Evaluating Convective Quasi-Equilibrium in a Global CRM

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GMAO
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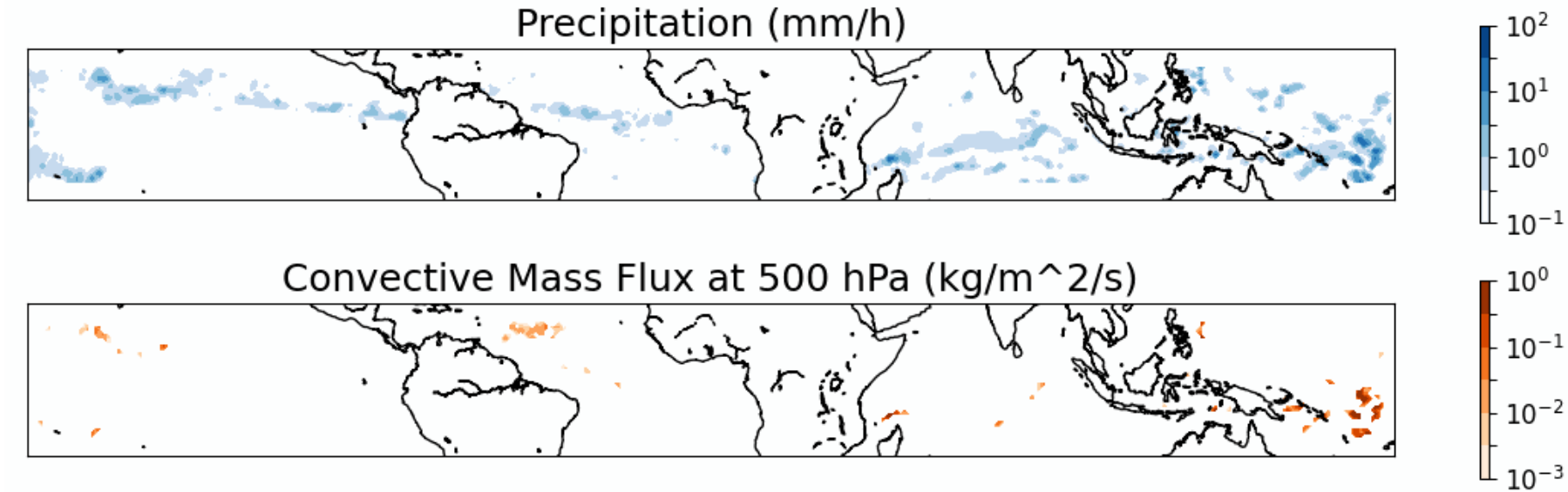
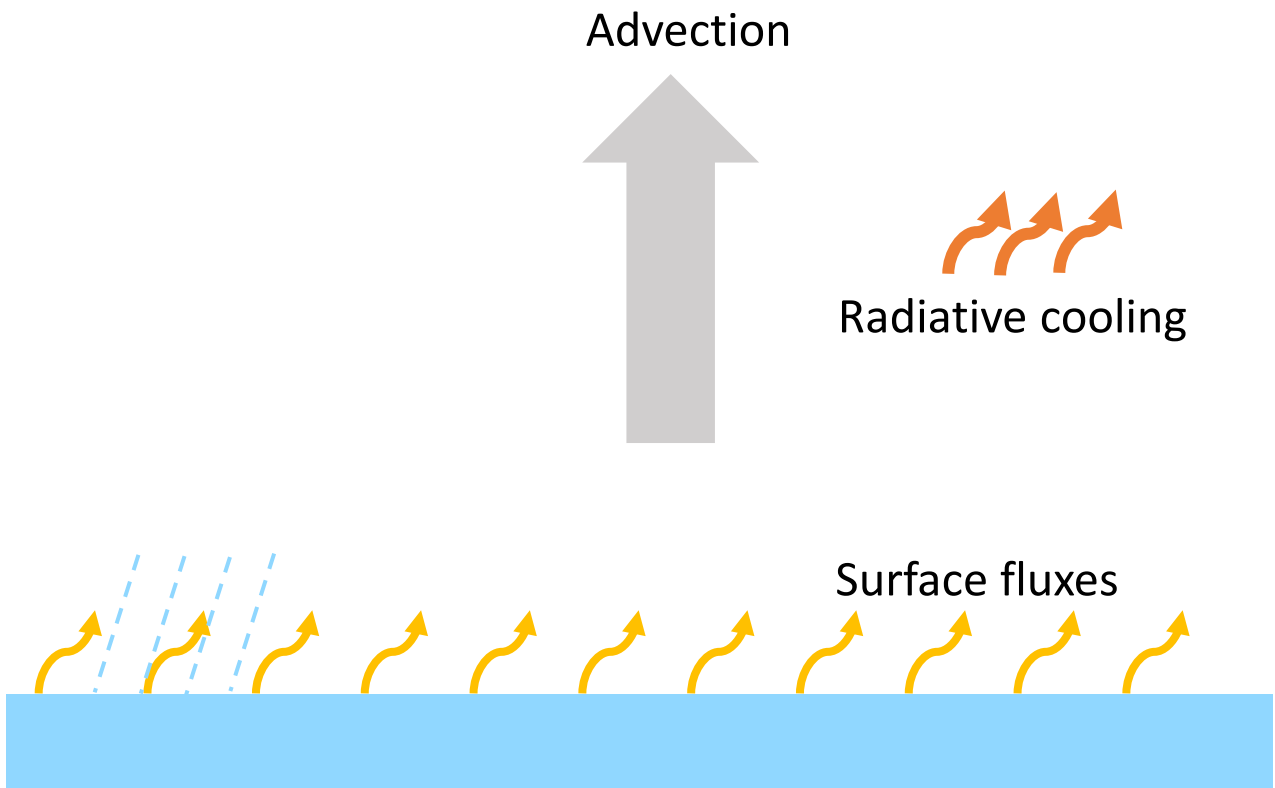
NPP
NASA Postdoctoral Program



The closure problem: Given large-scale forcings, how much convection is there?



