Northward Propagation Mechanisms of the Asian Summer Monsoon in the ERA-Interim Reanalysis and the SP-CCSM

Charlotte A. DeMott[1], Cristiana Stan[2,3], David A. Randall[1]

[1]*Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado USA*

[2]*Center for Ocean Land Atmosphere Studies, Calverton, Maryland, USA* [3]*Department of Atmospheric, Oceanic, and Earth Sciences, George Mason University, Fairfax, Virginia, USA*

Tropical waves and a northward-propagating monsoon

An eastward-propagating, tilted rainband

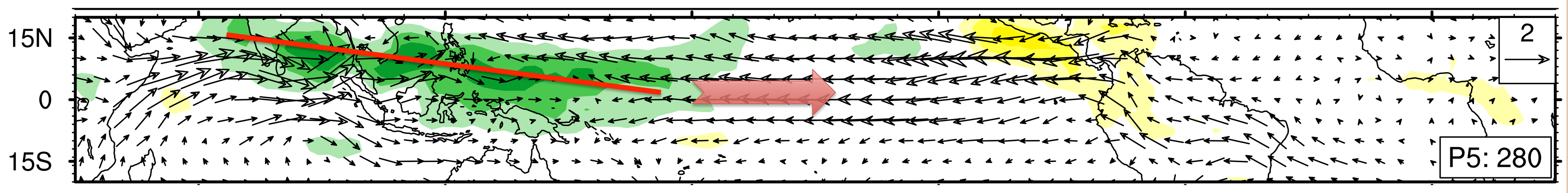


Fig. 1. Composite May-Oct OLR anomalies based on the first two a multivariate EOFs of Wheeler and Hendon (2004). Cold OLR anomalies (green shading) resemble a NW-SE oriented band (solid red line), which propagates eastward at ~5 m/s (faint red arrow).

