The Cumulus Parameterization Problem in the Context of MJO Simulations

by

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ECMWF Collaboration with

Peter Bechtold, Adrian Tompkins

&

Thanks to Anton Beljaars

Outline

Overview:

Cumulus Parameterization Problem

MJO Identification

(with Adrian Tompkins, Peter Bechtold)

Global Analysis (ECMWF Model)

(with P. Bechtold, J.Y. Grandpeix, I. Musat)

Convective-Scale Analysis

(with J.P. Chaboureau, F. Guichard)

Data Sets: TOGA-COARE Period

(1 Sept. 1992 – 28 Feb. 1993)

- **Observation: ERA40 Reanalysis**
  (12 hourly-data averaged over a day)
  (precipitation from 12-36 h forecasts)
- **ECMWF Model (3 ensemble runs):**
  6 months: T95 (200km):
  IFS cycle 26R3 with analyzed SST
  (precipitation: from a single run)
- **CRM Experiments:** Three 5-day periods:
  2D, ~100 km domain: T95 (200km):

Cumulus Parameterization Problem

CISK or WISHE

(moisture) ? (CAPE

i.e., energetics)

Quasi-Equilibrium

(Quasi-Stationairy Balance)

or

Self-Criticality

(1/f-Noise)

?

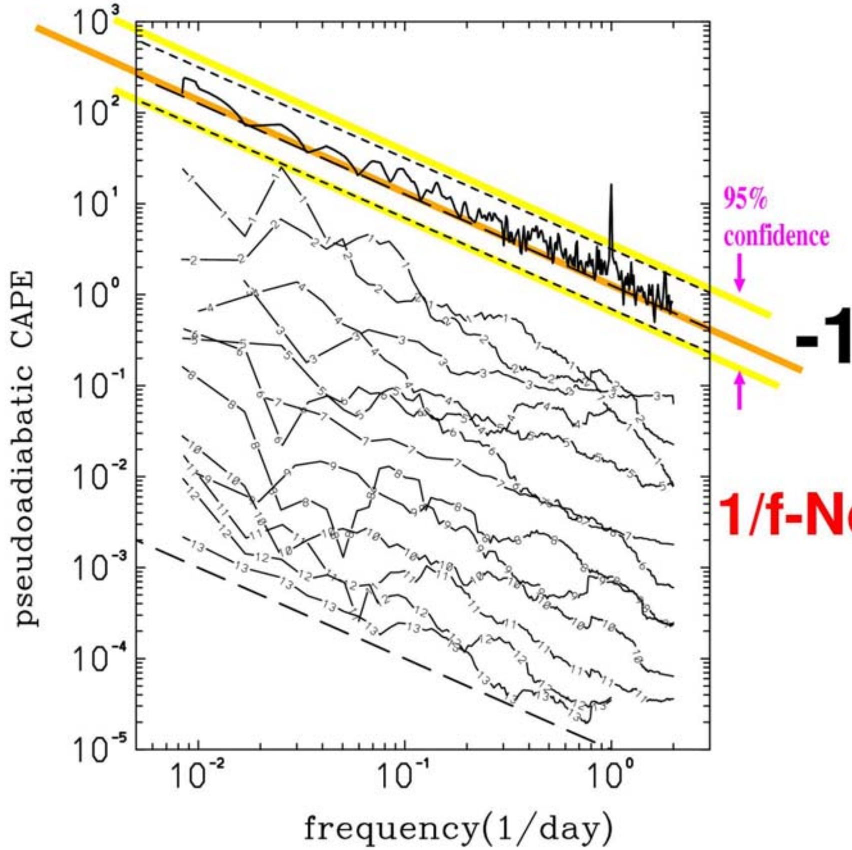
Tropical Convective Variability

Tropical Western Pacific Observations

(TOGA-COARE)

Frequency-Spectra of CAPE:

(Degree of Convective Instability



1/f-Noise

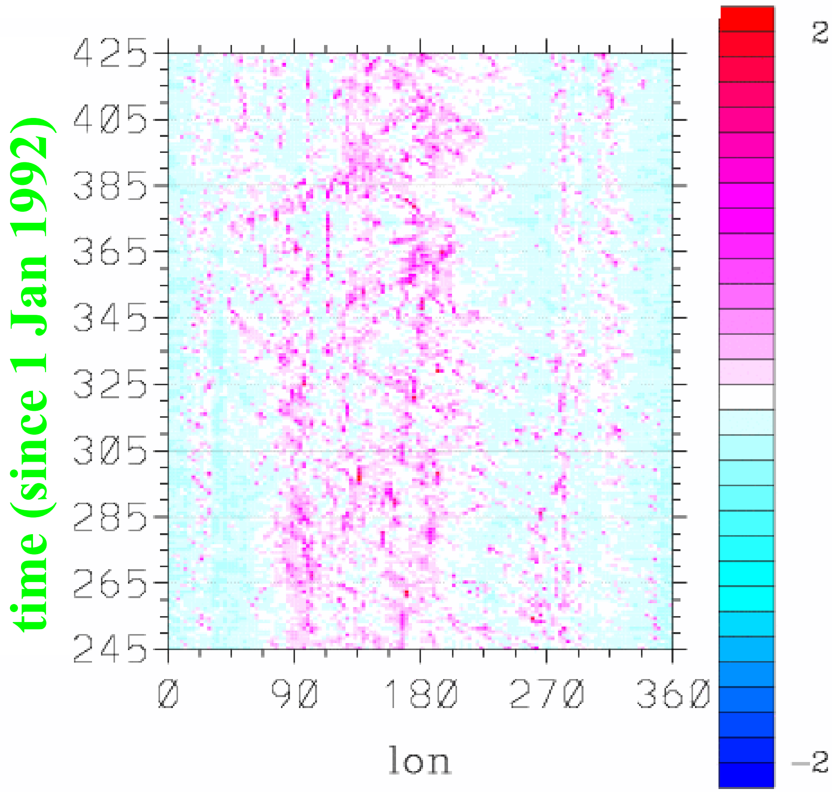
Self-Criticality ?

(Yano, Fraedrich, Blender 2001)

