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The Impact of Roughness Changes by Sea State under Typhoon Field.

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Contents

- Introduction
- Outline of Calculation
- Results
- Discussion
- Summary

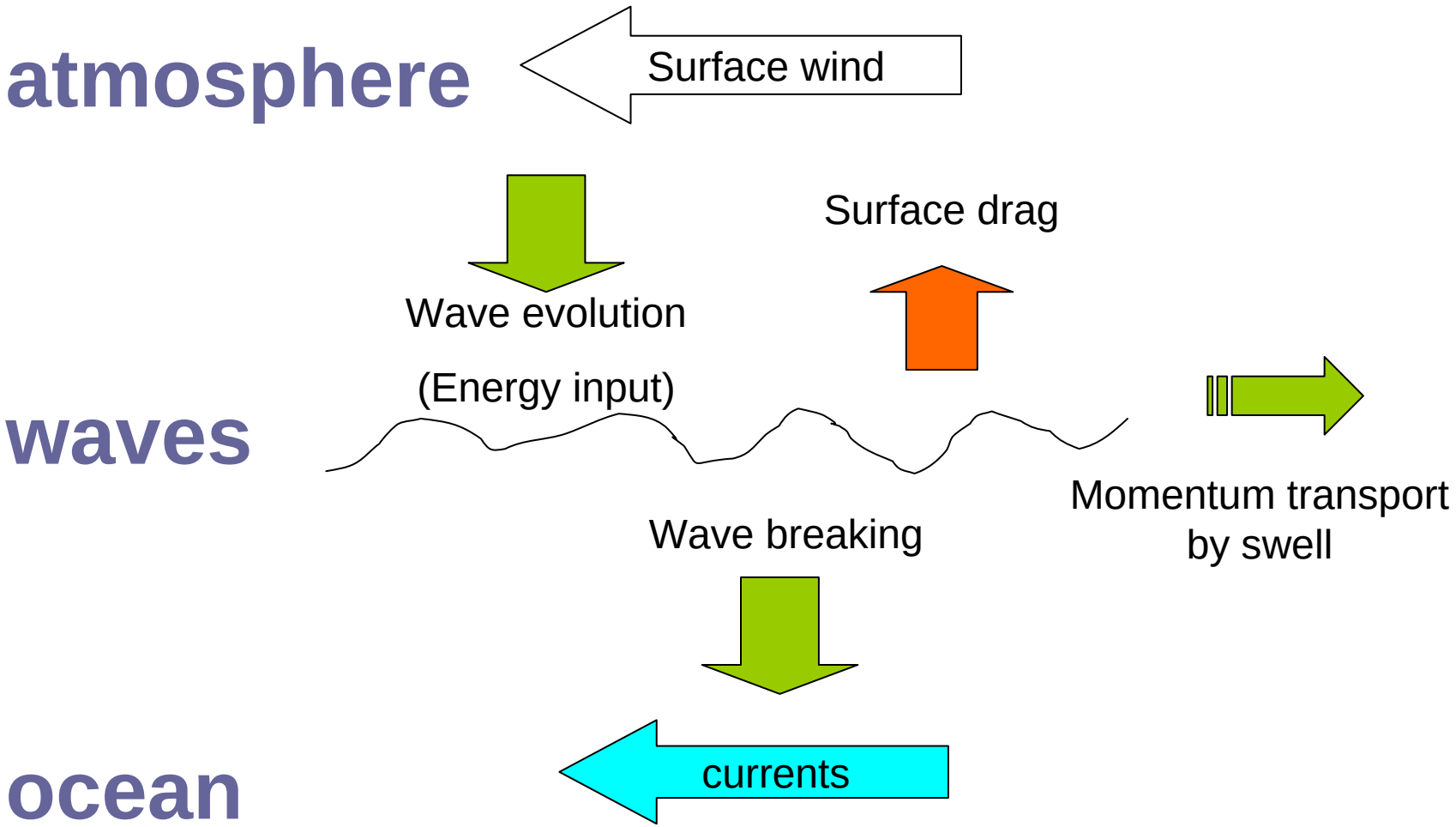
Introduction

Air-sea interaction : the phenomenon via sea surface

- **Does it depend on sea state (ocean waves)?**
  - **It is not yet to be cleared even though there are so many researches with observations and theoretical considerations.**
  - **There are so many opinions about the momentum flux dependency on waves.**
- **Many kinds of numerical models have been developed to satisfactory level.**
  - **Several researches have been done in a unified system with an aid of these models.**
  - **However, the uncertainty of drag coefficient is still contained when a wave model is coupled.**

It should be significant to check the sensitivity (error bar) in these formulae.

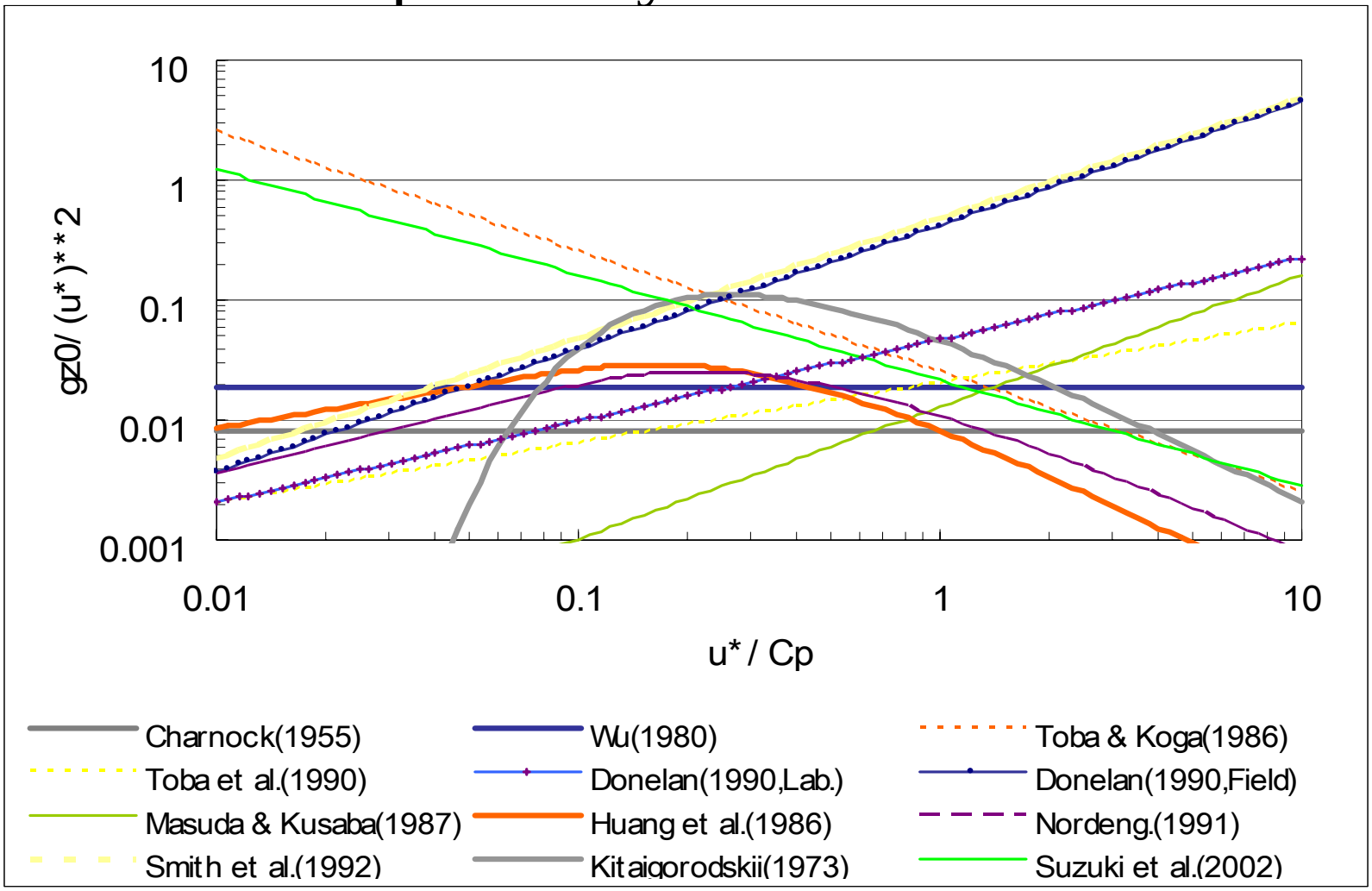
Schematic image of momentum exchange



So many opinions about the sea-state dependency on momentum exchange

- **Dependent on waves**
  - **Function of wave age**
    - Toba et al. (1981)
    - Kusaba and Masuda (1988)
    - Jannsen (1989)
    - Donelan et al.(1993)
    - Komen et al.(1998)
    - Suzuki et al. (2002)
  - **Function of wave steepness**
    - Taylor and Yelland (2001)
    - Drennan et al.(2003)
    - Smedman et al.(2003)
- **Independent on waves**
  - Charnock (1955)
  - Yelland and Taylor (1998)
  - Ueno and Deushi(2003)

