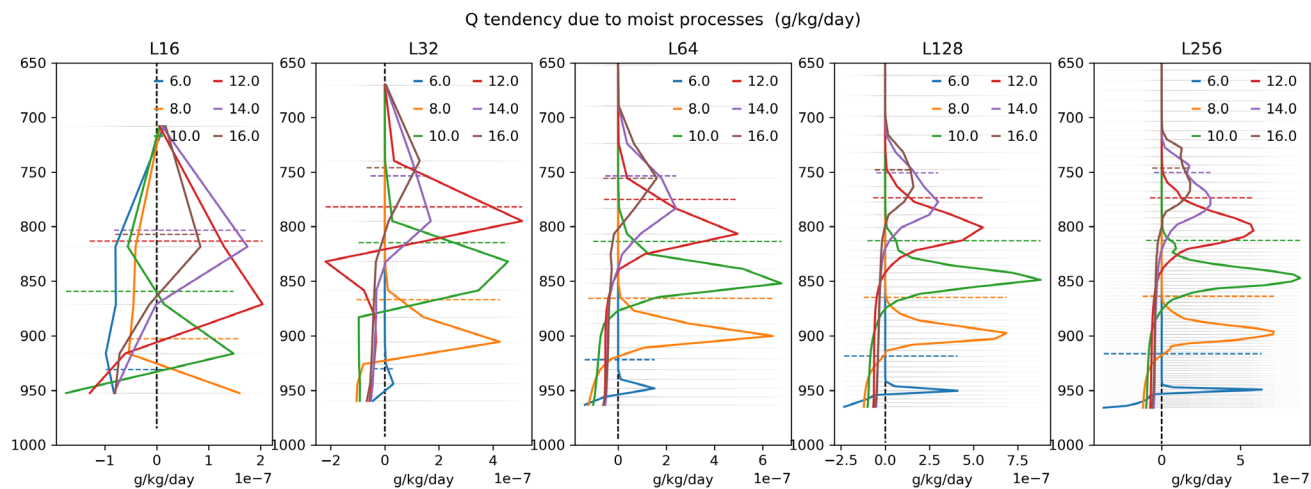
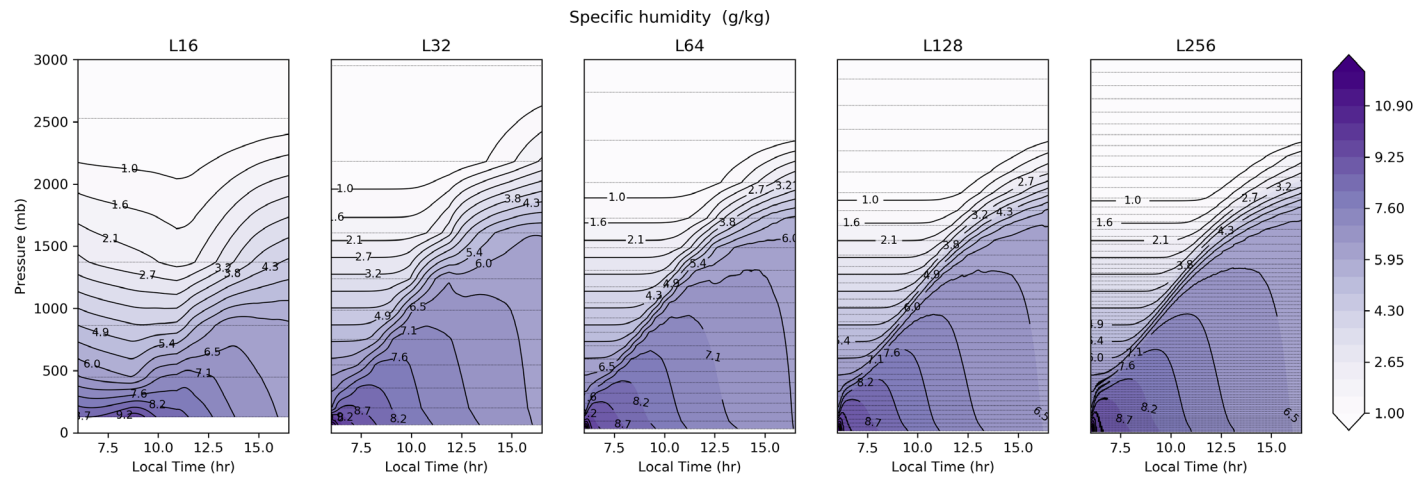


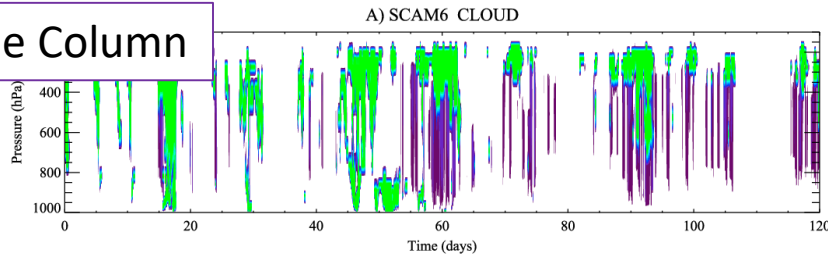
# CAM6 Boundary Layer Evolution Over An Idealized Diurnal Cycle



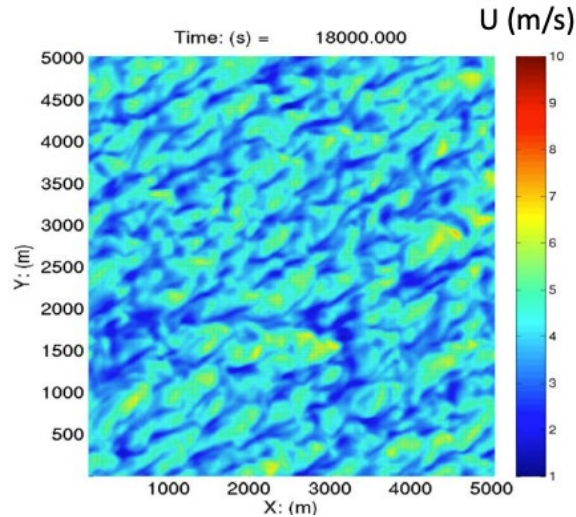
**Rich Neale**  
John Truesdale, Julio Bacmeister  
*NCAR*  
CESM Workshop (AMWG session)  
June 16, 2020

