The Climate Response of Convective Parcel Modification in CAM

Community Earth System Model CESM

Vertical Level Thickness

L58
L48
L32
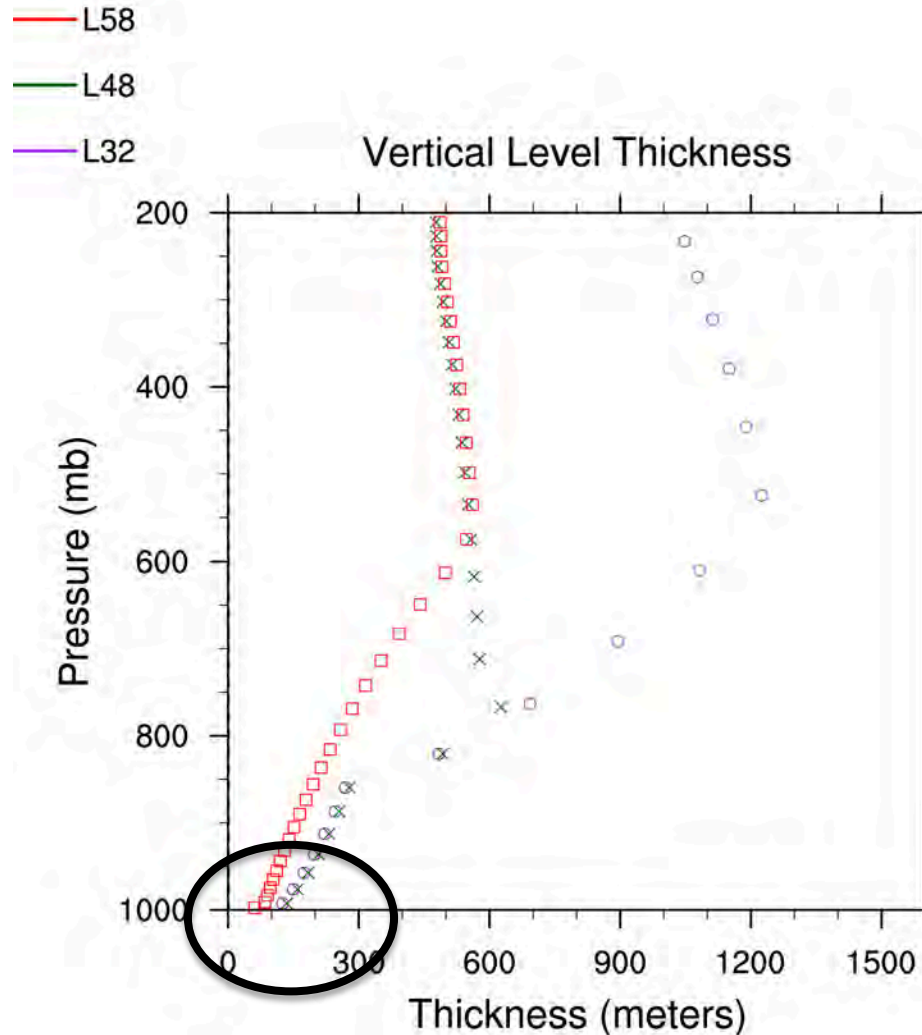
Rich Neale

Cecile Hannay, Adam Herrington, Julio Bacmeister, Ben Stephens, Thomas Toniazzo
+AMP/AMWG

NCAR

2022 CESM Workshop

CAM7 Vertical Resolution and ZM Deep Convection
- Target Workhorse Model (L58/L93)
- +16 levels (L48): Stable, minimal loss of climate skill
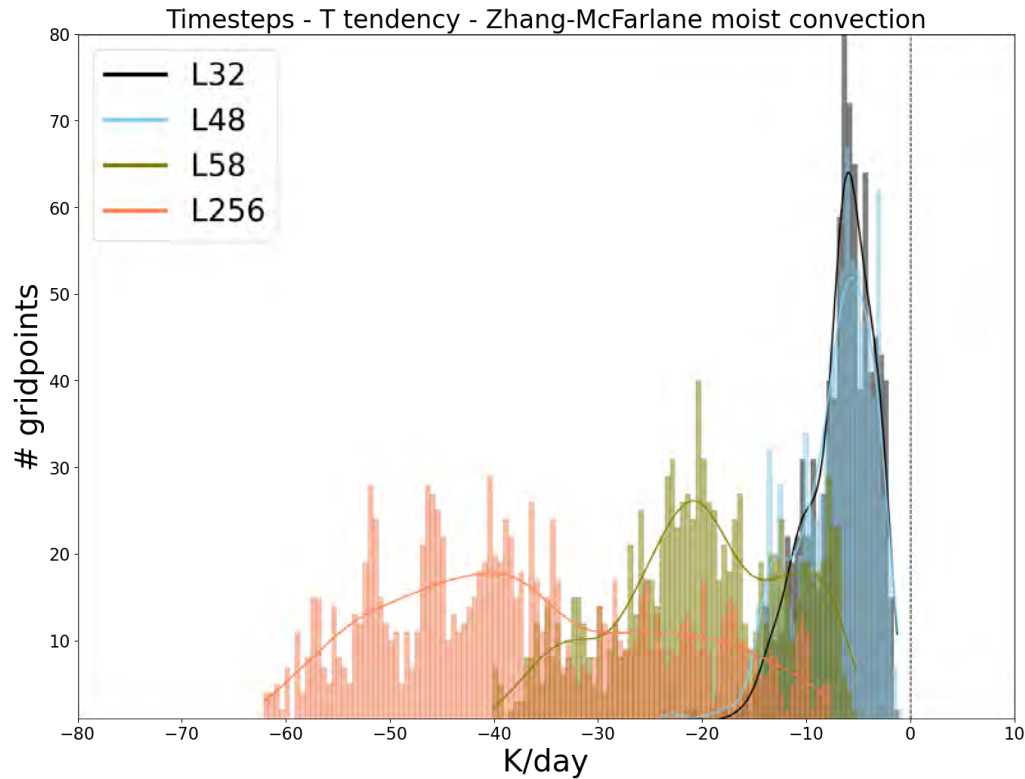- +10 levels (L58): Sporadic crashes, significant loss of skill

Modifying convective parcel properties near the surface
Fixing the implementation over land
Do we need to desensitize convection in the vertical?

