OPERATIONAL USE OF A WIND PROFILER FOR AVIATION METEOROLOGY

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ABSTRACT

A wind profiler placed in Madrid-Barajas Airport is used to detect the wind -speed and direction- at various elevations above the ground up to 3000 meters. Readings are made at each approximately 200 feet in periods of ten minutes. These data are very useful for flight planning, in special when the aeroplane is in the approximation area of the airport. As the low level wind shear (LLWS) plays a very important role for the pilots when the aeroplane is landing or taking off, we focus on the possibility of obtaining a measure of this LLWS in the approximation of the runway, according to the severity categories of LLWS expressed in terms of vertical wind shear. In addition, some meteorological mesoscale phenomena in the region of the airport can be shown by the wind profiler data. Thermal inversion at surface is also observed using the temperature data measured by the profiler in periods of thirty minutes at various elevations. Some real cases of vertical wind shear and thermal inversion are presented.

Introduction

Since recent years there is an increasing use of wind profiler radars and the development of operational wind profiler radars is evolving rapidly (1). Efforts have been addressed to detect and/or prevent some relevant meteorological phenomena, such as turbulent wind, possible wind shear, instability of the atmosphere in the approximation of the runway, and mesoscale phenomena related to the wind. The profiler is also useful for air quality meteorology applications and boundary layer upper-air observations. Wind shear induced by thunderstorms (wind gusts), microburst and downburst are observed by Low Level Wind Advisory Systems (LLWAS), but wind shear induced by frontal activity, temperature inversions and surface obstructions are very well measured by wind profilers (2). In addition, some mesoscale structures which affect to some airports are observed and described in good conditions by this instrument.

This is the case of the wind profiler placed in Madrid-Barajas (Spain) some years ago. This wind profiler is part of the E-PROFILE Programme of EUMETNET (former E-WINPROF) which provides vertical profiles on wind measurements from radar wind profilers (vertically pointing radars) and weather radars from a network of locations across Europe. The main goal of the programme is to improve the overall usability of wind profiler data for operational meteorology and to provide support and expertise to both profiler operators and end users. The vertical data are taken into account by the models and are very useful to the operational aviation meteorology. The data of the Madrid-Barajas profiler are also sent to the UK Met Office which, in collaboration with European partners, has developed an infrastructure for network operations and real time Internet display.

By using this wind profiler several mesoscale structures typical of the area of Madrid have been observed. These structures are meanly related to the wind near surface and affects to the navigation operations of the airport (i.e. changing the runway for landing and take off). In the case of the presence of vertical wind shear the wind profiler has been a help in the preparation and sending of wind shear warning. To achieve this improvement a software application has been developed. In the same way, an improvement has been made to observe the temperature inversion and to warn to the airport. Some real cases are exposed in this paper. Firstly, the equipment characteristics are mentioned. Afterwards, measurements and main results are shown, and finally some conclusions are presented.

Equipment characteristics

The equipment used is a a Vaisala LAP-3000 Wind Profiler, a radio frequency remote sensing instrument (3). A photo is viewed in figure 1. The instrument provides wind profile with vertical resolution of 60 m and typical averaging period of 10 minutes. A volumetric measurement is made directly above the site with 3-5 Doppler beams.

Figure 1. LAP-3000 Wind Profiler in Madrid-Barajas Airport

An application software (LAP-XM) acquires and processes the signal data, and displays and saves the meteorological data products. During the process quality control is operated and finally wind and temperature profiles are generated. The instrument offers a range of alternative measurement configurations, depending on the interest of the measurements: time resolution (10 or 30 minutes), vertical resolution, the altitude range, etc. In our case time resolution set to 10 minutes for the wind and 30 minutes for the temperature, with a vertical resolution of 60 meters in order to detect vertical wind shear and inversion of temperature. Two different groups of measures has been made: one for a height of 3000 meters above the terrain and other for a height around 1700 meters. In the case of the temperature, an optional RASS (Radio Acoustic Sounding System) is used and the temperature is determined as a function of the height, up to 1500 meters, in periods of 30 minutes. The reason of using a radio acoustic signal is the dependence of the sound velocity on the temperature.

