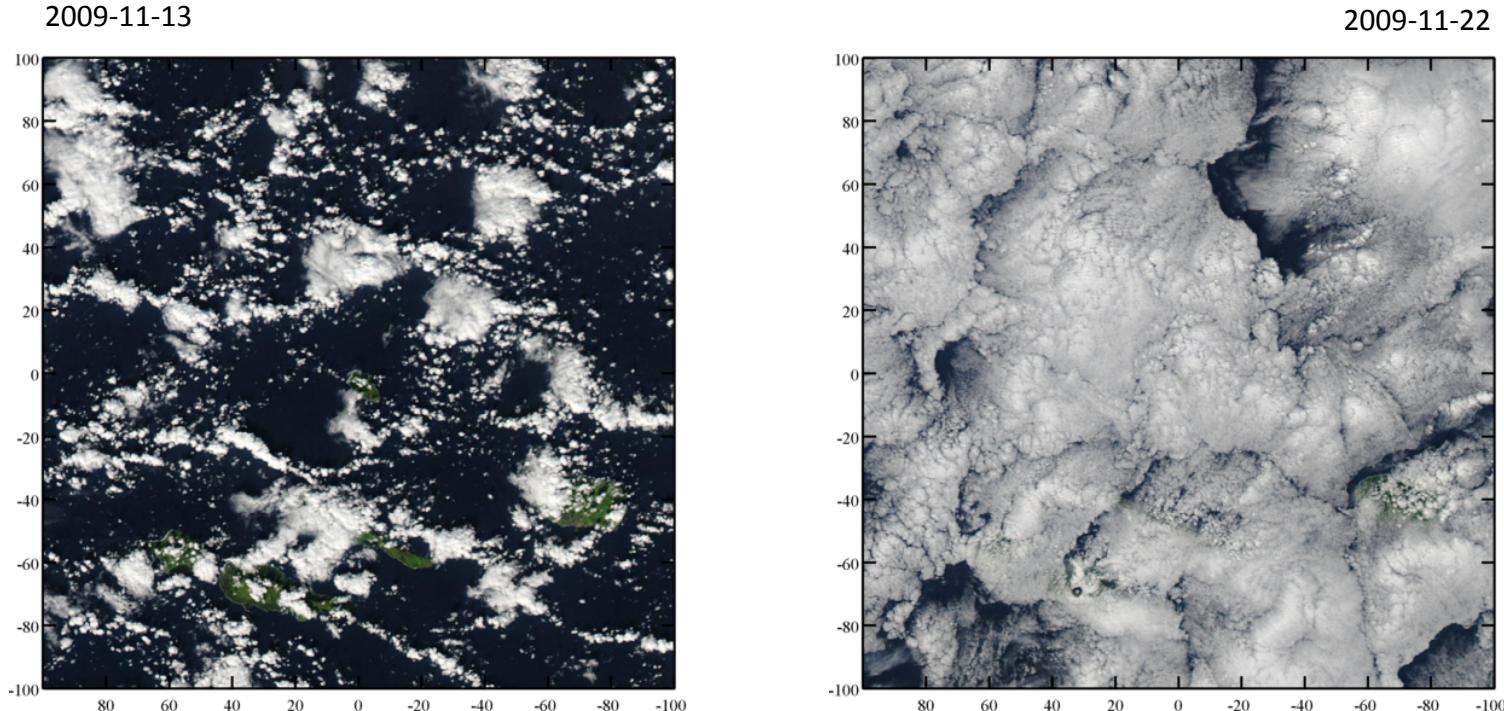
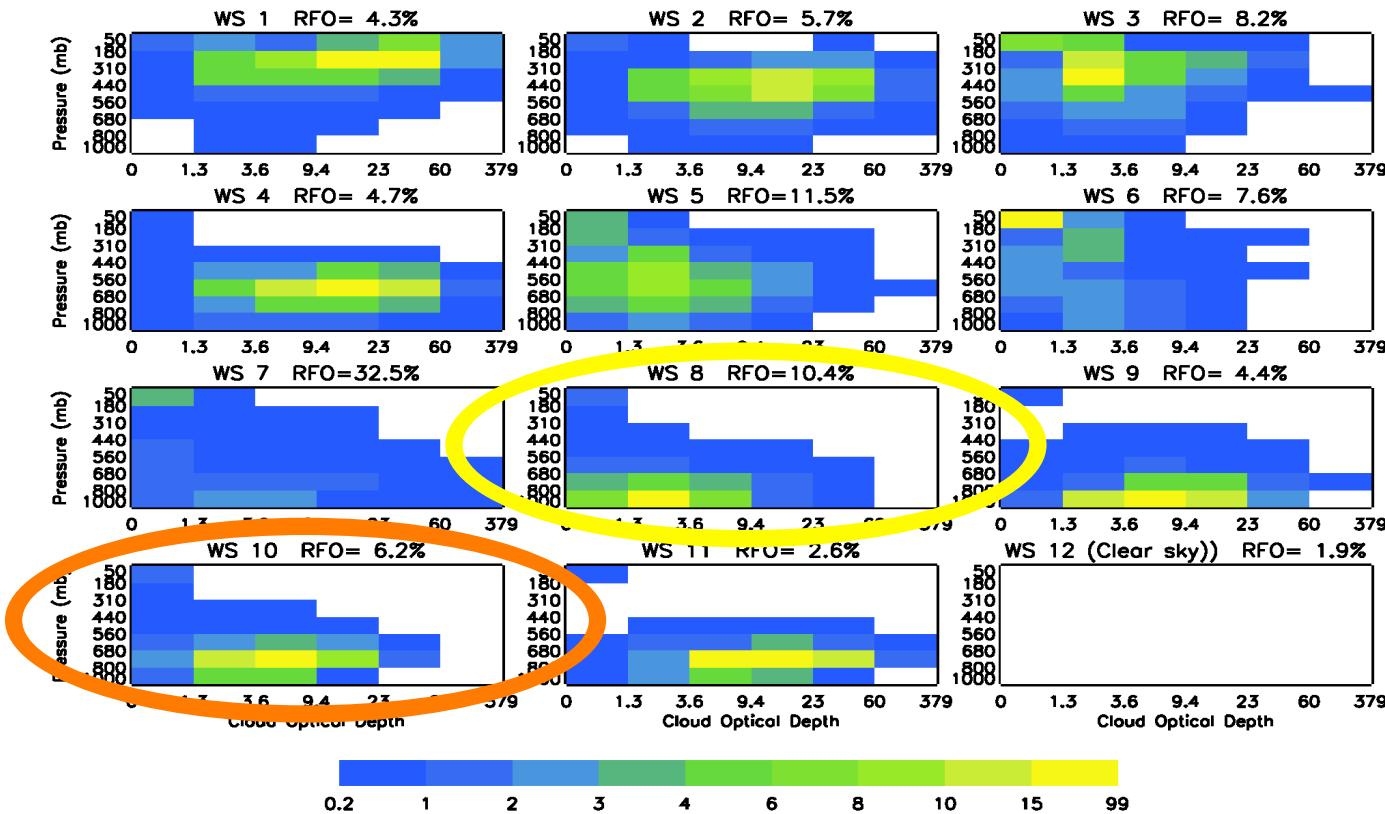


# Evaluation of large-eddy and SCM simulations using *in situ* observations and satellite retrievals: Toward improving low clouds in GISS ModelE2

Andrew Ackerman, Ann Fridlind,  
George Tselioudis, Jasmine Remillard, Maxwell Kelley  
*NASA Goddard Institute for Space Studies*

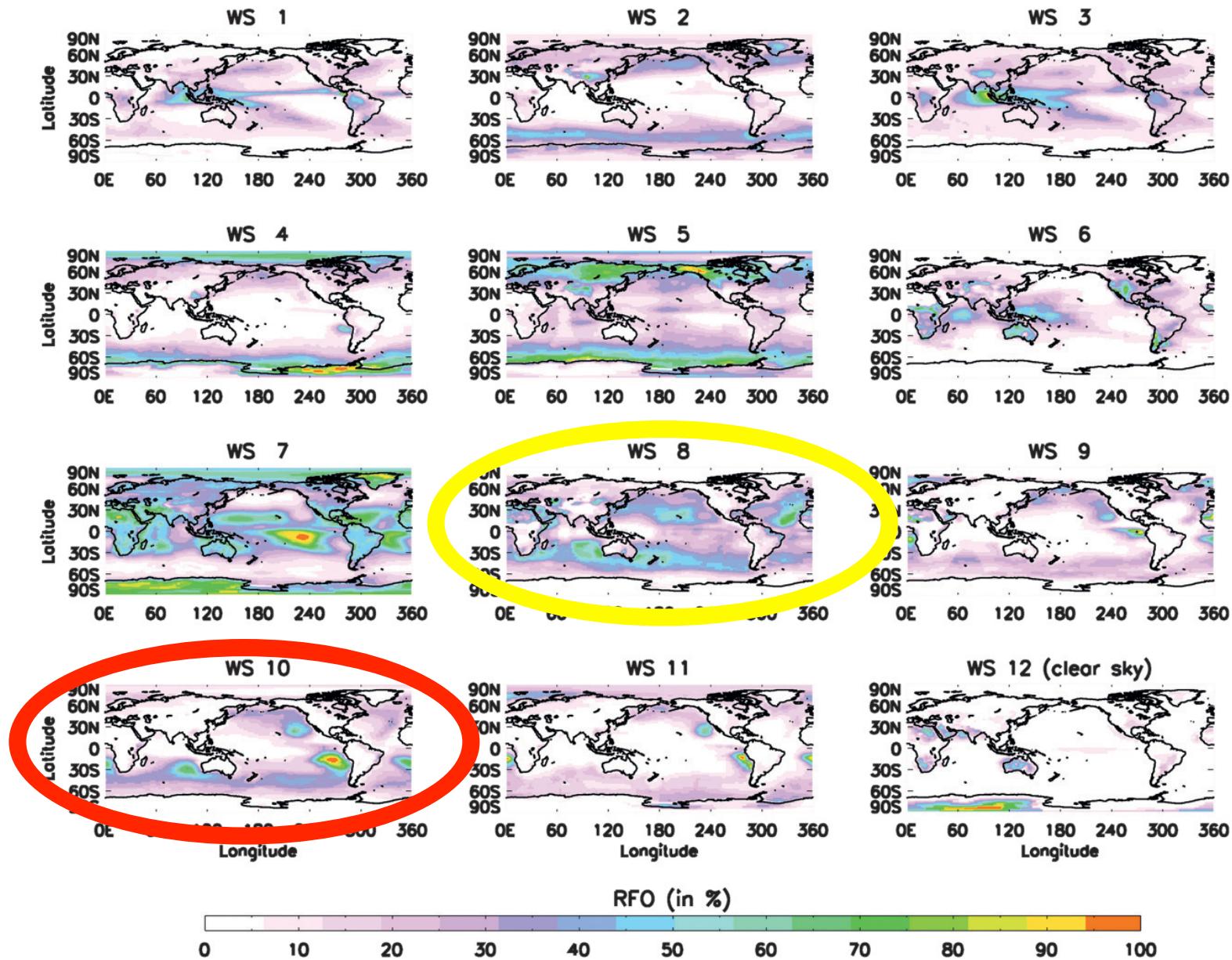


# ISCCP global weather states

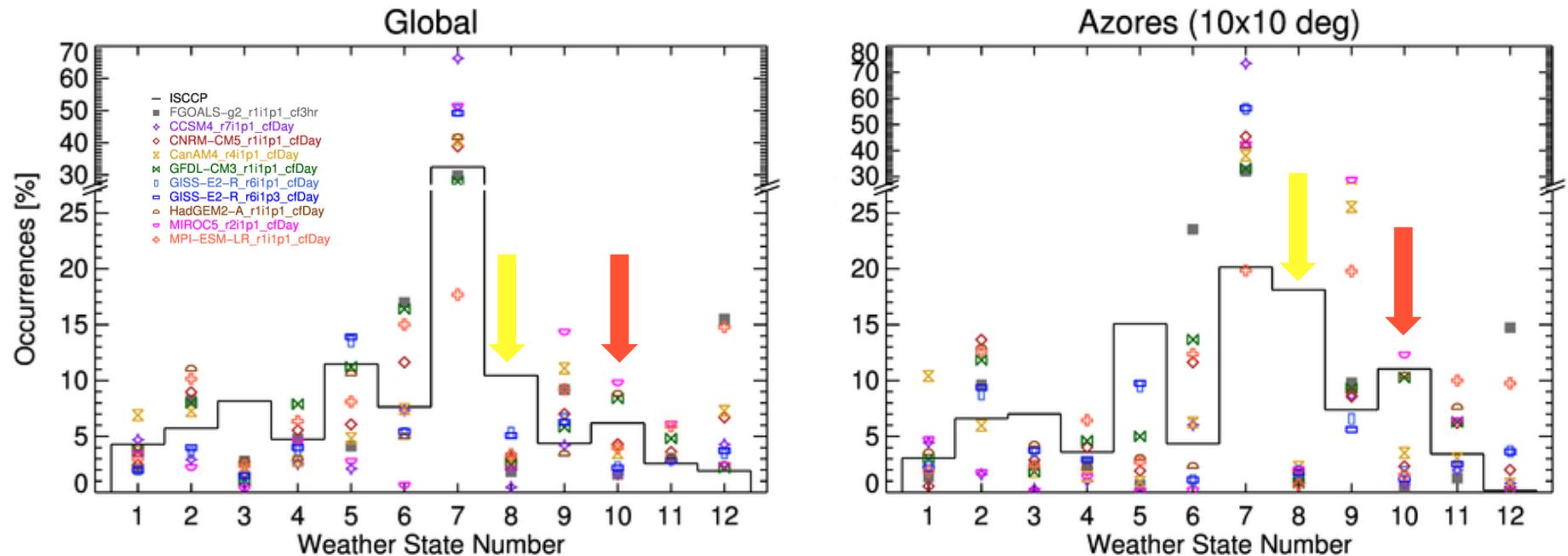


- Focus here on WS 8 (shallow Cu) and WS 10 (Sc)

