EUMETSAT

AVHRR Level 2 Polar Winds Product Generation Specification

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1 INTRODUCTION

1.1 Purpose, Scope and Structure of this Specification

The purpose of this specification is to present the requirements that are specific to the Metop AVHRR Polar Winds Product Generation Function (PGF). This specification encompasses not only the required algorithm functions but also the supporting functions pertaining to the PGF.

The structure of this document is as follows:

- Section 1 is the introduction.
- Section 2 provides a short overview of the AVHRR/3 instrument.
- Section 3 describes the system and the operations concept.
- Section 4 lists the requirements for the PGF.
- Section 5 describes the scientific and mathematical algorithms supporting the requirements.

1.2 Relation to EPS Core Ground Segment

This document addresses all requirements pertaining to the corresponding PGF of the EPS. The PGF encompasses all functions (algorithmic, scientific and supporting functions) required for the product generation.

Since the AVHRR Polar Winds PGF is a constituent of the CGS, all the requirements of the Core Ground Segment Requirement Document (CGSRD, [**AD1**]) shall apply to this PGF, unless otherwise specified. In particular, the PGF shall comply with all the requirements of the generic Product Generation Environment (PGE) services and testing requirements.

1.3 Applicable Documents

The following documents are applicable to the AVHRR Polar Winds PGF:

AD1 EPS Core Ground Segment Requirements Document (EPS/GGS/REQ/95327).
AD2 AVHRR Level 2 Polar Winds Product Format Specification (EUM/OPS-EPS/SPE/08/0338)
AD3 EPS Generic Product Format Specification (EPS/GGS/SPE/96167)
AD4 AVHRR Level 1 Product Format Specification (EPS/MIS/SPE/97231)
AD5 EPS Mission Conventions Document (EPS/GGS/SPE/990002)
AD6 EPS Product Conventions Document (EPS/SYS/TEN/990007)

2 INSTRUMENT DESCRIPTION

2.1 Instrument

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. It is currently flying on NOAAs-15 to 19 and Metop-A satellites. AVHRR/3 has six spectral channels between 0.63 and 12.00 micrometres: 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 is operated during the night-time portion of the orbit. The transition from Channel 3a to 3b and vice versa is done by telecommand and is reflected in the science data.

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

Channel	Central wavelength (µm)	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
3a	1.610	1.580 - 1.640	S/N 20:1 @ 0.5 % reflectance
3b	3.740	3.550 - 3.930	<0.12 K, 0.0031 mW/(m^2sr cm^{-1}) @ 300 K
4	10.800	10.300 - 11.300	<0.12 K, 0.20 mW/(m^2sr cm^{-1}) @ 300 K
5	12.000	11.500 - 12.500	<0.12 K, 0.21 mW/(m^2sr cm^{-1}) @ 300 K

Table 2-1: 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 instantaneous field of view (IFOV) of each channel is approximately 1.3 milliradians (0.0745 deg) leading to a square instantaneous field of view 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 deg). 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 (e.g. by vicarious calibration).
- The calibration of the infrared channels (channels 3b, 4 and 5) is performed by viewing an internal black body and cold space. The internal rotating scan mirror views 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	s
Sampling interval	0.025	ms
Sampling interval	0.0541	deg
Pixels per scan	2048	-
Swath	± 55.37	deg
Swath width	± 1446.58	km
IFOV	0.0745	deg
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 2-2: Scanning Characteristics of AVHRR/3

2.2 EUMETSAT Level 1 Products

Level 1a and 1b products are produced by EUMETSAT from the Metop-A AVHRR/3 instrument, and these are described and specified in [**AD4**]. Specifically, the Level 1b Product Dissemination Units, which include pixel-based information about channel radiances, cloud data and navigation information, are used as input to the AVHRR Level 2 Polar Winds PGF.

3 SYSTEM AND OPERATIONS CONCEPT

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

3.1 Mechanisms and Controls

G/S Commands: This data stream corresponds to the transfer of commands generated by the G/S and controlling the operation of the product generation function. Note: these are only influencing 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 e.g. the selection of a method or a data set.

The external data flows are described in the next two sections.

3.2 Inputs

Level 1b Data Flow: A sequence of operational mode AVHRR/3 Level 1b Processing Dissemination Units (PDUs), each containing 1080 lines of data covering a 3 minute time period.

Config. Data Sets: Indicates to the product generation function the data set version of the set-up 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.

Set-up Parameters: The configurable set-up parameters are required for the product generation function. These shall include segment definition variables, target identification parameters, image enhancement, target mapping, target matching, scenes analysis, height assignment and quality control parameters.

NWP Forecast Data: These data contain three-dimensional fields of temperature and wind speed and direction.

3.3 Outputs

Level 2 Data Flow: Corresponds to the contents of Level 2 data as defined in the corresponding Product Format Specification [**AD2**]. The Level 2 data are output as a sequence of Level 2

PDUs to cover each 3 minute time period, corresponding to the input Level 1b PDUs which cover the polar regions.

Reporting/Quality Information: Information produced by the product generation function (on the received data, on the quality of the processing and on the performance of the winds processing) 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 Controller 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 data, processing functions, links, etc. In addition, the information contains also events and command acknowledgements raised by the product generation function.

3.4 System Concept

In the following, the detailed system and operations concept reflects the current state of knowledge acquired through the use of a prototyping processor.

