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THE FOEHNS IN THE KHIBINY MOUNTAINS

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Abstract. The synoptic situations causing the foehn phenomena in the Khibiny mountains are studied. Three types of the foehns above the Khibiny mountains are detected by the meteorological observations at the mount-avalanche stations "Vostochnaya" and "Centralnaya".

Introduction

The foehn is a catabatic wind in the mountainous region accompanied by an increase in the temperature and a decrease in the relative humidity. The classical interpretation of the foehn effect suggests a forced rising of the moist air at the windward slope of the mountain ridge and lowering at the leeward slope. However, the real picture appears more complicated. There are some types of the foehns depending on the mechanism of catabatic motions (see, e.g., [1- 4]). We should recognize that none of the known approaches are quite satisfactory. This is so because of great varieties of local foehn situations. There are numerous descriptions of the foehns in the Carpathian mountains, in the Crimea, in the Caucasus, however, the foehns in the Khibiny mountains have not been studied yet. We describe three types of foehns in the Khibiny mountains.

Observation and diagnostics of the foehns

1. **The valley foens**

The "classical" foehn arises when an air stream crosses the mountain ridge. The air rises on the windward slope with the moist-adiabatic gradient (about 5-6°C/km). It cools and reaches the condensation level. Here the cloudiness forms (or condenses), and the precipitations intensify. The air is downslide on the leeward slope with the dry-adiabatic gradient (9.8°C/km). Here the cloudiness dissipates, the air heats and dries. As a result, the air temperature on the leeward slope is by a few degrees higher than on the windward, and the relative humidity decreases to very low values.

The foehn effects are caused by the air crossing the mountain detected by thermogram and hygrogram records at the mount-avalanche station "Vostochnaya", which is located 2 km to the south-west of the Khibiny mountains. The air temperature increases sharply by 6-10°C, while the relative humidity reduces by 20-40 %.

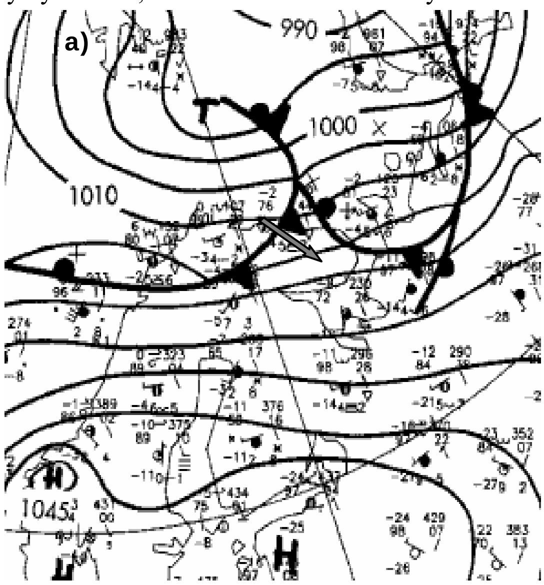

Figure 1. Surface analysis on 16 February 2003, 00 UT (the direction of cold front movement is shown by the arrow)

A foehn, caused by the air crossing the Khibiny mountains, was observed on February 16, 2003. A cold front passed over the Kola Peninsula at night on February 16 (Figure 1). The northwest stream behind the front created conditions for overflowing the Khibiny mountains (the mount-avalanche station "Vostochnaya" was on the leeside). The air crossing caused a foehn, which persisted for more than one hour. The temperature increased by 8.8 ^{o}C (from

-7.1 ºC to 2.3°C) for 10 minutes. At the same time, the relative humidity decreased from 98 to 65 % (Figure 2). The air temperature and relative humidity on the plateau Lovchorr did not vary in the considered period. This means that the changes described above did not result from advection but were caused by air descending motions. The relative altitude of the plateau Lovchorr is about 800 m above the meteorological platform of the mount-avalanche station "Vostochnaya". The air temperature on the plateau Lovchorr at 03 LT was -5.2 ºC. The steam partial pressure was 3 gkg^{-1}. The estimations indicate that under such conditions the air descending along the slope in accordance with the dry-adiabatic curve will lead to the temperature increase equal to: -5.2 ºC+800m*0.0098 ºC/m =-5.2 ºC+7.8 ºC=2.6 ºC (in fact 2.3 ºC), and the relative humidity should make 3.0 gkg^{-1}/4.5 gkg^{-1} *100 % = 66.7 % (in fact 65%). Such a good correspondence of the calculated and measured values proves the validity of the assumption about the foehn character of the described variations in the temperature and humidity.

