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

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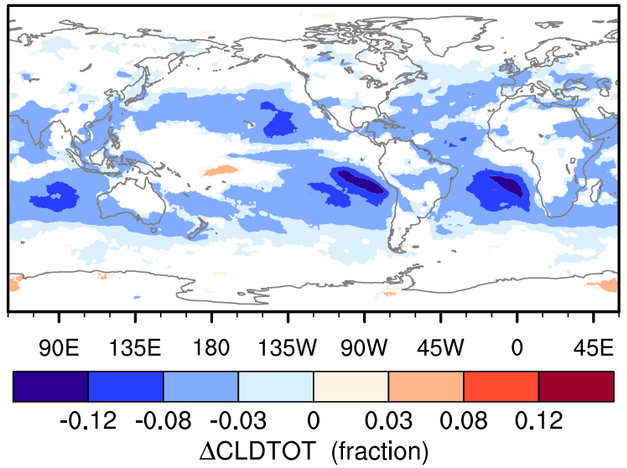
Background

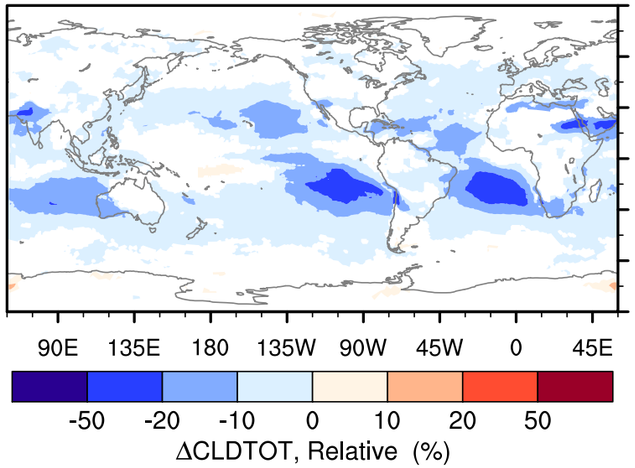
- SciDAC project aims at reducing time-stepping error and addressing time-step convergence issues in atmospheric physics parameterizations in E3SM
- Importance of time-stepping error demonstrated by time-step sensitivities in present-day climate simulations
  - EAMv1, F_2000 compset
  - 1-degree horizonal resolution
  - Factor-of-6 reduction of time step length for major processes
  - Various changes in 10-year mean climate, physically and statistically significant

Differences in 10-year averages

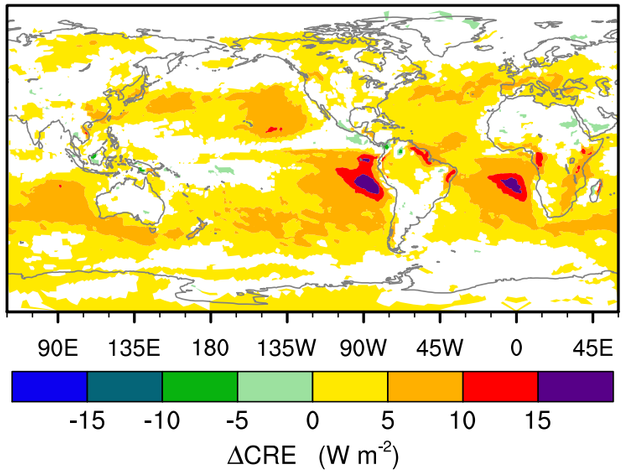
Total cloud cover, DT/6 - CNTL



Total cloud cover, relative diff.



Total CRE, DT/6 - CNTL



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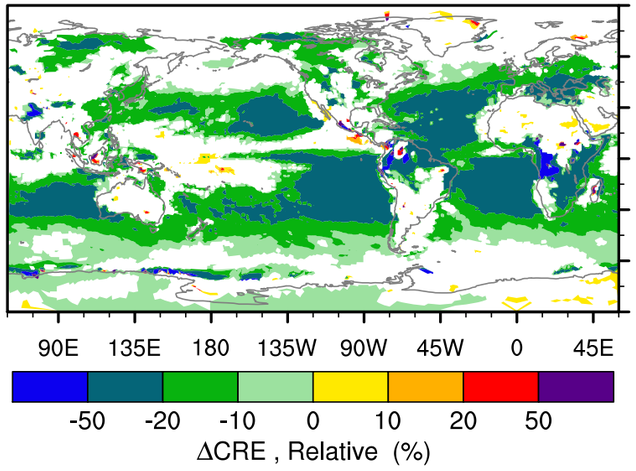
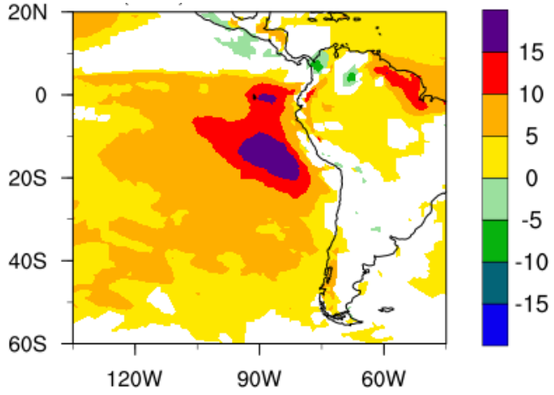


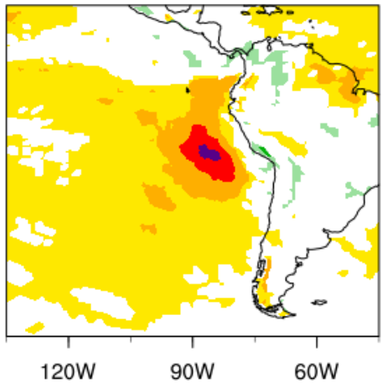
What caused those changes?