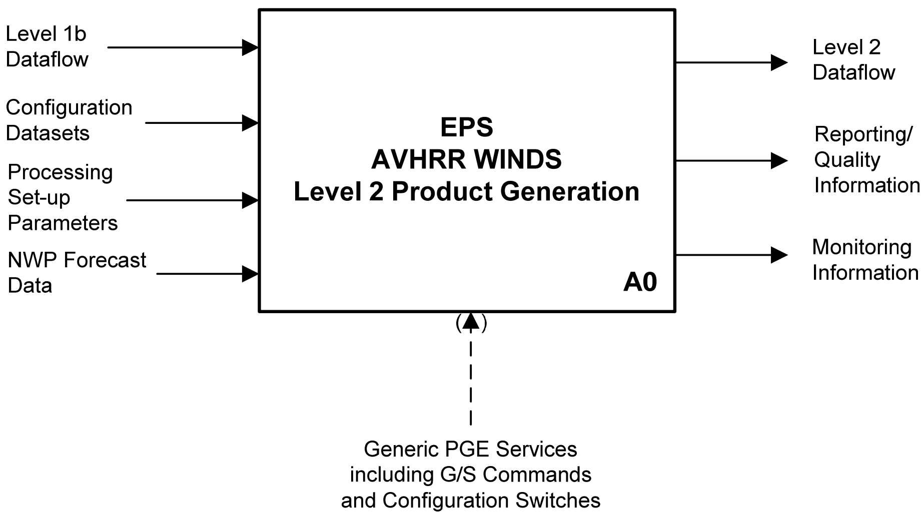

Figure 3-1: AVHRR Level 2 Polar Winds Context Diagram

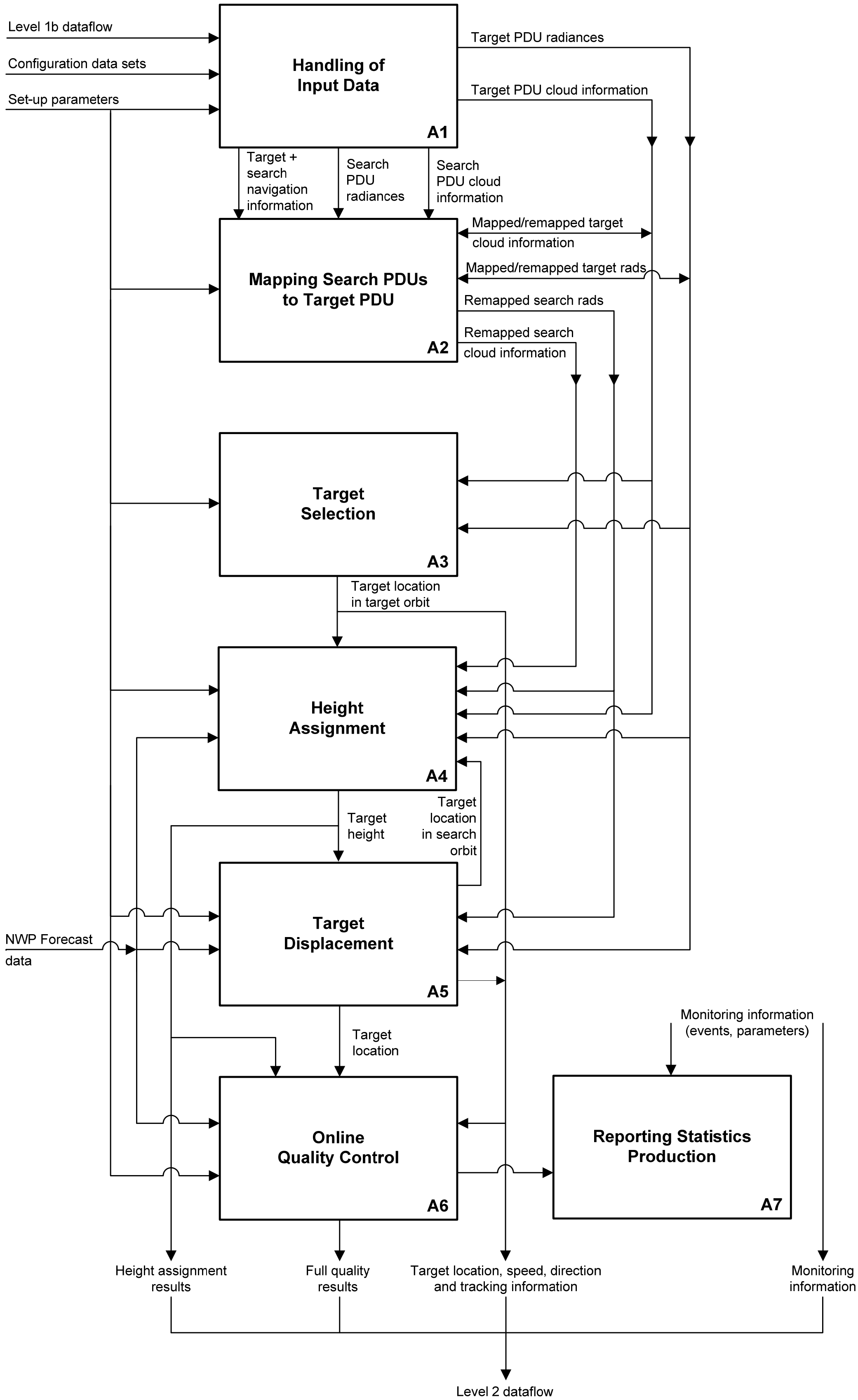

Figure 3-2: Level A0 Decomposition

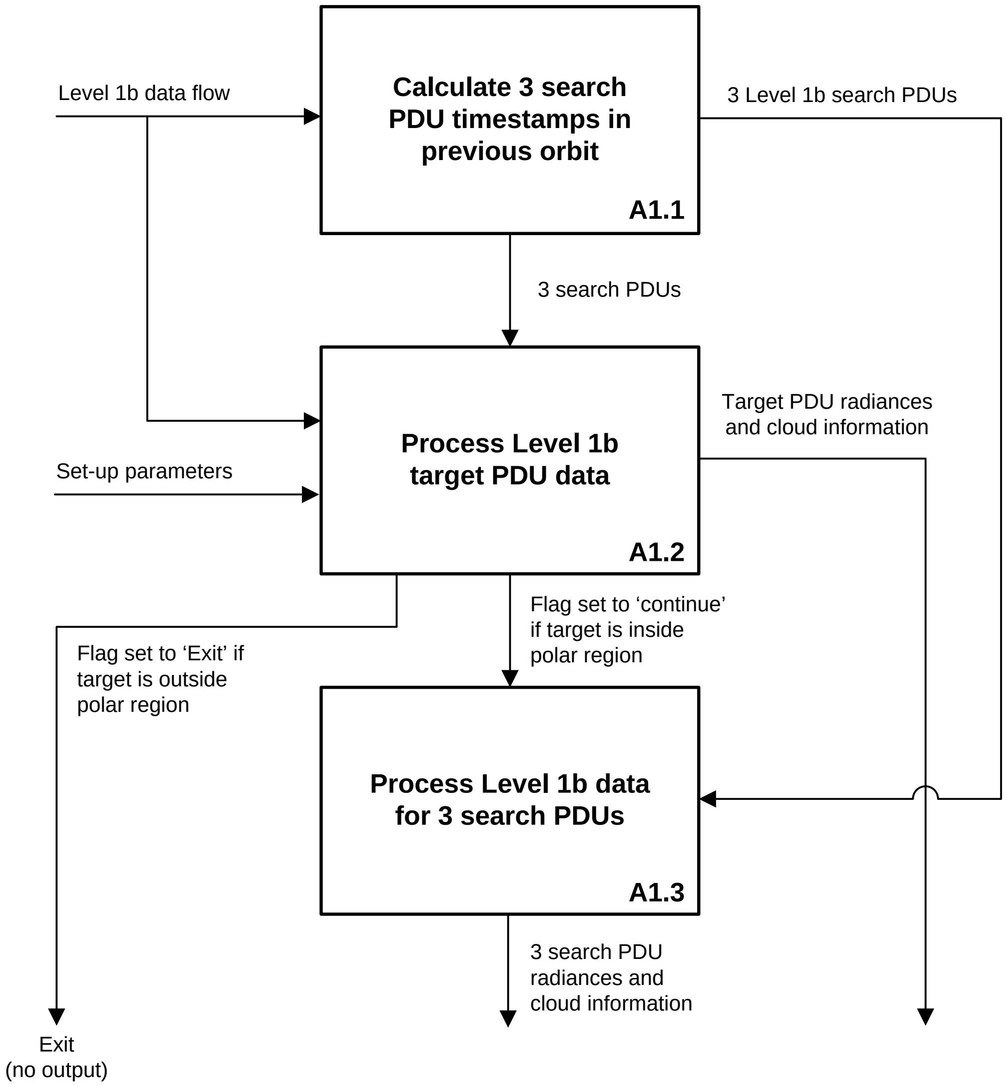

Figure 3-3: Level A1 Decomposition (Handling of Input Data)

