The Case of the Disappearing Condensate

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Problem:

In cldwat2m_macro.F90:

```
! ------------------------------ !
! This is case III : Empty Cloud !
! ------------------------------ !
elseif( al0_st .gt. 0._r8 .and. ql0_pre .eq. 0._r8 ) then
      ! ------------------------------------------------ !
      ! Condense until qc_st                             !
      ! ------------------------------------------------ !
      Tmin = Tmin0
      Tmax = Tmax0
      call instratus_core( ncol, i, p,
                           ql0, qi0, 0._r8,
                           qc, qi_dc,
                           ql_sc, qi_sc, ai0_st,
                           qlst_min, Tmin, Tmax, landfrac(i),
                           T, qv, ql, qi )

      idxmod = 1
      caseid = 3
      goto 10
```

Careful consistency-checking in macro ensures that clouds have both mass and volume

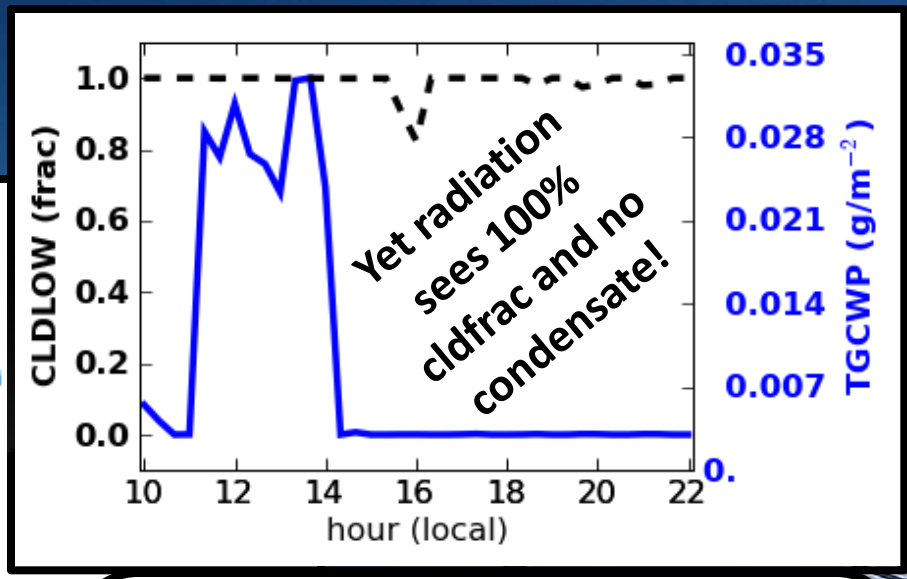


Fig: **cell-ave condensate path (TGCWP)** and liq+ice cloud fraction (**CLDLOW**) from MPACE-B (mixed-phase stratocumulus) single-column run using branch from cam5_1_16 (aerosol=constant, no activation fix)

- *Sequential splitting* (using output from one process as input for next) can cause inconsistencies in initially balanced states.

Questions:

1. How frequent is this kind of issue?
2. What is the cause?
3. What is the impact on climate?
4. How can we fix it?

Micro Depletion Frequency:

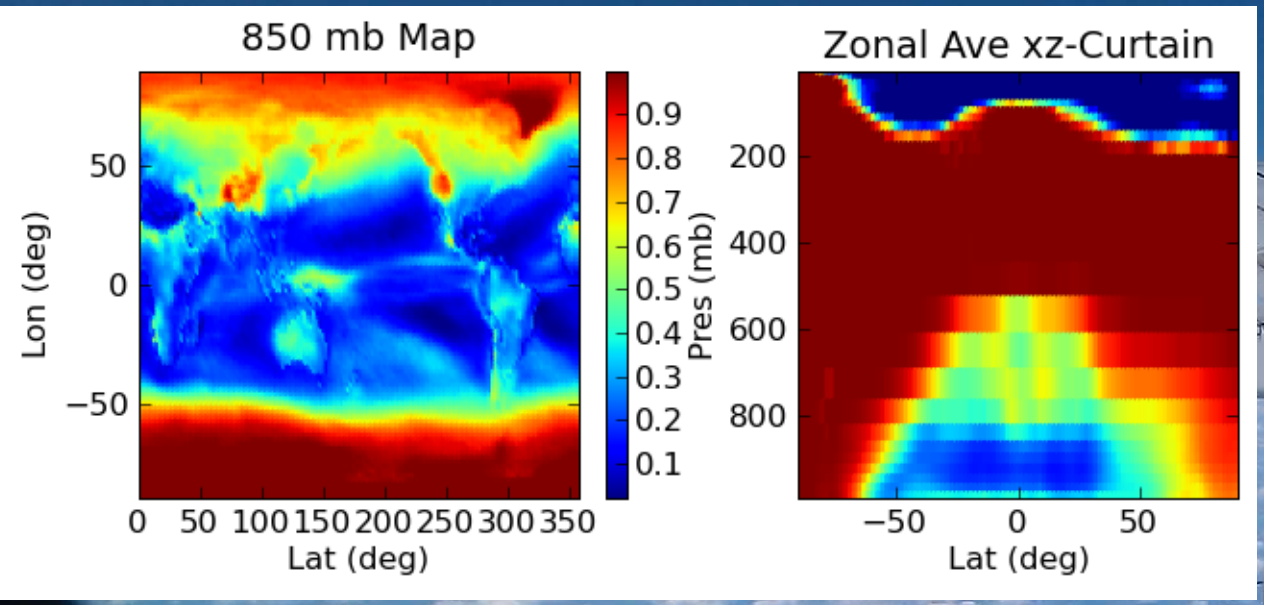
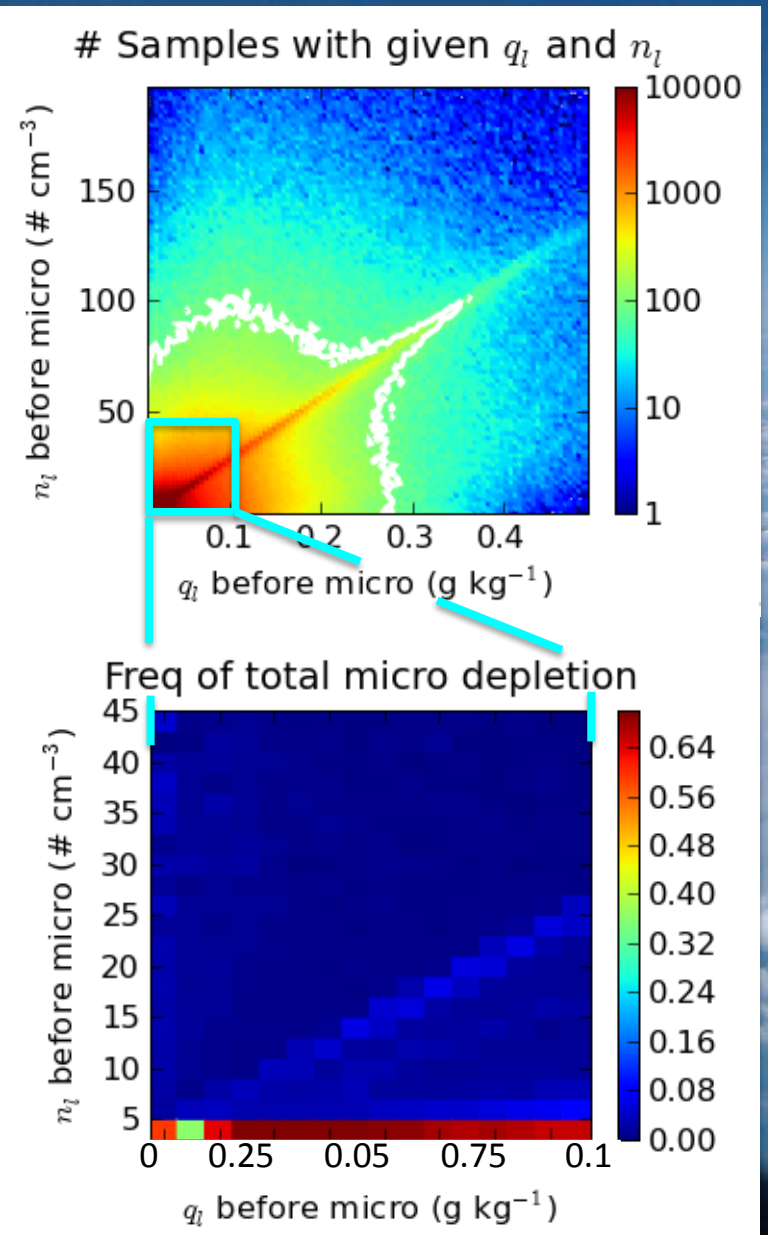