# NCAR Boundary Layer Activity

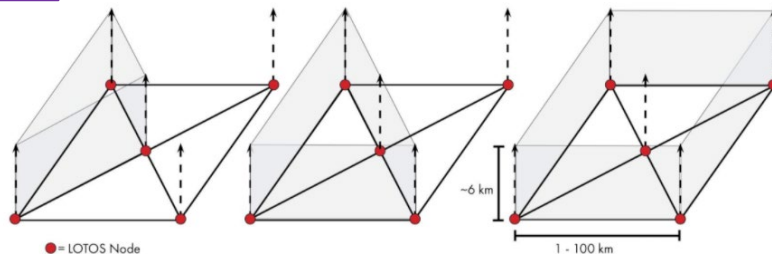
## Single Column



## LES



## LOTOS

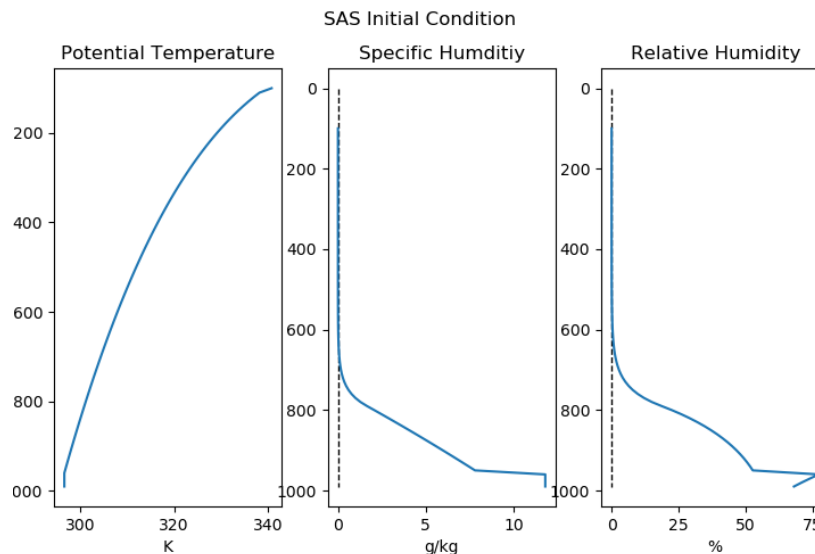
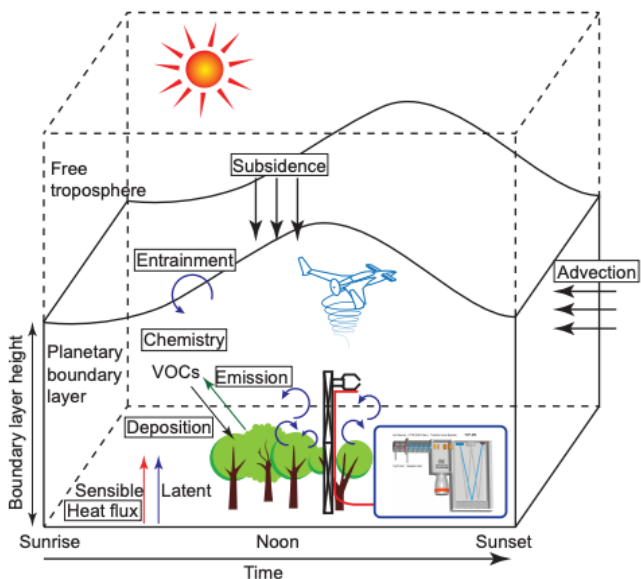


- Consolidate NCAR resources across labs. (2019)
- Multi-scale parameterization development
- Large-Eddy Simulation (LES)
  - NCAR LES
  - FastEddy
  - WRF-LES
  - MPAS-LES
- Column Models (SCAM/WRF)
- Targeted observational sampling
- Lower-tropospheric observing system (LOTOS, EOL)
- Testing reference cases SAS (also Perdigo)
- Common experiment, data and analysis framework

Lab. Leads: Ned Patton (MMM), Mary Barth (ACOM), Branko Kosovic (RAL), Steve Oncley (EOL), Rich Neale (CGD)

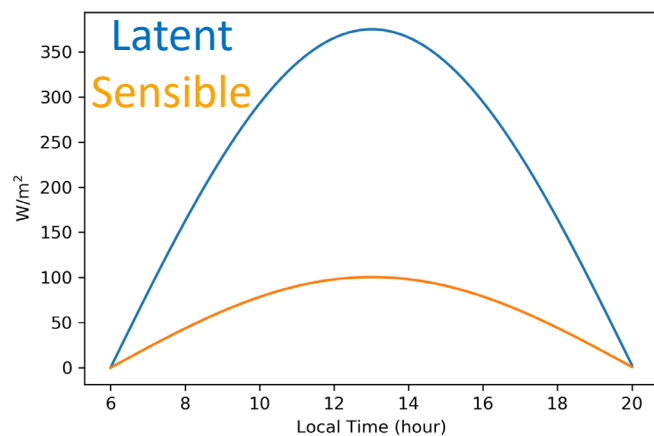
# Southeast Atmosphere Study (SAS)

Community Earth System Model **CESM**



## Southeast Atmosphere Study

- SAS is an umbrella for a number of field campaigns (inc. NOMADSS)
- June-July 2013
- Region in Alabama is flat and forested
- Primary focus was photo-chemistry (VOCs) and boundary layer mixing



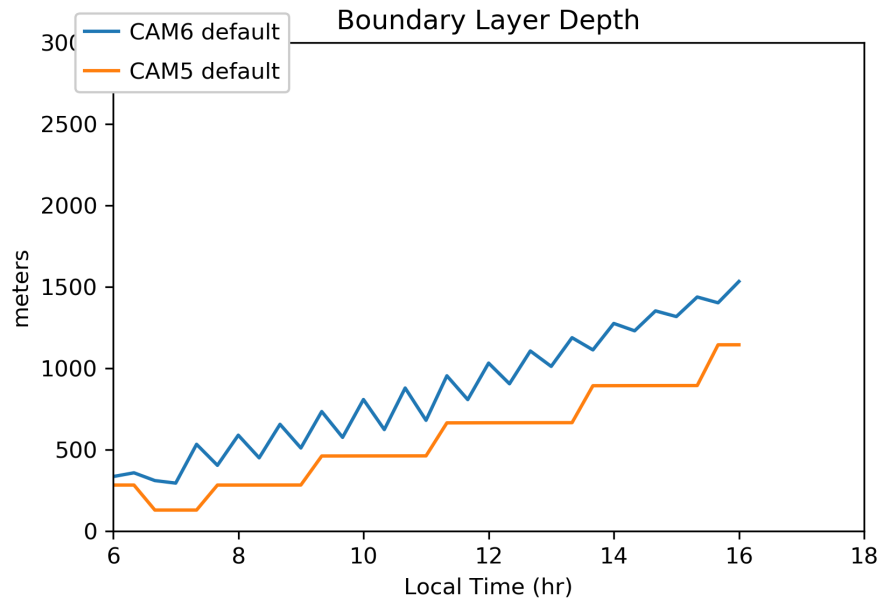
## IOP CASE (for SCAM-CAM6 and LES)

- Ideal/composite day of surface forcing
- Latent and sensible heat fluxes
- Semi-analytical initial conditions
- Dry boundary layer case (no clouds!)
- No large scale advective forcings
- Chemistry: Next step

