

Jupiter : Longitudinal drifts computation from image pairs

by Grisca Hahn (Translation: Michel Jacquesson)

WinJUPOS version 9.1.3 contains a robust and precise method to compute automatically the atmospheric wind speeds, particularly on Jupiter.

It requires two images with similar definition in a time interval of 10 or 20 hours (corresponding to one or two rotations of the planet). With a higher time interval, the clouds structures would have so changed that the automatic processing could find no or insufficient correspondences.

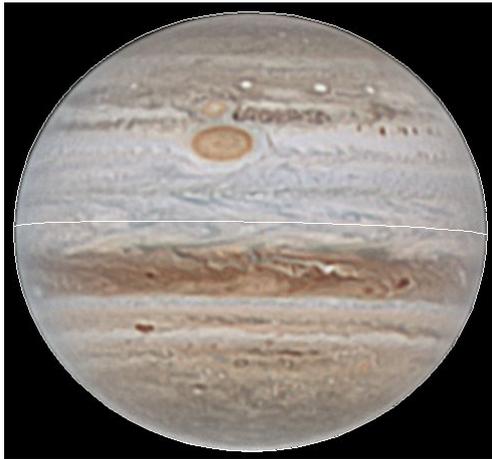


Fig. 1: Parker 2010-09-04 05:53 UT



Fig. 2: Yoshida 2010-09-04 15:48 UT

The speed components are computed parallel to the equator, corresponding to the longitudinal drift of an object. And so on in all latitudes, so that at the end, a speed profile of the whole atmosphere is produced.

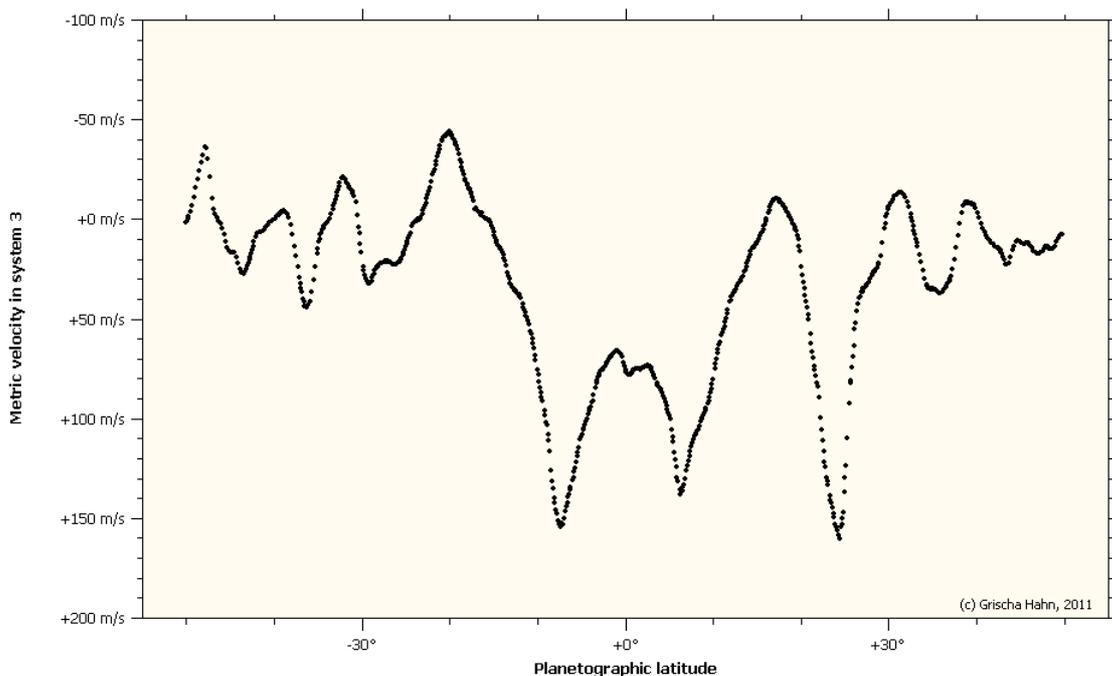


Fig. 3: Parker 2010-09-04 05:53-06:34 UT versus Yoshida 2010-09-04 14:52-18:07 UT

This method has several advantages compared to the precedent drift computing from objects positions measurements :

- longitudinal drifts of short living details can be computed
- the average longitudinal drift of a latitude contains not only a limited quantity of long living objects (which have besides their particular behaviour) but almost all atmospheric details of a latitude interval
- longitudinal drifts from image data can be produced where the observer sees no structures or only elusive ones, so that he cannot localize particular objects
- a complete longitudinal profile can be produced easily

Of course, the disadvantages must not be hidden :

- the search for useful image pairs requires much time
- the calibration of each image must be made carefully

1. Preparations

In fact, the minimal requirement concerning two particular Jupiter images is not sufficient because the calibration of the outline frame in the image measurement is not precise enough, except for images with one or several satellites which can be used for a more precise calibration. But it is rarely the case.

The following requirement gives a solution : instead of one image, a set of at least two images is selected with a time interval from half an hour to an hour and a half.

