Development of SO_2 retrieval algorithm for the GEMS

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01. Introduction

Sulfur dioxide (SO_2) retrieval algorithms

Author(Year)	Algorithm type	Operational satellite
Krotko et al. (2006)	**Band Residual Difference(BRD)**	OMI (PBL)
Yang et al. (2007)	**Linear Fitting(LF)**	OMI (Volcano)
Lee et al. (2009)	**Weight Function DOAS(WF DOAS)**	-
M.Rix et al. (2012)	**Differential Optical Absorption Spectroscopy(DOAS)**	GOME – 2, SCIAMACHY
Li et al. (2013)	**Principal Component Analysis**	OMI(PBL, Volcano)
N.Theys et al. (2015)	**Multi window DOAS**	Tropomi(2017)
N.Theys et al. (2017)		

01. Introduction

Principle component analysis (PCA) algorithm

Li et al., 2013

PCA for SO_2 retrieval

SO_2 VCD retrieval

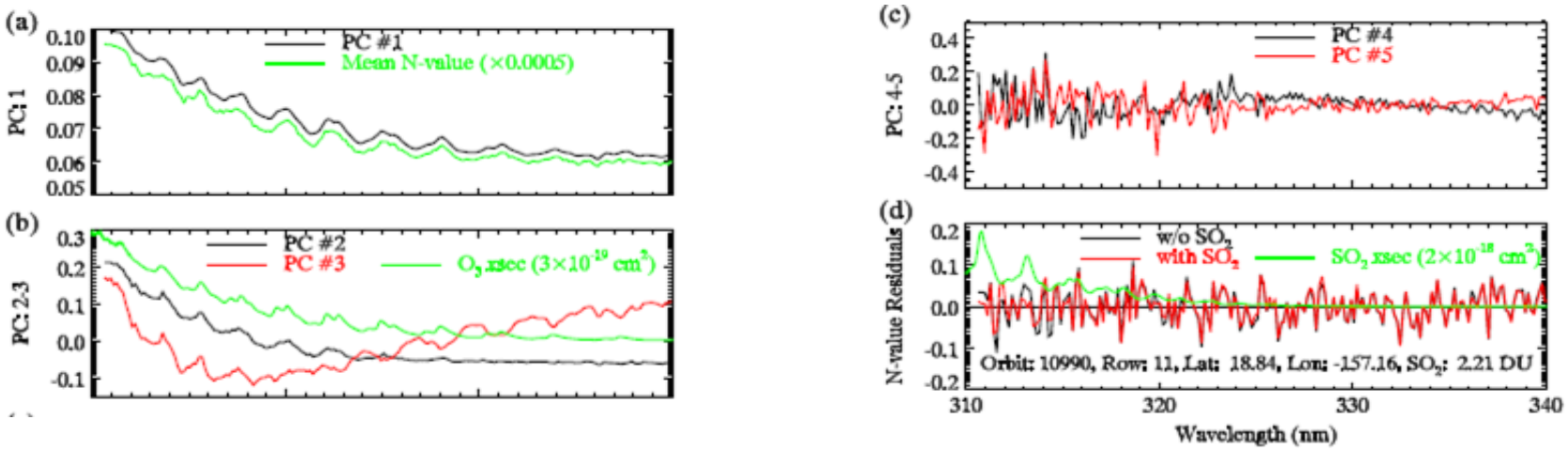
$$N(\omega, \Omega_{SO_2}) = \sum_{i=1}^{n_v} \omega_i v_i + \Omega_{SO_2} \frac{\partial N}{\partial \Omega_{SO_2}}$$

N : *N value spectrum* ($N(\lambda) = -100 * \log_{10} I(\lambda)/I_0(\lambda)$)
Ω_{SO2} : *VCD of* SO_2
ω_i : *the coefficient of PCs*
v : *PCs*
n_v: *the number of PCs*
$\partial N / \partial \Omega_{SO2}$: *the sensitivity of the radiances to the* SO_2 *column* (SO_2 *Jacobians*)

SO_2 SCD retrieval

$$N = \sum_{i=1}^{n_v} \omega_i v_i + S_{SO2} \sigma_{SO2}$$

N : normalized radiance
S : slant column density(SCD)
σ : cross section



<The retrieved PCs from the analysis>

01. Introduction

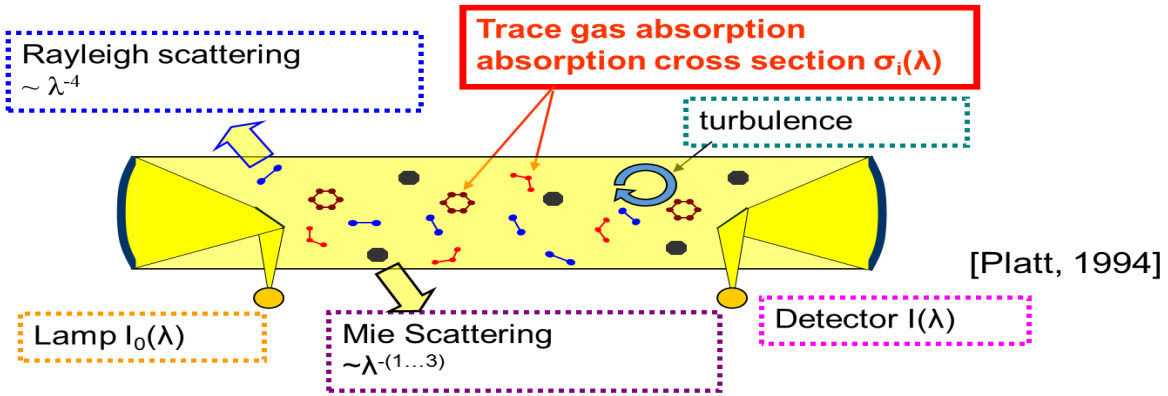
DOAS Principle

Remove by high-pass filtering

Lambert-Beer's Law:

$$I(\lambda) = I_0(\lambda) \cdot e^{-[\Sigma \sigma'_i(\lambda) \cdot c_i \cdot L + (\sigma_{bi} \cdot c_i + \varepsilon_{Ray}(\lambda) + \varepsilon_{Mie}(\lambda)) \cdot L] \cdot T(\lambda))}$$

narrow- *wide band extinction*



[Platt, 1994]