Fig: Fraction of steps when microphysics starts with enough cloud water to act but depletes all water within that step. From 5 yr CAM5.0 AMIP 2° run.

- Micro runs out of liquid *most* of the time over much of the globe!
- Microphysical treatment is ad hoc when condensate is depleted within a timestep
- Is initial liquid negligibly small in depletion cases?

Microphysical Depletion – Joint PDF

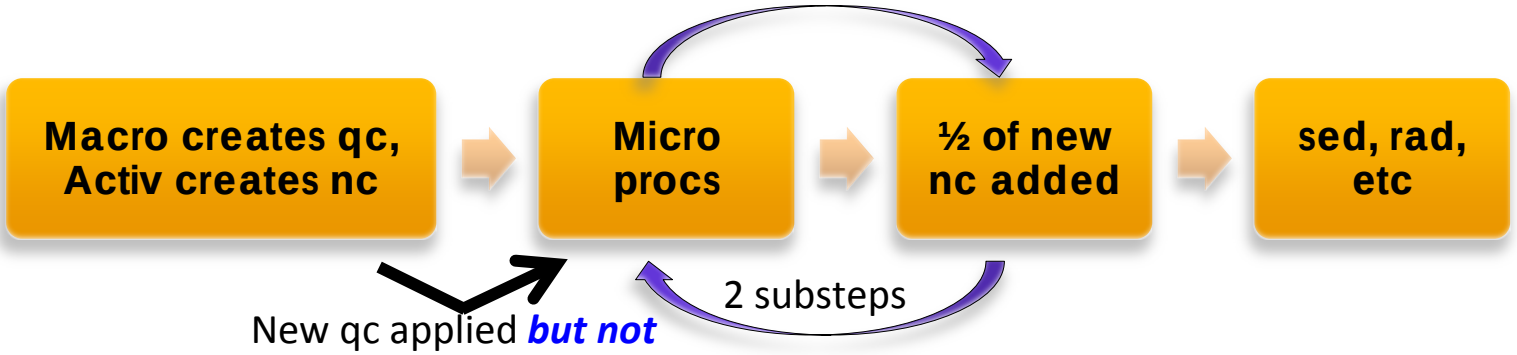


- q_l is typically < 0.1 g/kg and n_l typically < 50 cm^{-3}
- Something pathological happens along dn_l/dq_l=250
- Depletion is frequent when n_l<5 cm^{-3}. Otherwise not.

Top: # of samples with given cell-ave liquid water (q_l) and droplet concentration (n_l) just after macro & before micro. **Bottom**: Frequency of total depletion by micro given pre-micro q_l and n_l. From ~900mb lev of 1 month CAM5.1.06 2^o run after 3 months spinup. White line=100 sample level.

