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

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- 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,…)

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- 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?

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

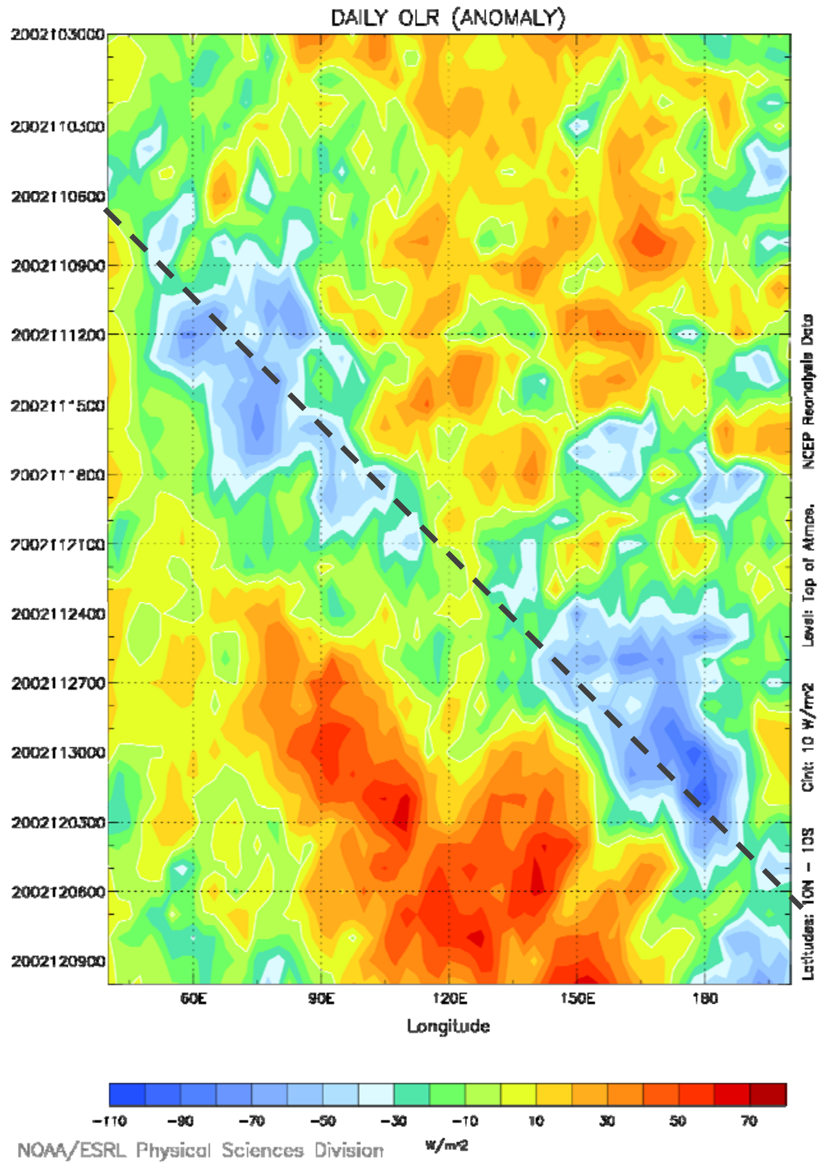
ASCAT L2 NRT retrievals from OSI SAF via JPL PODAAC
12-hourly, 12.5km (really 25)

Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee III, G. L. Smith, and J. E. Cooper, "Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment," Bull. Amer. Meteor. Soc., **77**, 853-868, 1996.