Measurements, results and operational use

Using the wind profiler to detect low level vertical wind shear is considered taking into account the interest for meteorology aviation in the airport of Barajas. No LLWAS is installed in the airport, so it would be useful to make use of the Wind Profiler (WP) to observe low level vertical wind shear and maybe alert to the aviation control centre. At present, warning of low level vertical wind shear is made using a simple model which calculates the wind at several levels and compares it to the wind at surface. Although this system does not work wrong, it could improve. Then, the measures of the WP could support this improvement.

Vertical wind shear is a meteorological phenomenon associated with a sudden variation of wind speed and/or wind direction between two vertical levels, and this difference in wind can be measured between two points spaced vertically 60 meters (approx. 200 feet) in the direction of the runway (the plane is taking off or landing in this direction at low levels). According to some aviation meteorology references (4) moderate vertical wind shear appears for values between 4 and 8 knots per 100 feet and strong vertical wind shear for values between 8 and 12 knots per 100 feet. Then, once the vertical wind shear is calculated by using the data of the WP, an operational value is given and it could be use to alert to the control centre for the wind shear observed. It could also be use to modify or to give a weight to the wind shear warning, if there is any.

Some examples of several dates are presented. The fourth of July 2013 the WP showed the wind of figure 2. As it can be seen at 400 m approximately a discontinuity appears (see white broken line) because of the change of the wind direction, although the speed has no high values (weak wind). However it is enough to cause low vertical wind shear at this level for the runway 18-36 of Madrid-Barajas Airport, as it is shown in figure 3. Moderate wind shear is observed and even strong wind shear is found at 4 UTC for 1200-1300 feet (400 m). At the same time only 4ºC of

temperature inversion is observed. The structure of the winds is related to a local phenomenon due to the northwest range of mountains which cause the wind to be northerly at the surface during the night, but at higher levels the wind is southerly due to the presence of a low over the Iberian Peninsula. Numerical models warned about the possibility of low level vertical wind shear in the airport but pilots did not report wind shear, maybe because winds were weak.
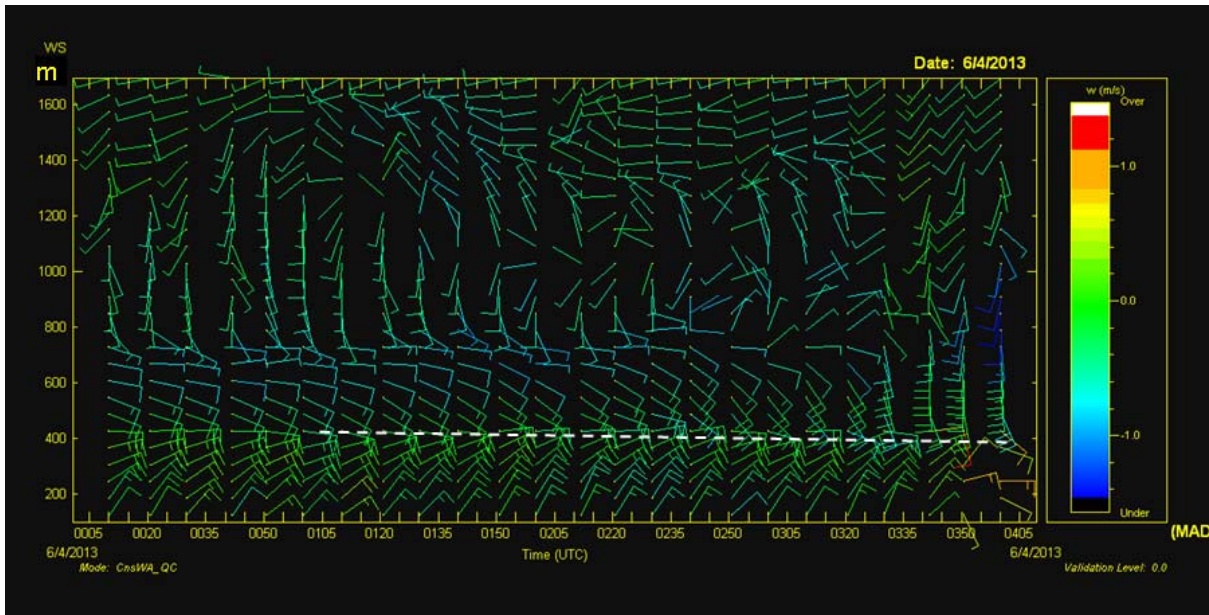

