THE CAUSE OF UNREALISTIC, INTENSE PRECIPITATION EVENTS IN HIGH RESOLUTION SIMULATIONS WITH CAM4

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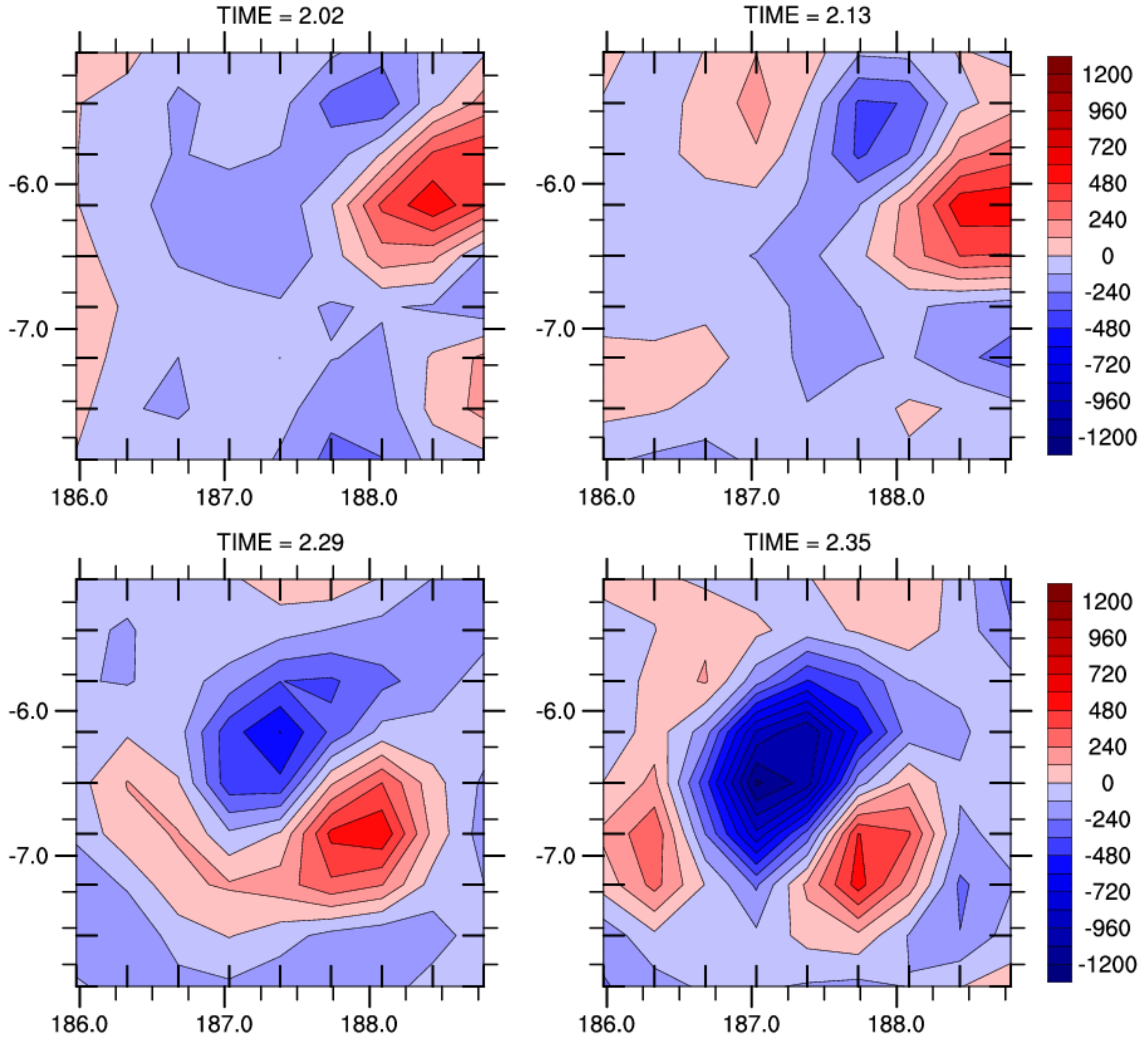
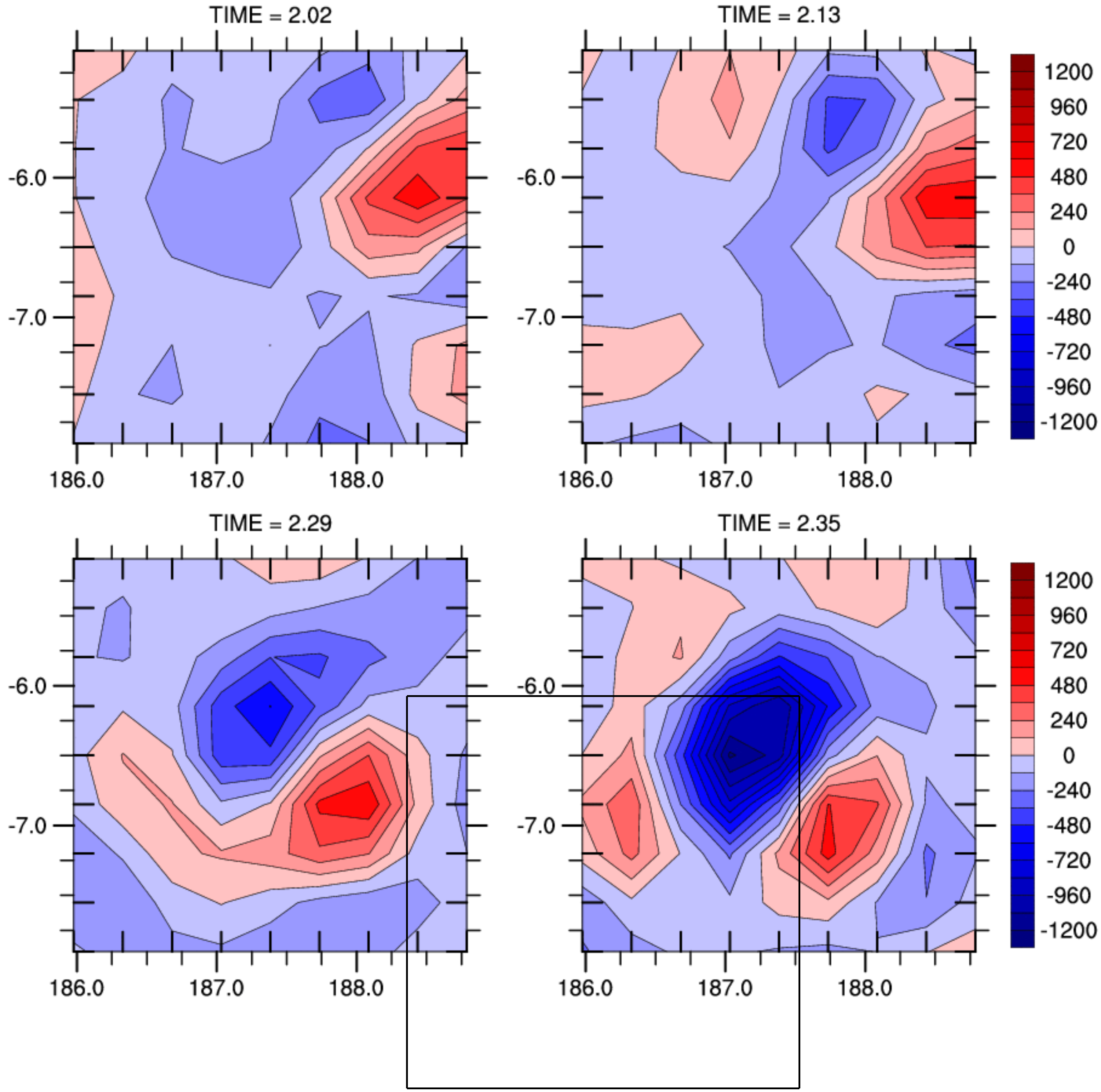
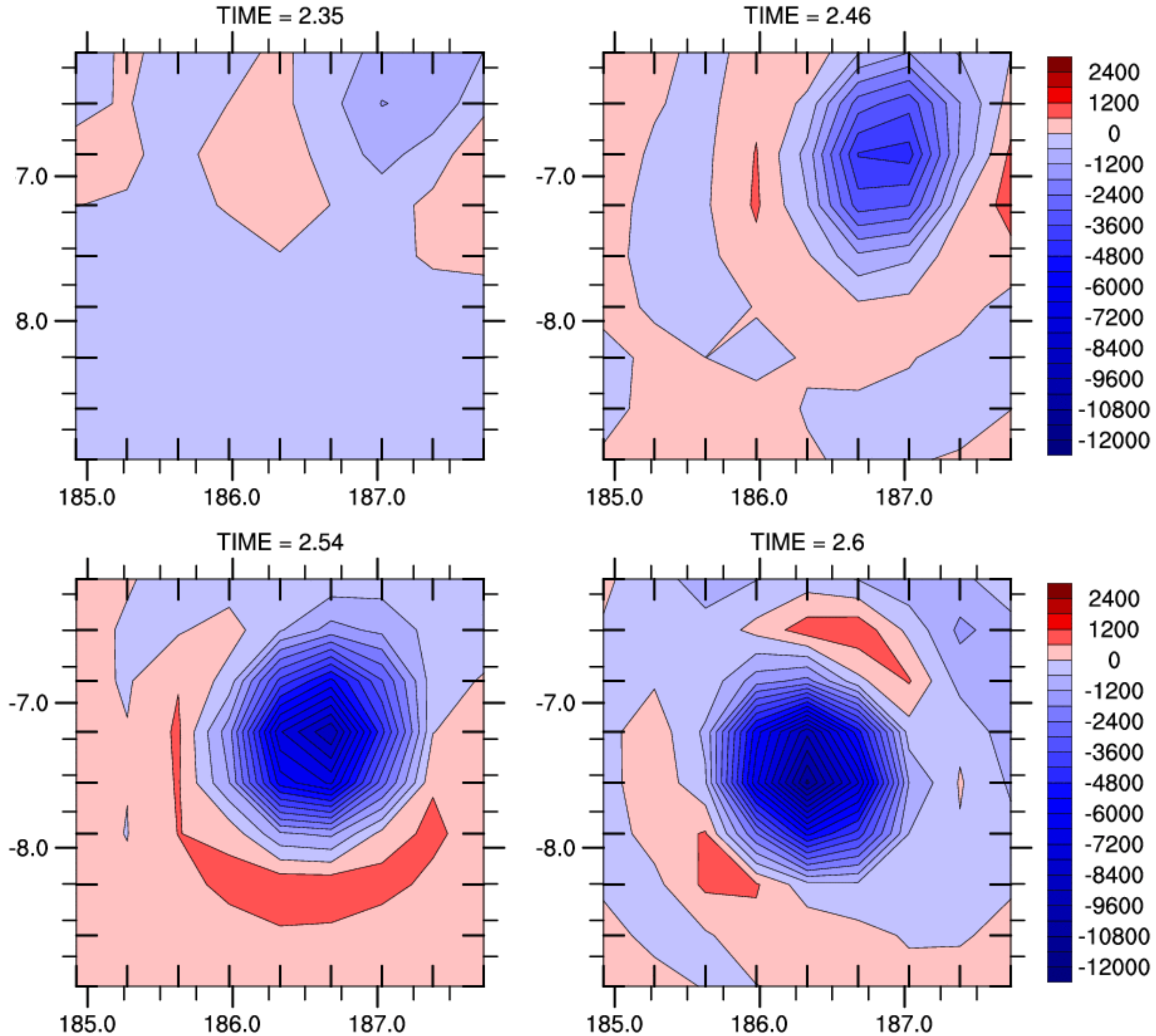
OMEGA AT 600 mb (mb / day) EARLY PERIOD