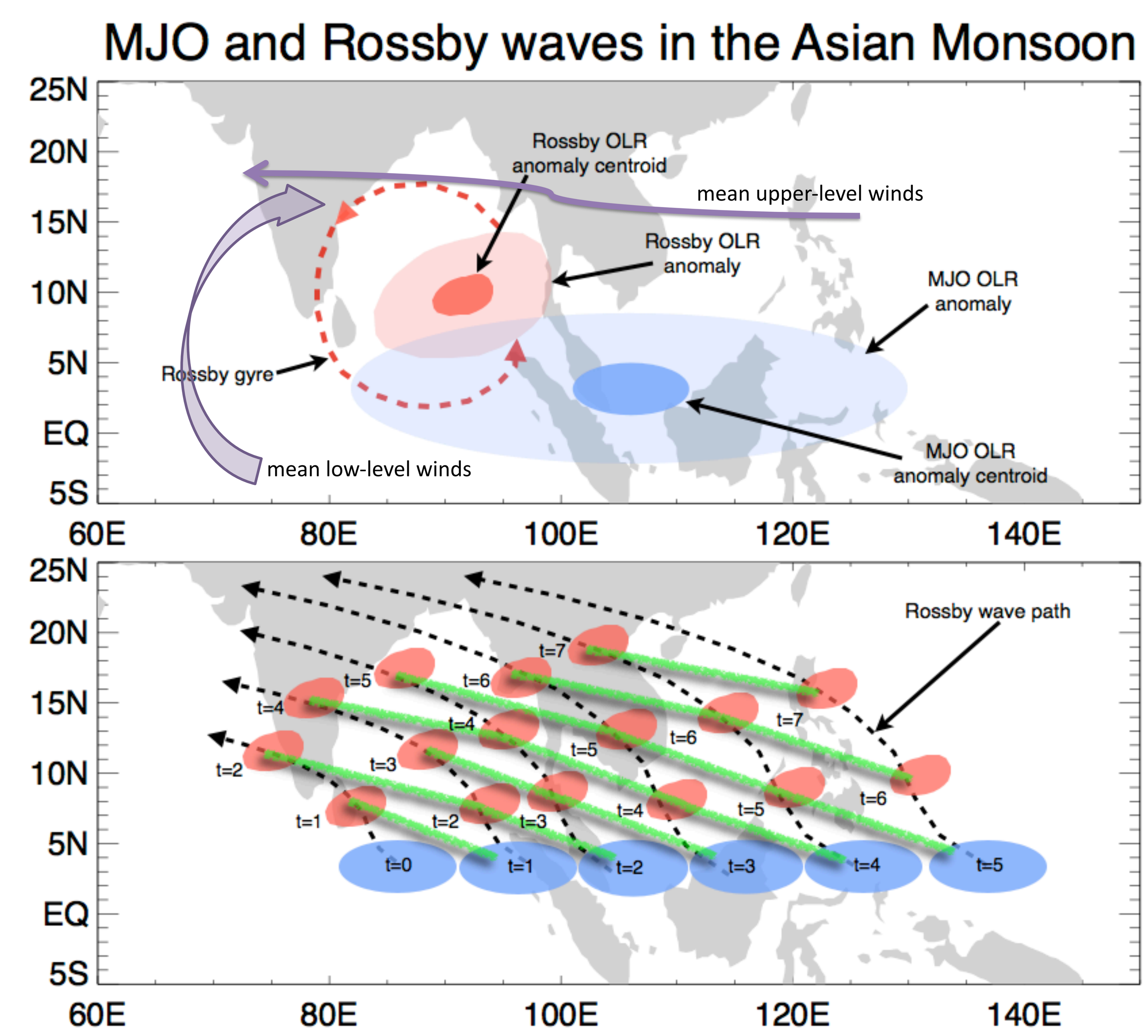


Fig. 2. Schematic illustration of the relationship between easterly shear, the MJO, equatorial Rossby waves, and the eastward-moving tilted rainband. Eastward-moving MJO convection excites westward-moving equatorial Rossby waves, which propagate to the NW.

