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DSMR-00262 Version 1.0

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Data Stewardship Maturity Report for NCEI Standard Product: World Ocean Database (WOD)

Table 1 Legend				
Level 1	Level 2	Level 3	Level 4	Level 5
Ad Hoc	Minimal	Intermediate	Advanced	Optimal
Little or no management	Limited Management	Defined Management, partially implemented	Well-defined Management, fully implemented	Full Management, audited, measured, controlled

Table 1. Scores for the Nine DSMM Key Components at a Glance		
Preservability - 5	Accessibility - 5	Usability - 4.75
Production Sustainability - 4	Data Quality Assurance - 4.75	Data Quality Control/Monitoring - 4
Data Quality Assessment - 3	Transparency/Traceability - 2.5	Data Integrity - 3

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Cover Image: Data Stewardship Rating Diagram for NCEI Standard Product: World Ocean Database (WOD)

Shades of green are used to represent level 1 through level 5 ratings; denoting Ad Hoc, Minimal, Intermediate, Advanced, and Optimal stages for each of the nine key components, respectively. The dark green level indicates all the practices are completely satisfied. The lighter green levels indicate only some of the practices are satisfied. The lightest green level indicates none of the practices are satisfied.

The stewardship maturity of NCEI data product, NCEI Standard Product: World Ocean Database (WOD), is assessed based on a reference stewardship maturity framework. The current maturity ratings of NCEI Standard Product: World Ocean Database (WOD) are at Level 1 or higher for all nine key components with zero Level 1, one Level 2, two Level 3, four Level 4, and two Level 5 key components.

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The National Environmental Satellite, Data, and Information Service (NESDIS) manages the Nation's civil Earth-observing satellite systems, as well as global national data bases for meteorology, oceanography, geophysics, and solar-terrestrial sciences. From these sources, it develops and disseminates environmental data and information products critical to the protection of life and property, national defense, and the national economy, energy development and distribution, global food supplies, and the development of natural resources.

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Copies of earlier reports may be available by contacting NESDIS Chief of Staff, NOAA/ NESDIS, 1335 East-West Highway, SSMC1, Silver Spring, MD 20910, (301) 713-3578.

ASSESSMENT REVISION HISTORY

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Data Stewardship Maturity Report for NCEI Standard Product: World Ocean Database (WOD)

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Preface

In response to the President's Open Government Initiative and related policies, NOAA has committed to providing improved public access to all of its environmental information, to enable research and commercial innovation through ease of data discovery and use [*Casey*, 2016].

OneStop supports NOAA's efforts by leveraging existing access technologies and infusing specific innovations to provide improved discover, access, and visualization services for NOAA's data. Also, OneStop is viewed by a NESDIS as a pathfinder effort with an initial focus on selected high-priority datasets from NESDIS and other program data meeting OneStop standards, but eventually scalable across NOAA's data. Lastly, OneStop is implementing the USGEO Common Framework for Earth Observation Data and leveraging/supporting the NOAA Big Data Project (BDP) and Big Earth Data Initiative (BEDI) [*Casey*, 2016].

As with any process of improvement planning, agencies need to find out where they are in terms of their compliance to the federal regulations and what they need to do if any areas of non-compliance are identified. To this end, a unified framework would be beneficial for assessing the current stage of stewardship practices applied to individual datasets and for providing a road map that will guide future investments towards enhanced stewardship of environmental datasets. The value and quality of a dataset depends in part on the stewardship practices applied after its development and production. Therefore, a unified framework providing a holistic view of the quality of stewardship practices applied to individual datasets is beneficial to data stewards and users [*Casey*, 2016].

The Data Stewardship Maturity Matrix (DSMM), jointly developed by domain (data management, technology, and science) subject matter experts from NOAA's National Centers for Environmental Information (NCEI) and Cooperative Institute for Climate and Satellites – North Carolina (CICS-NC), provides such a consistent framework [*Peng et al.,* 2016]. The DSMM, leveraging institutional knowledge and community practices and standards, defines a graduated maturity scale for each of nine key components of scientific data stewardship to enable a consistent assessment of the measureable stewardship practices applied to a given data set or product.

The NOAA Data Stewardship Maturity Technical Series captures stewardship maturity assessment results for individual datasets, provides consistent representation and citable documents of those assessments, ensures transparency, and allows better data quality information integration and content-based search and discovery of NOAA data.

