Ultra-Parameterization: Explicit low clouds in a global model

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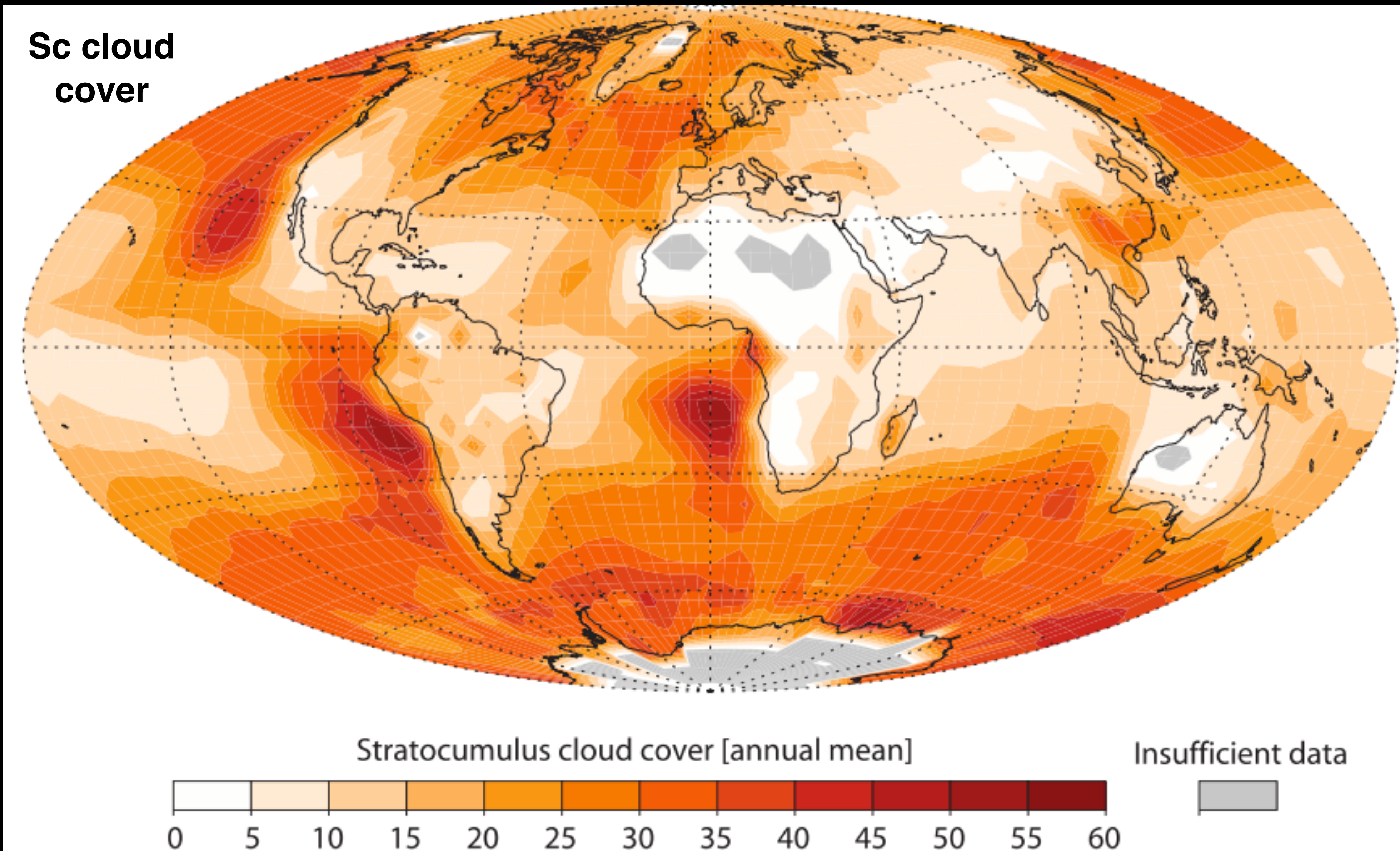
"Uncertainty in the sign and magnitude of the cloud feedback is due primarily to continuing uncertainty in the impact of warming **on low clouds**"

— IPCC AR5, Ch. 7

Long standing problem, been this way for decades…

Problem: shallow clouds are hard to simulate globally

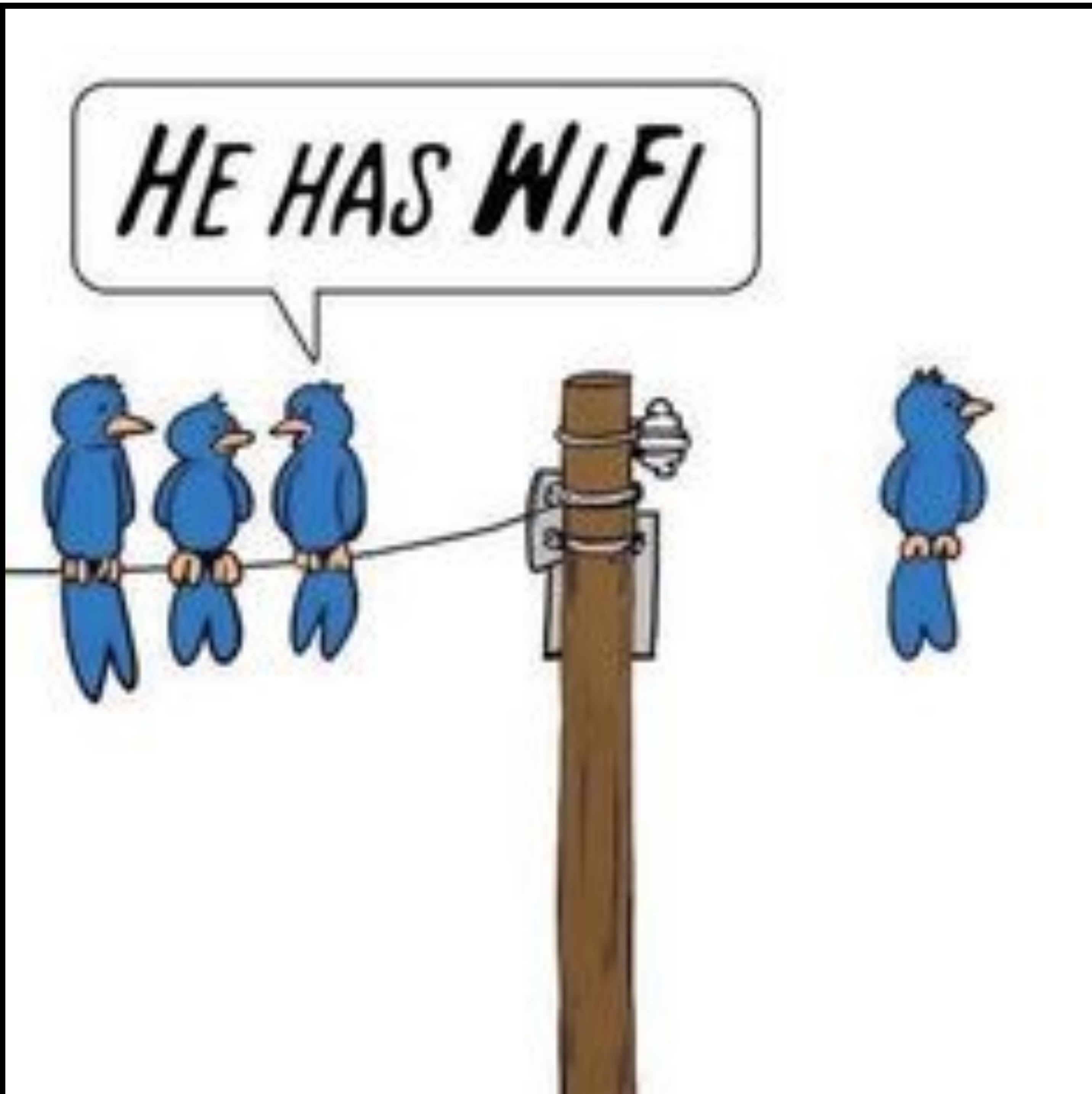


R. Wood, Monthly Weather Rev., 2012

NCAR Bluefire
(retired)

