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

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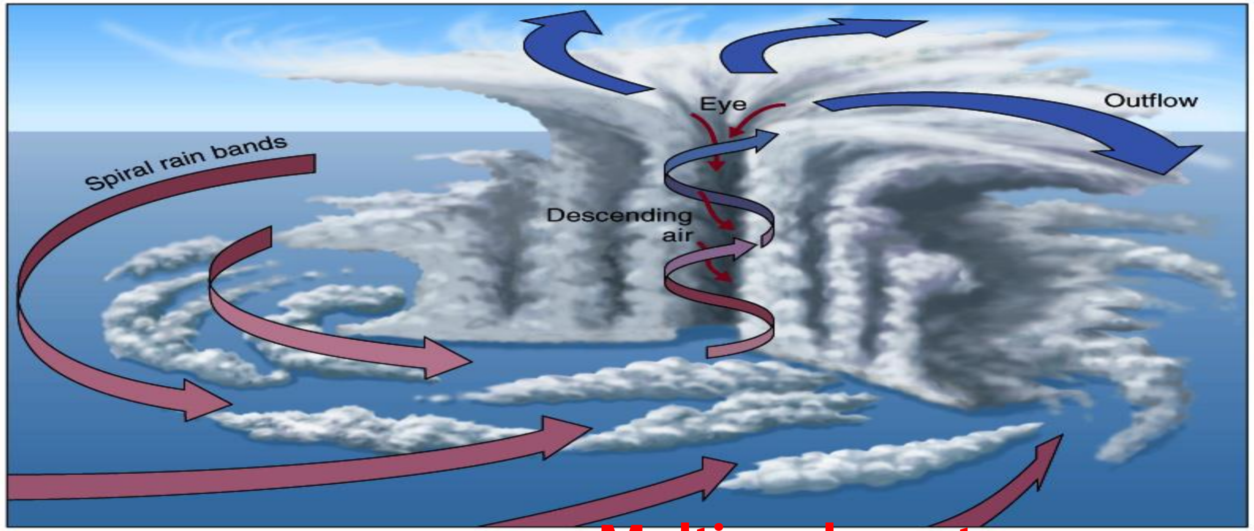
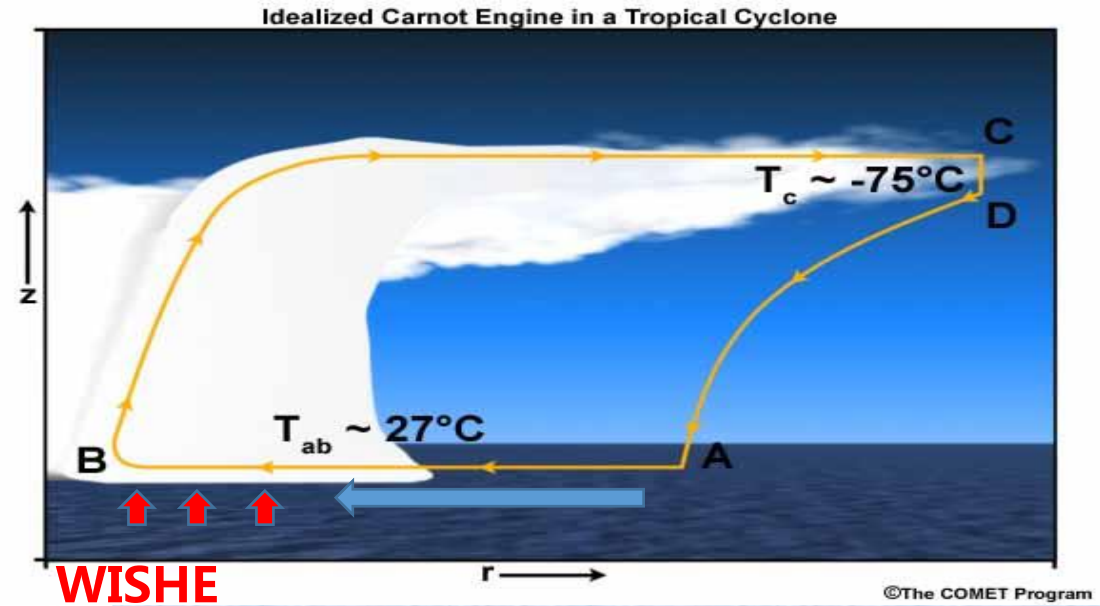
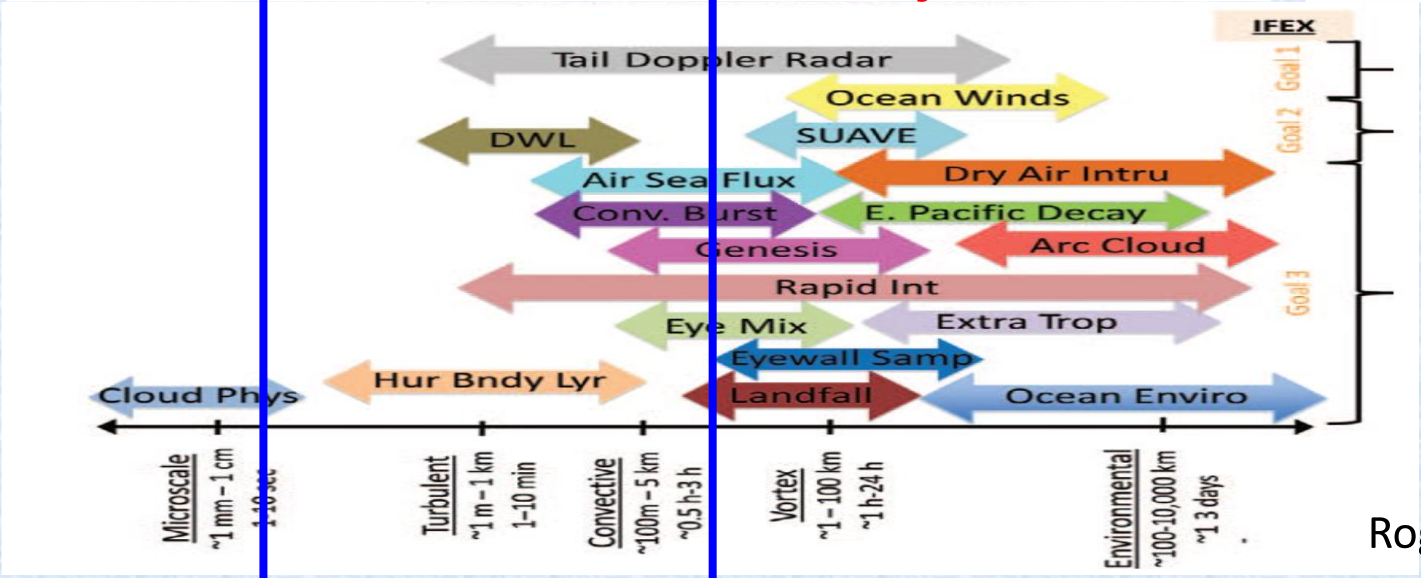
Motivation



Multi-scale system



WISHE

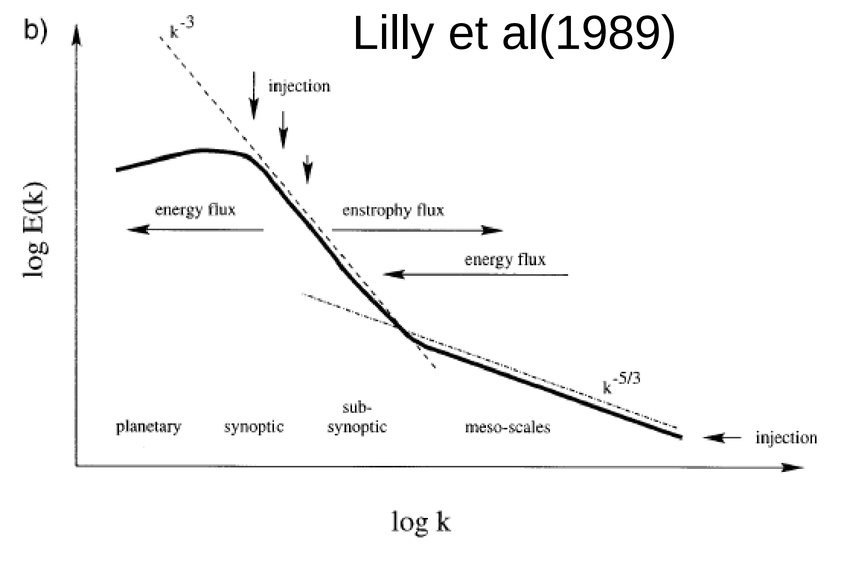


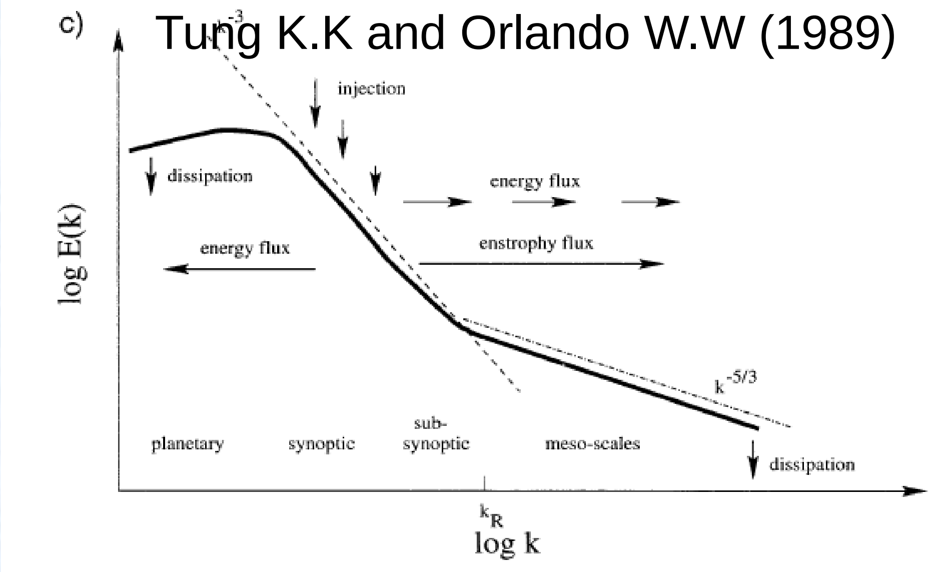
Interaction between turbulence and other scale ?

Surface flux VS BL inflow ?

Rogers et al.2013 BAMS

Turbulence in atmosphere





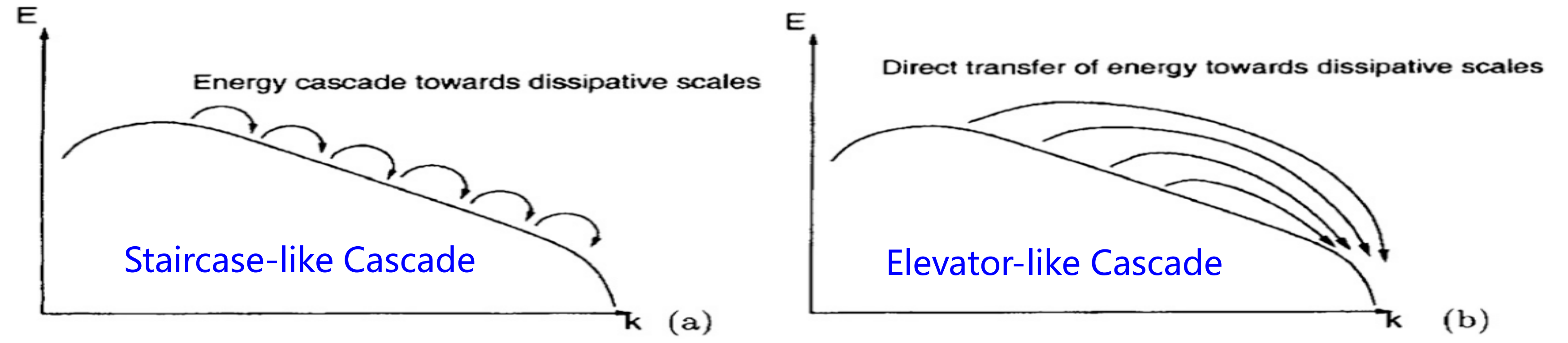
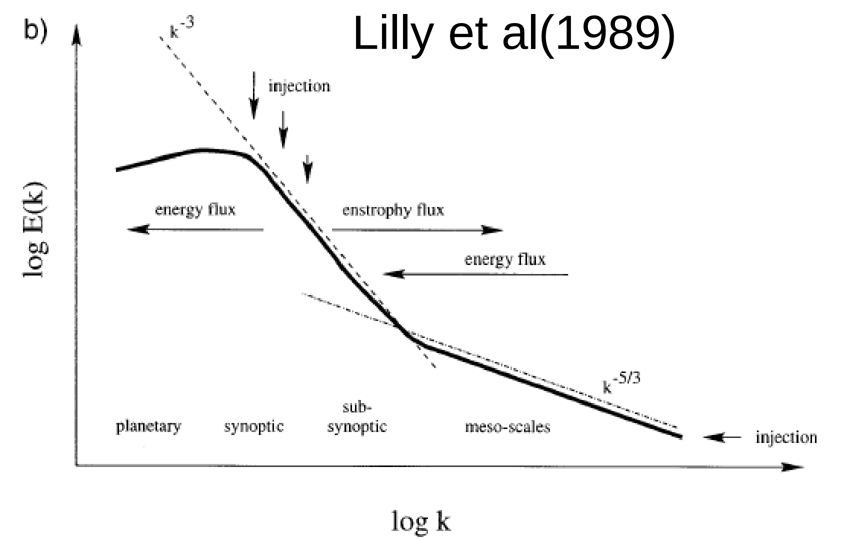


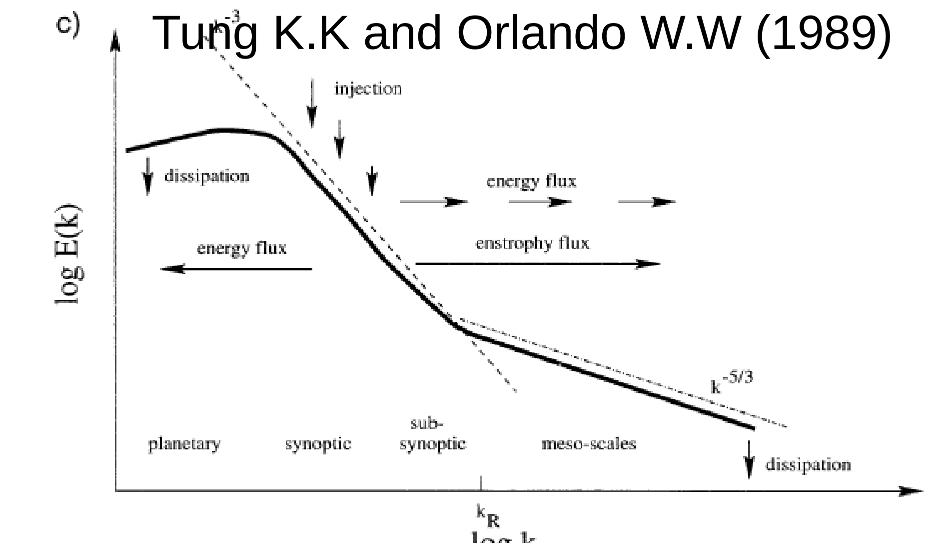
FIG. 6. Schematic of energy cascade process: (a) local interaction or staircaselike cascade and (b) long-range interaction or elevator-like cascade (adopted from Hunt and Carlotti 2001).