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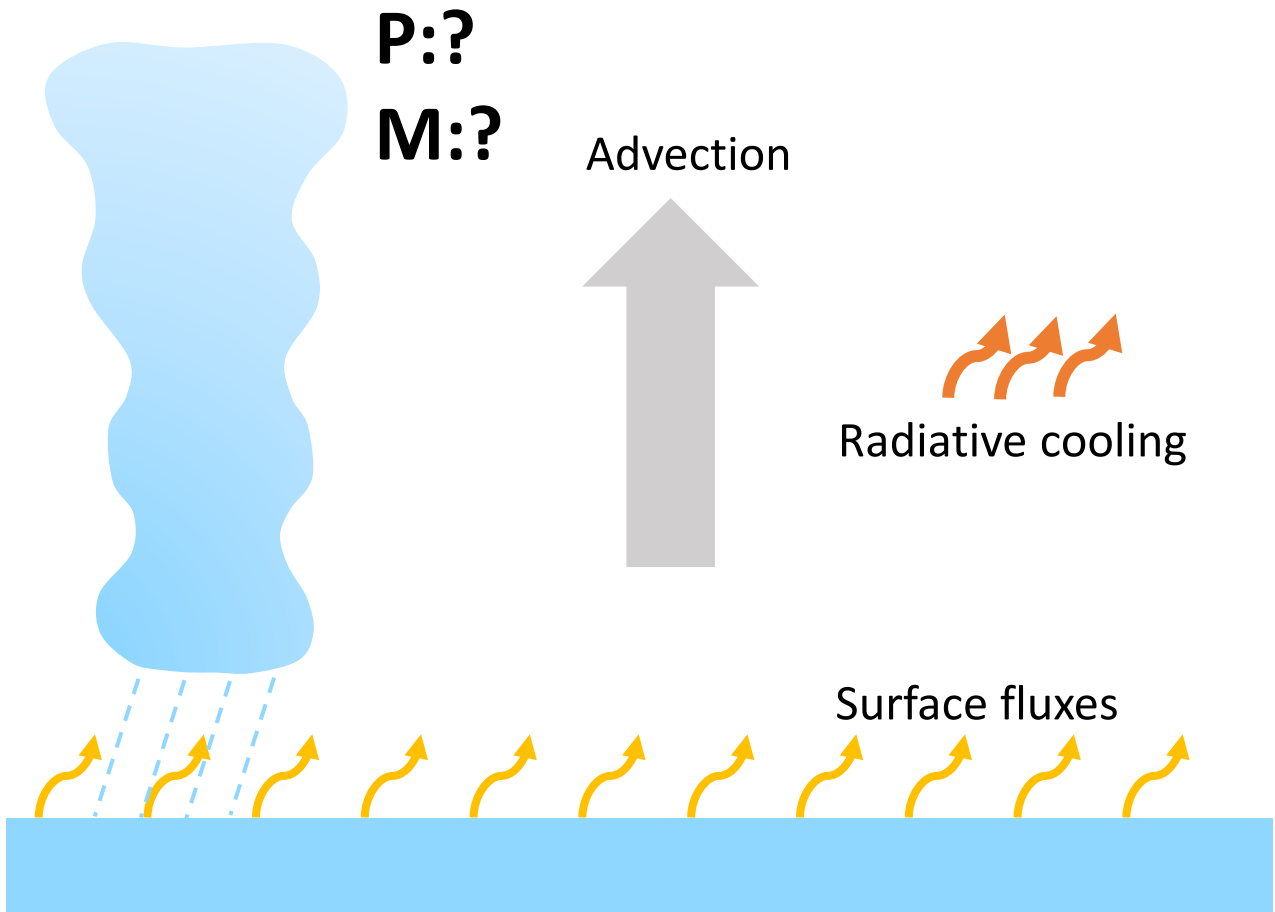
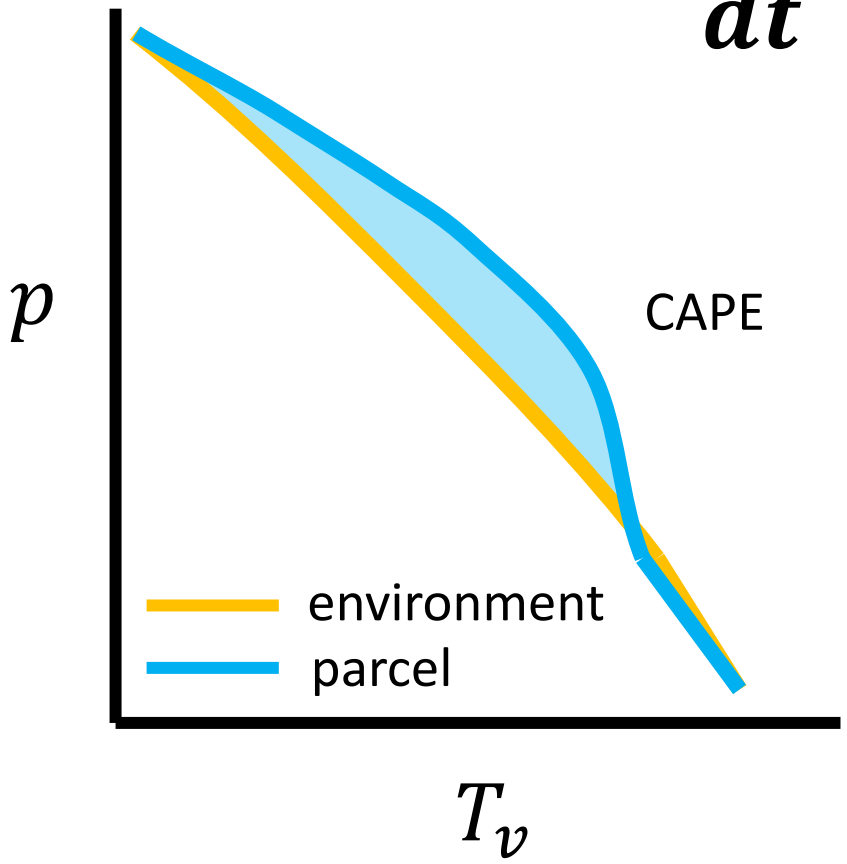
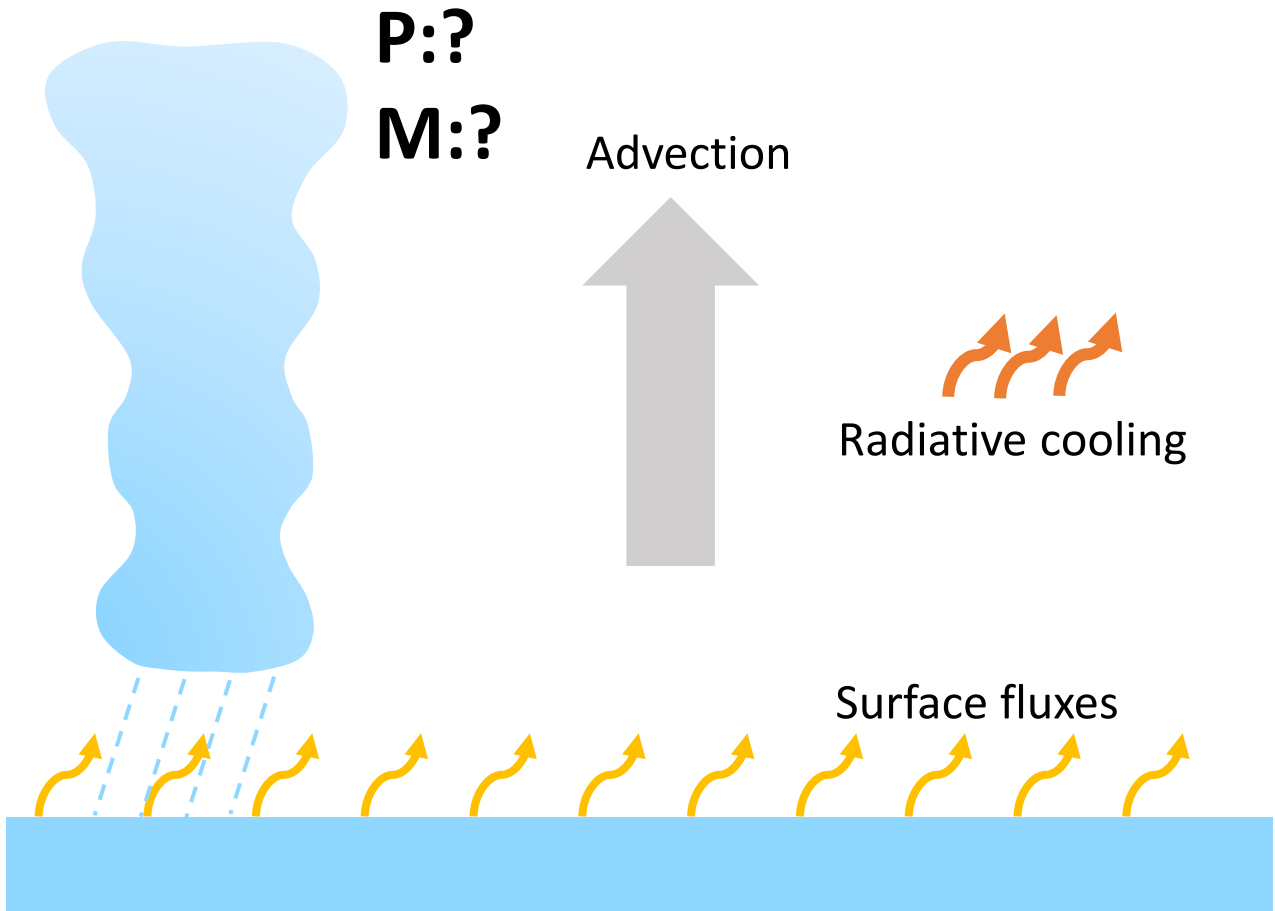


Convective Quasi-Equilibrium (CQE): Convective instability is fixed.

$$\frac{dCAPE}{dt} = 0$$



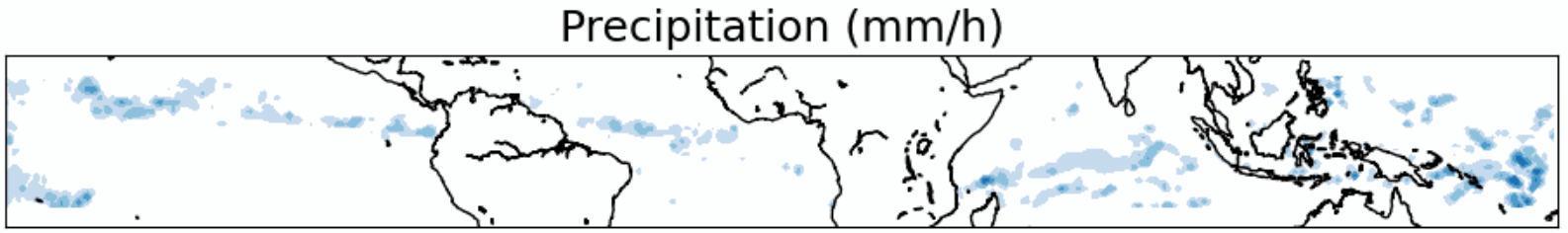


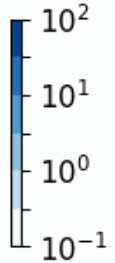
How well does CQE hold in a NASA GEOS convection-permitting simulation? ($\Delta x \approx 3\ \mathrm{km}$).

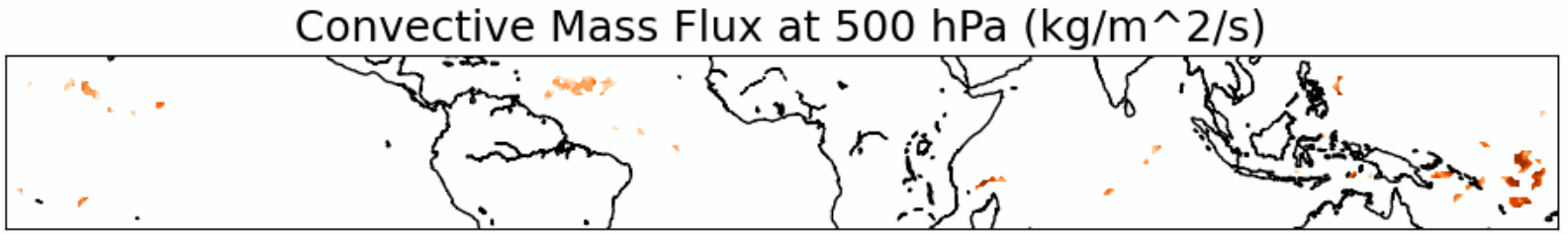
DYAMOND v2 simulations:
January-March 2020

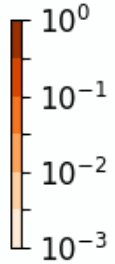
”Large Scale”: All fields regridded to 1° horizontal resolution

Deep tropical (±15°) domain of interest:



