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## 1. Introduction and Purpose

Distributions of fisheries resources are closely related to the ocean conditions in the surface layer (e.g. water temperature, current velocity, allocation of fronts and warm/cold eddies). Hence, the in-situ CTD observation network in the Japan Sea is maintained by the national and the prefectural fisheries research institutes of Japan. However, in-situ CTD data observed by research vessels are highly limited in space and time, especially offshore area.

In this study, a numerical forecasting system with data assimilation of sea surface temperature (SST), sea surface height anomaly (SSH) and also in-situ CTD data is introduced for reproducing and forecasting the oceanographic conditions of the Japan Sea continuously in space and time.

## 2. Operational Forecasting System

### 2.1. General Circulation Model

- **RIAM Ocean Model** developed by Kyushu Univ. (Lee *et al.*, 2003; Hirose *et al.*, 2007)
  - Primitive equation OGCM
  - Hydrostatic and Boussinesq approximation
  - B-grid, z-coordinate, free surface
  - Generalized Arakawa scheme (Ishizaki and Motoi, 1999)
  - Mixed layer scheme (Noh and Kim, 1999)
  - Isopycnal diffusion scheme (Gent and McWilliams, 1990)
- Model resolution
  - Horizontal: 1/12° Vertical: 36 layers (0-3600m)

### 2.2. Input data

- Surface atmospheric conditions: Grid Point Value, JMA
- Sea surface temperature: New Generation Sea Surface Temperature, Tohoku Univ
- Sea surface height: Only along-track data, Naval Research Laboratory Stennis Space Center (Figure 1)
- CTD data: Observed by national and prefectural fisheries research institutes, summarized by the Japan Sea National Fish. Res. Inst. (Figure 2).
- Inflow through the Tsushima Strait: ADCP data from ferryboat "Camellia"

### 2.3. Data assimilation method

- **SSH**: Assimilated using an approximate Kalman filter (Hirose *et al.*, 2007)
- **SST, SSS**: Restoring with optimized nudging (Manda *et al.*, 2005)
- **CTD**: In this study new scheme is introduced; **dynamic height calculated from CTD profile is assimilated using an approximate Kalman filter**

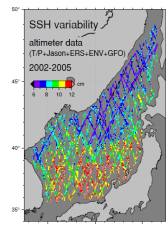


Figure 1. Standard deviations of SSH along the satellite tracks (after Hirose *et al.*, 2007).

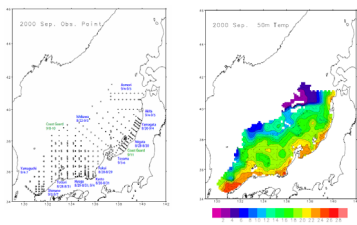


Figure 2. (a) Monthly CTD observation network constructed by national and prefectural fisheries research institutes of Japan. (b) Temperature distribution at the depth of 50m in September 2000.

## 3. Effect of the CTD assimilation scheme

As a result of adding the CTD assimilation scheme, warm/cold eddies distribution was well improved (Figures 3, 4) and the accuracy of reproducibility increases (Table 1). For example, the RMS difference between the observation and the assimilation result by using SST and SSH is estimated as 1.00 °C. On the other hand, that by using SST, SSH and CTD is estimated as 0.95 °C. In particular, CTD is highly effective in reproducing coastal ocean conditions, because SSH is inaccurate in the coastal area (Figure 5).

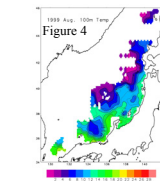
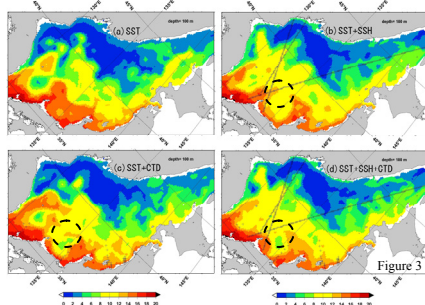


Figure 3. Assimilated temperature distributions in August 1999 at the depth of 100m by using (a) only SST, (b) SST+SSH, (c) SST+CTD and (d) SST+SSH+CTD

Figure 4. Observed temperature distribution in August 1999 at the depth of 100m.