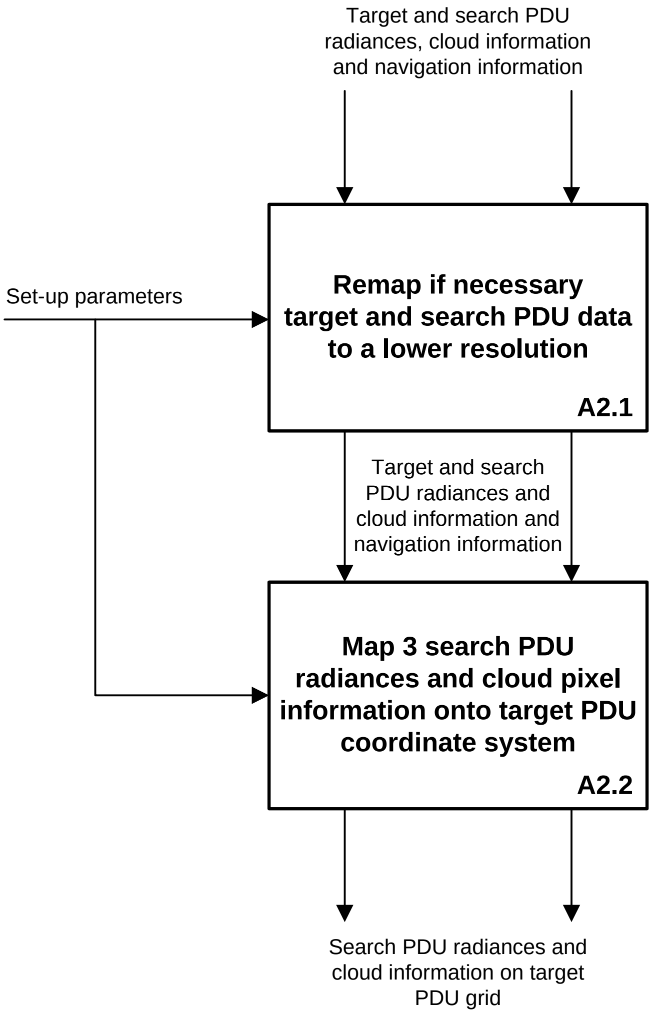

Figure 3-4: Level A2 Decomposition (Mapping of Search PDUs to Target PDU)

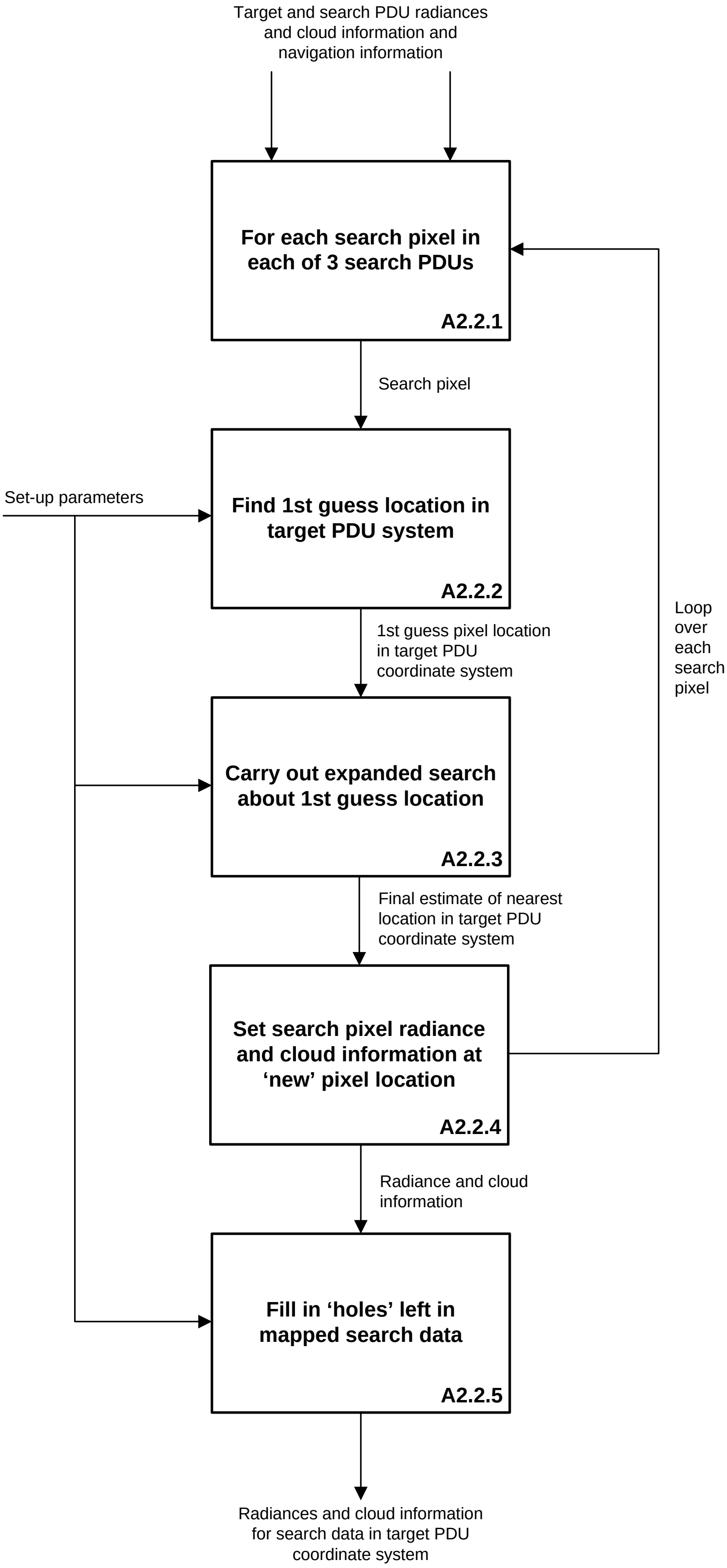

Figure 3-5: Level A2.2 Decomposition (Map Search PDU Information onto Target PDU Coordinate System)

