Multi-Platform Analyses of MJO Convection on Sub-Daily Timescales

Jeremiah Brown and Ralph F. Milliff
NWRA, Colorado Research Associates (CoRA) Division
Boulder, CO USA
Multi-Platform Analyses of MJO Convection on Sub-Daily Timescales

Jeremiah Brown and Ralph F. Milliff
NWRA, Colorado Research Associates (CoRA) Division
Boulder, CO USA

• Tropics as a source region for important weather and climate events
  (e.g. moisture supply to mid-latitudes, easterly waves, monsoons, TC’s, MJO, ENSO)

• Shorter timescales, unique phenomena associated with tropical deep convection
  (organization; e.g. mesoscale convective systems or MCS, tropical waves)

• Human impacts (e.g. agriculture, fisheries, fresh water supply, drought, flood, fire,...)
**Multi-Platform Analyses of MJO Convection on Sub-Daily Timescales**

Jeremiah Brown and Ralph F. Milliff  
*NWRA, Colorado Research Associates (CoRA) Division  
Boulder, CO USA*

- Tropics as a source region for important weather and climate events  
  (e.g. moisture supply to mid-latitudes, easterly waves, monsoons, TC's, MJO, ENSO)

- Shorter timescales, unique phenomena associated with tropical deep convection  
  (*organization*; e.g. mesoscale convective systems or MCS, tropical waves)

- Human impacts (e.g. agriculture, fisheries, fresh water supply, drought, flood, fire,...)

- Madden-Julian Oscillation (MJO) as a marker for observation and model capabilities for  
  tropical processes (slow eastward propagation, large scale, unknown initiation and  
  propagation mechanisms)

- What are the limits imposed by temporal sampling inherent in multiple polar-orbiting  
  satellite systems?

IOVWST Barcelona, May 2010
Datasets from Multi-Sensor Satellite Observations

**Convective Cloud Signatures**

Outgoing Longwave Radiation (OLR) Estimates from Clouds and Earth’s Radiant Energy System (CERES) on Terra (1030) and Aqua (1330)
daily average, 2.5 degree

Synoptic scale synthesis OLR product (SYN) from NASA Langley (LaRC)
Combines GOES and CERES observations
3-hourly, 1 degree

**Zonal Wind and Surface Convergence**

Blended QuikSCAT and NCEP Reanalysis (BLN) surface vector winds (SVW) from Milliff et al., (2004); Chin et al., (1998) (old Level 3 product)
6-hourly (really 12), 0.5 degree

ASCAT L2 NRT retrievals from OSI SAF via JPL PODAAC
12-hourly, 12.5km (really 25)

MJO Signal in OLR Anomaly Time vs. Longitude Diagram

November 2002
MJO in Plan View: 3-hourly OLR anomaly from SYN (top) and running 24hr mean (bottom)

- MCS organization and variability embedded within MJO cloud shield
- smaller, faster, westward difference signals at leading edges, throughout MJO supercluster
- active synoptic background affects and is affected by MJO
Recent Conceptual Models of the MJO: Upscale transfers

Transfer momentum and/or energy *upscale* from convection processes that occur on space and timescales smaller than the MJO supercluster.

Convective cloud source

Equatorial $\beta$-plane equations (non-dimensional).

\[
\begin{align*}
    u_t - yv - \theta_x &= 0 \\
    yu - \theta_y &= 0 \\
    \theta_t - u_x - v_y &= \bar{H}a \\
    q_t - \bar{Q}(u_x + v_y) &= -\bar{H}a \\
    a_t &= \Gamma\bar{a}q
\end{align*}
\]

$y$ is in the meridional direction, $u$, $v$ are the zonal and meridional winds, $\theta$ is the potential temperature, $\bar{H}$ is a constant heating rate, $\bar{Q}$ is the mean background vertical moisture gradient and $\Gamma q$ is the dynamic growth and decay rate of the convective wave activity, $a$.


Recent Conceptual Models of the MJO: Upscale transfers

**Momentum source**

Equatorial $\beta$-plane equations (non-dimensional).

\begin{align*}
u_t - \beta y u &= -\eta_x + \nu \nabla^2 u \\
v_t + \beta y u &= -\eta_y + \nu \nabla^2 v \\
\eta_t + H(u_x + v_y) &= -Q(u, v, \eta) - \frac{1}{\tau} \eta \\
Q &= \max[0, A|u + U|(\eta - \eta_{sat})]
\end{align*}

$H$ is equivalent depth, $\eta$ is the perturbation dynamic pressure, $\nu$ is the eddy diffusivity, and $\tau$ is a Newtonian cooling timescale. $Q$ is the explicit heating (or "WISHE") term involving the mean easterlies $U$, and a specified length scale $A$ proportional to fetch in the surface wind perturbations (e.g. westerly wind bursts) due to WISHE (Wind-Induced Surface Heat Exchange; Emanuel, 1987; Neelin et al., 1987).


