PICES-2011 Annual Meeting

BIO-P-7683

Forecast of the giant jellyfish *Nemopilema nomurai* appearance in the Japan Sea

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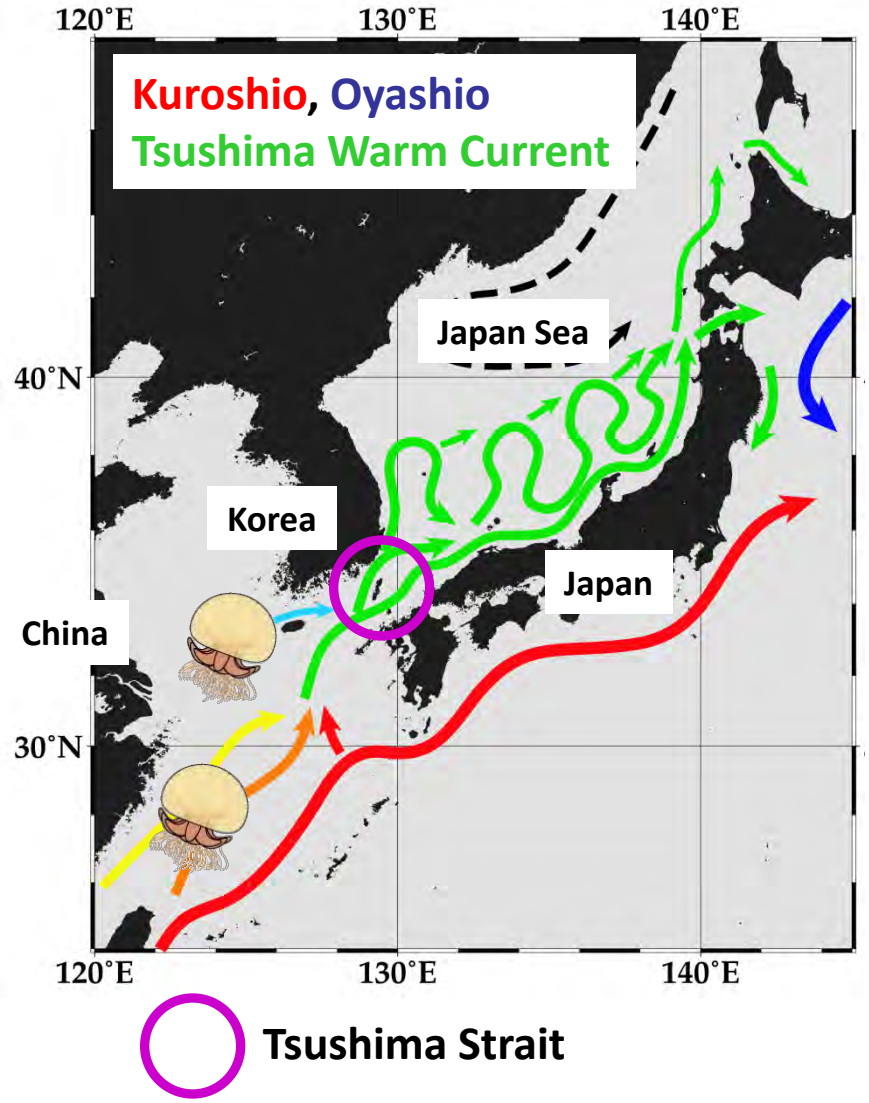
21 Oct 2011, Khabarovsk

Nemopilema nomurai (The giant jellyfish)



Nemopilema nomurai

Nomura's Jellyfish

For large individuals,

Bell diameter > 1 m

Wet weight > 100 kg

Strobilation season: Spring

Objective

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

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

➔ **Numerical system for the jellyfish forecast**

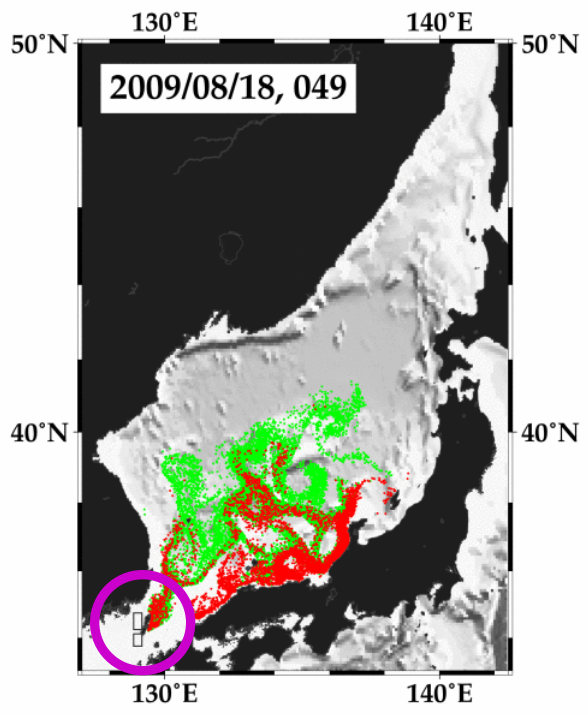
Concept of the jellyfish forecast

Ocean forecast system
analysis and prediction of oceanic state

Oceanic velocity

Particle tracking simulator
analysis and prediction of jellyfish transport

Release conditions



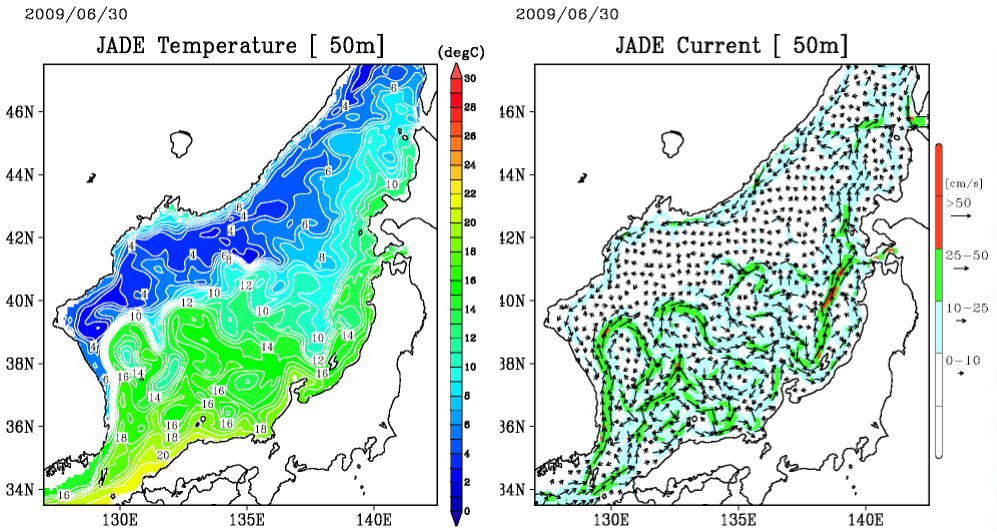
- Sighting surveys in the Tsushima Strait
- Jellyfish appearance reports from fishermen

Ocean forecast system

JADE (JApan sea Data assimilation Experiment)

An eddy-resolving ocean forecast system for the Japan Sea operated at Japan Sea National Fisheries Research Institute every Wednesday.

