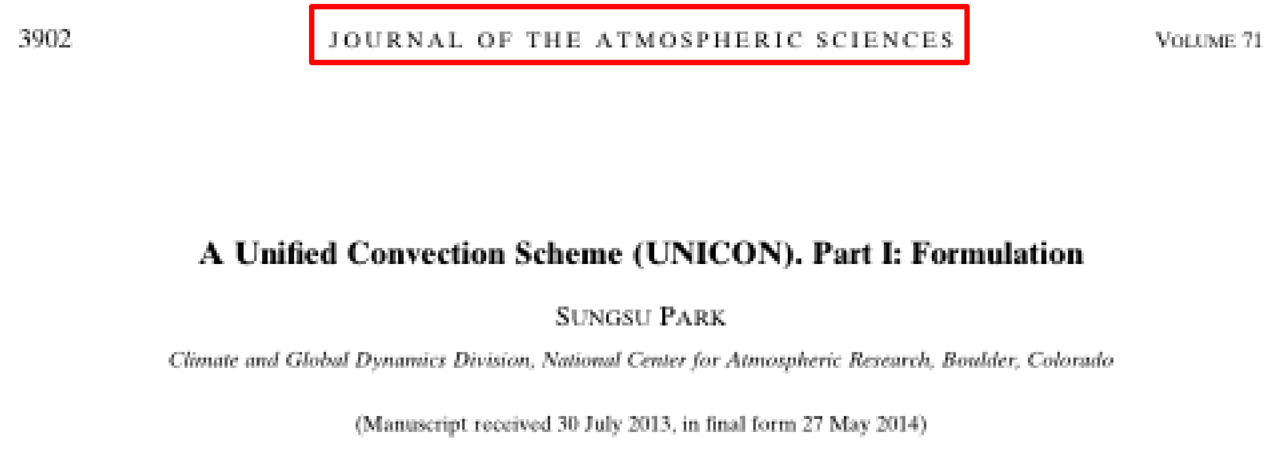
A Unified Convection Scheme, ‘UNICON’

Atmospheric Modeling Working Group Meeting, NCAR.

February. 19, 2015.

Sungsu Park

AMP. CGD. NESL. NCAR. Boulder, CO, USA.

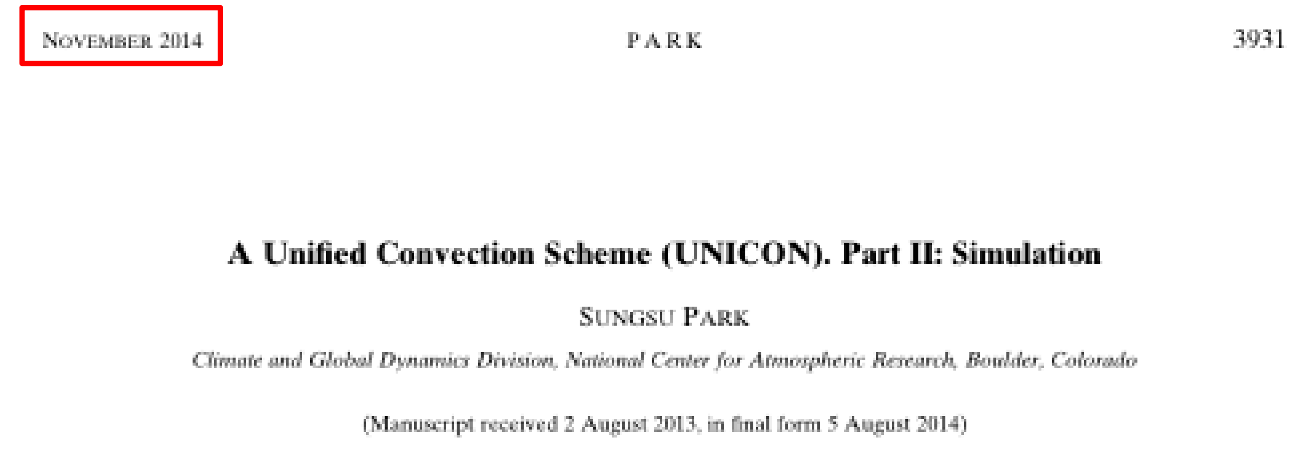


3902 JOURNAL OF THE ATMOSPHERIC SCIENCES VOLUME 71

A Unified Convection Scheme (UNICON). Part I: Formulation

SUNGSU PARK
Climate and Global Dynamics Division, National Center for Atmospheric Research, Boulder, Colorado

(Manuscript received 30 July 2013, in final form 27 May 2014)



NOVEMBER 2014 PARK 3931

A Unified Convection Scheme (UNICON). Part II: Simulation

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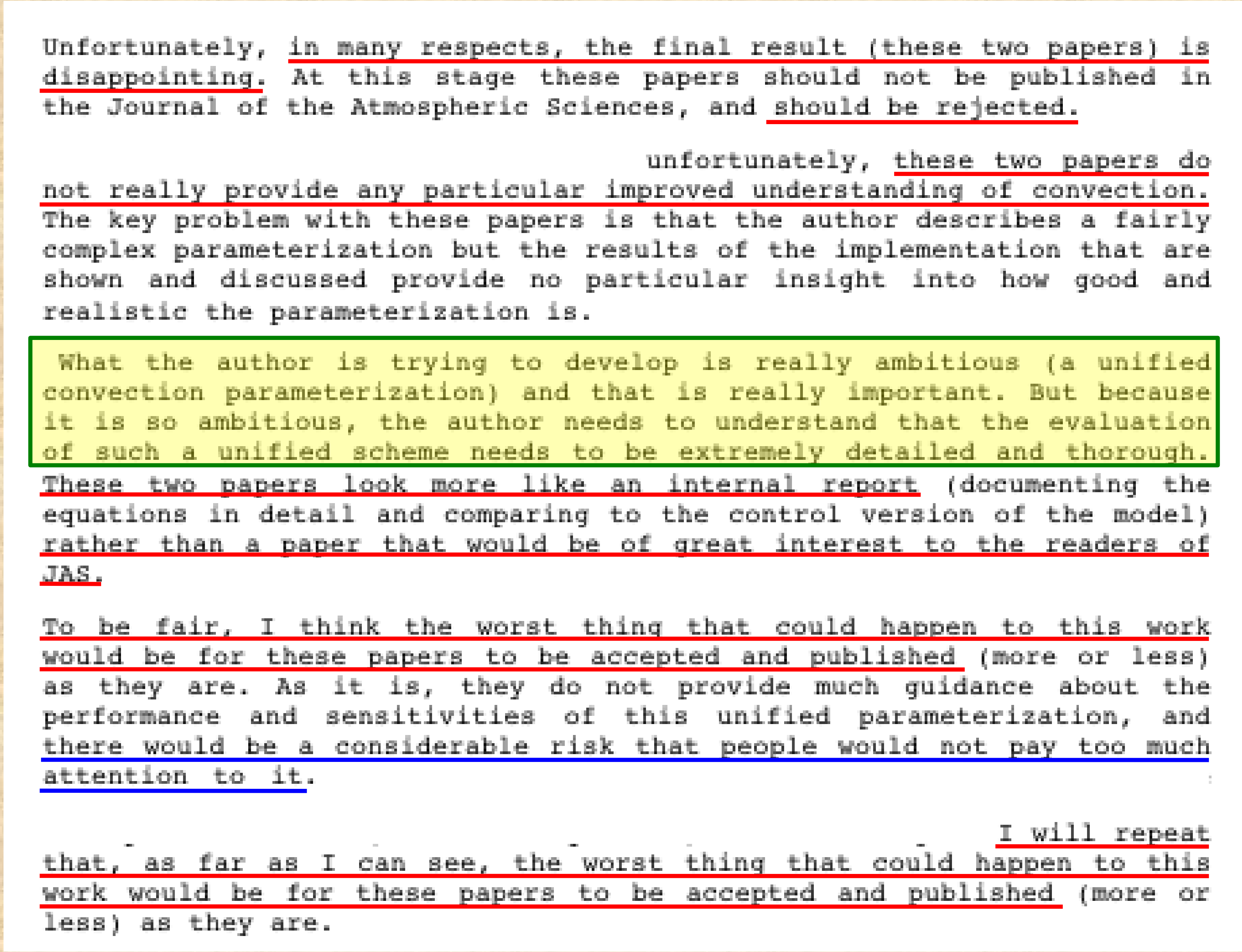
(Manuscript received 2 August 2013, in final form 5 August 2014)

One of the Reviewer’s Comments on the UNICON Papers



Unfortunately, in many respects, the final result (these two papers) is disappointing. At this stage these papers should not be published in the Journal of the Atmospheric Sciences, and should be rejected.

unfortunately, these two papers do not really provide any particular improved understanding of convection. The key problem with these papers is that the author describes a fairly complex parameterization but the results of the implementation that are shown and discussed provide no particular insight into how good and realistic the parameterization is.

What the author is trying to develop is really ambitious (a unified convection parameterization) and that is really important. But because it is so ambitious, the author needs to understand that the evaluation of such a unified scheme needs to be extremely detailed and thorough. These two papers look more like an internal report (documenting the equations in detail and comparing to the control version of the model) rather than a paper that would be of great interest to the readers of JAS.

To be fair, I think the worst thing that could happen to this work would be for these papers to be accepted and published (more or less) as they are. As it is, they do not provide much guidance about the performance and sensitivities of this unified parameterization, and there would be a considerable risk that people would not pay too much attention to it.

I will repeat that, as far as I can see, the worst thing that could happen to this work would be for these papers to be accepted and published (more or less) as they are.

Various Responses from the General Community

"…What a daring masterwork, so rare these days. And what a humble privilege you have had, 5 years to see it through. I am reminded of Vic Ooyama's unusual and not very publication-numerous yet profound career and deep thinking style..."

"…It is a great pleasure to read your recent two papers on a new cumulus parameterization scheme (i.e. the UNICON), which is a nice frame work for future high-resolution modeling due to its scale-adaptive capability and a prototype scheme for organized convection..."

"…I like your philosophy particularly for the development of a new-generation cumulus parameterization, like the Tiedtke scheme, which took many years to develop, but becoming very useful even in many coming years..."

"…I am writing this email firstly to congratulate you for your two nice articles published recently in JAS on your UNICON scheme. I have enjoyed so much both papers. Many other colleagues also commented me that your recent papers are the best in convection..."

"…I am very impressed by theoretical basis as well as the simulation characteristics…"

Top 10
Most Read JAS Articles

(previous 12 months)

A Study of Aerosol Impacts on Clouds and Precipitation Development in a Large Winter Cyclone - Thompson & Eidhammer

Atmospheric Predictability: Why Butterflies Are Not of Practical Importance - Durran and Gingrich

A Unified Convection Scheme (UNICON). Part I: Formulation - Park

Three-Dimensional Structure and Evolution of the MJO and Its Relation to the Mean Flow - Adams & Wallace

Representing Equilibrium and Nonequilibrium Convection in Large-Scale Models - Bechtold et al.

Isolating the Role of Surface Evapotranspiration on Moist Convection along the Eastern Flanks of the Tropical Andes Using a Quasi-Idealized Approach - Sun & Barros

The Formation of Wider and Deeper Clouds as a Result of Cold-Pool Dynamics - Schlemmer & Hohenegger

Nonlinear Feedback in a Five-Dimensional Lorenz Model - Shen

A Unified Convection Scheme (UNICON). Part II: Simulation - Park

Rainfall, Convection, and Latent Heating Distributions in Rapidly Intensifying Tropical Cyclones - Zagrodnik & Jiang

http://journals.ametsoc.org/loi/atsc

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 (14) 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 Iacono 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 - *BGC*	POP2.2
Land	CLM3	CLM3.5	CLM4 - *CN*	CLM4
Sea Ice	CSIM4	CSIM4	CICE	CICE

MOTIVATION for developing UNICON

- In nature, a continuous transition from shallow to deep convection widely occurs both in space and time. This seamless transition from shallow to deep cumulus cannot be adequately simulated by separate shallow and deep convection schemes.

- CAM5 uses a process splitting, in which shallow convection scheme is operating on the input state updated from the proceeding deep convection scheme. The performance of model, however, is sensitive to the sequence of deep and shallow convection schemes.

- A direct association between the observations and the parameterized physical processes in the existing convection schemes is very weak (e.g., an inherent problem of equilibrium-based convection scheme).

- Developing a suite of scale-adaptive physics parameterizations is one of the most important but ambiguous subjects in the modeling community. Developing an appropriate convection scheme is at the heart of this mission.

- Many biases in the GCM-simulated climate are associated with the convection schemes.

OUTLINE

I. Introduction of UNICON
- Conceptual Overview
- 3 Key Physical Processes

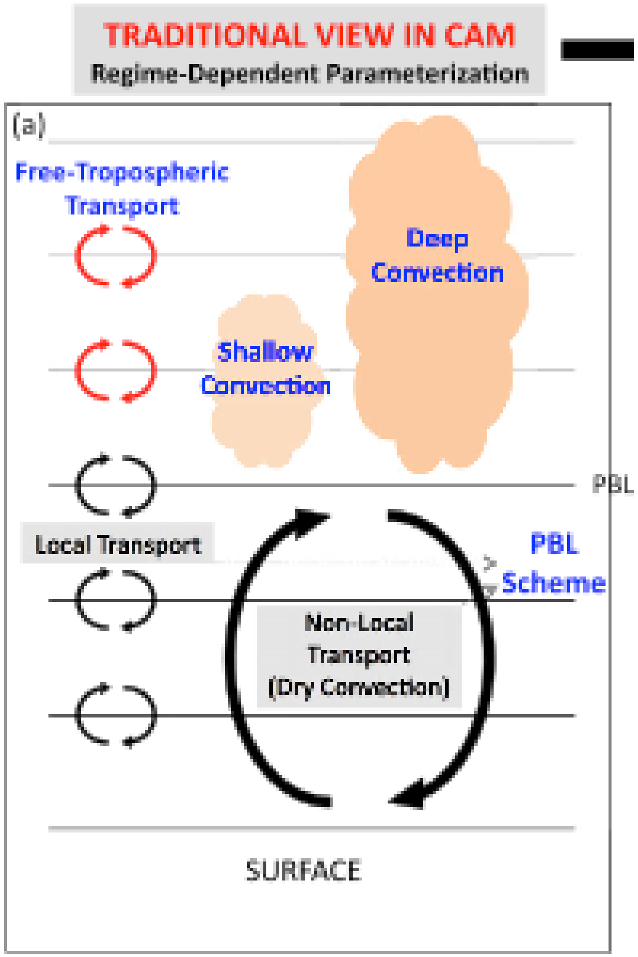
II. Single-Column Simulations
- Dry Convection
- Stratocumulus-to-Cumulus Transition
- Shallow Convection
- Deep Convection

III. Global Simulations
- Climatology
- Variability (ENSO, MJO, Diurnal Cycle of Precipitation, Tropical Cyclone)

I. Future Works

WHAT IS UNICON ?

A subgrid vertical transport scheme by non-local asymmetric turbulent eddies, consisting of subgrid *convective updrafts*, *convective downdrafts*, and *meso-scale organized flow*.

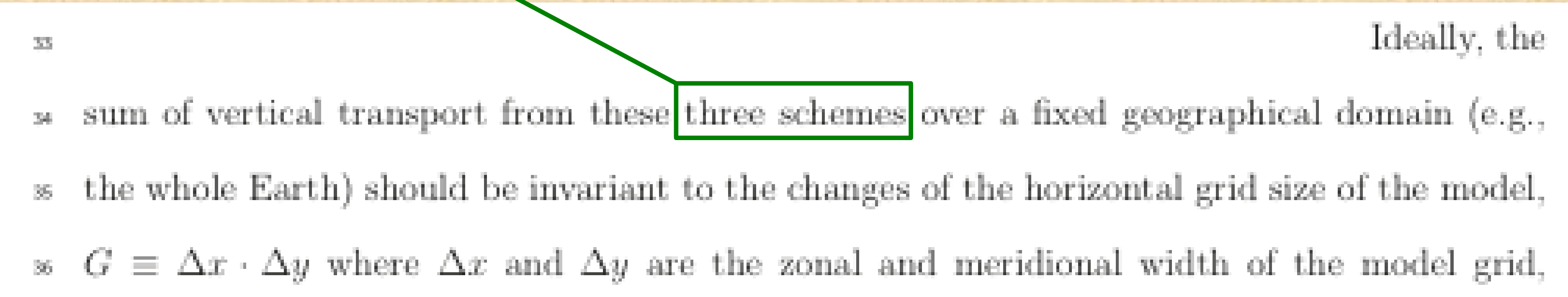


UNICON is *not* designed to simulate *the observed convection but* designed to simulate *subgrid non-local asymmetric turbulent eddies* → UNICON is a *scale-adaptive* parameterization.