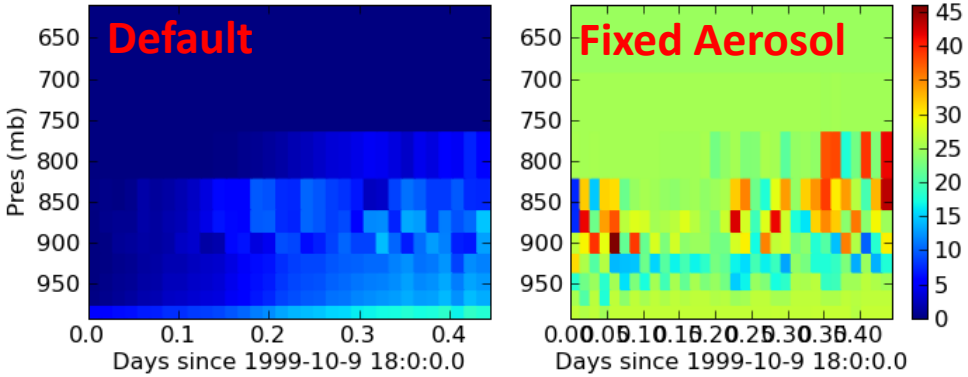
About n_l...

Activation currently applied inconsistently:



Known issue – will be fixed in future releases

In Single-Column mode (SCAM):

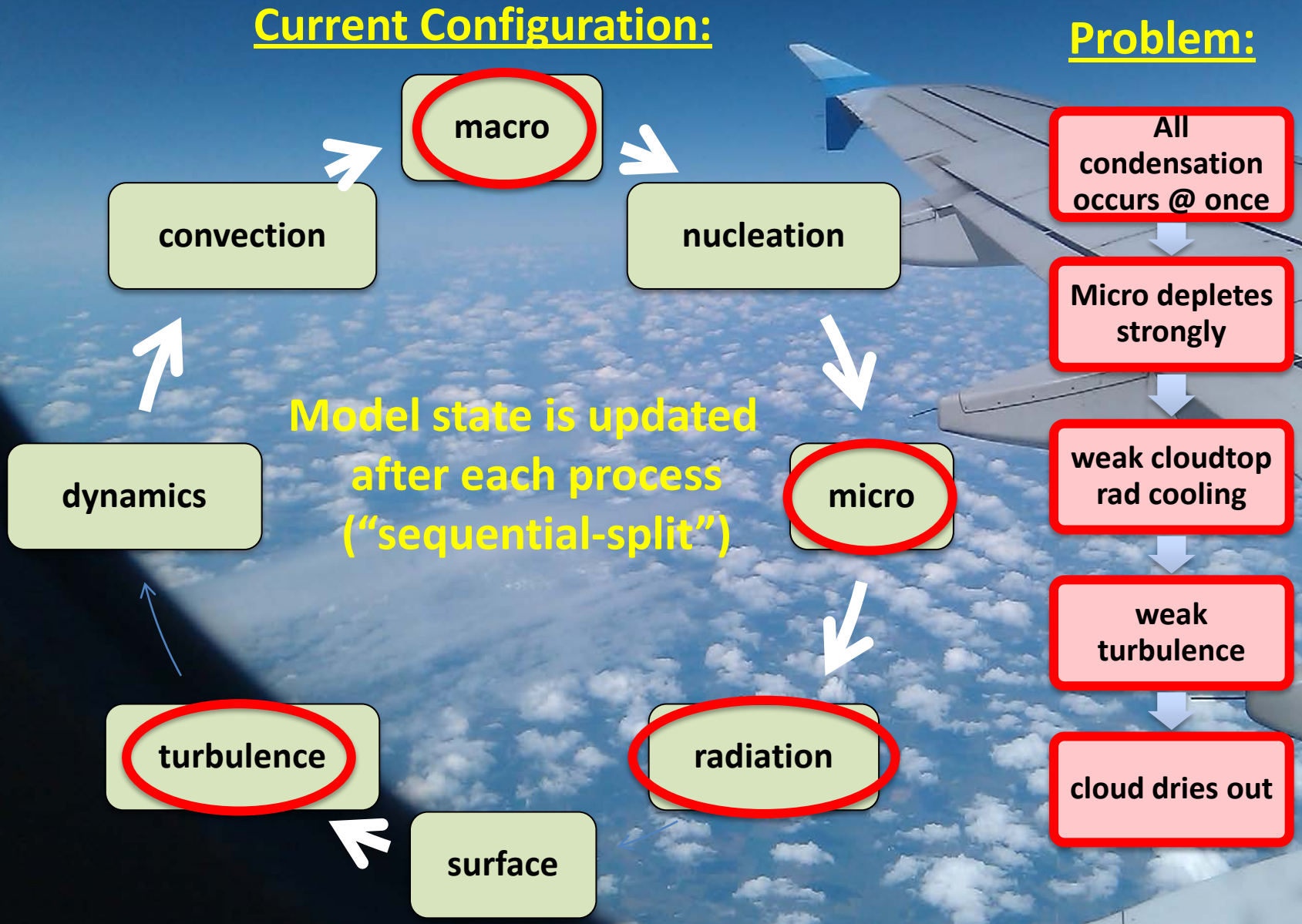


- **Without code changes, $n_l \approx 0$!**

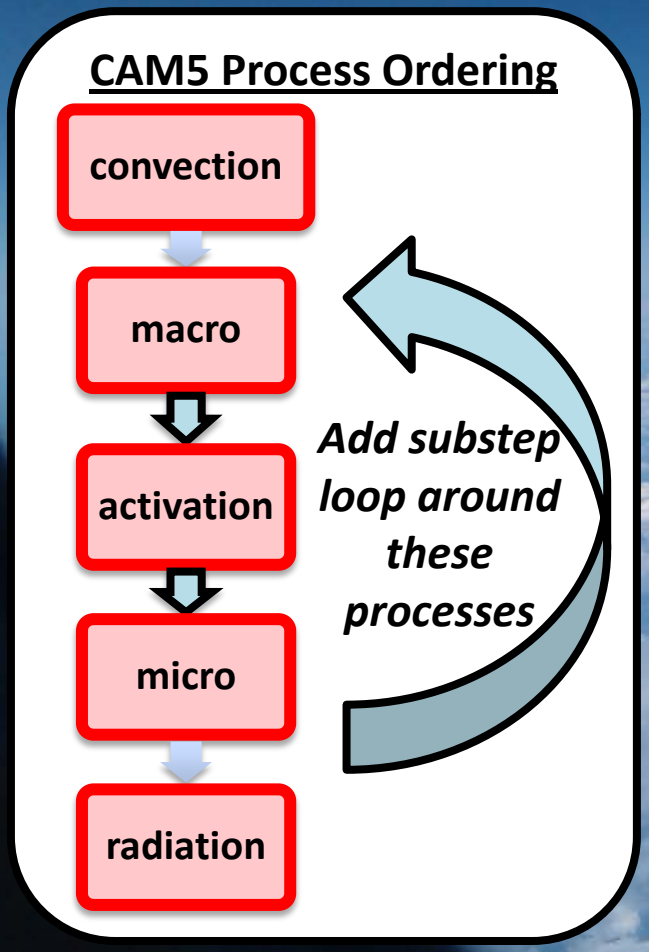
Fig: CCN @ 0.1% super-saturation for MPACE-B SCAM run.

