June 28, 2011
JAMSTEC

JAMSTEC scientists succeed in observing a detailed structure of Arctic cyclogenesis

Introduction
Jun Inoue and Masatake Hori, Research Institute for Global Change (RIGC), JAMSTEC, successfully obtained in situ observations on the genesis and development of an Arctic cyclone that occurred near the Arctic marginal ice zone (79.0° N) on its expedition in September 2010.

The observations, carried out aboard JAMSTEC's Oceanographic Research Vessel "Mirai," revealed that the Arctic cyclone had a structure and features very similar to those observed at mid-latitudes. The heat content of the water column between before and after the cyclone's passage suggests the supply of a large amount of oceanic heat to the atmosphere in a short period of cyclogenesis. The findings provide invaluable clues to understanding mechanisms of sea ice retreat and Arctic warming, which is happening at an unprecedented speed and considered to be a contributor to ongoing global warming.

Their work will appear in the Geophysical Research Letters on 28 June, 2011.

Title: Arctic cyclogenesis at the marginal ice zone: A contributory mechanism for the temperature amplification?
Authors: Jun Inoue, Masatake Hori

Results
During the 2010 Arctic expedition by R/V Mirai, researchers encountered a developing low pressure system with a cold front and a warm front along the latitude of 79.0° N (Fig.1). The frontal system traveled southeastward, and within two days grew in a size and intensity comparable to those observed at mid-latitudes. The process of this cyclogenesis was closely observed by researchers using shipboard radiosondes and a Doppler radar (Fig.2). Such direct and detailed observations of high-latitude cyclogenesis had never been obtained before.

The results suggest that some Arctic cyclones occur along the marginal ice zone and that their cyclogenesis and development are similar to mid-latitude cyclones. The heat content analysis of the water column before and after the cyclogenesis revealed a 2 degree decrease in temperature, resulting in the southward expansion of the sea ice margin from 80.0° N to 78° N. The oceanic heat loss during this four-day cyclogenesis event is estimated to be 123 MJ/m^2, which is equivalent to the amount of solar radiation absorbed into the ocean during the latter half of September (Fig. 3).

The in situ observations obtained in this study, offer invaluable clues to a possitive feedback loop possibly taking place in the Arctic; where the arctic cyclone in autumn, induced by summer sea ice melting, helps transport a large amount of oceanic heat to the atmosphere, warms up the Arctic winter and hinders sea ice formation, resulting in thinner and reduced sea ice extent in summer.

Background

Sea ice in the Arctic recovers to its previous levels when the winter refreezing begins to cover the Arctic in November. This means that heat stored in the ocean during summer is cooled and lost by the time of freeze onset in autumn, regardless the extent of sea ice during the preceeding summer. This indicates that in autumn, the heat exchange between the warm ice-free ocean surface and the atmosphere must become larger; however, little observational evidence of the heat exchange has been reported due to limited in situ observations.

Summary of methods

The drastic decline in Arctic sea ice, observed in recent years, has broadened the navigable range of the Arctic Ocean for ships, including R/V Mirai. During its expedition from September to October 2010, the vessel reached 79°11" N on September 24, breaking its northernmost record again. Intensive meteorological surface observations were made from 23 to 28 September immediately after the onset of cyclogenesis,

The observations included:

1) Doppler radar observations to measure clouds with precipitation and horizontal wind direction and velocity (detection range: 300 km)
2) Three-hourly radiosonde observations (the balloon can ascend to an altitude of 20km) to measure the vertical profile of atmospheric temperature, moisture, pressure, and wind direction and velocity
3) Sea surface temperature and salinity measurements along a survey line to examine the thermal change in the water column before and after the passage of the cyclone (at an interval of two weeks)

Future studies

The Arctic region is among the most vulnerable to climate change. Continuous and in-depth monitoring on its hydro and meteorological conditions, therefore, is one of the most important challenges for scientist to better evaluate the present and future global warming. Yet the mechanism of sea ice retreat, along with air-sea heat exchange details involving arctic cyclogenesis, remain elusive due to the limited number of observations. The air-sea heat exchange process in autumn, revealed by the use of advanced observational equipment on board the Mirai, will help researchers to better project Arctic warming and associated meteorological events.
These include the projection of navigation hazards, such as strong winds, high waves and resultant southward migration of sea ice, which affects the safety of Arctic summer navigation.