- **Spatial resolution: 1/12° regular horizontal grid, 36 vertical levels.**
- **Time interval of output data: 1 day.**
- **Data assimilative past/present analyses and 10-week forecast.**

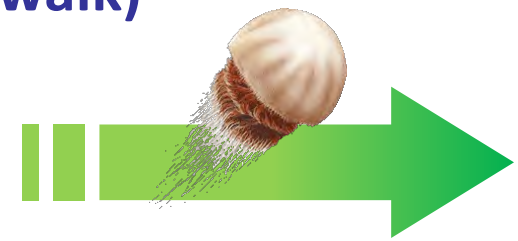


http://jade.dc.affrc.go.jp/jade/

Horizontal movement of particles

Stochastic dispersion (Random walk)

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



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)

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

The random walk "step width"

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

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

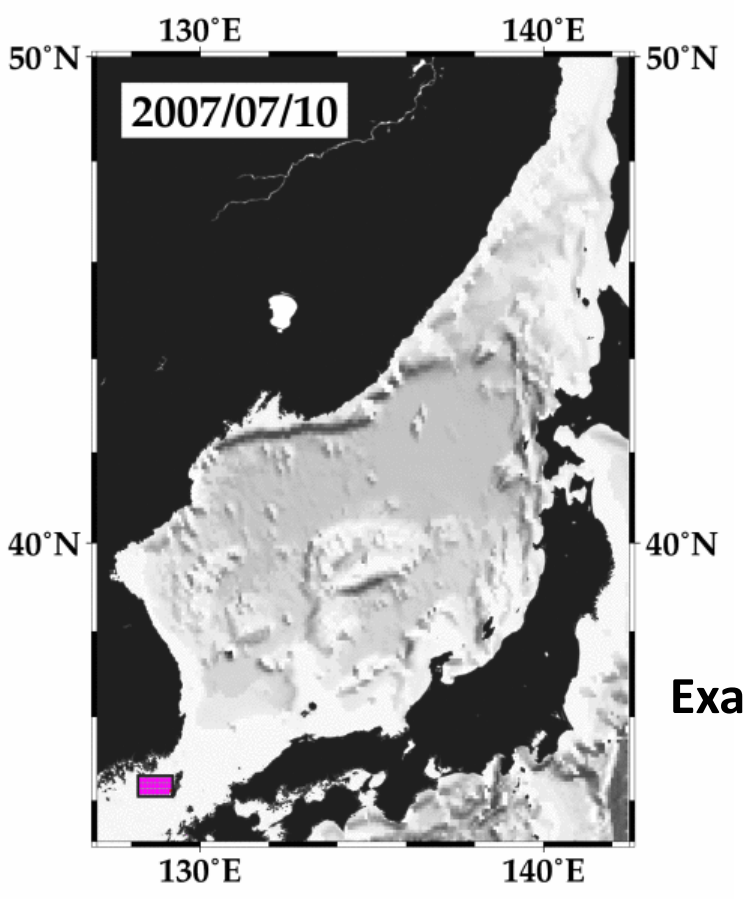
R_1, R_2 : $N(0,\ 1)$ Random Numbers

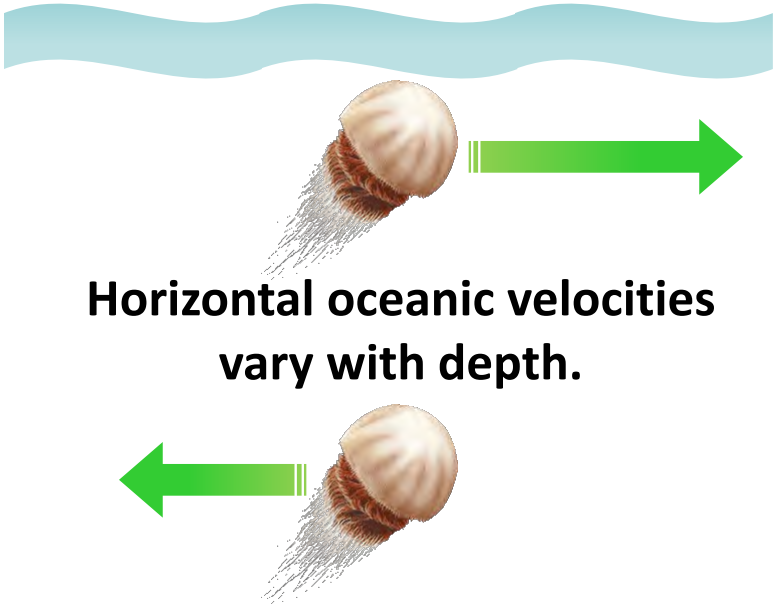
Adjustment Constant $A = 0.05$

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

Importance of the swimming depth

We must model the vertical migration of jellyfishes adequately.





Horizontal oceanic velocities vary with depth.

Examples of fixed swimming depths.

Red: 8.75 m

Blue: 42.5 m

Purple: to indicate superposition

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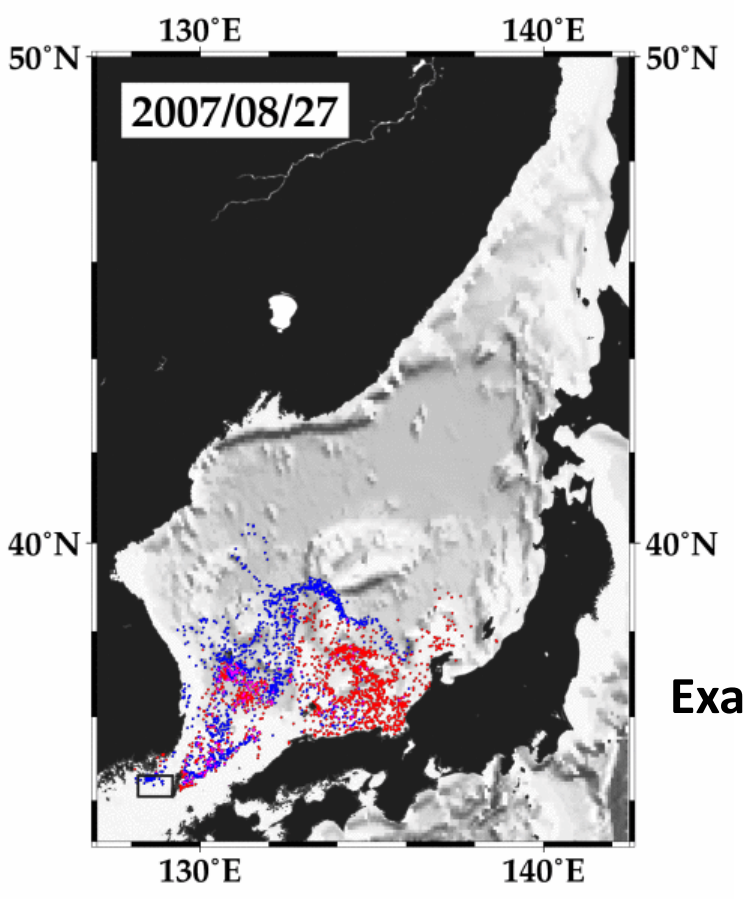

