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Application of POM08 to wave-current interaction study around the Yaeyama Islands, southwest Japan

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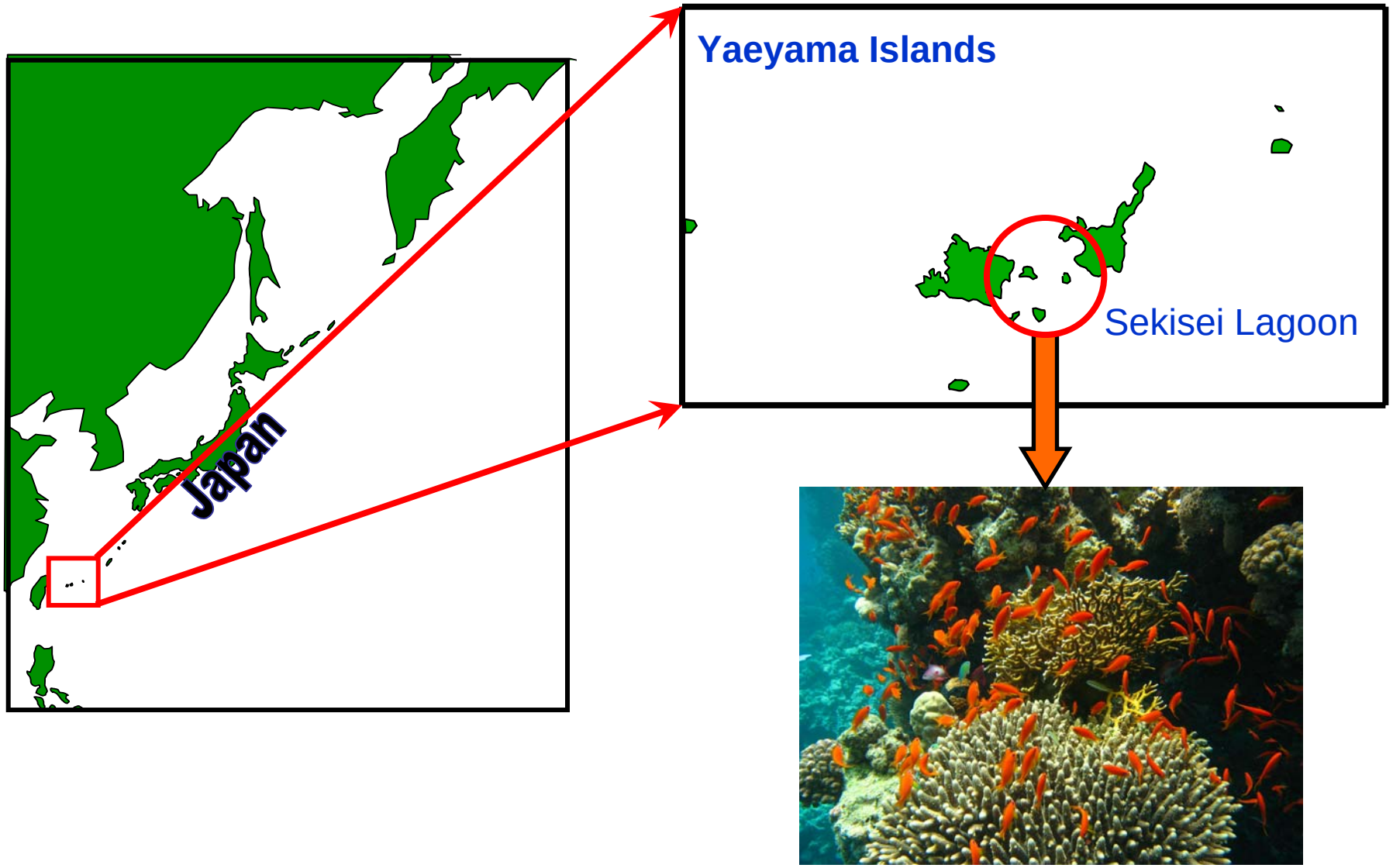
Outline

- Introduction
- POM08 model
  - problems and our solutions
- Modeling results
- Summary and future work

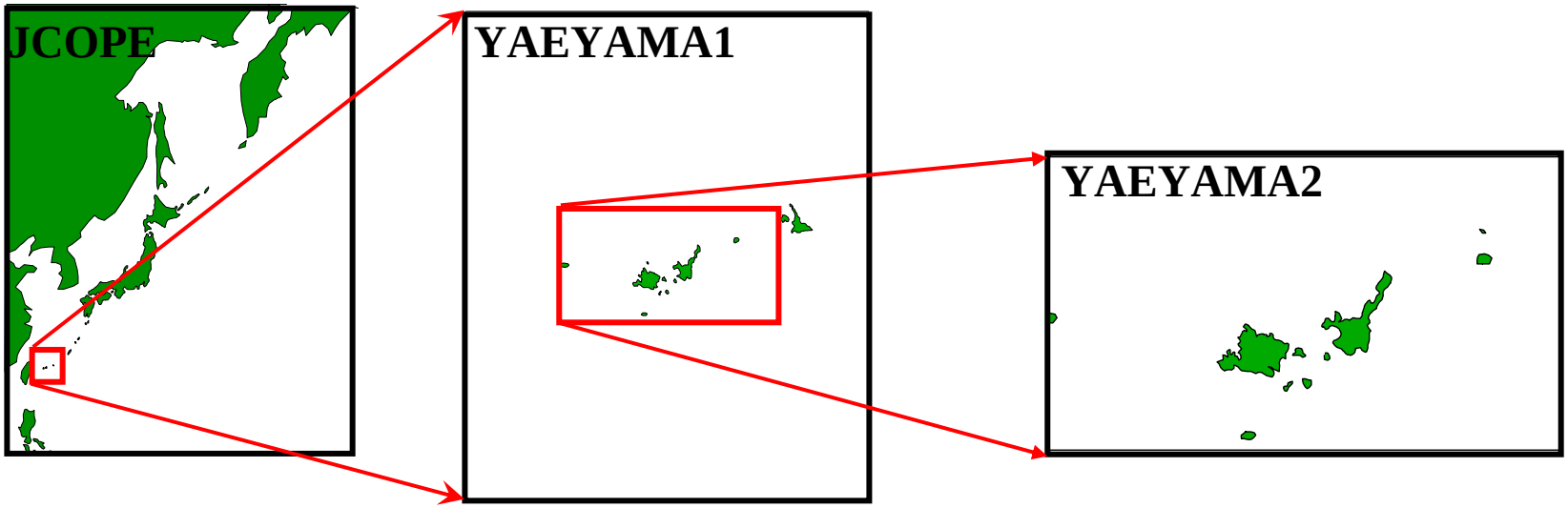
Yaeyama Islands



Yaeyama models

JCOPE2 ⟶ YAEAYAMA1 ⟶ YAEYAMA2

One-way Nesting method (Kagimoto et al., 2008)



Model	Domain	Horizontal resolution	Sigma levels
JCOPE2	117º-180ºE, 12º-62ºE	1/12º	45
YAEYAMA1	122º-126ºE, 22.5º-26.5ºE	1/60º	45
YAEYAMA2	123º-125ºE, 24º-25ºE	1/300º	60