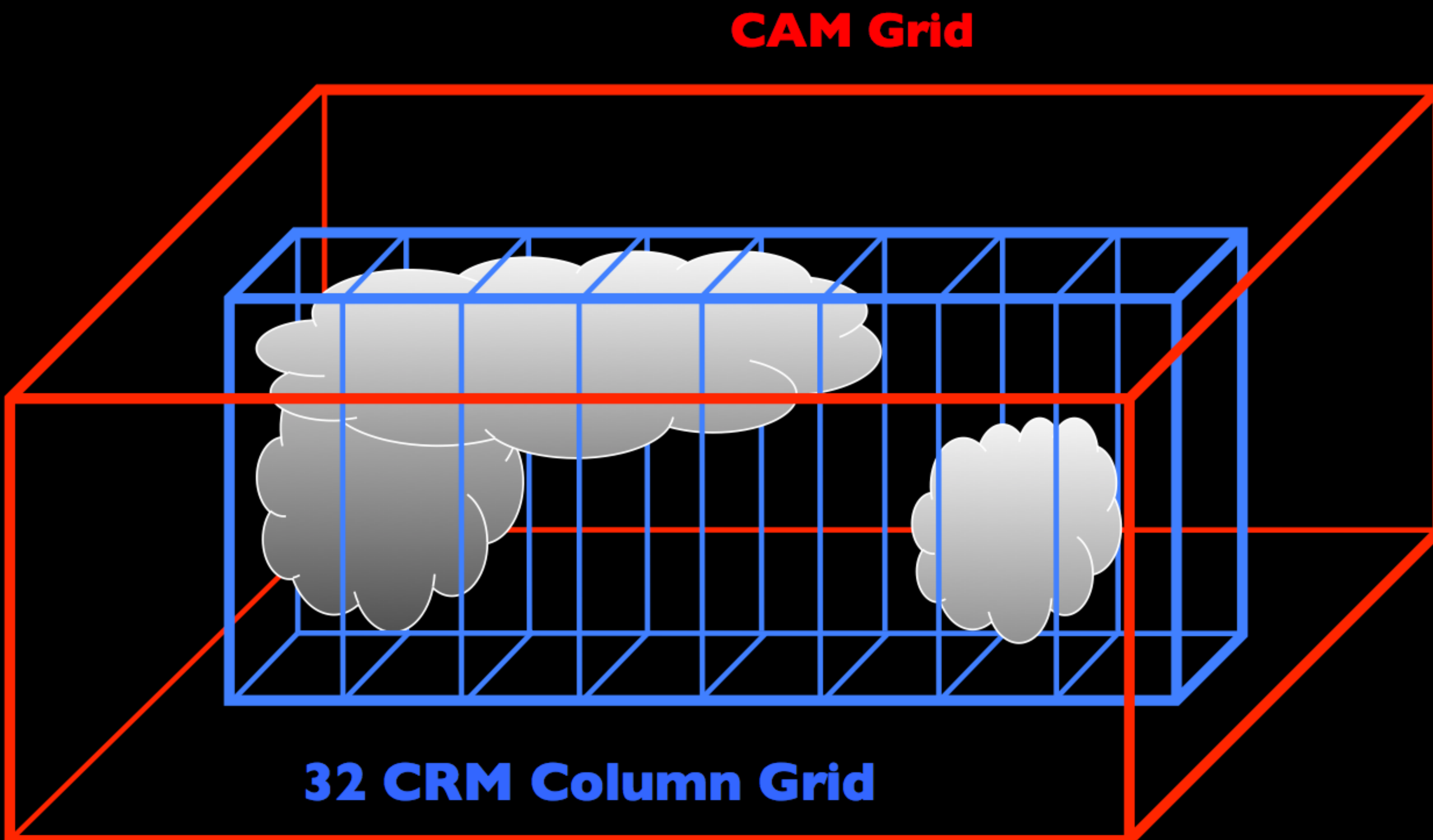
NCAR Yellowstone

Bigger, faster …



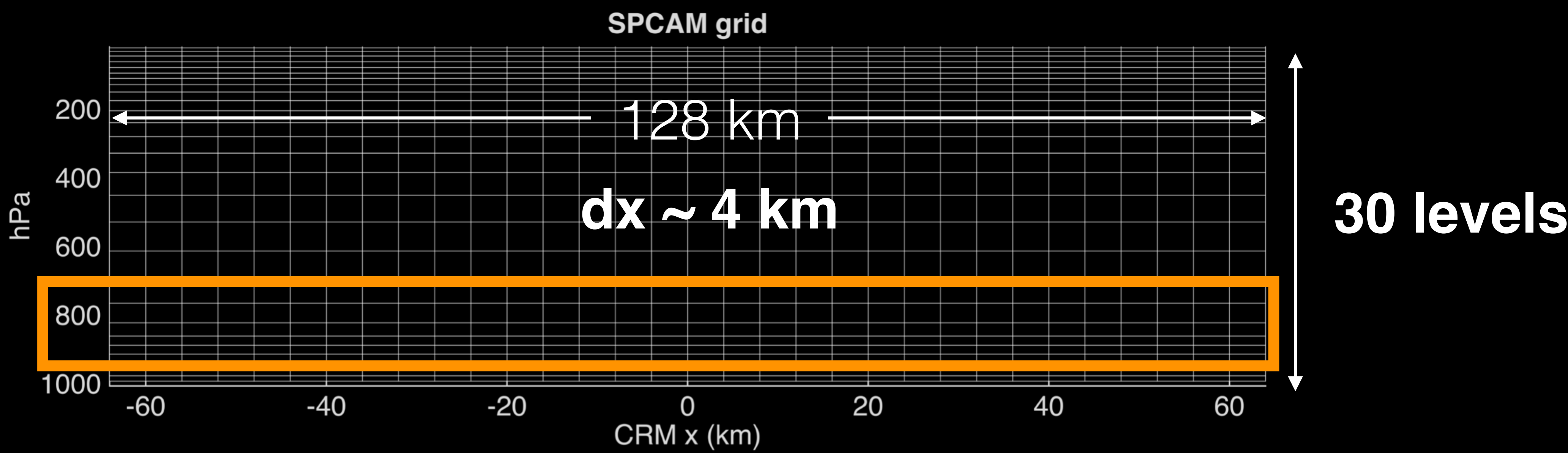
Opportunities to include explicit low-cloud physics.

