Evaluation et correction du straylight dans la chaîne opérationnelle du spectromètre-imageur multispectral OLCI

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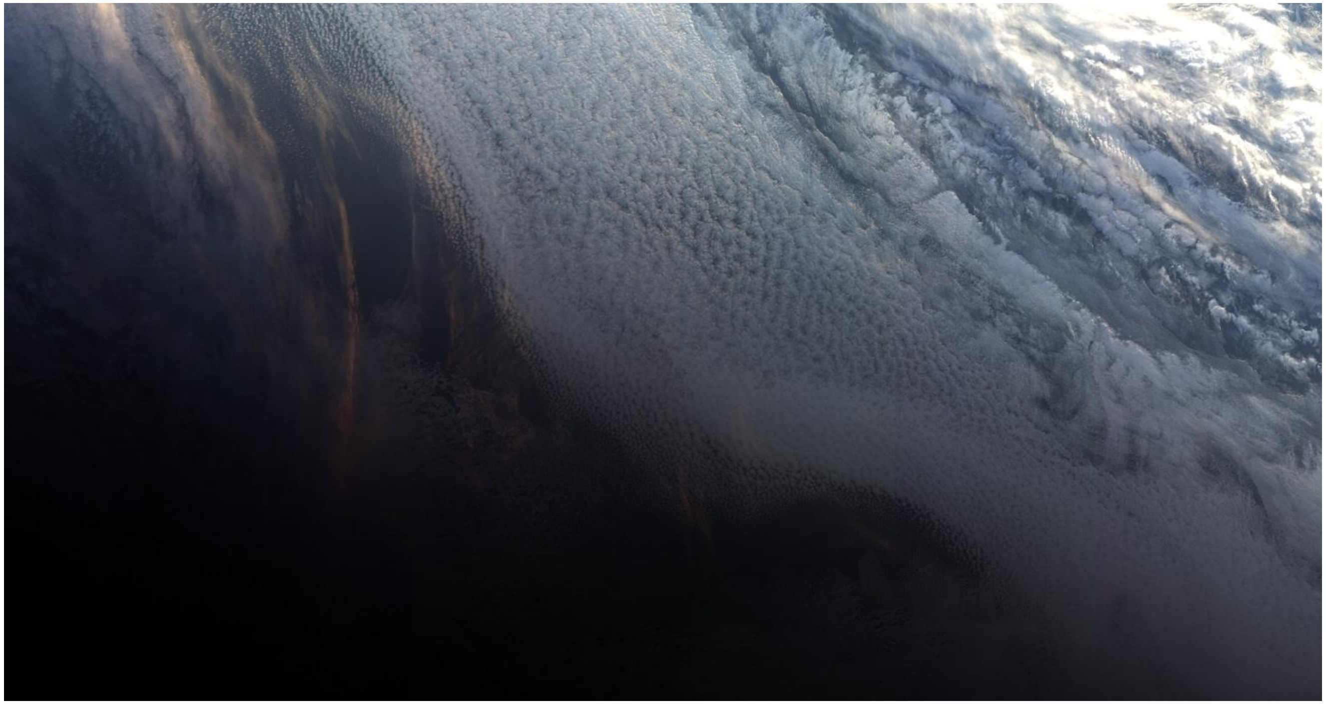
Sentinel-3 mission and OLCI

- **Sentinel-3:** measure sea surface topography, sea and land surface temperature, and **ocean and land surface colour** with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring
- **S3A**: Feb 16th 2016
- **S3B**: Apr 25th 2018
- Revisit < 2 days



Antarctica - Sentinel-3B's very first sight
https://www.eumetsat.int/website/home/News/DAT_3912999.html

- **OLCI**: Ocean and Land Colour Instrument
- VNIR, 21 bands
- GSD: 300 m at nadir (FR)
- Swath width: 1270 km
- 5 cameras, tilt to avoid glint

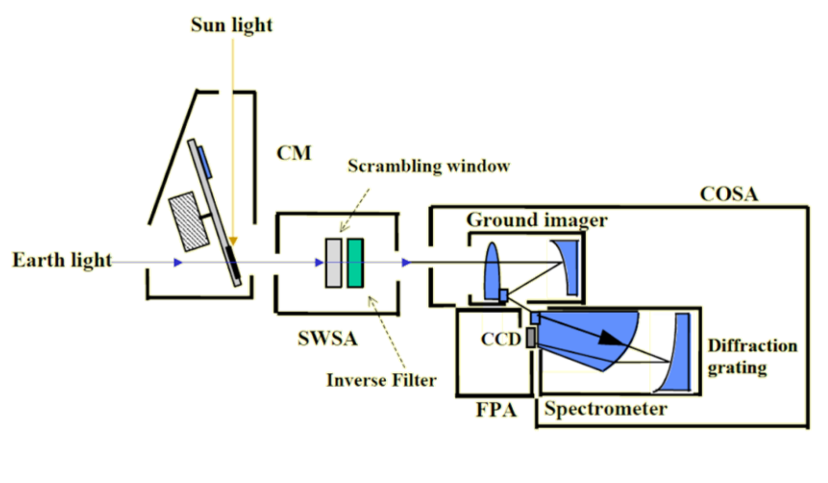
Outline

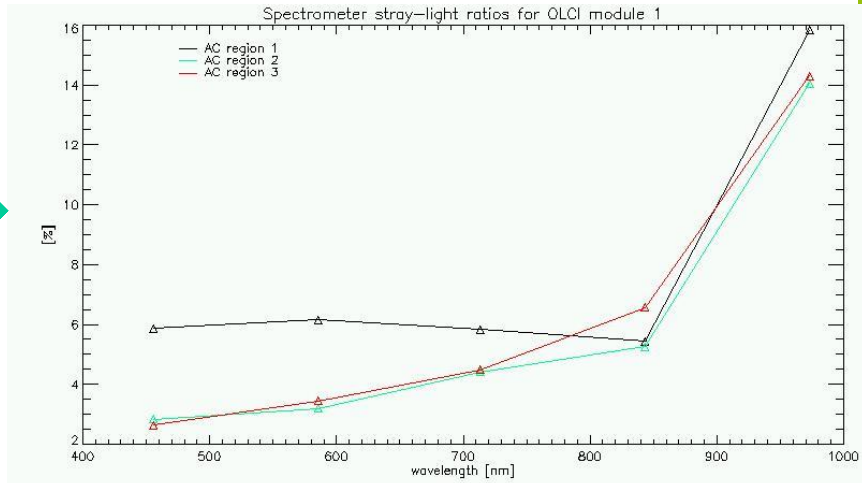
- **OLCI straylight characteristics**
  - Sources of straylight
  - On-ground characterization
- **OLCI straylight correction algorithm**
  - Principle and MERIS heritage
  - Implementation and performance aspects
- **OLCI straylight results**
- **Comparison to requirements**
- **Conclusions**

OLCI Straylight characteristics: sources

- **As all spectro-imagers, OLCI is very sensitive to straylight**

- **Straylight sources:**
  - **Imaging optics**
    - Straylight higher at short wavelengths
  - **Spectrometer**
    - Dominant term (10 times contribution from imager)
    - Straylight increases at long wavelengths
  - **CCD above 900 nm (B20, B21)**
    - NIR scatter straylight

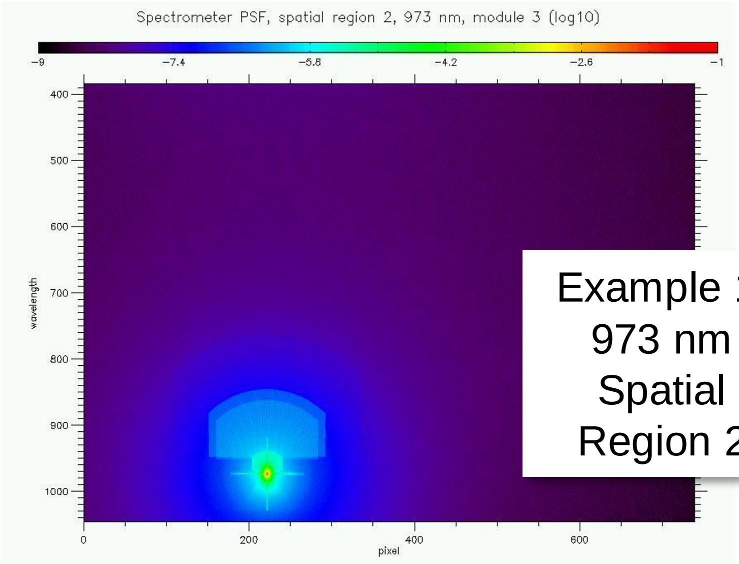




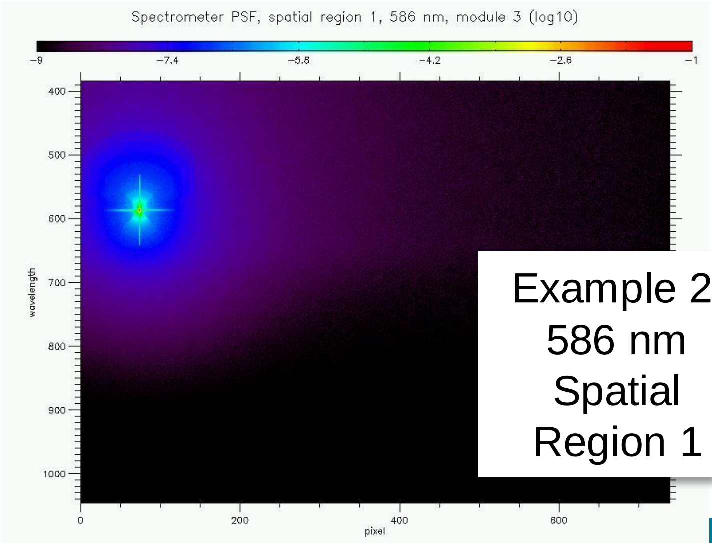
Ratio spectrometer straylight / total signal for 3 spatial regions, as a function of wl