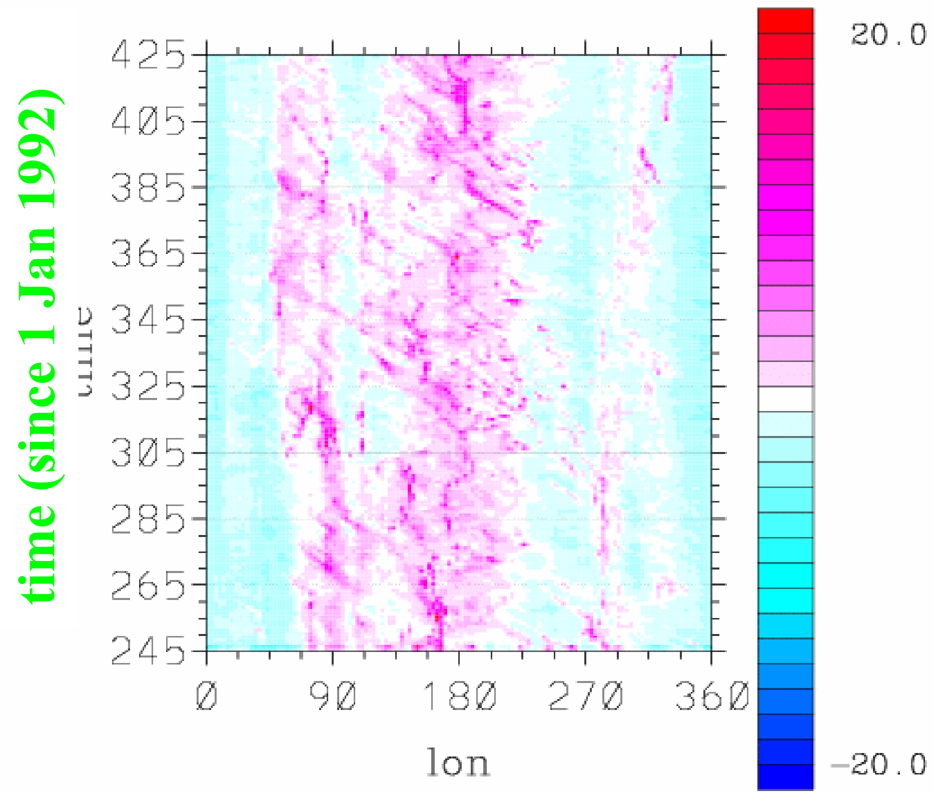
MJO in TOGA-COARE Period

Precipitation, 20S-20N

Global Analysis: ERA40



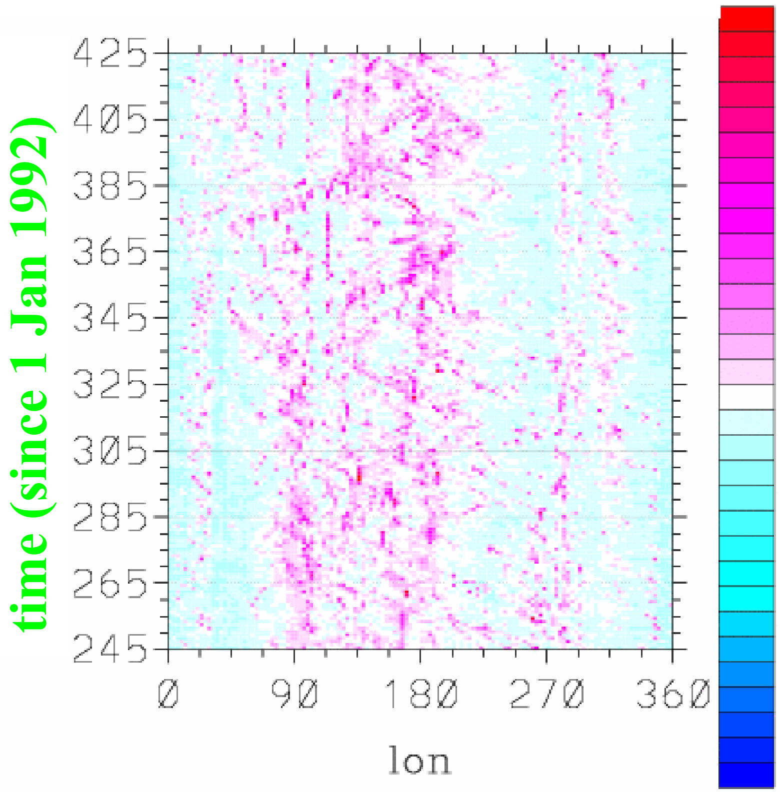
Model Forecast: IFS 26R3



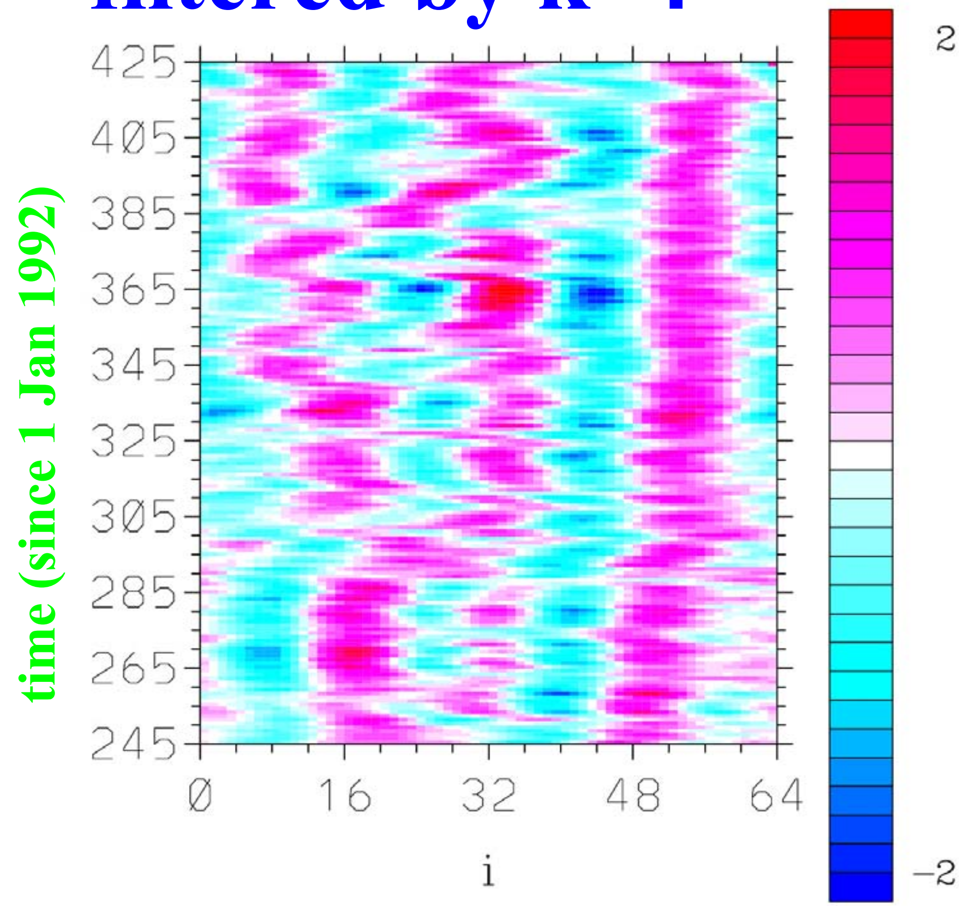
MJO in TOGA-COARE Period

Precipitation, 20S-20N

Global Analysis: ERA40



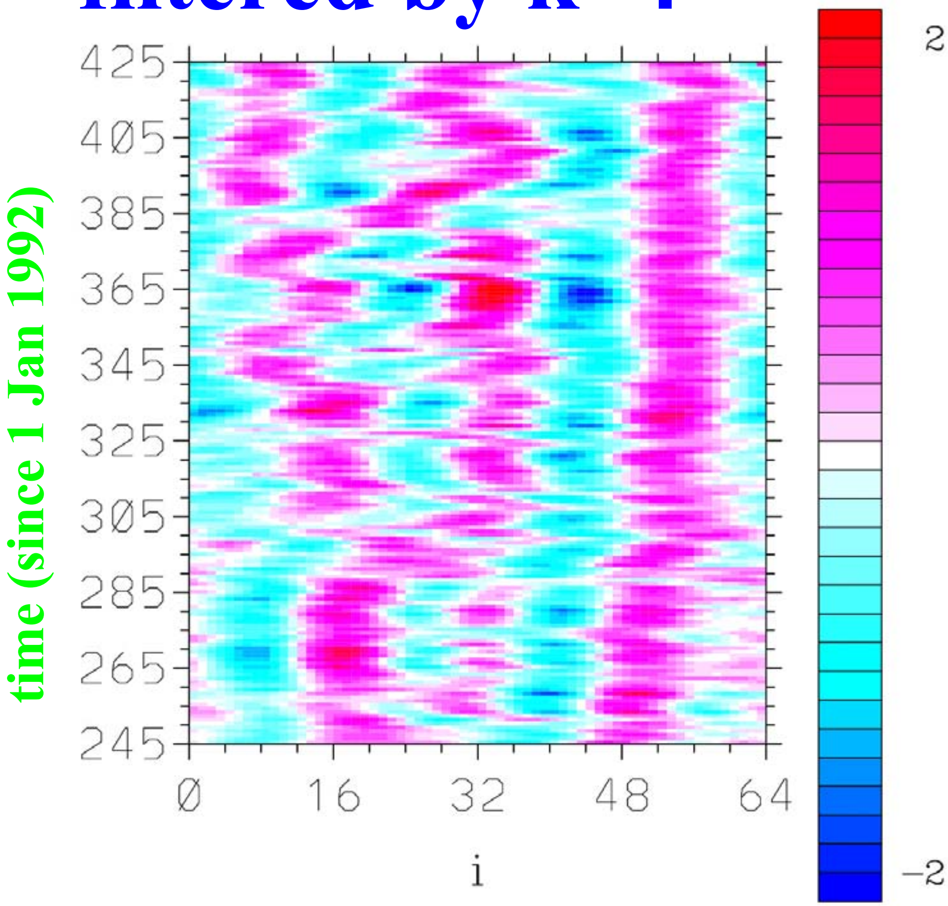
Global Analysis: filtered by k=4



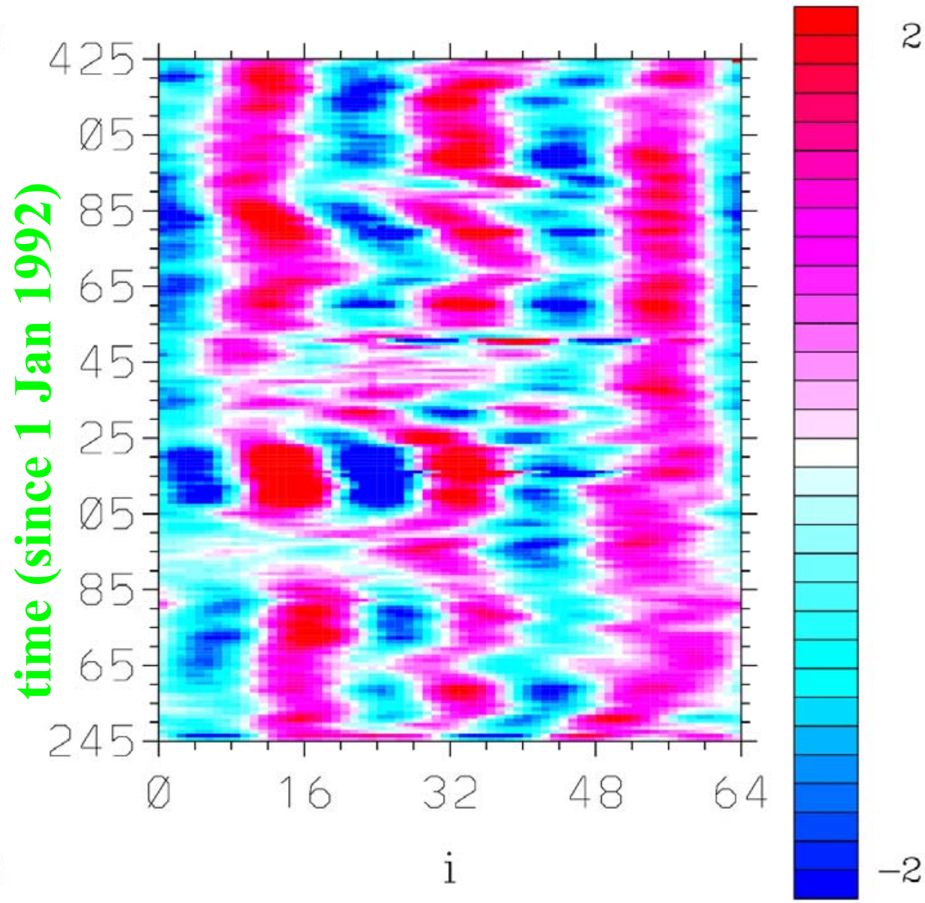
MJO in TOGA-COARE Period

Precipitation, 20S-20N

Global Analysis: filtered by k=4



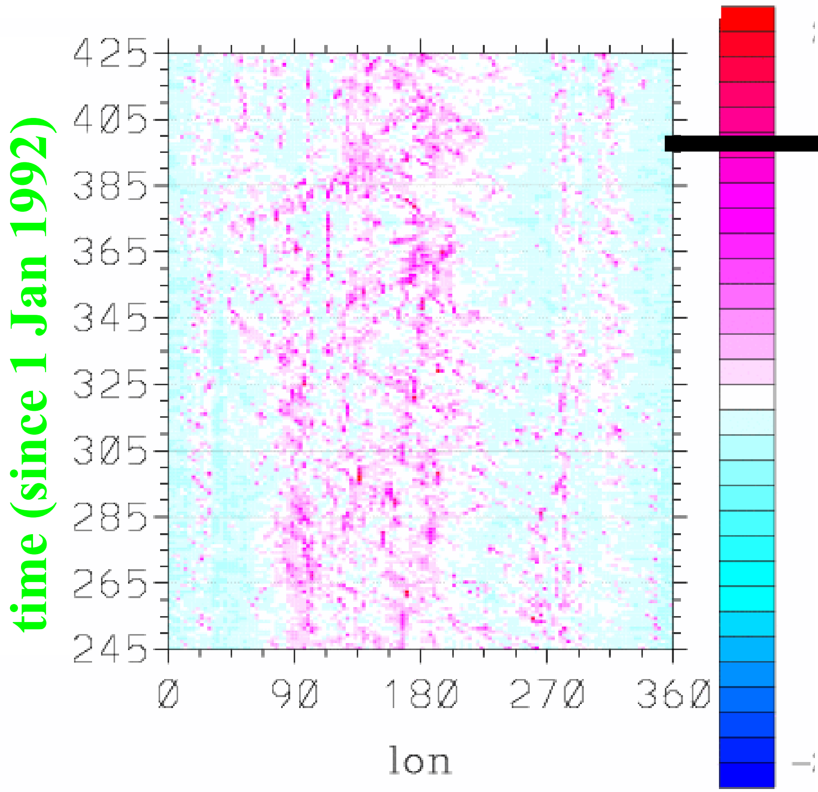
Global Forecast: filtered by k=4



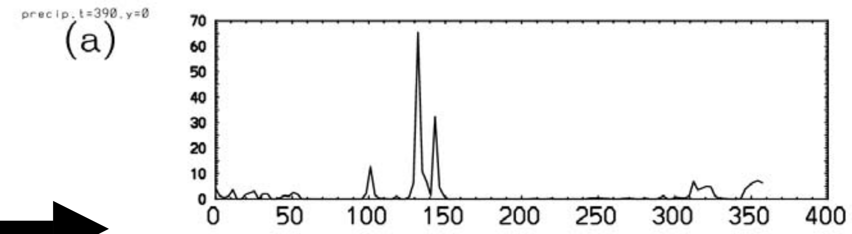
MJO in TOGA-COARE Period

Precipitation, 20S-20N

Global Analysis: ERA40



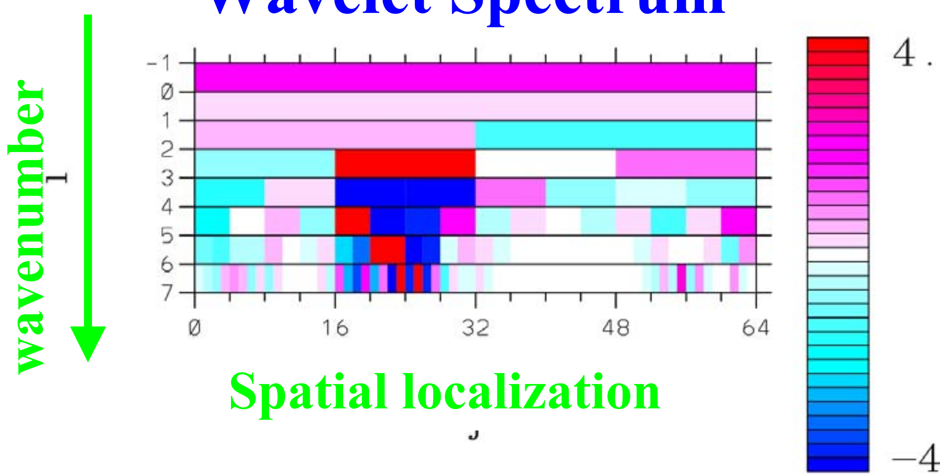
Precipitation (mm/day)



longitude

t= 390, y = 0

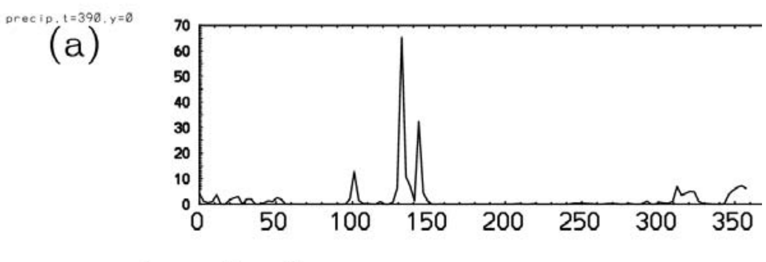
Wavelet Spectrum

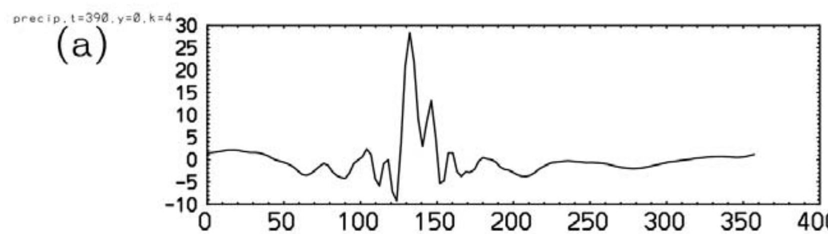


Spatial localization

MJO in TOGA-COARE Period

Precipitation (mm/day), t=390,Equator



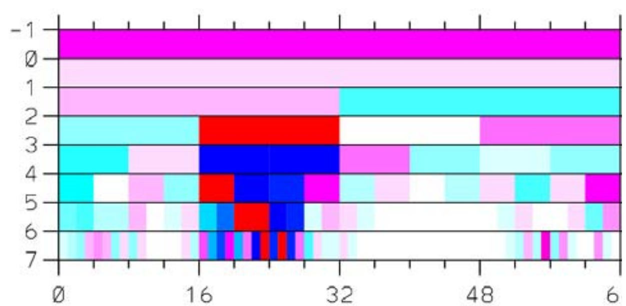


longitude

longitude

Total → **k=4-pulse**

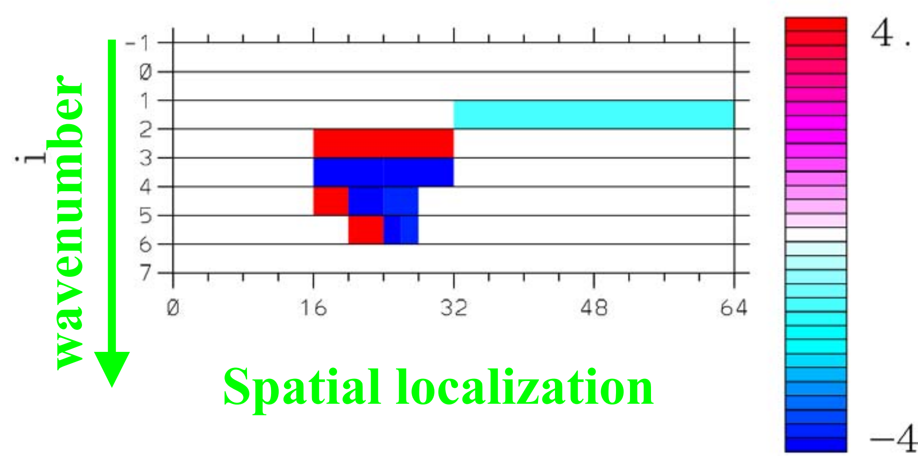
Wavelet Spectrum



wavenumber

Spatial localization

Wavelet Spectrum



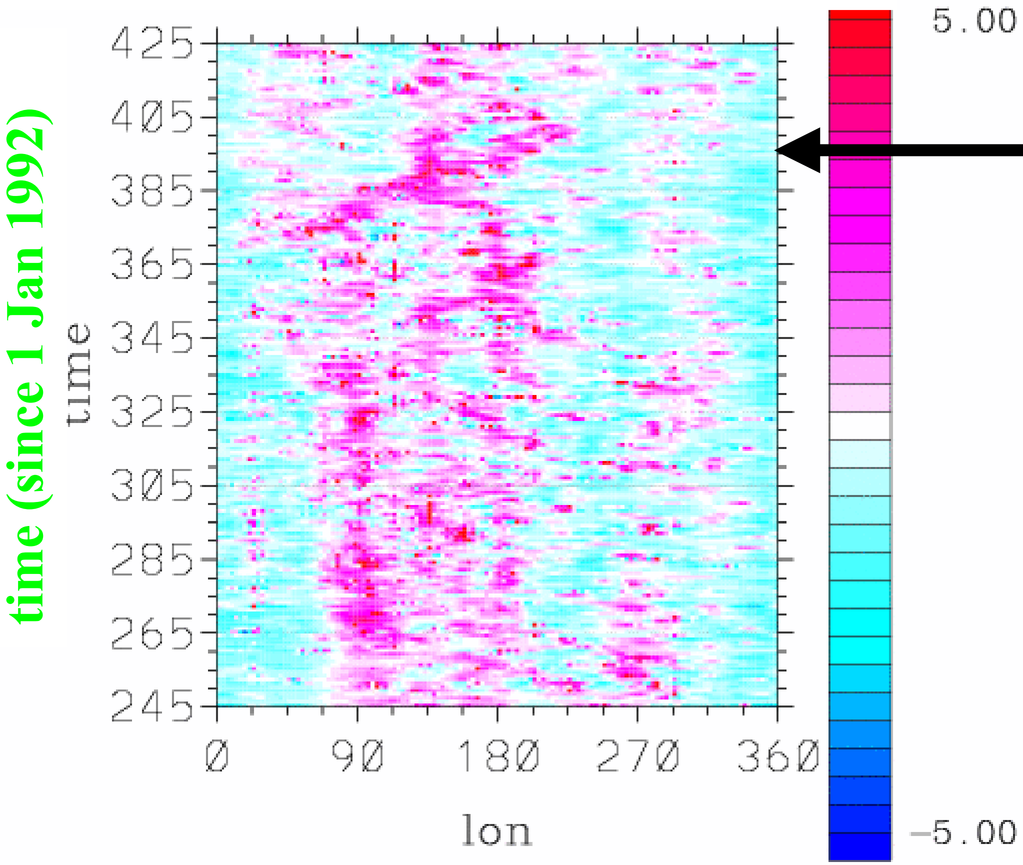
wavenumber

Spatial localization

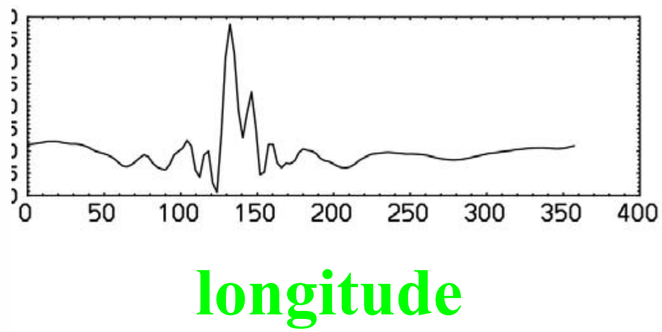
MJO in TOGA-COARE Period

Precipitation, 20S-20N

Global Analysis:
ERA40 (pulse k=2-8)

