Scale-Adaptive Physics Parameterization with Inter-Process Consistency :

A **Uni**fied **Con**vection Scheme, 'UNICON'

AMWG. Feb. 10. 2014.

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Acknowledgment : Brian Eaton, Changhuyn Yoo, Minho Kwon

A Unified Convection Scheme, UNICON.

Part I. Formulation

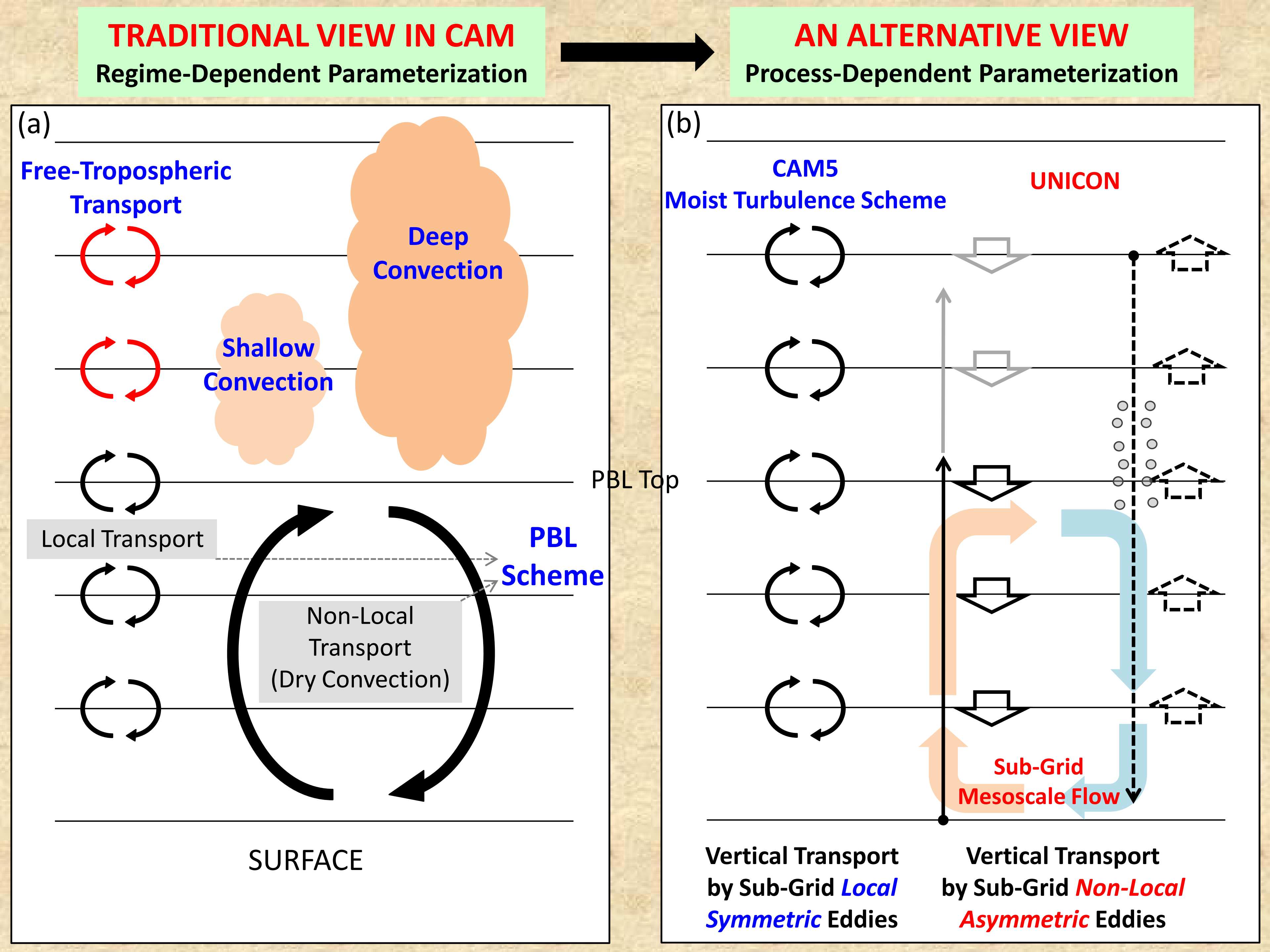
Sungsu Park *

A Unified Convection Scheme, UNICON.

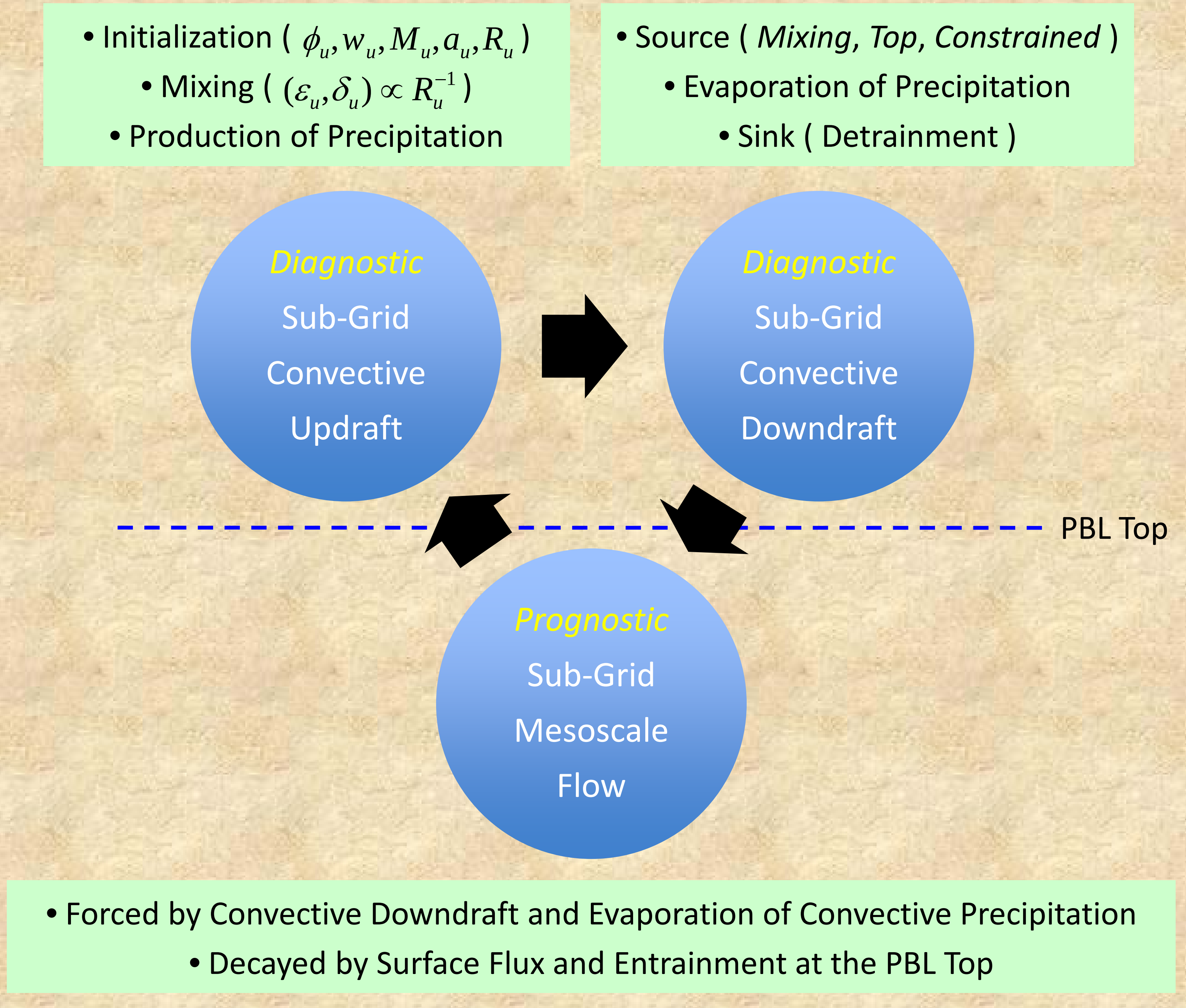
Part II. Simulation

Sungsu Park *

Journal of the Atmospheric Sciences. 2014. Revised.



