ATom: Merged Atmospheric Chemistry, Trace Gases, and Aerosols

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Documentation Revision Date: 2020-09-24

Dataset Version: 1.5

Summary

This dataset provides information on greenhouse gases and human-produced air pollution, including atmospheric concentrations of carbon dioxide (CO2), methane (CH4), tropospheric ozone (O3), and black carbon (BC) aerosols, collected during airborne campaigns conducted by NASA's Atmospheric Tomography (ATom) mission. This dataset includes merged data from all instruments plus additional data such as numbered profiles and distance flown. Merged data have been created for seven different sampling intervals. In the case of data obtained over longer time intervals (e.g. flask data), the merge files provide (weighted) averages to match the sampling intervals. ATom deploys 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 4 seasons from 2016 to 2018. Flights originate from the Armstrong Flight Research Center in Palmdale, California, fly north to the western Arctic, south to the South Pacific, east to the Atlantic, north to Greenland, and return to California across central North America. ATom establishes a single, contiguous, global-scale dataset. This comprehensive dataset will be used to improve the representation of chemically reactive gases and short-lived climate forcers in global models of atmospheric chemistry and climate. Profiles of the reactive gases will also provide critical information for the validation of satellite data, particularly in remote areas where in situ data is lacking. Complete aircraft flight information including, but not limited to, latitude, longitude, and altitude are also provided. This data release provides results from all instruments on all four ATom flight campaigns.

This dataset includes 28 data files in NetCDF (*.nc) format. Files are organized by merge type (based on sampling interval) and airborne campaign (i.e., Atom-1, 2, 3 or 4).

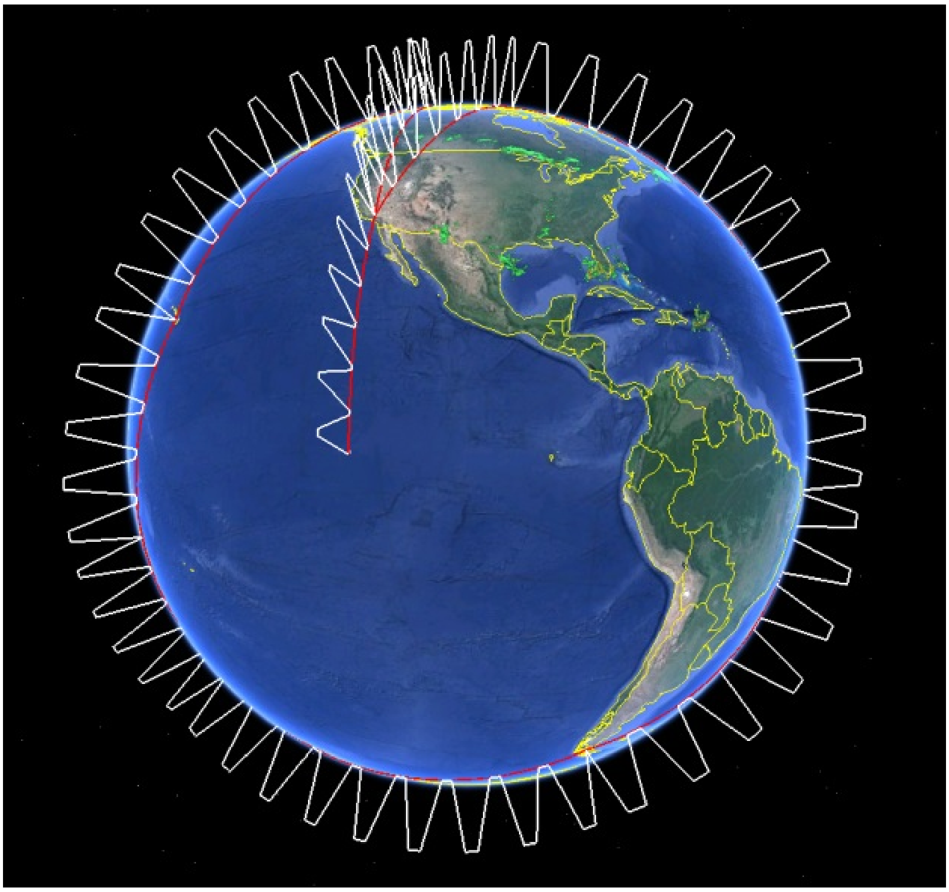

Figure 1: Generalized overview of ATom flights. During each of the four campaigns, ATom flights originated from California, flew south over the Pacific Ocean, then north to the western Arctic, southwest to New Zealand, east to Chile and the Atlantic Ocean, north to Greenland, and returned to California across North America. During flights, the aircraft continuously profiled the atmosphere from 0.2 to 12 km altitude.