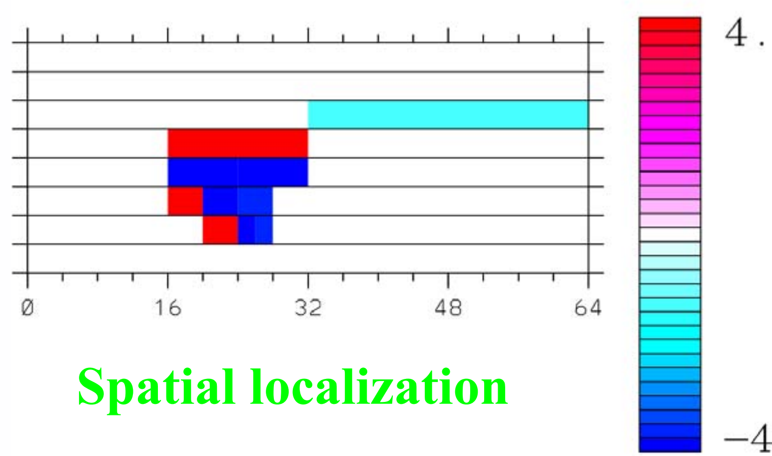


Precipitation (mm/day), t=390,y=0



4-pulse

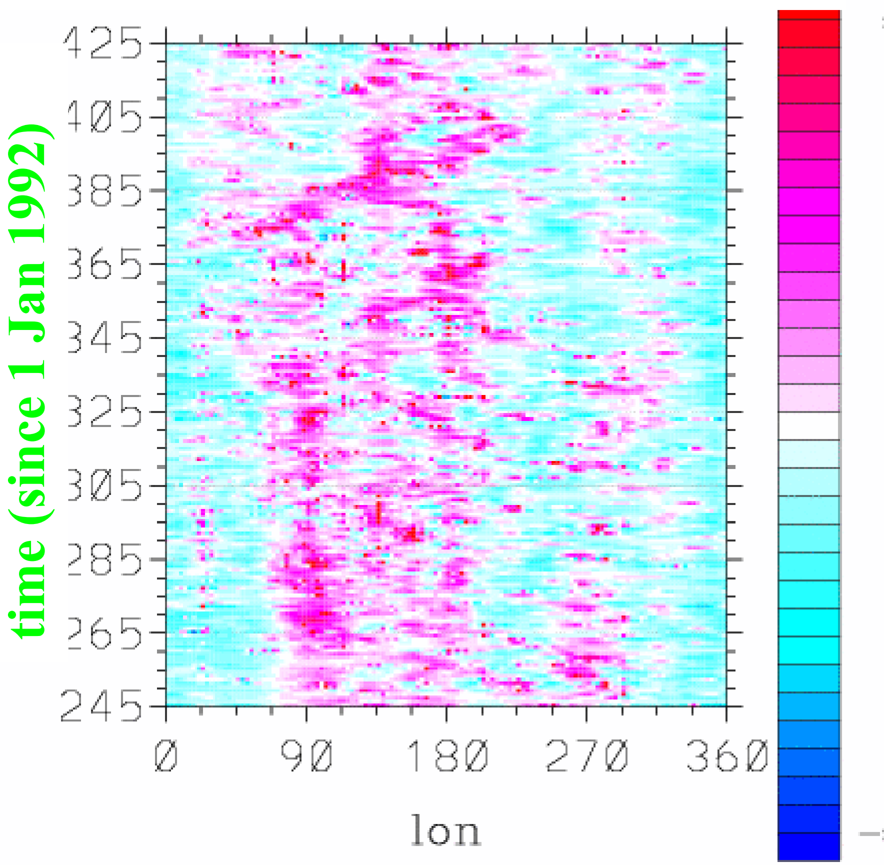
Wavelet Spectrum



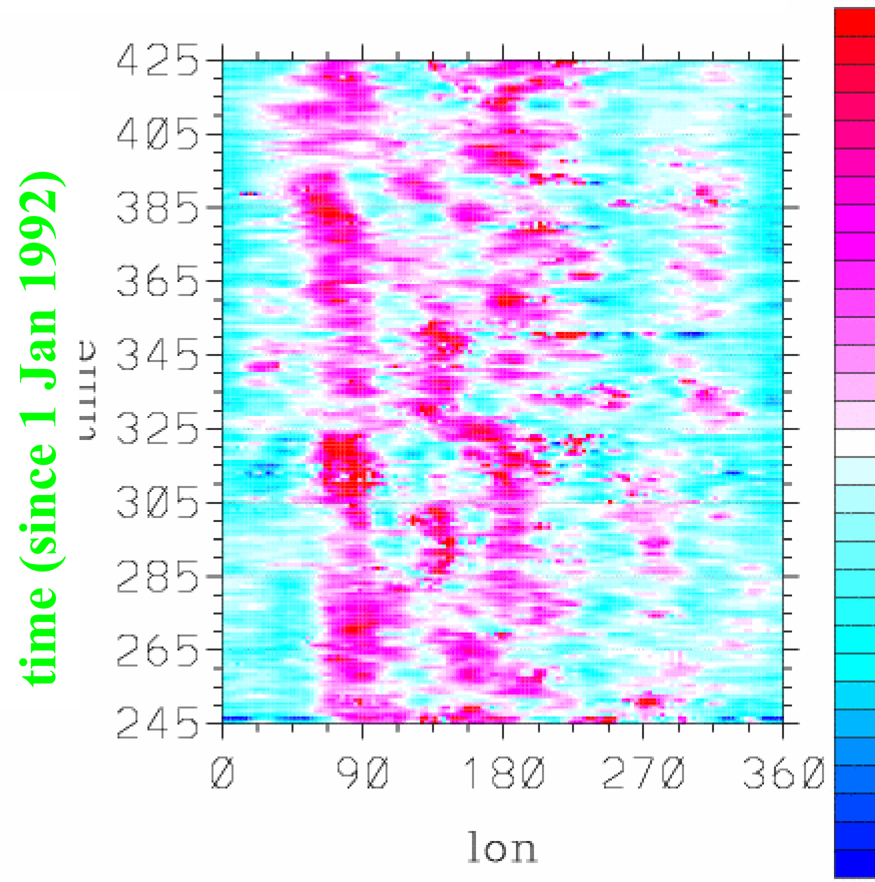
MJO in TOGA-COARE Period

Precipitation, 20S-20

Global Analysis: ERA40 (pulse k=2-8)



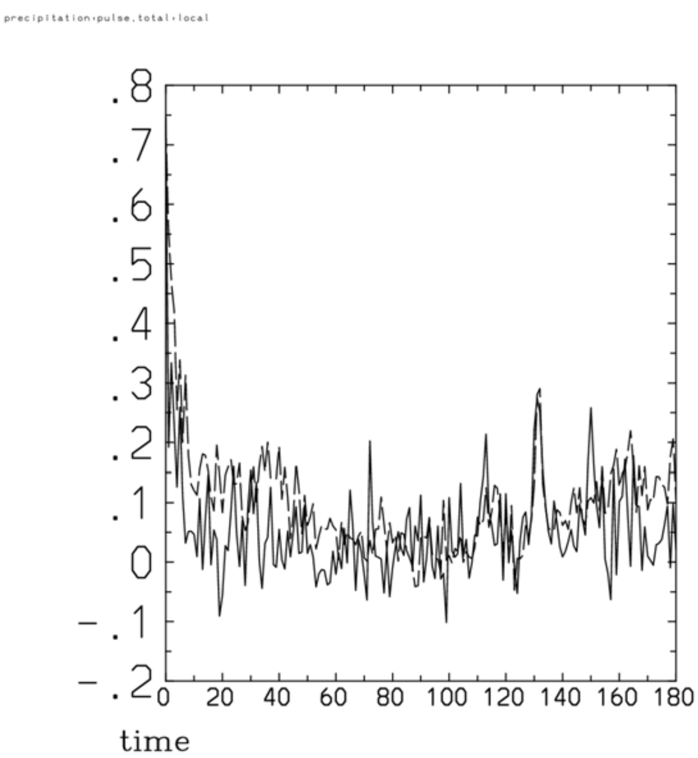
EC Model Forecast: 26R3 (pulse k=2-8)



