FORECASTING OF LEE WAVES OVER COMPLEX TERRAIN BY MEANS OF A NON-HYROSTATIC FORECAST MODEL

By Dr. Herbert Leykauf, Dr. Ralf Thehos
Deutscher Wetterdienst, Offenbach a. Main
Presented at the XXVI OSTIV Congress, Bayreuth, Germany

For more than 50 years research into lee waves has been one of the most interesting chapters of gliding meteorology. Initially important knowledge was obtained from reports of research flights over the Riesen Gebirge and the Alps as well as the famous Sierra Wave Project. From the most important theoretical studies, in the first place by Scorer, it was known how the profile of the Scorer parameters, temperature and wind speed being the input parameters, had to look qualitatively so that the waves would form. In a second phase these results were further developed into methods for forecasting waves. With simplifying assumptions with respect to the orography and the vertical profiles of temperature and wind, the wave equations were solved and nomograms calculated offering a relatively simple possibility of forecasting wave lengths and vertical wind speeds. The simplification in the model orography was rather massive as the calculations were based on rectangular or sinecurved mountains.

In practice, however, the application of these methods was too time-consuming. The results obtained were also only partly satisfactory as the simplifications necessary to obtain simple nomograms or formulae often do not correspond with nature. Especially over the Alps the application of these methods proved to be a particular problem because of the complex topography. Consequently, the lee wave forecast has been stagnant for decades, and in practice it was mostly based on plausibility considerations taking into account the synoptic situation and the measured or forecast vertical profile of the horizontal wind components.

The normal operational numerical forecast models also did not offer a suitable possibility of forecasting waves as the equation of the 3rd group of motions is reduced by the hydrostatic approximation, and the horizontal resolution of these models with a typical mesh width of 15 to 50 kilometers, does not reproduce the actual topography precisely enough.

The new non-hydrostatic forecast models such as the MM5 of the U.S. National Weather Service or the so-called "Lokale Model" (LM) of the Deutscher Wetterdienst (DWD) now offer the possibility of carrying out numerical experiments on the forecast of lee waves also over complex terrain, as these models not only describe the physical processes but even cover the suitable topography with a high resolution.

With an experimental version of the LM operated with a resolution of 2.5 kilometers, several cases of north foehn situations have been calculated for the Alpine region.

The following example shows a forecast for March 17, 1998, 15:00 UTC. In a typical north foehn situation with current speeds of 25 kt in FL 100 and of 30 kt in FL 180 in the lee of the Alps in the Valais, several stationary lee waves formed. At several spots the waves were marked by rotors. The wave in the lee of the Monte Rosa generated a beautiful Altocumulus Lenticularis wave cloud. Flight measurements were carried out with a Duo Discus within 6 waves, which were successfully climbed and measured.

The Table shows the vertical speed for a cross-section extending from north to south across the western Alps along the Les Diablerets - Aosta - Col di Lis line.

