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Project : **SST-CCI-Phase-II**

Title : **SST CCI System Verification Report**

Abstract : This document describes the verification of SST-CCI products and prototype system elements.

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AMENDMENT RECORD

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

AMENDMENT RECORD SHEET

ISSUE	DATE	REASON FOR CHANGE
B	2015-05-29	For internal review
E	2015-06-12	For ESA review
F	2015-09-25	Integrated suggested changes by ESA
1	2015-09-26	Final version for signature by ESA
2	2016-06-20	Updated to reflect phase II changes, quality assessment of version EXP1.3 SST dataset

RECORD OF CHANGES IN THIS ISSUE

Issue	Section	Reason	Change

EXECUTIVE SUMMARY

The SST-CCI project is part of the ESA Climate Change Initiative, which aims to produce long-term sea surface temperature (SST) essential climate variable (ECV) products. Within Phase II of the project four elements of the system interfaces have been implemented: the CCI SST processor, the multi-sensor match-up system, tools for aggregating SST data and data provision. All aspects of these interfaces have been verified to ensure that scientific algorithms are correctly implemented, data products are compliant with community standards (Group for High Resolution SST data standard), tools are available for data aggregation and data is publicly accessible prior to validation activities. Minor corrections to the processors are required during future reprocessing to L2P and L3U data, and are documented here. Some updates required for the PSD have been found and documented. In other aspects the system has been verified and found to be acceptable.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose and scope

In accordance with the applicable statement of work [AD.1], this Sea Surface Temperature (SST) System Verification Report gives a complete report of all activities executed and the results achieved from a technical assessment of the SST-CCI system for generation of SST climate data records. These activities verify that the system is compliant with the requirements and ideas laid out in the Statement of Work (SoW) [AD.1], the Product Specification Document (PSD) [AD.2], and the System Specification Document (SSD) [AD.3].

1.2 References

The following documents are applicable to this document:

ID	Title	Issue	Date
[AD.1]	ESA Climate Change Initiative Phase II – Scientific User Consultation and Detailed Specification Statement of Work (SoW), including Annex G: Sea Surface Temperature ECV	1	2013-07-02
[AD.2]	Sea Surface Temperature CCI Phase-II Product Specification Document, SST_CCI-PSD-UKMO-201 (PSD)	2	2014-04-11
[AD.3]	Sea Surface Temperature CCI Phase-II System Specification Document, SST_CCI-SSD-BC-201 (SSD)	2	2016-02-10
[AD.4]	Sea Surface Temperature CCI Phase-II User Requirements Document, SST_CCI-URD-UKMO-201 (URD)	3	2015-12-14
[AD.5]	Sea Surface Temperature CCI Phase-II Data Access Requirements Document, SST_CCI-DARD-UOL-201 (DARD)	2	2014-09-23
[AD.6]	CCI System Requirements, CCI-PRGM-EOPS-TN-12-0031	1	2013-07-02
[AD.7]	Data Standards Requirements for CCI Data Producers, CCI-PRGM-EOPS-TN-13-0009	1.1	2013-05-24
[AD.8]	GHRSST Science Team, cited 2010: The Recommended GHRSST Data Specification (GDS) Revision 2.0 Technical Specifications.	2.0	2010-10-01

The following documents are referenced in this document:

ID	Title
RD.184	Embury, O., C. J. Merchant and G. K. Corlett (2012), A Reprocessing for Climate of Sea Surface Temperature from the Along-Track Scanning Radiometers: Initial validation, accounting for skin and diurnal variability, Rem. Sens. Env., pp62 – 78 DOI:10.1016/j.rse.2011.02.028

ID	Title
RD.232	SST_CCI Multi-Sensor Match-up Dataset Specification, SST_CCI-REP-UoL-001
RD.258	SST CCI System Requirements Document, SST_CCI-SRD-BC-001 (SRD)
RD.264	Lisa A. Horrocks, Andrew R. Harris, and Roger W. Saunders, Modelling the diurnal thermocline for daytime bulk SST from AATSR, NWP FRTR No. 418, Met Office, 2003
RD.296	Merchant, C. J., O. Embury, N. A. Rayner, D. I. Berry, G. Corlett, K. Lean, K. L. Veal, E. C. Kent, D. Llewellyn-Jones, J. J. Remedios, and R. Saunders (2012), A twenty-year independent record of sea surface temperature for climate from Along Track Scanning Radiometers, J. Geophys. Res., 117, C12013, DOI:10.1029/2012JC008400
RD.305	ESA SST CCI Algorithm Theoretical Basis Document, SST_CCI-ATBDv2-UOE-001 (ATBD)
RD.319	Saunders, P. M., (1967), The temperature at the ocean-air interface, Journal of Atmospheric Science, 24, 269-273
RD.329	ESA SST CCI System Verification Report, SST_CCI-SVR-UOR-001 (SVR)
RD.330	ESA SST CCI Product User Guide, SST_CCI-PUG-UKMO-201

1.3 Acronyms

The following SST-specific acronyms are used in this report.

Acronym	Definition
ARC	ATSR Reprocessing for Climate
(A)ATSR	(Advanced) Along-Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BADC	British Atmospheric Data Centre
CCI	Climate Change Initiative
CF	Climate Forecast
CMIP5	Coupled Model Intercomparison Project Phase 5
DARD	Data Access Requirements Document
DPM	Detailed Processing Model
ECDF	Edinburgh Compute and Data Facility
ECMWF	European Centre for Medium-Range Weather Forecasts
ECSS	European Cooperation for Space Standardisation
ECV	Essential Climate Variable
ESA	European Space Agency
GBCS	Generalised Bayesian Cloud Screening

Acronym	Definition
GDS	GHRSST Data Processing Specification
GHRSST	Group for High-Resolution SST
GMPE	GHRSST Multi Product Ensemble
IR	Infrared
MetOp	Meteorological Operational (EUMETSAT)
MD	Match-up Dataset (single-sensor)
MMD	Multi-sensor Match-up Dataset
MMS	Multi-sensor Match-up System
NOAA	National Oceanic and Atmospheric Administration
NEODC	NERC Earth Observation Data Centre
NERC	Natural Environment Research Council
NWP	Numerical weather prediction
OSI-SAF	Ocean & Sea Ice Satellite Application Facility (EUMETSAT)
OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PMW	Passive Microwave
SDI	Saharan Dust Index
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SGE	Sun Grid Engine
SNAP	SentiNel Application Platform
SST	Sea Surface Temperature
UoE	University of Edinburgh

1.4 Document structure

Section 1	Formal introduction.
Section 2	Description of the objectives and scope of the processor, including a listing of the elements that have been tested.
Section 3	Description (with summary) of test activities carried out against criteria, including test cases and procedures.
Section 4	Record of test results.
Section 5	Discussion and conclusions.

2. SEA SURFACE TEMPERATURE SYSTEM OVERVIEW

2.1 Objective and scope of the SST-CCI system

The document giving a full description of the SST-CCI system is the "System Specification Document" (SSD) [AD.3].

We distinguish the "SST-CCI system" from the "SST-CCI processor". The SST-CCI system is the more general term covering the end-to-end capabilities developed within SST-CCI project. The SST-CCI processor specifically refers to the chain by which products specified in the Product Specification Document (PSD, AD.2) are created.

The end-to-end system ultimately required for SST-CCI to deliver its users' needs includes a range of interfaces, as illustrated in Figure 2-1 below, from the SST-CCI System Requirements Document (SRD, RD.258). Each existing interface requires verification. However, not all interfaces have been fully implemented. Therefore, in Section 2.3 there is a list that identifies which elements have been implemented, and verified as described in this report.

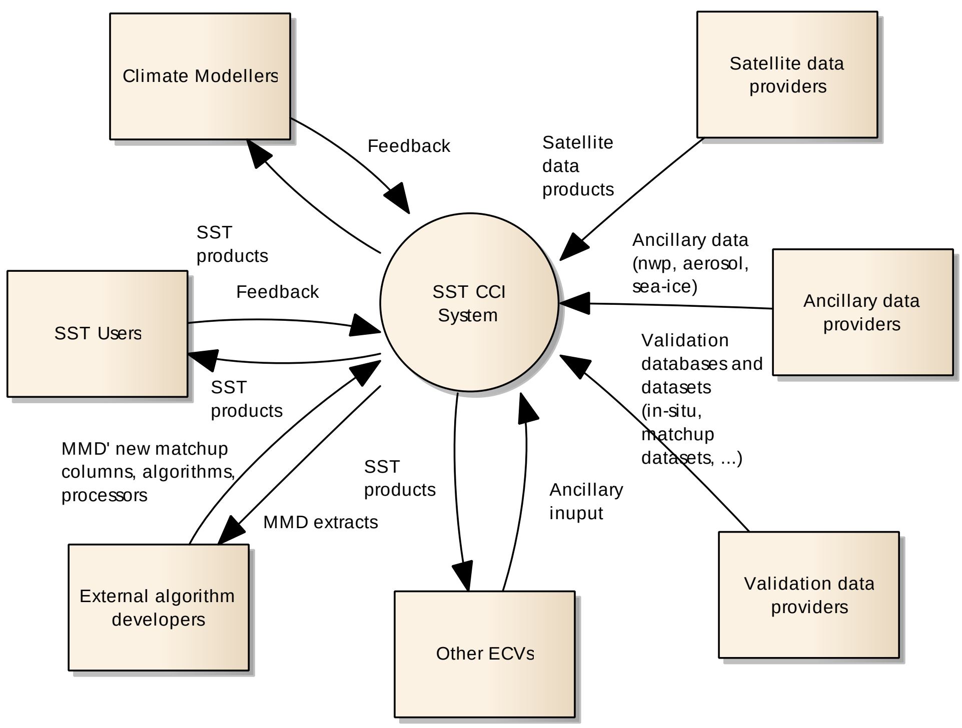


Figure 2-1: The required SST-CCI system in the context of its interfaces

Within the central SST-CCI system in Figure 2-1, there have been five areas of software functionality in the SST-CCI project:

1. The Level-2, Level-3, and Level-4 processors that create the SST-CCI products
2. The multi-sensor match-up system that supports developing the CCI science behind the products
3. Product tools applicable to SST-CCI products for aggregating and re-gridding the nominal SST data to lower-resolution

4. Data provision (user access to Climate Data Research Package and SST-CCI products)
5. Report tools for supporting the writing of validation and assessment reports

In the following subsections, the objectives and scope of each of these is described, as required by the statement of work. Please note that the primary reference for descriptions of the SST-CCI system is the SSD [AD.3], which gives more complete information.

2.1.1 SST-CCI processing

The objective of the SST-CCI processors is to create climate data records for SST at levels between Levels 2 and 4. In Phase-I of the SST-CCI project two variants of SST processing were developed: the demonstrator and the long-term processing systems. The processing occurred at different locations: ECDF carried out the Level-2 and Level-3 processing of NOAA AVHRR GAC, ATSRs and passive microwave satellite data, CMS produced Level-3 SST from MetOp AVHRR and SEVIRI satellite data, and the Met Office OSTIA produced Level-4 SST from Level-2 and Level-3 data produced by ECDF.

Due to additional CCI cardinal requirements for Phase-II, in particular the integration of major new data sources like the Sentinels, Earth Explorers, and non-ESA Missions the decision was made to migrate the SST ECDF and Met Office OSTIA systems to the Climate and Environmental Monitoring from Space (CEMS) Facility hosted at the UK Centre for Environmental Data Archival (CEDA). CEMS is a purpose-built facility offering space-based Climate Change and Earth Observation (EO) data and services. Its goal is to nurture growth in EO and climate-based services by providing, within a single facility, high performance computing, extensive data collections and various user services and software applications. In particular the provision and stewardship of Sentinel-3 SLSTR and EUMETSAT AVHRR datasets is of essential interest in the SST-CCI project.

In consequence of the migration to CEMS, the former ECDF sub-system for producing Level-2 and Level-3 SST has been further developed to use MetOp AVHRR as well, so that the functionality of the CMS demonstrator sub-system has been integrated into the ECDF software. The CMS demonstrator sub-system is not used anymore in Phase-II.

2.1.2 SST-CCI multi-sensor matchup system (MMS)

In Phase-I, the objective of the MMS was to create a multi-sensor matchup datasets (MMD) adequate to support SST science. The science supported includes:

- SST retrieval development (algorithm selection)
- Improvement of image classification
- Improvement of diurnal variability adjustments
- Improvement of uncertainty estimates
- Product verification (the use in this report)
- Product validation
- Climate assessment

In Phase-II the principle of the MMS as a one-off use to generate MMD files from static MD files has been further developed to take into account the various use cases for Phase-II and to simplify the definition of MMD workflows.

2.1.3 SST-CCI product tools

SST-CCI products are larger than some climate users want or need. Therefore, a set of tools has been developed to support users. These tools operate on SST-CCI products at levels 2 (L2P) and 3 (L3U and L3C) to (1) re-grid SST to lower spatiotemporal resolutions, and (2) generate basin to global scale SST anomaly time series.

2.1.4 SST-CCI data distribution

All SST-CCI products and many additional data sets form part of the Climate Data Research Package (CDRP). The data distribution function is to give any user convenient access to the CDRP and its constituents, along with the associated documentation.

2.1.5 SST-CCI report tools

In Phase-II new tools are being developed to facilitate a semi-automated generation of product validation and inter-comparison and climate assessment reports from report templates and figures automatically created from SST-CCI product data.

2.2 Subsystems of the SST-CCI processing

2.2.1 Level-2 and Level-3 (ARC CCI) processors

The Level-2 and Level-3 processors consist of the optical and infrared (ARC) SST processor, the diurnal variability (DV) model, and the microwave SST processor. Level-1b AVHRR GAC and ATSR satellite data are the main input of the optical and microwave SST, with ECMWF Interim and sea ice concentration auxiliary data. The outputs of the processors are SST-CCI L2P and L3U SST. The DV model uses the same inputs as the SST processor in order to modify the L2P and L3U SST. The microwave processor retrieves SST from AMSR2 L1R. All inputs required for the processing are hosted in the ultrafast PANFS storage at CEMS.

At the time of writing this version of the SVR the development of the microwave SST processor is in progress. Verification of the microwave processing will therefore be covered in the next major version of the SVR.

2.2.2 Level-4 (OSTIA) processor

The OSTIA processor receives SST-CCI L2P and L3U and produces SST-CCI L4 SST. Sea ice concentration auxiliary data are used.

At the time of writing this version of the SVR the migration of a stand-alone version of the OSTIA processor is in progress. Verification of the Level-4 processing will therefore be covered in the next major version of the SVR.

2.3 Listing of system interfaces and elements

Table 2-1 below lists the system interfaces and elements and indicates the degree to which these have been developed in Phase-II, using the terms defined as follows:

Not developed	System element has not been developed in Phase-II, but is identified as a requirement in the SRD. There is therefore no verification activity reported here.

Illustrated	System element has been implemented in Phase-I to a minimal degree, illustrating the principles of how the element can function, but short of prototyping. There is therefore no verification activity reported here.
Developed	System element has been developed or prototyped in Phase-II and system verification activities are reported in this document.

Table 2-1: Processing system elements and interfaces and degree to which these have been developed

System interface / element	**Current status**	**Comments**
Satellite data interface	Illustrated	One-off collection of data at start of project
Ancillary data interface	Illustrated	One-off collection of data at start of project
Validation data interface	Illustrated	One-off collection of data at start of project
Other ECV interface	Illustrated	One-off collection of data
External algorithm developers' interface	Illustrated	One-off extraction of dataset (subset of MMD) for Round Robin exercise. One-off receipt of inputs from external participants.
SST users	Developed (in part)	User access to CDRP. (Feedback from users not prototyped, however.)
Climate modellers' interface	Not developed	Climate researchers and SST community use SST-CCI products. The SST-CCI team actively seeks user feedback.
SST-CCI processing	Developed	Comprises a system with two subcomponents, as described in Section 2.2 and listed in the table below.
Multi-sensor match-up system	Developed	One-off generation for project. Corresponding data used in verification of products.
Tools	Developed	Re-gridding and Regional Averaging tools.

The components of the prototype processor constitute the bulk of the verification activities in this report. As required by the statement of work, Table 2-2 lists the tested components, their mode of use, platform and interfaces.

Table 2-2: SST-CCI processing components for which system verification activities have been undertaken

Component	Mode of use	Platform / sub-system	External inter-faces
ARC CCI processor	When processing ATSR-series inputs toL2P/L3U SST outputs	CEMS / Lotus	Satellite data providers Ancillary data providers
ARC CCI processor	When processing AVHRR GAC or AVHRR FRAC L1C pre-processor inputs to L2P/L3U SST outputs	CEMS / Lotus	Ancillary data providers
AVHRR GAC pre-processor	When pre-processing AVHRR GAC L1B inputs to L1C outputs	CEMS / Lotus	Satellite data providers
DV model processor	N/A	CEMS / Lotus	N/A
MMS	When processing match-up datasets for validation	CEMS / Lotus	Satellite data providers Ancillary data providers

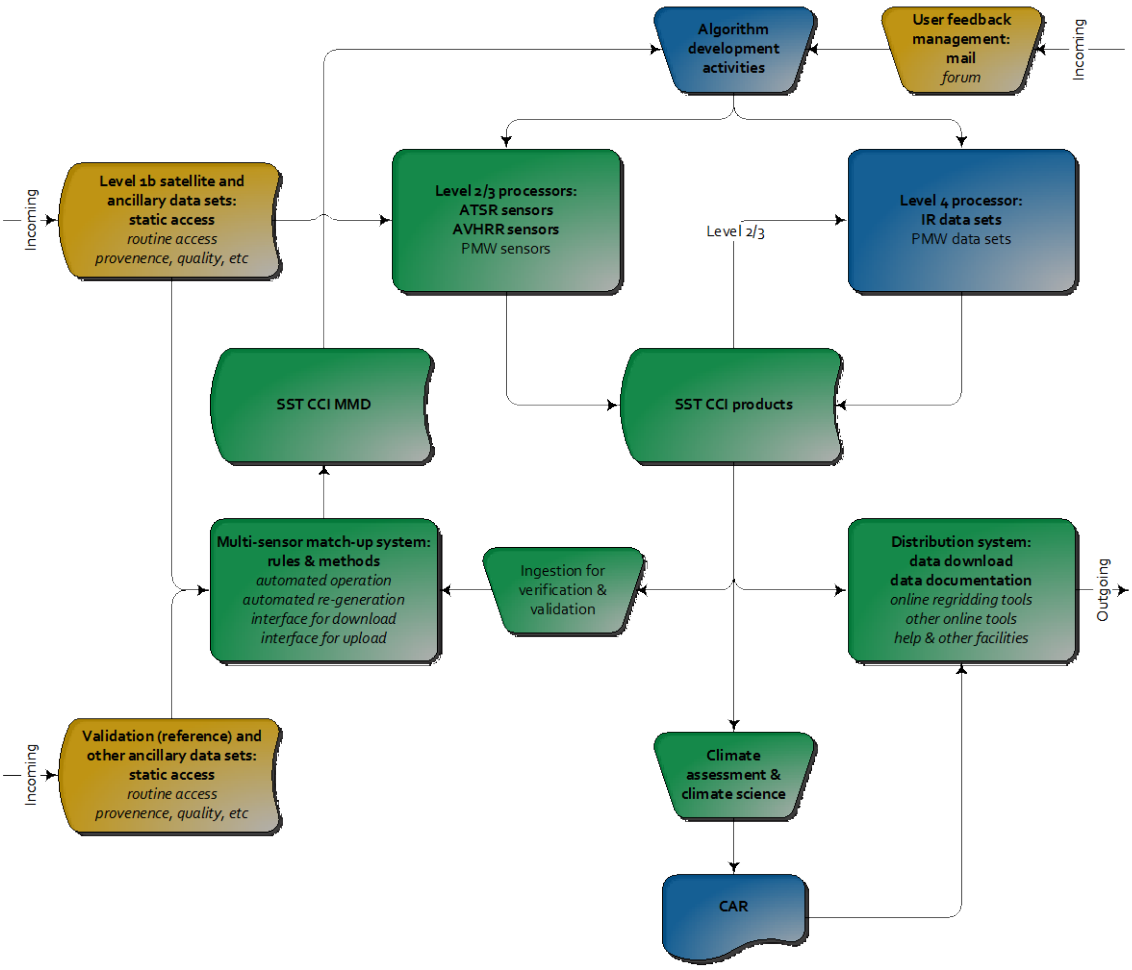


Figure 2-2: Schematic view of the SST-CCI system

Figure 2-2 above is a schematic view of the entire SST-CCI system. Rectangular shapes indicate technical elements (Level 2/3 and 4 processors, MMS, distribution system for documents, data, and tools). Cylindrical shapes indicate data storage elements (satellite and ancillary input data, validation and other ancillary data, SST-CCI products and MMD files) while trapezoidal shapes indicate manual activities (user feedback management, algorithm development, data ingestion for verification and validation). Note that the Development Team does not appear in the diagram explicitly, though it conducts the manual activities and operates the system as a whole. The colouring of shapes is used to discern elements receiving external input (orange), elements distributing output to external users and core elements. Boldface letters denote elements, activities or functions that have been prototyped in Phase-I; functions denoted in plain style, elements that have been prototyped in the demonstration but not in the long-term system of Phase-I; functions denoted in italic letters have not been prototyped in Phase-I, but will be addressed in the future system in Phase-II and beyond. Elements verified in this version of the SVR have green colour.

2.4 Requirements review

Table 2-3 below provides a review of all SST-CCI requirements for Phase-II and how these have been addressed as part of the work conducted in the project, and within the SVR, where applicable. Where appropriate, readers are referred to other project documents where requirements are addressed.

Table 2-3: SST-CCI requirements (Phase-II) addressed during the system verification process

Relevant Requirements	How addressed	SVR section
Cardinal requirements		
CR-2 Produce and validate the most complete and consistent possible time series of multi-sensor global satellite data products for climate research and modelling, for the period where data are available including up to the present day. This will include at least one full ECV reprocessing.	Verification that the products contain SSTs that are faithful implementations of the scientific algorithms selected for climate products.	4.1 4.2
CR-4 Generate and fully document an operational production system […] capable of processing and reprocessing at least once the data in CR-2.	The SST-CCI system will be developed toward an operational system as far as possible in Phase-II. Maturity of the system has been assessed with respect to the CORE-CLIMAX metrics. Compliancy of the system with respect to CCI system and data standard requirements [AD 6,7] has been assessed. A processing of the FCDR to CDR has been carried out. A re-processing is foreseen later in Phase-II. The system is fully documented in the SSD and the MMS Implementation Plan.	N/A

Relevant Requirements	How addressed	SVR section
CR-5 Develop the system to integrate major new data sources e.g. Sentinels, Earth Explorers […] and other non-ESA Missions as they become available.	Using Sentinel-3 SLSTR data is foreseen later in Phase-II when the data become available.	N/A
Framework		
SST-TR-1 The CCI SST ECV project shall use netCDF CF compliant definitions of 'SSTskin', 'SSTsub-skin', 'SSTfnd' and 'SSTdepth' […] the misleading term 'Bulk SST' […] shall not be used.	The SST-CCI Product Specification Document (PSD) has adopted the required netCDF CF compliant definitions of SSTs. The products produced in SST-CCI comply with the PSD by design and are verified here.	4.1 4.2
SST-TR-2 The SST cube conceptual product framework, used in SST-CCI Phase-I and by GHRSST, shall be maintained for SST-CCI Phase-II.	The cube has been maintained in Phase-II.	N/A
SST-TR-3 SST data products shall comply with the GHRSST Data Processing Specification […].	The SST-CCI Product Specification Document (PSD) has adopted GHRSST compliant definitions of SSTs. The products produced in SST-CCI comply with the PSD and GHRSST by design and are verified here.	4.1.1 4.2.1
SST-TR-4 Changes to the GDS specification shall be proposed for climate SST data sets […] in consultation with the GHRSST Climate Data Records Technical Advisory Group and other related GHRSST groups for approval.	The GDS has been further developed to take SST-CCI sensors, platforms and products into account as required	N/A
SST-TR-5 SST-CCI Phase-II shall produce sea-surface temperature products for the baseline time period of 1981-2016.	This has been implemented in Phase II for L2P and L3U data.	4.1.1 4.2.1
General product requirements		
SST-TR-6 SST-CCI shall produce integrated sea-surface temperature analyses based on SST-CCI L2/L3 satellite data records from 1981-2016. Products shall push as far as scientifically and technically possible to address GCOS user requirements using both IR and MW data, within the time and resource constraints of the project.	L2P and L3U SST products have been produced for the period 1979-2016 and are verified here.	4.1.1 4.1.2 4.2.1 4.2.2
SST-TR-7 SST-CCI shall produce L2/L3 SST products from the AVHRR series of satellite infrared radiometers for the period 1981 – 2016.	L2P and L3U SST products have been produced for the period 1979-2016 and are verified here.	4.1.1 4.1.2 4.2.1 4.2.2
SST-TR-8 SST-CCI shall produce L2/L3 SST products from the (A)ATSR series of satellite infrared radiometers for the period 1991-2012.	L2P and L3U SST products have been produced for the period 1991-2012 and are verified here.	4.1.1 4.1.2 4.2.1 4.2.2

Relevant Requirements	How addressed	SVR section
SST-TR-9 SST-CCI shall produce L2/L3 SST products from Passive Microwave satellite instruments within the period 1997-2016, selecting the sensor(s) and period(s) shown to be most likely to add value to blended IR datasets.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-10 IR satellite FCDR data products shall provide an 'SSTskin' measurement as single sensor orbital swath/scene products.	This is done as defined in PSD.	4.2.1
SST-TR-11 MW satellite FCDR data products shall provide an 'SSTsub-skin' measurement as single sensor orbital swath/scene products.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-12 Aggregated satellite SST products shall be made available to users at daily, weekly, monthly, seasonal and annual resolutions.	Re-gridding and regional averaging tools have been developed to present CDR data at different spatial and temporal resolutions. Tools have been applied for internal purposes and for supporting requests by external scientific users (M. Scharffenberg, University of Hamburg)	4.5
SST-TR-13 All SST-CCI SST products shall include an estimate of uncertainty rigorously propagated from known instrument uncertainties, measurements and retrieval/merging models.	The inclusion of uncertainty estimates in the products has been ensured by design. The consistency checking is a validation activity (uncertainty is a part of the product to be validated in its own right) and will be described in the PVIR. The presence of per-pixel uncertainties in the products is verified here.	4.1.1 4.1.2 4.2.1 4.2.2
SST-TR-14 Appropriate communication tools to help users understand uncertainty estimates how to apply them shall be provided.	Addressed via Products User Guide (PUG).	N/A
SST-TR-15 SST retrievals shall be provided for all conditions that may potentially provide a useful SST in all L2P products.	SST retrievals are supplied for all potentially clear-sky pixels in L2P.	N/A
SST-TR-16 Quality Flags shall be provided in all L2P products that allow users to select the quality of SST data to use for their application.	Quality level flags are provided for all L2P and L3U products. The presence and consistency of per-pixel quality flags is verified here.	4.1.1 4.1.2 4.2.1 4.2.2
Product performance		

Relevant Requirements	How addressed	SVR section
SST-TR-17 SST-CCI sea-surface temperature L4 analysis products shall provide products with global coverage.	L4 processor is still under development	In next major versions of this document
SST-TR-18 The SST-CCI integrated sea-surface temperature L4 analyses shall have a grid resolution of 10 km or finer.	L4 processor is still under development	In next major versions of this document
SST-TR-19 The SST-CCI integrated sea-surface temperature L4 analyses shall have a temporal resolution of 24 hours or finer.	L4 processor is still under development	In next major versions of this document
SST-TR-20 The SST-CCI integrated sea-surface temperature L4 analyses shall target an accuracy of 0.1 K over 100 km scales. L4 product accuracy shall be assessed using the SST-CCI Independent Reference Data Set (SIRDS) defined in SST-TR-55.	L4 processor is still under development	N/A
SST-TR-21 The SST-CCI sea-surface temperature products shall target a stability of 0.03 K per decade over 100 km scales, assessed to the extent possible using the SST-CCI Independent Reference Data Set (SIRDS).	Results will be reported in the next PVIR.	N/A
Requirements management		
SST-TR-22 The SST-CCI Consortium shall take pro-active steps to increase the number of users participating in the review of SST-CCI user requirements.	A user workshop was held at the Met Office. A new user survey will be conducted in Phase-II. Will be reported in the next URD.	N/A
SST-TR-23 Starting from the Phase-I SST-CCI User Requirement Document, user requirements for an SST ECV product shall be reviewed on a regular basis through consultation with new and existing users of SST climate products.	Feedback from the user workshop and a user survey will be incorporated in time to influence the third reprocessing cycle of Phase-II. Will be reported in the next URD.	N/A
SST-TR-24 The SST-CCI Consortium shall establish a long-term approach to communicating to the user community the benefits, outcomes, data products, tools, flag definitions and other aspects of SST-CCI project on a regular […] basis.	A communications strategy was defined. This includes the use of websites and blogs and strategy for presentations such as a standard overview presentation.	N/A

Relevant Requirements	How addressed	SVR section
SST-TR-25 In addition to the Product Specification Document (PSD) requirements set […] the SST ECV PSD shall include for all products: 1. File metadata format and structure specifications, 2. Community data discovery metadata and structure specifications, 3. Long-term document revision control procedures for the PSD, 4. Any other requirements relevant to SST ECV product specification.	These are already included in the Phase-I PSD and will be updated as appropriate in Phase-II. The products produced in SST-CCI comply with the PSD by design and are verified here.	4.1.2 4.2.2
SST-TR-26 The international SST community embodied in GHRSST shall be requested to review the SST ECV URD and PSD to ensure an appropriate level of consensus regarding the product content is achieved.	This will be addressed when major revisions of the documents are performed in Phase-II. Will be reported in CAR.	N/A
Algorithm development		
SST-TR-27 New techniques shall be developed and applied to optimize the exploitation of the (A)ATSR (and in the future SLSTR) as a dual-view reference SST sensor series	This is an ongoing activity in algorithm development work packages	N/A
SST-TR-28 SST-CCI shall exploit, and where possible contribute to, improved multi-instrument calibration knowledge developed and applied to optimize the calibration of the AVHRR sensor series from 1981-2016	This is an ongoing activity in scientific work packages and supported by the multi sensor match-up system and datasets.	3.5 4.4
SST-TR-29 New IR SST retrieval algorithms shall be tested and/or developed that have increased sensitivity and/or performance based on an improved radiative transfer modelling and optimal estimation models […].	Scientific developments are ongoing through Phase-II.	N/A
SST-TR-30 New techniques shall be developed and tested for Passive Microwave sensor series Brightness Temperatures (BT) to derive SSTs that are better harmonised with IR measurements.	Scientific developments are ongoing through Phase-II.	N/A
SST-TR-31 The potential for improved PM SST retrieval algorithms shall be analysed based on comprehensive Information Content (IC) analyses using PM instrument characteristics.	Scientific developments are ongoing through Phase-II.	N/A
SST-TR-32 Based on radiative transfer modelling and optimal estimation and the outcome of SST-TR-31, new MW SST retrieval algorithms for individual MW satellite instruments shall be developed and applied. Discrepancies with respect to theoretical performance derived from IC analyses […] shall be established.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-33 Uncertainty estimates shall be developed for MW SST data products and shall be included in all MW SST-CCI products.	Scientific developments towards this are ongoing. No system verification yet.	N/A

Relevant Requirements	How addressed	SVR section
SST-TR-34 A method to routinely maximize the consistency between MW and IR SST records using the dual-view (A)ATSR/SLSTR reference missions shall be developed and tested.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-35 ATSR-1, ATSR-2 and AATSR sensor overlap periods shall be reanalysed using the latest available L1b data to improve stability.	Version 3 data have been used in the Phase-II reanalysis	N/A
SST-TR-36 Synergy techniques […] shall be developed/tested to re-assess Pinatubo and other stratospheric aerosol events for impact on the SST record stability.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-37 […] overlap techniques for harmonising AVHRRs pre-1991 shall be developed and applied to pre-1991 sensors.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-38 An approach to bridge and fill the gap in the dual-view AATSR and Sentinel-3 […] satellite SST climate record shall be developed.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-39 Improved probabilistic cloud detection and flagging algorithms shall be tested and/or developed in routine and marginal situations that have increased sensitivity and performance […].	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-40 Cloud flag definitions within SST-CCI data products shall be reviewed and updated as required.	Reviewed, but no changes made with respect to Phase-I	N/A
SST-TR-41 Improved atmospheric aerosol detection and flagging algorithms shall be tested and/or developed that have increased sensitivity and performance […].	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-42 Aerosol contamination flag definitions within SST-CCI data products shall be reviewed and updated […].	Scientific development is ongoing, final validation required.	N/A
SST-TR-43 Algorithms shall be tested and/or developed that improve the discrimination of ice-free and ice-covered water (i.e. clear/cloud/ice) classification in the MIZ to improve SST-CCI data products.	Scientific developments towards this are ongoing. No system verification yet.	N/A
SST-TR-44 Appropriate data quality and indicator algorithms shall be tested and/or developed for MW SST data.	Scientific developments towards this are ongoing. No system verification yet.	N/A
System evolution		
SST-TR-45 The SST-CCI system prototype system shall be implemented on a sustainable cost effective platform (e.g. the CEMS platform) enabling multiple re-processing of SST-CCI data building on the SRD developed in Phase-I.	The ECDF and Met Office components of the SST-CCI system from Phase-I have been migrated to CEMS. The migration of the L2/L3 processing was completed in early Phase-II. The migration of the OSTIA system is in progress.	N/A

Relevant Requirements	How addressed	SVR section
SST-TR-46 The OSTIA SST analysis for SST-CCI shall be improved (e.g. adaptive correlation length scales, improved background error covariance) and modified to produce the SST data sets […].	Scientific developments are scheduled for later in the project and will be included in the third reprocessing cycle of Phase-II.	N/A
SST-TR-47 A processing chain shall be implemented to generate SST-CCI MW SST products based on the results of SST-CCI algorithm development.	Scientific developments towards this are ongoing. No system verification yet.	In next major versions of this document.
SST-TR-48 The SST-CCI multi-sensor match-up system prototyped in SST-CCI Phase-I shall be fully implemented as a sustainable extensible and modular system (i.e., web-interactive visualisation of results, fully configurable from a user query perspective, optimised data management etc) with an emphasis on extensibility and re-use.	The multi-sensor match-up system (MMS) was migrated from ECDF to the CEMS in early Phase-II. Improving the coverage of unit tests has consolidated the code base. The MMS is in continuous development in order to support the use cases required by on-going work in the project. Detected issues are resolved immediately, if possible.	4.4
SST-TR-49 SST-CCI shall implement more integrated and consistent radiative transfer modelling across IR and MW wavelengths.	RTTOV v11 is now used for all fast radiative transfer.	N/A
SST-TR-50 Web-based tools shall be provided for users to visualise SST-CCI data products via diagnostic plots (e.g. canonical time series plots, Hovmoller plots, spatial maps, animations of time series etc in a format suitable for use in promotional activities.	As agreed at AR2, this functionality shall be covered by the CCI Open Data Portal.	N/A
Product generation		
SST-TR-51 At least two re-processing runs shall be performed during Phase-II SST-CCI activities. One of these shall deliver a data set (1981-2016) in sufficient time for the climate assessment work to be completed in good time prior to the end of the project.	This is an ongoing activity.	N/A
SST-TR-52 An interim re-processing shall be performed that tests the functionality of the sustainable SST-CCI system and provides a data set suitable for validation of the system and data sets produced.	This is an ongoing activity.	N/A
SST-TR-53 SST-CCI data products, documentation and technical publications shall be made available to the climate user community via dedicated interfaces.	Data products, documentation and publications are available through the web site of the SST CCI project. All products and information will also be available through the upcoming common CCI Portal.	4.6

Relevant Requirements	How addressed	SVR section
SST-TR-54 Feedback from the climate user community shall be gathered on the utility and performance of SST-CCI products in a pro-active manner. User conclusions and recommendations based on SST test products shall be analysed and translated into new requirements for further algorithm tuning or development steps.	A user workshop was held at the Met Office. Feedback will be sought on the data produced in Phase-II.	N/A
SST-TR-55 The SST-CCI system shall be upgraded to address new requirements subject to scientific and technological constraints, Agency approval and available resources.	The SST CCI system is in continuous development.	N/A
SST-TR-56 SST-CCI shall define, collect and deliver an SST-CCI Independent Reference Data Set (SIRDS) that are quasi-independent of satellite SST products for the period 1981-2016 for use in validation, verification and other SST-CCI SST product performance assessments […].	This is an ongoing activity.	In next major versions of this document.
Climate assessment		
SST-TR-57 An approach shall be established and implemented to assess, on a regular basis, the performance of satellite SST climate data records. The approach shall be developed in close cooperation with relevant international activities.	Developments towards an automatic system for production of a comprehensive suite of diagnostics are ongoing.	N/A
SST-TR-58 Validation of CCI SST satellite data products shall include global and regional aspects (spatially and in time series analysis) and at daily, weekly, seasonal, annual and inter-annual timescales.	Methods to do this were developed and implemented in Phase-I. They will be adapted in Phase-II to align with the measures defined in the GHRSST CDAF.	N/A
SST-TR-59 Ensemble techniques (e.g. the GHRSST Multi-Product Ensemble) shall be used to compare international SST climate data products as part of the validation exercise.	The GMPE system will be set up to run automatically as part of the third reprocessing cycle of Phase-II.	N/A
SST-TR-60 The SST-CCI validation of SST products shall include the use of methods developed in Phase-I (i.e. including the validation of uncertainty information).	The methods developed and implemented in Phase-I (including validation of uncertainty information) will be applied in Phase-II.	N/A
SST-TR-61 The long-term stability of each SST record produced by SST-CCI shall be established and reported in a submitted peer reviewed journal article.	The GHRSST CDAF stability methodology will be applied and submitted for publication	N/A
SST-TR-62 A quantitative analysis shall establish the long-term trend of SST using the SST-CCI data sets at global and regional spatial scales that is reported in a submitted peer reviewed journal article.	This will be addressed by the end of Phase-II in conjunction with SST-TR-61.	N/A

Relevant Requirements	How addressed	SVR section
SST-TR-63 The impact of CCI SST ECV proto-type products on end user applications shall be tested working with the user community […] and SST ECV Science Teams.	Feedback from users will be solicited and incorporated into the Climate Assessment Reports.	N/A
SST-TR-64 Tools necessary to perform the model integration of satellite products (e.g. translation tool to format SST-CCI data in the Coupled Model Inter-comparison Project (CMIP) format to help users apply data) shall be tested and/or devel-oped.	Tools will be developed in later Phase-II with advice from and cooperation with the CCI Portal Consortium.	In next major versions of this docu-ment.
SST-TR-65 Dedicated climate model experi-ments/analyses shall be specifically designed and implemented to test the impact of SST-CCI data sets in a specific and controlled manner.	Dedicated experiments are planned for the third year of Phase-II.	N/A
Option 8: Argo network		
SST-OP8-1 The use of globally distributed Argo float surface SST measurements to provide long-term information on the stability of the SST-CCI climate data record shall be analysed.	Work to be done in CP2/3.	N/A
SST-OP8-2 Agreed methods (e.g. penalized maximal t-test Wang, 2007) shall be established and applied to detect step changes in the long-term SST-CCI data record.	Work to be done in CP2/3.	N/A
SST-OP8-3 Techniques shall be developed and implemented to compute stability confidence in-tervals for SST-CCI data records.	Work to be done in CP2/3.	N/A
SST-OP-4 All activities and results […] shall be presented in a Technical Note that may be written in the form of a peer-reviewed paper.	Work to be done in CP2/3.	N/A
Option 11: Passive microwave SST production		
SST-OP11-1 Building on the results of [SST-TR-9, SST-TR-30, SST-TR-32, SST-TR-33, SST-TR-45] SST-CCI shall produce L2/L3 SST products from Passive Microwave satellite instruments for the period 1997-2016.	Work to be done in CP2/3.	In next major versions of this docu-ment.
SST-OP11-2 SST-CCI shall produce integrated sea-surface temperature analyses based on SST-CCI L2/L3 satellite data records from 1981-2016 using both IR and MW data, within the time and resource constraints of the project.	Work to be done in CP2/3.	In next major versions of this docu-ment
SST-OP11-3 The impact of MW SST data proc-essed in this option on the SST- ECV shall be evaluated.	Work to be done in CP2/3.	N/A
SST-OP11-4 All activities and the results […] shall be presented in a Technical Note that may be written in the form of a peer-reviewed paper.	Work to be done in CP2/3.	N/A

3. DESCRIPTION OF VERIFICATION ACTIVITIES

For each of the verified components, a description of verification activities and associated criteria is provided in the following subsections.

3.1 Verifying the ARC CCI processor (L3U)

For verifying the content of the L3U products the automated verification procedure developed in Phase-I has been re-implemented from scratch. The new Python scripts have improved the verification procedure in several aspects:

- The verification procedure has fully been integrated into the CEMS environment, using the p-monitor intermediate layer to control and monitor individual processing jobs. The source code has been integrated into the source code tree of the MMS. Verification procedures are executed massively parallel.
- A verification report is generated for each product file checked. The report is written in the JSON format, which is easily readable by humans and machines. Python supports the JSON format natively. Verification reports translate into Python dictionaries, where the keys are text and the values are either numbers or text. Checks for all product types (L2P, L3U and L4) have been implemented.
- Product verification reports are accumulated into summary reports; one summary report per product type and sensor. For each check, the summary report traces failures back to individual product files. The format of the summary report again is JSON.
- For each summary report a set of bar charts is generated. The format of the bar charts is PDF.

Figure 3-1 below illustrates the workflow of the content verification procedure, which is split into daily chunks per product type and sensor.

Content verification is comprised of checks that are conducted per product or per pixel, which are listed and explained in Table 3-1 and Table 3-2 for product checks and Table 3-3, Table 3-4 and Table 3-5 for pixel checks below. Checks conducted per pixel count the number of pixels in a product where an asserted condition fails. Individual checks in the verification procedure that have been added or modified with respect to the previous SVR checks have been iterated with the production team.

A summary of verification activities is given in Table 3-6. A detailed verification and validation of SST will be summarised in the “Product Verification and Intercomparison Report” (PVIR).

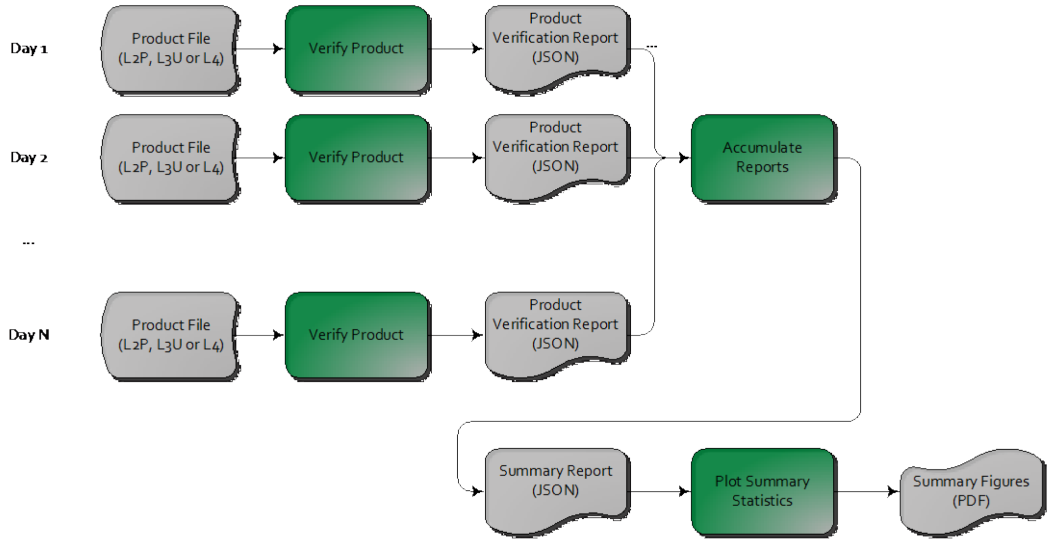


Figure 3-1: Processing workflow of the content verification procedure

Table 3-1: Checks conducted per product file for L2P and L3U

Name	**Description**
Is File	Fails if a product file is not a regular is a file (but e.g. a link or a directory)
Filename	Fails if the name of a product file does not comply with the naming convention defined in the PSD
Can Open	Fails if a product file is not readable or not a netCDF file
Lat Exists	Fails if the 'lat' variable does not exist
Lon Exists	Fails if the 'lon' variable does not exist
SST Exists	Fails if the 'sea_surface_temperature' variable does not exist
Time Exists	Fails if the 'time' variable does not exist
SST DTime Exists	Fails if the 'sst_dtime' variable does not exist
SSES Bias Exists	Fails if the 'sses_bias' variable does not exist
SSES St Dev Exists	Fails if the 'sses_standard_deviation' variable does not exist
Large Scale Unc Exists	Fails if the 'large_scale_correlated_uncertainty' variable does not exist
Adjustment Unc Exists	Fails if the 'adjustment_uncertainty' variable does not exist
Synoptic Unc Exists	Fails if the 'synoptically_correlated_uncertainty' variable does not exist
Uncorrelated Unc Exists	Fails if the 'uncorrelated_uncertainty' variable does not exist
SST Depth Exists	Fails if the 'sea_surface_temperature_depth' variable does not exist
SST Depth Unc Exists	Fails if the 'sst_depth_total_uncertainty' variable does not exist
Wind Speed Exists	Fails if the 'wind_speed' variable does not exist
L2P Flags Exist	Fails if the l2p_flags' variable does not exist
Quality Level Exists	Fails if the 'quality_level' variable does not exist

Name	Description
Aerosol Dyn Ind Exists	Fails if the ‘aerosol_dynamic_indicator’ variable does not exist
Probability Clear Exists	Fails if the ‘probability_clear’ variable does not exist (only for L2P)
Sensitivity Exists	Fails if the ‘sensitivity’ variable does not exist
SST Corrupt	Fails if all values of the ‘sea surface temperature’ variable are invalid

Table 3-2: Additional checks conducted per product file for L3U

Name	Description
Lat Bounds Exists	Fails if the ‘lat_bnds’ variable does not exist
Lon Bounds Exists	Fails if the ‘lon_bnds’ variable does not exist
Time Bounds Exists	Fails if the ‘time_bnds’ variable does not exist

Table 3-3: Checks conducted per pixel for L2P and L3U

Name	Description
Lat Min	Counts the number of pixels where the value of the ‘lat’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Lat Max	Counts the number of pixels where the value of the ‘lat’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Lon Min	Counts the number of pixels where the value of the ‘lon’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Lon Max	Counts the number of pixels where the value of the ‘lon’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SST DTime Min	Counts the number of pixels where the value of the ‘sst_dtime’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
SST DTime Max	Counts the number of pixels where the value of the ‘sst_dtime’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SST Min	Counts the number of pixels where the value of the ‘sea_surface_temperature’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
SST Max	Counts the number of pixels where the value of the ‘sea_surface_temperature’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SST Geophysical Min	Counts the number of pixels where the ‘SST – SST depth’ difference is less than -5 K. Fails if number counts are greater than zero.