Cloud super-parameterization: A scalable technique for convection-permitting global climate simulation



Repeat globally for each grid column.

super-parameterization grid



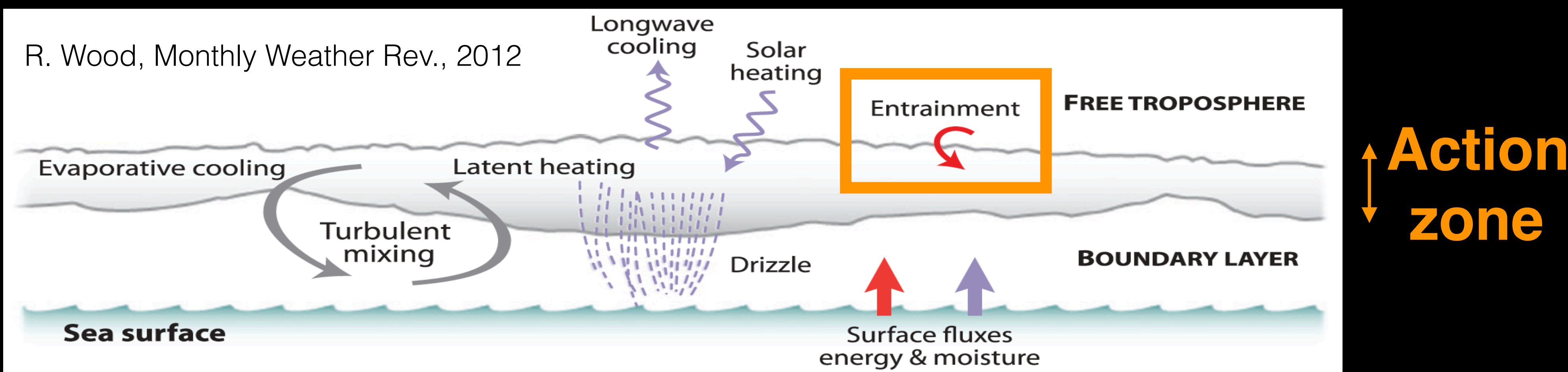
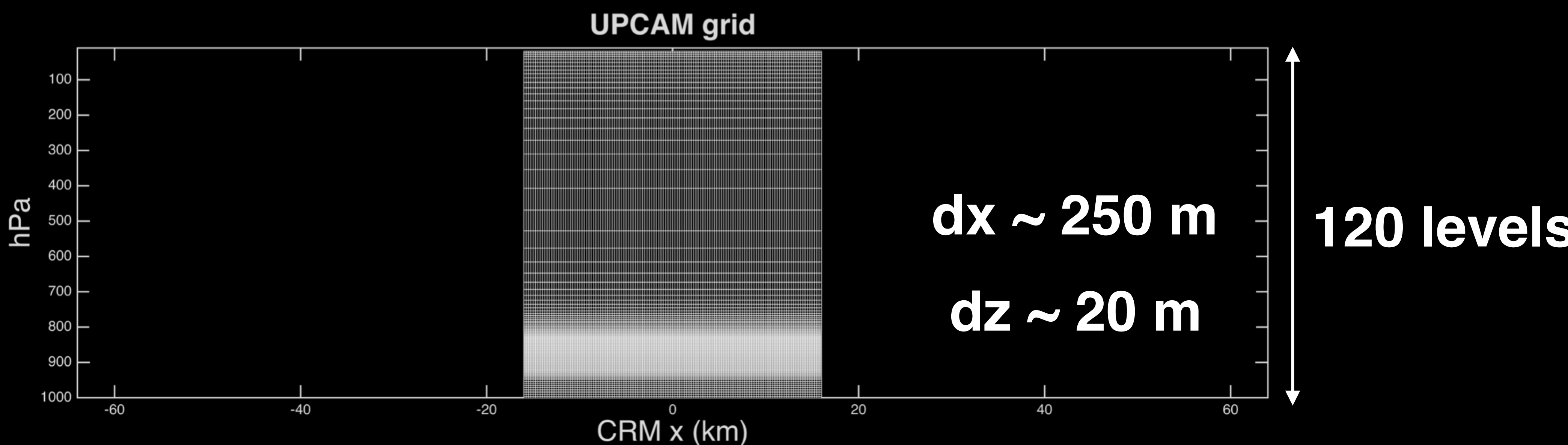


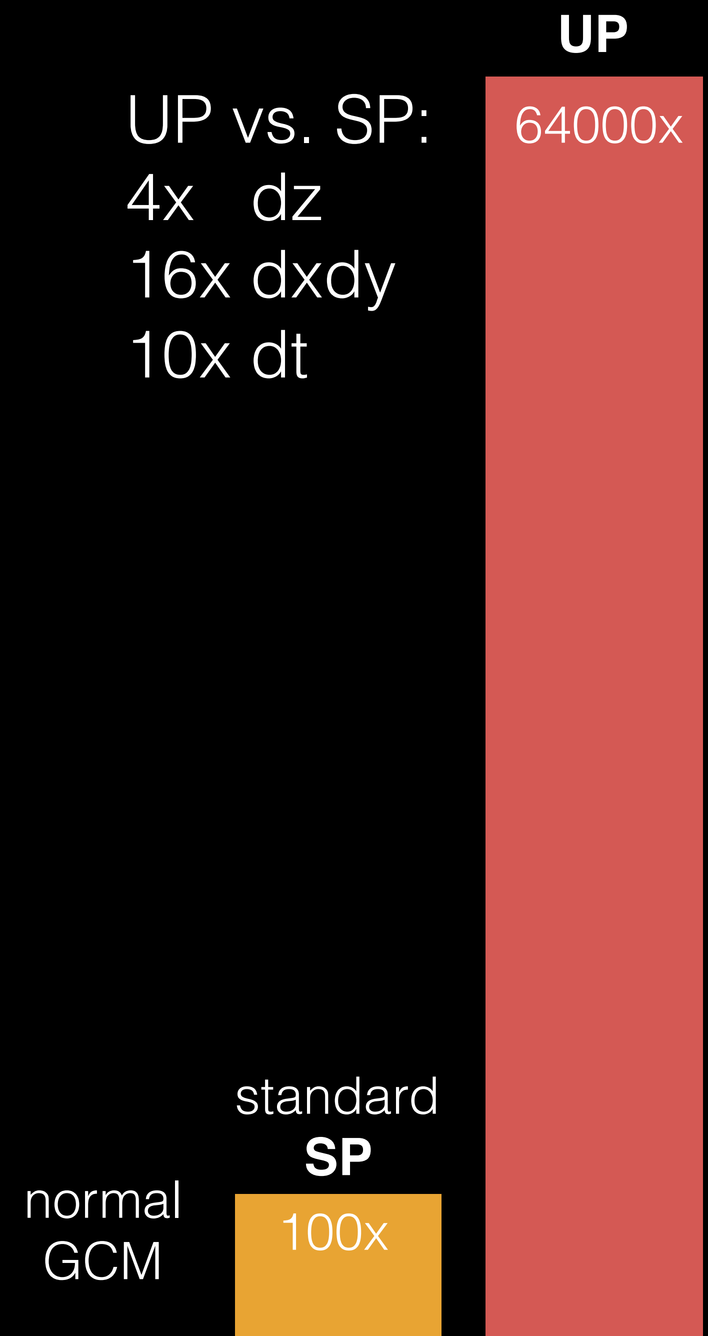
FIG. 2. Schematic showing the key processes occurring in the stratocumulus-topped boundary layer.

