Employing PBL Mixing and Simple Parcel Dynamics in CAM Convection

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Modified ZM Parcel Properties

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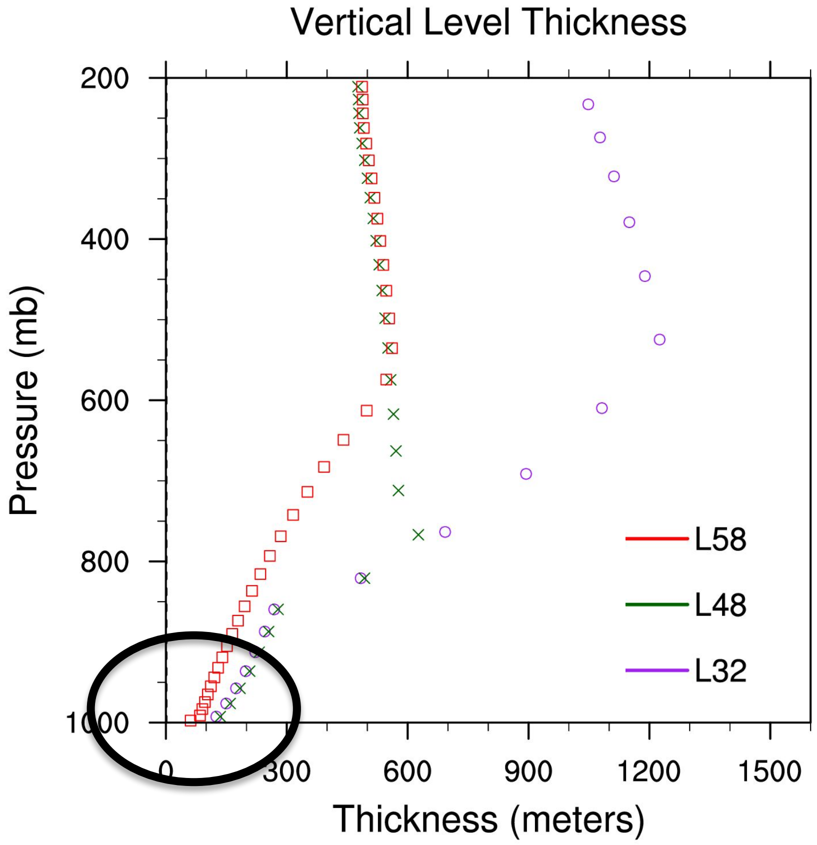
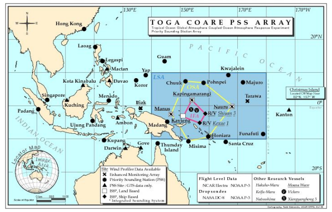
Strong Lowest Level Heating (L58)

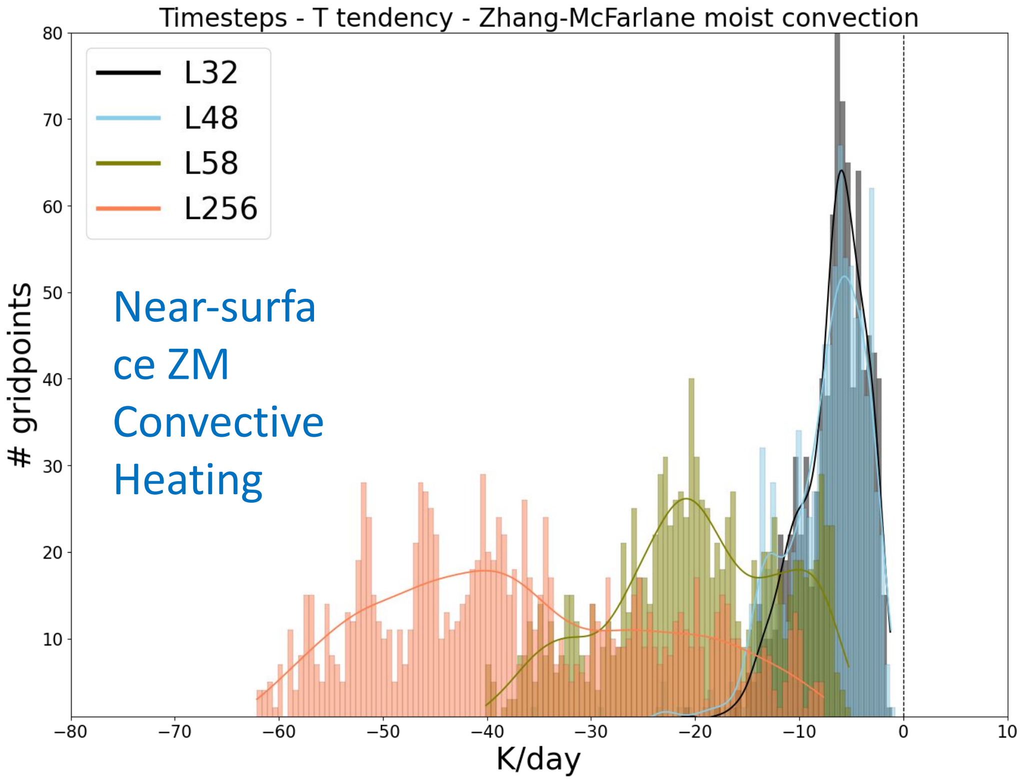
- Thin lowest level (20m)
- Excessive (?) below convection cooling
- Large compensation by CLUBB heating

Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific) Dec/Jan - 1992-93





Original Parcel

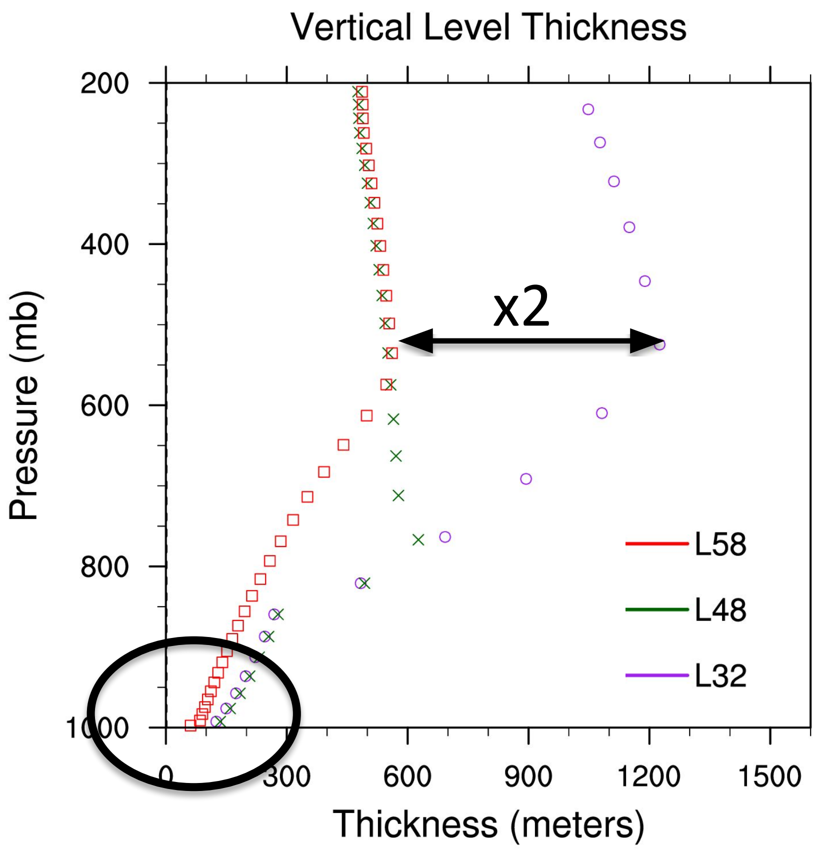


Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

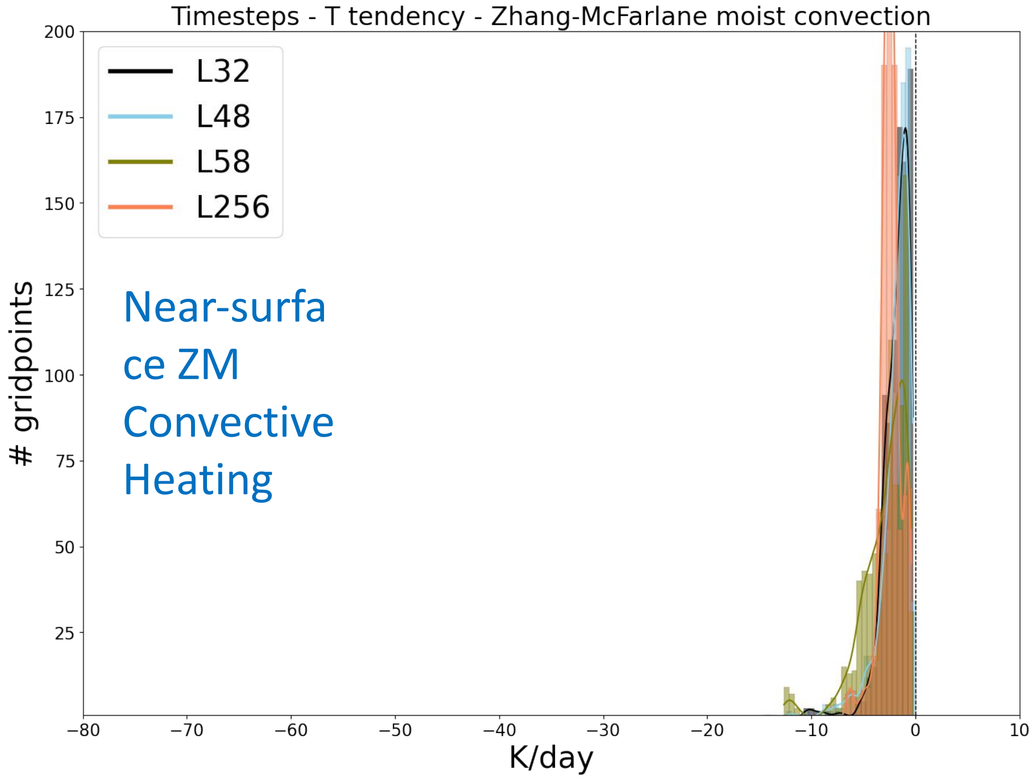
Modified ZM Parcel Properties

Parcel modification based on PBL mixing

- Parcel launch level and properties based on mixing scale (0.5xPBLH)
- ‘Scale aware’ below cloud depth
- <u>Could there be other sensitivities?</u> - thin layer stability



PBL Parcel



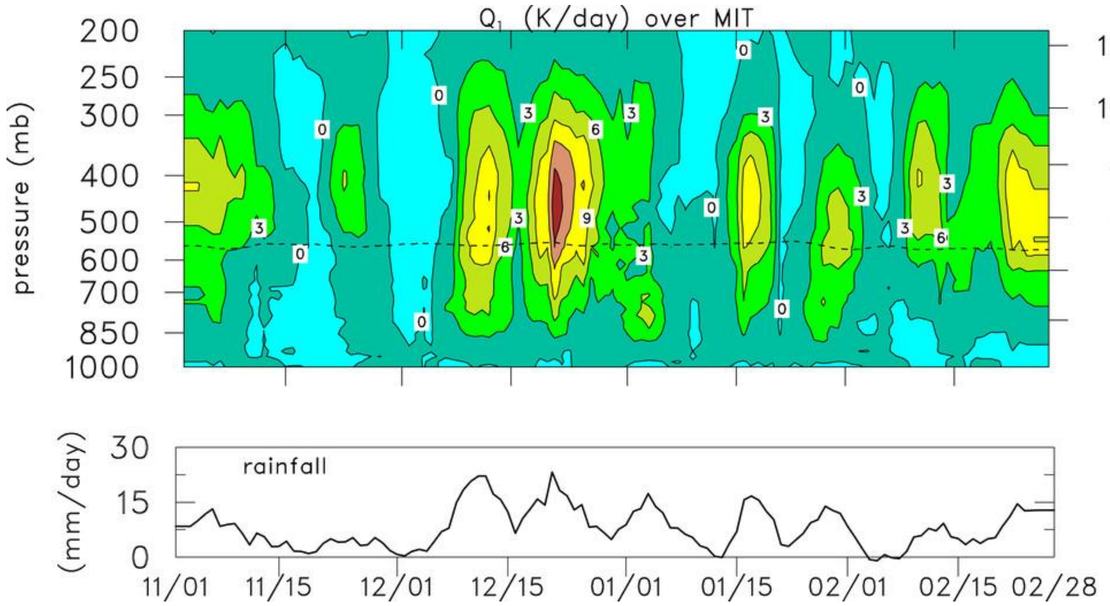
Single Column CAM (SCAM) – TOGA COARE (Tropical W. Pacific)

