P1.29 HIGH RESOLUTION REGIONAL CLIMATE SIMULATIONS OVER ICELAND USING POLAR MM5

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1. INTRODUCTION

Iceland is a high latitude land area that contains a variety of mcroclimates because its complex mesoscale terrain and landuse. An important issue is how to use large-scale atmospheric analyses in conjunction with high-resolution topography and landuse to reconstruct the historical states of local climate over Iceland. An alternative approach to climate modeling is limited area modeling wherein the horizontal resolution typical for the mesoscale is applied to a limited area of interest.

The Polar MM5 is based on extensive previous research into mesoscale modeling of high latitudes by the Polar Meteorology Group of the Byrd Polar Research Center at The Ohio State University, MM5 has been modified for use in polar regions and is referred to as the Polar MM5. The key modifications are: revised cloud / radiation interaction; modified explicit ice phase microphysics; optimal turbulence (boundary layer) parameterization; implementation of a sea ice surface type; and improved treatment of heat transfer through snow / ice surfaces. Model validations and case studies of Polar MM5 simulations over Greenland and Antarctica have been performed, and the model is currently being used for synoptic and climate studies in the data sparse high latitudes.

A complete annual cycle over the Greenland ice sheet was simulated with the Polar MM5 (Cassano et al. 2001). The simulation results show a high degree of skill for all variables verified with AWS data. Guo et al. (2003) evaluate a complete annual cycle of 72h nonhydrostatic mesoscale model simulations of the Antarctic atmospheric circulation for 1993 using the Polar MM5. The evaluation shows that simulations with the Polar MM5 accurately capture both the large and regional scale circulation features with minimal bias in the modeled variables. Bromwich et al. (2001) verify two months, April and May 1997, of 48 h mesoscale model simulations of the atmospheric state around Greenland using the Polar MM5. The model is found to reproduce the observed atmospheric state with a high degree of realism. Rognvaldsson and Olafsson (2002) did downscaling experiments with the standard MM5 model to determine an optimal configuration for climatological downscaling studies of precipitation in Iceland.

In this study the Polar MM5 version 3.5 is used to simulate the high-resolution regional climate from 1998 to 2000 over Iceland. A comparison simulation is performed using standard MM5 and Polar MM5 for January 1998 to investigate the performance of Polar MM5 over Iceland in winter time.

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2. MODEL DESCRIPTION

Polar MM5 with 8 km resolution has been applied to simulate the regional climate over Iceland. Three nested model domains are used. The horizontal resolution and grid points are 73x85, 72km for domain 1; 121x103, 24km for domain 2; and 73x85, 8km for domain 3. The vertical discretization consists of 28 irregularly spaced levels in σ-coordinates from the surface up to 10 hPa. The model physics options are: mixed phase explicit moisture scheme for three domains; Grell cumulus scheme for domain 1 and domain 2; CCM2 atmospheric radiation scheme; and the MRF planetary boundary layer scheme. The 2.5^{o} horizontal resolution ECMWF TOGA surface and upper air operational analyses are used to provide the initial and boundary conditions for the model. The Polar MM5 is used to produce short duration (30 h) simulations from 1998 to 2000. The integration strategy is a sequence of 30 h simulations, with the first 6h being discarded for spin-up reasons.

A sixth-order finite-difference scheme is used to calculate the horizontal pressure gradient to reduce the computational error and improve the simulation over steep topography of Iceland.

3. COMPARISON BETWEEN MM5 AND POLAR MM5

Two test simulations are performed using standard MM5 and Polar MM5 for January 1998 to investigate the performance of Polar MM5 over Iceland in winter. Figure.1 shows the sea ice during January 1998 in Polar MM5. There is no sea ice in standard MM5. Figures 2c-d show the differences in January 1998 between Polar MM5 and MM5.

The difference of monthly mean temperatures simulated at 2 m above ground for January 1998 between Polar MM5 and MM5 is shown in Fig.2a. The monthly mean temperature simulated by Polar MM5 is lower than that simulated by MM5 along the coast of Iceland. The pattern of the difference is similar to the distribution of the sea ice in Fig.1.

The specific humidity at 2 m above ground simulated by Polar MM5 is lower than that simulated by MM5 over sea ice and north and west coast of Iceland but higher over the remainder of Iceland (Fig.2b).