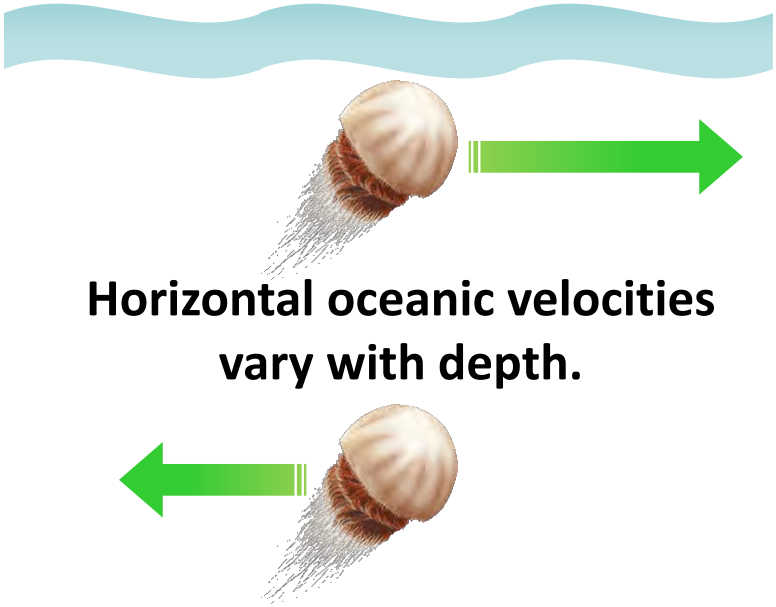

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Examples of fixed swimming depths.

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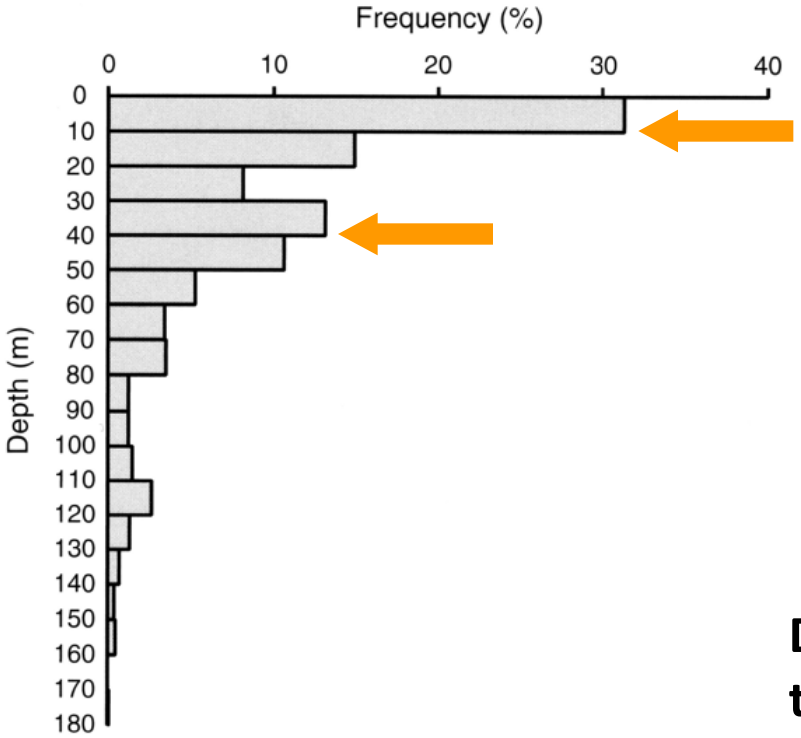
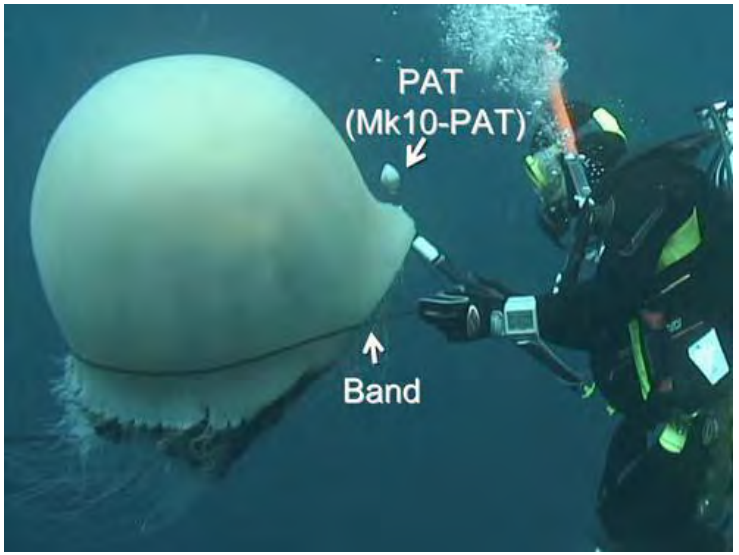
Vertical migration of *N. nomurai*

N. nomurai **shows vigorous vertical migration, and the migration manner is quite complicated.**

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

Frequency of the observed swimming depths.





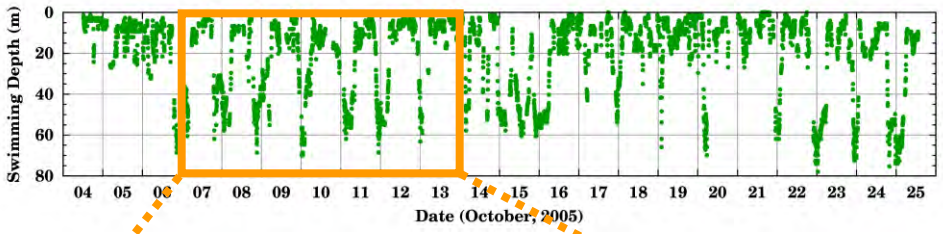
Direct observation using pop-up archival transmitting tags and pingers.

