AVHRR L1 Product Generation Specification

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Document Change Record

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
Issue 3 Draft A	15.11.2000	DCN.SYS. DCN.018	Re-structuring of the Document
Issue 4 Draft A	23.05.2001		Section 3.1 “System Concept” on page 9: 13 block diagrams showing the decomposition of the Level 1 product generation by means of the SADT were added.
			Section 3.2 “System Context” on page 23: a short description of the system context was included
			Section 3.3 “Data Flow and Interfaces” on page 23: The definition for instrument ancillary data was rewritten NWP forecast data was defined as new input data flow AMSU-A Brightness Temperatures were defined as new input data flow Level 0 Appended information was defined Level 1a appended information was defined Level 1b Appended Information was defined Scenes Analysis dataflow was defined as a new output data flow
			Section 3.5.3 “Level 1b Processing” on page 29: A short description of the geolocation processing was included The description of the Fast Radiative Transfer Model was removed The description of the Scenes Analysis was updated
			Section 4.4.2 See “Infrared Radiances and Brightness Temperatures” on page 46. and Section 4.4.3 See “Visible / Near-Infrared Radiances and Reflectances” on page 46.: the requirements were reformulated
			Section 4.3.4 “Perform Geolocation Processing” on page 43: This section was completely revised and new requirements concerning the landmark processing were added.
			The requirements related to the Fast Radiative Transfer Model were removed
			Section 4.4.4 “Cloud Model (Scenes Analysis)” on page 49: The section was updated according to the requirements of the new cloud detection scheme to be used.
			Section 5.4 “Supporting Science to Level 1b Processing” on page 78: The section that describes the Fast Radiative Transfer Model was removed
			Section 5.4.3.1 “Landmark Processing” on page 81: A detailed scientific rationale of landmark processing was included
			Section 5.4.4 “Scenes Analysis” on page 84: Complete revision including the definition of all thresholds and the test

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
			sequences for different conditions. The description of the cloud detection test was adapted to the cloud detection scheme that is currently used in the prototyping processor.
			Annex A “list of equations SYMBOLs” on page 115: the list was extended to new variables Annex B “CONFIGURABLE AUXILIARY DATA SETS” on page 120: The data sets related to the Fast Radiative Transfer Model were removed A data set with the climatological values of sea surface temperature was defined A data set with the threshold values for the brightness temperature difference tests in the scenes analysis was defined The names of all data sets were adapted to their names in the previous sections
Issue 5	28.02.2002		Complete revision of section 3.1 (System Concept): new SADT diagrams
			’Level xx Data Flow’ and ’Level xx Appended Information’ are merged into ’Level xx Data Flow and Appended Information’
			A5 ’Parameter Estimation’ is removed
			3.5.3 and 3.5.4 (’Level 1a Processing’ and ’Level 1b Processing’) are revised and completed
			The requirements in sections 4.3.4 (’Perform Geolocation Processing’), 4.3.5 (’Satellite Zenith and Azimuth’), and 4.3.7 (’Solar Zenith and Azimuth’) are completed and updated
			The requirements in section 4.4.4 (’Cloud Model [Scenes Analysis]) are completed and updated
			The requirement section 4.6 (’Non-nominal Operations’) is added
			Section 5.3.2.4 (’Satellite Zenith and Azimuth’) and section 5.3.2.5 (’Solar Zenith and Azimuth’) are added
			Section 5.3.2.6 (’Size reduction of navigation information’) is added.
			Section 5.4.3 (’Geolocation Processing for each Pixel’) is added
			The derivation of the Fresnel coefficient is described in detail
			The computation of ThresholdVIS2 and the atmospheric correction is described in detail
			The computation of ThresholdVIS1 and the atmospheric correction is described in detail
			The test sequence for all cloud detection tests is updated
			The computation of ThresholdVIS2 and the atmospheric correction is described in detail
			The section 5.6 ’Non-nominal Processing’ is added.

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
			The Annex B ('Configurable Auxiliary Data Sets') is updated.
Issue 5 Rev 1	05.06. 2002	EUM.EPS. SYS. DCR.02.109	Section 1.4 ('Acronyms') is updated
			Sections 1.7 ('Applicable Documents') and 1.8 ('Reference Documents') are updated
			Section 3.2 ('System Context') is modified
			Section 3.5.1 ('Introduction to NRT Operations Concept') is shortened
			All TBD's and TBC's are removed
			Table 3.4 ('Non-nominal operations') is modified
			The requirements AVHRR-L1-PGS-4.1-0080, AVHRR-L1-PGS-4.1-0090, and AVHRR-L1- PGS-4.1-0100 are removed
			The requirement AVHRR-L1-PGS-4.3.1-0220 is modified
			AVHRR-L1-PGS-4.1-0130 is modified
			Section 4.3.8 ('Create Level 1a Data Representation') is removed
			The note on AVHRR-L1-PGS-4.4.2-0020 is removed
			AVHRR-L1-PGS-4.4.5-0220 is modified
			All requirements on 4.5.2. ('Online Parameter Estimation') are removed
			The Section 5.4.4.3 ('Overview of Tests') is corrected
			The rationale of the cloud detection tests is described more comprehensively.
			The Section 5.6 ('Non-nominal Processing') is updated
			Minor editorial changes throughout
Issue 5 Revision 2	6/04/2004		corrected 110 samples to 33 samples refined the description of the total precipitable water content towards non-symmetrical limb correction of brightness temperatures
Issue 5 Revision 3	04/06/2013	EPS_DOCET_228	Added the new function AVHRR-L1-PGS- 4.3.2-100 on page 42. Function describes the Noise Equivalent Delta T calculation. Added subsection 5.3.2.2 for Channels 3B, 4, and 5 to describe the algorithmic calculations for NEAT values for each scan line. Each segment in the scan line algorithm was detailed. Added Figure 5.1 to summarize the procedure. Updated all table and figure lists to reflect the update and new pagination.
V 5D	17/12/2013		Document was transcribed from Framemaker format with multiple files (books) to a single Word document. Version of new word document was given as 5D when this document was brought into the DM Tool.
V6	18/12/2013		Doc control created new major version listing per requirements.

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1 INTRODUCTION

1.1 Purpose, Scope and Structure

The purpose of this Product Generation Specification (PGS) is to present all requirements specific to the Metop and NOAA AVHRR/3 product generation function. This specification encompasses not only the required algorithm functions but also the identified supporting functions pertaining to the product generation function (PGF). The document structure is as follows:

1	This introduction.
2	A short overview of the AVHRR/3 Instrument.
3	Outlines the operational modes of the AVHRR/3 PGF. It also introduces the AVHRR/3 PGF as a component in a larger system.
4	Includes the requirements on the AVHRR/3 PGF.
5	Introduces the scientific and mathematical algorithms that support the requirements.
Appendix A	Lists the equation symbols used in Section 5
Appendix B	Lists the configurable auxiliary data sets used in the AVHRR/3 PGF
Appendix C	Provides an example of the format and content of the configurable auxiliary data sets.
Appendix D	Provides tables with estimates of the navigation interpolation errors.

Note: The detailed operations concept and associated requirements are illustrated in this version of the document by a WorkFlow Modeller Diagram.

1.2 Relation to EPS Core Ground Segment (CGS)

In this document, all the requirements pertaining to the corresponding instrument PGF of the EPS are addressed. The PGF encloses all functions (algorithmic, scientific and supporting functions) required for the generation of the products, including instrument specific usage of the PGE (Product Generation Environment) services and testing requirements.

The product generation function of the AVHRR instrument is a constituent of the CGS. Consequently, unless otherwise specified, all the requirements of the Core Ground Segment Requirement Document (CGSRD) shall apply to this product generation function. In particular, the PGF shall comply with all the requirements of the generic PGE services.

In case of conflict between the PGF requirements and the CGSRD requirements, the latter shall take precedence.

1.3 Document Status

The current issue of this document is based on the information available to EUMETSAT at the time of CGS KO and on actual results of the prototyping processor. The backlog processing, reprocessing and other non-nominal processing functions are specified in this issue and may undergo only minor alterations.

1.4 Applicable Documents

The following documents are applicable to the Instrument Product Generation Function:

No.	*Document Title*	*EUMETSAT Reference*
AD 49	Core Ground Segment Requirements Documents	EPS/GGS/REQ/95327
AD 19	Product Processing Software to Product Generation Element I/F Requirement Document	EPS/GGS/IRD/980255
AD 36	EPS Generic Product Format Specification	EPS/GGS/SPE/96167
AD 37	AVHRR Level 1 Product Format Specification	EPS/MIS/SPE/97231
AD 48	EPS Mission Conventions Document	EPS/GGS/SPE/990002
AD 1	EPS Product Conventions Document	EPS/SYS/TEN/990007

1.5 Reference Documents

No.	*Document Title*
RD 1	Bordes Phillipe, Pascal Brunel and Anne Marsouin, 1992: *Automatic Adjustment of AVHRR Navigation;* Journal of Atmospheric and Oceanic technology; Vol. 9, 15-27.
RD 2	NOAA KLM USER'S GUIDE (http://www2.ncdc.noaa.gov/docs/klm/html).

1.6 Acronyms Used in this Document

Acronym	*Meaning*
AMSU-A	Advanced Microwave Sounding Unit - A
API	Application Program Interface
ATOVS	Advanced TIROS Operational Vertical Sounder
AQC	Automatic Quality Control
AVHRR	Advanced Very High Resolution Radiometer
BB	Black Body
BDRF	Bi-Directional Reflection Function
CFI	Customer Furnished Items
CGS	EPS Core Ground Segment
CGSRD	EPS CGS Requirements Document
DEM	Digital Elevation Model
EBB	Equivalent Blackbody
EPS	EUMETSAT Polar System
FD	Flight Dynamics
FIR	Finite Impulse Response
GAC	Global Area Coverage
GQA	Geometric Quality Analysis
G/S	Ground Segment
HIRS	High Resolution Infrared Radiation Sounder
IFOV	Instantaneous Field of View

Acronym	*Meaning*
IR	Infrared
IRD	Interface Requirement Document
ISRF	Instrument Response Function
LOS	Line –of- Sight
LSB	Least Significant Bit
LUT	Look-Up-Table
M&C	Monitor & Control
MHS	Microwave Humidity Sounder
MMI	Man Machine Interfaces
MSG	Meteosat Second Generation
MTF	Modulation Transfer Function
MTTR	Mean Time To Recovery
NIR	Near Infrared
NOAA	National Atmospheric and Oceanic Administration
NRT	Near Real Time
OBT	On Board Time
PGE	Product Generation Environment
PGF	Product Generation Facility
PRT	Platinum Resistor Thermometer
RMS	Root Mean Square
RQA	Radiometric Quality Analysis
SADT	Structured Analysis and Design Technique
SOL	Start-Of-Line
SSP	Sub-Satellite-Point
S/C	Spacecraft
S/N	Signal-to-Noise Ratio
S/W	Software
TM	Telemetry and Monitoring
TP	Tie Point
U-MARF	Unified Meteorological Archive and Retrieval Facility
UTC	Coordinated Universal Time
WMO	World Meteorological Organisation

1.7 System Definitions

Element	*Meaning*
Operational Situation	An operational state of the AVHRR/3 Instrument
Operational Mode	An operational state of the AVHRR/3 PGF
Auxiliary Data	This encompasses any non-AVHRR/3 data needed to carry out the PGF's tasks. Auxiliary Data includes but is not limited to the platform TM.
Configurable Data Sets	In the context of this document, these are the data sets listed in Annex B that contain the set of user-configurable parameters for the AVHRR/3 processing.

1.8 Identification of Algorithm-Related Requirements

The numbering of the requirements follows the following convention:

AVHRR-L1-PGS-SXXX-NNNN

where:

- **AVHRR** stands for Advanced Very High Resolution Radiometer;
- **L1** stands for Level 1;
- **PGS** stands for Product Generation Specification;
- **SXXX** stands for the Subsection number (4.3.2.1)
- **NNNN** is the number of the requirement;
- **TYPES** indicate the relevant types of the requirement, according to the list above.

The following TYPES are listed in this document:

DES	Design Constraints
FUNCT	Functional Requirements
INT	Interface Requirements
MMI	Man-Machine Interface Requirements
PERF	Performance (including Accuracy) Requirements
RES	Resource Usage Requirements
RAMS	Reliability, Availability, Maintainability and Safety Requirements
TEST	Testing Requirements

2 INSTRUMENT DESCRIPTION

The Advanced Very High Resolution Radiometer/3 (AVHRR/3) is a multipurpose imaging instrument used for global monitoring of cloud cover, sea surface temperature, ice, snow and vegetation cover characteristics and is currently flying on NOAA-15 and NOAA-16. The AVHRR/2 version of the instrument is currently flying on the NOAA/TIROS-N series of spacecraft in a five-channel version. The spectral channels of AVHRR/3 are not exactly the same as AVHRR/2, and include an additional channel 3a in the near infrared (NIR). AVHRR/3 has six spectral channels between 0.63 micrometers and 12.00 micrometers: three in the visible/near infrared and three in the infrared. Channel 3 is a split channel. Channel 3a is in the solar spectral region (1.6 µm) whereas Channel 3b operates in the infrared around 3.7 µm. Channel 3a is operated during the daytime portion of the orbit, and 3b will be operated during the night-time portion of the orbit. The transition from Channel 3a to 3b and vice-versa will be done by telecommand and will be reflected in the science data.

The following table summarises the spectral and the scanning characteristics of AVHRR/3:

Channel	*Central wavelength*	*Half power points (µm)*	*Channel Noise specifications*
1	0.630	0.580 - 0.680	S/N 9:1 @ 0.5 % reflectance
2	0.865	0.725 - 1.000	S/N 9:1 @ 0.5 % reflectance
3	1.610	1.580 - 1.640	S/N 20:1 @ 0.5 % reflectance
4	3.740	3.550 - 3.930	< 0.12 K, 0.0031 mW /(m^2 sr cm^{-1}) @ 300 K
5	10.800	10.300 - 1.300	< 0.12 K, 0.20 mW/(m^2 sr cm^{-1}) @ 300 K
6	12.000	11.500 - 12.500	< 0.12 K, 0.21 mW/(m^2 sr cm^{-1}) @ 300 K

Table 1: Spectral Characteristics of AVHRR/3

AVHRR/3 is an across-track scanning system with a scan range of ± 55.37° with respect to the nadir direction. The field of view (IFOV) of each channel is approximately 1.3 milliradians (0.0745 degree) leading to a square instantaneous field of view (FOV) size of 1.08 km at nadir for a nominal altitude of 833 km. The scanning rate of 360 scans per minute is continuous (1 scan every 1/6 second). There are 2048 Earth views per scan and per channel for a swath width of about ± 1447 km (sampling time of 0.025 ms). The sampling angular interval is close to 0.944 milliradians (0.0541°). The distance between two consecutive scans is approximately equal to 1.1 km.

The AVHRR/3 calibration is different for the visible and the IR channels:

- There is no on-board calibration for the visible channels (channels 1 and 2) and channel 3a. The calibration coefficients for these channels are determined before launch. The calibration function on the ground can act on the visible calibration (by vicarious calibration).
- The calibration of the infrared channels (channels 3b, 4 and 5) is performed by viewing an internal black body and the cold space. The internal rotating scan mirror views the deep space or a thermal calibration source at each rotation: a minimum of 55 scan lines is needed to obtain a complete set of calibration coefficients. The temperature of the internal black body is measured by four platinum resistance thermometers (PRTs).

The following table summarises the scanning characteristics.

Characteristics	***Value***	***Unit***
Scan type	continuous	
Scan rate	0.1667	second
Sampling interval	0.025	ms
Sampling interval	0.0541	degree
Pixels/scan	2048	
Swath	± 55.37	degree
Swath width	± 1446.58	km
IFOV	0.0745	degree
IFOV size (nadir)	1.08	km
IFOV size (edge) - across track	6.15	km
IFOV size (edge) - along track	2.27	km
Scan separation	1.1	km

Table 2: Scanning characteristics of AVHRR/3

3 SYSTEM AND OPERATIONS CONCEPT

In the following, the detailed system and operations concept is illustrated by use of the Structured Analysis and Design Technique (SADT) diagrams. This detailed system and operations concept reflects the current state of knowledge acquired through the use of a prototyping processor.

3.1 System Concept

The following is purely a functional description of the AVHRR/3 product generation function and will not prejudge on the actual implementation. The context diagrams of the product generation function are shown in the following figures:

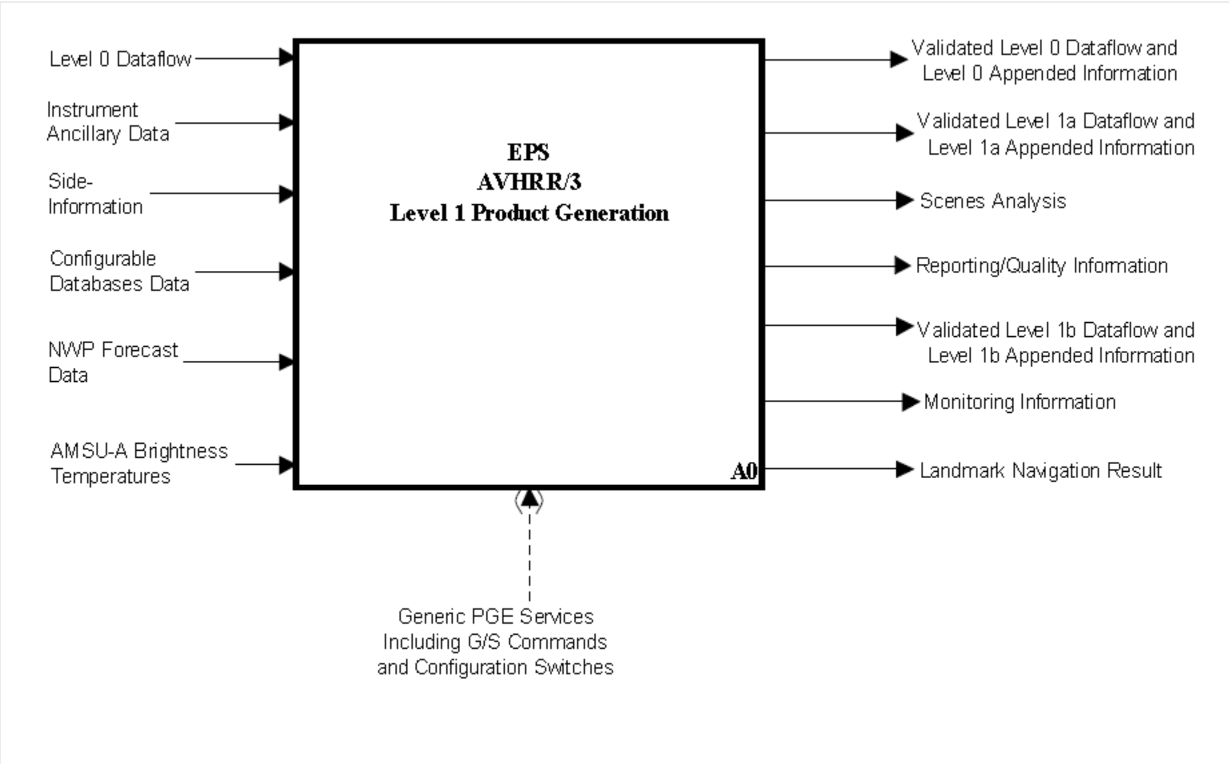


Figure 1: AVHRR Context Diagram

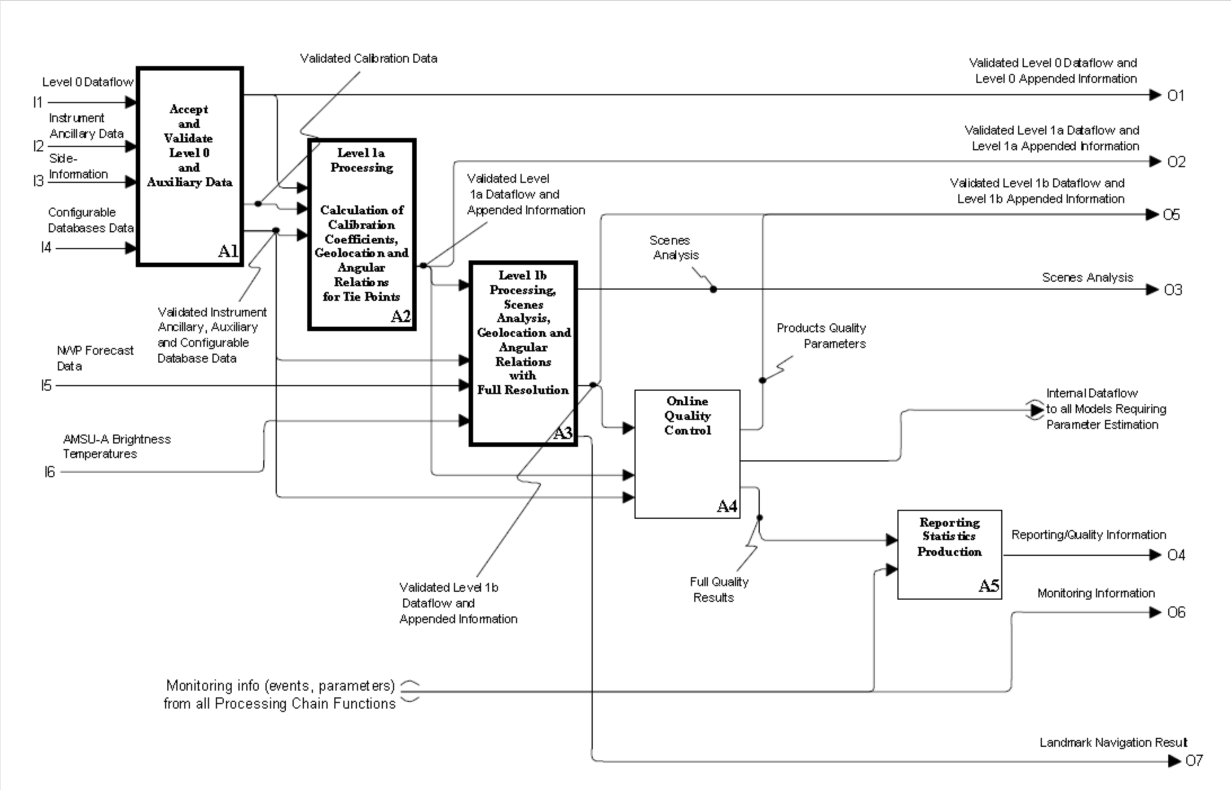


Figure 2: Level A0 Decomposition

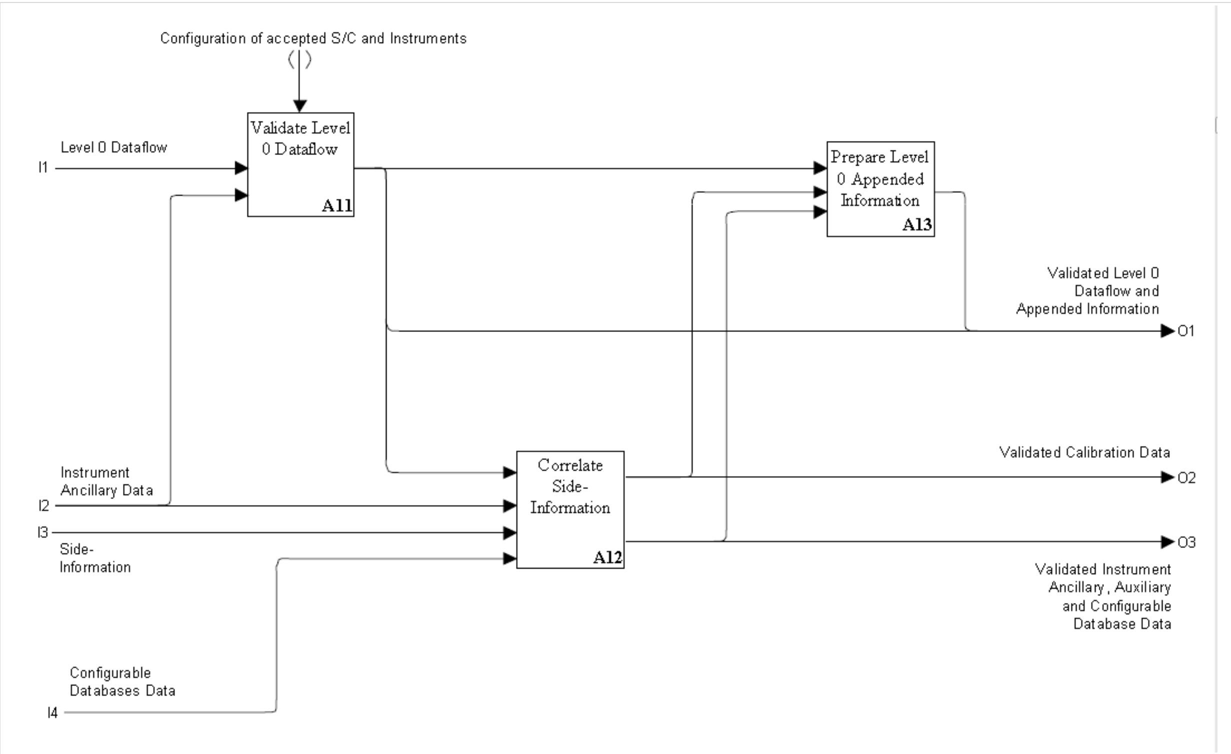


Figure 3: A1 Decomposition (Accept and Validate Level 0 and Auxiliary Data)

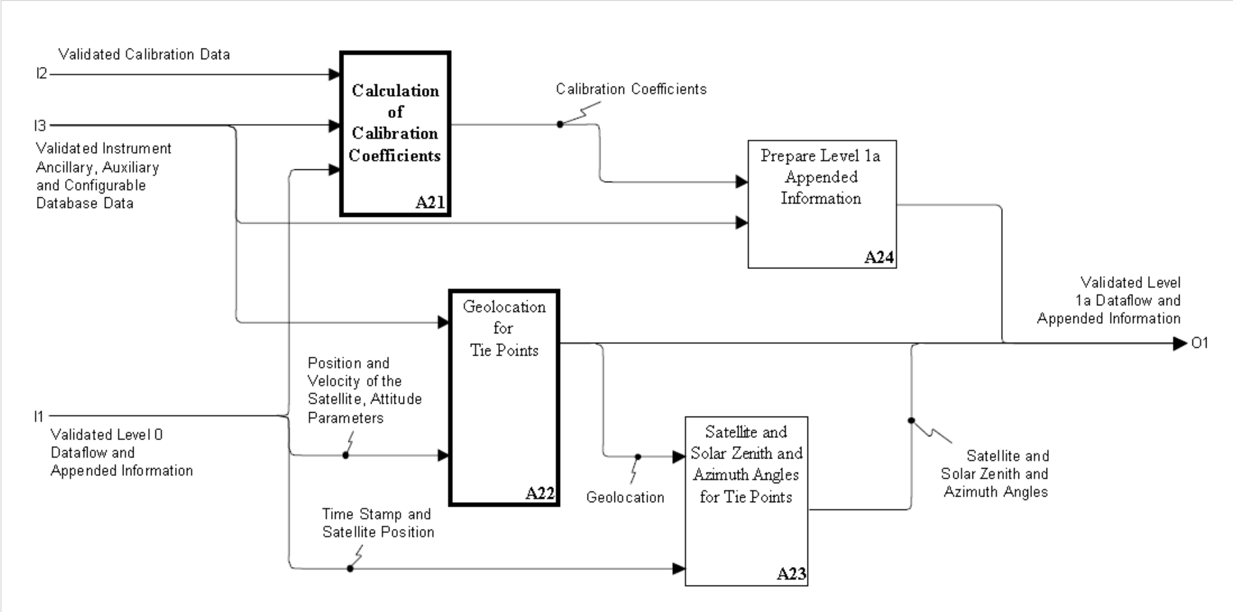


Figure 4: A2 Decomposition (Level 1a Processing)

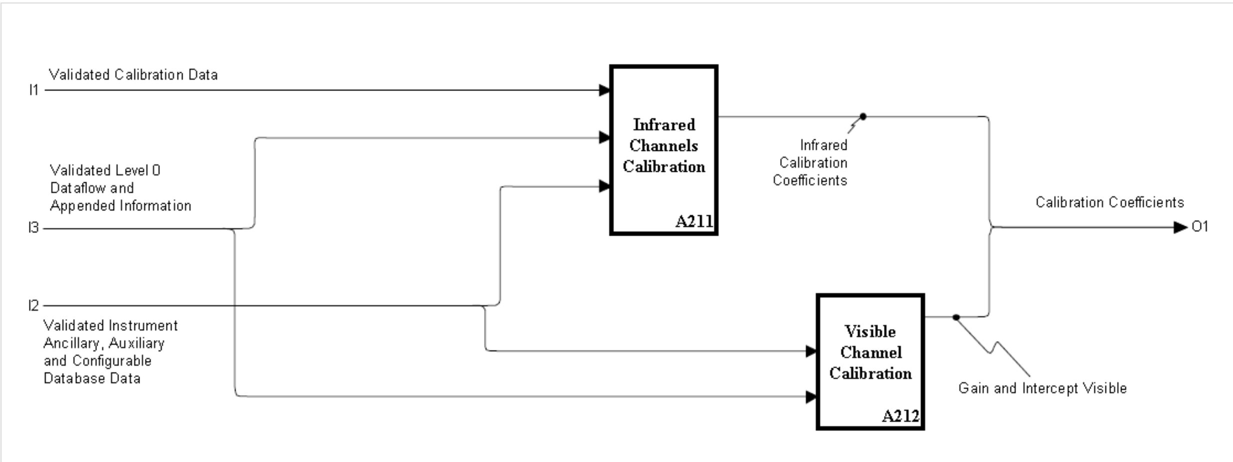


Figure 5: Level A21 Decomposition (Calculation of Calibration Coefficients)

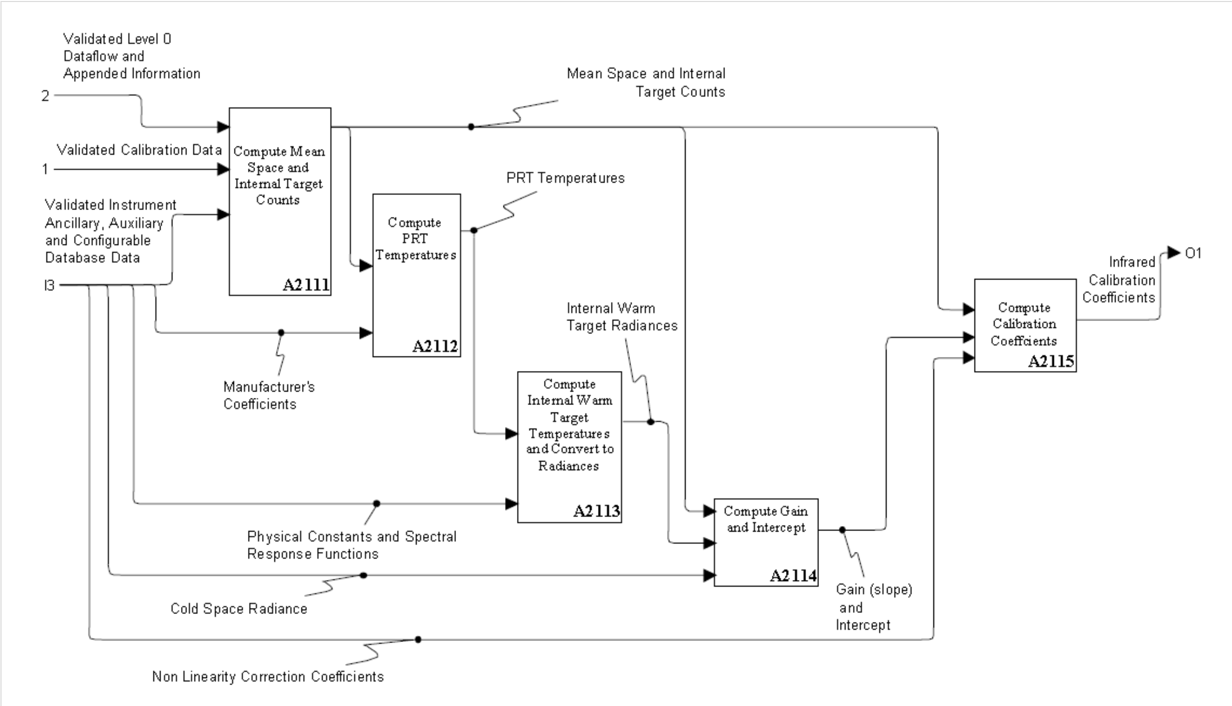


Figure 6: Level A211 Decomposition (Infrared Channels Calibration)

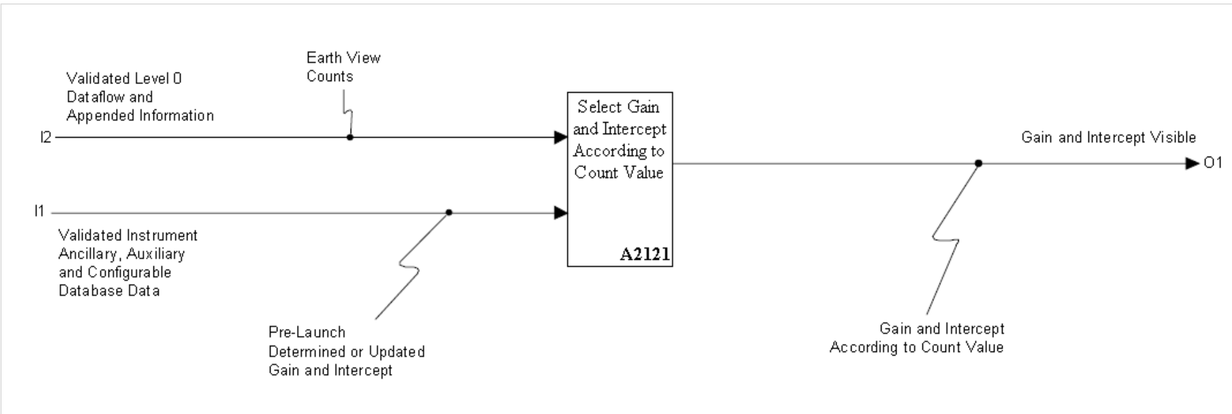


Figure 7: A212 Decomposition (Visible Channels Calibration)

