RECOMMENDATION ITU-R P.836-2

Water vapour: surface density and total columnar content

(Question ITU-R 201/3)

(1992-1997-2001)

The ITU Radiocommunication Assembly,

considering

a) that for the calculation of refractive effects and gaseous attenuation information is needed on water vapour density in the atmosphere;

b) that this information is needed for all locations on Earth and for all seasons,

recommends

1 that the information in Annexes 1 and 2 is used for global calculations of propagation effects that require an estimation of surface water vapour density or total columnar content of water vapour and its seasonal variation, where more accurate local data are not available.

ANNEX 1

1 Water vapour density at ground level

Atmospheric water vapour and oxygen cause absorption at mm wavelengths especially in the region of absorption lines (see Recommendation ITU-R P.676). The concentration of atmospheric oxygen is relatively constant whereas that of water vapour is not.

Seasonal and annual contours of water vapour density, ρ (also known as absolute humidity) are provided in Figs. 1 to 5.

For ready reference, the relationships between water vapour density, water vapour pressure and relative humidity are given in Recommendation ITU-R P.453.

Digital representations of the maps are available from that part of the ITU-R Website dealing with Radiocommunication Study Group 3.

FIGURE 1

Annual surface water vapour density (g/m³)

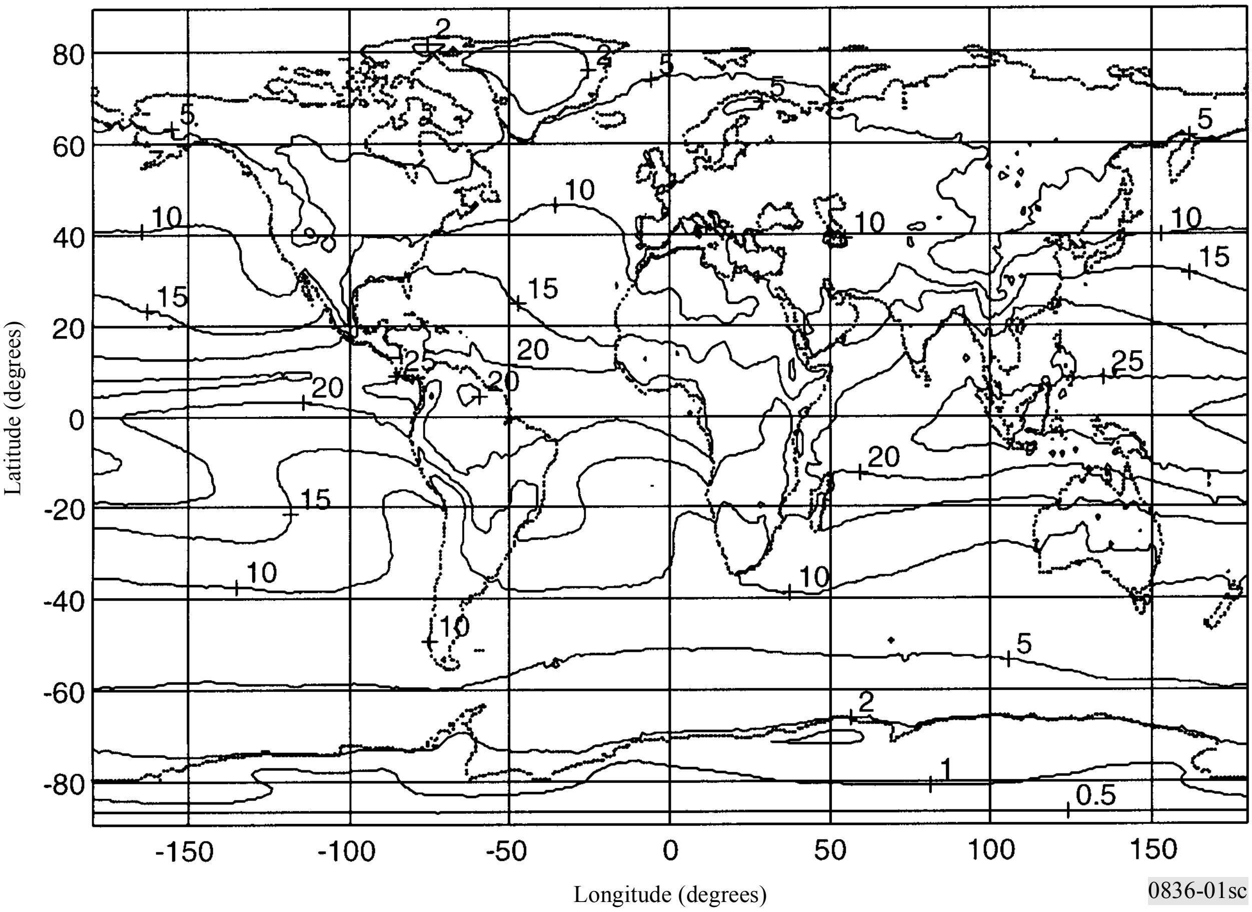

FIGURE 2

December, January, February: surface water vapour density (g/m³)