OLCI Straylight characteristics: characterization

- **On-ground characterization methodology**
  - **Simulation with ray tracing to generate PSF**
    - The simulation uses the ground characterization database for each camera
    - Simulations at several wavelengths and positions in the Field of View
  - **The Straylight PSF is obtained by subtracting the straylight-free PSF (no scatter, no reflections) from the full simulation PSF**



Example 1:
973 nm
Spatial
Region 2



Example 2:
586 nm
Spatial
Region 1

OLCI Straylight correction algorithm

- ## Correction algorithm

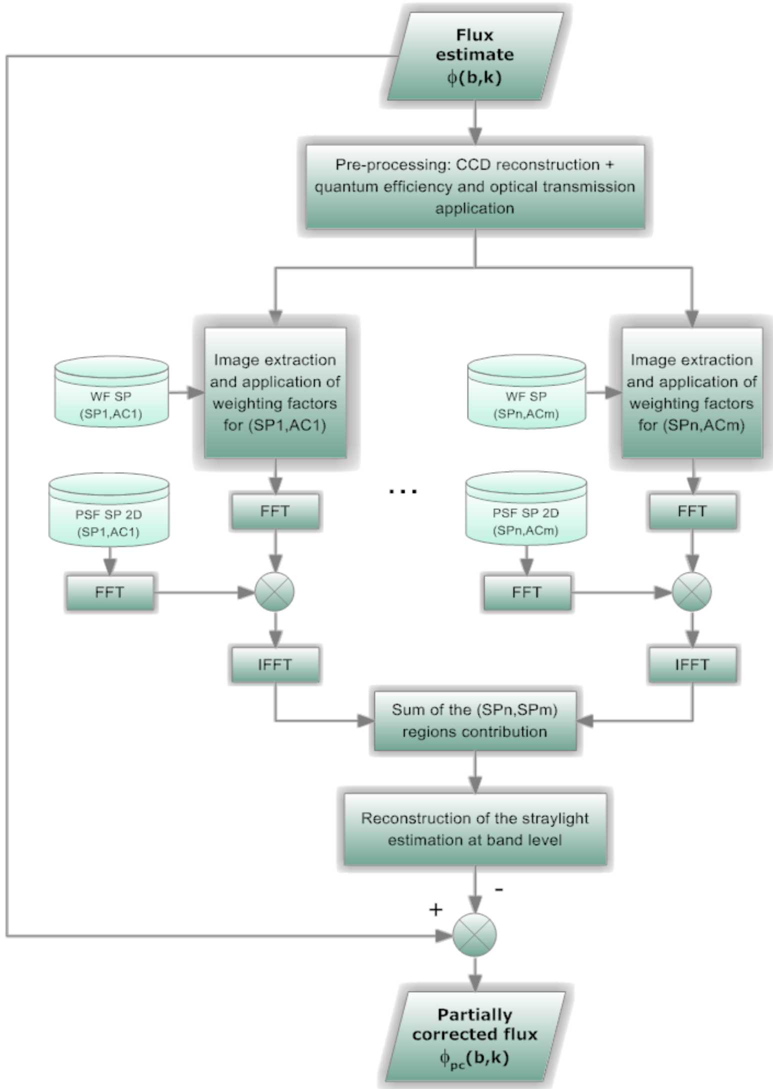
  - **Correction applied for each component following the light path backwards (spectrometer (including CCD) then imaging optics)**

  - **Spectrometer correction (for each camera)**
    - 1D-spatial x 1D-spectral whole CCD image rebuilt ([390, 1040] nm at 1.25 nm resolution)

  - **Ground Imager correction**
    - 2D spatial (across-track x along-track) convolutions (mixing of energy from the whole FOV, no spectral mixing)

OLCI Straylight correction algorithm

- **Correction algorithm**
  - **Spectro correction**
    - First the CCD spectral x spatial image is recreated (using spectral interpolation) at 1.25 nm
    - The CCD is decomposed in N x M regions in the spectral x spatial domain. The straylight PSF is characterized for each subregion
    - To apply the correction, the image is split in N x M copies images
    - The relevant PSF is applied to each subregion
    - Then the contributions for each subregion are summed up to get the full CCD image
    - Straylight contribution is removed from the signal



Correction algorithm

- **Imager correction**
  - Less impacting total SL
  - Same principle applied to the 2D spatial image, but linear interpolation between straylight PSF is not needed: use nearest neighbour

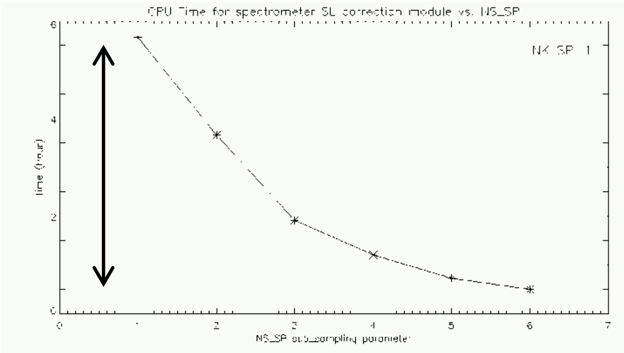
- **Implementation details:**
  - Need to manage margins (use of data from neighbouring cameras/granules) and boundary conditions
  - Use of prior/next granules for imager (along-track dimension) SL correction
  - Use of adjacent cameras for imager and spectrometer SL correction

CPU Performance aspects

- Main impact is on the spectro correction
- Optimization has been extensively studied

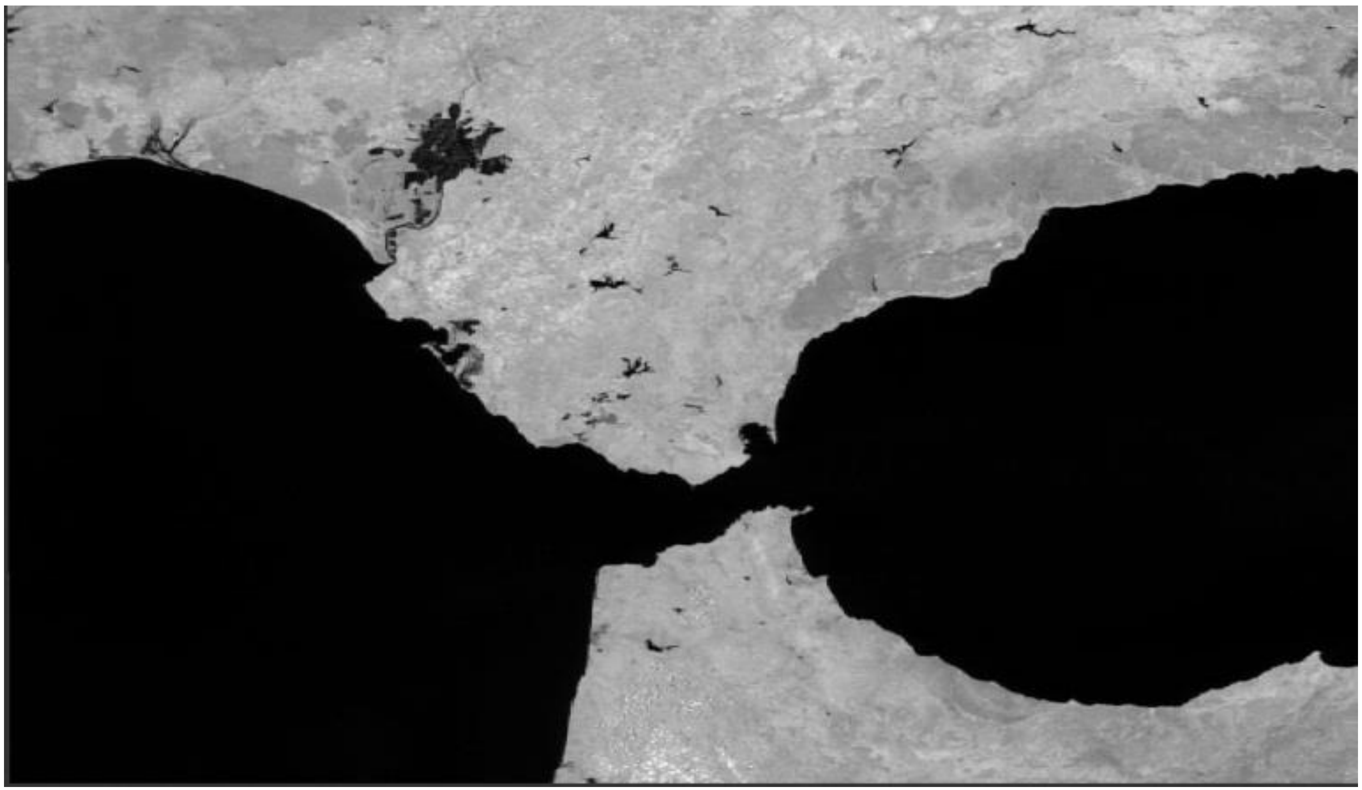
Approach	Efficiency	Remark
GPU (Graphical Processing Unit)	++	Reduced portability
Parallelization / multi-threading	+	Optimization of number of threads vs size of kernel
FFT mathematical libraries	+/++	Licensing issues
Sub-sampling	+/++	Optimization of sub-sampling parameters