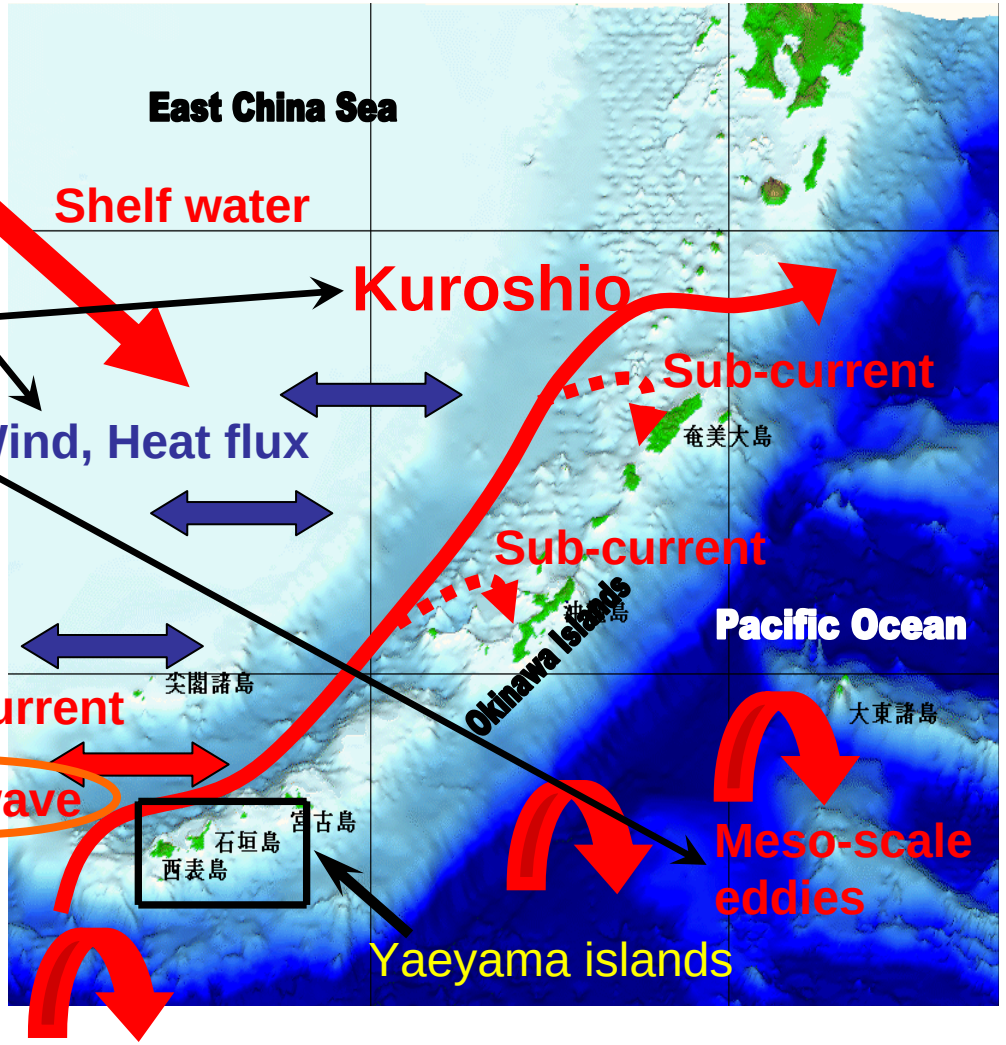
Factors influencing current structure near Yaeyama Islands

NCEP/NCAR Reanalysis data

JCOPE2 reanalysis data

NAO.99 tide model
(Matsumoto et al., 2000)
---Dr. Varlamov

POM08 (Mellor 2003, 2008)
Wave-current interaction



Main equations

(Mellor et al., 2008)

Momentum equation :

$$\frac{\partial(\mathrm{DU}_\alpha)}{\partial t}+\frac{\partial(\mathrm{DU}_{\alpha\beta})}{\partial x_\beta}+\frac{\partial(\Omega U_\alpha)}{\partial\zeta}-\varepsilon_{\alpha\beta z} f_z DU_\beta=-D\int^0\left(D\frac{\partial b}{\partial x_\alpha}-\frac{\partial b}{\partial\zeta}\zeta\frac{\partial D}{\partial x_\alpha}\right)d\zeta-D\frac{\partial}{\partial x_\alpha}(g\hat{\eta}+p_{atm})-\frac{\partial}{\partial x_\beta}\left(D\overline{S_{\alpha\beta}}^{\theta}\right)-\frac{\partial\bar{\tau}_\alpha}{\partial\zeta}$$

Wave energy equation :

$$\frac{\partial E_\theta}{\partial t}+\frac{\partial}{\partial x_\alpha}\left[\left(\bar{c}_{g\alpha}+\bar{u}_{A\alpha}\right)E_\theta\right]+\frac{\partial}{\partial\theta}\left[\bar{c}_\theta E_\theta\right]+\int_{-1}^{0}\bar{S}_{\alpha\beta}\frac{\partial U_\alpha}{\partial x_\beta}Dd\zeta=S_{\theta in}-S_{\theta Sdis}-S_{\theta Bdis}$$

Directionary dependent frequency equation :

$$\frac{\partial\sigma_\theta}{\partial t}+(\bar{c}_{g\alpha}+\bar{u}_{A\alpha})\frac{\partial\sigma_\theta}{\partial x_\alpha}=-\frac{\partial\sigma_\theta}{\partial k}\left(\frac{k_\alpha k_\beta}{k}\frac{\partial\bar{u}_{A\alpha}}{\partial x_\beta}\right)+\frac{\partial\sigma_\theta}{\partial D}\left(\frac{\partial D}{\partial t}+\bar{u}_{A\alpha}\frac{\partial D}{\partial x_\alpha}\right)+\Re$$

Wave → Currents

<u>Depth dependent</u> wave radiation stress

Wind stress for ‘wave surface’

Turbulence scale on surface

Currents → Wave

Wave-currents interaction term in wave energy equation

Refraction in both wave energy and frequency equations

Group velocity

POM08：

Doppler velocity= ocean current
+ Stokes velocity

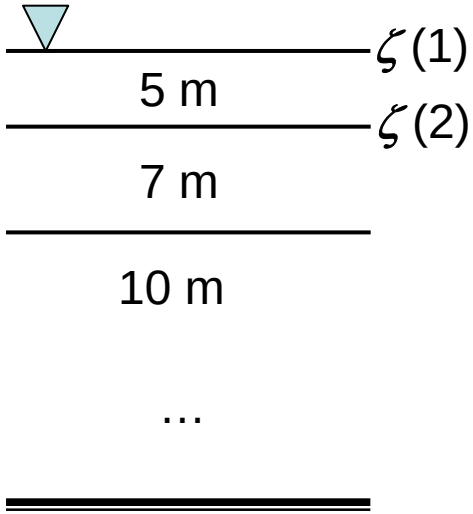
$$\bar{u}_{A\alpha} = \int_{-1}^{0} U_\alpha F_3 d\varsigma$$

for deep water

F3	ς
366.052	0.000
198.205	-0.001
138.853	-0.002
…	…
4.511	-0.018
3.775	-0.019
3.167	-0.020

Yaeyama2 model:

Generalized sigma coordinate



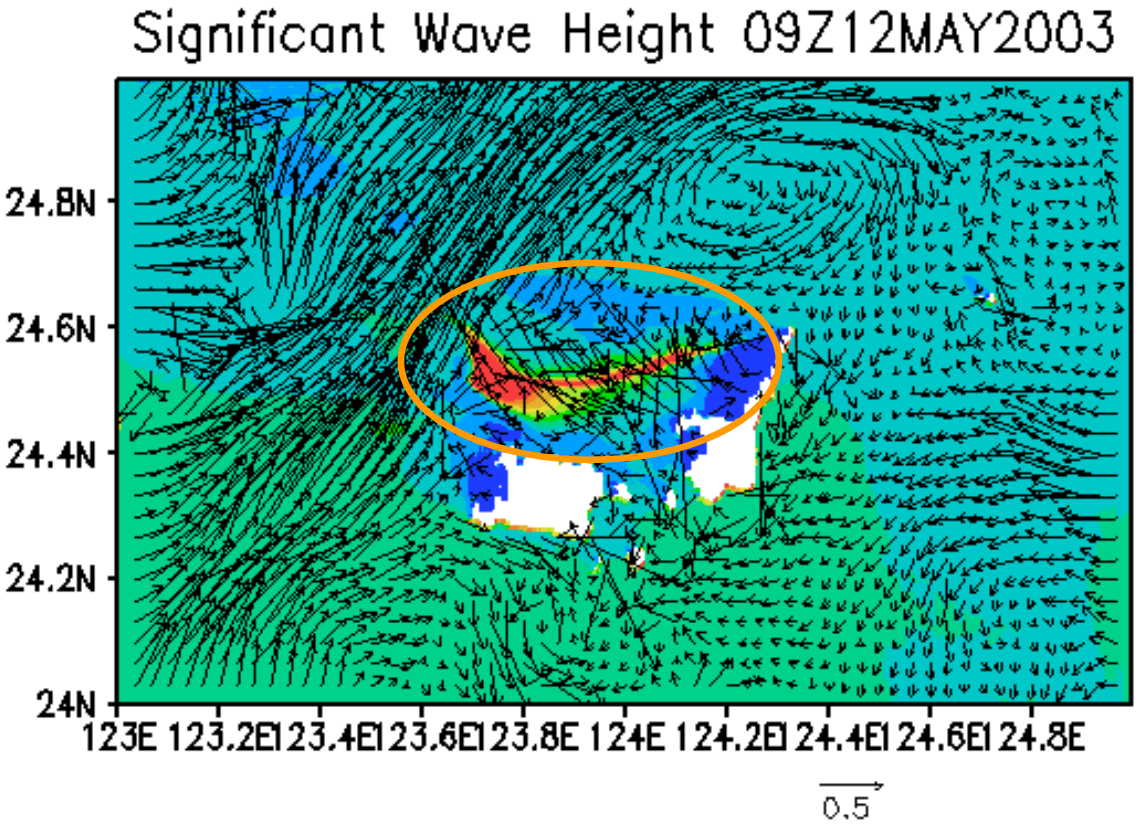
For the first layer thicknesses $(\zeta(2))$ > 0.02, abnormally large Doppler velocity is obtained. The upper formula fails to express Doppler velocity

We let the Doppler velocity directly equals surface velocity, that is

$$\bar{u}_{A\alpha} = U_1$$

When wind direction changes greatly….

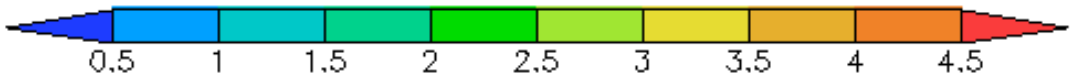
00:00 May 7th, 2003---



Wind ~ 6 m/s

When calculating the wave radiation stress, the **averaged wave number** over all directions is used instead of the peak wave number (kp)

Significant wave height (m)