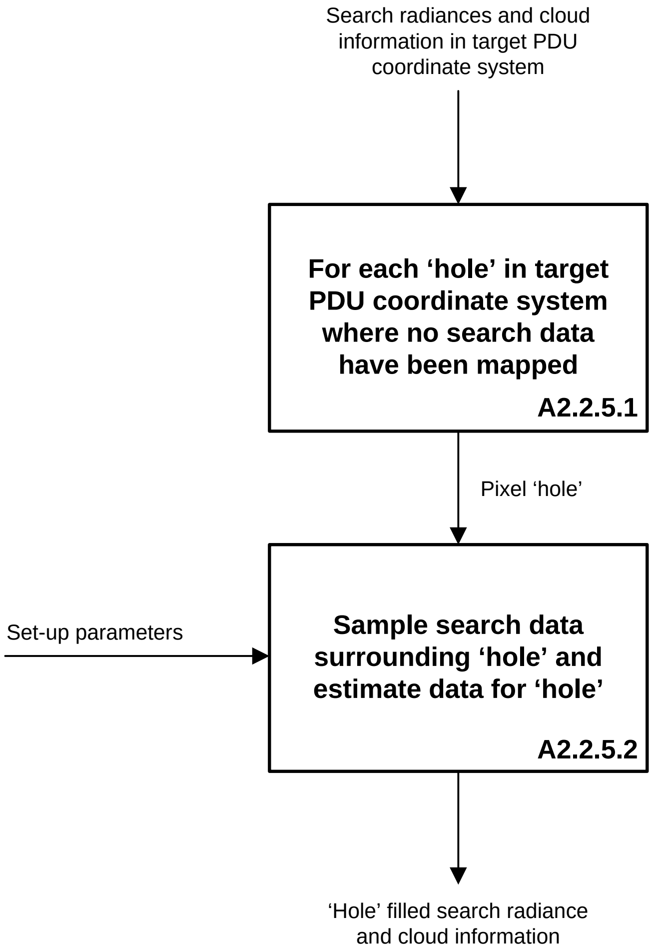

Figure 3-6: Level A2.2.5 Decomposition (Fill in 'holes' in Mapped Search Data)

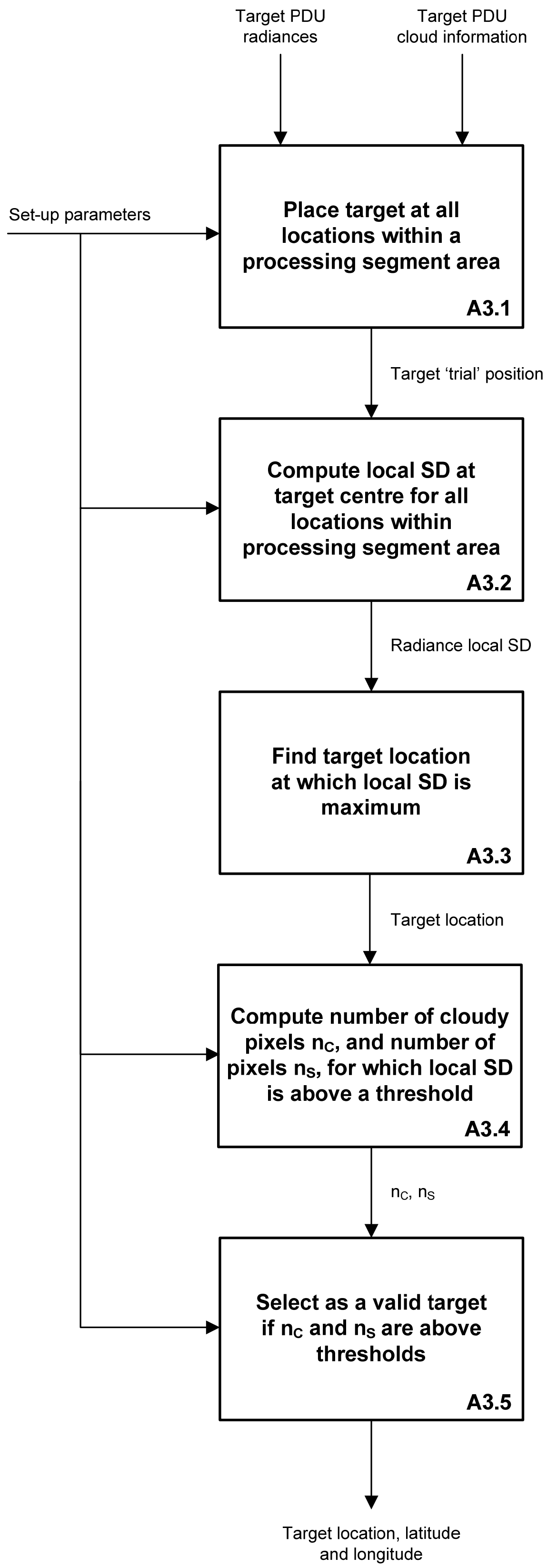

Figure 3-7: Level A3 Decomposition (Target Selection)

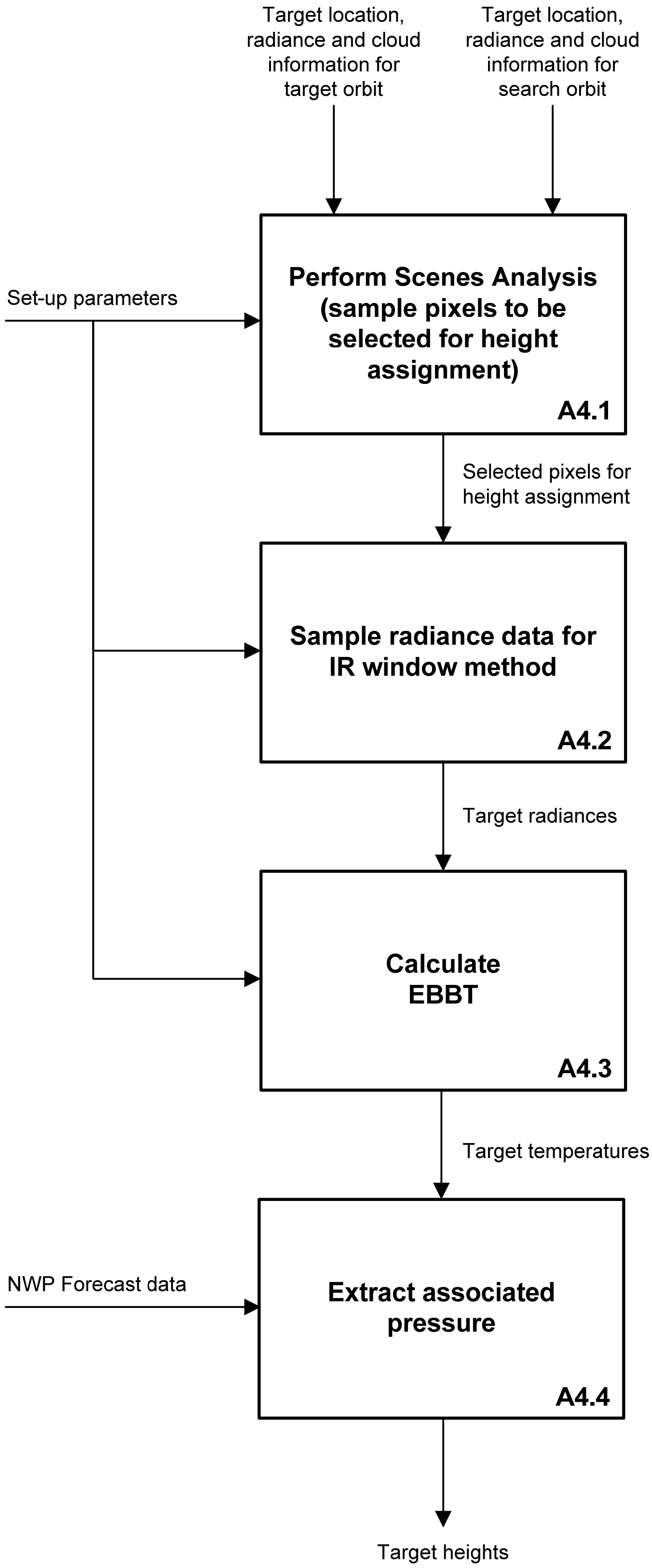

Figure 3-8: Level A4 Decomposition (Height Assignment)