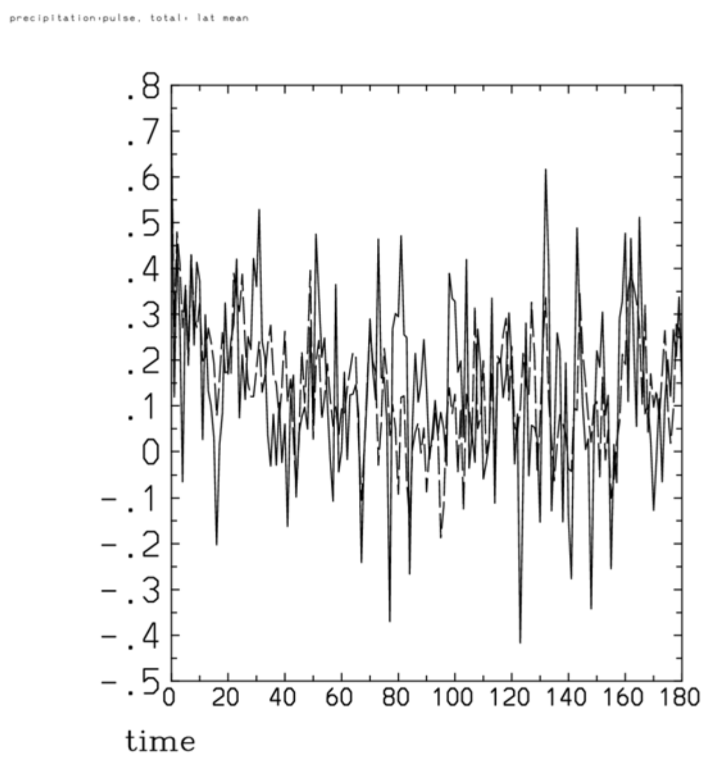
MJO in TOGA-COARE Period

Precipitation, 20S-20N: Correlation

Local

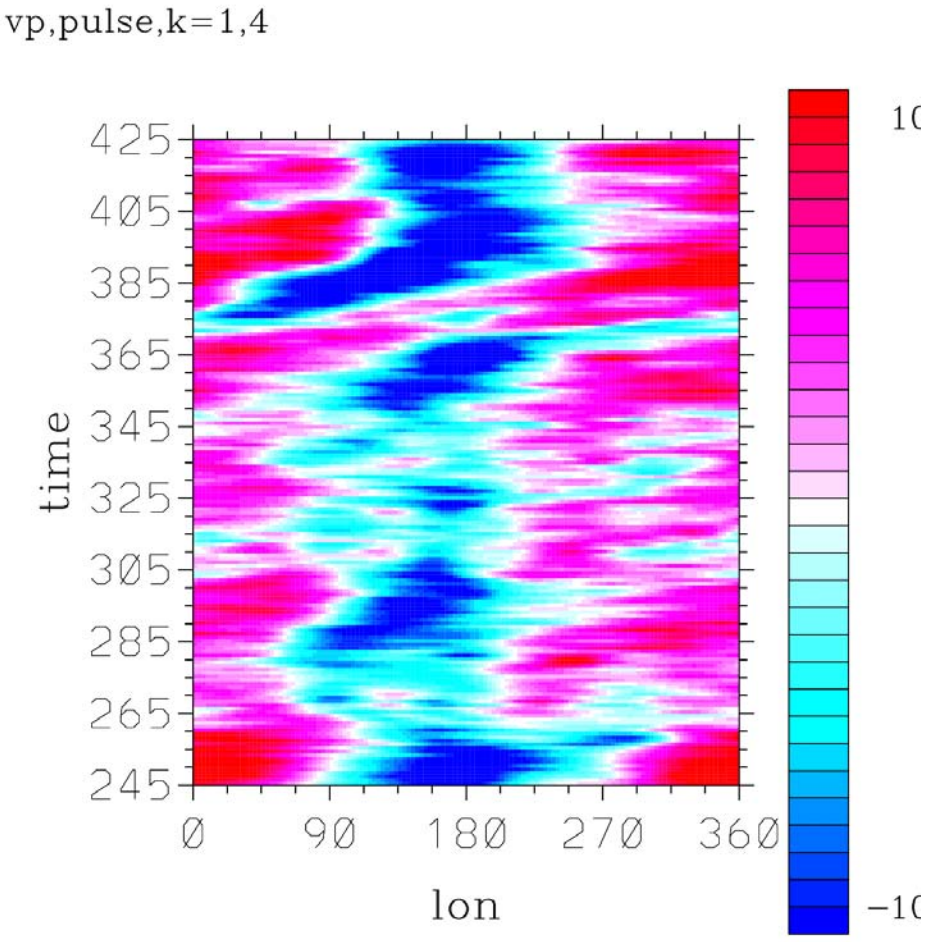


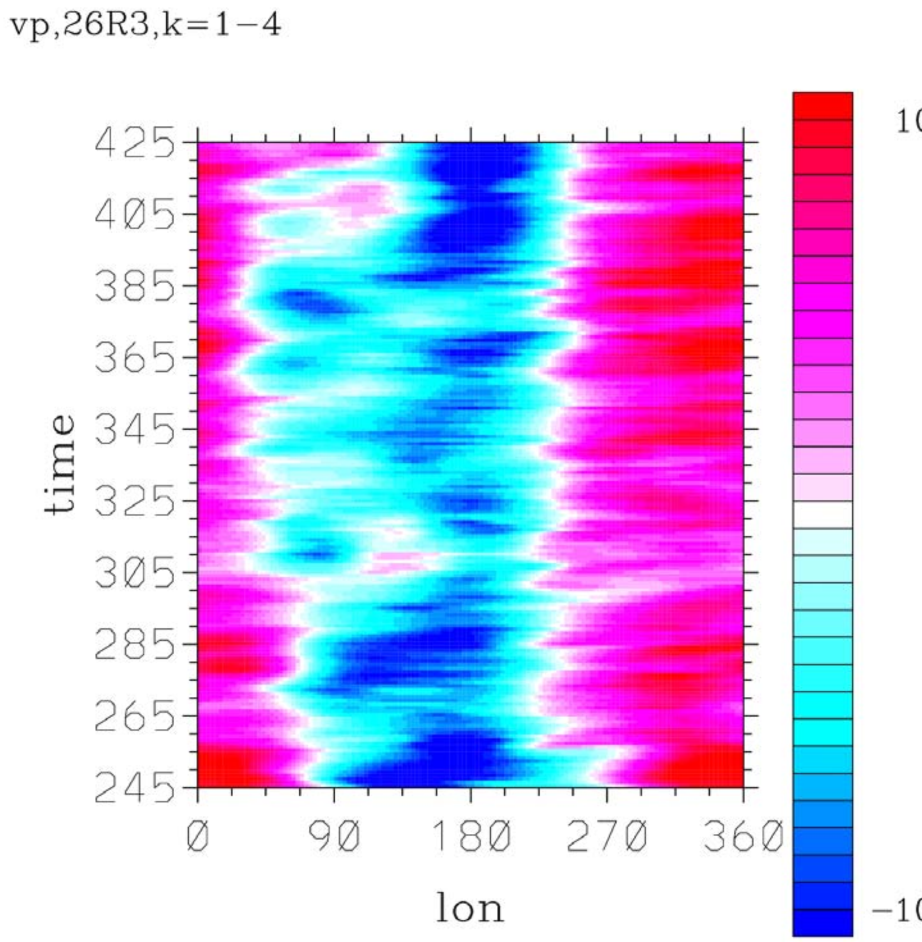
mean



MJO in TOGA-COARE Period

Velocity Potential, 20S-20N

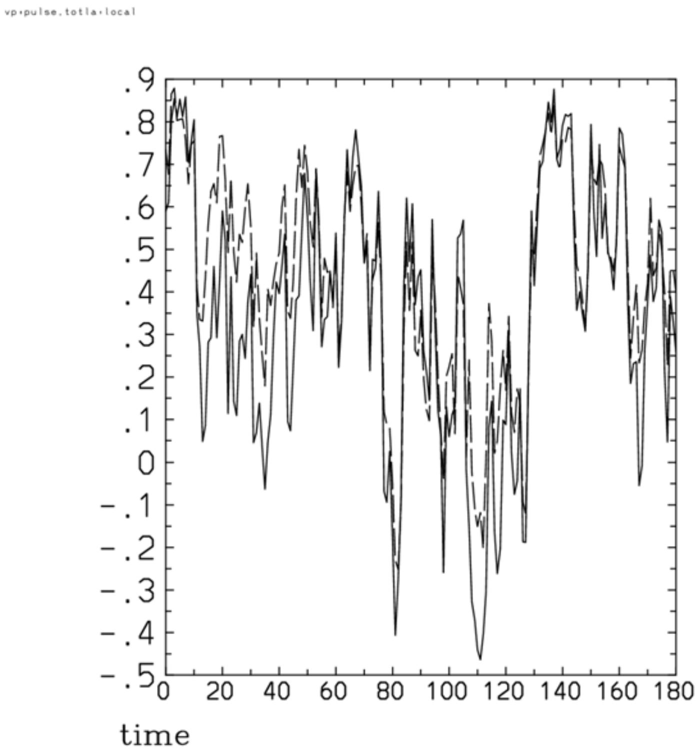




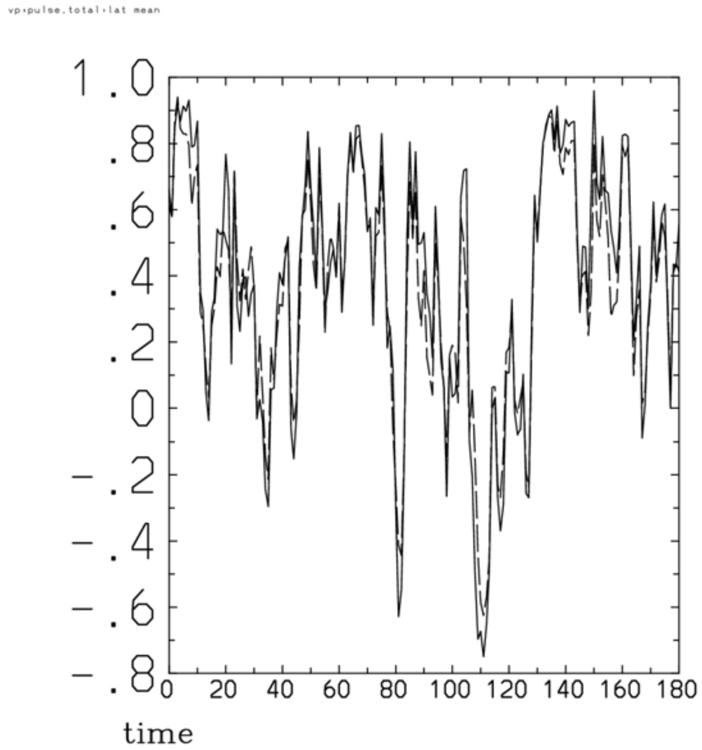
MJO in TOGA-COARE Period

Velocity Potential, 20S-20N: Correlation

Local

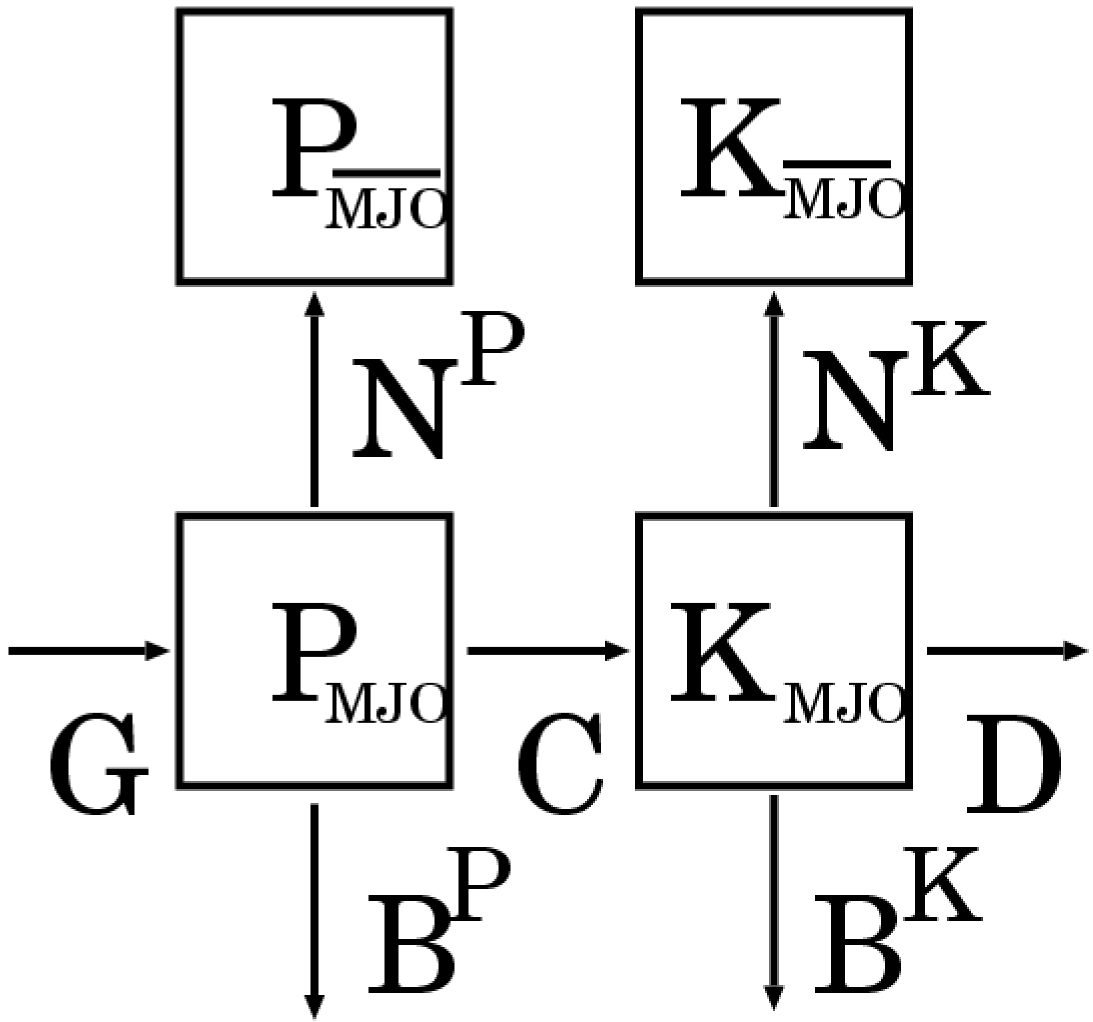


Latitudinal mean



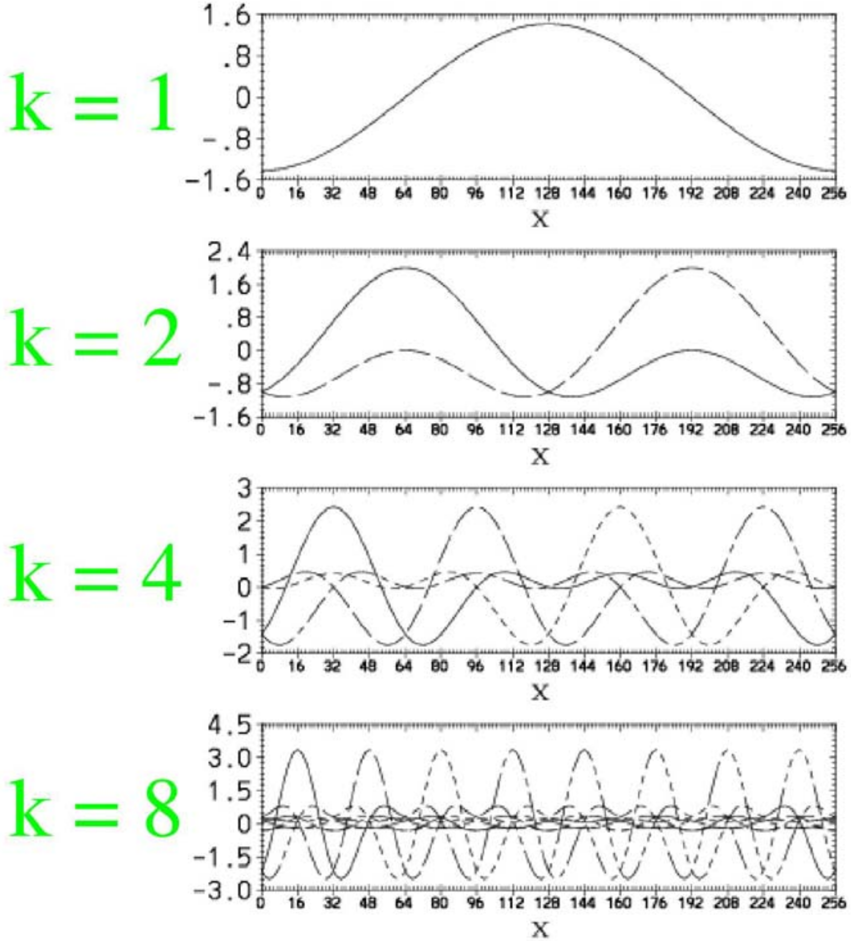
How MJO is maintained?:

Energy-Cycle Analysis



Discrete orthogonal Wavelets

(Meyer) : complete set

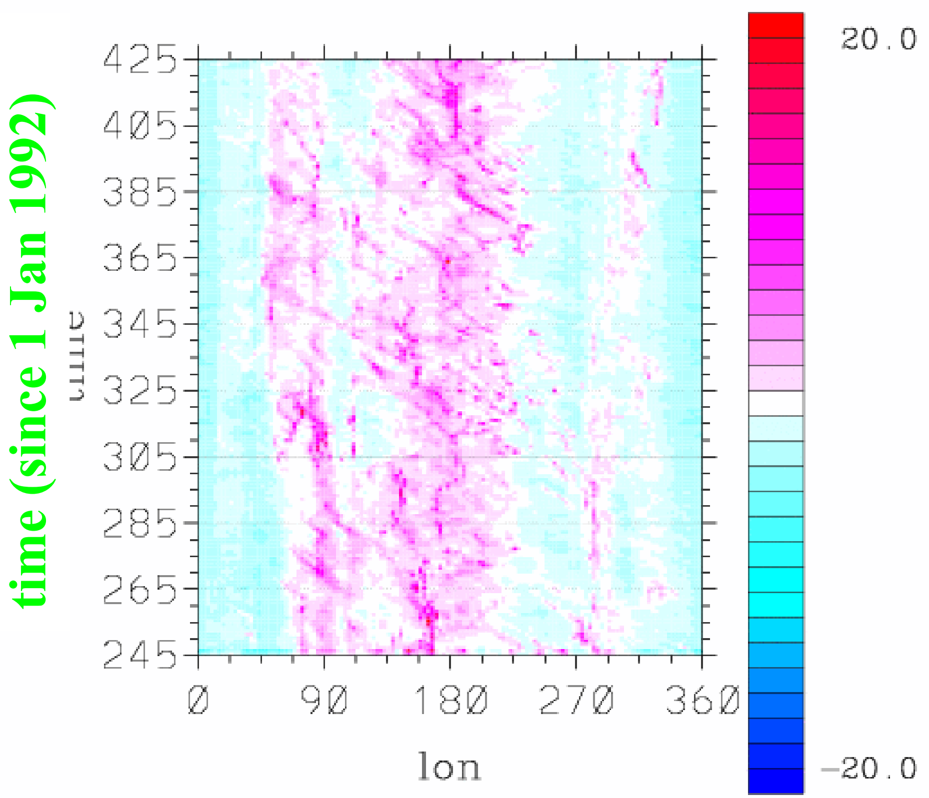


MJO in TOGA-COARE Period

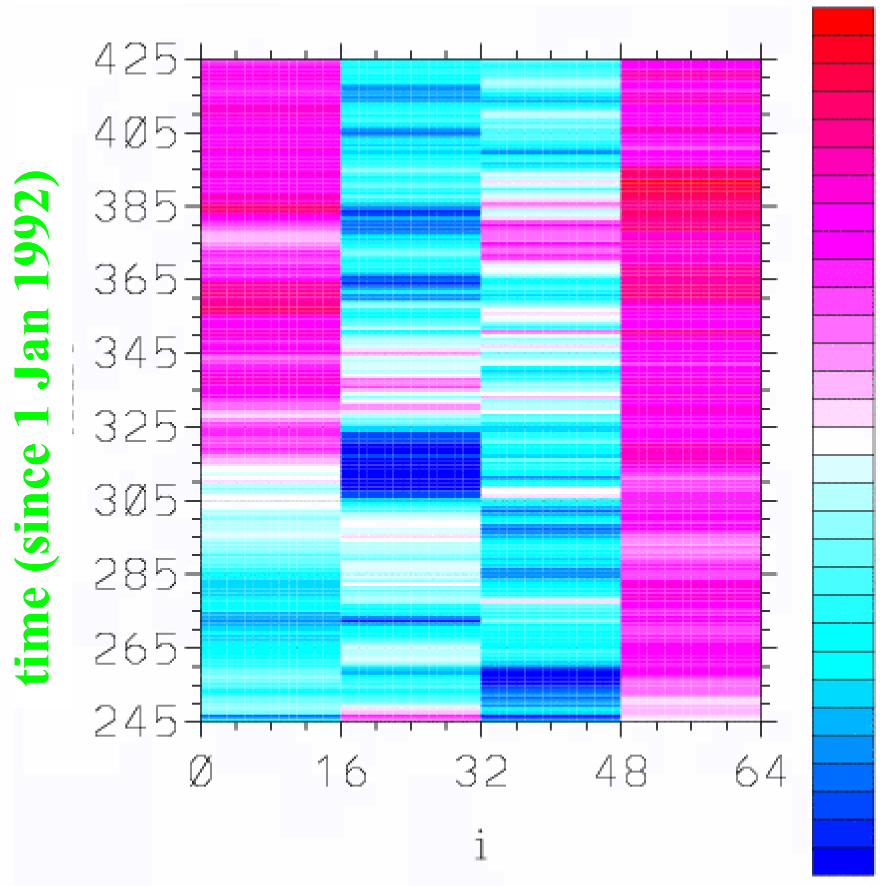
ECMWF Model Forecast:

