VEGETATION Geometrical Image Quality

Sylvia SYLVANDER*, Patrice HENRY, Christophe BASTIEN-THIRY****
Frédérique MEUNIER, Daniel FUSTER***

* IGN/CNES
**CNES
CNES, 18 avenue Edouard Belin, 31044 Toulouse
e_mail : Sylvia.Sylvander@CNES.fr

Abstract:
The use of VEGETATION data for multidate applications needs severe geometrical specifications, especially for multitemporal registration. To comply with them, it was decided to improve the image location by a systematic use of ground control points. A ground control points (or GCP) data base was so generated through *VEGETATION* chips using space triangulation method. The current GCP data base used by the processing center CTIV is composed of about 3500 ground control points, regularly distributed on the globe. Their location accuracy is estimated to 100m RMS.
A monitoring of the geometrical performance has been processed and shows that the absolute location accuracy and the multispectral registration accuracy quite comply with the users requirements. In particular, the absolute location accuracy, estimated to 330m RMS, is very good. The multitemporal registration accuracy is also very good compared to the pixel resolution, but it is not fully complient with the users requirement.
In order to improve the multitemporal registration accuracy, several actions have been already carried out, in particular to try to increase the number of images corrected by GCP pointing: densification of the CTIV GCP data base, modifications of the CTIV GCP software, and so on…

Keywords:
Geometrical image quality, absolute location accuracy, multitemporal registration, multispectral registration, space triangulation, Ground Control Points data base.

1 Introduction

The geometrical specifications for *VEGETATION* images are very severe, especially for the multitemporal registration. This paper aims to present the method used to improve the location accuracy of *VEGETATION* images, in order to comply with the specifications.
The geometrical performance have been measured since the launch of SPOT4. They are showed in this paper.
Finally, the actions carried out to improve the multitemporal registration are described.

2 Users requirements

The main use of *VEGETATION* data is the monitoring of vegetation evolution for agriculture (crop monitoring,...), forestry or environment (human settlement, gaz exchanges...). These applications imply the use of a set of images covering a large period of time: a complete growing season for agriculture, several years for global change studies... Moreover, the final product elaborated in the *VEGETATION* ground processing center CTIV is a decade synthesis at 1 km resolution, merging all the data acquired during 10 days.
This stresses the need for a very accurate multitemporal registration which will have to be, in any case, much less than the 1 km resolution of the product.

The users requirements concerning the geometry are that

- the absolute location accuracy of *VEGETATION* images shall be less than 1 km;
- the multitemporal registration shall be better than 500 m for 95% of the points (i.e. at 2σ in the case of a Gaussian distribution); an objective of 300 m is even asked on a best effort basis;
- the multispectral registration shall be better than 300m.

From a system point of view, the requirement on multitemporal registration is the most demanding. Assessments performed before the launch had demonstrated that, as far as geometrical performances were concerned, all the users requirements should be met at the exception of the multitemporal registration. Without any complementary correction, the multitemporal registration does depend directly on the absolute location. One can indeed assume, in a first approximation, that the RMS multitemporal registration accuracy is the RMS absolute location accuracy multiplied by $\sqrt{2}$. Preflight assessment predicted a RMS absolute location accuracy around 1 km (not far from the 800 m effectively measured in orbit), and so, gave no hope to reach the requested multitemporal registration accuracy. It was so decided to improve the image location by a systematic use of ground control points, or GCP, inside the ground processing center CTIV.

The first idea was to try to use a coastline data base. However, none of the existing data base is accurate enough to reach the final 500 m requirement (at 2σ).
In a second step, the use of SPOT/HRV chips was studied. That seemed a good idea but it turned out to be difficult to achieve from a technical point of view, limited in earth coverage (no cloud free images or no useable maps are available for some parts of the globe) and, above all, very expensive...
Finally, it was decided to build a data base with well located *VEGETATION* chips, the location of the chips being obtained by a spacetriangulation method.

3 Geometrical calibration

Before the generation of the GCP data base, VEGETATION was calibrated by the CNES experts in geometry during the commissioning phase, from March to June 1998.

The calibration of the reference camera B3 was processed in order to optimize the *VEGETATION*/HRVIR co-location. This calibration lead to supply the CTIV with a new viewing directions set for the reference camera before the beginning of the commercial operations in March 1999.

