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MASTER: FIREX-AQ Airborne Campaign, Western-Central USA, Summer 2019

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Documentation Revision Date: 2023-02-23

Dataset Version: 1.2

Summary

This dataset includes Level 1B (L1B) and Level 2 (L2) data products from the MODIS/ASTER Airborne Simulator (MASTER) instrument. The spectral data were collected as part of the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) program during 21 flights aboard a NASA DC-8 aircraft over the central and western U.S. from 2019-07-22 to 2019-09-03. The purpose of these flights was to measure emissions and to characterize the aerosols in the smoke plume above and downwind of the fire, and to determine the overall spatial extent of wildfires and prescribed fires. Data products include L1B georeferenced multispectral imagery of calibrated radiance in 50 bands covering wavelengths of 0.460 to 12.879 micrometers at approximately 20-meter spatial resolution. Derived L2 data products are emissivity in 5 bands in thermal infrared range (8.58 to 12.13 micrometers) and land surface temperature. The L1B file format is HDF-4, and L2 products are provided in ENVI and KMZ formats. In addition, the dataset includes the flight path, spectral band information, instrument configuration, ancillary notes, and summary information for each flight, and browse images derived from each L1B data file.

The MODIS/ASTER Airborne Simulator (MASTER) is a modified Daedalus Wildfire scanning spectrometer that flies on a variety of multi-altitude research aircraft and provides spectral information similar to that provided by the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which are aboard two NASA Earth Observing System Satellites, TERRA & AQUA.

The overarching objective of the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) campaign is to provide measurements of trace gas and aerosol emissions for wildfires and prescribed fires in great detail, relate them to fuel and fire conditions at the point of emission, characterize the conditions relating to plume rise, follow plumes downwind to understand chemical transformation and air quality impacts and assess the efficacy of satellite detections for estimating the emissions from sampled fires. FIREX-QA is a joint venture between NOAA and NASA. This deployment includes 21 flights with a total of 354 flight tracks.

This dataset includes a total of 996 data files: 354 files in Hierarchical Data Format (HDF-4; *.hdf) format, 108 ENVI raster files (*.dat and *.hdr) that are compressed (*.zip), 27 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 27 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 84 text (*.txt) files, 21 archives of text files that are zipped (*.zip), 21 flight maps as GIF (*.gif) images, and 354 browse images in JPEG (*.jpg) format.

FIREX—AQ Campaign — 29 Jul 2019
Montana (North Hills Fire)
Flight #19—817—15 Track #8

23:20:44 0.65μm (#5)   1.60μm (#12)   3.76μm (#30)   10.71μm (#47)   RGB (#32,#22,#12) 23:20:44

23:21:48 0.65μm (#5)   1.60μm (#12)   3.76μm (#30)   10.71μm (#47)   RGB (#32,#22,#12) 23:21:48