(Quantity shown is the 10-year mean ΔCRE)

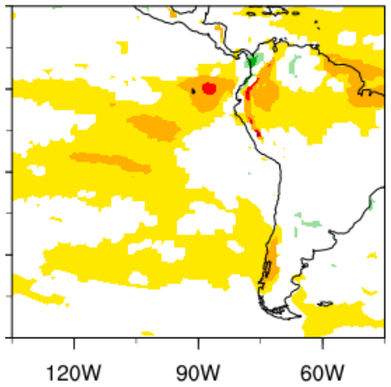
Step sizes reduced for **all major processes**



Step sizes reduced for **all other processes**



Step sizes reduced for **CLUBB+MG2**



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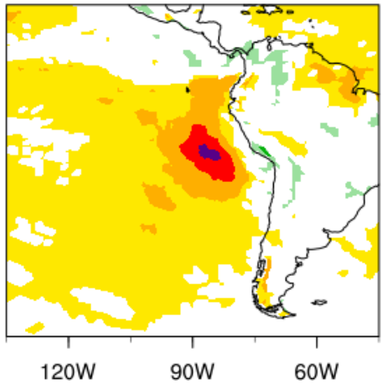
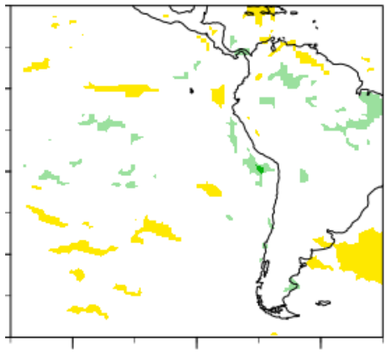
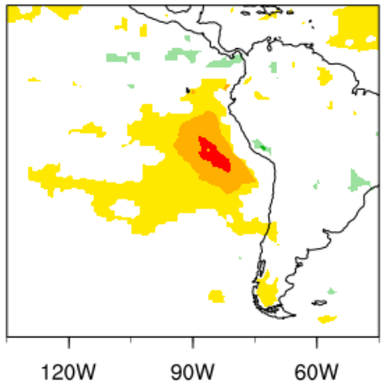