Factor 12 in CPU time (6 h vs 30 min) between no sub-sampling and high sub-sampling

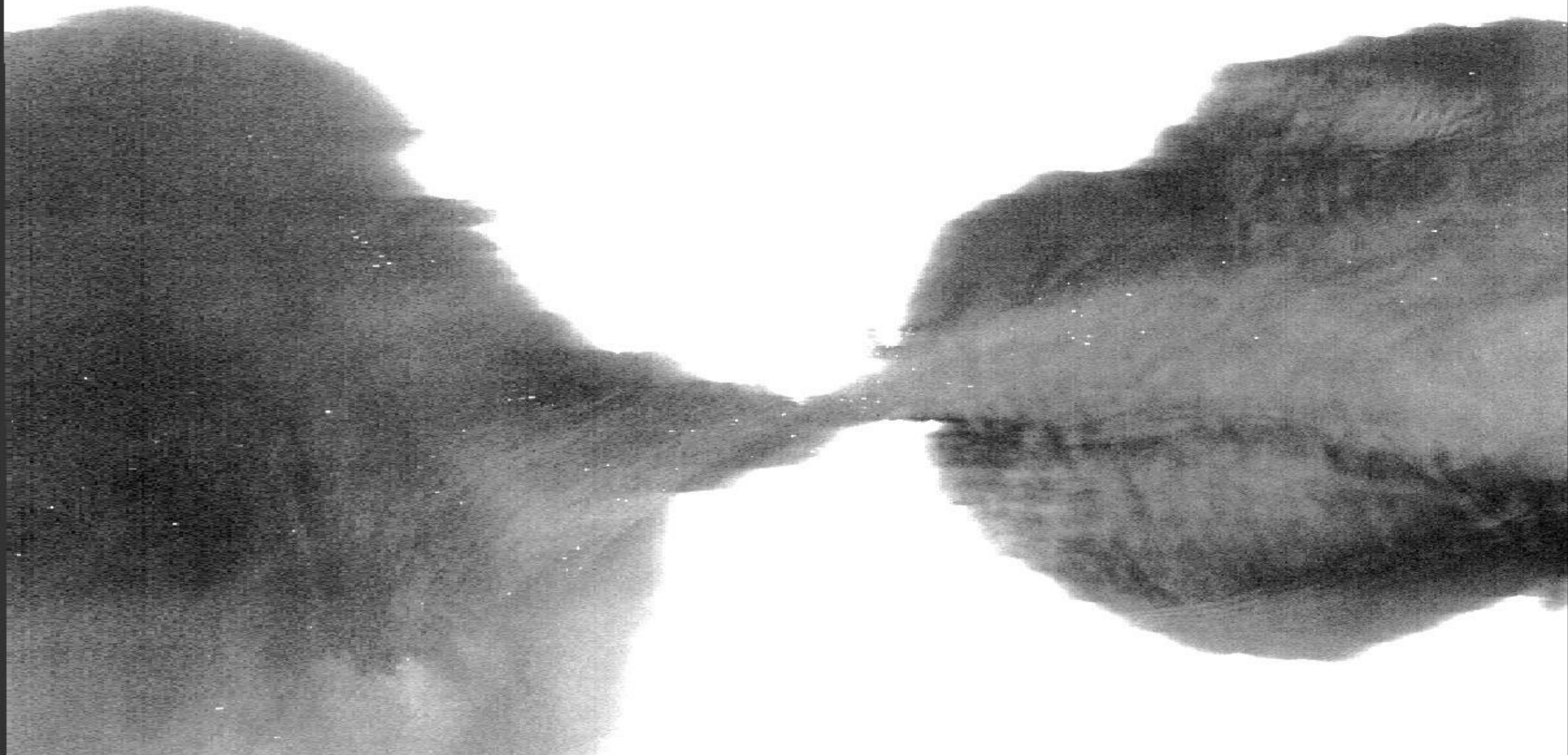


OLCI Straylight results

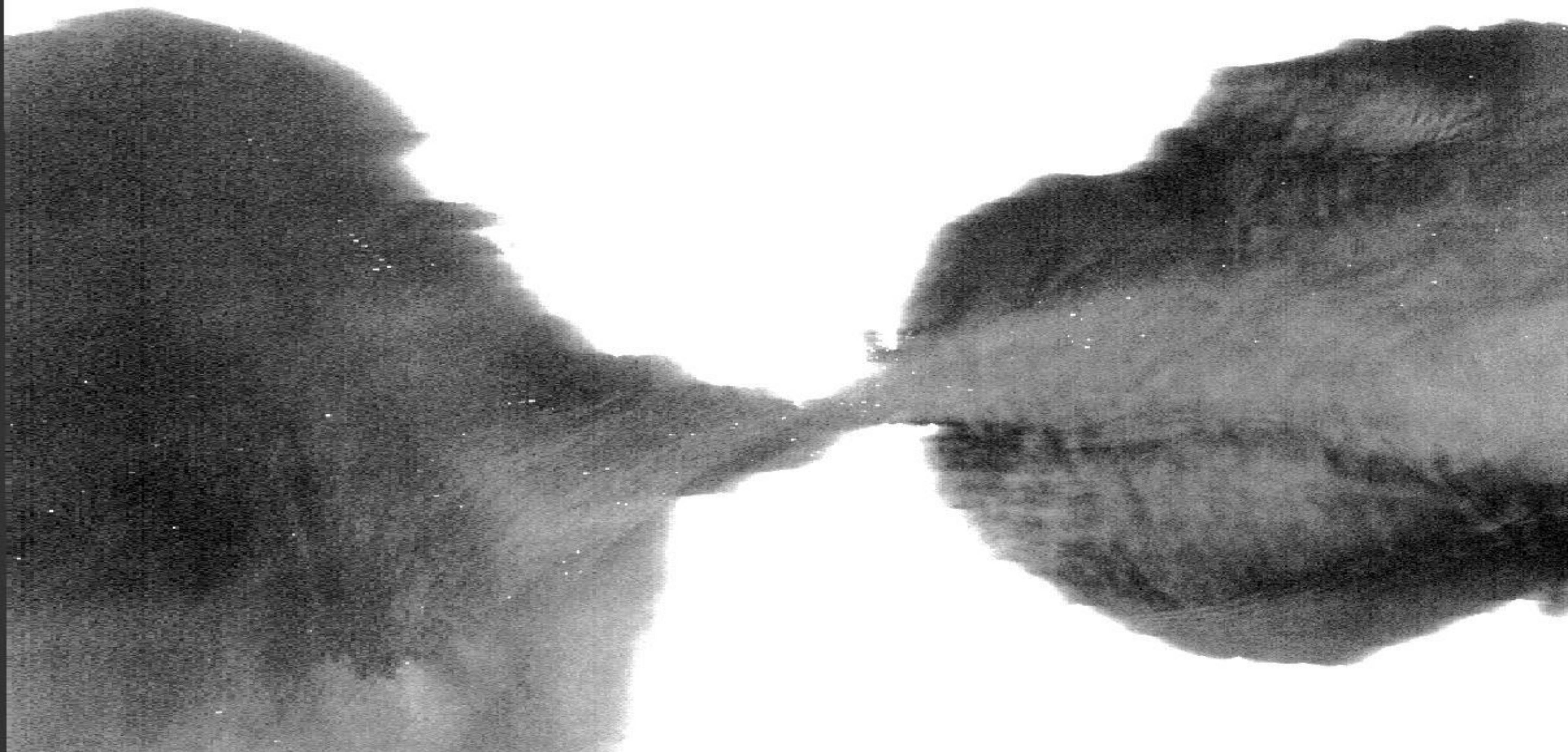
- **First results**
  - **Tests on highly contrasted image of the straight of Gibraltar**
  - **L1 TOA radiance B21 (1020 nm), worst case**