MJO Signal in OLR Anomaly Time vs. Longitude Diagram

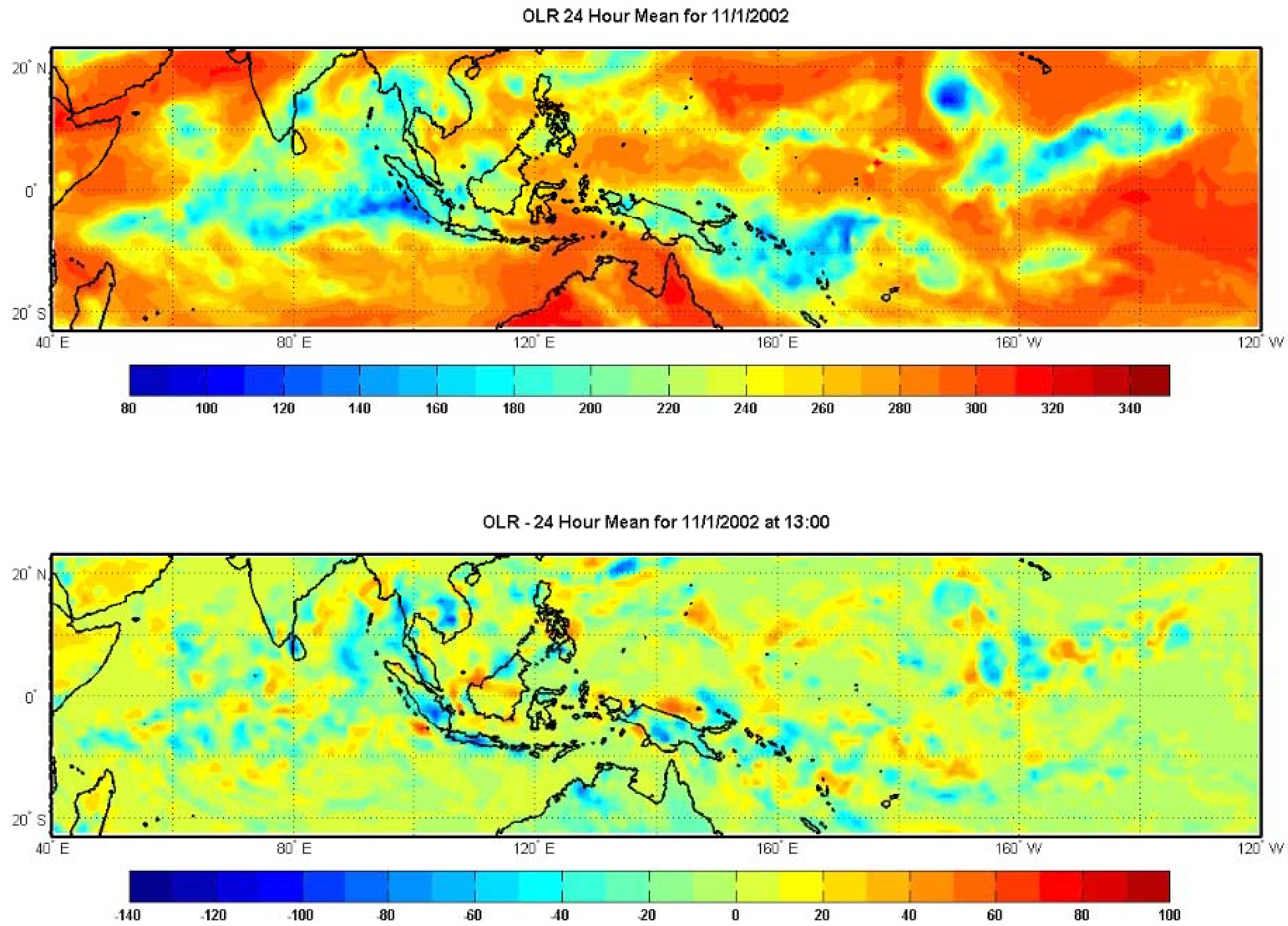
Indian Ocean Western Pacific Ocean

November 2002



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

November 2002



- 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 β-plane equations (non-dimensional).

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

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

Majda, A.J. and S.N. Stechmann, 2009a: The skeleton of tropical intraseasonal oscillations. *Proc. Natl. Acad. Sci.*, **106**, 8417-8422.

Majda, A.J. and S.N. Stechmann, 2009b: The Madden-Julian Oscillation and the multiscale hierarchy of organized convection. *UCLA Tropical Meteor. and Climate Newsletter*, 88, section A, Prof. M. Yanai (Ed.).

Recent Conceptual Models of the MJO: Upscale transfers

Momentum source

Equatorial β-plane equations (non-dimensional).