Fixed n_l and fixed aerosol options will be available soon

Numerical Coupling Errors



Convergence Test for Coupling Error



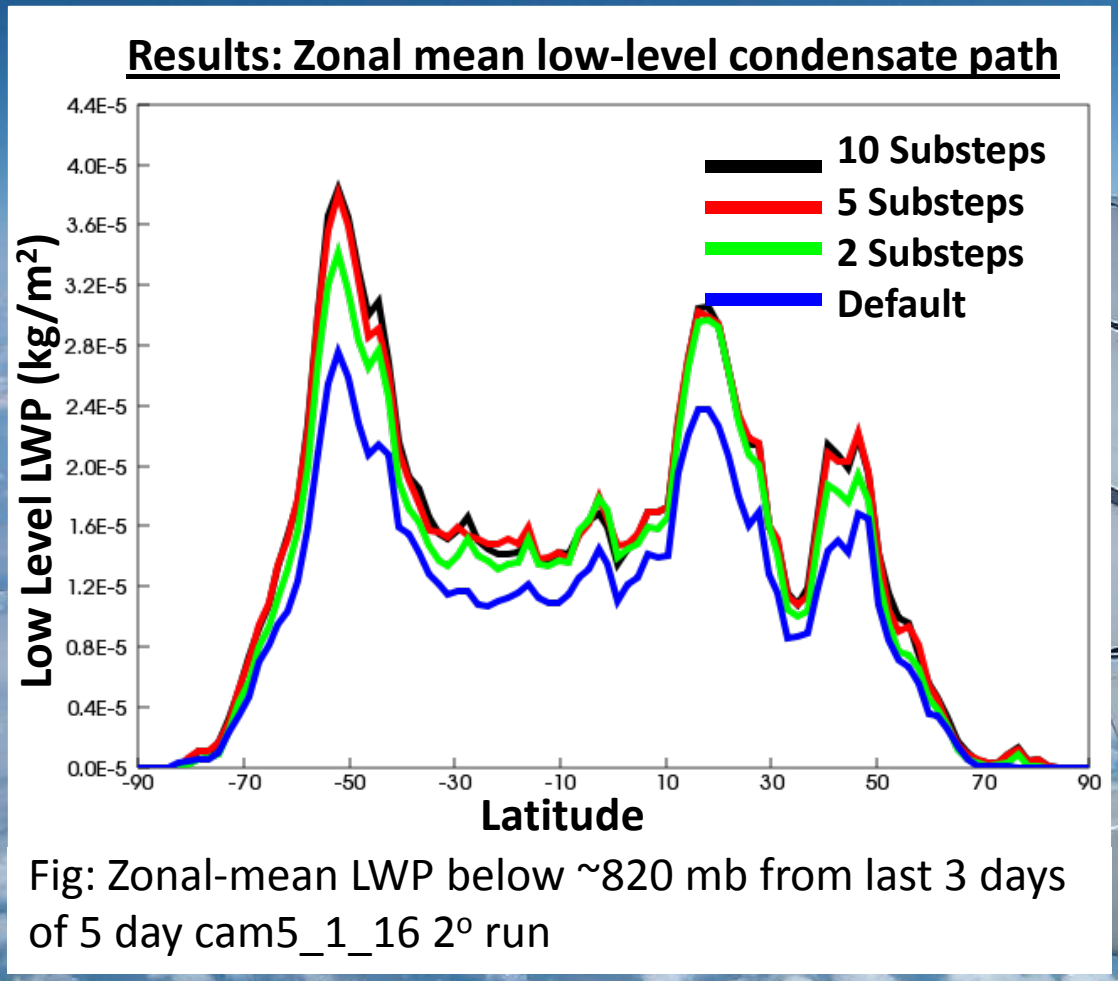
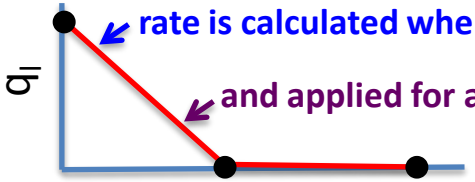


Fig: Zonal-mean LWP below ~820 mb from last 3 days of 5 day cam5_1_16 2° run

- Coupling @ 20 min dt (default) ⇒ LWP too low
- 10 min coupling (2 substeps) appears sufficient

Effect of Shorter Micro dt

@ 2 micro substeps (default):



With more substeps:

Is *this* the basis for timestep sensitivity?