Name	Description
SST Geophysical Max	Counts the number of pixels where the 'SST – SST depth' difference is greater than 10 K. Fails if number counts are greater than zero.
Quality Level Min	Counts the number of pixels where the value of the 'quality_level' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Quality Level Max	Counts the number of pixels where the value of the 'quality_level' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SSES Bias Min	Counts the number of pixels where the value of the 'sses_bias' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
SSES Bias Max	Counts the number of pixels where the value of the 'sses_bias' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SSES St Dev Min	Counts the number of pixels where the value of the 'sses_standard_deviation' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
SSES St Dev Max	Counts the number of pixels where the value of the 'sses_standard_deviation' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Large Scale Unc Min	Counts the number of pixels where the value of the 'large_scale_correlated_uncertainty' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Large Scale Unc Max	Counts the number of pixels where the value of the 'large_scale_correlated_uncertainty' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Adjustment Unc Min	Counts the number of pixels where the value of the 'adjustment_uncertainty' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Adjustment Unc Max	Counts the number of pixels where the value of the 'adjustment_uncertainty' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Synoptic Unc Min	Counts the number of pixels where the value of the 'synoptically_correlated_uncertainty' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Synoptic Unc Max	Counts the number of pixels where the value of the 'synoptically_correlated_uncertainty' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.

Name	Description
Uncorrelated Unc Min	Counts the number of pixels where the value of the 'uncorrelated_uncertainty' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Uncorrelated Unc Max	Counts the number of pixels where the value of the 'uncorrelated_uncertainty' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SST Depth Min	Counts the number of pixels where the value of the 'sea_surface_temperature_depth' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
SST Depth Max	Counts the number of pixels where the value of the 'sea_surface_temperature_depth' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
SST Depth Unc Min	Counts the number of pixels where the value of the 'sst_depth_total_uncertainty' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
SST Depth Unc Max	Counts the number of pixels where the value of the 'sst_depth_total_uncertainty' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Wind Speed Min	Counts the number of pixels where the value of the 'wind_speed' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Wind Speed Max	Counts the number of pixels where the value of the 'wind_speed' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
L2P Flags Min	Counts the number of pixels where the value of the 'l2p_flags' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
L2P Flags Max	Counts the number of pixels where the value of the 'l2p_flags' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Aerosol Dyn Ind Min	Counts the number of pixels where the value of the 'aerosol_dynamic_indicator' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Aerosol Dyn Ind Max	Counts the number of pixels where the value of the 'aerosol_dynamic_indicator' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Sens Min	Counts the number of pixels where the value of the 'sensitivity' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.

Name	Description
Sens Max	Counts the number of pixels where the value of the 'sensitivity' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Time Min	Counts the number of pixels where the value of the 'time' variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Time Max	Counts the number of pixels where the value of the 'time' variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Quality Level Mask N	For each quality level L ∊ {2, 3, 4, 5} counts the number of pixels where the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'quality level' variable is equal to L (i.e. is not masked). Fails if number counts are greater than zero.
Quality Level Mask P	Counts the number of pixels where the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'quality level' variable is equal to 0. Fails if number counts are greater than zero.
SSES Bias Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'sses_bias' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.
SSES Bias Mask P	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'sses_bias' variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
SSES St Dev Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'sses_standard_deviation' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.
SSES St Dev Mask P	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'sses_standard_deviation' variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
Adjustment Unc Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'adjustment_ uncertainty' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.

Name	Description
Adjustment Unc Mask P	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'adjustment_uncertainty' variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
Large Scale Unc Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'large_scale_correlated_uncertainty' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.
Large Scale Unc Mask P	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'large_scale_correlated_uncertainty' variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
Synoptic Unc Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'synoptically_correlated_uncertainty' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.
Synoptic Unc Mask P	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'synoptically_correlated_uncertainty' variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
Uncorrelated Unc Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'uncorrelated_uncertainty' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.
Uncorrelated Unc Mask P	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is not equal to the fill value (i.e. is not masked) but the value of the 'uncorrelated_uncertainty' variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
SST Depth Mask N	For each quality level L ∊ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the 'quality_level' variable is equal to L, the value of the 'sea_surface_temperature' variable is equal to the fill value (i.e. is masked) but the value of the 'sea_surface_temperature_depth' variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.

Name	Description
SST Depth Mask P	For each quality level L ∈ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the ‘quality_level’ variable is equal to L, the value of the ‘sea_surface_temperature’ variable is not equal to the fill value (i.e. is not masked) but the value of the ‘sea_surface_temperature_depth’ variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.
SST Depth Unc Mask N	For each quality level L ∈ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the ‘quality_level’ variable is equal to L, the value of the ‘sea_surface_temperature_depth’ variable is equal to the fill value (i.e. is masked) but the value of the ‘sst_depth_total_uncertainty’ variable is not equal to the fill value (i.e. is not masked). Fails if number counts are greater than zero.
SST Depth Unc Mask P	For each quality level L ∈ {0, 1, 2, 3, 4, 5} counts the number of pixels where the value of the ‘quality_level’ variable is equal to L, the value of the ‘sea_surface_temperature_depth’ variable is not equal to the fill value (i.e. is not masked) but the value of the ‘sst_depth_total_uncertainty’ variable is equal to the fill value (i.e. is masked). Fails if number counts are greater than zero.

Table 3-4: Checks conducted per pixel only for L2P

Name	Description
Prob Clear Min	Counts the number of pixels where the value of the ‘probability_clear’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Prob Clear Max	Counts the number of pixels where the value of the ‘probability_clear’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.

Table 3-5: Checks conducted per pixel only for L3U

Name	Description
Lat Bnds Min	Counts the number of pixels where the value of the ‘lat_bnds’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Lat Bnds Max	Counts the number of pixels where the value of the ‘lat_bnds’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Lon Bnds Min	Counts the number of pixels where the value of the ‘lon_bnds’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Lon Bnds Max	Counts the number of pixels where the value of the ‘lon_bnds’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.
Time Bnds Min	Counts the number of pixels where the value of the ‘time_bnds’ variable is not equal to the fill value but less than the minimum valid value. Fails if number counts are greater than zero.
Time Bnds Max	Counts the number of pixels where the value of the ‘time_bnds’ variable is not equal to the fill value but greater than the maximum valid value. Fails if number counts are greater than zero.

Table 3-6: Summary of activities for verifying L3U products

Component and mode of use	ARC CCI processor when processing ATSR-series inputs to L3U SST outputs	
Requirements Addressed	CR-2, SST-TR-1,3,8,13,16,25,33	
Summary description of verification	• A sample of L3U output files are checked for completeness of content and consistency with product specification • All files are checked for content ensuring that all variables have values within the specified limits or fill values	
L3U content verification	Files	All SST-CCI L3U files (not listed)
	Verification activities	• Scripting the automated verification • Checking file name complies with naming convention • Checking file is a netCDF file and can be read • Checking following fields are present and have values within valid range or correct fill values o SST skin o SST depth o All flags o Uncertainty fields • Verifying geophysical validity of key fields within plausible ranges • Verifying mask consistency
L3U sample verification	Files	• One early and one late L3U file per sensor (listing in Section 4.1.2)
	Verification activities	• Manual inspection of all fields against PSD

3.2 Verifying the ARC CCI processor (L2P)

For verifying the content of the L2P products the same verification checks were conducted as described in the previous section for L3U products. A summary of verification activities is given in Table 3-7 below.

No activities were carried out for verifying the high-latitude classification in Phase-II, because the code from Phase-I has not been modified. The report of verification results in Phase-I is replicated here (Section 4.2.3) for completeness.

Table 3-7: Summary of activities for verifying L2P products

Component and mode of use	ARC CCI processor when processing AVHRR GAC inputs to L2P SST outputs.	
Requirements Addressed	CR-2, SST-TR-1,3,8,13,16,25,33	
Summary description of testing	• A sample of L2P output files are checked for completeness of content and consistency with product specification • All files are checked for content ensuring that all variables have values within the specified limits or fill value	
L2P content verification	Files	All SST-CCI L2P files (not listed)

	Verification activities	• Scripting the automated verification
		• Checking file name complies with naming convention
		• Checking file is a netCDF file and can be read
		• Checking following fields are present and have values within valid range or correct fill values
		  o SST skin
		  o SST depth
		  o All flags
		  o Uncertainty fields
		• Verifying geophysical validity of key fields within plausible ranges
		• Verifying mask consistency

L2P sample verification	Files	• One early and one late L2P file per sensor (listing in Section 4.2.2).
	Verification activities	• Manual inspection of all fields against PSD.

3.3 Verifying the AVHRR GAC pre-processor

AVHRR GAC data are pre-processed to level L1C prior to generating MMS data and running the ARC CCI processor on these data. Due to the length of the GAC data archive, the file format has evolved over time and the pre-processing step harmonises the data format across the archive. It also has the function of inserting missing lines in earlier data acquisitions where these may have been omitted from the original data download. This is an important pre-processing step for the cloud detection element of the ARC CCI processing as it prevents the interpolation of NWP data over invalid distances (due to un-flagged missing scan lines).

The L1C pre-processor uses the GBCS code base and reads the L1B data, which it then saves out in NetCDF format after checking for missing scan lines and inserting these where appropriate. Verification of the pre-processor was undertaken by a number of members of the consortium to ensure that the L1C files contained the appropriate information for the various applications of the data. The file contents had to be verified for inclusion in the MMS, SST processing and AVHRR calibration improvements. The verification process included printing and plotting of file contents, checking output and metadata content. L1C data have been successfully used to generate the AVHRR SST archive and MMS outputs.

3.4 Verifying the DV processor

At the time of writing this document a new DV model is being worked on. No verification activities on the new DV model have been carried out in Phase-II yet.

The activities for verifying the DV processor developed in Phase-I, which has also been used in Phase-II so far, is described in the previous version of this "System Verification Report" [RD.329] and replicated here (Section 4.3) for completeness.

3.5 Verifying the MMS

The MMS has been in continuous development in order to address the various use cases of the SST CCI project, and continuous testing of code units has been an integral part of the coding process. Not every line of code is covered by unit-level tests. But in Phase-II considerable effort has been put into increasing the test coverage from 11 to 38.5 per cent of lines.

Code related to the geo-location of satellite swaths and image pixels has been developed in pair programming. A fast point-in-polygon test function that has been particularly developed for the MMS has been verified with representative example geometries explicitly, in addition to the more primitive unit-level tests. For each MMD file produced, a plot showing the distribution of samples was produced routinely and spot-checked occasionally.

The correct location of matches in MMD files and the correct extraction of satellite, ancillary and in-situ data have been spot-checked. Implementing routine tests integrated into the automated test-suites also for these functions is planned. Verification of correct extraction was also carried out in the product inter-comparison and validation work package.

The science team has used the produced MMD files within their work packages. Any problems identified were reported to the development team, which solved the problems as quick as possible. A record of problem reports exists in form of e-mail exchanges but is not included in this System Verification Report.

The verification procedures for the MMS address requirement SST-TR-48.

3.6 Verifying tools

A summary of activities for verifying the regional averaging and re-gridding tools is given in Table 3-8 below.

Table 3-8: Summary of activities for verifying the regional averaging and regridding tools

Component and mode of use	Tools for regional averaging and re-gridding of L2P, L3U, L3C and L4 products
Requirements Addressed	SST-TR-12
Summary description of testing	• Routine end-to-end tests to verify regional averaging tool • Routine end-to-end tests to verify re-gridding tool
Regional Averaging Tool	• Regional averaging tool is tested at daily, monthly, seasonal and yearly resolution for example L2P, L3U, L3C and L4 files
Re-gridding Tool	• Re-gridding tool is tested at 1 day, 5 day, 7 day and monthly resolutions for L2P, L3U and L3 data • Re-gridding of the whole L2P and L3U products from Phase-I for use by M. Scharffenberg (University of Hamburg) • Re-gridding tool used to generate the NCEO SST dataset

3.7 Verifying the CEMS and CCI Open Data Portal data download

A summary of activities for verifying the CEMS and CCI Open Data Portal data download function is given in Table 3-9 below.

Table 3-9: Summary of activities for verifying data download

Component and mode of use	NEODC web interface for download of SST-CCI data from the CEMS facility
Requirements Addressed	SST-TR-53
Summary description of testing	• Test registration for dataset access • Download individual L2P, L3U and L4 data files • Download multiple files or directories of L2P, L3U and L4 files
Component and mode of use	CCI Portal web interface for download of SST-CCI data
Requirements Addressed	SST-TR-53
Summary description of testing	• Check that links to CEMS facility are working and point to the correct target pages

4. RECORD OF VERIFICATION RESULTS

4.1 ARC CCI processor (L3U)

4.1.1 Content verification

Content verification checks have been carried out for all L3U products obtained from ATSR1, ATSR2, AATSR and AVHRR series of sensors. The results of the L3U product and pixel checks are represented in horizontal bar charts shown in Figure 4-1 to Figure 4-34 below.

For all bar charts the left vertical axis lists the names of the checks conducted as defined in Table 3-1 and Table 3-2. The right vertical axis lists the number of occurrences where the check named on the left vertical axis has failed. For each check, a horizontal bar visualises the failure permillage (failure rate measured per thousand). If there is no bar drawn for a check, the check has been passed completely, without any failures. The number of product files (or pixels) checked in total is given in the label of the horizontal axis at the bottom.

The mask consistency tests defined in Table 3-3 are conducted per quality level. The results for these tests are visualised per quality level in form of a stacked bar. The total lengths of the stacked bar corresponds to the total permillage of failures for all quality levels. If the check does not distinguish between quality levels, the colour for “all” is used. The failure counts appearing on the right vertical axis also refer to the total number of failures.

In summary, all of the checks have been passed without failures. The only exception within the product checks is ‘SST Corrupt’ that has failed with a rate of less than 6 percent of products. This is a significant increase with respect to the previous dataset. The failure is due to L1b products that do not contain any valid pixel data.

The pixel checks have revealed mask inconsistencies between the sea surface temperature and uncertainty and bias data for quality levels 0 (no_data) and 1 (bad_data) that were not expected. The failure rate of these checks is in most cases above 10 percent. Nevertheless, the overall usability of the data is not affected by these masking inconsistencies. This issue is being added to the issue tracking system and investigated by the development team.

