

**SPOT
IMAGE QUALITY PERFORMANCES**

	Grade And Name	Date	Signature	Diffusion	For :	
					Action	Info
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CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : i.1 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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SUMMARY

1	<i>DOCUMENT OBJECT</i>	1
2	<i>RADIOMETRIC PERFORMANCES</i>	2
2.1	Absolute calibration	2
2.1.1	Definitions	2
2.1.2	Temporal evolution.....	3
2.1.3	Last results	6
2.2	Signal to noise ratio	7
2.3	Modulation Transfer Function (MTF)	9
3	<i>GEOMETRIC PERFORMANCES</i>	11
3.1	Location accuracy	11
3.1.1	Introduction.....	11
3.1.2	SPOT2 location accuracy.....	13
3.1.3	SPOT4 location accuracy.....	15
3.1.4	SPOT5 location accuracy evolution since the launch	17
3.1.5	SPOT5 location accuracy before September 2003	19
3.1.6	SPOT5 HRG location accuracy after September 2003.....	23
3.1.7	SPOT5 HRS location accuracy after September 2003	26
3.1.8	Synthesis	29
3.2	Length Distortion	30
3.3	Multi-spectral registration	31
3.4	Elevation performance	32
4	<i>CONCLUSION</i>	33

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 1 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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1 DOCUMENT OBJECT

This document provides an overview of SPOT1, SPOT2, SPOT3, SPOT4 and SPOT5 image quality performances. As the two instruments (HRV, HRVIR, HRG, HRS) on the same SPOT satellite have similar performances, we do not distinguish between them here.

These performances are updated once a year after the annual SPOT Exploitation Review. The results presented in this issue correspond to October 2006.

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 2 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	---

2 RADIOMETRIC PERFORMANCES

2.1 Absolute calibration

2.1.1 Definitions

After radiometric correction (detector sensitivity and dark current correction), the numerical level in the image X_k is directly proportional to the input radiance L_k :

$$X_k = A_k G_{mk} L_k$$

where:

k is the spectral band,

A_k is the absolute calibration coefficient,

G_{mk} is the electronic gain: $G_{mk} = 1.3 \text{ m}^{-3}$, $m_k \in [1, 8]$ for SPOT1 and SPOT2, $G_{mk} = 1.5 \text{ m}^{-2}$, $m_k \in [1, 6]$ for SPOT4, and G_{mk} is given by the following table for the different SPOT5 channels:

m (gain number)	HM, HX	HRS	SWIR
1	0,6	1/2	0,591716
2	0,8	1/√2	0,7692308
3	1	1	1
4	1,2	√2	1,3
5	1,6	2	1,69
6	2,2	2√2	2,197
7	2,8	4	2,8561
8	3,8	4√2	3,71293
9	4,8		4,826809
10	6,2		

L_k is the normalized radiance:

$$L_k = \frac{\int L(\lambda) S_k(\lambda) d\lambda}{\int S_k(\lambda) d\lambda} \quad (\text{W} \cdot \text{m}^{-2} \cdot \text{sr}^{-1} \cdot \mu\text{m}^{-1})$$

where: $L(\lambda)$ is the spectral radiance and $S_k(\lambda)$ the spectral sensitivity of the sensor.

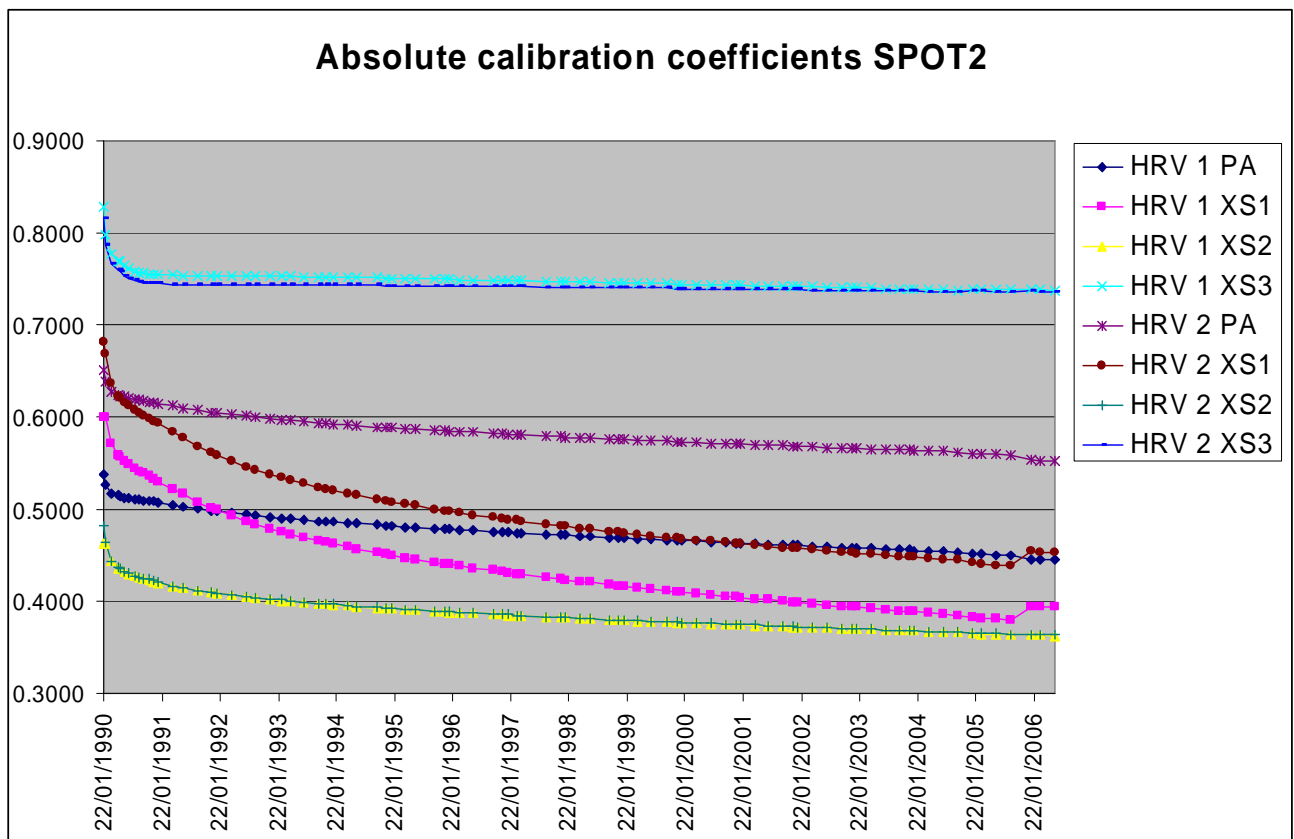
The absolute calibration of the viewing system consists in estimating and monitoring the parameter A_k ($\text{W}^{-1} \cdot \text{m}^2 \cdot \text{sr} \cdot \mu\text{m}$). This is done with the following accuracy:

Calibration accuracy	Pa, B1, B2, B3	SWIR
Absolute calibration	6%	7.5%
Cross-band calibration	3%	5%
Multi-temporal calibration	2%	2%

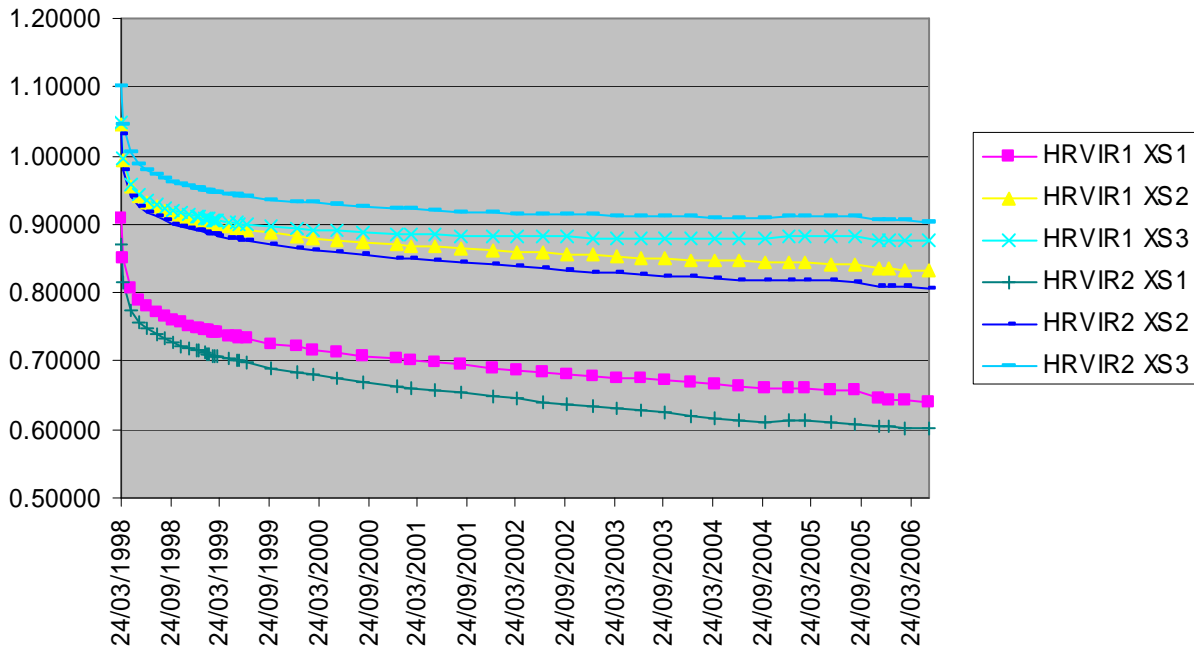
2.1.2 Temporal evolution

The graphs above give the temporal evolution of the SPOT2/ SPOT4 / SPOT5 absolute calibration coefficients since the launch.

