The Damping Effect of Greenland on an Extratropical Cyclone

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ABSTRACT

A cyclone passing over the Greenland ice cap is simulated with the topography of Greenland set to zero and with a reference topography. Greenland turns out to hamper the development of the cyclone, that becomes significantly deeper when Greenland is removed. The damping of the cyclone development by Greenland can be split into two stages. In a first stage, the warm air advection in front of the cyclone when it moves over Greenland is reduced when the Greenland topography is present. In a second stage, the advection of cold air at low levels to the rear of the cyclone is hampered by Greenland, leading to less vorticity at upper levels. In the NoGreen simulation, the abundant upper level vorticity is advected downstream where it contributes to the further development of the cyclone.

1. Introduction

Large scale orography can affect extratropical cyclones in various ways. The most celebrated impact of mountains on synoptic scale cyclones is probably the genesis of cyclones in the lee of the European Alps (see f. inst. Trigo et al., 2002). Greenland is situated close to the northern edge of the N-Atlantic storm-track. Its rises more than 3000 m above sea level with steep slopes in all directions. Studies of individual cases have shown that Greenland can hamper the growth of cyclones moving to the NE between Iceland and Greenland (Kristjánsson and McInnes, 1999; Rögnvaldsson and Ólafsson, 2003), while in other cases Greenland can lead to rapid deepening of cyclones (Shapiro et al., 2002) that develop at the southeast coast of Greenland. Numerical studies have also shown that Greenland can contribute to the deepening of cyclones moving across the N-Atlantic, far to the south of Greenland (Petersen et al., 2003). Here, a cyclone that moves directly over S-Greenland from west to east is studied. The evolution of the cyclone is simulated with and without the topography of Greenland and the results are discussed in view of classical quasi-geostrophic theory and basic features of orographic flows.

2. The simulated flows

2.1. The synoptic evolution

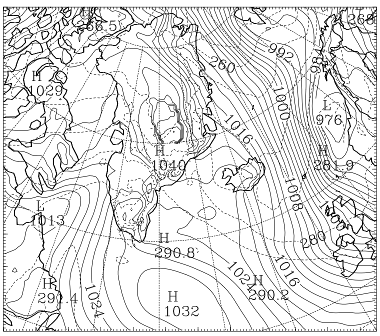

Figure 1: The mean sea level pressure (hPa) and potential temperature at 850 hPa (K) on 25/00UTC.

On 25 December 2001 at 00 UTC, there is a shallow cyclone forming at the east coast of Labrador (Fig.1) The cyclone moves slowly to the ENE, towards Greenland. On 26 Dec. at 03UTC, the cyclone has crossed the icecap and is situated at the east coast of S-Greenland (Fig.2 (a)). In the following, the cyclone moves further to the east and deepens slowly. With strong westerly wind at middle and upper tropospheric levels and baroclinicity at low levels the situation can be characterized as typical for cyclone development in the region.

2.2. Greenland vs. No-Greenland

When the flow is simulated again, but with the topography of Greenland set to sea level, the cyclone still moves across Greenland, but develops quite differently. On 26 Dec. at 03UTC, the cyclone is situated at the east coast of Greenland, but further to the north than in the Reference simulation, when the topography