Upper Left Lat, Lon =   46.7°, −112.0°
Lower Right Lat, Lon =   46.8°, −111.9°
Aircraft Heading =   26.4°
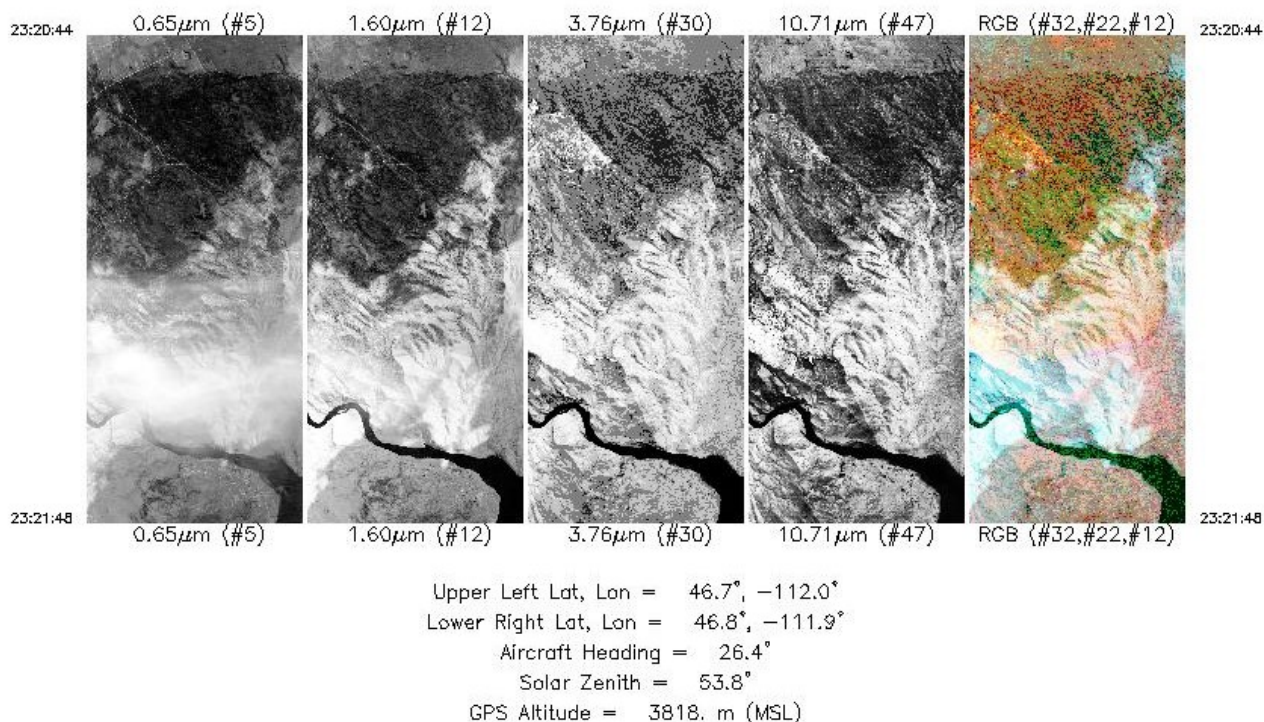Solar Zenith =   53.8°
GPS Altitude =   3818. m (MSL)

Figure 1. Single-band images and an RGB composite image from flight track 08 acquired on 29 July 2019 over the North Hills Fire in Montana, California, U.S. Source: MASTERL1B_1981715_08_20190729_2320_2321_V01.jpg

Citation

Hook, S.J., J.S. Myers, K.J. Thome, M. Fitzgerald, A.B. Kahle, Airborne Sensor Facility NASA Ames Research Center, J.H. Crawford, C. Warneke, and J.P. Schwarz. 2021. MASTER: FIREX-AQ Airborne Campaign, Western-Central USA, Summer 2019. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1941

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1. Dataset Overview

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The MODIS/ASTER Airborne Simulator (MASTER) is a modified Daedalus Wildfire scanning spectrometer that flies on a variety of multi-altitude research aircraft and provides spectral information similar to that provided by the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which are aboard two NASA Earth Observing System Satellites, TERRA & AQUA.

The overarching objective of the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) campaign is to provide measurements of trace gas and aerosol emissions for wildfires and prescribed fires in great detail, relate them to fuel and fire conditions at the point of emission, characterize the conditions relating to plume rise, follow plumes downwind to understand chemical transformation and air quality impacts and assess the efficacy of satellite detections for estimating the emissions from sampled fires. FIREX-QA is a joint venture between NOAA and NASA. This campaign includes 21 flights with a total of 354 flight tracks.

Project: MODIS/ASTER Airborne Simulator

The MODIS/ASTER Airborne Simulator (MASTER) is a scanning spectrometer which flies on a variety of multi-altitude research aircraft and provides data

similar to the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). MASTER first flew in 1998 and has ongoing deployments as a Facility Instrument in the NASA Airborne Science Program (ASP). MASTER is a joint project involving the Airborne Sensor Facility (ASF) at the Ames Research Center, the Jet Propulsion Laboratory (JPL), and the Earth Resources Observation and Science Center (EROS).