The monthly mean wind speed of Polar MM5 is higher than MM5 in the east and south of Iceland, and lower in the northwest. Over the sea to the northwest, north and south of Iceland, the wind speed simulated Polar MM5 is higher than MM5 (Fig.2c).

The monthly precipitation bias between Polar MM5 and MM5 is given in Fig.2d. The monthly precipitation simulated by Polar MM5 in comparison to MM5 is larger over the sea to the north of Iceland and over flat areas ,and smaller in the mountainous areas of Iceland.

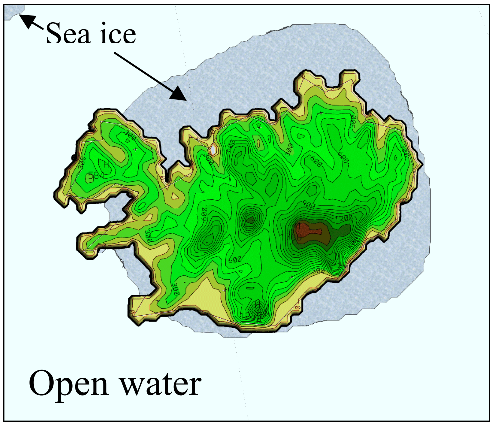
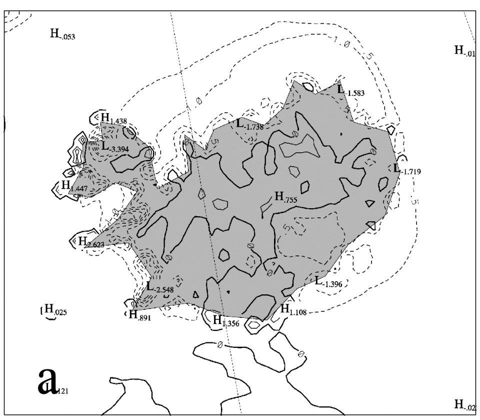
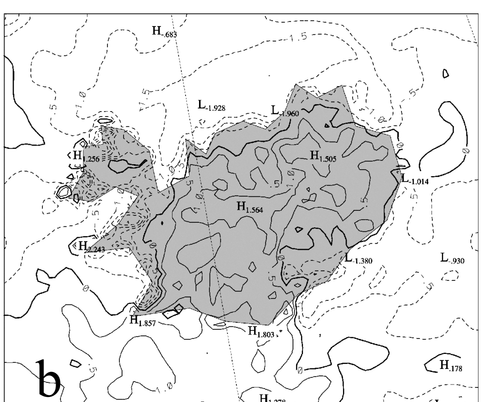
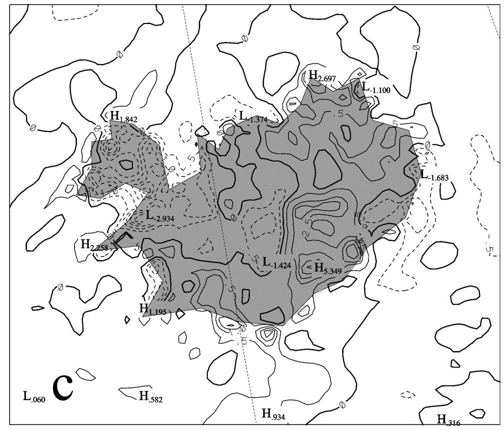


Fig.1 The monthly mean sea ice for Polar MM5 in January 1998.

In general, the monthly mean temperature simulated by Polar MM5 is lower than MM5 in winter. The comparison between the two simulations indicates that Polar MM5 more reasonably reproduces the mesoscale meteorological fields over Iceland than standard MM5 in winter time.