Step sizes reduced for **CLUBB+MG2**

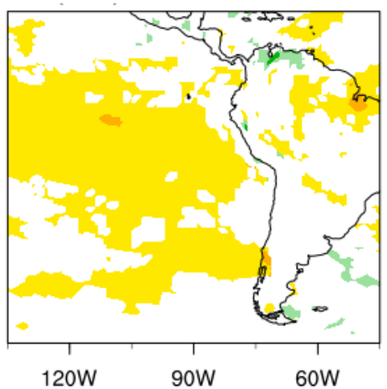
Radiation + Dynamics



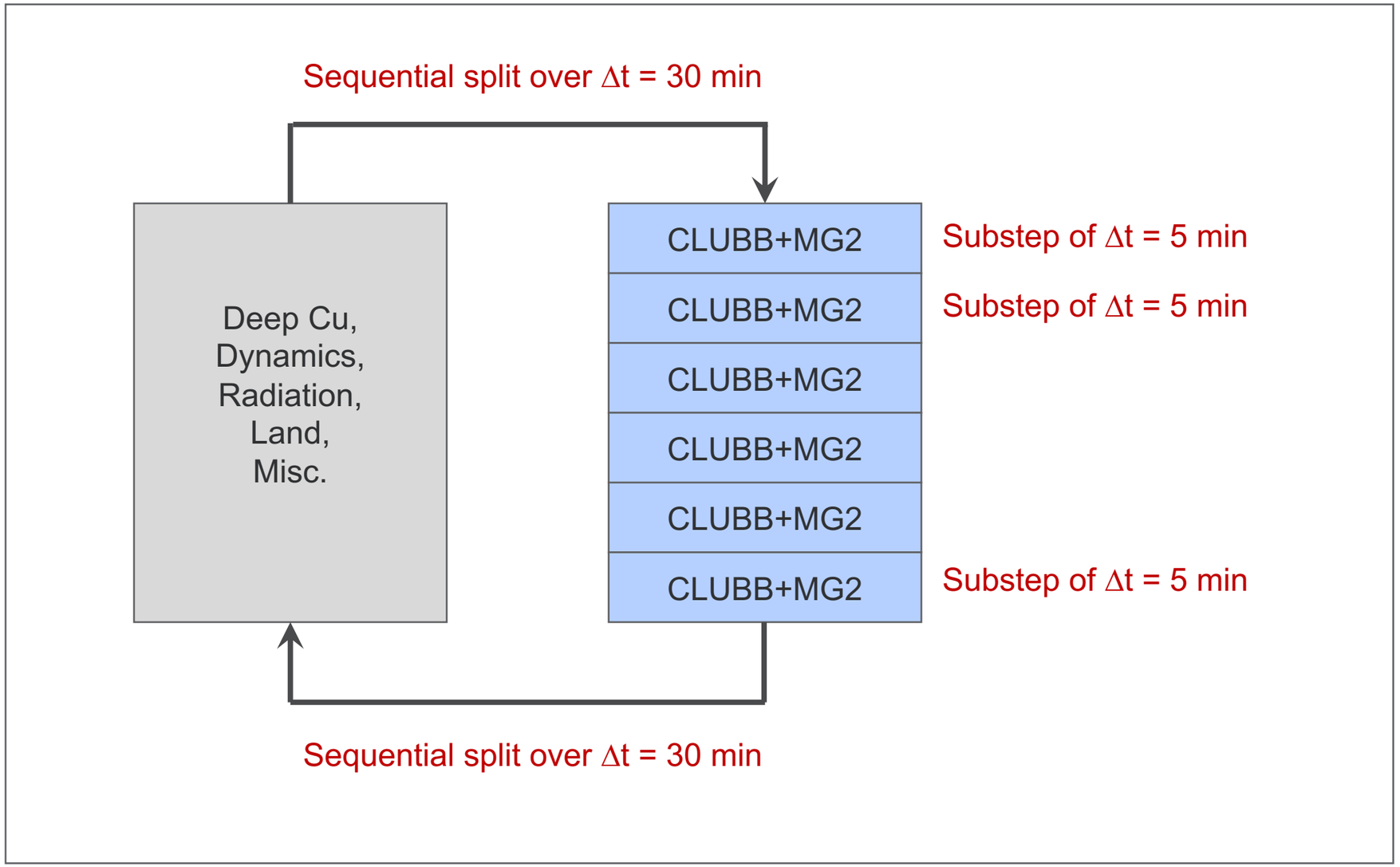
Process coupling



Deep Cu + Misc.

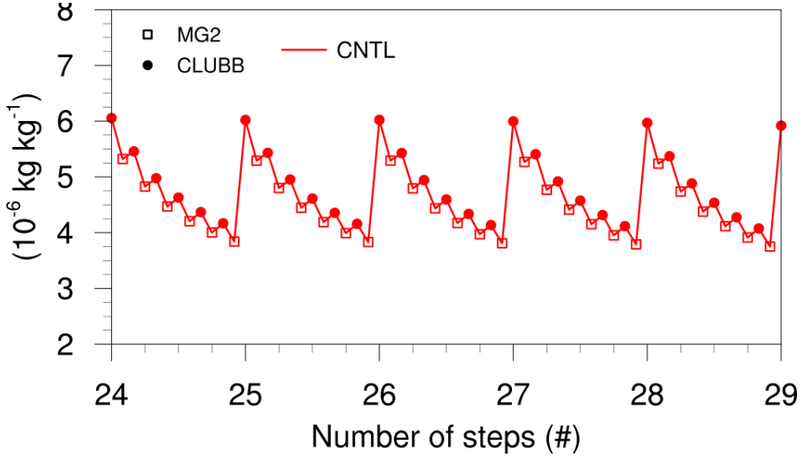


Coupling of CLUBB+MG2 with other processes

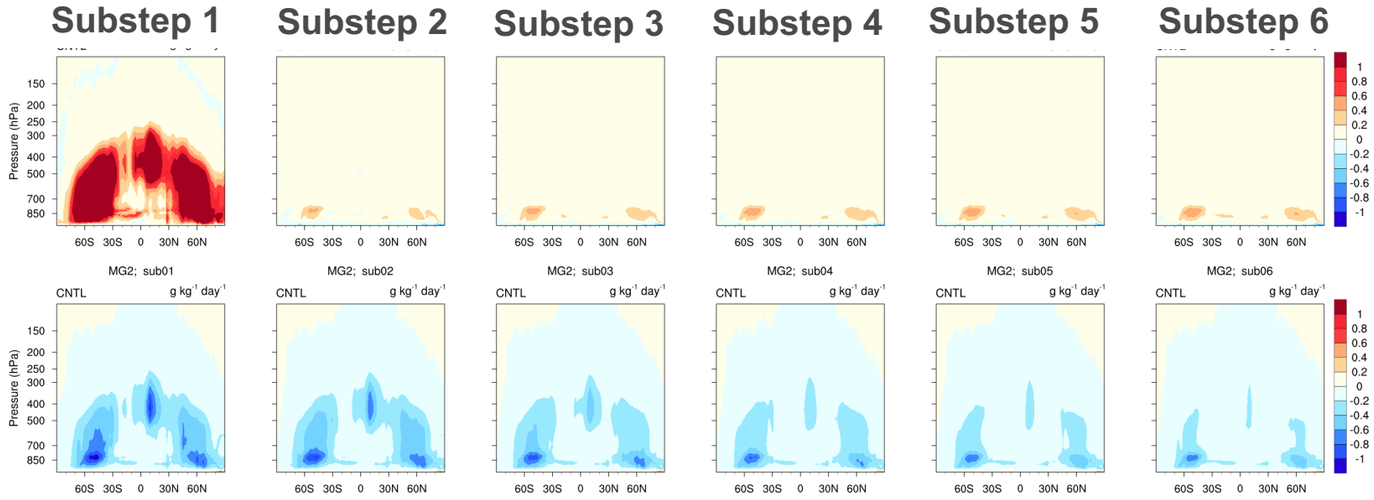


Cloud liquid amount and tendencies

Global mean CLDLIQ



Zonal mean CLDLIQ tendencies



Why does CLUBB behave differently in the first substep?