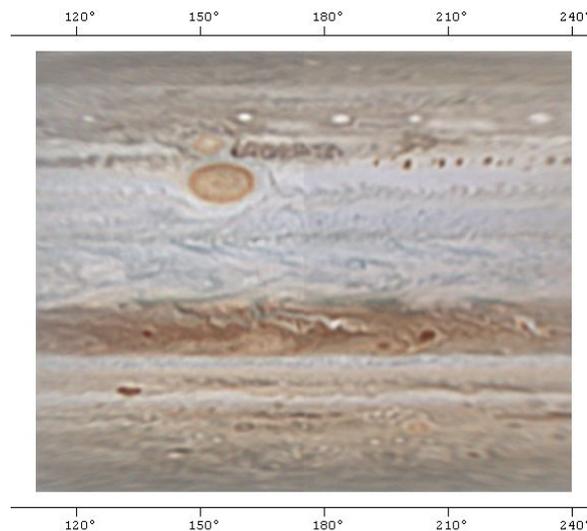


Fig. 4: Parker 2010-09-04 05:53-06:34 UT

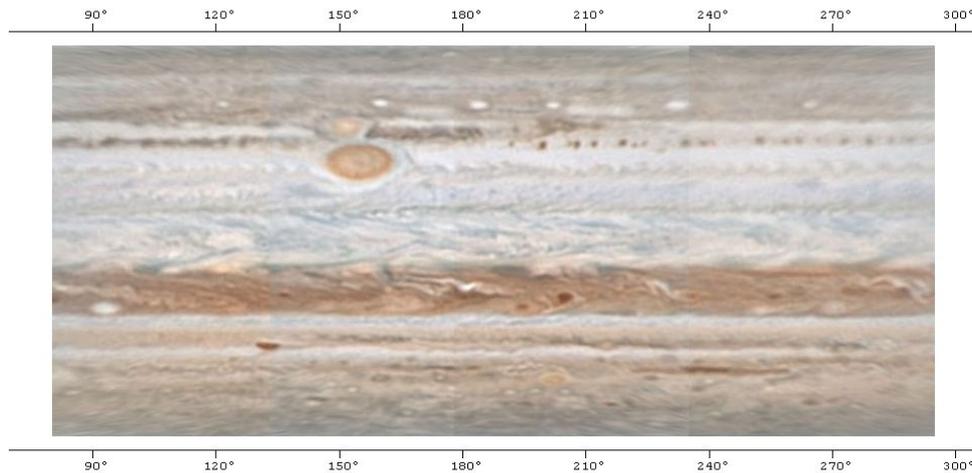


Fig. 5: Yoshida 2010-09-04 14:52-18:07 UT

A (partial) map is made from this set of images. The limit between the two images allows the verification of the correct rotation of the outline frame of the WinJUPOS image measurements. Then, with the help of two well visible objects, one in the northern latitudes and another in the southern latitudes, it is possible to adjust the size and translation of the outline frame so that the coordinates of an object are the same in the two images of the set. In addition, the latitudes of the objects must fit with those of the second set. This requires some care but the consequence is a considerable reduction of the errors in the position of the outline frame. An absolute error in longitude can remain, caused either by a systematic translation error parallel to the equator of the outline frame or/and a wrong time of the images. This error cannot be directly corrected but the computed drifts can be corrected later by a linear shift. Using well known drifts of particular objects, the whole drift profile can be adjusted.

Tip :

In the computation of the maps, the high latitudes must be left aside. A limit of $-70^\circ.. +70^\circ$ planetographic latitude is correct. Another meaningful limit is 60° of longitude on each side of the central meridian so that the brightness of the different images can be fitted easier because the polar and limb zone are too disturbed despite the limb darkening correction.

In the maps, the brightness levelling is often insufficient. A very easy method to get almost perfect results in maps computing is the option "Brightness levelling specially for "Longitudinal drift determination from image pairs" (slow)"

To compute longitudinal drifts, you must choose a colour channel because this computation can be made only with a monochromatic image. You can choose red, green, blue or grey. If you want high precision computations, you must proceed as follows :

- If the colour channels of the original image are not exactly superimposed, the colour channels of the image must be measured separately.
- A separate map must be computed for each colour channel red/green/blue
- An average value of the corresponding drifts in each colour channel red, green and blue must be then computed. In that purpose, the module "Computation of longitudinal drift averages" can be used.

The high resolution image formats PNG and TIFF must be used for the map computation. WinJUPOS saves in these formats each pixel with 48 bit of resolution (RGB). An ideal solution would be of course images with a resolution of 16 bits (grey levels images) or 48/64 bits (colour images).

2. Images calibration

Longitudinal drifts computation works always only with monochromatic images or with a particular channel in a colour image.

The automatic calibration of the outline frame uses always only the green channel of a colour image (this channel corresponds very often to the image time).

The manual calibration of the outline frame should be done with the green channel as well.

With the JPEG format, the green channel gives the best image.

2.1 Image calibration with the satellites or satellites shadows

The ephemerides of the satellites and shadows are accurate enough to be used as fix points for the outline frame calibration. In that purpose, the functions "Adjustment according to two known points" or "Rotation and scaling according to one known point" can be used :