The calibration of the three other cameras relatively to the reference camera confirmed the pre-flight measurements for the biases between cameras and the distorsion laws. Consequently, no new viewing directions set was supplied for the secondary cameras.

4 The generation of the global GCP data base

4.1 Spacetriangulation principle

The global GCP data base was generated using space triangulation method, inside the QIV (Quality Image Vegetation), which is the division of the CNES responsible for the monitoring of the image quality.

The space triangulation method allows to simultaneously optimize the geometric models describing the terrain-to-image correspondence of a set of images. The absolute location is provided by ground control points; the relative location is provided by tie points located on the overlapping areas between images. This method is based on a physical description of the image acquisition process. It allows to choose physical correction parameters as representative as possible and therefore to limit the number of unknowns to be determined.

The generation of the GCP data base by space triangulaion needed to select enough *VEGETATION* images to have:

- a global and continuous cover of all the emerged lands,
- all the images linked by tie points on the overlapping areas in order to ensure the strengthening of the system by closing the cover.

Moreover it was necessary to dispose of initial ground control points to ensure the absolute location of the images.

At the orbit scale, some viewing parameters are unknown with a large uncertainty. These parameters are :

- the time,
- the along-track position of the satellite,
- the absolute attitude data of the satellite : the gyrometers provide us with the relative attitude data, that is to say the relative position of the satellite on its orbit (pitch, roll and yaw), but we don't know it in absolute.

An error on the time, an error on the along-track position of the satellite and an error on the pitch angle have very comparable effects on the image and cannot be separated. Consequently, three attitude biases have been chosen to represent the unknowns of the geometrical model: a pitch bias (which can include time and along track satellite location errors), a roll bias and a yaw bias. At each *VEGETATION* orbit is so associated a set of three biases.

For each *VEGETATION* image, correlation operations are processed, on one hand with initial ground control points (if possible), on the other hand with homologous points on neighbouring images. The space triangulation process can then estimate simultaneously:

- the real ground location of the points,
- the unknowns of the geometric models.

4.2 Initial ground control points

The process of the initial ground control points was carried out by the Satellitbild Swedish company. About one hundred SPOT HRV chips were extracted from SPOT Quick Look images. They have been chosen as regularly as possible on the globe (cf. figure 1). They were then located with maps and rectified in a cartographic projection at a resolution of 800m. Finally they were validated: their location accuracy was estimated to 100m.

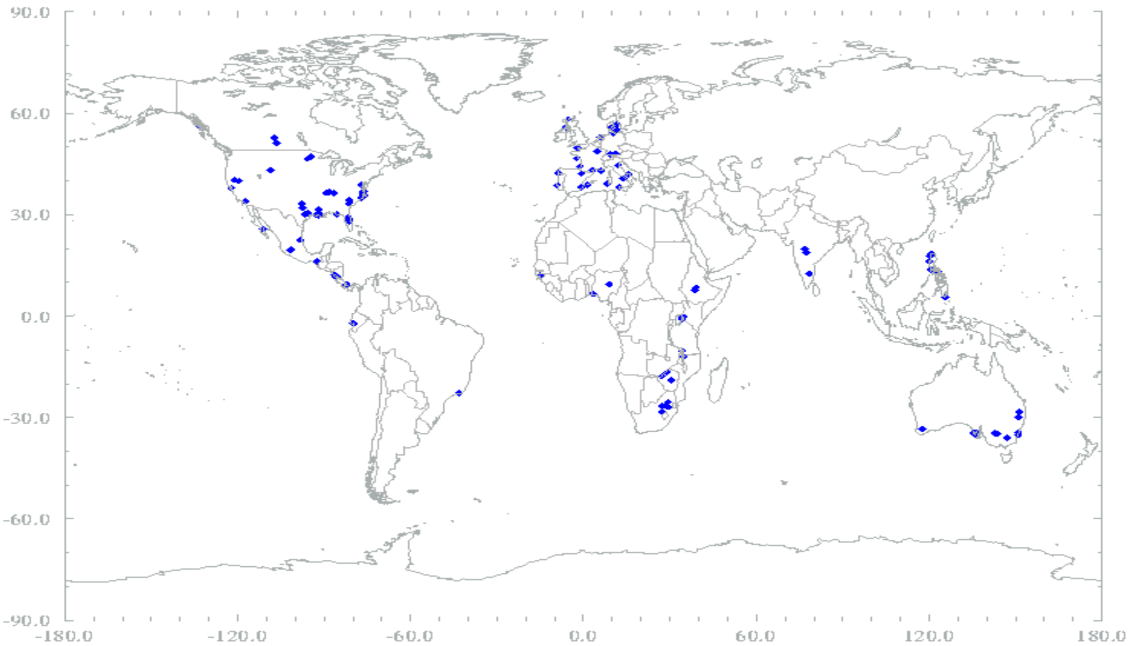

Figure 1: Initial ground control points (represented by blue points).