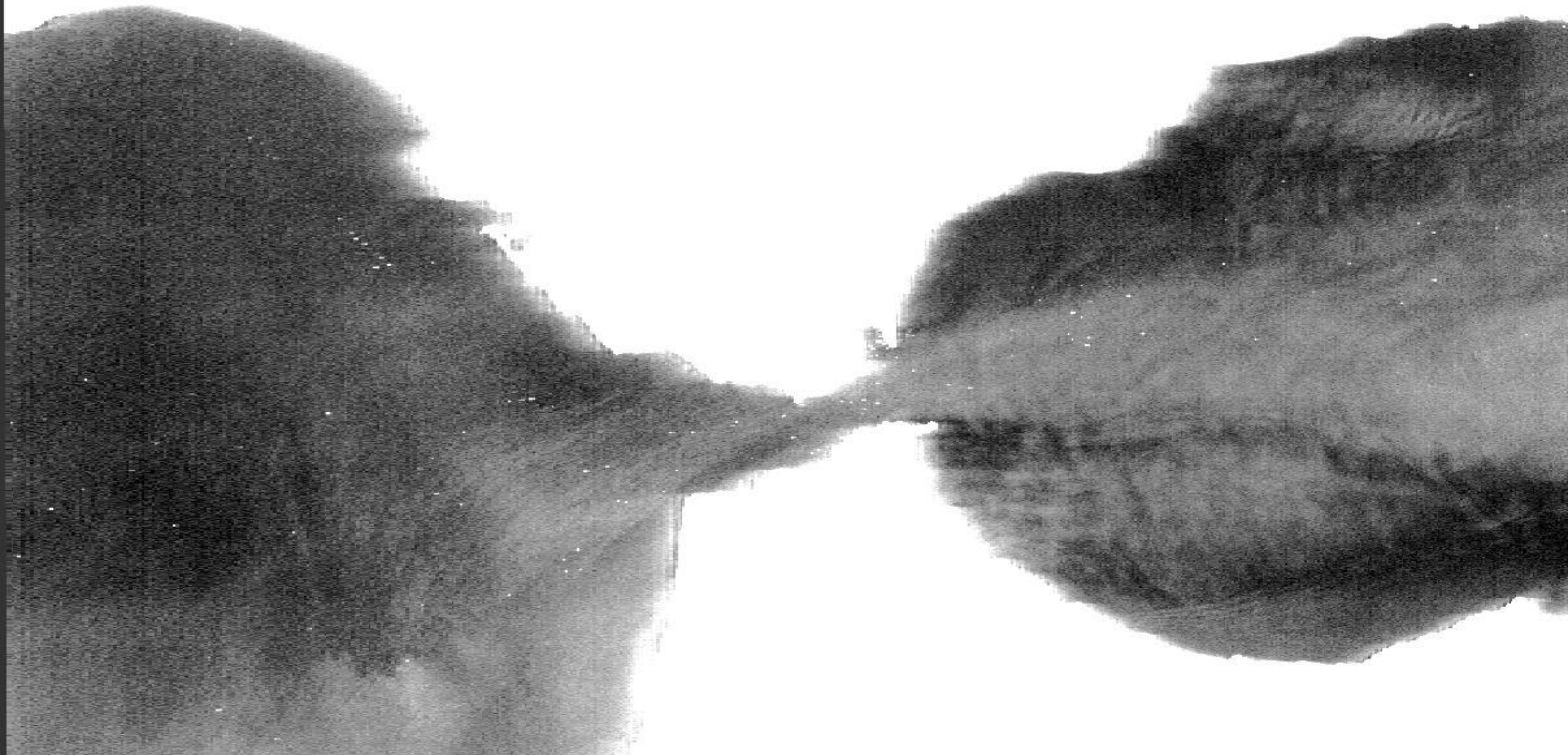
No straylight correction (contrast on small radiances): most effect across-track (spectro mainly impacts)



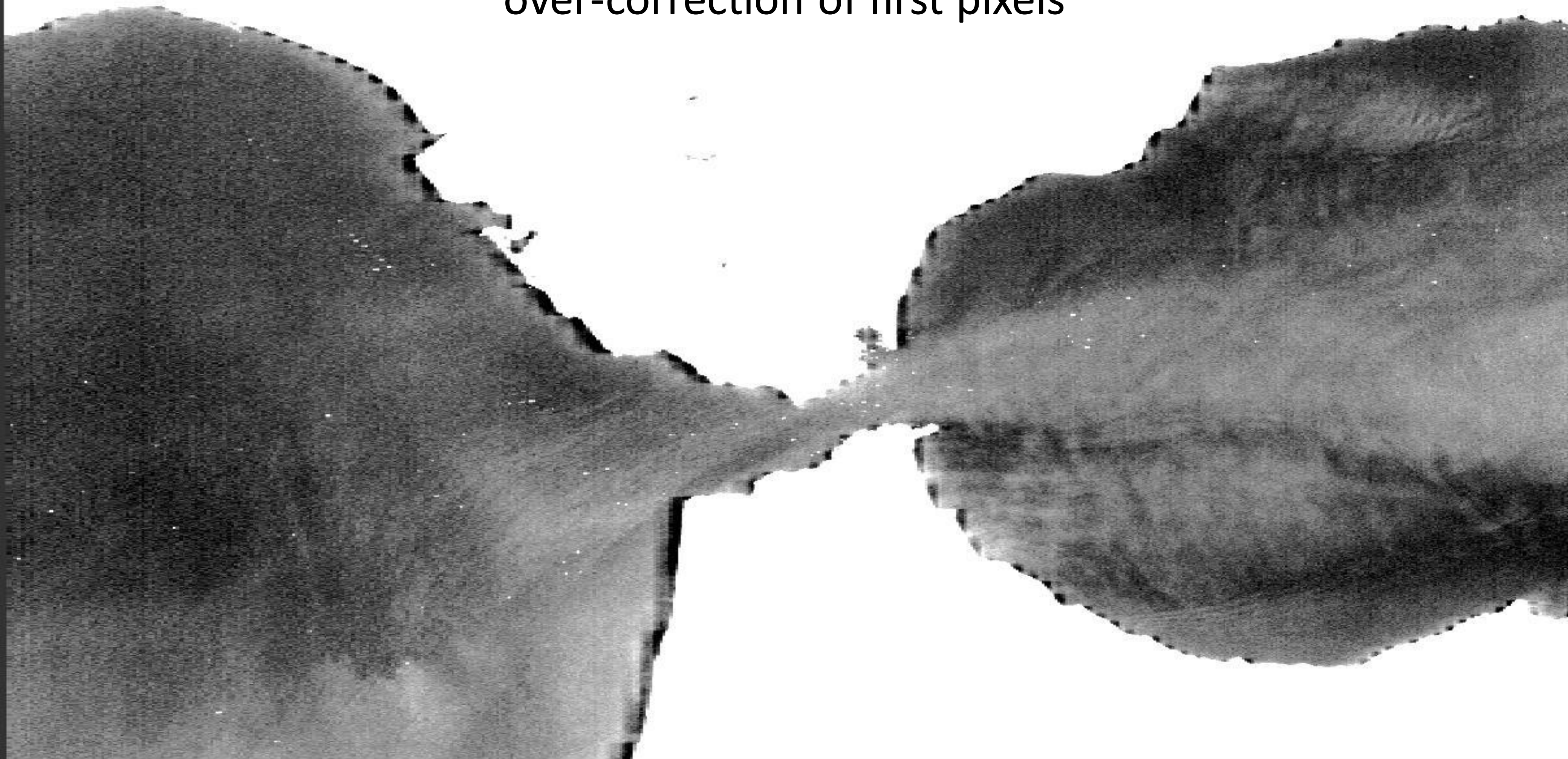
Straylight correction, **no** sub-sampling:
still some SL, correction under-estimated at B21