**MJO in Plan View:** 12-hourly zonal wind (top) and divergence (bottom) from QuikSCAT L3

- Anomalous easterlies (red) propagate slowly eastward
- Divergence extrema associated with leading edge of MJO propagation
- Zonal wind and divergence associated with background state as well
**MJO in Plan View:** 3-hourly OLR (SYN; top) and 12-hourly DIV (QuikSCAT L3; bottom)

November 2002

- Divergence extrema associated with MCS, embedded within MJO
MJO Signal in OLR Anomaly Time vs. Longitude Diagram

October 2009

November 2009

December 2009

January 2010

Indian Ocean

Western Pacific Ocean
**MJO in Plan View:** 2x-daily zonal wind from ASCAT (L2)

- Need L3 products, sufficiently accurate to yield reliable divergence, vorticity fields (CCMP?)
Summary:

- Tropical events have important weather and climate-scale implications
  - multiple, nested temporal and spatial scales
  - deep convective plume to MJO, monsoon, ENSO, etc.
  - MCS building blocks resolvable, organization processes not well understood
  - challenge to space-borne observing systems

- Require simultaneous, O(hourly), high-resolution observations of critical quantities
  - multi-scale convective cloud systems and momentum (as shown)
  - moisture (humidity, precip), temperature
  - coarse resolution vertical structure (i.e. 2-layer)

- Bayesian Hierarchical Model (BHM) approach to MJO propagation mechanism in the tropical Indo-Pacific
  - data stage inputs from multi-platform satellite observations
  - new process models (upscale transfers)
The Mesoscale Convective System (MCS) life cycle

Major processes (expressed as GCM parts & parameterizations):
- dynamics, PBL
- PBL, shallow cumulus
- PBL, cumulus, stratiform cloud
- stratiform cloud & precip

Key variables measured by TropSat:
- SST, $\nabla^2$SST
- $\nabla \bullet V_{sfc}$ in inflows, gravity waves
- $\nabla \times V_{sfc}$ Ekman pumping
- $\nabla \bullet V_{sfc}$ column vapor, cloud top, rainrate & rainwater
- net latent heating, momentum effects
- production of atm & ocean cold pools
- SST, $\nabla^2$SST
- $\nabla \bullet V_{sfc}$ outflows, gravity waves
- $\nabla \times V_{sfc}$ cyclogenesis, planetary waves
TROPSAT Concept: seeking community interest/input

active/passive microwave instrument
low-inclination orbit
wide swath, MCS resolution
SVW (convergence, curl)
SST, T(z)
**Total column H₂O, rain cloud**

![Image of TROPSAT data](Image courtesy S. Nesbitt via B. Mapes 2004)

<table>
<thead>
<tr>
<th>6°</th>
<th>10°</th>
<th>12°</th>
<th>14°</th>
<th>18°</th>
<th>22°</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>☄</td>
<td>☄</td>
<td>☄</td>
<td>☄</td>
<td>☄</td>
</tr>
<tr>
<td>2°</td>
<td>30°, 5°, 10°, 12°, 15°, (20°)</td>
<td>9°, 10°, 9°, 10°, (70°)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4°</td>
<td>9°, 15°, 8°, 10°, (0°)</td>
<td>8°, 20°, 7°, 5°, (0°)</td>
<td>7°, 5°, 8°, 20°, 7°, 5°, (70°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6°</td>
<td>7°, 25°, (0°)</td>
<td>7°, 25°, (0°)</td>
<td>7°, 20°, 6°, 5°, (0°)</td>
<td>7°, 15°, 6°, 5°, 7°, 10°, (70°)</td>
<td></td>
</tr>
<tr>
<td>8°</td>
<td>6°, 20°, 5°, 5°, (0°)</td>
<td>6°, 20°, 5°, 5°, (0°)</td>
<td>6°, 20°, 5°, 20°, (0°)</td>
<td>6°, 5°, 6°, 20°, (0°)</td>
<td></td>
</tr>
<tr>
<td>10°</td>
<td>5°, 7°, (20°)</td>
<td>5°, 20°, 6°, 5°, (0°)</td>
<td>6°, 12°, 5°, 15°, (0°)</td>
<td>6°, 15°, 5°, 7°, (0°)</td>
<td>6°, 22°, 5°, 5°, (0°)</td>
</tr>
<tr>
<td>12°</td>
<td>5°, 10°, (17°)</td>
<td>5°, 10°, (5°)</td>
<td>6°, 3°, 5°, 22°, (0°)</td>
<td>6°, 10°, 5°, 15°, (0°)</td>
<td></td>
</tr>
<tr>
<td>14°</td>
<td></td>
<td></td>
<td></td>
<td>b, 10°, (15°)</td>
<td>b, 25°, (0°)</td>
</tr>
<tr>
<td>16°</td>
<td></td>
<td></td>
<td></td>
<td>5°, 10°, (15°)</td>
<td>5°, 25°, (0°)</td>
</tr>
<tr>
<td>18°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>