Project on consistency of OMI and GOME-2 HCHO retrievals – overview and preliminary results

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	Ozone Monitoring Instrument (OMI)	**Global Ozone Monitoring Experiment-2 (GOME-2A)**
Launch	Aura, July 2004	Metop-A, October 2006
Orbit	Ascending polar, sun-synch., ~**13:40 LST**	Descending polar, sun-synch., **9:30 LST**
FOV, km	Push-broom, 60 (30) FOV; 24(48) X 13	Scanning; 80 X 40; 40 X 40 after July 2013
Sp. coverage, nm	264-504	240-790
Sp. resolution, nm	**0.42**-0.63	**0.26**-0.51
Solar observations	Daily, @ each FOV	Daily, single FOV
Detector(s)	2 * 2-D CCDs; 780 × 576 pix (spectral × spatial)	4 * 1-D CCDs, 1024 pix each

Formaldehyde (HCHO):

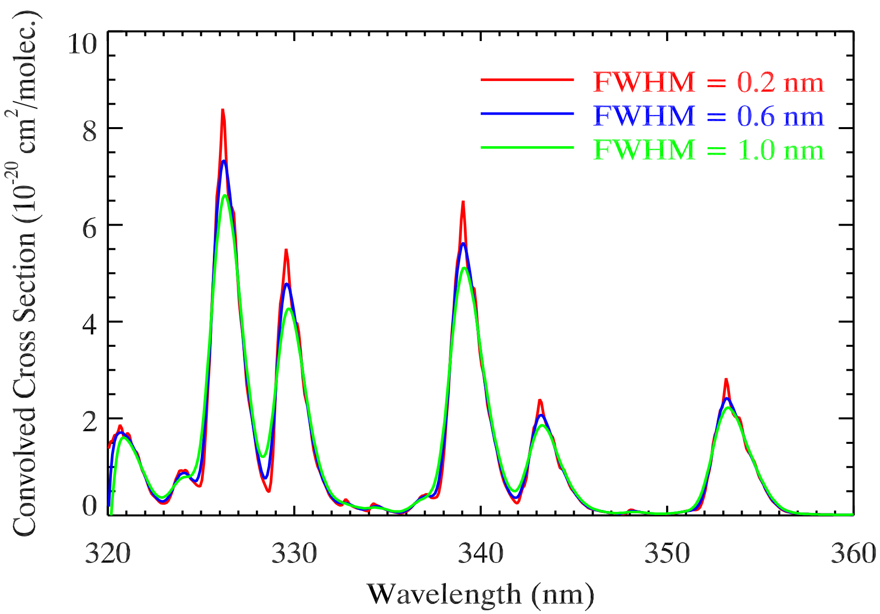
-- one of the highly reactive species, influencing the oxidative capacity of the Earth atmosphere;

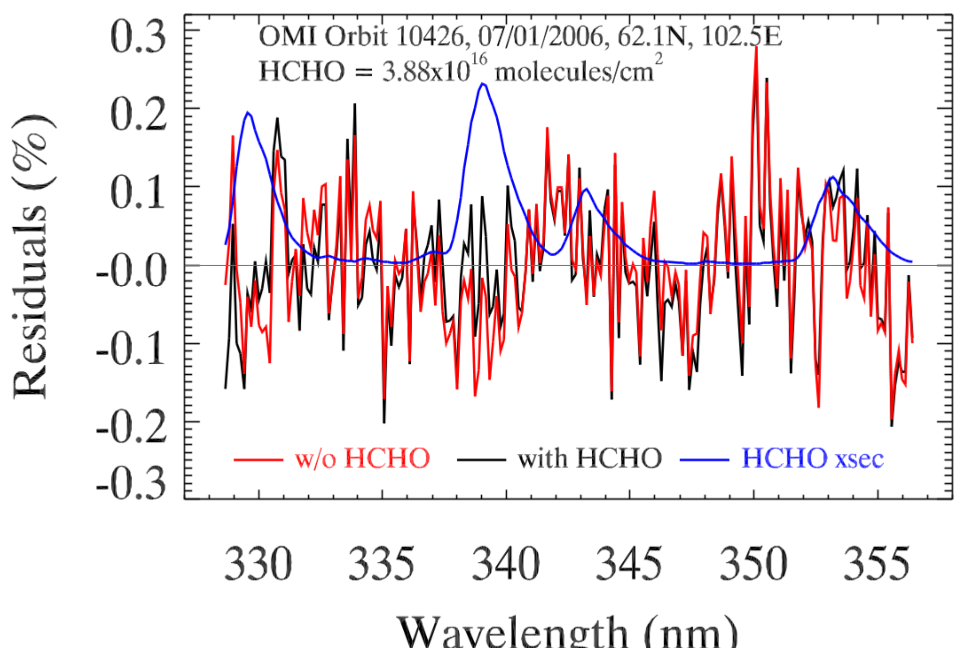
-- an intermediate oxidation product of

- non-methane volatile organic compounds (VOC: biogenic, pyrogenic, anthropogenic), with concentrations >~10 ppb;
- methane (remote oceanic regions), ~0.1-1.0 ppb;

-- short lifetime (~hours) and pronounced diurnal cycle (De Smedt et al., 2015; Franco et al., 2016) ➔ high spatio-temporal variability;

-- used as a proxy for biogenic VOC emissions (precursors of organic aerosols) ➔ air quality control and monitoring.





OMI (v3: Gonzalez Abad et al. 2015):

- ‘irradiances’ in the **328.5 – 356.5 nm** window;
- basic optical differential spectroscopy (BOAS) approach:
  1. least-square spectral fits to modified solar irradiances → slant-column densities (SCDs);
  2. air mass factor evaluations (AMF, radiative transfer) ;
  3. Vertical column densities (VCDs):

$$VCD = (SCD - SCD_{corr}) /AMF$$

GOME-2 (V14: De Smedt et al. 2015):

