Wave Information Sensitivity for Upper Ocean Structure under Typhoon Condition

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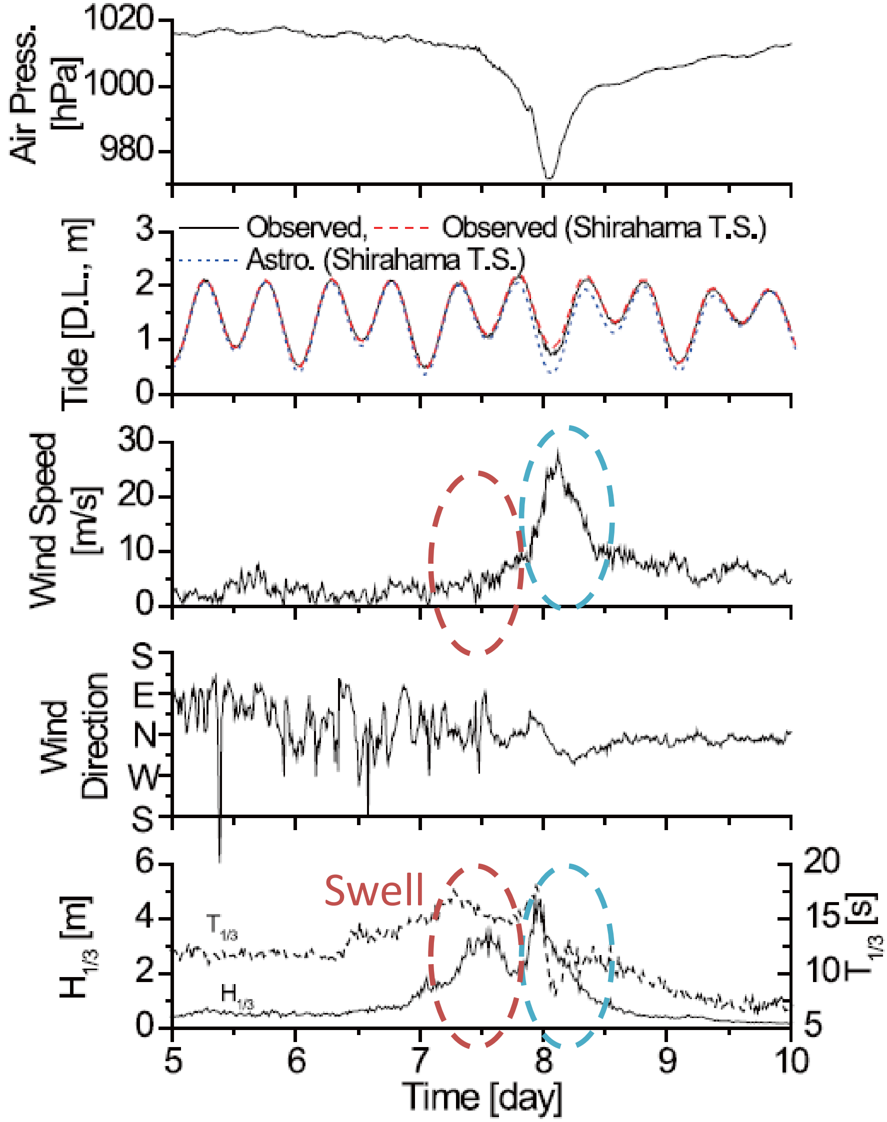
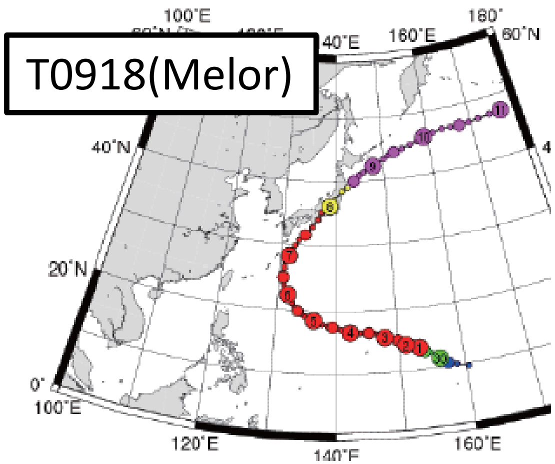
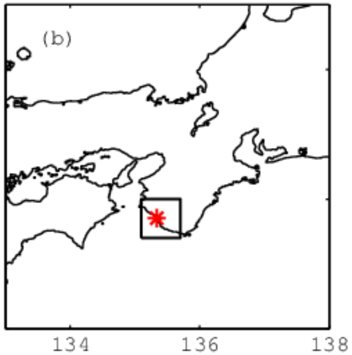
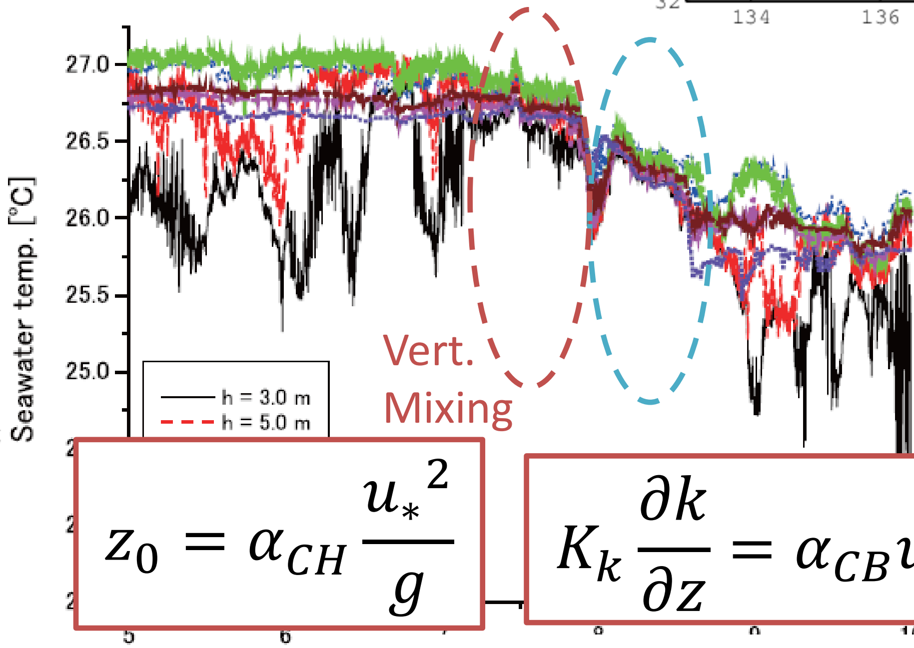
Motivation









$$z_0 = \alpha_{CH} \frac{{u_*}^2}{g}$$

$$K_k \frac{\partial k}{\partial z} = \alpha_{CB} {u_*}^3$$

-> Wave information?

