sentinel-5p

Straylight in TROPOMI

TROPOMI

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Summary

In-flight measurements show that calculated straylight *in both straylight regions* is too low. An improved CKD, based on on-ground reanalysis, would make this discrepancy smaller.
However, the discrepancy *also* increases in time: ratio observed straylight / calculated straylight in UVIS detector is 6% higher in three years (30% for UV)
The ongoing increase of straylight is difficult to correct for using IF calibration. In the UV detector, the increase of SL (additive) in Band 1 (280,286 nm) is hidden in the multiplicative negative radiometric degradation CKD.)

Straylight definition

Definition: "any light that falls on a detector pixel which by optical design is not intended to detect that light".

For TROPOMI, part of signal intended for certain row/wavelength arrives at pixels at certain spectral/spatial distances. This results for example in the partial 'filling' of absorption lines…

Theory: Straylight mathematics

For a 1024x1024 detector, the linear operator R of size 1M x 1M defines the *redistribution* of light on each pixel:

$$S_{stray} = R\, S_{intended}$$

$$S_{meas} = S_{intended} + S_{stray}$$

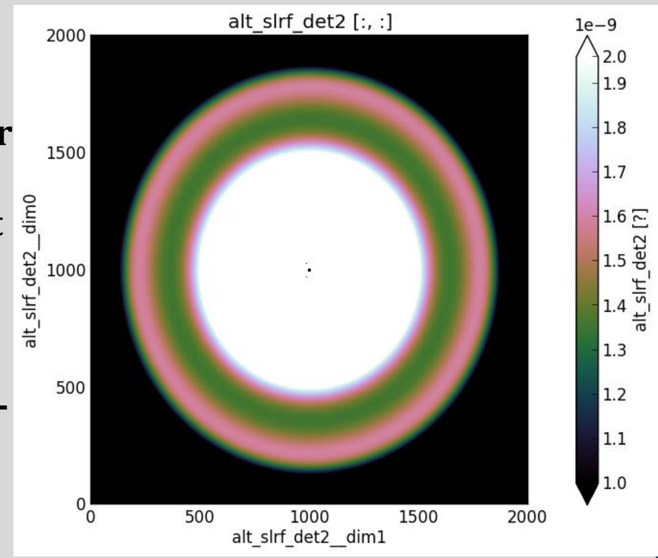
For the signal-without-straylight, we need the inverse of R. In 'practice', one Jacobi iteration is sufficient, giving:

$$S_{intended} \approx \quad S_{corr} = S_{meas} - R\, S_{meas}$$

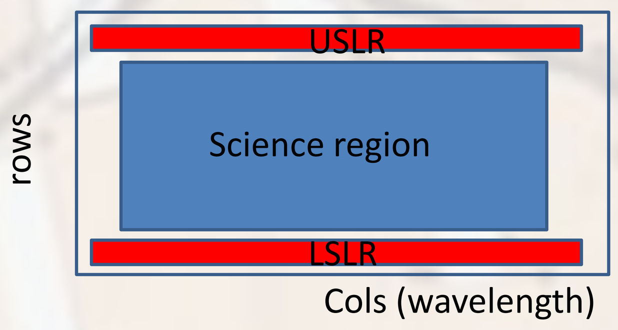
With complete knowledge, correction of straylight will be perfect.
Of course, R is far too large to be useful. So we need a simplification.

Practice: Straylight convolution kernel

- The huge straylight operator R has a repetitive property: rows look similar
- An 'average' row, back-raveled to a 2D image, represents a *convolution kernel*
- The straylight can be computed simply by *convolving* the 2D detector image with this kernel
- Using FFT, the straylight algorithm in the L1B Processor is (just) fast enough.
- The *price* for the kernel concept as workable approximation: assumption of pixel location independence
- The sum of all values in the kernel is the *straylight mass* (typically 1-4%): the amount of light that is re-distributed.
- At the centre is a hole: no straylight defined inside ISRF/PRF region
- Region just outside the hole is called *near-field* part of the convolution kernel; the outer region is the *far-field*.



Tools: Straylight in-flight monitoring….



On each detector, two regions exist that receive no direct light ('straylight regions', LSLR/USLR).

These regions are binned (factor 37) to one row each, for all (ir)radiance measurements.

