TECHNICAL SPECIFICATION

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Geographic information — Calibration and validation of remote sensing imagery sensors and data —

Part 1:
Optical sensors

Information géographique — Calibration et validation de capteurs de télédétecion —

Partie 1: Capteurs optiques

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Foreword

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The committee responsible for this document is ISO/TC 211, *Geographic information/Geomatics*.

ISO 19159 consists of the following parts, under the general title *Geographic information — Calibration and validation of remote sensing imagery sensors*:

— *Part 1: Optical sensors*

Part 2 is planned to cover laser scanning, also known as light detection and ranging (LIDAR), SAR/InSAR (RADAR) and SONAR (sound). Parts 3 and 4 are planned to cover RADAR (radio detection and ranging) with the subtopics SAR (synthetic aperture radar) and InSAR (interferometric SAR) as well as SONAR (sound detection and ranging) that is applied in hydrography

Introduction

Imaging sensors are one of the major data sources for geographic information. Typical spatial outcomes of the production process are vector maps, Digital Elevation Models, and three-dimensional city models. There are typically two streams of spectral data analysis, that is, the statistical method, which includes image segmentation, and the physics-based method, which relies on characterization of specific spectral absorption features.

In each of the cases, the quality of the end products fully depends on the quality of the measuring instruments that has originally sensed the data. The quality of measuring instruments is determined and documented by calibration.

A calibration is often a costly and time-consuming process. Therefore, a number of different strategies are used that combine longer time intervals between subsequent calibrations with simplified intermediate calibration procedures that bridge the time gap and still guarantee a traceable level of quality. Those intermediate calibrations are called validations in this part of ISO 19159.

This part of ISO 19159 standardizes the calibration of remote sensing imagery sensors and the validation of the calibration information and procedures. It does not address the validation of the data and the derived products.

Many types of imagery sensors exist for remote sensing tasks. Apart from the different technologies, the need for a standardization of the various sensor types has different levels of priority. In order to meet those requirements, ISO 19159 has been split into more than one part. Part 1 covers optical sensors, i.e. airborne photogrammetric cameras and spaceborne optical sensors. Part 2 is intended to cover laser scanning, also known as LIDAR (Light detection and ranging).

Parts 3 and 4 are planned to cover RADAR (radio detection and ranging) with the subtopics SAR (synthetic aperture radar) and InSAR (interferometric SAR) as well as SONAR (sound detection and ranging) that is applied in hydrography.

Geographic information — Calibration and validation of remote sensing imagery sensors and data —

Part 1: Optical sensors

1 Scope

This part of ISO 19159 defines the calibration and validation of airborne and spaceborne remote sensing imagery sensors.

The term "calibration" refers to geometry, radiometry, and spectral, and includes the instrument calibration in a laboratory as well as *in situ* calibration methods.

The validation methods address validation of the calibration information.

This part of ISO 19159 also addresses the associated metadata related to calibration and validation which have not been defined in other geographic information International Standards.

The specified sensors include optical sensors of the frame camera and line camera types (2D CCD scanners).

2 Conformance

This part of ISO 19159 standardizes the service metadata for the calibration procedures of optical remote sensing sensors as well as the associated data types and code lists. Therefore conformance depends on the type of entity declaring conformance.

Mechanisms for the transfer of data are conformant to this part of ISO 19159 if they can be considered to consist of transfer record and type definitions that implement or extend a consistent subset of the object types described within this part of ISO 19159.

Details of the conformance classes are given in the Abstract test suite in Annex A.

3 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable to its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19115-2:2009, *Geographic information — Metadata — Part 2: Extensions for imagery and gridded data*

ISO/TS 19130:2010, *Geographic information — Imagery sensor models for geopositioning*

4 Terms and definitions

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

4.1
blooming
overflow of an over-saturated signal of one pixel to the neighbouring pixel

4.2
calibration
process of quantitatively defining a system's responses to known, controlled signal inputs

[SOURCE: ISO/TS 19101-2:2008, 4.2]

Note 1 to entry: A calibration is an operation that, under specified conditions, in a first step, establishes a relationship between indications (with associated *measurement* (4.16) uncertainties) and the physical *quantity* (4.27) values (with measurement uncertainties) provided by measurement standards.

4.3
calibration curve
expression of the relation between indication and corresponding measured *quantity* (4.27) value

Note 1 to entry: A calibration curve expresses a one-to-one relation that does not supply a *measurement* (4.16) result as it bears no information about the measurement *uncertainty* (4.38).

[SOURCE: ISO/IEC Guide 99:2007, 4.31]

4.4
calibration validation
process of assessing the validity of parameters

Note 1 to entry: With respect to the general definition of validation the "calibration validation" does only refer to a small set of parameters (attribute values) such as the result of a *sensor* (4.32) calibration.