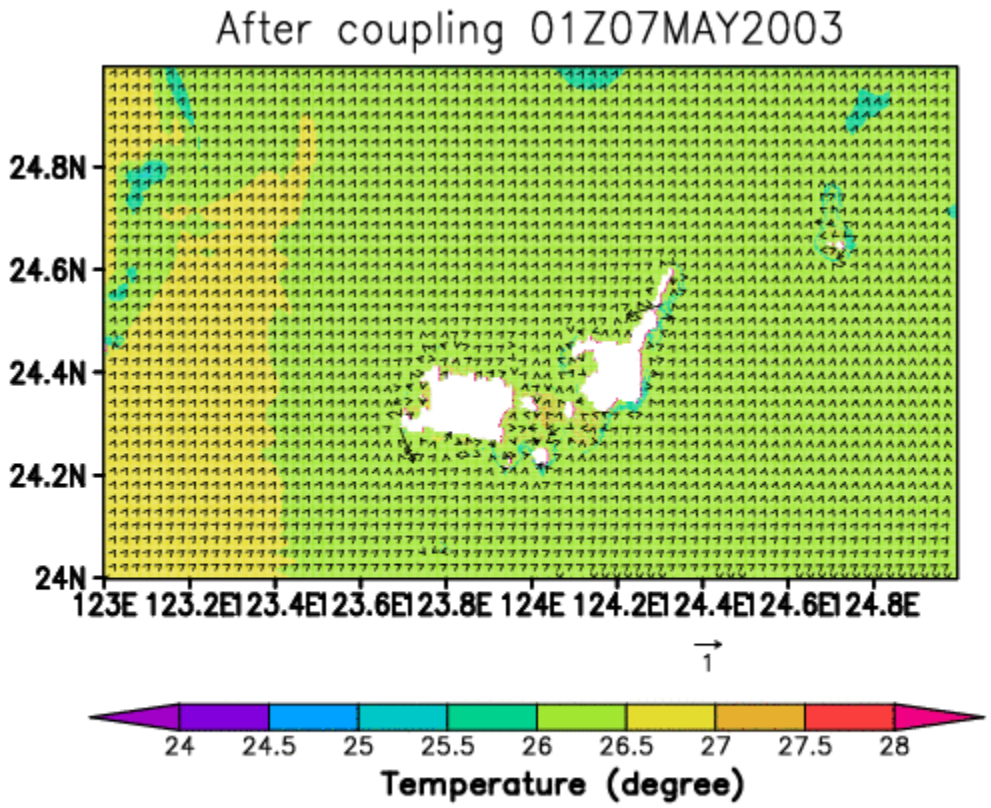


Boundary conditions of wave model

Direction: same as wind
Time period: 7 sec
Wave height: 1.5m

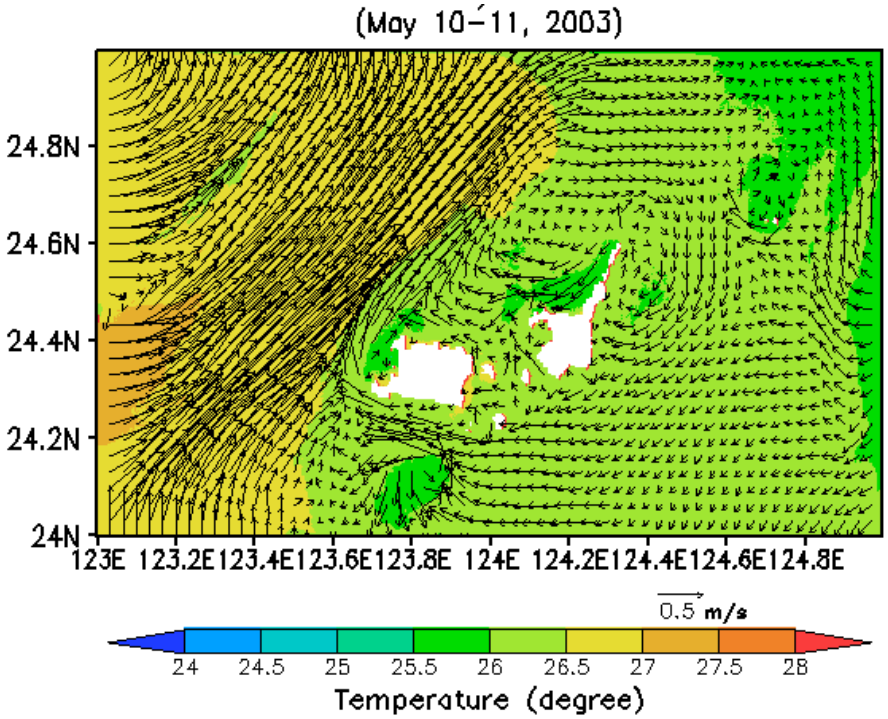
Simulation period: May 7 - 11, 2003

Horizontal distributions of surface currents and temperature

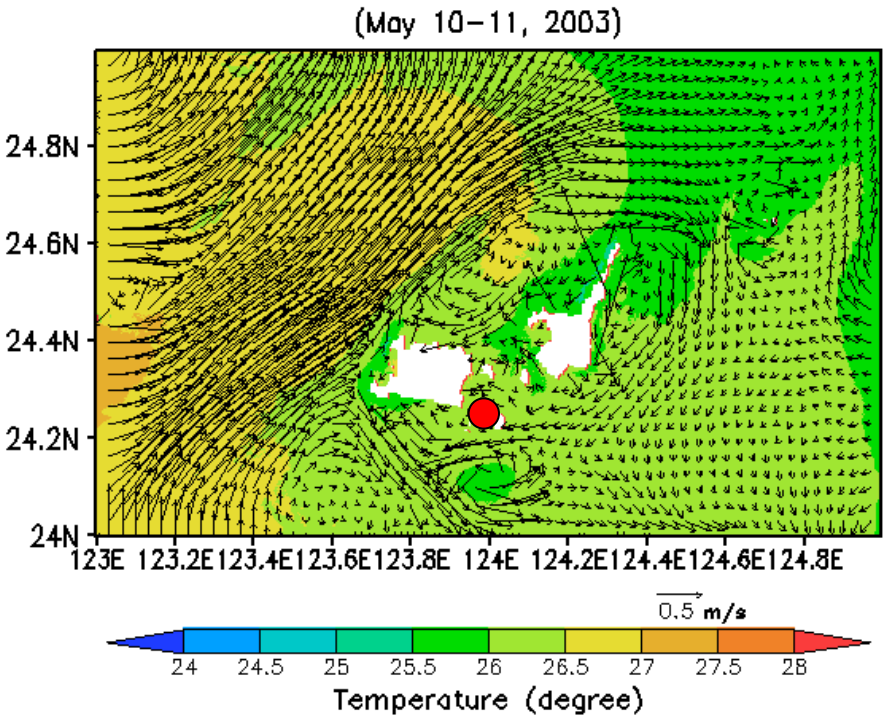


Daily mean surface currents and temperature (May 10-11, 2003)

Before coupling



After coupling



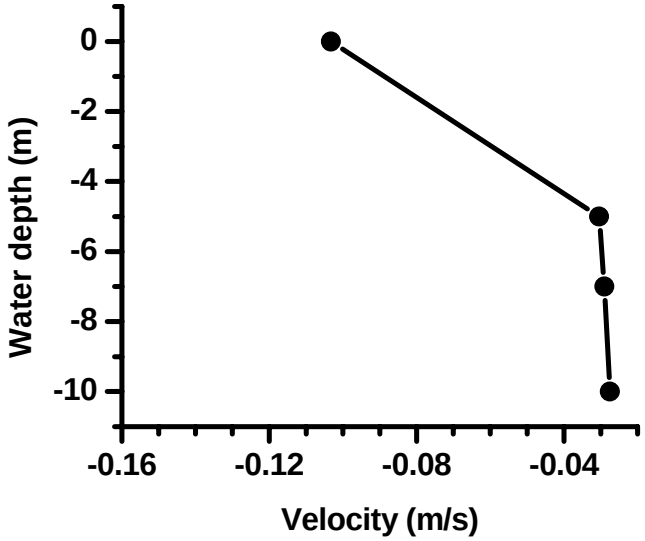
Vertical profile of velocity

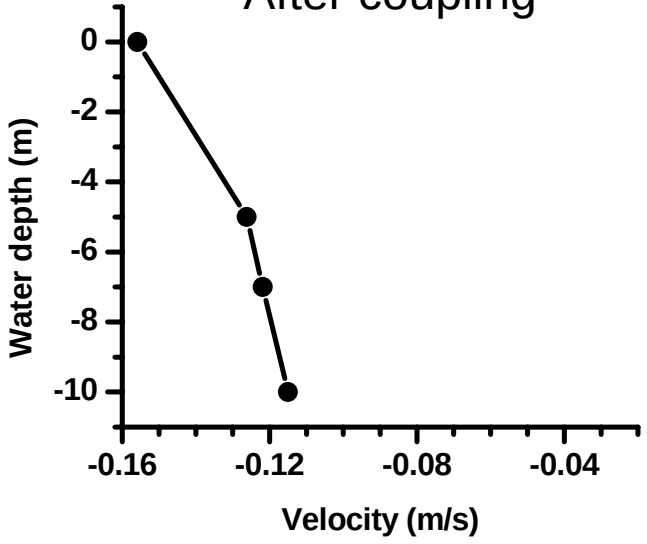
(Daily mean: May 10-11, 2003)