OMEGA AT 600 mb (mb / day) EARLY PERIOD

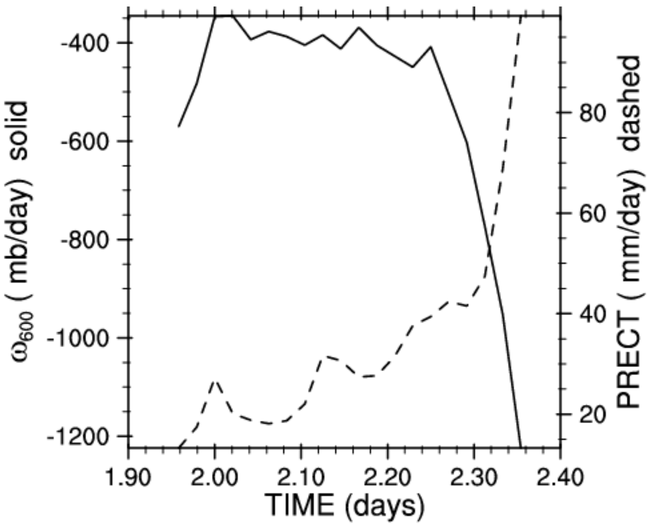


OMEGA AT 600 mb (mb / day) LATE PERIOD

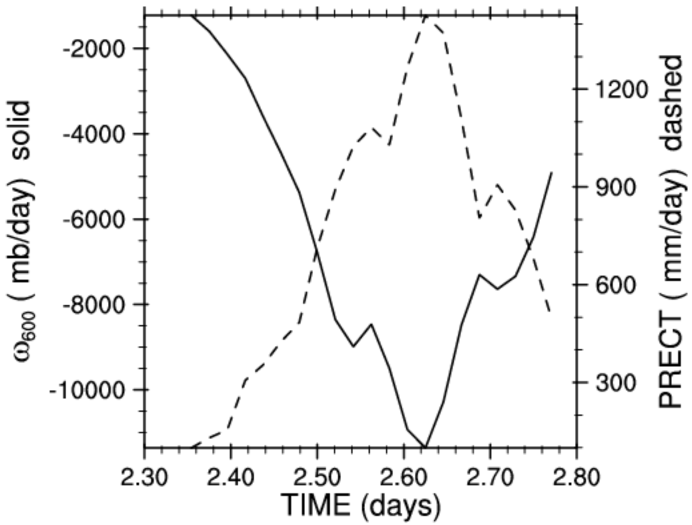


OMEGA AT 600 mb (mb / day) --- SOLID LINE
PRECIPITATION (mm / day) --- DASHED LINE