Appendix

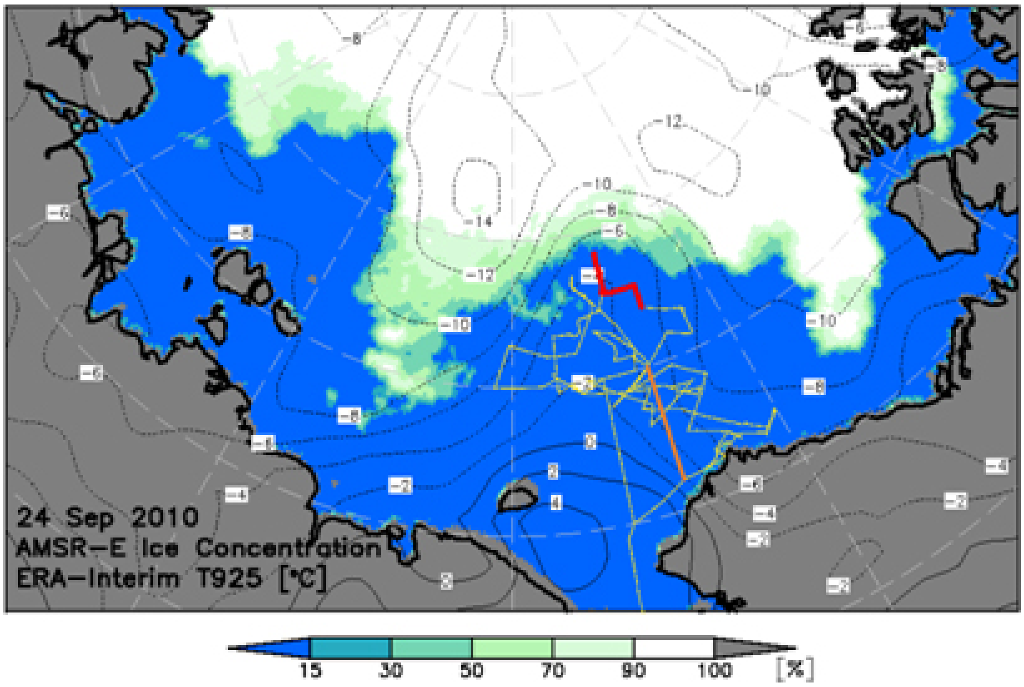

Figure 1. Sea ice map with tracks of Mirai in 2010. The red line shows the cruise track during the period for intensive cyclogenesis observations (23–27 September), The orange line shows the cruise track for hydro observations. The cyclone traveled southeast during this period. The white area and counters denote sea-ice concentration (%) derived from the AMSR-E, and air temperature at 925 hPa on 4 September 2010, respectively.

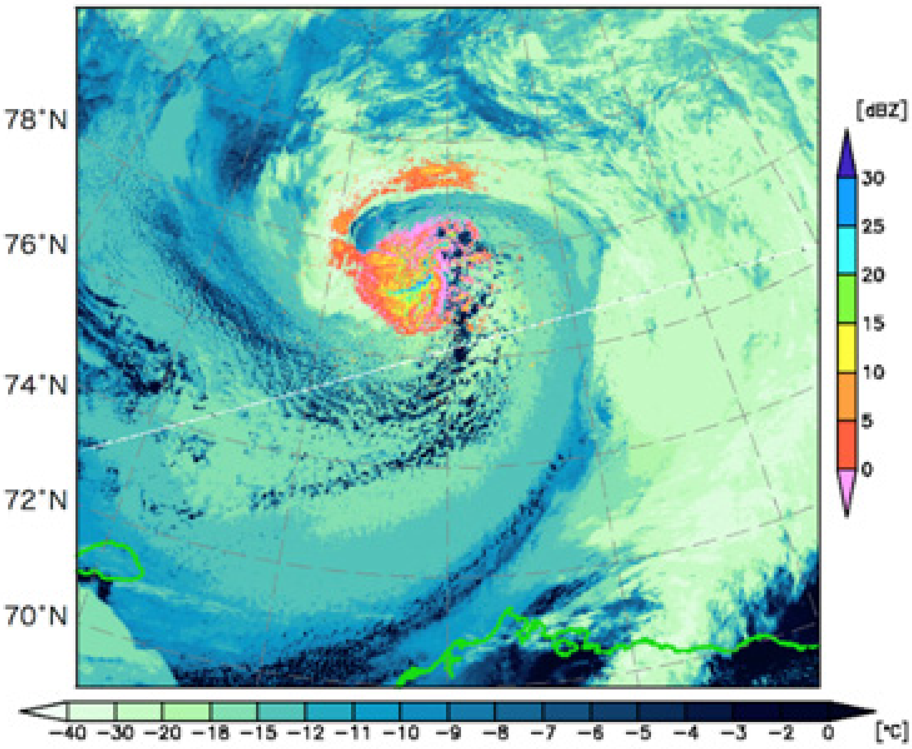

Figure 2. Satellite image and corresponding meteorological fields (1,300 square meters). NOAA/AVHRR infrared images on 24 September were combined with radar reflectivity. Cool surface air flows eastward behind the cold front. This makes the ocean to release large amounts of heat and

moisture into the atmosphere, resulting in the development of cloud streaks across a wide area.