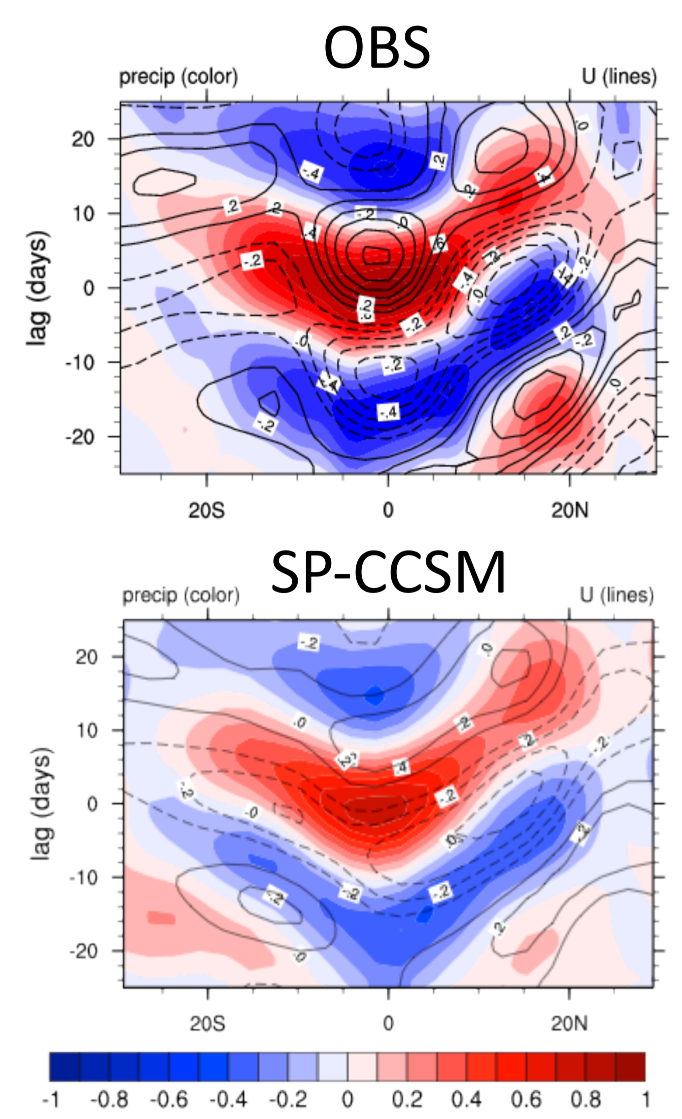
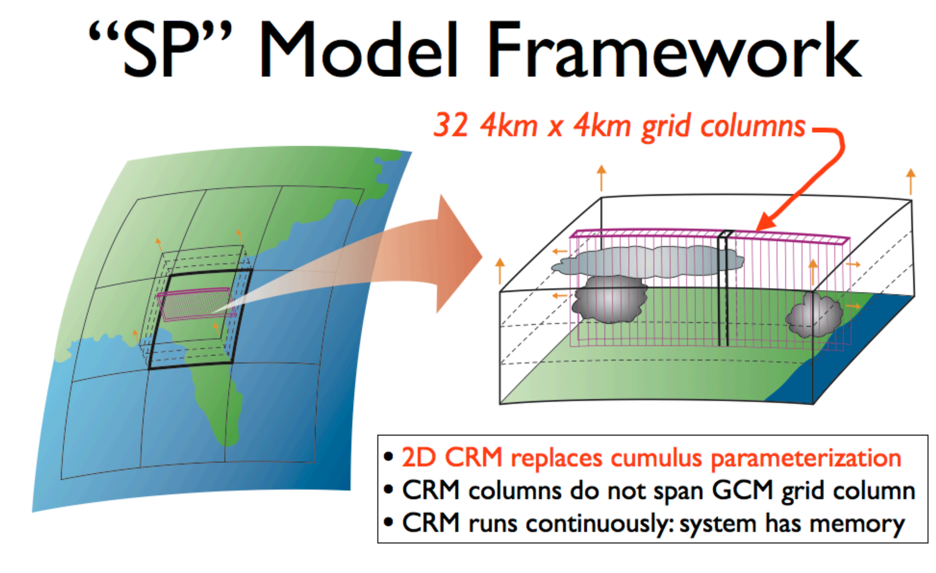


Fig. 3. May-Oct latitude vs. lag correlation of 20-100 day filtered precipitation anomalies averaged over 10ºS-5ºN, 75-100ºE with 20-100 day filtered precipitation and U850 winds averaged over the same longitudes.

Model, Data, Method

Super-Parameterized CCSM (SP-CCSM)



Schematic illustration of "super-parameterization"

SP-CCSM: CCSM3.0 with CRM in place of cumulus parameterization. 24 year simulation; last 20 years analyzed. Ocean initialized at rest with climatological SSTs. Monthly and daily mean output saved.

Data

- ERA-Interim Reanalysis daily means (1989-2010)
- NOAA OLR (1989-2010)
- TRMM TMI SST 3-day running mean (1998-2010)

Method

- Filter OLR anomalies for 20-100 day periods (MJO) and equatorial Rossby (ER) waves.
- Base point (BP) time series: normalized MJO or ER wave filtered OLR anomalies at a given location.
- For JJA, regress unfiltered normalized time series onto BP time series.
- At each point and lag, northward propagation mechanism (described below) with the greatest regression coefficient is dominant method.

What mechanisms are associated with June-August poleward propagation?

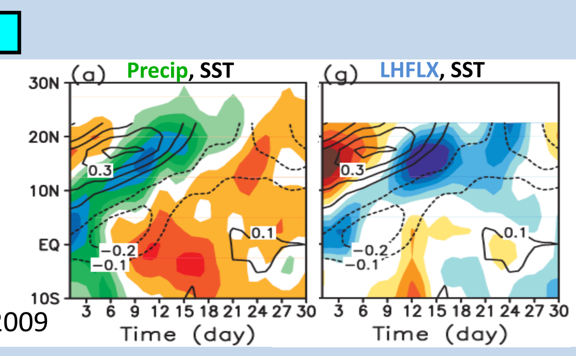
Mechanisms

Surface temperature destabilization: (cyan)

Many studies have demonstrated improved simulation of northward propagation when atmosphere-only models are coupled to ocean models. Warm surface temperature anomalies ahead of deep convection may destabilize the lower atmosphere.

