SEA SURFACE TEMPERATURE
VIRTUAL CONSTELLATION

GHRSST
Group for High Resolution
Sea Surface Temperature

Curation of sensor information, for climate data records from space

15 November 2013

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Document Change Record

Author	Modification	Issue	Rev	Date
CJM	Original	1	1	15 November 2013

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1 Executive Summary

CEOS SIT is requested to task member space agencies with concrete action to ensure long-term curation of satellite sensor information.

This request emerges from the needs of the Virtual Constellation for Sea Surface Temperature to provide and improve climate data records on sustained basis. It may have wider relevance, however, to other essential climate variables/VCs.

The forms of information to be curated are broad, including instrument design, calibration records and in-orbit event logs. Loss of such information will greatly diminish the long-term legacy of satellite missions for climate and Earth System science. It is proven that the stability and accuracy of satellite climate data records can be improved even decades after missions, if such information is available.

Sensor documentation exists in a range of forms, different degrees of accessibility and different degrees of resourcing for preservation. Action is urgent because of loss of "collective memory" for many missions (through retirement, etc), threat of decay of unique paper archives, and loss of capability to read old digital formats.

The forms of sensor information relevant are:

1. Test reports & instrument guides.
2. Radiance calibration.
3. FOV characterization.
4. Design.
5. Cal/val results.
6. Logs.
7. Third party.
8. In situ.

The sensors relevant to the SST VC are listed, and those which should be first priority are also identified. For two examples, an illustrative assessment has been made using an extended traffic-light system (black/red/amber/green) for both "STATUS OF CURATION" and "STATUS OF ACCESS", in each of the above categories of information.

The actions needed are:

- to assess the status of curation and access to sensor information, for a broader range of sensors, starting with the first priority sensors
- for responsible agencies to develop and implement plans to curate and make accessible their sensor information
- thereafter, to monitor progress on curation and access regularly, via the assessment system proposed

2 Introduction

This is to request CEOS SIT to task member space agencies with concrete action with regards to the long-term curation of satellite sensor information.

This topic is raised on behalf of the community represented by the CEOS Virtual Constellation for Sea Surface Temperature, although we consider it likely to be relevant to all VCs concerned with long-term climate applications and services.

In "satellite sensor information" we include all archives relating to:

- instrument specification and design, and platform design
- pre-launch testing including, crucially, all calibration activities
- commissioning phase cal/val activities
- performance monitoring of the sensor in orbit, including all studies to improve calibration in flight after the cal/val period

The importance of this information is that loss of the information will greatly diminish the long-term legacy of the satellite data records for climate and Earth system science.

- Satellite data records provide arguably the richest perspective available on the state of the global environment in our time. We should assume that Earth system science will still be exploiting contemporary satellite data in 100 years' time, just as today we use the measurements of 19th century scientists to understand global environmental change.
- We have also learned that the calibration stability and accuracy of satellite data records can be usefully improved even decades after the measurements were made, if new insight can be applied to adequately documented satellite sensor information. These aspects of data are crucial to their use in quantifying long-term environmental change.

The threats to preservation of this information are:

- Decay and accidental loss of single-copy paper archives
- Non-transfer of digital archives to modern media storage
- Deliberate discarding of information after personnel leave/retire, by successors unaware of its importance and/or uniqueness

Additional problems in relation to satellite sensor information are:

- Archives that are physically preserved, but are inaccessible to the community
- Archives that are physically preserved, but are not indexed or organized such as would allow their practical use
- Non-linkage of information collected by different units (e.g., expert support laboratories and operations teams)

Action to deliberately and systematically address this issue is urgent:

- To minimize the extra complication and expense arising from "loss of collective memory" as experts on past missions retire, etc
- Because paper archives from the early satellite era will deterioriate and come under threat during office relocations, space-saving, etc
- To ensure digital archives on historic media can still be read and reproduced at reasonable cost
- To ensure satellite data records are perceived as transparent, traceable and reliable sources of quantitative observations in the context of emerging climate services

3 Standards of curation and access

The objective is to preserve all ancillary records and information that may assist future generations to interpret, improve and regenerate climate data records (in this case for sea surface temperature).