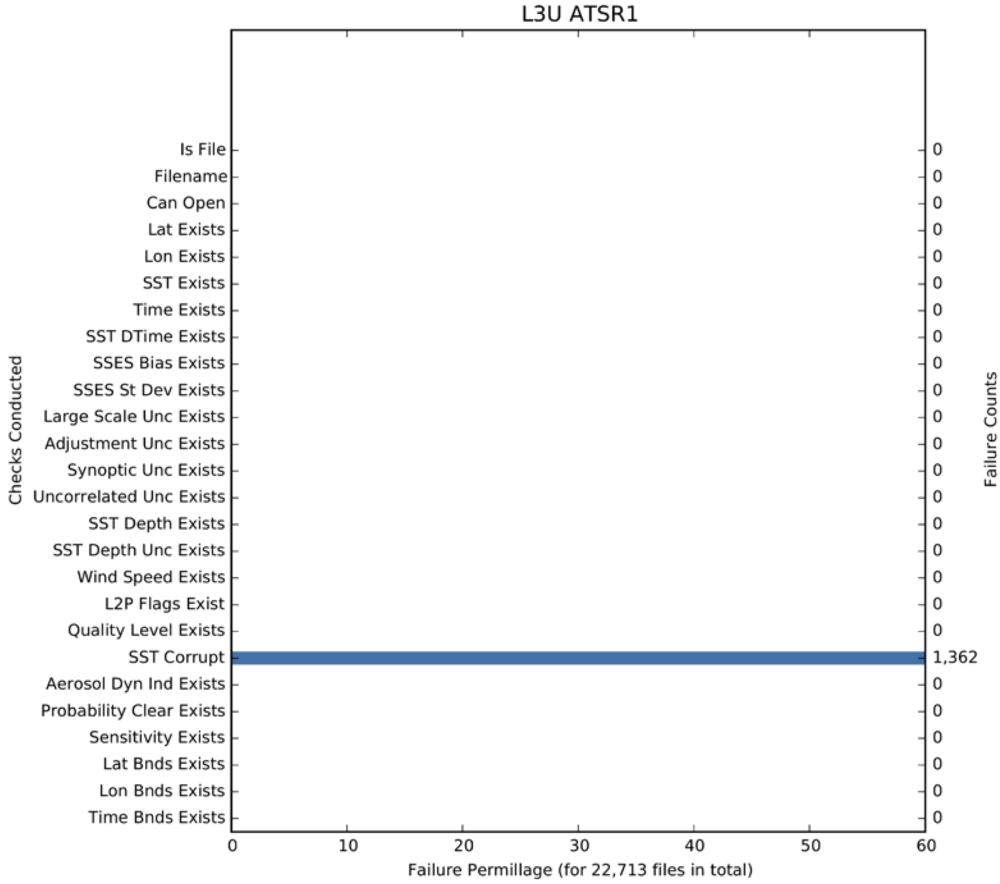


Figure 4-1: Results of L3U product checks for ATSR1

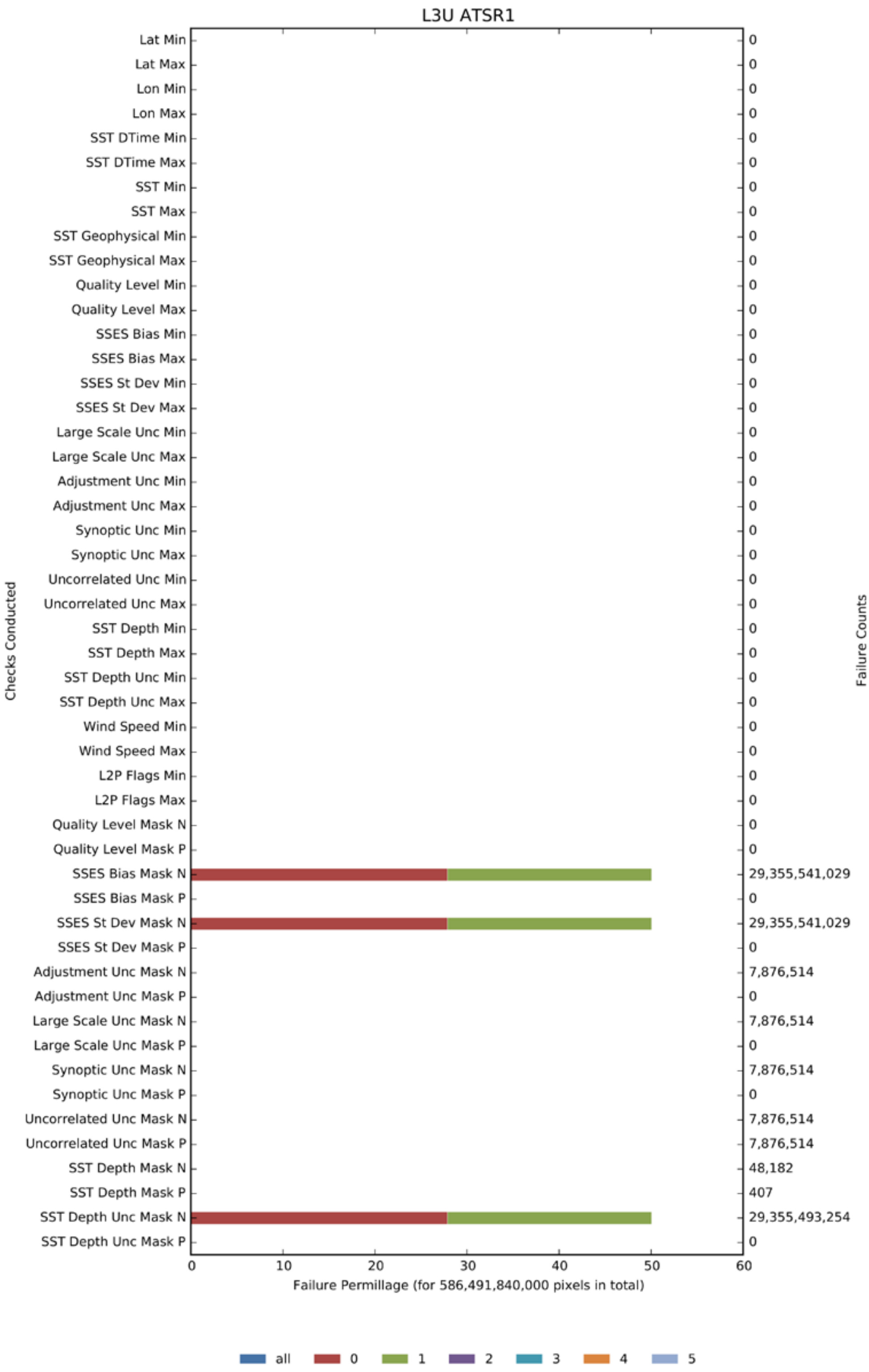


Figure 4-2: Results of L3U pixel checks for ATSR1

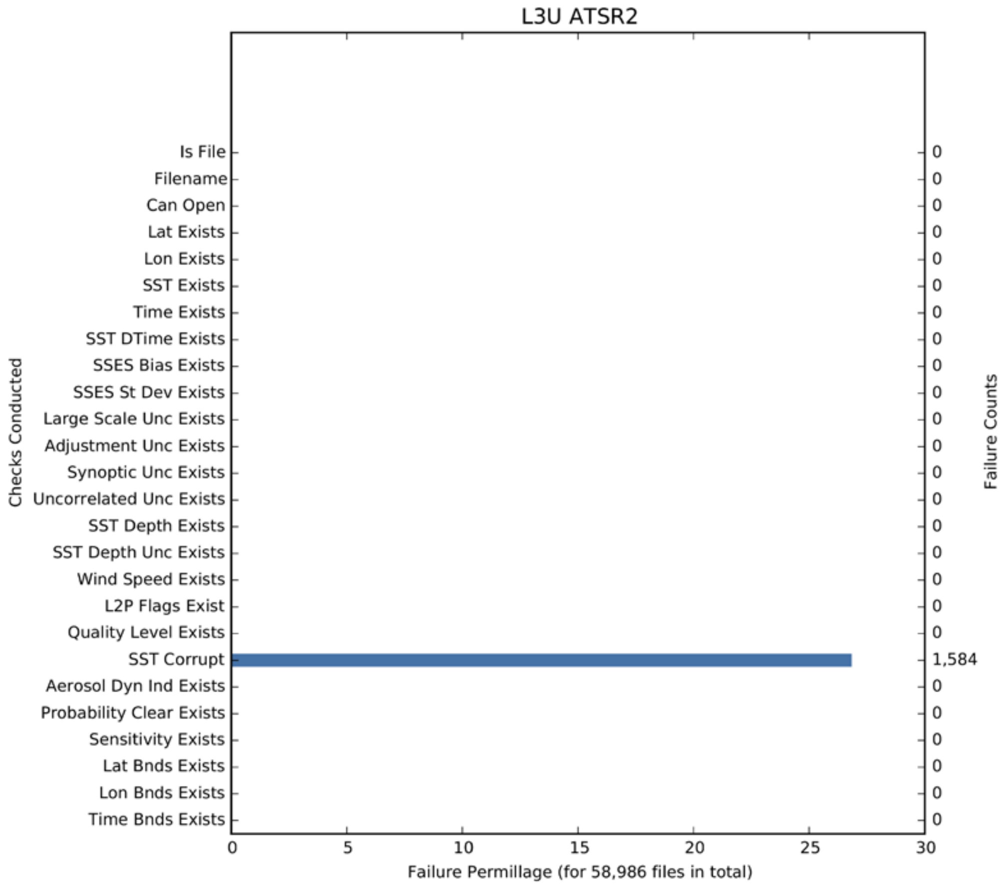


Figure 4-3: Summary of L3U product checks for ATSR2

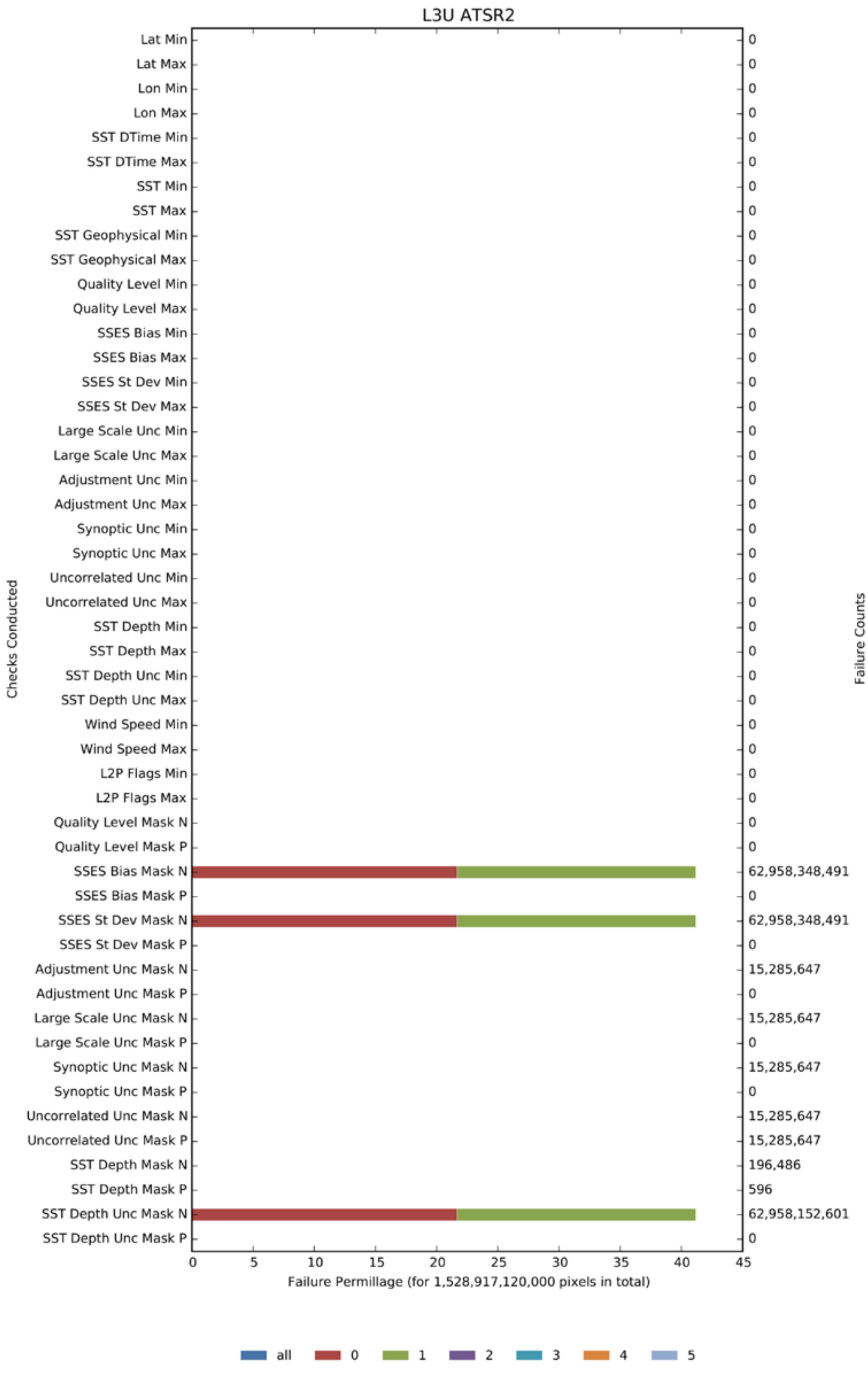


Figure 4-4: Results of L3U pixel checks for ATSR2

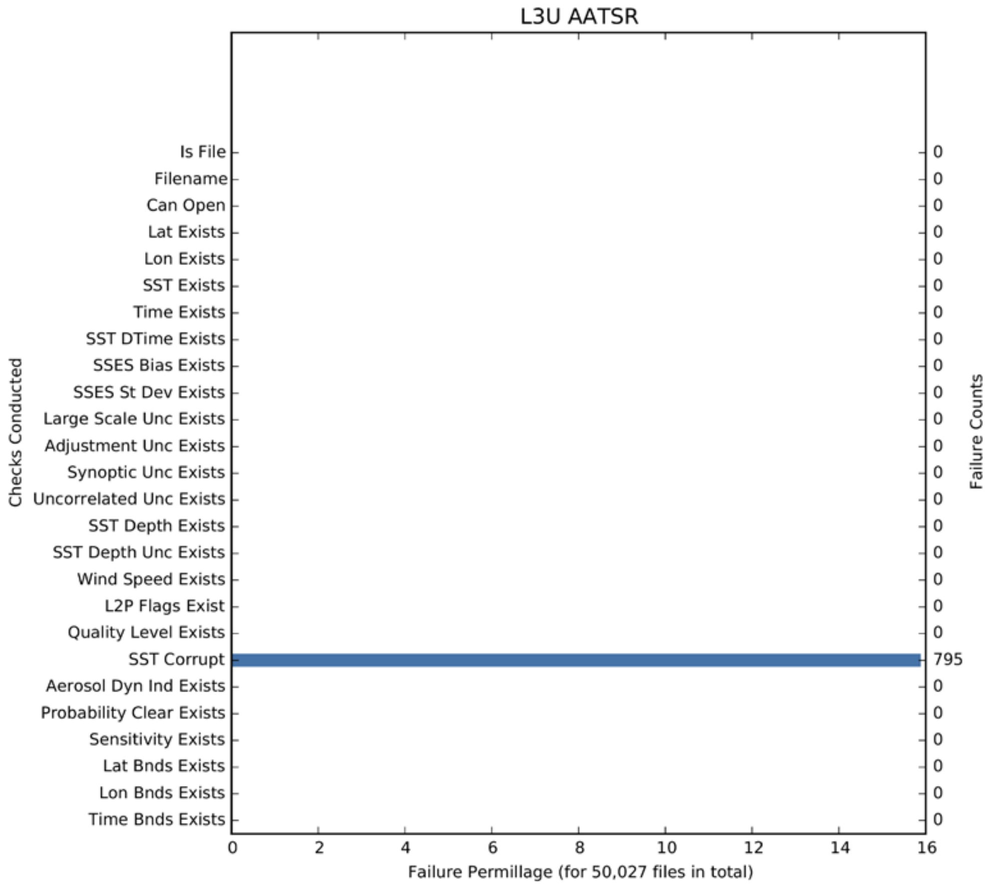


Figure 4-5: Summary of L3U product checks for AATSR

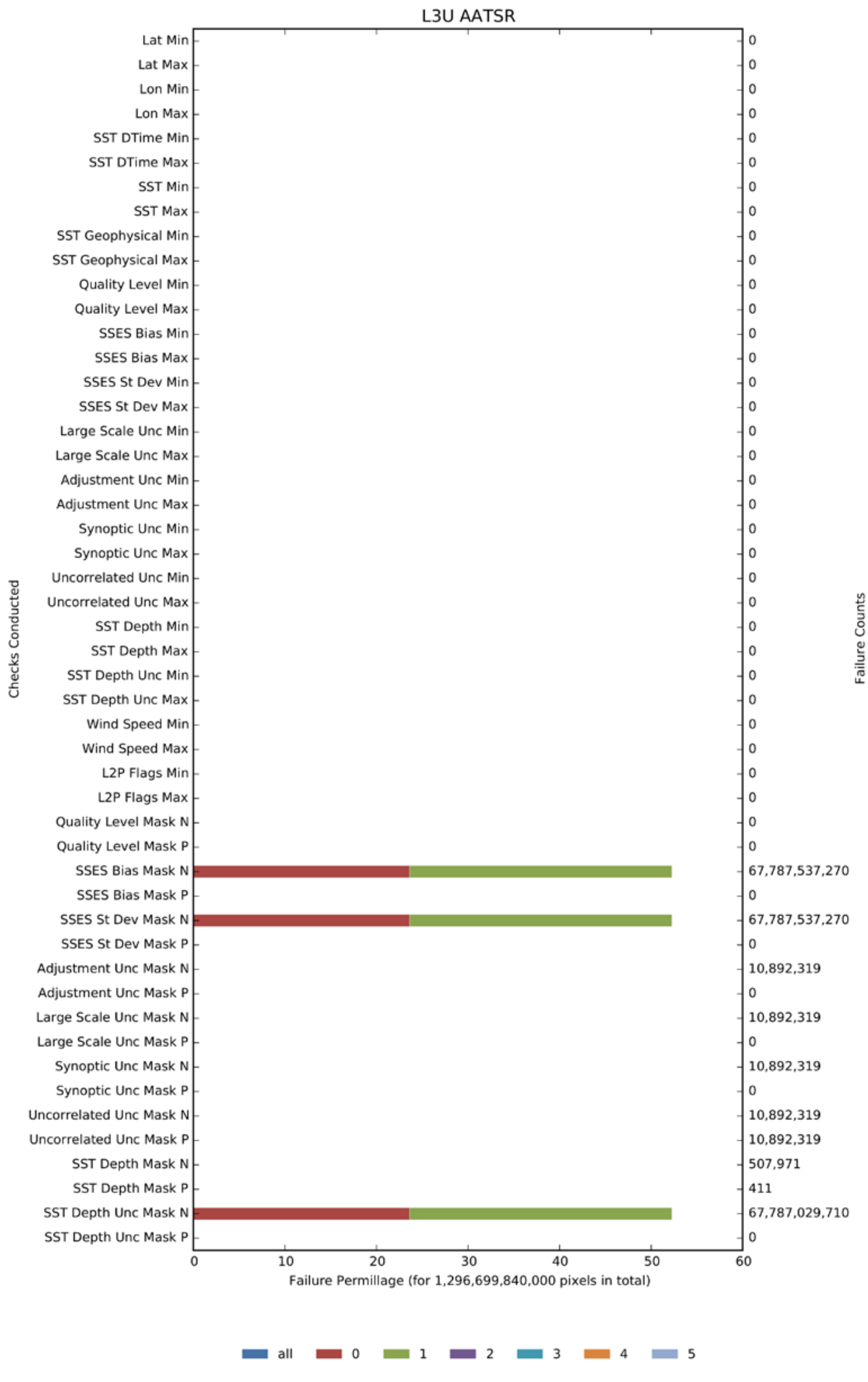


Figure 4-6: Results of L3U pixel checks for AATSR

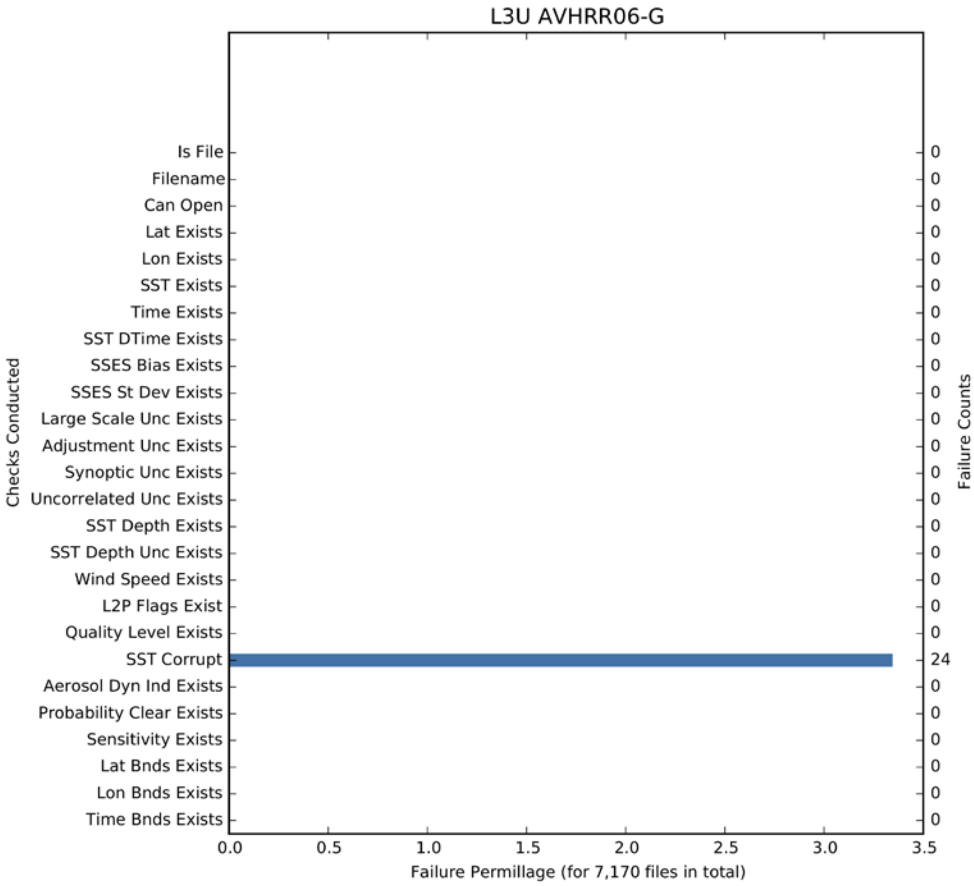


Figure 4-7: Summary of L3U product checks for AVHRR06_G

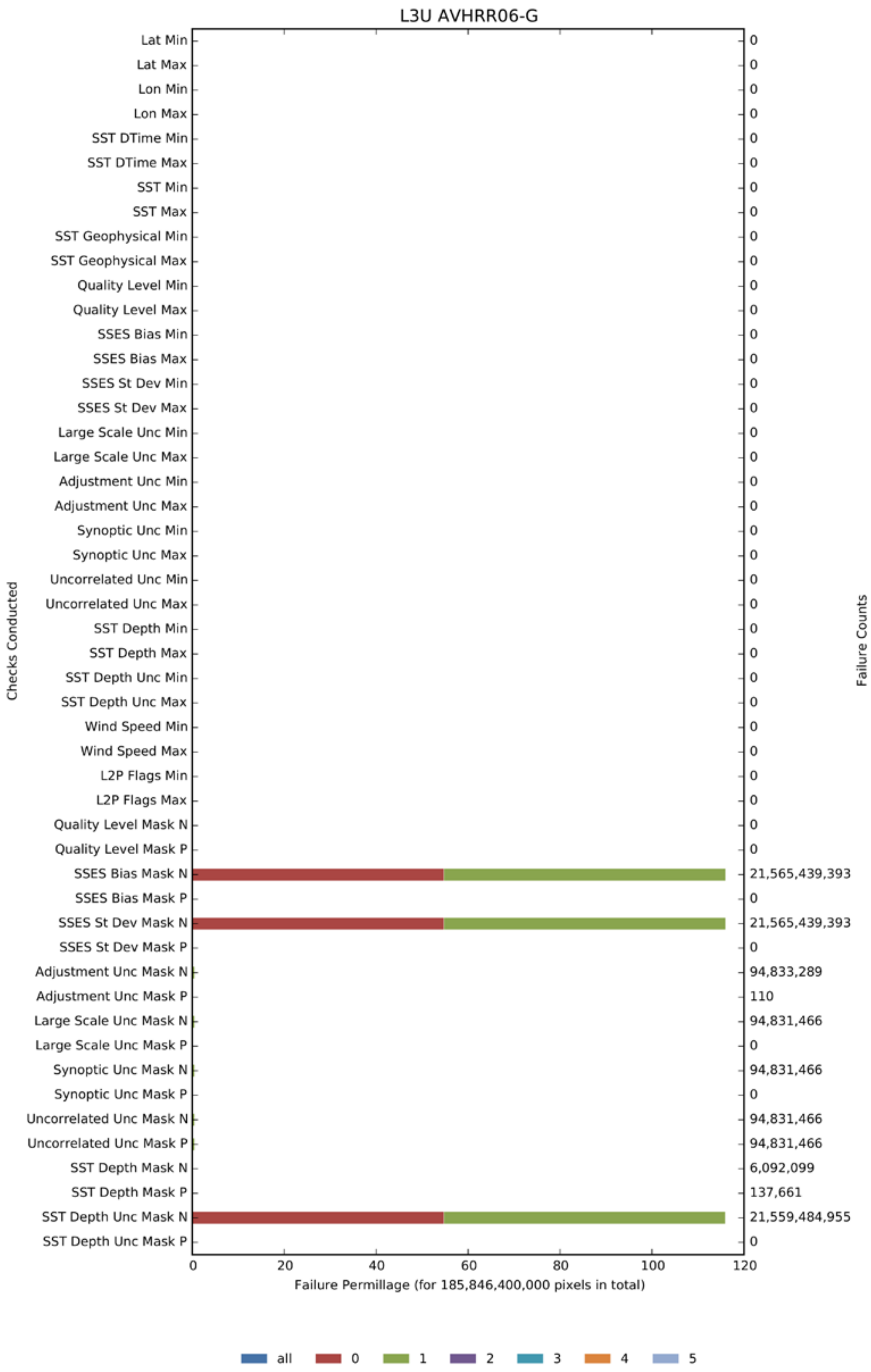


Figure 4-8: Results of L3U pixel checks for AVHRR06_G

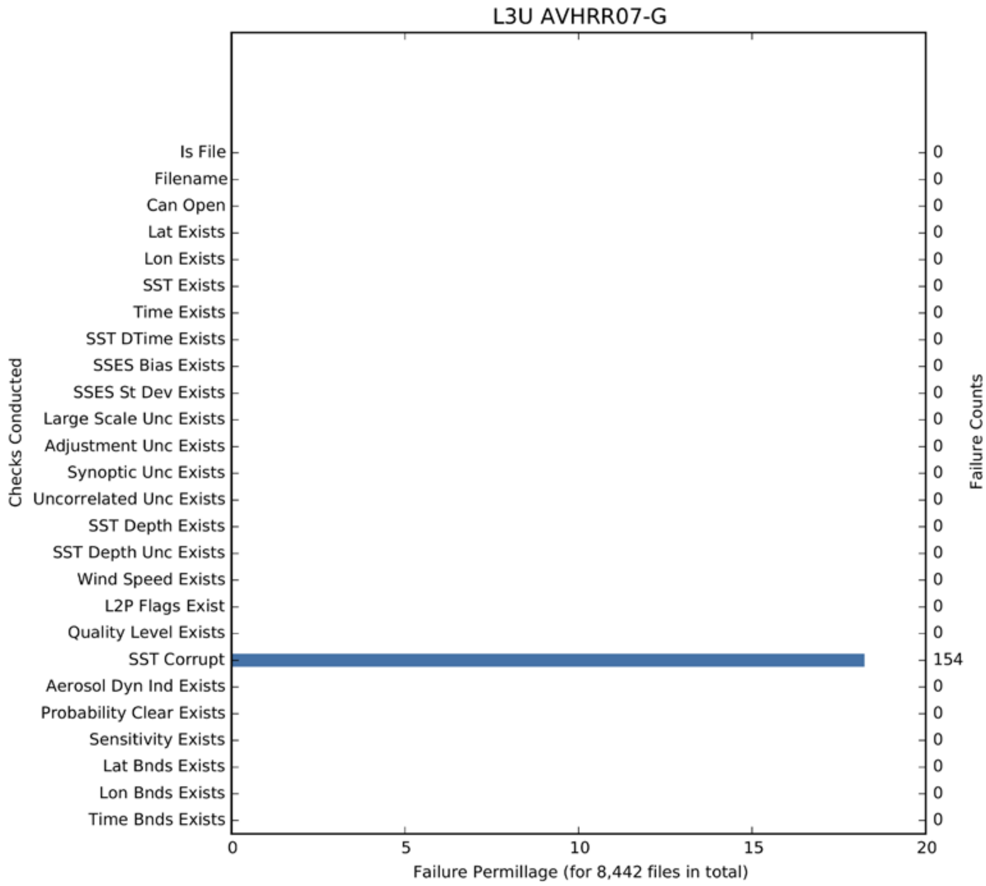


Figure 4-9: Summary of L3U product checks for AVHRR07_G

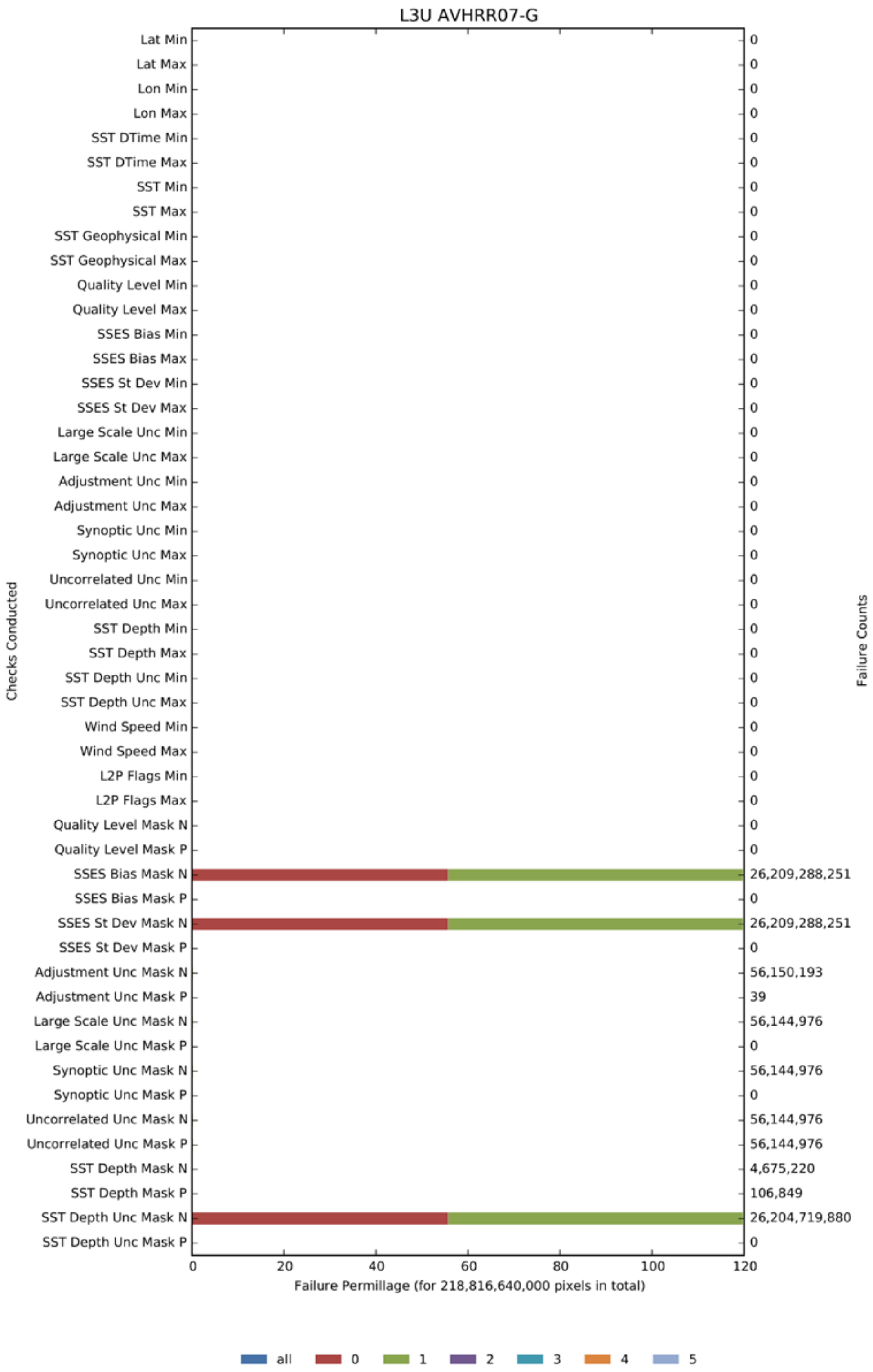


Figure 4-10: Results of L3U pixel checks for AVHRR07_G

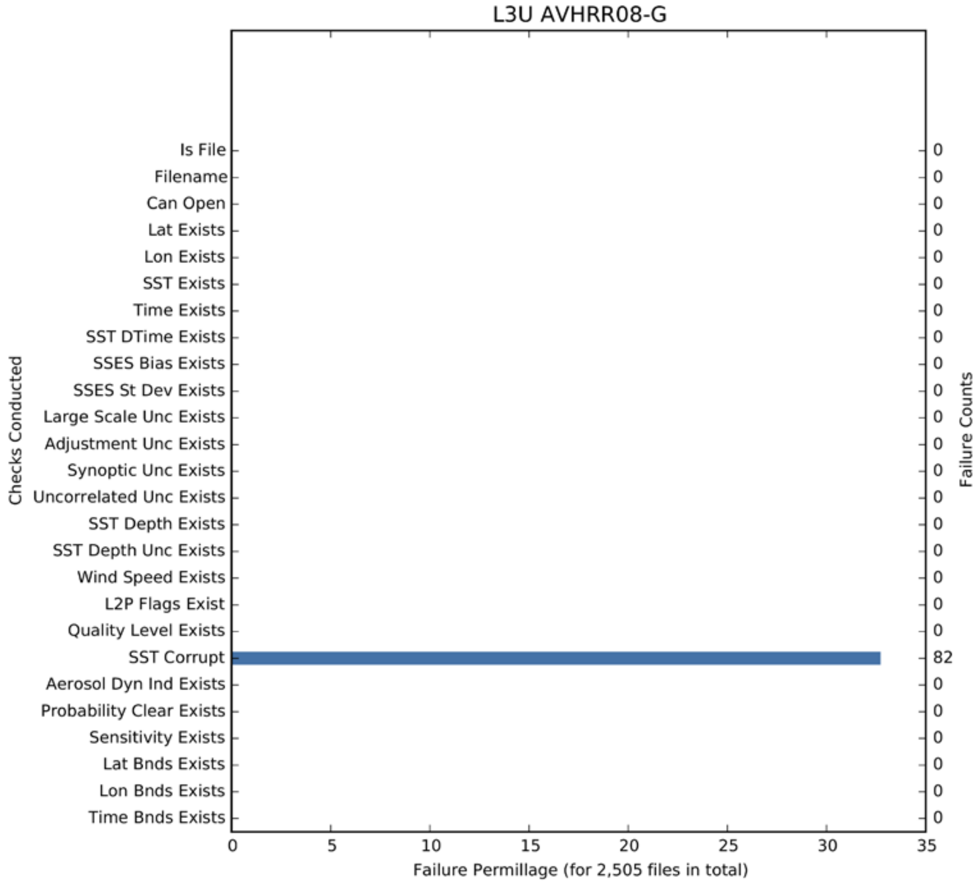


Figure 4-11: Summary of L3U product checks for AVHRR08_G

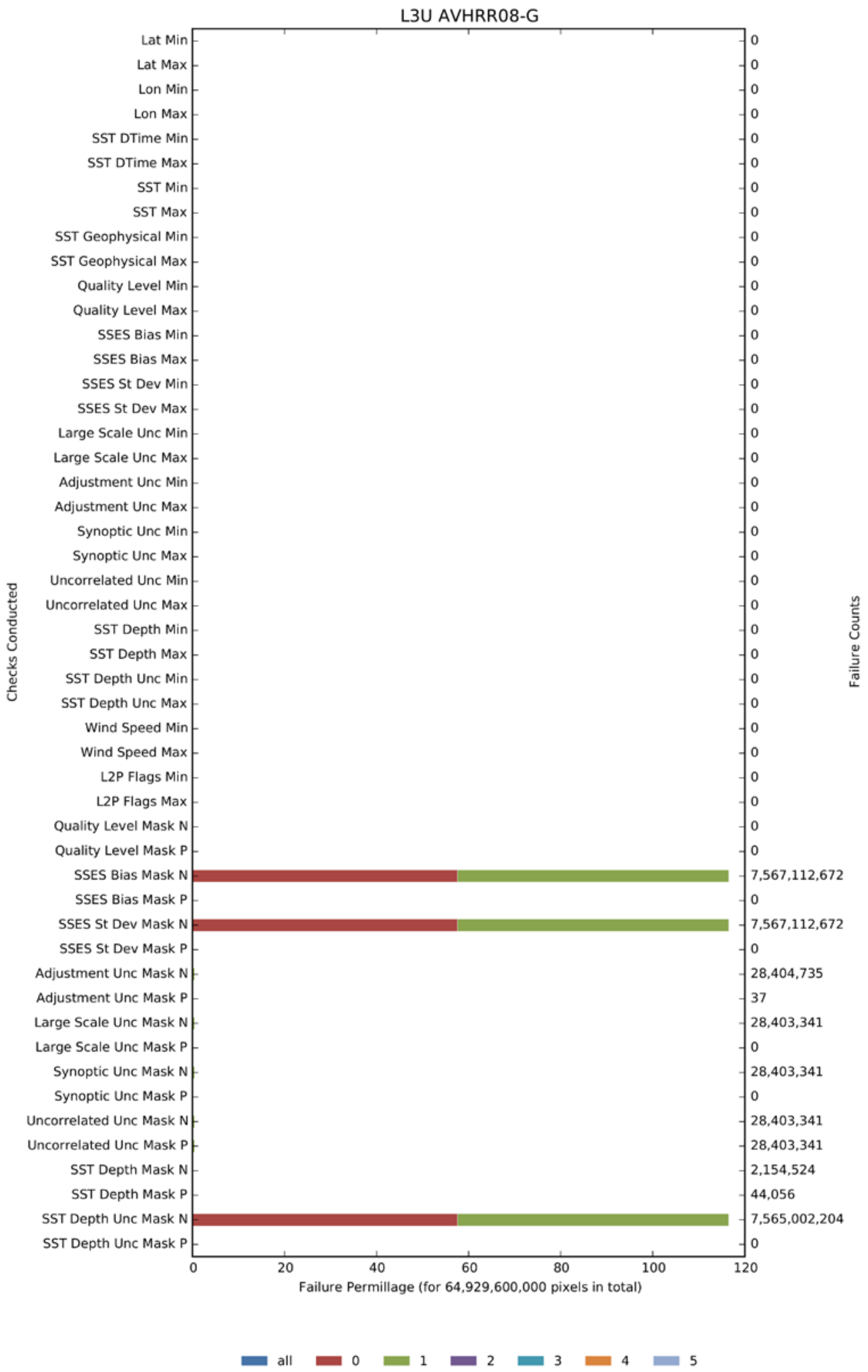


Figure 4-12: Results of L3U pixel checks for AVHRR08_G

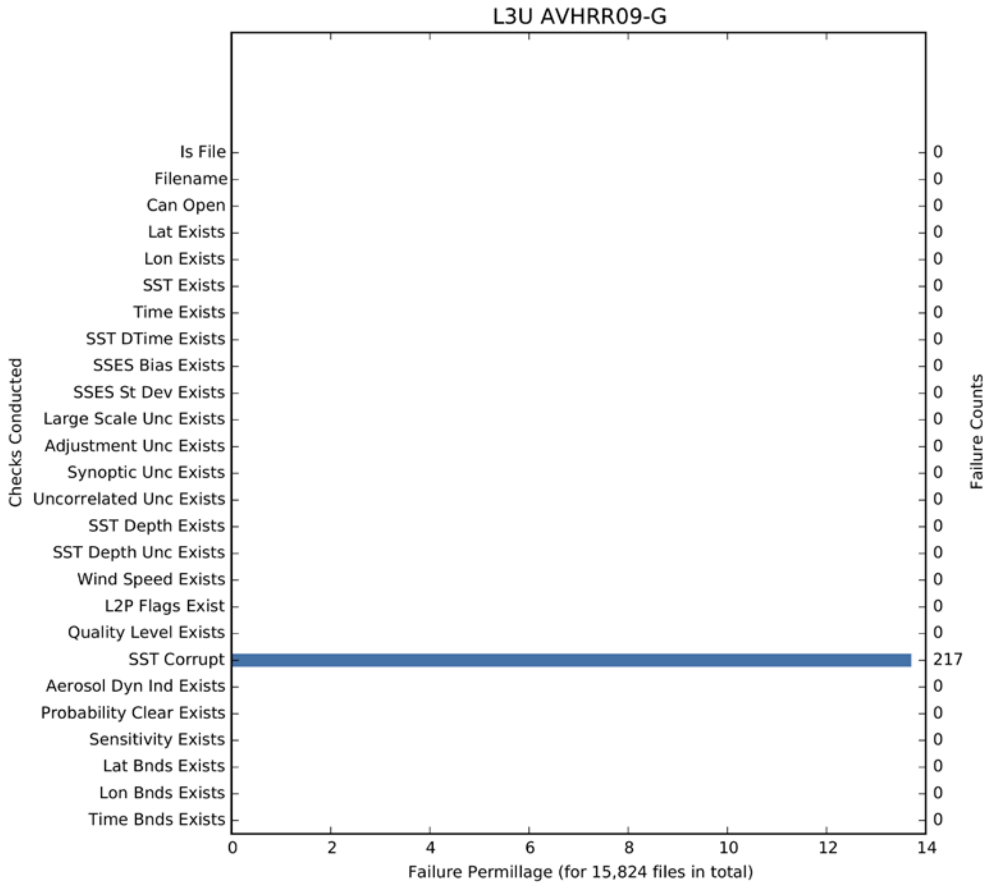


Figure 4-13: Summary of L3U product checks for AVHRR09_G

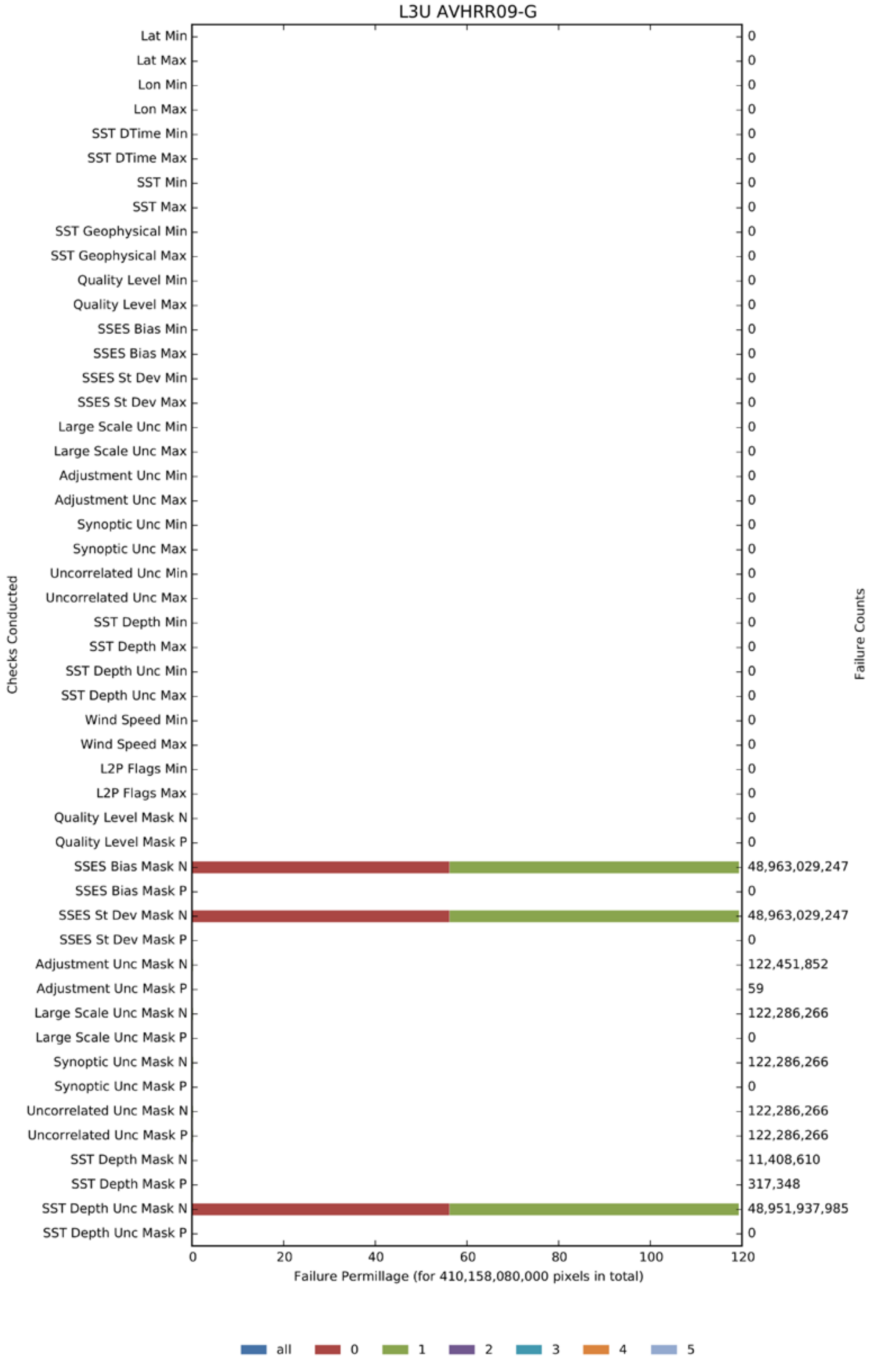


Figure 4-14: Results of L3U pixel checks for AVHRR09_G

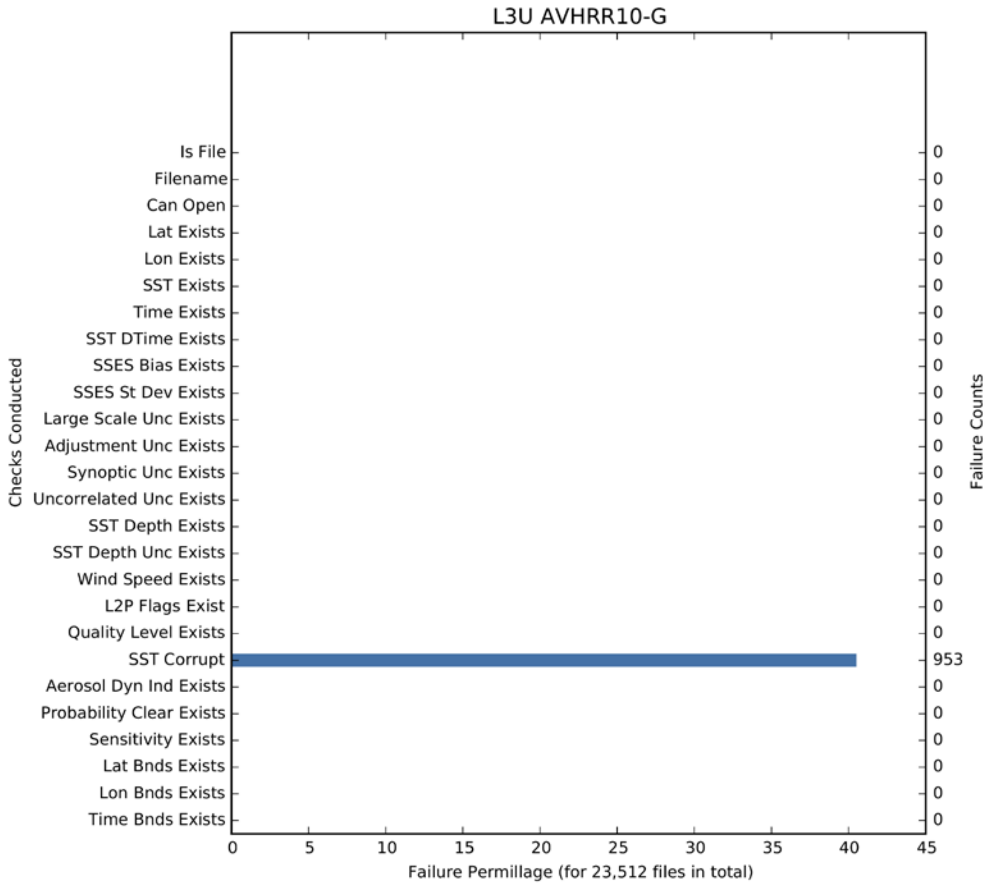


Figure 4-15: Summary of L3U product checks for AVHRR10_G

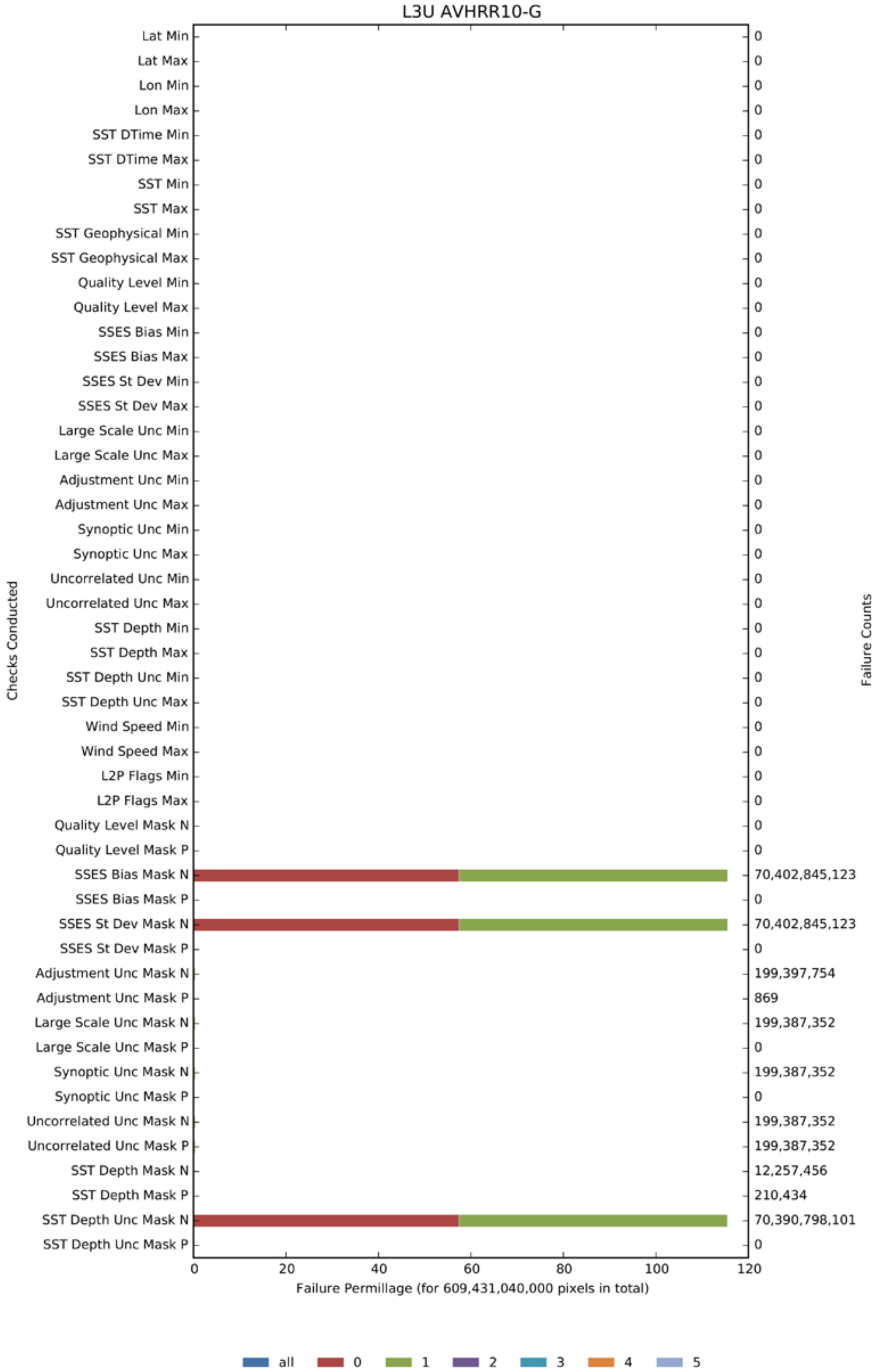


Figure 4-16: Results of L3U pixel checks for AVHRR10_G

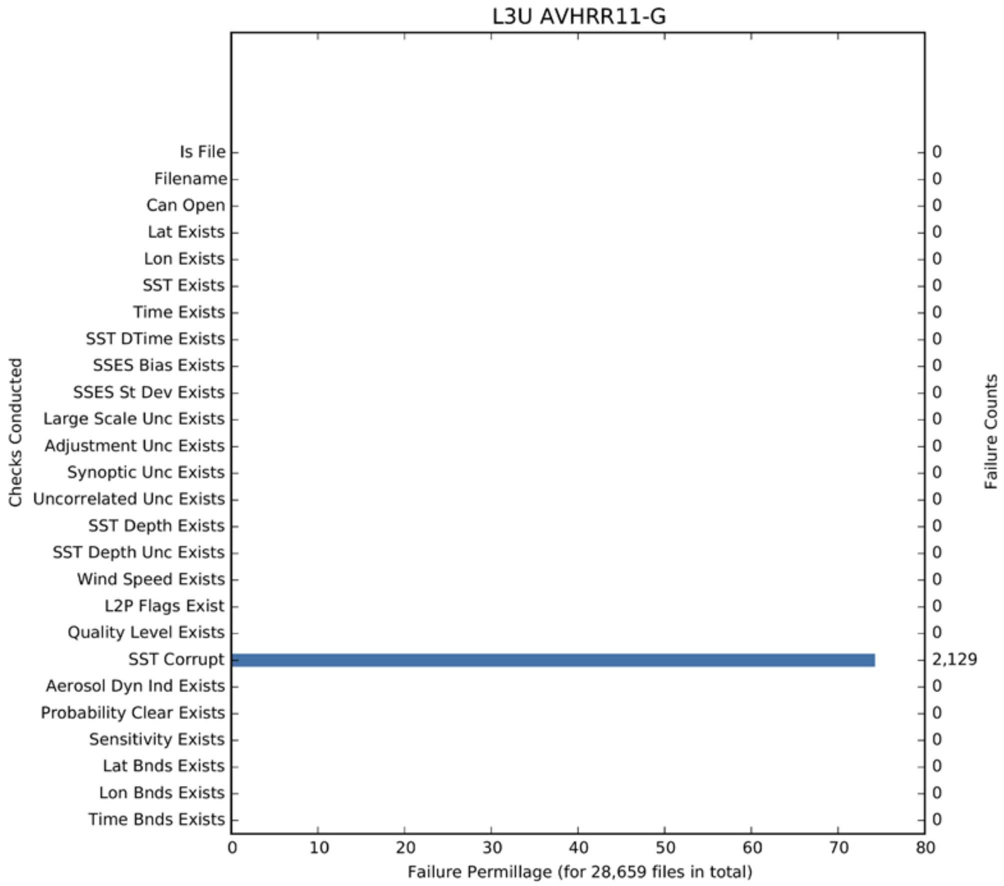


Figure 4-17: Summary of L3U product checks for AVHRR11_G

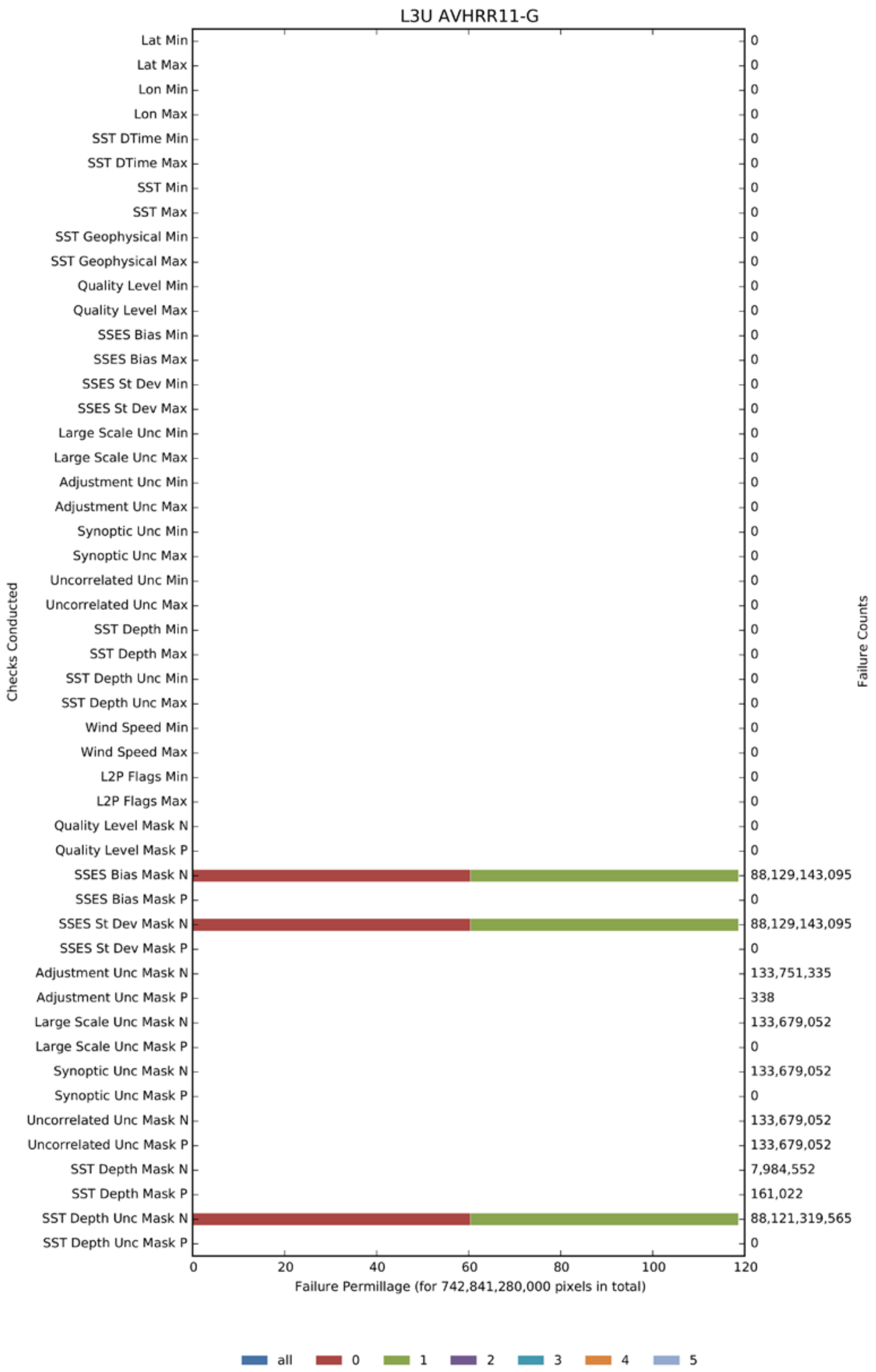


Figure 4-18: Results of L3U pixel checks for AVHRR11_G

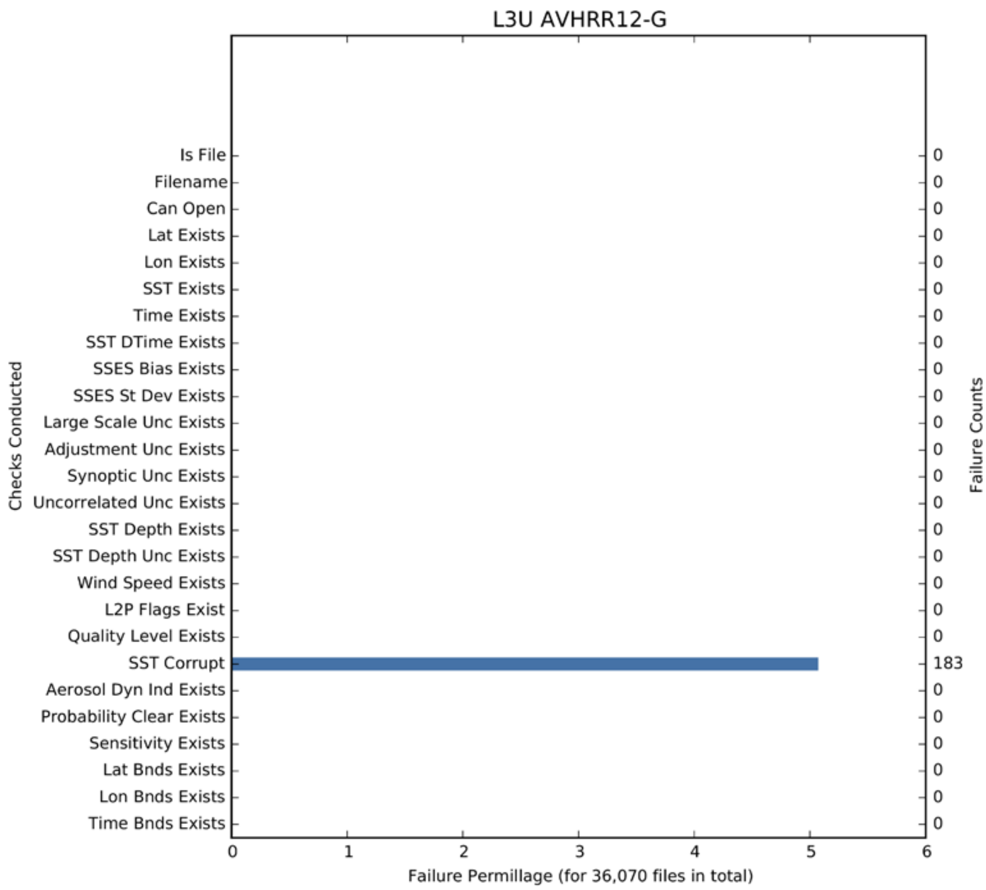


Figure 4-19: Summary of L3U product checks for AVHRR12_G

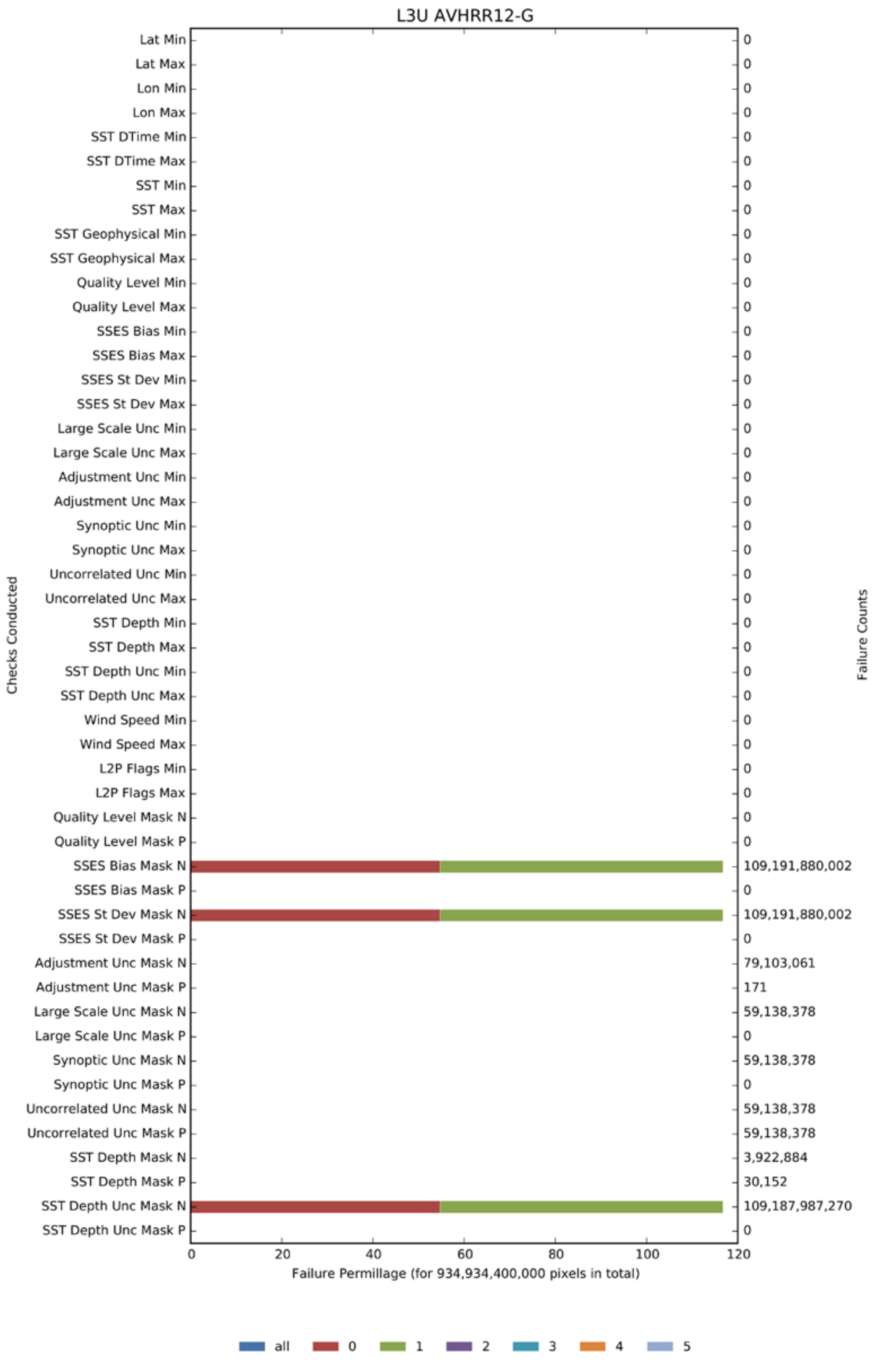


Figure 4-20: Results of L3U pixel checks for AVHRR12_G

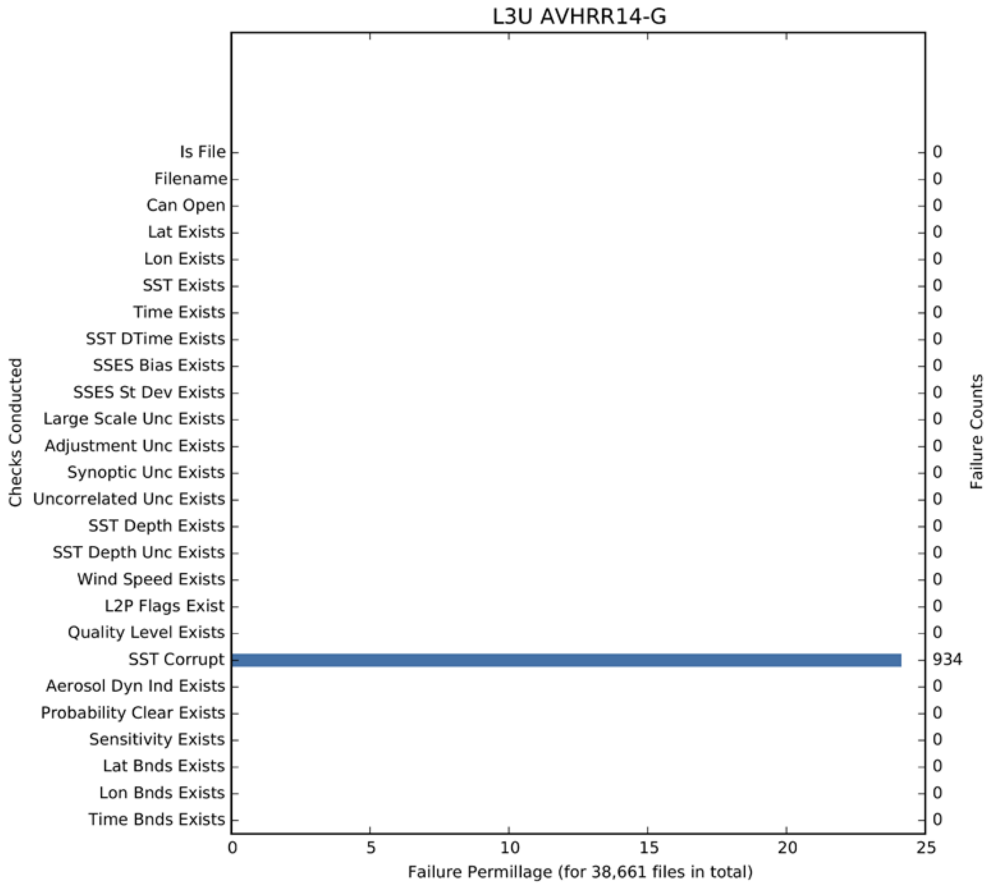


Figure 4-21: Summary of L3U product checks for AVHRR14_G

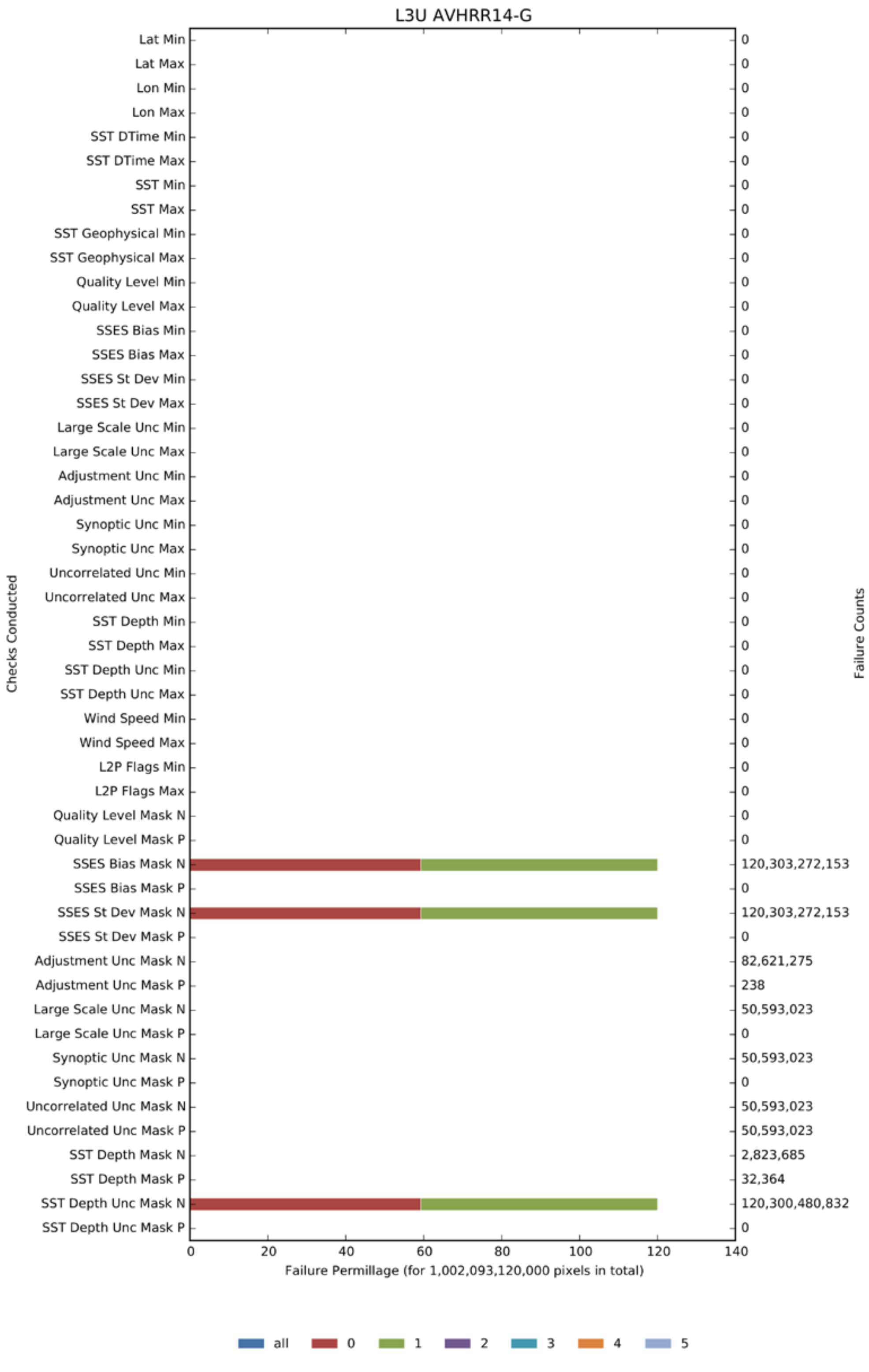


Figure 4-22: Results of L3U pixel checks for AVHRR14_G

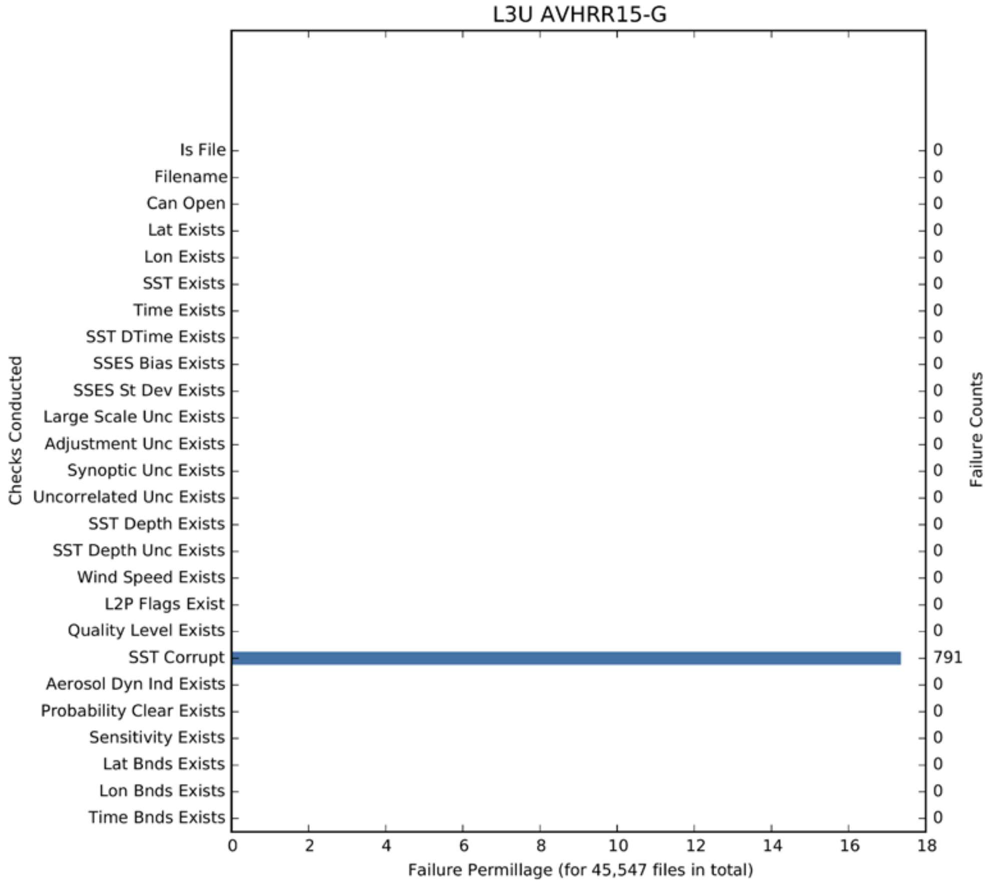


Figure 4-23: Summary of L3U product checks for AVHRR15_G

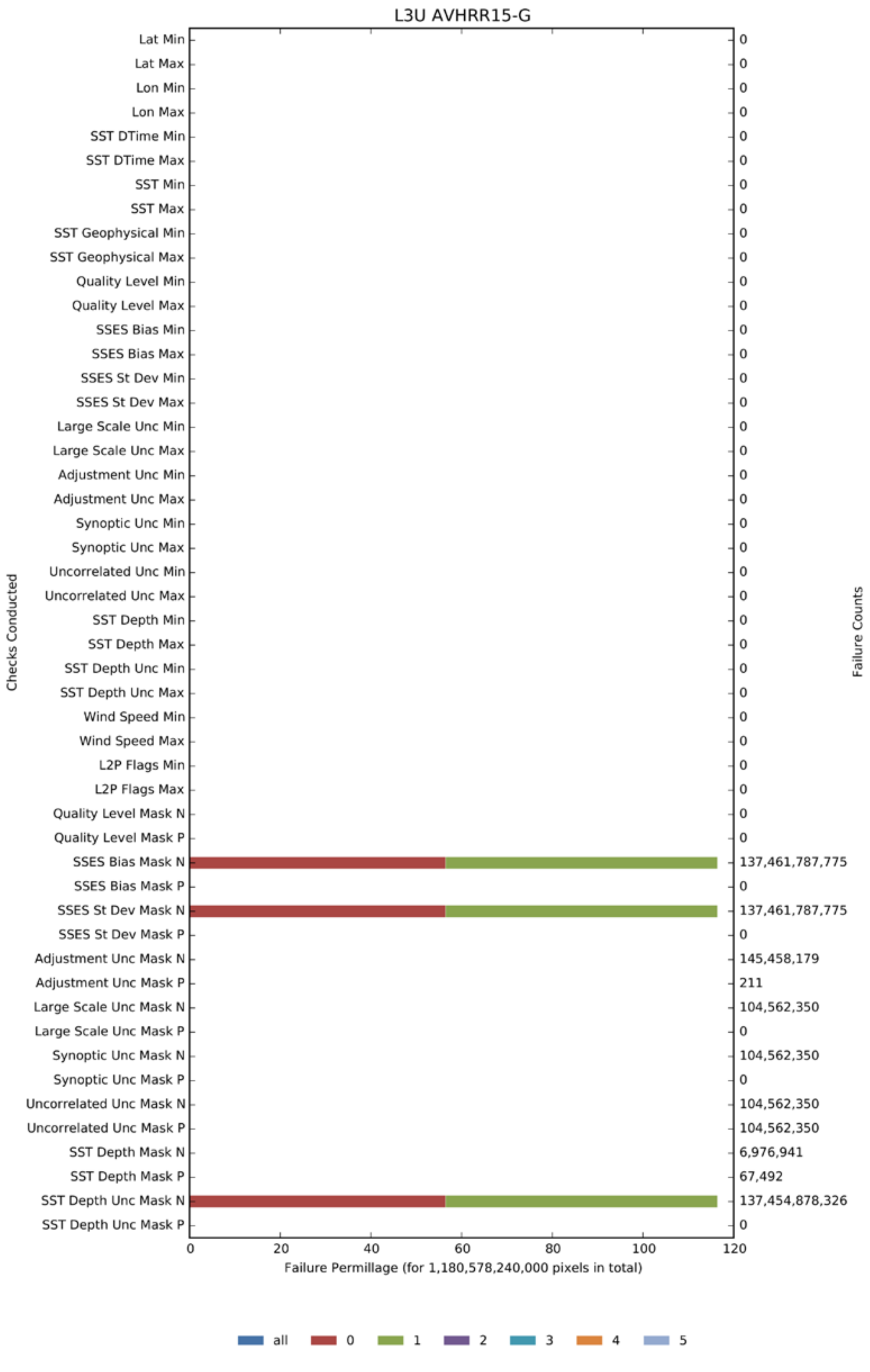


Figure 4-24: Results of L3U pixel checks for AVHRR15_G

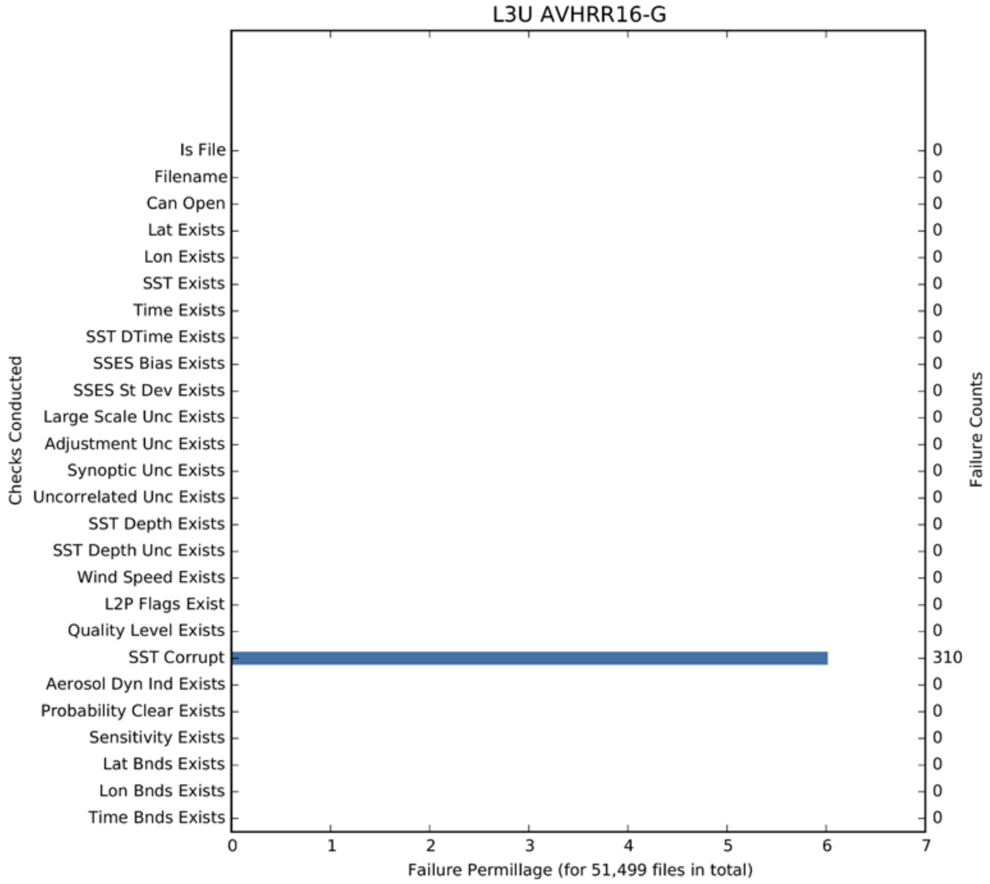


Figure 4-25: Summary of L3U product checks for AVHRR16_G

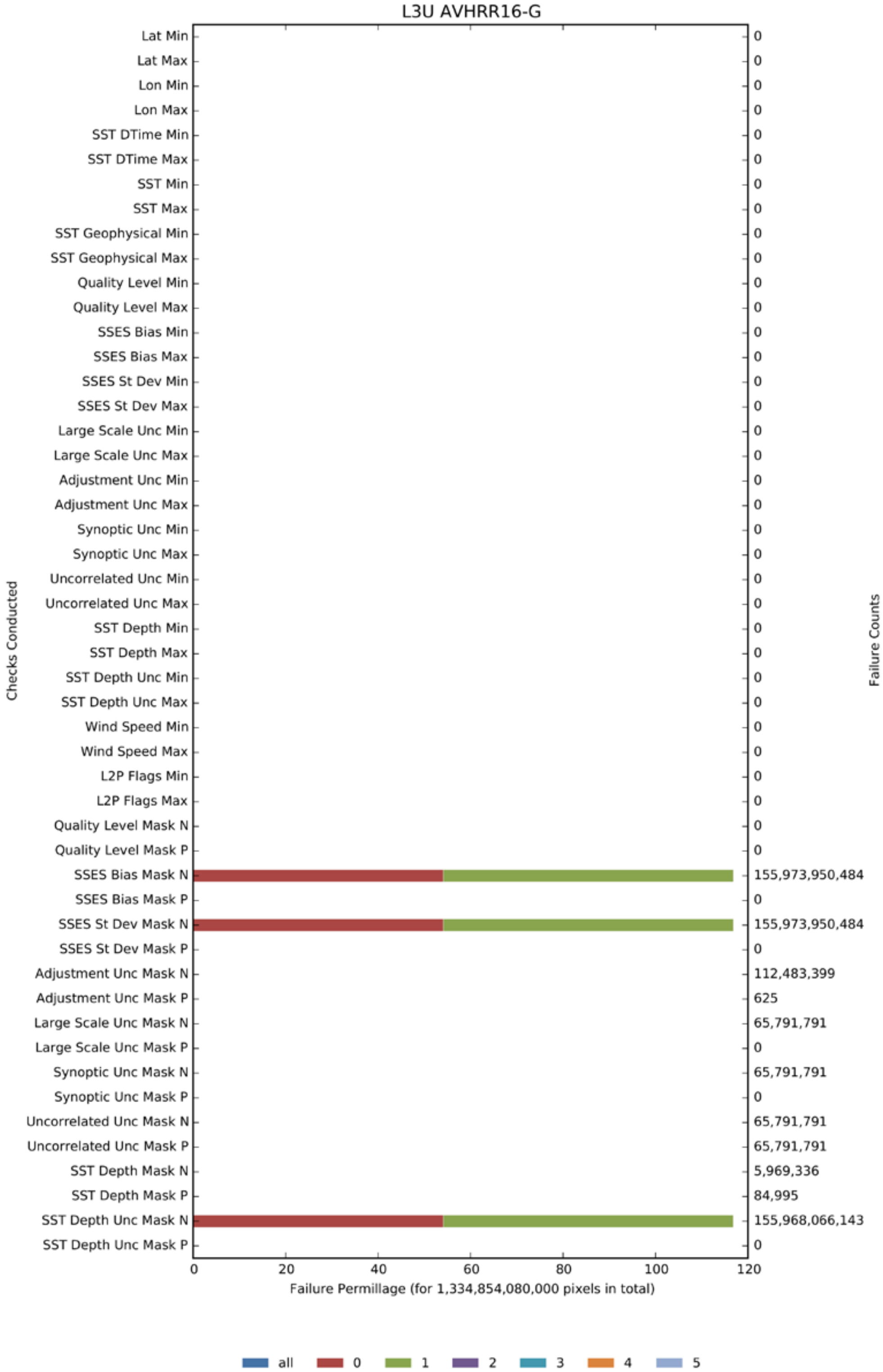


Figure 4-26: Results of L3U pixel checks for AVHRR16_G

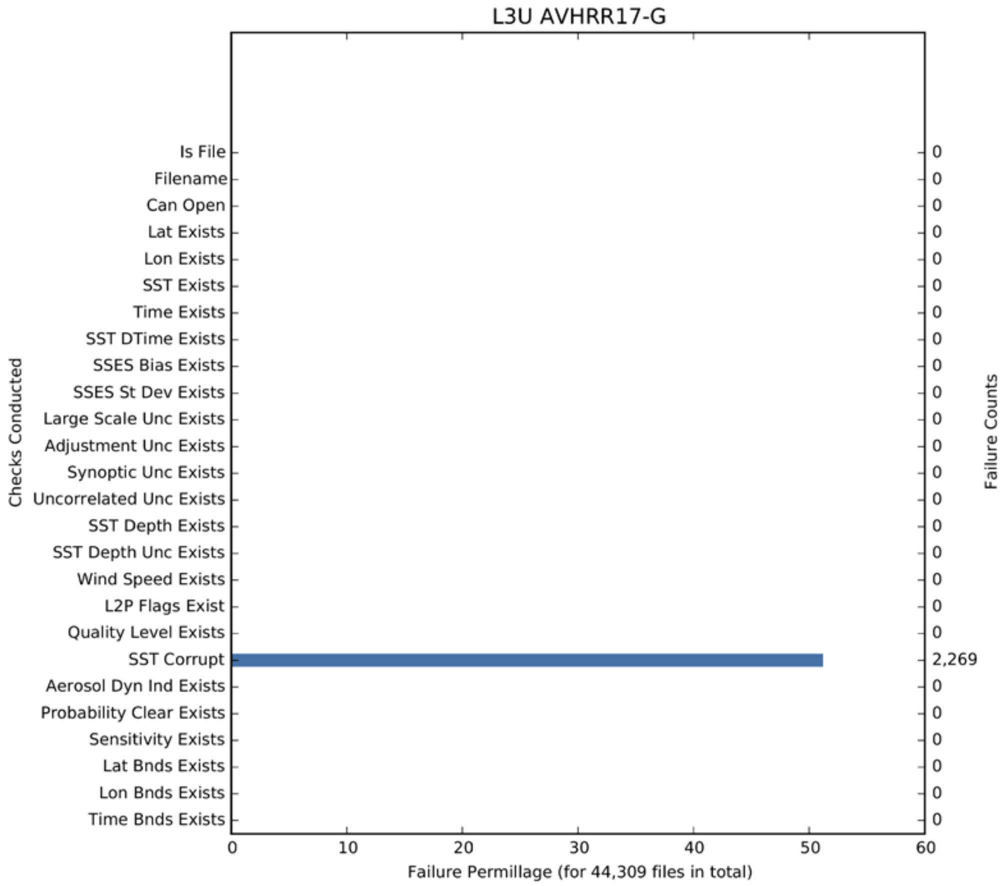


Figure 4-27: Summary of L3U product checks for AVHRR17_G

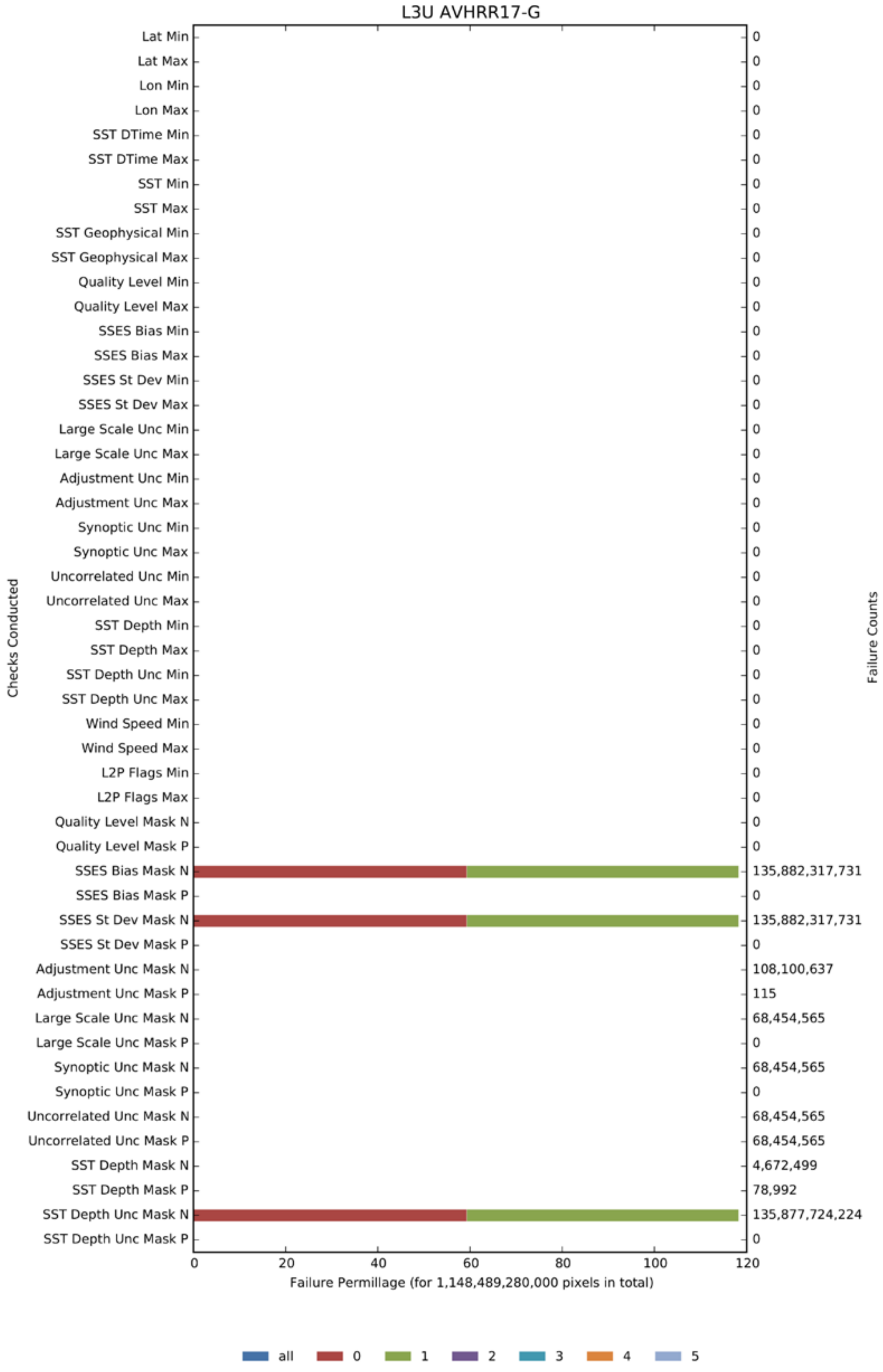


Figure 4-28: Results of L3U pixel checks for AVHRR17_G

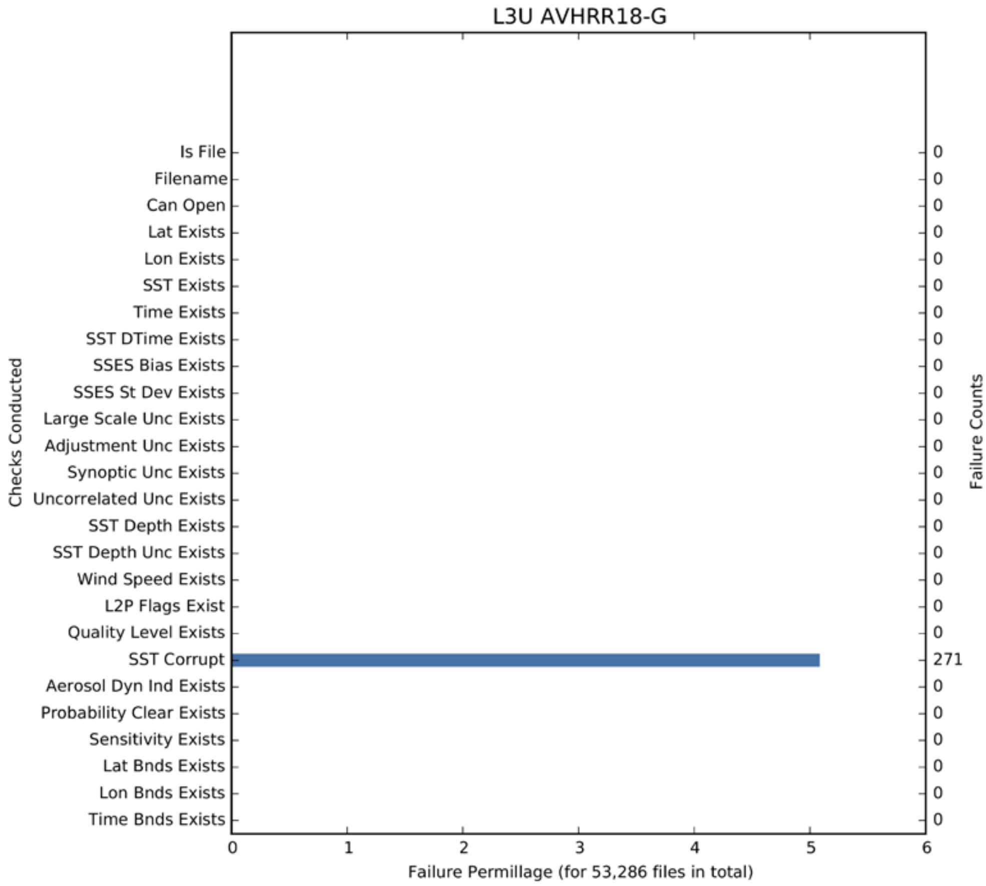


Figure 4-29: Summary of L3U product checks for AVHRR18_G

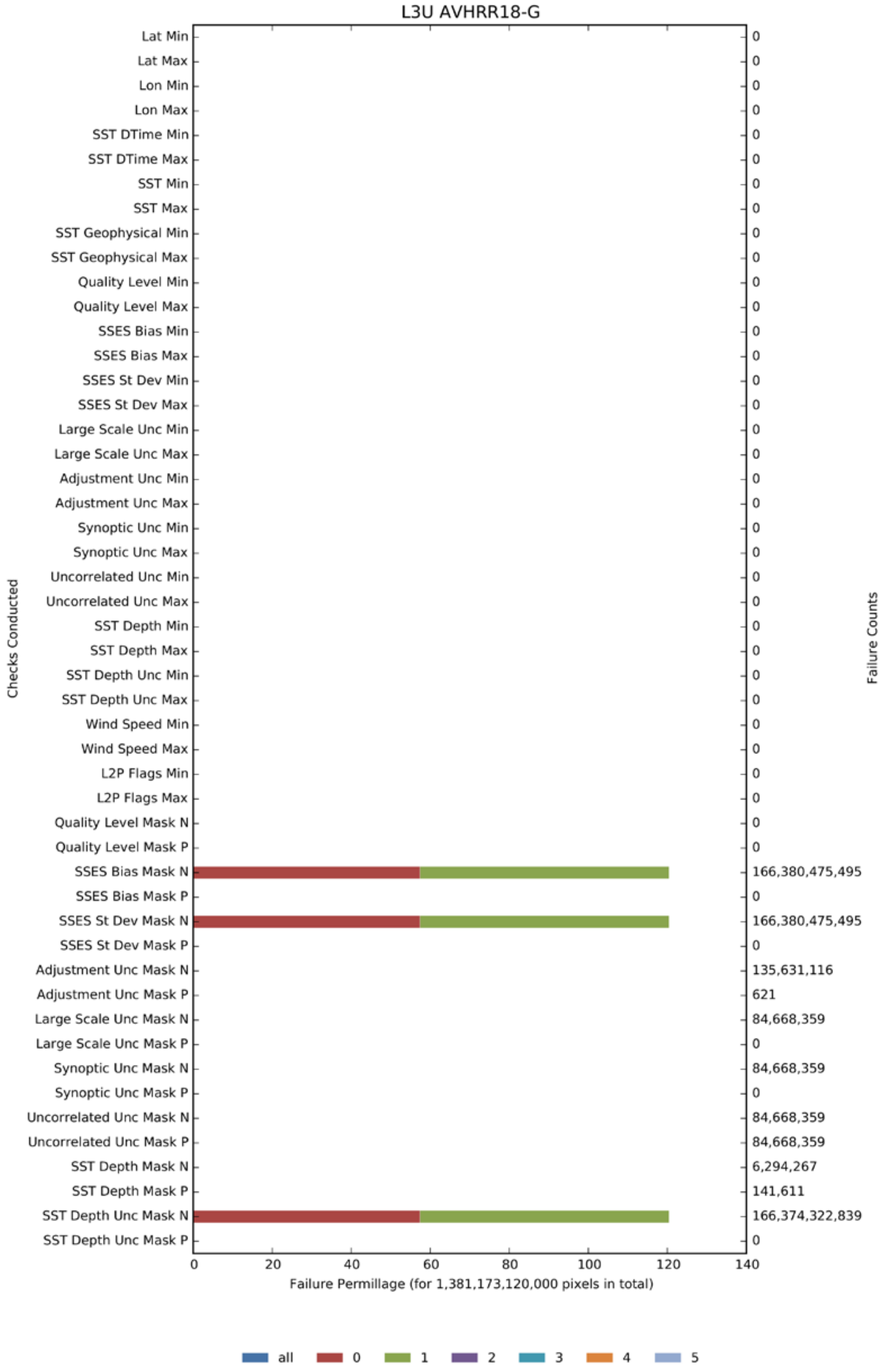


Figure 4-30: Results of L3U pixel checks for AVHRR18_G

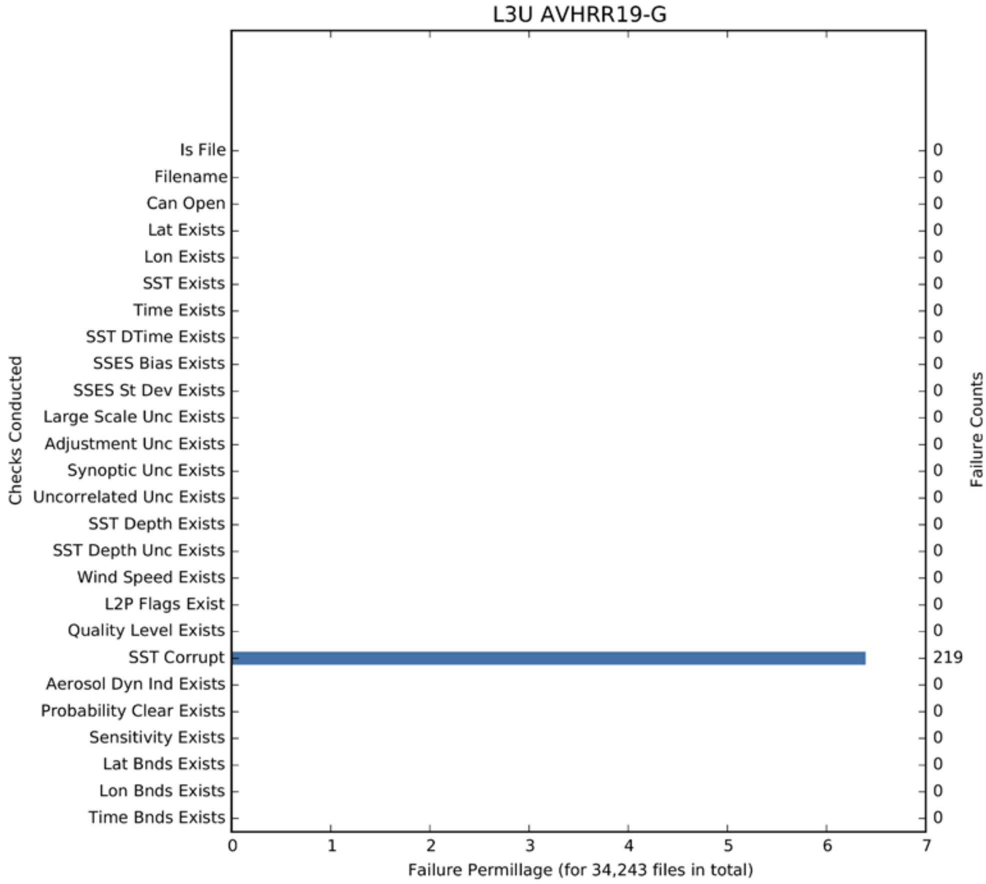


Figure 4-31: Summary of L3U product checks for AVHRR19_G

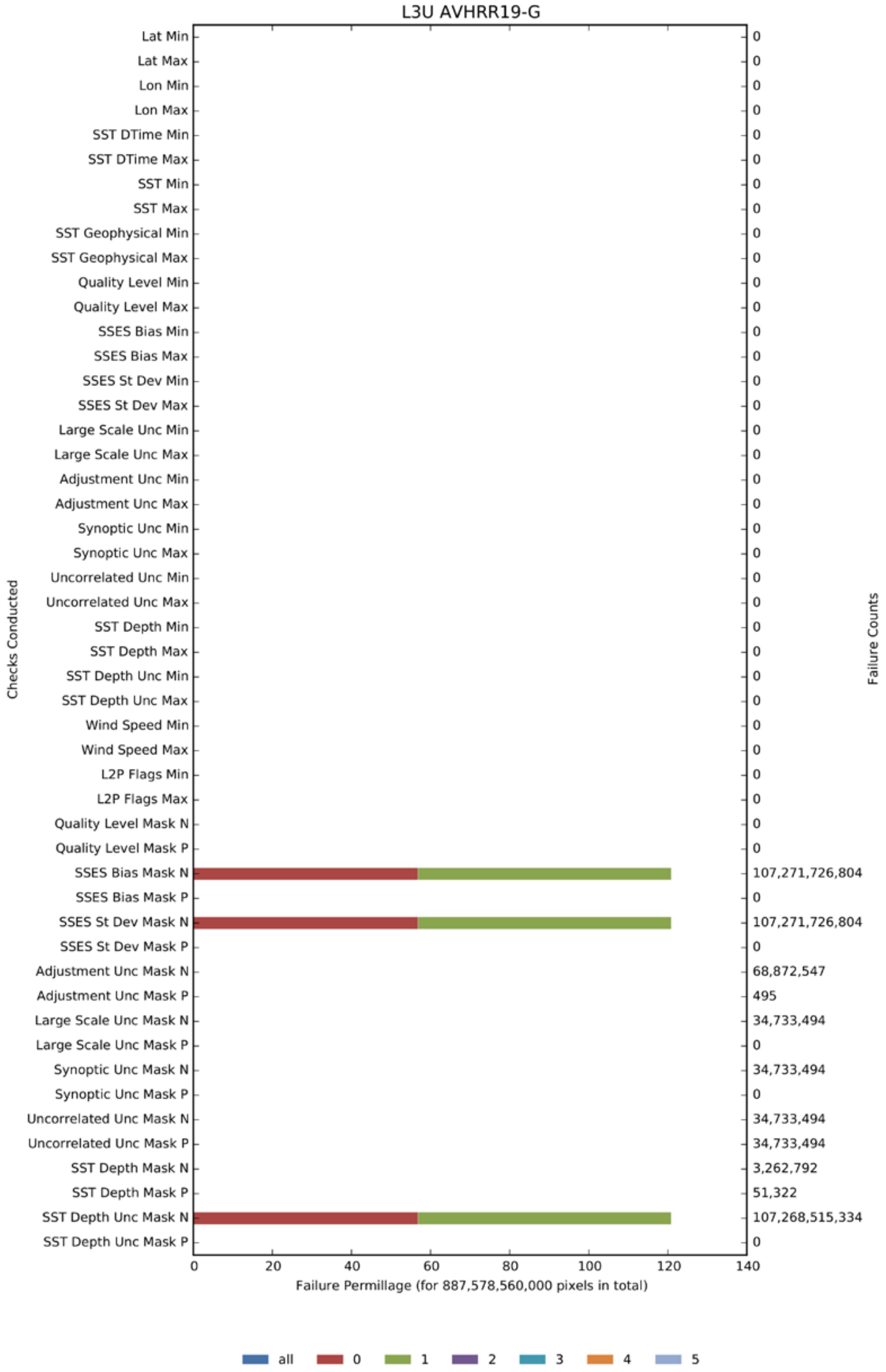


Figure 4-32: Results of L3U pixel checks for AVHRR19_G

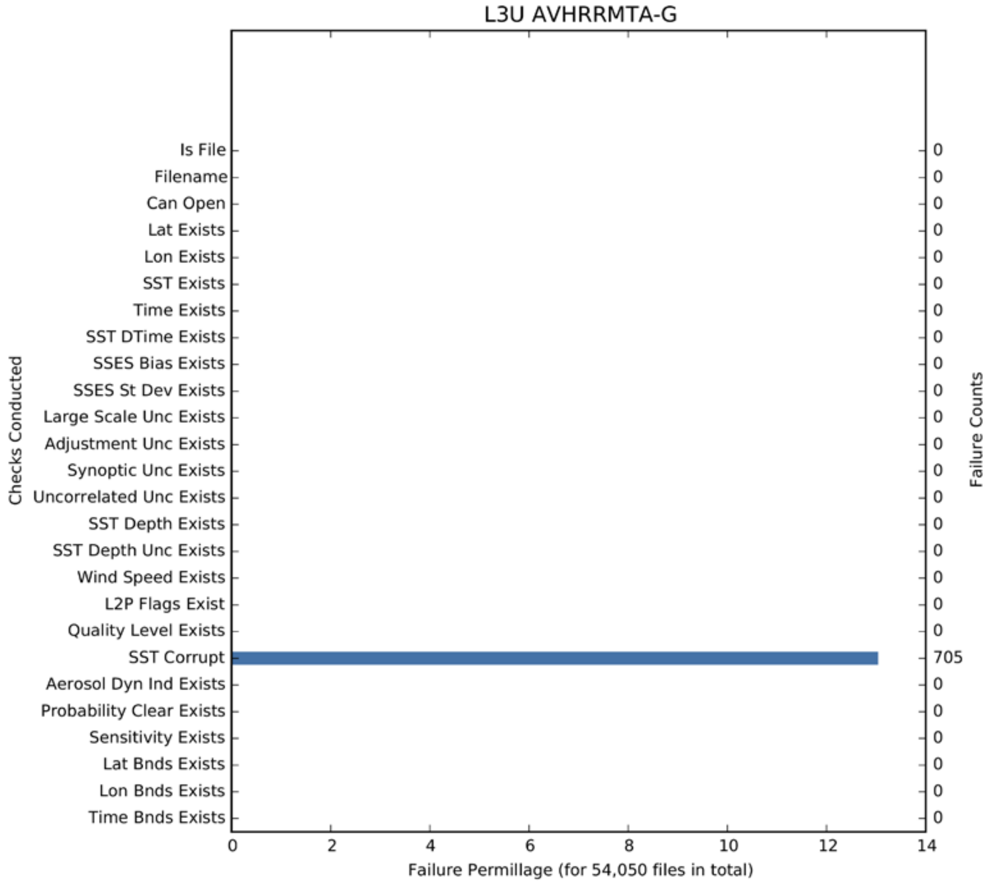


Figure 4-33: Summary of L3U product checks for AVHRRMTA_G

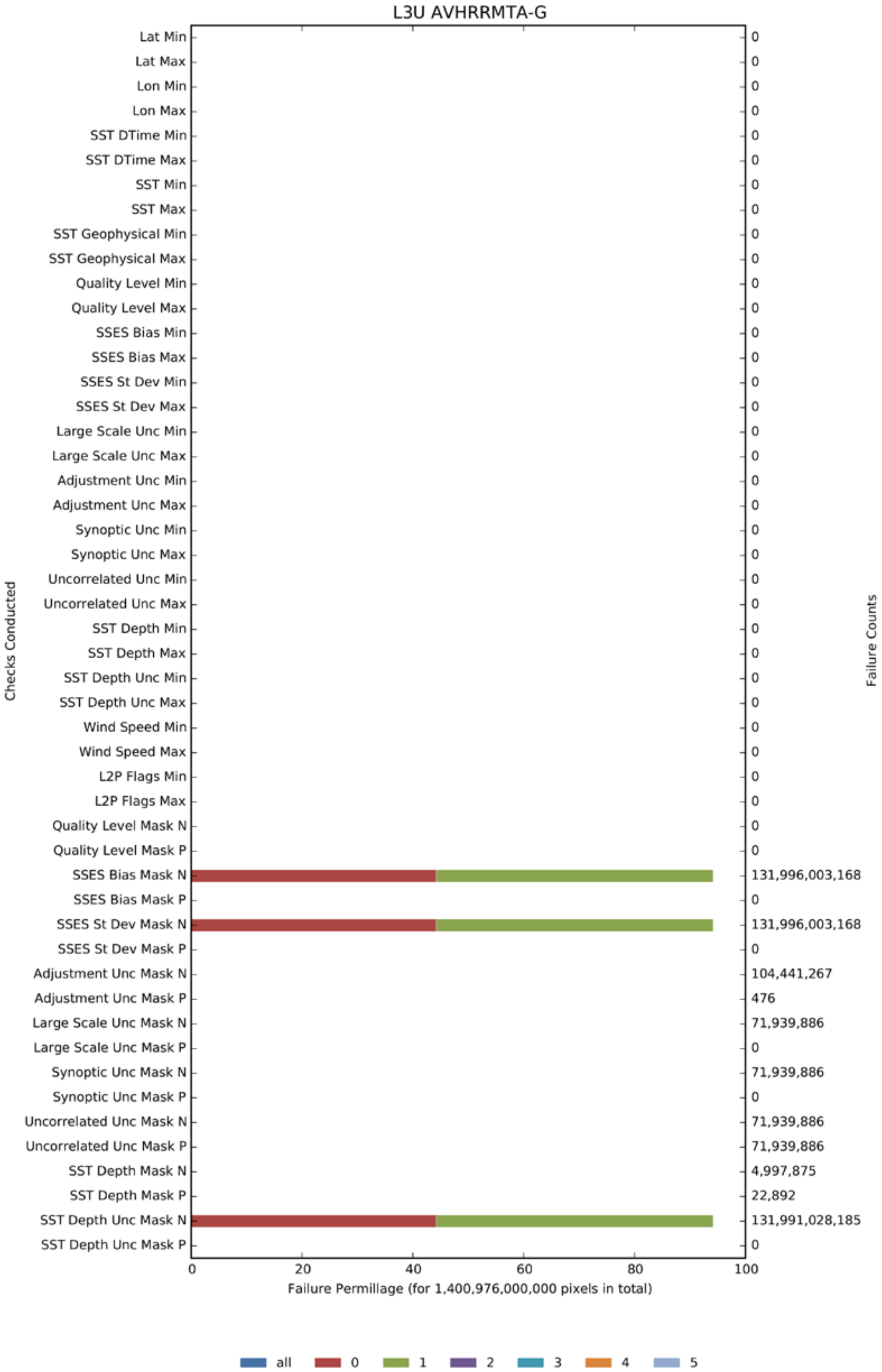


Figure 4-34: Results of L3U pixel checks for AVHRRMTA_G

4.1.2 Sample verification