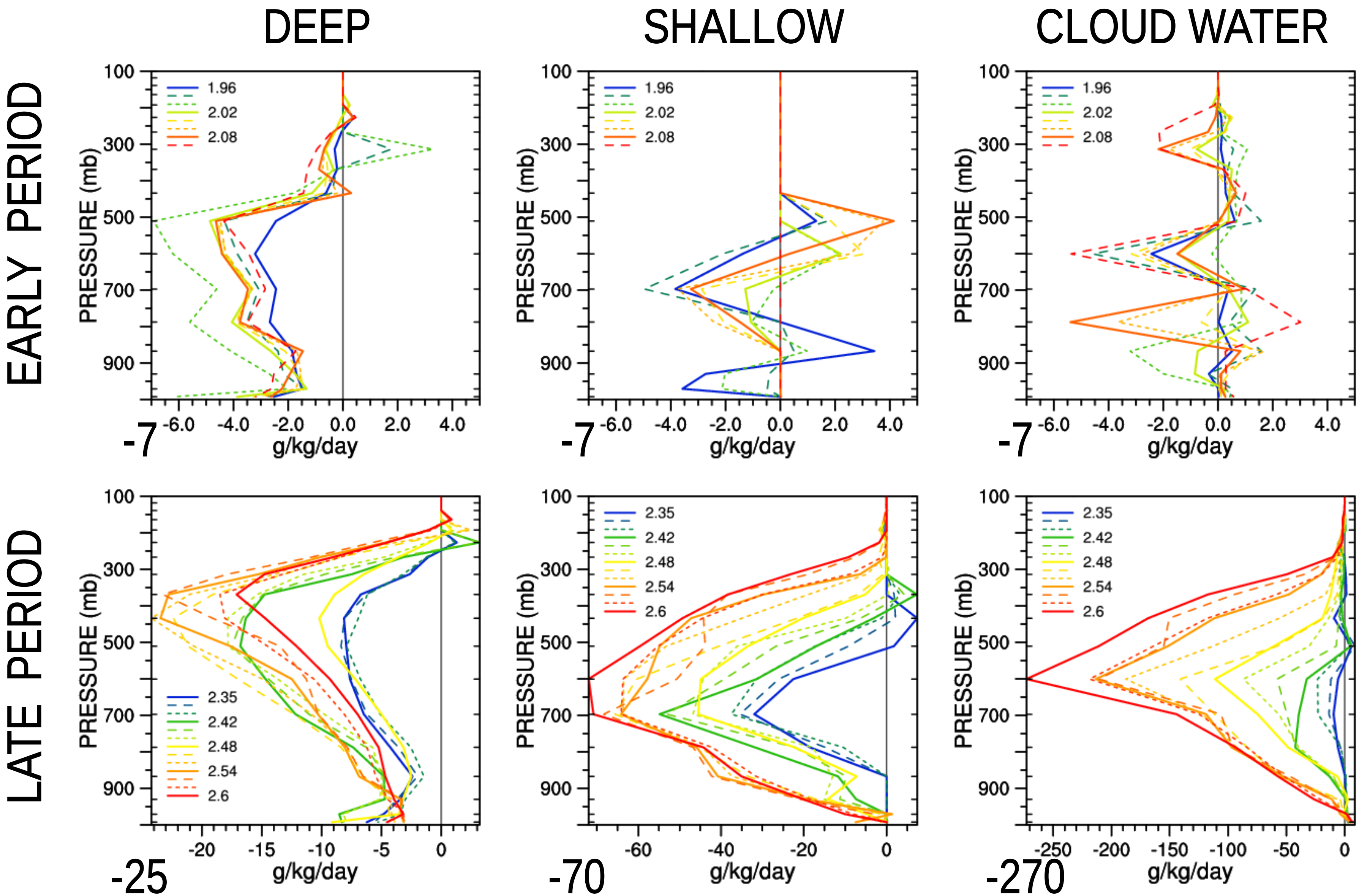
EARLY PERIOD



LATE PERIOD



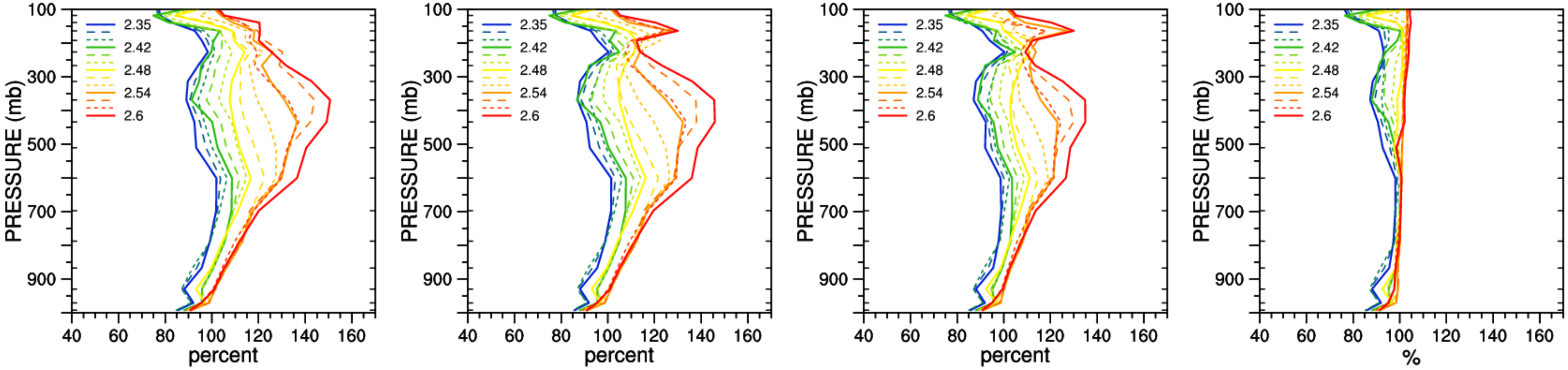
SPECIFIC HUMIDITY PARAMETERIZATION TENDENCIES



RELATIVE HUMIDITY

BEFORE MOIST | AFTER DEEP | AFTER SHALLOW | AFTER CLOUD WATER

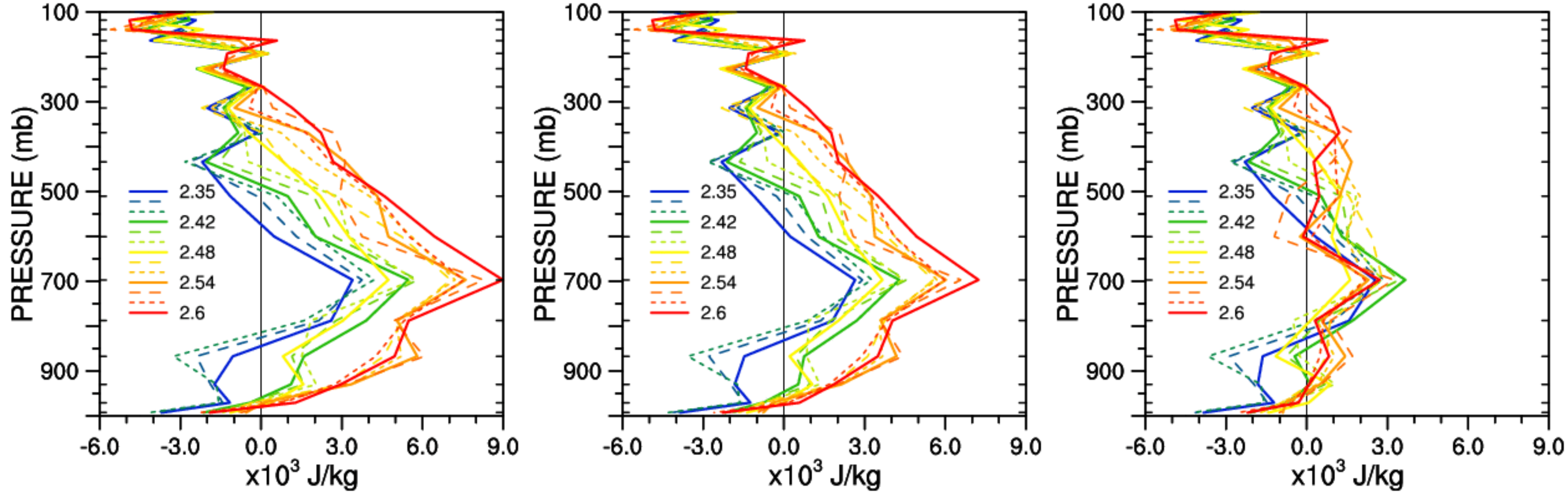
LATE PERIOD



$$h_{k+1} - h_k^*$$

BEFORE MOIST | AFTER SHALLOW | AFTER CLOUD WATER