Convective Tendencies
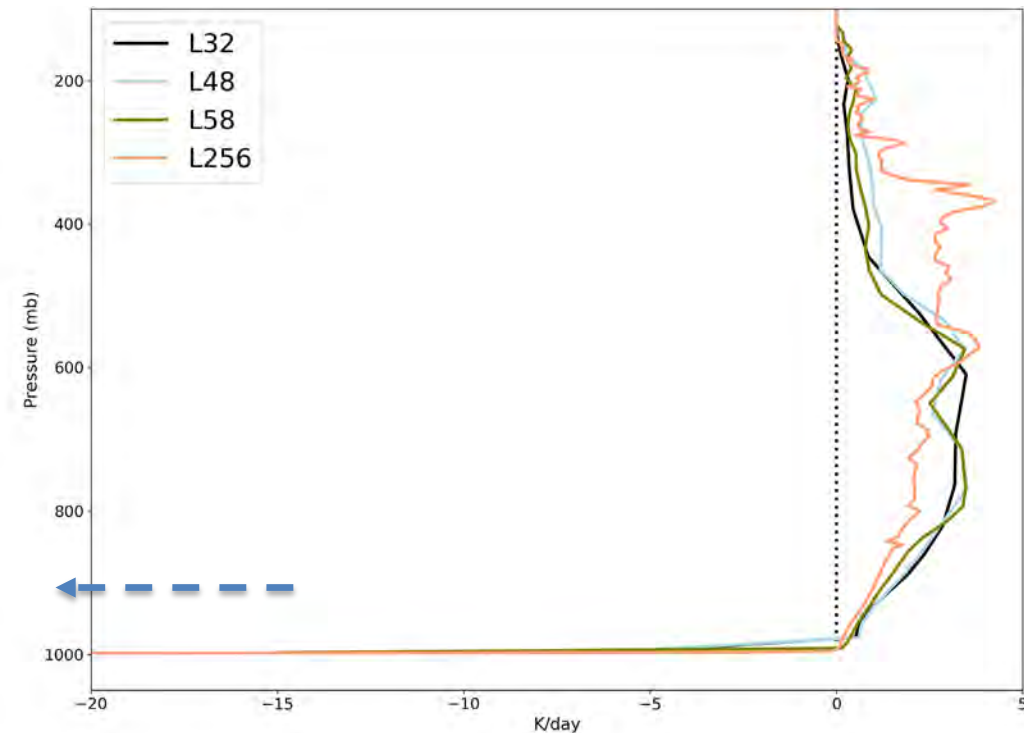
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Lowest Level Convective Heating

- Zhang McFarlane (ZM) sensitivity to surface layer thickness
- Cooling tendencies don't converge, compensation from CLUBB
- Minimal impact on the precipitation distribution
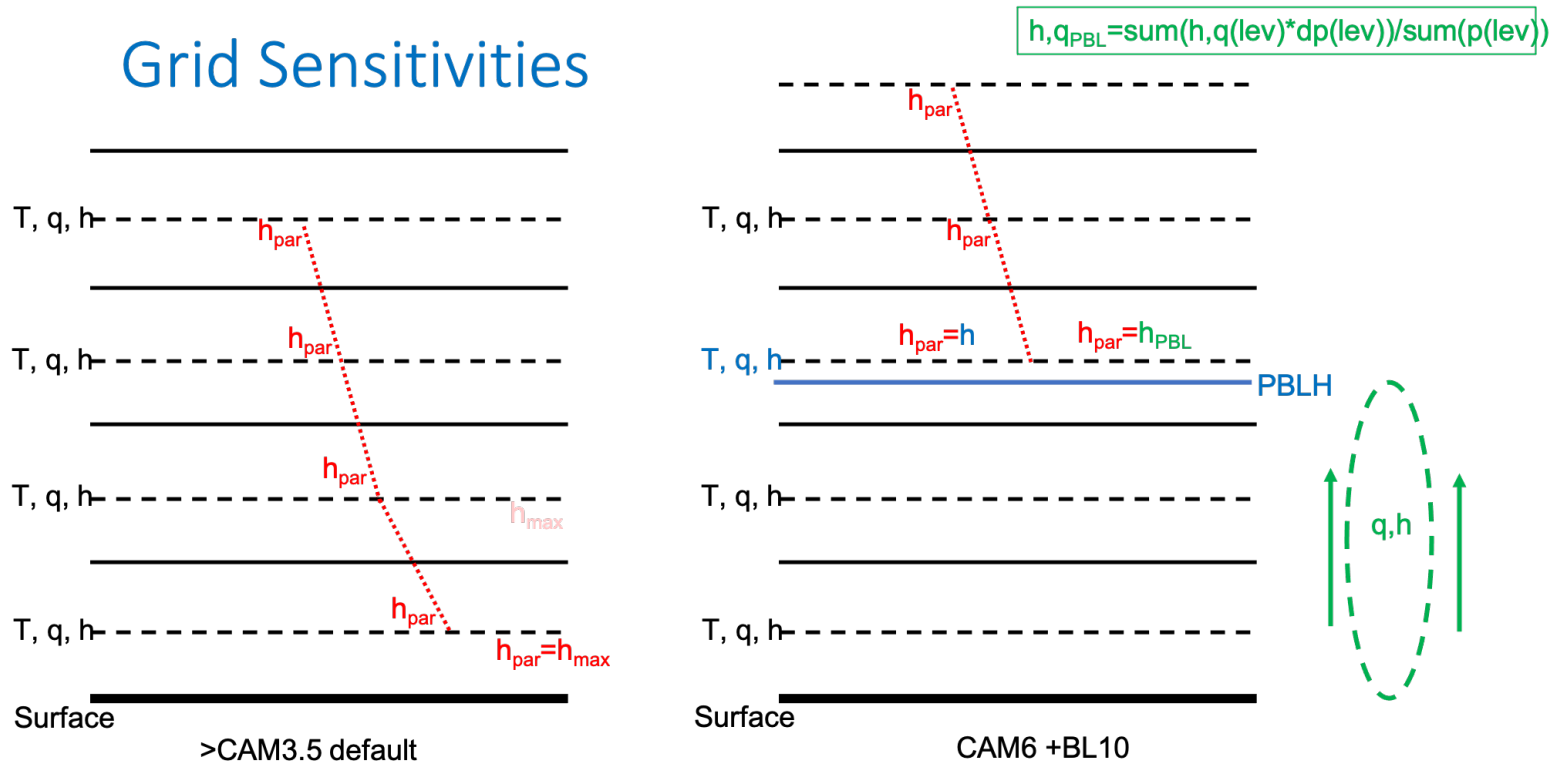
ZM Temperature Tendencies (K/day) - Timesteps

ZM Temperature Tendencies (K/day) - Average

Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

Modified Convective Parcel Properties

Grid Sensitivities

$h, q_{PBL} = sum(h, q(lev)*dp(lev))/sum(p(lev))$

h_{par}

T, q, h — — — — — h_{par}

T, q, h — — — — — h_{par}

h_{max}

T, q, h — — — — — h_{par}

T, q, h — — — — — h_{par}

$h_{par} = h_{max}$

Surface

>CAM3.5 default

h_{par}

T, q, h — — — — — h_{par}

$h_{par} = h$ $h_{par} = h_{PBL}$

T, q, h — — — — — PBLH

T, q, h — — — — —

q, h

T, q, h — — — — —

Surface

CAM6 +BL10

Existing Launch Parcel Calculation

- Depends on **level** of maximum moist static energy
- Almost always the near-surface level over the ocean
- No inherent vertical scale
- No direct recognition of turbulent eddies

Modified Launch Parcel Calculation

- Depends on MSE and depth of PBL
- Introduces vertical length scale
- 0.5x of PBL depth ('ZM2')