Related Publication

Hook, S.J. Myers, J.J., Thome, K.J., Fitzgerald, M. and A.B. Kahle. 2001. The MODIS/ASTER airborne simulator (MASTER) - a new instrument for earth science studies. Remote Sensing of Environment 76:93–102. https://doi.org/10.1016/S0034-4257(00)00195-4

Related Datasets

Additional MASTER datasets are available on the ORNL DAAC MASTER project page.

Acknowledgments

The MASTER instrument is maintained and operated by the Airborne Sensor Facility (ASF) at NASA Ames Research Center in Mountain View, California, under the oversight of the EOS Project Science Office at NASA Goddard. Data processing was conducted at NASA Ames Research Center and the Jet Propulsion Laboratory at the California Institute of Technology in Pasadena, California. FIREX-AQ is a joint venture between NOAA and NASA.

2. Data Characteristics

Spatial Coverage: Central and western U.S.

Spatial Resolution: 1 to 20 m

Temporal Coverage: 2019-07-22 to 2019-09-03

Temporal Resolution: One-time estimates

Study Area: Latitude and longitude are given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Central and western U.S.	-121.506	-83.158	48.577	30.786

Data File Information

This dataset includes a total of 996 data files: 354 files in Hierarchical Data Format (HDF-4; *.hdf) format, 108 ENVI raster files (*.dat and *.hdr) that are compressed (*.zip), 27 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 27 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 84 text (*.txt) files, 21 archives of text files that are zipped (*.zip), 21 flight maps as GIF (*.gif) images, and 354 browse images in JPEG (*.jpg) format. (Table 1).

There are different numbers of each type of file, which corresponds to the number of "flights" and "flight tracks". A "flight" is flown on a single day, and a "flight track" typically refers to a segment of a given flight. The number of flight tracks varies among flights (Table 2).

- There are 21 flights with 354 flight tracks.
- For each of 354 flight tracks, there is one L1B data file in HDF format and one auxiliary browse image (*.jpg).
- L2 data are included for 27 of the 354 flight tracks. For each track, there is one L1B data file in KMZ format and five L2 data files in ZIP format.
  - Four of the ZIP files contain L2 ENVI data for emissivity, land surface temperature, geographic coordinates, and quality assurance status. Each ZIP includes a binary data file (*.dat) and its header file (*.hdr).
  - One ZIP file contains three L2 PNG files: RBG composite, single-band emissivity, and land surface temperature.
- For each flight, there is a collection of auxiliary files providing information about the flight and instrument configuration.

The primary data files are named MASTERL**AA_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_**V0**J-X**.hdf (e.g., MASTERL1B_1981715_01_20190729_2215_2217_V01.hdf).

The flight track-level browse images are named MASTERL**AA_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_**V0**J-X**.jpg (e.g., MASTERL1B_1981715_01_20190729_2215_2217_V01.jpg).

The flight-level auxiliary files are named MASTER**_BBBBBBBB_YYYYMMDD_X**.ext (e.g., MASTER_1981715_20190729_config.txt).

Elements of file names are described as:

 AA = "1B", indicating L1B data level,
BBBBBBBB = the flight number,
CC = flight track,
YYYYMMDD = date of sampling,
EEFF = starting time at EE hour and FF minute,
GGHH = ending time at GG hour and HH minute,
J = version number for file,
X = the file content (see Table 1), and
ext = "hdf", "gif", "jpg", "txt", "kmz", or "zip", indicating the file extension.

Table 1. File names and descriptions.

