S8-8634

Importance of swimming-depth model of jellyfishes *Nemopilema nomurai* in simulation of their migration in the Japan Sea

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Fisheries Research Agency

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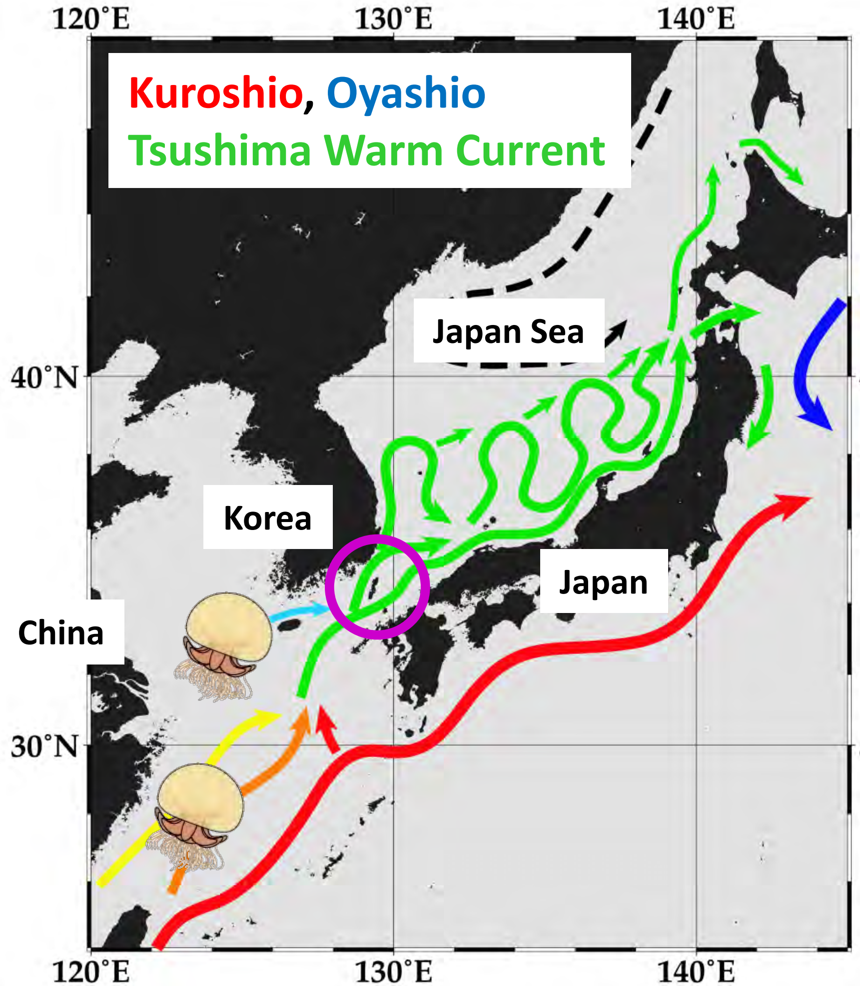
Nemopilema nomurai



Tsushima Strait

Nemopilema nomurai

Nomura’s Jellyfish

For large individuals,

Bell diameter > 1 m

Wet weight > 100 kg

Blooming season: Spring

Needs for Jellyfish Simulation

Recently, massive blooms of *N. nomurai* frequently occurred.
2002, 2003, 2004, 2005, 2006, 2007, 2009, 2012

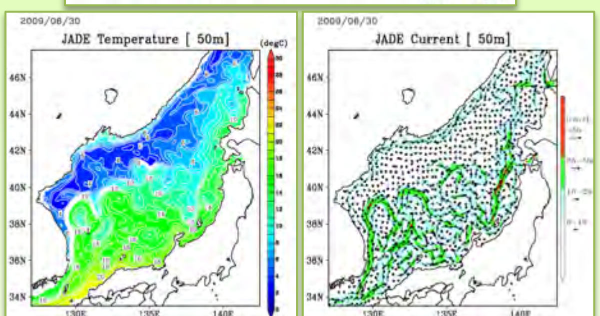
To avoid severe damages on fisheries in the Japan Sea, prediction of *N. nomurai* appearance is highly needed.

→ Numerical simulation system for jellyfish migration

Jellyfish Tracking Simulator of JSNFRI

Japan Sea National Fisheries Research Institute developed a jellyfish tracking simulator for analyses/forecasts of *Nemopilema nomurai* migration in the Japan Sea.

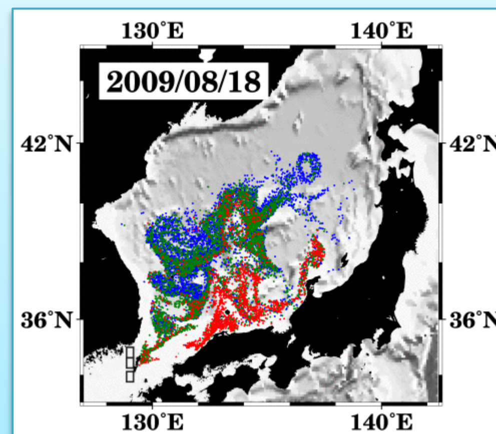
Operational Ocean Forecast System



http://jade.dc.affrc.go.jp/jade/

Hydrodynamic data

Particle Tracking Simulator



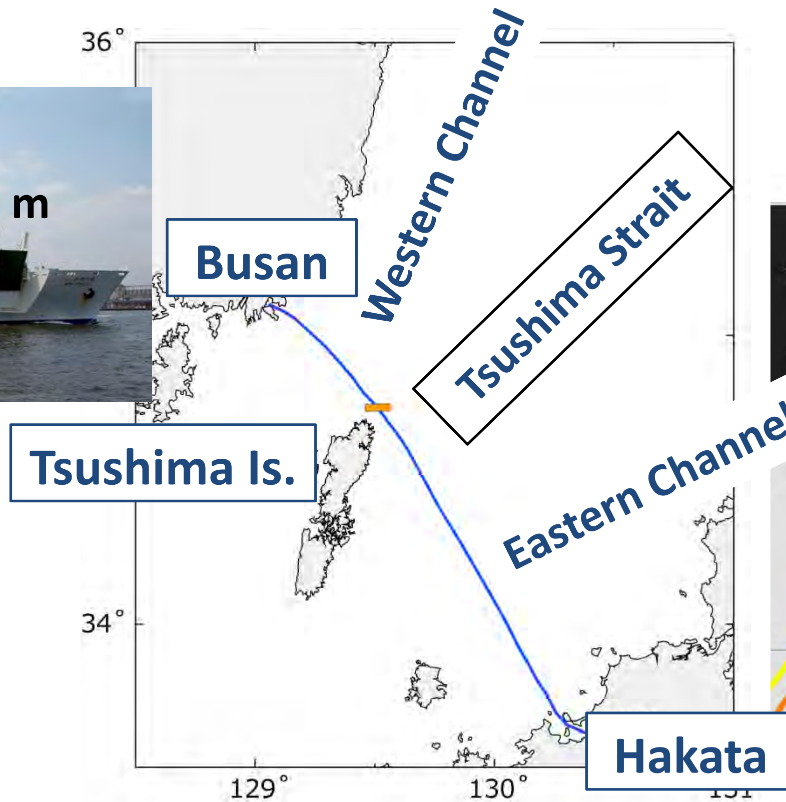
Camellia Sighting Survey & Appearance Reports from Fishermen