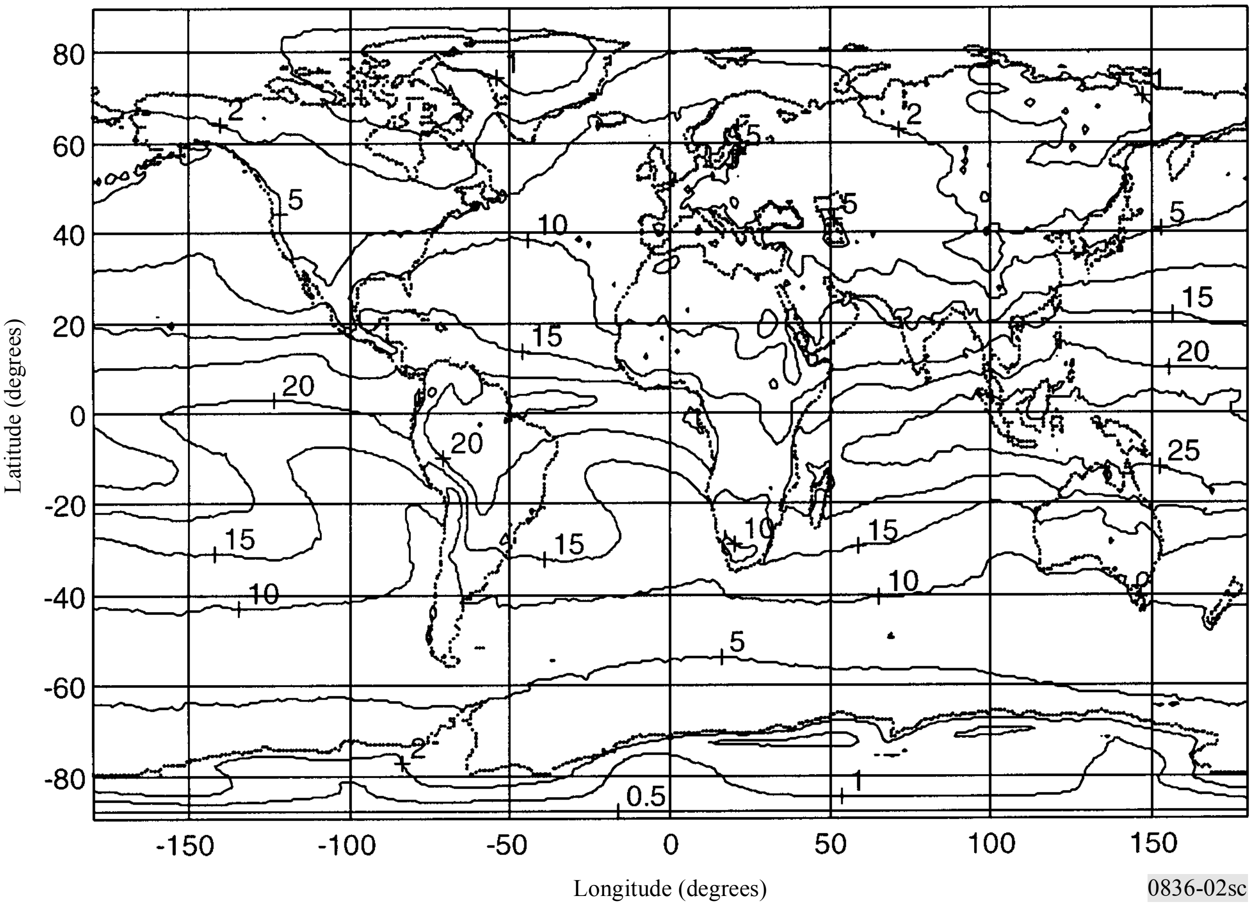

FIGURE 3

March, April, May: surface water vapour density (g/m³)

