ATom: L2 Trace Gas and Isotope Measurements from Medusa Whole Air Sampler, Version 2

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Dataset Version: 2

Summary

This dataset provides O2/N2, CO2, Ar/N2, and stable isotope ratios of CO2 measured in flasks collected by the Medusa Whole Air Sampler during airborne campaigns conducted by NASA's Atmospheric Tomography (ATom) mission. 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 4 seasons from 2016 to 2018. Medusa collected 32 cryogenically dried, flow, and pressure-controlled samples per flight. The samples are collected by an automated sampler into 1.5 L glass flasks that integrate over 25 seconds. Medusa provides discretely-sampled comparisons for onboard in situ O2/N2 ratio and CO2 measurements and unique measurements of Ar/N2 and 13C, 14C, and 18O isotopologues of CO2. Medusa flasks are analyzed on a sector-magnet mass spectrometer and a LiCor non-dispersive infrared CO2 analyzer by the Scripps O2 Program at Scripps Institution of Oceanography.

The complementary Medusa flask measurements allow ground-truthing of onboard instrument measurements in a laboratory setting, where analysis conditions can often be more stringently controlled and carefully monitored. Isotope and argon measurements can provide additional information about land and ocean controls over the carbon cycle and about the age and source of the air sampled.

This dataset includes 94 data files in ICARTT (*.ict) format, with two files per flight (i.e., Medusa measurements and Medusa-Kernel averaging weights).