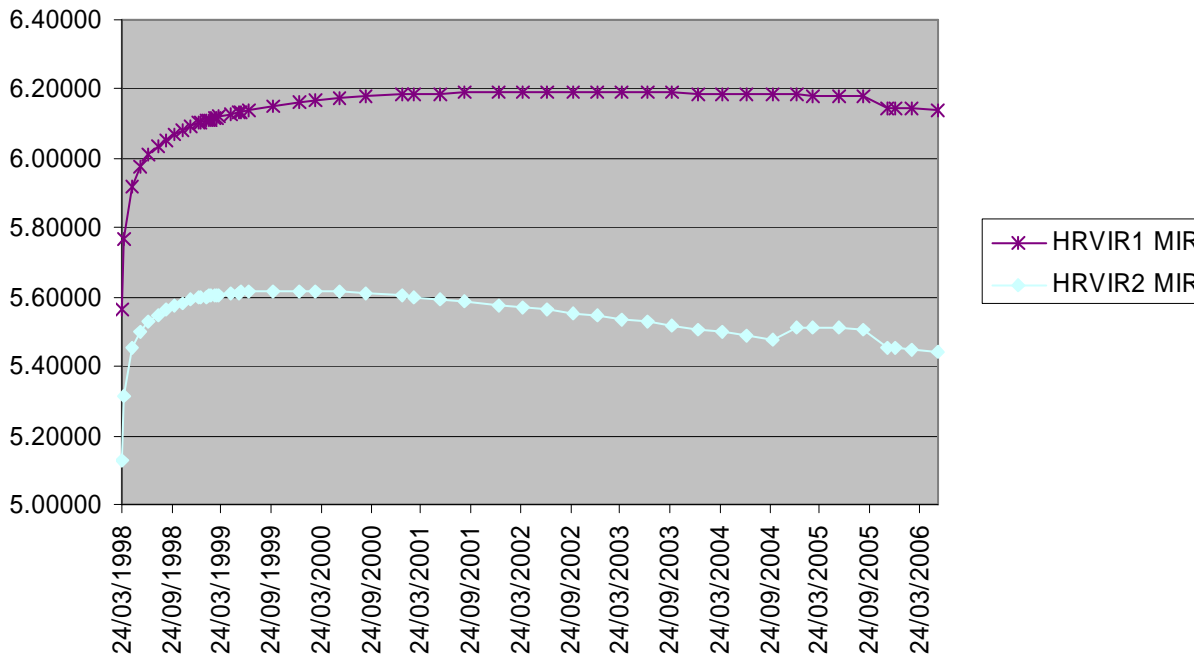
If necessary, the document « SPOT Absolute calibration: Synthesis » (S5-NT-0-2880-CNES) give detailed explanations about the temporal evolution of these coefficients.



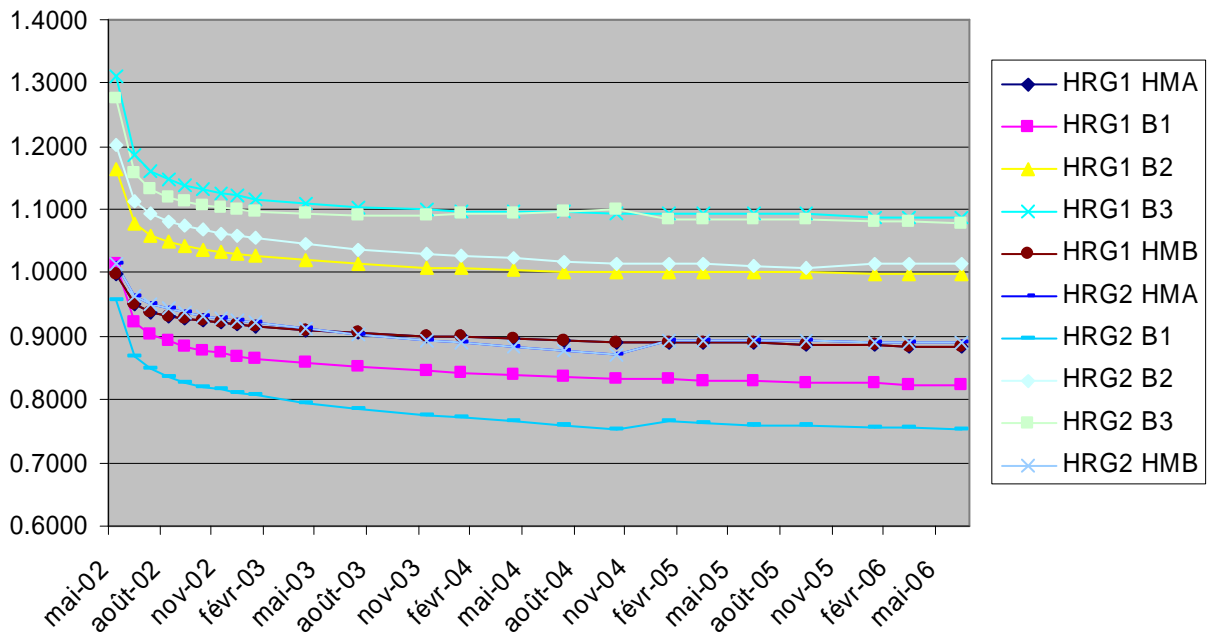
Absolute calibration coefficients - SPOT4



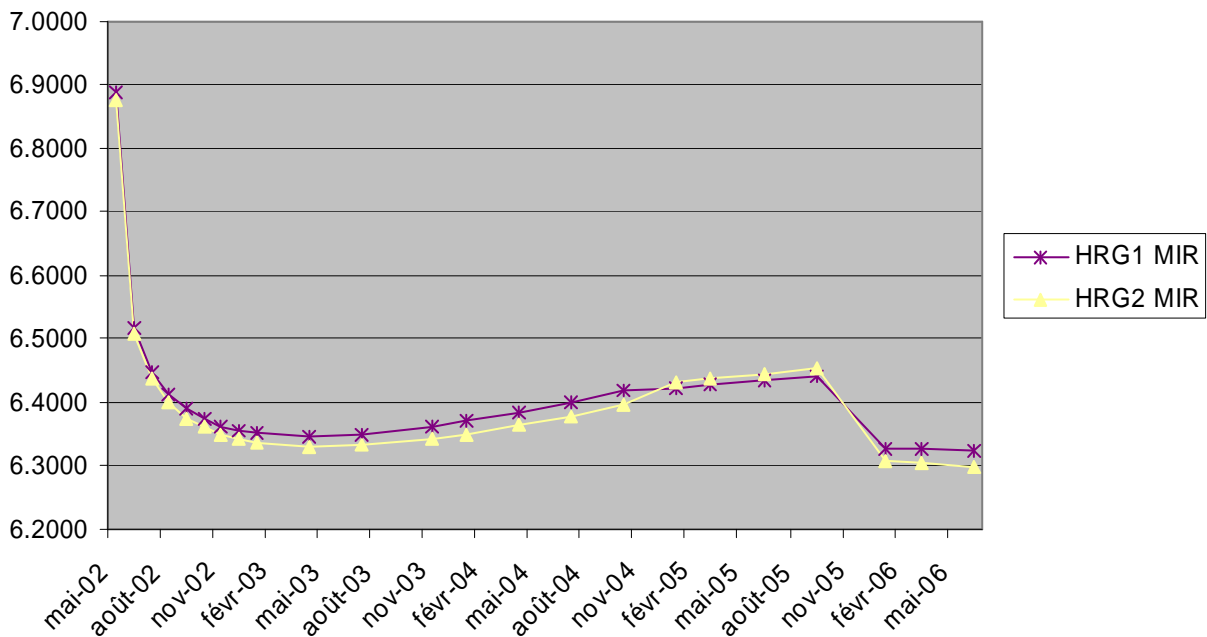
Absolute calibration coefficients - SWIR SPOT4



Absolute calibration coefficients SPOT5



Absolute calibration coefficients SWIR SPOT5



CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 6 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	---

2.1.3 Last results

The last update of the absolute calibration coefficients values are given in the following table

		Pa	B1	B2	B3	SWIR
SPOT1 Oct-2001	HRV1	0.469	0.329	0.269	0.489	
	HRV2	0.443	0.322	0.304	0.510	
SPOT2 June-2006	HRV1	0.4447	0.3934	0.3630	0.7378	
	HRV2	0.5520	0.4536	0.3637	0.7362	
SPOT4 June-2006	HRVIR1		0.64004	0.83189	0.87558	6.13755
	HRVIR2		0.60075	0.80672	0.90376	5.44363
SPOT5 June-2006	HRG1	0.8831	0.8234	0.9977	1.0876	6.3242
	HRG2	0.8893	0.7542	1.0145	1.0795	6.2993
	HRS1	0.904				
	HRS2	0.907				

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 7 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	---

2.2 Signal to noise ratio

The signal-to-noise ratio is representative of the radiometric resolution. The image noise quantifies the variations of the radiometric counts for a uniform landscape. It is the combination (quadratic sum) of two separate noises :

- Columnwise noise, also called instrumental noise : caused by the Poisson fluctuation of the signal delivered by the detector and various constant electronic onboard chain noises.
- Linewise noise, also called normalization noise : following image normalization, the residuals (radiometric model deviations) may cause visible "columns" on a uniform landscape.

Measurements for the different SPOT are done for different radiances according to the viewed landscape, but a noise model depending on the instrument input normalized radiance (L) is used to estimate the signal-to-noise ratio performance for a reference radiance (Lref). This reference radiance corresponds to the same target (reflectance=0.5, solar zenithal angle=60°, standard atmosphere: visibility=23km, [O₃]=0.35cm.atm, [H₂O]=2g.cm⁻²) seen by the different SPOT instruments. This model also depends on the electronic gain and we use as a reference the lowest operational gain for SPOT1 and SPOT2 and the neutral gain (Gmk=1) for SPOT4 and SPOT5.

The following table gives for the different channels of SPOT instruments:

- the reference radiance expressed in W/m²/sr/μm (the small difference between the different SPOT is explained by the slight spectral sensitivity difference between them),
- the corresponding radiometric count (RC) in the image expressed in LSB for the reference electronic gain,
- the signal-to-noise ratio measured along column and line and computed on 50x50 pixels images.

The last measurement date is given for each satellite.

Remark: HRS results correspond to the ground measurements: on-board measurements are not applicable to this instrument because it is not possible to have acquisitions on the same landscape simultaneously with HRS1 and HRS2.