LATE PERIOD

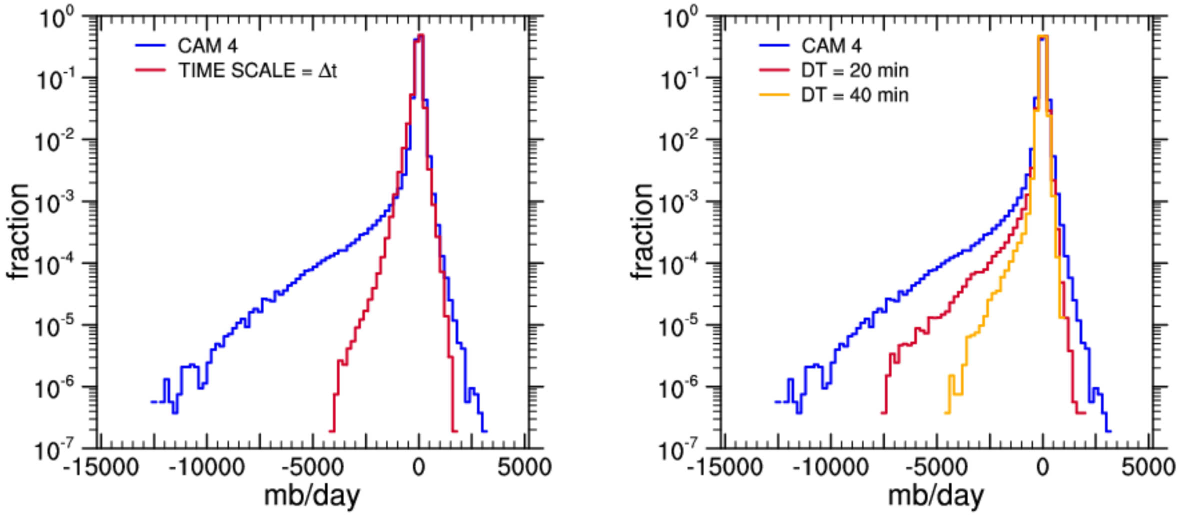


$$\text{UNSTABLE WHEN}: \quad h_{k+1} + pert > h_k^*$$

$$\text{MOIST STATIC ENERGY}: \quad h = C_pT + gz + Lq$$

$$\text{SATURATED MOIST STATIC ENERGY}: \quad h^* = C_pT + gz + Lq^*$$

OMEGA AT 600 mb (mb / day)



Problem arises because some individual parameterizations
    do not produce atmospheric-like state