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

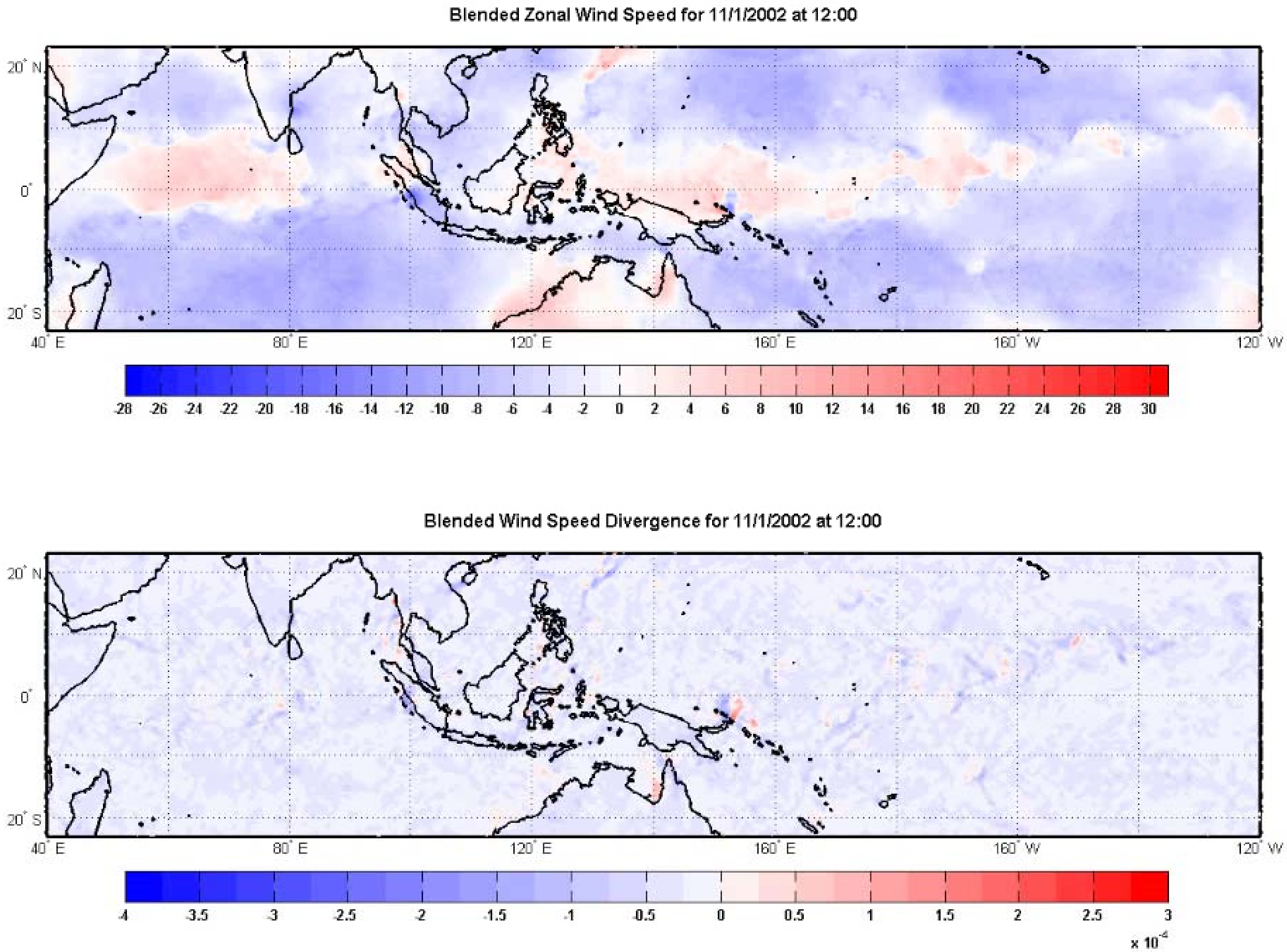
H is equivalent depth, η is the perturbation dynamic pressure, ν is the eddy diffusivity, and τ is a Newtonian cooling timescale. Q is the explicit heating (or "WISHE") term involving the mean easterlies U, and a specified length scale A proportional to fetch in the surface wind perturbations (e.g. westerly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

Solodoch, A., W. Boos, Z. Kuang and E. Tziperman, 2010a: Excitation of slow MJO-like Kelvin waves in the equatorial atmosphere by Yanai wave-group via WISHE-induced convection., *arXiv:1002.2340v1, physics-ao-ph, http://arxiv.org/abs/1002.2340v1.*

Solodoch, A., W. Boos, Z. Kuang and E. Tziperman, 2010b: MJO-like signal due to Yanai-wave forcing in intermediate-complexity atmospheric models., *in prep*.