TRADITIONAL VIEW IN CAM
Regime-Dependent Parameterization
AN ALTERNATIVE VIEW
Process-Dependent Parameterization
(a)
Free-Tropospheric Transport
Deep Convection
Shallow Convection
PBL Top
Local Transport
PBL Scheme
Non-Local Transport (Dry Convection)
SURFACE
(b)
CAM5 Moist Turbulence Scheme
UNICON
Sub-Grid Mesoscale Flow
Vertical Transport by Sub-Grid Local Symmetric Eddies
Vertical Transport by Sub-Grid Non-Local Asymmetric Eddies



• 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

CLIMATOLOGY

(1.9^olat x 2.5^olon)

BOMEX Single-Column Simulation

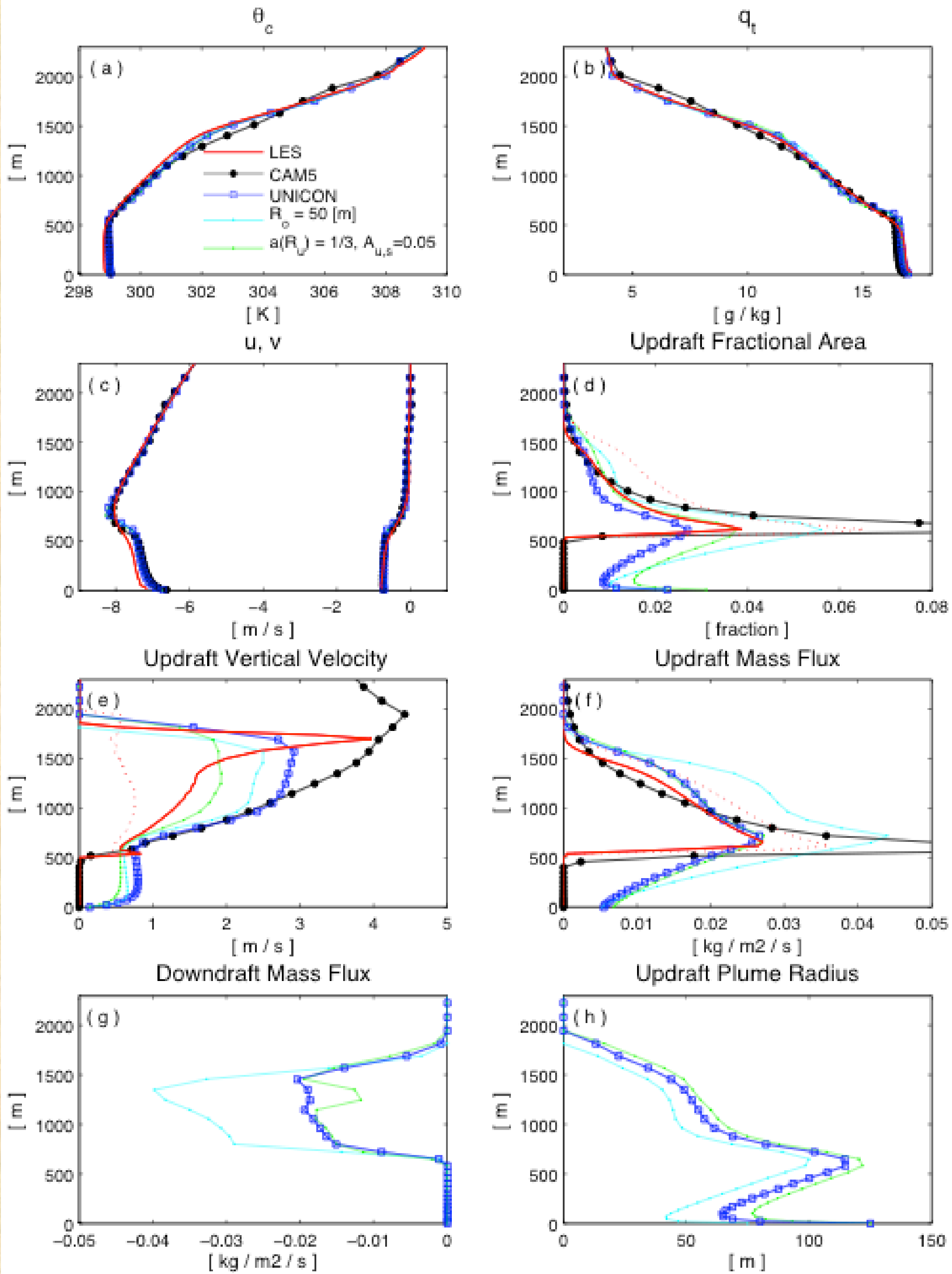
Seasonal Precipitation (Monsoon)

SWCF / LWCF

Aerosol Optical Depth (AOD)

