4.1 THE EVOLVING RESEARCH TO OPERATIONS PROCESS FOR NOAA'S SATELLITE CLIMATE DATA RECORDS

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ABSTRACT

In support of NOAA's mandate to provide climate products and services to the Nation, the National Climatic Data Center (NCDC) recently initiated the satellite Climate Data Record Program (CDRP, hereafter referred to as the "Program"). The Program develops and sustains objective climate information products derived from satellite data that NOAA has collected over the past 30+ years. These are the longest sets of continuous global measurements in existance. Data from other environmental satellite programs, including those in NASA, the Department of Defense, and foreign space agencies, are also used. NOAA is now applying advanced analysis techniques -- which have improved remarkably over the last decade -- to these data. This process will unravel the underlying climate trend and variability information and return new value from the historic data. However, the transition of complex data processing chains, voluminous data products and documentation into an operational context involves many challenges. In this article, we focus on the Program's process for research-to-operations evolution. Initially, the Program is adopting a two-phase process defined by an Initial Operational Capability and a Full Operational Capability. The principles and procedures for IOC are described.

1. INTRODUCTION

As part of its climate mandate, NOAA has a responsibility to provide the Nation with trustworthy and objective Climate Data Records (CDRs) that meet appropriate standards for public release and informed use (Privette et al., 2008; Privette et al., 2009). The National Research Council (NRC, 2004) defines a Climate Data Record (CDR) as "a time series of measurements of sufficient length, consistency and continuity to determine climate variability and change." Appropriate release standards include CDRs being well-documented, developed through best-practice and transparent processes, reproducible and scientifically defensible.

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To address these challenges, NOAA's Climate Data Record Program (the "Program") has established steps and procedures for the evolution of mature research algorithms into NOAA's operational context. This context includes the archiving, access and stewardship of CDR algorithm source codes, documentation and data products, as well as sustained product generation.

In developing its research-to-operations (R2O) approach, the Program has sought to adopt and adapt guidelines, best practices and lessons-learned from expert bodies, such as the National Academy of Sciences and the Global Climate Observing System (GCOS), as well as other satellite programs including those in NOAA, NASA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). For example, the Program has adapted industry-defined documentation standards used in NOAA's Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite-R (GOES-R) programs. Further, the Program works closely with elements of NASA's Earth Observing System (EOS) to adapt proven processing architectures and software (Saunders et al., 2011). Increasingly, as CDR generation efforts become more commonplace, guidelines promoting inter-program consistency will be offered by the World Meteorological Organization's (WMO's) Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM; WMO, 2009) and other coordination bodies.

The Program's initial R2O procedures have been documented, implemented and successfully demonstrated through the transition of three CDRs to operations in Year 2010. In this article, we outline the R2O procedures defined to date. As these procedures are still undergoing some refinement, readers may wish to consult the Program website: http://www.ncdc.noaa.gov/sds or http://www.ncdc.noaa.gov/cdr for updates.

2. CDR INITIAL AND FINAL CAPABILITIES

The Program has adopted a two-phase development approach – commonly used in the Defense Department programs and elsewhere – to providing full operational capabilities. The first phase, or Initial Operational Capability (IOC), is achieved when a CDR is publicly released in its earliest useful form. The second phase, or Full Operational Capability (FOC), is achieved when a CDR meets all Program requirements for operational generation, archiving, and stewardship.

The IOC is characterized by the application of a quantitative maturity matrix, documentation of algorithm development, archiving and public release of source code and data, and provisions for feedback from the scientific community.

The FOC is characterized by the CDR – including the complete record and supporting data, documentation, source code and stewardship activities -- residing in a NOAA archive. Further, NOAA is responsible for the sustained forward extension of the data record. This sustainment includes ensuring ongoing CDR quality assessment and validation, exercising configuration and version control, and ensuring the timely release of incremental extensions to the time series. Note that the Program anticipates significant algorithm upgrades to occasionally occur as fostered through external research programs. The Program provides an avenue to replace heritage algorithms and data sets with improved versions once they are successfully demonstrated, validated and available.

3. INITIAL CDR RESEARCH TO OPERATIONS OVERVIEW

The process for achieving IOC status is outlined in Table 1. There are six key steps, including assessment, submission, transfer, validation, archival and access. The process is a collaborative effort between algorithm developers and multiple divisions of NCDC.

Table 1. CDR Research-to-Operations Steps to IOC

Phase ⇨					
1) Assessment	2) Submission	3) Transfer	4) Validation	5) Archival	6) Access
CDR Maturity Assessment Key Decision Point	Submission Agreement Documentation of code header information Sample data transfer	Source code transfer Entering of code into configuration control Documents transfer Main data transfer	Validate code archival package Validate supporting documents Validate data	Archive code Archive documents Archive product data Archive ancillary data	Code publicly available Documentation available Data available

Candidate CDRs first undergo a scientific assessment to determine suitability for transition to operations. Essential to this assessment is the Maturity Matrix (Privette et al., 2009). The Maturity Matrix defines six maturity levels for each of the following criteria:

- Sensor Use
- Code Stability
- Metadata and Quality Assurance (QA)
- Documentation
- Validation
- Public Release
- Science and Application

The primary documentation required for IOC is the Algorithm Theoretical Basis Document (ATBD). The ATBD provides the scientific basis of remote sensing retrieval algorithm by detailing the physical theory, mathematical procedures and assumptions. In particular, the ATBD details:

- Observing System Overview
- Algorithm Description
- Test Datasets and Outputs
- Practical Considerations
- Assumptions

After the Program assesses and approves a CDR algorithm for transition to IOC, a final CDR package is submitted to the Program. The package includes fully commented source code as well as all necessary data. The package then undergoes a submission process, highlighted by the completion of a Submission Agreement, to place it into the NOAA archive. This process includes assessing the research algorithm's conformance with security and coding standards. The codes, documentation and data sets are placed under configuration or version control as appropriate. After validation and archival steps are completed, the published CDR code, documentation and data are made available to the public via the Program website.

4. TRANSITIONING TO CDR FINAL CAPABILITY

The initial R2O processes for achieving IOC are an interim step to FOC. At present, the definitions, milestones and characteristics of FOC have not been fully developed. However, as the Program evolves, it will develop the resources and processes to apply and enforce rigorous standards on the operational algorithms, documentation and data sets such that they are more easily and economically used and maintained over their life cycles. The Program will continue dialog with CDR users, expert bodies, and the scientific community in developing its FOC specifications.

5. CONCLUSIONS

NOAA's new satellite Climate Data Record Program (Program) transitioned its first set of CDRs into operations in Year 2010. The transitioning allowed the Program to test, modify and ultimately successfully demonstrate its process for evolving research algorithms and products to IOC. The IOC is the first phase of a two-phase process that culminates in FOC that will be developed in consultation with users, scientists and expert bodies.

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