Numerical simulation of lee-side downslope winds near Siorapaluk in northwest Greenland

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1. Introduction

We conducted the scientific traverse expedition "Snow impurity and glacial microbe effect on the abrupt warming in the Arctic (SIGMA) Traverse 2018", which has close connection with our research project "Recent surface darkening and abrupt melting of Greenland ice sheet" (SIGMA-II), across the ice sheet in northwest Greenland for studying the systematic change in surface mass balance depending on geographical conditions. During the expedition, snow pit works were performed on the way from Siorapaluk to the point marked as SIGMA-A as well as along the return path (Fig. 1). The expedition crews had initially planned to depart Siorapaluk on April 2, 2018. However, their departure was delayed by four days because of strong winds and snow blocking the way. Numerical simulations performed during the expedition to provide local weather information to the expedition team predicted strong downslope winds from the ice sheet in the northern part of Siorapaluk. This report will present the preliminary results pertaining to features of this strong wind obtained via simulation.

2. Numerical prediction system

The numerical prediction system was established based on Japan Meteorological Agency's nonhydrostatic model (JMA-NHM), using the same configuration as described in Hashimoto et al. (2016, 2017). However, the computational domain was extended to the east to cover the Icelandic islands, Svalbard Islands, and North Sea, and a new subdomain was embedded for dynamical downscaling simulation.

Prediction via numerical simulation was performed twice per day. Each time, simulation was first performed with a horizontal resolution of 5 km (5 km-NHM). A computational domain of 4000 km × 3500 km with 5 km-NHM (800 × 700 grid cells) was used. Next, simulation with a horizontal resolution of 1 km (1 km-NHM) was performed in the subdomain (650 × 650 grid cells) embedded within the domain corresponding to 5 km-NHM (Fig. 2). For both simulations, the standard latitude and longitude were 70.00° N and 39.00° W, respectively, in the polar stereographic projection. The southwest corner of each domain was located at 54.963° S, 61.719 °W and 74.00° N, 69.18° W for 5 km-NHM and 1 km-NHM, respectively (Fig. 2), and its maximum height was 22 km. There were 50 layers in the vertical direction, increasing in thickness from 40 m at the surface to 886 m at the top, in a terrain-following coordinate system.

For the 5 km-NHM, an integration time of 42 h was used with a time step of 10 s. The radiative processes were computed every 15 min with a horizontal grid spacing of 10 km. The initial and boundary conditions were obtained from JMA's global forecast. The simulation was started at 0400 and 1600 Western Greenland Summer Time (WGST) (WGST is 2 h behind Coordinated Universal Time (UTC)), corresponding to the forecast time (FT) of 6 h in JMA's global forecast starting at 0000 or 1200 UTC, respectively. Boundary conditions were specified every 6 h. For the 1 km-NHM, the simulation was started corresponding to a FT of 9 h in the 5 km-NHM simulation. An integration time of 18 h was used with a time step of 8 s. Computations of the radiative process were performed every 15 min using a horizontal grid

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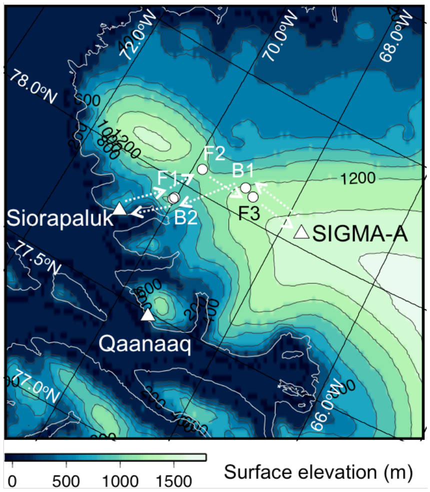

Fig. 1. Pathway of the SIGMA Traverse 2018.

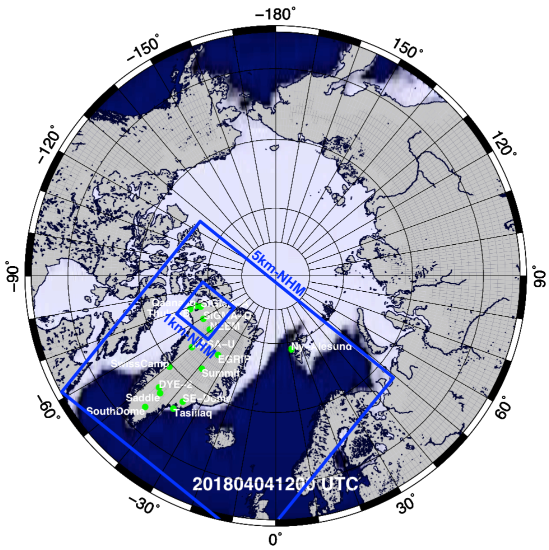

Fig. 2. Computational domains of weather predictions using 5km-NHM and 1km-NHM (blue boxes).