The range of potentially relevant information is large. Two real world examples: 1. issued calibration reports may omit data (such as black-body PRTs) not used within a particular calibration procedure, but relevant to a retrospective calibration using improved physical modeling of the instrument; 2. the location of a sensor on a platform relative to other components (e.g., solar panels) may affect heating of the instrument by reflected sunlight in certain seasons.

Because of the volume and variety of relevant information, "curation" must include organization (indexing) of the information, as well as long-term, secure preservation. Ideally, from the point of view of climate science, the curation implies information will be

- organized in a structured way, e.g., catalogued accounting for version of information
- securely preserved,
- digitized and made freely searchable and accessible online.

4 Why is so much information useful?

Pre-launch data enable characterization of instrument behavior. Retrospective use of pre-launch data can include detailed analysis with new physical models of the instrument to assess quality of data. Engineering data allow potential construction of (real or virtual) models of sensors including thermal and radiative effects, which can be validated using PRT records, given details of PRT locations, etc.

Official test reports and data books do not always include all details that a later investigator (using a new model of instrument behaviour, for example) can exploit. Therefore, all possible original data/telemetry (all measurements recorded during tests/calibration) and laboratory notes should be preserved (which may involve conversion from out-dated formats).

Event logs during operations are important metadata for changes in performance during a mission, instrument problems, implemented solutions, etc.

Third parties may develop useful ancillary information and data to help improve CDR contents in various ways. (An example is additional timing/geolocation information for early AVHRRs from U. of Miami.) Agencies may be involved in collecting and sharing inflight performance information from calibration and validation activities during the commissioning phase of missions.

5 Categories of information

1. **Test reports & instrument guides.** All official, published reports covering categories 2. to 4. below and other performance tests: calibration reports, technical notes, test reports (e.g., thermal and vibration tests). Instrument guides and manuals.
2. **Radiance calibration.** All recorded (including unpublished) sensor radiance calibration and characterization records (often paper archives).[1]
3. **FOV characterization.** All recorded (including unpublished) sensor geometric/field-of-view characterization records (often paper archives).[2]
4. **Design.** Engineering design drawings and specifications for whole sensor and its integration on platform.
5. **Cal/val results.** Minutes, presentations and reports associated with in-flight cal/val and commissioning phases.
6. **Logs.** Operational event logs throughout mission. These should note anomalies (any non-nominal operation of instrument, platform pointing, etc) at the level of detail required to identify individual orbits/segments affected.
7. **Third party.** Third-party algorithms/auxiliary data for improving data quality (e.g., vicarious calibration results, empirical improvements for geo-location).[3]
8. **In situ.** In situ validation/campaign data specifically funded by or collected for satellite agencies for cal/val.

[1] Included here are the "raw" data as measured and daily laboratory records/books kept during calibration activities. Within this class of information, some may be classified by government, some may be proprietary, and most will be undigitized and unpublished in raw form. Nonetheless, for sensors relevant to climate data record generation, all efforts should be made to obtain and curate such information.

[2] Included here are the "raw" data as measured and recorded and daily laboratory records/books kept during calibration activities. Within this class of information, some may be classified by government, some may be proprietary, and most will be undigitized and unpublished in raw form. Nonetheless, for sensors relevant to climate data record generation, all efforts should be made to obtain and curate such information.

[3] There is no simple means to identify the appropriate range of information here: virtual constellations will need to develop and maintain an appropriate list through an expert group.

6 Sensors for which curation of sensor information is required (for SST VC only)

Table 1 below lists the sensors the SST VC considers should be addressed first, and Table 2 lists all those relevant to the SST CDR.