I_0 : light intensity of light source

I : light intensity of detector

λ : wavelength

σ_i : absorption cross section of trace gas *i*

ci : concentration of trace gas i

L : light path

T : turbulence

εRay : Rayleigh scattering

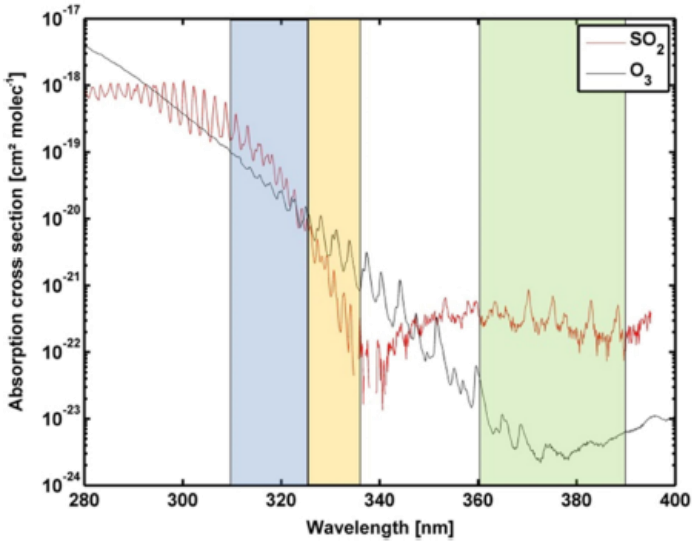
ε Mie : Mie scattering

Multi Window DOAS Algorithm

Theys et al., 2015

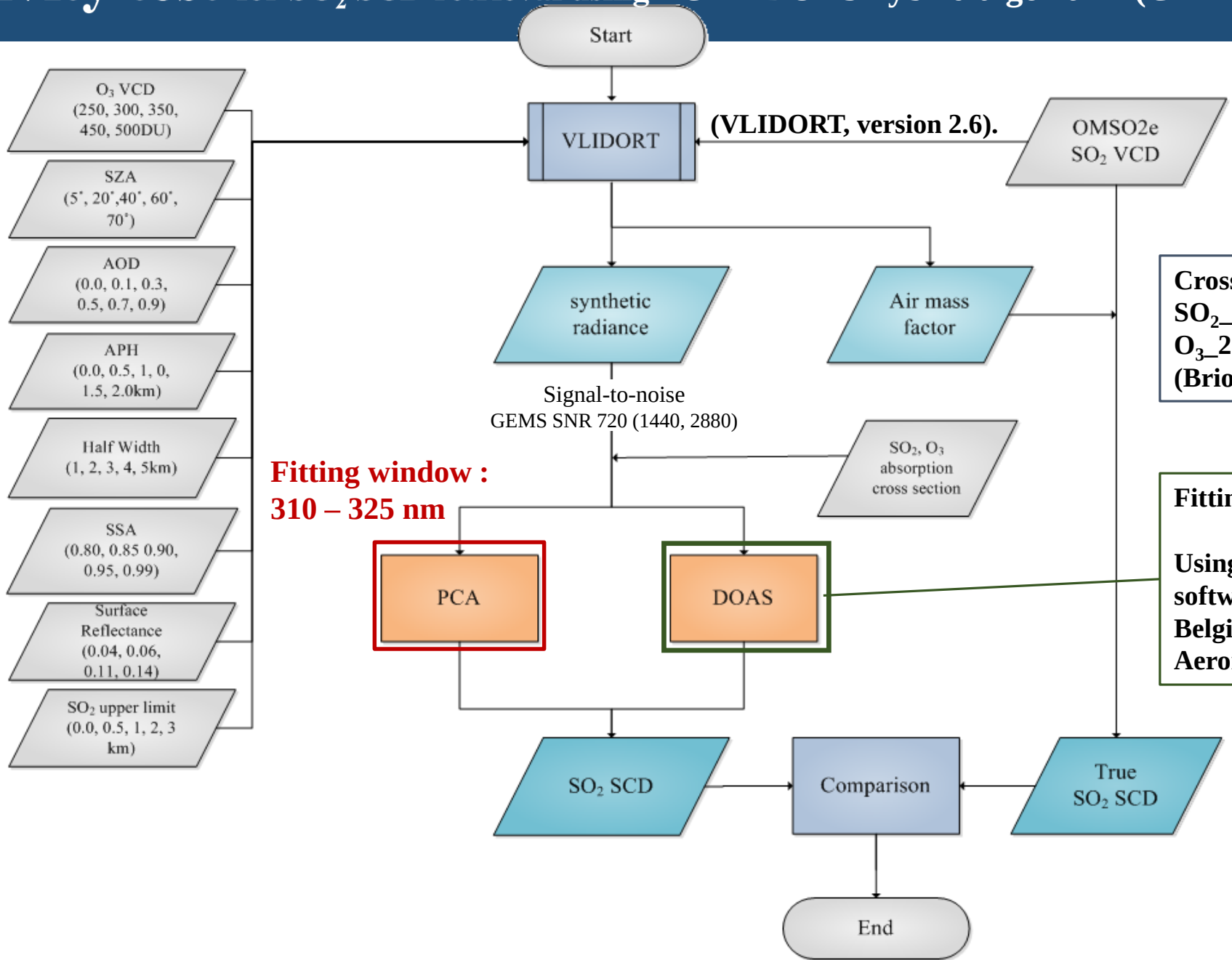
Window number	w1	w2	w3
Wavelength range	312–326 nm	325–335 nm	360–390 nm
Derived slant column	S1	S2	S3
Application	Baseline for every pixel	S1 > 15 DU and S2 > S1	S2 > 250 DU and S3 > S2

<Criteria for selecting alternative fitting windows.>



<Absorption cross sections of SO_2 and O_3. The blue, yellow and green boxes delimit the three SO_2 fitting windows 312–326, 325–335 and 360–390 nm, respectively.>

02 Sensitivity test for SO_2 SCD retrieval using PCA – DOAS hybrid algorithm (GEMS SO_2 algorithm)



Cross section :
SO_2_298K (BIRA-IASB)
O_3_218K with I0 correction (Brion et al., 1998)

Fitting window : 310 – 326 nm

Using QDOAS spectral fitting software developed at the Royal Belgian institute for Space Aeronomy (BIRA-IASB).

