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MASTER: Geological Earth Mapping Experiment (GEMx), Summer 2025

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Documentation Revision Date: 2025-12-12

Dataset Version: 1

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 during 29 flights aboard a NASA ER-2 aircraft over California, Oregon, Nevada, and Arizona, US, from 2025-05-23 to 2025-09-23. 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 HDF-5 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 μm). 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 2274 data files: 267 files in Hierarchical Data Format (HDF-4; *.hdf) format, 261 files in HDF-5 (*.hdf5) format, 1044 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 261 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 116 text (*.txt) files, 29 archives of text files that are zipped (*.zip), 29 flight maps as GIF (*.gif) images, and 267 browse images in JPEG (*.jpg) format.
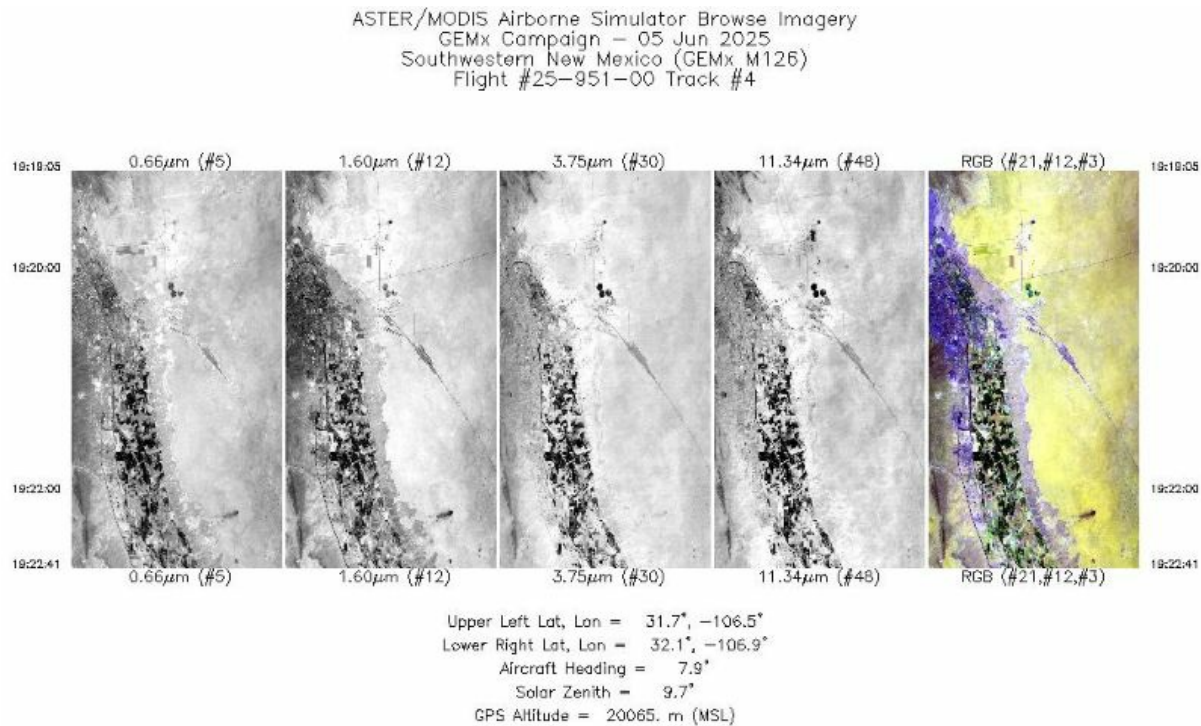

Figure 1. Single band images and an RGB composite image from flight track 4 acquired on 05 June 2025 south of Las Cruces, New Mexico, US (approx. 32.193 lat, -106.699 lon). Source: MASTERL1B_2595100_04_20250605_1919_1922_V01.jpg

Citation

Hook, S.J., J.S. Myers, K.J. Thome, M. Fitzgerald, A.B. Kahle, Airborne Sensor Facility NASA Ames Research Center, T. Hoefen, and R.F. Kokaly. 2025. MASTER: Geological Earth Mapping Experiment (GEMx), Summer 2025. ORNL DAAC, Oak Ridge, Tennessee, USA.

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1. Dataset Overview

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 during 29 flights aboard a NASA ER-2 aircraft over California, Oregon, Nevada, and Arizona, US, from 2025-05-23 to 2025-09-23. 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 HDF-5 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 µm). 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

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

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. 2025. MASTER: Geological Earth Mapping Experiment (GEMx), Spring 2024. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2370

- Level-1 and Level-2 products from MASTER for GEMx in 2023 and 2024.

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, Utah, Idaho, Arizona, New Mexico, and Texas, U.S.

