Atlantic/Caribbean Basin Tropical Waves and TUTT Induced Inverted Troughs

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Part 2: Practical Exercises
## Summary of Characteristics

<table>
<thead>
<tr>
<th>TUTT Induced Trough</th>
<th>Tropical Wave</th>
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| **Cold core dominates**  
  o Cannot evolve directly into a Tropical cyclone (warm core system).  
  o Could first evolve into a subtropical cyclone (hybrid system) | **Combination of warm/cold core.**  
  o Could directly evolve into a tropical cyclone (is the seed). |
| **Movement:** Controlled by upper flow. | **Movement:** Controlled by the lower troposphere. |
| **Origin:** Induced by a trough generally to its northwest | **Origin:** Instability along on the African Easterly Jet and latent heat release in organized deep convection and also monsoon trough of Tropical North Africa |
## Tools to differentiate wave type

<table>
<thead>
<tr>
<th>Water Vapor Image</th>
<th>Induced Trough</th>
<th>Tropical Wave</th>
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<tbody>
<tr>
<td>Best tool to assess the presence and depth of an upper cyclone (TUTT).</td>
<td>Determine sources of upper level ventilation, or the lack of.</td>
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</tbody>
</table>
| IR and Visible Images | • Good to find inverted “V” troughs in low-level cloud fields.  
• Ci/Cs might hint presence of upper trough. | Good to find inverted “V” troughs in low-level cloud fields. |
| Flow analysis | 500-200 hPa for upper trough, 850-700 hPa for low level trough. | 850-700 hPa |
| Movement of low-level trough | • It moves **in-tandem** with upper trough.  
• Could remain stationary or, if the TUTT is retrogressing, progress at 05-15 kt. | • Low-level trough moves **independent** from upper systems.  
• They move at 10-20 kt.  
• Negatively tilted tend to be faster. |
Part 2 – Poll Questions
(Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
• Perturbation in the easterly trades was not evident
• Looks like the tropical wave is in phase with a TUTT
• None of the above
Case Study
20 April 2004
Is the low level trough moving?

Hint: Try to ignore the high clouds

Low Level Flow
Visible Animation:
Find Outflow Aloft

Hint: Focus on high clouds (Ci/Cs Shield)
Water Vapor Satellite (Upper Level Circulations)

GOES-12 WV Mid/Upper Circulation

Is the upper level trough moving?
GFS Analysis of Upper (400hPa) Circulation

ST Ridge

TUTT

SE Ridge
Low-Level Circulations (850 hPa)
Winds and EPT (θe) at 850 hPa
Cross Section: Winds

TUTT clearly evident between 500-150hPa

Low level trough below 700 hPa
Part 2 – Poll Question #1
(Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
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• None of the above
Observations

• **Visible satellite imagery** analysis shows an inverted trough at low levels.
  – Visible imagery clearly shows an inverted trough at low levels. It is yet not clear whether or not it relates to an upper level system.
  – It could easily be confused with a perturbation in the easterlies/tropical wave.

• **Water vapor satellite imagery**, in combination with visible imagery, clearly shows an upper trough with a ridge to its east.
  – This suggests a dependency of the low-level perturbation on the upper level trough.
  – The dependency can be confirmed by the model’s vertical cross section of the winds.
Visible Satellite Animation:
Find Low-Level Circulation

Is the low level trough moving?
Water Vapor Image Animation (Upper Circulations)

Is the upper level trough/low moving?

Is a TUTT or TUTT low evident on the GOES-12 WV images?

Is the upper level trough/low moving?
Low level inverted trough evident, upper circulation?
GFS analysis: 200 hPa winds

SE Ridge
GFS Analysis: 850 hPa winds

Inverted "V"
Winds and EPT ($\theta_e$) at 850 hPa

Warm and Moist
Cross Section: Winds and Relative Vorticity
(Cyclonic in Red)

Is the upper level trough deep enough to sustain a perturbation in the easterly trades?

TUTT Above 300 hPa

Trough below 700 hPa
Animation:
Winds and relative vorticity

Is the low level perturbation moving in-tandem with the upper level trough?
Part 2 – Poll Question #2
(Select one)

- Is this a TUTT with an induced trough in the easterly trades?
- Is this a tropical wave?
- Perturbation in the easterly trades was not evident
- Looks like the tropical wave is in phase with a TUTT
- None of the above
Observations

• Visible and IR imagery show an inverted trough in the low-level trades.

• Water vapor satellite image shows a TUTT/Low.

• Satellite and model data indicates that perturbation in the easterlies propagates independently from that in the upper levels.
  
  – But there is *positive interaction* among systems at different scales. This is leading to strong convection across the Leeward Isles.
Case Study
06 August 2008
Visible Satellite Image Animation

Find the Low Level Circulation

Is the low level trough moving?