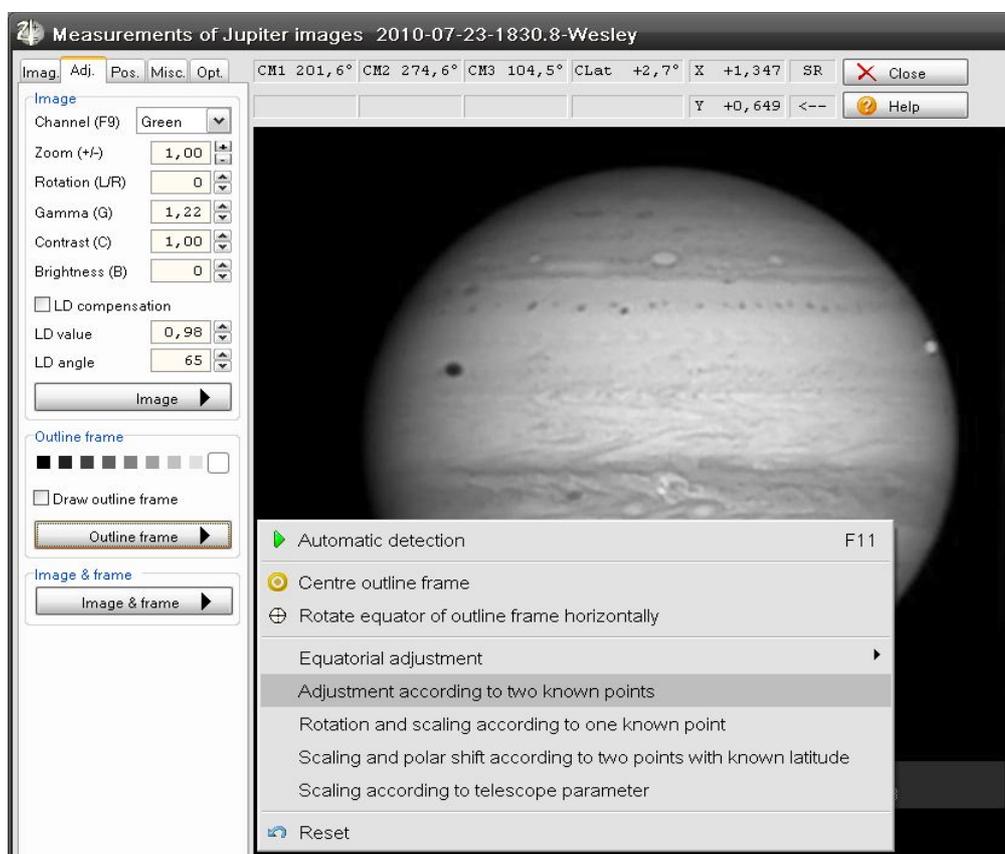


Fig. 6: Adjustment according to two known points

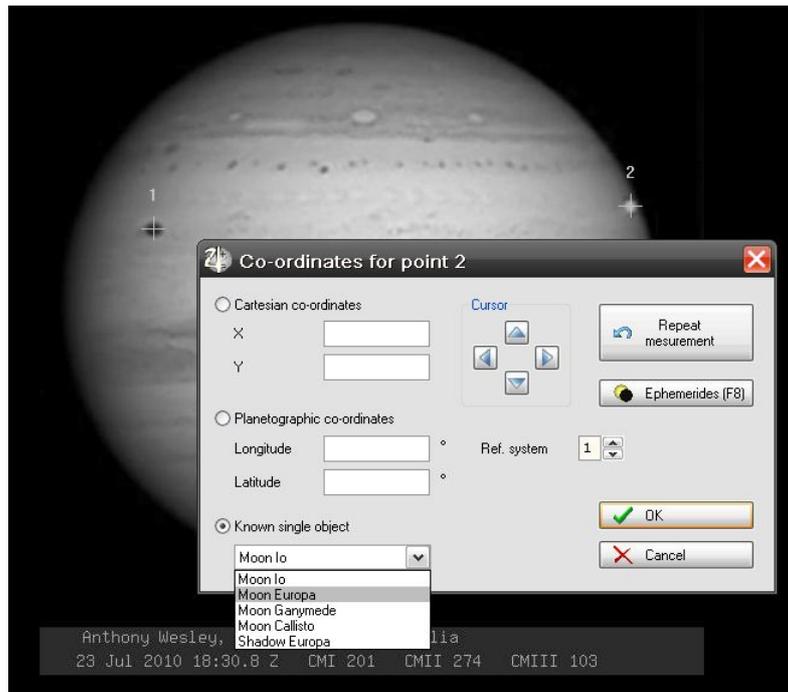


Fig. 7: Choice of known single objects

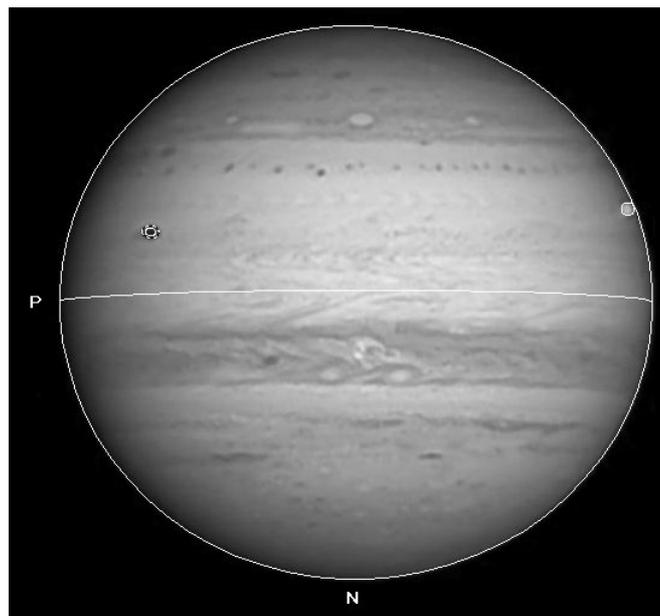


Fig. 8: Result of "Adjustment according to two known points"

If only one satellite or shadow is visible, only the size and rotation of the outline frame can be determined. The centre remains indeterminate. The outline frame is adjusted first manually with an increased value of the gamma (3-4) and then the function "Rotation and scaling according to one known point" is used.

Of course, the satellites or shadows should be as far as possible from the centre.

It can happen, that despite a careful work after using these functions, the outline frame appears suddenly displaced or bad scaled. The reason is often a bad time input. Usually, the shift is one or

two minutes. Instead of the mean time, the beginning or the end of the video sequence has been chosen as the image time (usually, the video sequences have a duration of about 2 minutes), or it is the time of another colour channel or another colour image.

2.2 Calibration of images knowing the parameter of the recording system

If you know the real focus length and the size of the camera pixel used for an image, you can determine exactly the size of the outline frame with the function "Scaling according to telescope parameter".

