RECOMMENDATION ITU-R P.840-2

ATTENUATION DUE TO CLOUDS AND FOG

(Question ITU-R 201/3)

(1992-1994-1997)

The ITU Radiocommunication Assembly,

considering

a)   that there is a need to give guidance to engineers in the design of Earth-space telecommunication systems for frequencies higher than 10 GHz;

b)   that attenuation due to clouds may be a factor of importance especially for microwave systems well above 10 GHz or low-availability systems,

recommends

1   that the curves, models and maps given in Annex 1 should be used for the calculation of attenuation due to clouds and fog.

ANNEX 1

1   Introduction

For clouds or fog consisting entirely of small droplets, generally less than 0.01 cm, the Rayleigh approximation is valid for frequencies below 200 GHz and it is possible to express the attenuation in terms of the total water content per unit volume. Thus the specific attenuation within a cloud or fog can be written as:

$$\gamma_c = K_l\,M \qquad \text{dB/km} \tag{1}$$

where:

   γ_c :   specific attenuation (dB/km) within the cloud

   K_l :   specific attenuation coefficient ((dB/km)/(g/m^3))

   M :   liquid water density in the cloud or fog (g/m^3).

At frequencies of the order of 100 GHz and above, attenuation due to fog may be significant. The liquid water density in fog is typically about 0.05 g/m^3 for medium fog (visibility of the order of 300 m) and 0.5 g/m^3 for thick fog (visibility of the order of 50 m).

2   Specific attenuation coefficient

A mathematical model based on Rayleigh scattering, which uses a double-Debye model for the dielectric permittivity $\varepsilon(f)$ of water, can be used to calculate the value of K_l for frequencies up to 1 000 GHz:

$$K_l = \frac{0.819f}{\varepsilon''(1 + \eta^2)} \qquad \text{(dB/km)/(g/m}^3) \tag{2}$$

where f is the frequency (GHz), and:

$$\eta = \frac{2 + \varepsilon'}{\varepsilon''} \tag{3}$$

The complex dielectric permittivity of water is given by:

$$\varepsilon''(f) = \frac{f(\varepsilon_0 - \varepsilon_1)}{f_p\left[1 + (f/f_p)^2\right]} + \frac{f(\varepsilon_1 - \varepsilon_2)}{f_s\left[1 + (f/f_s)^2\right]} \tag{4}$$

$$\varepsilon'(f) = \frac{\varepsilon_0 - \varepsilon_1}{\left[1 + (f/f_p)^2\right]} + \frac{\varepsilon_1 - \varepsilon_2}{\left[1 + (f/f_s)^2\right]} + \varepsilon_2 \tag{5}$$

where:

$$\varepsilon_0 = 77.6 + 103.3\,(\theta - 1) \tag{6}$$

$$\varepsilon_1 = 5.48 \tag{7}$$

$$\varepsilon_2 = 3.51 \tag{8}$$

$$\theta = 300 / T \tag{9}$$

with T the temperature (K).

The principal and secondary relaxation frequencies are:

$$f_p = 20.09 - 142\,(\theta - 1) + 294\,(\theta - 1)^2 \qquad \text{GHz} \tag{10}$$

$$f_s = 590 - 1\,500\,(\theta - 1) \qquad \text{GHz} \tag{11}$$

Figure 1 shows the values of K_l at frequencies from 5 to 200 GHz and temperatures between –8° C and 20° C. For cloud attenuations, the curve corresponding to 0° C should be used.

FIGURE 1

**Specific attenuation by water droplets at various
temperatures as function of frequency**

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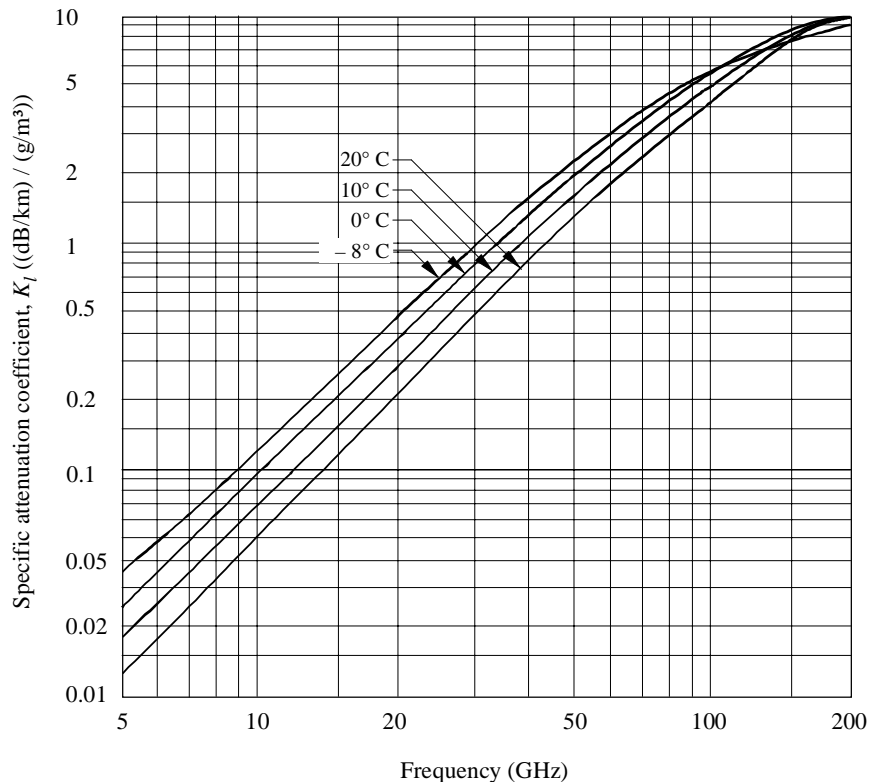
3 Cloud attenuation

