International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.836-4

(10/2009)

Water vapour: surface density and total columnar content

P Series

Radiowave propagation

International Telecommunication Union

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R P.836-4

Water vapour: surface density and total columnar content

(Question ITU-R 201/3)

(1992-1997-2001-2001-2009)

Scope

This Recommendation provides methods to predict the surface water vapour density and total columnar water vapour content on Earth-space paths.

The ITU Radiocommunication Assembly,

considering

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

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

recommends

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

Annex 1

1 Surface water vapour density

Atmospheric water vapour and oxygen cause absorption at millimetre wavelengths especially in the proximity of absorption lines (see Recommendation ITU-R P.676). The concentration of atmospheric oxygen is relatively constant; however, the concentration of water vapour varies both geographically and with time.

The annual values of surface water vapour density, ρ in g/m^3, exceeded for 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, and 99% of an average year are available in the form of digital maps from the Radiocommunication Study Group 3 website in the data files SURF_WVxx_v4.TXT, where xx = 01, 02, 03, 05, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99. The data is from 0° to 360° in longitude and from +90° to –90° in latitude, with a resolution of 1.125º in both latitude and longitude. This data is to be used in conjunction with the companion data files ESALAT1dot125.TXT and ESALON1dot125.TXT containing the latitudes and longitudes of the corresponding entries (gridpoints) in data files SURF_WVxx_v4.TXT. The surface water vapour density at any desired location on the surface of the Earth can be derived by the following interpolation method:

a) determine the two probabilities, p_{above} and p_{below}, above and below the desired probability, p, from the set: 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99%;

b) for the two probabilities, p_{above} and p_{below}, determine the surface water vapour densities, ρ'_1, ρ'_2, ρ'_3 and ρ'_4 at the four closest grid points;

c) using the water vapour scale height data file, VSCH_xx_v4.TXT, where xx corresponds to the probabilities p_{above} and p_{below}, determine the water vapour scale height at the four closest grid point, $vsch_1$, $vsch_2$, $vsch_3$ and $vsch_4$ for each probability, p_{above} and p_{below};

d) using Recommendation ITU-R P.1511, determine the topographic altitudes, alt_1, alt_2, alt_3 and alt_4, of the four closest grid points;

e) for each of the four closest grid points and each probability, determine the water vapour densities, ρ_1, ρ_2, ρ_3 and ρ_4, at the desired altitude, alt, by scaling the water vapour densities, ρ'_1, ρ'_2, ρ'_3 and ρ'_4, using the following relation:

$$\rho_i = \rho'_i e^{-\frac{alt - alt_i}{vsch_i}} \qquad \text{for } i = 1, 2, 3, 4 \tag{1}$$

f) determine the water vapour densities, ρ_{above} and ρ_{below}, at the probabilities p_{above} and p_{below} and at the desired location by performing a bi-linear interpolation of the four values of water vapour density, ρ_1, ρ_2, ρ_3 and ρ_4, at the four grid points as described in Recommendation ITU-R P.1144 (for reference the procedure to determine ρ_{above} and ρ_{below} from ρ'_1, ρ'_2, ρ'_3 and ρ'_4 is shown in Fig. 1);

g) determine the water vapour density, ρ, at the desired probability, p, by interpolating ρ_{above} and ρ_{below} vs. p_{above} and p_{below} to p on a linear ρ vs. log p scale.

Note that the digital maps of surface water vapour contain the symbol NaN (Not-a-Number) when there is no value of surface water vapour density corresponding to a given annual probability of exceedance.

An example contour of the water vapour scale height is provided in Fig. 2 for an exceedance probability of 1%. Example contours of the annual average water vapour density are provided in Figs. 3, 4, 5, 6, 7, 8 and 9 for exceedance probabilities of 0.1, 0.5, 1, 5, 10, 20 and 50%.

Contours of the seasonal average water vapour density are provided in Figs. 10, 11, 12 and 13. Note that this seasonal average data was derived from a different data set than the annual average data.