        because constrained by assumed time-scale
Other unconstrained parameterizations
    work in unintended ways

As time step goes to zero
    convection parameterizations become less active
    large scale condensation takes over

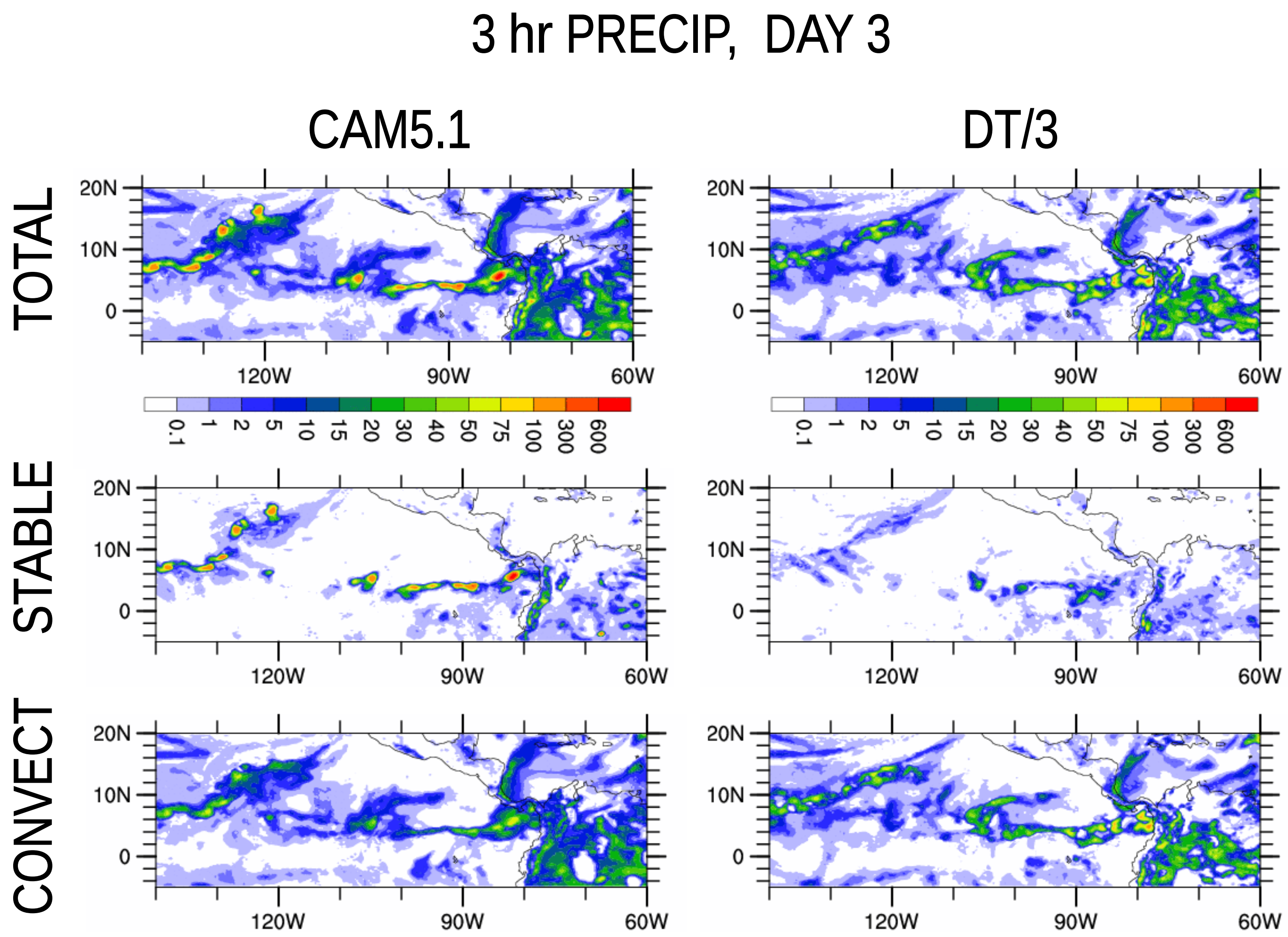
When time scales are shortened or
    time step is lengthened
        strong storms do not form

