Structure of Stratospheric Wave Responses to ENSO Convection

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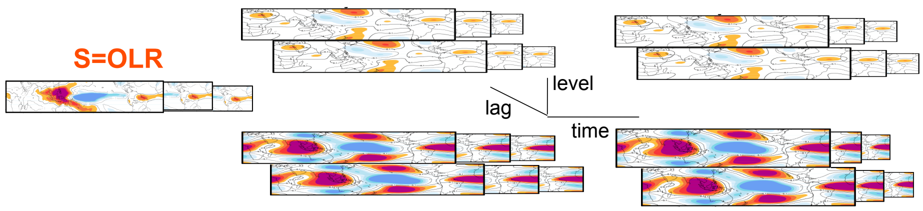
Generalized Maximum Covariance Analysis (GMCA) has been developed and applied to diagnosing the relationships between ENSO tropospheric heating variations and tropical stratospheric waves. GMCA identifies the most important patterns of co-variability between interannual heating variations and eddy zonal and meridional velocities, temperatures, and ozone mixing ratios in the tropics between 200 and 10 hPa. The first two sets of GMCA time coefficients have variations which are strongly related to ENSO and are highly correlated at a lag of about a year. The diagnosed spatial patterns have broad wave number one characteristics, which are associated with ENSO.

Method: GMCA is the decomposition of a covariance (or correlation) matrix **C** in terms of right **R** and left **L** matrices of vectors ordered by the squared covariance (correlation) explained. **S** matrix is calculated from the five principle components (PC) of an Empirical Orthogonal Function (EOF) analysis of OLR variations for the 30ºS-30ºN domain The **Z** matrix in the present GMCA analysis is calculated using the Fourier/Hermite coefficients of the adjusted departures from the instantaneous zonal means of u, v, T and O3 for the region between 45°S and 45°N at eight levels (10, 20, 30, 50, 70, 100, 150 and 200 hPa) at lags from -20 to +20 months for the period 1981-1999

Covariance (Correlation) matrix C = S Z

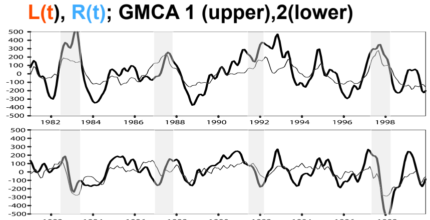
is decomposed in terms of $C = L \omega R^T$

$Z = U \;\; V \;\; T \;\; O_3$



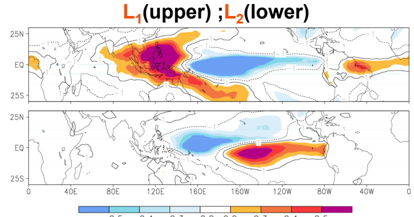
Results: The first two sets of GMCA time coefficients (L(t),R(t)) have variations which are strongly related to ENSO (gray bars) and are highly correlated at a lag of about a year. The associated patterns of tropical OLR (L_1,L_2) are similar to the canonical ENSO SST patterns with strong negative sign regions stretching along the equator from the western to the eastern Pacific.

L(t), R(t); GMCA 1 (upper),2(lower)



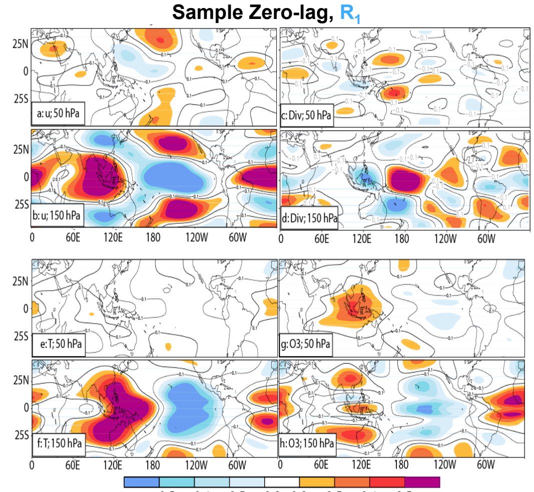
Shaded blocks ENSO warm events

L_1(upper) ;L_2(lower)



