#### A Unified Convection Scheme : 'UNICON'

HFIP Meeting. Washington D.C. Aug. 9. 2011

Sungsu Park

AMP. CGD. NESL. NCAR. Boulder. CO.

"The Unicorn is the only fabulous beast that does not seem to have been conceived out of human fears. He is fierce yet good selfless yet solitary, but always mysteriously beautiful. He could be captured only by unfoir means, and his single horn was said to neutralize poison". From the 'The Unicorn and the Lake' by Marianna Mayer.

# $\frac{\partial \overline{A}}{\partial t} = -\overrightarrow{V} \cdot \nabla \overline{A} + \overline{Q}_A - \frac{\partial}{\partial z} \overline{w'A'}$

#### Adiabatic Mixing by Turbulences



Symmetric Turbulence

( PBL Scheme ~ Symmetric Turbulence Scheme )



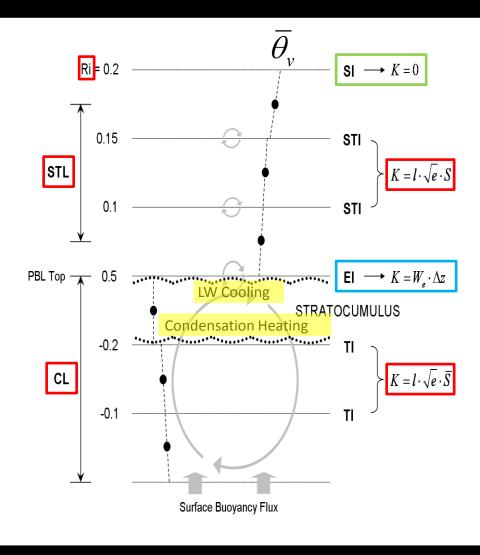
Asymmetric Turbulence

( Convection Scheme ~ Asymmetric Turbulence Scheme )

# Evolutions of CAM-CESM1

r						
Model	CCSM3 ( 2004 )	CCSM3.5 ( 2007 )	CCSM4 ( Apr 2010 )	CESM1 ( Jun 2010 )		
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4 (L26)	CAM5 (L30)		
Boundary Layer Turbulence	Holtslag-Boville (93) Dry Turbulence	Holtslag-Boville	Holtslag-Boville	Bretherton-Park (09) UW Moist Turbulence		
Shallow Convection	Hack (94)	Hack	Hack	Park-Bretherton (09) UW Shallow Convection		
Deep Convection	Zhang-McFarlane (95)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)		
Cloud Macrophysics	Zhang et al. (03)	Zhang et al. with Park & Vavrus' mods.	Zhang et al. with Park & Vavrus' mods.	Park-Bretherton-Rasch (10) Revised Cloud Macrophysics		
Stratiform Microphysics	Rasch-Kristjansson (98) Single Moment	Rasch-Kristian. Single Moment	Rasch-Kristian. Single Moment	Morrison and Gettelman (08) Double Moment		
Radiation / Optics	CAMRT (01)	CAMRT	CAMRT	RRTMG lacono et al.(08) / Mitchell (08)		
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Liu & Ghan (2009)		
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume	Finite Volume		
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2 - <i>BGC</i>	POP2.2		
Land	CLM3	CLM3.5	CLM4 - <i>CN</i>	CLM4		
Sea Ice	CSIM4	CSIM4	CICE	CICE		

#### MOIST TURBULENCE SCHEME in CAM5 C. Bretherton and S. Park. 2009

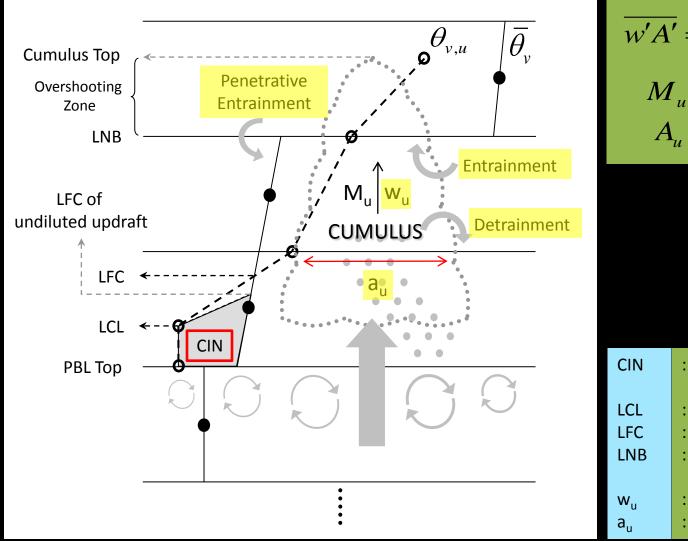


$$\frac{\partial \overline{A}}{\partial t} = -\frac{\partial}{\partial z} \overline{w'A'} = \frac{\partial}{\partial z} \left( K \frac{\partial \overline{A}}{\partial z} \right)$$

#### K : eddy diffusivity

Ri	: Moist Richardson Number
SI	: Stable Interface
STI	: Stably Turbulent Interface
EI	: Entrainment Interface
TI	: Turbulent Interface
STL	: Stably Turbulent Layer
CL	: Convective Layer
l	: Turbulent length scale
S	: Stability function ( fcn of Ri )
e	: TKE
W <sub>e</sub>	: Entrainment rate

#### SHALLOW CONVECTION SCHEME in CAM5 S. Park and C. Bretherton. 2009



$$\overline{v'A'} = \rho \cdot M_u \cdot (A_u - \overline{A})$$

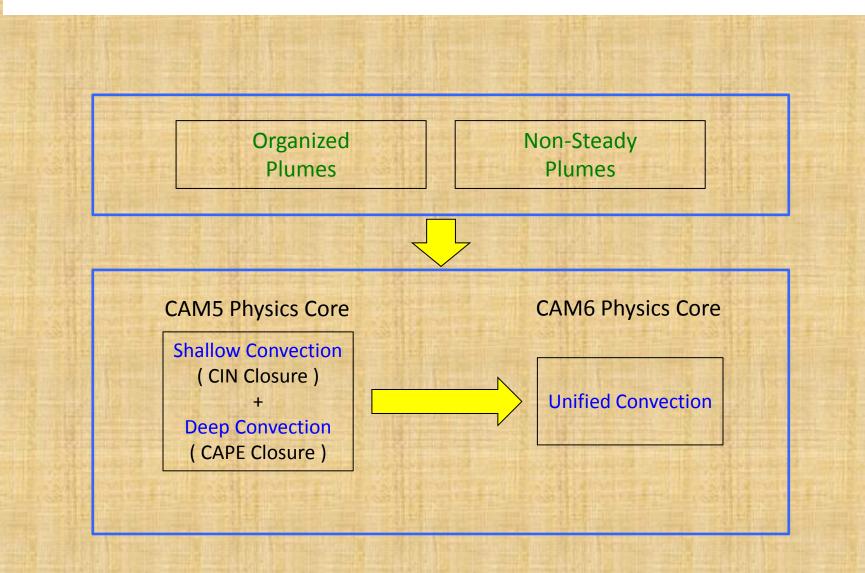
 $M_u$  : updraft mass flux  $A_u$  : updraft scalar