SCALE ADAPTIVITY

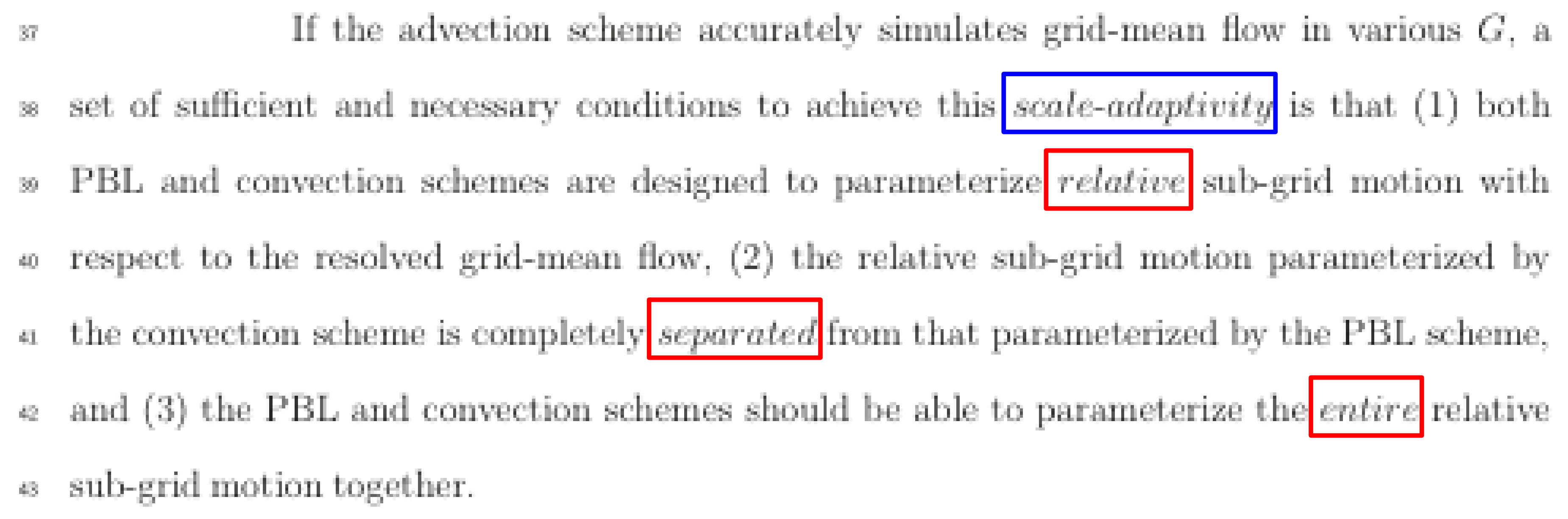
DEFINITION

Advection, PBL, Convection

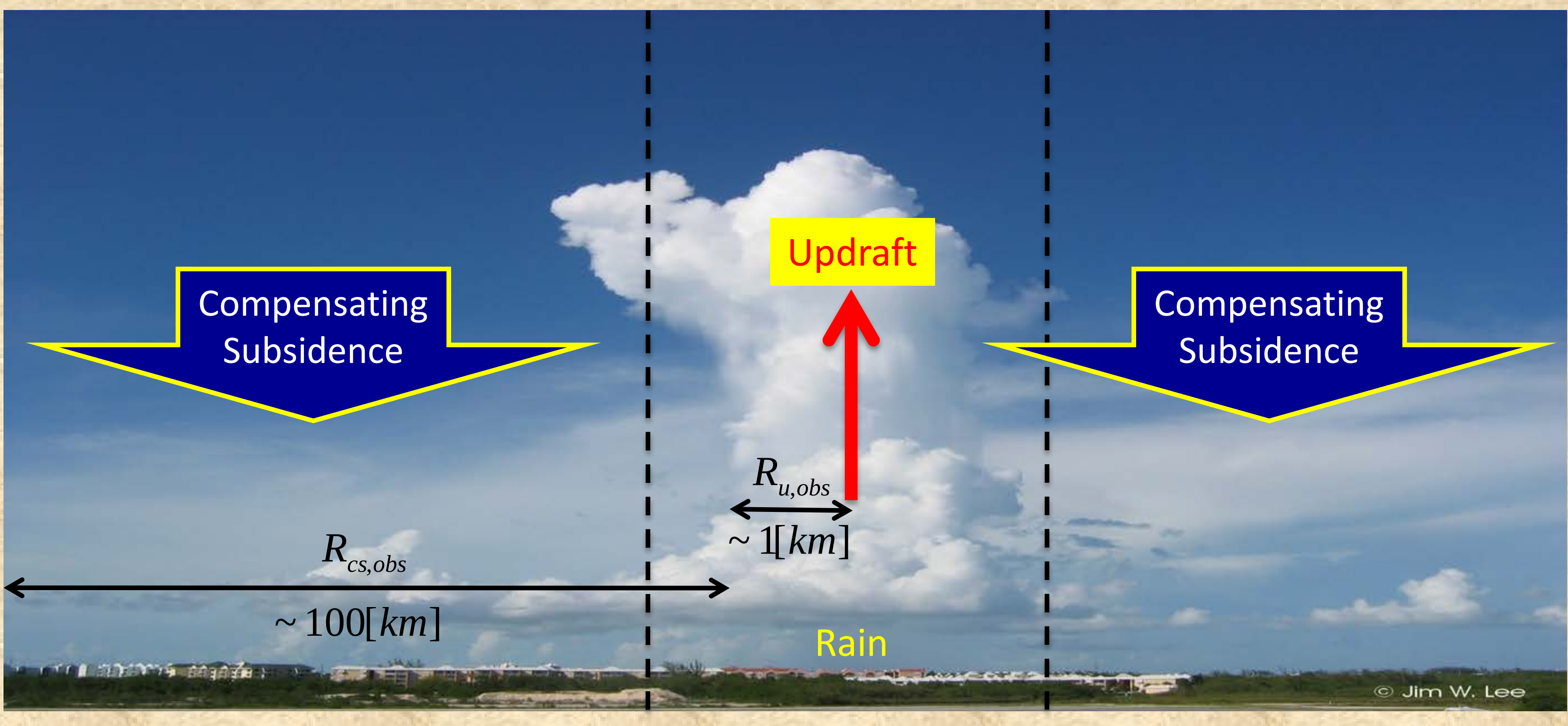


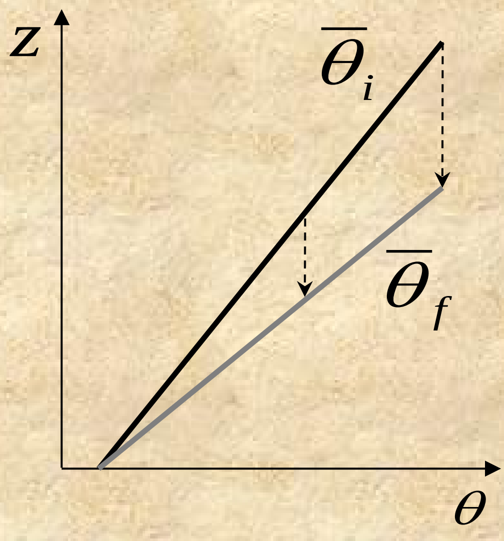
Ideally, the sum of vertical transport from these three schemes over a fixed geographical domain (e.g., the whole Earth) should be invariant to the changes of the horizontal grid size of the model, $G \equiv \Delta x \cdot \Delta y$ where Δx and Δy are the zonal and meridional width of the model grid,

CONDITIONS



If the advection scheme accurately simulates grid-mean flow in various G, a set of sufficient and necessary conditions to achieve this *scale-adaptivity* is that (1) both PBL and convection schemes are designed to parameterize *relative* sub-grid motion with respect to the resolved grid-mean flow, (2) the relative sub-grid motion parameterized by the convection scheme is completely *separated* from that parameterized by the PBL scheme, and (3) the PBL and convection schemes should be able to parameterize the *entire* relative sub-grid motion together.



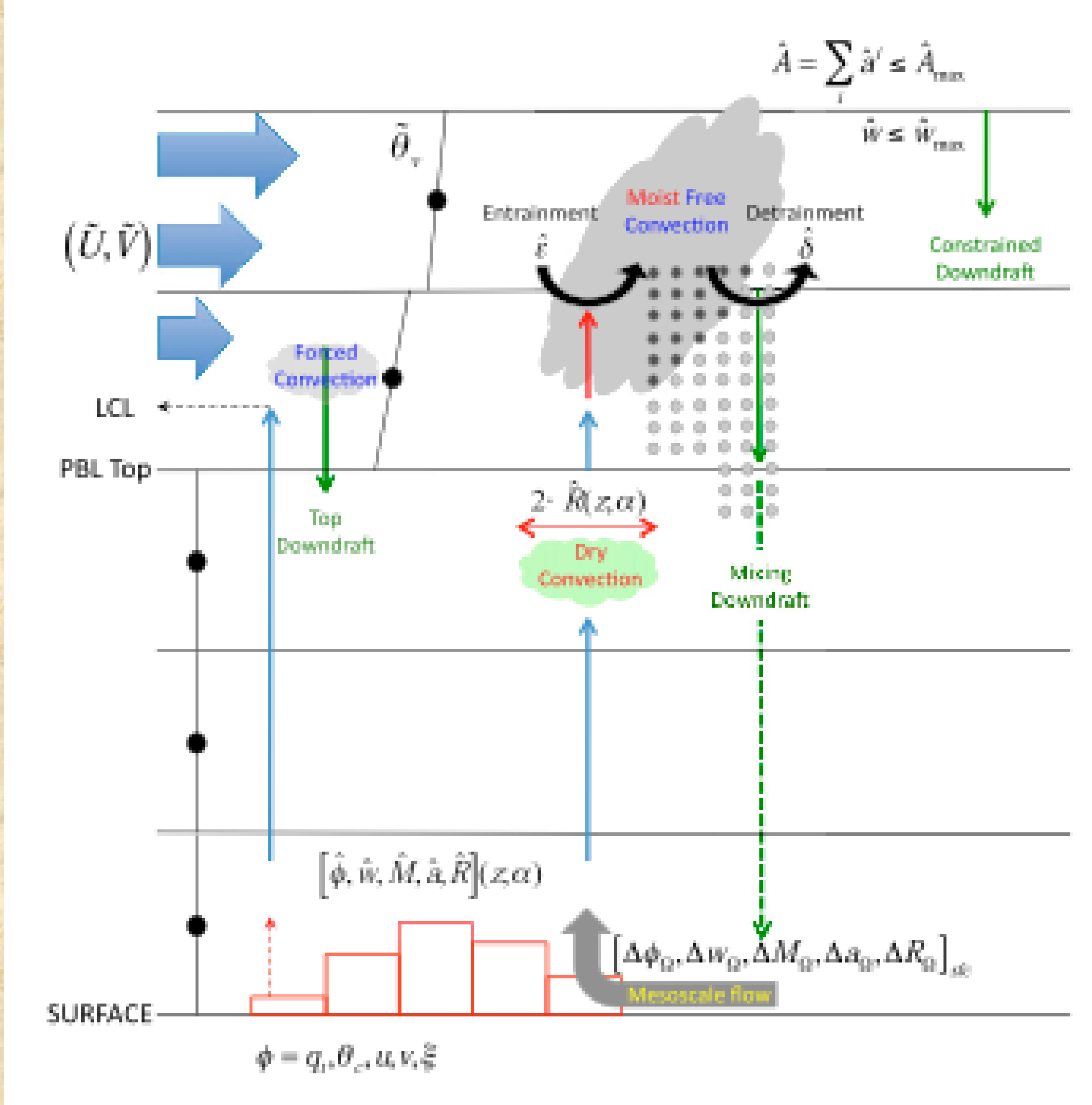


Convection stabilizes atmosphere by compensating subsidence.

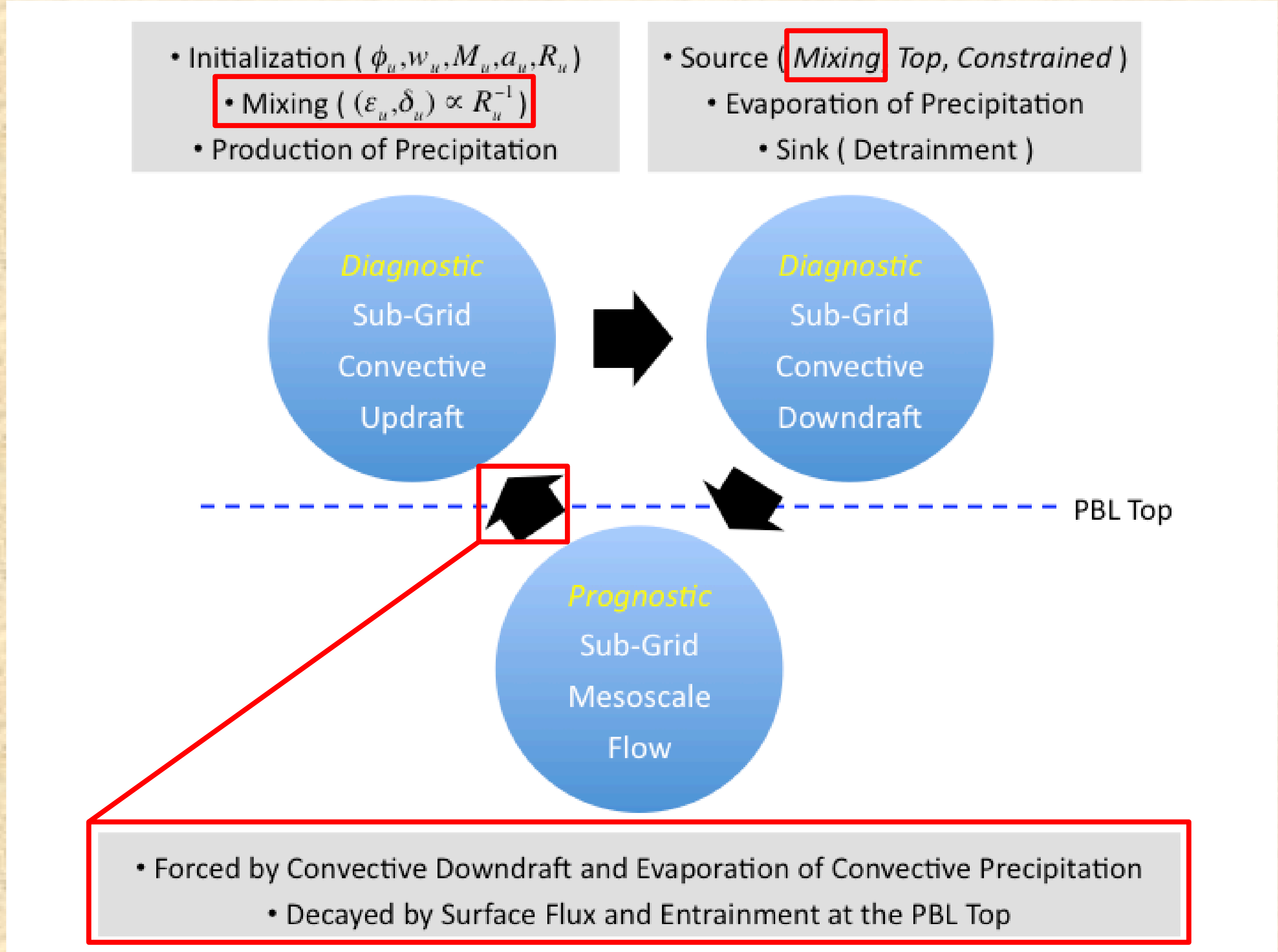
Quasi-Equilibrium (QE) Assumption:

Whenever a grid-column is destabilized by non-convective processes (e.g., radiation), convection tries to stabilize the grid-column within a certain convective-overturning time scale.

UNICON simulates all ***dry-moist***, ***forced-free***, and ***shallow-deep*** convection within a single framework in a seamless, consistent and unified way.



UNICON consists of *subgrid* *Convective Updraft*, *Convective Downdraft*, and *Mesoscale Organized Flow*.



- Initialization ($\phi_u, w_u, M_u, a_u, R_u$)
- Mixing ($(\varepsilon_u, \delta_u) \propto R_u^{-1}$)
- Production of Precipitation

- Source (*Mixing Top, Constrained*)
- Evaporation of Precipitation
- Sink (Detrainment)

Diagnostic
Sub-Grid
Convective
Updraft

Diagnostic
Sub-Grid
Convective
Downdraft

PBL Top

Prognostic
Sub-Grid
Mesoscale
Flow

- Forced by Convective Downdraft and Evaporation of Convective Precipitation
- Decayed by Surface Flux and Entrainment at the PBL Top

Prognostic treatment of mesoscale organized flow allows UNICON to carry the convective plume memory across the model time steps.

3 Key Physical Processes unique in UNICON

I. Parameterization of Updraft Mixing Rate

$$\hat{\epsilon}_o(z) = \left[\frac{a_1}{\rho g \hat{R}(z)}\right](1 + a_2 E), \quad E = \sqrt{(\hat{q}_l + \hat{q}_i)(1 - \overline{\mathrm{RH}}_u)}$$

II. Generation of Mixing Downdraft

$$\tilde{M}_m = 2\hat{f}_m \hat{M}^{\mathrm{bot}} \hat{\epsilon}_0 \Delta p \int_{\chi_{d,\min}}^{\chi_{d,\max}} P(\chi)\, d\chi \qquad \tilde{\phi}_m = \hat{\phi}^{\mathrm{bot}} + \left[\frac{\displaystyle\int_{\chi_{d,\min}}^{\chi_{d,\max}} \chi P(\chi)\, d\chi}{\displaystyle\int_{\chi_{d,\min}}^{\chi_{d,\max}} P(\chi)\, d\chi}\right](\hat{\phi}_u^{\mathrm{bot}} - \hat{\phi}^{\mathrm{bot}}),$$

III. Mesoscale Cold-Pool and its Feedback on Convective Updraft

$$\frac{\partial a_D}{\partial t} = -U_{\mathrm{PBL}}\frac{\partial a_D}{\partial x} - V_{\mathrm{PBL}}\frac{\partial a_D}{\partial y} + (\epsilon_c - \delta_c) + \frac{g}{\Delta p_h}\sum_j \tilde{M}^j_{D,h} - \frac{g}{\Delta p_h}\left[\sum_j (\tilde{M}^j_{D,h} + \tilde{M}^j_{U,h}) - \sum_i \hat{M}^i_h\right] a_D,$$

$$\begin{aligned}
\frac{\partial}{\partial t}(\Delta\phi_U) &= -U_{\mathrm{PBL}}\frac{\partial}{\partial x}(\Delta\phi_U) - V_{\mathrm{PBL}}\frac{\partial}{\partial y}(\Delta\phi_U) \\
&\quad - \frac{g}{\Delta p_h}\left\{\sum_j\left[\tilde{M}^j_{D,h}(\tilde{\phi}^j_{D,h} - \phi_{\mathrm{PBL}}) - \frac{a_D}{a_U}\tilde{M}^j_{U,h}(\tilde{\phi}^j_{U,h} - \phi_{\mathrm{PBL}})\right] + \frac{a_D}{a_U}\sum_i \hat{M}^i_h(\hat{\phi}^i_h - \phi_{\mathrm{PBL}})\right\} \\
&\quad + g\left\langle \frac{a_D}{a_U}\sum_i \hat{M}^i \hat{S}^i_\phi + \sum_j\left(\frac{a_D}{a_U}\tilde{M}^j_U \tilde{S}^j_{\phi,U} - \tilde{M}^j_D \tilde{S}^j_{\phi,D}\right)\right\rangle_0^h + \langle (S_{e,U} - \overline{S}_e)_\phi \rangle_0^h \\
&\quad - \left\{\frac{\delta_c}{a_D a_U} + \frac{g}{\Delta p_h}\left[\sum_j\left(\tilde{M}^j_{G,h} + \frac{1}{a_U}\tilde{M}^j_{U,h}\right) + \rho_s C_d V_s + \rho_h W_{e,h} - \frac{1}{a_U}\sum_i \hat{M}^i_h\right]\right\}\Delta\phi_U, \quad \text{and}
\end{aligned}$$

$$\begin{aligned}
\hat{A}_s(\Omega) &= \hat{A}_s|_{\Omega=0} + \Omega \times (\hat{A}_s|_{\Omega=1} - \hat{A}_s|_{\Omega=0}) \\
&= \hat{A}_s|_{\Omega=0} \times [1 - \Omega \times (1 - \hat{A}_{\max})],
\end{aligned}$$

$$R_o(\Omega) = R_o|_{\Omega=0} + \Omega^\gamma \times (R_o|_{\Omega=1} - R_o|_{\Omega=0}),$$

$$\sigma_R(\Omega) = \sigma_R|_{\Omega=0} + \Omega^\gamma \times (\sigma_R|_{\Omega=1} - \sigma_R|_{\Omega=0}),$$

$$\hat{\phi}_u(z,t) = \begin{cases} \hat{\phi}(z,t) + \Delta\phi_\Omega, & \text{if} \quad z < h, \\ \hat{\phi}(z,t) + \Omega_s \times [\phi_r(z, t - \Delta t) - \hat{\phi}(z, t - \Delta t)], & \text{if} \quad z > h, \end{cases}$$

I. Parameterization of the Updraft Mixing Rate, $\hat{\varepsilon}_o$

$$\frac{\partial\bar{\phi}}{\partial t} + \bar{\mathbf{V}}\cdot\nabla\bar{\phi} = -g\frac{\partial}{\partial p}\left[\sum_i \hat{M}^i(\hat{\phi}^i - \bar{\phi}) + \sum_j \check{M}^j(\check{\phi}^j - \bar{\phi})\right] + g\left(\sum_i \hat{M}^i\hat{S}^i_\phi + \sum_j \check{M}^j\check{S}^j_\phi\right) + \tilde{a}\left(\frac{\partial\tilde{\phi}}{\partial t}\right)_s,$$

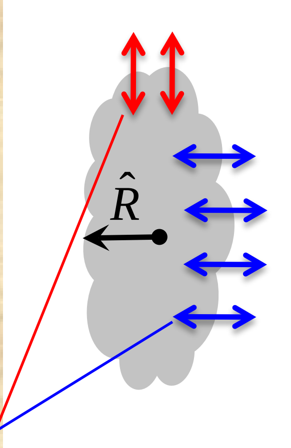
$\phi = q_1, \theta_c, u, v, \xi, q_v, q_l, q_i, n_l, n_i$, S_ϕ : *Source*, a : *area*

Here, superscripts hat ($\hat{\phi}$), check ($\check{\phi}$), and tilde ($\tilde{\phi}$) denote convective updraft, downdraft, and environment, respectively, and the indices i and j denote individual components of convective updrafts and downdrafts.

$$\frac{1}{\hat{M}}\frac{\partial\hat{M}}{\partial p} = \hat{\varepsilon} - \hat{\delta}$$

$$\frac{\partial\hat{\phi}}{\partial p} = -\hat{\varepsilon}(\hat{\phi} - \tilde{\phi}) + \hat{S}_\phi + \hat{C}_\phi$$

C_ϕ : *Conversion* $(\phi = u, v)$



$$\hat{\varepsilon}_o(z) = \left[\frac{a_1}{\rho g\hat{R}(z)}\right](1 + a_2 E),$$

where $a_1 = 0.2$ is a dry mixing coefficient, a_2 is a moist mixing coefficient, and E is the evaporative enhancement factor defined as

$$E = \sqrt{(\hat{q}_l + \hat{q}_i)(1 - \overline{\mathrm{RH}})},$$

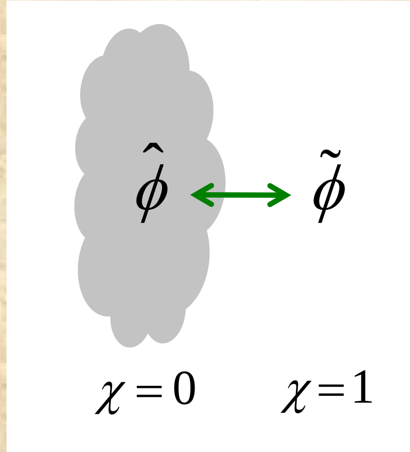
where $\hat{q}_l + \hat{q}_i$ is in-cumulus condensate and $\overline{\mathrm{RH}}$ is the relative humidity of environmental air.