Citation

Wofsy, S.C., S. Afshar, H.M. Allen, E.C. Apel, E.C. Asher, B. Barletta, J. Bent, H. Bian, B.C. Biggs, D.R. Blake, N. Blake, I. Bourgeois, C.A. Brock, W.H. Brune, J.W. Budney, T.P. Bui, A. Butler, P. Campuzano-Jost, C.S. Chang, M. Chin, R. Commane, G. Correa, J.D. Crounse, P. D. Cullis, B.C. Daube, D.A. Day, J.M. Dean-Day, J.E. Dibb, J.P. DiGangi, G.S. Diskin, M. Dollner, J.W. Elkins, F. Erdesz, A.M. Fiore, C.M. Flynn, K.D. Froyd, D.W. Gesler, S.R. Hall, T.F. Hanisco, R.A. Hannun, A.J. Hills, E.J. Hintsa, A. Hoffman, R.S. Hornbrook, L.G. Huey, S. Hughes, J.L. Jimenez, B.J. Johnson, J.M. Katich, R.F. Keeling, M.J. Kim, A. Kupc, L.R. Lait, J.-F. Lamarque, J. Liu, K. McKain, R.J. Mclaughlin, S. Meinardi, D.O. Miller, S.A. Montzka, F.L. Moore, E.J. Morgan, D.M. Murphy, L.T. Murray, B.A. Nault, J.A. Neuman, P.A. Newman, J.M. Nicely, X. Pan, W. Paplawsky, J. Peischl, M.J. Prather, D.J. Price, E.A. Ray, J.M. Reeves, M. Richardson, A.W. Rollins, K.H. Rosenlof, T.B. Ryerson, E. Scheuer, G.P. Schill, J.C. Schroder, J.P. Schwarz, J.M. St.Clair, S.D. Steenrod, B.B. Stephens, S.A. Strode, C. Sweeney, D. Tanner, A.P. Teng, A.B. Thames, C.R. Thompson, K. Ullmann, P.R. Veres, N. Vieznor, N.L. Wagner, A. Watt, R. Weber, B. Weinzierl, P.O. Wennberg, C.J. Williamson, J.C. Wilson, G.M. Wolfe, C.T. Woods, and L.H. Zeng. 2018. ATom: Merged Atmospheric Chemistry, Trace Gases, and Aerosols. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1581

Table of Contents

1. Dataset Overview

This dataset provides information on greenhouse gases and human-produced air pollution, including atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), tropospheric ozone (O_3), and black carbon (BC) aerosols, collected during airborne campaigns conducted by NASA's Atmospheric Tomography (ATom) mission. This dataset includes merged data from all instruments plus additional data such as numbered profiles and distance flown. Merged data have been created for seven different sampling intervals. In the case of data obtained over longer time intervals (e.g., flask data), the merge files provide (weighted) averages to match the sampling intervals. ATom deploys an extensive gas and aerosol payload on the NASA DC-8 aircraft for a systematic, global-scale sampling of the atmosphere, profiling continuously from 0.2–2 km altitude. Flights occurred in each of 4 seasons from 2016–2018. Flights originate from the Armstrong Flight Research Center in Palmdale, California, fly north to the western Arctic, south to the South Pacific, east to the Atlantic, north to Greenland, and return to California across central North America. ATom establishes a single, contiguous, global-scale dataset. This comprehensive dataset will be used to improve the representation of chemically reactive gases and short-lived climate forcers in global models of atmospheric chemistry and climate. Profiles of the reactive gases will also provide critical information for the validation of satellite data, particularly in remote areas where in situ data is lacking. Complete aircraft flight information including, but not limited to, latitude, longitude, and altitude are also provided. This data release provides results from all instruments and four ATom flight campaigns.

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 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 Data

ATom Flight Track and Navigational Data. Flight path (location and altitude) data for each of the four campaigns provided in KML and CSV format: https://doi.org/10.3334/ORNLDAAC/1613

HIAPER Pole-to-Pole Observations (HIPPO) of Carbon Cycle and Greenhouse Gases Study (2009-2011). Data available at https://www.eol.ucar.edu/field_projects/hippo

Acknowledgments

Table 1. The ATom team would like to thank the following individuals for their contributions to the success of the ATom Mission.

