ATom: Sulfur Dioxide by Laser Induced Fluorescence (LIF-SO2) for ATom-4 Campaign

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Summary

This dataset provides concentrations of sulfur dioxide (SO2) measured by the Laser Induced Fluorescence Instrumentation for Sulfur Dioxide (SO2-LIF) on the ATom-4 campaign in April and May 2018. The LIF-SO2 instrument detects SO2 at the single-part per trillion level using red-shifted laser-induced fluorescence. Measurements are reported at 1-second intervals along the flight paths. Sources of SO2 atmosphere from natural sources include volcanic eruptions and wildfires; however, most anthropogenic sources, such as fossil fuel combustion, arise. SO2 influences some negative health and environmental impacts and is an important precursor of aerosols in the nucleation of new particles globally.

This dataset includes 13 data files in ICARTT (*.ict) format.

Figure 1. Photograph of the laser-induced fluorescence instrument described in Rollins et al. (2016) during development. Source: https://csl.noaa.gov/groups/csl6/instruments/so2/

Citation

Rollins, A.W. 2021. ATom: Sulfur Dioxide by Laser Induced Fluorescence (LIF-SO2) for ATom-4 Campaign. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1890

Table of Contents

1. Dataset Overview

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Project: Atmospheric Tomography Mission

The Atmospheric Tomography Mission (ATom) was a NASA Earth Venture Suborbital-2 mission. It studied the impact of human-produced air pollution on greenhouse gases and on chemically reactive gases in the atmosphere. ATom deployed an extensive gas and aerosol payload on the NASA DC-8 aircraft for a systematic, global-scale sampling of the atmosphere, profiling continuously from 0.2 to 12 km altitude. Flights occurred in each of four seasons over a 4-year period.

Related Publication

Decker, Z. C. J., M. A. Robinson, K. C. Barsanti, I. Bourgeois, M. M. Coggon, J. P. DiGangi, G. S. Diskin, F. M. Flocke, A. Franchin, C. D. Fredrickson, S. R. Hall, H. Halliday, C. D. Holmes, L. G. Huey, Y. R. Lee, J. Lindaas, A. M. Middlebrook, D. D. Montzka, R. H. Moore, J. A. Neuman, J. B. Nowak, B. B. Palm, J. Peischl, P. S. Rickly, A. W. Rollins, T. B. Ryerson, R. H. Schwantes, L. Thornhill, J. A. Thornton, G. S. Tyndall, K. Ullmann, P. Van Rooy, P. R. Veres, A. J. Weinheimer, E. Wiggins, E. Winstead, C. Womack, and S. S. Brown. 2021, April 12. Nighttime and Daytime Dark Oxidation Chemistry in Wildfire Plumes: An Observation and Model Analysis of FIREX-AQ Aircraft Data. Copernicus GmbH. https://doi.org/10.5194/acp-2021-267

Kupc, A., C. J. Williamson, A. L. Hodshire, J. Kazil, E. Ray, T. P. Bui, M. Dollner, K. D. Froyd, K. McKain, A. Rollins, G. P. Schill, A. Thames, B. B. Weinzierl, J. R. Pierce, and C. A. Brock. 2020. The potential role of organics in new particle formation and initial growth in the remote tropical upper troposphere. Atmospheric Chemistry and Physics 20:15037–15060.âÂÂÂÂ https://doi.org/10.5194/acp-20-15037-2020

Ranjithkumar, A., H. Gordon, C. Williamson, A. Rollins, K. Pringle, A. Kupc, N. L. Abraham, C. Brock, and K. Carslaw. 2021. Constraints on global aerosol number concentration, SO2 and condensation sink in UKESM1 using ATom measurements. Atmospheric Chemistry and Physics 21:4979–5014. https://doi.org/10.5194/acp-21-4979-2021

Related Datasets

Wofsy, S.C., et al. 2018. ATom: Merged Atmospheric Chemistry, Trace Gases, and Aerosols. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1581

- Data from all ATom instruments and all four flight campaigns, including aircraft location and navigation data, merged to several different time bases.

Wofsy, S.C., and ATom Science Team. 2018. ATom: Aircraft Flight Track and Navigational Data. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1613

- Flight path (i.e., location and altitude) data for each of the four campaigns provided in KML and CSV formats.

2. Data Characteristics

Spatial Coverage: Global, primarily over the oceans

Spatial Resolution: Point measurements

Temporal Coverage: Periodic flights occurred during the ATom-4 campaign only

Deployment	Date Range
ATom-1	July 29 - August 23, 2016
ATom-2	January 26 - February 21, 2017
ATom-3	September 28 - October 28, 2017
ATom-4	**April 24 - May 21, 2018**

Temporal Resolution: 1 second

Data File Information

This dataset includes 13 data files in ICARTT (*.ict) format. Files are associated with the ATom-4 campaign. Data files conform to the ICARTT File Format Standards V1.1. Files are named SO2-LIF_DC8_**YYYYMMDD_R#**.ict, where **YYYYMMDD** is the date of the flight and **R#** is the revision number.

Table 1. File names and descriptions.

File Name	Description
SO2-LIF_DC8_YYYYMMDD_R#.ict	SO2 measurements at every second along the flight path.

Data File Details

Missing values are represented by -9999.

No spatial coordinates are provided in the data files. Merge with Wofsy et al. (2018; https://doi.org/10.3334/ORNLDAAC/1613) by date and time (i.e., the UTC variable) for Aircraft Flight Track and Navigational Data.