Figure 2. Wind detected by the wind profiler at several vertical levels

Other case happened the 27th of January 2014. In this case winds were strong (40 knots were reached) and pilots reported vertical wind shear in the airport. Both in the sounding at 12 UTC and in the WP strong winds were observed and the application based on WP detected low level vertical wind shear (moderate and strong), as it is showed in figure 4 for the 32 runway of Madrid-Barajas Airport. Then, although models had not given wind shear, the monitoring of the data reported by the WP would have been enough to issue the warning and to alert to the control centre.

Finally, WP observed vertical wind shear at various levels up to 5000 ft the 3rd of March 2014. This can be seen in figure 5 for 14-32 runway of Madrid-Barajas Airport. The wind shear was reported by the pilots from 12:30 UTC. According to the models a warning was issued for all runways between surface and 2500 ft. In the soundings it could be seen the strong winds at various levels too, and not only near the surface. This is also the case when thunderstorms are in o near the airport and strong wind is frequent at surface and at higher levels.
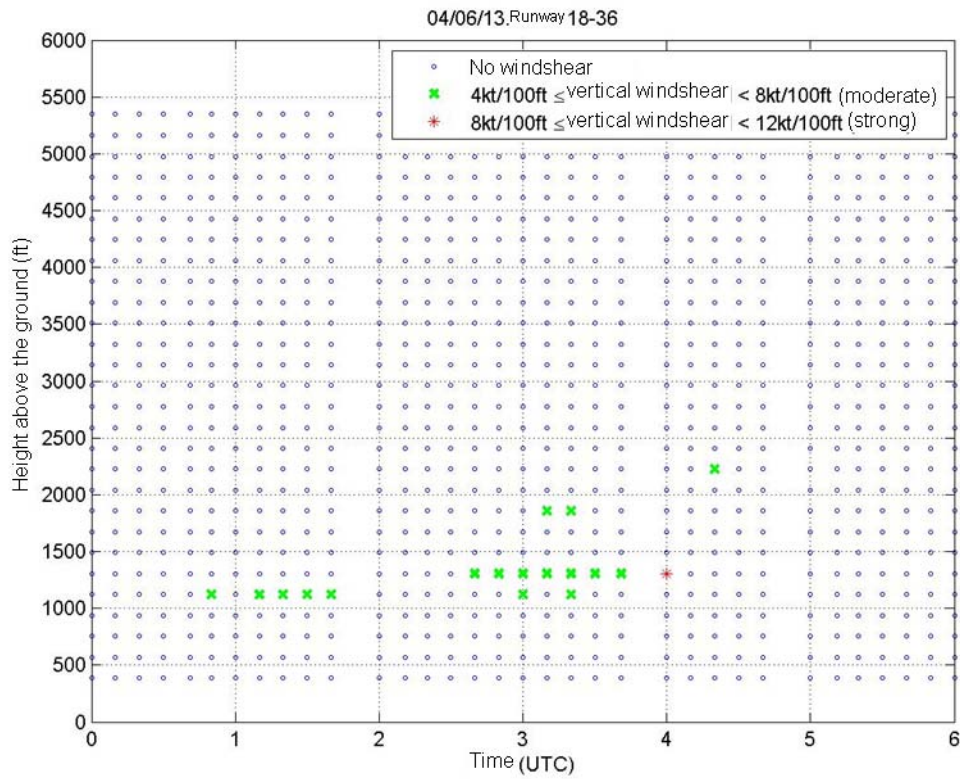
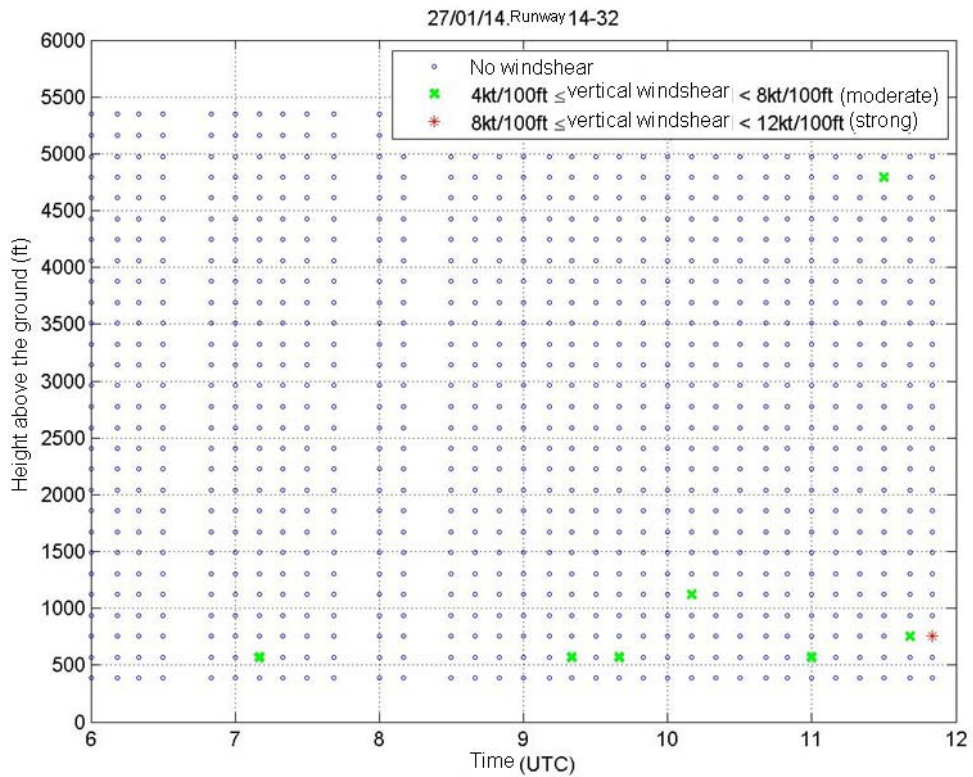**Figure 3. Vertical wind shear at 1300 ft for 18-36 runway**

