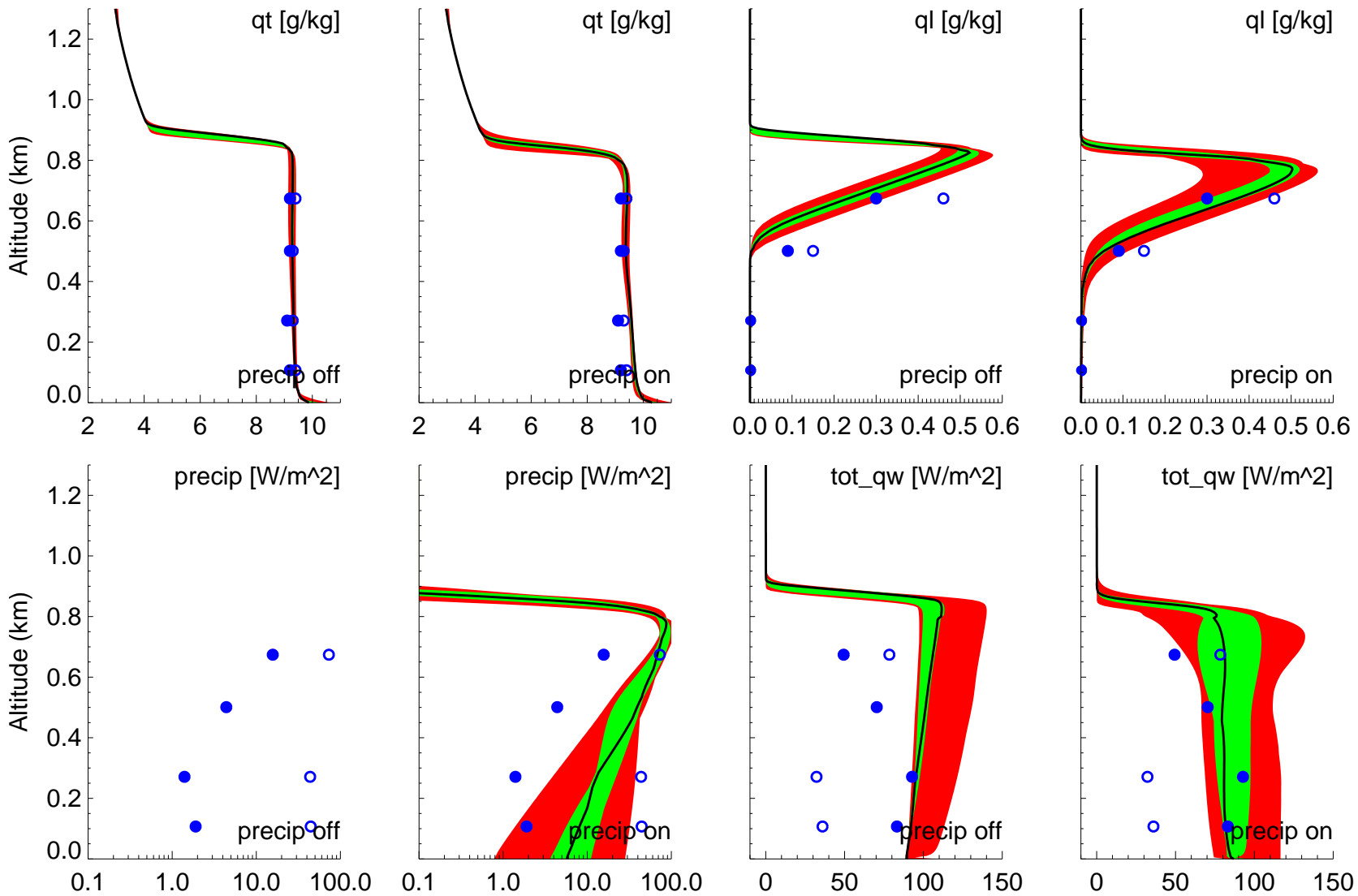
Domain Averages (3-6 h)



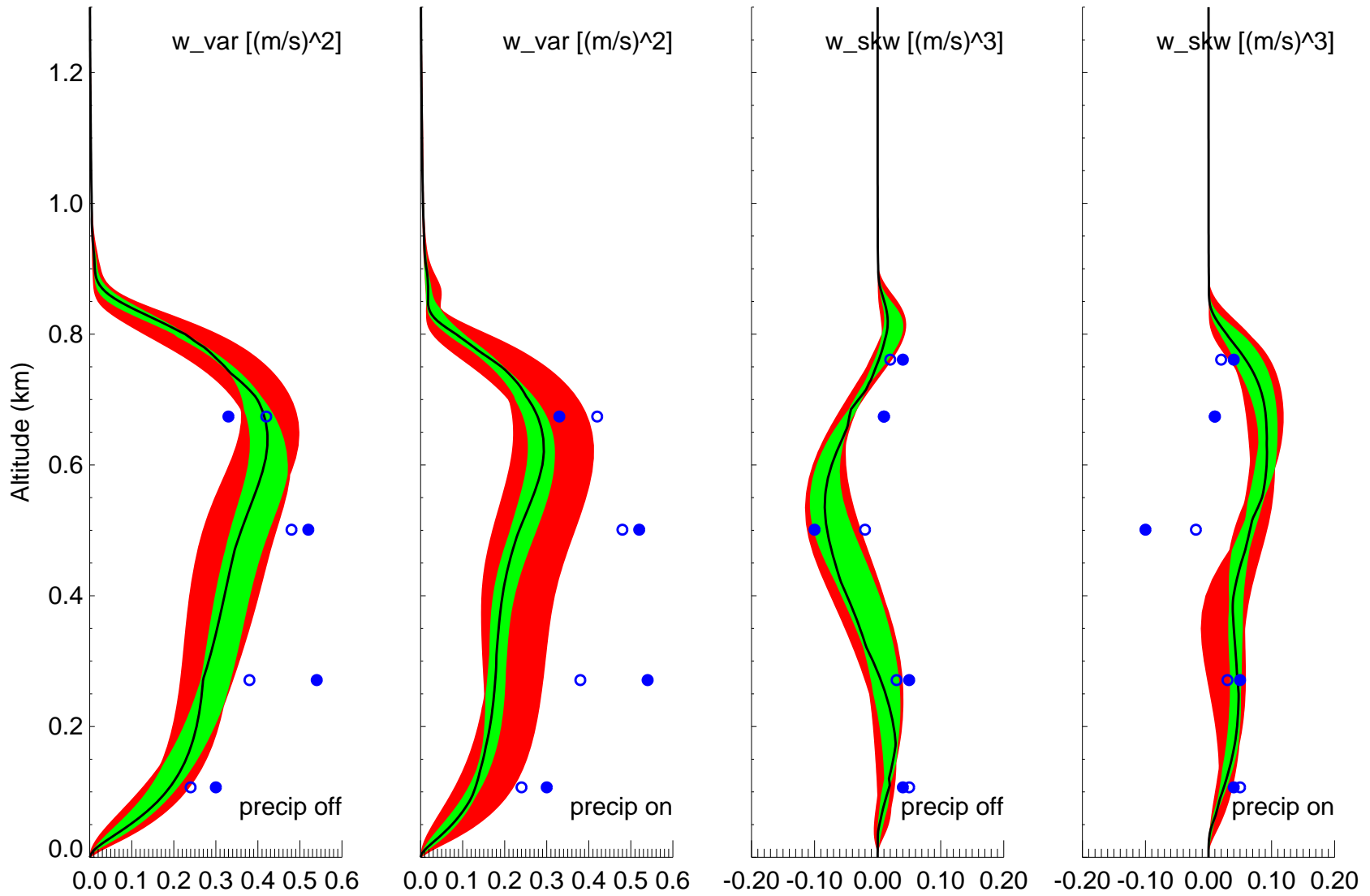
Time Series (ensemble cut)



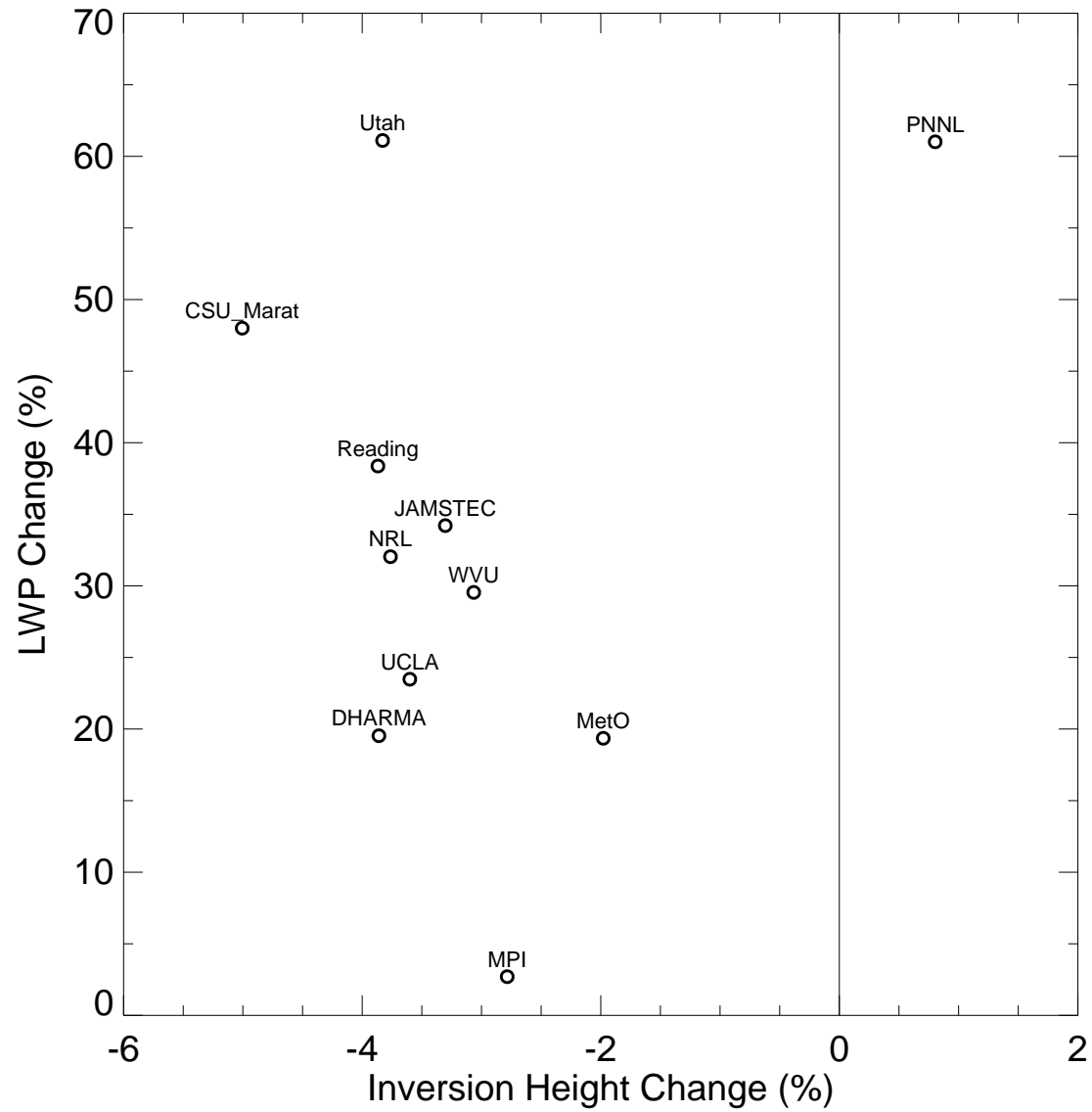
Ensemble Profiles



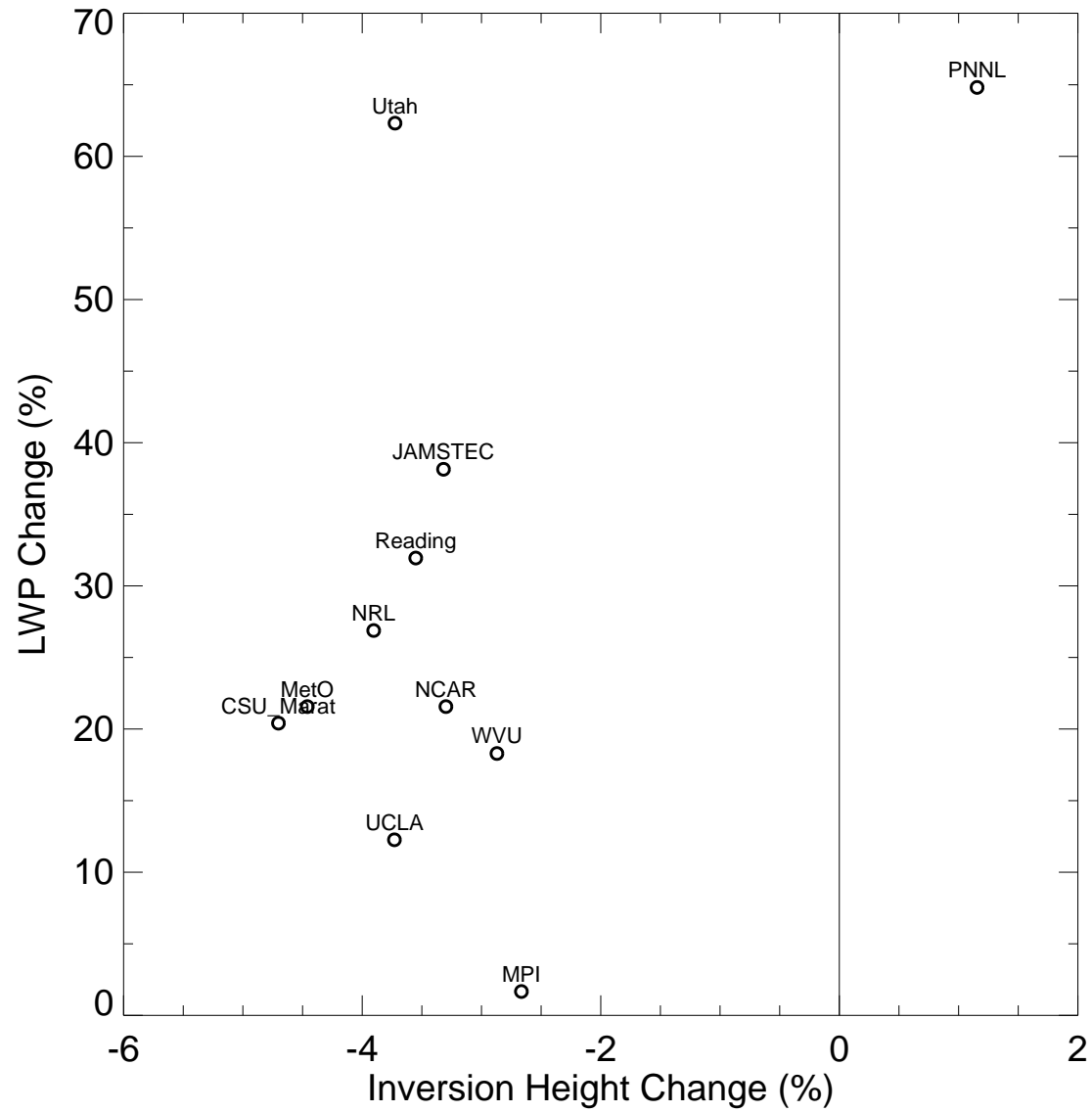