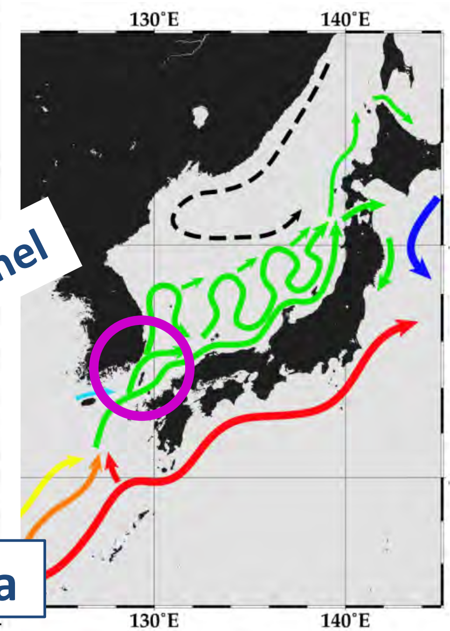
Release conditions

Sighting Survey in the Tsushima Strait

Since 2006, regular (roughly 2-week interval) sighting surveys of *N. nomurai* are conducted every year in the jellyfish season, to monitor the inflow of the jellyfishes. → Release conditions

Ferry New Camellia





Horizontal Movement of the Particles

The horizontal migration of *N. Nomurai* is basically passive to the oceanic velocities.
Honda *et al.* (2009) Fish. Sci. 75:947-956.

Stochastic dispersion
(Random walk)

Deterministic advection
by ambient oceanic velocity

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{U} + \boldsymbol{u}_{\mathrm{R}} \longrightarrow \boldsymbol{x}(t+\Delta t) = \boldsymbol{x}(t) + \boldsymbol{U}(t)\Delta t + \Delta\boldsymbol{x}_{\mathrm{R}}$$ **Explicit Euler discretization**

$\boldsymbol{x}$ **: horizontal position**
$\boldsymbol{U}$ **: ambient velocity (JADE)**

Horizontal diffusivity: Smagorinsky (1963)

$$K_{\mathrm{h}} = A\,\delta x \delta y\,\sqrt{\left(\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2}$$

$\delta x, \delta y$: Grid Spacing

Adjustment Constant $A = 0.05$

The random walk "step width"

$$\Delta\boldsymbol{x}_{\mathrm{R}} = (\Delta x_{\mathrm{R}},\ \Delta y_{\mathrm{R}}) = \sqrt{2K_{\mathrm{h}}\Delta t} \times (R_1, R_2)$$

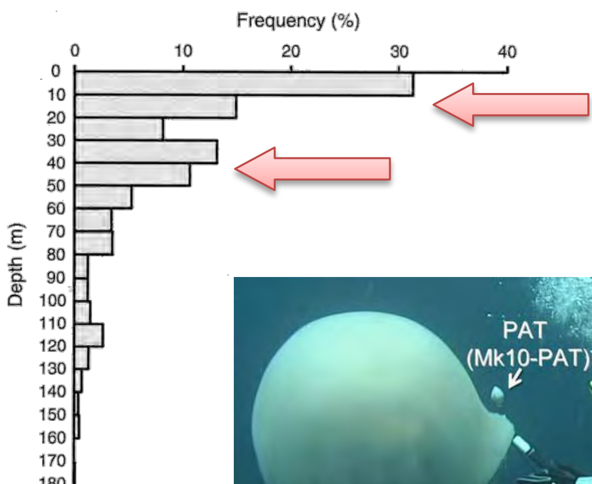
R_1, R_2 : $N(0,\ 1)$ Random Numbers

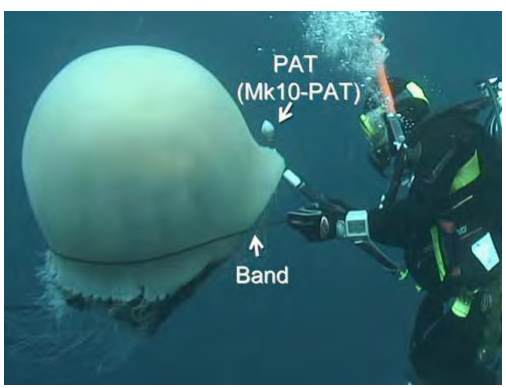
The jellyfish icon is provided by M/Y/D/S (http://animal.myds.jp/aquatic/nomuras_jellyfish/).

Potential Importance of the Swimming Depth

N. nomurai **shows vigorous and complicated vertical migration, and the swimming depth is potentially important in determination of the migration path. But we don't know how important is it.**

Observed swimming-depth frequency





Oceanic velocities vary with depth.

Direct observation using pop-up archival transmitting tags and ultrasonic pingers.