Convective Heating Profiles

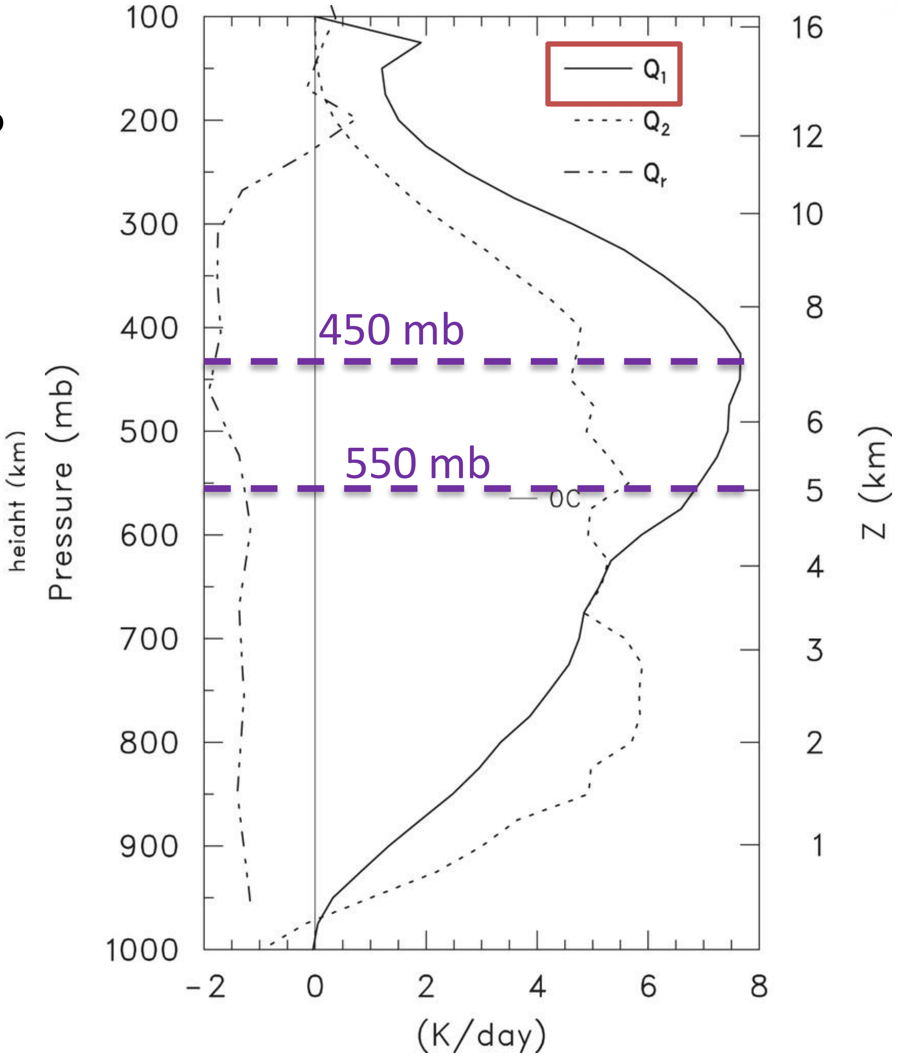
Observed Convection Heating (Q1)

- Peak level depends on organization type
- Convective lower; stratiform higher
- How does this relate to separation of response?

Convective (ZM) vs. Large scale (CLUBB)



Johnson and Ciesielski (2016)



TOGA COARE (Tropical W. Pacific)

Remaining Deep Convection Issues

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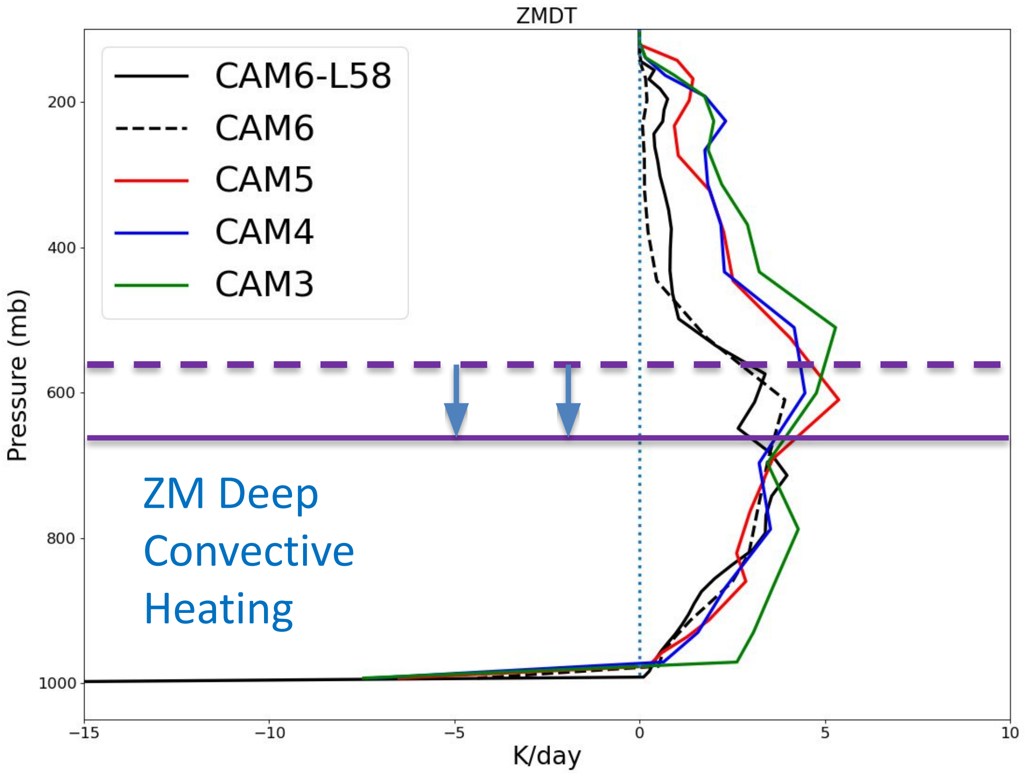
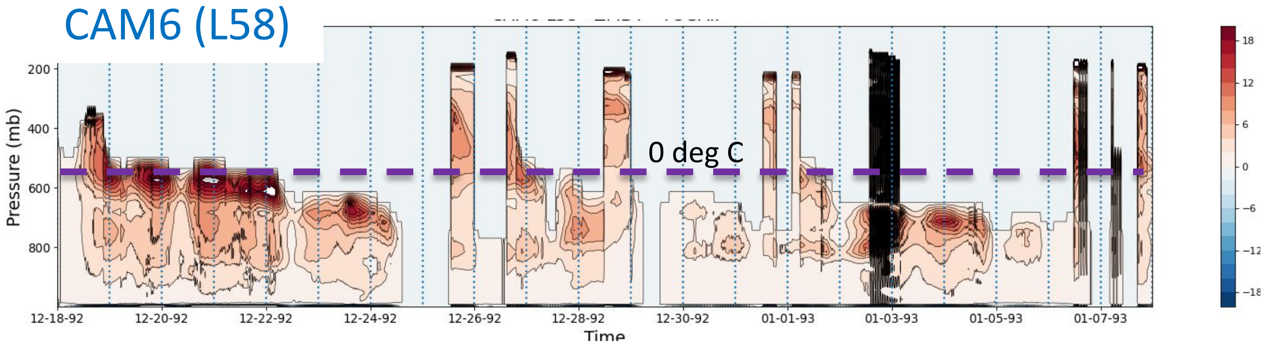
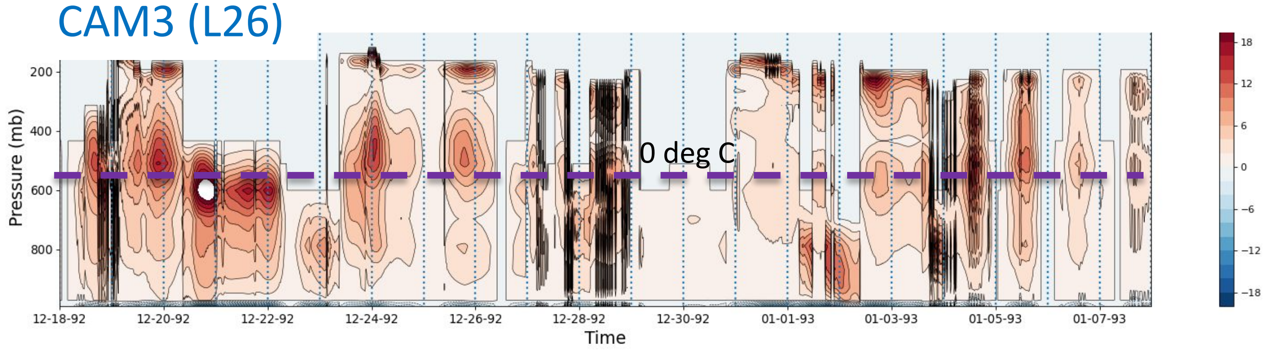
Top Heaviness

- 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)?







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

Simple Plume Dynamics (KE/PE)

Reference	Acronym	Equation	a	b	Remarks
Simpson and Wiggert (1969)		(1)	$\frac{2}{3}$		$\frac{1}{2}\frac{\partial w_c^2}{\partial z} = aB_c - 0.18\frac{w_c^2}{R}$, where R is cloud radius
Bechtold et al. (2001)	BBGMR	(12)	$\frac{2}{3}$	1	
Gregory (2001)	G01	(11)	$\frac{1}{6}$	1	$\frac{1}{2}\frac{\partial w_c^2}{\partial z} = aB_c - (b'\delta + b\epsilon)w_c^2, b' = \frac{1}{2}$
Von Salzen and McFarlane (2002)	SF	(29)	$\frac{1}{6}$	1	
Jakob and Siebesma (2003)	JS	(7)	$\frac{1}{3}$	2	
Bretherton et al. (2004)	BMG	(17)	1	2	
Cheinet (2004)	C04	(1)	1	1	
Soares et al. (2004)	SMST	(6)	2	1	
Rio and Hourdin (2008)	RH	(5)	1	1	$\frac{\partial \sigma w_c^2}{\partial z} = a\sigma B_c - b'\delta\sigma w_c^2, b' = \frac{1}{2}$ b value found after substitution of Eq. (4)
Neggers et al. (2009)	NKB	(12)	1	$\frac{1}{2}$	$\frac{1}{2}(1-2\mu)\frac{\partial w_c^2}{\partial z} = aB_c - b\epsilon w_c^2, \mu = 0.15$
Pergaud et al. (2009)	PMMC	(7)	1	1	
Rio et al. (2010)	RHCJ	(9)	$\frac{2}{3}$	1	$\frac{1}{2}\frac{\partial w_c^2}{\partial z} = aB_c - (b' + b\epsilon)w_c^2, b' = 0.002$
De Rooy and Siebesma (2010)	RS	(27)	0.62	1	
ECMWF (2010)	ECMWF	(6.9)	$\frac{1}{3}$	1.95	
Kim and Kang (2011)	KK	(11)	$\frac{1}{6}$	2	$\frac{1}{2}\frac{\partial w_c^2}{\partial z} = a(1 - C_\epsilon b)B_c, C_\epsilon = 1/\overline{RH} - 1$

Bulk Convective Parcel Energetics

$KE_p(k)$ = pe2ke_eff*$PE_p(k)$+$KE(k-1)$+$KE_{LS}(k)$

$KE_p(k)$ = Kinetic energy at level k
$PE_p(k)$ = Potential energy at level k (buoyancy based)
$KE_{LS}(k)$ = Kinetic energy of resolved K

pe2ke_eff = Efficiency of PE->KE conversion (**0.1** – 0.05,0.2)
P_{ini} = Cloud base parcel energy (**5** – 2,20) J/kg

Roode, Stephan R. et al. "Parameterization of the Vertical Velocity Equation for Shallow Cumulus Clouds." *Monthly Weather Review* 140 (2012): 2424-2436.