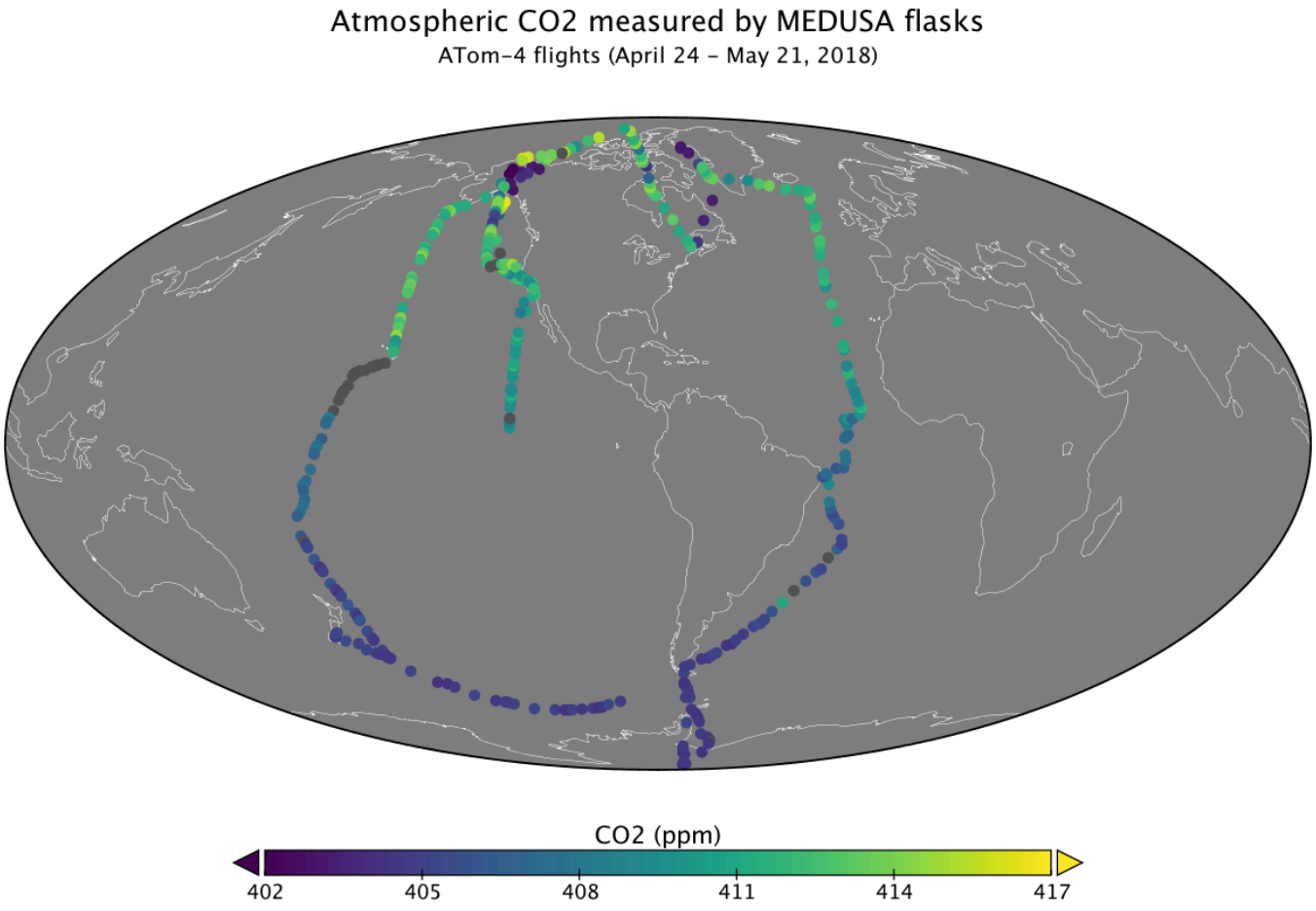

Figure 1. Measurements of atmospheric carbon dioxide concentration from flasks collected by the Medusa system during ATom-4 flights in 2018.

Citation

Morgan, E.J., B.B. Stephens, J. Bent, A. Watt, S. Afshar, W. Paplawsky, and R.F. Keeling. 2021. ATom: L2 Trace Gas and Isotope Measurements from Medusa Whole Air Sampler, Version 2. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1881

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1. Dataset Overview

This dataset provides O_2/N_2, CO_2, Ar/N_2, and stable isotope ratios of CO_2 measured in flasks collected by the Medusa Whole Air Sampler during airborne campaigns conducted by NASA's Atmospheric Tomography (ATom) mission. 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 4 seasons from 2016 to 2018. Medusa collected 32 cryogenically dried, flow, and pressure-controlled samples per flight. The samples are collected by an automated sampler into 1.5 L glass flasks that integrate over 25 seconds. Medusa provides discretely-sampled comparisons for onboard in situ O2/N2 ratio and CO2 measurements and unique measurements of Ar/N_2 and ^{13}C, ^{14}C, and ^{18}O isotopologues of CO_2. Medusa flasks are analyzed on a sector-magnet mass spectrometer and a LiCor non-dispersive infrared CO_2 analyzer by the Scripps O2 Program at Scripps Institution of Oceanography.

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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 Datasets

Morgan, E.J., B.B. Stephens, J. Bent, A. Watt, S. Afshar, W. Paplawsky, and R.F. Keeling. 2019. ATom: L2 Measurements from Medusa Whole Air Sampler (Medusa). ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1729

- Version 1 of the current dataset. Now superseded and available only upon request.

Wofsy, S.C., S. Afshar, H.M. Allen, E.C. Apel, E.C. Asher, B. Barletta, 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 flight campaigns merged to several different time bases, including aircraft location and navigation data.

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 (location and altitude) data for each of the four campaigns provided in KML and CSV format.

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 campaign.

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: 32 flask samples were collected during each flight. Each whole air flask sample integrates over 25 seconds.

Study Area: All latitude and longitude are given in decimal degrees.

Site	Northernmost Latitude	Southernmost Latitude	Easternmost Longitude	Westernmost Longitude
Global	90	-90	180	-180

Data File Information

This dataset includes 94 files in in ICARTT (*.ict) format with two files per flight (i.e., Medusa measurements and Medusa-Kernel averaging weights). No data are available from the 2017-02-13 flight. Data files conform to the ICARTT File Format Standards V1.1. Files are named MEDUSA_DC8_**YYYYMMDD_R#**.ict or MEDUSA-Kernel_DC8_**YYYYMMDD_R#**.ict, where **YYYYMMDD** is the start date (in UTC time) of the flight and **R#** is the file version or revision number.

The companion file Medusa_readme_210520.pdf provides additional information about the Medusa instrument and data processing.

Table 1. File names and descriptions.

File Name	Description
MEDUSA_DC8_YYYYMMDD_R#.ict	47 files providing the measurements from each of 32 flasks collected per flight.
MEDUSA-Kernel_DC8_YYYYMMDD_R#.ict	47 files providing the weight in the averaging kernel used to generate the Mean_UTC timestamps (representative sampling time) provided in the corresponding file.

Data File Details

No data are available from the 2017-02-13 flight. Missing data are indicated by -99999.

Table 2. Variables names and descriptions for MEDUSA_DC8_YYYYMMDD_R#.ict.

