Changes in Track and Structure Associated With Tropical Cyclone Landfall

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Outline

- Changes in track
- Convection distribution
- Summary
Changes in Track
Track – $f$ plane experiments
Track – $f$ plane experiments
Asymmetric flow RD experiment Day 1

boundary layer (0.9<σ<1.0) m s⁻¹

lower layer (LL) (0.55<σ<0.9)

upper layer (UL) (0.25<σ<0.55)
Asymmetric flow RD experiment Day 6

boundary layer
(0.9<σ<1.0)

lower layer
(0.55<σ<0.9)

upper layer
(0.25<σ<0.55)
PV budget at LL (RD experiment Day 6)
Track – β plane experiments NS-oriented coastline

- Rough, wet land
- Smooth, dry land

~ 15 km
Track – β plane experiments EW-oriented coastline

- WERW
- CTRL
- WESD
- CTRL

rough, wet land

smooth, dry land

~ 30 km
Hypothesis:
TC circulation = Symmetric flow + Asymmetric flow

Asymmetric flow = Beta gyres + Land-induced Flow

Land-induced Flow = Asymmetric flow – Beta gyres

= (Asymmetric flow)_{Landfall} – (Asymmetric flow)_{CTRL}
Land-induced Flow with different coastline orientation

LL Asymmetric flow (0.9 ≥ η ≥ 0.55) $t = 36 - 48$ h

Rough and dry land
Evolution of asymmetric flow NSRD experiment

Thick:
Within LL
(0.9 ≥ η ≥ 0.55)

Dashed:
Within BL
(1.0 ≥ η ≥ 0.9)
Evolution of asymmetric flow EWRD experiment

Thick:
Within LL
$(0.9 \geq \eta \geq 0.55)$

Dashed:
Within BL
$(1.0 \geq \eta \geq 0.9)$
Changes in the location of onshore vs. offshore flow.
Track – $f$ plane experiments River Delta

~ 20 km
Track – f-plane experiments Differential roughness

north Rough south Smooth

north Smooth south Rough
Summary on track changes

- An inherent vortex motion in the presence of a discontinuity in surface friction.

- Such motion is caused by two main processes:
  - the development of a “ventilation flow” associated with a vortex pair through the generation of relative vorticity from the divergent term in the vorticity equation
  - diabatic heating due to differential convergence
Summary on track changes

- Such an inherent motion modifies the beta effect so that different coastline orientation will cause the TC track to deviate differently.

- Differential friction over land will also cause track deviations towards rougher land.
Convection Distribution
Convection associated with Hurricane Hugo (1989) at landfall

(from Powell 1991 WF)
Convection associated with Typhoon Sam (1999) at landfall

(a) 199908220300 3km CAPPI

(b) 199908220400 3km CAPPI

(c) 199908220600 3km CAPPI

(d) 199908220600 3km CAPPI
Landfall Along the China Coast
Hourly Rain Rate within 200 km of TC centre (right minus left)

Left type

Other type
Mean Zonal Wind
Mean Meridional Wind

(b)

- Left
- Left (except for Bilis)
- Other

left type without Bilis
other type
left type
Shear-induced convective asymmetry – left type
Shear-induced convective asymmetry – other type
Rainfall distribution over land at landfall

1 --- inner front left
2 --- middle front left
3 --- outer front left

4 --- inner front right
5 --- middle front right
6 --- outer front right

25N

20N

110E 115E 120E
## Rainfall distribution over land (within 300 km radius)

<table>
<thead>
<tr>
<th></th>
<th>Mean (mm/h)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At landfall</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Front Quadrant</td>
<td>16.31</td>
<td>15.16</td>
</tr>
<tr>
<td>Right Front Quadrant</td>
<td>31.05</td>
<td>21.93</td>
</tr>
<tr>
<td><strong>50 km from coastline</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Front Quadrant</td>
<td>15.04</td>
<td>16.38</td>
</tr>
<tr>
<td>Right Front Quadrant</td>
<td>34.80</td>
<td>21.09</td>
</tr>
</tbody>
</table>
Areas of composite reflectivity ≥ 55 dBZ within 75 km from TC centre
Points of Max Rainfall (land moving towards TC)
(from Tuleya and Kurihara 1978 JAS)
Points of Max Rainfall \((U = -10 \text{ m s}^{-1})\)
Rainfall (0-300 km) with increased friction over land and no moisture flux
Summary

- Convection asymmetries appear to be prevalent around landfall.

- Such asymmetries are not only related to friction and moisture differences, but also to vertical wind shear, and topography.