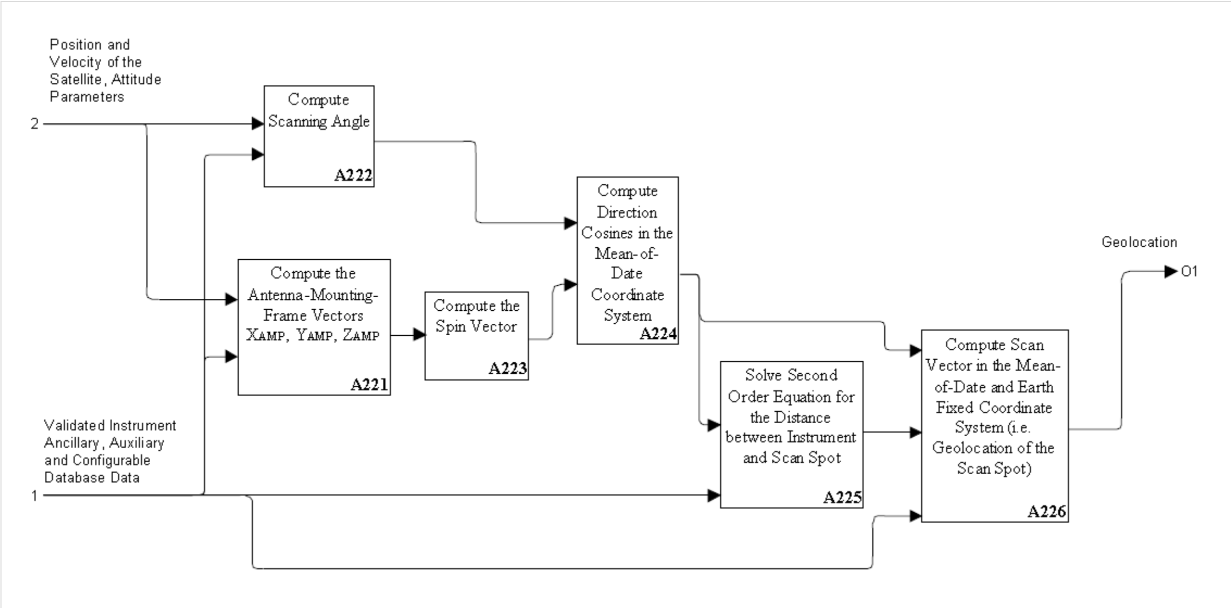


Figure 8: A22 Decomposition (Geolocation for Tie Points)

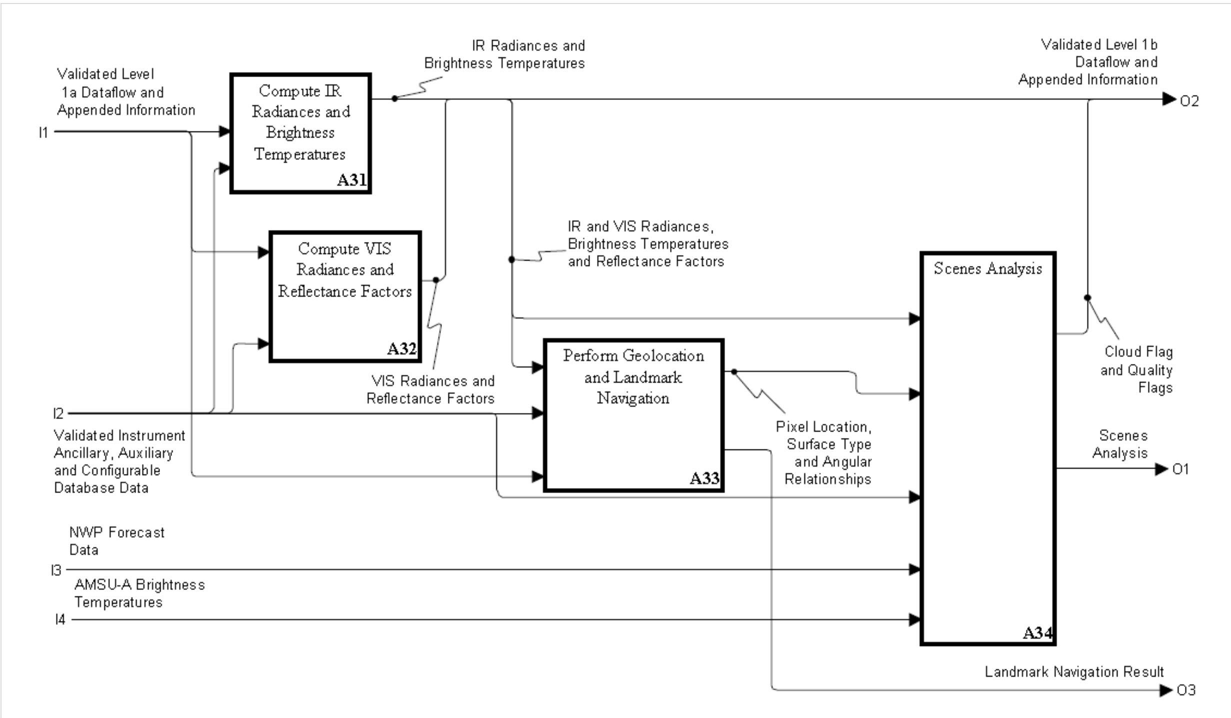


Figure 9: A3 Decomposition (Level 1b Processing)

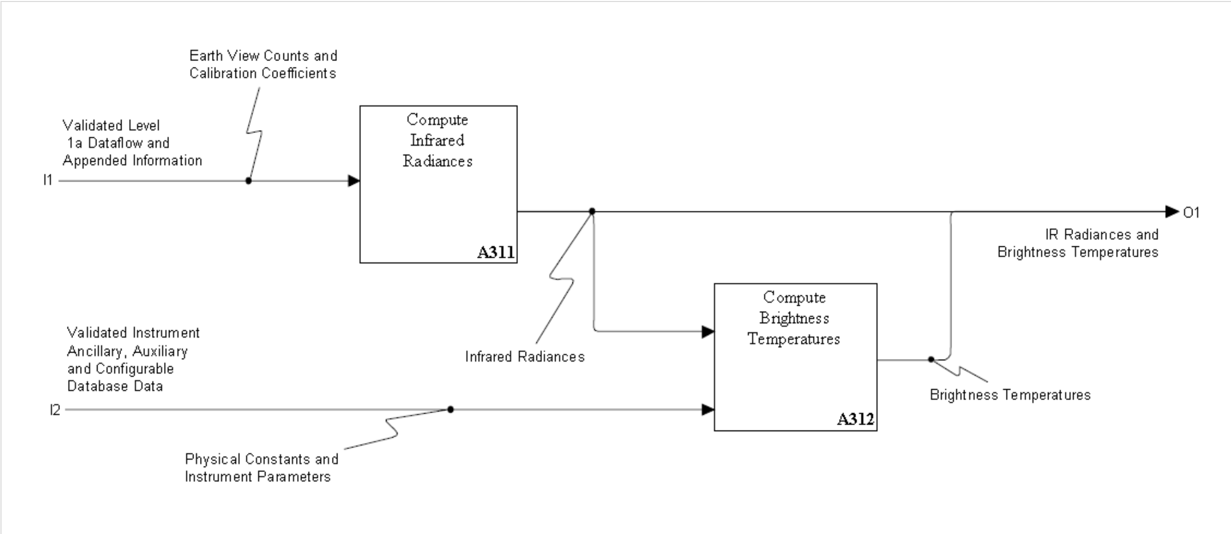


Figure 10: A31 Decomposition (Compute IR Radiances and Brightness Temperatures)

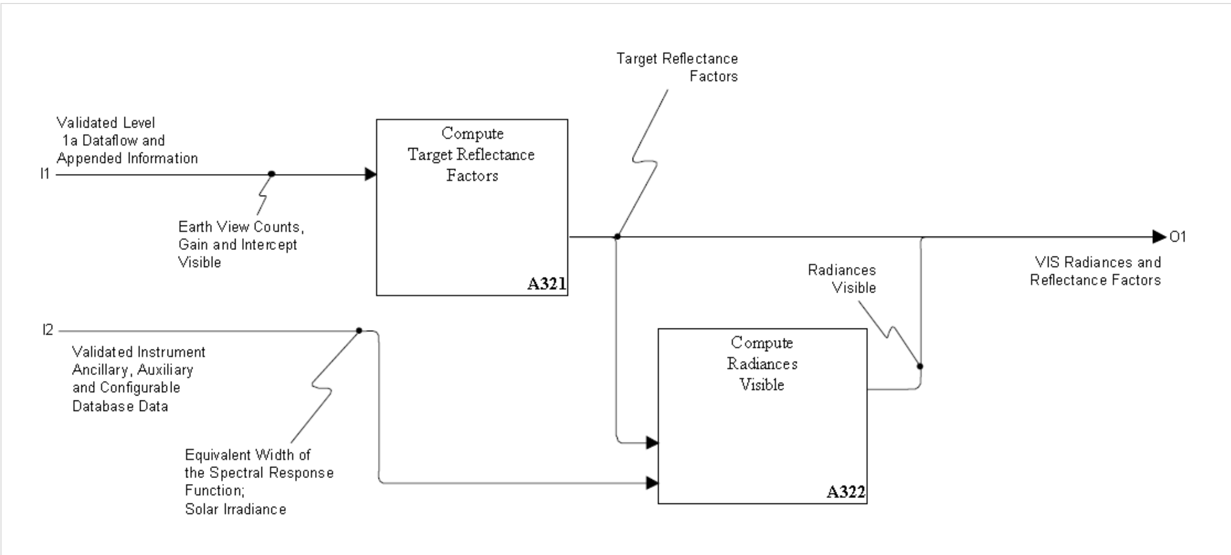


Figure 11: A32 Decomposition (Compute VIS Radiances and Reflectance Factors)

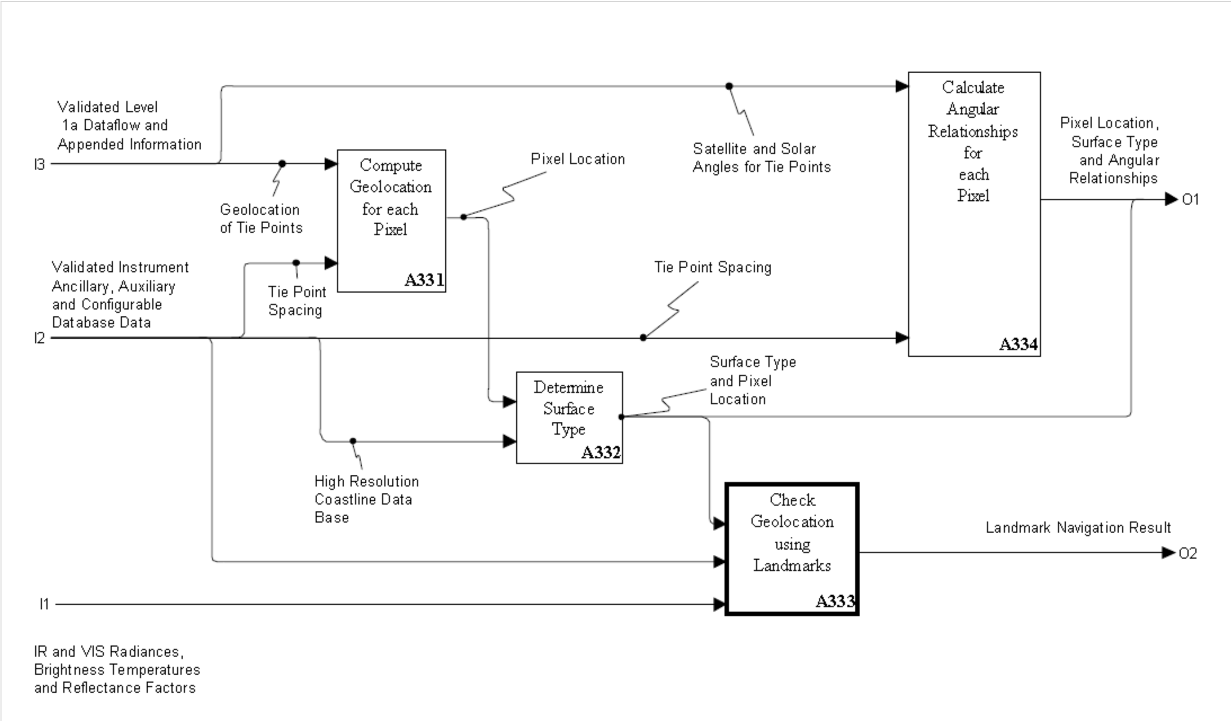


Figure 12: A33 Decomposition (Geolocation and Landmark Navigation)

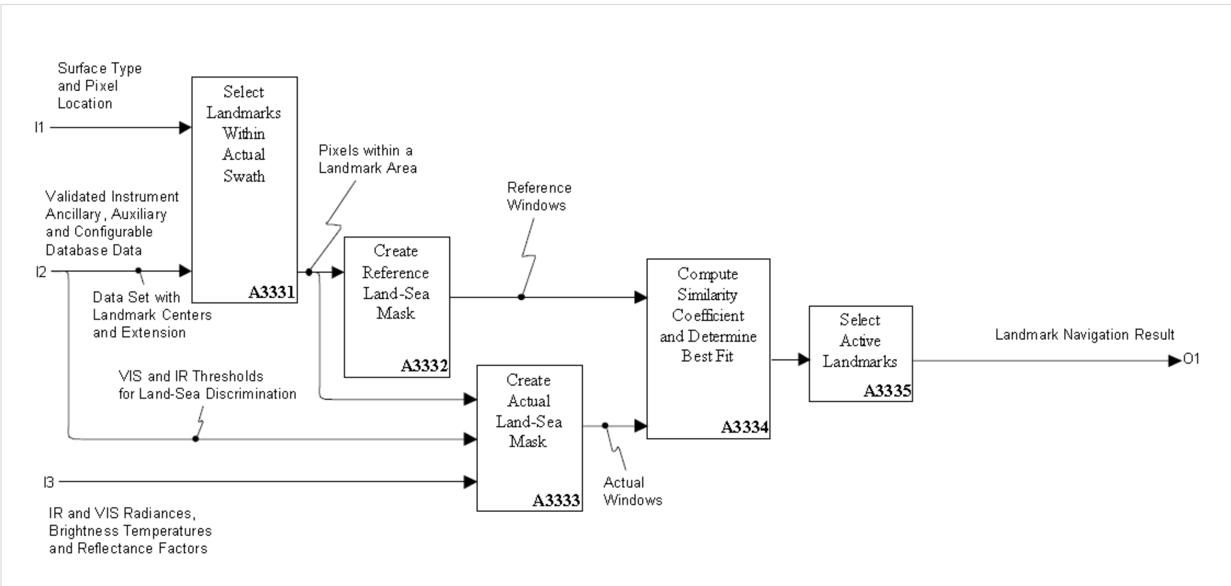


Figure 13: A333 Decomposition (Refine Geolocation Using Landmarks)

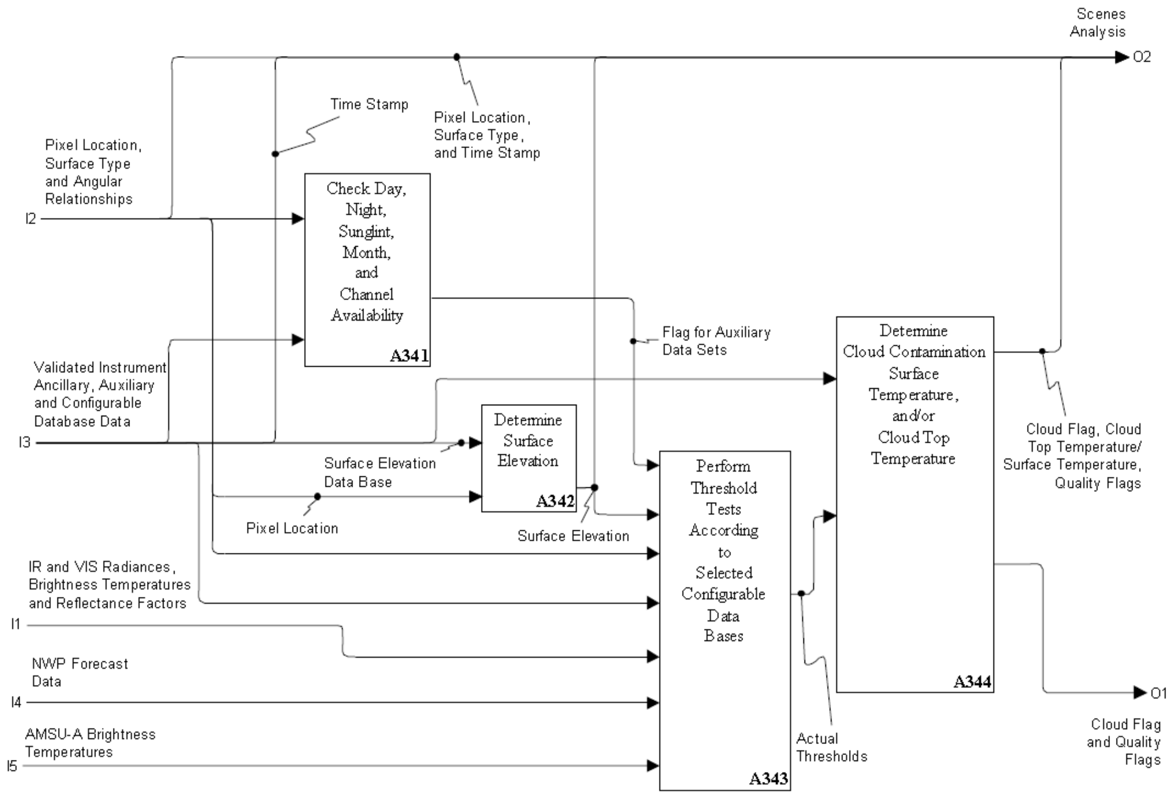


Figure 14: A34 Decomposition (Scenes Analysis)

3.2 System Context

The AVHRR Level 1Product Generation Function (PGF) interacts with the Core Ground Segment M&C functionality by means of the Product Generation Environment (PGE). Furthermore, the PGE provides the means by which the AVHRR Level 1 Product Generation Function acquires satellite and instrument data downlinked via the CDA functionality. The PGE also provides the means by which auxiliary data required by the processing is fed into the AVHRR Level 1 Product Generation Function.

3.3 Data Flow and Interfaces

The external data flow consists the input and output data flow and the interfaces are described by the mechanism and control data streams.

Mechanisms and Controls:

G/S Commands:	This datastream corresponds to the transfer of commands generated by the G/S and controlling the operation of the product generation function. ***Note:*** These only influence the way the processing is done and are not related to any instrument/platform commands.
Configuration Switches:	This corresponds to (a) switch(es), selecting (a) configured Product Generation option(s). This influences the selection of a method or a data set.

The external dataflows are defined as follows:

Inputs:

Level 0 dataflow:	Operational scan mode AVHRR/3 level 0 data in a line by line manner. Note that there is a difference in the data received from NOAA (GAC data) and Metop (full resolution data) ***Note:*** In case the product generation function operates in reprocessing mode, the information is received via the CGS function providing the reprocessing support. The data might also originate from one of the test tools if the product generation function is being tested standalone.
Instrument Ancillary Data	This dataflow corresponds to the platform telemetry that is required in addition to the level 0 data. The dataflow typically contains all the relevant spacecraft/platform parameters and status flags required by the processing that are not included in the instrument level 0 data.
Auxiliary data:	Corresponds to all data that are required from the G/S and that are not present in the Platform Telemetry and the level 0 data. These are typically all derived information (orbit, attitude, required derived/extracted platform parameters)
Configuration. Data Sets:	Indicates to the product generation function the data set version of the static parameters (these are indicated as the user-configurable parameters) that are to be used for the processing. They define, together with the version of the installed processing S/W, the configuration of the processing that is used to derive the products. The configurable static parameters are required for the product generation function. These shall include land/sea mask, land surface topography, land marks, instrument scan/time parameters, pre-flight and manufacturer provided calibration coefficients, plausibility thresholds etc. Access to these data is provided by the PGE. The particular solution details have to be defined in the IRD [AD19]
NWP Forecast Data:	These data contain three-dimensional fields of temperature, and water vapour, as well as the surface temperature from weather forecast models or observational data.
AMSU-A Brightness Temperatures:	These data contain limb-corrected AMSU-A brightness temperatures of 23 GHz, 31 GHz, and 50 GHz along with the geolocation information about the pixel center.

Outputs:

Validated Level 0 dataflow:	Corresponds to the contents of Level 0 data as defined in the corresponding Product Specification [AD36] .
Level 0 Appended Information:	Includes information about the availability of instrument auxiliary data sets and configurable database data. Checks the compilation of these data sets into the Level 0 appended information representation. Indicates the availability of the Level 0 data flow (availability of single channels).
Validated Level 1a dataflow:	Corresponds to the contents of Level 1a data as defined in the corresponding Product Specification [AD37].
Appended Information:	Includes information about the availability and quality of Level 1b products (radiances, brightness temperatures and target reflectance factors) and scenes analysis quality (angular relationships, geolocation etc.)
Analysis dataflow:	Information on geophysical parameters of each AVHRR/3 pixel. This information includes geolocation, cloud contamination and cloud top temperature or surface temperature in case of cloud free conditions. Furthermore, surface elevation and surface type are added to the scenes analysis data flow. The corresponding time stamp is given for the beginning of each scan line
Reporting/Quality Information:	Information produced by the product generation function (about the received data, about the instrument performance, about the quality of the processing and about the performance of the mission) that are transferred to the reporting function of the Core Ground Segment. ***Note***: the information includes also all quality information required by the offline Quality Control function of the CGS.
Monitoring Information:	Information on the product generation function, providing the G/S M&C function with the information on the status of the instrument, data, processing functions, processing platforms, links, and other information. In addition, the information contains also all events and command acknowledgements raised by the product generation function.

3.4 Operations Concept

The operations concepts set out in this document will be extensively revised and developed.

This section describes the Operational Modes of the AVHRR PGF, that is:

- Near-real Time (NRT) Mode
- Backlog Processing Mode
- Reprocessing Mode

In the frame of this document, only the NRT mode is described in detail.

Although the PGF runs through the same basic states (Initial, Active, Emptying, and Stopped) whatever the mode, care should be taken in the actual implementation since subtle differences exist among them. For example, the satellite data supplied to the PGF have different origins depending on the mode; the selection of the Auxiliary Data to use in the processing characterises the Reprocessing mode.

Note: While the Operational Modes are part of the specification as per [AD49], the description of the “states” and of the “operational scenarios” is only provided as a guideline to the Contractor in order to clarify the PGF Requirements. In particular, operational scenarios do not specify the actual implementation.

3.5 NRT Operations Concept

An overview of the functionality implemented by the AVHRR processing under nominal continuous is given in this section. This means that the processor has been started and is running in near-real-time (NRT) mode. The following general notes apply to the product generation functions:

- The AVHRR/3 instrument will be operated continuously and the five channels transmitted will be processed. Out of the six channels available the data of five channels only are transmitted to the ground. The channels 3a or 3b will be selected by telecommand – the channel 3a during daytime and the channel 3b during night-time. All remaining channels will be used continuously;
- The AVHRR/3 instrument product generation function will be supported for the following S/C platforms: Metop 1, 2 & 3 NOAA-N, N’(NOAA-18, 19);
- AVHRR/3 operates in continuous mode, which is the nominal mode of operation and the only one. Potential deviations of the nominal mode are identified in subsection 3.5.5 "Non-nominal operation";
- AVHRR/3 processing will cover the processing of full resolution AVHRR/3 provided from the Metop and also the processing of reduced resolution Global Area Coverage (GAC) data, provided from the NOAA satellite.
- The processing to level 1a/1b is specified for 24-hours/day fully automated operation during the full mission time of the EPS programme.

The product generation function for AVHRR itself can be divided into the following main functions:

- Level 0 processing (Acceptance and validation of the Level 0 and Auxiliary data)
- Level 1a processing (calculation of the calibration coefficients, geolocation and angular relationships for tie points)

- Level 1b processing (calculation of radiances, brightness temperatures and reflectance factors, scenes analysis)
- Post processing (online quality control, online parameter estimation, and production of reporting statistics)

3.5.1 Level 0 Processing

The first level of data decomposition is discussed in the CGSRD [AD49]. In addition to the generic checks identified in the CGSRD, this function performs the instrument-specific acceptance and checking of the input data. This has three purposes:

- *Receive & Validate Level 0 Data Flow:* This function encompasses the check and validation of the level 0 dataflow from the instrument. The generic checks identified in the CGSRD are followed by the verification against the expected instrument's S/C configuration.
- *Receive, Validate and Correlate Side information*: This function receives the side-information (typically the relevant platform TM and the auxiliary data), validates them and relates them to the level 0 data flow. The function also extracts the mode/state of the instrument/platform.
- *Prepare Level 0 Appended Information:* This function "fills" the format of the level 0 appended information with the received input data and auxiliary data. The format of the appended data shall be user-configurable to allow evolution.

Note: The function has to be able to cope with all the different Metop spacecraft and with the NOAA platforms, including the handling of the different data formats.

The requirements for the Level 0 Processing function can be found in section 4.2.

3.5.2 Level 1a Processing

This function performs the processing of the appended calibration data, using the information from the instrument on-board calibration cycles, the data from the Level 0 processing and the information/ parameters from on-ground characterisation. The first operation is to validate the received on-board calibration information by verifying the consistency with previous calibration occurrences (if available). The purpose is to avoid corrupted calibration information to propagate through the whole product generation function and the subsequent product extraction. For this function, all the parameters used in the calibration processing must be user-configurable and S/C / Instrument specific.

In addition, with the information about satellite position and velocity, the geolocation and the solar and satellite azimuth and zenith angles are computed for tie points. This function uses the validated geolocation information of the satellite position, an Earth model and a model of the instrument/platform to derive the geolocation information for the tie points.

The Create Calibration Information function uses the validated calibration data from the spacecraft, the instrument characteristics and the output of the Level 0 processing function to produce the calibration information for each channel. The outputs are the calibration parameters, which are needed for the subsequent level 1b processing and will be appended to the level 1a counts. In the level 1a processing calibration coefficients are calculated for channels 3b, 4, and 5. In the level 1b processing, the calibration coefficients are used to convert the numerical counts returned by the instrument into radiances for IR channels and percent reflectance factor for channels 1, 2, and 3a. These coefficients are measured before launch (all channels) or measured in-flight (channels 3b, 4, and 5 only). It is obvious that for this function it has to be checked whether channel 3a is used or channel 3b.

The AVHRR/3 calibration is different for the visible and the IR channels. Thus, this function has three subfunctions:

- Create Infrared Calibration Information
- Create Visible/Near-Infrared Calibration Information
- Create Level 1a Data representation

Create Infrared Calibration Information
This function has also to extract the calibration information of the infrared channels. The calibration coefficients for the infrared channels (channels 3b, 4 and 5) are determined in-flight by viewing the internal blackbody target and cold space. The calibration is performed at each scan rotation. This is sufficient to determine only a linear approximation of the real curve. The radiances will be estimated from the instrument output counts by using this linear calibration curve. The calibration information extraction comprises the following functions: • Compute Mean Space and Internal Target Counts • Compute PRT Temperatures • Compute Internal Warm Target Temperature and Radiances • Compute Gain and Intercept • Compute Calibration coefficients

Create Visible/Near-Infrared Calibration Information
The task of this function is to extract the calibration information of the visible channels. The calibration coefficients for the visible channels (channels 1 and 2) and channel 3a are determined before launch. There is no calibrated source of visible radiation within the AVHRR/3 instrument. Updates of the calibration coefficients will be done during the lifetime of the instrument through the on ground calibration function and/or vicarious calibration campaigns. The Gain and Intercept are selected according to Count Value:

Perform Geolocation Processing for Tie Points	The function performs the geolocation processing for tie points and generates the corresponding level 1a appended data. It computes the pixel geolocation by means of an ephemeris model and a scanning model. This step of the navigation function performs the navigation assuming default attitude values, directly after data acquisition. From the flight dynamics function, the satellite position, velocity and attitude is obtained and interpolated at the time resolution specified in [AD37]. In addition, the orbit state vector is provided for the start time of the orbit. The flight dynamics information is specified in [AD-48]. The following subfunctions make up the geolocation for tie points function:
	Calculate the Instrument Scanning Angle: From the pixel number within one scan line, the actual scanning angle is determined

	Calculate the Antenna-Mounting Frame Vectors This step uses the position and the velocity of the satellite to define the actual direction of the Antenna-Mounting Frame vectors.
	Calculate the Spin Vector The components of the spin vector is part of a tranformation matrix and can be calculated from the Antenna Mounting Frame vectors using cross-product rules.
	Calculate Direction Cosines of the Scan Spot Using the transformation matrix and the actual scanning angle, the direction cosines of the scan line are expressed in the Mean-of-Date Coordinate System.
	Calculate Scan Spot Location For that purpose, a second order equation (expression of an ellipse in Cartesian coordinates) is solved.
	Calculate Scan Spot Location in an Earth Fixed Coordinate System Using the Greenwich Hour Angle, the coordinates of the scan spot are transformed from the mean-of-date Coordinate system into the Earth-fixed Coordinate System.

Compute Satellite and Solar Zenith and Azimuth Angles for Tie Points	For the calculation of the satellite zenith and azimuth, both the position of the satellite and the tie point are given in the Earth-fixed coordinate system. A transformation matrix allows the determination of both angles. The solar zenith and azimuth is solved with the equation of time and hence, the actual solar declination. For that purpose, the time stamp of the corresponding scan line must be given.

Create Level 1a Data Representation	The Level 1a data is created by reformatting the Level 0 data into the Level 1a data representation and by appending Level 1a data based on the output of the calibration processing and the geolocation for tie points. In addition, this function extracts and compiles any relevant data from the validated platform, instrument and G/S auxiliary data that is required to complete the format of the appended Level 1a data.

The requirements for the Level 1a Processing function can be found in section 4.3 and the scientific aspects of this function are discussed in section 5.3.

3.5.3 Level 1b Processing

From the output of the Level 1a processing function and the auxiliary data, this function produces the level 1b data (via data transformation and representation conversion– converting the Earth view data counts into physical quantities, reflectivity (channels 1, 2, 3a) and radiances (channels 3b, 4 and 5)). Applying a cloud detection algorithm, this function also generates the geolocation information and the satellite and solar zenith and azimuth for each pixel via interpolation from the tie points. In addition, the geolocation is checked using a landmark navigation algorithm.

It has to be noted that the parameters of the models used are either user-configurable or are re-estimated by the parameter estimation function. In any case, these parameters are S/C & Instrument dependent. In addition, it is also producing the appropriate level 1b appended information that is a constituent of the level 1b product. Like any other function, it is generating statistics on the processing being performed and provides monitoring information to the measurement and calibration interfacing function.

The Level 1b processing function can be decomposed into the following sub-functions:

Infrared Calculation	This function applies the calibration coefficients to the Earth view counts and thus the engineering information is converted into physical parameters. The following tasks will be performed:
	Compute Radiances
	Compute Brightness Temperatures

VIS Calculation	The Gain and Intercept selected according to the count value and channels are applied to the Earth view counts and thus the engineering information is converted into physical parameters. These are reflectance factors and radiances. Thus, the following tasks will be performed:
	Compute Reflectance Factors
	Compute Radiances

Geolocation and Landmark Navigation	The geolocation for the tie points is already known from the level 1a processing step. For the scene analysis and the landmark navigation, the geolocation of each pixel has to be computed. There should be two options to perform this step: linear interpolation from the two neighbouring tie points or Lagrangian interpolation from the three neighbouring tie points. The same interpolation schemes should also be used to calculate the satellite and solar azimuth and zenith angles for each pixel. Thus, the function should include the following steps:
	Geolocation for Each Pixel As already mentioned, two different schemes for interpolation are considered: linear interpolation and Lagrangian interpolation. The switch between these two schemes should be configurable.
	Surface Type From the geolocation information and a high resolution coastline data base, the surface type of each pixel is determined
	Landmark processing This function computes the position of each pixel as a function of time, satellite position (calculated with the orbit prediction model) and the

	attitude information (estimated). The function also converts the (pixel, line) co-ordinates into geodetic (latitude, longitude) co-ordinates. To check the required positioning accuracy, an automatic adjustment procedure based on landmark position processing will be performed. With this step, actually estimated attitude information can be provided, also, but the computation is not considered to be a part of operational processing
	Angular Relationships for Each Pixel Two different schemes for interpolation from the tie points are considered: linear interpolation and Lagrangian interpolation. The switch between these two schemes should be configurable.

Scenes Analysis	The main functionality of the Scenes Analysis algorithm is to determine whether a pixel is contaminated by clouds or not. Partially cloudy pixel or pixels covered with semi-transparent clouds will be declared as cloudy. The algorithm also identifies clear pixels which may be covered with snow or ice. In addition, for pixels identified as clear, the surface temperature is determined, and for pixels identified as cloudy the cloud top temperature is computed. The Scenes Analysis algorithm is based on a threshold technique and works nominally on a pixel-by-pixel basis. The threshold technique is comparing the image data with thresholds which mark the border between the physical signal (brightness temperature and reflectance factor) of a pixel without clouds and a pixel containing clouds. The Scenes Analysis algorithm uses a prediction, based either on forecast data of the current AVHRR level 1b scene or on climatological values from a data base. Also, spatial information (mean, standard deviation) is used to supplement the Scenes Analysis process. The threshold technique makes use of the spectral information provided for each pixel with the measurements in all available channels. Mainly, there are six steps performed in the Scenes Analysis:	
	Step 1	Solar Zenith Angle Check
	Step 2	Channel availability and quality check:
	Step 3	Prediction of the clear sky brightness temperature and reflectance
	Step 4	Threshold Determination
	Step 5	Scenes type identification
	Step 6	Automatic Quality Control

The requirements for the Level 1b Processing function can be found in section 4.4. The scientific aspects of this function are discussed in section 5.4.

3.5.4 Post processing

Online Quality Control	This function covers both the radiometric and the geometric quality assessment. The radiometric quality assessment consists of the production of a detailed set of radiometric characteristics of the data for each detector/channels, this for different imaged scenes during the dump (Day/night sides, calibration viewing). The geometric quality control extracts from the level 1b data areas corresponding to geographical areas of interest (landmarks), applies the projection using the attached tie-point information and compares this with landmarks extracted from a high-accuracy digital map. The produced information will be used to generate detailed quality statistics for analysis purposes. This information (subset) will also be used for reporting on the mission performance/product accuracy. In addition, the derived accuracy information will be post-processed and via trend analysis, information on the misalignments between instruments and mis-registration between channels can be derived by subsequent functions. The Quality Control function will also support the offline analysis functionality. These MMIs allow analysis of all data received and produced by the product generation function and the extracted quality information. The following aspects are user-configurable: parameters defining the windows/locations used for the extraction of radiometric statistics, the landmarks data set used for the geometric quality assessment. ***Note:*** The set of landmarks and statistics produced is different for each instrument chain, as the characteristics of the instrument make a common approach not practical.
Online parameter Estimation	This function is using the accumulation of statistics produced by the quality control function to perform trend analysis and to derive the update of the model parameters for the platform/instrument being processed. This information allows compensating for slow drifts and changes in these parameters. This set of parameters that are re-estimated regularly to best approximate the spacecraft status at a given moment in time are called the “warmstart” set of parameters. These are required to be stored and can be pre-loaded in case of reprocessing. The reasons are the following: • Fast convergence: The models use their internal state and this state vector does not need to be regenerated before the reprocessing can start. • Controlled configuration: With the same initial conditions and the same input data, results of algorithm upgrade can be compared accurately with the initial version.

Verification of the Completeness	This function performs the verification of the completeness of the Level 0, Level 1a, and Level 1b information. It generates detailed reporting information on the achieved timeliness and completeness of the information. Information is considered sent if the required data has been made available to the receiving function of a function external to the product generation function.
Production of Reporting Statistics	This function gathers all the reporting information produced by the different functions of the product generation function and generates the input data for the full product generation function for the CGS reporting function. Both the reporting inputs and the full quality information are transferred to the G/S for centralised mission reporting and offline analysis.

The requirements for the Post- Processing function can be found in Section 4.5.

3.5.5 Non-nominal operation

The following table provides an overview of non-nominal processing situations. It presents the behaviour of the product generation function in some specific operational situations. In cases where some degradation of the product quality may be expected this is indicated.

