TECHNICAL SPECIFICATION

ISO/TS 19159-3

First edition
2018-05

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

Part 3:
SAR/InSAR

Information géographique — Calibration et validation de capteurs de télédétection —

Partie 3: SAR/InSAR

Reference number
ISO/TS 19159-3:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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Foreword

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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).

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For an explanation on 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 the following URL: 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 19159 series can be found on the ISO website.

Introduction

Imaging sensors are one of the major data sources for geographic information.

The image data captures spatial and spectral measurements and has numerous applications ranging from road/town planning to geological mapping. Typical spatial outcomes of the production process are vector maps, digital elevation models, and 3-dimensional city models.

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

Calibration is often a costly and time consuming process. Therefore, a number of different strategies are in place 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.

This document 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 a different priority. In order to meet those requirements ISO/TS 19159 has been split into several parts. ISO/TS 19159-1 addresses the optical sensors. ISO/TS 19159-2 addresses the airborne lidar (light detection and ranging) sensors. ISO/TS 19159-3 (this document) covers synthetic aperture radar (SAR) and interferometric SAR (InSAR).

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

Part 3:
SAR/InSAR

1 Scope

This document defines the calibration of SAR/InSAR sensors and validation of SAR/InSAR calibration information.

This document addresses earth based remote sensing. The specified sensors include airborne and spaceborne SAR/InSAR sensors.

This document also addresses the metadata related to calibration and validation.

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 19103, *Geographic information — Conceptual schema language*

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

ISO/TS 19130-2:2014, *Geographic information — Imagery sensor models for geopositioning — Part 2: SAR, InSAR, lidar and sonar*

ISO 19157, *Geographic information — Data quality*

ISO/TS 19159-1:2014, *Geographic information — Calibration and validation of remote sensing imagery sensors and data — Part 1: Optical sensors*

ISO/TS 19159-2, *Geographic information — Calibration and validation of remote sensing imagery sensors — Part 2: Lidar*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

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

Note 1 to entry: In this document, the true value can be a reference value that is accepted as true.

[SOURCE: ISO 3534-2:2006, 3.3.1, modified — NOTES 1, 2 and 3 have been deleted. New Note 1 to entry has been added.]

3.2
antenna pattern

ratio of the electronic-field strength radiated in the direction θ to that radiated in the beam-maximum direction

3.3
aperture reference point
ARP

3D location of the centre of the synthetic aperture

Note 1 to entry: It is usually expressed in ECEF coordinates in metres.

[SOURCE: ISO/TS 19130:2010, 4.4]

3.4
attitude

orientation of a body, described by the angles between the axes of that body's coordinate system and the axes of an external coordinate system

[SOURCE: ISO 19116:2004 4.2]

3.5
azimuth resolution

<SAR> resolution in the cross-range direction

Note 1 to entry: This is usually measured in terms of the impulse response of the SAR sensor and processing system. It is a function of the size of the synthetic aperture, or alternatively the dwell time (e.g. larger aperture → longer dwell time → better resolution).

Note 2 to entry: 3 dB width of the impulse response is the normal value of measurements.

Note 3 to entry: Cross-range direction is also the same as along-track direction.

[SOURCE: ISO/TS 19130:2010, 4.7, modified — Notes 2 and 3 to entry have been added.]

3.6
backscattering coefficient

average radar cross section per unit area

Note 1 to entry: If the radar return from the illuminated area is contributed by a number of independent scattering elements, it is described by the backscattering coefficient instead of radar cross section used for the point target. It is calculated as:

$$\sigma^0 = \frac{\sigma}{A}$$

where

σ is the total radar cross section of an area A;

σ^0 is a dimensionless parameter and is usually expressed in decibels (dB) as follows:

$$\sigma^0_{\mathrm{dB}} = 10\log_{10}\sigma^0$$

Note 2 to entry: “Backscattering coefficient” is sometimes called “normalized radar cross section”.

3.7
calibration
process of quantitatively defining a system's responses to known, controlled signal inputs

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

3.8
calibration coefficient
ratio of SAR image pixel power to radar cross section without considering additive noise, after the processor gain is normalized to one, and elevation antenna pattern, range and atmospheric attenuation are all corrected

3.9
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]

3.10
cross-talk
any signal or circuit unintentionally affecting another signal or circuit

Note 1 to entry: For PolSAR sensor, if the transmitting channel is horizontally (H) polarized, the cross-talk on transmitting defines the ratio of V polarization transmitting power to H polarization transmitting power, expressed in decibels (dB). The cross-talk on receiving is similar to that on transmitting.