Various formulae about the dependency of waves on u_*



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The models

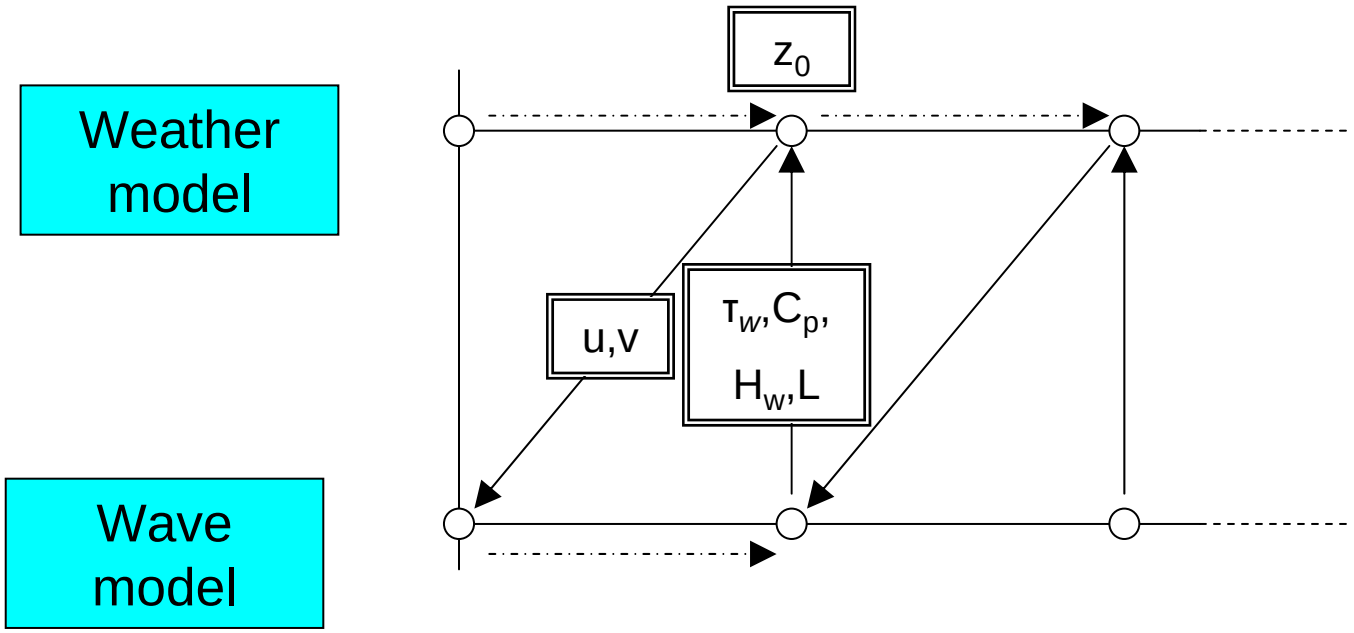
- **WEATHER MODEL**
  - the Non-Hydrostatic Model of the Meteorological Research Institute / Numerical Prediction Division of JMA （NHM）（*Saito et al.*, 2001）
  - Grid resolution:5km, 50 layers in vertical
  - Modified to use z_0 calculated in model directly.

- **WAVE MODEL**
  - The third generation wave model of MRI(MRI-III)（*Ueno and Kohno*, 2004）
  - Grid resolution:5km,
  - Wave spectrum : 900 components (25 in frequency and 36 in direction)
  - Max freq. 0.3H z (3.3sec.), Min freq. 0.0375Hz (26.7sec.)

- **Test case : Typhoon Tokage (0423) in 2004**
  - 00UTC19/Oct/2004 to 12UTC/Oct/2004(36hours calculation)

The coupling scheme

- 2way-interaction same as Janssen and Veturbo (1996)
  - Parameters are r e v i s e d in every 30 minutes.



The default estimation of Cd (control calculation)

- Kondo(1975)

$$Cd = \begin{cases} \left(1.08u^{-0.15}\right)\times 10^{-3}, & u \le 2.2 \\ \left(0.771 + 0.0858u\right)\times 10^{-3}, & 2.2 < u \le 5.0 \\ \left(0.867 + 0.0667u\right)\times 10^{-3}, & 5.0 < u \le 8.0 \\ \left(1.20 + 0.025u\right)\times 10^{-3}, & 8.0 < u \le 25.0 \\ \left(0.073u\right)\times 10^{-3}, & 25.0 < u \end{cases}$$

Only a function of U_{10}
Increase with wind speed

The formulae of drag coefficients compared

1) Wave Induced stress (Janssen, 1989)

$$\tau \approx \tau_t + \tau_w, \quad \frac{gz_0}{u_*^2} = 0.010\left(1-\frac{\tau_w}{\tau}\right)^{-1/2} \qquad \tau_w = \rho_w g \int \frac{S_{in}}{c_p} df d\omega$$

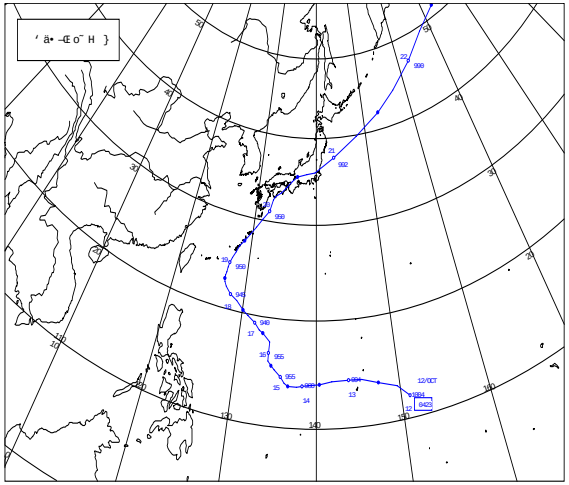
2) Wave Age (Smith et al., 1992)

$$\frac{gz_0}{u_*^2} = 0.48\left(\frac{u_*}{c_p}\right)$$

3) Wave Steepness (Taylor and Yelland, 2003)

$$\frac{z_0}{H_w} = 1200\left(\frac{H_w}{L}\right)^{4.5}$$

Typhoon Tokage(0423)



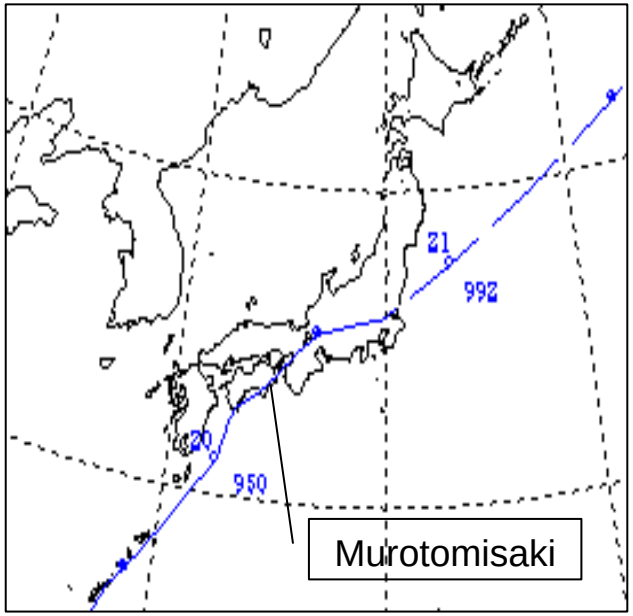
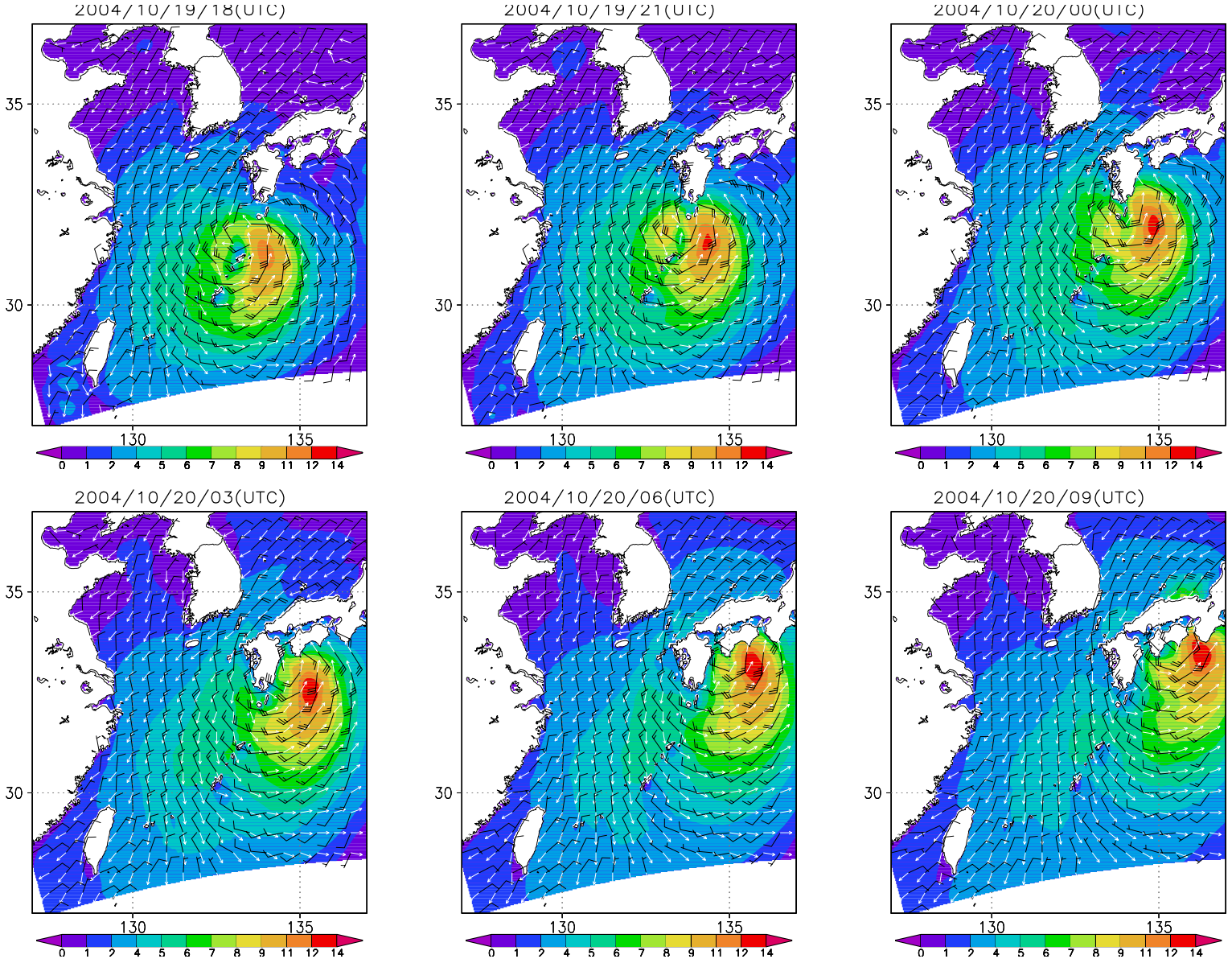


