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SEASONAL VARIATIONS OF RADAR ANOMALOUS PROPAGATION CONDITIONS IN A COASTAL AREA

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1. Introduction

Severe superrefractive anomalous propagation conditions have a well known effect of increasing and intensifying ground clutter echoes in weather radar observations. This is particularly negative for quantitative precipitation estimates as such spurious echoes may not be filtered completely (Moszcowicz et al, 1994), even with modern Doppler radars, and are difficult to discriminate from real rainfall echoes when they appear simultaneously.

Since 1997, radiosonde observations have been made in Barcelona to support the operations of the regional government's Subdirectorate of Air Quality and Meteorology. In this study, radiosonde observations are used to characterize radar anomalous propagation (anaprop) conditions and their potential effects on a regional weather radar network currently under development. Most radars of the network will be located in coastal areas, which could be potentially prone to anomalous propagation.

2. Methodology

As anomalous propagation is due to relatively small variations of the air refractive index n, the magnitude known as refractivity N, defined as one milionth of n-1, is commonly used in anaprop studies. Bean and Dutton (1968) showed that N can be written as:

$$N = (n-1)10^6 = \frac{77.6}{T}\left(p + \frac{4810 \cdot e}{T}\right), \quad (1)$$

where T is the air temperature (K), p atmospheric pressure (hPa) and e is the water vapour pressure (hPa).

A related magnitude is the modified refractivity M, which is defined as:

$$M = N + \frac{z}{10^{-6} r} \quad , \quad (2)$$

where z is altitude and r is the radius of the Earth in m. Modified refractivity is very useful to characterize propagation conditions as for constant M the curvature of the ray path is that of the Earth's surface and, therefore, when there are negative M vertical gradients the ray path is bent towards the surface and radio waves get trapped like in a wave guide (ducting). Propagation characteristics may vary largely, depending on the type of air mass (Gossard, 1977). When characterizing the radio propagation environment it is usual to consider the vertical refractivity gradient of the air of the first kilometer above ground level to estimate propagation effects such as ducting, surface reflection and multipath on terrestrial line-of-sight links.

However, the effect on weather radar beam refraction not only depends on the refractivity gradient of a layer but also on the angle of incidence between the beam and the trapping layer considered or the frequency of the electromagnetic wave. For weather radar applications, if the refractivity gradient of the first kilometer of the atmosphere is around -1/4a (i.e. -39 N units km^{-1} or 118 M units km^{-1}) then standard propagation will occur for any angle of incidence (Doviak and Zrnic, 1992).

Using more than 1700 valid radiosonde observations collected between 1997 and 2001, a median gradient of modified refractivity for the first kilometer above ground (MG1000) was found to be of 111 M units per km. Annual variation of monthly MG1000 medians is shown in Figure 1.

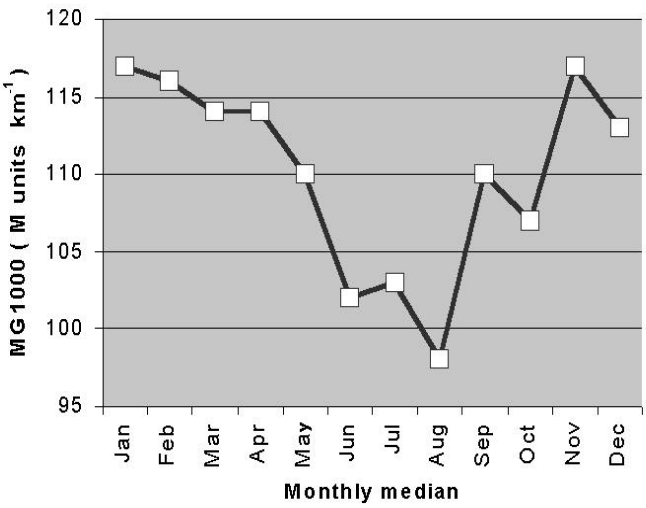

Fig. 1. Annual variation of MG1000.