Operational Situation	***Handling / Behaviour of the algorithms***	***Impact on Product***
Corrupted Level 0 data	Processing identifies and flags the corrupted data. Processing continues as specified, output products are of degraded quality.	Degraded and flagged as such
Invalid or missing side information (and/or Instrument Aux, platform TM, G/S aux data)	The processing continues in degraded mode using either interpolated, previous or default side-information (this is case-by-case as per requirements)	Degraded and flagged as such
Missing Channels	Processing uses a reduced algorithm (to the extent specified) and flags the results as degraded	Degraded and flagged as such
Invalid Calibration information	No calibration update – older calibration results applied	Nominal if old calibration still within the specified accuracy

Table 3: Domain of application and behaviour in non-nominal situations

The requirements for the Non-Nominal Processing function can be found in Section 4.6. The scientific aspects of this function are discussed in section 5.6.

4 REQUIREMENTS

4.1 General Requirements

The requirements in this section apply to the entirety of the product generation facility and derive directly from the basic requirements on the mission this product generation facility is supporting.

Note: This instrument-specific functionality is in addition to the generic functions identified in [AD49].

AVHRR-L1-PGS-4.1-0010	**FUNCT**
The product generation function shall provide all the functionality required to support the following: 1. Reception and acceptance of the level 0 data; 2. Reception and acceptance and validation of all other input data required by the processing (instrument TM, G/S auxiliary data, other products); 3. Calibration processing and radiometric processing to level 1a; 4. Geolocation processing to the level 1b via the PGE service providing attitude and orbit information; 5. Online quality control of the products; 6. Estimation of the channels/instrument misregistration and derivation of the correction to be applied (only applicable for specific instruments); 7. Estimation of the time-varying parameters used by the processing models; 8. Measurement and Calibration interfacing functions using the generic PGE services; 9. Generation of monitoring information on the observed AVHRR/3 instrument status and the AVHRR/3 Level 1 product generation function status via the PGE services.	

AVHRR-L1-PGS-4.1-0020	FUNCT
Each function of the product generation function shall monitor its performance and raise events of user-configurable severity on the occurrence of the following: 1. Any abnormal instrument behaviour being detected; 2. Any occurrence and transition to/from a degraded mode of product generation; 3. Any non-nominal operation of the function; 4. Any occurrence likely to affect the product quality.	

AVHRR-L1-PGS-4.1-0030	FUNCT, PERF, INT
The product generation function shall support the production of Level 1a/1b products in a nominal manner for input data acquired by the following Instruments and Platforms configurations: 1. Metop-1/ AVHRR/3 Instrument (full resolution) 2. Metop-2/AVHRR/3 Instrument (full resolution) 3. Metop-3/AVHRR/3 Instrument (full resolution) 4. NOAA-N /AVHRR/3 Instrument (GAC resolution) 5. NOAA-N′/AVHRR/3 Instrument (GAC resolution)	

AVHRR-L1-PGS-4.1-0040	FUNCT, PERF
The product generation function shall process the level 0 data and produce level 1a/1b data of a nominal quality for all nominal modes and states of the instrument.	

AVHRR-L1-PGS-4.1-0050	FUNCT, PERF
The product generation function shall process the level 0 data and produce level 1a/1b data in a degraded manner in the following modes and states of the instrument: 1. Continuous operation with missing channels 2. Continuous operation with reduced scanning angle 3. Continuous operation with instrument misalignment.	

AVHRR-L1-PGS-4.1-0060	FUNCT, PERF
The product generation function shall process the level 0 data and produce level 0 products in a degraded manner in the following cases, if applicable: 1. Missing, corrupt, or repeated instrument level 0 or TM packets. 2. Missing, corrupt, or repeated auxiliary data.	

AVHRR-L1-PGS-4.1-0070	FUNCT, PERF
The AVHRR/3 Instrument Product Generation Function shall support, in nominal operational situations, the following: the processing before and after data, gaps, and at the beginning and the end of the dataset , in addition to the operation of data from the continuous part of a dump.	

AVHRR-L1-PGS-4.1-0110	FUNCT, PERF, INT
The AVHRR/3 Instrument Product Generation Function instance for Metop shall support, in nominal operational situation, in addition to the operation at nominal full resolution the processing in GAC resolution.	

AVHRR-L1-PGS-4.1-0120	FUNCT, PERF
The geolocation accuracy of the full-resolution AVHRR data near nadir shall be better than 1 km in geodetic co-ordinates. For GAC products, the geolocation shall have an accuracy of 1 km near nadir.	

AVHRR-L1-PGS-4.1-0130	FUNCT, PERF
A product shall be considered complete if all the required data content as per [AD37] was produced nominally from the full set of data supplied and the complete product made available.	

AVHRR-L1-PGS-4.1-0140	FUNCT, PERF
The PGF shall deliver all the functionality specified in Section 5 of this document.	

4.2 Level 0 Processing Requirements

4.2.1 Receive and Validate Level 0 Data Flow

AVHRR-L1-PGS-4.2-0010	**FUNCT, INT**
The level 0 dataflow shall be validated and checked by at least the following aspects: 1. Each line shall be validated based on an uncorrupted synchronisation word 2. S/C and instrument identification shall be validated against the expected configuration; 3. Time coherency (which is to be monotonic and increasing) of the level 0 data shall be validated against time increments of scan.	

AVHRR-L1-PGS-4.2-0020	**FUNCT, PERF**
Level 0 data detected as corrupted, missing, or duplicated shall be identified/flagged as such, allowing the subsequent processing to handle the corrupted data without impacting the processing of the remaining data.	

4.2.2 Receive, Validate and Correlate Side information

AVHRR-L1-PGS-4.2-0030	**FUNCT**
Information on the received data for the purpose of reporting shall be extracted or generated. This information shall include: 1. Parameters describing the validity of the received data; 2. Completeness information on the received data.	

AVHRR-L1-PGS-4.2-0040	**FUNCT, RAMS**
It shall be possible to extract a user-configurable subset of data for an offline geolocation and calibration processing. This data set includes UTC time, the orbit state vector, the position of every n^{th} pixel, azimuth and zenith angles of satellite and sun position, and Earth parameters.	

4.2.3 Prepare Level 0 Appended Information

AVHRR-L1-PGS-4.2-0050	**FUNCT, INT**
The level 0-appendend information shall be compiled and formatted in accordance with [AD37], using the validated input data.	

4.3 Level 1a Processing Requirements

4.3.1 General Requirements

AVHRR-L1-PGS-4.3.1-0010	**FUNCT, PERF, INT**
The function shall select the processing for AVHRR/3 full resolution data from Metop and GAC processing data from NOAA according to the validated input data stream.	

AVHRR-L1-PGS-4.3.1-0020	**FUNCT, PERF, INT**
The usage of channel 3a or channel 3b shall be determined from the instrument level 0 data flow.	

AVHRR-L1-PGS-4.3.1-0030	**FUNCT, PERF, INT**
The function shall perform the following: 1. Processing of the on-board calibration information; 2. Processing of the validated level 0 data to level 1a data; 3. Processing of all on-board temperature information; 4. Preparation of all the side information required to compile the level 1a data format.	

AVHRR-L1-PGS-4.3.1-0040	**FUNCT**
For this function, all the parameters used in the calibration processing shall be user-configurable and S/C and instrument specific.	

AVHRR-L1-PGS-4.3.1-0050	**FUNCT**
The static parameters, coefficients, instrument characteristics, gross limits, weighting factors etc. required to perform the calibration and related quality checks, shall be read from in the user configurable data set, in this document called AVHRR_L1_PGS_COF_CAL (see ANNEX B. CONFIGURABLE AUXILIARY DATA SETS). ***Note***: This function receives all extracted information required to perform the calibration processing. It is first validating the content of this information, then deriving all the calibration parameters needed for the creation of the level 1a appended information.	

AVHRR-L1-PGS-4.3.1-0060	**FUNCT, PERF**
All the input data to the online calibration processing shall be validated to the source of the data, the data content and the completeness of the information before being used to perform the calibration processing.	

AVHRR-L1-PGS-4.3.1-0070	**FUNCT, PERF**
This input data content online validation must include at least the checking of the time consistency with previous valid calibration inputs, if these are available.	

AVHRR-L1-PGS-4.3.1-0080	**FUNCT, PERF**
The input data for the calibration shall undergo a gross limit check to eliminate outliers. The limits shall be extracted from the configurable data set, in this document called AVHRR_L1_PGS_COF_CAL (see also APPENDIX B. CONFIGURABLE AUXILIARY DATA SETS).	

AVHRR-L1-PGS-4.3.1-0090	**FUNCT, PERF**
The result of the online calibration processing (processed calibration information) shall be checked for consistency with previously generated calibration values for the same instrument/platform, if available.	

AVHRR-L1-PGS-4.3.1-0100	**FUNCT, PERF**
The following occurrences shall give rise to an event of user-configurable severity: 1. On-Board Calibration occurrence; 2. Successful completion of the online calibration processing; 3. Successful completion of the Level 1a processing for the corresponding dump; 4. Any failure of the above validation checks.	

AVHRR-L1-PGS-4.3.1-0110	**FUNCT**
The function shall produce reporting information on the performance of the calibration and level 1a production, including the following: 1. Information on occurrences of on-board calibration events 2. Resulting calibration values; 3. Information on completeness of the produced Level 1a data	

AVHRR-L1-PGS-4.3.1-0120	**FUNCT, PERF**
The function shall reformat the level 0 data into the level 1a binary representation.	

AVHRR-L1-PGS-4.3.1-0130	**FUNCT, PERF**
The binary representation and format of the level 1a data shall be as per specifications in [AD6].	

AVHRR-L1-PGS-4.3.1-0140	**FUNCT, PERF**
The function shall generate the appended level 1a data in accordance with [AD 49] from the following information: 1. Results of the calibration processing 2. Relevant validated platform, instrument and G/S auxiliary data 3. Relevant quality control parameters	

AVHRR-L1-PGS-4.3.1-0150	**FUNCT, PERF, MMI**
The function shall provide all required near real time MMI functionality according to [AD49] with the following instrument-specific aspects: 1. Identified mode and mode transitions of the instrument; 2. Display of a user-configurable subset of the instrument telemetry; 3. Display of multispectral images of up to three channels at level 1a; 4. Display of multispectral images with flexible colour coding, including pseudo-true colours.	

AVHRR-L1-PGS-4.3.1-0160	**FUNCT**
The function shall perform the creation of the calibration information for each part of the earth view data in the orbit.	

AVHRR-L1-PGS-4.3.1-0170	**FUNCT**
The function shall use a user-configurable (default 55) number of scan lines for the calibration estimation.	

AVHRR-L1-PGS-4.3.1-0180	**FUNCT**
The function shall perform the distinction whether AVHRR/3 channel 3a or channel 3b is used.	

AVHRR-L1-PGS-4.3.1-0190	**FUNCT**
The function shall perform the distinction between channel 3a and channel 3b use in an automated way during nominal operations.	

AVHRR-L1-PGS-4.3.1-0200	FUNCT
The function shall perform the calibration of all visible and near infrared channels (channel 1, channel 2 and channel 3a, if used), which are currently in use.	

AVHRR-L1-PGS-4.3.1-0210	FUNCT
The function shall perform the calibration of all infrared channels (channel 3b, if in use, channel 4 and channel 5), which are currently in use.	

AVHRR-L1-PGS-4.3.1-0220	FUNCT
The function shall check which channel–Channel 3a or Channel 3b–is currently in use.	

4.3.2 Create Infrared Channel Calibration Information

4.3.2.1 Compute Mean Space and Internal Target Counts

AVHRR-L1-PGS-4.3.2-0010	FUNCT
The numerical mean of the space counts and numerical mean of the internal target counts shall be computed. ***Note:*** The calibration cycle start is determined through checking the thermistor counts sum. This sum is lower than a threshold value (default 20, but should be configurable) in case the reference value of the calibration cycle is addressed. The value is taken from the AVHRR_L1_PGS_COF_CAL data set. In a cycle of five scan lines, there are PRT counts for each of the four thermistors, followed by the reference value discussed above. The numerical mean count of the internal target is obtained during the calibration sequences for the PRT number i [mean value computed over, as default, 11 scan lines for each PRT sampling are used. Consequently, as default, 55 scan lines (but should be configurable) are required to allow for the averaging over 11 scan lines for each PRT and hence, to perform a complete calibration cycle].	

4.3.2.2 Compute PRT Temperatures

AVHRR-L1-PGS-4.3.2-0020	FUNCT
The PRT temperatures shall be computed according to Equation 1 in Section 5.3.2.1.	

4.3.2.3 Compute Internal Warm Target Temperature and Radiances

AVHRR-L1-PGS-4.3.2-0030	FUNCT
The internal warm target temperatures shall be computed as a weighted mean according to Equation 2 in Section 5.3.2.1.	

AVHRR-L1-PGS-4.3.2-0040	FUNCT
From the internal warm target weighted mean temperature the radiances shall be derived according to Equation 3–Equation 5 in Section 5.3.2.1.	

4.3.2.4 Compute Gain and Intercept

AVHRR-L1-PGS-4.3.2-0050	FUNCT
For each infrared channel (3b, 4, and 5) the gain and intercept shall be calculated using the internal target radiances, the cold space radiance, the respective count values and predetermined values for each channel taken from the AVHRR_L1_PGS_COF_CAL data set. The calculation shall be performed according to Equation 8 and Equation 9 in Section 5.3.2.1.	

AVHRR-L1-PGS-4.3.2-0060	FUNCT
For each infrared channel (3b, 4, and 5) the linear radiance shall be calculated using the gain, the intercept and the counts. The calculation shall be performed according to Equation 10 in Section 5.3.2.1.	

AVHRR-L1-PGS-4.3.2-0070	FUNCT
The gain and intercept shall be appended to the Level 1a data.	

4.3.2.5 Compute Calibration coefficients

AVHRR-L1-PGS-4.3.2-0080	FUNCT
For each infrared channel (3b, 4, and 5) the calibration coefficients shall be computed using the gain, intercept, the cold space radiance, the respective cold space count value and predetermined values for each channel taken from the AVHRR_L1_PGS_COF_CAL data set. The calculation shall be performed according to Equation 13-Equation 15 in Section 5.3.2.1.	

AVHRR-L1-PGS-4.3.2-0090	FUNCT
The calibration coefficients shall be appended to the Level 1a data.	

AVHRR-L1-PGS-4.3.2-0100	FUNCT, PERF
For the channels 3b, 4, and 5, the Noise Equivalent Delta T shall be calculated. It comprises the following steps: 1. Use the scan line calibration to check the completeness and reliability of the space view and the warm target view counts. 2. Using the warm target counts and the cold space counts and the blackbody temperature derived from the PRTs, this function shall calculate the Noise-Equivalent temperature for AVHRR/3 channels 3b, 4, and for channel 3B, and this information can be extracted only for those portions of the orbit, where the channel 3A is de-activated. 3. The information of the NEΔT-value is written into the array NEDT_VALUE. 4. The actual NEΔT value is checked against a predefined threshold. It exceeds the threshold, a corresponding flag should be set in the "CALIBRATION_QUALITY" bit field.	

4.3.3 Create Visible Channels Calibration Information

AVHRR-L1-PGS-4.3.3-0010	FUNCT
For each visible/near- infrared channel (1, 2, and 3a) the calibration coefficients shall be extracted from the AVHRR_L1_PGS_COF_CAL data set.	

AVHRR-L1-PGS-4.3.3-0020	FUNCT
For each visible/near- infrared channel (1, 2, and 3a) the gain and intercept values shall be determined as illustrated in Equation 16 in Section 5.3.2.2, and in Table 1.	

AVHRR-L1-PGS-4.3.3-0030	**FUNCT**
The visible calibration coefficients shall be added to the Level 1a data.	

4.3.4 Perform Geolocation Processing

AVHRR-L1-PGS-4.4.4-0004	**FUNCT**
The function shall distinguish between AVHRR full resolution and AVHRR GAC resolution.	

AVHRR-L1-PGS-4.4.4-0005	**FUNCT**
The algorithm shall perform the generation of the geolocation data for the tie points of each scan line. The geolocation data comprise the geodetic latitude and longitude with an accuracy of 1 km near nadir	

4.3.4.1 Get satellite Orbit State and Position

AVHRR-L1-PGS-4.4.4-0006	**FUNCT**
From the flight dynamics information the satellite position, velocity and attitude shall be obtained and shall be interpolated to the actual time of the beginning of the scan line. ***Note***: The flight dynamics information is specified in [AD 48]	

AVHRR-L1-PGS-4.4.4-0010	**FUNCT, PERF, DES**
The function shall use the generic orbit and attitude services of the PGE to perform the geolocation processing. The following information should be extracted: • The position and the velocity of the satellite in the Mean-of-Date Coordinate frame • The Greenwich sidereal angle • The misalignment of the instrument • Timing and angular displacements of AVHRR/3 in the scanning angle	

4.3.4.2 Compute Geolocation of tie points

AVHRR-L1-PGS-4.4.4-0020	**FUNCT, PERF**
The function shall perform the geolocation processing for a user-configurable density of tie points, the default density being every 40th pixel and every line. The density of the tie points at each scan line and the information necessary to perform the geolocation is stored in the configurable data set (AVHRR_L1_PGS_COF_NAV)	

4.3.5 Satellite Zenith and Azimuth

AVHRR-L1-PGS-4.4.4-0030	**FUNCT**
The function shall distinguish between AVHRR full resolution and AVHRR GAC resolution.	

AVHRR-L1-PGS-4.4.4-0040	**FUNCT**
Using the pixel geolocations and the satellite position, the algorithm shall compute the satellite zenith and azimuth for the tie points with geolocation information of each scan line (nominally, each 40th pixel and each 8th pixel for GAC resolution). Both angles should have an accuracy of 0.5 degrees	

AVHRR-L1-PGS-4.4.4-0050	**FUNCT**
The function shall distinguish between AVHRR full resolution and AVHRR GAC resolution.	

AVHRR-L1-PGS-4.4.4-0060	**FUNCT**
Using the pixel geolocations and information of local time the algorithm shall compute the solar zenith and azimuth for the tie points with geolocation information and satellite and solar azimuth angles of each scan line (nominally, each 40th pixel from pixel 25–2025 for full resolution and each 8th pixel from pixel 5–405 for GAC resolution). Both angles should have an accuracy of 0.5 degrees. This function makes use of the astronomical data base AVHRR_L1_PGS_DAT_ASTRO.	

4.4 Level 1b Processing Requirements

4.4.1 General Requirements

AVHRR-L1-PGS-4.4.1-0010	**FUNCT, PERF**
The function shall derive the level 1b data from the level 1a data by using the following information: 1. Appended level 1a data, in particular the derived calibration parameters 2. The on-ground characterised data, made available as configurable data sets (for the non-linear correction).	

AVHRR-L1-PGS-4.4.1-0020	**FUNCT, RAMS, DES, PERF**
It shall be possible to configure the product generation function such that the transformation to level 1b is as follows: 1. Enforcing the usage of a user-definable calibration (user-defined LUT); 2. Applying an additional correction function (polynomial of up to 3rd degree) to the derived level 1a information; 3. Applying the level 1a derived information only if this information is indicated as valid; in the absence of valid information, user-configurable default values shall be applied and the level 1b shall be flagged as such.	

AVHRR-L1-PGS-4.4.1-0030	**FUNCT, PERF**
The application of the calibration to the pixels shall be performed with an accuracy of better than 0.6 LSB (Least Significant Bit) maximum and 0.3 LSB RMS. ***Note 1:*** The LSB corresponds to the LSB of the final level 1b binary representation. ***Note 2:*** It is expected that the transformation would be based on a LUT transformation mapping the level 1a representation to the level 1b representation. To achieve this accuracy, the derivation of the LUT would need to be performed with Floating point accuracy, followed by the rounding to the final binary representation.	

AVHRR-L1-PGS-4.4.1-0040	**FUNCT, PERF**
The function shall produce reporting information on the following: 1. Completeness of the produced level 1b data; 2. Validity of the processing to level 1b;	

4.4.2 Infrared Radiances and Brightness Temperatures

AVHRR-L1-PGS-4.4.2-0010	**FUNCT**
Radiances (expressed in $W/(m^2\text{-sr-}cm^{-1})$) shall be computed from the measured earth view counts using the channel dependent calibration coefficients, according to the calibration in Equation 50 in Section 5.4.1.	

AVHRR-L1-PGS-4.4.2-0020	FUNCT
Brightness temperatures (expressed in K) shall be derived from the radiances channel-dependent Planck function and the linear correction of the effective temperature, according to Equation 51 and Equation 52 in Section 5.4.1.	

4.4.3 Visible / Near-Infrared Radiances and Reflectances

AVHRR-L1-PGS-4.4.3-0010	FUNCT
The target reflectance factor (expressed in percentage) shall be computed from the earth view counts using the channel dependent gain and intercept values, according to calibration in Equation 53 in Section 5.4.2.	

AVHRR-L1-PGS-4.4.3-0020	FUNCT
The scene radiance (expressed in (W m^{-2} sr^{-1})) shall be computed from the derived target reflectance factor, according to Equation 54 in Section 5.4.2.	

4.4.3.1 Geolocation for Each Pixel

AVHRR-L1-PGS-4.4.4-0022	FUNCT
The function shall perform an interpolation of the geolocation information from the tie-points to the remaining pixels. At the edges, an extrapolation shall be performed. The function shall support two different interpolation schemes: 1. Linear interpolation between the two nearest tie points 2. Lagrangian interpolation between the three nearest tie points	

AVHRR-L1-PGS-4.4.4-0024	FUNCT
The function shall perform an interpolation of the satellite and the solar azimuth and zenith from the tie points to the remaining pixels. At the edges, an extrapolation shall be performed. The function shall support two different interpolation schemes: 1. Linear interpolation between the two nearest tie points 2. Lagrangian interpolation between the three nearest tie points	

AVHRR-L1-PGS-4.4.4-0120	FUNCT
Using a global high resolution coastline map (AVHRR_L1_PGS_DAT_LAMASK), on the basis of the geolocation information, this function determines the surface type of each pixel. The following three types should be identified: 1. Land 2. Sea 3. Coast	

4.4.3.2 Landmark Processing

AVHRR-L1-PGS-4.4.4-0040	FUNCT
The function shall distinguish between AVHRR full resolution and AVHRR GAC resolution. Landmark navigation is performed only for full resolution data.	

AVHRR-L1-PGS-4.4.4-0032	FUNCT
The landmark processing function shall implement the following operations: 1. Compute the position of each pixel as a function of time (corrected from the clock error), satellite position (calculated with an orbit prediction model) and the attitude information 2. Convert the (pixel, line) co-ordinates into geodetic (latitude, longitude) co-ordinates with an accuracy of better than 10 km. 3. Perform the navigation with the default attitude values, directly after data acquisition. 4. Perform an automatic adjustment procedure based on the landmark position processing and derive corrected information. ***Note:*** The Automatic Adjustment Procedure is described in detail in RD1.	

AVHRR-L1-PGS-4.4.4-0034	FUNCT
The function shall extract, apply automatic quality control and refine the position of the subset of the landmarks that are used for the navigation.	

AVHRR-L1-PGS-4.4.4-0036	FUNCT, PERF
The accuracy of the extracted landmark information (after refinement and Quality Control) shall be better than 0.25 AVHRR sampling distance RMS.	

AVHRR-L1-PGS-4.4.4-0038	**FUNCT**
There shall be user configurable number of landmarks covering the coastal areas over the whole Earth. The landmark centers and extensions are extracted from the data set AVHRR_L1_PGS_DAT_LANMARK.	

AVHRR-L1-PGS-4.4.4-0060	**FUNCT**
This function shall identify the center pixels of the landmarks. In addition, the function selects a rectangular area around this center pixel with an extension of +20 pixels.	

AVHRR-L1-PGS-4.4.4-0070	**FUNCT**
For the selected pixels, this function extracts the following quantities: • Normalized difference vegetation index • Channel 2 target reflectance • Brightness temperature difference between channel 4 and channel 5 • Channel 4 brightness temperature	

AVHRR-L1-PGS-4.4.4-0080	**FUNCT**
For the selected landmark areas (actual windows), the actual binary windows are generated. This is performed in two different ways: • For the visible criteria, constant thresholds are applied (–0.1 for the normalized vegetation index, and 6 for the channel 2 reflectance. These thresholds should be user-configurable.) • For the infrared criteria, thresholds are applied that are calculated from histogram analysis of the corresponding actual window	

AVHRR-L1-PGS-4.4.4-0090	**FUNCT**
This function extracts the binary reference window by selecting the pixels located within a landmark area. The resulting windows are the binary reference windows. Pixels of the type ’coast’ are contributed to the type ’land’.	

AVHRR-L1-PGS-4.4.4-0100	FUNCT
This function compares the actual binary windows with the reference binary window by means of a similarity coefficient as described in Equation 59 and Equation 60 in Section 5.4.3.1. The maximum similarity coefficient determines the correction along and across the flight direction of the orbiter. If the maximum similarity coefficient is lower than a configurable threshold (currently 0.95), the corresponding landmark is excluded from further refinement of geolocation.	

AVHRR-L1-PGS-4.4.4-0102	FUNCT
There shall be a quality control step, which eliminates questionable results.	

AVHRR-L1-PGS-4.4.4-0104	FUNCT
There shall be quality tests relative to individual landmarks.	

AVHRR-L1-PGS-4.4.4-0106	FUNCT
There shall be quality tests relative to the average landmark errors computed for one dump.	

AVHRR-L1-PGS-4.4.4-0110	FUNCT
From the accepted landmarks, this function returns the following parameters: • Pixel number of the landmark center • Start time of the corresponding scan line • Deviation between the actual binary image and the reference binary image expressed in pixel coordinates	

4.4.4 Cloud Model (Scenes Analysis)

AVHRR-L1-PGS-4.4.5-0010	FUNCT, PERF
Based on the complete set of AVHRR/3 Channels, a Scenes Analysis shall be performed.	

AVHRR-L1-PGS-4.4.5-0020	FUNCT, PERF
There shall be separate modes for Metop (full AVHRR/3 resolution) and NOAA (GAC resolution) and also depending on day/night situation (usage of channels 3a/3b).	

AVHRR-L1-PGS-4.4.5-0030	FUNCT, PERF
The algorithm shall work on a pixel-by-pixel basis in its nominal configuration.	

AVHRR-L1-PGS-4.4.5-0032	FUNCT
The function shall extract and validate actual atmospheric water vapour and temperature profiles from NWP forecast data.	

AVHRR-L1-PGS-4.4.5-0034	FUNCT
The function shall extract and validate actual AMSU-A brightness temperatures of 23 GHz, 31 GHz, and 50 GHz and the corresponding scanning angle of AMSU-A.	

AVHRR-L1-PGS-4.4.5-0036	FUNCT
The function shall determine the water vapour content from AMSU-A brightness temperatures of 23 GHz, 31 GHz, and 50 GHz and the corresponding scanning angle of AMSU-A. The result of this algorithm is used for the scenes analysis only over sea and for geographical latitudes between 50° N and 50° S.	

AVHRR-L1-PGS-4.4.5-0038	FUNCT
Using a high resolution digital elevation model (AVHRR_L1_PGS_DAT_SFCTOP) this function determines the surface elevation for each pixel.	

AVHRR-L1-PGS-4.4.5-0060	FUNCT
The cloud detection within the Scenes Analysis algorithm shall perform six main processing steps, which are as follows: 1. Solar zenith angle check 2. Channel availability and quality check 3. Prediction of clear sky brightness temperatures and clear sky reflectance factors 4. Threshold determination 5. Scenes type identification 6. Automatic quality control	

AVHRR-L1-PGS-4.4.5-0070	FUNCT
The Scenes Analysis shall be able to generate the Sea Surface Temperature (SST) on the pixels identified as clear over land according to Equation 133 and Equation 134 in Section 5.4.4.6.	

AVHRR-L1-PGS-4.4.5-0080	**FUNCT**
The Scenes Analysis shall be able to generate the Sea Surface Temperature (TSurf) on the pixels identified as clear over ocean according to Equation 137 and Equation 138 in Section 5.4.4.8.	

AVHRR-L1-PGS-4.4.5-0090	**FUNCT**
The Scenes Analysis shall be able to generate the Cloud Top Temperature (CTT) for pixels identified as blackbody clouds according to Equation 135 and Equation 136 in Section 5.4.4.7.	

AVHRR-L1-PGS-4.4.5-0100	**FUNCT,PERF**
The following threshold tests shall be used in the Scenes Analysis algorithm: Test 1a: reflectance test using AVHRR Channel 1 (twilight and daylight over coast and land only) Test 1b: reflectance test using AVHRR Channel 2 (twilight and daylight over coast and sea only) Test 2a: temperature test using AVHRR Channel 4 Test 4a: temperature difference AVHRR Channel 4 AVHRR Channel 3b (night time only) Test 4b: temperature difference AVHRR Channel 4 AVHRR Channel 5 Test 4c: temperature difference AVHRR Channel 3b AVHRR Channel 5 (night time only) Test 5a: standard deviation of AVHRR Channel 4 brightness temperature for n × n pixel segment (n nominally set to 3; over sea only) Test 6: cloud test for sunglint conditions, using AVHRR Channels 3b and 4 (over sea only). Test 7: Snow and ice test using the difference (AVHRR Channel 3b AVHRR Channel 4) and threshold tests with AVHRR/3 Channel 1, 2, 3a,and 4.	

AVHRR-L1-PGS-4.4.5-0110	**FUNCT,PERF**
The algorithm shall be designed and implemented such that it can be extended with other tests.	

AVHRR-L1-PGS-4.4.5-0112	**FUNCT,PERF**
The scenes analysis shall also be performed in case of missing channel data or degraded channels data.	

AVHRR-L1-PGS-4.4.5-0114	**FUNCT,PERF**
The scenes analysis shall also be performed in case of degraded geolocation information or degraded information about sun and/or satellite zenith and azimuth angles.	

AVHRR-L1-PGS-4.4.5-0120	**FUNCT,PERF**
There shall be user-configurable setup parameters, that define which of the tests are overall enabled, enabled over land only, enabled over sea only, enabled for Metop only, enabled for NOAA only, overall disabled.	

AVHRR-L1-PGS-4.4.5-0130	**FUNCT**
It shall be assumed at the beginning of the cloud threshold tests that the scene is unknown for each pixel. .	

AVHRR-L1-PGS-4.4.5-0140	**FUNCT,PERF**
There shall be a quality check for all cloud contaminated pixels in the Scenes Analysis results.	

AVHRR-L1-PGS-4.4.5-0150	**FUNCT,PERF**
The results of the individual threshold test, which flagged a pixel as cloudy, shall be used to generate a quality mark.	

AVHRR-L1-PGS-4.4.5-0160	**FUNCT, PERF**
The scenes analysis shall be performed in five steps, as described below, for each pixel.	

AVHRR-L1-PGS-4.4.5-0170	**FUNCT, PERF**
All static application data–thresholds, parameters and constants–shall be configurable.	

AVHRR-L1-PGS-4.4.5-0180	**FUNCT, PERF**
The result of step 3 (channel availability and quality check) and each threshold test of step 5 shall be marked with a flag indicating whether or not the test failed. This flag is called the “test flag”.	

AVHRR-L1-PGS-4.4.5-0190	**FUNCT, PERF**
For all tests, the test flag shall be able to reflect three conditions: *test failed*, *cloud detected*, and *clear scene*.	

AVHRR-L1-PGS-4.4.5-0210	FUNCT,PERF
The scenes type shall consist (per pixel) of the following: 1. For pixel with no image data available, the scenes type shall be set to a value stating *no scenes identified, missing data* 2. For a pixel identified as clear, the scenes type shall be set either to the value of the surface type given from the surface type map– including the surface type ice/snow, or it shall be set to a value stating *sunglint* if for a clear pixel the sunglint criteria is fulfilled. 3. For a pixel identified as cloudy, the scenes type shall be set to *cloudy*.	

AVHRR-L1-PGS-4.4.5-0220	FUNCT,PERF
The output of the Scenes Analysis shall consist (per pixel) of the following: 1. The cloud flag 2. The geographical information 3. The surface type 4. The surface elevation 5. The cloud top temperature or the surface temperature 6. The time of the beginning of the corresponding scan line and the pixel number 7. The VIS and IR radiances	

4.4.4.1 Step 1: Solar Zenith Angle Check

AVHRR-L1-PGS-4.4.5-0230	FUNCT
The scenes analysis algorithm shall use information about the elevation of the sun in the form of solar zenith angle for each pixel. 1. Day, if the solar zenith angle is lower or equal a threshold 2. Night, if the solar zenith angle is greater or equal a threshold 3. Twilight (at dawn and dusk), if the solar zenith angle is between the above thresholds for day and night	

AVHRR-L1-PGS-4.4.5-0231	FUNCT
The scenes analysis algorithm shall use information about sun and satellite azimuth and zenith angle to identify sunglint conditions for each pixel (see Section 5.4.4.1.1).	

4.4.4.2 Step 2: Check Channel availability and quality

AVHRR-L1-PGS-4.4.5-0232	**FUNCT**
To allow an optimal performance of the scenes analysis algorithm all AVHRR channel shall be available	

AVHRR-L1-PGS-4.4.5-0236	**FUNCT**
The data shall be tested for unrealistic values–like temperatures below a minimum threshold and above a maximum threshold.	

AVHRR-L1-PGS-4.4.5-0238	**FUNCT**
If channels are not available, any tests using these channels shall be disabled via the update of the test enable/disable setup parameters.	

AVHRR-L1-PGS-4.4.5-0240	**FUNCT**
If for a distinct pixel no data are available, or if all channels show unrealistic values and are flagged as not usable, then 1. The scenes_type shall be set to a default value, stating *no scene identified, data not available* 2. The test flag for this test shall be set to a value *test failed* 3. The quality flag shall be set to a default value 4. The steps that follow this shall not be done.	

4.4.4.3 Step 3: Prediction of the clear sky conditions

AVHRR-L1-PGS-4.4.5-0242	**FUNCT**
The clear sky reflectance factors shall be determined in hundreds of percent for AVHRR channels 1, 2, and 3a for the reflectance tests.	

AVHRR-L1-PGS-4.4.5-0243	**FUNCT**
The clear sky reflectance factors shall be determined in hundreds of percent for AVHRR channels 3b, 4, and 5 for the temperature tests.	

AVHRR-L1-PGS-4.4.5-0244	**FUNCT**
The Scenes Analysis algorithm shall be able to use forecasted data of temperature (2m temperature) and total column water vapour content for the actual threshold determinations. These data should be extrapolated in time (time of forecast data generation to scan line time) and interpolated to space (to pixel location).	

AVHRR-L1-PGS-4.4.5-0250	FUNCT
The extracted physical parameters from the forecast data shall be stored as an intermediate product for further use.	

AVHRR-L1-PGS-4.4.5-0265	FUNCT
The actual water vapour content shall be taken from forecasted data over land and from AMSU-A brightness temperatures at 23, 31 and 50 GHz over sea, if available. ***Note:*** in any case, AMSU-A retrieved water vapour content data must be supplemented by either forecast data or climatological values for mainly three reasons: • The AMSU-A data do not cover the whole AVHRR area, because of the reduced swath. • Gaps between the AMSU-A-retrieved total column water vapour content should be filled. • The validity of the applied algorithm is restricted to sea surfaces between 50° N and 50° S.	

AVHRR-L1-PGS-4.4.5-0270	FUNCT, PERF
If AMSU data are not available or flagged as degraded, the algorithm shall use water vapour content from forecast data over sea.	

AVHRR-L1-PGS-4.4.5-0272	FUNCT, PERF
If forecast data are not available or flagged as degraded, the algorithm shall use water vapour content from monthly mean climatological data over land and over sea.	

