Numerical Coupling of Atmospheric Processes and Its Impact on Subtropical Marine Clouds in EAMv1

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AMWG Meeting, March 10, 2020
Background

- SciDAC project aims at reducing time-stepping error and addressing time-step convergence issues in atmospheric physics parameterizations in E3SM
- Importance of time-stepping error demonstrated by time-step sensitivities in present-day climate simulations
  - EAMv1, F_2000 compset
  - 1-degree horizontal resolution
  - Factor-of-6 reduction of time step length for major processes
  - Various changes in 10-year mean climate, physically and statistically significant
What caused those changes?
(Quantity shown is the 10-year mean $\Delta$CRE)

Step sizes reduced for all major processes

Step sizes reduced for all other processes

Step sizes reduced for CLUBB+MG2
What caused those changes?
(Quantity shown is the 10-year mean $\Delta$CRE)

Step sizes reduced for all major processes
Step sizes reduced for all other processes
Step sizes reduced for CLUBB+MG2

Radiation + Dynamics
Process coupling
Deep Cu + Misc.
Coupling of CLUBB+MG2 with other processes

Sequential split over $\Delta t = 30$ min

Deep Cu, Dynamics, Radiation, Land, Misc.

CLUBB+MG2
CLUBB+MG2
CLUBB+MG2
CLUBB+MG2
CLUBB+MG2

Substep of $\Delta t = 5$ min
Substep of $\Delta t = 5$ min
Substep of $\Delta t = 5$ min

Sequential split over $\Delta t = 30$ min
Cloud liquid amount and tendencies

Global mean CLDLIQ

Zonal mean CLDLIQ tendencies

CLUBB

MG2
Why does CLUBB behave differently in the first substep?

- Effectively the large-scale condensation parameterization
- Responds to supersaturation generated by other processes
- Assumes instantaneous condensation (like most other cloud schemes in global models)

Sequential splitting

- Substep 1: CLUBB responds to all other processes outside the subcycles
- Substeps 2-6: CLUBB responds to MG2

Dribbling tendencies into the subcycles

- CLUBB responds to all other processes every substep
Time series of cloud liquid amount
In the VOCALS region

∆CRE, DRIB - CNTL

LWP over 5 days, written out after every 6th substep

Dribbling turned on at step 21

Mean CLDLIQ between 700 hPa and 1000 hPa
10-year mean changes in the VOCALS region

Dribbling minus sequential split

LWP

CLDLOW

SW CRE
Why decreases in cloud amount?

Total T-tendency due to processes outside the subcycles

T-tendency introduced by individual processes
Sequential splitting v.s. dribbling

**T increment**

- **Applied over a 30-min time step if sequentially split**
- **Applied before 1st 5-min substep if dribbling**
- **All substeps of dribbling**
Effects of dribbling

- The atmosphere “seen” by CLUDB is warmer in the boundary layer and cooler above the clouds
- Radiative cooling near cloud top and subsidence-induced warming above cloud top are applied more “gently”
- Boundary layer becomes more convective
- Clouds become more cumulus-like
- These features are confirmed by diagnostics from CLUDB
Conclusions

• Shorter time steps lead to decreased cloud fraction, cloud liquid amount, and weaker CRE for subtropical marine stratocumulus in EAMv1
• Primary reason is more frequent coupling between CLUBB+MG2 and the rest of the model
• Dribbling tendencies from other processes into the CLUBB+MG2 subcycles is more consistent with the assumption of instantaneous condensation
• Dribbling has impacts in the tropics and over the storm tracks, too. We know how the climate statistics change in those regions and are trying to understand why.
Backup slides
Coupling of CLUBB+MG2 with other processes: dribbling

State variables (T, qv, ql, qi, Nl, Ni)

Deep Cu, Dynamics, Radiation, Land, Misc.

Tendencies

CLUBB+MG2
CLUBB+MG2
CLUBB+MG2
CLUBB+MG2
CLUBB+MG2
Cloud liquid tendencies: with dribbling

Zonal mean CLDLIQ tendencies

CLUBB

MG2