# ISCCP weather states: Geographical distribution



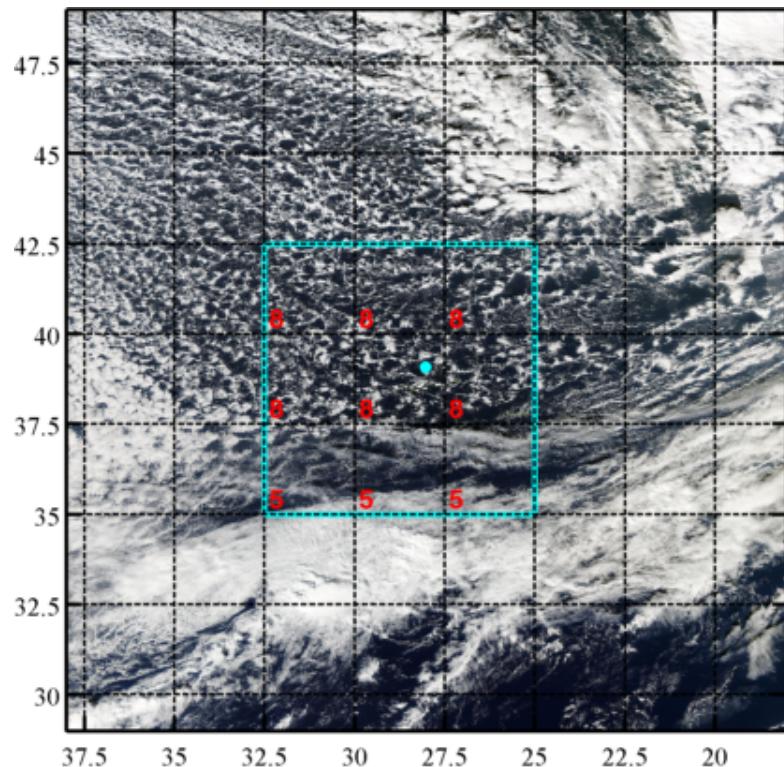
# ISCCP weather states in CMIP5 models



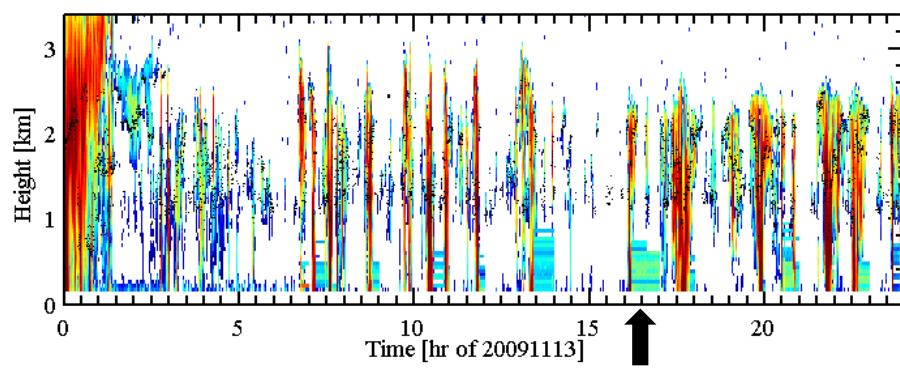
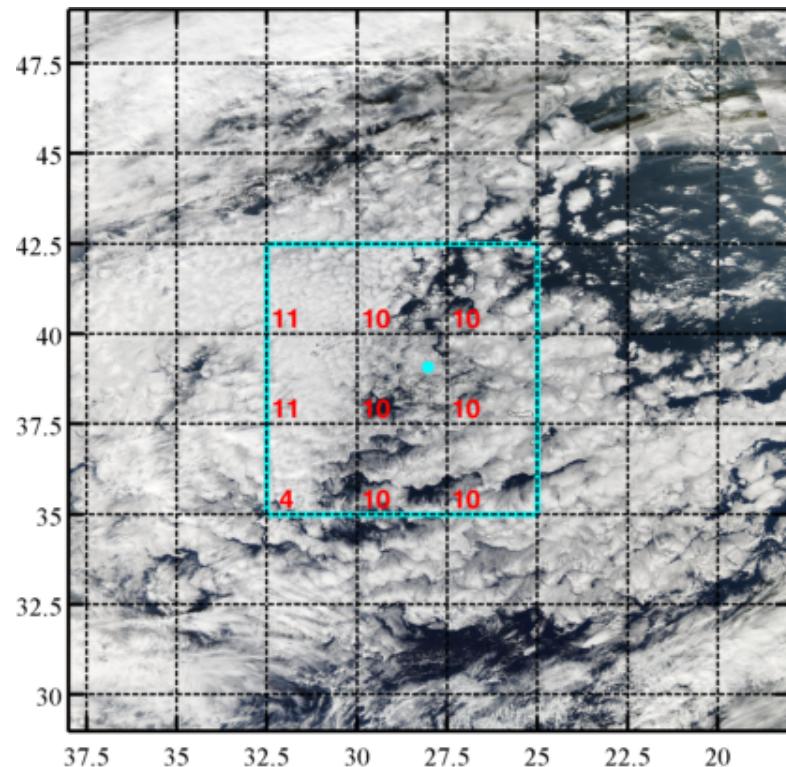
- WS 8 (shallow Cu) under-represented, globally and particularly near Azores
- WS 10 (Sc) commonly under-represented (including GISS-E2), particularly near Azores

# Two case studies from CAP-MBL, 2009

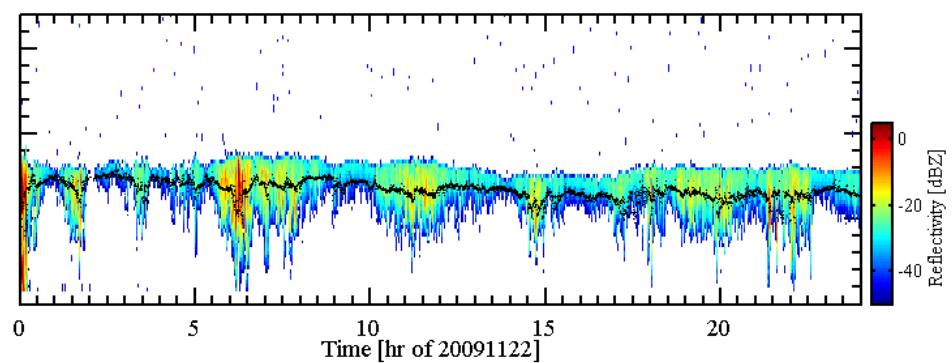
Cu: 11/13 post-frontal cold-air outbreak



Sc: 11/22, Azores high

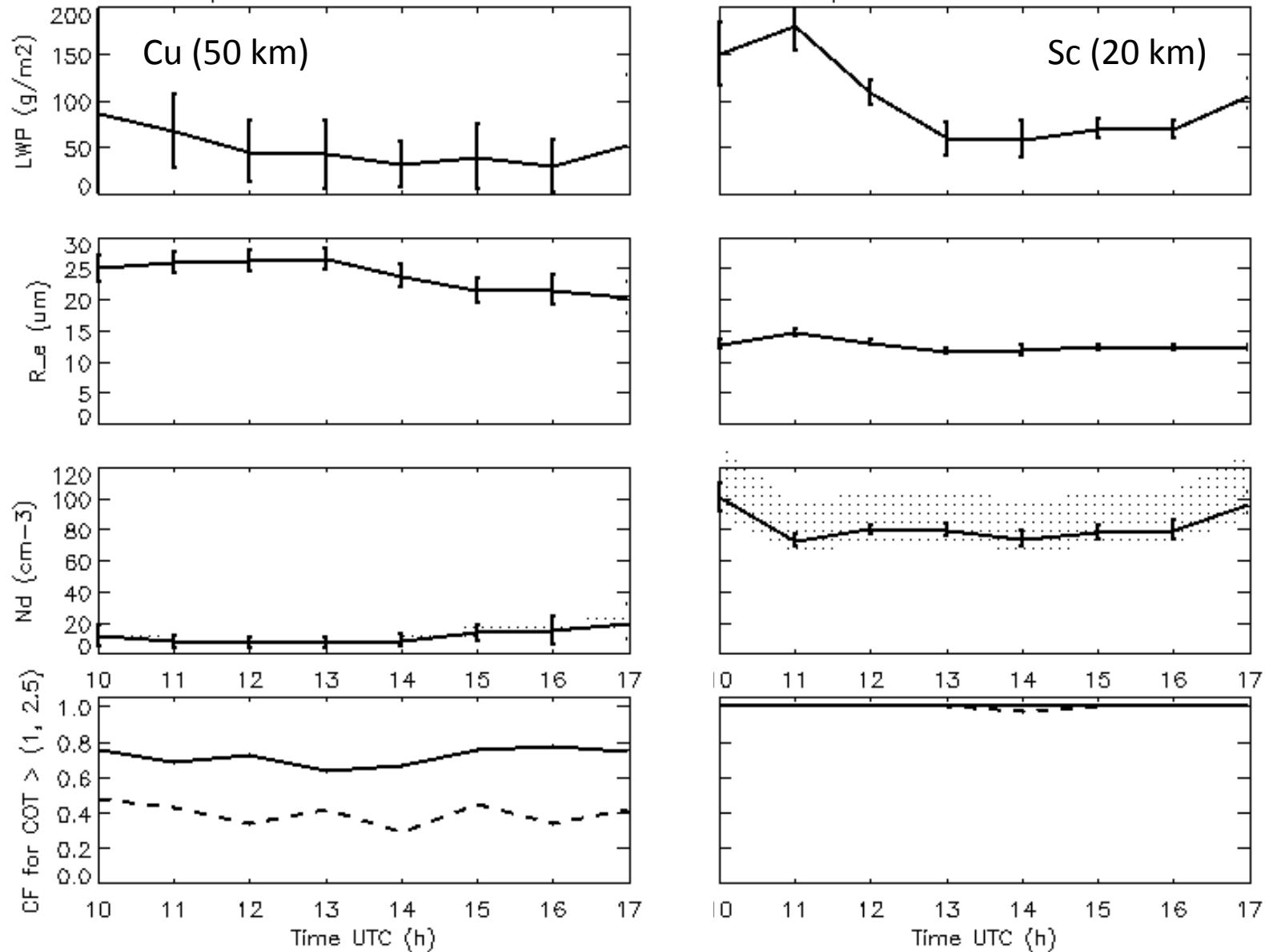


$$\theta_{\text{skin}} - \theta_{800\text{mb}} = 1.6 \text{ K}$$



Reflectivity [dBZ]

# VISST cloud retrievals



(data from Kirk Ayers, NASA LaRC)

# DHARMA setup

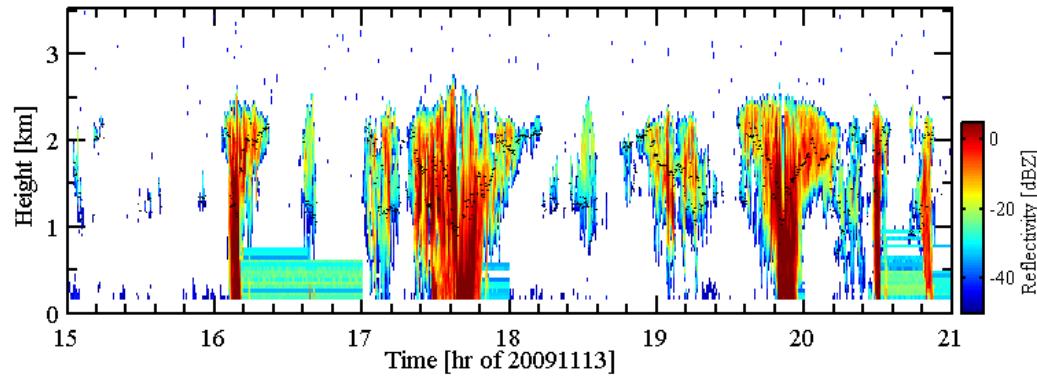
- LES framework (*Stevens and Bretherton 1997*) with dynamic SGS model (*Kirkpatrick et al. 2006*) on eddy-permitting grids:
  - Cu:  $20 \times 20 \times 3.5$  km,  $\Delta x = 100$  m,  $\Delta z = 35$  m
  - Sc:  $10 \times 10 \times 2.5$  km,  $\Delta x = 100$  m,  $\Delta z = 15$  m
- 2-moment Morrison microphysics (Cu) or bin microphysics (Sc), with diagnostic bimodal aerosol fit to CCN measurements, scaled
- parameterized LW cooling only
- subsidence profiles loosely based on MERRA, tuned
- interactive surface fluxes (SST fixed)
- winds and free troposphere thermo nudged with  $\tau = 2$  h
- 6-h simulations (for now)

## GISS ModelE2 SCM

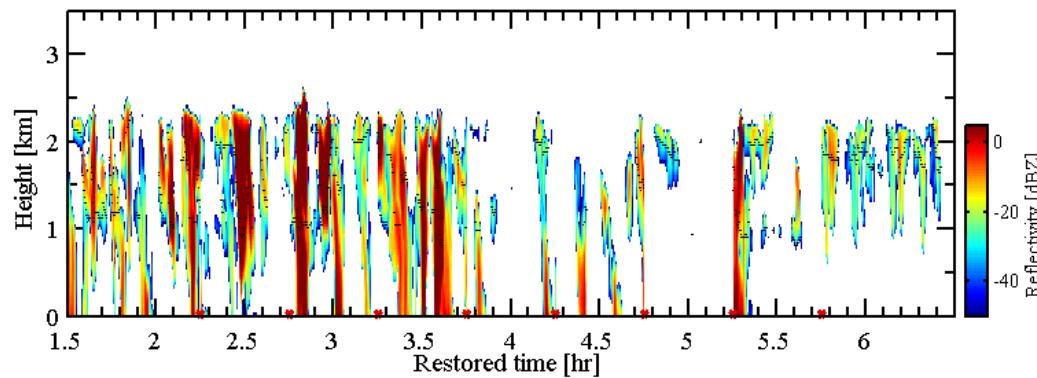
- Since AR5 version, SCM machinery completely overhauled by Fridlind and Kelley, now easy to run and configure new cases
- Components used here:
  - *Del Genio et al. 1996* stratiform cloud scheme (Sundqvist)
  - *Del Genio et al. 2007* moist convection
  - *Cheng & Yao 2012* turbulence scheme (non-local in PBL, 2<sup>nd</sup> order closure above, dry variables)
- Same forcings and initial conditions as LES

