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# MASTER: Geological Earth Mapping Experiment (GEMx), Spring 2024

## Get Data

Documentation Revision Date: 2025-02-19

Dataset Version: 1

### Summary

This dataset includes Level 1B (L1B) data products from the MODIS/ASTER Airborne Simulator (MASTER) instrument. The spectral data were collected during 26 flights aboard a NASA ER-2 aircraft over California, Oregon, Nevada, and Arizona, US, from 2024-04-02 to 2024-06-24. The Geological Earth Mapping Experiment (GEMx) research project used NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), Hyperspectral Thermal Emission Spectrometer (HyTES), and MODIS/ASTER Airborne Simulator (MASTER) instruments to collect the measurements over the country's arid and semi-arid regions, including parts of California, Nevada, Arizona, and New Mexico, to map portions of southwest US for critical minerals. Data products include L1B georeferenced multispectral imagery of calibrated radiance in 50 bands covering wavelengths of 0.460 to 12.879 micrometers at approximately 50-meter spatial resolution. Derived L2 data products are emissivity in five 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 MASTER instrument 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 and Aqua. MASTER provides data in 50 channels spanning visible to thermal infrared wavelengths (0.4 – 13  $\mu\text{m}$ ). Its data have been used to study geological patterns, land covers, ecological disturbances, and other phenomena that affect Earth surface properties.

This dataset includes a total of 2036 data files: 235 files in Hierarchical Data Format (HDF-4; \*.hdf) format, 940 ENVI raster files (\*.dat and \*.hdr) that are compressed (\*.zip), 235 files in Keyhole Markup Language Zipped (KMZ; \*.kmz) format, 235 Portable Network Graphics (PNG; \*.png) files that are compressed (\*.zip), 104 text (\*.txt) files, 26 archives of text files that are zipped (\*.zip), 26 flight maps as GIF (\*.gif) images, and 235 browse images in JPEG (\*.jpg) format.

ASTER/MODIS Airborne Simulator Browse Imagery  
 GEMx Campaign – 02 Apr 2024  
 Ivanpah Playa  
 Flight #24-934-00 Track #1

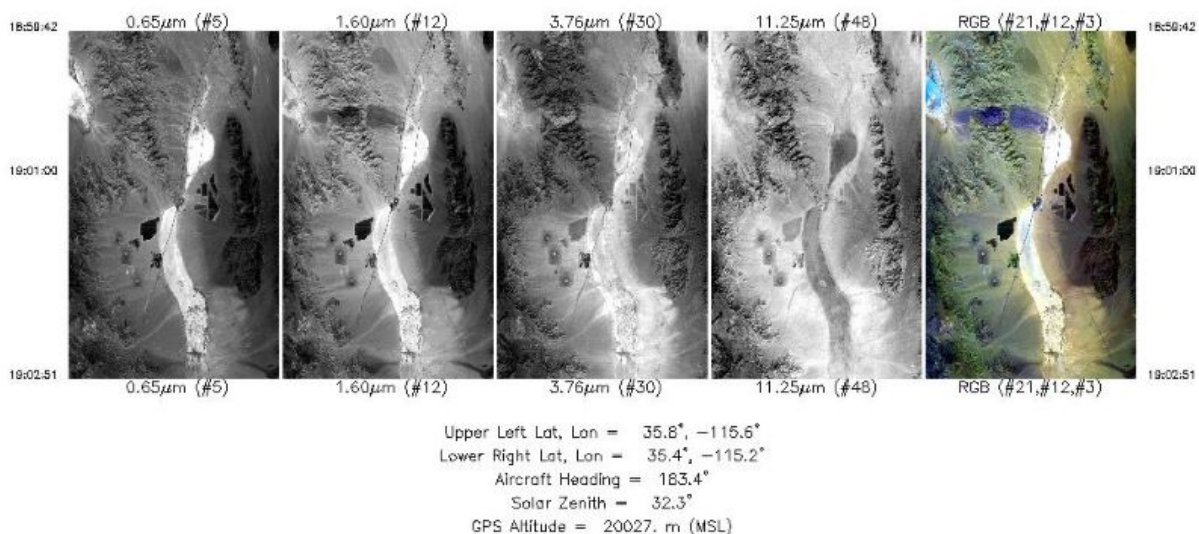


Figure 1. Single band images and an RGB composite image from flight track 1 acquired on 02 April 2024 over Primm, Nevada, US (approx. 35.60 lat, -115.40 lon). Source: MASTERL1B\_2493400\_01\_20240402\_1859\_1902\_V01.jpg