Modified Convective Parcel Properties

Launch Level changes

- No longer always lowest model layer
- Largely resolution independent
- Depends more on environmental conditions -> improved precip. timing
- Elevated launch levels occur when dryer
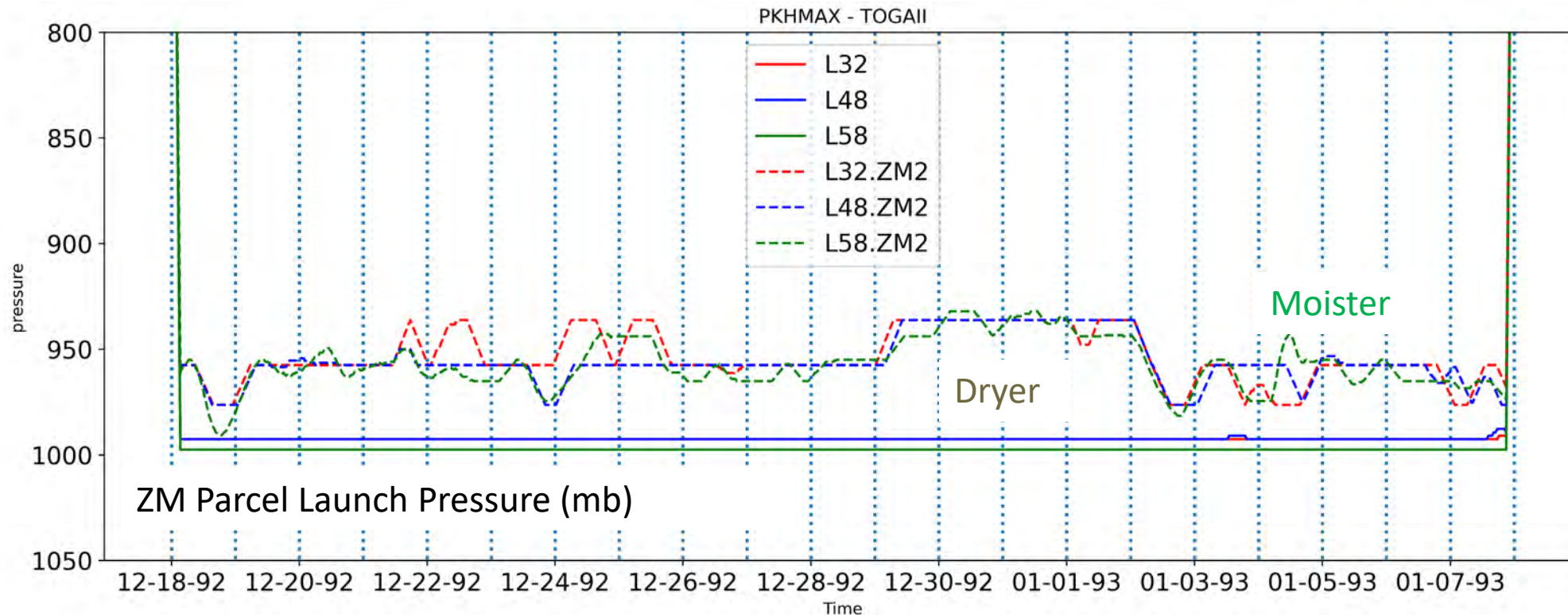
Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

Modified Tendencies

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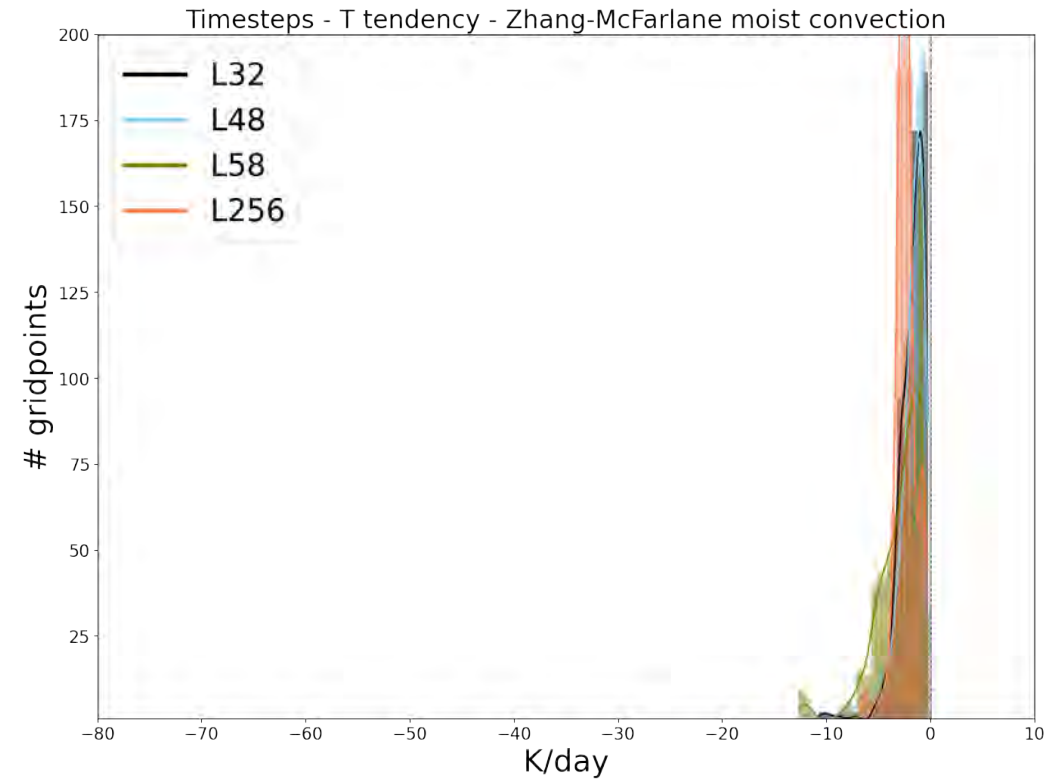NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Lowest Level Heating

- Much weaker, therefore weaker compensation from CLUBB
- More insensitive to surface layer thickness
- And yet, minimal impact on the precipitation distribution

