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JAMSTEC

# R/V Mirai Survey Reveals Features and Biological Impact of Large Warm-Core Eddy in the Arctic Ocean

## 1. Overview

A large eddy, filled with warmer water (with a maximum temperature of ~ 7ºC) than surroundings (~ 0ºC) and spanning approximately 100 km in diameter, was found in the Canada Basin of the Arctic Ocean during the research cruise of JAMSTEC Research Vessel (R/V) Mirai from September to October in 2010. Detailed hydrographic surveys were conducted on the eddy to characterize its hydrographic conditions, which brought back valuable insights into the role and impact of this large warm-core eddy on the Arctic marine ecosystem.

Hydrographic surveys revealed:

(1) The warm-core eddy was spinning anti-cyclonically (clockwise) and was unusually large compared to those generally observed in the Arctic Ocean. The eddy contained water of high ammonium concentrations, which was likely to originate from the Chukchi Sea shelf.
(2) The eddy with high ammonium concentrations seemed to play an important role in supplying nutrients to the surface layer of the Canada Basin, where nitrate was depleted, affecting the marine ecosystem of the Arctic.

This study was carried out by Shigeto Nishino and his colleagues at the Research Institute for Global Change (RIGC), JAMSTEC. Their work was published in the August 26 issue of Geophysical Research Letters.

Title: Impact of an unusually large warm-core eddy on distributions of nutrients and phytoplankton in the southwestern Canada Basin during late summer/early fall 2010
Authors: Shigeto Nishino, Motoyo Itoh, Yusuke Kawaguchi, Takashi Kikuchi, and Michio Aoyama

## 2. Background

Eddies are often observed in the oceans including the Arctic basins. The Arctic eddies are generally small cold-core eddies, about 10 to 20 km in diameter. They commonly occur at water depths between 100 and 200 meters and thus are less likely to influence biological activities in the surface layer.

Meanwhile, large subsurface eddies, more than several tens of kilometers in diameter, have been found in satellite images. Some studies have also confirmed the development of a large eddy in numerical simulations. Yet, due to a low occurrence of large features, their hydrographic characteristics and impact on marine biological activities remained elusive.

In the Arctic basins, nitrogenous nutrient is much lower than that in the continental shelf water. Also, its sea surface used to be covered by ice year-round. These two factors combined led to low biological activity.
In recent years, however, the sea ice retreat has brought more sunlight to the Arctic surface layer, enhancing photosynthesis and phytoplankton production. On the other hand, increasing sea ice melt accelerates freshening and acidification of the Arctic Ocean, resulting in the inhibition on biological activity.

To understand changes in the Arctic marine biological activity, it is crucial to identify pathways of nutrient supplies to the euphotic zone – the layer where sufficient sunlight reaches for photosynthesis. Yet, details are still not fully understood. If a warm-core eddy in the surface layer is a provider of nutrients to the euphotic zone in the Canada Basin, it could enhance the growth of phytoplankton.

**3. Data collection**
Led by Chief Scientist, Motoyo Itoh, the Arctic Ocean cruise was carried out on board R/V Mirai during late summer/early fall (September to October) in 2010. Data were collected on oceanographic and metrological parameters from the open water area in the Pacific side of the Arctic Ocean.

During the cruise, a large area of warm water was found north of the Chukchi Sea shelf in the southwestern Canada Basin, at around 74°N 160°W. The warm water extended from the surface to a depth of 200 meters. To characterize hydrographic and biological properties of this water mass, detailed surveys were conducted along north-south and east-west transects covering the area (Fig. 1).

**4. Results**
The vertical section of the temperature along the survey lines shows that the warm water was in a huge anticyclonic (clockwise) eddy, approximately 100 km in diameter. The core temperature reached up to 7ºC warmer than the surrounding water. With an estimated diameter of 100 km and a depth of 50-200 meters (150 meter thick), the total volume of the eddy was estimated at 1.2 trillion $m^3$(Fig. 2A).

The warm-core eddy also showed high ammonium concentrations compared to those in the surrounding water (Fig. 2B). As ammonium is produced from the decomposition of organisms on the seabed of the shelf during summer, it is suggested that the high ammonium water in the eddy originated from the Chukchi Sea shelf adjacent to the Canada Basin. The concentrations of chlorophyll *a*, a photosynthetic pigment in phytoplankton cells, were also high in the euphotic zone of the warm-core eddy area, especially those of picophytoplankton (< 2μm cell size; e.g., flagellate), which utilized ammonium for their growth (Fig. 2C, D).