A sample of L3U files consisting of one early and one late product from each of the (A)ATSR/AVHRR sensors, selected at random, were verified by manual inspection of the data fields. All of these files were also used for the verification of all metadata against the Product Specification Document (PSD) [AD.2]. The files manually inspected are listed in Table 4-1 below.

The metadata verification against the product specification included both global and variable attributes. Some discrepancies were found between the file content and the product specification as listed in Table 4-2 further below.

The manual inspection of the data fields within the L3U file sample was carried out with the ESA Sentinel Toolbox (SNAP) (see Figure 4-35) and included the following checks:

- Plotting sea_surface_temperature data and checking data coverage and histogram
- Plotting sea_surface_temperature_depth and checking data coverage and histogram
- Plotting sst_dtime data and checking data coverage and histogram
- Plotting sses_bias and checking data coverage and histogram (always equal to zero)
- Plotting sses_standard_deviation and checking data coverage and histogram
- Plotting sst_depth_total_uncertainty and checking data coverage and histogram
- Plotting wind_speed data and checking data coverage and histogram
- Plotting l2p_flags and checking data coverage and histogram
- Plotting quality_level and checking data coverage and histogram
- Plotting large_scale_correlated_uncertainty and checking data coverage and histogram (always equal to 0.1)
- Plotting synoptically_correlated_uncertainty and checking data coverage and histogram
- Plotting uncorrelated_uncertainty and checking data coverage and histogram
- Plotting adjustment_uncertainty and checking data coverage and histogram
- Plotting aerosol_dynamic_indicator and checking data coverage and histogram
- Plotting sensitivity and checking data coverage and histogram

These checks did not reveal any major issues on the data. No erroneous structural artefacts have been found in any of the data fields plotted. For the large-scale correlated uncertainty all valid data points are set to 0.1 K.

Some of the test files manually inspected (7, 29, 33 and 34) contained a small number of pixels with a very small negative wind_speed value (-3.8e-7 m/s). Another set of test files contained a small number of pixels with extremely high sst/sst_depth values beyond 310 Kelvin. Both issues are being added to the issue tracking system and investigate by the processing team.

A comparison was also made between the square root of the sum of the squares of the uncertainty values and total uncertainty provided in the file. In the L3U products, the SSES standard deviation is given with a precision of about 0.005 K, whereas for all other uncertainties the precision is about 0.0005 K. Propagating these numbers gives an expected accuracy of about 0.0051 for the difference in sea surface temperature total uncertainties and of about 0.0011 for the difference in sea surface temperature depth total uncertainty. These checks could not be conducted for products 2 and 23 as the files did not contain valid sst measurements and hence no uncertainties.

In the files checked manually the differences listed in Table 4-3 below were found. File numbers are taken from those specified in Table 4-1. All uncertainty value differences comply very well with the expected accuracies.

Table 4-1: Files verified manually for data content.