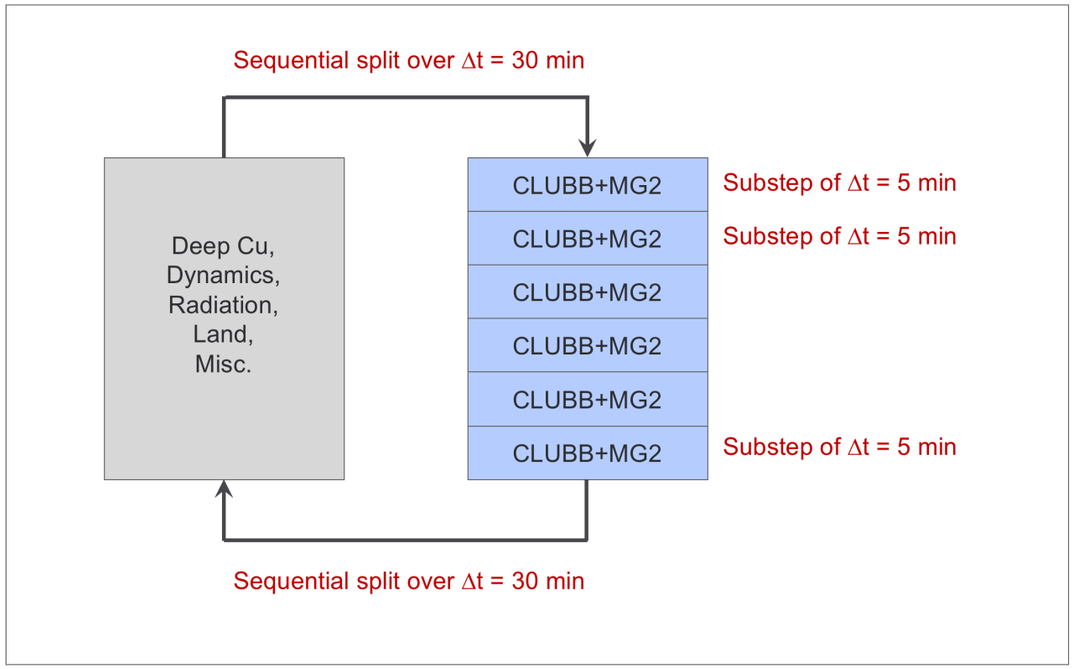
- Effectively the large-scale condensation parameterization
- Responds to supersaturation generated by other processes
- Assumes instantaneous condensation (like most other cloud schemes in global models)

Sequential splitting

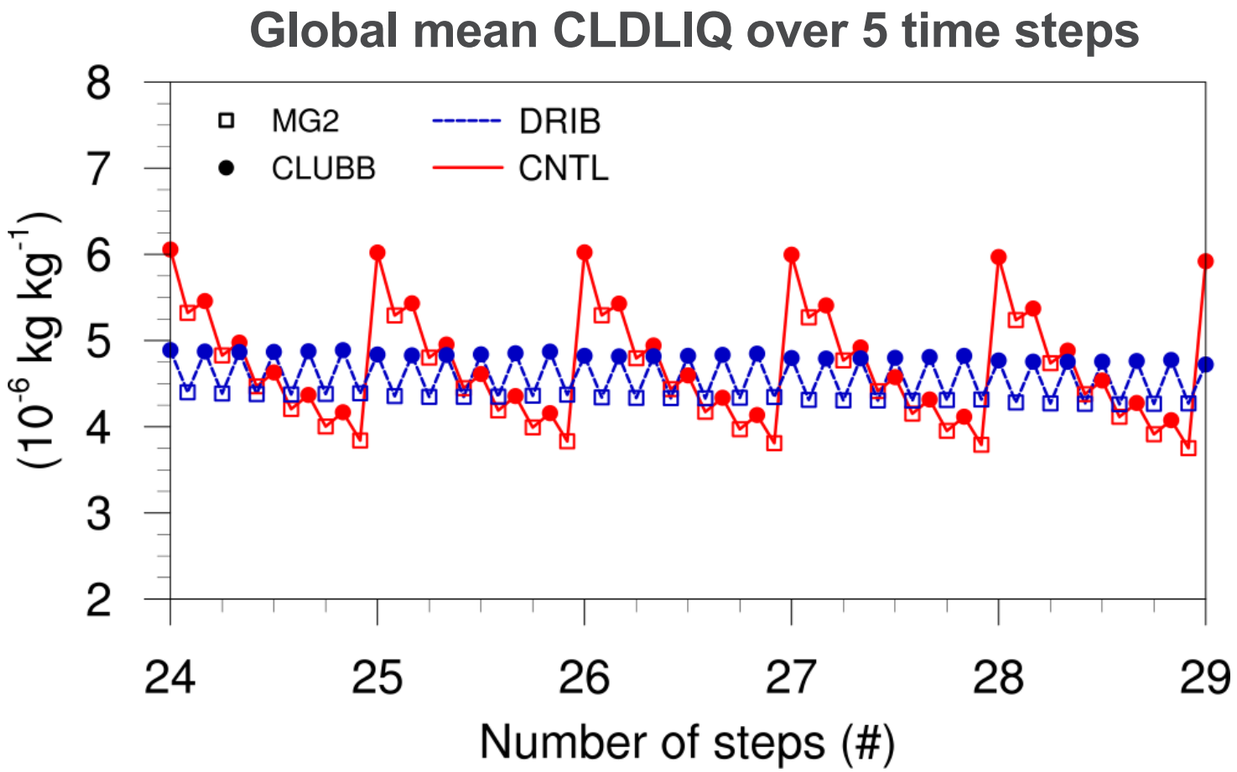
- Substep 1: CLUBB responds to all other processes outside the subcycles
- Substeps 2-6: CLUBB responds to MG2