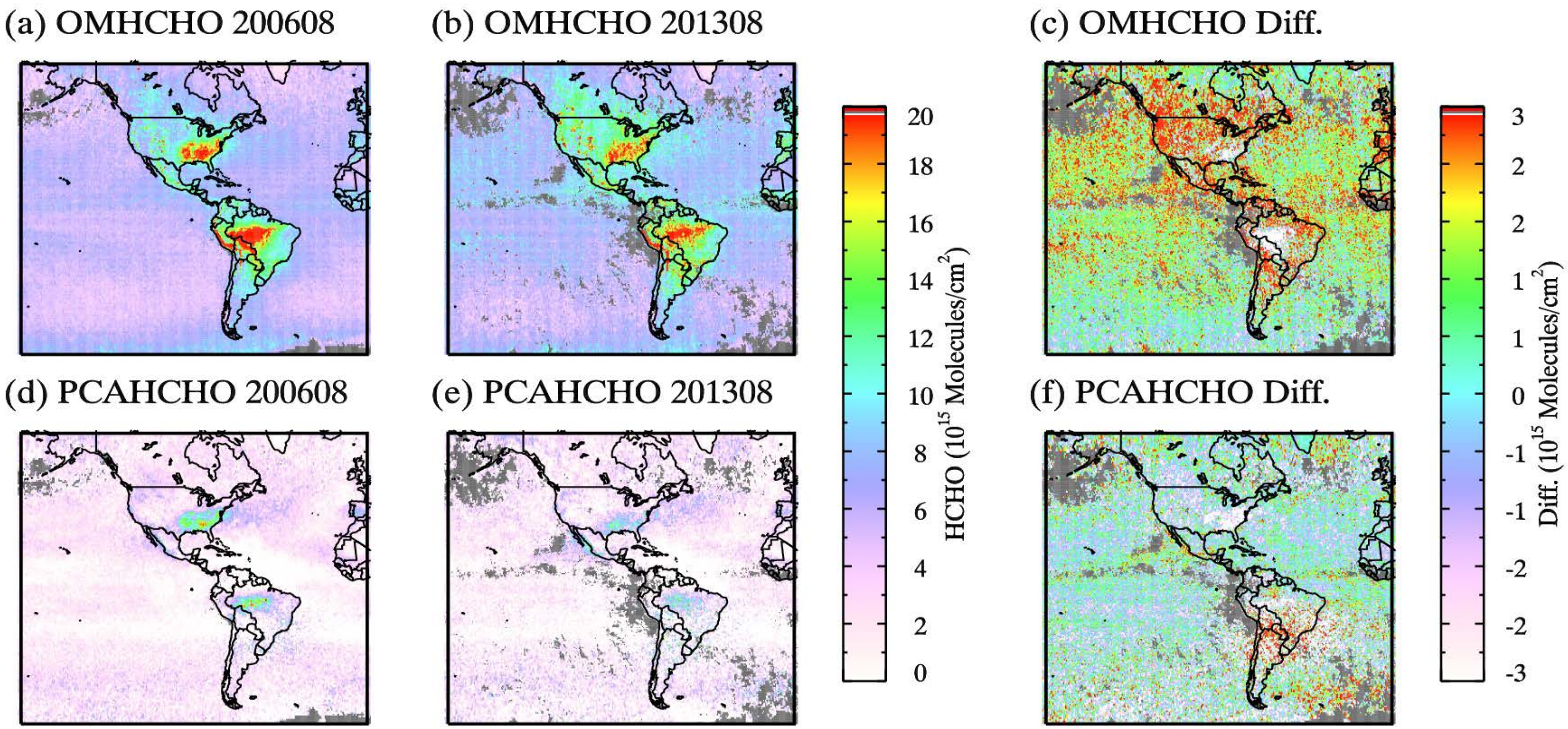
- reflectances in the **328.5 – 346.0 nm** window;
- differential optical absorption spectroscopy (DOAS) approach:
  1. least-square spectral fits to reflectances → SCDs;
  2. AMF evaluations;
  3. VCD estimates:

$$VCD = (SCD - SCD_{corr})/AMF + VCD_{corr}$$

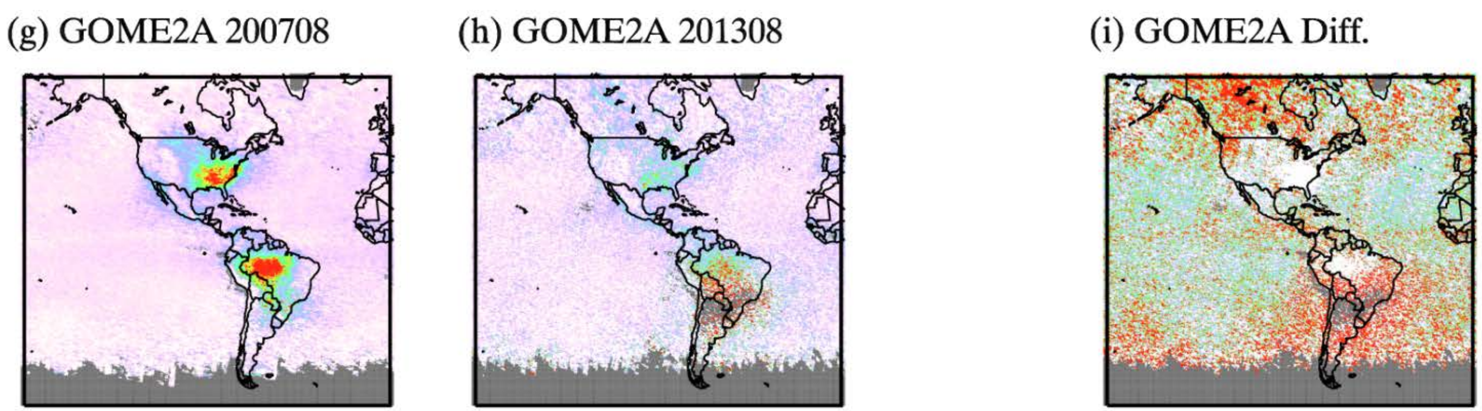
Applying the currently implemented (OMI, SO2: Li et al, 2013; OMPS, HCHO: Li et al., 2015) principal component analysis (PCA) to the OMI and GOME-3 HCHO retrievals:

- all–orbit retrieval (reflectances) in the **327.0 – 356.5 nm** window, however avoiding zones of high O3 (> 2500 Du) ; fixed Jacobian → 1st-step PCA;
- sub-sample of FOVs with the lowest HCHO values; fixed Jacobian → 2nd -step PCA;
- FOVs with the lowest HCHO values; Jacobians from LUTs → VCD (HCHO)

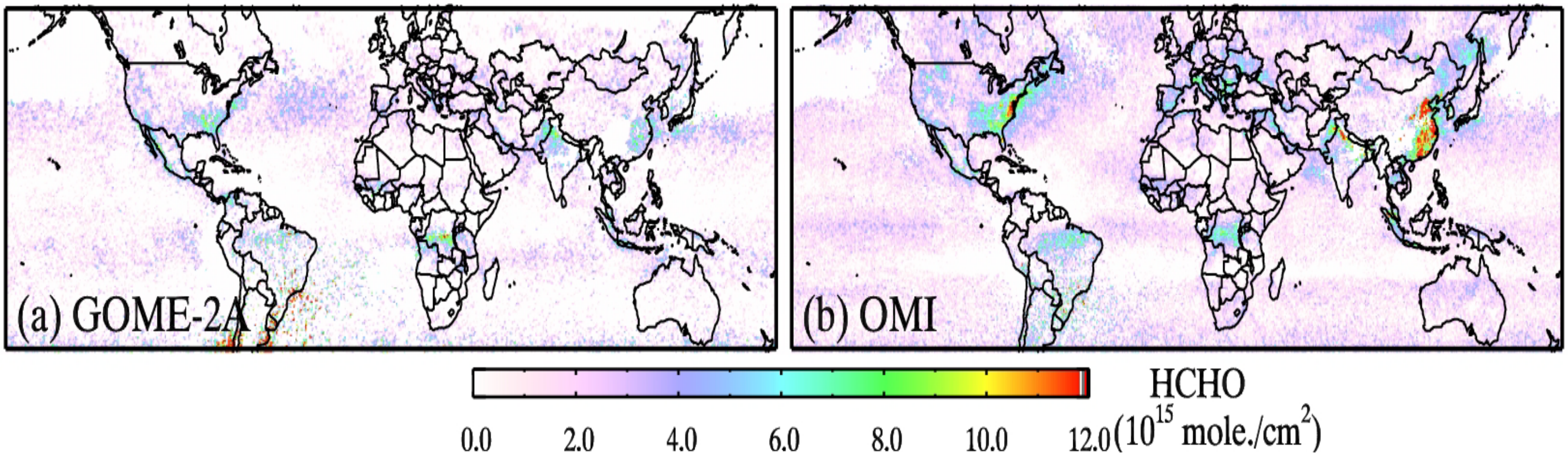
The OMI operational (OMHCHO, V3) and the proposed (PCAHCHO) retrievals