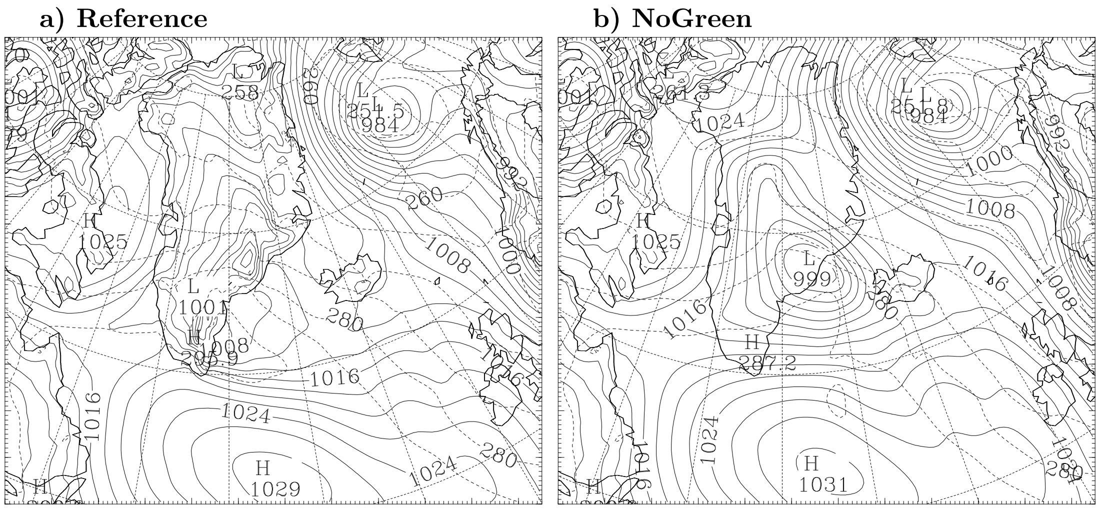

Figure 2: The mean sea level pressure (hPa) and potential temperature at 850 hPa (K) on 26/03UTC in a) the Reference simulation and b) the NoGreen simulation.

of Greenland is present (Fig.2 (b)). Figure 3 shows the evolution of the minimum sea level pressure in the two simulations. It is clear that when the topography of Greenland is present, the cyclone deepens much less than if Greenland is not present. To focus better on the differences in the flows in these two simulations we plot the difference in potential temperature at the 850 hPa level on 26/03UTC (Fig. 4). There is a clear warm anomaly to the east of the southernmost part of Greenland in the reference run, while in the NoGreen-run there is a strong warm anomaly immediately west of Iceland, extending all the way to Greenland. The latter warm airmass is associated with the rapid deepening of the cyclone in the NoGreen case. Rapid deepening of cyclones is generally associated with anomalies in vorticity or potential vorticity (PV) at upper levels. Figure 5 shows the geopotential height and the temperature at 300 hPa in the NoGreen-run on 26/15UTC. There is strong flow from WNW, over Greenland and Iceland. On 26/15UTC there is a trough over Greenland and the sea between Greenland and Iceland. A figure showing the differences in the two simulations reveals that the upper level PV is much greater in the NoGreen-run than in the reference run in these regions (Fig.6).

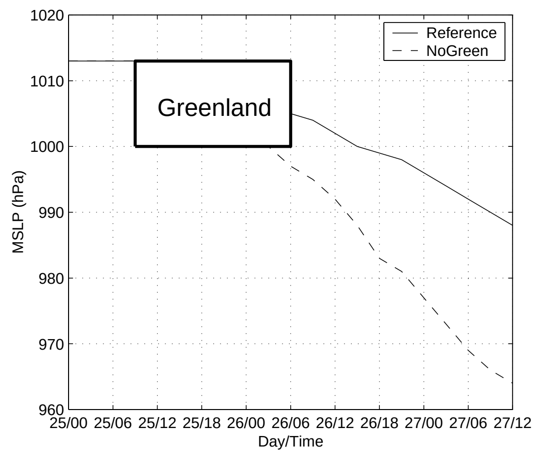

Figure 3: The evolution of the depth of the cyclone in the two simulations. the mean sea level pressure is set to 1000 hPa when the cyclone is over Greenland in the Reference run.

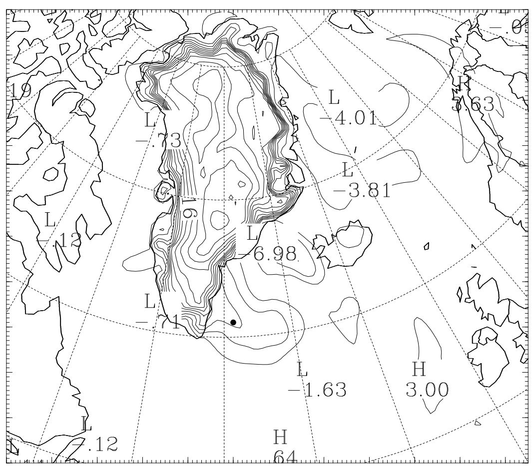

Figure 4: Potential temperature at 850 hPa (K) in the Reference simulation minus the NoGreen simulation, both on 26/03UTC.