Dribbling tendencies into the subcycles

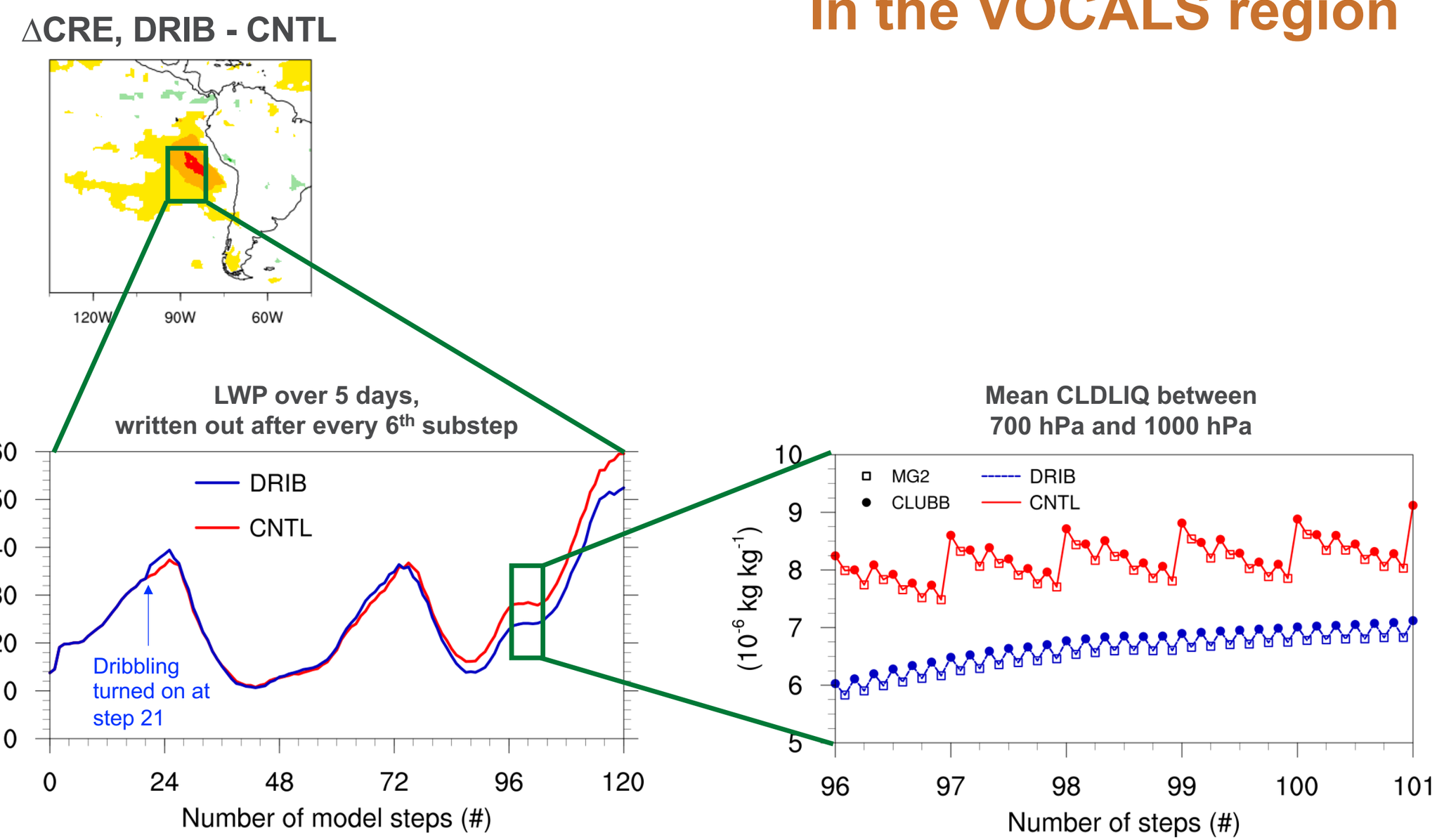
- CLUBB responds to all other processes every substep



