Tropical Waves and Tropical Analysis

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Tropical Cyclone Workshop
Tropical Analysis Basics
Why analyzing the tropics is a challenge?

- Poor data coverage
- Lack of understanding of tropical weather systems
- Many tropical weather systems have small amplitude
- Local effects
  - coastal, topographical, diurnal, semi-diurnal,…and they tend to be more noticeable
- Most textbooks teach mid-latitude systems
Why is a good analysis important

• Real-time analysis - May lead to better forecast

• Case studies – Can help understand weather systems better
  – A good knowledge is the basis for a better real-time analysis and forecast

(Don’t believe everything you read. Do your own analysis if possible)
When the data is very limited, and the knowledge about the subject is almost none, people sometimes come up with all kinds of interpretation based on the limited data they’d collected.
Some Useful Analysis Practices

- Check the data/analysis over a longer period of time
- Time series analysis
- Check vertical cross sections
- Space-time analysis
- Use wind analysis when possible
Some Useful Analysis Practices

- Use all observations you have
- Filtering
- If necessary, use continuity – extrapolation
  If necessary, use short term forecast from previous global model run
- When nothing else is available, use climatology
Tropical Waves Basics
What are tropical waves?

* Perturbations / disturbances in the tropical easterlies that typically move from east to west.

* Often seen as inverted troughs of low pressure (inverted-V pattern in satellite imagery). Significant rain producers.

* Convection typically on the east side. Subsidence/clearing on the west side.

* Convection highly modulated by atmospheric moisture, upper level features, topography, etc.

* Develop into tropical cyclones.

* Around 60 tracked per year (little annual variability)
Tropical Wave Research

Tropical wave basics

Significance known as far back as 1930s (Piersig, Regula)

Patterns of rain, cloudiness, and windshifts received increased attention during WWII (Riehl, 1945)

With the growth of rawinsonde networks and better surface synoptic data, easterly waves were studied with 3 approaches:

Synoptic (Carlson, 1969)
Spectral analysis (Burpee, 1972)
Compositing (Reed et al. 1971 (Pacific), 1977, 1979 (Atlantic))

The composite from Reed (1977) still serves as the primary ‘text book’ description of AEWs.
How/where they form

- Generated by an instability (baroclinic-barotropic) of the African easterly jet
- Jet arises as a result of reversed lower tropospheric temperature gradient over west-central north Africa due to extremely warm temperatures over the Sahara Desert and substantially cooler temperatures along the coast of Guinea.
AEW synoptic structure over West Africa.

Synthesis of Carlson (1969a, b), Burpee (1972, 1974), Reed et al (1977)
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AEW synoptic structure over West Africa.

~20°N

AEJ Axis

~10°N Max Convection (and rainfall).

Synthesis of Carlson (1969a, b), Burpee (1972, 1974), Reed et al (1977)
Tropical waves/African easterly waves move westward within the trade wind flow south of the Bermuda-Azores high.
Tropical wave activity in terms of numbers is highest June-August
Classic inverted V-shape near the eastern Caribbean
At what pressure level is the maximum amplitude?

(a) 700 mb
(b) 500 mb
(c) 200 mb
(d) surface
Notice eastward slope will height
Maximum amplitude is around 700 mb
* wavelength of about 2000 km
* period of 3 to 4 days.
* typically move westward at 10 to 15 kt
Tools to track tropical waves
Satellite Imagery
Surface Observations

Up to 4 mb pressure falls associated with a strong wave
Scatterometer

QUIKSCAT NRT Winds OB08O2 ascending

Note: 1) Times are GMT, 2) Times correspond to 10N at right swath edge – time is right swath for overlapping swaths at 10N, 3) Data buffer is 24 hms for OB08O2, 4) Black barbs indicate possible rain contamination.
Total Precipitable Water
Wave Splitting

The northern portion of the wave often fractures but the southern extension continues moving westward.
Upper-Air Time Sections

Dakar

Sal
Can we identify these waves at the surface as they passed Dakar?
Can we identify these waves at the surface as they passed Guadeloupe?