CIN	: Convective INhibition
LCL	: Lifting Condensation Level
LFC	: Level of Free Convection
LNB	: Level of Neutral Buoyancy
w <sub>u</sub>	: Updraft vertical velocity
a <sub>u</sub>	: Updraft fractional area

# Evolutions of CAM-CESM1

Model	CCSM3 ( 2004 )	CCSM3.5 ( 2007 )	CCSM4 ( Apr 2010 )	CESM1 ( Jun 2010 )		
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4 (L26)	CAM5 (L30)		
Boundary Layer Turbulence	Holtslag-Boville (93) Dry Turbulence	Holtslag-Boville	Holtslag-Boville	Bretherton-Park (09) UW Moist Turbulence		
Shallow Convection	Hack (94)	Hack	Hack	Park-Bretherton (09) UW Shallow Convection		
Deep Convection	Zhang-McFarlane (95)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)	Zhang-McFarlane Neale et al.(08) Richter-Rasch (08)		
Cloud Macrophysics	Zhang et al. (03)	Zhang et al. with Park & Vavrus' mods.	Zhang et al. with Park & Vavrus' mods.	Park-Bretherton-Rasch (10) Revised Cloud Macrophysics		
Stratiform Microphysics	Rasch-Kristjansson (98) Single Moment	Rasch-Kristian. Single Moment	Rasch-Kristian. Single Moment	Morrison and Gettelman (08) Double Moment		
Radiation / Optics	CAMRT (01)	CAMRT	CAMRT	RRTMG lacono et al.(08) / Mitchell (08)		
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Liu & Ghan (2009)		
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume	Finite Volume		
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2 - <i>BGC</i>	POP2.2		
Land	CLM3	CLM3.5	CLM4 - <i>CN</i>	CLM4		
Sea Ice	CSIM4	CSIM4	CICE	CICE		

#### A Strategic Plan for Next Generation CAM6



## Overview of UNICON

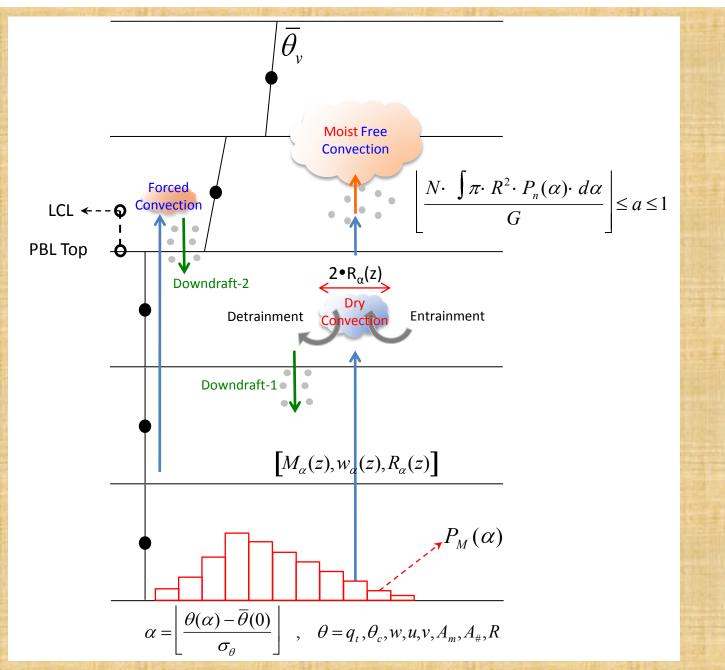
I. A completely new vertical transport scheme by asymmetric turbulences designed for addressing the major issues associated with the parameterization of convection :

- Developing a conceptual framework : July. 2006 ~ Jan. 2009.
- Mathematical formulation and coding : Jan.2009 ~ Nov. 2009.
- Intensive debugging and *consistency check* : Nov. 2009 ~ Nov. 2010.
- Testing and consistency check : Nov.2010 ~ Present.
- Code : ~ 10,000 Lines, Computation time : ~ CAM5 shallow convection scheme when n=1.

#### *II.* Some of unique aspects of UNICON are

- Consistent closure for all scalars ( $q_t$ ,  $\theta_c$ , u, v, w,  $A_m$ ,  $A_{\#}$ ) controlled by the surface fluxes
- Updraft plume mixing rate as a function of plume radius R
- Launch correlated multiple plumes with different thermodynamic properties and R
- Generic treatments of 'convective downdraft' and 'detrainment'
- Treatment of vertical tilting of updraft plume : 'cumulus-precipitation overlap' and associated 'evaporation of convective precipitation'
- No CIN/CAPE closures : Fully dynamic plume model without any equilibrium assumptions
- Unified treatment of 'shallow/deep', 'dry/moist', and 'forced/free' convections
- Explicit treatment of convective organization
- Well-harmonized with the CAM5 symmetric turbulence scheme (i.e., moist PBL scheme)

#### UNICON (S. Park 2011)



Park and Bretherton 09 Updraft Plume Dynamics

Kane and Fritsch 90 Updraft Buoyancy Sorting

UNICON

No CIN/CAPE Unified Shallow-Deep Unified Forced-Free R-based Lateral Mixing Downdraft Dynamics Self-Consistent Closure Convective Tilting

Super-Param. 03. No Scale Barrier Raymond and Blyth 86 Emanuel 91 <u>Downdraft Buoyancy Sorting</u>

EDMF – ECMWF. 07. Unified Dry-Moist Convection Arakawa and Schubert 74 Zhang and McFarlane 95 Deep Convective Plumes