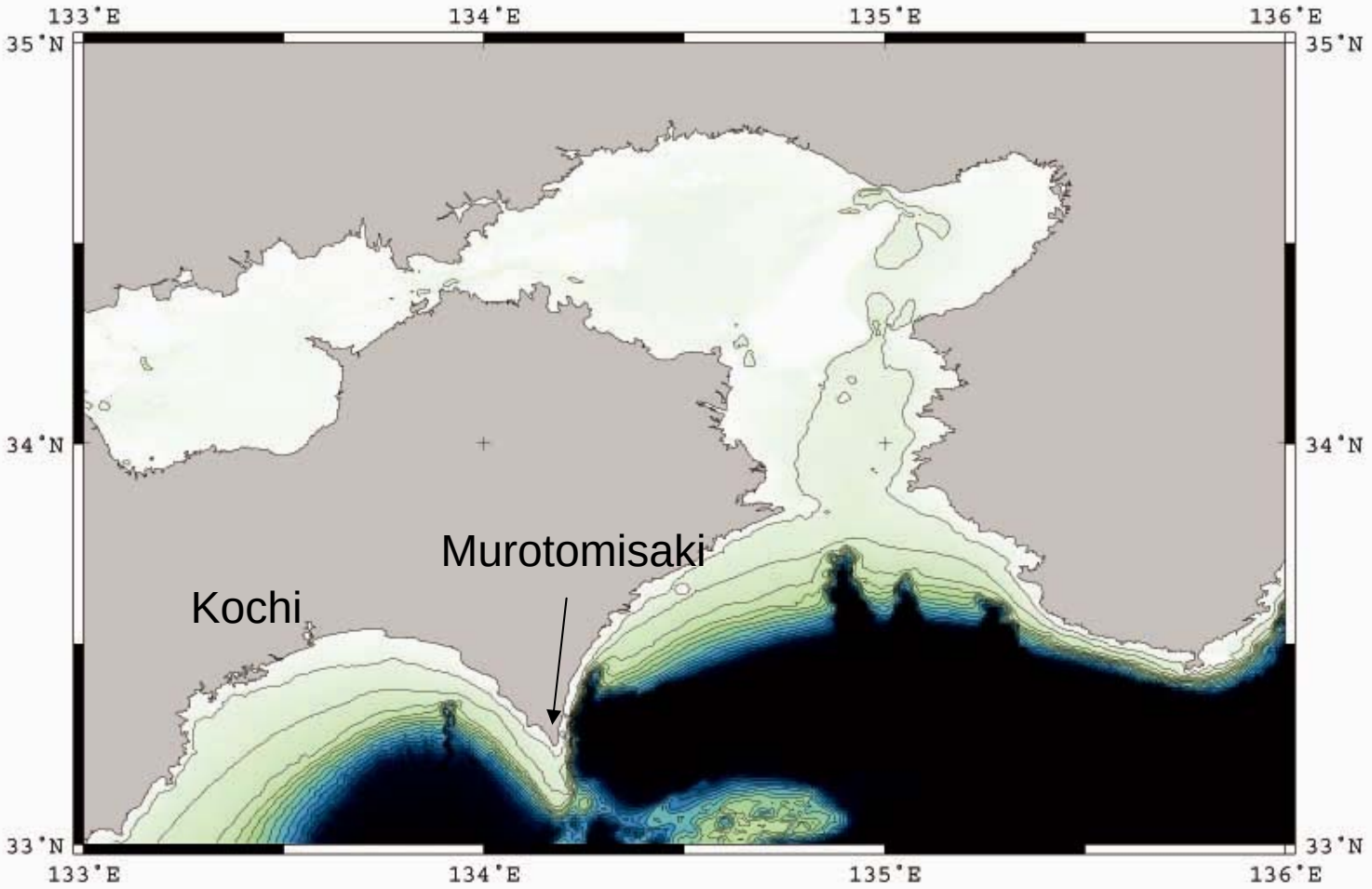
Table.1 data of TY Tokage
(2004/Oct/19/18 to 20/15)

Date (UTC)	Lat. (deg.)	Lon. (deg.)	Ps (hPa)	Max wind (kt)	Storm Area (NM)
Oct/19/18	29.1	130.4	950	80	170/130
Oct/19/21	30.1	131.3	950	80	180/150
Oct/20/00	31.1	132.2	950	80	180/150
Oct/20/03	32.4	132.7	950	80	180/120
Oct/20/06	33.4	133.9	955	75	180/100
Oct/20/09	34.8	135.7	970	70	150/90
Oct/20/12	35.4	136.6	980	60	150/90
Oct/20/15	35.7	138.3	985	50	-

The wave and wind condition



Sea topography



The contours are drawn in every 50m.