AVHRR-L1-PGS-4.4.5-0275	FUNCT
The secant of the satellite zenith angle is computed.	

AVHRR-L1-PGS-4.4.5-0285	FUNCT
Climatological values of the surface reflectance over land shall be extracted from look-up tables depending on season and geographical location	

AVHRR-L1-PGS-4.4.5-0290	FUNCT
Over sea, the reflection function shall be calculated using Fresnel's Equations 84–Equation 98 in Section 5.4.4.5.1.1.	

AVHRR-L1-PGS-4.4.5-0300	FUNCT
An atmospheric correction of surface reflectance shall be applied over land and water surfaces. See Equation 99–Equation 105 in Section 5.4.4.5.1.1. The transmission coefficients are different over land and over sea and are taken from look-up tables. ***Note:*** The values stored in these LUTs can be determined only with the knowledge of the channel window spectral response function. Hence, they are instrument specific.	

AVHRR-L1-PGS-4.4.5-0295	FUNCT
This function shall use the actual satellite and solar angles to correct the surface for anisotropic effects. The algorithm is defined by Equation 108–Equation 113 in Section 5.4.4.5.1.1.	

4.4.4.4 Step 4: Threshold determination

AVHRR-L1-PGS-4.4.5-0320	FUNCT
For each of the temperature difference tests, thresholds shall be determined from look-up tables. The selection of the corresponding look-up table depends on the surface type (sea/coast or land). The actual threshold selected from a distinct table depends on the atmospheric water vapour content and on the secant of the satellite zenith angle.	

AVHRR-L1-PGS-4.4.5-0321	FUNCT
For the temperature test, the threshold depends on the surface type and shall be calculated according to Equation 68–Equation 72 in Section 5.4.4.5.1.1. The selection of the corresponding value further depends on the availability of forecasted temperature fields. If no forecasted temperature fields are available, climatological values should be used instead. These values have to be corrected for the surface altitude using a vertical temperature lapse rate of 6.5 K/km This should be configurable.	

AVHRR-L1-PGS-4.4.5-0322	FUNCT
For daytime conditions over sea (no sunglint), the threshold for the reflectance test shall be computed according to Equation 106 and Equation 107, Section 5.4.4.5.1.1.	

AVHRR-L1-PGS-4.4.5-0323	FUNCT
For daytime conditions over land, the threshold for the reflectance test shall be computed according to Equation 114–Equation 116 in Section 5.4.4.5.1.1.	

AVHRR-L1-PGS-4.4.5-0324	FUNCT
For sunglint conditions, the thresholds depend on the solar zenith angle and are computed according to Equation 118 and Equation 119 in Section 5.4.4.5.2.1.	

AVHRR-L1-PGS-4.4.5-0326	FUNCT
The thresholds for the tests during night time should be determined according to the description in Section 5.4.4.5.3.1.	

AVHRR-L1-PGS-4.4.5-0328	FUNCT
The thresholds for the tests during twilight conditions should be determined according to the description in Section 5.4.4.5.4.1.	

4.4.4.5 Step 5: Scenes type identification

AVHRR-L1-PGS-4.4.5-0330	FUNCT
For daytime conditions, the threshold tests in step 5 shall be performed as described in Section 5.4.4.5.1.2. See Table 5.	

AVHRR-L1-PGS-4.4.5-0332	FUNCT
For sunglint conditions, the threshold tests in Step 5 shall be performed as described in Section 5.4.4.5.2.2.	

AVHRR-L1-PGS-4.4.5-0334	FUNCT
For night time conditions, the threshold tests in step 5 shall be performed as described in Section 5.4.4.5.3.2. See Table 6.	

AVHRR-L1-PGS-4.4.5-0336	FUNCT
For twilight conditions, the threshold tests in step 5 shall be performed as described in Table 5.4.4.5.4.2. See Table 7.	

AVHRR-L1-PGS-4.4.5-0338	FUNCT
During daytime conditions, a snow and ice detection test shall be performed according to the description in Section 5.4.4.5.5.	

AVHRR-L1-PGS-4.4.5-0340	FUNCT
The tests in step 5 shall be applied independently of each other, according to their enabled/disabled setting and to the local time type (day/twilight/night).	

AVHRR-L1-PGS-4.4.5-0350	FUNCT
The scenes analysis threshold test flag shall be set indicating for each test on each pixel whether it detected a cloud (cloud detected) or not (no cloud detected). It shall be possible to include future additional tests in the threshold test flags.	

4.4.4.6 Step 6: Automatic Quality Control (AQC)

AVHRR-L1-PGS-4.4.5-0360	FUNCT
The automatic quality control (AQC) shall collect all the flags relevant for the cloud detection.	

AVHRR-L1-PGS-4.4.5-0370	FUNCT
The algorithm shall be implemented such that new automatic quality control (AQC) checks can be added.	

4.5 Post-Processing Requirements

4.5.1 Online Quality Control

4.5.1.1 General Requirements

AVHRR-L1-PGS-4.5.1-0010	FUNCT
There shall be a check of each AVHRR scan line on scan numbering.	

AVHRR-L1-PGS-4.5.1-0020	FUNCT
There shall be a check of each AVHRR scan line on the scan time.	

AVHRR-L1-PGS-4.5.1-0030	FUNCT
There shall be the determination of the first calibration sequence in the data.	

AVHRR-L1-PGS-4.5.1-0040	FUNCT
There shall be the determination of the active channel 3 (channel 3a and channel 3b).	

AVHRR-L1-PGS-4.5.1-0050	FUNCT
There shall be quality indicators at data set level according to the specification in the AVHRR/3 Level 1 Product Format Specification [AD37].	

AVHRR-L1-PGS-4.5.1-0060	FUNCT
There shall be quality indicators at scan line level according to the specification in [AD37].	

4.5.1.2 Radiometric Quality Control

AVHRR-L1-PGS-4.5.1-0070	FUNCT, PERF, INT
The function shall produce the following set of radiometric statistics on the level 1a data for all the channels of the instrument and per detector of the instrument: 1. minimum and maximum count of full product; 2. dynamic range of product; 3. mean and standard deviation of product; 4. line histograms; 5. full image histogram; 6. Image centre swath histogram; 7. entropy (zeroth, first order) of full image; 8. entropy (zeroth, first order) of image centre swath ; 9. image power spectral density of a selected area (2D user-definable square) ; 10. image power spectral density of the full image (accumulated line along track, and accumulated pixels across-track); 11. noise level.	

AVHRR-L1-PGS-4.5.1-0080	**FUNCT, PERF, INT**
The function shall produce the same set of radiometric statistics on the Level 1b data as for the level 1a data, for all the channels of the instrument and per detector of the instrument.	

AVHRR-L1-PGS-4.5.1-0090	**FUNCT, PERF**
There shall be a gross limit check and a 1-Sigma and 2-Sigma filtering of the PRT counts, the internal black body counts and the space counts for one calibration cycle.	

4.5.1.3 Geometric Quality Control

AVHRR-L1-PGS-4.5.1-0100	**FUNCT, PERF, INT**
The function shall perform geometrical quality control of the level 1a/1b data for the following aspects: 1. Absolute accuracy 2. Channel misregistration	

AVHRR-L1-PGS-4.5.1-0120	**FUNCT, PERF**
Geometric quality and absolute accuracy shall be based on an averaging of landmark measurements over time.	

AVHRR-L1-PGS-4.5.1-0130	**FUNCT, PERF**
The function shall also measure the relative geometrical quality based on the following: 1. The comparison with the preceding dump; 2. The comparison of the geolocation of the same area in the previous coverage.	

4.5.1.4 Misregistration estimation

VHRR-L1-PGS-4.5.1-0150	**FUNCT, PERF, INT**
The misregistration between two channels shall be defined as the apparent displacement of the barycenters of the instrument response for the channels to be co-registered, once all the other effects have been corrected.	

AVHRR-L1-PGS-4.5.1-0160	**FUNCT, PERF**
The function shall estimate the misregistration between any two channels of AVHRR.	

AVHRR-L1-PGS-4.5.1-0170	**FUNCT, PERF, DES**
To estimate the misregistration, the function shall accumulate measurements of landmarks and/or sensor information over a user-configurable period of time and derive the coherent part of the difference in barycenter position between the channels to be aligned.	

AVHRR-L1-PGS-4.5.1-0180	**FUNCT**
The derived misregistration information shall be validated before being provided to the processing, in particular the following shall be verified: 1. Density and quality of the input data used to derive the misregistration values; 2. Consistency of the derived values with previously derived one (unless there was an event, change of mode, manoeuvre, etc...) that can explain an important sudden change; 3. Residual error on the derived values.	

AVHRR-L1-PGS-4.5.1-0190	**FUNCT**
The function shall raise events of user-configurable severity in any of the following cases: 1. The misregistration is higher than a given threshold; 2. The misregistration variation rate is higher than a given rate; 3. The misregistration could not be derived; 4. The misregistration failed any of the validation checks	

4.5.1.5 Limit Checking

AVHRR-L1-PGS-4.5.1-0200	**FUNCT, PERF**
All PRT counts shall be compared against limits specified in the calibration parameter data set (AVHRR_L1_PGS_COF_CAL).	

AVHRR-L1-PGS-4.5.1-0210	**FUNCT**
All on-board temperatures shall be compared against limits and flags generated for any temperatures outside these limits.	

AVHRR-L1-PGS-4.5.1-0220	**FUNCT**
The total number of out of limit flags generated within a “calibration cycle” shall be computed and included in the Output Quality Parameters.	

AVHRR-L1-PGS-4.5.1-0230	**FUNCT**
The difference between the maximum and minimum PRT temperatures of the on-board target and the standard deviation of all the PRT temperatures of the on-board target shall be computed and included in the Output Quality Parameters.	

4.5.2 Production of Reporting Statistics

AVHRR-L1-PGS-4.5.4-0010	
All reporting shall be performed in accordance with document [AD49].	

AVHRR-L1-PGS-4.5.4-0020	
The Product Generation Function shall have the capability to select any of the following parameters (user configurable) for forwarding to the CGS M&C function for routine monitoring: 1. Any parameter derived from the contents of the pixel data contained in the level 0 data stream (raw counts for a given pixel, calibrated radiance for a given pixel, averaging counts over a target view, gain value, offset value etc.) 2. Any parameter of the product generation function software itself.	

4.6 Non-Nominal Operations

AVHRR-L1-PGS-4.6.1-0010	**FUNCT**
The function shall collect all non-nominal processing flags listed in Table 8 of Section 5.6. In particular, the following categories should be considered: 1. Instrument status 2. Time sequence 3. Earth location 4. Calibration 5. Navigation	

AVHRR-L1-PGS-4.6.1-0020	**FUNCT**
Depending on the instrument status flags, this function should modify the operational processing in the following way: 1. Motor/telemetry off: no processing 2. Electronic/telemetry off: no processing 3. Channel 1 disable: No Ch1 processing, landmark navigation without NDVI test, scenes analysis without reflectance test over land and with degraded snow/ice detection 4. Channel 2 disable: No Ch2 processing, landmark navigation without NDVI and reflectance test, scenes analysis without reflectance test over sea and with degraded snow/ice detection 5. Channel 3a disable: No Ch3a processing, scenes analysis with degraded snow/ice test 6. Channel 3b disable: No Ch3b processing, scenes analysis without brightness temperature difference tests: T11µm–T3.7µm and T3.7µm–T12µm', computation of SST and TSurf without T3.7µm 7. Channel 4 disable: No Ch4 processing, landmark navigation without brightness temperature and brightness temperature difference test, scenes analysis without tests T11µm, T11µm–T12µm, T11µm–T3.7µm, and T11µmSpatial Coherence, no SST, TSurf and CTT computation 8. Channel 5 disable: No Ch5 processing, degraded landmark navigation without brightness temperature difference test, scenes analysis without tests T11µm–T12µm, T3.7µm–T12µm, use T11µm as SST, TSurf and CTT 9. Voltage calibrate status off: No processing 10. Cooler heat off: Processing of degraded radiances, target reflectance factors, and brightness temperatures, degraded landmark navigation, degraded scenes analysis 11. Scan motor low: Processing of degraded radiances, target reflectance factors, and brightness temperatures, degraded landmark navigation, degraded scenes analysis 12. Earth shield disable: Processing of degraded radiances, target reflectance factors, and brightness temperatures, degraded landmark navigation, degraded scenes analysis	

AVHRR-L1-PGS-4.6.1-0030	**FUNCT**
Depending on the time sequence flags, this function should modify the operational processing in the following way: 1. Time field is bad but can probably be inferred from previous good time: Processing of degraded geolocation information, degraded scenes analysis 2. Time field is bad and cannot be inferred from the previous good time: No geolocation data, no angular relations, no scenes analysis 3. Scan line starts a sequence that is inconsistent with previous times: Processing of degraded geolocation, degraded scenes analysis 4. Start of a sequence that apparently repeats previously accepted scan times: Processing of degraded geolocation, degraded scenes analysis 5. Scan time not corrected for clock drift: Processing of degraded geolocation, degraded scenes analysis.	

AVHRR-L1-PGS-4.6.1-0040	**FUNCT**
Depending on the Earth location flags, this function should modify the operational processing in the following way: 1. No earth location of the scan line: No geolocation, no angular relations, no scenes analysis 2. Earth location of the scan line questionable: Processing of degraded geolocation, degraded scenes analysis 3. Earth location questionable-only marginal agreement with reasonableness check: Processing of degraded geolocation, degraded scenes analysis 4. Earth location questionable-fails reasonableness check: Processing of degraded geolocation, degraded scenes analysis.	

AVHRR-L1-PGS-4.6.1-0050	FUNCT
Depending on the calibration flags, this function should modify the operational processing in the following way: 1. Scan line was not calibrated because of bad time: Use previous or prelaunch calibration data. Processing of degraded IR radiances and brightness temperatures, degraded landmark navigation, degraded scenes analysis 2. Scan line was calibrated but with fewer than the preferred number (55) of scan line information: Use previous or prelaunch calibration data. Processing of degraded IR radiances and brightness temperatures, degraded landmark navigation, degraded scenes analysis 3. Scan line is not calibrated because of bad or insufficient PRT data: Use previous or prelaunch calibration data. Processing of degraded IR radiances and brightness temperatures, degraded landmark navigation, degraded scenes analysis 4. Scan line was calibrated with a reduced number of PRT data: Use previous or prelaunch calibration data. Processing of degraded IR radiances and brightness temperatures, degraded landmark navigation, degraded scenes analysis 5. Uncalibrated channels in this scan line: Use previous or prelaunch calibration data. Processing of degraded IR radiances and brightness temperatures, degraded landmark navigation, degraded scenes analysis	

AVHRR-L1-PGS-4.6.1-0060	**FUNCT**
Depending on the navigation flags, this function should modify the operational processing in the following way: 1. Ephemeris file older than one day: use latest available ephemeris file. 2. No Earth location: No geolocation, no angular relations, no scenes analysis. 3. Attitude exceeds nominal tolerance: Processing of degraded geolocation, degraded scenes analysis. 4. Rate nulling mode on: Processing of degraded geolocation, degraded scenes analysis. 5. YGC (Yaw Gyros Compression) mode on: Processing of degraded geolocation, degraded scenes analysis. 6. Search mode on: Processing of degraded geolocation, degraded scenes analysis. 7. Coast mode on: Processing of degraded geolocation, degraded scenes analysis. 8. Yaw axis test in progress: Processing of degraded geolocation, degraded scenes analysis. 9. Roll axis test in progress: Processing of degraded geolocation, degraded scenes analysis. 10. Pitch axis test in progress: Processing of degraded geolocation, degraded scenes analysis.	

5 SUPPORTING SCIENCE

5.1 Introduction

This chapter describes the scientific and mathematical algorithms that support the requirements. Depending on the results of current and future prototyping activities, parts of this description may undergo alterations.

Note: the instrument data do not contain explicit scan line numbers and pixel numbers. Nevertheless, for convenience of referencing, line and pixel numbers are used in the specifications of this chapter. They are defined by following convention.

Line numbers of a satellite data dump are an uninterrupted sequence of increasing integers, which are dependent on the scanning time of the lines. Which number is assigned to the first complete line of a dump is arbitrary; 1 might be convenient. Missing scan lines are identified by inappropriate jumps in the scanning times of existing lines.

The pixels of a scan line are numbered in the sequence of their scanning times starting with 1 for the first pixel of a line. A consequence of this definition is that HIRS pixels are counted from left to right and AVHRR pixels from right to left when looking in satellite track direction.

5.2 Supporting Science to Level 0 Processing

For the time being, there are no additional scientific and mathematical algorithms that support the requirements of the Level 0 processing, other than already specified in section 4.

5.3 Supporting Science to Level 1a Processing

5.3.1 Introduction to the Level 1a processing

In the following subsection the scientific and mathematical algorithms that support the requirements of the Level 1a processing are described in a similar order than the requirements in section 4.

5.3.2 Create Calibration Information

5.3.2.1 Create Infrared Channels Calibration Information

5.3.2.1.1 Compute Mean Space and Internal Target Counts

The calibration cycle start is determined through checking the thermistor counts sum. This sum is lower than a threshold value (the default 20, but this should be user-configurable) in case the reference value of the calibration cycle is addressed. The value is taken from the AVHRR_L1_PGS_COF_CAL data set. In a cycle of five scan lines, there are PRT counts for thermistors i, $i = 1,..,4$, followed by the reference value discussed above. The numerical mean count Xi of the internal target is obtained during the calibration sequences for the PRT number i. This is the mean value computed over, as default, 11 scan lines for each PRT sampling. Consequently, by default, 55 scan lines are required to allow for the averaging over 11 scan lines for each PRT and hence, to perform a complete calibration cycle. This should be user-configurable.

5.3.2.1.2 Compute PRT Temperatures

Information concerning the blackbody target temperature is obtained from four PRT (Platinum Resistance Thermometer) output values. See Equation 1:

$$T_i = c_0 + c_1\overline{X}_i + c_2\overline{X}_i^2 + c_3\overline{X}_i^3 + c_4\overline{X}_i^4 + c_5\overline{X}_i^5$$

Equation 1

The coefficients *ck* , *k* = 0,1,2,3,4,5 are characterised before launch and taken from AVHRR_L1_PGS_COF_CAL. There are 6 coefficients per PRT. $\overline{x}_i$ is the mean numerical count obtained during the calibration sequences for the PRT number *i* [mean value computed over 11 scan lines (33 samples for each PRT *i*)].

5.3.2.1.3 Compute Internal Warm Target Temperature and Radiances

A weighted average value of the 4 PRT's mean output data is computed (Equation 2) and is assumed to be representative for the temperature of the blackbody target. The dimensionless coefficients b_i are characterised before launch and checked in-flight ($b_i = 0.25$ if the respective PRT is good, else $b_i = 0$). Equation 2 does not need necessarily normalised coefficients.

$$\overline{T} = \frac{\sum_{i=1}^{4} b_i \cdot T_i}{\sum_{i=1}^{4} b_i} + \Delta T$$

Equation 2

The coefficients b_i may change during the instrument lifetime if, for example, a PRT appears to work not correctly. ΔT is a correction term (set to 0 in the beginning). The coefficients are characterised in AVHRR_L1_PGS_COF_CAL data set.

The next step consists of converting this mean temperature into a radiance R_{ict} of the internal calibration target:

$$R_{ict}(\bar{T}) = \frac{\int_{\gamma 1}^{\gamma 2} B(\gamma, \bar{T})\phi(\gamma)d\gamma}{\int_{\gamma 1}^{\gamma 2} \phi(\gamma)d\gamma}$$

Equation 3

where γ is the wave number (in cm^{-1})

γ_1 and γ_2	are the lower and upper spectral limits of the channel,
ϕ	is the AVHRR/3 spectral response function of the channel,
$B(\gamma, \bar{T})$	is the Planck function defined by:

$$B(\gamma, \bar{T}) = \frac{C_1 \cdot \gamma^3}{e^{\frac{c_2 \cdot \gamma}{\bar{T}}} - 1}$$

Equation 4

The internationally agreed values for the constants C_1 and C_2 are equal to 1.191062 10^{-5} $mW/(m^2.sr.cm^{-4})$ and 1.4387863 K/cm^{-1} respectively. See [AD6]. Numerically, Equation 3 can be solved by

$$R_{ict}(\bar{T}) = \frac{\sum_{i=1}^{n} B(\gamma_i, \bar{T})\phi(\gamma_i)\Delta\gamma_i}{\sum_{i=1}^{n} \phi(\gamma_i)\Delta\gamma_i}$$

Equation 5

In Equation 5, γ_i denote the wave numbers within a particular channel and the spacing interval is $\Delta\gamma_i$. The number n of intervals must be chosen sufficiently high to avoid any significant lack of information with regard to the channel response function. Thus, $R_{ict}(\bar{T})$ is the radiance emitted by the calibration target within the considered wave number interval convolved with the spectral transmittance of the AVHRR/3 channel. Accordingly, the numerical counts X_{ict} measured by AVHRR/3 during its view on the internal target are assigned to $R_{ict}(\bar{T})$ for the calibration.

In practice, however, Equation 5 is not used for AVHRR/3. Instead, to account for the window response function, a linear correction of $\bar{T}$ is performed according to the following:

$$T^* = \frac{\bar{T} - A_{lin}}{B_{lin}}$$

Equation 6

The coefficients A_{lin} and B_{lin} are different for each channel and listed in AVHRR_L1_PGS_COF_CAL. They are also stored in the level 1a data product, or by inverting Planck's function according to the following:

$$R_{ict}(\bar{T}) = \frac{C_1 \cdot \gamma_c^{\,3}}{\left(e^{\frac{c_2 \cdot \gamma_c}{T^*}} - 1\right)}$$

Equation 7

The values of the central wavelength γ_c for each channel are stored in AVHRR_L1_PGS_COF_CAL and are appended to the level 1a product.

5.3.2.1.4 Compute Gain and Intercept

For each infrared channel (3b, 4 and 5) the linear radiance is computed. Gain G_{IR} and Intercept I_{IR} are calculated from the internal target radiances $R_{ict}[R_{ict} = R_{ict}(\overline{T})]$, the radiance of space including nonlinearity correction R_{SP} with predetermined (negative) values for each infrared channel (and taken from AVHRR_L1_PGS_COF_CAL data set) and the respective measured counts X_{ict} and X_{sp} according to this equation:

$$G_{IR} = (R_{ict} - R_{sp})/(X_{ict} - X_{sp})$$

Equation 8

and

$$I_{IR} = R_{sp} - G_{IR} \cdot X_{sp}$$

Equation 9

Consequently, the linear radiance R_{lin} is given by the equation:

$$R_{lin} = G_{IR} \cdot X_s + I_{IR}$$

Equation 10

In Equation 10, X_s is the Earth-view count measured by the instrument.

5.3.2.1.5 Compute Calibration coefficients

The non-linear calibration function is as follows:

$$R_s = A \cdot R_{lin} + B \cdot R^2{}_{lin} + C$$

Equation 11

where *A,B,* and *C* are known for each AVHRR channel, and are determined pre-launch (and taken from AVHRR_L1_PGS_COF_CAL). If the conversion from counts to radiances is expressed through this:

$$R_s = a_0 + a_1 \cdot X_s + a_2 \cdot X_s^2$$

Equation 12

the calibration coefficients a_0, a_1 and a_2 can be computed from *A, B, C,* G_{IR} , R_{SP} , and the cold space measurements X_{SP} at each scan line:

$$a_0 = C + A \cdot R_{sp} - A \cdot G_{IR} \cdot X_{sp} + B \cdot (R_{sp} - G_{IR} \cdot X_{sp})^2$$ ***Equation 13***

$$a_1 = A \cdot G_{IR} - 2 \cdot (B \cdot G_{IR}^2) \cdot X_{sp} + 2 \cdot B \cdot G_{IR} \cdot R_{sp}$$ ***Equation 14***

$$a_2 = B \cdot G_{IR}^2$$ ***Equation 15***

For the channel 3b, a linear relationship between R_s and X_s is assumed. Hence, the coefficients a_0, a_1 and a_2 are computed via Equation 13 to Equation 15 with $A = 1$ and $B = C = 0$, which gives the expression of Equation 10. The calibration coefficients a_0, a_1 and a_2 for the channels 3b, 4, and 5 are stored in appended data section of the level 1a product.

5.3.2.2 NEΔT FOR CHANNELS 3B, 4, AND 5

Using a block of five subsequent scan lines, the algorithm calculates a value for every scan line. The variability of the *NEΔT* is driven by the standard deviation of the 10 internal warm target views of this scan line ***n***. For calculating the slope and the PRT temperature, however, information from the five scan lines ***n-2*** to ***n+2*** is used.

The PRT counts for the four AVHRR PRT sensors, which are needed to calculate the internal warm target temperature (sometimes referred to as blackbody [BB] temperature), are distributed over a set of five scan lines, with three measurements from one individual PRT for each scan line. In such a cycle of five scan lines, there are PRT counts for thermistors *i*, i = 1,...,4, followed by the reference value '0 0 0' (see Figure 1). The numerical mean count X_i of the internal target is obtained during the calibration sequences for the PRT number *i* and the PRT temperature of the calibration target is obtained by averaging over the four PRT temperatures retrieved from the PRT counts using Equation 1. Thus, a BB temperature T_{BB}^n for a distinct scan line ***n*** ***t***akes all four PRT values into account when using the information from scan lines in the range [n-2, n+2].

Taking the same five scan lines, an average is calculated over all 50 warm target views (10 for each scan line) and all 50 space views (10 for each scan line) for the scan lines in the range [n - 2, n + 2]. These values are denoted as $\overline{X_{ict}^n}$ for the warm target views and $\overline{X_{sp}^n}$ for the cold space views, respectively.

Replacing $\overline{T}$ in Equation 6 by T_{BB}^n, the in-band radiance $B_Y(T_{BB}^n)$ for this PRT temperature is calculated using Equation 7. According to Equation 8 , the gain *Gn,* which has the same value for scan lines ***n-2*** to ***n+2***, is retrieved via the equation:

$$G_n = \frac{B_\Upsilon(T^n_{BB}) - B_\Upsilon(T_{SPACE})}{\overline{X^n_{ict}} - \overline{X^n_{sv}}}$$

Equation 16

where:

$B_\gamma(T^n_{BB})$	is the internal calibration target radiance at wave-number γ.
$B_\gamma T_{SPACE}$	is the space radiance TSPACE~3K which is assumed to have zero radiance.
x^n_{ict}	is the average of the 50 internal warm target counts of five subsequent scan lines.
$\overline{x^n_{sv}}$	is the average of the 50 space view counts of five subsequent scan lines.

For the *NEΔN* (Noise Equivalent Radiance) calculation, this quantity has to be multiplied with the standard deviation SD_n of the 10 warm target view counts of the actual scan line ***n*** (not an average of five scan lines). This standard deviation over the 10 individual samples (***N=10***) of one scan line is given by the following:

$$SD_n = \sqrt{\frac{1}{N}\sum_{ict,\,i}^{N}(x^n_{ict,\,i} + \langle x^n_{ict}\rangle)^2}$$

Equation 17

with:

$$\langle x^n_{ict}\rangle = \frac{1}{N}\sum_{i=1}^{N} x^n_{ict,\,i}$$

Equation 18

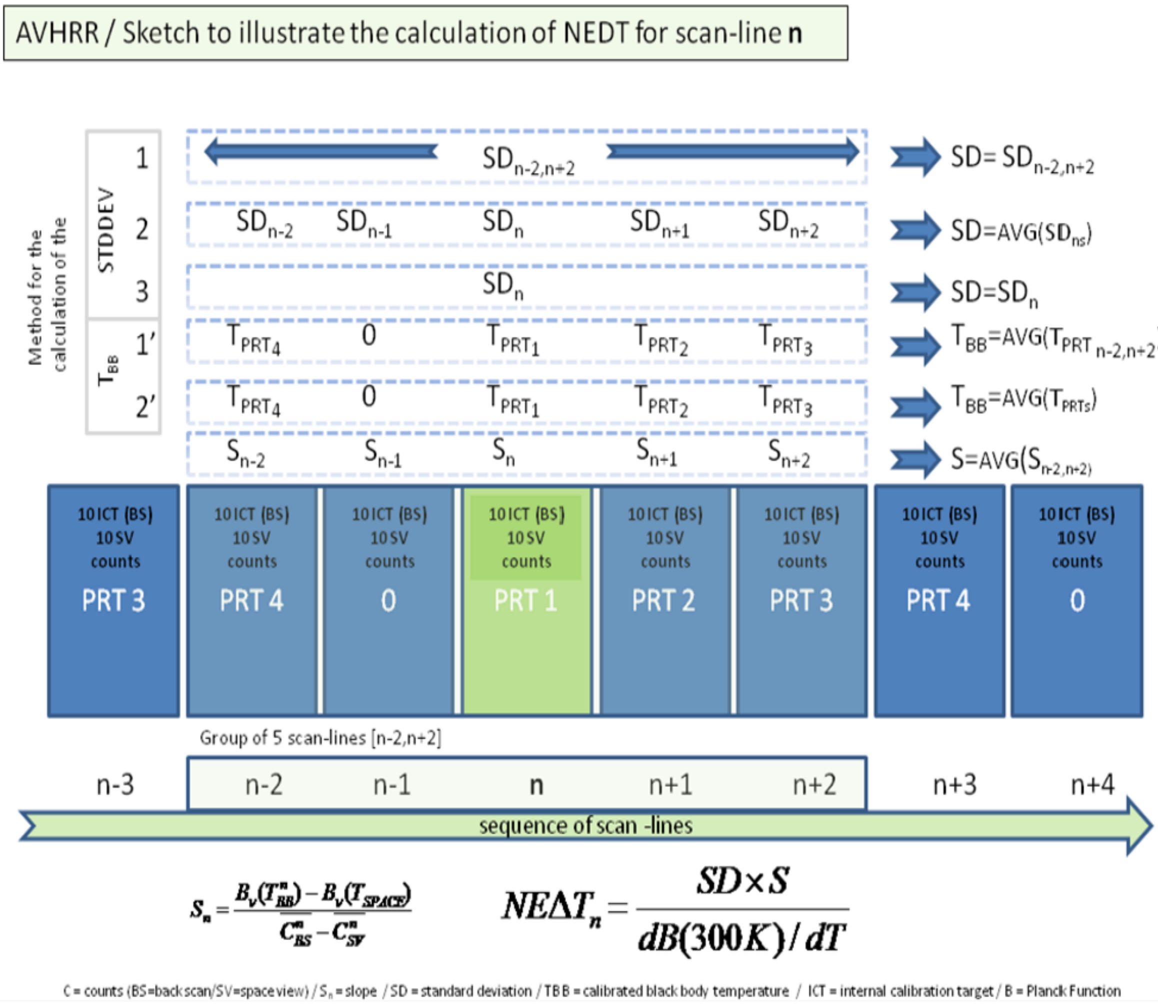
The product of SDn and Gn constitutes the Noise Equivalent Radiances $NE\Delta N_n$ for scan line n. For the $NE\Delta T_n$ calculation at 300 K, the value of $NE\Delta N_n$ is divided by the deriative of the Planck function with respect to the temperature (evaluated at 300 K):

$$NE\Delta T_n = \frac{G_n \times SD}{\partial B_\Upsilon(300K)/\partial T}$$ ***Equation 19***

with

$\frac{\partial B_\Upsilon(300K)}{\partial T}$	Derivative of the Planck function in mW/(m^2 sr cm^{-1} K).

For AVHRR/3 onboard Metop-A, the values are 0.0251293, 1.68813, and 1.74992 for channels 3B, 4, and 5 respectively. The following figure summarises the procedure described above. For the standard deviation calculation, Option 3 is the one to be implemented into the operational processing chain.



$$S_n = \frac{B_\nu(T_{BB}^n) - B_\nu(T_{SPACE})}{C_{BS}^n - C_{SV}^n} \qquad NE\Delta T_n = \frac{SD \times S}{dB(300K)/dT}$$

Figure 15: AVHRR Scan line PRT Assignment

5.3.2.3 Create Visible Channels Calibration Information

The calibration coefficients for the visible channels (channels 1 and 2) and channel 3a are determined before launch. There is no calibrated source of visible radiation within the AVHRR/3 instrument. Updates of the calibration coefficients will be done during the lifetime of the instrument through the on ground calibration function and/or vicarious calibration campaigns.

The gain and intercept values are selected according to the count values. For AVHRR/3 a dual slope/gain function is used for the visible (channels 1 and 2) and near infrared (channel 3a) channels to enhance the radiometric resolution at low radiance or reflectance values. The dual gain settings are summarised in Table 5.1 and illustrated in Figure 5.1. It should be noted that the specifications of the split gain ranges are not fixed but may alter from instrument to instrument and during the life time of the instrument.

Channel Number	*Range*	
	Reflectance factor / percentage	*Counts X_s*
1 and 2	0–25	0–500
	0–26-100	501–1023
3a	0–12.5	0–500
	12.6–100	501–1023

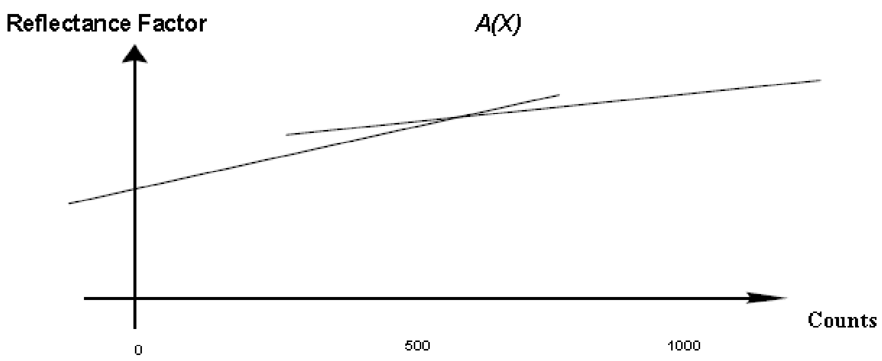
Table 4: Split gain ranges for channels 1, 2 and 3a of AVHRR/3

The target reflectance factor is related to the instrument counts X_S by the relation:

$$A(X_s) = G(X_s) \cdot X_s + I(X_s)$$

Equation 20

The slope $G(X_s)$ and the intercept $I(X_s)$ depend on the count (there is a split slope/intercept over two ranges of the counts). This takes into account the estimated non-linearity in the computation of the reflectance from the counts. As explained above, the values of $G(X_s)$ and of $I(X_s)$ are characterised before launch. $G(X_s)$ is expressed in units of percent reflectance per count unit and $I(X_s)$ is expressed in percent reflectance. These values are selected according to the count value X_s.



5.3.2.4 Geolocation of Pixels from Scanning Radiometers

The following description of the Earth location of pixels from scanning radiometers is contained in [RD2], but with symbols and reference frames given in [AD48]. From the CGS, the following information should be provided:

- The position and the velocity of the satellite in an initially-fixed coordinate system such as the Mean-of-Date coordinate frame. Eventually, this information should be corrected by the clock drift. These vectors are defined as follows:

$$\overrightarrow{r_{qm}}(t) = (x_{sat}, y_{sat}, z_{sat})$$

Equation 21

$$\overrightarrow{v_{qm}}(t) = (\dot{x}_{sat}, \dot{y}_{sat}, \dot{z}_{sat})$$

Equation 22

In Equation 22, the dot over the letter (*x*, *y*, and *z*)denotes the derivation of the respective parameter with a standard time *t* such as UTC.

- The nutation term resulting from the rotation of the Earth. This term is mainly governed by the Greenwich sidereal angle *G(t)*.
- The misalignment of the instrument. Both constant and time varying errors should be part of the AOCS (Attitude and Orbit Control System).
- The timing and angular displacements of the instrument in the scanning cycle.