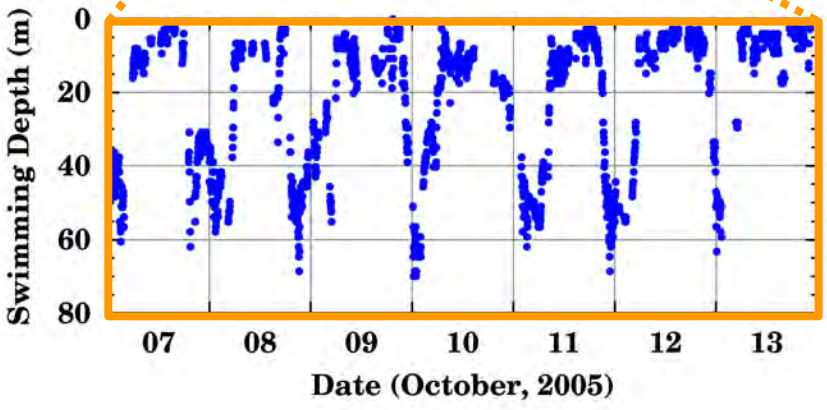
Vertical movement of particles

We prescribe the vertical movement of particles based on the observed diel vertical migration of *N. nomurai*.

A pop-up archival tag record.