Inverted “V”
Visible Satellite Image Animation

TUTT Low

Find the Upper Level Circulation

Is the upper level trough/low moving?
Is the upper level trough/low moving?
- Is the low level trough evident?
- Is the TUTT evident?
GFS Analysis: 200 hPa Winds

SE Ridge
GFS Analysis: 850 hPa winds

Inverted “V”
Winds and EPT ($\theta_e$) at 850 hPa
Cross Section:
Winds and relative vorticity

Is the TUTT deep enough to sustain a perturbation in the easterly trades?

TUTT Above 300 hPa

Inverted “V”
Animation:
Winds and relative vorticity

Are the upper and low level troughs moving in-tandem?
Part 2 – Poll Question #3
(Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
• Perturbation in the easterly trades was not evident
• Looks like the tropical wave is in phase with a TUTT
• None of the above
Observations

• TUTT Low supports deep trough across the Caribbean Basin.

• Visible imagery and wind analysis clearly shows perturbation in the easterlies.

• Low-level perturbations *seems to be in phase* with cyclonic core at upper levels.

• However, the model data show upper trough weakening while low level trough persists.
Case Study
11 June 2020
Find the Upper Level Circulation TUTT/TUTT Low?
SE Ridge?

Hint: Focus on high clouds (Ci/Cs Shield)
Analyze low level flow.

Inverted “V”?  
Closed lows?

Are the low level troughs moving?

Hint: There are two waves and two surface lows south of 20N.
Are the low level troughs moving?
GOES-16 Split Window (10.3-12.3 um)
Find the Upper Level Circulation TUTT/TUTT Low? SE Ridge?
GOES-16 10.3um

Find the Upper Level Circulation and inverted “V”
GFS – 200 hPa
GFS – 550 hPa
GFS – 700 hPa

Inverted "V"

Trof
GFS – 850 hPa & EPT
Cross Section – Winds and RVRT

- Trof Below 750hPa
- Cyclonic Max. at 900 hPa
Cross Section – Winds & Divergence
Part 2 – Poll Question #4
(Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
• Perturbation in the easterly trades was not evident
• Looks like the tropical wave is in phase with a TUTT
• None of the above
Observations

• WV Imagery shows the subequatorial ridge branching across the Tropical Atlantic to northern South America, with a TUTT low over Cuba-Western Caribbean

• Visible imagery and wind analysis clearly shows perturbation in the easterlies below 700 hPA.

• Cross sectional analysis confirms that the low level perturbation is not related to upper level feature.
TUTT Enhanced Convection

Severe Thunderstorms
April 28-29, 2019
TUTT’s Impact on Severe Convection

- Source of upper divergence
  - Vents deep convection

- Cyclonic vorticity advection
  - Enhances upward vertical motion

- Enhances Convective Instability-Cold Core
  - GDI
  - Traditional Indices (LI, SSI, TTI, KI)
TUTT – Divergence Aloft

Animation: 200 hPa Flow (kt) and 200-400 hPa Divergence
TUTT – Divergence Aloft
TUTT – Mid Level Cyclonic Vorticity

28 Apr 00-30 Apr 06 UTC
TUTT - Stability

Note: Use the GDI and EGDI to determine potential of deep or shallow convection.
EGDI and Low Level Flow
Diagnostic Tools : GR02T

INPUT 4 CHARACTER COMMANDS AND DELIMITERS OR EXIT
GR02T (Galvez & Santayana, Dec 2019) - NOT AN OFFICIAL FORECAST
GFS FORECAST 0000 UTC WED 30 APR 2019  GFS8
SEVERITY POTENTIAL SHADES: Gray=Strong Convection: Green=Marginal/Low
Red=Low/Moderate; Fuscia=Elevated. Increases if boxes appear.
Observations and Impacts

Apr 29: Local Flooding and hail in Hispaniola

HAIL
5% of stations
Heavy rain (>2in)
11% of stations
Moderate rain (1-2in)
13% of stations

Note: Hail reported in lower elevations
Observations and Impacts

Apr 28: Severe Weather in Cuba

Santa Clara, Cuba - Severe Thunderstorm

- Winds topped near 100 kph
- Nickel-size hail
- Airport and 60 houses affected

Damage in Santa Clara Airport
Satellite Loop over Hispaniola/Cuba on April 28

- April 28: Day of the Cuba event, one day before the Hispaniola event.
- Does not capture Santa Clara in Cuba, but clearly shows
  - Severe convection signatures in Cuba:
    - Long lasting cells
    - Cell propagation in different directions
    - Overshooting tops
    - V-shapes
  - Trough pattern to the west
  - Upper jet (transversal bands)
  - Vertical wind shear.
TUTT Enhanced Convection

Flash Flood
December 24, 2013
Kathy-Ann Caesar, CIMH
WV Animation
IR4 and GFS 250 hPa Streamlines

Upper level features and cloudiness
Is the TUTT deep enough to sustain an induced trough in the easterly trades?
Soundings 1200 UTC 24-12-2013

78897 TFFR Le Raizet, Guadeloupe

78954 TBPB Grantley Adams

12Z 24 Dec 2013

University of Wyoming
Soundings 1200 UTC 25-12-2013

78897 TFFR Le Raizet, Guadeloupe

78954 TBPN Grantley Adams

12Z 25 Dec 2013

University of Wyoming
Surface Obs and IR4 Animation
A quick view using GOES-E imagery

Evidence of surface circulation over Virgin Islands
GFS 250 hPa Winds
VT: 20131225/00UTC

Diffuent pattern aloft
+ Left Exit Region of Jet Maxima
Animation 700 hPa RH and Winds
Model data

GFS 850 winds
GFS 250 winds
GDI instability

- GFS model run from 22\textsuperscript{nd} and 23\textsuperscript{rd}
Note the southwest to northeast propagation of heavier echoes.

