GCSS Boundary Layer Cloud WG Report

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Dedicated to the memory of Peter Duynkerke, GCSS WG1 chair from 1996-2001, who died in January.

(courtesy of Stephan de Roode)
...a tightly coupled system involving the interaction of turbulence, cloud microphysics, radiation and surface processes.
Observations...

↔ LES models...

↔ 1D models/parameterizations

Bretherton (1993)
WG1 Themes and Activities

Focal questions

• Do 3D eddy-resolving (LES) models agree with each other and with observations when run on the same case? (cloud properties, turbulence, entrainment)

• How well do parameterizations (1D models) do? Find ways to use LES to improve them.

Workshops - have brought together leading cloud-topped boundary layer LES/parameterization groups in the world.

• Choose cases that address interesting fundamental science.


1995: Radiatively-driven smoke cloud (MacVean et al. 1999)

and: ASTEX Lagrangian 1 (Bretherton et al. 1999)

1996: Drizzling stratocumulus case from ASTEX Lagr. 1 (Duynkerke 1997)

1997: BOMEX trade cumulus (Siebesma et al. 2002)

1998: ATEX transitional Cu (Stevens et al. 2000)

2000: ARM continental shallow Cu (Brown et al. 2002)

2001: Diurnal cycle of FIRE stratocumulus

...plus EUROCS.

Interesting things we have learned...
- Stratocumulus entrainment under a strong inversion is difficult to simulate. With vertical resolutions of 5-10 m, different LES agree to within 50%, but still tend to entrain more than observations suggest. 2D models strongly overestimate efficiency of entrainment.

- Several suggested CTBL entrainment parameterizations have been proposed by WG1 members, but even the right general form is actively debated when evaporative feedbacks present.

Smoke cloud case

MacVean et al. (1999)
ASTEX Lagrangians

- ASTEX Lagrangian 1 (June 12-14, 1992) observations (Bretherton and Pincus 1995, Bretherton et al. 1995) of drizzling stratocumulus changing to cumulus-under-Sc as PBL advects over increasing SSTs.
- Relaxation used above inversion to maintain time-varying observed sounding.
- General boundary layer structure and evolution similar between models (esp. the three 2D models), but differences in cloud cover.
- Participating 1D models were not too bad, despite the many important interacting physical processes!
2D models

1D models

Bretherton et al. 1999
BOMEX

Trade cumulus case

• Can LES reproducibly simulate boundary layer structure and cloud distributions in a trade cumulus boundary layer with less than 20% cloud fraction?

• Test 1D shallow Cu parameterizations.

Set up to minimize intermodel physics differences

- Specified surface fluxes, advective, radiative tendencies, geostrophic winds.
- No precipitation
- $\Delta x = \Delta y = 100$ m, $\Delta z = 40$ m, $6.4 \times 6.4 \times 3$ km.
- LES models run with $\Delta x = \Delta y = 100$ m, $\Delta z = 40$ m agree reassuringly well on profiles of cloud fraction, mass flux, momentum flux etc.

Siebesma et al. (2002)
Shallow Cu are not on average very buoyant...

- Spinoff studies looked at shallow Cu momentum transport, similarity theory for shallow Cu, pdf’s, etc.
- Cumulus cloud size/structure can be resolution-dependent.
• 1D shallow Cu models were not initially in good agreement with LES, but have used this case heavily for tuning
ATEX

- Transitional trade cumulus case

- Idealized cloud-radiation feedback causes large dispersion between models, even though turbulence stats are similar.
Effect of resolution on cloud structure

\[ q_l \text{ (g kg}^{-1} \text{)} \text{ at 1400 m} \]

D. Stevens et al. (2002)
ARM

- Diurnal development of shallow cumulus (20 June 1997)
- As in BOMEX, surface fluxes specified and no radiation feedback. LES models again agreed quite well

Brown et al. (2002)
• Also a good test for 1D models; deepening of the cumulus layer regulated by the large lateral entrainment in the clouds.
NE Pacific transects (EUROCS-Jakob, Siebesma, Teixeira)


ECMWF analyzed specific humidity - July 1998
Specific humidity (GCM)

- arpege - Specific Humidity (g/kg)
- ukmo_stnd - Specific Humidity (g/kg)
Cloud cover

arpege - Cloud Cover (%)

ukmo_stnd - Cloud Cover (%)

Pressure (hPa)

Latitude


**Plans**

Microphysical intercomparisons for Sc and shallow Cu
- Assess the impact of precipitation processes on BL cloud amount/thickness/albedo.
- ...and our ability to parameterize this process.

- EPIC 2001 (Oct. 2001) - SE Pacific Sc
- DYCOMS-II (Jul. 2001) - nocturnal NE Pac. Sc
  First study will be led by Margreet VanZanten (UCLA) on a DYCOMS-II case.

Shallow to deep Cu transition (with WG4) over Amazonia
- Deep convective initiation
- Impact/parameterization of unresolved shallow cu processes in CRM.
Shallow, hi-res

Grabowski

Deep, CRM-res
Conclusions

• GCSS WG1 intercomparisons have been a major factor in setting the agenda for CTBL LES and parameterization research.

• In addition to the studies themselves, there have been numerous spinoff studies due to the interesting scientific issues raised.

• The focus from now on is on combining LES with other less well understood physics.