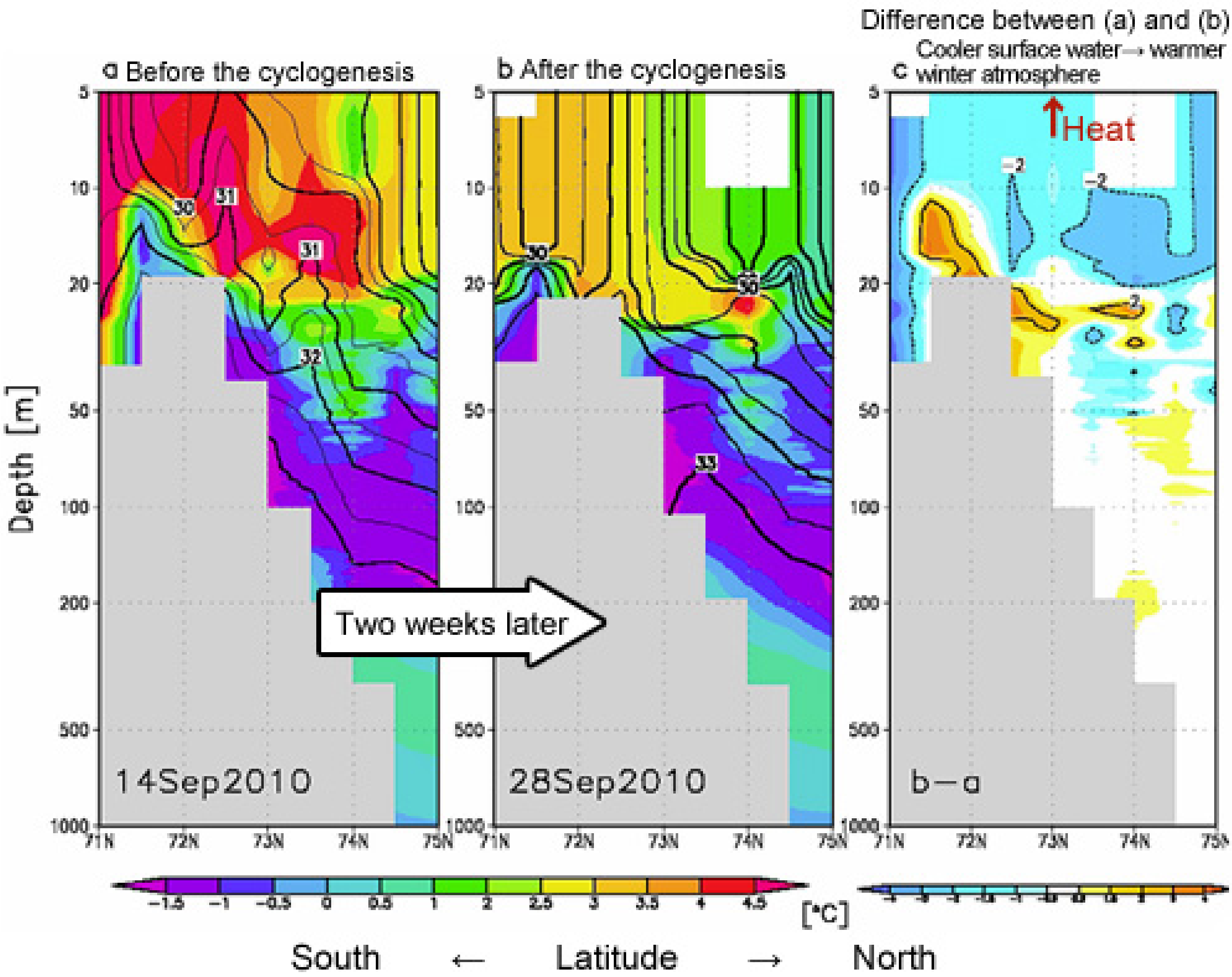

Figure 3. Ocean sections along 162°W. Latitude-depth cross-sections of water temperature (°C: shade) and salinity (psu: contour) on: (a) 14 September, (b) 28 September and (c) The difference between the water temperature in respective days. The gray area indicates the seafloor area. After the passage of the cyclone, the water temperature decreased dramatically in the upper 20 meters, suggesting the surface heat exchange between the ocean and the atmosphere. The released heat warms surface air temperature during the transitional season from autumn to winter, which contributes to an Arctic temperature amplification during winter. Salinity levels, shown in black contours in (a) and (b), represent the water mass structure.

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