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 8 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	---

			Signal to noise ratio				
			Lref _k	RC	Column	Line	50x50 pixels Image
SPOT1 Nov-2001	HRV	PA	107	61	140	230	120
		B1	119	65	158	233	130
		B2	103	69	130	240	112
		B3	93	62	180	226	140
SPOT2 Oct-2006	HRV	PA	108	67	200	296	165
		B1	122	58	188	240	148
		B2	104	58	164	237	135
		B3	95	84	247	336	199
SPOT4 Oct-2006	HRVIR	B2M	102	82	178	312	155
		B1	118	74	270	276	192
		B2	102	82	264	312	201
		B3	92	76	297	304	213
		SWIR	18	109	277	61	60
SPOT5 Jan-2006	HRG	HM	120	111	111	845	111
		B1	128	113	179	1050	177
		B2	108	110	190	1099	188
		B3	103	117	218	1080	213
		SWIR	21	108	307	295	260
	HRS	PAN	118	107	190	1070	187

The signal to noise ratio for column is correct and above the specifications for all the satellites and all the channels, except for the SPOT5 HM channels: the measured value is 111, whereas the specification is 148. A possible explanation for this result is the number of uniform and simultaneous scenes we had (only 3). Another reason is the possible variation of the dark noise, one of contributors to the columnwise noise. The results of the next Groenland acquisitions for Spot5 will give more reliable values and an indication about the necessity to calculate new values for the dark noise.

Concerning the signal to noise ratio for the image, which includes the linewise noise, results are strongly under the specifications for the SWIR channels (SPOT4 satellite): it is due to the increase of the number of aberrant detectors (sensitivity to the radiation effects). What's more, HM channels results are also slightly under the specifications: the results for the year 2007 will confirm this evolution.

2.3 Modulation Transfer Function (MTF)

The MTF is a way of characterizing the spatial resolution of the instruments. Restitution of the landscape contrasts viewed through the instrument is related to the MTF that is the Fourier transform of the impulse response (response at a point source or PSF). The MTF results from the cumulative effects of the instrumental optics (diffraction, aberrations, focusing errors), integration on a photosensitive surface, charge diffusion along the array and image motion induced by the movement of the satellite during imaging.

The absolute MTF values of the different SPOT instruments are provided in the following tables respectively along lines and columns in the image.

MTF - linewise	f/fe	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
SPOT1 HRV	Pa	1	0,82	0,64	0,49	0,36	0,25	0,16	0,10	0,05	0,02	0
	B1	1	0,92	0,82	0,71	0,58	0,46	0,34	0,23	0,14	0,06	0
	B2	1	0,90	0,78	0,65	0,52	0,40	0,29	0,19	0,11	0,05	0
	B3	1	0,82	0,64	0,49	0,36	0,25	0,16	0,10	0,05	0,02	0
SPOT2 HRV	Pa	1	0,84	0,68	0,53	0,40	0,29	0,19	0,12	0,06	0,03	0
	B1	1	0,93	0,84	0,73	0,61	0,49	0,37	0,26	0,15	0,07	0
	B2	1	0,92	0,82	0,70	0,58	0,46	0,34	0,23	0,14	0,06	0
	B3	1	0,89	0,76	0,63	0,50	0,38	0,27	0,18	0,10	0,04	0
SPOT3 HRV	Pa	1	0,85	0,70	0,55	0,42	0,31	0,21	0,13	0,07	0,03	0
	B1	1	0,94	0,85	0,74	0,62	0,50	0,38	0,26	0,16	0,07	0
	B2	1	0,92	0,82	0,70	0,58	0,46	0,34	0,23	0,14	0,06	0
	B3	1	0,89	0,76	0,63	0,50	0,38	0,27	0,18	0,10	0,04	0
SPOT4 HRVIR	M	1	0,86	0,71	0,57	0,44	0,32	0,22	0,14	0,08	0,03	0
	B1	1	0,94	0,86	0,76	0,64	0,52	0,40	0,28	0,17	0,08	0
	B2	1	0,92	0,83	0,71	0,59	0,47	0,35	0,24	0,14	0,06	0
	B3	1	0,90	0,78	0,65	0,52	0,40	0,29	0,19	0,11	0,05	0
	MIR	1	0,88	0,75	0,62	0,49	0,37	0,26	0,17	0,10	0,04	0
SPOT5 HRG	HM	1	0,85	0,69	0,55	0,41	0,30	0,20	0,13	0,07	0,03	0
	B1	1	0,88	0,74	0,61	0,48	0,36	0,25	0,17	0,09	0,04	0
	B2	1	0,88	0,74	0,61	0,48	0,36	0,25	0,17	0,09	0,04	0
	B3	1	0,81	0,63	0,47	0,34	0,24	0,15	0,09	0,05	0,02	0
	MIR	1	0,94	0,85	0,74	0,62	0,50	0,37	0,26	0,16	0,07	0
HRS1	Pa	1	0,84	0,68	0,54	0,40	0,29	0,20	0,12	0,07	0,03	0
HRS2	Pa	1	0,85	0,70	0,56	0,43	0,31	0,21	0,13	0,07	0,03	0

SPOT MTF along lines as a function of the normalized spatial frequency (f/f_e , f_e is the sampling frequency). Results are above the specifications for all satellites and all channels.

Remark: the values which vary each year correspond to the SPOT5 measurements (HRG, HM). Other values come from the ground measurements before flight because of the spatial resolution: the edge method with the Salon target can be used only with SPOT 5 HRG instruments, panchromatic channels. Nevertheless, the relative evolution of the MTF between two instruments on the same satellite is measured on flight for all the satellites and is quite stable.

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 10 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	--

MTF- columnwise	f/fe	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
SPOT1 <i>HRV</i>	Pa	1	0,80	0,60	0,42	0,27	0,16	0,08	0,04	0,01	0,00	0
	B1	1	0,91	0,80	0,67	0,53	0,40	0,28	0,18	0,10	0,04	0
	B2	1	0,90	0,78	0,65	0,51	0,38	0,26	0,17	0,09	0,04	0
	B3	1	0,89	0,76	0,63	0,49	0,36	0,25	0,16	0,08	0,03	0
SPOT2 <i>HRV</i>	Pa	1	0,85	0,67	0,50	0,34	0,21	0,12	0,05	0,02	0,00	0
	B1	1	0,92	0,81	0,69	0,55	0,42	0,30	0,19	0,11	0,04	0
	B2	1	0,92	0,81	0,69	0,55	0,42	0,30	0,19	0,11	0,04	0
	B3	1	0,91	0,80	0,67	0,54	0,41	0,29	0,18	0,10	0,04	0
SPOT3 <i>HRV</i>	Pa	1	0,87	0,70	0,53	0,37	0,24	0,13	0,06	0,02	0,00	0
	B1	1	0,92	0,81	0,69	0,55	0,42	0,30	0,19	0,11	0,04	0
	B2	1	0,92	0,81	0,68	0,55	0,42	0,29	0,19	0,11	0,04	0
	B3	1	0,92	0,80	0,68	0,54	0,41	0,29	0,19	0,10	0,04	0
SPOT4 <i>HRVIR</i>	M	1	0,85	0,68	0,51	0,35	0,22	0,12	0,06	0,02	0,00	0
	B1	1	0,93	0,83	0,71	0,58	0,45	0,32	0,21	0,12	0,05	0
	B2	1	0,93	0,83	0,70	0,57	0,44	0,31	0,21	0,12	0,05	0
	B3	1	0,93	0,82	0,70	0,57	0,43	0,31	0,20	0,11	0,05	0
	MIR	1	0,85	0,68	0,50	0,34	0,21	0,12	0,05	0,02	0,00	0
SPOT5 <i>HRG</i> <i>HRS1</i> <i>HRS2</i>	HM	1	0,88	0,74	0,59	0,44	0,31	0,20	0,12	0,06	0,02	0
	B1	1	0,88	0,74	0,59	0,46	0,33	0,22	0,14	0,07	0,03	0
	B2	1	0,88	0,74	0,59	0,46	0,33	0,22	0,14	0,07	0,03	0
	B3	1	0,88	0,75	0,61	0,47	0,34	0,23	0,14	0,08	0,03	0
	MIR	1	0,88	0,72	0,55	0,39	0,25	0,14	0,07	0,02	0,00	0
	Pa	1	0,84	0,68	0,52	0,38	0,25	0,16	0,08	0,04	0,00	0
Pa	1	0,88	0,74	0,59	0,44	0,31	0,20	0,11	0,05	0,01	0	

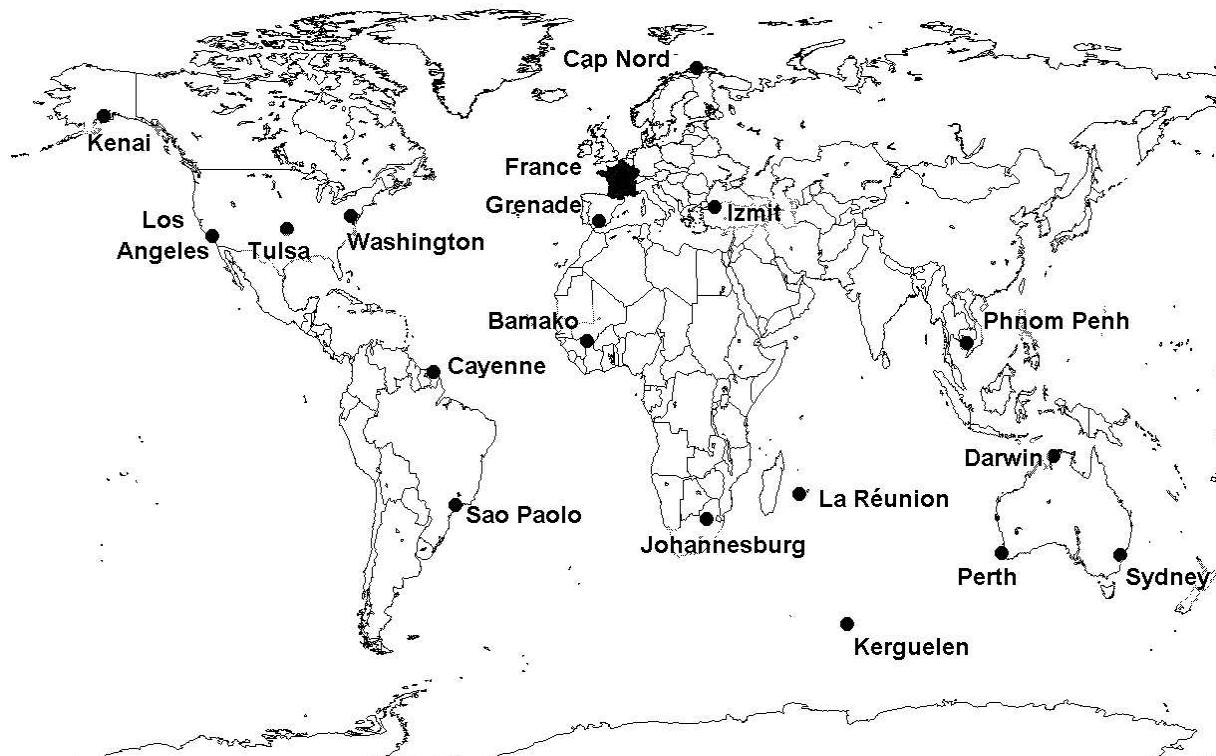
SPOT MTF along columns as a function of the normalized spatial frequency (f/fe , fe is the sampling frequency).

