HIGH RESOLUTION NWP MODELLING OF THE ATMOSPHERIC CONDITIONS ACROSS VATNAJÖKULL (ICELAND)

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Abstract: We investigate the skill of an operational NWP model (HIRLAM) to reproduce the near-surface atmospheric conditions across the Vatnajökull Ice Sheet (Iceland). The study focuses on a mesoscale glaciometeorological observation campaign of summer 1996, which provided a wealth of meteorological and glaciological data. The modelling concept is based on nesting fine-scale (2.8km horizontal resolution) hydrostatic HIRLAM experiments into the downscaled ERA40 analyses. The results of a reference run are compared to a subset of observations following a height transect across Breidamerkurjökull, a southern outlet glacier of Vatnajökull, which reveals some severe deficiencies regarding the treatment of the surface energy balance.

Keywords: *HIRLAM, parametrization, Vatnajökul Ice Cap, mass and energy balance*

1. INTRODUCTION

The role of the cryosphere in the global climate system has gained increased attention during the last decades. Thus, much effort has been devoted to enhanced geophysical monitoring of ice sheets and glaciers all over the world, to interpretation of paleoclimatic records or to modelling the interactions between ice masses and the atmosphere. The last decades have seen considerable progress in the understanding of the associated processes, which has been fostered by specific measurement and modelling efforts in different fields of research. Regional climate models and mesoscale meteorological models have recently been involved in different contexts, too.

However, the specific impact of ice masses on the performance of operational weather forecast models has gained less emphasis (Olafsson, 1998). Nowadays, the resolution of these models approaches the relevant scale, which is fostered by enhanced computer resources and ongoing progress of data assimilation, downscaling and parametrization methods. Therefore, the potentially important features like topographically modified atmospheric flow and their impact on precipitation or surface energy exchanges are treated with increasing skill in mountainous regions. This topic is of essential interest in the Arctic, northern and alpine countries. Thus motivated, we investigate the performance of the High Resolution Limited Area Model (HIRLAM; Undén et al. (2002)) in reproducing the near-surface atmospheric conditions across the Vatnajökull Ice Sheet (Iceland).

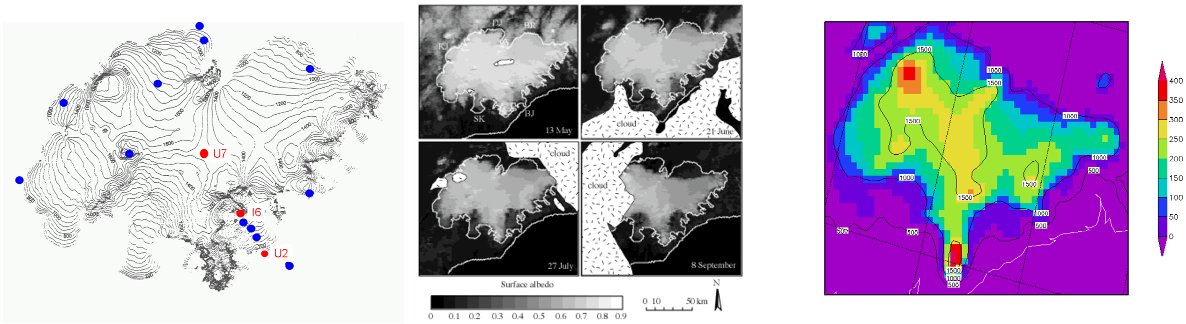
2. OBSERVATIONAL DATA

Vatnajökull is the largest ice sheet in Europe, situated at the southeastern edge of Iceland where it extends over 8000 km^2 and covers an elevation from sea level to about 2000 m. For several reasons, Vatnajökull presents special interest for mesoscale atmospheric modelling. The size of the ice sheet (150km diameter) allows for a reasonable spatial discretisation of the atmospheric model. Its bell-shaped topography is not too complex for modelling, while pronounced topographical effects are induced by a vital synoptic-scale forcing with strikingly different characteristics.

This results in specific atmospheric and glaciological conditions, which have been revealed in a comprehensive glacio-meteorological experiment during summer 1996 (Oerlemans et al., 1999). The available observations comprise synoptic data, tethered balloon and radio soundings plus detailed measurements of the micrometeorological profiles, turbulence and radiation from 15 automatic weather stations across the ice sheet.

Snow pits, ablation stakes and satellite images provide glaciologically relevant data. The observation period lasted from May 1996 until September 1996, when the ice sheet's surface was mostly melting. This implies some methodical benefits regarding e.g. the closure of the energy budget (isothermal conditions in the near surface snow/ice layers). The data set was used for glaciological modelling (Ruyter et al., 2003), but it has not yet been applied for evaluation of the mesoscale NWP models.

