Sensitivity of stratocumulus to droplet concentration in LES and SCAM5

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Outline

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*).

Findings from Sc-Cu transition
(presented at last year's AMWG meeting)

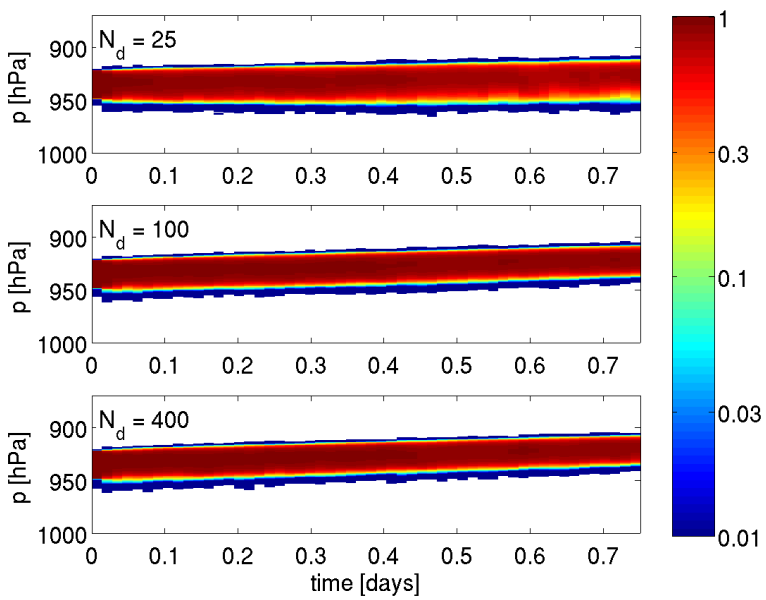
- Sc-Cu transition case highlighted LWP sensitivity to N_d had opposite sign between LES and SCAM.
- SCAM sensitivity not due to entrainment-sedimentation response.
- SCAM sensitivity tied to precipitation processes.

Non-precipitating nocturnal stratocumulus
DYCOMS-II RF01 (Stevens et al, 2005)

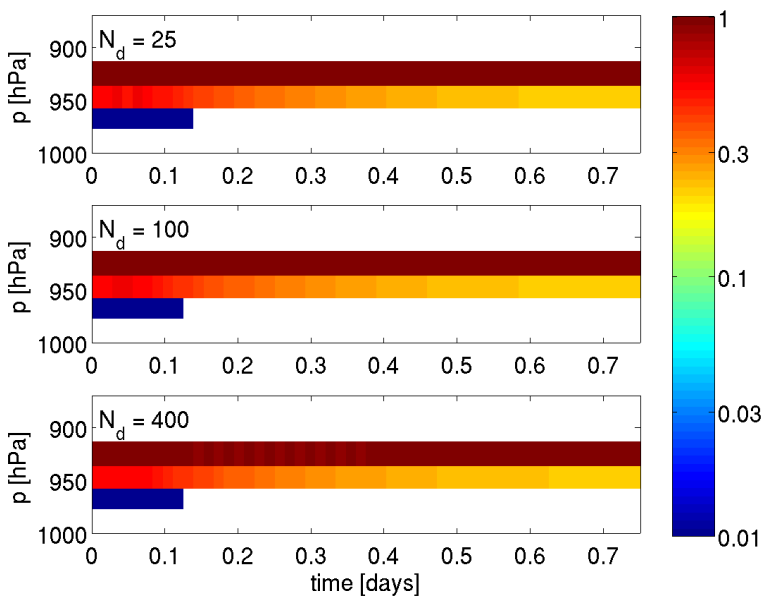
- Fixed cloud droplet concentration ($N_d = 25, 100, 400$ cm^{-3}).
- Idealized radiation.
- Fixed SST, LHF, and SHF.
- Geostrophic winds.
- No advective or radiative forcing above BL.
- SCAM:
  - Version: `scamcpt_cam5_0_12` (from Sungsu Park).
  - Vertical levels: L30, L80
- LES:
  - Model: SAM (Khairoutdinov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