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

FIGURE 1

Interpolation procedure at probabilities above and below desire probability

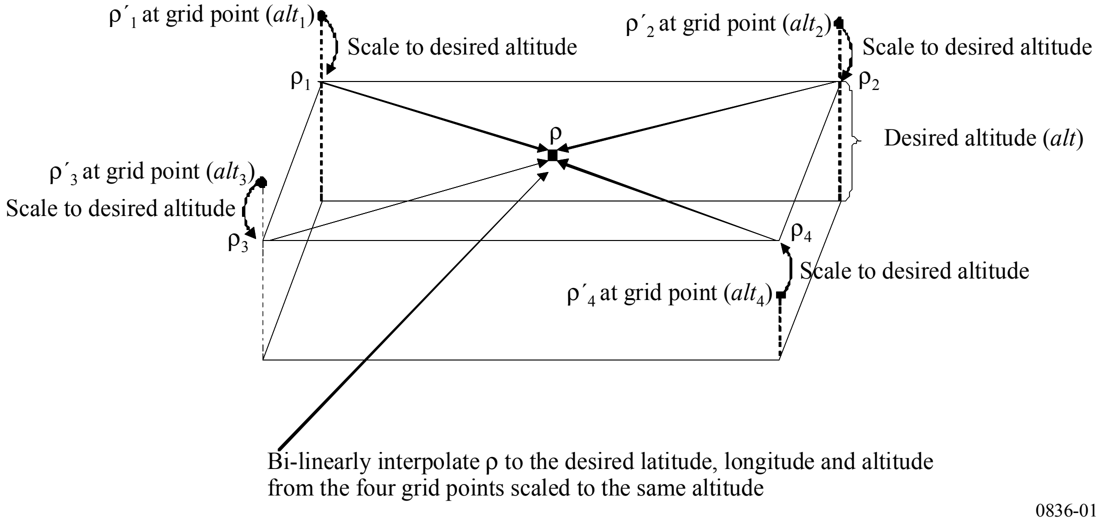

FIGURE 2

Water vapour scale height (km) exceeded for 1% of the year

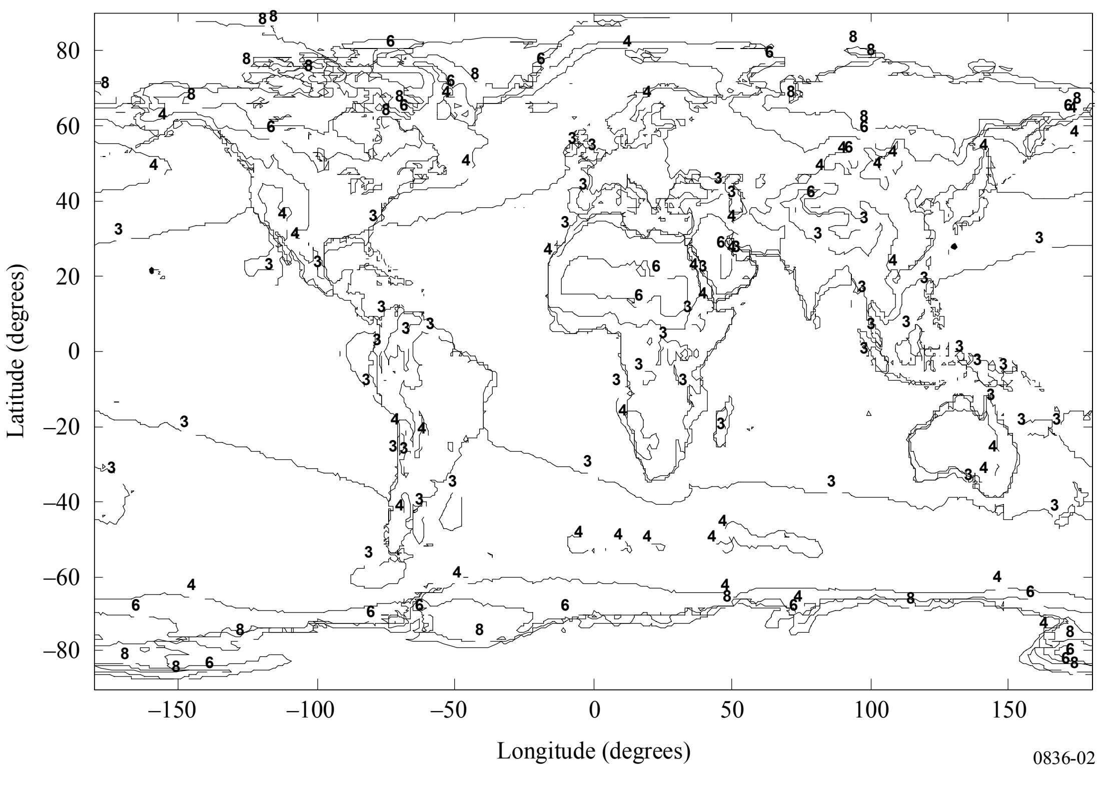

FIGURE 3

Water vapour density (g/m^3) exceeded for 0.1% of the year

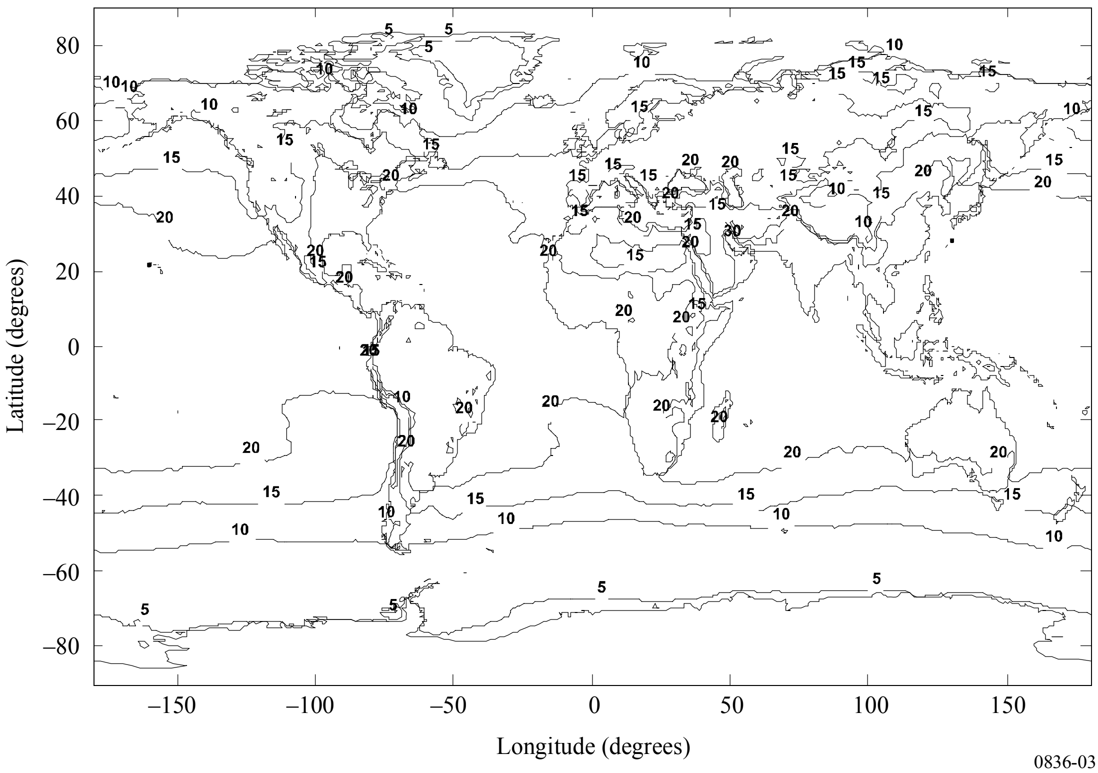

FIGURE 4