Methodology

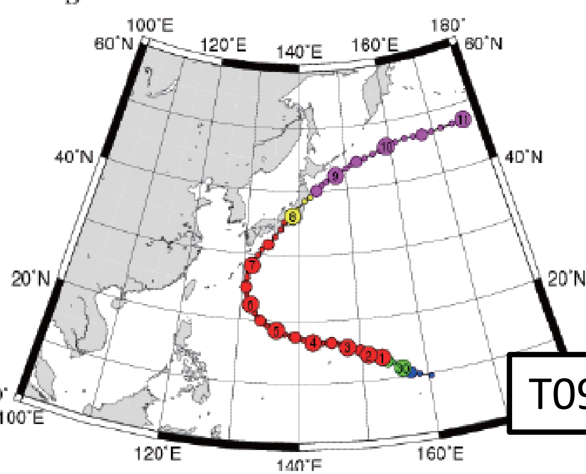
- Momentum bulk formulas

$$z_0 = max\left(\frac{\alpha_{CH}}{g}(u_*)^2, z_{0_{min}}\right)$$

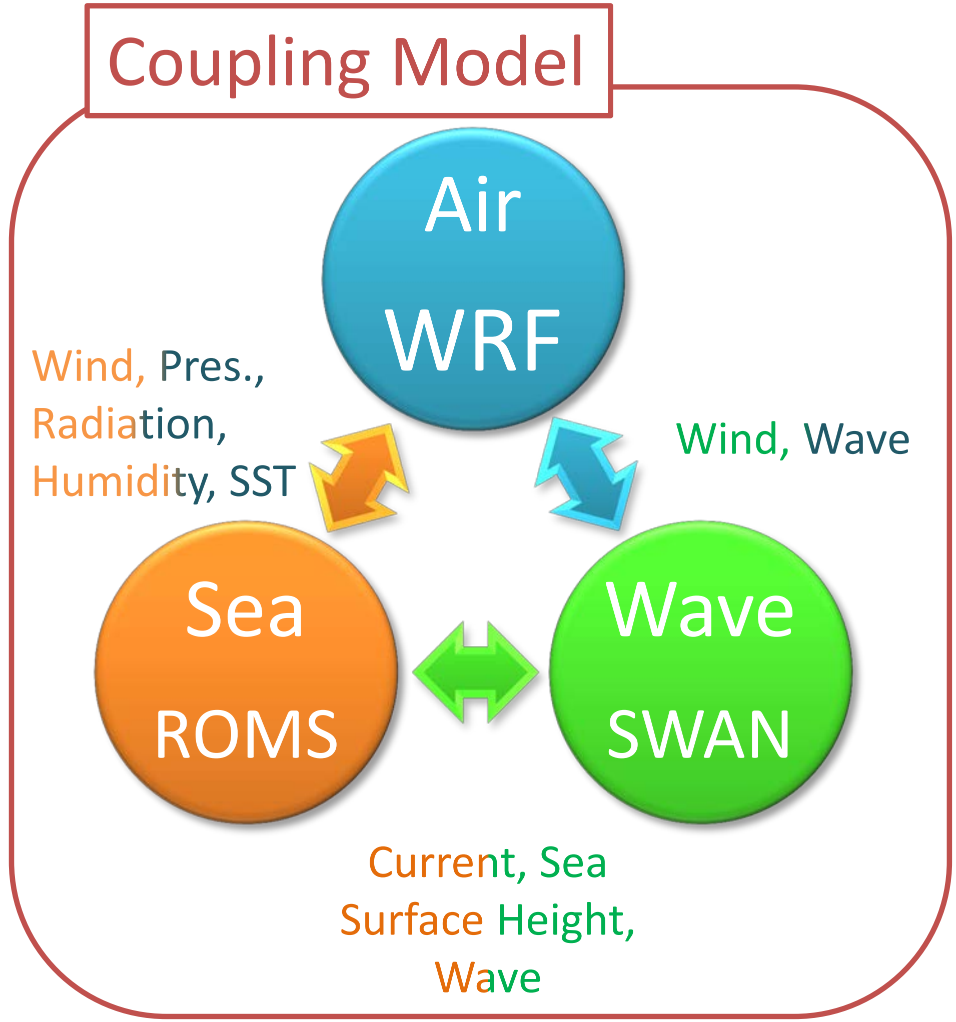
$$\frac{z_0}{H_s} = A\left(\frac{H_s}{L_p}\right)^B$$

$$\frac{z_0}{L_p} = \frac{C}{\pi}(u_*/C_p)^D$$

$$\frac{z_0}{H_s} = E(u_*/C_p)^F$$



T0918(Melor)

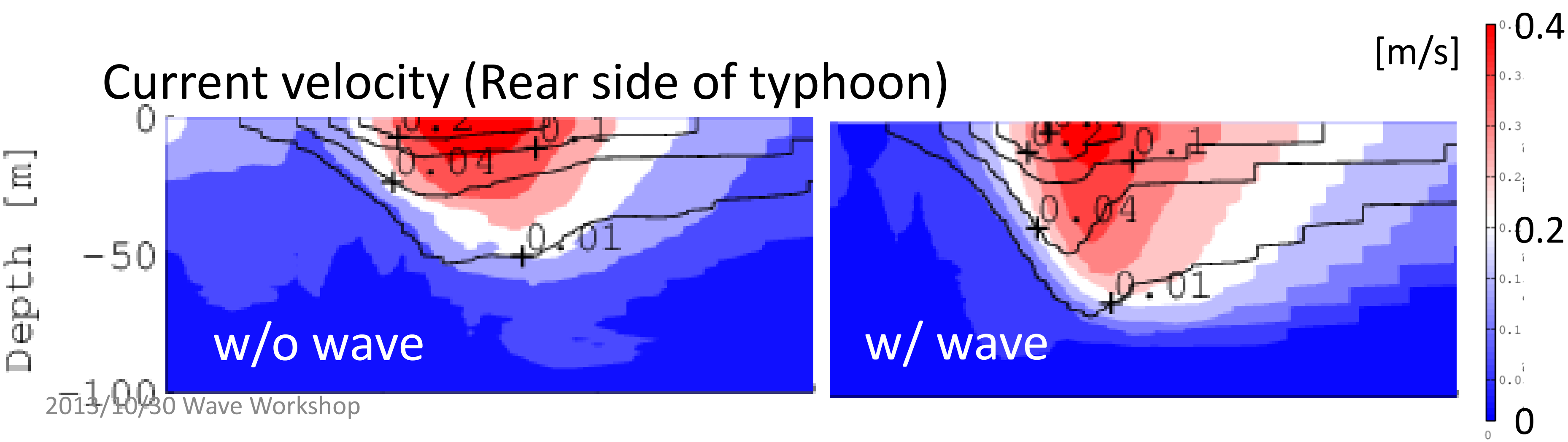


+ Air side roughness + Sea side roughness
+ TKE flux

Conclusions

- Numerical experiments for typhoon using four bulk formulas were carried out.
- Sensitivity of bulk formulas were found
  - Distribution according to direction from typhoon center
  - Large influence of wave information on current velocity, sensible and latent heat, and vertical wind profile

Current velocity (Rear side of typhoon)



Typical Proposed Bulk Formulas at Sea Surface

Air side Roughness

1. Charnock (1955) : Friction Velocity

$$z_0 = max\left(\frac{\alpha_{CH}}{g}(u_*)^2, z_{0_{min}}\right)$$

$$\alpha_{CH} = 0.018 \quad for \quad 18.0 < u$$

$$\alpha_{CH} = 0.011 + 0.125(0.018 - 0.011)(u - 10.0) \quad for \quad 10.0 < u < 18.0$$

$$\alpha_{CH} = 0.011 \quad for \quad u < 10.0$$

2. Taylor and Yelland (2001) : Wave Slope

$$\frac{z_0}{H_s} = A\left(\frac{H_s}{L_p}\right)^B$$

$A = 1200, B = 4.5$

Hs:Wave height, *Lp*:Wave length

WRF default setting:

$$z_0 = \max(z_{0CH}, 1.59 \times 10^{-5})$$

$$\alpha_{CH} = 0.018$$

3. Oost (2002) : Wave age, Wave length

$$\frac{z_0}{L_p} = \frac{C}{\pi}(u_*/C_p)^D$$

$C = 25.0, D = 4.5$

Cp:Wave velocity

4. Drennan (2003) : Wave age, Wave height

$$\frac{z_0}{H_s} = E(u_*/C_p)^F$$

$E = 3.35, F = 3.4$

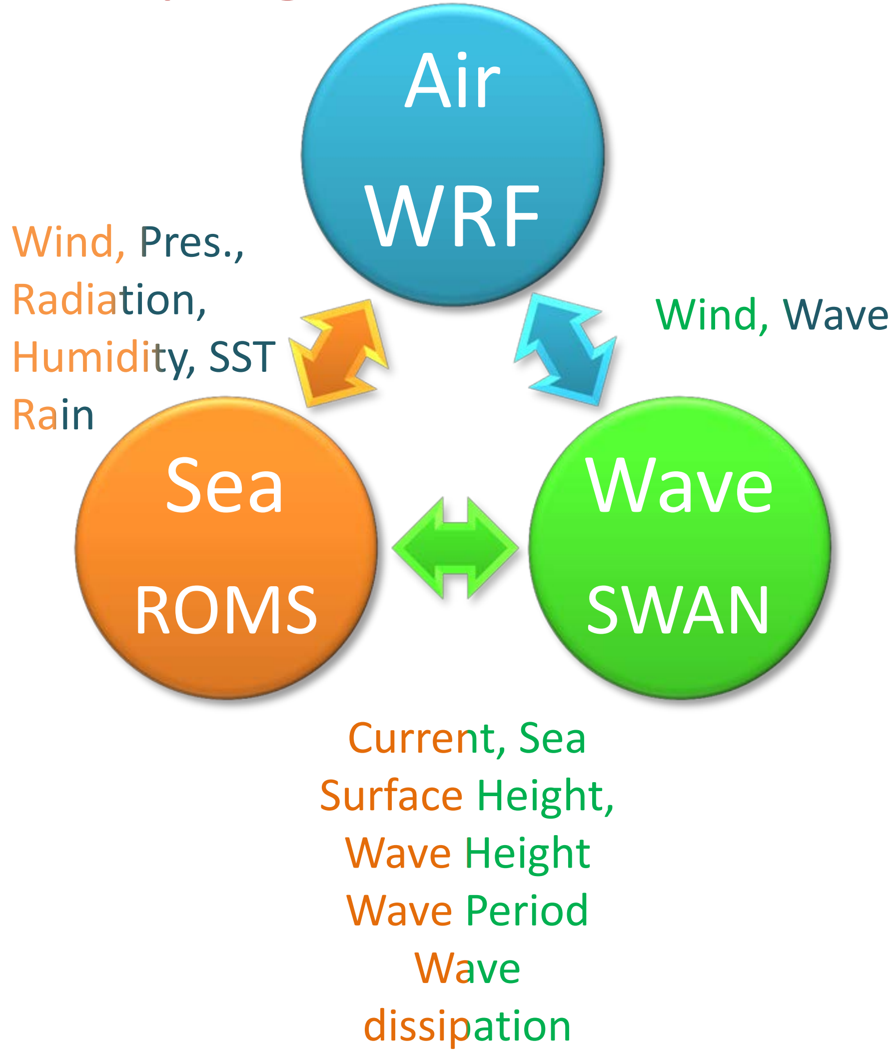
$$u_* = \frac{\kappa u_{ref}}{log(z_{ref}/z_0)}$$

$$\tau = \rho_a u_*^2$$

Model Setup

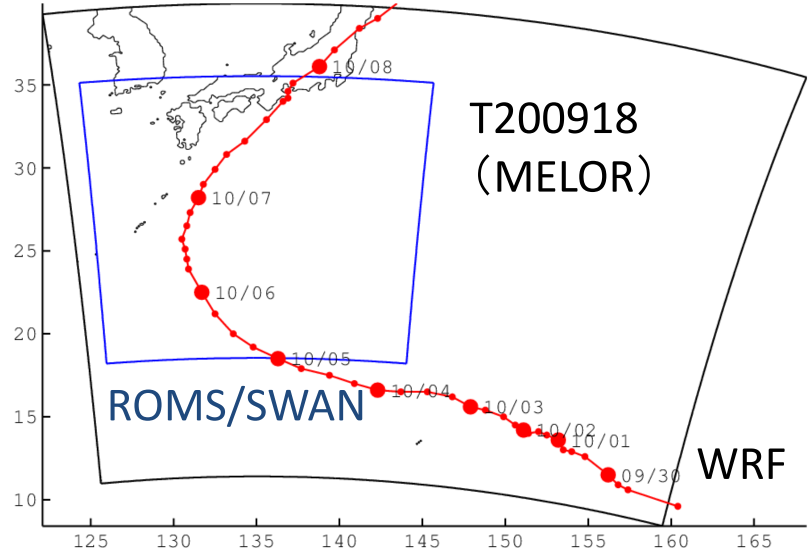
- Initial, Boundary Condition
  - WRF
    - NCEP FNL (Final) Operational Global Analysis data
      - Resolution：1 degree，6 hour
  - ROMS
    - JCOPE2（JAMSTEC）
      - Resolution：1/12 degree，1 day
  - SWAN
    - WW3（NOAA Reanalysis）
      - Resolution：1/2 degree，3 hour
- Bulk formula at the surface
  - Air side roughness
  - Ocean side roughness
  - TKE flux

Coupling Model



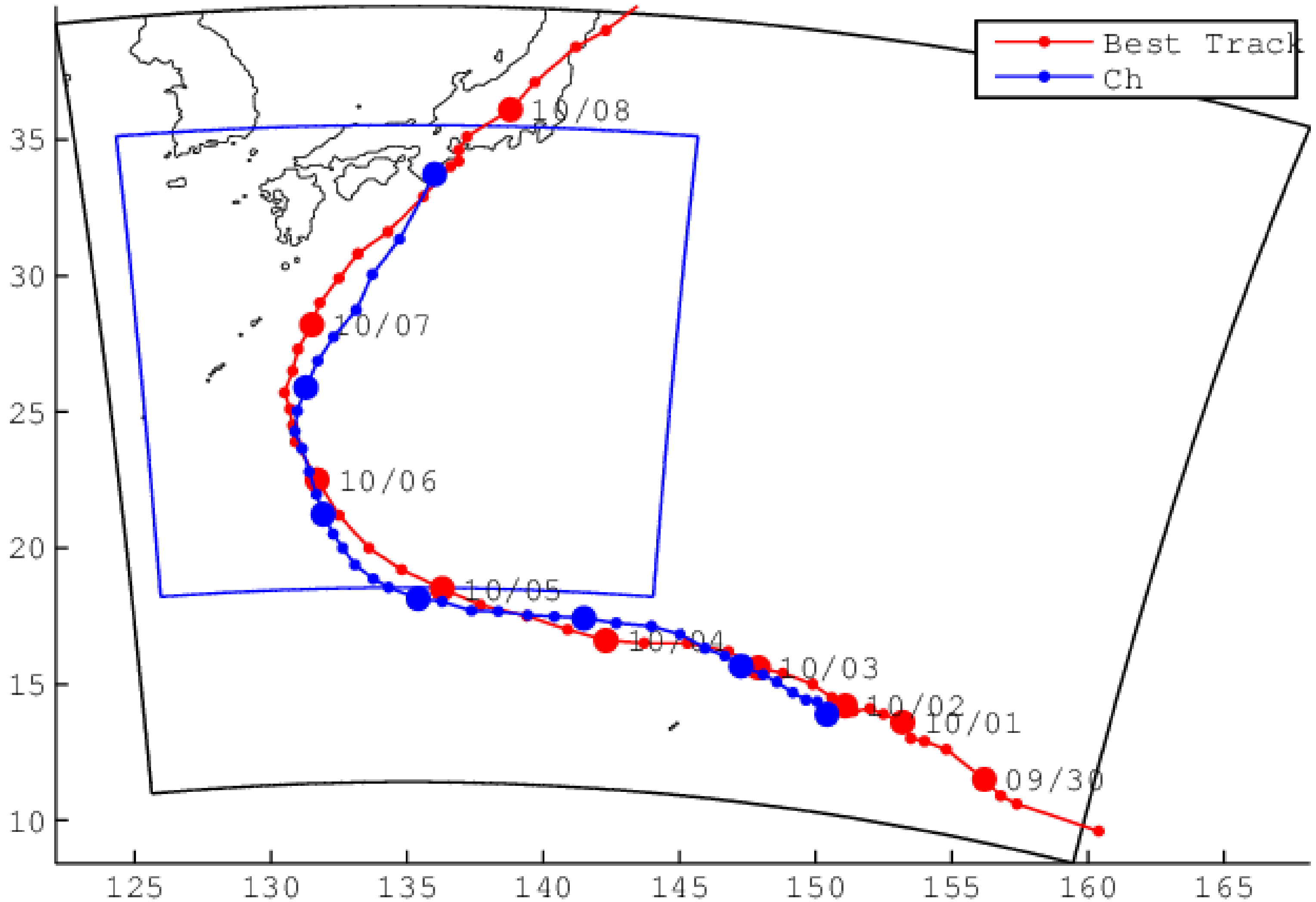
Model Setup for TC Melor (2009)