LES vs. SCAM: Cloud fraction

LES

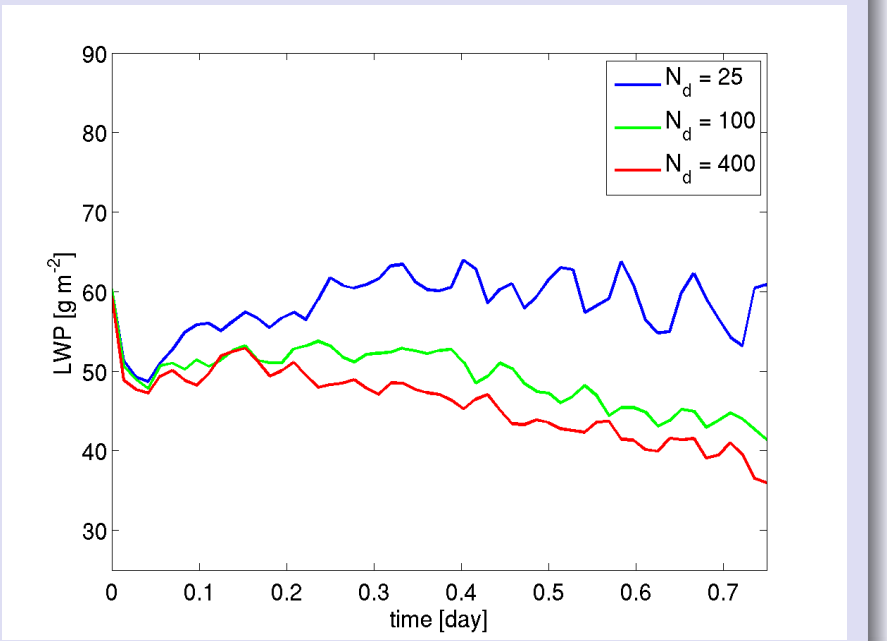


SCAM

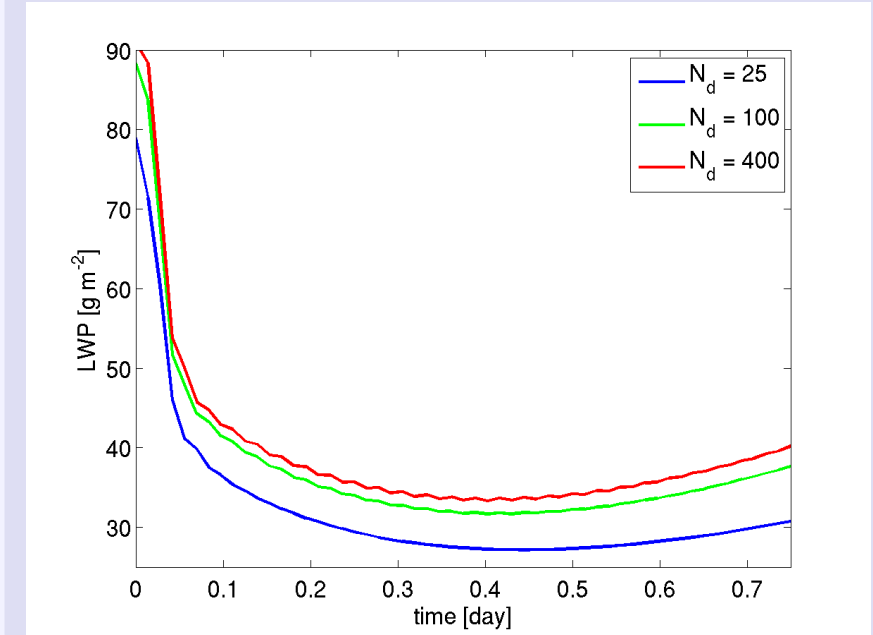


LES vs. SCAM: Liquid Water Path

LES



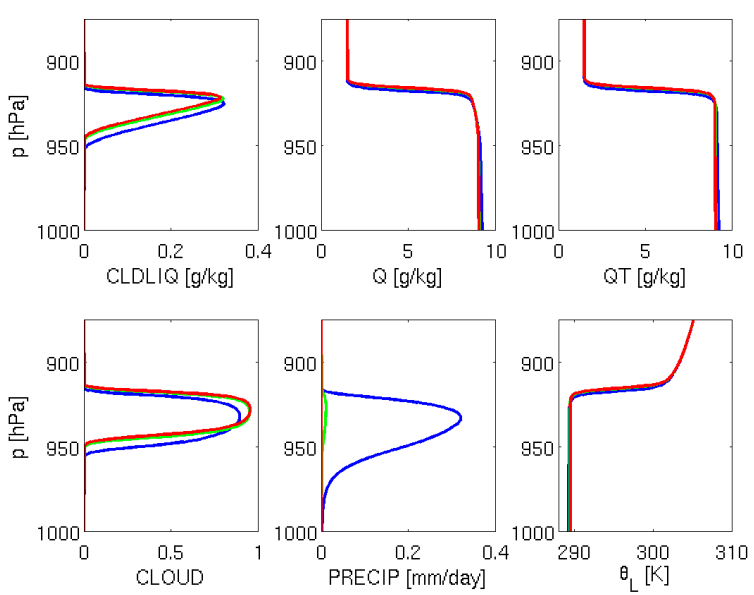
SCAM



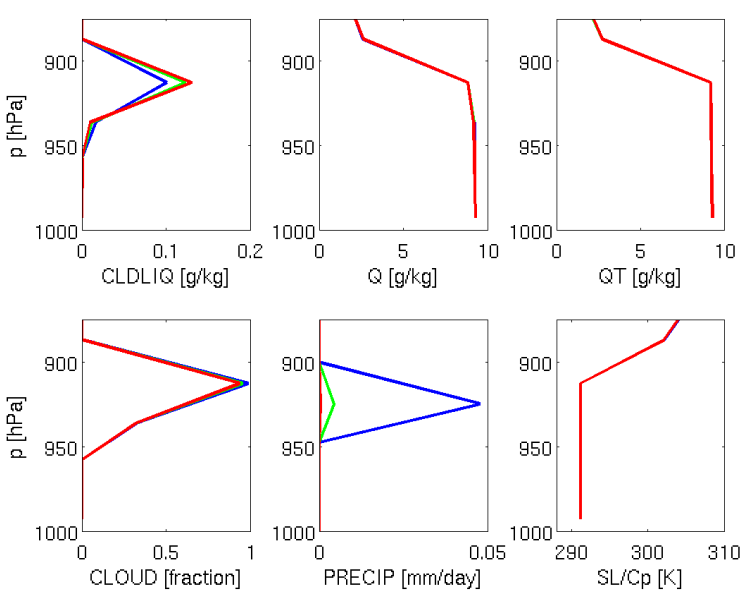
LES vs. SCAM: Vertical profiles (4-8 hour average)

- BL is well-mixed in q_t and s_L (both LES and SCAM).
- q_t is very slightly highest for $N_d = 25$ cm^{-3}, consistent with reduced entrainment (both LES and SCAM).
- Despite that, cloud liquid smallest for $N_d = 25$ in SCAM.

