International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.836-6

(12/2017)

Water vapour: surface density and total columnar content

P Series

Radiowave propagation

International Telecommunication Union

Foreword

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The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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SM	Spectrum management
SNG	Satellite news gathering
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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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Geneva, 2017

RECOMMENDATION ITU-R P.836-6*

Water vapour: surface density and total columnar content

(Question ITU-R 201/3)

(1992-1997-2001-2001-2009-2013-2017)

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

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, and corresponding water vapour scale height, *vsch*, in km, 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 an integral part of this Recommendation and are available in the form of digital maps provided in the Supplement file R-REC-P.836-6-201712-I!!ZIP-E.zip.

The monthly values of surface water vapour density, ρ, in g/m^3, and corresponding water vapour scale height, *vsch*, in km, exceeded for 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, and 99% of an average month are an integral part of this Recommendation and are available in the form of digital maps provided in the Supplement file.

* Radiocommunication Study Group 3 made editorial amendments to this Recommendation in the year 2021 in accordance with Resolution ITU-R 1.

The surface water vapour density 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. The surface water vapour density at any desired location on the surface of the Earth can be derived by the following interpolation method (if local data for the height above mean sea level at the desired location is not available, the map in Recommendation ITU-R P.1511 can be used):

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% for annual statistics and from the set: 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99% for monthly statistics;

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 annual or the monthly water vapour scale height data file corresponding to the probabilities p_{above} and p_{below}, determine the corresponding 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 the TOPO_0DOT5.txt topographic altitude digital map that is an integral part of this Recommendation and is provided in the Supplement file, determine the topographic altitudes, alt_1, alt_2, alt_3 and alt_4, at the four closest grid points using the bicubic interpolation method specified in Annex 1 of Recommendation ITU-R P.1144 (the TOPO_0DOT5 data is from -0.5° to 360.5° in longitude and from +90.5° to −90.5° in latitude, with a resolution of 0.5° in both latitude and longitude);

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[1]:

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

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.

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

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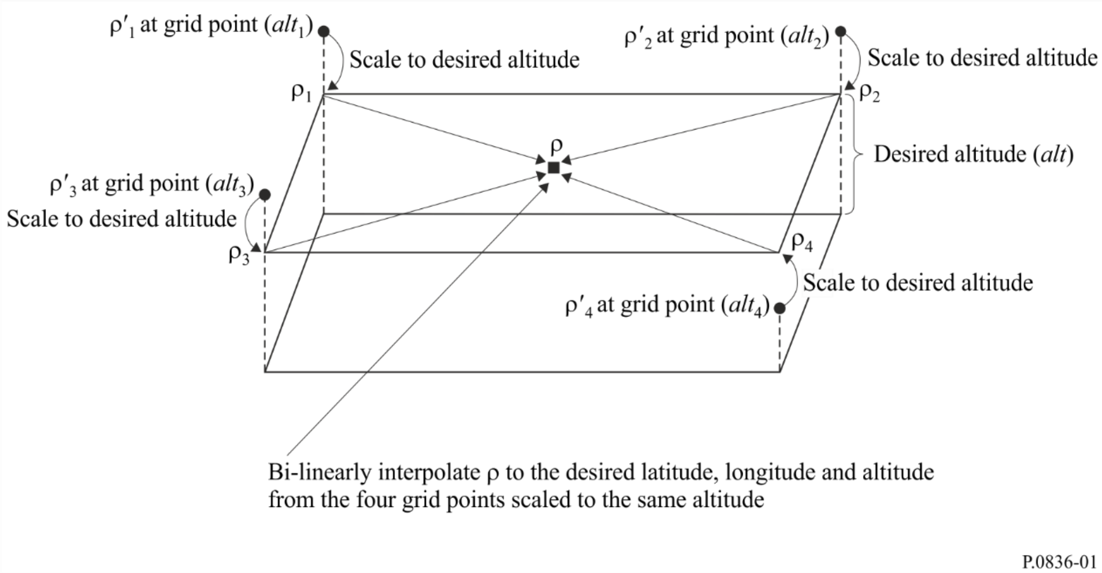
[1] The units of alt, alt_i, and $vsch_i$ must be identical (e.g. either km or m).

FIGURE 1

Interpolation procedure at probabilities above and below the desired probability



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, in kg/m^2 and corresponding water vapour scale height, *vsch*, in km, 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 an integral part of this Recommendation and are available in the form of digital maps provided in the supplement file.

The monthly values of total columnar water vapour content, V, in kg/m^2 and corresponding water vapour scale height, *vsch*, in km, exceeded for 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95, and 99% of each average month are an integral part of this Recommendation and are available in the form of digital maps provided in the supplement file.

The total water vapour content data is from 0° to 360° in longitude and from +90° to −90° in latitude, with a resolution of 1.125° in both latitude and longitude. The total water vapour content at any desired location on the surface of the Earth can be derived by the following interpolation method (if local data for the height above mean sea level at the desired location is not available, the map in Recommendation ITU-R P.1511 can be used):

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% for annual statistics and from the set: 1, 2, 3, 5, 10, 20, 30, 50, 60, 70, 80, 90, 95 and 99% for monthly statistics;

b) for the two probabilities, p_{above} and p_{below}, determine the total columnar water vapour content, V_1', V_2', V_3' and V_4' at the four closest grid points;

c) using the annual or the monthly water vapour scale height corresponding to the probabilities p_{above} and p_{below}, determine the corresponding 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 the TOPO_0DOT5.txt topographic altitude digital map that is an integral part of this Recommendation and is provided in the Supplement file, determine the topographic altitudes, alt_1, alt_2, alt_3, and alt_4, at the four closest grid points using the bicubic interpolation method specified in Annex 1 of Recommendation ITU-R P.1144 (the TOPO_0DOT5 data is from -0.5° to 360.5° in longitude and from +90.5° to −90.5° in latitude, with a resolution of 0.5° in both latitude and longitude);

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_3' and V_4', using the following relation[2]:

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

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_3' and V_4' is shown in Fig. 2);

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.

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[2] The units of alt, alt_i, and $vsch_i$ must be identical (e.g. either km or m).

FIGURE 2

Interpolation procedure at probabilities above and below the desired probability