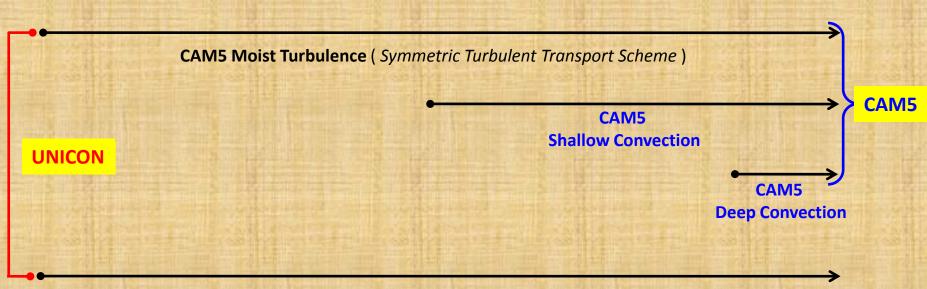
STCU

ARM95, ARM97, GATEIII, TOGAII

BOMEX

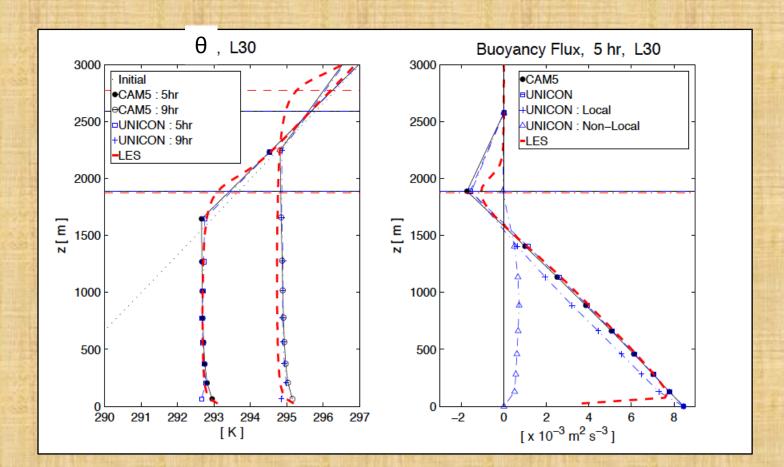
Stable PBL  $\rightarrow$  Dry Conv.  $\rightarrow$  Sc. Conv.  $\rightarrow$  Sc to Shallow Cu  $\rightarrow$  Shallow Cu  $\rightarrow$  Deep Cu

DYCOMS



**UNICON** (Asymmetric Turbulent Transport Scheme)

**Dry Convection Case. DCBL.** 



#### SCAM comparison of UNICON and CAM5

( T, Q<sub>v</sub> )

**SKILL SCORE** = rmse (UNICON,OBS) / rmse (CAM5,OBS)

CASES	SKILL SCORE OF UNICON RELATIVE TO CAM5								
	<b>L30</b> . Δt = 1200 [sec]	<b>L80</b> . Δt = 300 [sec]							
DCBL	0.89	1.01							
DYCOMS	0.99	0.92							
STCU	0.90	0.39							
BOMEX	0.50	0.50							
ARM95	0.98	1.28							
ARM97	0.62	0.92							
GATEIII	0.95	1.03							
TOGAII	0.71	0.90							
Average	0.82	0.87							

