Terms and definitions applicable to the quality assurance of Essential Climate Variable data records

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Executive Summary

This document contains a selection of standard terms and definitions relevant to the quality assurance of Essential Climate Variable (ECVs) data records. It reproduces appropriate terms and definitions published by normalization bodies, mainly by BIPM/JCGM/ISO in their International Vocabulary of Metrology (VIM) [RD18] and Guide to the Expression of Uncertainties (GUM) [RD4]. It also reproduces selected terms and definitions related to the quality assurance and validation of Earth Observation (EO) data, available publicly on the ISO website and on the Cal/Val portal of the Committee on Earth Observation Satellites (CEOS) [RD2]. Several of those terms have been recommended by CEOS in the GEO-CEOS Quality Assurance framework for Earth Observation (QA4EO) [RD17] and, as such, are applicable to virtually all Copernicus data sets of EO origin. Terms and definitions are expected to evolve as normalization organisations regularly update their standards.

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1. Terms and definitions

TERM	DEFINITION	SOURCE
accuracy	closeness of agreement between a measured quantity value and a true quantity value of a measurand. Note that it is not a quantity and it is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.	VIM/ISO:99 [RD18], GUM [RD4]
area (volume) of representativeness	the area (volume) in which the concentration does not differ from the concentration at the station by more than a specific range	Larssen [RD12]
audit	systematic, independent and document process for obtaining objective evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled	ISO:9000 [RD7]
bias	(1) systematic error of indication of a measuring system (2) estimate of a systematic measurement error (3) estimate of a systematic forecast error	(1) VIM/ISO:99 [RD18] (2) VIM/ISO:99 [RD18] (3) MACC-II [RD13]
calibration	(1) the process of quantitatively defining the system responses to known, controlled signal inputs (2) operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication	(1) CEOS/ISO:19159 [RD10] (2) VIM/ISO:99 [RD18]
climate data record (CDR)	a time series of measurements of sufficient length, consistency and continuity to determine climate variability and change	NOAA [RD16]

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correction	compensation for an estimated systematic effect. Note: The compensation can take different forms, such as an addend or a factor, or can be deduced from a table.	VIM/ISO:99 [RD18]
(measurement) covariance matrix	symmetric positive semi-definite matrix of dimension N × N associated with an estimate of a real vector quantity of dimension N × 1, containing on its diagonal the squares of the standard uncertainties associated with the respective components of the estimate of the quantity, and, in its off-diagonal positions, the covariances associated with pairs of components of that estimate	GUM S2 [RD6]
coverage probability	probability that the set of true quantity values of a measurand is contained within a specified coverage interval	VIM/ISO:99 [RD18]
dead band (or neutral zone)	maximum interval through which a value of a quantity being measured can be changed in both directions without producing a detectable change in the corresponding indication	VIM/ISO:99 [RD18]
detection limit	measured quantity value, obtained by a given measurement procedure, for which the probability of falsely claiming the absence of a component is β, given a probability α of falsely claiming its presence	VIM/ISO:99 [RD18]
error	(1) measured quantity value minus a reference quantity value (2) difference of quantity value obtained by measurement and true value of the measurand (3) difference of forecast value and a, estimate of the true value Note: (1) and (2) refer to measurement error, while (3) refers to a forecast error	(1) VIM/ISO:99 [RD18] (2) CEOS/ISO:19159 [RD10] (3) MACC-II [RD13]
indication	quantity value provided by a measuring instrument or a measuring system	VIM/ISO:99 [RD18]
fiducial	used as a fixed standard of reference for comparison or measurement (fiducial point)	WordNet [RD20]

fiducial mark	index mark on a test system that allows automatic geometric identification and orientation detection of an object using imaging systems	ISO:19262 [RD11]
fiducial reference measurement	the suite of independent ground measurements that deliver, for a satellite mission, and to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission	Donlon and Zibordi [RD21]
field-of-regard	an area of the object space scanned by the field-of-view of a scanning sensor	NIST [RD15]
field-of-view	the solid angle from which the detector receives radiation	NIST [RD15]
footprint	the area of a target encircled by the field-of-view of a detector of radiation, or irradiated by an active system	NIST [RD15]
geometrical resolution	ability of a sensor system to record signals separately from neighboring object structures	DIN 18716-3 [RD3]
ground sampling distance (GSD)	linear distance between pixel centres on the ground	CEOS/ISO:19159 [RD10]
influence quantity	quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result	VIM/ISO:99 [RD18]
in situ measurement	(1) a direct measurement of the measurand in its original place (2) any sub-orbital measurement of the measurand	(1) CEOS/ISO:19159 [RD10] (2) GEOSS
instantaneous field of view (IFOV)	opening angle corresponding to one detector element	ISO:19130 [RD9]
instrumental drift	continuous or incremental change over time in indication, due to changes in metrological properties of a measuring instrument. Note that instrumental drift is related neither to a change in a quantity being measured nor to a change of any recognized influence quantity.	VIM/ISO:99 [RD18]