Ensemble Profiles



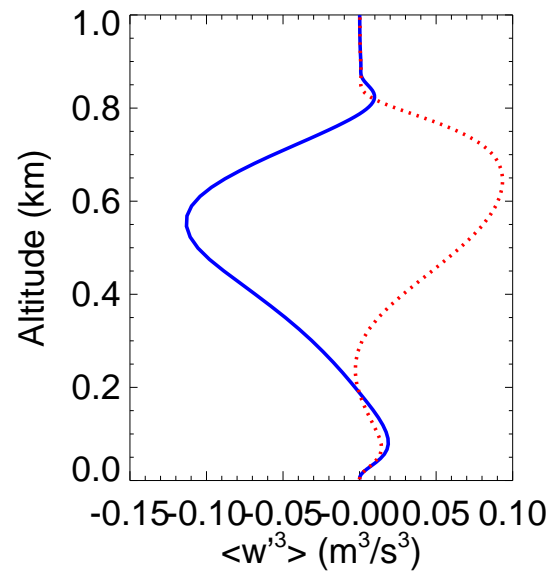
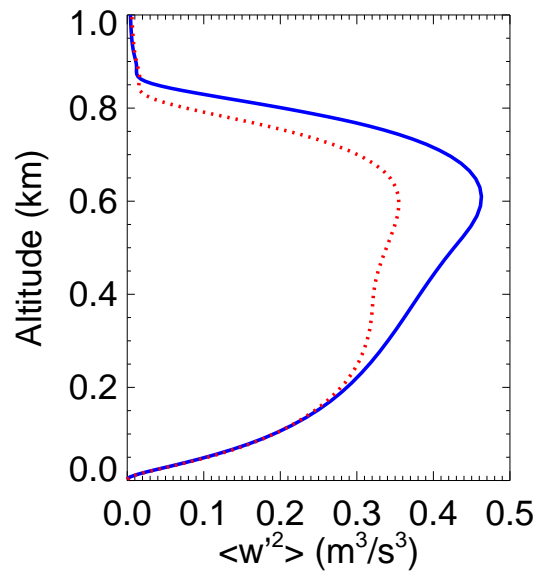
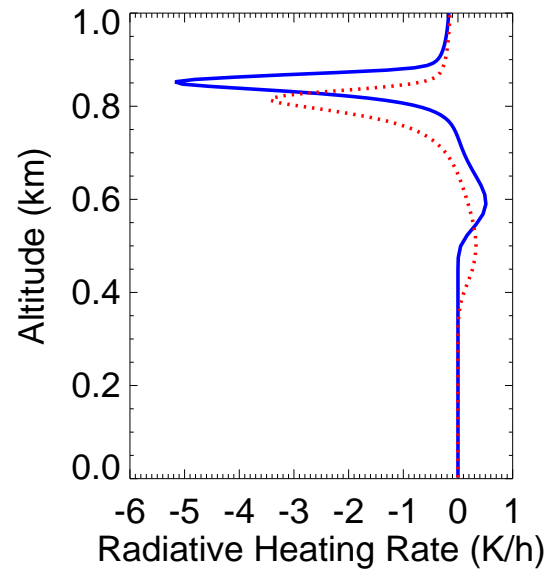
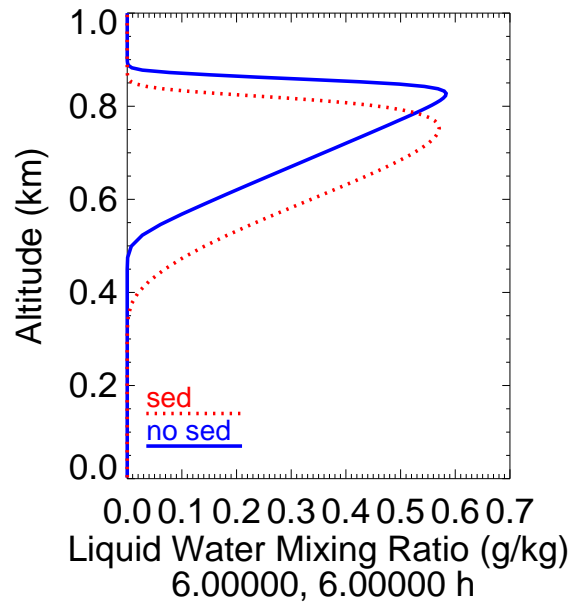