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



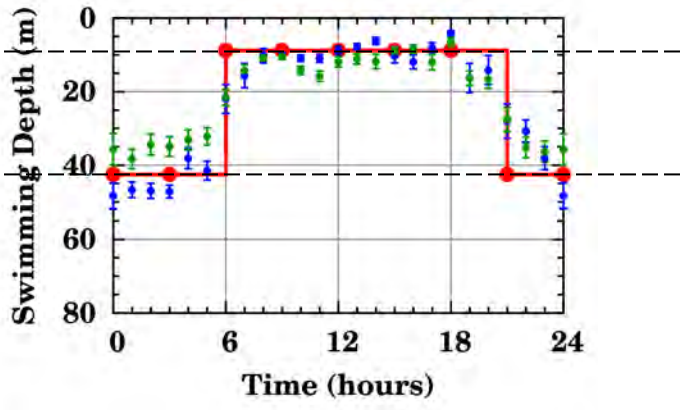


8.75 m

42.5 m

15 hours at 8.75 m

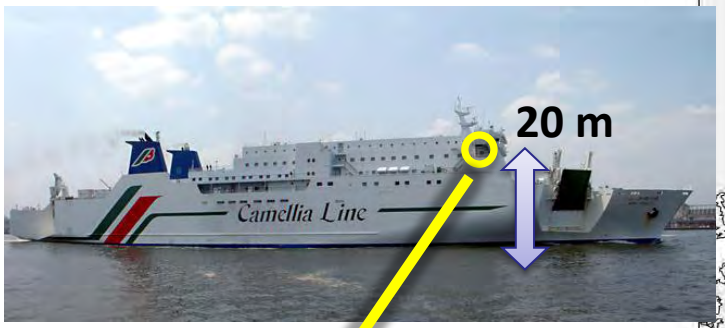
9 hours at 42.5 m

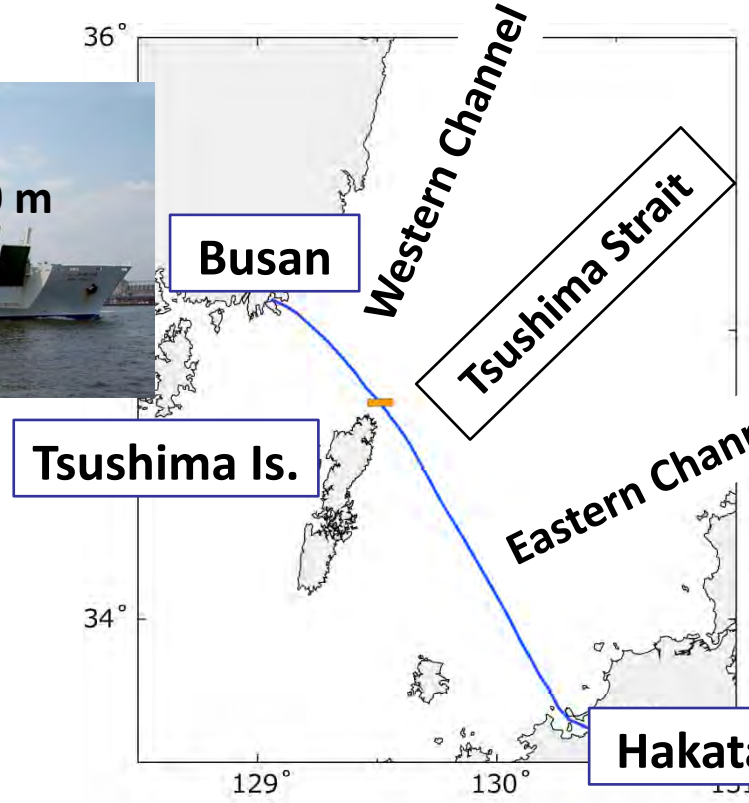


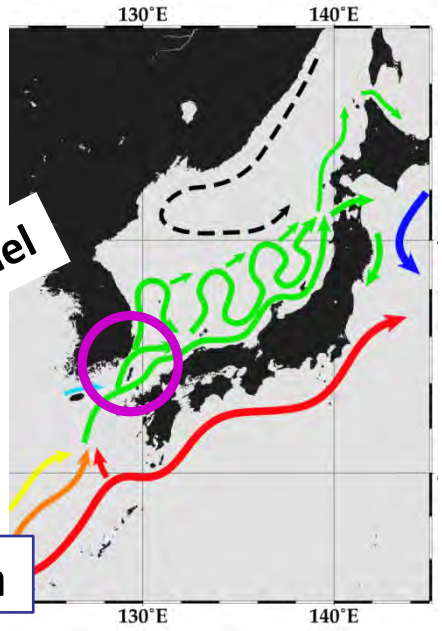
Sighting survey in the Tsushima Strait

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



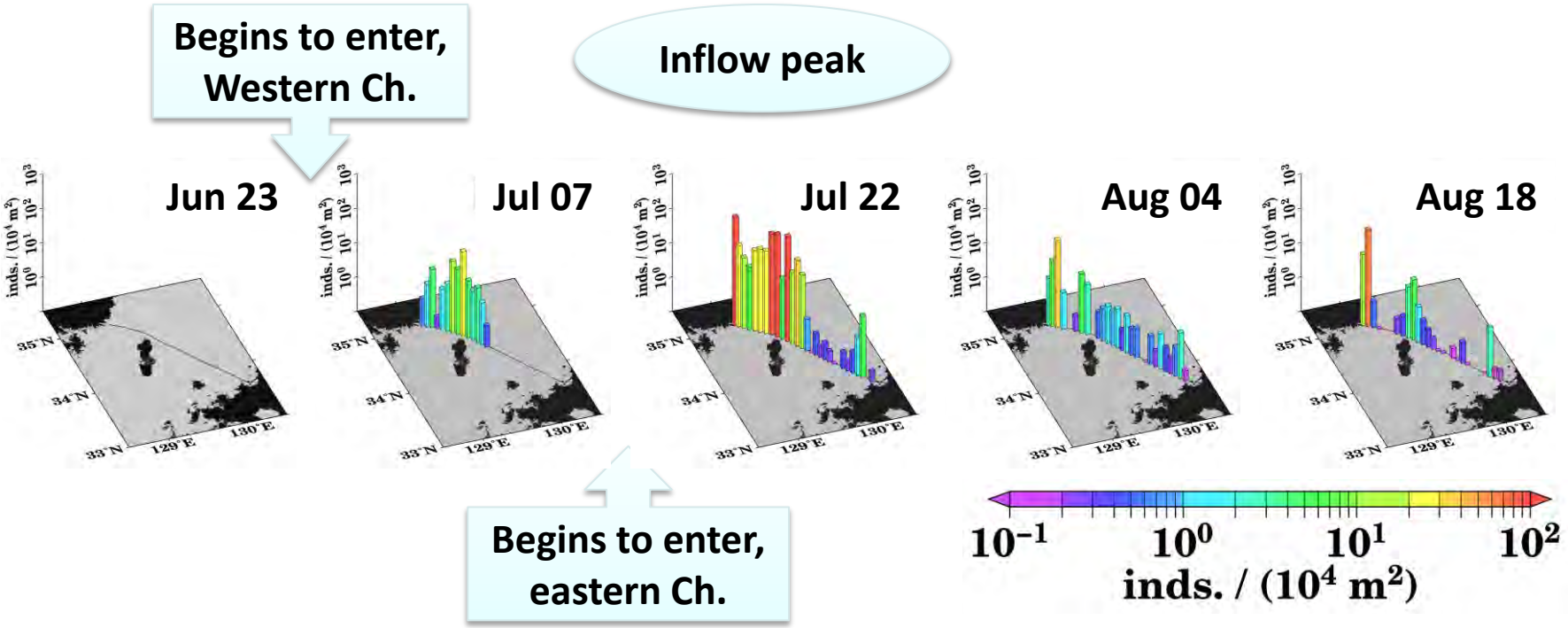




Jellyfish forecast in 2009 (1/5)

Example: Forecast of the jellyfish "front edge".
The computation was carried out on Aug 10, 2009.

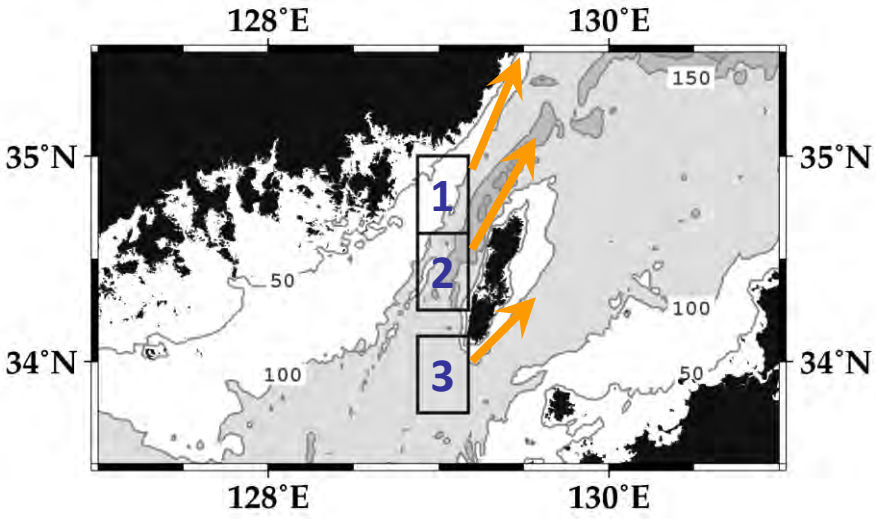
The sighting surveys in the Tsushima Strait successfully monitored the inflow of jellyfishes.



Jellyfish forecast in 2009 (2/5)

Example: Forecast of the jellyfish "front edge".
The computation was carried out on Aug 10, 2009.

We configured the particle release conditions for the forecast based on the sighting surveys and jellyfish appearance reports from fishermen.



Particle release: Once per day

For Domain 1: from Jun 25 to Jul 13
For Domain 2: from Jun 30 to Jul 13
For Domain 3: from Jul 9 to Jul 13

Number of particles for a release = 400

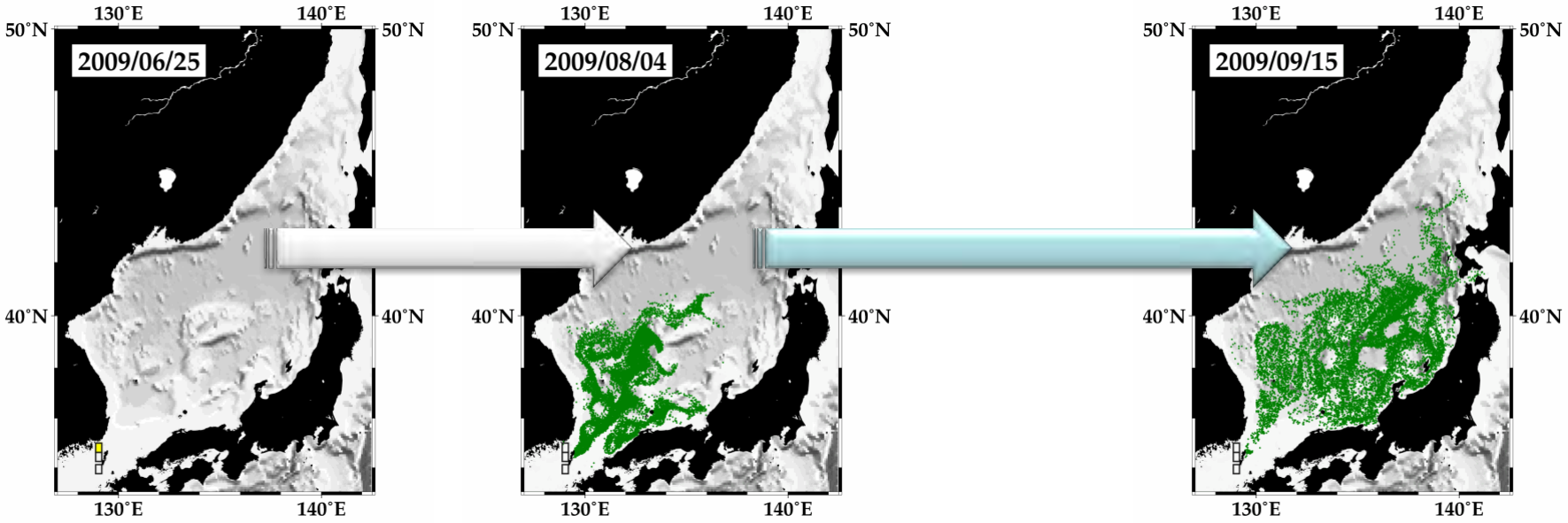
Jellyfish forecast in 2009 (3/5)

Example: Forecast of the jellyfish "front edge".
The computation was carried out on Aug 10, 2009.

We first analyzed the past transport of *N. nomurai*, then extended the computation to make a forecast.

Jun 25 – Aug 04: Hindcast (Analysis)
= Based on data-assimilative JADE data.