BOMEX

Shallow Convection Case



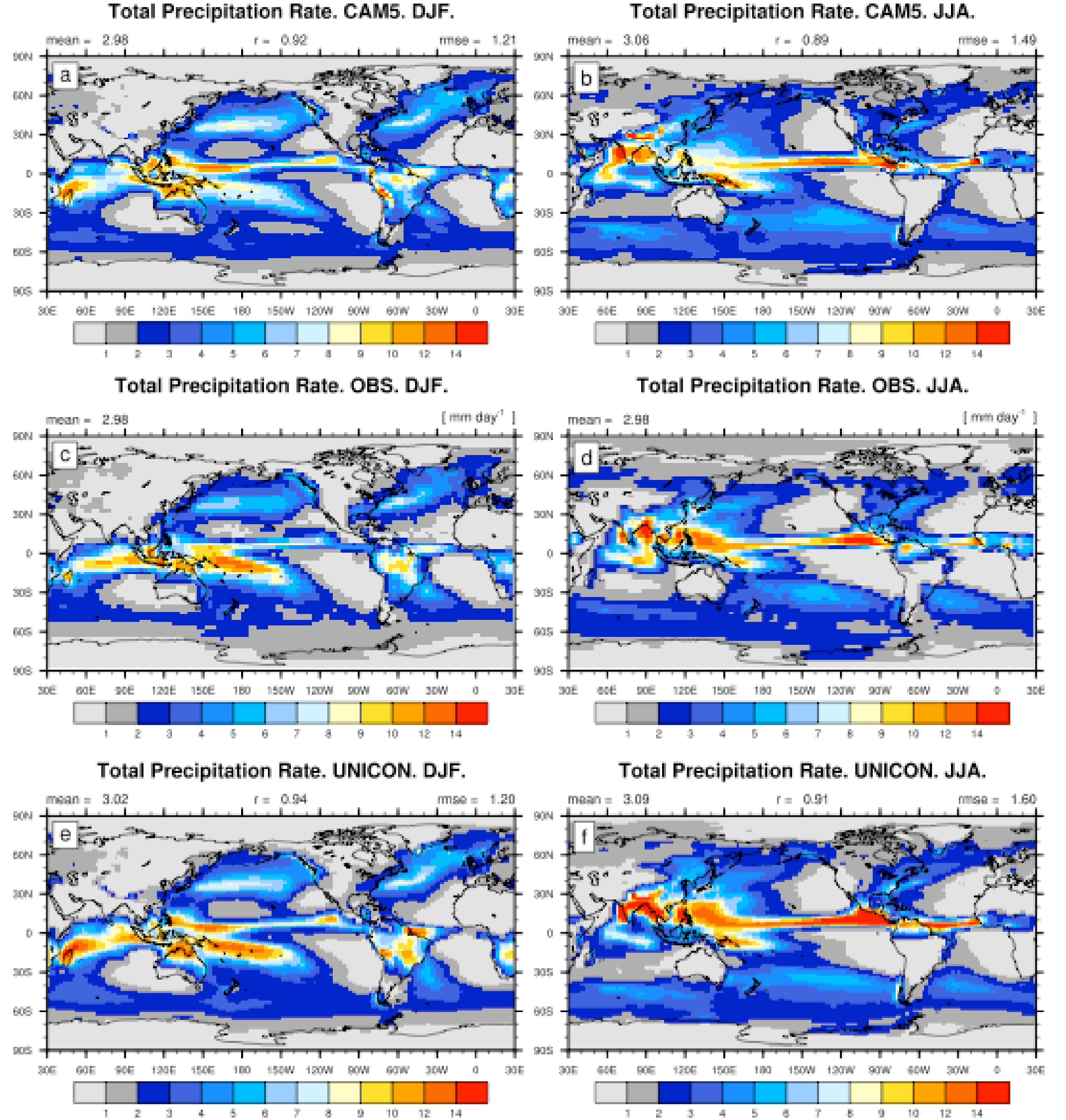
PRECT

DJF : JJA

CAM5

OBS

UNICON

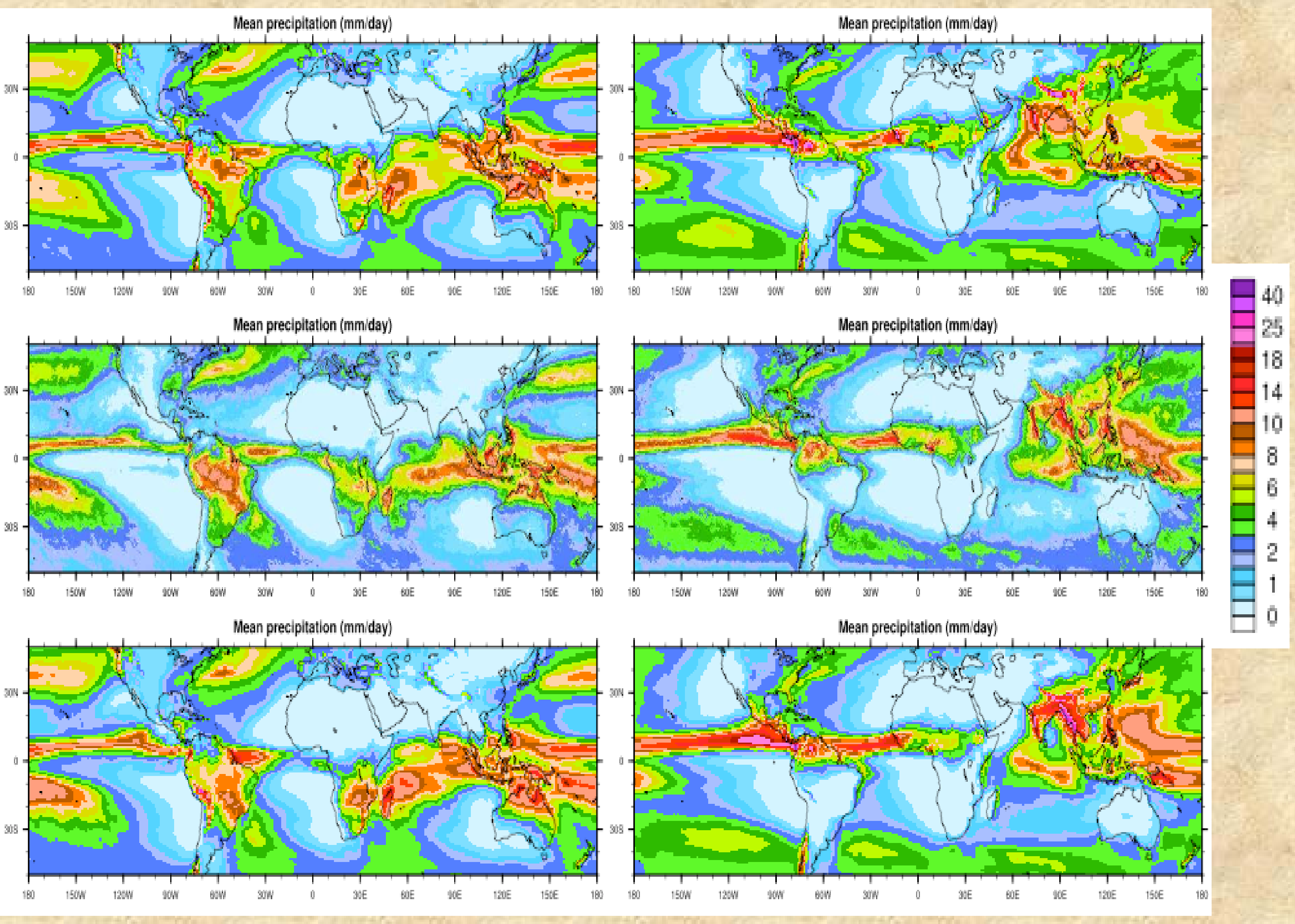


DJF | **0.95°lat x 1.25°lon** | **JJA**

CAM5

OBS

UNICON

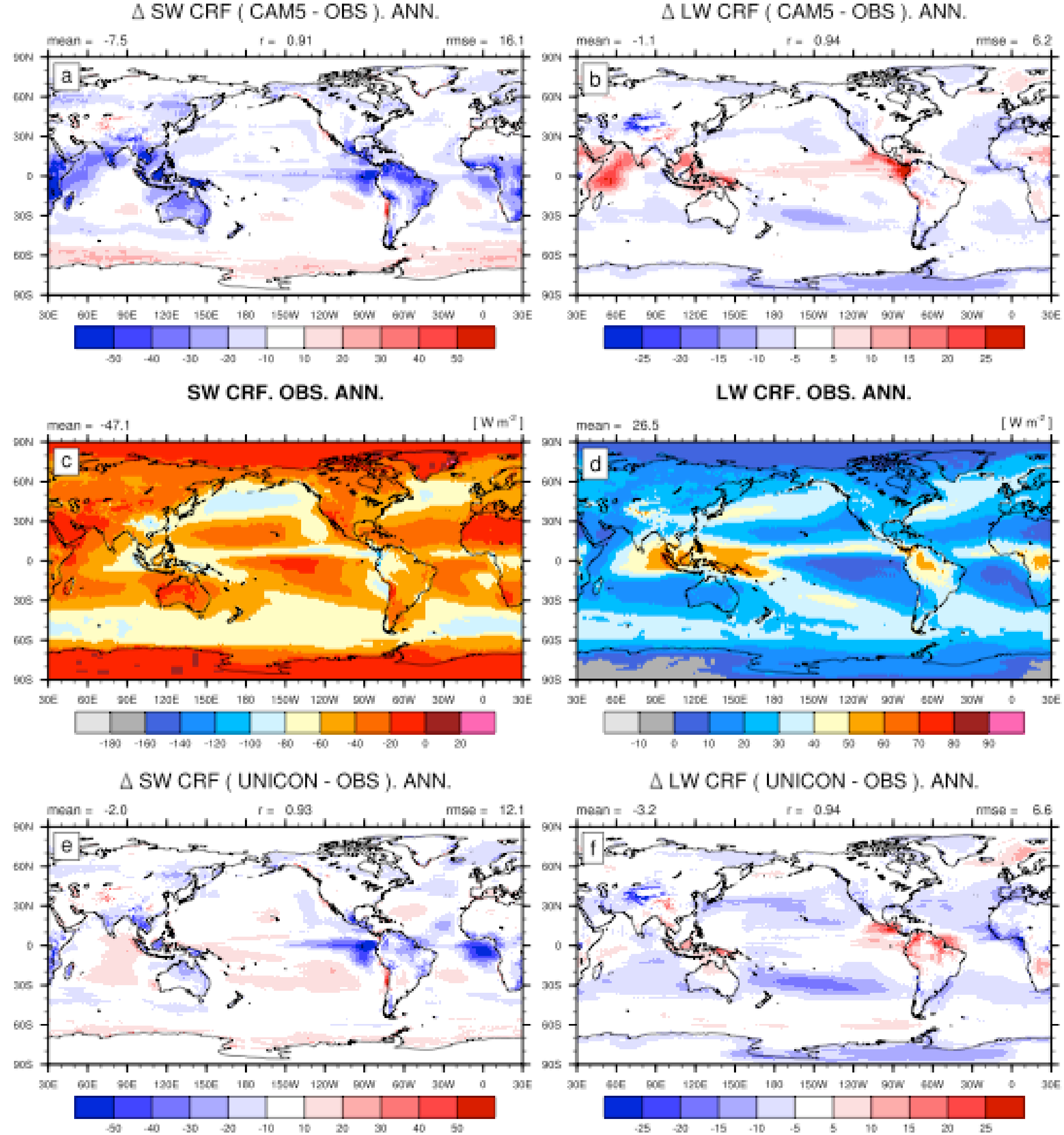


SWCF:LWCF

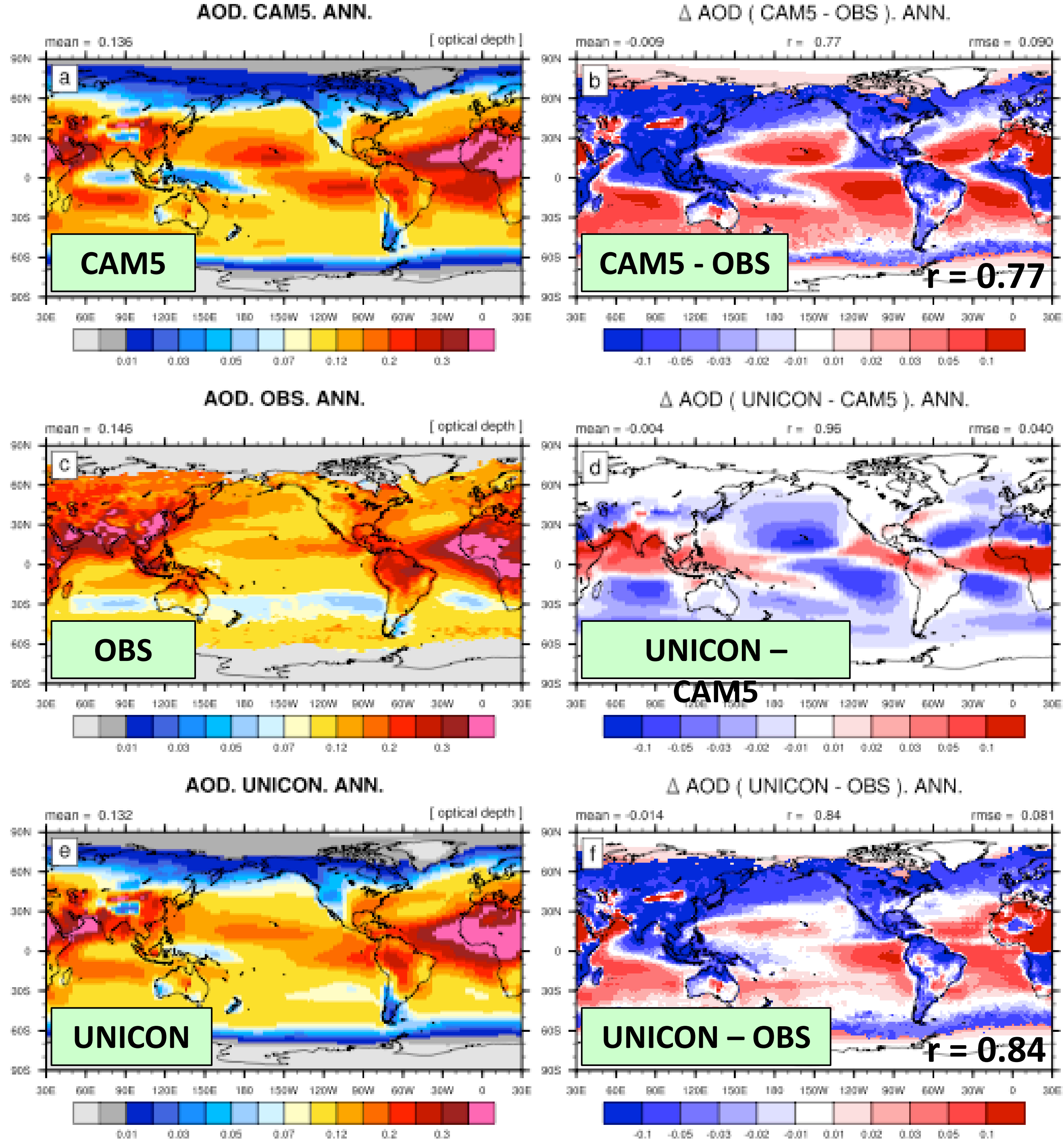
CAM5 - OBS

OBS

UNICON - OBS



AOD


AOD. CAM5. ANN.
mean = 0.136
[optical depth]
a
CAM5
Δ AOD (CAM5 - OBS). ANN.
mean = -0.009
r = 0.77
rmse = 0.090
b
CAM5 - OBS
r = 0.77
AOD. OBS. ANN.
mean = 0.146
[optical depth]
c
OBS
Δ AOD (UNICON - CAM5). ANN.
mean = -0.004
r = 0.96
rmse = 0.040
d
UNICON – CAM5
AOD. UNICON. ANN.
mean = 0.132
[optical depth]
e
UNICON
Δ AOD (UNICON - OBS). ANN.
mean = -0.014
r = 0.84
rmse = 0.081
f
UNICON – OBS
r = 0.84
0.01 0.03 0.05 0.07 0.12 0.2 0.3
-0.1 -0.05 -0.03 -0.02 -0.01 0.01 0.02 0.03 0.05 0.1