3 GEOMETRIC PERFORMANCES

3.1 Location accuracy

3.1.1 Introduction

The location accuracy is the ability to locate a point in the image using its coordinates (row, line) in the image and the viewing model available through ancillary data. The location accuracy is regularly assessed on specific sites world-wide distributed in order to reflect the global accuracy of the system.



Location assessment test sites

A new site, Rosario in South America, was added in 2006.

Following results of location measurements are given for each satellite :

- number of measures ;
- time period of measures ;
- statistical results : mean, standard deviation (std), root mean square (rms) and maximum for 90% of images are given for across the track, along the track and global location performance.

We also present for each satellite the graph of the distribution of the measurements across the track and along the track : one point represents one image's performance measure. An ellipse centred on the mean performance shows the across the track and along the track root mean square boundary.

In the following paragraphs, we present the results estimated on images acquired between September 2005 and August 2006. But we also recall the results since the launch in order to show a potential evolution function of time. In particular, we have to distinguish two periods for SPOT5

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 12 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	--

results, because a modification has been brought on board SPOT5 on the fourth of September 2003 which leads to a significant improvement of the location performance. Therefore, we present SPOT5 location performances before and after the modification. A possible way to improve location accuracy for images acquired before the modification is detailed in paragraph 3.1.5.3.

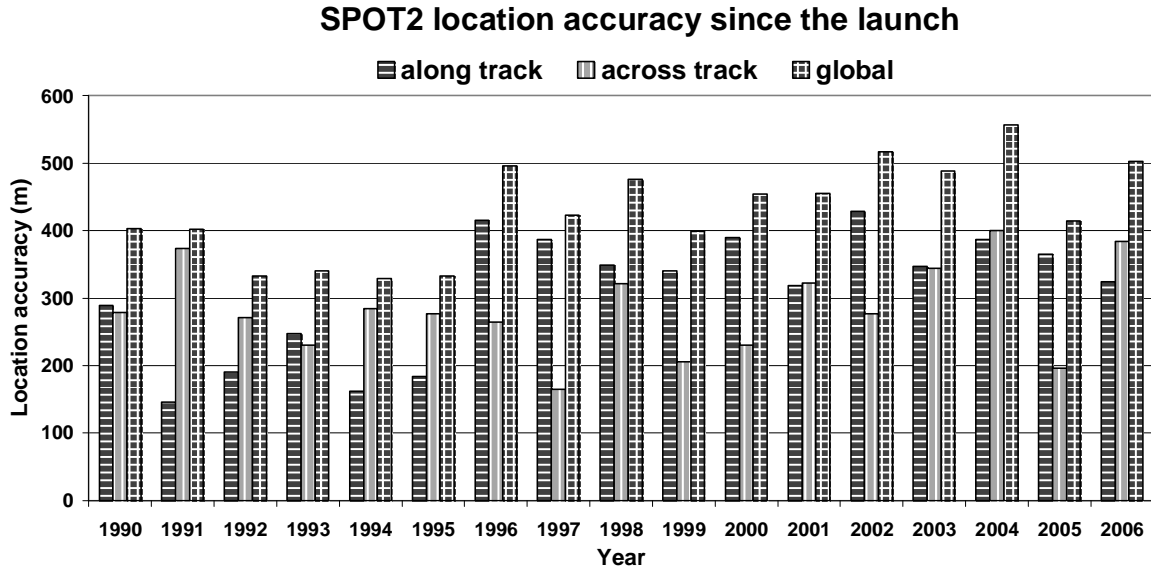
For SPOT5, we also present the synthesis of residuals alignment biases and their evolution function of different parameters such as time, latitude and so on...

Finally, at the end of the document, a synthesis of the performance is presented for SPOT1, SPOT2, SPOT4 and SPOT5, based on images acquired between September 2005 and August 2006.

3.1.2 SPOT2 location accuracy

3.1.2.1 Evolution since the launch

The following graph shows the evolution of SPOT2 location accuracy since the launch in 1990.

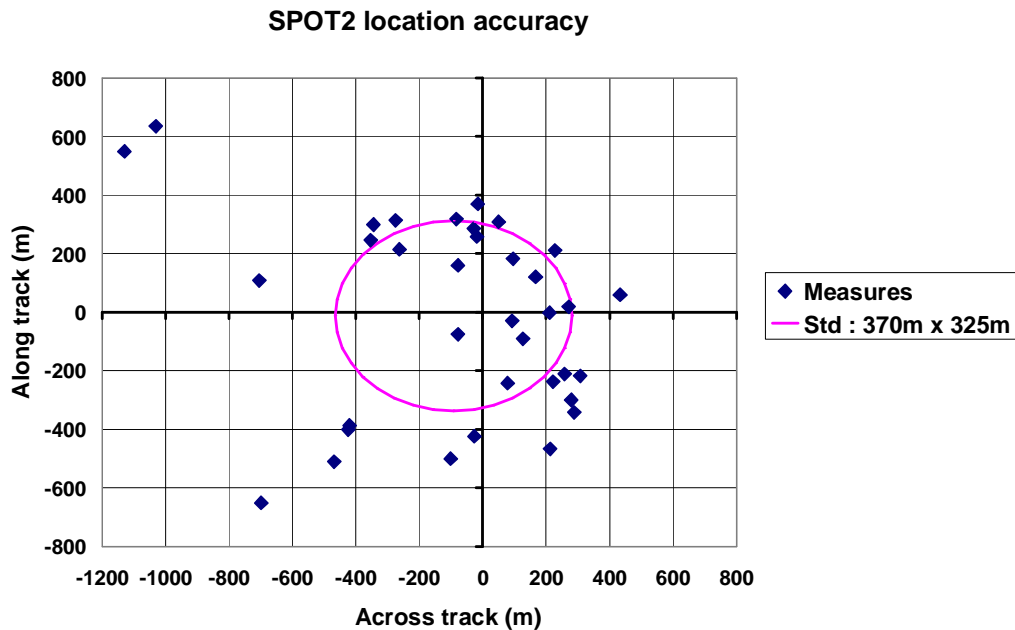


The graph shows stable results compared to previous years.

3.1.2.2 Results estimated between September 2005 and August 2006

SPOT2 location accuracy is assessed on an annual basis for every exploitation review.

The following graph shows the distribution of the measures estimated on images acquired between September 2005 and August 2006. One point corresponds to the location accuracy of one image.



CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 14 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	--

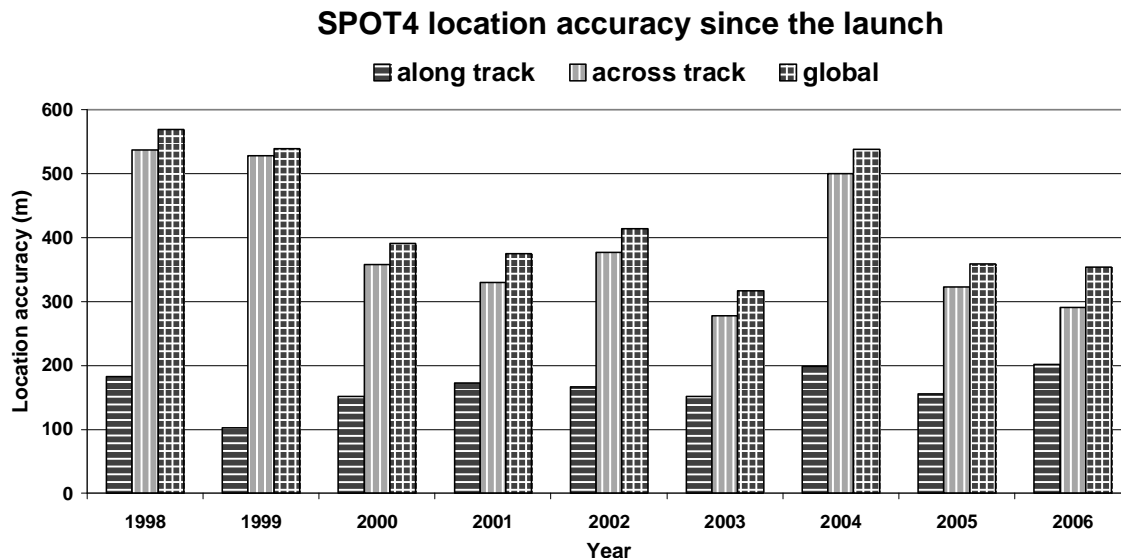
The following table shows the detailed statistical results estimated on images acquired between September 2005 and August 2006.

SPOT2 HRV 2006			
35 images - 09/2005 to 08/2006			
meters	across track	along track	global
Mean	-92	-12	
Standard dev.	373	324	
RMS	384	324	503
Max for 90 %	699	511	713

3.1.3 SPOT4 location accuracy

3.1.3.1 Evolution since the launch

The following graph shows the evolution of SPOT4 location accuracy since the launch in 1998.

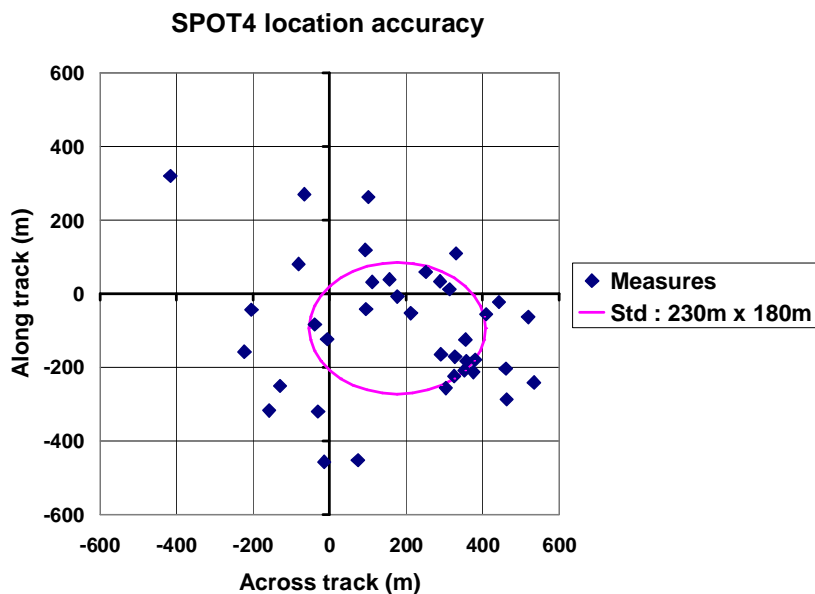


The graph shows stable results compared to previous years.