3. Discussion

As the cyclone travels across a flat Greenland, it continues to develop at low levels and southerly flow with warm advection is initiated ahead of the cyclone. In the case where the topography of Greenland is present, there is, of course, no circulation at levels below the ice cap. The southerly wind and warm advection ahead of the cyclone to the east of Greenland is consequently very weak. In fact, the warm advection in the reference run takes place to the south of the cyclone, where a föhn wind creates a warm anomaly and strong N-S pressure gradient to the south of the cyclone. Once the cyclone has passed Greenland, there is much greater southward advection of cold air to the rear of the cyclone at low levels in the NoGreen run than in the Reference run. This is direct consequence of Greenland blocking low level advection. The upper level potential vorticity anomaly that provides supplementary fuel for the cyclone is associated with the advection of cold air at lower levels. In this manner, blocking of the low level flow contributes again to hampering the growth of the cyclone.

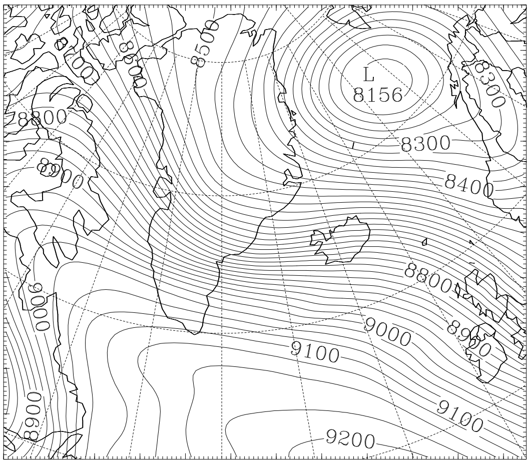

Figure 5: The 300 hPa geopotential height (m) at 26/15UTC.

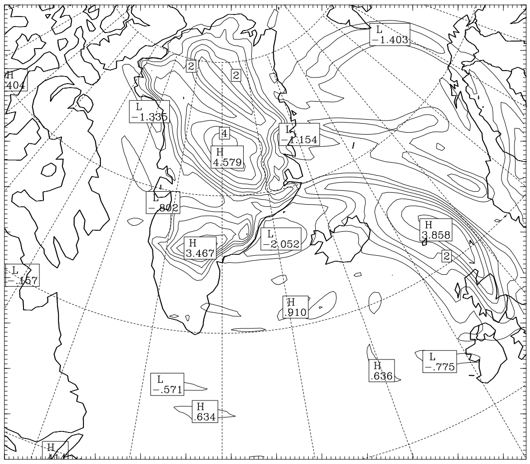

Figure 6: Potential vorticity at 300 hPa (PVU) on 26/15UTC in the Reference simulation minus the NoGreen simulation.

LITERATURE

Kristjánsson, J. E. and H. McInnes, 1999: The impact of Greenland on cyclone evolution in the North Atlantic. *Quart. J. Roy. Meteor. Soc.*, **125**, 2819-2834.

Petersen, G. N., H. Ólafsson and J. E. Kristjánsson, 2003. Flow past idealized mountains and Greenland. *J. Atmos. Sci.*. In press.

Rögnvaldsson, Ó and H. Ólafsson, 2003: A case study of the Icelandic trough. ICAM 2003 Proc.

Shapiro, M. E., S. Low-Nam, H. Ólafsson, J. Doyle and Piotr K. Smolarkiewicz, 2002: Large-amplitude gravity wave breaking over the Greenland lee and the subsequent formation of a downstream synoptic-scale tropopause folding and stratospheric-tropospheric exchange. 10th Conf. Mount. Meteorol., Amer. Met. Soc.

Trigo, I. F., G. R. Bigg and T. D. Davies, 2002: Climatology of cyclogenesis mechanisms in the Mediterranean. *Mon. Wea. Rev.*, **130**(3). 549-569.