MASTER: Westcoast-Heartland Hyperspectral Microwave Sensor Intensive Exp, Spring 2024

Get Data

Documentation Revision Date: 2025-07-28

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 as part of the Westcoast & Heartland Hyperspectral Microwave Sensor Intensive Experiment (WH2yMSIE) airborne campaign during 10 flights aboard a NASA ER-2 aircraft across the central US from Arkansas to California, U.S., and along the west coast and eastern Pacific Ocean. Flights occurred from 2024-10-18 to 2024-11-13. WH2yMSIE demonstrates the first-of-its-kind hyperspectral microwave airborne measurements and is complemented by other passive (infrared, visible) and active (lidar) sensors onboard the aircraft. It serves as a future NASA planetary boundary-layer (PBL) mission prototype and aims to capture a wide variety of thermodynamic, moisture, and PBL regimes across a variety of surface types. 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. The primary goal of this airborne campaign was to demonstrate important science and applications research that is uniquely enabled by the full suite of MASTER thermal infrared bands as well as the contiguous spectroscopic measurements of the AVIRIS (also flown in similar campaigns), or combinations of measurements from both instruments.

This dataset includes a total of 828 data files: 128 files in Hierarchical Data Format (HDF-4; *.hdf) format, 128 files in HDF-5 format, 256 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 128 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 40 text (*.txt) files, 10 archives of text files that are zipped (*.zip), 10 flight maps as GIF (*.gif) images, and 128 browse images in JPEG (*.jpg) format.

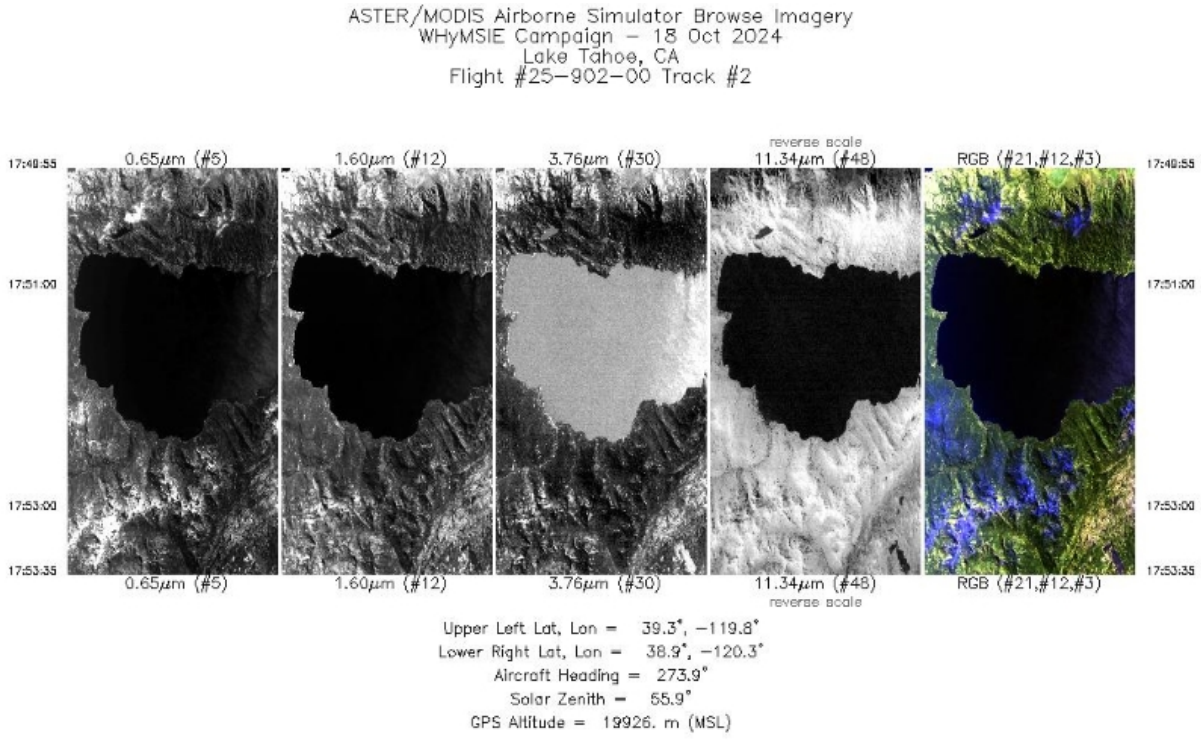

Figure 1. Single band images and an RGB composite image from flight track 2 acquired on 18 October 2024 over Lake Tahoe in eastern California, US (approx. 39.176 lat, -120.023 lon). Source: MASTERL1B_2590200_02_20241018_1749_1753_V01.jpg

Citation

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Table of Contents

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 as part of the Westcoast & Heartland Hyperspectral Microwave Sensor Intensive Experiment (WH2yMSIE) airborne campaign during 10 flights aboard a NASA ER-2 aircraft across the central US from Arkansas to California, U.S., and along the west coast and eastern Pacific Ocean. Flights occurred from 2024-10-18 to 2024-11-13. WH2yMSIE demonstrates the first-of-its-kind hyperspectral microwave airborne measurements and is complemented by other passive (infrared, visible) and active (lidar) sensors onboard the aircraft. It serves as a future NASA planetary boundary-layer (PBL) mission prototype and aims to capture a wide variety of thermodynamic, moisture, and PBL regimes across a variety of surface types. 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.