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

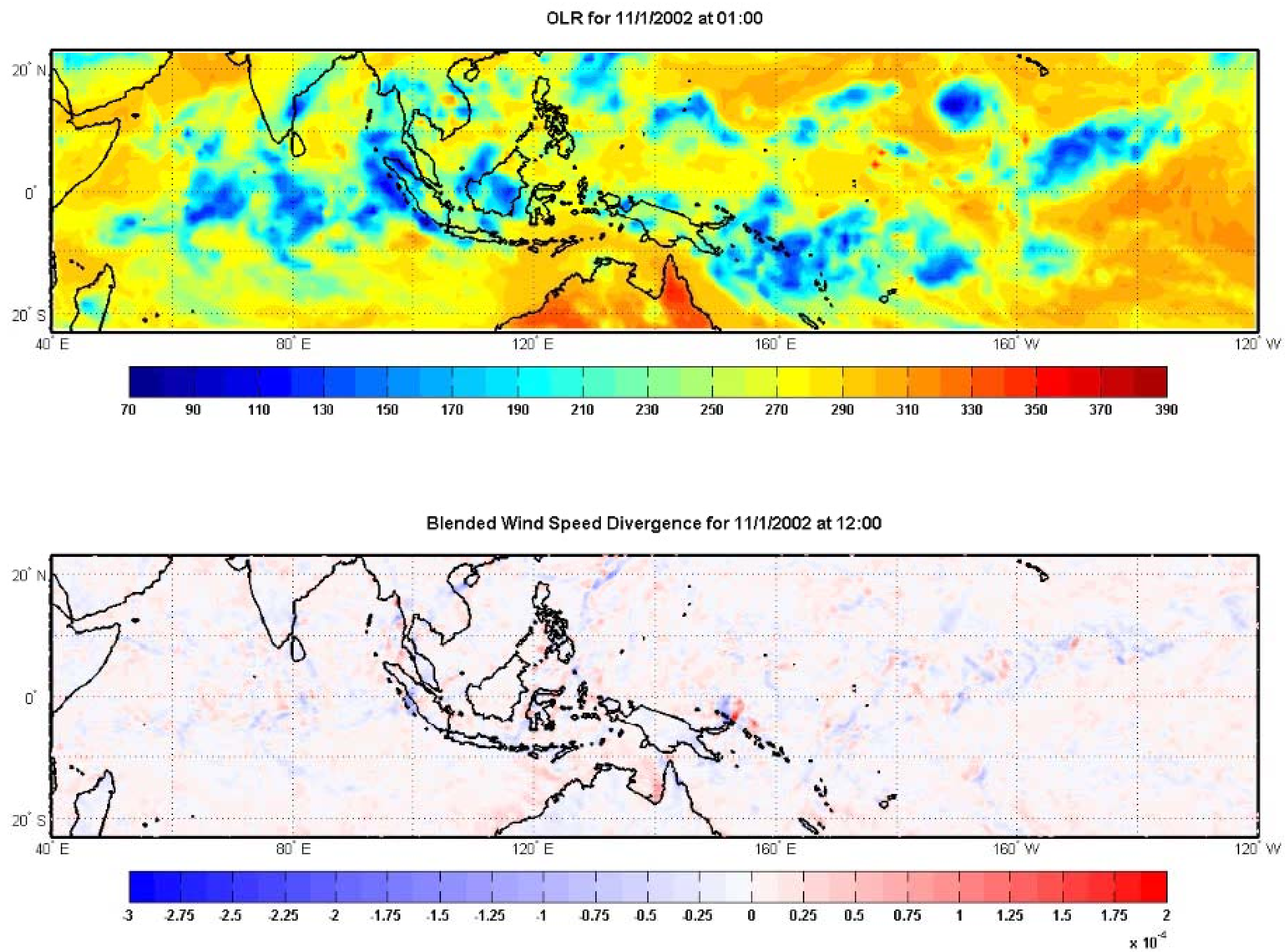
November 2002



- 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