Level 0 data	reconstructed, unprocessed instrument and payload data at full resolution, with any and all measurement and communications artifacts removed	CEOS [RD2]
Level 1a data	reconstructed, unprocessed data at full resolution, time referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and geo-referencing parameters (e.g., ephemeris) computed and appended but not applied to the Level 0 data	CEOS [RD2]
Level 1b data	calibrated, geo-located Earth reflectance and radiance spectra in all spectral bands; solar irradiance data, annotation data and references to used calibration data	CEOS [RD2]
Level 2 data	geophysical measurand at the same resolution and geolocation as the Level 1 source data from which it is derived	CEOS [RD2]
Level 3 data	data or retrieved geophysical parameters (i.e. derived from Level 1 or 2 data products) mapped on uniform space-time grid scales, usually with some completeness and consistency. Such re-sampling may include averaging, compositing, kriging, use of Kalman filters…	CEOS [RD2]
Level 4 data	model output or results from analyses of lower level data, i.e., parameters that are not directly measured by the instruments, but are derived from these measurements	CEOS [RD2]
measurand	quantity intended to be measured	VIM/ISO:99 [RD18]
metadata	data about the data; parameters that describe, characterise, and/or index the data	WMO [RD19]
monitoring	(1) systematic evaluation over time of some quantity (2) by extension, evaluation over time of the performance of a system, of the occurrence of an event etc.	(1) NIST [RD15] (2) MACC-II [RD13]
point-to-area (point-to-volume) representativeness	the probability that a point measurement lies within a specific range of area-average (volume-average) concentration value	Nappo [RD14]

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positional accuracy	closeness of coordinate value to the true or accepted value in a specified reference system	ISO:19116 [RD8]
precision	(1) measure of the repeatability of a set of measurements. Note that precision is usually expressed as a statistical value based upon a set of repeated measurements such as the standard deviation from the sample mean (2) closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions	(1) ISO:19116 [RD8] (2) VIM/ISO:99 [RD18]
procedure	specified way to carry out an activity or a process	ISO:9000 [RD7]
process	set of interrelated or interacting activities that use inputs to deliver an intended result	ISO:9000 [RD7]
process validation	establishing documented evidence of a high degree of assurance that a specific process will consistently produce a product meeting its pre-determined specifications and quality characteristics	CDRH [RD1]
product	output of an organization that can be produced without any transaction taking place between the organization and the customer	ISO:9000 [RD7]
quality	the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs	ISO:9000 [RD7]
quality assessment	term referring to the derivation of quality indicators providing sufficient information to assess whether quality requirements are fulfilled	CEOS [RD2]
quality assurance (QA)	part of quality management focused on providing confidence that quality requirements will be fulfilled; it is different from quality assessment and from quality control	CEOS/ISO:19159 [RD10], ISO:9000 [RD7]
quality control (QC)	(1) QC refers to the activities undertaken to check and optimise accuracy and precision of the data after its collection (2) part of quality management focused on fulfilling quality requirements	(1) CEOS/ISO:19159 [RD10] (2) ISO:9000 [RD7]

quality indicator (QI)	a means of providing a user of data or derived product with sufficient information to assess its suitability for a particular application. This information should be based on a quantitative assessment of its traceability to an agreed reference or measurement standard (ideally SI), but can be presented as a numeric or a text descriptor, provided the quantitative linkage is defined.	QA4EO [RD17]
radiometric calibration	a determination of radiometric instrument performance in the spatial, spectral, and temporal domains in a series of measurements, in which its output is related to the true value of the measured radiometric quantity	NIST [RD15]
random error	(1) component of measurement error that in replicate measurements varies in an unpredictable manner; note that random measurement error equals measurement error minus systematic measurement error. Note: Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance. (2) component of forecast error that varies in an unpredictable manner	(1) VIM/ISO:99 [RD18] (2) MACC-II [RD13]
relative standard uncertainty	standard measurement uncertainty divided by the absolute value of the measured quantity value	VIM/ISO:99 [RD18]
repeatability	measurement precision under set of conditions including the same measurement procedure, same operator, same measuring system, same operating conditions and same location, and replicated measurements over a short period of time	VIM/ISO:99 [RD18]
representativeness	the extent to which a set of measurements taken in a given space-time domain reflect the actual conditions in the same or different space-time domain taken on a scale appropriate for a specific application	Nappo [RD14]