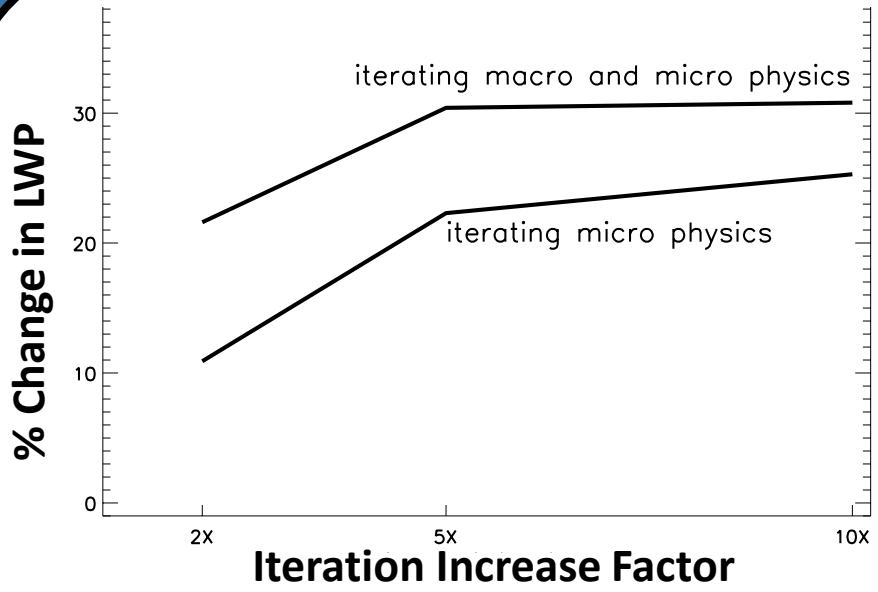


Fig: Global-ave % LWP change as macro+micro and micro-only iterations are increased.

- Micro iteration is more important than coupling
- Micro substepping also acts to increase LWP.

Answers:

1. How frequent is this kind of issue?

- Very frequent

2. What is the cause?

- Sequential splitting
  - macro/micro coupling error ⇒~10% LWP low bias (after subtracting micro non-convergence)
- Total depletion only occurs for very low n_l…
  - Suggests microphysics is behaving reasonably
    - though micro substepping not converged (resulting in ~20% low bias)
  - Low n_l is the culprit(?)


Thanks!
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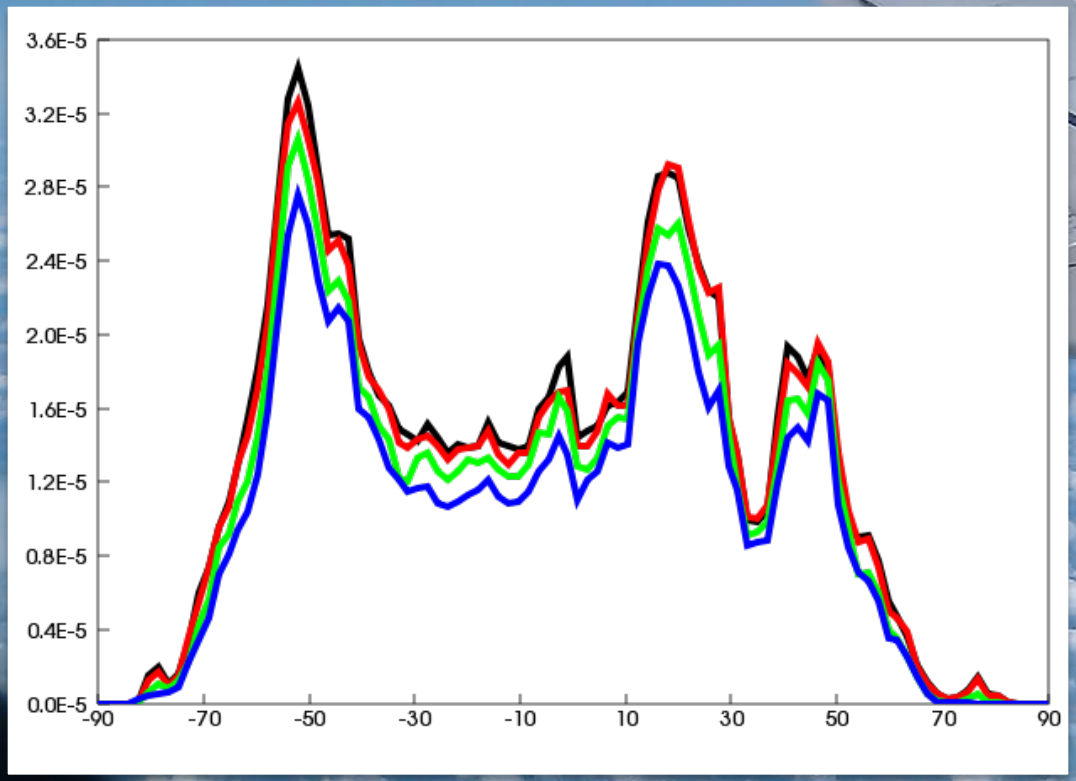
Micro Substepping Only.