VARIABILITY

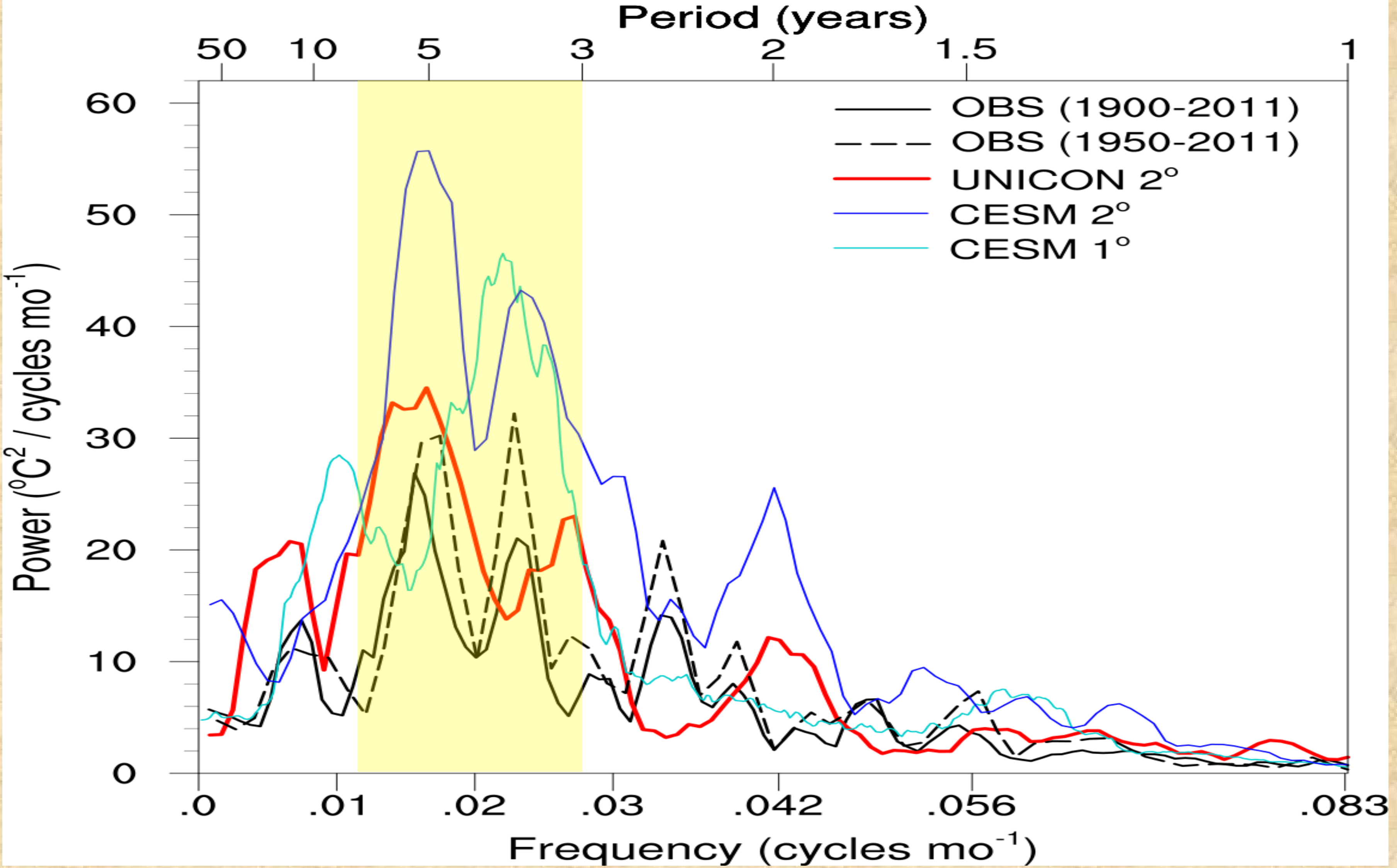
ENSO

Madden-Julian Oscillation

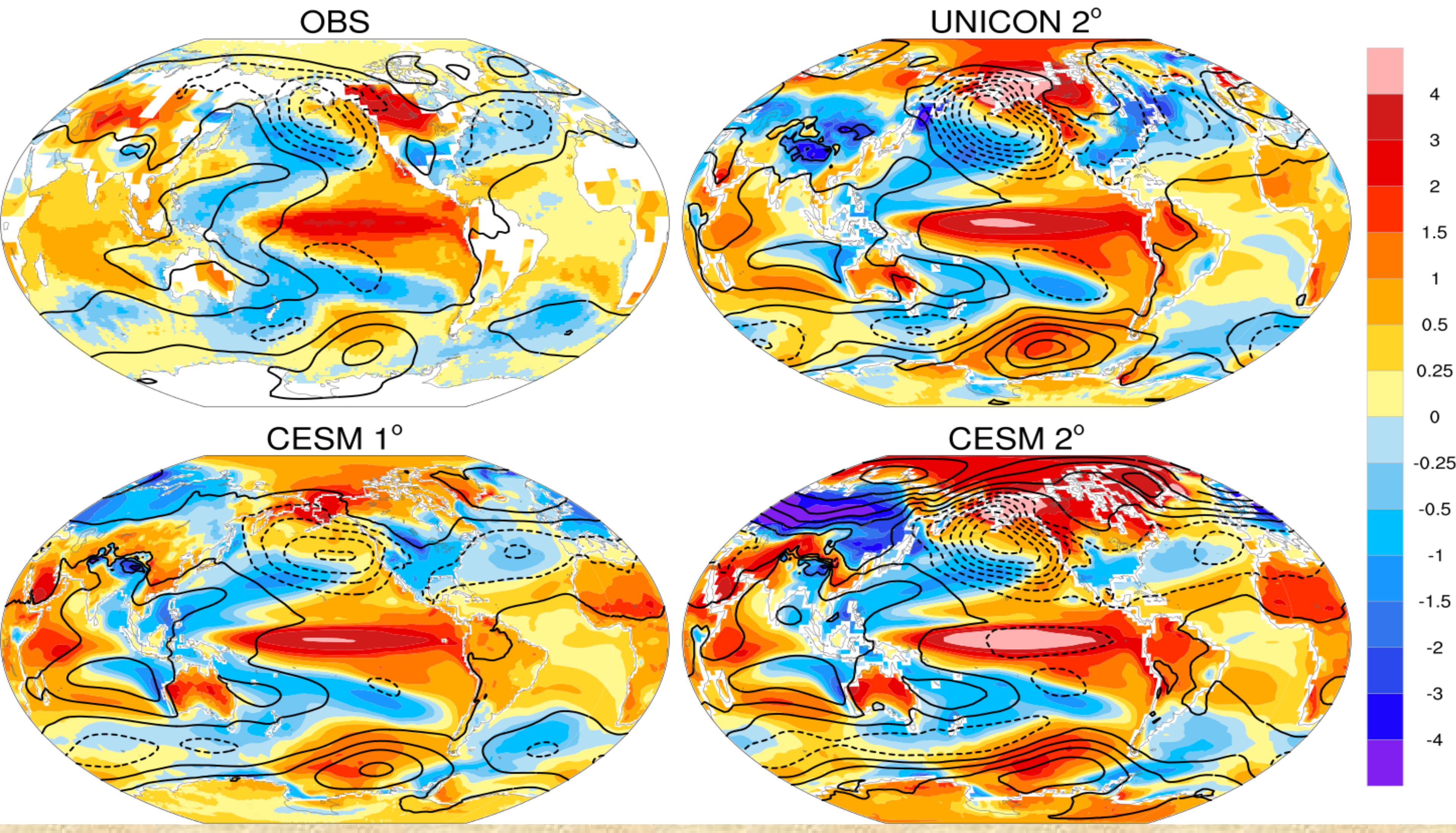
Diurnal Cycle of Precipitation
(1.9^olat x 2.5^olon, 0.95^olat x 1.25^olon)

Tropical Cyclone
(0.95^olat x 1.25^olon)

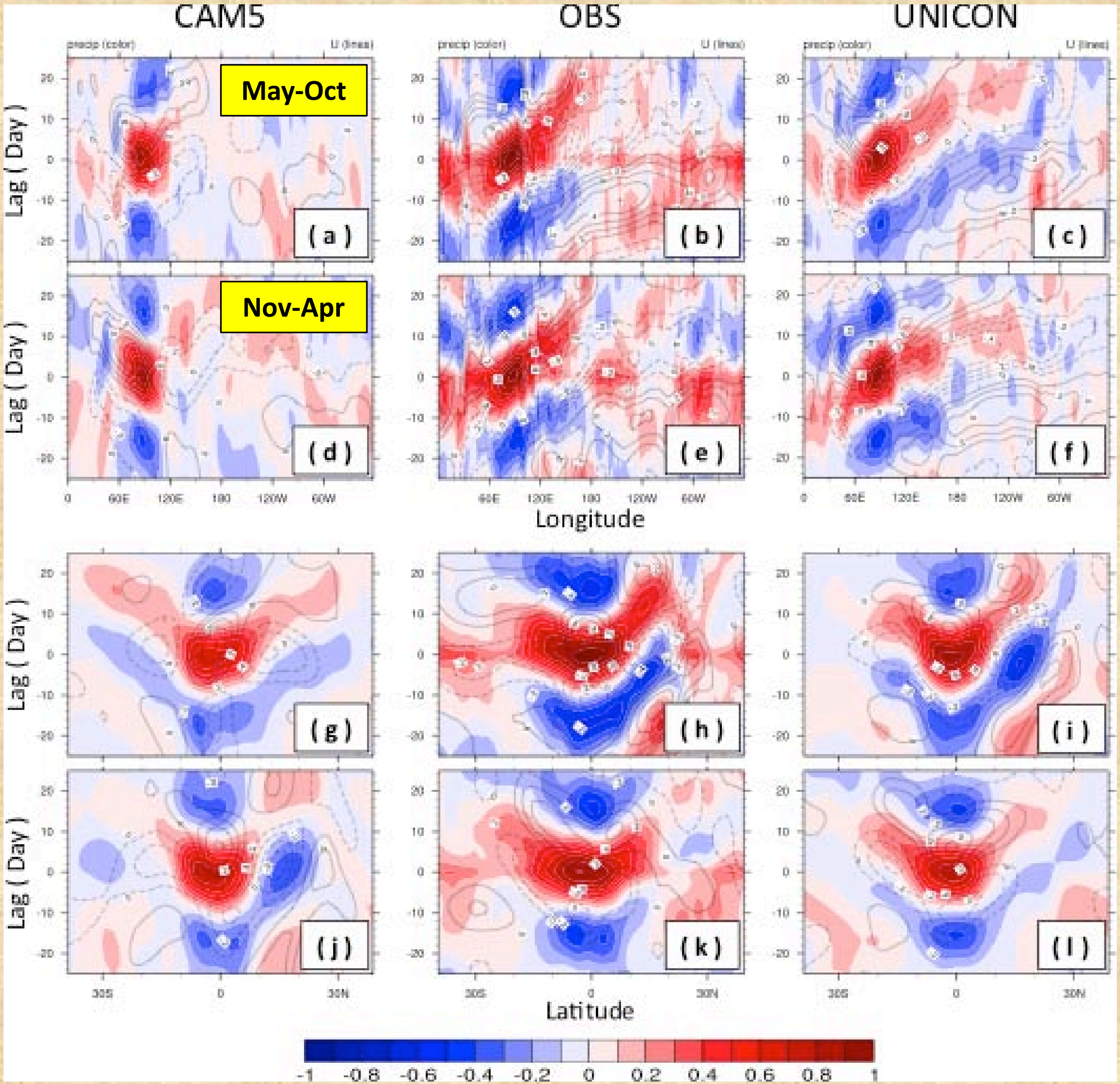
Power Spectrum of Nino3.4 SST. ENSO.