# Radar curtains: Cumulus (11/13)

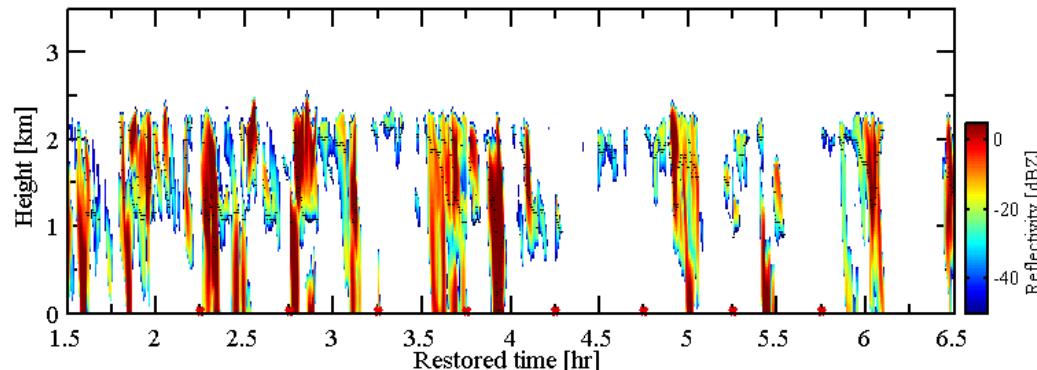
Observations



20-km grid

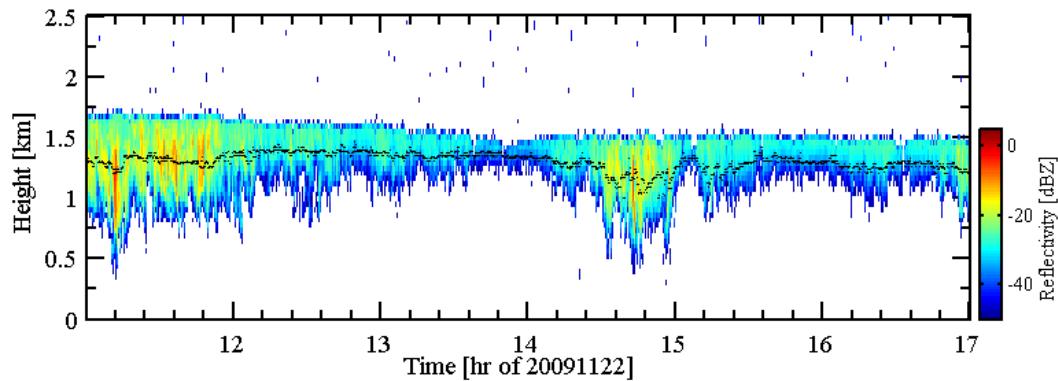


100-km grid

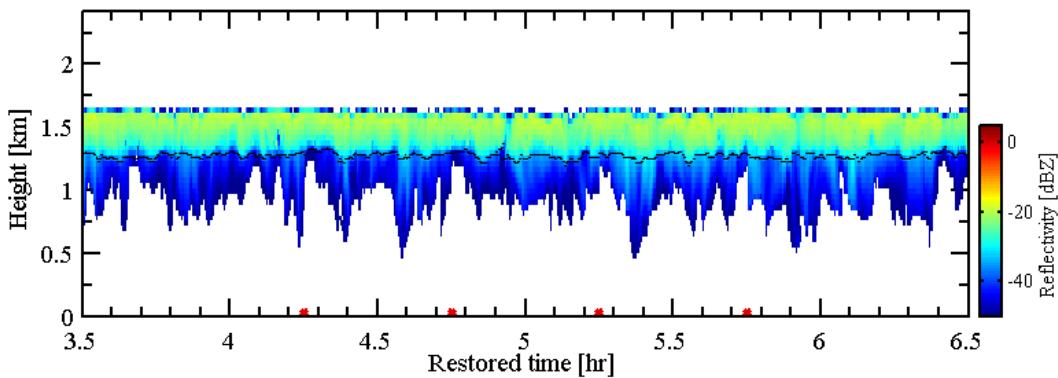


# Radar curtains: Stratocumulus (11/22)

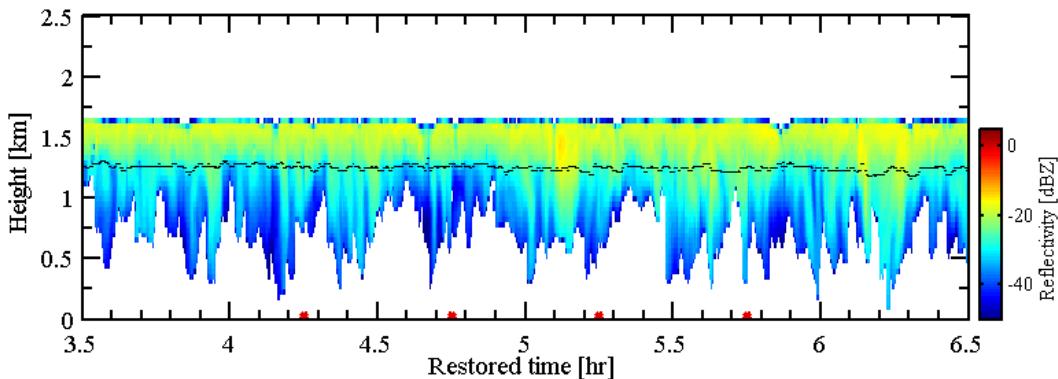
Observations



260/mg CCN

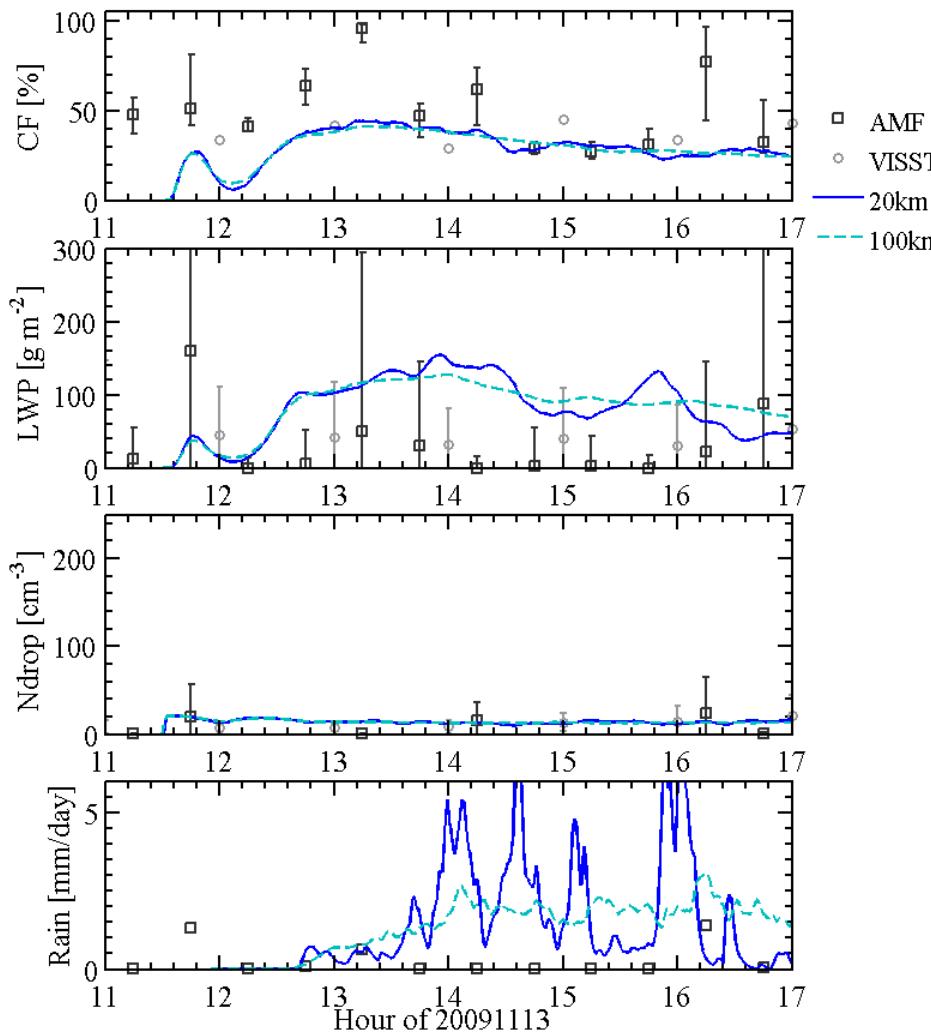


130/mg CCN

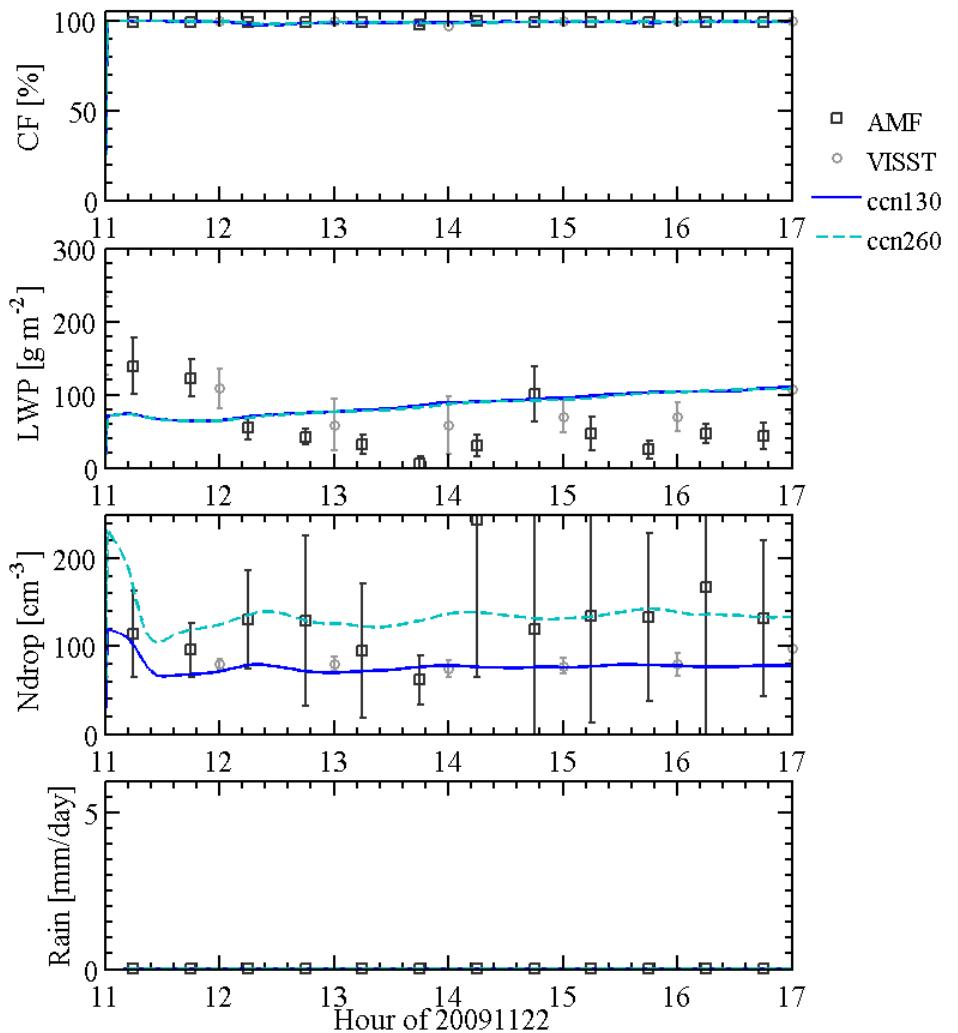


# Domain averages

Cumulus



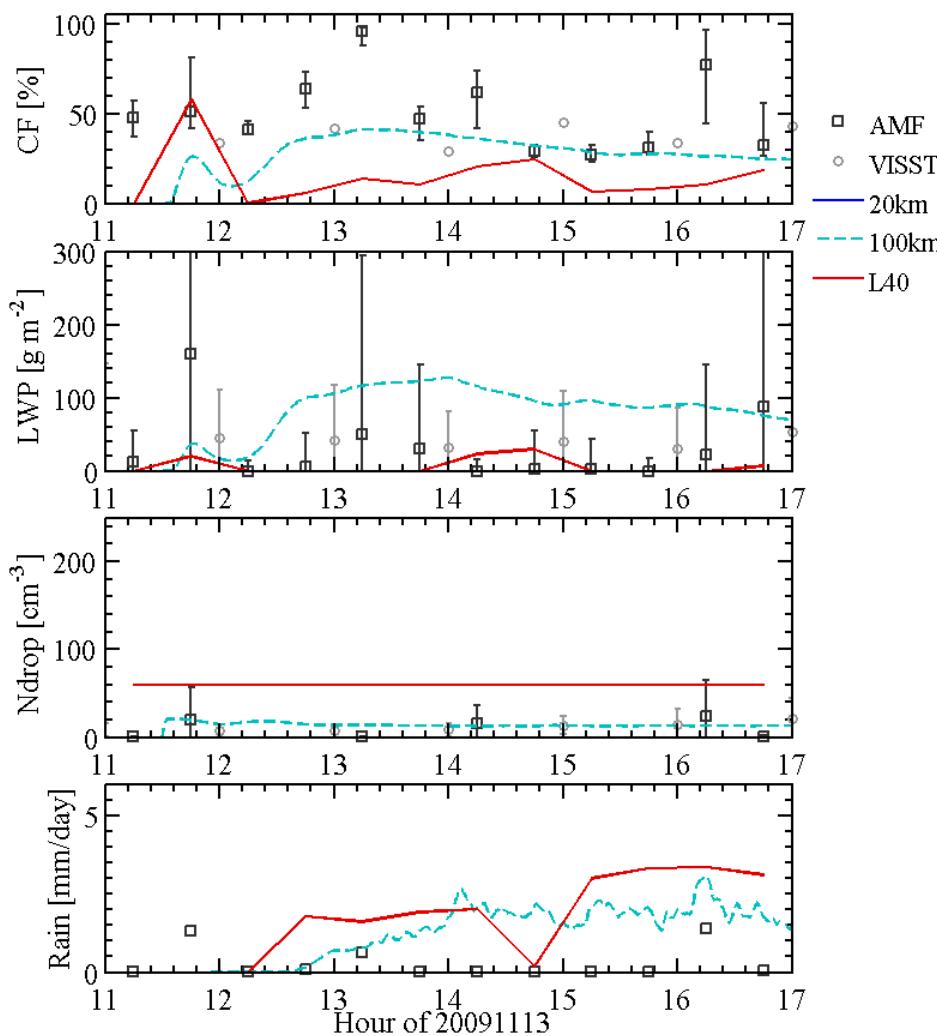
Stratocumulus



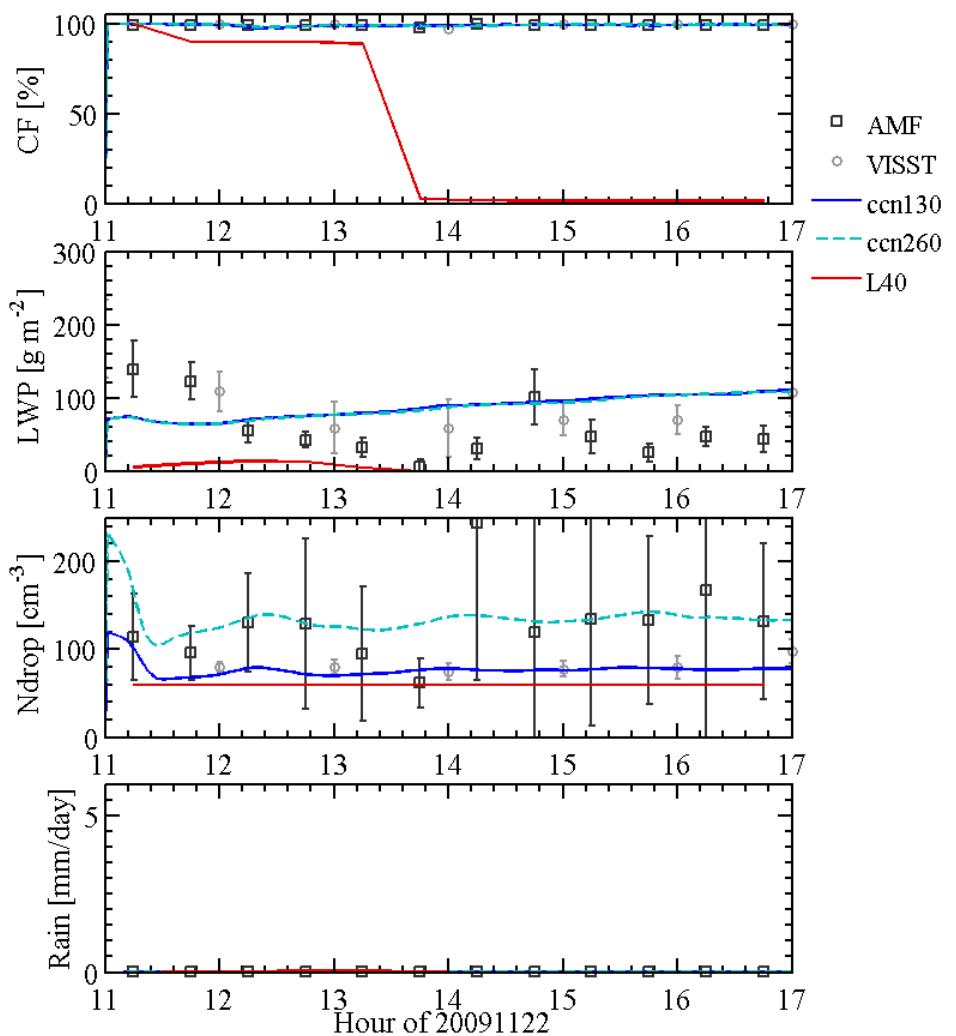
→ LES setups seem plausible, on to SCM...