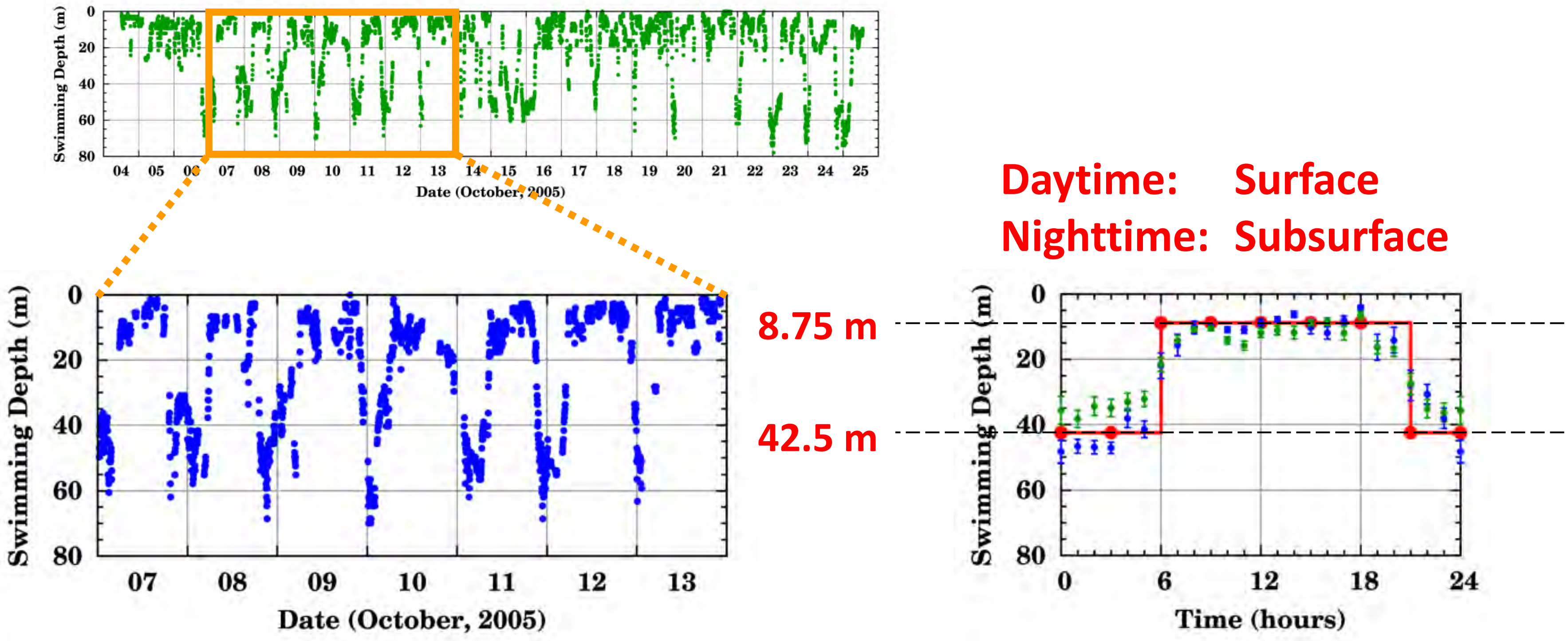
Honda *et al.* (2009) Fish. Sci. 75:947-956.

Diel Vertical Migration of the Jellyfish

From the direct observation,
It is known that the jellyfish shows diel vertical migration**.**

Honda *et al.* (2009) Fish. Sci. 75:947-956.

A pop-up archival tag **record.**

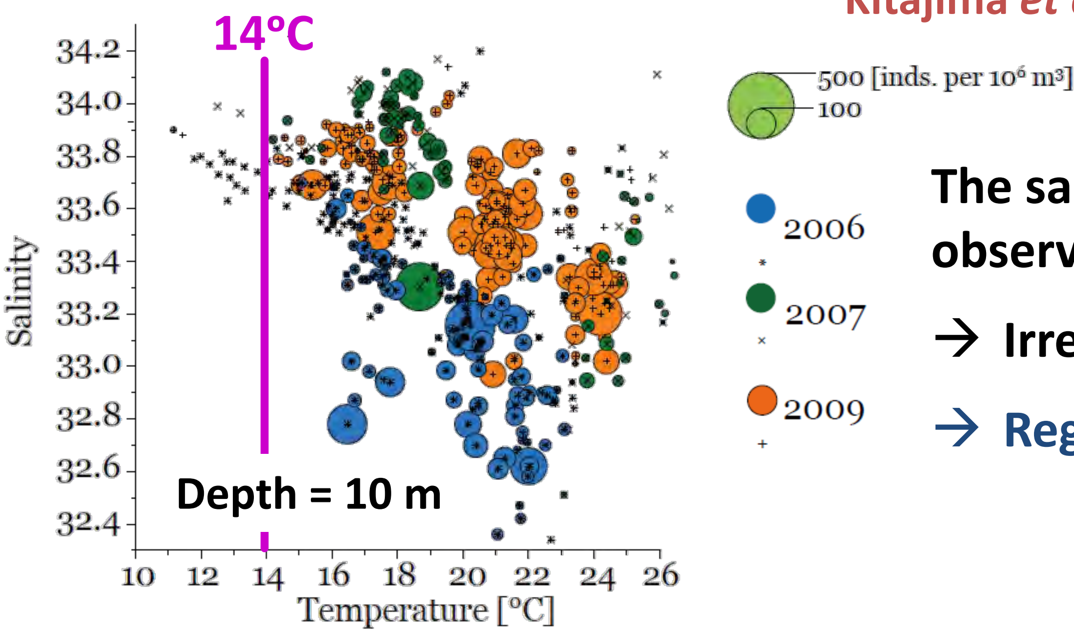


Habitat Regulation by Temperature

Recently, it is suggested that the habitat of *N. nomurai* in the Japan Sea is regulated by temperature.

Relation between salinity, temperature and *N. nomurai* abundance.

Kitajima *et al*. (2012): This meeting, Poster S7-5



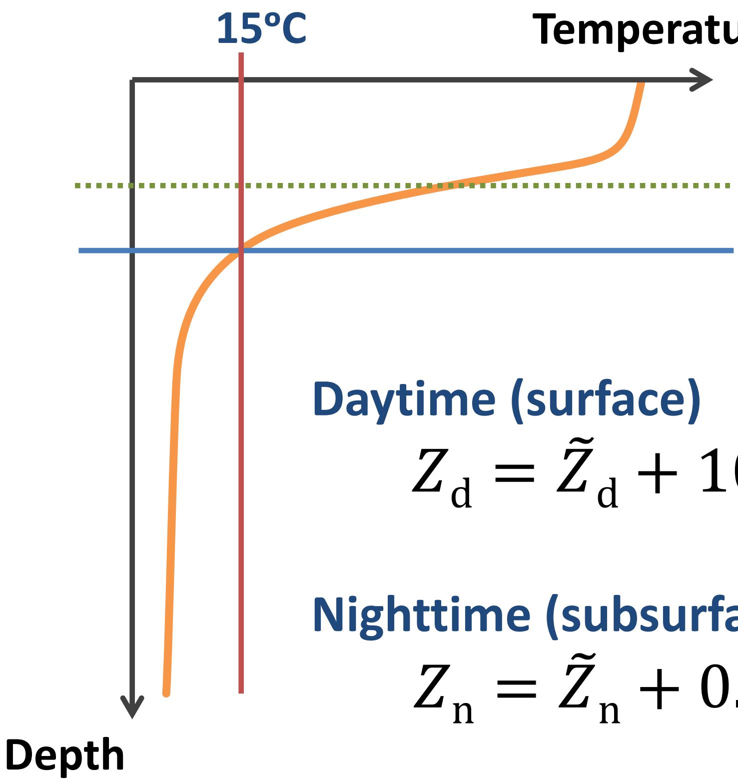
The same tendency was also observed at 30 and 50 m depths.