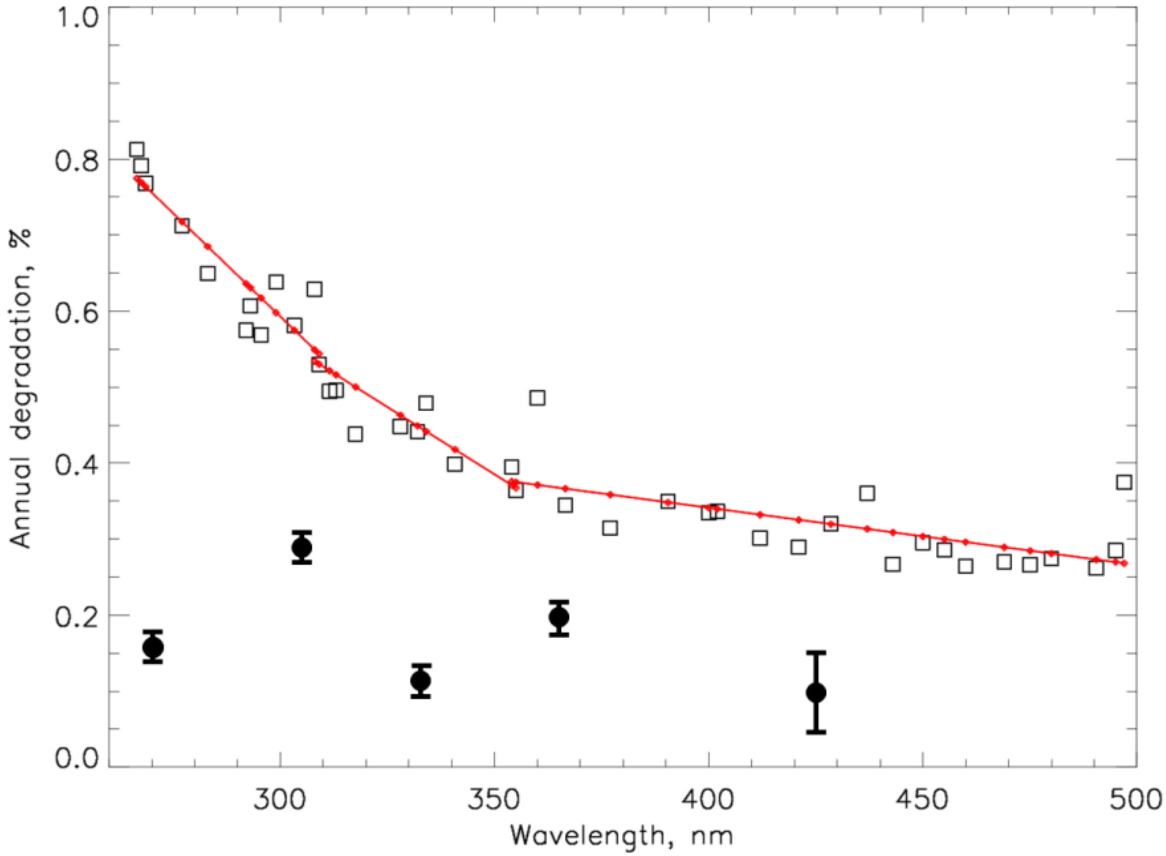


The GOME-2A operational (V14) retrieval



July 2007, similar (PCA) retrieval for GOME-2A and OMI





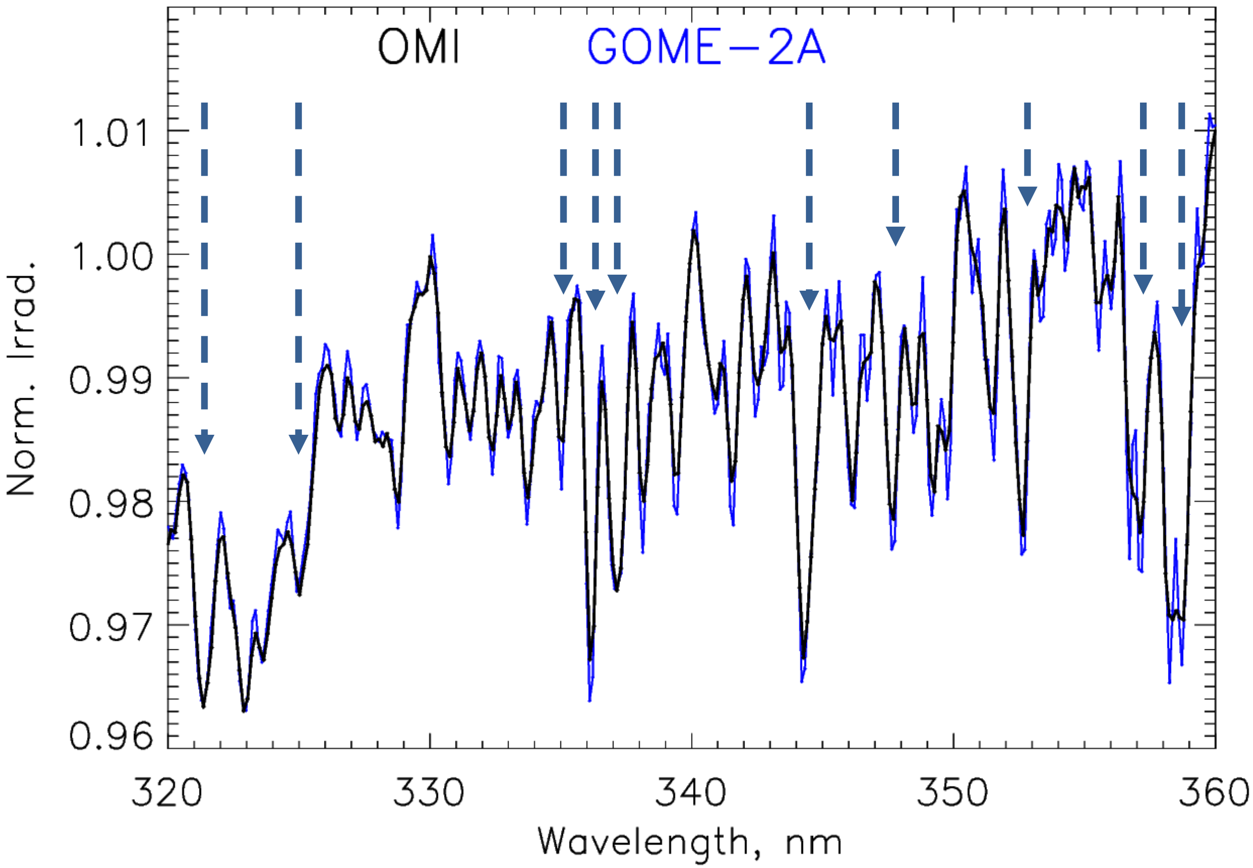
OMI:

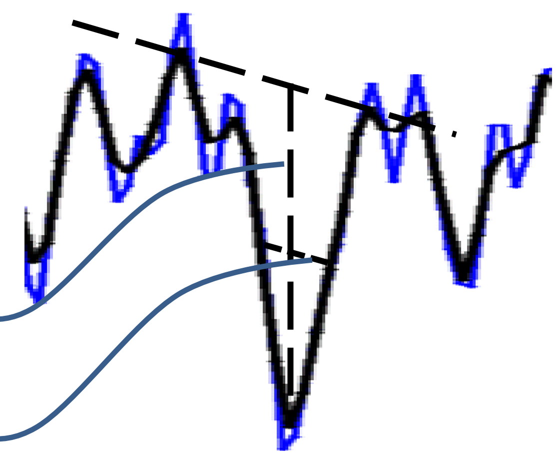
□ - Solar data

● - Earthshine

GOME-2A degradation (Munro et al. 2015) at 320-360 nm:

~60% btw. 2007 and 2014, wavelength-dependent



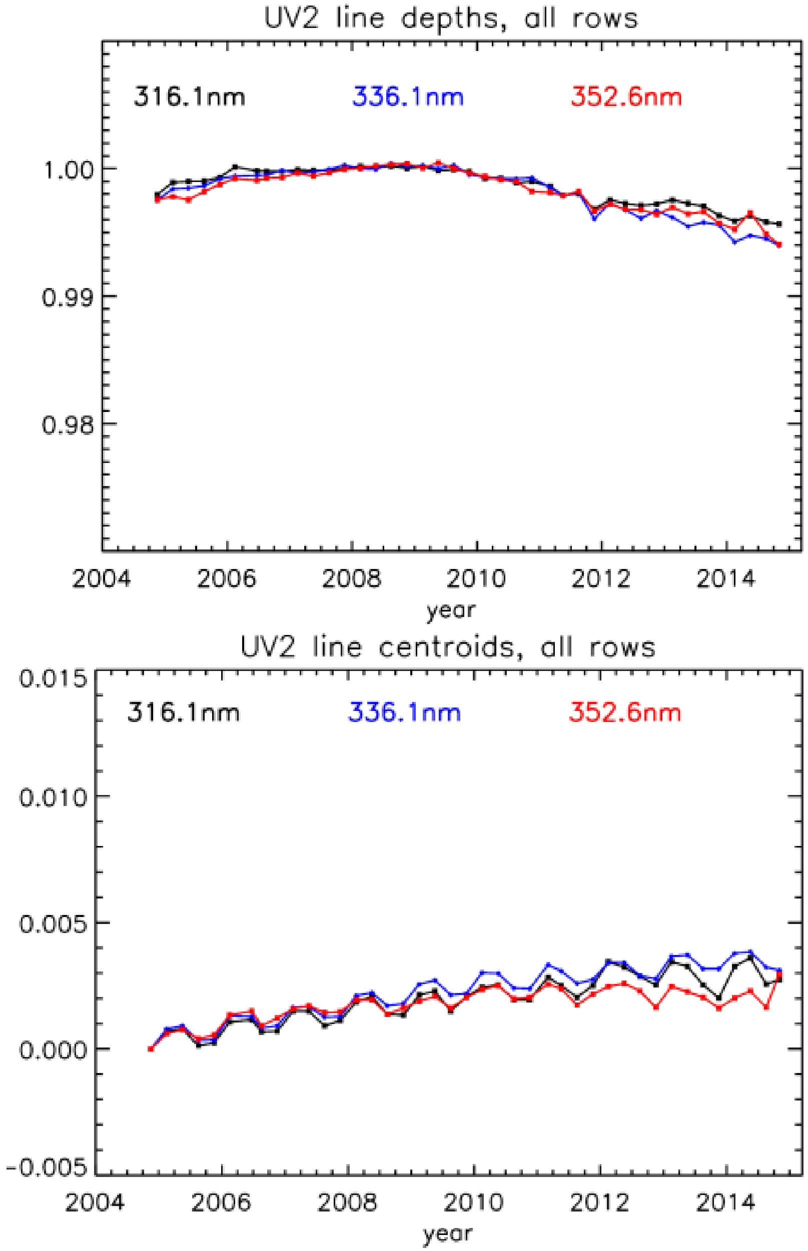


1. Line centroid:

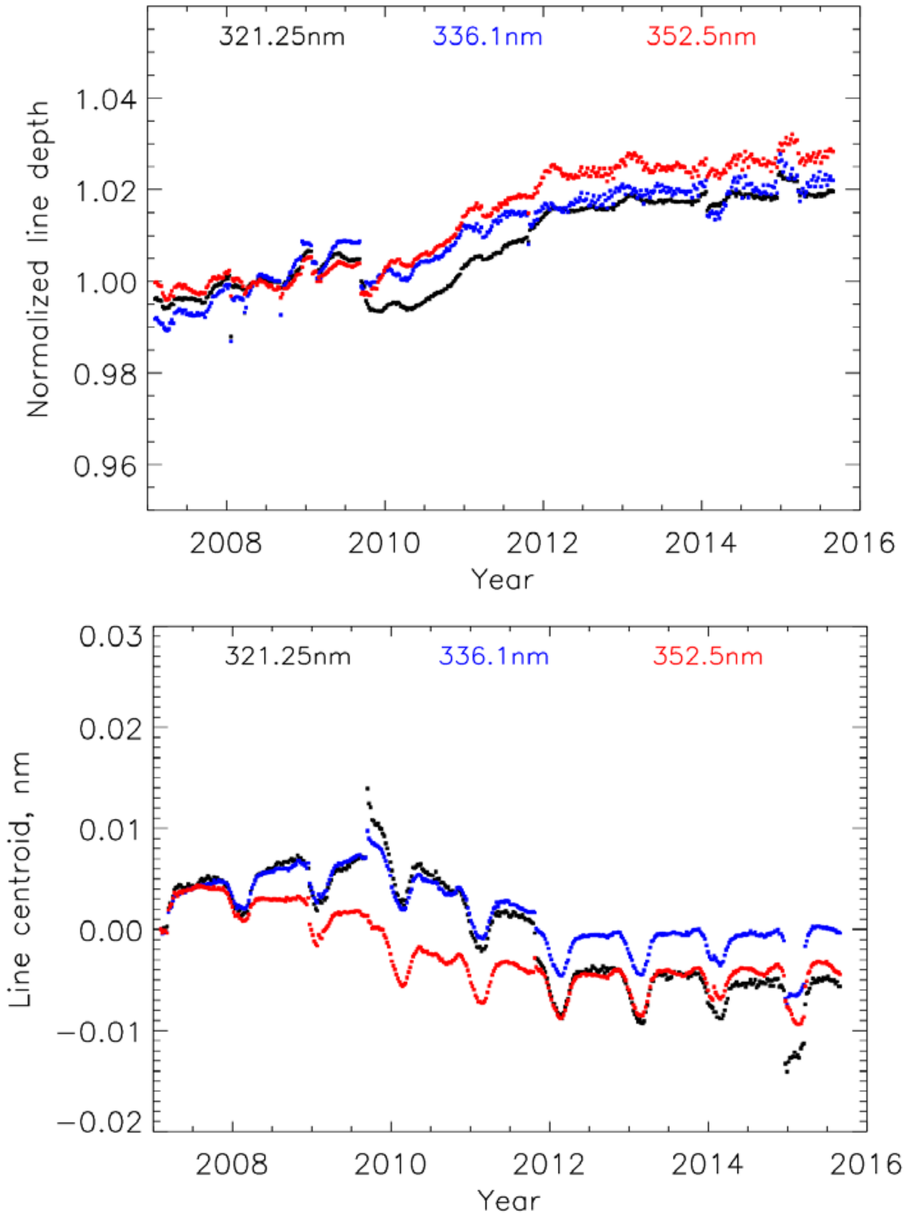
$$\sum \lambda_i I_i / \sum \lambda_i$$