Hunt and Carlotti 2001

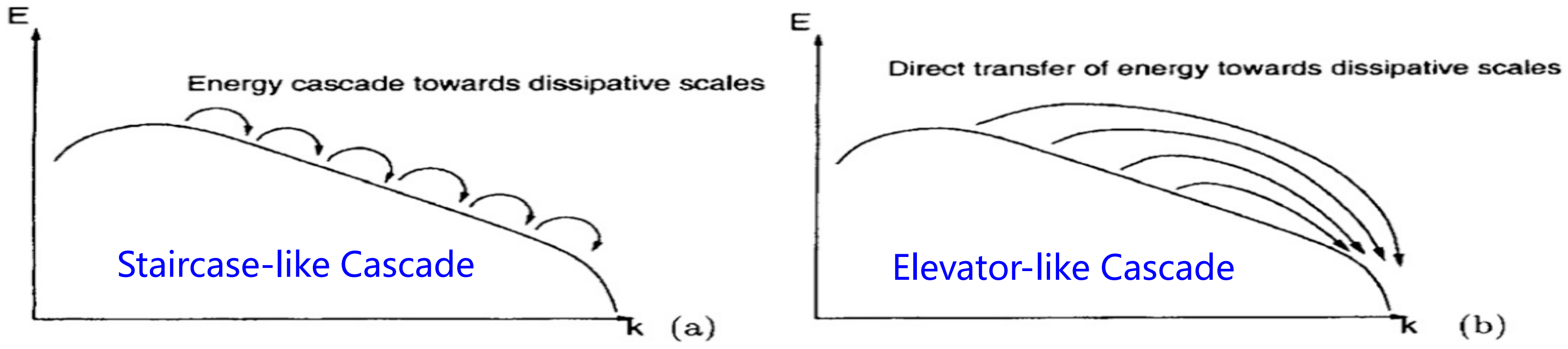
Zhu et al. (2010)

Turbulence in atmosphere





How about the turbulence cascade in TCBL?



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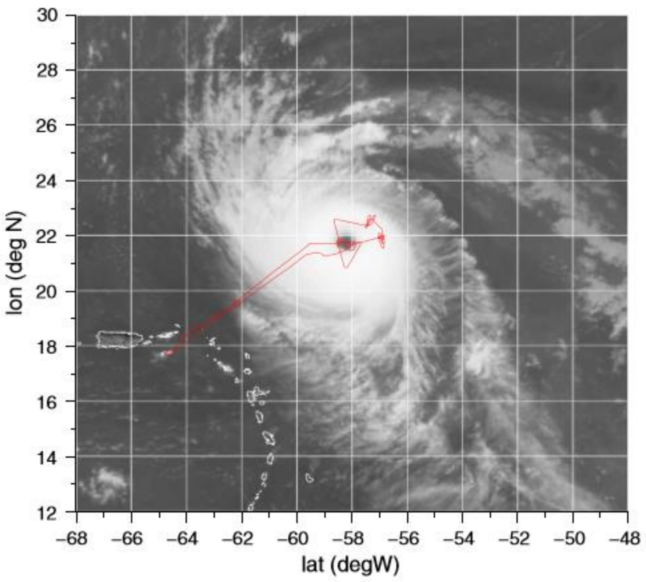
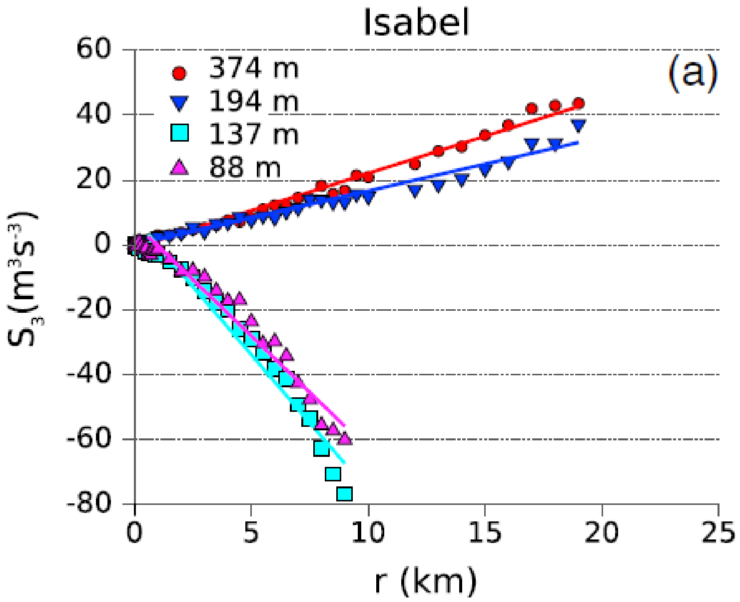
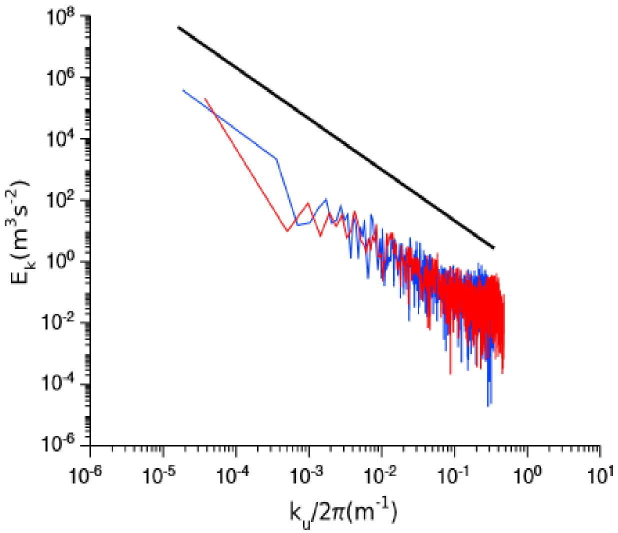
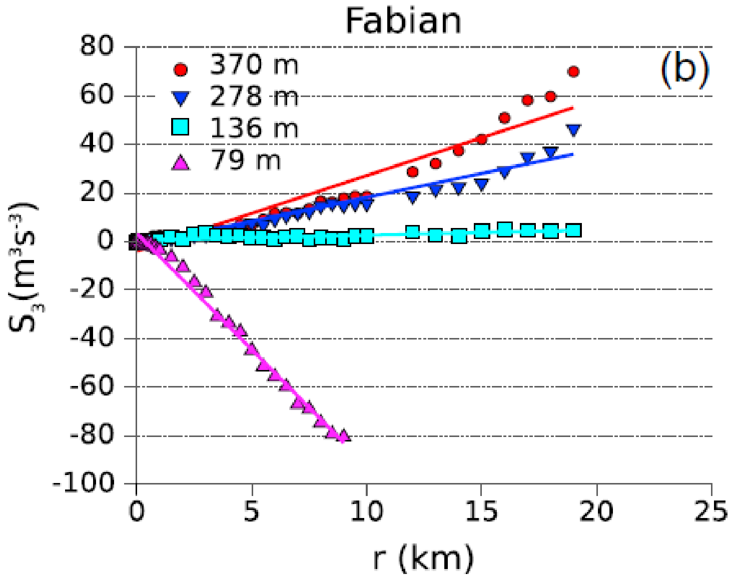
Cascade translate with Height in TC









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

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

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

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

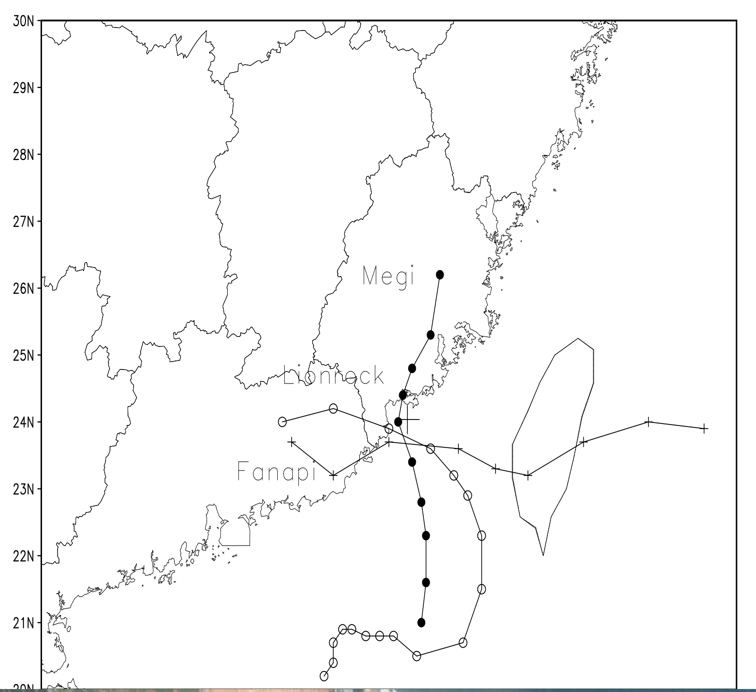
(Xia et al.2011)

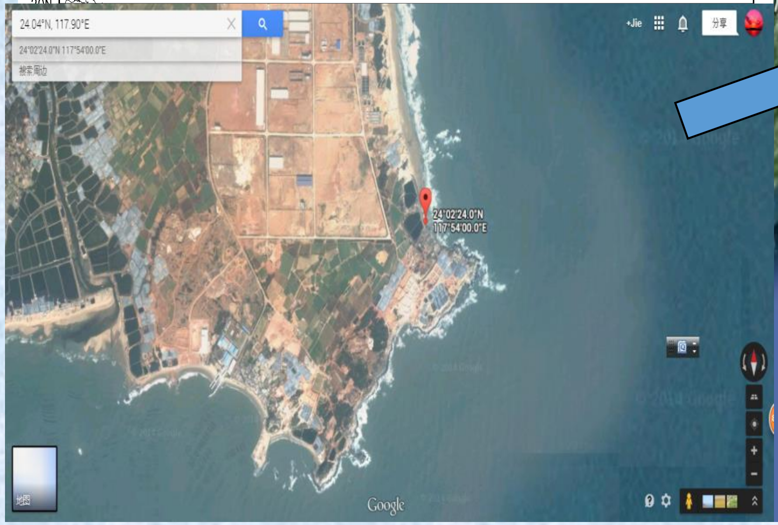
Inverse Cascade in Higher level
Direct Cascade in Lower Level

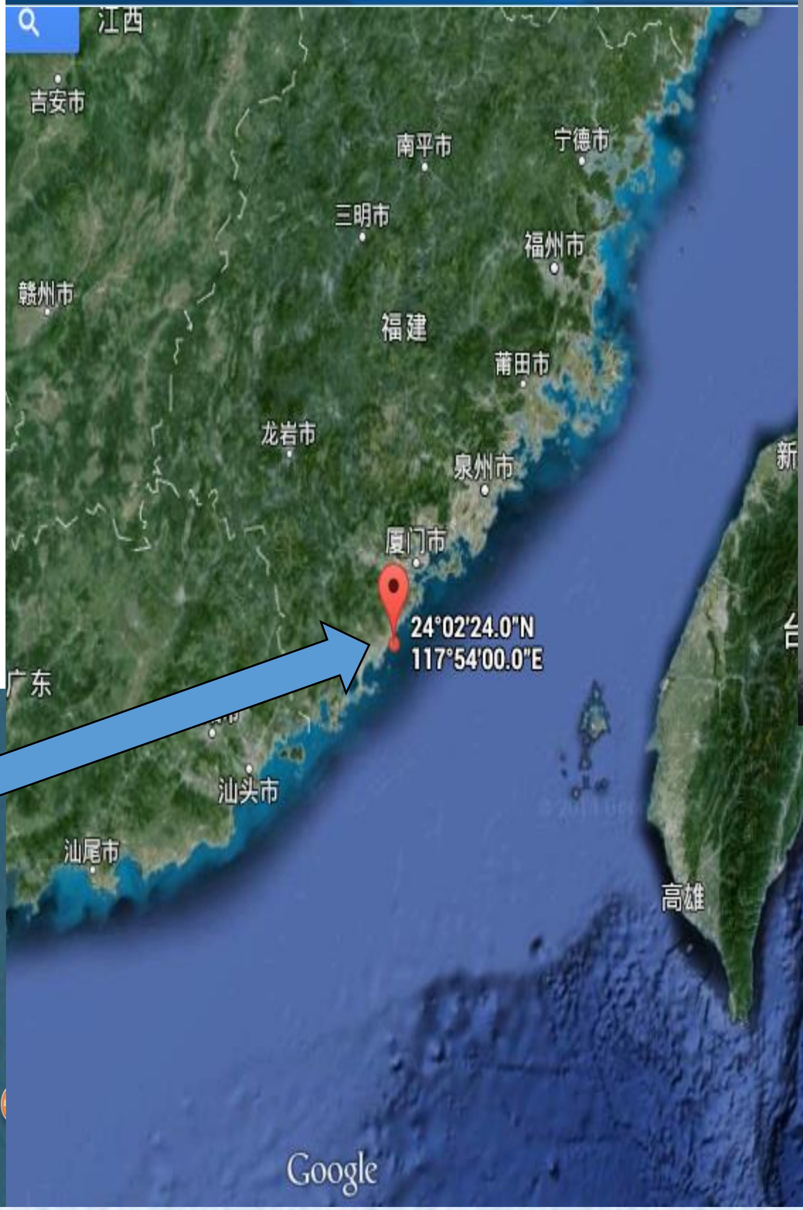
Byrne and Zhang (2013,GRL)