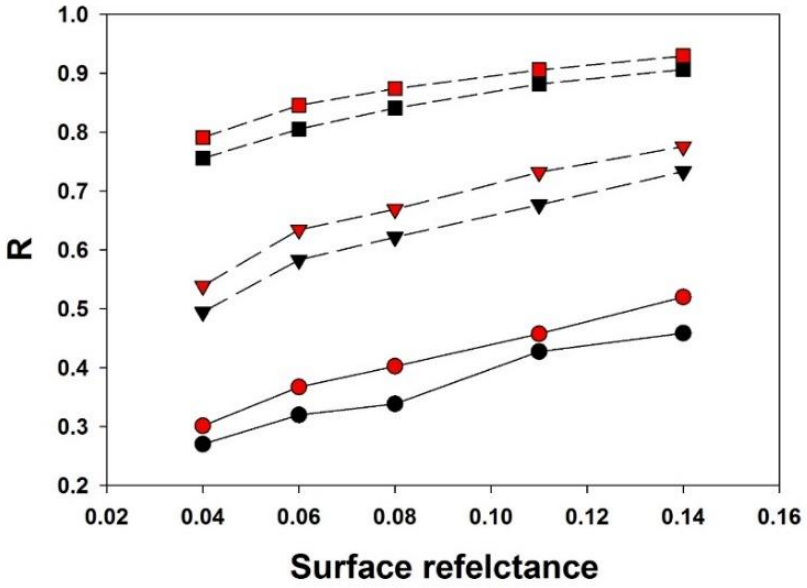
02 Sensitivity test

Comparison between true SO_2 SCDs and those retrieved (Correlation)

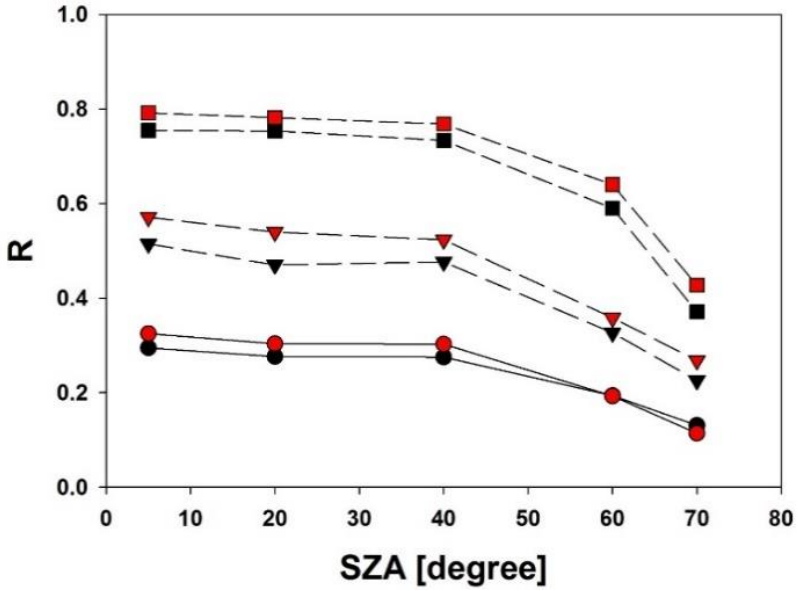
Using DOAS
Using PCA

= SNR 720
= SNR 1440
= SNR 2880

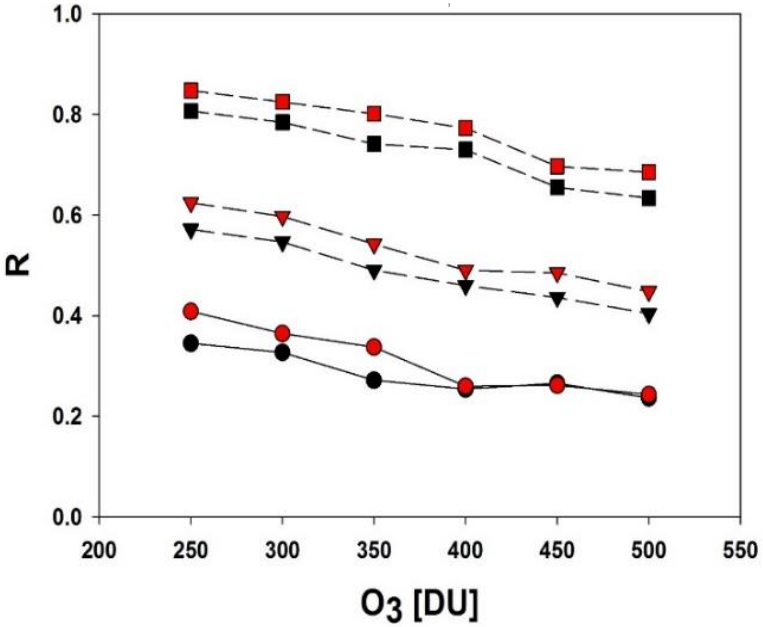
(a) Surface reflectance



(b) Solar zenith angle



(c) Ozone

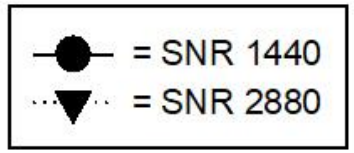


(Yang et al., to be submitted)