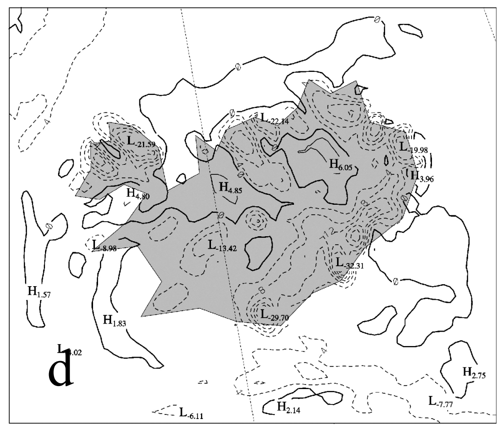


Fig. 2 Difference in January 1998 between Polar MM5 and MM5 of (a) monthly mean temperature at 2m above ground (^oC), (b) monthly mean specific humidity at 2m above ground (1000*g/kg), (c) monthly mean wind speed at 10m above ground (m/s), (d) monthly total precipitation (mm).

4. COMPARISON WITH SURFACE OBSERVATIONS

The surface observations are from NCEP ADP daily Global Surface Observations from February 1975 to near present. The wind speed, wind direction, temperature, dew point and sea level pressure are used for comparison to simulation. The data are obtained from NCAR.

Nine surface observation stations are selected to compare with simulation results. The monthly time series of modeled and observed surface wind direction, wind speed, temperature dew point, sea level pressure at station 04013 and 04018 are shown in Figs.3a and 3b. Tables 1 and 2 show the locations of the observed stations, the biases, RMSs and correlation coefficients between the simulated and observed for January 1998.

The simulated wind direction basically matches the observed; the bias of wind direction is from -3.0 to 47 degrees. RMSs are large, and the correlation coefficients range from 0.29 to 0.57. The wind speed is generally underestimated for January. The simulated wind speed well matches the observed. The bias of wind speed is from -3.0 to 1.0 m/s, RMSs are less than

5 m/s, and the correlation coefficients are larger than 0.62.

The simulated surface temperature well matches the observed, but is typically 2.0 °C lower than observation. Biases are negative in January because the model terrain is different from real terrain due to the relatively low resolution of the model. The correlation coefficients for temperature between simulated and observed are higher, from 0.76 to 0.95. RMS is less than 3.5 °C. The simulated dew point well matches the observed. The biases are -3.3 to 0.5 °C lower than observation. The correlation coefficients for dew point between simulated and observed are from 0.75 to 0.93, and the RMS is less than 3.8 °C. The forecast skill of Polar MM5 is high for surface temperature and dew point in January.

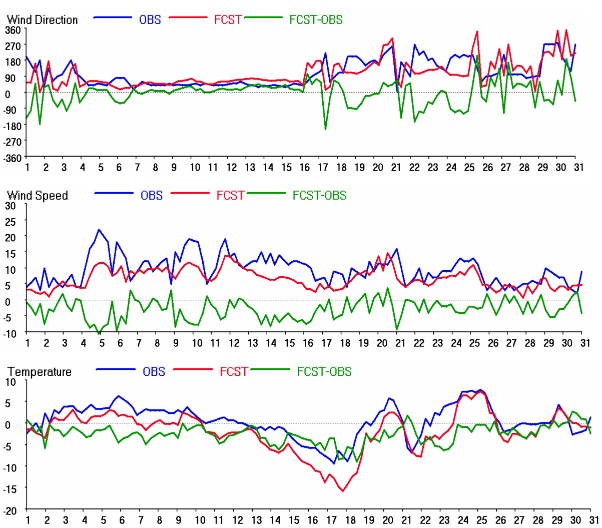
The simulated sea level pressure is in good agreement with the observed in January. The biases are -1.85 to 0.17 hPa, the RMS is less than 3.0 hPa, and the correlation coefficients are larger than 0.99. The forecast skill of Polar MM5 for sea level pressure is very high over Iceland.

Table 1 The locations of the observed stations, and statistics of the simulated and observed wind direction and wind speed in January 1998 for Polar MM5

Stat name	Latitude(N) and longitude(W)		Wind direction (degree) Bias	RMS	Corr	Wind speed (m/s) Bias	RMS	Corr
04013	65.08	22.73	-3.94	68.15	0.57	-2.89	4.24	0.70
04014	63.82	22.72	35.65	92.38	0.55	2.11	3.92	0.66
04018	63.97	22.60	10.77	86.62	0.53	0.15	2.92	0.78
04038	63.87	21.15	47.69	113.11	0.31	-3.14	4.70	0.78
04048	63.40	20.28	9.93	128.38	0.39	-2.27	5.49	0.64
04065	66.53	18.02	19.49	115.89	0.29	-0.30	2.37	0.80
04077	66.45	15.95	13.65	99.81	0.55	0.05	2.27	0.82
04082	64.25	15.18	39.51	133.14	0.46	-0.43	3.52	0.69
04097	65.27	13.58	-1.05	109.09	0.56	1.45	4.58	0.62