Straylight correction, **moderate** sub-sampling: introduces slight artefacts

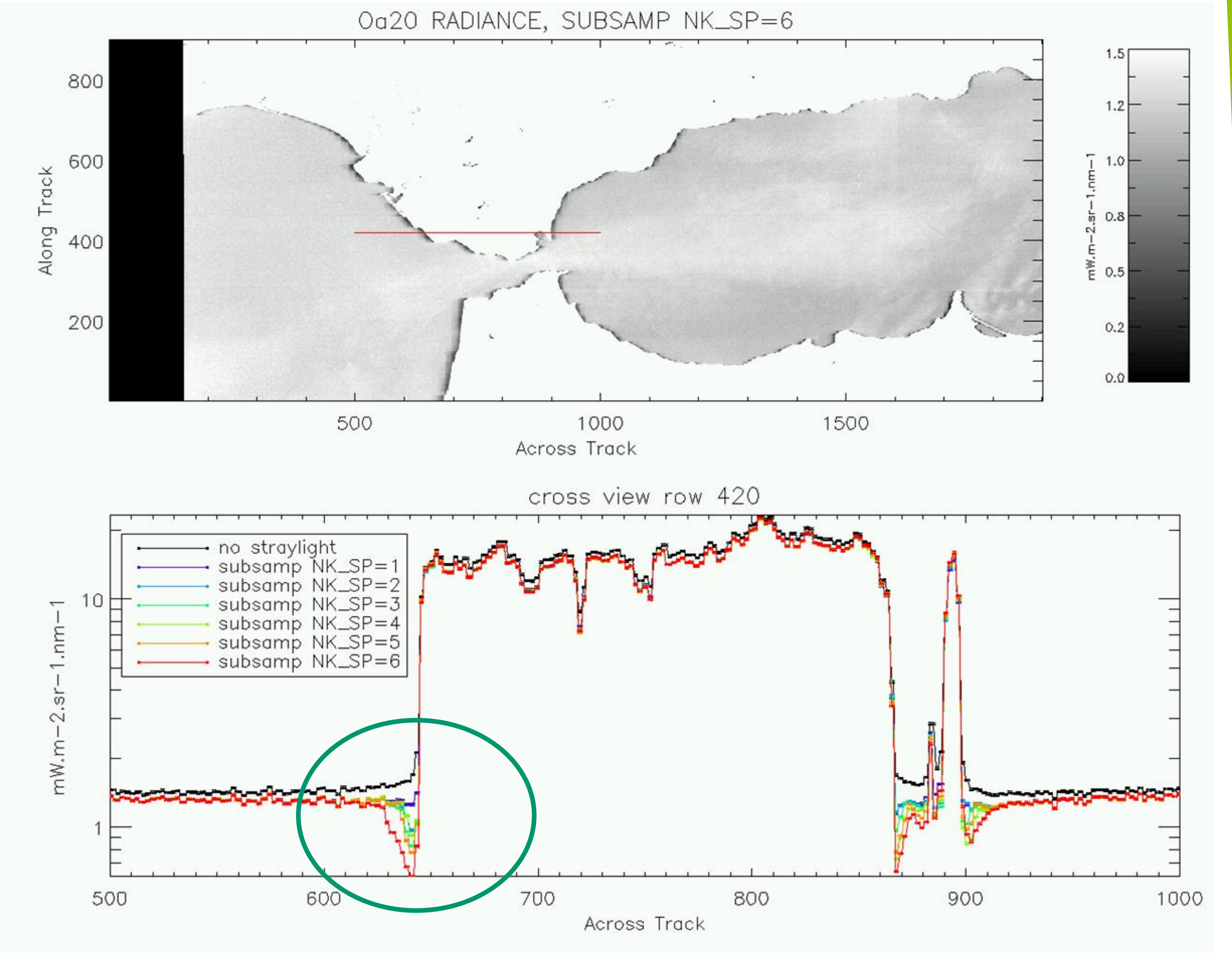


Straylight correction, **strong** sub-sampling:
introduces stronger artefacts
over-correction of first pixels

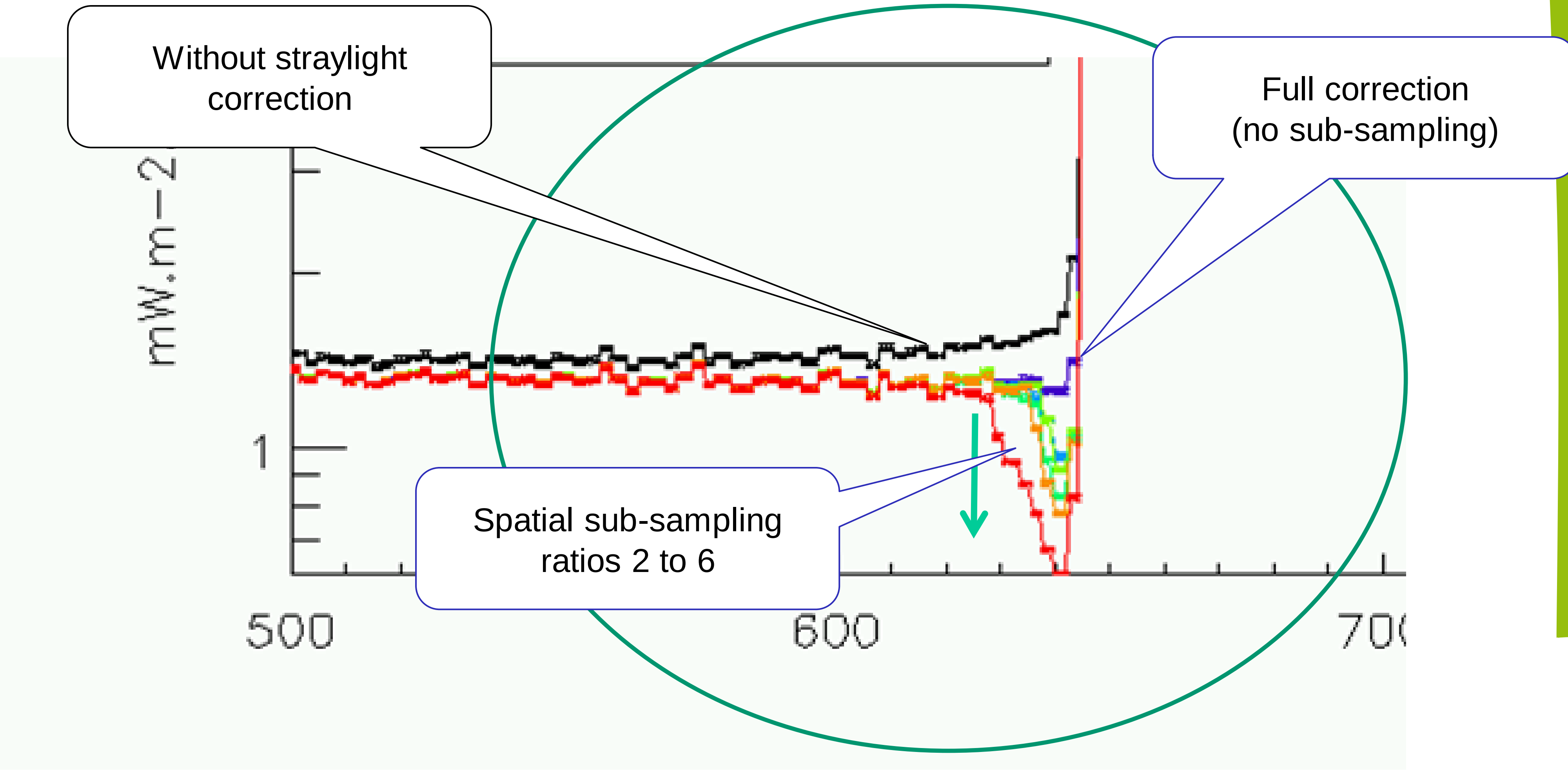


OLCI Straylight results

Straylight from land side induces an increase of the radiometry over the water side

