Changes in Tropical Cyclone Behavior Related To Changes in the Upper Air Environment

Roger B. Weldon

August 2007
Today’s Talk

Summary of a 200 page Technical Report
Currently in second draft form for review
and
8 Years of Research
Tropical Cyclone Behavior

Visible and Infrared Satellite Imagery
Track & Intensity Data from Tropical Centers

Joint Typhoon Warning Center
US National Hurricane Center

Upper Air Environment

6.7 μm Water Vapor Satellite Imagery
500mb to 300mb Wind & Density Data

Forecast model   Initial and 3 hour forecasts
AVN and GFS   models
Examined and Archived Data for more than 400 Tropical Cyclones World Wide 1999 through 2005
**EVENTS**

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**Storm Behavior Events** 361  
**Environmental Change Events** 376  
**Total Number of Events:** 737

Event Categories were defined in 2002. Storm weakening and intensification are well addressed in the context of other events.
An Introduction

Rusa - Sinlaku Comparison

Two Different 48 Hour Periods in late August and early September 2002 about one week apart (6.5 days)
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“DZ” = “Deformation Zone” ------ the stretching axis of a col in the wind field

26 Formations  2 No Development  6 Intensification (storm already present)
DZ Development

P = “Division Point”

DZ = Stretching Axis of Col

Deformation Zone Boundary
Dry Air NW Moist Air SE

Moist Air

Mid Trop Flow 600 - 300mb

Upper Trop Flow 200 - 100 mb
300mb Winds

Merged Views from Meteosat 5 and GMS Satellites
1800z 24 October 00

Formation of Cyclone 2B
Bay of Bengal

500mb Winds
Drying with time on NW side of boundary which becomes more distinct & better defined. WV Loop showed significant drying over Mexico and moving SW off shore Adolph formed at 40 knots intensity at 00z 27 May 01.
WP-02 MITAG

300mb AVN Winds

00z 26 Feb 02  Top-Left panel
Same time as last panel Figure 5-05

Mitag Intensity 30 knots
Named 6 hours later
1. **Ridge** holds in place, sending sequential **speed maxima** generally toward the same location. The **TC** is likely to meander and weaken, or be destroyed.

2. The **Ridge** retrogrades; the next **speed maximum** digs to the west of the **TC**. The **TC** is likely to turn right in advance of the newly retrograded trough. It may intensify moving NE; but, weakening is most likely.

3. **Ridge** “ROLLS OVER” eastward on the poleward side of the **TC**. The **TC** is likely to turn left, or accelerate westward and intensify.
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“Ridge Roll” shortened from the original “Ridge Roll Over” The term originated from the appearance on time lapse motion winds or satellite imagery of a giant wheel “rolling over” the storm position.
70 to 85 kts in 12 hours moving 290 degrees
65 to 100 knots intensification entire 48 hour period
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Many “Ridge Roll” events contributed to turns by repositioning or changing the intensities of the local subtropical anticyclones or ridges.
Large View 30 hour period

TA-03 Isabel

R1 R2

R1

T

A

Ridge Roll with Anticyclogenesis

Left Turn 305 to 280 degrees

(03z to 12z 10 Sep 03)

115 to 110 knots intensity changes.

(115 to 110 knots 18z 9 Sep to 00z 10 Sep Level to 06z 10 Sep)
NHC Storm Track TA-03  Isabel

Left Turn  305 to 280 degrees

NHC Maximum Wind Speeds
120 Ridge Roll Events Identified

In 23 cases the Tropical Cyclones Formed and Intensified

Of the 97 cases in which storms were present at the beginning of the ridge roll event:

77 (79%) Storms intensified significantly from the beginning to end of the ridge roll event.

20 storms did not intensify significantly (10 from the ridge roll itself and 10 for other reasons)

100 storms (83%) either intensified, or formed and intensified, during the 120 ridge roll events.
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Eye Structure Changes:
- CDO intrusions observed
- 19 storms completed an eye replacement cycle

Dry Air Effects:
- Dry air was observed entering the storm’s cold cloud shield on the 6.7 μm WV imagery

43 cases were coincident in both categories
Dry Air Effects
WP-02 Phanfone

Dry Air Ingest  CDO Intrusions

with CDO Restructure and Eye Replacement
Typhoon Phanfone
130 knots Intensity

IR Image 1232z
15 August 2002

300mb AVN Winds
21z 15 Aug 02

CDO
Central Dense Overcast
Black Region
Min T -81 C
300mb AVN Winds
15z 15 Aug 02

Slot
The cold low west of Phanfone slowed its westward movement, dry air formed a slot.