Aug 05 – Sep 15: Forecast
= Based on JADE forecast data.



Jellyfish forecast in 2009 (4/5)

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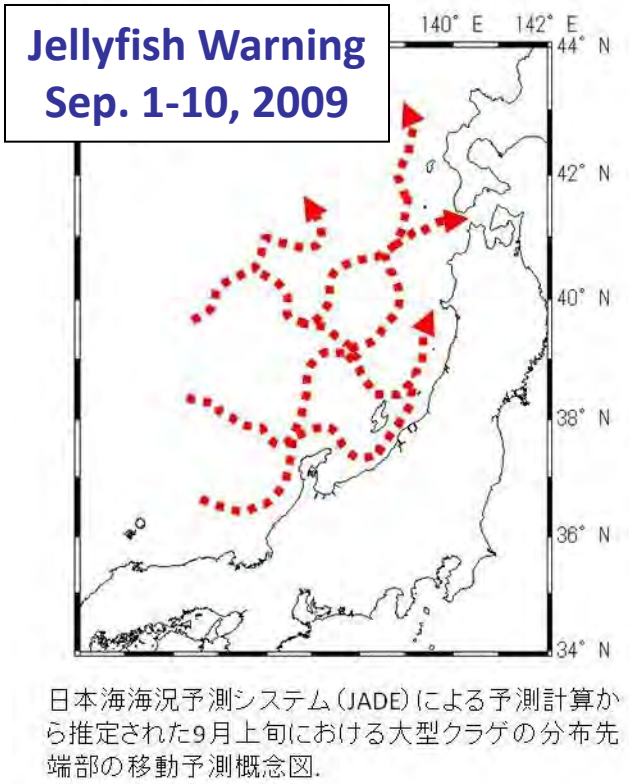

日本海海況予測システム(JADE)による予測計算から推定された9月上旬における大型クラゲの分布先端部の移動予測概念図.

Through a guidance process,
we made "jellyfish warning".
→ Information more easy to understand like a weather forecast.

The warning was released via WWW,
then evaluated and utilized by fishermen.

Fisheries Research Agency, 2009 (http://www.fra.affrc.go.jp/)

Jellyfish forecast in 2009 (5/5)

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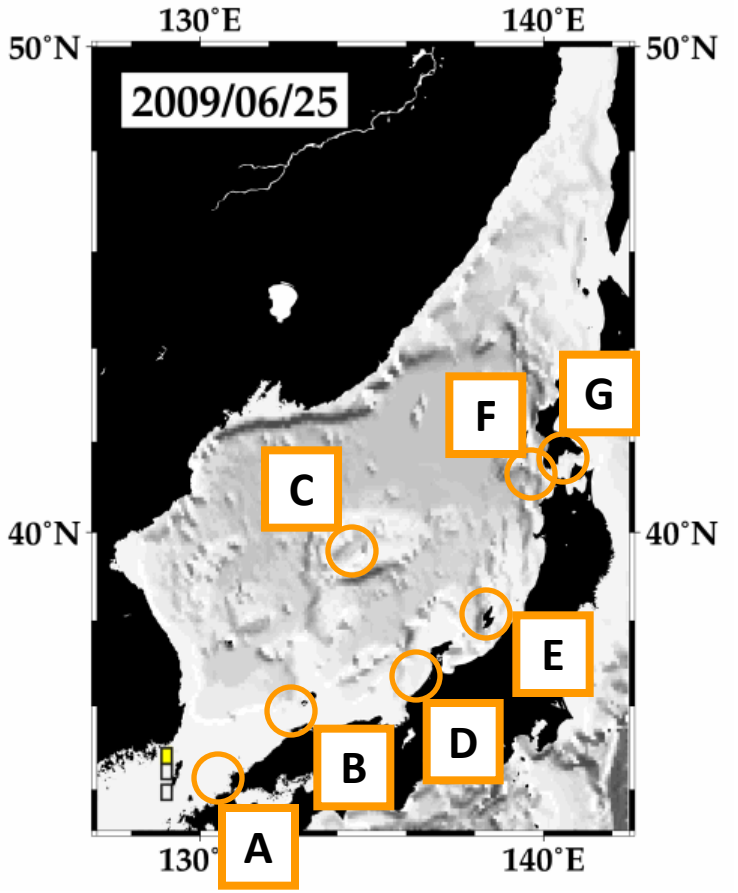

Appearance report vs. Computation

vs. Hindcast (Analysis)

A:	Jul 14	(the first appearance)
B:	Jul 21	(the first appearance)
C:	Jul 23-27	(the first appearance)

vs. Forecast

D:	Aug 12	(the first appearance)
E:	Aug 24-26	(the first appearance)
F:	Aug 31-Sep 1	(the first appearance)
G:	Sep 11-14	(enhanced outflow)

Jellyfish forecast in 2009 (5/5)

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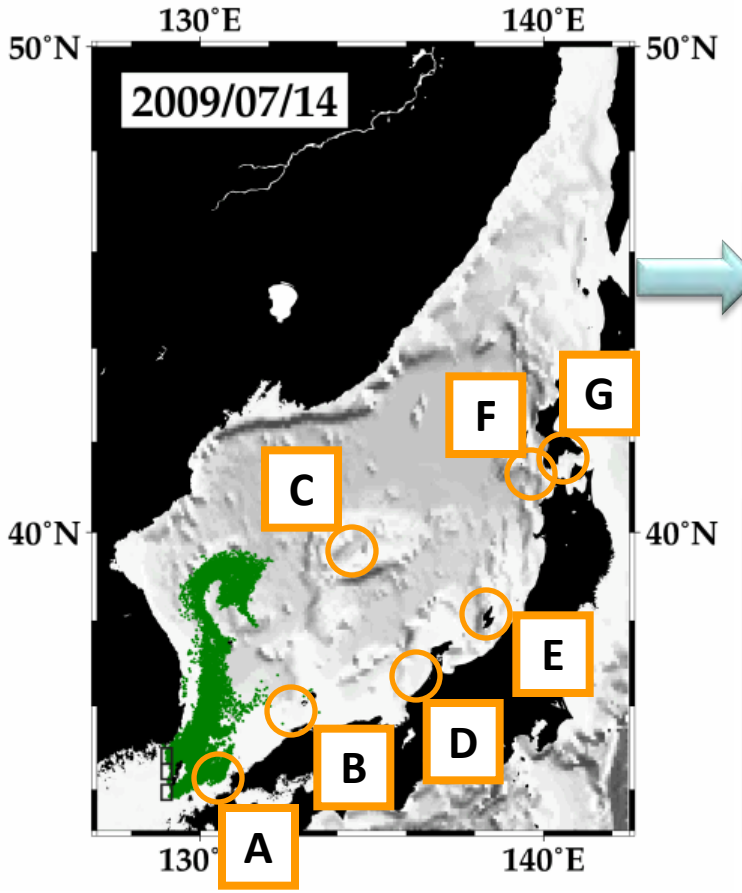