## Citation

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## 1. Dataset Overview

This dataset includes Level 1B (L1B) data products from the MODIS/ASTER Airborne Simulator (MASTER) instrument. The spectral data were collected during 26 flights aboard a NASA ER-2 aircraft over California, Oregon, Nevada, and Arizona, US, from 2024-04-02 to 2024-06-24. The Geological Earth Mapping Experiment (GEMx) research project used NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), Hyperspectral Thermal Emission Spectrometer (HyTES), and MODIS/ASTER Airborne Simulator (MASTER) instruments to collect the measurements over the country's arid and semi-arid regions, including parts of California, Nevada, Arizona, and New Mexico, to map portions of southwest US for critical minerals. Data products include L1B georeferenced multispectral imagery of calibrated radiance in 50 bands covering wavelengths of 0.460 to 12.879 micrometers at approximately 50-meter spatial resolution. Derived L2 data products are emissivity in five 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 Geological Earth Mapping Experiment (GEMx) is a five-year research project funded by the USGS Earth Mapping Resources Initiative through investments from the Bipartisan Infrastructure Law. The GEMx uses NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), Hyperspectral Thermal Emission Spectrometer (HyTES), and MODIS/ASTER Airborne Simulator (MASTER) instruments flown on NASA's ER-2 and Gulfstream V aircraft to collect measurements over the country's arid and semi-arid regions, including parts of California, Nevada, Arizona, and New Mexico. These observations record the spectroscopic fingerprints of surface minerals across hundreds of wavelength bands. The GEMx capitalizes on both the technology developed by NASA for spectroscopic imaging as well as the expertise in analyzing the datasets and extracting critical mineral information including primary rock-forming minerals and mineral weathering or alteration. Beyond providing additional detail over the mineral maps made by the Earth Surface Mineral Dust Source Investigation (EMIT), GEMx will provide NASA with critical high-resolution data at regional scales to support development of the Surface Biology and Geology (SBG) mission.

The MASTER instrument 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 and Aqua. MASTER provides data in 50 channels spanning visible to thermal infrared wavelengths (0.4 – 13  $\mu\text{m}$ ). Its data have been used to study geological patterns, land covers, ecological disturbances, and other phenomena that affect Earth surface properties.

**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](https://doi.org/10.1016/S0034-4257(00)00195-4)

### Related Datasets

Hook, S.J., J.S. Myers, K.J. Thome, M. Fitzgerald, A.B. Kahle, Airborne Sensor Facility NASA Ames Research Center, and R.F. Kokaly. 2024. MASTER: Geological Earth Mapping Experiment (GEMx), California-Arizona, Summer 2023. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/2319>

- Level-1 and Level-2 products from MASTER for GEMx in 2023.

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.

## 2. Data Characteristics

**Spatial Coverage:** Portions of California, Nevada, Oregon, and Arizona, U.S.

**Spatial Resolution:** 50 m

**Temporal Coverage:** 2024-04-02 to 2024-06-24

**Temporal Resolution:** One-time estimate

**Study Area:** All latitudes and longitudes given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
California, Nevada, Oregon, and Arizona, U.S.	-124.2642	-106.8749	45.0890	31.1419

**Data File Information**

This dataset includes a total of 2036 data files: 235 files in Hierarchical Data Format (HDF-4; \*.hdf) format, 940 ENVI raster files (\*.dat and \*.hdr) that are compressed (\*.zip), 235 files in Keyhole Markup Language Zipped (KMZ; \*.kmz) format, 235 Portable Network Graphics (PNG; \*.png) files that are compressed (\*.zip), 104 text (\*.txt) files, 26 archives of text files that are zipped (\*.zip), 26 flight maps as GIF (\*.gif) images, and 235 browse images in JPEG (\*.jpg) format.

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 26 flights with 235 flight tracks (Table 2).
- For each flight track, there is one L1B data file in HDF format and an auxiliary browse image (\*.jpg).
- L2 data are included for each flight track. For each track, there are five L2 data files in ZIP format and one KMZ file.
  - 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: RGB composite, single-band emissivity, and land surface temperature.
  - L2 land surface temperature (\*LST.kmz) in KMZ format.
- For each flight, there is a collection of auxiliary files providing information about the flight and instrument configuration.

The primary data files are named MASTERLAA\_BBBBBBBB\_CC\_YYYYMMDD\_EEFF\_GGHH\_V0J-X.ext (e.g., MASTERL1B\_2493400\_01\_20240402\_1859\_1902\_V01.hdf).