Water vapour density (g/m^3) exceeded for 0.5% of the year

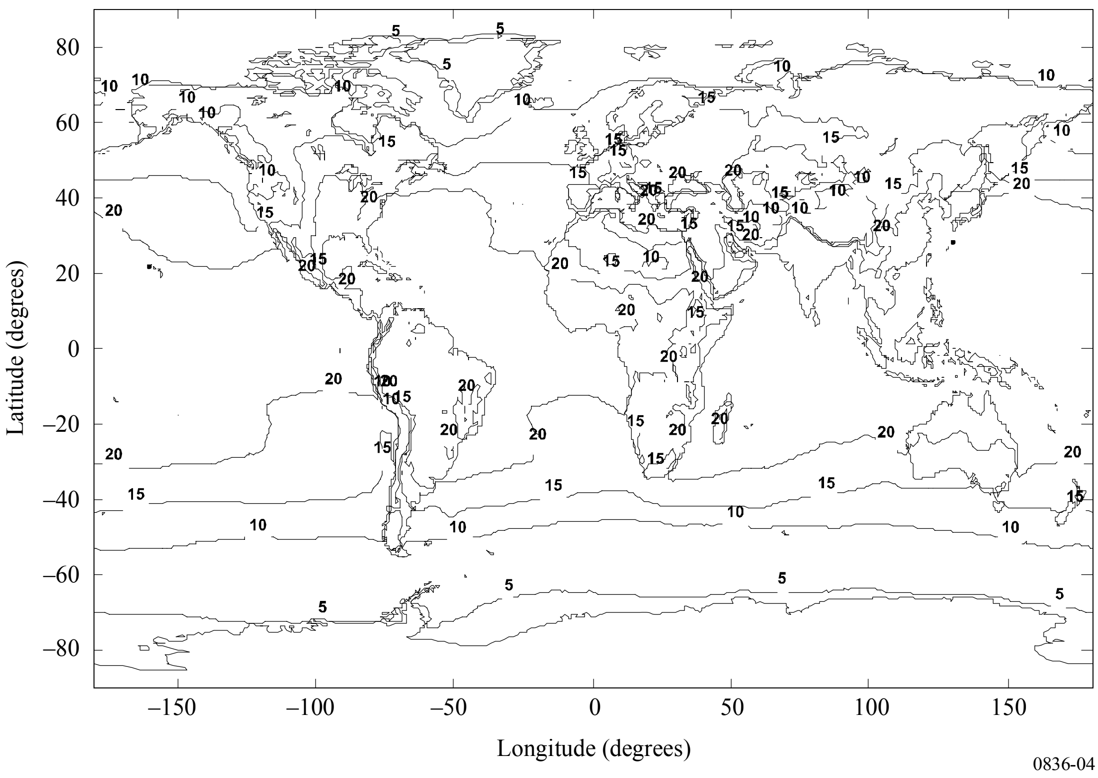

FIGURE 5

Water vapour density (g/m^3) exceeded for 1% of the year

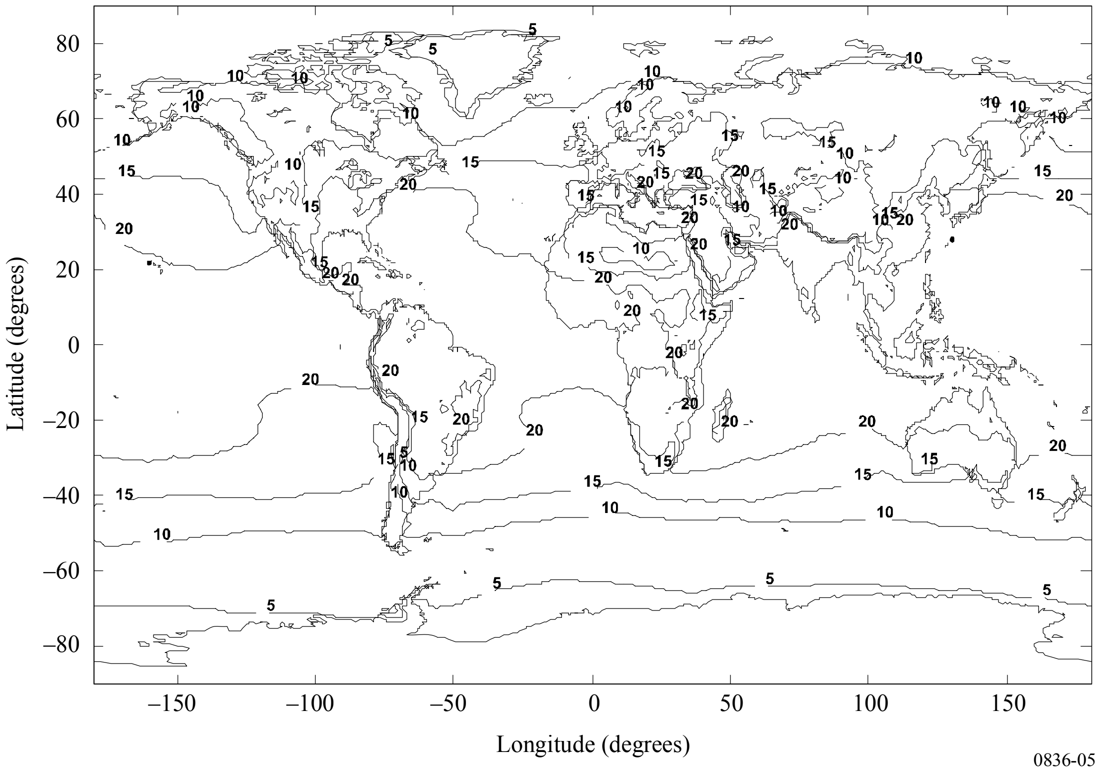

FIGURE 6

Water vapour density (g/m^3) exceeded for 5% of the year

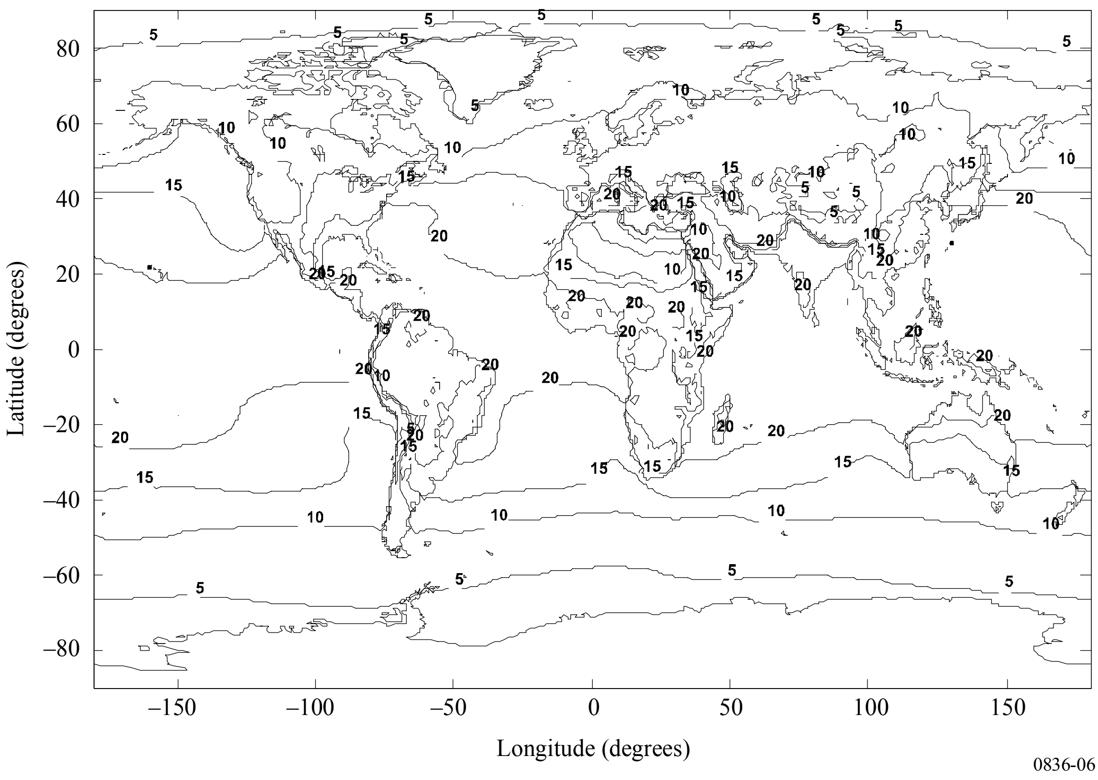

FIGURE 7

Water vapour density (g/m^3) exceeded for 10% of the year

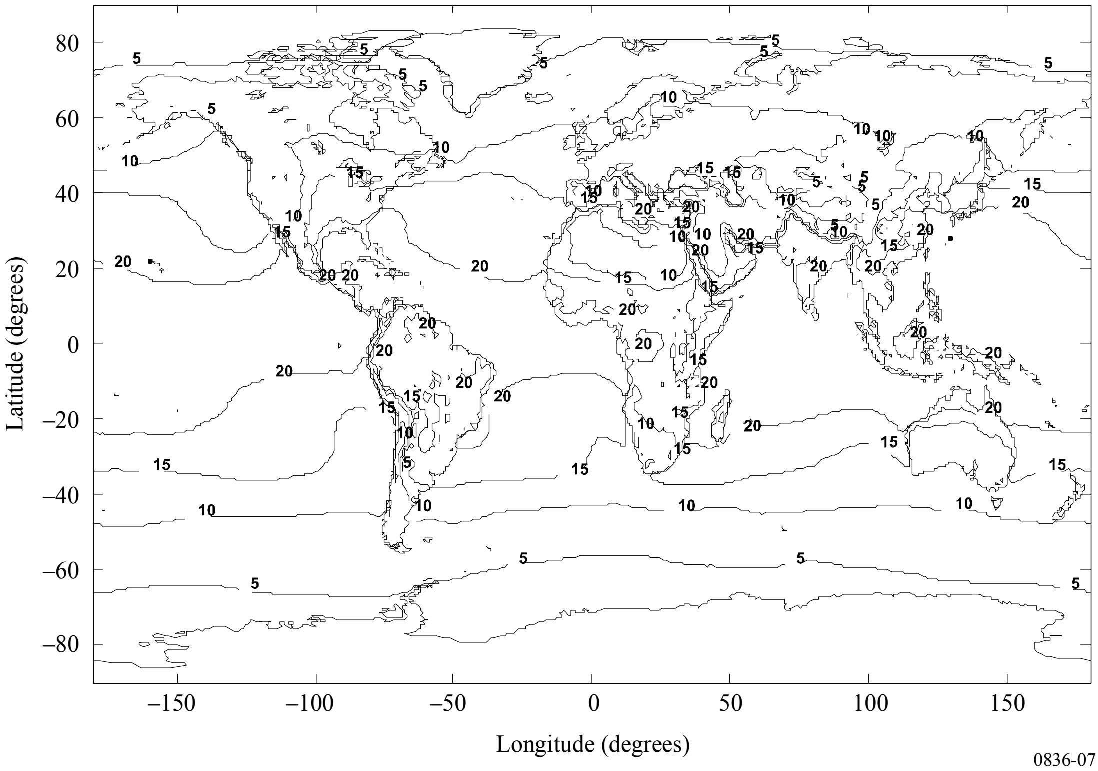