3.1.3.2 Results estimated between September 2005 and August 2006

SPOT4 location accuracy is assessed on an annual basis for every exploitation review.

The following graph shows the distribution of the measures estimated on images acquired between September 2005 and August 2006. One point corresponds to the location accuracy of one image.



CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 16 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	--

The following table shows the detailed statistical results estimated on images acquired between September 2005 and August 2006.

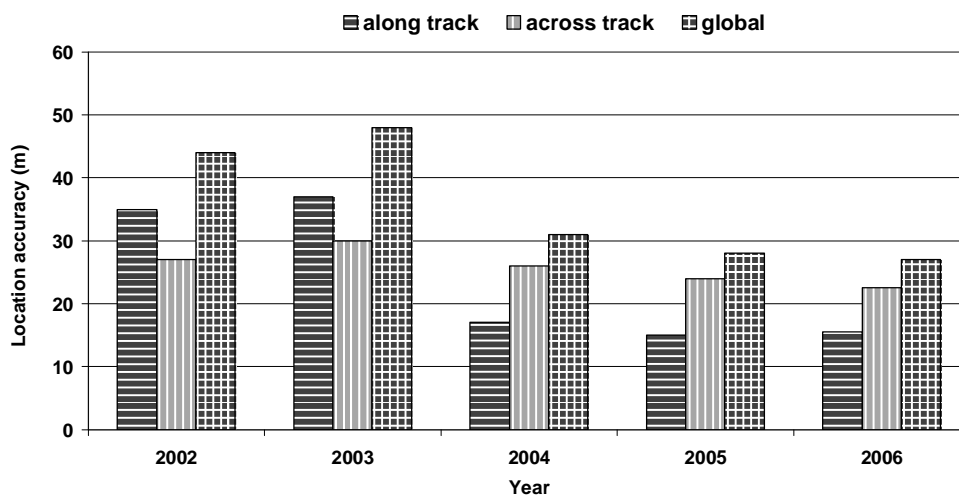
SPOT4 HRVIR 2006			
38 images - 09/2005 to 08/2006			
meters	across track	along track	global
Mean	177	-94	
Standard dev.	231	179	
RMS	291	202	354
Max for 90 %	443	317	503

3.1.4 SPOT5 location accuracy evolution since the launch

3.1.4.1 Evolution of SPOT5 HRG location accuracy since the launch

The following graph shows the evolution of SPOT5 HRG location accuracy since the launch in 2002.

SPOT5 HRG location accuracy since the launch

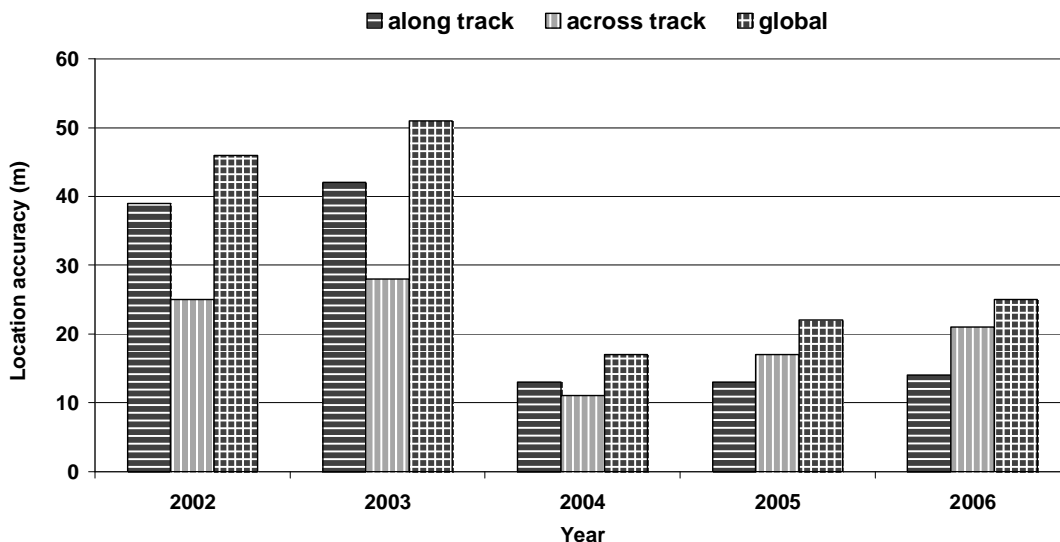


The graph clearly shows an improvement of the results since September 2003. This improvement is due to a modification which has been brought on board SPOT5 on the fourth of September 2003, as explained in paragraph 3.1.5.3. Therefore, we distinguish two periods in the following paragraphs : before and after September 2003.

3.1.4.2 Evolution of SPOT5 HRS location accuracy since the launch

The following graph shows the evolution of SPOT5 HRS location accuracy since the launch in 2002.

SPOT5 HRS location accuracy since the launch



CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 18 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
-------------	---	--

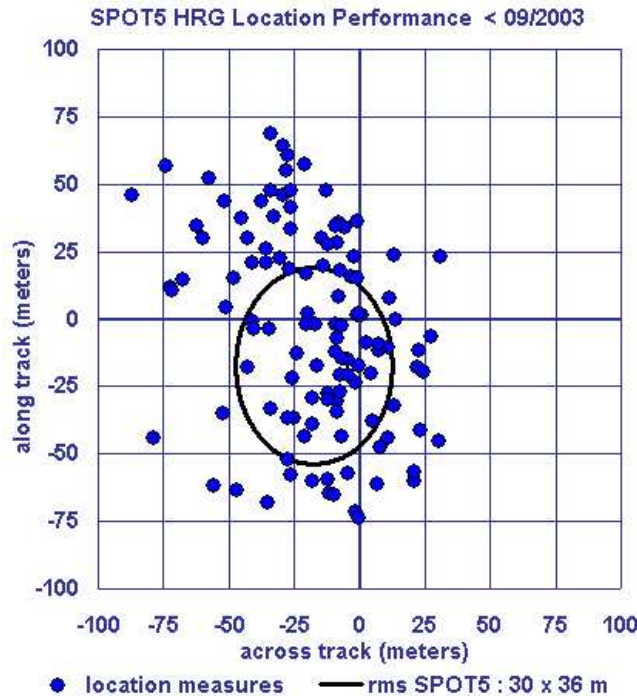
The graph clearly shows an improvement of the results since September 2003. This improvement is due to a modification which has been brought on board SPOT5 on the fourth of September 2003, as explained in paragraph 3.1.5.3. Therefore, we distinguish two periods in the following paragraphs : before and after September 2003.

We can also observe a significant evolution of the results since 2004. It is explained in paragraph 3.1.7.2.

3.1.5 SPOT5 location accuracy before September 2003

3.1.5.1 SPOT5 HRG location accuracy before September 2003

The following graph shows the distribution of the measures estimated on HRG images acquired before September 2003. One point corresponds to the location accuracy of one image.



The following table shows the detailed statistical results estimated on HRG images acquired before September 2003.

SPOT5 HRG < 09/2003			
116 images - 09/2002 to 09/2003			
<i>meters</i>	⊥ track	// track	global
<i>Mean</i>	-17	-4	18
<i>Std</i>	25	36	44
<i>Rms</i>	30	36	47
<i>Max / 90 %</i>	51	60	79

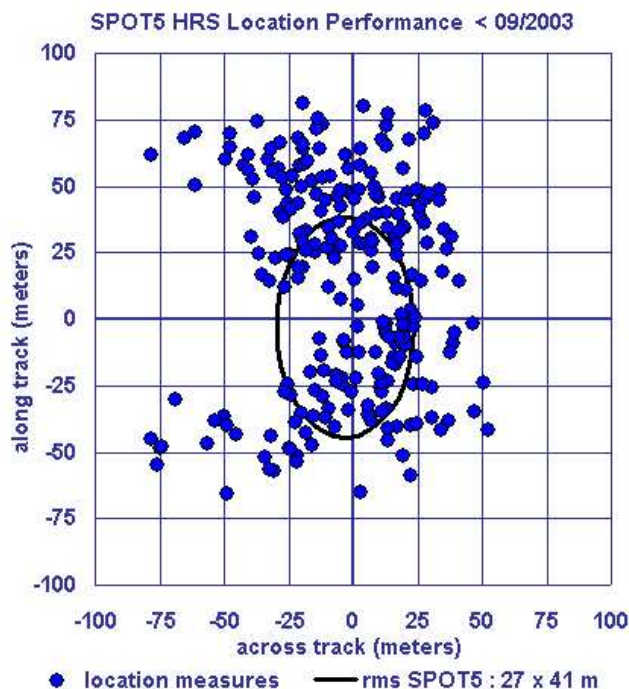
Comment :

SPOT5 HRG instrument are checked on a monthly basis. These figures are related to measurements held from September 2002 to September 2003. During this period, the location performance was impacted by a bad initialisation of the on board star tracker's relativist compensation process. This problem is described in paragraph 3.1.5.3.

The average location performance, is not close to 0, especially along track, because location is optimised for latitudes around 20°N.

3.1.5.2 SPOT5 HRS location accuracy before September 2003

The following graph shows the distribution of the measures estimated on HRS images acquired before September 2003. One point corresponds to the location accuracy of one image.



The following table shows the detailed statistical results estimated on HRS images acquired before September 2003.

SPOT5 HRS < 09/2003			
246 images - 09/2002 to 09/2003			
<i>meters</i>	⊥ track	// track	global
<i>Mean</i>	-3	13	14
<i>Std</i>	26	39	47
<i>Rms</i>	27	41	49
<i>Max / 90 %</i>	40	64	75

Comment :

For SPOT5/HRS instrument, we present a monoscopic performance assessment for both cameras. SPOT5 HRS instrument are checked on a monthly basis. These figures are related to measurements held from September 2002 to September 2003. During this period, the location performance was impacted by a bad initialisation of the on board star tracker relativist compensation process. This problem is described in paragraph 3.1.5.3.

