MASTER: Geological Earth Mapping Experiment (GEMx), Spring 2026

Documentation Revision Date: 2026-07-28

Dataset Version: 1

Summary

This dataset includes Level 1B (L1B) data products from the MODIS/ASTER Airborne Simulator (MASTER) instrument. Spectral data were collected during 10 flights aboard a NASA ER-2 aircraft over California, Colorado, Nevada, Utah, Arizona, New Mexico, and Texas, US, from 2026-03-17 to 2026-04-24. As part of the Geological Earth Mapping Experiment (GEMx) mission, NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and MASTER instruments were used to collect the measurements over the country's arid and semi-arid regions 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. The L1B data is provided in HDF-4 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 has been used to study geological patterns, land covers, ecological disturbances, and other phenomena that affect Earth surface properties.

This dataset includes a total of 278 data files: 61 files in Hierarchical Data Format (HDF-4; *.hdf) format, 96 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 40 text (*.txt) files, 10 archives of text files that are zipped (*.zip), 10 flight maps as GIF (*.gif) images, and 61 browse images in JPEG (*.jpg) format.

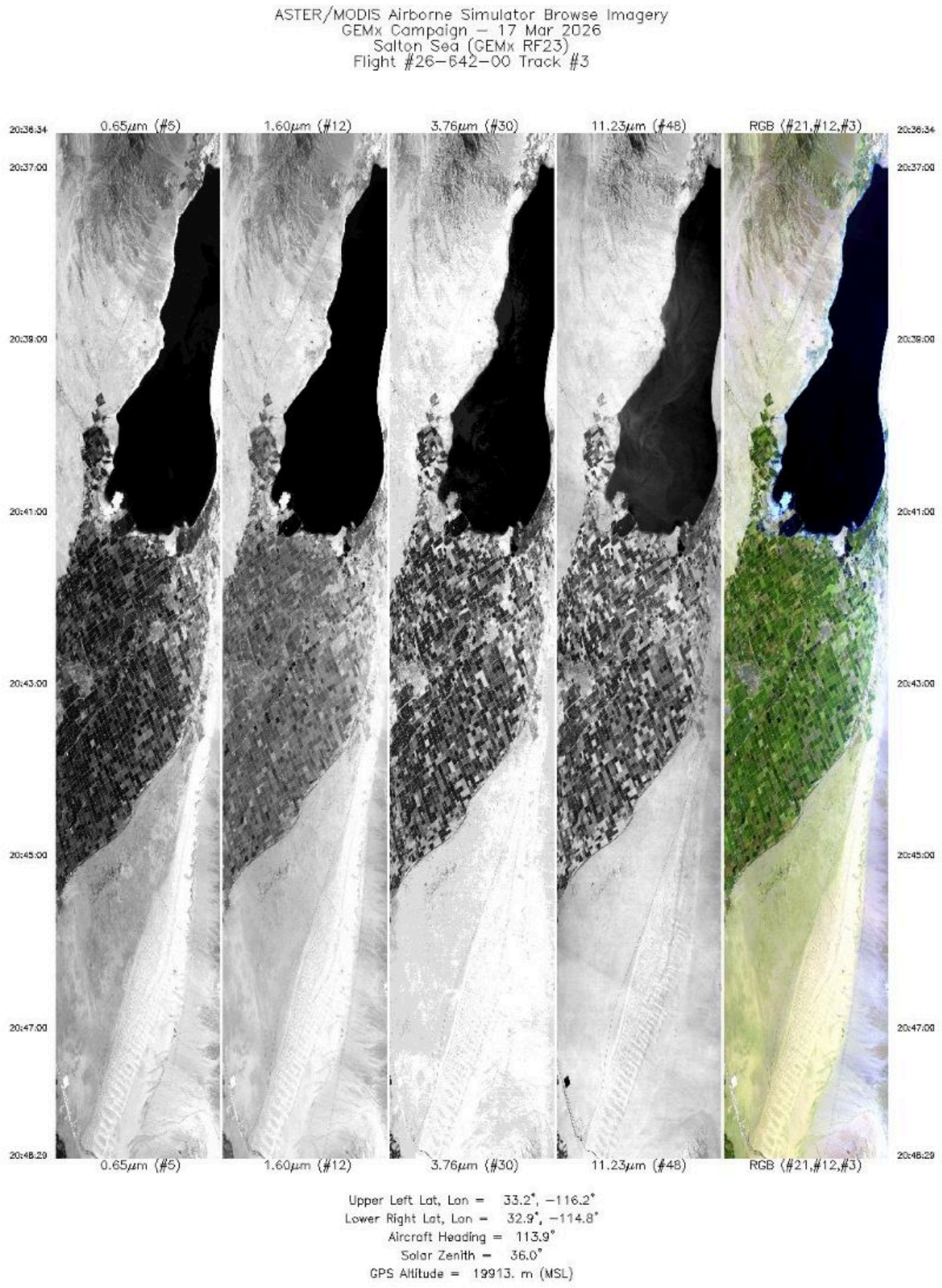

Figure 1. Single band images and an RGB composite image from flight track 3 acquired on 17 March 2026 over the Salton Sea and Calipatria, California (approx. 33.00 lat, -115.50 lon). Source: MASTERL1B_2664200_03_20260317_2036_2048_V01.jpg

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. 2026. MASTER: Geological Earth Mapping Experiment (GEMx), Spring 2026. ORNL DAAC, Oak Ridge, Tennessee, USA.

https://doi.org/10.3334/ORNLDAAC/2513

Table of Contents

1. Dataset Overview

This dataset includes Level 1B (L1B) data products from the MODIS/ASTER Airborne Simulator (MASTER) instrument. Spectral data were collected during 10 flights aboard a NASA ER-2 aircraft over California, Colorado, Nevada, Utah, Arizona, New Mexico, and Texas, US, from 2026-03-17 to 2026-04-24. As part of the Geological Earth Mapping Experiment (GEMx) mission, NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and MASTER instruments were used to collect the measurements over the country's arid and semi-arid regions 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. The L1B data is provided in HDF-4 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., J.S. Myers, K.J. Thome, M. Fitzgerald, 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