In this study we refer to data from three sites only, which are located at different elevations along the flow line of Breidamerkurjökull, a southerly outlet glacier of Vatnajökull (Fig. 1). During the observation campaign, site U2 was all the time free of snow, while U7 was always snow-covered and at I6 the snow cover disappeared in the end of June. The pronounced topographical effects on atmospheric flow and specific boundary layer features have been discussed by Oerlemans et al. (1999), Zingerle (1998), Kaltenböck et al. (1999), Obleitner (2000). The local circulations affect the energy and mass balance of the glacier, which will be addressed also in the present model verification study, too.



(a) (b) (c)

Figure 1: (a) The Vatnajökull Ice sheet and the measurement locations during the mesoscale experiment 1996. Sites considered in this study are denoted in red (U2: 50m asl., I6: 715m asl., U7: 1530m asl.). (b) Surface albedo at Vatnajökull as seen by the satellite (AVHRR, Reijmer et al. (1999)) at 13 May (upper left), 21 June (upper right), 27 July (lower left) and 8 September (lower right). (c) Snow depth 30 May (mm of water equivalent, colour scale) as analysed by HIRLAM. Surface elevation (m) of the HIRLAM fine-scale experiments is shown by contours (500,1000 and 1500m).

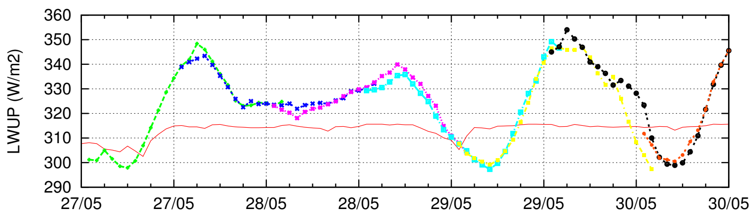


Figure 2: Predicted and observed upwelling long-wave radiation at station I6, 27-30 May 2007. Observations are shown by the thin solid line and the consequtive (71b2) forecasts, starting at 00 and 12UTC, by coloured lines with markers. See discussion in section 4.

3. MODEL SETUP

The modelling concept is based on downscaling ECMWF ERA40 analyses (Uppala et al., 2005) in an upper air and surface data assimilation cycle, utilizing conventional observations in an Arctic domain. The synoptic-scale HIRLAM (analyses four times a day, horizontal resolution 17 km, 40 levels in vertical = 17km/40L) is applied for downscaling. Next, fine-scale hydrostatic HIRLAM forecasts over Iceland (reference resolution 2.8km/60L, forecast lead times till 27 hours) are nested into the outer domain analyses. The integration domains are shown in Fig. 3.

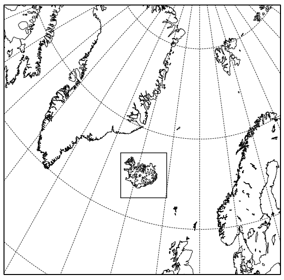


Figure 3: HIRLAM integration domains: whole map area - Arctic domain (horizontal resolution 17km), inner square: domain of fine-scale experiments (2.8km), with selected surface isohypses.

Table 1: Planned fine-scale HIRLAM experiments

experiment	**resolution**	**parametrizations**	**period**
71b2	2.8km/60L	reference HIRLAM	27 May - 30 June
71a3ns	2.8km/60L	new surface scheme	27 May -
71a3nv	2.8km/90L	new surface scheme	27 May -

Main properties of the fine-scale model experiments are listed in Table 1. The reference HIRLAM refers to version 7.1beta2. The new surface scheme (Gollvik and Samuelsson (2006)) aims at improved handling of heat transfer over snow-covered surfaces and forest. In all fine-scale experiments, surface data assimilation was applied by using the conventional observations only, while the upper air analysis was provided by the synoptic-scale HIRLAM.

4. PRELIMINARY RESULTS

The first fine-scale simulations (experiment 71b2) show, that the present reference HIRLAM is not capable of representing snow and glaciers in a good manner. However, Fig. 4 (grey diamonds) demonstrates that the basic atmospheric parameters are reasonably well simulated in terms of average values. This is essentially true with respect to air pressure (not shown) and temperature at site U7, which is located at the crest of the ice sheet. On the the other hand, the skill of the simulations decreases for sites at lower elevation (I6) or bare ground beyond the margin of the glacier (U2). The latter show an increasing overestimation of the daytime temperatures, reflecting improper treatment of the surface energy balance. This is confirmed by a comparison of measured and simulated albedo (not shown) and upwelling long-wave radiation flux (Fig. 2). Instead of keeping the temperature over melting snow close to the measured zero degrees, the reference model creates a diurnal cycle of unreasonably large amplitude. In-depth investigation of the problem indicates, that this is primarily related to improper spatial representation of permanent snow and ice in the model (Fig. 1). There is evidence that this is related to inadequate parameterizations of soil heat flux in conditions of snow and ice. On the other hand, application of (surface) data assimilation tends to improve the behaviour of the screen-level temperature (not shown).