FIGURE 8

Water vapour density (g/m^3) exceeded for 20% of the year

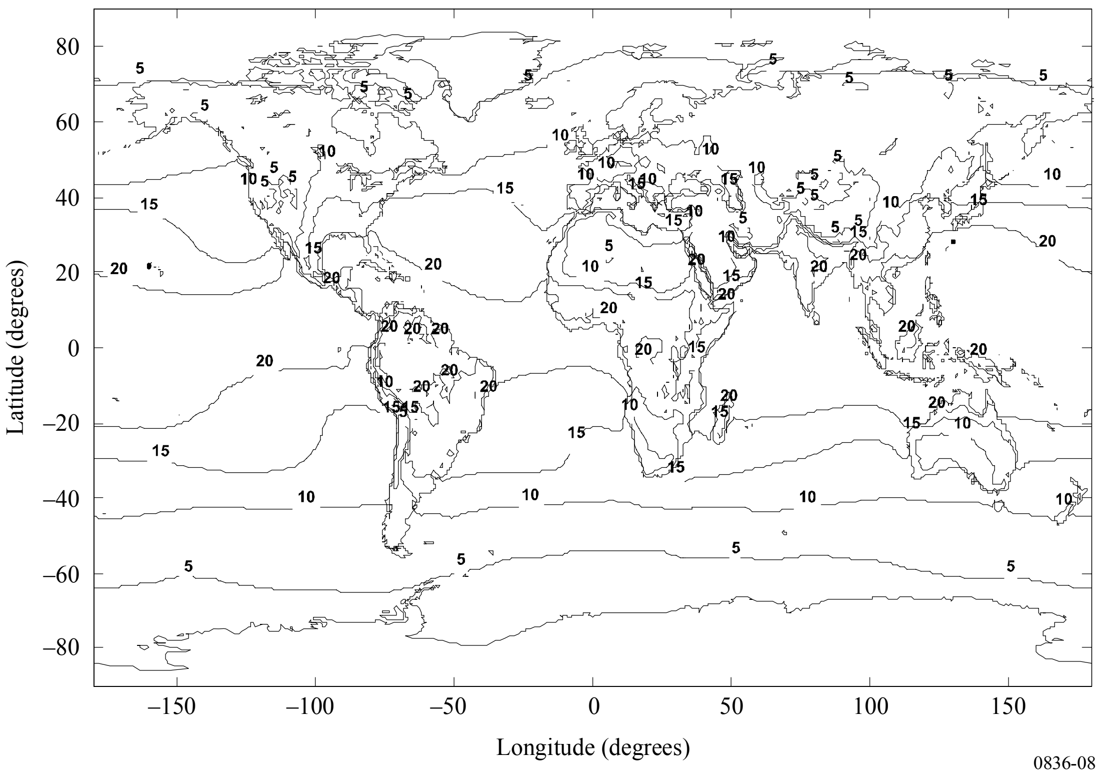

FIGURE 9

Water vapour density (g/m^3) exceeded for 50% of the year

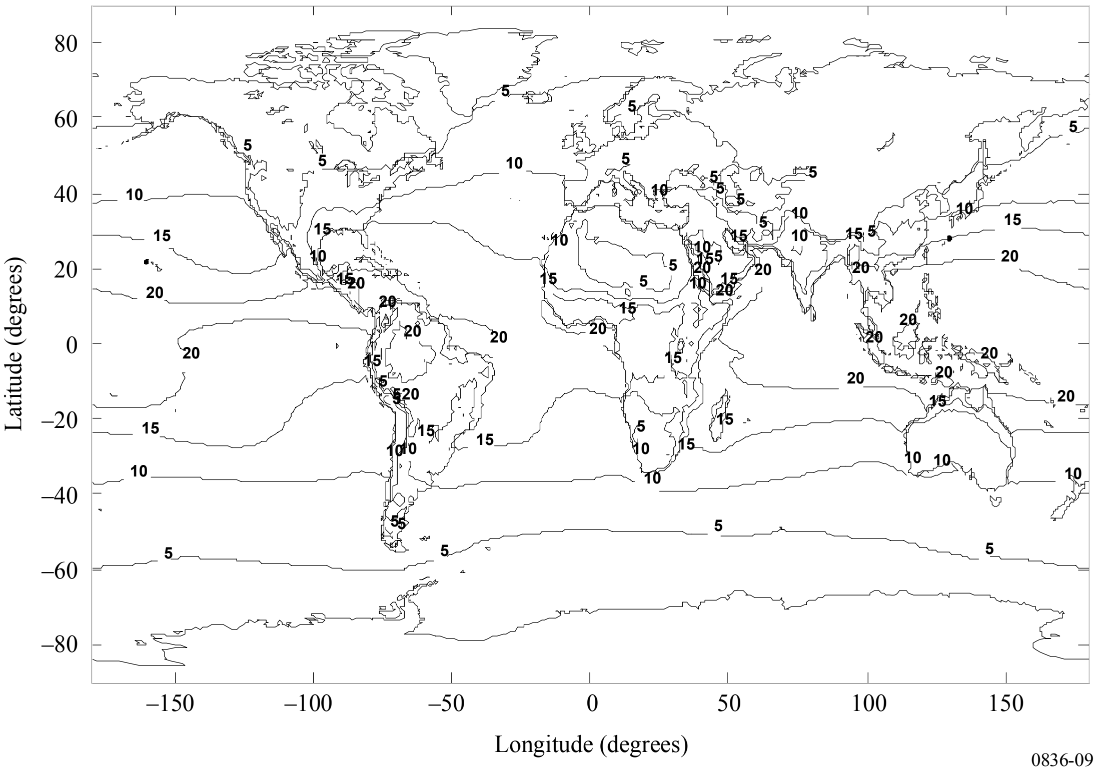

FIGURE 10

December, January, February: surface water vapour density (g/m^3)

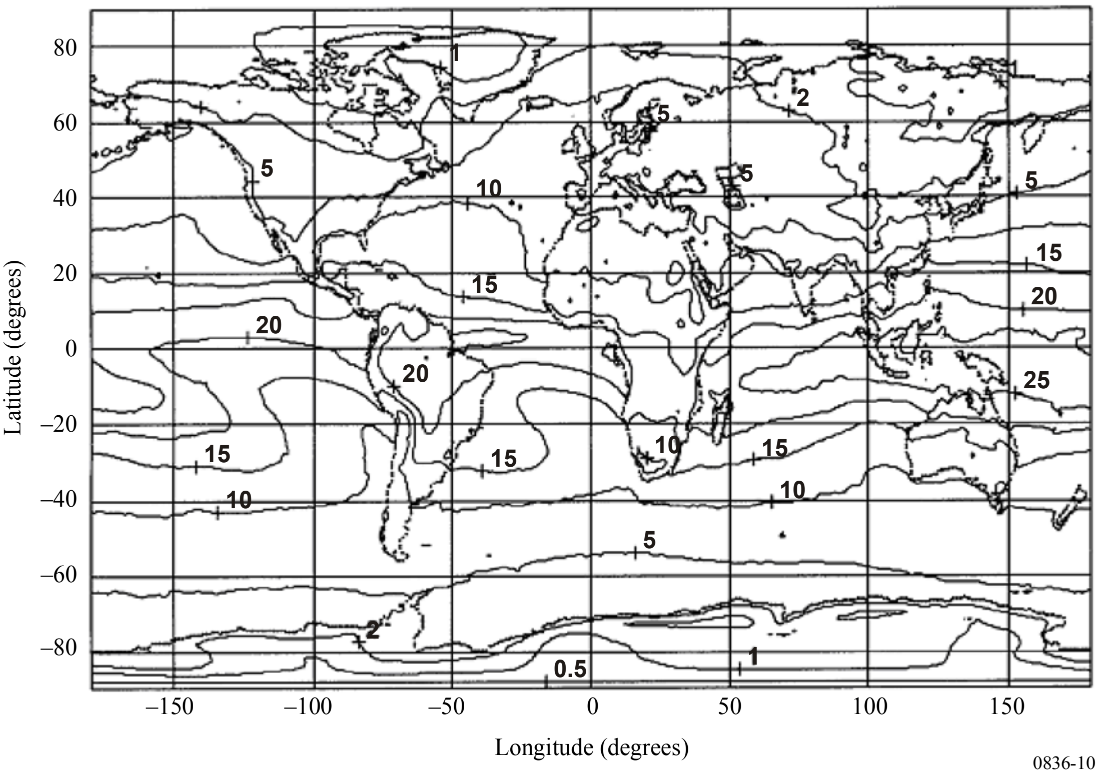

FIGURE 11

March, April, May: surface water vapour density (g/m^3)

