# Scale-Adaptive Physics Parameterization with Inter-Process Consistency :

# A Unified Convection Scheme, 'UNICON'

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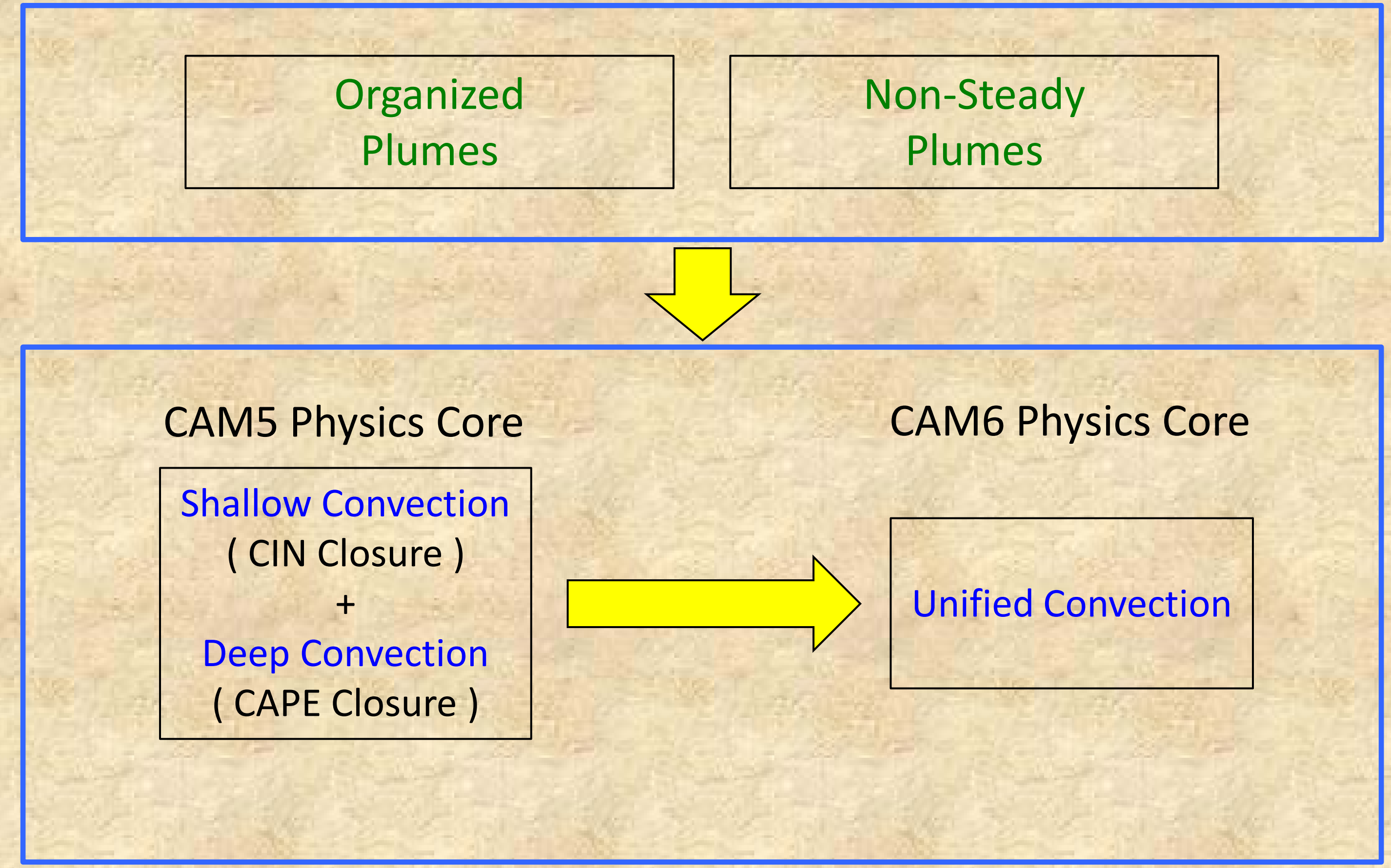
Andrew Mai, Adam Phillips, Dani Coleman

# A Strategic Plan for the Next Generation CAM6



# Overview of UNICON

I. *A new sub-grid vertical transport scheme by non-local asymmetric turbulent eddies* :

- Development History : July. 2006 ~ Present.
- Code : ~ 23,000 Lines

II. *Some of unique aspects of UNICON are*

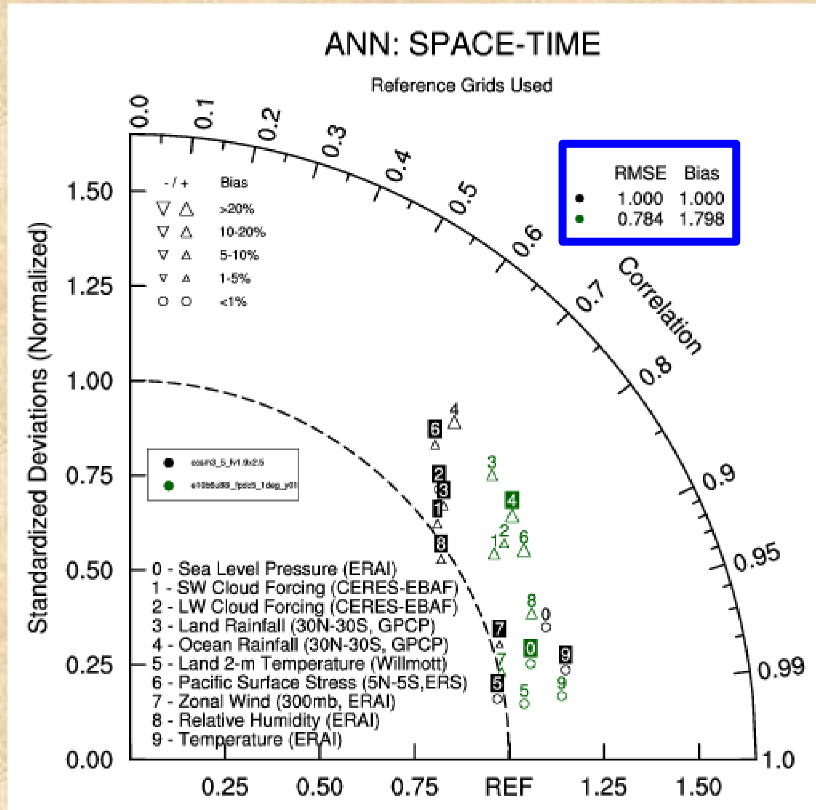
- Consistent closure for all scalars ( $q_t$, $\theta_c$, u, v, w, $A_m$, $A_\#$, R )
- Updraft plume mixing rate as an inverse function of plume radius R
- Launch correlated multiple plumes with different thermodynamic properties and R
- Generic treatments of 'convective downdraft' and 'detrainment'
- Treatment of 'vertical tilting of updraft plume'
- Parameterization of sub-grid 'meso-scale organized flows'
- Unified treatment of 'shallow/deep', 'dry/moist', and 'forced/free' convections
- No CIN/CAPE closures : 'fully dynamic plume model' without any equilibrium assumptions
- Well-harmonized with CAM5 local symmetric turbulence scheme ( i.e., moist PBL scheme )
- Scale-adaptive parameterization – minimal sensitivity to $\Delta x \bullet \Delta y$, $\Delta z$, $\Delta t$
- Process-based vertical transport and wet deposition of aerosols and chemical species

# Summary of Simulations

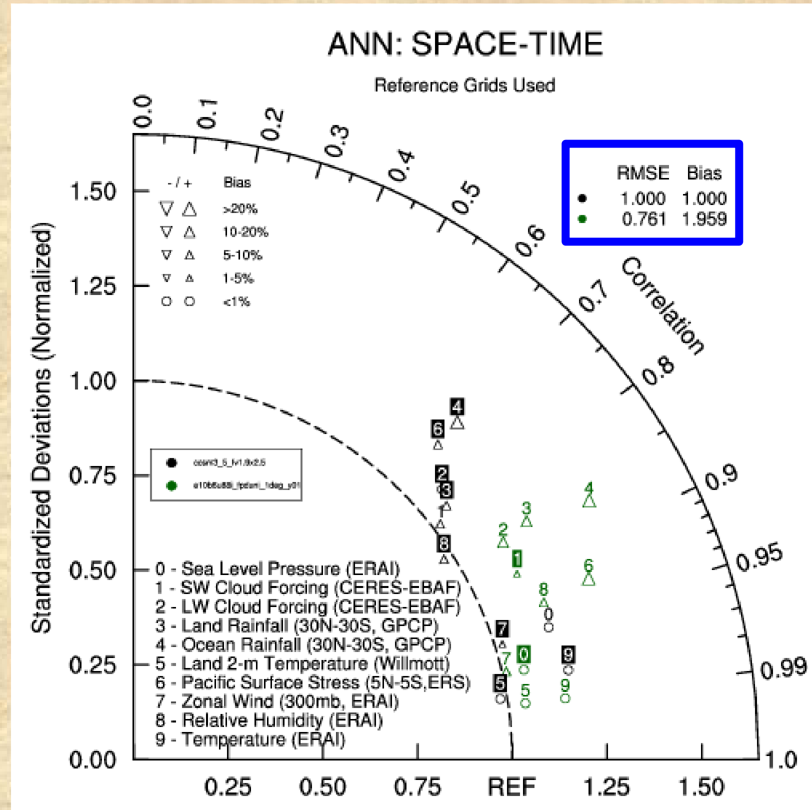
| | 2° X 2° | 1° X 1° Workhorse | 0.5° X 0.5° | 0.25° X 0.25° Exp.Hurricane | L60 Exp | |
|---|---|---|---|---|---|---|
| Standalone (Yr.2000, 10-yrs, P.D.) | Y | Y | Y | | | Clim. Diurn. |
| AMIP (Jan.1979-Dec.2005) | Y | | | | | MJO |
| 1850 Coupled (100 yrs) | Y | | | | | ENSO |
| 20th Century (Jan.1850-Dec.2005) | | | | | | |
| Standalone AIE (Yr.2000, 10-yrs, P.I.) | Y | | | | | AIE |