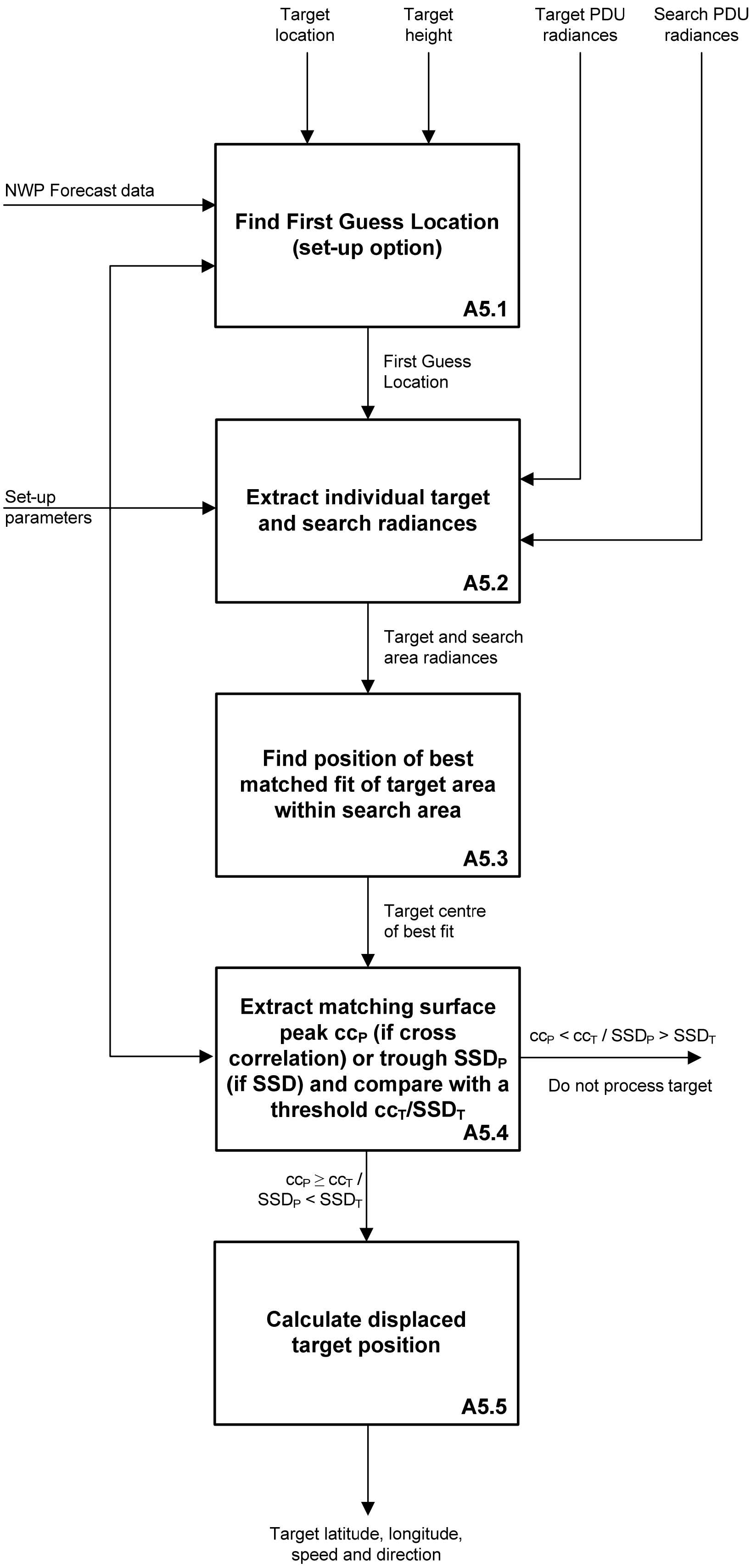

Figure 3-9: Level A5 Decomposition (Target Displacement)