Surface pressure with mean and diurnal and semi-diurnal tide removed.
Models

- Relative vorticity
- Streamlines
- Moisture fields
- Sea Level Pressure
Tools to track easterly waves:
Tropical Wave Diagnostics
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 22 Jun 18Z, Forecast: 0 hr, Valid: 22 Jun 18Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 23 Jun 00Z, Forecast: 0 hr, Valid: 23 Jun 00Z

[Map of potential vorticity and wind with specific regions highlighted in yellow and green circles]
GFS 310K Potential Vorticity and Wind

PV (PVU = 10⁶ K kg⁻¹ m² s⁻¹, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 23 Jun 18Z, Forecast: 0 hr, Valid: 23 Jun 18Z

[Map showing potential vorticity and wind vectors with contours and color shading for 310K level]
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 24 Jun 00Z, Forecast: 0 hr, Valid: 24 Jun 00Z
GFS 310K Potential Vorticity and Wind

PV (PVU = $10^6$ K kg$^{-1}$ m$^2$ s$^{-1}$, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 24 Jun 12Z, Forecast: 0 hr, Valid: 24 Jun 12Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^-2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 24 Jun 18Z, Forecast: 0 hr, Valid: 24 Jun 18Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs) Run: 25 Jun 06Z, Forecast: 0 hr, Valid: 25 Jun 06Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 25 Jun 18Z, Forecast: 0 hr, Valid: 25 Jun 18Z

[Diagram showing potential vorticity and wind patterns with PVU color scale]
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 26 Jun 00Z, Forecast: 0 hr, Valid: 26 Jun 00Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^-2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 26 Jun 06Z, Forecast: 0 hr, Valid: 26 Jun 06Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^(-1) m^2 s^(-1), shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 26 Jun 12Z, Forecast: 0 hr, Valid: 26 Jun 12Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^-1 m^2 s^-1, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 26 Jun 18Z, Forecast: 0 hr, Valid: 26 Jun 18Z
GFS 310K Potential Vorticity and Wind

PV (PVU = 10^6 K kg^{-1} m^2 s^{-1}, shaded; 1.5 PVU bold black contour) and Wind (kts, barbs)

Run: 27 Jun 00Z, Forecast: 0 hr, Valid: 27 Jun 00Z
Trinidad upper air sounding v anomaly. The PV streamer passed Trinidad June 27 (yellow oval).
Tropical Wave Interactions
Waves in Westerly Shear

Clouds/rain displaced to the east of the wave axis
Waves in Easterly Shear

Clouds/rain displaced to the west of the wave axis
What happens when tropical waves interact with upper-level lows and troughs?

(a) Convection decreases  
(b) Convection increases  
(c) A tropical cyclone forms
Although interaction with upper-level lows are unfavorable for tropical cyclogenesis, it can often induce heavy rainfall.
Eastern Caribbean: Floods and Landslides - Dec 2013

- Severe rains and high winds due to a low level trough caused floods and landslides in St. Vincent and the Grenadines, Saint Lucia and Dominica from 23-25 Dec 2013

- Torrential rains on Christmas Eve, with 15 inches falling in 24 hours, led to dramatic floods and landslides
A quick view using GOES-E imagery
200 mb heights and wind
00Z Dec 15 – 18Z Dec 27
IR image and 250 mb streamlines at 0000 UTC
Dec 25, 2013
Sounding winds Dec 16 – Dec 30

Was the low level southerly winds related to the upper level low only?
Was the heavy rainfall over the Windward Islands caused by the upper level low and a shortwave, or by the low level trough, or both?
700 mb relative vorticity and wind
00 Z Dec 15 – 18Z Dec 27
GFS analysis
GFS analysis
Local Effects
Sea-breeze convergence, upslope flows, and afternoon heating can cause convection to become chaotic and difficult to predict.
Wind shift between Kingston and Montego Bay at 18Z on those days, suggesting a trough over the island.