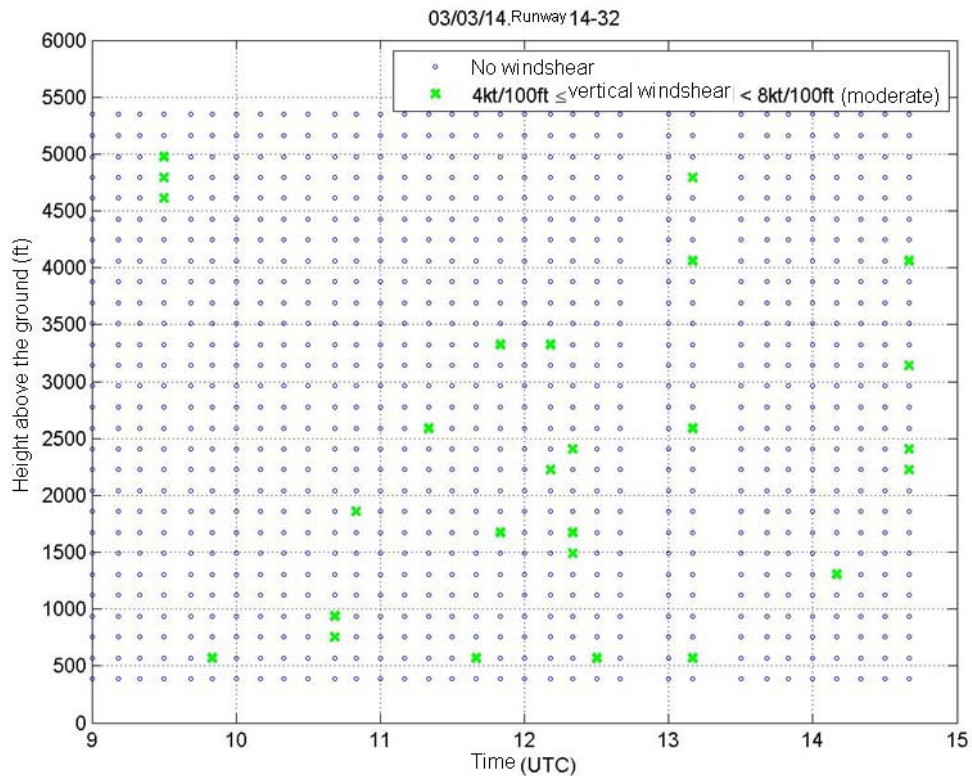**Figure 4. Vertical wind shear at 600-800 ft for 14-32 runway**

Ilustración 1Figure 5. Vertical wind shear detected at various levels in the Madrid-Barajas Airport

Using the RASS module the inversion of temperature is continuously calculated every 30 minutes, with respect to the ground. Then, this observation can support a warning of inversion of temperature, which has issued using a model. In the Airport of Madrid-Barajas an inversion of 7 degrees or more is considered in order to provide a warning to the