There are simple model problems that illustrate the
    ramifications of the time-scale time-step mismatch

Partition of the total tendency into individual process tendencies
should not depend on the time step

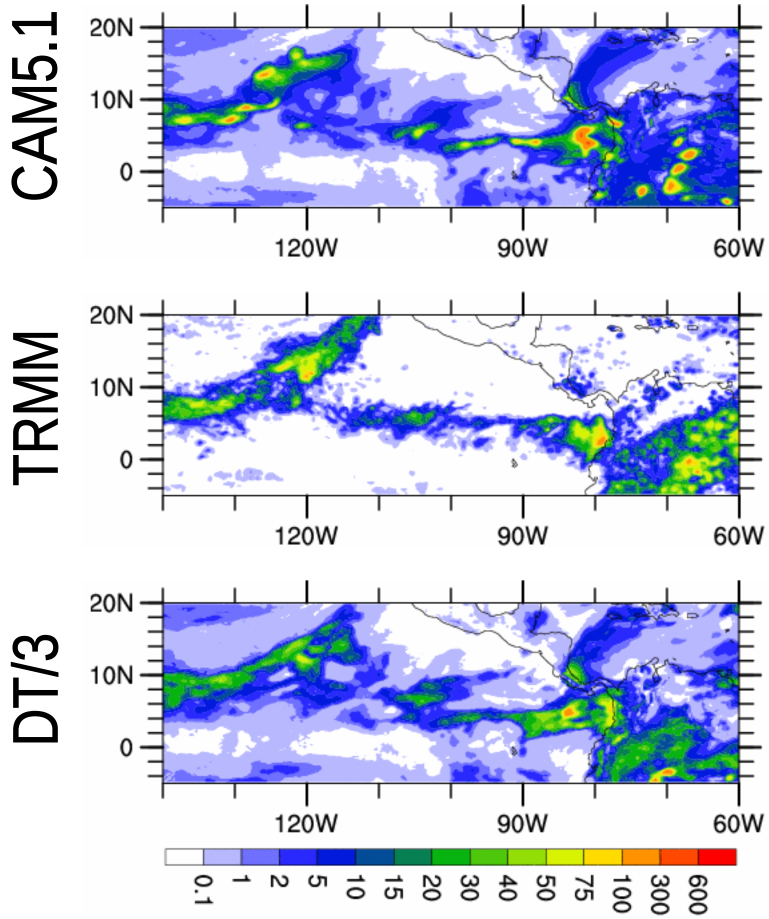
In the limit of small time steps there should be a reasonable
distribution between parameterized processes

Parameterizations should be formulated
without an explicit time scale
so they complete their processes in a single application
Or all processes formulated with appropriate time scales
and be allowed to interact in a fully nonlinear manner
by eliminating numerical splitting of processes