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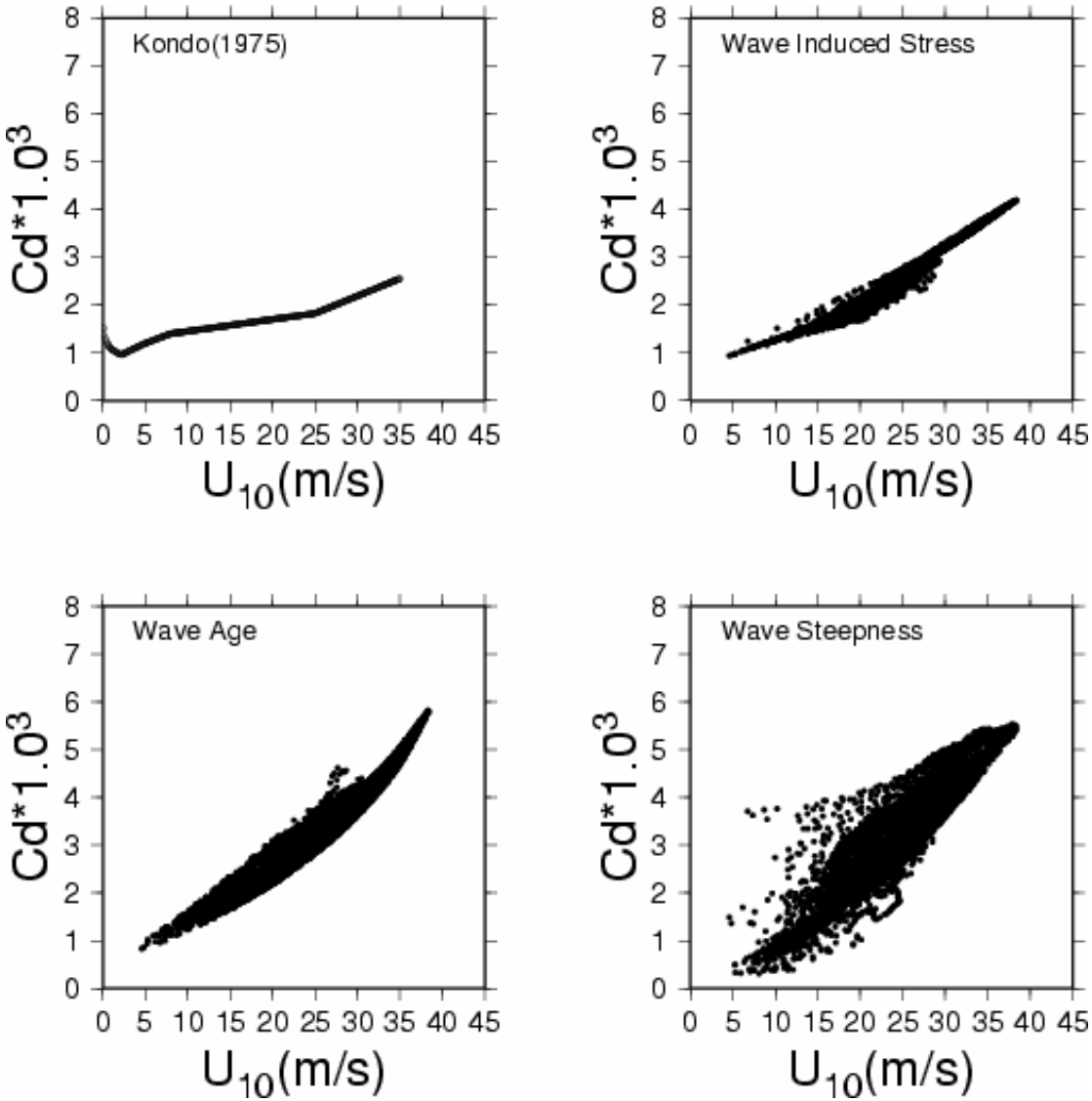
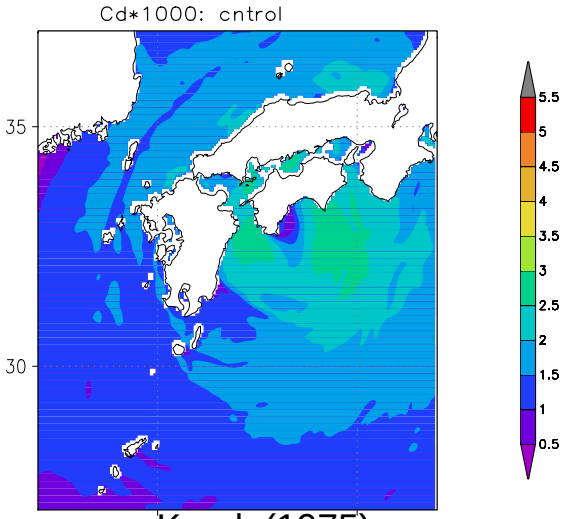
The scatter plots of C_d vs U_{10}

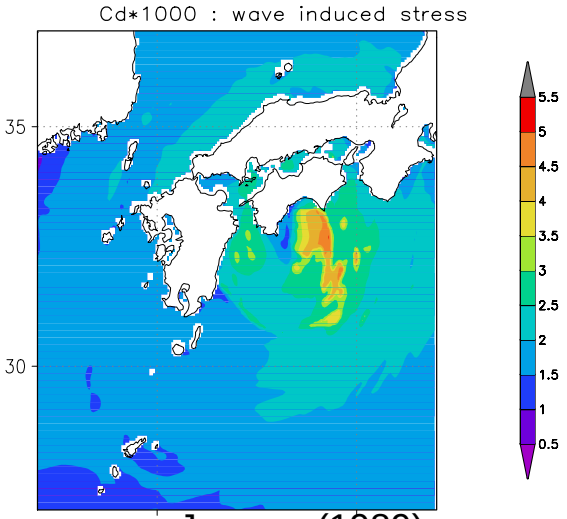


Kondo(1975)	$Cd = 0.520 + 0.073U_{10}$ ($25.0 < U_{10}$)
Janssen(1989)	$Cd = 0.1318 + 0.1078U_{10}$ $(Cd = 0.9293 + 0.0116U_{10} + 0.0020U_{10}^2)$
Smith(1992)	$Cd = 0.2146 + 0.1397U_{10}$ $(Cd = 0.8260 + 0.0454\ U_{10} + 0.0020U_{10}^2)$
Taylor and Yelland(2001)	$Cd = 0.6426 + 0.1574\ U_{10}$

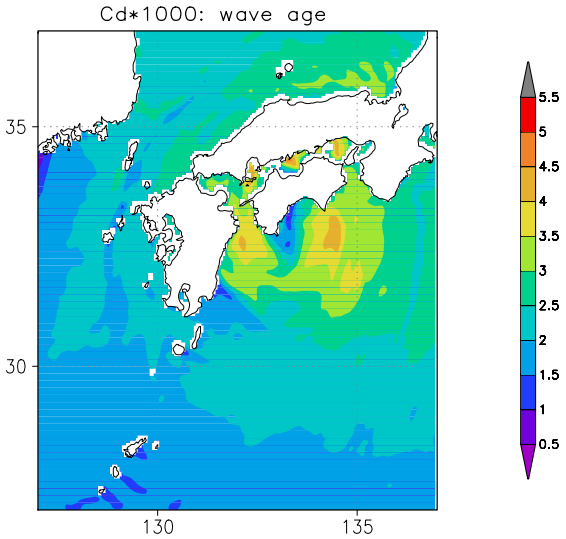
Horizontal distribution of drag coefficients
(2004/10/20/05UTC)



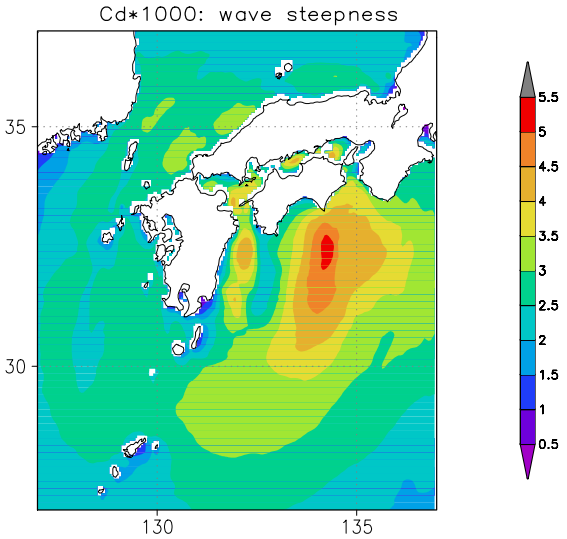
Kondo(1975)



Janssen(1989)



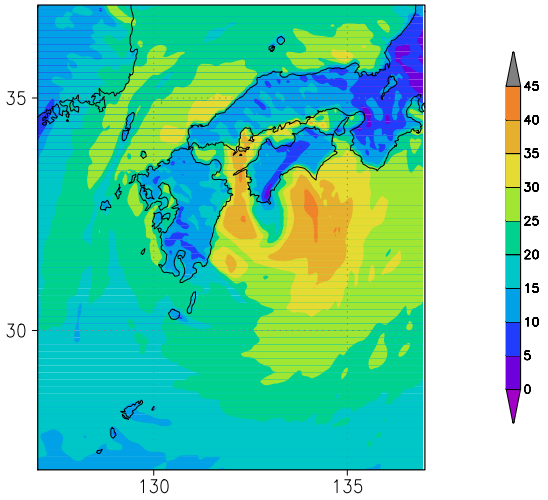
Smith et al.(1992)



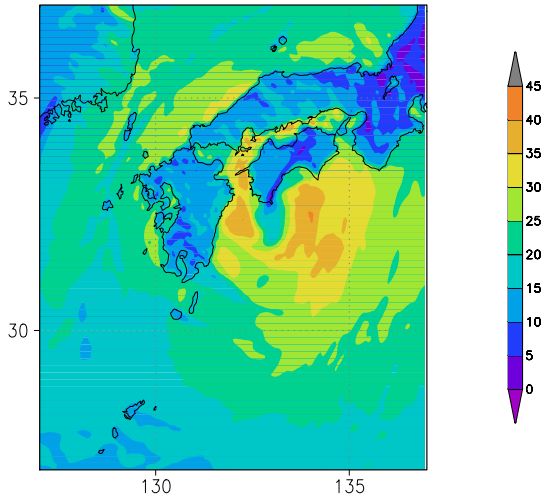
Taylor and Yelland(2001)

Horizontal distribution of surface wind speed (2004/10/20/05UTC)