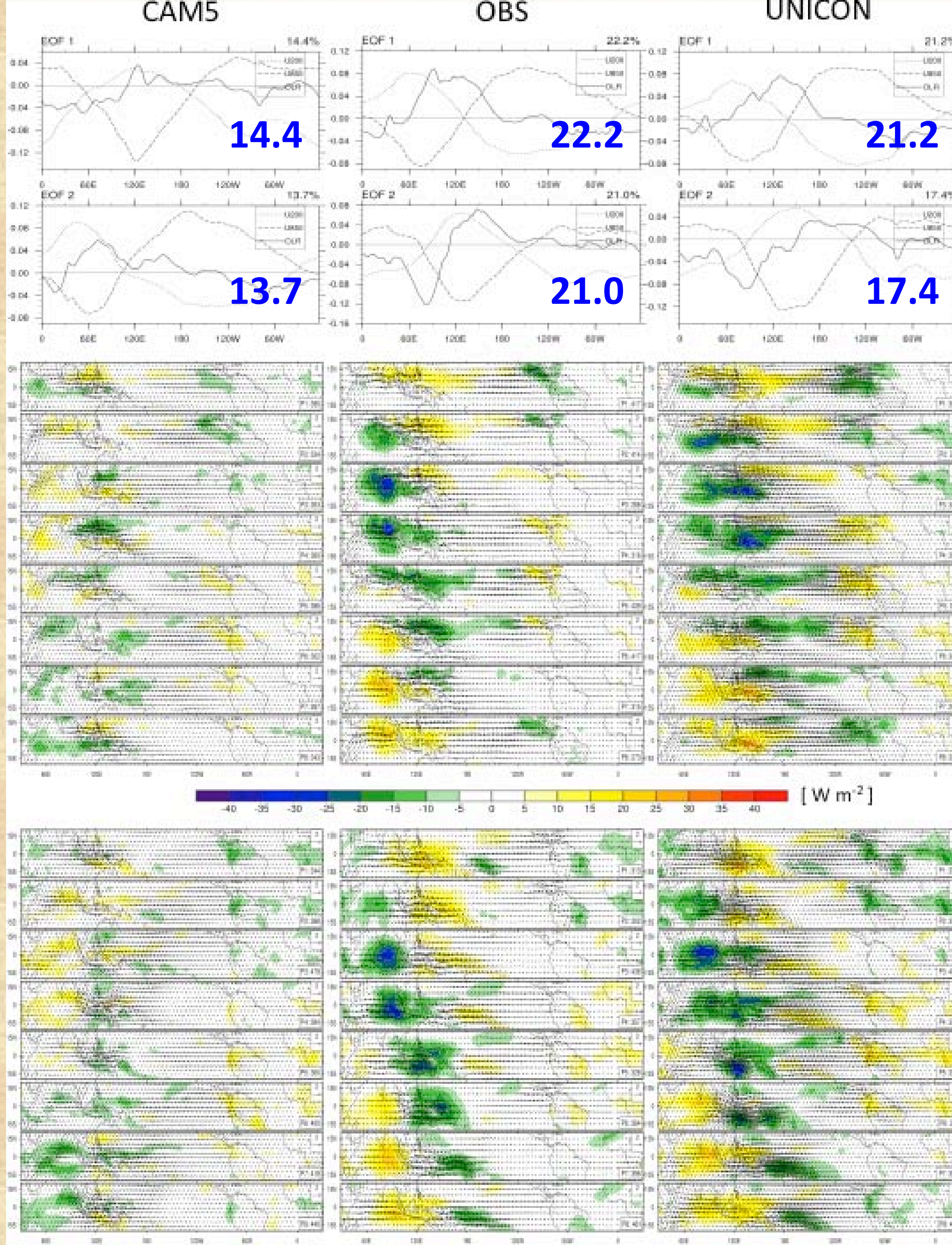
ENSO Composite of TS (Color) and SLP (Line). DJF.



MJO
Lead-Lag Corr.
PRECT & U850



MJO
EOF MODES of OLR, U850, U200



May-Oct

MJO
COMPOSITE LIFE CYCLE

Nov-Apr

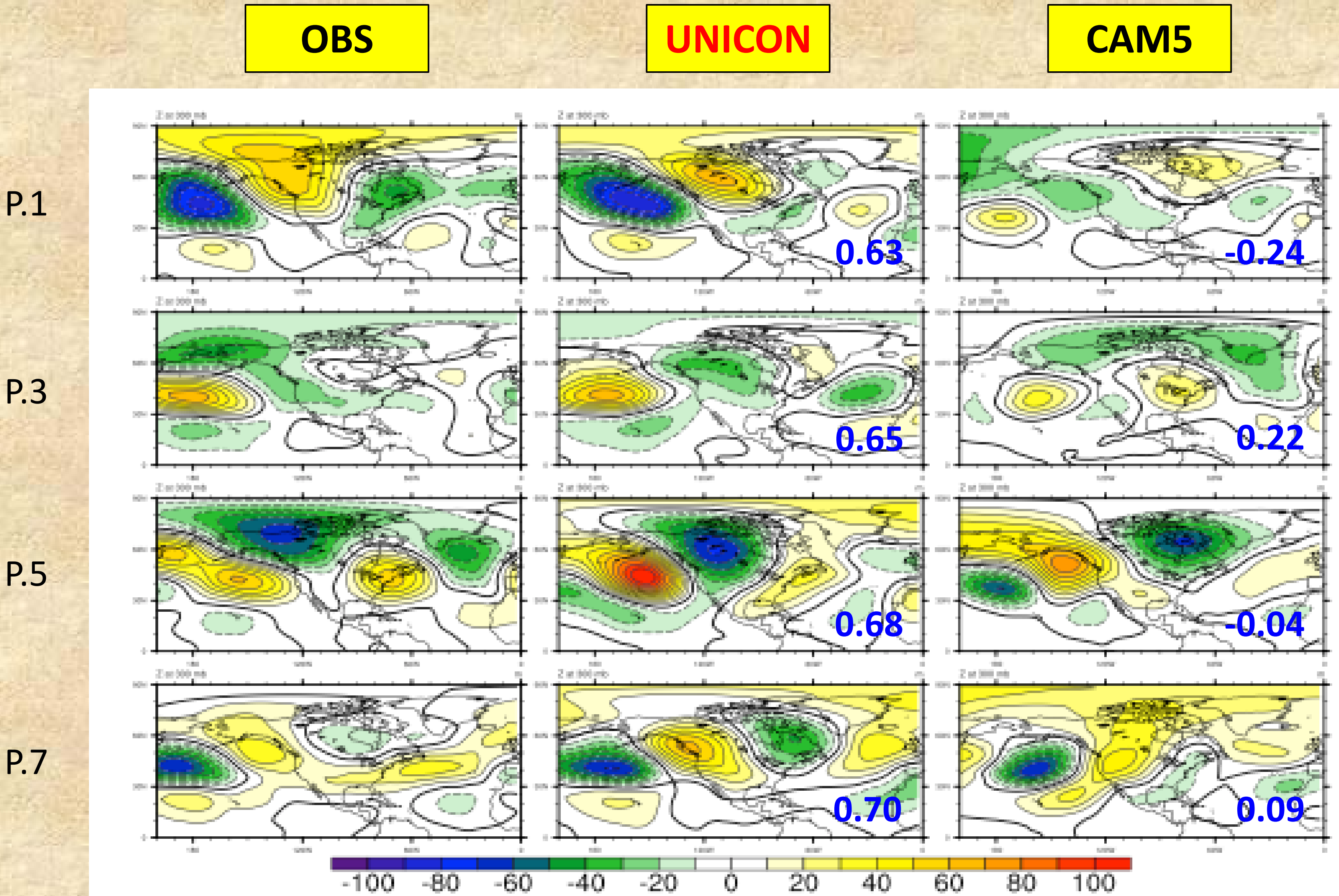


Figure 1: The composites of 300 hPa geopotential height anomalies associated with the MJO phases 1, 3, 5, and 7 (top to bottom) using ERA-interim, UNICON, and CAM (left to right).

