GCSS WG1 Summary

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Major WG1 activities

- Last WG meeting: Broomfield, Oct. 2003
  Preliminary results of DYCOMS RF01 nocturnal non-drizzling Sc intercomparison.
- Two papers submitted in Aug. 2004 to MWR about intercomparison:
  B. Stevens et al. – LES
  P. Zhu et al. – SCM
- Duynkerke et al. EUROCS paper on FIRE Sc diurnal cycle is in press at QJRMS, with similar conclusions.
- Next case: DYCOMS RF02 (nocturnal drizzling Sc), led by A. Ackerman and B. Stevens, specs in preparation.
  Next WG1 meeting to discuss this case: Athens, May 2005?
RF01 LES intercomparison

LES case specs realistic enough for meaningful observational intercomparison, but constrained such that models differ only in their transport and subgrid turbulent mixing algorithms (of which we had a diverse assortment). Based on past WG1 experience, all LES models were 3D, and had high vertical resolution (no more than 5 m in inversion layer).

Questions (revisiting WG1’s very first intercomparison):

Can most current LES models correctly predict the entrainment rate and evolution of LWP in a well-mixed nocturnal nonprecipitating Sc-topped boundary layer?

If not, why not?
Case specifications

Initial sounding has sharp 8K inversion at $z=850$ m over well-mixed Sc-topped BL with LWP = 60 g m$^{-2}$. Above BL, sounding is in radiative-subsidence balance.

Idealized radiative flux profile tuned to Fu-Liou and checked vs. obs. Flux at $z$ depends on LWP above and below $z$, plus a clear-air radiative cooling profile above the initial inversion height.
Further case specs.

- No precipitation (as observed).
- Surface fluxes fixed (based on obs.)
- Specified hor. divergence (inferred from obs.)
- $\Delta x = \Delta y = 35$ m, 96 x 96 columns, $L_z \sim 1500$ m.
- LES models run out 4 hrs; 3-4 hr avg. used for comparison.
LES results (as anticipated in Broomfield)

• 10 groups submitted 16 model simulations.
• Observed cloud deepens and thickens very slightly in 8 hrs with well-constrained $w_e = 0.35 \text{ cm s}^{-1}$. Almost all LES models predict $w_e$ to within 30% (good) but most considerably underestimate LWP.
$w_e$, LWP, and radiative flux divergence

LES with small LWP have higher entrainment efficiency

\[ \alpha = \rho c_p w_e \Delta \theta / \Delta F_{rad}, \]

presumably due to their SGS and advection schemes. LWP and $\Delta F_{rad}$ vary more between models than $w_e$. 

\[
\Delta F_{rad} \quad [W \ m^{-2}]
\]

\[ W_e \quad [\text{mm s}^{-1}] \]

\[ \alpha \]

\[ LWP \quad [g \ m^{-2}] \]
A subset (4 of 16 models) predicted LWP better. These models used subgrid schemes which strongly inhibited SGS vertical mixing within the inversion layer (even though their physical basis was not clearly superior to SGS schemes employed in other models). Their $w_e$ and turbulent velocity variance profiles were also most consistent with observations.
SCM intercomparison

10 SCMs from 8 groups, including most major GCM schemes, ECMWF, and some higher-order-closure models.

Two main cases:

• A: $\Delta z = 5 \text{ m}, \Delta t = 10 \text{ s}$, 6 hr simulation, identical specs to LES case.
  Goal: Test model performance with minimal complication from discretization errors.

• B: Like A, but default SCM resolution, 48 hr simulation, SST specified instead of fluxes.
  Goals:
  (1) Impact of realistic discretization over first 6 hrs
  (2) Do models head toward very different steady states?
Almost all SCMs maintain the observed well-mixed boundary layer structure and an adiabatic cloud layer.
Case A LWP and entrainment evolution

- Within an hour, SCMs diverge toward a wide range of LWP bracketing obs.

- After this time, in most models LWP becomes quasisteady with \( w_e \) within 50% of observed.
Energy balance considerations constrain the equilibrium $w_e$ to roughly match observations. The equilibrium LWP in each SCM adjusts to allow that SCM’s turbulence scheme to produce the observed $w_e$. 

\begin{figure}
\centering
\begin{tikzpicture}
    \node (we) at (0,0) {$W_e$};
    \node (qt) at (2,2) {$\theta_l, q_t$};
    \node (lwp) at (4,0) {LWP};

    \draw[->] (qt) -- (we) node[midway, below] {slow};
    \draw[->] (qt) -- (lwp) node[midway, above] {fast};
    \draw[<->] (we) -- (lwp) node[midway, below] {moist turbulence};
\end{tikzpicture}
\end{figure}
SCM results – Case B

- Hour 3-4 LWP in Case B is well correlated with Case A, suggesting discretization errors are not dominating formulaic differences between SCM turbulent mixing schemes.
At hour 36, the spread of LWP between SCMs is qualitatively similarly as after hours 3-4. Case specs. prevent achievement of a steady state.

A UCLA LES simulation suggests a deeper boundary layer at hour 36 than predicted by any of the SCMs! Thus we should not assume that the SCM ensemble brackets the ‘truth’.

B: 36 hr

- At hour 36, the spread of LWP between SCMs is qualitatively similarly as after hours 3-4. Case specs. prevent achievement of a steady state.
- A UCLA LES simulation suggests a deeper boundary layer at hour 36 than predicted by any of the SCMs! Thus we should not assume that the SCM ensemble brackets the ‘truth’.
Sensitivity studies

• Allowing precipitation had little impact on this case (as hoped) in 4 SCMs in which this was tested.

• This case should have no shallow cumulus convection, but in the NCAR SCAM, its default shallow convection scheme had a huge, resolution-dependent impact on LWP. Effects were smaller or negligible in 3 other SCMs.
How successful was this case?

+ Some LES did produce very good simulations of the case, apparently due to weak SGS entrainment mixing. Are these LES also more reliable for other Sc cases?
+ This case is a nice LES benchmark, simple for an LES to run and with a well-constrained, internally consistent, and clean observational comparison. This improves on the Duynkerke et al. (2004) and Moeng et al. (1996) intercomparisons.
+ Most SCMs were at least in the ballpark even at operational resolution, consistent with continuing Sc parameterization improvements.
- Despite hopes to the contrary, we relearned that most SCM and even LES models still can’t reliably predict LWP of subtropical marine stratocumulus clouds under strong inversions. This corroborates Duynkerke et al.’s recent EUROCS FIRE intercomparison.
The RF02 microphysical intercomparison for Athens

- Obs. suite similar to RF01.
- Moister aloft, cleaner.
WG1 RF02 case, cont.

- Same level of idealization as RF01 case except for activation of microphysics (bulk or bin-resolved).
- Goal is to test model drizzle production vs. LWP, $N_{\text{cl}}$ in LES and SCM. Interpreting model comparison more challenging than for RF01. Would be nice to compare multiple microphysics schemes in same LES (or SCM) dynamical framework – individual groups may be inspired to try this.
- Case specs out ~ 1 Nov 2004 on WG1 web page. LES results to be submitted by ~ 30 Apr 2005 to A. Ackerman.
  No definite SCM plan as yet, but my U. Washington group can probably process SCM submissions.