Original Parcel

PBL Parcel

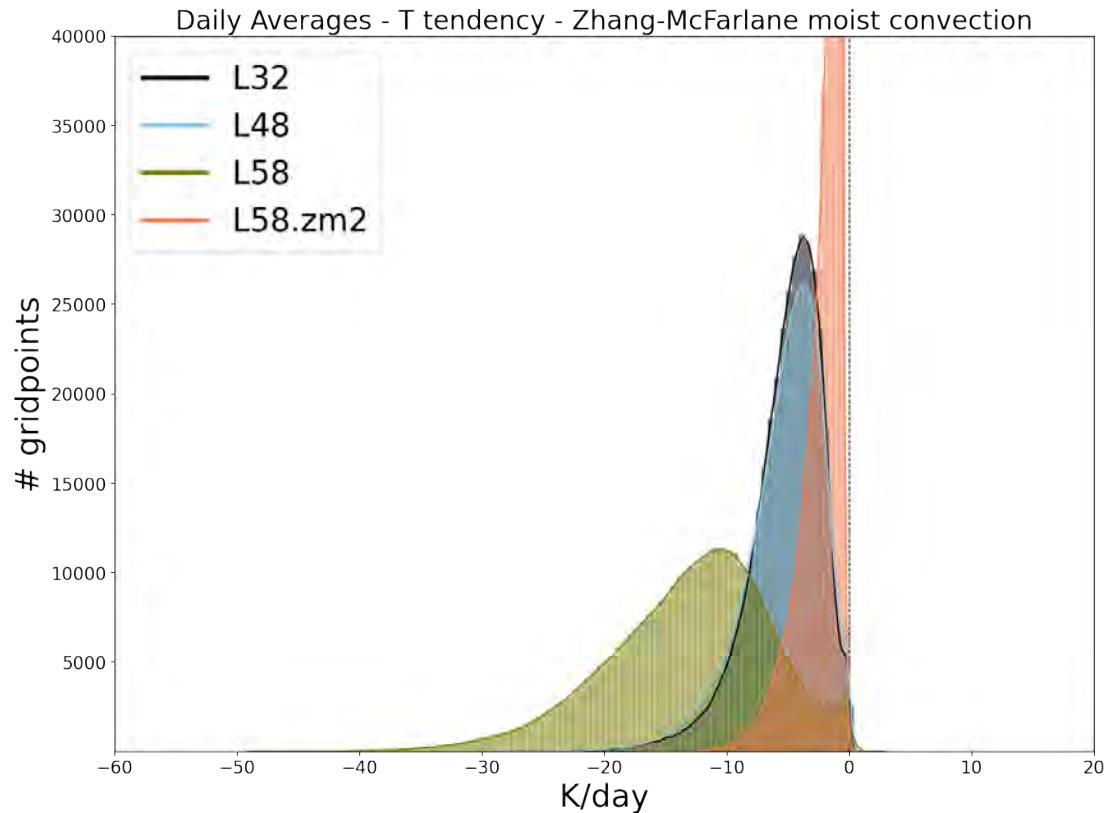Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)
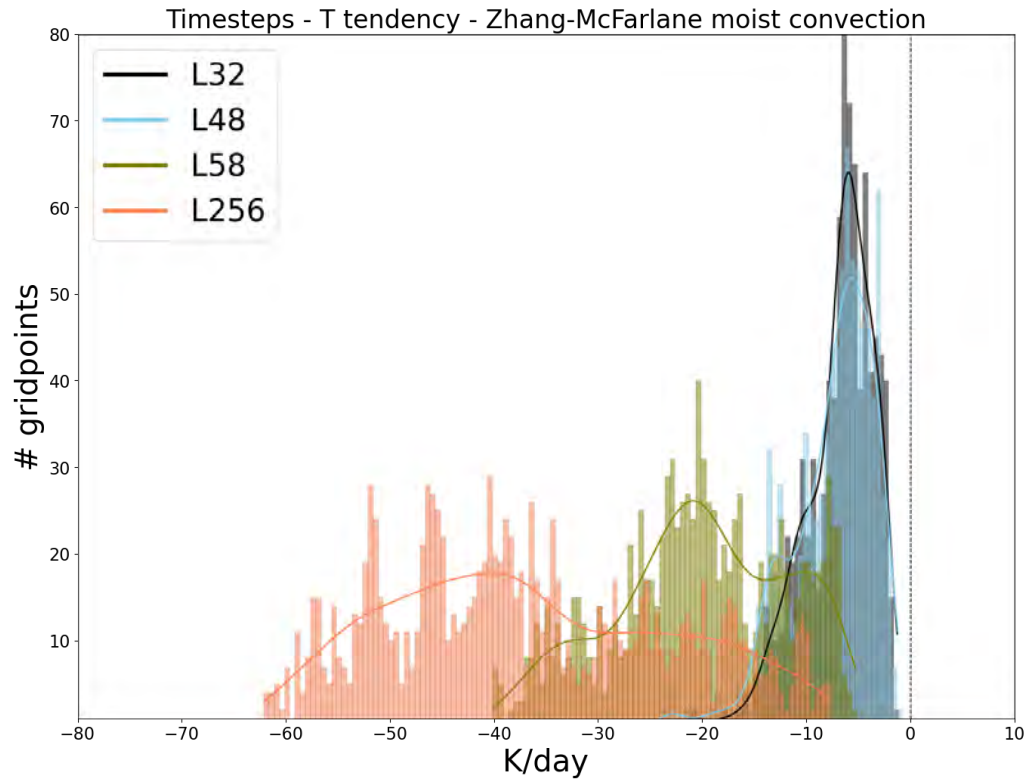
AMIP Simulations: Tendencies
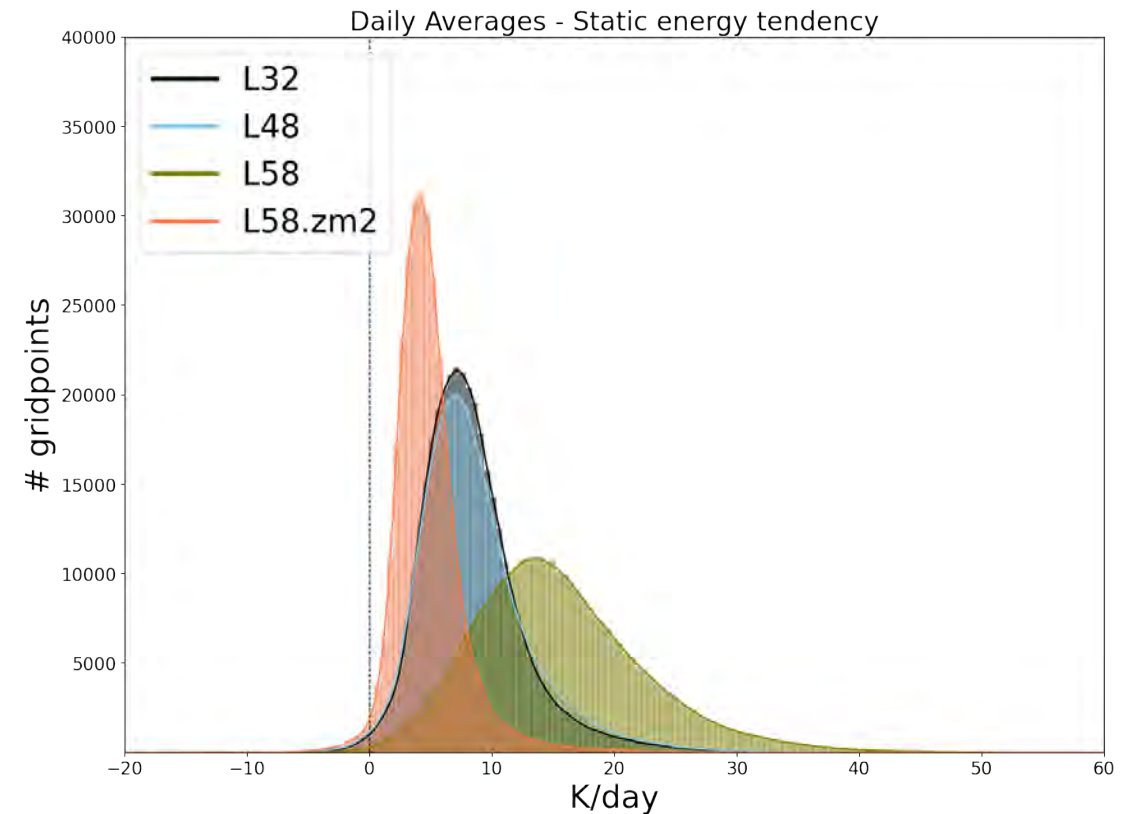
ZM and CLUBB near-surface tendencies

- L32 and L48 almost indistinguishable
- ZM and CLUBB daily values > +/-40K
- Is the ZM2 modification overcorrecting (smaller length scale?)

