Possibilities to avoid row anomaly rows

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Issue	**Date**	**Comments**	**Affected pages**
Draft	June 28 2010	Draft issue	All

1 Introduction

1.1 OMI row anomalies

A row anomaly is an anomaly which affects all wavelengths for a particular viewing direction of OMI. This corresponds to a binned row on the CCD detectors, and hence the term 'Row Anomaly'. Several row anomalies have occurred in the recent past. These anomalies affect the quality of the Level 1B and Level 2 data products.

- Anomaly 1: Since June 25th, 2007, cross-track scenes 53-54 (0-based).
- Anomaly 2: Since May 11th, 2008, cross-track scenes 37-44 (0-based)
- Anomaly 3: Since January 24th, 2009, cross-track scenes 27-44 (0-based).

Since "anomaly 3" the row anomaly exhibits a more dynamic behavior than before. Which rows are affected and to what extent varies with time.

The row anomalies have four distinct effects on the OMI radiance spectra:

1. Blockage effect

   A decrease in the radiance level for several viewing directions. It is currently assumed that this is caused by a partial blocking of the OMI nadir port. The blocking object is assumed to be opaque. This is effectively a multiplicative error on the radiances with a factor smaller than unity.

2. Solar radiation

   An increase in the radiance level for the northern part of the orbit. This type of anomaly occurs when the part of OMI containing the nadir port is directly illuminated by the sun. This is assumed to be caused by reflection of sunlight into the nadir port via the blocking object (outside of OMI). This is an additive error on the radiances. This increase in the radiance level is not observed for the first anomaly in rows 53-54 (0-based).

3. Wavelength shift

   The blocking object causes an inhomogeneous illumination of the spectral slit in OMI. This causes a change in the slit function, shifting the center of weight away from the nominal center. This causes light of a specific wavelength to hit the detector in a slightly different location than expected with a fully illuminated entrance slit.

4. Earth radiance from outside nominal field of view

   Light reflected by the earth from outside the nominal field of view is coupled into the nadir port. This light is collected over a large area, giving an additive error on the radiances, with a term which is not constant.

A correction for the wavelength shift has been implemented in the L0 -> L1b data processor. The other anomalies are currently under investigation to examine whether corrections for these effects can be implemented in the Level 1b data. Correcting for these row anomaly effects might prove to be difficult.

In section 2 is investigated whether it is possible to minimize the effect of the row anomaly on the measurements by only using the (at the moment still) unaffected part of the CCD. Also the consequences for operations, calibrations, science and row anomaly monitoring are discussed.

2 Avoiding row anomaly rows

Without row anomaly OMI achieves daily global coverage in global mode (resolution 13x24 km^2) and if only spatial zoom-in mode (resolution 13x12 km^2) were used global coverage would be achieved within 5 days. As can be seen in Figure 1 the row anomaly affects about 37% of the global measurement image area reducing the global coverage from daily to once every 2 days. In Figure 2 can be seen that the spatial zoom-in measurements are affected by 66%. Thus the spatial zoom-in measurements are the most affected by the row anomaly. On the other hand they are only run once a month during 14 consecutive orbits, and most L2 products are not set up to use them and no analysis uses the high resolution data. However, the question arose whether the effect of the row anomaly on spatial zoom-in measurements could be reduced and whether it is possible to reduce the row anomaly effect also for global measurements.

There are two possible ways to reduce the effect of the row anomaly on spatial zoom-in measurements:

1. Replace them by measurements with global settings
2. Shift the image area to part of the CCD that is unaffected by the row anomaly.

If one also aims at reducing the row anomaly effect on global measurements one could replace them by shifted spatial zoom-in measurements. The amount of work involved, costs and benefits are discussed in the following sections.

2.1 Feasibility and Impact of choices for improvement of spatial zoom-in measurements

2.1.1 Replace zoom-in measurements by global measurements

The first option to just replace the zoom-in measurements by global measurements is by far the most simplest option that requires the least amount of work. It is a small change of the nominal baseline to exclude the monthly zoom-in measurements. There is no impact calibration wise and also monitoring of the row anomaly can continue as before. Science wise there is also no impact except for the fact that OMI will loose its high resolution measurements. However, it seems no one is really using the high resolution data.