The coloured symbols present in some rows correspond to the status of curation and access respectively, as explained in section 6. These are an initial assessment done as an example.

Key (see section 6 for details):

Black = worst status
Red = poor status
Amber = intermediate status
Green = satisfactory status

Diamonds = Status of curation
Circles = Status of access

See table in Appendix 1 for Acronyms and more information on corresponding missions.

Sensor	Reps. & guides	Rad Cal	FOV Char	Design	Cal/val results	Logs	3rd Party	In situ
ATSR 1	◆ ○	◆ ○	◆ ○	◆ ○	N/A	◆ ○	◆ ○	N/A
ATSR 2								
AATSR								
SLSTR								
AVHRR-N[4]								
AVHRR-6								
AVHRR-7								
AVHRR-8								
AVHRR-9								
AVHRR-10								
AVHRR-11								
AVHRR-12	◆ ○	◆ ○	◆ ○	◆ ○	◆ ○	◆ ○	◆ ○	N/A
AVHRR-14								
AVHRR-15								
AVHRR-16								
AVHRR-17								
AVHRR-18								
AVHRR-19								
AVHRR-A								
AVHRR-B								
AVHRR-C								
MODIS-T								
MODIS-A								
VIIRS								
AMSR-E								
AMSR-2								

Table 1. Sensors recommended to address first, if phasing of effort is required.

[4] AVHRRs are labeled: TIROS-N AVHRR/1 is "AVHRR-N"; NOAA series AVHRR/2s are "AVHRR-6" to 14 (13 didn't exist); NOAA-series AVHRR/3 are "AVHRR-15" to 19; and Metop-A to C are labeled "AVHRR-A" etc.

Sensor	Rad Cal	FOV Char	Design	Test Reps.	Cal/val results	Logs	3rd Party	In situ
MVIRI 6								
MVIRI 7								
SEVIRI 8								
SEVIRI 9								
SEVIRI 10								
SEVIRI 11								
TMI								
VIRS								
VHRR 2E								
VHRR 3A								
MSMR								
GOES 8								
GOES 9								
GOES 10								
GOES 11								
GOES 12								
GOES 13								
GOES 14								
GOES 15								
AIRS								
IASI-A								
WindSat								
MVISR 1D								
IVISSR 2C								
IVISSR 2D								
IVISSR 2E								
IVISSR 2F								
MTSAT 1								
MTSAT 2								
COCTS A								
COCTS B								
COCTS C								
COCTS D								
VIRR A								
VIRR B								
MERSI A								
MERSI B								
MWI A								
MWI B								
IKFS 2								
MSU-MR 1								
MSU-MR 2								
MI 1								
NIRST								
VIIRS								
MCSI								
SGLI								

Table 2. All sensors recommended to address for SST CDR and not listed in Table 2.

7 Status monitoring using table

Each element of the table will require two colours in a traffic light system, indicating the status regarding, first, curation (preservation and organization) of information and, second, access to information.

Curation traffic-light:

BLACK – known that information exists or existed, none or little (<10%) of the information actively curated
RED -- known that information exists or existed, with some (10 to 50%) of the information curated
AMBER – 50 to 99% of required information curated
GREEN – All information curated
BLANK – Unknown
N/A – this sort of information not generated by operating agencies

Access traffic-light:

BLACK – No mechanism to access information
RED – Highly restrictive access to information (e.g., access only through visiting physical archives by special arrangements)
AMBER – Information available digitally, but access is not obvious or is restricted: e.g., only under license, restricted to certain nationalities, obtainable by personal application, etc
YELLOW – Some information restricted access, some information freely available on the web
GREEN – Information freely accessible online

Examples of application of the traffic light are given in Appendix 2 with outcomes recorded in Table 1.