# Overall Performance

**CAM5**




**UNICON**




| G=Δx•Δy | 2° X 2° | 1° X 1° | 0.5° X 0.5° | 0.25° X 0.25° |
|---|---|---|---|---|
| CAM5 | 0.824 | 0.784 | 0.791 | ? (0.800) |
| UNICON | 0.834 | 0.761 | 0.754 | ? (0.750) |

# Climatology

Seasonal Precipitation

SWCF

Stratocumulus-to-Cumulus Transition

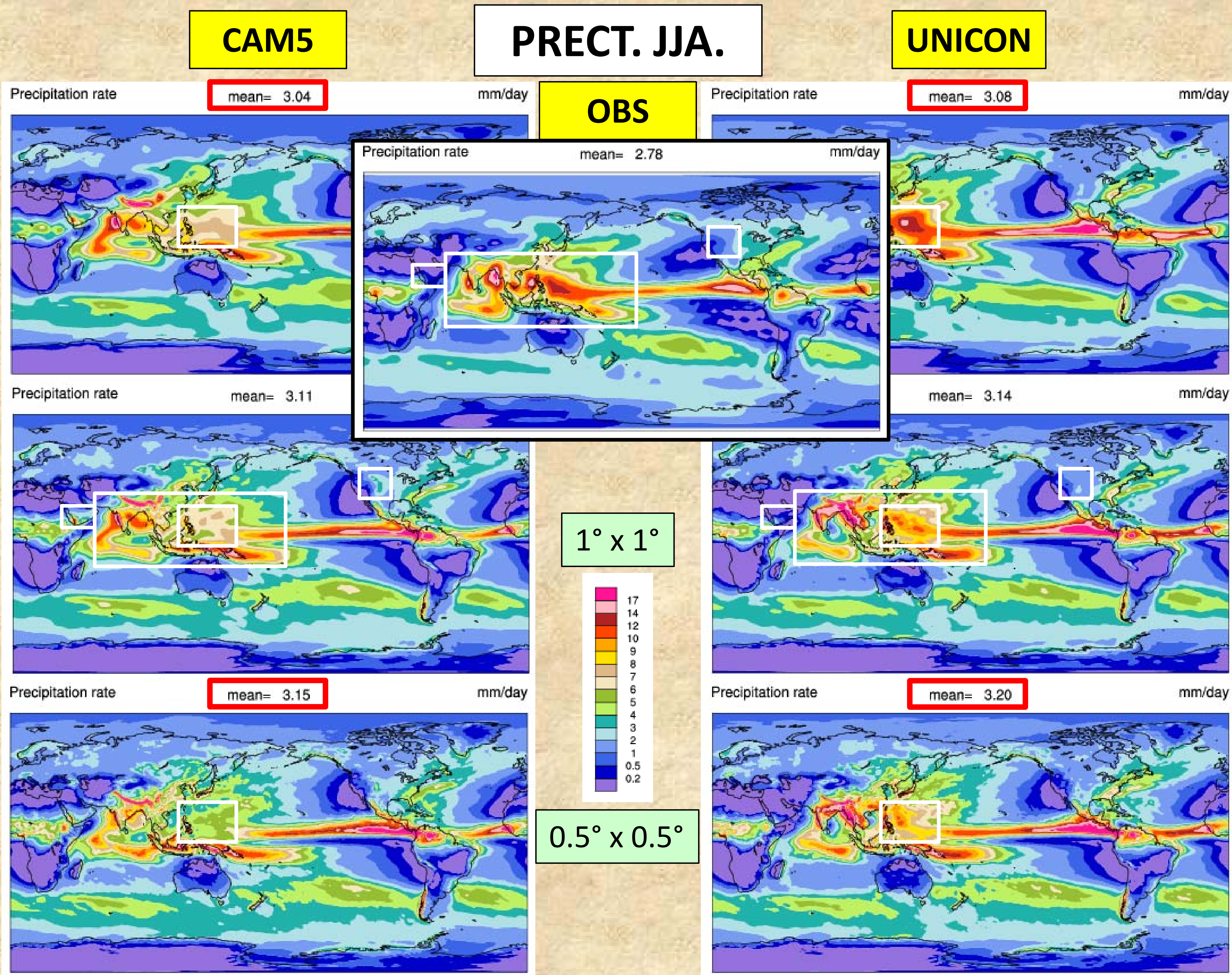
Cumulus Properties

Moist Static Energy Profiles

Aerosol Optical Depth

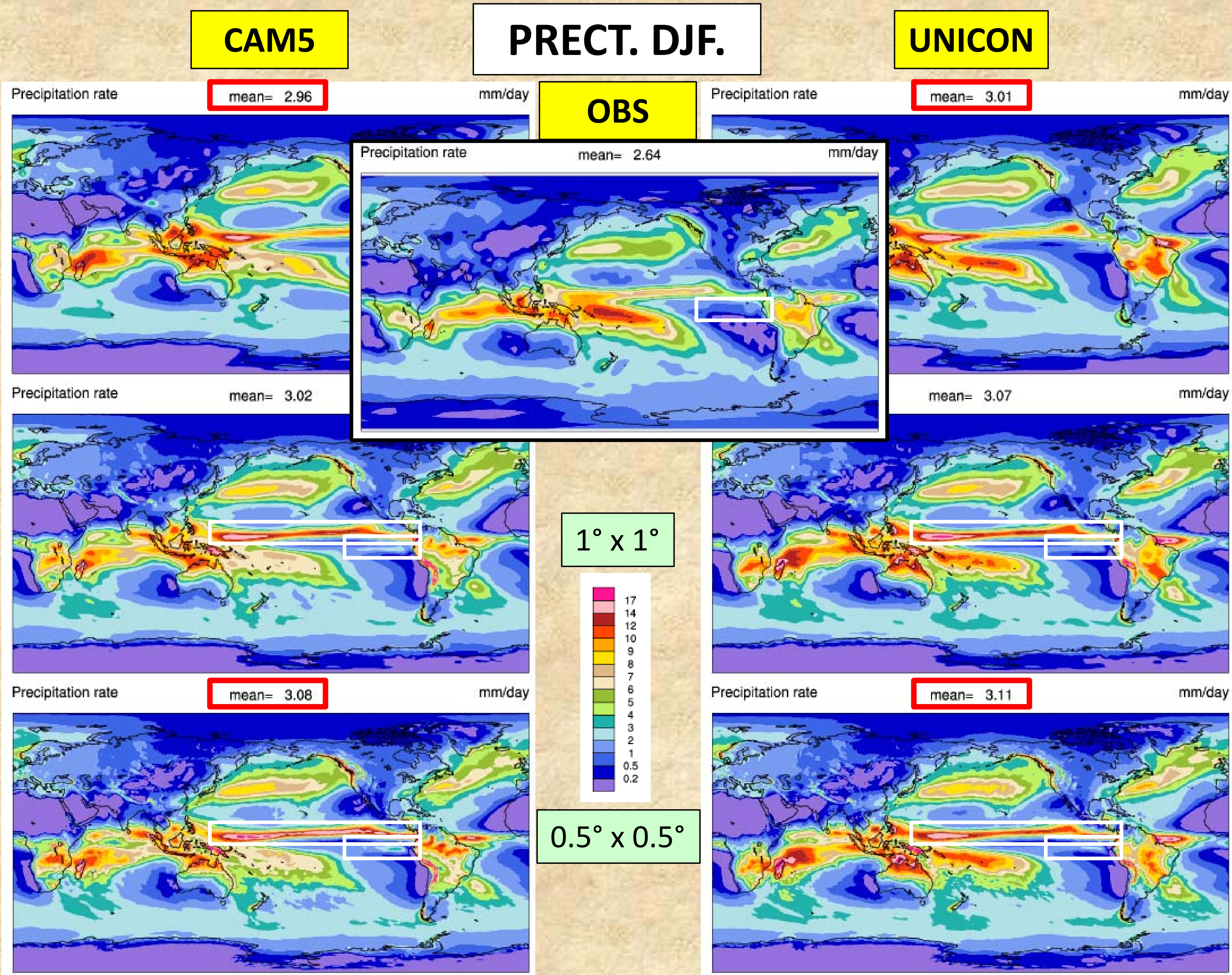
Aerosol Indirect Effect (A.I.E.)

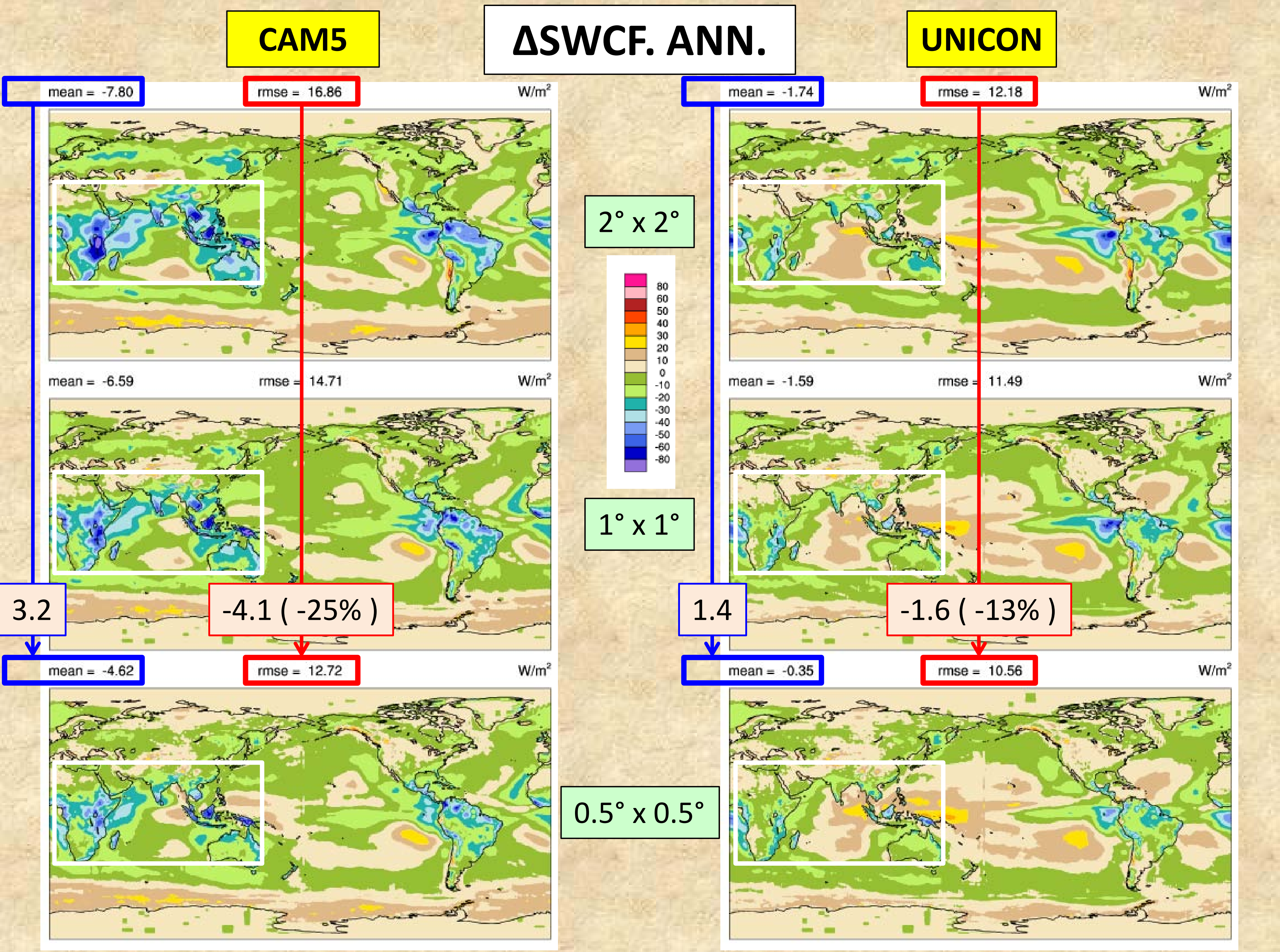
# PRECT. JJA.