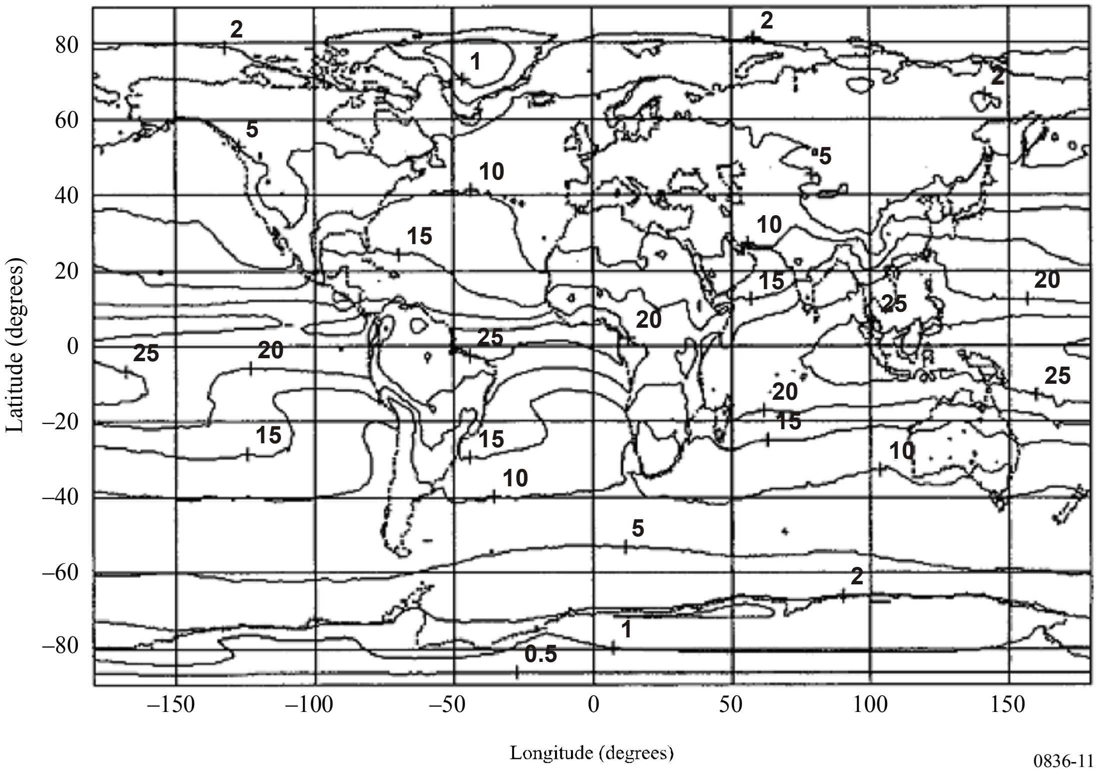

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FIGURE 12

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

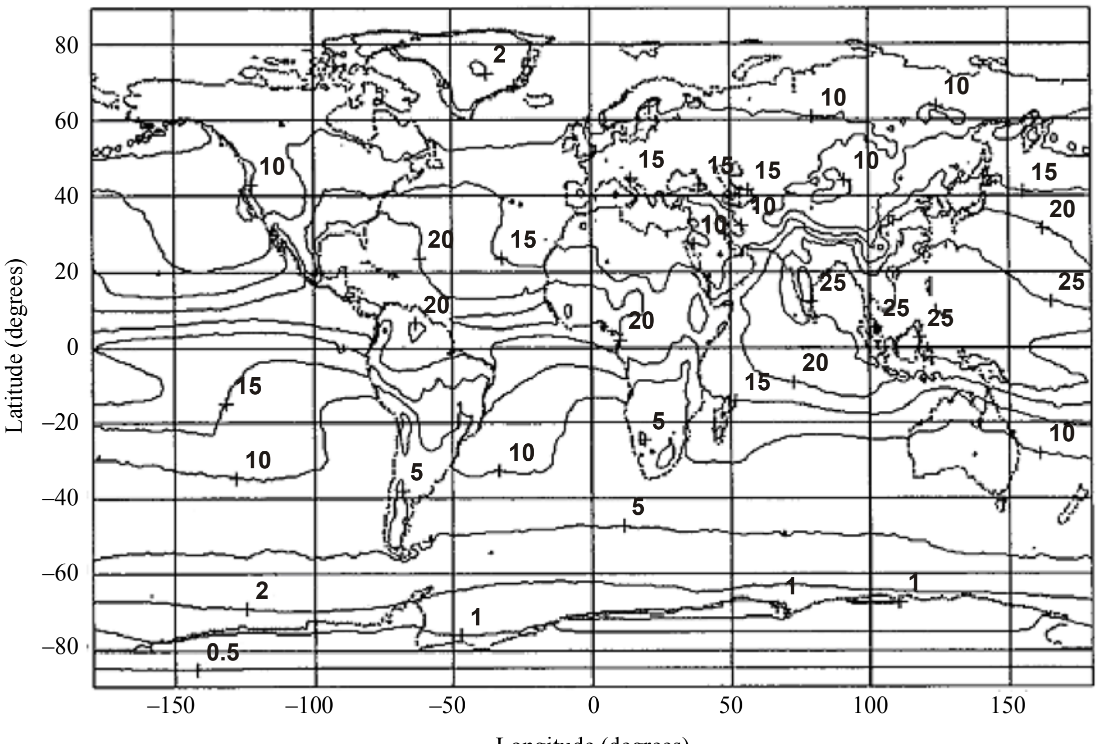

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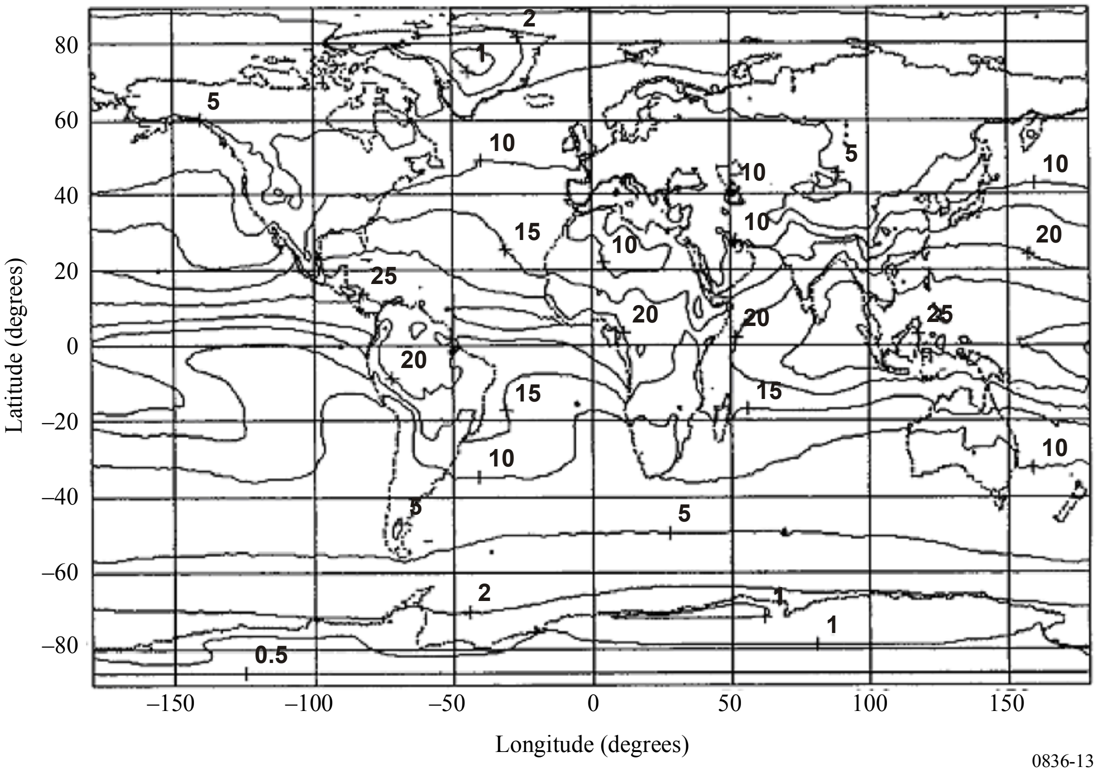
FIGURE 13

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



Annex 2

1 Total water vapour content

For some applications, the total water vapour content along a path can be used for the calculation of excess path length and for the attenuation due to atmospheric water vapour, where the attenuation due to atmospheric water vapour is assumed to be proportional to the total water vapour 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 from radiosonde soundings, navigation satellite measurements, and radiometric observations. Radiosonde data is widely available; however, it has limited time resolution and is only applicable to zenith paths. The total water vapour content can be retrieved from radiometric measurements at appropriate frequencies along the desired path.