→ Irrespective of depth.

→ Regulation by Temperature.

Temperature-Based Swimming-Depth Model

The nighttime (subsurface) staying depth is controlled in relation with the depth of 15ºC isothermal surface, and moderate variance is given to the two staying depths.



$N(0,1)$: Normal random number

$\tilde{Z}_{\mathrm{n}}$

Z_{15} : 15ºC depth

Daytime (surface)

$$Z_{\mathrm{d}} = \tilde{Z}_{\mathrm{d}} + 10 \cdot |N(0,1)|, \quad \tilde{Z}_{\mathrm{d}} = 2.5\ \mathrm{m}$$

Nighttime (subsurface)

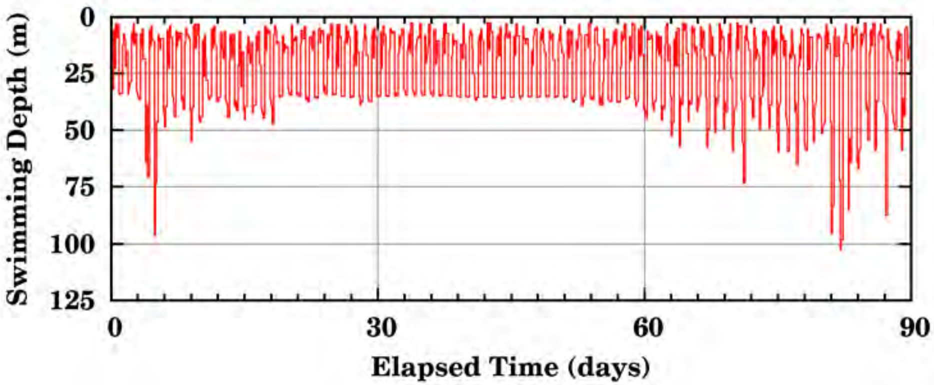
$$Z_{\mathrm{n}} = \tilde{Z}_{\mathrm{n}} + 0.5 \cdot \left(\tilde{Z}_{\mathrm{n}} - Z_{15}\right) \cdot |N(0,1)|, \quad \tilde{Z}_{\mathrm{n}} = 35\ \mathrm{m}$$

Skill of the Swimming-Depth Model

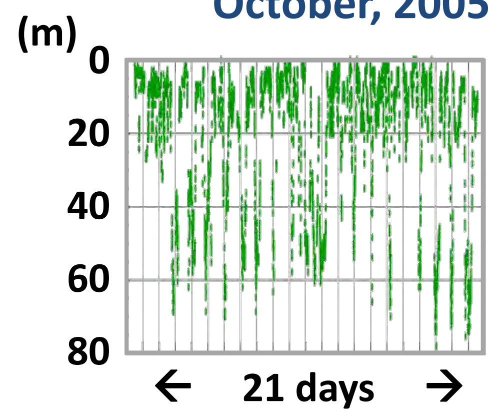
The temperature-based swimming-depth model can represent observed behavior of the jellyfish.

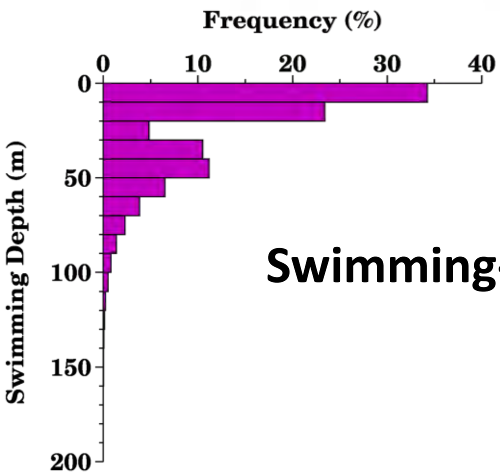
Vertical migration

Sim.

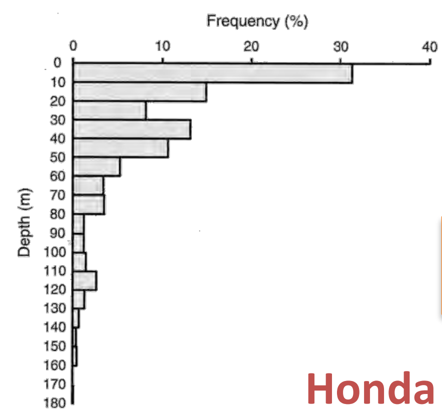


October, 2005





Swimming-depth frequency



Obs.

Honda *et al.* (2009)