4.3 Selection of *VEGETATION* images

The GCP data base has been generated progressively, as showed on figures 2 and 3, from about 200 orbits acquired between April and August 1998. It was densified in Februray 2000, using about 60 new orbits acquired between October 1998 and February 1999.
All in all, about 5900 tie points were pointed. A same point is seen in average 4 times, in order to have chips from different seasons and different angular directions for this same point. The location accuracy of these tie points is estimated to 100m RMS.

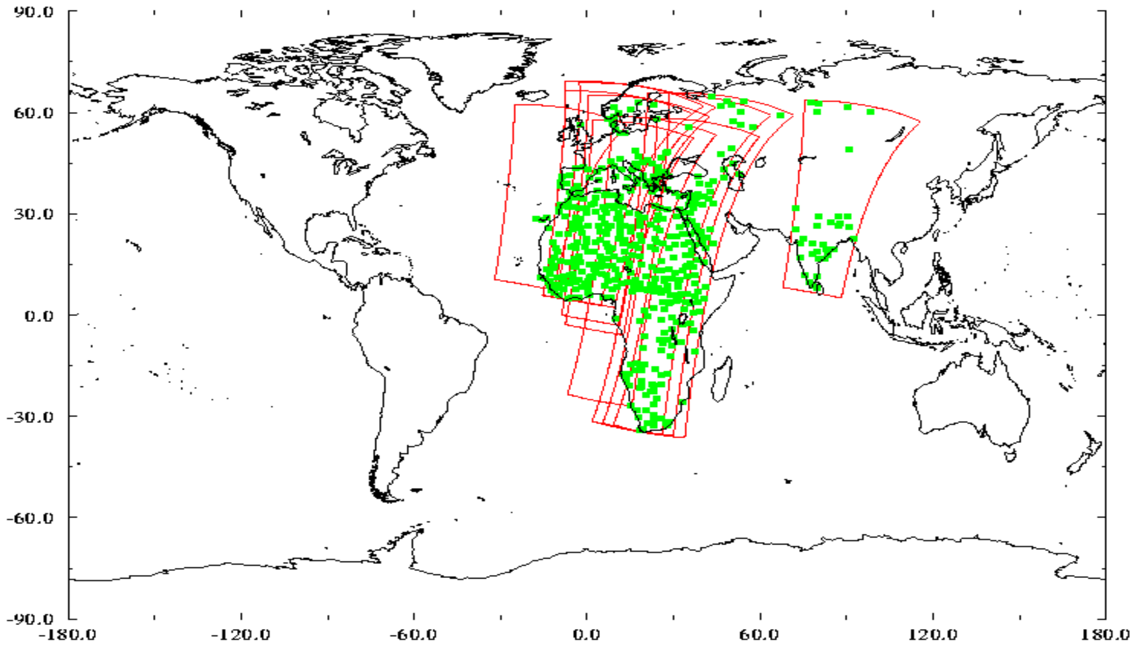

Figure 2: Intermediary step in the generation of the global GCP data base

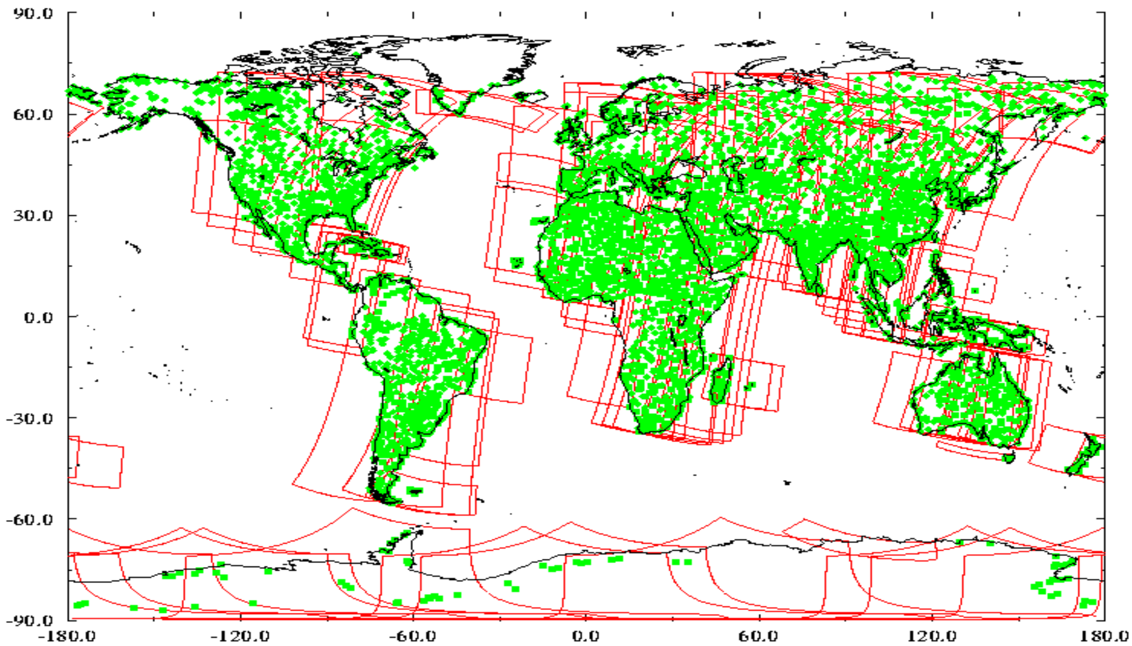

Figure 3: Further intermediary step in the generation of the global GCP data base

5 Extraction of a GCP data base for the CTIV

A GCP data base was extracted from the global GCP data base in order to allow the processing center CTIV to correct any *VEGETATION* image.

5.1 The CTIV GCP data base

The CTIV GCP data base was extracted from the global GCP data base and sent to the CTIV before the beginning of the image distribution in March 1999. This GCP data base was densified in February 2000.
The current CTIV GCP data base is therefore composed of about 3650 regularly distributed ground control points (cf. figure 4), with an average of 4 *VEGETATION* chips from different seasons and different angular directions per point.
The location accuracy of the ground control points is estimated to 100 m RMS.