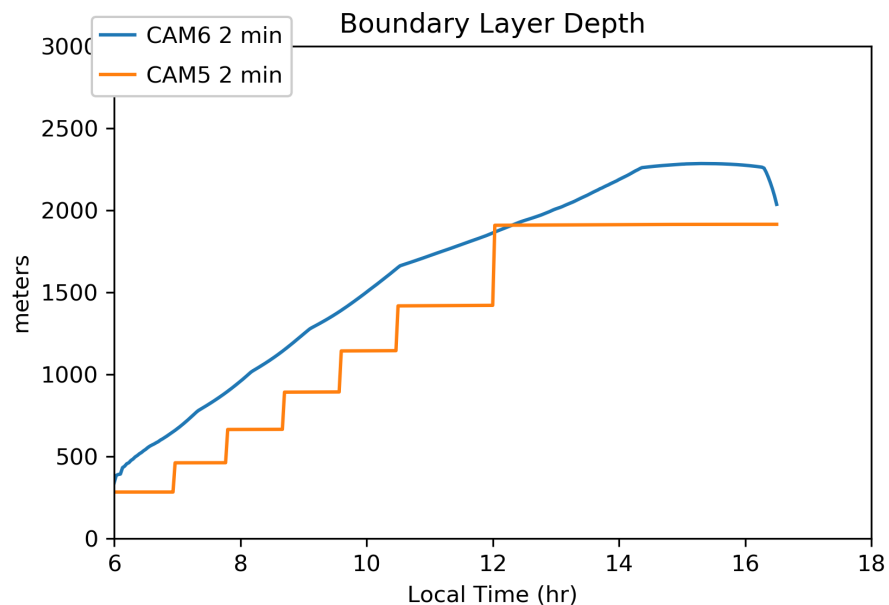
Liu et al., (2016)

<https://www.atmos-chem-phys.net/16/7725/2016/>

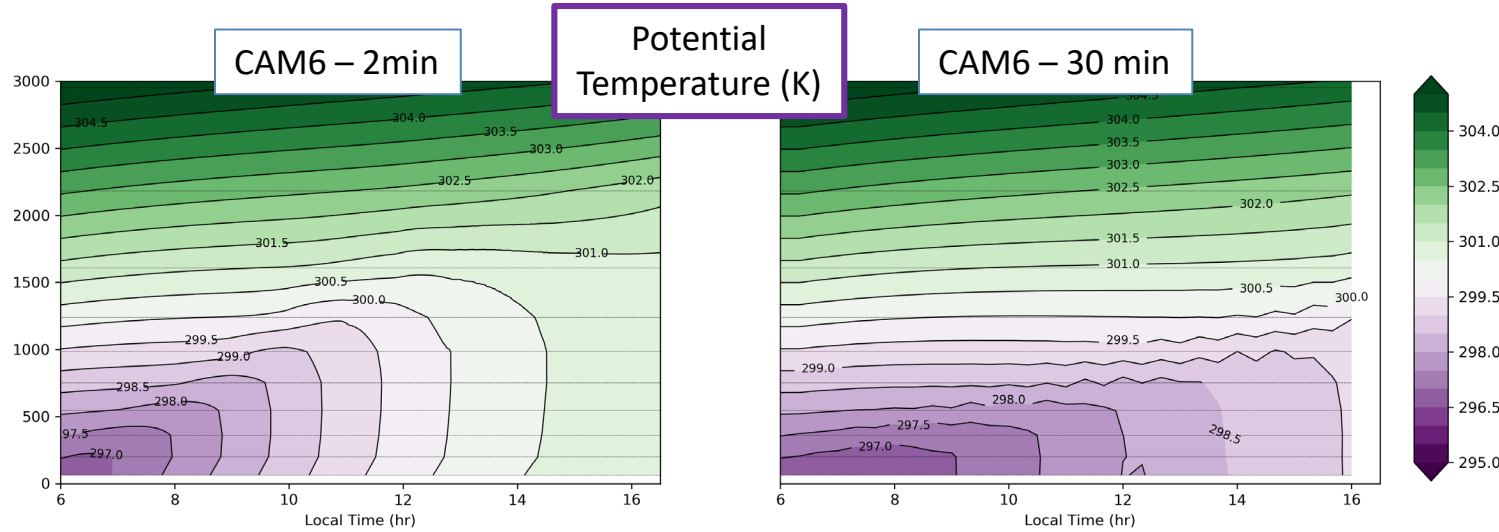
# Physics/Settings Sensitivities



- Move towards LES configuration
- Time-step: 30->2min
- Vertical resolution: 32->256 levels
- Default settings from 3D model
- 30 minute timestep/radiation/land coupling
- Linear increase in PBLH (1500m/1000m)
- Switch to 2 minutes (dt/rad/coupling)
- Deeper PBLH (2200m/2000m)
- CAM6 (CLUBB): Smoother evolution
- CAM5 (UW): Retains step-changing behavior