LES



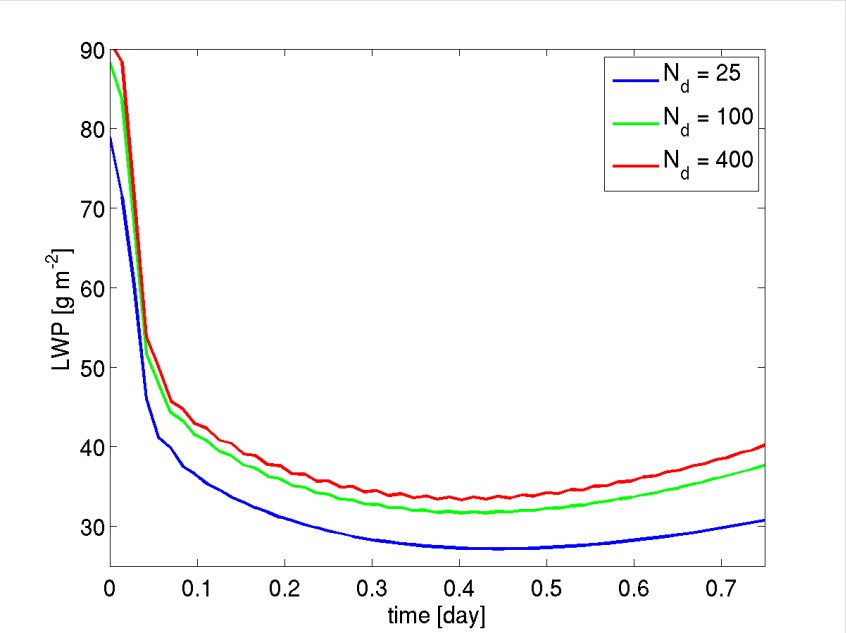
SCAM



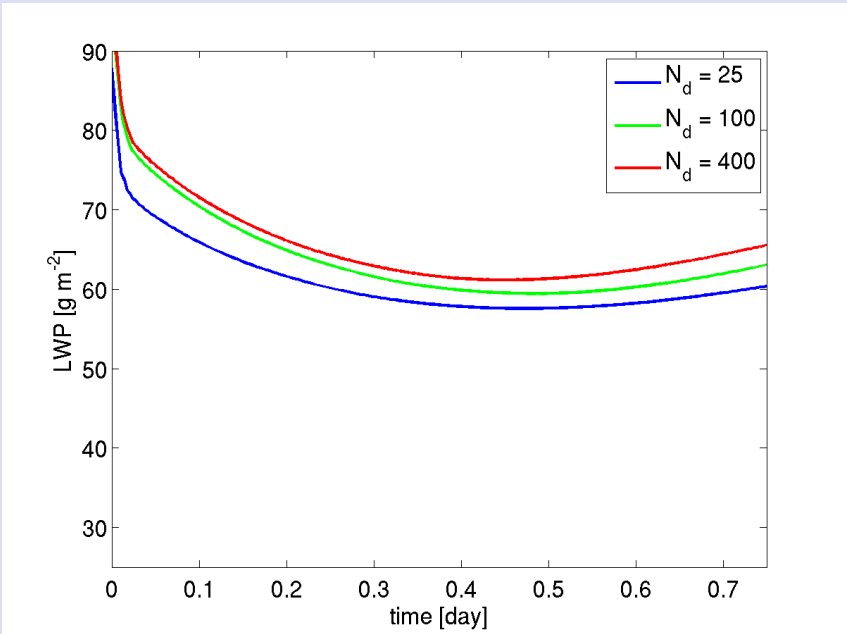
SCAM Sensitivity to Time Step

Mean LWP is sensitive to time step, but ΔLWP is less so.

Default (dt = 1200 s)