aviation control centre. Therefore, if an inversion of this value is observed by the WP and there is no warning, a new warning is issued. As an example, an inversion of 7ºC at 500 meters is calculated from the data of the WP (figure 6). In the figure each number represents the inversion of temperature between surface and height where the number is placed.
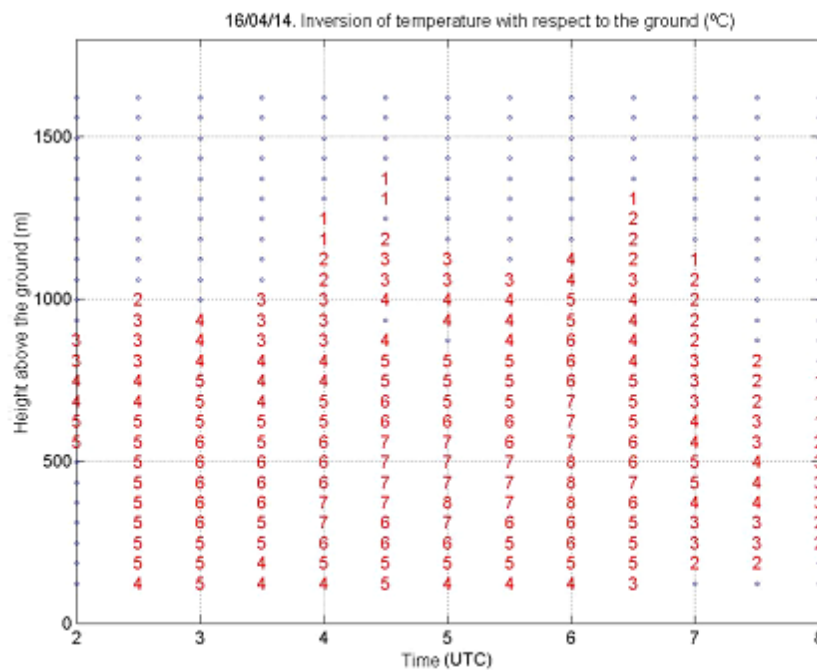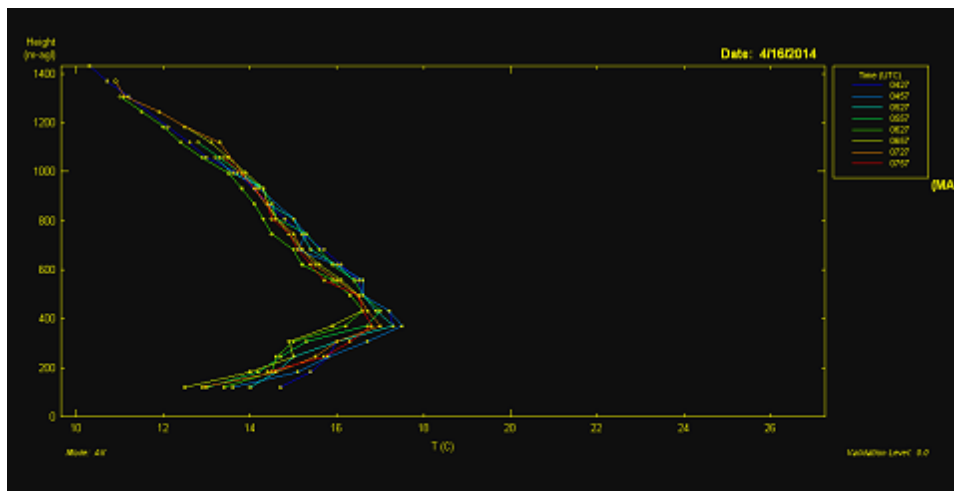
Figure 6. Temperature detected by the WP (above) and inversion of temperature calculated with respect to the ground (below)