The annual values of total columnar water vapour content, V (kg/m^2), exceeded for 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99% of the year are available in the form of digital maps from the Radiocommunication Study Group 3 website in the data files ESAWVC_xx_v4.TXT, where xx = 01, 02, 03, 05, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99. The data is from 0° to 360° in longitude and from +90° to –90° in latitude, with a resolution of 1.125º in both latitude and longitude. This data is to be used in conjunction with the companion data files ESALAT_1dot125.TXT and ESALON_1dot125.TXT containing the latitudes and longitudes of the corresponding entries (gridpoints) in data files ESAWVC_xx_v4.TXT. The total water vapour content at any desired location on the surface of the Earth can be derived by the following interpolation method:

a) determine the two probabilities, p_{above} and p_{below}, above and below the desired probability, p, from the set: 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99%.

b) for the two probabilitis, p_{above} and p_{below}, determine the total columnar water vapour content, V_1', V_2', V_1' and V_4' at the four closest grid points;

c) using the water vapour scale height data file, VSCH_xx_v4.TXT, where xx corresponds to the probabilities p_{above} and p_{below}, determine the water vapour scale height at the four closest grid points, $vsch_1$, $vsch_2$, $vsch_3$, and $vsch_4$ for each probability, p_{above} and p_{below};

d) using Recommendation ITU-R P.1511, determine the topographic altitudes, alt_1, alt_2, alt_3, and alt_4, of the four closest grid points;

e) for each of the four closest grid points and each probability, determine the total columnar water vapour content, V_1, V_2, V_3 and V_4, at the desired altitude, alt, by scaling the total columnar water vapour content, V_1', V_2', V_1' and V_4', using the following relation:

$$V_i = V_i' \mathrm{e}^{-\frac{alt - alt_i}{vsch_i}} \qquad \text{for } i = 1, 2, 3, 4 \tag{2}$$

f) determine the total columnar water vapour content, V_{above} and V_{below}, at the probabilities p_{above} and p_{below} and at the desired location by performing a bi-linear interpolation of the four values of total columnar water vapour content, V_1, V_2, V_3 and V_4, at the four grid points as described in Recommendation ITU-R P.1144 (for reference the procedure to determine V_{above} and V_{below} from V_1', V_2', V_1' and V_4' is shown in Fig. 14);

g) determine the total columnar water vapour content, V, at the desired probability, p, by interpolating V_{above} and V_{below} vs. p_{above} and p_{below} to p on a linear V vs. log p scale.

Note that the digital maps of total columnar water vapour content contain the symbol NaN (Not-a-Number) when there is no value of total water vapour content corresponding to a given annual probability of exceedance.

Example contours of the total columnar water vapour content are provided in Figs. 15, 16, 17, 18, 19, 20 and 21 for exceedance probabilities of 0.1, 0.5, 1, 5, 10, 20 and 50%.

