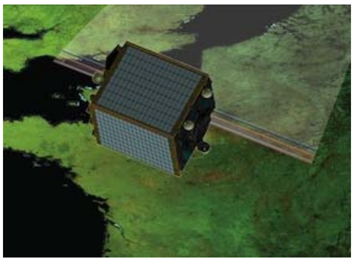

Reference: N77D7-PV02-US-13-IQC-GC-CAL-CS-108

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PROBA-V IQC-GC
Technical Note: Contribution to US Calibration Plan
13-11-2012

Prepared by	ACS GC team	Date	12-10-2011
Verified by	A. Arledler	Date	12-10-2011
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Version	Date	Description	Affected sections
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1.1	28/01/2011	Version proposed to address the PDR-Rids on the document	Sections 4.x
1.2	28/03/2011	PDR-045, PDR-062 and PDR -097	Sections 4.x
2.0	14/06/2011	Version submitted to the CDR	GC DDR RIDs: 012 Sec. 4.2.3 and 4.2.4; 013 Sec. 1.1; 014 Sec. 4.1.2.2; 015 Sec. 4.1.2; 017 Sec. 4.1.2.1; 021 Sec. 4.2.1; 022 (file naming convention) Sec. 4.2.2; 024 Sec. 4.2.2; 025 independent camera calibration; 026 Sec. 4.2.3.2 and Sec. 4.2.3.3; 027 Sec. 4.2.3.2. PV02-CDR RIDs: 062 Sec. 4.1.2.3; 064 Sec. 4.2.1. Completed all the TBW Sections (in response to all the related RIDs).
2.1	12/10/2011	Version proposed to address the CDR-Rids on the document	GC-CDR RIDs: 020 Sec. 4.2.3.1; 050 Sec. 4.2.1; 053 Sec. 4.2.2 (Fig 4.2-4); 054 Sec. 4.2.3.1; 056 Sec. 4.2.3.2; 059 Sec. 4.4; 072 Sec. 4.2.3.2; 074 Sec. 4.2.3.2; 092 Sec. 1.1; 113 Sec. 4.2.3.1. GC-CDR RIDs: 005 the Geometrical accuracy budget is included in Error Analysis document N77D7-PV02-US-09-IQC-GC-ARPT-ACS-0110-1.1

Version	**Date**	**Description**	**Affected sections**
2.2	13/11/2012	Removed sentence	rid QR-PV02-063 sec.4.2.1

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1. INTRODUCTION

1.1 Scope

This document gives the geometric calibration plan for the PROBA-V GC subsystem. This document gives a summary of the Geometrical Calibration method, and elaborates the geometric calibration activities after the launch of the satellite in terms of :

- calibration data management plan which specifies the input and output data flows;
- calibration strategy for the GC model validation and ICP generation and validation;
- calibration activity planning during and after commissioning phase .

The commissioning plan elaborates the activity planning for the nominal case and for the two main degraded cases.

Please note that the Geometric Calibration Plan document contains material extracted from the [ATBD] and [SDD]. However, this duplication is needed in order to make the document as much as possible self-consistent.

1.2 Applicability

It is an ACS contribution to section 5 of the US Calibration plan US-13-US-CAL-GC. This document has to be provided at PDR in draft version, at CDR in almost definitive version and should be updated to account for any changes at successive milestones.

2. REFERENCES

All applicable and reference documents, are listed in the SOW [N77D7-PV02-PM-19-IQC-GC-SoW-v1_0-draft].

2.1 Applicable documents

The documents that have been used for the preparation of underlying document are:

Doc. reference	Document Title
[SOW]	N77D7-PV02-PM-19-IQC-GC-SoW Proba-V PV02 User Segment Geometrical Calibration Statement of Work
[CPL]	N77D7-PV02-US-13-US-CAL PROBA-V US Calibration Plan
[ATBD]	Algorithm Theoretical Baseline N77D7-PV02-US-5-IQC-GC-ATBD-ACS-0102-2.1
[SDD]	Technical Note: Contribution to US Calibration Plan N77D7-PV02-US-14-IQC-GC-SDD-ACS-0103-3.2
[ARPT]	PROBA-V IQC-GC-Technical Note: Contribution to US Calibration Plan PROBA-TN-ACS-VITO-0108-1.1

Table 1: Applicable documents

2.2 Reference documents

Doc. reference	Document Title
[GLOS]	PROBA-V Terms, Definitions and Abbreviations N77D7-PROBA-V-TDA-v2_11
[JU-ROY]	Junchang Ju and David P. Roy “The availability of cloud-free Landsat ETM+ data over the conterminous United States and globally”. Remote Sensing of Environment 112 (2008) 1196–1211

Table 2: Literature references

3. TERMS, DEFINITIONS AND ABBREVIATED TERMS

General terms, definitions and abbreviations used within the scope of this document can be found in [GLOS]. In addition, the following are used:

ACS Advanced Computer Systems A.C.S.S.p.A.

4. GEOMETRIC CALIBRATION

4.1 Geometric Calibration Background

4.1.1 Basic concepts

The goal of geometric calibration of an optical sensor system is to model the line-of-sight for each pixel element of the imaging system. This is usually performed pre-flight in laboratory conditions where precise measurements enable to characterize the various aspects of the system.

Due to possible launch effects, distinct operational conditions and thermal deformation, a post-launch self-calibration is performed on a regular basis (e.g. every 60 days) to ensure geometric system stability.

PROBA-V is a small satellite, which provides only passive thermal control onboard, so temperature can play a major role in the geometric calibration process. This means that in order to ensure the total geometric system accuracy as specified in the PROBA-V requirements, a quite complex geometrical model is needed.

The in-flight geometrical calibration shall be able to estimate and monitor on a regular basis the boresight misalignment angles and focal plane deformations for the 3 cameras of the PROBA-V sensor, and there dependence on temperature and orbit position.

These geometrical calibration parameters shall be used to update the ICP (Instrument Calibration Parameter) file, which is used by the Processing Facility in order to guarantee the geometrical system accuracy of the system corrected products.

One of the principal design features of the GC subsystem is the division of the Proba-V L1C calibration datasets in “scenes” of a configurable length, of approximately 800 km along track, for which the calibration parameters can be assumed to be approximately constant with respect to camera CCD temperature or other currently unknown parameters, but large enough to make a reasonable estimate of the calibration parameters.

The calibration can be divided in 4 main processing chains which can be used to monitor and calibrate the Proba-V sensor.

GenChipsDB is used generate a Geocover Chips GCP Database from the Landsat Geocover data. The whole database covering all land between latitude 60N and 56S should be prepared before launch of the satellite.

JProcNewScenes is used to calculate scene specific calibration parameters (boresight angles and focal plane distortion parameters) whenever new calibration datasets are available. This could be launched automatically with a configurable time span to process any newly available data.

EstTrend is used to generate a new ICP file when it is considered necessary. This could be set automatically, for example once a month, or could be run by an operator when it is considered necessary on the basis of the geometric monitoring.

GeoMonitor is used to monitor the current condition of the PROBA-V system from a geometric calibration point of view. It can be used to see the calibration situation both in the form of numerical error statistics and graphical plots, both scene based and against possible variables such as CCD temperature and latitude, both with current ICP values and with optimal ones.

4.1.2 Description of the method

This section gives an overview of the method used for the geometrical calibration. It contains material mainly extracted from the [ATBD]. However, this duplication is needed in order to make the Geometric Calibration Plan document self-consistent.

The PROBA-V instrument is made up of three camera's. Each camera has two sensors: the VNIR sensor is associated with the visible bands and the SWIR sensor with the infra-red band.

A detector is associated with a full swath line of observations in a given band. While the VNIR sensor contains three detectors that each corresponds to a single strip, the SWIR sensor contains only one and it is made up of three strips.

Summarizing, the PROBA-V instrument has the following characteristics:

- 3 camera's, i.e. the Left camera, the Center camera and the Right camera
- 4 bands and hence 4 detectors/camera, i.e. BLUE, RED, NIR and SWIR
- 2 sensors/camera, i.e. the VNIR sensor (associated with the BLUE, RED and NIR bands) and the SWIR sensor (associated with the SWIR band)
- 6 strips/camera, i.e. BLUE, RED, NIR, SWIR1, SWIR2 and SWIR3

An image consists of one or more [image] bands, each consisting of a given number of columns and rows of [image] pixels:

- BLUE, RED and NIR strips are composed by 5200 pixels;
- SWIR1, SWIR2 and SWIR3 strips are composed by 1024 pixels;

Each pixel corresponds to a value of a given data type representing a specific type of information, e.g. a radiometric value (in the form of a DN, or a reflectance value, etc.), lon/lat coordinates, etc.

The lines of observations returned by a strip are (transmitted to earth and) stored in successive rows of a band. Each [image] pixel in each row, and hence each column in the band, corresponds to a given detector pixel.

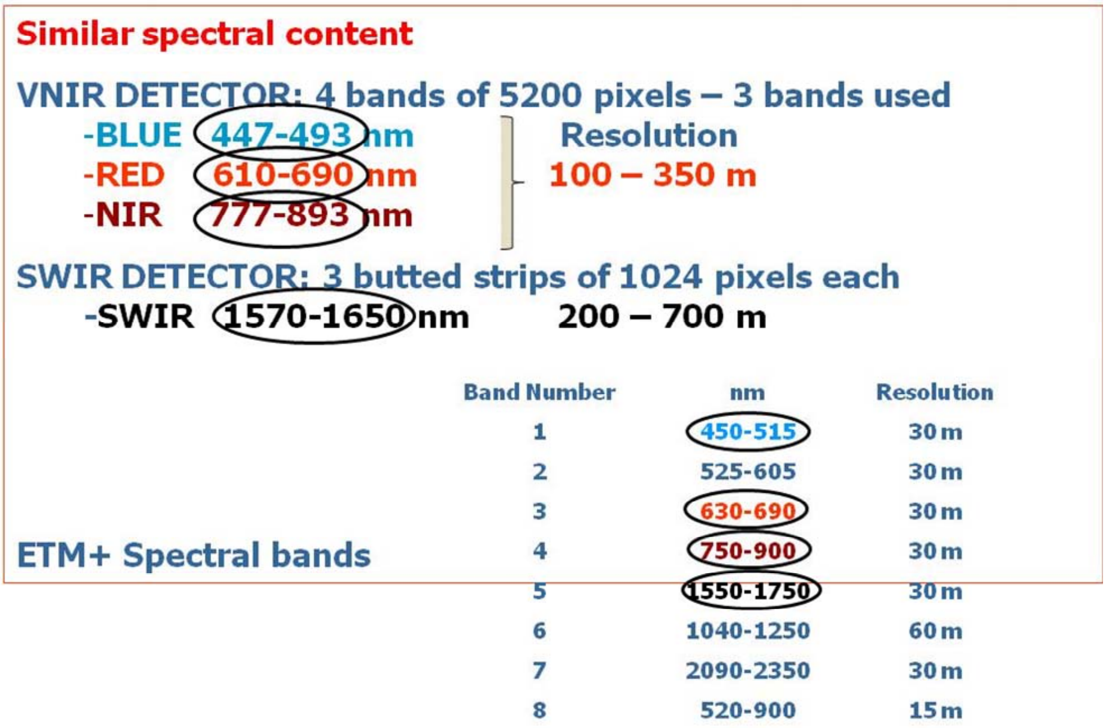


Figure 4.1-1: Rationale of the PROBA-V/Landsat Geocover bands selection for the geometric calibration. Details are given in Section "GCP Chips Generation".

The calibration is made by registering each band directly and independently with corresponding Landsat Geocover band chips:

- NIR band is used to calibrate the boresight angles and NIR band focal plane distortions;
- Other bands are used to calibrate the respective focal plane distortions;

The rationale of the PROBA-V/Landsat Geocover bands selection for the geometric calibration is reported in Figure 4.1-1, more details can be found in [ATBD] "GCP chips generation" section.

In the previous version of the ATBD document, an alternative calibration approach was proposed: first calculating camera boresight angles and NIR band focal plane distortions using a database of georeferenced image chips generated from band 4 of the Landsat Geocover dataset, and then calculating focal plane distortions of other bands from band to band registration.

However, the inter-band calibration approach has been discarded mainly for the difficulties of matching NIR to other four spectral bands of the surface areas with variable spectral characteristics as pointed out in RID-PDR-066.

Sensor Exterior and Interior Orientation parameters are expected to depend on camera CCD or TMA temperature and on the time starting from eclipse.

Two different strategies for estimating the Sensor Exterior and Interior Orientation parameters are foreseen (see [MOM-PM6]):

- Baseline calibration strategy at scene level;
- Optional calibration strategy (if needed) at global level. This option is not currently implemented but it is possible by a relative simple reconfiguration of the production chains (see [SDD]).

Assumptions and Limitations

The basic assumption of the **baseline calibration strategy** is that a scene size can be chosen so that the orientation parameters can be considered constant within the scene and that the scene is large enough to make a reasonable estimate of the parameters. The parameters can therefore be estimated for each scene separately and the parameter trend can be plotted vs. temperature and/or orbit position.

If necessary the 'global solution' (**optional calibration strategy**) is possible by a relative simple customization of the SW: the Sensor Exterior and Interior Orientation parameters are estimated considering a set of (multiple) scenes acquired at the same temperature and time starting from eclipse. The advantage of the 'global solution' is that the number of ground control points increases allowing an accurate estimation of the parameters in case of failure of the baseline calibration strategy.

However, it is expected that the baseline calibration strategy is fully adequate for PROBA-V calibration. In fact, sufficient number of GCPs (about 1600) are expected in a scene 800 km long acquired over land for each camera.

This estimation is done by using the updated version of the MMIO SW originally developed for Landsat TM/ETM+ for Proba-V as described in section 6. We used 8 Landsat scenes over land obtaining about 100 GCP chips for each scene and per band. Considering that a Proba-V scene of 800 km x 800 km is composed by about 16 Landsat scenes the number of GCP chips per band is about 1600. Please note that if needed the number of GCPs can be increased by changing the threshold value for the Moravec Interest Operator (see [ATBD] 6.5.4) without significantly affecting the quality of the GCPs (e.g. eliminating low contrast features like water bodies, desert, dry lands, etc. in the GeoCover scenes).

Of course only a fraction of them are effectively used for the calibration (seasonal effects, clouds, etc.), but it is expected to have a sufficient number of GCP used for the calibration.

Please note that:

1) scene selection can be done for the parameter calibration, e.g. selecting only the scenes cloud-free (or few clouds);
2) MMIO extracts chips well distributed over the image avoiding that most of the chips are concentrated over a small region of the image;

3) calibration parameters errors are computed via error propagation ([ATBD] section 8.2.5) and these errors shall be considered during the least square fitting; it means that in the case that a scene have less GCPs in same part of the field of view larger errors are expected and the contribution to the final fitting is less important.