ZM dT/dt

CLUBB dT/dt

AMIP Experiments – Tropics

CAM6 Simulations

Resolution	ANN	DJF	MAM	JJA	SON
L32	0.90	1.10	1.06	1.47	1.13
L48	1.00	1.18	1.07	1.52	1.19
L58	1.10	1.39	1.23	1.64	1.38
L58.zm2	1.02	1.28	1.10	1.52	1.17
L58.bline	1.20	1.50	1.36	1.63	1.42
L58zm2new	0.98	1.30	1.13	1.46	1.19

Global Precipitation
(1981-1989) - RMSE

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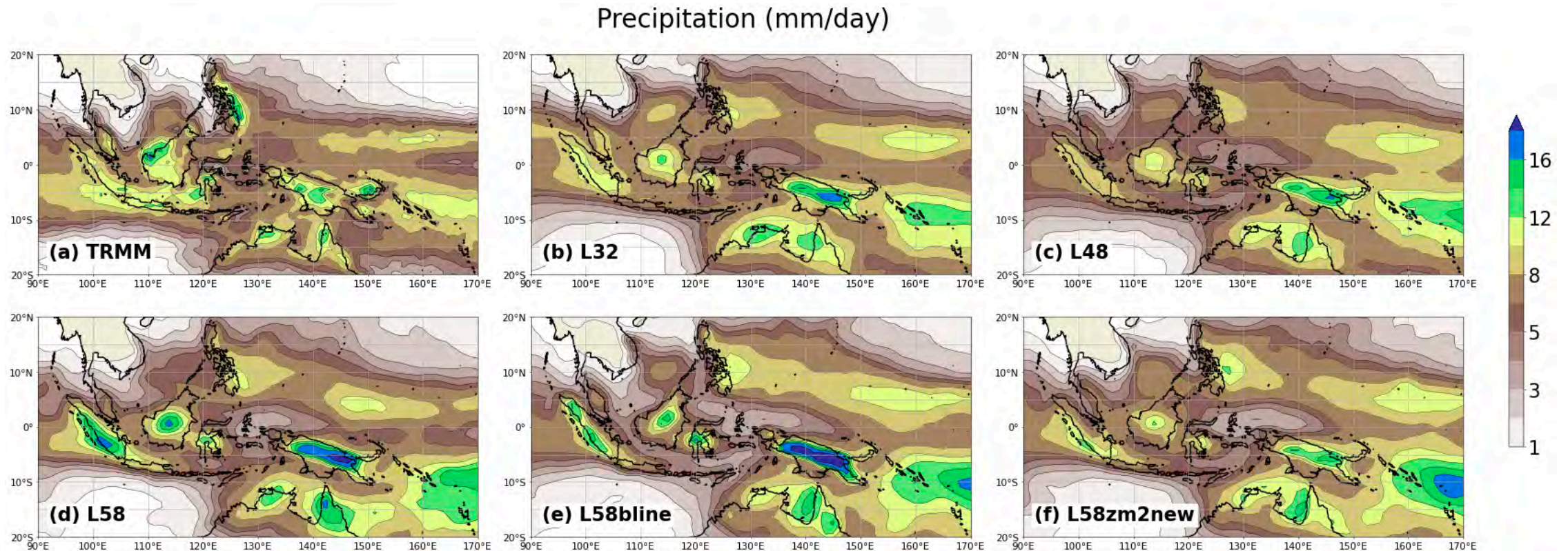
AMIP Simulations

- Global degradation with increasing vertical levels, esp. L58 (10-20%)
- With parcel modification looks closer to L48
- Excessive mean surface ZM cooling dominates tropics
- Offset by CLUBB in the tropics
- Surface fluxes do not seem impacted
- ZM2: Consistent with SCAM, 0.5PBLH is too large to be consistent with L48/L32
- Should that be a target?

ZM dT/dt (sfc level, 1981)
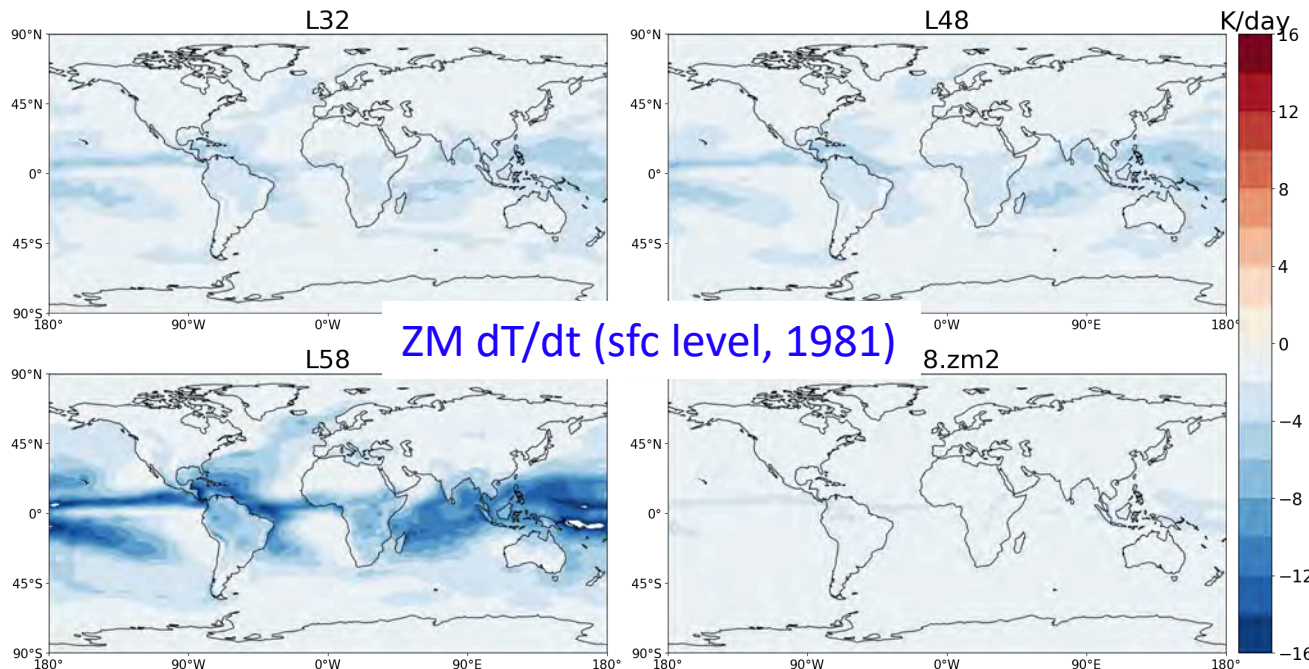
Convective Parcel Fix Over Orography

AMIP Performance

- PBL levels in particular (L58) lead to intense orographic maximum
- Most recent ZM2 implementation moderates large Guinea maximum
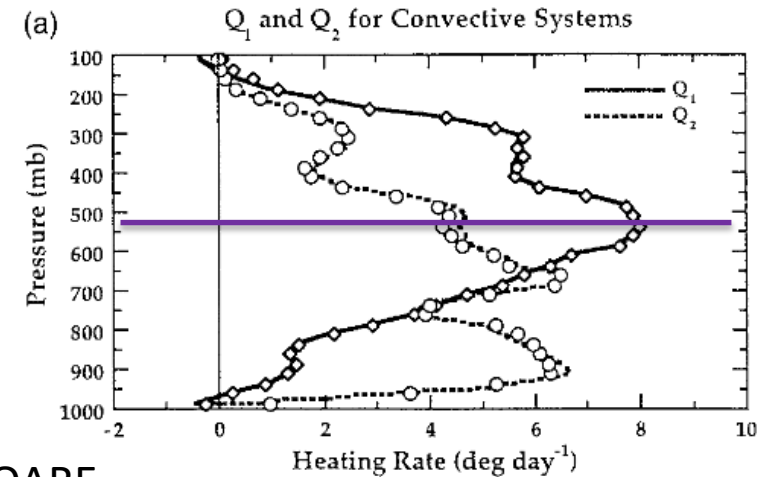- Response more in line with L32/L48 climate

Precipitation (mm/day)