Simple Plume Dynamics

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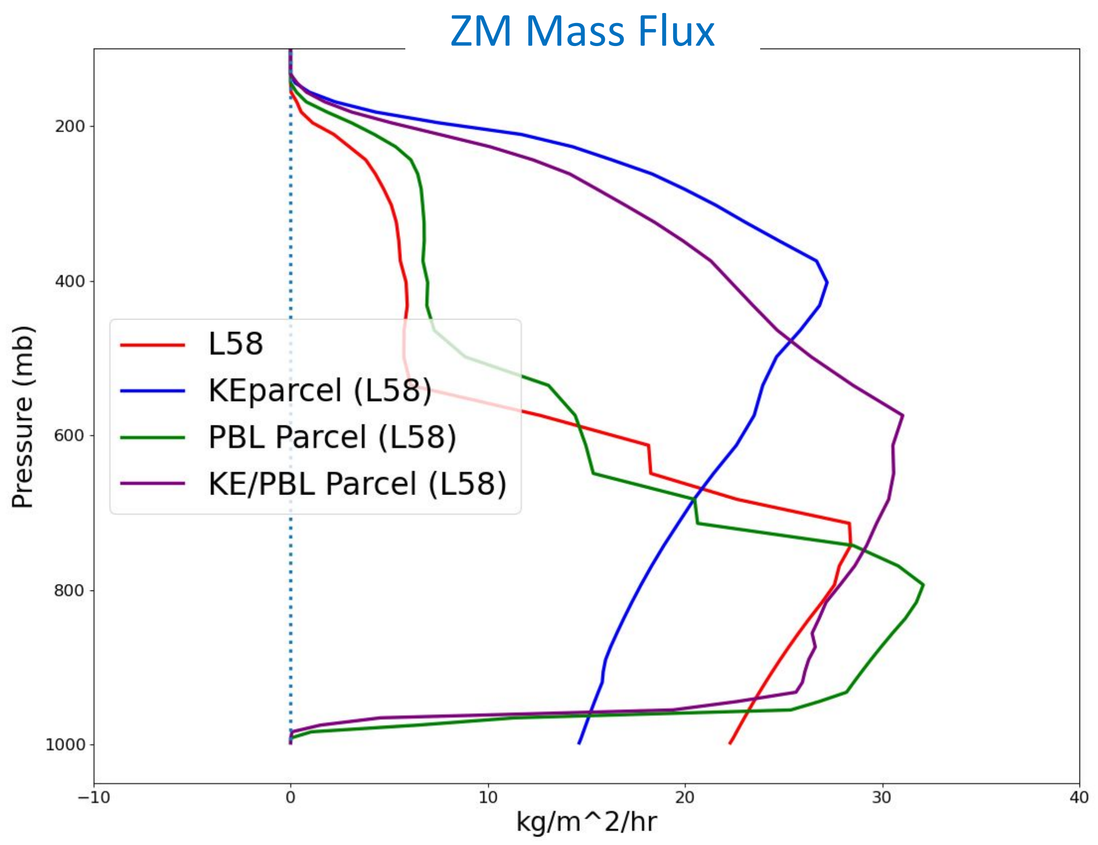
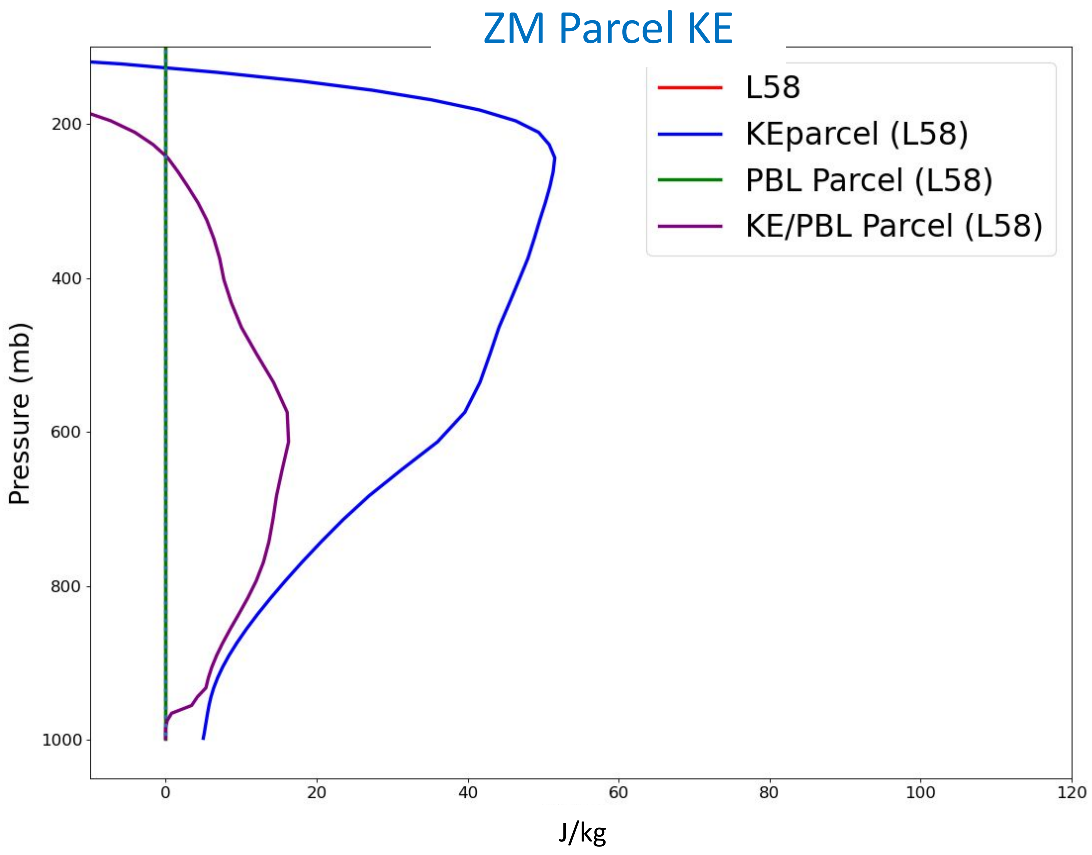
Vertical Profile of Convection

- Convective top is where KE equals zero
- Top heavy convective mass flux, steady increase near surface
- Overshooting?





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

Convective Heating Change

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Top Heaviness

- Near surface tendencies reduced
- Deep heating restored
- Maximum convective heating elevated

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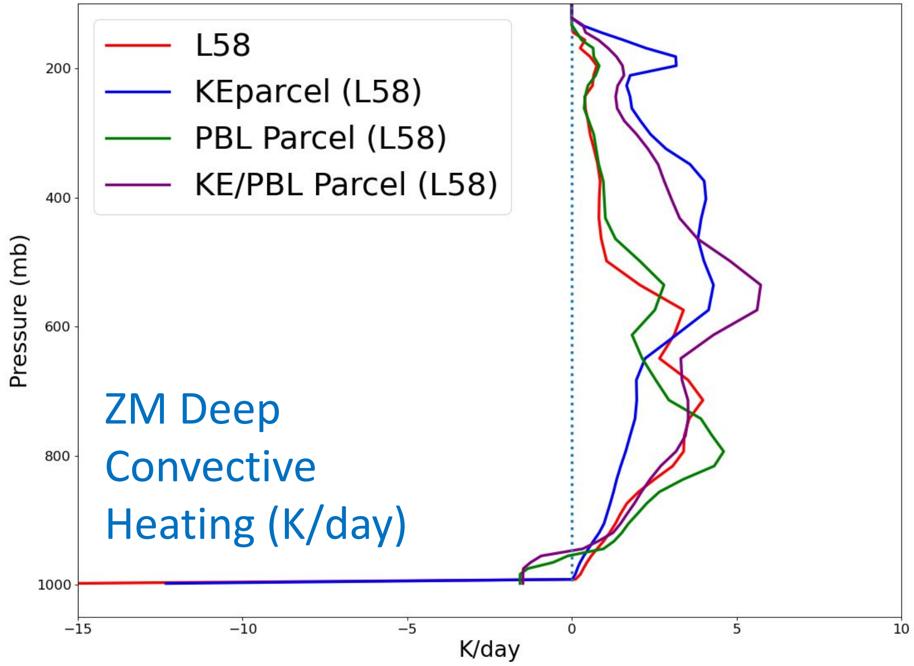

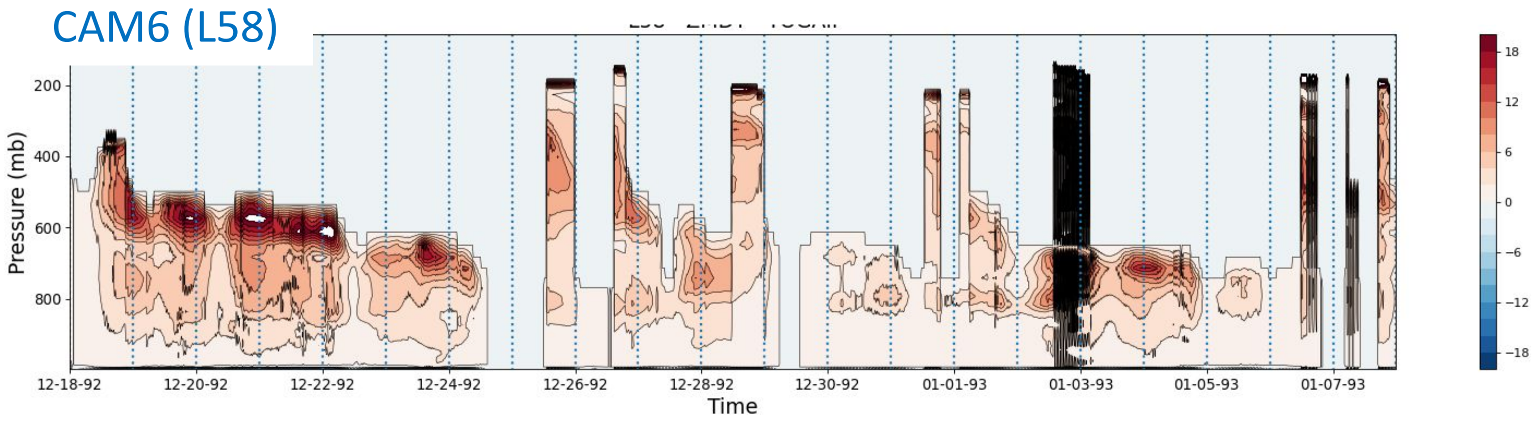

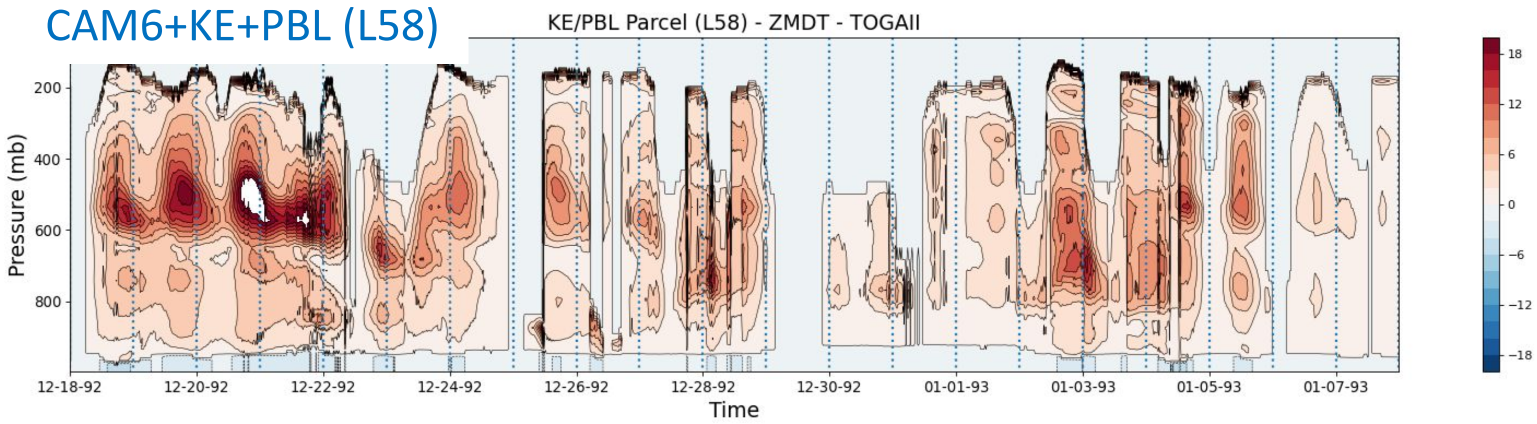

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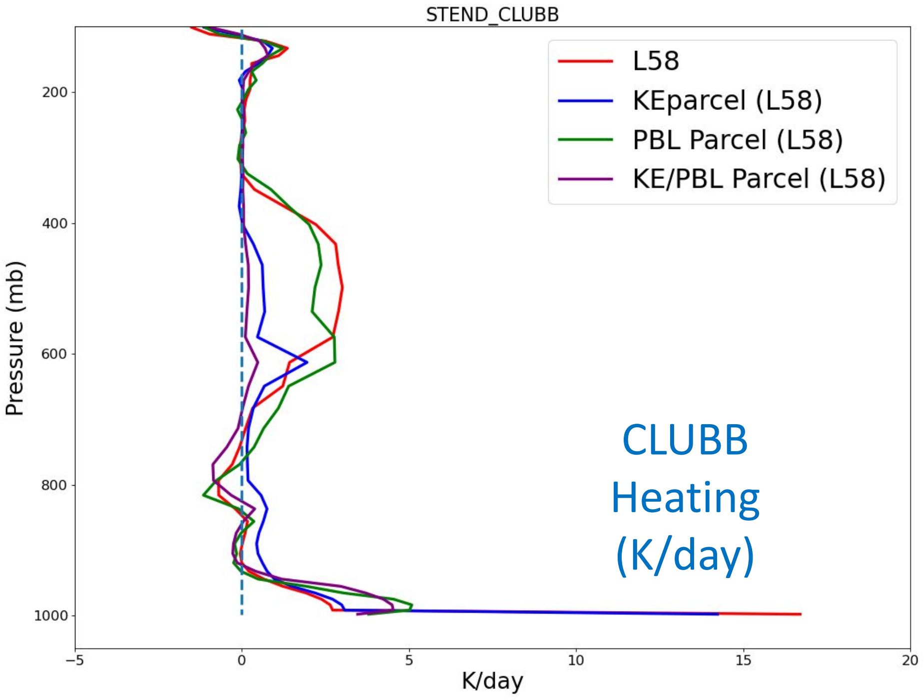