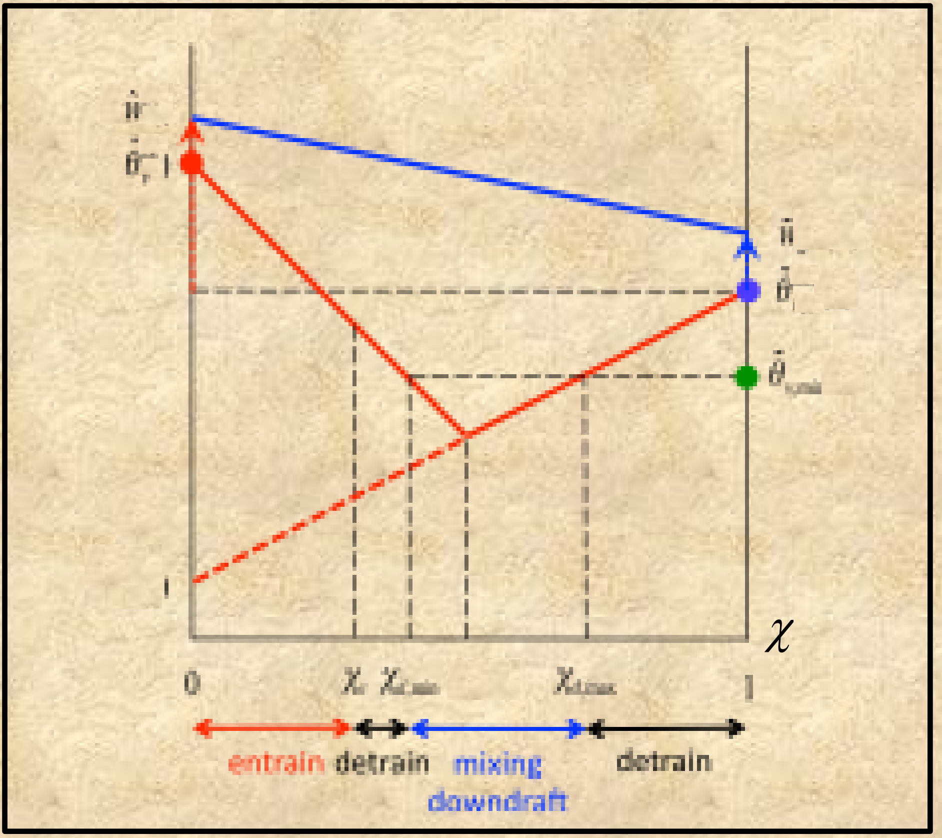
$$\hat{\varepsilon} = \hat{\varepsilon}_o\left[2\int_0^{\chi_c}\chi P(\chi)\,d\chi\right]$$

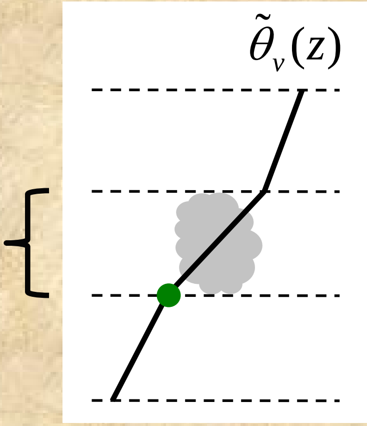
$$\hat{\delta} = \hat{\varepsilon}_o\left[1 - 2\int_0^{\chi_c}(1-\chi)P(\chi)\,d\chi\right]$$

$$P(\chi) = [\chi(1-\chi)]^{p-1}\left[\frac{\Gamma(2p)}{\Gamma(p)\Gamma(p)}\right], \quad p > 0$$

II. Generation of Mixing Downdraft







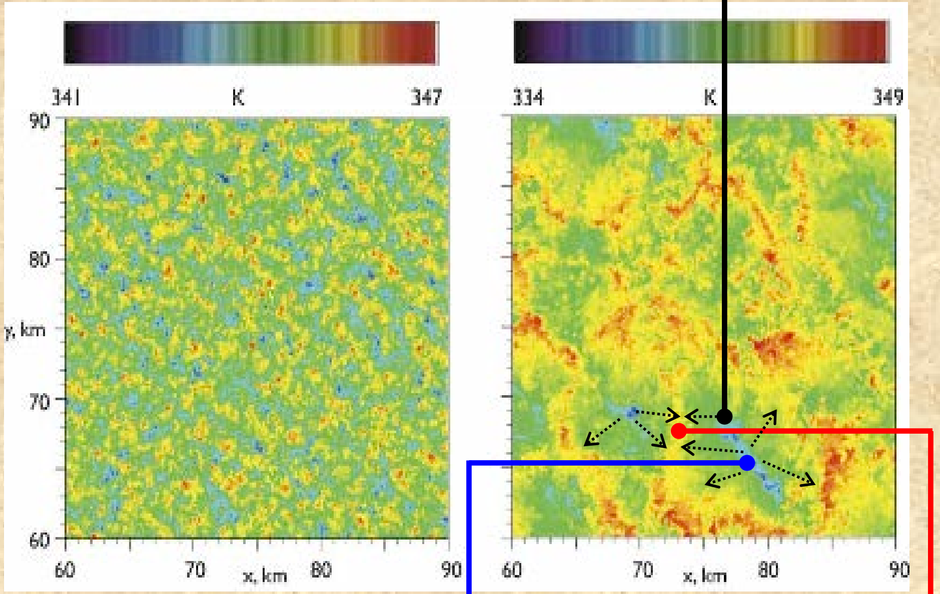
$$\bar{M}_m = 2\hat{f}_m \hat{M} \quad \hat{\varepsilon}_0 \Delta p \int_{\chi_{d,\min}}^{\chi_{d,\max}} P(\chi)\, d\chi$$

$$\bar{\phi}_m = \hat{\phi} + \left[\frac{\int_{\chi_{d,\min}}^{\chi_{d,\max}} \chi P(\chi)\, d\chi}{\int_{\chi_{d,\min}}^{\chi_{d,\max}} P(\chi)\, d\chi} \right] (\tilde{\phi} - \hat{\phi})$$

$$\hat{f}_m = \{\exp[(\hat{\varepsilon} - \hat{\delta})\Delta p] - 1\} / [(\hat{\varepsilon} - \hat{\delta})\Delta p]$$

LES-Simulated Moist Static Energy
(Khairoutdinov and Randall, *JAS* 2006)

Density Current



Non-Precipitating
Shallow Convection

Precipitating
Deep Convection

Dry
Cold-Pool

Precipitating
Mesoscale Upflow

Non-Organized Shallow Convection

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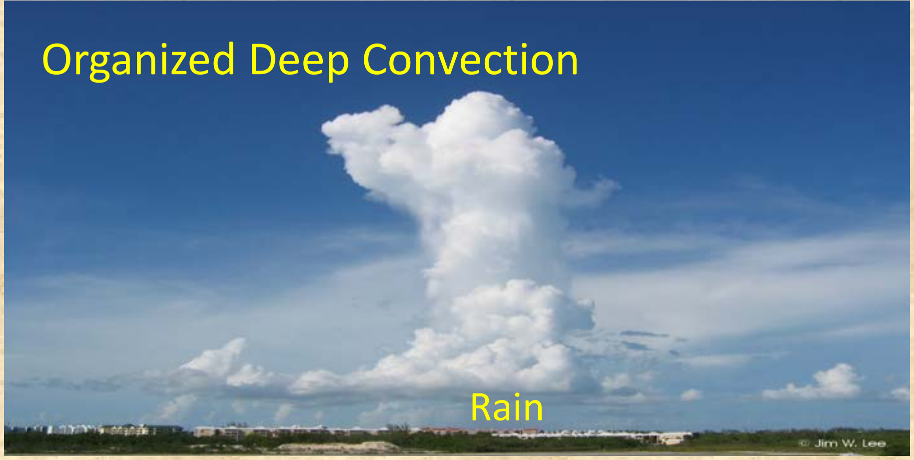

Organized Deep Convection

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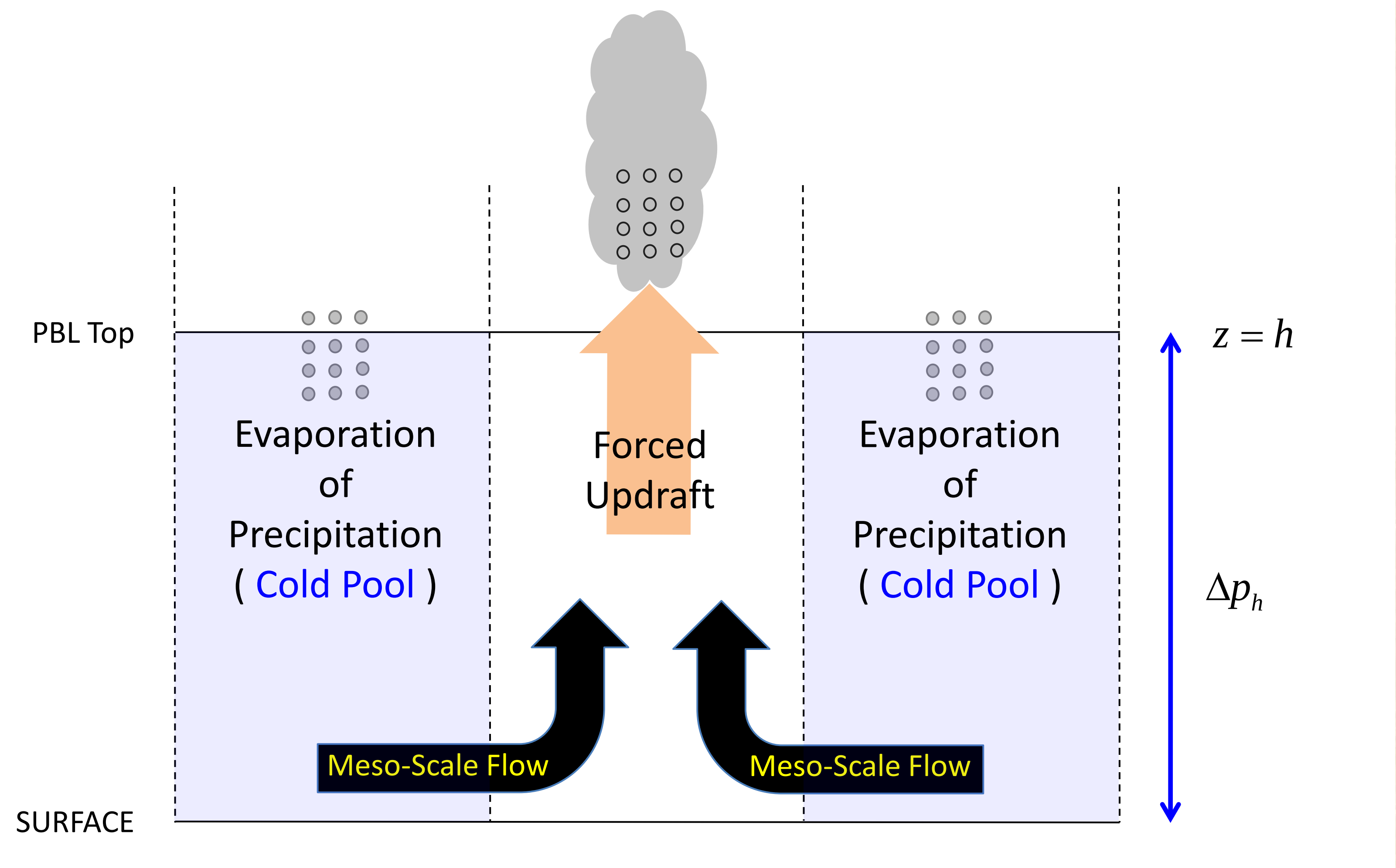
Cold-Pool and Density Current

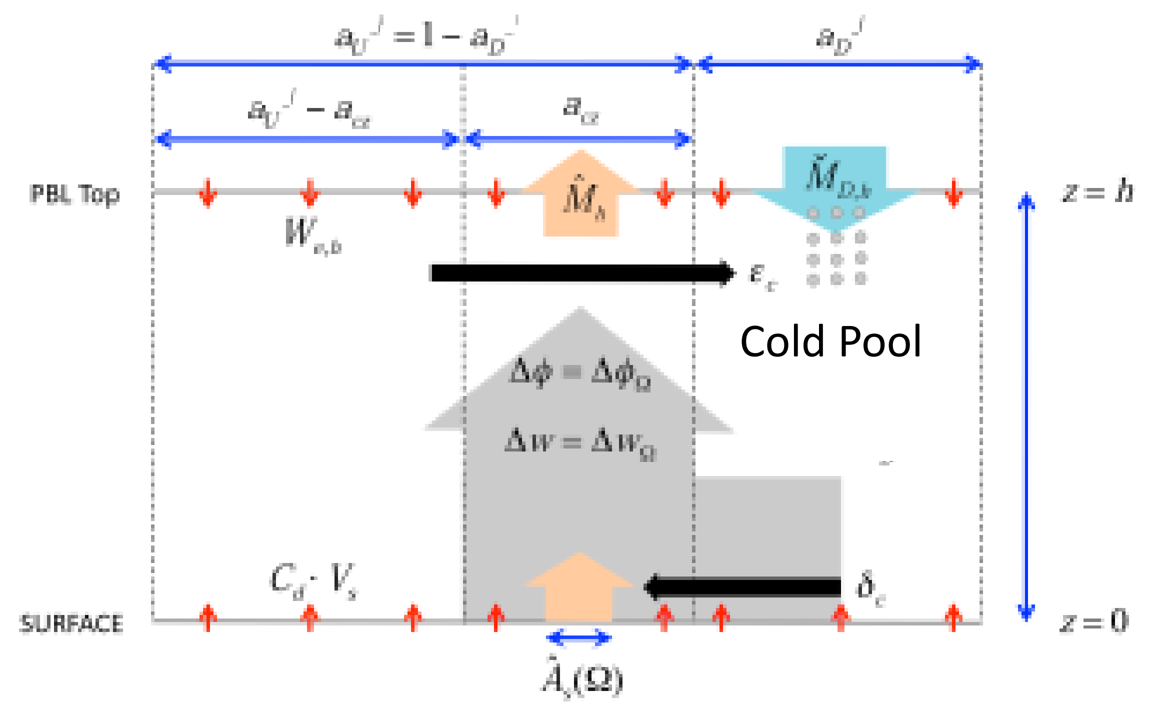
Precipitation forces the cloud structure to be more organized (or heterogeneous).

How does precipitation induce an organized convection ?



Can we simulate this meso-scale organized flow induced by precipitation in GCM ?

III. Formation of Prognostic Cold Pool and Its Feedback to Convective Updraft



$$\frac{\partial a_D}{\partial t} = \ldots\ldots$$

$$\frac{\partial}{\partial t}\left(\Delta\phi_\Omega \equiv \phi_{cz} - \phi_{PBL}\right) = \ldots\ldots$$

$$\Omega \equiv a_D$$

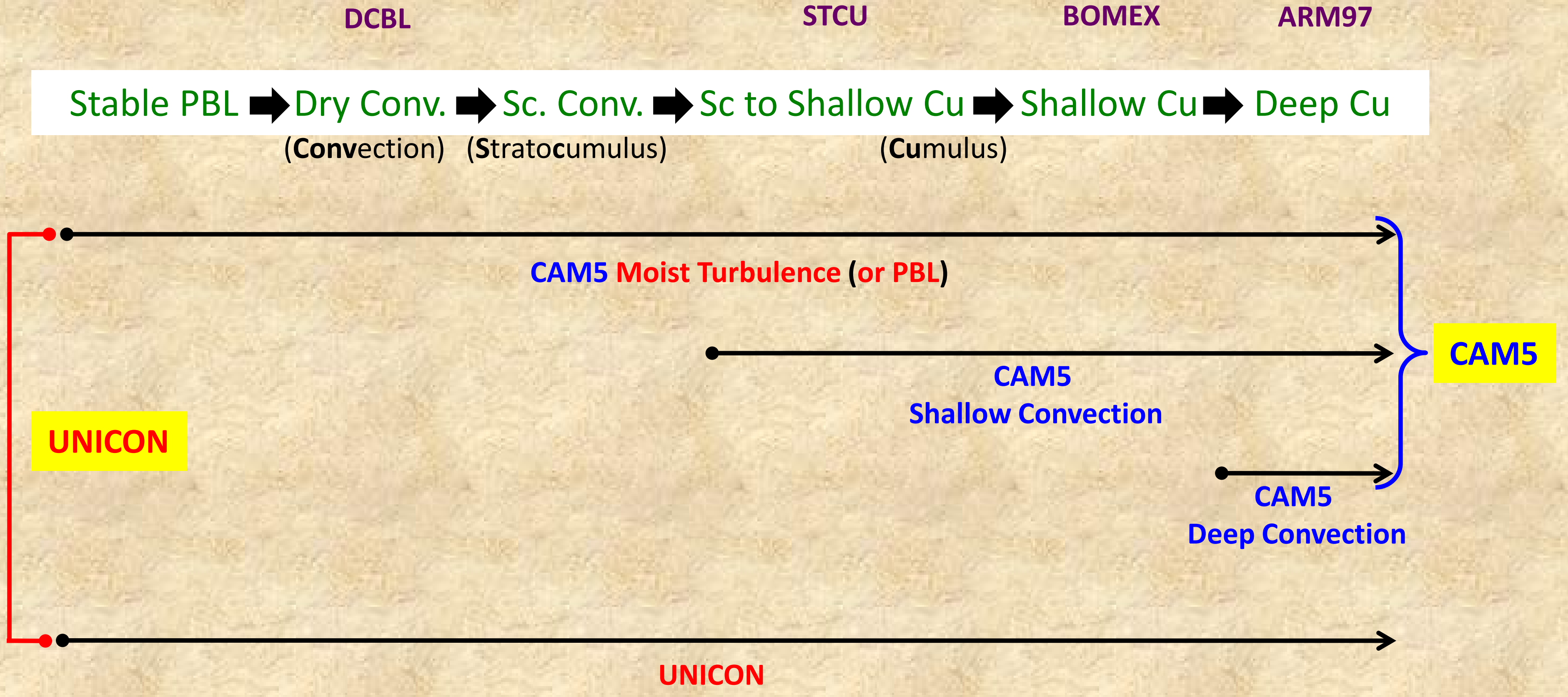
$$\hat{\phi}_{sfc} = \hat{\phi}_{sfc}\Big|_{\Omega=0} + \boxed{\Delta\phi_\Omega}$$

$$\hat{w}_{sfc} = \hat{w}_{sfc}\Big|_{\Omega=0} + \boxed{\Delta w_\Omega}$$

$$\hat{R}_{sfc} = \hat{R}_{sfc}\Big|_{\Omega=0} + \boxed{\Omega \times \left(\hat{R}_{sfc}\Big|_{\Omega=1} - \hat{R}_{sfc}\Big|_{\Omega=0}\right)}$$

As convection is more organized (Ω>0), convective updraft becomes stronger and wider.

