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| **Recommendation ITU-R P.836-5**  **(09/2013)** |
| **Water vapour: surface density  and total columnar content** |
| **P Series**  **Radiowave propagation** |

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

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

# Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU‑T/ITU‑R/ISO/IEC and the ITU-R patent information database can also be found.

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| Series of ITU-R Recommendations  (Also available online at <http://www.itu.int/publ/R-REC/en>) | |
| **Series** | Title |
| **BO** | Satellite delivery |
| **BR** | Recording for production, archival and play-out; film for television |
| **BS** | Broadcasting service (sound) |
| **BT** | Broadcasting service (television) |
| **F** | Fixed service |
| **M** | Mobile, radiodetermination, amateur and related satellite services |
| P | Radiowave propagation |
| **RA** | Radio astronomy |
| **RS** | Remote sensing systems |
| **S** | Fixed-satellite service |
| **SA** | Space applications and meteorology |
| **SF** | Frequency sharing and coordination between fixed-satellite and fixed service systems |
| **SM** | Spectrum management |
| **SNG** | Satellite news gathering |
| **TF** | Time signals and frequency standards emissions |
| **V** | Vocabulary and related subjects |

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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.836-5[[1]](#footnote-1)\*

Water vapour: surface density and total columnar content

(Question ITU-R 201/3)

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

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/m3, 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 and are provided in the file [R-REC-P.836-5-201309-I!!ZIP-E](http://www.itu.int/rec/R-REC-P.836-5-201309-I/en).

The monthly values of surface water vapour density, ρ in g/m3, 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 and are provided in the file   
[R-REC-P.836-5-201309-I!!ZIP-E](http://www.itu.int/rec/R-REC-P.836-5-201309-I/en).

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. 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, *pabove* and *pbelow*, 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, *pabove* and *pbelow*, determine the surface water vapour densities, , ,  and  at the four closest grid points;

c) using the annual or the monthly water vapour scale height data file corresponding to the probabilities *pabove* and *pbelow*, determine the water vapour scale height at the four closest grid point, *vsch*1, *vsch*2, *vsch*3 and *vsch*4 for each probability, *pabove* and *pbelow*;

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, ρ1, ρ2, ρ3 and ρ4, at the desired altitude, *alt*, by scaling the water vapour densities, , ,  and , using the following relation:

           for *i* = 1, 2, 3, 4 (1)

f) determine the water vapour densities, ρ*above* and ρ*below*, at the probabilities *pabove* and *pbelow* and at the desired location by performing a bi-linear interpolation of the four values of water vapour density, ρ1, ρ2, ρ3 and ρ4, 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 , ,  and  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. *pabove* and *pbelow* 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.

FIGURE 1

Interpolation procedure at probabilities above and below desire 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/m2 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/m2), 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.

The monthly values of total columnar water vapour content, *V* (kg/m2), 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.

The 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:

a) determine the two probabilities, *pabove* and *pbelow*, 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 probabilitis, *pabove* and *pbelow*, determine the total columnar water vapour content, , ,  and  at the four closest grid points;

c) using the annual or the monthly water vapour scale height corresponding to the probabilities *pabove* and *pbelow*, determine the water vapour scale height at the four closest grid points, *vsch*1, *vsch*2, *vsch*3, and *vsch*4 for each probability, *pabove* and *pbelow*;

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, , ,  and , using the following relation:

           for *i* = 1, 2, 3, 4 (2)

f) determine the total columnar water vapour content, *Vabove* and *Vbelow*, at the probabilities *pabove* and *pbelow* 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 *Vabove* and *Vbelow* from , ,  and  is shown in Fig. 2);

g) determine the total columnar water vapour content, *V*, at the desired probability, *p*, by interpolating *Vabove* and *Vbelow* vs. *pabove* and *pbelow* to *p* on a linear *V* vs. log *p* scale.

FIGURE 2

Interpolation procedure at probabilities above and below desired probability



1. \* Radiocommunication Study Group 3 made editorial amendments to this Recommendation in April 2015 in accordance with Resolution ITU-R 1. [↑](#footnote-ref-1)