FIGURE 14

Interpolation procedure at probabilities above and below desired probability

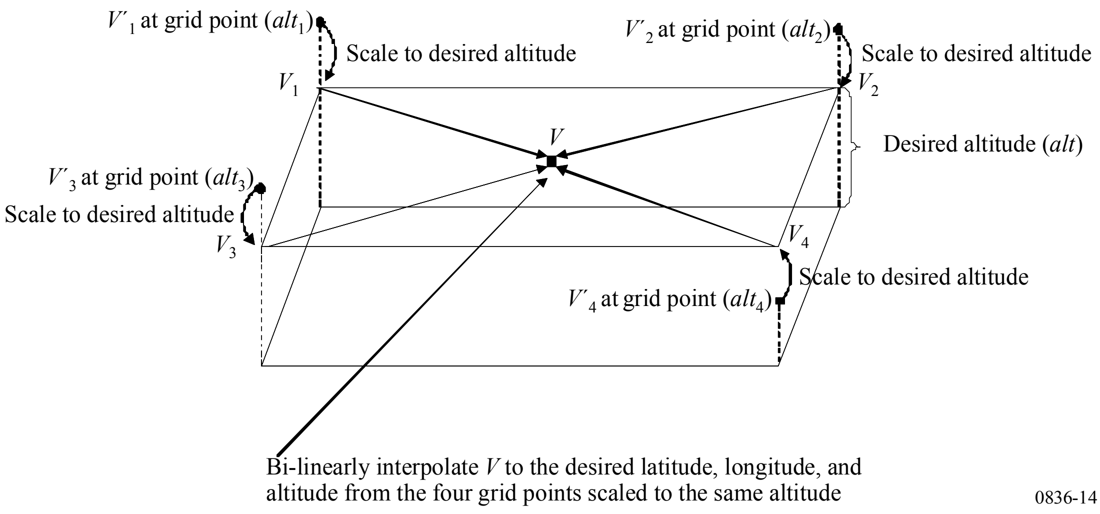


FIGURE 15

Columnar water vapour (kg/m^2) exceeded for 0.1% of the year

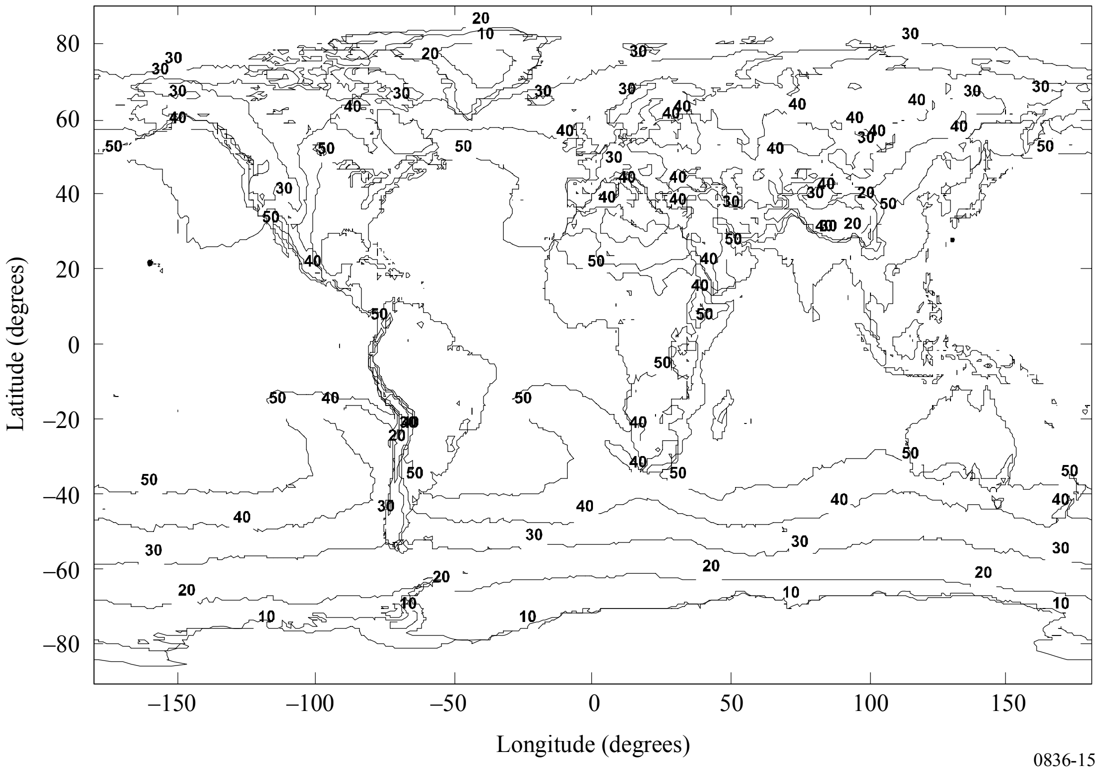


FIGURE 16

Columnar water vapour (kg/m^2) exceeded for 0.5% of the year

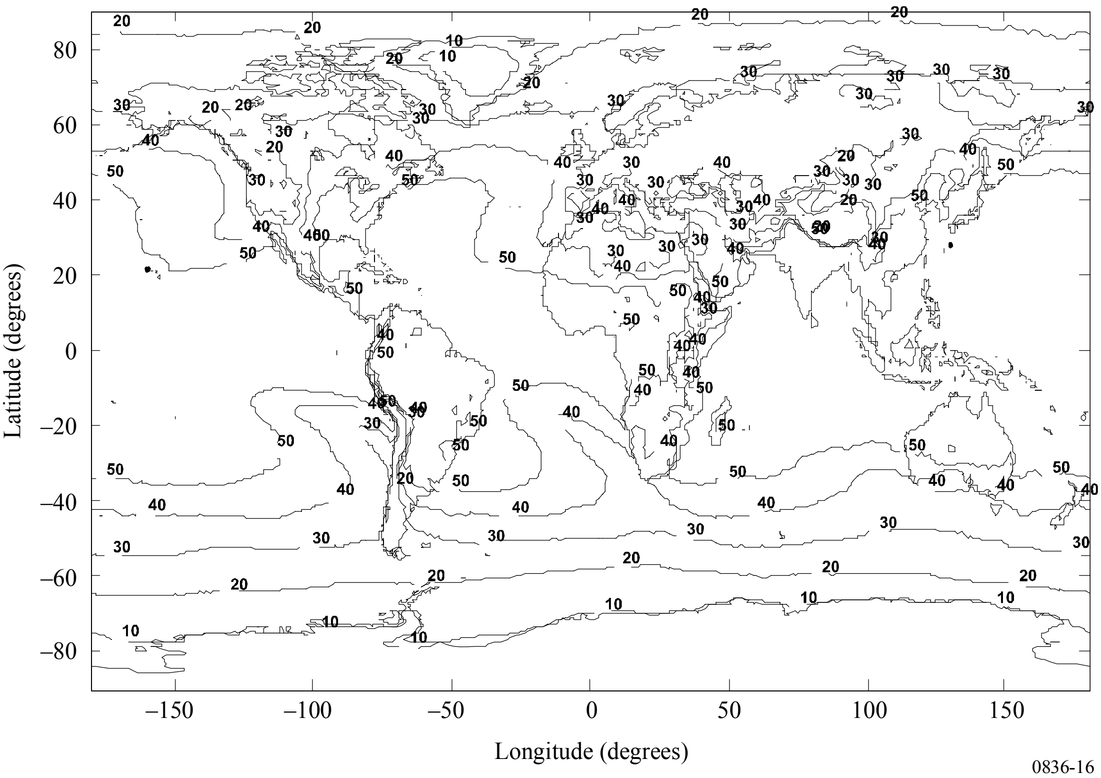


FIGURE 17

Columnar water vapour (kg/m^2) exceeded for 1% of the year

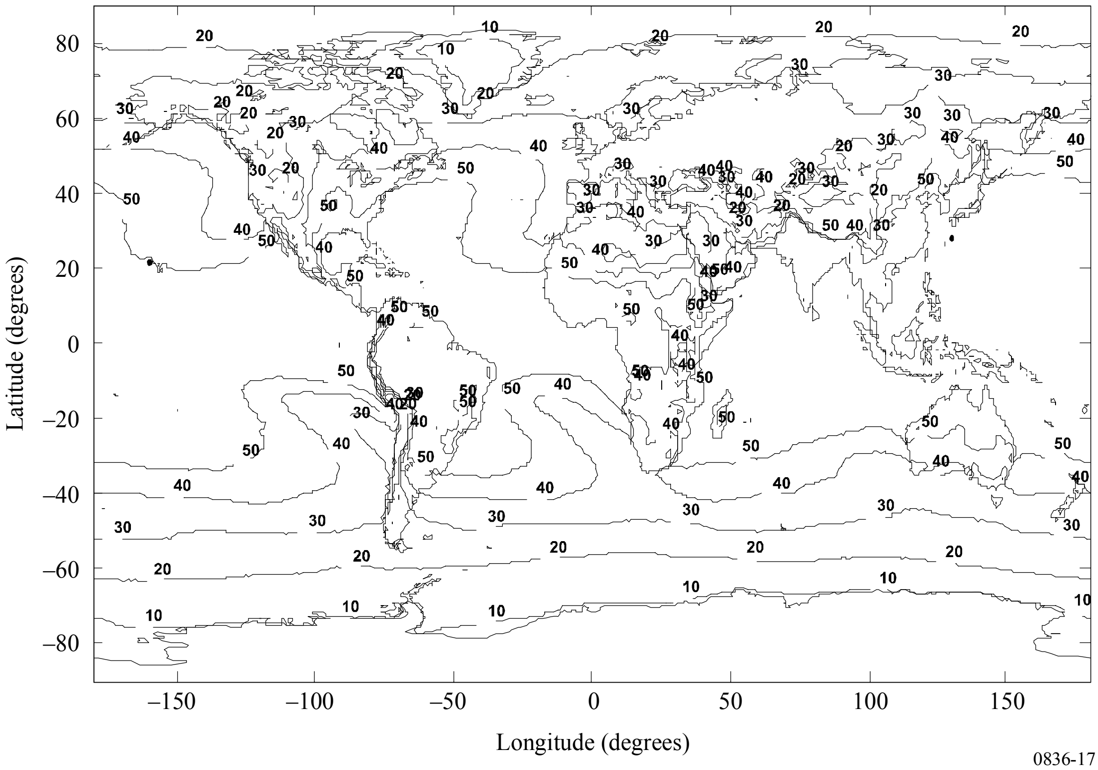


FIGURE 18

Columnar water vapour (kg/m^2) exceeded for 5% of the year