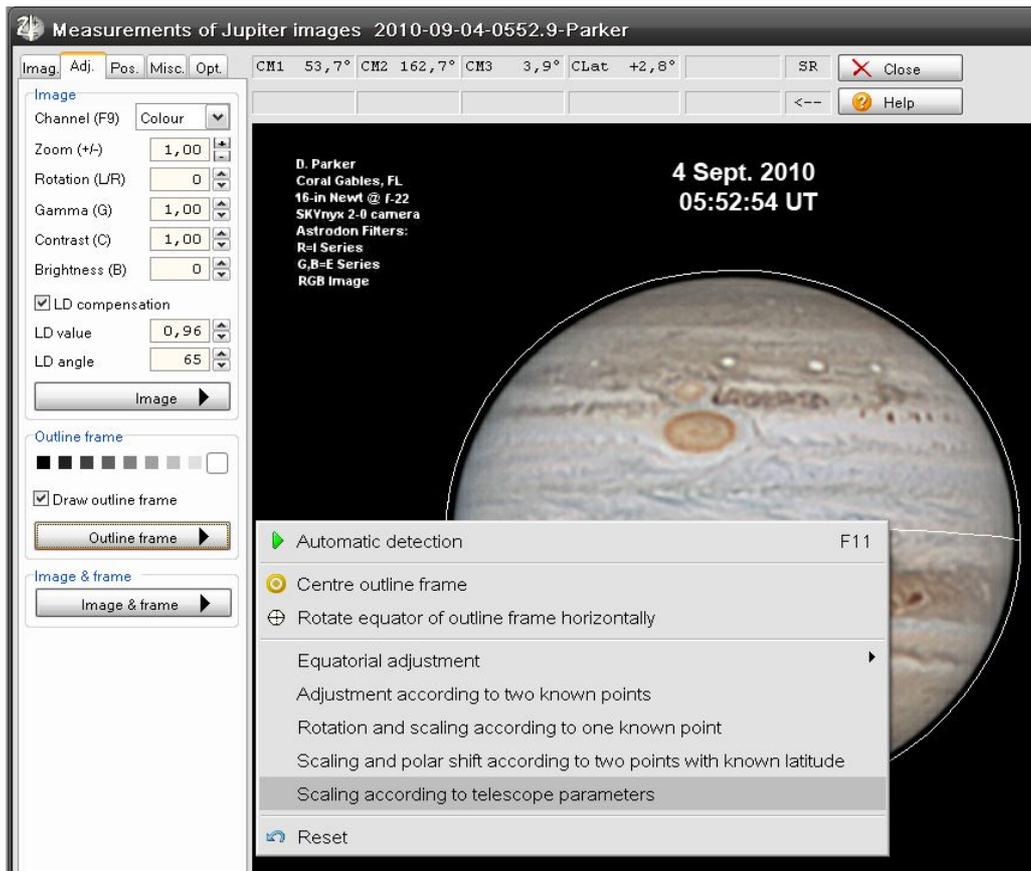


Fig. 9: Scaling of outline frame according to telescope parameters

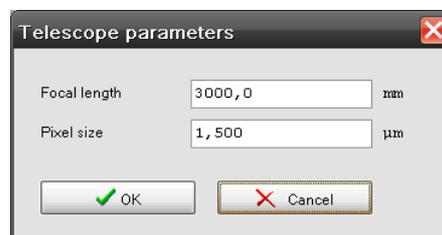


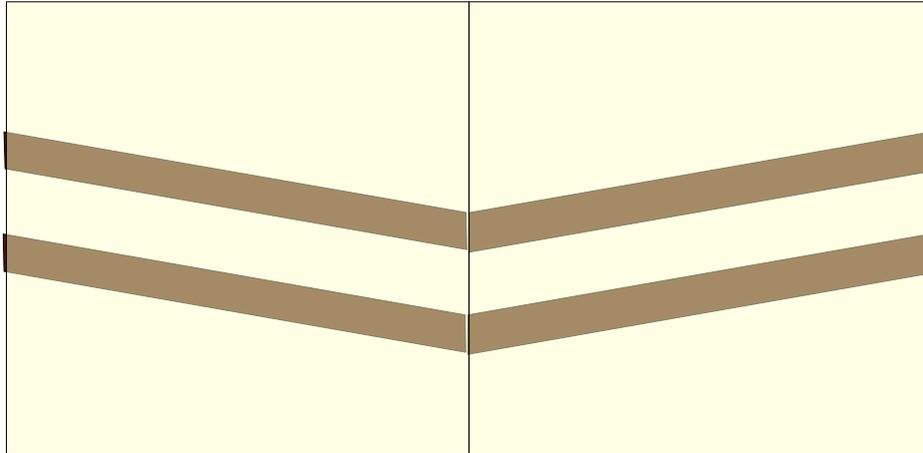
Fig. 10: Telescope parameters

The outline frame is scaled according to the input values. Its centre remains indeterminate. The quality of the outline frame adjustment with the telescope parameters is given by the value of **SF** (scaling factor) displayed in the bottom right corner of the screen.

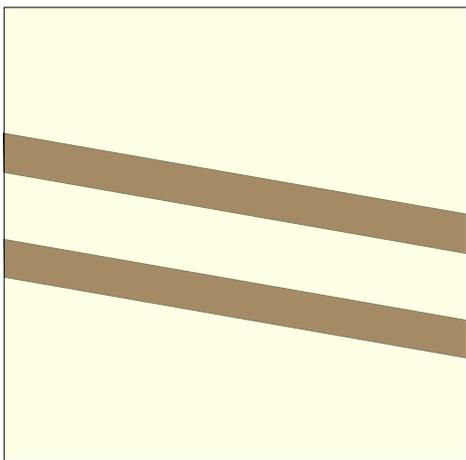
2.3 Calibration of an image of a set

Step 1)

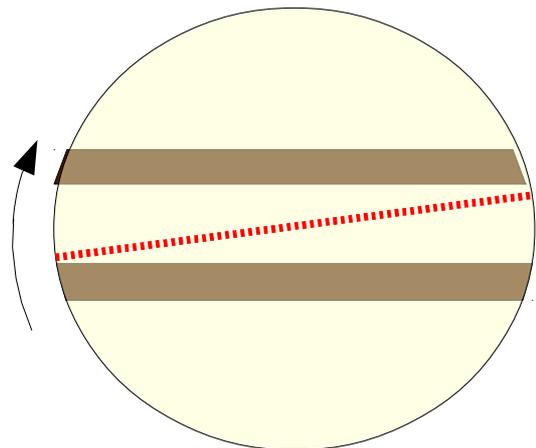
The bands limits of the images of a set must be parallel. → If necessary, the outline frame must be corrected



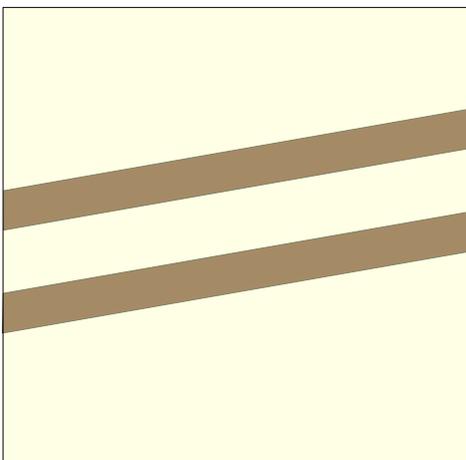
Drawing 1: Map with wrong rotation of the outline frame in the image measurement



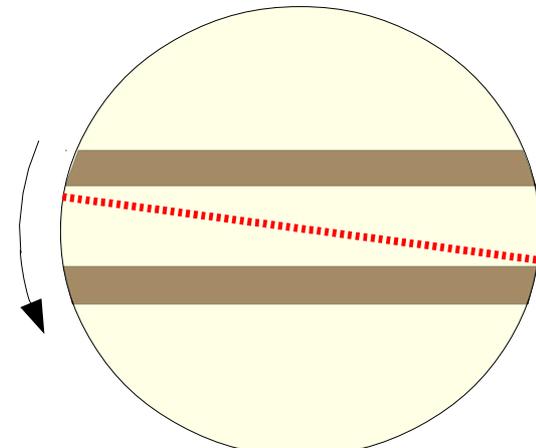
Drawing 2: Positive shift of the outline frame



Drawing 3: Correction with a negative rotation



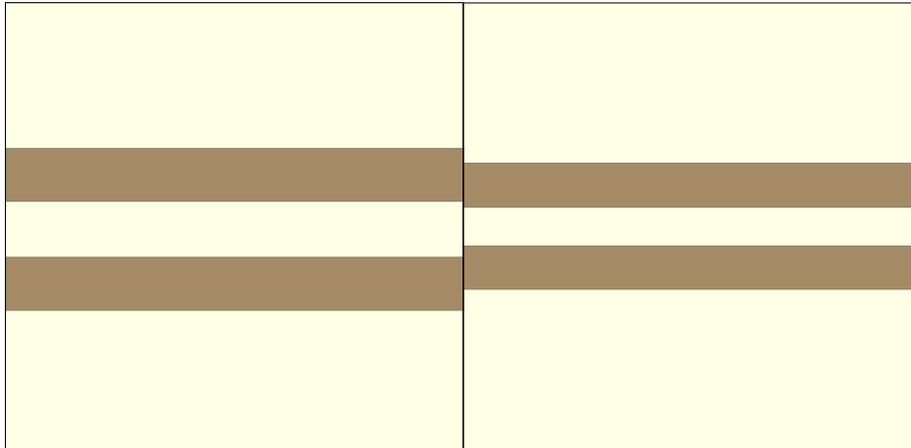
Drawing 5: Negative shift of the outline frame



Drawing 4: Correction with a positive rotation

Step 2)

A band limit must be at the same height in all images of the set. → If necessary, the outline frame must be corrected by a Y shift and scaling



Drawing 6: Map with a wrong scaling of the outline frame in the image measurement

Tip :

For a better correction of the scaling and Y shift, please, run first the functions "Rotate equator of the outline frame (and image) horizontally" and "Centre outline frame (and image)" in the image measurement.