Effects of Including Cloud Droplet Sedimentation (No Drizzle)



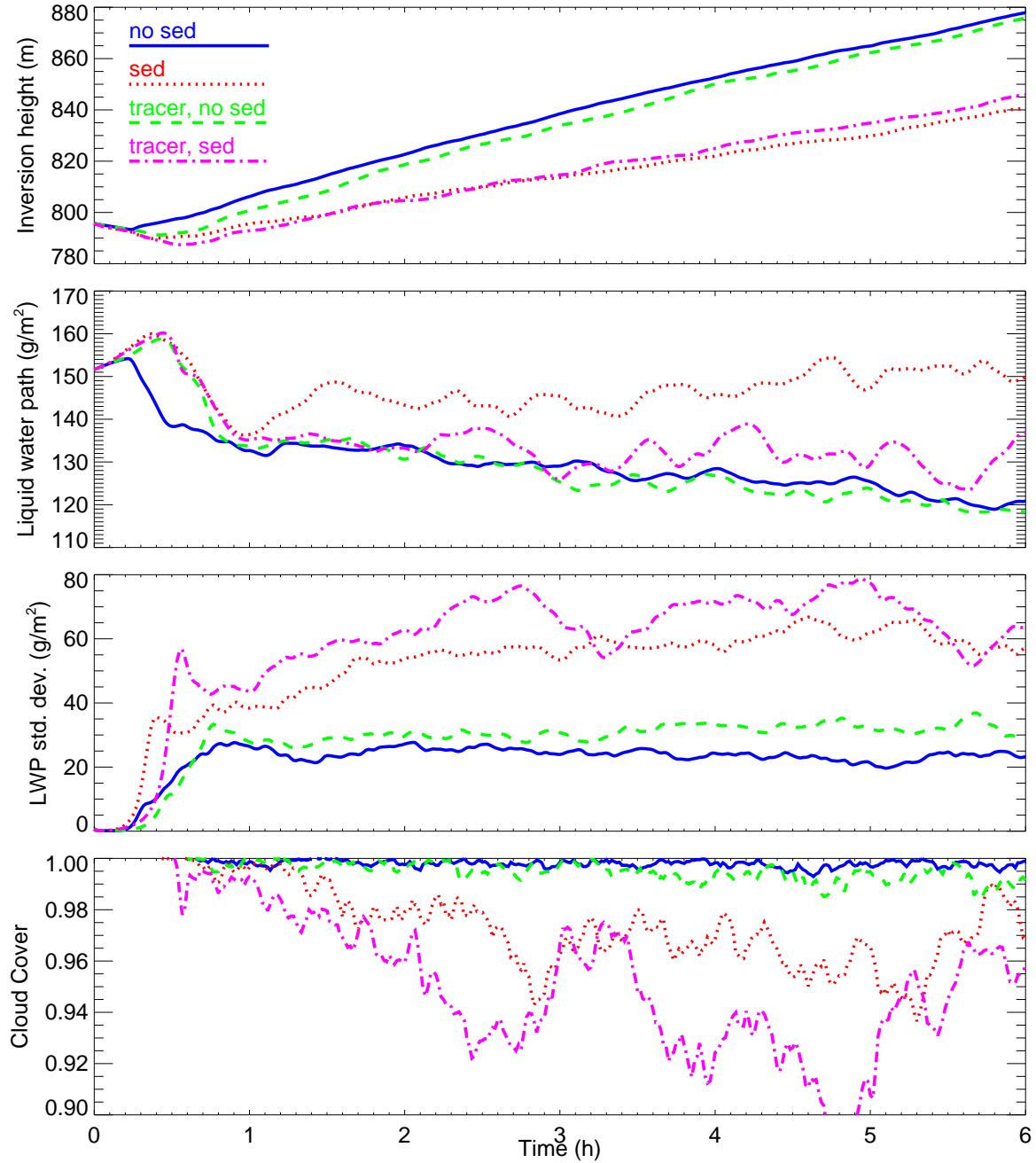
Effects of Including Cloud Droplet Sedimentation (With Drizzle)



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

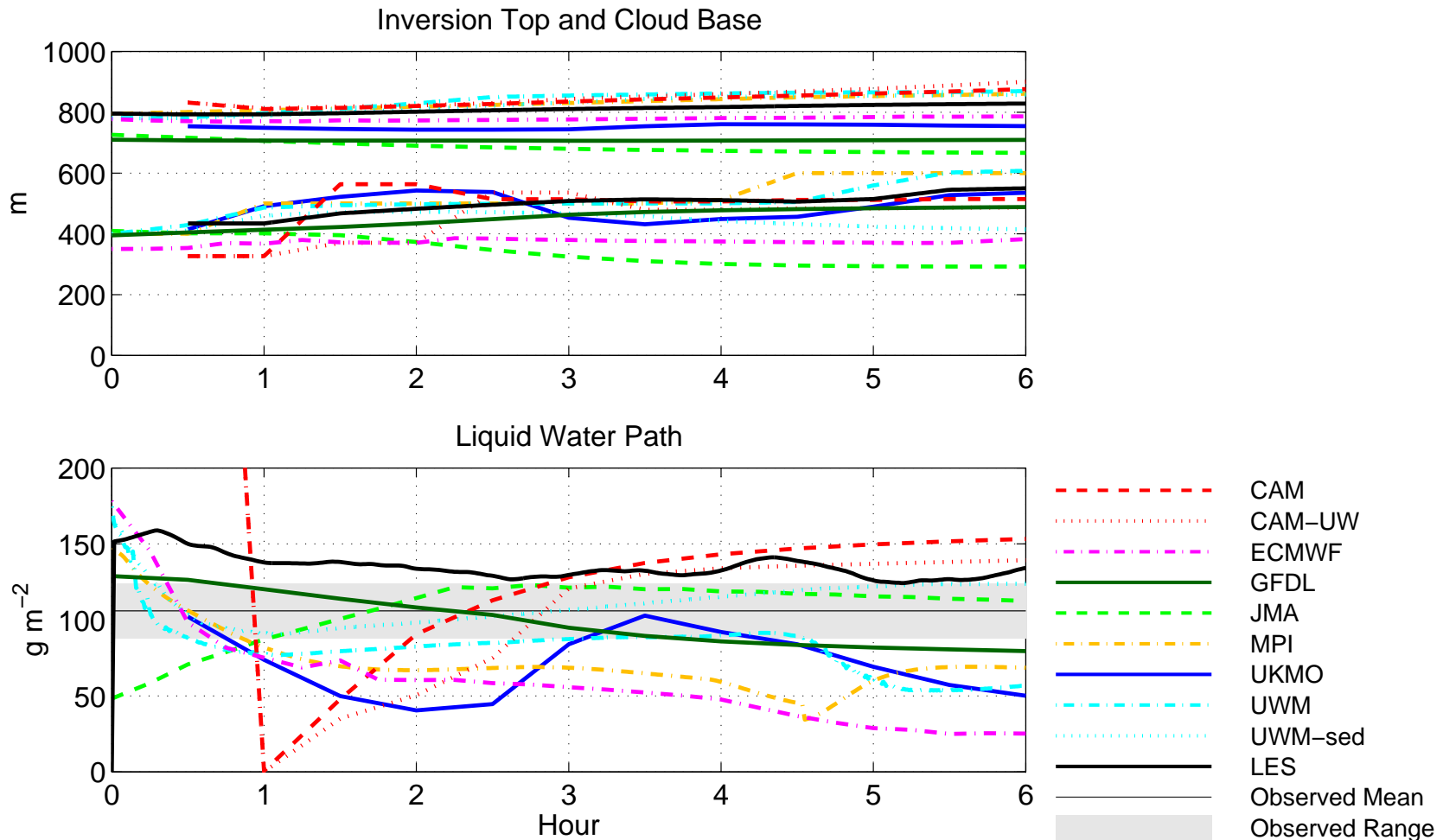
