5.3 FLOW IN THE LEE OF GREENLAND-SIZE MOUNTAINS

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1 INTRODUCTION

Greenland is a large mountain, in fact the third largest on the Northern Hemisphere. Despite the fact that Greenland is near the North Atlantic storm track its influence on the air flow has been little investigated. Cyclonic developments near Greenland and Iceland are often poorly captured by NWP models (Ólafsson, 1998) which can not only have large impact over Iceland in short range forecasting but also over the continental Europe some days later. Studies by Kristjánsson and McInnes (1999) and Doyle and Shapiro (1999) indicate that Greenland has an impact on the atmospheric flow in its vicinity. The aim of this study is to get a better understanding of Greenland's effect on the airflow over the North Atlantic, by studying both idealized and real flow.

2 NUMERICAL SETUP

The numerical model MM5 (Grell et al., 1995) is applied in this study. The model is run with 40 σ-levels in the vertical and a 36 km horizontal resolution. To prevent wave reflection, a Rayleigh damping layer is placed above 13 km height. A series of simulations with constant upstream profile of wind and stability is carried out. The flow is perturbed by an elongated mountain oriented perpendicular to the incoming flow, see figure 1. The mountain's aspect ratio is 4 and its height in the range of 1000-6000 m.

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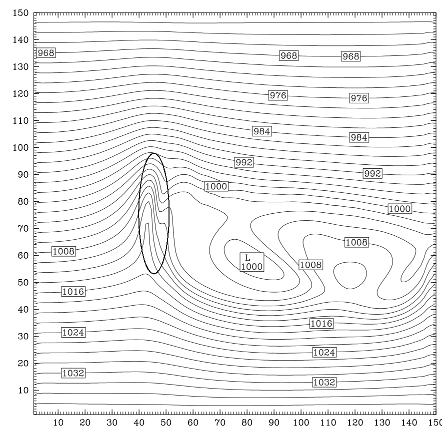

Figure 1: Sea level pressure (hPa) for $\hat{h}$=3.0 at nondimensional time unit $t^*=Ut/L_x$=43.2. The topography is shown at $0.35h$.

With U=10 $m\,s^{-1}$, N=0.01 s^{-1} and f=1.2·10^{-4} s^{-1}, the Rossby number, Ro=U/fL_x, is 0.42 and the nondimensional mountain height, $\hat{h}=Nh/U$, varies from 1.0 to 6.0. Further information on the setup is given in Petersen et al. (2002).

3 IDEALIZED FLOW

A hydrostatic, frictionless, Boussinesq flow on a nonrotating plane is governed by the mountain shape, its aspect ratio and its nondimensional mountain height (Smith and Grønås, 1993). When the Coriolis force is included in the equations, the Rossby numer enters as an additional parameter.

The simulations show, see figure 1, that in the lee of Greenland sized mountains there is a permanent