- Period
  - 2009/9/30 – 10/8
    - Coupling Interval: 600s
- Domain

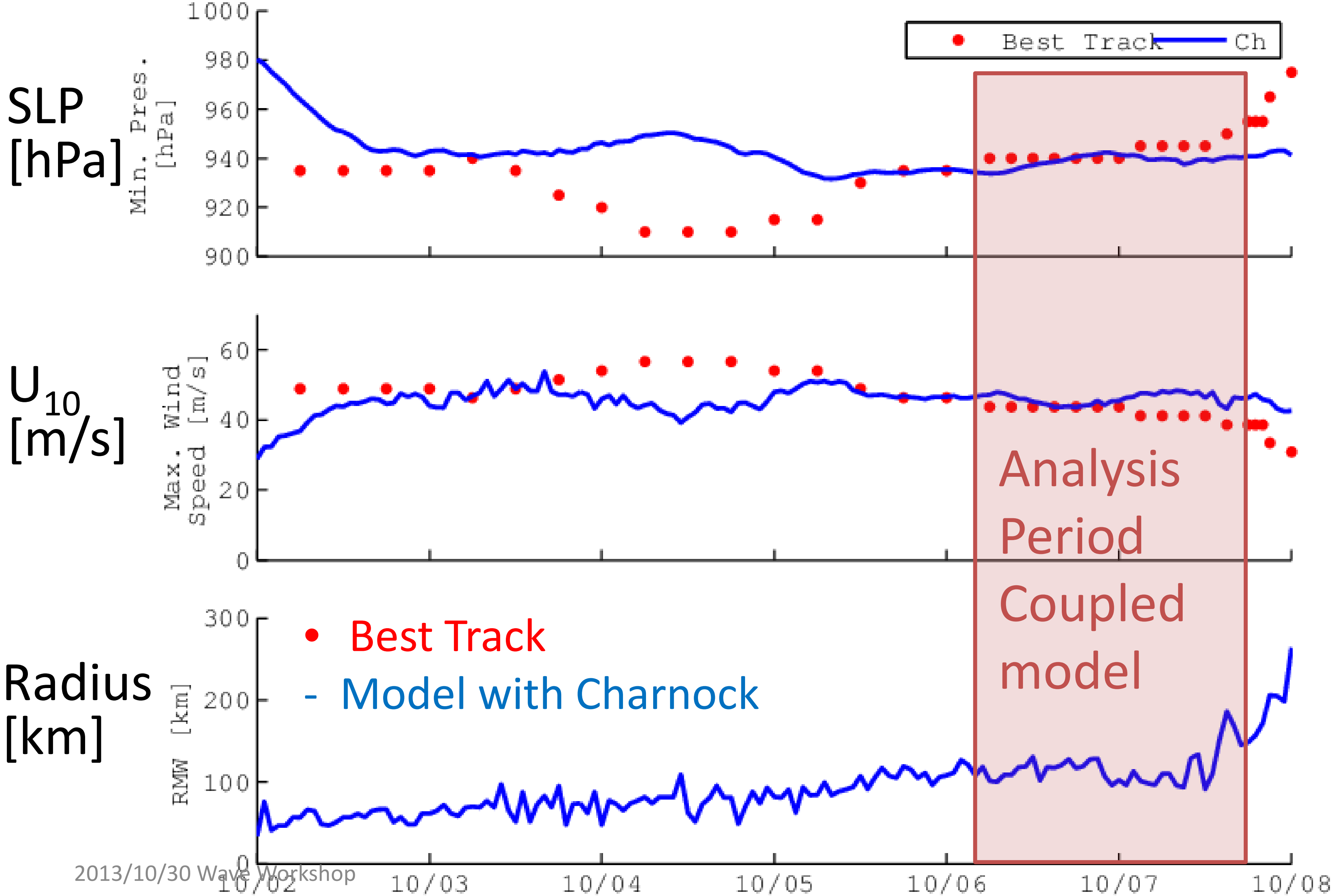


<table>
<tr><th></th><th>Resolution</th><th>Horizontal grids</th><th>Vertical grids Directions etc.</th><th>Dt [s]</th></tr>
<tr><td>WRF</td><td rowspan="3">12km</td><td>338x270</td><td>40</td><td>50</td></tr>
<tr><td>ROMS</td><td rowspan="2">195x190</td><td>40</td><td>40</td></tr>
<tr><td>SWAN</td><td>Dir.: 24
Freq.: 24
(0.05-0.5Hz)</td><td>75</td></tr>
</table>