File Name	Level	File Type	Total Files	Description
Primary Data Files				
MASTERL1B_*BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH*_V0J.hdf	L1B	HDF-4	354	Multispectral radiance in 50 bands, pixel coordinates, sensor configuration, aircraft platform data, analysis parameters. The "CalibratedData" variable provides estimates of radiance in units of W m^{-2} sr^{-1} per micron.

File Name	Level	File Type	Total Files	Description
MASTERL1B_*BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH*V0J-RGB.kmz	L1B	KMZ	27	RGB composite browse image (in KMZ format) derived from corresponding bands of RGB wavelengths of L1B data.
MASTERL2_*BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH*_V0J-emissivity_tes.zip	L2	ENVI	27	Map of atmospheric corrected emissivity; Temperature and Emissivity Separation (TES) corrected data in 5 bands (wavelengths: 8.58, 9.02, 10.62, 11.32, and 12.13 µm).
MASTERL2_*BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH*_V0J-images.zip	L2	PNG	27	Three non-georeferenced images depicting (a) RGB composite using selected bands, (b) emissivity from a single band, and (c) land surface temperature.
MASTERL2_B*BBBBBBBB_CC_ YYYYmmDD_EEFF_GGHH*_V0J-location.zip	L2	ENVI	27	Latitude and longitude coordinates for pixels in ENVI files.
MASTERL2_*BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH*_V0J-QAmap.zip	L2	ENVI	27	QA status for each pixel from TES algorithm, where 1 = divergence and 0 = convergence.
MASTERL2_*BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH*_V0J-surface_temp.zip	L2	ENVI	27	Map of land surface temperature (TES LST) in degrees Kelvin.
Auxiliary Files				
MASTERLAA_*BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0J.jpg	L1B	JPEG	354	Browse figures; one image per flight track; multiple tracks per flight.
MASTER_*BBBBBBBB_YYYYMMDD*_ancillary.txt	-	Text	21	Ancillary information about flight including notes on aircraft platform, mission objective, and data evaluation.
MASTER_*BBBBBBBB_YYYYMMDD*_config.txt	-	Text	21	Instrument configuration information for flight.
MASTER_*BBBBBBBB_YYYYMMDD*_flightpath.gif	-	GIF	21	Map showing flight paths.
MASTER_*BBBBBBBB_YYYYMMDD*_spectral_band_info.txt	-	Text	21	Spectral band information for flight.
MASTER_*BBBBBBBB_YYYYMMDD*_spectral_response_table.zip	-	Text	21	Spectral response tables by band (ZIP archive of 50 text files).
MASTER_*BBBBBBBB_YYYYMMDD*_summary.txt	-	Text	21	Time and coordinates for start and end of flight tracks along with the number of scan lines, solar and instrument angles, and aircraft altitude. FTLT = flight track number.

Data File Details

The HDF-4 files contain swath trajectory data using longitude and latitude coordinates. The spatial resolution ranges from 1 to 31 m and is a function of aircraft altitude.

Table 2. Flight track details for each MASTER flight during this 2019 deployment.

Date	Flight Number	Locations (USA)	Flight Tracks		
		Data Level		L1B	L2
2019-07-22	1981712	California / Nevada / Oregon (Ferry to Idaho)		7	4
2019-07-24	1981713	Idaho (Sheep Fire)		6	2
2019-07-25	1981714	Idaho (Shady Fire)		7	4
2019-07-29	1981715	Montana / California / Oregon (North Hills / Tucker Fires)		19	6
2019-07-30	1981716	Northwestern U.S. (North Hills / Tucker / Left Hand Fires)		13	7
2019-08-02	1981717	Montana / Idaho (Ridgetop / Mica Creek / Lick Creek Fires)		14	0
2019-08-03	1981718	Idaho / Washington (Lick Creek / Williams Flats Fires)		12	0
2019-08-06	1981719	Washington / Montana (Williams Flats / Snow Creek / Horsefly Fires)		10	0
2019-08-07	1981720	Washington / Montana (Williams Flats Fire)		9	0
2019-08-09	1981721	Washington (Williams Flats Fire)		5	0
2019-08-12	1981722	Nevada / California / Arizona (Spring / Castle Fires)		14	0
2019-08-13	1981723	Arizona (Trumbull / Castle Fires)		11	0
2019-08-16	1981724	Arizona (Sheridan / Saber / Boulin / Trumbull Fires)		14	0
2019-08-17	1981725	Arizona (Sheridan / Boulin / Ikes / Castle Fires)		7	0