2.1.2 Shift the spatial zoom-in measurements to (almost) unaffected part of CCD

The second option to shift the zoom-in image area to the part of the CCD that is (as yet) not affected by the row anomaly is more complicated.
In Figure 1 is drawn the partitioning of the OMI CCD for global measurements settings. Please note that in this section the word “row” refers to an unbinned row unless otherwise specified. Row 0 is the read-out row. The lower and upper dark areas are defined by 20 and 14 rows respectively, indicated in the figure by the dark grey areas. The lower and upper stray light areas are defined by 12 and 20 rows respectively, indicated by the light blue areas in the figure. The position of these areas on the CCD is determined by optics and should not change. This is also true for the image area of 480 rows indicated by the yellow area in the figure.

The rows in between those different areas are skipped, the so-called skip rows SKR1 (12), SKR2 (4), SKR3 (4) and SKR4(4) are indicated by the red areas in the figure. The hatched area indicates the part of the CCD that has been affected by the row anomaly (176). In principle it should be possible to reduce the image area to the lower unaffected part of the CCD (200 rows). But then, in order not to change the position of the upper stray light area the SKR3 value must be increased.
Unfortunately, the design of the ELU doesn’t allow the value of SKR3 to be large enough and would result in an overlap of the upper stray light area with the image area which is not allowed. However, it will be possible to skip half of the image region (east part of swath) and reduce the number of rows affected rows to 40 (17%) on a total of 240 image rows as can be seen in Figure 3.
Note that the pixel sizes will no longer be symmetric around ‘nadir’ (defined as middle of the image area in swath direction) as can be seen in Figure 4 as OMI will be looking towards the west, but this should not affect the L2 products.
There should not be any consequences science wise, since hardly anybody uses the high resolution data.
Also there is no consequence calibration wise or validation wise. However, there is a big impact operations wise. Three (tropics, midlat and arctic) new SCSs (science measurements programs) and 2 SIS (Solar Cal SIS and Dark SIS) (calibration measurements programs) need to be updated. This also involves testing by FOT and NGES. Especially the throughput time for SISs is long since testing needs to be done by NGES and manpower and budget are limited and testing might take 4-6 weeks.
So all in all this change would cost a few months of work by the OMI IOT with the benefit of high resolution measurements that are less affected by the row anomaly, but that are not used by anybody.

2.2 Feasibility and Impact of choices for improvement of global measurements

If one aims to improve the global measurements the only option is to replace them by shifted spatial zoom-in measurements. This improves the spatial resolution, but global coverage is only obtained after 3 days as can be seen in Figure 5.
This involves not only work for the OMI IOT as described in previous section, but also a complete redefinition of the OMI operations baseline and update of many orbit-type activities, including all special ozone hole orbit-type activities.
Also L2 products, data processing, TDOPF, validation and calibration will be highly impacted by this change.
It is unclear at the moment how much work is required for L2 products to change to use (shifted) zoom-in data. First L2 PGEs should be tested on the currently available spatial zoom-in data. This involves not only some technical changes, but also a check of the quality of the products, because, although the resolution is improved, also more noise is introduced through smaller pixel sizes. This could result in a trend break of the product.
Especially the ozone profile product is affected since it is the most complicated analysis product and a lot of work is involved to make it possible to use spatial zoom-in data. Furthermore also a big part of the UV1 area will be lost. The UV1 area consists at present of 240 rows of which 160 rows (67%) are affected by the row anomaly. In the new scheme the UV1 area will be reduced to 96 rows of which 32 rows (42%) are affected by the row anomaly.
One other problem to be taken into account is the irradiance measurements needed to correct the radiance measurements. At present a clever yearly average of irradiance measurements is used. There exists no shifted spatial zoom-in irradiance measurements record and as a consequence stripes might appear in several if not all OMI products. Possible work around: half of the swath of rebinned global irradiance measurements could be used in first instance until enough shifted spatial zoom-in measurements will be available for a proper clever averaged irradiance product.
Where data processing and calibration are concerned it is expected that a few months of work will be needed to adapt the TDOPF to deal with spatial zoom-in measurements and update the L1 processing. Some algorithms (like smear and stray light corrections) might prove more susceptible for the increase in noise and become less accurate. Furthermore, products might need to be revalidated. But according to our validation scientist all tools are in place and only sufficient data is needed to redo the validation.
Another point to bring forward is the fact that it will no longer be possible to properly monitor the row anomaly and provide flags since it can not be compared to the same kind of measurements before the row anomaly started. However, it is of course possible to continue running once a day a special daily orbit with extended arctic measurements for monitoring and flagging purposes.
So all in all this change would cost a few months of work by the OMI IOT, calibrations, data processing, validation people and an unknown amount of work for L2 developers with the benefit of high resolution measurements all the time that are less affected by the row anomaly of which it is unclear if L2 products can be obtained without problems (loss of quality, trend break,…)
First, the L2 developers should perform a feasibility study on current spatial zoom-in measurements.