The position of the scan spot in the Mean-of-date coordinate system is defined as follows:

$$\overrightarrow{L_{qm}} = (x_{qm}, y_{qm}, z_{qm})$$

Equation 23

With *R* - the distance between the instrument and the position of the considered scan spot, by rules of vector addition, the following expression is obtained:

$$\overrightarrow{L_{qm}} = \overrightarrow{r_{qm}}(t) + R \cdot \overrightarrow{d_{qm}}$$

Equation 24

where:

$$\overrightarrow{d_{qm}} = (d_x, d_y, d_z)$$

Equation 25

consists of the direction cosines of the scan line in the Mean-of-Date coordinate system. The objective of the following calculations is to retrieve $\overline{L_{qm}}$. For this purpose, the direction vector should first be expressed in a coordinate frame such as the Instrument or Antenna Mounting Reference Frame (X_{AMP}, Y_{AMP}, Z_{AMP}) defined in [AD48]. Nominally, this coordinate system is parallel to the satellite reference frame (X_S, Y_S, Z_S). The transformation from (X_{AMP}, Y_{AMP}, Z_{AMP}) to the Mean-of-Date coordinate system is as follows:

$$Z_{AMP} = \left(\frac{x_{sat}}{\sqrt{x^2_{sat} + y^2_{sat} + z^2_{sat}}}, \frac{y_{sat}}{\sqrt{x^2_{sat} + y^2_{sat} + z^2_{sat}}}, \frac{z_{sat}}{\sqrt{x^2_{sat} + y^2_{sat} + z^2_{sat}}} \right)$$
$$= (-x_p, -y_p, -z_p)$$

Equation 26

$$Y_{AMP} = \left(\frac{-\dot{x}_{sat}}{\sqrt{\dot{x}^2_{sat} + \dot{y}^2_{sat} + \dot{z}^2_{sat}}}, \frac{-\dot{y}_{sat}}{\sqrt{\dot{x}^2_{sat} + \dot{y}^2_{sat} + \dot{z}^2_{sat}}}, \frac{-\dot{z}_{sat}}{\sqrt{\dot{x}^2_{sat} + \dot{y}^2_{sat} + \dot{z}^2_{sat}}} \right)$$
$$= (-v_x, -v_y, -v_z)$$

Equation 27

$$X_{AMP} = \frac{Y_{AMP} \times Z_{AMP}}{|Y_{AMP} \times Z_{AMP}|} = (x_q, y_q, z_q)$$

Equation 28

In addition, the spin vector $\hat{s}$ can be written as follows:

$$\begin{aligned}\hat{s} &= -Z_{AMP} \times X_{AMP} = -Z_{AMP} \times (Y_{AMP} \times Z_{AMP}) \\ &= (y_p z_q - z_p y_q, z_p x_q - x_p z_q, x_p y_q - y_p x_q) \\ &= (x_{spin}, y_{spin}, z_{spin})\end{aligned}$$

Equation 29

With the definitions:

$$\begin{aligned}\hat{p} &= -Z_{AMP} \\ \hat{v} &= -Y_{AMP} \\ \hat{q} &= X_{AMP}\end{aligned}$$

Equation 30

the operator for any transformation of a vector from the local coordinate system ($\hat{p}, \hat{q}, \hat{s}$) and hence from the ($X_{AMP}$, Y_{AMP}, Z_{AMP}) coordinate system to the Mean-of-Date coordinate system is as follows:

$$\begin{bmatrix} x_p & x_q & x_{spin} \\ y_p & y_q & y_{spin} \\ z_p & z_q & z_{spin} \end{bmatrix}$$

Equation 31

Accordingly, since the unit vector in scan direction in the ($\hat{p}, \hat{q}, \hat{s}$) coordinate system is written as follows:

$$\hat{d} = \begin{bmatrix} \cos\sigma & \sin\sigma & 0 \\ -\sin\sigma & \cos\sigma & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Equation 32

The corresponding vector in the $\overline{d_{qm}}$ in the Mean-of-Date coordinate system is as follows:

$$\overrightarrow{d_{qm}} = \begin{bmatrix} x_p & x_q & x_{spin} \\ y_p & y_q & y_{spin} \\ z_p & z_q & z_{spin} \end{bmatrix} \begin{bmatrix} \cos\sigma & \sin\sigma & 0 \\ -\sin\sigma & \cos\sigma & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

Equation 33

The scanning angle of the instrument is denoted with σ.

For the determination of *R* it is clear that the solution vector $\overline{L_{qm}}$ lies on the surface of the Earth ellipsoid. Thus, it satisfies the equation:

$$\frac{x_{qm}^2}{a_E^2} + \frac{y_{qm}^2}{a_E^2} + \frac{z_{qm}^2}{b_E^2} = 1$$

Equation 34

Here, a_E and b_E denote the semi-major axis (6378137 m) and the semi-minor axis (6356752.3142 m), respectively, of the Earth's ellipsoid. An equivalent expression is this:

$$\frac{(x_{sat}+Rd_x)^2}{a_E^2} + \frac{(y_{sat}+Rd_y)^2}{a_E^2} + \frac{(z_{sat}+Rd_z)^2}{b_E^2} = 1$$

Equation 35

Since the equation is quadratic, there exist two solutions for the distance *R*:

$$R_{1/2} = \frac{-B_R \pm \sqrt{B_R^2 - 4A_R C_R}}{2A_R}$$

Equation 36

with the coefficients:

$$A_R = \frac{d_x^2}{a_E^2} + \frac{d_y^2}{a_E^2} + \frac{d_z^2}{b_E^2}$$
$$B_R = 2\left(\frac{x_{sat}d_x}{a_E^2} + \frac{y_{sat}d_y}{a_E^2} + \frac{z_{sat}d_z}{b_E^2}\right)$$
$$C_R = \frac{x_{sat}^2}{a_E^2} + \frac{y_{sat}^2}{a_E^2} + \frac{z_{sat}^2}{b_E^2} - 1$$

Equation 37

For the solutions of R, the following rules apply:

- No real solution for R exists, when the scan ray does not hit the Earth.
- One real solution for R exists, when the scan ray is tangential to the Earth's ellipsoid.
- Two real solutions for R exist, when the scan ray intersects the Earth's surface. The point of intersect that is closer to the satellite is visible for the radiometer and thus, the desired solution.

Accordingly, the solution for the scan vector $\overline{L_{qm}}$ in the Mean-of-Date coordinate system is this:

$$\begin{bmatrix} x_{qm} \\ y_{qm} \\ z_{qm} \end{bmatrix} = \begin{bmatrix} x_{sat} \\ y_{sat} \\ z_{sat} \end{bmatrix} + R \begin{bmatrix} d_x \\ d_y \\ d_z \end{bmatrix} = \begin{bmatrix} x_{sat} + Rd_x \\ y_{sat} + Rd_y \\ z_{sat} + Rd_z \end{bmatrix}$$

Equation 38

For the transformation of $\overline{L_{qm}}$ into the Earth fixed coordinate system (ITRF) is described in [AD48 EPS Mission Conventions Document] However, for practical purposes, the change of the obliquity of the ecliptic and the nutation are neglected. Consequently, the transformation of $\overline{L_{qm}}$ into $\overline{L_E}$ is a simple rotation around the z-axis by the amount of the Greenwich Hour Angle $G(t)$ (in radians):

$$G(t) = G_0 + 0.01720279 \cdot t_1 + 6.3003881 \cdot t_2$$

Equation 39

with the following variables:

with the following variables:

G_0	East longitude of Greenwich at the beginning of the year
t_1	Day of year
t_2	Fraction of the day

With that rotation angle, the transformation into the Earth fixed coordinate system for the components of $\overline{L_{qm}}$ is as follows:

$$\begin{bmatrix} x_E \\ y_E \\ z_E \end{bmatrix} = \begin{bmatrix} \cos[G(t)] & \sin[G(t)] & 0 \\ -\sin[G(t)] & \cos[G(t)] & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{qm} \\ y_{qm} \\ z_{qm} \end{bmatrix}$$

Equation 40

The geodetic longitude λ_{geo} is computed according to this equation:

$$\lambda_{geo} = \operatorname{atan}\left[\frac{y_E}{x_E}\right]$$

Equation 41

and the geodetic latitude φ_{geo} is this:

$$\varphi_{geo} = \operatorname{atan}\left[\frac{z_E \cdot a_E^2}{b_E^2 \cdot \sqrt{x_E^2 + y_E^2}}\right]$$

Equation 42

5.3.2.5 Satellite Zenith and Azimuth

Once the geodetic longitude λ_{geo} and geodetic latitude φ_{geo} on the Earth's Reference Ellipsoid is known, the satellite position vector $\overline{r_{qm}}$ is also transformed into the Earth-fixed coordinate system using the Greenwich Hour Angle. The resulting vector is $\overline{r_{sat(E)}}$ with its components $x_{sat(E)}$, $y_{sat(E)}$, and $z_{sat(E)}$. The satellite zenith and azimuth are calculated in a reference frame that has its origin at the considered geographical location with the x-axis pointing southward, the y-axis positive to the east, and the z-axis directed to the local zenith. If the satellite's position in this station local reference frame has the components $x_{sat(St)}$, $y_{sat(St)}$, and $z_{sat(St)}$, the solution for the transformation is this:

$$\begin{bmatrix} x_{sat(St)} \\ y_{sat(St)} \\ z_{sat(St)} \end{bmatrix} = \begin{bmatrix} \sin\varphi_{geo}\cdot\cos\lambda_{geo} & \sin\varphi_{geo}\cdot\sin\lambda_{geo} & -\cos\varphi_{geo} \\ -\sin\lambda_{geo} & \cos\lambda_{geo} & 0 \\ \cos\varphi_{geo}\cdot\cos\lambda_{geo} & \cos\varphi_{geo}\cdot\sin\lambda_{geo} & \sin\varphi_{geo} \end{bmatrix} \begin{bmatrix} x_{sat(E)} - x_E \\ y_{sat(E)} - y_E \\ z_{sat(E)} - z_E \end{bmatrix}$$

Equation 43

Finally, the satellite zenith angle Θ_{sa} can be computed:

$$\theta_{sa} = \mathrm{acos}\left[\frac{z_{sat(St)}}{\sqrt{x^2_{sat(St)} + y^2_{sat(St)} + z^2_{sat(St)}}}\right]$$

Equation 44

For the satellite azimuth angle φ_{sa}, the following formula is valid:

$$\left(\varphi_{sa} = \pi - \mathrm{atan}\left[\frac{y_{sat(St)}}{x_{sat(St)}}\right]\right), \varphi_{sa} \le \pi$$

$$\left(\varphi_{sa} = -\mathrm{atan}\left[\frac{y_{sat(St)}}{x_{sat(St)}}\right] - \pi\right), \varphi_{sa} > \pi$$

Equation 45

5.3.2.6 Solar Zenith and Azimuth Angle

To compute the solar zenith and azimuth angle for a given tie point, the following input information is necessary:

- Year *yy*, day *dd*, and time *tt* of day in ms
- Geodetic latitude φ_{geo}
- Geodetic longitude λ_{geo}

The computation consists of three steps: to solve the equation of time *e*, to calculate the solar declination δ_{so} and to determine solar azimuth angle φ_{so} and zenith angle Θ_{so}.

For a given day *dd* in a distinct year *yy*, the number of days since 0 January 1900 (the century day *ddcen*) is determined according to the following integer equation:

$$dd_{cen} = (yy - 1900)\cdot 365 + dd + (yy - 1901)/4$$

Equation 46

Normalization of the fraction of days *Rc* elapsed in one century gives:

$$R_c = dd_{cen} / 36525$$ ***Equation 47***

Accordingly, the mean longitude *L* of the sun can be calculated:

$$L = [(R_c \cdot 36000.769) + 279.697] \cdot \pi / 180$$ ***Equation 48***

The solution for the equation of time in seconds is as follows:

$$\begin{aligned} e = & -([93. + (14.23 \cdot R_c) - (0.0144 \cdot R_c^{\,2})] \cdot \sin(L)) - \\ & ([432.5 - (3.71 \cdot R_c) - (0.2063 \cdot R_c^{\,2})] \cdot \cos(L)) + \\ & ([596.9 - (0.81 \cdot R_c) - (0.0096 \cdot R_c^{\,2})] \cdot \sin(2L)) - \\ & ([1.4 + (0.28 \cdot R_c)] \cdot \cos(2L)) + \\ & ([3.8 + (0.6 \cdot R_c)] \cdot \sin(3L)) + \\ & ([19.5 - (0.21 \cdot R_c) - (0.0103 \cdot R_c^{\,2})] \cdot \cos(3L)) - \\ & ([12.8 - (0.03 \cdot R_c)] \cdot \sin(4L)) \end{aligned}$$ ***Equation 49***

The second step is the calculation of the solar declination according to the following:

$$\delta_{so} = \operatorname{atan}\left\{[0.43382 - (0.00027 \cdot R_c)] \cdot \sin\left[L - \frac{e \cdot \pi}{43200}\right]\right\}$$ ***Equation 50***

For the computation of the solar angles, the Local hour angle is given by the expression:

$$\Lambda = \left\{\left[\lambda_{geo} + \frac{e}{240} + \frac{tt}{240000}\right] \cdot \frac{\pi}{180}\right\} + \pi$$ ***Equation 51***

The solar zenith angle Θ_{so} can be readily calculated without further information:

$$\theta_{so} = \frac{\pi}{2} - \mathrm{asin}\{\sin(\delta_{so}) \cdot \sin(\varphi_{geo}) + \cos(\delta_{so}) \cdot \cos(\varphi_{geo}) \cdot \cos(\Lambda)\}$$

Equation 52

The solar azimuth angle calculation is given by the following formula:

$$\varphi_{so} = \mathrm{acos}\left\{\frac{\sin(\delta_{so}) - [\sin(\pi/2 - \theta_{so}) \cdot \sin(\varphi_{geo})]}{\cos(\varphi_{geo}) \cdot \cos(\pi/2 - \theta_{so})}\right\}$$

Equation 53

5.3.2.7 Size Reduction of Navigation Information

The computations for the geolocation and the satellite and solar angles described in the previous sections are performed for the following pixel numbers of each scan line:

- For full resolution data: Pixel 25– 2025, each 40^{th} pixel. This range should be user-configurable.
- For GAC resolution data: Pixel 5–405, each 8^{th} pixel. This range should be user-configurable.

In both cases, the number of tie points is 51 for one scan line.

5.4 Supporting Science to Level 1b Processing

5.4.1 Infrared Radiances and Brightness Temperatures

The calibration coefficients are applied to the Earth view counts and thus the engineering information is converted into physical parameters.

5.4.1.1 Compute Radiances

Radiances are computed according to the calibration equation from the calibration parameters (see Equation 10) a_i , $i = 0,1,2$ and the measured earth view counts X_s:

$$R_s = a_0 + a_1 \cdot X_s + a_2 \cdot X_s^2$$

Equation 54

5.4.1.2 Compute Brightness Temperatures

Using the Planck function and the spectral response functions, the radiances are transformed into Brightness Temperatures. This transformation may be performed by using a LUT derived from Equation 5 or by inverting Planck’s function according to the following:

$$T^* = \frac{C_2 \cdot \gamma_c}{\log\left(1 + \frac{C_1 \cdot \gamma_c^3}{R_S}\right)}$$

Equation 55

The values of the central wavelength γ_c for each channel are stored in AVHRR_L1_PGS_COF_CAL. To obtain the brightness temperature T, the effective temperature T^* is linearly corrected:

$$T = A_{lin} + B_{lin} \cdot T^*$$

Equation 56

The coefficients A_{lin} and B_{lin} are different for each channel and listed in AVHRR_L1_PGS_COF_CAL. They are also stored in the level 1a data product.

5.4.2 Visible/Near-Infrared Radiances and Reflectance Factors

The Gain and Intercept are selected according to the count value and the considered channels. Their application to the Earth view counts converts the engineering information into physical parameters. These are reflectance factors and radiances.

5.4.2.1 Compute Reflectance Factor

The target reflectance factor $A(X_s)$ is related to the instrument counts by the relation:

$$A(X_s) = G(X_s) \cdot X_S + I(X_s)$$

Equation 57

The slope and the intercept depend on the count (there is a split slope/intercept over two ranges of the counts). This takes into account the estimated non-linearity in the computation of the albedo from the counts.

As explained above, the values of the slope $G(X_s)$ and of the intercept $I(X_s)$ are characterised before launch. $G(X_s)$ is expressed in units of reflectance factor in percent per count unit. $I(X_s)$ and $A(X_s)$ are expressed in reflectance factor in percent.

5.4.2.2 Compute Radiances

The conversion between the scene reflectance factor and the scene radiance is done using this:

$$R_{VIS} = \frac{F}{\pi} \cdot \frac{A(X_s)}{100}$$

Equation 58

where:

R_{VIS}	is the estimated scene radiance (W/(m^2.sr)),
$A(X_s)$	is the target reflectance factor defined above
F	is the integrated solar spectral irradiance weighted by the spectral response function of the channel (W/m^2), values of F are stored in AVHRR_L1_PGS_COF_CAL,

Note: To improve the performance of the algorithm, an off-line calculated look-up table may be used to compute the value of F as a function of the wavelength and as a function of the date. The values are not corrected for the solar zenith angle.

5.4.3 Geolocation Processing for Each Pixel

The geolocation information derived directly from orbital parameters is given for 51 tie points (but should be user-configurable) at each scan line. The geolocation information for interior points is computed using either linear interpolation between two tie points of a scan line or Langrangian interpolation between the three nearest tie points in one scan line. The two or three surrounding tie points have a known spacing which increases with scan angle across track.

The elements of geolocation information are:

- Geodetic pixel latitude,
- Geodetic pixel longitude,
- Pixel number
- Time of the beginning of the scan line

Obviously, any data set size reduction is a source for errors. The following sources of geometry error are identified in the geo-location processing:

- Timing error;
- Orbit propagator accuracy;
- Attitude model error;
- Projection model error;
- Error due to circle approximation;
- AVHRR/3 pointing knowledge error.

The error in the geo-location due to the interpolation between tie points increases with an increase in the tie point interval. The tie point interval will be chosen such that the error in the geo-location due to the interpolation is smaller than the error due to the uncertainty in the parameters listed above.

The worst case error made when interpolating the location (longitude, latitude) of a pixel, from those of the two neighbouring tie points, is analysed. That worst-case error corresponds to the pixels closest to the pole of the orbit, West End of the swath, halfway between two tie points. Assuming that one will use linear interpolation, the interpolation error depends on the difference between the curved surface and the lane on which is interpolated.

Two values of distances between tie points are listed: 20 pixels and 40 pixels. The evaluation criteria is the distance, in km on Earth, between the exact location of the pixel half way between tie points, and its interpolated location. That distance is shown next to the group of pixels where it has been evaluated.

Worst case = North pole pixel size at the edge of the swath = 4.4 km
Tie point every 20 pixels : error max = 1.096 km (at West edge – latitude = 87 °) error = 0.058 km (at East edge – latitude = 68 °)
Tie point every 40 pixels : error max = 4.03 km (at West edge - latitude=86 °) error = 0.200 km (at East edge - latitude=69 °)

Table 5: Worst-case Error

5.4.3.1 Landmark Processing

The scientific background for the Landmark Navigation processing is described in detail in [RD1].

The objective of the landmark processing is to improve the accuracy of the AVHRR/3 pixel geolocation that is provided by an ephemeris model and a scanning model. The automatic adjustment procedure of landmark processing is based on the correlation of small windows of an AVHRR image (actual windows) and small windows of selected coastal landmarks (reference windows). From the configurable databases data, for the landmark processing, AVHRR_L1_PGS_DAT_LANMARK and AVHRR_L1_PGS_DAT_LAMASK are required. In principle, the landmark processing consists of four steps: the identification of the landmark center, the creation of binary images from the actual scene (actual binary windows), the generation of the reference binary images from the selected coastline data (reference binary windows), and the determination of the geographical distortions for the distinct landmarks. In the following, the latter three steps are described in more detail.

5.4.3.1.1 Actual windows

Once the location of a landmark center is identified within an actual AVHRR/3 scene, all pixels surrounding the center pixel (the pixel that is closest to the geographical location of a distinct landmark center given in AVHRR_L1_PGS_DAT_LANMARK) within a distance of ± 20 pixels along and across the flight direction of the orbiter are collected. For this rectangular area with an extension of 41 × 41 pixels, the following physical criteria are used to create the actual windows:

- The normalized difference vegetation index *NDVI* [*NDVI = (A2-A1)/(A2+A1)*]
- The channel 2 target reflectance *A2*
- The brightness temperature difference $\Delta T = T4 - T5$
- The brightness temperature *T4*

It should be noted that *A2* and *T4* may be useful for the case of processing degraded data where not all channels are available. For each of these physical criteria, an actual binary window (land = 1, water = 0) is generated by use of a threshold technique. This threshold technique for the discrimination between land and water is different for the visible and the infrared physical parameters: for the physical parameters derived from VIS channels' measurements, fixed thresholds can be used that do not depend on geographical or seasonal variations. The determination of these thresholds will be part of the commissioning phase. Since the calibration coefficients for the visible channels are determined through pre-launch calibration, the thresholds should be constant during the lifetime of the instrument unless a vicarious calibration is performed during the Metop mission. From current prototyping activities, the following thresholds are expected to provide useful results with regard to the creation of the actual binary windows:

$$NDVI \geq -0.1 \rightarrow land$$ **Equation 59**

$$NDVI < -0.1 \rightarrow water$$ **Equation 60**

and

$$A2 > 6 \rightarrow land$$ **Equation 61**

$$A2 \leq 6 \rightarrow water$$ **Equation 62**

The thresholds for actual windows in the infrared (*T4* and ΔT) cannot be uniquely determined for a larger area. The threshold test for ΔT relies on the water vapour content of the atmosphere: since over water surfaces evaporation is usually larger than over an adjacent land surface, ΔT should have larger values over water than over land. However, due to advection, air masses over the coastline are more or less mixed. As a consequence, an abrupt change of ΔT cannot be expected in all cases and hence the method depends on the actual state of the atmosphere.

To generate the actual binary window from the measurements of *T4,* it is also not useful to apply a fixed threshold, because of the natural variability of surface temperatures for different climatic regions. Thus, the thresholds for both infrared actual windows must be adapted to the actual distribution of ΔT and *T4* within the corresponding actual window. This is done by means of histogram analysis: the number of intervals for the actual windows depends on the difference between the maximum and the minimum value of either ΔT or *T4*. Once these values are found, the corresponding interval between maximum and minimum is divided by 0.15 (for ΔT) or 1 (for *T4*). If it is possible to identify two maxima of either ΔT or *T4* from the corresponding histogram, the minimum between these two maxima is a reasonable threshold for the land/sea discrimination and hence, for the generation of the actual binary images in the infrared. Obviously, even for a distinct geographical area, the values of the thresholds of either ΔT and *T4* depend on both, local time and season. Thus, they have to be recalculated for each actual window. In addition, the determination of this dynamical threshold is sometimes ambiguous because it requires a clear identification of the 'land peak' and the 'sea peak' and the gap between these maxima in the histograms of *T4* and ΔT.

In summary, the outcome of this processing step consists of four actual binary windows for each landmark. These windows are compared with the corresponding reference binary window whose creation is discussed below.

5.4.3.1.2 Reference Window

The reference binary window is generated for each landmark and must be re-calculated at each orbit because in general, the viewing angle of the AVHRR/3 instrument on a distinct geographical location varies from orbit to orbit. The position of each pixel on the Earth's surface is computed with a linear interpolation from the tie points given by each 40th pixel at each scan line. These tie points are calculated with the orbit and scanning model that was discussed previously. The size of the reference binary window that has the same center pixel location as the corresponding actual binary window depends on the maximum geolocation inaccuracy that can be expected from the output of the orbit and the scanning model. Current prototyping purposes have shown that a displacement of 8 pixels across and 10 pixels along the flight direction of the orbiter should be sufficient. Hence, the extension of the binary reference window is 37 pixels (21+8+8) across and 41 pixels (21+10+10) along the flight direction of the orbiter.

Using a high-resolution global coastline data set, for the pixels that consist the reference window (37×41 pixels) the surface type is determined and each pixel is assigned with a value of either 1 (land) or 0 (water). This procedure has to be done in a computationally efficient way, because it is a very time consuming processing step. Basing on current knowledge, a *quadtree* structure is preferred to perform the land-water discrimination in a computationally efficient way. The result of this procedure is the reference binary window that consists the (true) shape of the coastline within the landmark area.

5.4.3.1.3 Correlation Function

The output from the foregoing calculations is five binary windows for each considered landmark. The first four ones are constructed with the previously discussed threshold technique, the second one is generated by the computation of the land-sea discrimination using a high resolution global coastline data base.

To calculate the correlation function, each of the actual binary windows is compared with the reference binary window by displacing one image relative to the other one. If the displacement is denoted with *i* across and with *j* along the flight direction of the orbiter, for each position (*i*,*j*) a similarity coefficient *S(i,j)* is computed according to:

$$S(i,j) = 1 - \frac{\sum_{k=i+1}^{N_x+i} \sum_{l=j+1}^{N_y+j} \left|Ref_{k+i,\,l+j} - Act_{i,j}\right|}{N_x N_y}$$

Equation 63

In Equation 63, N_x and N_y, and denote the pixel numbers of the actual binary window across and along the flight direction, respectively (= 21 for the considered case). The abbreviations *Ref* and *Act* label the pixel of the reference binary window and one of the four actual binary windows, respectively. In the current version of the prototyping processor, for AVHRR/3 full resolution data, the values of *i* range between -8 and +8 pixels, and the values of *j* take any integer between -10 and +10.

For an ideal agreement between the actual binary window and the reference binary window, *S(i,j) = 1*.

Any deviation between these two windows results in a decrease of *S(i,j)*. On the other hand, the validity *S(i,j)* = 0 also gives a perfect land-water discrimination and thus, allows identification of the coastline within the corresponding actual binary window. The latter case will occur for example, if the water surface is snow-covered, but the snow is already melted from the neighbouring land areas, or if the evaporation over land is higher than over sea.

The correction for each landmark is performed as follows: for each of the four actual binary windows, the maximum and the minimum of *S(i,j)* are identified. These two values are denoted $S(i,j)_{max}$ and $S(i,j)_{min}$, respectively. To select which of these two values is used for further processing, the following relation is applied:

$$S(i,j)_{sel} = max\left|S(i,j)_{max}, 1 - S(i,j)_{min}\right|$$

Equation 64

Thus, for each landmark $S(i,j)_{sel}$, four values of are computed–one for each physical criterion derived from the actual window. The maximum out of the four values of is considered to correspond to the most likely correction of the landmark position. This maximum is accepted for the image correction only, when the following relation is satisfied:

$$S(i,j)_{sel} \geq 0.95$$

Equation 65

This high value for the threshold of the similarity coefficient ensures that an a priori cloud detection is not necessary. The occurrence of clouds cannot degrade the outcome of the landmark processing because of the following: if, for example, clouds occur only over land, the values of *NDVI* are similar to that of snow covered areas and hence, higher than the values of *NDVI* over water surfaces. In that case, the same actual binary window is generated with and without clouds, because its creation depends on the threshold for NDVI only. Obviously, for that case, the rejection of landmarks with clouds over land would only reduce the usefulness of the landmark processing. On the other hand, if the clouds are located over sea only, the value of $S(i,j)_{sel}$ for the *NDVI* criterion is either diminished to values below 0.95 and the landmark is excluded from further processing or the cloud amount is so small that it does not significantly affect the result of the actual binary window generation.

There is one last check to determine if a landmark navigation result is usable: compute the relation between land and sea pixels within the actual binary window then correct it by the actual pixel displacement. If this relation is less than 20 % or larger than 80 %, the corresponding landmark is rejected.

It should be noted that any cloud detection without knowledge of the surface properties is highly uncertain. This is especially the case for coastal areas, where the true position of the coastline is not known, but some assumptions about the surface properties must be used as a prerequisite for the cloud detection tests. Thus, from the physical point of view, cloud detection and scene analysis should be performed after the refinement of the geolocation with the landmark processing, because for accurately navigated data, cloud detection especially in coastal areas can be performed with more realistic surface type properties. However, this cannot be respected in operational mode, but only in backlog processing.

The result of the previous three evaluation steps (Actual Window, Reference Window, Correlation Function) is a distinct number of unequally spaced landmarks for which the pixel correction along and across the flight direction of the orbiter is known by matching the actual windows with the reference window. For each active landmark, the following parameters consist of the output 'Landmark navigation result':

- Pixel number of the landmark center
- Start time of the corresponding scan line
- Deviation between the actual binary image and the reference binary image expressed in pixel coordinates Δx and Δy.

5.4.4 Scenes Analysis

The objective of the AVHRR/3 data analysis is cloud masking–the discrimination between cloudy and cloud free pixels. The cloud algorithm specified below detects cloud-contaminated AVHRR/3 pixels, and will be used in the subsequent product generation to describe the cloud amount within the other ATOVS instruments and IASI FsOV. To determine the cloud amount of a distinct AVHRR/3 scan line, the information of the previous and the subsequent scan line is used, too. Thus, nominally, three subsequent scan lines of AVHRR/3 data are necessary to perform the cloud detection tests.

The principle of the cloud detection consists of a sequence of threshold tests that is applied to every AVHRR/3 FOV: for a distinct test situation depending on surface type, daylight conditions and season, a threshold is computed which is an estimate for the actual value of the radiometer measurement that would be expected under cloud-free conditions. This threshold is compared to a physical quantity (target reflectance factor, brightness temperature difference, sea surface temperature, brightness temperature) deduced from the real value of the radiometer measurement for the considered pixel. The tested AVHRR/3 FOV is declared 'cloudy' if one of the tests is *not passed*. Consequently, an AVHRR/3 FOV shall be declared 'not cloudy', if all tests are passed.

5.4.4.1 Test Situations

The tests applied and the thresholds used depend on the surface type (Land/Sea/Coast), the solar zenith angle–which determines the daylight conditions (day, twilight, night) and, over sea, if there is specular reflection present or not (sunglint). Consequently, 11 different test situations are considered and treated separately:

- Day over sea (Test 1)
- Day over coast (Test 2)
- Day over land (Test 3)
- Sunglint over sea (Test 4)
- Sunglint over coast (Test 5)
- Night over sea (Test 6)
- Night over coast (Test 7)
- Night over land (Test 8)
- Twilight over sea (Test 9)
- Twilight over coast (Test 10)
- Twilight over land (Test 11)

The location and the surface type of a considered pixel is already known from the geolocation procedure, this includes the landmark processing. To discriminate between different daylight conditions, the actual value of the solar zenith angle is used for the specification:

Day	solar zenith angle less than 83 °
Night	solar zenith angle larger than 90 °
Twilight	Twilight: solar zenith angle is equal to or 83° – 90°

In addition, to detect sunglint conditions, the discrimination of the 11 test situations listed above requires information about angular relationships between the satellite, the sun, and the pixel location. These relationships were determined after the geolocation procedure. Thus, before a distinct threshold test can be applied, sunglint conditions over sea should be identified. This procedure is shortly described in the following Section 5.4.4.1.1.

5.4.4.1.1 Sunlight Check

For the detection of sunglint, the following expression for specular reflectance according to Phulpin shall be computed:

$$\mu_n = \frac{(\mu_{so} + \mu_{sa})}{\sqrt{2(1+\psi)}}$$ ***Equation 66***

$$\psi = \sin\theta_{so}\sin\theta_{sa}\cos\Delta\varphi + (\mu_{so}\mu_{sa})$$ ***Equation 67***

$$\Delta\varphi = |\varphi_{so} - \varphi_{sa}|$$ ***Equation 68***

where:

Θ_{so}	is the solar zenith angle
Θ_{sa}	is the satellite zenith angle
$\mu_{so} = \cos\Theta_{so}$	
$\mu_{sa} = \cos\Theta_{sa}$	
φ_{so}	is the solar azimuth angle
φ_{sa}	is the satellite azimuth angle

If $\mu_n \geq 0.999$ → specular reflection

Else, if $\mu_n \geq 0.999$ then:

$$val = nint\left[\frac{(200\exp(-1))}{4\mu_{sa}\mu_{so} \cdot |\mu_n^2 - \mu_n^4|}\right]$$ ***Equation 69***

val > 1000 → specular reflection

Once specular reflectance is detected, it is possible to discriminate between all 11 test situations listed above. The tests for these situations are discussed separately below. In each explanation, the situation in which a distinct test should be applied is indicated.

5.4.4.2 Overview of Tests

The different types of cloud detection tests are briefly listed below. In the following, the physical quantities deduced from the AVHRR/3 measurements are referred to as follows:

Channel 1 (0.6 µm)	*A1*
Channel 2 (0.9 µm)	*A2*
Channel 3a (1.6 µm)	*A3*
Channel 3b (3.7 µm)	*T*3
Channel 4 (11µm)	*T*4
Channel 5 (12.5 µm)	*T*5

The tests applied for each combination of conditions are specified in the following sections. The threshold values may also be computed with the aid of climatological data from an atlas of monthly mean values. These climatological data include surface reflectance (alb_{clim}), sea surface temperature (sst_{clim}), temperature at 1000 hPa, and total column water vapour content of the atmosphere.

Apart of snow and ice detection, the following tests should be applied:

T11µm Test (all situations)

This test reveals low temperature FOV corresponding to medium height or high clouds. The main problem is the threshold definition. At night time or at twilight it is most important to detect medium height clouds. Over sea, the threshold is either computed from a dataset of climatological sea surface temperatures which is available on a monthly basis, or from the actual maximum of brightness temperature within one analysis box of 3 × 3 pixels (but should be user-configurable), centered at the considered pixel. A distinct value depending on the geographical location and the time of the day is subtracted from that maximum value to take into account atmospheric absorption and the defects of the climatology.

T11µm-T12µm Test (all situations).

The test uses the differences between the AVHRR/3 Channel 4 and Channel 5 brightness temperature and is applied to detect cirrus clouds. This type of clouds is characterised by higher $T4 – T5$ brightness temperature differences than cloud free surfaces. It is assumed that the differences $T4 – T5$ depend on the surface type, the actual state of the atmosphere with respect to the water vapour content, and daytime or night time conditions. The threshold is defined as a function of the satellite zenith angle and the water vapour content and is taken from look-up tables. As an example, see Table 4 below.

T11µm-T3.7µm Test (all situations, where T3.7µm is available and Θ_{so} > 110 °
The purpose of this test is to detect low-water clouds. It can be applied during night-time (because the 3.7 µm channel 3b measurements should not be affected by solar irradiance). The test efficiency is based on the spectral variation of the emissivity of water clouds, which is smaller at 3.7 µm than at 11 µm. The difference $T4 - T3$ in brightness temperature is large for clouds composed of small water particles, where over continental or oceanic surfaces channels 3b and channel 4 have similar brightness temperatures (not over sandy African deserts). The threshold used depends on the surface type, the satellite zenith angle, and the water vapour content of the atmosphere.

T3.7µm-T12µm Test (all situations, where T3.7µm is available and Θ_{so} > 110 °
The purpose of this test is to detect semi-transparent ice clouds or sub-FOV cold clouds during night time. The rationale of this test is the assumption that the contribution of the relatively warm ground to the brightness temperature is higher at channel 3b (3.7 µm) that at channel 5 (12 µm) due to the lower transmittance of ice clouds and to the high grade of non-linearity of the Planck-function at 3.7 µm. The difference of brightness temperatures $T3 - T5$ is a function of cloud height, cloud thickness for cirrus and cloud cover for sub-FOV clouds. The selected threshold depends on the surface type, the satellite zenith angle, and the water vapour content of the atmosphere.

