TECHNICAL SPECIFICATION

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First edition

Geographic information — Calibration and validation of remote sensing data and derived products —

Part 1: Fundamentals

PROOF/ÉPREUVE

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*.

A list of all parts in the ISO 19124 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 19124 series addresses post-launch calibration and validation (Cal/Val) of remotely sensed data and products derived from the data. This document, ISO 19124-1, provides the fundamentals and a common framework on Cal/Val of remote-sensing data and derived products. Subsequent parts of the ISO 19124 series deal with sensor- or product-specific Cal/Val.

NOTE In contrast to the ISO 19124 series, the ISO 19159 series focuses on the pre-launch Cal/Val process of the sensor and hardware.

This document was drafted based on material provided by the major organizations that are active in this field such as CEOS (international), NASA (USA), ESA (Europe), JAXA (Japan), CSIRO (Australia, and the Chinese space agency.

In accordance with the ISO/IEC Directives, Part 2, 2018, Rules for the structure and drafting of International Standards, in International Standards the decimal sign is a comma on the line. However, the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures) at its meeting in 2003 passed unanimously the following resolution:

“The decimal marker shall be either a point on the line or a comma on the line.”

In practice, the choice between these alternatives depends on customary use in the language concerned. In the technical areas of geodesy and geographic information it is customary for the decimal point always to be used, for all languages. That practice is used throughout this document.

Geographic information — Calibration and validation of remote sensing data and derived products —

Part 1: Fundamentals

1 Scope

The ISO 19124 series is focused on calibration and validation (Cal/Val) of remote sensing data, which are collected by a sensor on-board a platform in a mission, and products derived in part or whole from the data. The ISO 19124 series defines the metadata related to the calibration and validation process that has not been defined in other ISO/TC 211 International Standards. The metadata allows the data providers to provide a standardized description of the Cal/Val process they have applied to the data and the data users to get the same forms of metadata from different data providers.

This document addresses the overall framework and common calibration and validation processes related to Earth observation data and derived products from different types of remote sensors.

Subsequent parts in the ISO 19124 series will target data from specific sensors, e.g. infrared, ultraviolet/visible/near-infrared, microwave, or broadband, products derived from those data, and calibration and validation sites.

Calibration addresses a geometric, radiometric, or spectral correction of the data. Validation addresses an evaluation of the quality and the accuracy of the data and the derived products.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 19157-1, *Geographic information — Data quality — Part 1: General requirements*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
accuracy
closeness of agreement between a test result or measurement result and the true value

[SOURCE: ISO 3534-2:2006, 3.1.1, modified — Notes to entry have been removed.]

3.2
bias
magnitude of the non-random or systematic errors of a result

Note 1 to entry: A bias can be positive or negative.

Note 2 to entry: This entry is adapted from Reference [9].

3.3
calibration
process of quantitatively defining a system’s responses to the known, controlled signal inputs

[SOURCE: ISO 19101-2:2018, 3.2]

3.4
calibration curve
expression of the relation between indication and corresponding measured quantity value

[SOURCE: ISO/IEC Guide 99:2007, 4.31, modified — Note 1 to entry has been removed.]

3.5
calibration equation
equation relating the primary measure and that of the radiometer, for example the brightness temperature, to subsidiary measurands, such as powers, and to calibration quantities, such as standard values

[SOURCE: ISO/TS 19159-4:2022, 3.15]

3.6
calibration parameters
information generated (or that will be generated) during the course of a calibration that quantifies and/or describes the Earth observation (EO) sensor performance

Note 1 to entry: These parameters may be laboratory measurement, thermal vacuum (TVAC) performance plots, or sheets (as allowed).

Note 2 to entry: This entry is adapted from Reference [12].

3.7
co-location
<coordinate> procedure to match the location of two or more spatial datasets

3.8
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]

3.9
cross-calibration
process of relating the measurements of one instrument to another instrument which is usually well-calibrated, serving as a reference

Note 1 to entry: Cross-calibration of instruments operating during the same period requires careful collocation wherein instrument outputs are compared when the instruments are viewing the same Earth scenes, at the same times, from the same viewing angles.

