A Relationship Between Convectively-Coupled Atmospheric Kelvin Waves and Atlantic Tropical Cyclogenesis

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Introduction

- Schreck and Molinari (2011) found the geneses of Rammasun and Chataan (2002) was the result of the passage of a series of convectively-coupled atmospheric Kelvin waves (CCKWs) during the convectively-active phase of the Madden Julian Oscillation (MJO).
- Do CCKWs influence the large-scale environmental conditions (shear, moisture, vorticity, etc.) over the Atlantic's main development region?
- Is there a relationship with tropical cyclogenesis and the passage of a CCKW over the tropical Atlantic?

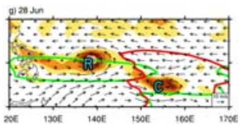

Figure 6. Unfiltered 850-hPa PV (shading), Kelvin-filtered rainfall (red contours), MJO-filtered rainfall (green contours), and unfiltered 850-hPa wind vectors. Kelvin-filtered and MJO-filtered anomalies are contoured at +4 mm day−1.

Summary

Kelvin wave index (9°N, 15°W)
- Negative Kelvin filtered OLR anomalies < -1.5 standard deviations in magnitude during the 1989-2009 JJAS seasons.
- 164 Kelvin waves were objectively identified using this methodology.
- "Day 0" is when the minimum Kelvin filtered OLR anomaly moves over our selected base point.

Convection
- The convectively suppressed phase of the CCKW (red contour) acts to weaken local convection over the Atlantic ITCZ and tropical African regions.
- The convectively active phase of the CCKW progresses eastward and acts to locally enhance convection.
- A second convectively suppressed phase of the CCKW follows the convectively active phase, again acting to reduce local convection.
- The "suppressed-active-suppressed" convective pattern associated with the CCKW travels eastward with an average phase speed of roughly 15 ms^{-1}.

Large-scale Environmental Conditions
- The vertical wind shear over the southern MDR reduces after the passage of the convectively active phase of the CCKW.
- Deep convection associated with the convectively active phase of the CCKW is consistent with an increase of atmospheric moisture.
- Low-level cyclonic relative vorticity is enhanced over the MDR during the passage of the CCKW.

Atlantic Tropical Cyclogenesis
- A rapid increase in the number of tropical cyclogenesis events is observed between Day -1 and Day +2, a statistically significant peak in tropical cyclogenesis frequency.
- One day prior to the convectively active phase of the CCKW (Day -1), a statistically significant minimum of tropical cyclogenesis is observed.
- *This relatively low-period of tropical cyclogenesis activity occurs within the leading convectively suppressed phase of the CCKW.*
- A rapid decrease of tropical cyclogenesis events occurs between Day +2 and Day +3.
- *This reduction of tropical cyclogenesis events occurs within the second convectively-suppressed phase of the CCKW, which follows the convectively active phase.*

Operational Viewpoint on Convectively-Coupled Kelvin Waves
- Extreme precipitation events over tropical regions such as Africa (e.g., Mekonnen et al. 2008).
- Modulate tropical cyclogenesis over the MDR.
- Wheeler and Weickmann (2001) investigated forecasting convectively-coupled tropical wave modes by using their "real-time filtering" approach.
- Roundy and Schreck (2009) provide a statistical approach to real-time filter convectively-coupled tropical waves.

2011 Atlantic Hurricane Season – NASA's HS3 Campaign
- CCKW forecasting will be provided at: http://www.atmos.albany.edu/student/ventrice.htm under Tropical Wave Monitoring.
- Forecasts will be performed by using hovmoellers of TRMM's 3b42 rainrate.
- The TRMM 3b42 dataset captures convectively-coupled atmospheric waves exceptionally well (Carl Schreck's dissertation)

Acknowledgements and References

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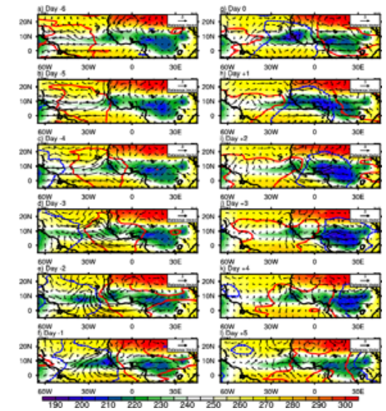
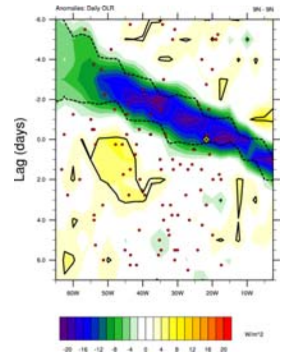
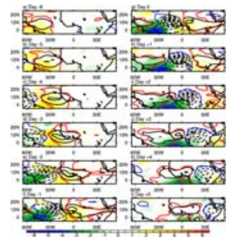


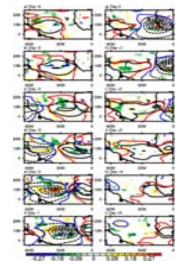
NOAA daily averaged interpolated total OLR (shaded), Kelvin filtered OLR anomalies (contoured), and 850 hPa wind anomalies (vectors) averaged over the Northern Hemisphere summer months (JAS) from 1989-2009 for each CCKW day lag. Positive (Negative) Kelvin filtered OLR anomalies are indicated by the red (blue) line and are statistically different than zero at the 99% level. Shade interval is 5 Wm^{-2}; reference wind vector is 0.5 ms^{-1}.