4.5
correction
compensation for an estimated systematic effect

Note 1 to entry: See ISO/IEC Guide 98-3:2008, 3.2.3, for an explanation of "systematic effect".

Note 2 to entry: The compensation can take different forms, such as an addend or a factor, or can be deduced from a table.

[SOURCE: ISO/IEC Guide 99:2007, 2.53]

4.6
dark current
output current of a photoelectric *detector* (4.9) (or of its cathode) in the absence of incident radiation

Note 1 to entry: For calibration of optical *sensors* (4.32) dark current is measured by the absence of incident optical radiation.

4.7
dark current noise
noise (4.22) of current at the output of a *detector* (4.9), when no optical radiation is sensed

4.8
dark signal non uniformity
DSNU
response of a *detector* (4.9) element if no visible or infrared light is present

Note 1 to entry: This activation is mostly caused by imperfection of the detector.

4.9
detector
<electro-optical> device that generates an output signal in response to an energy input

Note 1 to entry: The energy input may be provided by electro-magnetic radiation. The output may be a measurable and reproducible electrical signal.

[SOURCE: ISO/TS 19130:2010, 4.18, modified]

4.10
ground sampling distance
GSD
linear distance between pixel centres on the ground

Note 1 to entry: GSD is a *measure* (4.15) of one limitation to image *resolution* (4.30), that is, the limitation due to sampling distance on the ground that corresponds to the pixel distances in the image plane.

Note 2 to entry: The GSD is the distance between the centre points of surface elements represented by adjacent elements in the image matrix.

Note 3 to entry: The GSD depends on flying height, terrain height and observation angle.

Note 4 to entry: The GSD can also be named ground sample distance.

Note 5 to entry: This definition also applies for water surfaces.

[SOURCE: ISO/TS 19130:2010, 4.45, modified — Notes 1 to 4 have been added.]

4.11
in situ measurement
direct *measurement* (4.16) of the measurand in its original place

4.12
instantaneous field of view
IFOV
instantaneous region seen by a single *detector* (4.9) element, measured in angular space

[SOURCE: ISO/TS 19130-2:2014, 4.36]

4.13
irradiance
electro-magnetic radiation energy per unit area per unit time

Note 1 to entry: The SI unit is watts per square metre (W/m^2).

4.14
keystone effect
distortion of a projected image caused by a tilt between the image plane and the projection plane resulting in a trapezoidal shaped projection of a rectangular image

4.15
measure
value described using a numeric amount with a scale or using a scalar reference system

Note 1 to entry: When used as a noun, measure is a synonym for physical *quantity* (4.27).

[SOURCE: ISO 19136:2007, 4.1.41]

4.16
measurement
set of operations having the object of determining the value of a *quantity* (4.27)

[SOURCE: ISO/TS 19101-2:2008, 4.20]

4.17
measurement accuracy
accuracy of measurement
accuracy
closeness of agreement between a test result or *measurement* (4.16) result and the true value

Note 1 to entry: The concept “measurement accuracy” is not a *quantity* (4.27) and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller *measurement error* (4.18).

Note 2 to entry: The term "measurement accuracy" should not be used for measurement trueness and the term *measurement precision* (4.19) should not be used for "measurement accuracy", which, however, is related to both these concepts.

Note 3 to entry: "Measurement accuracy" is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

[SOURCE: ISO 6709:2008, 4.1, modified — The preferred term is "measurement accuracy" rather than "accuracy" and Notes 1 to 3 have been added.]

4.18
measurement error
error of measurement
error
measured *quantity* (4.27) value minus a reference quantity value

Note 1 to entry: The concept of "measurement error" can be used both

a) when there is a single reference quantity value to refer to, which occurs if a calibration is made by means of a *measurement* (4.16) standard with a measured quantity value having a negligible measurement *uncertainty* (4.38) or if a conventional quantity value is given, in which case the measurement error is known, and

b) if a measurand is supposed to be represented by a unique true quantity value or a set of true quantity values of negligible range, in which case the measurement error is not known.

Note 2 to entry: Measurement error should not be confused with production error or mistake.

[SOURCE: ISO/IEC Guide 99:2007, 2.16]

4.19
measurement precision
precision
closeness of agreement between indications or measured *quantity* (4.27) values obtained by replicate *measurements* (4.16) on the same or similar objects under specified conditions

Note 1 to entry: Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.

Note 2 to entry: The "specified conditions" can be, for example, repeatability conditions of measurement, intermediate precision conditions of measurement, or reproducibility conditions of measurement (see ISO 5725-3).