To obtain the attenuation due to clouds for a given probability value, the statistics of the total columnar content of liquid water L (kg/m^2) or, equivalently, mm of precipitable water for a given site must be known yielding:

$$A = \frac{L\,K_l}{\sin\theta} \qquad \text{dB} \qquad\qquad (12)$$

where θ is the elevation angle and K_l is read from Fig. 1. Note that K_l is identical to the mass absorption coefficient a_L introduced in Recommendation ITU-R P.836, equation (1).

Statistics of the total columnar content of liquid water may be obtained from radiometric measurements or from radiosonde launches.

In the absence of local measurements, the total columnar content of cloud liquid water (normalized to 0°C) values shown in Figs. 2 to 5 should be used to derive cloud attenuation.

The values shown in the figures are in kg/m^2 for four different yearly exceedance probability levels (80%, 90%, 95% and 99%). The maps were derived from two years of data with a spatial resolution of 1.5° in latitude and longitude. Data files containing these data can be obtained from the ITU Radiocommunication Bureau (BR).

FIGURE 2

Normalized total columnar content of cloud liquid water (kg/m^2) exceeded for 80% of the year

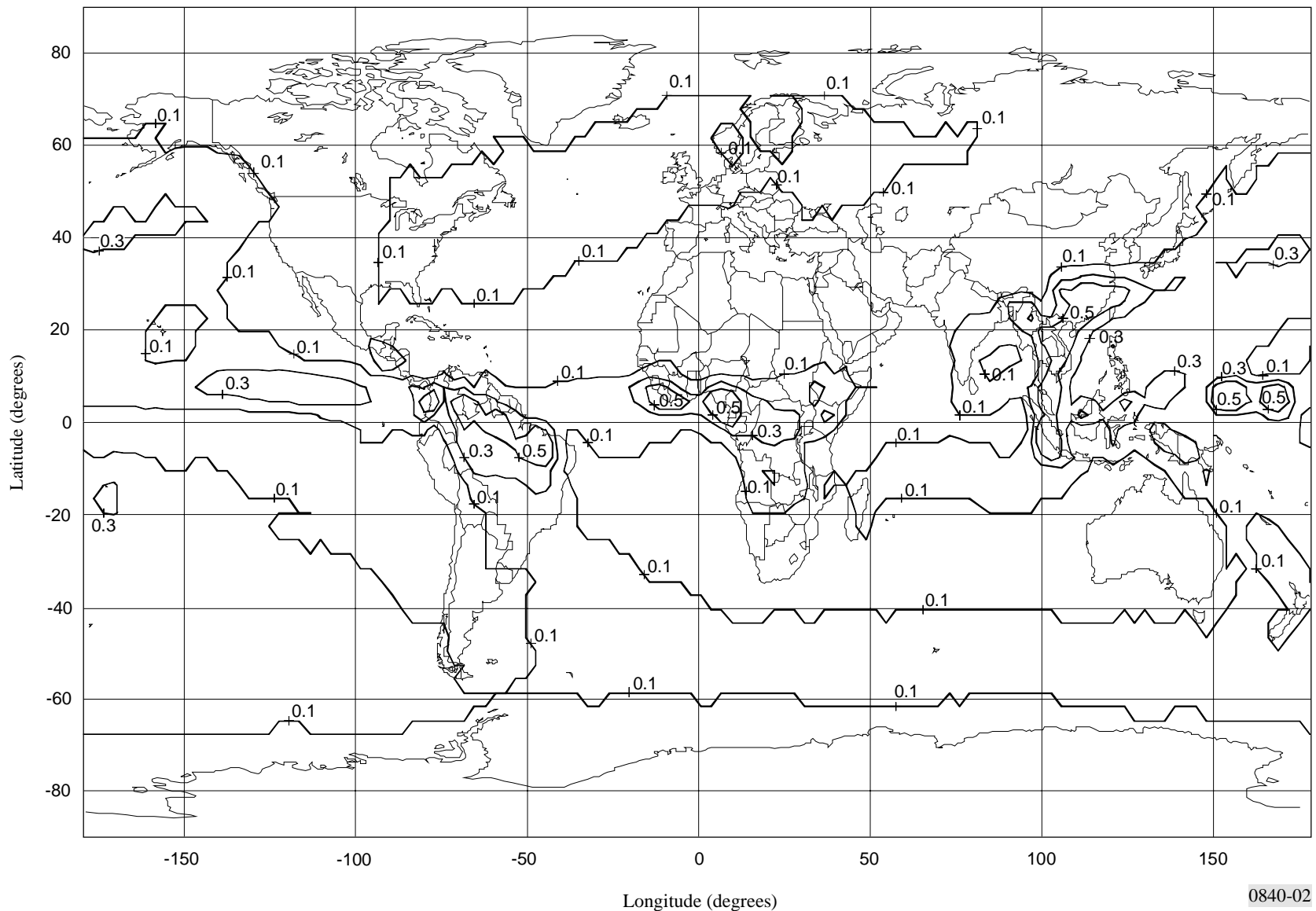0840-02

FIGURE 3

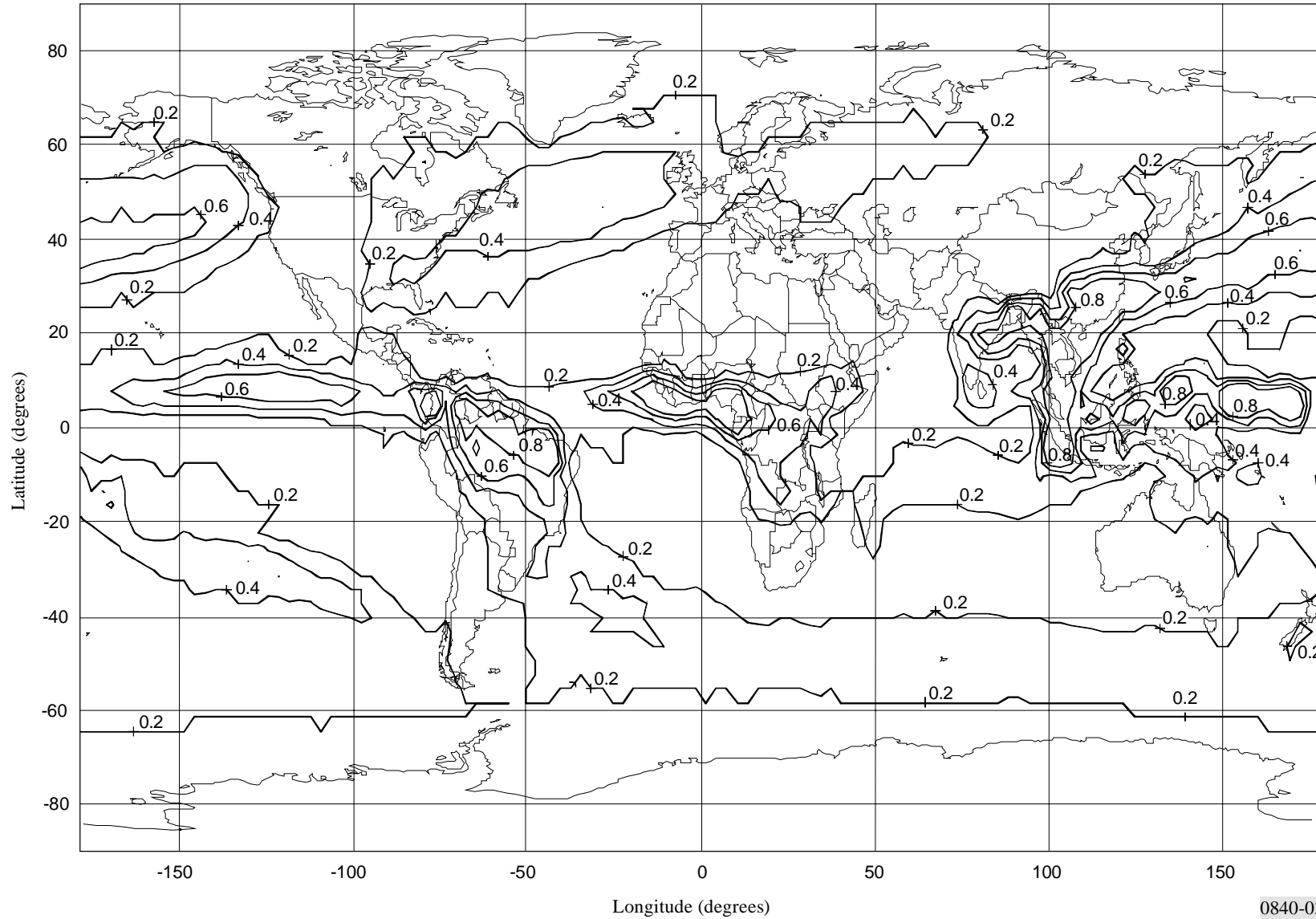**Normalized total columnar content of cloud liquid water (kg/m^2) exceeded for 90% of the year**