NOAA Technical Information Series NESDIS DSMR-00262 Version 1.0

Data Stewardship Maturity Report for NCEI Standard Product: World Ocean Database (WOD)

1. Introduction

1.1 Purpose

The purpose of this document is to describe the results of stewardship maturity assessment for NOAA Climate Data Record for Mean Layer Temperature (Upper Troposphere & Lower Stratosphere from UCAR, Version 2, utilizing the Scientific Data Stewardship Maturity Matrix or DSMM [Peng, et al, 2016]. DSMM defines levels of stewardship maturity stages for Preservability, Accessibility, Usability, Production Sustainability, Data Quality Assurance, Data Quality Control/Monitoring, Data Quality Assessment, Transparency/Traceability, and Data Integrity key components. Each of these components is ranked from 'Ad hoc' to 'Optimal' (see Appendix I). This report is based on evaluation performed by NOAA OneStop metadata specialists working with Subject Matter Experts and utilizing the DSMM template [Peng, 2016].

1.2 Scope

Assessing stewardship maturity - the current state of how datasets are documented, preserved, stewarded, and made accessible publicly, is a critical step towards meeting U.S. federal regulations, organizational requirements, and user needs [Peng et al., 2016]. The goal of this document is to provide consistent and transparent stewardship maturity information to data users and decision-makers.

1.3 Dataset Abstract

The World Ocean Database (WOD) is the world's largest publicly available uniform format quality controlled ocean profile dataset. Ocean profile data are sets of measurements of an ocean variable vs. depth at a single geographic location within a short (minutes to hours) temporal period in some portion of the water column from the surface to the bottom. To be considered a profile for the WOD, there must be more than a single depth/variable pair. Multiple profiles at the same location from the same set of instruments is an oceanographic cast. Ocean variables in the WOD include temperature, salinity, oxygen, nutrients, tracers, and biological variables such as plankton and chlorophyll. Quality control procedures are documented and performed on each cast and the results are included as flags on each measurement. The WOD contains the data on the originally measured depth levels (observed) and also interpolated to standard depth levels to present a more uniform set of iso-surfaces for oceanographic and climate work.

The source of the WOD is more than 20,000 separate archived datasets contributed by institutions, project, government agencies, and individual investigators from the United States and around the world. Each dataset is available in its original form in the National Centers for Environmental Information data archives. All datasets are converted to the same standard format, checked for duplication within the WOD, and assigned quality flags based on objective tests. Additional subjective flags are set upon calculation of ocean climatological mean fields which make up the World Ocean Atlas (WOA) series.

The WOD consists of periodic major releases and quarterly updates to those releases. Each major release is associated with a concurrent release of a WOA release, and contains final quality control flags used in the WOA, which includes manual as well as automated steps. Each quarterly update release includes additional historical and recent data and preliminary quality control. The latest major release was WOD 2018 (WOD18), which includes nearly 16 million oceanographic casts, from the second voyage of Captain Cook (1772) to the modern Argo floats (end of 2017).

The WOD presents data in netCDF ragged array format following the Climate and Forecast (CF) conventions for ease of use mindful of space limitations.

1.4 Document Maintenance

This document is generated and maintained by NOAA's National Centers for Environmental Information. More on policy is available at https://www.ncei.noaa.gov/.

2. Results

The data stewardship maturity assessment information is summarized in Table 1. Each component is displayed along with its corresponding score in a color-coded table.