Sensor	Filename	File number
ATSR 1	19910902155110-ESACCI-L3U_GHRSST-SSTskin-ATSR1-EXP1.2-v02.0-fv1.0.nc	1
ATSR 1	19960602010132-ESACCI-L3U_GHRSST-SSTskin-ATSR1-EXP1.2-v02.0-fv1.0.nc	2
ATSR 2	19970126232115-ESACCI-L3U_GHRSST-SSTskin-ATSR2-EXP1.2-v02.0-fv1.0.nc	3
ATSR 2	20071217050417-ESACCI-L3U_GHRSST-SSTskin-ATSR2-EXP1.2-v02.0-fv1.0.nc	4
AATSR	20030619180125-ESACCI-L3U_GHRSST-SSTskin-AATSR-EXP1.2-v02.0-fv1.0.nc	5
AATSR	20120311040938-ESACCI-L3U_GHRSST-SSTskin-AATSR-EXP1.2-v02.0-fv1.0.nc	6
AVHRR 06	19791106012309-ESACCI-L3U_GHRSST-SSTskin-AVHRR06_G-EXP1.2-v02.0-fv1.0.nc	7
AVHRR 06	19820218223122-ESACCI-L3U_GHRSST-SSTskin-AVHRR06_G-EXP1.2-v02.0-fv1.0.nc	8
AVHRR 07	19811011063927-ESACCI-L3U_GHRSST-SSTskin-AVHRR07_G-EXP1.2-v02.0-fv1.0.nc	9
AVHRR 07	19841025124640-ESACCI-L3U_GHRSST-SSTskin-AVHRR07_G-EXP1.2-v02.0-fv1.0.nc	10
AVHRR 08	19830603025240-ESACCI-L3U_GHRSST-SSTskin-AVHRR08_G-EXP1.2-v02.0-fv1.0.nc	11
AVHRR 08	19850812113914-ESACCI-L3U_GHRSST-SSTskin-AVHRR08_G-EXP1.2-v02.0-fv1.0.nc	12
AVHRR 09	19850923214854-ESACCI-L3U_GHRSST-SSTskin-AVHRR09_G-EXP1.2-v02.0-fv1.0.nc	13
AVHRR 09	19880426100232-ESACCI-L3U_GHRSST-SSTskin-AVHRR09_G-EXP1.2-v02.0-fv1.0.nc	14
AVHRR 10	19870317231758-ESACCI-L3U_GHRSST-SSTskin-AVHRR10_G-EXP1.2-v02.0-fv1.0.nc	15
AVHRR 10	19901226040345-ESACCI-L3U_GHRSST-SSTskin-AVHRR10_G-EXP1.2-v02.0-fv1.0.nc	16
AVHRR 11	19881202012556-ESACCI-L3U_GHRSST-SSTskin-AVHRR11_G-EXP1.2-v02.0-fv1.0.nc	17

Sensor	Filename	File number
AVHRR 11	19940513124226-ESACCI-L3U_GHRSST-SSTskin-AVHRR11_G-EXP1.2-v02.0-fv1.0.nc	18
AVHRR 12	19940726143855-ESACCI-L3U_GHRSST-SSTskin-AVHRR12_G-EXP1.2-v02.0-fv1.0.nc	19
AVHRR 12	19960119230246-ESACCI-L3U_GHRSST-SSTskin-AVHRR12_G-EXP1.2-v02.0-fv1.0.nc	20
AVHRR 14	19960214042523-ESACCI-L3U_GHRSST-SSTskin-AVHRR14_G-EXP1.2-v02.0-fv1.0.nc	21
AVHRR 14	20020328192852-ESACCI-L3U_GHRSST-SSTskin-AVHRR14_G-EXP1.2-v02.0-fv1.0.nc	22
AVHRR 15	20001103172923-ESACCI-L3U_GHRSST-SSTskin-AVHRR15_G-EXP1.2-v02.0-fv1.0.nc	23
AVHRR 15	20070911014010-ESACCI-L3U_GHRSST-SSTskin-AVHRR15_G-EXP1.2-v02.0-fv1.0.nc	24
AVHRR 16	20010623175232-ESACCI-L3U_GHRSST-SSTskin-AVHRR16_G-EXP1.2-v02.0-fv1.0.nc	25
AVHRR 16	20091208044023-ESACCI-L3U_GHRSST-SSTskin-AVHRR16_G-EXP1.2-v02.0-fv1.0.nc	26
AVHRR 17	20030408032131-ESACCI-L3U_GHRSST-SSTskin-AVHRR17_G-EXP1.2-v02.0-fv1.0.nc	27
AVHRR 17	20100511213150-ESACCI-L3U_GHRSST-SSTskin-AVHRR17_G-EXP1.2-v02.0-fv1.0.nc	28
AVHRR 18	20050922171011-ESACCI-L3U_GHRSST-SSTskin-AVHRR18_G-EXP1.2-v02.0-fv1.0.nc	29
AVHRR 18	20150702053545-ESACCI-L3U_GHRSST-SSTskin-AVHRR18_G-EXP1.2-v02.0-fv1.0.nc	30
AVHRR 19	20090628160121-ESACCI-L3U_GHRSST-SSTskin-AVHRR19_G-EXP1.2-v02.0-fv1.0.nc	31
AVHRR 19	20150309061616-ESACCI-L3U_GHRSST-SSTskin-AVHRR19_G-EXP1.2-v02.0-fv1.0.nc	32
AVHRR-MTA	20080114173703-ESACCI-L3U_GHRSST-SSTskin-AVHRRMTA-EXP1.2-v02.0-fv1.0.nc	33
AVHRR-MTA	20141129214903-ESACCI-L3U_GHRSST-SSTskin-AVHRRMTA-EXP1.2-v02.0-fv1.0.nc	34

4.1.2.1 File Naming Issues

All test files listed in Table 4-1 were checked to follow the file naming conventions for SST-CCI data as defined in the PUG (AD.2) and being derived from the GDS (AD.8).

Table 4-2: Discrepancies between actual L3U file names and PSD

File naming part	Product specification
File Version: “-fv1.0”	File Version: “-fvxx.x”
Additional Segregator: “EXP1.2”	Optional, but should match the actual processor version used: “EXP1.3”

4.1.2.2 Meta Data Issues

Table 4-3: Discrepancies between L3U metadata and the PSD. Shaded cells indicate true discrepancies, while the non-shaded cells indicate where the PSD is mistaken

Variable name or *global*	Attribute or property	File content	Product specification
Global	geospatial_vertical_max	-1.0E-5	-10^{-6} **or** **-**0.001 **or** -0.2 **or** -10 (update PSD)
Global	geospatial_lon_max	-180	Identical to easternmost_longitude (which is +180)
Global	geospatial_lon_min	+180	Identical to westernmost_longitude (which is -180)
Global	id	Processor version number incorrect, should be v1.3	n/a
sst_depth_difference_time	N/A	Not present	Present
l2p_flags	_FillValue	-32768	Not specified (update PSD)
quality_level	_FillValue	0	-128 (update PSD)
wind_speed	time_offset	“0.” Value is a truncated float	n/a
large_scale_correlated_uncertainty	scale_factor	0.001	0.01 (update PSD)
synoptically_correlated_uncertainty	scale_factor	0.001	0.01 (update PSD)
uncorrelated_uncertainty	scale_factor	0.001	0.01 (update PSD)
uncorrelated_uncertainty	long_name	Uncertainty from errors unlikely to be correlated between SSTs	Uncertainty from errors likely to be uncorrelated between SSTs

Variable name or *global*	**Attribute or property**	**File content**	**Product specification**
adjust-ment_uncertainty	scale_factor	0.001	0.01 (update PSD)
sst_depth_total_uncertainty	scale_factor	0.001	0.01 (update PSD)
aero-sol_dynamic_indicator	n/a	n/a	Experimental variable. If decided to keep PSD has to be updated.
sensitivity	n/a	n/a	Experimental variable. If decided to keep PSD has to be updated.

Table 4-4: Differences between total uncertainties absolute min and max values and mean value provided in the L3U product and the total uncertainty calculated by combining individual uncertainty components

File no.	Min SST Uncert delta	Max SST Uncert. delta	Mean SST Uncert. delta	Min SST_depth Uncert delta	Max SST_depth Uncert. delta	Mean SST_depth Uncert. delta	Number Pixels
1	0.0	0.0055	0.0025	0.0	0.0011	3.0694E-4	50155
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	0.0	0.0055	0.0026	0.0	0.0011	3.0693E-4	90109
4	0.0	0.0053	0.0039	0.0	0.0010	2.8361E-4	4842
5	0.0	0.0055	0.0025	0.0	0.0011	2.9995E-4	124599
6	0.0	0.0055	0.0027	0.0	0.0011	2.9747E-4	104323
7	0.0	0.0056	0.0025	0.0	0.0012	3.1590E-4	533429
8	0.0	0.0056	0.0025	0.0	0.0012	3.2073E-4	70268
9	0.0	0.0056	0.0025	0.0	0.0012	3.2111E-4	446114
10	0.0	0.0056	0.0025	0.0	0.0012	3.2207E-4	450928
11	0.0	0.0056	0.0026	0.0	0.0012	3.1254E-4	721143
12	0.0	0.0056	0.0026	0.0	0.0012	3.1598E-4	550078
13	0.0	0.0056	0.0025	0.0	0.0012	3.2048E-4	720599
14	0.0	0.0056	0.0025	0.0	0.0012	3.2159E-4	572667
15	0.0	0.0056	0.0025	0.0	0.0012	3.1463E-4	632290
16	0.0	0.0055	0.0027	0.0	0.0012	3.0957E-4	243567
17	0.0	0.0056	0.0025	0.0	0.0012	3.1931E-4	558408
18	0.0	0.0056	0.0025	0.0	0.0013	3.2214E-4	540263
19	0.0	0.0056	0.0025	0.0	0.0012	3.1980E-4	503355
20	0.0	0.0056	0.0025	0.0	0.0012	3.2022E-4	514751
21	0.0	0.0056	0.0025	0.0	0.0012	3.1966E-4	500314
22	0.0	0.0056	0.0025	0.0	0.0012	3.2039E-4	376707
23	n/a	n/a	n/a	n/a	n/a	n/a	n/a
24	0.0	0.0056	0.0025	0.0	0.0012	3.2088E-4	724547
25	0.0	0.0056	0.0025	0.0	0.0012	3.2051E-4	440753
26	0.0	0.0056	0.0025	0.0	0.0012	3.2069E-4	618921
27	0.0	0.0056	0.0025	0.0	0.0011	3.1705E-4	576526
28	0.0	0.0056	0.0025	0.0	0.0012	3.1694E-4	733806
29	0.0	0.0056	0.0025	0.0	0.0012	3.2102E-4	494124

30	0.0	0.0056	0.0025	0.0	0.0012	3.2293E-4	596956
31	0.0	0.0056	0.0025	0.0	0.0012	3.1943E-4	415493
32	0.0	0.0056	0.0025	0.0	0.0012	3.2022E-4	526669
33	0.0	0.0056	0.0025	0.0	0.0012	3.1703E-4	986239
34	0.0	0.0056	0.0025	0.0	0.0012	3.1850E-4	1100490

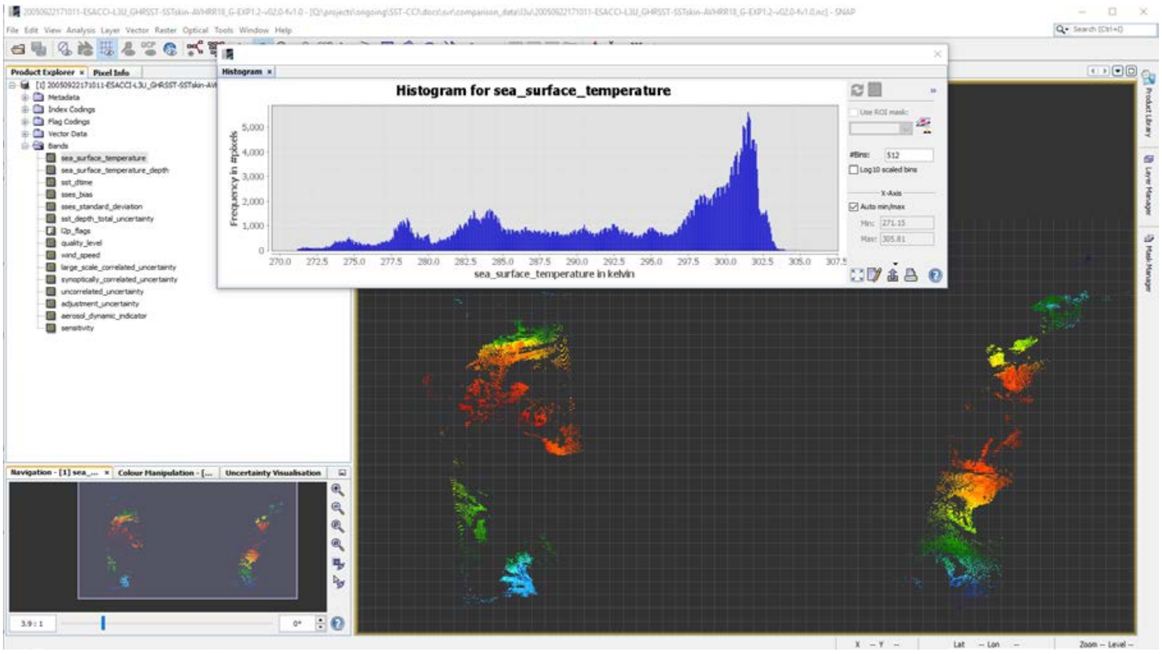


Figure 4-35: Manual inspection of fields in L3U products with SNAP. Verification that all expected geophysical variables are present and contain meaningful data, histogram inspection.

4.2 ARC CCI processor (L2P)

4.2.1 Content verification

Content verification checks have been carried out for all L2P products obtained from all flavours of ATSR and AVHRR-GAC sensors. The results of the L2P product and pixel checks are represented in horizontal bar charts shown in Figure 4-36 to Figure 4-69 below.

For all bar charts the left vertical axis lists the names of the checks conducted as defined in Table 3-1, Table 3-3 and Table 3-4. The right vertical axis lists the number of occurrences where the check named on the left vertical axis has failed. For each check, a horizontal bar visualises the failure permillage (failure rate measured per thousand). If there is no bar drawn for a check, the check has been passed completely, without any failures. The number of product files (or pixels) checked in total is given in the label of the horizontal axis at the bottom.

The mask consistency tests defined in Table 3-3 are conducted per quality level. The results for these tests are visualised per quality level in form of a stacked bar. The total lengths of the stacked bar corresponds to the total permillage of failures for all quality levels. If the check does not distinguish between quality levels, the colour for “all” is used. The failure counts appearing on the right vertical axis also refer to the total number of failures.

In summary, the product checks have been passed without failures, except for 'SST Corrupt'. The failure rate is less than 6 percent of products for the ATSR sensors and less than 8 percent for the NOAA AVHRR sensors. In the EXP1.3 release, about a third of MetOp-A L2P files contain no data during the period July 2011 to April 2013 (because all values have been masked as cloud. It is assumed that these inconsistencies are caused by ~~d~~a temporal change in data format/quality as the input data was delivered during this period as half-orbit files instead of the standard pole-to-pole data. (See also PUG [RD.330])

The pixel checks show mask inconsistencies for L2P from all sensors at quality level 1 (bad data). These inter-data flagging issues are currently being resolved; they do not affect the overall usability of the SST data. No other flag masking inconsistencies have been detected at any other quality level.

For some of the AVHRR NOAA 15 based L2P products, a high number of failures due to longitude and latitude values below the valid range have been detected. This was caused by products containing only invalid pixels, where the longitude and latitude variables were set to a fill value (-32768) which is not defined as a standard NetCDF CF attribute. Additionally, in these products the complete dataset was flagged as "Lake". These issues are being entered to the issue tracker as tickets 169 and 170.