Comparison between Best Track and CT



Comparison between Best Track and CT



Results

Air side roughness

Ch: Charnock（Friction velocity）

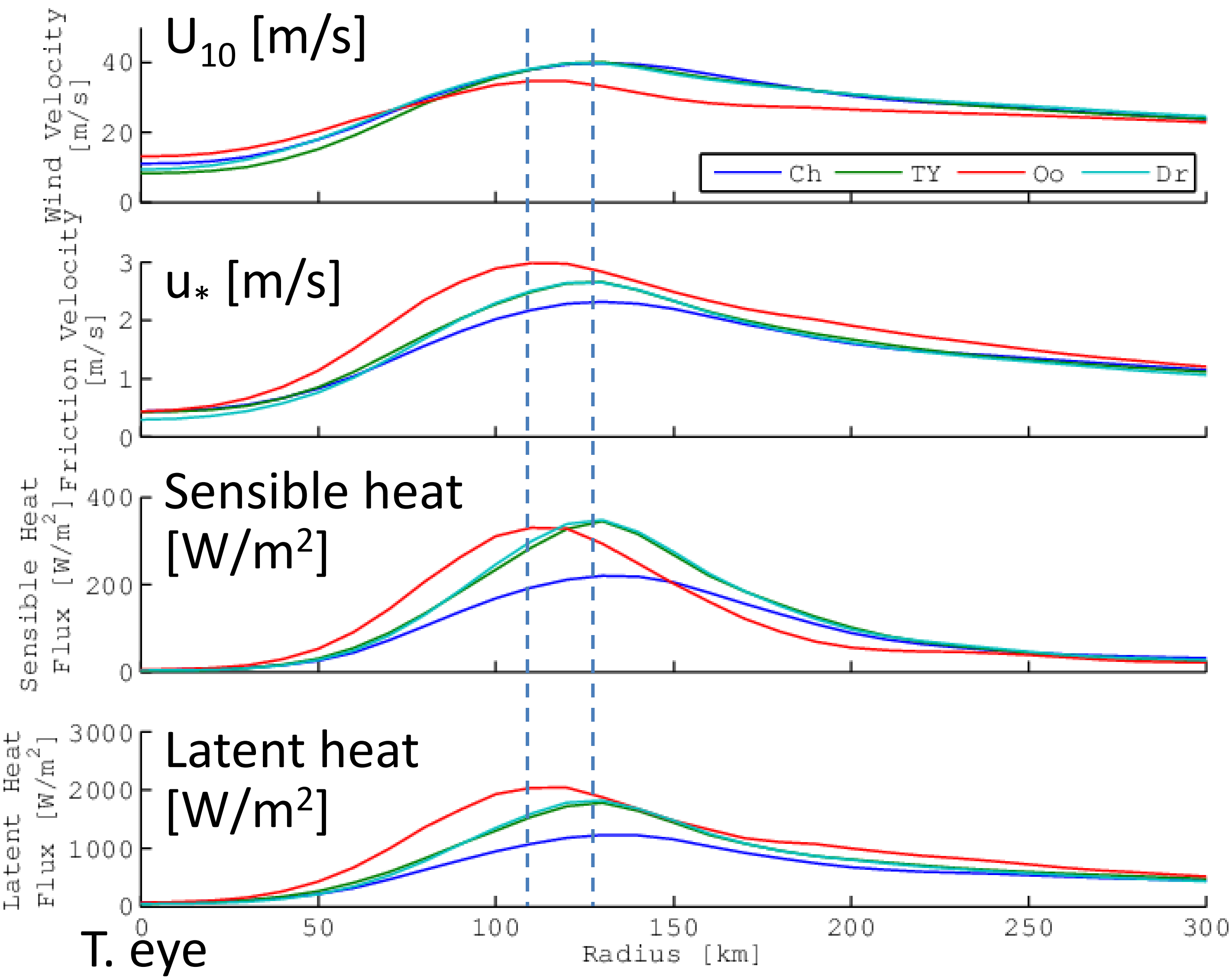
TY: Taylor and Yelland（Wave slope）

Oo: Oost（Wave age – Wave length）

Dr: Drennan（Wave age – Wave height）

Friction Velocity, Sensible/Latent heat flux (time and direction averaged)

2009/10/6 18:00 – 10/7 00:00 UTC



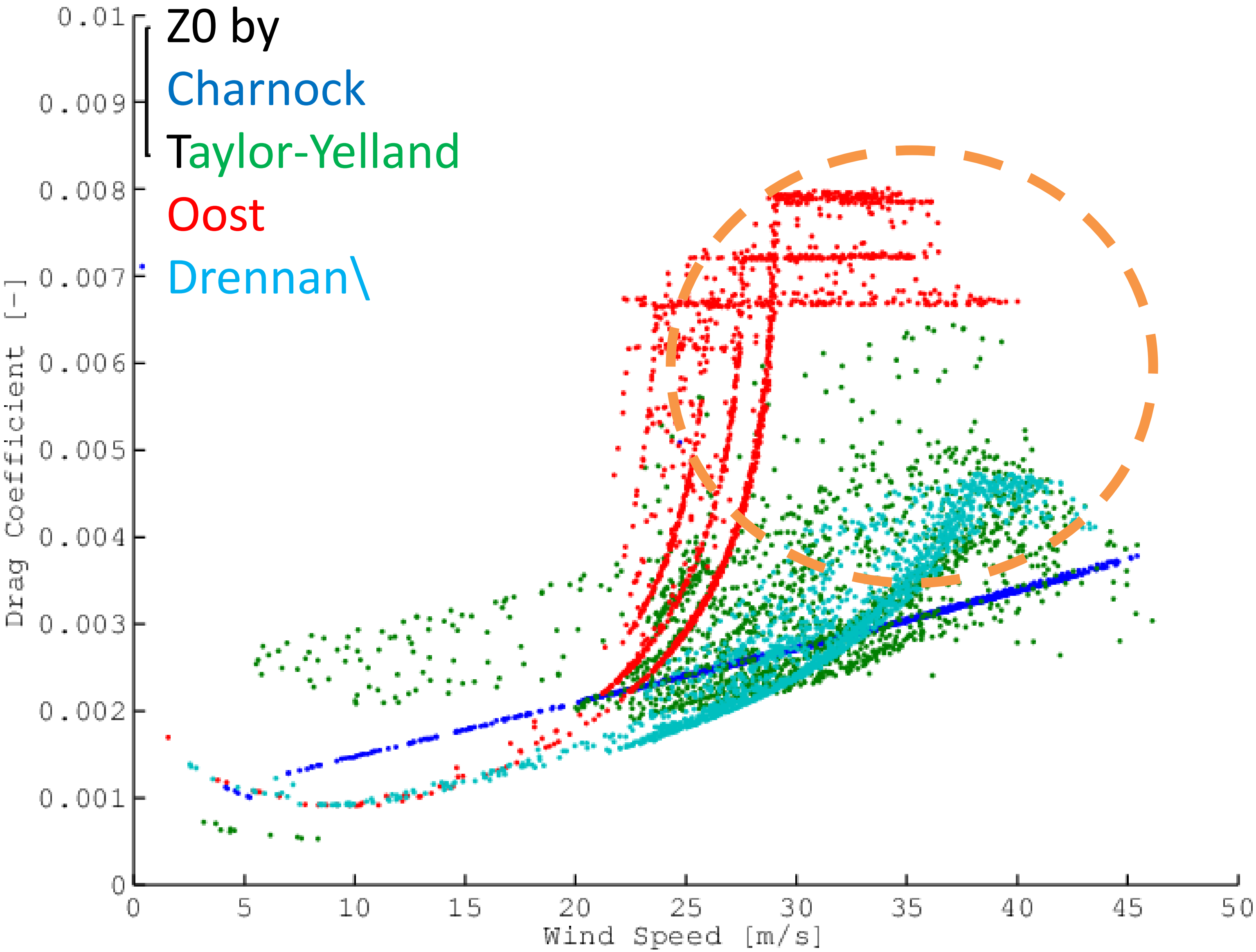
Z0 by
Charnock
Taylor-Yelland
Oost
Drennan

Oost formula estimates peak value at closer to center of typhoon.

Wave based formulas estimate large friction velocity and heat flux.