Before coupling

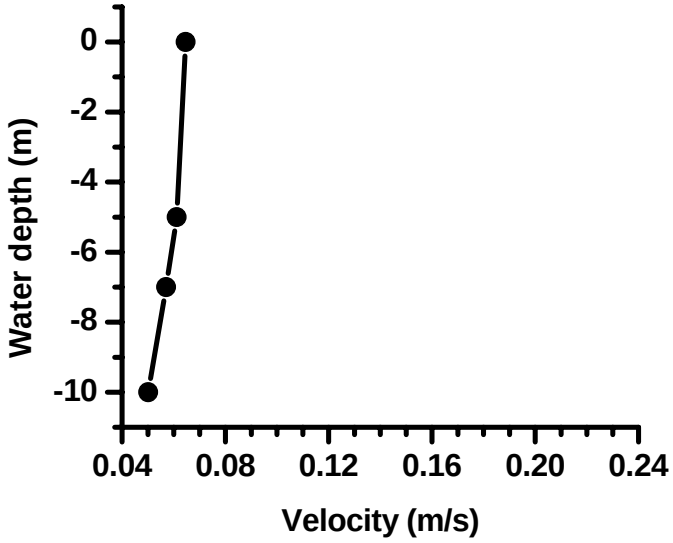
After coupling

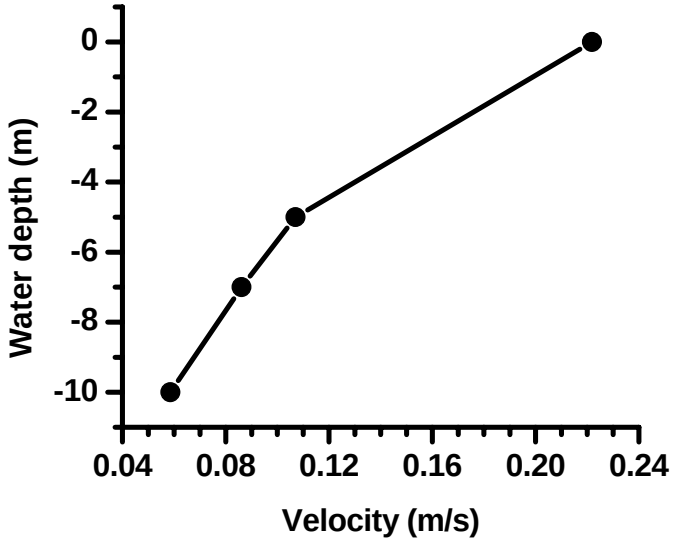
eastward





northward

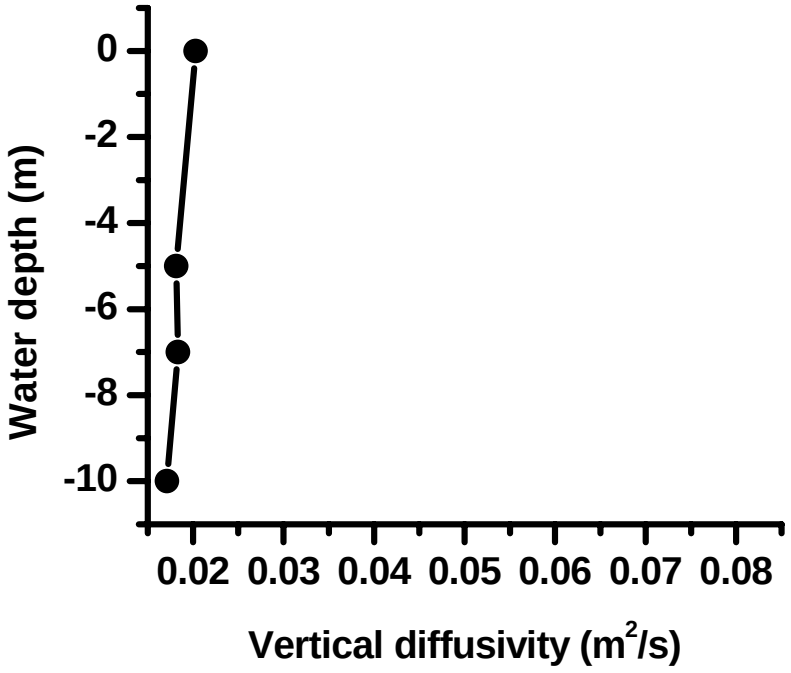




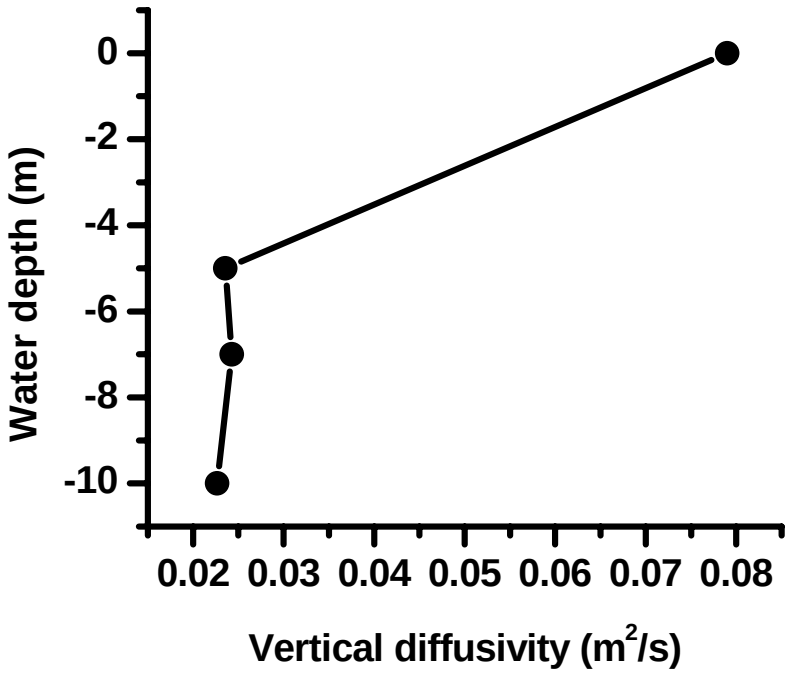
Vertical profile of vertical diffusivity

(Daily mean: May 10-11, 2003)