Table 2. Dataset and Data Stewardship Maturity Assessment Metadata	
Dataset Title	NCEI Standard Product: World Ocean Database (WOD)
Dataset Information URL	https://www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.nodc%3ANCEI-WOD/html#
Data Provider POC (Name; Email; Affiliation)	National Centers for Environmental Information, NESDIS, NOAA, U.S. Department of Commerce301-713-3277 ncei.info@noaa.gov
Dataset POC (Name; Email; Affiliation)	National Centers for Environmental Information, NESDIS, NOAA, U.S. Department of Commerce 301-713-3277 ncei.info@noaa.gov
SMM Version (Document ID and Version Number)	NCDC-CICS-SMM_0001_Rev.1 12/09/2014
SMM POC (Name; E-mail; Affiliation)	Ge Peng, ge.peng@uah.edu, University of Alabama-Huntsville
SMM Template Version (Document ID and Version Numbers)	NCDC-CICS-SMM_0001_Rev.1 v4.0 06/23/2015
SMM Template POC	Ge Peng, ge.peng@uah.edu, University of Alabama-Huntsville
SMM Assessment Version (v<nn>r<mm>, e.g., v01r00)	v01r02
SMM Assessment Date (MM/DD/YYYY)	05/02/2019
SMM Assessment POC (Name; E-mail; Affiliation)	Raisa Ionin, raisa.ionin@noaa.gov, Earth Resources Technology, Inc.
Stewardship Maturity Ratings (each key component) (kc1/kc2/kc3/kc4/kc5/kc6/kc7/kc8/kc9)	5 /5 /4.75 /4 /4.75 /4 /3 /2.5 /3
SMM Original Assessment Date (MM/DD/YYYY)	08/07/2017
SMM Original Assessment POC (Name; E-mail; Affiliation)	Raisa Ionin, raisa.ionin@noaa.gov, Earth Resources Technology, Inc.
SMM Last Modified Date (MM/DD/YYYY)	10/21/2021
SMM Last Modification POC (Name; E-mail; Affiliation)	Lori Hager, lori.hager@noaa.gov, CASE Consultants International
SMM Modified Date (MM/DD/YYYY)	05/02/2019
SMM Modification POC (Name; E-mail; Affiliation)	Raisa Ionin, raisa.ionin@noaa.gov, Earth Resources Technology, Inc.

Table 3. Stewardship Maturity Levels and Detailed Justifications for Each of Nine DSMM Key Components for the Dataset.	
DSMM Key Component	Stewardship Maturity Rating, Justification, and Comments
Preservability	Level 5 ▪ Archived by NCEI, which is NOAA designated repository. NOAA is compliant to NARA standards ▪ Metadata following ISO 19115-2 standards. ▪ Compliant to OIAS RM ▪ Plans to update metadata to ISO 19115-1 at a later date ▪ Using NCEI Silver Spring Archive Management System, AMS. Comments:
Accessibility	Level 5 ▪ Collection level searchable online ▪ Granule level is searchable online ▪ Additional search options available from collection level site ▪ Direct file download available from ▪ THREDDS: https://www.ncei.noaa.gov/thredds-ocean/catalog/ncei/wod/catalog.html ▪ HTTP: https://data.nodc.noaa.gov/ncei/wod ▪ FTP: ftp://ftp-oceans.ncei.noaa.gov/pub/data.nodc/ncei/wod/ ▪ Dissemination reports for World Ocean Database are available publicly: https://www.nodc.noaa.gov/webstats/wod/index.html ▪ Future technology changes are planned, the data is NetCDF compliant. ▪ World Ocean Database Search and Select option is available: https://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html ▪ Access to Data sorted geographically: https://www.nodc.noaa.gov/OC5/WOD/datageo.html ▪ Access to World Ocean Database Time Sorted Data https://www.nodc.noaa.gov/cgi-bin/OC5/WOD/getyearlydata.pl?Go=TimeSorted ▪ WOD secchi disk and water color data and format description https://www.nodc.noaa.gov/OC5/WOD/secchi-data-format.html Comments: * When a link to the dissemination reports becomes publicly available, then score for the Accessibility category will be 5 Project description page: https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html World Ocean Atalas-13 landing page: https://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0114815 World Ocean Database 2013 https://data.nodc.noaa.gov/cgi-bin/iso?id=granule:NCEI-WOD.0117075 World Ocean Database 2013 updates through 2016-12-31 https://data.nodc.noaa.gov/cgi-bin/iso?id=granule:NCEI-WOD.0162576