Droplet Activation Consistency

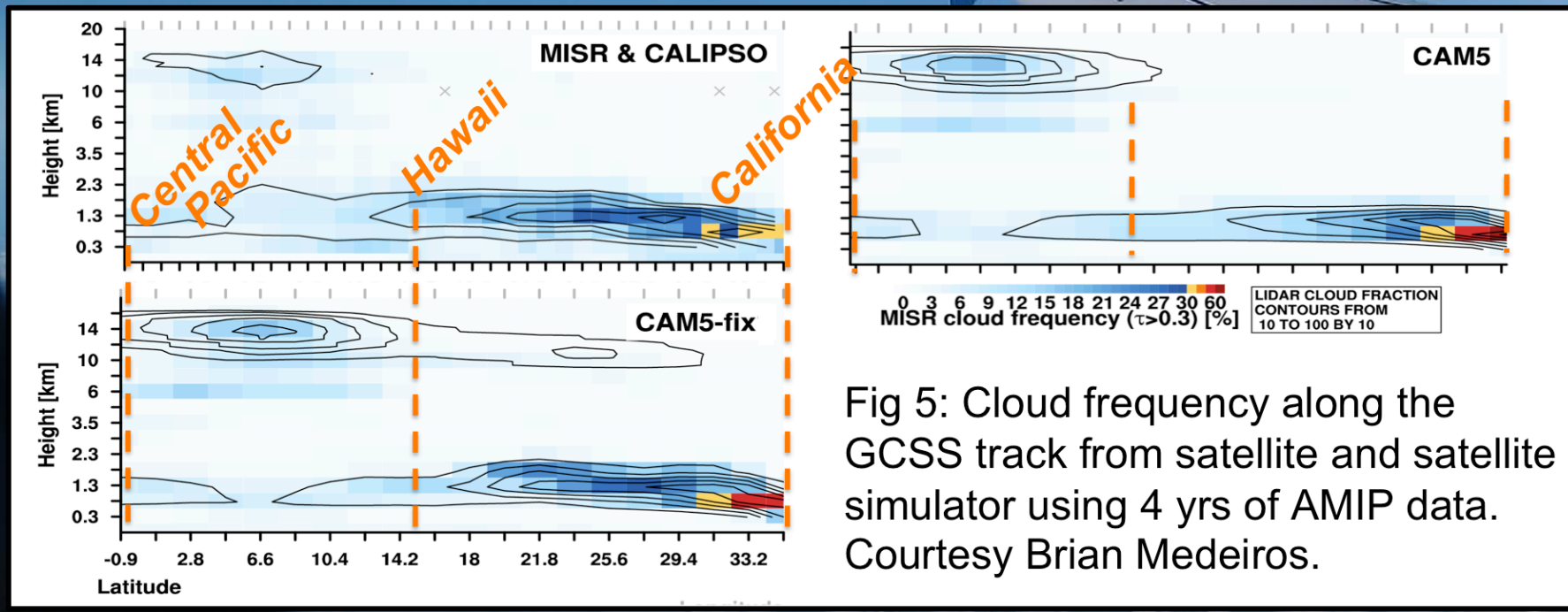
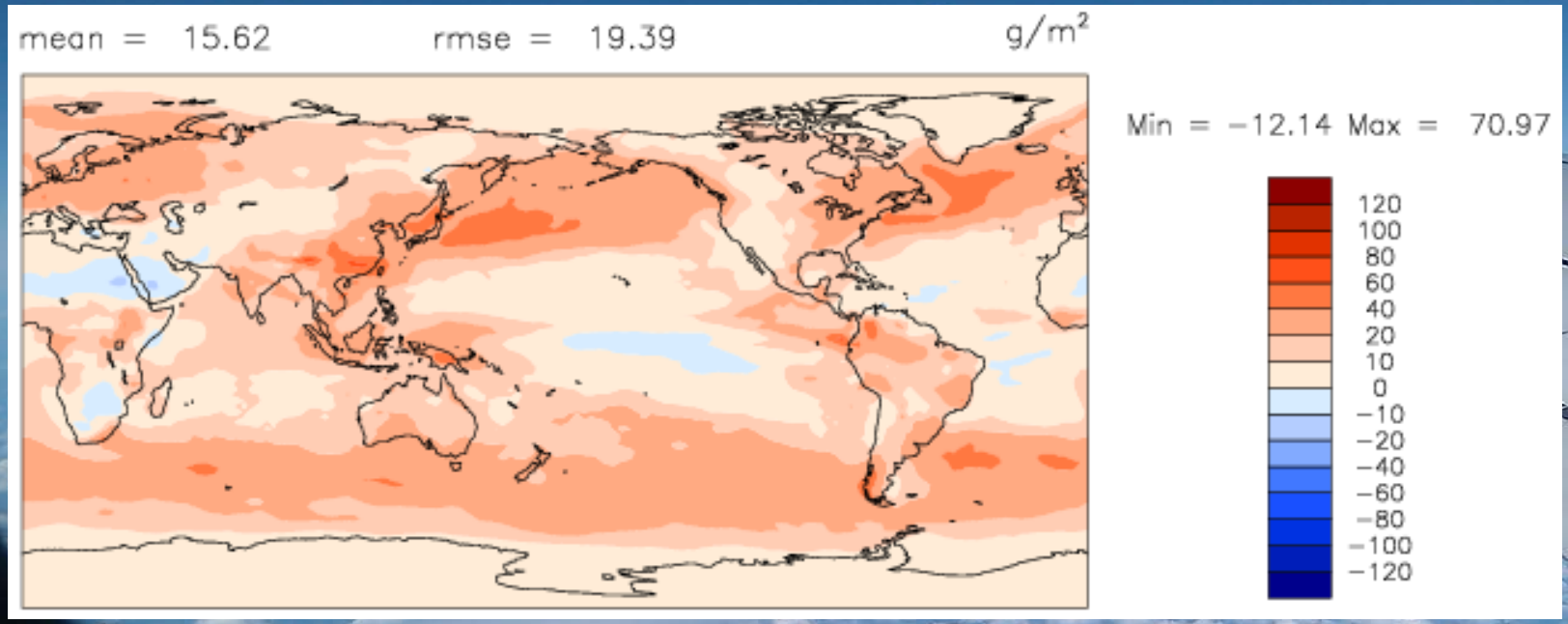