8 Appendix 1: Further mission details

Mission Name Short	Launch Date	End of Life (EOL) Date	Mission Status	Mission Instruments
Meteosat series	20 November 1993	31 January 2021	Currently being flown	MVIRI: 6, 7 SEVIRI: 8, 9, 10, 11
ERS series	1991	31 December 2011	Currently being flown	ATST-1 and ATSR-2
POES series	01 May 1981	01 March 2016	Currently being flown	AVHRR/2: 7,9, 11, 14 AVHRR/3: 15, 16, 17, 18, 19
TRMM	28 November 1997	?	Currently being flown	TMI, VIRS
INSAT series	03 April 1999	10 April 2013	Currently being flown	VHRR: 2E, 3A
OCEANSAT-1	26 May 1999	31 December 2009	Currently being flown	MSMR: 1
Terra	18 December 1999	30 September 2011	Currently being flown	MODIS
GOES series	03 May 2000	01 January 2028	Currently being flown	ABI: R, S Imager: 11, 12, 13, O, P Sounder: 11, 12, 13, O, P
NMP series	21 November 2000	30 September 2011	Currently being flown	ALI: 1 Hyperion: 1
Envisat	01 March 2002	31 December 2013	Currently being flown	AATSR
Aqua	04 May 2002	30 September 2011	Currently being flown	AIRS, AMSR-E, MODIS
FY-1 series	15 May 2002	31 December 2009	Currently being flown	MVISR (10 channels): 1D
Coriolis/Windsat	06 January 2003		Currently being flown	Windsat
KALPANA-1	12 September 2002	09 December 2012	Currently being flown	VHRR
FY-2 series	19 October 2004	31 December 2016	Currently being flown	IVISSR (FY-2): 2C, 2D, 2E, 2F
MTSAT series	26 February 2005	28 June 2015	Currently being flown	IMAGER/MTSAT-2: 2 JAMI/MTSAT-1R: 1R
EPS series	19 October 2006	01 December 2021	Currently being flown	AVHRR/3: 1, 2, 3 HIRS/4: 1, 2 IASI: 1, 2, 3
HY-1 series	11 April 2007	01 January 2013	Currently being flown	COCTS: B, C, D
FY-3 series	27 May 2008	31 December 2024	Currently being flown	IRAS: 3A, 3B, 3C, 3D, 3E, 3F, 3G, MVIRS: 3F, 3G, VIRR: 3A, 3B, 3C, 3D, 3E, 3F, 3G
Meteor series	18 September 2009	31 December 2015	Currently being flown	IKFS-2: N2 MSU-MR: N1, N2 MTVZA: N1, N2
COMS series	26 June 2010	01 November 2016	Currently being flown	MI: 1
GOMS/ELECTRO series	31 December 2009	31 December 2021	Approved	MSU-GS: N1, N2, N3
HY-2 series	01 January 2010	01 January 2011	Currently being flown	RAD: A
SAC series	22 May 2010	22 May 2015	Currently being flown	NIRST: D/Aquarius
NPP	25 October 2011	02 June 2015	Approved	VIIRS
GCOM-W series	01 February 2012	01 February 2025	Approved (W1) Planned (W2,W3)	AMSR-2: W1, W2, W3

Sentinel-3 series	01 August 2013	01 July 2026	Approved	SLSTR: A, B, C
FY-4 series	31 December 2012	31 December 2024	Planned	MCSI: O/A, O/B, O/C, O/D, O/E
GCOM-C series	January 2014	January 2020	Approved (C1) Planned (C2,C3)	SGLI: C1, C2, C3
JPSS series	2017	01 January 2027	Approved	MIS: 2, 3, 4 VIIRS: 1, 2, 3, 4
MTG-I (imaging) series	15 December 2016	15 December 2037	Approved	FCI: 1, 2, 3, 4

9 Appendix 2: Example application of traffic light methodology

The selected examples are: ATSR-1 and NOAA-12

9.1 ATSR-1

1. **Test reports & instrument guides.** All official, published reports covering categories 2. to 4. below and other performance tests: calibration reports, technical notes, test reports (e.g., thermal and vibration tests). Instrument guides and manuals.