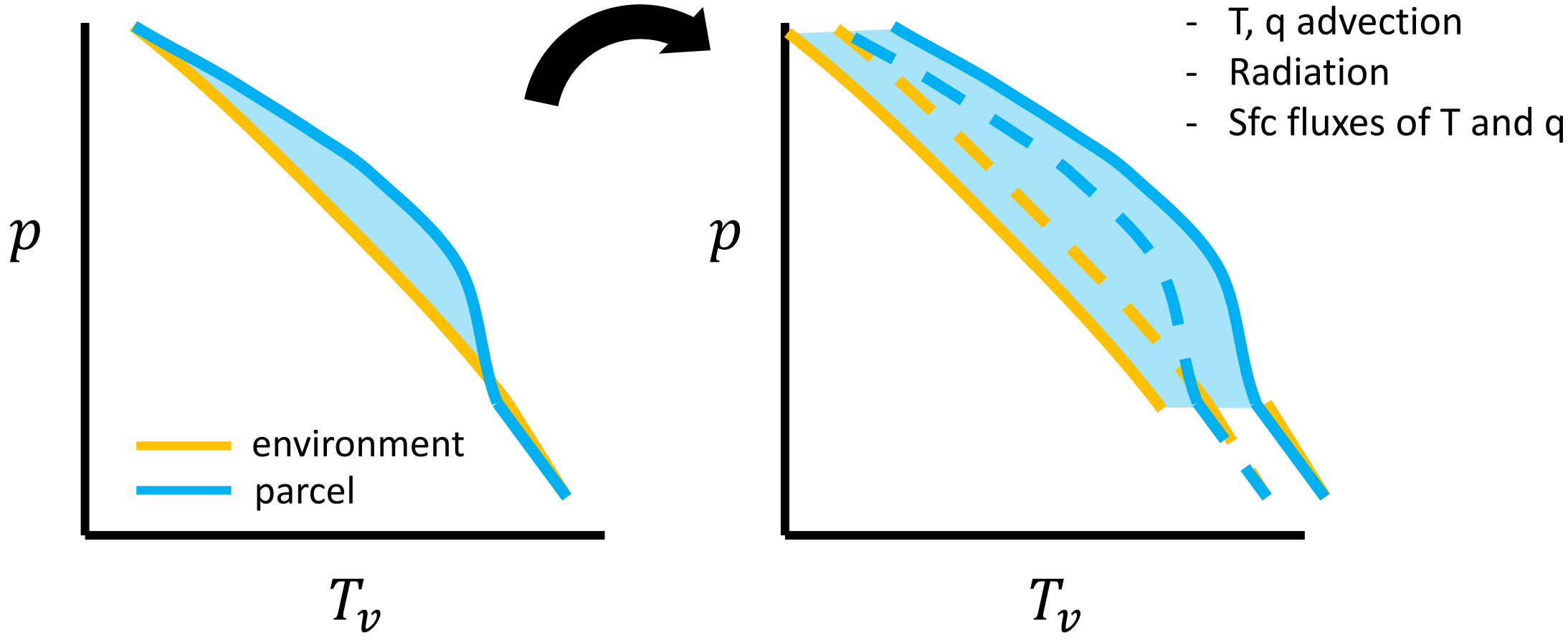






500 hPa Mass flux: from cloudy model grid cells with w > 0.5 m/s

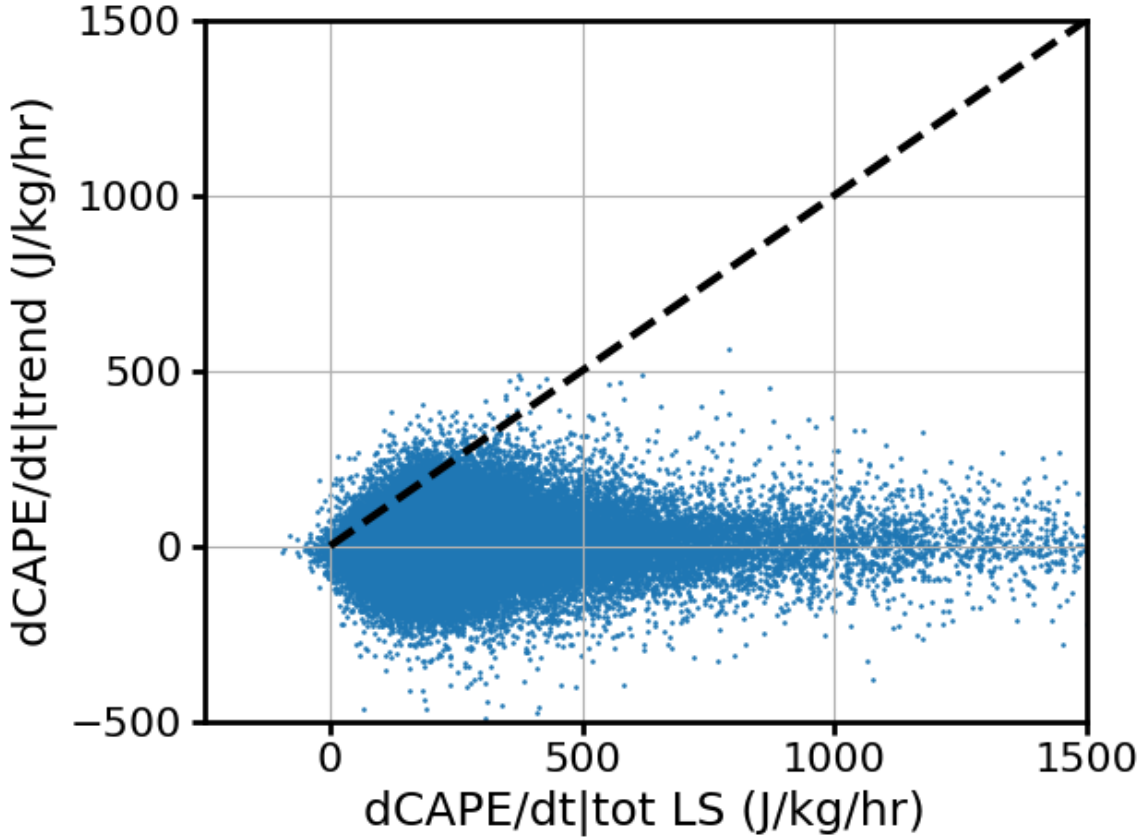
We calculate the large-scale forcing on CAPE.

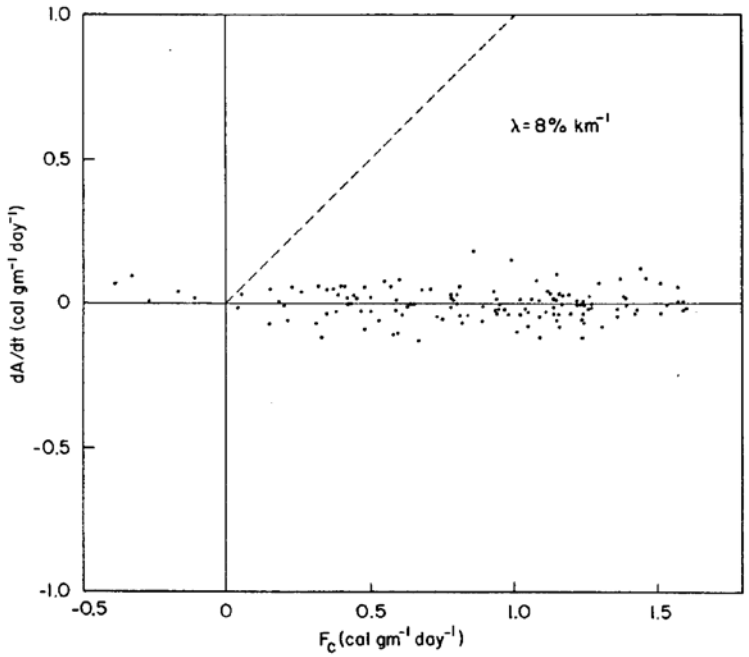


Tendencies:

- T, q advection
- Radiation
- Sfc fluxes of T and q

CAPE is generally fixed regardless of large-scale forcing.





Arakawa & Schubert 1974

Data are 6-hour averages.

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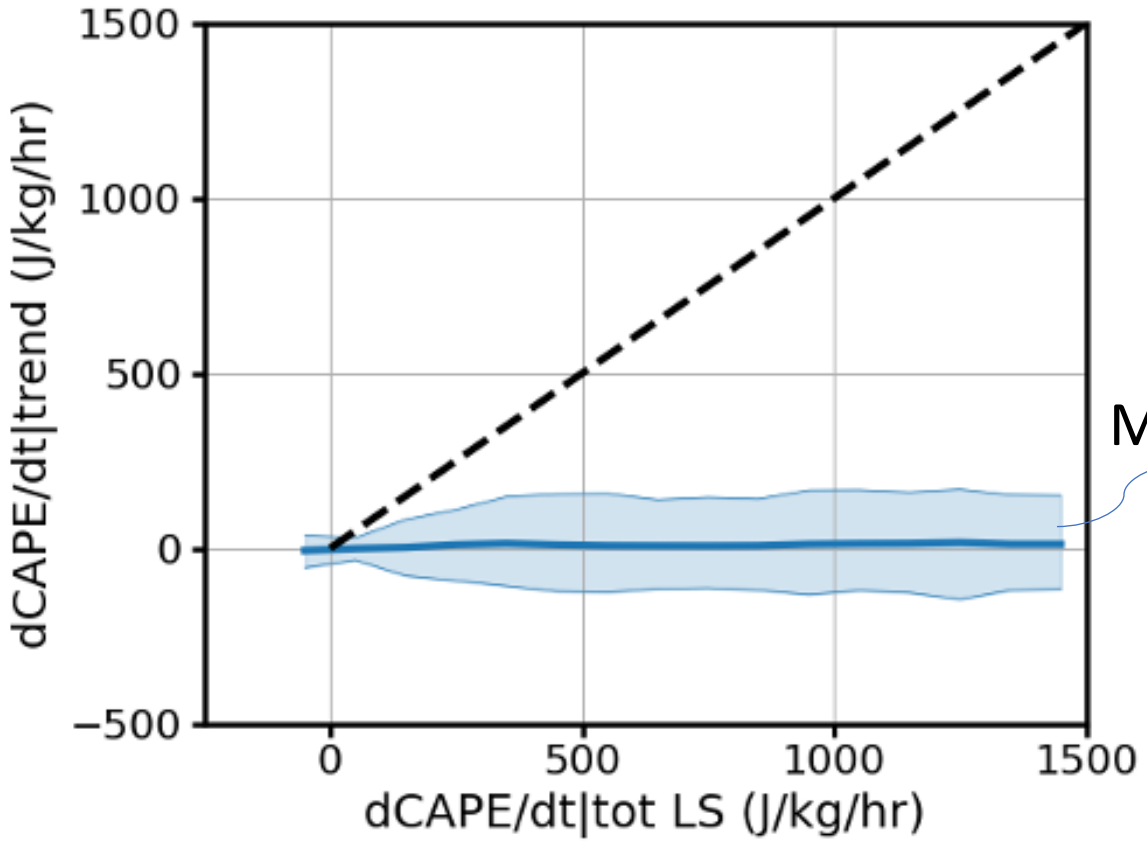

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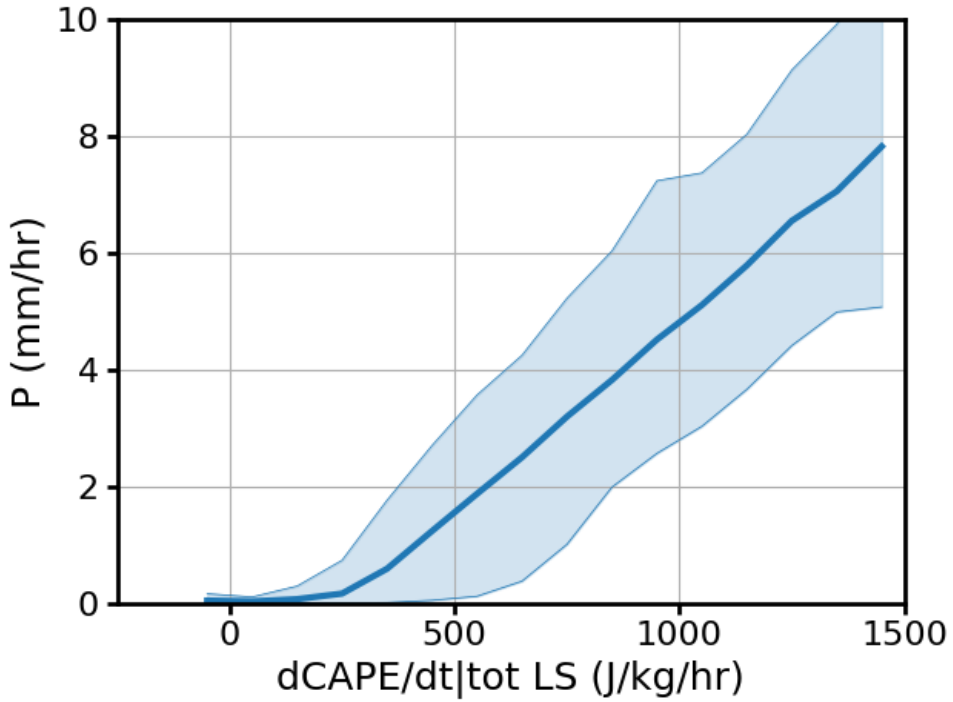
$$\left.\frac{dCAPE}{dt}\right|_{LS} \sim convection$$

There is a clear relationship between CAPE production and convection.