Obsvertation and Datasets

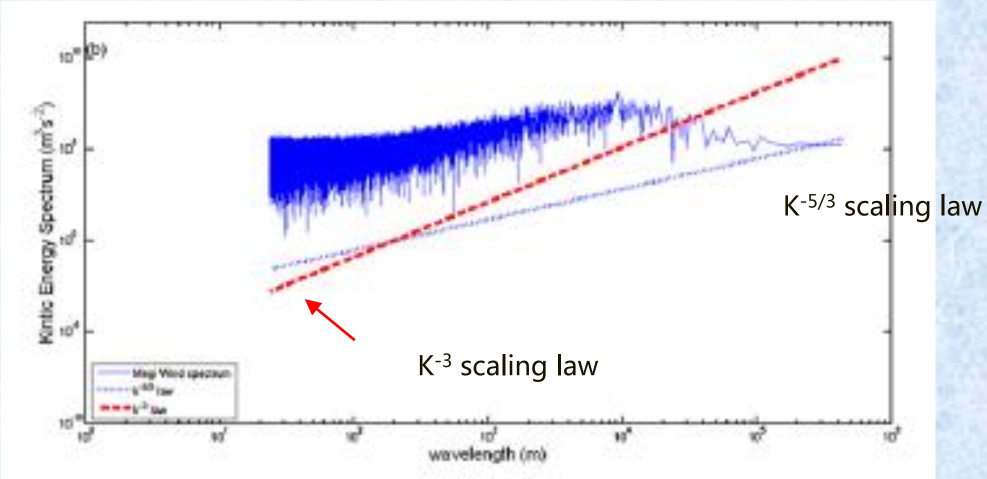
56,72,89 and 111 meters



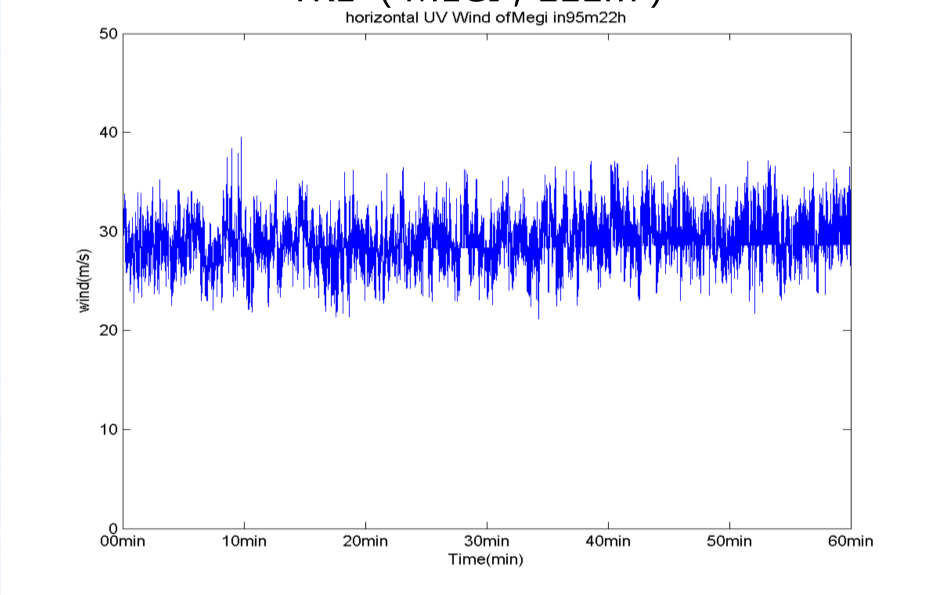




Data and Method



TKE（MEGI，111m）



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

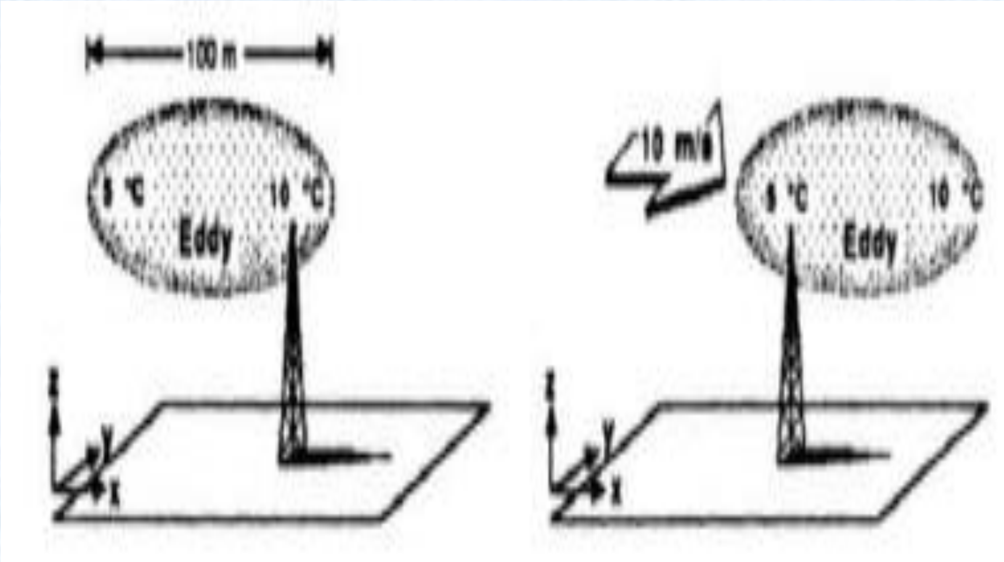
Upscale : $\epsilon > 0; S_{3L} < 0$ Invecascade，2D

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

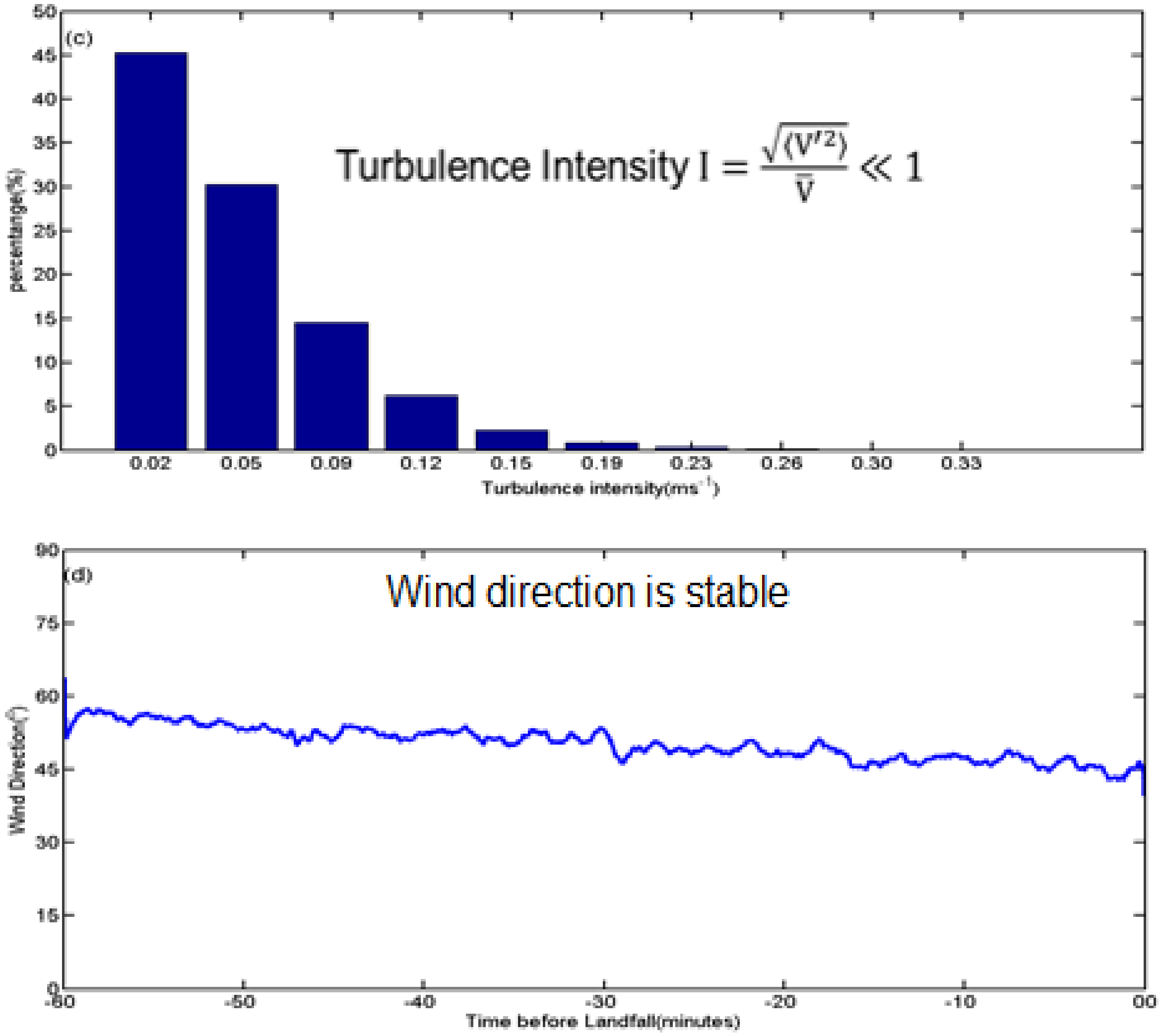
(Xia et al.2011)

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)