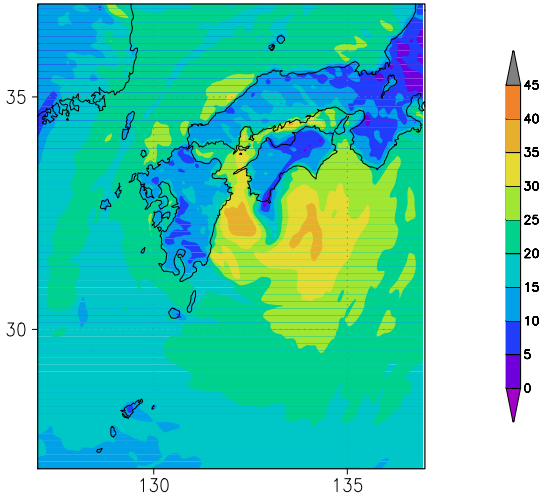
Wind Speed(m/s) : control



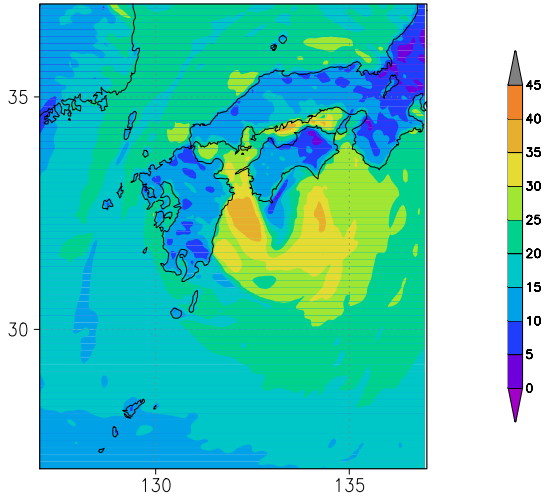
Wind Speed(m/s) : wave induced stress



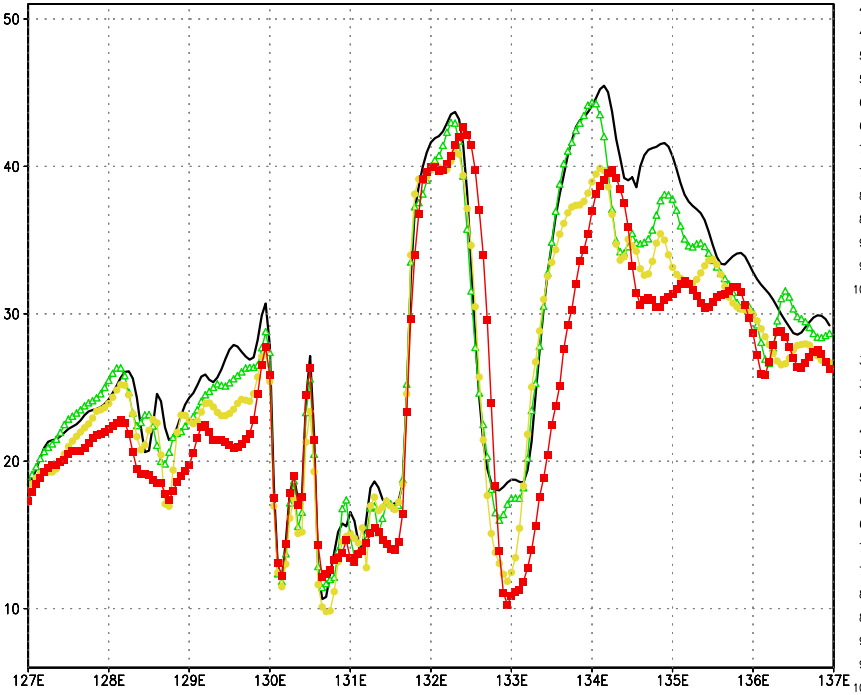
Wind SpeedS(m/s) : wave age

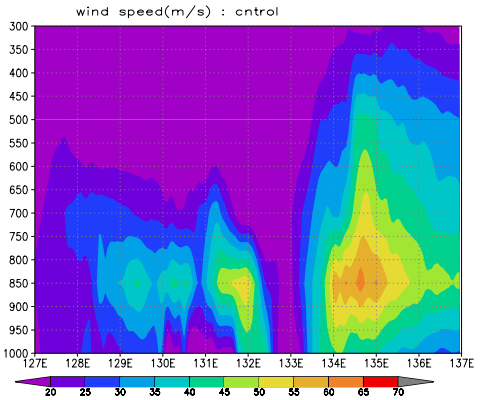


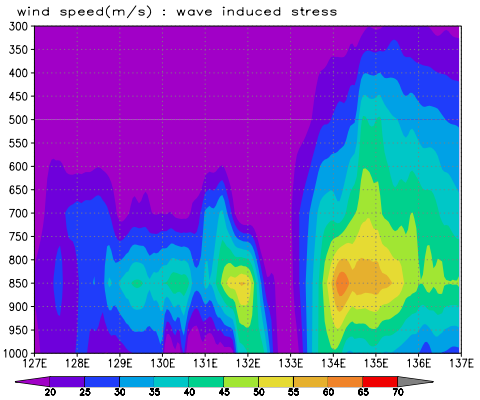
Wind Speed(m/s) : wave steepness

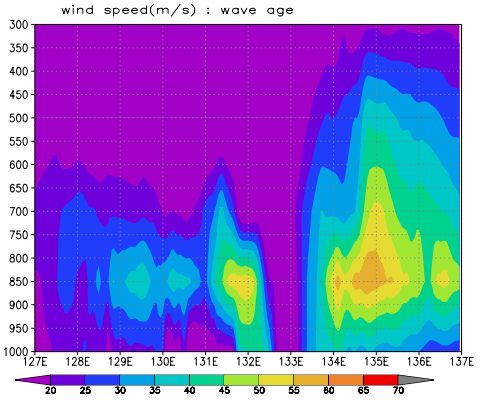


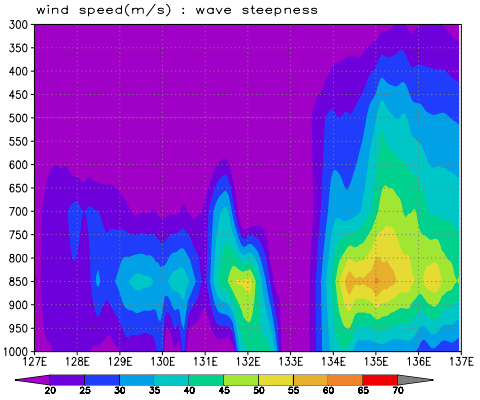
Wind profile at lat. 32.5N (2004/10/20/05UTC)









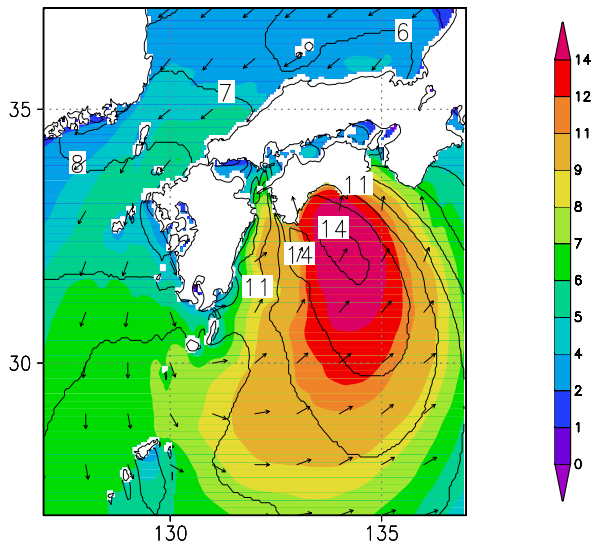


: control : wave induce stress

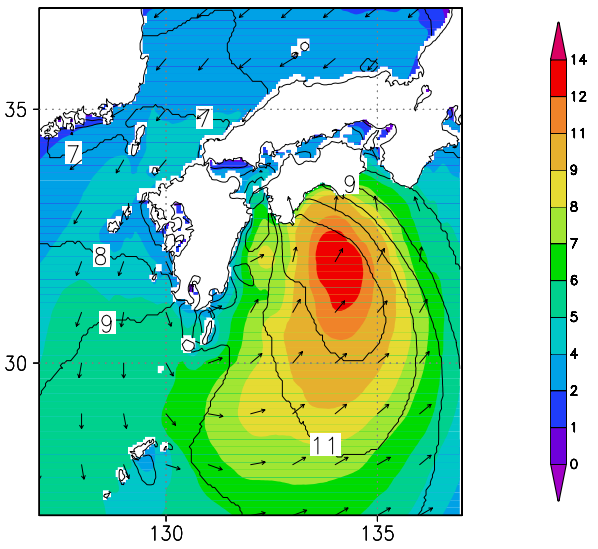
: wave age : wave steepness

wave condition (2004/10/20/05UTC)

