Extremely fast retrieval of volcanic SO$_2$ layer heights from UV satellite data using inverse learning machines

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Overview and Motivation

- SO$_2$ is a clear indicator of volcanic activity
- Regular **ground-based monitoring** limited to few volcanoes
- **Satellites** allow for **global daily** measurements of SO$_2$
- SO$_2$ is (relatively) easy to detect but information about SO$_2$ LH **unknown**
- So far: only time-consuming direct-fitting techniques
  - Not applicable in NRT environment
- **Novel FP-ILM** (Full Physics Inverse Learning Machine) approach:
  - Combination of PCA and NN approach
  - Extremely fast yet accurate
    - Slow offline training phase
    - Fast operational phase:
      - Processing speed: 2ms / TROPOMI Pixel,
      - Accuracy: <2km for SO$_2$ > 20 DU
Raikoke eruption Jun-Jul 2019 (Hedelt et al. 2019)

FP_ILM: Low SO$_2$ LH close to source (~4km) and high SO$_2$ LH (~12-15km) in extended plume
Very good agreement with IASI SO$_2$ LH products and CALIPSO (not shown)
Summary

- Novel method for precise and extremely fast retrieval of SO$_2$ LH based on UV satellite data
  - Combined Principal Components Analysis (PCA) & Neural Network approach (NN)
- Extremely fast yet accurate retrieval of SO$_2$ LH:
  - SO$_2$ LH information for an entire S5P orbit retrieved in a matter of few minutes
  - Applicable in NRT retrieval
- Development in framework of ESA S5P+I: SO2 LH project: https://atmos.eoc.dlr.de/so2-lh/
- Hourly S5P SO$_2$ LH results for volcanic eruptions @Twitter: @DLRSO2
- Application to recent volcanic eruptions shows very good results

Algorithm details can be found in