Turbulene Frozen Taylor hypothesis

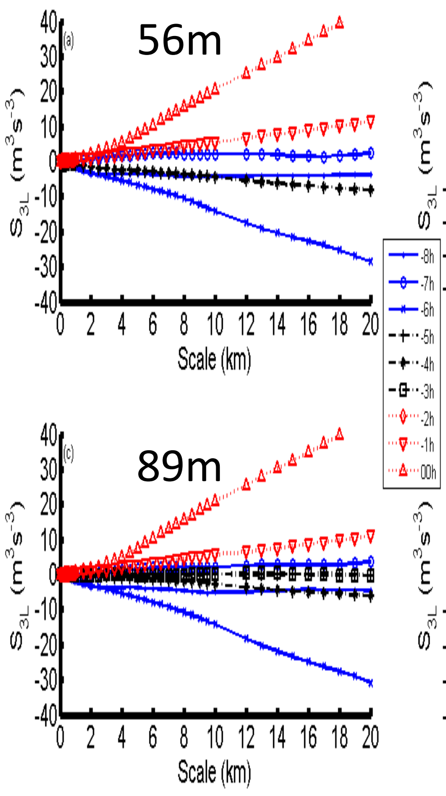


With courtesy to Trujillo et al. 2010

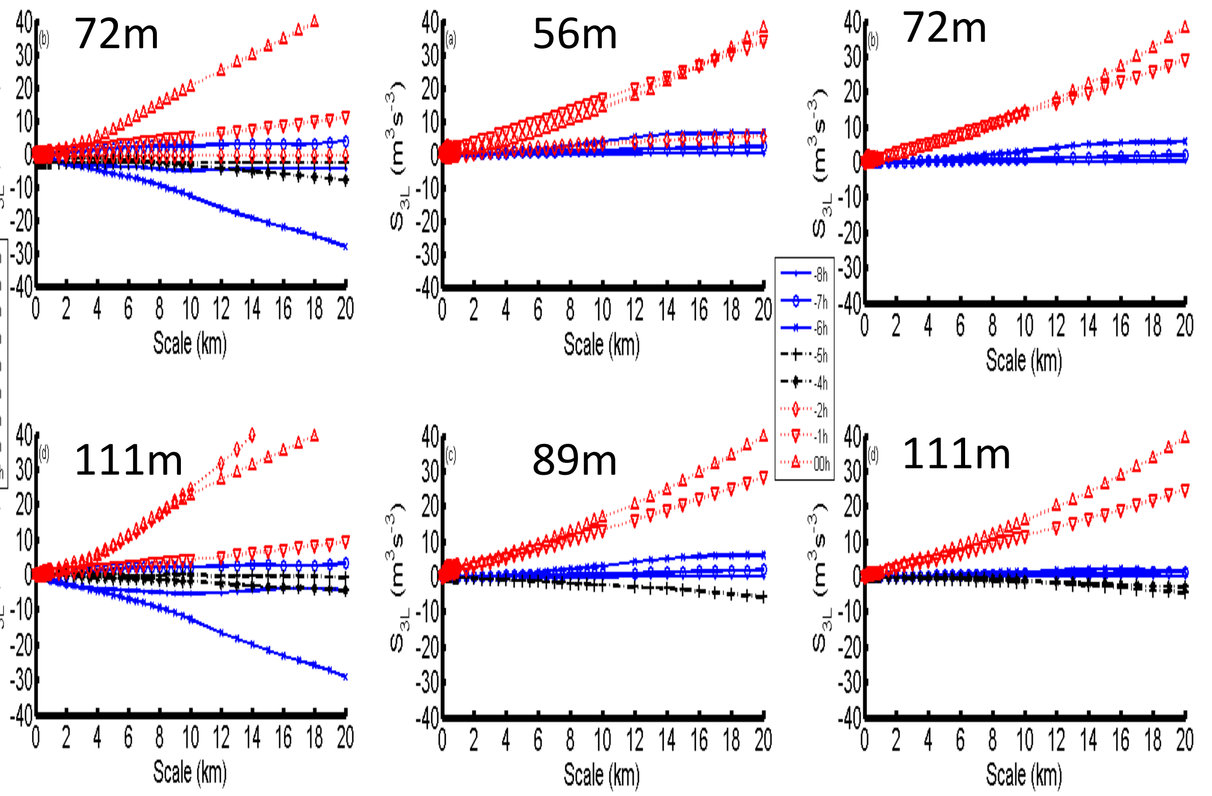


Cascade translate with time in TC

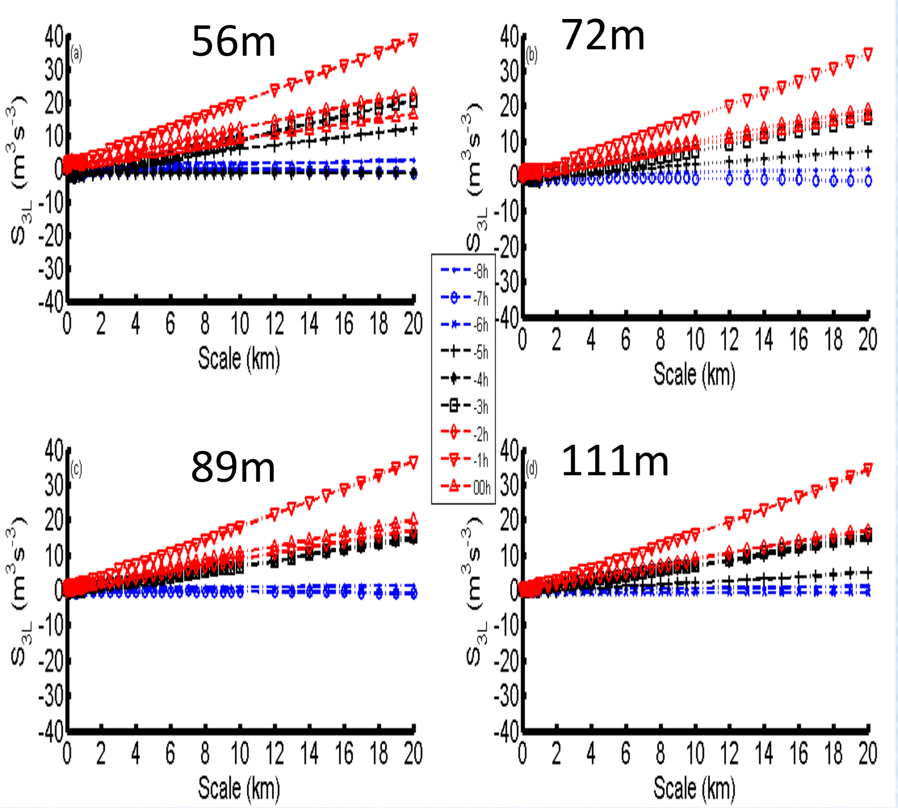
Typhoon Fanapi



Typhoon Lionrock



Typhoon Megi



Vertical : 3nd structure function

Horizontal: horizontal scale

Symbols: Different Time(position)

Color: Different Height

Cascade translate with time in TC

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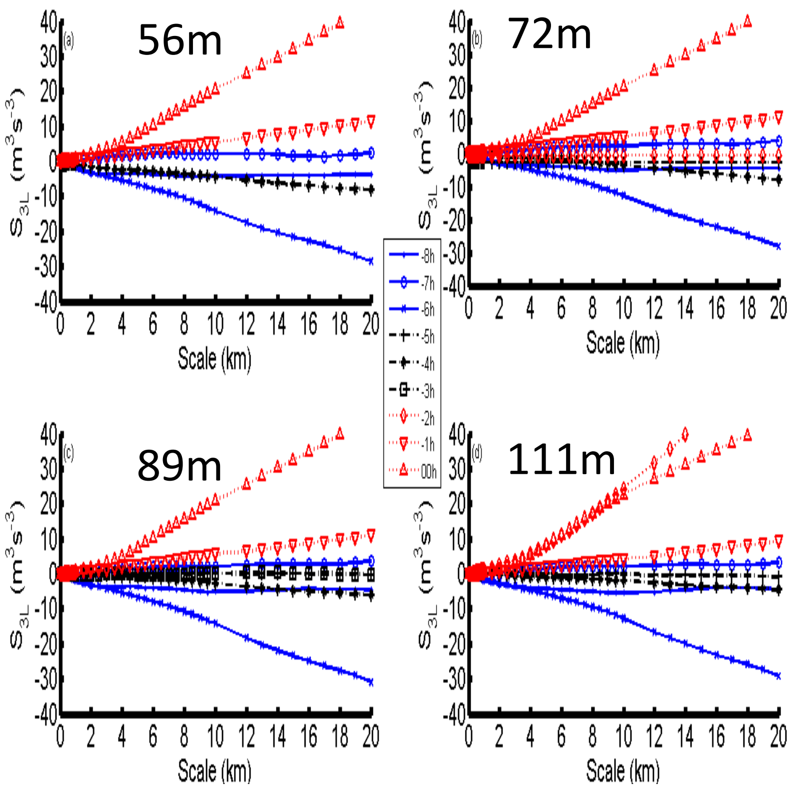
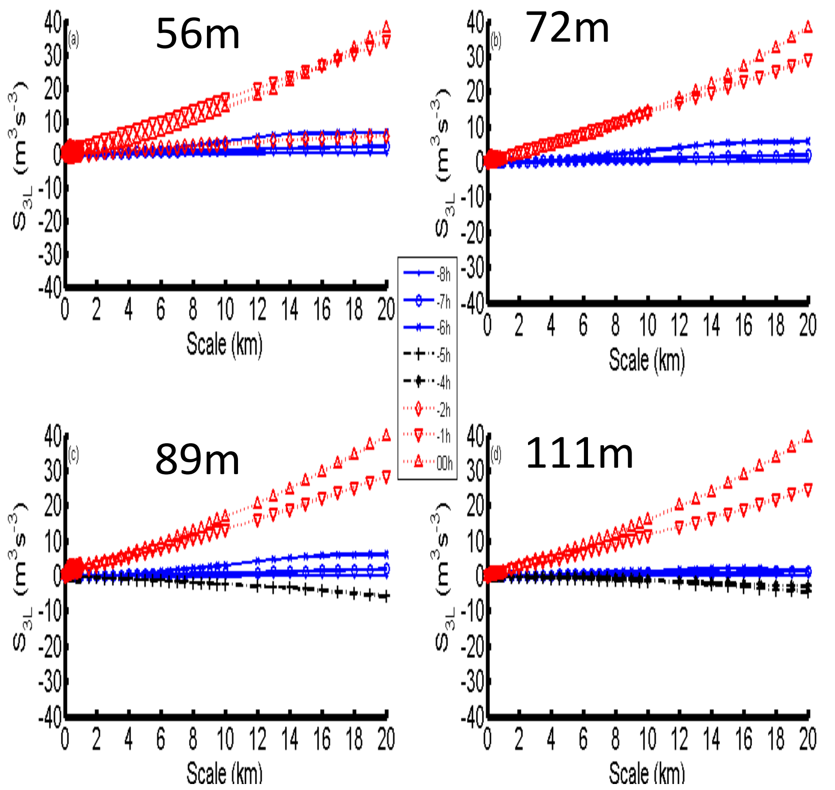
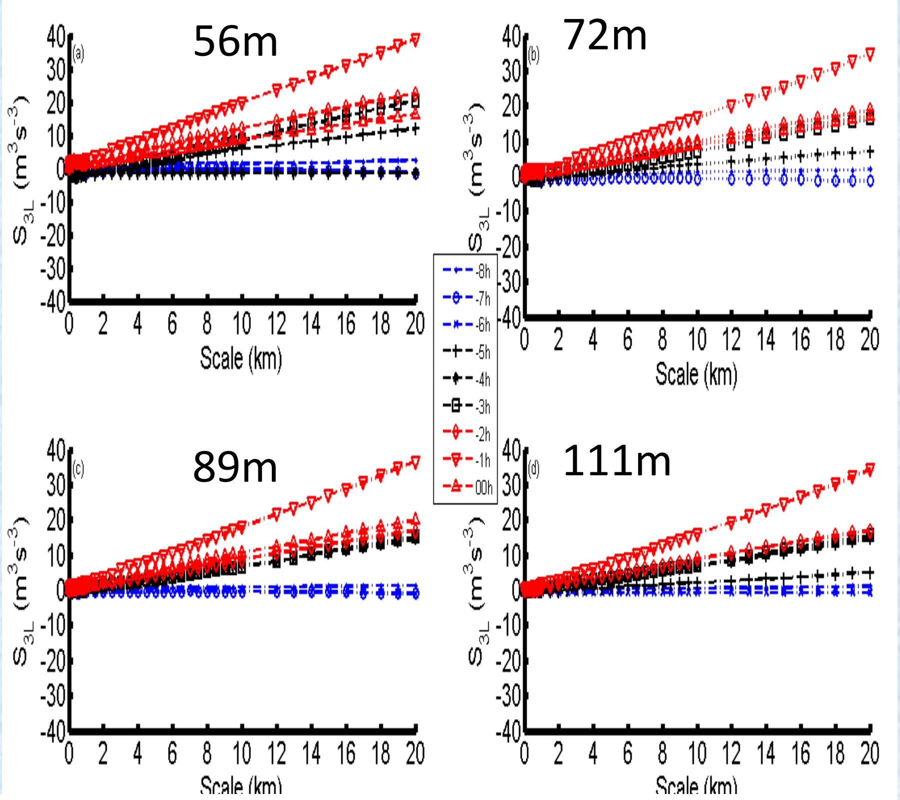


Typhoon Lionrock



Typhoon Megi



Turbulence translate from negative to positive with time but not with height

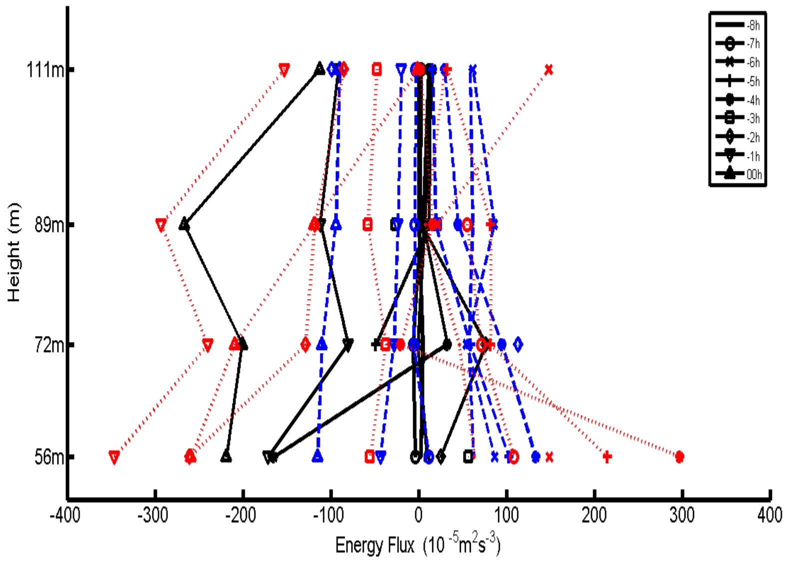
Vertical : 3nd structure function
Horizontal: horizontal scale

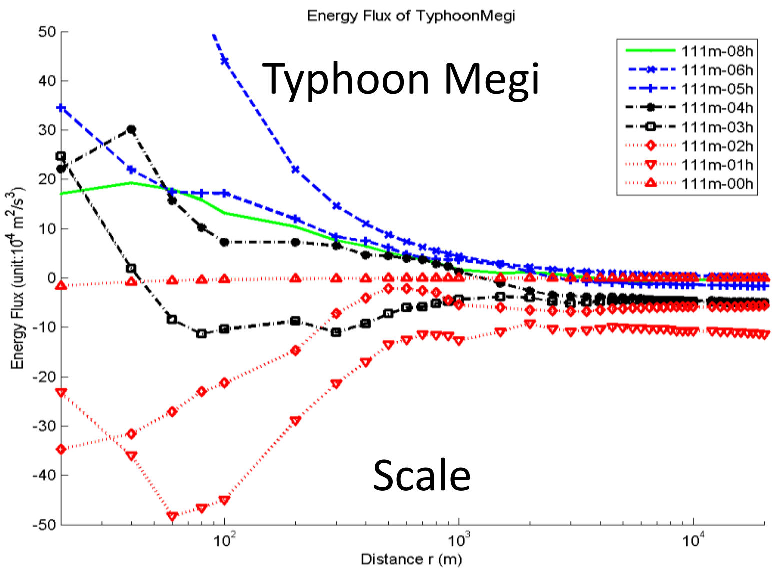
Symbols: Different Time(position)
Color: Different Height