Index = $(+Tsfc_R - LTS_R)/2$

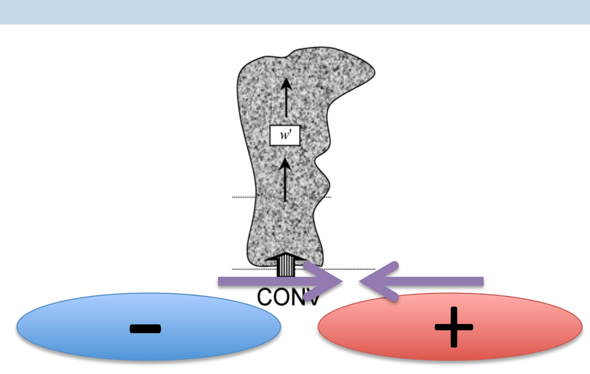
Notes: $LTS = \theta_{700} - \theta_{1000}$; R indicates regression coefficient



Source: Wang et al. 2009

SST gradients: (blue)

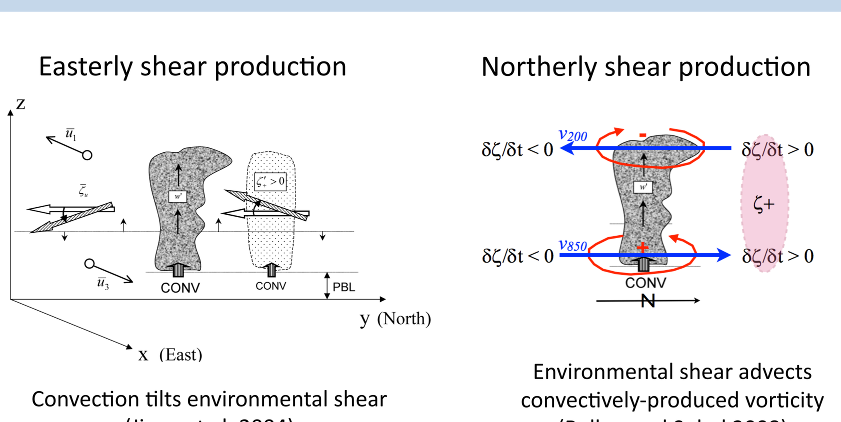
Anomalous SST gradients may drive boundary layer convergence on intraseasonal timescales.



Index: $(+\nabla^2 SST_R - DIV_{1000R})/2$

Barotropic vorticity: (red)

Easterly zonal shear and northerly meridional shear interact with anomalous convection to induce a barotropic vorticity anomaly north of the convection center. The anomalous barotropic vorticity produces barotropic divergence which is balanced by boundary layer convergence, generating new convection ahead of the existing convection.



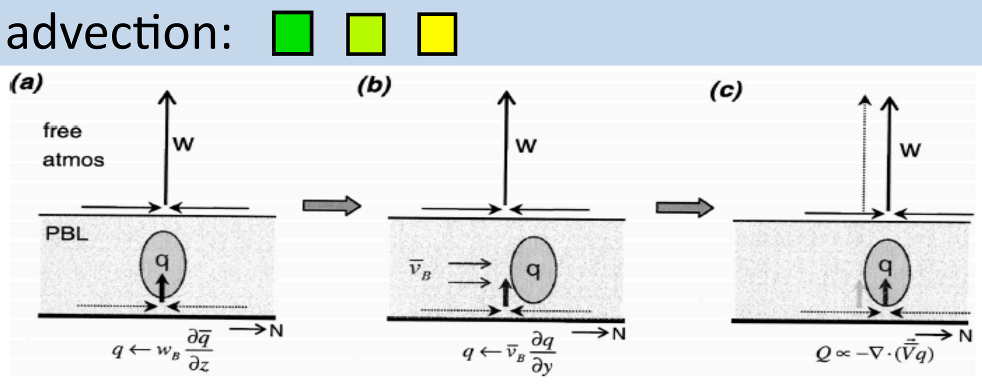
Convection tilts environmental shear (Jiang et al. 2004)