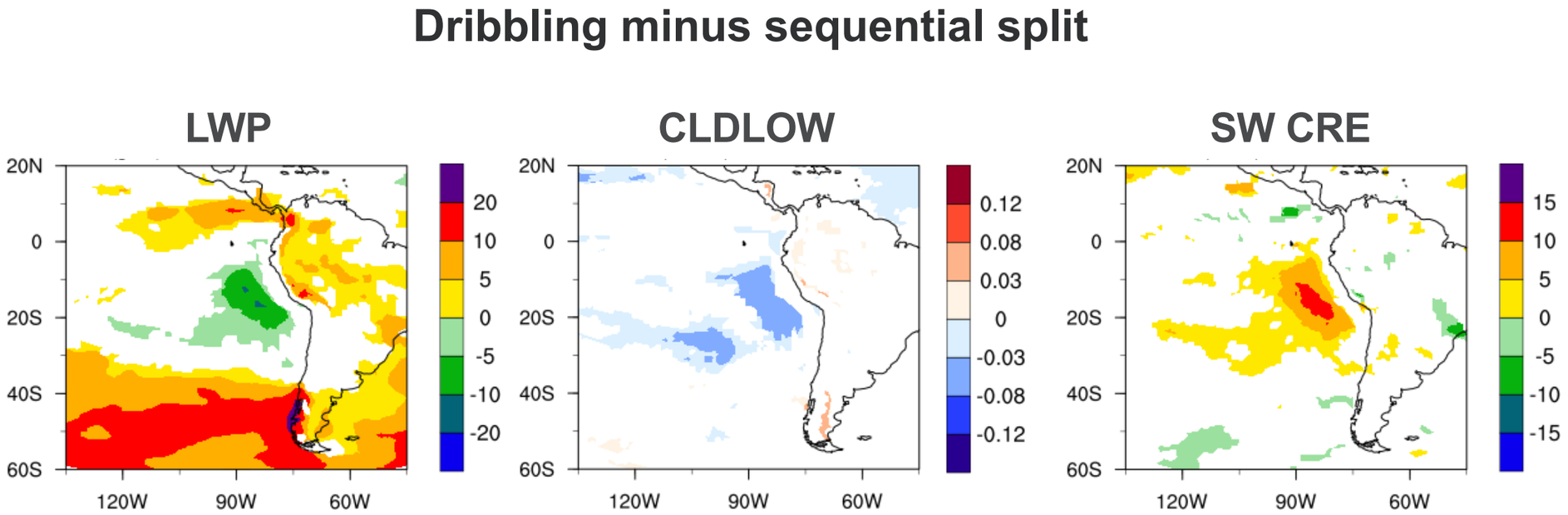
Time series of cloud liquid amount



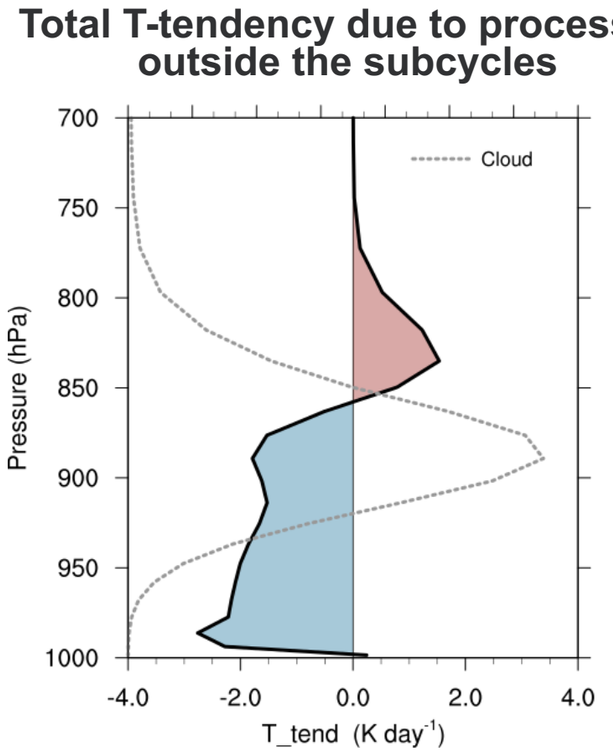
In the VOCALS region

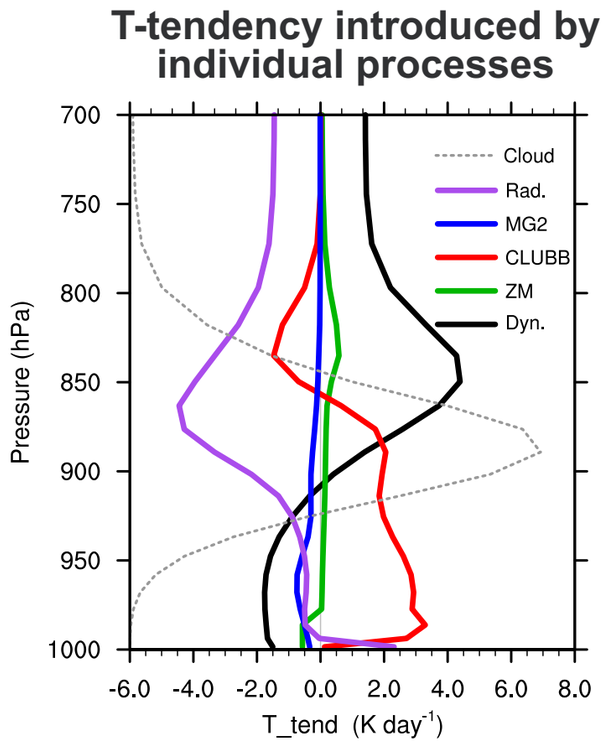


10-year mean changes in the VOCALS region



Why decreases in cloud amount?