Table 3. Stewardship Maturity Levels and Detailed Justifications for Each of Nine DSMM Key Components for the Dataset.	
DSMM Key Component	Stewardship Maturity Rating, Justification, and Comments
Usability	Level 4.75 ▪ The format is interoperable: NetCDF; nc for granules ▪ Product documentation is available online: ▪ User Manual [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ Introduction/Description document [Boyer, 2013] is available online https://data.nodc.noaa.gov/woa/WOD/DOC/wod_intro.pdf ▪ WOD Tutorial [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ Algorithm information is present in Introduction/Description document [Boyer, 2013] is available online https://data.nodc.noaa.gov/woa/WOD/DOC/wod_intro.pdf ▪ Enhanced online capability: World Ocean Database collection has enhanced online capability (e.g., visualization, multiple data formats): TDS, DAP, LAS (*data servers maintained at NCEI); access from metadata main landing page. ▪ Data visualization: available; data can be imported and made available by an outside organization: ▪ The latest version and software requirement can be obtained from the Ocean Data View (ODV) web site http://odv.awi.de/ ▪ Community metrics of data characterization (regional, cell, online are met. Any info about spatial data is in NetCDF and external documentation. Temporal span is covered in NetCDFs as well. ▪ No external ranking. Data set is measured on how much the data set is being cited. Comments:
Production Sustainability	Level 4 ▪ Over 20-years institutional support for WOD, demonstrated by the continuous support and updates. Updates to the product are released approximately every 3 months. ▪ The dataset is archived and available publicly and considered as high scientific quality by NCEI and high impact dataset (over 100 citations in the literature). ▪ Product improvement is in place: https://www.nodc.noaa.gov/OC5/indprod.html ▪ https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html ▪ The current version for WOD contains updates from May 2017. ▪ https://www.nodc.noaa.gov/OC5/WOD/wod_updates.html ▪ WOD started as early as 1994 and gone through a number of releases. https://www.ncei.noaa.gov/products/ocean-climate-laboratory Comments: List of citations is available internally at the NCEI.

Table 3. Stewardship Maturity Levels and Detailed Justifications for Each of Nine DSMM Key Components for the Dataset.	
DSMM Key Component	Stewardship Maturity Rating, Justification, and Comments
Data Quality Assurance	Level 4.75 ▪ DQA procedure well documented, fully implemented and available online with master reference data based on the publications: ▪ [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ File level quality flags exist which can be considered Limited Data Quality Assurance Metadata. https://data.nodc.noaa.gov/woa/WOD/CODES/PDF/DefinitionQualityFlags.pdf https://data.nodc.noaa.gov/woa/WOD/CODES/TXT/Definition_of_Quality_Flags.txt ▪ Conforming to community quality metadata & standards – No <gmd:DQ_DataQuality> tags in the metadata file, but quality metadata exists in pdf and txt formats: ▪ https://data.nodc.noaa.gov/woa/WOD/CODES/TXT/Definition_of_Quality_Flags.txt ▪ https://data.nodc.noaa.gov/woa/WOD/CODES/PDF/DefinitionQualityFlags.pdf ▪ External review – The data set is being reviewed externally by IQUOD, International Quality Controlled Ocean Database (national climate data publishing groups). Reviews are informal http://www.iquod.org/ Comments: World Ocean Database and World Ocean Atlas are part of IQUOD, International Quality Controlled Ocean Database http://www.iquod.org/documents.html *IQUOD – international effort to QC data. They produce new and QC flags.
Data Quality Control/ Monitoring	Level 4 ▪ Anomaly detection procedure well-documented and fully implemented using community metrics, automatic, tracked and reported based on Quality Control sections of World Ocean Database publications: ▪ [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ [Boyer, 2013] is available online https://data.nodc.noaa.gov/woa/WOD/DOC/wod_intro.pdf ▪ [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ Qualifies for Limited Quality Monitoring Metadata, contains Complete Listing of Comments of the WOD13 Updates : https://www.nodc.noaa.gov/OC5/WOD/comch13.html Comments: World Ocean Database and World Ocean Atlas are part of IQUOD, International Quality Controlled Ocean Database http://www.iquod.org/documents.html *IQUOD – international effort to QC data. They produce new and QC flags.Conforming to community quality metadata & standards – No <gmd:DQ_DataQuality> tags in the metadata file, but Limited Quality Metadata exists in pdf and txt formats:https://data.nodc.noaa.gov/woa/WOD/CODES/TXT/Definition_of_Quality_Flags.txthttps://data.nodc.noaa.gov/woa/WOD/CODES/PDF/DefinitionQualityFlags.pdf