CAM5
OBS
UNICON
Precipitation rate
mean= 3.04
mm/day
Precipitation rate
mean= 3.08
mm/day
Precipitation rate
mean= 2.78
mm/day
Precipitation rate
mean= 3.11
mean= 3.14
mm/day
1° x 1°
17
14
12
10
9
8
7
6
5
4
3
2
1
0.5
0.2
0.5° x 0.5°
Precipitation rate
mean= 3.15
mm/day
Precipitation rate
mean= 3.20
mm/day

# PRECT. DJF.


CAM5
OBS
UNICON
Precipitation rate
mean= 2.96
mm/day
Precipitation rate
mean= 3.01
mm/day
Precipitation rate
mean= 2.64
mm/day
Precipitation rate
mean= 3.02
mean= 3.07
mm/day
1° x 1°
17
14
12
10
9
8
7
6
5
4
3
2
1
0.5
0.2
0.5° x 0.5°
Precipitation rate
mean= 3.08
mm/day
Precipitation rate
mean= 3.11
mm/day

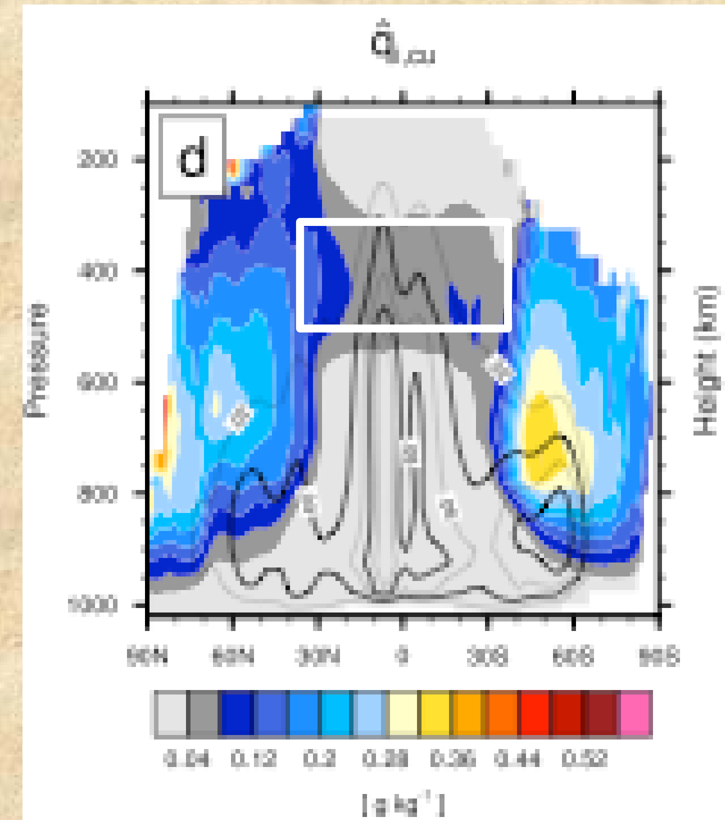


CAM5
ΔSWCF. ANN.
UNICON
mean = -7.80
rmse = 16.86
W/m²
mean = -1.74
rmse = 12.18
W/m²
2° x 2°
80
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-80
mean = -6.59
rmse = 14.71
W/m²
mean = -1.59
rmse = 11.49
W/m²
1° x 1°
3.2
-4.1 ( -25% )
1.4
-1.6 ( -13% )
mean = -4.62
rmse = 12.72
W/m²
mean = -0.35
rmse = 10.56
W/m²
0.5° x 0.5°

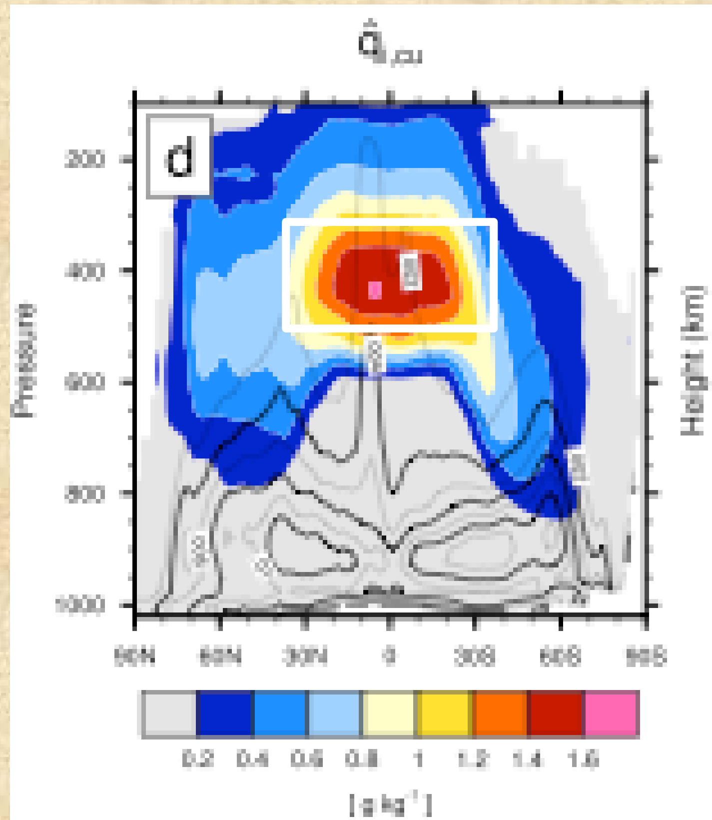
# Cumulus Properties

[ In-Cumulus IWC (Color) and Cumulus Fraction (Line: 0.02 CAM5, 0.002 UNICON) ]

**CAM5**




**UNICON**

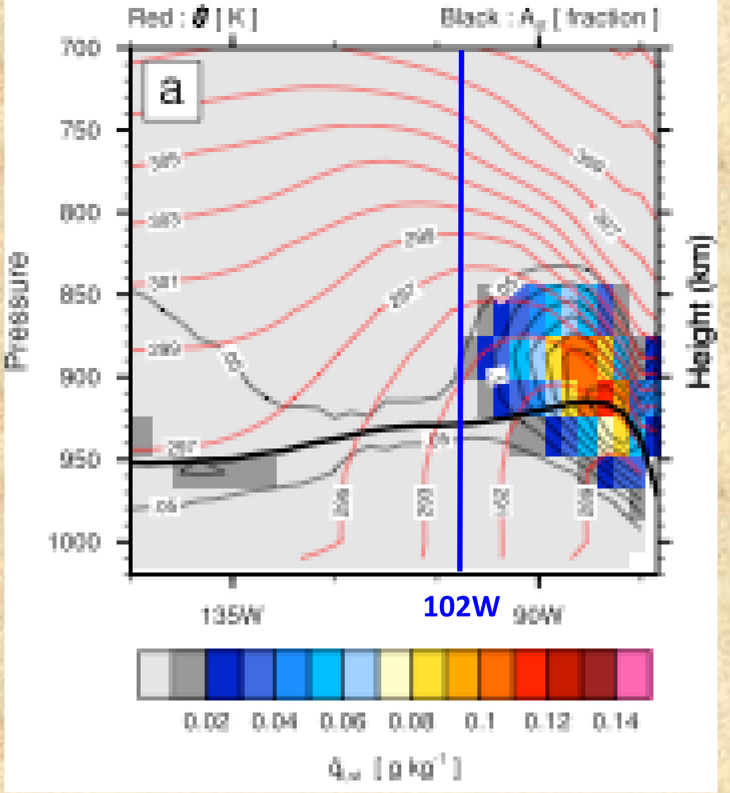


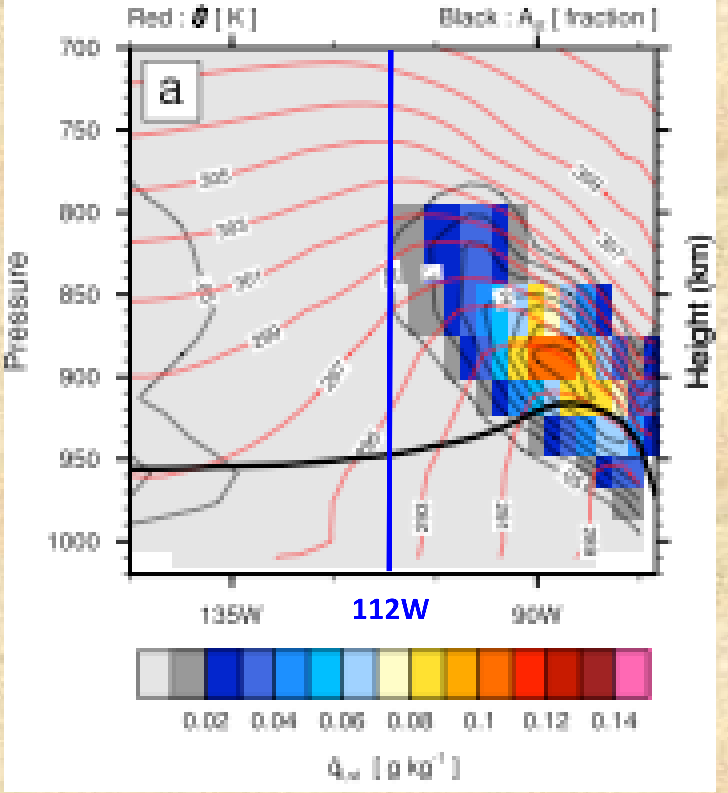

UNICON simulates less Cu-Fraction but more In-Cumulus IWC/LWC than CAM5.