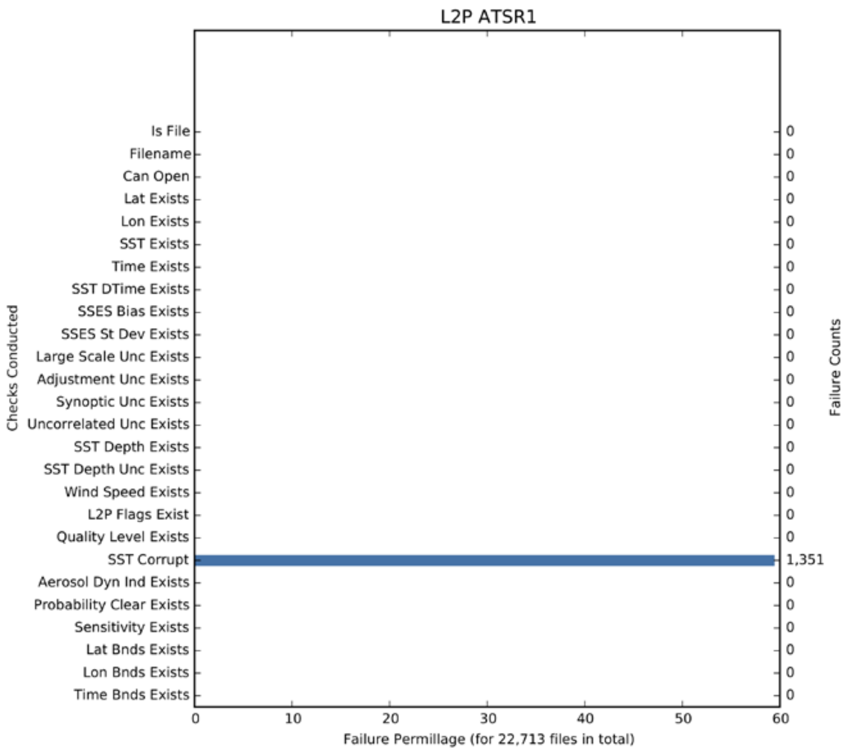


Figure 4-36: Results of L2P product checks for ATSR1

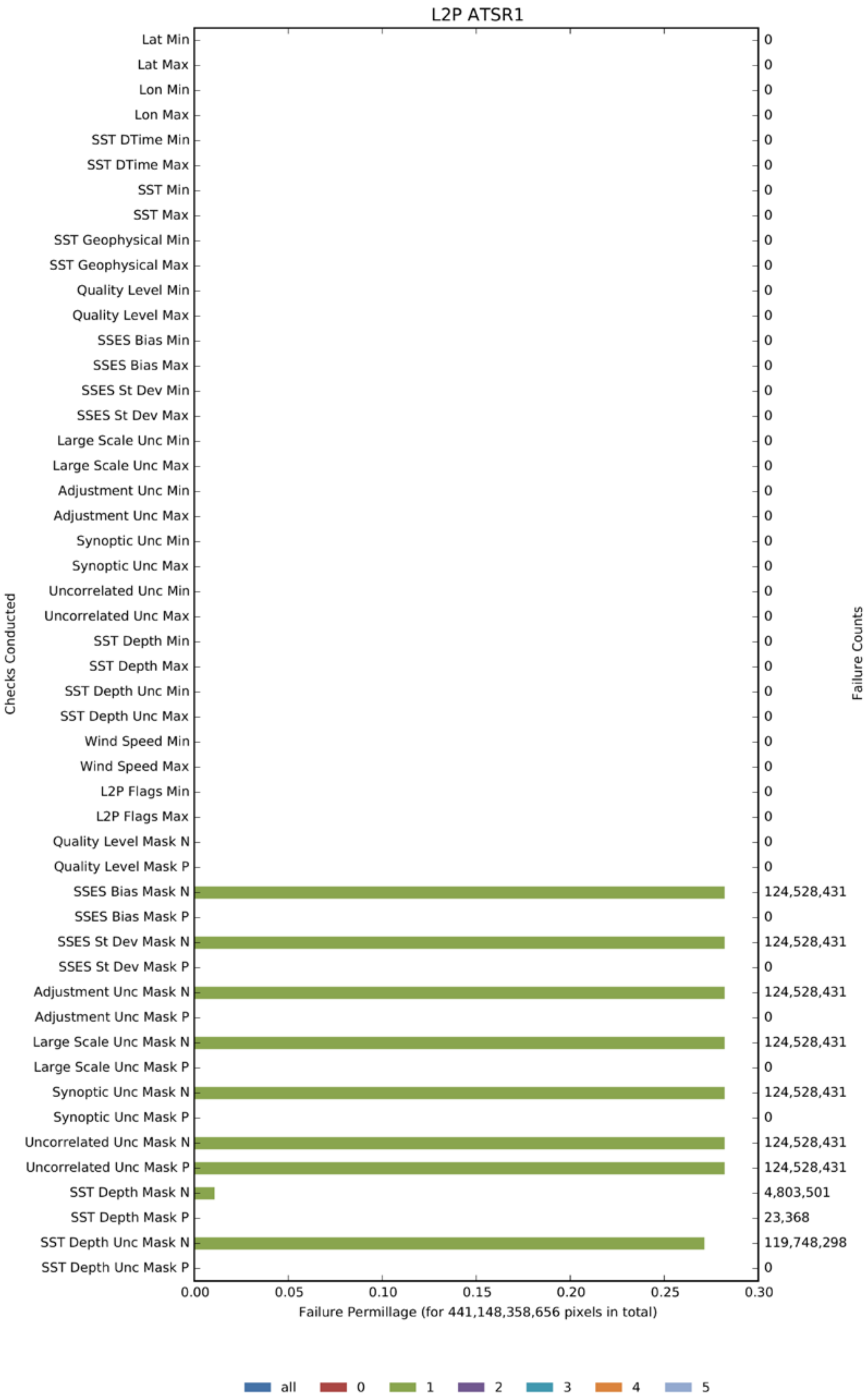


Figure 4-37: Results of L2P pixel checks for ATSR1

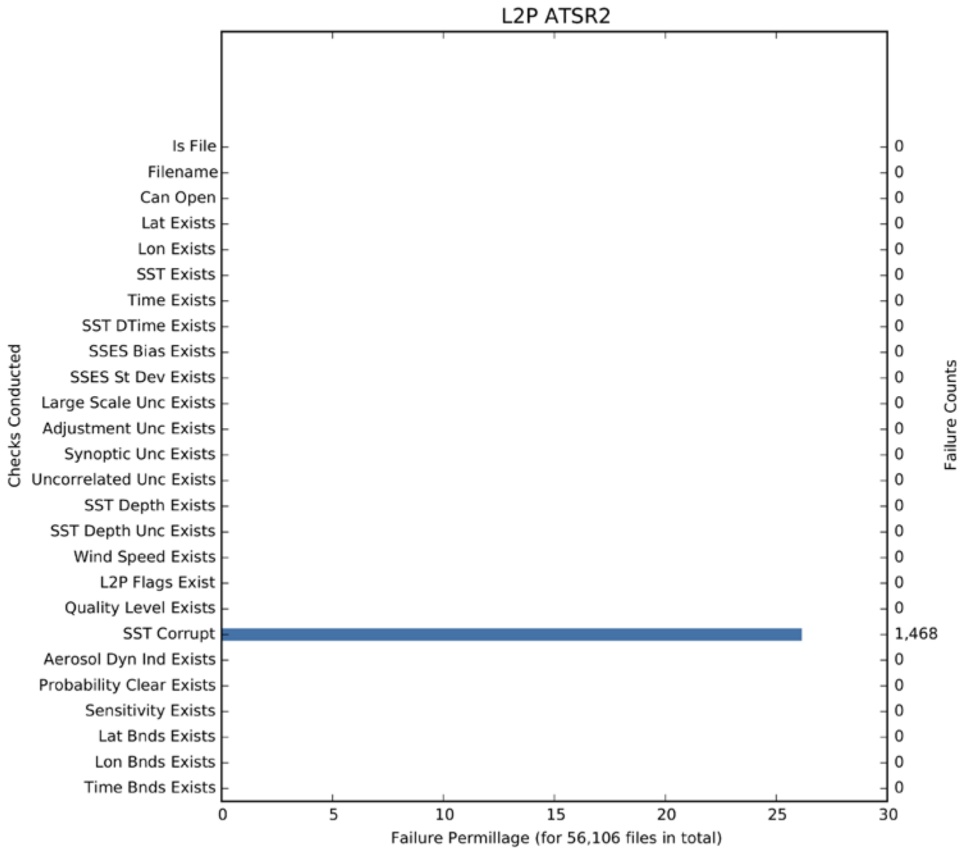


Figure 4-38: Results of L2P product checks for ATSR2

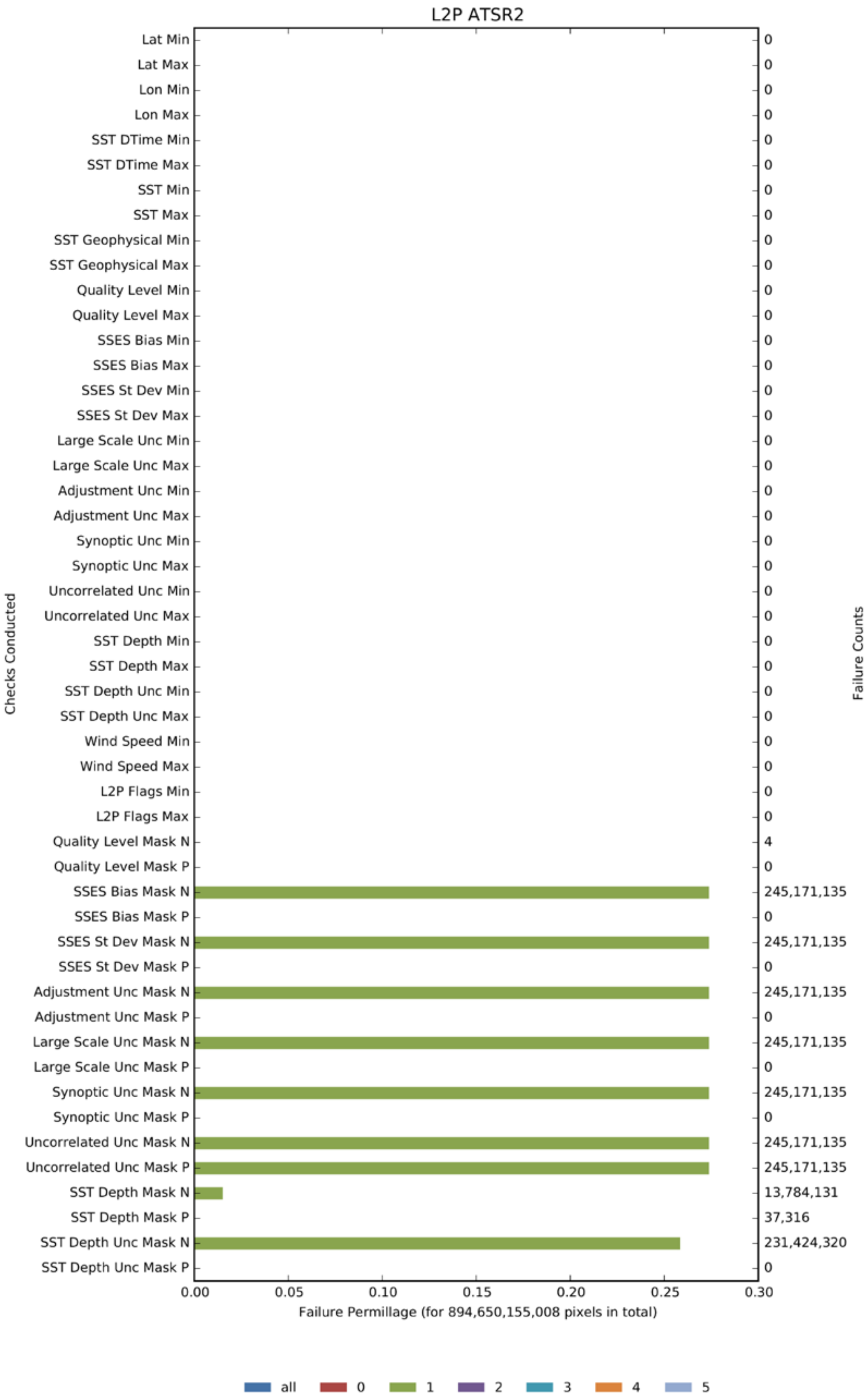


Figure 4-39: Results of L2P pixel checks for ATSR2

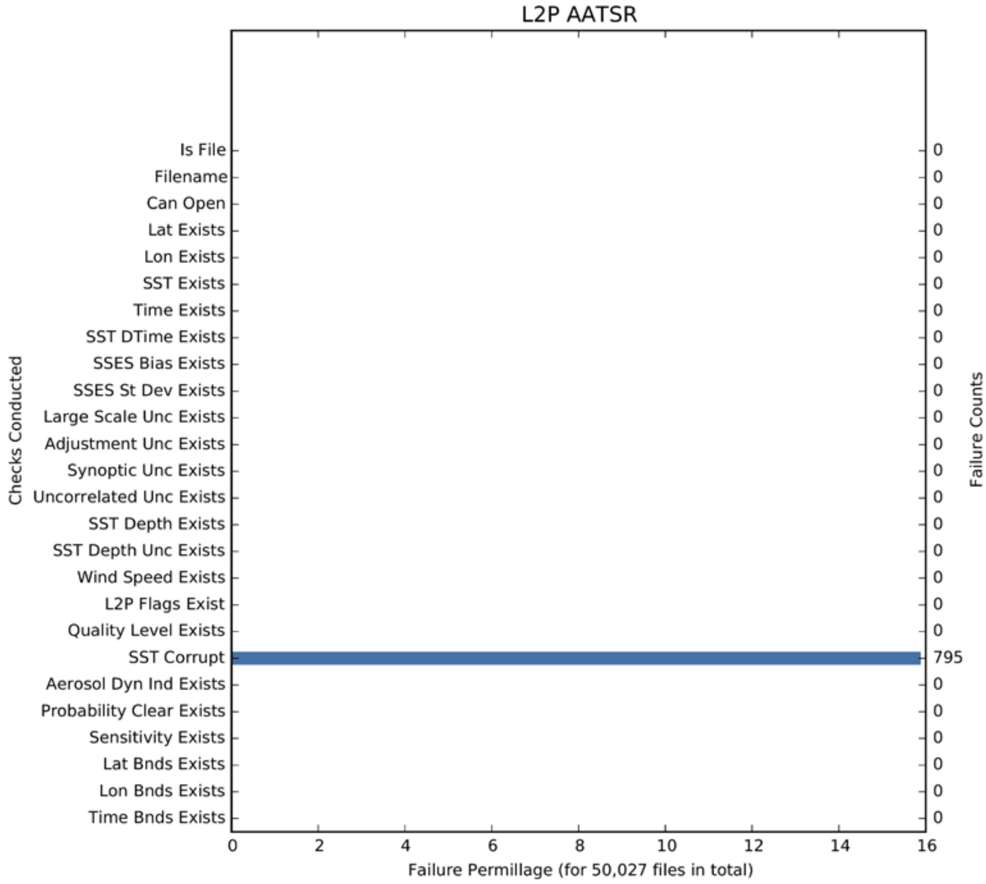


Figure 4-40: Results of L2P product checks for AATSR

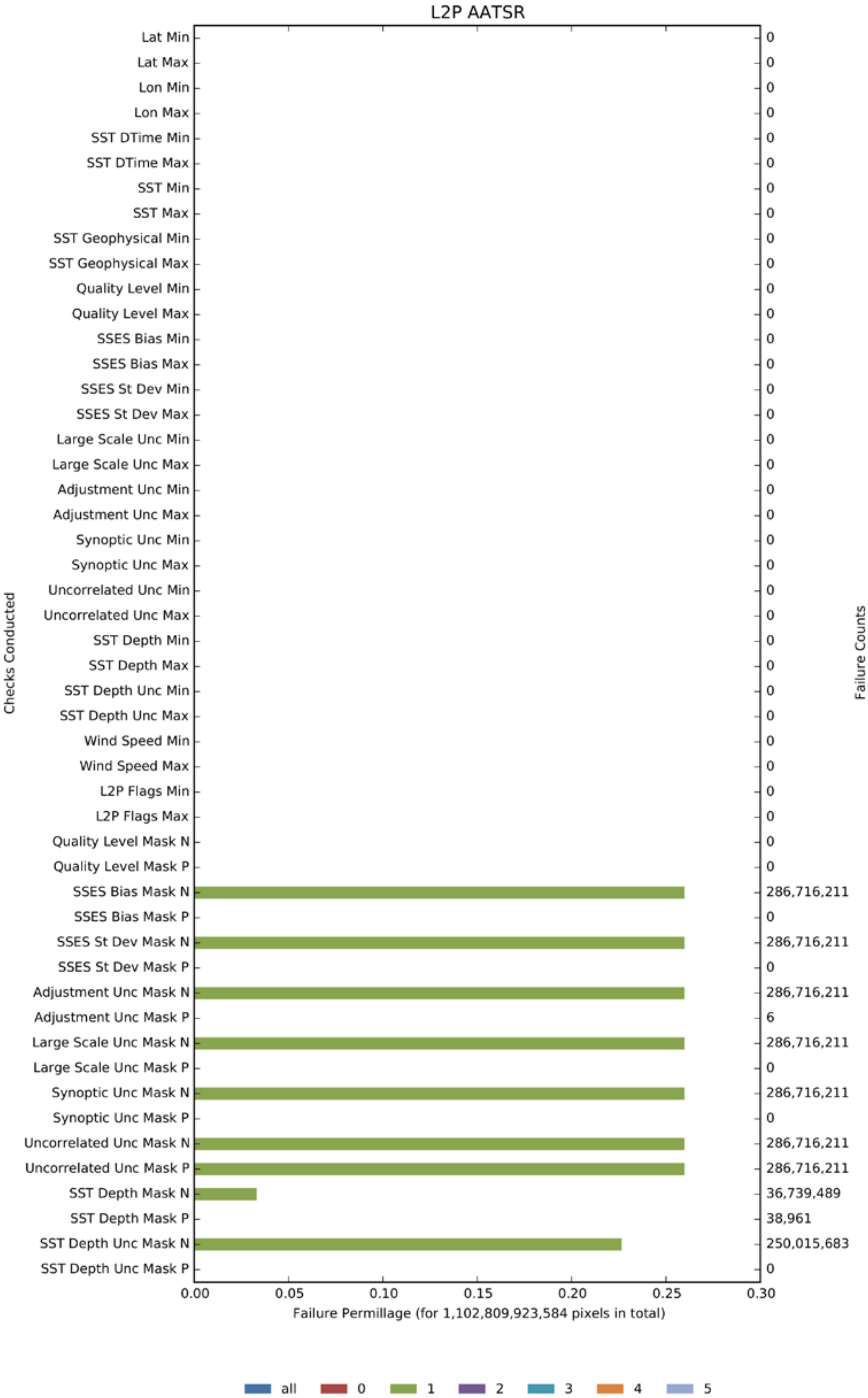


Figure 4-41: Results of L2P pixel checks for AATSR

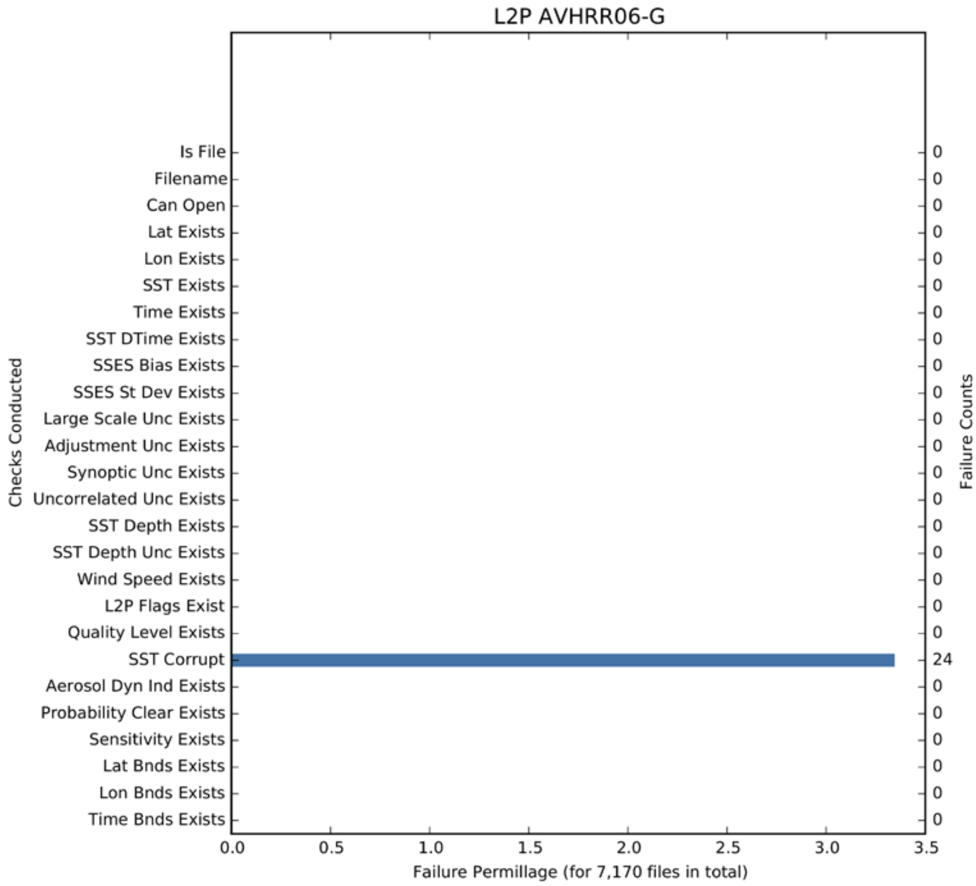


Figure 4-42: Results of L2P product checks for AVHRR06 GAC

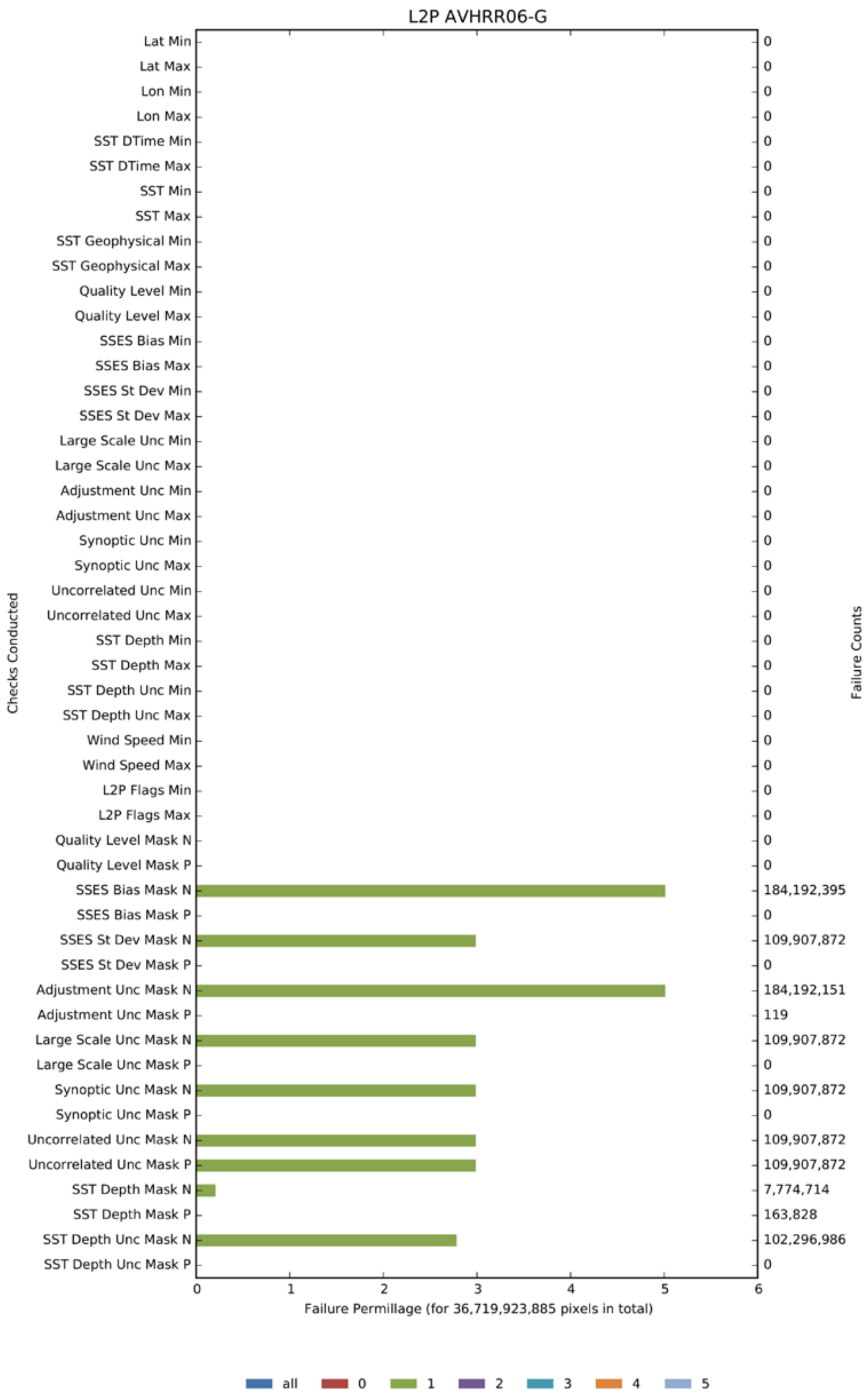


Figure 4-43: Results of L2P pixel checks for AVHRR06 GAC

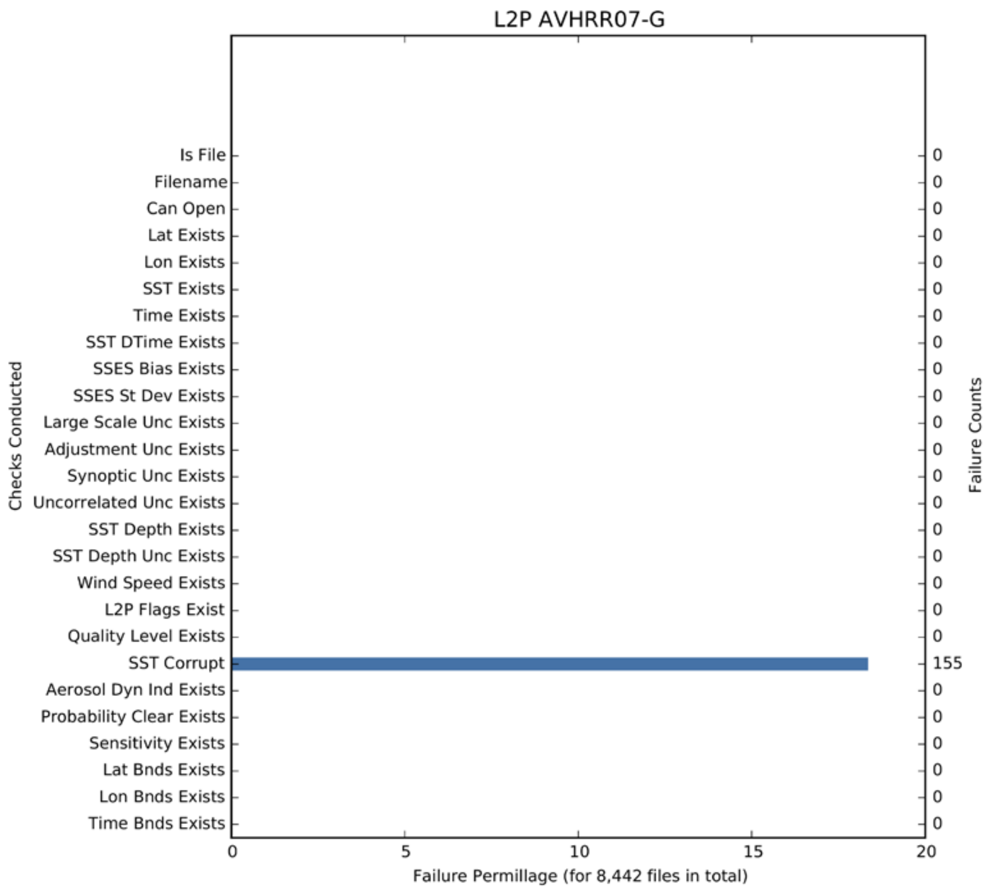


Figure 4-44: Results of L2P product checks for AVHRR07 GAC

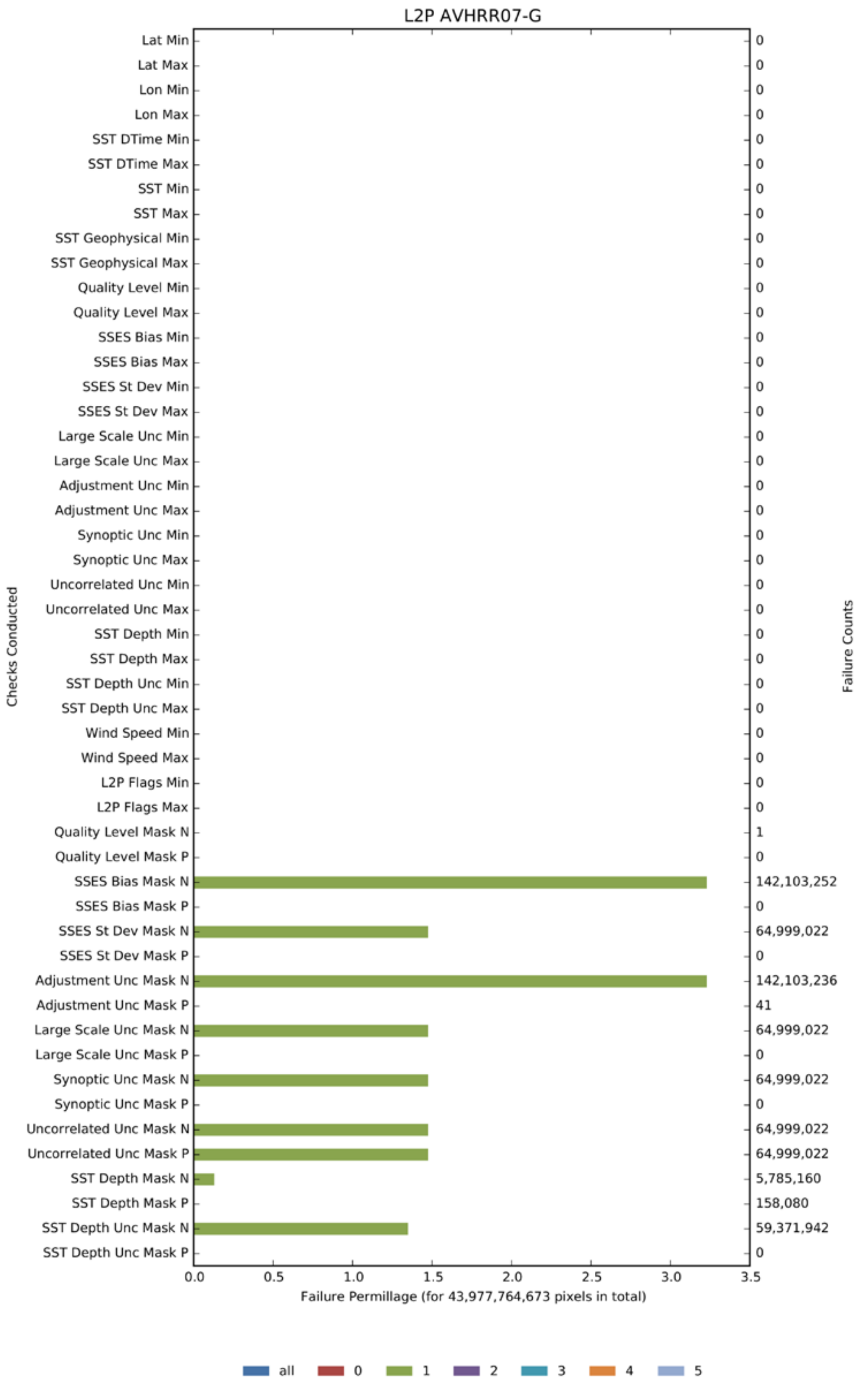


Figure 4-45: Results of L2P pixel checks for AVHRR07 GAC

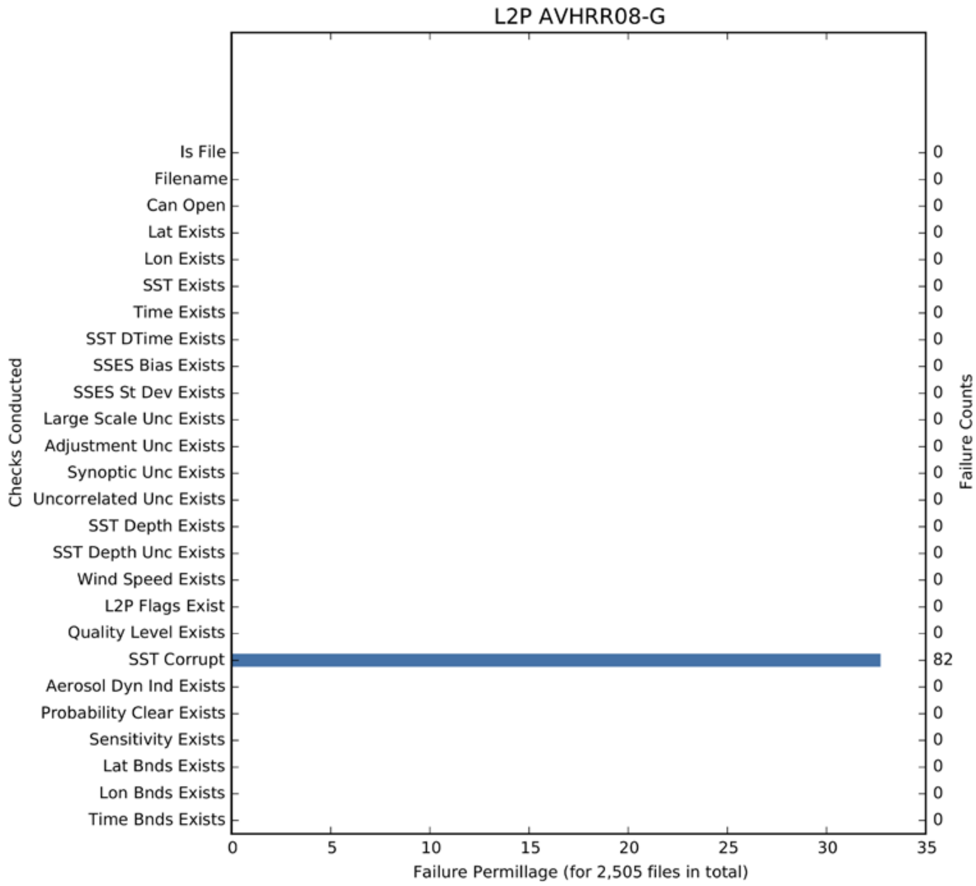


Figure 4-46: Results of L2P product checks for AVHRR08 GAC

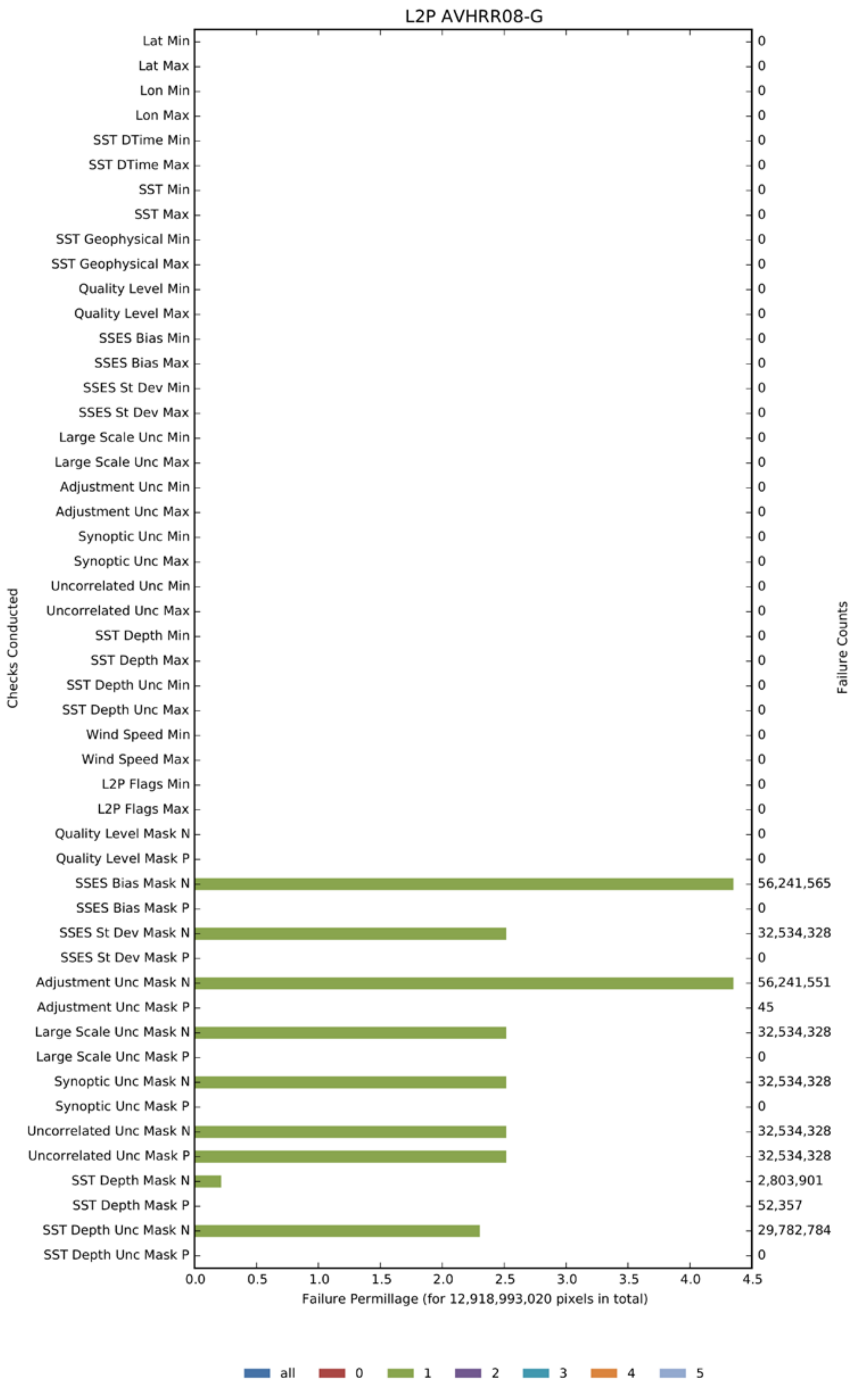


Figure 4-47: Results of L2P pixel checks for AVHRR08 GAC

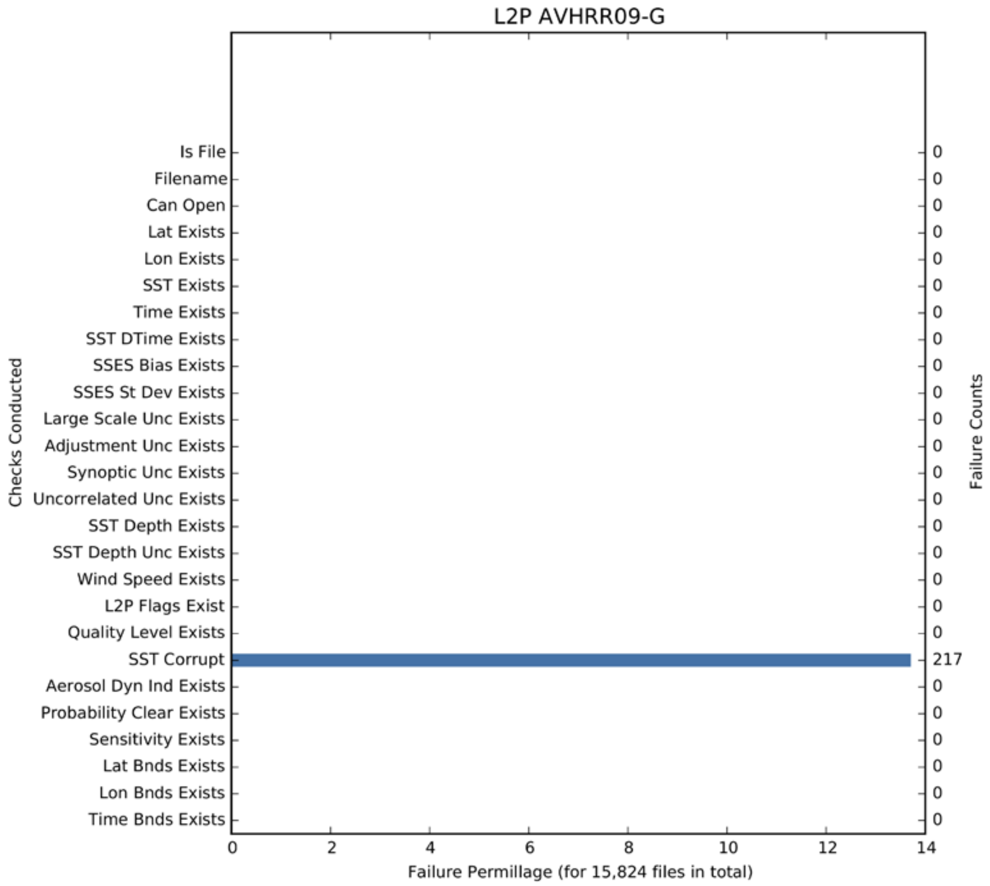


Figure 4-48: Results of L2P product checks for AVHRR09 GAC

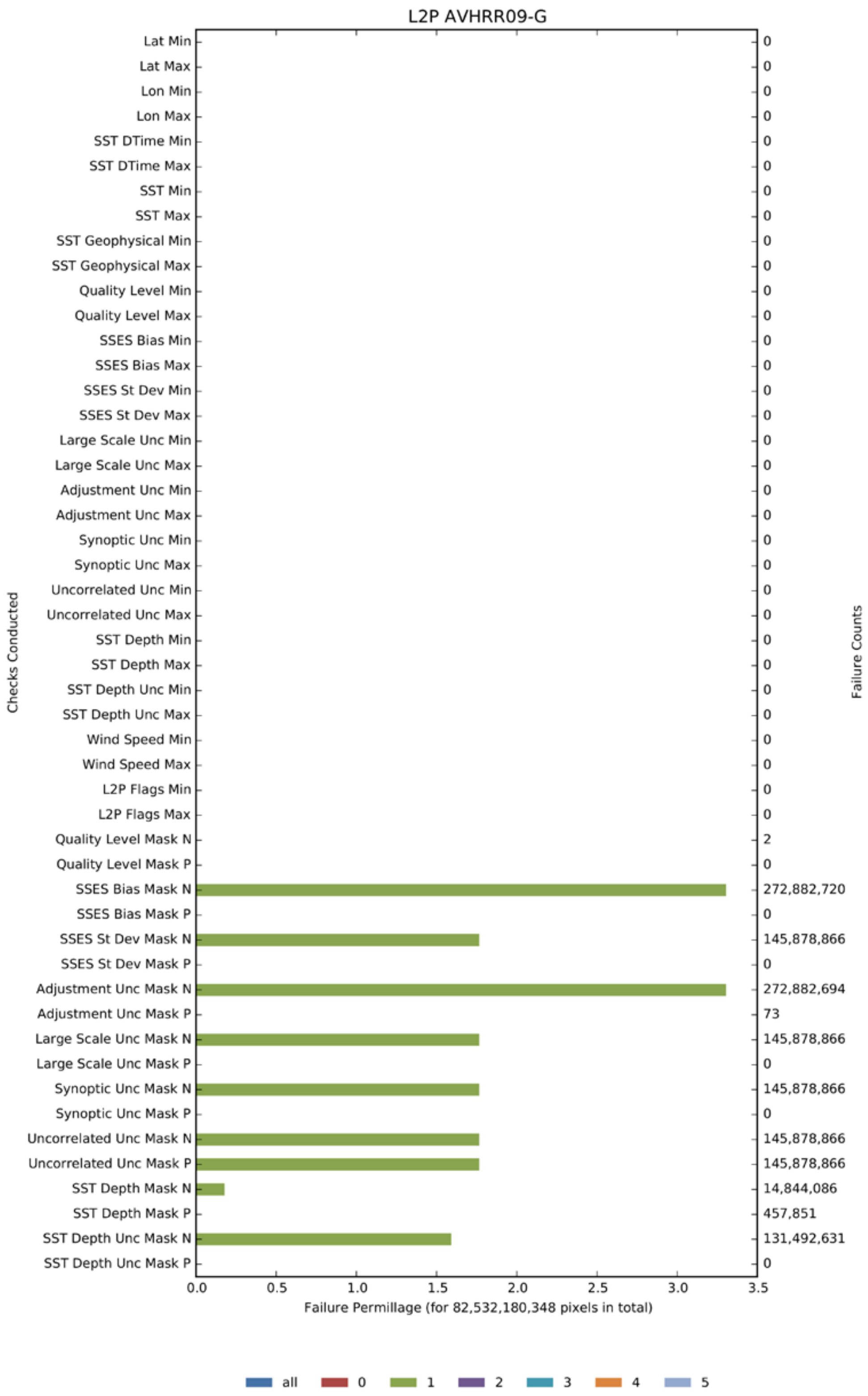


Figure 4-49: Results of L2P pixel checks for AVHRR09 GAC

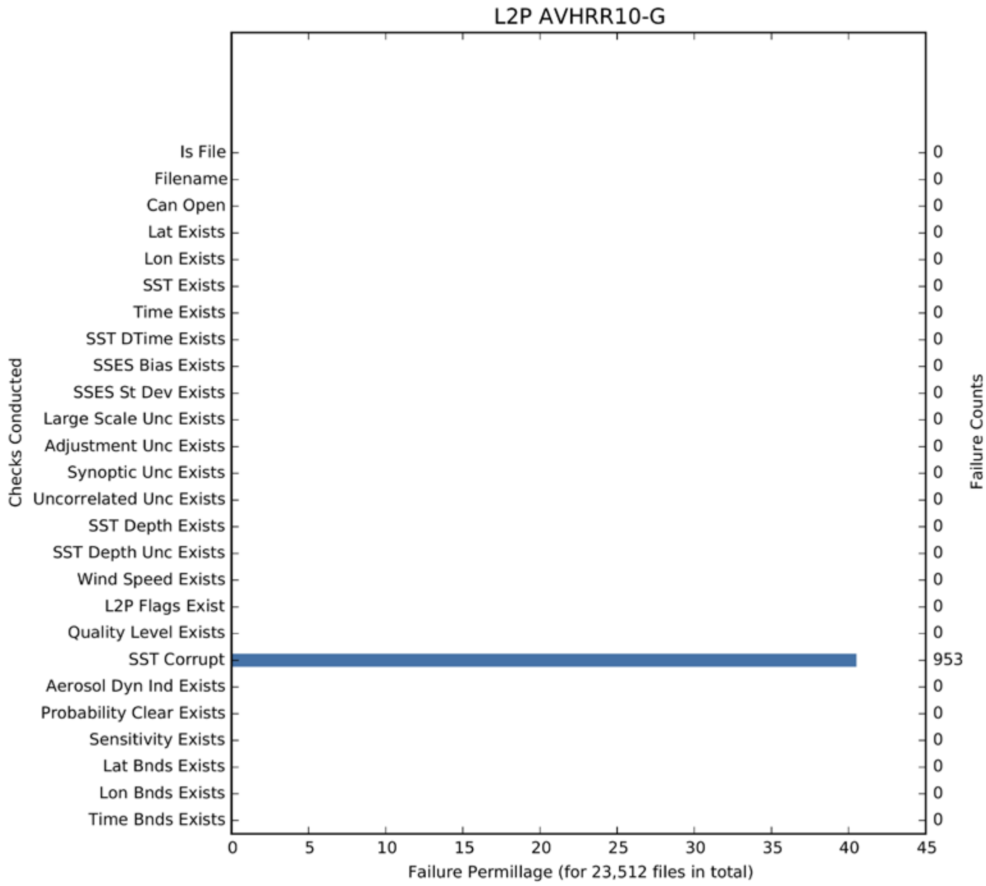


Figure 4-50: Results of L2P product checks for AVHRR10 GAC

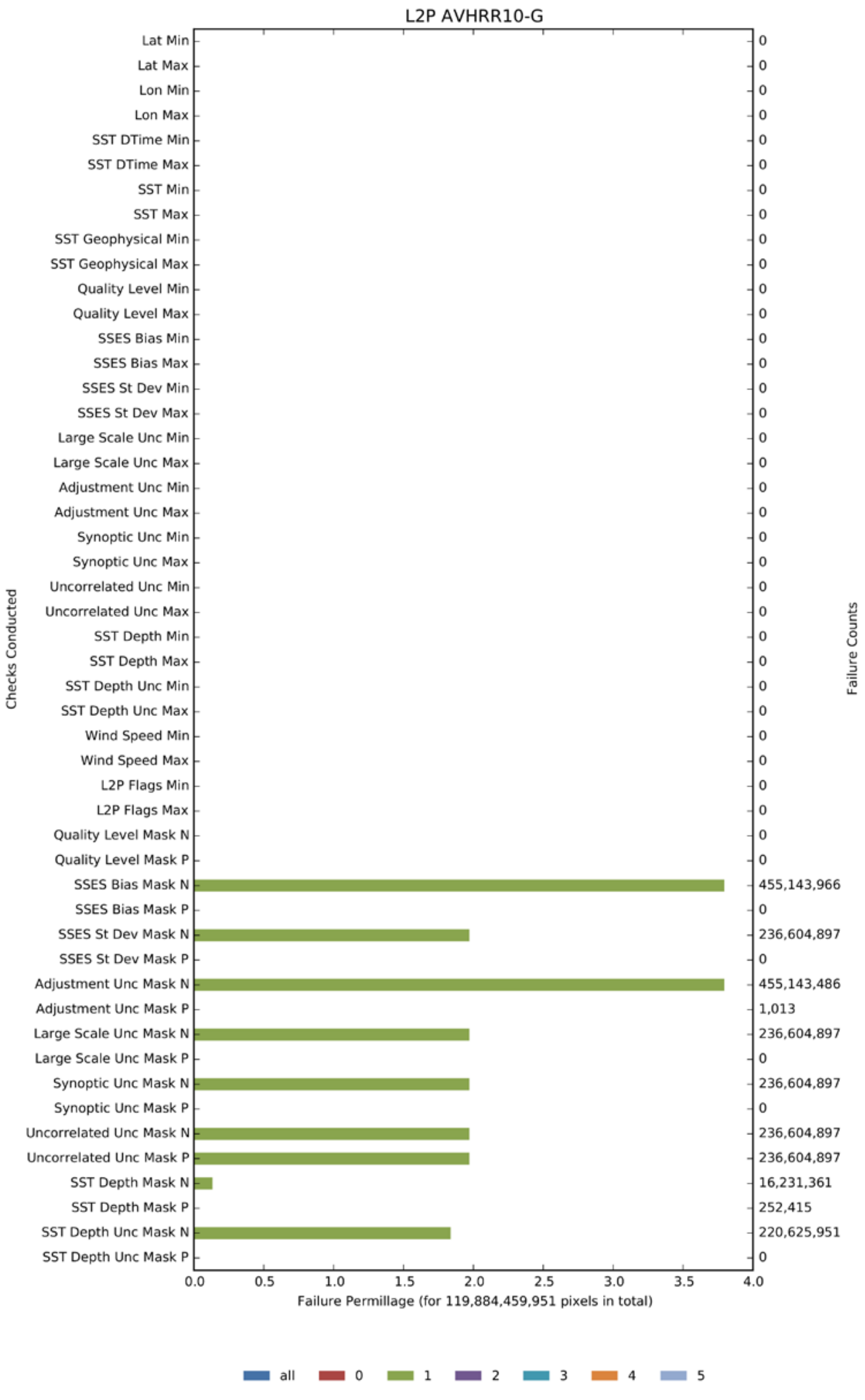


Figure 4-51: Results of L2P pixel checks for AVHRR10 GAC

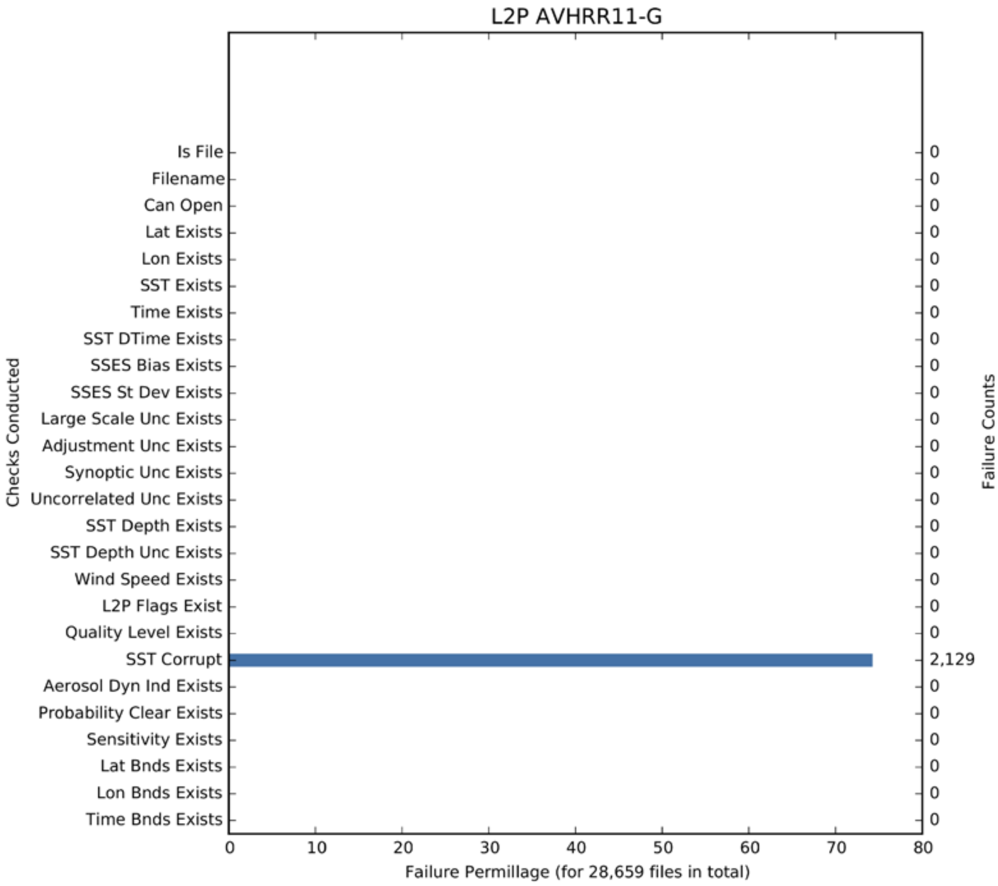


Figure 4-52: Results of L2P product checks for AVHRR11 GAC

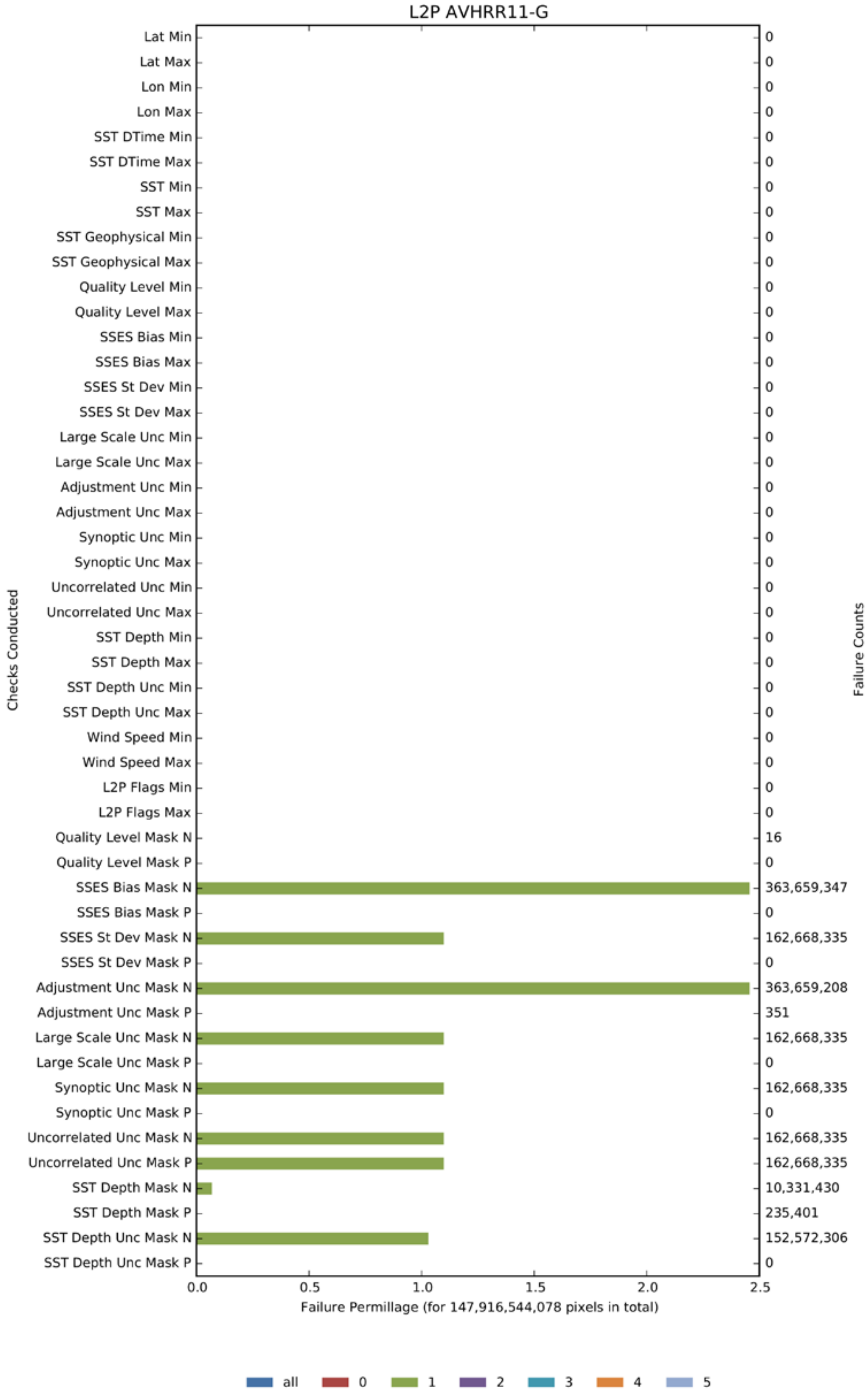


Figure 4-53: Results of L2P pixel checks for AVHRR11 GAC

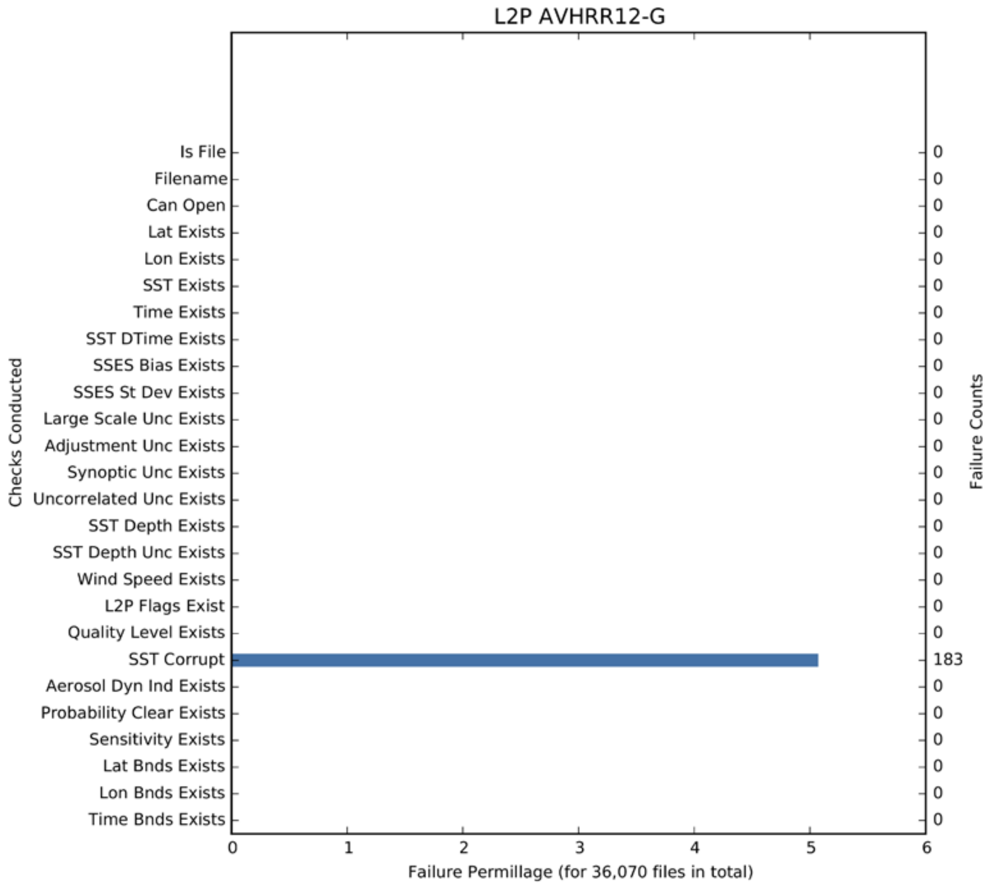


Figure 4-54: Results of L2P product checks for AVHRR12 GAC

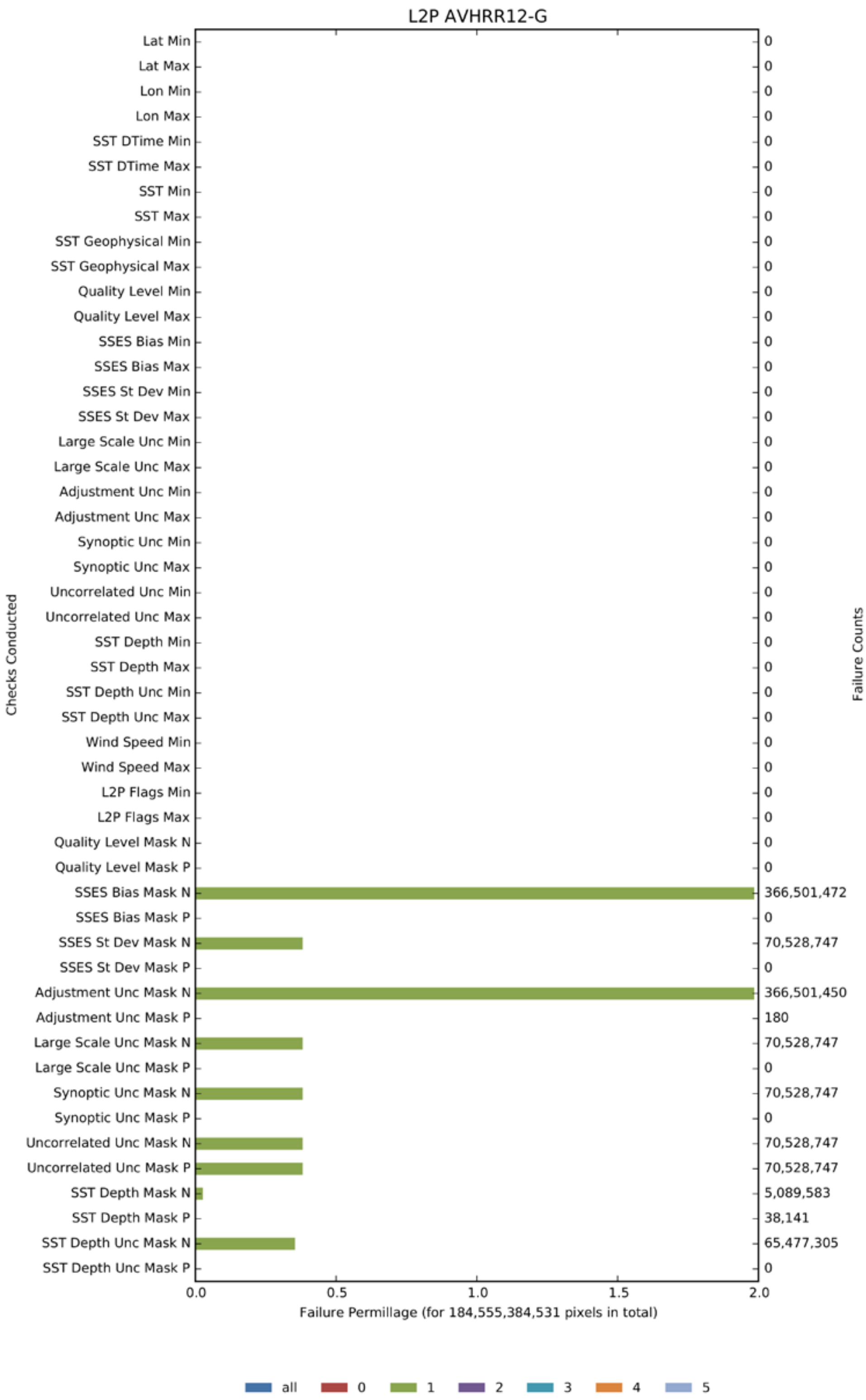


Figure 4-55: Results of L2P pixel checks for AVHRR12 GAC

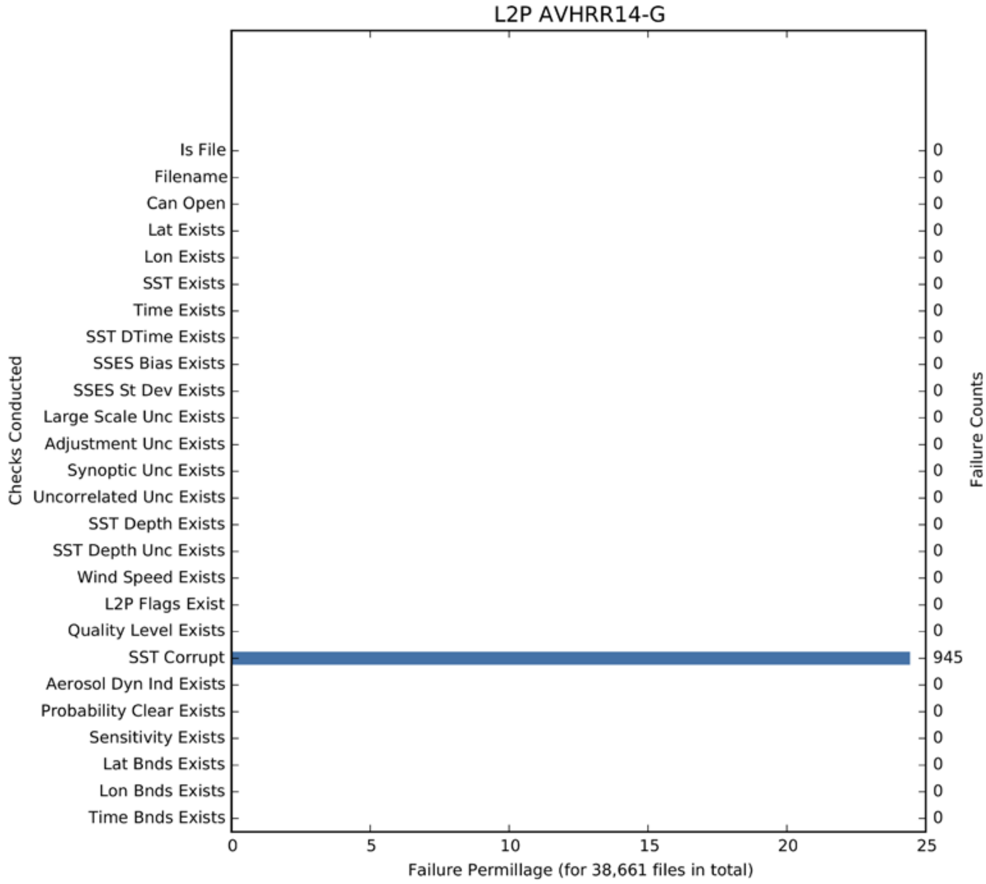


Figure 4-56: Results of L2P product checks for AVHRR14 GAC

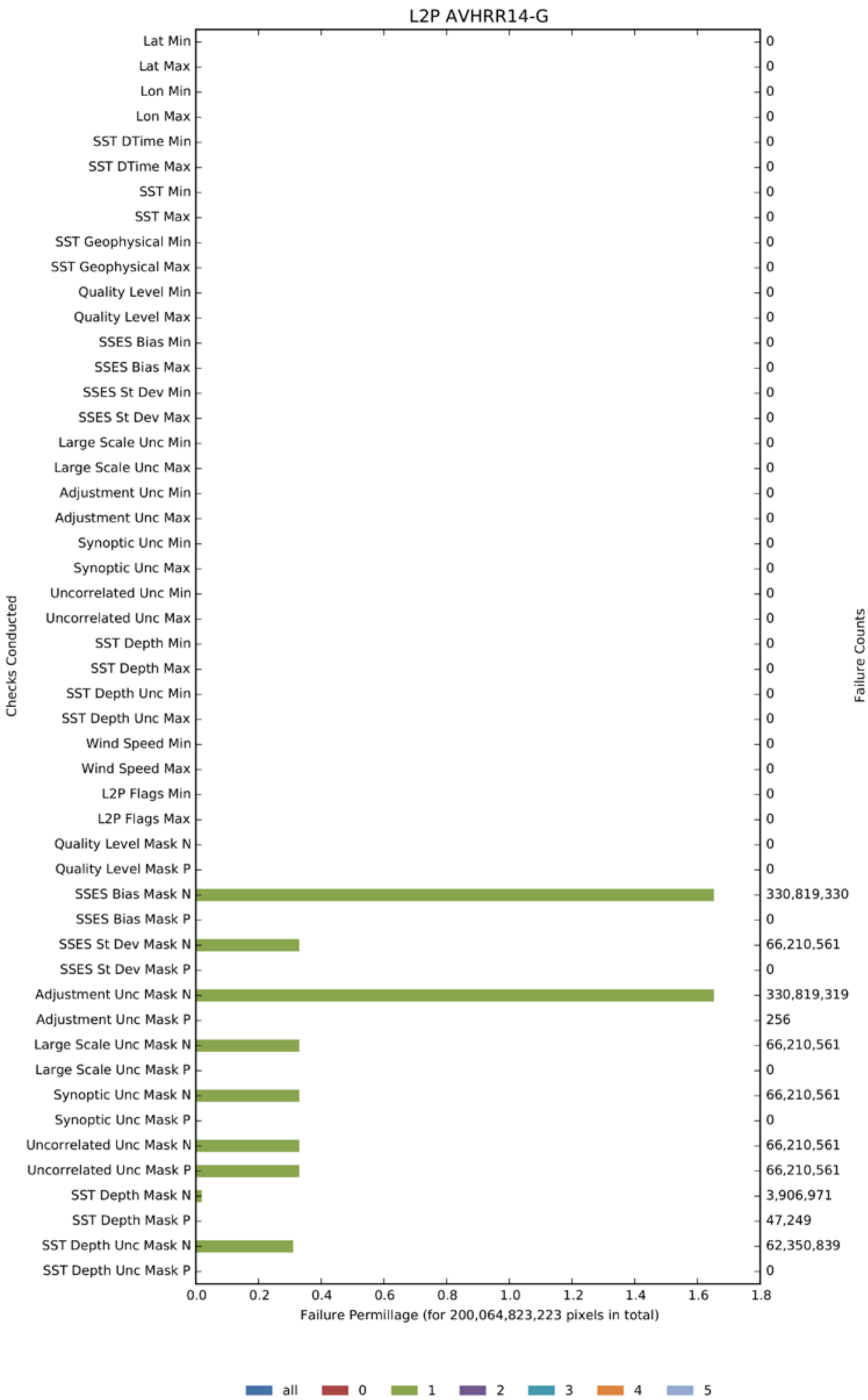


Figure 4-57: Results of L2P pixel checks for AVHRR14 GAC

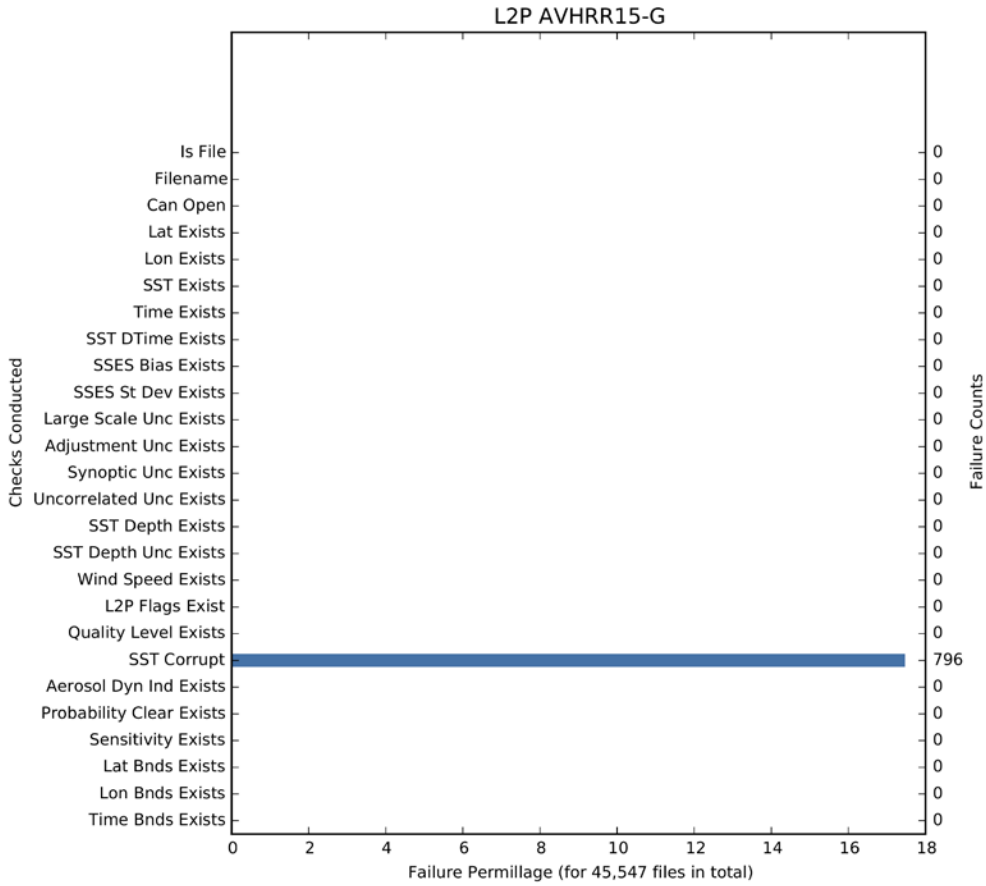


Figure 4-58: Results of L2P product checks for AVHRR15 GAC

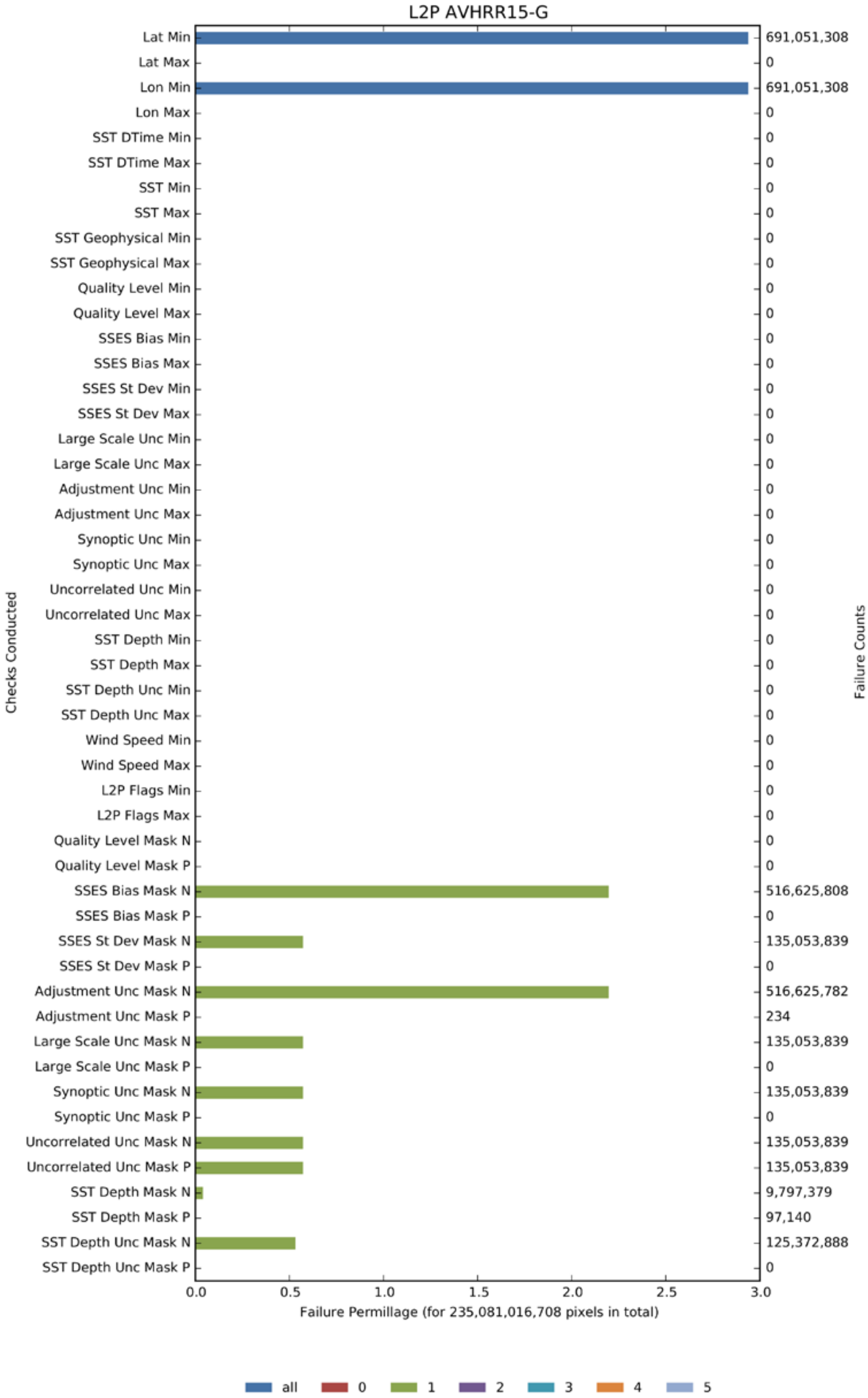


Figure 4-59: Results of L2P pixel checks for AVHRR15 GAC

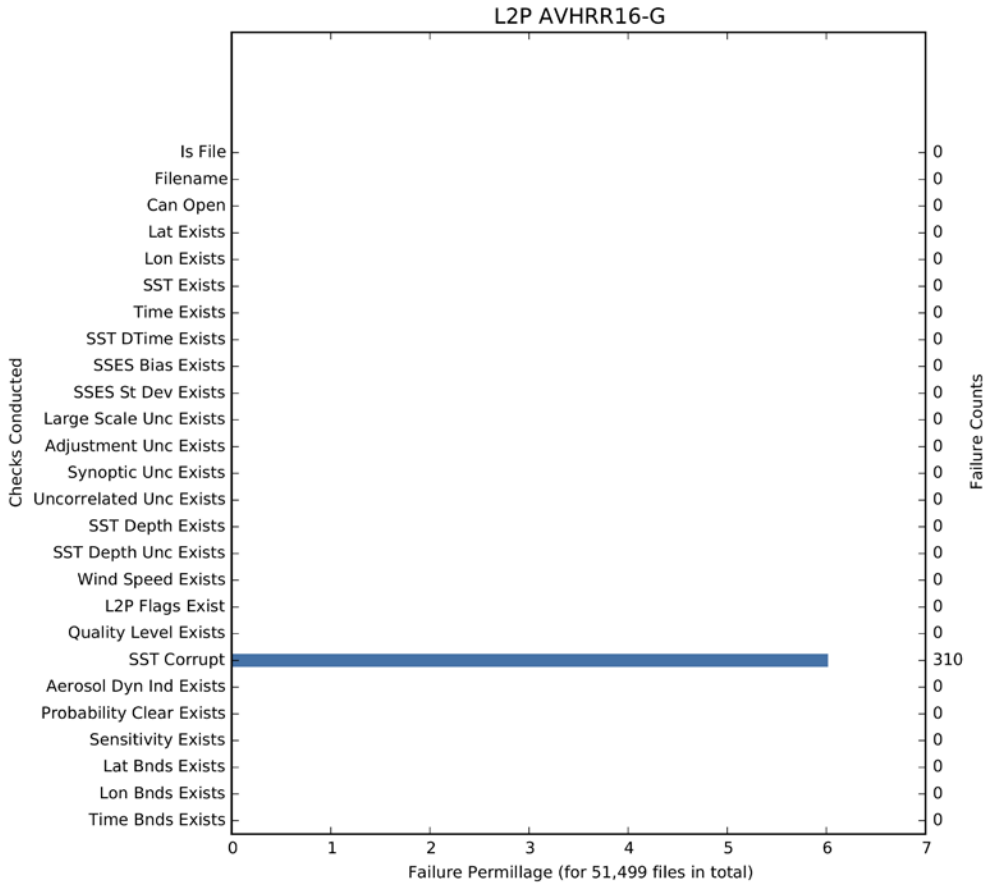


Figure 4-60: Results of L2P product checks for AVHRR16 GAC

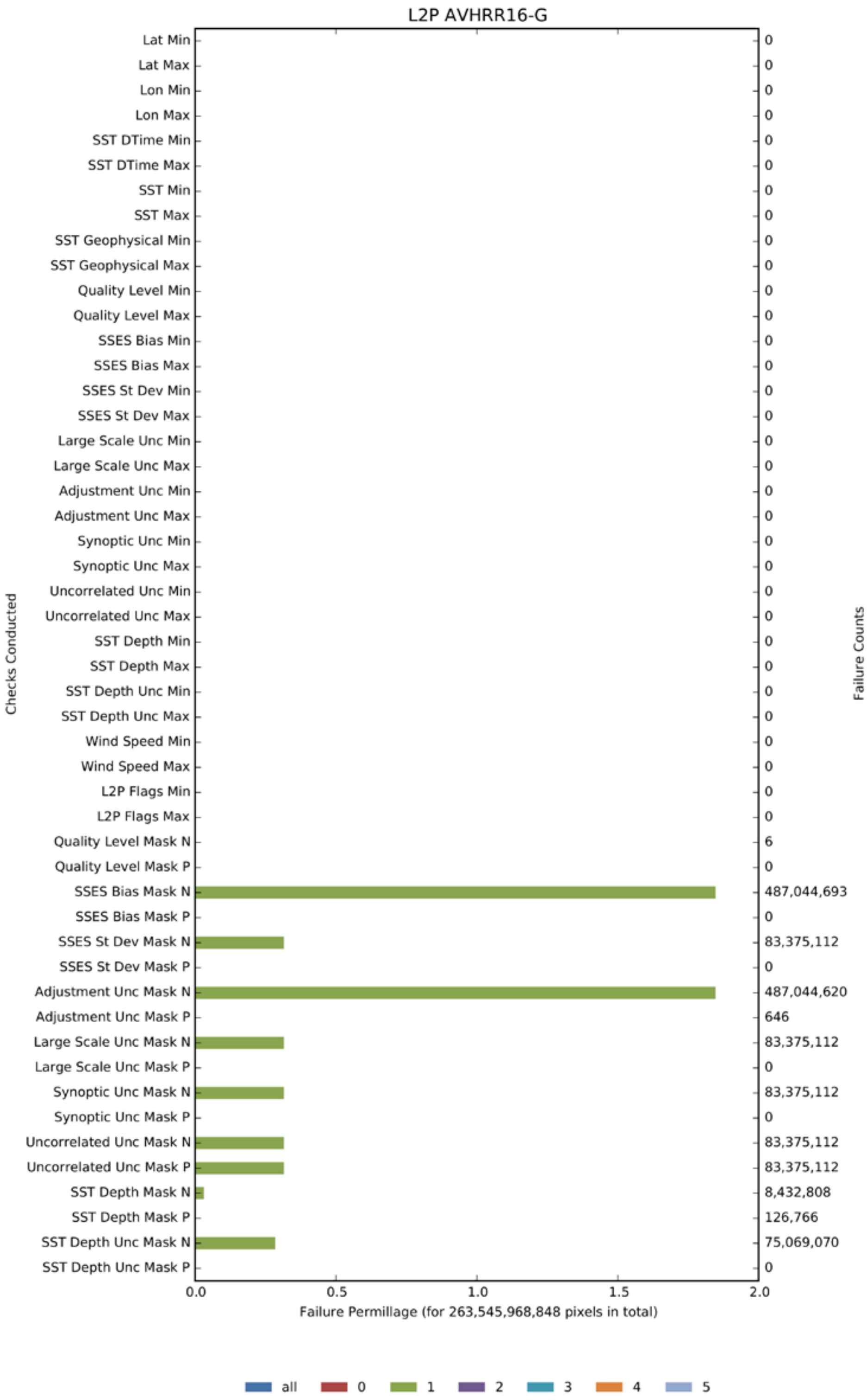


Figure 4-61: Results of L2P pixel checks for AVHRR16 GAC

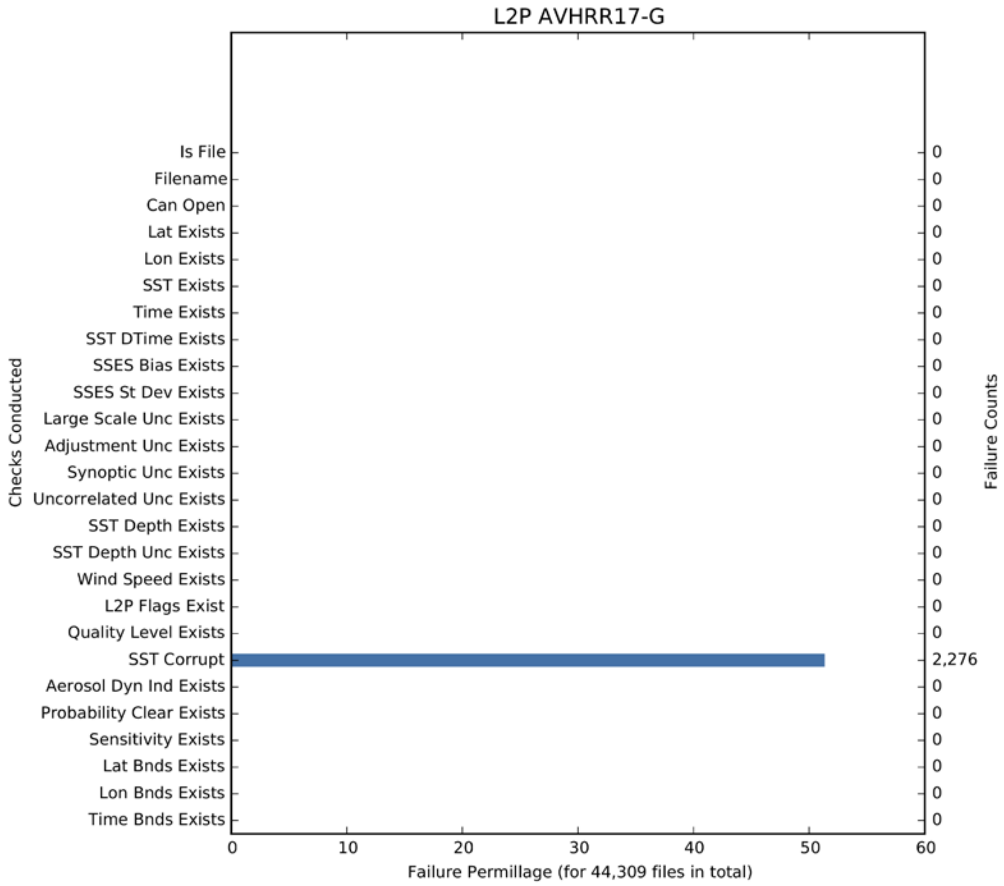


Figure 4-62: Results of L2P product checks for AVHRR17 GAC

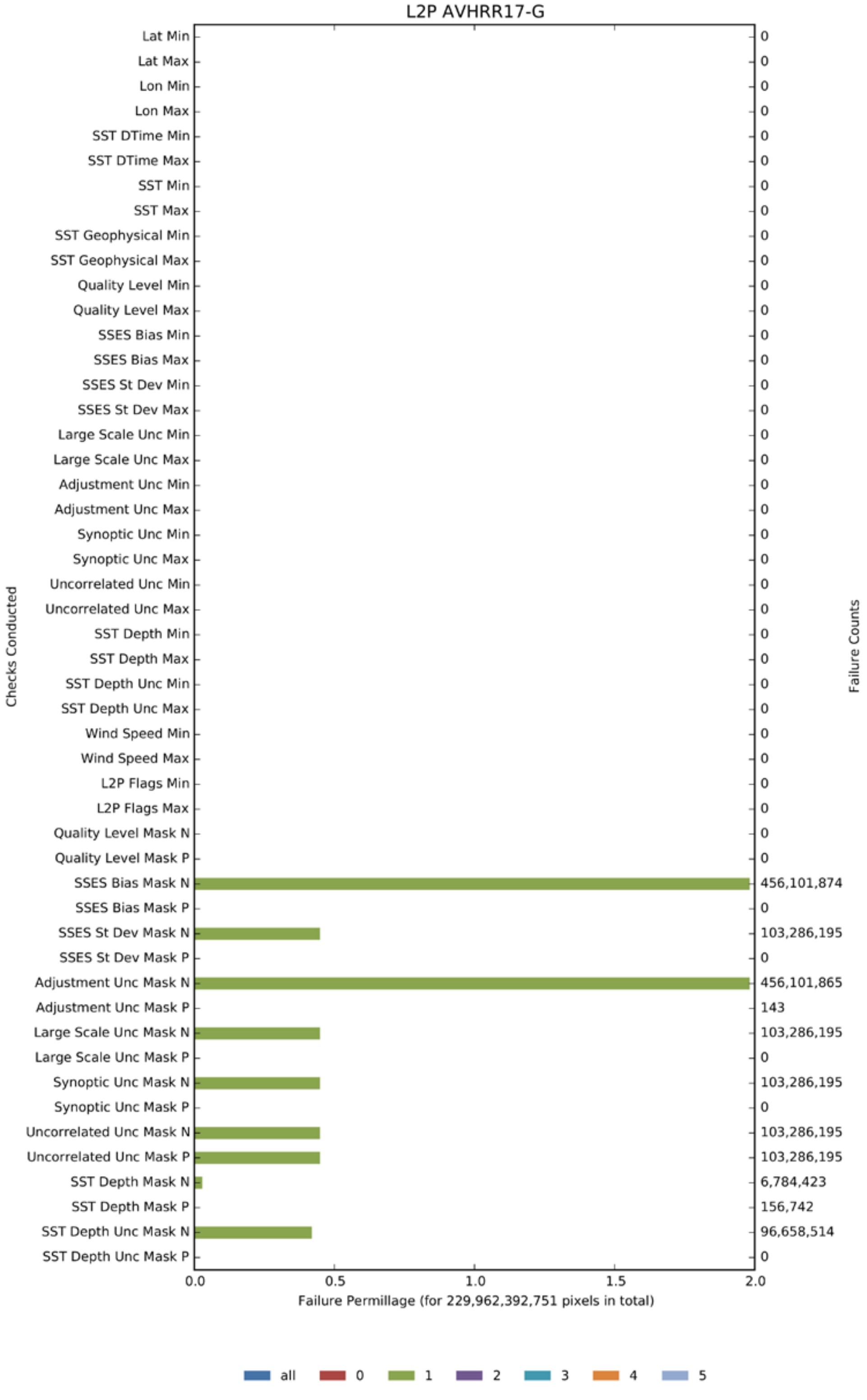


Figure 4-63: Results of L2P pixel checks for AVHRR17 GAC

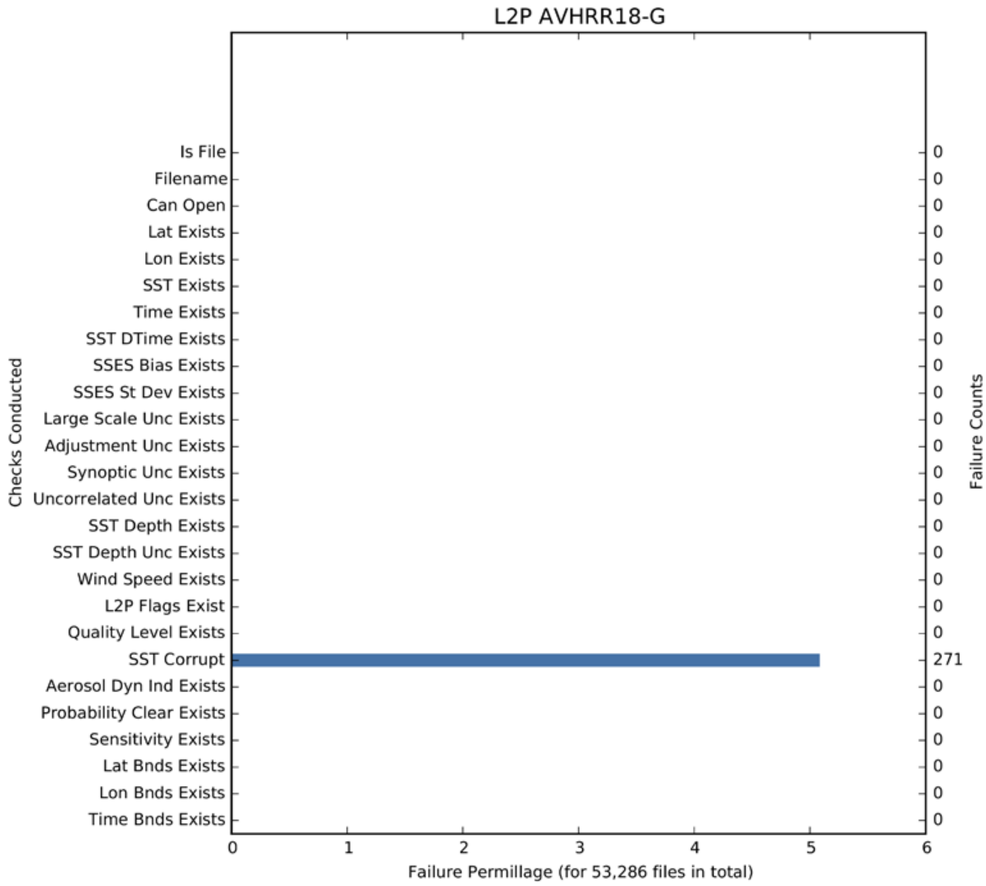


Figure 4-64: Results of L2P product checks for AVHRR18 GAC

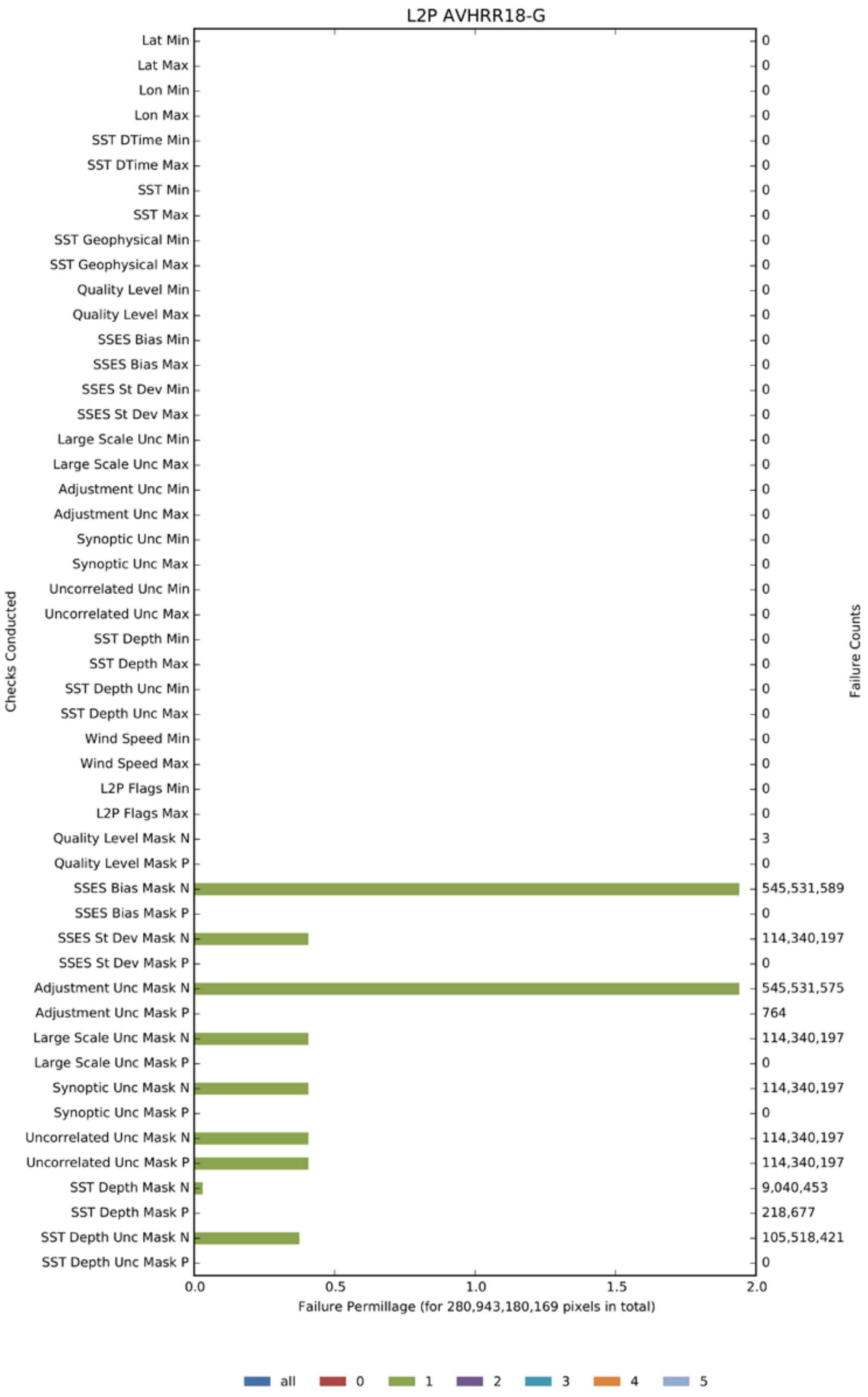


Figure 4-65: Results of L2P pixel checks for AVHRR18 GAC

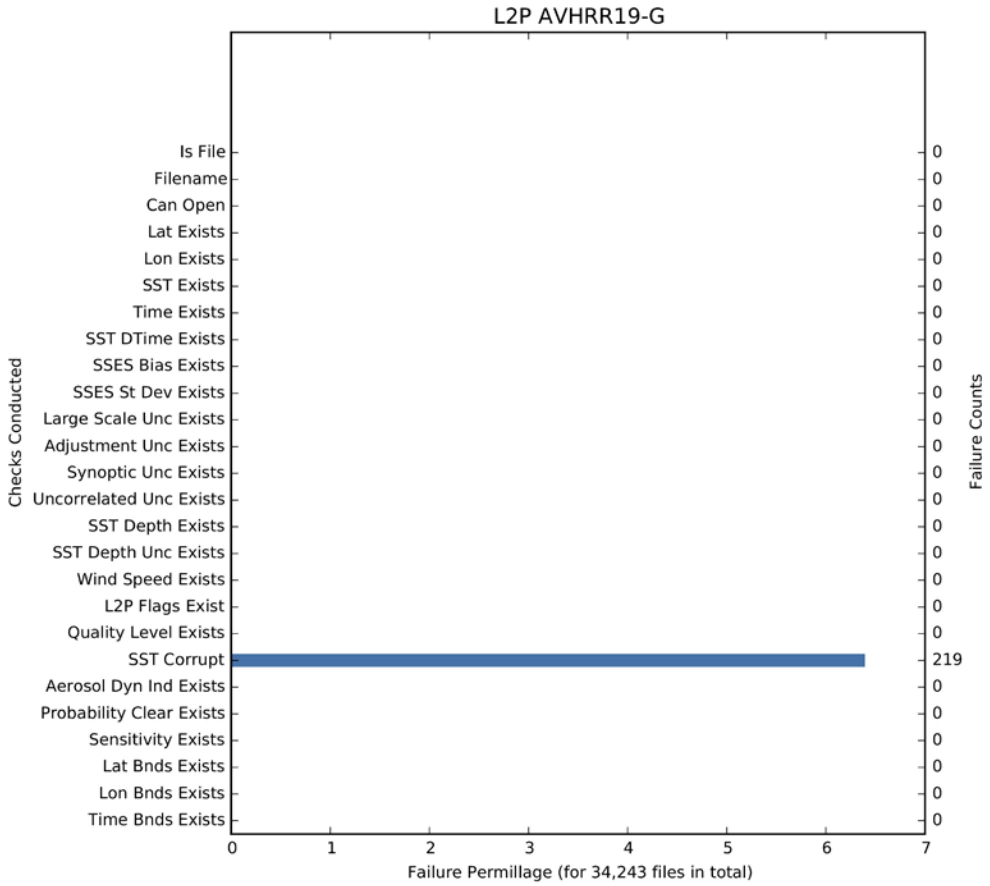


Figure 4-66: Results of L2P product checks for AVHRR19 GAC

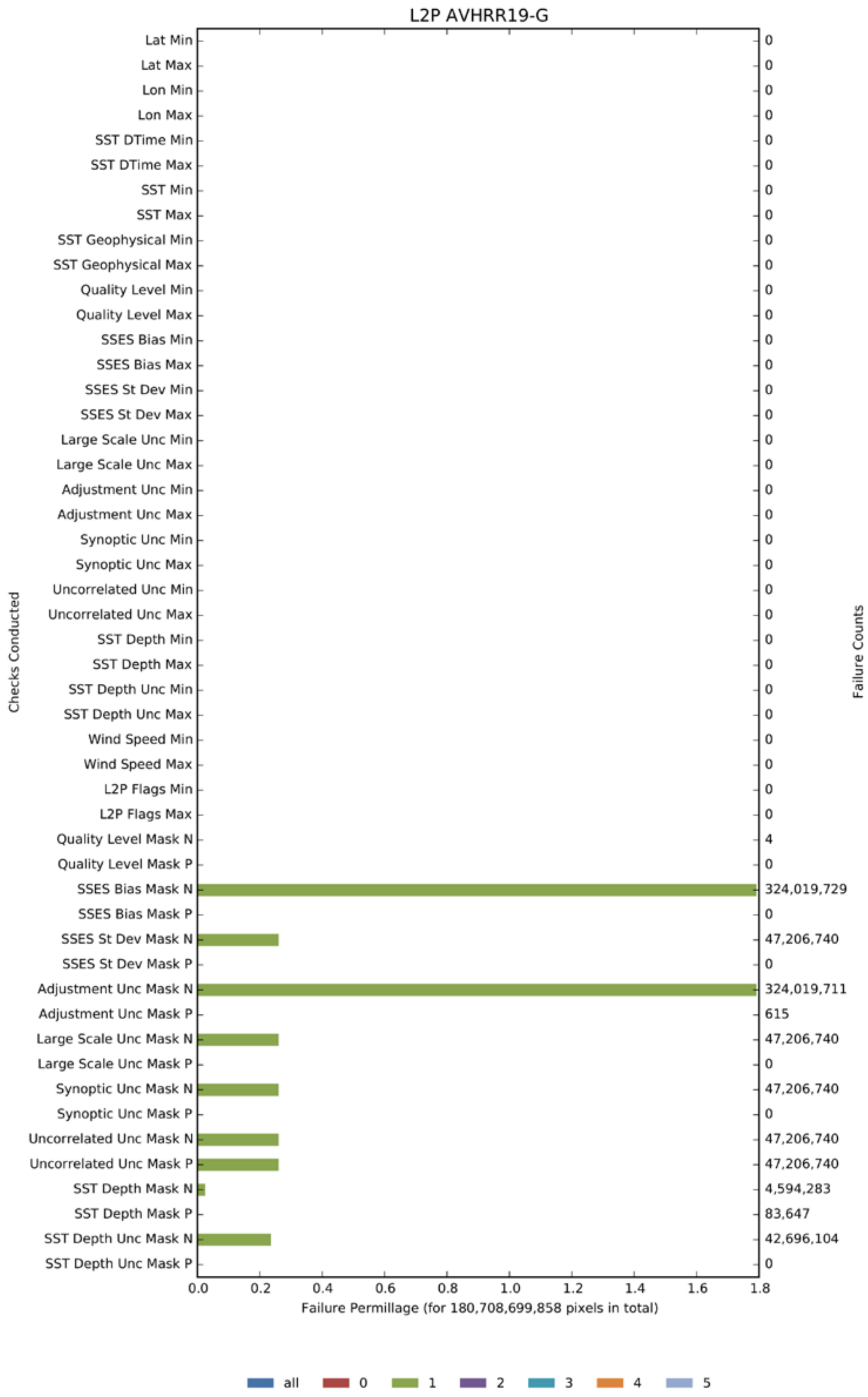


Figure 4-67: Results of L2P pixel checks for AVHRR19 GAC

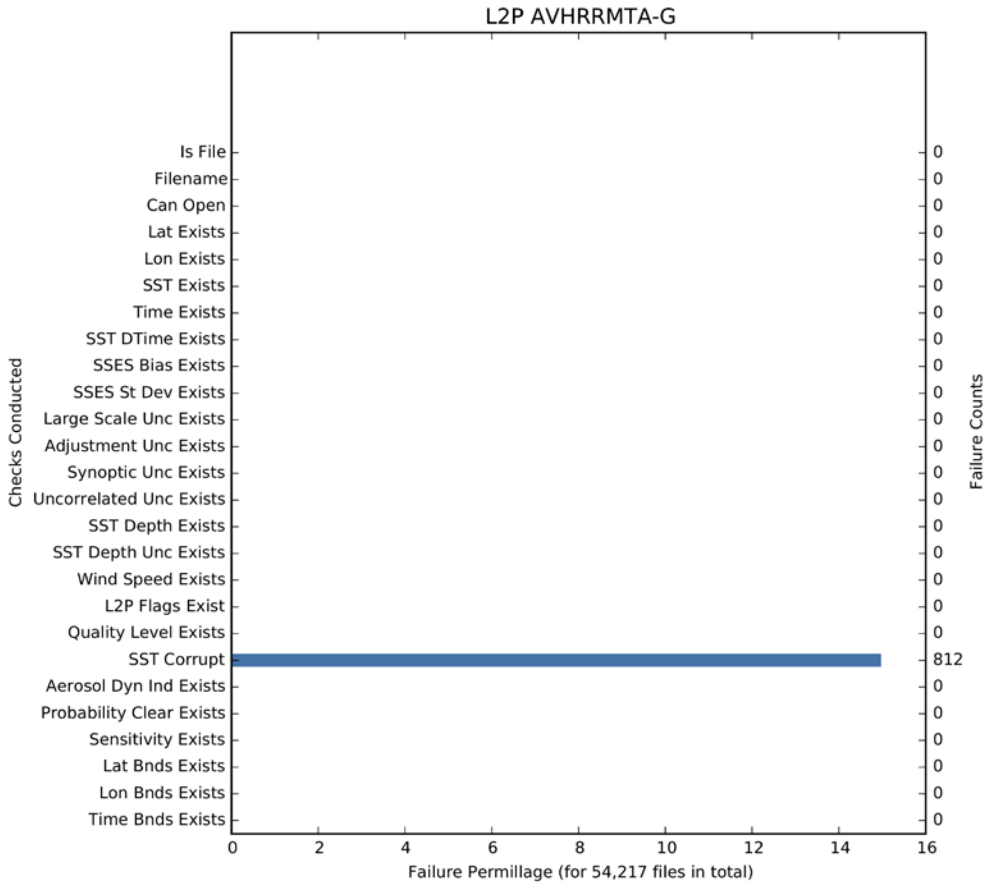


Figure 4-68: Results of L2P product checks for AVHRR MetOp-A GAC

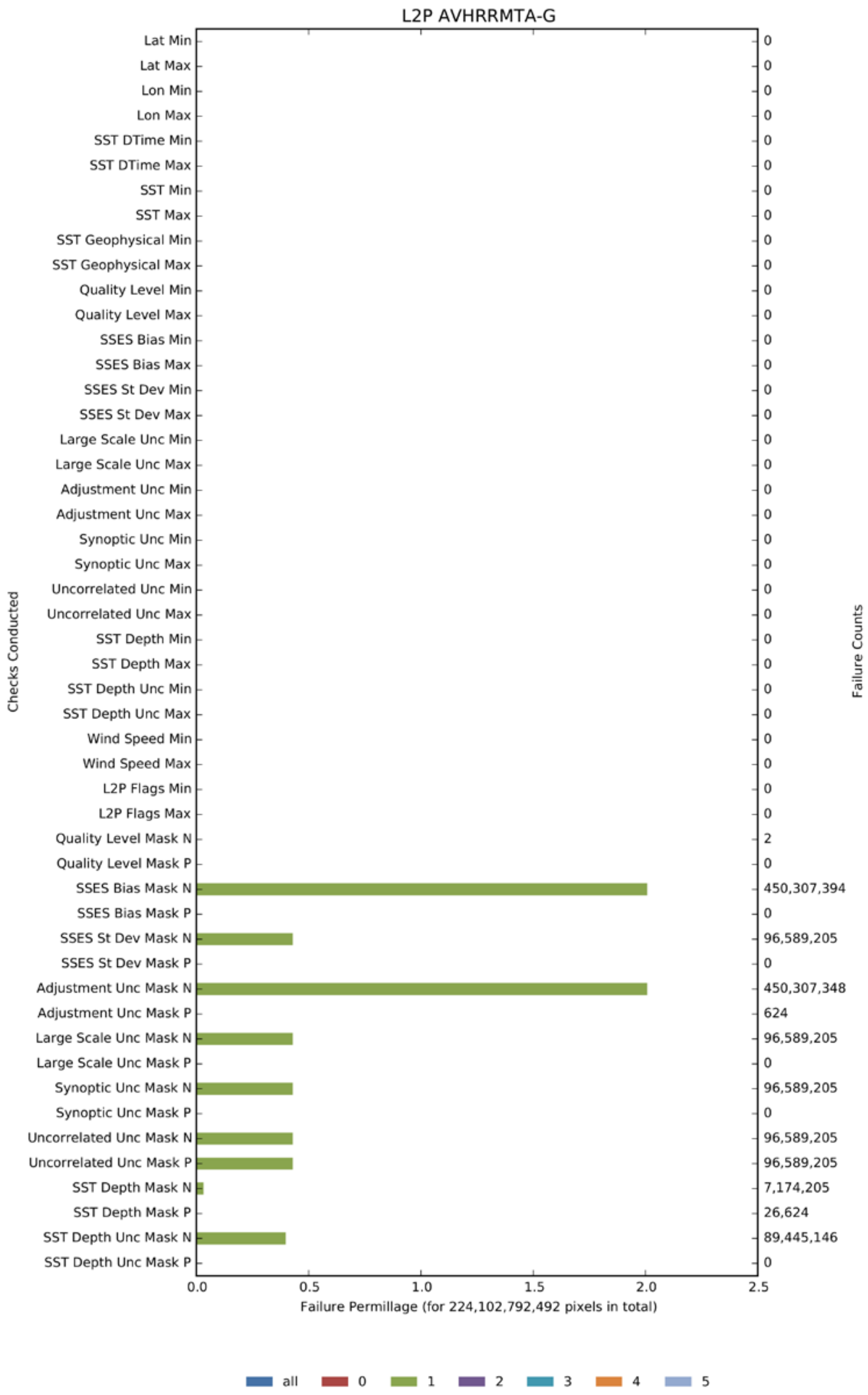


Figure 4-69: Results of L2P pixel checks for AVHRR MetOp-A GAC

4.2.2 Sample verification

A sample of L2P files consisting of one early and one late product from each of the (A)ATSR and AVHRR sensor periods, selected at random were verified by manual inspection of the data fields. All of these files were also used for the verification of all metadata against the Product Specification Document (PSD) [AD.2]. The files manually inspected are detailed in Table 4-4 below.

The metadata verification against the product specification included both global and variable attributes. A few discrepancies found between the file content and the product specification, which are listed in Table 4-7 further below.

The manual inspection of the data fields within the L2P file sample included the following checks:

- Plotting sea_surface_temperature data and checking data coverage and histogram
- Plotting sea_surface_temperature_depth data and checking data coverage and histogram
- Plotting sst_dtime data and checking data coverage and histogram
- Plotting sses_bias and checking data coverage and histogram (bias always equal to zero)
- Plotting sses_standard_deviation and checking data coverage and histogram
- Plotting sst_depth_total_uncertainty and checking data coverage and histogram
- Plotting wind_speed data and checking data coverage and histogram
- Plotting l2p_flags and checking data coverage and histogram
- Plotting quality_level and checking data structure coverage and histogram