Table 3. Stewardship Maturity Levels and Detailed Justifications for Each of Nine DSMM Key Components for the Dataset.	
DSMM Key Component	Stewardship Maturity Rating, Justification, and Comments
Data Quality Assessment	Level 2 ▪ Algorithm is available in Introduction/Description document [Boyer, 2013] is available online https://data.nodc.noaa.gov/woa/WOD/DOC/wod_intro.pdf ▪ Research products is assessed. World Ocean Database is cited by 100+ peer-reviewed papers. ▪ Operational product is not assessed: WOD is not an operational product, it is a research product. ▪ The following documents describe how the data gets from archive to World Ocean Database: ▪ User Manual - [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ Introduction/Description document - [Boyer, 2013] is available online https://data.nodc.noaa.gov/woa/WOD/DOC/wod_intro.pdf ▪ WOD Tutorial -[Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html Comments: Additional articles are available: {{Barnes, 1964} Barnes, S. L. (1964), A Technique for Maximizing Details in Numerical Weather Map Analysis, _Journal of Applied Meteorology_, 3(4), 396–409, doi:10.1175/1520-0450(1964)003<0396:atfmdi>2.0.co;2} is available online http://doi.org/10.1175/1520-0450(1964)003<0396:ATFMDI>2.0.CO;2{{Cressman, 1959} Cressman, G. P. (1959), An Operational Objective Analysis System, _Monthly Weather Review_, 87(10), 367–374, doi:10.1175/1520-0493(1959)087<0367:aooas>2.0.co;2} is available online http://doi.org/10.1175/1520-0493(1959)087<0367:AOOAS>2.0.CO;2
Transparency / Traceability	Level 2.5 ▪ Product information and algorithm are available in multiple literature publications, including: ▪ [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ Introduction/Description document - [Boyer, 2013] is available online https://data.nodc.noaa.gov/woa/WOD/DOC/wod_intro.pdf ▪ WOD Tutorial - [Johnson, 2013] is available online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html ▪ No DOI is assigned ▪ OID or Unique Object Identifier is assigned NCEI-WOD ▪ Dataset is not under Configuration management Comments: WOD-13 set has DOI https://data.nodc.noaa.gov/cgi-bin/iso?id=granule:NCEI-WOD.0117075

Table 3. Stewardship Maturity Levels and Detailed Justifications for Each of Nine DSMM Key Components for the Dataset.	
DSMM Key Component	Stewardship Maturity Rating, Justification, and Comments
Data Integrity	Level 3 ▪ Data archive integrity verifiable - Checksum technology is available, each WOD package is accompanied by a manifest in XML format containing hash digests generated using various algorithms, including MD5, SHA-1, SHA-384, etc. That includes checksums (. md5) for every file package. ▪ https://www.nodc.noaa.gov/archive/arc0001/0000137/0000137.1.1.xml ▪ https://www.nodc.noaa.gov/archive/arc0108/0162576/0162576.1.1.xml ▪ Data authenticity is verifiable (since data can be downloaded via HTTPS and HTTPS uses certificates to prove site authenticity) ▪ NCEI-MD does not provide digital signatures for data dissemination Comments:

3. Acknowledgment

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The draft of this data stewardship maturity report is systematically generated by a tool created by Kieran Hodnett and populated with the stewardship maturity assessment done by the author(s) of this report. The tool was developed based on a Word template created collaboratively by Robert Partee II, Raisa Ionin, Paul Lemieux III, Ge Peng, Don Collins, and Sonny Zinn with helpful input from the NOAA Central Library and the NCEI Communication Team.

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Johnson, D.R., H.E. Garcia, and T.P. Boyer (2013), World Ocean Database 2013 Tutorial. Sydney Levitus, Ed.; Alexey Mishonov, Technical Ed.; _NODC Internal Report 23_, NOAA Printing Office, Silver Spring, MD, 25 pp, retrieved online http://www.nodc.noaa.gov/OC5/WOD13/docwod13.html (Accessed 9 August 2017)

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Appendix I: The Scientific Data Stewardship Maturity Matrix (DSMM)

Table A1: This matrix (Version: NCDC-CICS-SMM-0001-Rev.1. 12/09/2014) describes the criterion used to evaluate data stewardship maturity for each of the nine DSMM key components [*Peng et al.*, 2015].