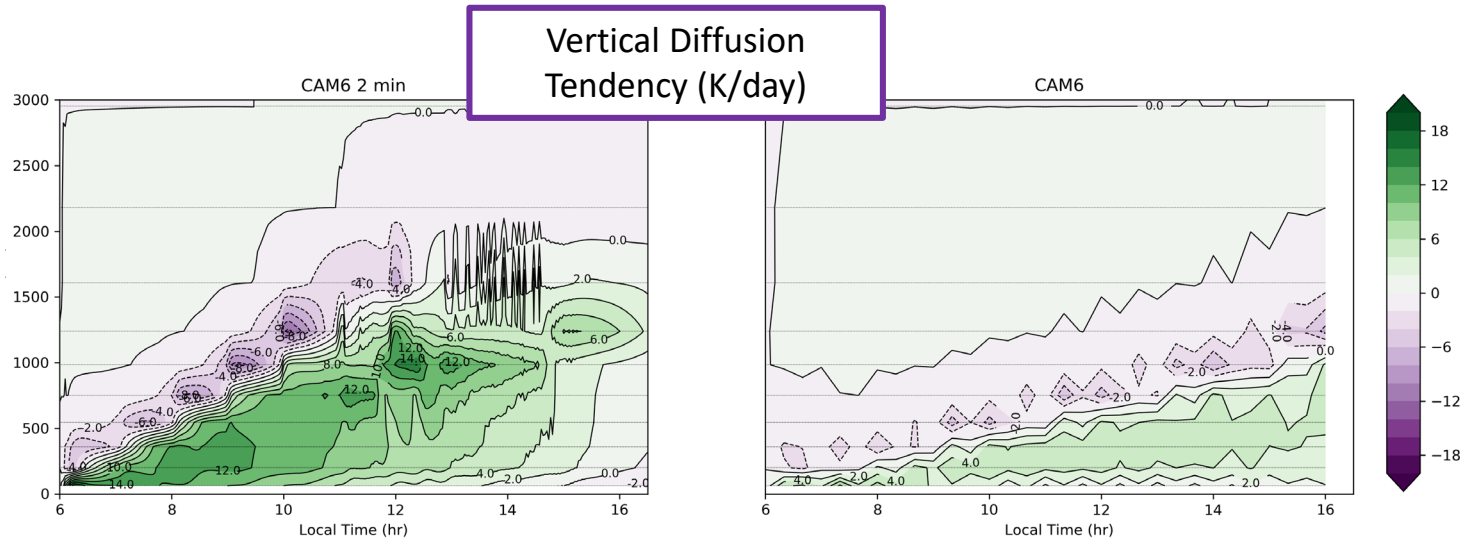


# Physics/Settings Sensitivities



## 2 min timestep

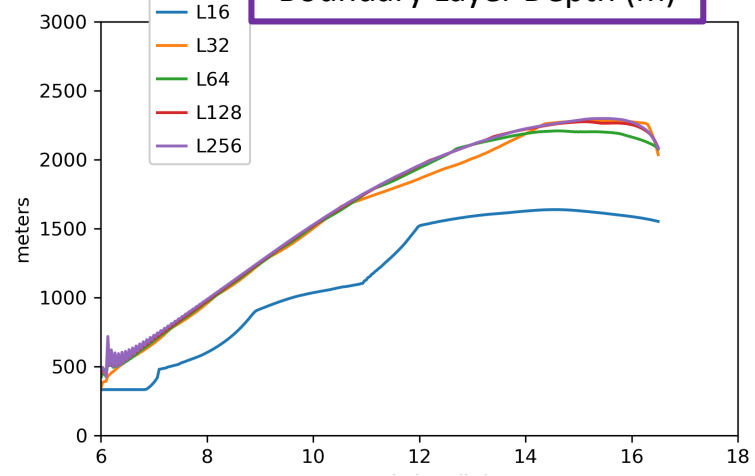
- Smoother evolution
- More rapid mixing (x2)
- Deeper PBL
- But, level-by-level jumps



# Vertical Resolution Sensitivities

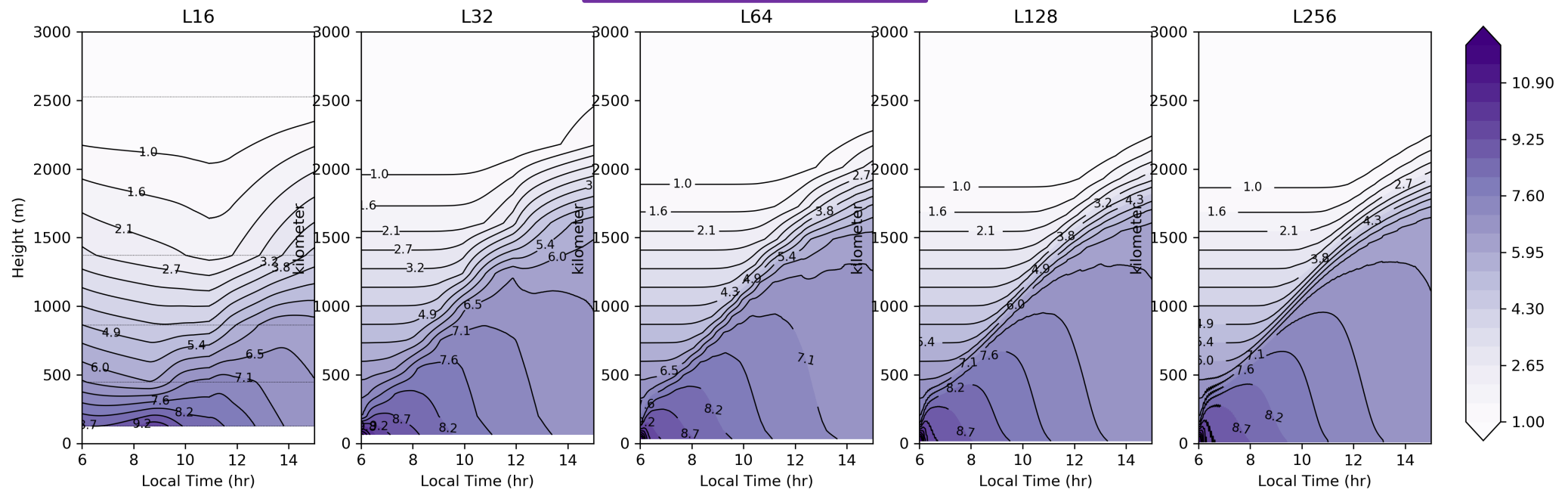


Boundary Layer Depth (m)