Precipitation, 20S-20N

real space



wavelet spectrum (k = 4)

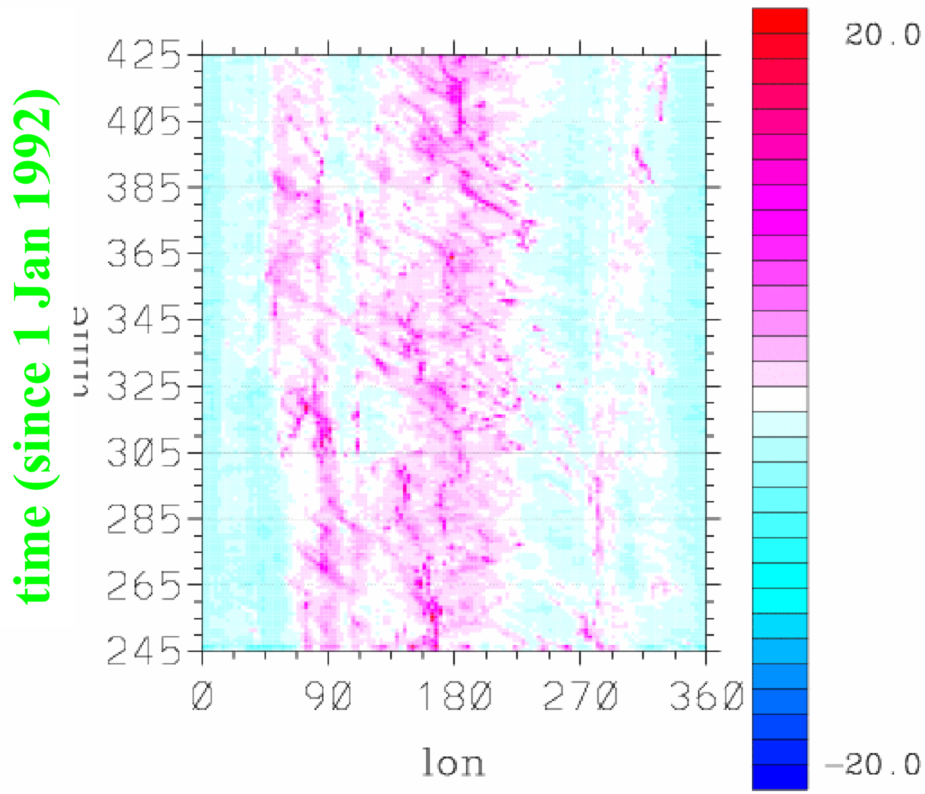


MJO in TOGA-COARE Period

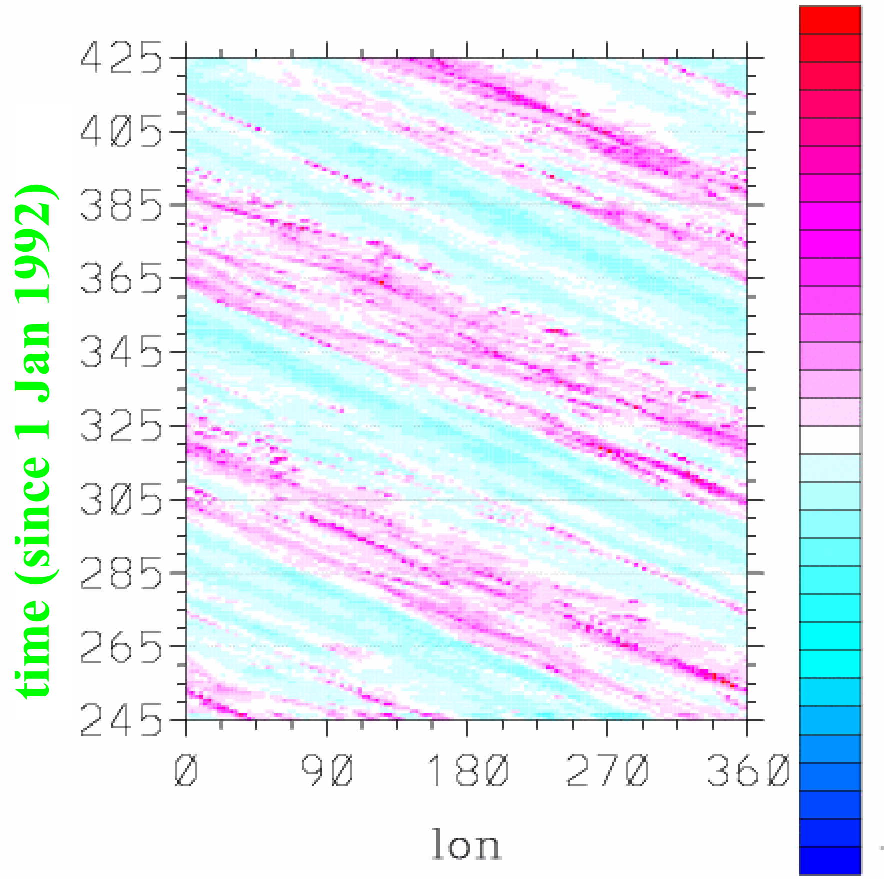
ECMWF Model Forecast:

Precipitation, 20S-20N

cp = 0 m/s



cp = 7 m/s

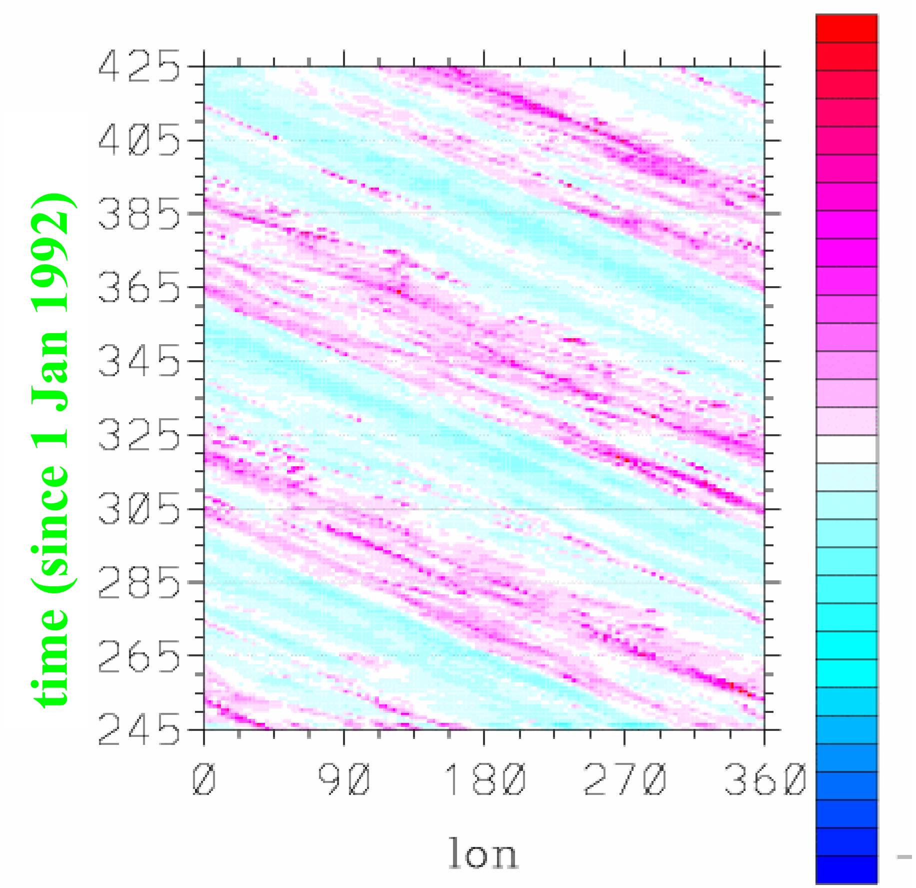


MJO in TOGA-COARE Period

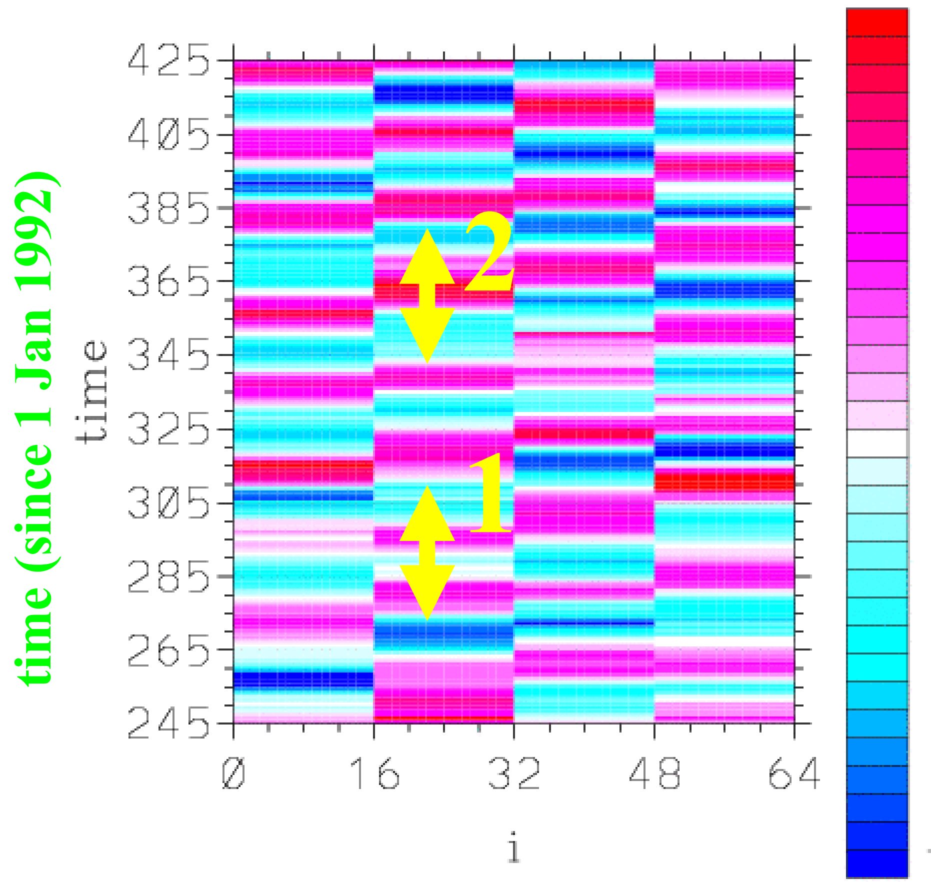
ECMWF Model Forecast:

Precipitation, 20S-20N

cp = 7 m/s

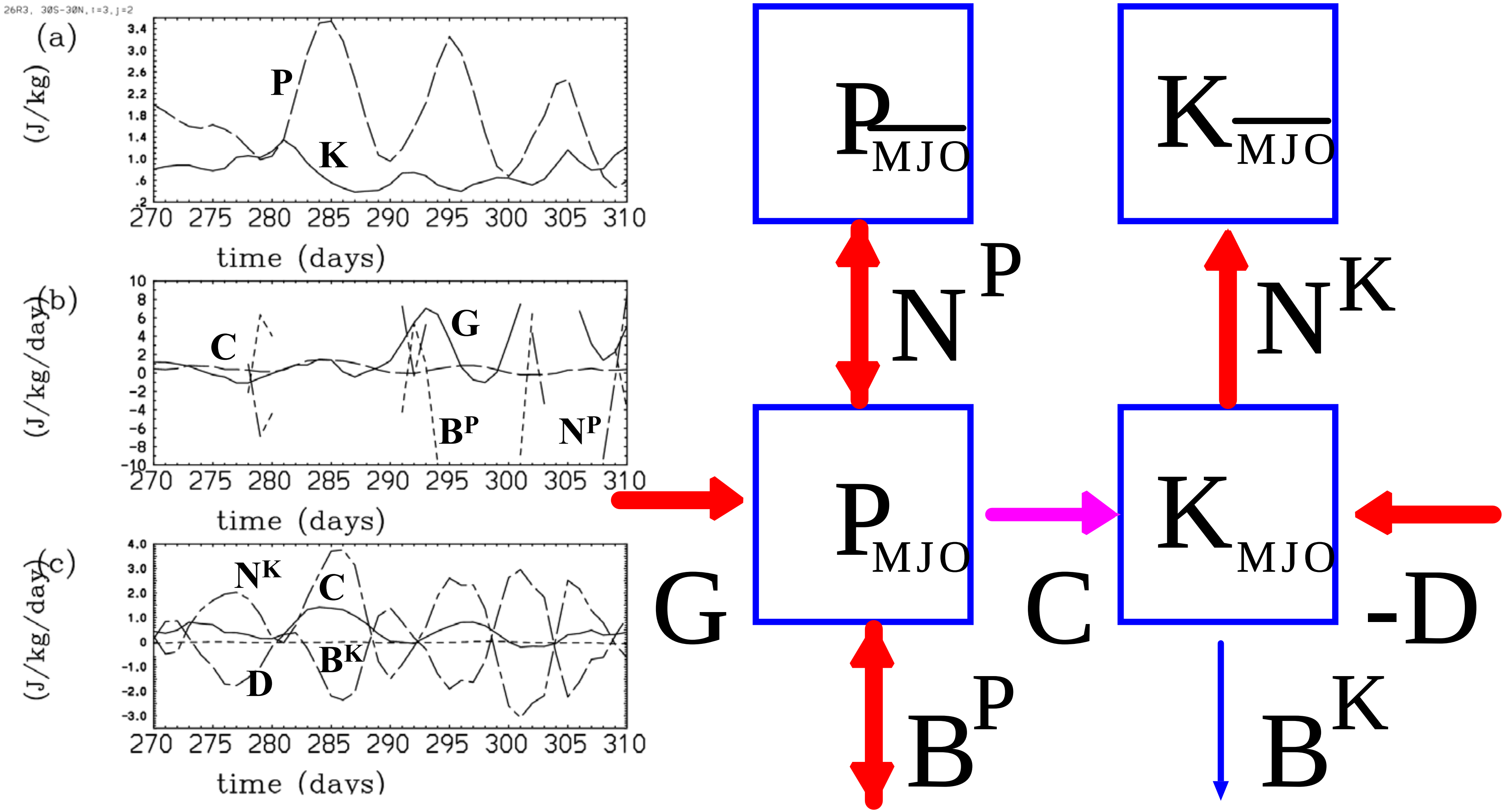


Wavelet spectrum (k = 4, cp = 7m/s)



