CAM6 Boundary Layer Evolution Over An Idealized Diurnal Cycle

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NCAR Boundary Layer Activity

- 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)

- 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
2 min timestep
- Smoother evolution
- More rapid mixing (x2)
- Deeper PBL
- But, level-by-level jumps
Vertical Resolution Sensitivities

- 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
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
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?

**Graph:**
- Boundary Layer Depth
- Lines for CAM6 and NCAR LES
- Plus signs for Ceilometer
- TS = 304K max
- TS = 300K max

**Graph 2:**
- Surface Temperature
- Lines for CAM6 2 min and CAM6
- Local Time (hr) scale from 6 to 18
Initial LES Comparisons (NCAR-LES)

- 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
Initial LES Comparisons (all LES)

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