OPERATING REGIMES UNICON vs CAM5



DCBL STCU BOMEX ARM97

Stable PBL ➡ Dry Conv. ➡ Sc. Conv. ➡ Sc to Shallow Cu ➡ Shallow Cu ➡ Deep Cu

(**Con**vection) (**S**trato**c**umulus) (**Cu**mulus)

CAM5 Moist Turbulence (or PBL)

CAM5 Shallow Convection

CAM5 Deep Convection

CAM5

UNICON

UNICON

CAM5 : CAM5 PBL + Shallow Convection + Deep Convection

UNICON : CAM5 PBL (*local*) + UNICON (*nonlocal*)

Single-Column Simulations

Dry Convection (**DCBL**)

Stratocumulus-To-Cumulus Transition (**STCU**)

Shallow Convection (**BOMEX**)

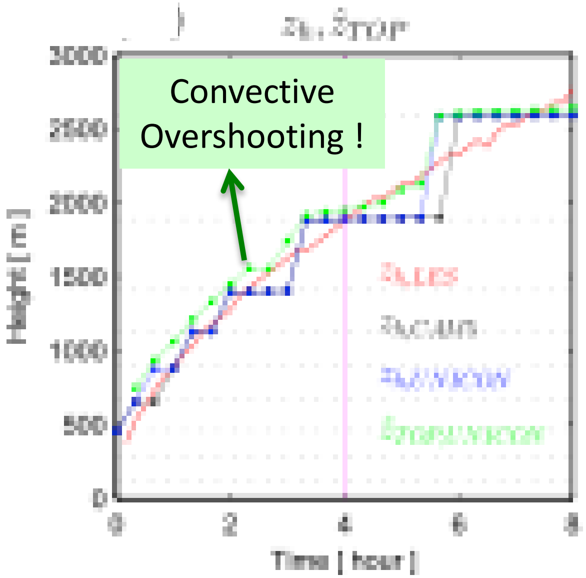
Deep Convection (**ARM97**)

Dry Convection (DCBL)

- Forced by a constant surface sensible heat flux, SHF = 300 Wm^{-2} starting from a stable initial profile of grid-mean potential temperature, $\overline{\theta}$.
- No moisture exists throughout the simulation

z_h : Inversion Base Height
$\hat{z}_{TOP}$: Updraft Top Height

$$F_B \equiv \left(\frac{g}{\overline{\theta}_v}\right) \cdot \overline{w'\theta'}$$

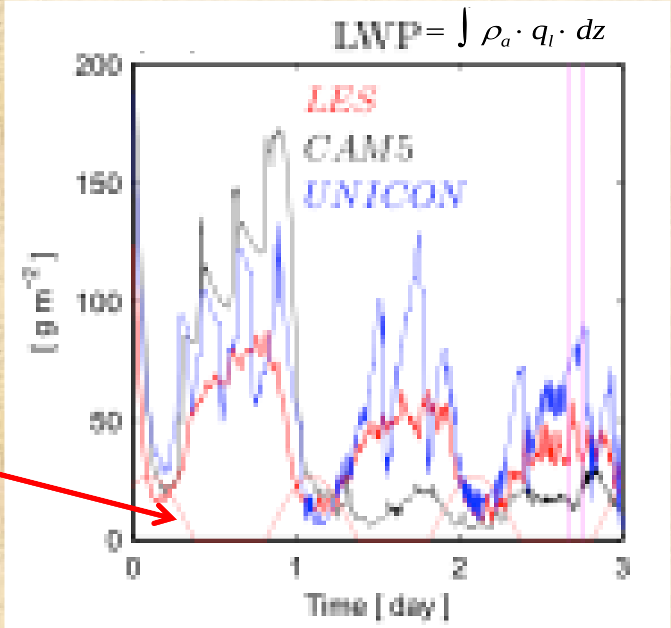


Convective Overshooting !

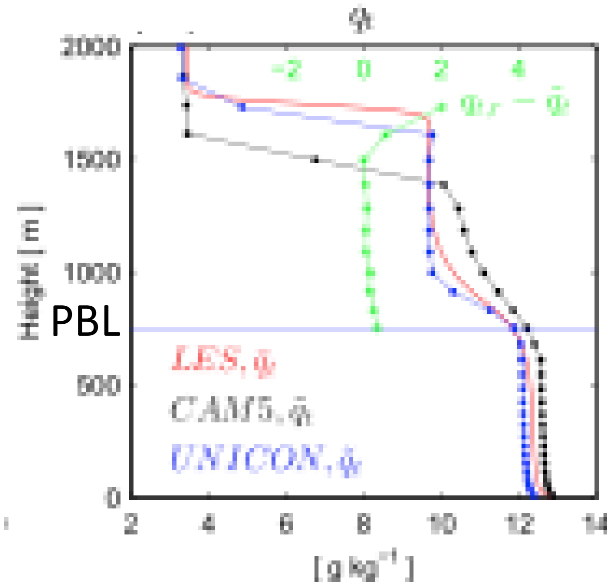
- UNICON simulates colder (warmer) airs in the lower (upper) PBL than CAM5, similar to LES.
- UNICON does a desired non-local transport in the dry convective PBL with overshooting.

Stratocumulus-To-Cumulus Transition (STCU)

- Simulate the stratocumulus-to-cumulus transition over the subtropical eastern Pacific ocean.
- Initial profile characterizes a well-mixed stratocumulus deck capped by a strong inversion.
- SST increases gradually from 293.75 to 299.17 K for 3 days with diurnal cycle of SW radiation (a red sign curve ●)



- UNICON simulates decoupled PBL better than CAM5



Shallow Convection over the Ocean (BOMEX)

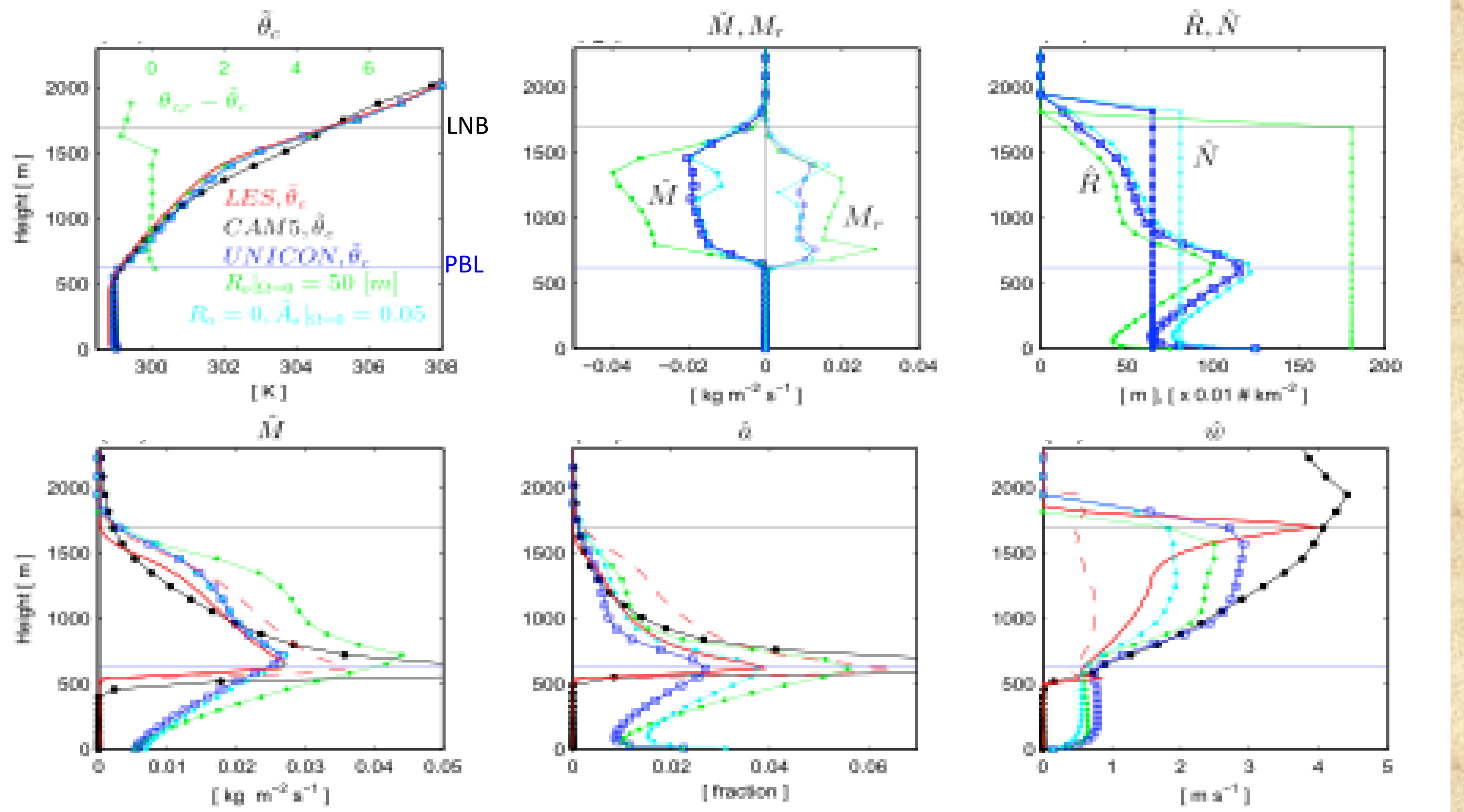
$$\theta_c \equiv \theta - \left(\frac{L_v}{C_p \cdot \pi}\right) \cdot q_l - \left(\frac{L_s}{C_p \cdot \pi}\right) \cdot q_i$$

$\breve{M}$: Downdraft Mass Flux

M_r : Detrained Mass Flux

$\hat{R}$: Updraft Plume Radius

$\hat{N}$: Updraft Number Density



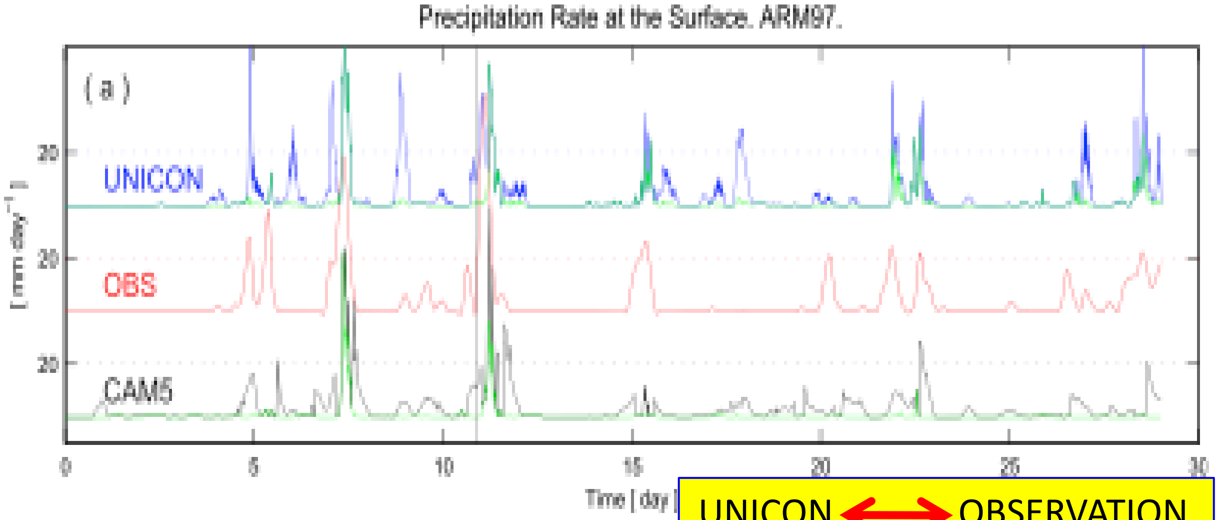
$\hat{M} = \rho \cdot \hat{a} \cdot \hat{w}$: Updraft Mass Flux

$\hat{a}$: Updraft Fractional Area

$\hat{w}$: Updraft Vertical Velocity

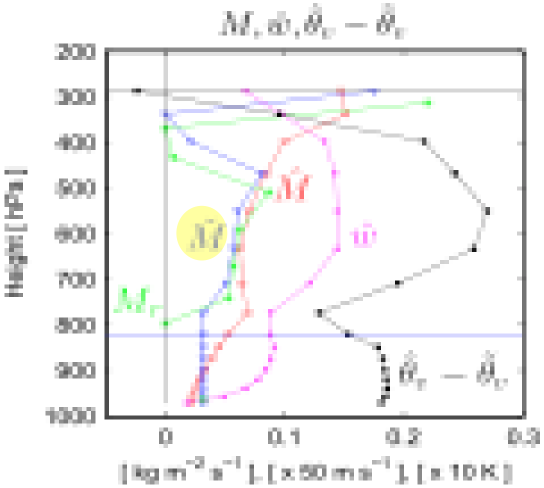
Deep Convection over the Southern Great Plain (ARM97)

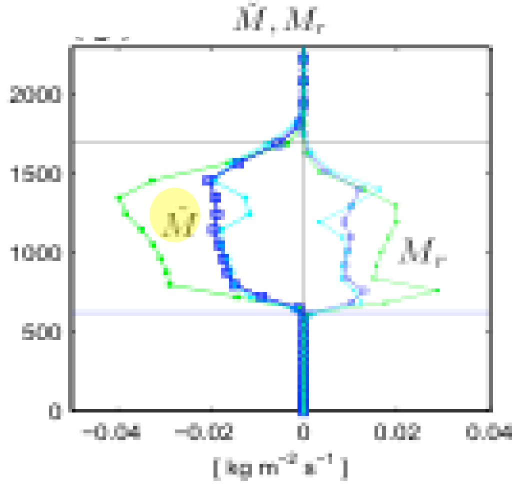
: Stratiform Precipitation Rate



UNICON ⟷ OBSERVATION

Deep Convection. ARM97





Shallow Convection. BOMEX

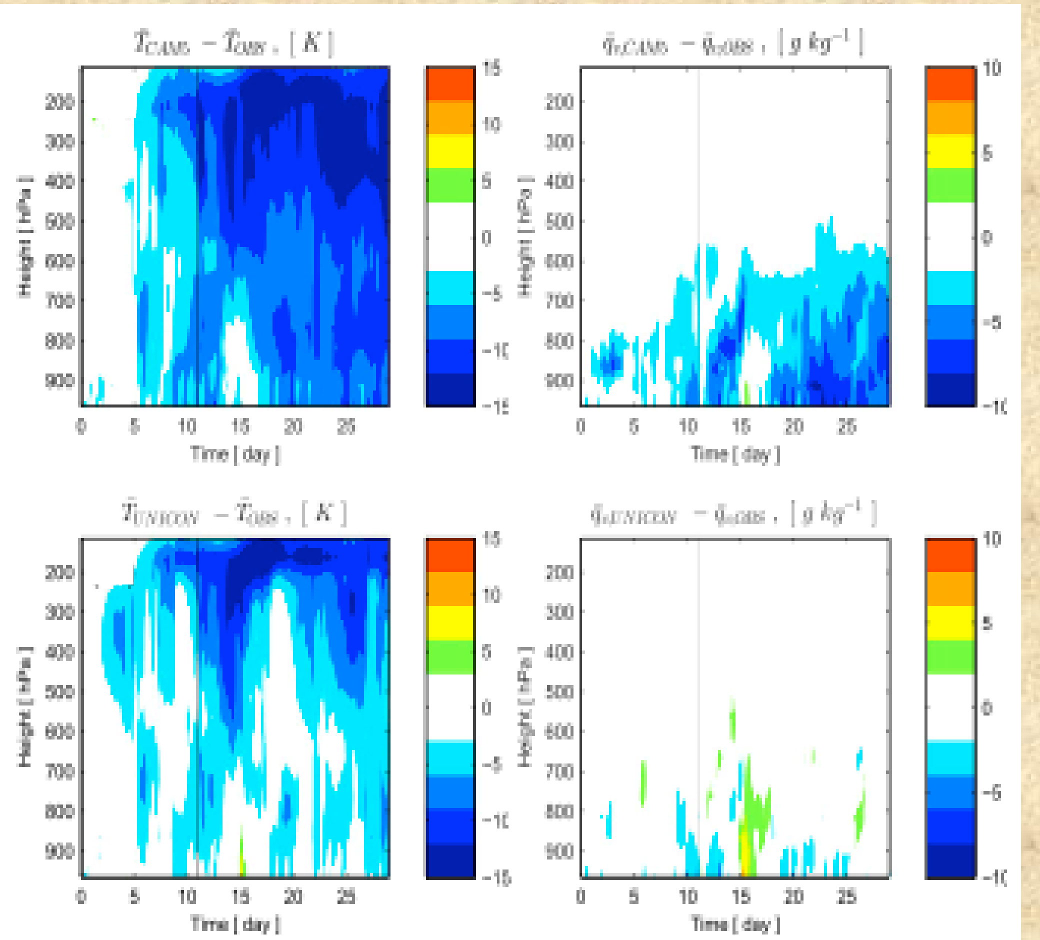
Deep Convection (Continued)

Model Biases against Observation

ΔT Δq_v

CAM5

UNICON



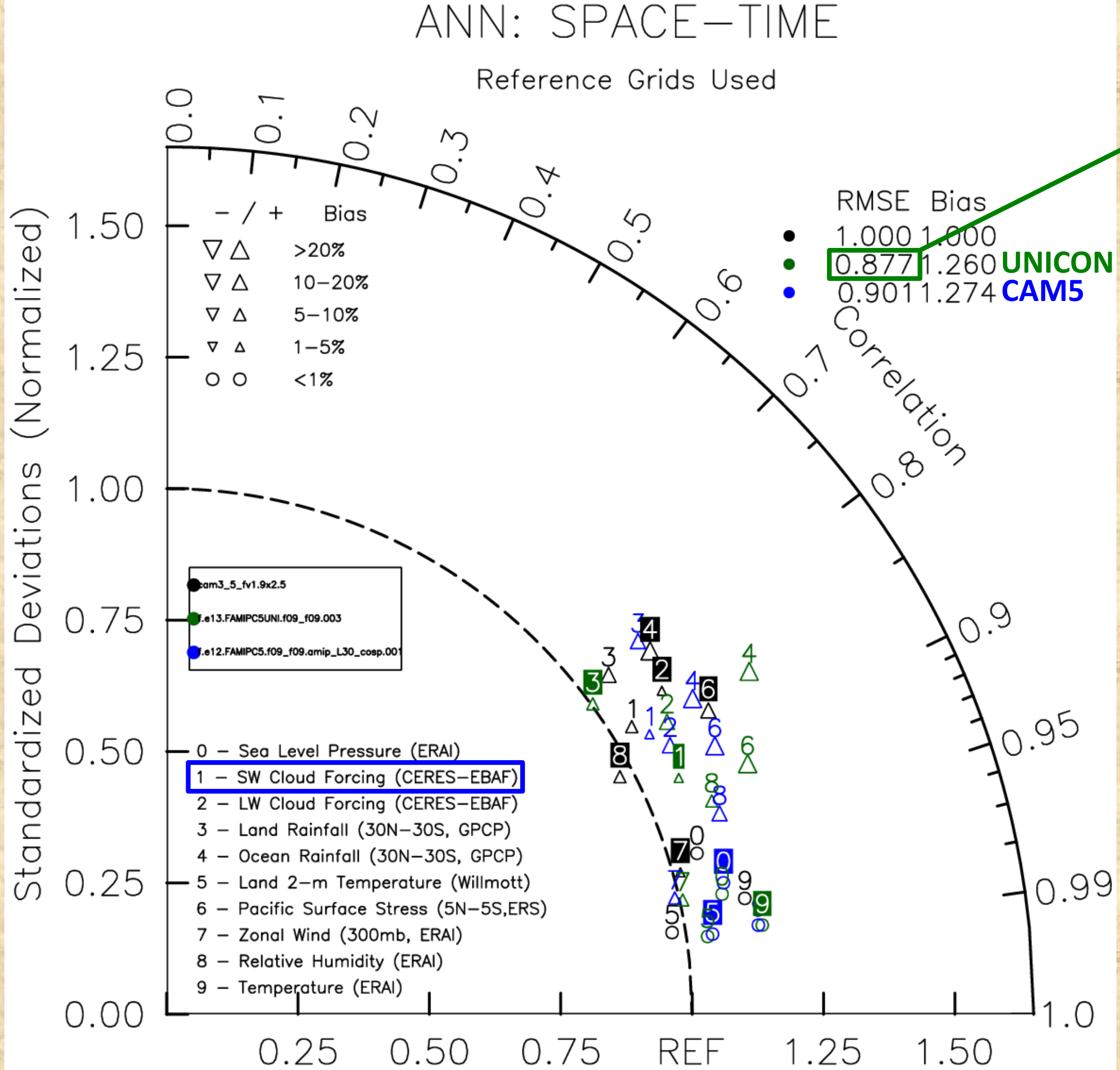
SKILL SCORE =
rmse (UNICON) / rmse (CAM5)

CASES	**SKILL SCORE**
DCBL	0.95
STCU	0.36
BOMEX	0.63
ARM97	0.54

GLOBAL SIMULATIONS

Mostly from the simulations submitted
for the evaluation,
except ENSO and Tropical Cyclone

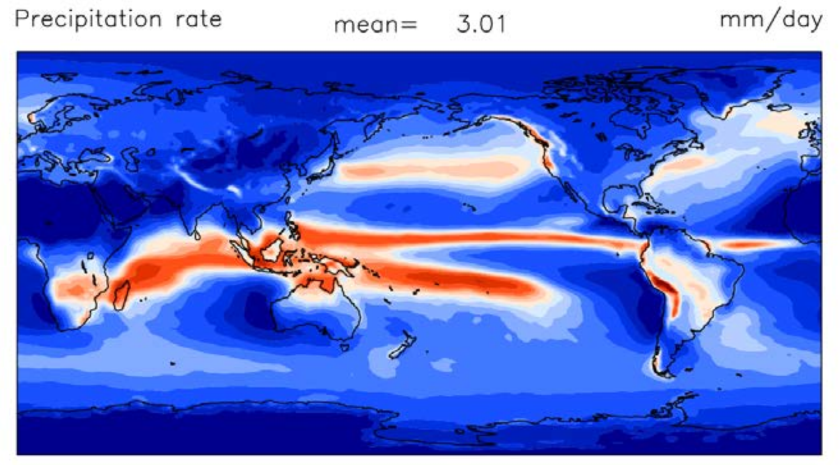
Taylor Diagram. AMIP (1995-2004). 1-degree.