Precipitation:



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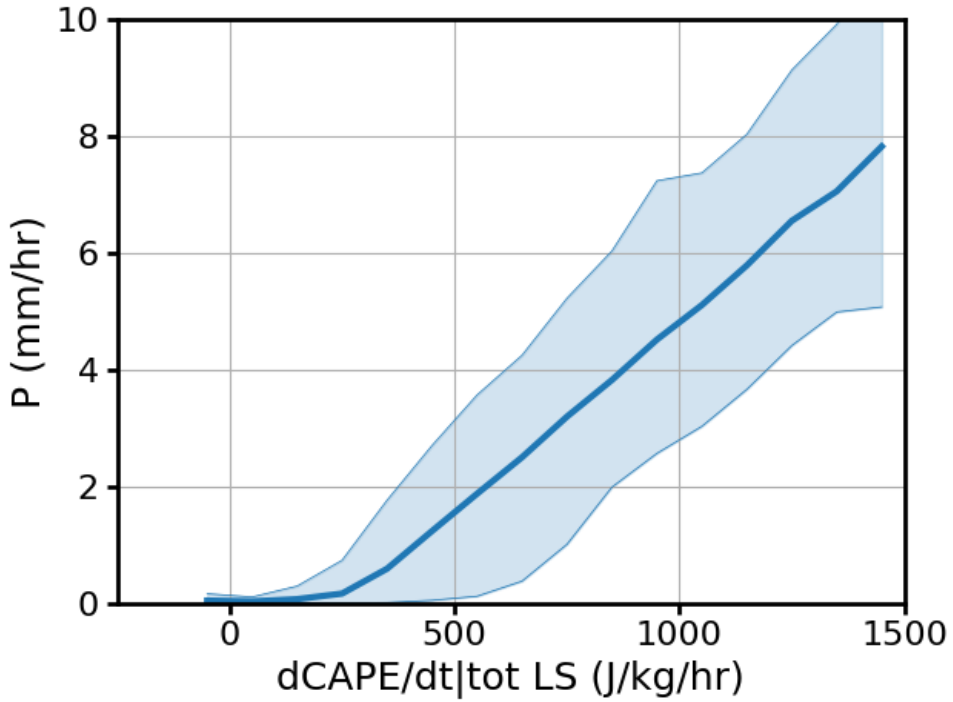
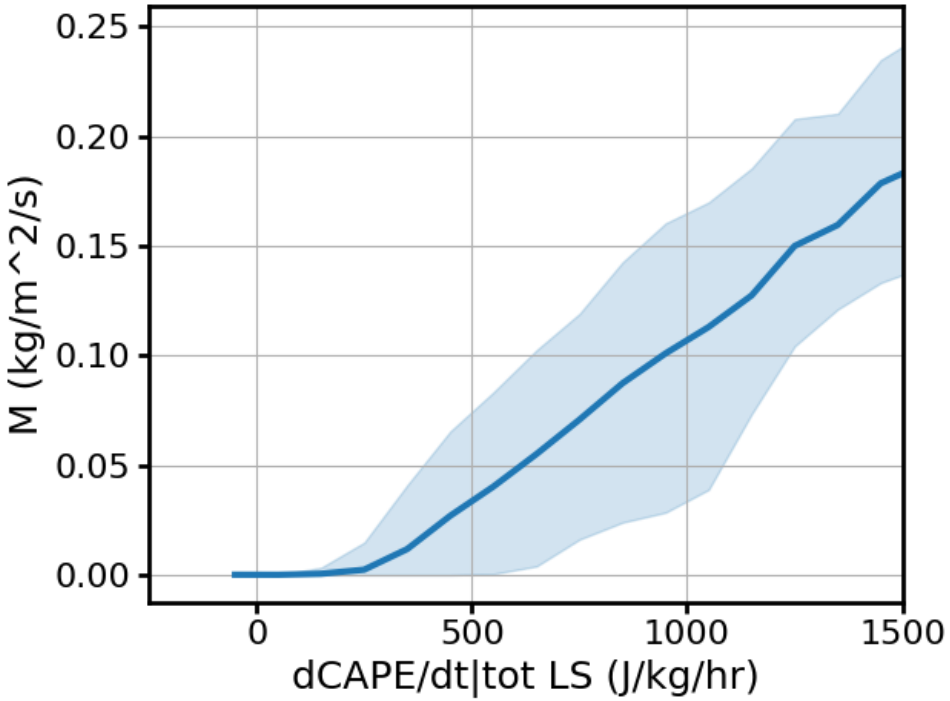


Updraft mass flux:



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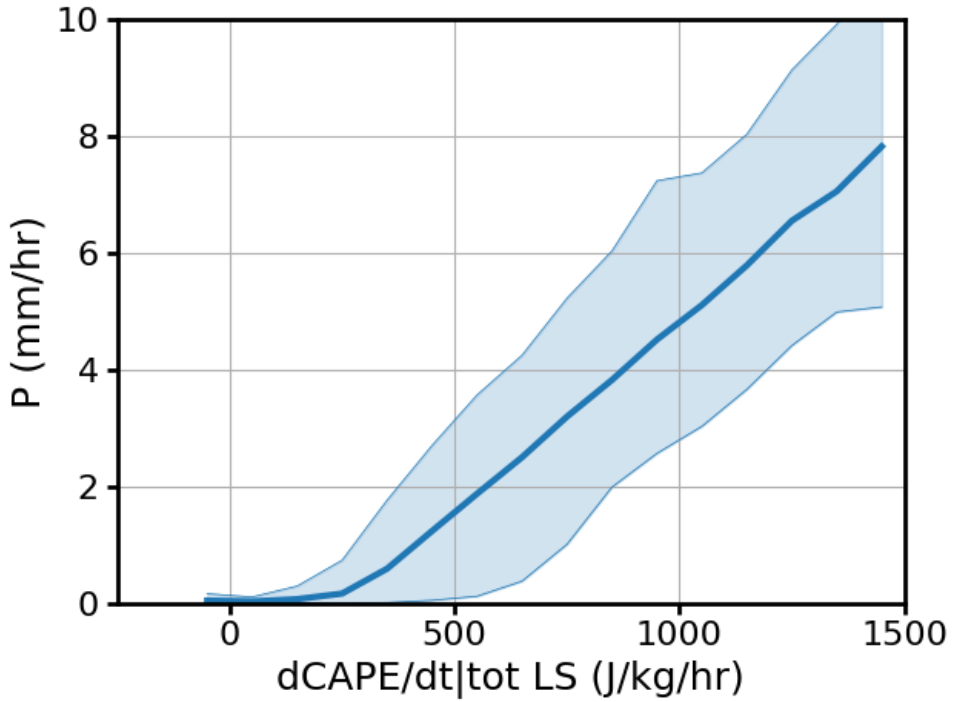
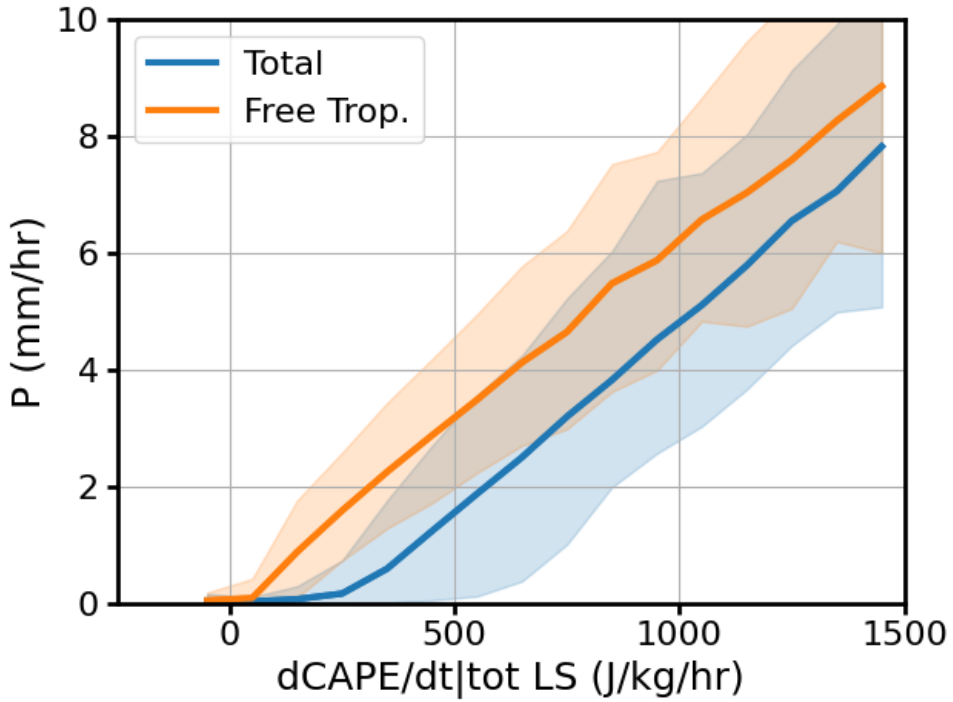


$$\left.\frac{dCAPE}{dt}\right|_{LS} \sim convection$$

Data are 6-hour averages.