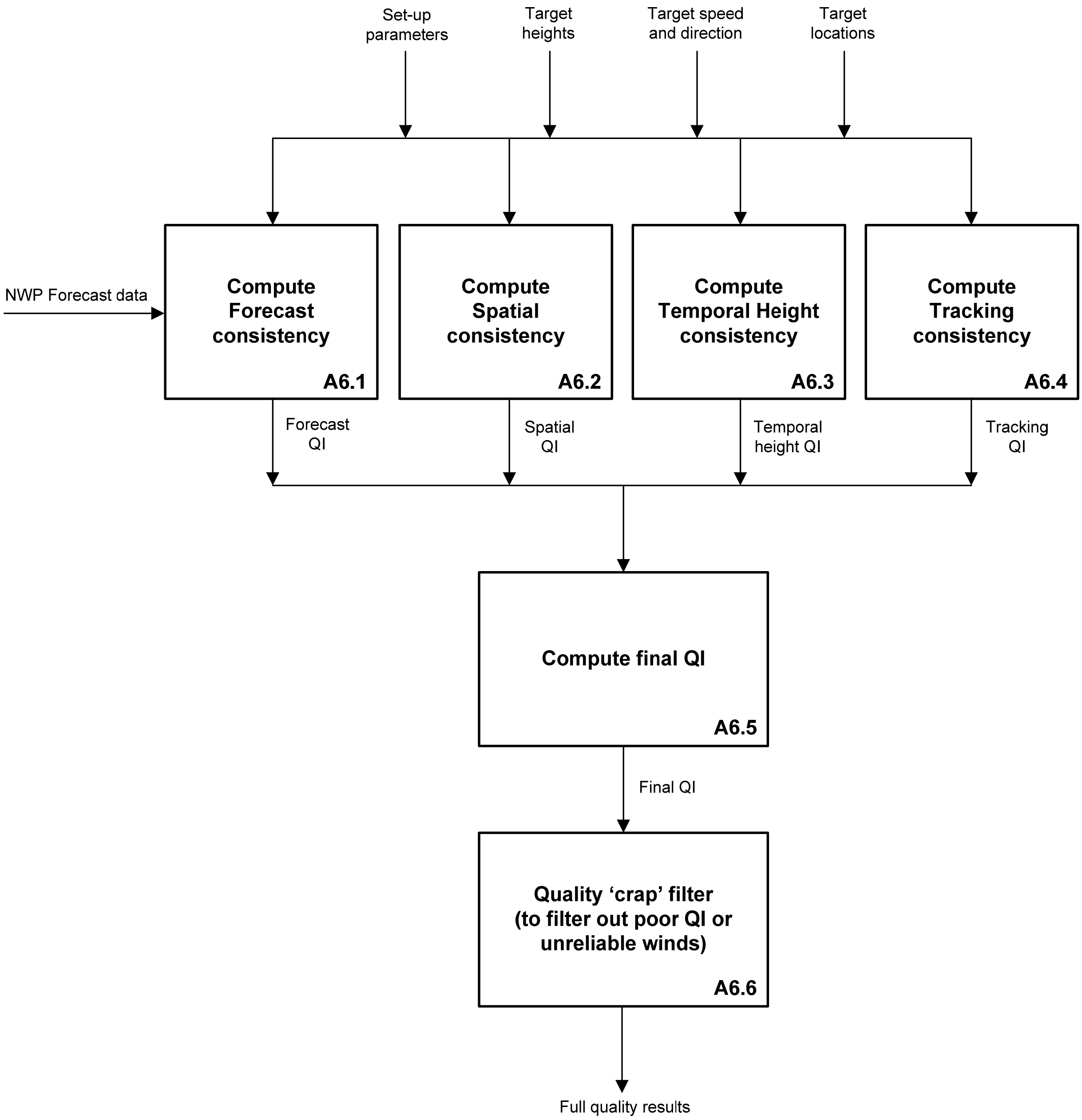

Figure 3-10: Level A6 Decomposition (<u>On-Line Quality Control</u>)

4 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 that this product generation facility is supporting. They should be considered in addition to the generic functions identified in [**AD1**].

AVHRR-L2-PGS-0010
The product generation function shall provide all the functionality required to support the following:
1. Reception and acceptance of the Level 1 data;
2. Reception and acceptance and validation of all other input data required by the processing (e.g. instrument TM, G/S auxiliary data, other products, etc.);
3. Online quality control of the products;
4. M&C interfacing functions using the generic PGE services;
5. Generation of monitoring information on the Level 2 product generation function status via the PGE services.

AVHRR-L2-PGS-0020
Each function of the product generation function shall monitor its performance and raise events of user-configurable severity on the occurrence of:
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-L2-PGS-0030
The product generation function shall support the production of Level 2 products in a nominal manner for input data acquired by the following instruments and platforms:
1. Metop-1 /AVHRR/3 Instrument (full resolution)
2. Metop-2 /AVHRR/3 Instrument (full resolution)
3. Metop-3 /AVHRR/3 Instrument (full resolution)

AVHRR-L2-PGS-0040
The product generation function shall process the Level 1 data and produce Level 2 data of a nominal quality for all nominal modes and states of the instrument.

AVHRR-L2-PGS-0050
The product generation function shall initially extract Atmospheric Motion Vectors (AMVs) from channel 4 data of the AVHRR/3 instrument.

As a future enhancement, the derivation of AMVs from other AVHRR/3 channels will be considered.

AVHRR-L2-PGS-0060
The product generation function shall process individual Product Dissemination Units (PDUs), which have a nominal length of 3 minutes. PDUs which do not contain any Earth

views poleward of ±67° latitude (or another user-defined value) will not be processed. A Level-2 product shall nonetheless be generated for such a PDU, but this product shall contain zero AMVs.

AVHRR-L2-PGS-0070
The product generation function shall support both backward tracking and forward tracking. The standard tracking method will be backward tracking.

AVHRR-L2-PGS-0080
For each PDU that is processed, the product generation function shall identify all PDUs from the previous orbit (or next orbit, in the case of forward tracking), that partially overlap with this PDU. The required information from these overlapping PDUs shall be mapped onto the current PDU, i.e. all data elements will be remapped so that they will have the same projection as the current PDU. The current PDU does not need to be re-projected.

AVHRR-L2-PGS-0090
For each PDU that is processed (and which is hereafter called the 'current PDU'), the product generation function shall define rectangular segments that cover the complete PDU and that are allowed to overlap each other. The segment size, as well as the maximum amount of overlap allowed, shall be controlled by set-up parameters. In addition to this, it shall define rectangular target areas, the size of which is smaller than or equal to the segment size. [NB: the Level 1b PDU is a rectangular 2048 pixels x 1080 lines representation.]

AVHRR-L2-PGS-0100
The product generation function shall identify the optimal target location within each segment. This shall be achieved by extracting the location of the target area within the segment for which the contrast within the target area is maximised.

AVHRR-L2-PGS-0110
The product generation function shall identify all cloudy pixels in the target areas. It shall therefore use the scene type information that is present in the Level 1 data.

AVHRR-L2-PGS-0120
The product generation function shall extract cloud targets, when enough cloudy pixels are present, in each target area of the current PDU. It shall then, by means of a matching algorithm, locate the position of this cloud target in the overlapping PDUs from the previous orbit (or next orbit, in the case of forward tracking). From the displacement of the targets it shall extract Atmospheric Motion Vectors (AMVs).

AVHRR-L2-PGS-0130
The product generation function shall assign a location to each AMV that is identical to the optimal target location. A correction for parallax will be carried out as a future enhancement.

AVHRR-L2-PGS-0140
The product generation function shall assign a cloud pressure to each vector that was successfully extracted. This assignment shall be based on the observed radiances in the IR10.8 channel, applying the so-called window channel EBBT method, which uses forecast temperature profiles. The observed radiances shall be associated with the cloudy pixels in the

target area. In a similar manner, the product generation function shall derive a second pressure for each vector, extracted from the target position in the adjacent orbit, located from the MCC method (see AVHRR-L2-PGS-120).

AVHRR-L2-PGS-0150
The product generation function shall apply automatic quality control to each vector that was successfully extracted. This shall comprise the following consistency checks, at least:
(a) Forecast vector consistency,
(b) Spatial vector consistency,
(c) Spatial height consistency,
(d) Tracking consistency (vector),
(e) Tracking consistency (speed),
(f) Tracking consistency (direction),
(g) Temporal pressure consistency.

AVHRR-L2-PGS-0160
The product generation function shall derive two final quality marks for each successfully extracted vector. The first one is a weighted average of all individual consistency checks. The second one is a weighted average of all individual consistency checks, but excluding the forecast vector consistency. The weights shall be provided as static set-up parameters.

AVHRR-L2-PGS-0170
The product generation function shall store the successfully extracted vectors in a Level 2 product. The time-stamp of this product will have the identical sensing start and stop times of the Level 1b product.

AVHRR-L2-PGS-0180
The product generation function shall store at least the following information related to each AMV:
- The derived pressure,
- The pressure standard deviation,
- The temperature,
- The temperature standard deviation.

AVHRR-L2-PGS-0190
For all AMVs with a pressure bigger than a threshold value, a correction to place the cloud height lower in the atmosphere shall be considered. This shall primarily be to correct for the effects of low-level temperature inversions.

AVHRR-L2-PGS-0200
The product generation function shall derive an overall product quality, for each PDU, which shall be the average of the final quality marks (excluding the forecast vector consistency) of all individual vectors.

AVHRR-L2-PGS-0210
The product generation function shall define a dissemination flag in each Level 2 product, indicating whether the product is suitable for dissemination. This shall, as a future enhancement, be based on the following criteria:

- The overall product quality should exceed a pre-defined threshold value,
- The number of ‘good’ winds (according to a threshold quality) should exceed a pre-defined minimum.