**5. Comparison with the past data**
According to the data from the 2002 R/V Mirai Arctic Ocean cruise, there were abundant and various nutrients in the euphotic zone of the Canada Basin (Fig. 3A), which allowed for the existence of large phytoplankton such as diatoms.

The recent sea ice melting, however, has accelerated the accumulation of freshwater in the euphotic zone, decreasing nutrient concentrations and thus making there uninhabitable for large phytoplankton.

The data obtained in the 2010 cruise revealed that the large warm-core eddy plays an important role in transporting ammonium-rich water to the nutrient-poor euphotic zone in the Canada Basin (Fig. 3B), which may result in a higher biomass of picophytoplankton over the warm-core eddy.

These findings were derived from the first and direct hydrographic and biological observations of a large eddy in the Arctic Ocean. The data obtained suggest that the large eddy was made of warm, nutrient-rich water and is largely affecting the distributions and production of phytoplankton in the Arctic basin.

**6. Perspective**

The rapid sea ice retreat in recent years has been causing a variety of changes to the Arctic Ocean and its ecosystem. To understand such changes and their effects on the environment, comprehensive in-situ observations and accumulation of data are necessary. The surveys by R/V Mirai serve to provide such valuable information to assess meteorological, physical oceanographic, chemical and biological changes in the ocean.

Combined with satellite monitoring and numerical modeling, JAMSTEC will continue conducting detailed surveys over a wide area of the Arctic Ocean. This will contribute to a better understanding of the climate change in the Arctic Ocean and its effects on the global climate system.