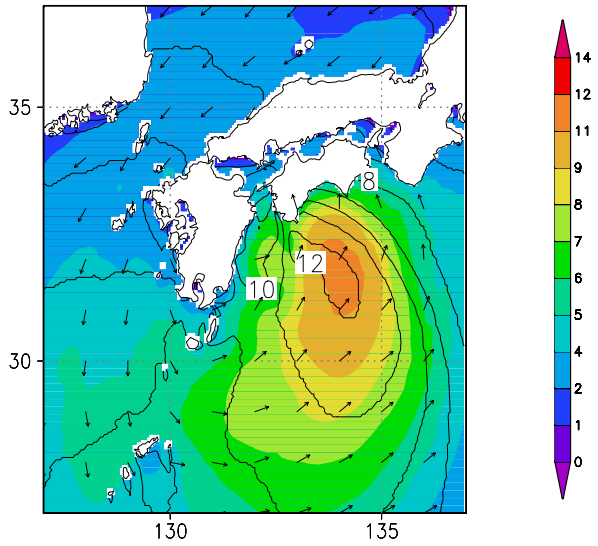
wave condition : control



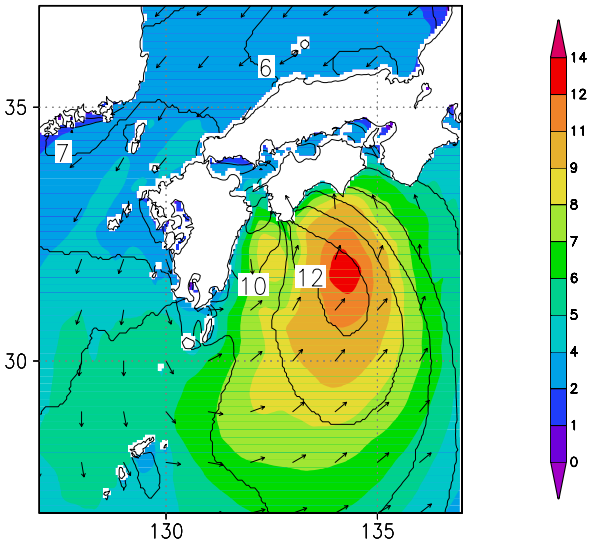
wave condition : wave induced stress



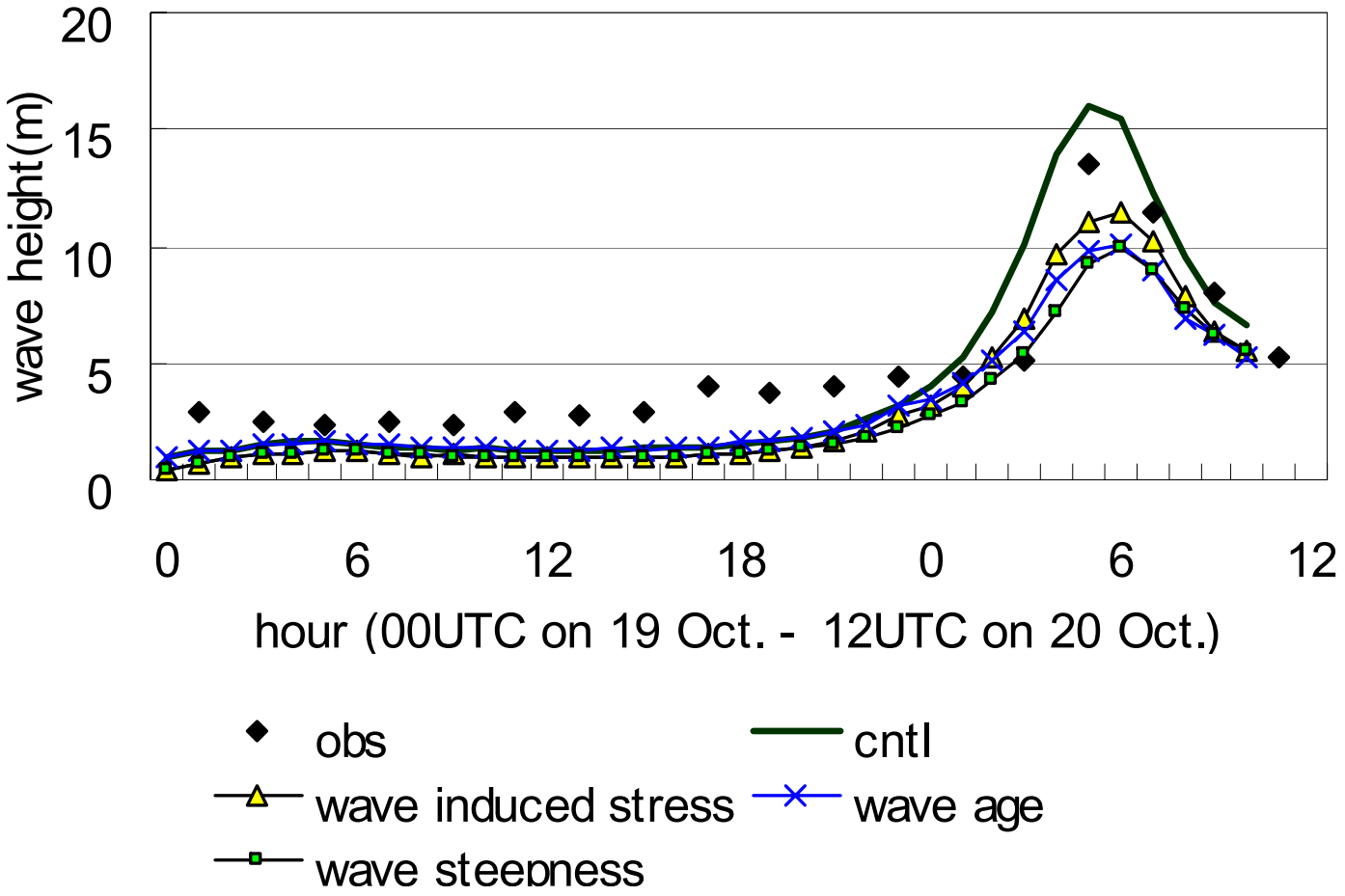
wave condition : wave age



wave condition : wave steepness



Wave heights at Murotomisaki



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Discussion

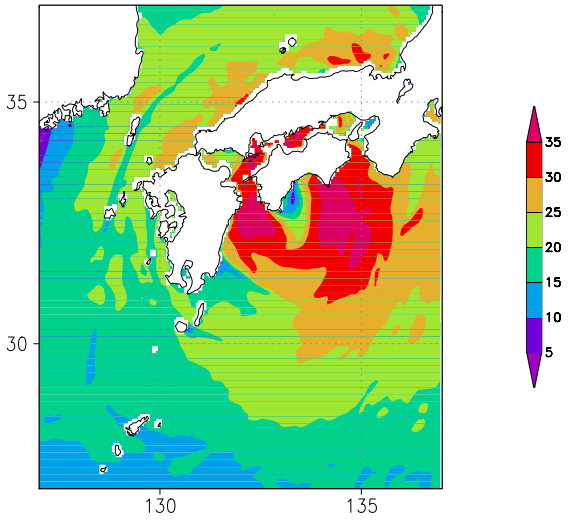
We will check two points:

- **What makes the difference of drag coefficients?**
  - **The difference of character of wave parameters.**
- **The influences on the atmosphere (typhoon).**
  - **A change of typhoon fields reflects a change of wave fields.**

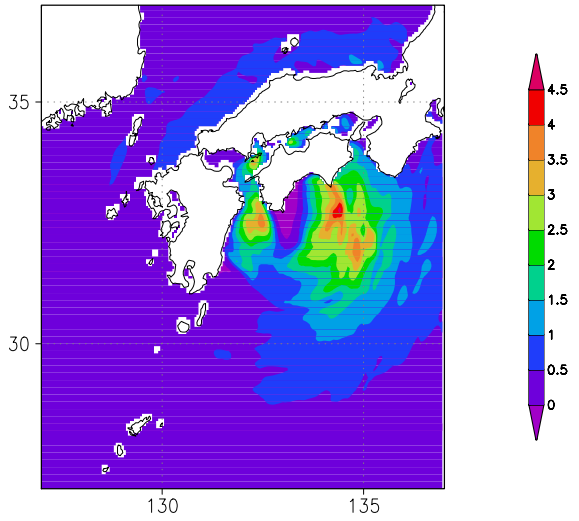
The horizontal distribution of parameters

(05UTC 20/Oct/2004)