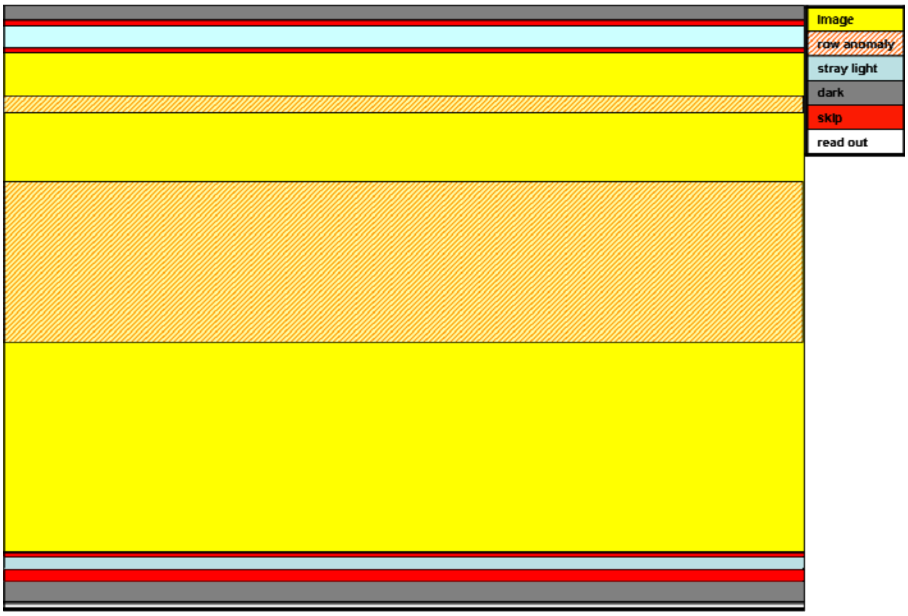

Figure 1. Current global CCD settings. Indicated are the image area (yellow) (480 unbinned rows (60 binned rows (binning factor 8 (BF8))) and the area affected by the row anomaly (hatched). The row anomaly affects in this case 176 unbinned rows (22 binned rows (BF8)) in the image area. This is about 37% of the image area.