Spatial Resolution: 50 m

Temporal Coverage: 2025-05-23 to 2025-09-23

Temporal Resolution: One-time estimate

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

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
western U.S.	-120.2297	-103.7019	44.2168	30.2245

Data File Information

This dataset includes a total of 2274 data files: 267 files in Hierarchical Data Format (HDF-4; *.hdf) format, 261 files in HDF-5 (*.hdf5) format, 1044 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 261 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 116 text (*.txt) files, 29 archives of text files that are zipped (*.zip), 29 flight maps as GIF (*.gif) images, and 267 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 29 flights with 267 flight tracks (Table 2).
- For each flight track, there is one L1B data file in HDF format, RGB overlays of TIR and VSWIR radiance in KMZ format, and an auxiliary browse image (*.jpg).
- L2 data are included for 261 flight tracks. For each of these tracks, there are four L2 data files:.
  - One HDF-5 file (*.hdf5) containing L2 data for emissivity, land surface temperature, geographic coordinates, and quality assurance status.
  - One ZIP file containing four L2 PNG files: two RBG composites, single-band emissivity, and land surface temperature.
  - One L2 RGB composite image of emissivity (*emiss-RGB-47-44-43.kmz) in KMZ format.
  - One L2 land surface temperature image (*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 MASTERL**AA_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_**V0**J-X.ext** (e.g., MASTERL1B_2594500_01_20250523_1656_1708_V01.hdf).

The flight track-level browse images are named MASTERL**AA_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_**V0**J**.jpg (e.g., MASTERL1B_2594500_01_20250523_1656_1708_V01.jpg).

The deployment-level auxiliary files are named MASTER_**BBBBBBBB_YYYYMMDD_X**.ext (e.g., MASTER_2594500_20250523_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", "hdf5","kmz", "gif", "jpg", "txt", or "zip", indicating the file format.

The "B200_SV01" element is included in some L2 file names and denotes the build ID and version of the Level 2 processing software employed.

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	267	Multispectral radiance at sensor 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_B200_SV01.hdf5	L2	HDF-5	261	Five sub datasets: (a) Atmospheric corrected emissivity: Temperature and Emissivity Separation (TES) corrected data in 6 bands (wavelengths: 8.3, 8.62, 9.06, 10.62, 11.33, and 12.13 µm). (b) Land surface temperature (LST) in degrees Kelvin. (c) Latitude and (d) longitude coordinates for pixels. (e) QA status for each pixel from TES algorithm, where 1 = divergence and 0 = convergence.
MASTERL1B_*BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_*V0J-TIR-47-44-43.kmz	L1B	KMZ	261	RGB representation of L1B thermal infrared radiance using bands 47 (red), 44 (green), and 43 (blue).
MASTERL1B_*BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_*V0J-VSWIR-21-12-03.kmz	L1B	KMZ	261	RGB representation of L1B short-wave, visible radiance using bands 21 (red), 12 (green), and 3 (blue).
MASTERL2_*BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_*V0J-images.zip	L2	PNG	261	Four non-georeferenced images: two RGB composites using selected bands, emissivity from a single band, and land surface temperature.

File Name	Level	File Type	Total Files	Description
MASTERL2_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0J_*B200_SV01*-LST.kmz	L2	KMZ	261	Map of land surface temperature in degrees Kelvin.
MASTERL2_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0J_*B200_SV01*-emiss-RGB-47-44-43.kmz	L2	KMZ	261	RGB representation of L2 emissivity using bands 47 (red), 44 (green), and 43 (blue).
Auxiliary Files				
MASTERL1B_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0J.jpg	L1B	JPEG	267	Browse figures; one image per flight track; multiple tracks per flight.
MASTER_*BBBBBBB_YYYYMMDD*_ancillary.txt	-	Text	29	Ancillary information about flight including notes on aircraft platform, mission objective, and data evaluation.
MASTER_*BBBBBBB_YYYYMMDD*_config.txt	-	Text	29	Instrument configuration information for flight.
MASTER_*BBBBBBB_YYYYMMDD*_flightpath.gif	-	GIF	29	Map showing flight paths.
MASTER_*BBBBBBB_YYYYMMDD*_spectral_band_info.txt	-	Text	29	Spectral band information for flight.
MASTER_*BBBBBBB_YYYYMMDD*_spectral_response_table.zip	-	Text	29	Spectral response tables by band (ZIP archive of 50 text files).
MASTER_*BBBBBBB_YYYYMMDD*_summary.txt	-	Text	29	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 and HDF-5 files contain swath trajectory data using longitude, latitude coordinates. The spatial resolution is a 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 2025 deployment over western U.S. states.