Before coupling

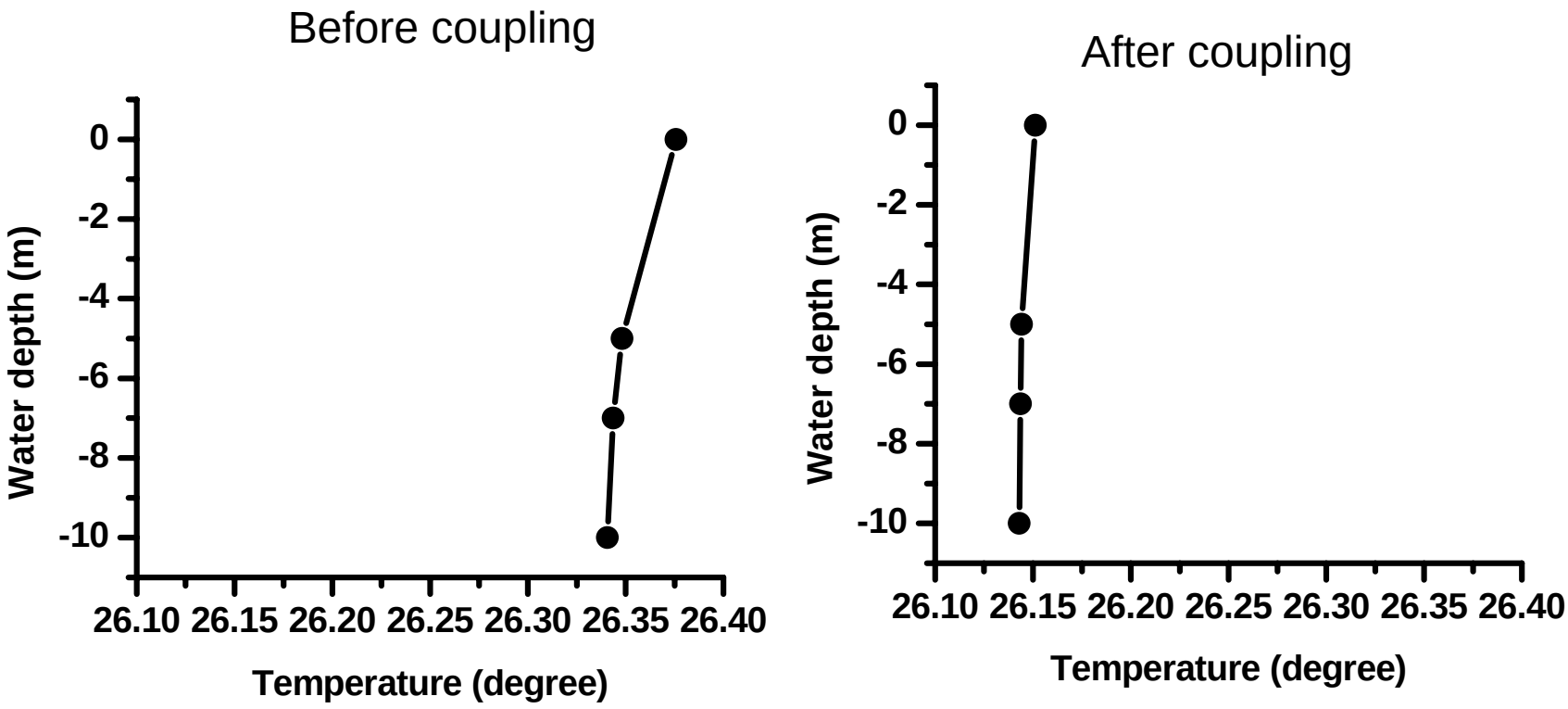


After coupling



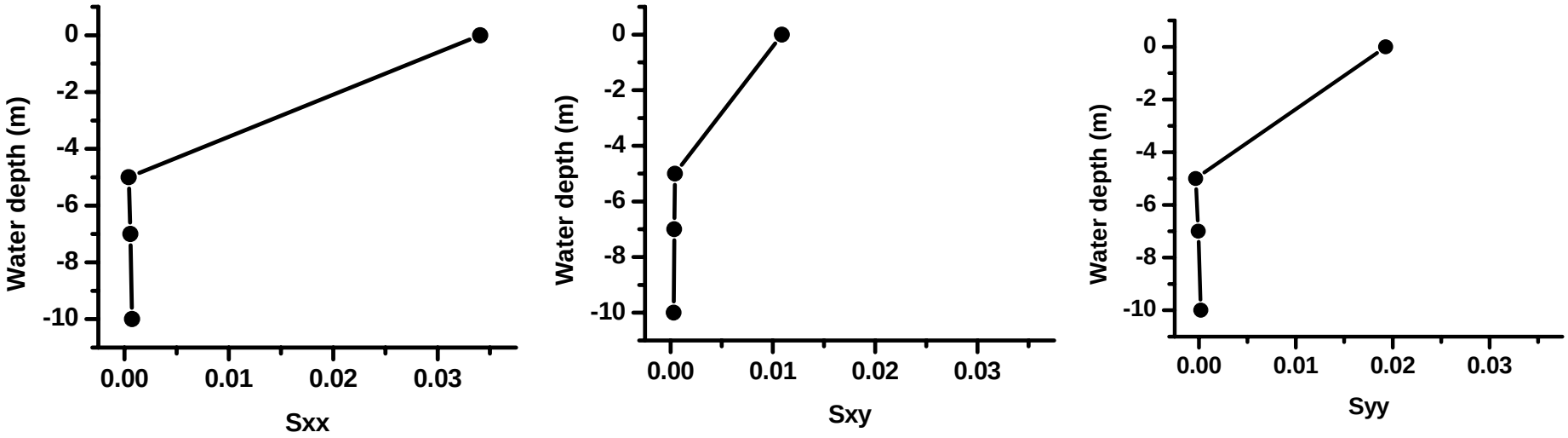
Vertical profile of temperature

(Daily mean: May 10-11, 2003)



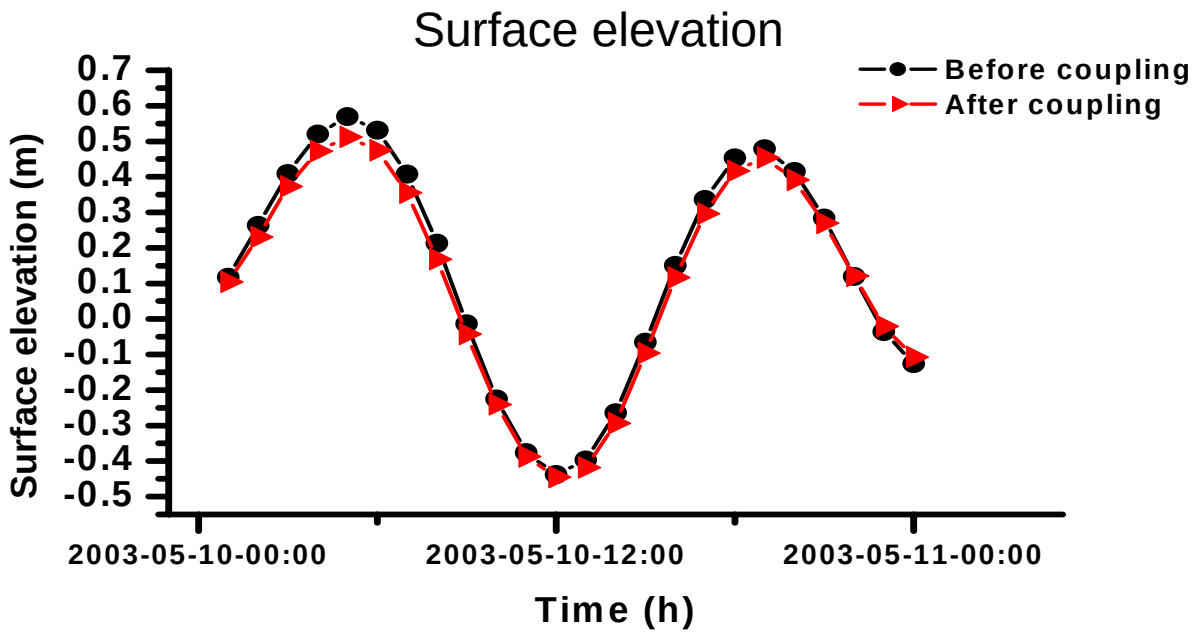
Vertical profile of radiation stress

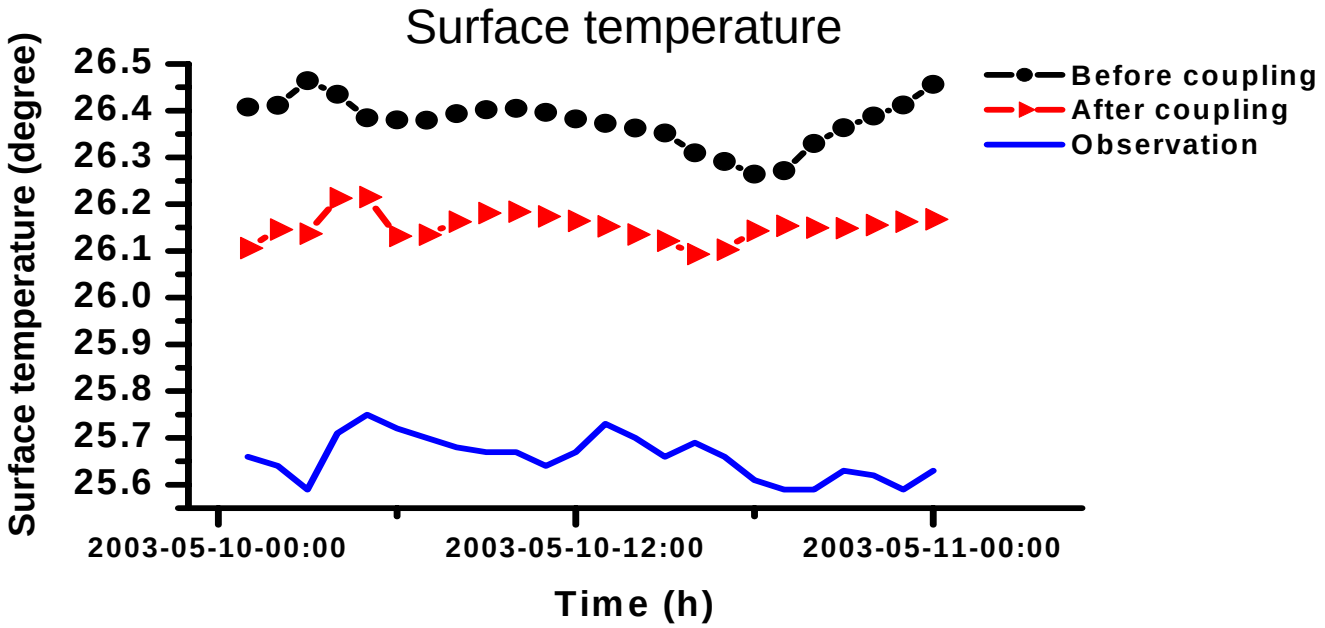
(Daily mean: May 10-11, 2003)