In addition, during the calibration campaign several scenes at the same temperature/latitude shall be processed therefore the final calibration parameters shall be a weighted average value with a reduced error with respect to the parameters extracted from a single scene.

Please note that, the PF interpolates the CG parameters stored in the ICP file according to temperature/time exit from eclipse, therefore no discontinuities are foreseen.

The main expected advantage of this method is that the computationally expensive part of the calibration processing can be done individually for each scene without making large assumptions on which known environment parameters the distortions depend. If the distortions actually depend on position in the orbit, or camera TMA temperature, or have a particular drift in time, this dependency can be noted from plots of scene calibration parameters, the sensor model can be modified, and new calibration parameters can be computed, without repeating the computationally expensive part of the processing. This method would not be the most effective if the distortions where to depend only on CCD temperature, exactly as expected, and the latter were to oscillate rapidly, so that the scene length would have to be too short to work. But this scenario does not seem probable at the moment.

It is worth noting that the current calibration approach foresees that each camera is calibrated separately, whereas in the previous version of the ATBD document all the three cameras are calibrated together considering Tie-Points in the inter-camera overlap regions. The multi-camera calibration approach has been discarded (see [MOM-PM06]) mainly because it requires a suitable set of test data to verify/evaluate results for inter-camera calibration which is not available.

The number of ground control points is crucial for the end-result of the per camera approach: it is expected that the number of GCPs per scene and camera extracted by the MMIO tool is adequate.
However, if necessary the number of ground control points can be increased:

- by changing the threshold value for the Moravec Interest Operator ([ATBD] see 6.5.4);
- by using the 'global solution' is possible by a relative simple customization of the SW (see above).

4.1.2.1 Baseline Geometric Calibration Dataflow

The diagrams that follow describe the high-level processing flows for baseline Geometric Calibration processing algorithms. In these figures, within each box indicating the principal algorithm processing step is reported the corresponding Section where the algorithmic method is described.

In all of these diagrams, the following naming convention is used:

- LoS model; set of parameters used to model the sensor Exterior Orientation parameters (boresigh angles) and Interior Orientation parameters (principal point offsets, polynomial CCD distortions) for each spectral band and camera. The LoS model is the result of an overall geometric calibration campaign performed over a set of PROBA-V scenes; more specifically the LoS model is computed from the current ICP file and thus includes temperature/time starting from eclipse depended fitting.

- Scene parameter values; sensor Exterior Orientation parameters (boresigh angles) and Interior Orientation parameters (principal point offsets, polynomial CCD distortions) extracted from the geometric calibration of a single scene;

- Scene parameter errors; errors associated to the Scene parameter values (Error analysis);

- Calibration Report contains the errors relative to the boresight angles and to the CCD pixel viewing directions;

The sensor Exterior Orientation parameters (boresight angles) are common among all the bands, and these parameters are calibrated using NIR images.

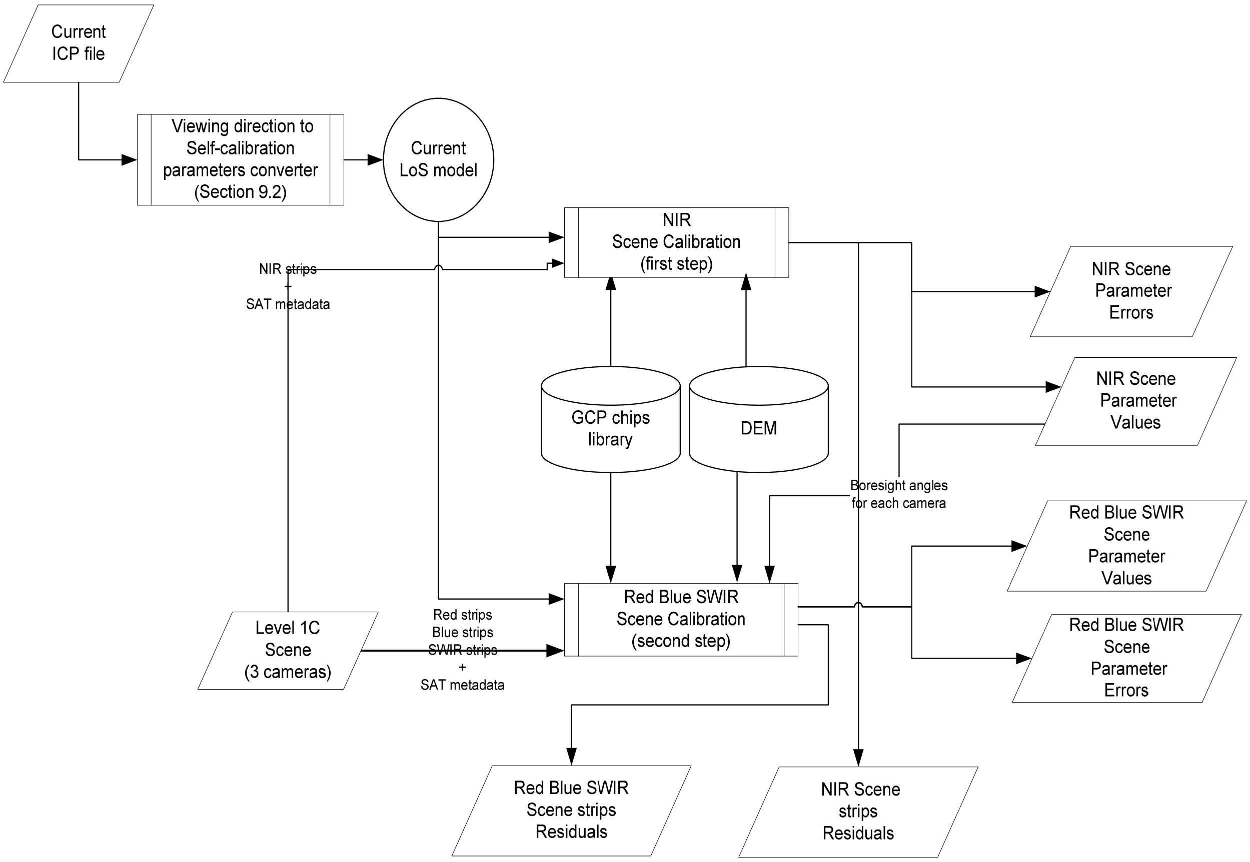


Figure 4.1-2: Scene Calibration composed by NIR scene calibration and Red-Blue-SWIR scene calibration

Figure 4.1-3 illustrates in more detail the NIR scene calibration processing flow. Absolute NIR geo-localization errors are computed during the NIR calibration by performing appropriate statistic computation on the GCPs residuals (difference between the observed and predicted/computed GCPs coordinates). The GCP residuals are computed on a set of GCPs used to validate the geolocation accuracy performance of the geometric calibration, and which are not used in the scene inversion model. In particular, scene residual includes for each strip:

- List of line/pixel position for each GCP found by image correlation;
- List of line/pixel position for each GCP predicted by using current version of the ICP
- List of line/pixel position for each GCP predicted by using the best fit (inversion model) on that scene
- List of flags indicating if the GCPs are used for inversion or not
- List of SNR correlation value for each GCP.

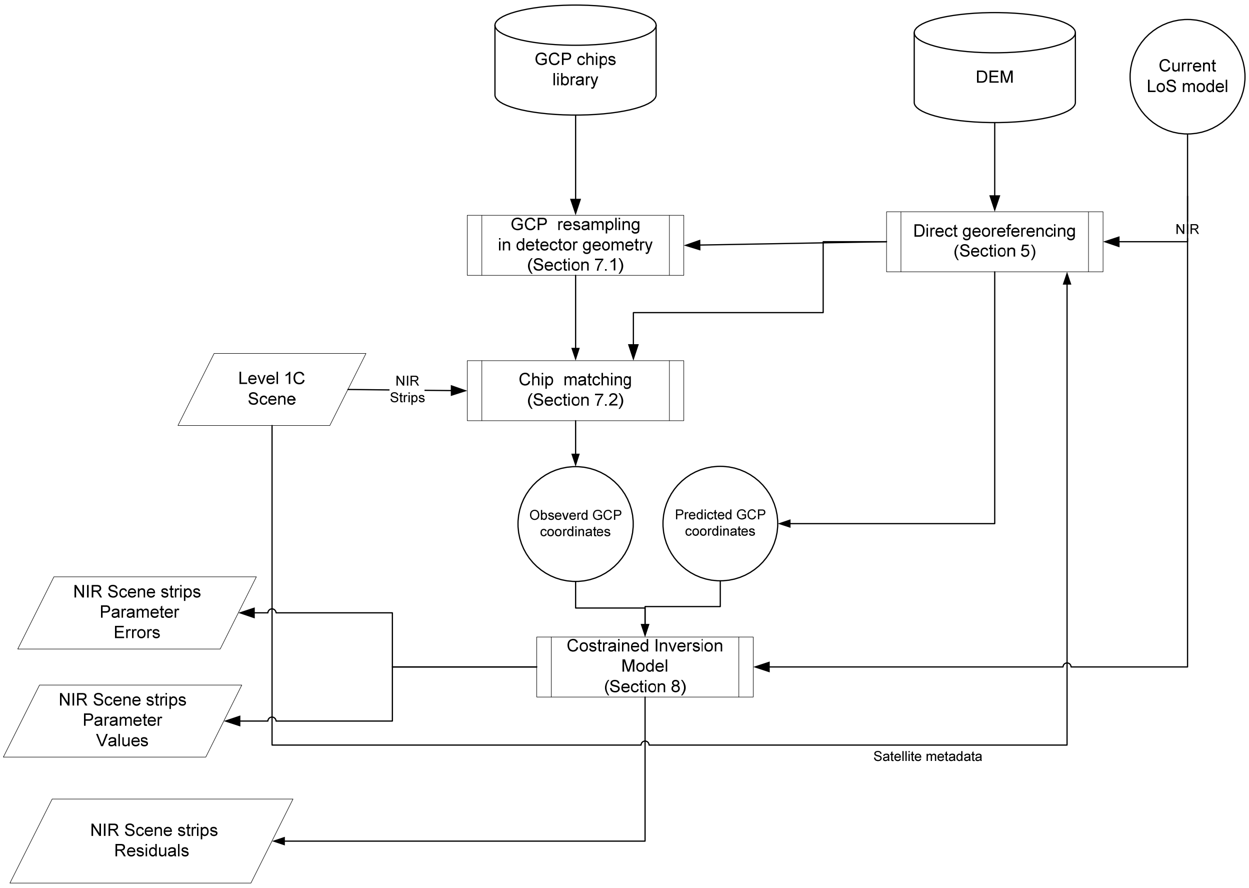


Figure 4.1-3: NIR scene strips calibration (performed first)

Figure 4.1-4 illustrates in more detail the Red, Blue and SWIR calibration processing flow. Again, absolute Red, Blue and SWIR geo-localization errors are computed during the calibration by performing appropriate statistic computation on the GCPs residuals (difference between the observed and predicted/computed GCPs coordinates). Again, the GCP residuals are computed on a set of GCPs used to validate the geolocation accuracy performance of the geometric calibration, and which are not used in the scene inversion model

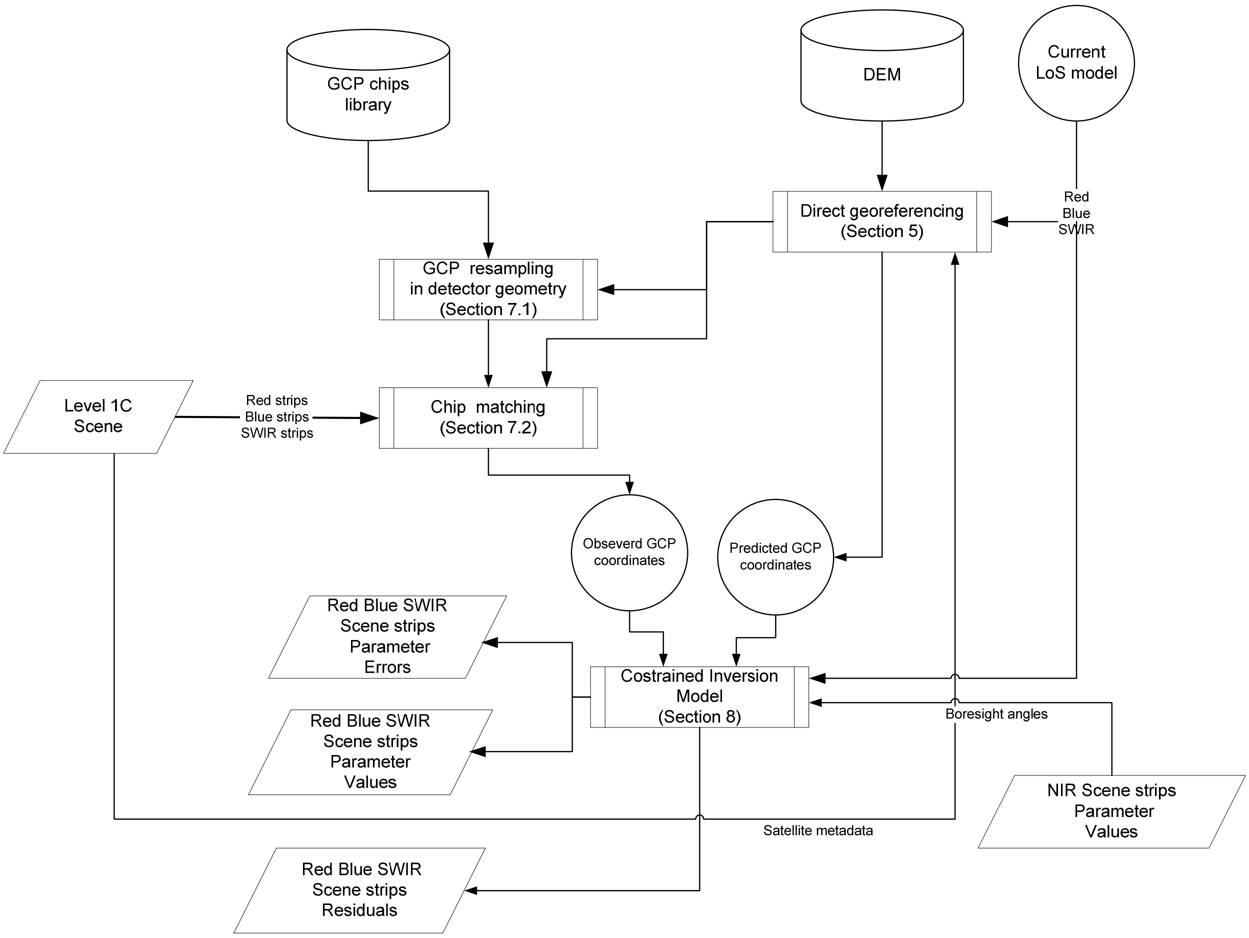


Figure 4.1-4: Red-Blue-SWIR scene calibration (performed after NIR band calibration)

From PV01 it is clear that there will be multiple temperature readings required spread over the instrument to define the relation to the viewing angles.