Radiometric and geometric test reports for ATSR-1 are considered to be relatively detailed. The calibration report for ATSR-1 is online next to the multi-mission archive at NEODC, behind a password.

Curation: GREEN
Access: AMBER

2. **Radiance calibration.** All recorded (including unpublished) sensor radiance calibration and characterization records (often paper archives).

ATSR-1 calibration was undertaken at University of Oxford, and the degree to which day-to-day information is retained there has not been ascertained. Instrument data were recorded on nine-track tape, which is now stored at RAL, but the condition and readability is not known. A single paper file of calculations relating to the spectral response characterization of ATSR-1 is kept at RAL. Some experts familiar with the archive continue to work at RAL, but many have retired. While the information is currently kept, it is not actively curated (see image). None is systematically digitized or “backed up” elsewhere. There is no formal mechanism or requirement for maintenance of the paper archive at RAL beyond the end of a mission, and so the paper holdings should be considered “at risk” and dependent on personal involvement of current staff.

Interested parties may arrange with RAL to visit the store of information.

Curation: BLACK
Access: RED


Part of the paper archives of the ATSR missions at RAL.

3. **FOV characterization.** All recorded (including unpublished) sensor geometric/field-of-view characterization records (often paper archives).

The situation is similar to that for radiance calibration.

Curation: BLACK
Access: RED

4. **Design.** Engineering design drawings and specifications for whole sensor and integration on platform.

Paper copies of documents exist at RAL and should also exist in ESA ESRIN, but completeness has not been ascertained. None is online to our knowledge. There is no formal mechanism or requirement for maintenance of the paper archive beyond the end of mission; the paper holdings should be considered "at risk" and dependent on the continuing interest of current staff.

Curation: BLACK
Access: RED

5. **Cal/val results.** Minutes, presentations and reports associated with in-flight cal/val and commissioning phases.

Journal papers on validation during the mission were published. ATSR-1 cal/val was not planned with formal validation reports in mind, thus this is N/A

Curation: N/A

Access: N/A

6. **Logs.** Operational event logs throughout mission. These should note instrument anomalies (any non-nominal operation of instrument, platform pointing, etc) at the level of detail required to identify individual orbits affected.

ESOC is thought to maintain a complete timeline of events involving them. An operations log for ATSR-1 is a text file log available on the ATSR-1 web site (transcription from paper records thought to have some minimal gaps). The web site is (for now) maintained and backed up at CEDA.

Curation: GREEN
Access: GREEN

7. **Third party.** Third-party algorithms/auxiliary data for improving data quality (e.g., vicarious calibration results, empirical improvements for geo-location).

The long-term drift correction for the reflectance channel are reported in a journal paper and the data are available on the ATSR-1 web site. This process remains with quality working group oversight.

Curation: GREEN
Access: GREEN

8. **In situ.** In situ validation/campaign data funded by or collected for satellite agencies for cal/val.

No Agency cal/val data were collected since the instrument was an "opportunity" mission.

Curation: N/A
Access: N/A

9.2 AVHRR-12 (AVHRR/2 on NOAA-12 platform)

1. **Test reports & instrument guides.** All official, published reports covering categories 2. to 4. below and other performance tests: calibration reports, technical notes, test reports (e.g., thermal and vibration tests). Instrument guides and manuals.

The AVHRR Users Guides (POD Guide and KLM Guide) exist on-line and describe the AVHRR system and operational calibration and are publically accessible online (http://www.ncdc.noaa.gov/oa/pod-guide/ncdc/docs/intro.htm).

There are a number of NESDIS Technical Reports which cover previous AVHRRs that are available online (http://www.nesdis.noaa.gov/technical_reports/), but none are online for specifically for NOAA-12. Other reports on general calibration exist in paper form at the NOAA Central library.

Curation status of specific NOAA-12 reports is unknown.