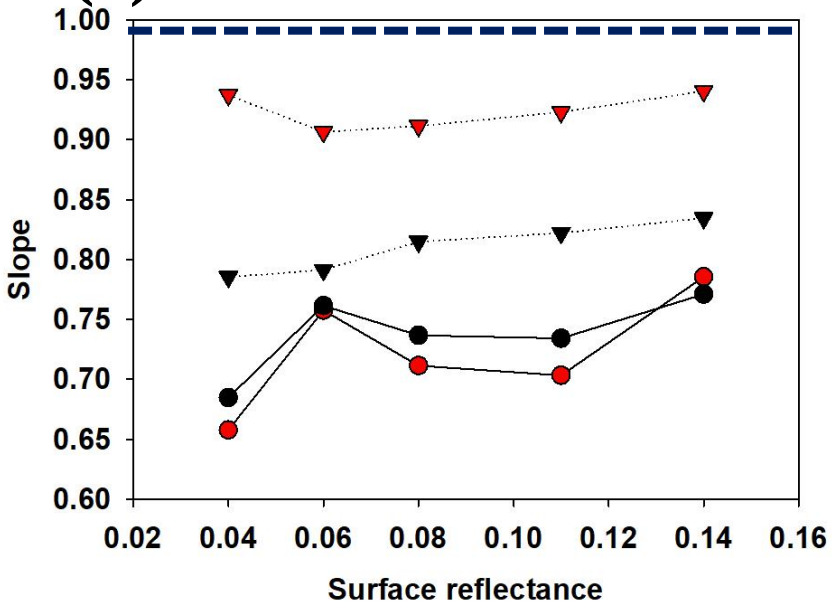
02 Sensitivity test

Comparison between true SO_2 SCDs and those retrieved (Slope)

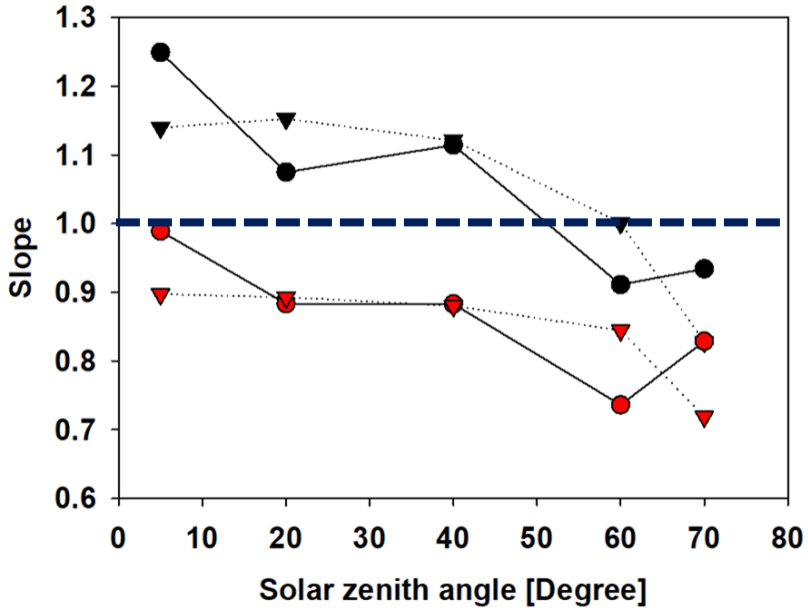
Using DOAS
Using PCA



(a) Surface reflectance

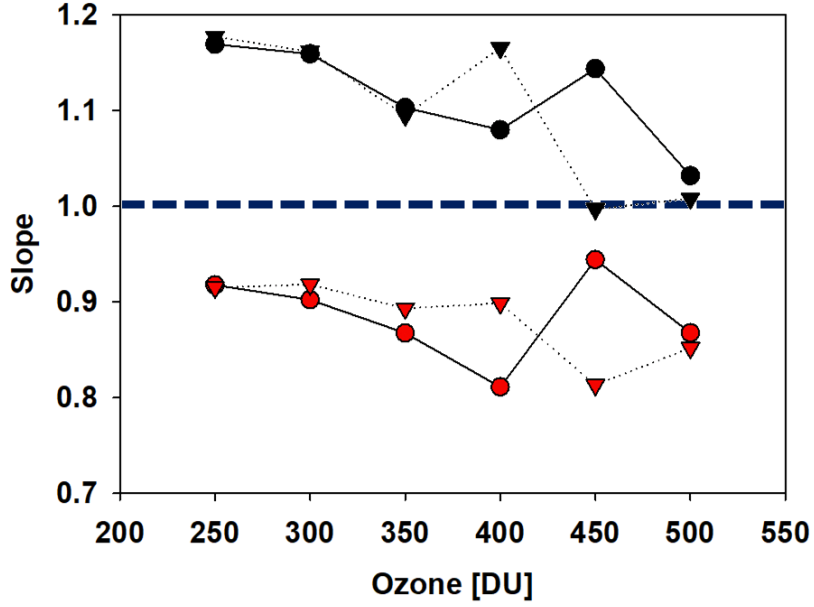


(b) Solar zenith angle



(Retrieved negative values included)

(c) Ozone



(Retrieved negative values included)

(Yang et al., to be submitted)

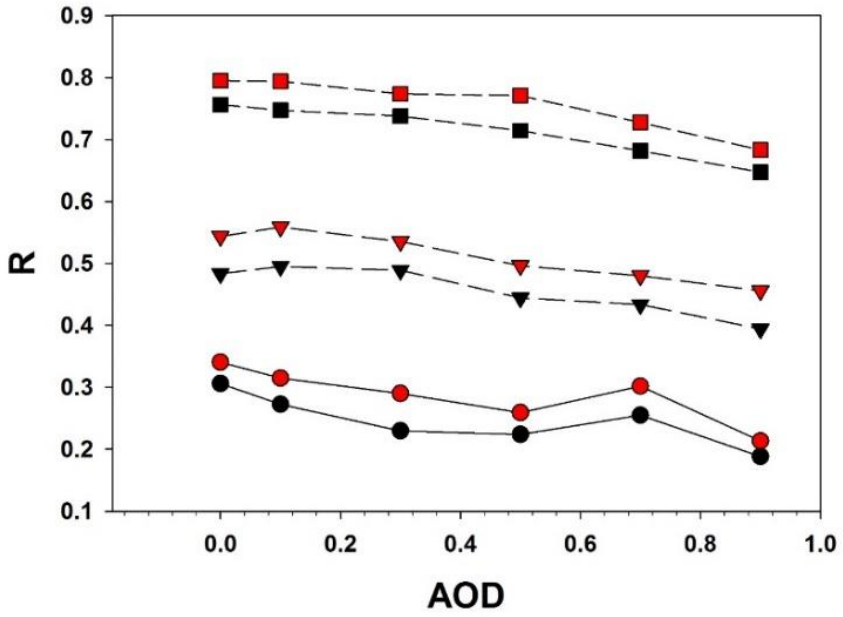
02 Sensitivity test

Comparison between true SO_2 SCDs and those retrieved (Correlation)

