Horizontal Transition of Turbulent Cascade in the Near-surface Layer of Tropical Cyclones and some discussion

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Motivation

Interaction between turbulence and other scale?

Surface flux VS BL inflow?

Rogers et al. 2013 BAMS
Turbulence in atmosphere

Hunt and Carlotti 2001

Zhu et al. (2010)
Turbulence in atmosphere

How about the turbulence cascade in TCBL?

Staircase-like Cascade

Elevator-like Cascade

Hunt and Carlotti 2001

Zhu et al. (2010)
Cascade translate with Height in TC

3rd Structure function: $S_{3L} = \langle \delta v_u^3 \rangle$

Energy flux: $\varepsilon = -\frac{2}{3} \frac{S_{3L}}{r}$

Upscale: $\varepsilon > 0; S_{3L} < 0$

Downscale: $\varepsilon < 0; S_{3L} > 0$

(Xia et al. 2011)

Inverse Cascade in Higher level
Direct Cascade in Lower Level

Byrne and Zhang (2013, GRL)
Observation and Datasets

56, 72, 89 and 111 meters
Data and Method

3rd Structure function: $S_{3L} = \langle \delta v_u^3 \rangle$

Energy flux: $\epsilon = -\frac{2}{3} \frac{S_{3L}}{r}$

Upscale: $\epsilon > 0; S_{3L} < 0$  Invecascade, 2D
Downscale: $\epsilon < 0; S_{3L} > 0$  Direct cascade, 3D

(Xia et al. 2011)

Height: 56, 72, 89, 111 m
Obs: 20 HZ
Instruments: WindMaster Pro 3D supersonic anemometers by British Gill
Cases: Lionrock(1006)  Fanapi(1011)  Megi(1015)
Turbulence Frozen Taylor hypothesis

With courtesy to Trujillo et al. 2010
Cascade translate with time in TC

Vertical: 3rd structure function
Horizontal: horizontal scale
Symbols: Different Time(position)
Color: Different Height
Turbulence translate from negative to positive with time but not with height.

Vertical: 3rd structure function
Horizontal: horizontal scale
Symbols: Different Time(position)
Color: Different Height
Energy Flux in TCBL

Energy Flux in different height

Typhoon Lionrock

Typhoon Fanapi

Typhoon Megi

Scale
Energy Flux in TCBL

Energy flux varied the direction in different scale/time for Typhoon Lionrock, Fanapi, and Megi.
## Cascade transition in TCBL

<table>
<thead>
<tr>
<th>Hours before Landing</th>
<th>Lionrock(1006)</th>
<th>Fanapi(1011)</th>
<th>Megi(1015)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Distance (km)</td>
<td>Intensity (m/s)</td>
<td>Average Energy Flux (10^{-5} m^2/s^3)</td>
</tr>
<tr>
<td>-8h</td>
<td>127.9</td>
<td>25</td>
<td>0.2</td>
</tr>
<tr>
<td>-7h</td>
<td>112.4</td>
<td>25</td>
<td>3.0</td>
</tr>
<tr>
<td>-6h</td>
<td>88.5</td>
<td>23</td>
<td>16.0</td>
</tr>
<tr>
<td>-5h</td>
<td>73.0</td>
<td>23</td>
<td>13.4</td>
</tr>
<tr>
<td>-4h</td>
<td>65.1</td>
<td>23</td>
<td>11.5</td>
</tr>
<tr>
<td>-3h</td>
<td>52.8</td>
<td>23</td>
<td>NaN³</td>
</tr>
<tr>
<td>-2h</td>
<td>38.6</td>
<td>23</td>
<td>NaN</td>
</tr>
<tr>
<td>-1h</td>
<td>28.2</td>
<td>23</td>
<td>-91.5</td>
</tr>
<tr>
<td>0h</td>
<td>42.1</td>
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**Average percentage of Energy flux to TKE production**: 26.2% 41.5% 43.5%

1) Turbulence flux translated its direction from positive direction to negative while typhoon moving close to the tower which means outer circulation
2) The amount of turbulence flux is comparable with the total variation of turbulent kinetic energy
### Cascade transition in TCBL

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<td>105.3</td>
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1) Turbulence flux translated its direction from positive direction to negative while typhoon moving close to the tower which means outer circulation  
2) The amount of turbulence flux is comparable with the total variation of turbulent kinetic energy
Turbulence cascade and WIND/RMW

WIND VS FLUX

Times of RMW VS FLUX
Turbulence cascade and WIND/RMW

- Energy flux VS WIND
- Energy flux: inverse/direct in inner/outer core
Tropical cyclones (TC) consist of a large range of interaction scales from hundreds of kilometers to only a few meters and a change in how energy is transferred amongst these scales i.e. from **smaller to larger scales (upscale)** or vice versa (**downscale**), can have profound impacts on TC energy dynamics due to the associated changes in available energy sources and sinks.

The energy flux provide a explanation for the evolution of TC intensity from the turbulent scale and interaction between different **scales** (*How the energy transferred from turbulent scale to mesoscale*).

Any more case?

Tuburlelt process and cascade are prevalent in TCBL

Effect?
turbulence before/after landfall

Vertical diffusion and mixing length of turbulent flux increased about 20% after landfall.

Is it important to TC evolution?

Turbulence structure are quite different in TCBL.
Different PBL Scheme may impact TC Intensity

RED: MYJ scheme including TKE; BLUE: GFS scheme

Turbulence process important to TCRI in HWRF model!

How could we know TCBL?

TANG AND ZHANG 2018
OTHER INTERTING OBSERVATION MATHOD IN TCBL(I)

NOAA P3 Doppler Wind Lidar (DWL)

Figure 1. The P3DWL as ... um coherent WTX (ARL/LMCT) 
P3 and other parts (NRL) 
Analyses software (SWA/CIRPAS)
OTHER INTERESTING OBSERVATION METHOD IN TCBL(II)

WIND PROFILE DURING TYPHOON MERANTI(1614)

Solid: GPS SONDE; DASH: WIND PROFILE
Boundary layer fine-scale structure and turbulent process play a very important role in the intensification of TC. Fine-scale structure in TCBL (<1 km) and turbulent process are very poorly known in the research and model communities. Many new techniques, including LIDAR, WIND PROFILER, SAR, and RADAR, have the potential to help people to understand TCBL. More targeted field campaigns based on new techniques should be launched.
Future Plan

Key scientific focus:

- Fine-scale structure and turbulent process in TCBL
- Boundary layer scheme of Typhoon Model based on observation
- Offshore Typhoon intensity identification by observation
- More new technique (UAV, SFMR, SAR and so on)