The role of convectively-coupled atmospheric Kelvin waves during the 2010 Atlantic Hurricane Season

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This Talk

1. Background information regarding convectively-coupled atmospheric equatorial Kelvin waves (henceforth CCKWs; Ventrice et al. 2011)
2. The 2010 August-September look on tropical cyclones (TCs) and CCKWs
3. Case Study of the genesis of Julia
4. An unexpected weakening of Hurricane Danielle
5. Conclusions
Data Sources & Methodology

- ECMWF-Interim Dataset (Simmons et al. 2007)
- NOAA’s Daily Average OLR Dataset (Liebmann and Smith 1996)
  - Wheeler and Kiladis (1999) for Kelvin wave filtering [period of 2.5-20 days, with eastward wavenumber 1-14]
- NASA’s Merged IR-dataset
Data Sources & Methodology

- Developed a time-series using Kelvin filtered OLR anomalies.
  - Selected dates where Kelvin filtered OLR anomaly was a minimum over 7.5°N, 15°W (**DAY 0**)
  - Used a daily lagged approach
  - Threshold was -1.5 standard deviations
    - 215 Kelvin waves (1979-2009)
    - 164 Kelvin waves (1989-2009)
Unfiltered total OLR, Kelvin filtered OLR, and 850 hPa wind anomalies

Key:
- Unfiltered total OLR field (Shaded)
- Kelvin filtered OLR (Contours)
- Positive (Negative) Kelvin filtered OLR anomalies statistically different than zero at the 99% level are within the solid (dashed) red (blue) line
- 850 hPa wind anomalies (Vectors)
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Unfiltered Total OLR

Mean Absolute Vertical Wind Shear

Total Column Water Vapor

600 hPa Potential Vorticity

Key:
- June-September
- Climatological Value

Averaged over 7.5-15°N, 15-60°W
**JJAS 1979-2009 Composite**

- Unfiltered OLR anomalies (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, 15-65°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.
Tropical cyclogenesis events over the MDR (5-25°N, 15-65°W) relative to the CCKW during June-September 1979-2009

- Day 0 highlights the transition to statistically significant negative unfiltered OLR anomalies, or the eastern-most side of the convectively active phase of the CCKW.
- Error bars indicate the 95% confidence interval.
Tropical cyclogenesis relative to the Kelvin wave
August – September 2010

- 8 named TCs inside the MDR
- 3 TCs formed under the convectively active phase of a CCKW
  - Collin, Julia, Lisa
- 7/9 consecutive AEWs developed over the MDR between mid August-September

Key:
- TD-type filtered negative OLR anomalies (shaded)
- Kelvin filtered OLR anomalies (contour)
- TC genesis points
Hurricane Julia

- Formed near the coast of West Africa
- Interacted with the convectively-active phase of a CCKW before undergoing tropical cyclogenesis
- Was already a vigorous easterly wave before the interaction with a strong CCKW
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The convectively active phase of a CCKW enhances tropical cyclogenesis over the MDR by:

1) Enhancing westward propagating African easterly waves by providing an environmental suitable for deep convection

2) Enhancing large-scale environmental conditions over the MDR to be favorable for TC genesis for a brief period of time

Question:
Can an unfavorable phase of a CCKW be destructive to a TC?

Hurricane Julia (2010)
(Reuters) – “Hurricane Danielle unexpectedly weakened in the open Atlantic Ocean on Tuesday and was downgraded to a Category 1 storm on the Saffir-Simpson scale, as winds eased from 100 miles per hour to 80 mph, the U.S. National Hurricane Center said.”
Healthy Category 2 Hurricane → Weak Category 1 Hurricane in only 12 hours!

10 mb pressure rise (12 hrs)

15 knot decrease (12 hrs)
After reaching an intensity of 80 kt around 0600 UTC 24 August, southwesterly shear associated with a shortwave trough moving southwestward in the subtropical Atlantic between 45-50°W caused Danielle to decrease in strength. The trough also weakened the subtropical ridge that was steering Danielle, which resulted in a turn toward the west-northwest. Despite a continuation of moderate southwesterly shear, Danielle maintained hurricane strength on 24 August and early on 25 August. Late on 25 August the hurricane turned northwestward and its forward speed decreased in response to a new weakness developing in the subtropical ridge over the central Atlantic. A decrease in shear around that time led to a gradual strengthening of the cyclone on 26 August, and the rate of deepening increased early on 27 August.

-National Hurricane Center - 15 December 2010
Sudden Increase in OLR
Pressure (mb)

18Z August 24

Time

8/22-00Z
8/22-12Z
8/23-00Z
8/23-12Z
8/24-00Z
8/24-12Z
8/25-00Z
8/25-12Z
8/26-00Z
8/26-12Z
8/27-00Z
8/27-12Z
8/27-21Z
8/28-00Z
8/28-12Z
8/29-00Z
Location of Danielle when the hurricane experienced a brief weakening
Composite of 200 hPa Velocity Potential Anomalies for a convectively-suppressed phase Kelvin wave index over the MDR

- 119 JAS (1989-2009) Kelvin waves
- +1.5 STDs at 7.5° N, 45° W (Day 0)
Concluding Remarks

• CCKWs are important!
  1) Modulate tropical cyclogenesis over the MDR
  2) Suppressed phase can weaken developed TCs

• CCKWs were directly associated with the genesis of three TCs over the MDR.
  - Collin, Julia, and Lisa
  - The formation of the Atlantic ITCZ before the genesis of Danielle was associated with a series of CCKWs.
    - Danielle, Earl, Fiona pre-cursor AEWs were enhanced by CCKWs

• A strong suppressed phase of a CCKW interacted with Hurricane Danielle during the time of unexpected weakening.
  - Inhibited convection over the southern half of Danielle
  - Weakened the moist inflow of the TC
    - Large-scale subsidence
Supplemental Figures
“The origin of Danielle was complex.”

-National Hurricane Center, 15 December 2010
“...an active Intertropical Convergence Zone (ITCZ) was detected a few hundred nautical miles south-southwest of the Cape Verde Islands.”

“...a smaller-scale circulation formed along the southwestern end of the larger gyre.”

“Embedded within strong low-level westerly flow...”
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