2. Line depth

3. Full width at half maximum

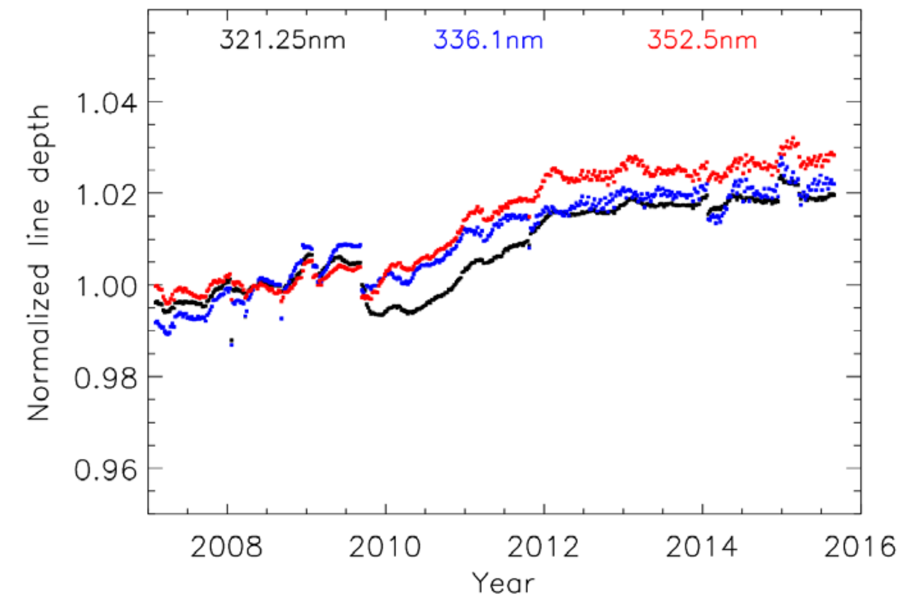


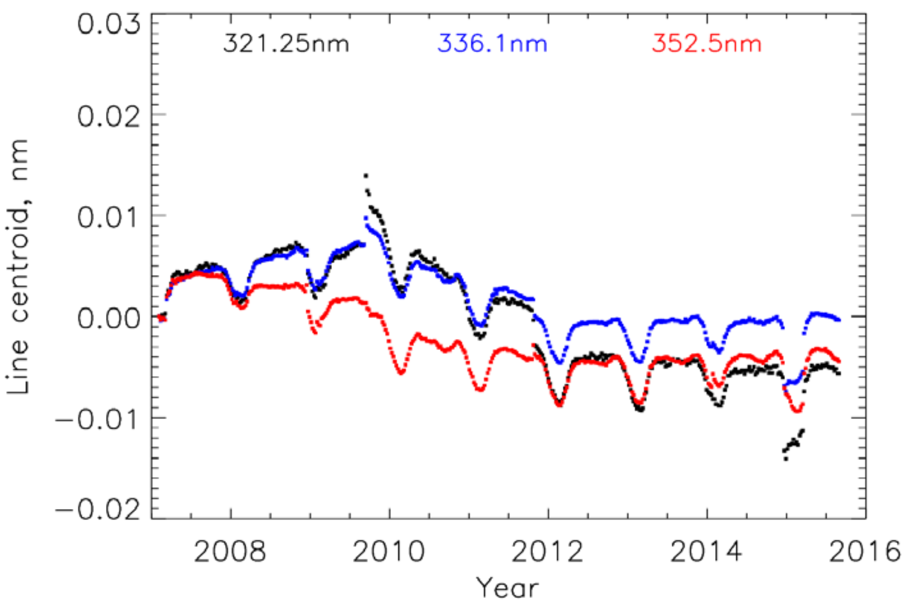
OMI: stable ITF (Beirle, 2016; Schenkeveld et al. 2017)



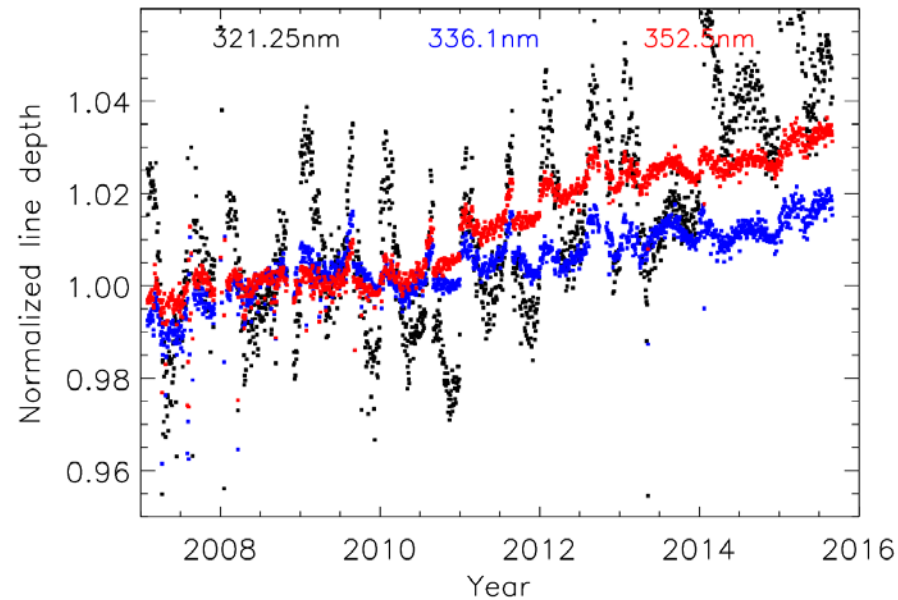
GOME-2A: variable ITF (Cai et al. 2012; De Smedt et al. 2012, Munro et al. 2015)