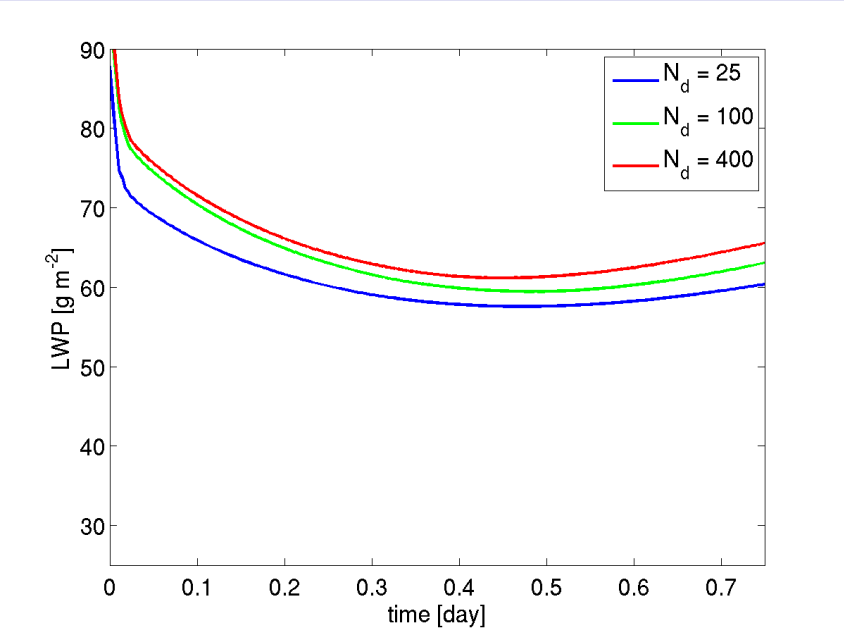
dt = 300 s



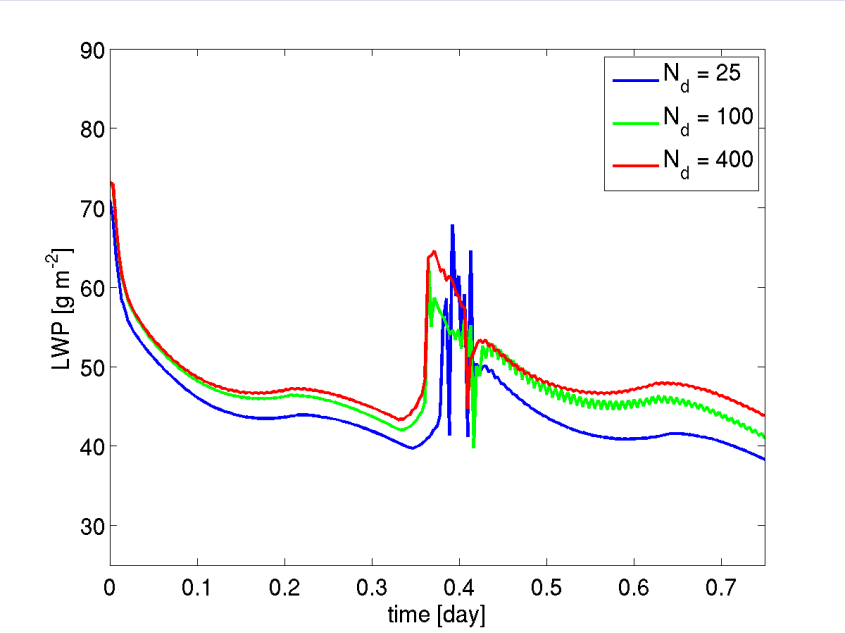
SCAM Sensitivity to Vertical Resolution

Mean LWP sensitive to vertical resolution, but similar ΔLWP response to ΔN_d.

L30 (dt = 300 s)



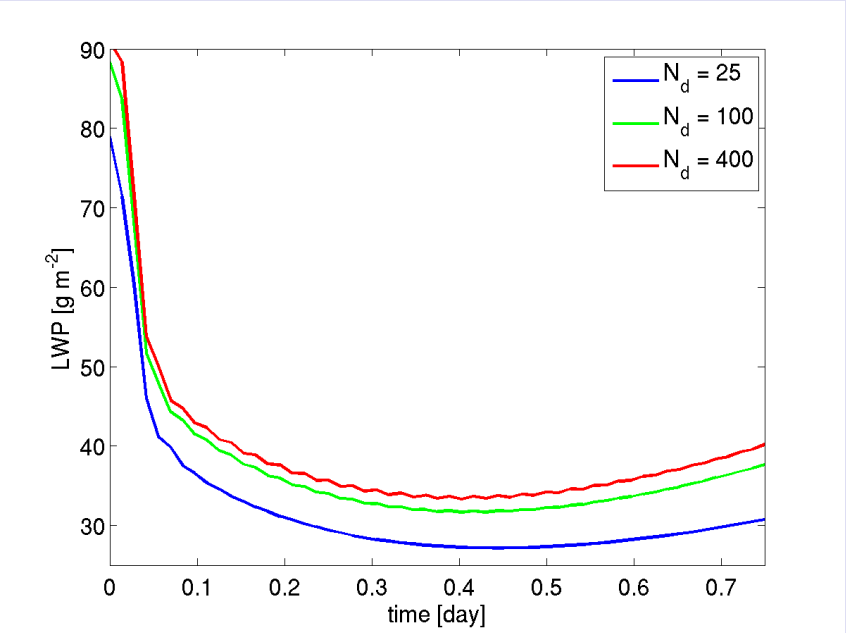
L80 (dt = 300 s)



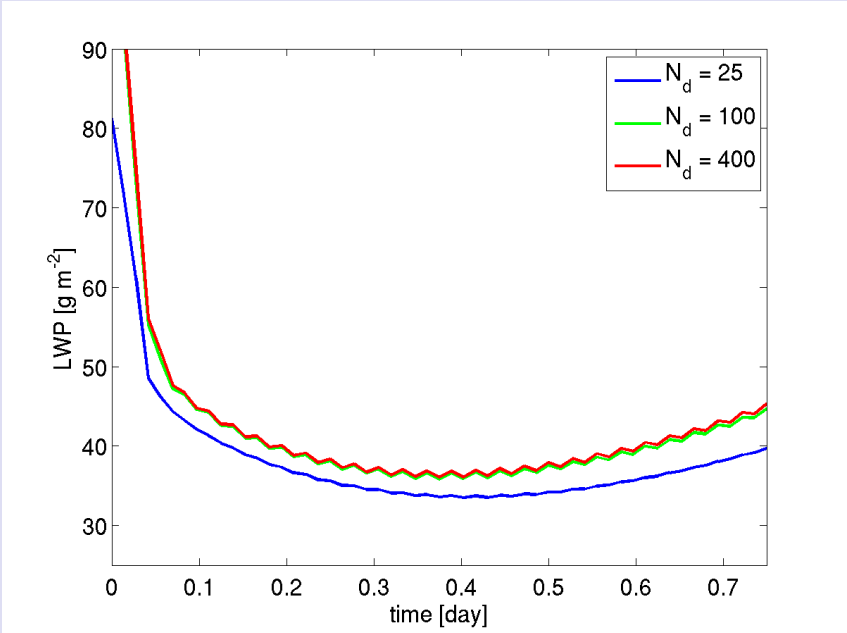
SCAM Sensitivity to Sedimentation

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

Default (L30, dt1200)