Like the simulated temperature, also humidity, wind speed and net solar insolation perform best at the crest height (Fig. 4). The combined effect of clouds and surface albedo to the net short-wave radiation flux deserves further attention.

5. CONCLUSIONS

This model verification study revealed some severe deficiencies of a preliminary fine-scale HIRLAM run to reproduce the surface related parameters at different elevations along a southern transect of Vatnajökull. A major problem was identified regarding the treatment of the (sub)surface processes, resulting in unrealistic surface temperature and reflected short-wave radiation. Further experiments will involve already developed

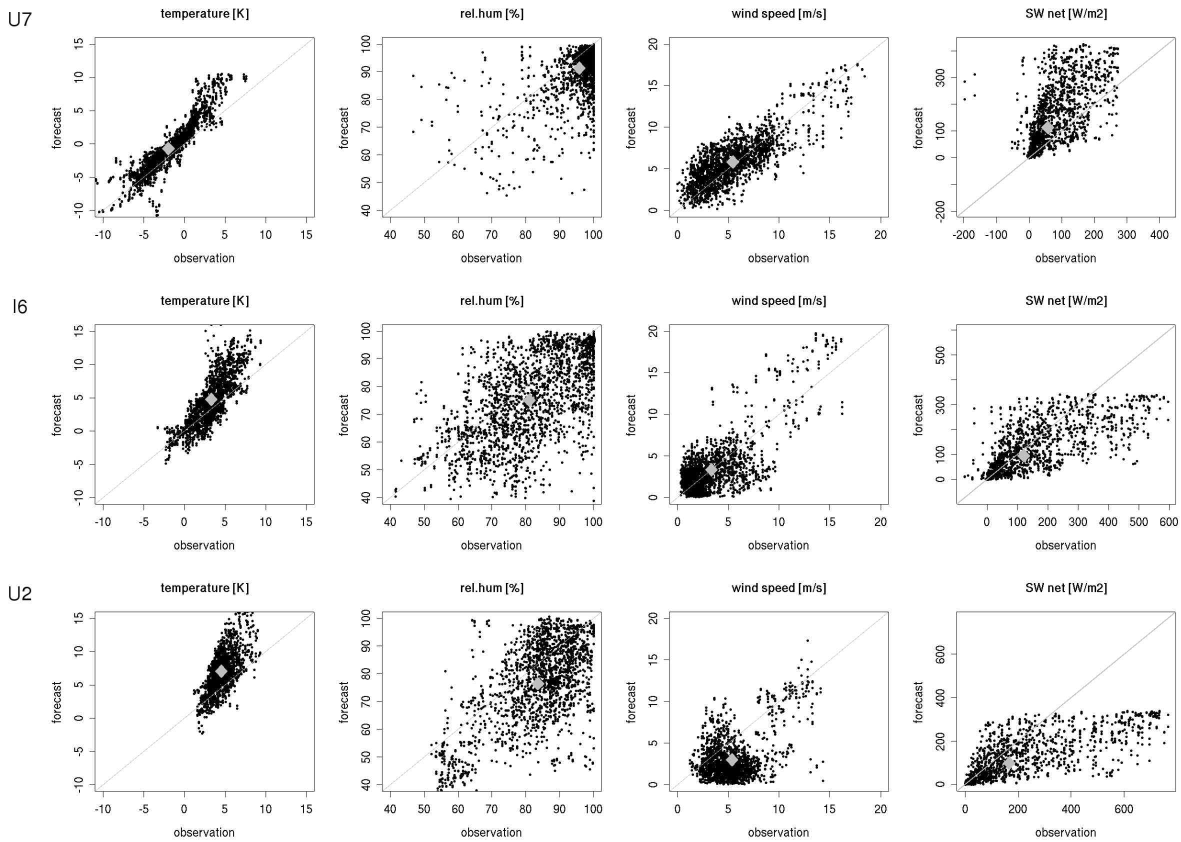


Figure 4: From 1 to 26 hour forecast versus observed near surface parameters of temperature, relative humidity, wind and net short-wave radiation at stations U7, I6 and U2 along the glacier. Grey diamonds represent the mean forecast against the mean verification over all timesteps and all forecasts.

modifications to the surface parametrizations over snow, which are likely to significantly improve the simulation results in glacier and permanent snow environments. These results will be discussed in more detail in the ICAM 2007 conference presentation.

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