Minimum values of MG1000 (the most superrefractive) occur in August (98 M units km^{-1}), when summer surface temperatures are higher. During that month, MG1000 is below 65 M units km^{-1} 10 % of the time and below 76 M units km^{-1} 80 % of the time. In the cold period ranging between November to April standard propagation conditions are predominant, with values around 113 to 117 M units km^{-1}. The rest of the year may be considered as made up of two transition periods before and after the summer peak.

The vertical gradient of refractivity in the first kilometer takes into account surface trapping layers such as surface ducts and ducts associated to temperature and moisture gradients of the boundary layer which extend to the surface (Babin, 1996).

Moreover, the existence of elevated ducts -when the bottom of the duct is above the surface- may also be significant from the point of view of the propagation environment.

Elevated ducts may be characterized for their vertical extension, the refractivity gradient, and also by the bottom of the trapping layer (where the modified refractivity gradient is zero). This height is also known as the optimum coupling height of the elevated duct (OHEL). Figure 2 shows the monthly variation of median values of OHEL.

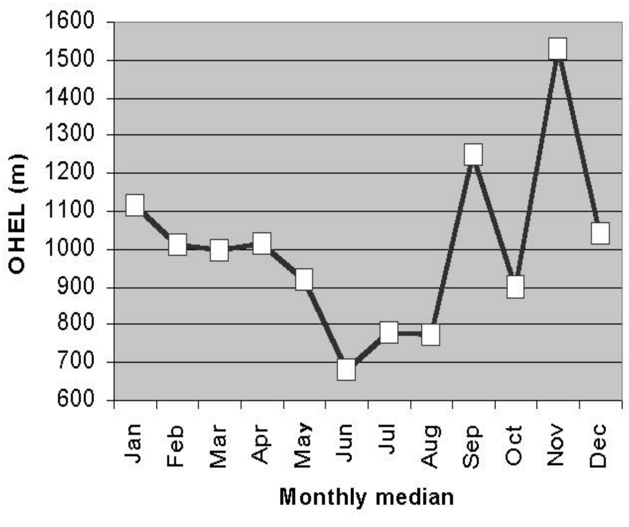

Fig. 2 . Annual variation of Optimum Coupling heights for Elevated Ducts.

It may be seen that OHEL ranges roughly between 1500 m (November) to 700 m (June). From May to August, values are below the first kilometer above ground so elevated ducts contribute during this period to increase the vertical refractivity gradient MG1000 above mentioned.

3. Conclusions

Seasonal variations of propagation conditions for Barcelona have been studied using radiosonde data collected between 1997 to 2001. Vertical refractivity median gradients for the first kilometer have been calculated and departures from normal propagation conditions have found in summer time, being most important in August.

The values obtained in this work may be compared with those shown by the International Telecommunications Union worldwide maps of vertical refractivity gradients (ITU, 1997). The maps provide a large scale overview of the vertical refractivity gradient. However, they agree relatively well. In particular, suggested monthly mean values for February, May, August and November for the Barcelona area are 117, 110, 90 and 107 M units km^{-1} while the mean values we found were 116, 108, 96 and 117.

Figure 3, taken from ITU (1997), represents monthly mean values of vertical refractivity gradient, ΔN, for August, when the annual low is reached in the Barcelona area. Note that the intense superrefractive area (below 60 N units km^{-1}) extends from the Persian Gulf -where the world extreme is achieved for that month with 100 N units km^{-1}- and the coast of North Africa to the Western Mediterranean.

The results shown confirm the occurrence of anaprop conditions which may have a significant effect on weather radar observations. In particular, quantitative precipitation estimates may be affected and processing procedures assuming standard propagation conditions, such as radar beam blockage correction schemes should be used with caution (Bech et al., 2001).

Taking into account that in the area studied there is a coastal range with heights around 400 to 700 m, and that several radar units are to be installed at those heights, the presence and type of elevated ducts has been considered. In particular, the variation of the optimum coupling height of elevated ducts, show that depending on their intensity and extension they could have effects on the lowest elevation radar beams. Another issue to be considered because of the maritime environment of the area studied, is the representativity of the radiosondes, as shown in several field campaign measurements (see for example Brooks, 2001).