Introducing ultra-parameterization grid

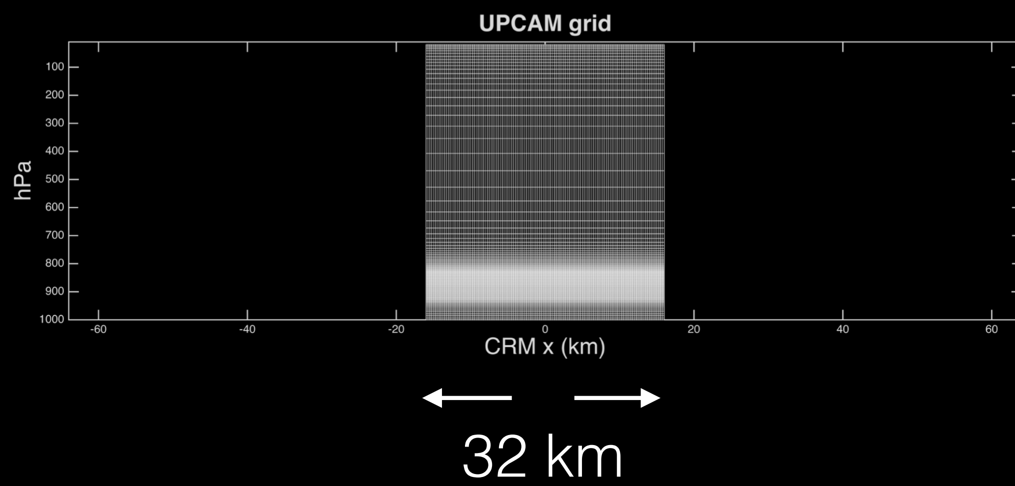


Following LES:
bleeding edge to capture physics faithfully

Ultra-parameterization: computational grand challenge



Domain reduction (4x)



CRM mean acceleration (4x)

...

CRM mean acceleration: Results are resilient up to 4x

Basis: The mean state evolution is slow.
Time-scale separation.

Jones, Bretherton and Pritchard, JAMES (2015)