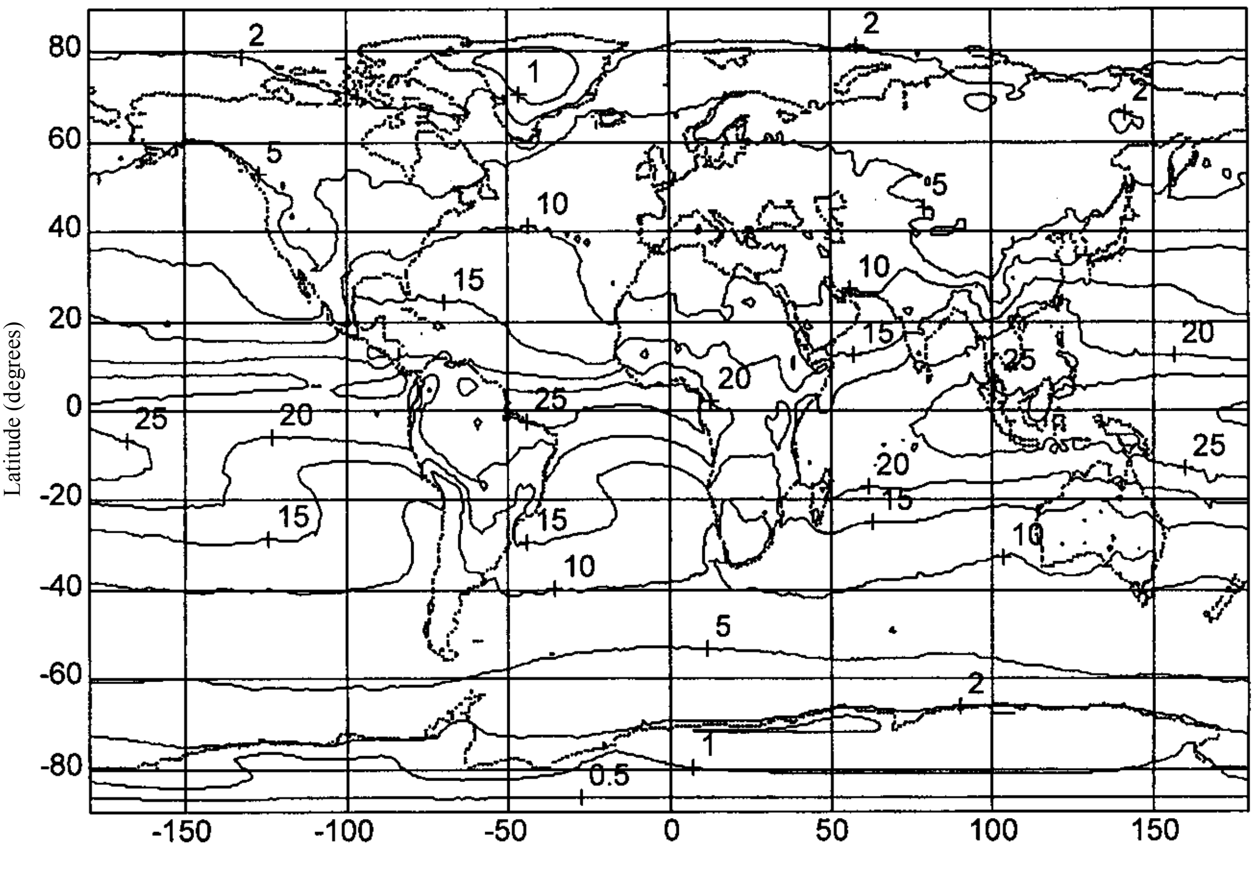

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FIGURE 4

June, July, August: surface water vapour density (g/m^3)