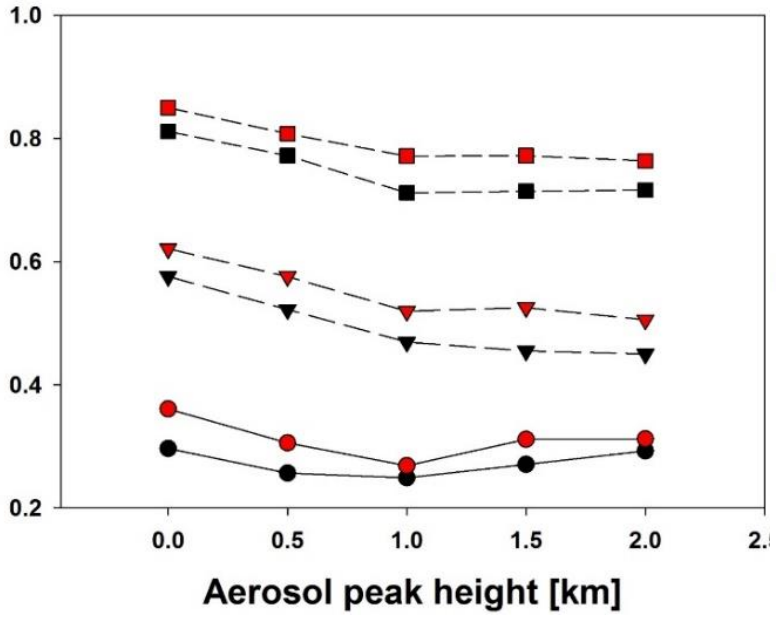
Using DOAS
Using PCA

= SNR 720
= SNR 1440
= SNR 2880

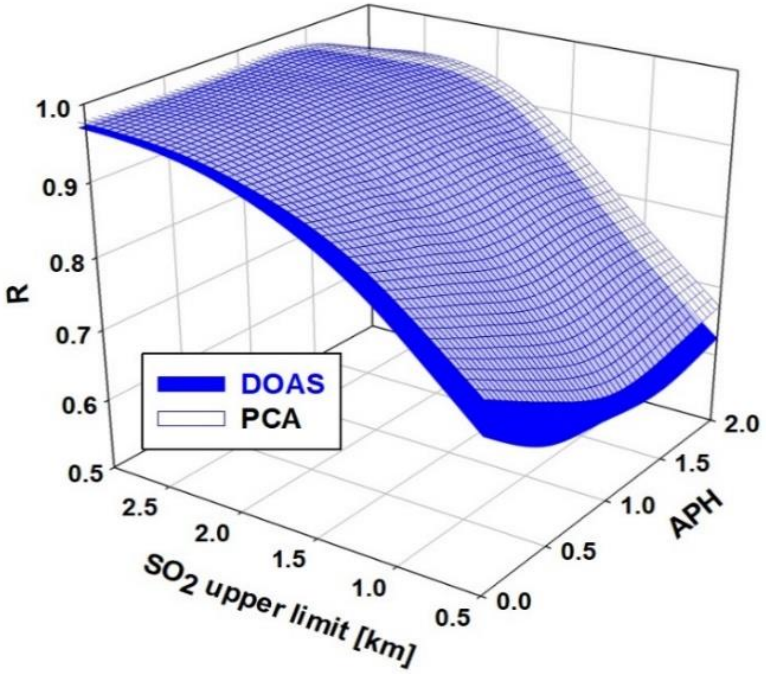
(d) Aerosol optical depth



(e) Aerosol peak height



(f) SO_2 upper limit & Aerosol peak height (SNR 2880)



(Yang et al., to be submitted)

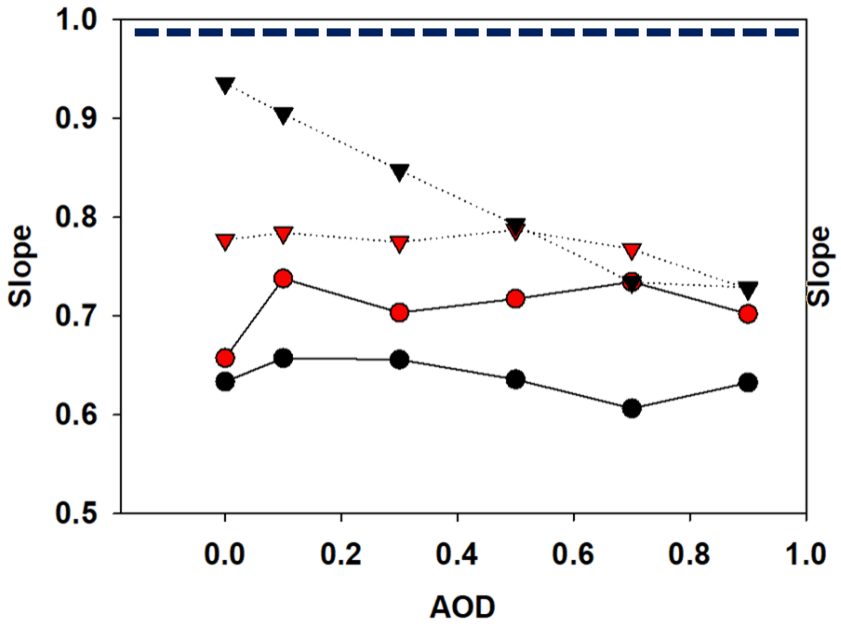
02 Sensitivity test

Comparison between true SO_2 SCDs and those retrieved (Slope)