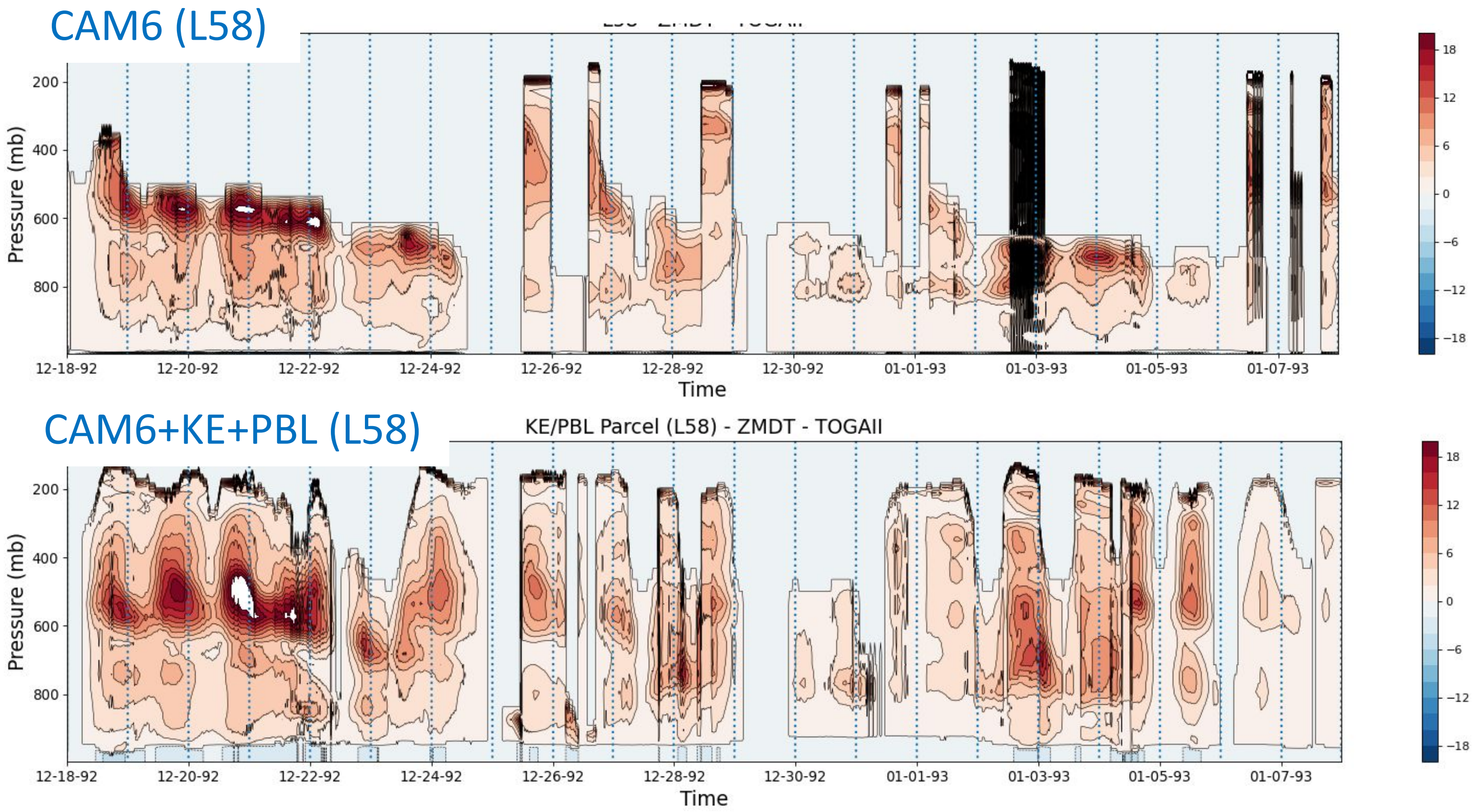

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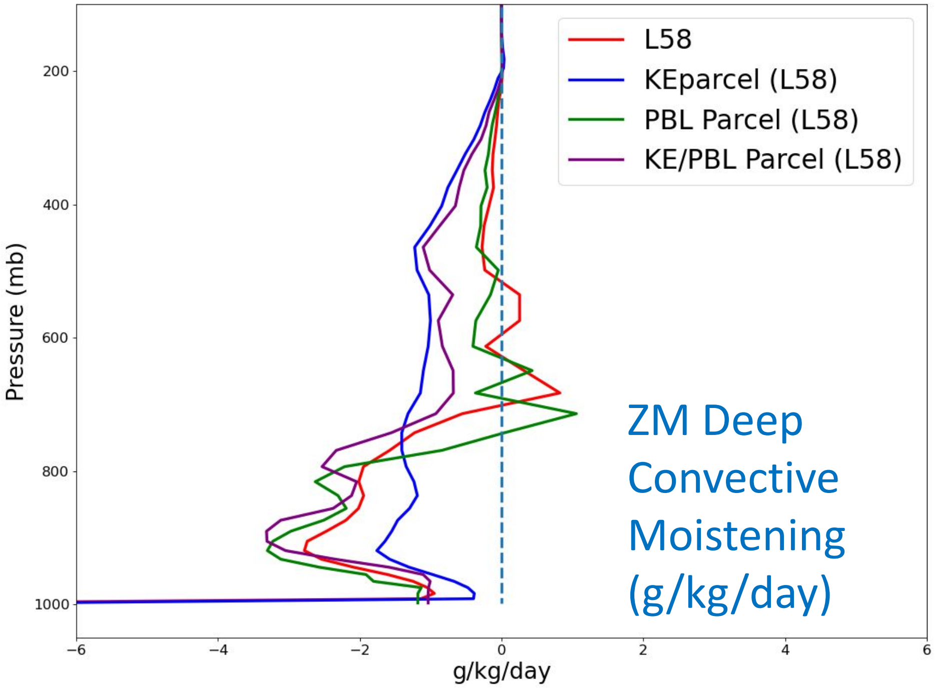
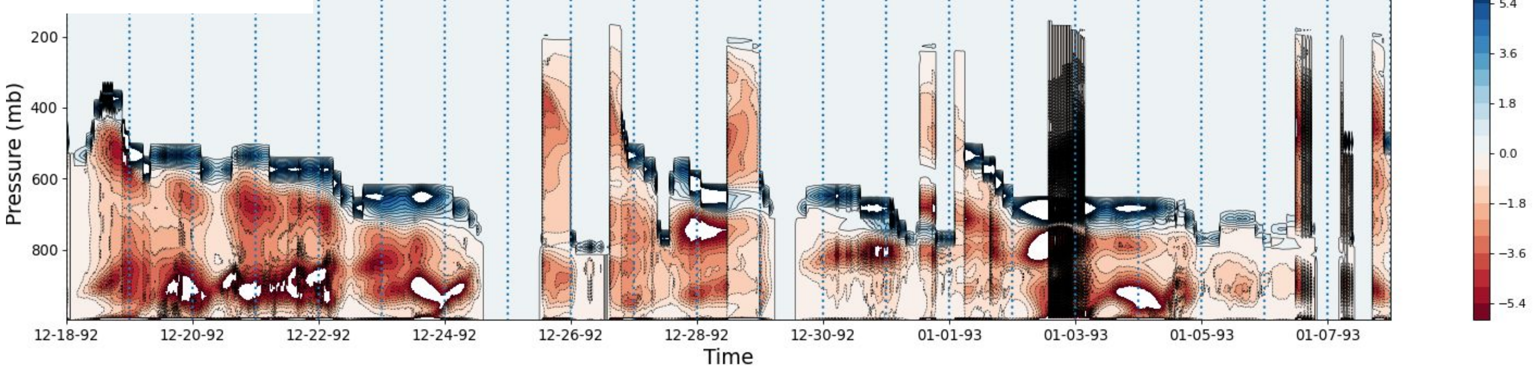
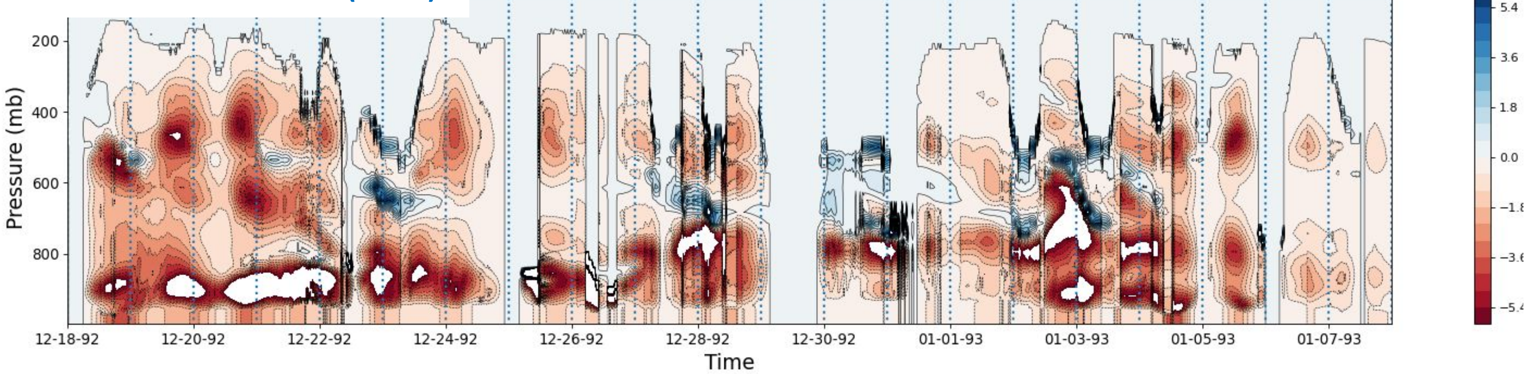


CAM6 (L58)



CAM6+KE+PBL (L58)



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

Cloud Base and Cloud Top

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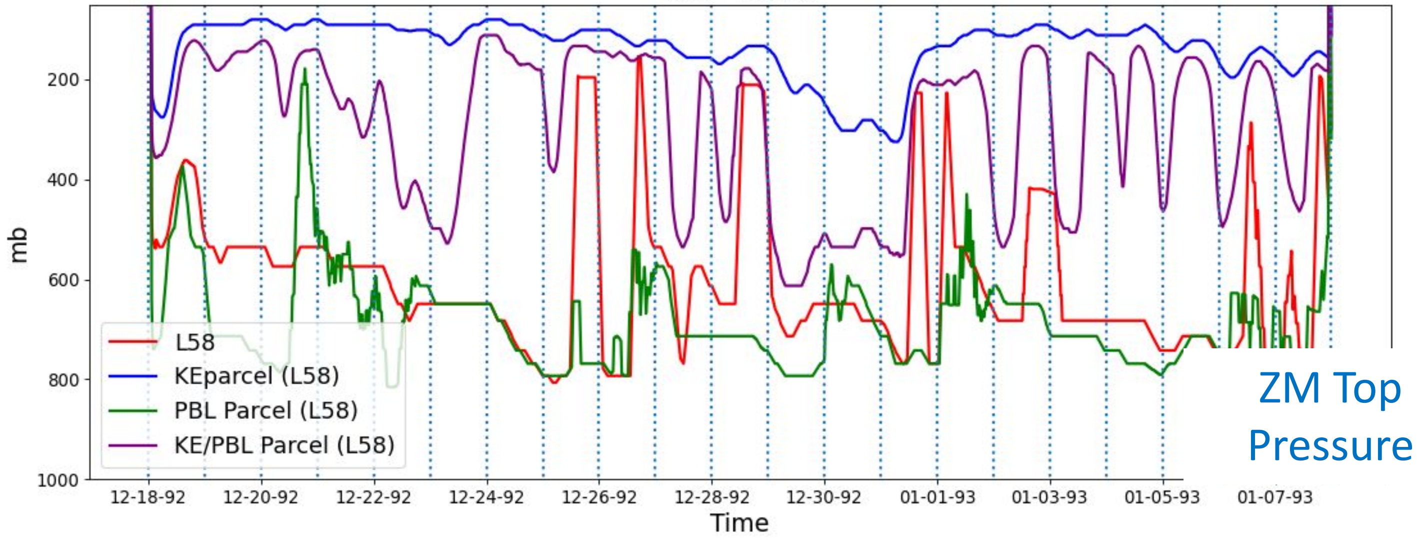