[SOURCE: ISO/TS 19159-4:2022, 3.18]

3.10
derived product
<earth observation> product that is not directly measured by sensors but derived from direct sensor measures by algorithms or models

3.11
detector
<electro-optical> sensing element that generates an output signal in response to an energy input

[SOURCE: ISO 19130-1:2018, 3.18, modified — The domain <electro-optical> has been added to the entry and "device" has been replaced by "sensing element" at the beginning of the definition.]

3.12
emissivity
ratio of the energy radiated by an emissive surface relative to that of an ideal blackbody source at the same temperature

Note 1 to entry: It is generally related as a function of wavelength or frequency, emissivity values range from 0 to 1.

Note 2 to entry: This entry is adapted from Reference [12].

3.13
evaluation
<earth observation> systematic determination of the extent to which an entity meets its specified criteria

Note 1 to entry: The entity can be an item or activity.

[SOURCE: ISO/IEC 25001:2014, 4.1, modified — The domain <earth observation> and a new Note 1 to entry have been added.]

3.14
filter
<earth observation> optical device that is placed in the optical path of an Earth observation (EO) sensor to select, restrict, reject, limit or adjust an EO sensor response

Note 1 to entry: The range of desired wavelengths/frequencies to be passed by an optical filter is called the "bandpass". This is generally defined by the cut-on and cut-off wavelengths/frequencies of the optical filter.

Note 2 to entry: The EO sensor response to the optical wavelengths/frequencies within the desired optical filter bandpass is called the "in-band response".

Note 3 to entry: The ability of an optical filter (or optical system) to reject optical energy outside the desired wavelengths/frequencies is referred to as "out-of-band (OOB) blocking". This can also refer to filter design specifications regarding the ability to reject optical energy outside the desired filter bandpass.

Note 4 to entry: Undesired optical energy that passes through an optical filter (or optical system) that has a spectral location outside the desired spectral bandpass is called " OOB leakage".

Note 5 to entry: An EO sensor's response to OOB leakage is called the "OOB response".

Note 6 to entry: The ratio of the open-path throughput of an optical path with and without the filter is called "transmittance". Generally expressed as a function of wavelength or optical frequency, transmittance values range from 0 to 1, or 0 % to 100 % if expressed in percent transmittance.

Note 7 to entry: This entry is adapted from Reference [12].

3.15
irradiance
electro-magnetic radiation energy per unit area per unit time

[SOURCE: ISO/TS 19159-1:2014, 4.13, modified —Note 1 to entry has been removed.]

3.16
measure
<GML> 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.

[SOURCE: ISO 19136-1:2020, 3.1.41]

3.17
measurement
set of operations having the object of determining the value of a quantity

[SOURCE: ISO 19101-2:2018, 3.21]

3.18
measurement error
error of measurement
error
measured quantity value minus a reference quantity value

[SOURCE: ISO/TS 19159-1:2014, 4.18, modified — Notes to entry have been removed.]

3.19
noise
unwanted signal which can corrupt the measurement

Note 1 to entry: In most measurement scenarios, measurement noise limitations challenge measurement objectives and are a major contributor to overall measurement uncertainty.

Note 2 to entry: Noise equivalent radiance (NER) is the entity of radiance that is most appropriate for the description of radiant flux from an extended area source. The NER is the amount of radiant flux that produces a signal equal to the system's noise when viewing an extended source.

[SOURCE: ISO/TS 19159-1:2014, 4.22, modified — The original Note 1 to entry has been removed and two new Notes to entry have been added.]

3.20
point source
source of electromagnetic radiation that is resolved in the ideal case to a single point or direction in space

Note 1 to entry: A natural star is an ideal point source. In the laboratory on the ground, a point source is simulated using an optical collimator.

Note 2 to entry: This entry is adapted from Reference [12].

3.21
post-launch calibration
all calibration activities that occur after a satellite-based Earth observation (EO) sensor is on-orbit

Note 1 to entry: The post-launch calibration may also be referred to as on-orbit calibration.

Note 2 to entry: The scope of the post-launch calibration varies from program to program and sensor to sensor, and includes considerations such as mission objectives, measurement requirements, mission operations capabilities, sensor data collection capabilities, and the ability to downlink low-level sensor response data to the ground.

Note 3 to entry: Post-launch calibration activities are included in the calibration plan and are executed according to the post-launch calibration procedures.

Note 4 to entry: This entry is adapted from Reference [12].