A2(0.9µm) Test (twilight and daytime situations over coast and sea).
For this test, the near infrared AVHRR/3 Channel 2 (0.9 µm) is used. Its main purpose is to detect low clouds which have a higher reflectivity than the sea surface without sun glint conditions. The threshold is determined as a function of the (angular dependent) surface reflectance corrected by the impact of atmospheric constituents.

A1(0.6µm) Test (twilight, day and sun glint situations over coast and twilight and daytime situations over land)
For this test the visible AVHRR/3 Channel 2 (0.9 µm) is used. Its main purpose is to detect low clouds which (under snow-free conditions) have a higher reflectivity than the underlying land surface. The threshold is determined as a function of the (angular dependent) surface reflectance corrected by the impact of atmospheric constituents. By using monthly averaged values for the surface reflectance, it is also accounted for seasonal variations of the surface properties.

T4(11µm) Spatial Coherence Test (all situations over sea)
The purpose of this test is to detect cloud edges, thin cirrus and small cumulus over sea. The standard deviation of the AVHRR/3 Channel 4 brightness temperature $T4$ of a FOV (central FOV) and its eight nearest neighbours (a 3 × 3 box) is computed. If this standard deviation is larger than a given threshold, the central FOV is classified as 'cloudy'. The test is carried out with a constant threshold: See below cst_{sd33s}.

In the text that follows, the thresholds are labelled as such: the threshold for the T11µm-T12µm Test is labelled Threshold45, the threshold for the T11µm-T3.7µm Test is labelled Threshold 34, and the threshold for the T3.7µm-T12µm Test is labelled Threshold35. All parameter sets used to compute these values have to be validated for the AVHRR/3 instrument flown on Metop1 during the commissioning phase. As default, the corresponding values for the AVHRR/3 instrument onboard of NOAA16 shall be used.

The thresholds for the tests that rely on the absolute value of a physical quantity are labelled as follows: in the infrared, only the threshold value for the brightness temperature of channel 4 has to be determined– henceforth, this value will be denoted as ThresholdIR. In the visible, the thresholds for channel 1 and channel 2 are denoted as ThresholdVIS1 and ThresholdVIS2, respectively.

The determination of these three thresholds depends on season, geographical location, daytime, satellite viewing angle and the availability of distinct data sets (forecast data and/or climatological data). Therefore, in the following, the computation of these thresholds is described separately for each test situation.

5.4.4.3 Use of Forecast Data and AMSU-A Data

It can be expected that the cloud detection is significantly improved if actual NWP forecast data are included into the evaluation scheme. These data consists of the air temperature at 2 m above the surface and the total column water vapour content.

Over sea, the best results for the cloud detection can be achieved, if actual AMSU-A brightness temperatures are used to determine the total water vapour content. Therefore, if AMSU-A data are available, the following algorithm should be applied to mid-latitude and tropical areas:

If Z denotes the viewing angle of the AMSU-A instrument and T23, T31, and T50 denote the brightness temperatures at 23 GHz, 31 GHz, and 50 GHz, respectively, the total water vapour content VAP is calculated with the following equations:

$$DF1 = 2.85 + 0.02T23 - 0.028T50$$
$$A = 247.92 - \cdot 69.235 - 44.177 \cos Z \cdot \cos Z$$
$$B = -116.27$$
$$C = 73.409$$

$$VAP = [A + B \times (\log(285 - T23)) + C \times (\log(285 - T31))] \times \cos Z$$
$$(|\varphi_{geo}| < 50^\circ \wedge DF1 < 0.2)$$

Equation 70

The limb correction applied to the brightness temperatures used in Equation 70 is valid only, if the correction can be assumed to be symmetrical. Since real AMSU-A data currently show a cross track asymmetry for larger scanning angles, limb corrected brightness temperatures should be used in the above formula. For the limb correction, see EUM.EPS.SYS.SPE.990005, the AMSU-A Level 1 Product Generation Specification. If the limb correction was already applied, *VAP* is computed by setting *cos Z =1* in Equation 70 and using the limb-corrected brightness temperatures.

This algorithm is valid over sea only. It has the advantage that it uses measurements taken simultaneously to the AVHRR/3 measurements. If applicable, it is expected to provide the best estimate for the total water vapour content.

5.4.4.4 Constants for the Threshold Determination

The following parameters are used to compute thresholds or are used as thresholds (the values given are examples used at Météo-France (CMS at Lannion) in the frame of the ATOVS and AVHRR Processing Package AAPP, [RD3]). The values listed were validated for different climatological regions, for the current NOAA satellites and thus, may be slightly different for AVHRR/3 flown on Metop. Consequently, all thresholds and constants used for the threshold determination should be user configurable. During the operation, it is envisaged to refine these values and subsequently use them in a latitude/longitude and season dependent dataset, which can be updated as desired. The corresponding dataset that includes the constants for the threshold determination is AVHRR_L1_PGS_DAT_SCENE.

Note: All constants for the threshold determination listed below are given in hundredths of Kelvin or hundredths of target reflectance factors.

5.4.4.4.1 Constants for IR-Threshold Determination

$Cst_{sstirs} = 400$	constant used to calculate IR threshold over sea
$cst_{ir} = 1000$	constant used to calculate IR threshold over land
$cst_{irs} = 600$	constant used to calculate IR threshold over sea
$Cst_{irsnd} = 300$	constant used for the IR threshold determination over sea if there is no climatological SST available
$S_{ir} = 1000$	for $0° < \varphi_{so} \leq 180°$, $\Theta_{so} \geq 60°$ (morning and night)
$S_{ir} = 700$	for $\varphi_{so} > 180°$, $\Theta_{so} < 60°$, (afternoon)
$sature3 = 32000$	Channel 3b saturation threshold
$Separ1637 = 18000$	Channel 3a/3b discrimination

5.4.4.4.2 Constant used as Uniformity Threshold

$cst_{sd}33s = 20$	Threshold for standard deviation of channel 4 brightness temperature in an AVHRR/3 3 × 3 box over sea

5.4.4.4.3 Constants used for Climatological IR-Threshold Determination

$cst_{lstmin} = 26315$	Minimum land surface temperature without snow coverage
$cst_{sstmin} = 27015$	Minimum SST without sea ice
$cst_{sst} = 27515$	Sea surface temperature for the *T4-T5* test decision

5.4.4.4.4 Constants used for Sunglint Threshold Determination

$Cst_{2g} = 1500$	Constant for the channel 2 reflectance threshold determination
$Cst_{13g} = 1000$	Constant for the calculation of the threshold for the target reflectance difference between channel 1 and channel 3a

5.4.4.5 Description of the Tests

The test sequence to decide whether an AVHRR/3 pixel is clear or cloudy is specified in the following subsections. No discrimination is made here between full resolution AVHRR/3 and GAC. This possibility must be taken into account in the respective threshold values.

5.4.4.5.1 Tests During Daytime without Sunglint

In this category, the following situations are included:

- Day over sea
- Day over coast
- Day over land

The threshold determination and the test sequence is as follows:

5.4.4.5.1.1 Threshold determination

Threshold IR Sea

If an actual forecast data set with the temperature at 2m altitude is available, the threshold is computed according to the following:

$$\text{Threshold IR} = T2m_{prev} - cst_{sstirs} \quad \textit{Equation 71}$$

If only a SST climatology is available (AVHRR_L1_PGS_DAT_CLISST. See Annex B):

$$\text{Threshold IR} = sst_{clim} - cst_{sstirs} \quad \textit{Equation 72}$$

else if neither SST climatology nor forecast data are available, the following expression is used:

$$\text{Threshold IR} = \max(cst_{sstmin}, (T4max - cst_{irsnd})) \quad \textit{Equation 73}$$

In Equation 73, $T4max$ denotes the maximum value of $T4$ in a 3 × 3 box centred at the actually-considered pixel .

For the snow and ice detection test, the determination of the threshold depends also on the availability of the auxiliary data sets. If only the SST climatology is available and, in addition, (sst_{clim}) > 27135, then:

$$\text{Threshold IR(SNOW)} = sst_{clim} - cst_{irs} \quad \textit{Equation 74}$$

if only a SST climatology is available and (sst_{clim}) ≤ 27135:

$$\text{Threshold IR(SNOW)} = 24315 \quad \textit{Equation 75}$$

If forecast data are available and (sst_{clim}) ≤ 27135:

$$\text{Threshold IR(SNOW)} = T2m_{prev} - s_{ir}$$ **Equation 76**

else if neither SST climatology nor forecast data are available, the following equation is used:

$$\text{Threshold IR(SNOW)} = \max(cst_{sstmin}, (T4max - cst_{irsnd}))$$ **Equation 77**

Threshold IR Land

If 2 m air temperature from forecast data is available ($T2m_{prev}$):

$$\text{Threshold IR} = T2m_{prev} - s_{ir}$$ **Equation 78**

else:

$$\text{Threshold IR} = \max(cst_{lstmin}, (T4max - cst_{ir}))$$ **Equation 79**

The corresponding values for the snow detection tests are calculated in the same way:

$$\text{Threshold IR(SNOW)} = \text{Threshold IR}$$ **Equation 80**

Threshold IR Coast

This threshold will be different depending, whether the AVHRR/3 pixel is over land or over sea. The determination, whether a distinct coastal pixel is treated as a pixel over sea or over land is performed using the normalized density vegetation index *NDVI [NDVI = (A2-A1)/(A2+A1)]*,and Equation 59 and Equation 60.

For pixels identified to be located over sea, the following sequence should be applied:

- If an actual forecast data set with the temperature at 2m altitude is available, the threshold is computed according to the following:

$$\text{Threshold IR} = T2m_{prev} - cst_{sstirs}$$ **Equation 81**

- If only a SST climatology (sst_{clim}) is available (AVHRR_L1_PGS_DAT_CLISST.) See Annex B.

$$\text{Threshold IR} = sst_{clim} - cst_{sstirs}$$ **Equation 82**

- Else if neither SST climatology nor forecast data are available, the following expression is used:

$$\text{Threshold IR} = \max(cst_{sstmin}, (T4max - (cst_{ir} \cdot 1.5))) \quad \textbf{Equation 83}$$

For the snow and ice detection test, the determination of the threshold depends also on the availability of the auxiliary data sets. If only the SST climatology is available and in addition $sst_{clim} > 27135$, then:

$$\text{Threshold IR(SNOW)} = sst_{clim} - cst_{ir} \quad \textbf{Equation 84}$$

if only a SST climatology is available and $sst_{clim} \leq 27135$:

$$\text{Threshold IR(SNOW)} = 24315 \quad \textbf{Equation 85}$$

If forecast data are available and $sst_{clim} \leq 27135$:

$$\text{Threshold IR(SNOW)} = T2m_{prev} - s_{ir} \quad \textbf{Equation 86}$$

else if neither SST climatology nor forecast data are available, the following equation is used:

$$\text{Threshold IR(SNOW)} = \max(cst_{sstmin}, (T4max - (cst_{ir} \cdot 1.5))) \quad \textbf{Equation 87}$$

where $T4max$ is the maximum $T4$ in the 3 × 3 box centred at the actually considered pixel .

Over land, Threshold IR and Threshold IR(SNOW) are determined like above Threshold IR Land.

Threshold VIS Sea

Using the theory of Cox and Munck, a surface albedo *suralb* is computed for the channel 2 specifications. For this purpose, the Fresnel Coefficient $R_{Fresnel}$ is calculated according to the following equations:

$$\psi_1 = \sqrt{\frac{1}{2}(1 + \psi)} \quad \textbf{Equation 88}$$

$$\psi_2 = \sqrt{\frac{1}{2}(1 - \psi)} \quad \textbf{Equation 89}$$

$$A_1 = \left|n_r^2 - n_i^2 - \psi_2^2\right|$$ ***Equation 90***

$$A_2 = \sqrt{A_1^2 + 4 \cdot n_r^2 \cdot n_i^2}$$ ***Equation 91***

In Equations, n_r and n_i, denote the real and the imaginary part of the refractive index for water, respectively. For a wavelength of 0.9 μm , the values for pure water are $n_r = 1.328$ and $n_i = 4.86 \times 10^{-7}$ For ocean water, the sea salt content is respected using a value of $n_r = 1.334$, whereas n_i remains unchanged. With this:

$$u = \sqrt{\frac{1}{2} \cdot (A_1 + A_2)}$$ ***Equation 92***

$$v = \sqrt{\frac{1}{2} \cdot (A_2 - A_1)}$$ ***Equation 93***

the coefficient R_1 is:

$$R_1 = \sqrt{\frac{(\psi_1 - u)^2 + v^2}{(\psi_1 + u)^2 + v^2}}$$ ***Equation 94***

The coefficient is R_2 is obtained in a similar manner:

$$B_1 = (n_r^2 - n_i^2) \cdot \psi_1$$ ***Equation 95***

$$B_2 = 2 \cdot n_r \cdot n_i \cdot \psi_1$$ ***Equation 96***

$$R_2 = \frac{(B_1 - u)^2 + (B_2 + v)^2}{(B_1 + v)^2 + (B_2 - v)^2}$$ ***Equation 97***

Finally, the expression for the Fresnel coefficient is as follows:

$$R_{Fresnel} = \frac{1}{2} \cdot (R_1 + R_2)$$ ***Equation 98***

For the determination of the surface reflectance *suralb*, three cases are considered that depend on the value of the parameter *ww*:

$$ww = \frac{(1/\mu_n^2) - 1.003}{0.00512}$$ ***Equation 99***

Case 1: *ww* < 0:

$$suralb = nint\left\{\frac{10000 \cdot R_{Fresnel} \cdot \exp\left[\frac{1 - 1/\mu_n^2}{0.003}\right]}{0.012 \cdot \mu_{sa} \cdot \mu_{so} \cdot \mu_n^4}\right\}$$ ***Equation 100***

Case 2: *ww* ≤ ww ≤ 20:

$$suralb = nint\left\{\frac{10000 \cdot R_{Fresnel} \cdot \exp[-1]}{4 \cdot \mu_{sa} \cdot \mu_{so} \cdot \left|\mu_n^2 - \mu_n^4\right|}\right\}$$ ***Equation 101***

Case 3: *ww* > 20:

$$suralb = nint\left\{\frac{10000 \cdot R_{Fresnel} \cdot \exp\left[\frac{1 - 1/\mu_n^2}{0.1054}\right]}{0.4216 \cdot \mu_{sa} \cdot \mu_{so} \cdot \mu_n^4}\right\}$$ ***Equation 102***

Taking into account the influence of water vapour and ozone, an atmospheric correction of *suralb* has to be performed. The scope of this correction is to determine three coefficients that depend on the atmospheric transmission of the trace gases H_2O, $O_3$and the Rayleigh scatterers, henceforth denoted as T_{H20}, and T_{O3} , and T_{O2} respectively. As a first approach, the transmissions are either constant or selected from look-up tables. The values of these look-up tables depend on the parameter ζ that is defined as follows:

$$\xi = \frac{1}{\mu_{so}} + \frac{1}{\mu_{sa}}$$

Equation 103

For T_{H20}, 391 values are stored in a table. Numerically T_{H20}, for a given value of δ is selected by the following formula:

$$i_{H_2O} = (10u_{H_2O} \cdot \xi) - 9$$

Equation 104

Per default $u_{H20} = 2$.

For T_{O2} , the selection is performed out of 32 values, whereas the corresponding index is this:

$$i_{O_2} = (4 \cdot \xi) - 7$$

Equation 105

For T_{O3}, a constant value of 09975 ($\delta \times u_{03}$) with $u_{03} = 0.35$ is chosen. The total transmission T_{air} is the product of all three contributions:

$$T_{air} = T_{H_2O}(i_{H_2O}) \cdot T_{O_2}(i_{O_2}) \cdot T_{O_3}$$

Equation 106

To account for the diffuse transmission T_{diff}, 19 values are given in a look-up table representing angles from 0° to 90° in equidistant steps of 5°. Given two distinct angles Θ_{so} and Θ_{sa}, the corresponding diffuse transmittances $T_{diff}(\Theta_{so})$ and $T_{diff}(\Theta_{sa})$ are computed by linear interpolation between the corresponding two nearest values in the look-up table.

The contribution of the atmospheric emission is accounted for by interpolating the corresponding values from a look-up table. These values of these tables depend on Θ_{so}, Θ_{sa}, and the azimuthal difference $\Delta\varphi$. The angular resolution of the corresponding values is different for the following two cases:

Case 1	$\Theta_{so} < 60^{\circ}$	8 values for equidistant values of Θ_{sa} between 0° and 70° 7 values for equidistant values of Θ_{so} between 0° and 60° 15 values for equidistant values of $\Delta\varphi$ between 0° and 180°
Case 2	$60^{\circ} \leq \Theta_{so} < 90^{\circ}$	8 values for equidistant values of Θ_{sa} between 0° and 70° 7 values for equidistant values of Θ_{so} between 60° and 90° 15 values for equidistant values of $\Delta\varphi$ between 0° and 180°

The result of this selection will be one value for atmospheric contribution, denoted as ρ_a. With the following definitions of the coefficients a_0, a_1, and a_2:

$$a_0 = \rho_a \cdot T_{air}$$

Equation 107

$$a_1 = T_{diff}(\theta_{so}) \cdot T_{diff}(\theta_{sa}) \cdot T_{air}$$

Equation 108

$$a_2 = 0.05998$$

Equation 109

the threshold can be expressed as:

$$\text{Threshold VIS2} = 100 \times \left(a_0 + \frac{a_1 \cdot suralb}{1 - (a_2 \cdot suralb)} \right) \times \cos\theta_{so}$$

Equation 110

If this expression fails, this means $\text{Threshold VIS2} \leq 0$, the following relation should be used to define a threshold:

$$\text{Threshold VIS2} = (C + Slope \cdot (\theta_{so} - L\theta_{so}) \cdot 100) \times \cos\theta_{so}$$

Equation 111

where:

Θ_{so}	solar zenith angle in degrees
$L\Theta_{so}$	Limits of solar zenith angle (70.0, 80.0 and 85.0 degrees). Lower limit is taken except for angles lower than 70.0 degrees, so in that case $L\Theta_{so} = 70$
C	Coefficient applied to the origin (1000, 1000, 1500, 2000). This depends on the limits $L\Theta_{so}(\Theta_{so})$ falls between.
Slope	Slope of the curve (0.0, 0.5, 1.0, 3.75). It depends on the limits $L\Theta_{so}(\Theta_{so})$ falls between. ***Note:*** If $\Theta_{so} = 82.0$, then $L\Theta_{so} = 80.0$, $C = 1500$ and $Slope = 1.0$

Θ_{so}	0.0	70.0	80.0	85.0
$L\Theta_{so}$	70.0	70.0	80.0	85.0
C	1000	1000	1500	2000
Slope	0.0	0.5	1.0	3.75

Table 6: Parameters for the Computation of ThresholdVIS2

Threshold VIS Land And Coast

The surface albedo values in the global albedo atlas (AVHRR_L1_PGS_DAT_CLIALB. See Appendix B) do not account for any anisotropic effects of surface solar reflection. To account for this effect, a correction should be applied to the selected value of the climatological surface reflectance (alb_{clim}). First, depending on the value of alb_{clim} , two coefficients *k1* and *k2* are defined:

$$\left.\begin{aligned} k1 &= 0.15 \\ k2 &= 1.0 \end{aligned}\right\}(alb_{clim} \leq 20)$$

Equation 112

$$\left.\begin{aligned} k1 &= 0.05 \\ k2 &= 0.5 \end{aligned}\right\}(alb_{clim} > 40)$$

Equation 113

$$\left.\begin{aligned} k1 &= A \cdot 0.05 + 0.15 \cdot (1 - A) \\ k2 &= A \cdot 0.5 + 1.0 \cdot (1 - A) \end{aligned}\right\}(20 < alb_{clim} \le 40)$$

$$A = (alb_{clim} - 20)/20$$

Equation 114

Given a set of angular relationships between pixel location, sun, and the satellite position, the anisotropic correction *brdf* can be computed according to the following:

$$brdf = 1 + k1 \times f1 + k2 \times f2$$

Equation 115

The coefficients *f1* and *f2* contain the geometrical information. According to Roujean, they have the following form:

$$f1 = \frac{1}{2\pi} \cdot [(\pi - \Delta\varphi) \cdot \cos\Delta\varphi + \sin\Delta\varphi] \cdot \tan\theta_{so} \cdot \tan\theta_{sa} - \frac{1}{\pi}\left(\tan\theta_{so} + \tan\theta_{sa} + \sqrt{\tan\theta_{so}^{2} + \tan\theta_{sa}^{2} - (2 \cdot \tan\theta_{so} \cdot \tan\theta_{sa} \cdot \cos\Delta\varphi)}\right)$$

Equation 116

$$f2 = \left[\frac{4}{3\pi \cdot (\cos\theta_{so} + \cos\theta_{sa})}\right] \cdot \left[\left(\frac{\pi}{2} - \operatorname{acos}\psi\right) \cdot \psi + \sin(\operatorname{acos}\psi)\right] - \frac{1}{3}$$

Equation 117

Once *brdf* is determined, the threshold for channel 1 is computed according to the following:

$$\text{Threshold VIS1} = 100 \times \left(a_0 + \frac{a_1 \cdot alb_{clim} \cdot brdf}{1 - (a_2 \cdot alb_{clim} \cdot brdf)}\right) \times \cos\theta_{so}$$

Equation 118

The coefficients a_0, a_1, and a_2 result from the atmospheric correction due to the influence of water vapour and ozone on the radiation transmitting the atmosphere. These coefficients are determined in the same way as for the atmospheric correction over sea, but the look-up tables for the transmission values differ from those used for the atmosphere over the ocean. It should be pointed out that the values of these look-up tables depend on the window function of a distinct channel, and thus, are different for different AVHRR/3 instruments.

If Threshold VIS1 ≤ 0, then

If $\Theta_{so} \leq 70°$

$$\begin{aligned} &\text{If Threshold VIS1} \leq 0 \text{ then} \\ &\quad \text{If } \theta_{so} \leq 70° \\ &\qquad \text{Threshold VIS1} = 2000 \times \cos\theta_{so} \end{aligned}$$

Equation 119

else

$$\text{Threshold VIS1} = [2000 + 0.8 \cdot (\theta_{so} - 70) \cdot 100] \times \cos\theta_{so}$$

Equation 120

Threshold 45 Sea

This threshold is extracted from a configurable table, including thresholds to applied, for a given satellite zenith angle secant and the vertically-integrated water vapour content. Generally, the selection of the actual threshold for brightness temperature difference between channels 3b and 5, between channels 4 and 3b, and between channels 4 and 5 depend on three criteria:

- Surface type
- Vertically integrated water vapour content
- Satellite zenith angle secant defined as:

$$satsec = 1 / \cos(\theta_{sa})$$

Equation 121

The corresponding thresholds are stored in configurable look-up tables in AVHRR_L1_PGS_DAT_THRES. In these tables, the secant should take seven different values from 1–2.5 in steps of 0.25 and the water vapour content has 16 values between 0.25 and 7.75 g/cm^2 . Actually, these values are interpolated to give 16 different values of the satellite scan angle secant and 51 values for the vertically integrated water vapour content.

VAP g/cm2	**Satellite Zenith Angle Secants**						
	1	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**
0.25	140	158	178	211	245	278	311
0.75	156	176	196	226	255	284	313
1.25	185	207	226	254	278	303	328
1.75	223	246	265	289	310	331	351
2.25	257	281	299	320	337	354	371
2.75	285	308	325	342	356	370	384
3.25	310	331	345	359	370	381	392
3.75	338	356	366	376	383	390	398
4.25	361	376	384	390	394	399	403
4.75	382	395	401	405	407	410	413
5.25	404	415	420	423	425	426	428
5.75	429	440	444	446	446	447	447
6.25	454	464	466	467	465	463	462
6.75	477	486	489	488	485	482	479
7.25	497	505	507	505	501	496	492
7.75	518	525	525	522	516	511	505

Table 7: Example of T4-T5 Threshold (THRESHOLD 45) Values used in the T11µm – T12µm Test Over Sea for AVHRR/3 onboard NOAA16. The values are given in hundredths of Kelvin.

Threshold 45 Land

Same criteria listed under *Threshold 45 Sea*.
Note: There are other *r* values used besides those listed in Table 4.

Threshold 45 Coast

Same as *Threshold 45 Land*.

Spatial Coherence Test

From the 3 × 3 box centered at the actually-considered pixel, the standard deviation is computed for *T4*. This test is used over sea only and the resulting value for the standard deviation is denoted *SDT4*.

5.4.4.5.1.2 Test Sequences

In a test sequence, the computed threshold is compared to a constant or a physical quantity deduced from the actual AVHRR/3 measurement. Such quantities are target reflectance factors, brightness temperatures, brightness temperature differences or sea surface temperature SST derived from different combinations of brightness temperature measurements. The SST for the threshold test over sea is selected, if the sea surface temperature climatology (sst_{clim}) is used for the threshold determination. The corresponding value of SST is computed according to Equation 137. (See also Section 5.4.4.6.) The sequence of tests to determine whether the AVHRR pixel is clear, using the above specified thresholds, is outlined in Table 8 below:

Land	***Sea***
Snow detection (Snow → pixel is 'clear')	Ice detection (Ice → pixel is 'clear')
$T4 \geq$ Threshold IR Land	$T4 \geq$ Threshold IR Sea, sst_{clim} is not used $SST \geq$ Threshold IR Sea, sst_{clim} is used.
$A1 \leq$ Threshold VIS1	$A2 \leq$ Threshold VIS2
	Uniformity $\leq SDT4cst_{sd33s}$
$T4 - T5 \leq$ Threshold 45 Land	$T4 - T5 \leq$ Threshold 45 Sea
Coast	
Snow detection (Snow or ice → pixel is 'clear')	
$NDVI \geq -0.1$ → **Land**	$NDVI < -0.1$ → ***Sea***
$T4 \geq$ Threshold IR Land	***$T4 \geq$ Threshold IR Sea, if sst_{clim} is not used*** $SST \geq$ Threshold IR Sea, if sst_{clim} is used
$A1 \leq$ Threshold VIS1	$A2 \leq$ Threshold VIS2
$T4 - T5 \leq$ Threshold 45 Land	$T4 - T5 \leq$ Threshold 45 Sea

Table 8: AVHRR/3 Cloud Detection Test Sequences for Daytime Conditions

5.4.4.5.2 Tests During Daytime with Sun-Glint

This category comprises the following situations:

- Sunglint over sea
- Sunglint over coast

5.4.4.5.2.1 Threshold Determination for daytime tests with sunglint

Threshold IR Sea and Coast, Threshold 45 Sea and Coast, and Threshold VIS Sea

These thresholds are computed as above for daytime situations without sunglint. For the difference test, the threshold depends on the vertically integrated atmospheric water vapour content and on the secant of the satellite angle. These data are stored in lookup tables.

Threshold VIS Coast

This threshold will depend on whether the AVHRR/3 pixel is over land or over sea:

- Over sea, Threshold VIS2 is computed as 'Threshold VIS Sea' during daytime without sunglint.
- Over land, Threshold VIS1 is computed as 'Threshold VIS Land' during daytime without sunglint.
- Additional sunglint thresholds for pixels located over sea are computed as follows:

$$\text{Threshold VIS sunglint} = cst_{2g} \cdot \cos\theta_{so}$$ ***Equation 122***

$$\text{Threshold 13 sunglint} = cst_{\tilde{13g}} \cdot \cos\theta_{so}$$ ***Equation 123***

5.4.4.5.2.2 Test Sequence for Sunglint Conditions

The daytime test sequence for sunglint situations is outlined below for Sea and Coast. The SST for the threshold test over sea is selected, if the sea surface temperature climatology (sst_{clim}) is used for the threshold determination. The corresponding value of SST is computed according to Equation 137 (See also Section 5.4.4.6).

Over land the tests are the same as without sunglint:

Sea
Ice detection (Ice → pixel is 'clear')
$T4 \geq$ Threshold IR Sea sst_{clim} is not used
$SST \geq$ Threshold IR Sea, if sst_{clim} is used
Uniformity: SDT4 $\leq cst_{sd33s}$
$A2 \leq$ Threshold VIS2
$T4 - T5 \leq$ Threshold 45 Sea
Additional Sunglint-Specific Tests:
$A2 \leq$ Threshold VIS sunglint
$A1 - A3 \leq$ Threshold 13 sunglint

Coast
Snow and ice detection (Snow or ice → pixel is 'clear')
Land *(NDVI* ≥ -0.1):
Same test sequence as used for daytime conditions over land.
Sea *(NDVI* < -0.1):
$T4 \geq$ Threshold IR Sea sst_{clim} is not used
$SST \geq$ Threshold IR Sea, if sst_{clim} is used
$A2 \leq$ Threshold VIS2
$T4 - T5 \leq$ Threshold 45 Sea
Additional Sunglint Specific Tests:
$A2 \leq$ Threshold VIS sunglint
$A1 - A3 \leq$ Threshold 13 sunglint

5.4.4.5.3 Tests During Night time

Night-time test are specified below. They include the following situations:

- Night over sea
- Night over coast
- Night over land

5.4.4.5.3.1 Threshold Determination

Threshold IR Sea

Over sea, Threshold IR is computed as the 'Threshold IR Sea' under daytime conditions.

Threshold IR Coast

The determination of this threshold depends on the availability of SST climatology (sst_{clim}) and/or 2m air forecast temperature ($T2m_{prev}$) (AVHRR_L1_PGS_DAT_CLISST, See Appendix B).

If sst_{clim} and $T2m_{prev}$ are available :

$$\text{Threshold IR} = min(T2m_{prev} - s_{ir}, sst_{clim} - cst_{ir})$$

Equation 124

If no $T2m_{prev}$ available:

$$\text{Threshold IR} = max(cst_{lstmin}, T4max - cst_{ir})$$

Equation 125

If only $T2m_{prev}$ is available :

$$\text{Threshold IR} = T2m_{prev} - s_{ir}$$

Equation 126

If no sst_{clim} and no $T2m_{prev}$ are available:

$$\text{Threshold IR} = max(cst_{lstmin}, T4max - cst_{ir})$$

Equation 127

Threshold IR Land

Over land, the Threshold IR is determined in the same way as the 'Threshold IR Land' under daytime conditions. Note that the value of s_{ir} depends on the solar azimuth.

Threshold 45 Sea

This threshold is computed as above during daytime without sunglint. It depends on the vertically-integrated atmospheric water vapour content and on the secant of the satellite angle. The data are stored in a look-up table.

Threshold 45 Coast

The use of the $T4 - T5$ test depends on whether a SST climatology (sst_{clim})is available or not (AVHRR_L1_PGS_DAT_CLISST. See Annex B). If no climatologic sst_{clim} is available, this test is used. If a SST climatology sst_{clim} is available, the test is used only if sst_{clim} is greater than or equal to the constant value cst_{sst}. If the test is used, 'Threshold 45' is selected from a look-up table that contains values of $T_4 - T_5$ depending on the water vapour content of the atmosphere and the satellite zenith angle secant

Threshold 45 Land

The actual value for this threshold depends on the water vapour content of the atmosphere and the satellite zenith angle secant and is selected from a look-up table.

Threshold 34 Sea

This threshold is extracted from a configurable look-up table, including thresholds to be applied, for a given satellite zenith angle secant and the vertically-integrated water vapour content. This threshold is determined only if channel 3b measurements ($T3$) are available.

Threshold 34 Land

Same as above. A discrimination between desert regions on the one side and all other areas on the other side is performed. Desert regions are identified with the values of the surface reflectance given in the climatological data sets: if the value for a distinct area is larger than 25 %, the corresponding region is considered to be a desert. Over desert, a value of 200 is added to the 'Threshold 34 Land' selected from the corresponding look-up table.

Threshold 34 Coast

Same as above.

Threshold 35 Sea

This threshold is extracted from a configurable table, including thresholds to applied, for a given satellite zenith angle secant and the vertically-integrated water vapour content. A threshold value is only extracted if channel 3b measurements are available.

Threshold 35 Land

Same as above.

Threshold 35 Coast

Same as above.

Spatial Coherence Test

From the 3 × 3 box centered at the actually-considered pixel, the standard deviation is computed for *T4*. This test is used over sea only and the resulting value for the standard deviation is denoted *SDT4*.

5.4.4.5.3.2 Test Sequence

The test sequence used to estimate whether an AVHRR pixel is clear is specified in **Table 10**. The discrimination between sea, land and coast cannot be performed via *NDVI*. Instead, the result of the surface type determination with the high resolution coastline data base is used. If the sea surface temperature climatology (sst_{clim}) is used for the threshold determination, the SST for the threshold test over sea is selected. The corresponding value of SST is computed according to Equation 137 and Equation 138. See also Section 5.4.4.6, *Sea Surface Temperature Retrieval Function*.

Sea	***Land and Coast***
T4 ≥ Threshold IR Sea, if sst_{clim} is not used. SST ≥ Threshold IR Sea, if sst_{clim} is used.	*T4* ≥ Threshold IR Land and Coast
T3 – *T5* ≤ Threshold 35 Sea	*T3* – *T5* ≤ Threshold 35 Land and Coast
T4 – *T3* ≤ Threshold 34 Sea	*T4* – *T3* ≤ Threshold 34 Land and Coast
*SDT*4 cst_{sd33s}	
T4 – *T5* ≤ Threshold 45 Sea	*T4* – *T5* ≤ Threshold 45 Land and Coast

Table 9: AVHRR/3 cloud detection test sequences for night time conditions

5.4.4.5.4 Tests for Twilight Situations

These series of tests apply to the following situations:

- Twilight over sea
- Twilight over coast
- Twilight over land

For twilight situations, no snow and ice test is performed.

5.4.4.5.4.1 Threshold determination

Threshold IR Sea

Over sea Threshold IR is computed as above for daytime conditions.

Threshold IR Coast

If sst_{clim} and $T2m_{prev}$ are available :

$$\text{Threshold IR} = min(T2m_{prev} - s_{ir}, sst_{clim} - cst_{ir})$$

Equation 128

If only $T2m_{prev}$ is available:

$$\text{Threshold IR} = T2m_{prev} - s_{ir}$$

Equation 129

If only sst_{clim} is available :

$$\text{Threshold IR} = (sst_{clim} - cst_{ir})$$

Equation 130

If neither sst_{clim} nor $T2m_{prev}$ are available:

$$\text{Threshold IR} = max(cst_{lstmin}, T4max - cst_{ir})$$

Equation 131

Threshold IR Land

Over land Threshold IR is computed in the same way as during daytime conditions.

Threshold 45 , Threshold 34 Sea, Coast and Land

These thresholds are extracted from corresponding look-up tables, for a given satellite zenith angle secant and the actual atmospheric water vapour content.

Threshold VIS Sea, Coast and Land

The calculation of these thresholds is performed in the same manner than under daylight conditions but with the following modifications: for sea, in Equation 110 and Equation 111, and for land, in Equation 118 and Equation 120, a constant value for $\cos\Theta_{so}$ of 0.1218693 (corresponding to $\Theta_{so} = 83°$) is used.
Note: All other equations for the computation of Threshold VIS remain unchanged.

5.4.4.5.4.2 Test Sequence

The sequence of twilight tests is outlined in Table 10 below. The discrimination between sea, land and coast cannot be performed via *NDVI*. Instead, the result of the surface type determination with the high resolution coastline data base is used. The SST for the threshold test over sea is selected, if the sea surface temperature climatology (sst_{clim}) is used for the threshold determination. The corresponding value of SST is computed according to Equation 137. See also Section 5.4.4.6.