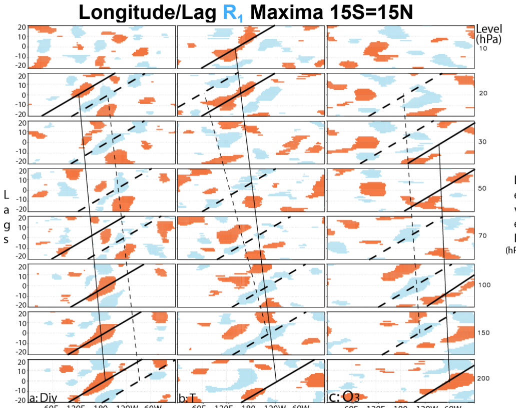
Negative regions associated with convection

Sample Zero-lag, R_1



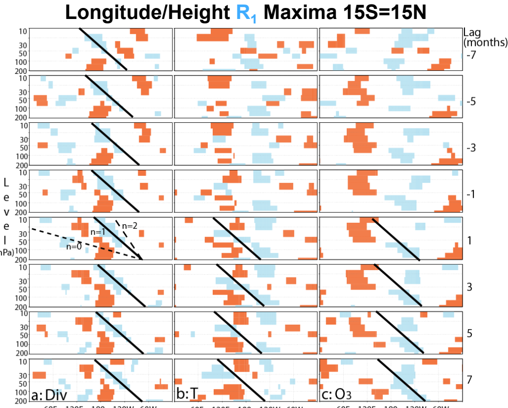
There is propagation upward and westward of the divergence, temperature and ozone (R_1) anomalies from the bottom to near the top of the domain. The longitude/height tilt of this propagation is consistent with a longitudinal and meridional wave number one. At the same time all features propagate slowly to the east along with the tropospheric heating anomaly. The patterns are such that in the lower stratosphere regions of divergence (convergence), corresponding to upward vertical motion are broadly associated with lower (higher) temperatures and reduced (enhanced) ozone mixing ratios.

Longitude/Lag R_1 Maxima 15S=15N



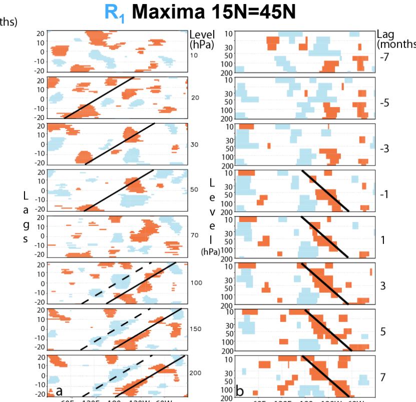
GMCA1 heterogeneous correlation maxima (dark shading) and minima (light shading) for eddy departures. Positive correlations correspond to increased convection along the equator in the central and eastern Pacific. Heavy diagonal lines show the west to east propagation speed of 0.2m/s. Lighter, nearly vertical, lines indicate the approximate vertical propagation of zero-lag features at the equator.

Longitude/Height R_1 Maxima 15S=15N



GMCA1 heterogeneous correlation maxima (dark shading) and minima (light shading) for eddy departures for the lags listed along the right as in figure to the left. Heavy solid diagonal lines show approximate vertical propagation of a zonal wave number one, meridional wave number one gravity wave. The short and long dashed lines correspond to the propagation of meridional wave number zero and two, respectively.

R_1 Maxima 15N=45N



(a) GMCA1 longitude/lag 15°N-45°N mean heterogeneous correlation maxima (dark shading) and minima (light shading) for eddy horizontal divergence and (b) longitude/height 15°N-45°N mean heterogeneous correlation maxima and minima for horizontal divergence.

Conclusions: The dominant modes of heating variations are linked to a rich three-dimensional pattern of stratospheric eddy perturbations over a wide range of lags. Generally, all major features propagate slowly to the east along with the tropospheric heating anomaly. In addition there is strong vertical coherence such that the strongest anomalies tilt westward from the bottom to the top of the domain. This tilt is associated with wave number one gravity waves propagating into the stratosphere. The patterns are such that in the lower stratosphere regions of divergence (convergence), corresponding to upward motion, are associated with lower (higher) temperatures and reduced (enhanced) ozone mixing ratios. These findings are consistent with adiabatic cooling of rising low ozone concentration tropospheric air.

Weare, B.C., 2008: Structure of Stratospheric Wave Responses to ENSO Convection**. J. of Climate,** in review.