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. https://doi.org/10.3334/ORNLDAAC/2472

- Level 1 and Level 2 products from MASTER for GEMx in 2023, 2024 and 2025.

Hulley, G.C., S.J. Hook, T.T. La, and G. Rivera. 2026. MASTER: Level 2 Emissivity and Land Surface Temperature. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2489

- Level 2 products for these 2026 GEMx flight lines are available in Hulley et al. (2026).

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: 2026-03-17 to 2026-04-24

Temporal Resolution: One-time estimate

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

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Southwestern U.S.	-119.8	-102.5	39.7	32.4

Data File Information

This dataset includes a total of 278 data files: 61 files in Hierarchical Data Format (HDF-4; *.hdf) format, 96 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 40 text (*.txt) files, 10 archives of text files that are zipped (*.zip), 10 flight maps as GIF (*.gif) images, and 61 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 10 flights with 61 flight tracks (Table 2).
- For each flight track, there is one L1B data file in HDF format and an auxiliary browse image (*.jpg). RGB overlays of TIR and VSWIR radiance in KMZ format for 48 flight tracks.
- 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_2664200_01_20260317_1945_2000_V01.hdf).

The flight track-level browse images are named MASTERL**AA_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH**_V0**J**.jpg (e.g., MASTERL1B_2664200_01_20260317_1945_2000_V01.jpg).

The deployment-level auxiliary files are named MASTER_**BBBBBBBB_YYYYMMDD_X**.**ext** (e.g., MASTER_2665200_20260424_config.txt).

- AA = ”1B”, indicating L1B 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", "kmz", "gif", "jpg", "txt", or "zip", indicating the file format.

Table 1. File names and descriptions.

File Name	Level	File Type	Total Files	Description
Primary Data Files				
MASTERL1B_*BBBBBBB_CC_YYYYmmDD_EEFF_GGHH*_V0*J*.hdf	L1B	HDF-4	61	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.
MASTERL1B_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*-TIR-47-44-43.kmz	L1B	KMZ	48	RGB representation of L1B thermal infrared radiance using bands 47 (red), 44 (green), and 43 (blue).
MASTERL1B_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*-VSWIR-21-12-03.kmz	L1B	KMZ	48	RGB representation of L1B short-wave, visible radiance using bands 21 (red), 12 (green), and 3 (blue).
Auxiliary Files				