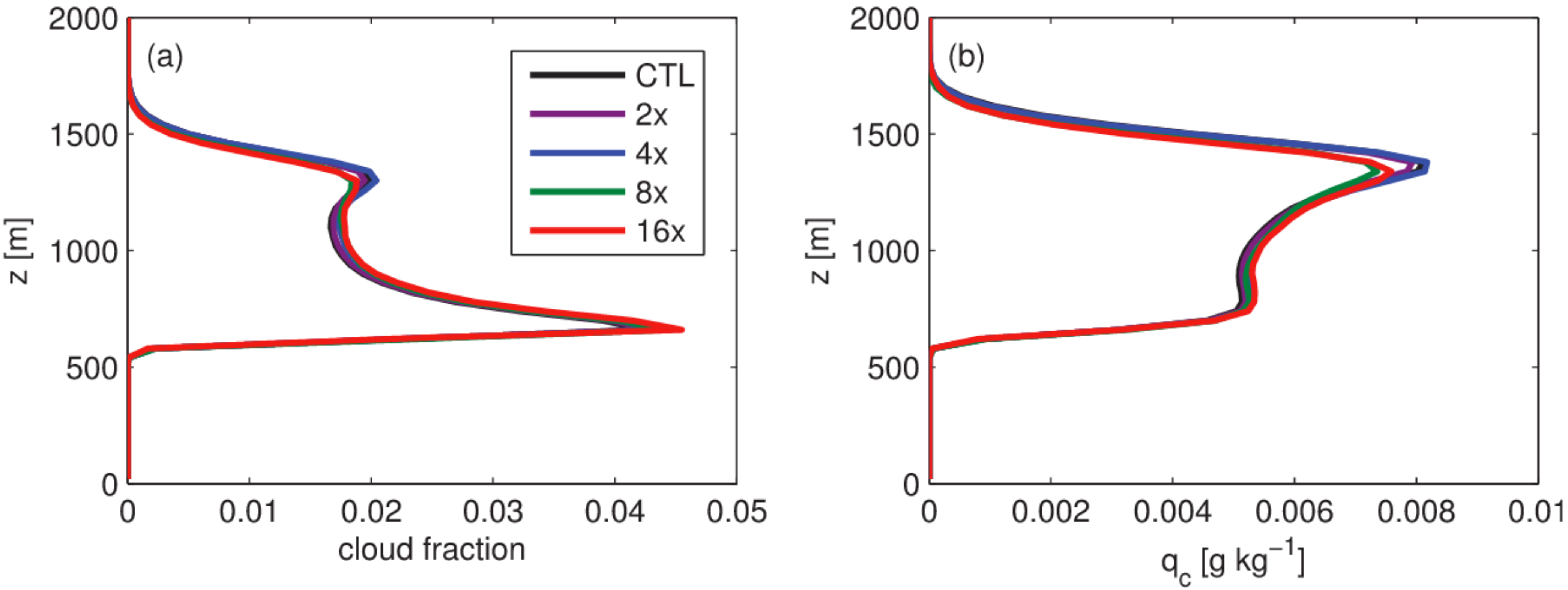
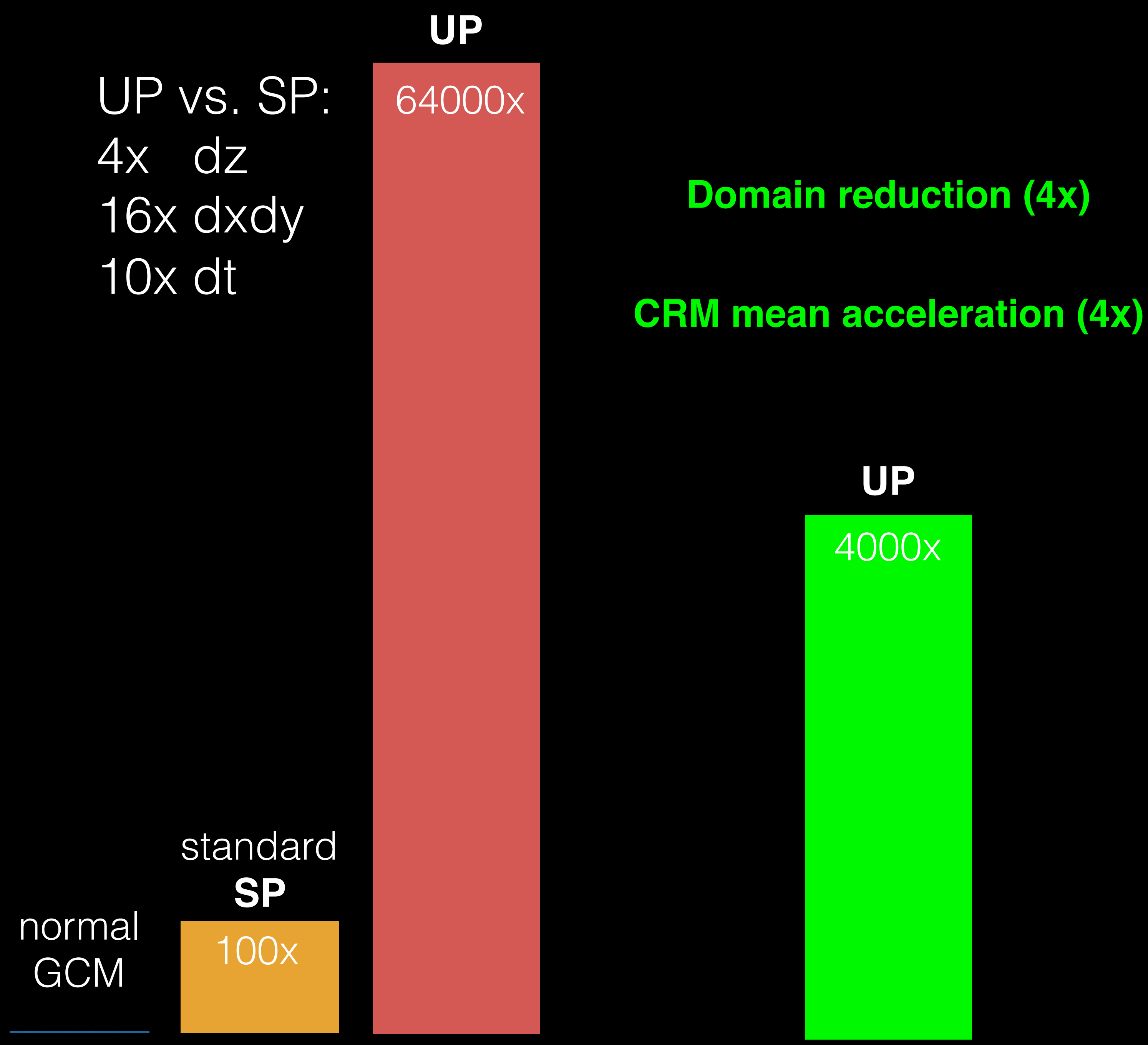
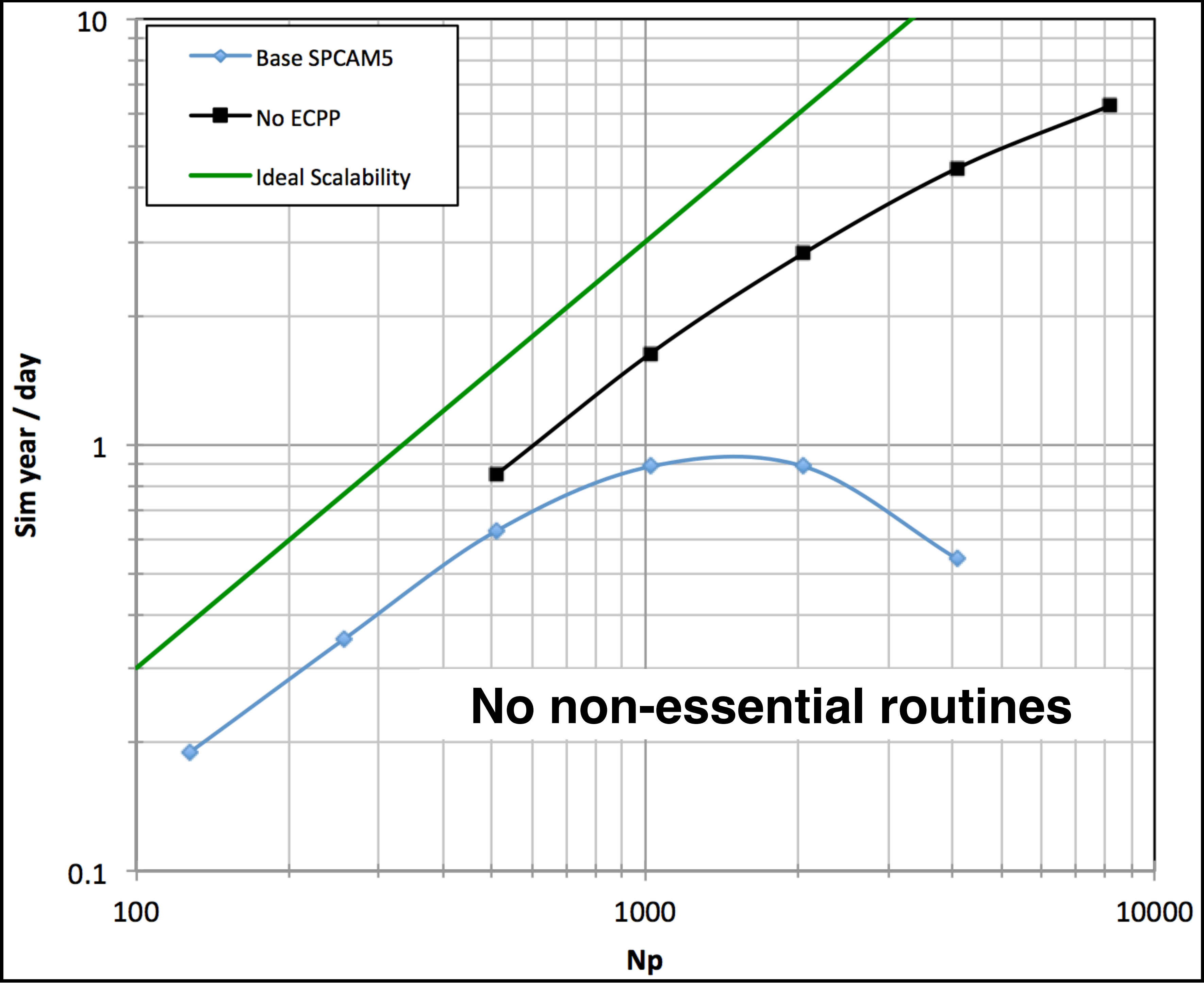


Figure 3. BOMEX 36–48 h mean profiles of (a) cloud fraction and (b) qc.