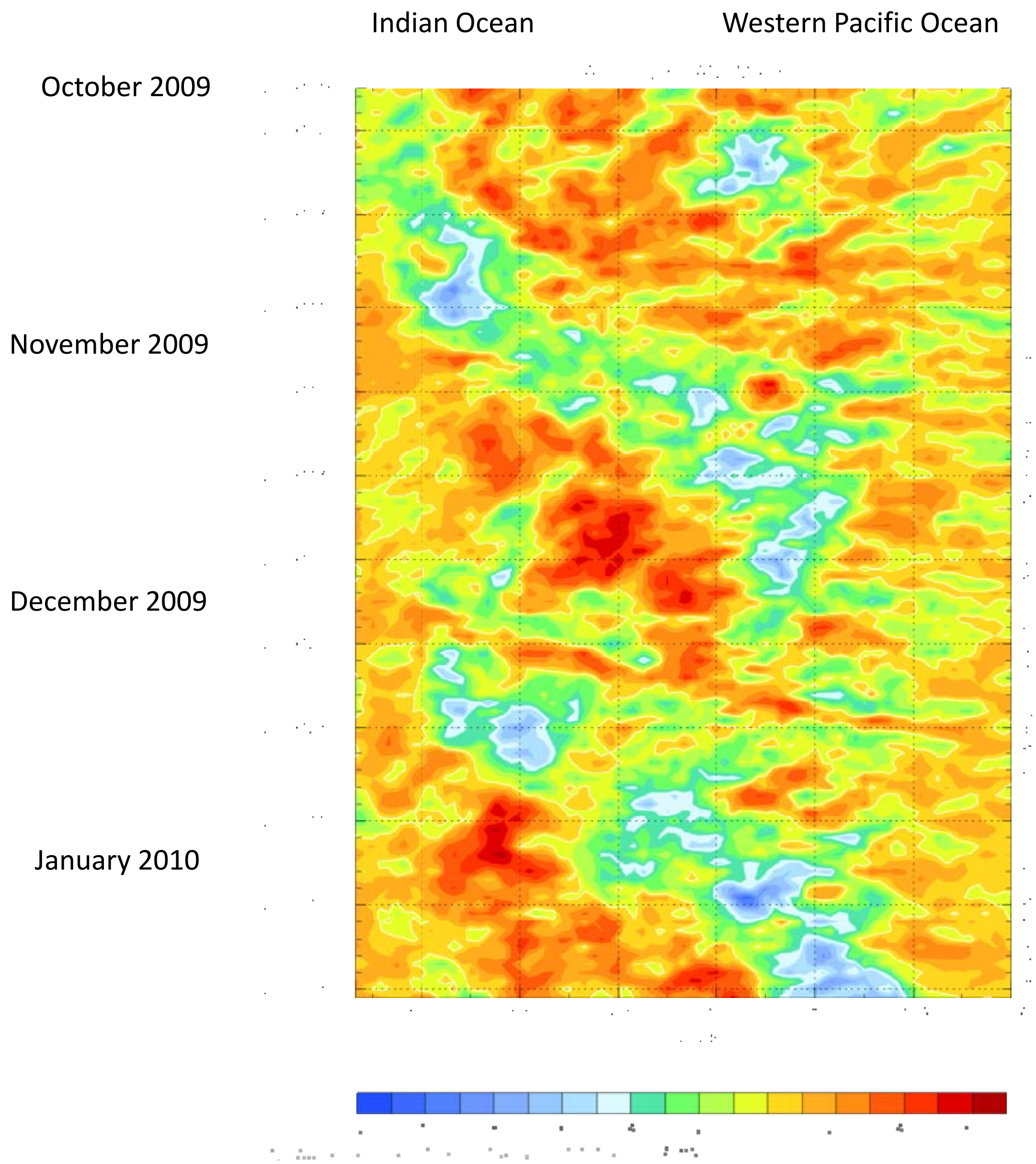
MJO in Plan View: 3-hourly OLR (SYN; top) and 12-hourly DIV (QuikSCAT L3; bottom)