For HRS, the average location performance is close to 0 because it is world-wide optimised.

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 21 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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3.1.5.3 SPOT5 enhanced location model for images before September 2003

For SPOT5/HRS instrument, we present some monoscopic location performance results. Location performances are computed separately for each camera, with no tie points taken into account. Global HRS figure are computed out of both cameras figures without taking into account the pair.

Before September 2003, SPOT5 location performances was impacted by a bad initialisation of the on board star tracker's relativist compensation process. This problem caused the location performance to vary with satellite position, indeed both with latitude and time.

We give in this paragraph an estimation of the impact of this problem estimated thanks to available measures on location sites. Impact linked with latitude (attitude correction model) and time (time correction remainders) are given.

Attitude polynomial correction model :

This model allows improvement of the location accuracy before September 2003 down to **30 m rms for HRS** and **40 m rms for HRG** (instead of 50 m rms without attitude correction model).

The model has been designed as a polynomial function of satellite corrected latitude. Satellite latitude corrected from seasonal effect is used in order to reflect an exact time delay after satellite's eclipse exit.

The tuning has been done specifically for HRS. For HRG, an adaptation of the bias is required.

Attitude correction model :

$$\begin{cases} \mathbf{R}'(t) = \mathbf{R}(t) + \mathbf{R}_0 + \mathbf{R}_1 \times \text{latcor} + \mathbf{R}_2 \times \text{latcor}^2 \\ \mathbf{P}'(t) = \mathbf{P}(t) + \mathbf{P}_0 + \mathbf{P}_1 \times \text{latcor} + \mathbf{P}_2 \times \text{latcor}^2 \\ \mathbf{Y}'(t) = \mathbf{Y}(t) + \mathbf{Y}_0 + \mathbf{Y}_1 \times \text{latcor} + \mathbf{Y}_2 \times \text{latcor}^2 \end{cases}$$

where R, P and Y respectively correspond to Roll, Pitch and Yaw.

Corrected latitude estimation :

$$\text{latcor} = \text{lat_sat} - 23,5 \times \cos\left(\frac{2\pi \times (\text{acq_date} - \text{date_ref})}{365}\right)$$

lat_sat : satellite latitude (degrees)

acq_date : acquisition date

date_ref : 21/06/2003

Correction model coefficients :

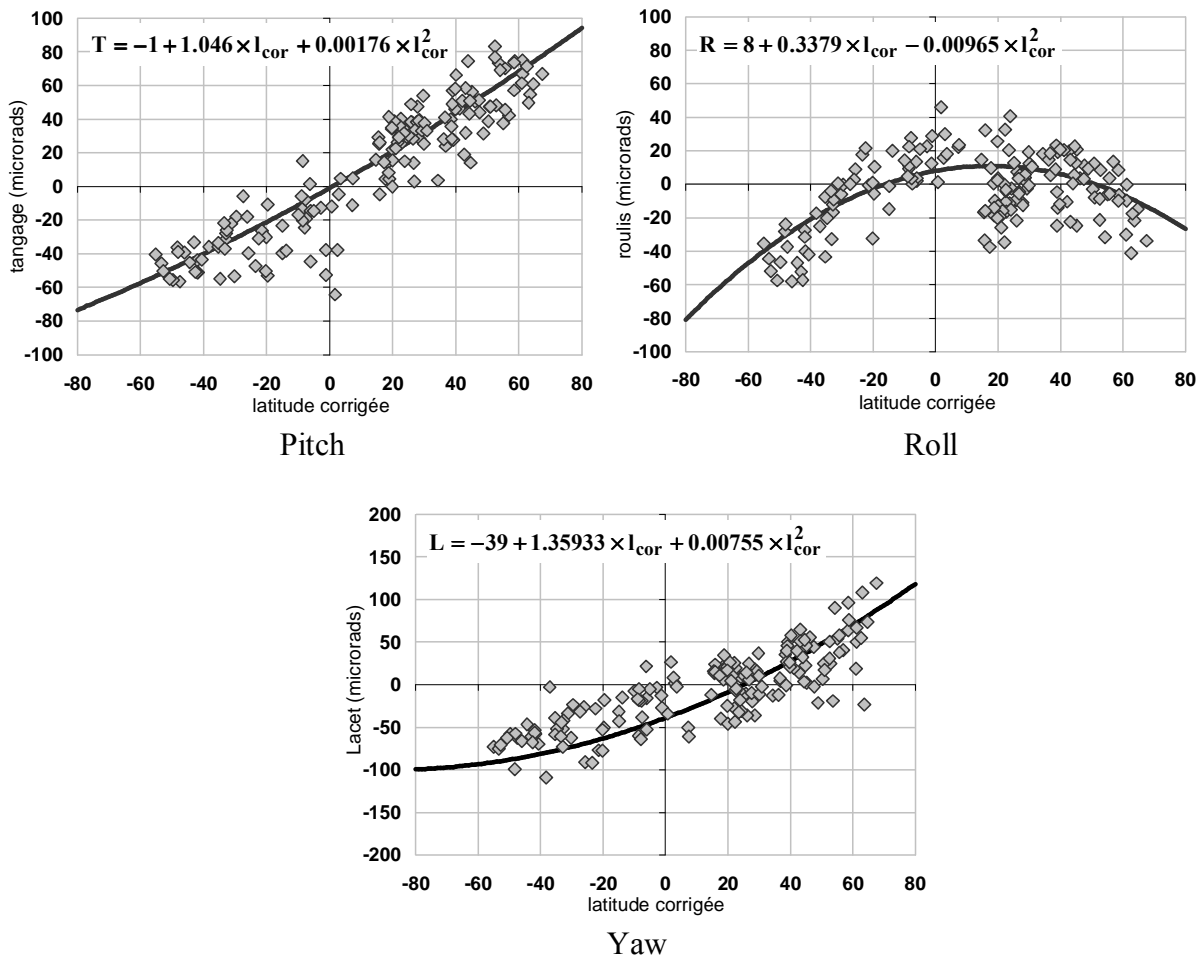
μrad	Roll	Pitch	Yaw
Bias (HRG)	14	29	-39
Bias (HRS)	8	-1	-39
Latcor	0.3379	1.046	1.35933
Latcor²	-0.00965	0.00176	0.00755

The bias line provides values for R0, P0 and Y0 and should be adapted to HRG or HRS.

The latcor line provides coefficients R1, P1 and Y1

The latcor² line provides coefficients R2, P2 and Y2

Attitude correction model tuning on HRS measures :



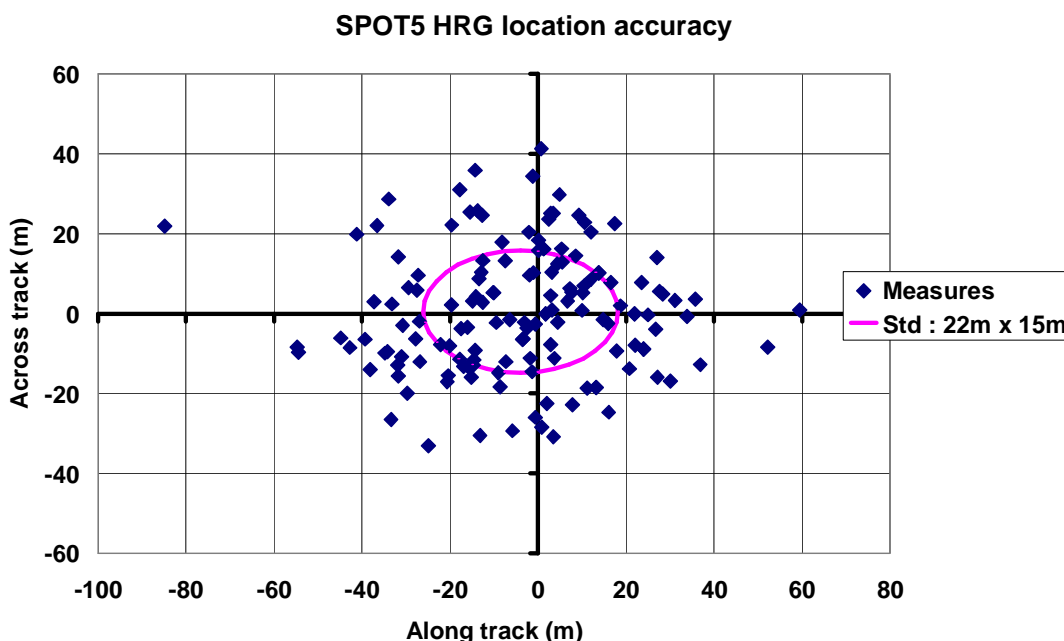
Comments :

These model doe's not reflect the real impact of the on-board problem but the best analytic model which can be fit on available measures. Its interpretation may be subject to caution while using it on sites or period which are not covered by our analysis.

3.1.6 SPOT5 HRG location accuracy after September 2003

3.1.6.1 Results estimated between September 2005 and August 2006

SPOT5 HRG location accuracy is assessed on an annual basis for every exploitation review. The following graph shows the distribution of the measures estimated on images acquired between September 2005 and August 2006. One point corresponds to the location accuracy of one image.



The following table shows the detailed statistical results estimated on images acquired between September 2005 and August 2006.

SPOT5 HRG 2006			
147 images - 09/2005 to 08/2006			
meters	across track	along track	global
Mean	-4	0	
Standard dev.	22	15	
RMS	22	15	27
Max for 90 %	34	25	39

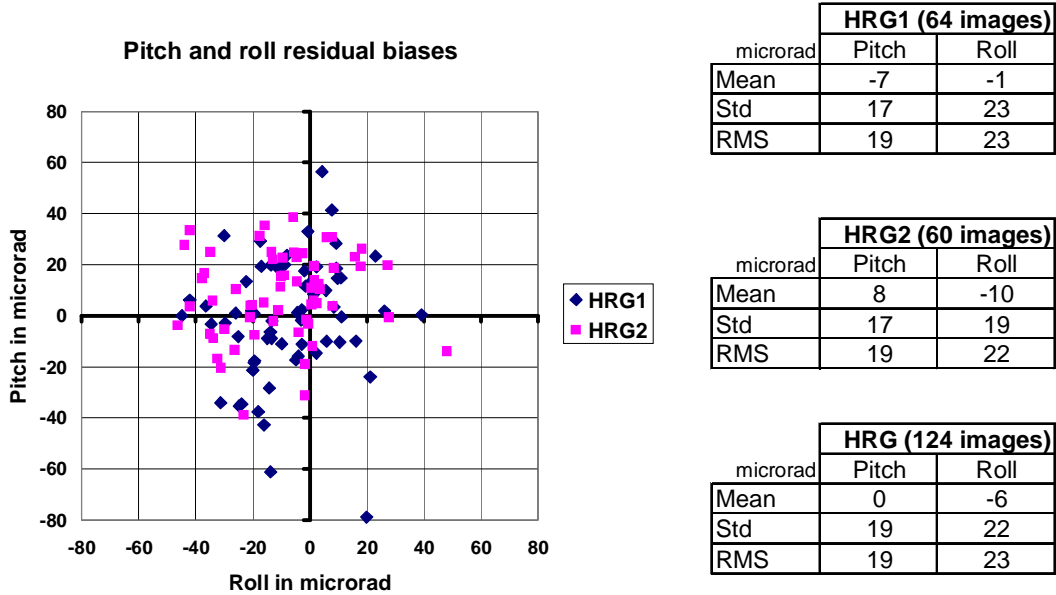
We can observe that the performance is better along track than across track : HRG across track location accuracy is mainly due to the steering mirror behavior.