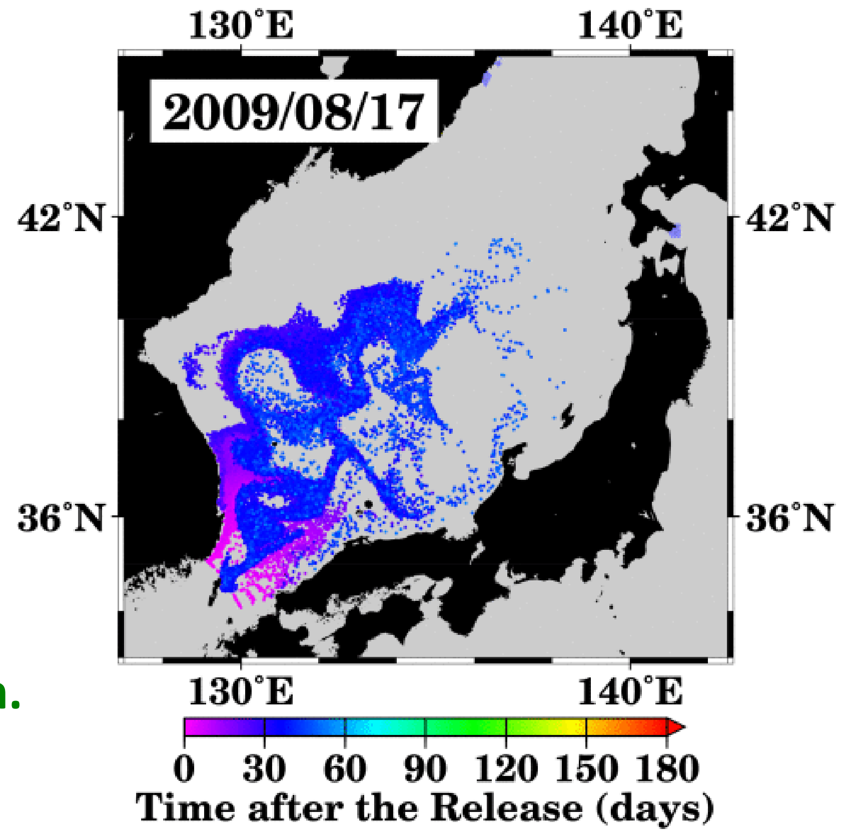
Sensitivity Tests by Hindcasts

We carried out hindcasts of the jellyfish migration for the massive blooms in 2006, 2007 and 2009 using three swimming-depth models.

Fixed swimming depth, at surface (8.75 m)

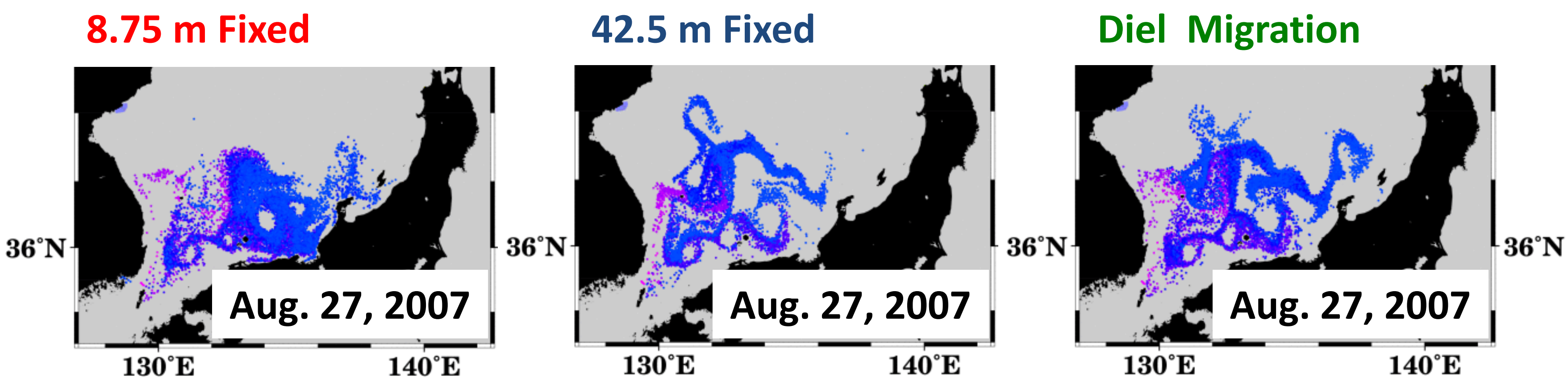
Fixed swimming depth, at subsurface (42.5 m).

The temperature-based diel migration.



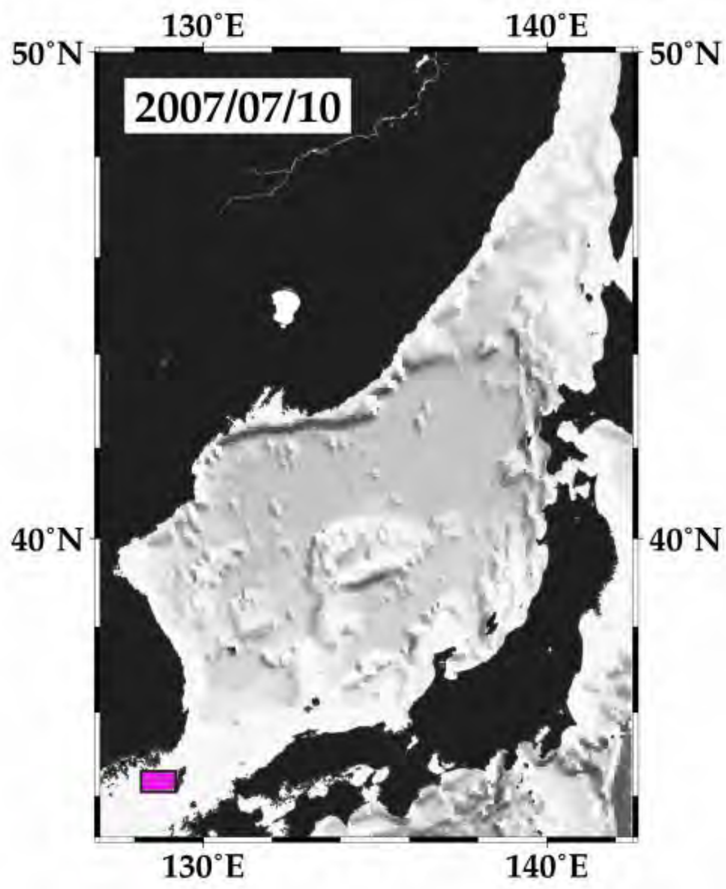
Comparison of the Hindcasts (2007)

The simulated migration of jellyfishes was quite sensitive to the selection of swimming depth model.



It was suggested that the selection of swimming-depth model can cause large bias in the simulated jellyfish migration/distribution.

