MJO Theme

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Activities

• Representation of MJO in CMMAP MMF via 2D CRM

• Observational evaluation (satellite and field data)
**MJO paradigm**: an envelope of interacting, finite-amplitude, multi-scale, propagating, organized convective systems

**Key entities**

- **Mesoscale convective systems (MCS)**
  \(~ 100 \text{ km}~\)

- **Super-clusters**
  \(~ 1000 \text{ km}~\)

- **Cumulonimbus**
  \(~ 1 \text{ – } 10 \text{ km}~\)

- **MJO**
  \(~ 10000 \text{ km}~\)
Contemporary Parameterization

Vertical kinetic energy

Micro-physics

Resolved scales of a climate model
~ 100 km

Cumulus scale
~ 1 km

Real scale gap

assumed scale gap
Superparameterization

Vertical kinetic energy

Microphysics

Scale gap

Cumulus scale ~ 1 km

Organized mesoscale convective systems

Mesoscale organization ~ 100 km

CRM grid-length ~ 1 km

Resolved scales of climate model

Horizontal scale

Superparameterization
MJO in the Community Atmospheric Model

Conventional parameterization

Superparameterization

Why do MJOs occur in MMFs?

• CRMs embedded in climate models simulate propagating MCS-like convective systems -- CRM strongpoint

i) cold pools/density currents trigger new cumulonimbus: scale ~ 10 km

ii) cumulonimbus families generate MCS: scale ~ 100 km

iii) families of MCS (superclusters) interacting with convectively-generated tropical waves
Stages of upscale evolution

1: Cumulonimbus

Stratiform ascent

Mesoscale downdraft

Δp

n + m

3: Mesoscale convective system

2: Cumulonimbus family

Cold-pool boundary-layer convergence triggers families of cumulonimbus
Tilted westward-traveling MCSs embedded in eastward-traveling waves, starting from a uniform motionless state.
Organized convection redistributes horizontal momentum

Vertically tilted airflow in MCS redistribute horizontal momentum (convective momentum transport) resulting in positive dynamical feedback via shear generation.
Energetics of MCS-type organization

\[ \frac{1}{2} (U_0 - c)^2 \]
3 energy forms: i) potential; ii) kinetic; iii) work done by convectively-generated pressure gradient

2 scaled quantities:

\[ E = \frac{\Delta p}{\rho \frac{1}{2} (U_0 - c)^2} \]

\[ R = \frac{CAPE}{\frac{1}{2} (U_0 - c)^2} \]

Hydraulic dynamics are key

MCS-type organization: at intersection of E-R space
Rearward-tilted 2-D morphology: i) efficient transporter water, energy, mass and momentum; ii) preferred regime of organization in CRMs and super-parameterized models.
Do tilted MCS-like systems (i.e., mesoscale-to-synoptic scale heat and momentum transport) help MJOs?
Upscale effects of MCS-like heat & momentum transport on MJO

\[
\bar{U}_t - y \bar{V} + \bar{P}_x = F^U - d_m \bar{U}
\]

\[
y \bar{U} + \bar{P}_y = 0
\]

\[
\bar{\theta}_t + \bar{W} = F^\theta - d_\theta + \bar{S}_\theta
\]

\[
\bar{P}_z = \bar{\theta}
\]

\[
\bar{U}_x + \bar{V}_y + \bar{W}_z = 0
\]

\[
F^U = - (v'u')_y - (w'u')_z
\]

\[
F^\theta = - (v'\theta')_y - (w'\theta')_z
\]

Biello, Majda and Moncrieff (2007)
Some discussion items

- 2-D SP: generates MCS-type organization
- Do overly extensive MCS-like systems contribute to over-active MJO precipitation, etc.
- More attention to quantifying role of convective momentum transport (theoretical-dynamical insight suggests it’s relevant)
- 3-D SP: computational domains too small to properly represent convective organization, but should improve explicit representation of cumulonimbus convection
- Representation of moist turbulence and PBL in CRMs, that CRMs do not resolve
- Parameterize MCS: needed for long climate integrations