

We present the inter-comparison and validation of a combined principle component analysis and neural network retrieval algorithm called *Full-Physics Inverse Learning Machine algorithm* [Hedelt et al., 2019]. The algorithm performs an extremely fast, ~3ms per S5P/TROPOMI pixel, yet accurate (<2km) SO₂ layer height [LH] retrieval. The algorithm was optimized and validated in the framework of the <u>ESA Sentinel-5p Innovations project (S5P+I)</u> and is performing S5P SO₂ LH retrievals in a semi-operational near-real time environment. Selected volcanic cases sensed by S5P/TROPOMI, OMI/Aura and GOME2/Metop and UV observations are inter-compared and validated against collocated IASI/Metop SO₂ plume and CALIOP/CALIPSO ash layer heights.

Raikoke eruption | Inter-satellite comparisons

TROPOMI/S5P vs IASI ULB/LATMOS



Collocations between S5P and IASI ULB/LATMOS SO₂ LHs for the Raikoke 2019 eruption. S5P SO₂ LHs associated with a qa>0.5, an LHflag < 16 and SO₂ load > 20 D.U. were gridded onto a 0.1x0.1 grid at 6h



GOME2/MetOpA vs IASI ULB/LATMOS

GOME2A LH vs ULB_LATMOS Raikoke



TROPOMI/S5P vs OMI/Aura



increments.

Mean S5P LH at 10±3km, mean IASI LH at 10±1km, mean difference at -0.2±3km for a total of 14286 collocated pixels.

Collocations between S5P and

OMI/Aura SO₂ LHs for June 23, 24

and 25, 2019. S5P SO₂ LHs

associated with a qa>0.5, an Lhflag

< 16 and SO₂ load > 20 D.U. were

gridded onto a 0.1x0.1 grid at 2h

increments. Mean S5P LH at

9±2km, mean OMI LH at 9.5±2km,

mean difference at 0.6±3km for a

total of 934 collocated pixels.

0.25x0.25 grid at 2h increments. ² Mean GOME2 LH at 8.7±4.5km, mean IASI LH at 10±1km, mean difference at 1.1±4.6km for a total of 1087 collocated pixels.

TROPOMI/S5P vs GOME2/MetOpA





Raikoke eruption | Comparisons to CALIOP/Calipso



between the S5P SO₂ and the CALIPSO ash LH.



Histogram representation of the differences between

Scatter plot between S5P SO₂ and CALIPSO ash LHs. Raikoke, all eruptive days, June 2019.

S5P SO₂ and CALIPSO ash LHs for pixels of seven days of the Raikoke June 2019 eruption with a **median of ~3km** and a **mean of -2.4±1.7km**.

Taal, Nishinoshima, La Soufrière & Raikoke Eruptions | Daily mean comparisons of the S5P SO₂ LH product



Scatter plot between daily mean S5P and IASI ULB/LATMOS daily mean SO₂ LHs. Nearly 20 days belong to the Raikoke eruptive period, and the rest to the Taal, Nishinoshima and La Soufrière eruptions. The mean SO₂ LHs follow quite closely a straight line, with slope of ~1 and y-intercept of ~0.8km, and a satisfactory correlation coefficient of 0.73. Scatter plot between daily mean S5P SO₂ and CALIPSO ash LHs. 7 days belong nearly to the Raikoke eruptive period, and the remainder 2 days the to Nishinoshima and La Soufrière eruptions. The comparison is very promising, with a slope close to 0.95, y-intercept of ~1 km and correlation coefficient of 0.86.



S5P Data available upon request from Pascal Hedelt | Pascal.Hedelt@dlr.de

RELEVANT PUBLICATIONS PROJECT WEBPAGES Hedelt, P., et al., Sulfur dioxide layer height retrieval from Sentinel-5 Precursor/TROPOMI using FP_ILM, Atmos. Meas. Tech., Sentinel-5p Innovation | <u>https://eo4society.esa.int/tag/sentinel-5p-innovation/</u> https://doi.org/10.5194/amt-12-5503-2019, 2019. Sentinel-5p Innovation - SO₂ Layer Height Project | <u>https://atmos.eoc.dlr.de/so2-lh/</u> Fedkin, et al., Volcanic SO₂ effective layer height retrieval for the Ozone Monitoring Instrument (OMI) using a machine-learning approach, Automated S5P volcanic eruptions tweets | https://twitter.com/DlrSo2 Atmos. Meas. Tech., <u>https://doi.org/10.5194/amt-14-3673-2021</u>, 2021. **PROJECT DOCUMENTS** Koukouli, M.E., et al., Volcanic SO₂ Layer Height by TROPOMI/S5P; validation against IASI/MetOp and CALIOP/CALIPSO observations, **Algorithm Theoretical Baseline Description** v4.0 (ATBD) submitted to Atmos. Chem. Phys., 2021. see Documentation and https://doi.org/10.5281/zenodo.5118540 Verification Report v2.0 (VR) is available, **ACKNOWLEDGMENTS** see <u>Documentation</u> and https://doi.org/10.5281/zenodo.5118558 This validation was performed within the Sentinel-5p Innovation SO₂ Layer Height Project. Results presented in this work have been Auxiliary User data Manual v2.0 (AUM2) is available, see Documentation produced using the AUTH High Performance Computing Infrastructure and Resources. The authors would like to acknowledge the

support provided by the AUTH IT Center throughout the progress of this research work. We further thank the <u>Atmospheric Toolbox®</u>.