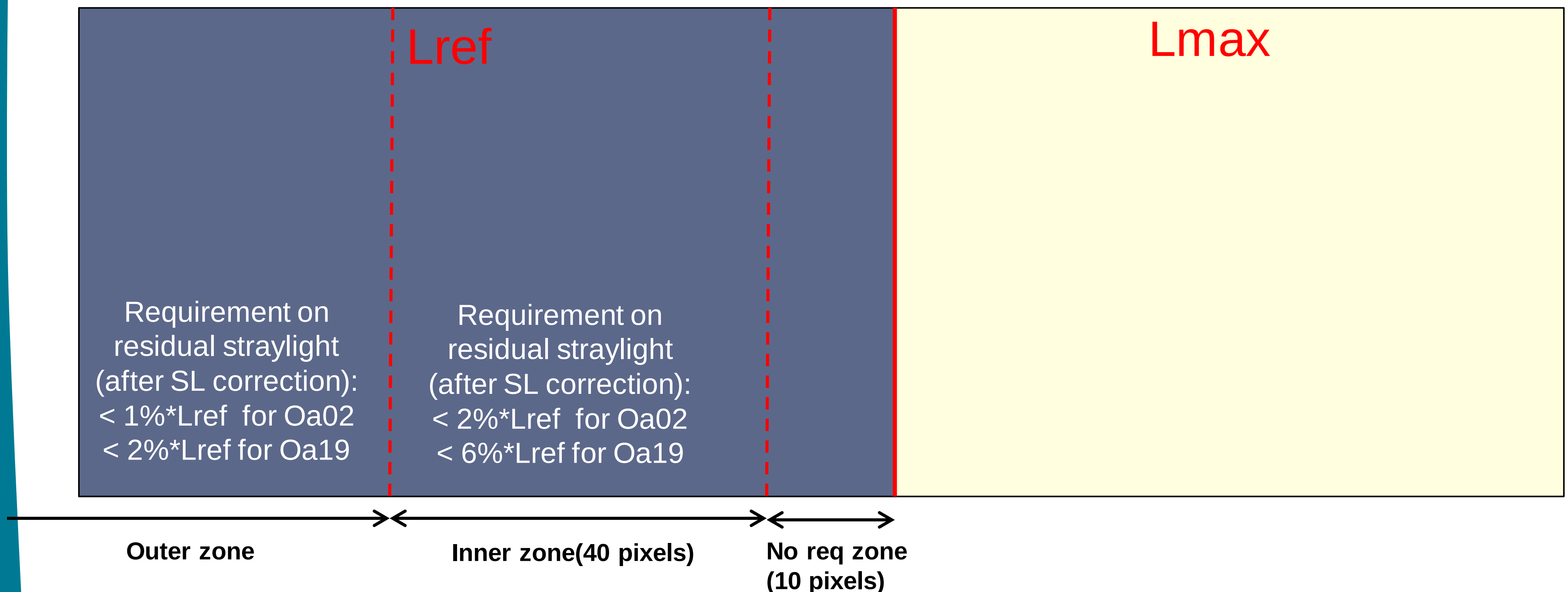


- **First results**

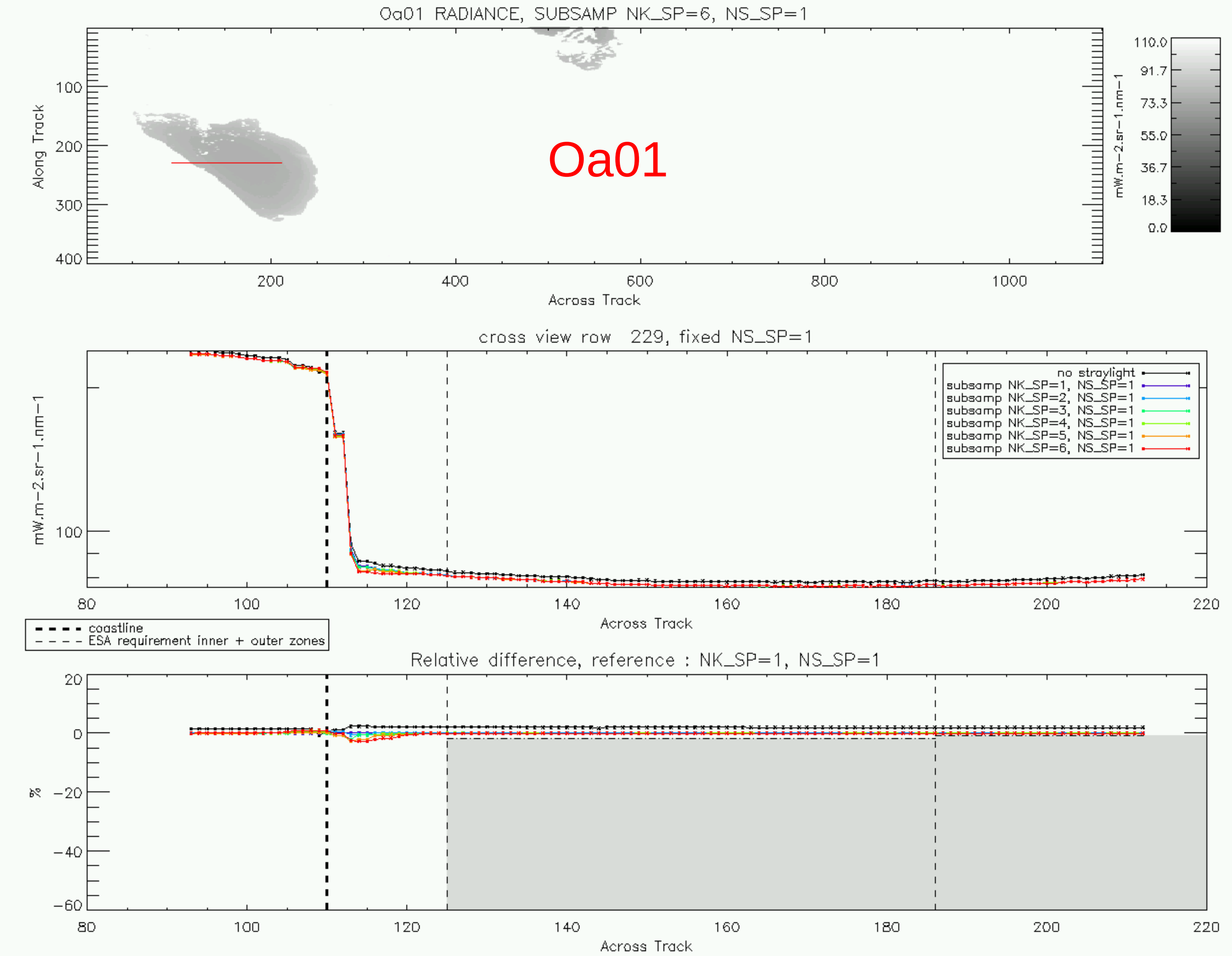


Comparison to requirements

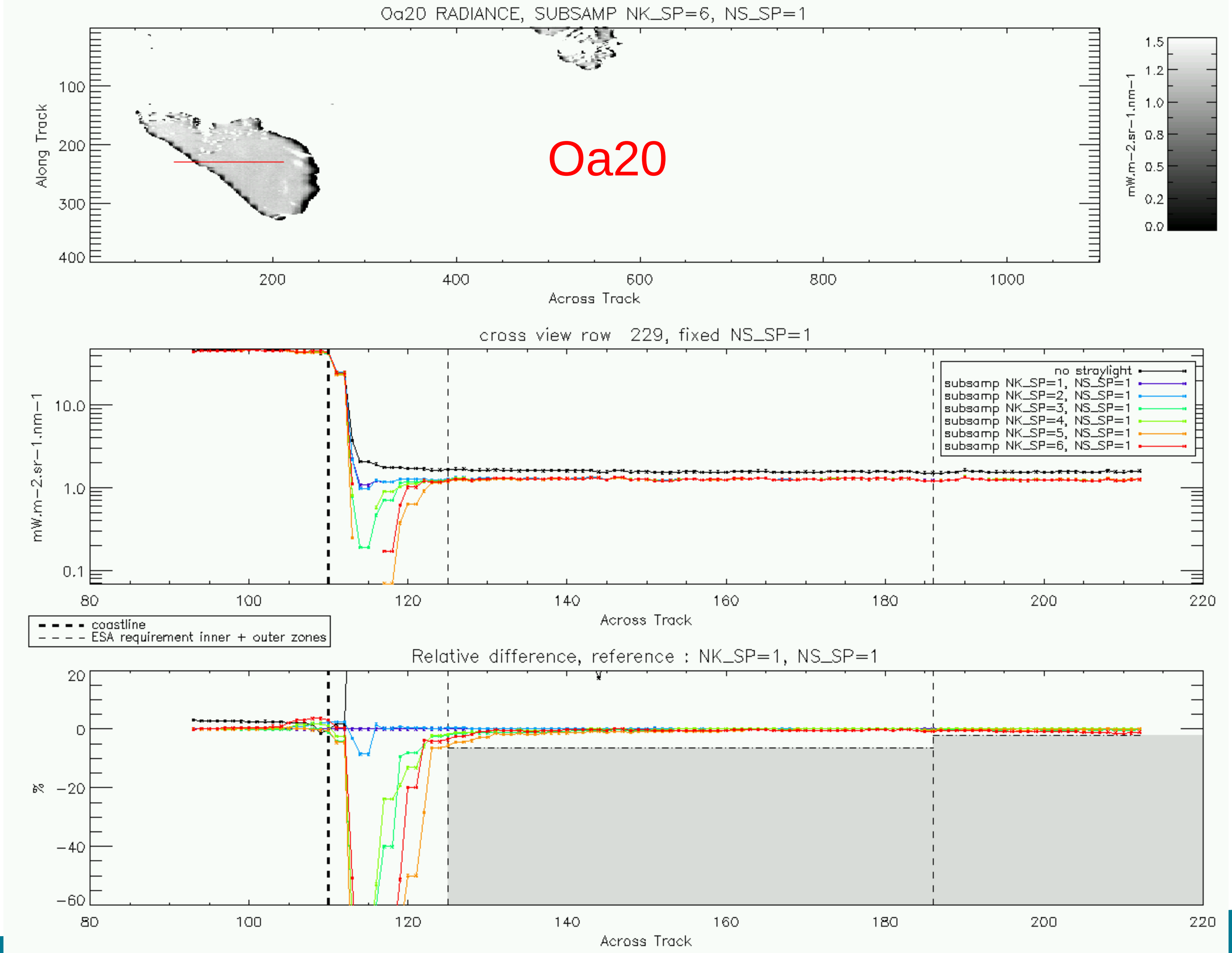
ESA requirement on Stray-light correction:



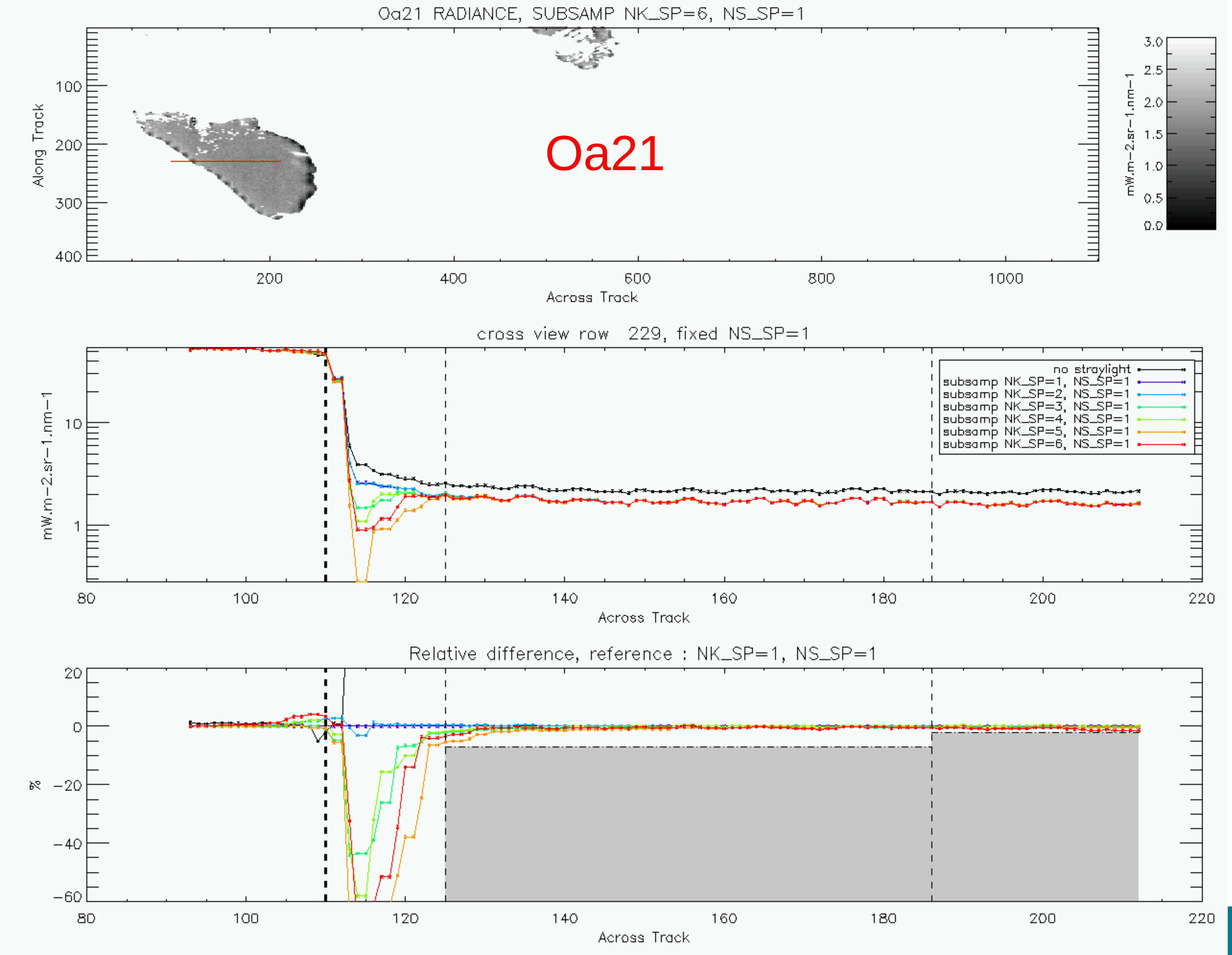
Comparison to requirements



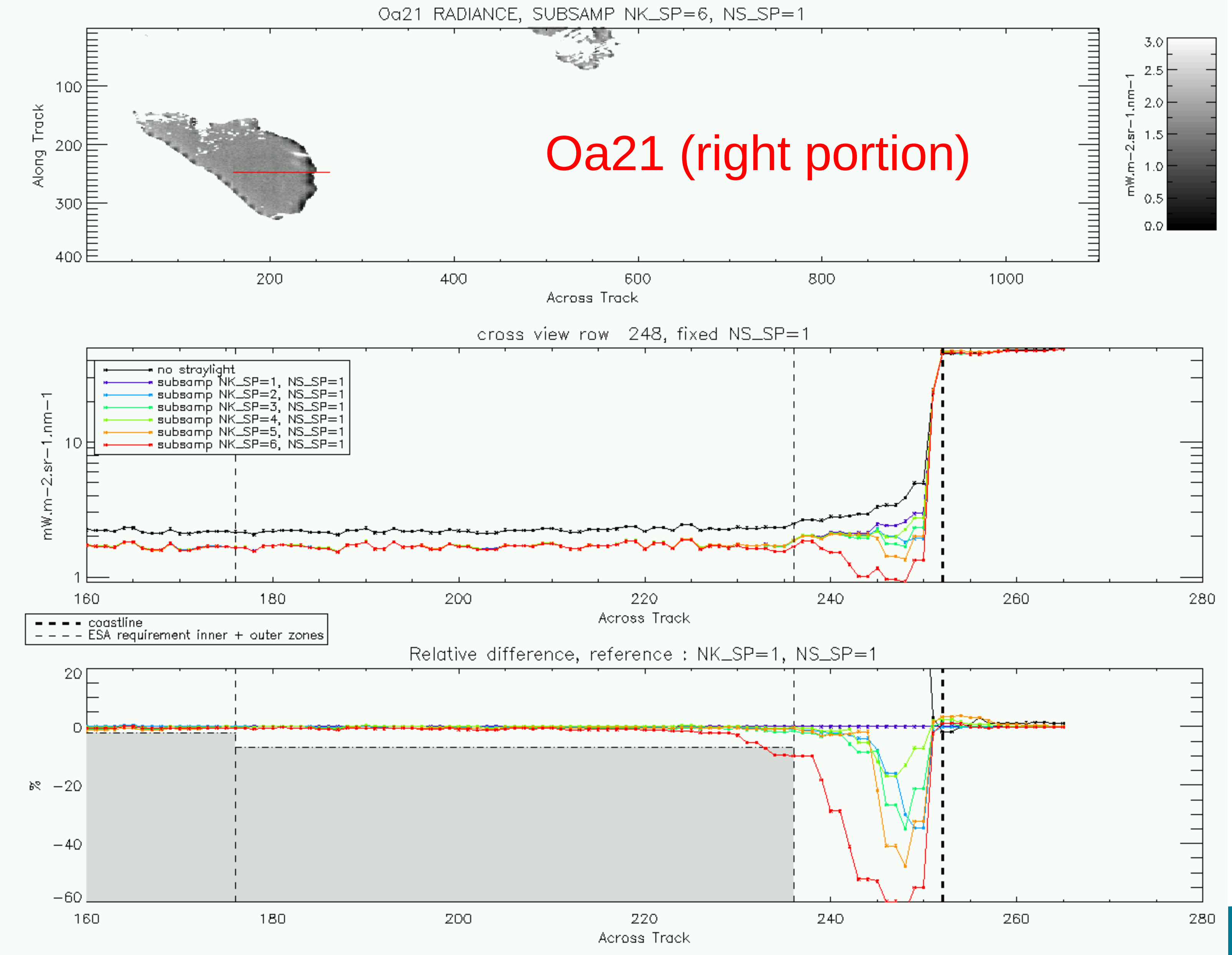
Comparison to requirements



Comparison to requirements



Comparison to requirements



Conclusions

- **Straylight correction efficiently restores expected radiometry level over ocean except on no req. zone**