3.1.6.2 Residual alignment biases analysis

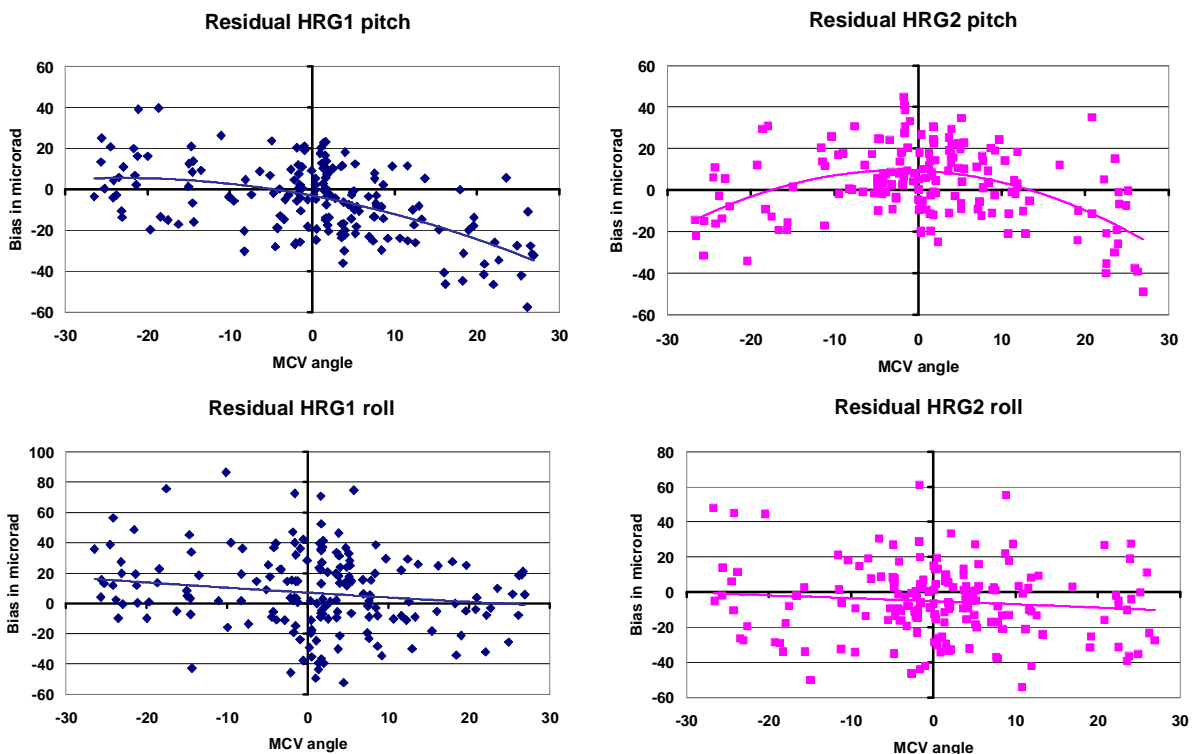
The analysis of the residuals alignment biases allows to understand the evolution of location accuracy relatively to different parameters such as time or latitude, and allows to know if a new alignment biases calibration is necessary.

We present in this paragraph only the main evolutions observed on HRG images since September 2003.

The following graph and tables show the difference between HRG1 and HRG2 : we can observe a little bias between both instruments. These results were measured on images acquired between September 2005 and August 2006.

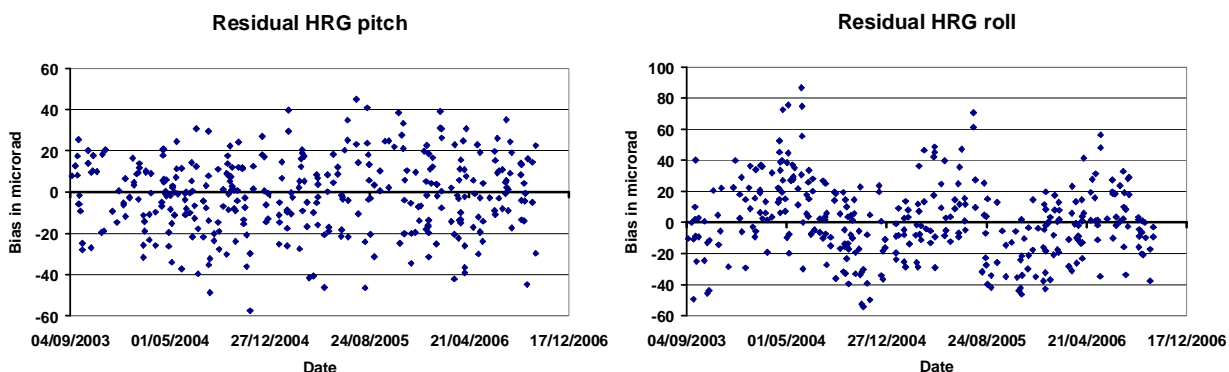


The following graphs show the evolution of the residual pitch and roll biases relatively to the MCV viewing angle. We can observe significant evolutions especially for pitch. All the measures since September 2003 were considered in order to be able to observe such a phenomena.

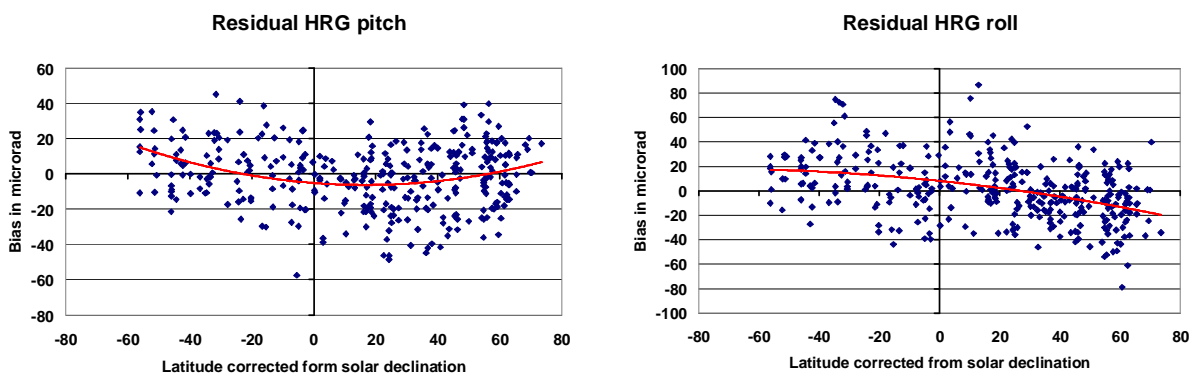


We can notice that the bias between HRG1 and HRG2 and the evolutions of the residual pitch and roll biases relatively to the MCV viewing angle could be improved through a new HRG geometrical calibration.

The two following graphs show the evolution of the residual HRG biases in pitch and roll relatively to the date since September 2003. We can observe a clearly seasonal evolution for roll bias, attributed to thermo-elastic effects.



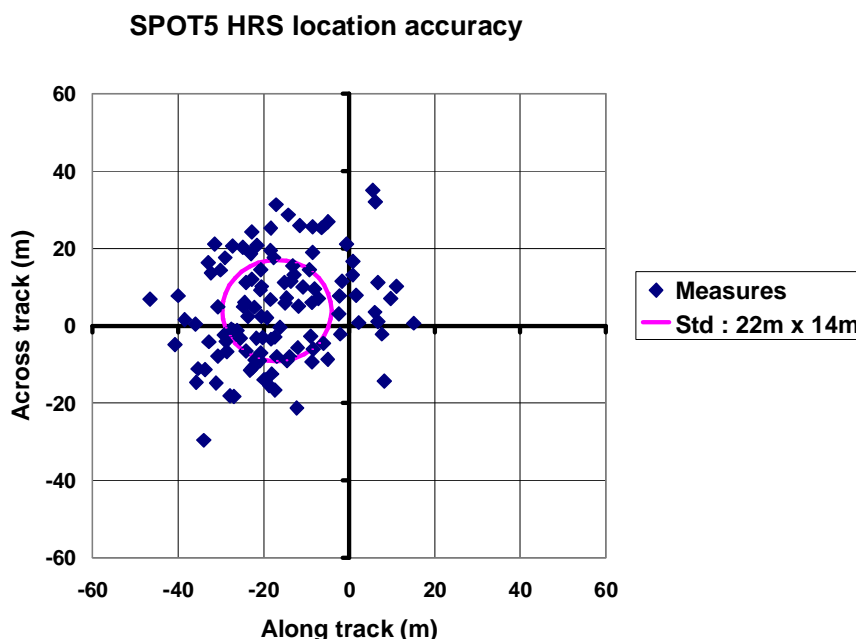
The two following graphs show the evolution of the residual HRG biases in pitch and roll relatively to the latitude corrected from solar declination. We can observe evolutions for both roll and pitch biases, attributed to thermo-elastic effects.



3.1.7 SPOT5 HRS location accuracy after September 2003

3.1.7.1 Results estimated between September 2005 and August 2006

SPOT5 HRS location accuracy is assessed on an annual basis for every exploitation review. The following graph shows the distribution of the measures estimated on images acquired between September 2005 and August 2006. One point corresponds to the location accuracy of one image.



The following table shows the detailed statistical results estimated on images acquired between September 2005 and August 2006.

