Sensitivity of stratocumulus to droplet concentration in LES and SCAM5

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More aerosol thins nearly nonprecipitating Sc clouds

Physical Mechanisms

Lower $N_d$ implies ... 

**Suppressed entrainment**

- Increased cloud top sedimentation depletes liquid water, reducing evaporative-enhancement of entrainment.
- For sufficiently dry overlying air, less entrainment implies *higher LWP*.

**Enhanced precipitation**

- Surface precipitation acts as a sink for cloud water (*lower LWP*).
- Evaporating precipitation:
  - suppresses turbulence and entrainment (*higher LWP*).
  - may stratify boundary layer (*lower LWP*).
Sc-Cu transition case highlighted LWP sensitivity to $N_d$ had opposite sign between LES and SCAM.

SCAM sensitivity not due to entrainment-sedimentation response.

SCAM sensitivity tied to precipitation processes.
Non-precipitating nocturnal stratocumulus
DYCOMS-II RF01 (Stevens et al, 2005)

- Fixed cloud droplet concentration \( (N_d = 25, 100, 400 \, \text{cm}^{-3}) \).
- Idealized radiation.
- Fixed SST, LHF, and SHF.
- Geostrophic winds.
- No advective or radiative forcing above BL.
- SCAM:
  - Version: scamcpt_cam5_0_12 (from Sungsu Park).
  - Vertical levels: L30, L80
- LES:
  - Model: SAM (Khairoutdinov and Randall, 2003). Simulations run by Peter Blossey.
  - 256 vertical levels from surface to \( \approx 2300 \, \text{m} \).
LES vs. SCAM: Cloud fraction

**LES**

- $N_g = 25$
- $N_g = 100$
- $N_g = 400$

**SCAM**

- $N_g = 25$
- $N_g = 100$
- $N_g = 400$
LES vs. SCAM: Liquid Water Path

**LES**

- $N_d = 25$
- $N_d = 100$
- $N_d = 400$

**SCAM**

- $N_d = 25$
- $N_d = 100$
- $N_d = 400$
LES vs. SCAM: Vertical profiles (4-8 hour average)

- BL is well-mixed in $q_t$ and $s_L$ (both LES and SCAM).
- $q_t$ is very slightly highest for $N_d = 25 \text{ cm}^{-3}$, consistent with reduced entrainment (both LES and SCAM).
- Despite that, cloud liquid smallest for $N_d = 25$ in SCAM.
Mean LWP is sensitive to time step, but $\Delta LWP$ is less so.

**Default (dt = 1200 s)**

- $N_d = 25$
- $N_d = 100$
- $N_d = 400$

**dt = 300 s**

- $N_d = 25$
- $N_d = 100$
- $N_d = 400$
Mean LWP sensitive to vertical resolution, but similar $\Delta LWP$ response to $\Delta N_d$. 

**L30 (dt = 300 s)**

**L80 (dt = 300 s)**
SCAM Sensitivity to Sedimentation

Turning off sedimentation has muted impact. Suggests that precipitation/evaporation is dominating factor.

Default (L30, dt1200)

SedOff (L30, dt1200)
Explicit entrainment-sedimentation feedback (L30)

A very small step in the right direction.
Explicit entrainment-sedimentation feedback (L80)

A larger step in the right direction.
SCAM Sensitivity to Model Version

scamcpt_cam5_0_12

convect36_cam5_1_31
PDF Cloud Macrophysics

With a short enough timestep, using PDF cloud macrophysics can reverse the sign.

PDF Macro (L30, dt1200)

PDF Macro (L30, dt100)
Conclusions

- LES and SCAM show opposite LWP sensitivity to $N_d$.
- In SCAM, the LWP sensitivity is associated with evaporating drizzle.
- PDF-based approach to cloud macrophysics seems to improve the behavior (decrease LWP sensitivity to $N_d$, better correspondence between LWP and CLDLOW).
- Variation between SCAM model versions is substantial and worrisome.
Conclusions

- LES and SCAM show opposite LWP sensitivity to $N_d$.
  - Physical basis sides with LES.
  - Mechanisms parametrized in SCAM have underwhelming impact.
- In SCAM, the LWP sensitivity is associated with evaporating drizzle.
  - Not qualitatively altered by time step or vertical resolution.
  - The sensitivity to an explicit parametrization of entrainment-sedimentation feedback is far weaker than in the LES.
  - Sensitive to details of parametrization (e.g., microphysics).
- PDF-based approach to cloud macrophysics seems to improve the behavior (decrease LWP sensitivity to $N_d$, better correspondence between LWP and CLDLOW).
- Variation between SCAM model versions is substantial and worrisome.
  - Poses a problem for using SCAM to interpret underlying physical mechanisms and connecting them back to global model.
Spurious surface precipitation

EntrSed

EntrSed (L80, dt300)
Unphysical surface precipitation contributes (but doesn’t dominate) in L80.

Doesn’t contribute to L30 sensitivity.