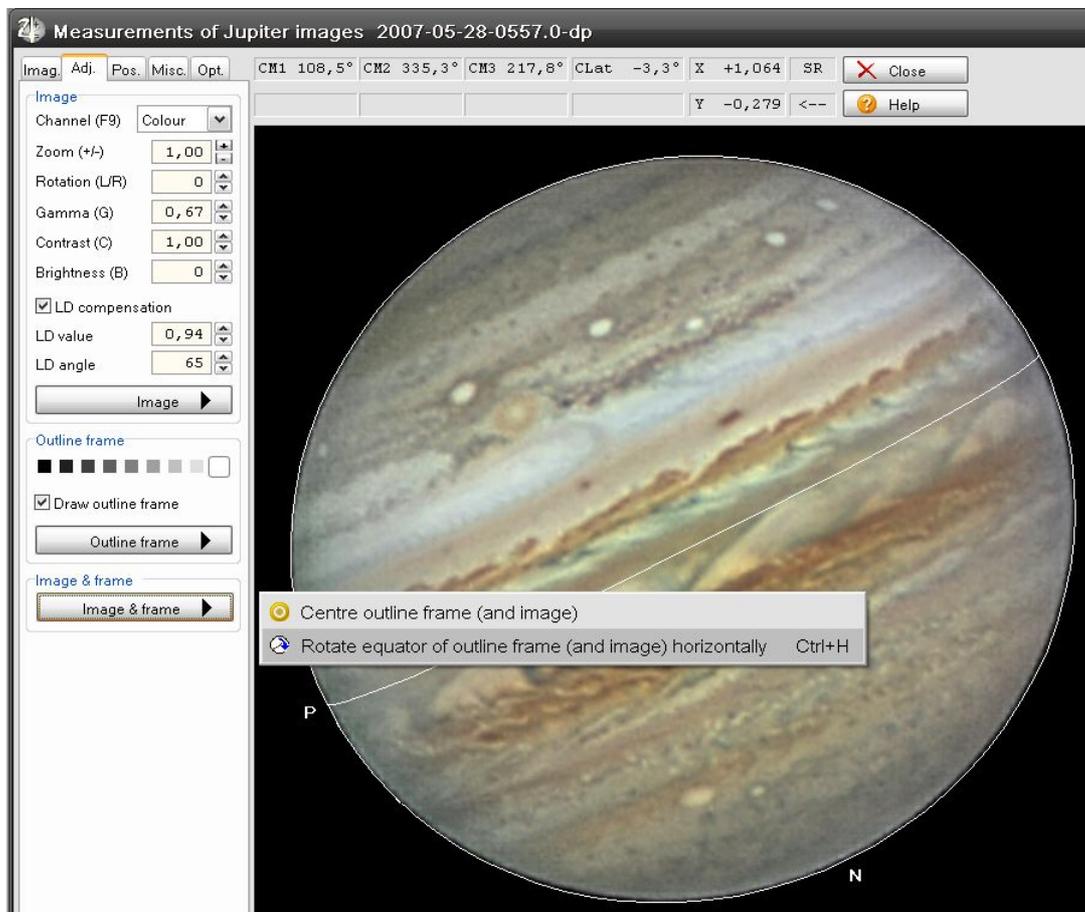


Fig. 11: Centre an image

Image and outline frame are parallel to the equator et centred on the measurement screen :

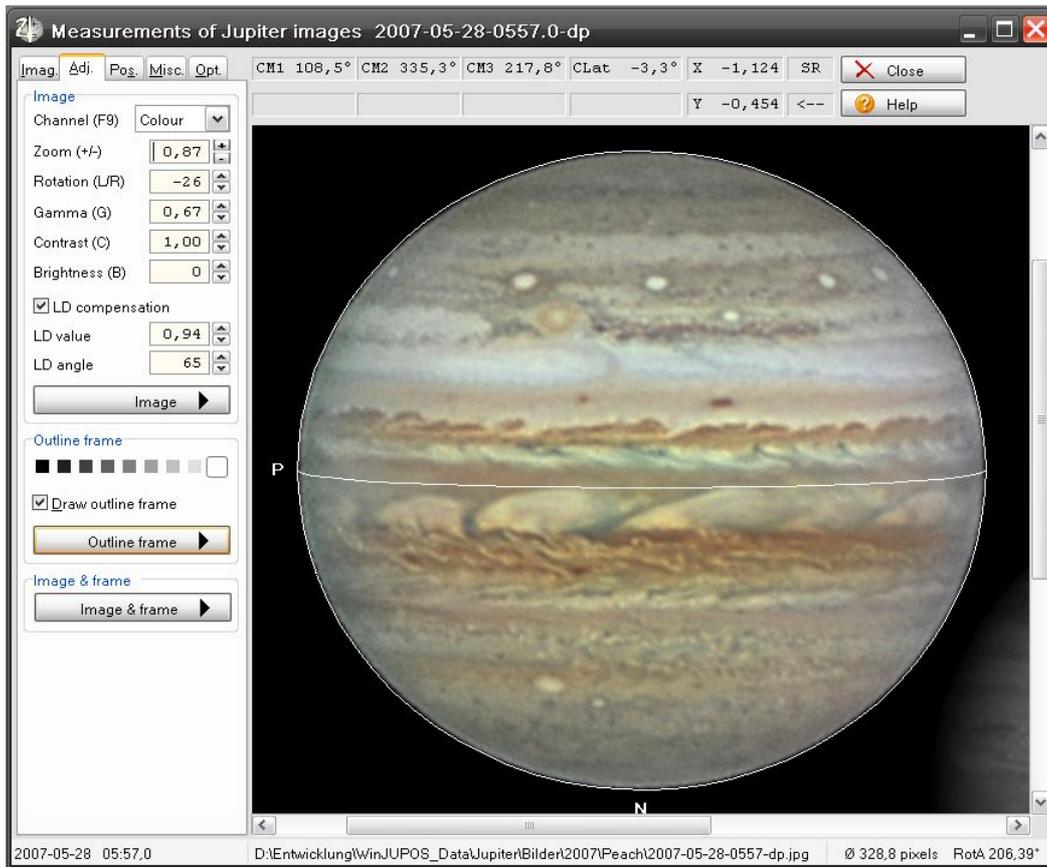
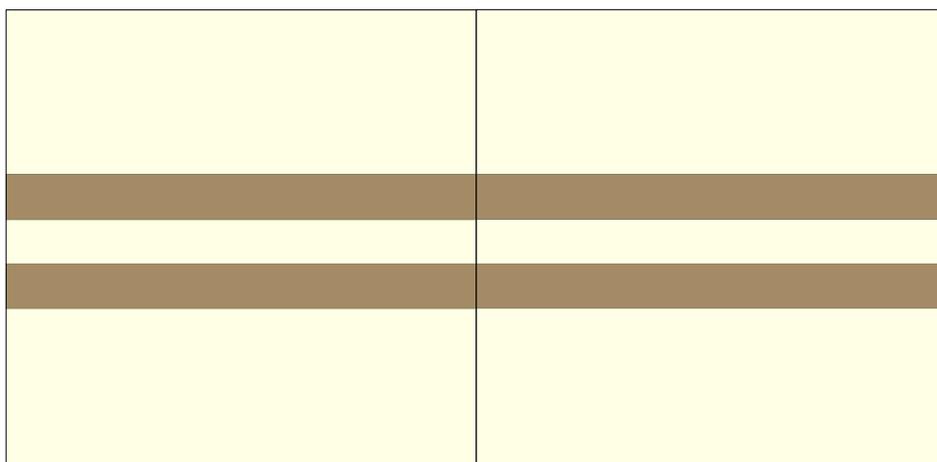