Acknowledgments

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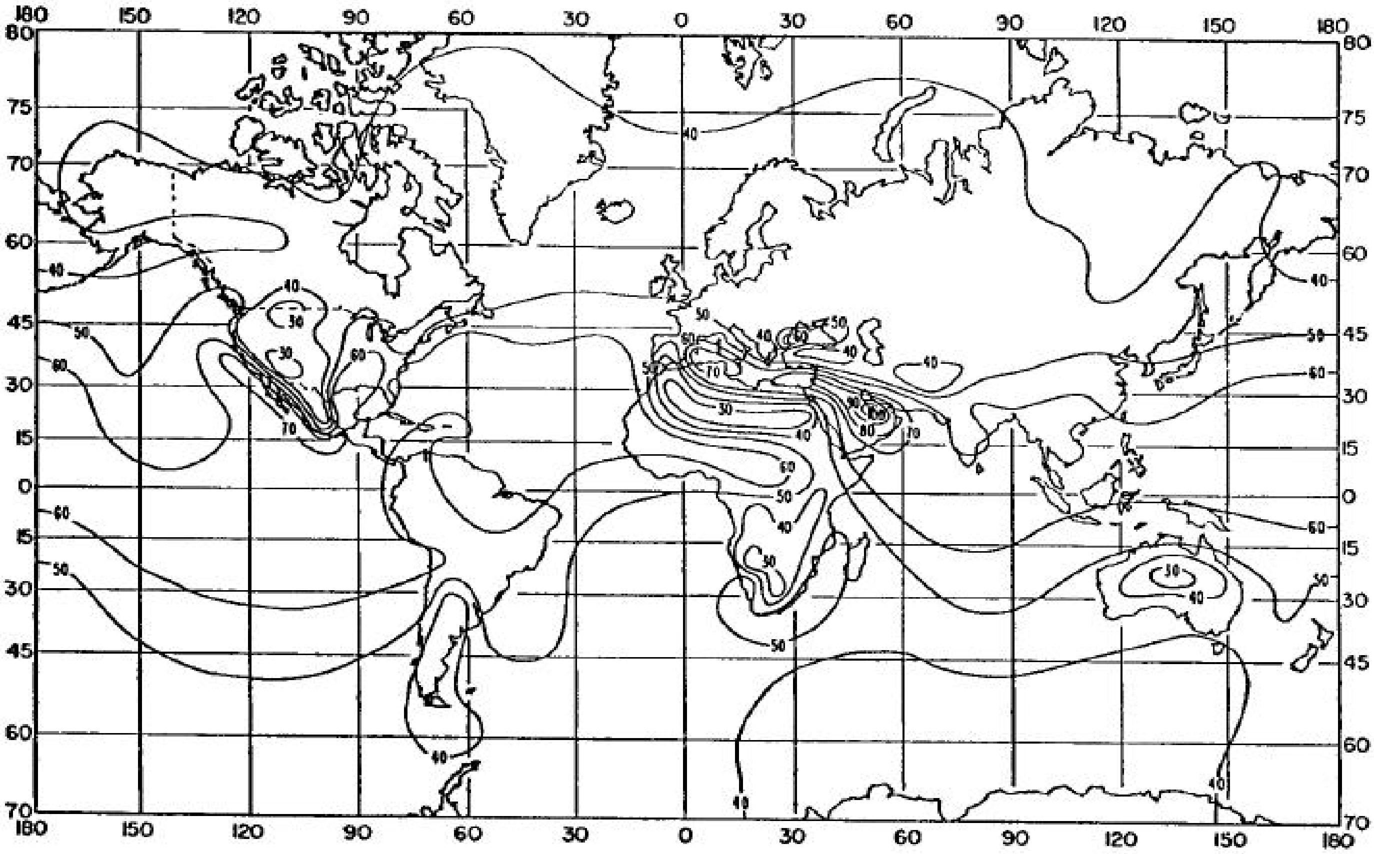

Fig. 3. August monthly average DN (ITU, 1997).

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