2019-08-21	1981727	Texas / Louisiana / Mississippi (Ag Fires)	22	0
2019-08-23	1981728	Mississippi / Louisiana / Arkansas (Ag Fires)	33	0
2019-08-26	1981729	Oklahoma / Arkansas / Texas / Louisiana (Ag Fires)	25	0
2019-08-29	1981730	Nebraska / Kansas / Oklahoma (Ag Fires)	19	0
2019-08-30	1981731	Florida (Prescribed Burn) / Georgia / Alabama (Ag Fires)	34	0
2019-08-31	1981732	Mississippi / Arkansas / Louisiana (Ag Fires)	38	0
2019-09-03	1981733	Louisiana / Mississippi / Arkansas / Missouri (Ag Fires)	35	4
		Total	354	27

3. Application and Derivation

The primary mission of MASTER is to: (a) collect ASTER-like and MODIS-like land datasets to support the validation of the ASTER and MODIS geophysical retrieval algorithms; (b) collect these datasets at a higher resolution than the spaceborne datasets to permit scaling studies and comparisons with in-situ measurements; and (c) under fly the EOS-AM1 ASTER and MODIS sensors to provide an additional radiometric calibration to assist with in-flight instrument performance characterization. Calibration is particularly important for ASTER where on-board calibration is dependent on a single black body in the TIR and only partial aperture illumination in the VNIR.

A secondary mission of MASTER is to: (a) provide both a backup instrument and backup modules for the current MODIS Airborne simulator, which is committed to a program of atmospheric and oceanic measurements; and (b) provide a wider spectral and dynamic range alternative to the use of the Thematic Mapper (TM) airborne simulator and Thermal Infrared Multispectral Scanner (TIMS) airborne scanners (JPL, 2021b).

MASTER imagery has been used for mapping wildfires and their impacts (Veraverbeke et al., 2011), land cover (Li and Moon, 2004), coral reefs (Capolsini et al., 2003), and urban heat islands (Zhao and Wentz, 2016).