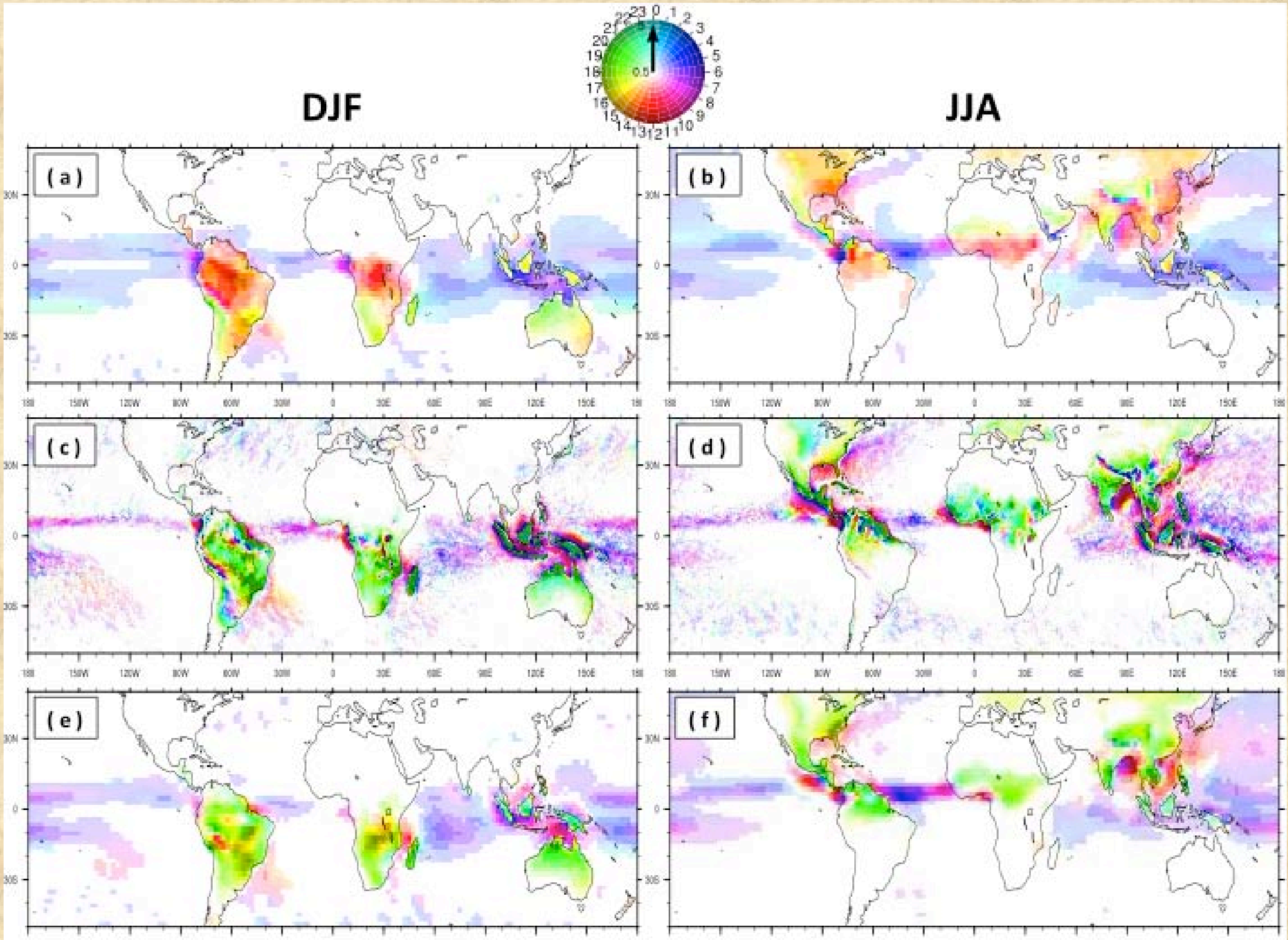
From Dr. Changhyun Yoo at NYU

DIURNAL CYCLE OF PRECIPITATION

CAM5

OBS

UNICON



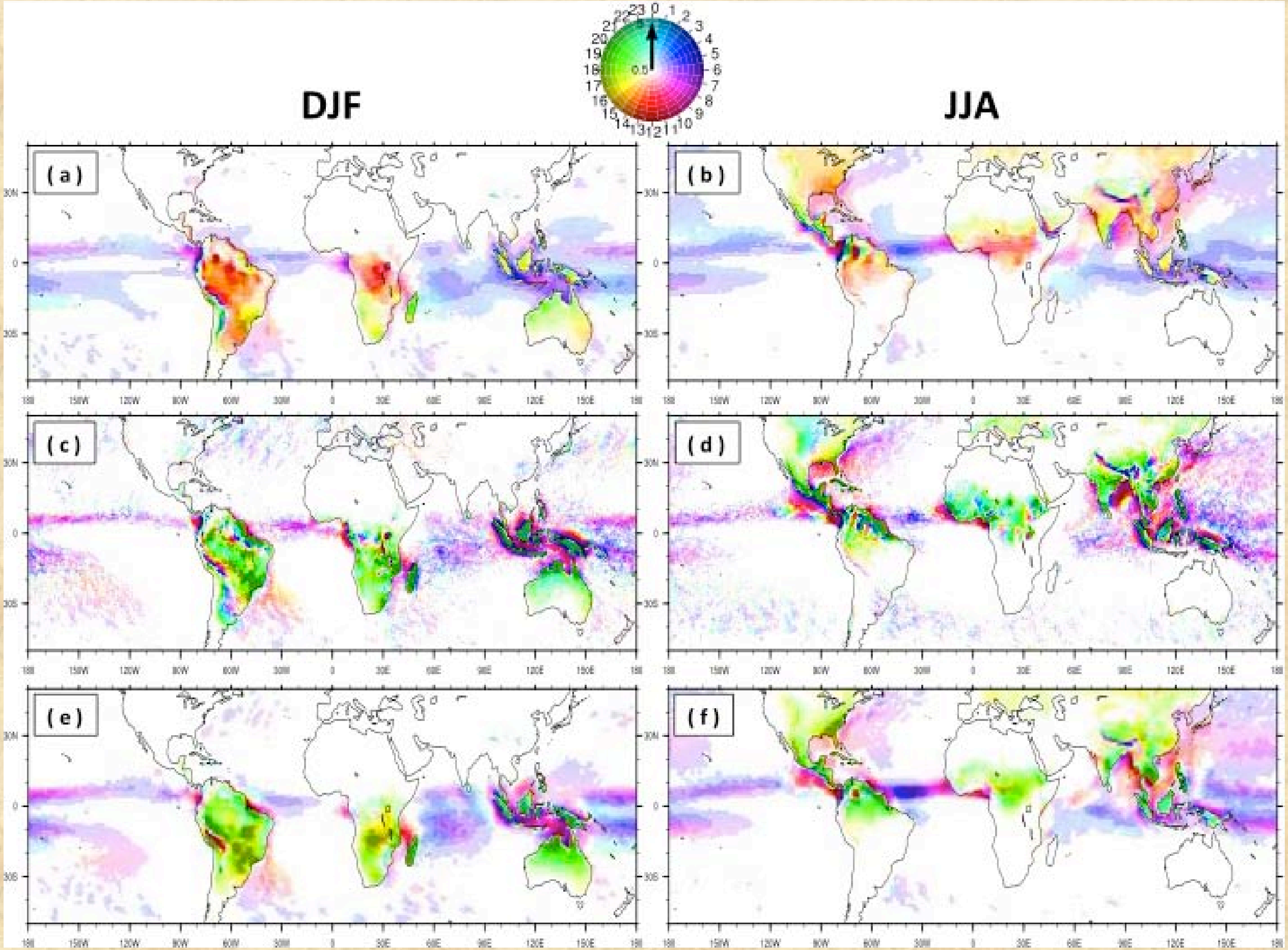
0.95°lat x 1.25°lon

DIURNAL CYCLE OF PRECIPITATION

CAM5

OBS

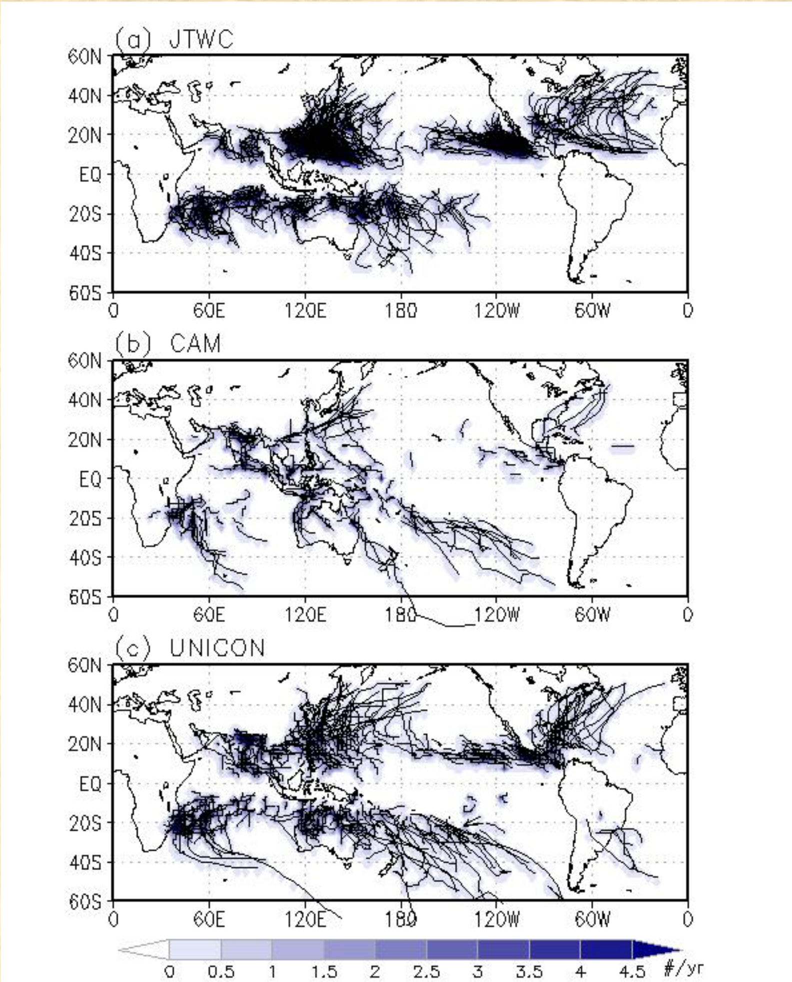
UNICON



Track and Passage FQ

TROPICAL CYCLONE

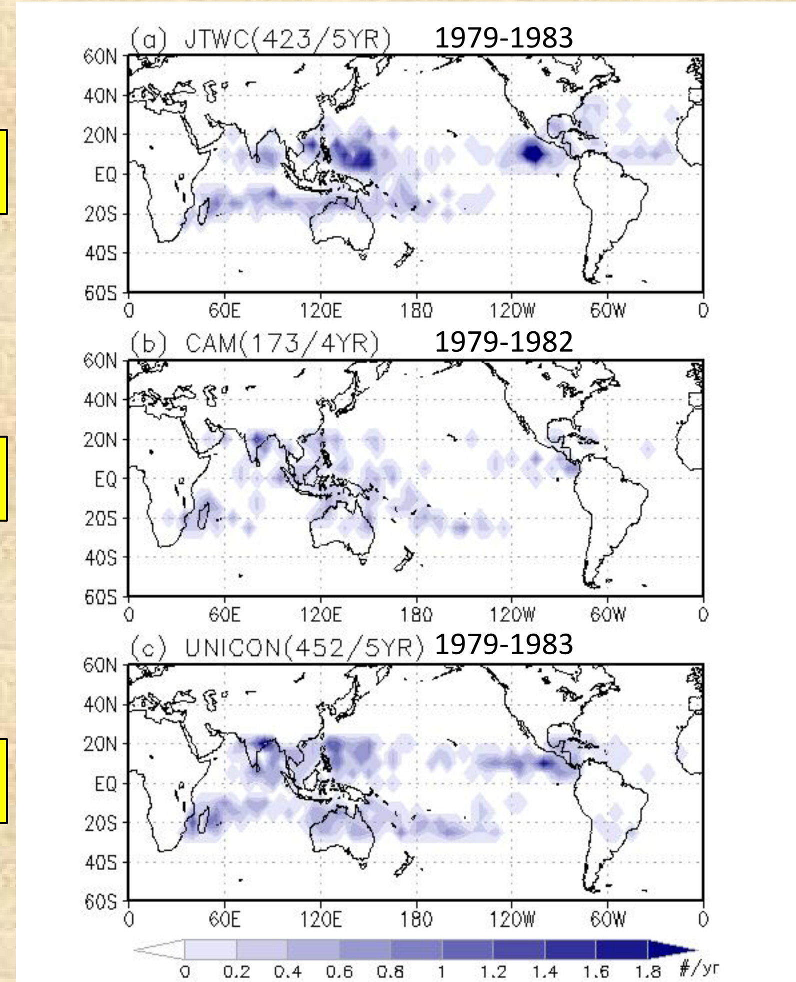
Genesis FQ



OBS

CAM5

UNICON



- Analysis of 6-hrly instantaneous output at 1°lat x 1°lon with the following 3 criteria:

  1. $\zeta_{850} > 12.5\cdot 10^{-5}[s^{-1}]$ 2. $\zeta_{850} - \zeta_{250} > 9\cdot 10^{-5}[s^{-1}]$ 3. Persist at least 2 days
- Averaged over 2.5°lat x 2.5°lon for Track/Passage FQ and 5°lat x 5°lon for Genesis FQ
- Analyzed by Dr. Minho Kwon at KIOST, S. Korea.

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*' (e.g., Seasonal Precipitation, SWCF/LWCF, AOD) and the '*variability*' (e.g., ENSO, MJO, Diurnal cycle of precipitation, Tropical Cyclone) with less sensitivity to G=Δx•⇘y than CAM5.

- On-going work and future plans :
  - Test in "coupled / high-resolution (both in Δx•⇘y and Δz)" configuration.
  - Improve computational efficiency (currently, 50% more time than CAM5).
