対流圏中層における凝結過程が北極低気圧の発達に及ぼす影響

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Influences of condensational process in the middle troposphere on developing of a summer Arctic cyclone

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A cyclone event that occurred on 8 September 2014 over the Chukchi sea was investigated forcusing on a role of condasational heating in the cyclone development. The radiosonde observations conducted during an Arctic research cruise by R/V Mirai indicated high relative huidity layers in the middle troposphere with strong southerly winds, suggesting that adiavatic heating associated with northward meridional heat and moisture transports was predominant during a passage of the frontal system. Based on an atmospheric reanalysis, this heating appeared to strengthen the vortex in the lower troposphere. This indicates that the Arctic cyclone developed via coupling between upper and lower tropospheric vortices, rather than via the effects of surface heat fluxes. The roles of surface conditions (sea-ice cover and sea surface temperature) and a condensation process at the middle of troposphere on the cyclone development will be discussed using numerical simulations.

1. In situ observations

With the aim of studying the thermodynamic and dynamic structure of an Arctic cyclone, an Arctic cruise by R/V Mirai was conducted in the Chukchi and Beaufort seas in September 2014. During a stationary observation period from 6-25 September at 74.75°N, 162.00°W, 3-hourly intensive radiosonde observations were made (RS92-SGPD, Vaisala). From the observation results (Fig. 1), warm and moist anomalies with southerly winds were prominent at the middle and lower troposphere at 0600 UTC on 8 September. On 7-8 September, sea level pressure (SLP) dropped by 10 hPa on the passage of a frontal system. The surface air temperature decreased from 2 to -1 °C during this event, but sea surface temperature (SST) remained almost constant. This suggests that the effects of condensational heating associated with moisture transports at middle troposphere could be more important for the cyclone development compared with a variability of surface conditions.

2. Numerical experiments

The Weather Research and Forecasting model (WRF : Shamrock et al., 2008) has been used in this study. The horizontal and vertical resolutions were set to 21km and 33 vertical levels up to 10 hPa. The initial conditions for SST and sea-ice concentration were obtained from the National Oceanic and Atmospheric Administration daily 1/4° OISST (optimal interpolation sea surface temperature) version 2 (Reynolds et al., 2007). The other prognostic variables were derived from Climate Forecast System Reanalysis Version 2 (CFSv2) (Saha et al., 2014). Lateral and bottom boundary conditions were updated in the model every 6 hour. The model was integrated from 00 UTC on 1 September to 18UTC on 13 September for all experiments. The experiments consisted of a control (CTL) and sensitivity runs. The CTL run is a realistic simulation of the conditions between 1 September and 13 September 2014. The sensitivity experiments comprise several simulations. No-ice run and on-ice run used the sea-ice concentration and SST on 1 September in 2012 and 1 March 2014 respectively. These experiments are based on the assumption that the change in the surface conditions modifies upward transports of heat, moisture and momentum through surface flux anomalies. Fig. 2 shows the modeled sea-ice concentration and SLP on 8 September 2014. The model reproduced the observed event very well. Comparing the results between the CTL and sensitivity runs, a value of baroclonicity in middle troposphere was almost similar each other, suggesting that the influence of lower boundary conditions on a development of this Arctic cyclone is less important (Fig. 3). In the presentation, we will also show additional sensitivity runs (dry experiments) to understand the role of condensational heating in developing of the cyclone, and will discuss the coupling process between upper and lower tropospheric vortices.