- **Spatial sub-sampling improves CPU time but at the price of a less efficient correction near the transition zone**
  - Far from the transition, correction is always beneficial
  - Need to trade between CPU time constraints and accuracy: fine-tuning for OLCI in progress
  - Spectral sub-sampling (not shown here) has less impact: can be used more systematically (latest configuration: NS_SP=5, NK_SP=6)

Lessons learnt and applicability for CHIME

- **A correction algorithm similar to OLCI's may be appropriate for CHIME** (Copernicus Hyperspectral Imaging Mission for the Environment, candidate for a future sentinel, currently in phase A)

- **Need to establish a straylight correction strategy from the start**
  - Modelling of straylight PSF
  - Characterization of instrument straylight performance
  - Early validation of straylight correction algorithm

- **Sub-sampling is an efficient way to optimize the processing time**
  - Optimal choice of spectral/spatial sub-sampling parameters is mission-dependent
  - Need to keep flexibility on sub-sampling parameters for future optimization

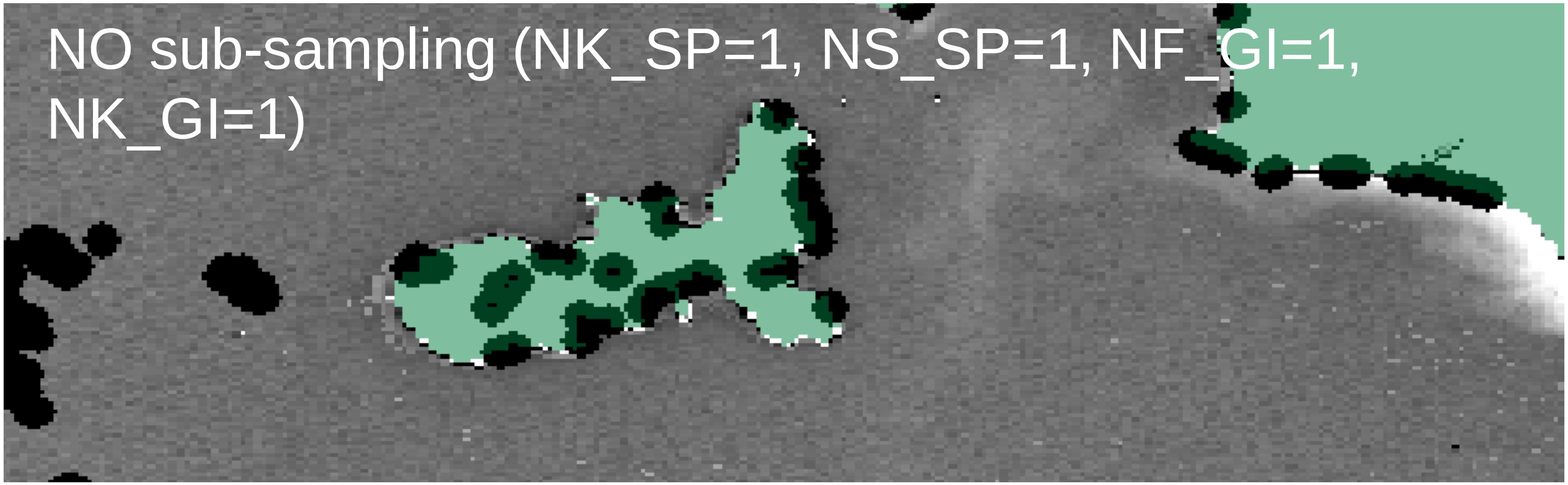
Thank you

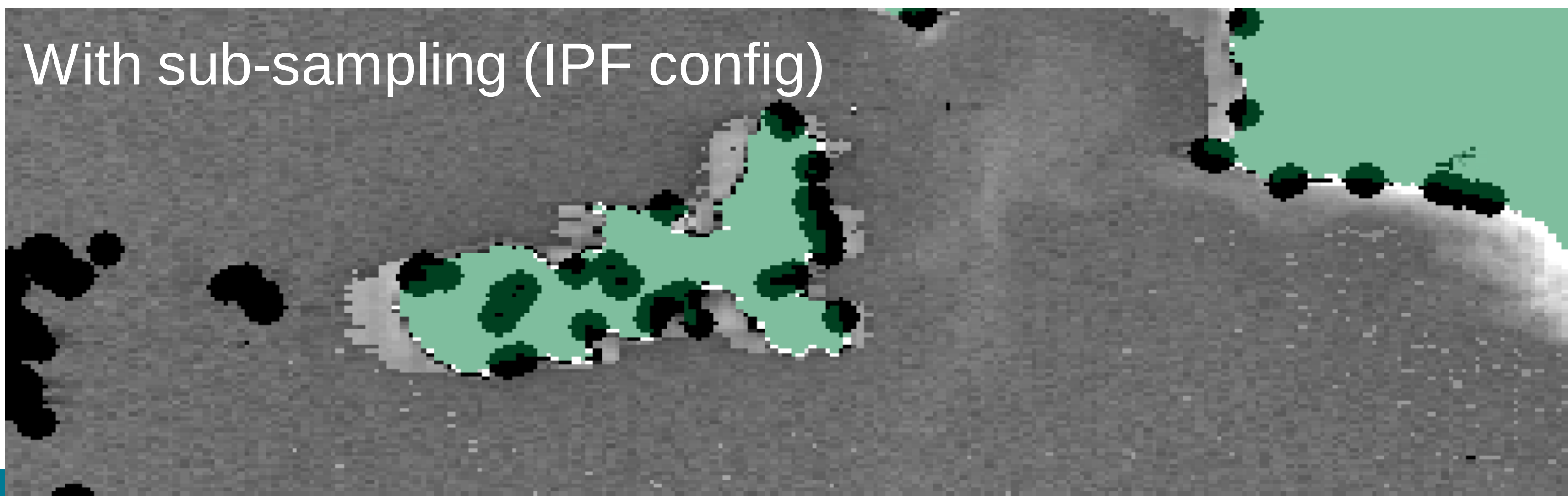
Back-up slides: impact at Level 2

GREEN=LANDS

BLACK SPOT = CLOUD FLAG

Water Leaving Reflectance Oa06



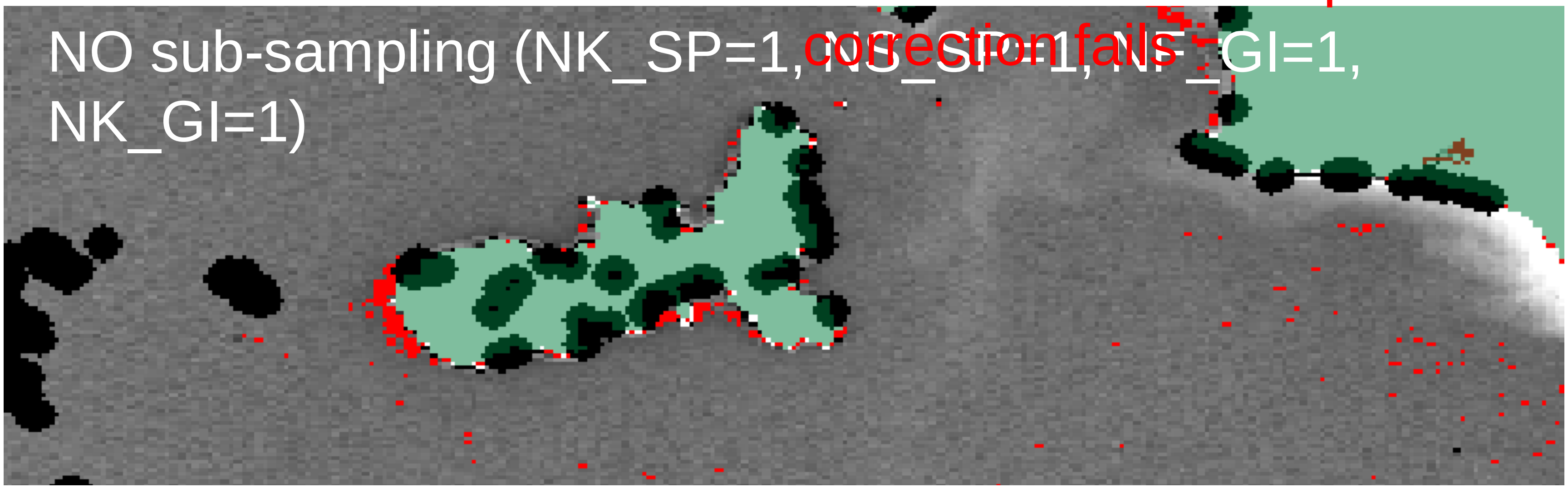


LEVEL 2

Water Leaving Reflectance Oa06

GREEN=LANDS
BLACK SPOT = CLOUD FLAG
RED = FLAG Atmospheric correction fails

NO sub-sampling (NK_SP=1, NS_SP=1, NF_GI=1, NK_GI=1)



With sub-sampling (IPF config)