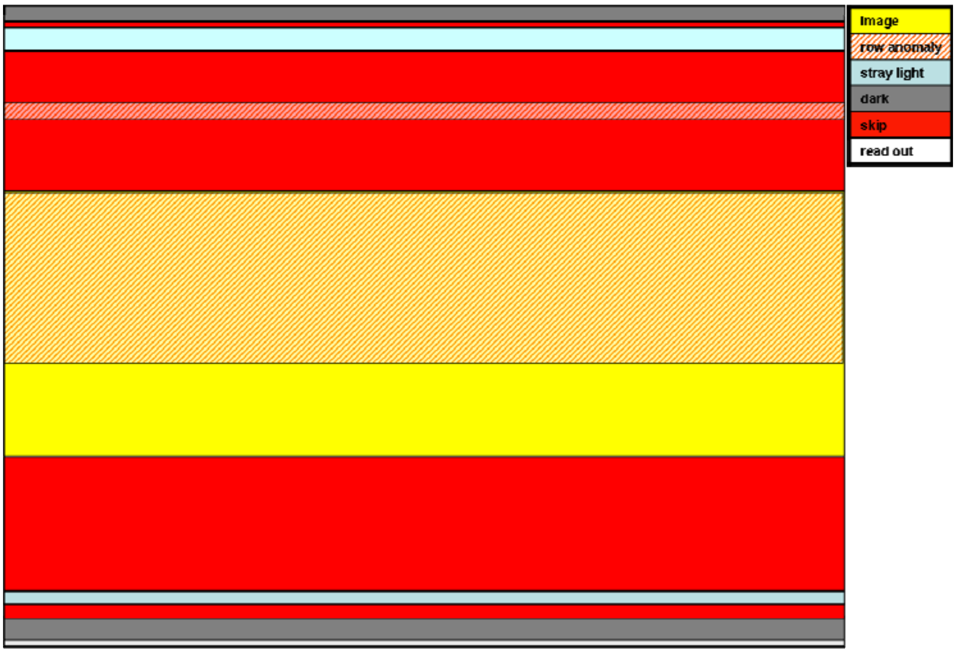

Figure 2. Current spatial zoom-in CCD settings. Indicated are the image area (yellow) (240 unbinned rows (60 binned rows (BF4)) and the area affected by the row anomaly (hatched). The row anomaly affects in this case 160 unbinned rows(40 binned rows (BF4)) in the image area. This is more than half (67%) of the image area.

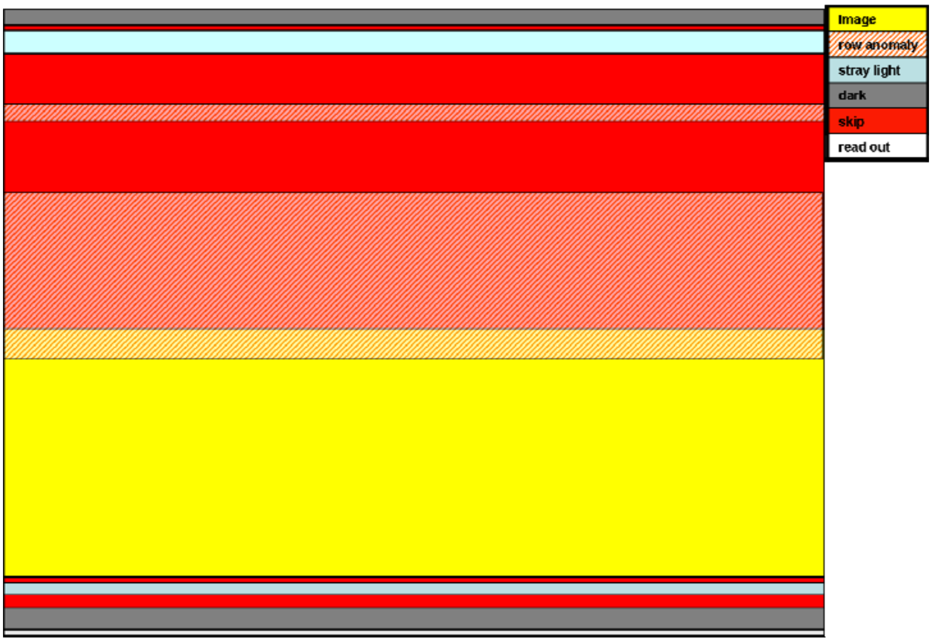

Figure 3. Shifted spatial zoom-in measurement avoiding the row anomaly rows as much as possible. Indicated are the image area (yellow) (240 unbinned rows (60 binned rows (BF4)) and the area affected by the row anomaly (hatched). The row anomaly affects in this case 40 unbinned rows (10 binned rows (BF4)) in the image area. This is about 17% of the image area.