However, currently the parameters are expected to depend linearly on a single temperature per camera (the temperature or a combination of temperatures having the highest impact due to distortions of the optical elements), so the parameters can be linearly fitted against camera temperature to determine the most probable linear law according to Figure 4.1-5. A weighted least squares fit is used according to what specified in [ATBD] Section 9.

It is important to point out that the input "current LoS model" in the first calibration campaign shall be generated starting from the “starting” ICP file. It is assumed that this “starting” ICP file is externally generated (outside the GC facility) using on-ground calibration and measurement data together with the validated thermal elastic model of PV01. For the following calibration campaigns (later on) the input ICP file is the latest one generated by the GC facility.

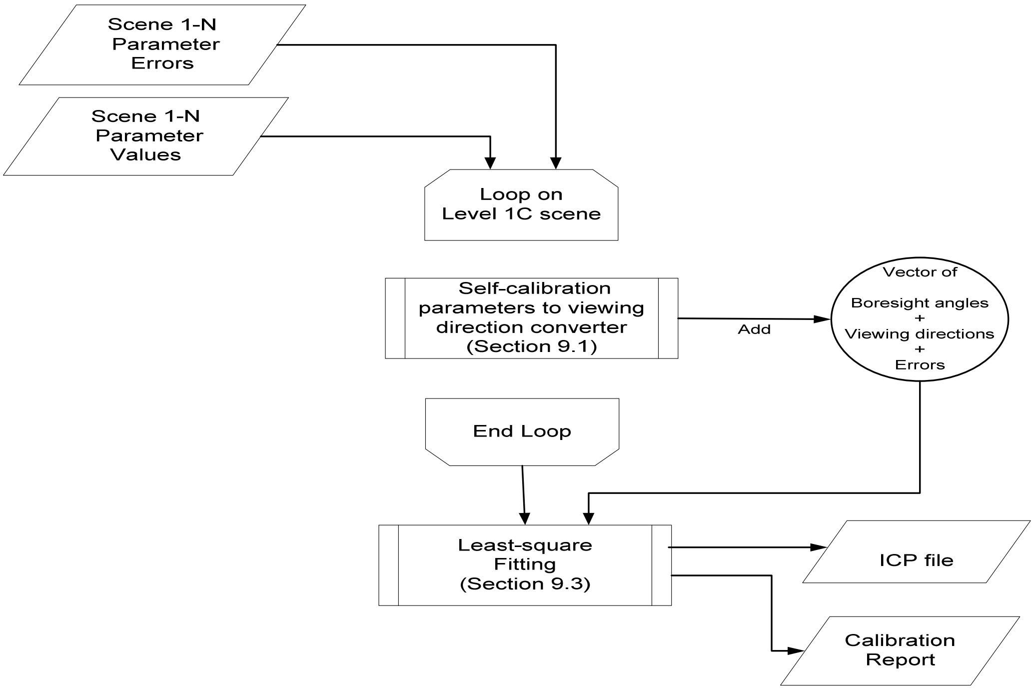


Figure 4.1-5: Temperature variation Calibration and ICP file generation. In this diagram Interior Orientation parameters (principal point offsets, and polynomial CCD distortions) are called Self-Calibration parameters

4.1.2.2 Optional Geometric Calibration Dataflow

The diagrams that follow describe the high-level processing flows for optional Geometric Calibration strategy at global level.

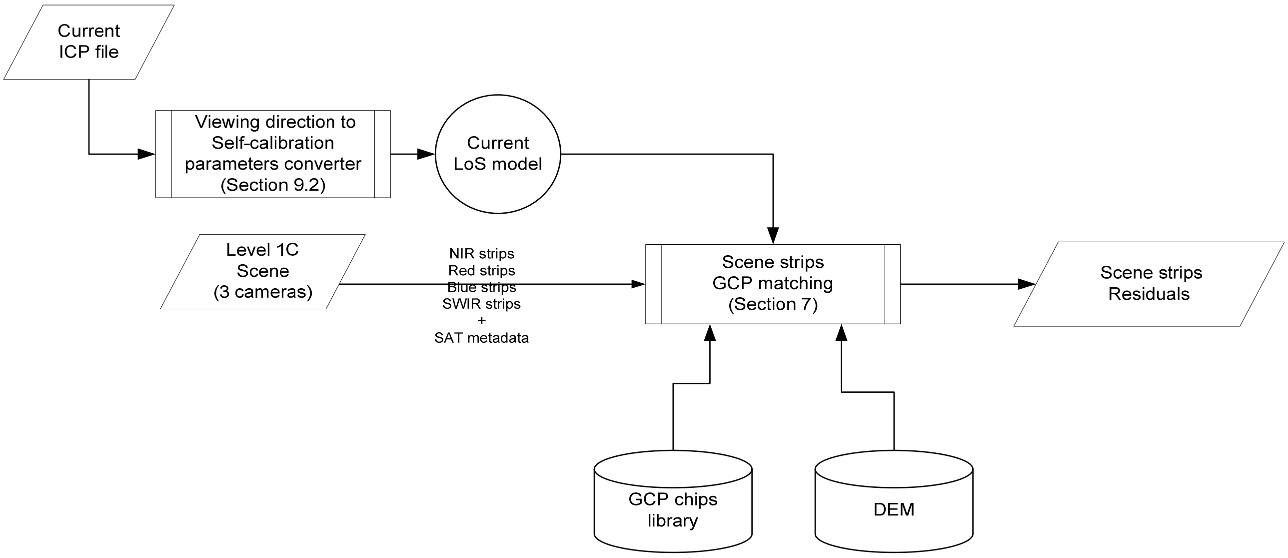


Figure 4.1-6: NIR and Red-Blue-SWIR Scene GCP matching

The GCP chips extraction and matching is performed independently for each band and camera (more exactly for each strip) and the result is collected in the scene strip residual file containing the GCPs residuals (difference between the observed and predicted/computed GCPs coordinates).

In particular, scene strip residual includes for each strip:

- List of line/pixel position for each GCP found by image correlation;
- List of line/pixel position for each GCP predicted by using current version of the ICP
- List of flags indicating if the GCPs are used for inversion or not
- List of SNR correlation value for each GCP.

The “global level” geometric calibration is illustrated in Figure 4.1-7 (NIR band) and Figure 4.1-8 (other bands). It is achieved by performing the inversion model over a set of scenes acquired at different times but with the same expected thermal deformations, e.g. with the same temperature and exit time from eclipse (within some margins).

The corresponding GCP residuals of this set of scenes are indicated in Figure 4.1-7 and Figure 4.1-8 as: Scene #1 Residuals, Scene #2 Residuals, .., Scene #N Residuals.

In line with the baseline approach, the sensor Exterior Orientation parameters (boresight angles) are common among all the bands, and these parameters are calibrated using NIR images (e.g. NIR calibration is performed first).

The output of the global-level geometric calibration are:

- Multi-scene Parameter values; sensor Exterior Orientation parameters (boresigh angles) and Interior Orientation parameters (principal point offsets, polynomial CCD distortions) extracted from the geometric calibration of the set of input scenes;

- Multi-scene Parameter errors; errors associated to the Multi-scene Parameter values (Error analysis);
- Scene strip complete residuals (a separate file for each scene); the scene strip residuals (see above) including the list of line/pixel position for each GCP predicted by using the global-level best fit (inversion model).

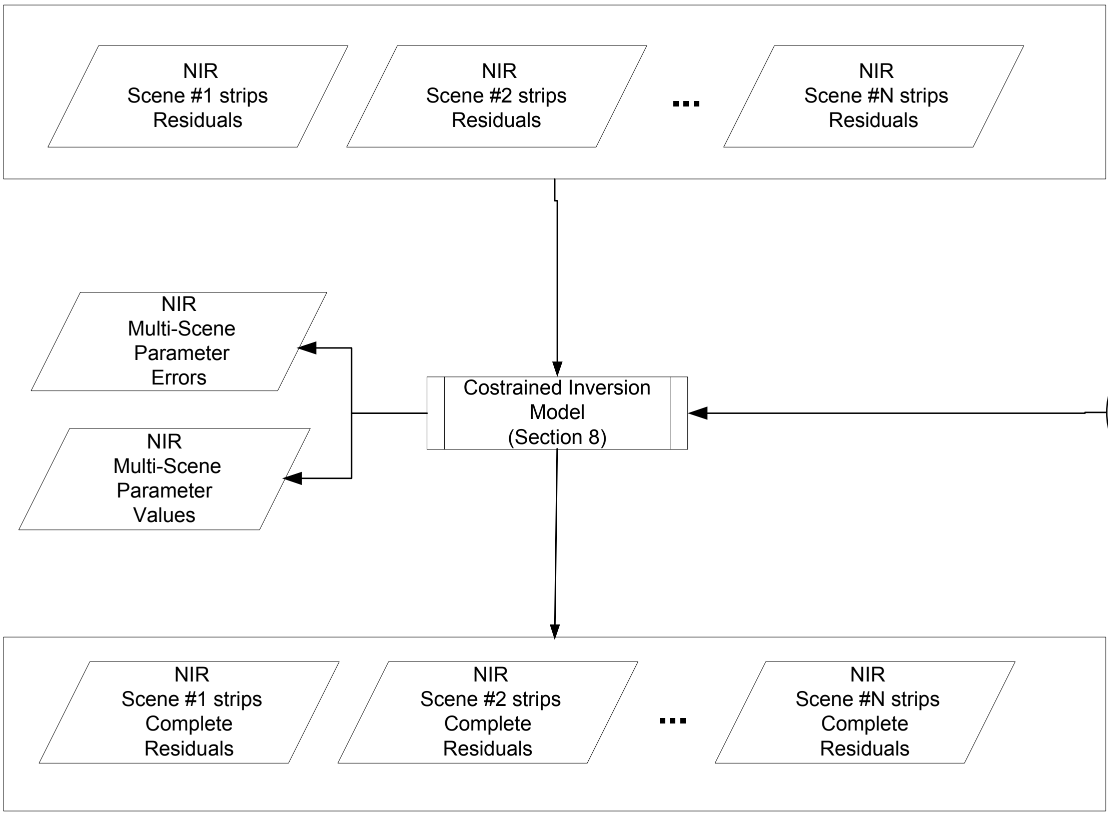


Figure 4.1-7: NIR global-level geometric calibration (performed first)

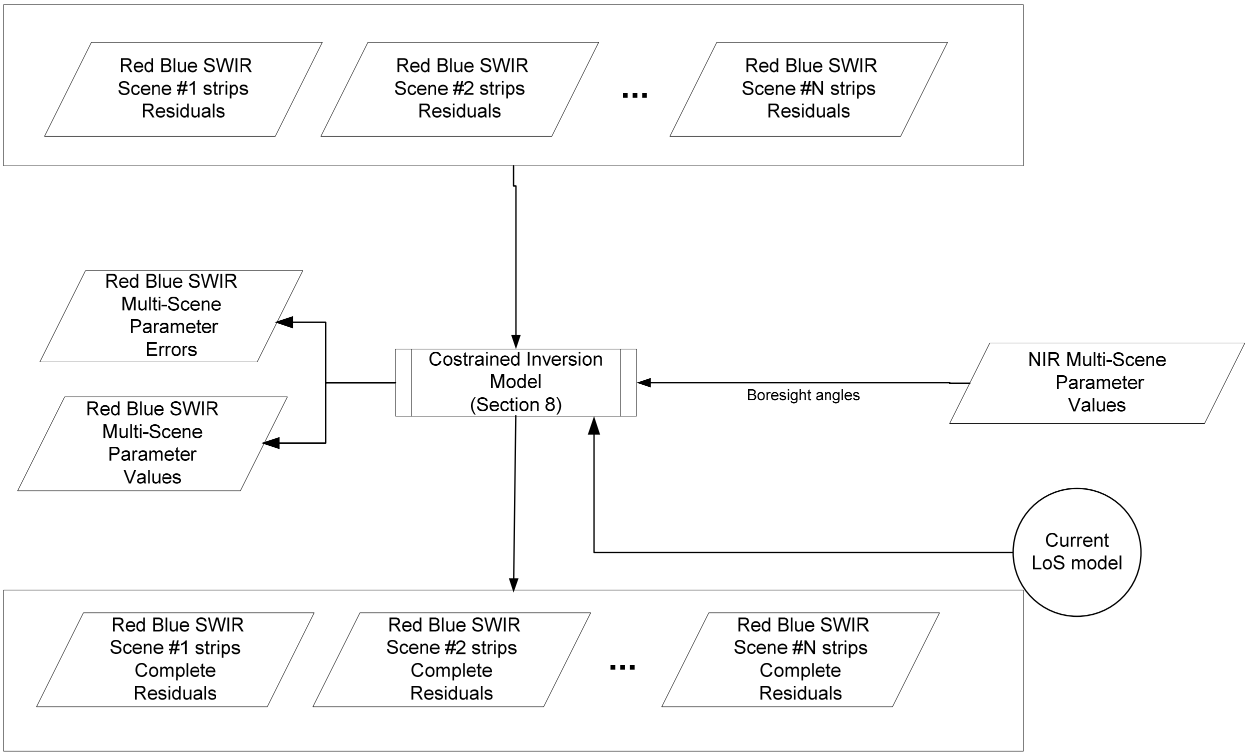


Figure 4.1-8: Red-Blue-SWIR global-level geometric calibration (performed after NIR band calibration)

The ICP generation method approach is the same of the baseline geometric calibration (see correspondingly dataflow reported in the previous section).

4.1.2.3 LoS modelling

For a given camera *C* and spectral imager *band*, the viewing direction vector (LoS) in the detector coordinate system (spectral imager SI coordinate frame see [PF-DPM]) is parameterized in the following way:

$$\begin{pmatrix} x_i^{band,C}(T) \\ y_i^{band,C}(T) \\ -f^{band,C}(T) \end{pmatrix} = \begin{pmatrix} \hat{x}_i^{band} - x_{PP}^{band,C}(T) - \Delta x_i^{band,C}(T) \\ \hat{y}_i^{band} - y_{PP}^{band,C}(T) - \Delta y_i^{band,C}(T) \\ -f^{band,C}(T) \end{pmatrix}$$

where:

- $i = 0, \ldots, N - 1$ where N = number of pixels of spectral imager *band* and camera *C*

- T is the temperature;
- $\hat{x}_i^{band}$ and $\hat{y}_i^{band}$ are the ideal sensor coordinates
- $f^{band,C}(T)$ is the effective focal length;
- $x_{PP}^{band,C}(T)$ and $y_{PP}^{band,C}(T)$ are the principal point shift (position of the CCD detector central pixel in the spectral imager SI coordinate frame);
- $\Delta x_i^{band,C}(T)$ and $\Delta y_i^{band,C}(T)$ are the CCD displacements with respect to the ideal sensor coordinate

From PV01 it is clear that there will be multiple temperature readings required spread over the instrument to define the relation to the viewing angles. However, currently the parameters are expected to depend linearly on a single temperature per camera (the temperature or a combination of temperatures having the highest impact due to distortions of the optical elements).