3.22
precision
measurement precision
closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions

[SOURCE: ISO/TS 19159-2:2016, 4.23, modified — Notes to entry have been removed and the original preferred term and admitted terms have been inversed.]

3.23
pre-launch calibration
sequence of measurement and characterization that takes place during and after instrument assembly and integration, prior to launch

Note 1 to entry: Pre-launch calibration provides the best or only chance to measure calibration key data (CKD) such as spectral response, linearity and polarization sensitivity, and also provides an important quality control and validation function to prevent unpleasant surprises and disappointment after launch.

Note 2 to entry: Pre-launch calibration is also called ground calibration.

Note 3 to entry: This entry is adapted from Reference [12].

3.24
quality
degree to which a set of inherent characteristics of an object fulfils requirements

[SOURCE: ISO 9000:2015, 3.6.2, modified — Notes 1 and 2 to entry have been removed.]

3.25
radiance
at a point on a surface and in a given direction, the radiant intensity of an element of the surface, divided by the area of the orthogonal projection of this element on a plane perpendicular to the given direction

[SOURCE: ISO 19101-2:2018, 3.30]

3.26
radiometric calibration
process of deriving coefficients, identifying and describing behaviours, and characterizing all aspects of a remote sensing instrument to relate the response of the sensor to a known quantity of flux entering the system

Note 1 to entry: A system that has undergone this process can then infer the value of an unknown quantity of flux based on the response of the instrument.

Note 2 to entry: This entry is adapted from Reference [12].

3.27
remote sensing
collection and interpretation of information about an object without being in physical contact with the object

[SOURCE: ISO 19101-2:2018, 3.33]

3.28
repeatability
stability of the response of a remote sensing instrument over time

Note 1 to entry: Repeatability or stability of a measurement between adjacent samples or within a single integrated measurement interval is referred to as "short-term" repeatability. Short-term repeatability is quantified from measurement noise with a timescale of typically seconds to minutes.

Note 2 to entry: Repeatability or stability of response from a stable input between consecutive or succeeding integrated measurement intervals is referred to as "medium-term" repeatability. Medium-term repeatability is typically quantified via benchmark tests that are included as part of a measurement sequence. Medium-term repeatability sources may include on-board stimulator sources, vicarious ground sources and stellar references. The medium-term repeatability timescale is typically minutes to hours.

Note 3 to entry: Repeatability or stability between widely separated measurement intervals is referred to as "long-term" repeatability. Long-term repeatability is typically quantified via benchmark tests that periodically measure constant radiometric source(s) over the life of the sensor. Long-term repeatability sources may include on-board stimulator sources, vicarious ground sources and stellar references. The long-term repeatability timescale is typically hours to days, up to the lifetime of the sensor.

Note 4 to entry: This entry is adapted from Reference [12].

3.29
sensor
element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured

[SOURCE: ISO/IEC Guide 99:2007, 3.8, modified — The Example and Note 1 to entry have been removed.]

3.30
spectral irradiance
entity of flux that describes a point source or a source of a fixed size and distance such as the Sun when viewed from Earth

Note 1 to entry: When irradiance includes wavelength dependence it is called spectral irradiance. Generalized units of spectral radiance are Watts/ $(cm^2 \cdot \mu m)$ or Photons/sec/$(cm^2 \cdot \mu m)$.

Note 2 to entry: This entry is adapted from [12].

3.31
stability
ability of a measuring instrument or measuring system to maintain its metrological characteristics constant with time

[SOURCE: ISO/TS 19159-4:2022, 3.38]

3.32
temporal stability
consistency of a linear trend

3.33
uncertainty
measurement uncertainty
parameter, associated with the result of measurement, that characterizes the dispersion of values that could reasonably be attributed to the measurand

Note 1 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.

[SOURCE: ISO 19116:2019, 3.28, modified — "measurement uncertainty" has been added as an admitted term; Note 1 to entry has been replaced with Note 2 to entry from ISO 19101-2: 2018, 3.40.]

3.34
validation
process of assessing, by independent means, the quality of the data products derived from the system outputs

Note 1 to entry: Reference [4] defines "validation" as the process of evaluating by independent means the accuracy of satellite-derived land products and quantifying their uncertainties by analytical comparison with reference data.

Note 2 to entry: Reference [12] defines "validation" as the process of confirming that the specifications and requirements set out in the design of an operation were sufficient to meet the objectives of the operation.