But the wind shift was mostly gone by 00Z.
Saharan Air Layer

Very dry/warm air in the low-mid levels of the atmosphere limits convection.
NHC Products
TAFB products: Surface Analysis

Analyze current positions every 6 h
TROPICAL WEATHER DISCUSSION FOR NORTH AMERICA...CENTRAL AMERICA...GULF OF MEXICO...CARIBBEAN SEA...NORTHERN SECTIONS OF SOUTH AMERICA...AND ATLANTIC OCEAN TO THE AFRICAN COAST FROM THE EQUATOR TO 32N. THE FOLLOWING INFORMATION IS BASED ON SATELLITE IMAGERY...METEOROLOGICAL ANALYSIS...WEATHER OBSERVATIONS...AND RADAR.

BASED ON 1800 UTC SURFACE ANALYSIS AND SATELLITE IMAGERY THROUGH 2315 UTC.

...TROPICAL WAVES...

A TROPICAL WAVE IS ALONG 32W S OF 17N MOVING W NEAR 13 KT. THIS WAVE COINCIDES WITH A DEEP LAYER MOISTURE MAXIMUM OBSERVED IN TOTAL PRECIPITATABLE WATER IMAGERY. ISOLATED MODERATE CONVECTION IS FROM 13N-15N BETWEEN 30W-34W.

A TROPICAL WAVE IS ALONG 49W S OF 14N MOVING W NEAR 16 KT. THIS WAVE REMAINS ON THE LEADING EDGE OF DRY SAHARAN AIR AND DUST INHIBITING DEEP CONVECTION ALONG THE WAVE AXIS. HOWEVER... SCATTERED ShowERS ARE FROM 10N-12N BETWEEN 46W-50W.

A TROPICAL WAVE IS ALONG 66W S OF 18N MOVING W NEAR 15 KT. THIS WAVE COINCIDES WITH A DEEP LAYER MOISTURE MAXIMUM THAT STRETCHES NWD INTO THE SW NORTH ATLIC DUE TO AN UPPER LEVEL LOW CENTERED NEAR 23N67W. INTERACTIONS BETWEEN THE TROPICAL WAVE AND UPPER LEVEL LOW ARE PRODUCING SCATTERED SHOWERS AND ISOLATED MODERATE CONVECTION FROM 10N-12N BETWEEN 60W-70W.

A TROPICAL WAVE IS ALONG 82W S OF 21N MOVING W NEAR 15 KT. THIS WAVE LIES IN A BROAD AREA OF DEEP LAYER MOISTURE OBSERVED IN TOTAL PRECIPITATABLE WATER IMAGERY. THIS WAVE CONTINUES MOVING BEHIND A DIFFUSION PATTERN ALOFT ENHANCING SCATTERED MODERATE CONVECTION OVER THE SW CARIBBEAN S OF 13N AND ACROSS PANAMA AND COSTA RICA. ALSO SCATTERED MODERATE/ISOLATED STEEL CONVECTION IS OVER THE NW CARIBBEAN N OF 16N BETWEEN 66W-65W...INCLUDING PORTIONS OF W RN CUEA AND THE YUCATAN PENINSULA.
TAFB products: graphical forecast

Predict future positions: 24h, 48h, and 72h
Approximately 60% of Atlantic tropical cyclones and 85% of major hurricanes originate from tropical waves.
What is more important for tropical cyclogenesis?

(a) the wave structure  
(b) the environment
Developing vs. Non-developing

Hopsch, Thorncroft, and Tyle (2009)

Very little different in structure between developing and non-developing waves
EXERCISE
July 13
July 14

Wave 1
July 15

Wave 1
July 23

Absorbed

Wave 2

Wave 3
Tropical Wave 1
Tropical Wave 2
Tropical Wave 3