# Domain averages

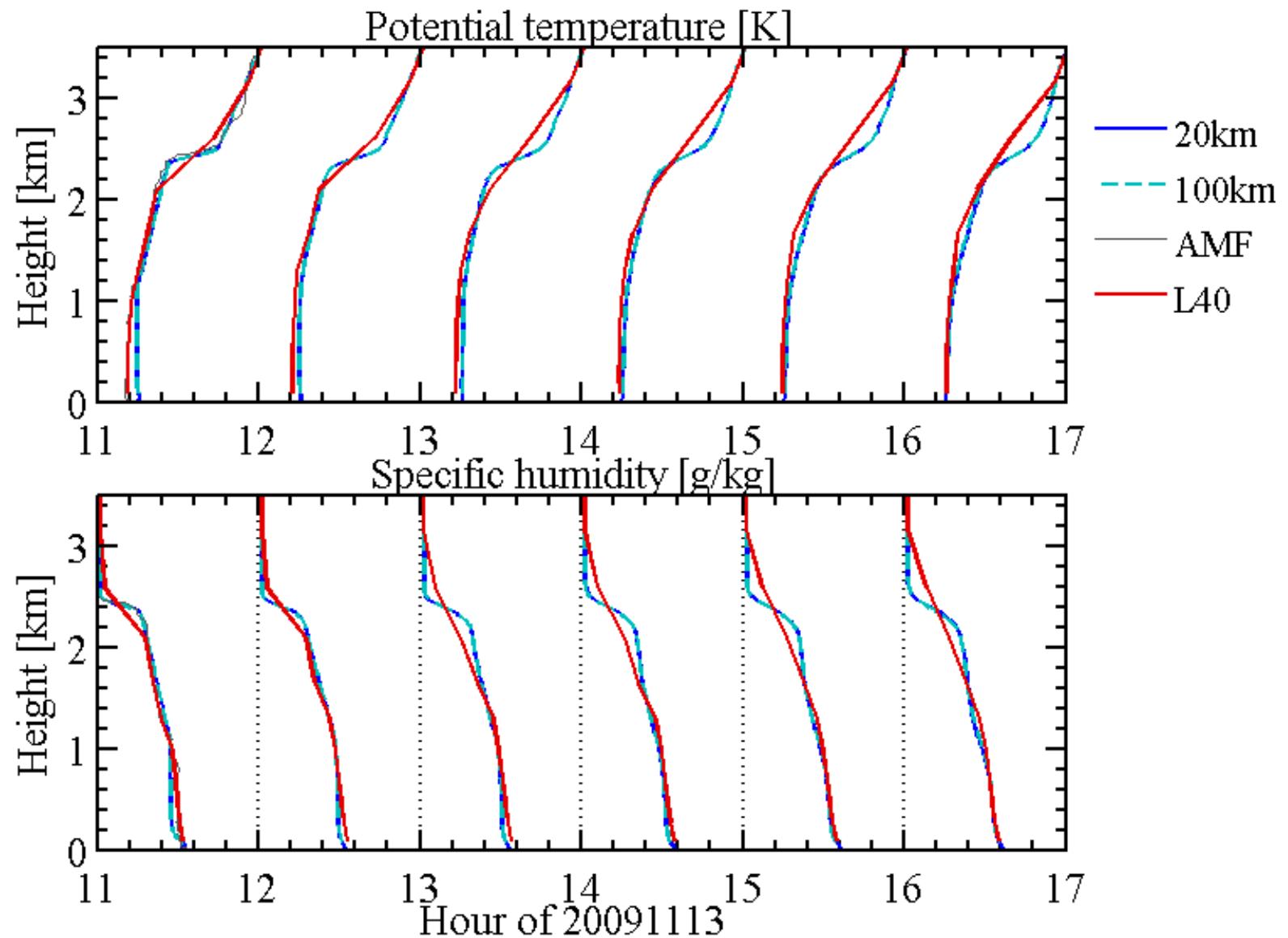
Cumulus



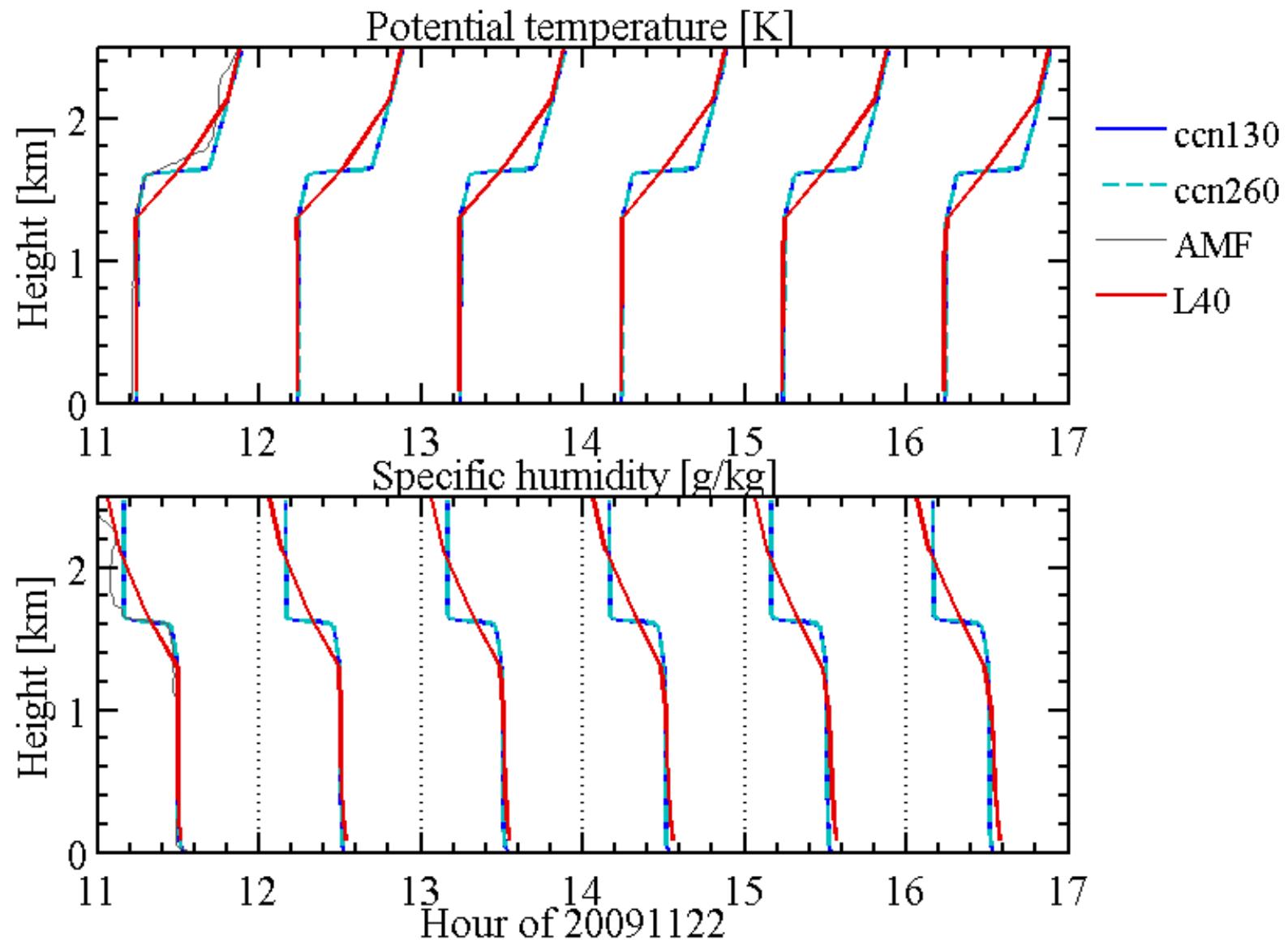
Stratocumulus



# Mean profiles: Cumulus

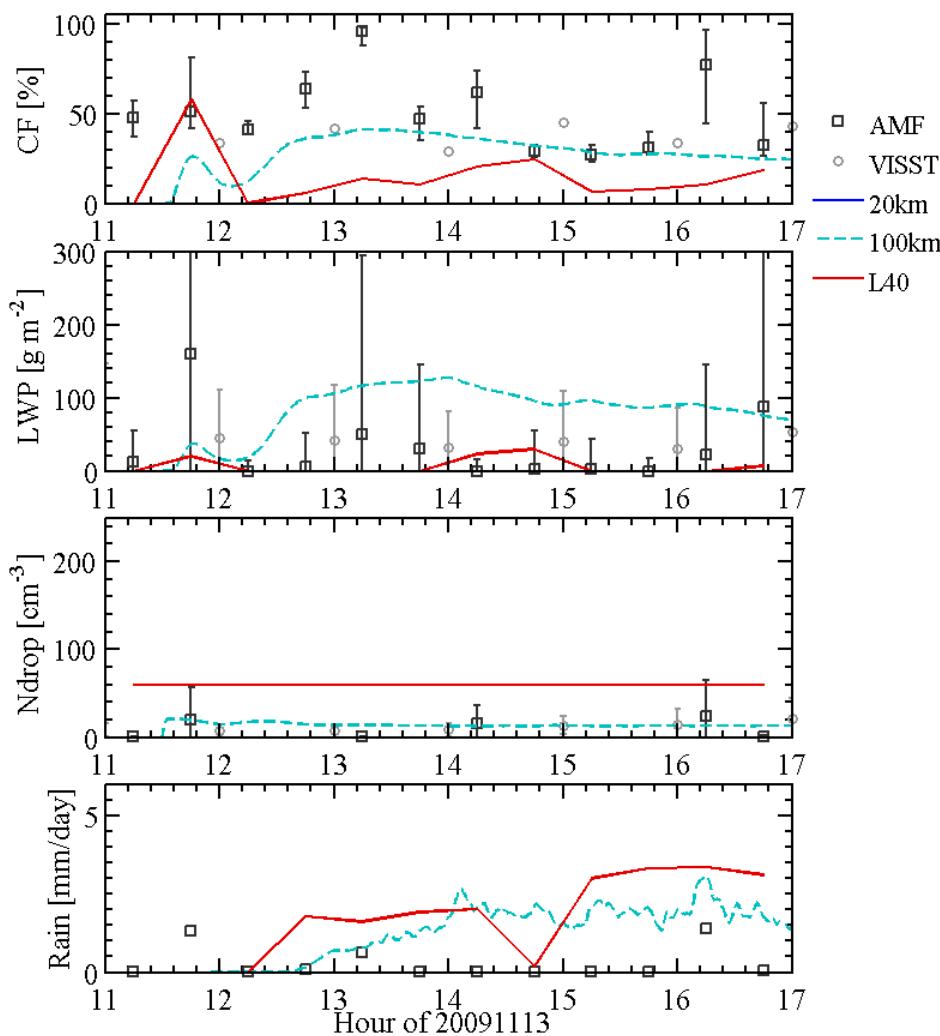


# Mean profiles: Stratocumulus

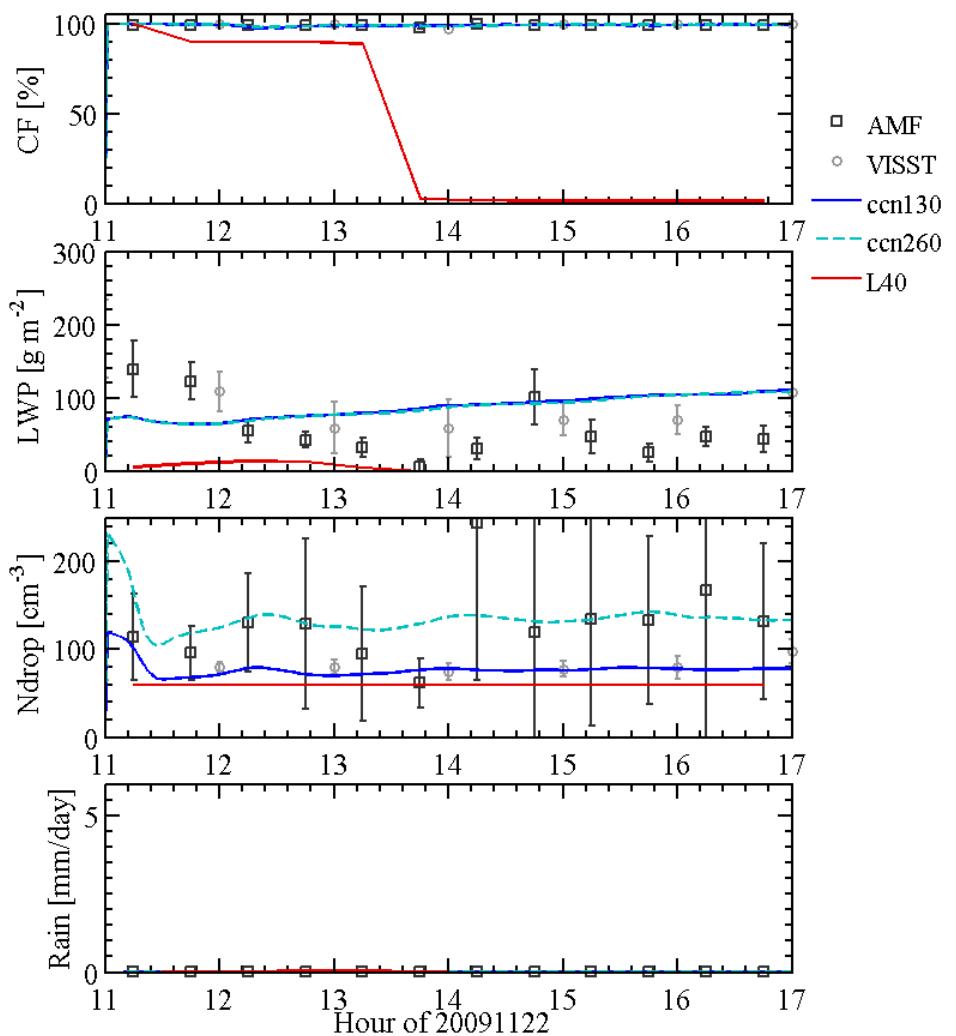