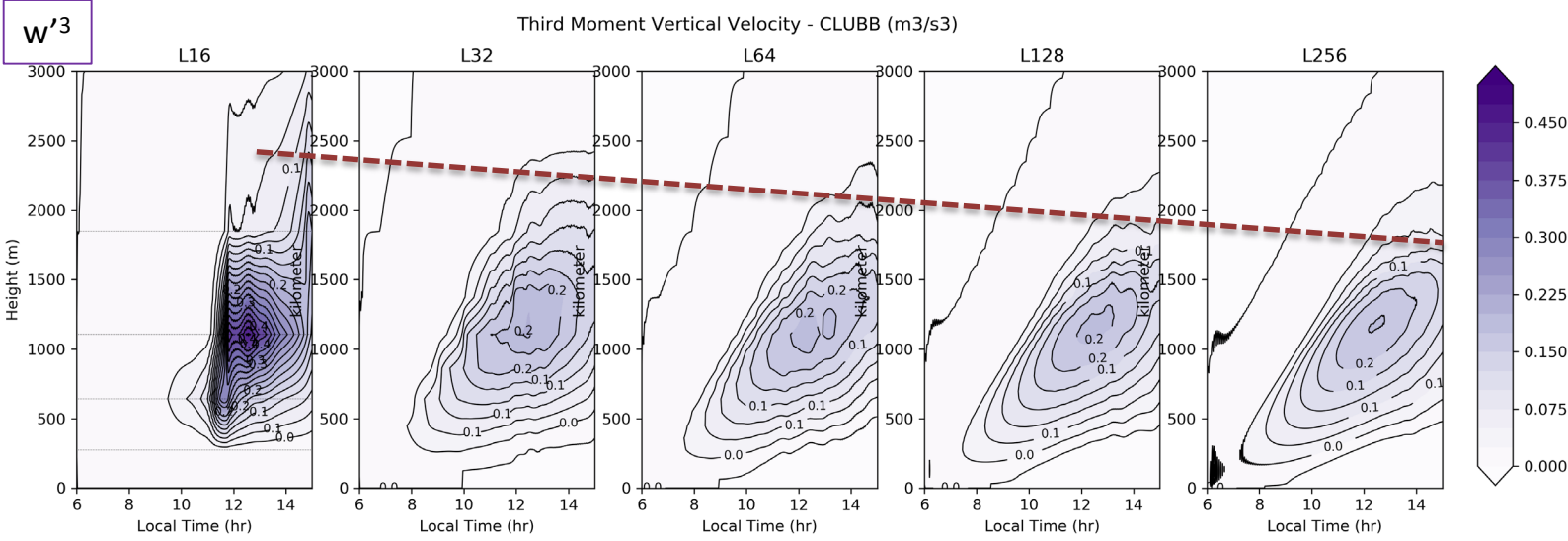
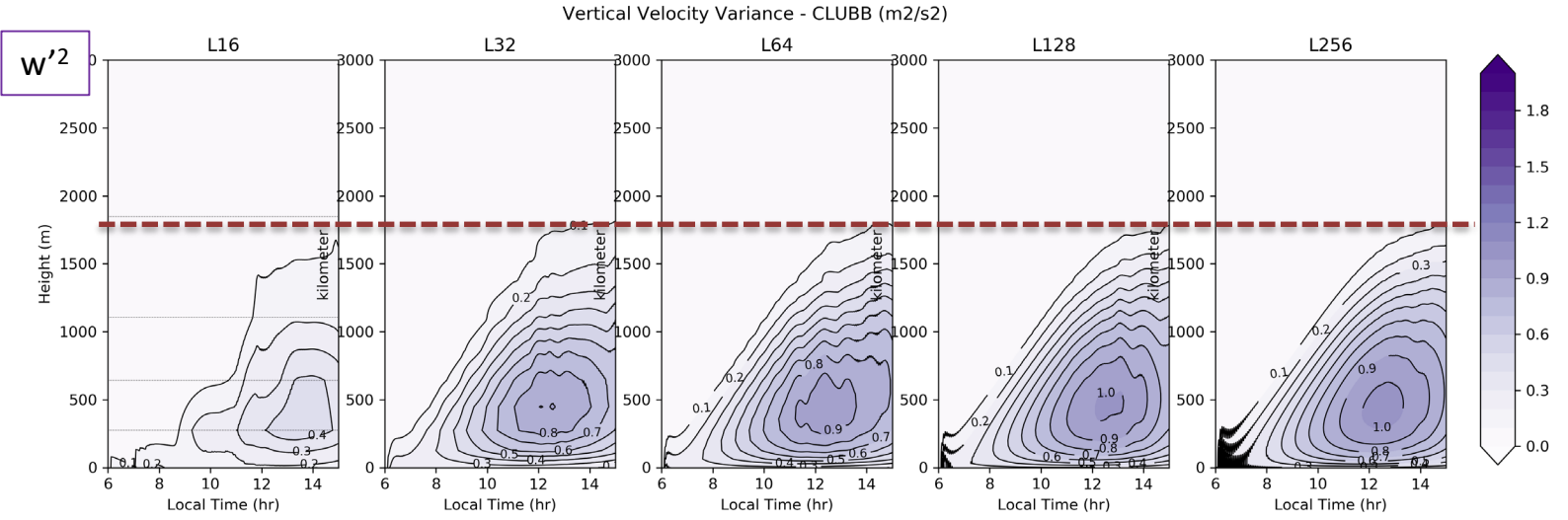
- Successive halving of resolution through column
- PBL depth mostly covers at 32 levels
- For a sharp humidity gradient, 64 levels
- Mixing of humidity does not change with resolution

Specific Humidity (g/kg)