- Plotting large_scale_correlated uncertainty and checking data coverage and histogram (uncertainty always equal to 0.1)
- Plotting synoptically_correlated_uncertainty and checking data coverage and histogram
- Plotting uncorrelated_uncertainty and checking data coverage and histogram
- Plotting adjustment_uncertainty and checking data coverage and histogram
- Plotting aerosol_dynamic_indicator and checking data coverage and histogram
- Plotting probability_clear and checking data coverage and histogram
- Plotting sensitivity and checking data coverage and histogram

During this manual inspection, no artefacts that could be hints for erroneous processing settings could be detected. For the large-scale correlated uncertainty all valid data points are set to 0.1, which is correct.

In some of the test-files (20, 24, 30 and 33 in Table 4-5) some pixels contained extremely high values for SST and SST_depth (more than 320 Kelvin). This is currently being investigated by the processing team.

A comparison was also made between the square root of the sum of the squares of the uncertainty values and total uncertainty provided in the file. In the L2P products, the SSES standard deviation is given with a precision of about 0.005 K, whereas for all other uncertainties the precision is about 0.0005 K. Propagating these numbers gives an expected accuracy of about 0.0051 for the difference in sea surface temperature total uncertainties and of about 0.0011 for the difference in sea surface temperature depth total uncertainty. In the files checked manually, the differences found (see Table 4-7) are in excellent agreement with the expected accuracies.

Table 4-5: Files verified manually for data content.

Sensor	Filename	File number
ATSR1	19921004172457-ESACCI-L2P_GHRSST-SSTskin-ATSR1-EXP1.2-v02.0-fv1.0.nc	1
ATSR1	19961230235123-ESACCI-L2P_GHRSST-SSTskin-ATSR1-EXP1.2-v02.0-fv1.0.nc	2
ATSR2	19970213203433-ESACCI-L2P_GHRSST-SSTskin-ATSR2-EXP1.2-v02.0-fv1.0.nc	3
ATSR2	20021127065930-ESACCI-L2P_GHRSST-SSTskin-ATSR2-EXP1.2-v02.0-fv1.0.nc	4
AATSR	20040427204516-ESACCI-L2P_GHRSST-SSTskin-AATSR-EXP1.2-v02.0-fv1.0.nc	5
AATSR	20111104054240-ESACCI-L2P_GHRSST-SSTskin-AATSR-EXP1.2-v02.0-fv1.0.nc	6
AVHRR 06	19801207012214-ESACCI-L2P_GHRSST-SSTskin-AVHRR06_G-EXP1.2-v02.0-fv1.0.nc	7
AVHRR 06	19820216010507-ESACCI-L2P_GHRSST-SSTskin-AVHRR06_G-EXP1.2-v02.0-fv1.0.nc	8
AVHRR 07	19830111151820-ESACCI-L2P_GHRSST-SSTskin-AVHRR07_G-EXP1.2-v02.0-fv1.0.nc	9
AVHRR 07	19850117000806-ESACCI-L2P_GHRSST-SSTskin-AVHRR07_G-EXP1.2-v02.0-fv1.0.nc	10
AVHRR 08	19830927114445-ESACCI-L2P_GHRSST-SSTskin-AVHRR08_G-EXP1.2-v02.0-fv1.0.nc	11
AVHRR 08	19850722034811-ESACCI-L2P_GHRSST-SSTskin-AVHRR08_G-EXP1.2-v02.0-fv1.0.nc	12
AVHRR 09	19850821191551-ESACCI-L2P_GHRSST-SSTskin-AVHRR09_G-EXP1.2-v02.0-fv1.0.nc	13
AVHRR 09	19870324024227-ESACCI-L2P_GHRSST-SSTskin-AVHRR09_G-EXP1.2-v02.0-fv1.0.nc	14
AVHRR 10	19881004225126-ESACCI-L2P_GHRSST-SSTskin-AVHRR10_G-EXP1.2-v02.0-fv1.0.nc	15
AVHRR 10	19890517051622-ESACCI-L2P_GHRSST-SSTskin-AVHRR10_G-EXP1.2-v02.0-fv1.0.nc	16
AVHRR 11	19881124024836-ESACCI-L2P_GHRSST-SSTskin-AVHRR11_G-EXP1.2-v02.0-fv1.0.nc	17
AVHRR 11	19920726193902-ESACCI-L2P_GHRSST-SSTskin-AVHRR11_G-EXP1.2-v02.0-fv1.0.nc	18
AVHRR 12	19920302065612-ESACCI-L2P_GHRSST-SSTskin-AVHRR12_G-EXP1.2-v02.0-fv1.0.nc	19

Sensor	Filename	File number
AVHRR 12	19950913024416-ESACCI-L2P_GHRSST-SSTskin-AVHRR12_G-EXP1.2-v02.0-fv1.0.nc	20
AVHRR 14	19970423174037-ESACCI-L2P_GHRSST-SSTskin-AVHRR14_G-EXP1.2-v02.0-fv1.0.nc	21
AVHRR 14	20020528214123-ESACCI-L2P_GHRSST-SSTskin-AVHRR14_G-EXP1.2-v02.0-fv1.0.nc	22
AVHRR 15	20020611125054-ESACCI-L2P_GHRSST-SSTskin-AVHRR15_G-EXP1.2-v02.0-fv1.0.nc	23
AVHRR 15	20090829003217-ESACCI-L2P_GHRSST-SSTskin-AVHRR15_G-EXP1.2-v02.0-fv1.0.nc	24
AVHRR 16	20010917163123-ESACCI-L2P_GHRSST-SSTskin-AVHRR16_G-EXP1.2-v02.0-fv1.0.nc	25
AVHRR 16	20070605192622-ESACCI-L2P_GHRSST-SSTskin-AVHRR16_G-EXP1.2-v02.0-fv1.0.nc	26
AVHRR 17	20031004043059-ESACCI-L2P_GHRSST-SSTskin-AVHRR17_G-EXP1.2-v02.0-fv1.0.nc	27
AVHRR 17	20081106170758-ESACCI-L2P_GHRSST-SSTskin-AVHRR17_G-EXP1.2-v02.0-fv1.0.nc	28
AVHRR 18	20080919052426-ESACCI-L2P_GHRSST-SSTskin-AVHRR18_G-EXP1.2-v02.0-fv1.0.nc	29
AVHRR 18	20150726212936-ESACCI-L2P_GHRSST-SSTskin-AVHRR18_G-EXP1.2-v02.0-fv1.0.nc	30
AVHRR-19	20101207105751-ESACCI-L2P_GHRSST-SSTskin-AVHRR19_G-EXP1.2-v02.0-fv1.0.nc	31
AVHRR-19	20140421182911-ESACCI-L2P_GHRSST-SSTskin-AVHRR19_G-EXP1.2-v02.0-fv1.0.nc	32
AVHRR-MTA	20090122014903-ESACCI-L2P_GHRSST-SSTskin-AVHRRMTA-EXP1.2-v02.0-fv1.0.nc	33
AVHRR-MTA	20150714182803-ESACCI-L2P_GHRSST-SSTskin-AVHRRMTA-EXP1.2-v02.0-fv1.0.nc	34

4.2.2.1 File Naming Issues

All test files listed in Table 4-5 were checked to follow the file naming conventions for SST-CCI data as defined in the PUG (AD.2) and being derived from the GDS (AD.8).