The following self-calibration parameters shall be analyzed and implemented during the project:

- General polynomial model of degree M:
  - $\Delta x^{band,C}(T) = \sum_{j=1}^{M} a_j^{band,C}(T) x^j$
  - $\Delta y^{band,C}(T) = \sum_{j=1}^{M} b_j^{band,C}(T) x^j$

Please note that the principal point shift is equivalent to polynomial constant term.

A preliminary analysis on the simulated data has been done. The main outcome is that this general polynomial model gives satisfactory results considering a 8th order of polynomial coefficients. However, more accurate assessment of the polynomial model can be done by using on-ground calibration and measurement data together with the validated thermal elastic model of PV01 (pre-launch) and by using real data during the commissioning phase. The model selection strategy is described in Section 4.3.2.

The following table gives an overview of the set of parameters to be calibrated for a given PROBA-V scene (approximately at constant temperature).

Calibration Parameters	Number of parameters
Exterior Orientation Parameters	
Boresigh angles for each camera	3 (angles) x 3 (cameras) = 9
Interior Orientation Parameters	
Principal Point for each camera and strip	2 (PP) x 3 (cameras) x 6 (strip) = 36
Self-Calibration Parameters	
Polynomial model for each camera and strip of degree M	M x 3 (cameras) x 6 (strip) = 18 * M

The number of calibration parameters to extract from a single strip scene (via GCPs/TPs correlation) is **6 + M**, where M is the degree of the self-calibration polynomial.

4.2 Geometric Calibration Plan

4.2.1 Overview

Once in orbit, any data collected in nominal mode and processed to form L1C products, covering land in the 60N to 56S latitude range can be used for Geometric Calibration.

Initially, during the commissioning phase, all available data should be used to determine, as soon as possible, first estimates of onboard calibration parameters and their errors, to verify that:

- the geometric distortions are as expected by the current model;
- the software is working correctly;

In addition, as detailed in 4.2.3, during the commissioning phase specific analysis is envisaged in order to perform calibration parameter tuning (e.g. order of deformation polynomial, etc.).

It is important to point out that a pre-launch model selection and calibration parameter tuning is performed by using on-ground calibration and measurement data together with the validated thermal elastic model of PV01, and the corresponding results are used as starting model/parameters-setting during the commissioning phase. ACS and VITO shall contribute to the pre-flight calibration by supporting the definition of the minimal set of parameters to retrieve from the on-ground calibration.

During the commissioning phase it is verified if the baseline calibration strategy (as described in section 4.1.2.1) is fully adequate for PROBA-V calibration or the ‘global solution’ (optional calibration strategy as described in section 4.1.2.2) is necessary.

Initially, during the commissioning phase, geometric calibration monitoring with the geo-monitor application and ICP updates will probably be quite frequent.

As the time goes on the percentage of data used for calibration and the frequency of calibration monitoring and ICP updates can be reduced according to trends and error statistics noted during monitoring.

We propose to use a set of geographic ROIs covering approximately 6 degrees latitude and going from 180 degrees west to 180 degrees east over the 60N to 56S latitude range and all the longitudes in order to skip the world regions without SRTM DEM.

The L1C files are expected to cover the whole swath across track and to be approximately 800 km long.

The following table and figure show a proposal set of such ROIs and the result of a simulation done by the PF of the coverage of datasets which would be produced in a day on the basis of these ROIs.

ROI	TL_LAT	TL_LON	BL_LAT	BL_LON
1	59	-180	53	180
2	47	-180	41	180
3	35	-180	29	180
4	23	-180	17	180
5	11	-180	5	180
6	-1	-180	-7	180
7	-13	-180	-19	180
8	-25	-180	-31	180
9	-37	-180	-43	180
10	-49	-180	-55	180

Table 4.2-1: input ROIs

The following figure shows the result of the ROI clipping:

- Red segments : segments acquired by the left camera
- Green segments : segments acquired by the center camera
- Blue segments : segments acquired by the right camera
- Black segments : segments resulting from the clipping (using the ROIs specified in the Table 4.2-1)

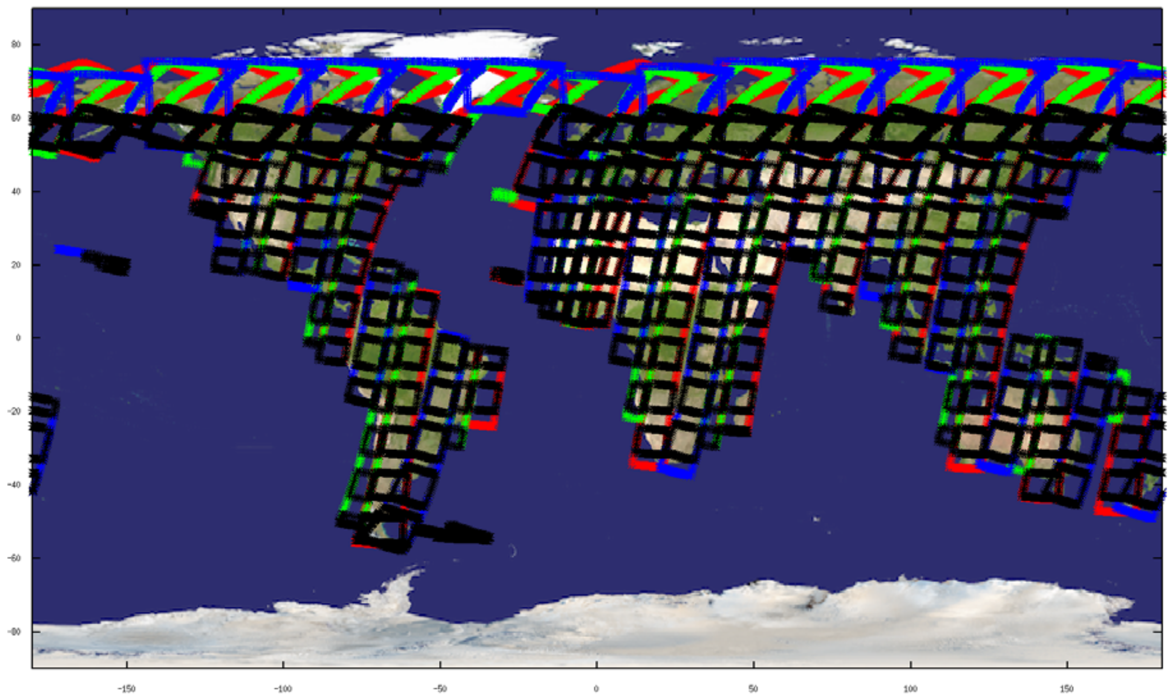


Figure Errore. Nel documento non esiste testo dello stile specificato.**.2-1 : Simulated coverage of 1 days calibration data**

The total size of the L1C data simulated for 1 day is 133.7Gb.

According to VITO if these were to be compressed with the hdf SZIP functionality their volume should be reduced by approximately 50%.

These data are processed regardless of their effective contribution to the Geometrical Calibration. Note that the GC will automatically give less weight to scenes where estimated precision of estimated parameters is lower and more weight to scenes in under represented conditions.

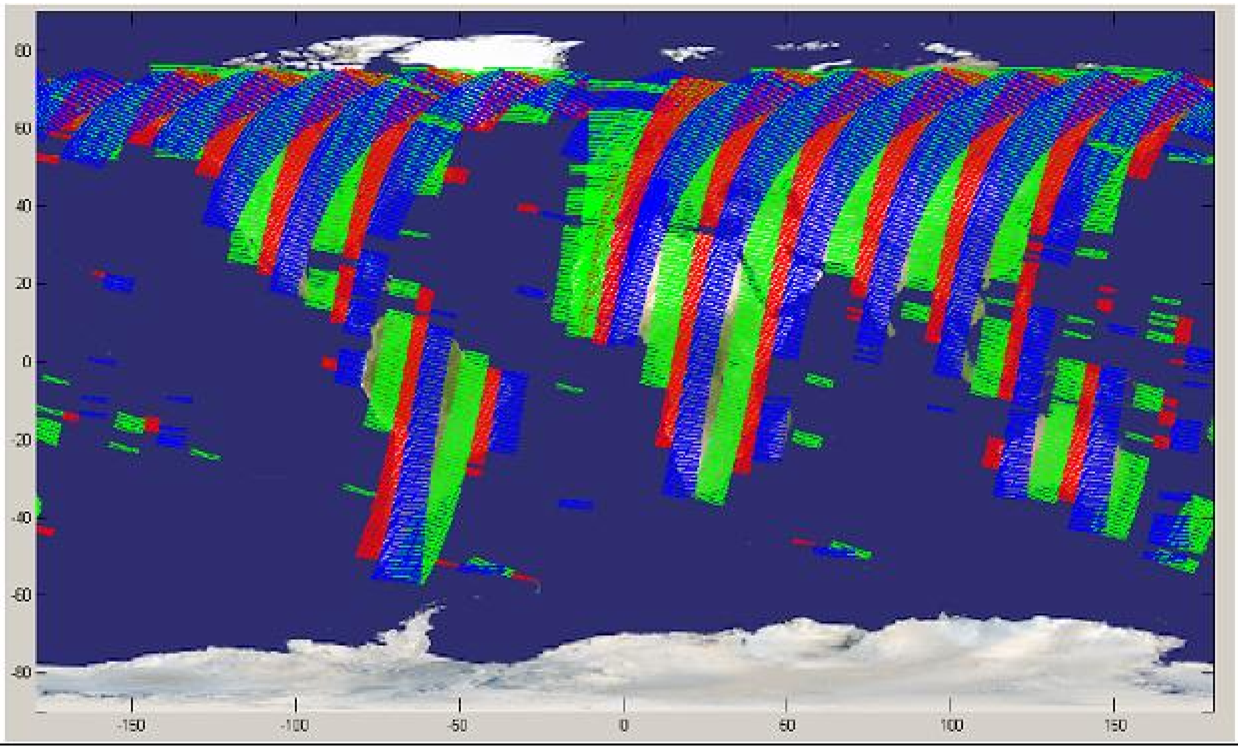


Figure 4.2 -2: Example of PROBA-V one day coverage of the 3 cameras (1 day orbiting with green=right camera, red= center camera, blue = left camera)

ICP parameters are stored in the form of a temperature-time starting from eclipse matrix, so that a full set of distortion parameters can be bi-linearly interpolated or extrapolated for every temperature- time starting from eclipse pair. If temperature and time starting from eclipse are totally correlated all the information in a temperature- time starting from eclipse matrix will lie on a single curve. If this is almost, but not quite, the case they will lie on a thin strip. Distortions are assumed to depend linearly with temperature and according to a low order polynomial (with order ≤ 3) with time starting from eclipse. The order used for the time starting from eclipse dependency will be the one which gives the best fit.

A pre-launch fitting order polynomial tuning is performed by using on-ground calibration and measurement data together with the validated thermal elastic model simulations at different temperatures and positions along the orbit, and the corresponding results are used as starting fitting order polynomial during the commissioning phase. (see section 4.2.3).

From PV01 it is clear that there will be multiple temperature readings required spread over the instrument to define the relation to the viewing angles. However, thermal elastic model simulations will be used in order to define the temperature or a combination of temperatures having the highest impact due to distortions of the optical elements.

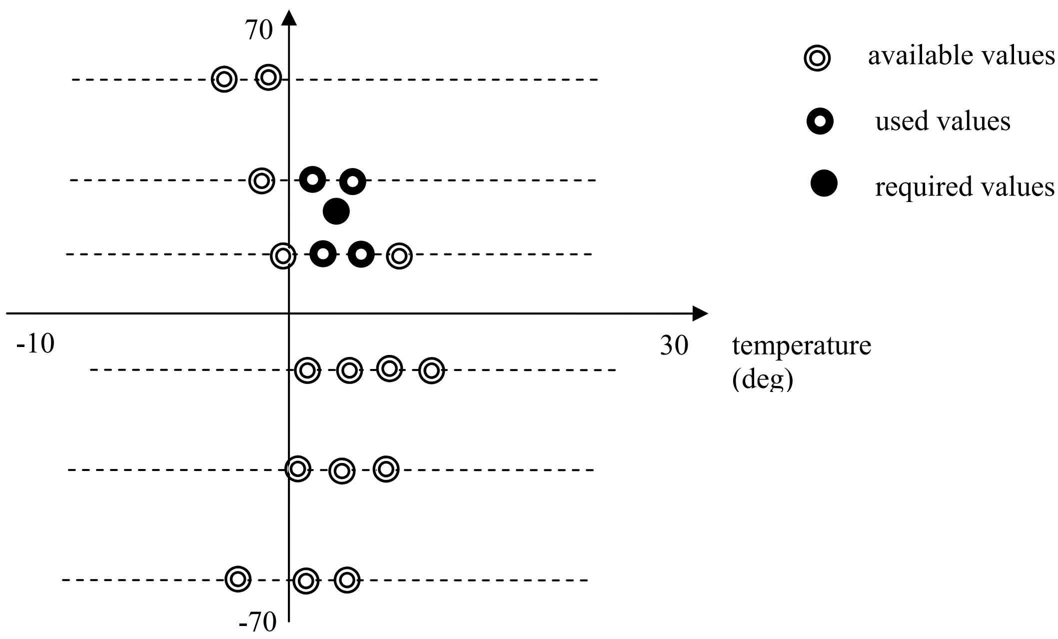


Figure 4.2 -3: Temperature-time exit from exlips matrix in ICP files

4.2.2 Data Management Plan

A calibration data management plan which specifies the input and output data flows is part of the calibration plan and it is described in this section.

The processing chain **GenChipsDB** is used generate a Geocover Chips GCP Database from the Landsat Geocover data. The whole database covering all land between latitude 60N and 56S should be prepared before launch of the satellite, and therefore the data flow relative to the GenChipsDB it is not described here in the calibration plan.

The GCP chips dataset is stored in file-system based repository**.** It is organized in directories by Landsat WRS2 paths and rows. For example the image chips corresponding to Landsat path 188 and row 42 are in directory 188/042.

Each directory contains (see [SDD] for more details):

- Chips - directory contains the actual image chips in 91x91 float raw binary format.
- GCPlist.txt - ASCII file in table format giving the list of chip filenames and chip center geodetic and map coordinates.
- GCPscene.txt - ASCII file in tag value format giving various info, including geocover scene metadata and chip extraction parameters.

The 3-arc second pixel spacing (corresponds to ~ 90m) SRTM V3 Digital Elevation Model (DEM) is used. It covers ~ 80% of land from the latitude 60° North to 56° South (see [SDD] for more details).
All the files are in a common srtm_v3/SRTM_Data_GeoTiff directory and are called Z_{$COL}_{$ROW}.TIF where 1 ≤ {$COL} ≤ 72 indicates the column and 1 ≤ {$ROW} ≤ 24 the row number in a grid of non-overlapping 5° x 5° cells, increasing respectively from 180W to 180E and 60N to 60S.

