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Air quality — Environmental meteorology —

Part 1:
Ground-based remote sensing of visual range by lidar

Qualité de l'air — Météorologie de l'environnement —

Partie 1: Télédétection de la portée visuelle par lidar basée sur le sol

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Contents

Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 28902-1 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 5, *Meteorology* in collaboration with the World Meteorological Organization (WMO).

ISO 28902 consists of the following part, under the general title *Air quality — Environmental meteorology*:

— *Part 1: Ground-based remote sensing of visual range by lidar*

The following part is under preparation:

— *Part 2: Ground-based remote sensing by Doppler wind lidar*

Introduction

This part of ISO 28902 describes the determination of the visual range via backscattering atmospheric lidar (“Light Detection And Ranging”). Lidars have proven to be valuable systems for remote sensing of atmospheric pollutants, of various meteorological parameters such as wind velocity and direction, cloud and aerosol distribution and composition, shape of the particles, gas concentration, and of optical properties of the atmosphere like extinction and backscatter. A specific feature of lidar methods is their ability to allow spatially resolved remote sensing. The measurements can be carried out without direct contact and in any direction as electromagnetic radiation is used for sensing. Lidar systems, therefore, supplement conventional measurement technology. They are suitable for a large number of tasks that cannot be adequately performed by using *in-situ* or point measurement methods.

Air quality — Environmental meteorology —

Part 1:
Ground-based remote sensing of visual range by lidar

1 Scope

This part of ISO 28902 mainly specifies the requirements in order to perform visual range lidar measurements for the determination of direction-dependent meteorological optical range (MOR). The term “visual-range lidar” is used in this part of ISO 28902 to apply to the lidar systems making visual-range measurements, commonly referred to as “visibility measurements”. Due to physical approximations, quantitative determination is limited to a meteorological optical range of between 30 m and 2 000 m. For this range, this part of ISO 28902 specifies the performance of visual-range lidar systems utilizing the method of range-integrated visual-range measurements based on light extinction. The following parameters can be calculated based on the direction-dependent meteorological optical range:

a) horizontal visual range;

b) vertical visual range;

c) slant visual range.

NOTE The measures for visibility are strongly related to the historical definitions of visibility, which are related to human observers. The lidar technique extends the definitions to various conditions, such as daylight and night-time conditions.

In addition, this measurement principle enables the user to retrieve information on cloud base height, boundary layer depth, fog banks and aerosol profiles due to the signal attenuation by water vapour and/or aerosols. Examples of these applications are given in Annex C.

This part of ISO 28902 can be applied in the following areas:

- meteorological stations;
- airports;
- harbours;
- waterways;
- roads and motorways;
- automotive;
- oil platforms.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60825-1:2007, *Safety of laser products — Part 1: Equipment classification and requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
visual-range lidar
laser-based instrument using particle backscatter and extinction to measure visual range

3.2
visibility
meteorological visibility
greatest distance at which a black object of suitable dimensions (located on the ground) can be seen and recognized when observed against the horizon sky during daylight or could be seen and recognized during the night if the general illumination were raised to the normal daylight level

[WMO, 1992[1]; WMO, 2003[2]]

NOTE 1 ICAO (International Civil Aviation Organization) gives a different definition specified for aviation purposes) and makes a clear distinction with regard to daytime and night-time contrast (see ICAO, 2007[3]):

> Visibility for aeronautical purposes is the greater of:
>
> a) the greatest distance at which a black object of suitable dimensions, situated near the ground, can be seen and recognized when observed against a bright background;
>
> b) the greatest distance at which lights in the vicinity of 1 000 candelas can be seen and identified against an unlit background.

NOTE 2 In this part of ISO 28902, WMO's more general definition is used. The ICAO definition uses the luminous intensity of the runway lights for the night-time definition, which is not available in general cases.

3.3
visual range
greatest distance at which a given object can be recognised in any particular circumstances, as limited only by the atmospheric transmissivity and by the visual contrast threshold

[IEC 60050-845[4] and IEC ELECTROPEDIA 845-11-23[5]]

3.4
meteorological optical range
MOR
V_{MOR}
length of path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp, at a colour temperature of 2 700 K, to 5 % of its original value

[WMO, 1992[1]; WMO, 2008[6]]

NOTE 1 The relationship between MOR and extinction coefficient (at the contrast threshold of $\alpha = 0{,}05$) using Koschmieder's law is: $V_{\mathrm{MOR}} = -\ln(0{,}05)/\alpha$[6].

NOTE 2 If the contrast threshold is 2 %, the measurement quantity is called standard visual range V_{N}; this was initially used by Koschmieder[7].

NOTE 3 In this part of ISO 28902, MOR is used as a variable for horizontal measurements of the visual range; for slant measurements, the slant optical range (3.7) is used.

3.5
runway visual range
RVR
range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line

[ICAO, 2005[8]]

3.6
vertical optical range
VOR
V_{VOR}
meteorological optical range in the vertical direction

3.7
slant optical range
SOR
V_{SOR}
horizontal projection of the maximum distance out to which a black target in a plane can be recognized from an observer at height h above the plane with a contrast of 5 %

NOTE 1 The contrast threshold for the slant optical range is 5 % and is identical to the meteorological optical range (MOR) threshold.

NOTE 2 This definition is based on the standard definition of MOR [see Equations (5) and (8)] in order to enable a generally applicable mathematic evaluation procedure.