Additional Experiment (2007)

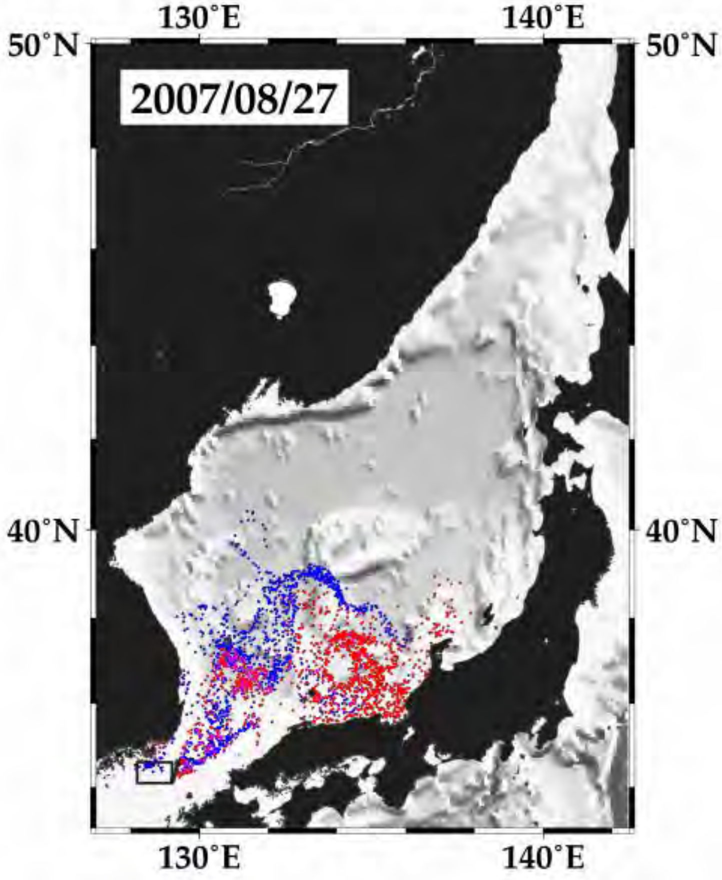


The particles were repeatedly released in the vicinity of the Tsushima Strait once per day from July 10 to July 19, and tracked.

The swimming depth is fixed at ...

- **Red: 8.75 m**
- **Blue: 42.5 m**
- **Purple: to indicate superposition**

Additional Experiment (2007)



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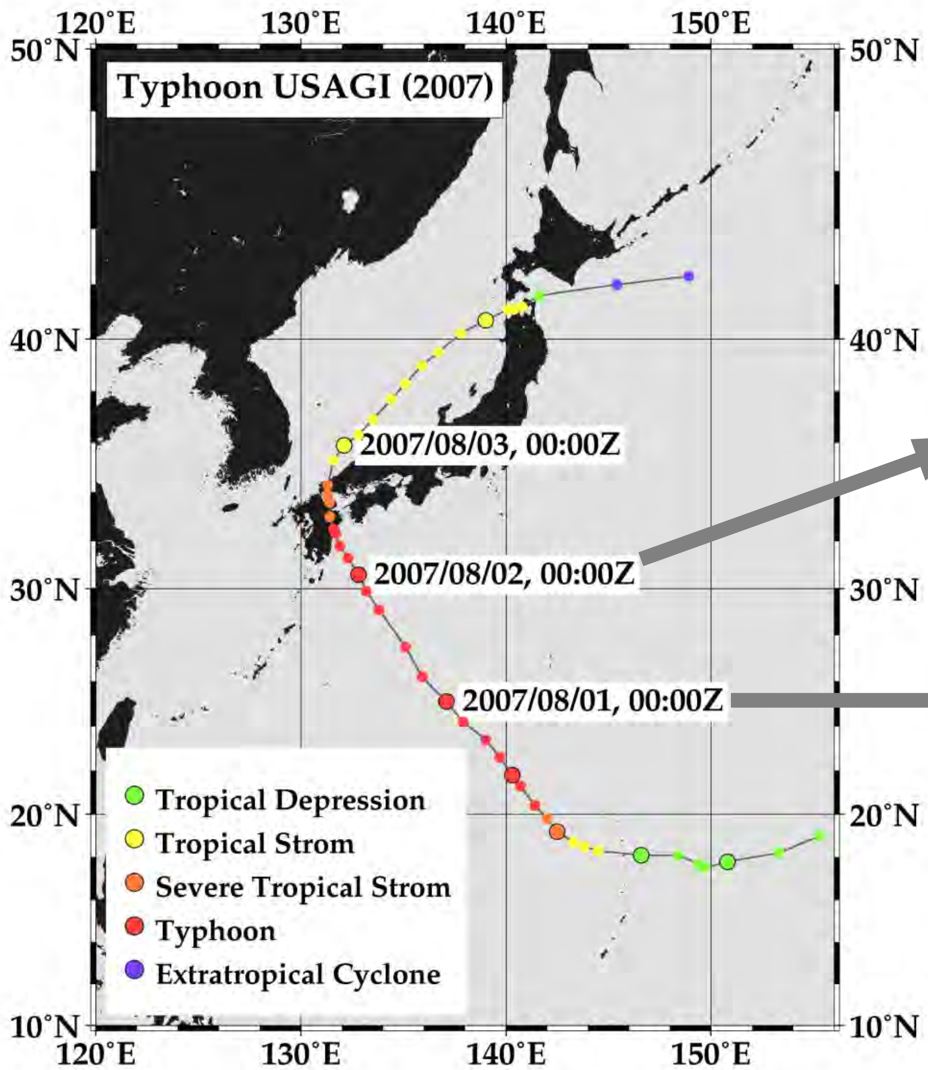
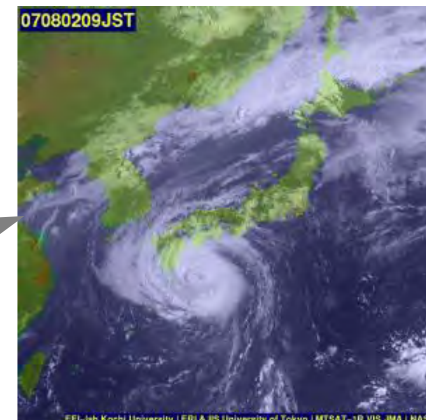
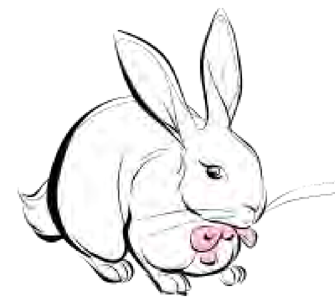
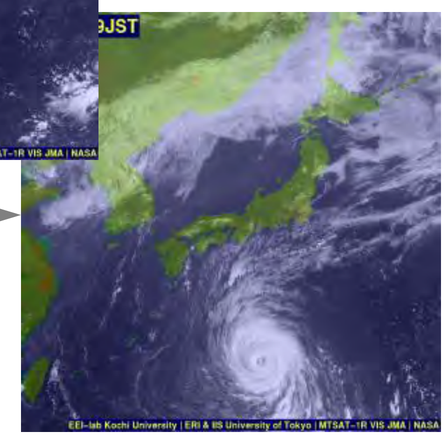
Trigger of the Particle Separation (2007)



The particle separation was triggered by the passing of Typhoon USAGI.