3 hr PRECIP, DAY 3
CAM5.1
DT/3
TOTAL
STABLE
CONVECT
20N
10N
0
120W
90W
60W
0.1
1
2
5
10
15
20
30
40
50
75
100
300
600

24 hr PRECIP, DAY 3



$$\frac{dq}{dt} = \mathrm{D} + \mathrm{P}$$

$$\mathrm{D}: \quad \frac{dq}{dt} = \alpha$$

$$q^{t+\Delta t} = q^t + \alpha \Delta t$$

$$\mathrm{P}: \quad \frac{d(q - q_s)}{dt} = \begin{cases} -(q - q_s)/\tau & \text{if } q > q_s \\ 0 & \text{if } q \leq q_s \end{cases}$$

$$\left(q^{t+\Delta t} - q_s\right) = \left(q^t - q_s\right) e^{-\Delta t/\tau}$$

Let $t = n\Delta t$

$$q^* = q^{n\Delta t} + \alpha \Delta t$$

$$\left(q^{(n+1)\Delta t} - q_s\right) = \left(q^* - q_s\right) e^{-\Delta t/\tau}$$

$$\left(q^{(n+1)\Delta t} - q_s\right) = \left[\left(q^{n\Delta t} - q_s\right) + \alpha \Delta t\right] e^{-\Delta t/\tau}$$

ASSUME $q^0 = q_s$, THEN

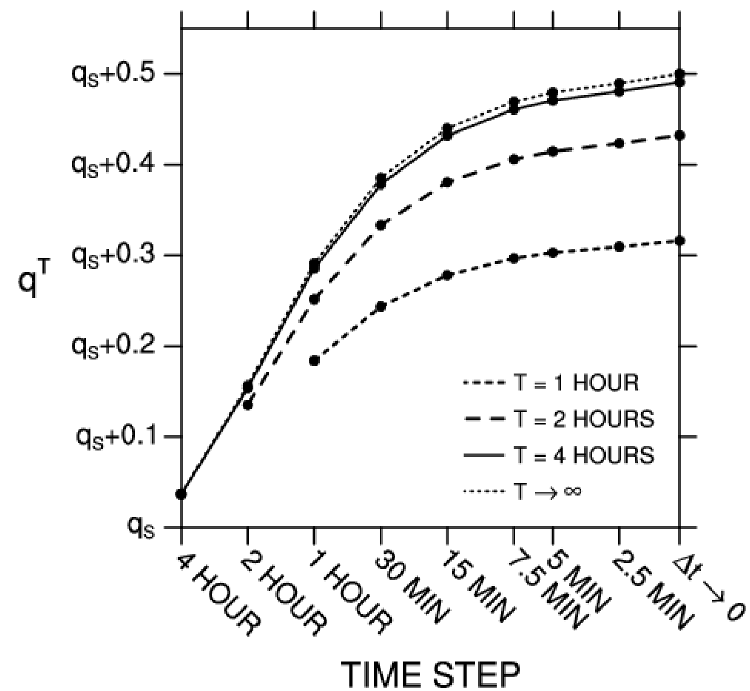
$$\left(q^{n\Delta t} - q_s\right) = \alpha \Delta t \left[\frac{e^{-(n+1)\Delta t/\tau} - e^{-\Delta t/\tau}}{e^{-\Delta t/\tau} - 1}\right]$$

FOR FIXED TIME $T = n\Delta t$ AS $\Delta t \to 0$

$$\left(q^{n\Delta t} - q_s\right) \to \tau\alpha \left(1 - e^{-T/\tau}\right)$$

$$\tau = 1 \text{ hour}$$

$$\alpha = \frac{1}{2} \text{ hour}^{-1}$$



$$\frac{dq}{dt} = \mathrm{D} + \mathrm{P} + \mathrm{Q}$$

$$\mathrm{D}: \quad q^{t+\Delta t} = q^t + \alpha \Delta t$$

$$\mathrm{P}: \quad \left(q^{t+\Delta t} - q_s\right) = \left(q^t - q_s\right) e^{-\Delta t/\tau}$$

$$\mathrm{Q}: \quad q^{t+\Delta t} = \begin{cases} q_s & \text{if } q^t > q_s \\ q^t & \text{if } q^t \le q_s \end{cases}$$

Let $t = n\Delta t$

$$q^* = q^{n\Delta t} + \alpha \Delta t$$

$$(q^{**} - q_s) = (q^* - q_s)\, e^{-\Delta t/\tau}$$

$$q^{(n+1)\Delta t} = q_s$$

$$\mathrm{D}: \quad q^* - q_s = \alpha \Delta t$$

$$\mathrm{P}: \quad q^{**} - q^* = \alpha \Delta t \left(e^{-\Delta t/\tau} - 1\right)$$

$$\mathrm{Q}: \quad q^{(n+1)\Delta t} - q^{**} = -\alpha \Delta t\; e^{-\Delta t/\tau}$$

$$T = 4 \text{ hours}$$

$$\tau = 1 \text{ hour}$$

$$\alpha = \frac{1}{2}\, \text{hour}^{-1}$$