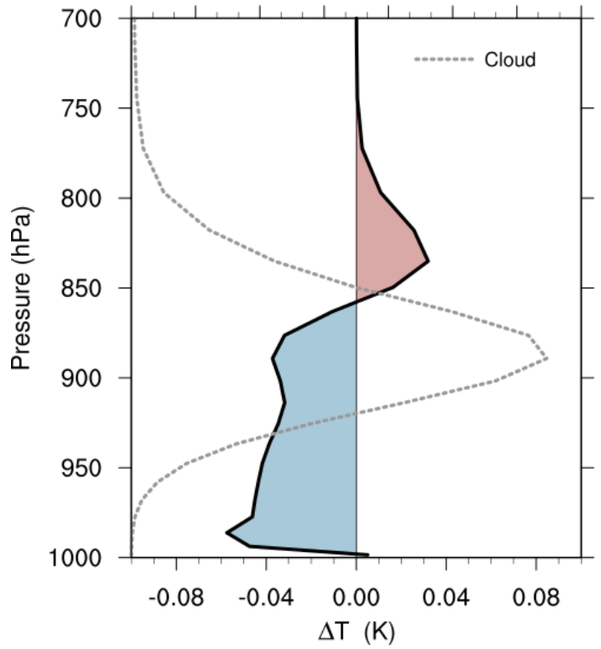




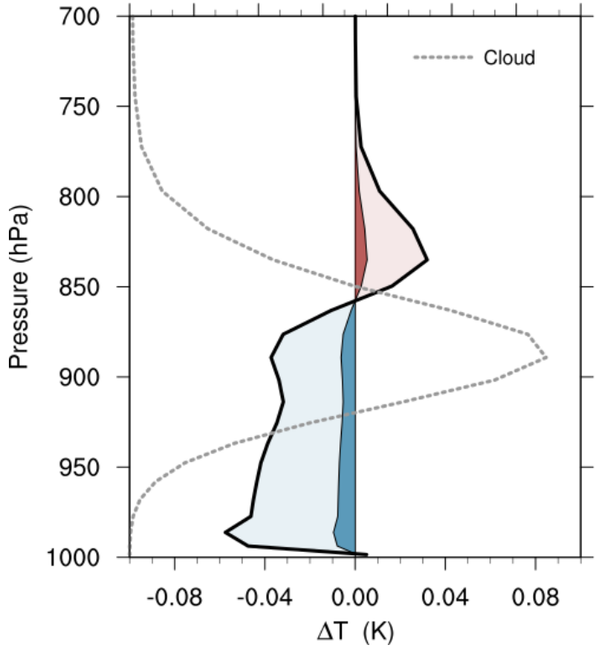
Sequential splitting v.s. dribbling

T increment

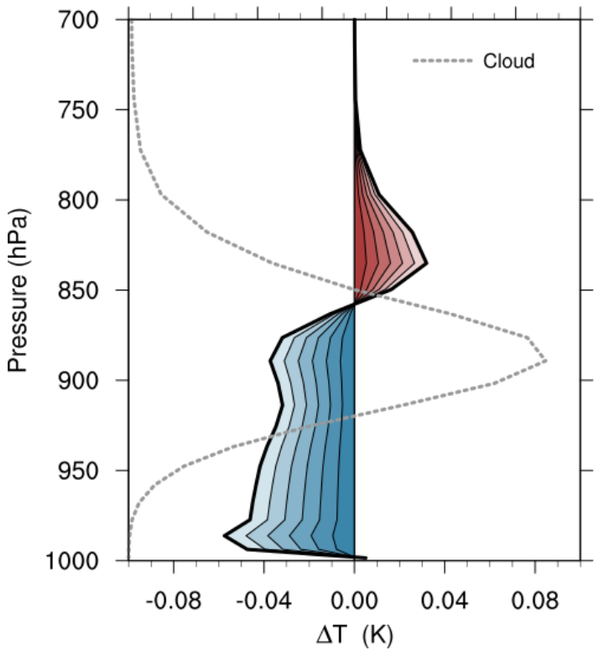
Applied over a 30-min time step if sequentially split