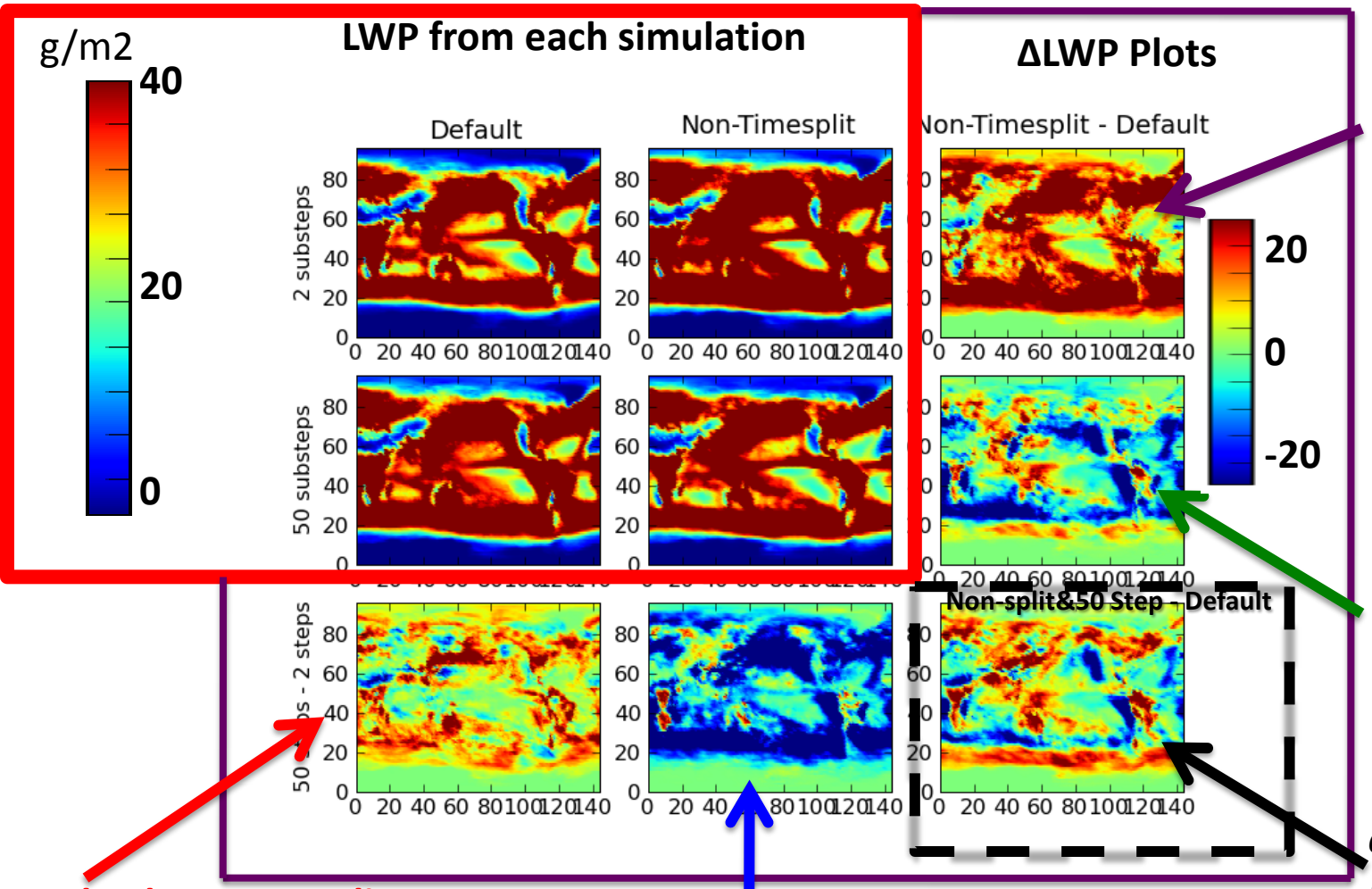
Fig 5: Cloud frequency along the GCSS track from satellite and satellite simulator using 4 yrs of AMIP data. Courtesy Brian Medeiros.

ΔLWP due to non-timesplit



- Huge global-ave LWP increase
  - surprising b/c macro replentishment should allow micro to maintain high rates?
- ΔLWP particularly big in storm tracks and Sc regions
- Coding this was *really* hard.

Effect of substepping on LWP



W/ fix, 1st MG substep acts on state w/out *any* macro update, 2nd step has ½ of new macro qc -> less qc, less depletion

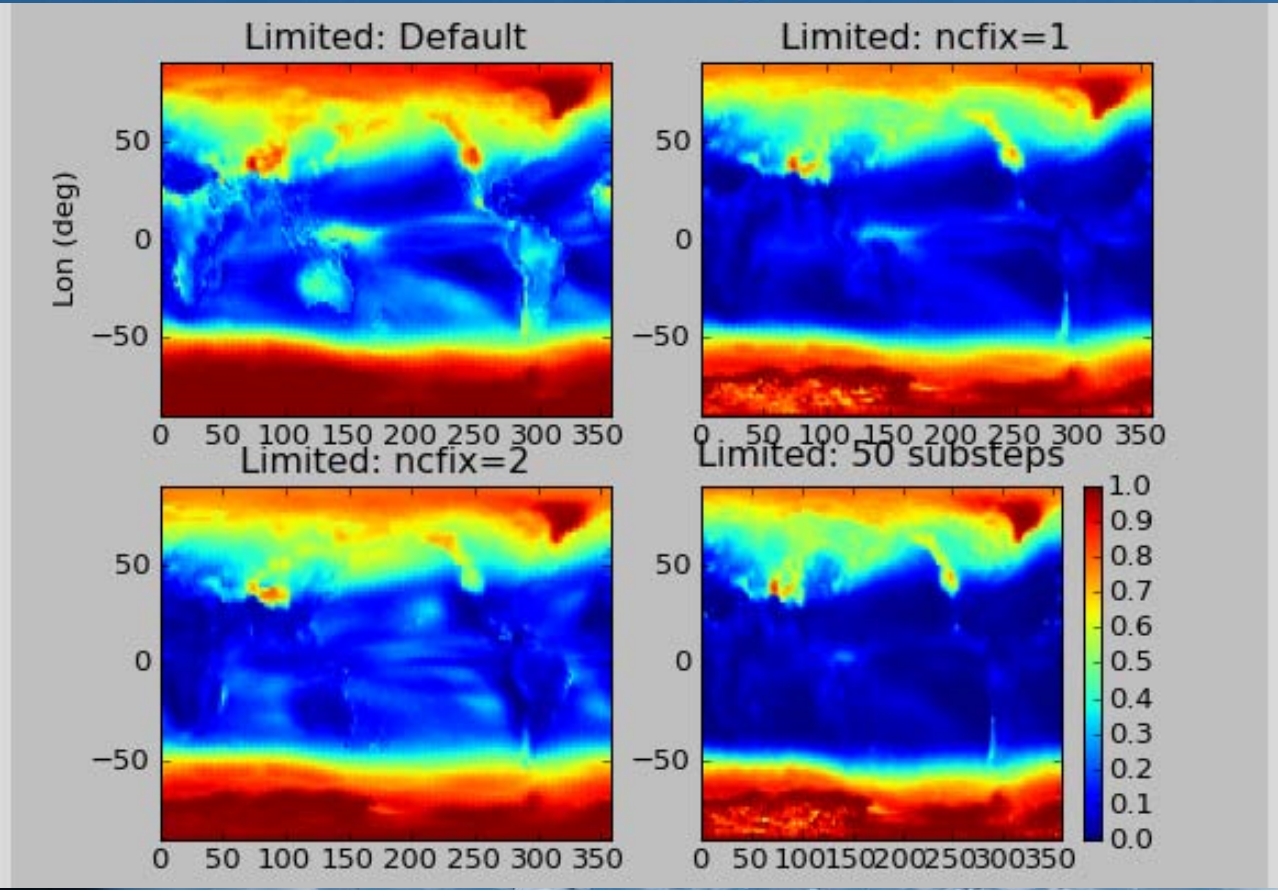
W/ 50 substeps, macro replentishing -> sustained high micro rates, decreasing LWP in some areas

combining macro/micro & improved numerics have opposing but not

Fwd Euler overpredicts depletion. More realistic time-integration has lower depletion -> higher LWP