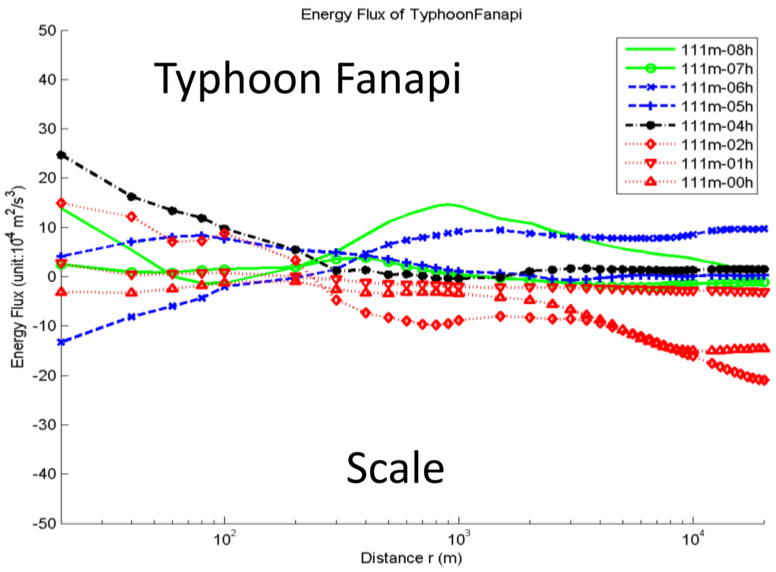
Energy Flux in TCBL

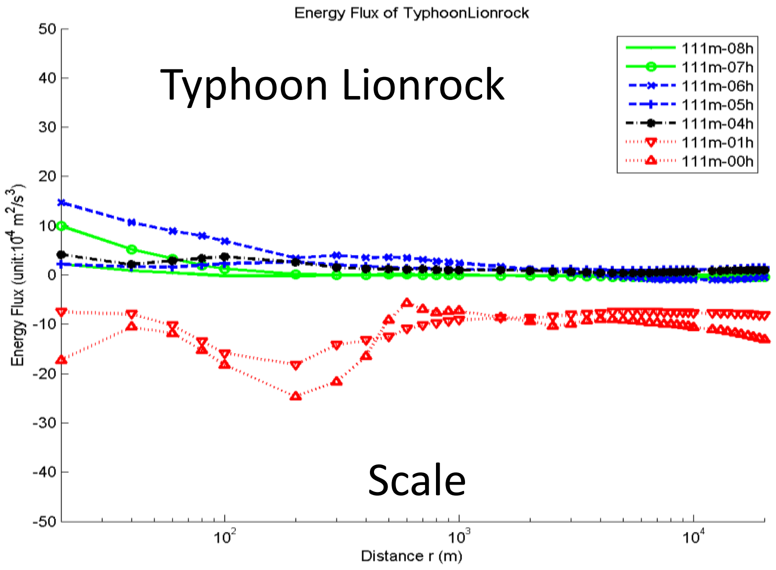
Energy Flux in different height

Height









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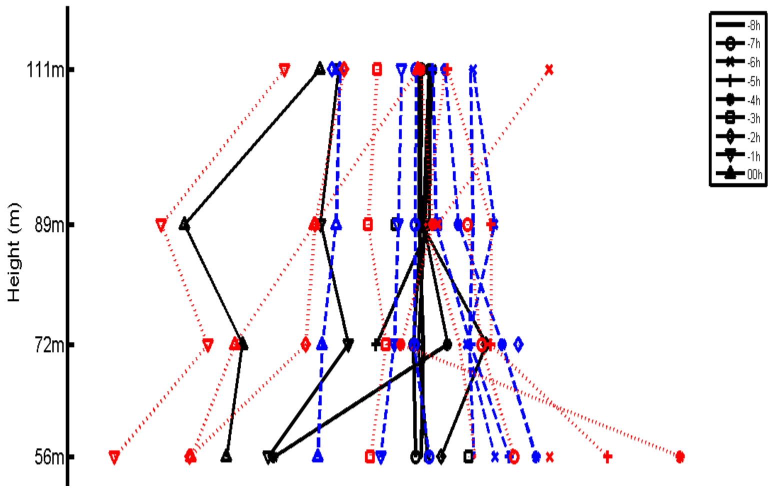
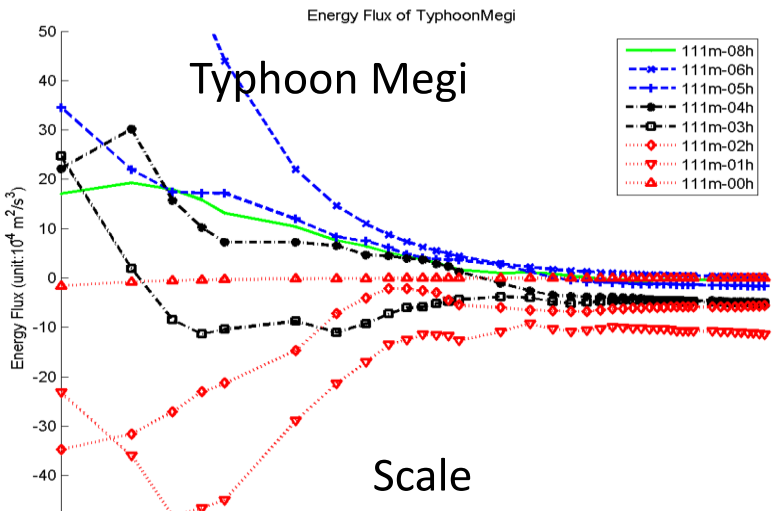
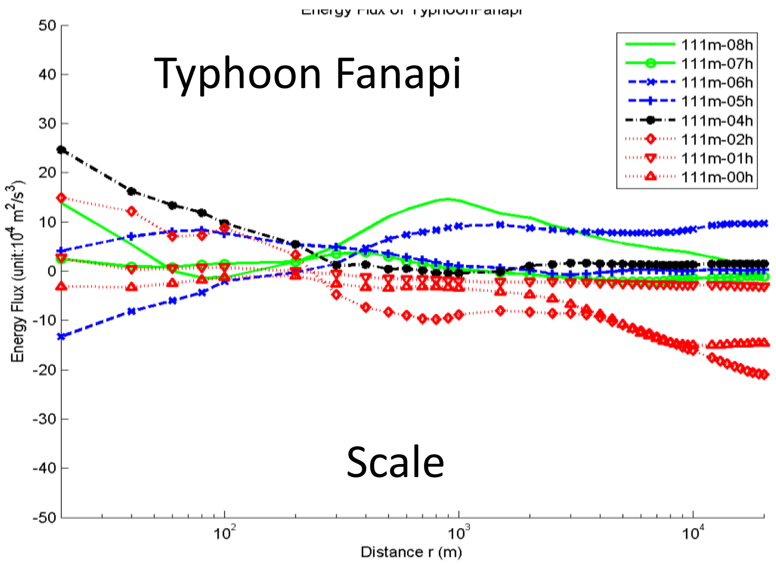
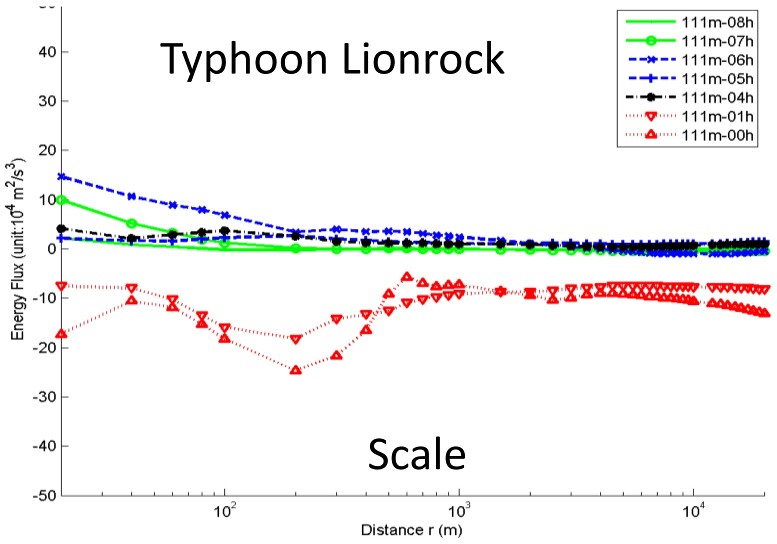




Energy flux varied the direction in different scale/time





Cascade transition in TCBL

	Lionrock(1006)				Fanapi(1011)					Megi(1015)		
Hours before Landing	Distance (km)	Intensity (m/s)	Average Energy Elux ($10^{-5}m^2/s^3$)	Tke production ($10^{-5}m^2/s^3$)	Distance (km)	Intensity (m/s)	Average Energy Elux ($10^{-5}m^2/s^3$)	Tke production ($10^{-5}m^2/s^3$)	Distance (km)	Intensity (m/s)	Average Energy Elux ($10^{-5}m^2/s^3$)	Tke production ($10^{-5}m^2/s^3$)
-8h	127.9	25	**0.2**	8.8	179.2	35	**58.5**	65.8	105.3	40	**29.8**	109
-7h	112.4	25	**3.0**	96.8	164.9	35	**-3.3**	42.3	92.6	40	**NaN**	15
-6h	88.5	23	**16.0**	211.7	140.4	35	**61.7**	135.3	81.7	40	**148.3**	222.3
-5h	73.0	23	**13.4**	36.3	130.2	35	**16.0**	52.0	70.8	40	**32.9**	112.6
-4h	65.1	23	**11.5**	26.7	116.1	38	**29.5**	144.1	59	40	**2.3**	153.3
-3h	52.8	23	NaN[3]	NaN	89.2	38	NaN	NaN	48	40	**-47.5**	141.5
-2h	38.6	23	NaN	NaN	66.1	38	**-98.4**	139.6	38.6	38	**-84.8**	93
-1h	28.2	23	**-91.5**	141.8	34.2	35	**-19.6**	82.7	28.2	38	**-153**	161.7
0h	42.1	23	**-112.8**	441.1	42.1	35	**-89.9**	149.8	26.6	38	**-1.1**	27.8
Average percentage of Energy flux to TKE production[4]				**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