5 ALGORITHMS

5.1 Target Selection

The selection of the target shall be achieved by extracting the location of the target area within the segment for which the contrast within the target area is maximised. The contrast shall be calculated by computing the local standard deviation (nominally over a 3x3 area) at the target centre.

5.2 Height Assignment

The height assignment is calculated by sampling a user-defined percentage (nominally 25) of the coldest cloudy pixels in the target. The mean radiance of the sampled set is calculated and converted to an EBBT. This is matched against the forecast profile to obtain an estimate of the pressure associated with the wind.

5.2.1 Inversion Height Assignment

A specific inversion height assignment correction has previously been developed for winds observed in non-polar low-level temperature inversion regions. This was an empirical based method. However, the low-level temperature inversions in the polar regions cannot be expected to have the same characteristics as those observed in other latitude regions. Hence, it cannot be assumed that the same correction scheme is applicable. As a default, no inversion height assignment correction is applied.

An empirical based correction scheme will be developed as a future enhancement.

5.3 Derivation of Target Displacement

5.3.1 Introduction

The derivation of the target displacement **shall** utilise the image data at locations centralised around the locations provided by the target selection scheme. It will be based on the derivation of a matching surface derived by matching the selected target within the defined search area in the previous PDU (or next PDU, depending on the tracking direction). There is a user-defined option of using the forecast data to provide a first guess estimate of the displaced target position. In this case, the first guess location is used as the centre of the defined search area, otherwise the search area centre is that provided by the target selection scheme.

The matching **shall** be performed by a matching algorithm selected by a user-defined parameter. The following alternative matching methods **shall** be supported:

- Cross Correlation (CC) in time domain,
- Cross Correlation in the Fourier domain (CCF),
- Sum of Squared Distances (SSD), also known as Euclidean distance, and
- Centre of mass (already prototyped, to be considered as a future enhancement).

Only one method will be used operationally.

5.3.2 Perform Matching

The matching process is the core of the AMV task. This is both from a mathematical point of view, because it is the basic scheme retained for the measurement of the tracers displacement, and also from a computational load point of view. For these reasons, a detailed mathematical definition is presented here, followed by three alternative suggestions for implementing this operation.

5.3.2.1 Cross Correlation in the Time Domain

The correlation used for AMV extraction **shall** be based on the classical formula defining the correlation coefficient CC between two random variables T and S:

$$CC = \frac{E\{(T - \overline{T})\cdot(S - \overline{S})\}}{\sigma_T \cdot \sigma_S} = \frac{E\{T \cdot S\} - E\{T\}\cdot E\{S\}}{\sigma_T \cdot \sigma_S} \qquad \text{(Equation 1)}$$

Assuming a square target size with a side length of N_T, the total number of pixels used to compute one correlation value is $N = N_T^2$. If we identify the pixels within the target area with (i,j) and the target location within the search area with (n,m), such that the target is always fully contained within the search area, then $T_{i,j}$ and $S_{n+i,m+j}$ **shall** uniquely define pixel count values within the target and search areas. The expression for the CC **shall** then be expanded by:

$$E\{T\} = \overline{T} = \frac{1}{N_T^2}\sum_{i=1}^{N_T}\sum_{j=1}^{N_T} T_{i,j} \qquad \text{(Equation 2)}$$

$$E\{S\}_{n,m} = \overline{S}_{n,m} = \frac{1}{N_T^2}\cdot\sum_{i=1}^{N_T}\sum_{j=1}^{N_T} S_{n+i,m+j} \qquad \text{(Equation 3)}$$

$$E\{T.S\}_{n,m} = \frac{1}{N_T^2}\sum_{i=1}^{N_T}\sum_{j=1}^{N_T} T_{i,j}\bullet S_{n+i,m+j} \qquad \text{(Equation 4)}$$

$$\sigma_T = \sqrt{\frac{1}{N_T^2}\cdot\sum_{i=1}^{N_T}\sum_{j=1}^{N_T}(T_{i,j} - \overline{T})^2}$$

$$\sigma_{S\,n,m} = \sqrt{\frac{1}{N_T^2}\cdot\sum_{i=1}^{N_T}\sum_{j=1}^{N_T}(S_{n+i,m+j} - \overline{S}_{n,m})^2}$$

(Equations 5, 6)

5.3.2.2 Cross_Correlation - Fast Fourier Transform Implementation

Implementing convolutions or correlations in the frequency domain using Fast Fourier Transform (FFT) is a classical solution for reducing the computational load. The larger the arrays having to be correlated, filtered or convolved, the more efficiently these can be implemented. The precise form of FFT implementation is based on the Mixed-Radix FFT method. When considering the set of formulae defined in Section 5.3.2.1, the basic Cross-Correlation term *E{T · S}* can be implemented in the Fourier domain by three Fourier transforms.

$$R_{ij} = \left[F^{-1}\left\{F(S)F^{*}(T)\right\}\right]_{ij} \qquad \text{(Equation 7)}$$

This method **shall** deliver all the correlation coefficients in full resolution.

5.3.2.3 Sum of Squared Distances

The Sum of Squared Distances (SSD) is equivalent to the squared Euclidean distance or norm. Using the same assumptions and definitions as for cross correlation, the normalised SSD can then be expressed by:

$$\overline{SSD}_{n,m} = \frac{1}{N_T^2} \bullet \sum_{i=1}^{N_T} \sum_{j=1}^{N_T} \left(S_{n+i,m+j} - T_{i,j}\right)^2 \qquad \text{(Equation 8)}$$

By expanding the above expression, the algorithm can be more efficiently calculated by evaluating the E(S.T) term (see Equation 4) using the Mixed Radix FFT.

5.3.3 Derivation of Displacement

The matching surface **shall** be considered as valid, and computed, only for relative positions of target and search areas such that the target area is always completely included in the search area. The positions in the output arrays corresponding to invalid cross correlation positions **shall** be set to zero in all the result arrays. The point corresponding to zero relative displacement **shall** be the centre of the output surface.

Based on the extracted maximum correlation value (or minimum distance) at pixel level accuracy, the measured displacement as a function of pixels **shall** be converted to longitude and latitude positions as defined by the central location of the target in the image pair.

In the second step the distance between the two latitude/longitude locations **shall** be derived and an 'instantaneous' wind speed and direction **shall** be computed from these locations.

5.4 Automatic Quality Control (AQC)

The Automatic Quality Control applies a set of tests to the extracted vectors. Each test provides a normalised output value such that they can be linearly combined to obtain a final quality estimate of each of the vectors, or can be used as a multiplicator on the obtained final quality estimate. This final reliability estimate forms the basis of further evaluation of the vectors and shall be disseminated together with the vectors. The AQC provides the flexibility to easily introduce new tests.

5.4.1 Forecast Consistency Test

This process generates the quality mark $M_{forecast}$ which is a measure of the consistency of the forecast AMV. To do this, the vector difference of the AMV vector and the forecast vector interpolated to the same location and pressure level is computed.
The computation is done for all AMV vectors, according to the following equation:

$$M_{forecast}(i) = 1 - \left(\tanh\left(\frac{|S(x,y) - F(x,y)|}{\max(AQC\_FC\_A \cdot |S(x,y) + F(x,y)|/2, AQC\_FC\_B) + AQC\_FC\_C} \right) \right)^{AQC\_FC\_D}$$

(Equation 9)

where AQC_FC_A to AQC_FC_D are set-up parameters included in the static data file.