Contributor	Affiliation
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B. Wehr	NASA Armstrong Flight Research Center
R. Williams	NASA Armstrong Flight Research Center
J. Wilson	NASA Armstrong Flight Research Center and Jacobs Technology, Inc.

2. Data Characteristics

Spatial Coverage: Global; flights circumnavigate the globe, primarily over the oceans

Spatial Resolution: Point measurements

Temporal Coverage: Periodic flights occurred during each deployment

Table 2. ATom airborne campaign schedule.

Campaign	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: native resolution ranges from <1–2 seconds, depending on instrument and flight. Merge files present the data from different instruments averaged to various time bases, including 10-seconds and 1-second.

Data File Information

This dataset includes 28 data files in NetCDF (*.nc) format. Files are organized by merge type (based on sampling interval) and flight campaign (ATom-1, 2, 3 or 4). NetCDF files are structured as GeoTrajectory files, where the observations for a flight segment are connected along a one-dimensional track in space, with time increasing monotonically along the track.

File Naming Conventions

Files are organized by merge type and flight date such as **MER-TYPE_aircraft_ATom-N.nc**, where

MER-TYPE = merge type
aircraft = DC8
ATom-N = flight campaign, either ATom-1, 2, 3 or 4

Table 3. Merge Types

Merge Type	Description
MER-1HZ	Merge of flight data at 1-second intervals across all instruments
MER-MED	Data merge to MEDUSA sampling interval
MER-PFP	Data merge to PFP sampling interval
MER-SAGA-AERO	Data merge to SAGA-AERO sampling interval
MER-TOGA	Data merge to TOGA sampling interval, from 1-second merge file
MER-WAS	Data merge to WAS sampling interval
MER10	Merge of flight data with 10-second means

Companion Files

There are over 450 individual variables measured by the 24 instruments onboard the NASA DC-8. A list of all data variables is provided in the companion file **ALLNAMES.txt** and in the header information of the NetCDF files themselves.

Table 4. Companion files included in this dataset.

File Name	Description
ALLNAMES.txt	A list of all data variables included in the merge files
ATom_merge.pdf	A PDF copy of this user guide
ATom_merging_Rcode_20170628.pdf	A script in the R language that takes data from all the instrument files and merges them to the various temporal bases provided here
FILELIST.ATom_**MER-TYPE**_Dataset.**YYYYMMDD_R**.txt	A list of files used generating the merge of MER-TYPE, where YYMMDD = merge date, R = version number; there are six FILELIST files
README.ATom_**MER-TYPE**_Dataset.**YYYYMMDD_R**.txt	Additional documentation about the merge of MER-TYPE, where YYMMDD = merge date, R = version number; there are six README files provided

3. Application and Derivation

ATom builds the scientific foundation for mitigation of short-lived climate forcers, in particular, methane (CH4), tropospheric ozone (O3), and Black Carbon aerosols (BC).

ATom Science Questions

Tier 1

- What are chemical processes that control the short-lived climate forcing agents CH4, O3, 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 Cloud Condensation Nuclei (CCN)-active sizes? How well are these processes represented in models?
- What type of variability and spatial gradients occur 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 Chemistry-Climate Models (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

Quality assessment procedures differ by instrument. Quality flags are provided within the data files for many of the measured parameters.

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.