(a) TRMM (b) L32 (c) L48 (d) L58 (e) L58bline (f) L58zm2new

AMIP Experiments - DJF
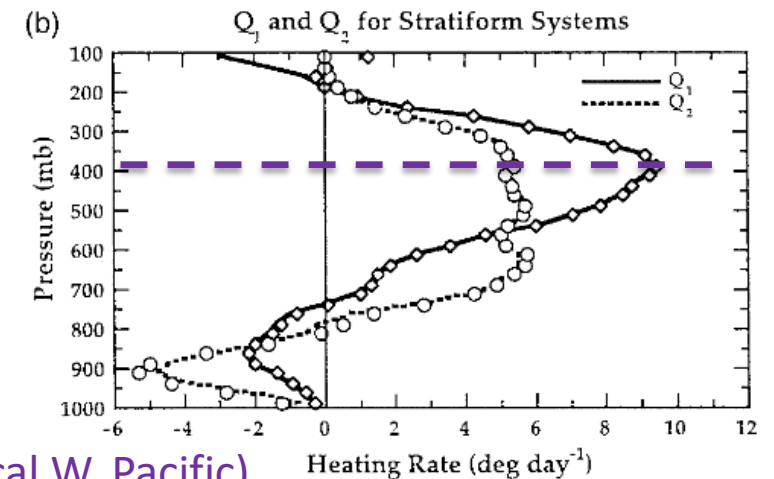
Remaining Deep Convection Issues

Top Heaviness

- Shallowed over time CAM3->CAM6
- Increased sensitivity to moisture (good for MJO, diurnal cycle)
- Compensation from non-convection physics
- Implications for lower stratosphere (QBO, tape recorder)?

ZM Deep Convective Heating (TOGA-COARE, 1992)
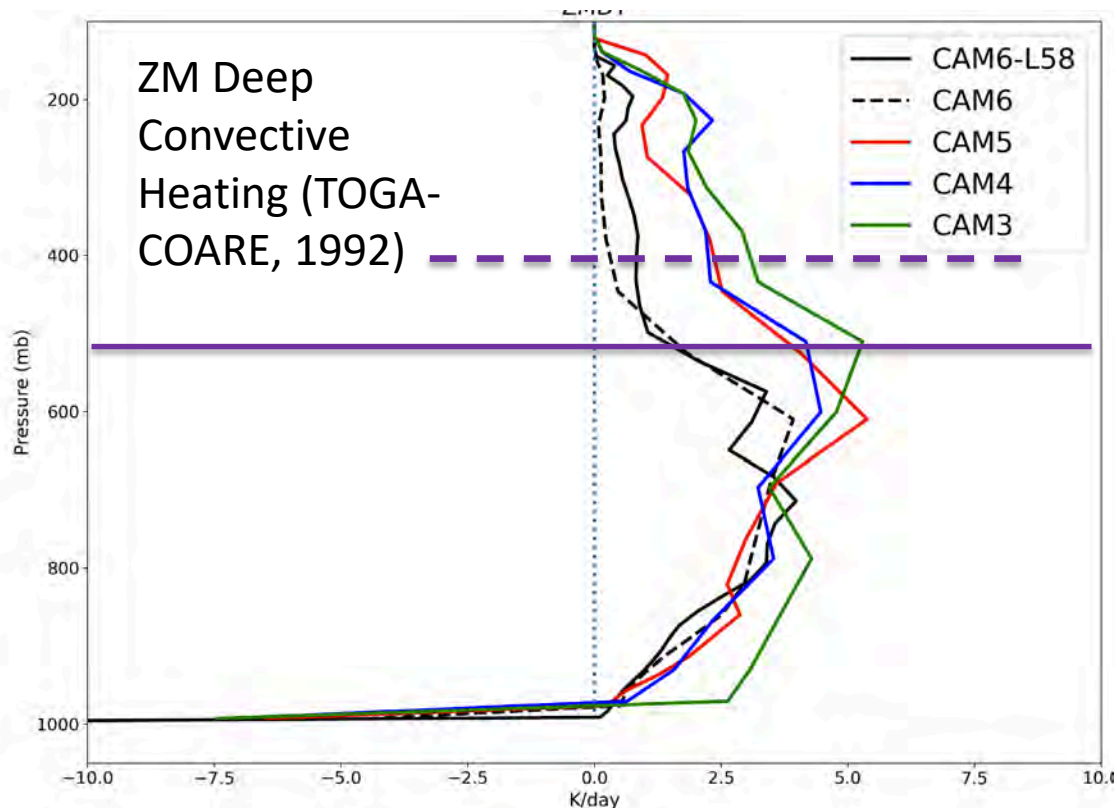
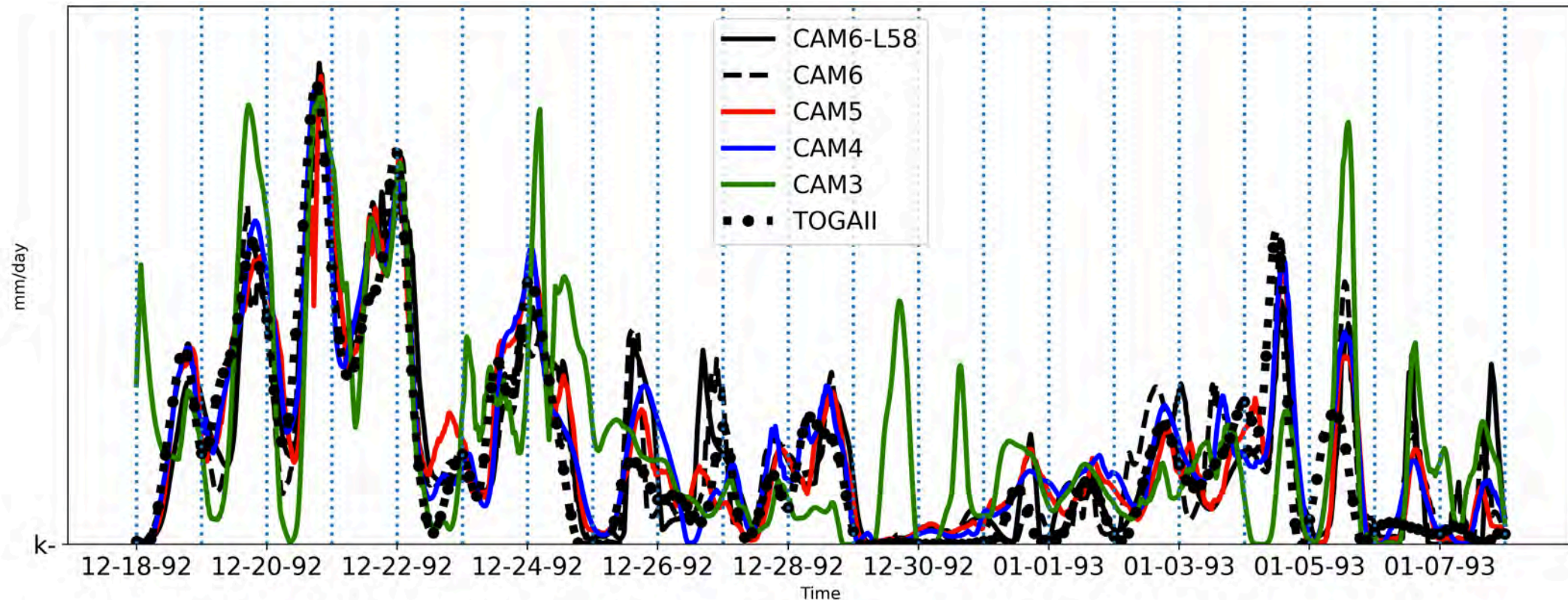Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

TOGA-COARE IFA

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Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