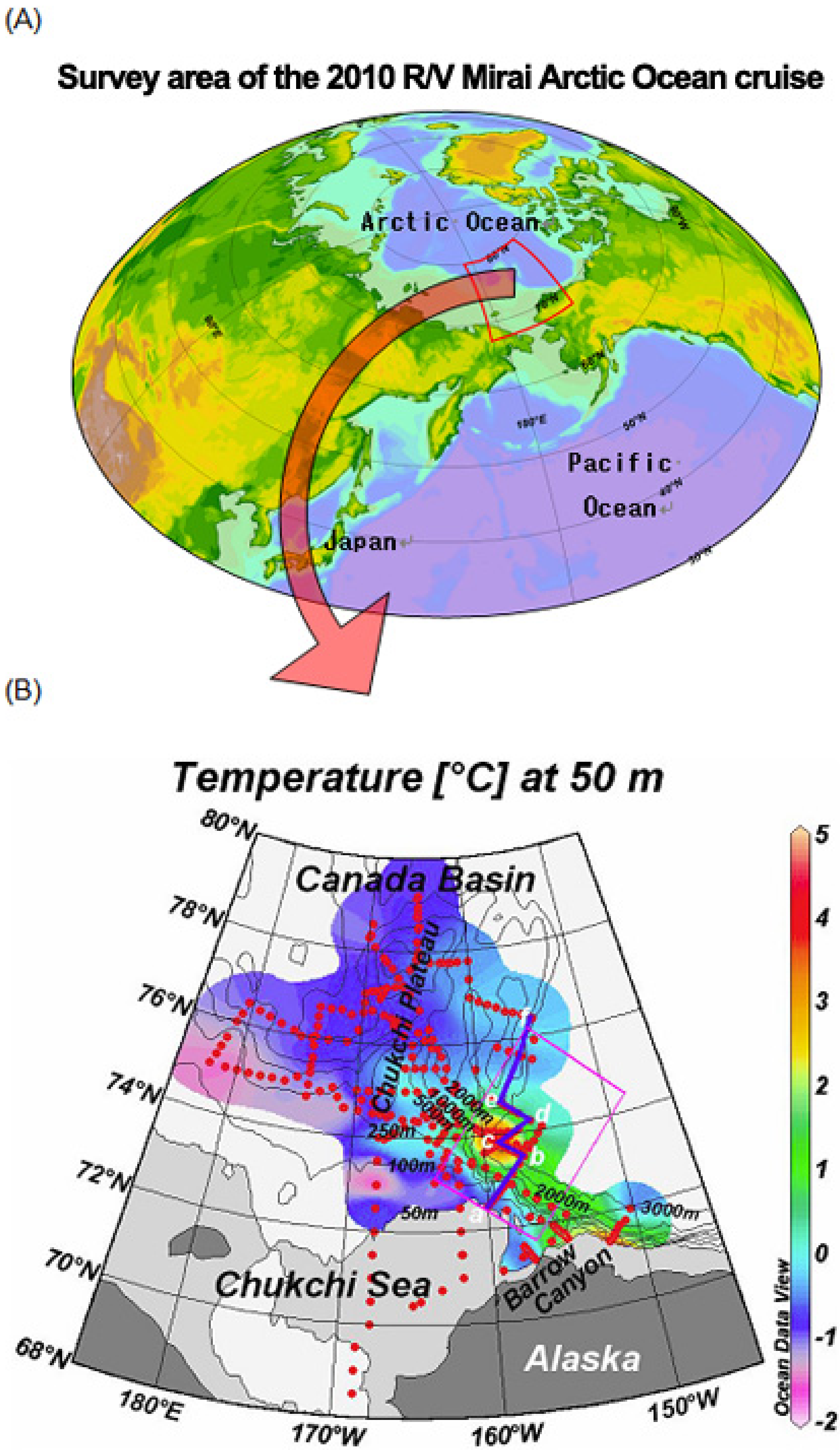
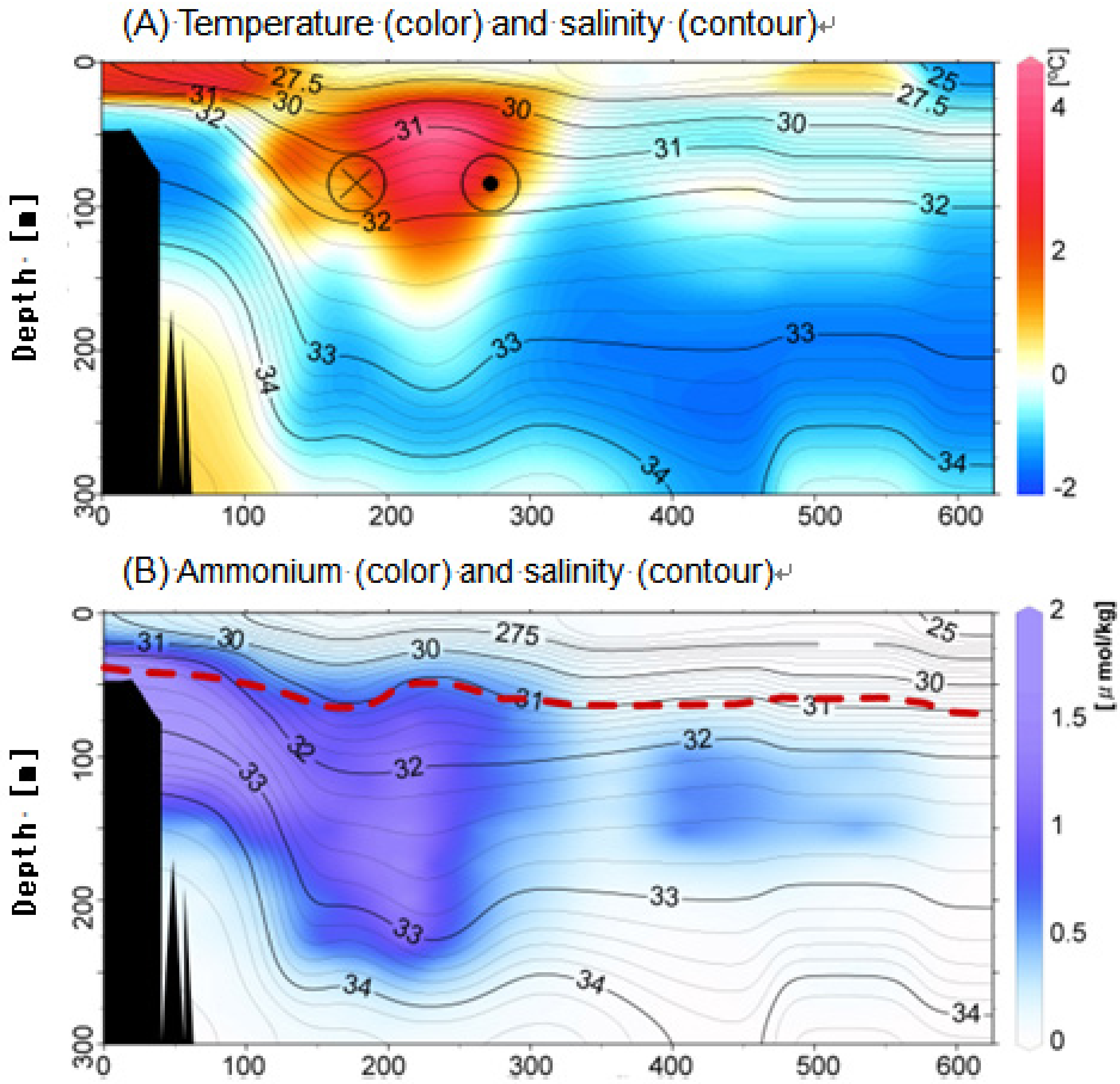