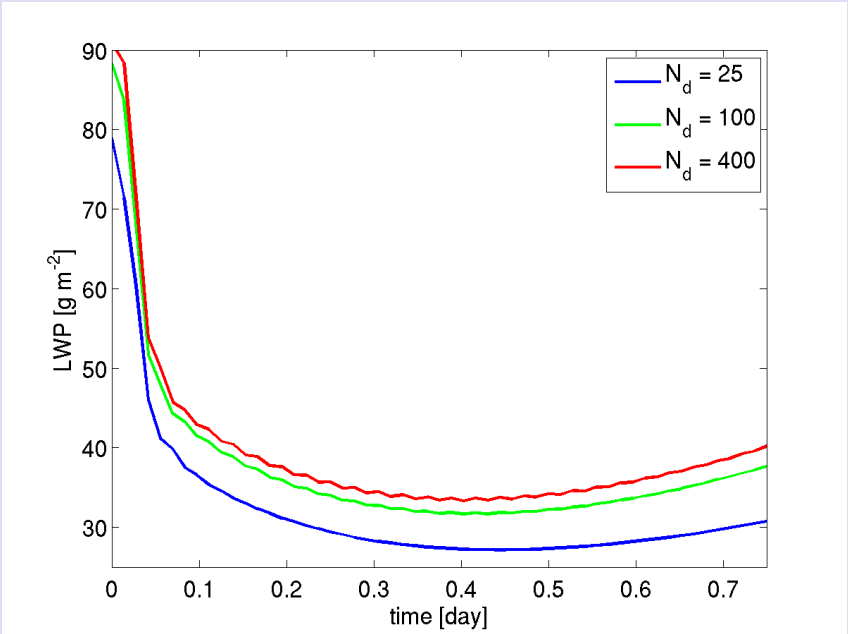
SedOff (L30,dt1200)



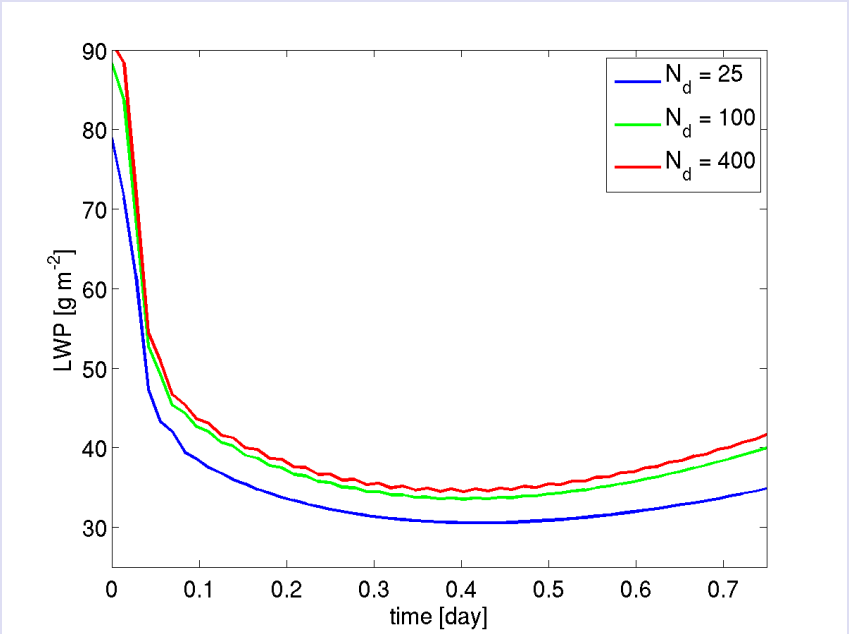
Explicit entrainment-sedimentation feedback (L30)

A very small step in the right direction.

Default (L30, dt1200)



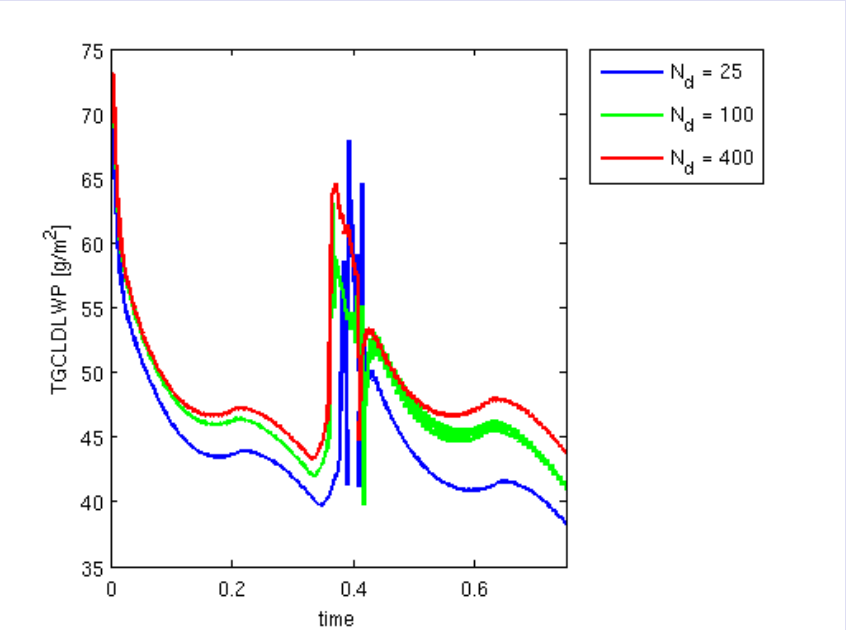
EntrSed (L30,dt1200)