Land	***Sea***
$T4 \geq$ Threshold IR Land	$T4 \geq$ Threshold IR Sea, if sst_{clim} is not used $SST \geq$ Threshold IR Sea, sst_{clim} is used.
$T4 - T5 \leq$ Threshold 45 Land	$T4 - T5 \leq$ Threshold 45 Sea
$T4 - T3 \leq$ Threshold 34 Land	Uniformity $\leq SDT4cst_{sd33s}$
$A1 \leq$ Threshold VIS1	$T4 - T3 \leq$ Threshold 34 Sea
	$A2 \leq$ Threshold VIS2
Coast	
$T4 \geq$ Threshold IR Coast, if sst_{clim} is not used. SST $\geq$ Threshold IR Coast, if sst_{clim} is used.	
$T4 - T5 \leq$ Threshold 45 Coast	
$T4 - T3 \leq$ Threshold 34 Coast	
$A1 \leq$ Threshold VIS1 $A2 \leq$ Threshold VIS2	

Table 10: AVHRR/3 Cloud Detection Twilight Test Sequences

5.4.4.5.5 Snow and Ice Test

The discrimination between snow surfaces and cloud is one of the most challenging tasks to be performed with AVHRR/3 data. The test specified here is only applied for situations with solar elevation angles above 7°, that is to say solar zenith angles of less than 83°.

The rationale of the test is based on analysis of the solar reflection in the AVHRR/3 channel 1 and the Infrared Channel 3a. Cloud free snow will reflect sunlight relatively weak at 1.6 µm whereas the reflectance of snow is high at 0.6 µm. Water clouds have rather large reflectances in both channels. The shadows of higher clouds on top of lower clouds are characterised by the lack of solar reflection in the near infrared, but rather high reflectances in the visible channel. This increases the danger to confuse them with snow. In the end however, they may be distinguished from snow by their lower reflectance in the near infrared.

Cirrus clouds, stratus as well as stratocumuli, can have rather small $T3 - T4$ differences in brightness temperatures (< 10 K). Whereas cirrus clouds may be relatively good detected by the high difference in $T4 - T5$ brightness temperatures, the stratus and stratocumuli cannot be detected that easily. One attempt is the use of the near infrared channel, but a perfect distinction from snow is not possible.

It should be mentioned that the both expressions ’snow’ and ’ice’ are used to determine snow and ice coverage either for land (’snow’) or for sea (’ice’). In practice, no discrimination between snow and ice can be performed with AVHRR/3 measurements.

The thresholds used currently by the AAPP software are summarised in the following subsection. They contain ’constants’ that may undergo alterations in operational processing. Thus, these constants should be added to a configurable auxiliary dataset (AVHRR_L1_PGS_DAT_THRES).

The following thresholds shall be computed for the snow/ice detection:

$$\text{Threshold IR(SNOW)} = \max(24315, \text{Threshold IR(SNOW)} - 500)$$ ***Equation 132***

$$\text{Threshold VIS Min} = \text{Threshold VIS Land}$$ ***Equation 133***

$$\text{Threshold VIS Shadows} = 2000 \cdot \cos\theta_{so}$$ ***Equation 134***

$$\text{Threshold VIS Max} = 7000 \cdot \cos\theta_{so}$$ ***Equation 135***

Threshold VIS3

The determination of the threshold for channel 3a is similar to the determination of Threshold VIS1 and Threshold VIS2 in case of daylight conditions: In the first step, the coefficients coefficients a_0, a_1, and a_2 are computed in dependence of the angular relationships and the water vapour and ozone content. According to a model of Le Roux, the reflectance alb_{snow} is calculated depending on the satellite and solar angles, respectively. The corresponding value is extracted from linearly interpolating the reflectance values given in a look-up table . The angular resolutions of these values are 10 ° for Θ_{sa} ranging between 0°and 70°, 45° for $\Delta\varphi$ between 0 ° and 180 °, and 10 ° for Θ_{so} between 40 ° and 90 °. For $\Theta_{so} \leq 40$ °, the values of the tabulated reflectance for $\Theta_{so} = 40$ ° are used.

The Threshold VIS3 is given by:

$$\text{Threshold VIS3} = 100 \times \left(a_0 + \frac{a_1 \cdot alb_{snow}}{1 - (a_2 \cdot alb_{snow})} \right) \times \cos\theta_{so}$$

Equation 136

The coefficients a_0, a_1, and a_2 of the atmospheric correction are computed in the same way as for the threshold over land and sea, but with values of the coefficients adapted to the radiative properties of channel 3.

5.4.4.5.5.1 Snow and Ice Detection Test Sequence

The test sequence is performed only if $\Theta_{so} \leq 83$ °

$T4 \leq 27915$
$T4 \geq$ Threshold IR(SNOW) for snow (over land only):
$A1 \geq$ Threshold VIS Min
$A1 \leq$ Threshold VIS Min for ice (over sea only):
$A2 \geq$ Threshold VIS Min
$A2 \leq$ Threshold VIS Max for snow and ice (over land and sea):
$A2 \geq$ Threshold VIS shadows
$A3 <$ Threshold VIS3 (if channel 3a is available for plains–altitude ≤ 700m)
$-20 \leq T4 - T5 \leq 200$
$A3 <$ Threshold VIS3 (if channel 3a is available For mountains – altitude > 700m): no additional test

If all test criteria are fulfilled, then classify pixel as Snow/Ice.

5.4.4.6 Sea Surface Temperature Retrieval Function

To establish the boundary conditions, the surface characteristics of the retrieval profile need to be known. This functionality determines the sea surface temperature in cloud free areas, based on split or triple window techniques with the AVHRR/3 Infrared channels. The cloud mask (Clear/Cloudy flag) as well as the Land/ Sea mask (Land/Sea/Coast flag) are taken into account

(AVHRR_L1_PGS_DAT_LAMASK, See Annex B). The coefficients a_1, b_1, c_1, d_1 for the split window technique, and the coefficients a_2, b_2, c_2, d_2, e_2, f_2 for the use of three channels, respectively, will be user-configurable (AVHRR_L1_PGS_COF_SSTSW). Depending on the availability of the channels (*T*3, *T*4, and *T*5–or *T*4 and *T*5 only), the sea surface temperature *SST* is computed according to ($\chi = \cos\theta_{sa}^{-1} - 1$):

$$SST = a_1 + b_1 \cdot T4 + c_1 \cdot \chi \cdot (T4 - T5) + d_1 \cdot (T4 - T5)^2 ; if(\theta_{so} \le 110°)$$

Equation 137

$$SST = a_2 + b_2 \cdot T3 + c_2 \cdot (T3 - T4) + d_2 \cdot (T4 - T5) + e_2 \cdot \chi \cdot (T4 - T5); if(\theta_{so} > 110°)$$

Equation 138

5.4.4.7 Cloud-Top Temperature Retrieval Function

For pixels identified as cloudy, this functionality retrieves the Cloud Top Temperature (*CTT*). A simple black-body check is performed according to the following:

$$T4 - T5 < 100 \Rightarrow blackbody$$

Equation 139

If Equation 139 is valid, then

$$CTT = T4$$

Equation 140

5.4.4.8 Surface Temperature Retrieval Function

For pixels identified as cloud free, this functionality retrieves the surface temperature T_{Surf}. As in the case of the *SST* computation, the algorithm depends on the availability of Channel 3b:

$$T_{Surf} = a_3 + b_3 \cdot T4 + c_3 \cdot \chi \cdot (T4 - T5) + d_3 \cdot (T4 - T5)^2 ; if(\theta_{so} \le 110°)$$

Equation 141

$$T_{Surf} = a_4 + b_4 \cdot T3 + c_4 \cdot (T3 - T4) + d_4 \cdot (T4 - T5)^2 + e_4 \cdot \chi \cdot (T4 - T5); if(\theta_{so} > 110°)$$

Equation 142

The coefficients a_3, b_3, c_3 and a_4, b_4, c_4, d_4, e_4, shall be user-configurable (AVHRR_L1_PGS_COF_SSTSW).

5.5 Handling of Edge-of-Dump/Data-Gap Conditions

At the edge of a dump as well as at possible data gaps, the calibration procedure is applied as follows: in the case of data gaps, the calibration is performed with x-n scan lines for the scan line x, where x denotes the last scan line before the gap, and with the x' + n lines after the gap, where x' denotes the first good scan line after the gap. The number n is the total number of one calibration cycle–. nominally 55 scan lines.

If a dump between two data gaps comprises less than 55 scan lines, all the scan lines within this dump are used for the calibration and hence, the calibration cycle contains less than 55 scan lines.

5.6 Non-nominal Processing

Non-nominal processing includes all cases where incomplete or degraded data are processed. To identify those data sets, the following indicators should be set each scan line (abbreviations for each indicator are given in rectangular brackets):

Instrument Status (if all following flags are set to 1, the nominal instrument status is given)	
a. Motor/telemetry (0 = off, 1= on)	[*I*MoT]
b. Electronics/telemetry (0 = off, 1= on)	[*I*ElT]
c. Channel 1 status (0 = disable, 1= enable)	[*I*Ch1]
d. Channel 2 status (0 = disable, 1= enable)	[*I*Ch2]
e. Channel 3A status (0 = disable, 1= enable)	[*I*Ch3a]
f. Channel 3B status (0 = disable, 1= enable)	[*I*Ch3b]
g. Channel 4 status (0 = disable, 1= enable)	[*I*Ch4]
h. Channel 5 status (0 = disable, 1= enable)	[*I*Ch5]
i. Voltage calibrate status (0 = off, 1= on)	[*I*VoC]
j. Cooler Heat (0 = off, 1= on)	[*I*CoH]
k. Scan motor (0 = low, 1= high)	[*I*ScM]
l. Earth shield (0 = disable, 1= deploy)	[*I*EaS]

Time sequence	
a. Time field is bad but can probably be inferred from the previous good time	*T*InfPT]
b. Time field is bad and can't be inferred from the previous good time	*T*NInfPT]
c. This scan line starts a sequence that is inconsistent with previous times (if there is a time discontinuity). This may or may not be associated with a spacecraft clock update.	[*T*IncPT]
d. Start of a sequence that apparently repeats scan times that have been previously accepted.	[*T*RepPT]
e. Scan time not corrected for clock drift	[*T*NCorr]

Earth location	
a. No earth location of the scan line because of bad time stamp	[*E*BadT]
b. Earth location of the scan line questionable	[*E*Ques]
c. Earth location questionable — only marginal agreement with reasonableness check	[*E*MagC]
d. Earth location questionable— fails reasonableness check	[*E*FailC]

Calibration	
a. Scan line was not calibrated because of bad time	[*C*BadT]
b. Scan line was calibrated but with fewer than the preferred number (55) of scan line information because of proximity to start or end of dump or to missing scan lines	[*C*FewInf]
c. Scan line is not calibrated because of bad or insufficient PRT data	[*C*BadPRT]
d. Scan line was calibrated with a reduced number of PRT data	[*C*FewPRT]
e. Uncalibrated channels in this scan line	[*C*UncCh]

Navigation	
a. Ephemeris file older than one day	[*N*EpOld]
b. No earth location	[*N*NoLoc]
c. Attitude exceeds nominal tolerance	[*N*AttEx]
d. Rate nulling mode	[*N*RNMo]
e. YGC mode	[*N*YGCMo]
f. Search mode	[*N*SeaMo]
g. Coast mode	[*N*CoaMo]
h. Yaw axis test in progress	[*N*Ytest]
i. Roll axis test in progress	[*N*Rtest]
j. Pitch axis test in progress	[*N*Ptest]

Table 11 that follows summarizes the non-nominal processing indicators, their influence on distinct processing steps, and the effectiveness on the operational processor.

Note: All processing steps are explained in Table 12 that follows Table 11.

Summary of Non-nominal Processing Indicators

Non-Nominal Situation	*Affected Processing Step*	*Operational Situation*	*Influence on Processing*
*I*MoT	A2, A3, A4 and all lower levels	No data	No processing possible
*I*ElT	A2, A3, A4 and all lower levels	No data	No processing possible
*I*Ch1	A2, A21, A212, A2121, A3, A32, A321, A322, A33, A333 and lower levels, A34, A343, A344	No Ch1 data	No Channel 1 processing, landmark navigation without NDVI test, scenes analysis without reflectance test over land and with degraded snow/ice detection
*I*Ch2	A2, A21, A212, A2121, A3, A32, A321, A322, A33, A333 and lower levels, A34, A343, A344	No Ch2 data	No Channel 2 processing, landmark navigation without NDVI and reflectance test, scenes analysis without reflectance test over sea and with degraded snow/ice detection
*I*Ch3a	A2, A21, A212, A2121, A3, A32, A321, A322, A34, A343, A344	No Ch3a data	No Channel 3a processing, scenes analysis with degraded snow/ice test
*I*Ch3b	A2, A21, A211 and lower levels, A31, A311, A312, A34, A343, A344	No Ch3b data	No Ch3b processing, scenes analysis without brightness temperature difference tests: T11µm – T3.7µm T3.7µm – T12µm, computation of *SST* and *TSurf* without T3.7µm
*I*Ch4	A211 and lower levels, A31, A311, A312, A33, A333 and lower levels, A34, A343, A333, A344	No Ch4 data	No Ch4 processing, landmark navigation without brightness temperature and brightness temperature difference test, scenes analysis without tests: T11µm T11µm- T12µm T11µm-T3.7µm T11µmSpatial Coherence, no *SST*, *TSurf* and *CTT* computation

Summary of Non-nominal Processing Indicators

Non-Nominal Situation	*Affected Processing Step*	*Operational Situation*	*Influence on Processing*
*I*Ch5	A2, A21, A211 and lower levels, A31, A311, A312, A33, A333 and lower levels, A34, A343, A333, A344	No Ch5 data	No Channel 5 processing, degraded landmark navigation without brightness temperature difference test, scenes analysis without tests: T11µm–T12µm T3.7µm–T12µm, use T11µm as *SST*, *TSurf* and *CTT*
*I*VoC	A2, A3, A4, and lower levels	No data	No processing possible
*I*CoH	A2, A21, A3,		
*I*ScM *I*EaS	A31, A32, A33, A34, A333, A343, A344	Degraded data	Processing of degraded radiances, target reflectance factors, and brightness temperatures, degraded landmark navigation, degraded scenes analysis
*T*InfPT	A2, A22 and lower levels, A23, A34, A341	Degraded time stamp	Processing of degraded geolocation information, degraded scenes analysis
*T*NInfPT	A2, A22 and lower levels, A23, A333 and lower levels, A334, A34 and lower levels	No time stamp	No geolocation data, no angular relations, no scenes analysis
*T*IncPT, *T*RepPT, *T*NCorr	A22 and lower levels, A23, A34	Degraded time stamp	Processing of degraded geolocation, degraded scenes analysis
*E*BadT	A2, A22 and lower levels, A23, A333 and lower levels, A334, A34 and lower levels	No satellite position and velocity	No geolocation, no angular relations, no scenes analysis
*E*Ques *E*MagC *E*FailC	A22 and lower levels, A23, A34	Degraded information on satellite position and velocity	Processing of degraded geolocation, degraded scenes analysis

Summary of Non-nominal Processing Indicators			
Non-Nominal Situation	***Affected Processing Step***	***Operational Situation***	***Influence on Processing***
*C*BadT *C*FewInf *C*BadPRT *C*FewPRT *C*UncCh	A211 and lower levels, A31, A311, A312, A34, A333 and lower levels	Degraded or incomplete input data for Ch3b, Ch4, and Ch5 calibration	Use previous or prelaunch calibration data Processing of degraded IR radiances and brightness temperatures, degraded landmark navigation, degraded scenes analysis
*N*EpOld	A22, A23, A33, A34	Degraded ephemeris data	Use latest available ephemeris file Processing of degraded geolocation, degraded scenes analysis
*N*NoLoc	A2, A22 and lower levels, A23, A333 and lower levels, A334, A34 and lower levels	No information about geolocation	No geolocation, no angular relations, no scenes analysis
*N*AttEx *N*RNMo *N*YGCMo *N*SeaMo *N*CoaMo *N*Ytest *N*Rtest *N*Ptest	A22, A23, A33, A34	Degraded satellite attitude	Processing of degraded geolocation, degraded scenes analysis

Table 11: Summary of Non-nominal Processing Indicators

Processing Steps Nomenclature Key

Step	*Means*
A0	EPS AVHRR/3 Level 1 Product Generation
A1	Accept and Validate Level 0 and Auxiliary Data
A11	Receive & Validate Level 0 Dataflow
A12	Receive, Validate and Correlate Side-Information
A13	Prepare Level 0 Appended Information
A2	Level 1a Processing Calculation of Calibration Coefficients, Geolocation and Angular Relations for Tie Points
A21	Calculation of Calibration Coefficients
A211	Infrared Channels Calibration
A2111	Compute Mean Space and Internal Target Counts
A2112	Compute PRT Temperatures
A2113	Compute Internal Warm Target Temperatures and Convert to Radiances
A2114	Compute Gain and Intercept
A2115	Compute Calibration Coefficients
A212	Visible Channel Calibration
A2121	Select Gain and Intercept According to Count Value
A22	Geolocation for Tie Points
A221	Compute the Antenna-Mounting-Frame Vectors XAMP, YAMP, ZAMP
A222	Compute Scanning Angle
A223	Compute the Spin Vector
A224	Compute Direction Cosines in the Mean-of-Date Coordinate System
A225	Solve Second Order Equation for the Distance between Instrument and Scan Spot
A226	Compute Scan Vector in the Mean-of-Date and Earth Fixed Coordinate System (Geolocation of the Scan Spot)
A23	Satellite and Solar Zenith and Azimuth Angles for Tie Points
A24	Prepare Level 1a Appended Information
A3	Level 1b Processing, Scenes Analysis, Geolocation and Angular Relations with Full Resolution
A31	Compute IR Radiances and Brightness Temperatures
A311	Compute Infrared Radiances
A312	Compute Brightness Temperatures
A32	Compute VIS Radiances and Reflectance Factors
A321	Compute Target Reflectance Factors
A322	Compute Radiances Visible
A33	Perform Geolocation and Landmark Navigation
A333	Check Geolocation using Landmarks
A3331	Select Landmarks Within Actual Swath

Step	***Means***
A3332	Create Reference Land-Sea Mask
A3333	Create Actual Land-Sea Mask
A3334	Compute Similarity Coefficient and Determine Best Fit
A3335	Select Active Landmarks
A331	Compute Geolocation for each Pixel
A332	Determine Surface Type
A333	Check Geolocation using Landmarks
A3331	Select Landmarks Within Actual Swath
A3332	Create Reference Land-Sea Mask
A3333	Create Actual Land-Sea Mask
A3334	Compute Similarity Coefficient and Determine Best Fit
A3335	Select Active Landmarks
A334	Calculate Angular Relationships for each Pixel
A34	Scenes Analysis
A341	Check Day, Night, Sunglint, Month, and Channel Availability
A342	Determine Surface Elevation
A343	Perform Threshold Tests According to Selected Configurable Data Bases
A344	Determine Cloud Contamination Surface Temperature, and/or Cloud Top Temperature
A4	Online Quality Control
A5	Reporting Statistics Production

Table 12: Processing Steps Key

Appendix A: List Of Equations Symbols

Derived from the processing steps detailed above, the following table presents the list of the parameters, coefficients and intermediate values used to translate the earth view counts into calibrated radiances for the AVHRR/3 instrument. Column O indicates the origin of the variable:

C means *Computed*
M means *for Measurement data*
Aux means *auxiliary* data
Anc means *ancillary* data.

Symbol	*Description*	O
R_S	earth view calibrated radiances	C
X_s	earth view counts	M
X_{ict}	warm internal target counts	M
X_{sp}	cold space target counts	M
R_{ict}	radiance of the warm internal target computed from the PRT measurements	C
R_{sp}	computed radiance of the cold space target	C
G_{IR}	gain of the 2-point law calibration	C
I_{IR}	intercept of the 2-point law calibration	C
A	coefficient for the computation of the coefficients a_0, a_1 and a_2	C
B	coefficient for the computation of the coefficients a_0, a_1 and a_2	C
C	coefficient for the computation of the coefficients a_0, a_1 and a_2	C
a_0	zero-order calibration coefficient for the computation of the calibrated radiance	C
a_1	first-order calibration coefficient for the computation of the calibrated radiance	C
a_2	second-order calibration coefficient for the computation of the calibrated radiance	C
X_i	count for the i-th PRT (i = 1,..4)	C
$\overline{X_i}$	mean count (averaged over 11 scan lines) for the i-th PRT	C
$C_{i(i = 0,1,2)}$	polynomial coefficients for the computation of the PRT temperature	C
T_i	estimated temperature computed from Xi	C
ΔT	internal target temperature correction factor	Aux
b_i	weighting function for the computation of the PRT temperature	Aux
$\overline{T}$	estimated temperature of the internal warm target	C
γ	wave number	C
ϕ	instrument spectral response function (discretised)	Aux
γ_1, γ_2	lower and upper spectral limits of the channels	Aux
$\Delta\gamma_i$	spectral discretisation for the radiance computation	Aux

Symbol	*Description*	O
$B(\gamma,T)$	Planck function	C
C_1	first constant of the Planck function	Aux
C_2	second constant of the Planck function	Aux
A_{lin}	intercept for the conversion from effective temperature to brightness temperature (different values for channels 3b, 4, and 5)	Aux
B_{lin}	slope for the conversion from effective temperature to brightness temperature (different values for channels 3b, 4, and 5)	Aux
R_{lin}	calibrated radiances (linear calibration approximation)	C
$G(X_s)$	Gain of linear calibration as a function of counts for channels 1,2, and 3a	Aux
$I(Xs)$	Intercept of linear calibration as a function of counts for channels 1,2, and 3a	Aux
R_{VIS}	Visible scene radiance	C
F	Integrated solar spectral irradiance weighted by the spectral response function	Aux
W	Equivalent width of the spectral response function	Aux
$\overline{r_{qm}}$	Position of the satellite in the Mean-of-Date coordinate frame	C
$\overline{v_{qm}}$	Velocity of the satellite in the Mean-of-Date coordinate frame	C
t	Standard time (UTC)	C
$\overline{L_{qm}}$	Position of the scan spot in the Mean-of-Date coordinate frame	C
$\overline{d_{qm}}$	Direction cosines of the scan line in the Mean-of-Date coordinate frame	C
X_{AMP}, Y_{AMP}, Z_{AMP}	Antenna Mounting reference frame directions	C
X_S, Y_S, Z_S	Satellite Reference frame	C
$\hat{s}$	Spin vector	C
$\hat{d}$	Unit vector in scan direction	C
σ	Scanning angle of the instrument	C
a_E	Semi-major axis of the Earth ellipsoid	Aux
b_E	Semi-minor axis of the Earth ellipsoid	Aux
A_R, B_R, C_R	Coefficients for the solution of the geolocation equation	C
$\vec{L}_E$	Position of the scan spot in the Earth Fixed coordinate frame	C
$G(t)$	Greenwich Hour Angle	C
G_0	East longitude of Greenwich at the beginning of the year	Aux
λ_{geo}	Geodetic Longitude	C
φ_{geo}	Geodetic Latitude	C

Symbol	*Description*	O
$\overline{r_{sat}(E)}$	Satellite position in the Earth-fixed coordinate system	C
$\overline{r_{sat}(St)}$	Satellite position in the station local reference frame	C
dd_{cen}	Century day	C
R_c	Fraction of days elapsed in one century	C
L	Mean longitude of the sun	C
e	Solution for the equation of time	C
δ_{so}	Declination of the sun	C
Λ	Local hour angle	C
A1	Channel 1 reflectance	C
A2	Channel 2 reflectance	C
A3	Channel 3a reflectance	C
T3	Channel 3b brightness temperature	C
T4	Channel 4 brightness temperature	C
T5	Channel 5 brightness temperature	C
NDVI	Normalized Difference Vegetation Index	C
$S(i,j)$	Similarity coefficient between reference window and actual window	C
N_x, N_y	Extension of the binary window across and along the flight direction	C
Ref	Label for the reference windows	
Act	Label for the actual windows	
Δx, Δy	Geographical correction across and along the flight direction in pixel Coordinates	C
T23	AMSU-A brightness temperature at 23 GHz	C
T31	AMSU-A brightness temperature at 31 GHz	C
T50	AMSU-A brightness temperature at 50 GHz	C
Z	Viewing angle of AMSU-A	C
VAP	Water vapour content retrieved from AMSU-A measurements	Aux
cst_x	Threshold for a distinct test *x*	Aux
s_{ir}	Threshold for an IR test depending on the solar azimuth	Aux
sature3	Channel 3b saturation threshold	Aux
separ1637	Threshold for the channel 3a/3b discrimination	Aux
Θ_{SO}, Θ_S	Solar zenith angle	C
μ_{so}	Cosine of the solar zenith angle	C
Θ_{SA}, Θ_L	Satellite zenith angle	C
φ_{SO}, φ_{SA}	Solar and satellite azimuth angles	C
μ_n	Criterion for sunglint conditions	C
ψ	Cosine of the angle sun-reference point-satellite	C

Symbol	Description	O
sst_{clim}	Surface temperature climatology	Aux
$T2m_{prev}$	Air temperature at 2m from forecast	Aux
$T4_{max}$	Maximum channel 4 brightness temperature within a 3x3 pixels box	C
Ψ_1, Ψ_2	Variables calculated from Ψ	C
n_r, n_i	Real and imaginary part of the refractive index of water at 0.9 µm	Aux
A_1, A_2	Variables for the calculation of Fresnel coefficient	C
u, v	Variables for the calculation of Fresnel coefficient	C
B_1, B_2	Variables for the calculation of Fresnel coefficient	C
R_1, R_2	Components of the Fresnel coefficient	C
$R_{Fresnel}$	Fresnel Coefficient	C
ww	Threshold for the sea surface reflectance determination	C
$suralb$	Reflectance of sea surface at 0.9 µm	C
T_{H2O}, T_{O3}, T_{O2}	Atmospheric transmission of water vapour, ozone, and air molecules at 0.9 µm, 0.6 µm, and 1.6 µm ***Note:*** These data depend on the instrument spectral response function.	Aux
ξ	Conversion from vertical transmission to slant path transmission	C
T_{diff}	Diffuse transmission at 0.9 µm, 0.6 µm, and 1.6 µm ***Note***: These data depend on the instrument spectral response function ϕ.	Aux
ρ_a	Atmospheric emission ***Note***: These data depend on the instrument spectral response function ϕ.	Aux
alb_{clim}	Land surface reflectance at 0.6 µm from climatology ***Note***: these data depend on the instrument spectral response function ϕ.	Aux
k_1, k_2	Coefficients for the calculation of the surface reflectance at 0.6 µm.	Aux, C
f_1, f_2	Parameters with the geometrical information for the calculation of the surface reflectance At 0.6 µm.	C
$brdf$	Anisotropic correction factor of the surface reflectance at 0.6 µm.	C
a_0, a_1, a_2	Coefficients for the atmospheric correction of the surface reflectances at 0.9 µm, 0.6 µm, and 1.6 µm.	C
$SDT4$	Standard deviation of $T4$ for 3 × 3 pixels	C
alb_{snow}	Snow surface reflectance at 1.6 µm from climatology ***Note***: These data depend on the instrument spectral response function ϕ.	Aux
SST	Sea surface temperature	C
χ	Parameter for the surface temperature calculation	C
T_{Surf}	Land surface temperature	C

Table 13: AVHRR/3 Preliminary List of Symbols

Appendix B: Configurable Auxiliary Data Sets

Identifier	*Contents of data set*
AVHRR_L1_PGS_COF_CAL	AVHRR calibration parameters data set, containing for all AVHRR instruments PRT count conversion coefficients, PRT weighting factors, visible and near IR coefficients (Dual Slope and Intercept), equivalent widths, central wavelength, integrated solar irradiance, count limits for space view, Black body view, thermistor counts, visible counts, radiance correction coefficients, space radiance, band corrections
AVHRR_L1_PGS_DAT_LAMASK	Geographical land-sea distribution and land surface type
AVHRR_L1_PGS_DAT_SFCTOP	Geographical land-surface topography distribution
AVHRR_L1_PGS_DAT_CLISST	Climatological monthly mean values of surface temperature at MSL
AVHRR_L1_PGS_DAT_CLIALB	Atlas for the land surface reflectance (monthly mean values)
AVHRR_L1_PGS_DAT_CLICWV	Atlas for the global total column water vapour distribution (monthly mean values)
AVHRR_L1_PGS_COF_SSTSW	Coefficients used to determine sea or land surface temperature for pixels detected as cloud free.
AVHRR_L1_PGS_COF_NAV	Configurable navigation parameters, interpolation width for pixel and lines tie points of navigation information
AVHRR_L1_PGS_DAT_LANMARK	Landmark data set for the navigation step
AVHRR_L1_PGS_DAT_ASTRO	Data set with Astronomical information and Earth parameters
AVHRR_L1_PGS_DAT_THRES	Thresholds for the brightness temperature difference tests in the scenes analysis
AVHRR_L1_PGS_DAT_SCENE	All coefficients needed for the threshold determination of the scenes analysis
AVHRR_L1_PGS_COF_ISRF	Normalised window response functions and central wave numbers
AVHRR_L1_PGS_DAT_TRAMI	Values for the atmospheric transmission of water vapour, ozone, and air for the channels 1,2,and 3a
AVHRR_L1_PGS_DAT_SNOW	Values for the angular dependent snow surface reflectance for the channels 1,2,and 3a

Identifier	*Contents of data set*
AVHRR_L1_PGS_DAT_FORT2M	Global data set with actual forecasted air temperature at 2 m altitude
AVHRR_L1_PGS_DAT_FORCWV	Global data set with actual forecasted total column water vapour content
AVHRR_L1_PGS_DAT_AMSUBT	Time synchronized brightness temperatures from actual AMSU-A measurements for 23, 31, and 50 GHz
AVHRR_L1_PGS_COF_AVHSCE	Data set containing the following scenes analyses output: • cloud contamination and for cloudy conditions, cloud top temperature • for cloud-free conditions, surface temperature • surface elevation • surface type (land/sea) • time of the beginning of the scan line and pixel number • radiances