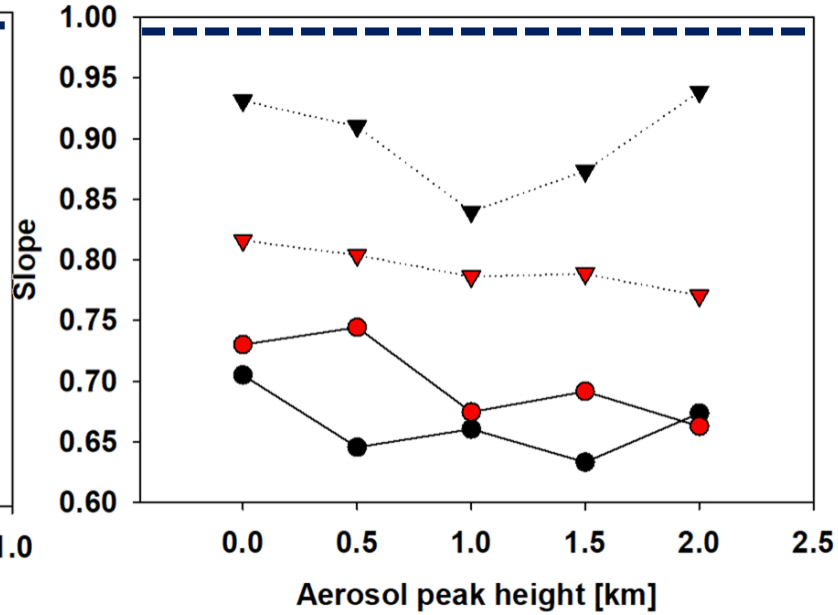
Using DOAS
Using PCA

= SNR 1440
= SNR 2880

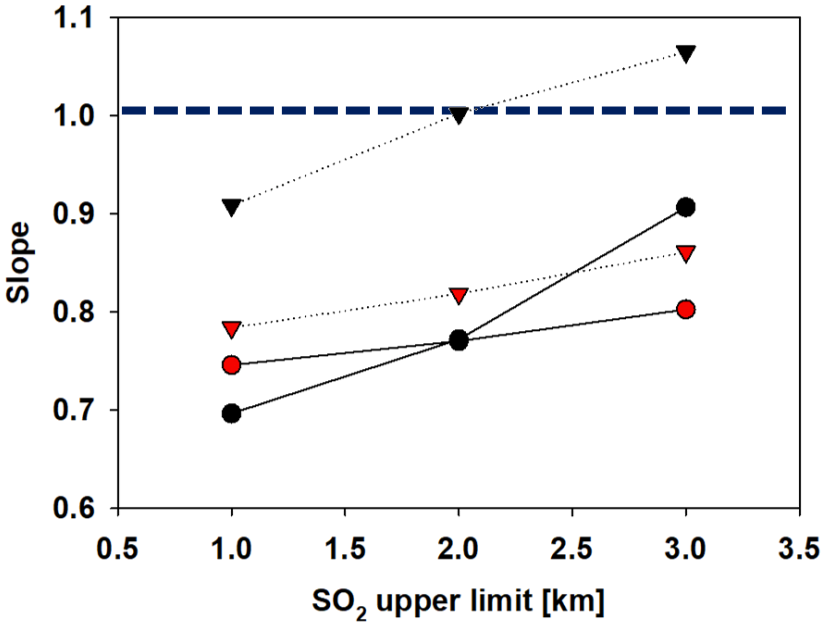
(d) Aerosol optical depth



(b) Aerosol peak height



(f) SO_2 upper limit



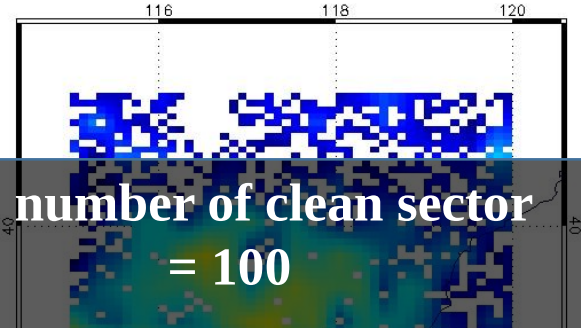
(Yang et al., to be submitted)

02 Sensitivity test

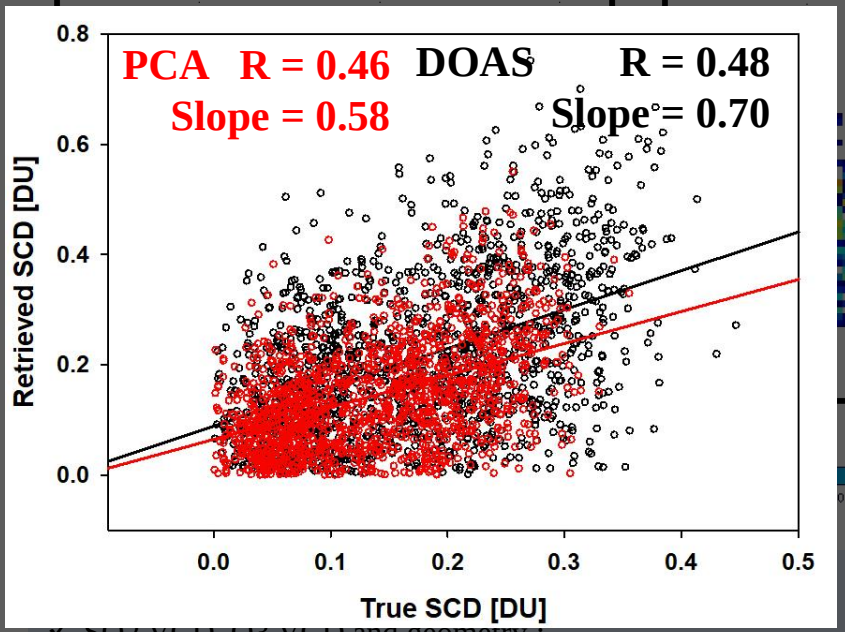
Effect on the number of clean sector pixels of PCA