Table 4-6: Discrepancies between actual L2P file names and PSD

File naming part	Product specification
File Version: “-fv1.0”	File Version: “-fvxx.x”
Additional Segregator: “EXP1.2”	Optional, but should match the actual processor version used: “EXP1.3”

4.2.2.2 Meta Data Issues

Table 4-7: Discrepancies between L2P metadata and the PSD. Shaded cells indicate true discrepancies, while the non-shaded cells indicate where the PSD is mistaken

Variable name or *global*	Attribute or property	File content	Product specification
Global	geospatial_lon_max	-180	Identical to easternmost_longitude (which is +180)
Global	geospatial_lon_min	+180	Identical to westernmost_longitude (which is -180)
Global	geospatial_vertical_min	-1.0E-5	-10^{-6} **or** -0.001 **or** -0.2 **or** -10 (update PSD)
Global	geospatial_vertical_max	-1.0E-5	-10^{-6} **or** -0.001 **or** -0.2 **or** -10 (update PSD)
Global	Source file	Filename of the input product	Not specified (update PSD)
Global	id	Processor version number incorrect, should be v1.3	n/a
sst_depth_dtime	N/A	Not present	Present
l2p_flags	_FillValue	-32768	Not specified (update PSD)
quality_level	_FillValue	0	-128 (update PSD)
sea_surface_temperature_depth	source	n/a	Data source according to table 9 PDS
large_scale_correlated_uncertainty	scale_factor	0.001	0.01 (update PSD)
synoptically_correlated_uncertainty	scale_factor	0.001	0.01 (update PSD)
uncorrelated_uncertainty	scale_factor	0.001	0.01 (update PSD)
uncorrelated_uncertainty	long_name	Uncertainty from errors unlikely to be correlated between SSTs	Uncertainty from errors likely to be uncorrelated between SSTs
adjustment_uncertainty	scale_factor	0.001	0.01 (update PSD)
sst_depth_total_uncertainty	scale_factor	0.001	0.01 (update PSD)

Variable name or *global*	Attribute or property	File content	Product specification
wind_speed	time_offset	"0." Value is a truncated float	n/a
aero-sol_dynamic_indicator	n/a	n/a	Experimental variable. If decided to keep PSD has to be updated.
probability_clear	n/a	n/a	Experimental variable. If decided to keep PSD has to be updated.
sensitivity	n/a	n/a	Experimental variable. If decided to keep PSD has to be updated.

Table 4-8: Differences between total uncertainties absolute min and max values and mean value provided in the L2P product and the total uncertainty calculated by combining individual uncertainty components

File no.	Min SST Uncert delta	Max SST Uncert. delta	Mean SST Uncert. delta	Min SST_depth Uncert delta	Max SST_depth Uncert. delta	Mean SST_depth Uncert. delta	Number Pixels
1	0.0	0.0055	0.0026	0.0	0.0011	3.0e-4	1435730
2	0.0	0.0055	0.0025	0.0	0.0011	2.8e-4	823972
3	9.1e-6	0.0054	0.0018	0.0	0.0011	2.9e-4	100493
4	0.0	0.0055	0.0024	0.0	0.0011	2.9e-4	1249074
5	0.0	0.0055	0.0023	0.0	0.0011	2.9e-4	2000361
6	0.0	0.0056	0.002	0.0	0.0012	2.9e-4	2605728
7	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	1018819
8	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	1031169
9	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	853161
10	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	862780
11	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	582265
12	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	1172264
13	0.0	0.0056	0.0024	0.0	0.0012	3.2e-4	651655
14	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	1086011
15	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	702656
16	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	798436
17	0.0	0.0056	0.0024	0.0	0.0012	3.2e-4	719298
18	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	732009
19	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	836720
20	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	1217620
21	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	944437

22	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	798420
23	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	749189
24	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	1523435
25	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	631360
26	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	594473
27	0.0	0.0055	0.0025	0.0	0.0011	3.2e-4	820377
28	0.0	0.0055	0.0024	0.0	0.0012	3.2e-4	868160
29	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	650647
30	0.0	0.0056	0.0026	0.0	0.0012	3.2e-4	539047
31	0.0	0.0055	0.0025	0.0	0.0012	3.2e-4	780548
32	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	885670
33	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	12206351
34	0.0	0.0056	0.0025	0.0	0.0012	3.2e-4	15988540

4.2.3 High-latitude classifier (replication from Phase-I)

The high latitude verification consists of an independent verification that the classifier is implemented correctly for the L2U files. The classifier and the prototype generation are described in the ATBD version 2 [RD.305]. In the classification, probabilities for water, ice and clouds are determined for all pixels in the L2U files that have passed the cloud clearing procedures used in CLAVR-X. All pixels with an ice probability exceeding the threshold of 0.9 have subsequently been classified as ice in the L2P flags variable in the L2P files. For this verification, the classifier has been obtained and implemented independently of the developer and the prototype generator.

The test cases used for the matches are the dummy match-up areas. These regions have been constructed within the MMD, to withhold certain areas where the classifier can be used. The independent results from the classifier applied on dummy regions selected for the MMD will then be compared with the content of the L2U files on a pixel-by-pixel basis. Matching pairs are found by selecting the L2P observations that are within 500 meters and 2 minutes from the dummy matchups. The classifier works separately on night, day and twilight conditions and the test results are therefore divided into these three categories. In addition, the test results have been divided into northern and southern hemisphere results.

Note that there is not a unique correspondence between the pixels classified with ice probability > 0.9 and the L2P flag variable in the L2U files, since the classifier in the prototype generation has only been run on pixels that have passed the CLAVR-X cloud clearing. Several tests can however be performed, to verify the implementation of the classifier in the prototype generation. The summary statistics of the results are described in Table 4.2.4.1 below. Note that there are no classification results for the AVHRR 15 or MetOp A sensors. For MetOp A there are no dummy match-ups, and for AVHRR 15 no L2P matches were found for the dummy match-ups.

The main results from the high latitude verification table above are listed below.

- Only a few matching pairs have been classified as ice by the classifier and passed the cloud clearing procedures.

- The tests carried out found agreement as expected, between the L2P flags ice pixels and the pixels with an ice probability greater than 90 % according to the independent classification results.
- No find discrepancies were found where pixels with the L2P flags variable set to ice were not classified as ice.

According to the verification performed here, it appears that the classifier has been implemented correctly in the prototype generation. This applies for all the verified satellites, for both hemispheres and for day/night and twilight conditions.

Table 4-9: High latitude classification verification using an independent implementation of the pixel classifier for AVHRR instruments. The superscripts used in the table have the following meanings: [1]The number of match-up pairs where sea surface temperature observations in the L2U files had an ice probability of more than 90% as calculated by the classifier; [2]the number of match-up pairs where sea surface temperature observations in the L2U files had a cloud probability of more than 90% as calculated by the classifier; [3]the number of match-up pairs that had an ice probability of more than 90 % and had L2P flags set to ice; [4]the number of match-up pairs that had an ice probability of more than 90% and had L2P flags not set to ice

Satellite	Hemi-sphere	Day/ twilight /night	Number of matches	Valid obs + Pice > 0.9 [1]	Valid obs + Pcloud > 0.9 [2]	Pice > 90% and L2P_flags = ice [3]	Pice > 0.9 and L2P_flags = no ice [4]
12	N	D	605	0	0	0	0
12	N	T	1369	0	0	0	0
12	N	N	4623	0	0	0	0
12	S	D	2865	0	0	81	0
12	S	T	1914	0	0	0	0
12	S	N	1097	0	0	0	0
14	N	D	1132	0	0	0	0
14	N	T	2478	0	0	0	0
14	N	N	3695	0	0	0	0
14	S	D	3619	0	0	75	0
14	S	T	458	0	0	0	0
14	S	N	1570	0	0	0	0
16	N	D	941	0	0	0	0
16	N	T	7187	0	0	0	0

Satellite	Hemi-sphere	Day/ twilight /night	Number of matches	Valid obs + Pice > 0.9 [1]	Valid obs + Pcloud > 0.9 [2]	Pice > 90% and L2P_flags = ice [3]	Pice > 0.9 and L2P_flags = no ice [4]
16	N	N	11779	0	36	0	0
16	S	D	2709	0	0	29	0
16	S	T	3300	0	0	0	0
16	S	N	2258	0	0	0	0
17	N	D	2479	0	0	0	0
17	N	T	10437	254	0	90	0
17	N	N	8861	0	0	0	0
17	S	D	2634	0	0	0	0
17	S	T	3720	73	0	0	0
17	S	N	2586	0	0	0	0
18	N	D	2000	0	0	0	0
18	N	T	7474	0	0	2	0
18	N	N	2586	0	4	0	0
18	S	D	2012	0	0		0
18	S	T	1634	0	0	10	0
18	S	N	544	0	0		0

4.3 DV processor (replication from Phase-I)

The SST-CCI processing chain uses a coupled Fairall-Kantha-Clayson model to make a correction between the SST skin and SST depth temperature, which accounts for diurnal variability in the skin temperature [RD.264]. Figure 4-33 below illustrates satellite SST (skin) to buoy (0.2 m depth) temperature differences as a function of wind speed. At wind speeds below 10 m s^{-1} night-time skin minus depth differences are negative ranging between -0.3K and -0.1K depending on wind speed. During the day the near surface is warmed by solar insolation reducing the temperature difference between the skin and depth measurements.

Figure 4-35 shows the satellite skin minus depth differences as a function of local time for SST-CCI AATSR day- and night-time observations. Data are from 3 months of L3U data between June-August 2006. The trends are as expected from Figure 4.3.2 with the similar rate of change in temperature. During the day the skin minus depth difference decreases as the near surface layer warms. At night-time the reverse trend is evident as the near surface cools. The maximum difference is ~0.2 K consistent with the skin effect [RD.319]. From this we conclude that the skin to depth SST adjustment, including diurnal variability has been successfully implemented within the CCI processing chain.

In order to verify the depth correction implemented in the CCI processing chain the satellite skin minus depth temperature differences are compared as a function of time. The local equator crossing times of the ENVISAT satellite are 1000 and 2200. SST observations are centred on these times, but can show a local time variation of up to +/- 6 hours. Figure 4-34 shows a comparison of satellite SST at 0.2 m depth minus buoy temperatures as a function of time. This can be interpreted such that when the satellite time is later (on the right side of the graph) the daytime bias (grey) becomes more positive as the near surface warms. When the satellite time is earlier (left side of the graph) the bias is more negative as the near surface is cool. For night-time observations, the bias decreases with time as the near surface cools.

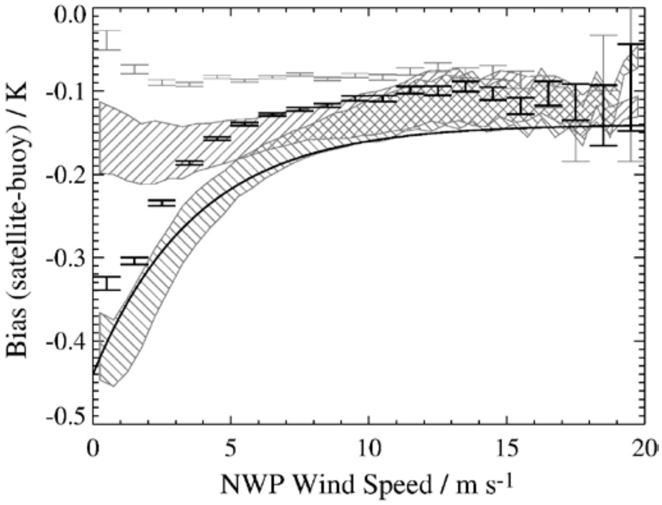


Figure 4-70: AATSR retrieved SST_{skin} minus drifting buoy SST as a function of wind speed. Bars show the range of median difference plus and minus one standard error for (black) night-time and (grey) day-time matches. Shading and solid lines represent model and empirical parameterisations [RD.184]

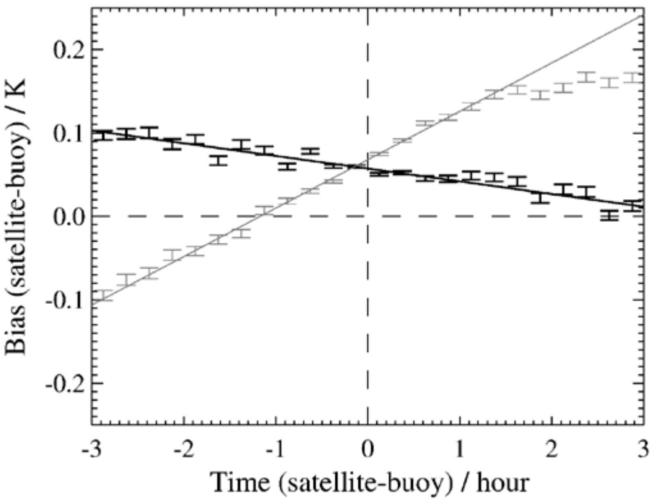


Figure 4-71: D2 (dual view, two channel) $SST_{0.2m}$ retrieval bias as a function of satellite-buoy time difference for daytime (grey) and night-time (black) matches. Solid lines show linear best fit to data, only using time differences < 1.5 h for daytime matches [RD.184]

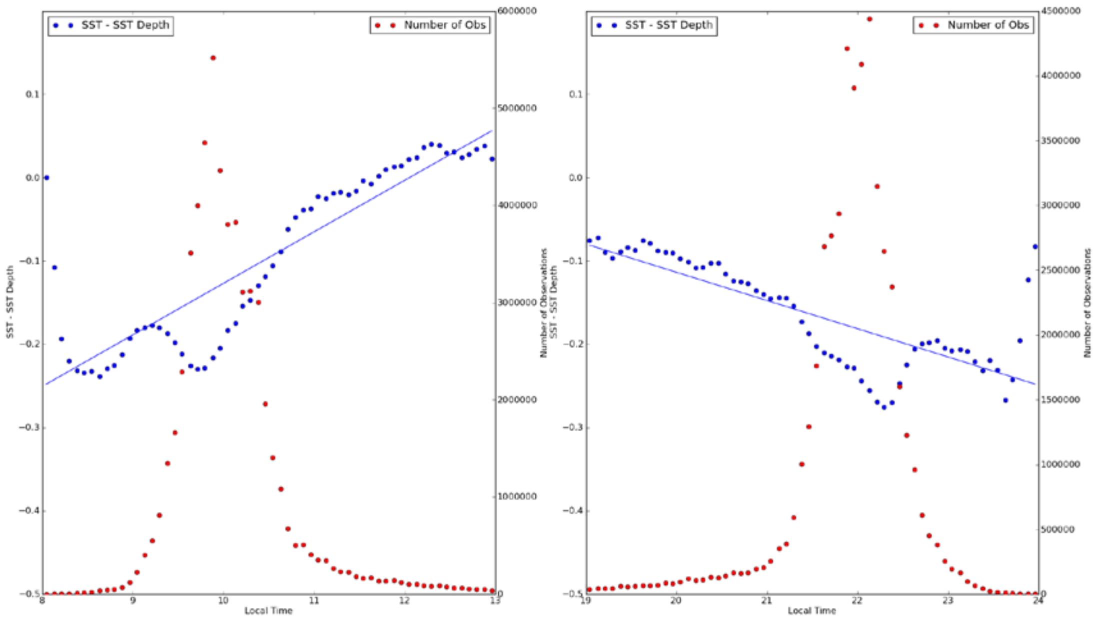


Figure 4-72: Satellite SST_{skin} minus SST_{depth} differences (blue) as a function of local time for 1000 (left) and 2200 (right) satellite overpasses. Differences are plotted at five-minute time increments with the corresponding number of observations (red). Data are averages from three months of AATSR L3U products between June and August 2006

4.4 MMS verification

4.4.1 Unit-level and integration tests

The software package developed for SST-CCI is mainly based on Java code with an additional layer of Python code for the LSF control on the lotus parallel cluster on CEMS.

Both the Java and the Python code are accompanied by test code that is executed automatically on the build-server at BC and at each developer's computer before a code-commit to the source code repository is performed.

The coverage of the MMS codebase with unit-level and integration tests is summarised in **Table 4-10** below. All unit-level tests listed in the table have been passed successfully.

There are 791 unit-level and integration tests in total, resulting in a total coverage (in terms of code lines) of 38.5 per cent.

The overall code test coverage has been slightly increased since the last SVR.

Table 4-10: Coverage of MMS classes, methods and code lines with unit tests (by package)

Package	Classes (%)	Methods (%)	Lines (%)
org.esa.beam.common	80% (4/ 5)	54,5% (24/ 44)	74,9% (128/ 171)
org.esa.beam.dataio.amsr2	14,3% (1/ 7)	2,1% (1/ 47)	0,6% (1/ 154)
org.esa.beam.dataio.cci.sst	40% (8/ 20)	33,3% (40/ 120)	37,6% (163/ 434)
org.esa.beam.dataio.metop	5,6% (1/ 18)	0,7% (1/ 137)	1,5% (12/ 820)

Package	Classes (%)	Methods (%)	Lines (%)
org.esa.beam.util	90% (9/ 10)	60,8% (31/ 51)	61,8% (218/ 353)
org.esa.cci.sst	100% (3/ 3)	75% (18/ 24)	65,7% (71/ 108)
org.esa.cci.sst.accumulate	100% (4/ 4)	100% (15/ 15)	100% (48/ 48)
org.esa.cci.sst.aggregate	100% (3/ 3)	75,6% (34/ 45)	61,9% (60/ 97)
org.esa.cci.sst.assessment	50% (2/ 4)	45,7% (21/ 46)	44,2% (126/ 285)
org.esa.cci.sst.auxiliary	0% (0 / 2)	0% (0 / 14)	0% (0 / 95)
org.esa.cci.sst.cell	80% (12/ 15)	73,5% (61/ 83)	63,1% (217/ 344)
org.esa.cci.sst.common	100% (9 / 9)	100% (47 / 47)	100% (192 / 192)
org.esa.cci.sst.data	84.6% (11 / 13)	82.8% (125 / 151)	85.2% (282 / 331)
org.esa.cci.sst.grid	54.2% (13 / 24)	53.8% (85 / 158)	43.6% (368 / 845)
org.esa.cci.sst.log	100% (3 / 3)	92.3% (12 / 13)	93.5% (43 / 46)
org.esa.cci.sst.netcdf	100% (1 / 1)	92.3% (12 / 13)	86% (49 / 57)
org.esa.cci.sst.orm	57.1% (4 / 7)	61.8% (42 / 68)	68.4% (169 / 247)
org.esa.cci.sst.product	68.2% (15 / 22)	52.8% (57 / 108)	32.2% (94 / 292)
org.esa.cci.sst.reader	92% (23 / 25)	37.3% (106 / 284)	35.3% (479 / 1358)
org.esa.cci.sst.rules	64,8% (114/ 176)	56,8% (246/ 433)	44,3% (630/ 1423)
org.esa.cci.sst.tool	100% (4 / 4)	75% (39 / 52)	54.7% (128 / 234)
org.esa.cci.sst.tools	41,7% (5/ 12)	22,7% (27/ 119)	15,7% (209/ 1331)
org.esa.cci.sst.tools.ingestion	25% (2 / 8)	4.9% (2 / 41)	1.7% (7 / 405)
org.esa.cci.sst.tools.mmdgen…	77.8% (7 / 9)	56.9% (41 / 72)	37.2% (175 / 470)
org.esa.cci.sst.tools.nwp	66,7% (2/ 3)	18,9% (7/ 37)	7,2% (48/ 664)
org.esa.cci.sst.tools.overlap	100% (6 / 6)	100% (29 / 29)	98.6% (141 / 143)
org.esa.cci.sst.tools.regavg	50% (3 / 6)	32.7% (16 / 49)	16% (61 / 382)
org.esa.cci.sst.tools.regavg.aux…	100% (2 / 2)	100% (8 / 8)	100% (33 / 33)
org.esa.cci.sst.tools.regrid	80% (8/ 10)	39,3% (24/ 61)	27,5% (149/ 541)
org.esa.cci.sst.tools.samplepoint	91,7% (22/ 24)	71,2% (109/ 153)	54,9% (394/ 718)
org.esa.cci.sst.util	72.4% (21 / 29)	65.2% (129 / 198)	53% (488 / 920)

4.4.2 Verification of data-location and content

For each MMD file produced, a plot showing the distribution of samples was produced routinely and spot-checked occasionally. Examples are shown in **Figure 4-73** and thereafter. No problems were found.

Sub-scenes extracted from satellite data were also spot-checked and compared to the original image pixels (see **Figure 4-77**). No discrepancies in geo-location or image data between the extracted and the original pixels were found.

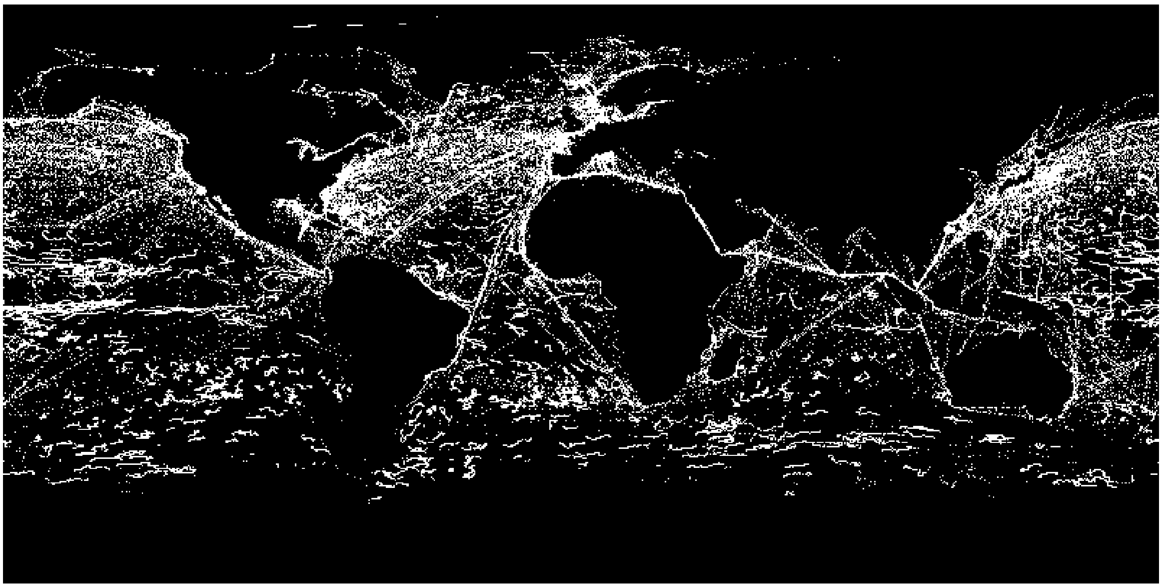


Figure 4-73: Location of samples in MMD files. Here AVHRR NOAA16 to in-situ matches for July 2005

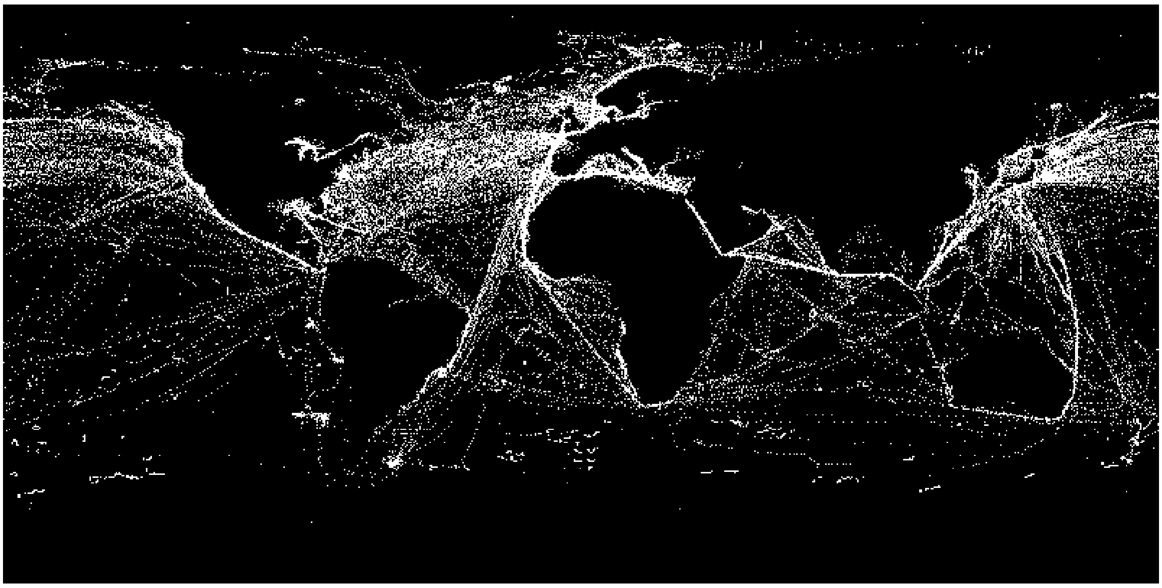


Figure 4-74: Location of matches MMD files. Here AVHRR NOAA08 to in-situ matches for September 1985

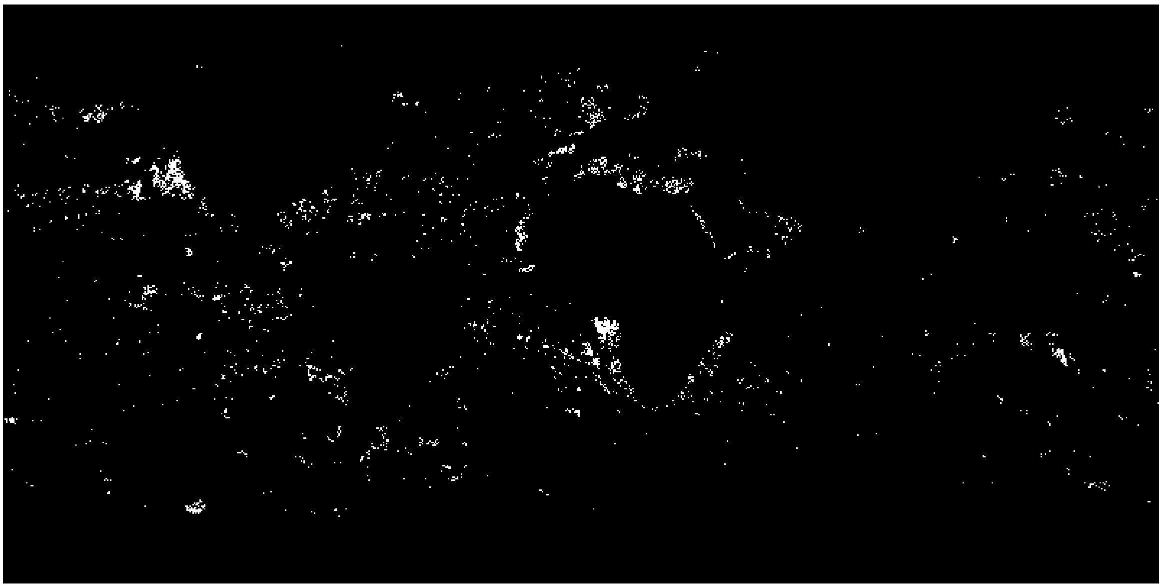


Figure 4-75: Location of samples in MMD files. Here ATSR2 to AVHRR matches for May 2001

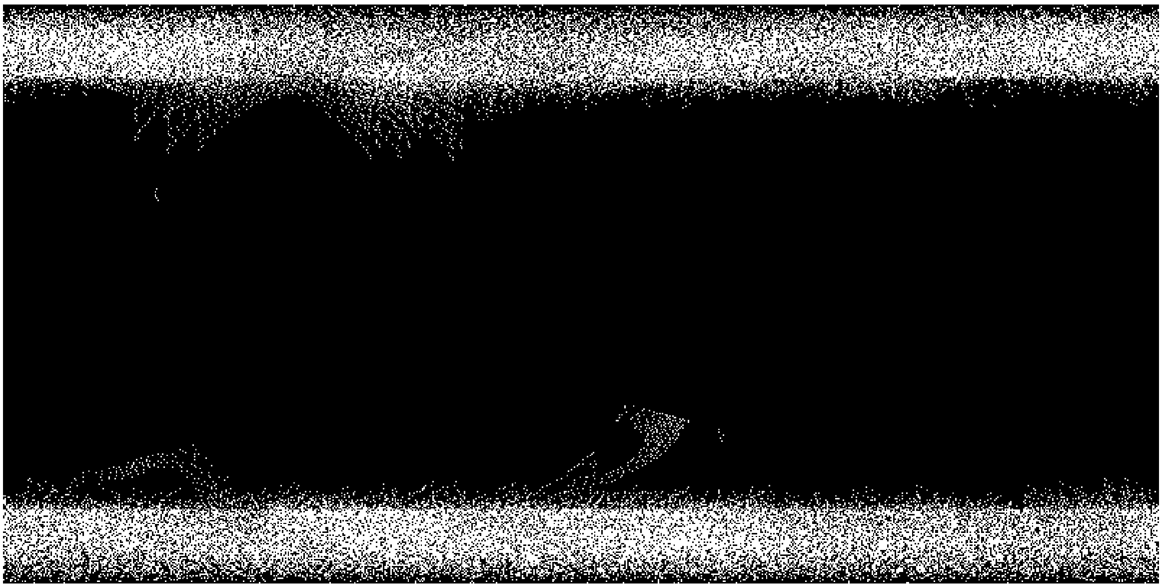
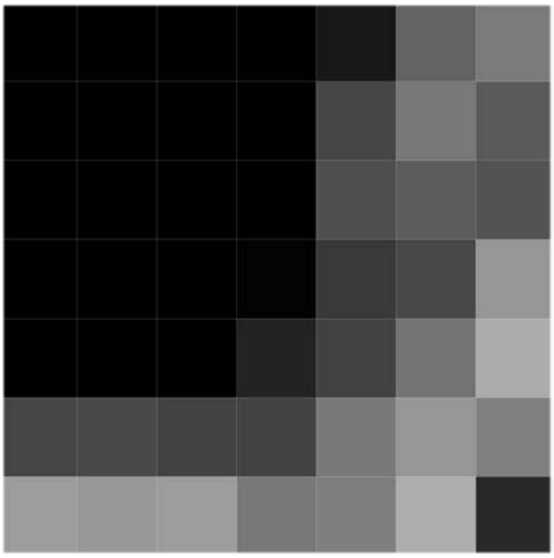


Figure 4-76: Location of samples in MMD files. Here AVHRR NOAA07 to AVHRR NOAA 08 matches for April 1984

Sub-scene image pixels in record 23 of MMD file atsr.3-mmd3-2010-07.nc for the 12 µm brightness temperature channel (viewed with Ncview)



Original image pixels from AATSR file no 7479 for the 12 µm brightness temperature channel (viewed with ESA SNAP)

Figure 4-77: Sub-scene in MMD compared to original image pixels

4.5 Tools Verification

Two user tools have been developed for the SST-CCI project: the regional averaging tool and the re-gridding tool [RD.258].

The purpose of the regional averaging tool is to read in the ARC 0.1° daily and SST-CCI L2P, L3C, L3U and L4 products at daily 0.05° latitude by longitude resolution and create regional averages of the SST anomaly relative to reference climatology, along with estimates of the uncertainty in those averages.

The purpose of the re-gridding tool is to read in the SST-CCI L2P, L3C, L3U and L4 products at daily 0.05° latitude by longitude resolution and output on other spatiotemporal resolutions, which are a multiple of this and divide neatly into 180 degrees, along with estimates of the uncertainties.

Scientists and software developers cooperating in an agile manner have developed the tools. Figure 4-78 below illustrates the activities of scientists and software developers for specifying and implementing the tools:

1. Software developers create a template of the tool's specification document.
2. Scientists to specify the tool complete the template to write a specification, which includes descriptions of use cases, input data output data, command line interface, and uncertainty propagation rules.
3. Both scientists and developers discuss the specification in order to avoid misunderstandings and implementation issues.
4. Scientists update the specification with clarifications resulting from the discussion, while software developers implement (or update) the tool.
5. Running of internal test cases is part of the software development and implementation work.
6. When the implementation cycle is finished the tool is distributed to the scientists.
7. Scientists run and test the tools and report issues; if no issues are found, the tool is ready for publication.
8. Software developers resolve the issues.
9. Both software developers and scientists discuss changes and updates of the specification, if applicable. Another implementation cycle is run (starting at Step 4). Scientists update the specification document while software developers implement tool updates, if applicable.

Table 4-11 below gives a summary of the tests routinely carried out for the regional averaging tool and their applicability to each of the SST-CCI products. All tests must be passed before the tool is made publically available. The input data to the test comprised a single month of data for each product type.

Table 4-12, Table 4-13, and Table 4-14 below provide a summary of the routine tests for the re-gridding tool for the SST-CCI L2P, L3U, and L4 products, respectively. All tests must be successfully passed before the tool is made publically available. Since the input data to the test comprised a single month of data for each product type, re-gridding to seasonal and yearly output was not covered in the routine tests.

In addition to the routine tests, the re-gridding tool was used to produce lower-resolution versions of the complete Phase-I L2P and L3U data products for use by Martin Scharffenberg (University of Hamburg) who asked for monthly aggregates on 0.25°. His use case is indicated with green shaded cells in Table 4-13 and Table 4-12.

Owen Embury used the re-gridding tool for the generation of the NCEO - SST-CCI products.

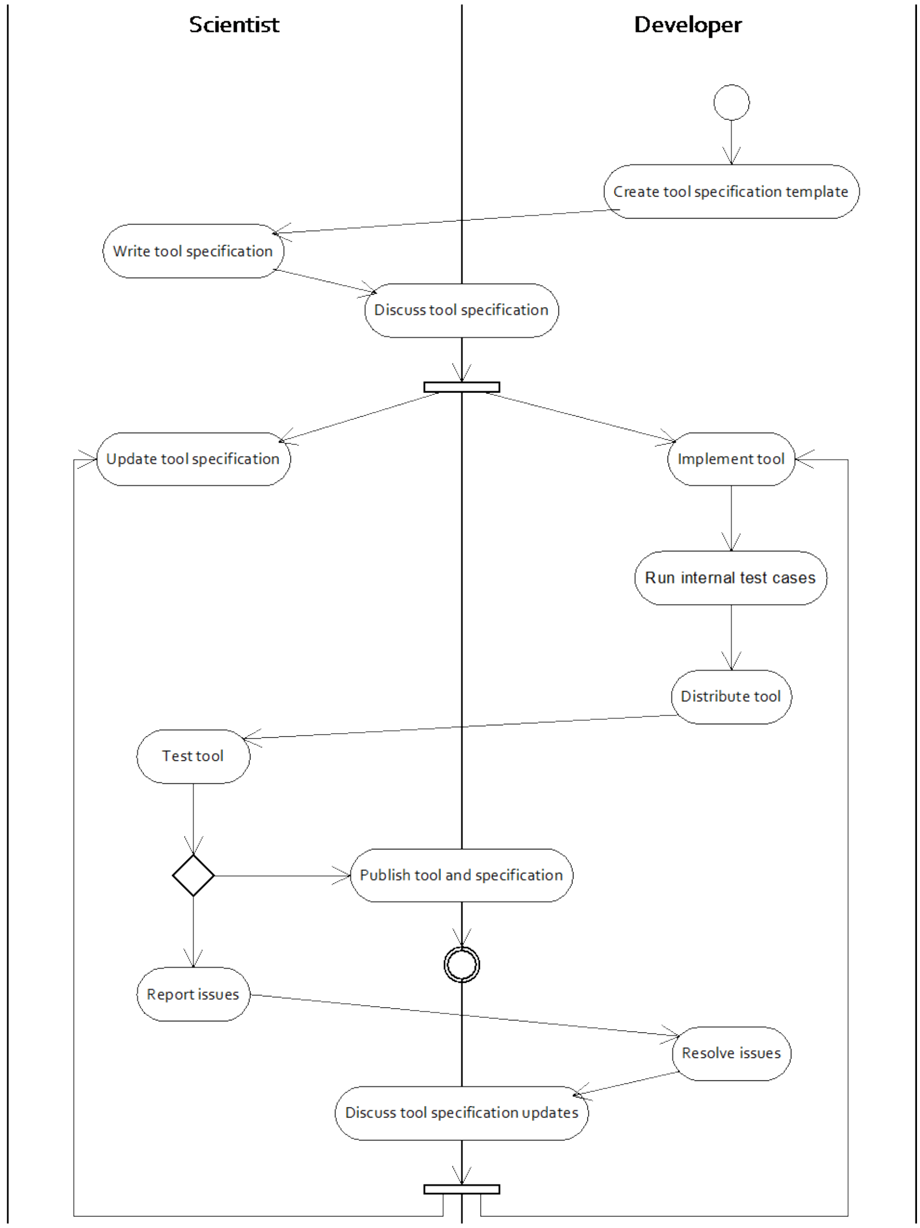


Figure 4-78: Activities of scientist and software developer for specifying and implementing regional averaging and re-gridding tools

Table 4-11: Routine testing of the regional averaging tool for SST-CCI products

File Type	1 day	Month	Season	Year
L3U	Passed	Passed	Passed	Passed
L3C	Passed	Passed	Passed	Passed
L4	Passed	Passed	Passed	Passed
L2P	Passed	Passed	Passed	Passed

Table 4-12: Routine testing of the re-gridding tool for SST-CCI L2P products

Resolution	1 day	5-days	7 days	Month	Season	Year
0.05°	Passed	Passed	Passed	Passed	-	-
0.10°	Passed	Passed	Passed	Passed	-	-
0.15°	Passed	Passed	Passed	Passed	-	-
0.20°	Passed	Passed	Passed	Passed	-	-
0.25°	Passed	Passed	Passed	Passed	-	-
0.30°	Passed	Passed	Passed	Passed	-	-
0.40°	Passed	Passed	Passed	Passed	-	-
0.50°	Passed	Passed	Passed	Passed	-	-
0.60°	Passed	Passed	Passed	Passed	-	-
0.75°	Passed	Passed	Passed	Passed	-	-
0.80°	Passed	Passed	Passed	Passed	-	-
1.00°	Passed	Passed	Passed	Passed	-	-
1.20°	Passed	Passed	Passed	Passed	-	-
1.25°	Passed	Passed	Passed	Passed	-	-
2.25°	Passed	Passed	Passed	Passed	-	-
2.40°	Passed	Passed	Passed	Passed	-	-
2.50°	Passed	Passed	Passed	Passed	-	-
3.00°	Passed	Passed	Passed	Passed	-	-
3.75°	Passed	Passed	Passed	Passed	-	-
4.00°	Passed	Passed	Passed	Passed	-	-
4.50°	Passed	Passed	Passed	Passed	-	-
5.00°	Passed	Passed	Passed	Passed	-	-
10.0°	Passed	Passed	Passed	Passed	-	-

Table 4-13: Routine testing of the re-gridding tool for SST-CCI L3U products

Resolution	1 day	5-days	7 days	Month	Season	Year
0.05°	Passed	Passed	Passed	Passed		-
0.10°	Passed	Passed	Passed	Passed	-	-
0.15°	Passed	Passed	Passed	Passed	-	-
0.20°	Passed	Passed	Passed	Passed	-	-
0.25°	Passed	Passed	Passed	Passed	-	-
0.30°	Passed	Passed	Passed	Passed	-	-
0.40°	Passed	Passed	Passed	Passed	-	-
0.50°	Passed	Passed	Passed	Passed	-	-

0.60°	Passed	Passed	Passed	Passed	-	-
0.75°	Passed	Passed	Passed	Passed	-	-
0.80°	Passed	Passed	Passed	Passed	-	-
1.00°	Passed	Passed	Passed	Passed	-	-
1.20°	Passed	Passed	Passed	Passed	-	-
1.25°	Passed	Passed	Passed	Passed	-	-
2.25°	Passed	Passed	Passed	Passed	-	-
2.40°	Passed	Passed	Passed	Passed	-	-
2.50°	Passed	Passed	Passed	Passed	-	-
3.00°	Passed	Passed	Passed	Passed	-	-
3.75°	Passed	Passed	Passed	Passed	-	-
4.00°	Passed	Passed	Passed	Passed	-	-
4.50°	Passed	Passed	Passed	Passed	-	-
5.00°	Passed	Passed	Passed	Passed	-	-
10.0°	Passed	Passed	Passed	Passed	-	-

Table 4-14: Routine testing of the re-gridding tool for SST-CCI L4 products

Resolution	1 day	5-days	7 days	Month	Season	Year
0.05°	Passed	Passed	Passed	Passed	-	-
0.10°	Passed	Passed	Passed	Passed	-	-
0.15°	Passed	Passed	Passed	Passed	-	-
0.20°	Passed	Passed	Passed	Passed	-	-
0.25°	Passed	Passed	Passed	Passed	-	-
0.30°	Passed	Passed	Passed	Passed	-	-
0.40°	Passed	Passed	Passed	Passed	-	-
0.50°	Passed	Passed	Passed	Passed	-	-
0.60°	Passed	Passed	Passed	Passed	-	-
0.75°	Passed	Passed	Passed	Passed	-	-
0.80°	Passed	Passed	Passed	Passed	-	-
1.00°	Passed	Passed	Passed	Passed	-	-
1.20°	Passed	Passed	Passed	Passed	-	-
1.25°	Passed	Passed	Passed	Passed	-	-
2.25°	Passed	Passed	Passed	Passed	-	-
2.40°	Passed	Passed	Passed	Passed	-	-
2.50°	Passed	Passed	Passed	Passed	-	-
3.00°	Passed	Passed	Passed	Passed	-	-
3.75°	Passed	Passed	Passed	Passed	-	-

Resolution	1 day	5-days	7 days	Month	Season	Year
4.00°	Passed	Passed	Passed	Passed	-	-
4.50°	Passed	Passed	Passed	Passed	-	-
5.00°	Passed	Passed	Passed	Passed	-	-
10.0°	Passed	Passed	Passed	Passed	-	-

4.6 CEMS data download verification

SST-CCI L2P, L3U/C and L4 data are stored on the CEMS facility and available for download via the NEODC web interface that forwards to the CEDA catalogue interface (see Figure 4-79 below). The dataset is fully available without access restrictions, nor is a login requested. Data access and download has been verified download of individual L2P, L3U and L4 files. Downloading single and multiple directories of files has tested the multiple download function. No problems were reported with the downloading of data from the CEMS facility.

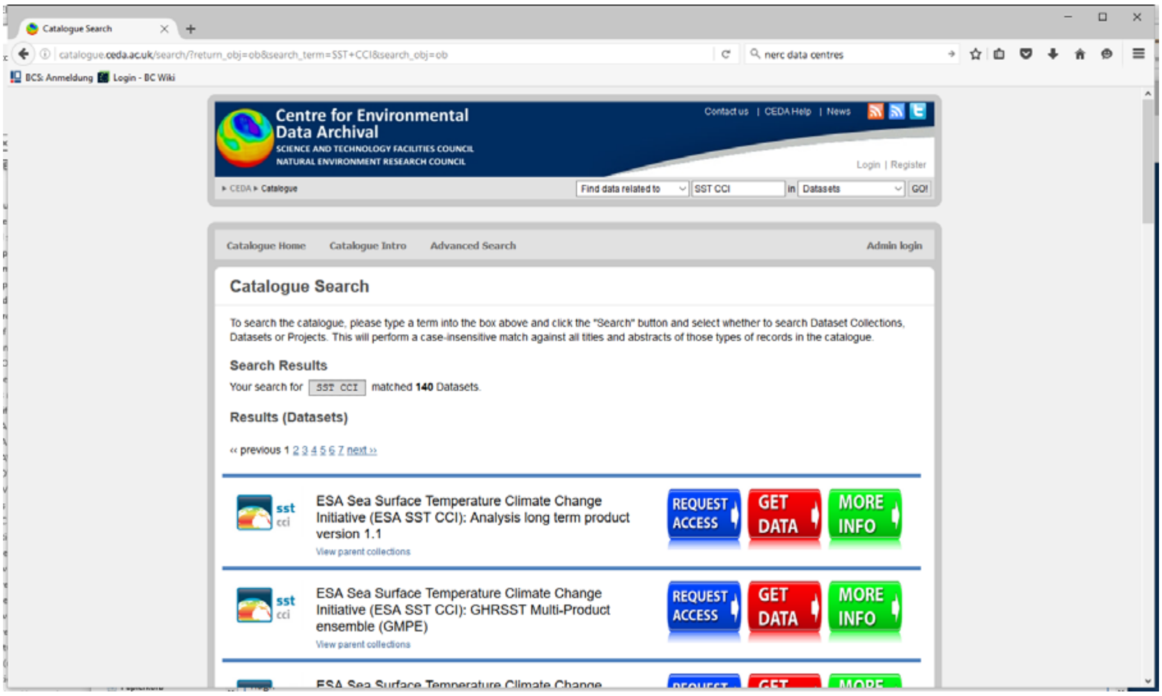


Figure 4-79: Screenshot of the CEDA catalogue search result

4.7 CCI Open Data Portal access verification

The new web-portal combining the information and data of all CCI ECV projects has also been tested to work properly in the context of this SVR.

Access to the SST data is granted using an anonymous FTP server access to the CCI data storage at CEMS facility. Download of L2P, L3u and L4 data using this FTP port has been tested successfully.

As a second option, the open data portal forwards to the project web-site. Download using the facilities offered there has been verified in chapter 4.6 and is not repeated here.

5. CONCLUSIONS

In all aspects the SST CCI system and processors implemented within Phase-II have been fully verified and found to be satisfactory. The verification procedures conducted for writing this document have shown to be effective. No major defects could be detected during the exhaustive QA exercises conducted.

For the final release of the SST CCI product data and the Product Specification Document (PSD) some minor items will have to be addressed in order to remove discrepancies between the product metadata and the PSD. These items are listed in Table 4-3 for L3U products and Table 4-7 for L2P data.

With respect to the data content, L3U products are affected by mask inconsistencies at quality level 0 and 1 (see Section 4.1.1). L2P products are affected by mask inconsistencies too, only affecting quality level 1. These masking inconsistencies do not affect the overall usability of the data record, but they need to be documented in the Product User Guide (PUG).