Table 2 Statistics of simulated and observed temperature, dew point and sea level pressure in January 1998 for Polar MM5

Stat name	Temperature (°C) Bias	RMS	Corr	Dew point (°C) Bias	RMS	orr	Sea level pressure (hPa) Bias	RMS	Corr
04013	-2.56	3.32	0.90	-3.25	3.75	0.89	-0.27	2.55	0.99
04014	0.35	1.54	0.94	0.46	3.28	0.93	-0.80	1.95	1.00
04018	-0.16	1.34	0.94	0.19	3.13	0.91	-0.84	1.84	1.00
04038	-2.37	3.01	0.95	-1.06	3.02	0.90	0.17	2.18	1.00
04048	-0.26	1.62	0.89	-0.44	3.72	0.75	-1.09	2.29	1.00
04065	-1.90	3.46	0.76	-2.21	3.70	0.76	-1.85	2.75	1.00
04077	-1.23	2.63	0.87	-1.50	3.35	0.86	-1.85	2.93	0.99
04082	-1.74	2.50	0.94	-0.63	3.73	0.86	-0.95	2.60	0.99
04097	0.04	1.93	0.88	-0.06	3.56	0.87	-1.51	2.75	0.99



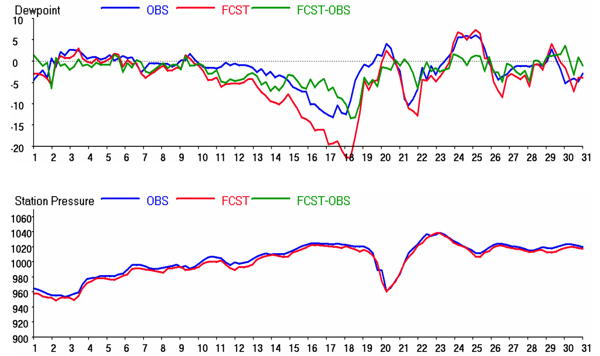


Fig. 3a The surface wind direction (degree), wind speed (m/s) , air temperature (°C), dew point (°C), and sea level pressure (hPa) time series of surface observation data and simulated by Polar MM5 over Iceland for January 1998 at station 04013. The wind direction and wind speed are at 10m above ground. The temperature and dew point is at 2m above ground.

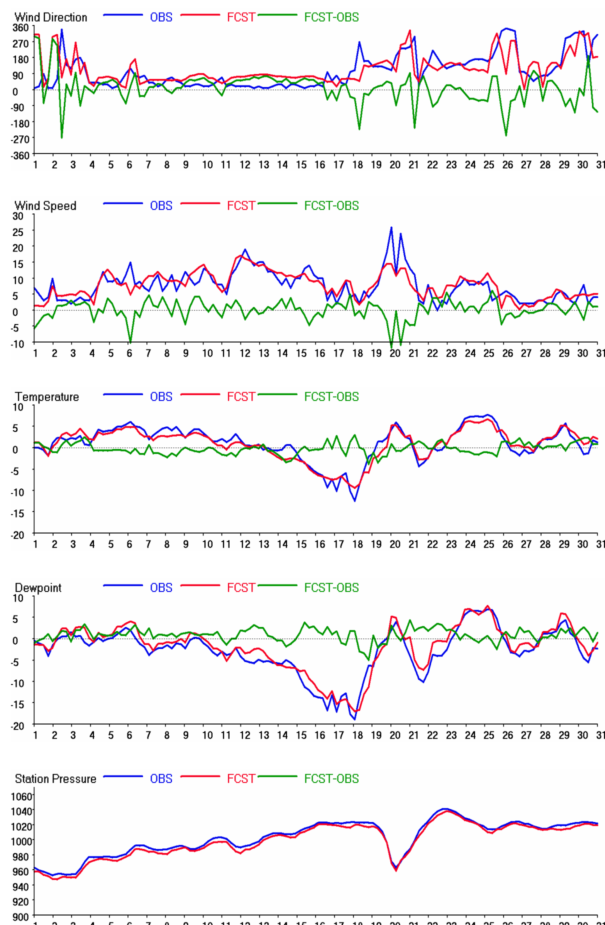


Fig. 3b The same as Fig. 3a but for station 04018.