Unprecedentedly Small RMSE

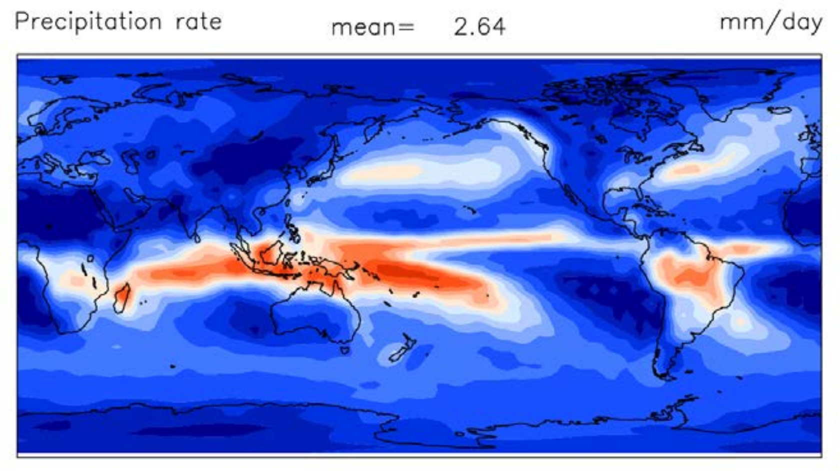
PRECT
DJF.Coupled.1-deg.

UNICON

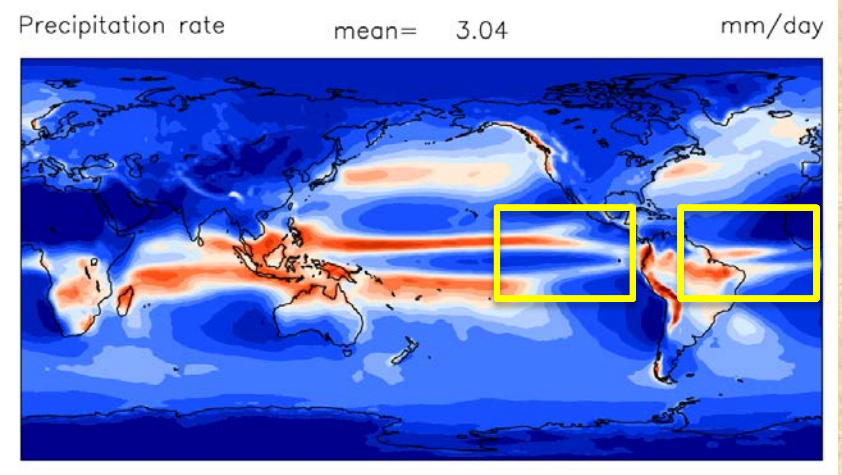


UNICON removes Double ITCZs

Xie-Arkin OBS

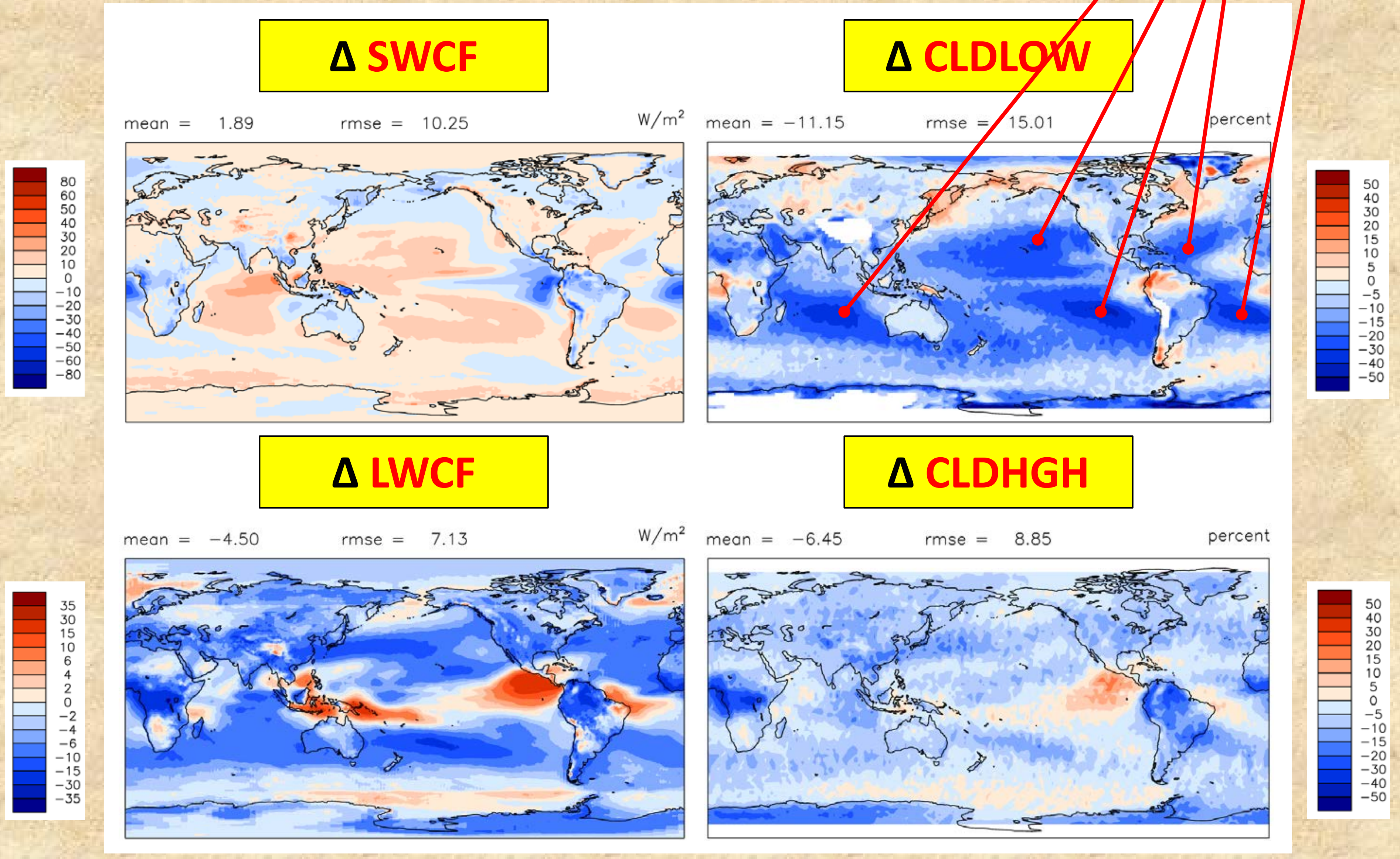


CESM



Cloud Biases in UNICON (vs CERES-EBAF, CALIPSO) ANN. AMIP. 1-degree.

Too Small CLDLOW

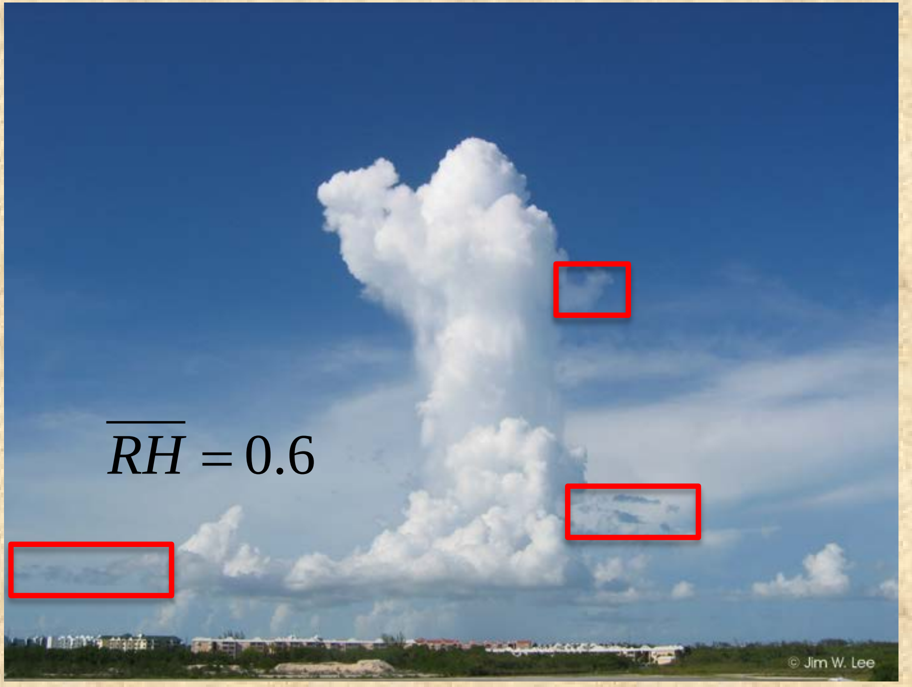


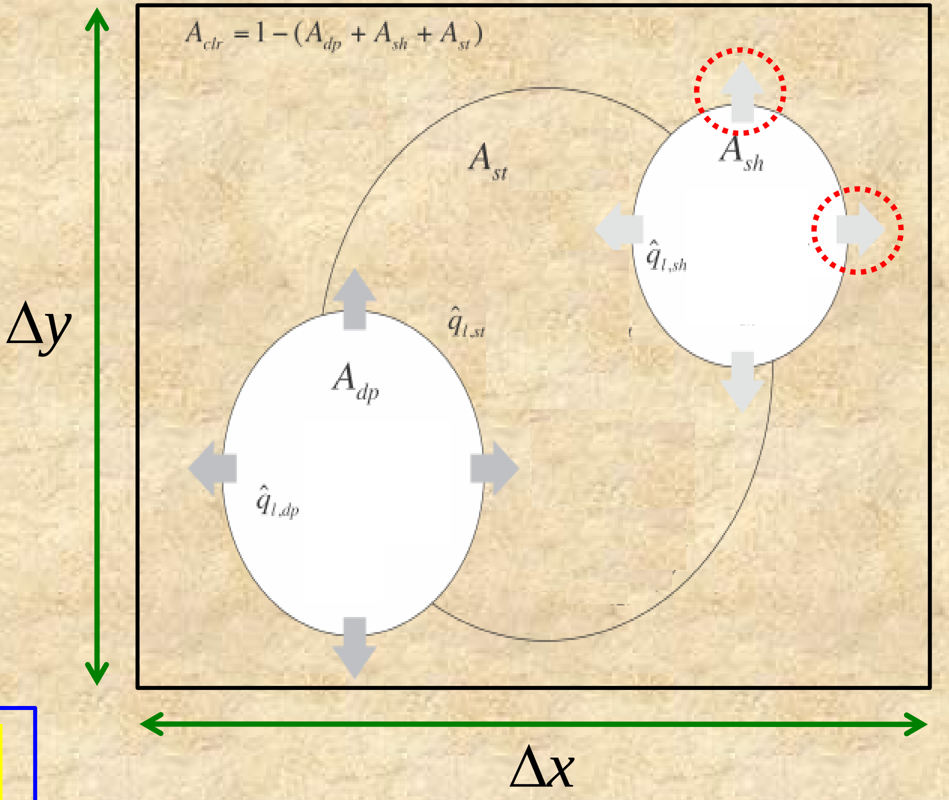
Δ SWCF

Δ CLDLOW

Δ LWCF

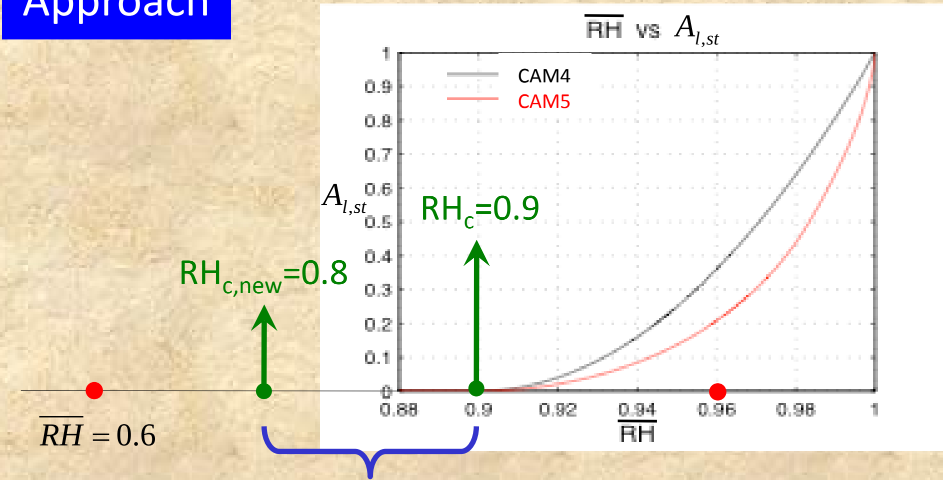
Δ CLDHGH





Current Approach

CAM5 Liquid Stratus Fraction



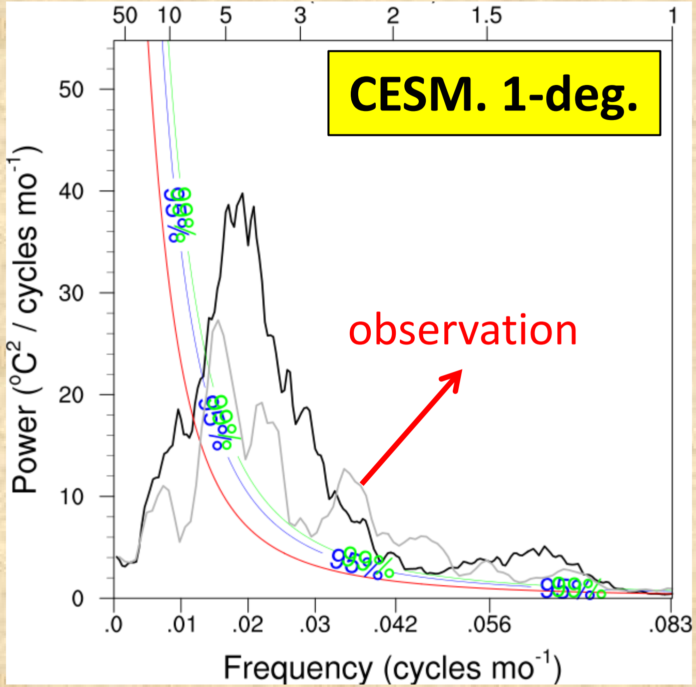
$$\Delta RH_c\big|_{\det} = -c\cdot\left(\frac{g}{\Delta p}\right)\cdot A_{clr}\cdot M_r\cdot q_{l,r}$$

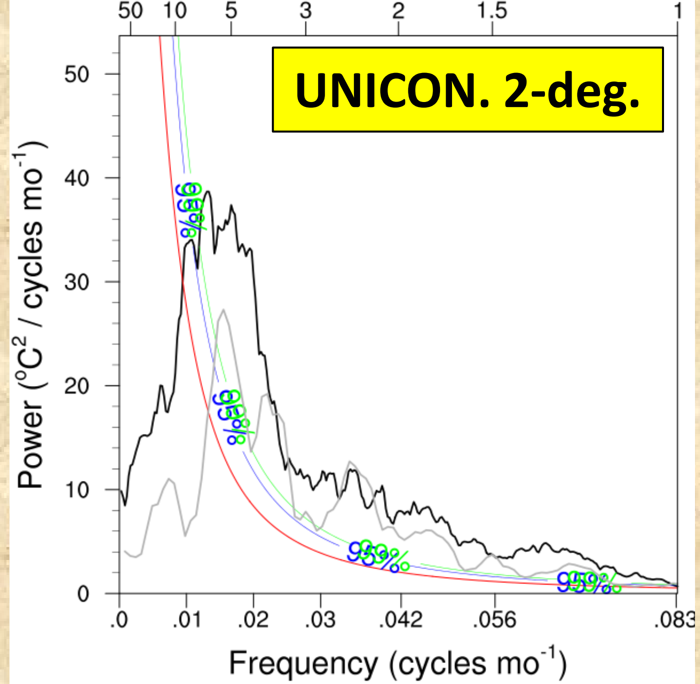
Alternative Approach

$$\Delta A_{st}\big|_{\det} = c\cdot\left(\frac{g}{\Delta p}\right)\cdot A_{clr}\cdot M_r\cdot q_{l,r}$$

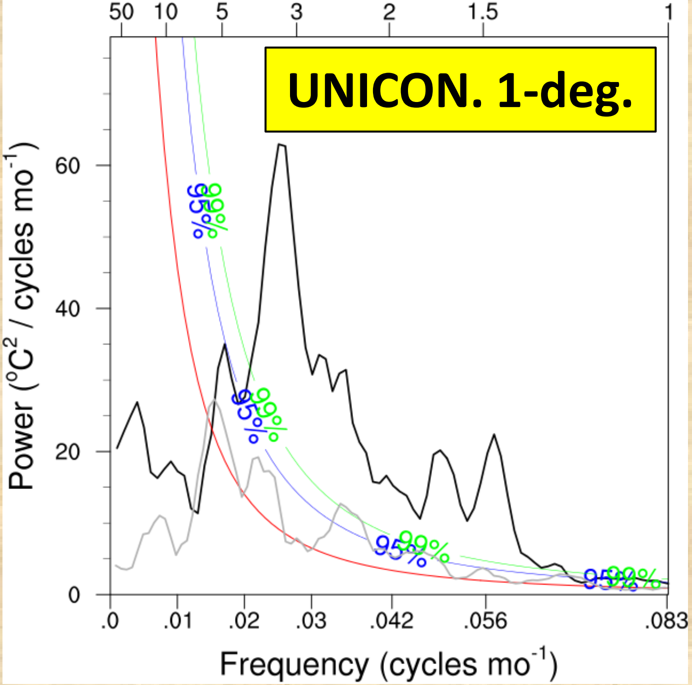
$$A_{st} = A_{st}(\overline{RH}) + \Delta A_{st}\big|_{\det}$$

ENSO
Power Spectra





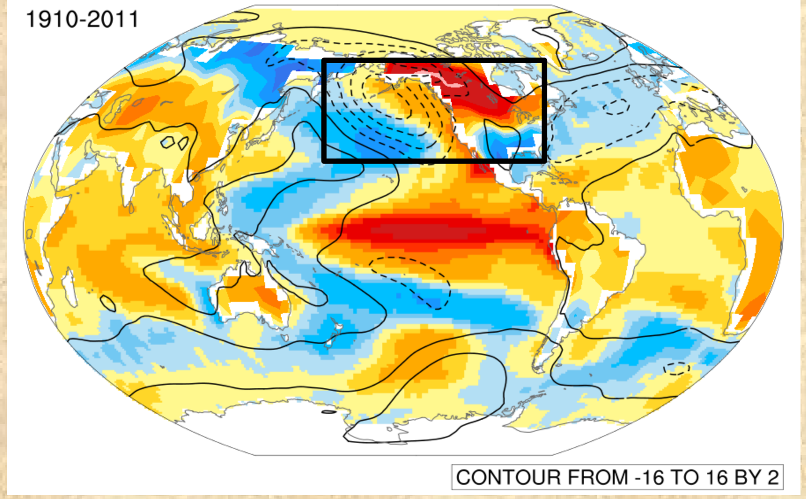
What did I do ?
: Retuning UNICON



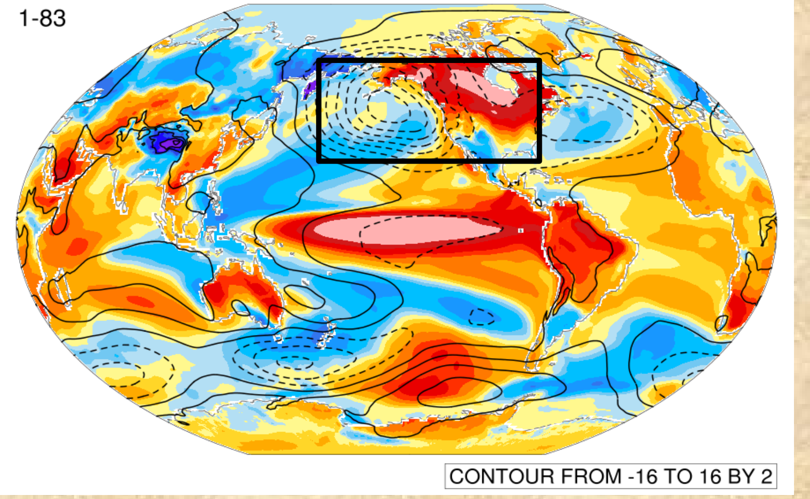
Strategy :
Run 1-deg with
2-deg Parameters.