The dry slot moved from the south side of the TC to the NE side during the 18 hours.
WP02 Phanfone  WV  Full Period  1232z 15 Aug - 1232zz 17 Aug 02  RES=8
The CDO cloud pattern became “intruded” with spiral shaped bands.
WP-02 Phanfone

0032z 16Aug02
130 kts

0632z 16Aug02

1232z 16Aug02

1832z 16Aug02

Warm Cold

A
WP-02 Phanfone

0032z 17Aug02
115 kts

0402z 17Aug02

0832z 17Aug02

1232z 17Aug02
110 kts

B
WP-04  Meari
41

T B R 06z 24 Sep 04                 12z 24 Sep 04                    18z 24 Sep 04               00z 25 Sep 04

T C

125 K

B B

C C C

R 06z 25 Sep 04                  12z 25 Sep 04                18z 25 Sep 04

WP-04  Meari
Weakened 125 knots
12z 24 Sep to
110 knots 12z 25 Sep
Ridge Roll “cuts off”
cyclone at base of
trough

IR Images shown on
the next figure

115 K

120 K

4-11
Two Types of CDO Cloud Top Changes with weakening storms

1. **CDO Intrusions**
   Alternating spirals of cold and warm clouds, often also accompanied with eye replacement process

   The upper level dry air arrives at the boundary of the Cold Cloud Shield at **small angles**. The dry air is **“ingested”**

2. **CDO “Deforming”**
   The CDO shape is “deformed” to a non circular pattern, often with the eye covered over, or no longer discernible.

   The dry air arrives at the boundary of the Cold Cloud Shield at **large angles**, with **OPEN flow**.

   The “open” flow need not be dry on the water vapor imagery to contribute to CDO Deforming and weakening
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Jet Stream Structure Changes, Cold Low Interactions, General Opening or Closing Systems of various categories
TA-03 Juan

Closing -Opening Systems
TA-03  Juan 00z 26 Sep 03              300mb GFS Winds          12z 26 Sep 03
00z 27 Sep 03     300mb GFS Winds

R R

TA-03  Juan Large View

24 Hour Period 1

Intensifies  55 to 65 to 75 knots

Moving 350  12 hours then 360
second 12 hours
TA-03 Juan CV 300mb Winds 00z 26 Sep - 00z 27 Sep 03
Winds back with time and begin to cross the boundaries at large angles.
Winds veer with time as an upstream ridge amplifies and become more parallel to boundaries.
0015z 26 Sep 03
00z 27 Sep 03
0915z 27 Sep 03
1815z 27 Sep 03

0015z 28 Sep 03
1215z 28 Sep 03

CLOSING
OPENING
CLOSING

Conditions
Holding
1815z 27th
to
0015z 28th
The 09z data are a 3 hour forecast.
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Inside Boundaries: “ER” position favorable for storms. 18 storms either intensified or formed there of the 23 cases (78%).
Moisture Boundaries

Base Surge Boundaries  73 Events

Inside Boundaries  23 Events
Base Surge East
WP-03  Lupit
Lupit 300mb GFS Winds 06z 22 Nov - 18z 23 Nov 03 65 to 95 knots
WP-03 Lupit

06z 22 Nov 03
Base Surge East Side

300mb GFS Winds

18z 23 Nov 03
Anticyclone Moved Equatorward
Lupit Intensified

65 to 95 knots. Right Turn 250 to 300 degrees

65   to  95 kts  Lupit

65  to  95 kts WP-03 Lupit

Base Surge East Side   Anticyclone Moved Equatorward Lupit Intensified
65 to 95 knots.   Right Turn   250 to 300 degrees  18z 23 Nov 03

18z 23 Nov 03
Storm Asymmetry
Rotated Anticyclonically
Southern Hemisphere

Left Turn

Storm Asymmetry
Rotated Anticyclonically

MOIST

DRY

TC

A

B

T

A

T
Base Surge East
SIO-03 Cela
SIO-03 Cela  300mb GFS Winds  00z 17 Dec - 00z 18 Dec 03  Pre Left Turn
Cela moving 210 degrees weakening 60 to 55 kts, local T brings dry air from NW. Ridge Roll starts Base Surge East side
Cela holds intensity, as base surge completes. Left Turn 210 to 120 degrees begins at end of the period. Holds at 55 kts during the turn.
73 Base Surge Events

Base Surge - Direct  13 Events  (10 of 13 storms weakened)

Base Surge - West  23 Events (12 storms weakened 11 intensified)

Base Surge - East    37 Events  ( 28 storms formed or intensified)  
(76%)

4 cases of formation

33 Cases with storms already present  (24 storms intensified. 73%)

In  28 of the 33 events  (85%) Right Turns occurred

15 of the 28 “A” or “R” pushed Equatorward
13 of the 28 “Shield Build” or “Phasing” occurred
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Includes “Left Turns” in the Southern Hemisphere
Right Turn by Ridge Roll

41 Right Turns in this category
Tokage moving 310 degrees. Eye Restructuring. Right Turn begins 03z 310 to 360 degrees.
Right Turn 310 to 360 degrees completes. Speed max east side intensified.
Hybrid Right Turn

31 Right Turns in this category
At the end of this period, Lupit turned right 320 to 360 degrees
8-05 WP-03 Lupit LV 300mb Winds 12z 28 Nov - 03z 29 Nov 03
Right Turn Categories

Digging Troughs  West Side -------------------------- 8  Cases
Hybrid Turns ------------------------------------------ 31  Cases
Cold Low Interactions ------------------------------- 4  Cases
Total Right Turns influenced by Troughs 43