# Domain averages

Cumulus

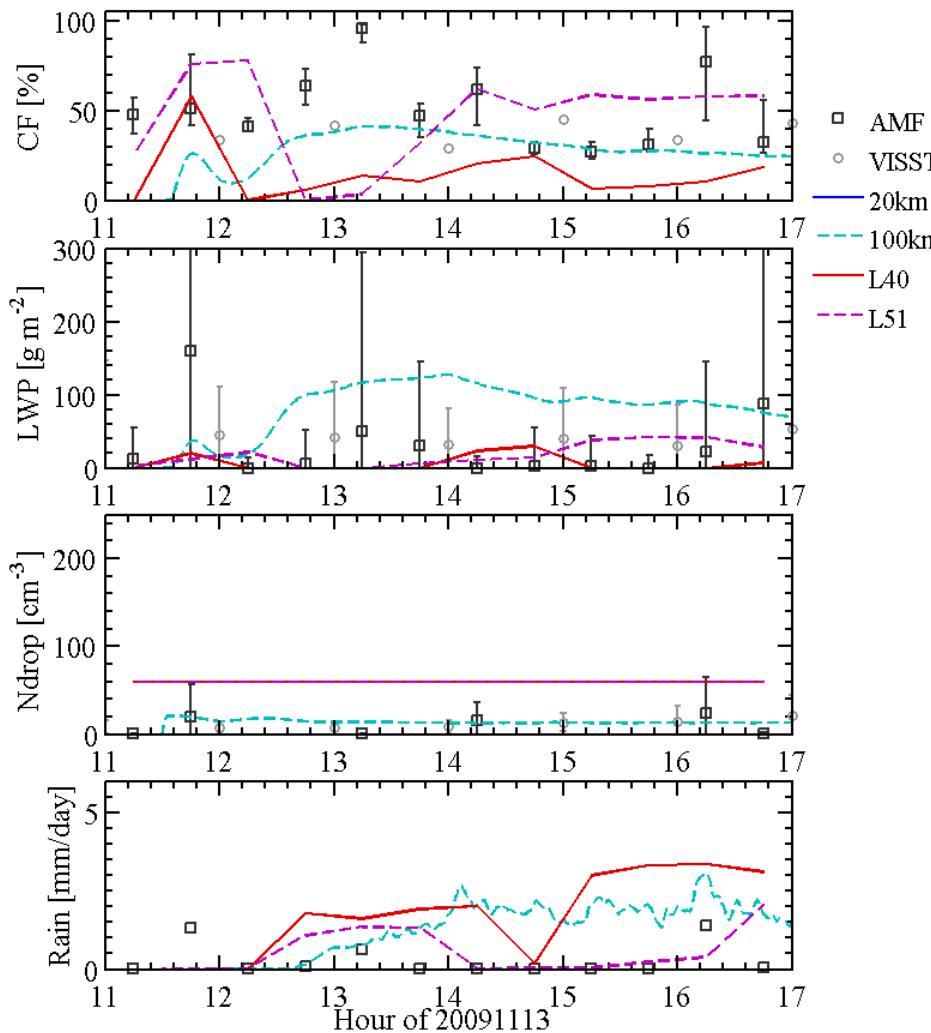


Stratocumulus

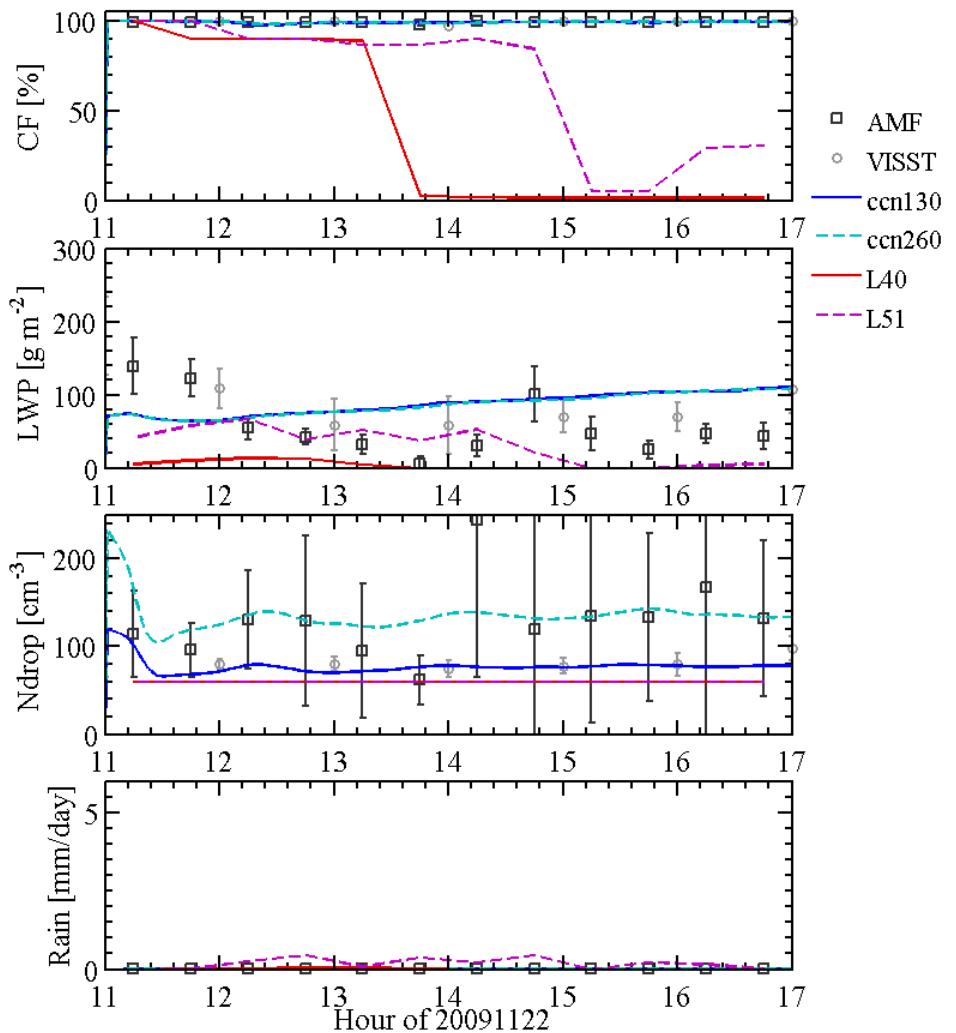


# Domain averages

Cumulus

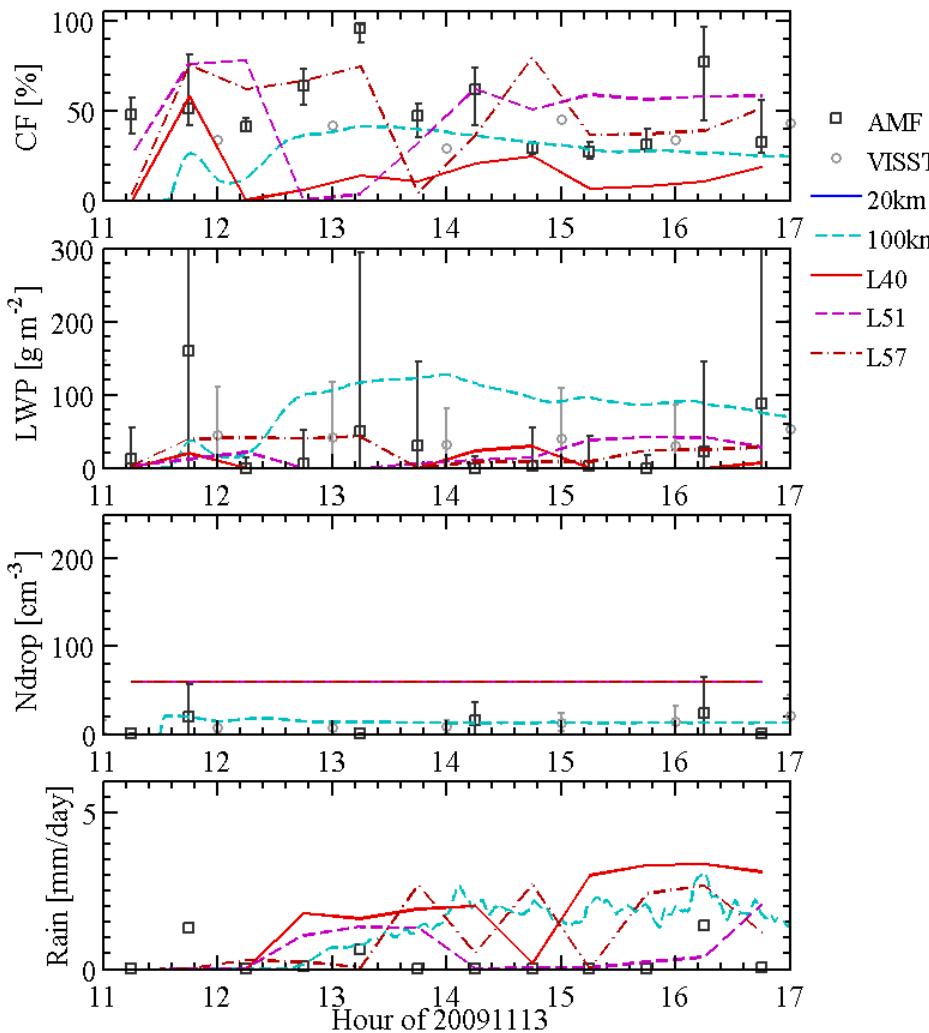


Stratocumulus

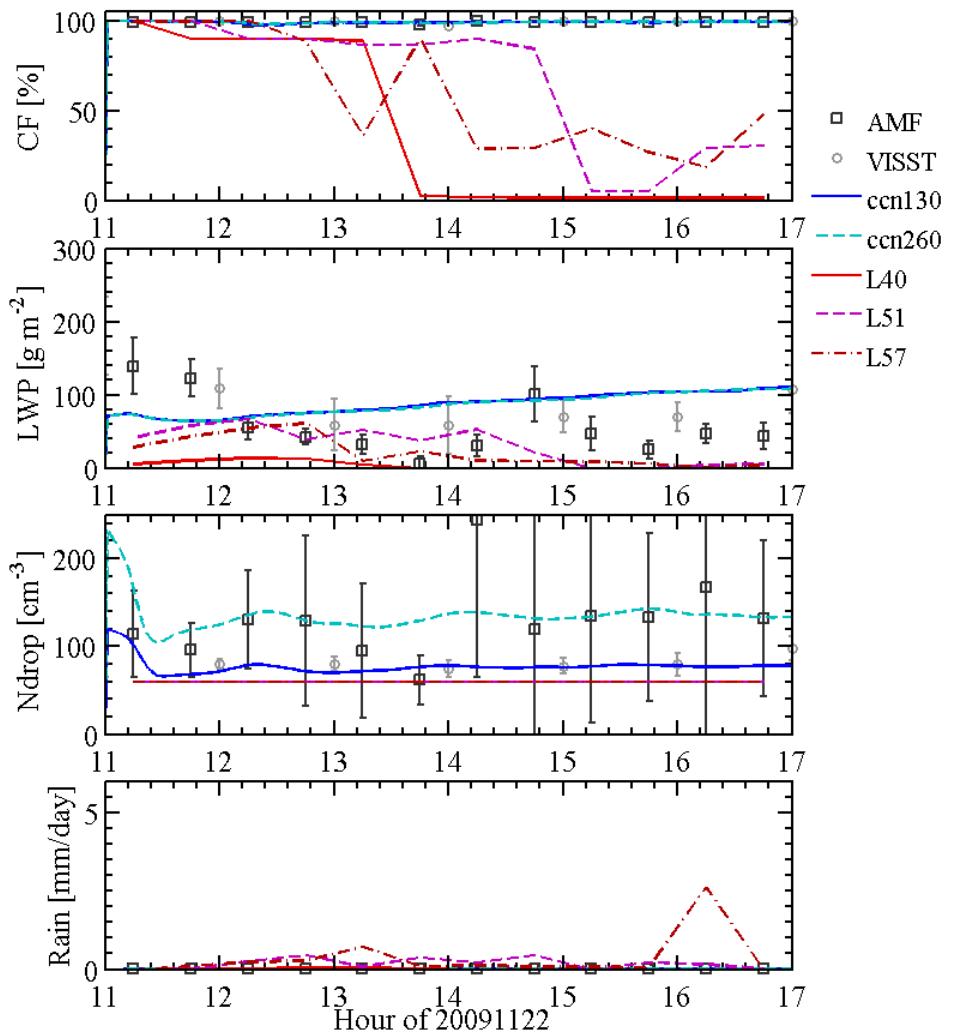


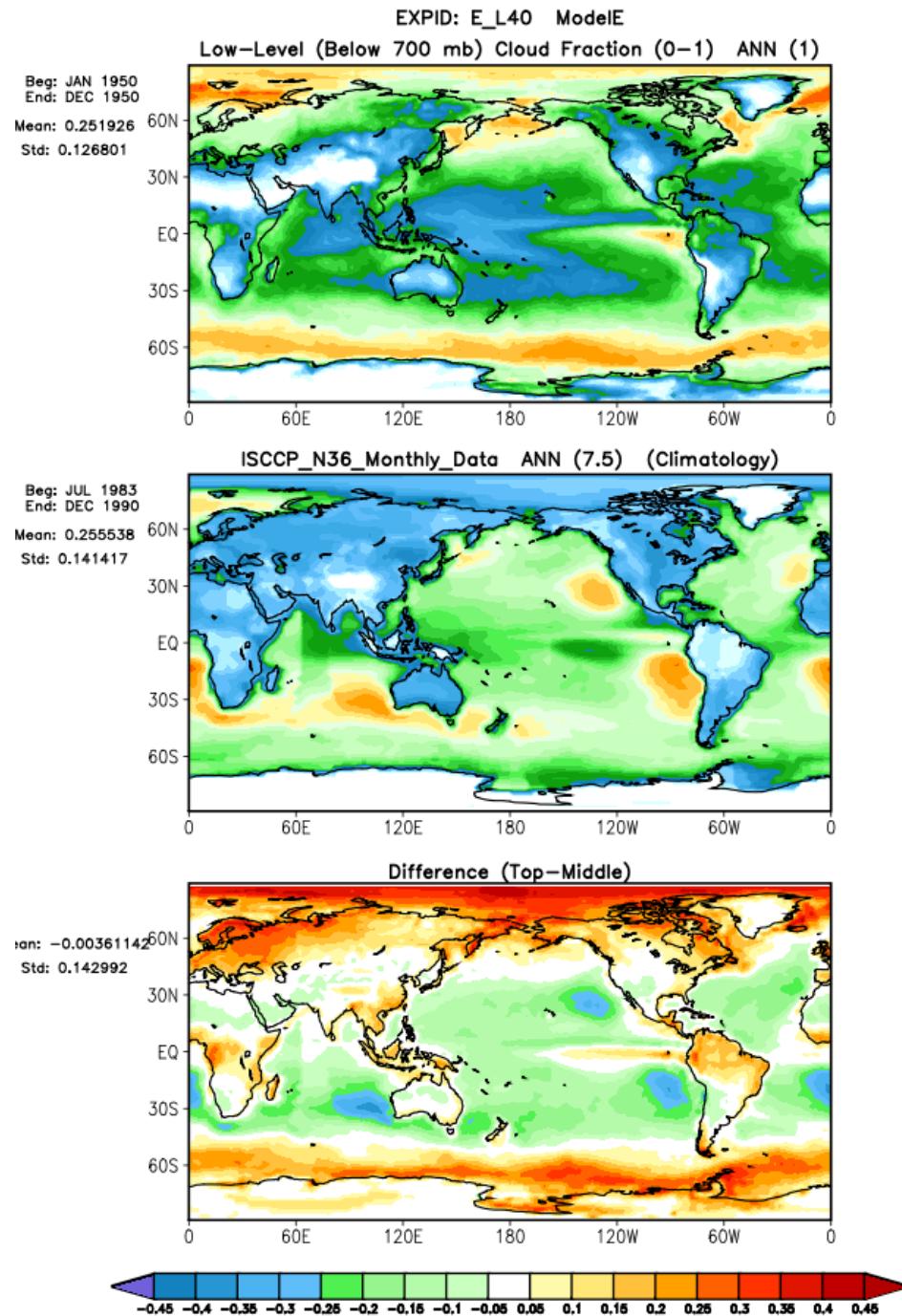