Energy Cycle with ECMWF Model

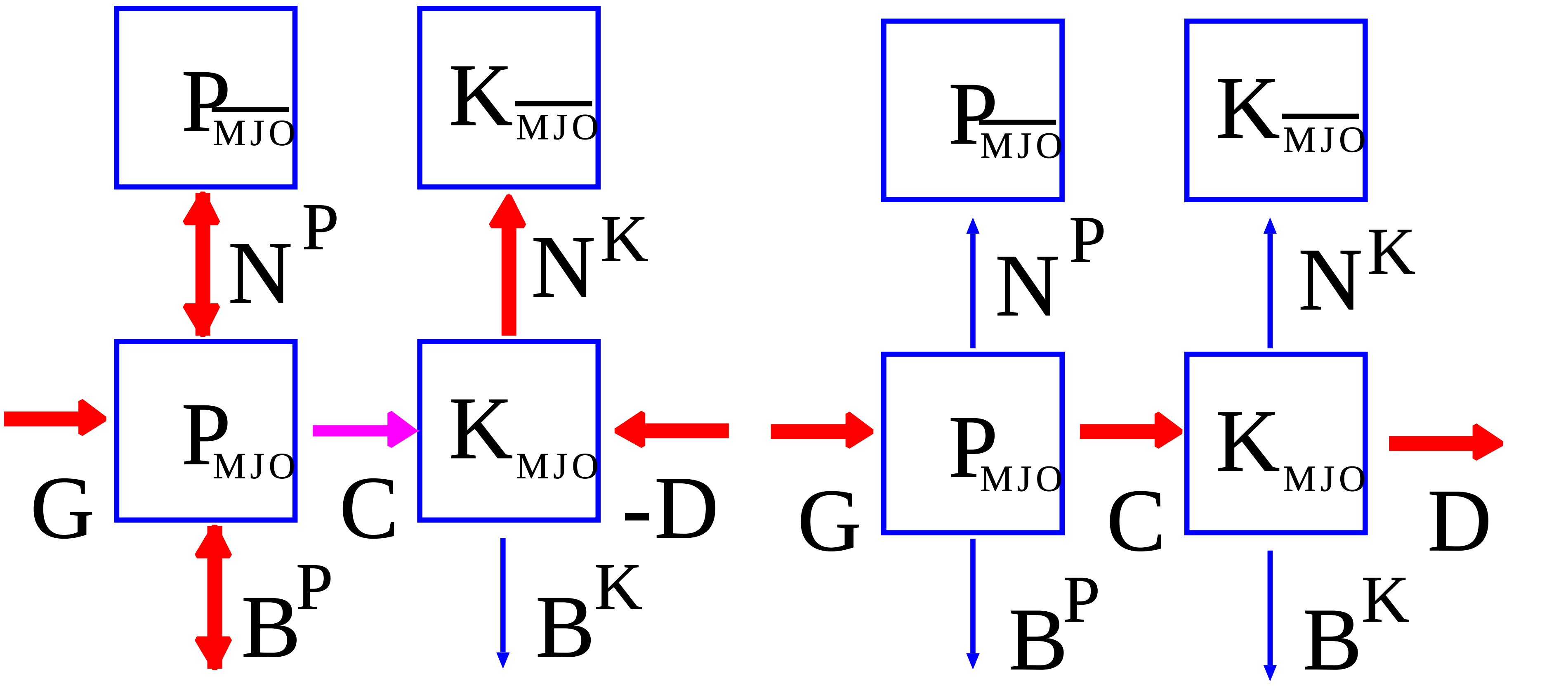
1st MJO event



Energy Cycle

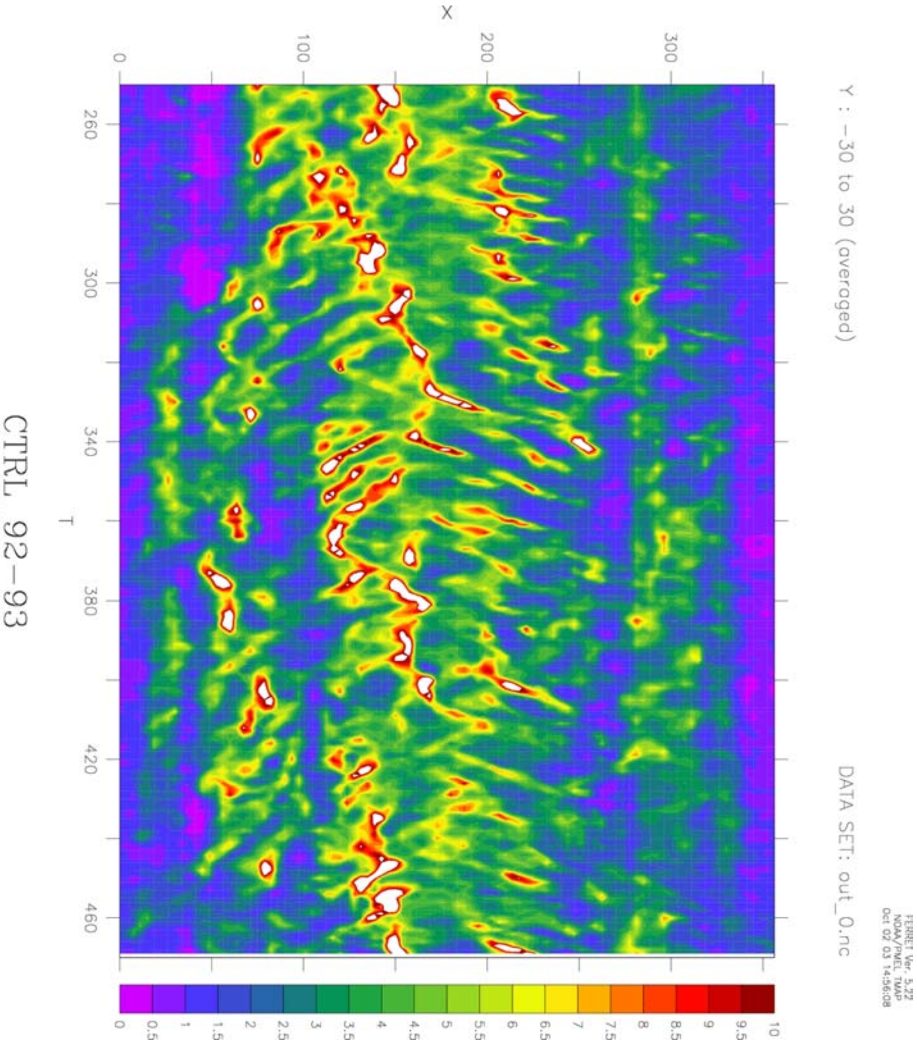
ECMWF Model

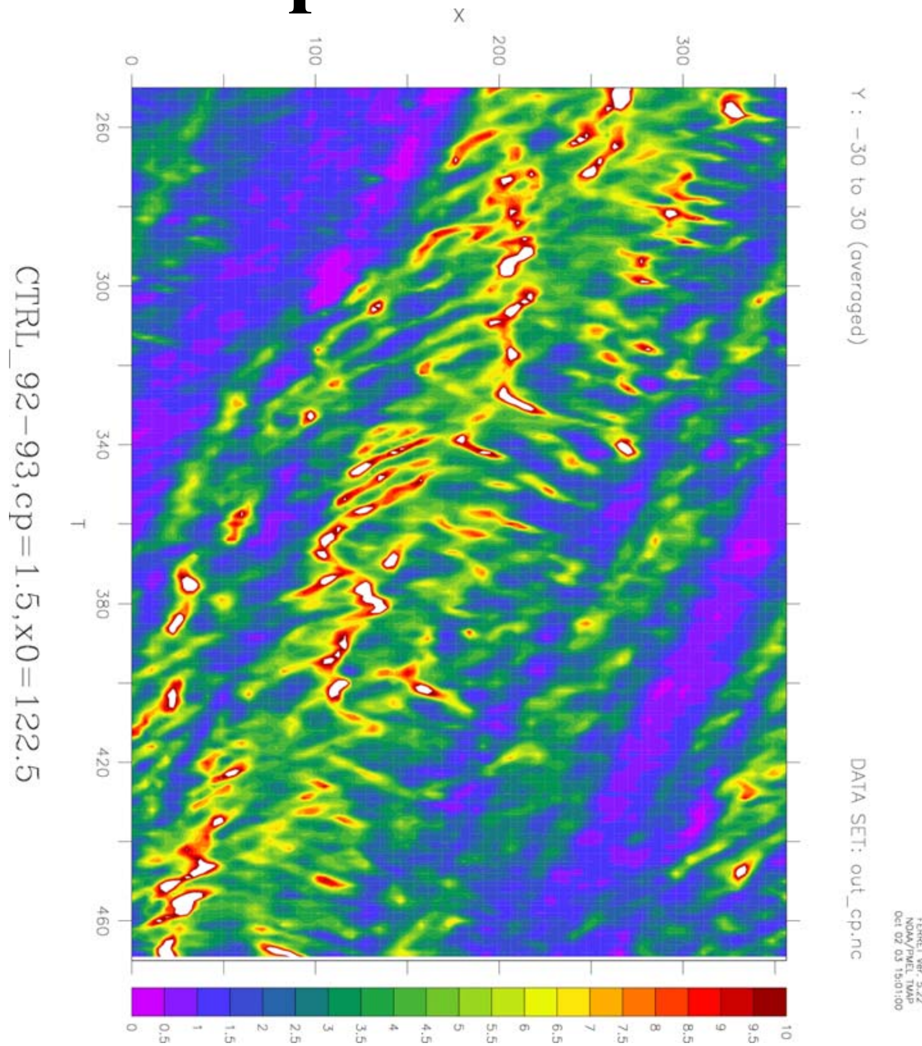
Standard Theory



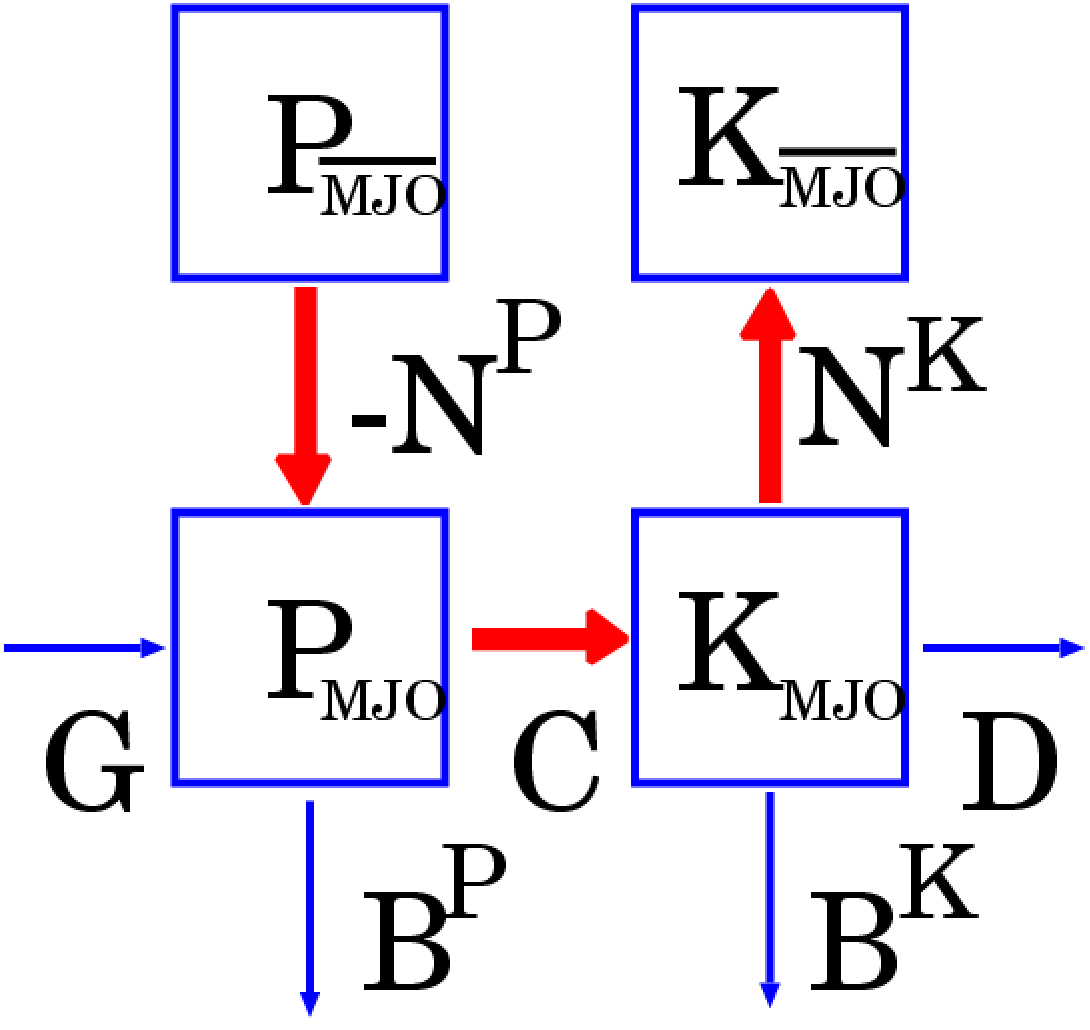
LMDZ Model Case

Cp = 1.5 m/s

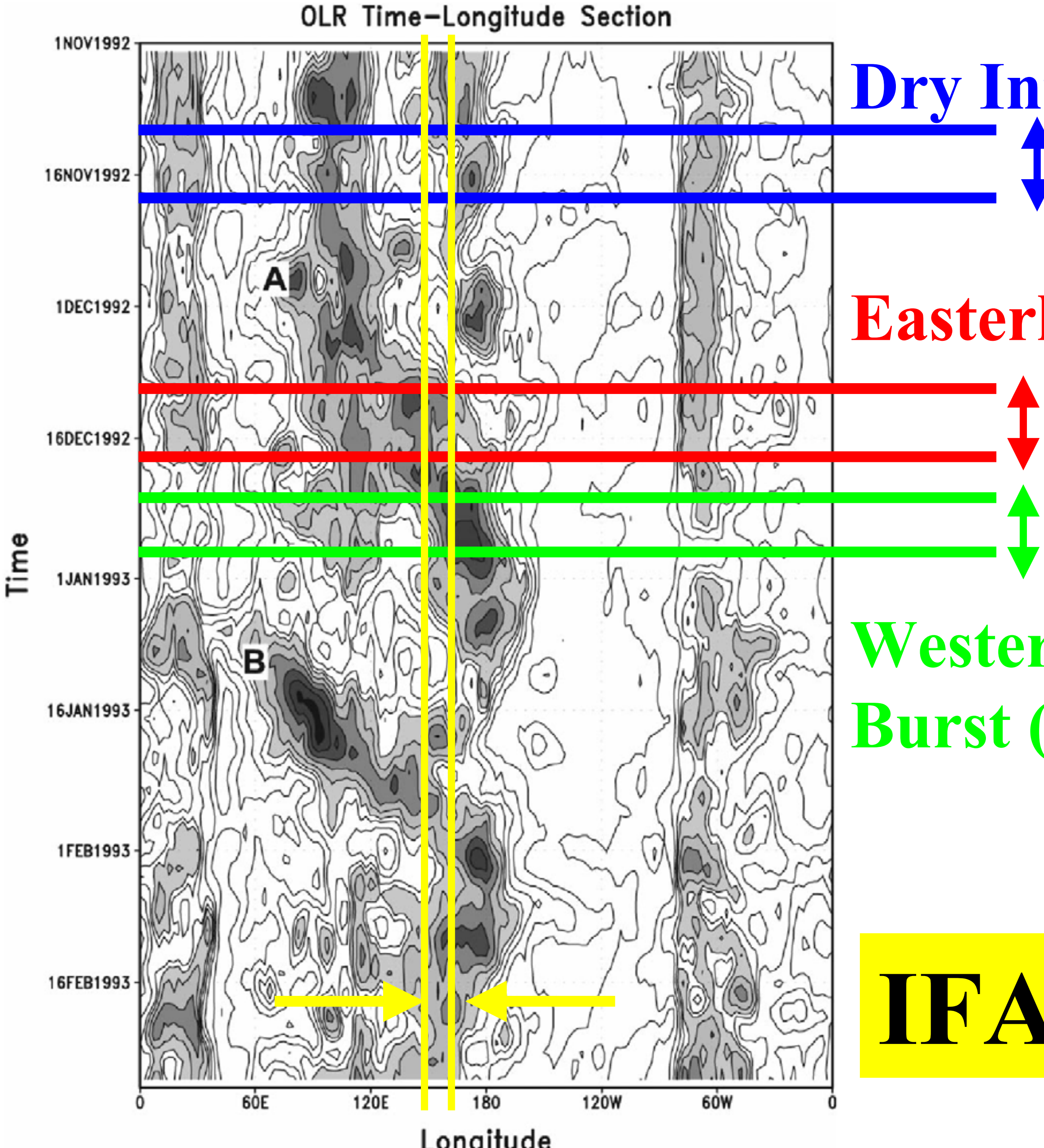




Energy Cycle with LMDZ Model



CRM Experiments (Redelsperger & Sommeria, 2D)