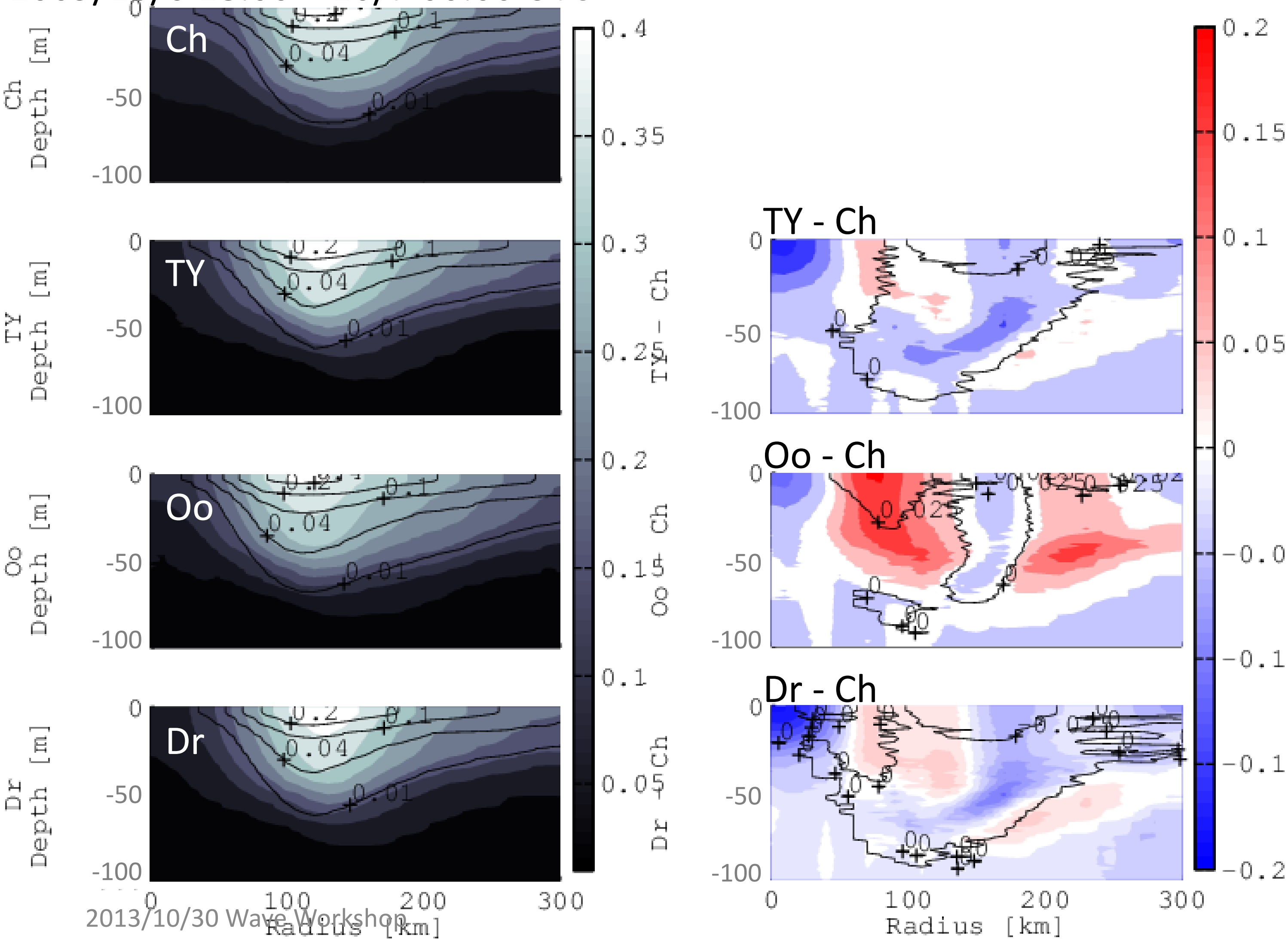
Internally Calculated Drag Coefficient

Drag coefficient is good indicator how roughness influence on the momentum transfer at air-sea interface.



Current Velocity, TKE (time and direction averaged)

2009/10/6 18:00 – 10/7 00:00 UTC

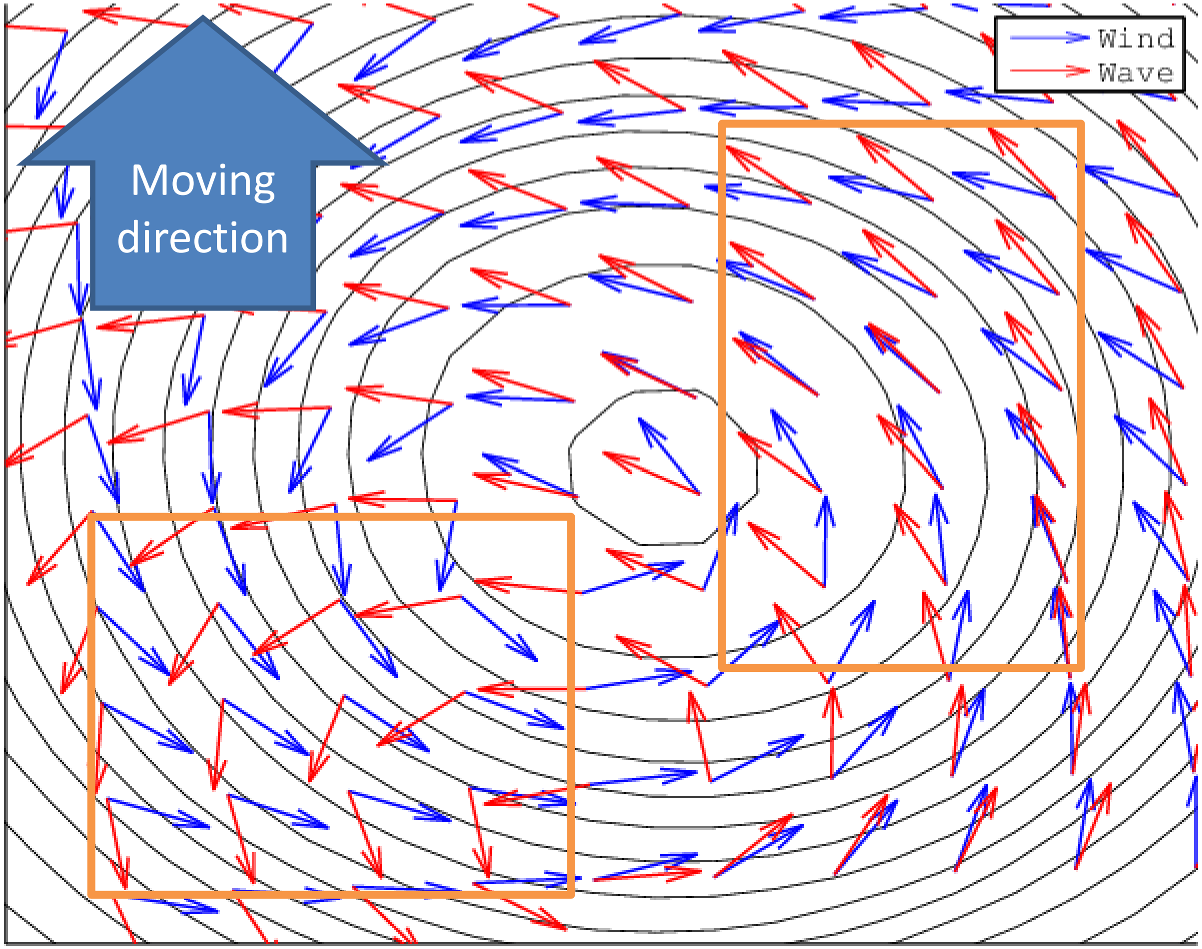


Ch, TY, Dr estimate similar distribution.

Oo estimate large current velocity.

H. Vel. : Shade
TKE : Contour

Wind and Wave Direction around Typhoon Eye



Wave direction agree with wind direction in front side, but disagree in rear side.

Front side

Friction Velocity, Sensible/Latent Heat Flux

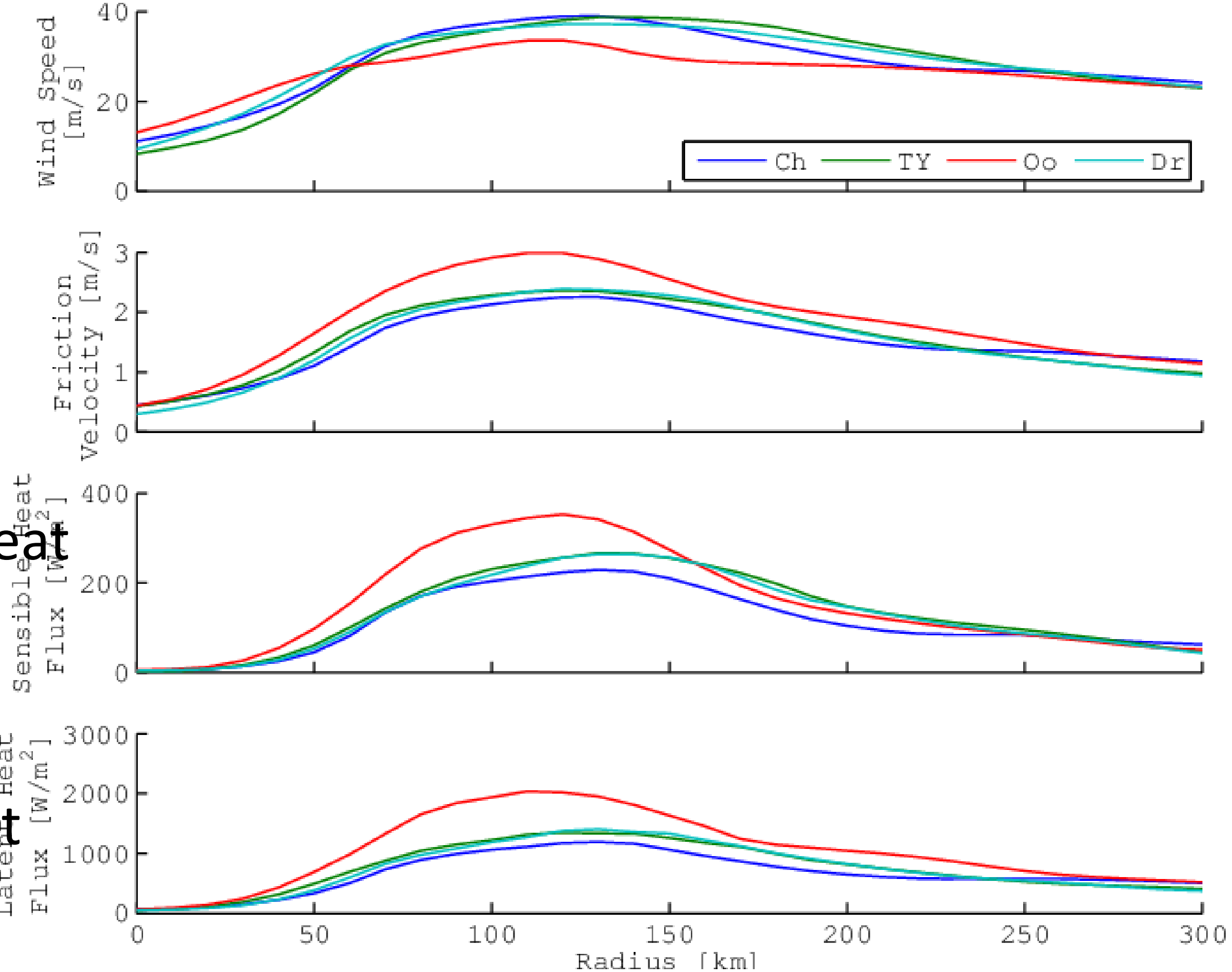
2009/10/6 18:00 – 10/7 00:00 UTC（Moving direction：North）