SCM Intercomparison

- Eight SCMs and the one LES are compared. For the UWM run, there is an additional run with a cloud-droplet-sedimentation parameterization.
- 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

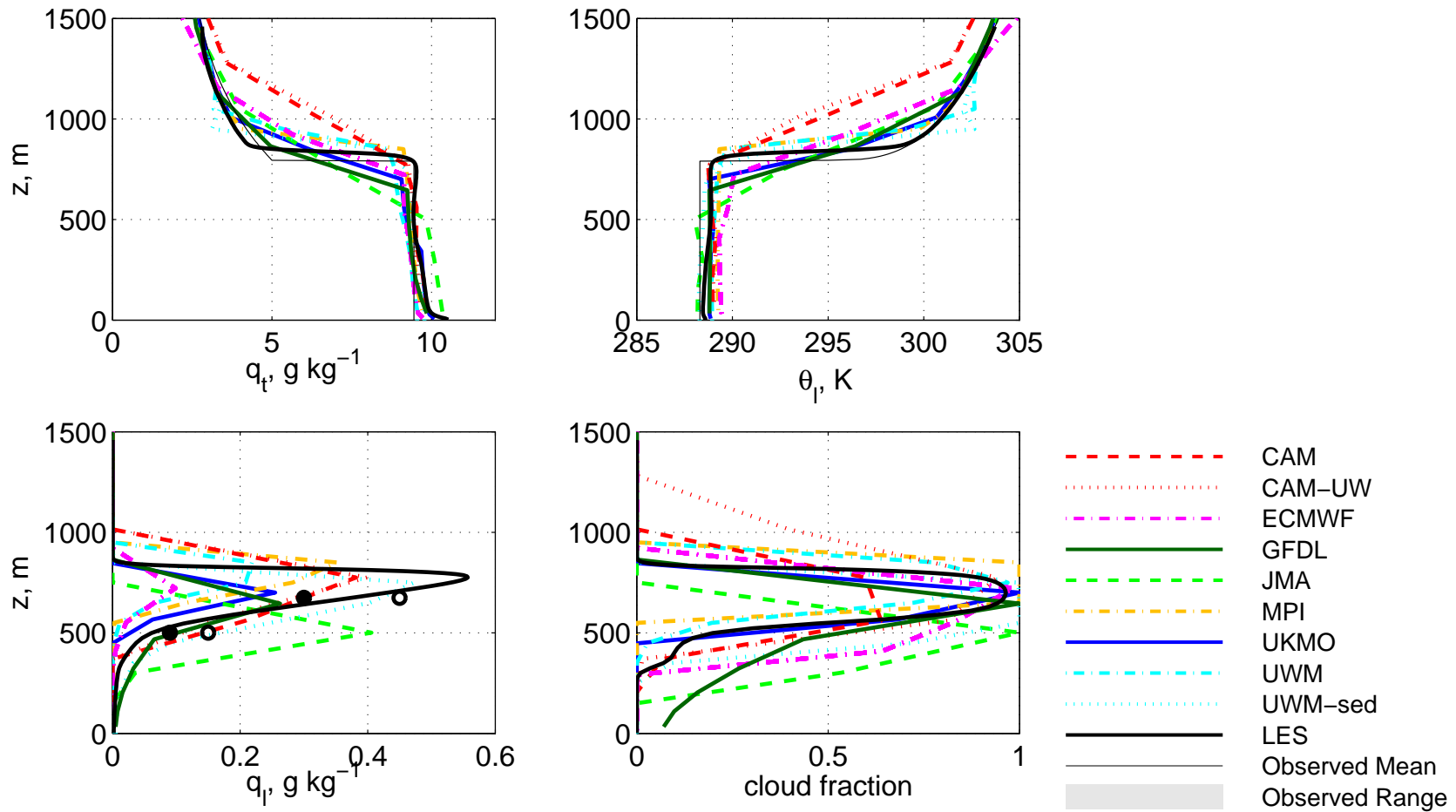
Model/Team	Microphysics	Turbulence
CAM 3 Lappen	autoconversion, collection	non-local, sfc-based
CAM 3-UW Lappen	same as CAM 3	K-profile, explicit w_e
ECMWF de Roode	Sundqvist	K-profile, explicit w_e