Name	Units	Description
Start_UTC	seconds	seconds since UTC midnight when flask was opened
Stop_UTC	seconds	seconds since UTC midnight when flask was closed
Mean_UTC	seconds	kernel-weighted representative sampling time
position	integer	order of flasks taken (1-32)
upstream_pressure	torr	kernel-weighted pressure reading at upstream pressure controller
downstream_pressure	torr	kernel-weighted pressure reading at downstream pressure controller
bypass_pressure	torr	kernel-weighted pressure of bypass line
sample_pressure	torr	kernel-weighted representative pressure in sampling line
flow	L/min	kernel-weighted representative mean flow during sampling
flask_pressure	torr	fill pressure of each flask
O2N2_MED	per meg	deviations in the ratio of O_2 to N_2 on the Scripps O2 Laboratory O2 Scale
ArN2_MED	per meg	deviations in the ratio of Ar to N_2 on the Scripps O2 Laboratory Argon Scale
O2N2star_MED	per meg	deviations in the ratio of O_2 to N_2 with thermal artifacts and variations due to air-sea exchange caused by solubility changes removed
CO2_MED	ppm	dry air mole fraction of CO_2 on Scripps O2 Laboratory CO2 Scale
d13CO2_MED	per mil	deviation in the $^{13}C/^{12}C$ Stable Carbon Isotope Ratio in CO_2 relative to Vienna Pee Dee Belemnite
d18OCO2_MED	per mil	deviation in the $^{18}O/^{16}O$ Stable Oxygen Isotope Ratio in CO_2 relative to Vienna Pee Dee Belemnite
D14CO2_MED	per mil	deviation from the Modern standard $^{14}C/C$ ratio

Table 3. Variables names and descriptions for MEDUSA-Kernel_DC8_YYYYMMDD_R#.ict.

Name	Units	Description
Start_UTC	seconds	seconds since UTC midnight on day of takeoff
Kernel	seconds	Weight in the averaging kernel. See Bent 2014 (PhD thesis, UCSD) for details.

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 the 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

Uncertainty information is not available.

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.

Medusa Whole Air Sampler

Medusa provides discretely-sampled comparisons for onboard in situ O_2/N_2 ratio and CO_2 measurements and unique measurements of Ar/N_2 and ^{13}C, ^{14}C, and ^{18}O isotopologues of CO_2. The complementary measurements allow ground-truthing of onboard instrument measurements in a laboratory setting, where analysis conditions can often be more stringently controlled and carefully monitored.

Medusa collects 32 cryogenically dried, flow, and pressure-controlled samples per flight. The samples are collected by an automated sampler into 1.5 L glass flasks that integrate over 25-second (1 e-fold) periods. Medusa consists of an onboard computer, two pressure controllers, two pumps, three multi-position selector valves, and a host of other hardware that control and direct the air samples. All air is dried by passing it through traps immersed in a -78 C dry ice bath, adjusted to match atmospheric pressure at sea level, and then automatically isolated in a flask.

Medusa flasks are analyzed on a sector-magnet mass spectrometer and a LiCor non-dispersive infrared CO_2 analyzer by the Scripps O2 Program at Scripps Institution of Oceanography. See the companion file Medusa_readme_210520.pdf for additional information about the Medusa instrument and data processing.

6. References

Bent, J.D. 2014. Airborne Oxygen Measurements over the Southern Ocean as an Integrated Constraint of Seasonal Biogeochemical Processes. UCSD PhD Thesis. Available at http://bluemoon.ucsd.edu/publications/jonathan/Bent_Dissertation__FINAL.pdf

Stephens, B.B., E.J. Morgan, J.D. Bent, R.F. Keeling, A.S. Watt, S.R. Shertz, and B.C. Daube. 2021. Airborne measurements of oxygen concentration from the surface to the lower stratosphere and pole to pole. Atmospheric Measurement Techniques 14:2543–2574. https://doi.org/10.5194/amt-14-2543-2021

7. Dataset Revisions

Version	Release Date	Revision Notes	DOI
1	2019-11-26	Initial release. Superseded by Version 2 and available only upon request.	https://doi.org/10.3334/ORNLDAAC/1729
2	2021-05-24	This version includes additional flask screening, updates to the Ar/N_2 correction, and the O_2 data have been updated for a span correction to the SIO O2 Scale. See Stephens et al. (2021) for details.	https://doi.org/10.3334/ORNLDAAC/1881