Date	Flight Number	Locations (USA)		Flight Tracks	
			Data Level	L1B	L2
2025-05-23	2594500	Salton Sea (GEMx RF23)		6	6
2025-05-30	2594800	Western Nevada (GEMx N407)		8	2
2025-06-03	2595000	Western Nevada (GEMx N411)		10	10
2025-06-05	2595100	Western NM -> West Texas (GEMx TY560)		10	10
2025-06-06	2595200	East AZ -> Southwest NM (GEMx TY517)		12	12
2025-06-11	2595400	California/Nevada Border (GEMx N001)		10	10
2025-06-12	2595500	California/Nevada Border (GEMx N301)		9	9
2025-06-27	2595600	California/Nevada Border (GEMx N012)		6	6
2025-07-01	2595700	Southwestern Nevada (GEMx N309)		8	8
2025-07-16	2596100	Northwestern Nevada (GEMx TY575)		8	8
2025-07-23	2596300	East Nevada / West Utah (GEMx TY568)		10	10
2025-07-24	2596400	Southern Nevada (GEMx TY529)		10	10
2025-07-25	2596500	Central Arizona (GEMx TY582)		9	9
2025-07-30	2596600	East Nevada / West Utah (GEMx TY568)		11	11
2025-07-31	2596700	North Rim Arizona / Dragon Bravo Fire		5	5
2025-08-01	2596800	Central Nevada (GEMx N315)		15	15
2025-08-05	2596900	Northeastern Nevada (GEMx N433)		10	10
2025-08-06	2597000	Yerington Nevada (GEMx YER4)		8	8
2025-08-08	2597100	NW Nevada - Winnemucca (GEMx TY575)		8	8
2025-08-12	2597200	Central Nevada (GEMx TY533)		10	10
2025-08-21	2597300	Northern NV - South Idaho (GEMx N525)		8	8
2025-08-25	2597400	El Paso / West Texas (GEMx TY523)		6	6
2025-08-29	2597500	California/Nevada Border (GEMx N214)		15	15

Date	ID	Location		
2025-09-12	2597700	Northern Arizona (GEMx A221)	8	8
2025-09-15	2597800	SE Oregon/ NE Nevada (GEMx TY541)	9	9
2025-09-16	2597900	East Nevada-North Arizona (GEMx TY505)	9	9
2025-09-17	2598000	Lake Tahoe	11	11
2025-09-22	2598100	Northeastern Nevada (GEMx TY544)	8	8
2025-09-23	2598200	Southern California (GEMx TY600)	10	10
		Total	267	261