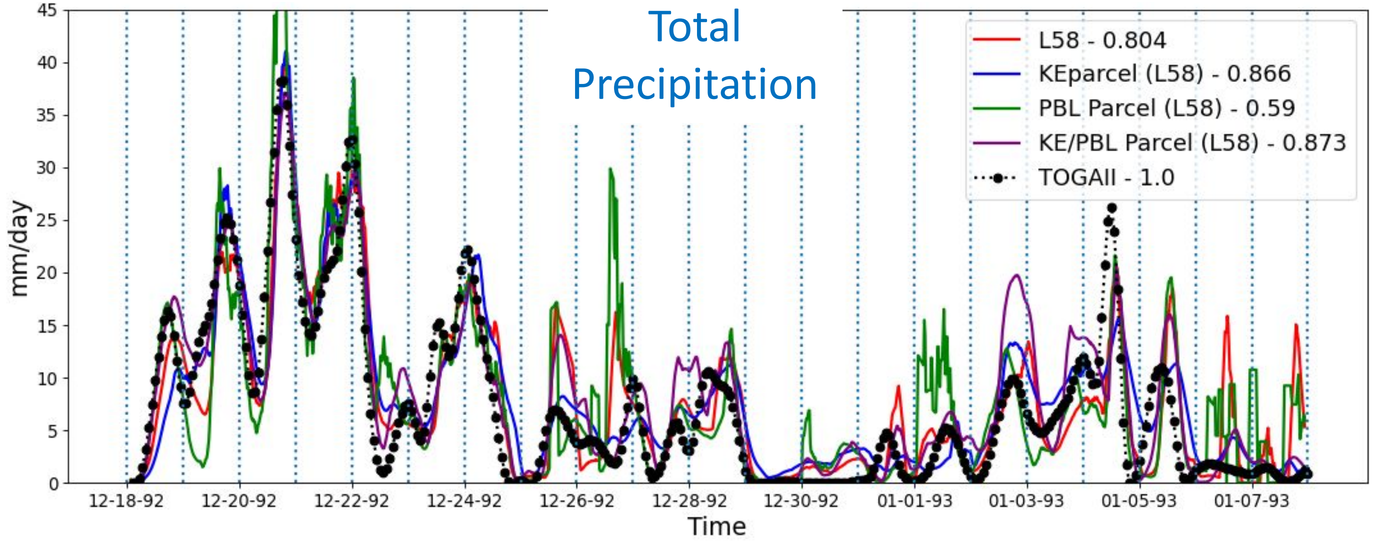

Parcel Vertical Range

- Cloud base more responsive to the environment with the PBL parcel changes
- Cloud top more responsive to the environment with the ZM KE changes

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

Parcel KE Characteristics

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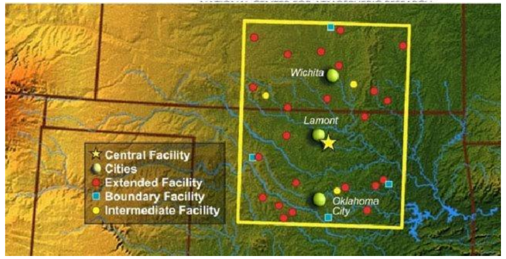
Regional sensitivities

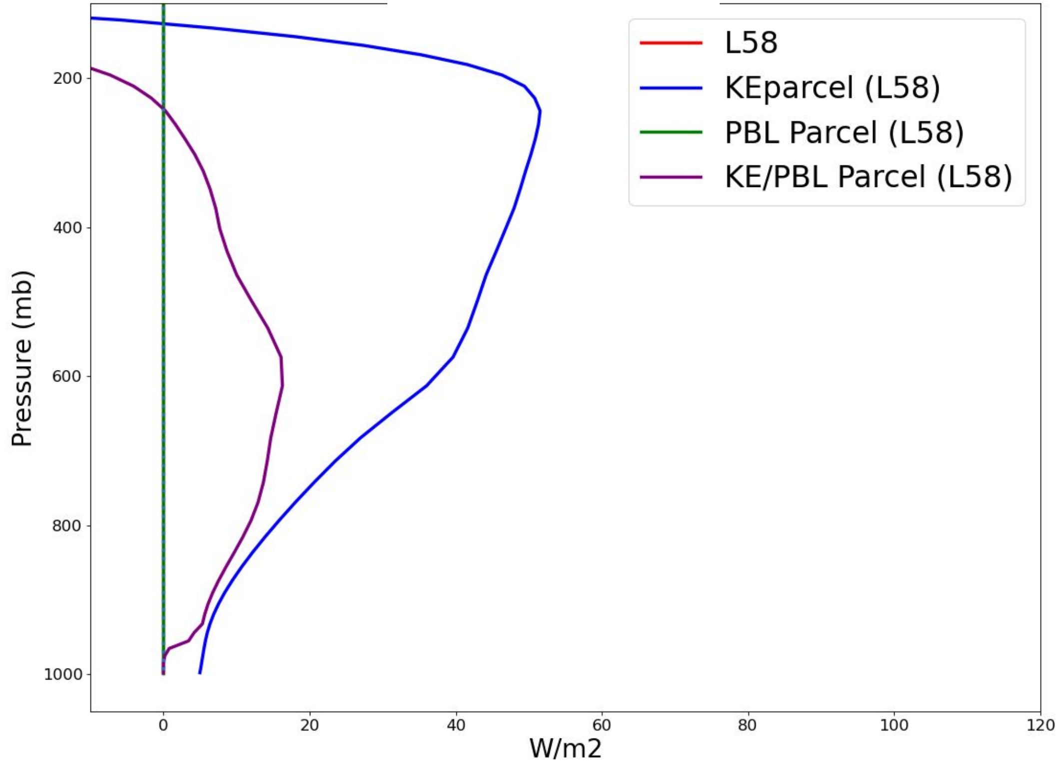
- Tropical convection: +ve buoyancy limited
- Continental convection: -ve buoyancy limited

Single Column CAM (SCAM) –
ARM95 (Oklahoma)
Dec/Jan - 1995

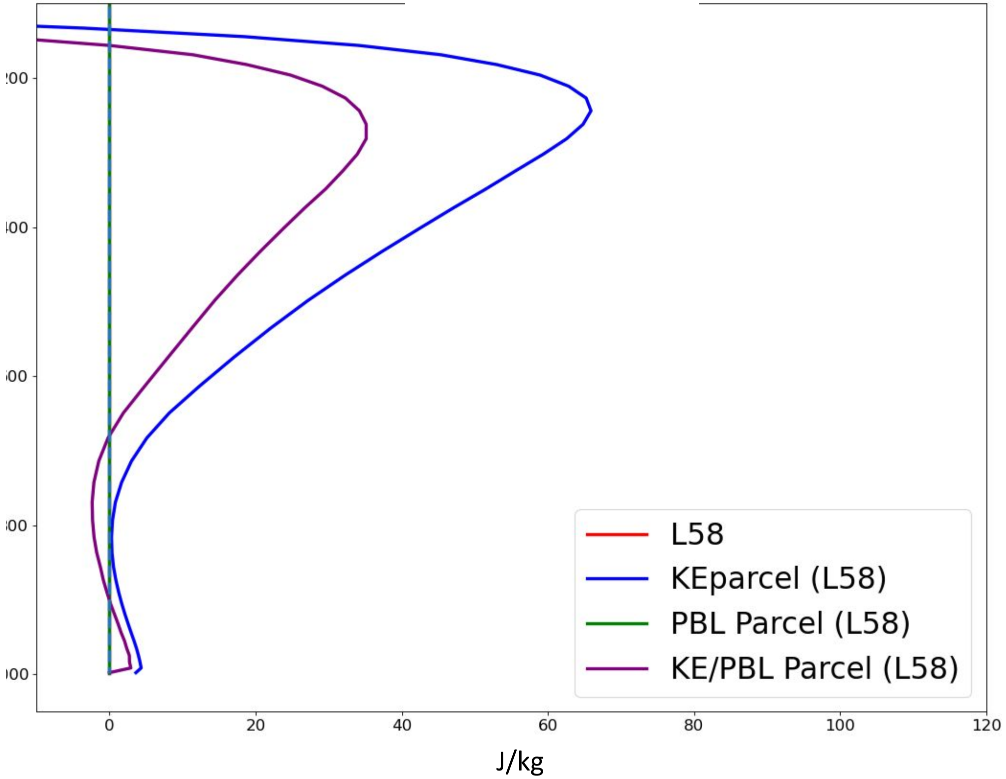


ZM Plume KE (J/kg)

TOGA-COARE



ARM95



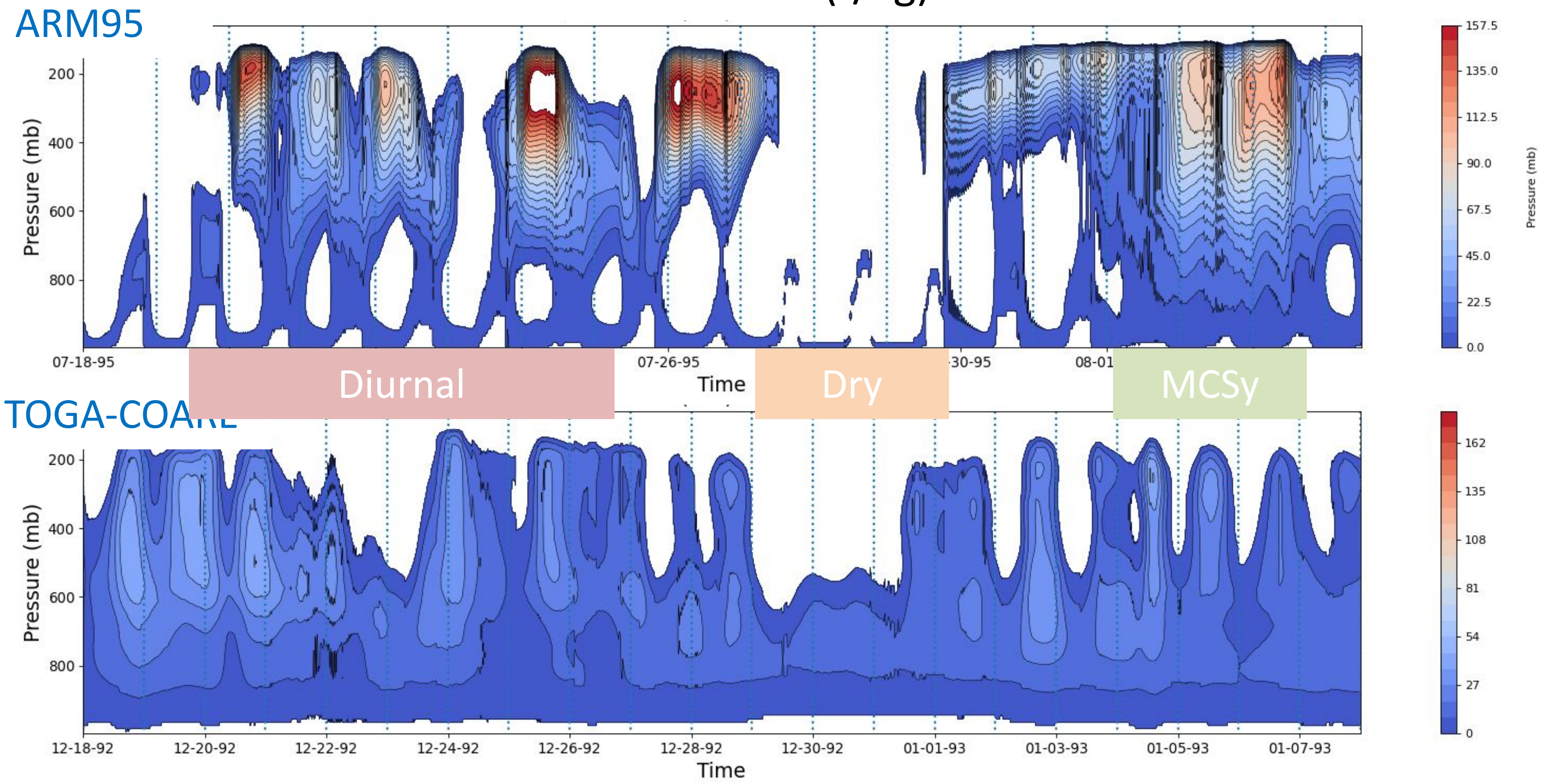
Single Column CAM (SCAM) – ARM SGP (Oklahoma - JJA)

Parcel KE Characteristics

Regional sensitivities

- Tropical convection: +ve buoyancy limited
- Continental convection: -ve buoyancy limited (pini_ke important)

ZM Plume KE (J/kg)