#### **Global CAM5 Simulation**

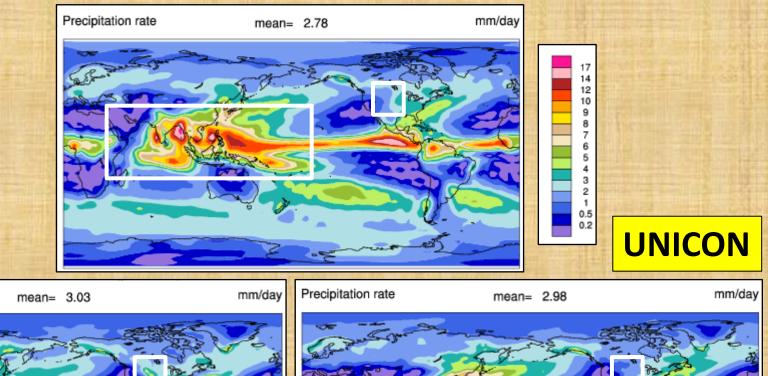
**Precipitation Climatology** 

**Diurnal Cycle of Precipitation** 

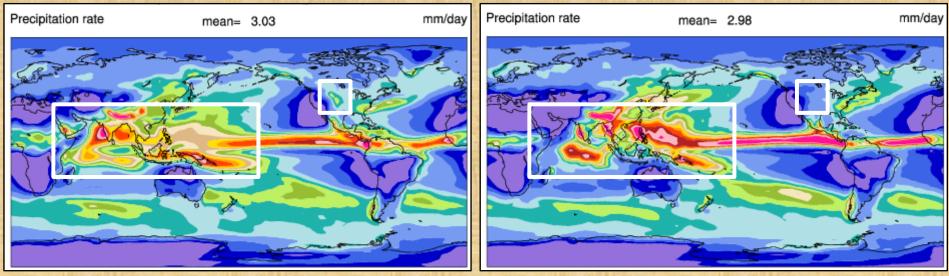
Madden-Julian Oscillation

# Precipitation Climatology. JJA.

## **OBSERVATION**

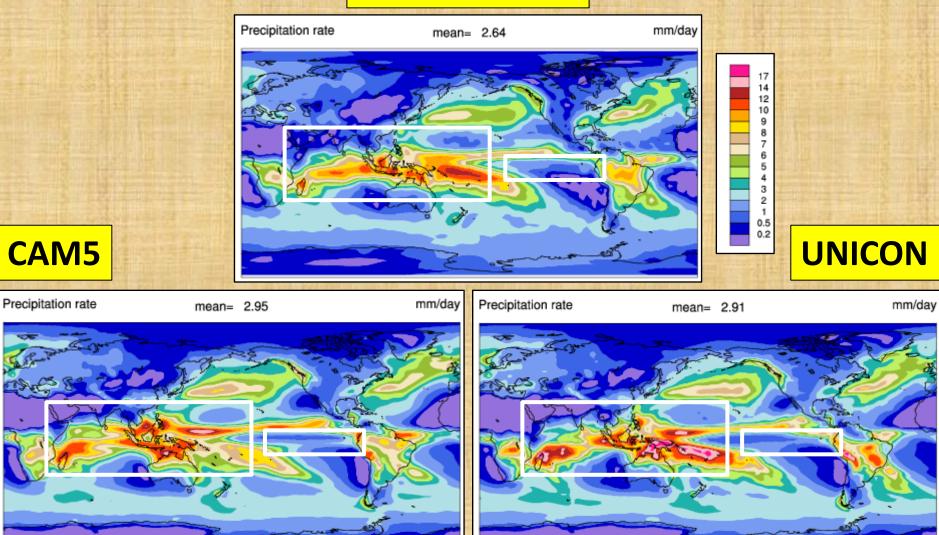


## CAM5

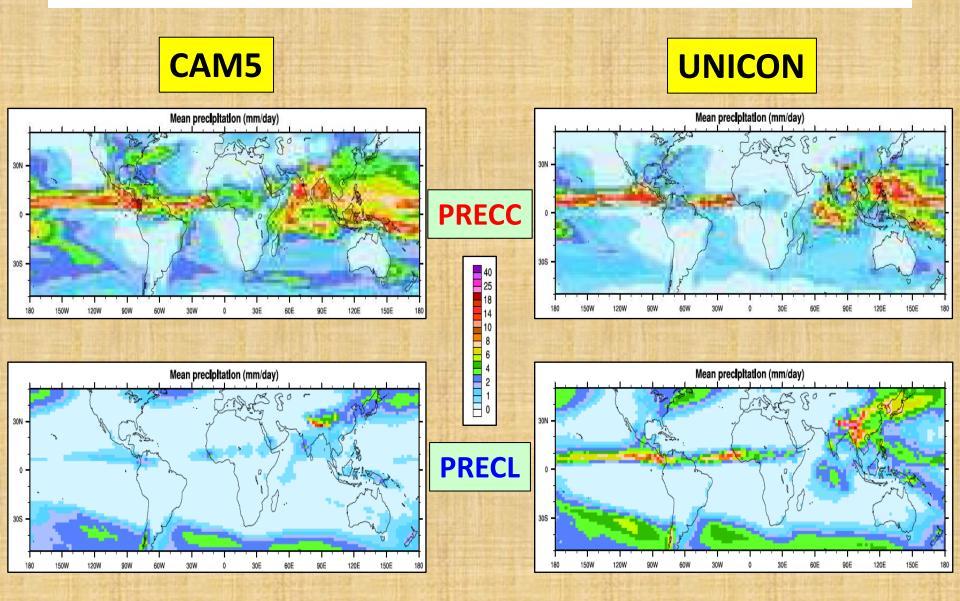


# **Precipitation Climatology. DJF.**

## **OBSERVATION**

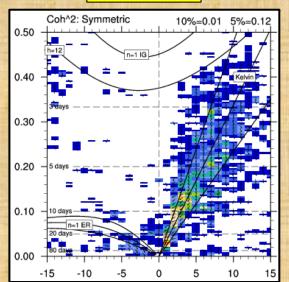


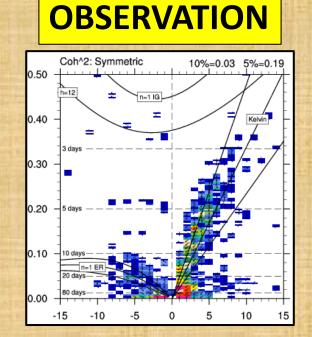
# **Convective ( PRECC ) vs Stratiform ( PRECL )** Precipitation. JJA.



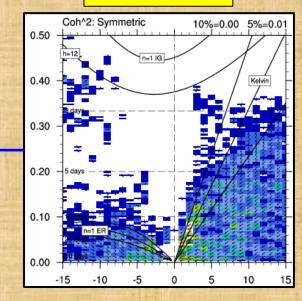
# **Madden-Julian Oscillation**

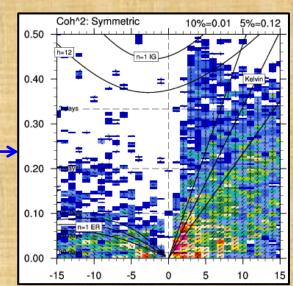






## **UNICON**





# Convection is forced to be weaker.

#### CAM5

OBS. Nov.-Apr.