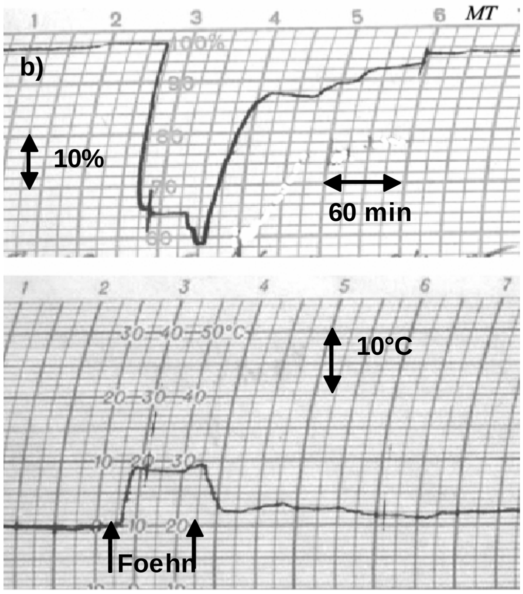

Figure 2. The fragment of the original records of hygrograph (a) and thermograph (b)

2. **Foehns on the mount tops**

2.1 Free air foehns

The foehn effects resulting from the air crossing are impossible on the top of the mountain Lovchorr because of its high location. There are free air foehns there. These foehns are caused by the inversion of subsidence in the anticyclone. The free foehns reach the ground layer very infrequently, but the inversions often cross the slopes and the tops at the height of 1000-3000 m. They cause air temperature increase and relative humidity decrease.

The meteorological characteristics of the free foehns differ from those of the valley foehns. The free foehns are observed in the almost total absence of the wind and characterized by the specific distribution of the temperature and relative humidity. For example, the temperature effect of the free foehn (an increase in the temperature at the station) can be exhibited only if the lowering air is warmed than the displaced air. That is, the temperature effect of the free foehn depends on the vertical distribution of the temperature and the temperature of the displaced air. Sometimes, a free foehn can be observed without an increase in the temperature rise or when this increase is small [2].

The lack or weakening of temperature effects is a specific feature of the free foehns. This makes us change the criteria for diagnostics of the free foehn. As the sign of the change in the relative humidity under stable stratification is always coincident with the sign of the vertical speed (a decrease in the relative humidity can be observed only in the presence of descending air motions), a decrease in the relative humidity is a major signature of the free foehns [2].

Various criteria of the free air foehns have been proposed. Bernhard [5] relates the free air foehn to the relative humidity lower than 40%. The attribute of the free foehn can be a decrease in the relative humidity down to 60 % and lower [6], when the diurnal variation of the relative humidity is excluded. The free foehn criteria of Flon [7] are the values of the relative humidity of 40 % and lower in the afternoon, and not greater than 60-65 % for all other times. Similar criteria were used in detecting the foehn situations in the Caucasus [8].

For the identification of the free air foehn, we used the relative humidity drop to 40 – 60 % (not typical for our region) in a corresponding foehn synoptic situation (descending motions in the anticyclone and the lower border of subsidence inversion being lower than the top of the Khibiny mountains). A qualitative estimation of the sign of the vertical motions was obtained from the dynamics of the ground pressure by the technique described in [9-11]. The absence of an appreciable wind and lower cloudiness, an increase in the horizontal visibility and, sometimes, synchronous fluctuations in the air temperature were additional signatures.

A free foehn at the top of the mount Lovchorr was detected from thermograph and hygrograph records on September 3-4, 2004.

A powerful anticyclone was above the Kola Peninsula during this period (Figure 3). The presence of descending motions in the lower troposphere was established by the dynamics of the ground pressure as described in [9,10]. The distortion of the vertical profile of the temperature, the values of humidity and the occurrence of subsidence inversion in the layer 900-1160m evidence the catabatic motions (the data of aerologic sounding at 00 UT in Kandalaksha are shown in Figure 4). The crossing of the station level (1089m) by the lower border of subsidence inversion provided the necessary conditions for the occurrence of a free foehn.

Indeed, the simultaneous records of the hydrograph and thermograph indicate that at 22:20, for 20 min, the relative humidity decreased from 90 % to 26 % and the air temperature increased by 1.5°C. This occurred in the conditions of the clear sky (2 points Ci) and a weak wind (the velocity was smaller than 2 ms $^{-1}$).

The preservation of the synoptic situation on the surface analysis maps (http://www.met.fu-berlin.de) and the absence of sharp changes in the meteorological parameters at the nearest meteorological stations "Apatity", "Monchegorsk" and "Lovozero" in the referred period, excluded the advection mechanism of the above variations. The relative variations of the air temperature were small, which corresponds to the specifics of the free foehns.

The second and the third bursts of the foehn observed at about 1 and 2 LT. They were also accompanied by the specific variations in the temperature and relative humidity. Their occurrence indicates an unstable vertical speed in the foehn zone. This instability can develop, in particular, by a change in the vertical motion sign in the boundary layer in the wave processes caused by atmospheric thermal stratification [2,4].