Fig. 12: Result of the image centring on the measurement screen

The displacement of the outline frame with [up / down arrows keys] correspond exactly to the Y shift perpendicular to the equator plane. The scaling with the keys [PgUp/PgDn] is now centred in the screen and correspond to the image centre.



Drawing 7: Map with correct rotation values of the outline frame. Scaling and Y-shift of the images are related.

Step 3)

Latitudes calibration with fix values or latitude informations from another images set. → If necessary, correction of Y-shift and scaling of the outline frame.

Tip : In that purpose, you can use the function "Scaling and polar shift according to two points with known latitude".

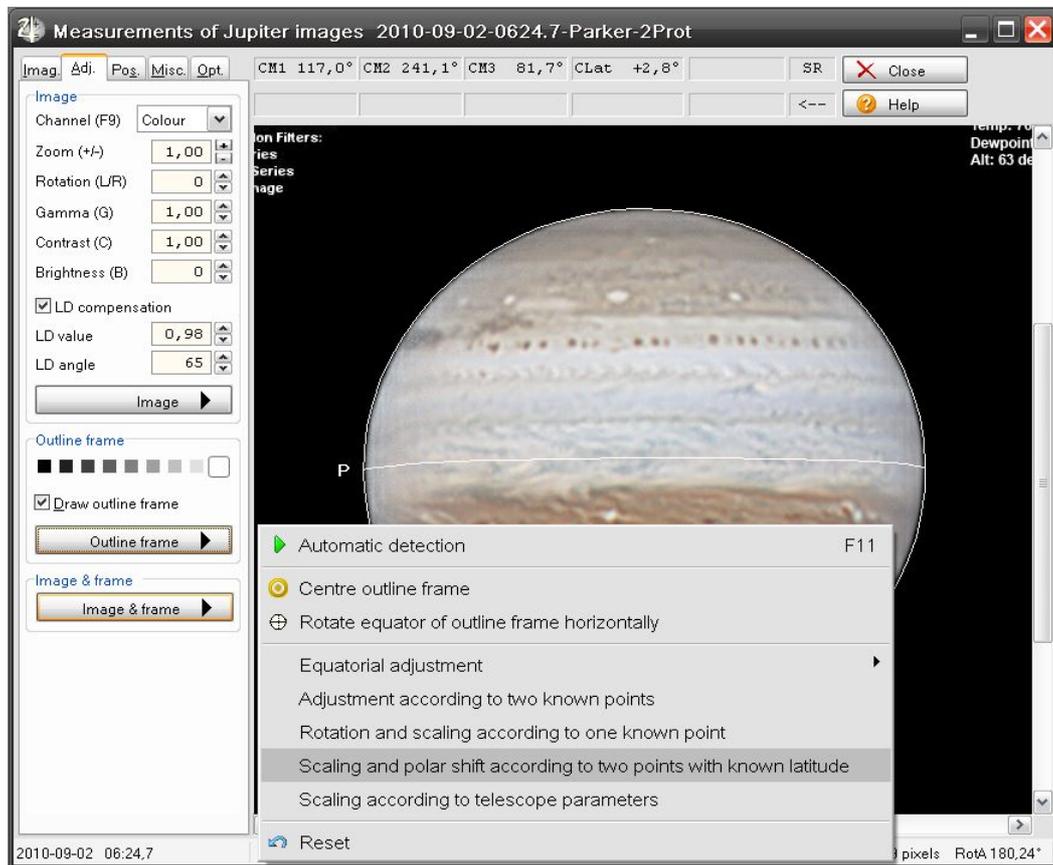


Fig. 13: Scaling and polar shift according to two points with known latitude

3. Advices for the parameters of longitudinal drift computation :

3.1 Longitudinal precision for the drift computation

As the drift value is computed by quadratic interpolation, it can be computed with relatively rough values (0.5°), particularly in the first tests. Only in the end computation it can be lowered to 0.1 or 0.05°. The computation time is, of course, 5 or 10 times longer.

3.2 From/To Longitude

In a partial map, the longitude interval must be reduced of 1° on both sides. If the smallest partial map covers a longitude from 100°...255°, **From Longitude** must be 101° and **To Longitude** 254°. If the map is complete (0°...360°), there is somewhere a time break from the second image to the

first. For mean drifting objects and for a global drift computation, there is no problem. But for rapid drifting zones like EZ or NEBs, when particular drifts are computed in small intervals or minimum/maximum values, the break must be excluded. For instance, if the break is at 120° and the longitude interval is 60° , **From Longitude** must be put at 180° and **To Longitude** at 60° . So, the longitude interval does not contain the break.

3.3 Minimum contrast

When the computations are made with a big interval (for instance 360°), a small value can be entered (for instance 20). Then, the risk of a wrong interpretation is small.