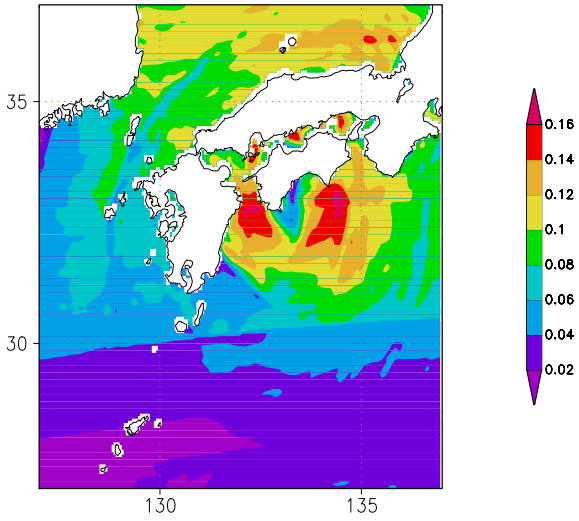
wind speed (m/s) : control



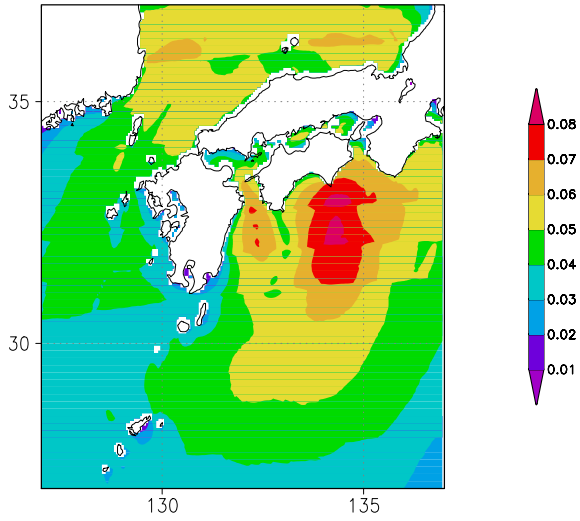
wave induced stress



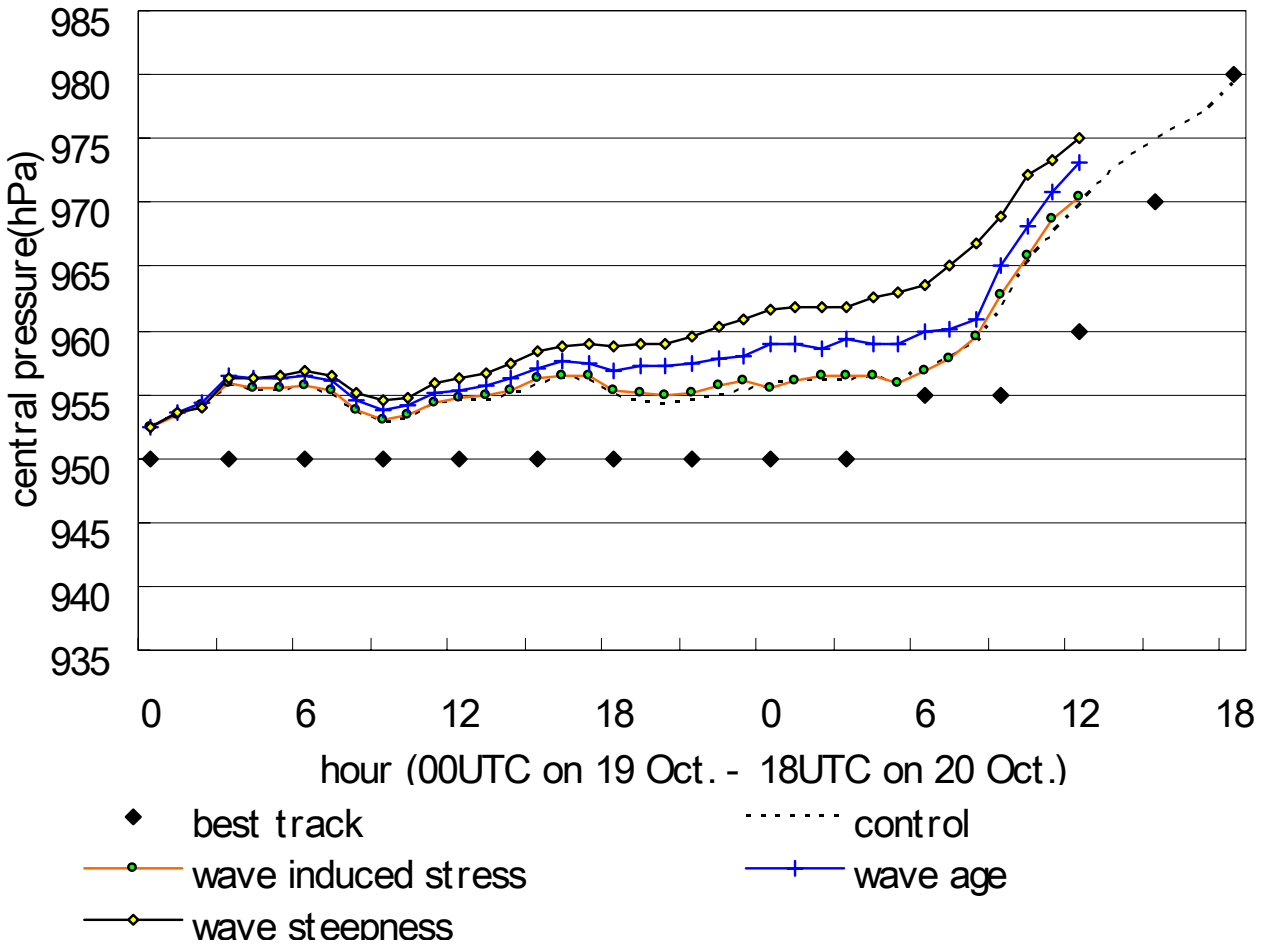
(inverse) wave age



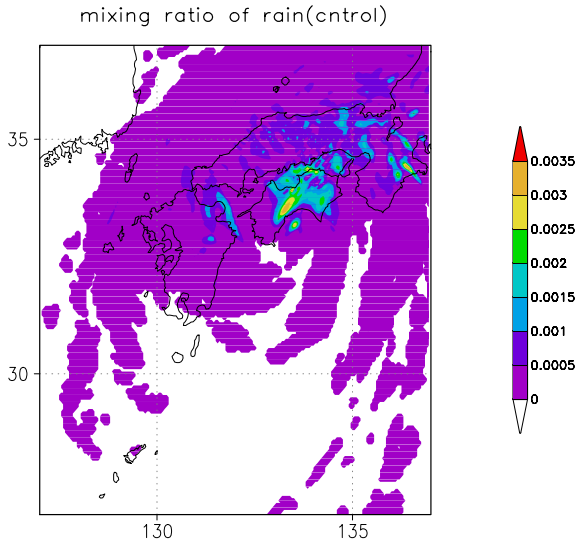
wave steepness

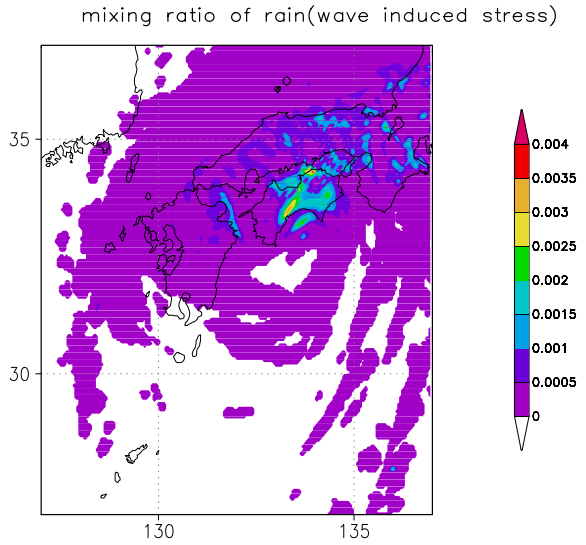


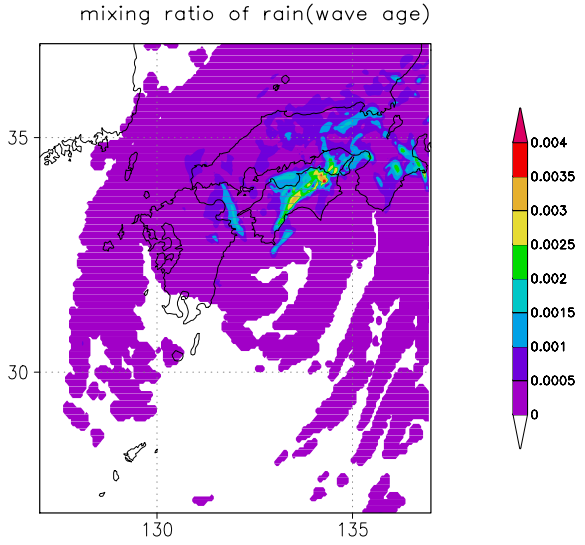
Time sequence of the central pressures

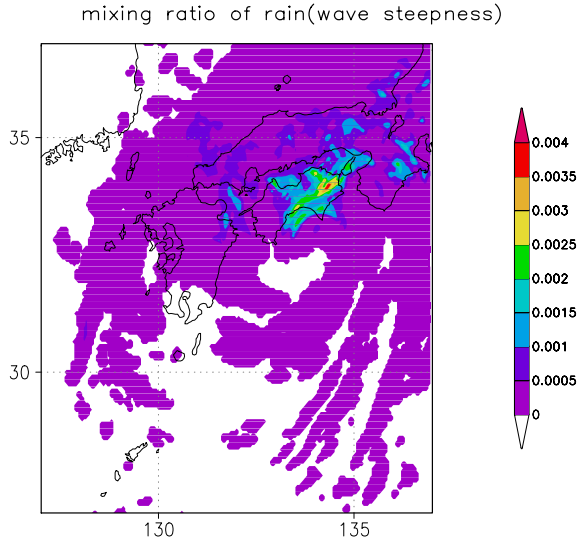


Rain content(2004/10/20/05UTC)