## UNICON

													A				
15N	. N	· • • • • • • • • • • • • • • • • • • •	· · · · · · · · · · · · · · · · · · ·		2	15N -	- 21/1	Ademanifican		and an and the second state	anno 2	15N	NZ.	· · · · · · · · · · · · · · · · · · ·	() + + + + <del>    + + + + + + + + + + + + + </del>	·····	
					in the second		. 17	a she at the second second the	· · · · · · · · · · · · · · · · · · ·		A second		1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	······	• • • • • • • • • • • • • • • • • • •		\+ + + + + + → + \+ + - \+ + + →
0	R /		**************	••••••••••••••••••••••••••••••••••••••	++++ <mark>++(++</mark> +	0	1.	PERSONAL PROPERTY AND	***********	and the restance	++-+++++++++++++++++++++++++++++++++++	0	÷./		•••• <del>••••••**</del> *		
				<b></b>	· · · · · · Di. 77		1-11	- and the second of the second	allebete and a correct	++++ ( +++++++++++++++++++++++++++++++	and contract			**************************************	•••• <mark>•••</mark> •••	55555 <mark>5</mark> 555,	
15S	240	eres a contraction and	/ <u>***</u> ********	····· fameration	···· (P1://	15S ·	2011	former any star 12/10	referent	· · · · · · · · · · · · · · · · · · ·	P1:55	15S	24:	·····		······	···· 1P1:49
15N		╸ <del>┪╺╱╍╲╡</del> ┙╇┸╍╔╻╴╴╴╸╸╸╸ ╸╇╍┣╍╍╔╢┲┙┝╺╺╠╗╸╸╸╸╸				15N ·	Nil)	Marine Marine	mannin	Stat - and courses	··· · · · 2			· · · · · · · · · · · · · · · · · · ·	• • • • • • <del>•</del> • • • • • • • • • • • •	<del>20124/12004/12005 (0000000000000000000000000000000000</del>	2
	· · · · / +	······································			Nuzze →					to part the service of	Ar reci→		/.	• • • • • • • • • • • • • • • • • • •	• • • • • • • • • • • • • • • • • •	<del>}}}}}€€</del>	Xerti
0	€ <b>,∕.</b> ,	·····	****		+++++++++++++++++++++++++++++++++++++++	0	· (m	·····	****				\$. / . <b>.</b>		••••••••••••••••	**************************************	••••••
	. 97.		•••••	•••••••••••••••••••••••••••••••••••••••			JAK.	phasel patterned and	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	++++++ / ( + ++++ + + + + + + + + + + +					•••••		
15S	124	· • • • • • • • • • • • • • • • • • • •	<b></b>	· · · · · · · · · · · · · · · · · · ·	P2:62	158	12	-11. all sugar frances	(menerging and	· · · · · · · · · · · · · · · · · · ·	P2: 54	15S	201	••••••••••••••	••••••••••••	·····	1P2:37
15N	NZ.			· · · · · · · · · · · · · · · · · · ·	2	15N -	. Nort	A.G. PALATER INTE		many		15N	1.1.2.			Veralla in the	2
		······································	**************************************	• • • • • • • • • • • • • • • • • • •	Ne zini →		57	C. M. B. S.	*********	are a Manuer of the	<u>(</u>		** Kari-	· · · · · · · · · · · · · · · · · · ·	*************	++++ a 1+++++++++++++++++++++++++++++++	v··→→ ···→→
0	<b>.</b> /		***********	· · · · · · · · · · · · · · · · · · ·	, <mark></mark> ()	0	· / · · ·	and an and a strange bigger	an this has a submaniput	vening to veriday of the		0			<del></del>	•••••	••••• <del>•</del> ••••
		····		a a a a a a a a a a a a a a a a a a a			a de a de la construcción de la	LARSE CONTRACTOR	1		en ha						***
15S	· A.	······	<b>,</b>	•••••••••••••••••••••••••••••••••••••••	•••• P3: 54	15S ·	A.	and the second	M	· · · · · · · · · · · · · · · · · · ·	P3:68	15S			<mark>* • • • • • • • • • • • • • • • •</mark>		P3: 59
15N	1.2	· · · · · · · · · · · · · · · · · · ·	*******	······································	2	15N	NOM	Marca and more	d+provenue de	Sabassin	2	15N	1.1.2		*****	Martin Contraction	2
	• • • • • • • • • • • • • • • • • • •	••••••••••••••••••••••••••••••••••••••	•••••••••••••••••	• • • • • • • • • • • • • • • • • • •	الحافظ والمعار		5/2	and a stand and a stand	***************************************	· · · · · · · · · · · · · · · · · · ·	te soil -		1. 1. 1. 1.	· · · · · · · · · · · · · · · · · · ·	444444444444444444444444444444444444444	444 / 1	ver +++ ver ∧++
0	p	**************************************	**************************************	•••••••••••••••••••••••		0.		and a state of the	11+4.5.5 <del>**********</del> ****	1444 4 Hans & A alga & & & &	in iskent	0	\$- <i>∕</i> ++		<del></del>	<del>(((((((()))))))))))))))))))))))))))))</del>	······································
	+++++++++++++++++++++++++++++++++++++++	a second a support of a state of a	****	••••••	· · · · · · · · · · · ·		*****	and the second	**************************************				<b>1</b>			<del>{{{{{{{}}}}{{{{}}}{{{}}{{{}}{{{}}{{{}</del>	· · · · · · · · · · · ·
15S	272	·····	· · · · · · · · · · · · · · · · · · ·	···· ··· <b>·</b> ··· · · · · · · · · · · · ·	∵ P4:63	158	ZK	~	approximation and a second	· · · · · · · · · · · · · · · · · · ·	P4: 68	15S		•••••	••••••		P4: 40
15N		·	*************	· · · · · · · · · · · · · · · · · · ·	2	15N -	NA	and ward in second	((Compared )))	Salar	2	15N	1.2	• <del>*</del> ••••			
		······································	······································		Xt Start →		1. 1. 210	- Harifa y granner	Magaaa	and Marian	(cgd→	1011	· · · · ·	•••••••••••••••••••••••••••••••••••••••	·····	444	k: <u>x</u> i→
0	þ. <b>/</b>	·····	*****	<mark></mark>	++++++++++++++++++++++++++++++++++++++	0	100	and a share the second	A Contraction	analt fallen and i	an areas	0	p. /	<mark>+                                    </mark>	• • • • • • • • <del>• • • • • • • • • • • </del>	<del></del>	•**•*••
		and a second state of the		· · · · · · · · · · · · · · · · · · ·			14	the state of the s	**************************************	and the second sec	<u></u>			······································	····	······································	· · · · · · · · · · · · · · · · · · ·
15S		<mark></mark> <mark></mark>	<u>, , , , , , , , , , , , , , , , , , , </u>	••••••••••••••••••••••••	P5: 81	15S ·	PA-	· 1/		and have be a life and from	· · · · P5: 49	15S	24	· · · · · · · · · · · · · · · · · · ·	x+++++++++++++++++++++++++++++++++++++	+ • · • · • • • • • • • • • • • • • • •	P5: 55
15N	NZ.	W. C. L.	·····	<u></u>	2	15N	LX LA	Aller and and a second	(11)	Safet Hanna	2	15N		NZ <mark>W</mark> V R			2
	a firm	······································	**************	••••••		10II	i-Fir	- group and I among	1111 Werenet	and the former and	V	1011	a tris	·····	• • • • • • • • • • • • • • <del>• • • • • </del>	ter the training	(÷ xii→
0	0 /	· · · · · · · · · · · · · · · · · · ·		·····		0.	17.2	and the off Barry Int		acception and	and and and	0	b /	· · · · · · · · · · · · · · · · · · ·	**************************************	••••••••••••••••••••••••••••••••••••••	••••••••••••••••••••••••••••••••••••••
		· · · · · · · · · · · · · · · · · · ·	********		+++++++++++++++++++++++++++++++++++++++			and a superior and a second	an Y V Spensor Antoine Bar An Barangan State ( 1997)	**************************************			<b>1</b>		<del>}}}}}</del>	<del>**************</del> ****	** * * * * *
15S	2/2	·····	••••••••••••••••	·····	••••••••••••••••••••••••••••••••••••••	158	1	Leave considered to be	A Commission	marily of free from	P6: 56	15S	$\mathbb{R}^{2}$	·····	***********************	· · · · · · · · · · · · · · · · · · ·	P6: 48
15N	·	· • • • • • • • • • • • • • • • • • • •	********	· · · · · · · · · · · · · · · · · · ·	27. 2	15N -	Nak.	A.C. Partin Marcell	man willing	. Mar wares	er . T. 2	15N	NºZ.		****	****	2
		• • • • • • • • • • • • • • • • • • •	••••••	and a factor of the second	(		1 - mpin	report of the reason	*****	1/1 top transmiss	$\langle \cdots \rangle$	1011	1. 1.7.	·······	******	****	(++ ++++ • + + + + + +
0	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	······································	**********	• • • • • • • • • • • • • • • • • • •	+++++(++++	0	/	and the sugarante		· · · · · · · · · · · · · · ·		0	0		<del>*************************************</del>	**************************************	•••• <del>••</del>
		•••••••••••	<del>((()))</del> , ())	••••••••••••••••••••••••••••••••••••••	****		dia		A	· · · · · · · · · · · · · · · · · · ·	an approx			· · · · · · · · · · · · · · · · · · ·	**************************************	••••••••••••••••••••••••••••••••••••••	***** <mark>*</mark> ***
15S	24	••••••••••• <mark>•••</mark> *•••	<b></b>	·····	P7: 56	15S ·	Art	real president bearing	Marrison	****************	P7:62	15S	24		*****	·····	••••• P7: 44
15N	N.Z.	, , , , , , , , , <del>, , , , , , , , , , </del>	***********	New Contraction of the	···· ··· · · · · · · · 2	15N	Nim	A Charles and	the second s	Str	2	15N	AZZ	+ + + + + + + + + + + + + + + + + + +	· · · · · · · · · · · · · · · · · · ·	Section to the sector	22.2.1.2
			·····	territe and the second	X: X: I→	1011	· Htt		****	and depatrice of the second	×+ + + + + + + +	1011	22		****** <mark>*******</mark>	****	N: titt
0	p++/+++	+ + + + + + + + + + + + + + + + + + +	*****************	• • • • • • • • • • • • • • • • • • •		0		PERSONAL PROPERTY AND	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	in office	0	0 1/144	Contractor of the second	* * * * * * * * * * * * * * * * * * *	<u>********</u> ****************************	
	$\cdot$			·····				The state of the state of the	dels spinisteries and a s fallels spinisteries and a second	and a for a set of a	() ( interest			· · · · · · · · · · · · · · · · · · ·	*****************	**************************************	
15S	H	····	·····		, P8:66	15S -	pq.	-11000 1 100 page 1/100	all and the second	and a start for	P8:62	15S	124		····	••••••••••••••••••••••••••••••••••••••	221 P8:60
1	08	F 120F	180 120W	W08	0		R	190E	180 100W	BOW	0		03	E 120E	180 120W	60W	0
	50	e reVe	16010	0011	v		0	1270	1201	00M	v		00	L IÉVL	12010	VV11	v