- Using synthetic radiance (SNR 1440)

True SCD (DOAS)

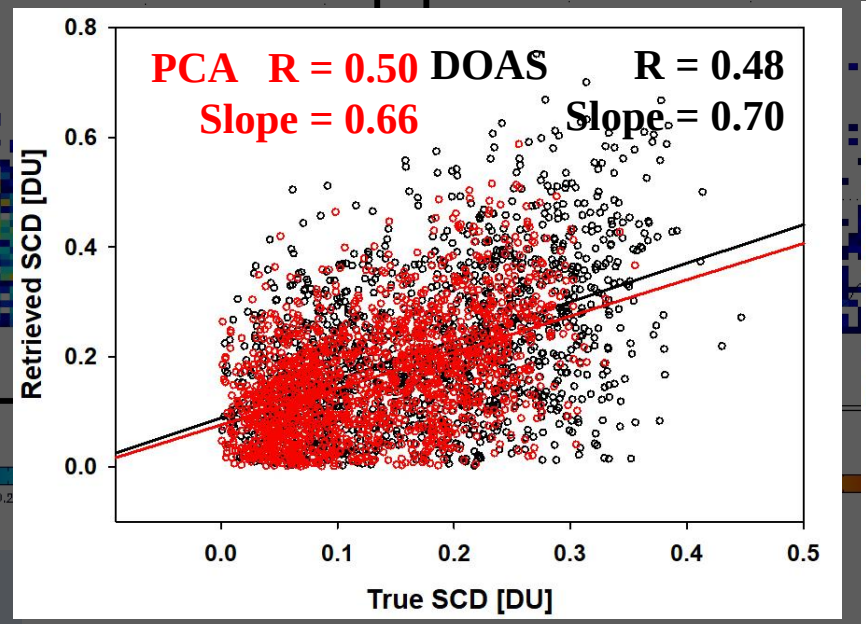


The number of clean sector = 50



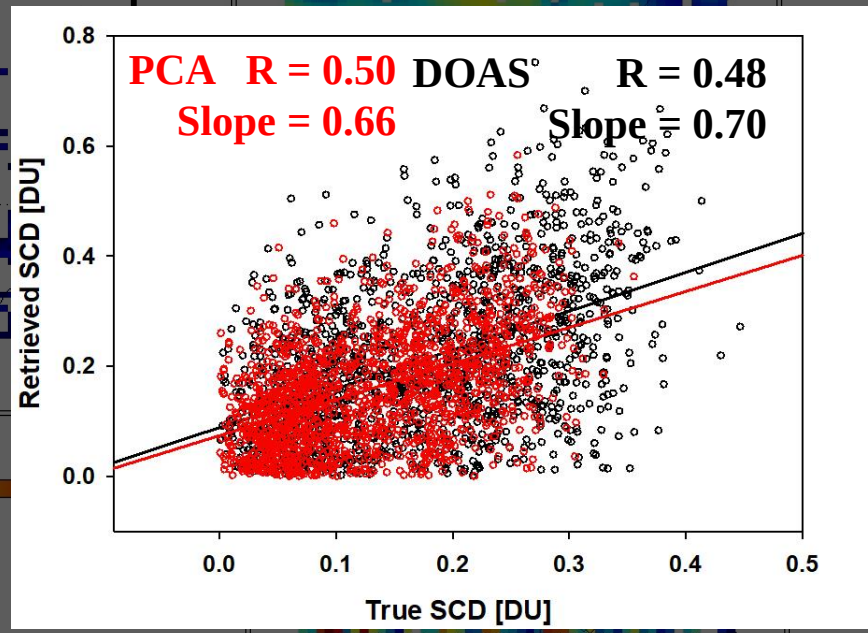
The number of clean sector = 50 (PCA)

The number of clean sector = 80



The number of clean sector = 80 (PCA)

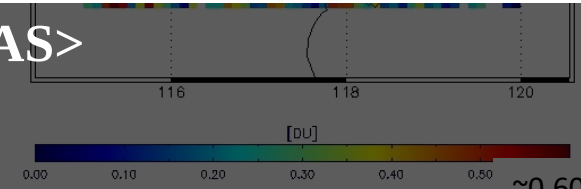
The number of clean sector = 100



<Comparison of Retrieved SO_2 SCDs using PCA and DOAS>

✓ SO2 VCD, O3 VCD and geometry :
Monthly OMI SO2 PBL VCD (L3 OMSO2e)
✓ AOD : MODIS monthly AOD (MYD04_3K)
✓ Surface reflectance : OMI climatology LER(L3 OMLER)
✓ SO2 profile shape : 1km box profile

