14.9 SPECTRAL ANALYZES OF OPTICAL SCINTILLATION: REFRACTION AND ABSORPTION COMPONENTS IN AN URBAN ZONE

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1. INTRODUCTION

Optical large aperture scintillometery (LAS) has been shown, in recent years, to provide reliable 'area averaged' turbulent sensible heat flux over of several hundreds of meters to several kilometers over both homogeneous (De Bruin et al 1995) and heterogeneous sites (Lagouarde et al 2002). Sensible heat flux (H) is derived from the refractive index structure parameter (Cn^2) which is directly related to the variance of the log amplitude fluctuations (σ^2) of the EM wave received by the LAS (Wang et al 1978). In an ideal (non-absorbing) atmosphere σ^2 is directly related to refraction of the emitted EM wave by turbulent eddies. Kagawa et al (1996) demonstrated that absorption (water vapor) can enhance the measured variance, which in turn can result in the overestimation of H. In practice σ^2 is bandpass filtered (0.03-400Hz) to eliminate absorption, instrument drift and high frequency noise. Following Nieveen et al (1998), for pastureland, this has been reduced (0.1-400 Hz). In order to control the quality of our scintillometery measurements and the adequacy of the filter used, spectral analyze has been performed.

2. THEORY

Tatarskii (1961) produced an equation for the spectral density of refractive index fluctuations. Thereafter Clifford (1971) derived an equation taking into account absorption, which Nieveen et al (1998) modified for receiving optical filter factors. From theory it is accepted that three regions can exist in LAS power spectra (figure 1): a low frequency absorption zone, present in lossy conditions, a refraction plateau, independent of frequency and high frequency roll off due to aperture damping.

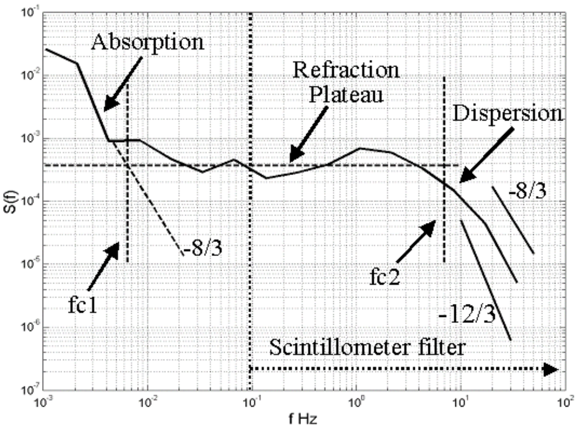

Figure 1 Typical Scintillation spectrum

The plateau and absorption spectral densities are given by Nieveen et al (1998)

$$S_{ar}(f) = 0.0389 L^3 D^{-7/3} Cn^2 \upsilon^{-1} \qquad (1)$$

$$S_{ai}(f) = 0.0326 k^2 L Cni^2 \upsilon^{5/3} f^{-8/3} \qquad (2)$$

where $S_{ar}(f)$ is the refractive spectral density, L the optical pathlength, D the aperture diameter, ν the transverse velocity; $S_{ai}(f)$ is the absorption spectral density, Cni^2 is the absorption structure parameter (assumed water vapor) and f natural frequency. The damping region Clifford (1971) states a $f^{-8/3}$ roll off whereas Nieveen et al (1998) calculated by numerical integration a $f^{-12/3}$ roll off. Medeiros Fihlo et al (1983) calculated upper and lower corner transition frequencies as follows:

$$f_{c2} = \frac{\upsilon}{1.25\,D} \qquad (3)$$

$$f_{c1} = 0.936 (k/L)^{3/4} D^{7/8} \upsilon \left(\frac{Cni^2}{Cn^2} \right)^{3/8} \qquad (4)$$

3. SITE AND METHODOLOGY

During the CLU/ESCOMPTE experimental campaign (June-July 2001) two optical LAS instruments (λ=0.93μm, D=0.15m) built by the

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Meteorology and Air Quality Group (University of Wageningen, The Netherlands) were installed over the city center of Marseille with pathlengths of approximately 2 kms and instrument heights ranging from 26 to 53 m. The trajectories were Pardis (P) → Nédelec (N) and Pardis (P) → Timone (T). PN was situated parallel to the sea and PT perpendicular. Furthermore the topography was significantly different.

Cn^2 output was recorded at 1 Hz along with raw 1 kHz σ^2 simultaneous for the two paths. Spectral densities (wavelet) were calculated from 30 minute data periods using raw 1 kHz σ^2 data filtered to 100 Hz. Figures are presented as the average of two spectral estimates per half hour period, each using 2^{16} points, using Matlab.

As ν was not directly available during the measurement campaign, estimates were made using (2) with a fit in the plateau region of each trajectory spectral density distribution to approximate $S_{ar}(f)$ and subsequently ν. As a next step ν was used to estimate $S_{ai}(f)$, with Cni^2 modeled using simple MO relations and a peak latent heat flux.

4. RESULTS AND CONCLUSION

Figure 2 presents the scintillation spectra from day 177 (15h00 to 15h30 UTC, general meteorological conditions: sensible heat 320 W/m^2, windspeed 4.7 m/s, direction 176°).

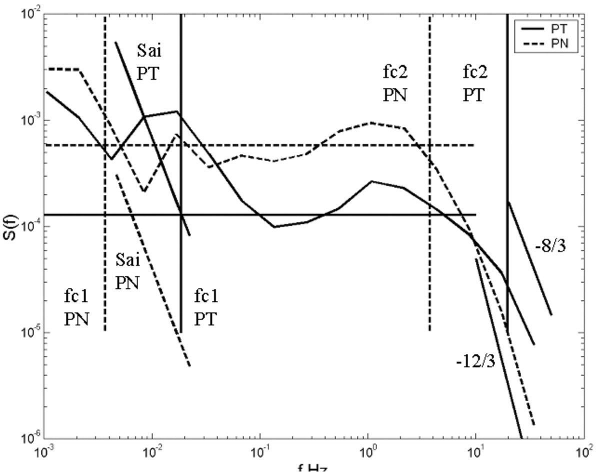

Figure 2 Scintillation spectra day 177 15h

This example was chosen as the direction corresponds with a perpendicular wind for PT and parallel for PN. Before commenting the differences between the two trajectories it can be noted that for both the three above mentioned regions exist (absorption, refraction, dispersion). Furthermore the instrument filter is sufficient to eliminate absorption induced errors in the measurement. Comparing the two it can be seen that PT is more influenced by absorption (this is always the case) and that the absorption over PT is not characterized by water vapor (as absorption begins at f > fc1). The dispersion roll off is found to be $f^{-12/3}$ for both however PT initially has a slighter roll off. This feature is affected by wind direction.

In conclusion spectra over a complex urban site are similar to those found over pastureland (Nieveen et al 1998) and follow theoretical predictions. Instrument filtering can be considered correct and flux estimates unaffected by absorption. Doubt over the dispersion roll off has been removed with a $f^{-12/3}$ confirmed. However, there is a wind direction factor. Finally PT is significantly more affected by absorption, which may be due to footprint differences (topography, sea).

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