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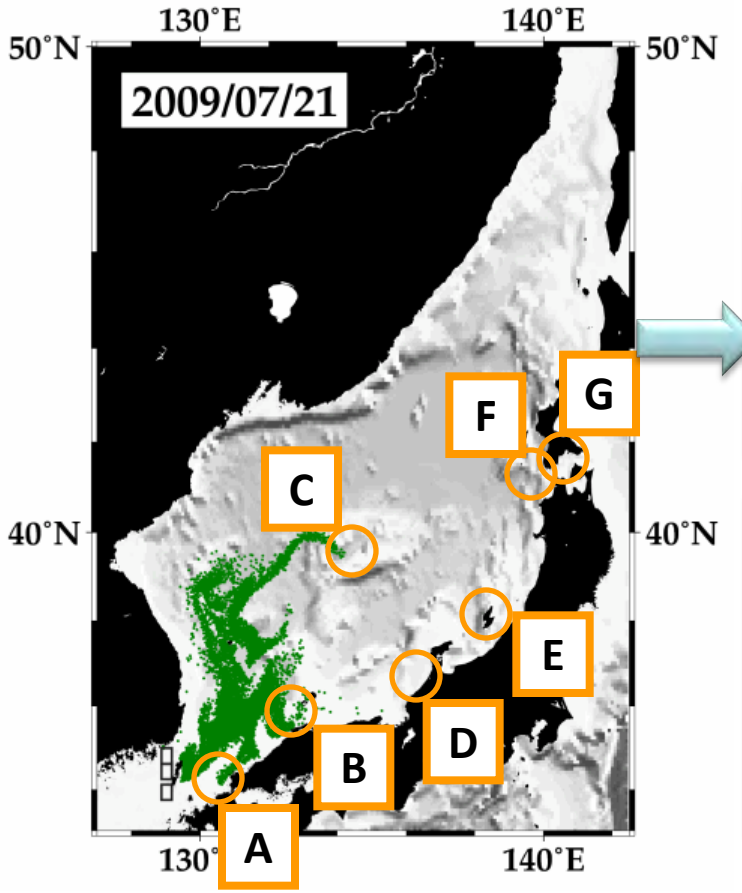

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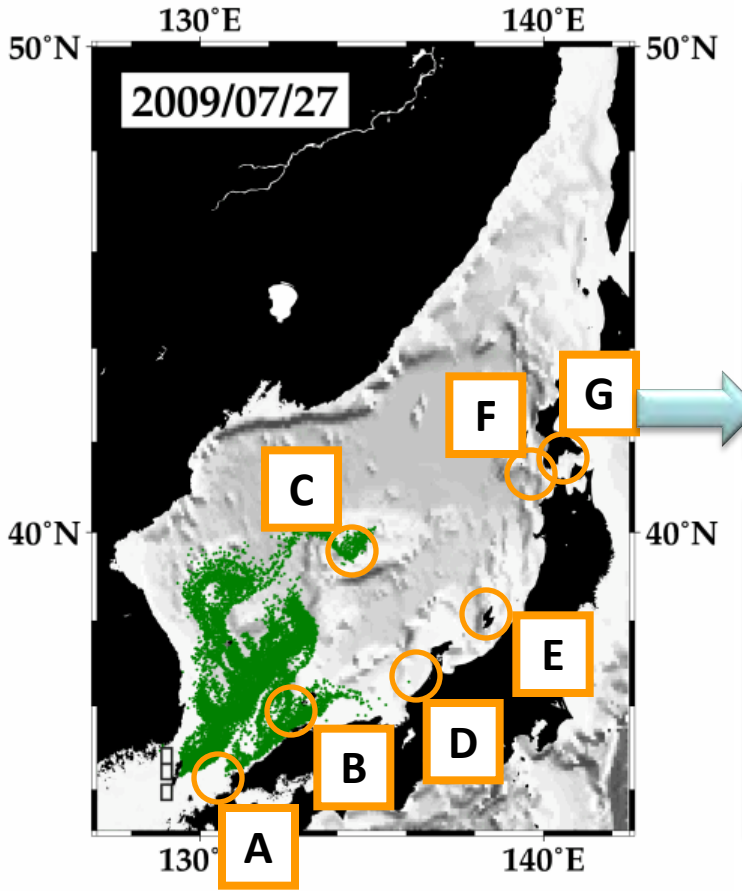

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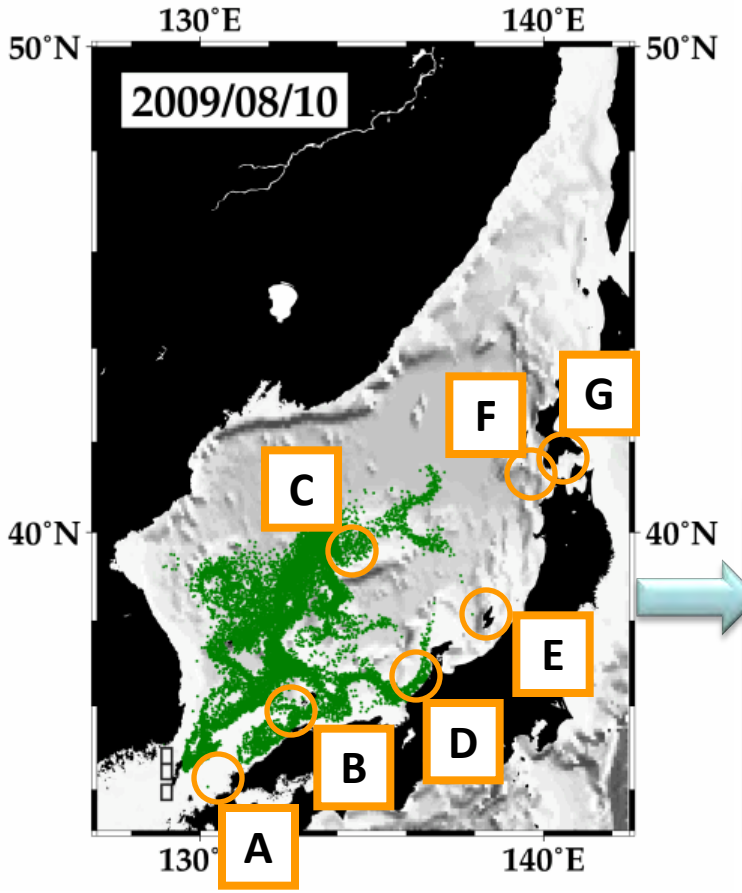