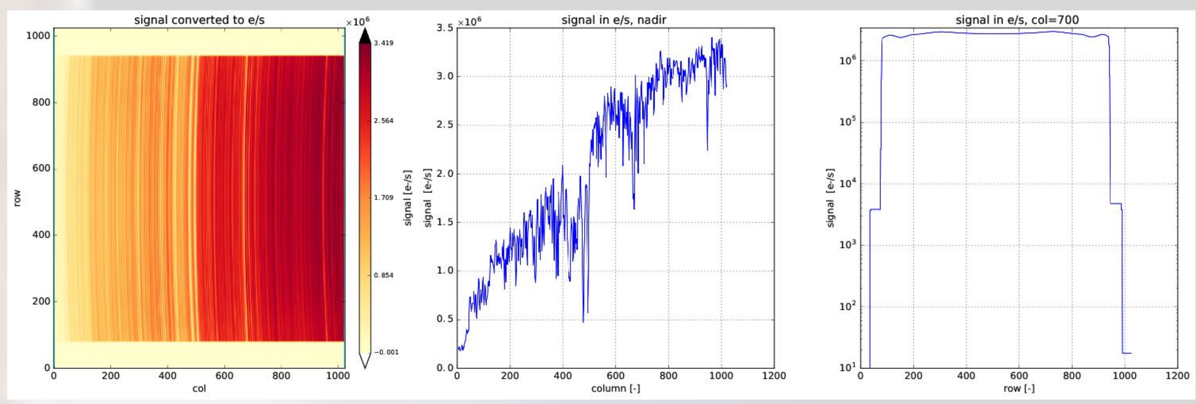
Signals in these region are monitored per scanline, in ICM product.

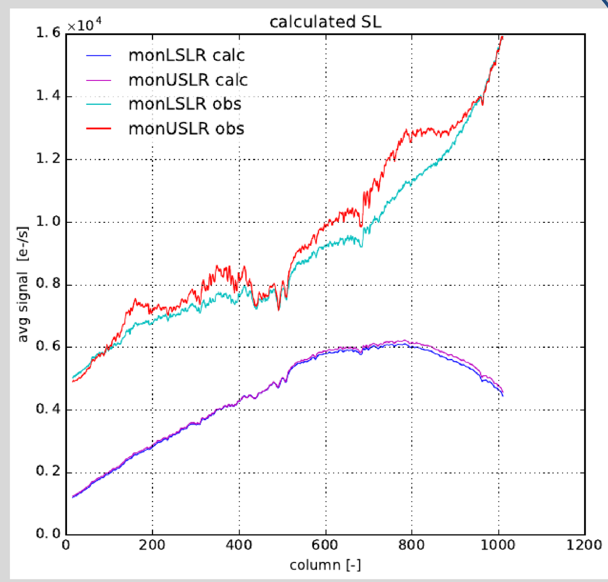
Monitor_straylight_observed: the measured signal (before SL correction algorithm)

Monitor_straylight_calculated: the *computed* straylight signal there (according to the convolution of image with straylight kernel CKD)

After the SL correction algorithm, the regions contain a signal: *observed - calculated* that ideally should be zero…