RMS	SST	SST+SSH	SST+CTD	SST+SSH+CTD
SSH [cm]	9.71	8.59	9.02	8.57
100m temp. [°C]	1.10	1.00	0.98	0.95

Table 1. RMS difference between the observation (SSH and T at 100m) and four cases of data assimilations.

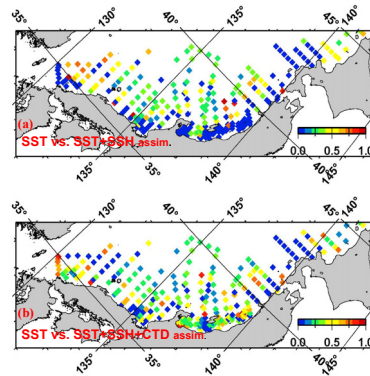


Figure 5. RMS decreasing score (a) between the only SST assimilation and the SST+SSH assimilation, (b) between the only SST assimilation and the SST+SSH+CTD assimilation, at 100m depth in 2001.

The score is defined by following equation.

$$\text{score} = 1 - \sqrt{\frac{\sigma_{\text{only SST}}^2 - \sigma_{\text{assim}}^2}{\sigma_{\text{only SST}}^2}}$$

If latter assimilation is effective, the score becomes nearly 1. If that is ineffective, it becomes nearly 0.

The CTD assimilation is highly effective in the coastal area.

## 4. Comparison between the result of the assimilation and in-situ CTD data

- Surface (0m) temperature distribution is well reproduced
- At the depth of 50-100m, in the Tsushima Warm Current region and the subarctic region it is basically reproduced. In the central region, it tends to be warm.
- At the depth of 200m, it tends to be warm generally.

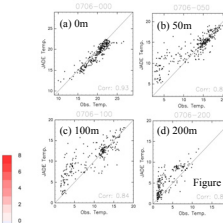
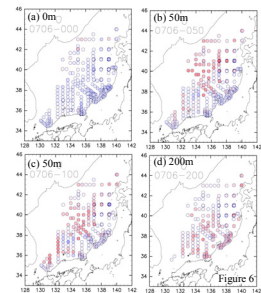


Figure 7. Comparison of the temperature between the assimilation and in-situ CTD at the depth of (a) 0m, (b) 50m, (c) 100m, (d) 200m

Figure 6. Distribution of the difference between the assimilation and in-situ CTD at the depth of (a) 0m, (b) 50m, (c) 100m, (d) 200m

## 5. Open on the website

The result of this operational forecasting system of the Japan Sea is now open on the website (<http://jade.dc.affrc.go.jp/>), which is called as the **JADE** (Japan sea Data assimilation Experiment) system. On the website the forecasting of the temperature distribution and the current velocity for 90 days in the Japan Sea can be seen. The website updates every week (sorry, now only in Japanese).

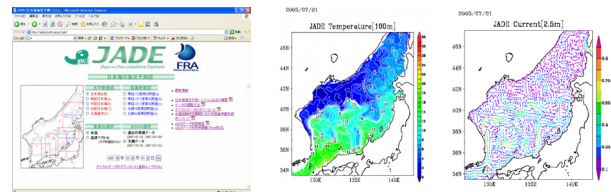


Figure 7. Entrance of the JADE website (left), an example of the temperature (center) and the current velocity (right).

## 6. Application to fishery environments

- Migration of the giant jellyfish "*Nemopilema nomurai*". Huge number of the jellyfish attacked to the Japanese coastal area in 2003, 2006 and 2007.
- Passive transport and survival process of the larvae of the Japanese common squid "*T. pacificus*".

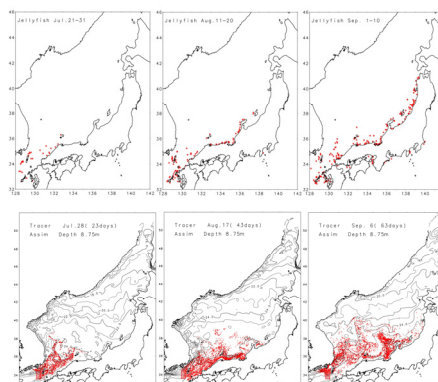


Figure 8. Sightings of the jellyfishes (upper panels) and the simulated distribution of the jellyfishes (lower panels) in July 21-31 (left panels), August 11-20 (center panels) and September 1-10 (right panels), respectively.

Migration of the giant jellyfishes to the Japanese coast in the Japan Sea can be reproduced and it was also basically successful in forecasting.