The flight track-level browse images are named MASTERLAA\_BBBBBBBB\_CC\_YYYYMMDD\_EEFF\_GGHH\_V0J.jpg (e.g., MASTERL1B\_2493400\_01\_20240402\_1859\_1902\_V01.jpg).

The deployment-level auxiliary files are named MASTER\_BBBBBBBB\_YYYYMMDD\_X.ext (e.g., MASTER\_2493400\_20240402\_config.txt).

- AA = "1B" or "2", indicating L1B or L2 data level,
- BBBBBBBB = flight number (Table 2),
- CC = flight track (Table 2),
- 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", "kmz", "txt", or "zip", indicating the file format.

**Table 1.** File names and descriptions.

File Name	Level	File Type	Total Files	Description
<b>Primary Data Files</b>				
MASTERL1B_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J.hdf	L1B	HDF-4	235	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.
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-emissivity_tes.zip	L2	ENVI	235	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 $\mu m$ ).
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-images.zip	L2	PNG	235	Three non-georeferenced images depicting (a) RGB composite using selected bands, (b) emissivity from a single band, and (c) land surface temperature.
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-location.zip	L2	ENVI	235	Latitude and longitude coordinates for pixels in ENVI files.
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-LST.kmz	L2	KMZ	235	Map of land surface temperature in degrees Kelvin.
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-QAmap.zip	L2	ENVI	235	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	235	Map of land surface temperature (TES LST) in degrees Kelvin.
<b>Auxiliary Files</b>				
MASTERL1B_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_V0J.jpg	L1B	JPEG	235	Browse figures; one image per flight track; multiple tracks per flight.

File Name	Level	File Type	Total Files	Description
MASTER_BBBBBBBB_YYYYMMDD_ancillary.txt	-	Text	26	Ancillary information about flight including notes on aircraft platform, mission objective, and data evaluation.
MASTER_BBBBBBBB_YYYYMMDD_config.txt	-	Text	26	Instrument configuration information for flight.
MASTER_BBBBBBBB_YYYYMMDD_flightpath.gif	-	GIF	26	Map showing flight paths.
MASTER_BBBBBBBB_YYYYMMDD_spectral_band_info.txt	-	Text	26	Spectral band information for flight.
MASTER_BBBBBBBB_YYYYMMDD_spectral_response_table.zip	-	Text	26	Spectral response tables by band (ZIP archive of 50 text files).
MASTER_BBBBBBBB_YYYYMMDD_summary.txt	-	Text	26	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, latitude coordinates. The spatial resolution is function of aircraft altitude. Resolution is approximately 50 m for these ER-2 flights.

**Table 2.** Number of flight tracks for each MASTER flight during this 2024 deployment over California, Nevada, Oregon, and Arizona.

Date	Flight Number	Locations (USA)	Flight Tracks	
			Data Level	L1B
2024-04-02	2493400	Ivanpah Playa	7	7
2024-04-03	2493500	Southwestern Arizona (GEMx AZ116)	8	8
2024-04-10	2493600	South Central Arizona (GEMx AZ122)	7	7
2024-04-11	2493700	South Central Arizona (GEMx TY107)	7	7
2024-04-16	2493800	South Central Arizona (GEMx TY107)	7	7
2024-04-17	2493900	South Central Arizona (GEMx TY107)	7	7
2024-04-23	2494000	Southeastern Arizona (GEMx AZ146)	6	6
2024-04-24	2494100	California/Arizona (GEMx TY103)	8	8
2024-04-30	2494200	Central California (GEMx CA223)	7	7
2024-05-01	2494300	Central California (GEMx TY202)	8	8
2024-05-02	2494400	Central California (GEMx CA211)	13	13
2024-05-06	2494500	Southern California (GEMx TY001)	18	18
2024-05-08	2494600	Southern California (GEMx CA253)	10	10
2024-05-09	2494700	Southern California (GEMx CA261)	9	9
2024-05-13	2494800	Southern CA and NV (GEMx CA279)	11	11
2024-05-16	2494900	Southern California (GEMx CA245)	9	9
2024-05-21	2495000	California Nevada Border (GEMx CA214)	10	10
2024-05-22	2495100	Northwestern Arizona (GEMx AZ203)	6	6
2024-05-28	2495200	Northwestern Arizona (GEMx AZ207)	8	8
2024-05-30	2495300	Southeastern Arizona (GEMx AZ156)	6	6
2024-05-31	2495400	Southern California (GEMx CA112)	22	22
2024-06-05	2495600	Southern California (GEMx CA245)	11	11
2024-06-06	2495700	Lake Tahoe	7	7
2024-06-10	2495800	Southeastern Arizona (GEMx AZ152)	6	6
2024-06-14	2495900	Ivanpah Tie Line part1 (GEMx X03)	8	8
2024-06-24	2496100	Northwestern California (GEMx TY407)	9	9
<b>Total</b>			<b>235</b>	<b>235</b>