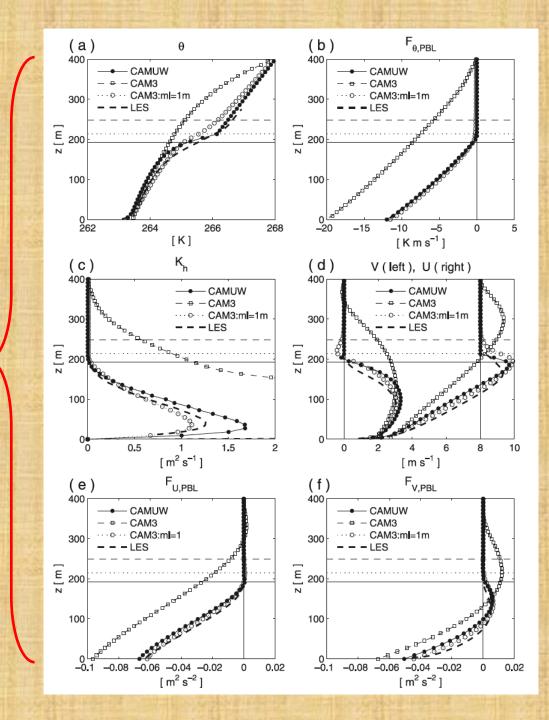
#### SUMMARY

- UNICON (Unified Convection Scheme or more precisely, sub-grid vertical transport scheme by asymmetric turbulences) was finally found after 5 years of intensive search. With CAM5 sub-grid vertical transport scheme by symmetric turbulences (i.e., PBL scheme), UNICON can simulate all sub-grid vertical transports without any missing or double-counting. Similar to CAM5 symmetric turbulence transport scheme, UNICON can be seamlessly applied across any GCM grid size as long as GCM horizontal grid size is larger than the maximum plume radius assumed in the UNICON (~1 km).
- In most of the SCAM tests, UNICON showed improved performances both in L30 and L80 with less sensitivity to vertical resolution. Non-local transport and penetrative entrainment are generically simulated by UNICON.
- Global simulation shows that UNICON well captures observed precipitation climatology, MJO and Sc-to-Cu transition. But diurnal cycle of precipitation needs to be further improved. UNICON can be served as an excellent tool to understand the dynamics of MJO and diurnal cycle of convection.
- UNICON is continuously growing. For mature UNICON, I need to provide the following ingredients : I. Objective and through training-tuning using reliable observation-LES test cases spanning a wide range of regimes and processes (e.g., diurnal cycle); II. implementation of detailed aerosol activation and convective microphysics.



