Discrete field of view sampling of OMI satellite pixels using MODIS imager data

ABSTRACT

The field of view (FOV) describes the spatial sensitivity distribution of optical instruments. Knowledge of its shape is essential for the interpretation of spectroscopic measurements of Earth’s atmosphere and surface. Spectroscopic instruments, like those designed for Differential Optical Absorption Spectroscopy (DOAS), typically feature a much lower spatial resolution than instruments with lower spectral resolution in order to provide a sufficient signal-to-noise ratio. It is common practice to describe the FOV of satellite instruments by a rectangle defined by its four corners. In principle, the instrument FOV can be either characterised under controlled conditions (i.e. in the lab) or simulated using ray tracing. In reality, however, the FOV may change during launch of a satellite-borne instrument or when a ground-based instrument is transported into the field. We present a method to assess the FOV of spectroscopic DOAS-type instruments during operation using correlated MODIS data. As a proof of concept, the method is applied to investigate the FOV of the OMI (Ozone Monitoring Experiment) satellite instrument using correlated measurements by MODIS (Moderate Resolution Imaging Spectroradiometer).

RESULTS – ENTIRE SWATH

METHOD

Resampling of MODIS data

- from topocentric lat/lon-grid (500 m)
- to normalised x-y-grid (2 km)
- via rotation matrices

Discrete FOV sampling

One measurement → one equation

\[ l = c_0 + \sum_{i=1}^{m} c_i h_i \]

- LR radiance
- \( h \) gridded HR radiances
- c FOV parameters

Many measurements → LES

\[ \begin{bmatrix} l_1 \\ \vdots \\ l_n \end{bmatrix} = \begin{bmatrix} 1 & h_1 & \cdots & h_m \\ \vdots & \ddots & \vdots \\ 1 & h_{m1} & \cdots & h_{mn} \end{bmatrix} \begin{bmatrix} c_0 \\ \vdots \\ c_m \end{bmatrix} \]

⇒ Solve LES using LSMR approximation!

Super-Gaussian in two dimensions

\[ F_{2D}(x,y) = \tau \gamma \exp \left( -\left( \frac{x-a_1}{a_2} \right)^2 - \left( \frac{y-b_1}{b_2} \right)^2 \right) \]

\( \gamma \) amplitude
- \( a_1 \) shape (Gaussian for \( a_1 = 2 \))
- \( a_2 \) width
- \( b_1 \) spatial offset
- \( b_2 \) respective y-parameters

RESULTS – OMI PIXEL 30 (NADIR)

Fit of 2D FOV model

The FOV results are used to fit the 2D super-Gaussian FOV model: (a) fit result, (b) fit residual, retrieved across-track FOV cross-section with 2D fit result compared to tiled pixel edges, and (d) retrieved along-track FOV cross-section with 2D fit result compared to theoretical FOV shape and tiled pixel edges.

Influence of LSMR damping parameter \( \tau \)

The LSMR tolerance threshold \( \tau \) can be used to balance between SN-ratio and spatial bandwidth of the approximation: greater smoothing results but on the cost of resolution. In this application for OMI, \( \tau = 10^{-3} \) provides sharpest results with minimal widening.

RESULTS – SCAN ANGLE DEPENDENCE

The presented method is applied on all OMI pixels within the MODIS swath (pixel 5−85) and the 2D parametrisation is fitted to the results.

(a) The results for the shape parameter \( b_1 \) in along-track direction indicate a FOV shape smoother than stated in Kurosu and Celarier (2010). However, this may be an artefact due to the approximative LSMR solution damping strong gradients.

(b) The 75 %-widths are calculated from the fit results. The widening of the FOVs towards the swath edges is more pronounced in across-track than in along-track direction.

CONCLUSIONS

Discrete FOV sampling

- basic linear model parametrises OMI FOV
- works on-orbit applying correlated MODIS data
- a-priori knowledge about FOV shape is not required
- also applicable to other instruments, e.g. GOME-2
- ideal for validation

OMI FOV

- is in a complex 2D pattern
- changes with scan angle (pixel number)
- spatial offset w.r.t. MODIS is systematic
- retrieval accuracy limited by 8 min overpass delay
- approximative solution suffers from damping

REFERENCES