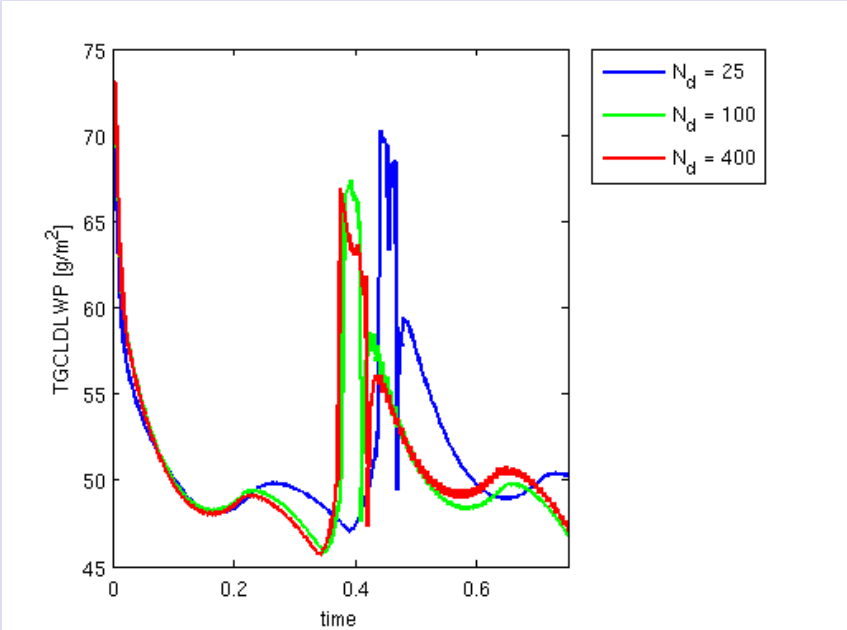
Explicit entrainment-sedimentation feedback (L80)

A larger step in the right direction.

Default (L80, dt300)

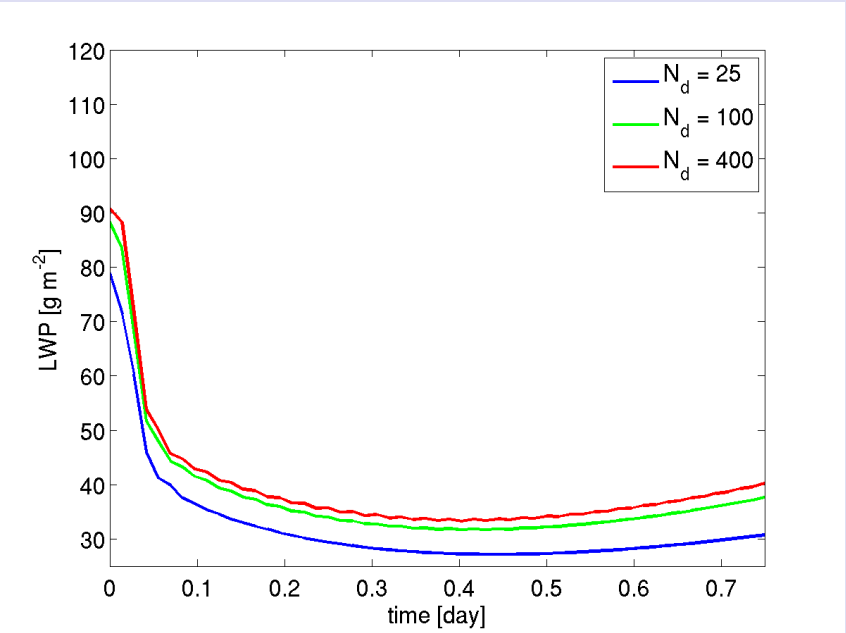


EntrSed (L80,dt300)