# Stratocumulus-to-Cumulus Transition
( Cross-section along the Southeastern Pacific Ocean. SON )

**CAM5**

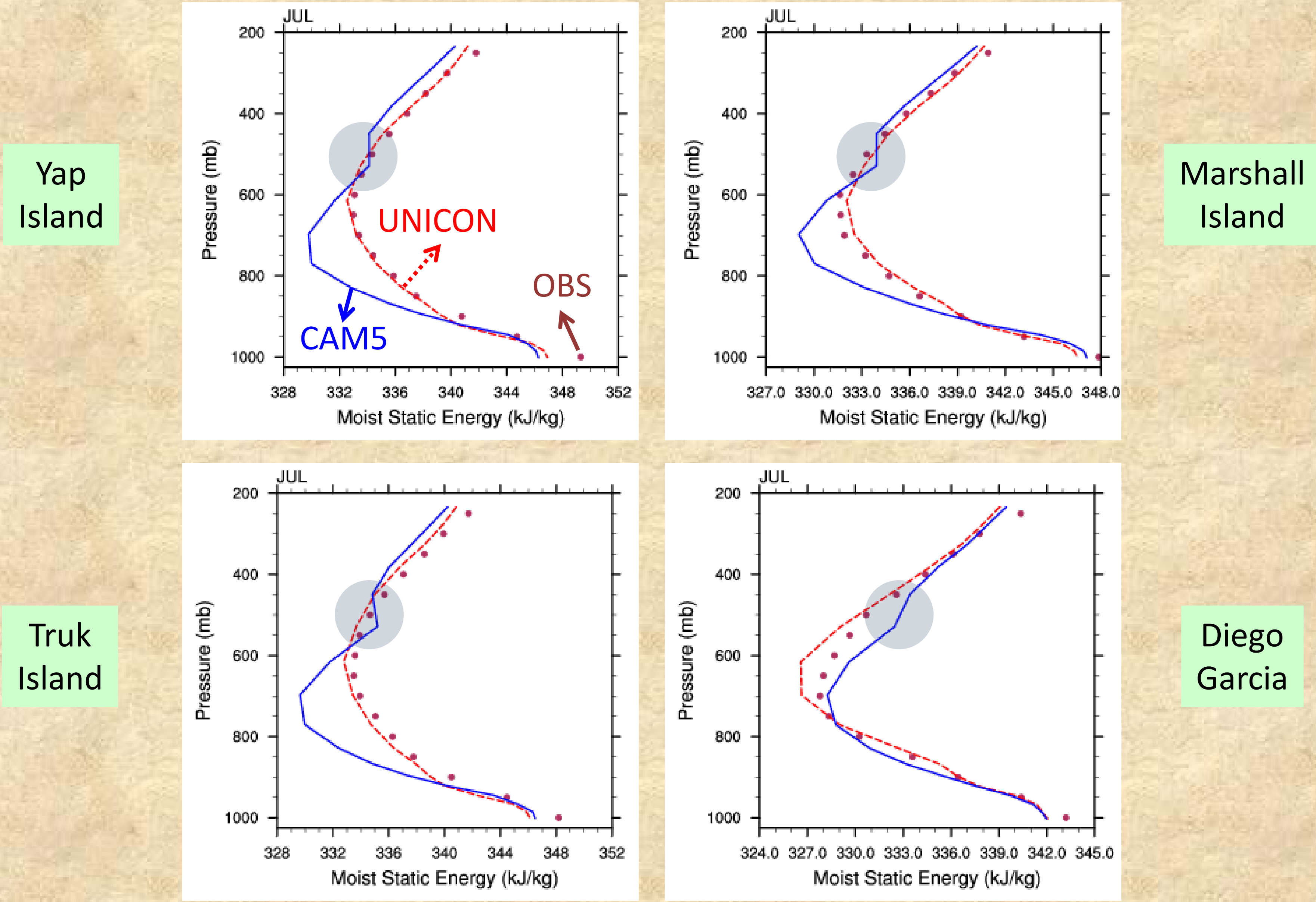
**UNICON**



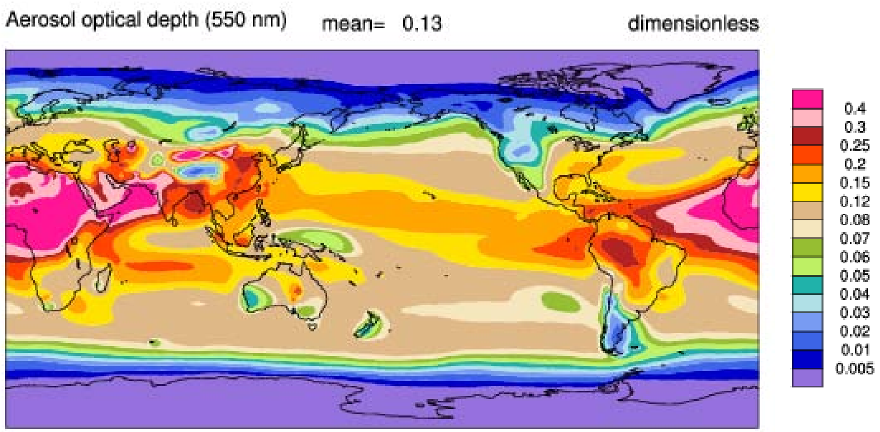

Line : Stratus Fraction
Color : Grid-mean Stratus LWC

# Moist Static Energy. JJA.

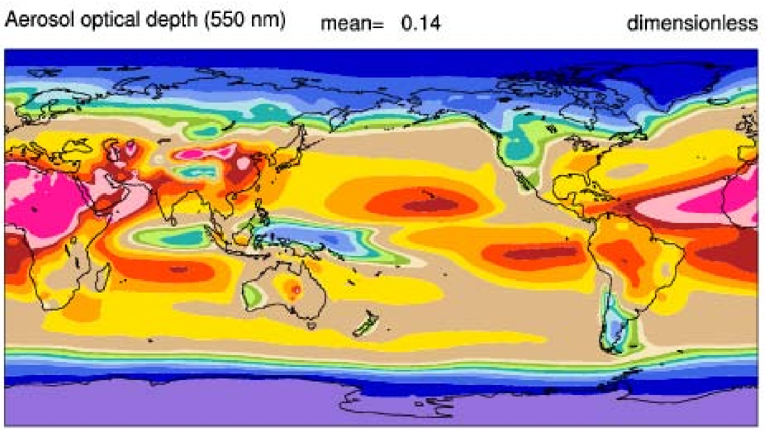


# Aerosol Optical Depth. ANN.

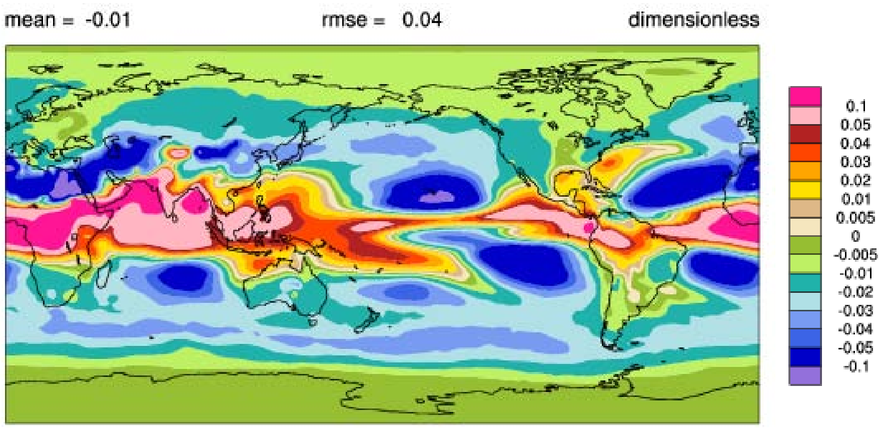
**UNICON**

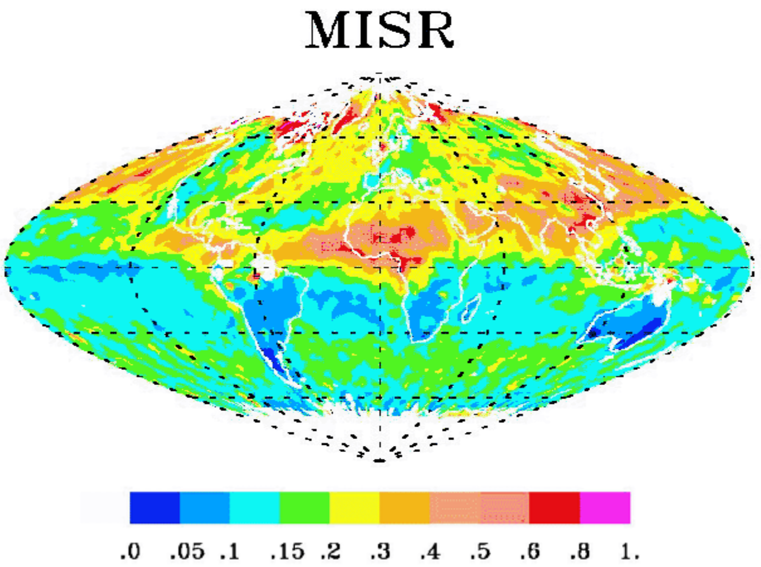



**CAM5**




**UNICON – CAM5**



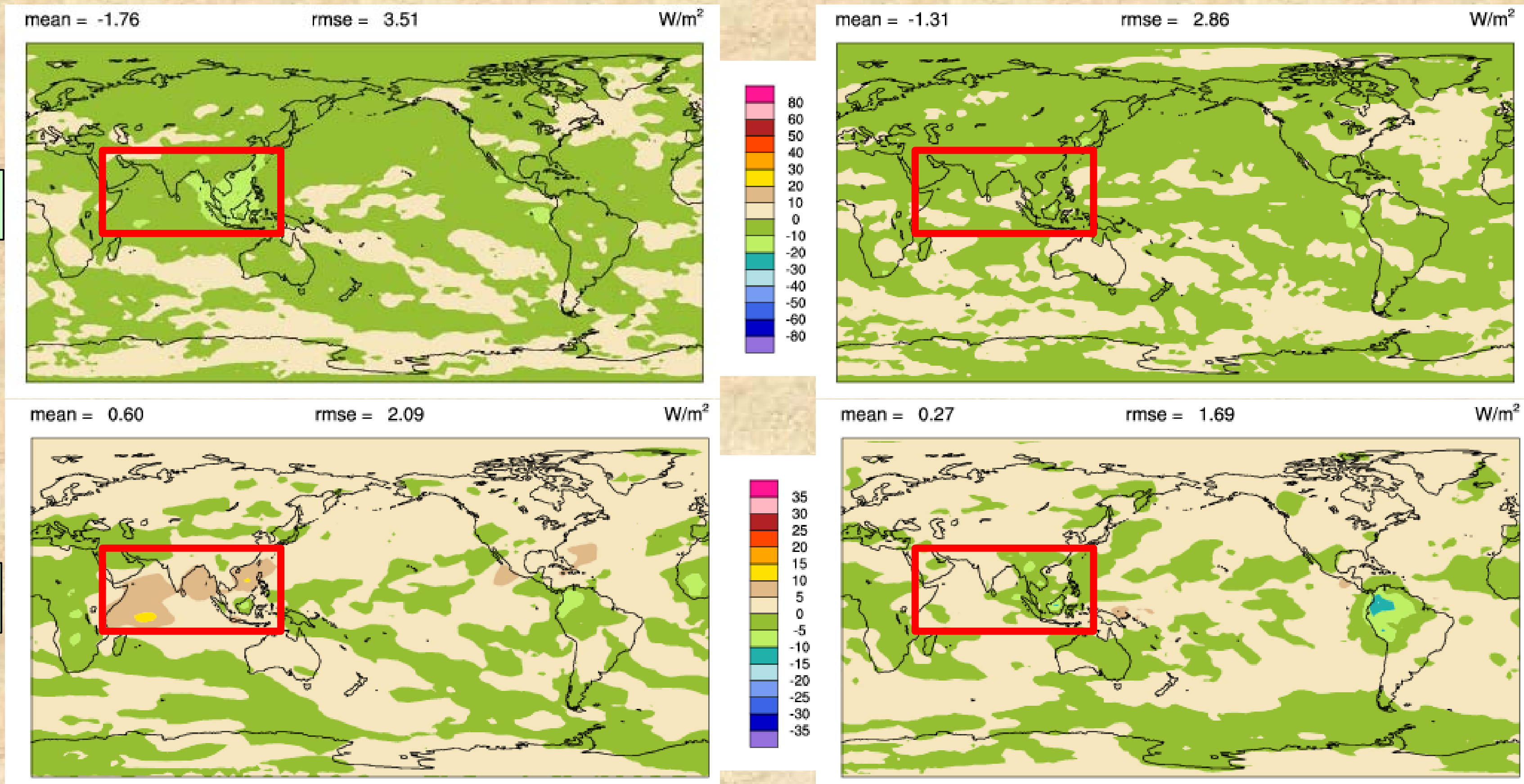



# Aerosol Indirect Effect. ANN.

**CAM5** **UNICON**

Δ SWCF

Δ LWCF




| | CAM5 | UNICON | UNICON + Fitch |
|---|---|---|---|
| SW AIE | -1.76 | -1.31 | -1.31 |
| LW AIE | 0.60 | 0.27 | 0.22 |
| Net AIE | -1.16 | -1.04 | -1.09 |