U_{10} [m/s]

u_* [m/s]

Sensible heat [W/m^2]

Latent heat [W/m^2]



In front side, Ch, TY and Dr estimate similar distribution. In rear side, formulas with wave information estimate large friction velocity and heat flux.

Rear side

Friction Velocity, Sensible/Latent Heat Flux

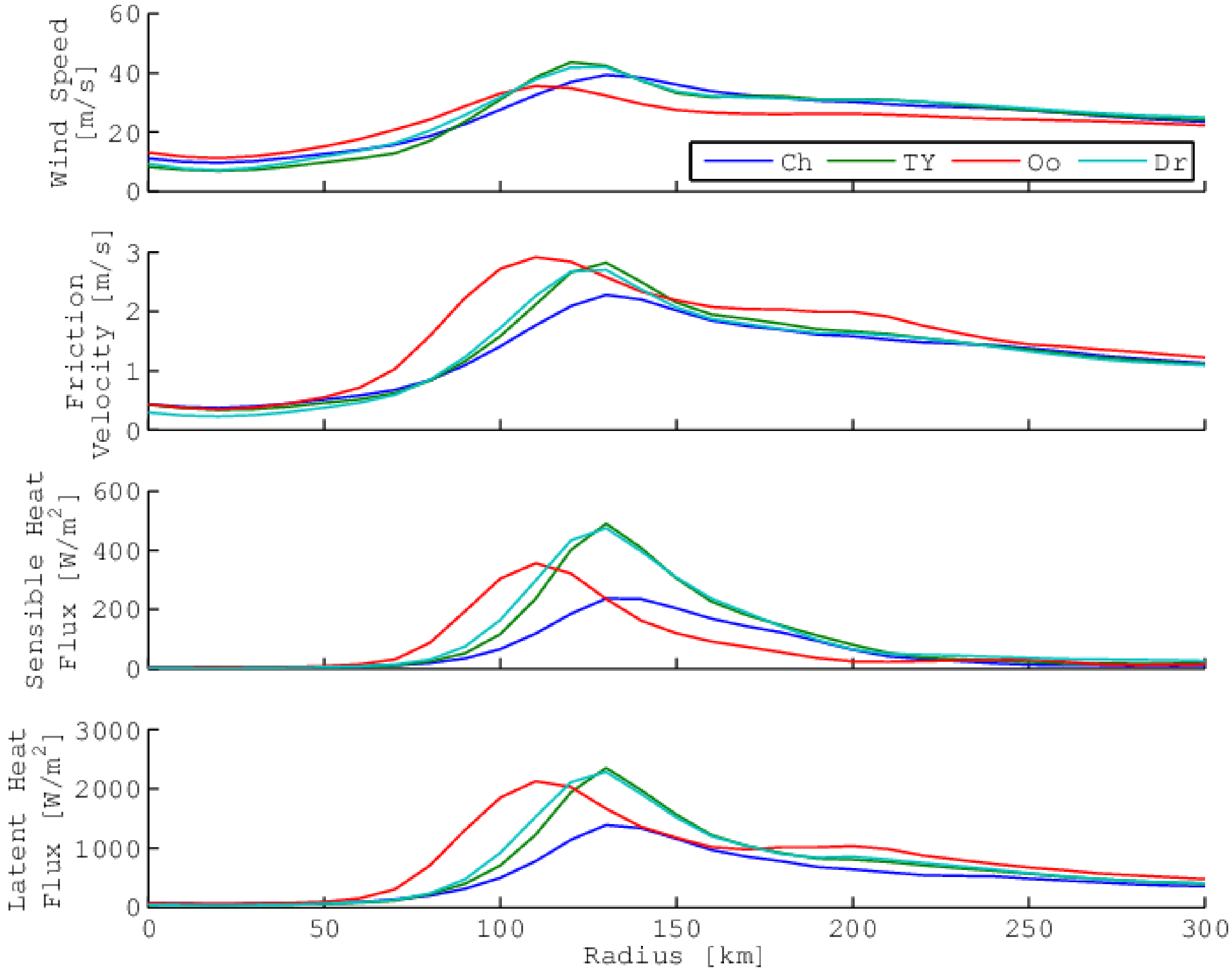
2009/10/6 18:00 – 10/7 00:00 UTC（Moving direction：North）

U_{10} [m/s]

u_* [m/s]

Sensible h
[W/m²]

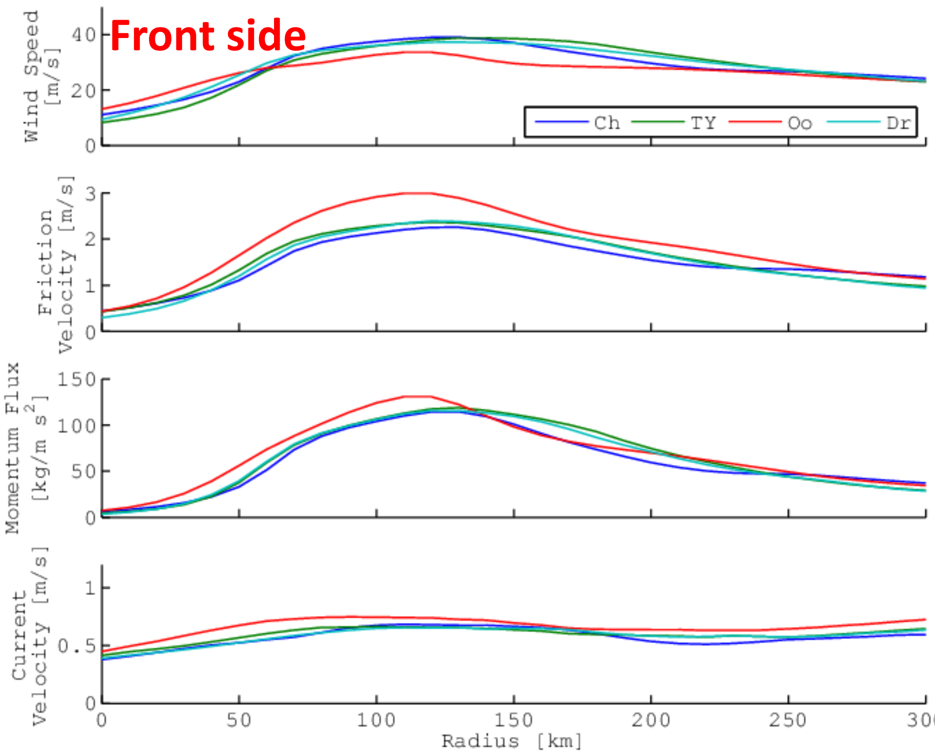
Latent hea
[W/m²]