An increasing frequency of wildfires and prescribed burns threaten to impact air quality at local and regional scales (Jaffe et al., 2020) The overarching objective of the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) program is to provide measurements of trace gas and aerosol emissions for wildfires and prescribed fires in great detail, relate them to fuel and fire conditions at the point of emission, characterize the conditions relating to plume rise, follow plumes downwind to understand chemical transformation and air quality impacts, and assess the efficacy of satellite detections for estimating the emissions from sampled fires. Additional data from the FIREX-AQ program are available from http://doi.org/10.5067/SUBORBITAL/FIREXAQ2019/DATA001.
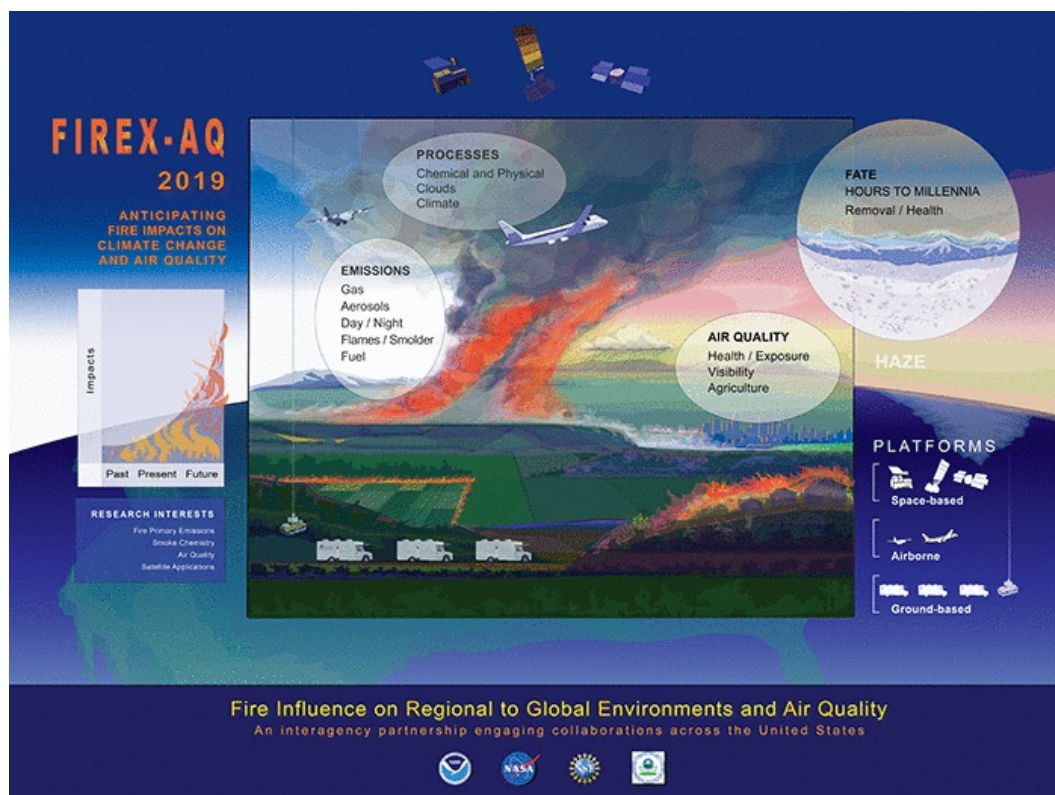

Figure 2. Themes of the FIREX-AQ program. Source: https://csl.noaa.gov/projects/firex-aq/about/

4. Quality Assessment

The MASTER instrument channels are calibrated spectrally and radiometrically in the laboratory preflight and postflight. The mid-infrared and thermal infrared channels (26–50) are also radiometrically calibrated in-flight by viewing an internal hot and cold blackbody with each scanline (Hook et al., 2001). Three calibration and validation experiments were conducted in 1998–2001 (Hook et al., 2001; JPL, 2021a). Spectral response information for this deployment is included in the files named MASTER_*BBBBBBBB_YYYYMMDD*_spectral_response_table.zip.

5. Data Acquisition, Materials, and Methods

The MASTER instrument was developed by the NASA Ames Research Center in conjunction with the Jet Propulsion Laboratory. The instrument consists of three key components: the scanning spectrometer, the digitizer, and the storage system. The scanning unit was built by Sensys Technology (formerly Daedalus Enterprises) and the digitizer was a collaborative effort between Berkeley Camera Engineering and the Ames Airborne Sensor Facility (ASF). The data storage system and overall system integration were also provided by the ASF.

The MASTER instrument is similar to the MODIS Airborne Simulator (developed by the MODIS project (King et al., 1996). However, it has two key differences. First, MASTER supports a variety of scan speeds allowing it to acquire contiguous imagery from a variety of altitudes with different pixel sizes. Second, the channel positions are configured to closely match those of ASTER and MODIS. A detailed description of the instrument and optical system are provided by Hook et al. (2001) and King et al. (1996), respectively.