Ultra-parameterization: computational grand challenge



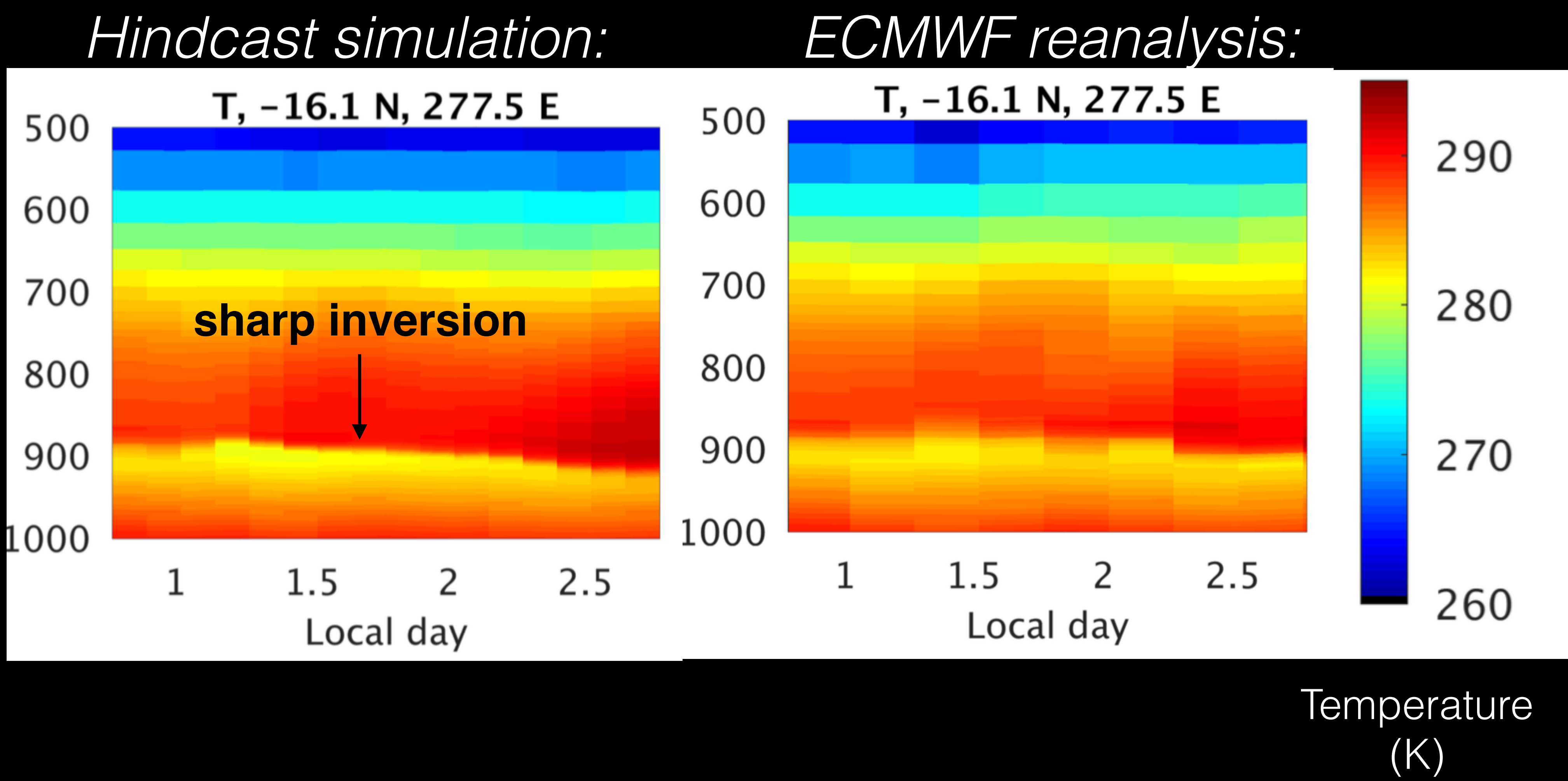
Software eng. has achieved ~4x throughput gain so far:



Ultra-parametrization:

Explicit global simulations of low clouds is now possible.

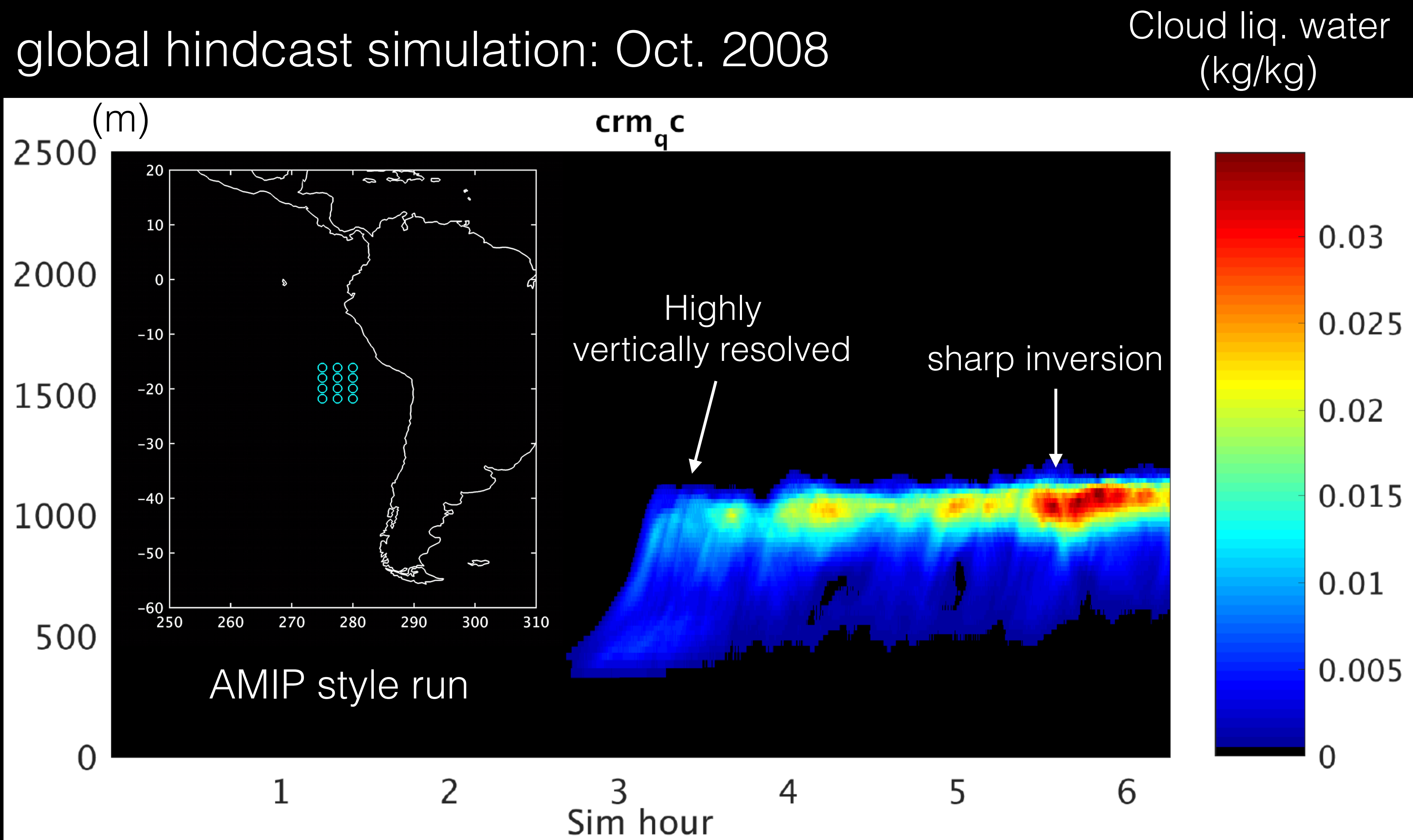
The BL hight and temp inversion are consistent with obs.