Table 2. Variables in the data file SO2-LIF_DC8_YYYYMMDD_R#.ict.

Name	Units	Description
time_utc	seconds	Number of seconds since 0000 UTC
SO2_LIF	pptv	Concentration of sulfur dioxide (SO_2) in parts per trillion by volume

3. Application and Derivation

ATom builds the scientific foundation for mitigation of short-lived climate forcers, in particular, methane (CH_4), tropospheric ozone (O_3), and Black Carbon aerosols (BC).

ATom Science Questions

Tier 1

- What are chemical processes that control the short-lived climate forcing agents CH_4, O_3, and BC in the atmosphere? How is the chemical reactivity of the atmosphere on a global scale affected by anthropogenic emissions? How can we improve chemistry-climate modeling of these processes?

Tier 2

- Over large, remote regions, what are the distributions of BC and other aerosols important as short-lived climate forcers? What are the sources of new particles? How rapidly do aerosols grow to CCN-active sizes? How well are these processes represented in models?
- What type of variability and spatial gradients occurs over remote ocean regions for greenhouse gases (GHGs) and ozone-depleting substances (ODSs)? How do the variations among air parcels help identify anthropogenic influences on photochemical reactivity, validate satellite data for these gases, and refine knowledge of sources and sinks?

Significance

ATom delivers unique data and analysis to address the Science Mission Directorate objectives of acquiring “datasets that identify and characterize important phenomena in the changing Earth system” and “measurements that address weaknesses in current Earth system models leading to improvement in modeling capabilities.” ATom will provide unprecedented challenges to the CCMs used as policy tools for climate change assessments, with comprehensive data on atmospheric chemical reactivity at global scales, and will work closely with modeling teams to translate ATom data to better, more reliable CCMs. ATom provides extraordinary validation data for remote sensing.

4. Quality Assessment

The SO_2 measurements were obtained using the laser-induced fluorescence instrument described in Rollins et al. (2016). Rollins notes that SO_2 mixing ratios at high altitudes are quite low (i.e., 1–10 parts per trillion) and it is difficult to measure the SO_2 mixing ratio at low pressure with high precision. However, this instrument is capable of retrieving precise measurements of SO_2 concentration at pressures as low as 35 hPa, making this instrument operable up to altitudes of 20 km. The instrument has a detection limit of 5 ppt at a 1-second measurement interval and 2 ppt at a 10-second measurement interval with an overall uncertainty of +/- (16% + 0.9 ppt) and accuracy of +/- (10% + 1 ppt). The instrument airborne time response is 5 Hz. (https://csl.noaa.gov/groups/csl6/instruments/so2/). See Rickly et al. (2021) for recent “improvements to a laser-induced fluorescence instrument for measuring SO_2 – impact on accuracy and precision.”

5. Data Acquisition, Materials, and Methods

Project Overview

ATom makes global-scale measurements of the chemistry of the atmosphere using the NASA DC-8 aircraft. Flights span the Pacific and Atlantic Oceans, nearly pole-to-pole, in continuous profiling mode, covering remote regions that receive long-range inputs of pollution from expanding industrial economies. The payload has proven instruments for in situ measurements of reactive and long-lived gases, diagnostic chemical tracers, and aerosol size, number, and composition, plus spectrally resolved solar radiation and meteorological parameters.

Combining distributions of aerosols and reactive gases with long-lived GHGs and ODSs enables disentangling of the processes that regulate atmospheric chemistry: emissions, transport, cloud processes, and chemical transformations. ATom analyzes measurements using customized modeling tools to derive daily averaged chemical rates for key atmospheric processes and to critically evaluate Chemistry-Climate Models (CCMs). ATom also differentiates between hypotheses for the formation and growth of aerosols over the remote oceans.

Laser Induced Fluorescence – Sulfur Dioxide (LIF-SO2)

The LIF-SO2 instrument detects SO_2 at the single-part per trillion level using red-shifted laser-induced fluorescence. Additional information can be found on the NOAA instrument page. Additional information relating to the instrument’s characteristics can be found in Rollins et al. (2016) and specific operating conditions on the ATom campaign can be found in Ranjithkumar et al. (2021).

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

ATom: Sulfur Dioxide by Laser Induced Fluorescence (LIF-SO2) for ATom-4 Campaign

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
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7. References

Decker, Z. C. J., M. A. Robinson, K. C. Barsanti, I. Bourgeois, M. M. Coggon, J. P. DiGangi, G. S. Diskin, F. M. Flocke, A. Franchin, C. D. Fredrickson, S. R. Hall, H. Halliday, C. D. Holmes, L. G. Huey, Y. R. Lee, J. Lindaas, A. M. Middlebrook, D. D. Montzka, R. H. Moore, J. A. Neuman, J. B. Nowak, B. B. Palm, J. Peischl, P. S. Rickly, A. W. Rollins, T. B. Ryerson, R. H. Schwantes, L. Thornhill, J. A. Thornton, G. S. Tyndall, K. Ullmann, P. Van Rooy, P. R. Veres, A. J. Weinheimer, E. Wiggins, E. Winstead, C. Womack, and S. S. Brown. 2021, April 12. Nighttime and Daytime Dark Oxidation Chemistry in Wildfire Plumes: An Observation and Model Analysis of FIREX-AQ Aircraft Data. Copernicus GmbH. https://doi.org/10.5194/acp-2021-267

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