File Name	Level	File Type	Total Files	Description
MASTERL1B_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0J.jpg	L1B	JPEG	61	Browse figures; one image per flight track; multiple tracks per flight.
MASTER_*BBBBBBB_YYYYMMDD*_ancillary.txt	-	Text	10	Ancillary information about flight including notes on aircraft platform, mission objective, and data evaluation.
MASTER_*BBBBBBB_YYYYMMDD*_config.txt	-	Text	10	Instrument configuration information for flight.
MASTER_*BBBBBBB_YYYYMMDD*_flightpath.gif	-	GIF	10	Map showing flight paths.
MASTER_*BBBBBBB_YYYYMMDD*_spectral_band_info.txt	-	Text	10	Spectral band information for flight.
MASTER_*BBBBBBB_YYYYMMDD*_spectral_response_table.zip	-	Text	10	Spectral response tables by band (ZIP archive of 50 text files).
MASTER_*BBBBBBB_YYYYMMDD*_summary.txt	-	Text	10	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 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 2026 deployment over western U.S. states.

Date	Flight Number	Locations (USA)	Flight Tracks
2026-03-17	2664200	Santa Catalina / Pacific Ocean, Salton Sea	4
2026-03-31	2664300	Mojave Desert -> Grand Canyon	3
2026-04-02	2664400	Mescalero Sands -> Hobbs NM (GEMx TY627)	4
2026-04-04	2664500	Southeastern Utah (GEMx U137)	10
2026-04-12	2664600	Northeastern New Mexico (GEMx TY642)	2
2026-04-15	2664700	Southeastern New Mexico (GEMx TY627)	6
2026-04-18	2664800	Southeastern New Mexico (GEMx M160)	8
2026-04-19	2664900	Northeastern New Mexico (GEMx M251)	10
2026-04-21	2665000	Central Colorado (GEMx O146)	8
2026-04-24	2665200	Central Colorado (GEMx TY691)	6
		Total	61

Level 2 (L2) data will be available in the related dataset (Hulley et al., 2026).

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 GEMx research project uses NASA's AVIRIS, HyTES, and 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 19,190 - 20,040 m above sea level.