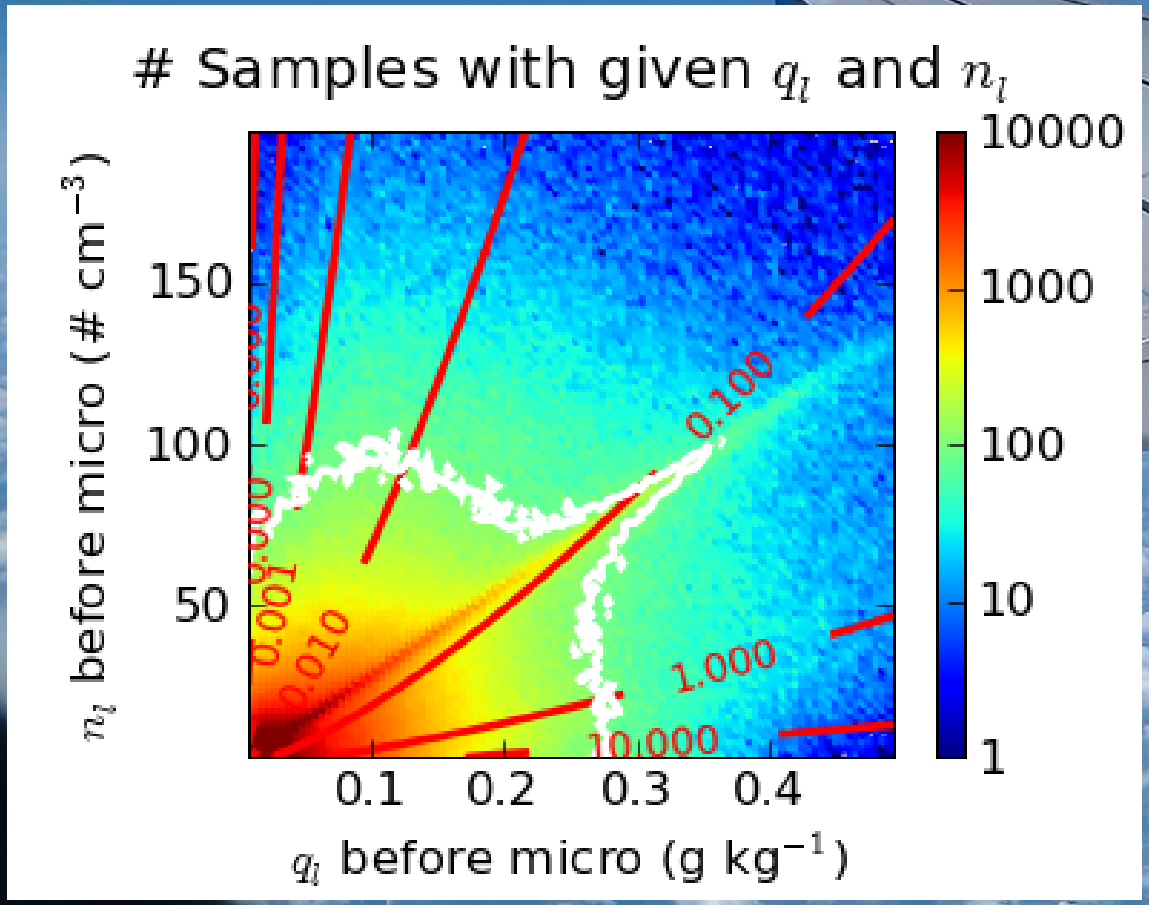
W/ 2 substeps, micro acts on states seeing ≤ ½ of new qc from macro. Mores substeps means micro sees more new qc from macro.

Effect of Fixes on Limiting Freq

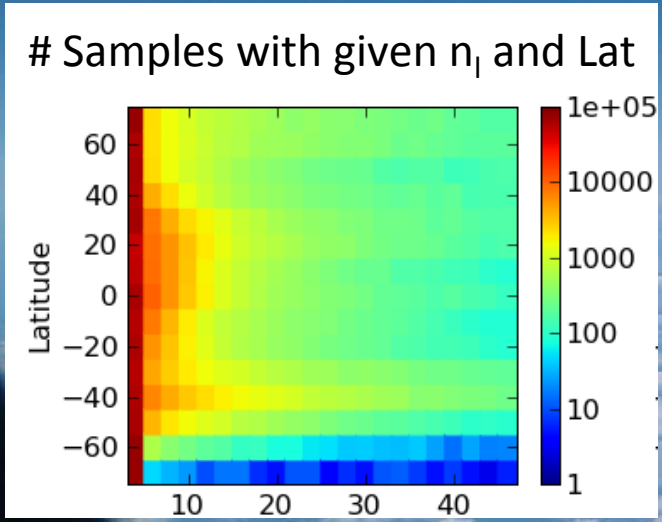


- Changes make surprisingly little difference?

Autoconversion Contours



Reconciling Previous Slides:



Top: # of samples with given lat and n_l just after macro & before micro. **Bottom**: Frequency of total micro depletion as a function of lat and n_l. From 5th lev from surf of 1 month CAM5.1.06 2° run after 3 months spinup.

- High lats have very low n_l most of the time

Conclusion: total micro depletion occurs only at very low n_l – which happens more often than it should(?)