[SOURCE: ISO 19101-2:2018, 3.41, modified — Notes 1 and 2 to entry have been added.]

3.35
verification
provision of objective evidence that a given item fulfils specified requirements

[SOURCE: ISO/IEC Guide 99:2007, 2.44, modified — The EXAMPLEs and Notes to entry have been removed.]

3.36
vicarious calibration
post-launch calibration of sensors that make use of natural or artificial sites on the surface of the Earth

[SOURCE: ISO/TS 19159-1:2014, 4.41]

4 Symbols and abbreviated terms

AK	averaging kernel
BRDF	bidirectional reflectance distribution function
Cal/Val	calibration and validation
CEOS	Committee on Earth Observing Satellites
CEOS WGCV	Committee on Earth Observing Satellites Working Group on Calibration and Validation
DFS	degree of freedom for signal
EO	Earth observation
FOV	field of view
FRM	fiducial reference measurement
GUM	Guide to the Expression of Uncertainty Measurement
InSAR	interferometric SAR
IR	infrared
K	Kelvin
LED	light-emitting diode
LEO	low Earth orbit
Lidar	light detection and ranging

MI mutual information

MIPAS Michelson Interferometer for Passive Atmospheric Sounding

MW microwave

MWIR mid-wave infrared

NIR near infrared (spectral region)

PDF probability density function

PICS pseudo-invariant calibration sites

PUM product user manual

RAR real aperture radar

RMS root mean square

RMSD root-mean-square deviation

RMSE root-mean-square error

SAR synthetic aperture radar

SNO simultaneous nadir overpass

SNR signal to noise ratio

SONAR sound navigation and ranging

SWIR shortwave infrared

TIR thermal infrared

TVAC thermal vacuum

UAV unmanned aerial vehicle

UV ultraviolet

VIM Vocabulary of International Metrology

VIS visible

WLS white light source

Table 1 provides the parameters and definitions used throughout this document, notably in Annex C.

Table 1 — Parameters and their definitions

Parameter	Definition
$\vec{x}$	first observation vector; can be either point-like (1D), an area (2D), or a volume (3D)
$\vec{y}$	second observation vector
$\theta(t,r)$	continuous geophysical field in space and time (t : time, r : space)
θ^{α}	first field of a true, but unknown geophysical variable
θ^{β}	second field of a true, but unknown geophysical variable

Table 1 *(continued)*

Parameter	Definition
α, β	multi-indices summarizing information on temporal and spatial resolution/averaging
n	number of samples in both space and time
h	first nonlinear mapping function, also called measurement operator
k	second nonlinear mapping function, also called measurement operator
$\vec{u}_x$	vector of measurement errors in x
$\vec{u}_y$	vector of measurement errors in y
$\vec{e}_x$	vector of differences between the sampled observation and the true, but unknown, state of the geophysical field
$\vec{\delta}$	vector of differences between the two sample vectors
$\vec{d}_\theta$	vector of differences between the two fields of geophysical variables
f_δ	probability density function (PDF) of δ
M	error model M that allows the prediction of the PDF of δ
μ_δ	mean of δ
σ_δ^2	variance of δ
$\hat{\mu}_\delta$	empirical estimator (denoted by the circumflex) of the mean of δ
$\hat{\sigma}_\delta^2$	empirical estimator (denoted by the circumflex) of the variance of δ
$E[\delta]$	expectation operator
f_x	1-dimensional function of x
f_y	1-dimensional function of y
$f_{x,y}$	2-dimensional function of x and y
x	first observation data set
y	second observation data set
σ_{xy}	covariance between the data sets x and y
b	bias
$\hat{\mu}_x$	empirical estimator (denoted by the circumflex) of the mean of x
$\hat{\mu}_y$	empirical estimator (denoted by the circumflex) of the mean of y
L_i	is the radiance measure of pixel i, the summation covers all pixels on the Moon N.
md	median
p_x^{50}	median of x
p_y^{50}	median of y
R	linear (Pearson) product-moment correlation coefficient
R^t	unknown truth
ρ	Spearman's rank correlation coefficient (nonparametric, nonlinear)
$\hat{\sigma}_x^2$	empirical estimator (denoted by the circumflex) of the variance of x
$\hat{\sigma}_y^2$	empirical estimator (denoted by the circumflex) of the variance of y