Time series results

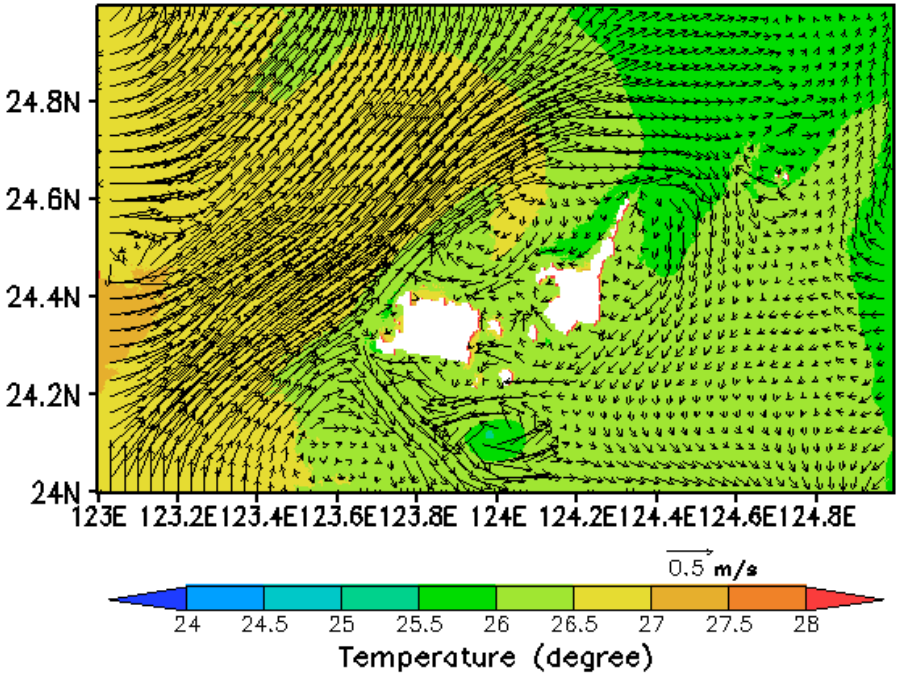
(May 10-11, 2003)



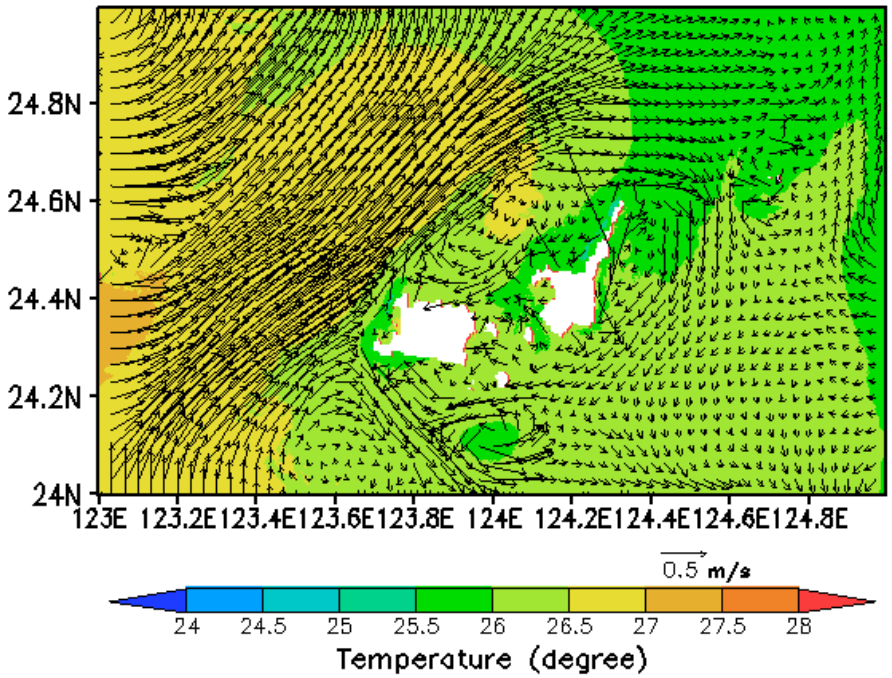


Sensitivity experiments

Results without radiation stress



Results with radiation stress

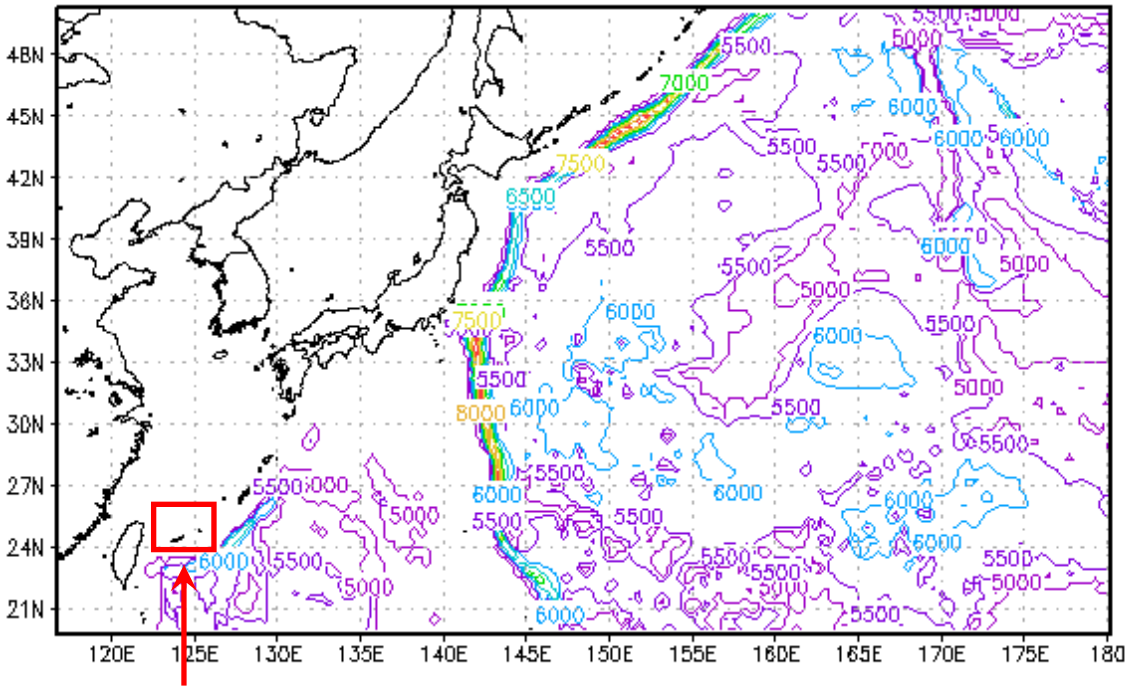


Conclusions

- Wave effects cause an eddy formed to the north of the Islands, and induce the warm water of Kuroshio intrude into the Lagoon.
- A cyclonic eddy with a cold water core is formed to the south of the Islands, and is strengthened by waves.
- In the shallow water region, waves cause the velocity and vertical diffusivity increase at the surface, which lead to lower surface temperature. Radiation stress plays an important role.