**Figure 1.**
**(A) Survey area of the 2010 R/V Mirai Arctic Ocean cruise**
**(B) Enlarged map of the area enclosed by red line in (A)**
Hydrographic stations of CTD/water sampling and XCTD (dots) of the R/V Mirai Arctic Ocean cruise in 2010 and temperature distribution at 50 m depth (color). Contour lines indicate isobaths of 50, 100, 250, 500, 1000, 2000, and

3000 m. The vertical sections along the blue lines are shown in Figure 2. The locations indicated by letters a, b, c, d, e, and f, correspond to the locations shown in Figure 2 (C). The warm-core eddy was observed at around 74°N 160°W.



(A) Temperature (color) and salinity (contour)
Depth [m]
[°C]
(B) Ammonium (color) and salinity (contour)
Depth [m]
[μ mol/kg]

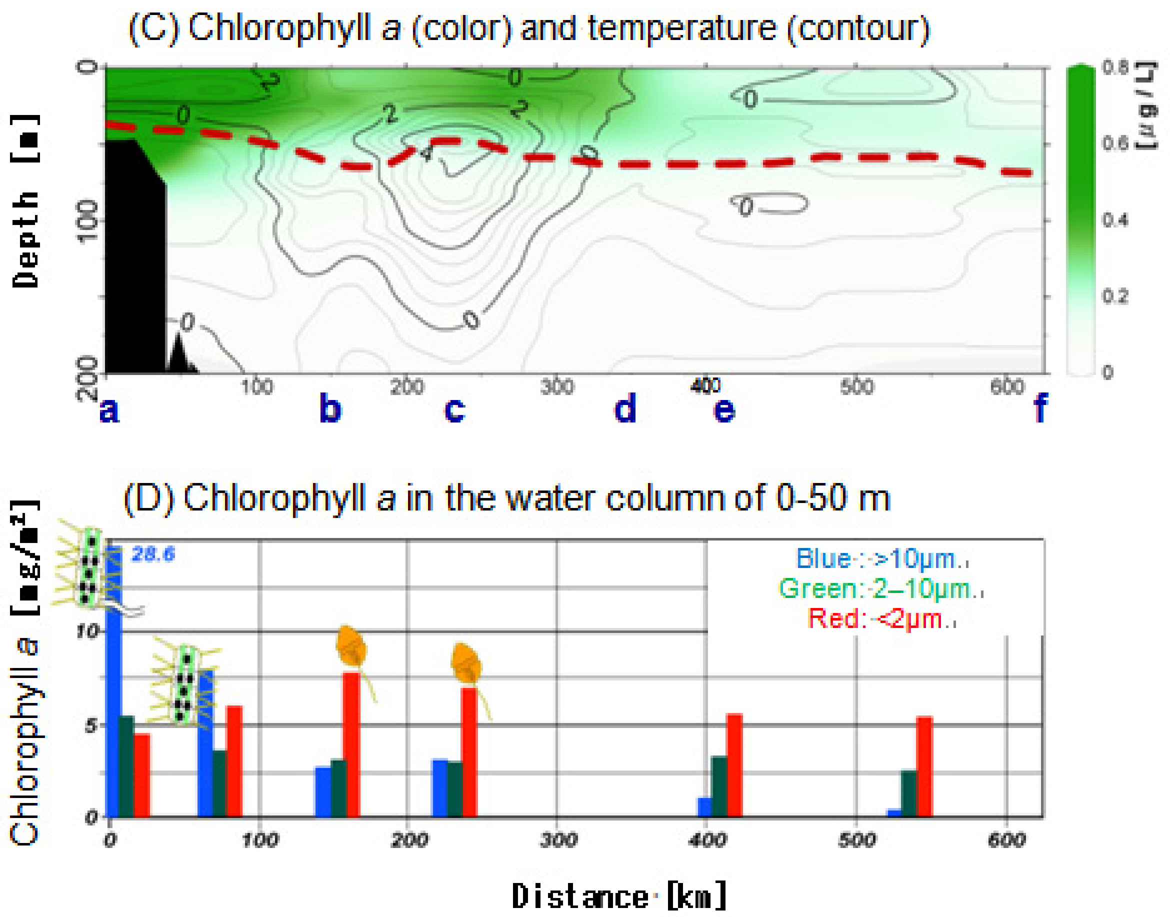



**Figure 2. Vertical sections of :(A) temperature [°C] (color) and salinity (contours); (B) ammonium concentration [μmol/kg] (color) and salinity (contours); (C) chlorophyll *a* concentration [μg/L] (color) and temperature [°C] (contours); and (D) phytoplankton biomass [mg/m$^2$] from the surface to a depth of 50m for phytoplankton chlorophyll *a* in cells >10μm (blue bars), cells 2–10μm (green bars), and cells <2μm (red bars) from the Chukchi Sea shelf to the Canada Basin along the blue lines illustrated in Figure 1.