Neglecting the boundary layer leads to a better constraint on precipitation.



$$\left.\frac{dCAPE}{dt}\right|_{LS} = \left.\frac{dCAPE}{dt}\right|_{FT} + \left.\frac{dCAPE}{dt}\right|_{BL}$$

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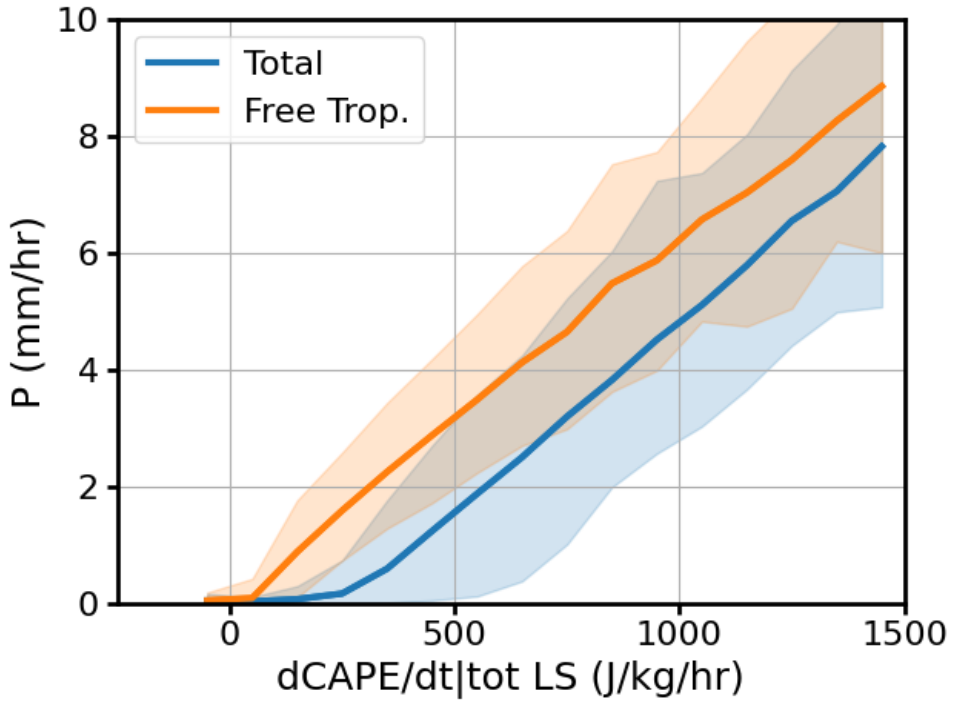

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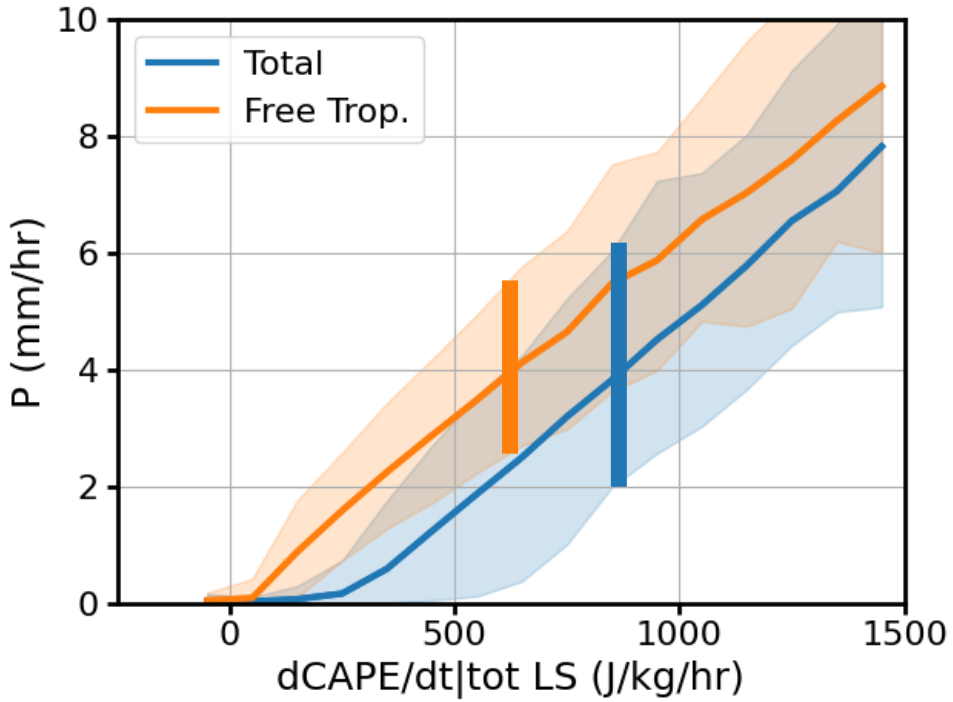

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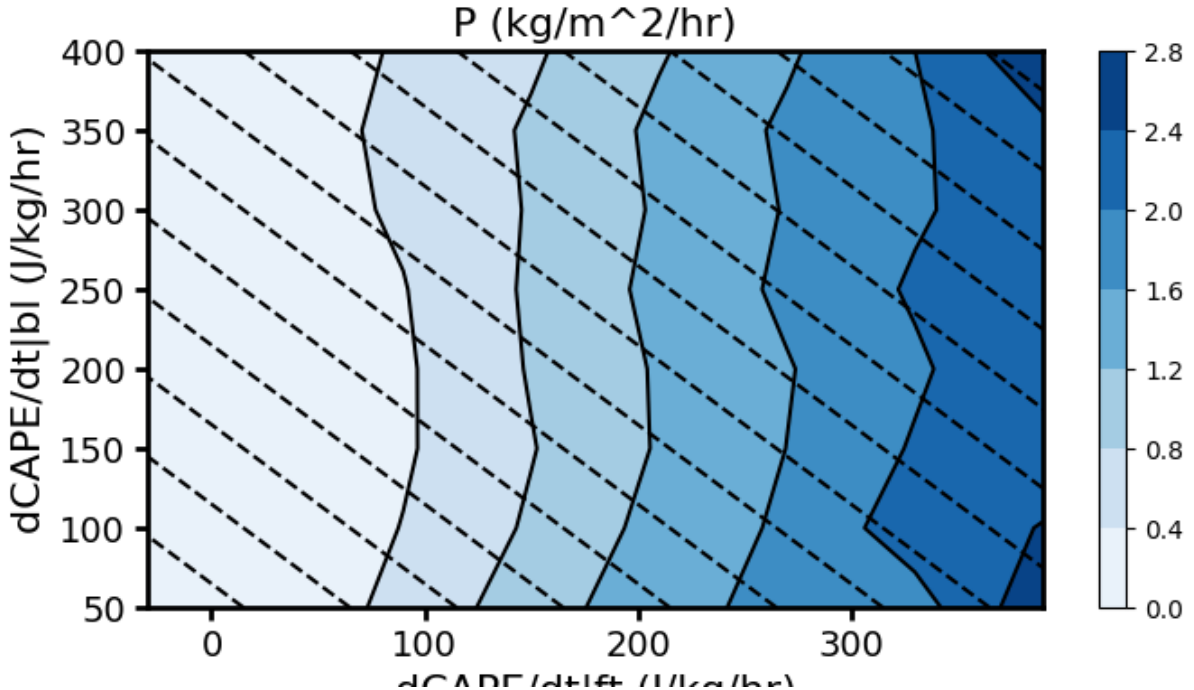
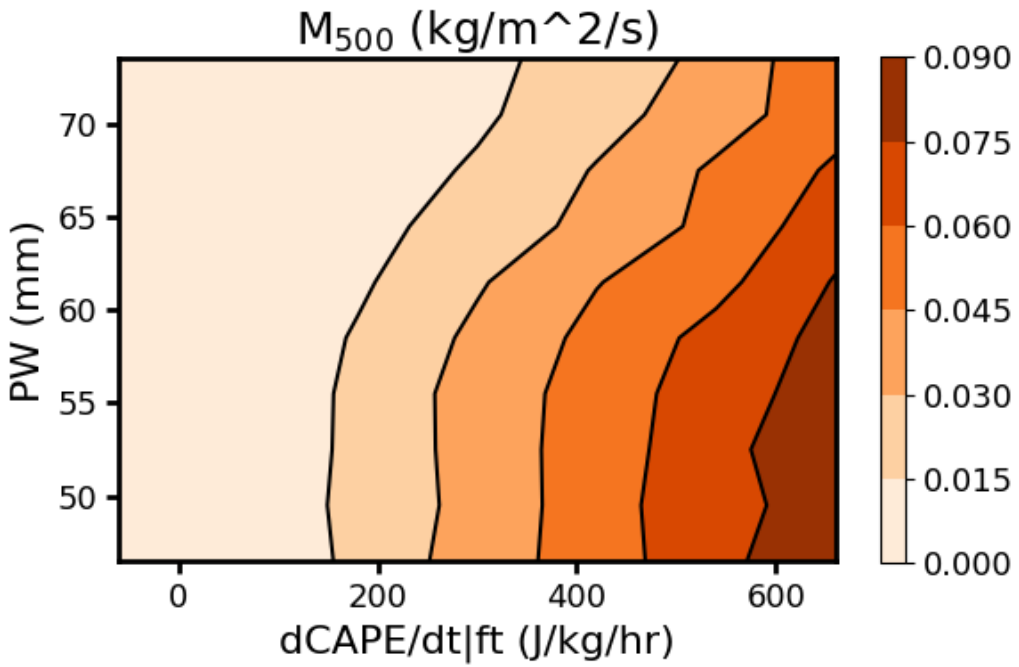
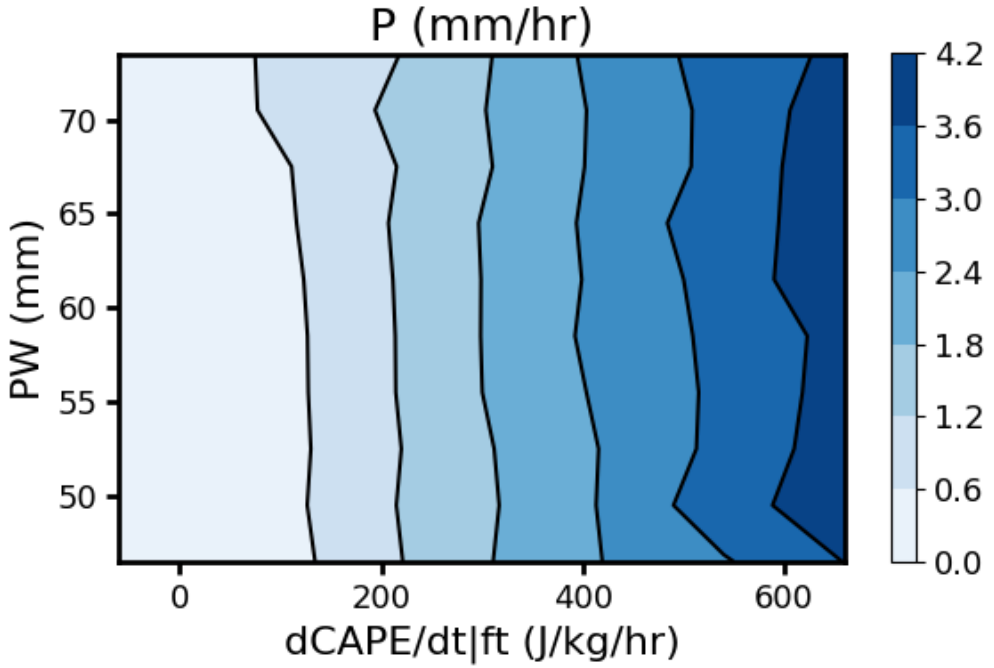
Boundary-layer CAPE forcing does not matter.