Note 3 to entry: Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.

Note 4 to entry: Sometimes "measurement precision" is erroneously used to mean *measurement accuracy* (4.17).

[SOURCE: ISO/IEC Guide 99:2007, 2.15]

4.20
metric traceability
property of the result of a *measurement* (4.16) or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

[SOURCE: ISO/TS 19101-2:2008, 4.23]

4.21
metrological traceability chain
traceability chain
sequence of *measurement* (4.16) standards and calibrations that is used to relate a measurement result to a reference

Note 1 to entry: A metrological traceability chain is defined through a calibration hierarchy.

Note 2 to entry: A metrological traceability chain is used to establish metrological traceability of a measurement result.

Note 3 to entry: A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the *quantity* (4.27) value and measurement *uncertainty* (4.38) attributed to one of the measurement standards.

[SOURCE: ISO/IEC Guide 99:2007, 2.42]

4.22
noise
unwanted signal which can corrupt the *measurement* (4.16)

Note 1 to entry: Noise is a random fluctuation in a signal disturbing the recognition of a carried information.

[SOURCE: ISO 12718:2008, 2.26]

4.23
pixel response non-uniformity
PRNU
inhomogeneity of the response of the *detectors* (4.9) of a detector array to a uniform activation

4.24
point-spread function
PSF
characteristic response of an imaging system to a high-contrast point target

[SOURCE: IEC 88528-11:2004]

4.25
positional accuracy
closeness of coordinate value to the true or accepted value in a specified reference system

Note 1 to entry: The phrase "absolute accuracy" is sometimes used for this concept to distinguish it from relative positional accuracy. Where the true coordinate value may not be perfectly known, accuracy is normally tested by comparison to available values that can best be accepted as true.

[SOURCE: ISO 19116:2004, 4.20]

4.26
quality assurance
part of quality management focused on providing confidence that quality requirements will be fulfilled

[SOURCE: ISO 9000:2005, 3.2.11]

4.27
quantity
property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

Note 1 to entry: A reference can be a *measurement* (4.16) unit, a measurement procedure, a reference material, or a combination of such.

Note 2 to entry: Symbols for quantities are given in the ISO 80000 and IEC 80000 series *Quantities and units*. The symbols for quantities are written in italics. A given symbol can indicate different quantities.

Note 3 to entry: A quantity as defined here is a scalar. However, a vector or a tensor, the components of which are quantities, is also considered to be a quantity.

Note 4 to entry: The concept "quantity" may be generically divided into, e.g. "physical quantity", "chemical quantity", and "biological quantity", or "base quantity" and "derived quantity".

[SOURCE: ISO/IEC Guide 99:2007, 1.1, modified — The Notes have been changed.]

4.28
reference standard
measurement (4.16) standard designated for the calibration of other measurement standards for quantities of a given kind in a given organization or at a given location

4.29
remote sensing
collection and interpretation of information about an object without being in physical contact with the object

[SOURCE: ISO/TS 19101-2:2008, 4.33]

4.30
resolution
<imagery> smallest distance between two uniformly illuminated objects that can be separately resolved in an image

Note 1 to entry: This definition refers to the spatial resolution.

Note 2 to entry: In the general case, the resolution determines the possibility to distinguish between separated neighbouring features (objects).

Note 3 to entry: Resolution can also refer to the spectral and the temporal resolution.

[SOURCE: ISO/TS 19130-2:2014, 4.61, modified: Notes 1 to 3 have been added]

4.31
resolution
<sensor> smallest difference between indications of a *sensor* (4.32) that can be meaningfully distinguished

Note 1 to entry: For imagery, *resolution* (4.30) refers to radiometric, spectral, spatial and temporal resolutions.

[SOURCE: ISO/TS 19101-2:2008, 4.34]

4.32
sensor
element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a *quantity* (4.27) to be measured

Note 1 to entry: Active or passive sensors exist. Often two or more sensors are combined to a measuring system.

[SOURCE: ISO/IEC Guide 99:2007, 3.8, modified — The Note has been changed.]

4.33
smile distortion
centre wavelength shift of spectral channels caused by optical distortion

Note 1 to entry: This distortion is often simply called smile.

4.34
spectral resolution
specific wavelength interval within the electromagnetic spectrum

Note 1 to entry: The spectral wavelength interval is the least difference in the radiation wavelengths of two monochromatic radiators of equal intensity that can be distinguished according to a given criterion.

Note 2 to entry: Spectral resolution determines the ability to distinguish between separated adjacent spectral features.