### 3. Application and Derivation

The primary objective 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 objective 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 (TMS) airborne scanners (JPL, 2021b).

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

The Geological Earth Mapping Experiment (GEMx) research project will use NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), Hyperspectral Thermal Emission Spectrometer (HyTES), and MODIS/ASTER Airborne Simulator (MASTER) instruments to collect the measurements over the country's arid and semi-arid regions, including parts of California, Nevada, Arizona, and New Mexico, to map portions of southwest US for critical minerals.

### 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 MASTER\_BBBBBBBB\_YYYYMMDD\_spectral\_response\_table.zip files.

### 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 (MAS) 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 ER-2 aircraft at altitudes of 19,895 - 20,655 m above sea level.

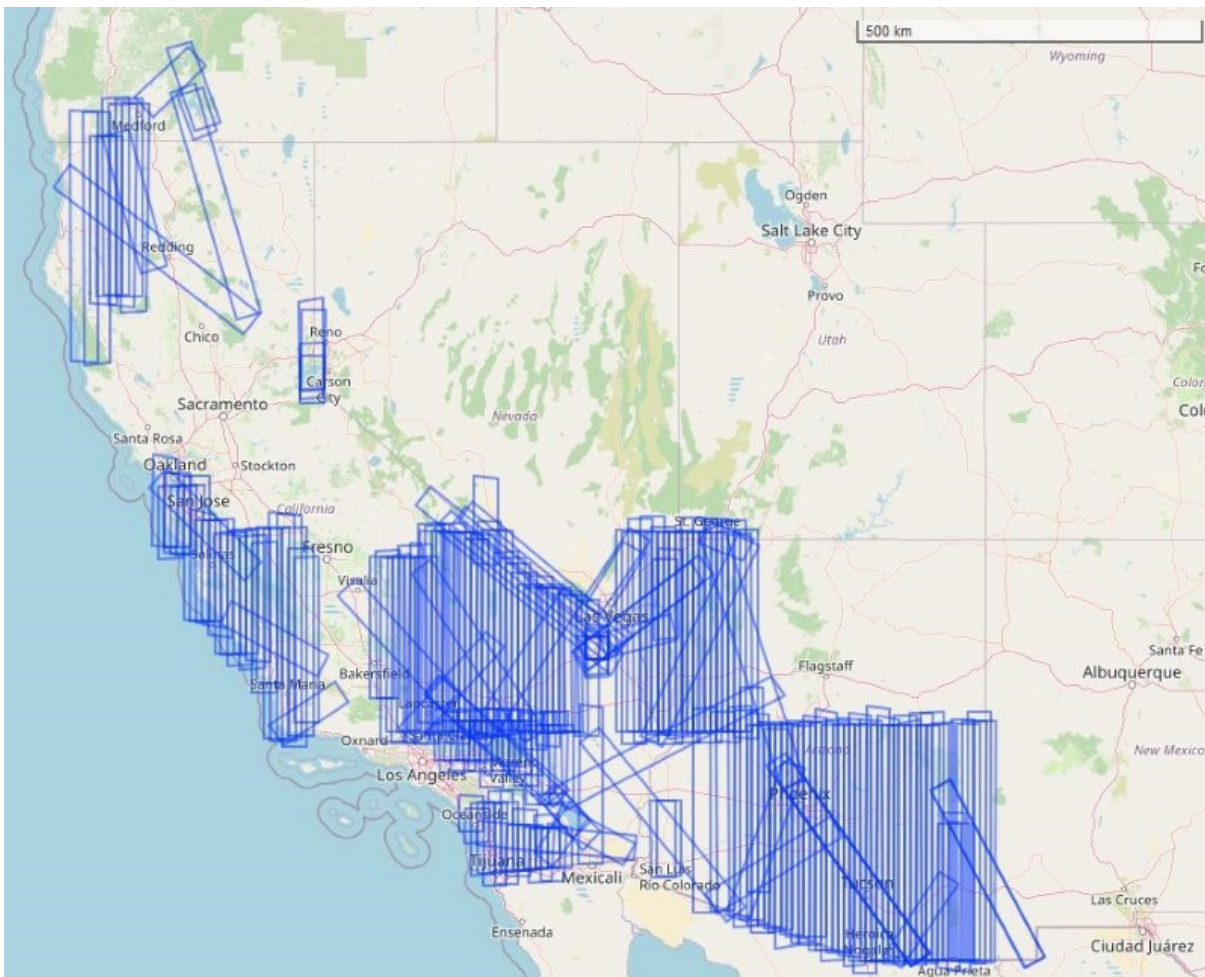


Figure 2. Flight tracks in this dataset represented as blue rectangular polygons over California, Oregon, Nevada, Arizona, and New