The principal external and internal interfaces are reported in the following Figure 4.2.2-1, which gives a static overview of the GC sub-systems input/output data.

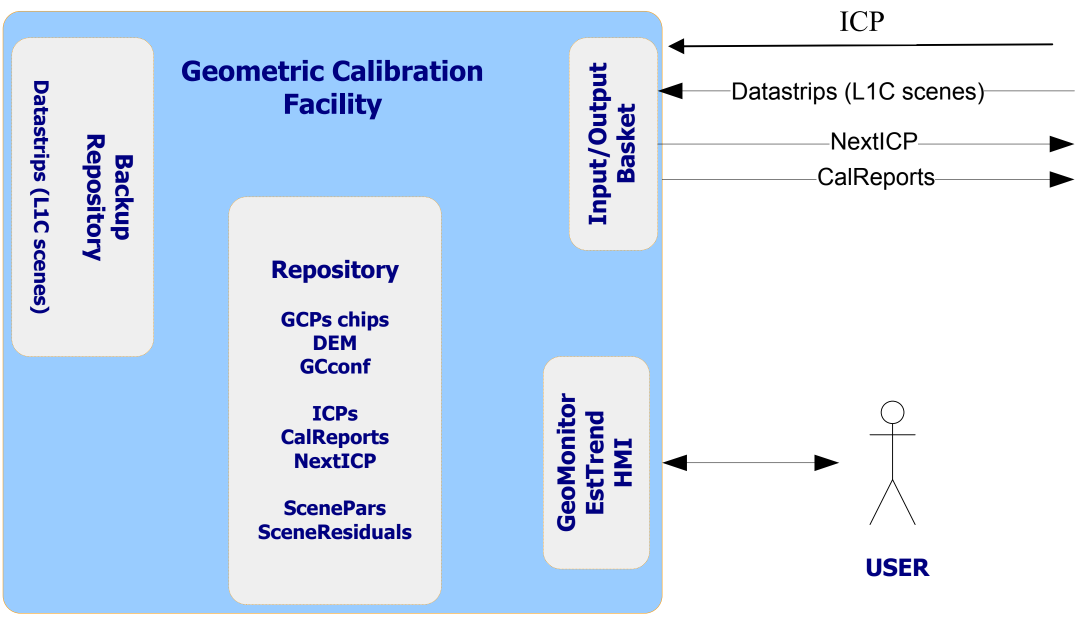


Figure 4.2-4: Geometric Calibration Facility main external and internal interfaces

The external inputs the current **ICP** (instrument calibration parameter) file and the Proba-V datastrips to be used for calibration.

The external outputs are the updated **ICP** to be used as current ICP until the next time it is calibrated, and the **CalReport** which is the GC part of the calibration verification report.

The main internal data are :

- The GCPs chips and DEM tiles for the georeferencing;
- GCconfs configuration files;
- ScenePars (sensor Exterior Orientation parameters and Interior Orientation extracted from the geometric calibration of each processed scene)
- SceneResiduals (residuals for each processed scenes used by GeoMonitor)

The main processing chain systematically used during the geometric calibration is **JProcNewScenes.** The JProcNewScenes is a Java program which uses the JODI framework in order to launch and monitoring the ProcNewScenes processing chain**.** ProcNewScenes is used to calculate scene specific calibration parameters (boresight angles and focal plane distortion parameters) whenever new calibration scenes are available. This is launched automatically with a configurable time span to process any newly available scenes.

The JProcNewScenes input/output dataflow is fully described by using the activity diagram reported in Figure 4.2-5 .

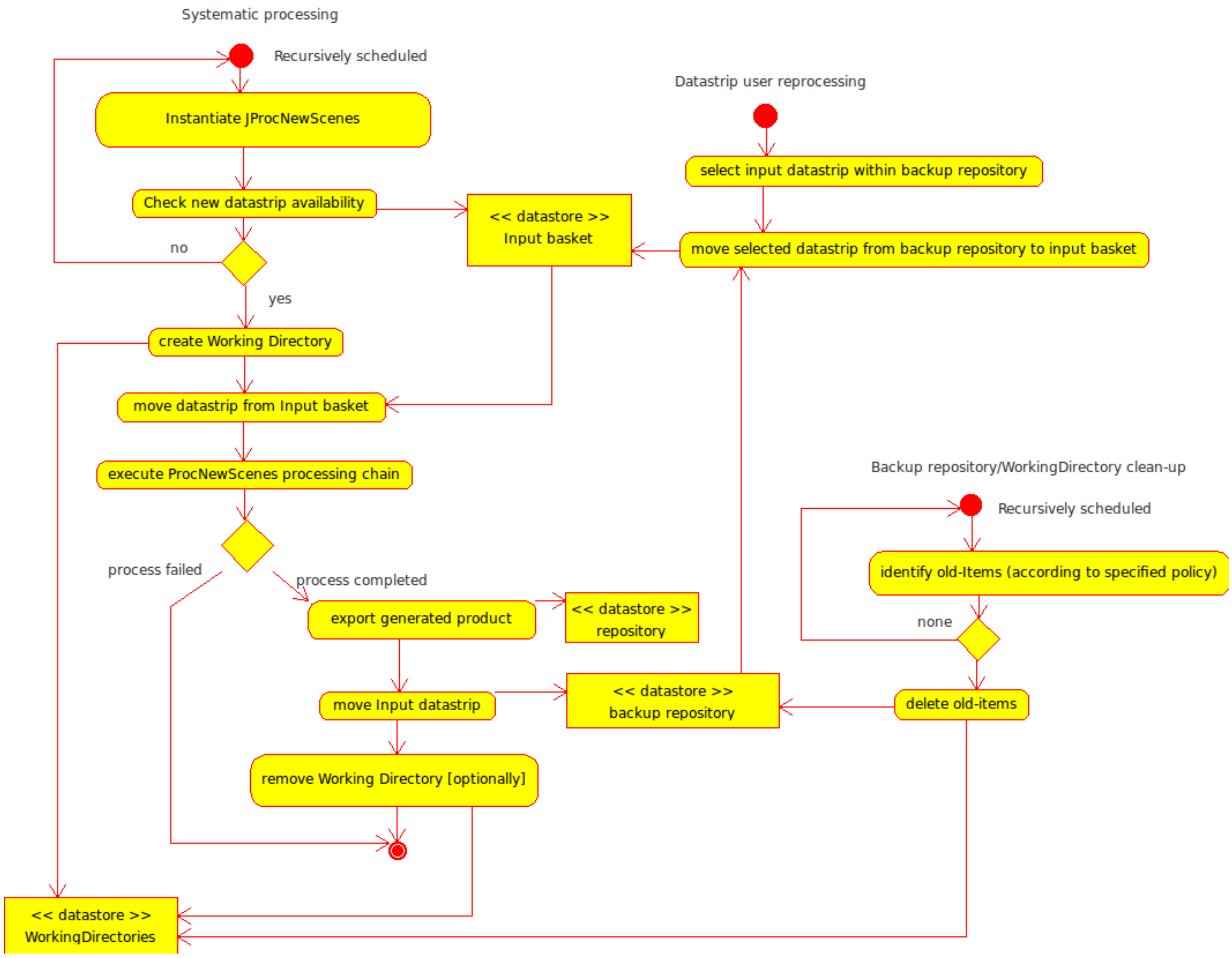


Figure 4.2-5: JProcnewScenes activity diagram

Some details about the activity diagram are given below:

- the JProcNewScenes is launched automatically with a configurable time span by using a Crontab demon;
- the first task of the JProcNewScenes is to check the availability of a datastrip (scene) in a configured Input Basket directory; in the case that no datastrip is available the JProcNewScenes terminates;
- if a datatrip is available, JProcNewScenes creates a Working Directory (WD) and moves the input datatrip from the Input Basket to the WD; in addition the current ICP file is copied in the WD (from Repository).
- if an error occur during the processing chain (ProcNewScenes), the WD is not removed for investigation;
- after the completion of the processing chain the generated products (ScenePars and SceneResiduals) are exported in the repository directory, the input datastrips are moved to the backup repository and then the WD is removed (optionally).

The processed scenes are stored in the backup repository for a configured time period according to a pre-defined cleaning-up policy. That gives the user the possibility to perform the data reprocessing by simply moving the selected scenes from the backup repository to the input basket. The data reprocessing is an important feature which is expected to be extensively used during the commissioning phase for the GC model verification/testing and parameter tuning.
In addition, also Working Directories not removed after the completion of the processing chain are kept within the system for a configured time period according to a pre-defined cleaning-up policy. This feature is very important especially for the Geometrical Calibration testing/investigation and model verification using real data during the commissioning phase.

The clean up policy is described in [SDD] Section 4.13.1.

The ProcNewScenes processing chain is composed by 2 tasks **SceneGcp** and **SceneInv**.:

- **SceneGcp** finds the positions of the geocover chips in the ProbaV images, by image cross-correlation, in the focal plane, near the predicted position;
- **SceneInv** finds optimal calibration parameters according to a weighted least squares criterium, including iterative outlier removal.

The complete static description of the ProcNewScenes input/output interfaces is given the Figure 4.2-6.

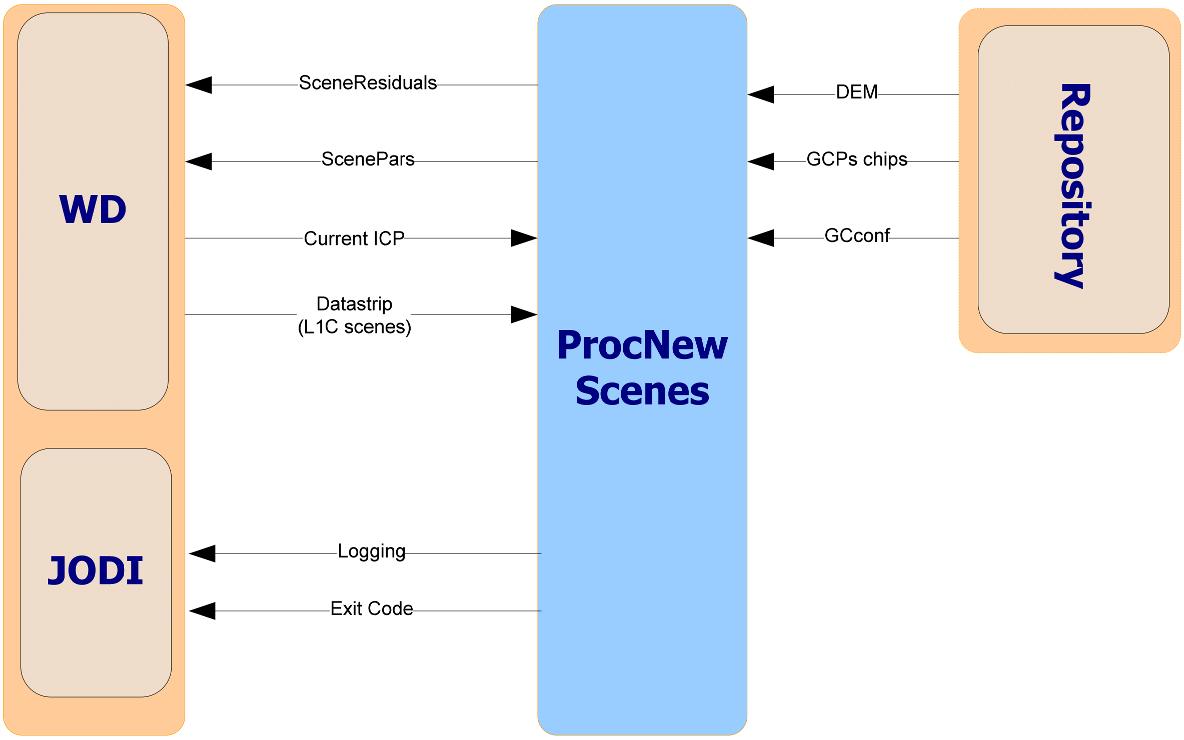


Figure 4.2-6: ProcNewScenes input/output data

GeoMonitor is used to monitor the current condition of the PROBA-V system from a geometric calibration point of view. It can be used to see the calibration situation both in the form of numerical error statistics and graphical plots, both scene based and against possible variables such as CCD temperature and latitude, both with current ICP values and with optimal ones. It is a commandline based interactive tool that can be launched whenever it is considered necessary to monitor the geometric calibration situation in the form of graphical plots and text.

The static description of the GeoMonitor input/output interfaces is given the Figure 4.2-7.

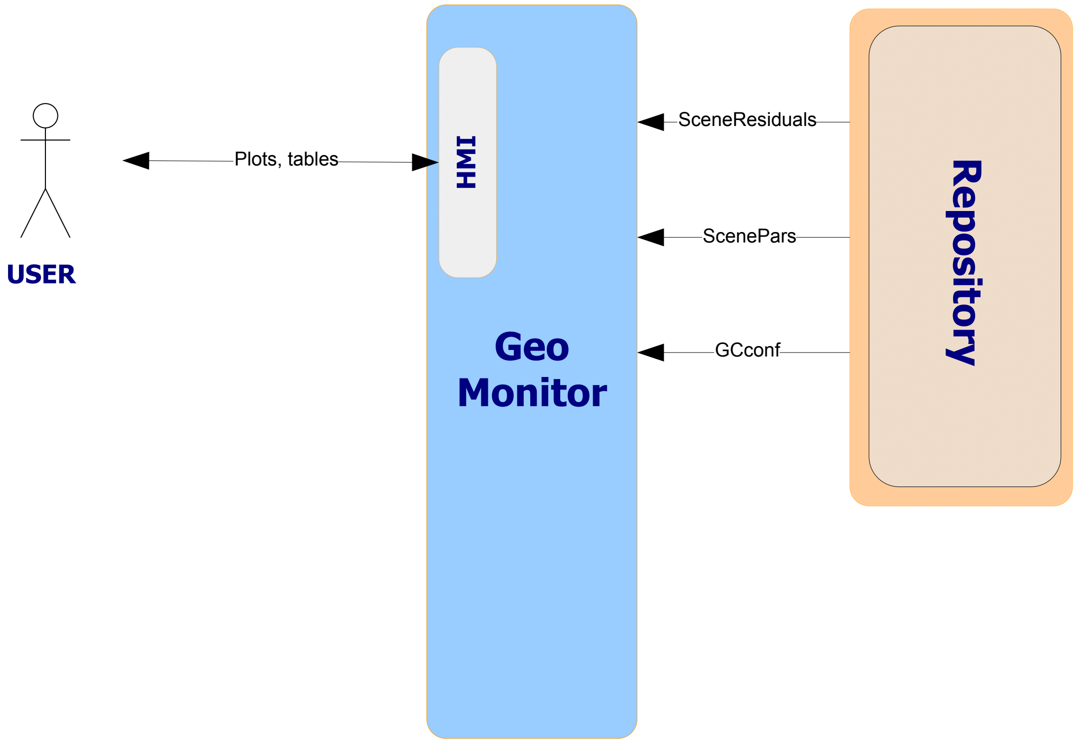


Figure 4.2-7: GeoMonitor input/output data

ScenePar contains for each scene (the complete ICD is reported in [SDD]):

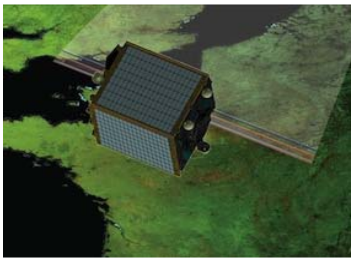
- Scene parameter values - sensor Exterior Orientation parameters and Interior Orientation parameters extracted from the geometric calibration of a single scene
- Scene parameter errors - errors associated to the Scene parameter values (covariance matrix)
- Scene condition parameters – parameters averaged or representative for the whole scene, with respect to which the orientation parameters may vary, such as TimeOutofEclipse, temperatures from various onboard sensors, latitude, date and time of scene, etc ...