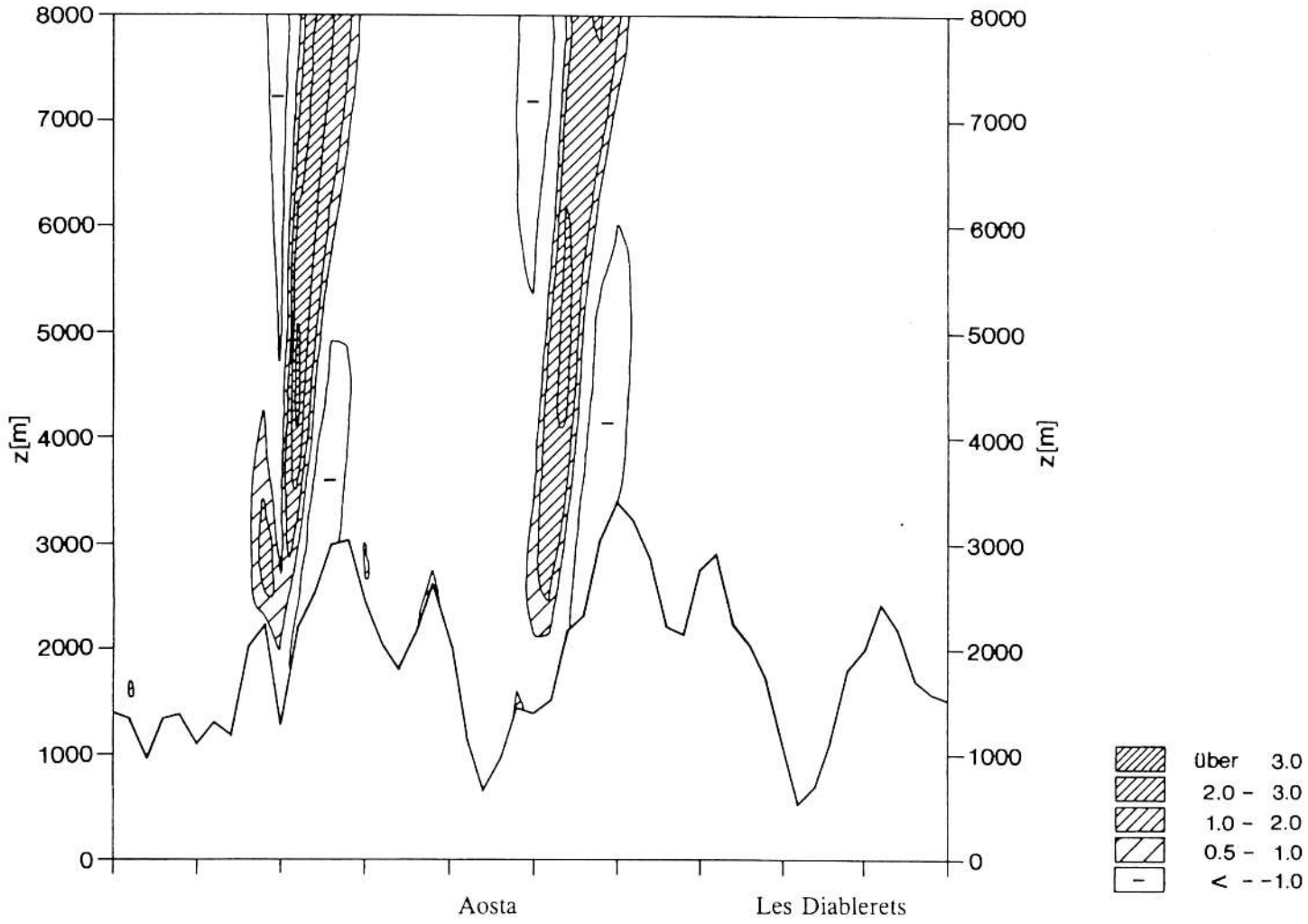
Air from the north is streaming towards the Alps. Directly at the south flank of the Grand Combin (just right of the center of the picture), a downdraught area reaching up to a height of 6000m is forecast, followed in the lee by a steep ascending motion reaching up to a height of 8000m. This wave in the Valpelline valley, which by the way was not correctly shown by the model topography was also climbed. The measured rates of ascent of 3 to 5 m/s were distinctly higher than the calculated vertical speeds with a maximum of 3.2 m/s only. Directly over the Aosta valley only weak vertical movements are calculated, the next strong ascending motion is found in the lee of the Grd. Paradiso (in the illustration th highest peak on the left of the picture).

The ascending motions measured over the valley of the Dora Baltea near Nus and in the lee of the Fallere as well as the waves of the Mont Blanc, the Grd. St. Bernhard and the Monte Rosa are correctly described in the numerical simulation as far as their position is concerned, however, the vertical speeds are underestimated in the model by ca. 20-30%.

SUMMARY

The examples show very impressively the possibilities offered by a high resolving non hydrostatic model for forecasting lee waves. Even if after the first test calculations it is too early to make definite statements on the quality of these forecasts, the results are astonishingly good in a comparison with the measured and calculated conditions. Position, horizontal extension and vertical structure of the ascending motions and downdraughts over the Alps in areas with high mountains and deep valleys are correctly described. However, in comparison to the measurements, the vertical speeds are too low. This deficiency results from the fact that the actual structure of the relief cannot yet be corectly described even with a 2.5 kilometer grid. In reality, the mountains are still slightly higher, the slopes and flanks of the mountains are steeper and the valleys are deeper than in the model. For numerical experiments this will not cause a problem, however for the purpose of operation and routine forecasts we will have to content ourselves for the time being with model versions with mesh widths of 7 and in 2000 or 2001 of 2.5 kilometers, as even the fastest computers in operation are too slow for higher resolutions.

From the beginning of 2000 the DWD will be making numerical forecasts of the vertical wind speed over the Alps available via the self briefing system pc_met. with the new cartographic representations and the selected cross sections across the Alps completely new possibilities will be opened up for the planning and performance of lee wave flights. The forecasts, however, will be beneficial to the entire aviation as the LM also offers new possibilities for a more accurate forecast of windward and lee effects and of mountain wave induced turbulence.



Vertical velocity (in m/s) for the cross-section Les Diablerets - Aosta - Col di Lis