Curation: YELLOW
Access: GREEN

2. **Radiance calibration.** All recorded (including unpublished) sensor radiance calibration and characterization records (often paper archives).

AVHRR-12 calibration was undertaken by ITT and was provided to NOAA in the form of an "Alignment and Calibration Data Book" which consists of descriptive text and tables/graphs of certain aspects of the pre-launch testing. Paper copies of these data handbooks are available from the NOAA Central Library so are to a degree archived in paper form, but no digitized versions are currently available. It is believed that ITT may have the original data tapes taken during the testing and their format and labeling is listed in the Data Book, but if they currently exist they are not readily available and may be lost/hard to access and the people at ITT who were originally involved in the testing are, or are close to being, retired.

Currently the data handbooks may be under ITAR (International Traffic in Arms Regulations) but the situation is changing. Even if not under ITAR it is likely that the information will be under EAR (Export Administration Regulations) and so access to the pre-launch data will still require an export license for those who are not US citizens/permanent residents.

Curation: RED
Access: YELLOW

1. **FOV characterization.** All recorded (including unpublished) sensor geometric/field-of-view characterization records (often paper archives).

Some information in the form of graphs and tables are present in the Alignment and Calibration Data Book provided by ITT. The curation and access are as discussed above.

Curation: RED
Access: RED

2. **Design.** Engineering design drawings and specifications for whole sensor and integration on platform.

Presumably existed at ITT but not currently accessible/may not exist.

Curation: BLACK
Access: BLACK

3. **Cal/val results.** Minutes, presentations and reports associated with in-flight cal/val and commissioning phases.

None seem to be publically available, but presumably existed.

Curation: BLACK
Access: BLACK

4. **Logs.** Operational event logs throughout mission. These should note instrument anomalies (any non-nominal operation of instrument, platform pointing, etc) at the level of detail required to identify individual orbits affected.

Event log summaries exist online for all the AVHRR sensors for aspects of the instruments in the NOAA POD Guide Appendix E and NOAA KLM Guide Appendix G (see http://www.ncdc.noaa.gov/oa/pod-guide/ncdc/docs/intro.htm, from 1998 onwards). The information is

The operational status exists for NOAA-12 at (http://www.oso.noaa.gov/poesstatus/spacecraftStatusSummary.asp?spacecraft=12). NOAA/NESDIS' Office of Satellite Data Processing and Distribution (OSDPD), Information Processing Division (IPD) Product Systems Branch (PSB) Pre-Product Processing (PPP) also maintains a website at: http://www.osdpd.noaa.gov/PSB/PPP/notices/notices.html which contains all the original email notices for Level 1b data that have been transmitted since June 9, 2000.

Log information at the level of detail required to identify individual orbits affected has not been identified/located. Such information must have been created "behind" the summaries on the web, but this is not clear. For this reason, the curation status cannot be green.

Curation: AMBER
Access: GREEN

5. **Third party.** Third-party algorithms/auxiliary data for improving data quality (e.g., vicarious calibration results, empirical improvements for geo-location).

Many different papers have been written on the problem of the visible channel calibration of the AVHRR which has no on-board calibration system. Work has also progressed on recalibrating all the AVHRR sensors such as the PATMOS-x project (http://cimss.ssec.wisc.edu/patmosx/), and the data and software to correct the visible channels is available on request. Other projects through the NOAA Climate Data Record Program to improve the visible channel calibration are also coming online and will be curated (http://www.ncdc.noaa.gov/cdr/index.html).

Other information regarding improving the navigation exists elsewhere. For example, The University of Miami has an archive of clock corrections for the AVHRR based on its own measurements. These are not officially curated but are currently available on request.

Curation: AMBER
Access: GREEN

6. **In situ.** In situ validation/campaign data funded by or collected for satellite agencies for cal/val.

No specific in-situ data were taken, though certain locations have been used for the vicarious calibration of the visible channels.

Curation: N/A, Access: N/A