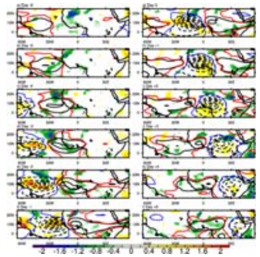
Time verse longitude section plot of composited OLR anomalies averaged along 9°N during June-September 1979-2009. Composite unfiltered OLR anomalies are shaded. Positive OLR anomalies statistically different than zero at the 95% level are within the solid contour. Negative OLR anomalies statistically different than zero at the 95% level are within dashed contour. Tropical cyclogenesis within the MDR (5-25°N, 65-15°W) for any given lag is denoted by a red circle. The genesis of Tropical Storm Debby is highlighted by the large yellow crossed circle. Shade interval is 2 Wm^{-2}.



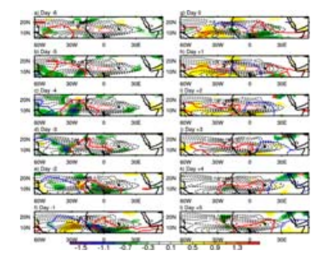
200-925 hPa vertical wind shear of the zonal wind anomalies averaged over each CCKW lag. Anomalies statistically different than zero at the 95% level are shaded. CCKW filtered OLR anomalies are contoured. Kelvin filtered negative OLR anomalies are dashed. Positive (Negative) Kelvin filtered OLR anomalies within the red (blue) line are statistically different than zero at the 99% level. Shade interval is 0.5 ms^{-1}; contour interval is 3 Wm^{-2}.



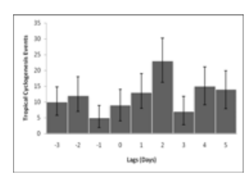
925 hPa relative vorticity anomalies averaged over each CCKW lag. Anomalies statistically different than zero at the 90% level are shaded. CCKW filtered OLR anomalies are contoured. Kelvin filtered negative OLR anomalies are dashed. Positive (Negative) Kelvin filtered OLR anomalies within the red (blue) line are statistically different than zero at the 99% level. Shade interval is 0.03 x 10^{-5} s^{-1}; contour interval is 3 Wm^{-2}.



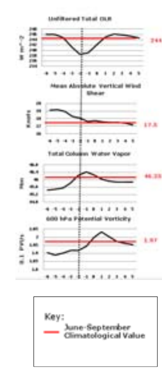
Total column water vapor anomalies averaged over each CCKW lag. Anomalies statistically different than zero at the 95% level are shaded. CCKW filtered OLR anomalies are contoured. Kelvin filtered negative OLR anomalies are dashed. Positive (Negative) Kelvin filtered OLR anomalies within the red (blue) line are statistically different than zero at the 99% level. Shade interval is 0.2 mm; contour interval is 3 Wm^{-2}.

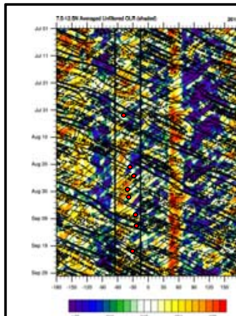


700 hPa zonal wind averaged over each CCKW lag. Zonal wind anomalies Statistically different than zero at the 95% level are shaded. Total zonal wind is contoured. Positive (Negative) Kelvin filtered OLR anomalies within the red (blue) line are statistically different than zero at the 99% level. Shade interval is 0.2 ms^{-1}; Contouring begins at 4 ms^{-1} and contour interval is 1 ms^{-1}.

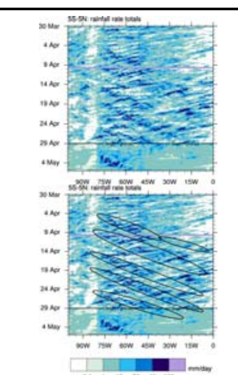


Tropical cyclogenesis events over the MDR (5-25°N, 65-15°W) relative to the CCKW during June-September 1979-2009. "Day 0" highlights the transition to statistically significant negative Kelvin filtered OLR anomalies, or the eastern-most side of the convectively active phase of the CCKW. Error bars indicate the 95% confidence interval.





2010 JAS season. Total OLR (shaded) overlaid with Kelvin filtered negative OLR anomalies. Red circles represent locations of tropical cyclogenesis. Kelvin space-time filtering was performed using eastward wave numbers 1-14 with a period of 2.5 to 20 days (Wheeler and Kiladis 1999).



Real-time forecasting example Mar-May 2011. TRMM rainfall rate is shaded. The convectively active phase of the Kelvin wave is highlighted subjectively by the black contours. The Black line on Apr 29 indicates the GFS forecast. See more at: www.atmos.albany.edu/student/ventrice/Kelvin.htm