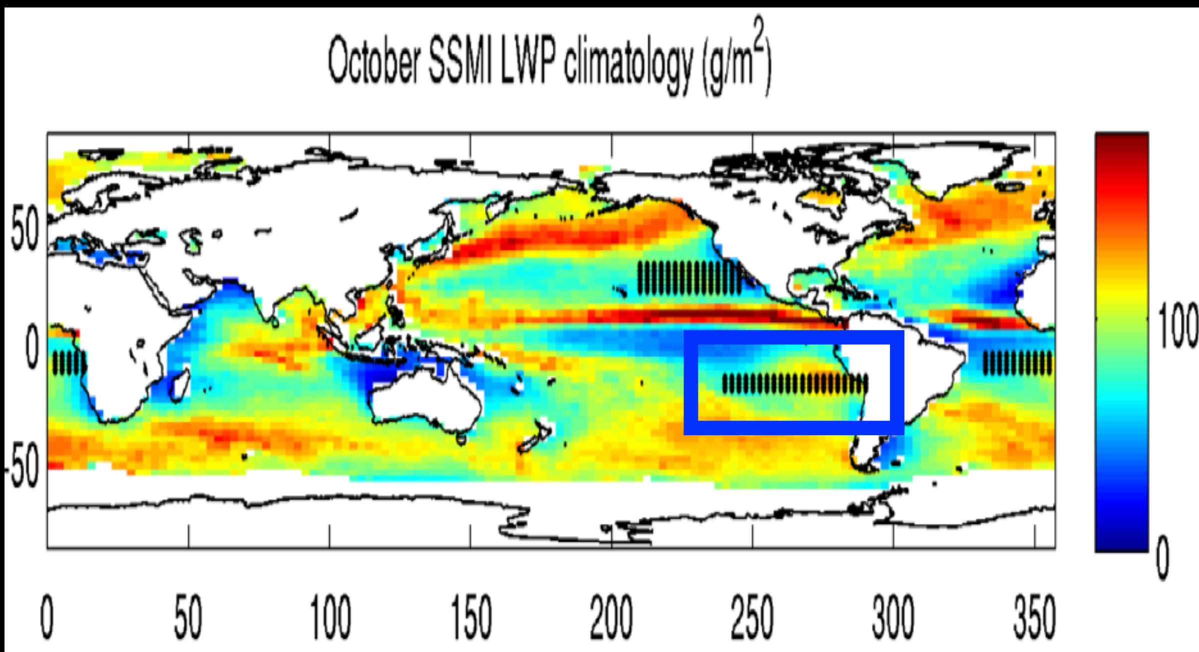
global hindcast simulation: Oct. 2008

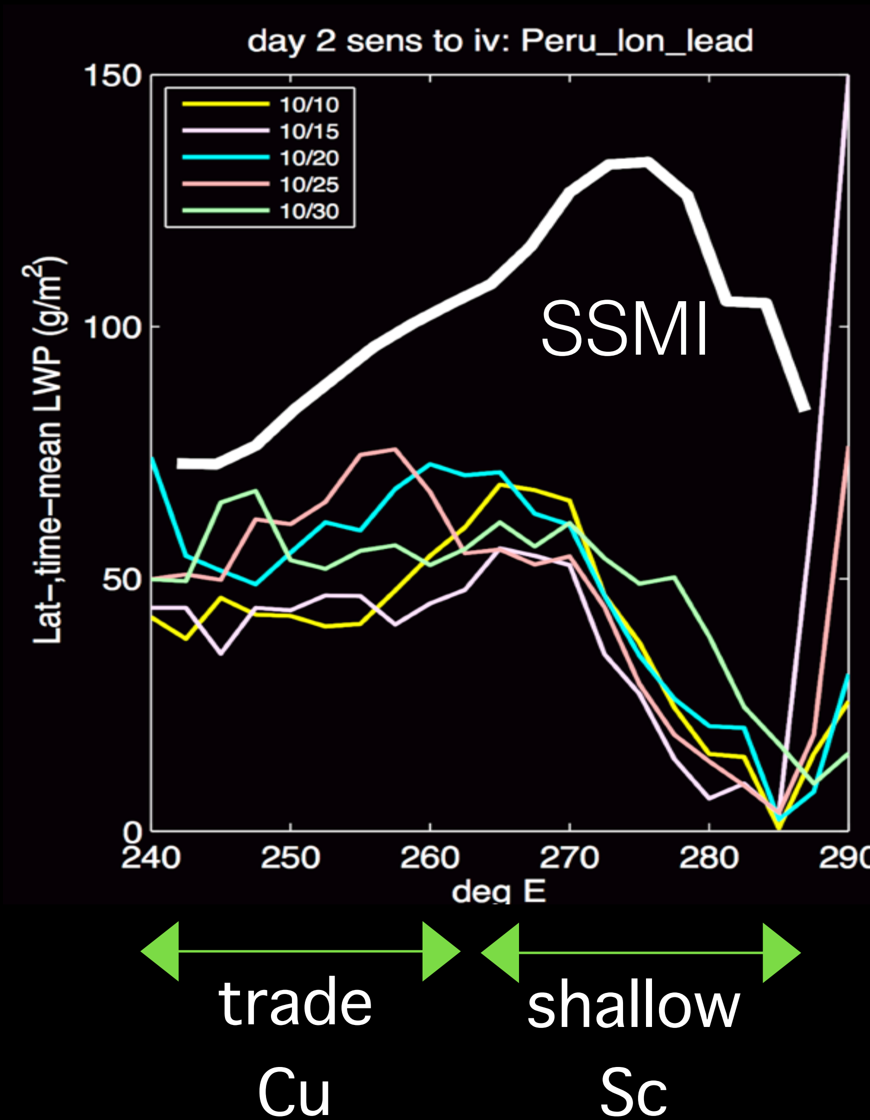
UltraCAM captures explicit marine stratocumulus

global hindcast simulation: Oct. 2008



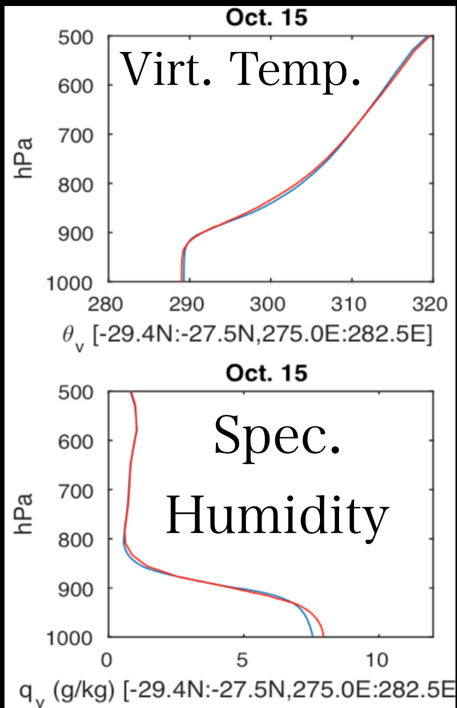
LWP bias: systematic across 5-member ensemble. October 2008 internal variability