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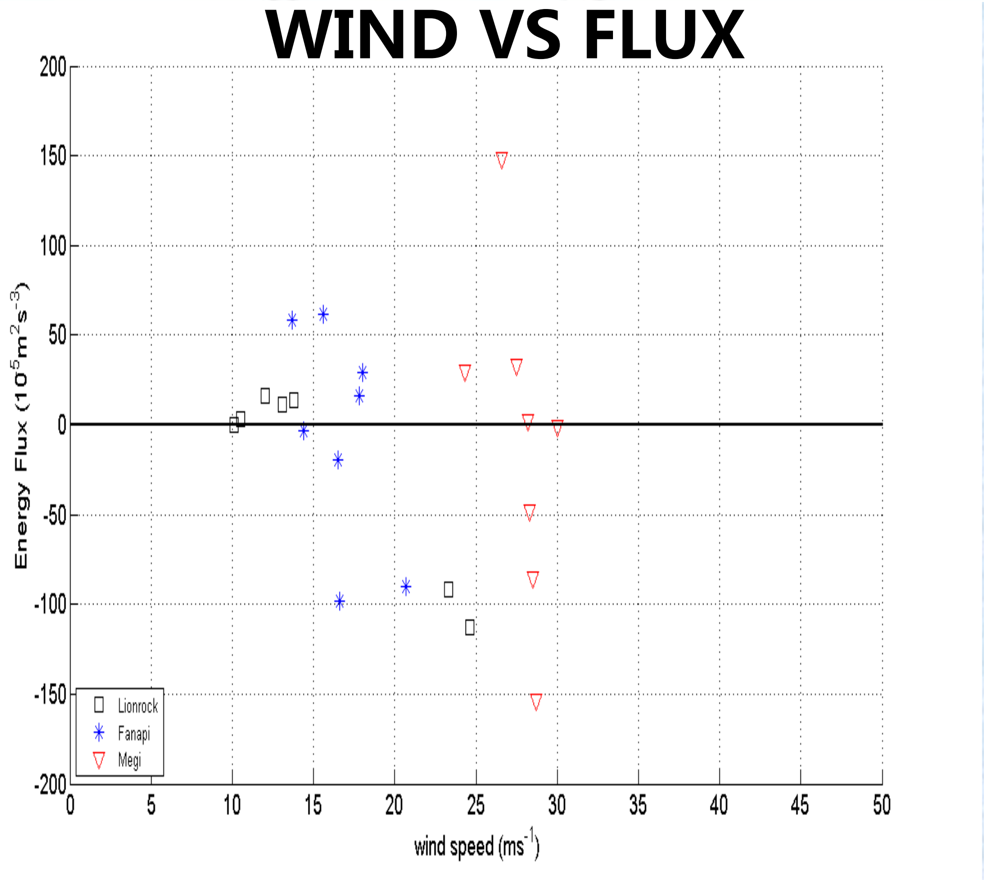
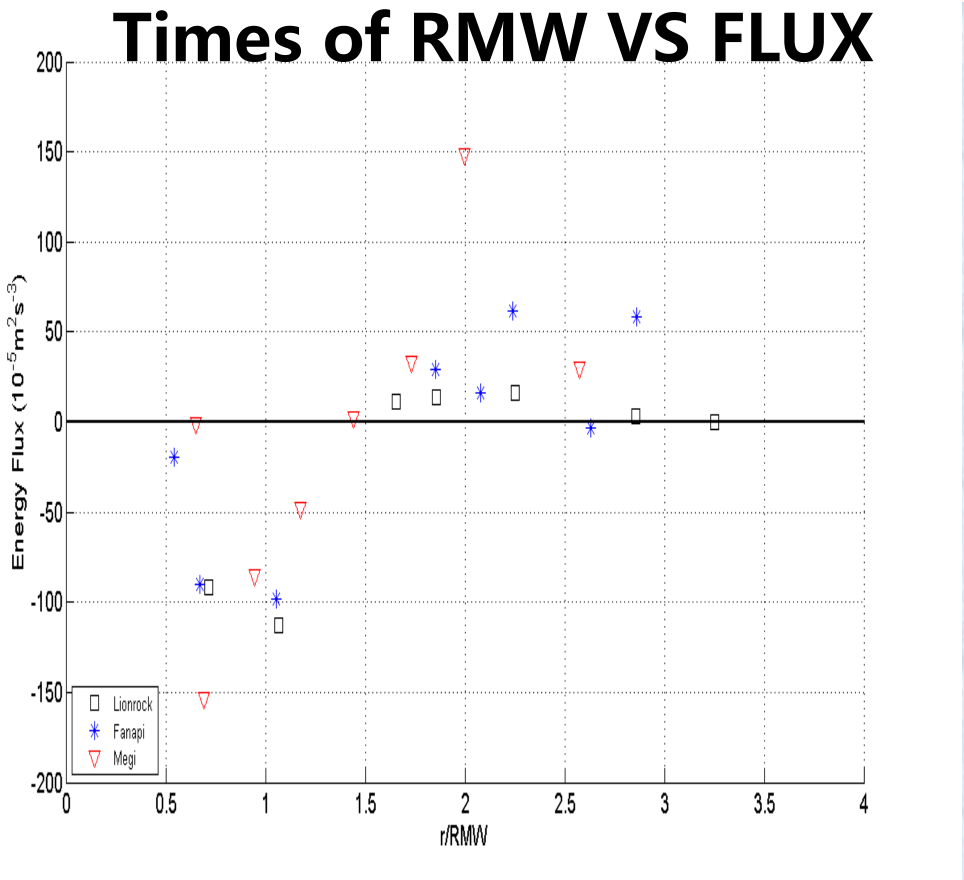
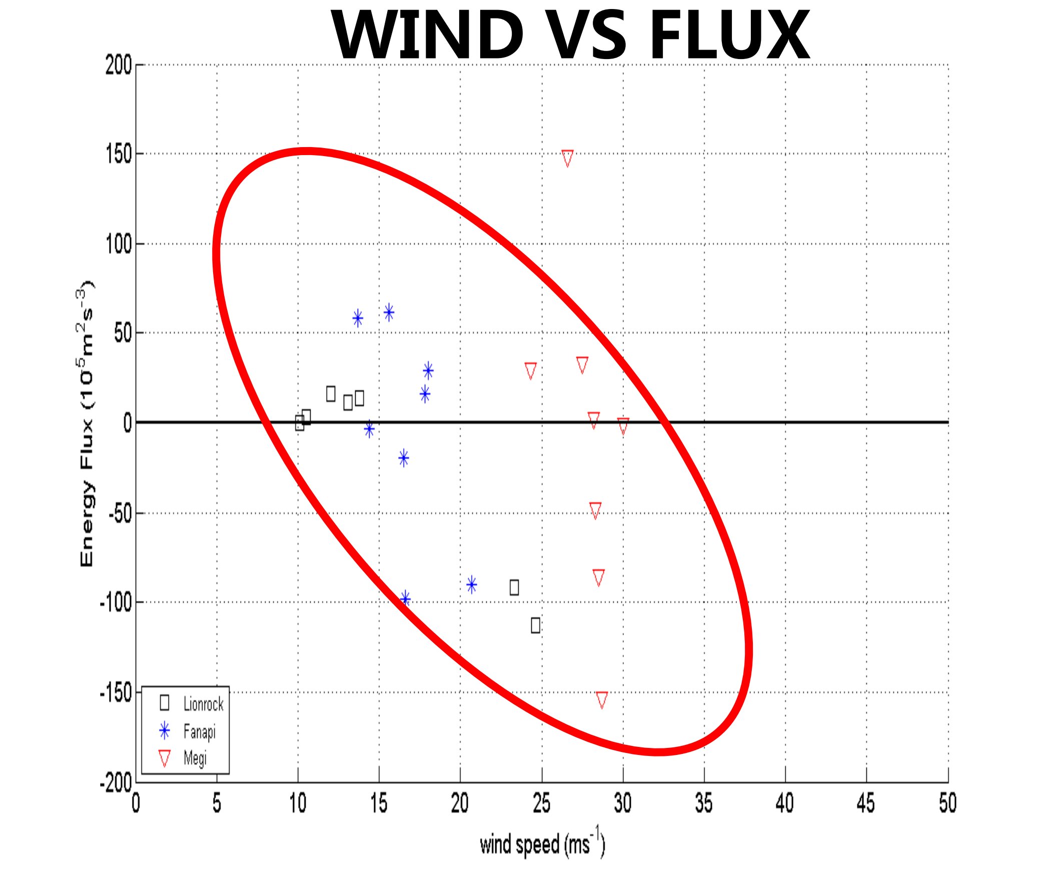
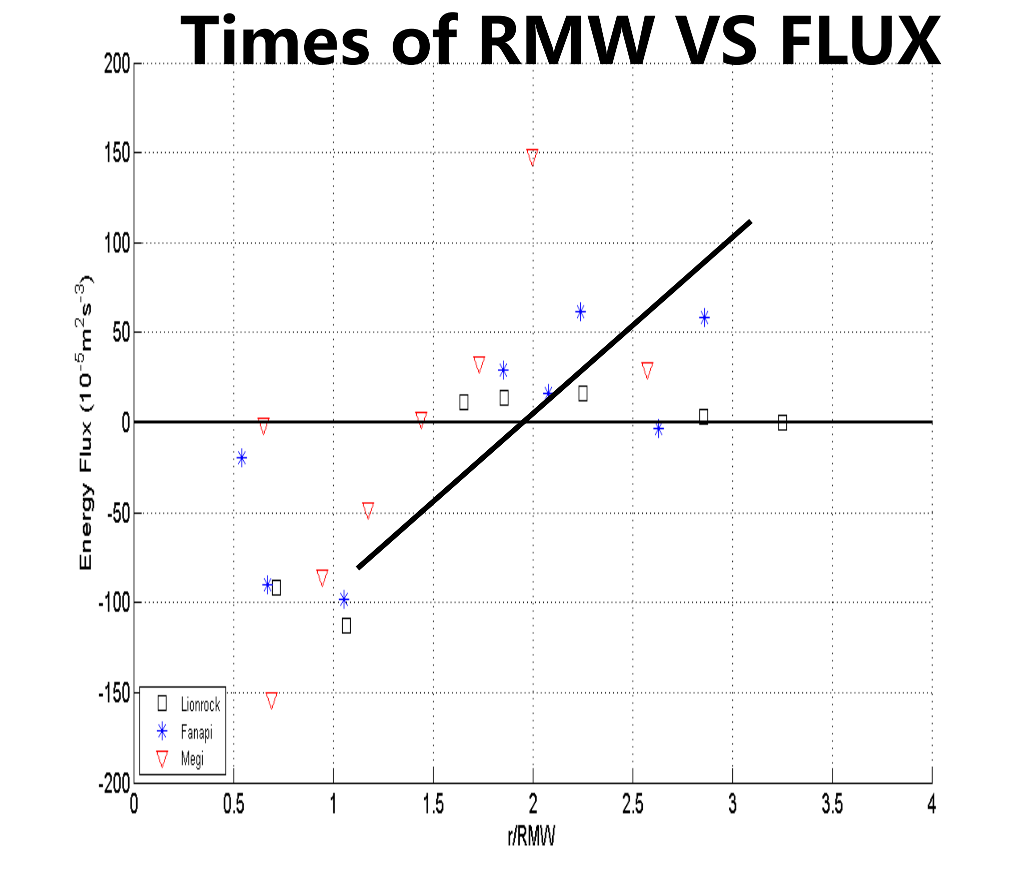
Turbulence cascade and WIND/RMW





Turbulence cascade and WIND/RMW





- **Energy flux VS WIND**
- **Energy flux ：inverse/direct in inner/outer core**

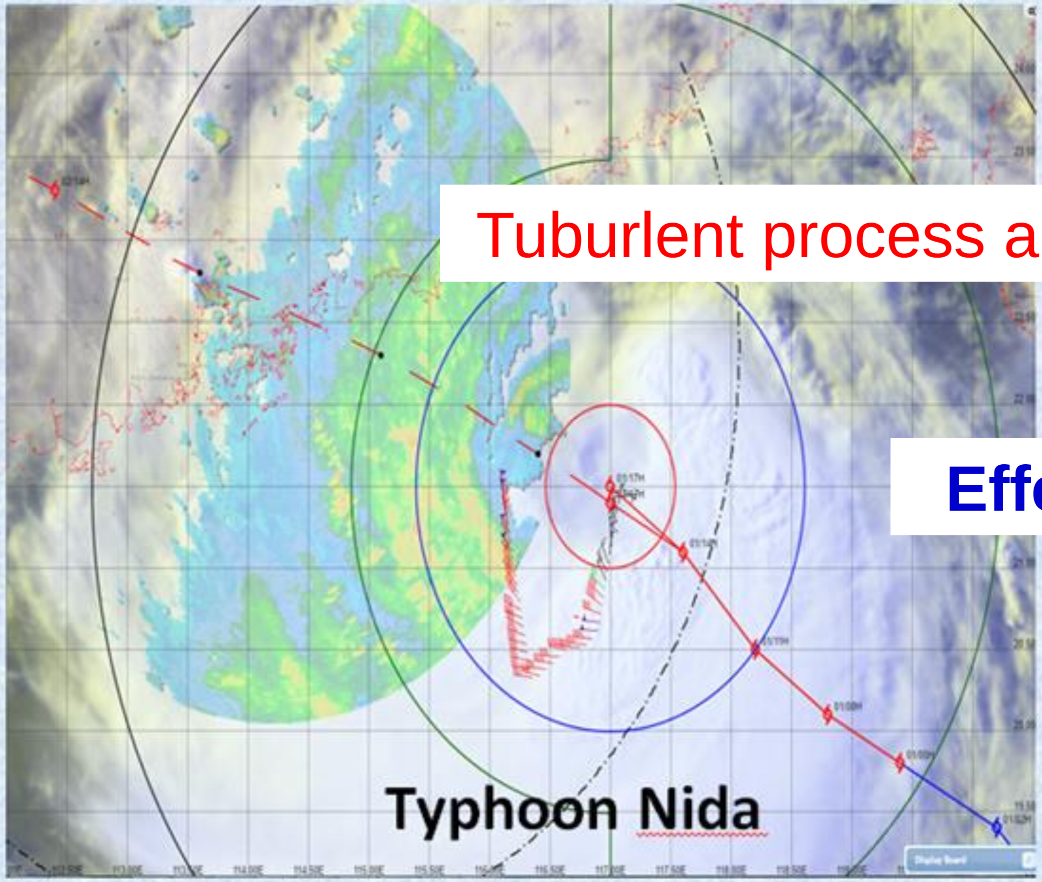
Scientific points

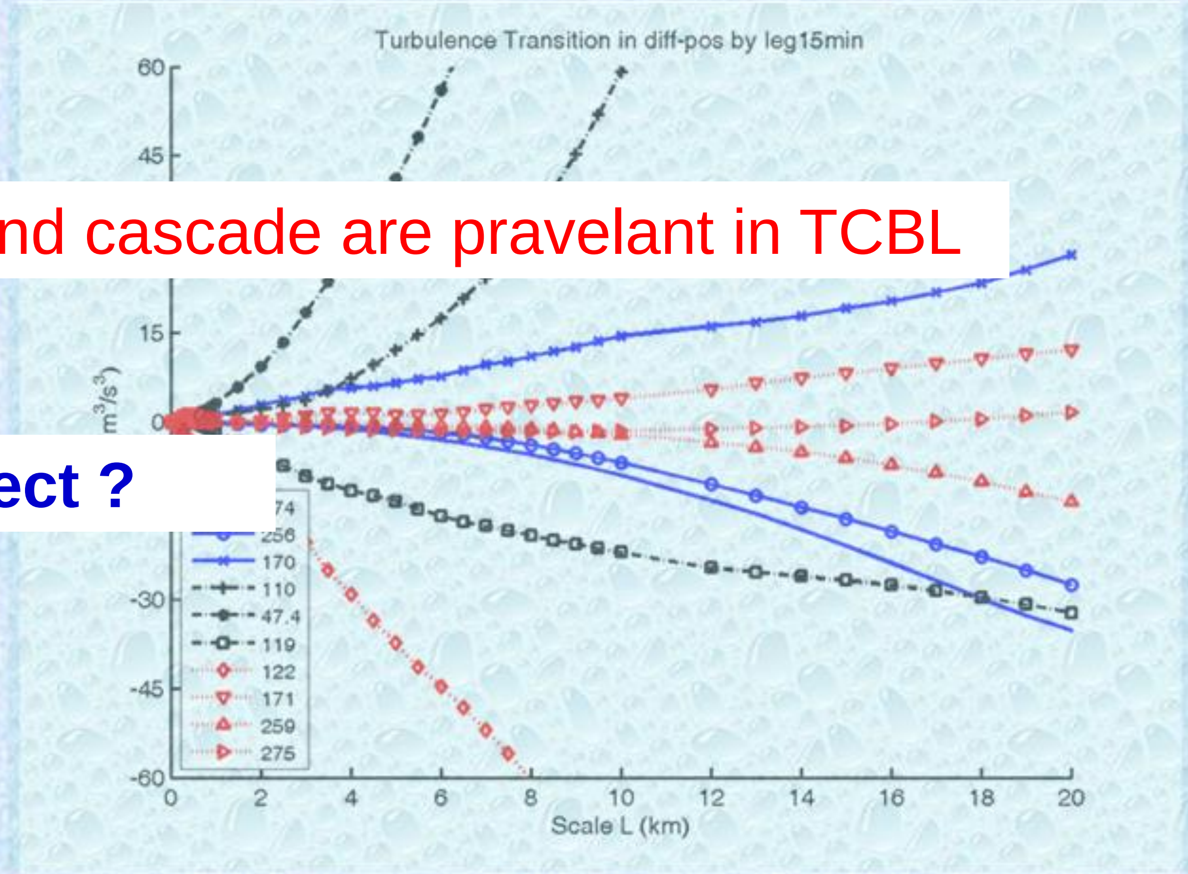
- Tropical cyclones (TC) consist of a large range of interaction scales from hundreds of kilometers to only a few meters and a change in how energy is transferred amongst theses scales i.e. from **smaller to larger scales (upscale)** or vice versa (**downscale**), can have profound impacts on TC energy 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**).

Tang, J., D. Byrne, J. Zhang, Y. Wang, X. Lei, D. Wu, P. Fang, and B. Zhao, 2015: Horizontal Transition of Turbulent Cascade in the Near-Surface Layer of Tropical Cyclones. J. Atmos. Sci., 72, 4915–4925, doi: 10.1175/JAS-D-14-0373.1.