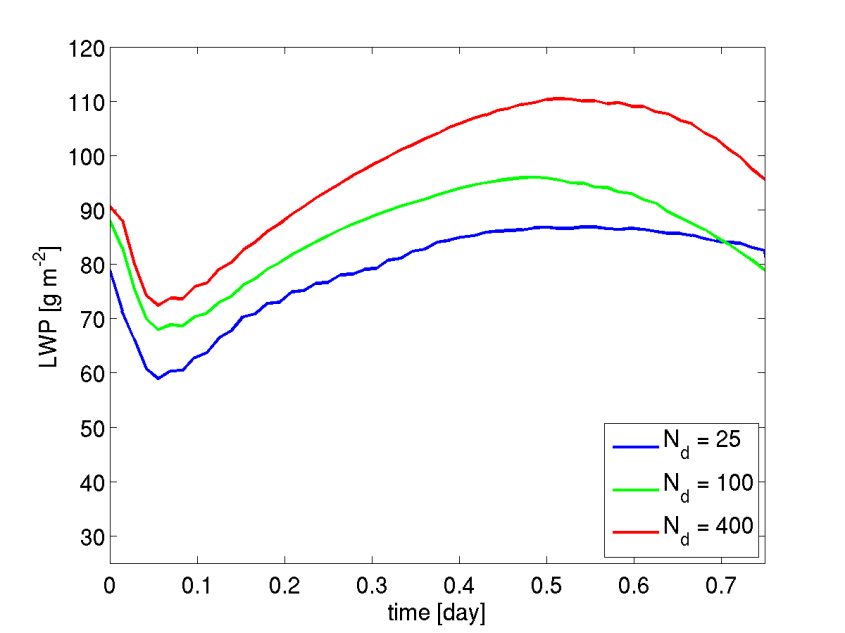


SCAM Sensitivity to Model Version

scamcpt_cam5_0_12



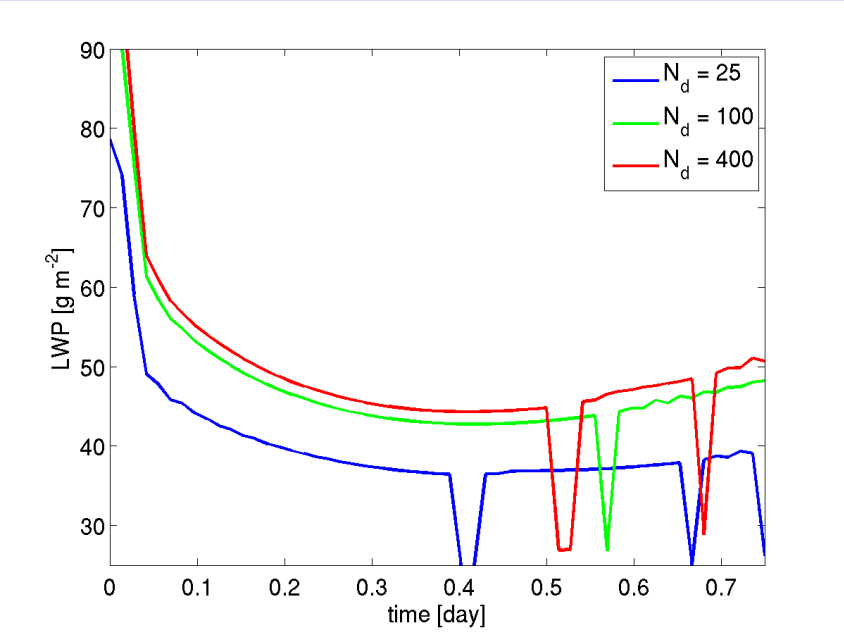
convect36_cam5_1_31



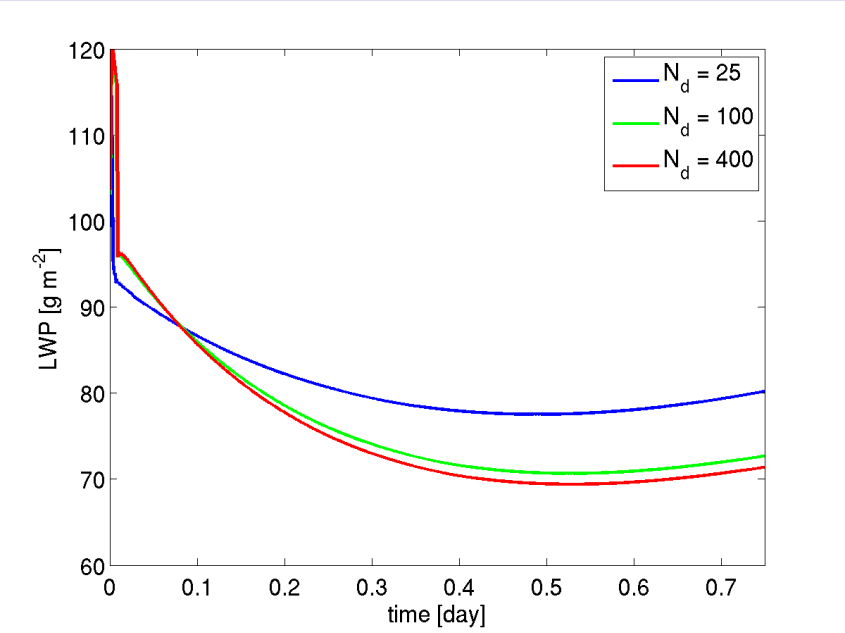
PDF Cloud Macrophysics

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

PDF Macro (L30, dt1200)



PDF Macro (L30, dt100)



Conclusions

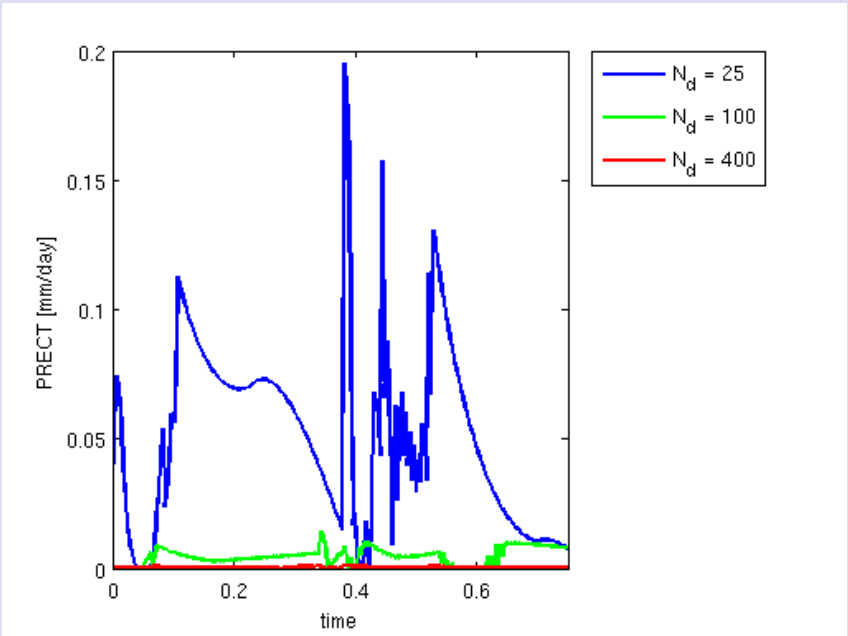
- LES and SCAM show opposite LWP sensitivity to N_d.
- In SCAM, the LWP sensitivity is associated with evaporating drizzle.
- PDF-based approach to cloud macrophysics seems to improve the behavior (decrease LWP sensitivity to N_d, better correspondence between LWP and CLDLOW).
- Variation between SCAM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