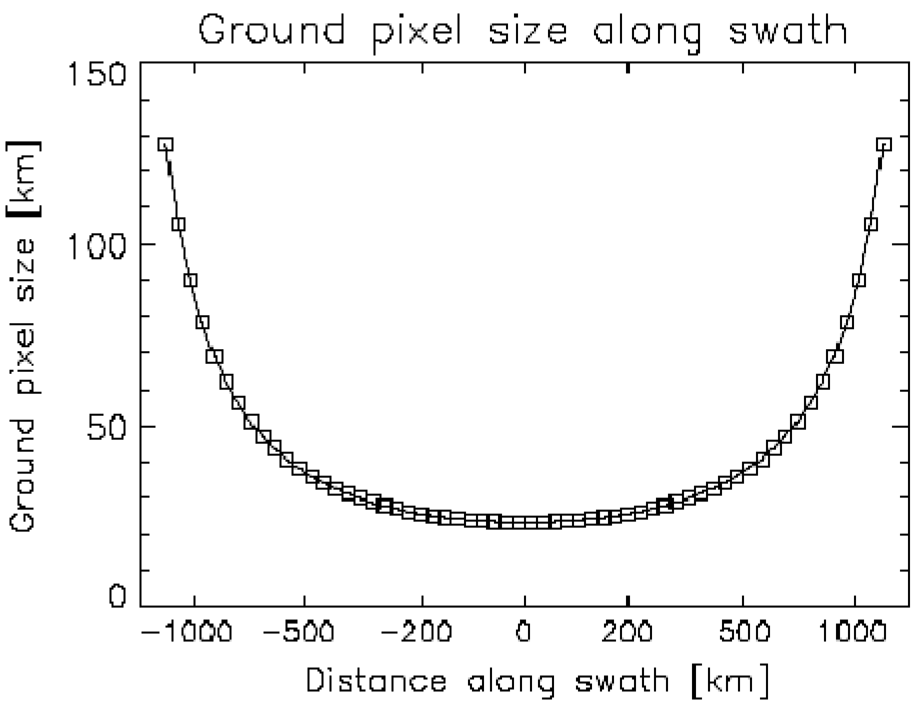

Figure 4. Ground pixel size along swath. For the shifted zoom-in measurements OMI will be looking west ward and will only be observing the left side of the OMI swath.