SceneResidual includes for each scene (the complete ICD is reported in [SDD]) :

- List of line/pixel position for each GCP found by image correlation
- List of line/pixel position for each GCP predicted using the current ICP file
- List of flag indicating if the GCPs are used for inversion or not
- List of SNR correlation value for each GCP

All ScenePars and SceneResiduals generated from a single L1C file are grouped together in a single directory and generically called a SceneVal.

The naming convention for the SceneVal directory is (see [SDD]):



<mission>_SCENEVAL_<camera>_<datetime>_<duration>_<purpose><version>

Where:

<mission> => PV1

<camera> => L,C or R to indicate left, center or right camera (1 byte).

<datetime> => *YYYYMMDD_HHMMSS* datetime of segment start as found in L1C name (15 bytes).

<duration> => duration of segment in seconds (3 bytes).

<purpose> => O,T, C… to indicate operational , test, commissioning phase…(1 byte).

<version> => integer unique file version identifier (3 bytes).

The GeoMonitor allows the user to choose what to see (scene, trend or sensitivity):

```
case scene:
        choose scene
        show scene residuals before fit
        show scene residuals after fit

case trend:
        show trend

case sensitivity:
        show sensitivity analysis
```

EstTrend is used to generate a new ICP file when it is considered necessary. EstTrend is run by an operator when it is considered necessary on the basis of the geometric monitoring (see Section 4.2.3).

The static description of the EstTrend input/output interfaces is given the Figure 4.2-8.

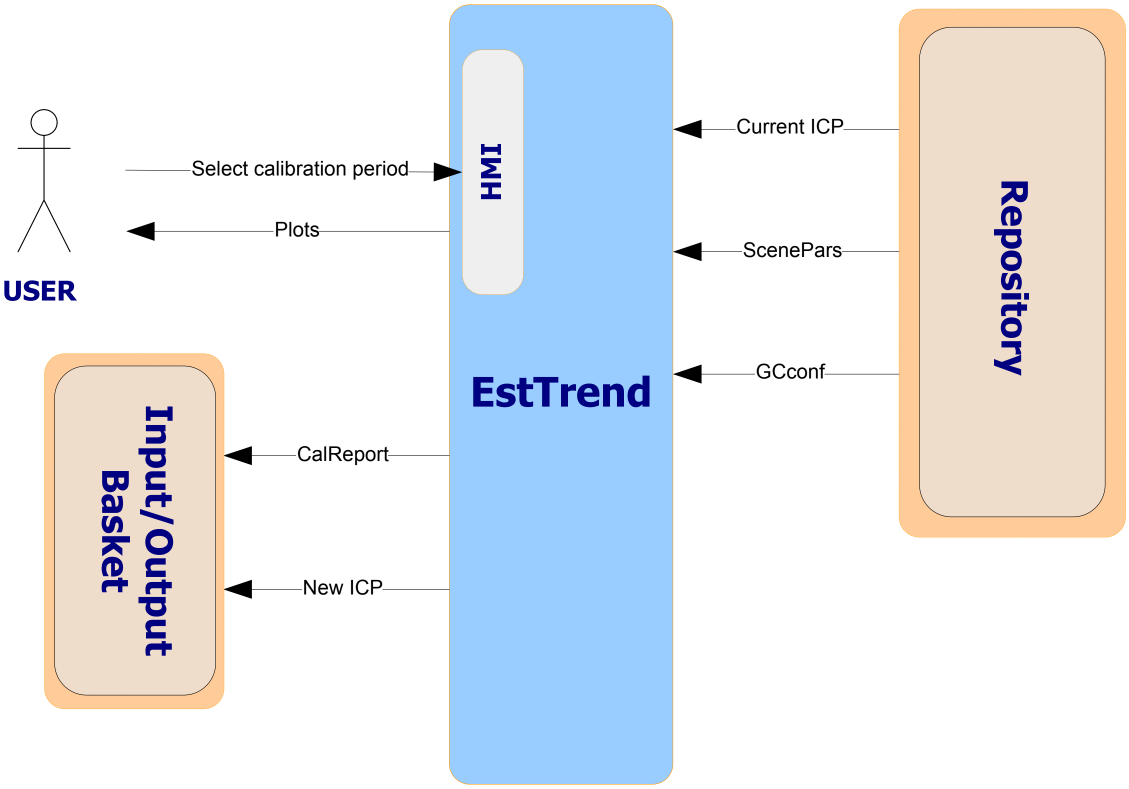


Figure 4.2-8: EstTrend input/output data

4.2.3 Calibration development strategy

4.2.3.1 Geometric Calibration validation

At the beginning of the commissioning phase the first goal to achieve is the complete validation of the Geometric Calibration facility using real data. It includes also the validation of the post launch calibration methods/algorithms used within the GC facility.

It is important to point out that the Geometric Calibration validation activity have to be done by GC developing team since it includes SW debugging and algorithmic implementation aspects.

Using real data during the commissioning phase, the calibration parameter are tuned (e.g. order of deformation polynomial, weighing factors, search windows, etc.).

In this phase the JProcNewScenes processing are properly configured in order to not delete the WDs allowing quality investigation of the generated products.

The product reprocessing are used in order process the same input datastrip by using different configuration parameters:

- General polynomial of degree #N;
- Weighting factors ($1/\sigma^2$, where σ is the expected standard deviation of the calibration parameters).
- Search windows;
- Other (TBC)

The generated results with different parameters are compared and analyzed by using GeoMonitor tool as described in Section 4.2.4.

Deformation Polynomial

A preliminary analysis on the simulated data has been done in the case of general polynomial model. The main outcome is that this general polynomial model gives satisfactory results considering a 8th order of polynomial coefficients. This reference has been used in defining the model.

A more accurate pre-launch order polynomial tuning is performed by using the “starting” ICP file which is externally generated (outside the GC facility) from the on-ground calibration and measurement data together with the validated thermal elastic model of PV01. The corresponding results are used as starting point during the commissioning phase.

Weighting factors

A pre-launch definition of the a-priori weight for each calibration parameters and for GCP measurements are used as starting values during the commissioning phase:

- The determination of the a-priori weight for each calibration parameters shall be done by using on-ground calibration and measurement data together with the validated thermal elastic model of PV01.

- An analysis of the a-priori weight for GCP measurements is done by using 375 image pairs extracted from overlap of geocover datasets from different WRS2 paths at higher latitudes (see [ATBD] Section 8.3.3 for more details).

ICP parameters are stored in the form of a temperature-time starting from eclipse matrix, so that a bi-dimensional fitting is performed. The polynomial order used for the temperature and for the time starting from eclipse dependency will be the one which gives the best fit.

A pre-launch fitting order polynomial tuning is performed by using on-ground calibration and measurement data together with the validated thermal elastic model simulations at different temperatures and positions along the orbit for a representative subset of CCD elements (e.g. in the form of the PV01 System Performance Simulator csv files), and the corresponding results are used as starting fitting order polynomial during the commissioning phase.

Search Window

The “starting” ICP accuracy defines the size of the search window and therefore the initial performance (enlarging the search window implies an increment of the processing time). However, the main inaccuracy is related to the boresight misalignment angles determined at the satellite launch, and therefore not predictable during the pre-flight calibration.

During the Geometric Calibration validation, the initial boresight angle is roughly estimated in “debug” mode by analysing the data by GC developing team and manually setting a suitable large search window. Once the first estimation of the boresight angle is done the search window size is reduced/tuned according to the real data.

In the case that the GC accuracy requirements are not satisfied by the baseline Geometric Calibration approach (nominal scenario), alternative approaches shall be analyzed and implemented (degraded scenario):

1. Firstly increasing the number of the GCPs per scene and camera extracted by the MMIO tool by changing the threshold values for the Moravec Interest Operator ([ATBD] see 6.5.4);
2. Secondly (if the first solution is still not adequate) by using the ‘global solution’ via a relative simple customization of the SW (see Section 4.1.2.2).

The first approach is straightforward to implement and requires only 3-4 days in order to generate the new set of GCPs chips. A pre-launch definition of the new threshold values for the Moravec Interest Operator is done in order to speed up the GCPs chips generation.

The second approach requires a reorganization of the SW tasks in new processing chains as described in [SDD], which needs about 1 month for developing and SW testing.

4.2.3.2 First ICP generation

After the consolidation of the calibration parameters tuning, the fist ICP file shall be generated by using the tuned calibration parameters set.

In order to generate the first set of ICP file it is expected to process a set of data at different latitudes and temperatures (e.g. about 10 different latitude/temperature spread over the latitude range from 60N to 56S). In addition for each couple (latitude/temperature) several scenes per camera (about 800 km long according to ATBD) are requested in order to reduce the calibration parameter errors (please note that the errors goes like 1/sqrt(n) where n is the number of scenes). A preliminary analysis is reported in the “PROBA-V IQC-GC-Technical Note: Contribution to US Calibration Plan” [ARPT]. An accurate analysis (estimation of n) can be done only during the commissioning phase using **EstTrend** tool, which provides the confidence intervals of the temperature/ time starting from eclipse least square fitting (algorithmic details are given in the [ATBD] section 9).

From a simulation done by PF according to the input ROI reported in Table 4.2-1, it is expected that approximately 75 scenes per camera per day have to be processed.

However, it is important to point out that an useful scene shall contain a sufficient number of GCPs therefore it shall be almost cloud-free or partially covered by clouds, therefore it is expected that only part of the acquired scenes can be used for the geometric calibration. This means that it is not guaranteed that all the necessary data can be acquired during a single day.

In addition, the user can check that there is an appropriate distribution of GCP across FOV by using GeoMonitor tool (see Section 4.2.4):

- visual check by using the GCP residual plot (e.g. Figure 4.2-12)
- looking at the polynomial coefficients confidence limit (e.g. Figure 4.2-16). In fact it is expected large errors for some polynomial coefficients in the case there are not GCPs in a part of the FOV.

Figure 4.2-9 show the mean annual cloudiness from the ISCCP dataset (http://isccp.giss.nasa.gov) composed by observations in the period ranging from July 1983 through June 2006.

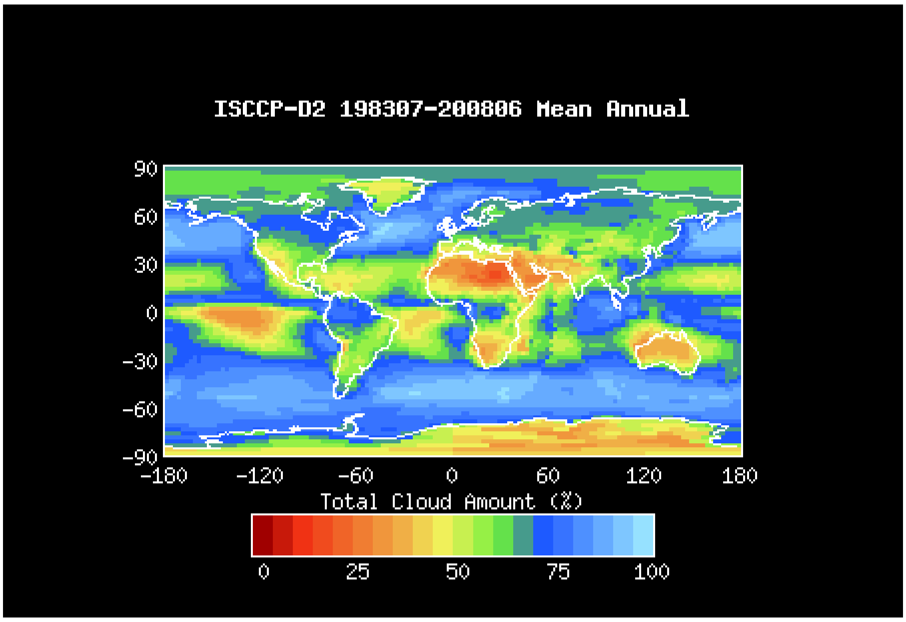


Figure 4.2-9: Mean annual Total Cloud Amount (%)

In order to illustrate the cloudiness variability within the different seasons the monthly cloudiness in January and July are reported in Figure 4.2-10 and 4.2-11 respectively.