GFDL AM2.12b Zhao	autoconversion, collection	non-local, K-profile, explicit w_e
JMA Kitagawa	Sundqvist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

Time Series



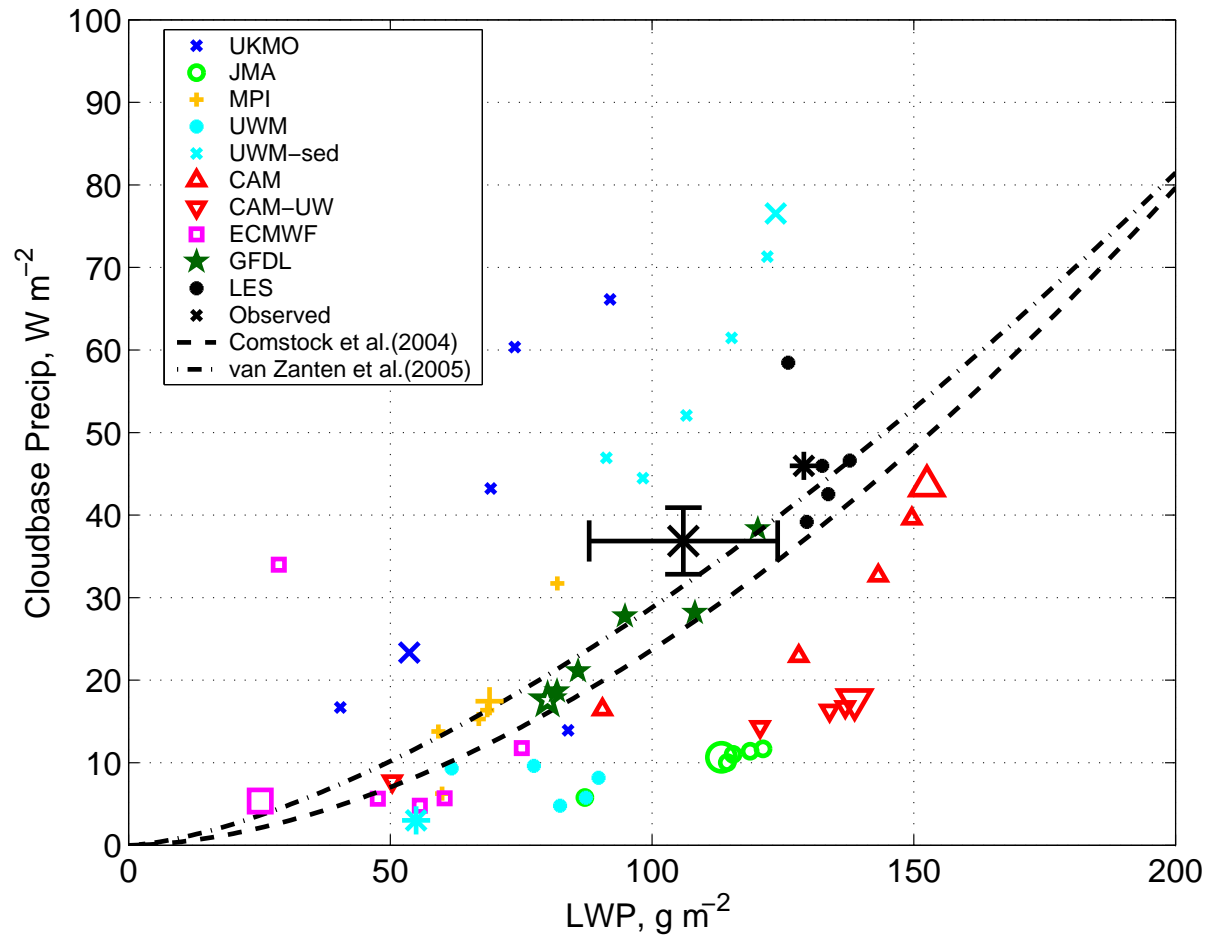