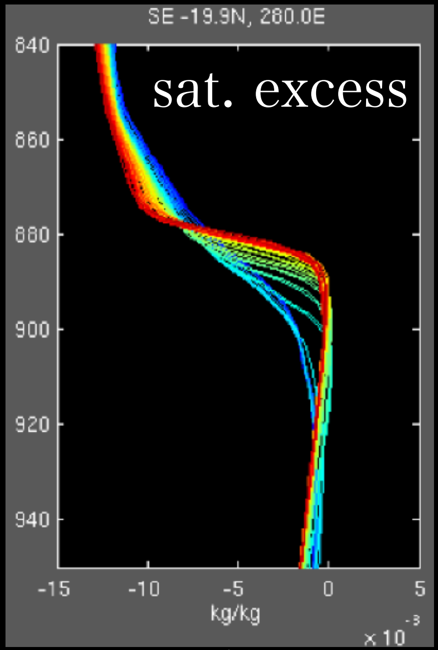


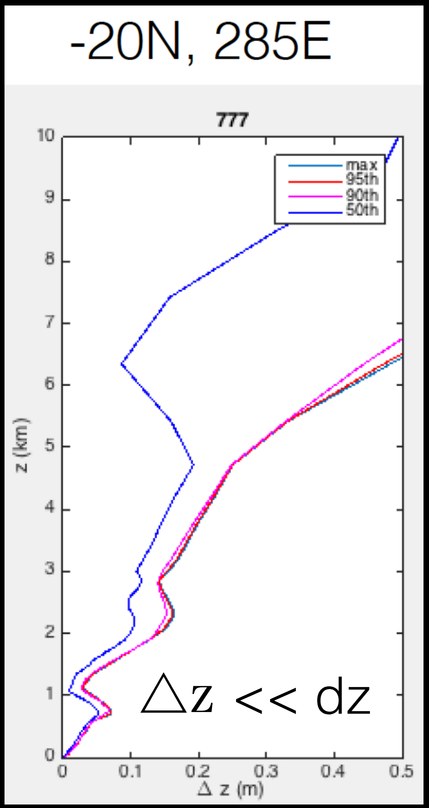


Systematic low bias.

Unlike LES benchmarks.







Low LWP bias in Sc is a mystery.

vertical resolution

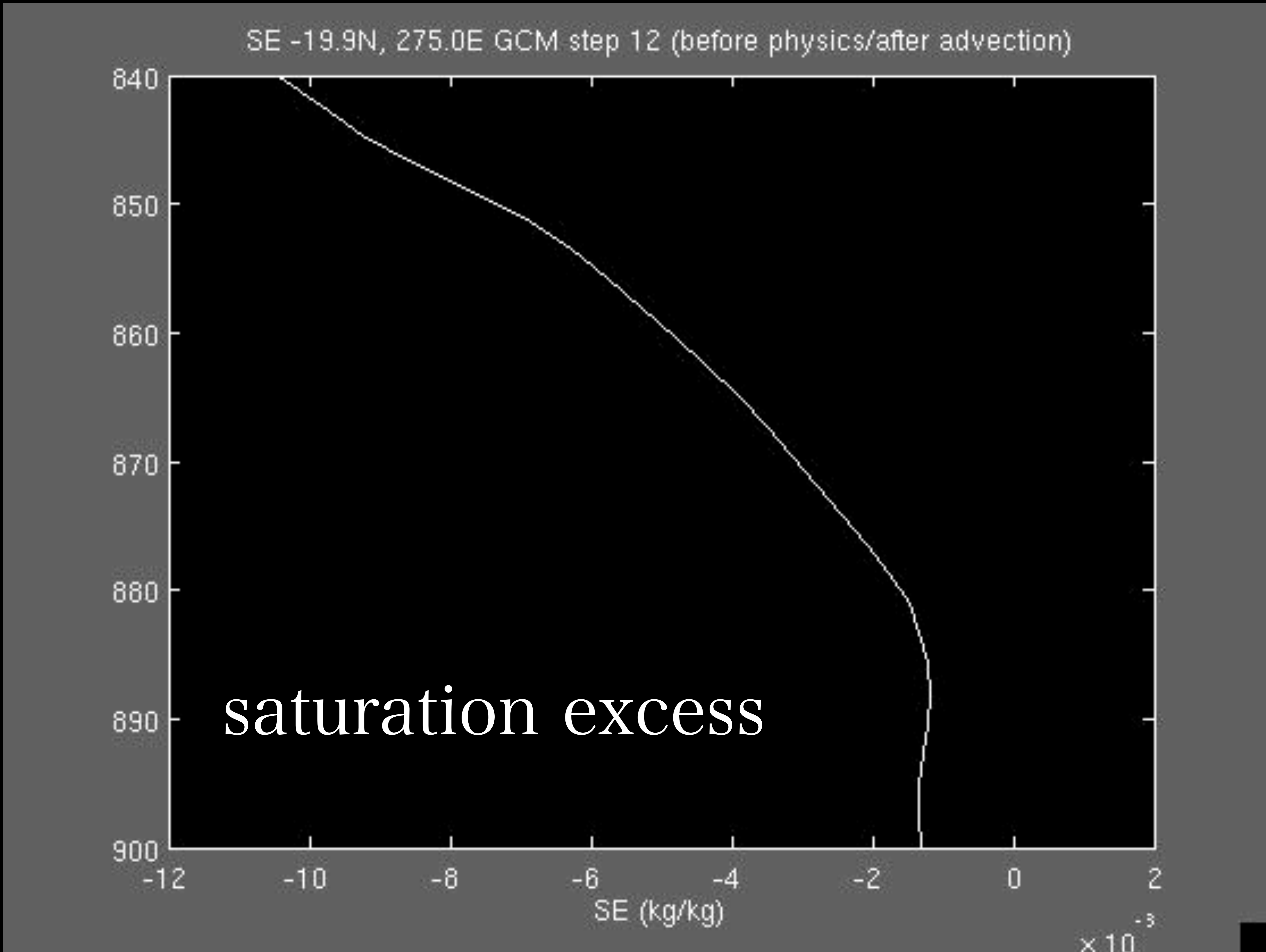
CRM dimensionality

artificial source of entrainment at cloud top

CAM advection/ diffusion constraints

order of advection scheme

CAM advection might be clashing with CRM



Roadmap

Accomplished

CRM mean acceleration

Software eng. ~4x throughput

Initial results promising in trade Cu

Ongoing

Investigating LWP bias

GPU co-processing

Coming year

Redesigning the parallel scaffold

Other CRM paradigms

Stoney Brook

MP
CAM

UW

UC Irvine

Other CRM paradigms:

1. Multiple CRMs: some for shallow and some for deep convection

2. SP-WRF potential

PNNL

Summary

- Explicit low clouds globally: ultra-parameterization.
- Feasible using: CRM acceleration + 4x software eng.
- Short sims: 10,000 cores in 1 hour = 1 day sim.
- Hangs together stratocumulus and inversion signals.
- Good LWP in trade Cu. Not dense at Sc regions.
- Ongoing: LWP bias in collaboration with LES studies from UW and Stony Brook.
- Frontiers of multi-scale: artificial entrainment

Thanks.

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