Dry Intrusion (D)

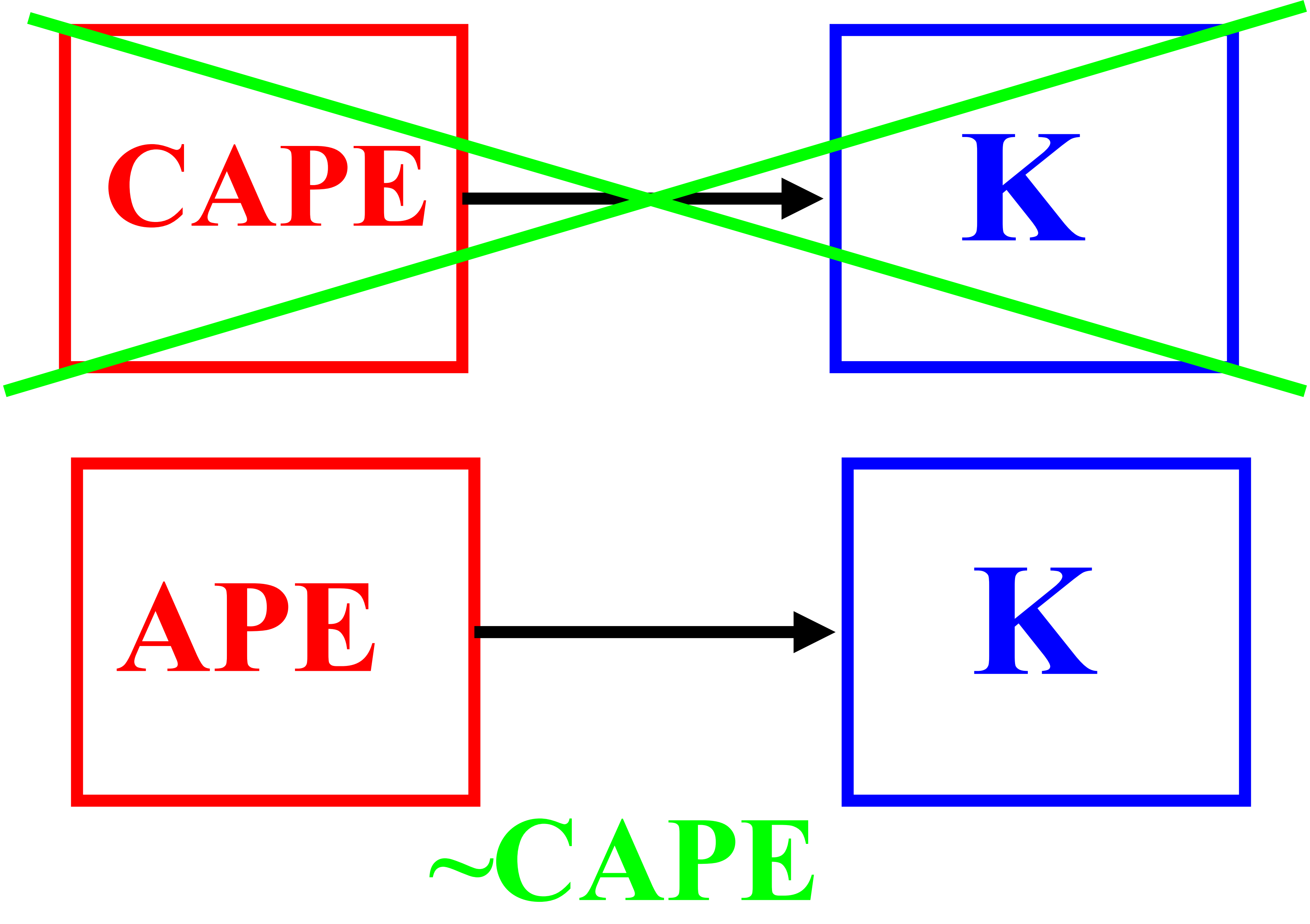
Easterly Wind (E)

Westerly-Wind Burst (W)

IFA

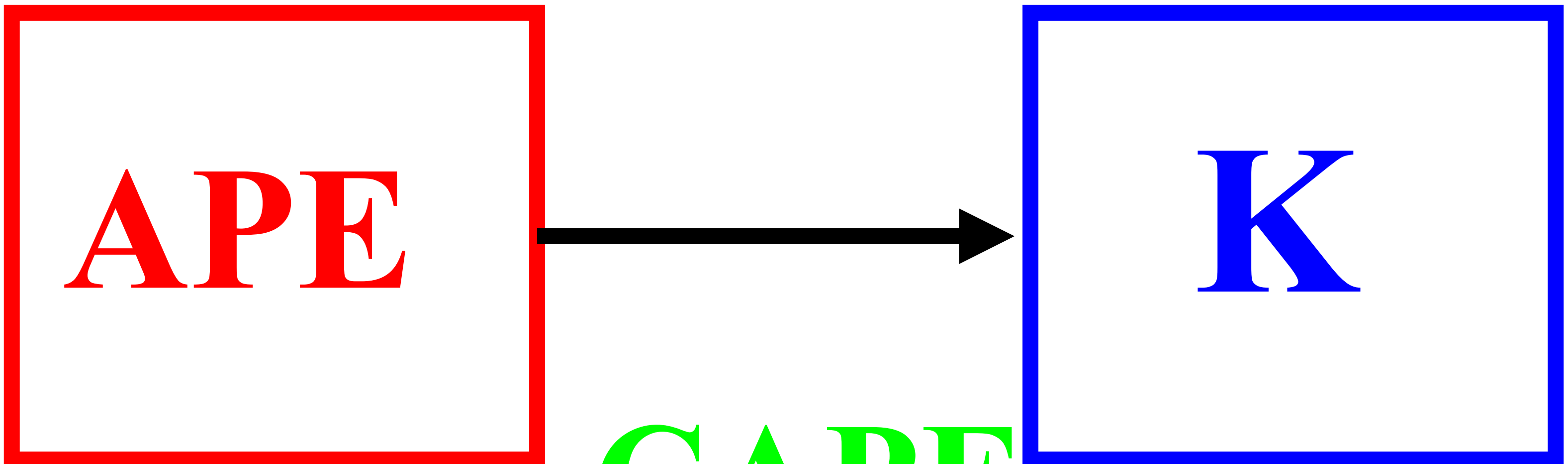
FIG. 3. Longitude–time section of OLR (W m^{-2}) averaged between 5°S and 5°N (contour interval: 15 W m^{-2}). Areas with

Energy Cycle of the Convective System



Energy Cycle of the Convective System

(cf., Eq. 132, Arakawa and Schubert 1974)

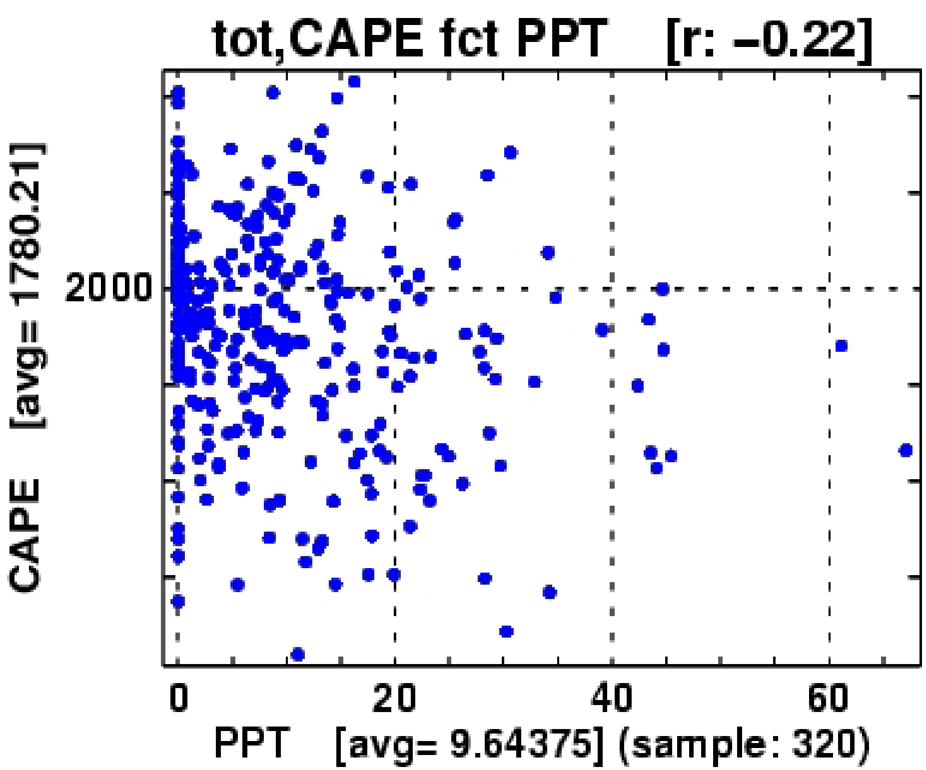


~CAPE

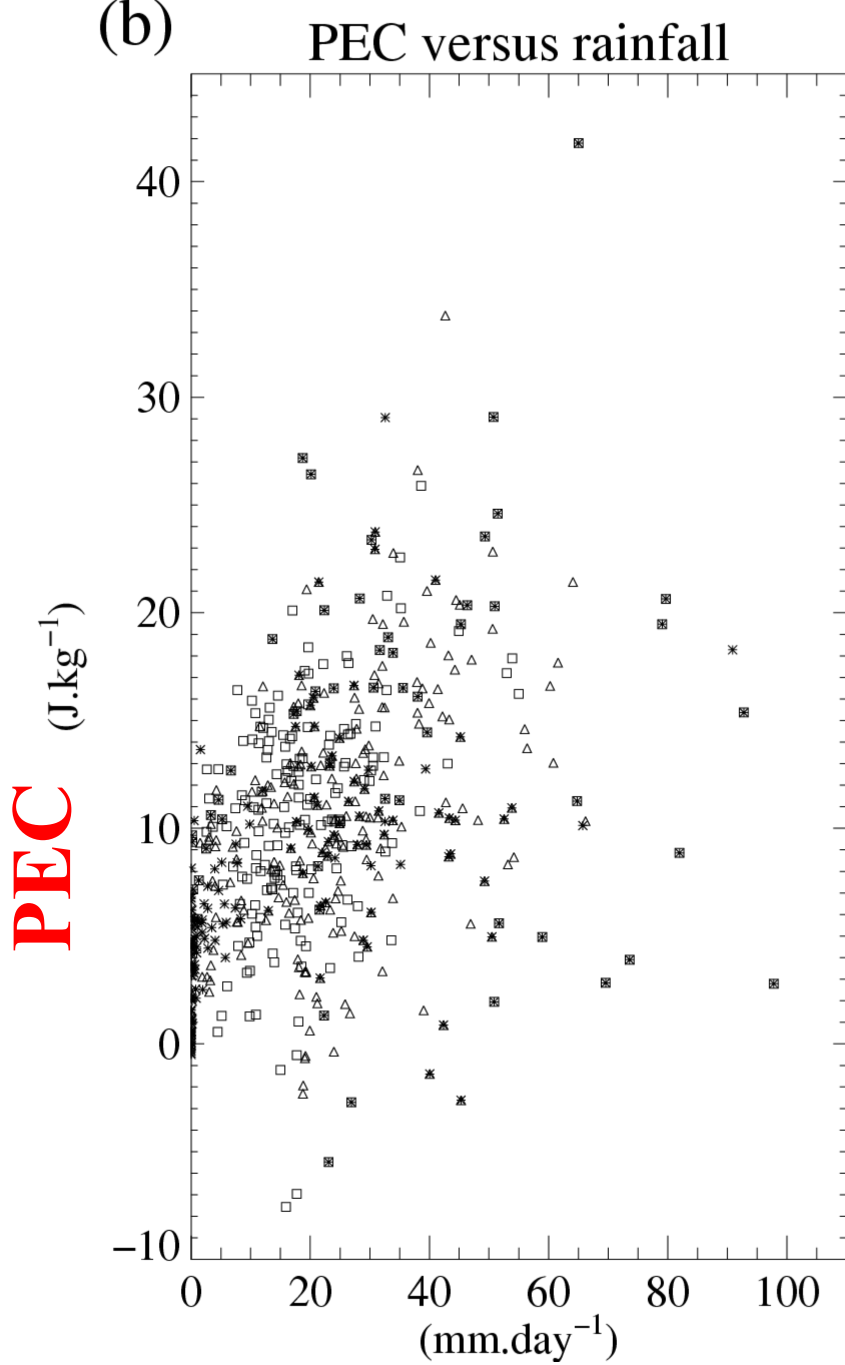
$=M_B A$ (cloud work function: entraining plumes)

$=(\rho w) * PEC$ (CRM: potential energy convertibility)