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.J. 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

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. The WH2yMSIE project was supported through a partnership between NASA and National Atmospheric and Oceanic Administration (NOAA).

2. Data Characteristics

Spatial Coverage: Flights over southern US from Arkansas to California; eastern Pacific Ocean

Spatial Resolution: 50 m

Temporal Coverage: 2024-10-18 to 2024-11-13

Temporal Resolution: One-time estimate

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

Site	Northernmost Latitude	Southernmost Latitude	Easternmost Longitude	Westernmost Longitude
southern US from Arkansas to California; eastern Pacific Ocean	41.0156	22.8254	-89.5892	-129.6213

Data File Information

This dataset includes a total of 828 data files: 128 files in Hierarchical Data Format (HDF-4; *.hdf) format, 128 files in HDF-5 format, 256 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 128 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 40 text (*.txt) files, 10 archives of text files that are zipped (*.zip), 10 flight maps as GIF (*.gif) images, and 128 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 10 flights with 128 flight tracks (Table 2).
- For each flight track, there is at one L1B data file in HDF-4 format and an auxiliary browse image (*.jpg).
- L2 data are included for all 128 flight tracks. For each track, 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 MASTER**LAA_BBBBBBB_CC_YYYYMMDD_EEFF_GGHH**_V0**J-X.ext** (e.g., MASTERL1B_2590700_03_20241031_1748_1811_V01.hdf).

The flight track-level browse images are named MASTERL1B_**BBBBBBB_CC_YYYYMMDD_EEFF_GGHH**_V0**J**.jpg (e.g., MASTERL1B_2590700_03_20241031_1748_1811_V01.jpg).

The deployment-level auxiliary files are named MASTER_**BBBBBBB_YYYYMMDD_X.ext** (e.g., MASTER_2590700_20241031_config.txt).

Elements of file names are described as:

- AA = ”1B” indicating L1B data level and "2" indicating L2 data level,
- BBBBBBB = the flight number (see Table 2),
- 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 ("1", "2", or "3"),
- X = the file content (see Table 1), and
- ext = "hdf", "hdf5","kmz", "gif", "jpg", "txt", or "zip", indicating the file extension.

The "B200_SV01" element is included in some 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_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*.hdf	L1B	HDF-4	128	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_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*_B200_SV01.hdf5	L2	HDF-5	128	Five sub datasets: (a) Atmospheric corrected emissivity: Temperature and Emissivity Separation (TES) corrected data in 5 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.
MASTERL2_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*-images.zip	L2	PNG	128	Four non-georeferenced images: two RGB composites using selected bands, emissivity from a single band, and land surface temperature.
MASTERL2_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J_B200_SV01*-LST.kmz	L2	KMZ	128	Map of land surface temperature in degrees Kelvin.
MASTERL2_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*_B200_SV01-emiss-RGB-47-44-43.kmz	L2	KMZ	128	Map of RGB representation of emissivity.
Auxiliary Files				
MASTERL1B_*BBBBBBB_CC_YYYYMMDD_EEFF_GGHH*_V0*J*.jpg	L1B	JPEG	128	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.

File Name	Level	File Type	Total Files	Description
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. Each Zip archive holds a collection of approximately 50 files detailing spectral responses by band and related information.
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 files contain swath trajectory data using longitude and latitude coordinates. The spatial resolution is approximately 44 to 51 m and is a function of aircraft altitude.

Table 2. Number of flight tracks for each MASTER flight during this 2024 deployment over southern US from Arkansas to California (CA) and eastern Pacific Ocean.

Date	Flight Number	Locations (USA)	Flight Tracks	
		Data Level	L1B	L2
2024-10-18	2590200	Sierra Nevada / Mono Lake, CA	14	14
2024-10-22	2590300	California / Arizona	12	12
2024-10-23	2590400	Southern California and eastern Pacific Ocean	12	12
2024-10-25	2590500	California / Arizona / New Mexico / Texas / Oklahoma / Arkansas	11	11
2024-10-30	2590600	Southern California and eastern Pacific Ocean	12	12
2024-10-31	2590700	California / Arizona	17	17
2024-11-04	2590800	Southern California and eastern Pacific Ocean	15	15
2024-11-07	2590900	Sierra Nevada Mts. and eastern Pacific Ocean	14	14
2024-11-12	2591000	Southern California and eastern Pacific Ocean	9	9
2024-11-13	2591100	Owens Valley, CA and eastern Pacific Ocean	12	12
		Total	128	128

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 cover (Li and Moon, 2004), coral reefs (Capolsini et al., 2003), and urban heat islands (Zhao and Wentz, 2016).