3.11
digital elevation model
DEM
dataset of elevation values that are assigned algorithmically to 2-dimensional coordinates

[SOURCE: ISO/TS 19101-2:2008, 4.5]

3.12
height
h, *H*
distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface

Note 1 to entry: A height below the reference surface will have a negative value.

Note 2 to entry: The terms elevation and height are synonyms.

[SOURCE: ISO 19111:2007, 4.29 — modified: Note 2 to entry has been added.]

3.13
incident angle
vertical angle between the line from the detected element to the sensor and the local surface normal (tangent plane normal)

[SOURCE: ISO/TS 19130:2010, 4.57]

3.14
interferometric baseline
distance between the two antenna phase centre vectors at the time when a given scatterer is imaged

3.15
integrated side lobe ratio
ISLR
ratio between the side lobe power and the main lobe power of the impulse response of point targets in the radar imaging scene

Note 1 to entry: The integrated side lobe ratio (ISLR) can be obtained by integrating the power of the impulse response over suitable regions. The ISLR is expressed as

$$\mathrm{ISLR} = 10\log_{10}\left\{\frac{P_{\mathrm{total}} - P_{\mathrm{main}}}{P_{\mathrm{main}}}\right\}$$

where

P_{total} is the total power;

P_{main} is the main lobe power.

Note 2 to entry: The main lobe width can be taken as α times the impulse response width (IRW), centred around the peak, where α is a predefined constant, usually between 2 and 2,5.

3.16
interferometric synthetic aperture radar
InSAR
technique exploiting two or more SAR images to generate maps of surface deformation or digital elevation through the differences in the phase of the waves returning to the radar

3.17
look angle
vertical angle from the platform down direction to the slant range direction, usually measured at the aperture reference point (ARP)

Note 1 to entry: “Off-nadir angle” has the same definition as “look angle”.

[SOURCE: ISO/TS 19130-2:2014, 4.42, modified — new Note 1 to entry has replaced the original Note 1 to entry.]

3.18
metadata
information about a resource

[SOURCE: ISO 19115-1:2014, 4.10]

3.19
peak side lobe ratio
PSLR
ratio between the peak power of the largest side lobe and the peak power of the main lobe of the impulse response of point targets in the SAR image

Note 1 to entry: The peak side lobe ratio is usually expressed in decibels (dB) and computed as follows:

$$\mathrm{PSLR} = 10\log_{10}\left\{\frac{P_{\mathrm{sidepeak}}}{P_{\mathrm{mainpeak}}}\right\}$$

where

P_{mainpeak} is the peak power of the main lobe;

P_{sidepeak} is the peak power of the largest side lobe

3.20

polarimetric synthetic aperture radar

SAR sensor enhanced by transmitting and receiving in different combinations of polarization

Note 1 to entry: By combining multiple polarization modes, it is possible to characterize the target more clearly. Quad-Pol SAR system both transmits and receives orthogonal (e.g. horizontal and vertical) polarizations, which creates four polarizations of a single imaging scene. The calibration of Quad-Pol SAR is addressed in this document.

3.21

polarization channel imbalance

bias in the estimation of the scattering matrix element ratio between coincident pixels from two coherent data channels

Note 1 to entry: Polarization channel imbalance includes the amplitude imbalance and phase imbalance.

3.22

pulse repetition frequency

number of times the system (e.g. LIDAR) emits pulses over a given time period, usually stated in kilohertz (kHz)

[SOURCE: ISO/TS 19130-2:2014, 4.53]

3.23

radar cross section

measure of the capability of the object to scatter the transmitted radar power

Note 1 to entry: Radar cross section is calculated as

$$\sigma = \lim_{R \to \infty} 4\pi R^2 \frac{|E_\mathrm{s}|^2}{|E_\mathrm{i}|^2}$$

where

σ is the radar cross section;

E_i is the electric-field strength of the incident wave;

E_s is the electric-field strength of the scattered wave at the radar with a distance R away from the target.

Note 2 to entry: Radar cross section has the dimensions of area, with the unit of square metres. Usually, it is expressed in the form of a logarithm with the unit of dBsm as follows:

$$\sigma_\mathrm{dBsm} = 10 \log_{10} \sigma$$

3.24

range

<SAR> distance between the antenna and a distant object, synonymous with slant range

[SOURCE: ISO/TS 19130-2:2014, 4.54]

3.25

range bin

<SAR> group of radar returns that all have the same range

[SOURCE: ISO/TS 19130:2010, 4.69]

3.26

range direction

slant range direction

<SAR> direction of the *range vector*

[SOURCE: ISO/TS 19130:2010, 4.70]

3.27

range resolution

spatial *resolution* in the range *direction*

Note 1 to entry: For a SAR *sensor*, it is usually measured in terms of the impulse response of the sensor and processing system. It is a function of the bandwidth of the pulse.