November 2002

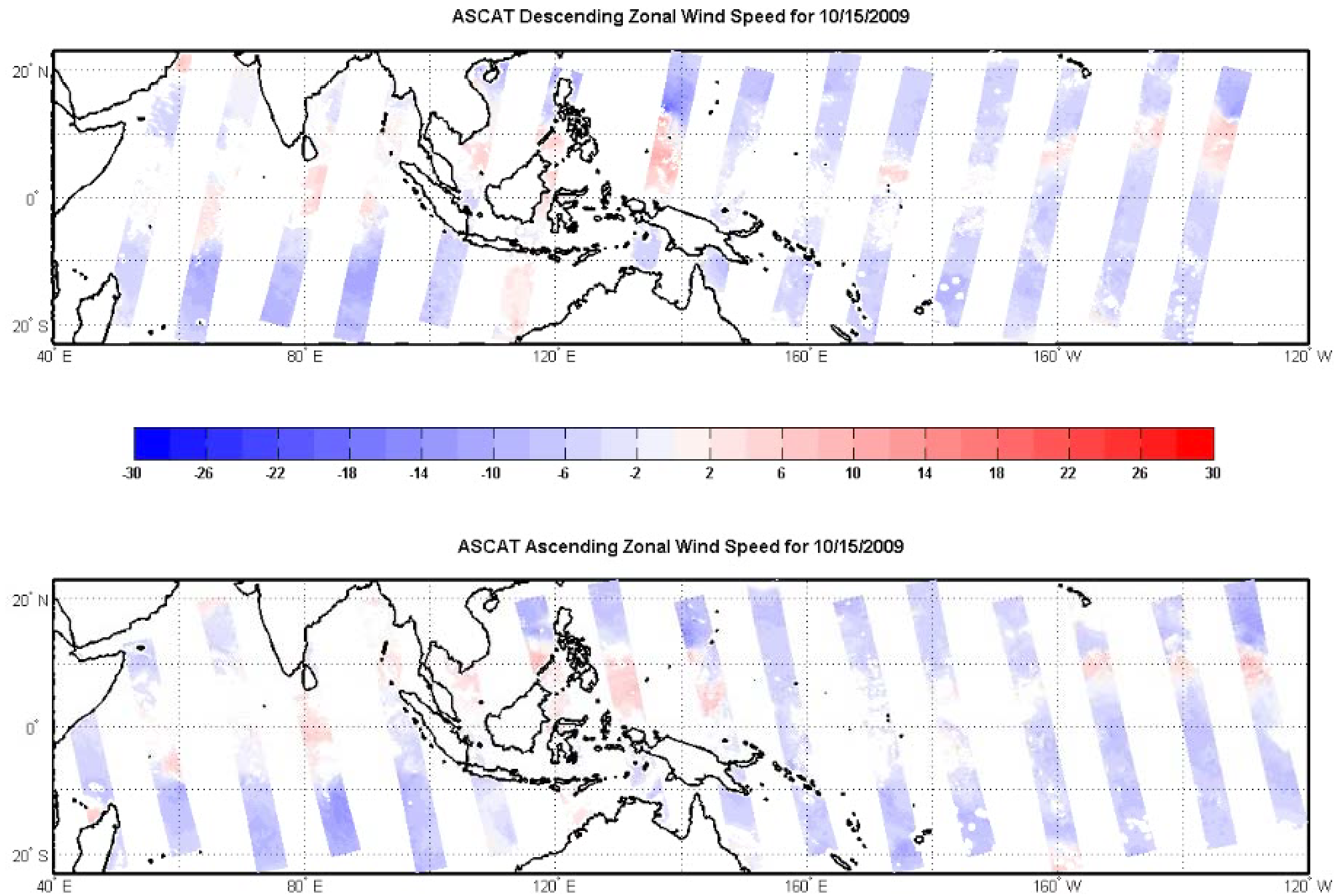


- Divergence extrema associated with MCS, embedded within MJO

MJO Signal in OLR Anomaly Time vs. Longitude Diagram



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



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

Summary:

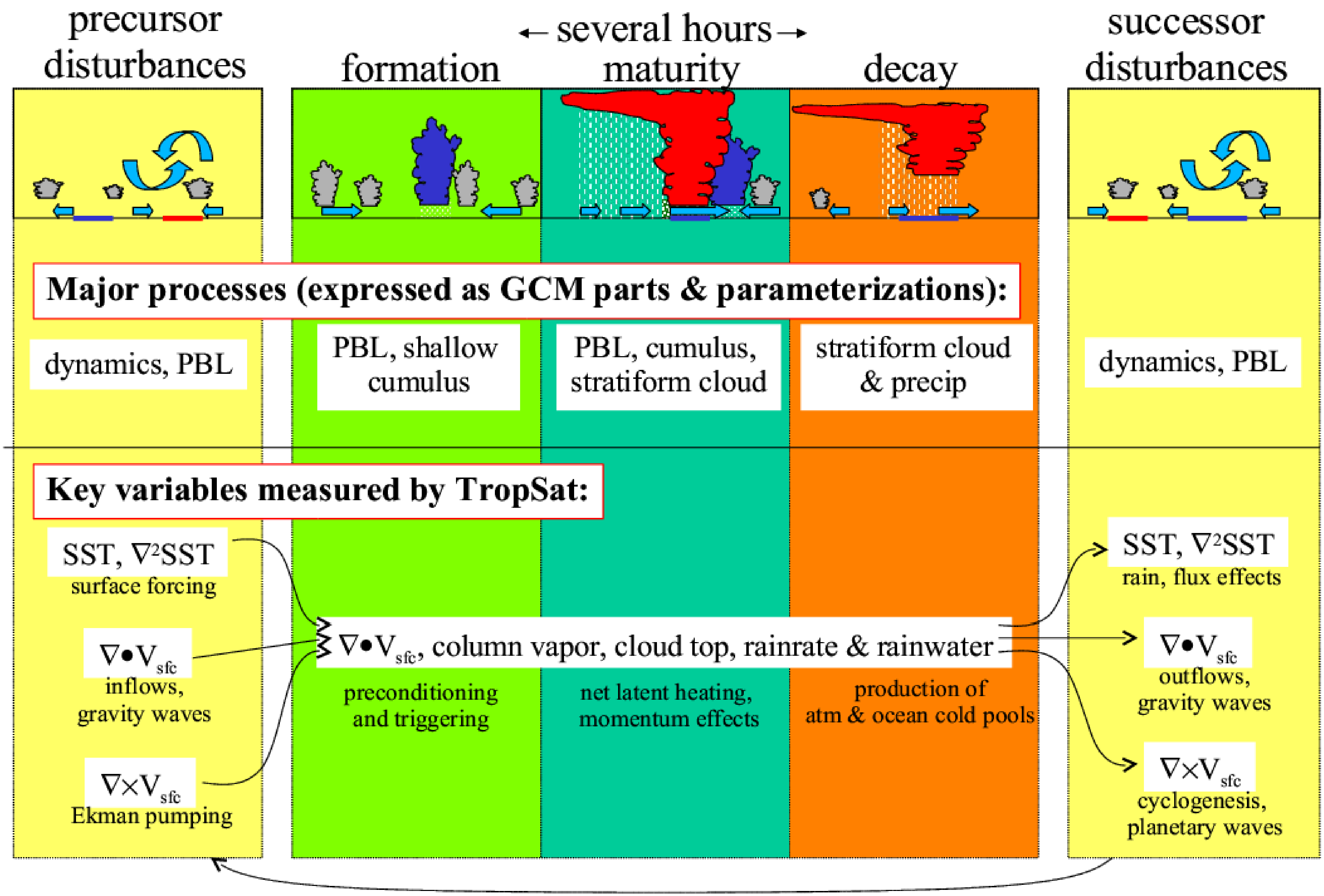
- Tropical events have important weather and climate-scale implications
    - multiple, nested temporal and spatial scales
    - deep convective plume to MJO, monsoon, ENSO, etc.
    - MCS building blocks resolvable, organization processes not well understood
    - challenge to space-borne observing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