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reproducibility	measurement precision under a set of conditions including different locations, operators, and measuring systems	VIM/ISO:99 [RD18]
resolution	(1) smallest change in a quantity being measured that causes a perceptible change in the corresponding indication (2) the least angular/linear/temporal/spectral distance between two identical point sources of radiation that can be distinguished according to a given criterion (3) the least vertical/geographical/temporal distance between two identical atmospheric features that can be distinguished in a gridded numerical product or in time series of measurements; resolution is equal to or coarser than vertical/geographical/temporal sampling of the grid or the measurement time series	(1) VIM/ISO:99 [RD18] (2) NIST [RD15] (3) MACC-II [RD13]
sensitivity of a measuring system	quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured. Note: sensitivity can depend on the value of the quantity being measured. The change considered in a value of a quantity being measured must be large compared with the resolution.	VIM/ISO:99 [RD18]
service	output of an organization with at least one activity necessarily performed between the organization and the customer	ISO:9000 [RD7]
stability	Property of a measuring instrument, whereby its metrological properties remain constant in time	VIM/ISO:99 [RD18]
standard uncertainty	measurement uncertainty expressed as a standard deviation	VIM/ISO:99 [RD18]

systematic error	component of measurement error that in replicate measurements remains constant or varies in a predictable manner Note that systematic measurement error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement error. (Note from GUM [RD4], 3.2.3): It is assumed that, after correction, the expectation or expected value of the error arising from a systematic effect is zero. (Note from GUM [RD4], 3.3.1): The result of a measurement after correction for recognized systematic effects is still only an estimate of the value of the measurand because of the uncertainty arising from random effects and from imperfect correction of the result for systematic effects.	VIM/ISO:99 [RD18]
system	set of interrelated or interacting elements	ISO:9000 [RD7]
traceability	(1) (*metrological traceability*) property of a measurement result relating the result to a stated metrological reference (free definition and not necessarily SI) through an unbroken chain of calibrations of a measuring system or comparisons, each contributing to the stated measurement uncertainty (2) ability to trace the history, application or location of an object, a product or a service	(1) VIM/ISO:99 [RD18] (2) ISO:9000 [RD7]
traceability chain	sequence of measurement standards and calibrations that is used to relate a measurement result to a reference	VIM/ISO:99 [RD18]
uncertainty	non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used	VIM/ISO:99 [RD18]
uncertainty budget	statement of a measurement uncertainty, of the components of that measurement uncertainty, and of their calculation and combination.	VIM/ISO:99 [RD18]

uncertainty of measurement method	uncertainty associated with the method of measurement, as there can be other methods, some of them as yet unknown or in some way impractical, that would give systematically different results of apparently equal validity.	GUM [RD4], section F.2.5
validation	(1) the process of assessing, by independent means, the quality of the data products derived from the system outputs (2) verification, where the specified requirements are adequate for an intended use (3) confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled (4) the process of assessing, by independent means, the degree of correspondence between the value of the radiometric quantity derived from the output signal of a calibrated radiometric device and the actual value of this quantity. (5) confirmation by examination and provision of objective evidence that specifications conform to user needs and intended uses, and that the particular requirements implemented through software can be consistently fulfilled	(1) CEOS/ISO:19159 [RD10] (2) VIM/ISO:99 [RD18] (3) ISO:9000 [RD7] (4) NIST [RD15] (5) CDRH [RD1]
verification	(1) provision of objective evidence that a given item fulfils specified requirements; note that, when applicable, measurement uncertainty should be taken into consideration. (2) confirmation, through the provision of objective evidence, that specified requirements have been fulfilled (3) the provision of objective evidence that the design outputs of a particular phase of the software development life cycle meet all of the specified requirements for that phase	(1) VIM/ISO:99 [RD18] (2) ISO:9000 [RD7] (3) CDRH [RD1]
vicarious calibration	post-launch calibration of sensors that make use of natural or artificial sites on the surface of the Earth	CEOS/ISO:19159 [RD10]

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2.   Reference documents

[RD1]   CDRH

Center for Devices and Radiological Health (CDRH), General Principles of Software Validation; Final Guidance for Industry and FDA Staff, CBER CDRH/OC Doc. N. 938, January 11, 2002. Publicly available via http://www.fda.gov/RegulatoryInformation/Guidances/ucm085281.htm

[RD2]   CEOS

CEOS Committee on Earth Observation Satellites (CEOS): Terms and Definitions and other documents and resources publicly available on http://calvalportal.ceos.org/