Conclusions

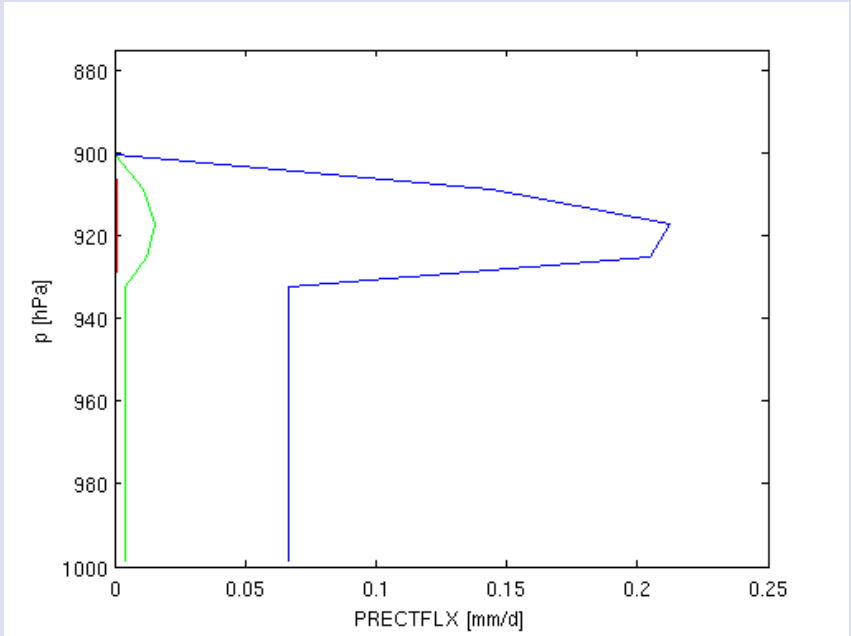
- LES and SCAM show opposite LWP sensitivity to N_d.
  - Physical basis sides with LES.
  - Mechanisms parametrized in SCAM have underwhelming impact.
- In SCAM, the LWP sensitivity is associated with evaporating drizzle.
  - Not qualitatively altered by time step or vertical resolution.
  - The sensitivity to an explicit parametrization of entrainment-sedimentation feedback is far weaker than in the LES.
  - Sensitive to details of paramatrization (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

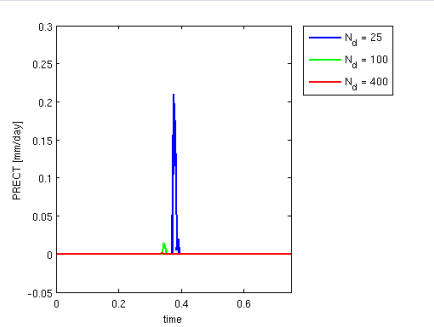


EntrSed (L80,dt300)

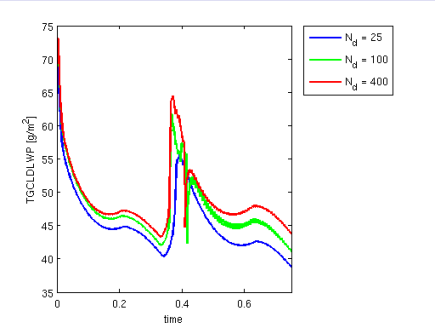


Modified Precip

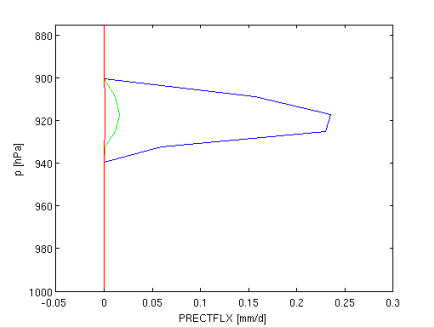
EntrSed-Mod



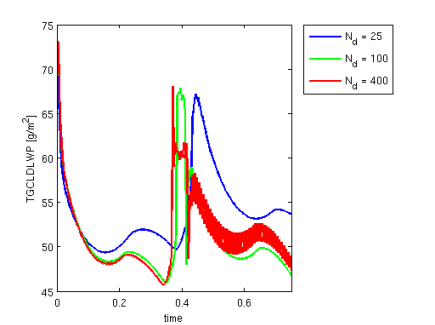
Default-Mod



EntrSed-Mod



EntrSed-Mod



- Unphysical surface precipitation contributes (but doesn't dominate) in L80.
- Doesn't contribute to L30 sensitivity.