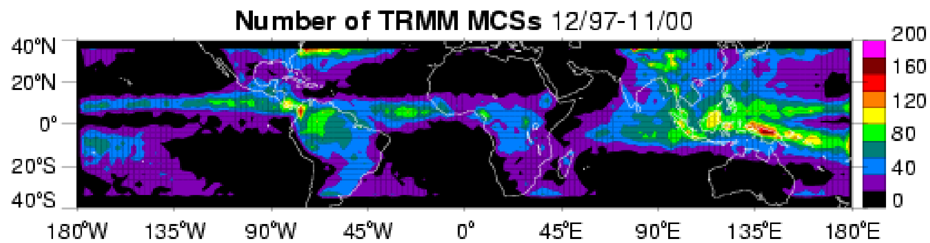
Supplementary Slides

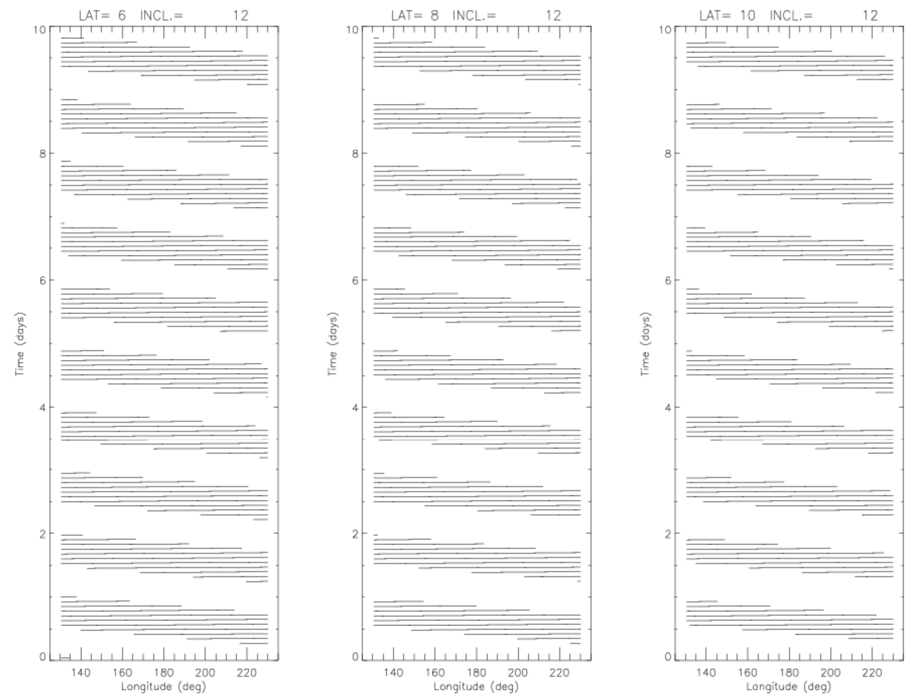
The Mesoscale Convective System (MCS) life cycle



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 H_2O, rain
cloud





	6°	10°	12°	14°	18°	22°
0°	∞, 360°					
2°	36, 5°; 10, 10°; 12, 10°; (0°)	9, 5°; 8, 10°; 9, 5°; (70°)				
4°	9, 15°; 8, 10°; (0°)	8, 20°; 7, 5°; (0°)	7, 5°; 8, 20°; 7, 5°; (70°)			
6°	7, 25°; (0°)	7, 25°; (0°)	7, 20°; 6, 5°; (0°)	7, 15°; 6, 5°; 7, 10°; (70°)		
8°	6, 20°; 5, 5°; (0°)	6, 25°; (0°)	7, 5°; 6, 20°; (0°)	7, 5°; 6, 20°; (0°)		
10°	5, 7°; (20°)	5, 20°; 6, 5°; (0°)	6, 12°; 5, 15°; (0°)	6, 15°; 5, 7°; (0°)	6, 22°; 5, 5°; (0°)	
12°		5, 10°; (17°)	5, 20°; (5°)	6, 3°; 5, 22°; (0°)	6, 10°; 5, 15°; (0°)	
14°				5, 10°; (15°)	5, 25°; (0°)	6, 10°; 5, 15°; (0°)
16°					5, 10°; (15°)	5, 25°; (0°)
18°						5, 12°; (12°)

Image courtesy S. Nesbitt via B. Mapes 2004