[SOURCE: ISO 19115-2:2009, 4.30, modified: Notes 1 to 2 have been added]

4.35
spectral responsivity
responsivity per unit wavelength interval at a given wavelength

Note 1 to entry: The spectral responsivity is the response of the *sensor* (4.32) with respect to the wavelengths dependent radiance.

Note 2 to entry: The definition is described mathematically in IEC 60050–845. The spectral responsivity is quotient of the *detector* (4.9) output d $Y(\lambda)$ by the monochromatic detector input $dX_e(\lambda) = X_{e,\lambda}(\lambda) \bullet d\lambda$ in the wavelength interval $d\lambda$ as a function of the wavelength λ

$$s(\lambda)=\frac{dY(\lambda)}{dX_c(\lambda)}$$

[SOURCE: IEC 60050-845]

4.36
standardization
activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context

Note 1 to entry: In particular, the activity consists of the processes of formulating, issuing and implementing standards.

Note 2 to entry: Important benefits of standardization are improvement of the suitability of products, processes and services for their intended purposes, prevention of barriers to trade and facilitation of technological cooperation.

[SOURCE: ISO/IEC Guide 2:2004, 1.1]

4.37
stray light
electromagnetic radiation that has been detected but did not come directly from the *IFOV* (4.12)

Note 1 to entry: Stray light may be reflected light within a telescope.

Note 2 to entry: This definition is valid for the optical portion of the spectrum under observation.

4.38
uncertainty
parameter, associated with the result of *measurement* (4.16), that characterizes the dispersion of values that could reasonably be attributed to the measurand

Note 1 to entry: The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.

Note 2 to entry: Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. The other components, which can also be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

Note 3 to entry: It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with *corrections* (4.5) and *reference standards* (4.28), contribute to the dispersion.

Note 4 to entry: When the quality of accuracy or *precision* (4.19) of measured values, such as coordinates, is to be characterized quantitatively, the quality parameter is an estimate of the uncertainty of the measurement results. Because accuracy is a qualitative concept, one should not use it quantitatively, that is associate numbers with it; numbers should be associated with measures of uncertainty instead.

Note 5 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned *quantity* (4.27) values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated

Note 6 to entry: The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 7 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 8 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quality value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

[SOURCE: ISO 19116:2004, 4.26]

4.39
validation
process of assessing, by independent means, the quality of the data products derived from the system outputs

Note 1 to entry: In this part of ISO 19159, the term validation is used in a limited sense and only relates to the validation of calibration data in order to control their change over time.

[SOURCE: ISO/TS 19101-2:2008, 4.41]

4.40
verification
provision of objective evidence that a given item fulfils specified requirements

Note 1 to entry: When applicable, *measurement* (4.16)*uncertainty* (4.38) should be taken into consideration.

Note 2 to entry: The item may be, e.g. a process, measurement procedure, material, compound, or measuring system.

Note 3 to entry: The specified requirements may be, e.g. that a manufacturer's specifications are met.

Note 4 to entry: Verification should not be confused with calibration. Not every verification is a *validation* (4.39).

[SOURCE: ISO/IEC Guide 99:2007, 2.44, modified — Note 6 has been deleted.]

4.41
vicarious calibration
post-launch calibration of *sensors* (4.32) that make use of natural or artificial sites on the surface of the Earth

5 Abbreviated terms and symbols

5.1 Abbreviated terms

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer [METI (Japan); NASA]
BRDF	Bi-directional reflectance distribution function
CA	Calibration and validation
CalVal	Calibration and validation
CCD	Charge coupled device
CEOS	Committee on Earth Observation Satellites

CEOS WGCV	Committee on Earth Observation Satellites Working Group Calibration Validation
ENVISAT	Environmental Satellite
EO	Earth observation
ERS	European Remote Sensing Satellite (ESA)
ESA	European Space Agency
FOV	Field-of-view
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GMES	Global monitoring earth system
GPS	Global positioning system
GS	Ground segment
GUM	ISO Guide to the expression of uncertainty in measurement
IEEE	Institute of Electrical and Electronics Engineers
METI	Ministry of Economy, Trade and Industry, Japan
MIR	Mid infrared
MTF	Modulation transfer function
NASA	US National Aeronautic and Space Administration
NIR	Near infrared (spectral region)
QA	Quality assurance
QA4EO	Quality assurance framework for earth observation
RMSE	Root mean square error
RTC	Radiative transfer code
SAA	Solar azimuth angle
SMAC	Simultaneous multiframe analytical calibration
SWIR	Shortwave infrared
SZA	Solar zenith angle
TIR	Thermal infrared
TOA	Top of the atmosphere
VAA	View azimuth angle
VIM	International Vocabulary of Metrology
VIS	Visible
VZA	View zenith angle