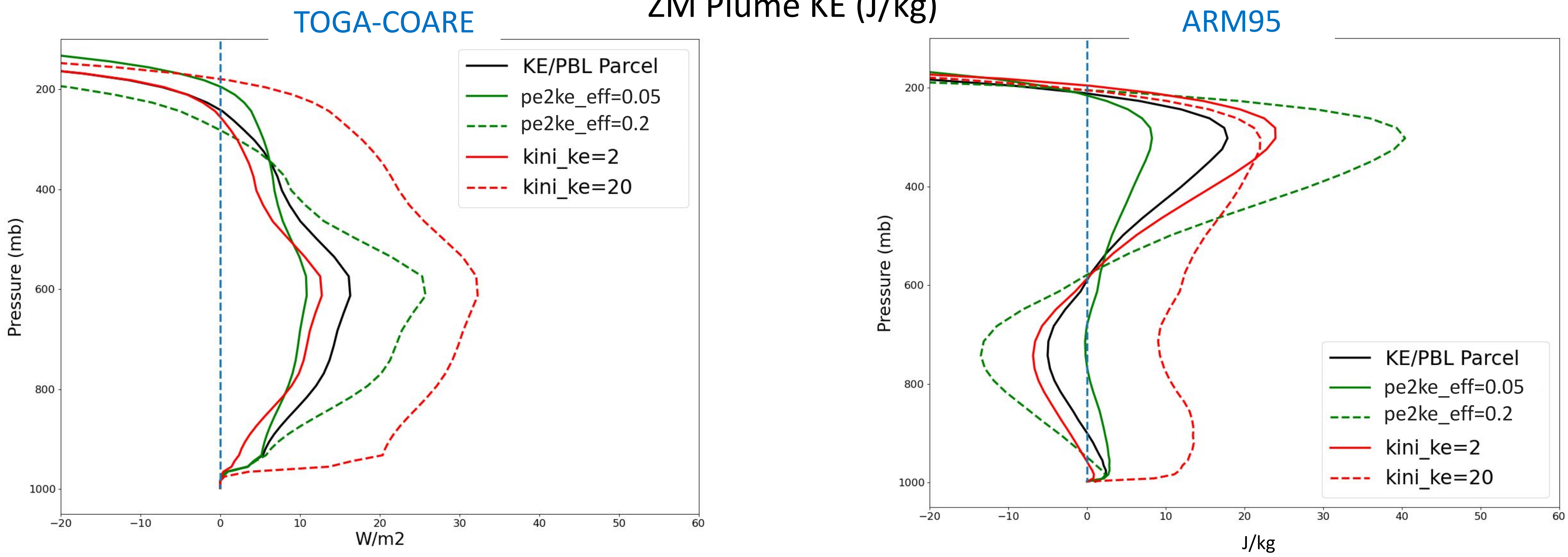
Single Column CAM (SCAM) – ARM SGP (Oklahoma - JJA)

Convective Parcel Sensitivity

Parameter Sensitivities

- Larger kini_ke important to overcome low-level CIN regions
- Larger pe2ke_eff impact has +/- buoyancy

ZM Plume KE (J/kg)



Single Column CAM (SCAM) – ARM SGP (Oklahoma - JJA)

Summary

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Motivation

ZM PBL-based launch level properties in CAM6-dev
Decreased ZM deep heating came in at CAM6 (single layer stability)
Potential for L58 to be more sensitive (2x thinner layers)

Talk

Implemented a KE criteria (>0) for ZM plume viability
Requires initial plume energy and PE->KE efficiency
Performs well for tropics; noise, deep heating, convective top
ARM site: marginal improvements, tuning of parameters needed

Next steps:

CAM simulations: Deeper convection, warmer tropopause
Improve realism of energetics
Implement a KE_{ini} based on CLUBB TKE.

Extra Slides

CAM6 Simulations (L32, 2 deg)

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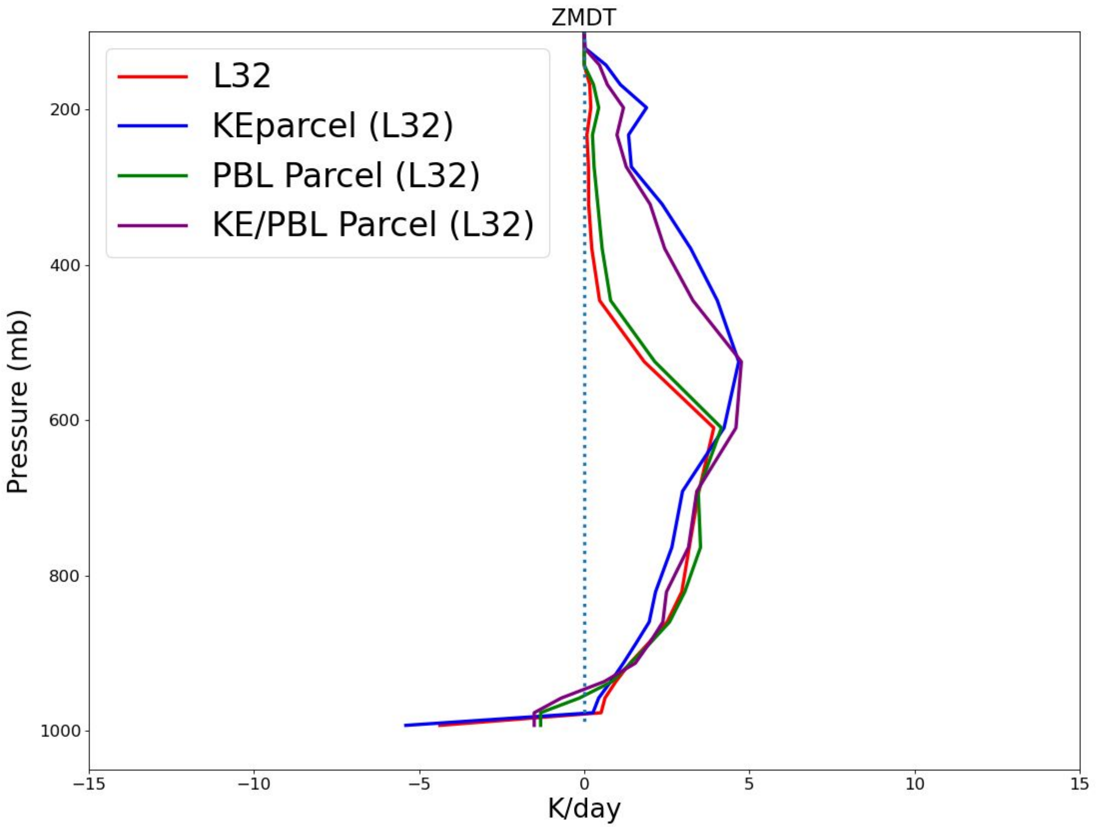
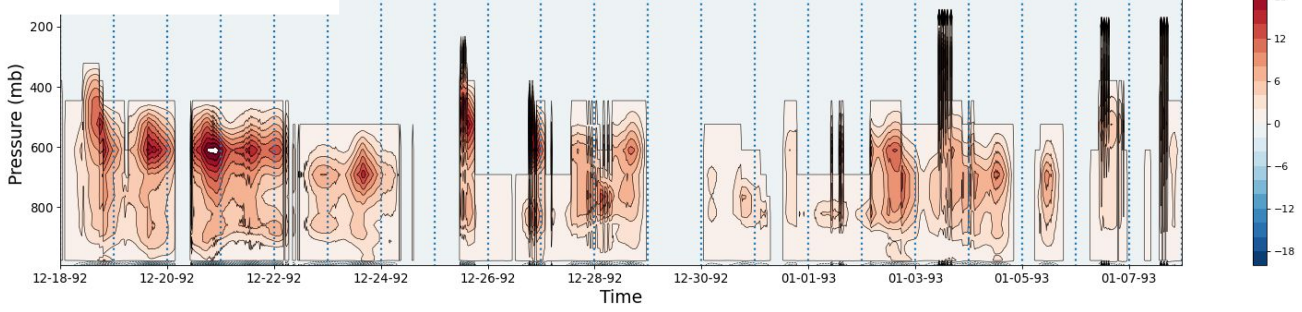
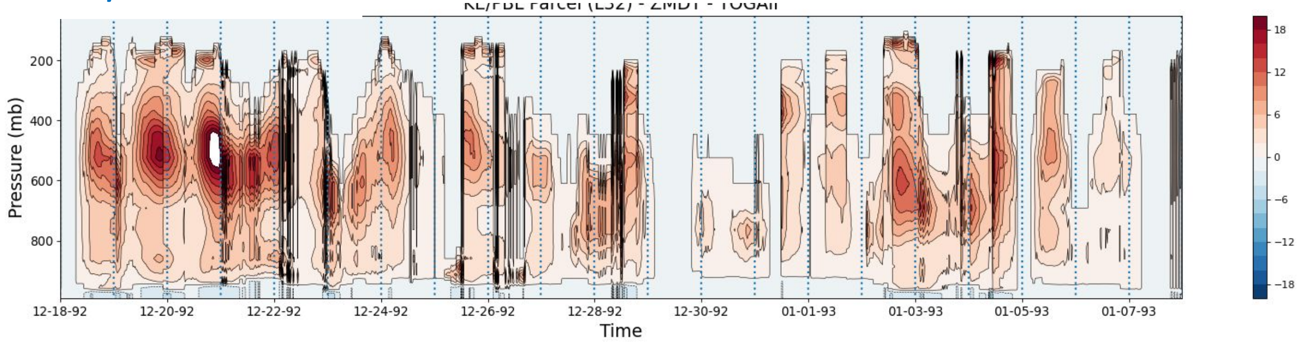


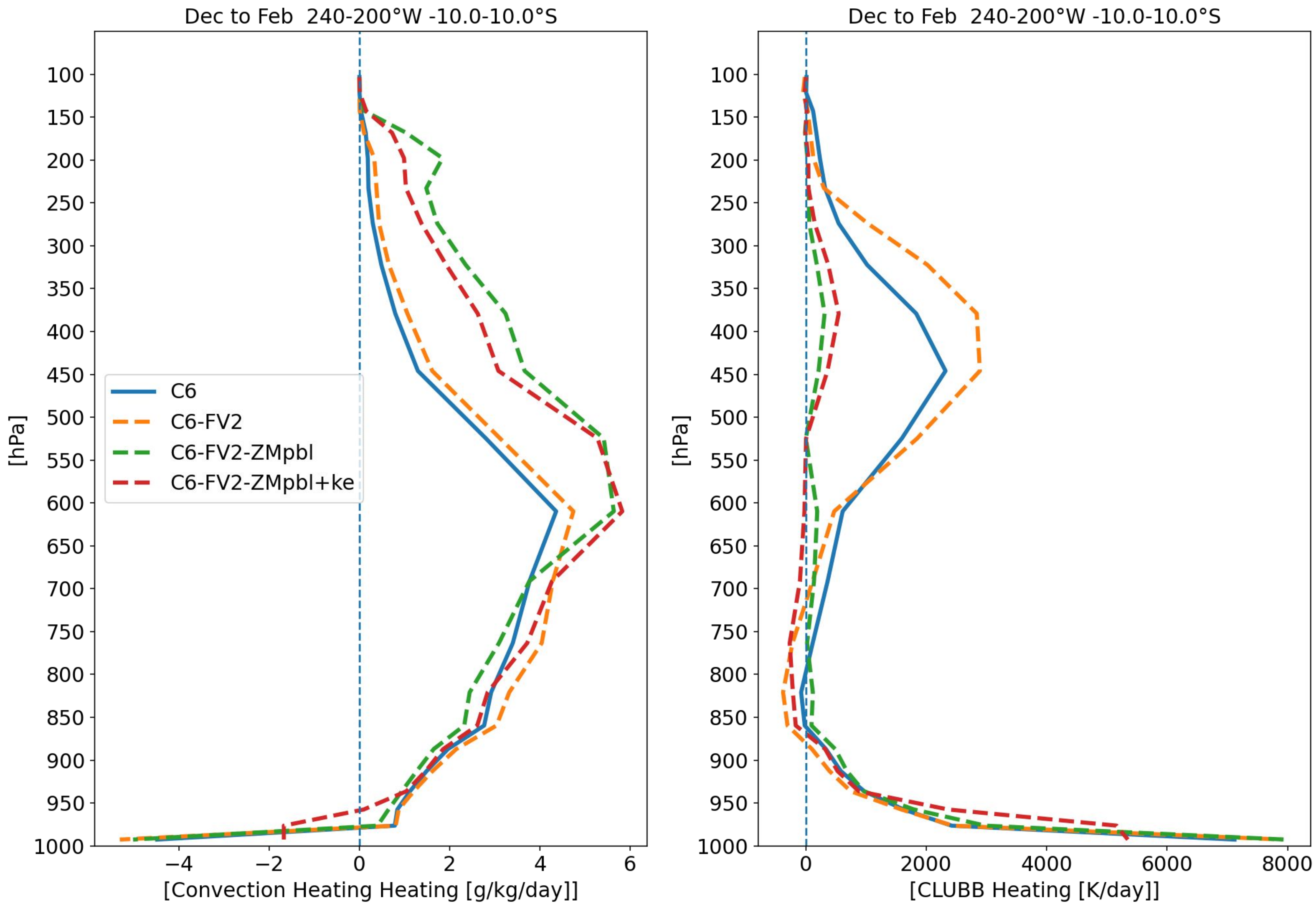
L32



KE/PBL Parcel



CAM Simulations (L32, 2 deg)