Applied before 1st 5-min substep if dribbling



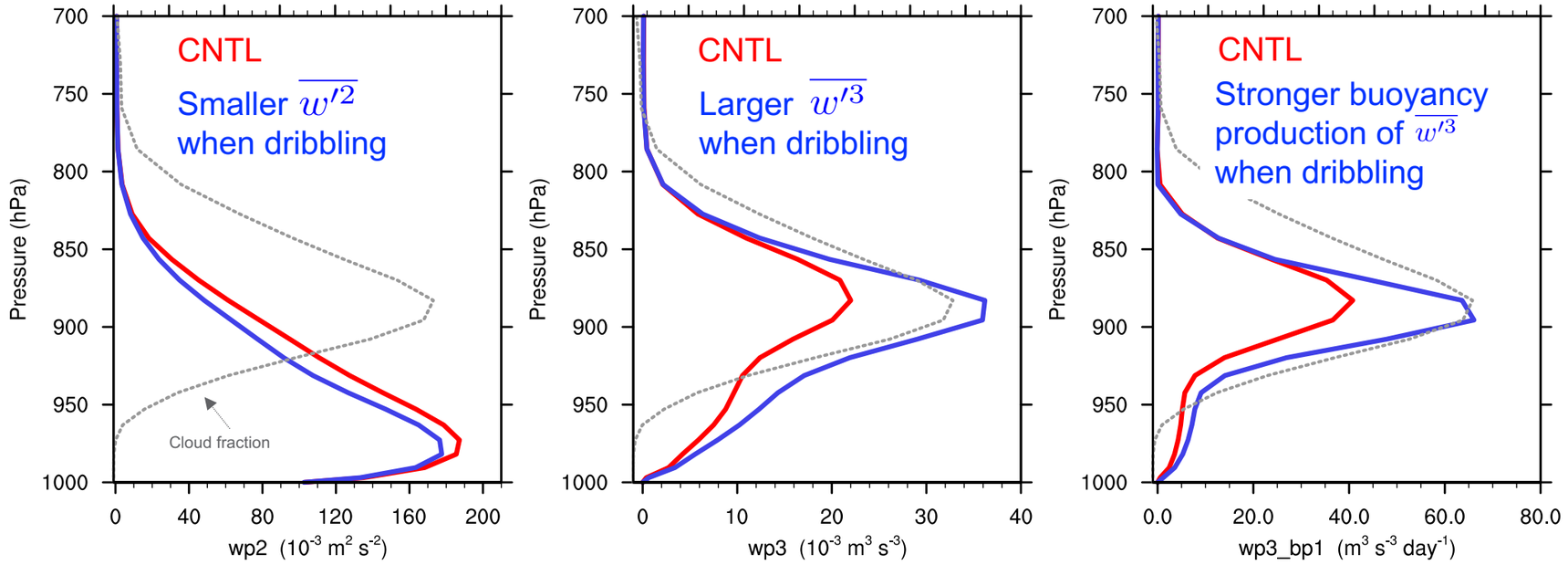
All substeps of dribbling



Effects of dribbling

- The atmosphere “seen” by CLUBB 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 CLUBB**

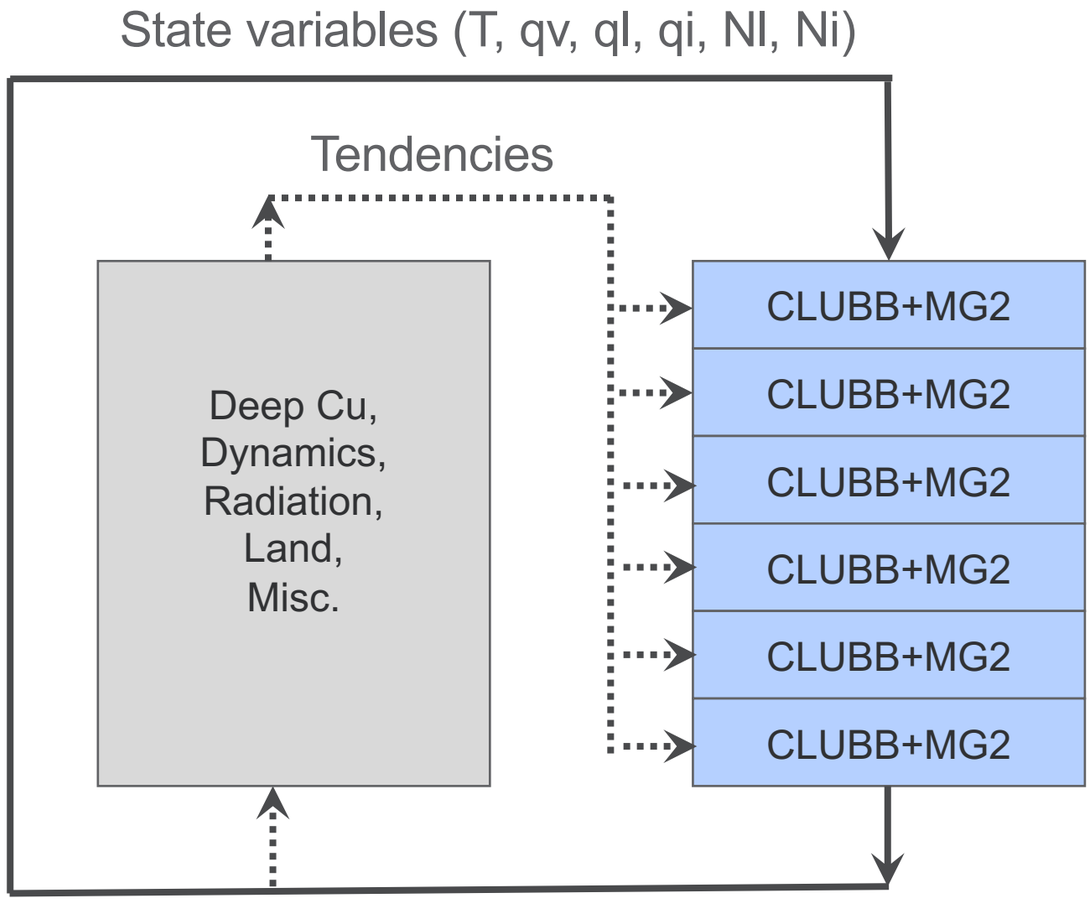


Conclusions

- 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 subcyles 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



Cloud liquid tendencies: with dribbling

Zonal mean CLDLIQ tendencies