5. LONG-TERM MEAN ANUUAL PRECIPITATION

The simulated long-term mean annual precipitation simulated by Polar MM5 for 1998-2000 is compared to the observed long-term mean annual precipitation. The observed mean annual precipitation distribution is shown in Fig.4a which is derived from station precipitation observations and statistical extrapolation. The simulated spatial distribution of precipitation simulated by Polar MM5 V3.5 from 1998 to 2000 is shown in Fig.4b.

The time-averaged annual mean mesoscale precipitation distribution over Iceland is reasonably well simulated by Polar MM5. There is an extra-simulated minimum and an extra-simulated maximum in the northern and western part of the Vatnajökull ice cap in relation to the observed. Consistent with the cyclonic forcing changes, the winter amounts are much larger than those during the summer. However, the spatial distribution is maintained in each season, reflecting the dominant control of topography, landuse, model physics and the persistent circulation pattern on the precipitation distribution. It seems that the 8 km model resolution is still too coarse to resolve all the observed small-scale variations of precipitation.

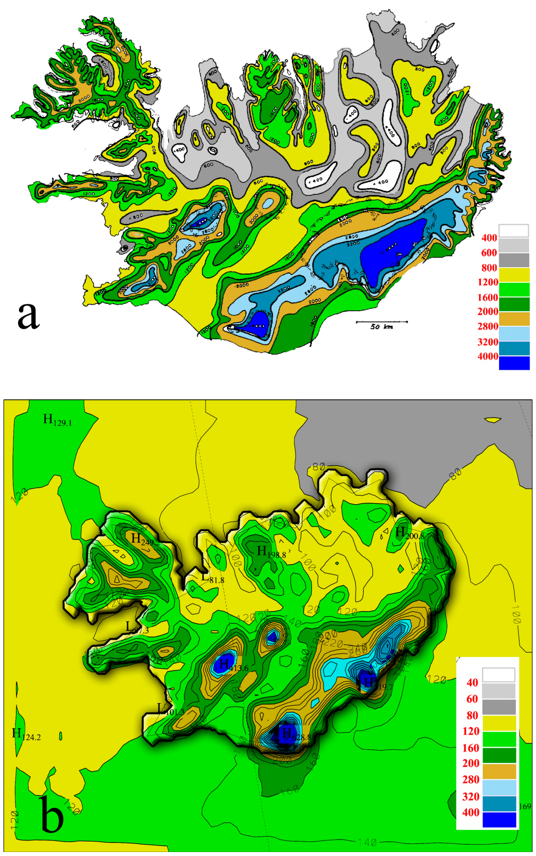


Fig. 4 (a) The observed mean annual precipitation distribution which is derived from station precipitation observations and statistical extrapolation (units: mm), contours interval is 200 mm. (b) The annual mean precipitation in (1998-2000) simulated by Polar MM5 V3.5 (units: cm) contour interval is 20 cm.

6. CONLUSIONS

High resolution regional climate simulations have been performed by Polar MM5 from 1998 to 2000 for Iceland. The validation test between MM5 and Polar MM5 shows that the Polar MM5 can give more realistic results than standard MM5. The physics of Polar MM5 is important for the high resolution regional climate simulation for Iceland. The time-averaged mesoscale precipitation pattern is well simulated by Polar MM5.

The simulation results show that the high-resolution regional climate in a limited area can be reconstructed using a limited area model with reasonable physical parameterizations, and high-resolution topography and landuse when forced at the lateral boundaries by global analysis data.

The Polar MM5 is a powerful tool for mesoscale, synoptic and climate studies in the data sparse high latitudes. The Polar MM5 will continue to be developed by: implementing 3DVAR in Polar MM5 which can be used to assimilate observational data over steep topography; developing the method for specifing the model lateral boundary conditions for climate studies to reduce the errors for long-term climate simulations; and using the NOAH LSM for high-resolution regional climate simulations over Iceland.

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