SPOT5 HRS 2006			
116 images - 09/2005 to 08/2006			
meters	across track	along track	global
Mean	-17	4	
Standard dev	13	13	
RMS	21	14	25
Max for 90 %	33	11	36

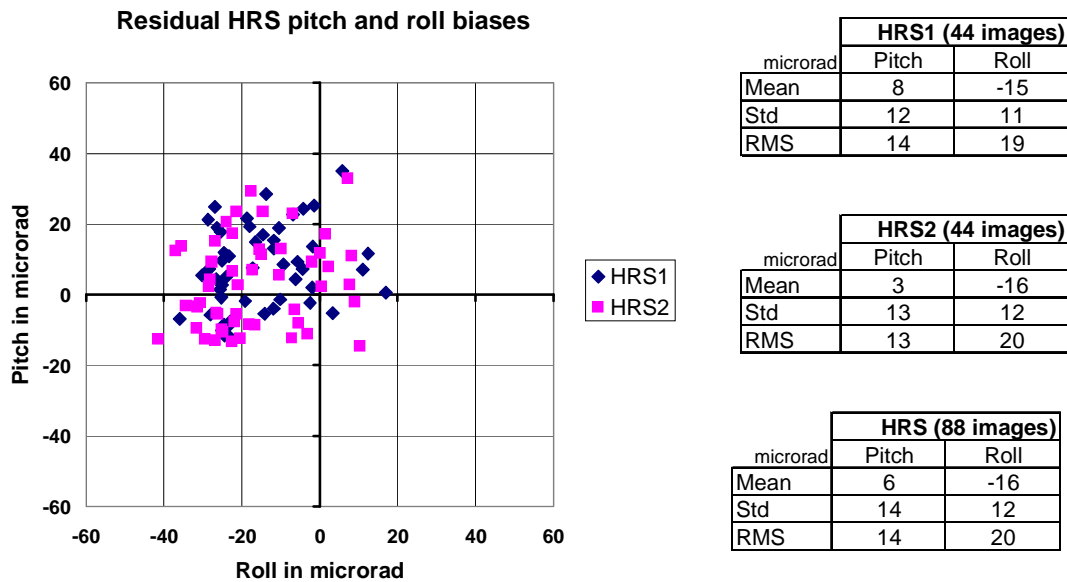
We can observe in the graph and in the table that the across track mean performance is relatively far from 0 : this is due to an evolution of the residual roll bias since September 2003, as explained in paragraph 3.1.7.2. Consequently, the 2006 performance is better along track than across track, which was not the case in 2004.

3.1.7.2 Residual alignment biases analysis

The analysis of the residuals alignment biases allows to understand the evolution of location accuracy relatively to different parameters such as time or latitude, and allows to know if a new alignment biases calibration is necessary.

We present in this document only the main evolutions observed on HRS images since September 2003.

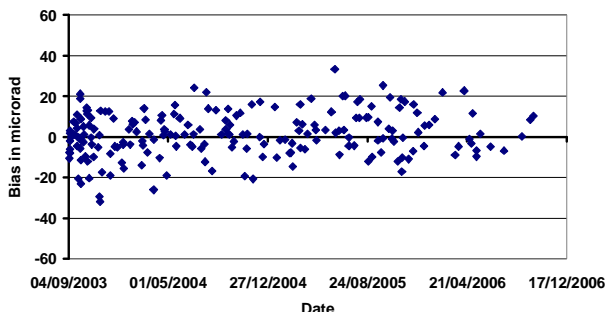
The following graph and tables show the results obtained on HRS1 and HRS2. These results were measured on images acquired between September 2005 and August 2006. We can observe a significant bias for roll bias (mean far from 0), which confirms the bias on across track location accuracy.



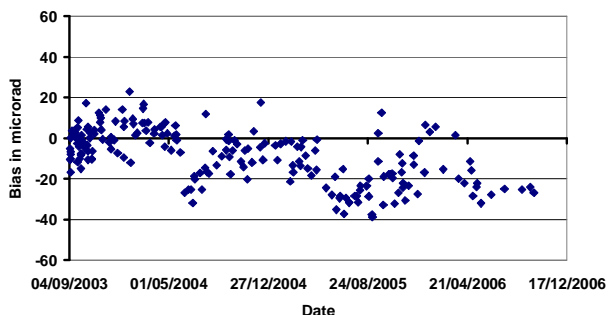
The two following graphs show the evolution of the residual HRS biases in pitch and roll relatively to the date since September 2003. We can clearly observe two types of evolutions for roll bias :

- a sinusoidal seasonal evolution, attributed to thermo-elastic effects,
- a slope, attributed to an ageing process, which explains the bias observed for across track location accuracy observed in 2006.

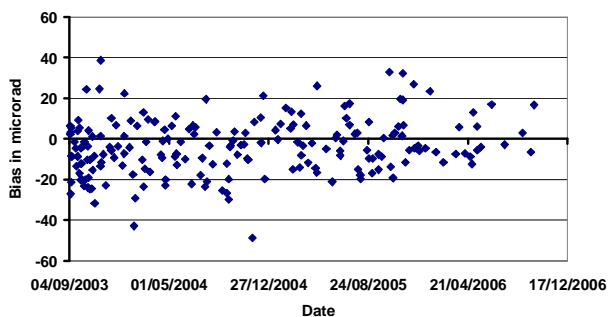
Residual HRS pitch bias



Residual HRS roll bias



residual HRS yaw bias



We can notice that the evolution of roll bias (slope) observed since September 2003 can be corrected through a new HRS alignment biases geometrical calibration. This calibration is planned in 2007. But such a calibration only allows to correct a bias, not a slope. Consequently, it will be necessary to regularly process new calibrations in the following years, if we want to regularly correct the roll slope.

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 29 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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3.1.8 Synthesis

Summary of the global location accuracy for every SPOT satellite is given in the following table. These results have been estimated on images acquired between September 2005 and August 2006 for SPOT2, SPOT4 and SPOT5. For SPOT1, the results have been estimated on images acquired in 2001 and 2002.

	SPOT5		SPOT4	SPOT2	SPOT1
	HRG	HRS	HRVIR	HRV	HRV
<i>Nb images</i>	147	112	38	35	62
<i>Global RMS</i>	27 m	25 m	354 m.	503 m.	628 m.

Location accuracy summary

3.2 Length Distortion

Length distortion is the accuracy of distances measures over images.

It is estimated over a set of images with ground control points by comparison of the real distance between pairs of ground control points (d) with the distance measured on the images (d').

We present 2 types of performances :

- for **distances under 5 km.** : rms of $\delta d = |d-d'|$ in meters \Leftrightarrow **measure precision in meters ;**
- for **distances over 5 km.** : rms of $\delta d/d$ in percent \Leftrightarrow **measure precision in percent.**

		Length Distortion	
		d<5km δd (meters rms)	d>5km $\delta d/d$ (% rms)
SPOT5	HRG	3.9 m.	$0.78 \cdot 10^{-1} \%$
	HRS	2.7 m.	$0.54 \cdot 10^{-1} \%$
SPOT4	HRVIR	4.5 m.	$0.90 \cdot 10^{-1} \%$
SPOT3	HRV	4.6 m.	$0.93 \cdot 10^{-1} \%$
SPOT2	HRV	3.6 m.	$0.73 \cdot 10^{-1} \%$
SPOT1	HRV	5.7 m.	$1.14 \cdot 10^{-1} \%$

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 31 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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3.3 Multi-spectral registration

The multispectral registration performance is the accuracy of superposition of the different bands of the multispectral mode. It is given by the diameter of the circle containing the centers of every pixel of each band. This performance was measured during commissioning phase for each satellite and every year for SPOT2, SPOT4 and SPOT5. We did not observe any evolution compared to previous years. Consequently, only latest figures are given in the following table. We can notice that SPOT5 performance is given after ground registration.

		Multispectral registration (XS pixel)		
		Resolution	With SWIR band	Without SWIR band
SPOT5 (2006)	HRG1	10 m	0.18 pixel RMS	0.12 pixel RMS
SPOT5 (2006)	HRG2	10 m	0.18 pixel RMS	0.12 pixel RMS
SPOT4 (2006)	HRVIR1	10 m	0.34 pixel RMS	0.30 pixel RMS
SPOT4 (2006)	HRVIR2	10 m	0.34 pixel	0.30 pixel
SPOT3 (1993)	HRV1/2	20 m.	<i>No SWIR band</i>	0.38 pixel
SPOT2 (2006)	HRV1	20 m.	<i>No SWIR band</i>	0.42 pixel
SPOT2 (2006)	HRV2	20 m.	<i>No SWIR band</i>	0.41 pixel
SPOT1 (1988)	HRV1/2	20 m.	<i>No SWIR band</i>	0.21 pixel

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 32 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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3.4 Elevation performance

The elevation performance represents the typical performance obtained while producing DTM with SPOT images. It usually depends on the lateral stereoscopy configuration (B/H ratio), on the time elapsed between the two acquisitions of the stereoscopic pair (for exhaustivity) and on the terrain's slopes.

The following table gives the typical performance for all instruments except HRS, considering a stereoscopic pair with a B/H ratio close to 0.5, an elapsed time lower than 4 months between the 2 images of the pair and medium terrain relief.

HRS B/H ratio is slightly higher than 0.8.

		Elevation performance (rms)
SPOT5	HRG 2.5 m./5 m.	4.9 m.
	HRG 10 m.	6.1 m.
	HRS	3.7 m.
SPOT4	HRVIR	6.7 m.
SPOT2	HRV	7.3 m.
SPOT1	HRV	7 m.

CNES	SYSTEME POUR L'OBSERVATION DE LA TERRE	REF. : C443-NT-0-296-CN PAGE : 33 EDIT. : 3 REV. : 0 DATE : 15 avril 2007
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4 CONCLUSION

The main performances have been successfully carried out in 2006.

Concerning the radiometric quality image, the results are in the continuity. The signal to noise ratio can be under the specifications for SPOT4 (SWIR channels) or SPOT5 (HM channels). The results for SPOT4 are indicative of the strong degradation of the SWIR detectors (radiations sensibility). The results for SPOT5 have to be confirmed during the year 2007.

Concerning geometrical quality image, the analysis shows a good stability of the results. Particularly, location accuracy remains very compliant and even much better than specification. We just notice a light evolution of HRS roll alignment bias since last calibration, which will be corrected in 2007 by a new HRS alignment biases calibration.