Ridge Rolls (Intensification or re-positions) ------- 41  Cases
Ridge or Anticyclone Pushed Equatorward----------- 19  Cases
   No Base Surge East Associated
Base Surge, Boundary Rotation  East Side -----------28  Cases
   Ridge or Anticyclone Pushed Equatorward---15
   Shield Build - Phasing--------------------------- 13
Moves around Anticyclone -------------------------- 7  Cases
Total Right Turns Influenced by Ridges 95

Unusual Turns or Causes------------------------------- 7  Cases
Puzzles ----------------------------------------------- 8  Cases
Total - 153 Cases 15
<table>
<thead>
<tr>
<th>Category</th>
<th>Intensified</th>
<th>Held Intensity</th>
<th>Weakened</th>
<th>Intensified plus Held</th>
<th>Total Cases</th>
</tr>
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<tbody>
<tr>
<td>Ridge Rolls (Sub-set)</td>
<td>31 (76%)</td>
<td>3 (7%)</td>
<td>7 (17%)</td>
<td>34 (83%)</td>
<td>41 (9)</td>
</tr>
<tr>
<td>“A” Driven Equatorward</td>
<td>12 (63%)</td>
<td>7 (37%)</td>
<td>12 (63%)</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>Base Surges E</td>
<td>12 (43%)</td>
<td>6 (21%)</td>
<td>10 (36%)</td>
<td>18 (64%)</td>
<td>28</td>
</tr>
<tr>
<td>Around “A”</td>
<td>1 (15%)</td>
<td>6 (85%)</td>
<td>1 (15%)</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Hybrid</td>
<td>5 (16%)</td>
<td>26 (84%)</td>
<td>5 (16%)</td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Digging Troughs</td>
<td>2 (25%)</td>
<td>6 (75%)</td>
<td>2 (25%)</td>
<td></td>
<td>8</td>
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<tr>
<td>Cold Low Interactions</td>
<td>4 (100%)</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
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“Puzzles” and “Unusual Turns and Causes” categories, are Not Listed
# Categories of Left Turns and Storm Intensity Changes

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<tr>
<th>Event Category</th>
<th>Intensified</th>
<th>Weakened</th>
<th>Held Intensity</th>
<th>Total Events</th>
<th>Average Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge Roll</td>
<td>16 59%</td>
<td>10 37%</td>
<td>1 4%</td>
<td>27</td>
<td>6.81</td>
</tr>
<tr>
<td>Digging System</td>
<td>4 22%</td>
<td>13 72%</td>
<td>1 6%</td>
<td>18</td>
<td>6.44</td>
</tr>
<tr>
<td>Intensification</td>
<td>6 75%</td>
<td>2 25%</td>
<td>0</td>
<td>8</td>
<td>5.75</td>
</tr>
<tr>
<td>Adjacent Anticyclone</td>
<td>6 75%</td>
<td>2 25%</td>
<td>0</td>
<td>8</td>
<td>5.75</td>
</tr>
<tr>
<td>“Col South”</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>7.33</td>
</tr>
<tr>
<td>Around Cold Low</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>5.17</td>
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Average Rating of 65 events in categories: 6.47  Average rating all 79 events 6.01
Summary and Conclusions

Changes in 6.7μm imagery and 500mb to 300mb Winds are well correlated to Changes in Tropical Cyclone Behavior

Ridge Rolls, Base Surges East Side, Closing Adjacent Systems, Inside Boundaries correlated to Formation and Intensification of Tropical Cyclones

Opening Adjacent Systems and Dry Air Ingests correlated to Storm Weakening
  1. CDO Intrusions and possible Eye Replacement Cycles
  2. CDO Deforming

Turn Forecasting: Strong Environmental Changes - Can predict the turn
  Most cases require quantitative information such as model results

Specific Categories of Environmental Change related to the turn related to intensification or weakening during and after the turn

When Model Results Diverge, Environmental Change Relationships useful in choosing among models, rather than using an ensemble
19 events were shown here. There were 737 events analyzed in study.

Rusa WP-02                Right Turn  Digging Trough West  
Sinclaku WP-02            Left Turn  Digging System  
Cyclone 2B  IND-00        DZ Formation  
Adolph  EP-01             DZ Formation  
Mitag  WP-02              DZ Formation  
Mitag  WP-02              Ridge Roll  Formation  
Isabel  TA-03             Ridge Roll  
                               Left Turn  
Phanfone WP-02             Dry Air Effects  
                               CDO Restructuring  
Meari  WP-04               Dry Air Effects  
Juan  TA-03                Adjacent Systems Changes  
Pabuk  WP-01               Inside Boundary Formation  
Lupit  WP-03               Base Surge East  
                               Right Turn  
Cela  SIO-03               Base Surge East  
                               Right Turn (LT - S.H.)  
Tokage  WP-04              Right Turn (Ridge Roll)  
Lupit  WP-03               Right Turn (Hybrid)  

Shown by 1 figure only
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**Environmental Change Events: 376**

**Total Number of Events: 737**

Numbers listed in black: Events not addressed in the report
Last Slide