TITLE: Analysis of African Easterly Wave Structures and Their Role in Influencing Tropical Cyclogenesis

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YEAR: 2010

REVIEWED: January 17, 2011

Reasons for Review:

- Defining attributes of AEWs that develop into tropical cyclones
- Nature of AEW structures over West African continent that increase/decrease probability of downstream tropical cyclogenesis
- Investigates AEW variability and if AEW characteristics can influence their own fate.

Abbreviations/Symbols:

- AEJ African Easterly Jet
- AEW African Easterly Wave
- BT Brightness Temperature
- GH Guinea Highlands
- JAS July, August, September
- MDR Main Development Region
- PV Potential Vorticity
- RV Relative Vorticity
- SST Sea-Surface Temperature
- TC Tropical Cyclone

Data:

- 40-yr European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (2.5°)
    - July-September, 1979-2001

- *I am weary of the ability to decipher detailed characteristics of AEWs as well as understanding whether or not they form TCs downstream*

- High-resolution ERA-40 data (1.125°) utilized to create composites
    - Composites smooth out small variations in AEW structures (!!)

- Cloud Archive User Service (CLAUS) Brightness Temperature

Notes:

- AEWs
    - Most Atlantic TCs form from AEWs
    - Synoptic scale
        - 2000-4000 km wavelength
    - Develop on AEJ
        - Peak amplitude is close to level of AEJ
    - Grow via mixed baroclinic-barotropic growth mechanism
    - Triggered by upstream convection
    - Subsynoptic-scale structures within

- Background Information
    - Thorncroft and Hodges (2001) found that most 850 hPa vorticity centers that reach the MDR cross the GH region.
    - The GH region could be important for topographically-enhanced convection, as well as introducing high values of PV.

- AEW Identification
    - Minimum in 600 hPa streamfunction (derived from 2-6-day-filtered winds)
    - AEW "Day 0" is defined when streamfunction minimum us between 7° and 20°N at 15°W (near West African coast)
        - At least 1 standard deviation below the JAS mean
    - Relatively even distribution of TC development throughout MDR
        - Although slightly more near West African coast than near Lesser Antilles

- Developing AEWs
    - More distinctive cold structure associated with developing AEWs 2 days before reaching West African coast.
    - GH region enhances convection
    - Increased low-level vorticity
        - Helps transition to warm-core structure
    - Convection is maintained as AEW moves offshore

- **Approx. 1 in 7 AEWs becomes a named TC**
  - This ratio varies month to month
  - July 1 in 16
  - August 1 in 4
  - September 1 in 5
- More coastal developments in September (17) than July (3)
  - Consistent with rainfall and vorticity generation near GH

- Non-developing AEWs
  - Have weaker amplitudes
  - Convection is not really enhanced near GH region
  - More prominent dry signal in mid- and upper- levels ahead of AEW
    - May be enhanced by stronger circulations
  - More intense convection
  - Stronger mid- and low-level circulations
    - May advect more dry air ahead of AEW

- Horizontal Structure of Developing AEWs
  - East of 30°W
    - AEWs exhibit stronger NE-SW tilt once offshore
      - More barotropic conversion
    - High PV associated with trough even as streamfunction decreases by Day +2
    - RV is to west of trough over continent; east of trough over Atlantic
      - Consistent with convection shifting to the east as AEWs emerge offshore
    - BT indicates convection within NNE winds onshore
      - SSW offshore
      - This is consistent with
    - **More intense troughs**
    - **Most travel along southern storm track**
    - **More convectively active near GH**

- Horizontal Structure of Non-developing AEWs
  - East of 30°W
    - Streamfunction is 50% weaker
    - PV is 33% weaker
    - Much weaker RV values
      - No clear maximum within AEWs
    - BT does not indicate strong convection as AEWs approach West African coast and more offshore
      - Very weak signal by Day +2

- Vertical Structure of Developing AEWs
    - East of 30°W
        - Warm-core structure is notable near West African coast (Day 0)
        - Mid- to upper-level RH is higher ahead of AEW
        - Vertical velocity of at least -0.32 hPa s^{-1}
        - More mid-tropospheric RV at Day -2
        - More low-level RV at Day 0
        - **Convectively active near West African coast**
        - **Stronger mid-level PV and low-level RV**
        - **More pronounced warm core near coast (Day 0)**
        - **More pronounced cold core over West Africa (Day -2)**
        - Stronger cold-core toughs and low convective inhibition make deep convection more favorable near GH and likely influences the cold- to warm-core transition.

- Vertical Structure of Non-developing AEWs
    - East of 30°W
        - RV is notably less on Day 0
        - Mid- to upper-level RH is notably lower ahead of AEW
            - More dryness for non-developing AEWs to overcome
                - May be self-induced
        - Vertical velocity is lower (-0.24 hPa s^{-1})
        - By Day +2, coherent vertical AEW structure is all but lost
        - Very little difference between low- and mid-level RV
        - **Drier mid- to upper-levels is key to lack of development**

- Strong non-developing AEW cases
    - Chosen based on high PV signature at 600 hPa
    - These AEWs are associated with stronger troughs at Day -2 and Day 0
    - At Day 0, more intense PV at 600 hPa, but circulation is advecting lower PV air ahead of system
        - Saharan Air Layer has a more significant effect on these AEWs
    - At Day 0, AEW is associated with more intense convection than the developing AEWs
    - By Day 2, PV signature is weakened and located to the east of the AEW axis
    - These AEWs remain cold-core through Day +2
    - Associated with much drier mid- to upper-level air
        - May be self-induced
    - As AEW moves offshore, strongest vertical velocities are left behind in GH region
    - Saharan Air Layer and dry air above that could have a role
    - **AEWs may become "too strong" to develop**

        - Their strong circulations spell their own demise

- AEWs associated with mid-Atlantic TCs
    - AEW structure over Africa likely plays a less important role in these regions
        - Still accounts for nearly 1/3 of MDR TCs
    - Streamfunction is not as strong as the east Atlantic developers but not as weak as the non-developers

- AEWs associated with western Atlantic TCs
    - AEW structure over Africa likely plays a less important role in these regions
        - Still accounts for nearly 1/3 of MDR TCs
    - Structure is still much different than for non-developers
    - **AEWs must be dynamically strong and convectively active upon exiting the West African coast**

- Impact of the Large-scale environment
    - Vertical Wind Shear
        - Not very different near the coast for developing and non-developing AEWs
        - In southern MDR, wind shear is higher for developing cases
            - This is likely due to an enhanced AEJ
    - SSTs
        - Up to 1° warmer right off the West African coast for developing AEW cases
        - Although most AEWs form south of the enhanced SSTs, wind traveling over this water will be warmer and, thus, should carry more moisture
            - May limit the impact of dry air intrusion