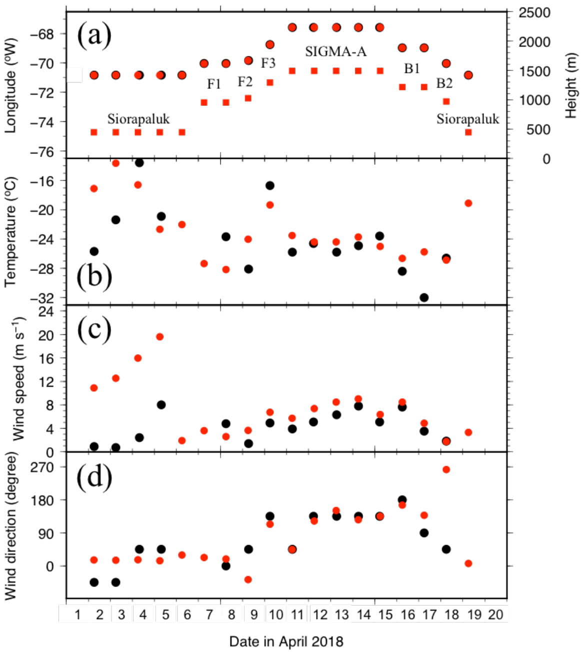

Fig. 3. Observed (black) and simulated (red) weather elements at the campsite every morning. (a) Longitude (circles) and height (squares), (b) air temperature, (c) wind speed, and (d) wind direction.

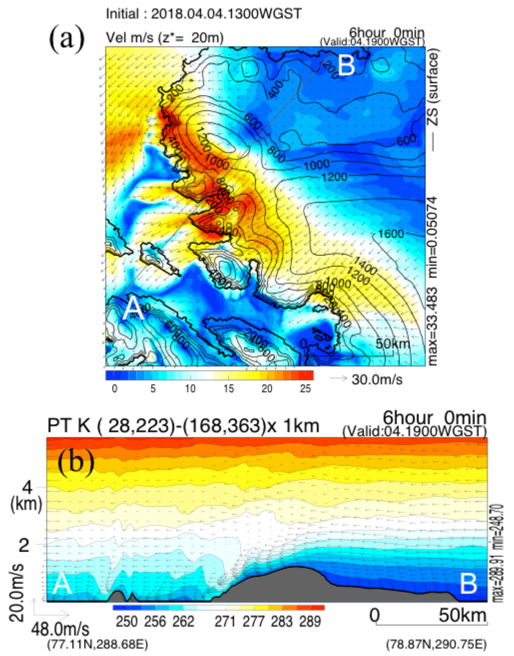

Fig. 4. (a) Surface wind speed (colored shade) and horizontal wind vectors. Black contours indicate the topography. (b) Potential temperature (colored shade) in the vertical plane along the line AB and projection of wind vectors on the plane.

spacing of 2 km. The initial and boundary conditions were obtained from the 5 km-NHM.

3. Simulation results

Figure 3 shows a comparison of the local weather elements reported every morning by an expedition crew through the satellite communication system (black) and those simulated using the 1 km-NHM (red). The simulation results are in agreement with the observation results. On April 2 and 3, the model predicted strong winds with speeds of approximately 12 ms^{-1}, while the observed wind speed was much less (< 2 ms^{-1}). However, conditions of blowing snow were clearly observed in the inland areas near Siorapaluk, indicating the approach of strong winds. In fact, over the next two days, the observed wind speeds increased to 8 ms^{-1}. Thus, the model overestimated the wind speed, but successfully reproduced the escalation.

Figure 4a shows the simulation results of surface winds at 1900 WGST on April 4, 2018. The results predicted the arrival of northerly winds from across the ridgeline, accelerating to greater than 30 ms^{-1} near Siorapaluk, and blowing further offshore. In contrast, in the upstream side of the ridge, the northerly winds were predicted to be weak. Figure 4b shows the vertical cross section of the predicted temperature along the line AB. The predicted temperature contours are distorted above the downstream slope, exhibiting characteristics of a hydraulic jump associated with a lee-side downslope wind. In the 850 hPa plane, low pressure exists over the northern Baffin Bay, while high pressure exists over the Arctic Sea, which increases the pressure gradient over northwest Greenland, thereby providing the environmental impetus for the northerly wind.

4. Summary

The lee-side downslope wind observed near Siorapaluk in northwestern Greenland was simulated using JMA-NHM. The simulation results reveal wind speeds up to 30 ms^{-1} near Siorapaluk, which is qualitatively consistent with the fact that the departure of the expedition crew was held up due to strong winds. According to the simulation results, the lee-side downslope wind is driven by environmental factors such as the northerly wind caused by the synoptic-scale pressure pattern resulting from the northern high and southern low pressure conditions. Additional studies indicate that this type of wind appears occasionally near Siorapaluk. It is possible that such winds cause nonnegligible effects on the cryosphere and atmosphere, as well as on the cultural anthropological aspect of the local community, which is a potential subject for future study.

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