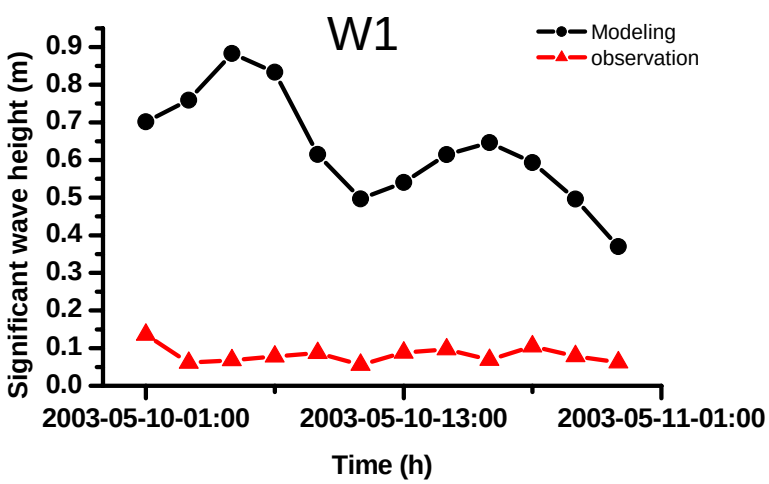
Wave Watch III

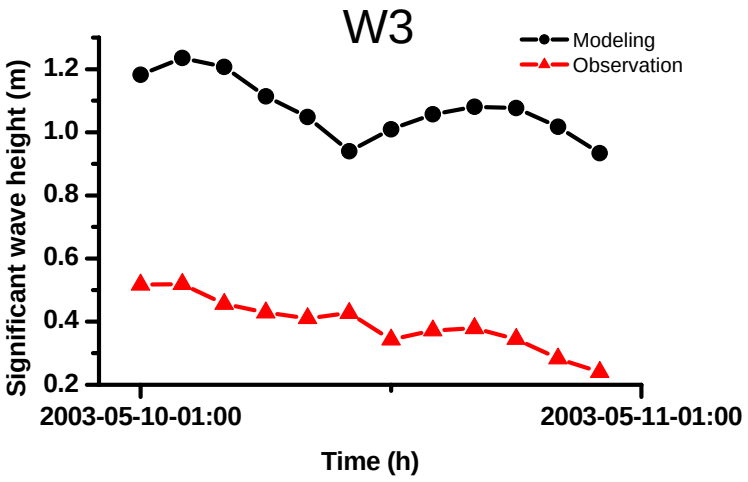
(Tamura, H.)



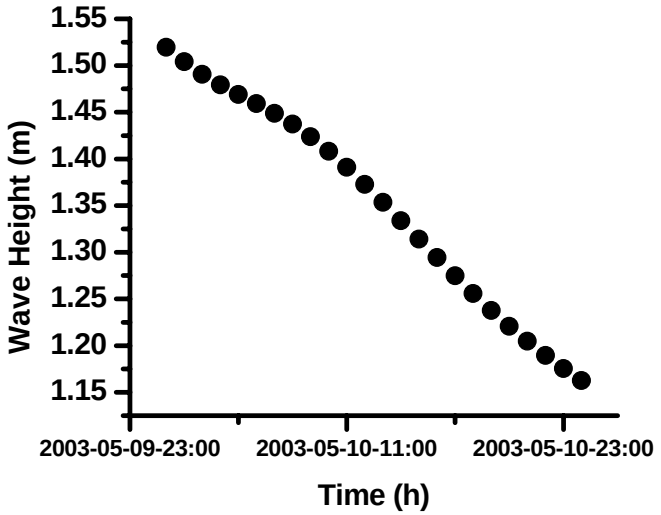
- Horizontal resolution 0.25deg
- Provide hourly data of wave height and wave period for the open boundaries of Yaeyama2

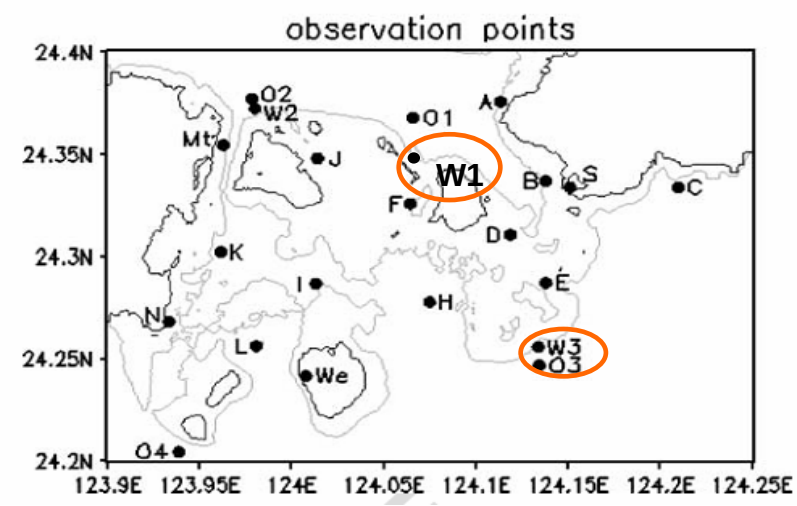
Yaeyama2 model results





WWIII model results

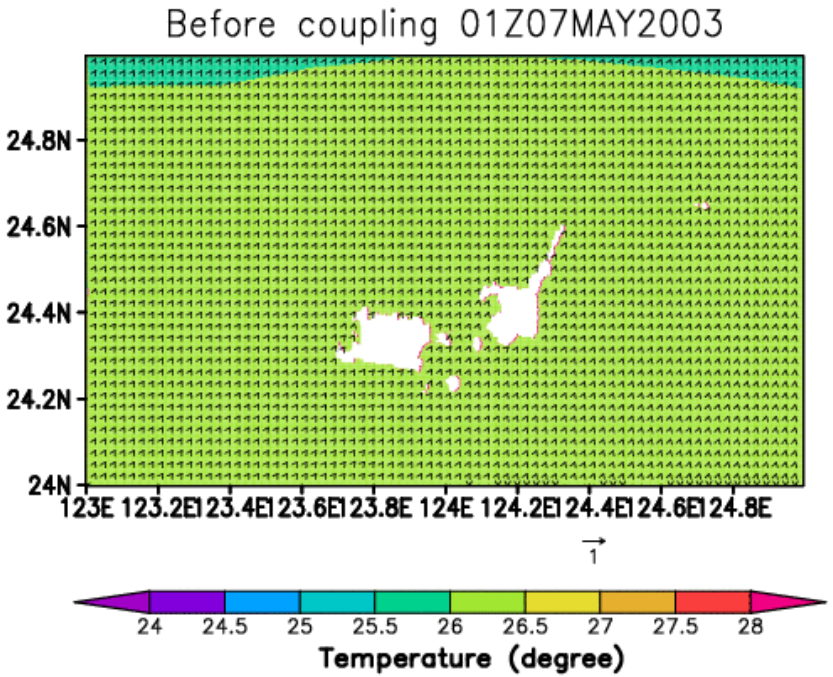




Thank you !

Horizontal distributions of surface currents and temperature

Before coupling



After coupling