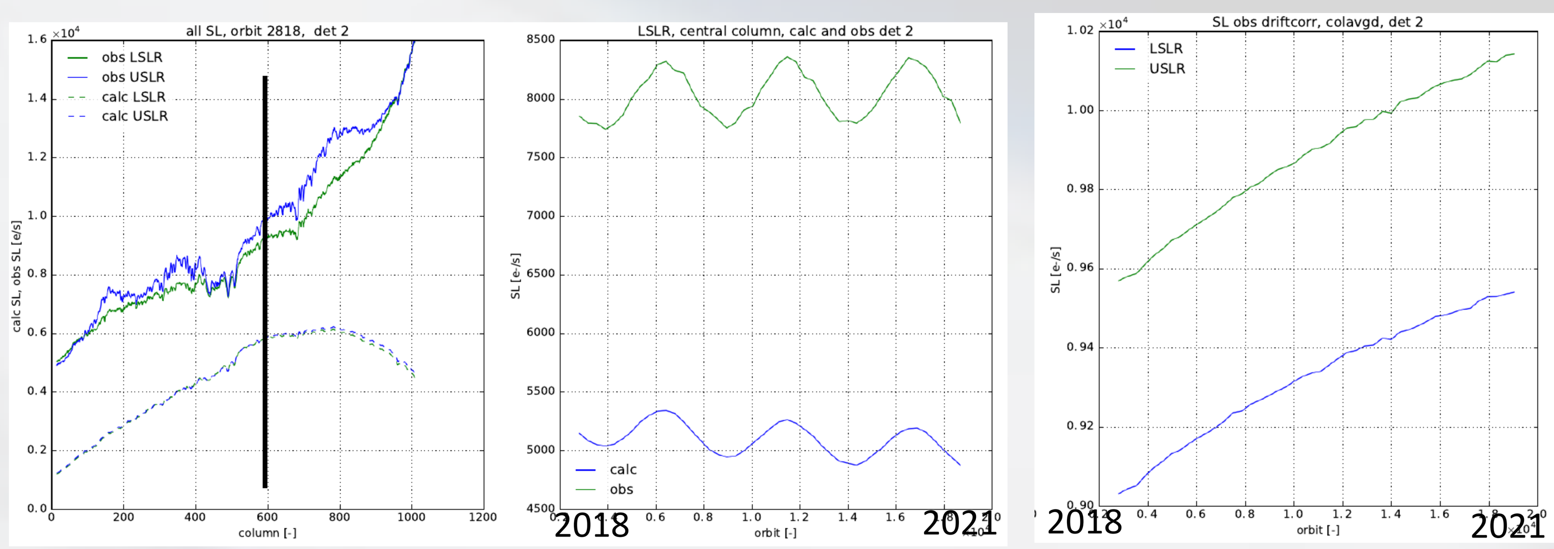
… and two inconvenient findings





1. The calculated SL *in the SL regions* is ca 50% lower than observed SL, largest discrepancy is near extreme columns (wavelengths)

2. Between orbits 2818 and 19018, the observed SL in the SL regions increases relatively, with 6%. Effect is especially severe in UV (30%) and less in NIR (3%)



Problem definition

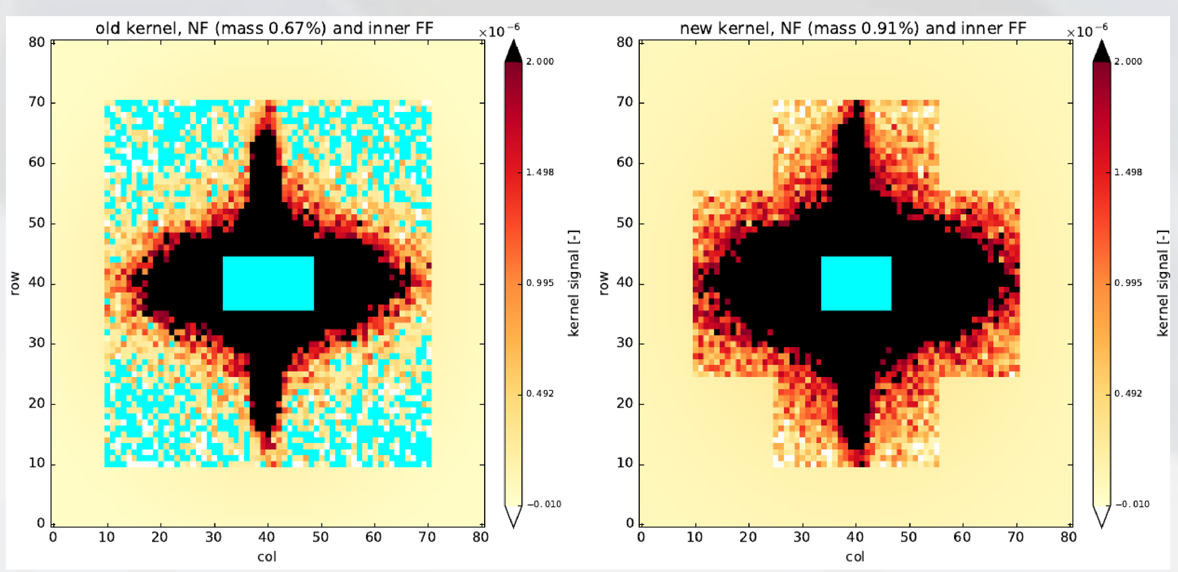
So, if the observed and calculated straylight in the straylight regions are reliable, then we have two problems:

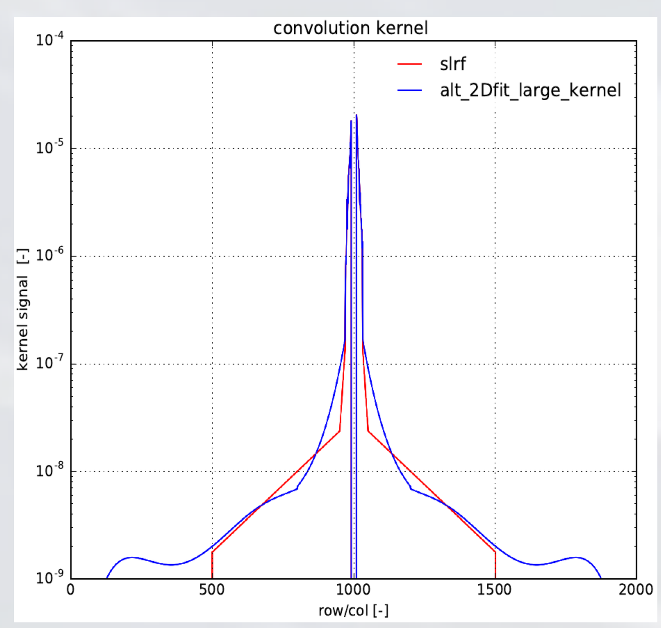
1. The computed (and therefore corrected) straylight (using the convolution kernel CKD) is underestimated by about half (better in centre, worse for extreme wavelengths)
2. The amount of straylight increases over time, making the correction incrementally worse.

Solution: Archaeology

On Problem 1: Re-analysis of the on-ground straylight measurements. Leads to improved CKD, both near-field and far-field.

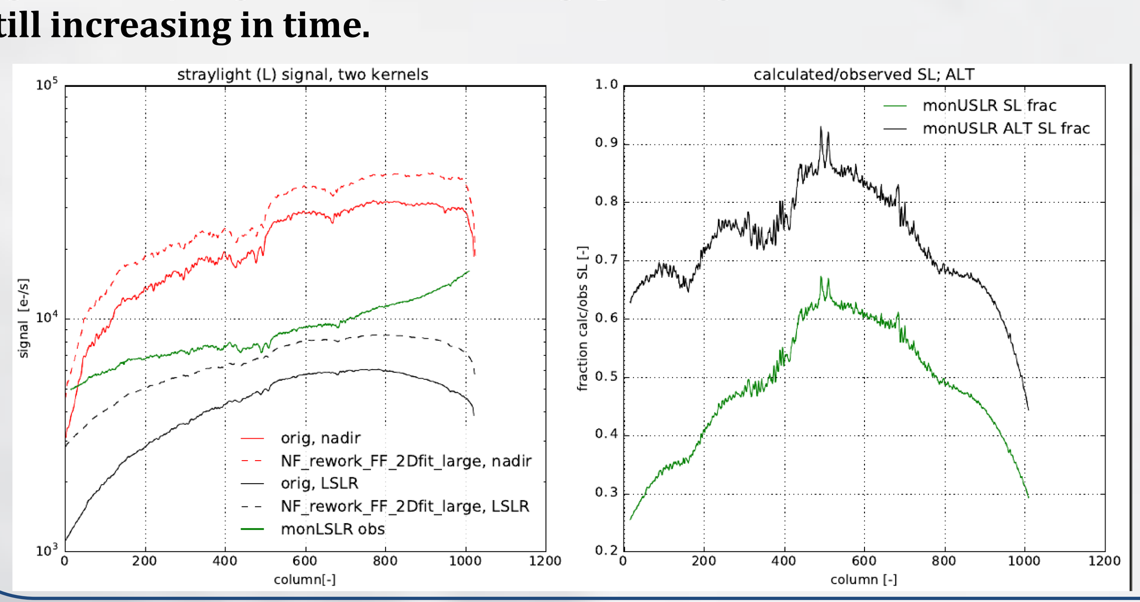
- Straylight CKD is a convolution kernel, constructed by combining a near-field (NF) and a far-field (FF) part
- NF-part: calibrated using laser measurements (simply averaging 18 processed images). Repaired low value clipping, improved consistency w.r.t. ISRF. Result: more mass in NF part, thus more straylight to correct
- FF-part: calibrated using external white light source measurements and *modeled* using a decay parametrization, and *assuming* axisymmetrical scattering. Introduced 2D (was 1D) parametrization, increased kernel size. Result: more UFF straylight reduction, no overcorrections.





Applying a better CKD

Proposed alternative kernel CKD reduces straylight in the in-flight (ir)radiance measurements. The *dashed* black line (calculated, new) is now nearer to the green line (observed).
Note that SL, and therefore SL *reduction*, in the interior (nadir) is also significantly higher. However, the gap is larger near extreme columns and is still increasing in time.



Conclusion and outlook

In-flight measurements show that calculated straylight *in the straylight monitoring regions* is too low. A new CKD based on re-analyzed on-ground measurements will make this discrepancy smaller.
A second problem is that the discrepancy increases in time. This is well monitored, but IF calibration is in general not feasible. In the UV detector, the increase of (additive) SL in Band 1 (280,286 nm) is hidden in the multiplicative negative radiometric degradation CKD and may be quantified (pending ongoing research).

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