Horizontal Lines on plots = model levels

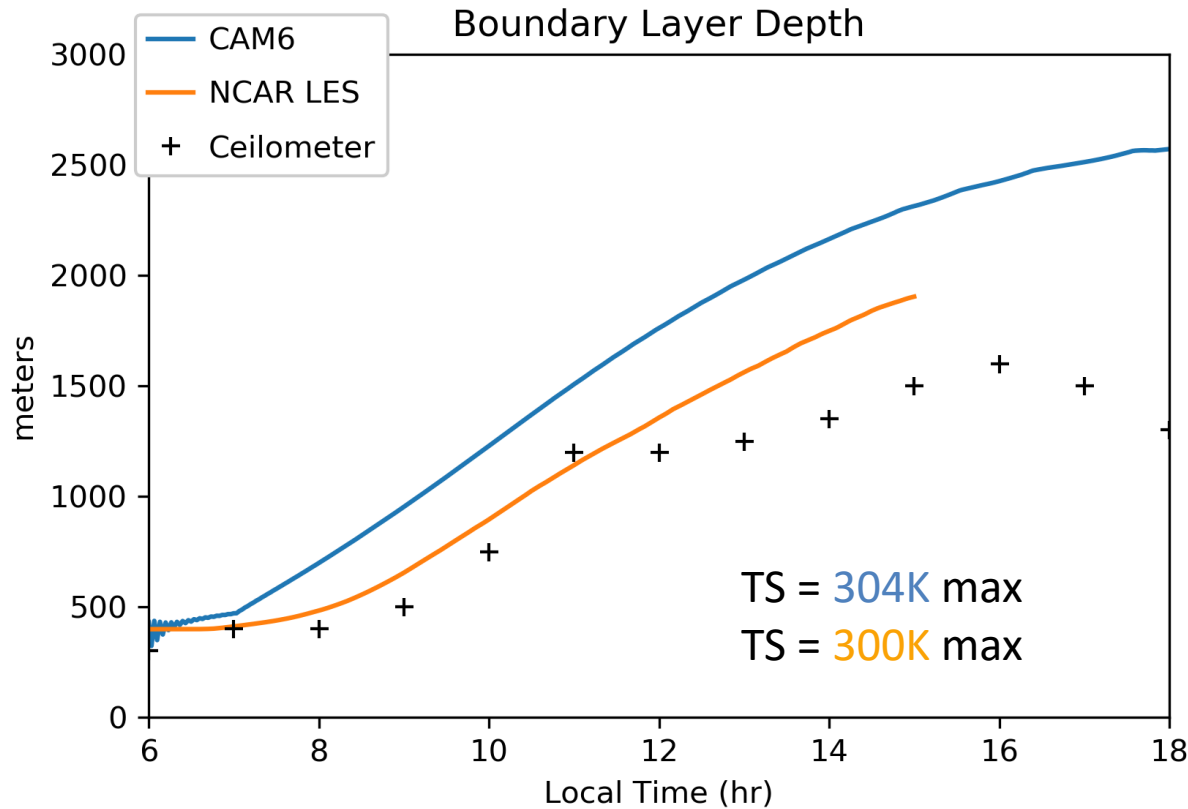
# Vertical Resolution Sensitivities



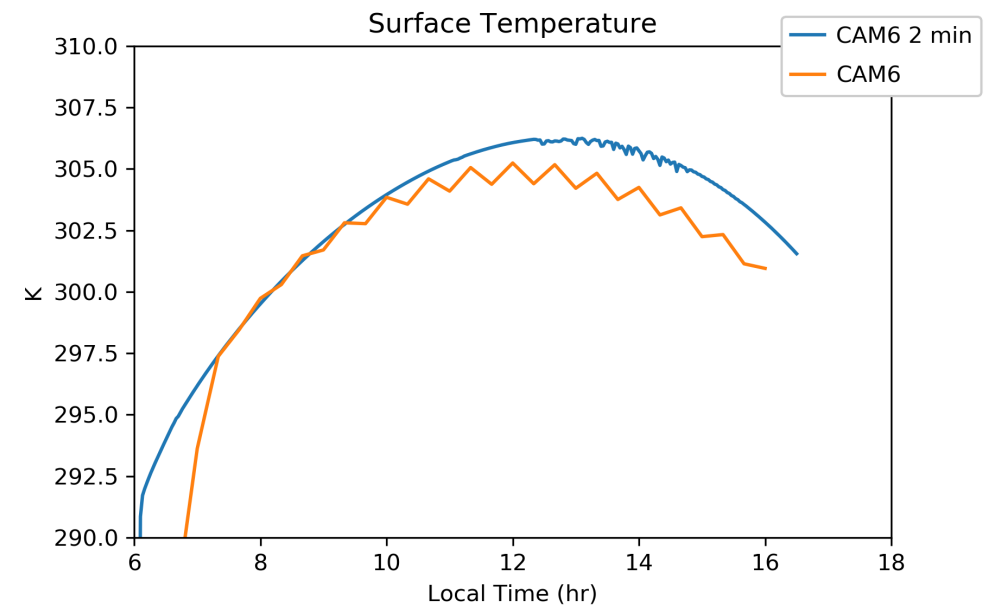
- Variance of vertical velocity ( $w'^2$ ) amplifies in situ
- Third moment ( $w'^3$ ) descends
- Symmetric turbulence within the PBL
- Asymmetric turbulence near PBL top
- Indicates L64 is preferable to L32

Horizontal Lines on plots = model levels

# Initial LES Comparisons (NCAR-LES)



- NCAR-LES (15m isotropic)
- 30m resolution
- 200 levels below 3km
- Shallower PBL height
- Interactive surface temperatures in SCAM
- Spun-up idealized land?



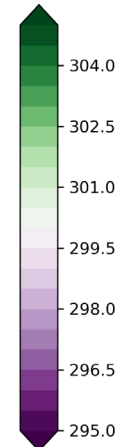
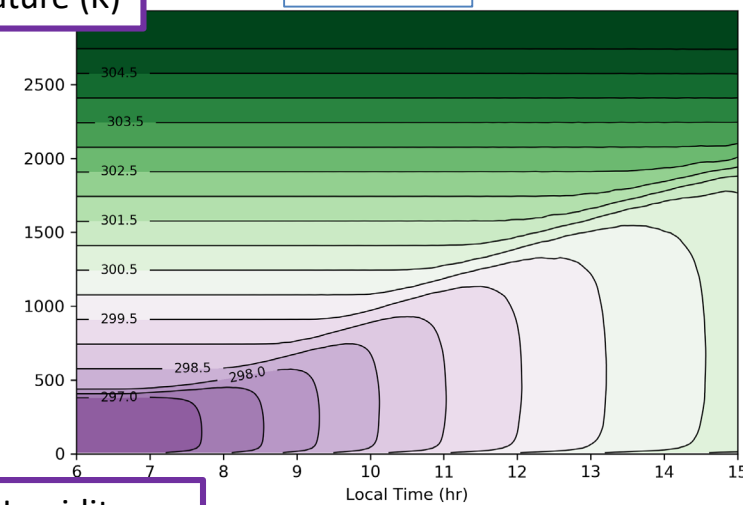
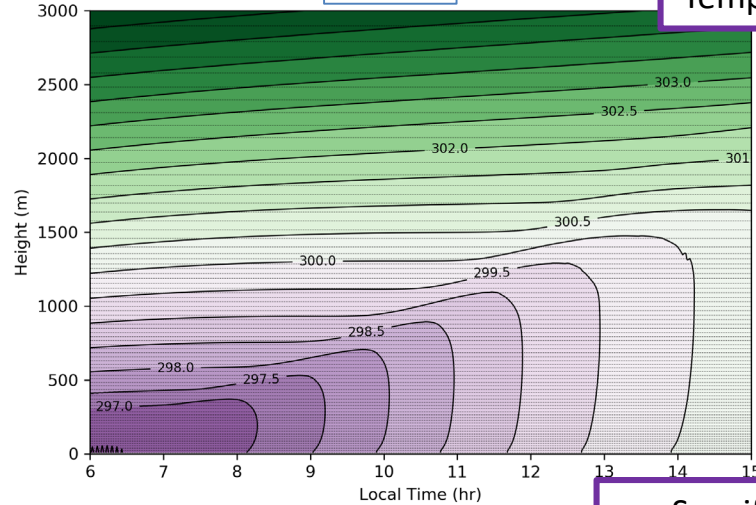


# Initial LES Comparisons (NCAR-LES)

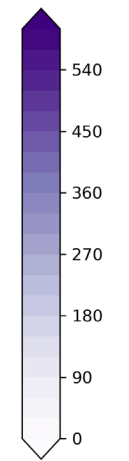
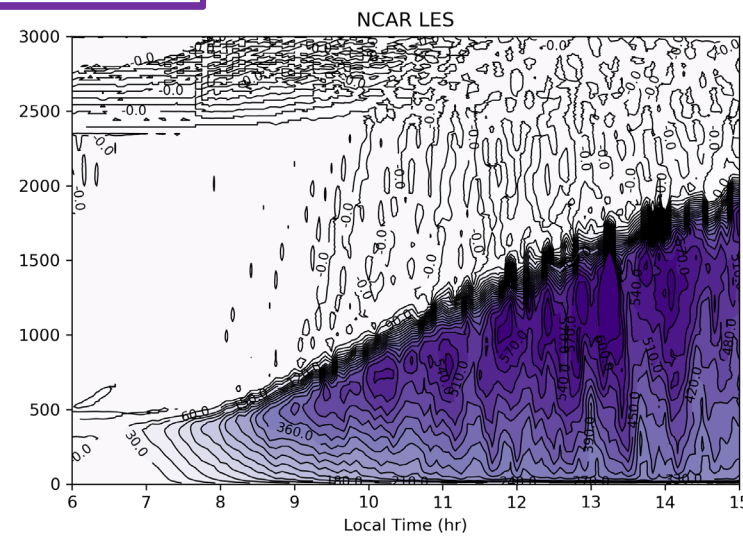
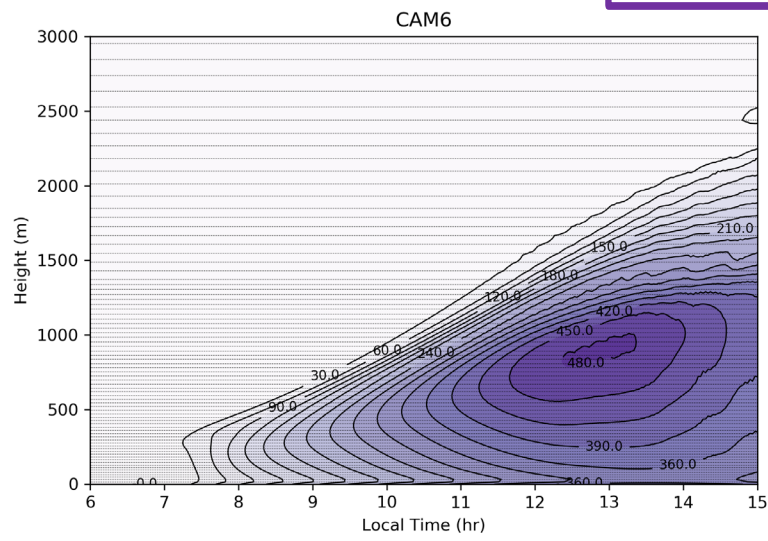
CAM6