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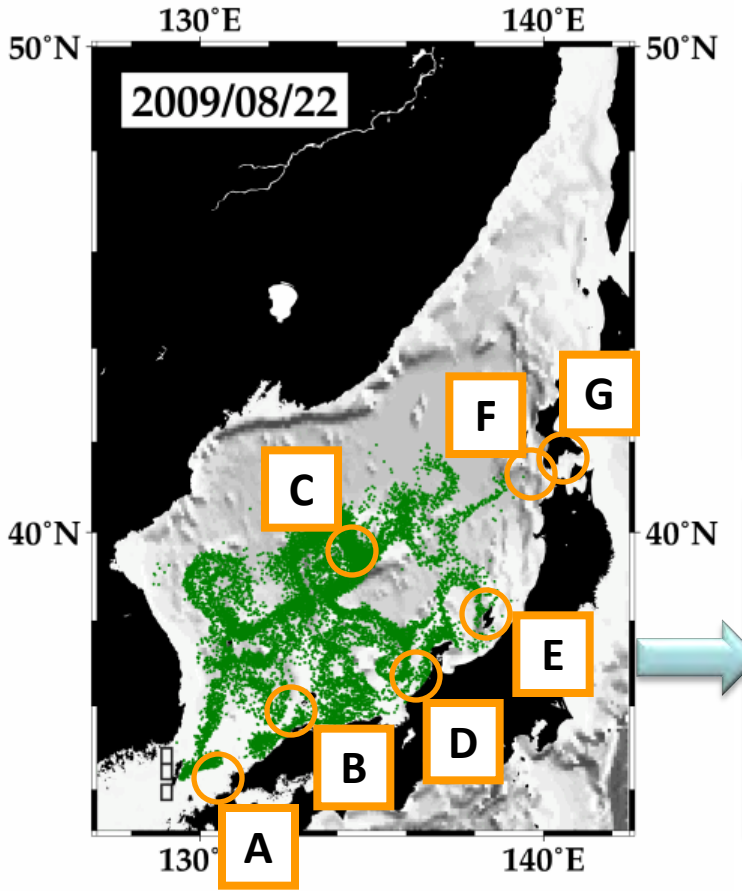

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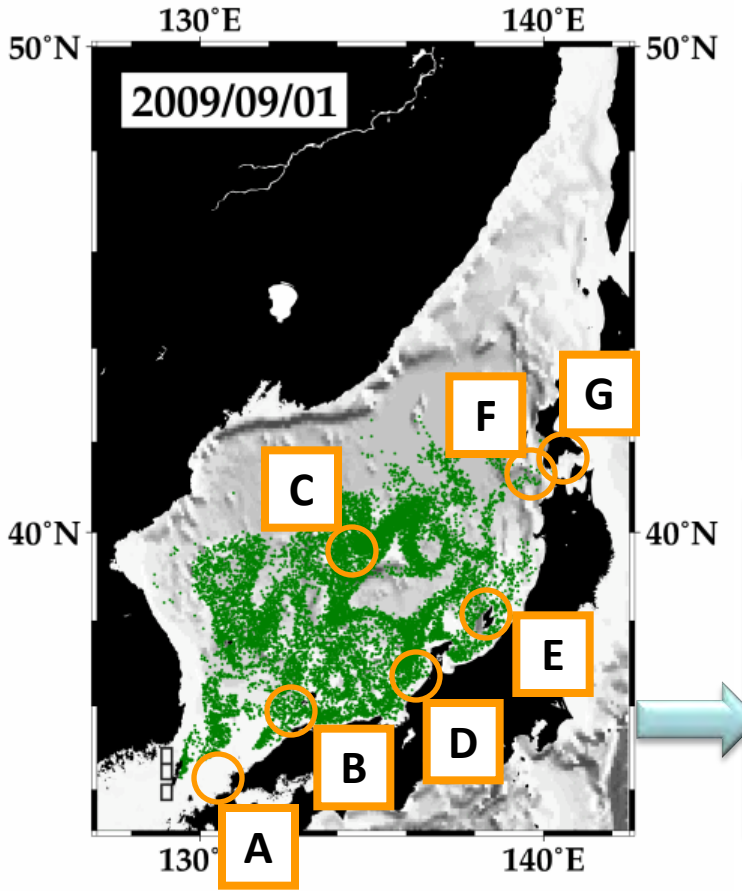

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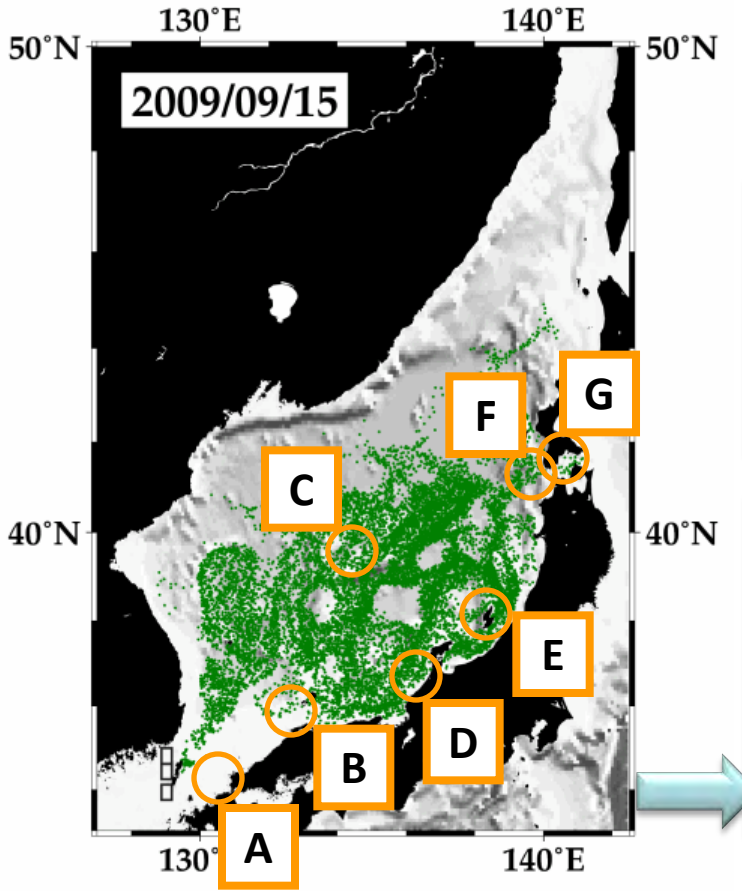

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Summary (1/2)

A numerical system to forecast appearance of the giant jellyfish *Nemopilema nomurai* in the Japan Sea was developed.

The system consists of an operational ocean forecast system (JADE) and a particle tracking simulator.

Virtual particles which mimic the jellyfish are released in the model ocean, then the movement of the particles is tracked.

The particle release conditions are configured based on sighting surveys in the Tsushima Strait and jellyfish appearance reports from fishermen.

The system successfully predicted the jellyfish migration in 2009.

Summary (2/2)

At present, the system can't produce any quantitative forecast of *N. nomurai*. To make quantitative forecasts, more intensive investigation and monitoring are still needed.

The forecast system was developed as a part of an international research project on *N. nomurai*, which is cooperatively conducted by China, Korea and Japan.

I hope that the international research network will be continued in future for more detailed investigation of *N. nomurai* and reduction of damages on fisheries.