Detection of mesoscale structures

Due to the place of the Airport of Madrid-Barajas –in a valley with a range of mountains at northwest– in some cases, under stable atmosphere, a moderate or strong synoptic flow is present, north-westerly. Then Madrid is located in the leeward side of the Central Range. With these conditions, due to a hydraulic jump, wind in the city, as well as in the airport, could be either calm or even southerly, whereas in the mountain ridge strong north-westerly winds can be recorded. The north-westerly flow passes over the mountains and curves and returns being southerly or south-easterly near the surface. Operationally it is critical because usually the main runway is oriented to the north, so when the flow changes it is needed to change the main runway

to the south, and this supposes waste of time and stop the operations. The structure of winds formed in these situations can be seen using the WP, as it is shown in figure 7: approximately at 23:00 UTC wind begins to blow from the South at surface and increases in height as time goes by and two regimes of wind are present at the same time. Near surface wind is southerly and at high levels wind is northerly. This variable wind near the surface could affect to a plane that is taking off or landing.
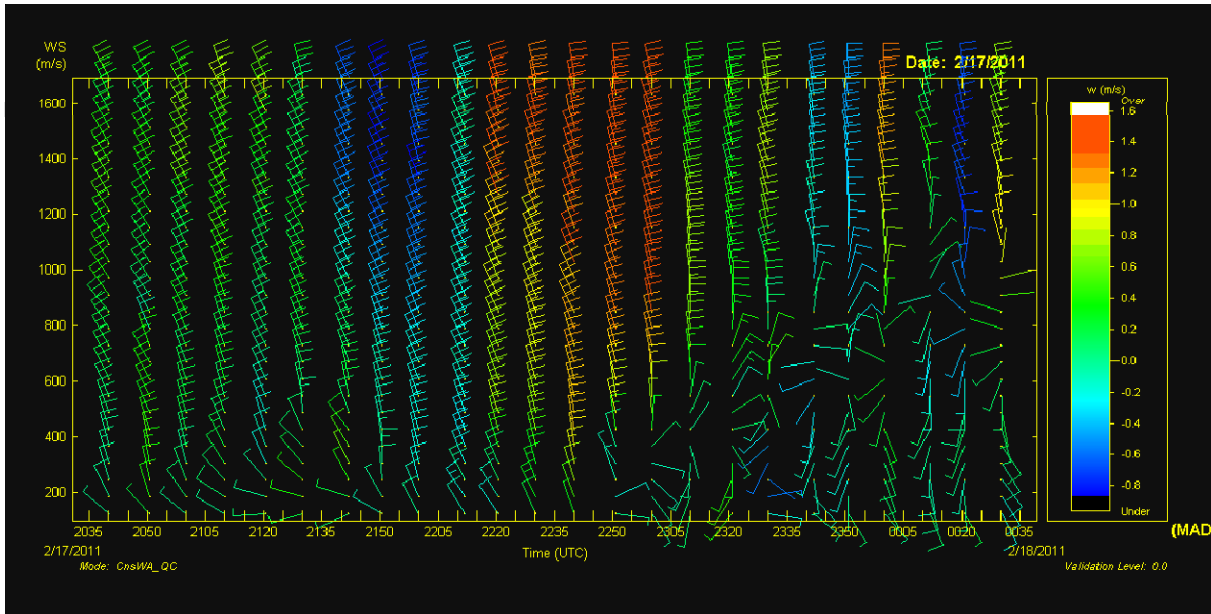