- After startup transients, most models appear to be approaching a quasi-steady state by the simulation end (though continuing to deepen).
- Liquid water paths and entrainment rates are quite diverse.

Profiles



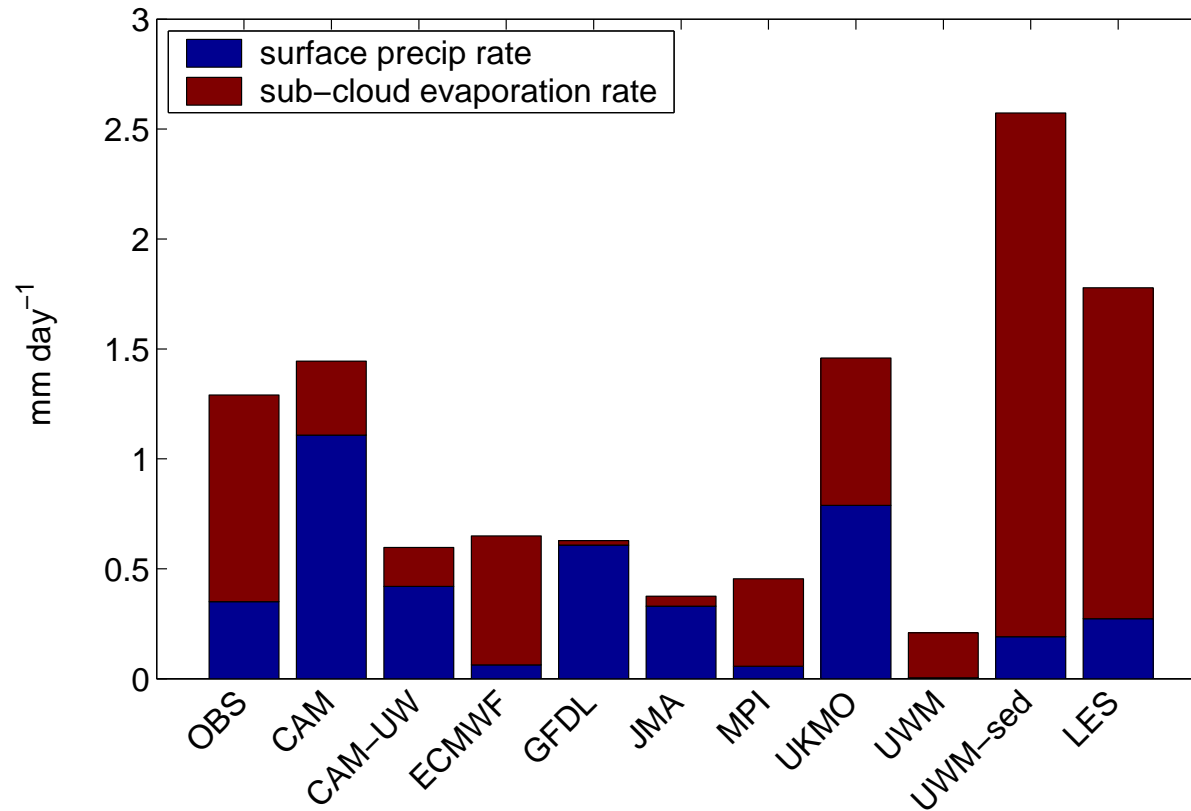
- Inversion not as well resolved as in LES.
- Profiles of q_l are diverse.
- All of the models except CAM maintain large cloud fraction.

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.