All interpolated forecast wind directions are derived by interpolating the u and v components, then calculating the resultant direction.

5.4.2 Spatial Consistency Check

This process generates two quality marks:

- M_{SWC}, which is a measure of the spatial vector consistency of the AMV, and
- M_{SHC}, which is a measure of the spatial height consistency of the AMV.

To calculate the spatial vector consistency, the AMV values are compared with the AMVs computed at the neighbouring grid points.

The quality mark is computed against all vectors within the height threshold, *AQC_SC_max_pp*, for which ELL_DIST < 1, where:

$$ELL\_DIST = (X/A)^2 + (Y/B)^2$$

where: A = A1 + SPD * A2
B = B1 + SPD * B2
X = RAD * sqrt(d_lat^2+ cos^2(lat)*d_lon^2) * cos(270 - DIR - atan(d_lat*cos(lat) / (cos(nlat)*d_lon)))
Y = RAD * sqrt(d_lat^2+ cos^2(lat)*d_lon^2) * sin(270 - DIR - atan(d_lat*cos(lat) / (cos(nlat)*d_lon)))

where: DIR = direction of central wind
SPD = speed of central wind
RAD = Earth radius
lat = wind latitude
nlat = neighbouring wind latitude
lon = wind longitude
d_lat = difference in location latitude
d_lon = difference in location longitude (if d_lon < 0, d_lon = d_lon + π)

The individual quality marks are calculated according to the following equation:

$$M_{SWC_{i,j}} = 1 - \left(\tanh \left(\frac{\left| S(x,y) - S(x-i,y-j) \right|}{\max\left(AQC\_SC\_A \cdot \left| S(x,y) + S(x-i,y-i) \right| / 2, AQC\_SC\_B \right) + AQC\_SC\_C} \right) \right)^{AQC\_SC\_D}$$

(Equation 10)

where AQC_SC_A to AQC_SC_D are set-up parameters included in the static data file.
The final quality mark shall be the distance-weighted average of the *N_best_lc* individual marks:

$$M_{SWC} = \frac{1}{1 / \sum ELL\_DIST} \left(\sum \frac{1}{ELL\_DIST} M_{SWC_{i,j}} \right) \qquad \text{(Equation 11)}$$

If no wind vectors are found the quality mark M_{SWC} is set to zero.

To calculate the spatial height consistency, the AMV values are compared with all neighbouring AMV vectors within the height threshold of the current segment, according to the following equation:

$$M_{SHC} = 1 - \left(\tanh \left(\frac{abs(P(x,y) - P(x-i,y-j))_{MIN}}{AQC\_HC\_A \cdot P(x,y) + AQC\_HC\_B} \right) \right)^{AQC\_HC\_C}$$

(Equation 12)

where AQC_HC_A to AQC_HC_C are set-up parameters included in the static data file.

5.4.3 Tracking Consistency Tests

A true temporal consistency test is not available, because it would require the presence of both forward and backward tracking results for each cloud target, relying on a sequence of three overlapping images. The polar wind processing, however, relies on one tracking direction only and the default is backward tracking. This implies that the search PDUs are associated with the previous satellite pass over the same area that contains the target PDU.

But the system provides the possibility to combine backward and forward tracking with just two images. The concept of this is straightforward: the backward tracking results in an optimal location of the target box in the search PDU, corresponding with a peak in the matching surface. It is then possible to use the original location of the target centre as the centre of the search area for a forward tracking, leading to a ‘new’ location of the original target. In the ideal case, the new location (i.e., the end point of the forward tracking) will coincide exactly with the original location (i.e., the starting point of the backward tracking). But in most cases these points will not coincide and the ‘forward’ vector will not be exactly the same as the ‘backward’ vector (taking into account the 180 degrees difference in orientation).

This process provides three quality marks related to tracking consistency:

(a) Tracking vector consistency test M_{TC},
(b) Tracking speed consistency test M_{TSC},
(c) Tracking direction consistency test M_{TDC}.

To calculate these quality marks, the ('backward') AMV, S is compared with the 'forward' AMV, S_N.

The tracking vector consistency M_{TC} is calculated as follows:

$$M_{TC} = 1 - \left(\tanh\left(\frac{\left|S(x,y) - S_N(x,y)\right|}{\max\left(AQC\_TC\_A \cdot \left|S(x,y) + S_N(x,y)\right| / 2, AQC\_TC\_B\right) + AQC\_TC\_C} \right) \right)^{AQC\_TC\_D}$$

(Equation 13)

where AQC_TC_A to AQC_TC_D are set-up parameters included in the static data file.

The tracking speed consistency M_{TSC} is calculated as follows:

$$M_{TSC} = 1 - \left(\tanh\left(\frac{\left|\left|S(x,y)\right| - \left|S_N(x,y)\right|\right|}{\max\left(AQC\_TSC\_A \cdot \left(\left|S(x,y)\right| + \left|S_N(x,y)\right|\right) / 2, AQC\_TSC\_B\right) + AQC\_TSC\_C} \right) \right)^{AQC\_TSC\_D}$$

(Equation 14)

where AQC_TSC_A to AQC_TSC_D are set-up parameters included in the static data file**.**

The tracking direction consistency M_{TSC} is calculated as follows:

$$M_{TDC} = 1 - \left(\tanh\left(\frac{\left|DIR(x,y) - DIR_N(x,y)\right|}{\left(AQC\_TDC\_A \cdot e^{-vel / AQC\_TDC\_B}\right) + AQC\_TDC\_C \cdot vel + AQC\_TDC\_D} \right) \right)^{AQC\_TDC\_E}$$

(Equation 15)

where AQC_TSC_A to AQC_TSC_D are set-up parameters included in the static data file and

$$vel = \frac{\left|S(x,y)\right| + \left|S_N(x,y)\right|}{2}$$

5.4.4 Temporal Pressure Consistency Test

The pressure associated with the AMV is based on radiance data of the cloudy pixels in the target area. An additional pressure is calculated which is derived from the cloudy pixels in the search area. Since the search PDU is associated with the previous satellite pass, the comparison between both pressure values can be used to say something about the temporal consistency of the pressure.

The quality mark M_{TPC} is a measure of this consistency. It is calculated as follows:

M_{TPC} = 0, if target and search pressures differ by more than AQC_TPC_C
= 1, otherwise (Equation 16)

AQC_TPC_C is nominally set to 100 hPa.

5.4.5 Final Quality

The final quality value (QI) for AMVs is a weighted mean of the forecast, the two spatial, and the three tracking consistency tests, which is then further **multiplied** by the temporal pressure consistency flag. The weights are defined by the set-up parameters *AQC_Q_Weights_**. The final quality indicator is always in the range 0 to 1, because of the way in which the individual quality marks have been defined.

A second final quality value is calculated that is similar to the first one, the only difference being that it does not include the forecast consistency.