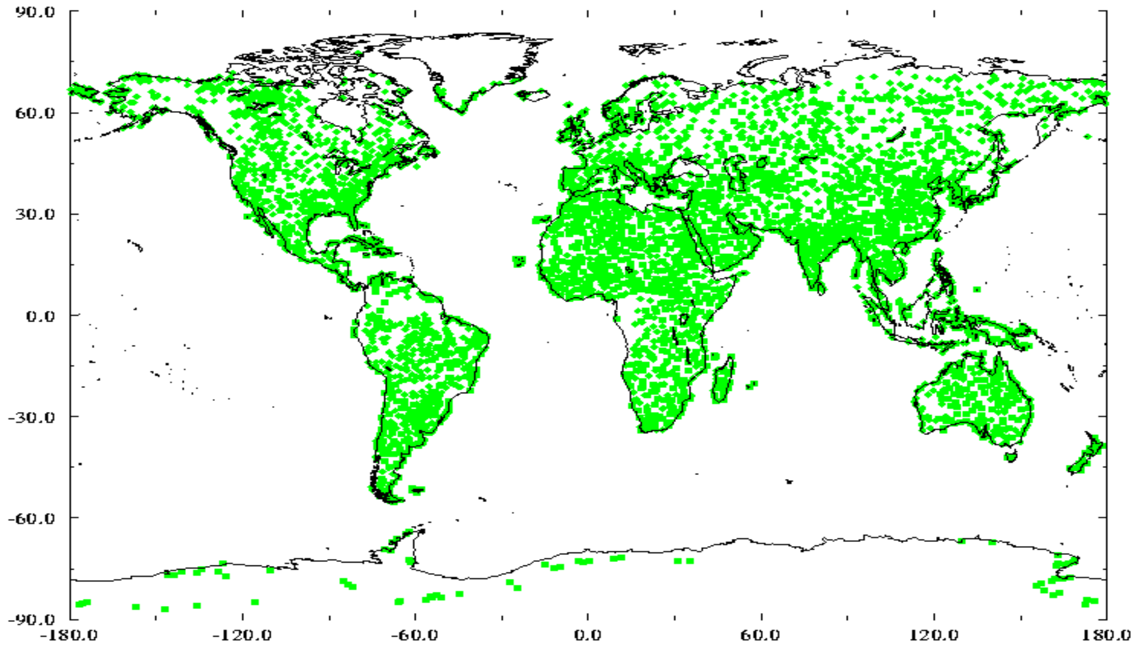

Figure 4: The CTIV GCP data base

5.2 Principle of the geometrical correction

The geometrical correction of *VEGETATION* images aims to improve the quality of the viewing parameters, using the ground control points of the CTIV GCP data base, and consequently the absolute location and the multitemporal registration. The ground control points are used to estimate three attitude biases per *VEGETATION* orbit, which model the uncertainties on the viewing parameters.
To estimate the three biases of a *VEGETATION* orbit, a relationship is established by correlation between ground control points and their homologous points on the *VEGETATION* images constituting this orbit. The goal of the estimation is to find the values of the attitude biases that best match the observed differences between the location of the ground control points and the ground location of their homologous points, calculated using the initial viewing parameters.

In order to estimate properly the three attitude biases, it is necessary to get ground control points regularly distributed on the *VEGETATION* image, in particular on both sides. If it not possible, the image is not corrected. That is why the CTIV needed a very dense GCP data base.

The CTIV GCP data base is used in a semi-automatic way: an operator selects the ground control points to be correlated and launches the biases estimation when he considers that there are enough regularly distributed ground control points on the *VEGETATION* orbit. For the moment, a great number of ground control points are selected if possible, but the objective is to use only 10 ground control points per orbit.

6 Geometrical performance

6.1 Principle of the geometrical performance measurement

6.1.1 Absolute location and multitemporal registration

The VEGETATION image quality is strictly monitored by the QIV. In particular, the geometrical performance is regularly measured.
For that, some ground control points from the global GCP data base have been kept as checking points. For any *VEGETATION* image, processed in the CTIV, which intersects one of these reference sites, the CTIV sends to the QIV an extract of this image. A measure of location is then processed by correlation between this extract and the reference site.
The absolute location accuracy is then the distance between the reference site location and the location of the homologous point in the image.
