Arc Clouds and Saharan Dust Storms in the Tropical Cyclone Environment

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Discussion Outline

• Motivation: How does moisture and vertical wind shear in the surrounding TC environment impact TC intensity...and where do arc clouds fit into all this?

• Background
  - Saharan Dust Storms
  - New Mean soundings for the tropical Atlantic
  - Arc clouds (midwest t-storms vs tropical cyclones)

• Brunch: 11:00-noon

• Arc Clouds & Tropical Cyclones
  - hypotheses
  - arc cloud/TC research (aircraft obs, modeling)

• 2010 Hurricane Field Campaigns
Saharan Air Layer (aka Saharan Dust Storms)
Saharan Dust: Forward vs Backscattering

Ping Yang (TX A&M), Bryan Baum

Barbados: Sept 2006

Miami: July 2009

Hurricane Helene (G-IV): Sept 2006

Miami: July 2009

Hurricane Bill (P-3): Aug 2009

Scattering Angle (°)
Hurricane Joyce G-IV Jet*
September 30, 2000

*Courtesy of The Chris Landsea Art Institute*
Hurricane Danielle 29 August 1998 00 UTC
GPS sondes launched from the NOAA G-IV Jet
Hurricanes Dennis/Cindy/Emily 1999
GOES SAL-Tracking Imagery
Re-Writing the Climatology of the Tropical Atlantic Atmosphere
The SAL in June vs September
The Jordan Mean Tropical Sounding (1958)

10 yrs of Caribbean sounding data: 1946-1955
Humidity up to 450 hPa; no winds;
Averaged over the months of the “hurricane season”: July-Oct
Jordan Mean Soundings (1958)
June-October (1948-1957)
“The smaller geographical and seasonal variability in the tropics make mean soundings for these areas much more representative of the conditions that may be expected at any given time and place” (Jordan 1958)
GOES SAL Imagery
Tracking Low to Mid-Level Dry Air
Moist Tropical, SAL & Mid-Latitude Dry Air Intrusions

DeMaria et al. 2001:
"During the hurricane season, mid-level moisture reaches a minimum in mid-July and rapidly increases in mid-Aug"

1995-2002
New Mean Moisture Soundings
Moist Tropical, SAL, and Mid-lat

MSLP
All: 1015.3 hPa
Moist Tropical: 1014.8 hPa
SAL: 1016.5 hPa
Mid-Lat: 1015.7 hPa
Arc Clouds
...aka Arcus Clouds
(Shelf Cloud; Roll Cloud)
## Arc Clouds: Thunderstorms vs TCs

<table>
<thead>
<tr>
<th></th>
<th>Midwest T-storm</th>
<th>Tropical Cyclone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Duration</strong></td>
<td>~30 min</td>
<td>~5 days (named)</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>~15 mi</td>
<td>~300-400 mi</td>
</tr>
<tr>
<td><strong>Motion</strong></td>
<td>~25-30 kt</td>
<td>~10-12 kt</td>
</tr>
<tr>
<td><strong>Downdrafts</strong></td>
<td>lead to dissipation phase</td>
<td>disruption to the system</td>
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*TCs have to stick it out in their environment*
Arc Clouds

Hypotheses

1. Null Hypothesis: Arc clouds: ubiquitous to the tropics...nice pictures...no tropical cyclone/ tropical wave impact;

2. The moist tropical sounding is insufficiently dry in the low to mid-levels (i.e. below the freezing level) to form substantial arc clouds...need Saharan air or some other dry air source;

3. Arc cloud formation inhibits TC development in the short term by:
   a) bringing cool, dry air down into the boundary layer;
   b) promoting low to mid-level outflow;
Hurricane Isabel: September 2003

Hurricane Isabel's "pinwheel eye"
1812 UTC on 13 September 2003
GOES-12 visible

16 Sept 1740 UTC
Arc Clouds (cont’d)

Vertical Shear
T(-24hr): SE 11 kt
T(0hr): NNW 6 kt

SAL
20090820h1/n1 (P-3 Orion & G-IV)
Hurricane Bill
TDR/SALEX/RI
Saharan Dust

SAL

mid-lat/subsid above

Longitude

Latitude

Morphed composite: 2009-08-20 06:00:00 UTC

SSMI/AMSRE Total Precipitable Water (mm)

SST 2009-08-20 07:15:00 UTC

Image Data 09/21/2009

Version 2.02 Expedited
Mid-latitude/subsidence jet at 52 kt ENE.

Saharan Air Layer (SAL) intrusion.

Downdraft?

76 kt ENE jet.

80 kt ESE jet.

Saharan Air Layer (SAL) intrusion (collocated with jet).

86 kt SE jet.

46 kt SSE jet.

Temperature and Relative Humidity versus Pressure.

Wind Speed and Wind Direction versus Pressure.

SAL intrusion.

46 kt SSE jet.
Hurricane Bill 20 August 2009
Hurricane Bill WRF Simulation
21-22 August 22-00 UTC
WRF/ARW

RH 22-00h00 max=1.00e+02, min=5.93e-06, int=9.09e+00
ad. Vel. (m/s) 22-00h00 max=3.30e+01, min=-2.50e+01, int=5.28e+00
20090825N (G-IV)

Pre-Danny

Genesis Experiment/Saharan Air Layer Experiment
SAL
600 mb: 42 kt ENE jet
900 mb: 42 kt E jet
Downdraft?
725 mb: 64 kt ESE Jet
SAL
625 mb: 25 kt NNE jet
2010 Hurricane Field Campaigns
PGI30 (Tropical Wave): NSF PREDICT

Morphed composite: 2010-08-23 12:00:00 UTC

Mid-Latitude Dry Air
SAL
TS Danielle
PGI30 (Tropical Wave)

SSN/AMSRE Total Precipitable Water (mm)

2010-Aug-23 12:42:00 - 13:28:48

RHUM (%)
Hurricane Earl: NOAA RI/Tail Doppler Radar Missions

Geographic coverage of P-3 flights
CALIPSO Satellite: 18 Aug 2010 1800 UTC

Saharan Air Layer

Saharan Air Layer

Saharan Air Layer
Global Hawk 60,000 ft Over Hurricane Earl
HAMS R Instrument (52 GHz)
Karl: Rapid Intensification (Cat 3 at Landfall)
2010...and beyond