ENSO Composite of TS (Color) and SLP (Line). DJF.

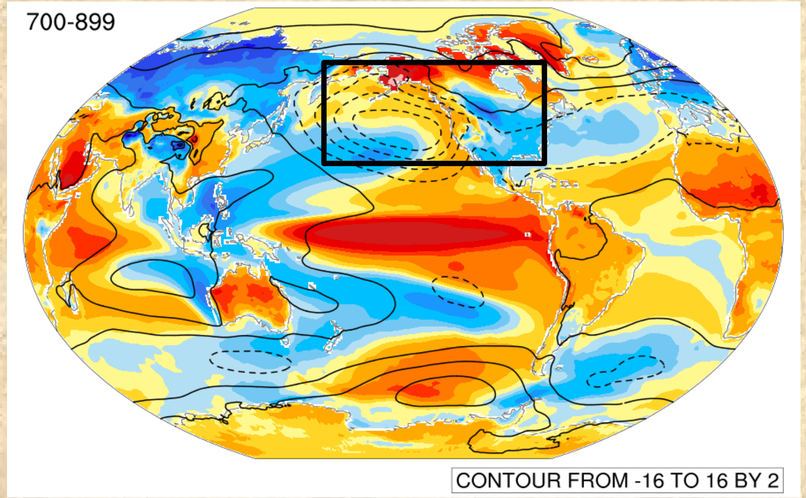
OBS



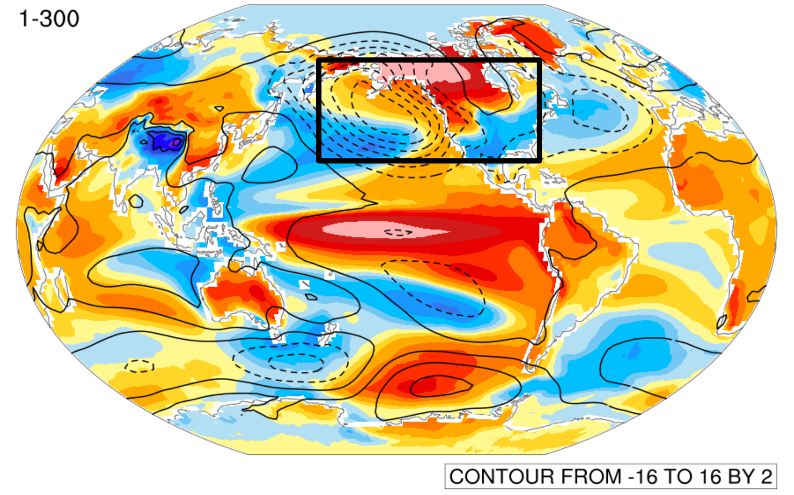
UNICON. 1-deg.

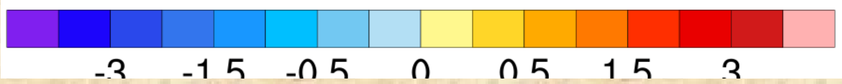


CESM. 1-deg.



UNICON. 2-deg.





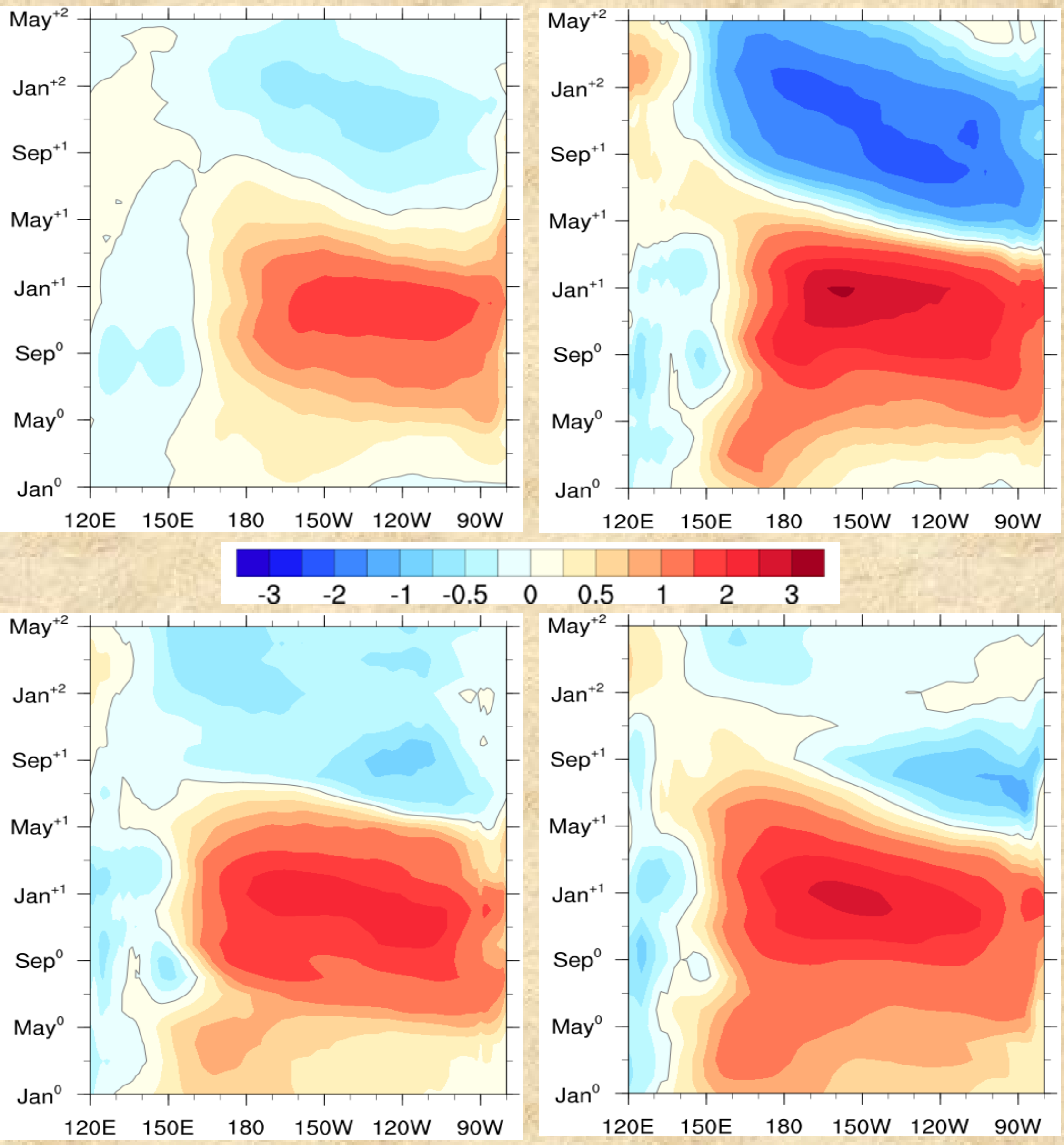
El-Nino Composite. SST.

OBS.

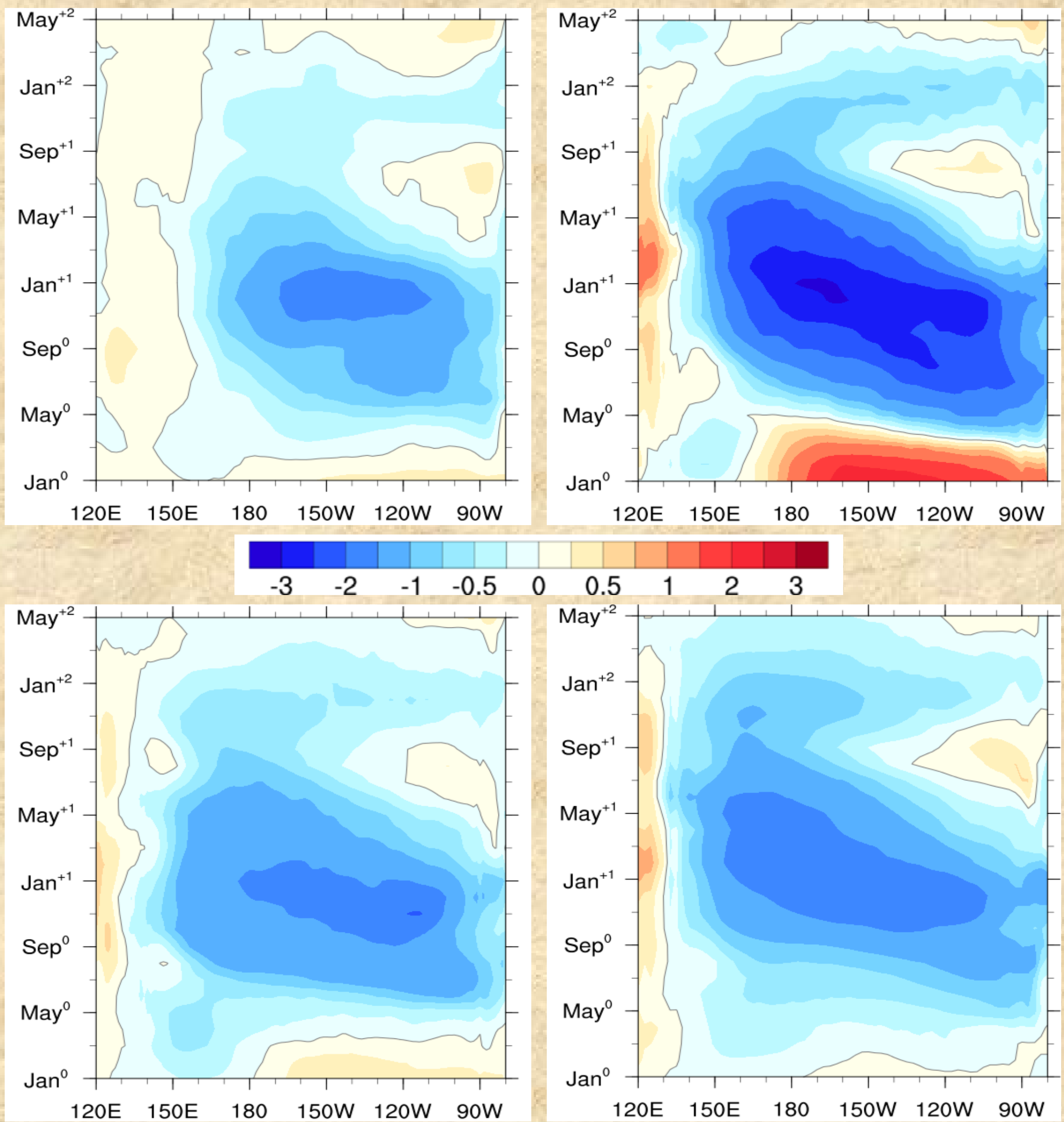
UNICON. 1-deg.

CESM. 1-deg.

UNICON. 2-deg.



La-Nina Composite. SST.



OBS

UNICON. 1-deg.

CESM. 1-deg.

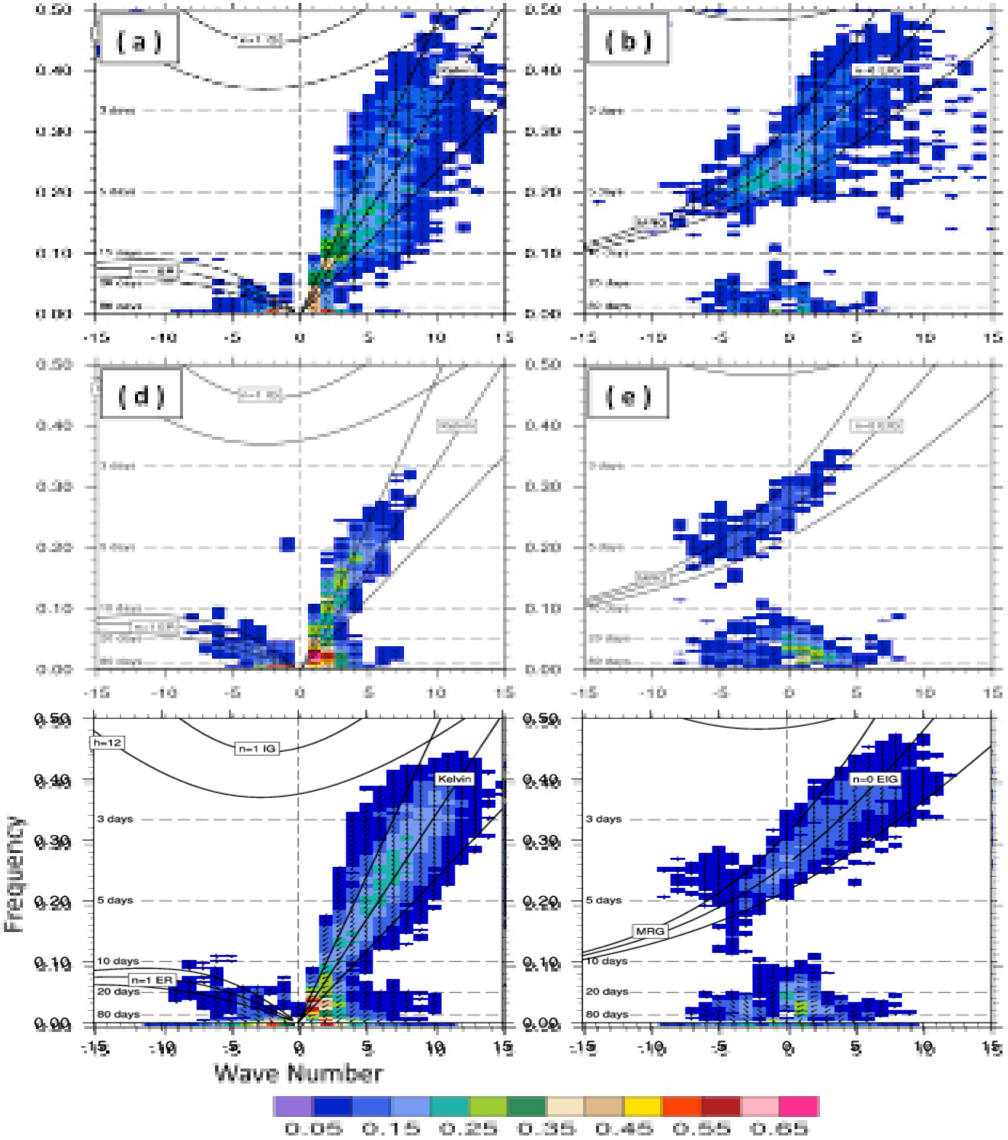
UNICON. 2-deg.

MJO COHERENCY & OLR POWER SPECTRA

SYMMETRIC

ASYMMETRIC

OLR SPECTRA



CAM5

OBS

UNICON

Committee :
too strong & fast
Kelvin wave ?