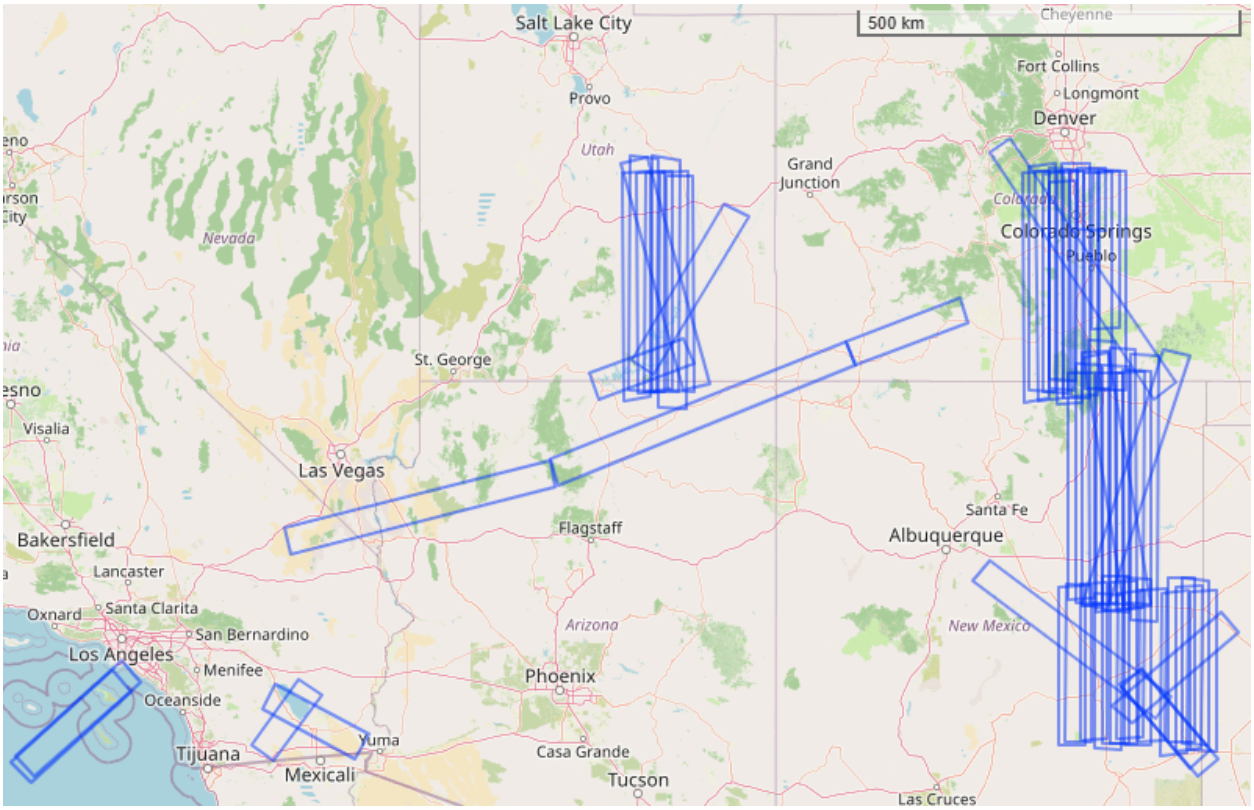

Figure 2. Flight tracks in this dataset represented as blue rectangular polygons over the southwestern United States. Basemap: © OpenStreetMap contributors.

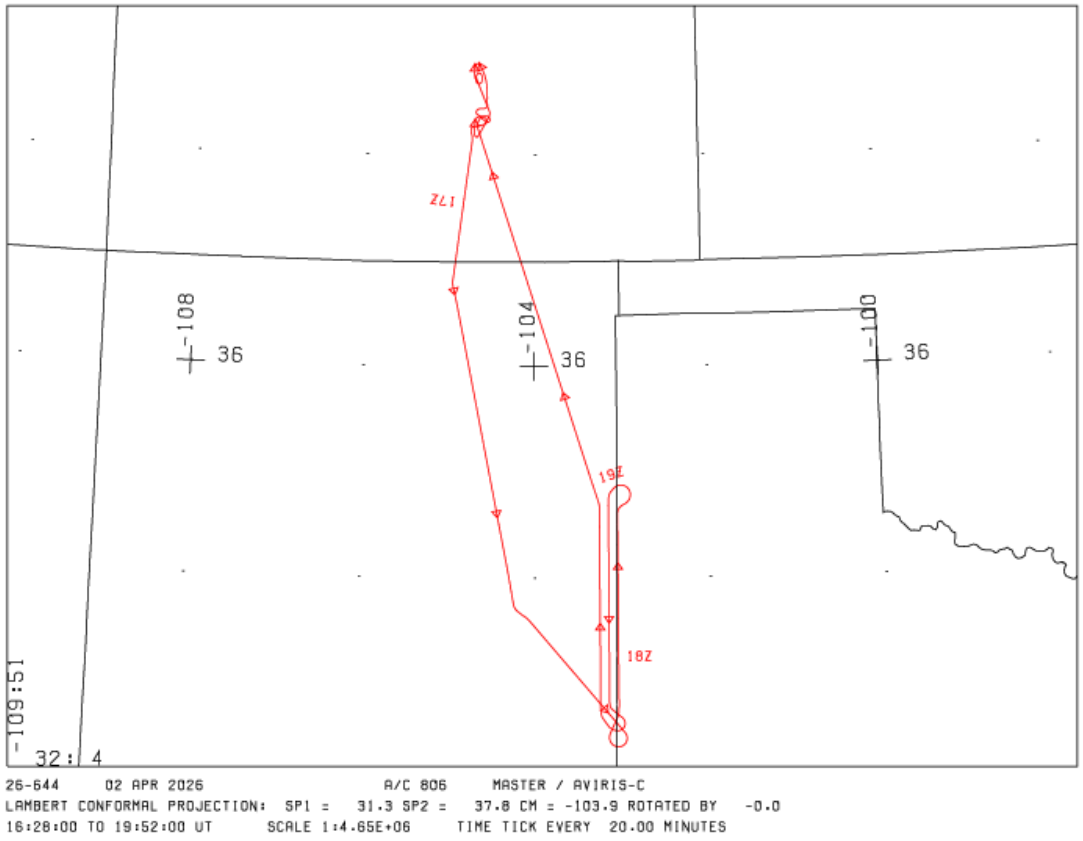

Figure 3. Typical flight path is shown for 02 April 2026. Flight 2664400 and four flight tracks occurred over New Mexico, U.S., near the border with Texas. Source: MASTER_2664400_20260402_flightpath.gif

6. References

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