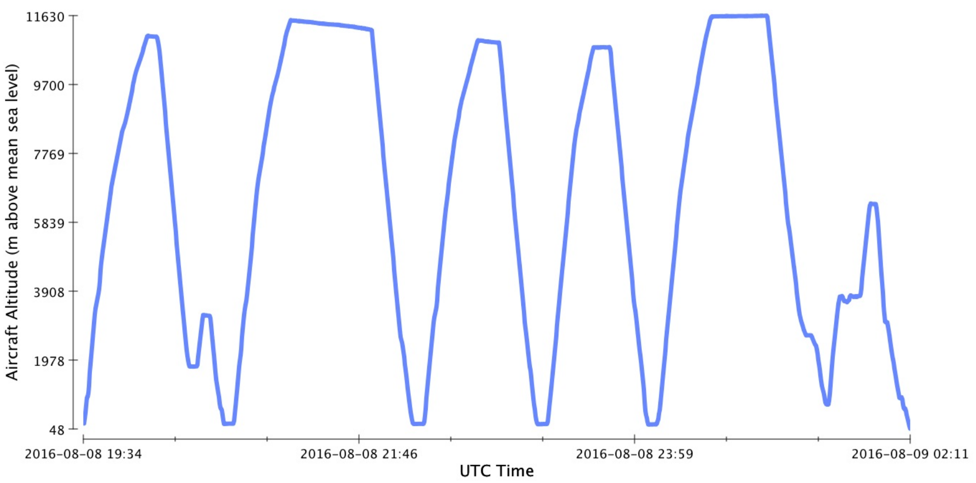

Figure 2. ATom flights continuously sampled atmospheric profiles. In this flight from Pago Pago, American Samoa to Christchurch, New Zealand, on August 8, 2016, the aircraft sampled 12 vertical profiles from about 50 to 11,000 meters above mean sea level. ATom measures more than 100 distinct chemical, aerosol, radiative, and physical parameters. Fast instrument sampling rates provide spatially resolved, simultaneous, and contiguous observational data, providing a nearly complete chemical description of each air parcel.

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 CCMs. ATom also differentiates between hypotheses for the formation and growth of aerosols over the remote oceans.

Table 5. Instruments on board the NASA DC-8 for ATom.

Instrument	Full Name	Contact	Type	Measurements	Data Variables
AMP	In Situ Measurements of Aerosol Microphysical Properties	Charles Brock	Spectrometer (in situ)	Dry aerosol particle size distribution	NAerosol
AO2	NCAR Airborne Oxygen Instrument	Britt Stephens		O2, CO2	AO2
ATHOS	Airborne Tropospheric Hydrogen Oxides Sensor	William H. Brune	Fluorescence	OH, Naphthalene, HO2, NO	ATHOS-HOx
CAFS	CCD Actinic Flux Spectroradiometers	Samuel R. Hall	Spectrometer (in situ)	Actinic flux	CAFS-FLUX-N, CAFS-FLUX-Z, CAFS-JV, CAFS-

					JV-2
CAPS Vienna	Second generation Cloud, Aerosol, and Precipitation Spectrometer – U Vienna	Bernadett Weinzierl	Spectrometer and imager (in situ)	Ambient aerosol particle, cloud droplet, and ice crystal size distributions, cloud liquid water content	Cloudindicator, NCoarseAerosol
CIT-CIMS	Chemical Ionization Mass Spectrometer	Paul Wennberg	CIMS	HNO3, H2O2, CH3OOH, HCN, PAA, PNA, SO2	CIT-H2O2, CIT-HCN, CIT-HNO3, CIT-MHP, CIT-PAA, CIT-PNA, CIT-SO2
DLH	Diode Laser Hygrometer	Glenn S. Diskin	Laser absorption	H2O	DLH-H2O
GT-CIMS	Chemical Ionization Mass Spectrometer	L. Greg Huey	CIMS	HNO3, SO2, HNO4, HCl, Br2, BrO, PAN	GTCIMSPANS
HR-AMS	CU Aircraft High-Resolution Time-of-Flight Aerosol Mass Spectrometer	Jose-Luis Jimenez	Spectrometer (in situ)	Cl, NH4, NO3, Organic aerosol, SO4	AMS, AMS-60s, AMSSD
ISAF	In Situ Airborne Formaldehyde	Thomas F. Hanisco	Fluorescence	CH2O	ISAF-H2CO
Medusa	Medusa Whole Air Sampler	Britt Stephens	Whole air sampling	O2, CO2, N2, Argon, CO2 isotopes	MEDUSA, MEDUSA-Kernel
MMS	Meteorological Measurement System	T. Paul Bui		Wind, turbulence, temperature, aircraft position	MMS-1HZ, MMS-20Hz
NOAA CIMS	Chemical Ionization Mass Spectrometer	Thomas B Ryerson	CIMS	H2O, HNO3, HCl	
NOAA Picarro	NOAA Picarro	Kathryn McKain	Spectrometer (in situ)	CO2, CH4, CO *See companion file (NOAA-Picarro_ATom1234_readme.pdf) for additional information about this instrument.*	NOAA-Picarro-CO2-CH4-CO
NOyO3	NOAA Nitrogen Oxides and Ozone	Thomas B Ryerson	Chemiluminescence	NO, NO2, NOy, O3	NOyO3-NO, NOyO3-NO2, NOyO3-NOy, NOyO3-O3
PALMS	Particle Analysis By Laser Mass Spectrometry	Karl Froyd	Spectrometer (in situ)	Particle composition, aerosol	PALMS
PANTHER	PAN and Trace Hydrohalocarbon ExpeRiment	James W. Elkins	Gas chromatography	(CH3)2CO, PAN, H2, CH4, CO, N2O, SF6, CFCl3, CF2Cl2, Halon-1211	GCECD, GCMSD
PFP	Programmable Flask Package Whole Air Sampler	Steve Montzka	Whole air sampling	N2O, SF6, H2, CS2, OCS, CO2, CH4, CO, CFCs, HCFCs, HFCs, solvents, methyl halides, hydrocarbons, perfluorocarbons	PFP
QCLS	Quantum Cascade Laser System	Bruce Daube	Laser absorption	CO2, CO, CH4, N2O	QCLS-CH4-CO-N2O, QCLS-CO2
SAGA	Soluble Acidic Gases and Aerosols	Jack Dibb	Ion chromatography	Na, NH4, K, Mg, Ca+2, Cl, Br-, NO3, SO4, C2O4-2, Be-7, Pb-210, HNO3, Fine aerosol SO4, Fine aerosol NO3	SAGA-AERO, SAGA-MC
SP2	Single Particle Soot Photometer (NOAA)	Joshua Schwarz	Photometer	Black carbon, scattering aerosols	SP2-BC
TOGA	Trace Organic Gas Analyzer	Eric Apel	Gas chromatography, spectrometer (in situ)	VOCs	TOGA
UCATS	UAS Chromatograph for Atmospheric Trace Species	James W. Elkins	Gas chromatography, spectrometer (in situ), photometer	N2O, SF6, CH4, CO, O3	UCATS-GC, UCATS-H2O, UCATS-O3
WAS (UCI)	Whole Air Sampler	Donald R. Blake	Whole air sampling	NMHCs, halocarbons, alkyl nitrates, OCS, DMS, CS2	WAS