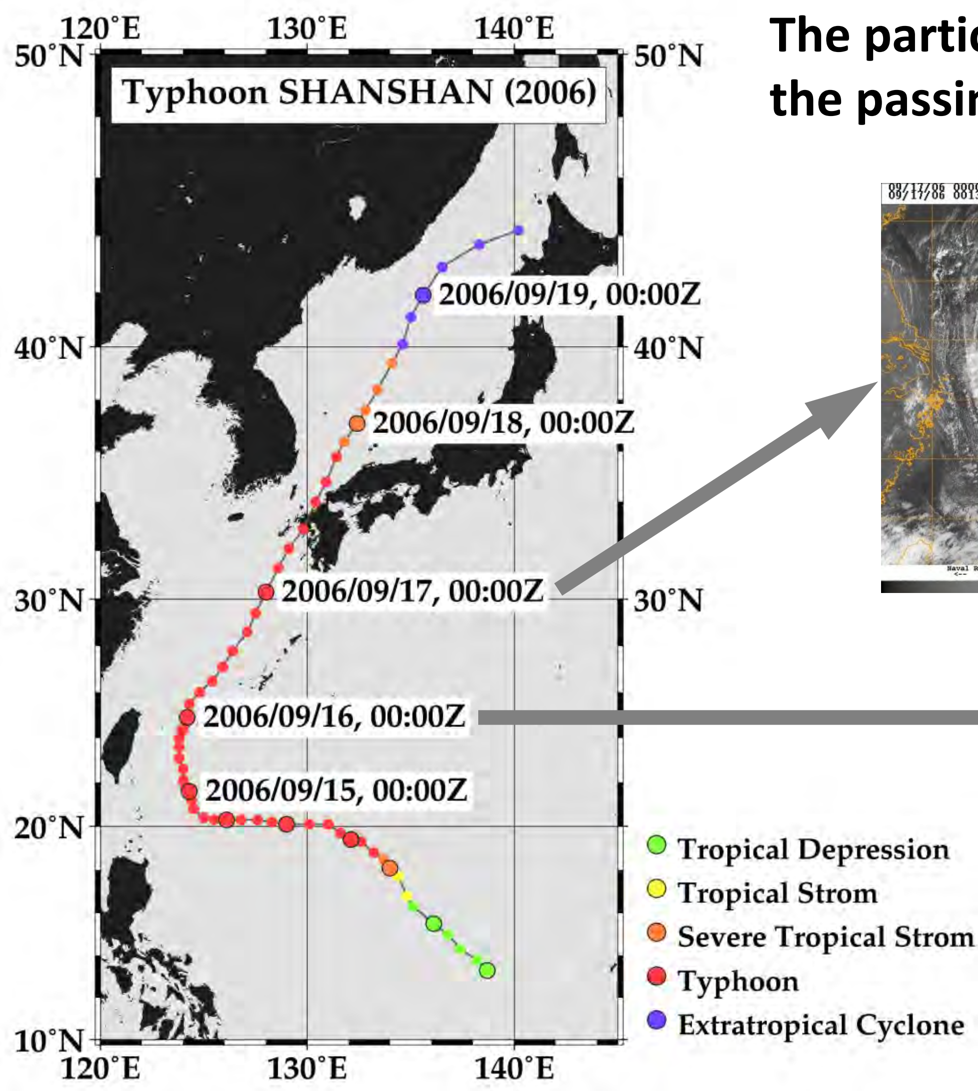




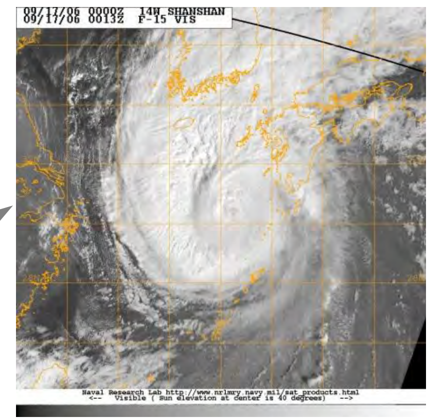


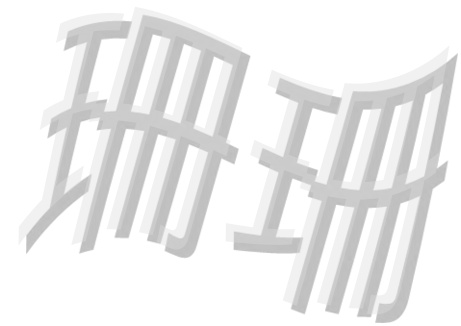
Kochi University Meteorological Information Page
http://weather.is.kochi-u.ac.jp/

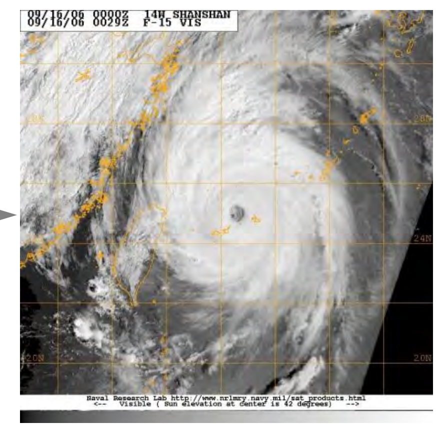
Trigger of the Particle Separation (2006)



The particle separation was triggered by the passing of Typhoon SHANSHAN.