Environmental shear advects convectively-produced vorticity (Bellon and Sobel 2008)

Index: $(+\zeta^+_R - DIV_{1000R})/2$

Meridional moisture advection: (green, yellow-green, yellow)

Boundary layer moisture anomalies may be advected northward by the boundary layer meridional wind, leading to new convection ahead of the initial convection. Anomalous winds can also advect mean and anomalous moisture.



Indices: $\left(-\bar{v}\frac{\partial q'}{\partial y}\right)_{1000}$; $\left(-v'\frac{\partial \bar{q}}{\partial y}\right)_{1000}$; $\left(-v'\frac{\delta q'}{\delta y}\right)_{1000}$

Examples for MJO (ISO) at lag = 0:

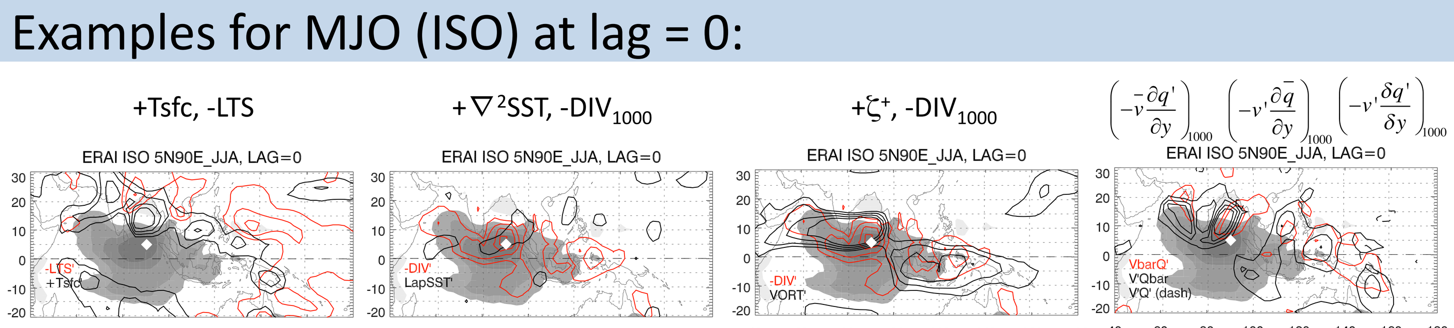
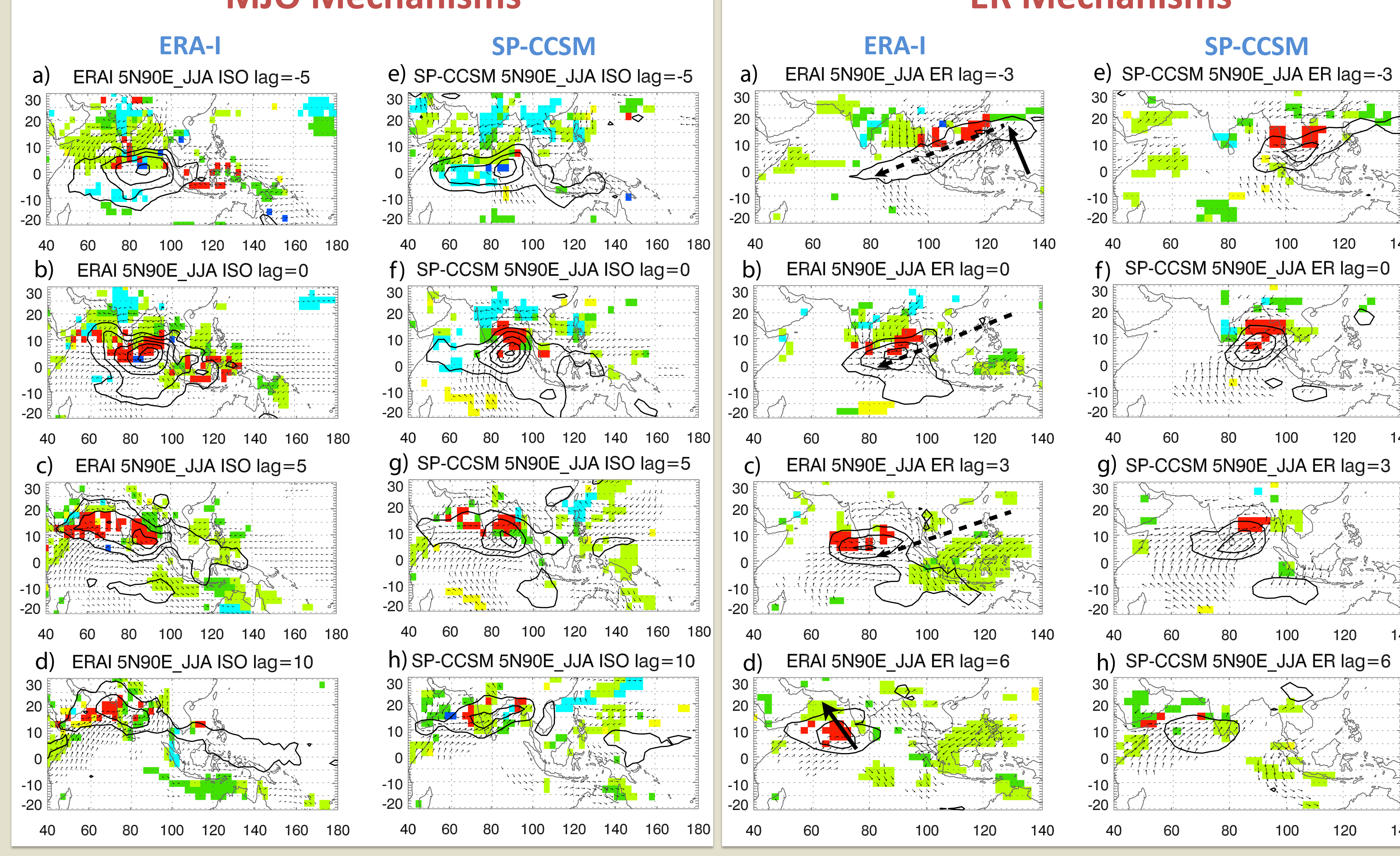