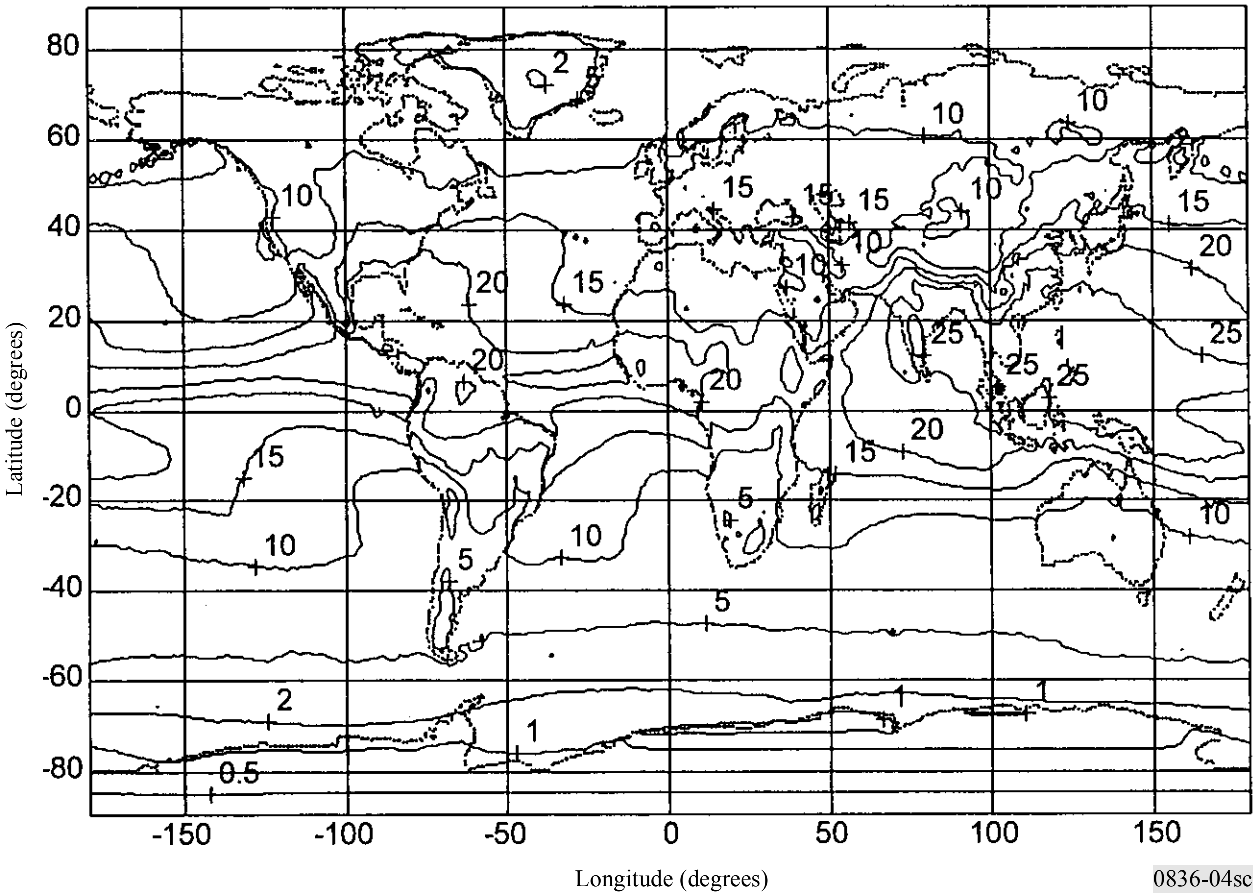

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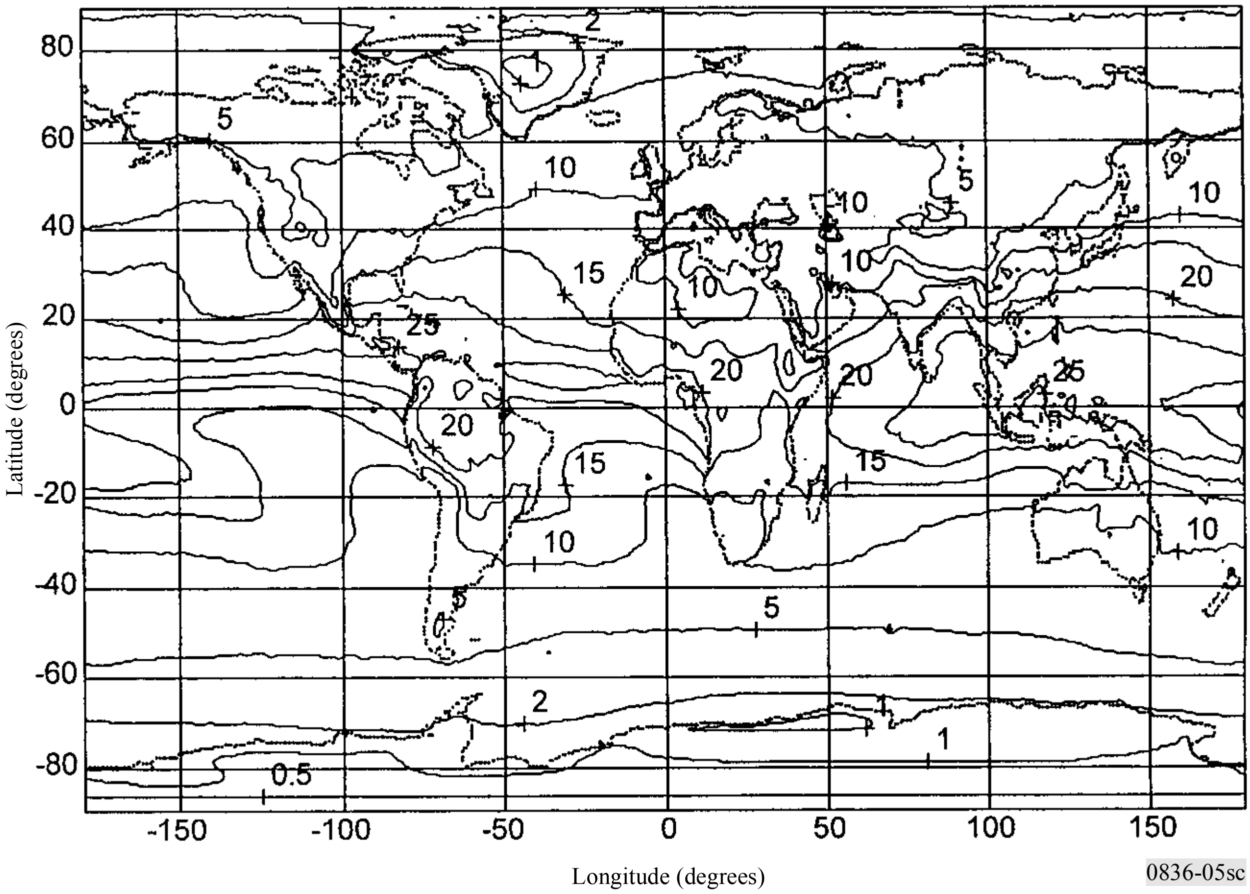
FIGURE 5

September, October, November: surface water vapour density (g/m³)



ANNEX 2

Atmospheric total water vapour content

For some applications, the total content of water vapour along the path can be used, typically for the calculation of the excess path length and of the attenuation due atmospheric water vapour, the latter assumed to be proportional to the vapour total content through its specific mass absorption coefficient.