For this deployment, the MASTER instrument was flown on NASA's DC-8 aircraft at altitudes of 264–12390 m above sea level. Flights targeted active wildfires and prescribed fires to record air quality metrics.
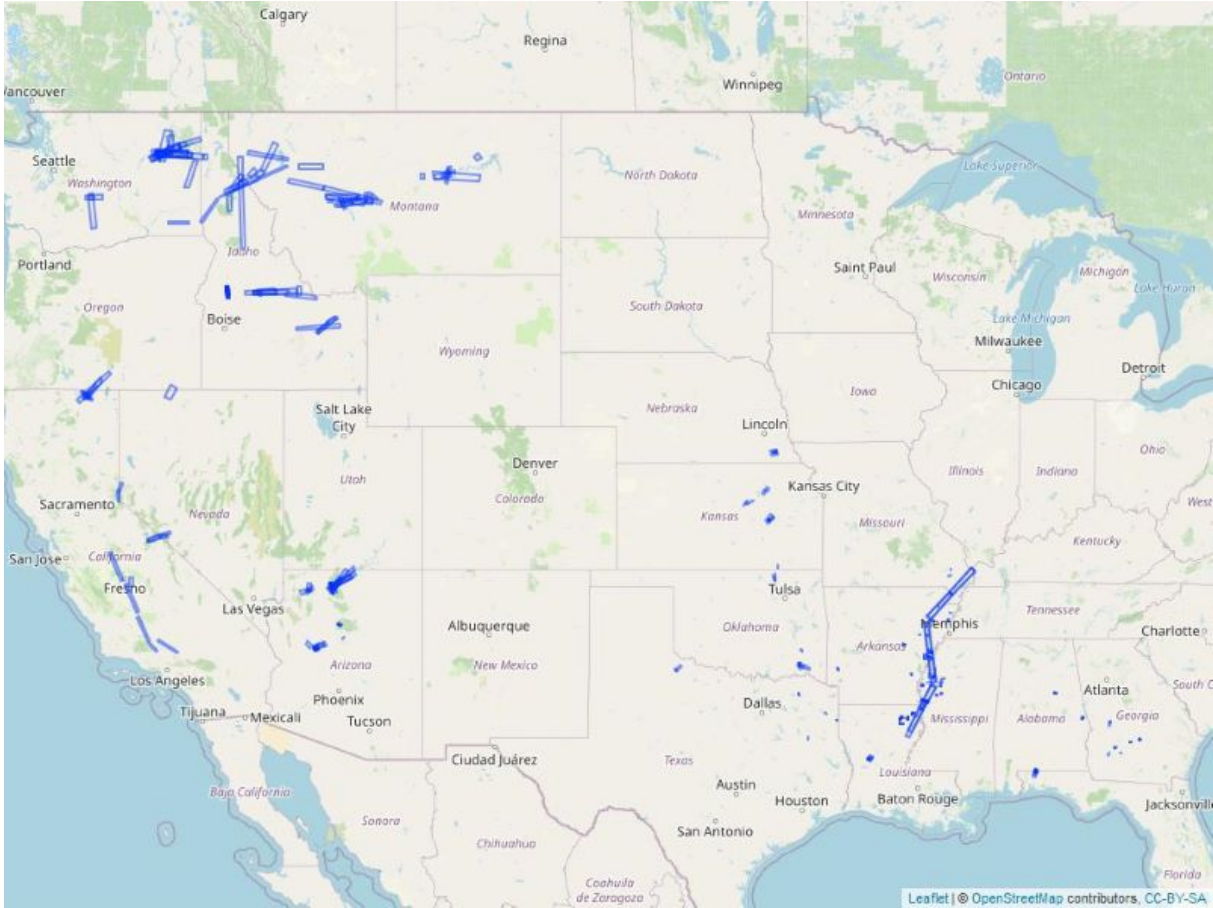

Figure 3. Flight tracks in this dataset represented as rectangular polygons. Basemap: © OpenStreetMap contributors.