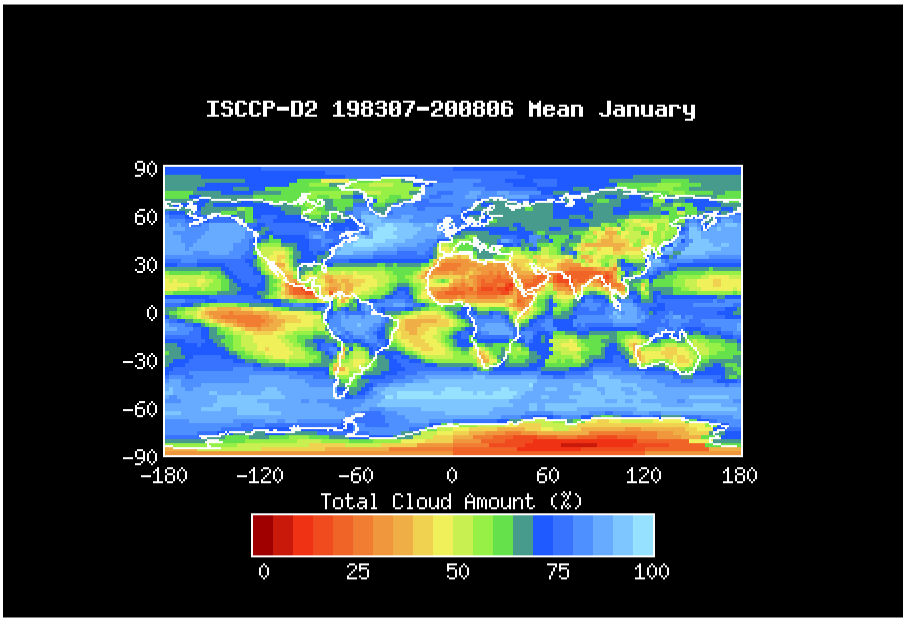


Figure 4.2-10: Mean January Total Cloud Amount (%)

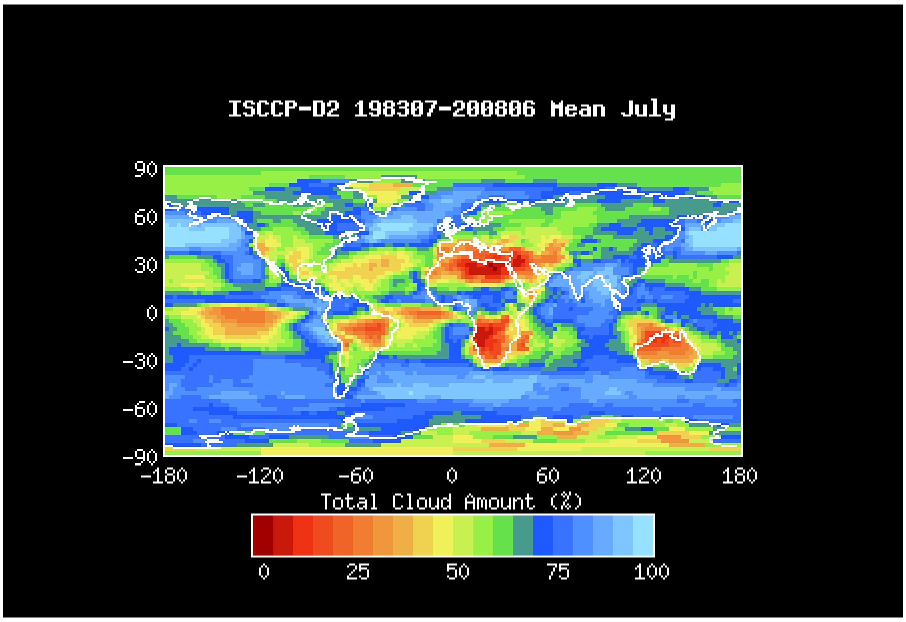


Figure 4.2-11: Mean July Total Cloud Amount (%)

The most critical areas are located at equatorial latitudes and at high latitude (please note that latitude over 60 degree north are not processed) during the winter: cloudiness about 80 % is expected therefore only 20 % of the GCPs can be processed (assuming that the probability of an observed Proba-V pixel being cloudy is equal to the percentage of cloudiness).

However, it is expected that several satellite passes over the same area highly increases the probability to process the GCPs. According to [JU-ROY], the probability of there being at least one cloud-free observation of a PROBA_V pixel within a given period is derived from the probability of all of the overpasses being cloudy:

$$P_{one} = 1 - \prod_{i=1}^{n} p_i$$

where n is the number of satellite overpasses in the period of interest and p_i is the probability of the i-th acquisition being cloudy.

Considering a period of 3 weeks the number of satellite overpasses is about 10 (the PROBA-V cycle is 2 days). However, the cloudiness is correlated over time. Here we assume that the cloudiness observations taken at 5 days intervals are slightly uncorrelated. the resultant probability of there being at least one cloud-free observation as a function of the cloudiness is given in Table 4.2-2.

Cloudiness (%)	P_{one}	Equivalent Cloudiness (%)
60	0.78	21
65	0.73	27
70	0.66	34
75	0.58	42
80	0.49	51
85	0.39	61
90	0.27	73

Table 4.2-1: Mean probability of there being at least one cloud-free observation as a function of the cloudiness in the case of n=3 (the number of "independent" satellite overpasses). The last column contain the P_{one} expressed in terms of equivalent cloudiness.

The first ICP file is generated by using EstTrend which performs the requested fit and it is able to show the plot of the result with the associated confidence error figure, which is the first element for the ICP validation.

In order to perform a more complete ICP validation (as requested), the GeoMonitor tool is used.

The main input of the GeoMonitor is the SceneResidual, which includes for each scene the list of line/pixel position for each GCP predicted by using current version of the ICP (in this case the pre-launch ICP file). The GCP residuals are also computed on a set of GCPs which are not used in the scene inversion model ("ground check points").

The first ICP file can be fully validated according to the following steps:

1. Select a set of scenes not used for the generation of the ICP file to be validated
2. Use the GeoMonitor with the generated set of SceneResiduals files

Once the ICP is fully validated the file is copied in the Output basket for the distribution.

4.2.3.3 New ICP generation

During the operational scenario new ICP files are generated according to a specified frequency in order to take into account seasonal thermal deformation variations. By default a monthly calibration campaign is performed, however a careful monitoring of the validity of the current ICP file shall be done over the time and in case of the accuracy requirements violations a new ICP shall be generated.

The **ICP monitoring** is performed by monitoring over the time the scene residuals of the new acquired scenes and in particular monitoring the line/pixel position for each GCP predicted by using current version of the ICP with respect to the line/pixel position found by image correlation. The GCP residuals are also computed on a set of GCPs which are not used in the scene inversion model ("ground check points").

The **validation of the new ICP** file is exactly the same procedure used for the validation of the first ICP file described in the section above by using the GeoMonitor with the generated set of SceneResiduals files.

4.2.4 Calibration monitoring

After running a bundle adjustment, a careful evaluation of its results will be performed in order to be sure that all the specifications and requirements are meet and that the results are valid – that is not contaminated by bad measurements or assumptions.

After the bundle adjustment is run, a qualitative evaluation is performed as a first step, in which the operator examines graphical representations of the adjustment's output in order to understand broad trends and to catch obviously bad inputs (e.g. GCP chips outliers not correctly detected). Finally, statistical analysis techniques are used to protect against bad observations and to quantify the quality of the adjustment.

Qualitative evaluation

The purpose of qualitative evaluation is to allow the operator to understand the properties of the adjustment and to diagnose any problem. It is difficult to recognize trends or outliers by looking at pages of numbers; instead, since this is geometric problem, it is best addressed by graphical displays of the solution outputs.

The plots proposed for qualitative evaluation of results of the bundle adjustment are of the image residuals, as in Figure 4.2-1. The image residuals should point in random directions and have comparable sizes.

Residuals all pointing in the same direction (either parallel or radially with respect to the center of the image) indicate the presence of a systematic effect. These effects may indicate uncorrected errors, or an image parameter that has been weighted too highly and not allowed to adjust.

A residual that is larger than its neighbors or points in the opposite direction to those near it indicates a bad measurement/outliers nor correctly removed during the bundle adjustment phase.

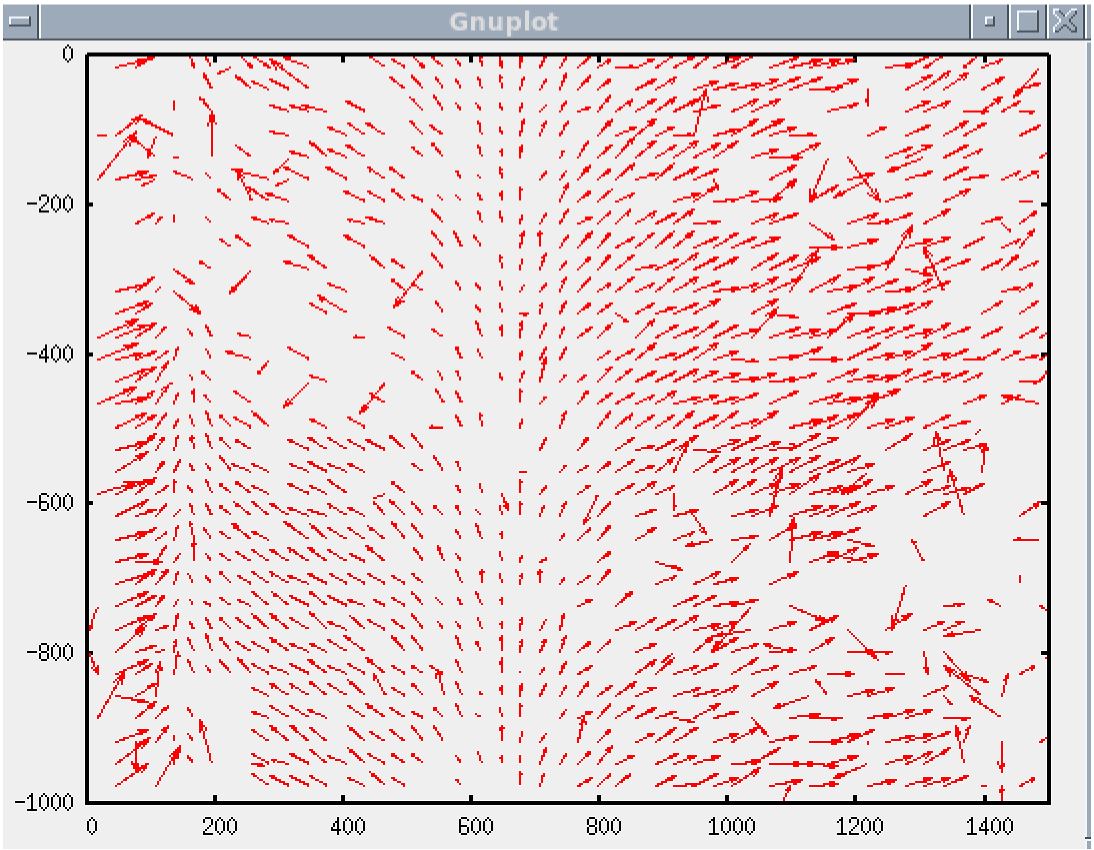


Figure 4.2-12: Example of residual plots

Statistical evaluation

As with any other least square solution, statistical methods are used to evaluate the results of a block adjustment.

We evaluate the **precision** of the solution by examining the covariances of the parameters as outlined in section 7.2.5. The diagonal elements of the covariance matrix are the parameter variances, and the off diagonal elements are the covariances between the parameters variances.

The relationship between the parameters covariance matrix and the on ground measurement accuracy is performed by the **Sensitivity Analysis**.

Figure 4.2-2 shows the principle components of the Sensitivity Analysis tool:

3 The values of parameters for the LoS model, necessary for the mapping process, have to be defined (position of the satellite, actual look direction, sensor parameters and errors…).

2 Subsets of parameters of the LoS model can be selected for the error simulation. The others will be assumed to be exact

1 The variation of the selected parameters is performed via Gaussian noise given by the standard deviation σ and/or covariance matrix of the parameters (Monte Carlo method)

4 Additional inputs for the LoS model are the sensor description and the processing definitions. For example to process not only one look direction but the whole FOV range.

5 The outputs of the geo-location error are given in terms of Root Mean Square Error (RMSE) and the Standard Deviation (STDV). Provided a parameter range is processed (for example the whole FOV) the error can be displayed in error curves.

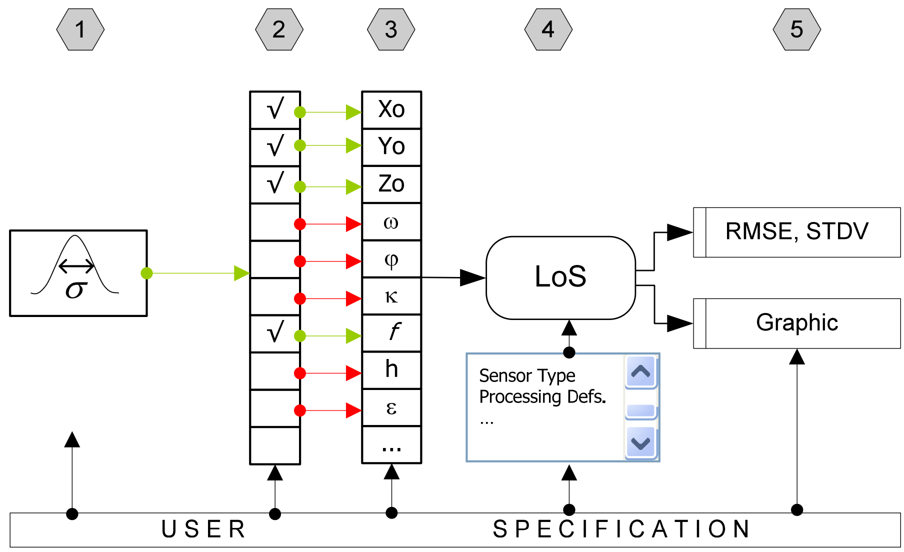


Figure 4.2-13: Flow chart of sensitivity analysis tool (the green arrows show a possible selected configuration; the red ones possible selections)

A fundamental requirement for the bundle adjustment is that it be **accurate** . Accuracy cannot be determined by examining the solution, since a solution can be very consistent within itself, but still not accurate. The accuracy can be determined by computing statistical average and covariance of the GCPs residuals.

In addition to the analysis at scene level, multiple-scenes monitoring is very useful including:

- An indication of which scenes are within specification with current ICP file.

- Plots of various calibration parameters and their 95% confidence errors against various external parameters including temperature, exit time from eclipse, date/time.
- Plots of expected absolute localization accuracy against various external parameters including temperature, exit time from eclipse, date/time. Plot of GCP residuals considering only the set of GCPs which are not used in the scene inversion model ("ground check points").
- Plots of estimated absolute geolocation errors within a processed scene, with current ICP and with optimal calibration parameters scene residuals with current ICP parameters and optimized scene parameters.

The most effective plots to show will be chosen when they have been implemented and tried with realistic data. The following are some mock examples and will be included in the GeoMonitor tool.

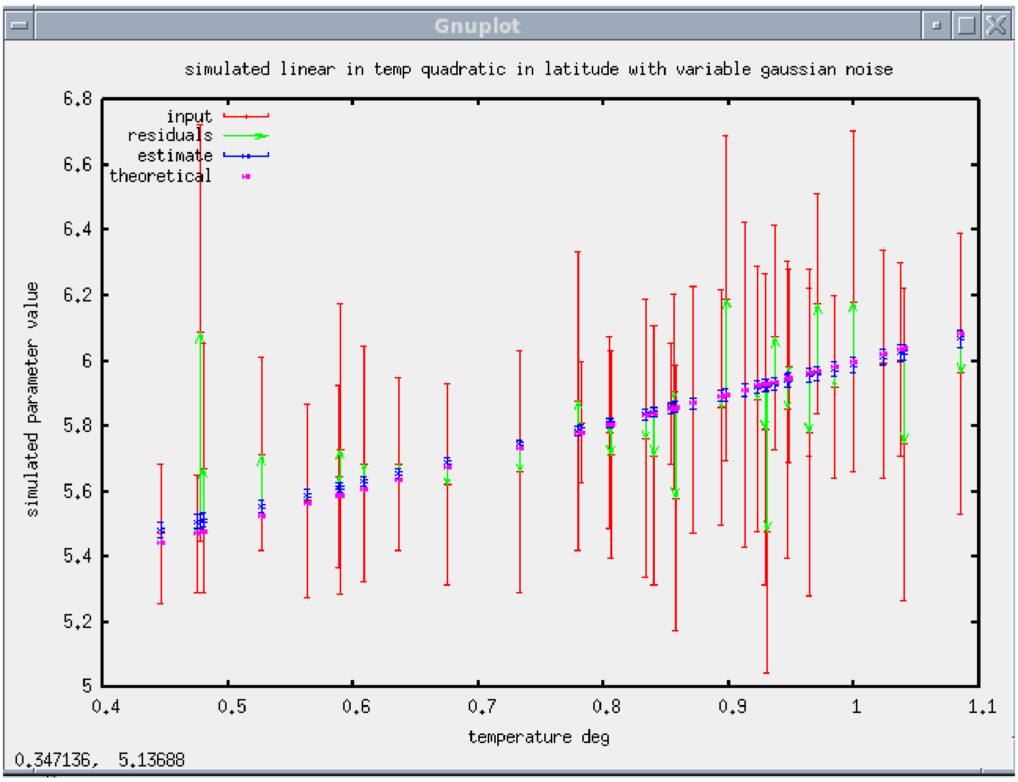


Figure 4.2-14 : example plot of a calibration parameter with 95% confidence against temperature.