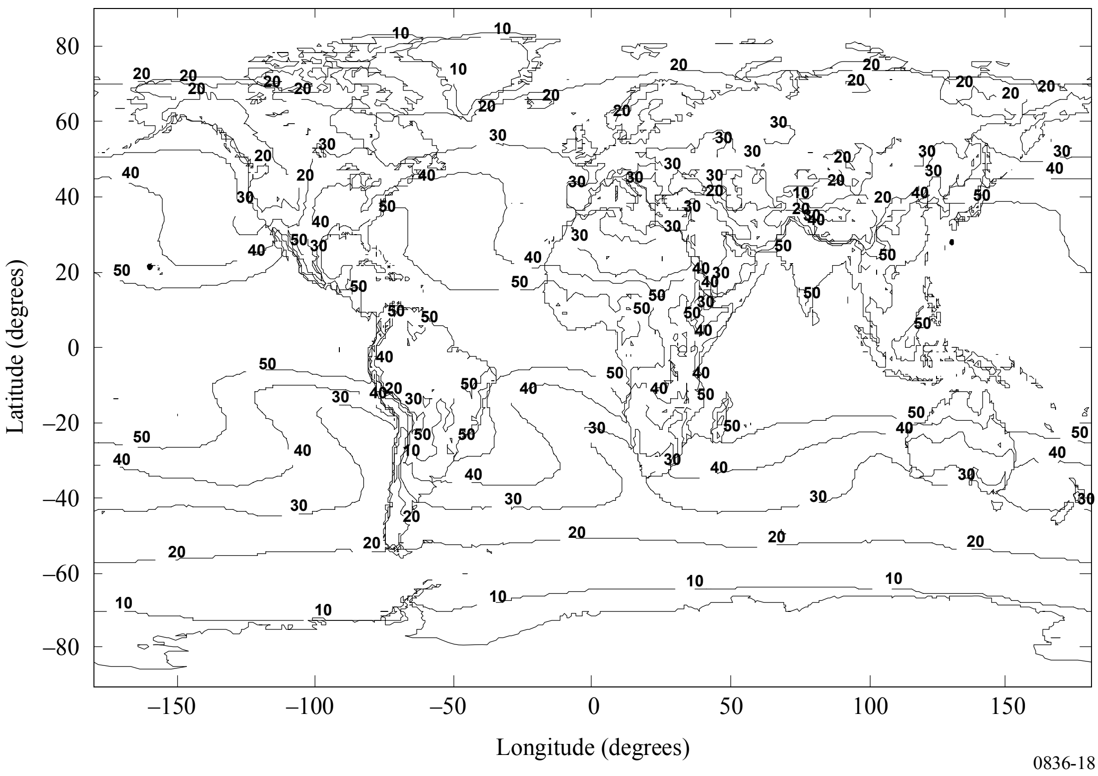


FIGURE 19

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

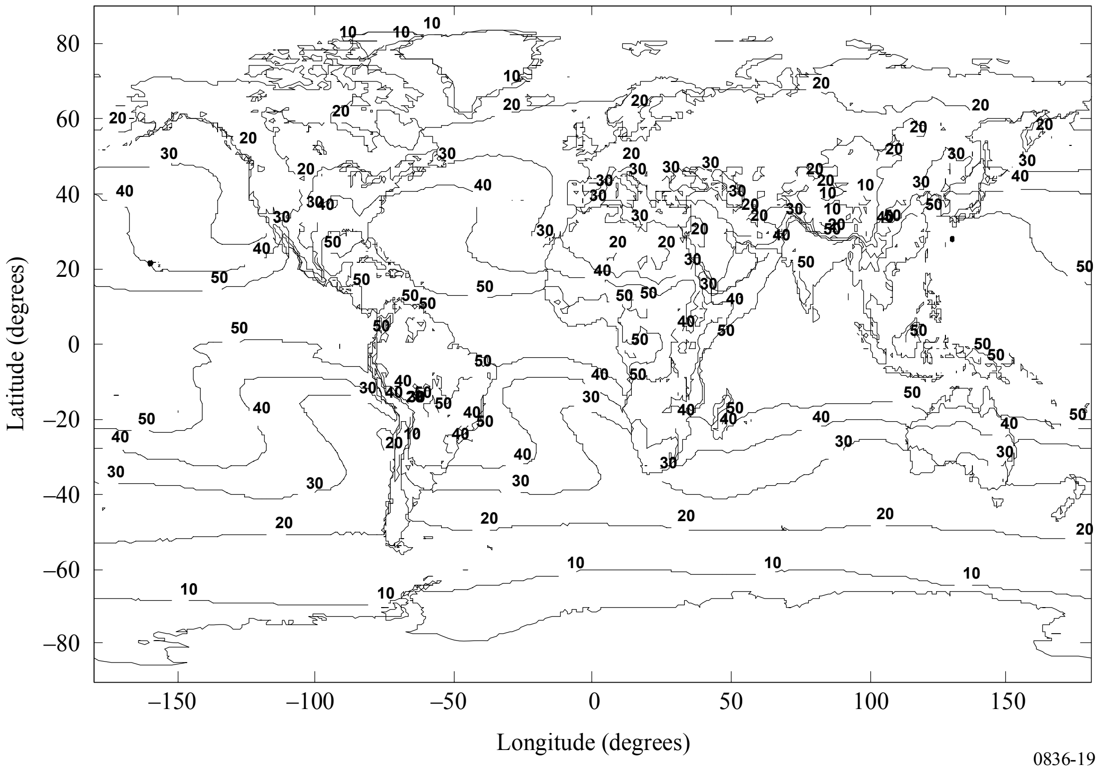


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FIGURE 20

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

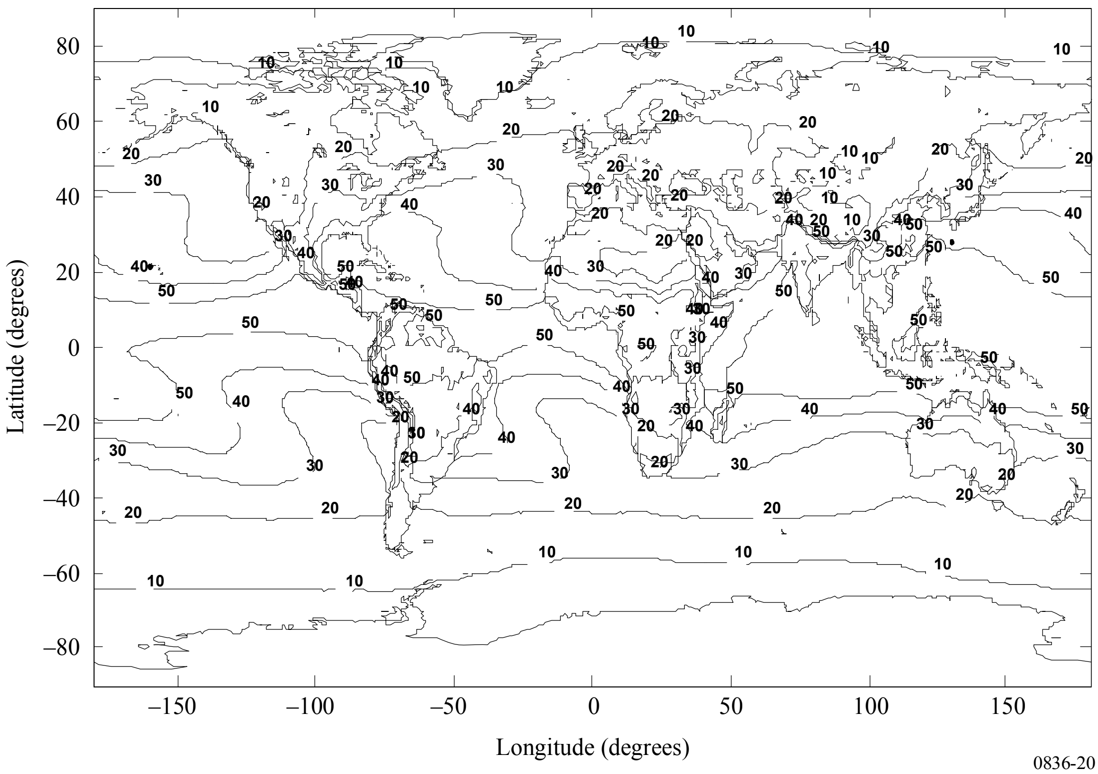

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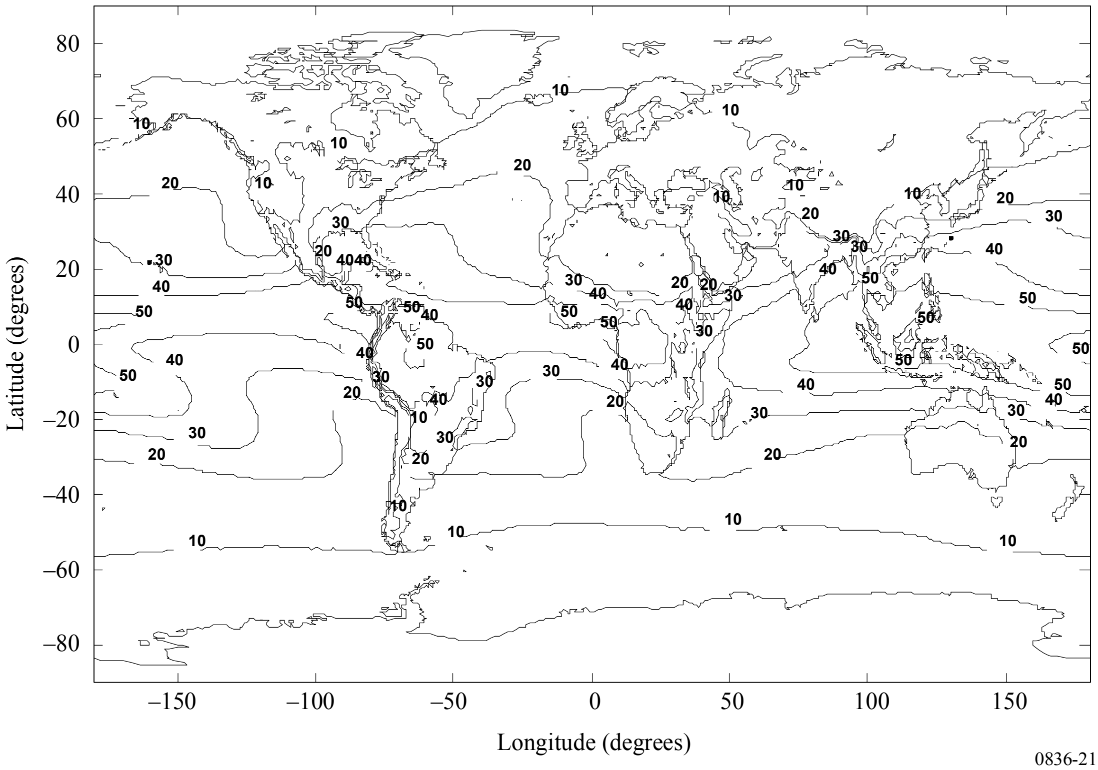
FIGURE 21

Columnar water vapour (kg/m²) exceeded for 50% of the year



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