The total water vapour content, expressed in kg/m^2 or, equivalently, in mm of precipitable water, can be obtained both from radiosonde soundings, available on a wide space-time scale, although rather limited in terms of time resolution and applying to zenith paths, as well as by retrieval of radiometric measurements at proper frequencies, directly along the path considered.

1 Maps of total columnar water vapour content

In the absence of local measurements, the total columnar water vapour content shown in Figs. 6 to 9 together with the procedures in Recommendation ITU-R P.676 should be used to derive water vapour absorption.

The values shown in the Figures are in kg/m^2 for four different yearly exceedance probability levels. The maps were derived from two years of data with a spatial resolution of 1.5° in latitude and longitude. Data files (ESAWVCxx.TXT) containing these data as well as data for additional probability levels can be obtained from the ITU Radiocommunication Bureau.

The latitude grid of the data files is from +90° N to –90° S in 1.5° steps; the longitude grid is from 0° to 360° in 1.5° steps.

For a location different to the grid points, obtain the total columnar content at the desired location by performing a bi-linear interpolation on the values at the four closest grid points.

To obtain the value exceeded for a probability different from those in the data files, use a semi-logarithmic interpolation (logarithmic on the probability in per cent and linear on the total columnar content).

2 Estimates of water vapour total content from radiometric measurements

The atmospheric attenuation in the absence of rain can be expressed as the sum of the oxygen absorption and of two terms proportional to the total content of the water vapour, V, and liquid water, L, through the relevant mass absorption coefficients, a_V and a_L, respectively.

For a dual-channel radiometer, operating at two frequencies f_1 and f_2, the following equations can be written:

$$\begin{aligned} A_1 &= A_{o1} + a_{V1} V + a_{L1} L \qquad \text{dB} \\ A_2 &= A_{o2} + a_{V2} V + a_{L2} L \qquad \text{dB} \end{aligned} \tag{1}$$

where:

- A_1 and A_2: radiometric attenuations measured at the two frequencies f_1 and f_2, respectively, according to the procedure indicated in Recommendation ITU-R P.1322
- A_{oj}: attenuation due to oxygen
- V and L: total contents of water vapour and liquid water along the path, respectively (mm or kg/m^2)
- a_{Vj} and a_{Lj}: water vapour and liquid water mass absorption coefficients at the frequency j.

The value of A_{oj} can be calculated from Recommendation ITU-R P.676, as well as the value of the water vapour mass absorption coefficient a_{Vj} at the desired frequency, which can be assumed equal to the specific attenuation due to water vapour γ_w given in the same Recommendation, divided by the water vapour density ρ (g/m^3) at the ground level. The value of a_{Lj} can be obtained from Fig. 1 of Recommendation ITU-R P.840.