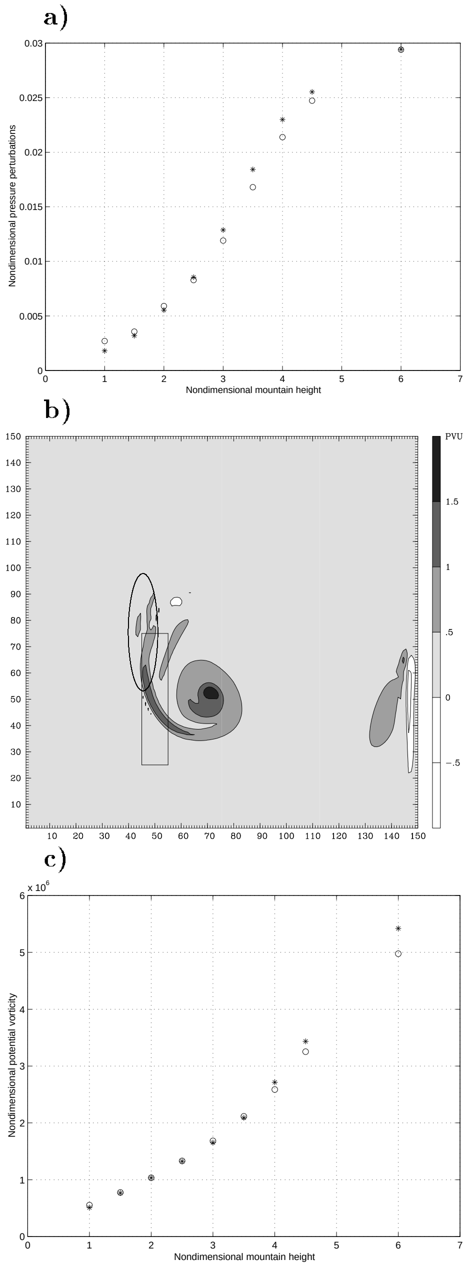

Figure 2: a) Absolute maximum pressure perturbations at sea level normalized with the sea level pressure in tha absence of a mountain, b) potential vorticity (PVU) at σ=0.943 when $\hat{h}$=6.0, $t^{*}=Ut/L_x$=51.84 and c) potential vorticity (PV) integrated over the rectangle in b), from sea level up to σ=0.607. The PV is normalized by $\frac{\theta_o N}{\rho_o h}$, where θ_o=280 K and ρ_o=1.2 $kg\,m^{-3}$. The stars represent simulations with N=0.01 s^{-1} and U=10 $m\,s^{-1}$, while the circles represent simulations with different combinations of N, h and U.

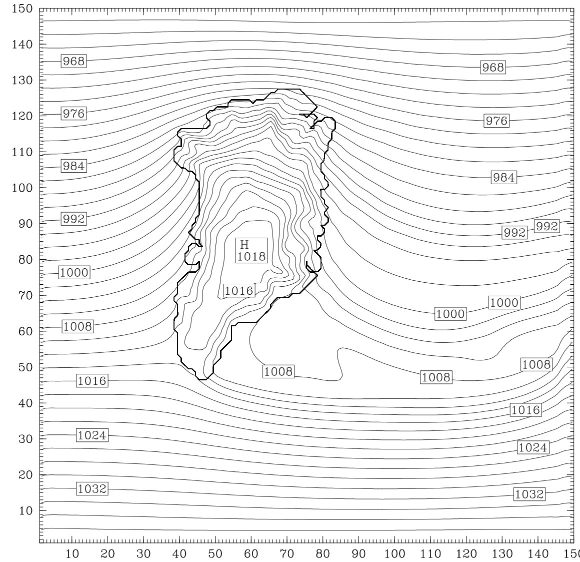

Figure 3: Sea level pressure (hPa) for the simple flow when impinging on Greenland, $\hat{h}$=3.2, at $t^{*}=Ut/L_x$=47.52. The thick line shows the outlines of Greenland.

pressure deficit, extending thousands of kilometers downstream. The pressure deficit is greatest at the surface and increases with increasing nondimensional mountain height, $\hat{h}$ (Figure 2a). The deficit also extends to levels far above the mountain crest. For low $\hat{h}$ ($\hat{h}$<3.5) the flow is unblocked even though there still is some eddy shedding at the end of the simulation in the case of $\hat{h}$=2.5 and 3.0. For lower $\hat{h}$, the flow reaches quasi-stationarity during the simulation. For $\hat{h}\geq$3.5 the flow experiences upstream blocking, and there is a continuous vortex shedding downstream from the mountain during the simulation. These vortices are associated with anomalies of potential vorticity (PV) that are generated over the southern part of the mountain (Figure 2b). The production of PV increases rapidly with increasing $\hat{h}$ and there is no indication of abrupt changes when the flow enters the blocked regime (Figure 2c). Nor are such abrupt changes found in the case of sea level pressure perturbations or perturbations of the geopotential at higher levels.

A simulation with idealized flow but applying Greenland's topography ($\hat{h}$=3.2) instead of the bell-shaped mountain shows results similar to the simulations with $\hat{h}$=3.0 (Figure 3). There is no upstream blocking and a decreasing vortex shedding throughout the simulation. The sea surface pressure in the vicinity of the mountain is surprisingly similar to the pressure pattern often seen on synoptic charts, with a pressure deficit just in the lee of South-Greenland and an area of high pressure over Greenland.

4 REAL FLOW

A numerical study of a case from FASTEX (Joly et al., 1999) was carried out. Two simulations were conducted, a control simulation and a simulation where Greenland's orography was reduced to 1 m, the "nogreen" simulation. A comparison of the simulations shows that Greenland's orography does not only affect the flow in the vicinity of the mountain but by intensifying the wind at middle-tropospheric levels, Greenland increases the speed and depth of a cyclone moving far south of Greenland towards Britain (not shown).

5 CONCLUSION

A series of idealized simulations shows an increase in pressure deficit with increasing $\hat{h}$, without any abrupt changes at the regime shift between unblocked and blocked flow. The smoothness of the transition is probably due to the Coriolis force (Thorpe et al., 1993). Increasing nondimensional mountain height intensifies the winds at middle-tropospheric levels south of the wake. These winds can have an impact on cyclones moving in the area. This was seen in the case study, where the presence of Greenland increased the speed and depth of a cyclone moving far south of the mountain, compared to the "nogreen" simulation. This implies that Greenland's orography is important for the flow over the North-Atlantic. Greenland's wake vortices may not only have an impact on cyclones in the lee of the mountain, but also on synoptic flow far downstream of the mountain and outside the wake.

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