Additional information about each instrument and the DC-8 platform is available at https://espo.nasa.gov/atom/instruments.

ATom is closely linked to satellites measuring atmospheric chemical composition: (i) ATom provides unique data for validation and algorithm development for OCO-2, GOME-2, TROPOMI, GOSAT, plus those planned for geostationary orbit (TEMPO), and the TCCON network. (ii) ATom uses satellite data to extend its airborne in-situ observations to global scale. (iii) ATom directly engages CCM groups and delivers a single, large-scale, contiguous in-situ dataset for model evaluation and improvement.

Merge File Methods

This dataset includes merged data from all instruments. A variety of merged file types have been created for each flight date. The merge files include additional data such as numbered profiles and distance flown. In the case of data obtained over longer time intervals (e.g., flask data), the merge files provide (weighted) averages of 1-second data to match the sampling intervals. The merge procedure was executed in the R language and the merge script (**ATom_merging_Rcode_20170628.pdf**) is provided as a companion file with this dataset. Additional details for each merge type can be found in the associated README file described in Companion Files of Section 2 above .

For more information, see the ATom website on the NASA Earth Science Project Office (ESPO) site at https://espo.nasa.gov/atom.

6. Data Access

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

ATom: Merged Atmospheric Chemistry, Trace Gases, and Aerosols

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

Northup, E., G. Chen, K. Aikin, and C. Webster, 2017. ICARTT File Format Standards V2.0. NASA. https://cdn.earthdata.nasa.gov/conduit/upload/6158/ESDS-RFC-029v2.pdf

8. Dataset Revisions

Version	Release Date	Description
1.5	2020-09-24	All previously-released data were updated to latest available versions.
1.4	2019-11-25	Initial release of MER-TOGA and MER-WAS data from ATom-4 campaign. All previously-released data were updated to latest available versions.
1.3	2019-06-14	Initial release of MER-TOGA and MER-WAS data from ATom-3 campaign. All previously-released data were updated to latest available versions.
1.2	2019-04-05	Initial release of partial ATom-3 & Atom-4 data. Data from Atom-1 and Atom-2 were updated to latest versions.
1.1	2018-08-23	Provides updated data from ATom-1 & ATom-2 with edits to author list, metadata, and user guide.
1.0	2018-03-28	Initial release of data from ATom-1 & ATom-2