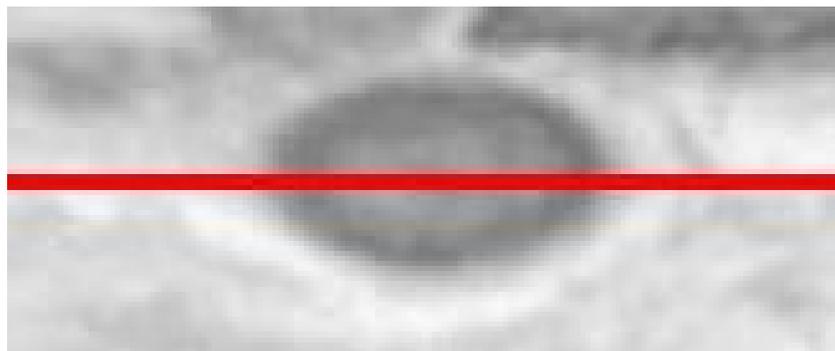
The smaller the intervals are, the more critical the drift computation is. The reasons are first in the automatic brightness and contrast regulation of the intensity values, second in the too important action of the noise and image errors. That is why, in case of small longitudinal intervals, it is recommended to put the minimal contrast at about 50. So, only real object structures are taken in account.

3.4 Minimum significance

If the computations are made on a big longitude interval (for ex. 360°), a value of about 2.1 can be entered. The risk of a wrong interpretation is small.

The smaller the longitude intervals are, the more a meaningful size for the minimal significance depends on the objects structures (intensity curve) in the longitudinal interval. Let us examine two examples.

Example 1 – A dominating extended object :



*Fig. 14: A longitudinal interval of about 50° around the GRS.
The red line is the section line for the intensity curve.*

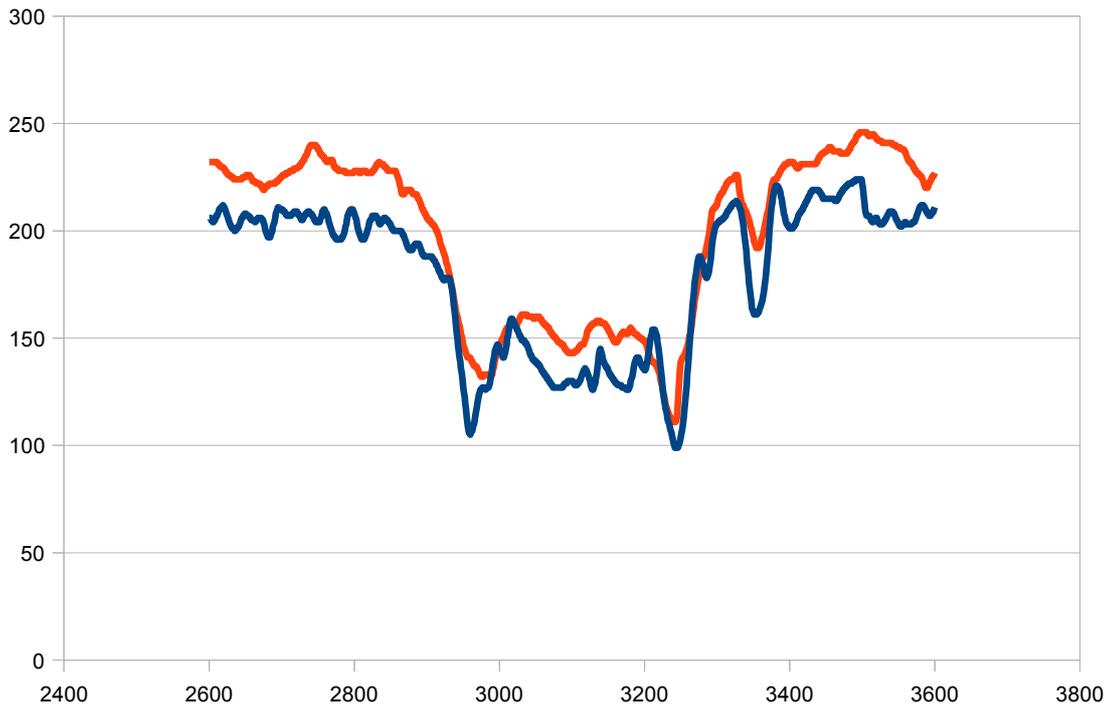
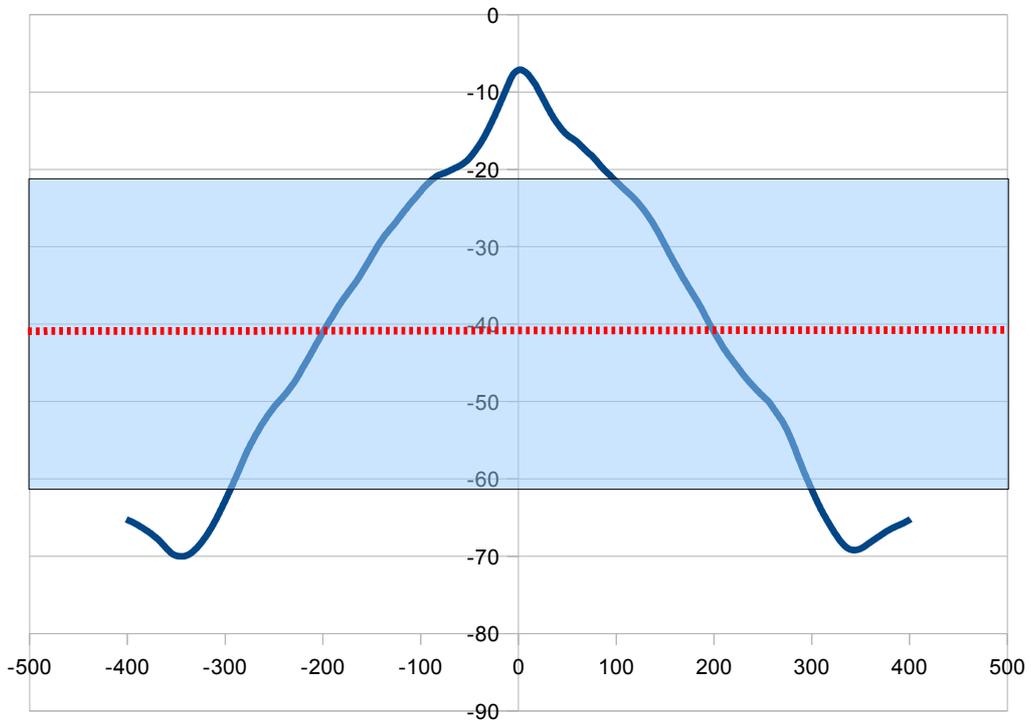


Fig. 15: Intensity curves of the two used images at the centre of the GRS



Drawing 8: Evaluation function against longitude (X-axis). Average value = -41 / standard deviation (s) 20 / maximum is 1.7 s above the average value

Example 2 – numerous small objects

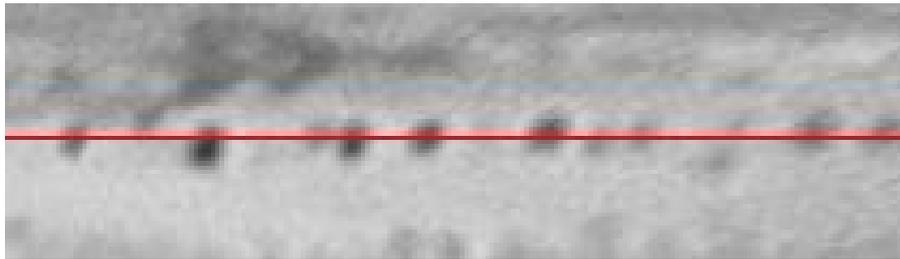


Fig. 16: Longitude interval of about 50° though dark spots in STB. The red line is the section line for the intensity curve.