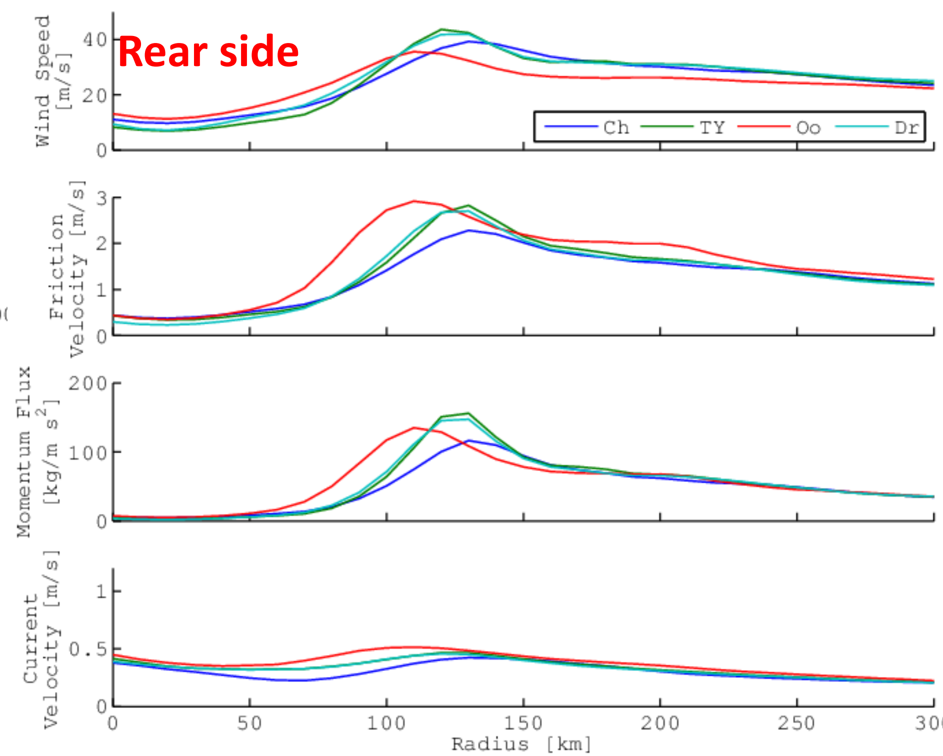
In front side, Ch, TY and Dr estimate similar distribution. In rear side, formulas with wave information estimate large friction velocity and heat flux.

Current Velocity at Sea Surface

2009/10/6 18:00 – 10/7 00:00 UTC



Bulk formulas except Oo estimate **similar distribution in front side**, but wave based formulas estimate 10 – 30 % **larger peak velocity** than wind based formula **in rear side**.

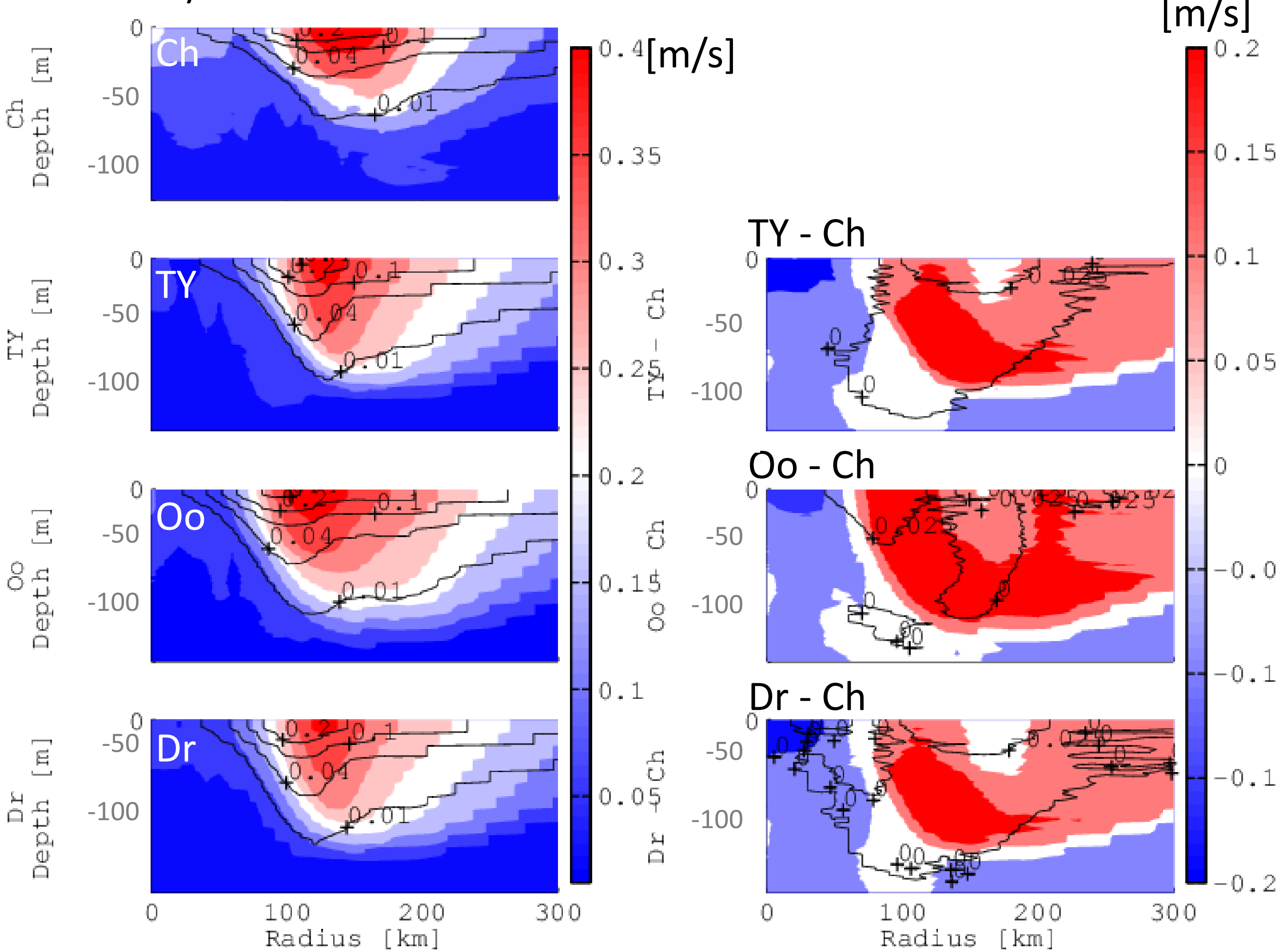


Rear side

Current Velocity, TKE

H. vel.: shaded
TKE : contour

2009/10/6 18:00 – 10/7 00:00 UTC



In rear side, Ch estimates smaller current velocity.

Wave based Formulas estimate wider and deeper current distribution.

Conclusions

- Numerical experiments using four bulk formulas of air side roughness were carried out.
    - Oost formula estimated larger friction velocity than the other formulas.
- Radial direction averaged value from typhoon center
    - Large influence of wave information
        - Friction velocity, sensible and latent heat flux
    - Small influence
        - Typhoon features, wind speed, current velocity, wave
- Distribution according to direction from typhoon center
    - Large influence
        - Front side: Current velocity in the distance from typhoon center
        - Rear side: Friction velocity, heat flux, current velocity
    - Small influence
        - Front side: Almost all parameters
        - Rear side: Wind speed, wave
- Improvement of parameterization gives significant impact on large scale atmosphere and ocean circulation

THE END

Project 2013
Air-sea interaction measurements for typhoon

We have accumulated more than 6 typhoon data by the tower.
We are going to compare the model with observed data.

Ocean observatory Tower
by Kyoto University