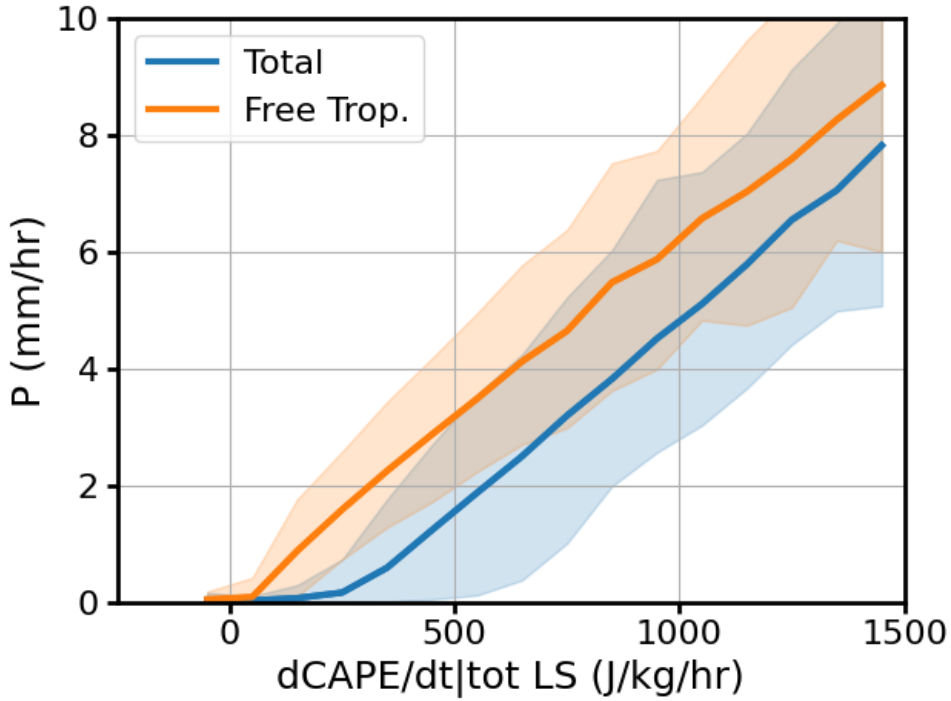
“Free troposphere quasi-equilibrium” (Zhang 2002)

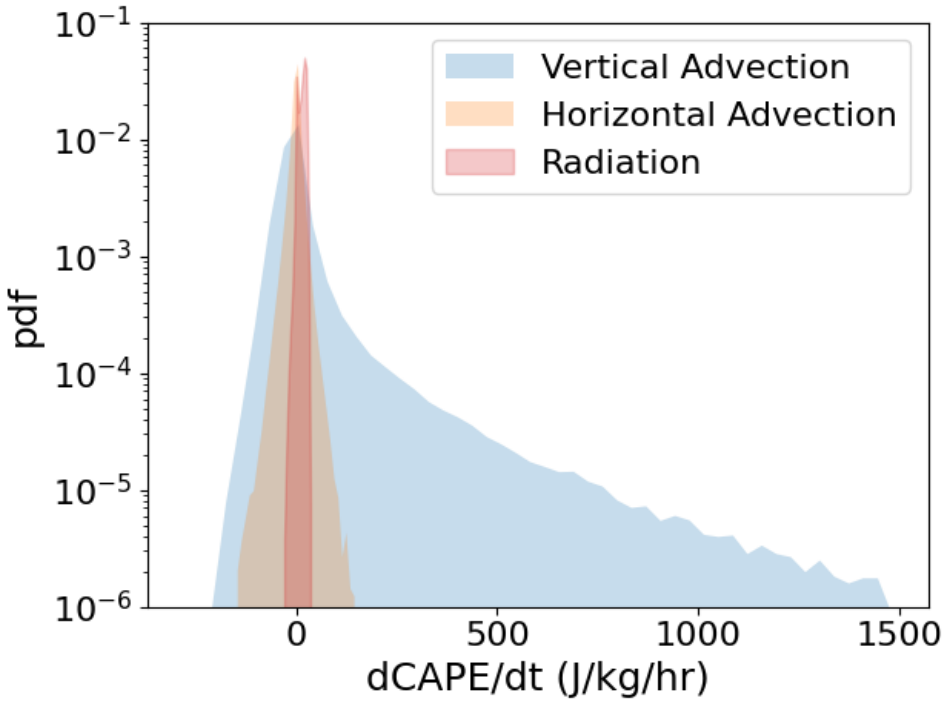
Column water vapor constrains 500 hPa mass flux, but not precipitation.





The variability of dCAPE/dt is dominated by a single process: Vertical advection of θ.





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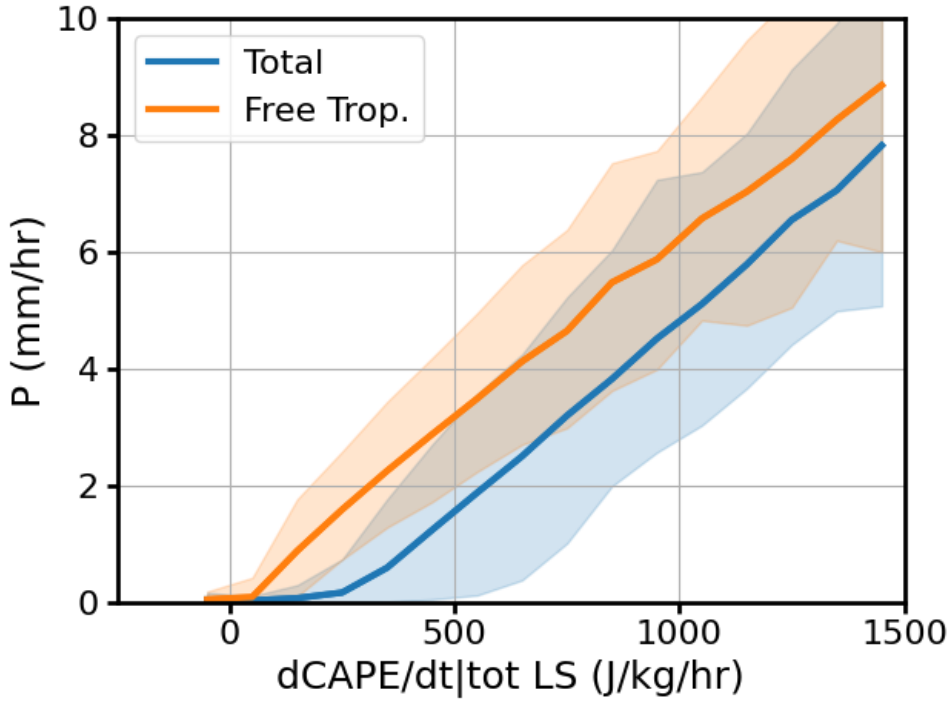
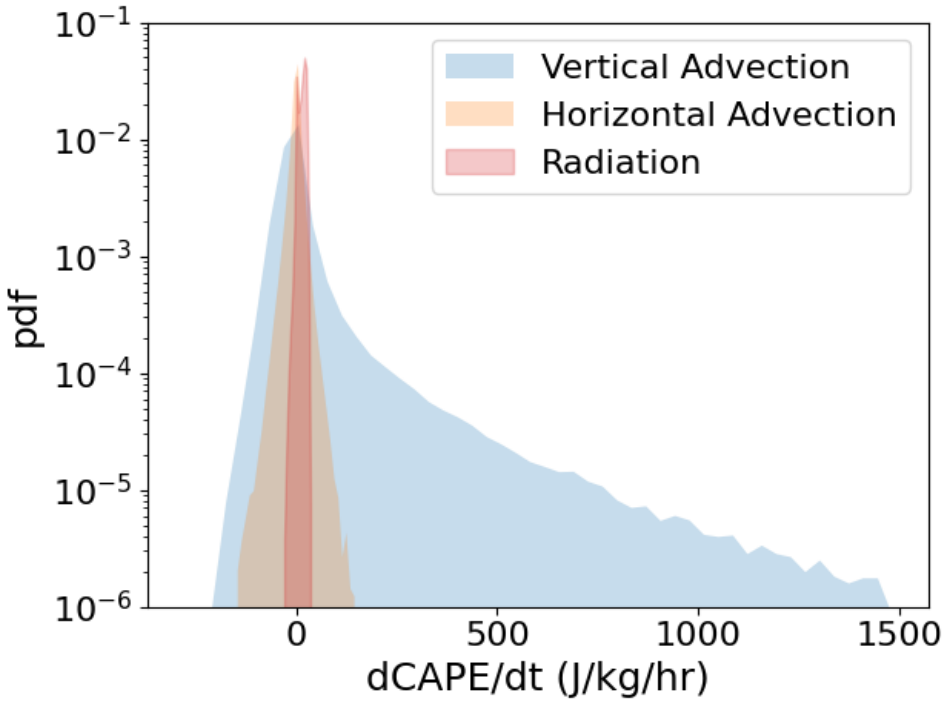
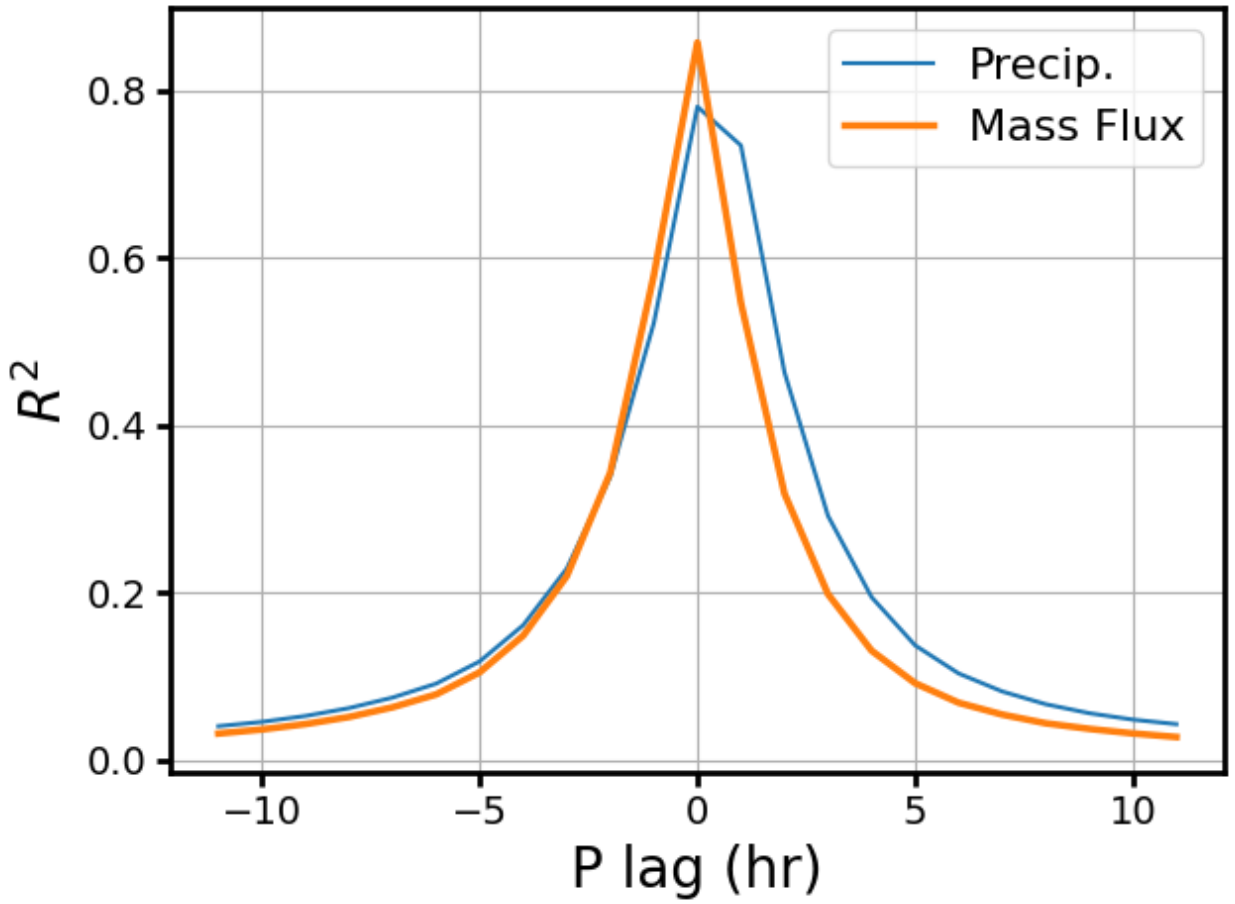