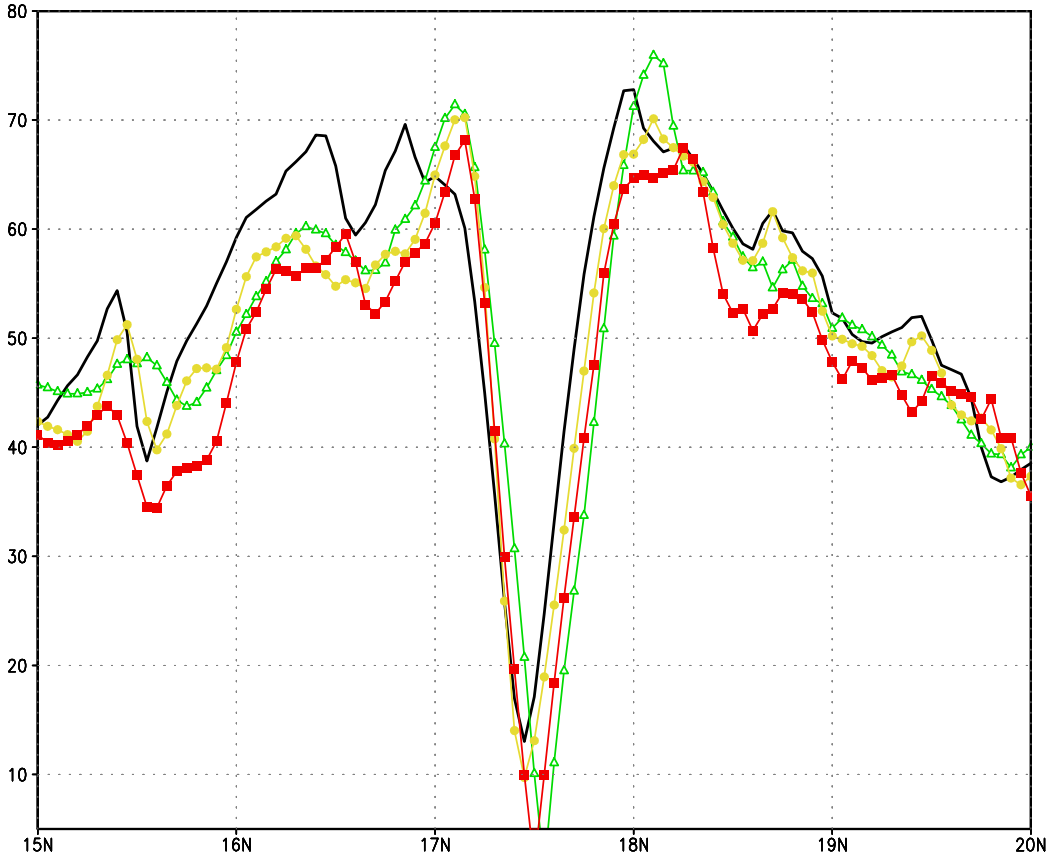








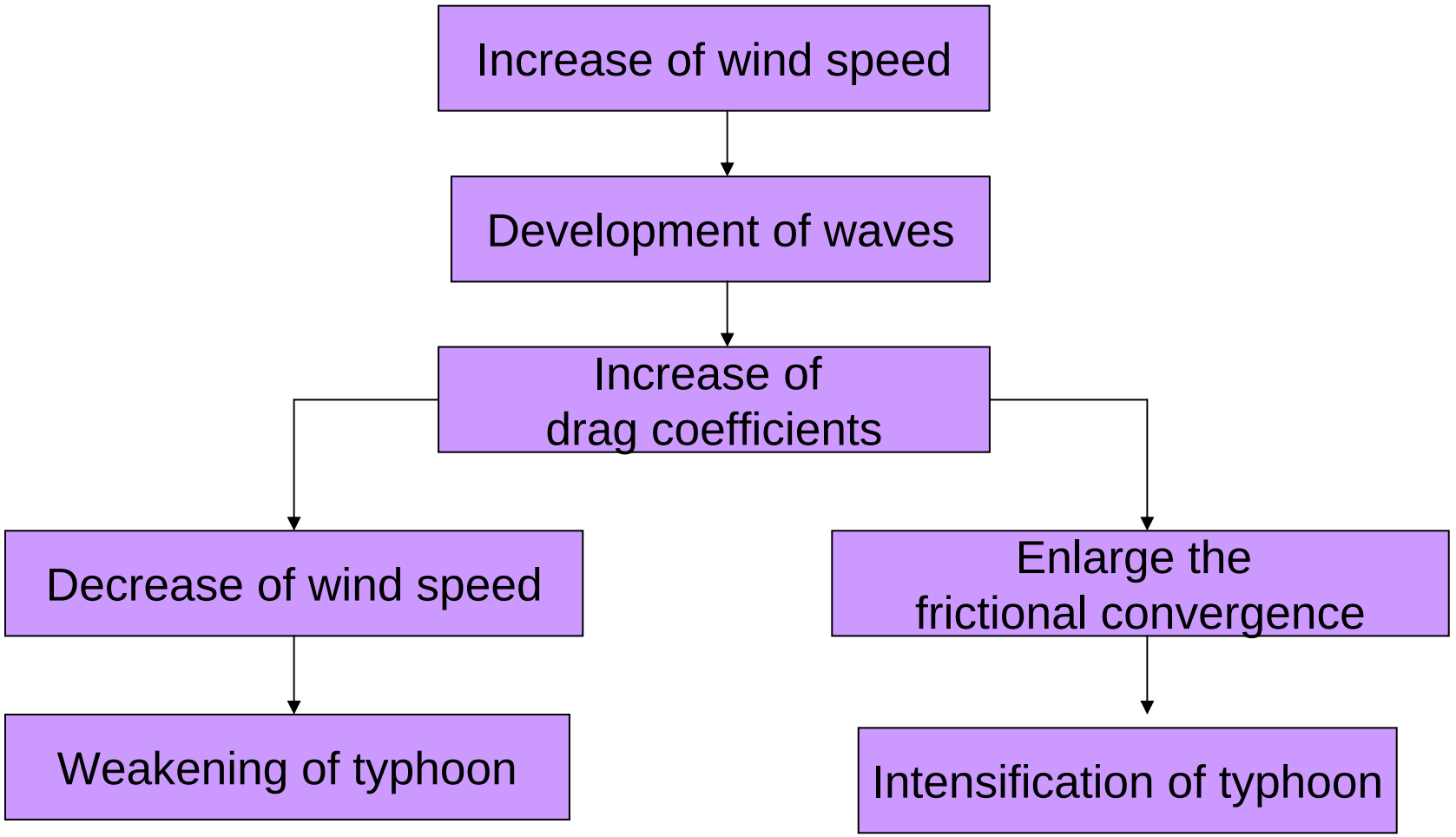
Wind profile at Lon.143.5E by Typhoon Chaba(0416) (2004/8/23/18UTC)



非結合：実線　波応力：△付実線

波齢：●付実線　波形勾配：■付実線

The effects of waves to typhoons



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Character of drag coefficients

- Wave induced stress
  - Large scatter in the middle wind speed range, but not so scatter other wind speed.
- Wave age
  - Large value in high wind speed
  - Scatter is small
  - Close to wind only dependency
- Wave steepness
  - Large scatter in all wind speed range
  - The values become slightly saturate in high wind.
  - It tends large values behind the typhoon

The influences on typhoon

- Wind speed within the typhoon central area tends to be weakened by large drag coefficients, which leads to weakening of typhoon structure (intensity). The difference of central pressure by drag coefficient formula is up to 7hPa and this should not be neglected.
- The asymmetry of wind field is enlarged. And the influence of the change of drag coefficients on typhoon occurs in upper air, which means the typhoon structure is changed by this change.
- In addition, especially in case of the wave induced stress, we can detect that the size of eye-wall become small by the frictional convergence which is strengthened by the large drag coefficient of rain-band area.

Conclusion

- The roughness estimated by several formulae may lead to the significant difference on both wave fields and typhoon intensity.
- To estimate the typhoon intensity and surface wind field correctly is necessary for accurate estimation of ocean waves, and thus it is important to estimate wave and meteorological field in a coupled system.
- However, We need further investigation since there are still so many unknown problems, since some result showed the opposite tendency.

Further problems

- Additional tests with other cases.
- Detection of the collect formula of drag coefficients.
- The improvement of boundary layer scheme in NWP
- Investigation of other factors（e.g. sea spray）

Drag coefficients in Moon et al.(2004)