  - Efforts will be continued to meet the requirements described in the CAM development protocols (e.g., update to the recent tag, 50-yrs 1850 coupled simulation, energy balance, Climate Error Score, etc.).
  - Develop a new double-moment cumulus microphysics interacting with aerosols.

Common Mis-Understanding

- UNICON + High-Order Turbulent Closure Model ?
  - A non-scientific approach due to apparent *double counting.*
  - For scale-adaptive parameterization, this approach should be avoided.
  -
- UNICON + Prognostic Microphysics ?
  - A non-scientific approach because UNICON is a *diagnostic plume* model.
  - This will generate energy and moisture conservation errors.
- A convective scheme allowing updraft fractional area to approach to 1 ?
  - Valid only when the convection scheme is prognostic.
  - With a diagnostic plume model, this approach is not correct.
- Is a sub-column generator necessary for the scale-adaptive parameterization ?
  - No.
  - Scale-adaptivity is determined by the way how to compute '*sub-grid variance/covariance*' *not by the way how to construct a set of sub-columns from a given 'sub-grid variance/covariance'.*

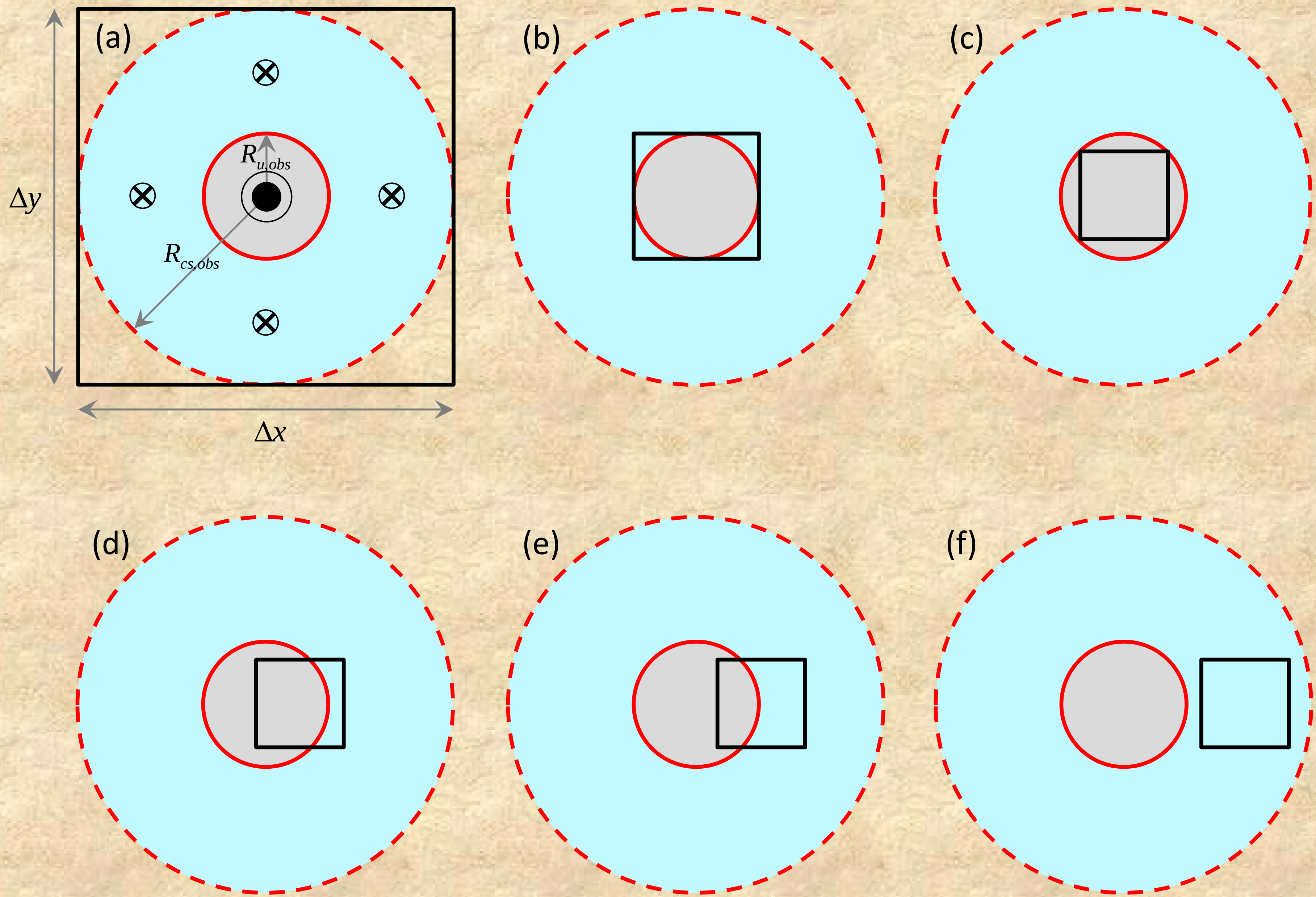
SCALE ADAPTIVITY

DEFINITION

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.



(a)
$R_{u,obs}$
$R_{cs,obs}$
Δy
Δx
(b)
(c)
(d)
(e)
(f)