Any more case ?





Tuburlent process and cascade are pravelant in TCBL

Effect ?

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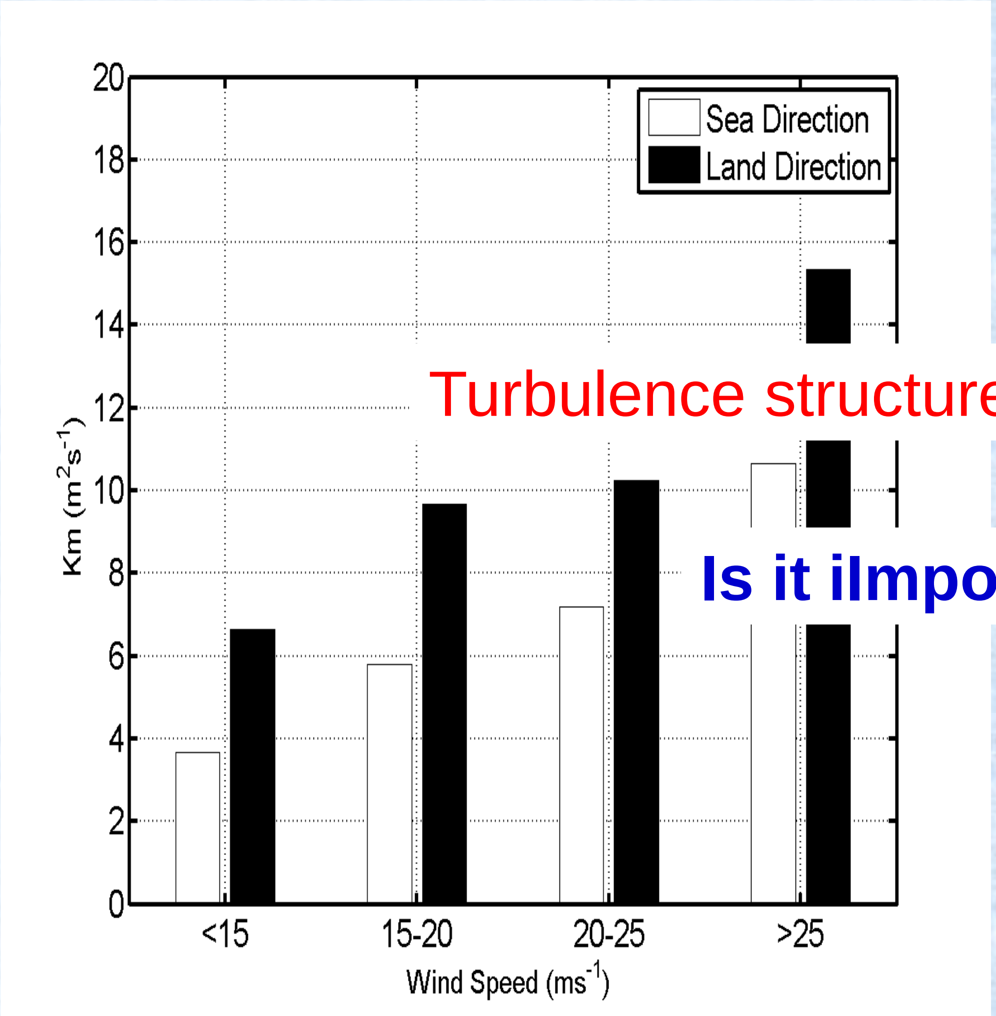
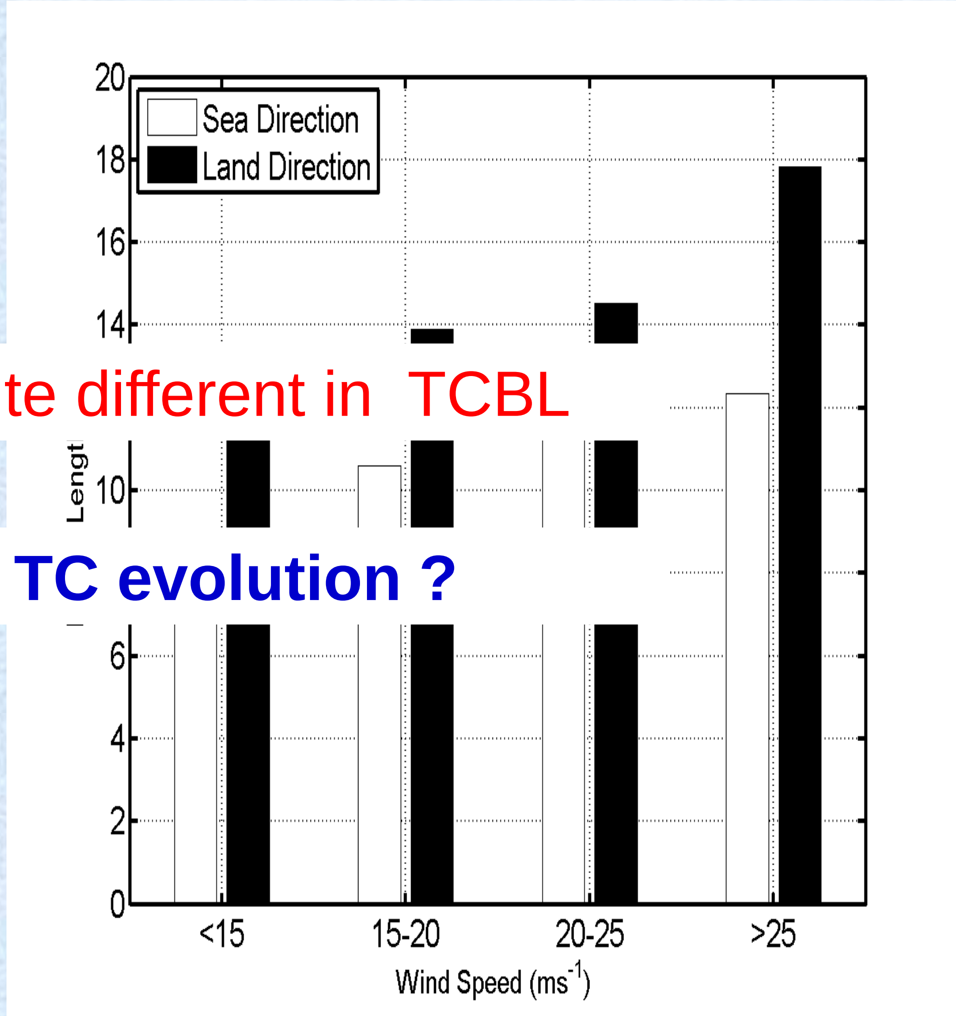
turbulence before/after landfall





Turbulence structure are quite different in TCBL

Is it iImportant to TC evolution ?

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

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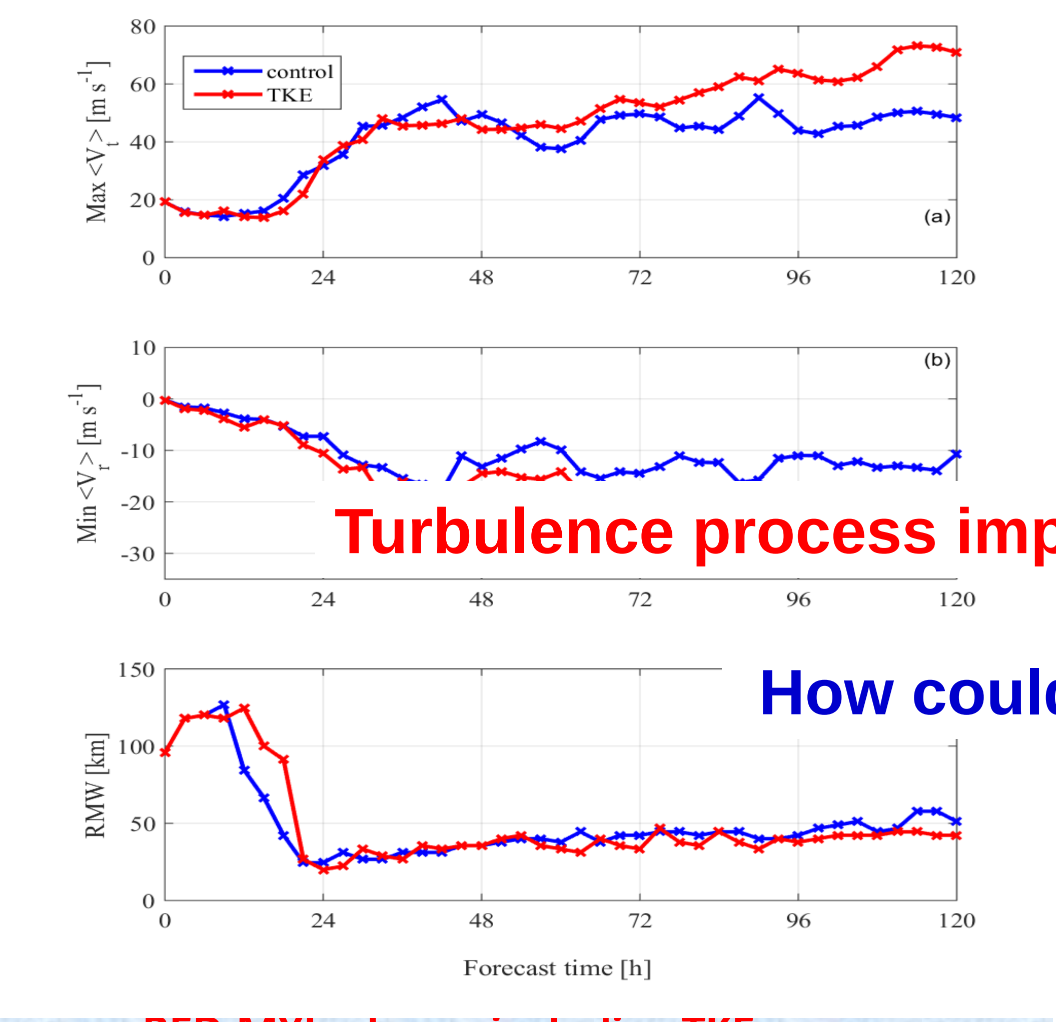
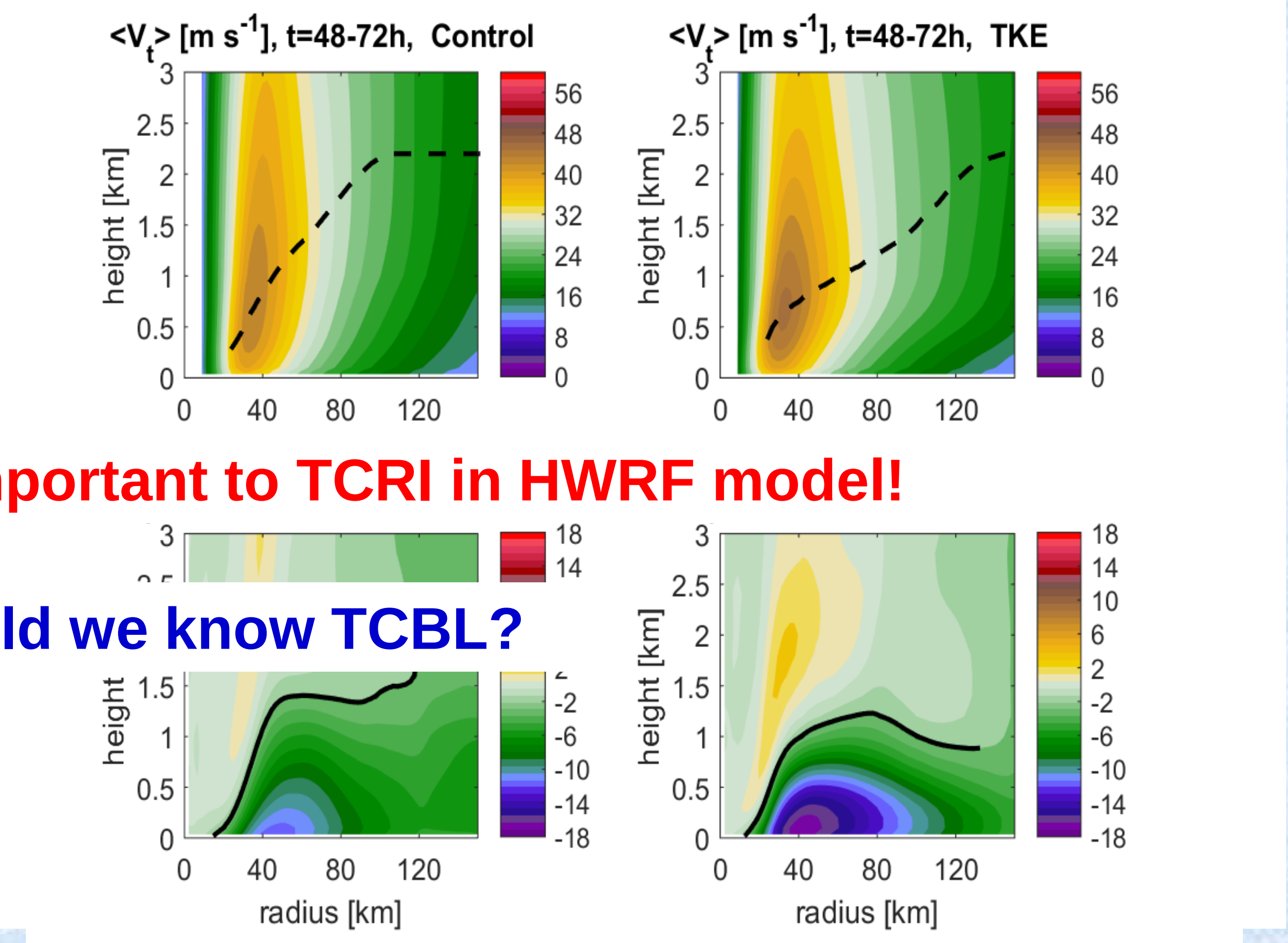
Different PBL Scheme may impact TC Intensity





Turbulence process important to TCRI in HWRF model!