The multitemporal registration accuracy is the distance between the location of a same point in two different images.

6.1.2 Principle of the multispectral registration measurement

The multispectral registration of an image is measured by correlation between the reference band B3 and the others.
The multispectral registration accuracy xS represents the diameter of the circle containing the four bands (cf. figure 5).

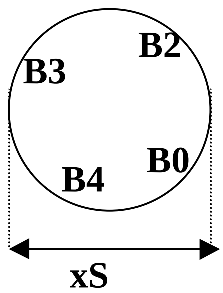

Figure 5: Multispectral registration accuracy xS

6.2 Geometrical performance results

6.2.1 Absolute location accuracy and multitemporal registration

It must be noted two important points having an impact on the location accuracy since SPOT4 was launched:

- the CTIV began the images distribution in March 1999: the images acquired before March 1999 were processed without correction by GCP pointing;
- a problem due to a new steering mode of SPOT4, inducing roll errors until 2 milliradians, was detected and corrected on the 9th of December 1999; this problem induced a degradation of the location accuracy for some of the *VEGETATION* images which are not corrected by GCP pointing. The number of images concerned by this degradation is difficult to estimate precisely, but we can affirm it is less than 10% of all the images, probably much less.

Consequently, the absolute location accuracy and the multitemporal registration have been both measured on three periods:

- before March 1999: on 400 extracts of image not corrected by GCP pointing,
- between March 1999 and the 9th of December 1999: on 710 extracts of image corrected by GCP pointing but with the steering problem of SPOT4,
- since the 10th of December 1999: on 180 extracts of image corrected by GCP pointing, without any steering problem.

6.2.1.1 Absolute location accuracy

The absolute location accuracy is given in table 1 by its root mean square and the maximum for 95% of the distance measures.

Period	RMS	MAX (95%)
Before March 99	725 m	1380 m
March 99 / 9 Dec. 99	345 m	520 m
10 dec. 99 / March 00	300 m	465 m

Table 1: Absolute location accuracy

We can observe from table 1 that there is an improvement of the absolute location accuracy with time. It seems that there is an improvement since the 10th of December 1999, but the number of measures is very different between the second and the third period, so it is not possible to conclude.
It must be noted that the absolute location accuracy is very good and quite complying with the users requirements.