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 (TIMS) 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 the southwest U.S. 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 19,780 - 20,480 m above sea level.
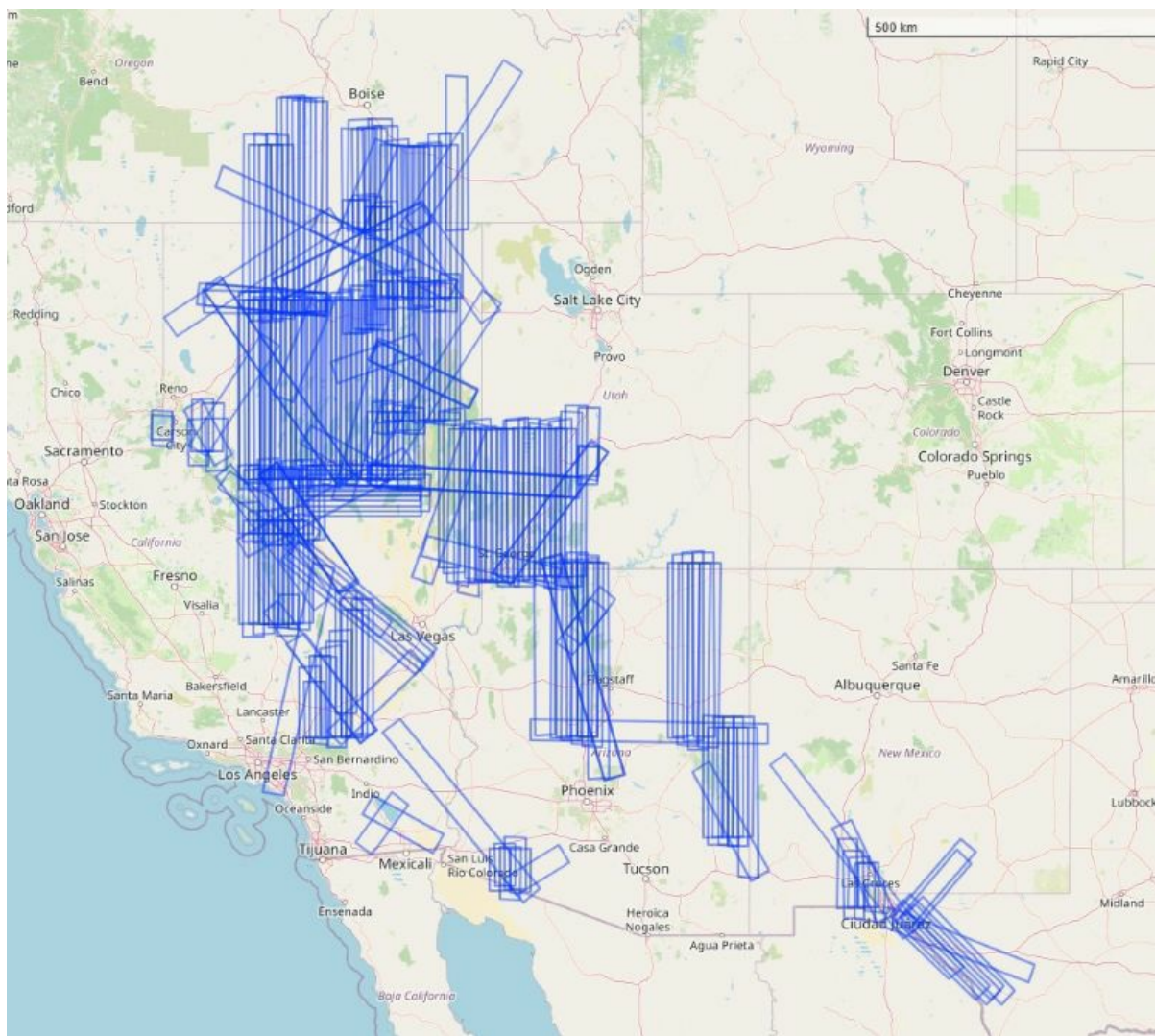
Figure 2. Flight tracks in this dataset represented as blue rectangular polygons over the western United States. Basemap: © OpenStreetMap contributors.
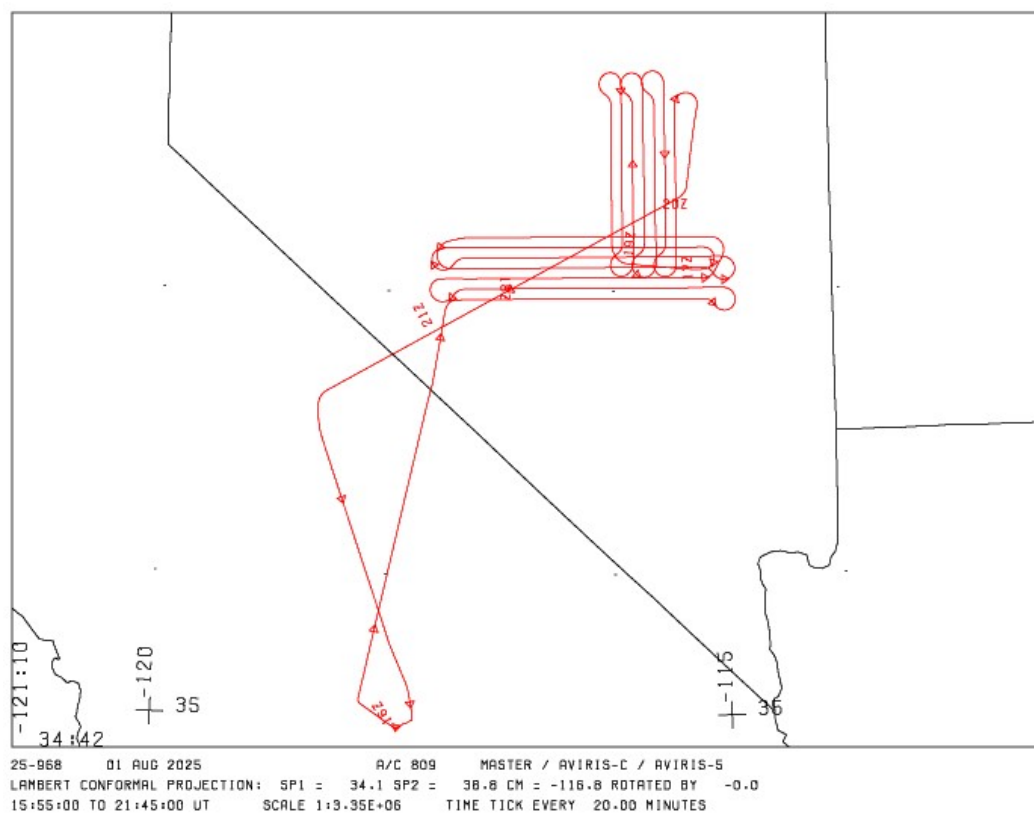

Figure 3. Typical flight path is shown for 01 August 2025. Flight 2596800 and 15 flight tracks occurred over central Nevada, U.S. Source: MASTER_2596800_20250801_flightpath.gif

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), Summer 2025

Contact for Data Center Access Information:

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

7. References

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