# Variability

Diurnal Cycle of Precipitation

Madden-Julian Oscillation

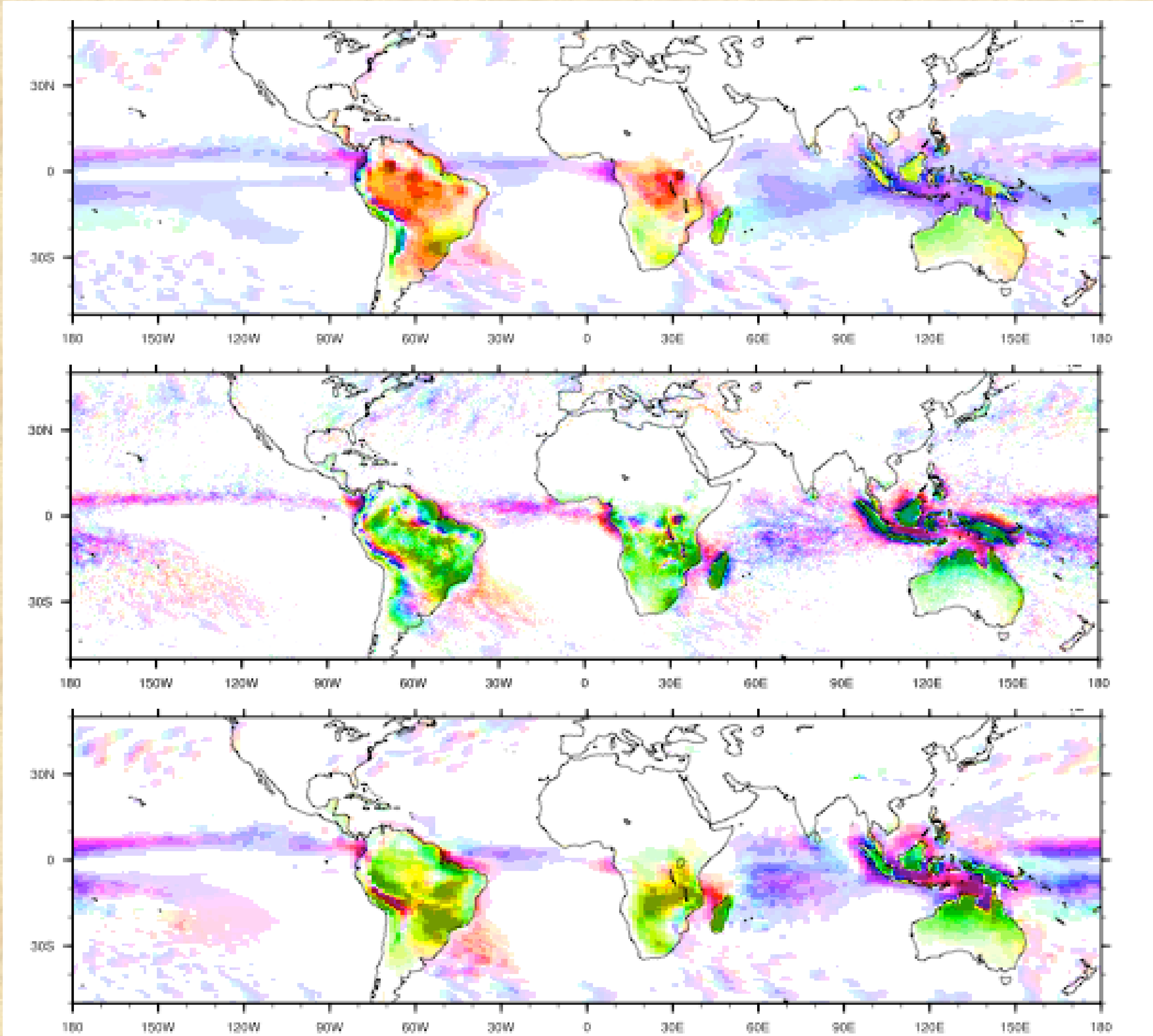
ENSO

# Diurnal Cycle of Precipitation. DJF. 1-Deg.

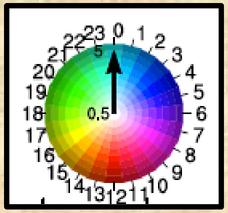
**CAM5**

**OBS**

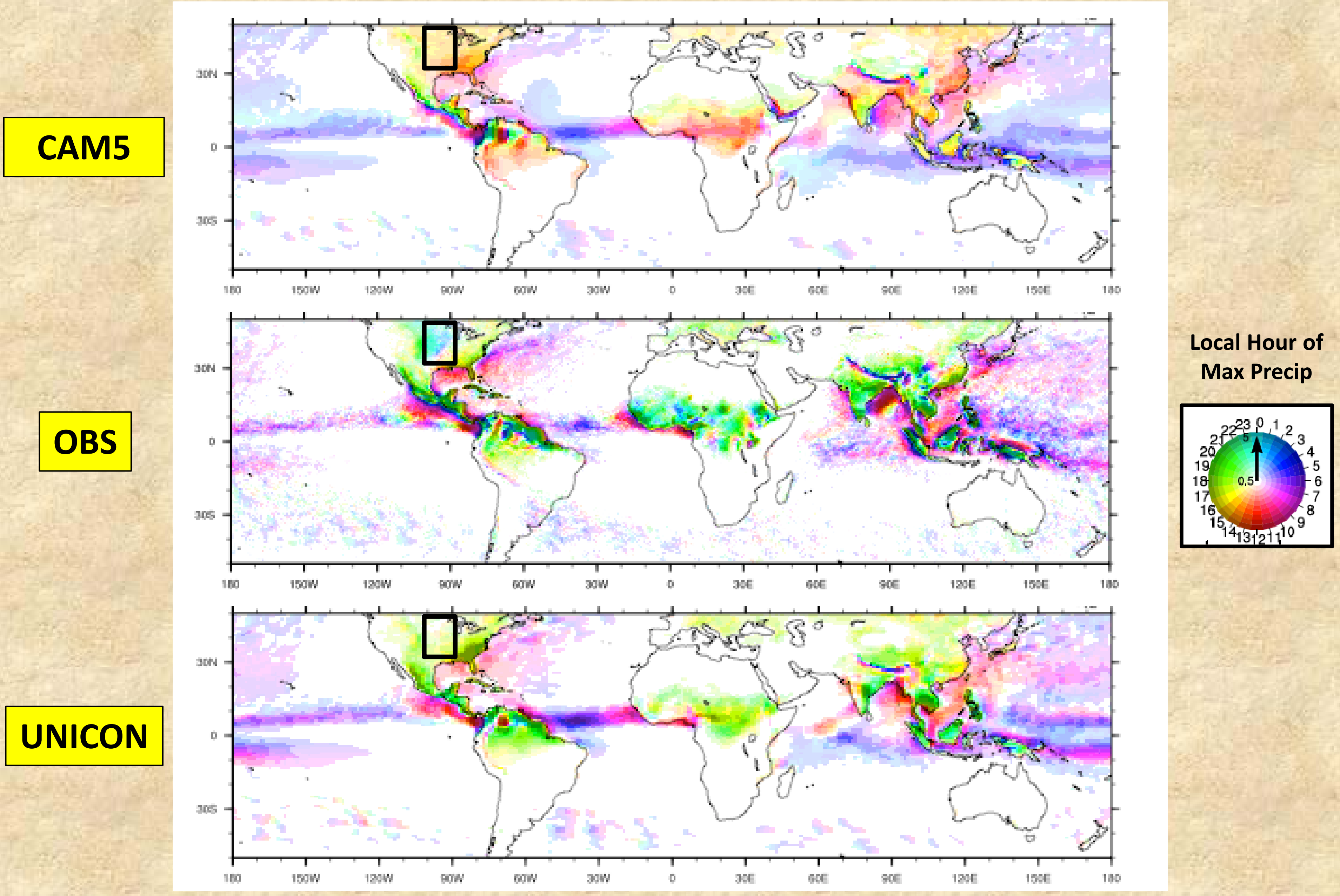