Three-Month Souding Data

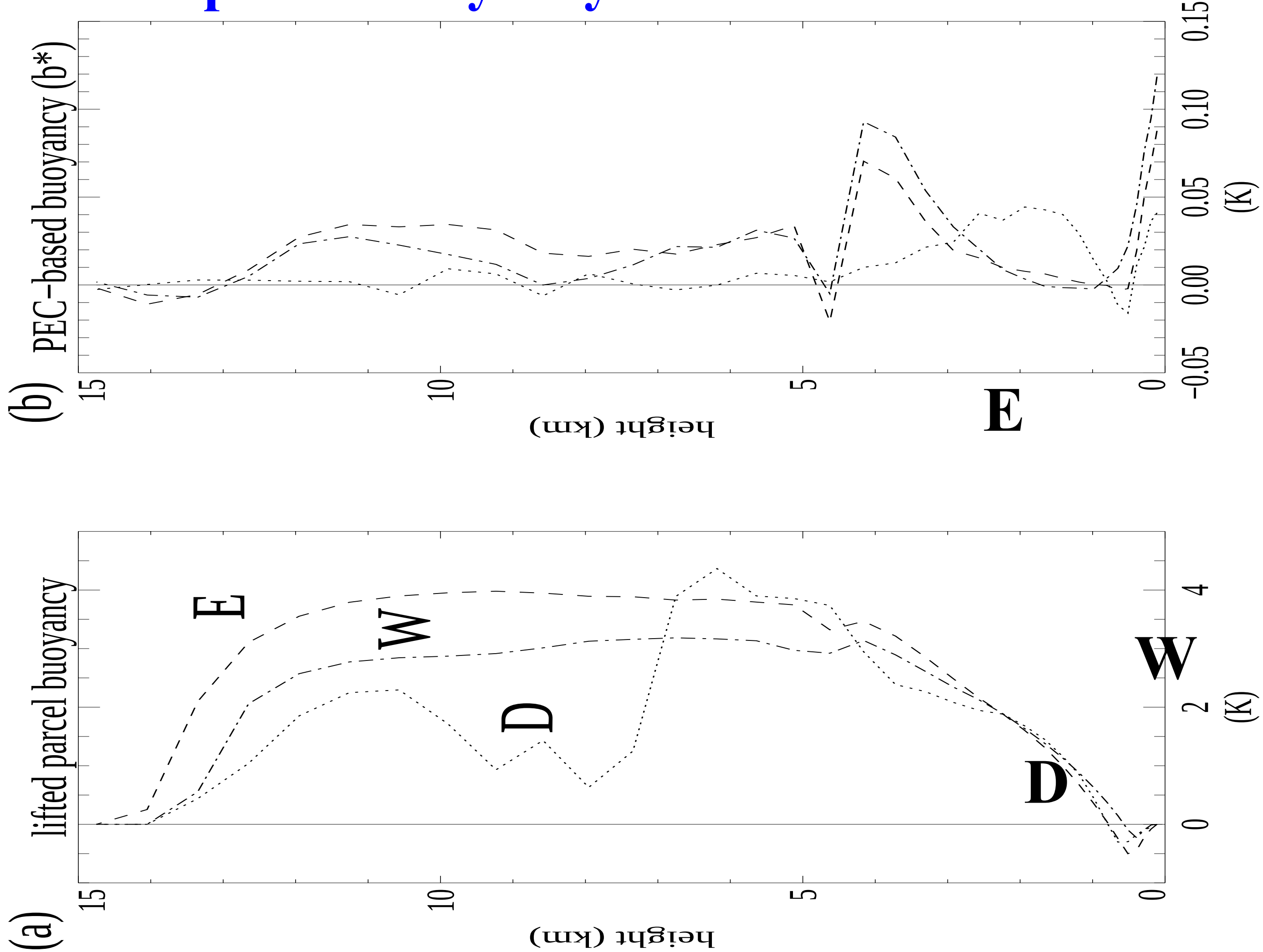


precipitation

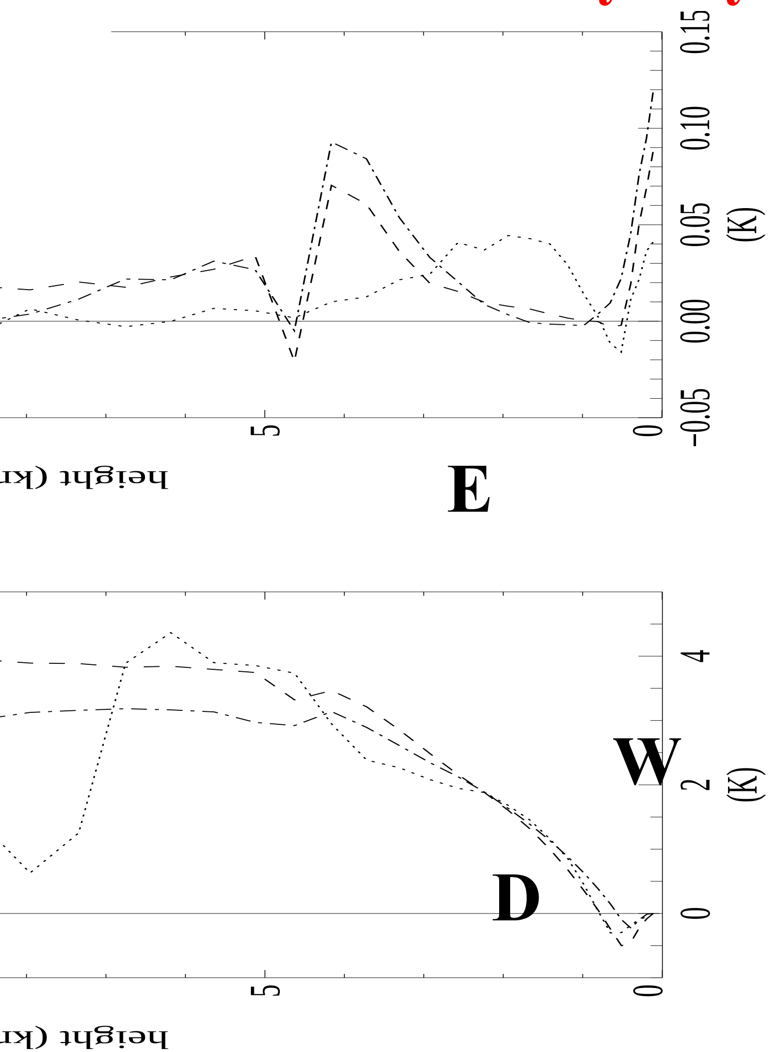


precipitation

Lifted parcel buoyancy **PEC-based buoyancy**

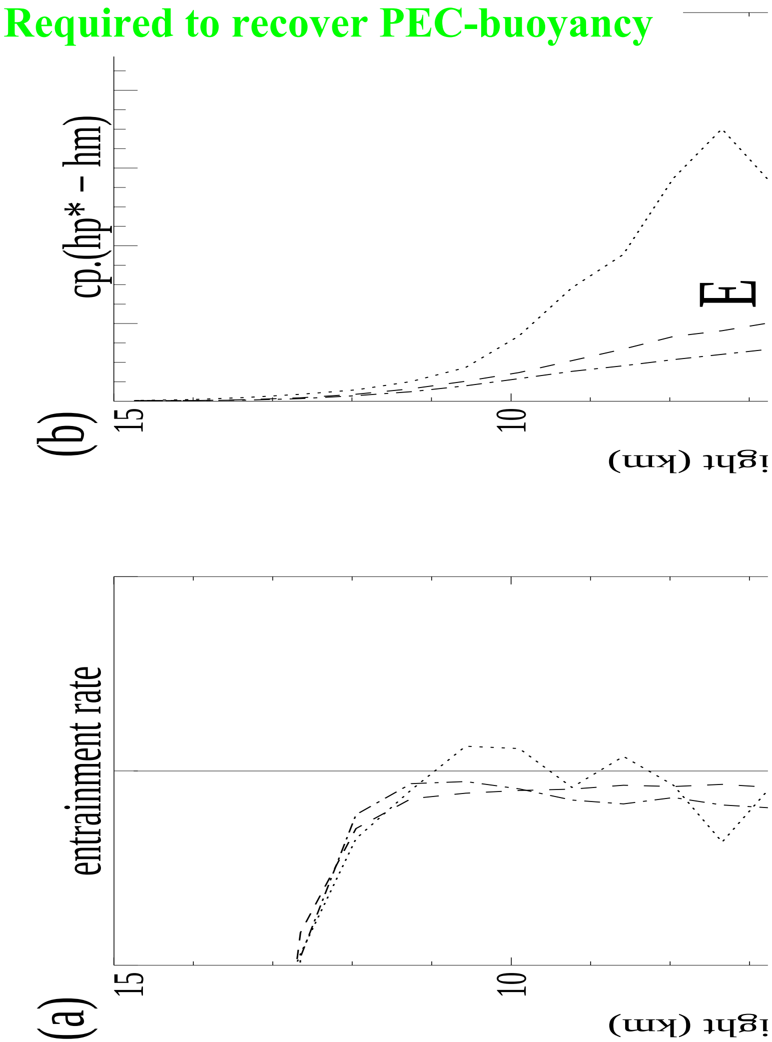


PEC-based buoyancy



Entrainment Rate

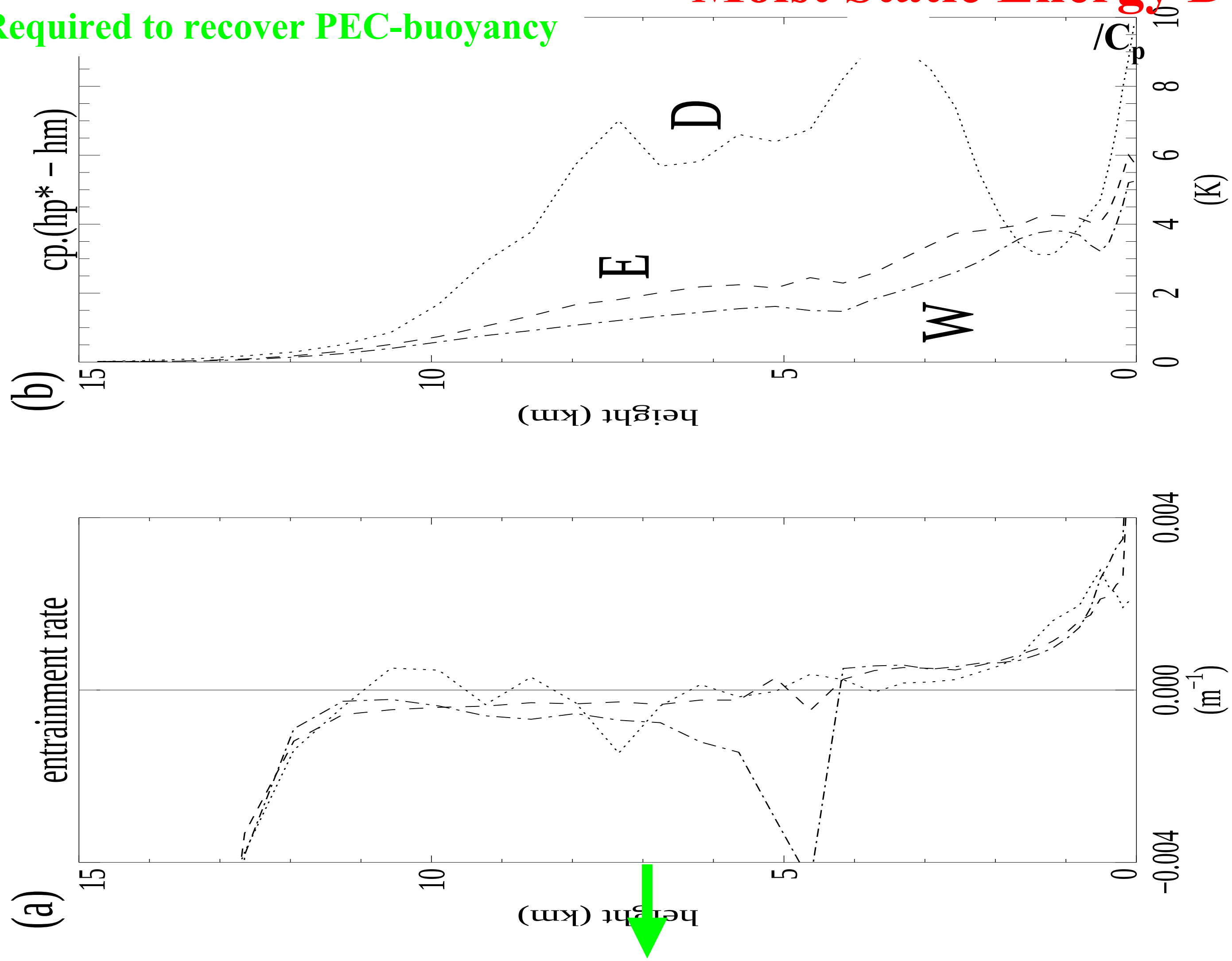
Required to recover PEC-buoyancy



Entrainment Rate

Required to recover PEC-buoyancy

Moist Static Energy Deficit



Quantification of Moisture-Convective Feedback

Approaches for the Global-Model Convective Representation

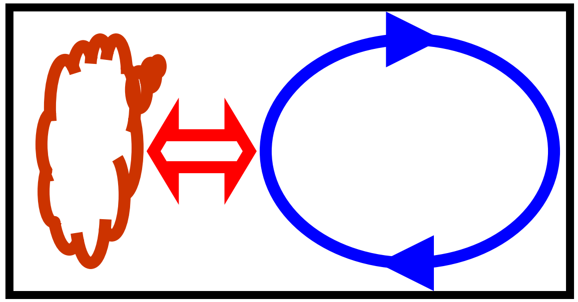
Traditional Approach (Critics)

Scale-Separation → **Quasi-Equilibrium** → **Mass Flux**

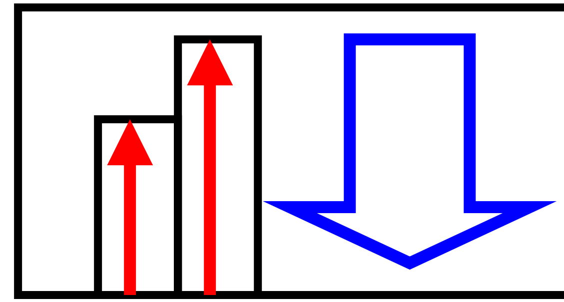
(Yano 1999)

$\tau_c << \tau_L$

(Yano, Grabowski, Roff, Mapes 2000; Yano 2003)



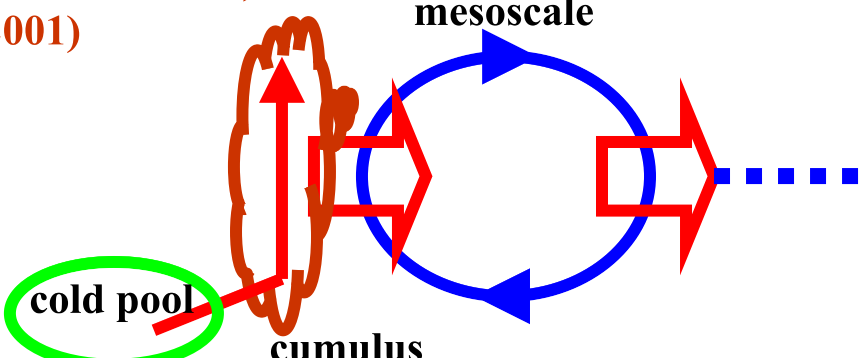
(Yano, Guichard, Lafore, Redelsperger, Bechtold 2003; Yano, Guichard, Bechtold, Redelsperger 2003g)



Proposed New Approach (references)

Scaling (Yano, Takeuchi 1987; Yano, Nishi 1989; Yano, Fraerich, Blender 2001) → **Self-Criticality** (Yano, Blender, Zhang, Fraedrich 2003) → **Wavelets** (Yano et al. 2001a, b, 2003e, f, g)

(fractal & 1/f-noise)



System =
cold pool mode
+
cumulus mode
+
mesoscale mode