Potential Temperature (K)

NCAR-LES



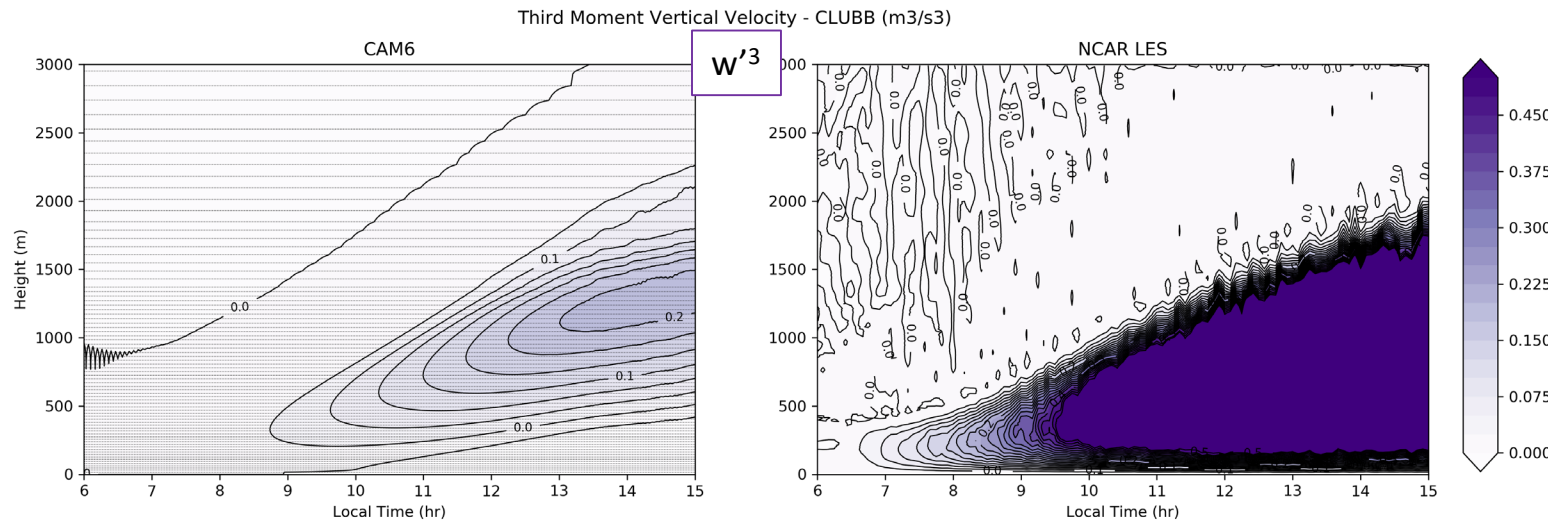
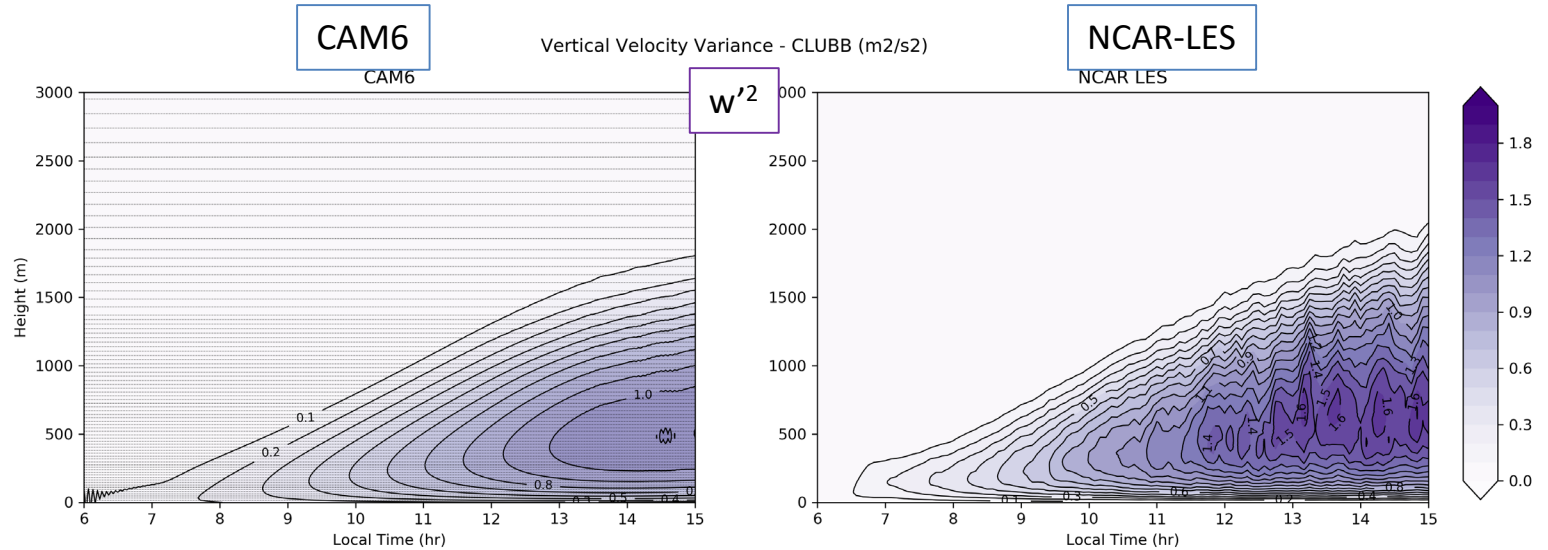
Specific Humidity  
Moisture Flux ( $Wm^{-2}$ )