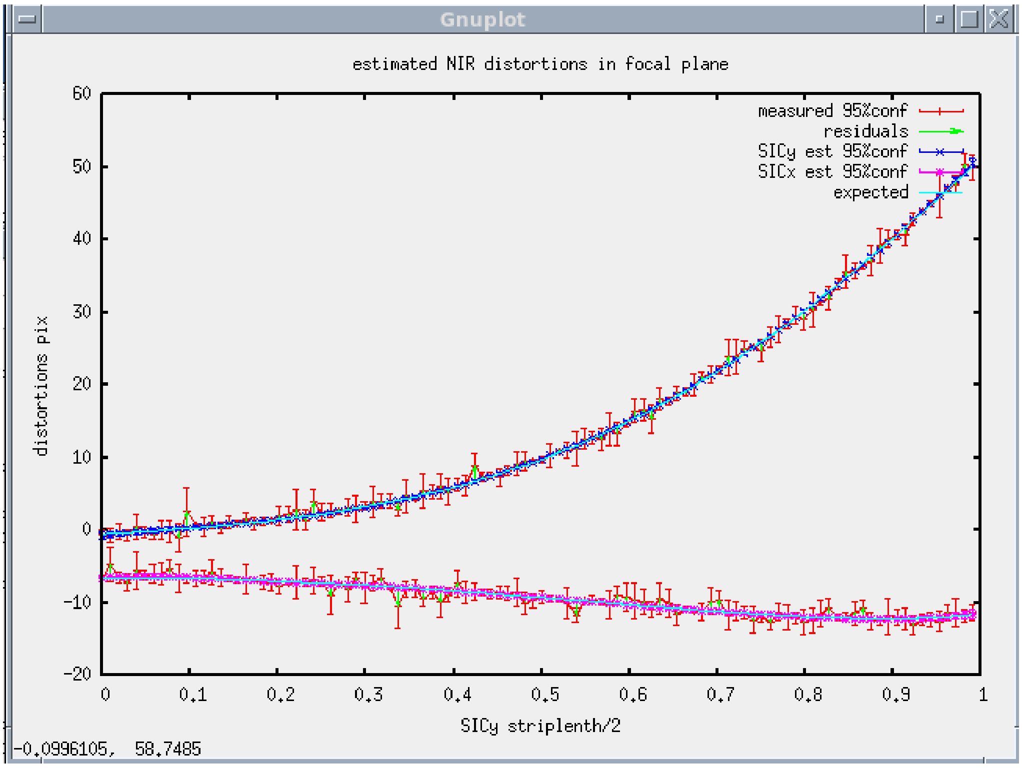


Figure 4.2-15 : example plot of NIR distortion in focal plane

Figure 4.2-16 : Example of Strip0 SICy output errors and 95% confidence limits

4.3 Commissioning plan

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A preliminary vicarious calibration plans for the commissioning phase are given.

Table 4.3-1: Nominal case. V stands for the ICP validation

Month 1				Month 2				Month 3			
week 1	week 2	week 3	week 4	week 1	week 2	week 3	week 4	week 1	week 2	week 3	week 4
GC Validation											
			First ICP generation		V	ICP generation		V	ICP generation		V

Table 4.3-2: Degraded case #1, V stands for the ICP validation

Month 1				Month 2				Month 3			
week 1	week 2	week 3	week 4	week 1	week 2	week 3	week 4	week 1	week 2	week 3	week 4
GC Validation											
			New GCP DB Build-up	GC Validation	First ICP generation		V	ICP generation			V

Table 4.3-3: Degraded case #2, V stands for the ICP validation

Month 1				**Month 2**				**Month 3**			
week 1	week 2	week 3	week 4	week 1	week 2	week 3	week 4	week 1	week 2	week 3	week 4
GC Validation											
			New GCP DB Build-up	GC Validation							
					'Global' GC customization			GC Validation	First ICP generation Data collection		V

4.4 Operational scenario

A preliminary vicarious calibration plan for the operational scenario is given.

Table 4.3-1: nominal case V stands for the ICP validation – the ICP monitoring is performed periodically at the end of second week of each month (in the middle of the ICP generation period)

Month 1				Month 2				Month 3				Month 4				Month 5				Month 6			
wk1	wk2	wk3	wk4	wk1	wk2	wk3	wk4	wk1	wk2	wk3	wk4	wk1	wk2	wk3	wk4	wk1	wk2	wk3	wk4	wk1	wk2	wk3	wk4
Data collection Routine monitoring			V	Data collection Routine monitoring			V	Data collection Routine monitoring			V	Data collection Routine monitoring			V	Data collection Routine monitoring			V	Data collection Routine monitoring			V

Table 4.3-2: degraded case V stands for the ICP validation – during the Month 3 the ICP monitoring forces for a generation of a new ICP file.

<table>
<tr><th colspan="4">Month 1</th><th colspan="4">Month 2</th><th colspan="4">Month 3</th><th colspan="4">Month 4</th><th colspan="4">Month 5</th><th colspan="4">Month 6</th></tr>
<tr><td>wk1</td><td>wk2</td><td>wk3</td><td>wk4</td><td>wk1</td><td>wk2</td><td>wk3</td><td>wk4</td><td>wk1</td><td>wk2</td><td>wk3</td><td>wk4</td><td>wk1</td><td>wk2</td><td>wk3</td><td>wk4</td><td>wk1</td><td>wk2</td><td>wk3</td><td>wk4</td><td>wk1</td><td>wk2</td><td>wk3</td><td>wk4</td></tr>
<tr><td colspan="3">Data collection
Routine monitoring</td><td>V</td><td colspan="3">Data collection
Routine monitoring</td><td>V</td><td colspan="4"></td><td colspan="3">Data collection
Routine monitoring</td><td>V</td><td colspan="3">Data collection
Routine monitoring</td><td>V</td><td colspan="3">Data collection
Routine monitoring</td><td>V</td></tr>
<tr><td colspan="7"></td><td colspan="3">Data collection
Routine monit.</td><td>V</td><td colspan="13"></td></tr>
<tr><td colspan="9"></td><td colspan="2">Data collection
Routine monit.</td><td>V</td><td colspan="12"></td></tr>
</table>

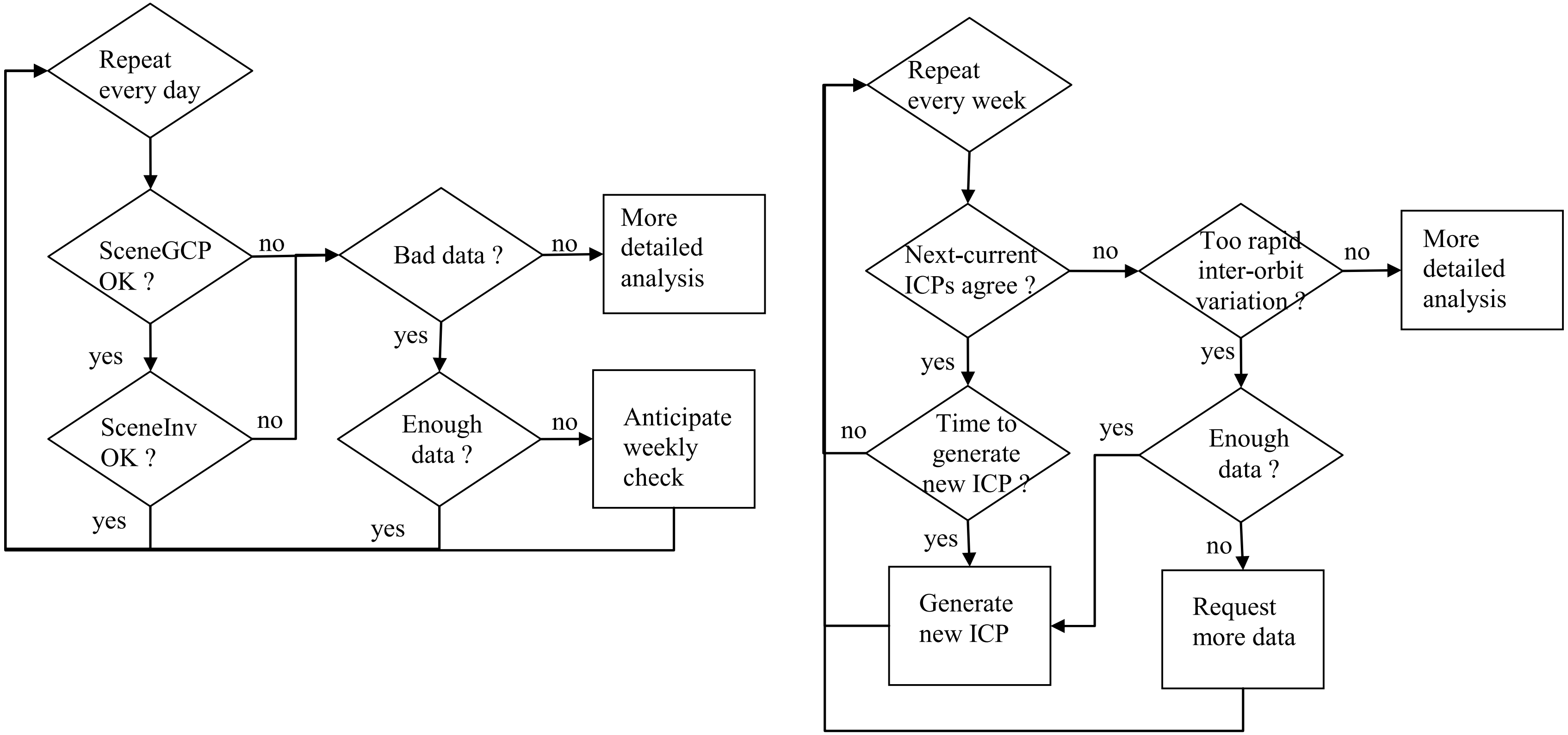

Figure.4.3- 1 : Daily and weekly routine monitoring cycles

The routine geometric monitoring will be organized in very quick and basic operations to do ~ every day and slightly longer operations to do ~ every week. If the daily operations indicate that something is wrong the weekly operations may be anticipated. If either the daily or weekly operations indicate that something is wrong, but it is not clear what is wrong, more detailed analysis will be necessary. Both the routine and more detailed analysis will be well documented in the software user manual once the software has been implemented and the most practical way to do the checks has been determined via simulations. In any case the preceding diagrams give a 1st overview of the routine operations and the text paragraphs below give a 1st description of the steps.

If during commissioning or operations certain problems with the system appear, specific checks for these problems will probably be intensified. On the contrary, if other problems never occur, the checks for other problems will become less frequent or more superficial.

4.4.1 Daily operations

SceneGCP OK ? – Have the L1Cs received in input been processed as expected and have the expected amount of GCPs been found ? This can be verified both from errors and warnings in the log files and by viewing the scene summary statistics with GeoMonitor (see Section 4.2.4). The number of GCPs found for each scene gives a good indication.

SceneInv OK ? – Has the scene inversion occurred as expected. Again errors and warnings in the log files can give a 1st indication. Number of outliers, RMSE of residuals, and estimated RMSE of estimated distortion, again visible in scene summary statistics with GeoMonitor good indications (see Section 4.2.4).

If all is as expected in the above 2 steps the daily checks have finished.

If not:

Bad Data ?- Are the encountered problems simply due to bad data ? Extensive cloud cover is the most probable cause but portions of data may be unusable for other reasons. If the percentage of scenes with few, or no GCPs, or high RMSE, is low or as expected no extra checks are necessary. If cloud or bad data statistics, or quicklooks are easily available from the PF they may be consulted to see if the degraded functioning of GC is due to these problems. Otherwise the full resolution images should still be available on local disk.

More detailed analysis – If the problem is not due to bad data a more detailed analysis is necessary which could be done by local personnel or ACS depending on the problems encountered. GeoMonitor can be used to see where errors are greatest or GCPs are found on specific scenes and strips.

Enough data ? – If the data is enough, even though some data is bad, the daily routine check can in any case be considered successfully finished. In case of doubt anticipate the weekly routine check.

4.4.2 Weekly operations

Next-current ICPs agree ? – Do the distortions predictions based on data from the current month agree with those of the current ICP, based on data from the previous month? After running EstTrend to fit and calculate statistics on data from the current month it can be compared to the current ICP. Current and next ICPs can be considered in agreement if their distortion values are within an excepted margin and/or their estimated 95% confidence regions overlap. Note that GC maintains statistics and confidence margins of each calculated ICP file.

Time to generate new ICP ? – Is it time to generate a new ICP ? Nominally a new operational ICP is generated each month. So if all is well and the time has come we can make the already generated ICP file operation with GeoMonitor (see Section 4.2.4). In any case if we have reached this point the weekly routine operations have finished.

Too rapid inter-orbit variation ? – Is the disagreement between current and next ICP due to an inter-orbit deformation which is more rapid that expected ? By viewing trend plots with GeoMonitor one can see if the long-term trend in deformations is different from expected. If for example linear trends have been modeled and the higher order terms are significant over the current period this should be visible. 95% confidence intervals can be used to help determine if the difference is due to random effects or not.

More detailed analysis – If the problem is not due to too rapid inter-orbit variation a more detailed analysis is necessary which could be done by local personnel or ACS depending on the problems encountered.

Enough data ? – The differences between the deformations estimated from data in the current period and deformations from current ICP may be because not enough data in the current period has been processed. This may be for example because in the current period there have been too many clouds at a particular latitude. In this case the 95% confidence limits visible with GeoMonitor on the final fit for that latitude should be wider than normal.

Request more data - If we want to generate a new ICP file but do not have enough data in the current period to generate it with the requested accuracy it may be sufficient to shift the start date of the estimation period back a little, if the long-term variations are not too rapid. If this is not the case one can try requesting more data by interleaving the current ROIs with other rows of ROIs.