6.2.1.2 Multitemporal registration

The multitemporal registration is given in table 2 by its root mean square and the maximum for 95% of the distance measures.

Period	RMS	MAX (95%)
Before March 99	885 m	1715 m
March 99 / 9 Dec. 99	440 m	780 m
10 dec. 99 / March 00	325 m	675 m

Table 2: Multitemporal registration

We can observe from table 2 that there is also an improvement of the multitemporal registration accuracy with time.
It must be noted that the multitemporal registration accuracy is very good compared to the pixel resolution, but the users requirements are not fully met. In fact, the multitemporal registration accuracy is less than 500m for 84% of the measures.

6.2.2 Multispectral registration

The multispectral registration accuracy has been measured on a few *VEGETATION* images and estimated to 0.11 pixels RMS, 0.2 pixels maximum. In particular, the registration accuracy between B2 and B3 is estimated to 0.09 pixels RMS, 0.15 pixels maximum.
Consequently, we can say that the multispectral registration accuracy is good and quite complying with the users requirements.

7 How to improve the multispectral registration?

The CTIV GCP data base is supposed to allow the correction of any *VEGETATION* image. In fact, a study has showed that only 70% of the images are really corrected by GCP pointing. Why are 30% of the images not corrected? generally because of a lack of ground control points, primarily due to clouds, sea or snow on these images. Since these images are not corrected by GCP pointing, their location accuracy may be much degraded. Of course, they are not all used in synthesises, especially if they are covered by clouds, but the visible lands of some of them are used and may create misregistration inside synthesises.
If we examine the images used to estimate the geometrical performance presented in tables 1 and 2, it appears that:

- 70 images among the 710 images acquired between March 1999 and the 9th of December 1999,
- 5 images among the 180 images acquired between the 10th of December 1999 and March 2000,

are not corrected by GCP pointing.

If we calculate now the geometrical performance on one hand on the 810 extracts of images acquired between March 1999 and March 2000 and corrected by GCP pointing, and on the other hand, on the 75 extracts of images of the same period and not corrected by GCP pointing, we can then observe the high improvement of the location accuracy due to GCP pointing (cf. tables 3 and 4). Consequently, if we want to improve the total multispectral registration accuracy (presented in table 2), it is first of all necessary to increase the number of images corrected by GCP pointing.

Period	RMS	MAX (95%)
Images not corrected (75 measures)	465 m	925 m
Images corrected (810 measures)	330 m	510 m

Table 3: Absolute location accuracy

Period	RMS	MAX (95%)
Images not corrected (75 measures)	620 m	1260 m
Images corrected (810 measures)	400 m	680 m

Table 4: Multitemporal registration

If we examine more attentively the multitemporal registration results obtained on the images corrected by GCP pointing, we can note that they are improved compared to the general results presented in table 2, but the final requirement is not still fully met. Here, 90% of the measures issued from corrected images comply with the users requirement which is of 500 m. Consequently more investigations are necessary to try to improve the results.
In particular, it is planned to try to improve the quality of the data base. A fine monitoring of the ground control points will be processed in the future months. It will be then possible to suppress the points which are bad for correlation, which are not reliable and so on…

8 Actions to improve the multitemporal registration

Some actions have been already carried out to improve the multitemporal registration.

8.1 Densification of the CTIV GCP data base

In order to improve the number of images corrected by GCP pointing, the CTIV GCP data base was densified in Februray 2000, as it is mentioned in §5.1:

- on areas where there was a lack of ground control points,
- with ground control points extracted from images acquired in autumn and winter (the ground control points of the first GCP data base had been extracted from images acquired in spring and summer), in order to correct more images of autumn and winter.

8.2 Modification of the CTIV GCP software

In order to estimate the attitude biases of a *VEGETATION* orbit properly, the ground control points need to be regularly distributed on the orbit, in particular on both sides. Consequently, until now, the CTIV GCP software did not corrected the images if the ground control points were not regularly distributed (cf. example figure 6).