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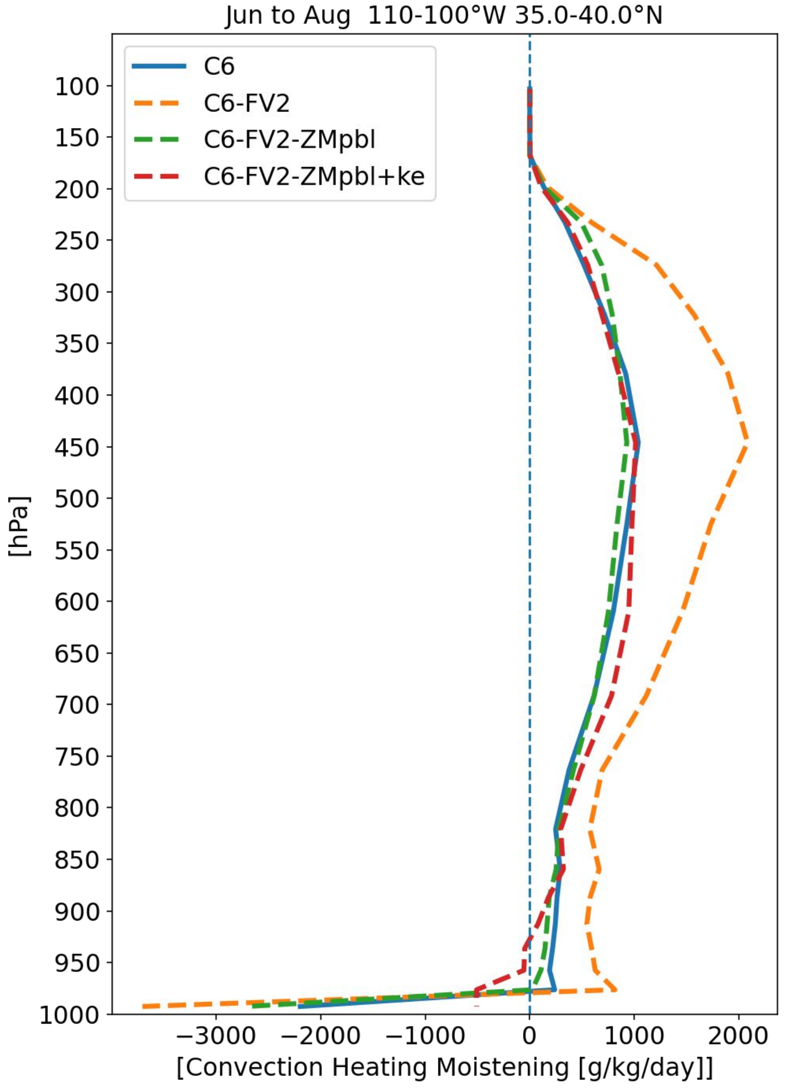

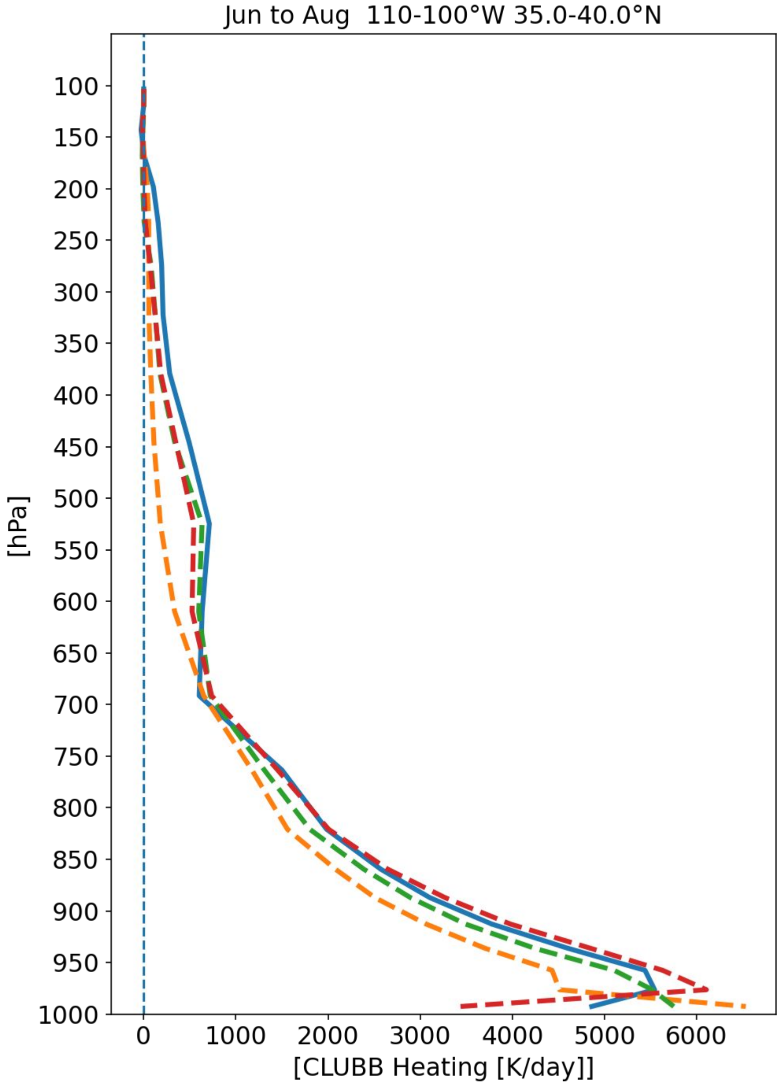

Remaining Deep Convection Issues

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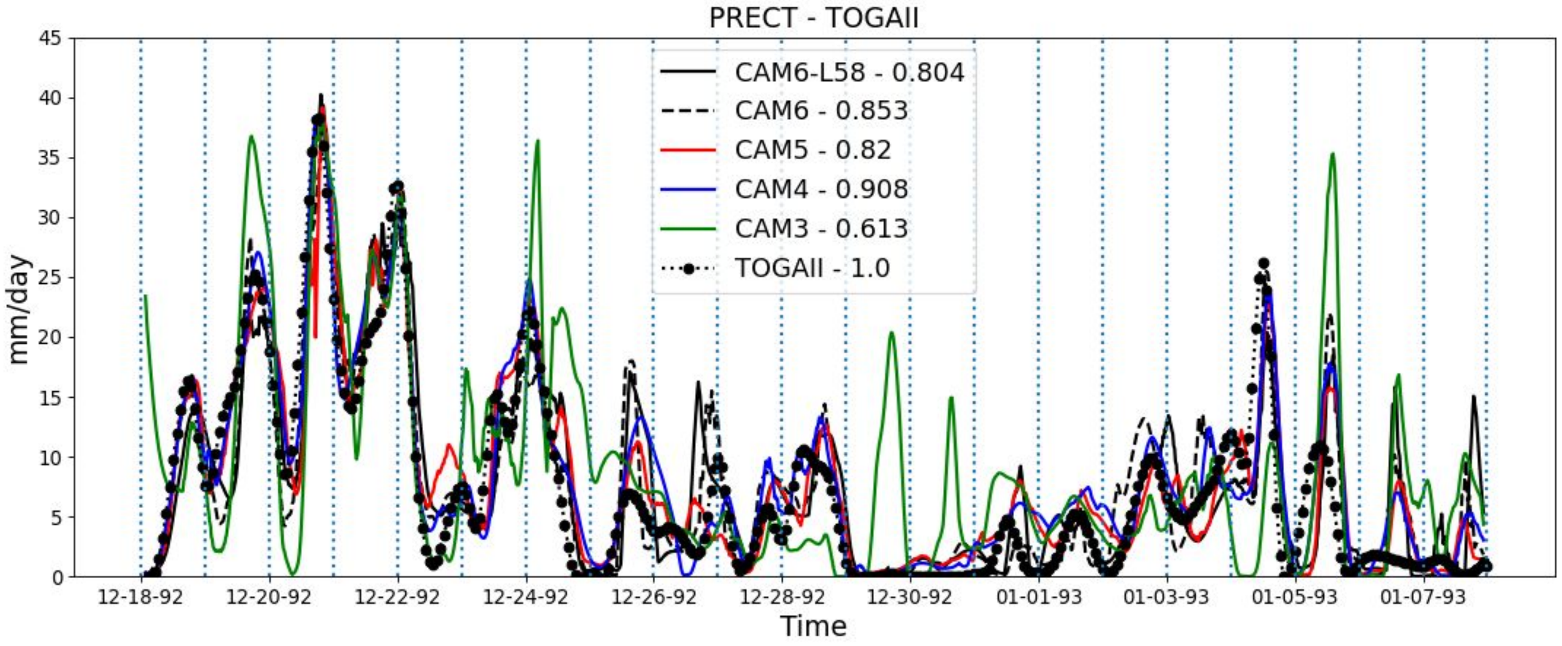
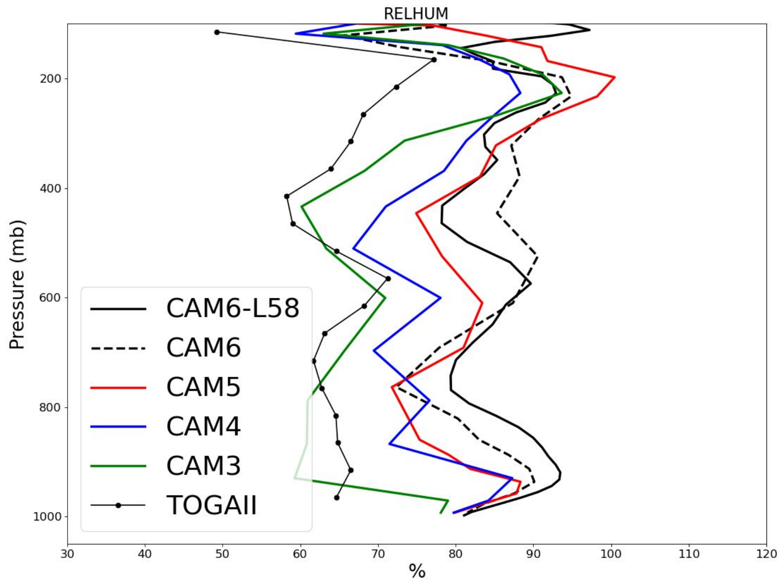
- Compensation from non-convection physics
- Implications for lower stratosphere (QBO, tape recorder)??





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

Cloud Base and Cloud Top

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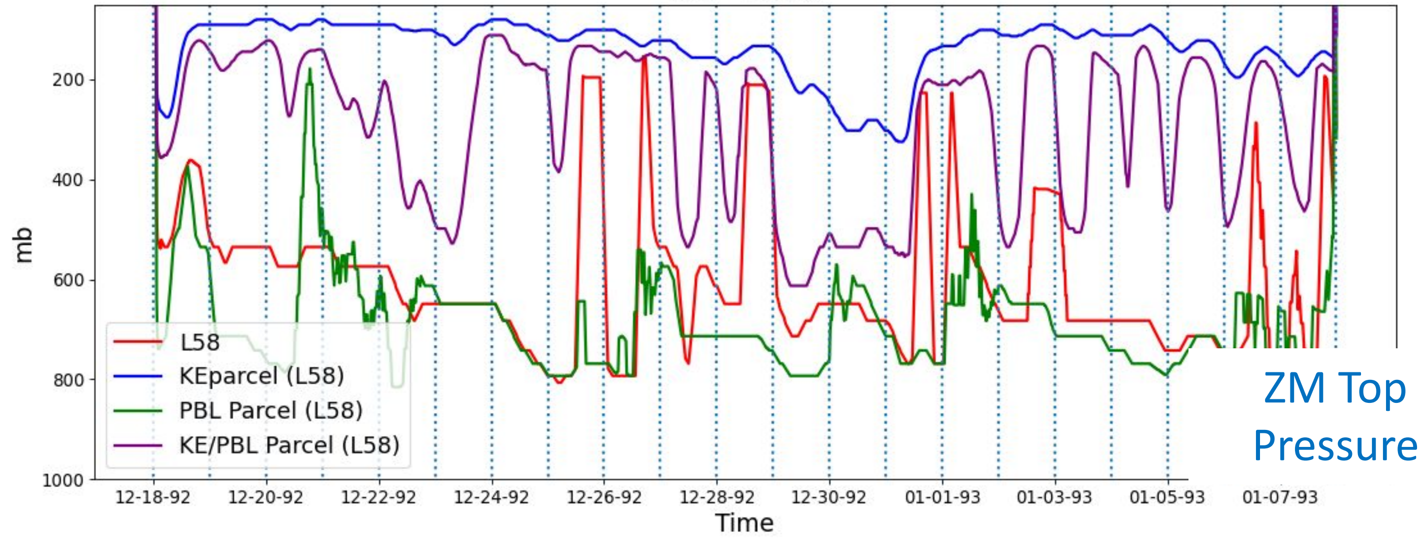
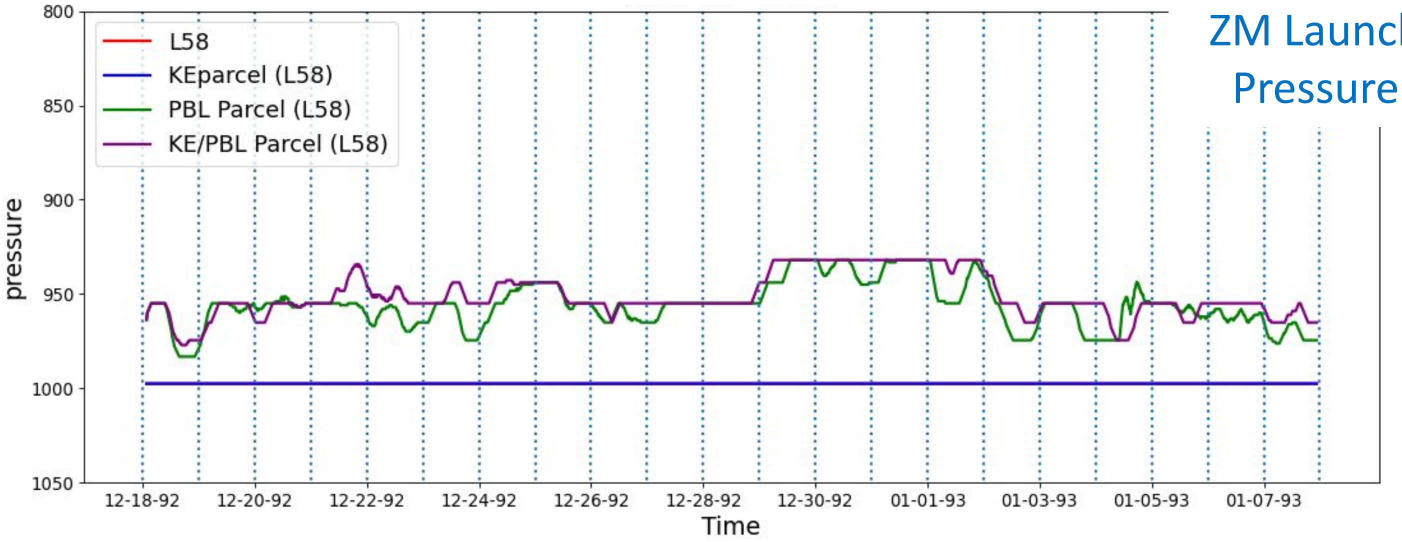