Table 14: List of configurable auxiliary data sets

Appendix C: Sample Auxiliary Data Set with Calibration Parameters (AVHRR Level 1a)

```
################################################################
### ###
### AVHRR calibration parameters data set ###
### ###
### version 02 added FM-203 satellite parameters ###
### version 03 added FM-302 satellite NOAA-K parameters ###
################################################################
03 ; version number
98 ; year of the version
092 ; day of year of the version
## satellite independent coefficients ##
## First & second radiation constants mW/(sqm.ster.cm^-4) & K/cm^-1 ##
1.191044D-05 , 1.438769
## noaa11 #### NOAA11 #### NOAA11 #### NOAA11 #### NOAA11 #### NOAA11 ##
#AVHRR FM-203
# PRT count to temperature conversion coefficients #
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
#
# PRT weighting factors #
0.25,0.25,0.25,0.25
# AVHRR FM-203 VISIBLE COEFFICIENTS #
# line 1 channel 1
# line 2 channel 2
# if channel 3A ==> line 3
#
0.095,0.095,-3.780,-3.780, ! for NOAA-K two slopes
0.09,0.09,-3.60,-3.60, ! and intercepts are provided
#
# equivalent widths, integrated solar irradiance, effective central wavelength
# from Neckel and Labs 1984
#
0.113,189.02, 0.635
0.229,237.71, 0.831
#
# AVHRR FM-203 Normalized RESPONSE FUNCTIONS
#
AVHRR CHANNEL 3
STARTING WAVE # 2484.47217
INCREMENT 7.13929
NUMBER OF POINTS 60
0.00000D+00 0.10945D-04 0.28150D-04 0.60983D-04 0.14006D-03
0.30581D-03 0.61175D-03 0.11183D-02 0.17813D-02 0.24182D-02
0.28923D-02 0.32167D-02 0.34267D-02 0.35421D-02 0.35775D-02
0.35651D-02 0.35534D-02 0.35689D-02 0.35852D-02 0.35727D-02
0.35346D-02 0.34888D-02 0.34493D-02 0.34248D-02 0.34216D-02
```

```
0.34349D-02 0.34568D-02 0.34775D-02 0.34852D-02 0.34733D-02
0.34581D-02 0.34613D-02 0.34858D-02 0.35114D-02 0.35197D-02
0.35126D-02 0.34999D-02 0.34871D-02 0.34715D-02 0.34493D-02
0.34129D-02 0.33519D-02 0.32592D-02 0.31470D-02 0.30333D-02
0.29110D-02 0.27154D-02 0.23767D-02 0.19012D-02 0.13852D-02
0.92617D-03 0.56593D-03 0.30800D-03 0.15192D-03 0.74249D-04
0.41157D-04 0.22843D-04 0.10043D-04 0.34684D-09 0.00000D+00
AVHRR CHANNEL 4
STARTING WAVE # 854.70068
INCREMENT 2.50516
NUMBER OF POINTS 60
0.12838D-04 0.00000D+00 0.00000D+00 0.56581D-04 0.17545D-03
0.31639D-03 0.42930D-03 0.52284D-03 0.79863D-03 0.14977D-02
0.27592D-02 0.43408D-02 0.59102D-02 0.71887D-02 0.81658D-02
0.89152D-02 0.95077D-02 0.99887D-02 0.10391D-01 0.10748D-01
0.11065D-01 0.11329D-01 0.11527D-01 0.11658D-01 0.11748D-01
0.11821D-01 0.11901D-01 0.11991D-01 0.12088D-01 0.12191D-01
0.12297D-01 0.12406D-01 0.12517D-01 0.12627D-01 0.12724D-01
0.12794D-01 0.12827D-01 0.12830D-01 0.12826D-01 0.12838D-01
0.12845D-01 0.12645D-01 0.11996D-01 0.10657D-01 0.86431D-02
0.63424D-02 0.41718D-02 0.25247D-02 0.14741D-02 0.86297D-03
0.52935D-03 0.32464D-03 0.19180D-03 0.11184D-03 0.65860D-04
0.37159D-04 0.19221D-04 0.84591D-05 0.12845D-05 0.00000D+00
AVHRR CHANNEL 5
STARTING WAVE # 781.24976
INCREMENT 2.06295
NUMBER OF POINTS 60
0.13817D-03 0.13106D-03 0.13327D-03 0.15412D-03 0.19677D-03
0.24099D-03 0.26101D-03 0.27834D-03 0.51016D-03 0.12242D-02
0.26155D-02 0.44979D-02 0.65607D-02 0.85105D-02 0.10182D-01
0.11472D-01 0.12285D-01 0.12691D-01 0.12880D-01 0.13042D-01
0.13290D-01 0.13626D-01 0.14043D-01 0.14516D-01 0.14965D-01
0.15298D-01 0.15437D-01 0.15392D-01 0.15223D-01 0.14989D-01
0.14741D-01 0.14516D-01 0.14351D-01 0.14271D-01 0.14252D-01
0.14254D-01 0.14235D-01 0.14171D-01 0.14062D-01 0.13910D-01
0.13708D-01 0.13402D-01 0.12918D-01 0.12181D-01 0.11144D-01
0.98207D-02 0.82362D-02 0.64174D-02 0.44925D-02 0.26917D-02
0.12499D-02 0.37444D-03 0.15195D-04 0.00000D+00 0.82010D-04
0.15007D-03 0.15868D-03 0.12764D-03 0.76770D-04 0.00000D+00
# CENTRAL WAVE NUMBERS, AVHRR FM-203
# TEMP CHANNEL 3 CHANNEL 4 CHANNEL 5
180 - 225 2663.50 926.81 841.40
225 - 275 2668.15 927.36 841.81
275 - 320 2671.40 927.83 842.20
270 - 310 2670.96 927.75 842.14
#
# space view counts limits min,max
1,100 ! channel 1
1,100 ! channel 2
880,1023 ! channel 3
880,1023 ! channel 4
880,1023 ! channel 5
```

```
# Black Body view counts limits min,max
400,1023 ! channel 3
250,1023 ! channel 4
250,1023 ! channel 5
# Black body thermistor counts min,max
100,500
100,500
100,500
100,500
# visible count where apply the second coefficient set to visible channels
512 channel 1
512 channel 2
# Radiance correction for AVHRR FM-203
# Channel 3 Channel 4 Channel 5
Coefficient A : 1.0000000 0.8412000 0.9460000
Coefficient B : 0.0000000 0.0008739 0.0002504
Coefficient C : 0.0000000 7.2100000 2.9200000
Space Radiance RSP: 0.0000 -8.05 -3.51
#
# band corrections
#
2684.255, 1.81748, 0.99758,
927.743, 0.34952, 0.99879,
841.959, 0.24968, 0.99906,
## noaa12 #### NOAA12 #### NOAA12 #### NOAA12 #### NOAA12 #### NOAA12 ##
#AVHRR FM-205
# PRT count to temperature conversion coefficients #
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
#
# PRT weighting factors #
0.25,0.25,0.25,0.25
# AVHRR FM-205 VISIBLE COEFFICIENTS #
# line 1 channel 1
# line 2 channel 2
# if channel 3A ==> line 3
#
0.1042235,0.1042235,-4.4490805,-4.4490805, ! for NOAA-K two slopes
0.1014400,0.1014400,-3.9925614,-3.9925614, ! and intercepts are provided
#
# equivalent widths, integrated solar irradiance, effective central wavelength
# from Neckel and Labs 1984
#
0.124 ,200.1, 0.638
0.219, 229.9, 0.8335
#
# AVHRR FM-205 Normalized RESPONSE FUNCTIONS
#
AVHRR CHANNEL 3
STARTING WAVE # 2439.02393
```

```
INCREMENT 9.41466
NUMBER OF POINTS 60
0.44399D-04 0.43179D-04 0.55936D-04 0.97795D-04 0.18920D-03
0.37930D-03 0.75692D-03 0.14601D-02 0.23085D-02 0.28790D-02
0.31477D-02 0.32420D-02 0.32708D-02 0.33021D-02 0.33566D-02
0.34098D-02 0.34272D-02 0.34366D-02 0.34663D-02 0.35015D-02
0.35179D-02 0.34885D-02 0.34301D-02 0.33948D-02 0.33967D-02
0.34267D-02 0.34769D-02 0.35333D-02 0.35484D-02 0.34981D-02
0.34954D-02 0.36188D-02 0.36995D-02 0.35961D-02 0.34420D-02
0.33216D-02 0.29562D-02 0.21401D-02 0.12370D-02 0.65119D-03
0.35555D-03 0.21053D-03 0.14129D-03 0.10082D-03 0.73649D-04
0.60597D-04 0.56961D-04 0.53706D-04 0.47812D-04 0.44102D-04
0.45278D-04 0.47985D-04 0.48839D-04 0.48308D-04 0.47904D-04
0.47980D-04 0.48140D-04 0.48160D-04 0.48099D-04 0.00000D+00
AVHRR CHANNEL 4
STARTING WAVE # 847.45752
INCREMENT 2.80419
NUMBER OF POINTS 60
0.23528D-03 0.24989D-03 0.24905D-03 0.21907D-03 0.20944D-03
0.34807D-03 0.75972D-03 0.15077D-02 0.26267D-02 0.40744D-02
0.55908D-02 0.68815D-02 0.78196D-02 0.84976D-02 0.90207D-02
0.94608D-02 0.98665D-02 0.10275D-01 0.10653D-01 0.10935D-01
0.11072D-01 0.11104D-01 0.11095D-01 0.11102D-01 0.11148D-01
0.11250D-01 0.11415D-01 0.11628D-01 0.11867D-01 0.12104D-01
0.12293D-01 0.12382D-01 0.12336D-01 0.12206D-01 0.12071D-01
0.11983D-01 0.11819D-01 0.11368D-01 0.10435D-01 0.90487D-02
0.74144D-02 0.57432D-02 0.41985D-02 0.28674D-02 0.18300D-02
0.11384D-02 0.73017D-03 0.51293D-03 0.39701D-03 0.33244D-03
0.30034D-03 0.28265D-03 0.26617D-03 0.25081D-03 0.23872D-03
0.23185D-03 0.23012D-03 0.23183D-03 0.23528D-03 0.00000D+00
AVHRR CHANNEL 5
STARTING WAVE # 787.40137
INCREMENT 2.09809
NUMBER OF POINTS 60
0.34277D-03 0.81468D-04 0.75120D-04 0.57879D-03 0.17627D-02
0.34788D-02 0.55052D-02 0.76087D-02 0.95132D-02 0.10932D-01
0.11658D-01 0.11897D-01 0.11984D-01 0.12216D-01 0.12624D-01
0.13116D-01 0.13603D-01 0.14051D-01 0.14467D-01 0.14858D-01
0.15207D-01 0.15466D-01 0.15585D-01 0.15547D-01 0.15433D-01
0.15340D-01 0.15351D-01 0.15442D-01 0.15531D-01 0.15538D-01
0.15451D-01 0.15348D-01 0.15313D-01 0.15387D-01 0.15383D-01
0.15044D-01 0.14117D-01 0.12541D-01 0.10500D-01 0.81903D-02
0.58119D-02 0.35862D-02 0.17429D-02 0.51081D-03 0.00000D+00
0.00000D+00 0.12053D-03 0.28451D-03 0.32615D-03 0.29113D-03
0.23141D-03 0.19459D-03 0.18866D-03 0.20050D-03 0.21681D-03
0.22623D-03 0.22785D-03 0.22429D-03 0.21813D-03 0.00000D+00
# CENTRAL WAVE NUMBERS, AVHRR FM-205
# TEMP CHANNEL 3 CHANNEL 4 CHANNEL 5
190 - 230 2632.713 920.0158 836.6847
230 - 270 2636.669 920.5504 837.0251
270 - 310 2639.61 921.0291 837.3641
290 - 330 2640.817 921.2741 837.5612
```

```
#
# space view counts limits min,max
1,100 ! channel 1
1,100 ! channel 2
880,1023 ! channel 3
880,1023 ! channel 4
880,1023 ! channel 5
# Black Body view counts limits min,max
400,800 ! channel 3
250,850 ! channel 4
250,850 ! channel 5
# Black body thermistor counts min,max
100,500
100,500
100,500
100,500
# visible count where apply the second coefficient set to visible channels
512 channel 1
512 channel 2
# Radiance correction for AVHRR FM-205
# Channel 3 Channel 4 Channel 5
Coefficient A : 1.0000000 0.8893000 0.9630000
Coefficient B : 0.0000000 0.0005968 0.0001775
Coefficient C : 0.0000000 5.1100000 1.9100000
Space Radiance RSP: 0.0000 -5.51 -2.51
#
# band corrections
#
2653.534, 1.93017, 0.99741,
921.083 , 0.41511, 0.99856,
837.138 , 0.23729, 0.99910,
## noaa14 #### NOAA14 #### NOAA14 #### NOAA14 #### NOAA14 #### NOAA14 ##
#AVHRR FM-204
# PRT count to temperature conversion coefficients #
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
276.597, .051275, 1.363E-06, 0.0, 0.0,
#
# PRT weighting factors #
0.25,0.25,0.25,0.25
# AVHRR FM-204 VISIBLE COEFFICIENTS #
# line 1 channel 1
# line 2 channel 2
# if channel 3A ==> line 3
#
0.1081 ,0.1081 ,-3.8648 ,-3.8648 ! for NOAA-K two slopes
0.1090 ,0.1090 ,-3.6749 ,-3.6749 ! and intercepts are provided
#
# equivalent widths, integrated solar irradiance, effective central wavelength
# from Neckel and Labs 1984
#
```

```
0.136, 221.42, 0.633
0.245, 252.29, 0.842
#
# AVHRR FM-204 Normalized RESPONSE FUNCTIONS
#
AVHRR CHANNEL 3
STARTING WAVE # 2439.02393
INCREMENT 7.92288
NUMBER OF POINTS 60
0.45873D-04 0.52313D-04 0.61172D-04 0.77791D-04 0.11592D-03
0.19256D-03 0.32879D-03 0.55500D-03 0.91766D-03 0.14292D-02
0.20411D-02 0.26523D-02 0.30875D-02 0.32711D-02 0.33031D-02
0.32812D-02 0.32686D-02 0.32987D-02 0.33478D-02 0.33947D-02
0.34446D-02 0.34994D-02 0.35288D-02 0.35051D-02 0.34626D-02
0.34527D-02 0.34667D-02 0.34616D-02 0.34307D-02 0.34035D-02
0.33940D-02 0.33839D-02 0.33583D-02 0.33299D-02 0.33153D-02
0.33055D-02 0.32779D-02 0.32262D-02 0.31661D-02 0.31204D-02
0.31326D-02 0.32400D-02 0.33575D-02 0.33204D-02 0.30323D-02
0.25347D-02 0.18938D-02 0.12394D-02 0.72931D-03 0.43543D-03
0.28618D-03 0.20207D-03 0.14867D-03 0.11270D-03 0.85083D-04
0.65241D-04 0.53482D-04 0.48081D-04 0.45873D-04 0.00000D+00
AVHRR CHANNEL 4
STARTING WAVE # 854.70068
INCREMENT 2.67931
NUMBER OF POINTS 60
0.23014D-03 0.27443D-03 0.34325D-03 0.46112D-03 0.64546D-03
0.90008D-03 0.12278D-02 0.16511D-02 0.22145D-02 0.29604D-02
0.38816D-02 0.49335D-02 0.60684D-02 0.72210D-02 0.83148D-02
0.92778D-02 0.10070D-01 0.10669D-01 0.11054D-01 0.11248D-01
0.11288D-01 0.11218D-01 0.11087D-01 0.10952D-01 0.10867D-01
0.10831D-01 0.10802D-01 0.10738D-01 0.10648D-01 0.10604D-01
0.10683D-01 0.10912D-01 0.11206D-01 0.11463D-01 0.11600D-01
0.11619D-01 0.11555D-01 0.11438D-01 0.11251D-01 0.10932D-01
0.10417D-01 0.96638D-02 0.86844D-02 0.75014D-02 0.61428D-02
0.47139D-02 0.33721D-02 0.22763D-02 0.15297D-02 0.10645D-02
0.78012D-03 0.57781D-03 0.40669D-03 0.26838D-03 0.16717D-03
0.10619D-03 0.78904D-04 0.74105D-04 0.80549D-04 0.00000D+00
AVHRR CHANNEL 5
STARTING WAVE # 787.40137
INCREMENT 1.74978
NUMBER OF POINTS 60
0.10568D-03 0.14907D-03 0.26039D-03 0.49931D-03 0.91686D-03
0.18490D-02 0.39154D-02 0.68996D-02 0.99628D-02 0.12261D-01
0.13237D-01 0.13583D-01 0.14026D-01 0.14395D-01 0.14533D-01
0.14626D-01 0.14784D-01 0.14956D-01 0.15077D-01 0.15088D-01
0.14993D-01 0.14853D-01 0.14730D-01 0.14682D-01 0.14698D-01
0.14731D-01 0.14731D-01 0.14655D-01 0.14508D-01 0.14323D-01
0.14132D-01 0.13963D-01 0.13806D-01 0.13634D-01 0.13416D-01
0.13131D-01 0.12838D-01 0.12645D-01 0.12663D-01 0.12985D-01
0.13384D-01 0.13364D-01 0.12859D-01 0.12317D-01 0.11981D-01
0.11725D-01 0.11199D-01 0.96217D-02 0.66253D-02 0.35059D-02
0.16572D-02 0.90176D-03 0.52967D-03 0.27114D-03 0.12649D-03
```

```
0.72636D-04 0.57373D-04 0.44226D-04 0.30198D-04 0.00000D+00
# CENTRAL WAVE NUMBERS, AVHRR FM-204
# TEMP CHANNEL 3 CHANNEL 4 CHANNEL 5
190 - 230 2638.652 928.2603 834.4496
230 - 270 2642.807 928.8284 834.8066
270 - 310 2645.899 929.3323 835.1647
290 - 330 2647.169 929.5878 835.374
#
# space view counts limits min,max
1,100 ! channel 1
1,100 ! channel 2
880,1023 ! channel 3
880,1023 ! channel 4
880,1023 ! channel 5
# Black Body view counts limits min,max
400,800 ! channel 3
250,850 ! channel 4
250,850 ! channel 5
# Black body thermistor counts min,max
100,500
100,500
100,500
100,500
# visible count where apply the second coefficient set to visible channels
512 ! channel 1
512 ! channel 2
# Radiance correction for AVHRR FM-204
# Channel 3 Channel 4 Channel 5
Coefficient A : 1.00359 0.92378 0.9619400
Coefficient B : 0 0.0003822 0.0001742
Coefficient C : -0.0031 3.72 2.0000000
Space Radiance RSP: 0.0069 -4.05 -2.29
#
# band correction coefficients
#
2659.474 , 1.9837, 0.99733
929.360 , 0.4407, 0.99848
834.602 , 0.2445, 0.99907
## noaa15 #### NOAA15 #### NOAA15 #### NOAA15 #### NOAA15 #### NOAA15 ##
#AVHRR FM-302
# PRT count to temperature conversion coefficients #
276.60157, 0.051045, 1.36328E-06, 0.0, 0.0
276.62531, 0.050909, 1.47266E-06, 0.0, 0.0
276.67413, 0.050907, 1.47656E-06, 0.0, 0.0
276.59258, 0.050966, 1.47656E-06, 0.0, 0.0
#
# PRT weighting factors #
0.25,0.25,0.25,0.25
# AVHRR FM-302 VISIBLE COEFFICIENTS #
# line 1 channel 1
# line 2 channel 2
# if channel 3A ==> line 3
```

```
#
0.0568,0.1633,-2.1874,-54.9928, ! for NOAA-K two slopes
0.0596,0.1629,-2.4096,-55.2436, ! and intercepts are provided
0.0275,0.1846,-1.0684,-78.1691,
#
# equivalent widths, integrated solar irradiance, effective central wavelength
# from Neckel and Labs 1984
#
0.084,138.7, 0.632
0.228,235.4, 0.843
0.044,10.6 , 1.607
#
# AVHRR FM-302 Normalized RESPONSE FUNCTIONS
#
AVHRR CHANNEL 3
STARTING WAVE # 2226.17993
INCREMENT 19.47456
NUMBER OF POINTS 60
0.22480D-06 0.00000D+00 0.00000D+00 0.16012D-06 0.00000D+00
0.00000D+00 0.20434D-04 0.17275D-04 0.00000D+00 0.10168D-06
0.75313D-06 0.40871D-05 0.17785D-04 0.74921D-04 0.22185D-03
0.48267D-03 0.74265D-03 0.99069D-03 0.15417D-02 0.27618D-02
0.39083D-02 0.39820D-02 0.40702D-02 0.42223D-02 0.41632D-02
0.40969D-02 0.40508D-02 0.39408D-02 0.37578D-02 0.35646D-02
0.32795D-02 0.12035D-02 0.18680D-03 0.34077D-04 0.71878D-05
0.16921D-05 0.55911D-06 0.88778D-06 0.00000D+00 0.16001D-06
0.00000D+00 0.55182D-07 0.35867D-06 0.33677D-07 0.20459D-06
0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00 0.68498D-07
0.00000D+00 0.23649D-06 0.45775D-07 0.90267D-07 0.19821D-06
0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00
AVHRR CHANNEL 4
STARTING WAVE # 782.47241
INCREMENT 6.10157
NUMBER OF POINTS 60
0.91441D-05 0.11615D-04 0.00000D+00 0.00000D+00 0.00000D+00
0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00 0.11532D-04
0.00000D+00 0.32498D-05 0.00000D+00 0.20139D-04 0.14238D-03
0.94296D-03 0.37084D-02 0.81656D-02 0.10917D-01 0.11776D-01
0.11977D-01 0.11974D-01 0.11508D-01 0.11398D-01 0.11640D-01
0.11725D-01 0.11593D-01 0.11377D-01 0.11138D-01 0.10369D-01
0.76897D-02 0.40091D-02 0.13444D-02 0.29657D-03 0.54774D-04
0.13854D-04 0.93097D-05 0.53660D-05 0.41669D-05 0.67957D-05
0.36303D-05 0.46783D-05 0.00000D+00 0.11191D-04 0.51980D-05
0.58223D-06 0.20847D-06 0.00000D+00 0.00000D+00 0.76611D-06
0.53901D-05 0.78106D-05 0.00000D+00 0.19177D-05 0.00000D+00
0.00000D+00 0.63347D-05 0.31430D-05 0.00000D+00 0.00000E+00
AVHRR CHANNEL 5
STARTING WAVE # 714.28564
INCREMENT 4.92611
NUMBER OF POINTS 60
0.00000D+00 0.96341D-06 0.00000D+00 0.00000D+00 0.33594D-05
0.00000D+00 0.00000D+00 0.79902D-05 0.00000D+00 0.00000D+00
```

```
0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00
0.00000D+00 0.29595D-04 0.34591D-03 0.36016D-02 0.11767D-01
0.13290D-01 0.13408D-01 0.13770D-01 0.14156D-01 0.14903D-01
0.15807D-01 0.16106D-01 0.15993D-01 0.16047D-01 0.15413D-01
0.13735D-01 0.12254D-01 0.10649D-01 0.16088D-02 0.89934D-04
0.15244D-05 0.00000D+00 0.11269D-04 0.00000D+00 0.00000D+00
0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00
0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00 0.00000D+00
0.11237D-06 0.00000D+00 0.76358D-06 0.79603D-06 0.00000D+00
0.55309D-06 0.00000E+00 0.28316E-05 0.00000E+00 0.00000E+00
# CENTRAL WAVE NUMBERS, AVHRR FM-302
# TEMP CHANNEL 3 CHANNEL 4 CHANNEL 5
180 - 225 2695.97 925.41 839.90
225 - 275 2695.97 925.41 839.90
275 - 320 2695.97 925.41 839.90
270 - 310 2695.97 925.41 839.90
#
# space view counts limits min,max
1,100 ! channel 1
1,100 ! channel 2
1,100 ! channel 3A
880,1023 ! channel 3B
880,1023 ! channel 4
880,1023 ! channel 5
# Black Body view counts limits min,max
400,1023 ! channel 3B
250,1023 ! channel 4
250,1023 ! channel 5
# Black body thermistor counts min,max
100,500
100,500
100,500
100,500
# visible count where apply the second coefficient set to visible channels
496 channel 1
511 channel 2
491 channel 3A
# Radiance correction for AVHRR FM-302
# Channel 3 Channel 4 Channel 5
Coefficient A : 1.0000000 0.9068000 0.9341000
Coefficient B : 0.0000000 0.0004524 0.0002811
Coefficient C : 0.0000000 4.7600000 3.8300000
Space Radiance RSP: 0.0000 -4.50 -3.61
#
# band corrections
#
2694.8017, 1.5942, 0.997771
925.6466, 0.3741, 0.998708
839.4431, 0.2186, 0.999172
```

Appendix D: Navigation Interpolation Errors

Table 1: Interpolation Errors Between Tie Points (DT=20)

AVHRR Geometry		**DT=20**				Other useful quantities		
Across-track Interpolation between tie points						R earth	6356,766	mean radius
						Z	841,173	altitude
Actual pixels at East end of swath radians						Input parameters: distance between tie points		
lon	lat	Θv	Θs	Δφ		DT (in pixels)	20	Pixels
0,97135554	1,19347891	1,19207989	1,3859535	2,093326		**1) Error using linear interpolation**		
0,97144258	1,1941709	1,19044297	1,3862992	2,093438			lon(degrees)	lat (degrees)
0,97152936	1,19485843	1,1888105	1,3866428	2,093549		TP1	55,65457291	68,38130448
0,97161588	1,19554156	1,18718243	1,3869842	2,093659		TP2	55,75168696	69,12920291
0,97170215	1,19622035	1,18555871	1,3873236	2,093769		center	55,70379691	68,76667532
0,97178818	1,19689485	1,18393927	1,3876608	2,093877		lin. Interp	55,70312993	68,75525369
0,97187396	1,19756512	1,18232407	1,387996	2,093985		Distance (km)		1,267472886
0,97195949	1,19823121	1,18071305	1,3883292	2,094091				
0,97204478	1,19889317	1,17910617	1,3886604	2,094197		**2) Error using Interpolation at Earth surface**		
0,97212984	1,19955105	1,17750336	1,3889896	2,094302		psiTP1	0,9673329	pointing angles
0,97221466	1,2002049	1,17590458	1,3893168	2,094406		psiTP2	0,9484489	
0,97229925	1,20085478	1,17430979	1,3896421	2,09451		psi mid	0,9578909	

Table 1: Interpolation Errors Between Tie Points (DT=20)

0,97238361	1,20150072	1,17271893	1,3899655	2,094612		alphaT1	0,233470719	swath angles
0,97246774	1,20214278	1,17113195	1,390287	2,094714		alphaT2	0,219707493	
0,97255165	1,202781	1,16954882	1,3906067	2,094815		alpha mid	0,226371206	
0,97263533	1,20341543	1,16796948	1,3909245	2,094915		weight	0,484167939	interp. Weight
0,9727188	1,2040461	1,16639389	1,3912405	2,095014		surf. Interp	55,70466745	68,76709447
0,97280205	1,20467308	1,16482201	1,3915547	2,095113		Distance (km)	**0,058189347**	
0,97288508	1,20529639	1,16325379	1,3918671	2,09521				
0,97296789	1,20591608	1,16168919	1,3921777	2,095307				
0,9730505	1,2065322	1,16012817	1,3924866	2,095404		Pixel size	4,403538878	
0,9731329	1,20714478	1,15857069	1,3927938	2,095499			4,396292435	
0,97321509	1,20775386	1,15701671	1,3930993	2,095594				
0,97329708	1,20835948	1,15546618	1,3934031	2,095688				
0,97337887	1,20896169	1,15391908	1,3937052	2,095782				
0,97346045	1,20956051	1,15237536	1,3940057	2,095874				
0,97354184	1,210156	1,15083499	1,3943045	2,095967				
0,97362303	1,21074817	1,14929792	1,3946018	2,096058				
0,97370402	1,21133707	1,14776413	1,3948974	2,096149				
0,97378483	1,21192274	1,14623357	1,3951915	2,096239				
0,97386544	1,21250521	1,14470621	1,395484	2,096328				
0,97394587	1,21308452	1,14318202	1,395775	2,096417				
0,97402611	1,21366069	1,14166097	1,3960644	2,096505				
0,97410616	1,21423377	1,14014301	1,3963524	2,096593				
0,97418603	1,21480378	1,13862812	1,3966388	2,09668				

Table 1: Interpolation Errors Between Tie Points (DT=20)								
0,97426572	1,21537075	1,13711627	1,3969238	2,096766				
0,97434523	1,21593473	1,13560741	1,3972072	2,096852				
0,97442456	1,21649573	1,13410153	1,3974893	2,096937				
0,97450371	1,2170538	1,13259859	1,3977699	2,097021				
0,9745827	1,21760895	1,13109857	1,3980491	2,097105				
0,9746615	1,21816123	1,12960142	1,3983268	2,097189				
Actual pixels west end of swath radians								
-2,5438921	1,51836973	1,12946486	1,6064324	1,020437		1) Error using linear Interpolation		
-2,5405014	1,51784731	1,13096116	1,6067211	1,020454			lon (degrees)	lat (degrees)
-2,5371598	1,51732158	1,13246032	1,6070114	1,020471		TP1	-145,7542809	86,99617727
-2,5338662	1,5167925	1,13396239	1,6073031	1,020489		TP2	-142,3426839	86,35990019
-2,5306197	1,51626006	1,13546739	1,6075964	1,020506		center	-143,9313658	86,68815172
-2,5274194	1,51572425	1,13697536	1,6078912	1,020524		lin. interp.	-144,0484824	86,67803873
-2,5242641	1,51518503	1,13848632	1,6081876	1,020542		Distance	0,117116584	0,010112992
-2,5211531	1,51464239	1,1400003	1,6084855	1,02056		Distance (km)		1,349949167
-2,5180853	1,5140963	1,14151734	1,608785	1,020579		**2) Error using interpolation at Earth surface**		
-2,51506	1,51354673	1,14303748	1,6090862	1,020597		psiTP1	0,9484489	pointing angles
-2,5120762	1,51299367	1,14456073	1,6093889	1,020616		psiTP2	0,9673329	
-2,5091332	1,51243708	1,14608715	1,6096933	1,020635		psimid	0,9578909	
-2,50623	1,51187694	1,14761675	1,6099994	1,020655		alphaT1	0,219707493	swath angles
-2,5033659	1,51131323	1,14914959	1,6103072	1,020675		alphaT2	0,233470719	

Table 1: Interpolation Errors Between Tie Points (DT=20)

-2,5005401	1,51074591	1,15068568	1,6106166	1,020695		alphamid	0,226371206	
-2,4977519	1,51017496	1,15222508	1,6109277	1,020715		weight	0,515832061	interp. weight
-2,4950005	1,50960034	1,15376781	1,6112406	1,020736		surf. interp.	-144,102495	86,68811231
-2,4922851	1,50902202	1,15531391	1,6115553	1,020756		Distance	0,171129194	3,94143E-05
-2,4896051	1,50843998	1,15686342	1,6118717	1,020778		Distance (km)		**1,096862641**
-2,4869598	1,50785419	1,15841638	1,6121899	1,020799				
-2,4843485	1,5072646	1,15997282	1,6125099	1,020821				
-2,4817705	1,50667118	1,1615328	1,6128317	1,020843				
-2,4792253	1,50607391	1,16309634	1,6131554	1,020865				
-2,4767121	1,50547274	1,16466349	1,613481	1,020888				
-2,4742303	1,50486764	1,1662343	1,6138085	1,02091				
-2,4717794	1,50425857	1,1678088	1,6141378	1,020934				
-2,4693588	1,50364549	1,16938704	1,6144692	1,020957				
-2,4669679	1,50302837	1,17096906	1,6148025	1,020981				
-2,4646061	1,50240716	1,1725549	1,6151377	1,021005				
-2,4622729	1,50178183	1,17414463	1,615475	1,02103				
-2,4599678	1,50115232	1,17573827	1,6158143	1,021055				
-2,4576902	1,50051861	1,17733588	1,6161557	1,02108				
-2,4554396	1,49988063	1,17893751	1,6164992	1,021105				
-2,4532156	1,49923836	1,1805432	1,6168448	1,021131				
-2,4510176	1,49859174	1,18215301	1,6171925	1,021157				
-2,4488451	1,49794072	1,18376699	1,6175424	1,021184				
-2,4466978	1,49728526	1,18538519	1,6178944	1,021211				

Table 1: Interpolation Errors Between Tie Points (DT=20)								
-2,4445751	1,49662531	1,18700767	1,6182487	1,021238				
-2,4424765	1,49596082	1,18863448	1,6186052	1,021266				
-2,4404018	1,49529173	1,19026567	1,618964	1,021294				
-2,4383503	1,49461799	1,1919013	1,6193252	1,021323				

Table 2: Interpolation Errors between Tie Points (DT = 40)

AVHRR Geometry		**DT=40**				Other useful quantities		
Across-track interpolation between tie points						R earth	6356,766	mean radius
						Z	841,173	altitude
Actual pixels at East end of swath radians						Input parameters: distance between tie points		
lon	lat	Θv	Θs	ΔΘ		**DT (in pix)**	**40**	pixels
0,97135554	1,19347891	1,19207989	1,3859535	2,093326		**1) Error using linear Interpolation**		
0,97144258	1,1941709	1,19044297	1,3862992	2,093438			lon(degrees)	lat (degrees)
0,97152936	1,19485843	1,1888105	1,3866428	2,093549		TP1	55,65457291	68,38130448
0,97161588	1,19554156	1,18718243	1,3869842	2,093659		TP2	55,84399058	69,79549725
0,97170215	1,19622035	1,18555871	1,3873236	2,093769		center	55,75168696	69,12920291
0,97178818	1,19689485	1,18393927	1,3876608	2,093877		Lineal interpretation	55,74928174	69,08840086
0,97187396	1,19756512	1,18232407	1,387996	2,093985		Distance (km)		4,527841935
0,97195949	1,19823121	1,18071305	1,3883292	2,094091				
0,97204478	1,19889317	1,17910617	1,3886604	2,094197		**2) Error using interpolation at Earth surface**		
0,97212984	1,19955105	1,17750336	1,3889896	2,094302		psiTP1	0,9673329	pointing angles
0,97221466	1,2002049	1,17590458	1,3893168	2,094406		psiTP2	0,9295649	
0,97229925	1,20085478	1,17430979	1,3896421	2,09451		psi mid	0,9484489	
0,97238361	1,20150072	1,17271893	1,3899655	2,094612		alphaT1	0,233470719	swath angles
0,97246774	1,20214278	1,17113195	1,390287	2,094714		alphaT2	0,207494125	

Table 2: Interpolation Errors between Tie Points (DT = 40)

0,97255165	1,202781	1,16954882	1,3906067	2,094815		alpha mid	0,219707493	
0,97263533	1,20341543	1,16796948	1,3909245	2,094915		weight	0,470168172	interp. weight
0,9727188	1,2040461	1,16639389	1,3912405	2,095014		surface interp.	55,75493242	69,13058882
0,97280205	1,20467308	1,16482201	1,3915547	2,095113		Distance (km)	**0,200240885**	
0,97288508	1,20529639	1,16325379	1,3918671	2,09521				
0,97296789	1,20591608	1,16168919	1,3921777	2,095307				
0,9730505	1,2065322	1,16012817	1,3924866	2,095404		Pixel size	4,403538878	
0,9731329	1,20714478	1,15857069	1,3927938	2,095499			4,396292435	
0,97321509	1,20775386	1,15701671	1,3930993	2,095594				
0,97329708	1,20835948	1,15546618	1,3934031	2,095688				
0,97337887	1,20896169	1,15391908	1,3937052	2,095782				
0,97346045	1,20956051	1,15237536	1,3940057	2,095874				
0,97354184	1,210156	1,15083499	1,3943045	2,095967				
0,97362303	1,21074817	1,14929792	1,3946018	2,096058				
0,97370402	1,21133707	1,14776413	1,3951915	2,096149				
0,97378483	1,21192274	1,14623357	1,3951915	2,096239				
0,97386544	1,21250521	1,14470621	1,395484	2,096328				
0,97394587	1,21308452	1,14318202	1,395775	2,096417				
0,97402611	1,21366069	1,14166097	1,3960644	2,096505				
0,97410616	1,21423377	1,14014301	1,3963524	2,096593				
0,97418603	1,21480378	1,13862812	1,3966388	2,09668				
0,97426572	1,21537075	1,13711627	1,3969238	2,096766				
0,97434523	1,21593473	1,13560741	1,3972072	2,096852				

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0,97442456	1,21649573	1,13410153	1,3974893	2,096937				
0,97450371	1,2170538	1,13259859	1,3977699	2,097021				
0,9745827	1,21760895	1,13109857	1,3980491	2,097105				
0,9746615	1,21816123	1,12960142	1,3983268	2,097189				
Actual pixels at west end of swath radians								
2,5438921	1,51836973	1,12946486	1,6064324	1,020437		**1) Error using linear interpolation**		
-2,5405014	1,51784731	1,13096116	1,6067211	1,020454			lon (degrees)	lat (degrees)
-2,5371598	1,51732158	1,13246032	1,6070114	1,020471		TP1	-145,7542809	86,99617727
-2,5338662	1,5167925	1,13396239	1,6073031	1,020489		TP2	-139,7071823	85,63530281
-2,5306197	1,51626006	1,13546739	1,6075964	1,020506		Center	-142,3426839	86,35990019
-2,5274194	1,51572425	1,13697536	1,6078912	1,020524		lin. interp.	-142,7307316	86,31574004
-2,5242641	1,51518503	1,13848632	1,6081876	1,020542		Distance	0,388047699	0,044160149
-2,5211531	1,51464239	1,1400003	1,6084855	1,02056		Distance (km)		5,610305184
-2,5180853	1,5140963	1,14151734	1,608785	1,020579		**2) Error using interpolation at Earth surface**		
-2,51506	1,51354673	1,14303748	1,6090862	1,020597		psiTP1	0,9295649	pointing angles
-2,5120762	1,51299367	1,14456073	1,6093889	1,020616		psiTP2	0,9673329	
-2,5091332	1,51243708	1,14608715	1,6096933	1,020635		psimid	0,9484489	
-2,50623	1,51187694	1,14761675	1,6099994	1,020655		alphaT1	0,207494125	swath angles
-2,5033659	1,51131323	1,14914959	1,6103072	1,020675		alphaT2	0,233470719	
-2,5005401	1,51074591	1,15068568	1,6106166	1,020695		alphamid	0,219707493	
-2,4977519	1,51017496	1,15222508	1,6109277	1,020715		weight	0,529831828	interp. weight

Table 2: Interpolation Errors between Tie Points (DT = 40)

-2,4950005	1,50960034	1,15376781	1,6112406	1,020736		surface interpolation	-142,9111276	86,35633741
-2,4922851	1,50902202	1,15531391	1,6115553	1,020756		Distance	0,568443703	0,003562776
-2,4896051	1,50843998	1,15686342	1,6118717	1,020778		Distance (km)		**4,02740851**
-2,4869598	1,50785419	1,15841638	1,6121899	1,020799				
-2,4843485	1,5072646	1,15997282	1,6125099	1,020821				
-2,4817705	1,50667118	1,1615328	1,6128317	1,020843				
-2,4792253	1,50607391	1,16309634	1,6131554	1,020865				
-2,4767121	1,50547274	1,16466349	1,613481	1,020888				
-2,4742303	1,50486764	1,1662343	1,6138085	1,02091				
-2,4717794	1,50425857	1,1678088	1,6141378	1,020934				
-2,4693588	1,50364549	1,16938704	1,6144692	1,020957				
-2,4669679	1,50302837	1,17096906	1,6148025	1,020981				
-2,4646061	1,50240716	1,1725549	1,6151377	1,021005				
-2,4622729	1,50178183	1,17414463	1,615475	1,02103				
-2,4599678	1,50115232	1,17573827	1,6158143	1,021055				
-2,4576902	1,50051861	1,17733588	1,6161557	1,02108				
-2,4554396	1,49988063	1,17893751	1,6164992	1,021105				
-2,4532156	1,49923836	1,1805432	1,6168448	1,021131				
-2,4510176	1,49859174	1,18215301	1,6171925	1,021157				
-2,4488451	1,49794072	1,18376699	1,6175424	1,021184				
-2,4466978	1,49728526	1,18538519	1,6178944	1,021211				
-2,4445751	1,49662531	1,18700767	1,6182487	1,021238				
-2,4424765	1,49596082	1,18863448	1,6186052	1,021266				

Table 2: Interpolation Errors between Tie Points (DT = 40)

-2,4404018	1,49529173	1,19026567	1,618964	1,021294				
-2,4383503	1,49461799	1,1919013	1,6193252	1,021323				