# Remaining Deep Convection Issues

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Dynamic Parcel Testing

- Solve simple vertical velocity equation
- Convective top where parcel KE<0 (allows overshoot)
- Prescribed initial parcel energy and conversion rates
- Couple with parcel modifications and testing in AMIP

ZM Temperature Tendencies (K/day) - Average
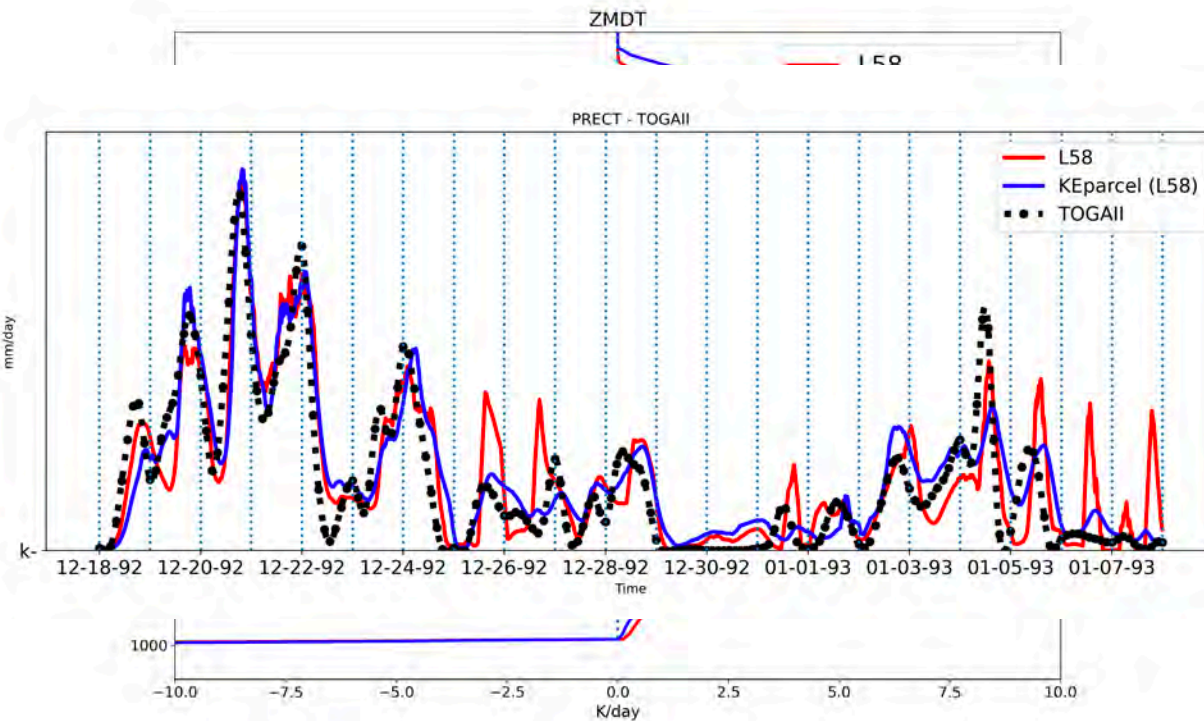
TOGA COARE (Tropical W. Pacific)

ARM (SGP 1997)

Summary
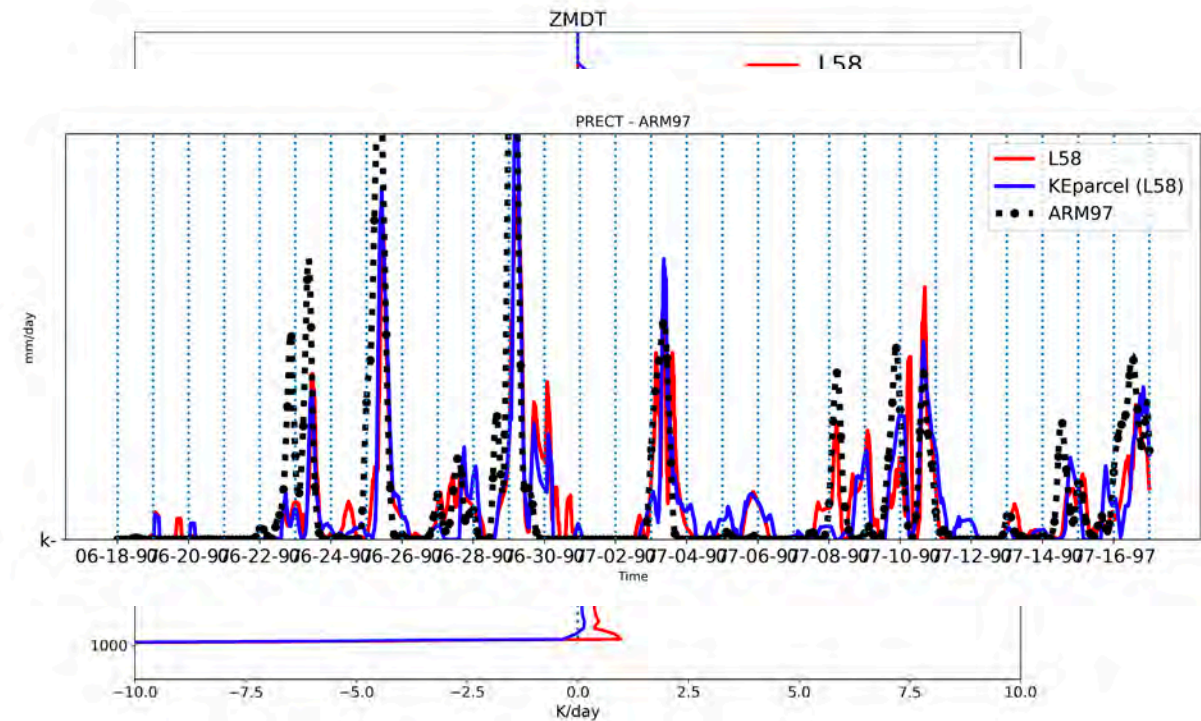
- Non-convergent response to surface level thickness
- In deep convection: Push-pull relationship between ZM and CLUBB
- Apply a PBL-scale ZM parcel modification, reduces sensitivity

- AMIP precipitation significant degraded w/o ZM2 with L58
- Significant push-pull exists through the tropics
- Correct implementation over ocean and land returns L32/L48 skill