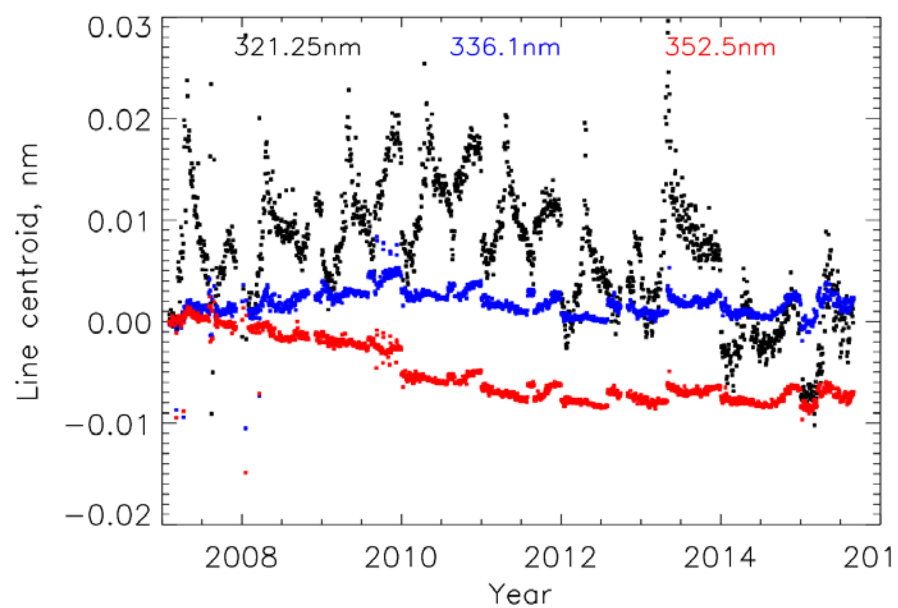
GOME-2; degradation-corrected irradiances



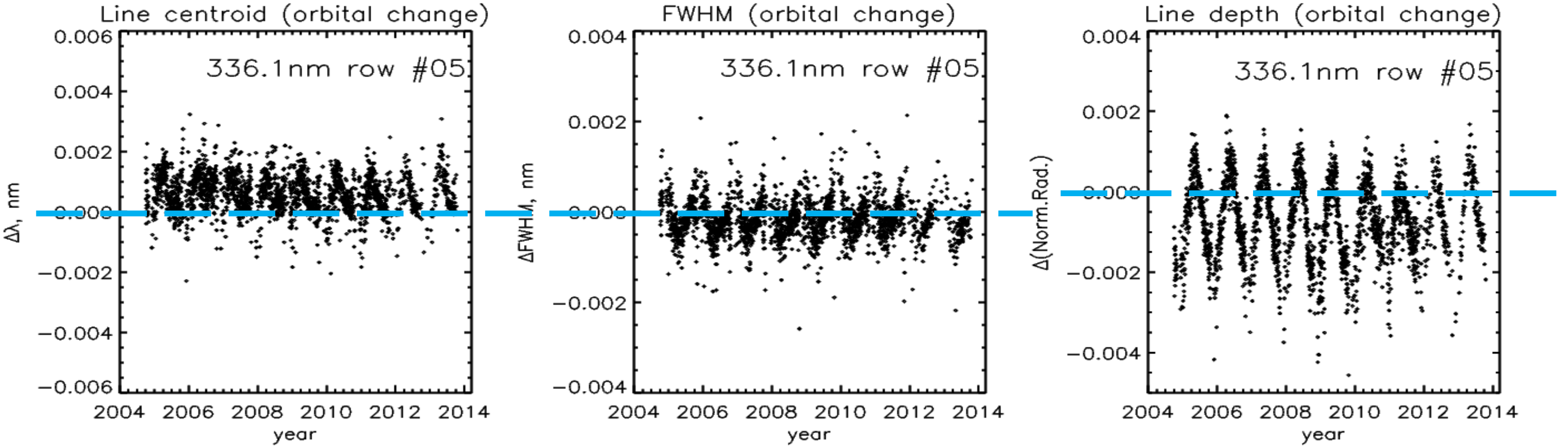


GOME-2; degradation-corrected radiances



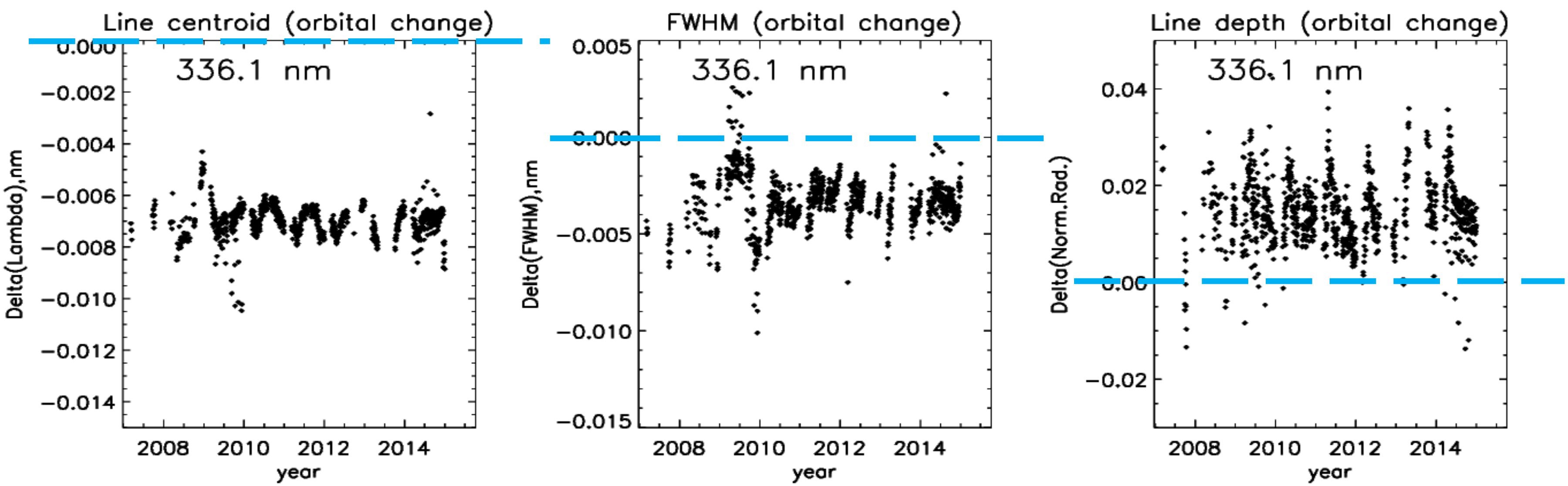


OMI



Line centroid (orbital change)
336.1nm row #05
Δλ, nm
year
FWHM (orbital change)
336.1nm row #05
ΔFWHM, nm
year
Line depth (orbital change)
336.1nm row #05
Δ(Norm.Rad.)
year