<Map of SO_2 SCDs for June 2006 over Beijing>



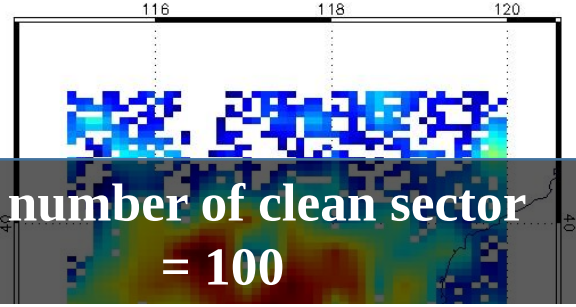
~0.60

02 Sensitivity test

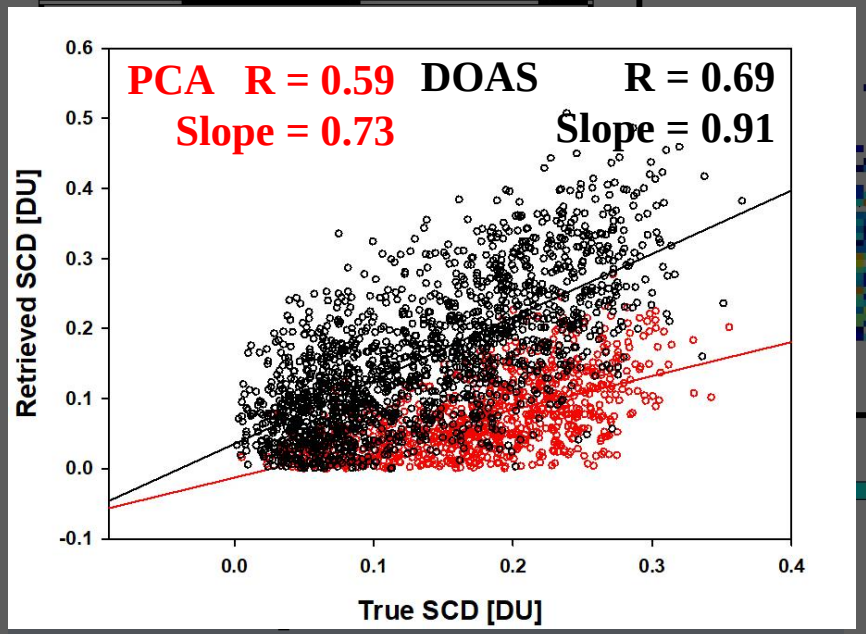
Effect on the number of clean sector pixels of PCA

- Using synthetic radiance (SNR 2880)

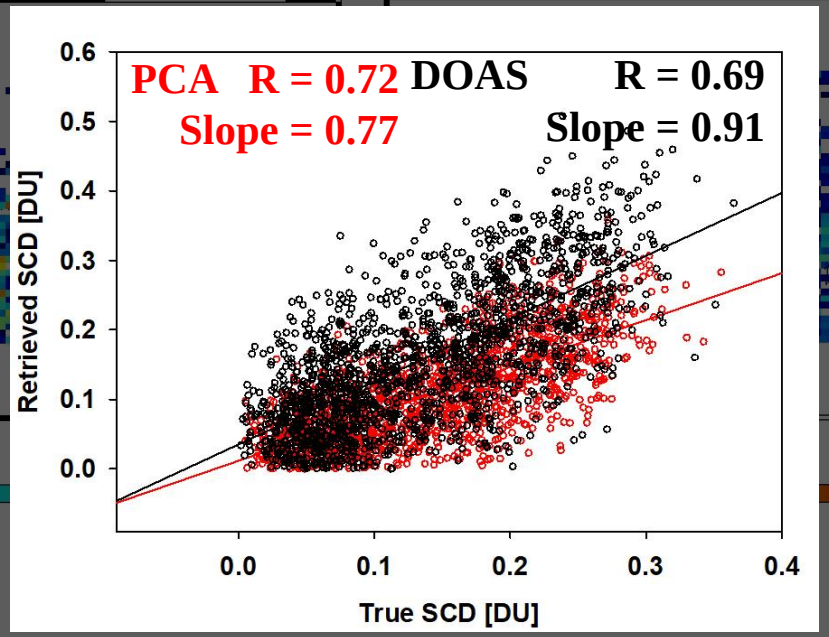
True SCD (DOAS)



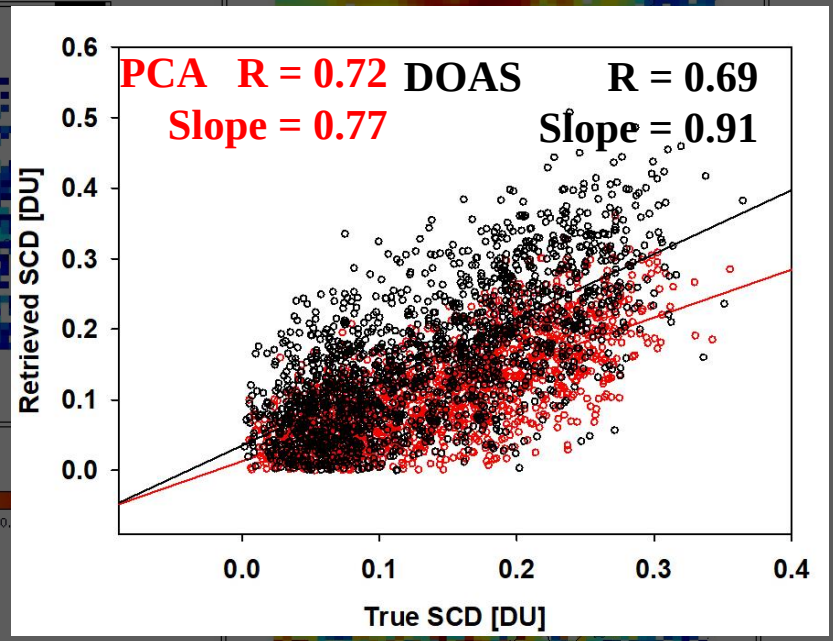
The number of clean sector = 50



The number of clean sector = 80



The number of clean sector = 100



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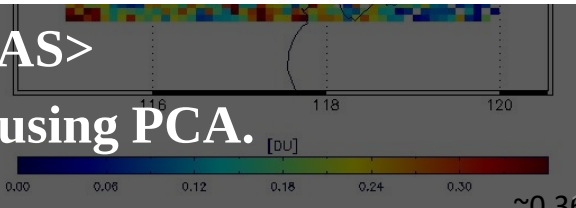

The higher the number of clean sector pixels, the better the correlation using PCA.

But the slope of the result using DOAS is better than PCA

~0.35

04 Summary and conclusion

- Conclusion

✓ We developed PCA – DOAS hybrid algorithm. (GEMS SO_2 algorithm)

✓ We found that SO_2 SCD is greatly influenced by aerosol, O_3 VCD, and solar zenith angle, and specially PCA algorithm have an effect of the number of the clean sector pixels.

✓ When we retrieved SO_2 SCD from the synthetic data using GEMS SO_2 algorithm, we found that the performance of DOAS algorithm in the region with fewer clean pixels is better than PCA.

- Future plan

✓ We will decide the clean sector of GEMS range and the specific threshold of the number of clean sector pixels for GEMS SO_2 algorithm, which determine One to use among the two algorithms.

✓ We will validate to find offset and slope using ground-based measurement data.

✓ We need to validate GEMS SO_2 algorithm using ground-based measurement data in Europe and Asia such as MAX-DOAS and Pandora network.

THANK YOU