# Domain averages

Cumulus

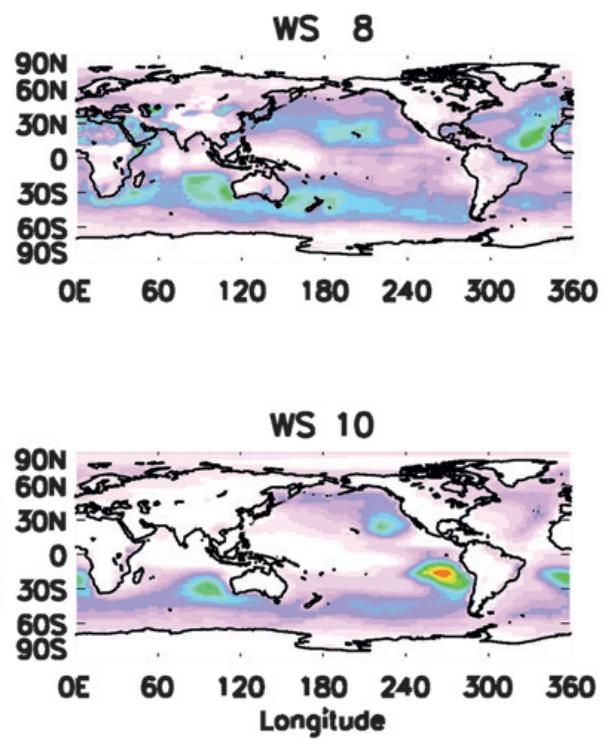


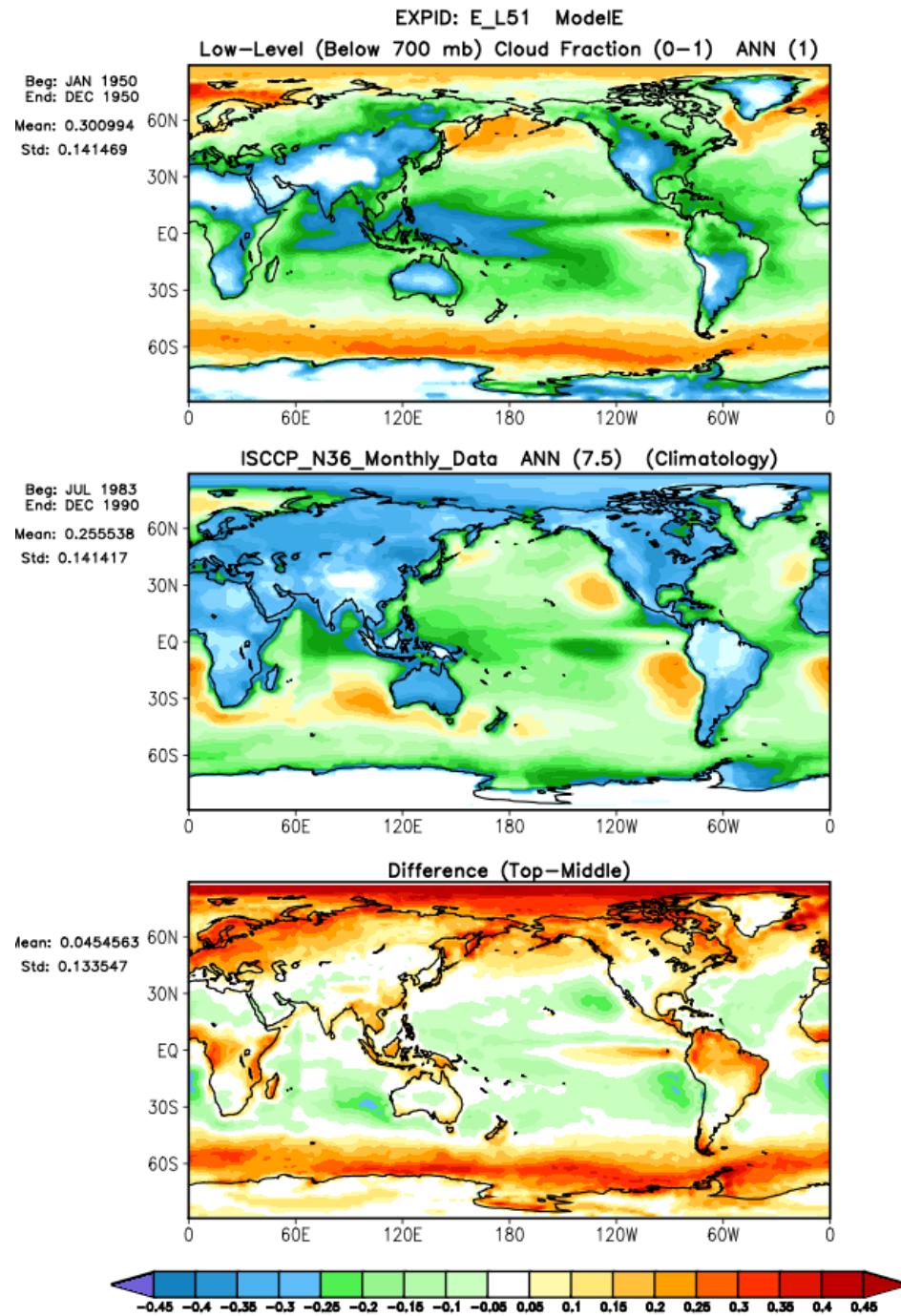
Stratocumulus



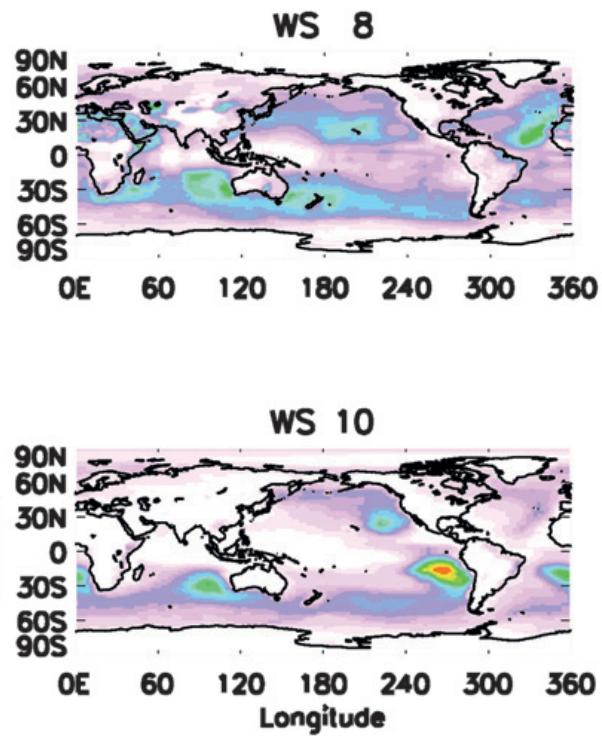


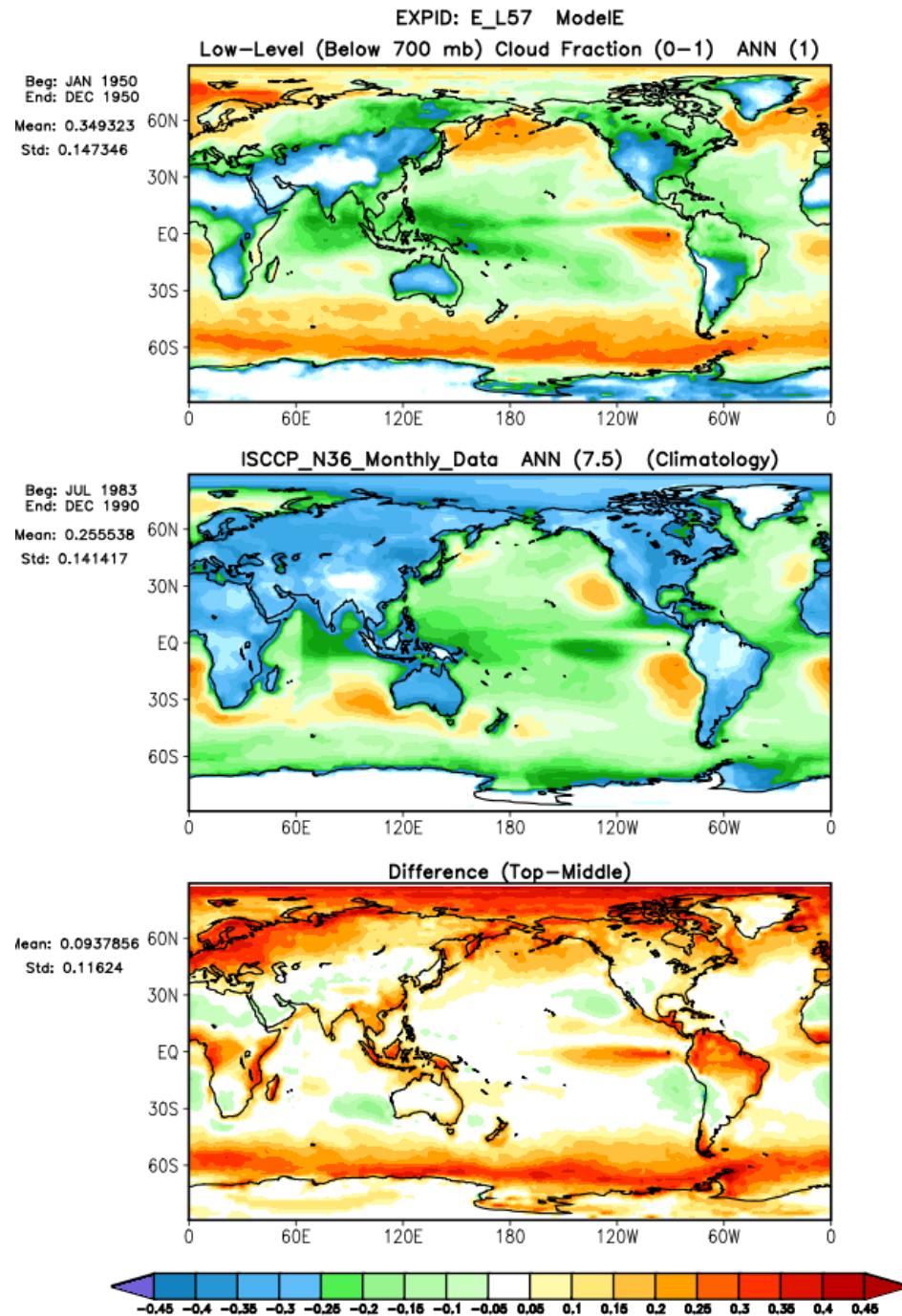
## GISS ModelE2 low-level cloud fraction: L40