ZM Top Pressure



ZM Launch Pressure

Parcel Vertical Range

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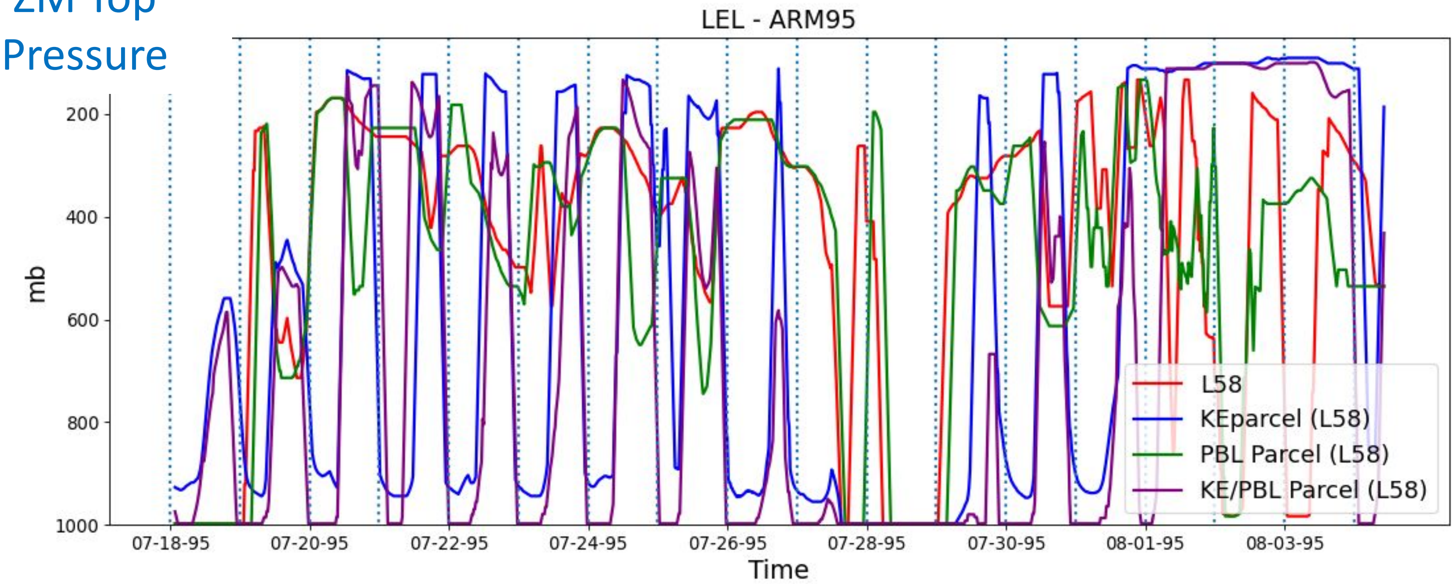
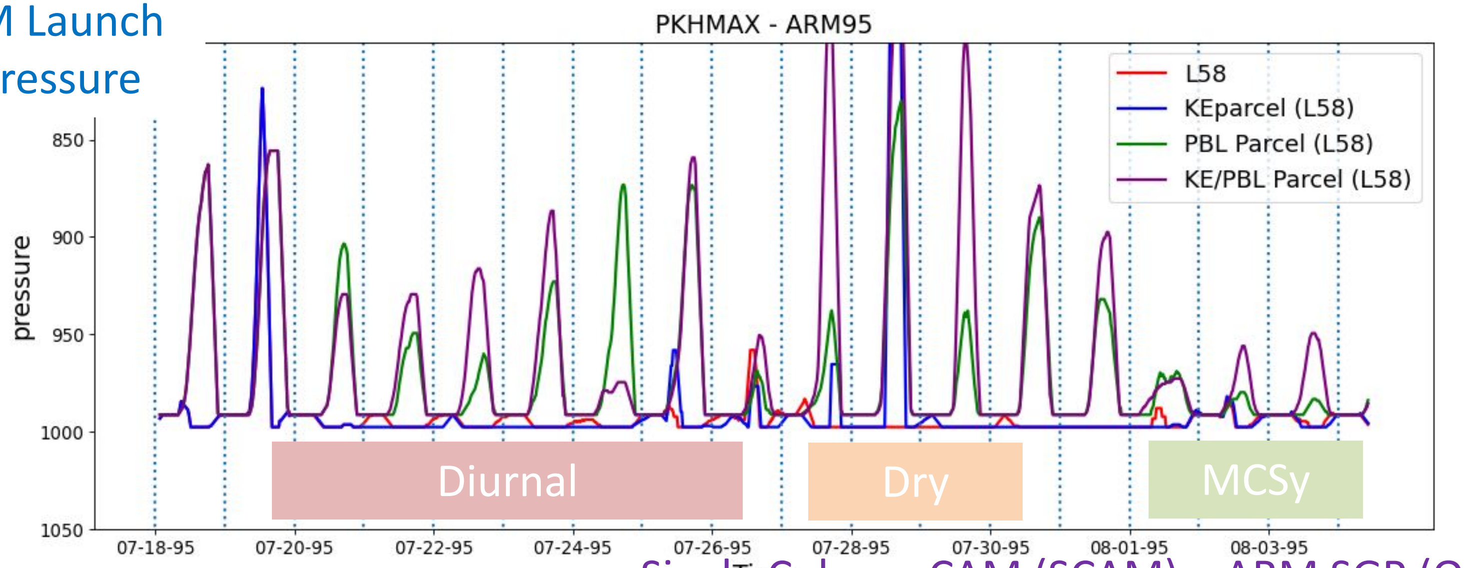
Cloud Base and Cloud Top

ZM Top Pressure



ZM Launch Pressure



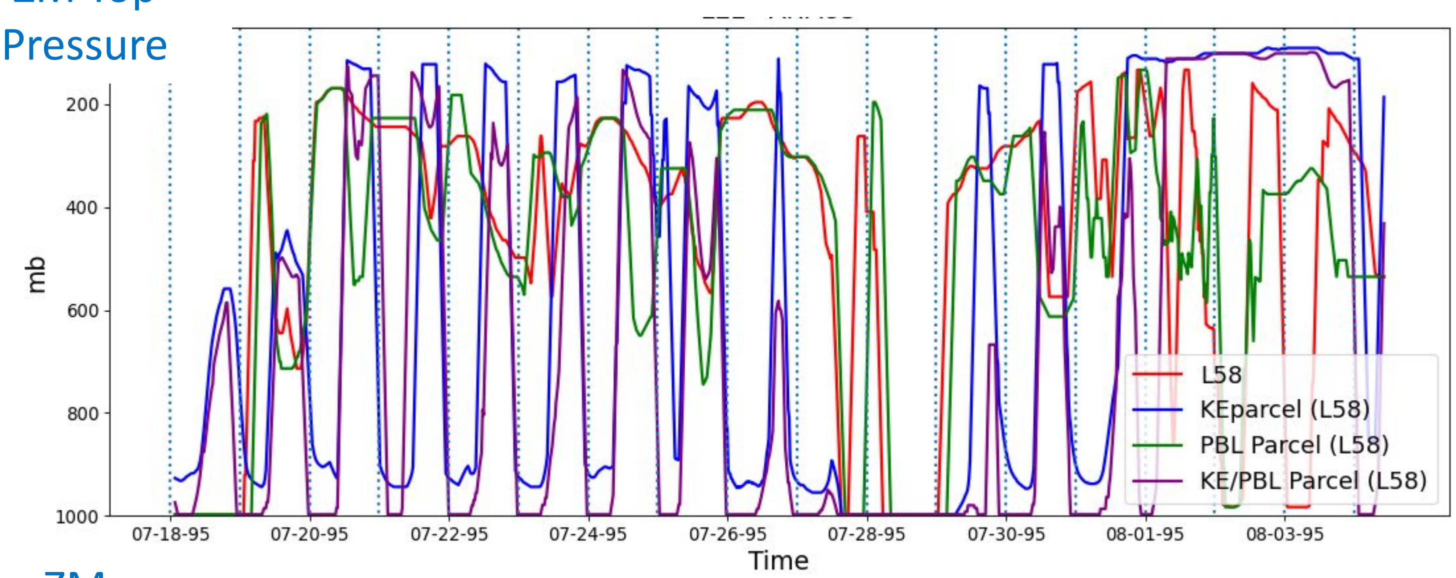
Parcel vertical range

- Solve

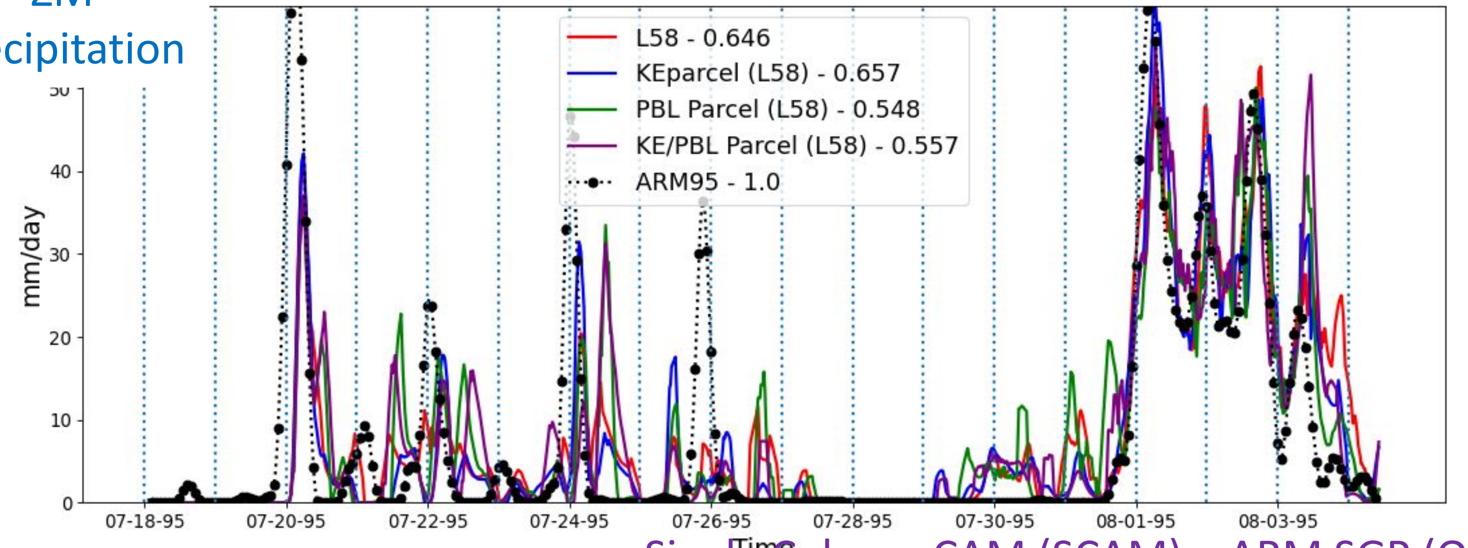
Single Column CAM (SCAM) – ARM SGP (Oklahoma - JJA)

Cloud Base and Cloud Top

ZM Top Pressure



ZM Precipitation



Single Column CAM (SCAM) – ARM SGP (Oklahoma - JJA)

Dynamic Parcel Testing

- Solve