How could we know TCBL?

RED:MYJ scheme including TKE;

BLUE:GFS scheme

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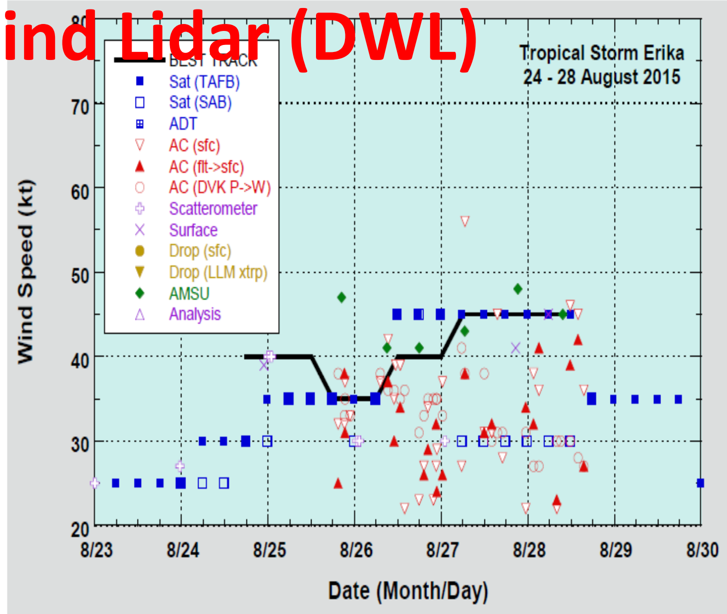
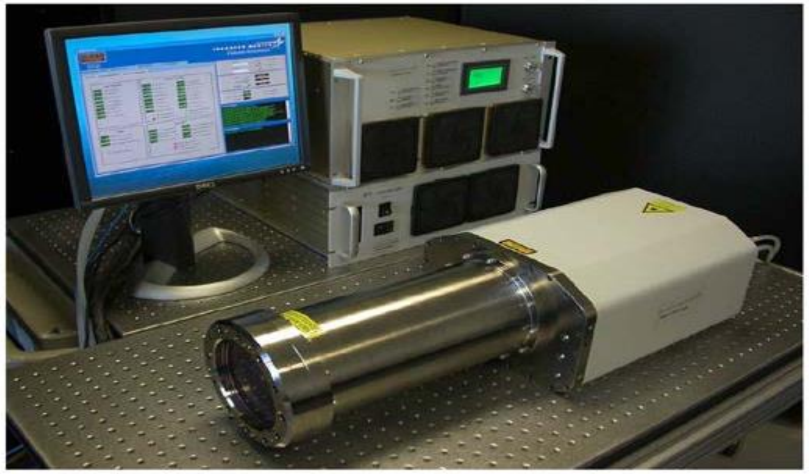
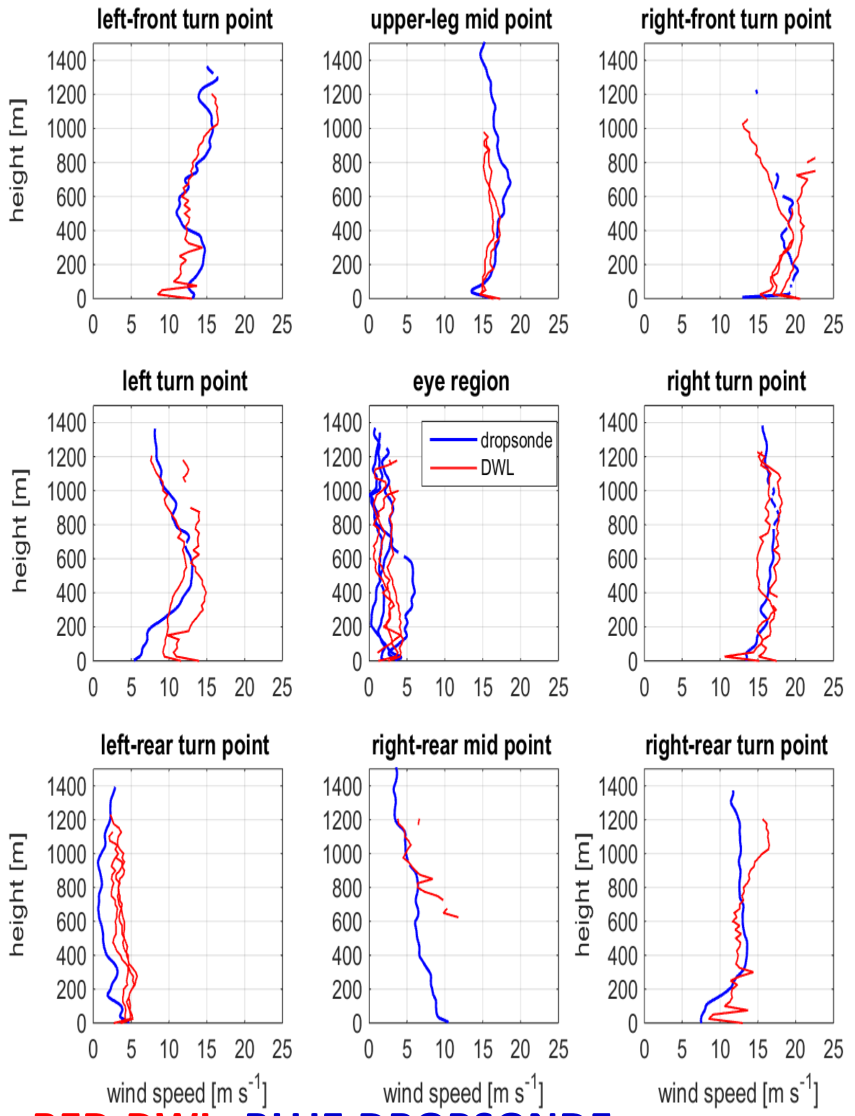
OTHER INTERTING OBSERVATION MATHOD IN TCBL(I)

NOAA P3 Doppler Wind Lidar (DWL)

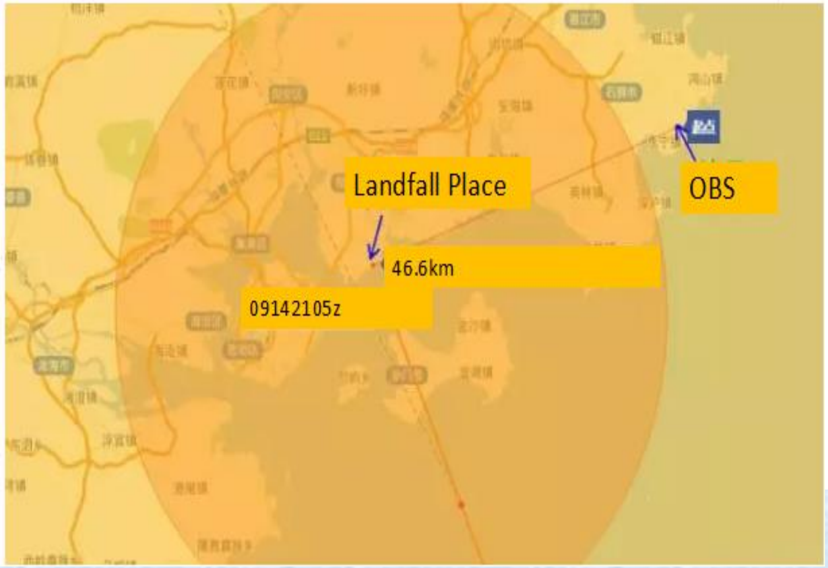




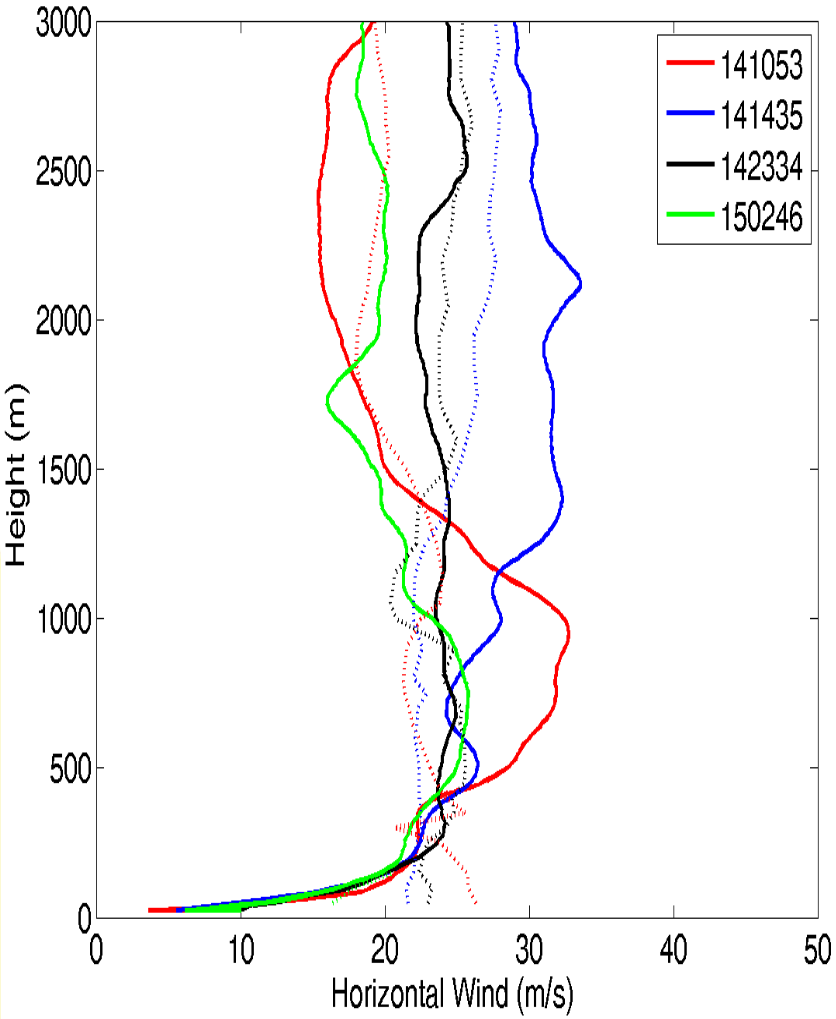


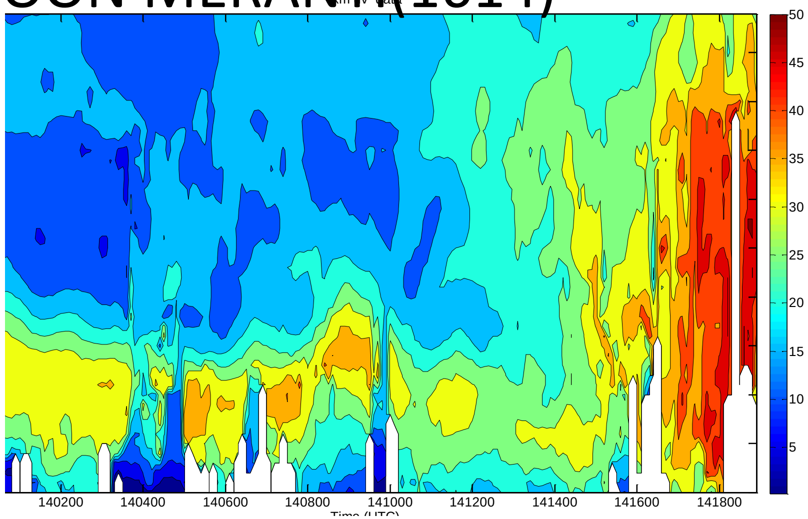
RED:DWL; BLUE:DROPSONDE

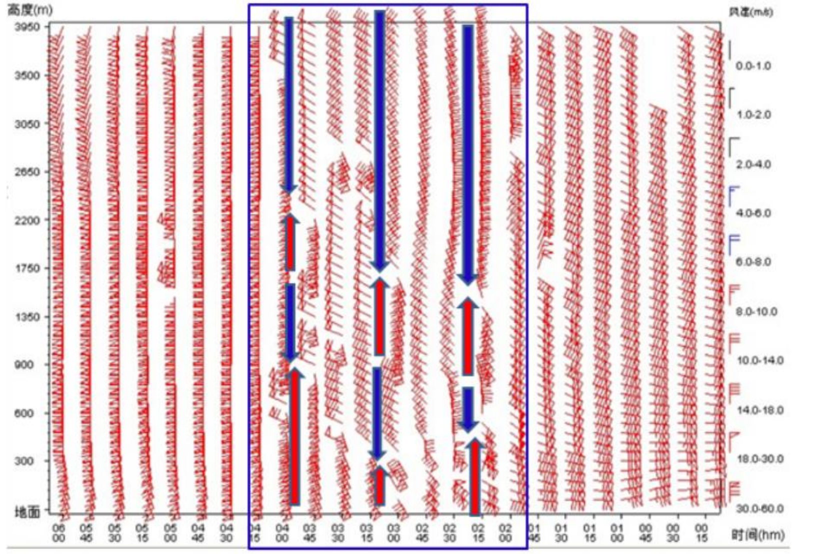
OTHER INTERTING OBSERVATION MATHOD IN TCBL(II)



WIND PORFILE DURING TYPHOON MERANTI(1614)







Solid:GPS SONDE;DASH: WIND PROFILE

HIGH LIGHTS

- Boundary layer fine-scale strucuture and turbulent process play a very implortant in the Intensification of TC
- Fince scale structure in TCBL (<1km) and turbulent process are very poor known in research community and model community
- Many new tenchnique including (LIDAR, WIND PROFILER;SAR RADAR and so on.) have the poetential to help people to know about TCBL
- More target field campaign about TCBL baed on new techniques should be lauched

THANKS!

Future Plan

Key scientific focus :

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