Radar Images (Reflectivity)

Radar loop
Courtesy MeteoFrance

0000 UTC 24-12-2013 to 12 00 UTC on 25-12-2013
Lightning Data
Impact

Chateaubelair

Buccament

Georgetown

Congo Valley

World Bank Report
Summary
**Tropical Wave or TUTT-Induced Wave?**

- **How do we identify a TUTT-induced wave?**
  - It develops in situ.
  - If it moves, follows upper air perturbations.
  - Important to see evolution (use previous analyses).
  - Tends to dissipate/weakens if TUTT dissipates.

- **How to recognize a tropical wave?**
  - It has African origins,
    - TPW Analysis
    - See Hovmöller diagram.
    - [http://www.nhc.noaa.gov/analysis_tools.shtml](http://www.nhc.noaa.gov/analysis_tools.shtml)
  - Propagates independently from upper level systems.
TUTT-Tropical Wave interactions

Can a tropical wave interact/merge with a TUTT induced wave?

- **YES**: But induced circulation at low-levels may end up “masking” tropical wave and end up appearing as an induced wave.
  - Something like this tends to occur across the southern Caribbean due to influence of the Panamanian low.

- **MAYBE**: As tropical wave approaches upper trough, it may encounter vertical wind shear. In some instances the tropical waves loses organization while induced trough persists.

- **NO**: A potent/well organized tropical wave can retain its integrity as it approaches upper trough. This will depend on intensity and depth of upper trough.
  - The deeper the upper trough, the lower the chances the tropical wave survives.
Questions?
Test
Questions

- Is a **cold core tropospheric** trough, with axis from surface to mid/upper levels of the atmosphere, considered a TUTT?
- Can we use the 6.2 micron water vapor images to identify low level circulations?
- Are tropical waves and induced troughs in the low level easterlies the same thing?
- What’s the primary role of the TUTT over the Caribbean Basin?
- Why do we typically see high equivalent potential temperature values in association with tropical waves and induced troughs in the low level easterlies?
Questions

• When the interaction between a tropical wave and a TUTT is considered positive/negative?

• How can we apply the three GOES-16 water vapor images to distinguish between a Tropical Wave and an induced trough?
WV and Visible Images.
Is the perturbation in the low level easterlies a tropical wave or a TUTT induced perturbation?

Is the upper level trough/low moving?

Is the low level trough moving?

Part 2 – Poll Question #5
Part 2 – Poll Question #5
(Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
• Perturbation in the easterly trades was not evident
• Looks like the tropical wave is in phase with a TUTT
• None of the above
Positive or Negatively Tilted Wave?

Part 2 – Poll Question #6
Part 2 – Poll Question #6
(Select all that apply)

• This is a negatively tilted wave
• Convection precedes (west) the wave
• This is a positively tilted wave
• Convection follows (east) the wave
• None of the above
Perturbation in the Atlantic is a TUTT-induced trough or a tropical wave?

Is the upper level trough/low moving?

Is the low level trough moving?

Part 2 – Poll Question #7
Part 2 – Poll Question #7
(Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
• Perturbation in the easterly trades was not evident
• Looks like the tropical wave is in phase with a TUTT
• None of the above
The perturbation in the Caribbean is a TUTT-induced wave or a Tropical Wave?

Part 2 – Poll Question #8
Part 2 – Poll Question #8 (Select one)

• Is this a TUTT with an induced trough in the easterly trades?
• Is this a tropical wave?
• Perturbation in the easterly trades was not evident
• Looks like the tropical wave is in phase with a TUTT
• None of the above
Positive or Negatively Tilted Wave?

Part 2 – Poll Question #9
Part 2 – Poll Question #9
(Select all that apply)

• This is a negatively tilted wave
• Convection precedes (west) the wave
• This is a positively tilted wave
• Convection follows (east) the wave
• None of the above
References

- NWS Southern Region Forecaster Notes Number 5, 01 September 1992. Easterly Waves, or TUTT Lows? Sources of Confusion over the Atlantic, Puerto Rico, and along the Gulf Coast in Summer.
- AFCC Theater Climatic File CD. Volume 4: South America, South of the Amazon River, Ver. 1.0 June 1998.
- Graphics generated using the Wingridds/PcGridds software to display the GFS/AVN global model.
- Satellite images provided by NOAA/NESDIS under permission.