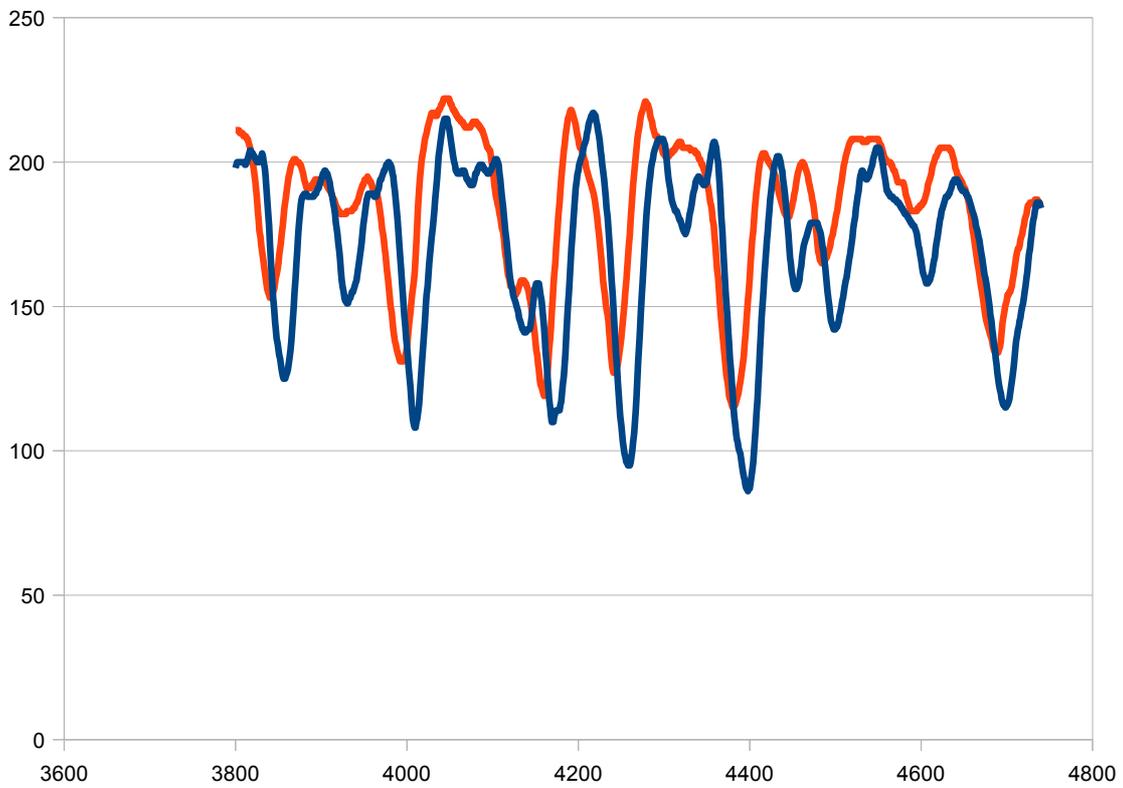
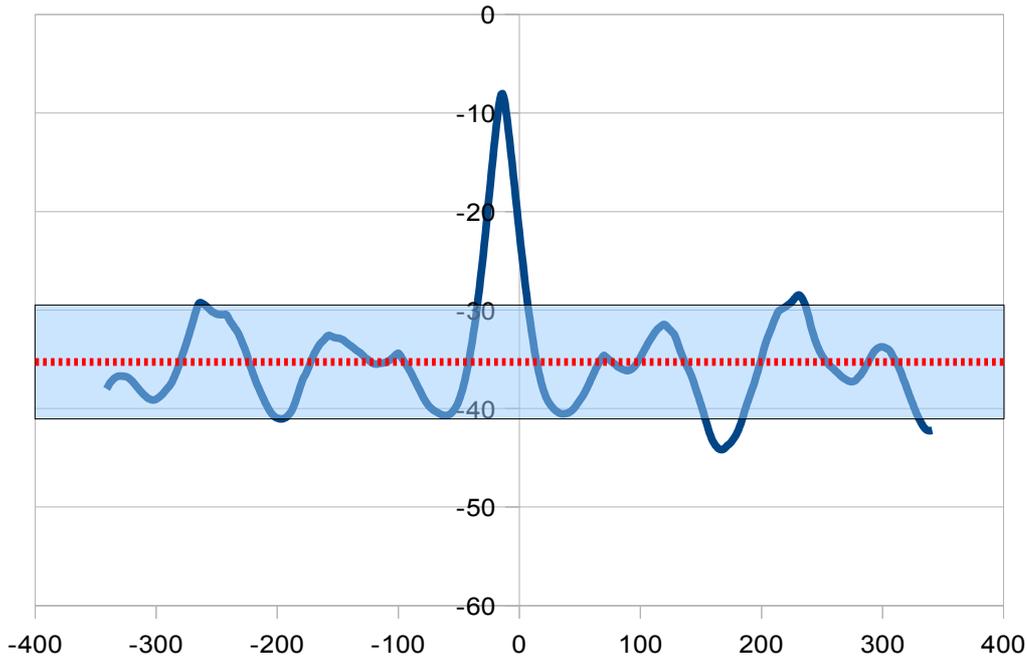


Fig. 17: Intensity curves of the two used images through the dark spots in STB



Drawing 9: Evaluation function against longitude (X-axe). Average value = -35 / standard deviation (s) 6 / maximum is 4.7 s above the average value.

Report

In these two cases, the drift computation with small longitudinal intervals requires a small value (for ex. 1.4) for the Minimal Significance. Unfortunately, this can arouse more interpretation errors, particularly when the longitude interval contains strong noise, lack of structures or numerous tiny structures. Such intensity variations arouse (like example 2) a very unstable evaluation function with doubtful maxima. To reduce the interpretation errors, the minimal contrast must be about 50.

Another strategy is to put different parameters according to the latitudes. EZ should have different parameter values from, for example STB or NtrZ/NTBs.

Dresden, March 25, 2011