**

The symbols ⊗ and ⊙ in (A) denote the directions of the current, flowing into and out of the paper (away from and towards readers), respectively. That is, the warm water is spinning clockwise. The red-dashed line denotes the depth of euphotic zone.

The symbols  and  in (D) represent large phytoplankton (diatoms) and picophytoplankton (e.g., flagellate), respectively. The former is dominant in the shelf area and the latter is dominant in the eddy.

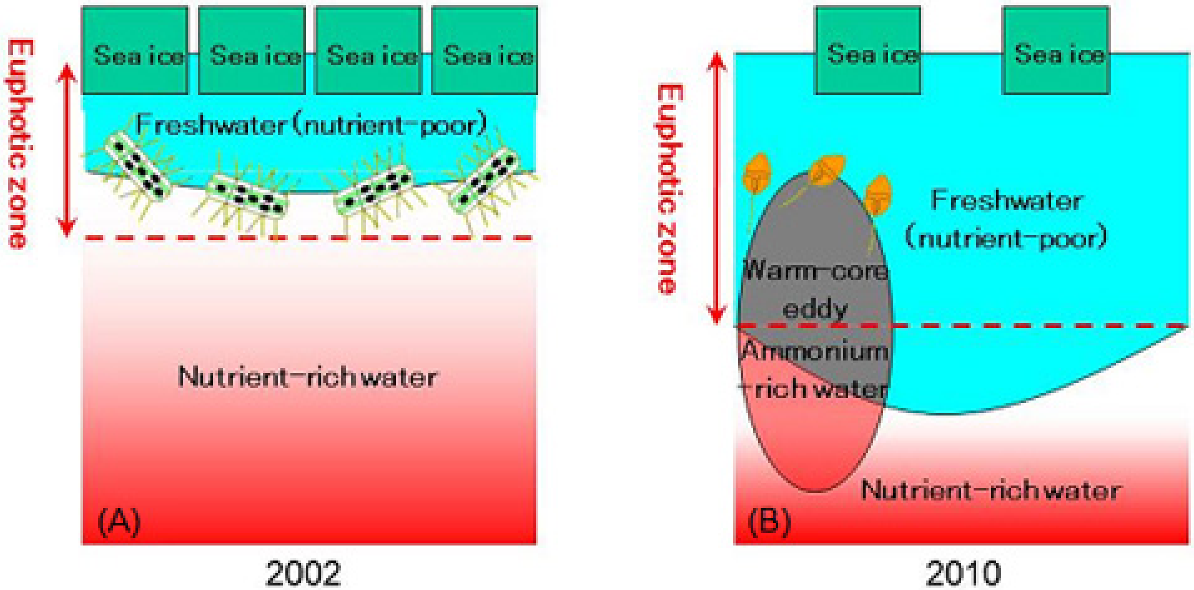



**Figure 3. Schematic diagrams of water column in the Canada Basin in 2002 and 2010.**
In 2002, nutrient-rich water existed in the euphotic zone, which was sufficient for large phytoplankton growth. In 2010, nutrient-poor freshwater was accumulated in the surface layer due to sea ice melt, resulting in the deepening of nutricline (the layer where the nutrient concentration increases rapidly with depth) and the removal of nutrient-rich water from the euphotic zone. This caused the disappearance of large phytoplankton (Diatoms). On the other hand, the supply of ammonium by the warm-core eddy to the euphotic zone sustained the growth of picophytoplankton (e.g., flagellate) over the eddy.

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