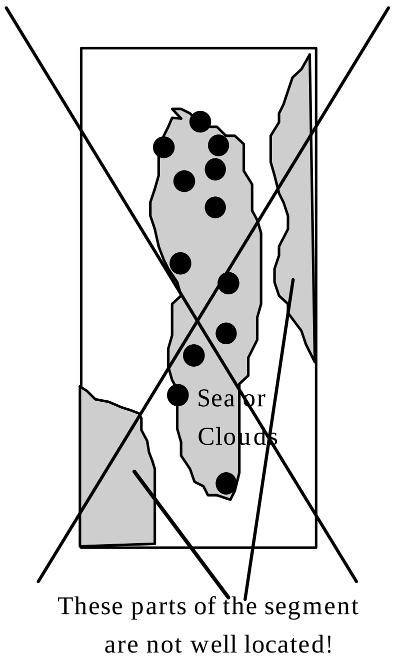

Figure 6: Example of a case where the attitude biases estimation is impossible: the visible parts of the image without ground control points (represented by black points) are not well located.

However, in some cases, it could be logical to accept that the ground control points are not well distributed on the image, for example if there are clouds or sea or snow on one side or on both sides (cf. figure 7 below). Of course, in that case, the estimation of the attitude biases will be degraded, but what is important is that the ground control points are regularly distributed on all the visible lands, in order to locate them properly. The CTIV GCP software has just been modified to accept such cases.

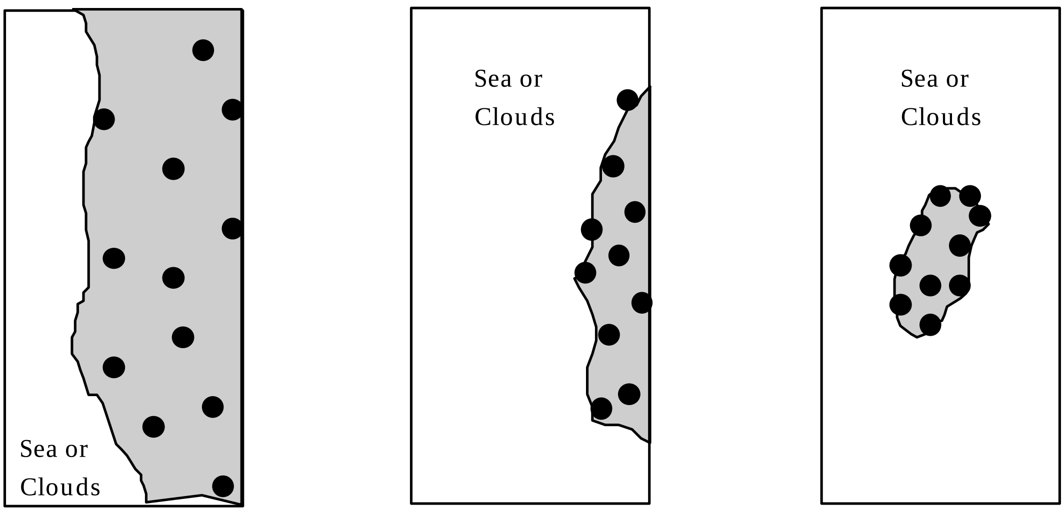

Figure 7: Examples where we can accept a bad distribution of ground control points (represented by black points)

Moreover, the CTIV GCP software has been modified to make easier the work of the operators. In particular, the checking of the ground control points distribution on the image and the checking of the model have been facilitated.

8.3 Improvement of the CTIV operators training

The semi-automatic use of the GCP data base needs a training of the CTIV operators: where to choose the ground control points, how to validate the model and so on… In order to increase the number of corrected images and improve the multitemporal registration, the operators training is being improving, in particular to allow them to adapt themselves to the new modifications of the software and to benefit of the experience after one year of operations.

8.4 Monitoring of the daily CTIV results

A fine monitoring of the daily CTIV results has begun, using daily reports, filling by the CTIV operators and giving for any processed image information such as: correction or no correction of the image, if necessary comments explaining why the image is not corrected or why the correction is degraded, and so on… Thanks to these reports, we expect for example to better understand why some images are not corrected.

9 Conclusion

The monitoring of *VEGETATION* image quality show very good geometrical performance.
The multispectral registration accuracy quite comply with the specifications.
The GCP data base, generated through VGT chips by space triangulation method, allows to substantially increase the image location. The absolute location accuracy is consequently very good and quite complient with the users requirement. The multitemporal registration accuracy is also very good compared to the pixel resolution, but not fully complient with the users requirement, very demanding. Several actions have already been carried out, especially to increase the number of images corrected by GCP pointing. An improvement of the CTIV GCP data base is also planned in the future months.