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FIGURE 4

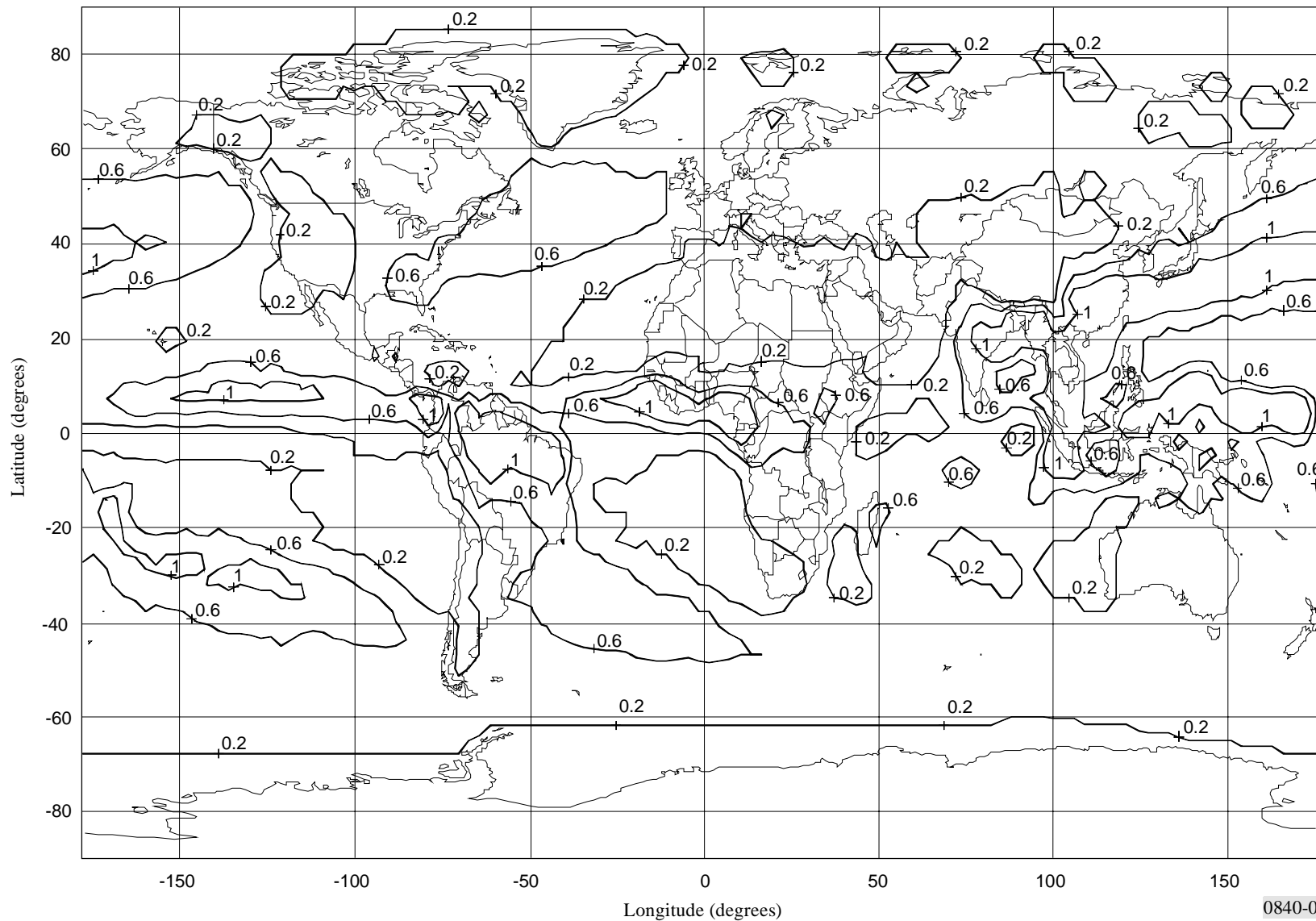**Normalized total columnar content of cloud liquid water (kg/m²) exceeded for 95% of the year**

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FIGURE 5

Normalized total columnar content of cloud liquid water (kg/m²) exceeded for 99% of the year

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