- Similarities with LES
- More distinct surface layer
- Super-adiabatic
- Stronger inversion
- More efficient moist mixing
- Effective PBL depth may be less than the diagnosed value in CAM
- CAM: Ri# based measure
- LES: Pot. Temp gradient

Horizontal Lines on plots = model levels

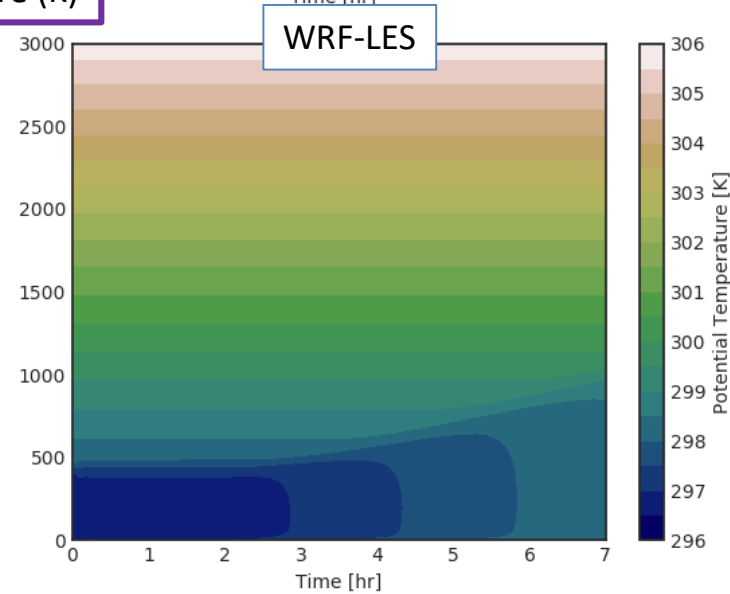
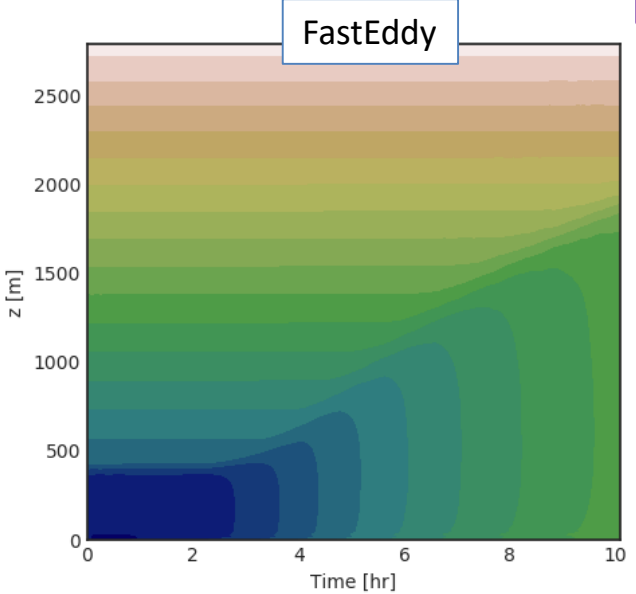
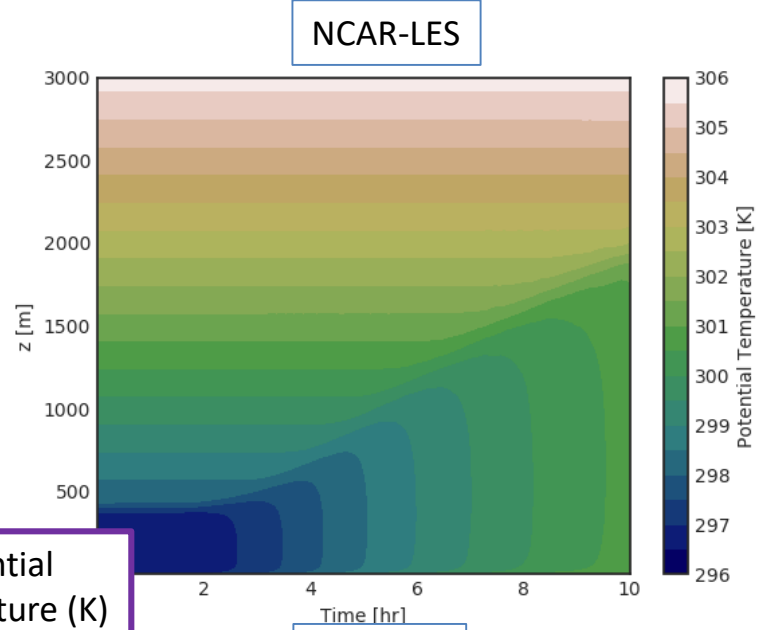
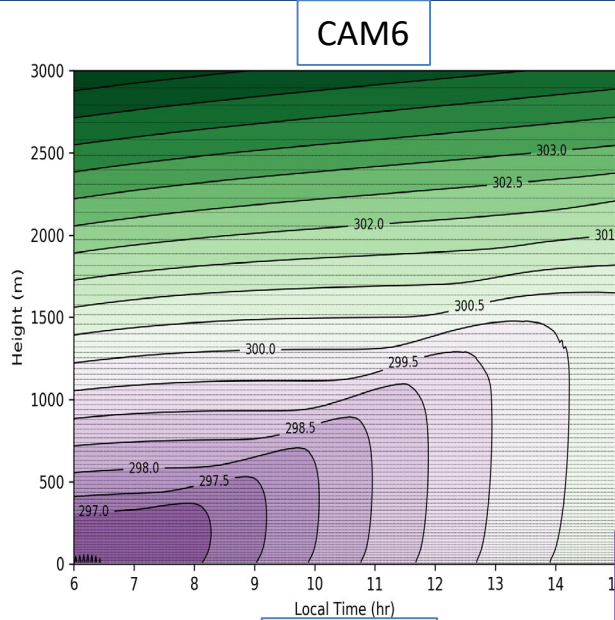
# Initial LES Comparisons (NCAR-LES)



- Predicted in CLUBB, resolved in LES
- Variance of vertical velocity ( $w'^2$ ) amplifies in-situ
- Much larger  $w'^3$  in the LES
- Also co-located with  $w'^2$
- Asymmetric/symmetric turbulence co-located

Horizontal  
Lines on plots  
= model levels

# Initial LES Comparisons (all LES)



- Qualitative agreement with NCAR/FastEddy
- WRF has less PBL growth

# Summary and Next

- SCAM6: Strong sensitivity to timestep/forcing/coupling
- Behavior convergent with vertical levels (PBL top stability)
- An argument for ~10 more levels in the boundary layer $\beta$
- With interactive land, equilibration is a challenge
- Deep PBL compared to LES (~1000m too deep at times)
- Asymmetric turbulence playing much larger role in LES
- PBL-top stability much greater in LES
  
- Equilibrated land
- Interactive isoprene photo-chemistry
- LES validation of higher order fluxes