**UNICON**



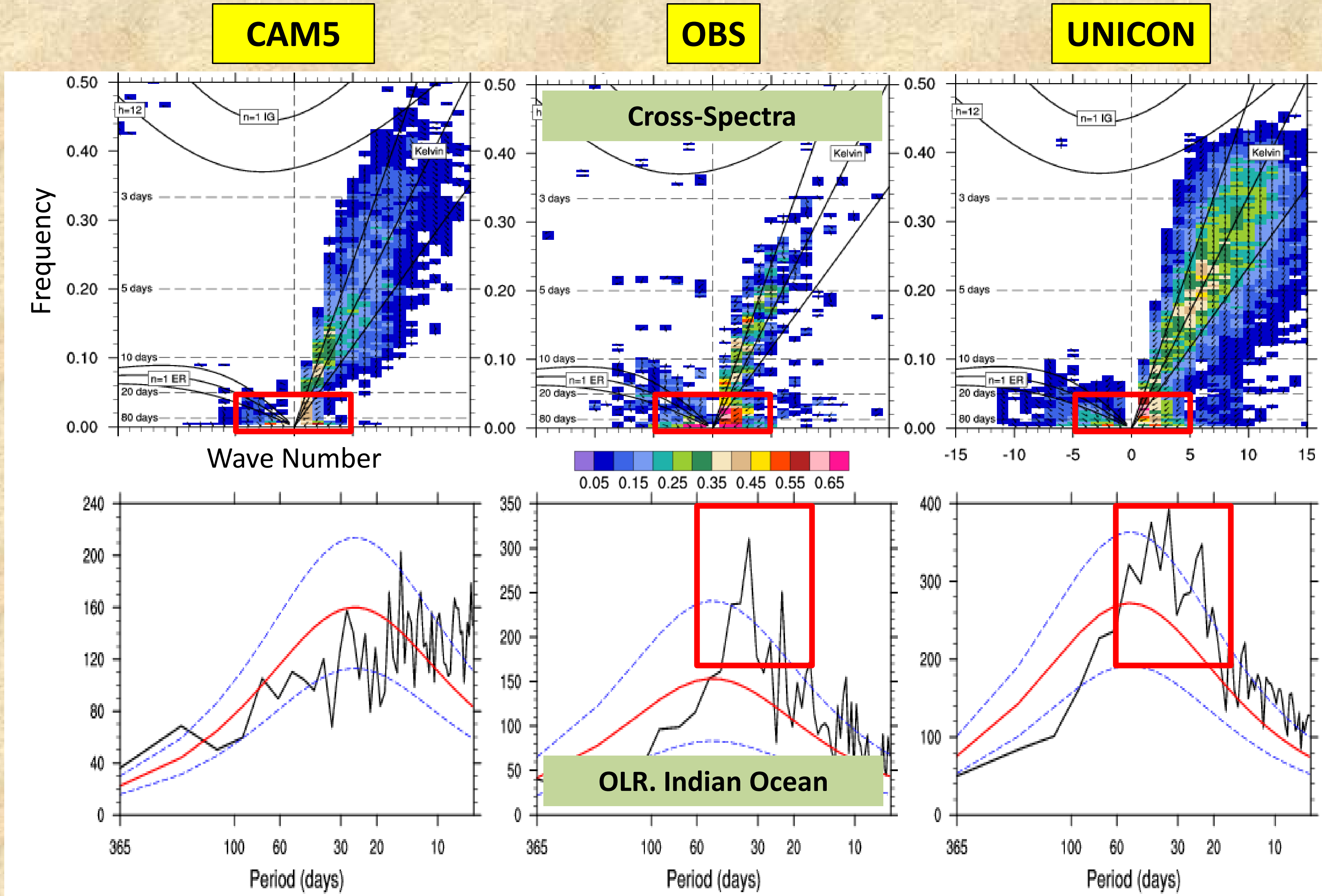

**Local Hour of Max Precip**

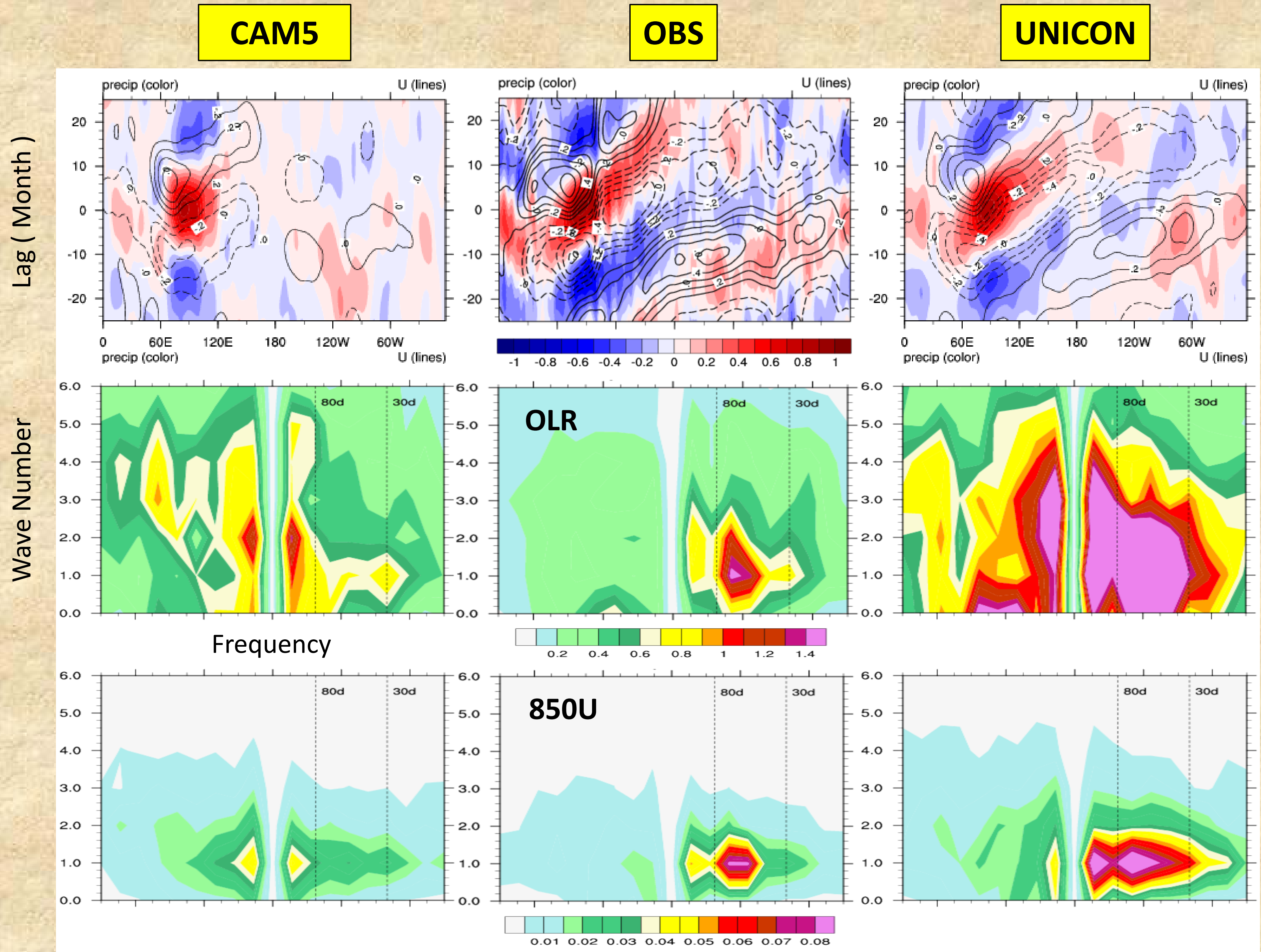


# Diurnal Cycle of Precipitation. JJA.

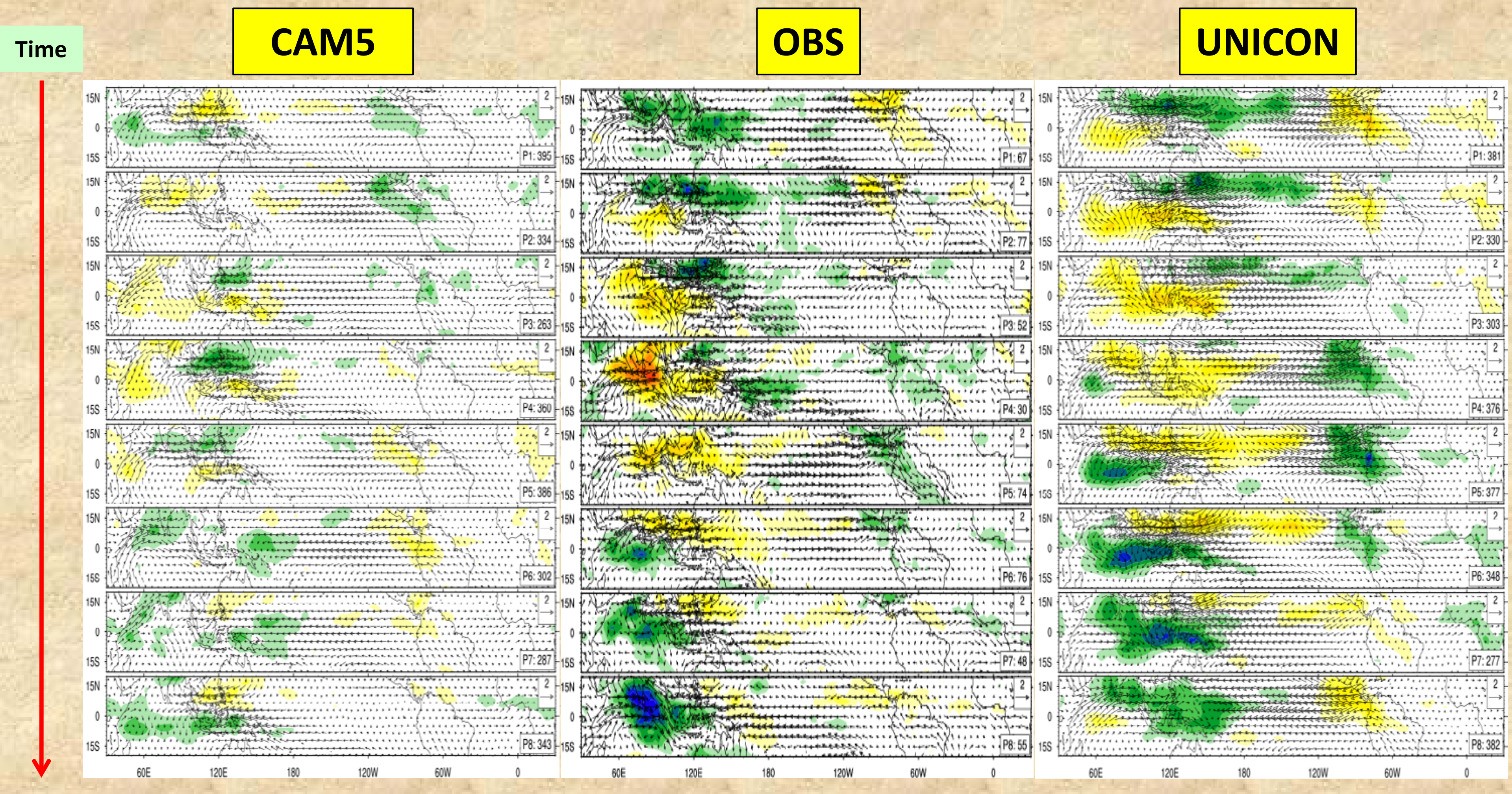