Note 2 to entry: 3 dB width of the impulse response is the normal value of measurements.

[SOURCE: ISO/TS 19130:2010, 4.71 — modified: Added Note 2 to entry.]

3.28

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]

3.29

resolution (of 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 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: Added Notes 1, 2 and 3 to entry.]

3.30

scattering matrix

matrix characterizing the scattering process at the target of interest for polarimetric SAR

Note 1 to entry: Scattering matrix is defined by

$$\begin{pmatrix} E_H^s \\ E_V^s \end{pmatrix} = \frac{e^{jkR}}{R} \begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix} \begin{pmatrix} E_H^i \\ E_V^i \end{pmatrix}$$

where

$\begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix}$ is the scattering matrix;

$\begin{pmatrix} E_H^i \\ E_V^i \end{pmatrix}$	is the electronic field vector of the wave incident on the scatterer;
$\begin{pmatrix} E_H^s \\ E_V^s \end{pmatrix}$	is the electronic field vector of the scattered wave;
k	is the wavenumber of the illuminating wave;
R	is the distance between the target and the radar antenna.

3.31
sensor

element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a *quantity* 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 EXAMPLE and NOTE were replaced by Note 1 to entry.]

3.32
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: 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 and reference standards, contribute to the dispersion.

Note 4 to entry: When the quality of accuracy or precision 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 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 modified: Added Notes 1, 2, 3, 5, 6, 7 and 8 to entry.]

3.33

validation

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

Note 1 to entry: In this document, 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 Symbols, abbreviated terms and conventions

In this document, conceptual schemas are presented in the Unified Modelling Language (UML). ISO 19103 conceptual schema language presents the specific profile of UML used here.

4.1 Symbols

A	area of the ground resolution cell
B	length of the interferometric baseline vector
f_d	doppler centroid frequency
f_s	sampling frequency
f_1	amplitude and phase imbalance between the H and V channels on receive
f_2	amplitude and phase imbalance between the H and V channels on transmit
G_p	imaging processor gain
G_r	gain in the radar receiver
G_t^A	transmit antenna gain in the maximum-gain direction
G_r^A	receive antenna gain in the maximum-gain direction
$g_\mathrm{r}^\mathrm{A}(\theta)$	receive antenna elevation pattern which is normalized to unit gain in the maximum-gain direction
$g_\mathrm{t}^\mathrm{A}(\theta)$	transmit antenna elevation pattern which is normalized to unit gain in the maximum-gain direction
H	height of the antenna relative to the reference plane
h	height of the target relative to the reference plane
K_c	calibration coefficient
K_s	overall radar system gain
L_a	atmospheric propagation attenuation loss
L_s	system loss

$\boldsymbol{N}$	matrix characterizes the additive noise term of PolSAR sensor
P_{I}	image pixel power
P_{n}	additive noise power
P_{t}	peak transmitted power
PRF	pulse repetition frequency
p	InSAR collection mode sign, $p = 1$ for standard mode and $p = 2$ for ping-pong mode
R	range from the antenna phase centre to the target
$\boldsymbol{R}$	matrix characterizes the radar receive system of PolSAR sensor
R_{e}	radius of earth at the equator
R_{p}	polar radius of earth
$\boldsymbol{S}$	ideal scattering matrix
$\boldsymbol{T}$	matrix characterizes the radar transmit system of PolSAR sensor
t_{i}	azimuth imaging time
t_0	azimuth imaging start time
$\boldsymbol{Y}$	measured scattering matrix
α	angle the interferometric baseline makes with respect to a reference horizontal plane
δ_1	cross-talk from H channel to V channel on receive
δ_2	cross-talk from V channel to H channel on receive
δ_3	cross-talk from H channel to V channel on transmit
δ_4	cross-talk from V channel to H channel on transmit
θ	look angle
λ	radar wavelength
σ	radar cross section
σ^0	scattering coefficient
τ_0	time delay from radar to the first range sample
φ	interferometric phase
$\vec{S}$	antenna phase centre position vector
$\vec{T}$	target position vector
$\vec{V}$	antenna phase centre velocity vector