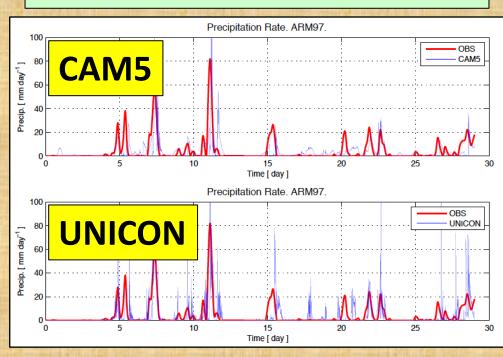


#### Dry Stable PBL : GABLS1

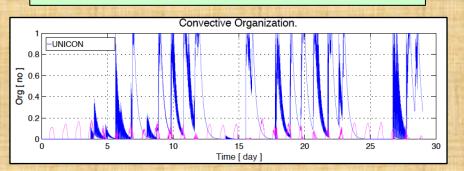


## **Deep Moist Convection. ARM97.**

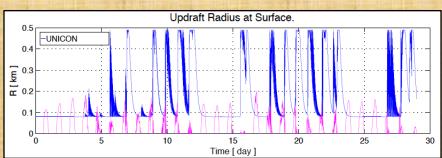
## **Precipitation Rate at Surface**



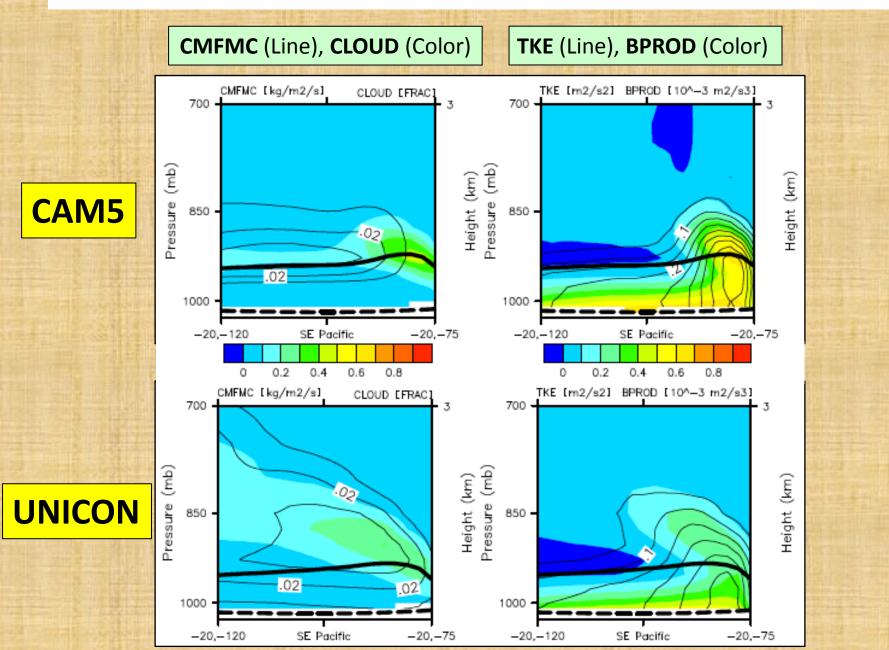
**Convective Organization. UNICON** 



#### **Updraft Radius at Surface. UNICON**

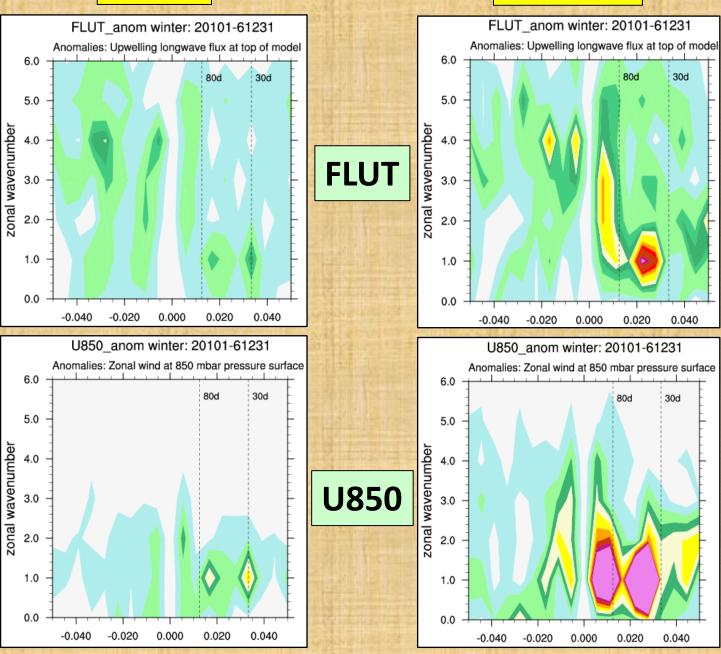


# Stratocumulus to Cumulus Transition. SON.



## CAM5

# UNICON



#### Major Remaining Issues in the Parameterization of Convection

- I. Unified Treatment of *Shallow* and *Deep* Convection
- II. Unified Treatment of Dry and Moist Convection
- III. Unified Treatment of Forced and Free Convection
- IV. Treatment of *Downdraft Dynamics*
- I. Parameterization of Lateral Mixing
- II. Formulation of *Self-Consistent Closure*
- I. Cloud Overlap for Microphysics, Radiation, and Aerosol Wet Deposition
- *II. Microphysics* interacting with *Aerosols*
- III. Convection across the Scale Barrier

- Some important 'features' (possibly) associated with convection scheme
  - Precipitation Climatology : Double ITCZ, Monsoon, Precipitation over Land, Precipitation FQ, Ratio of Convective to Stratiform Precipitation
  - Lack or weak Diurnal Cycle of Precipitation
  - Lack or weak Madden-Julian Oscillation
  - Too rapid transition from stratocumulus to cumulus along the subtropical transect
  - ENSO characteristics
  - Climate sensitivity of marine stratocumulus and cirrus clouds
  - Global teleconnection
  - Biases of water vapor & clear sky LW radiation (?)
  - Too strong subtropical high in summer (?)
  - Too strong hydrological cycle (?)
  - Hurricane forecast
  - Many other features since 'convection' is the 'pump' of the atmospheric circulation

#### OUTLINE

I. Brief Description on the UNICON

#### II. SCAM5 Simulation :

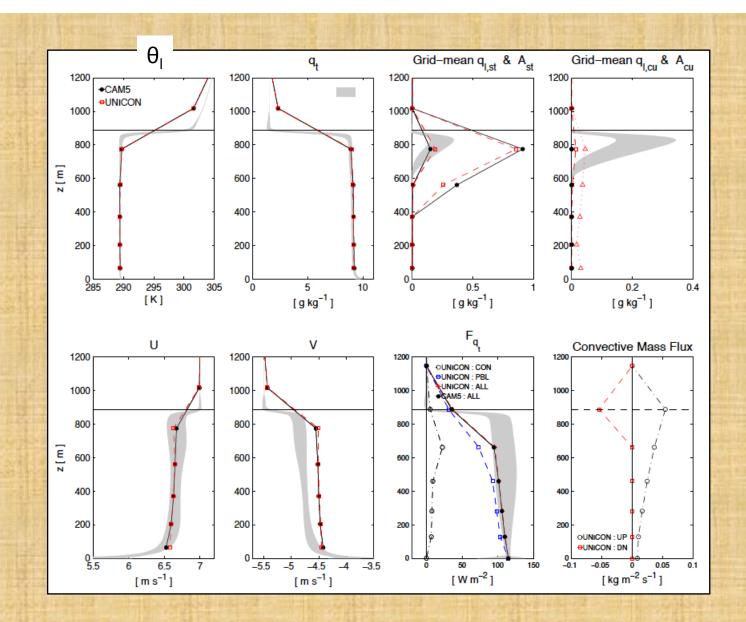
- Dry Convection (DCBL)
- Stratocumulus-Topped Convection (DYCOMS)
- Stratocumulus to Cumulus Transition (STCU)
- Shallow Convection (BOMEX)
- Deep Convection (ARM95, ARM97, GATEIII, TOGAII)