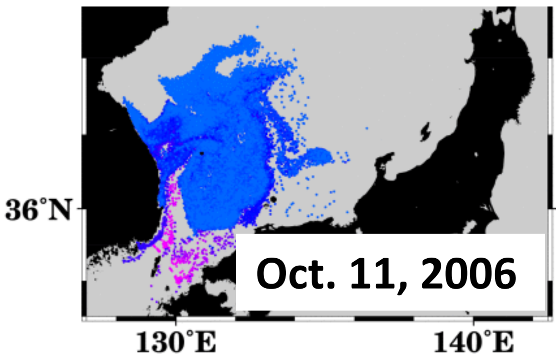


Naval Research Laboratory (NRL)
Monterey Marine Meteorology Division
Tropical Cyclone Web Page
http://www.nrlmry.navy.mil/TC.html

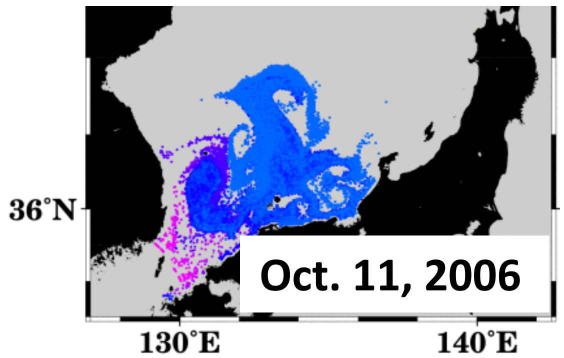
Comparison of the Hindcasts (2006)

The simulated migration of jellyfishes was quite sensitive to the selection of swimming depth model.

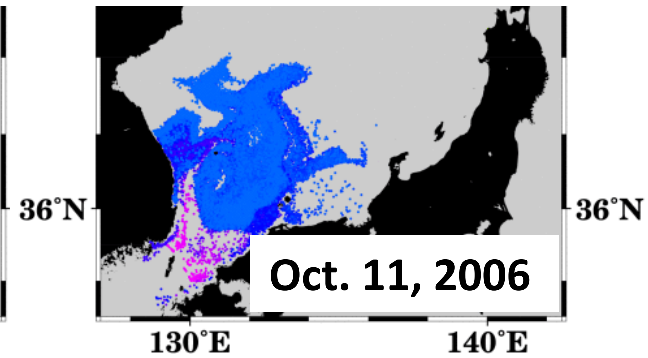
8.75 m Fixed



42.5 m Fixed



Diel Migration



Swimming-depth model is a critical factor in simulation of *N. nomurai* migration in the Japan Sea.
The assumption of a fixed (constant) swimming depth is not so good idea, since typhoon-passing is usual for the Japan Sea in the jellyfish season.

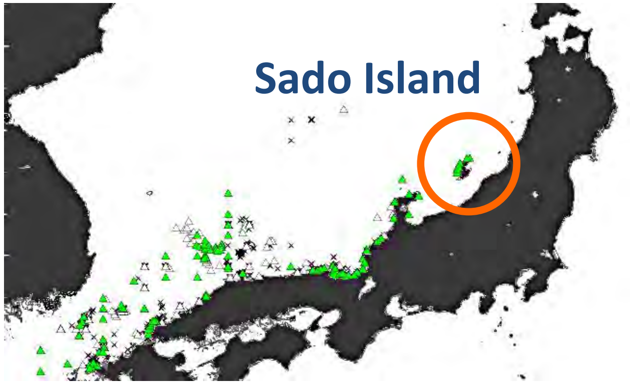
Comparison of the Hindcasts (2009)

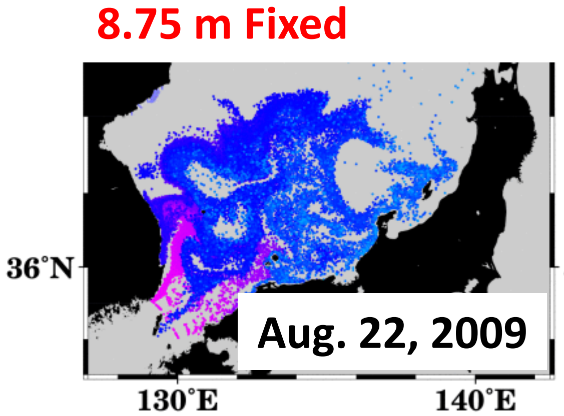
In 2009,
no typhoon passed over the Japan Sea.

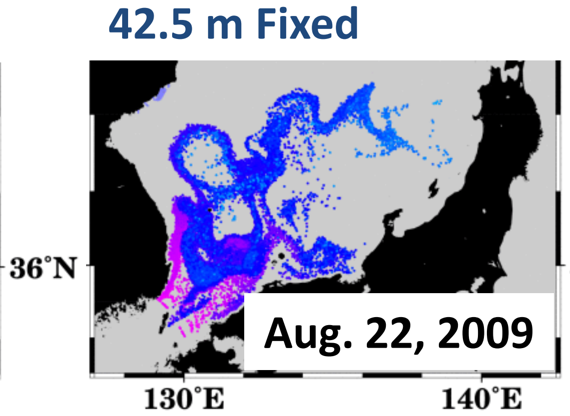
However, sensitivity to the swimming-depth model was still clear in the simulation.

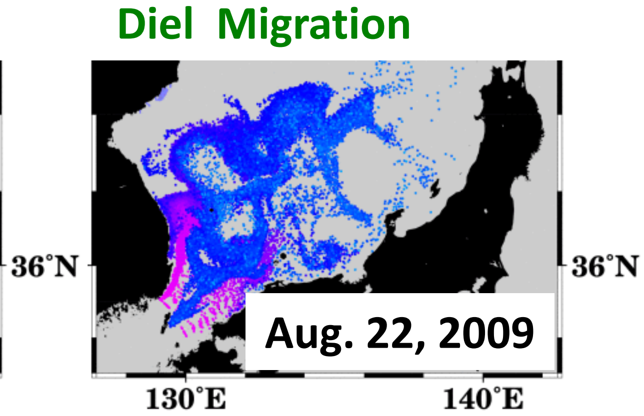
Observed appearance of the jellyfishes was explained best in the diel migration case.

Appearance Report (Aug. 22-28, 2009)
Japan Fisheries Information Center (2009)









Summary (1/2)

We carried out hindcasts of *Nemopilema nomurai* migration in the Japan Sea using the three swimming-depth models:

1. Fixed swimming-depth at surface (8.75 m)
2. Fixed swimming-depth at subsurface (42.5 m)
3. Temperature-based diel migration

It was shown that simulated migration of *N. nomurai* is quite sensitive to the selection of swimming-depth model.
Esp., large bias can be caused with severe weather events, e.g. typhoon passing.

The most valid result was given by the diel-migration model.

Summary (2/2)

The diel-migration model includes unknown factors, that is, the *amplitudes* of migration and the *reference depths.* At present, these factors must be determined ad-hoc.

We still need more detailed information about behavior and physiology of *N. nomurai,* for more precise simulation of *N. nomurai* migration and reduction of fisheries damages.