In the tropics, CQE works by predicting deep convection at locations of mean ascent.

We perform separate simple linear regressions at different time lags between M_{500} and dCAPE|ft.

Regression



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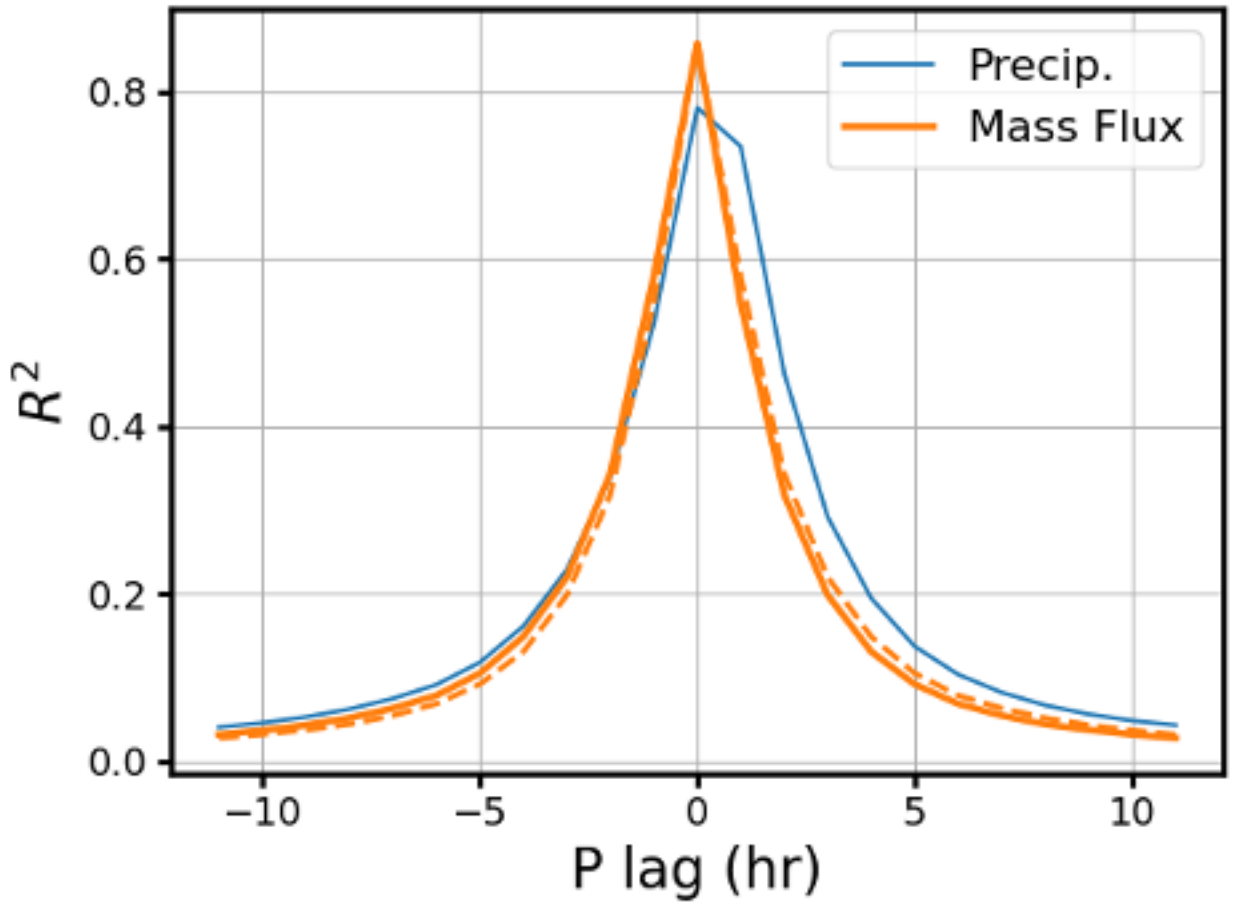
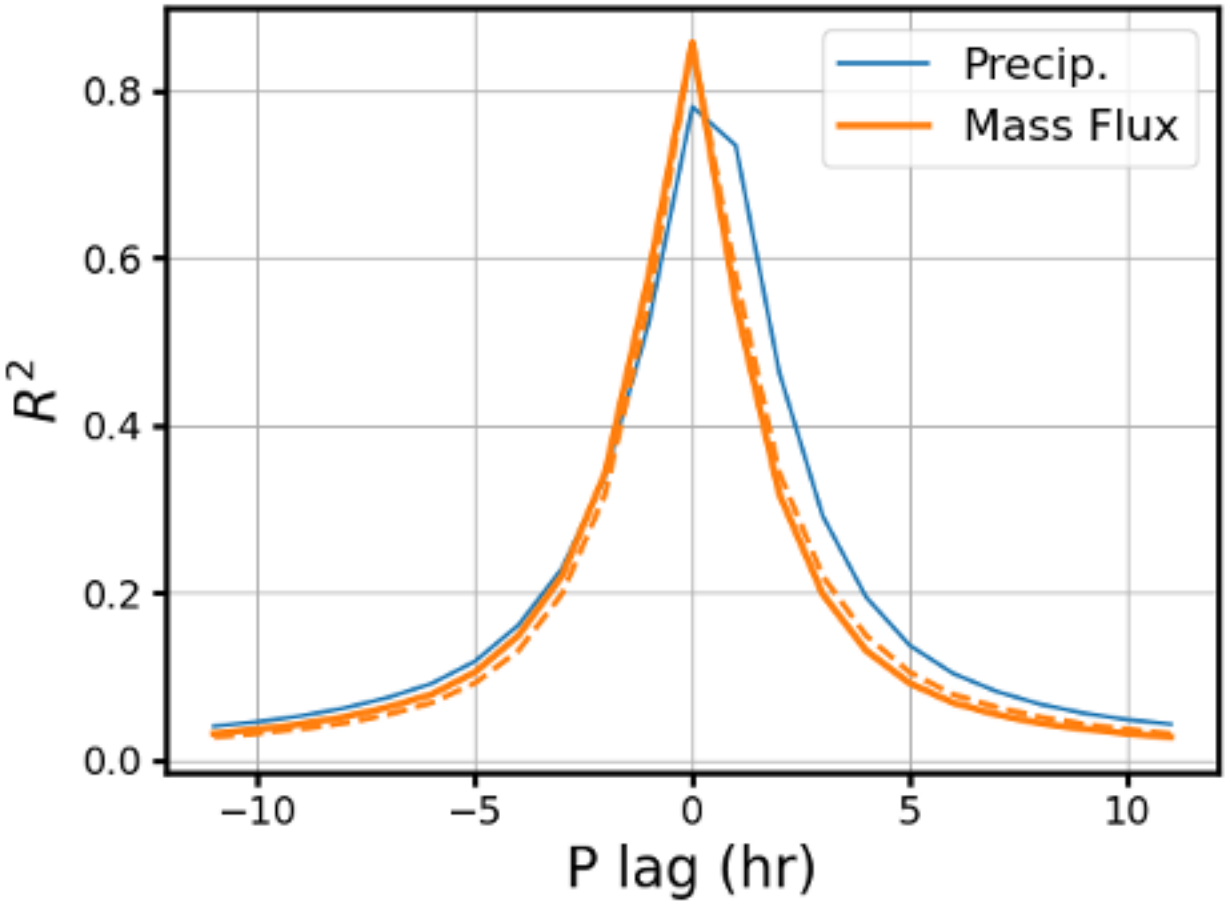
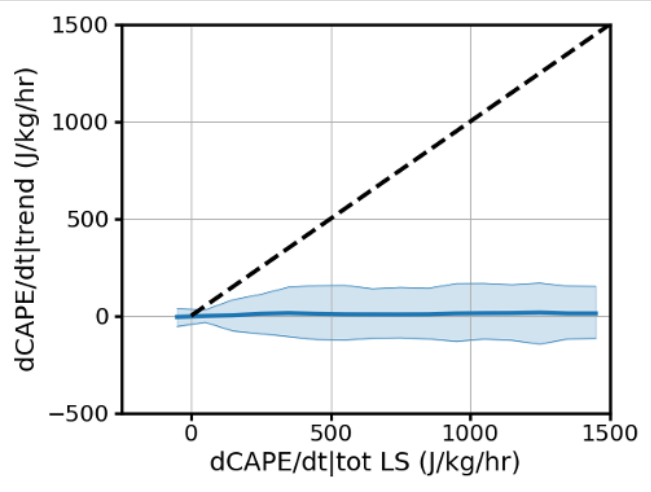


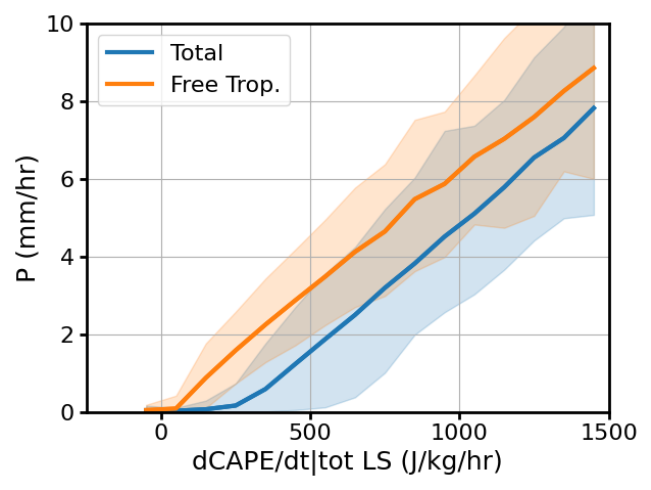
Convection occurs at the same time as the large-scale CAPE forcing.

