Simulation on low pressure systems over the Arctic Ocean using a cloud-resolving model

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Nagoya University continues to develop Cloud Resolving Strom Simulator (CReSS). CReSS is applied to analyze the structure of precipitation systems in the tropics and mid-latitude regions. However, we have never conducted the simulation around the Arctic region, except for a case of the cloud-streak structure over the Labrador Sea during a cold-air outbreak. The R/V Mirai (MR13-06) of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) made an intensive observation using a Doppler radar, upper-air soundings, and instruments for surface meteorological parameters at a fixed observation point (168.25W, 72.75N) in the Arctic Ocean in 2013. To confirm the performance of CReSS in the Arctic region, we conducted a simulation to reproduce low pressure systems observed by the R/V Mirai.

A numerical experiment using CReSS is examined. The horizontal grid spacing is 2.5 km, and the domain has an area of 2000 km times 2000 km, including the fixed observation point of the R/V Mirai. The vertical grids are consisted of 32 layers and the top of the domain is set at 12.8 km. The numerical experiment is conducted for 72 h, starting at 00Z on September 23, 2013. Data of the Global Spectral Model (GSM: Horizontal grid resolution was 0.5 degree) provided by Japan Meteorological Agency (JMA) are used as the initial and boundary conditions of the simulation. Sea surface temperature (SST) is initialized using the Optimum Interpolation Sea Surface Temperature (OISST) data provided by National Oceanic and Atmospheric Administration (NOAA). Vertical heat transfer below the land and sea surfaces are calculated, as a result, time variation of sea surface temperature (SST), sensible and latent heat fluxes (SHF, LHF) from the surface are calculated. No sea ice parameterization is included.

A synoptic scale low pressure accompanying weak precipitation (snow) less than 1 mm/h is reproduced in the north of Wrangel Island. A mesoscale low pressure around the synoptic scale one is confirmed by a satellite observation. The simulation can reproduce a vortex-like structure related to the mesoscale low pressure. Using the Mirai Doppler radar, deep convective clouds whose echo-top height reaches a height of 4 km are observed around the mesoscale low. However, the cloud-top height in the simulation is restricted only below a height of 1.5 km, thus the deep convective clouds cannot be reproduced. To compare the simulation result with the satellite observation, 3-dimensional distribution of the reflectivity in the frequency of the CloudSat-CPR (95 GHz) is calculated using Satellite Data Simulator Unit (SDSU). The low reproducibility of the depth of convection is confirmed by the composite analysis using 20 flight paths. High reflectivity greater than 0 dBZ with the convective structure is observed by the CloudSat-CPR, however, the simulation cannot reproduce the high reflectivity region.

Time series of SST at the R/V Mirai between the observation and simulation are analyzed. At the initial time, OISST are 0.2 degree Celsius lower than that of the observation. SST is almost constant in the observation during the period, however, that of the simulation decreases gradually by the SHF and LHF. As a result, SST difference increases 1.0 degree Celsius at the end of the simulation. The constant SST would be attributed to the northward horizontal advection of warm water by southerly surface wind and heat loss by the SHF and LHF. CReSS cannot reproduce the wind-driven ocean flow, thus we fail to reproduce time series of SST. The failure of the SST at the R/V Mirai influences on the LHF from the sea surface and unrealistic saturated atmospheric boundary layer (fog) in the last 24 hours. The weak forcing from the sea surface would contribute to the

failure of the development of deep convection. The air-sea interaction and three-dimensional ocean simulation would be important to reproduce the meteorological phenomena in the Arctic region.

Keywords: Arctic region, air-sea interaction, a cloud-resolving model, mesoscale polar low

