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

• 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 energetics)

**Quasi-Equilibrium**

(Quasi-Stationary Balance)

**or**

**Self-Criticality**

(1/f-Noise) ?
Tropical Convective Variability
Tropical Western Pacific Observations (TOGA-COARE)
Frequency-Spectra of CAPE:
(Degree of Convective Instability)

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)

Spatial localization

Wavelet Spectrum

\[ t = 390, \quad y = 0 \]
MJO in TOGA-COARE Period
Precipitation (mm/day), t=390, Equator

Total longitude

Wavelet Spectrum

Spatial localization

k=4-pulse longitude

Wavelet Spectrum

Spatial localization
MJO in TOGA-COARE Period

Precipitation, 20S-20N

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

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

Wavelet Spectrum
Spatial localization

Longitude

4-pulse
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

Time

Precipitation pulse, local

Precipitation pulse, total, lat mean

0 20 40 60 80 100 120 140 160 180

0 20 40 60 80 100 120 140 160 180

Precipitation pulse, total, lat mean

Localc

mean
MJO in TOGA-COARE Period
Velocity Potential, 20S-20N

$v_p, pulse, k=1, 4$

$v_p, 26R3, k=1-4$
MJO in TOGA-COARE Period

Velocity Potential, 20S-20N: Correlation

Local

Latitudinal mean
How MJO is maintained?:
Energy-Cycle Analysis

\[ P_{\text{MJO}} \quad K_{\text{MJO}} \]

\[ N^P \quad N^K \]

\[ G \quad C \quad D \]

\[ P^P \quad K^K \]
Discrete orthogonal Wavelets
(Meyer): complete set

\[ k = 1 \]

\[ k = 2 \]

\[ k = 4 \]

\[ k = 8 \]
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

\[ cp = 0 \text{ m/s} \]

\[ cp = 7 \text{ m/s} \]
MJO in TOGA-COARE Period

ECMWF Model Forecast:

Precipitation, 20S-20N

$\text{cp} = 7 \text{ m/s}$

Wavelet spectrum

$(k = 4, \text{cp} = 7\text{m/s})$
Energy Cycle with ECMWF Model

1st MJO event

(a) 

(b) 

(c) 

Energy Cycle with ECMWF Model

1st MJO event

(a) 

(b) 

(c)
Energy Cycle

ECMWF Model

Standard Theory
LMDZ Model Case

$C_p = 1.5 \text{ m/s}$
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

CAPE

APE

\sim CAPE

K

K
Energy Cycle of the Convective System
(cf., Eq. 132, Arakawa and Schubert 1974)

\[ \text{APE} \sim \text{CAPE} = M_{BA} \]

(cloud work function: entraining plumes)

\[ = (\rho w) \times \text{PEC} \]

(CRM: potential energy convertibility)
Three-Month Souding Data

tot, CAPE fct PPT [r: -0.22]
Lifted parcel buoyancy vs. PEC-based buoyancy

(a) Lifted parcel buoyancy

(b) PEC-based buoyancy

Height (km) vs. Buoyancy (K)

Legend:
- E
- W
- D

Graphs showing the comparison between lifted parcel buoyancy and PEC-based buoyancy over different heights.
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** →

(Yano 1999)

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

\[ \tau_c \ll \tau_L \]

**Mass Flux**

(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)

(Yano et al. 2001a, b, 2003e, f, g)

**Wavelets**

System =

- cold pool mode
- cumulus mode
- mesoscale mode