# Madden-Julian Oscillation ( MJO )

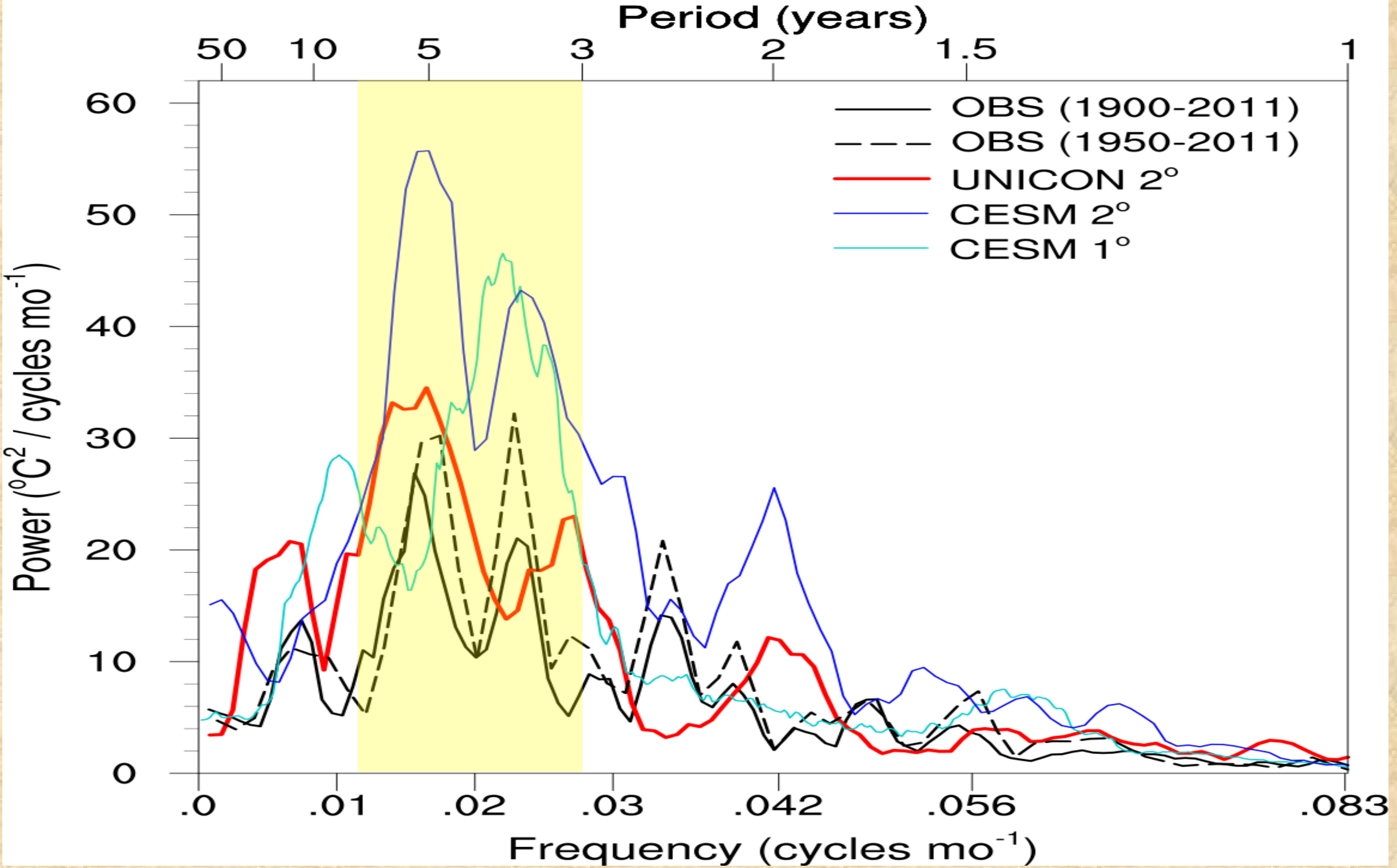



CAM5
OBS
UNICON
precip (color)
U (lines)
Lag ( Month )
Wave Number
Frequency
OLR
850U
80d
30d
0
60E
120E
180
120W
60W

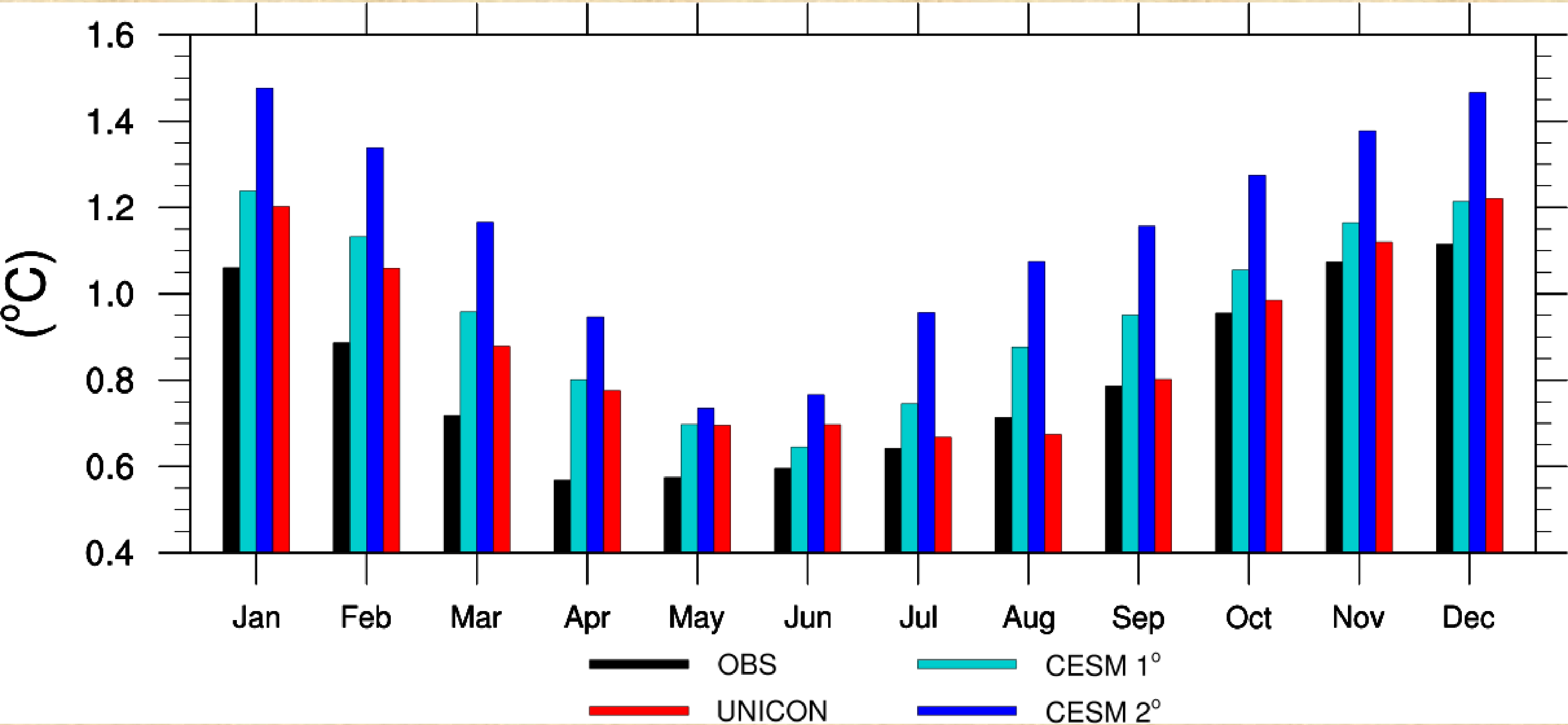
# MJO Composite of OLR (Color) and 850 Wind