## GISS ModelE2 low-level cloud fraction: L51





## GISS ModelE2 low-level cloud fraction: L57

# Conclusions

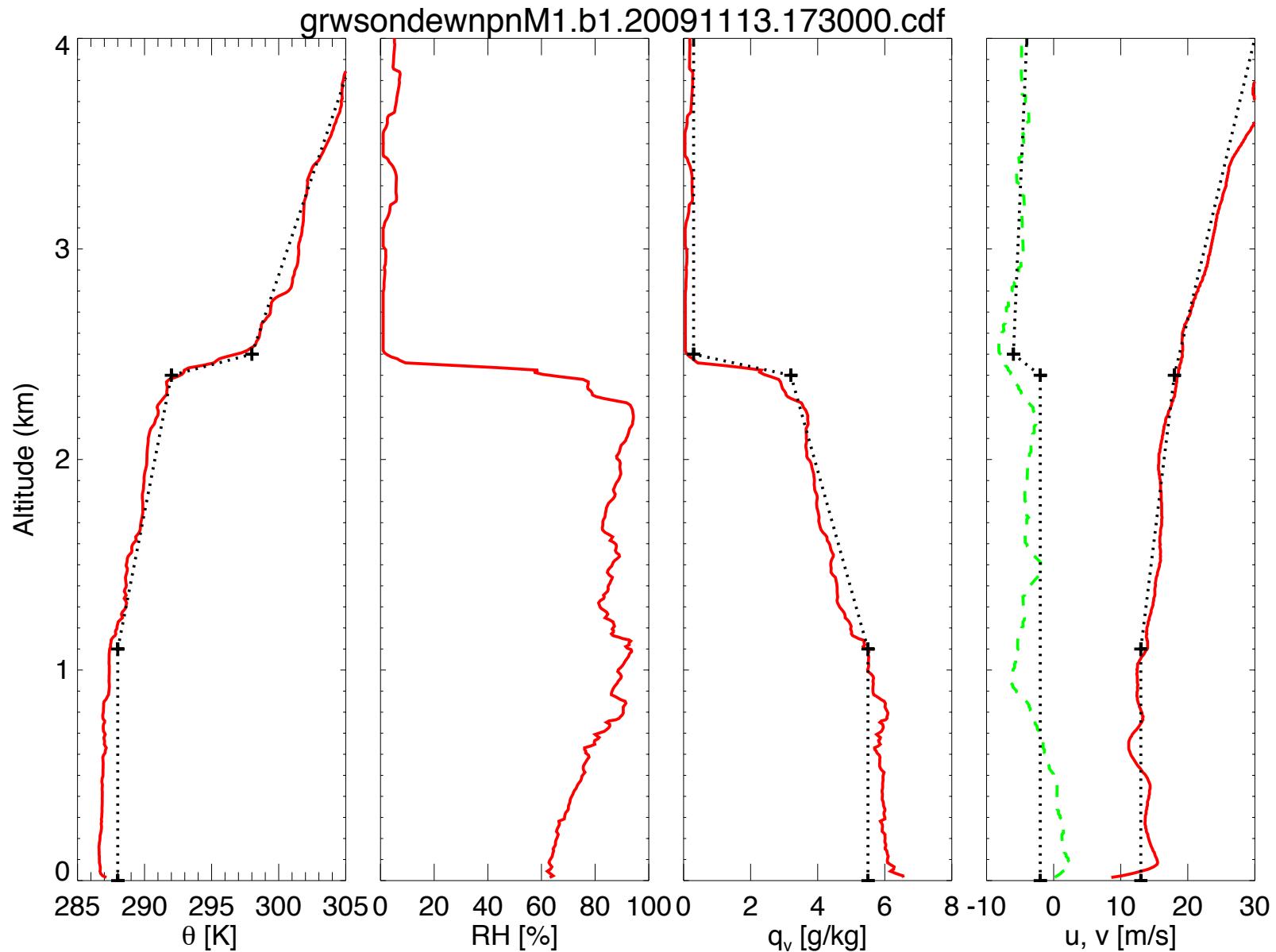
- ISCCP weather states
  - CMIP5 models deficient in shallow Cu and Sc to lesser extent
  - global problems also seen over Azores
- LES case studies from CAP-MBL
  - initial conditions and forcings produce plausible results
- ModelE2 SCM simulations
  - results not so great with operational vertical resolution, better with finer grid at  $P > 700$  mb
  - improvement better for Cu than Sc
- GCM simulations
  - finer vertical grid improves shallow Cu coverage in tropics and Sc coverage in sub-tropics

## Outlook

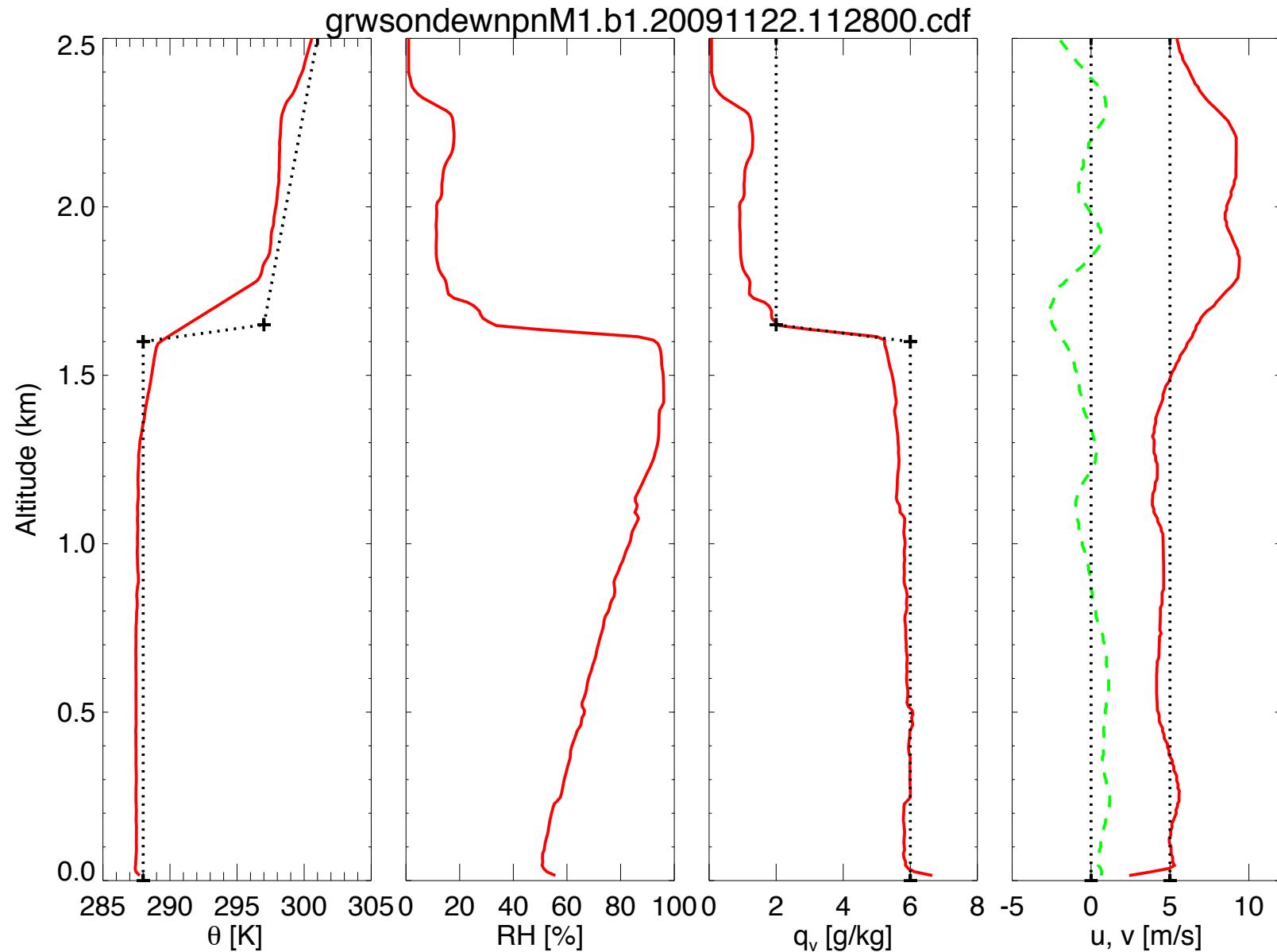
- Dig under the hood to understand particulars of stratocumulus inhibition in GISS SCM
- Adapting 2-moment microphysics (with prognostic precip) of *Gettelman & Morrison 2015*
- Mixing scheme: GISS turbulence group adopting (aspects of) *Park & Bretherton 2009*
- Replace Sundqvist with PDF scheme for stratiform cloud macrophysics?