Fig. 4. JJA regression coefficients of normalized anomalies onto normalized MJO OLR anomaly at 5°N, 90°E. Cold (warm) OLR anomalies are dark (light) shaded. Contour interval is 0.1 standard deviation for all fields.

MJO Mechanisms / ER Mechanisms



LEGEND

- (yellow) $\left(-v'\frac{\delta q'}{\delta y}\right)_{1000}$
- (green) $\left(-\bar{v}\frac{\partial q'}{\partial y}\right)_{1000}$
- (cyan) Tsfc destabilization
- (yellow-green) $\left(-v'\frac{\partial \bar{q}}{\partial y}\right)_{1000}$
- (red) ζ+ effect
- (blue) SST gradient effect

Fig. 5. Dominant mechanisms of northward propagation for MJO (ISO) and ER wave variability. The normalized index (see description on left) with the greatest regression coefficient when regressed onto the normalized OLR anomaly for that wave type is plotted according to the legend.

Conclusions

- Poleward propagation is accomplished by many mechanisms.
- Boundary layer moisture advection is the primary mechanism when convection is near the equator.
- Barotropic vorticity is the primary mechanism north of ~5°N for both the MJO and ER waves.
- SP-CCSM correctly simulates most of these mechanisms, suggesting that convective response to changes in the boundary layer may be critical to simulating northward propagation.