2.2 Cyclonic foehns

The cyclonic foehns arise in the periphery of the stationary anticyclones and the occlusion cyclones. For the illustration we will consider the events of February, 8 2005, when an occlusion cyclone was located above the north-east ETR, and the high-altitude anticyclone was above the Kola Peninsula. The air motions in such a synoptic situation lead to the formation of a horizontal stream with a descending component involved in a cyclone whirl. The data of the aerologic sounding in Kandalaksha at 12 UT on February, 8 show that the strong north-west wind arose in the layer above 1 km. It had a character of a jet current (the wind velocity exceeded 15-18 m/s). At the same time, the wind in the surface layer (up to 300 m) was weak or moderate (the velocity was lower than 5 m/s). The descending motions caused a relative humidity decrease from 100% to 42% and even down to 32 % in spite of the fact that there was an advection of the moist sea air. The temperature increase amounted to 6.3°C (from -7.5 °C to -1.2 °C). The foehn situation persisted for more than 12 hours.

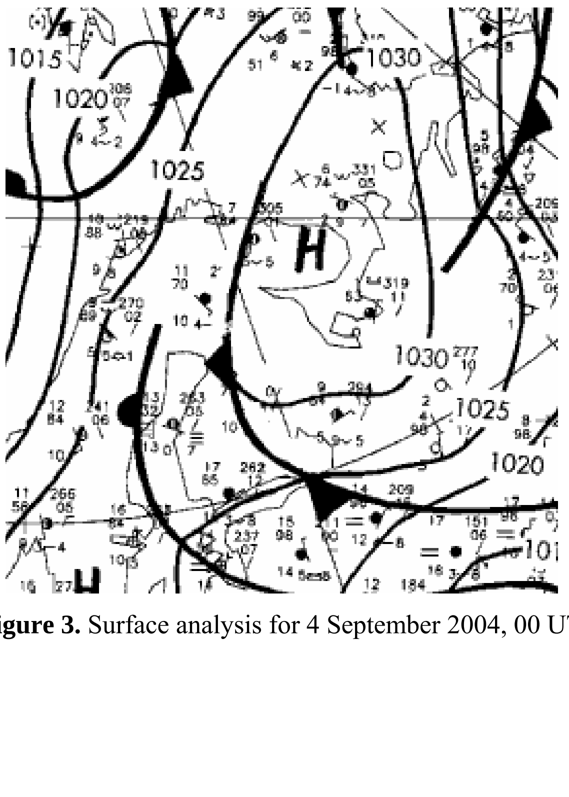

Figure 3. Surface analysis for 4 September 2004, 00 UT

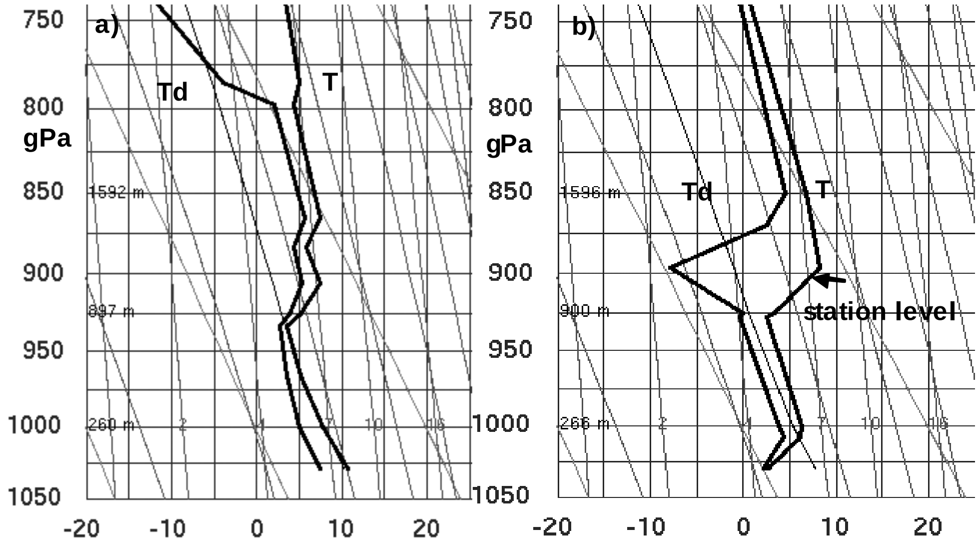

Figure 4. Aerology sounding in Kandalaksha on 3 September 2004 at 12 UT (a) and on 4 September 2004 at 00 UT (b)

Conclusions

We have identified 3 types of the foehn processes above the Khibiny mountains, using the meteorological observations at the mount-avalanche stations "Vostochnaya" and "Centralnaya":

1) The foehns in the mountain valleys and in the foothills are associated with air flowing over the mountain;

2) The free foehns at the tops of the mountains are caused by descending motions in the anticyclones;

3) The cyclonic foehns at the mountain tops are caused by descending motions in the periphery of anticyclones and cyclones .

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