# **Extras**

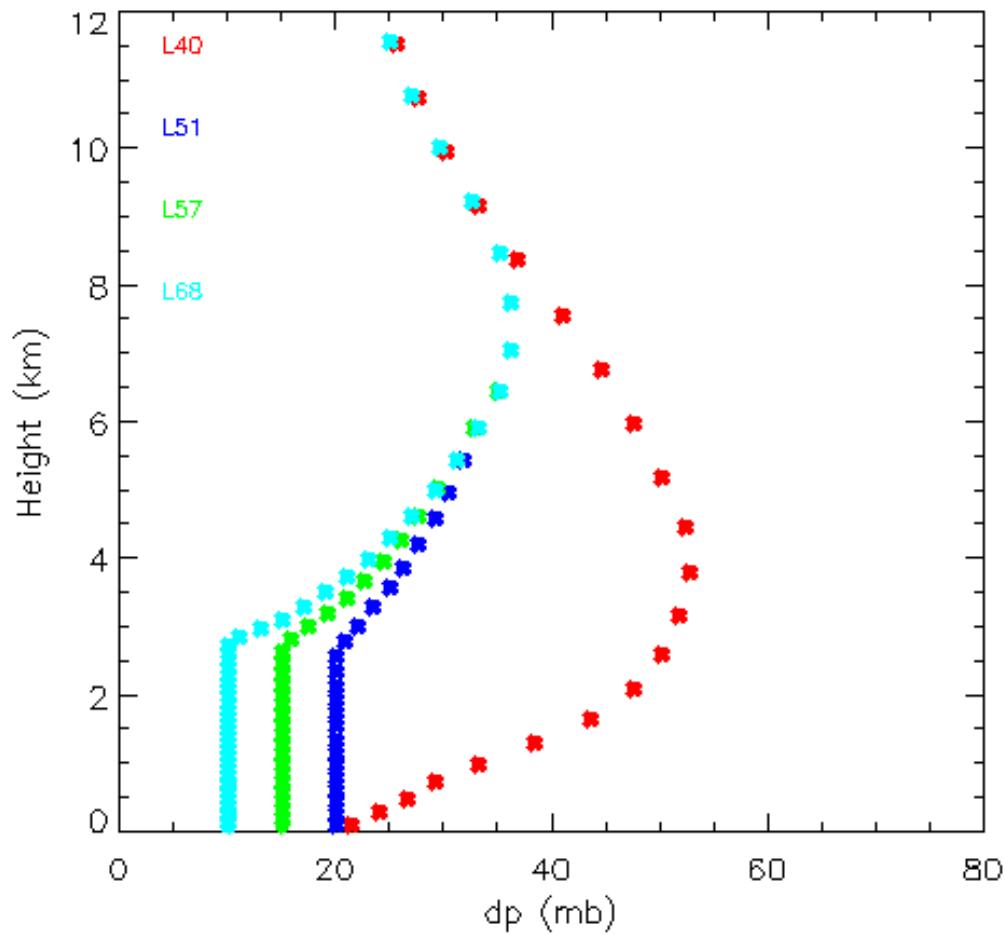
# Idealized initial soundings: Cumulus



# Idealized initial soundings: Stratocumulus

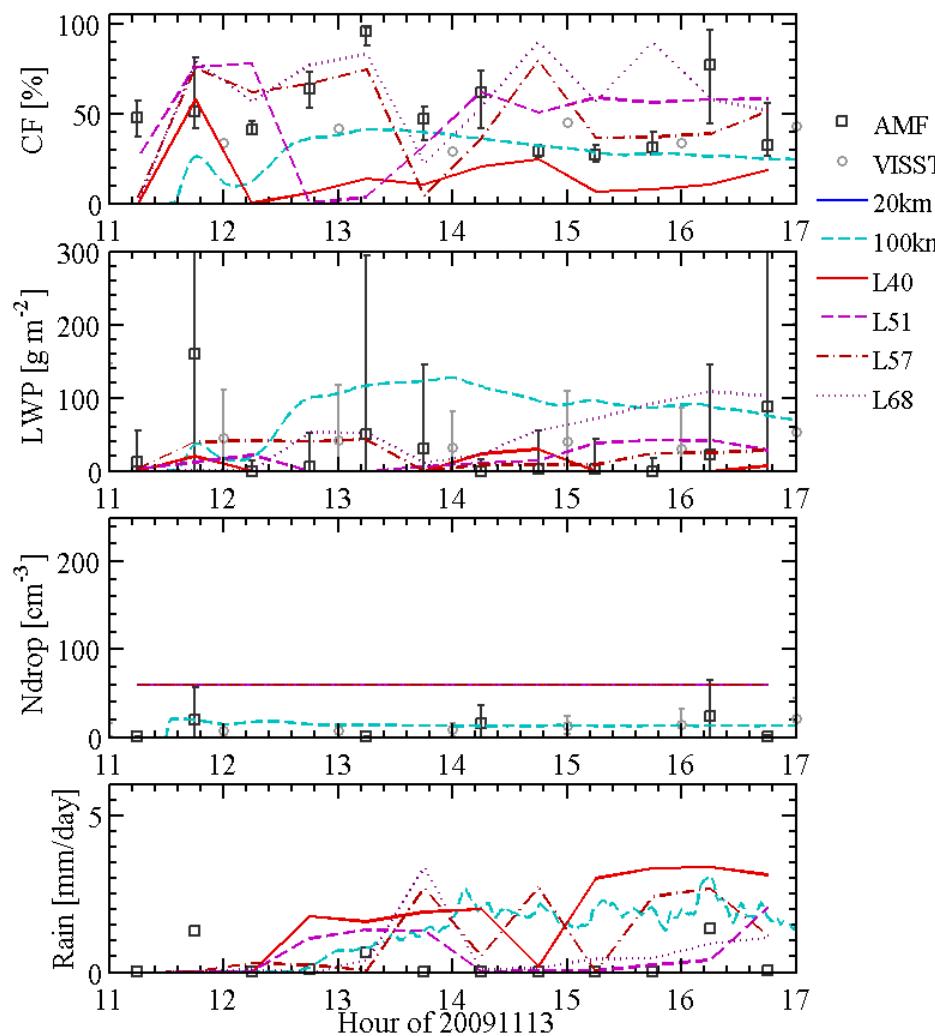


# SCM vertical grids

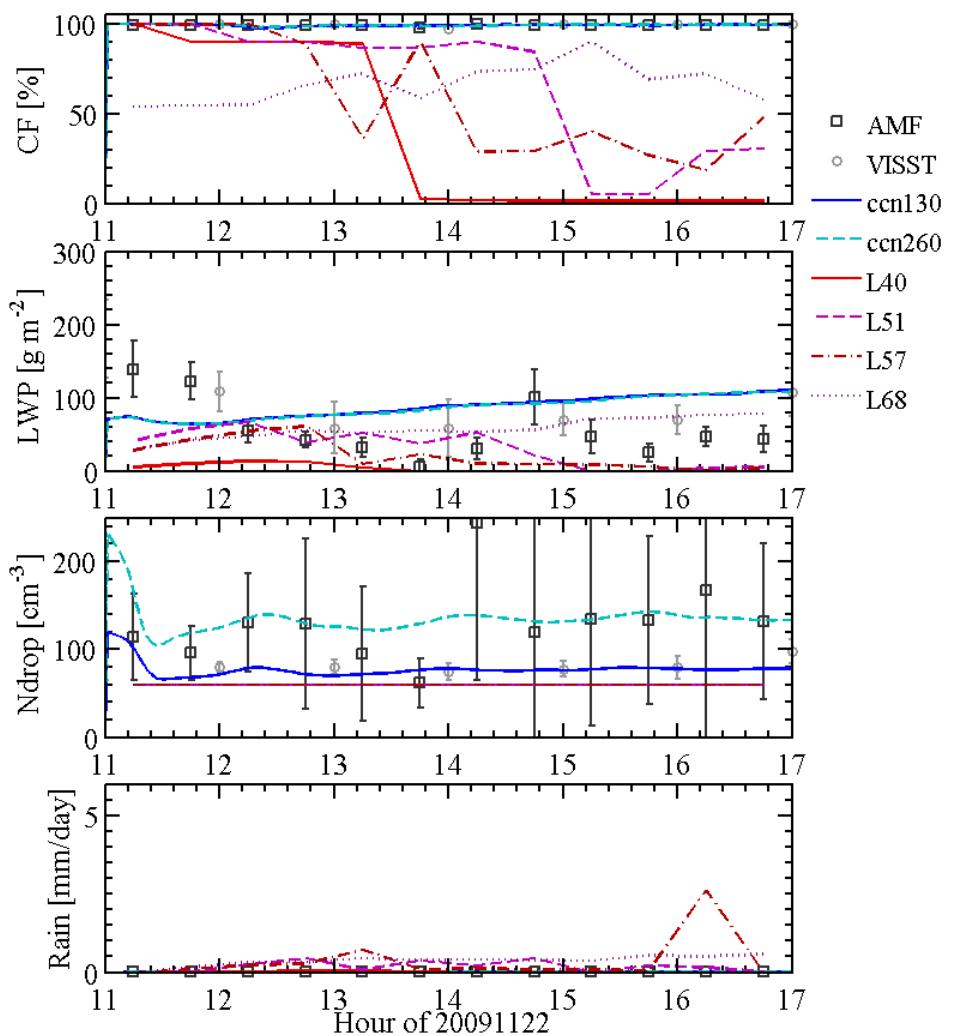


# Domain averages

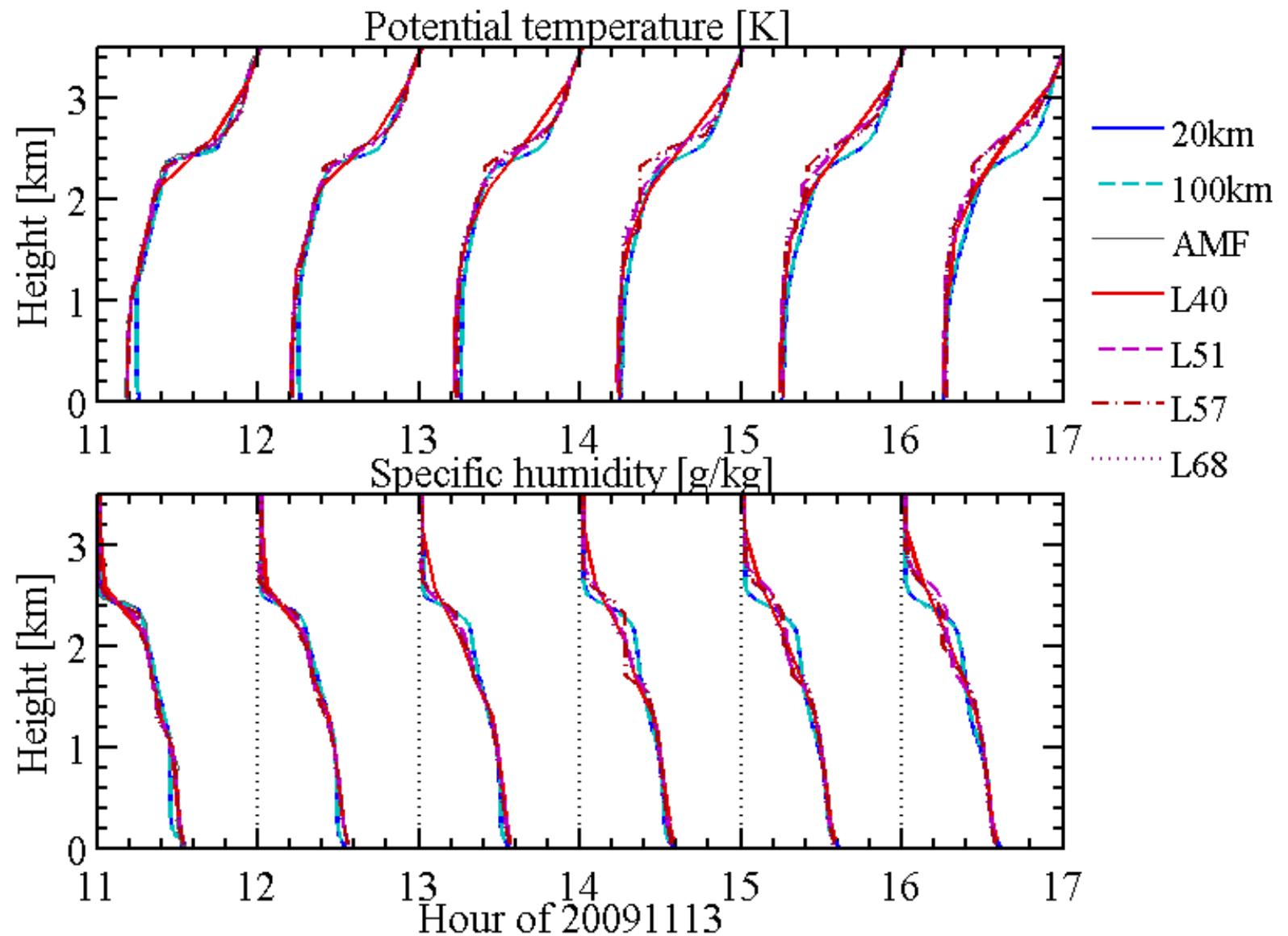
Cumulus



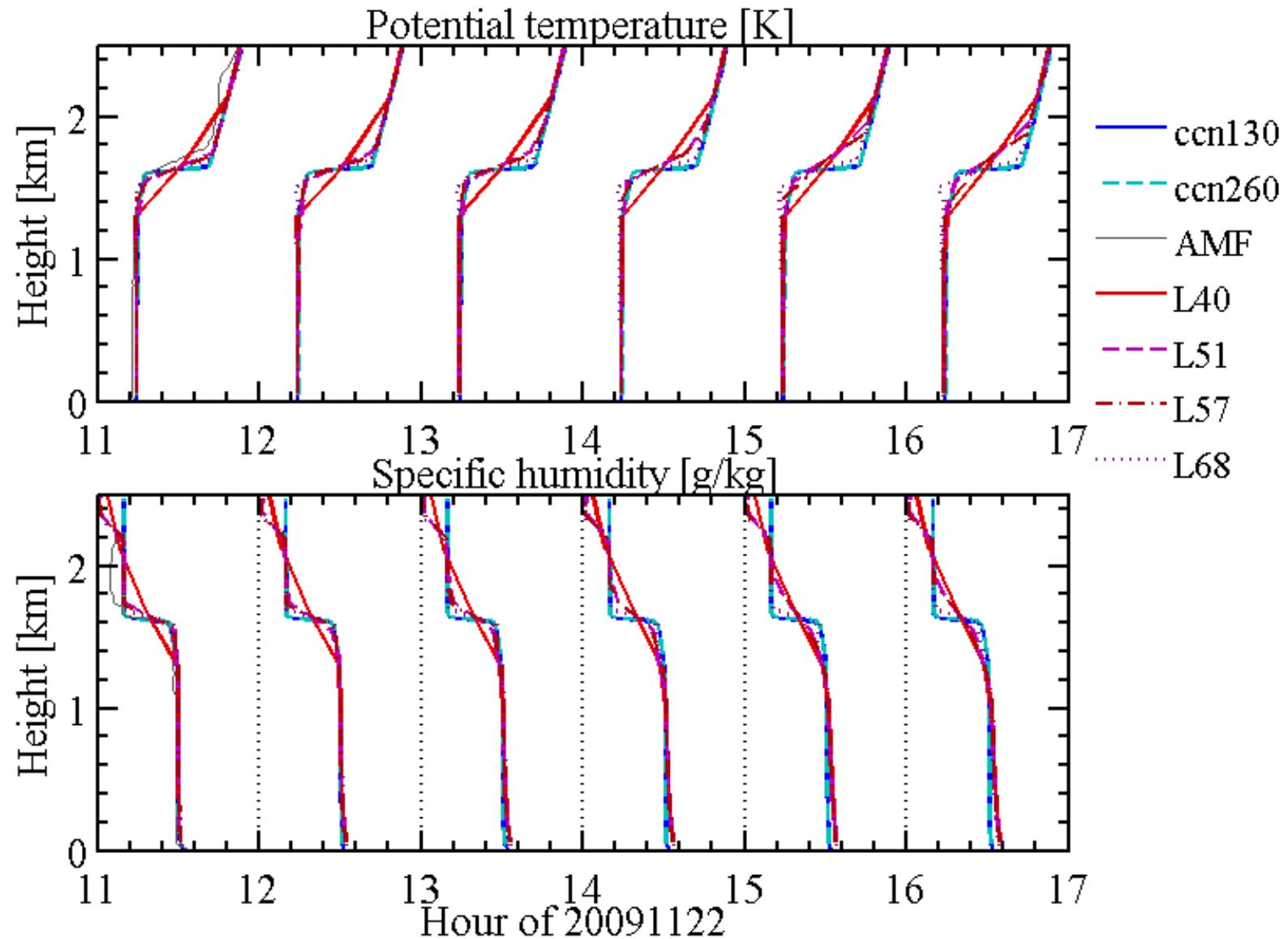
Stratocumulus



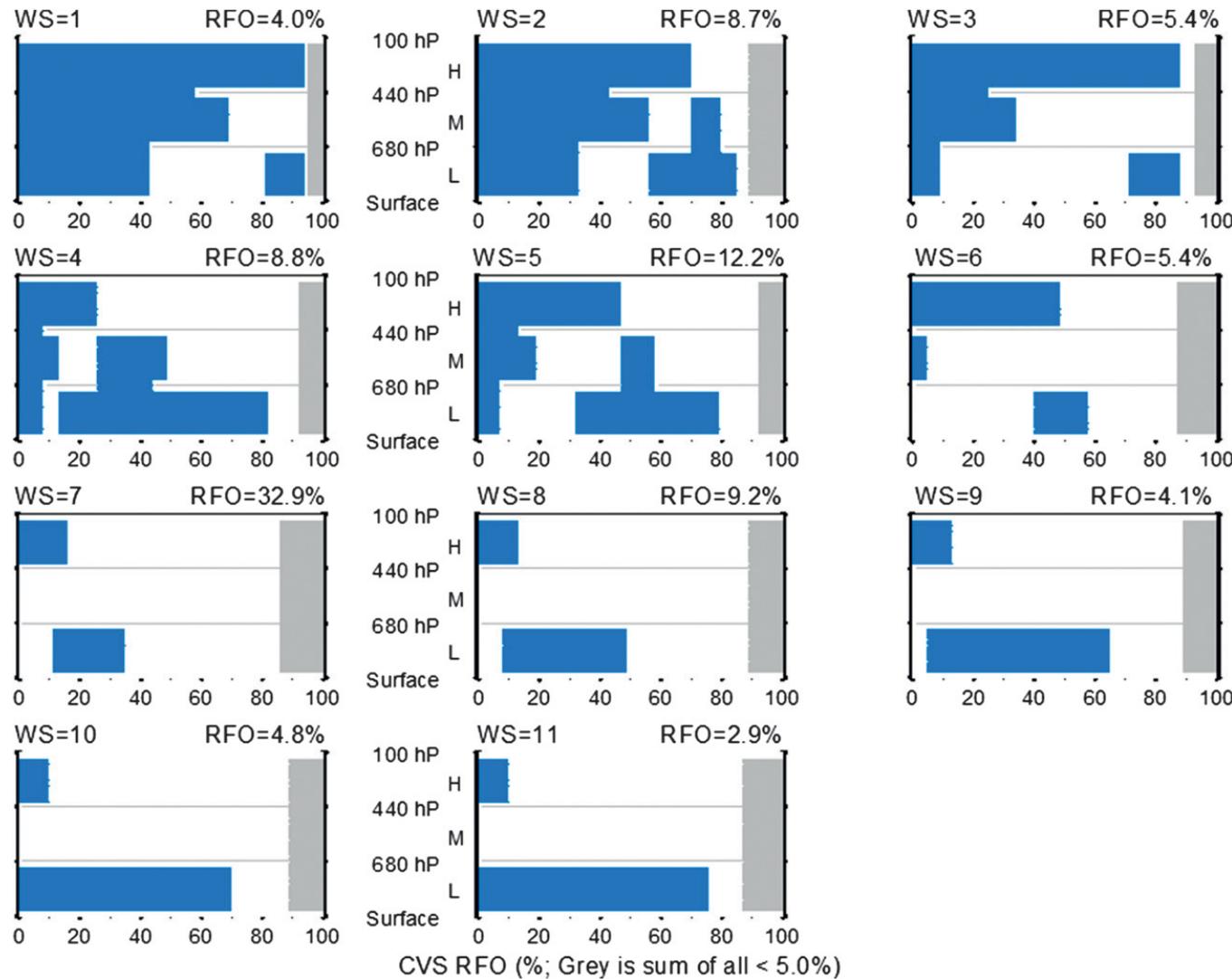
# Mean profiles: Cumulus



# Mean profiles: Stratocumulus



# WS cloud vertical structure from CloudSat and CALIPSO



# ISCCP weather states: 500-mb omega