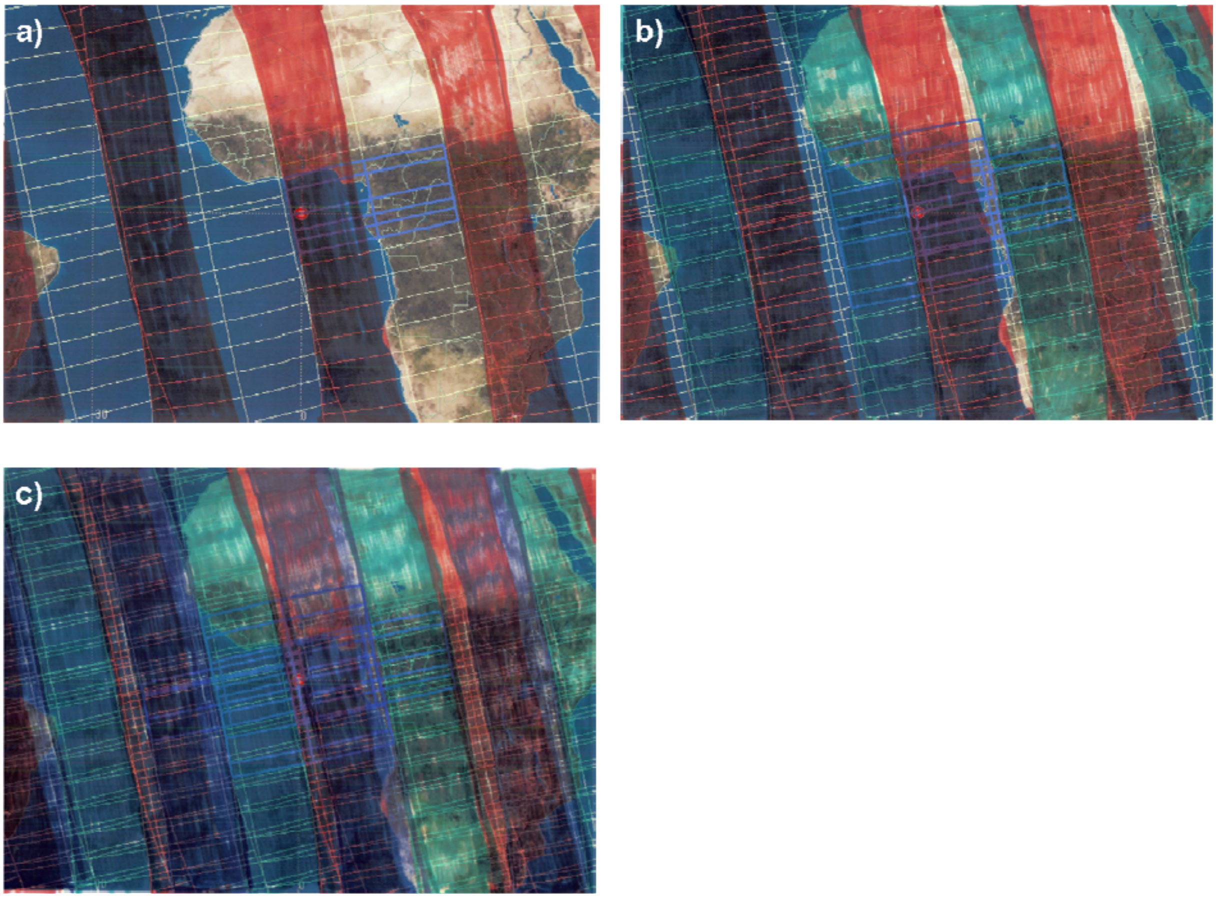

Figure 5. Drawn are 3 days of shifted zoom-in orbits over (tropics) area: latitude: -30 – +30 degrees, longitude: -30 – +30 degrees. On the first day (plot a)) the part of the swath that is covered by OMI in shifted spatial zoom-in mode and that is unaffected by the row anomaly is drawn in red. On the second day (plot b)) the part of the swath that is covered that day is drawn in green. As can be seen there are still some small bands of earth left that are uncovered after 2 days of OMI overpasses in shifted spatial zoom-in mode. On the third day (plot c)) the part of the swath that is covered on that day is drawn in blue. Full global coverage is achieved by OMI in shifted spatial zoom-in mode after 3 days.

3 Summary and Conclusions

There are 2 options to improve spatial zoom-in measurements:

1. replace the zoom-in measurements by global measurements
    a. benefit: only 37% of rows is affected by the row anomaly instead of the 67% at present. But who benefits from this? No one is using the spatial zoom-in measurements?
    b. costs:
        i. adaptation of OMI operations baseline by OMI IOT
        ii. no more high resolution measurements; hardly anyone uses this high resolution measurements
2. shift zoom-in measurements to (almost) unaffected part of CCD

   a. benefit: only 17% of rows is affected by the row anomaly instead of the 67% at present. But who benefits from this? No one is using the zoom-in measurements?
   b. costs:
      i. 2 months of work by OMI IOT to adapt measurements, update operations baseline and orbit-type activities.
      ii. Testing by FOT : new SCSs for tropical, midlat and arctic shifted spatial zoom-in measurements
      iii. Testing by NGES: updated Solar Cal SIS and Dark SIS. 4-6 weeks

Global measurements can be improved by changing to shifted spatial zoom-in measurements:

1. Benefits:
   a. only 17% of rows affected by row anomaly
   b. improved resolution
2. Costs:
   a. Science:
      i. Higher noise levels due to smaller pixel size.
      ii. Most L2 products don't use spatial zoom-in data. They need to be adapted. How much work this is going to take needs to be evaluated per product. Might be small for most products.
      iii. Problems for ozone profile algorithm
         1. Lot of work to adapt for spatial zoom-in measurements
         2. Reduced UV1 area (from 240 rows at present to 96 rows in new case; from 30 BF8 rows to 24 BF4 rows)
      iv. Data quality issues?
      v. Trending issues?
   b. OMI IOT:
      i. 2 months of work by OMI IOT to adapt measurements, update operations baseline and orbit-type activities.
      ii. Testing by FOT : new SCSs for tropical, midlat and arctic shifted spatial zoom-in measurements
      iii. Testing by NGES: updated Solar Cal SIS and Dark SIS. 4-6 weeks
   c. Data processing and calibration:
      i. Months of work to adapt L1B processing and TDOPF
      ii. Some algorithms (smear and stray light corrections) will suffer form lower accuracy due to higher noise levels.
   d. Validation:
      i. Revalidation effort. Tools present. Just rerunning validation software
   e. Row anomaly monitoring and flagging not possible, because no shifted spatial zoom-in data available that is not affected by the row anomaly. However, once a day a special global orbit type activity can be run for this purpose.
3. Need feasibility study using currently available (good) spatial zoom-in data to see:
   a. If L2 products can use spatial zoom-in measurements (technically)
   b. If quality of product is affected (due to higher noise levels)
   c. If trend will be broken

It should be noted that more work might be needed in case the row anomaly changes.