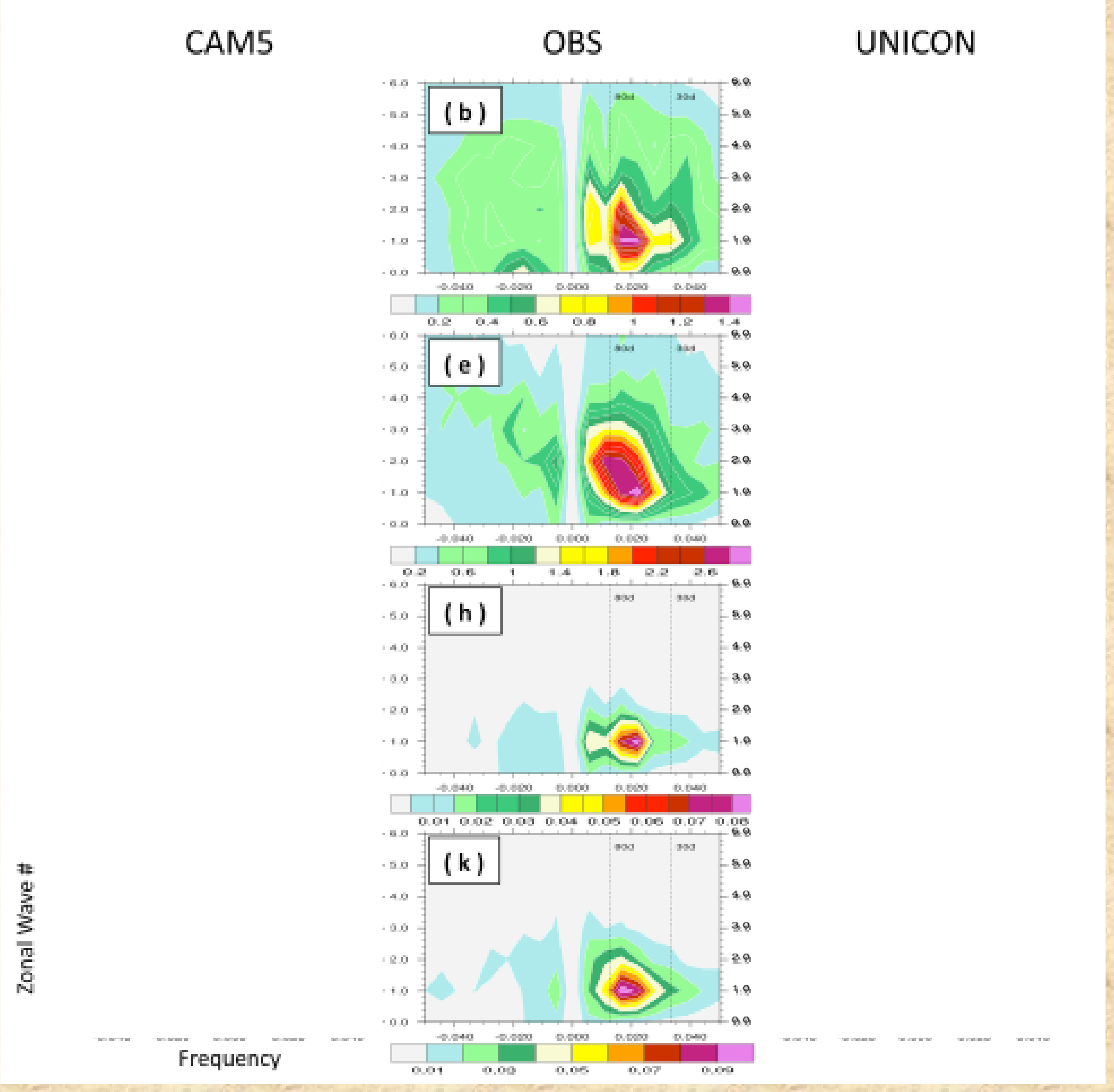
MJO
PWR SPECTRA

OLR. May-Oct

OLR. Nov-Apr

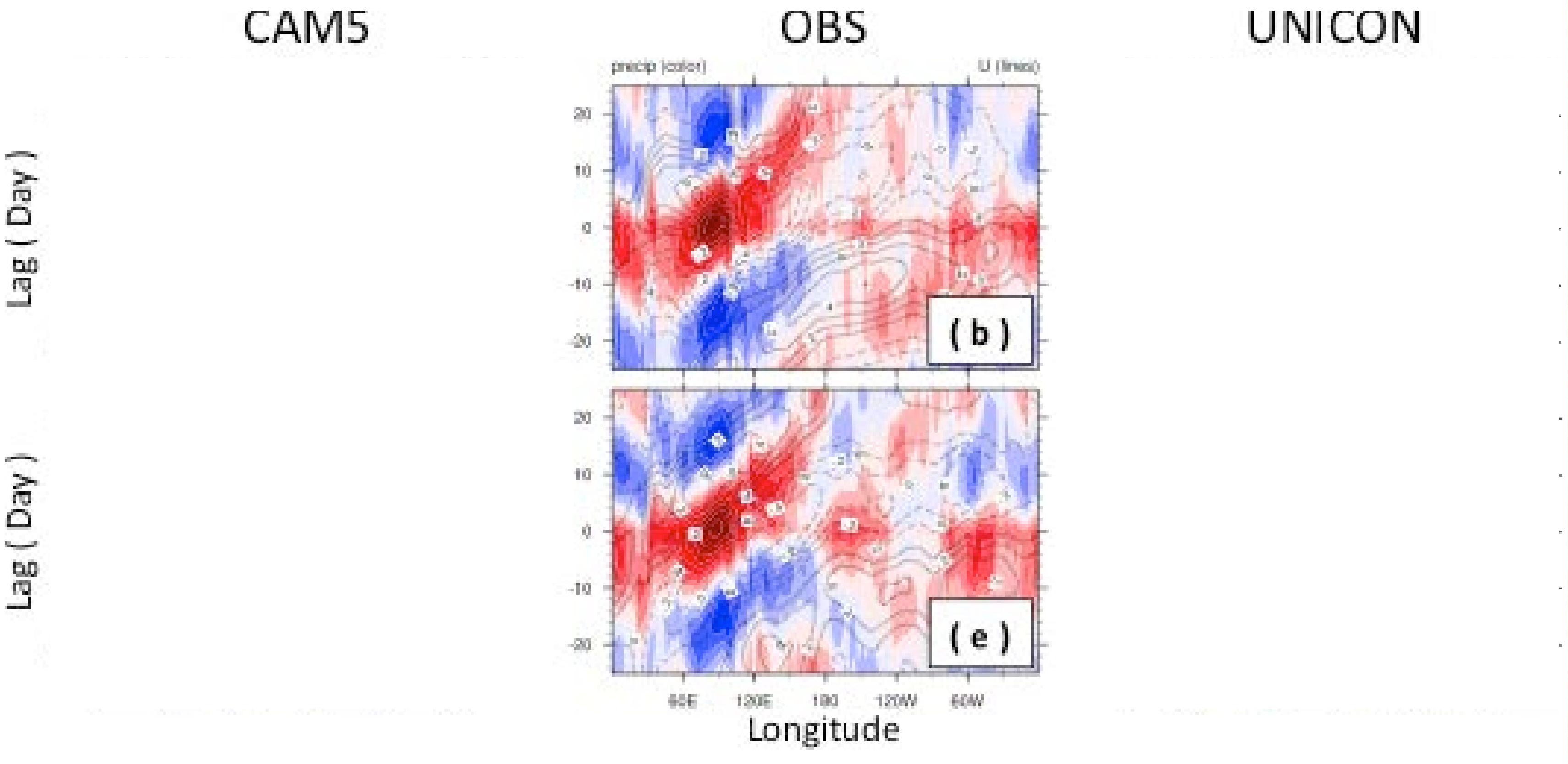
U850. May-Oct

U850. Nov-Apr



MJO Lead-Lag Corr.
PRECT & U850

May-Oct



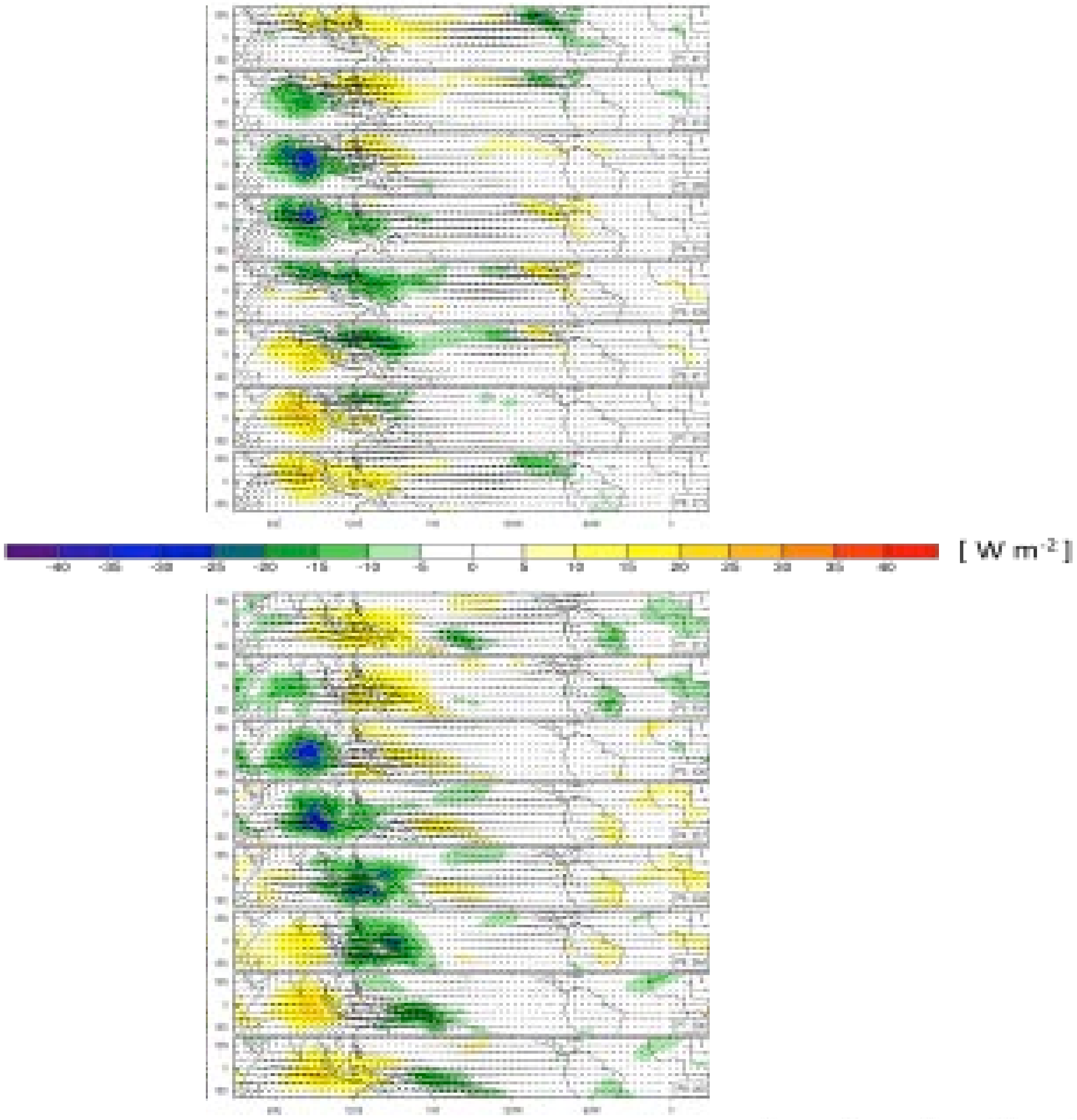
Nov-Apr

MJO COMPOSITE LIFE CYCLE

CAM5 **OBS** **UNICON**

May-Oct

Nov-Apr



OBS **UNICON** **CAM5**

P.1

P.3

P.5

P.7

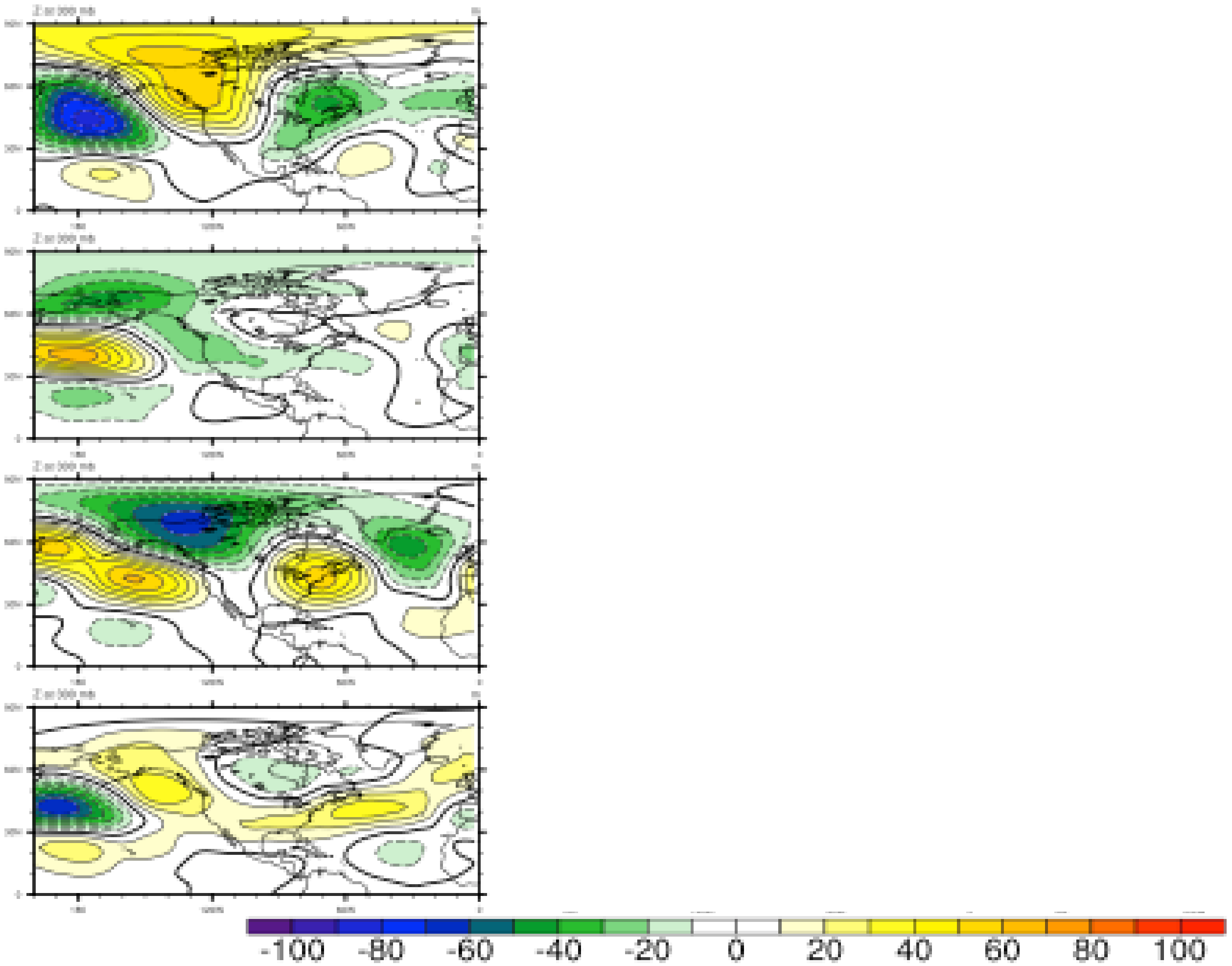


Figure 1: The composites of 300 hPa geopotential height anomalies associated with the MJO phases 1, 3, 5, and 7 (top to bottom) using ERA-interim, UNICON, and CAM (left to right).

From Yoo et al. J. Climate. Submitted.

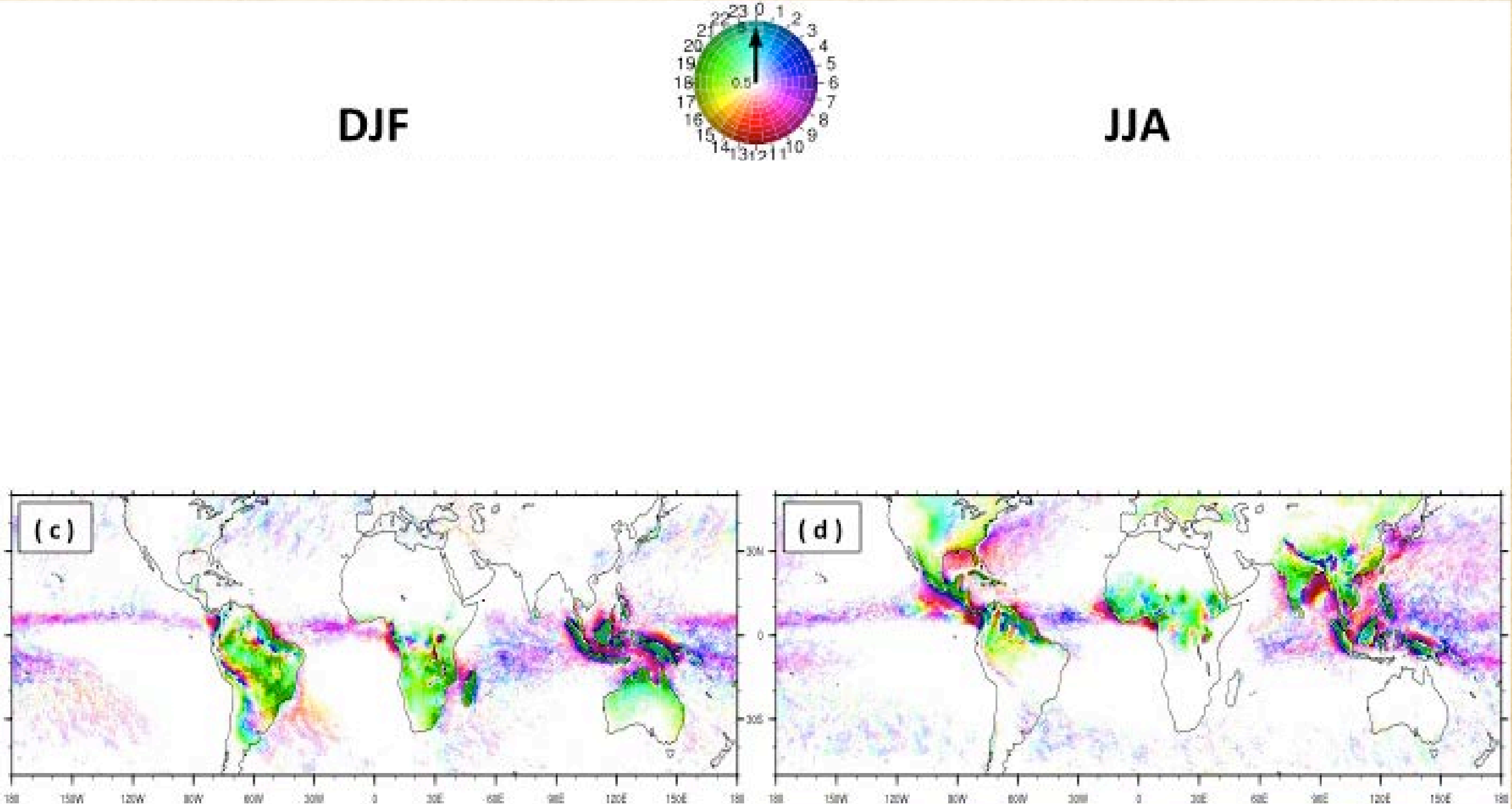
0.95°lat x 1.25°lon

DIURNAL CYCLE OF PRECIPITATION

CAM5

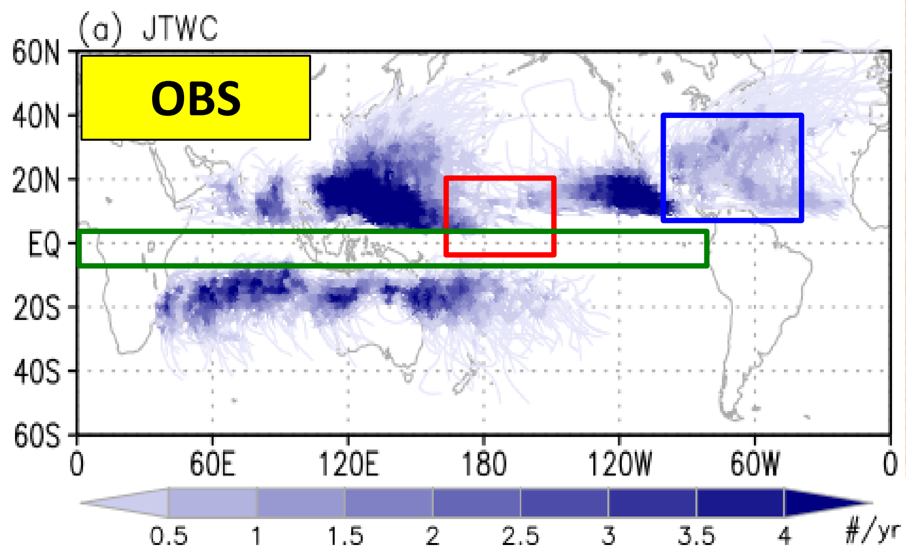
OBS

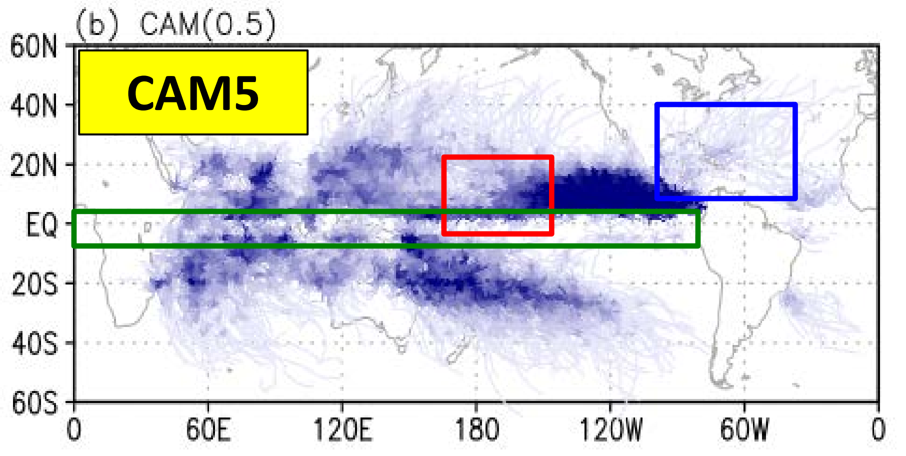
UNICON

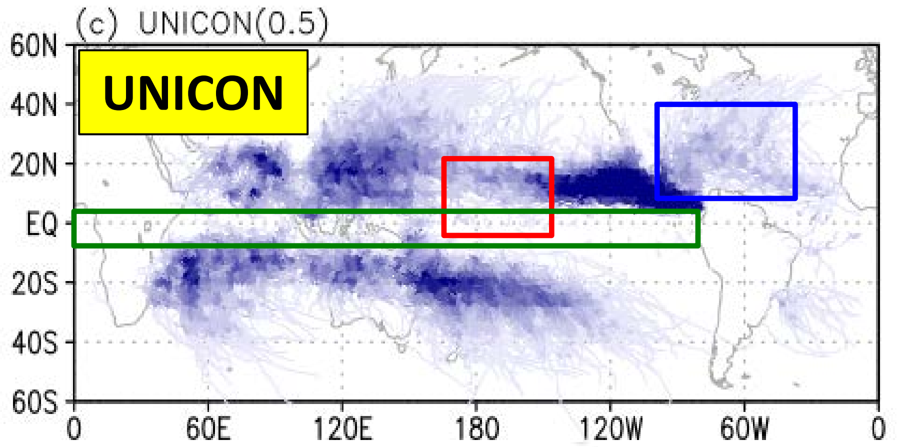

DJF

JJA

TROPICAL CYCLONE
Track and Passage FQ







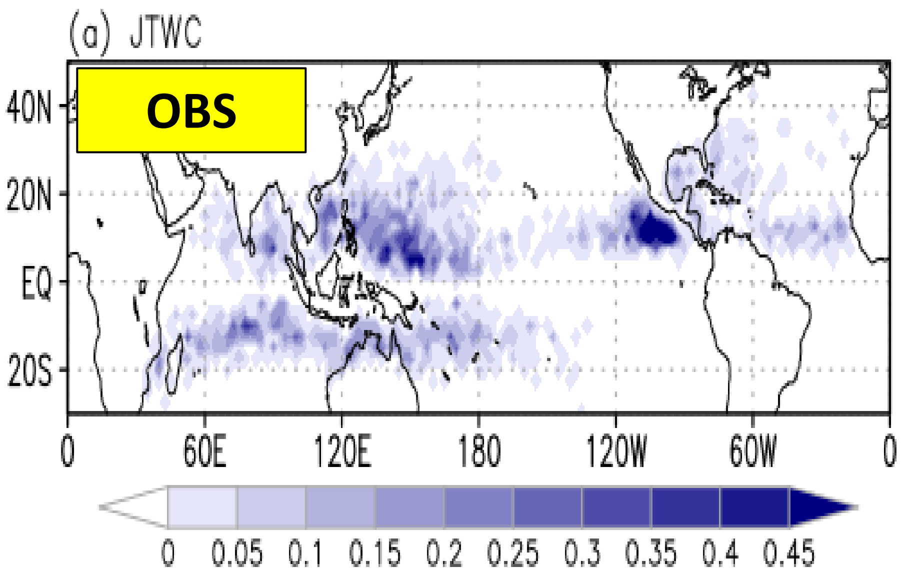
- Analysis of 6-hrly output at 0.5°lat x 0.5°lon (AMIP. 1979-1998) with the following 3 criteria:

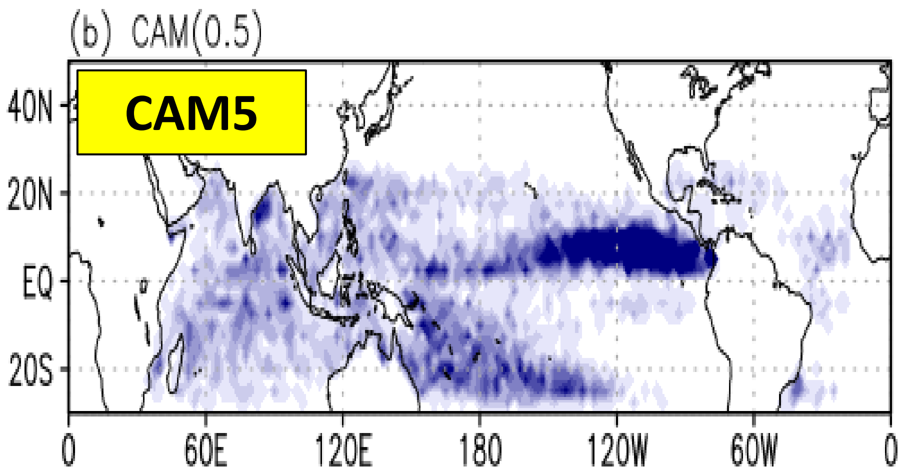
  1. $\zeta_{850} > \zeta_{cri}$
  2. $\zeta_{850} - \zeta_{250} > \Delta\zeta_{cri}$
  3. Persist at least 2 days

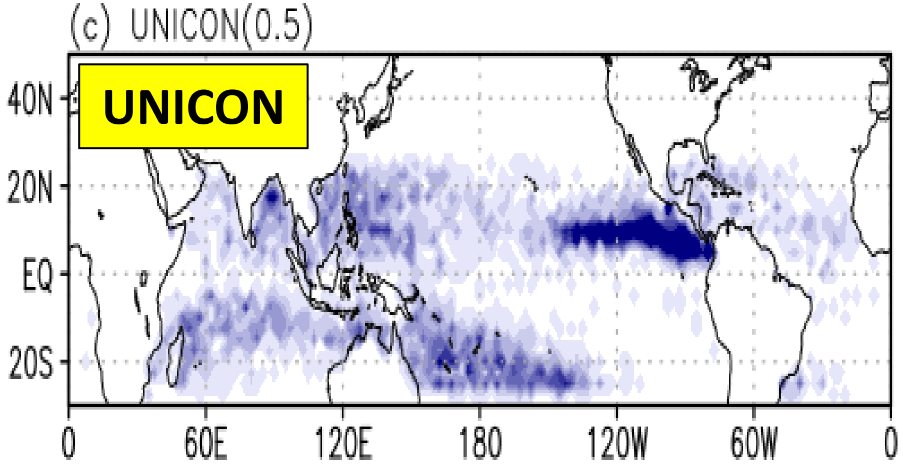
- Averaged over 2.5°lat x 2.5°lon

Analyzed by Dr. Minho Kwon. KIOST (Korea Institute of Ocean Science and Technology)

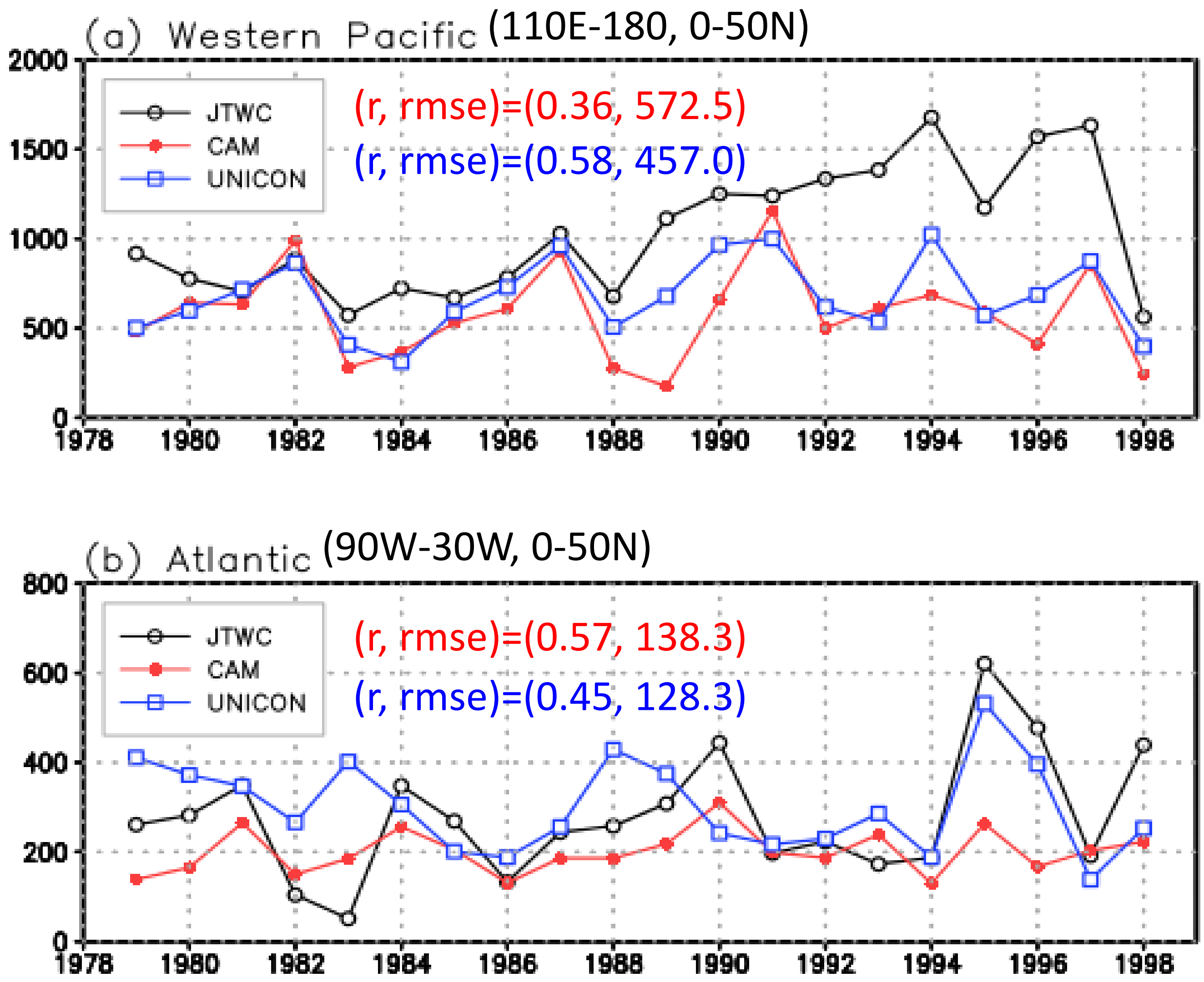
TROPICAL CYCLONE
Genesis FQ


(a) JTWC


(b) CAM(0.5)


(c) UNICON(0.5)

TROPICAL CYCLONE
Interannual Variability of Passage FQ



(110E-180, 0-50N)

(r, rmse)=(0.36, 572.5)

(r, rmse)=(0.58, 457.0)

(90W-30W, 0-50N)

(r, rmse)=(0.57, 138.3)

(r, rmse)=(0.45, 128.3)

SUMMARY

- UNICON – a subgrid vertical transport scheme by nonlocal asymmetric turbulent eddies – simulates all shallow-deep, dry-moist, and forced-free convections within a single framework in a seamless, consistent and unified way.

- UNICON is a process-based model without using the quasi-equilibrium assumption, so that it is, in principle, can be used as a scale-adaptive convection scheme in any size of GCM horizontal grid.

- UNICON improves the single-column simulations of stratocumulus-to-cumulus transition and shallow and deep convection cases.

- UNICON well simulates both the '*climatology*' and '*variability*' (e.g., MJO, Diurnal cycle of precipitation, Tropical Cyclone) compared to CAM5.

Future Works Until May.15.2015.

REDUCE ENSO AMPLITUDE

- Run “1-degree” UNICON coupled simulations with the already tuned “2-degree” UNICON model parameters (this seems to be the right way since UNICON is designed as a scale-adaptive scheme).

INCREASE CLDLOW IN THE TRADE-CUMULUS REGIME

- Compute “additional liquid stratus fraction, $\Delta A_{st}\big|_{\det}$” generated by the detrained liquid convective condensate, without assuming instantaneous homogeneous mixing over the entire grid.

IMPROVE COMPUTATIONAL EFFICIENCY

- Currently, UNICON takes about 60% more computation time than CAM5. Surprisingly, more than 50% of UNICON computation time is used for the initialization of variables. This needs to be addressed.

INCREASE SEA-ICE FRACTION

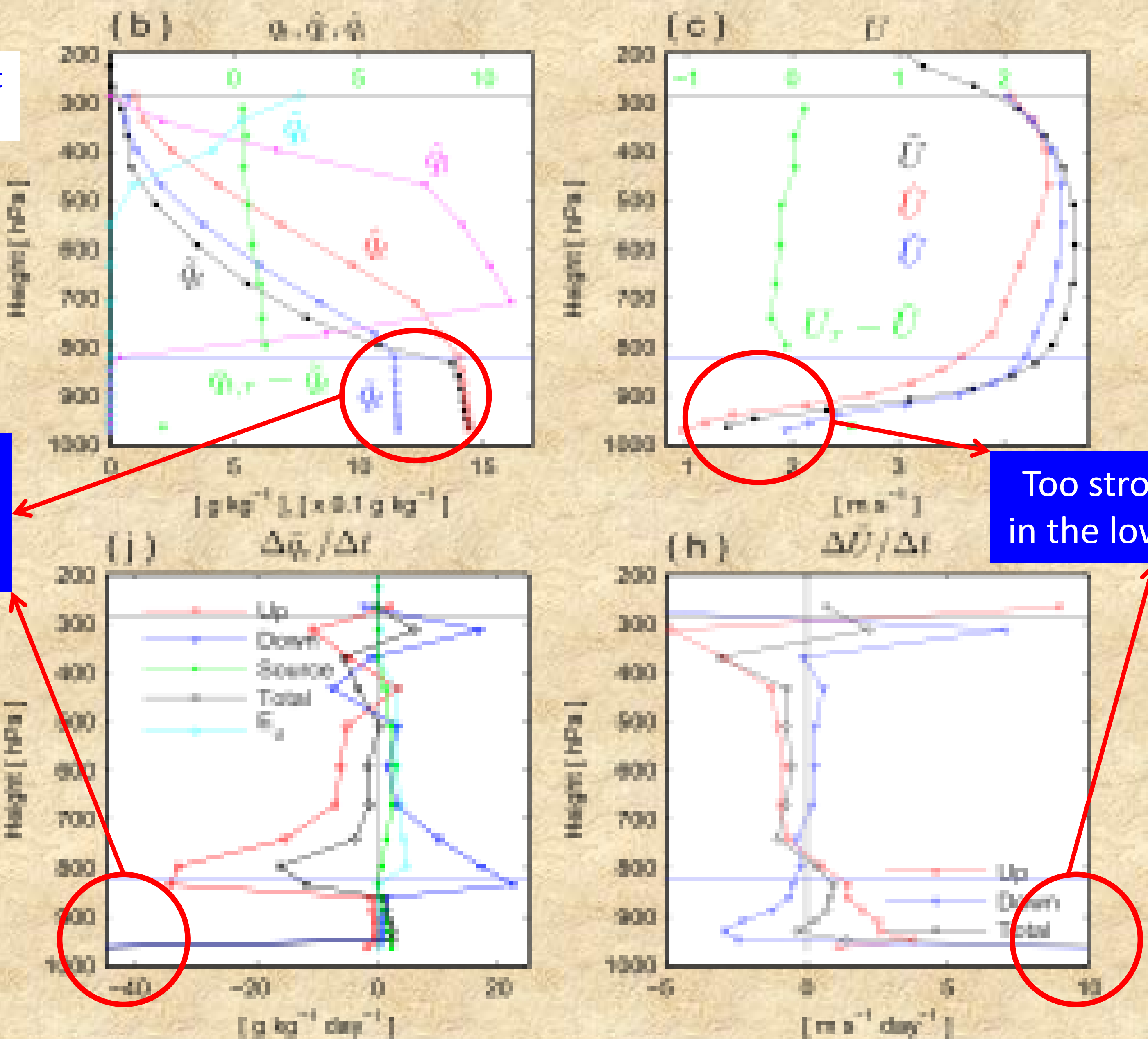
- UNICON simulates less sea-ice fraction than the observation. This may be associated with the tuning of turbulent mountain stress (TMS). This needs to be addressed either by retuning TMS or adjusting sea-ice parameters (e.g., the size of snow flake on the sea-ice) within allowable range.

PREVENT MODEL CRASH

- Occasionally, UNICON crashes with the error messages of very large values of “surface latent heat flux” and “dust concentration”. This is likely due to the neglect of the mixing between convective downdraft and environment. This can be easily addressed by allowing a certain lateral mixing for the convective downdraft (e.g., $\varepsilon_d = \delta_d = 2 \cdot e^{-4}[m^{-1}]$ as Tiedtke).

UNICON Single-Column Simulation. ARM97.

Blue : **Downdraft**
Black : Environ.



Too much drying in the lowest layer

Too strong wind in the lowest layer

Trust-Based Collaboration with UNICON

MODEL DEVELOPMENT

✓ Improving aerosol-precipitation interaction within UNICON:

- Collaboration among University of Wyoming, PNNL and NCAR within SciDAC.

✓ Coupling ‘turbulence statistics’ with ‘subgrid cloud-precipitation processes’:

- NCAR and KOPRI (Korea Polar Research Institute), possibly with Vincent Larson.

✓ Improving various other aspects of UNICON including detailed diagnosis of UNICON:

- NCAR, PNNL and University of Miami, etc.

✓ Contribution to other models:

- NCAR (WRF), NOAA (with Univ. of Washington, Columbia Univ., Univ. of Miami, Univ. of Texas; Univ. of Hawaii, etc.), CPTEC (Brazil), KIAPS (Korea)

VALIDATION

✓ Constrain model parameters using UQ, LES, observations and CAPT:

- UQ: DOE (PNNL)
- LES: Harvard and Columbia Univ.
- Observations and CAPT: DOE (LLNL), NCAR

✓ Test UNICON in a variable grid mesh as a scale-adaptive scheme:

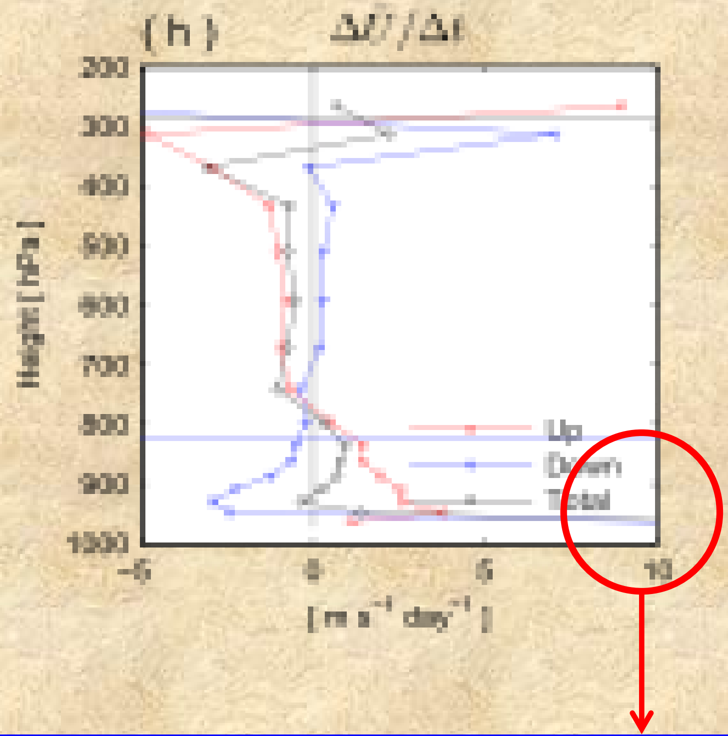
- NCAR and DOE (with CAM-SE; MPAS)

EVALUATION-APPLICATION

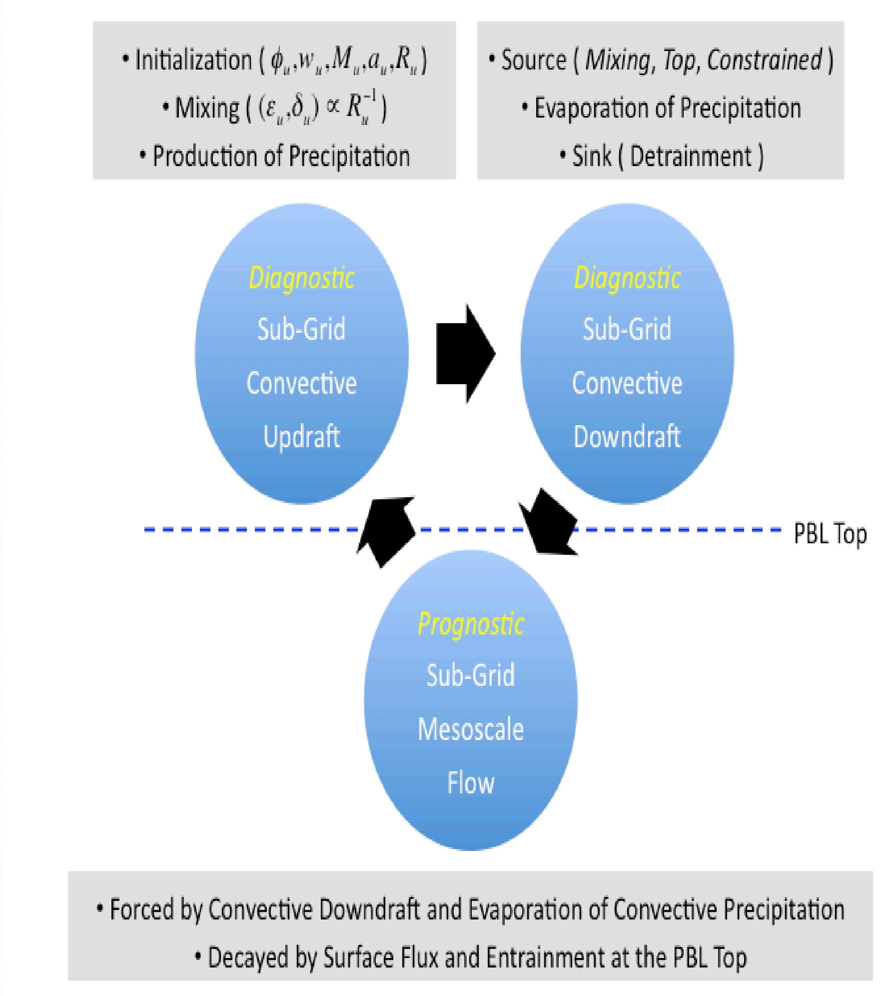
✓ MJO, ENSO, Tropical Cyclone, Diurnal Cycle of Precipitation, Seasonal-Decadal Prediction, Paleo-Climate, etc.:

- DOE (PNNL), Univ. of Washington, Stony Brook Univ., Yonsei Univ., KIOST (Korea Institute of Ocean Science and Technology); Univ. of Hawaii, etc.

SIMPLICITY vs CONSISTENCY



Too strong wind in the lowest layer
due to the simplifying assumption of $\varepsilon_d=\delta_d=0$,
which destabilizes the system.



- Initialization ($\phi_u, w_u, M_u, a_u, R_u$)
- Mixing ($(\varepsilon_u, \delta_u) \propto R_u^{-1}$)
- Production of Precipitation

- Source (*Mixing*, *Top*, *Constrained*)
- Evaporation of Precipitation
- Sink (Detrainment)

Diagnostic Sub-Grid Convective Updraft

Diagnostic Sub-Grid Convective Downdraft

PBL Top

Prognostic Sub-Grid Mesoscale Flow

- Forced by Convective Downdraft and Evaporation of Convective Precipitation
- Decayed by Surface Flux and Entrainment at the PBL Top