CAPE forcing and deep convection occur *together*.

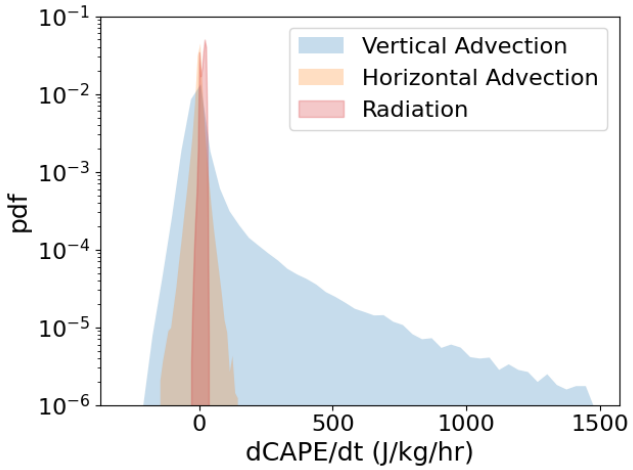


CQE holds up well in a global convection-permitting model.





The CAPE forcing is dominated by large-scale ascent.



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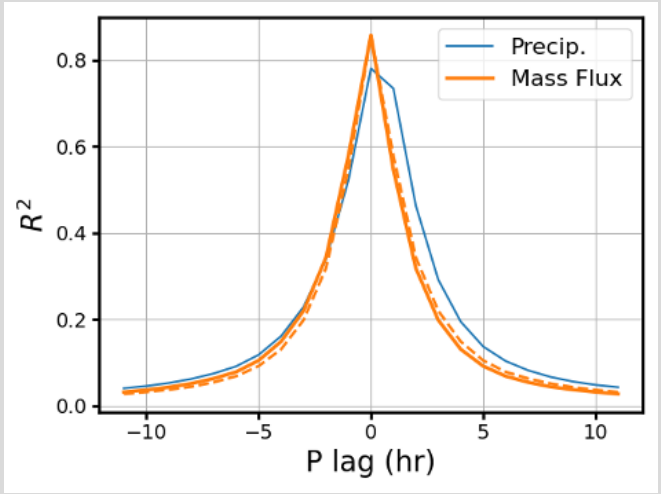
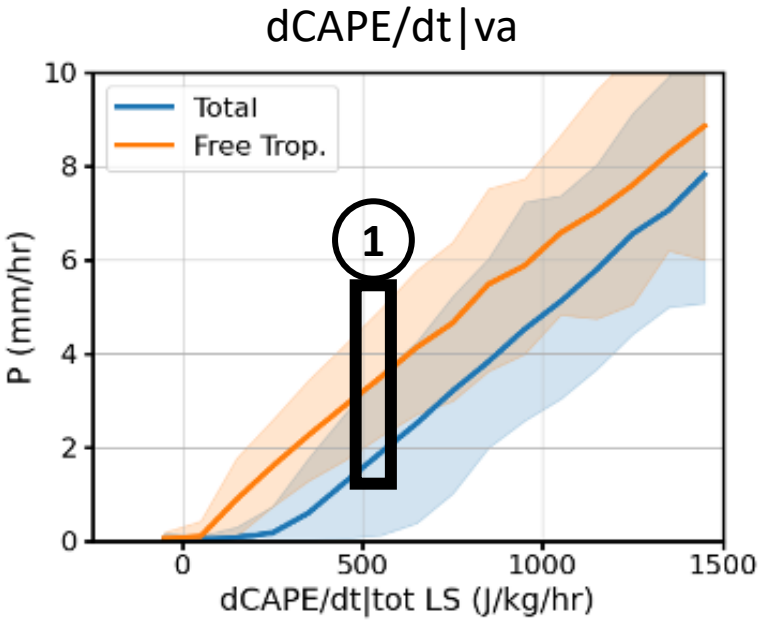
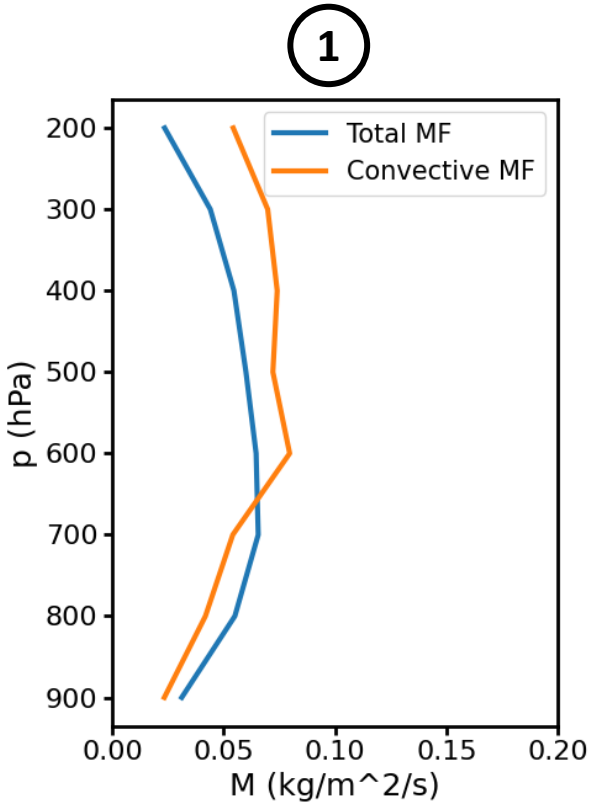


Backups

The large-scale ascent mostly consists of convective updrafts.





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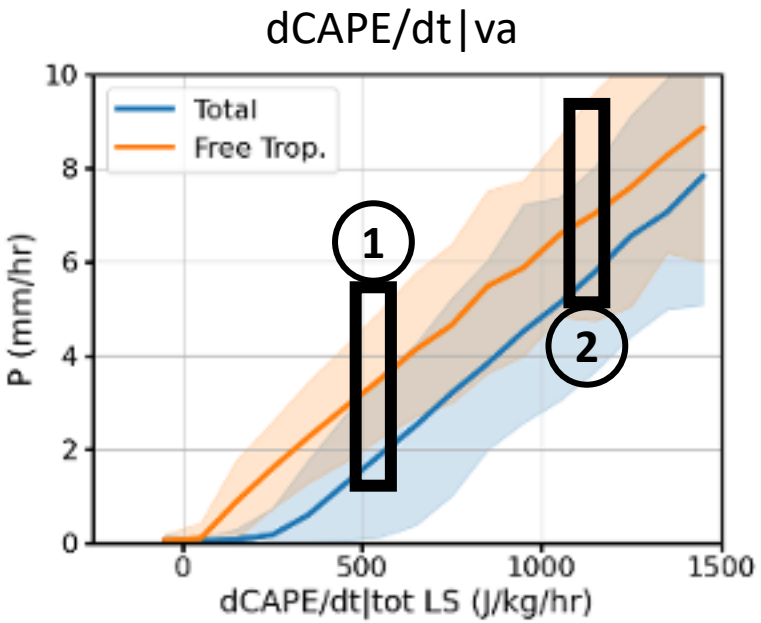

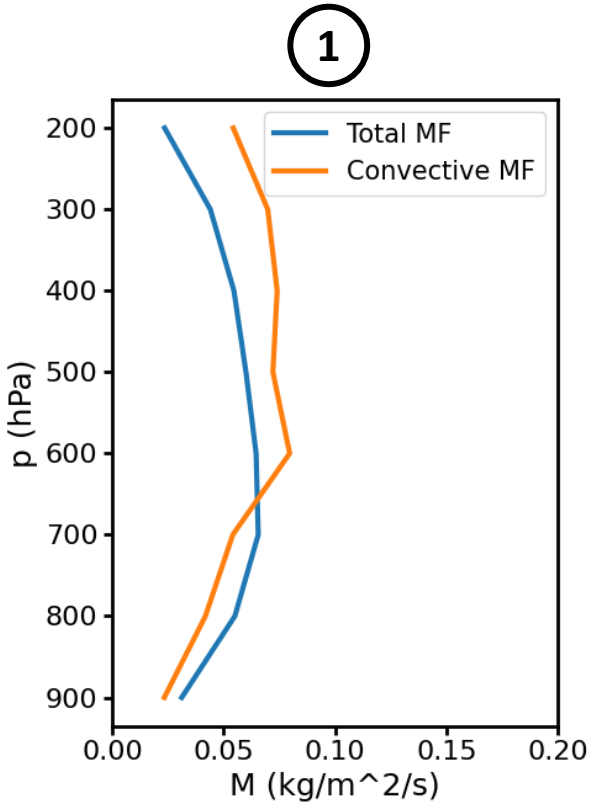

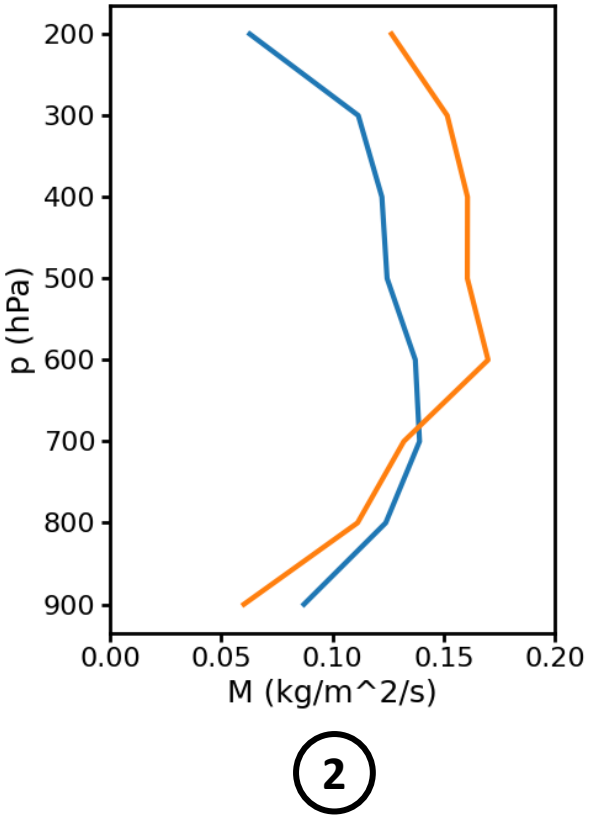

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