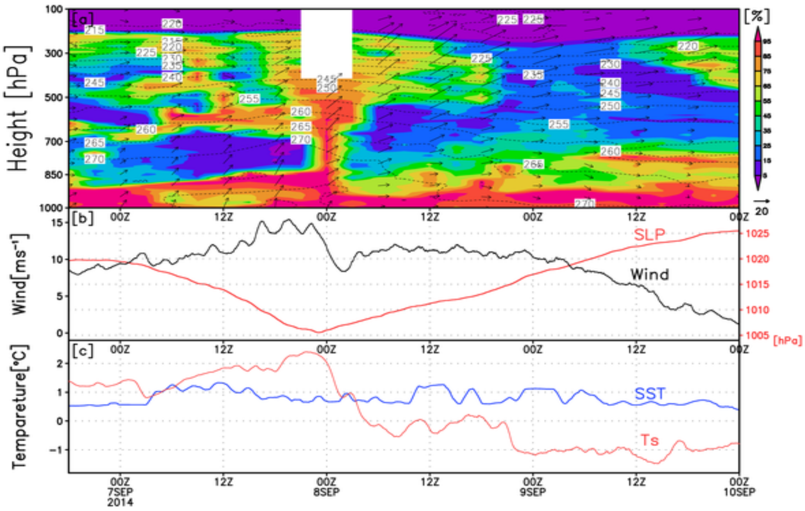

Figure 1: (a) Time–height cross sections of relative humidity (%, shading), air temperature (°C: contours), and horizontal winds (m s^{-1}: black vectors) derived from 3-hourly radiosonde observations. (b) Time series of SLP (red) and surface wind speed (black). (c) Time series of surface air temperature (red) and SST (blue).

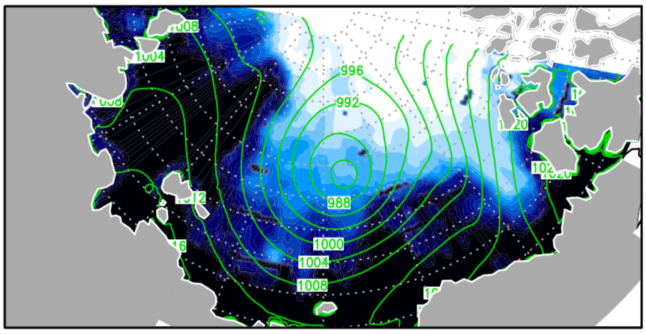

Figure 2: WRF model result of MSLP (solid contours at every 4 hPa) and sea ice concentration valid at 0900 UTC on 8 September 2014.

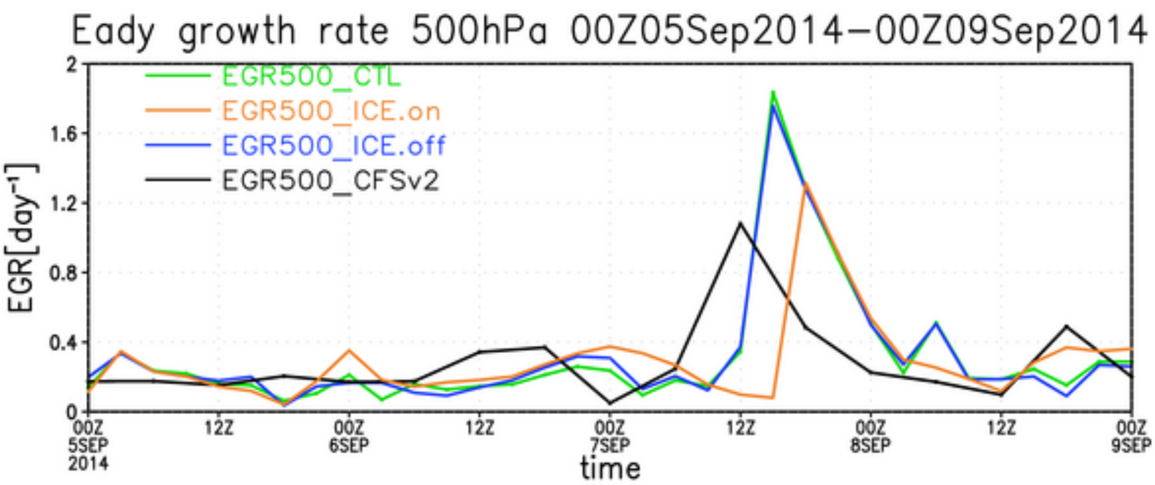

Figure 3 : Time series of EGR500 at the center of the cyclone.