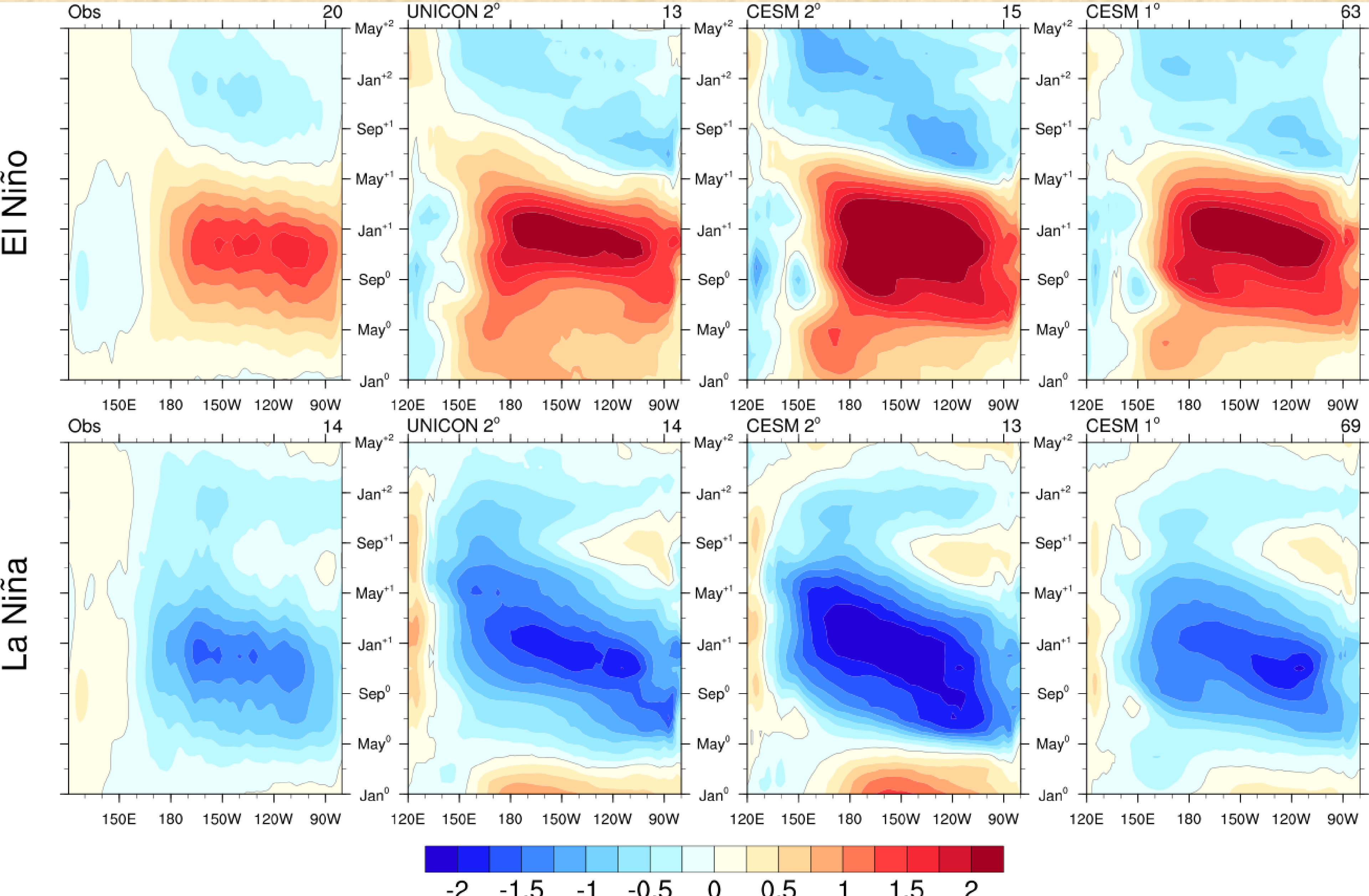
# Power Spectrum of Nino3.4 SST. ENSO.



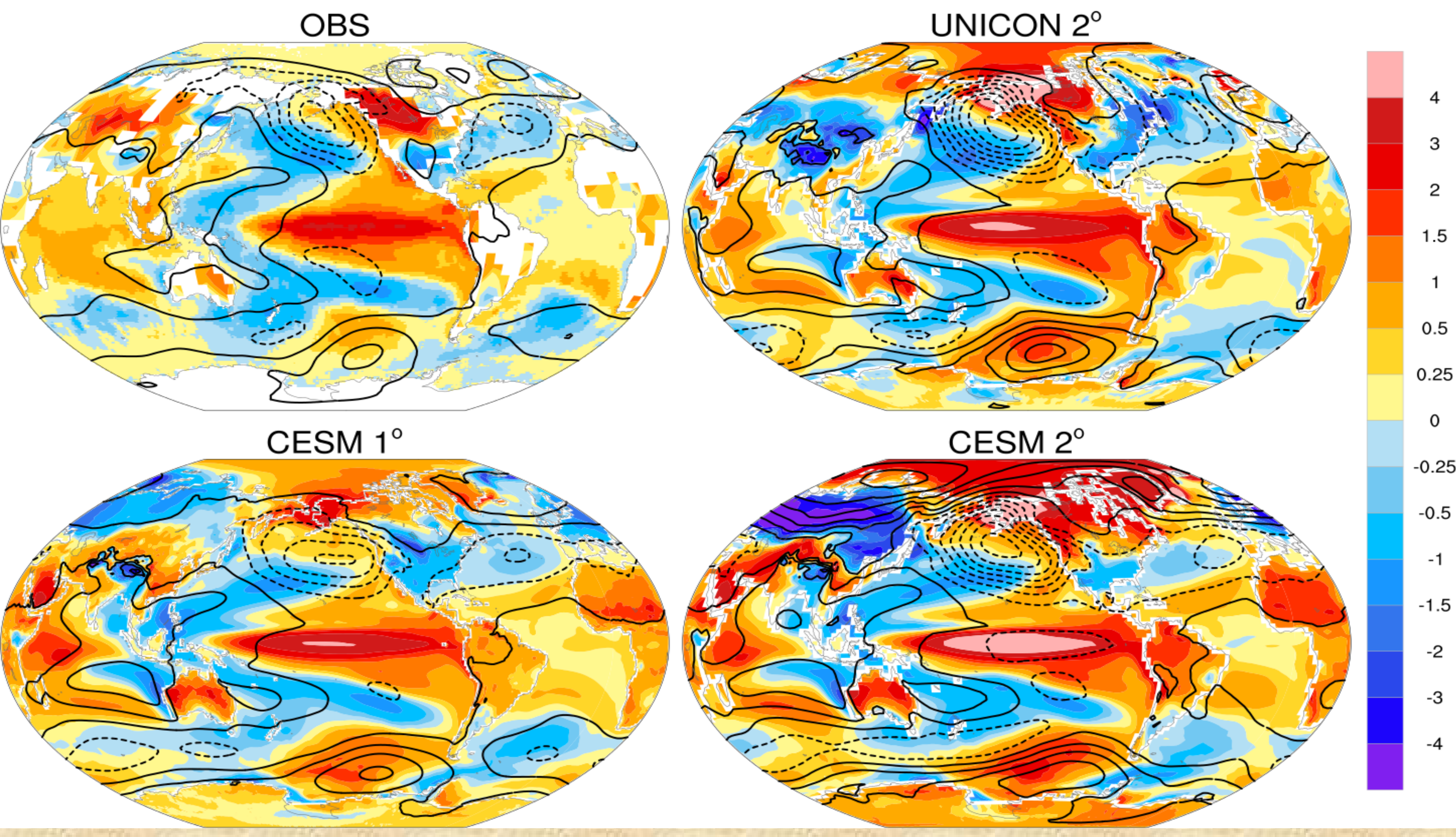
# Interannual Variability of Nino3.4 SST



**OBS** | **UNICON 2-Deg** | **CESM 2-Deg** | **CESM 1-Deg**



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



# SUMMARY

- UNICON is a new sub-grid vertical transport scheme by non-local asymmetric turbulent eddies and a scale-adaptive parameterization well harmonized with CAM5 moist turbulence scheme without double-counted transport.
- UNICON simulates all shallow-deep, dry-moist, and forced-free convections within a single framework in a seamless, consistent and unified way without relying on any equilibrium assumptions.
- UNICON well simulates both the '*climatology*' and '*variability*' (e.g., Diurnal cycle of precipitation, MJO, Monsoon, ENSO) with less sensitivity to $G=\Delta x \bullet \Delta y$ than CAM5.

- On-going work and future plans
  - Papers describing UNICON are in preparation (*A Unified Convection Scheme I,II. S. Park. 2013.*)
  - Test in "coupled / high-resolution (both in $\Delta x \bullet \Delta y$ and $\Delta z$)" configuration.
  - Develop a new compatible microphysics.
  - Impose consistency between physics and dynamics (with D. Williamson and J. Bacmeister).