#### III. CAM5 Simulation

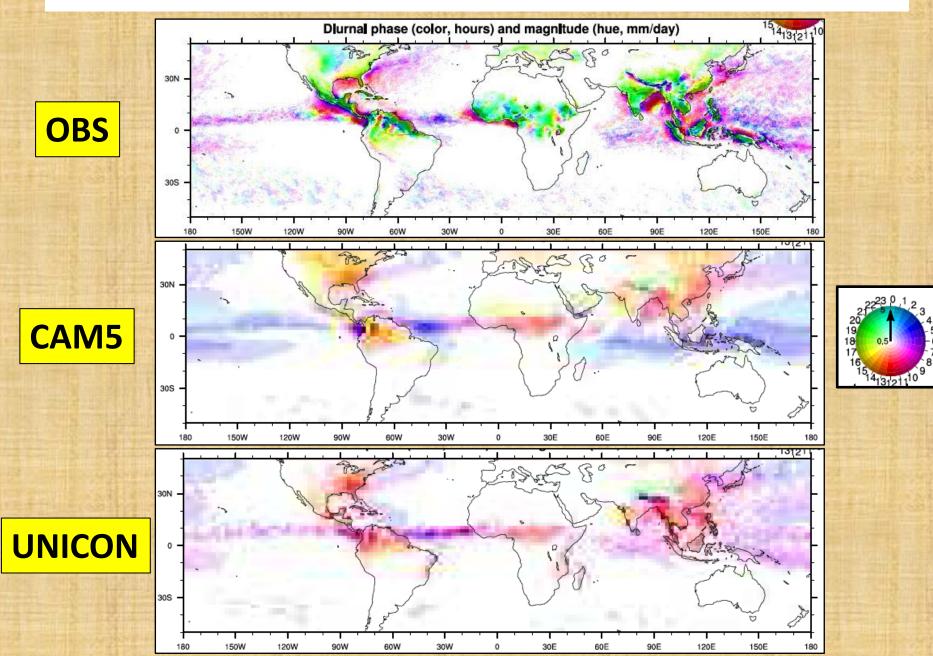
- Precipitation Climatology
- Diurnal Cycle of Precipitation
- Madden-Julian Oscillation
- Stratocumulus to Cumulus Transition

#### IV. SUMMARY

## Stratocumulus-Topped Convection. DYCOMS.



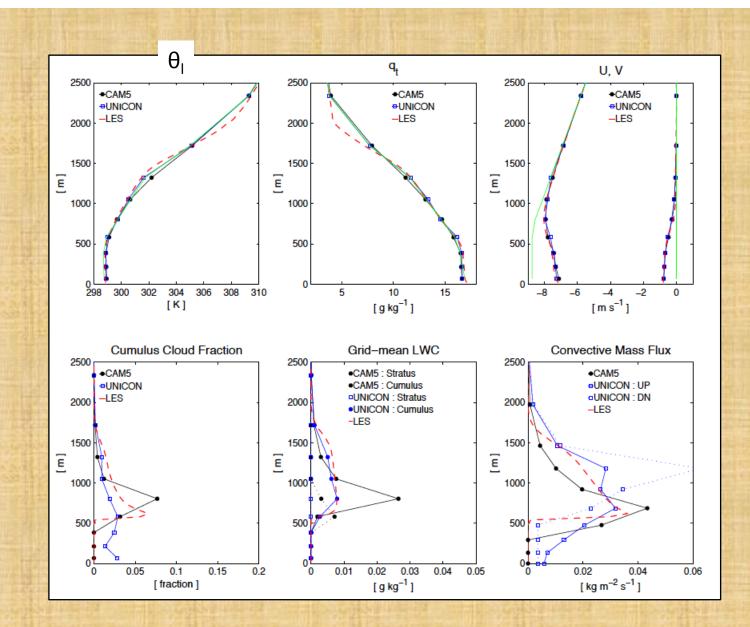
# **Diurnal Cycle of Precipitation. JJA.**



#### Moist Turbulence Scheme in CAM5 C. Bretherton and S. Park. 2009

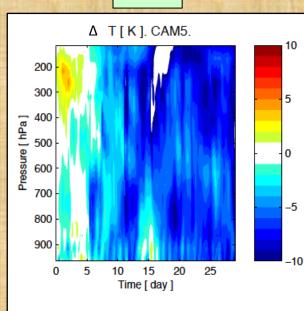
- Diagnostic TKE-based 1.5<sup>st</sup> order K diffusion scheme with entrainment param.
  - Numerically stable, physically realistic, conceptually clear
  - TKE is fed into 'shallow convection' and 'cloud microphysics', and regulates the onset of cumulus updraft and cloud droplet activation
- Stratus-Top LW Cooling and In-Stratus Condensation Heating into TKE
  - Sensitive to 'cloud macro-microphysics' and 'radiation' schemes
  - Treatment of Stratus-Radiation-Turbulence Interactions
  - Now, stratus is a dynamic (as well as radiative) driver of the climate
  - Handling of the full 2<sup>nd</sup> aerosol indirect effects
  - Removal of the stability-based KH stratus fraction
- Activate in any layers above as well as within PBL
  - Simulate turbulences in the mid-level clouds
- Compared to CAM4 PBL scheme,
  - Much better performance in cloud-topped regime
  - Similar or superior performance in dry stable and convective regimes

## **Shallow Moist Convection. BOMEX.**



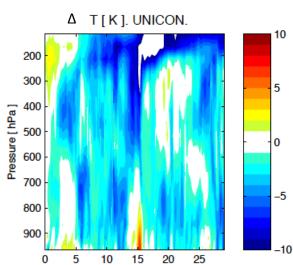
## **Bias against Observation. ARM97.**

Δ Τ



CAM5

**UNICON** 



Time [ day ]