The L2 data are derived from the L1B files, and the primary L2 products are emissivity in five bands (wavelengths: 8.58, 9.02, 10.62, 11.32, and 12.13 µm) and land surface temperature (LST). Emissivity and LST were corrected using a Temperature and Emissivity Separation (TES) algorithm (Coll et al., 2001).
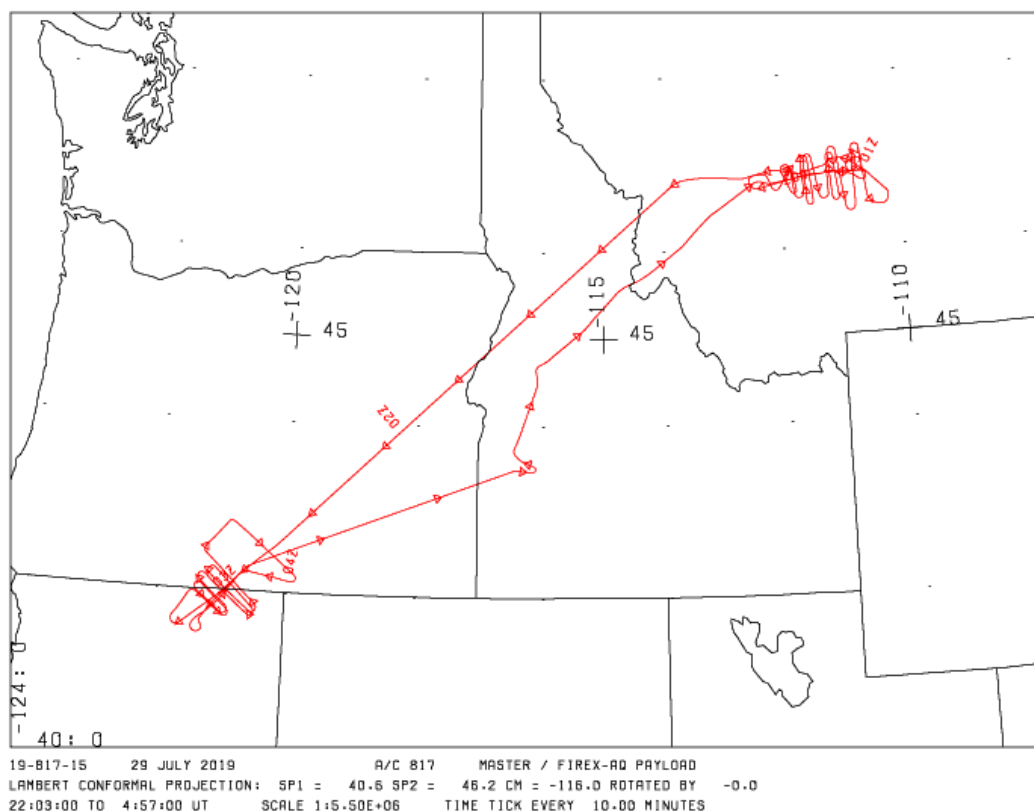
Figure 4. Flight path for Flight 1981715, flown on 2019-07-29. Flight 1981715 and 19 flight tracks occurred over Montana, Oregon, and California, U.S. Source: MASTER_1981715_20190729_flightpath.gif

6. Data Access

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

MASTER: FIREX-AQ Airborne Campaign, Western-Central USA, Summer 2019

Contact for Data Center Access Information:

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

7. References

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Zhao, Q., and E.A. Wentz. 2016. A MODIS/ASTER Airborne Simulator (MASTER) imagery for urban heat island research. Data 1:7. https://doi.org/10.3390/data1010007

8. Dataset Revisions

Version	Release Date	Revision Notes
1.2	2023-02-23	Level 2 data files were added to the dataset, and the User Guided was updated.
1.1	2022-06-22	Companion files from prior release were moved into data. Title was revised, and the User Guide was updated. Content of primary data files is unchanged.
1.0	2021-09-30	Original release under title "MASTER: Fire Influence on Air Quality (FIREX-AQ), Western-Central U.S., Summer 2019

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