DSMM Component	**Level 1** ***Ad hoc*** Little or no management	**Level 2** ***Minimal*** Limited management	**Level 3** ***Intermediate*** Defined management, partially implemented	**Level 4** ***Advanced*** Well-defined management, fully implemented	**Level 5** ***Optimal*** Full management, audited, measured, controlled
Preservability *(The state of being preservable)*	Any storage location Data only	Non-designated repository Redundancy Limited archiving metadata	Designated archive Redundancy Community-standard archiving metadata Conforming to limited archiving standards	Level 3 + Conforming to community archiving standards	Level 4 + Archiving process performance controlled, measured, and audited Future archiving standard changes planned
Accessibility *(The state of being searchable and accessible publicly)*	Not publically available person-to-person	Publically available direct file download (e.g., via anonymous FTP server) Collection or dataset level searchable online	Level 2 + Non-standard data service Limited data server performance Granule/file level searchable Limited search metrics	Level 3 + Community-standard data service Enhanced data server performance Conforming to community search metrics Dissemination report metrics defined and implemented internally	Level 4 + Dissemination reports available online Future technology and standard changes planned

Usability *(The state of being easy to use)*	Extensive product-specific knowledge required No documentation online	Non-standard data format Limited documentation (e.g., user's guide online)	Community standard-based interoperable format & metadata Documentation (e.g. source code, product algorithm document, processing or/and data flow diagram) online	Level 3 + Basic capability (e.g., subsetting, aggregating) & data characterization overall/global, e.g., climatology, error estimates) available online	Level 4 + Enhanced online capability (e.g., visualization, multiple data formats) Community metrics of data characterization (regional/cell) online External ranking
Production Sustainability *(The state of data production being sustainable and extendable)*	Ad Hoc or Not applicable To obligation or deliverable requirement	Short-term Individual PI's commitment (grant obligations)	Medium-term Institutional commitment (contractual deliverables with specs and schedule defined)	Long-term Institutional commitment Product improvement process in place	Level 4 + National or international commitment Changes for echnology planned
Data Quality Assurance *(The state of data quality being assured)*	Data quality assurance (DQA) procedure unknown or none	Ad Hoc and random QA procedure not defined and documented	DQA procedure defined and documented and partially implemented	DQA procedure well documented, fully implemented and available online with master reference data Limited data quality assurance metadata	Level 4 + DQA procedure monitored and reported Conforming to community quality metadata & standards External review

Data Quality Control/ Monitoring *The state of data quality being controlled and monitored*	None or Sampling unknown or spotty Analysis unknown or random in time	Sampling and analysis are regular in time and space Limited product-specific metrics defined & implemented	Level 2 + Sampling and analysis are frequent and systematic but not automatic Community metrics defined and partially implemented Procedure documented and available online	Level 3 + Anomaly detection procedure well-documented and fully implemented using community metrics, automatic, tracked and reported Limited quality monitoring metadata	Level 4 + Cross-validation of temporal & spatial characteristics Physical consistency check Conforming to community quality metadata & standards
Data Quality Assessment *(The state of data quality being assessed)*	Algorithm/ method/model Theoretical basis assessed (methods and results online)	Level 1 + Research product assessed (methods and results online)	Level 2 + Operational product assessed (methods and results online)	Level 3 + Quality metadata assessed Limited quality assessment metadata	Level 4 + Assessment performed on a recurring basis Conforming to community quality metadata & standards External ranking
Transparency/ Traceability *(The state of being transparent, trackable, and traceable)*	Limited product information available Person-to-person	Product information available in literature	Algorithm Theoretical Basis Document (ATBD) & source code online Dataset configuration managed (CM) Unique Object Identifier (OID) assigned (dataset, documentation, source code) Data citation tracked (e.g., utilizing Digital Object Identifier	Level 3 + Operational Algorithm Description (OAD) online, OID assigned, and under CM	Level 4 + System information online Complete data provenance online

Data Integrity *(The state of data integrity being verifiable)*	Unknown or no data ingest integrity check	Data ingest integrity verifiable (e.g, checksum technology)	(DOI) system) Level 2 + Data archive integrity verifiable	Level 3 + Data access integrity verifiable Conforming to community data integrity technology standard	Level 4 + Data authenticity verifiable (e.g., data signature technology) Performance of data integrity check monitored and reported