FIGURE 6

Columnar water vapour (kg/m²) exceeded for 1% of the year

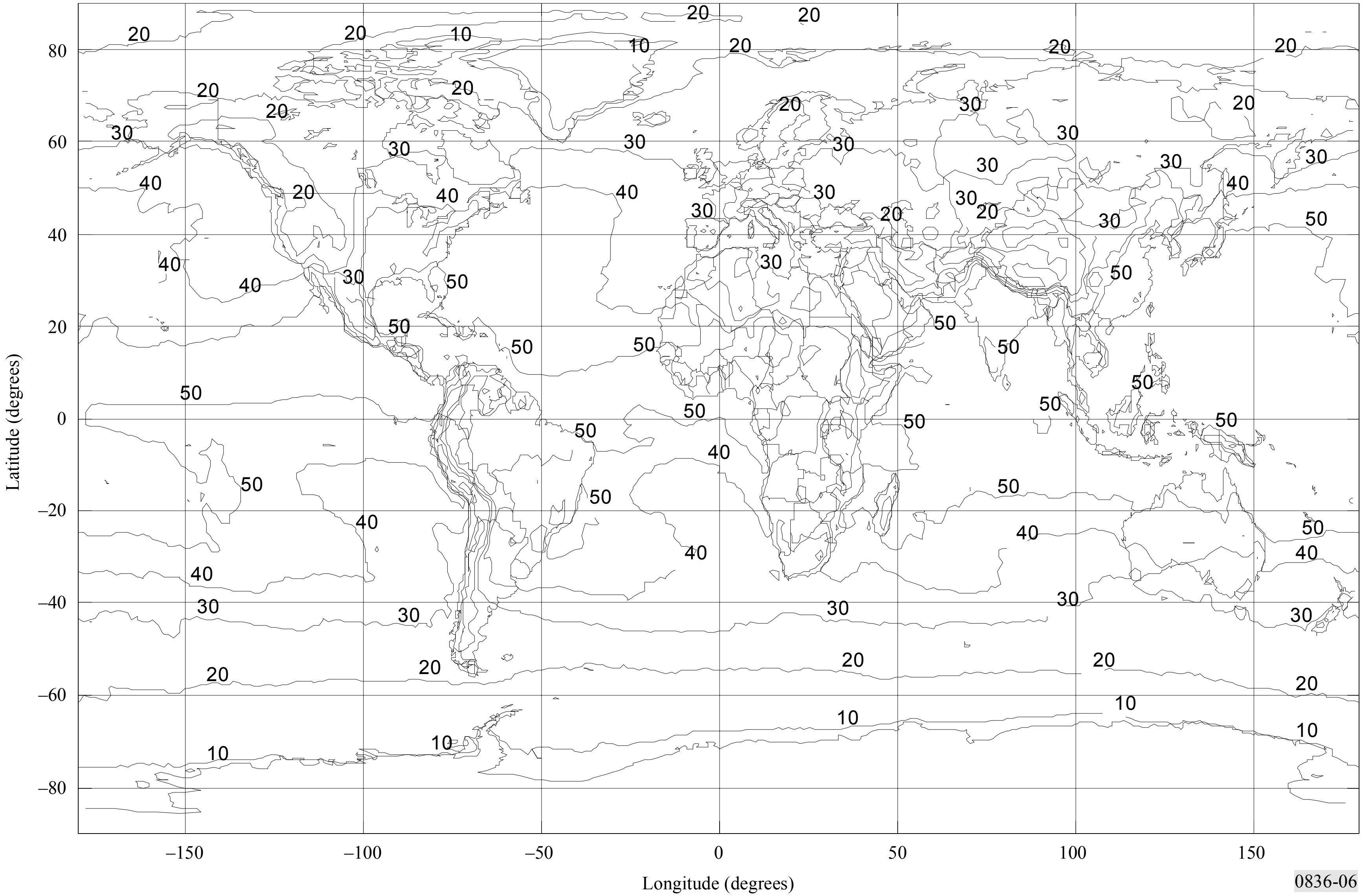


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FIGURE 7

Columnar water vapour (kg/m²) exceeded for 5% of the year

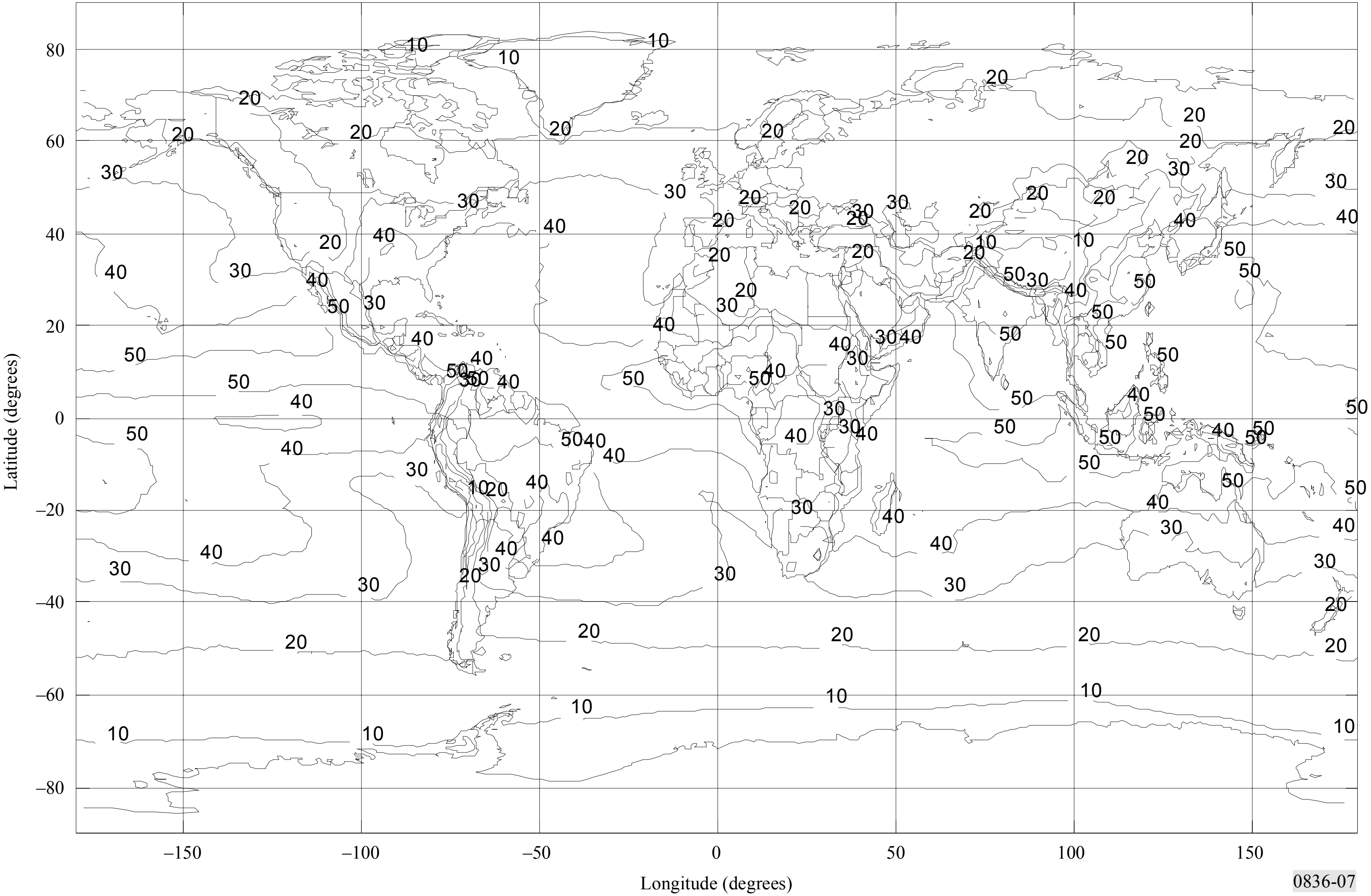

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FIGURE 8

Columnar water vapour (kg/m²) exceeded for 10% of the year

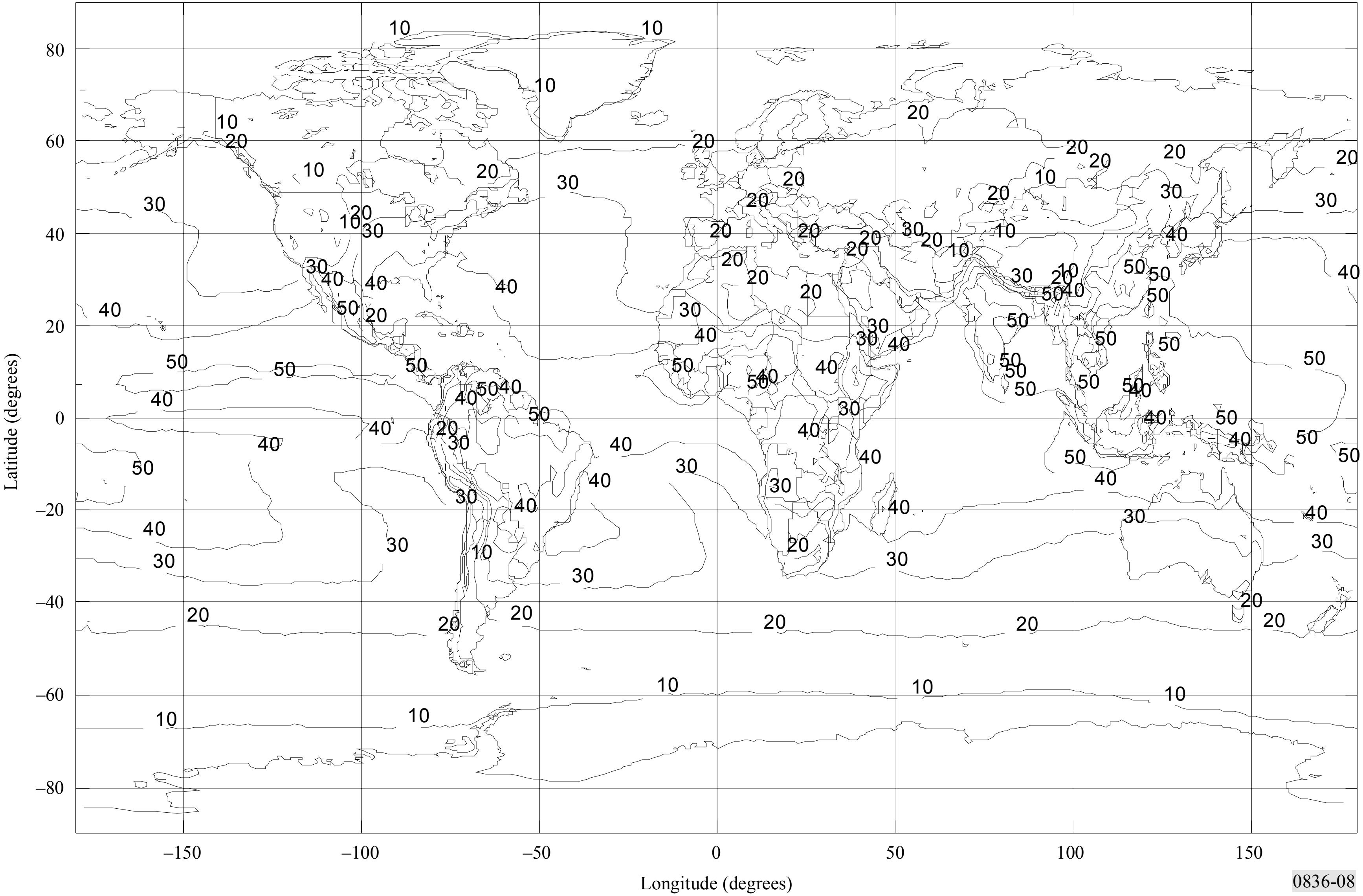

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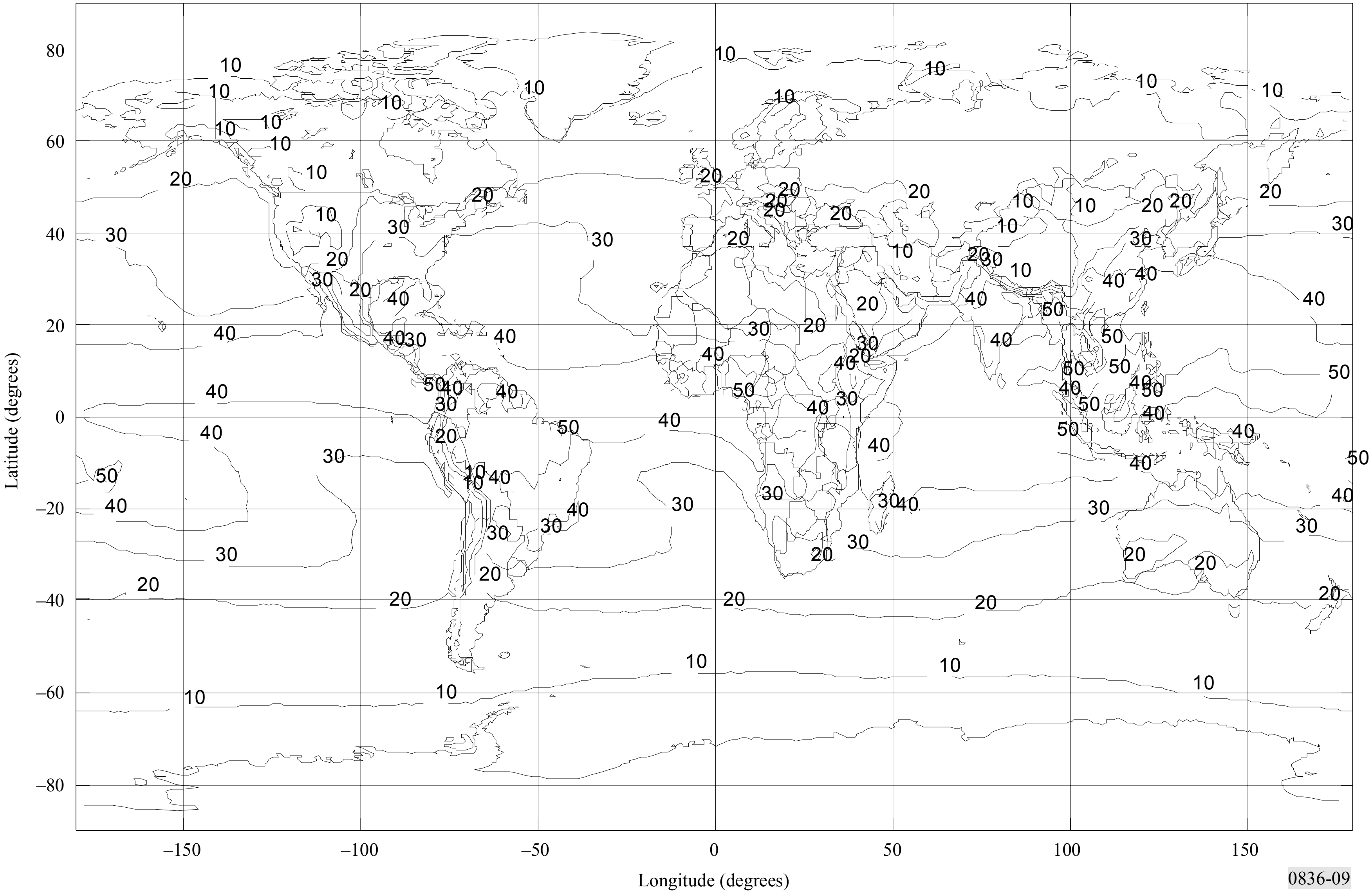
FIGURE 9

Columnar water vapour (kg/m²) exceeded for 20% of the year



The values of f_1 and f_2 should be properly chosen such that the sensitivity to the absorption of vapour and liquid water is different. In general the larger this difference, the better the accuracy of the retrieval. The lines 20.6 GHz or 23.8 GHz are often chosen as the lower frequency, having high sensitivity to water vapour. The higher frequency, which is more sensitive to liquid water, is typically chosen in the 31-36 GHz window.

Equation (1) can then be solved and the total water vapour content V can be obtained. Instead of the total columnar content calculated from a radiosonde, the value V is now estimated directly along the actual path. Much better time resolution is also obtained, allowing information on the short-time variability of the total water vapour content.

It should be stressed that the use of the above procedure for the calculation of L, can lead to serious inaccuracies due to the marked dependence of the relevant mass absorption coefficient a_{Lj} on the temperature.