Figure 7. Flow of wind observed by the WP in the Airport of Madrid-Barajas

Katabatic winds are also observed by the WP, as it is shown in figure 8. In this case the wind from the Central Range carries high density air from a higher elevation and down a slope under the force of gravity. In this example the flow at high levels is southerly and in Madrid the katabatic wind is northerly or variable.
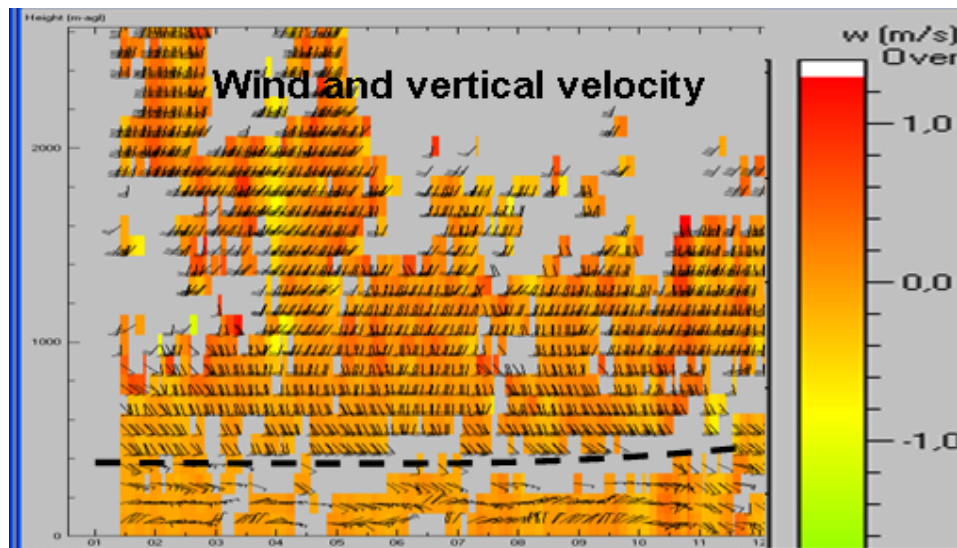
Figure 8. Katabatic winds in Madrid

Conclusions

By means of a software application wind profiler is used to detect low vertical wind shear and inversion of temperature in order to provide improvements to the models through which the warnings are made. Some examples of data from real cases have been shown for different scenarios, for low level wind shear and for inversion of temperature. In addition, some mesoscale structures which could affect to the planes have been observed in the Airport of Madrid-Barajas by using the wind profiler: winds, with different direction or speed near the surface, or changes of the temperature (depth inversions) and katabatic winds. Some examples of these conditions are shown by the profiler.

References

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