GOME-2A



Line centroid (orbital change)
336.1 nm
Delta(Lambda),nm
year
FWHM (orbital change)
336.1 nm
Delta(FWHM),nm
year
Line depth (orbital change)
336.1 nm
Delta(Norm.Rad.)
year

Challenges:

Spectral fitting:

- the long-term changes of the spectral instrument transfer function for GOME-2, with some Earthshine/Solar inconsistencies;

- the orbital (along-track) ITF changes in the GOME-2 data;

- the orbital (x-track) ITF variability is rather subtle, < 1%; it is more evident over the low-reflectance scenes. The current approach is not sensitive enough to characterize these ITF changes.

Spatial:

- descending/ascending orbits;
- different equator-crossing times;
- different footprints.

Path forward

Attempt to characterize changes in the instrument transfer function exploiting the PCA sensitivity to the Ring (RRS) spectrum, thus probably (??) deriving ITF from RRS.

Attempt to use, as a reference, the spatially- (viewing geometry) and time-dependent Earthshine radiances taken over clean and cloudy areas. [Eventually] addressing the orbital GOME-2A ITF changes.

Addressing the low-SCD bias in the PCA retrievals.

Bringing together the OMI and GOME-2A HCHO retrievals:

- comparison of the HCHO retrievals coming from the simultaneous nadir overpass events (to within ~15 min and +/- 0.15 degree; mostly circumpolar regions; ~few/day);
- match of the footprints (OMI – to-- GOME-2) and, if deemed important, spectral resolution (GOME-2 –to– OMI);
- quantifying the interference from aerosols and clouds.

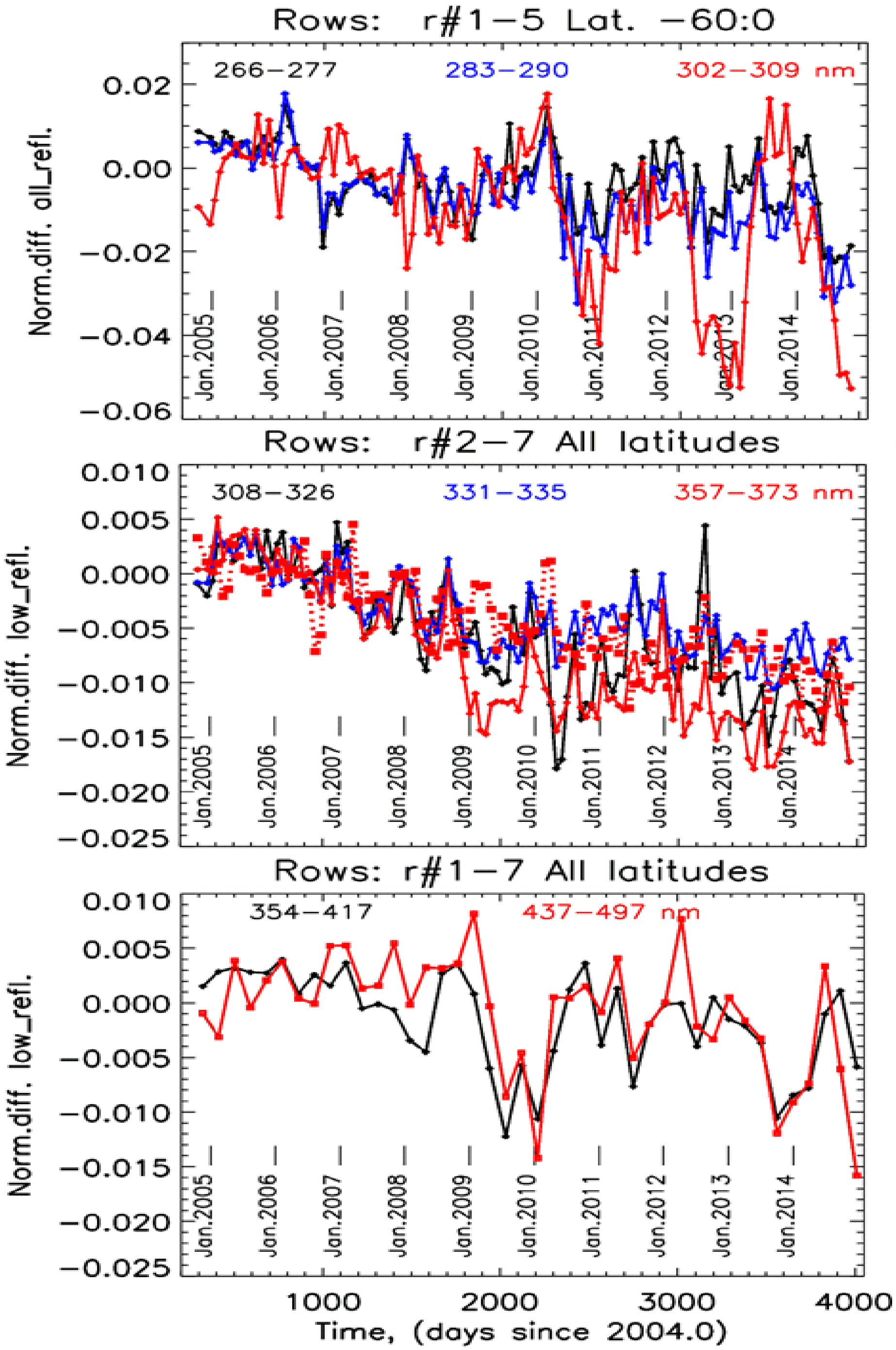
Partial support for this work comes from the NASA grant #NNX16AT07G

BACKUP

A set of n_v PCs ($v_{i,k}$, i = 1 … n_v representing the first n_v PCs, k = 1 … j, representing the j wavelengths in the spectral range) is introduced to account for various interferences and simultaneously estimate their coefficients (ω_i) and the vertical column density (VCD) of a trace gas (Ω_g). This is done by fitting the first n_v PCs along with the Jacobian of the target gas ($\frac{\partial N_k}{\partial \Omega_g}$) to the measured radiances:

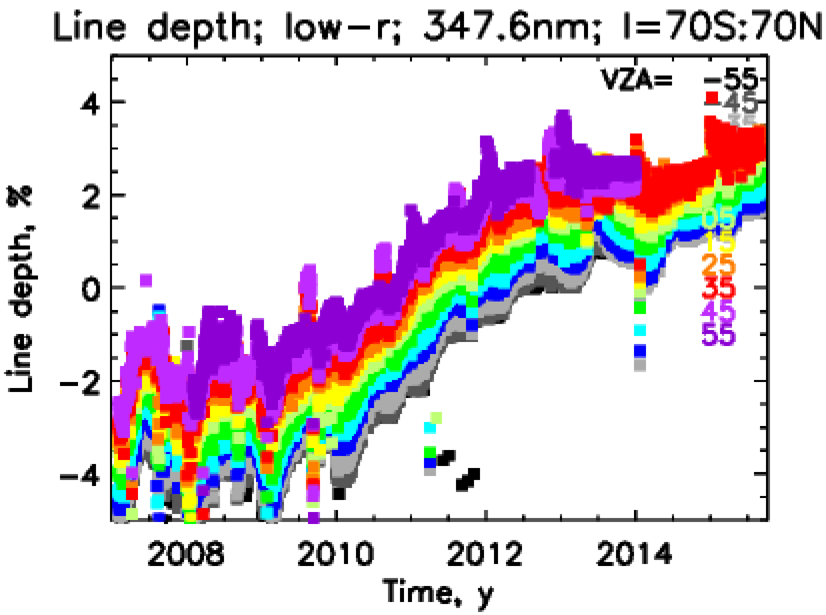
$$N_k(\omega, \Omega_g) = \sum_{i=1}^{n_v} \omega_i v_{i,k} + \Omega_g \frac{\partial N_k}{\partial \Omega_g}$$

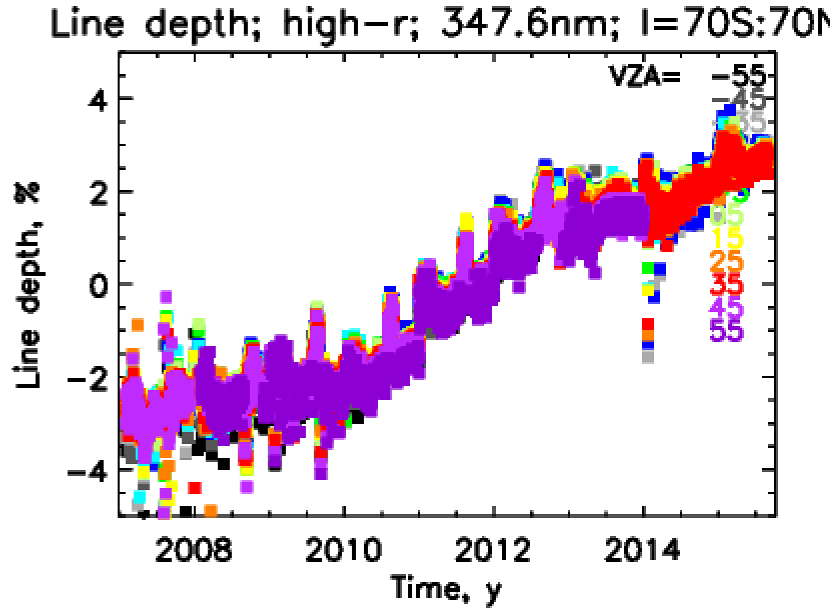
where N is the measured N value spectra for a given pixel, defined as $N = -100 \times log_{10}(I/I_0)$, with I and I_0 being the Earthshine radiances and solar irradiances at the top of the atmosphere, respectively.



OMI: open-water radiances

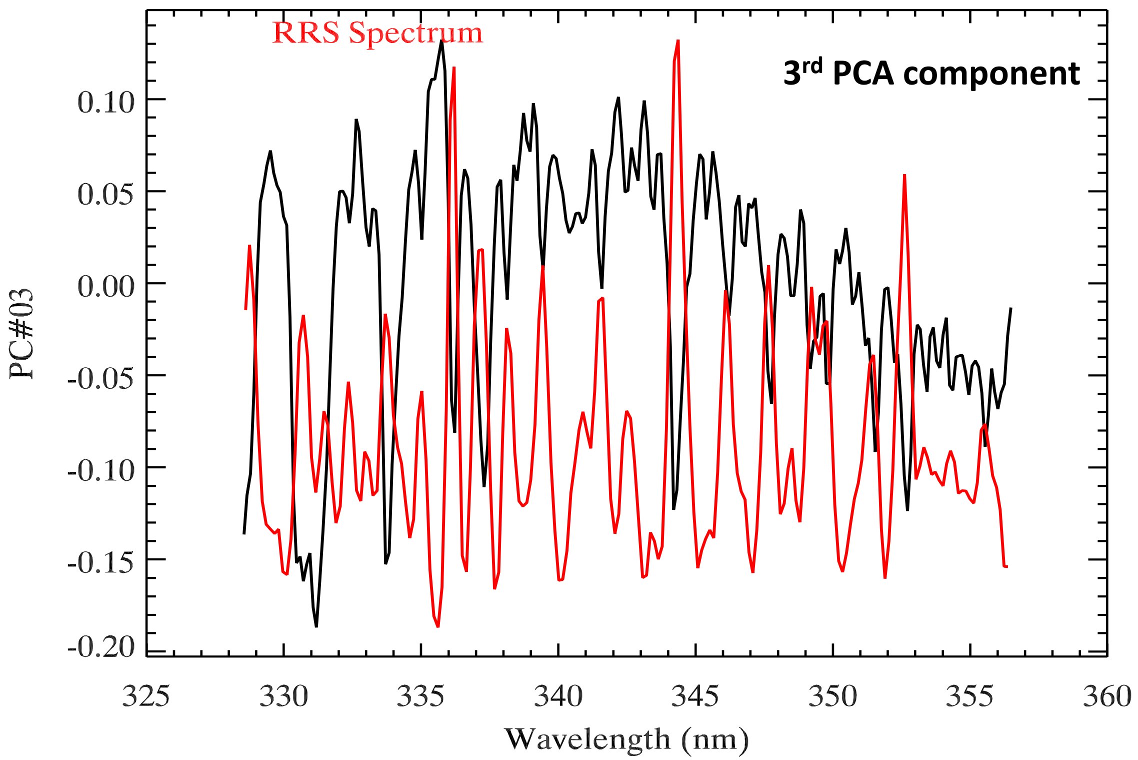
GOME-2; low (r<0.1) and high (r>0.3) reflectance scenes





Accounting for the ITF variability:

- **Using [time- and FOV-dependent] Earthshine (above-clouds) spectra for calibration**
- **Using the Ring spectrum (the corresponding PCA component) for assessment of the intra-orbit and x-track ITF changes in the GOME-2 data**



GOME-2A: orbit #09254, August 1, 2008