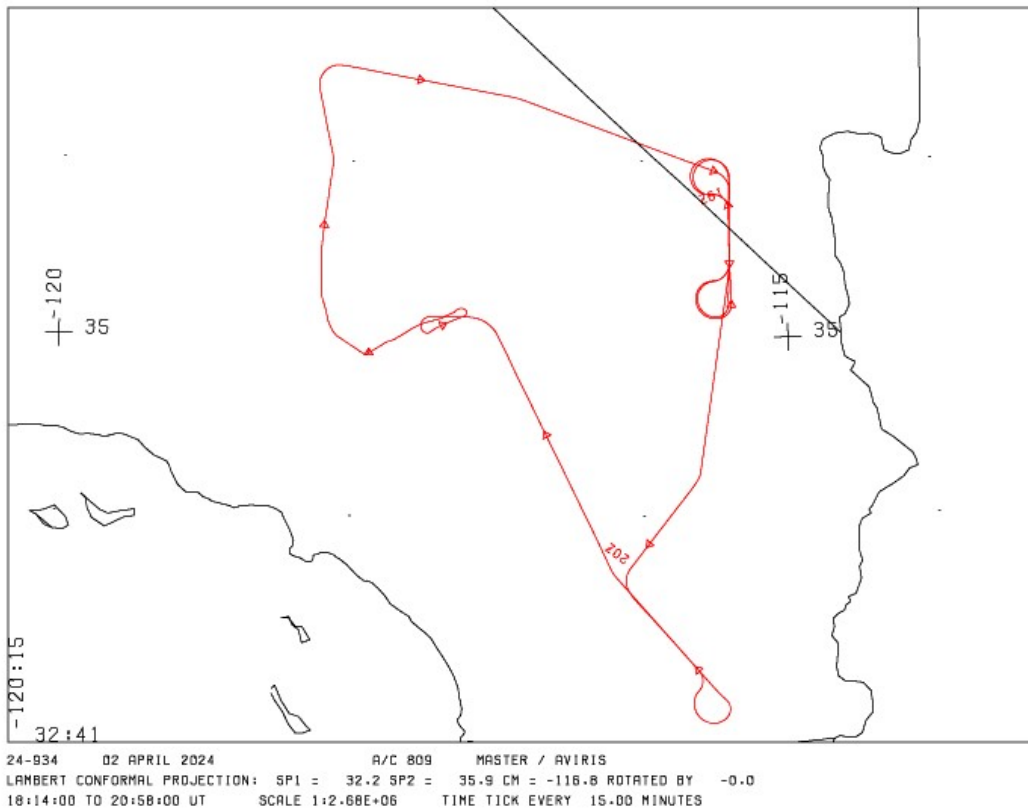


Figure 3. Typical flight path is shown for 02 April 2024. Flight 2493400 and 7 flight tracks occurred over southern California and Nevada. Source: MASTER\_2493400\_20240402\_flightpath.gif

## 6. Data Access

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

[MASTER: Geological Earth Mapping Experiment \(GEMx\), Spring 2024](#)

Contact for Data Center Access Information:

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

## 7. References

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## 8. Dataset Revisions

Version	Release Date	Revision Notes
1.0 update	2025-02-19	L2 files for each flight track were appended to this dataset.
1.0 update	2024-10-14	L1B files associated with the WDTS Spring 2024 deployment were removed from this collection. Those WDTS flight lines are 2495500, 2496000, 2496200, and 2496300, and their data will be published in <a href="https://doi.org/10.3334/ORNLDAAC/2383">https://doi.org/10.3334/ORNLDAAC/2383</a>
1.0	2024-09-30	Initial publication



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