[RD3]   DIN 18716-3

DIN 18716-3: 1997-07, Photogrammetry and remote sensing - Part 3: Remote sensing terms

[RD4]   GUM

Joint Committee for Guides in Metrology (JCGM/WG 1) 100:2008, Evaluation of measurement data – Guide to the expression of uncertainty in a measurement (GUM), ISO/IEC Guide 98-3:2008, http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf

[RD5]   GUM S1

Joint Committee for Guides in Metrology (JCGM/WG 1) 101:2008, Evaluation of measurement data - Supplement 1 to the "Guide to the expression of uncertainty in measurement" - Propagation of distributions using a Monte Carlo method, ISO/IEC Guide 98-3/Suppl.1:2008, http://www.bipm.org/utils/common/documents/jcgm/JCGM_101_2008_E.pdf

[RD6]   GUM S2

Joint Committee for Guides in Metrology (JCGM/WG 1) 102:2011, Evaluation of measurement data - Supplement 2 to the "Guide to the expression of uncertainty in measurement" - Extension to any number of output quantities, ISO/IEC Guide 98-3:2008/Suppl.2:2011, http://www.bipm.org/utils/common/documents/jcgm/JCGM_102_2011_E.pdf

[RD7]   ISO:9000

ISO 9000:2015(en), Quality management systems - Fundamentals and vocabulary

[RD8]   ISO:19116

ISO 19116:2004(en), Geographic information - Positioning services

[RD9]   ISO:19130

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

[RD10] ISO:19159

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

[RD11] ISO:19262

ISO:19262:2015(en), Photography — Archiving Systems — Vocabulary

[RD12] Larssen

Larssen, S., R. Sluyter, and C. Helmis, Criteria for EUROAIRNET – The EEA Air Quality Monitoring and Information Network, 1999, http://www.eea.europa.eu/publications/TEC12

[RD13] MACC-II

Lambert, J.-C., MACC II Service Validation Protocol, EC FP7 MACC-II Deliverable D153.1, May 2013, http://www.gmes-atmosphere.eu/documents/maccii/deliverables/man/MACCII_MAN_DEL_D_153.1_20130528_Lambert_V2.pdf

[RD14] Nappo

Nappo, C.J., Caneill J.Y., Furman R.W., Gifford F.A., Kaimal J.C., Kramer M.L., Lockhart T.J., Pendergast M.M, Pielke R.A., Randerson D., Shreffler J.H., and Wyngaard J.C., The Workshop on the Representativeness of Meteorological Observations, June 1981, Boulder, CO, Bull. Am. Meteorol. Soc. 63, 761-764, 1982.

[RD15] NIST

Prokhorov, A. V., R. U. Datla, V. P. Zakharenkov, V. Privalsky, T. W. Humpherys, and V. I. Sapritsky, Spaceborne Optoelectronic Sensors and their Radiometric Calibration. Terms and Definitions. Part 1. Calibration Techniques, Ed. by A. C. Parr and L. K. Issaev, NIST Technical Note NISTIR 7203, March 2005

[RD16] NOAA

Climate Data Records from Environmental Satellites: Interim Report, Committee on Climate Data Records from NOAA Operational Satellites; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies; National Research Council (2004), DOI: 10.17226/10944

[RD17] QA4EO

QA4EO – A Quality Assurance framework for Earth Observation, established by the CEOS. It consists of ten distinct key guidelines linked through an overarching document (the QA4EO Principles) and more community-specific QA4EO procedures, all available on http://qa4eo.org/documentation.html A short QA4EO "user" guide has been produced to provide background into QA4EO and how one would start implementing it (http://qa4eo.org/docs/QA4EO_guide.pdf)

[RD18] VIM/ISO:99

Joint Committee for Guides in Metrology (JCGM/WG 2) 200:2012 & ISO/IEC Guide 99-12:2007, International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM), http://www.bipm.org/en/publications/guides/vim.html

[RD19] WMO

WMO Quality Management Framework (QMF), home page at
http://www.bom.gov.au/wmo/quality_management.shtml

[RD20] WordNet

Princeton University "About WordNet." WordNet. Princeton University. 2010,
http://wordnet.princeton.edu.

[RD21] Donlon and Zibordi

Donlon, C., and G. Zibordi, 2014, In Situ Optical Radiometry, Chapter 3 of Optical Radiometry for Ocean Climate Measurements, Eds. G. Zibordi, C. Donlon and A. Parr; Experimental Methods in the Physical Sciences Series, Vol. 47, Elsevier Inc., ISBN: 978-0-12-417011-7, 17 November 2014