3.8
slant visual range
SVR
visual range of a specified object or light along a line of sight which differs significantly from the horizontal; for example, the visual range of ground objects or lights as seen from an aircraft on the approach

[ICAO, 2005[8]]

3.9
conventional range
maximum range measured under specified conditions in order to compare different systems

3.10
extinction coefficient
α
measure of the atmospheric opacity, expressed by the natural logarithm of the ratio of incident light intensity to transmitted light intensity, per unit light path length

3.11
temporal resolution
equipment-related variable describing the shortest time interval from which independent signal information can be obtained

3.12
effective temporal resolution
Δx_{eff}
application-related variable describing an integrated time interval for which the target variable is delivered with a defined uncertainty

EXAMPLE The time resolution of consecutive extinction coefficient profiles or calculated values of the meteorological optical range (MOR) or vertical optical range (VOR).

3.13
range resolution
equipment-related variable describing the shortest range interval from which independent signal information can be obtained

3.14
effective range resolution
application-related variable describing an integrated range interval for which the target variable is delivered with a defined uncertainty

EXAMPLE The range resolution of consecutive extinction coefficient profiles or calculated values of the meteorological optical range (MOR) or vertical optical range (VOR).

3.15
fog
reduction of visibility caused by hydrometeors at a meteorological optical range $V_{\mathrm{MOR}} < 1$ km and relative humidity near 100 %

3.16
mist
reduction of visibility caused by hydrometeors with a relative humidity ≥ 80 % or dew point differences ≤ 3 K for a meteorological optical range $V_{\mathrm{MOR}} \geq 1$ km

[WMO, 1992[1]; WMO, 2003[2]; WMO, 2008[6]]

NOTE 1 The definition of an upper limit of 5 km is given by ICAO[3].

NOTE 2 National regulations specify differing upper limits due to different definitions of clear sky (e.g. Germany 8 km, Canada 6 miles).

3.17
haze
reduction of visibility caused by lithometeors with a relative humidity < 80 % or dew point differences > 3 K for a meteorological optical range $V_{\mathrm{MOR}} \geq 1$ km

[WMO, 1992[1]; WMO, 2003[2], WMO, 2008[6]]

NOTE 1 The definition of an upper limit of 5 km is given by ICAO[3].

NOTE 2 National regulations specify differing upper limits due to different definitions of clear sky (e.g. Germany 8 km, Canada 6 miles).

4 Symbols and abbreviated terms

4.1 Symbols

Variable	Unit	Signification
A	m^2	area of the receiver optics
B	W m^3 sr	system parameter depending on geometry and range
c	m s^{-1}	speed of light
E_0	J	laser pulse energy
h	m	height
K'	1	luminance contrast threshold of the eye
O	1	(range-dependent) overlap function between the transmitted beam and the field of view of the receiver (complete overlap if $O = 1$)
P	W	received detector power
P_0	W	average power of laser pulse

Variable	**Unit**	**Signification**
S	$\mathrm{W\ m^2}$	lidar signature
T	K	temperature
t	s	time
Δt	s	laser pulse duration
Δt_{eff}	s	effective temporal resolution
x	m	range (distance from measuring system to scattering volume)
Δx_{eff}	m	effective range resolution
x_{CR}	m	conventional range for visual-range determination
x_{f}	m	starting distance for data evaluation by backward integration
x_{n}	m	starting distance for data evaluation by forward integration
x_{L}	m	baseline of a transmissometer
V_{MOR}	m	meteorological optical range
V_{N}	m	standard visual range
V_{SOR}	m	slant optical range
V_{VOR}	m	vertical optical range
α	$\mathrm{m^{-1}}$	extinction coefficient
$\alpha(x_{\mathrm{f}})$	$\mathrm{m^{-1}}$	initial value of extinction coefficient for backward integration
$\alpha(x_{\mathrm{n}})$	$\mathrm{m^{-1}}$	initial value of extinction coefficient for forward integration
$\Delta\alpha$	$\mathrm{m^{-1}}$	uncertainty of the extinction coefficient
β	$\mathrm{m^{-1}\ sr^{-1}}$	backscatter coefficient
δ	rad	laser divergence
γ	rad	field of view
η	1	efficiency of the receiver optics
λ	m	wavelength
$\Delta\lambda$	m	spectral width
ξ	m	variable for range integration
τ	1	atmospheric transmittance between lidar and scattering volume

4.2 Abbreviated terms

ICAO	International Civil Aviation Organization
MOR	meteorological optical range
RVR	runway visual range
SOR	slant optical range
SVR	slant visual range
VOR	vertical optical range
WMO	World Meteorological Organization

5 Fundamentals of visual-range lidar

5.1 General

Lidar methods are active methods for measuring selected physical variables of the atmosphere[9]. Lidar requires a pulsed light source and a detection system with good time resolution[10]. The emitted light interacts with the atmosphere through scattering[11][12], and the backscattered fraction is measured. The backscatter signals are used to determine the physical variables that describe the atmospheric conditions. Depending on the process of physical interaction of the light with the atoms, molecules, or aerosol particles in the atmosphere, a distinction is made between different variants of the lidar principle.

The visual-range lidar uses elastic scattering on particles for the measurement.

NOTE The wavelength is not changed during the scattering process.

In lidar, the propagation time of the light from the source to the object and back is used to determine distance. The distance x to the scattering volume is determined from the time t after emission of the laser pulse using the speed of light c:

$$x = \frac{c\,t}{2} \tag{1}$$

The factor 1/2 results from the doubled path traversed by the emitted light before it is recorded again by the lidar system.

After the emission of each individual laser pulse, the backscattering signal is detected in successive time bins. Each of these corresponds to a height or range interval and is characterized by its centre height or distance (see Figure 1).