- Convection top heaviness is weak
- Manifestation of large stability sensitivities in convection
- Simple parcel dynamics can correct for this
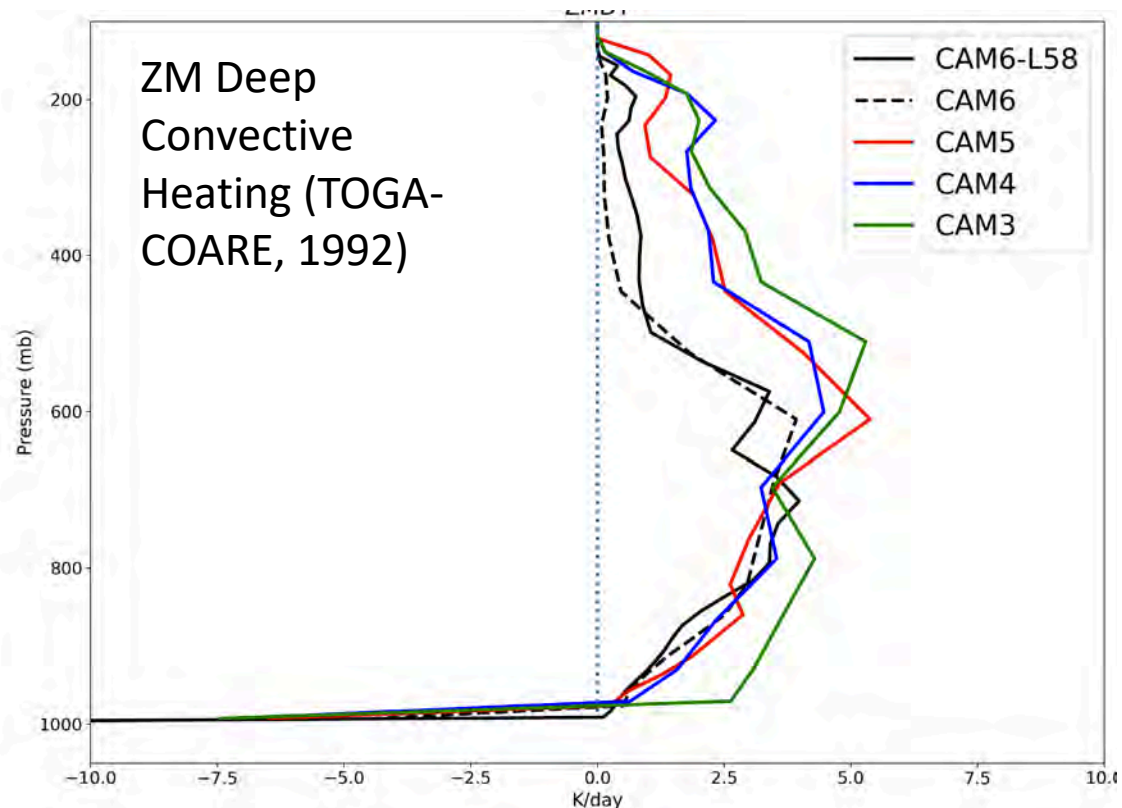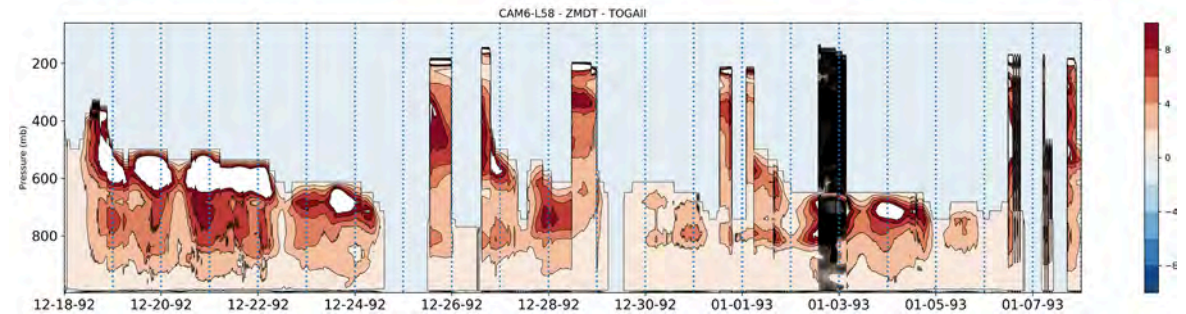
Extra Slides

Remaining Deep Convection Issues
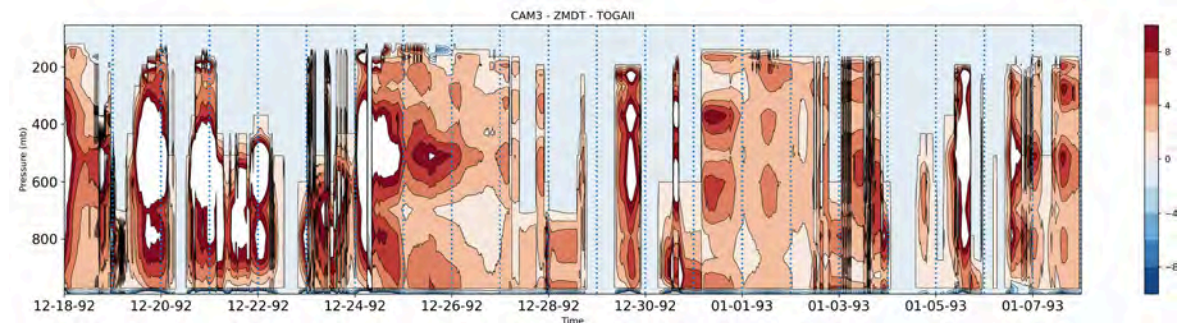
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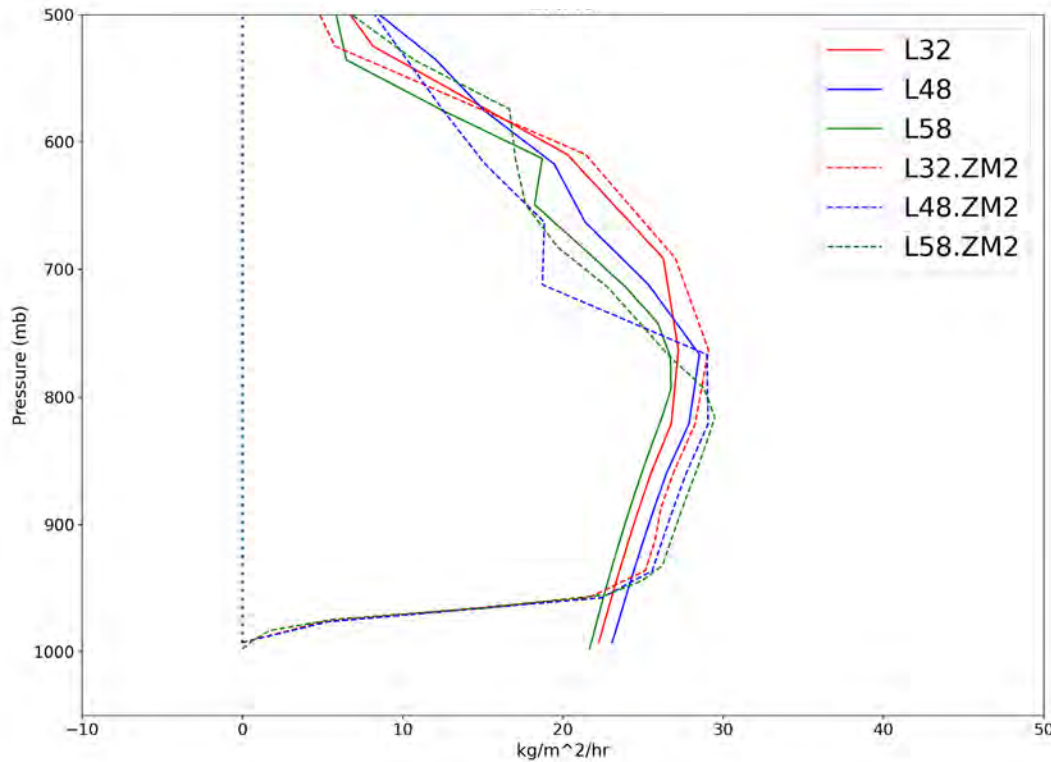
CAM6 (L58)

CAM3 (L26)

Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

Mass Flux Profiles

Low level flux convergence

- Reduced mass flux convergence/divergence in the lowest level
- Smoother ramping up/down through PBL
- Mostly independent of resolution

ZM Updraft Mass Flux

ZM Downdraft Mass Flux

Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)