The Westcoast & Heartland Hyperspectral Microwave Sensor Intensive Experiment (WH2yMSIE) (Gambacorta et al., 2024) demonstrated the first-of-its-kind hyperspectral microwave airborne measurements (the CoSMIR-H instrument) and was complemented by other passive (infrared, visible) and active (lidar) sensors (e.g., MASTER) onboard the NASA ER-2 aircraft. WH2yMSIE serves as a future NASA planetary boundary-layer (PBL) mission prototype, which aimed to capture a wide variety of thermodynamic, moisture, and PBL regimes across a variety of surface types. The ER-2 flew over a variety of land and ocean environments.

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_*BBBBBBB_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, 2021). 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 campaign, the MASTER instrument was flown on NASA's ER-2 aircraft at altitudes of 17,800–20,310 m above sea level.

Serving as a future NASA planetary boundary-layer (PBL) mission prototype, WHyMSIE (Gambacorta et al., 2024) captured a wide variety of thermodynamic, moisture, and PBL regimes across a variety of surface types. The ER-2 flew over a variety of land and ocean environments. Over land, the aircraft overflew radiosonde launch sites as well as locations with PBL relevant ground-based in situ and remote sensing measurements. The flight paths include the ARM Southern Great Plains (SGP) Central Facility (CF) for validating the retrieved temperature and water vapor profiles from the WHyMSIE instrument payload. Over water, a wide range of temperature and water vapor conditions were captured, with a specific focus on clear sky scenes for high quality comparisons with program of record (POR) satellite instruments (e.g. ATMS, AMSU). Comparing hyperspectral microwave retrievals from CoSMIR-H with in situ temperature and humidity information will allow for scientific advancement of remote-sensing techniques into the hyperspectral microwave era and improved understanding of the PBL at different measurement scales.

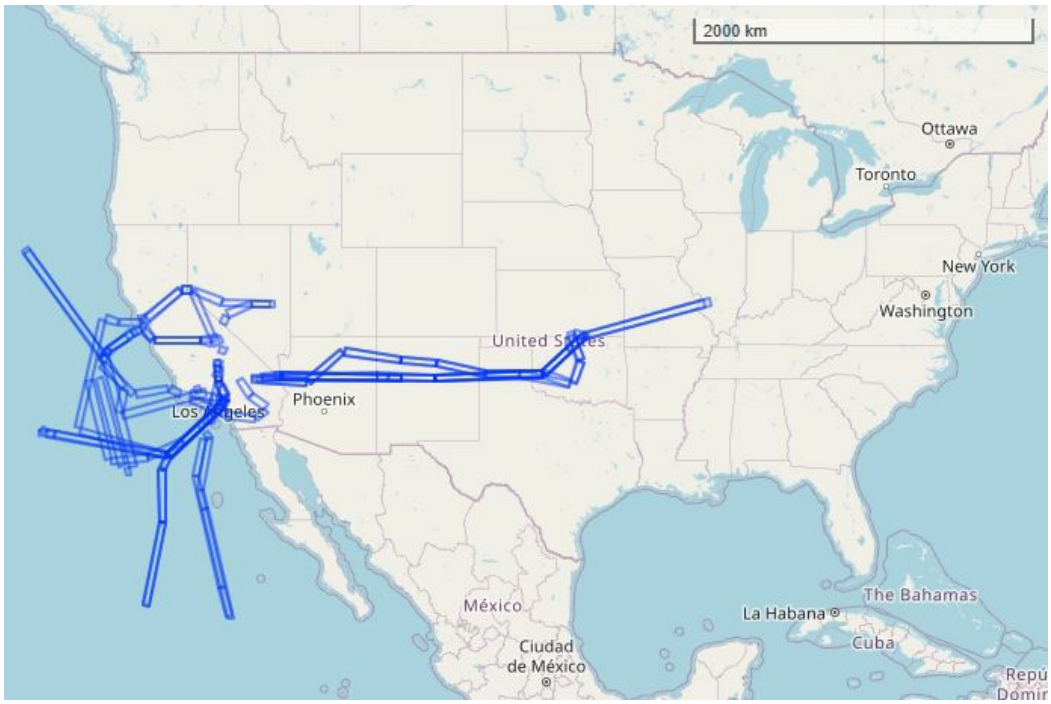

Figure 2. Flight tracks over U.S. and eastern Pacific Ocean represented as rectangular polygons. Basemap: © OpenStreetMap contributors.

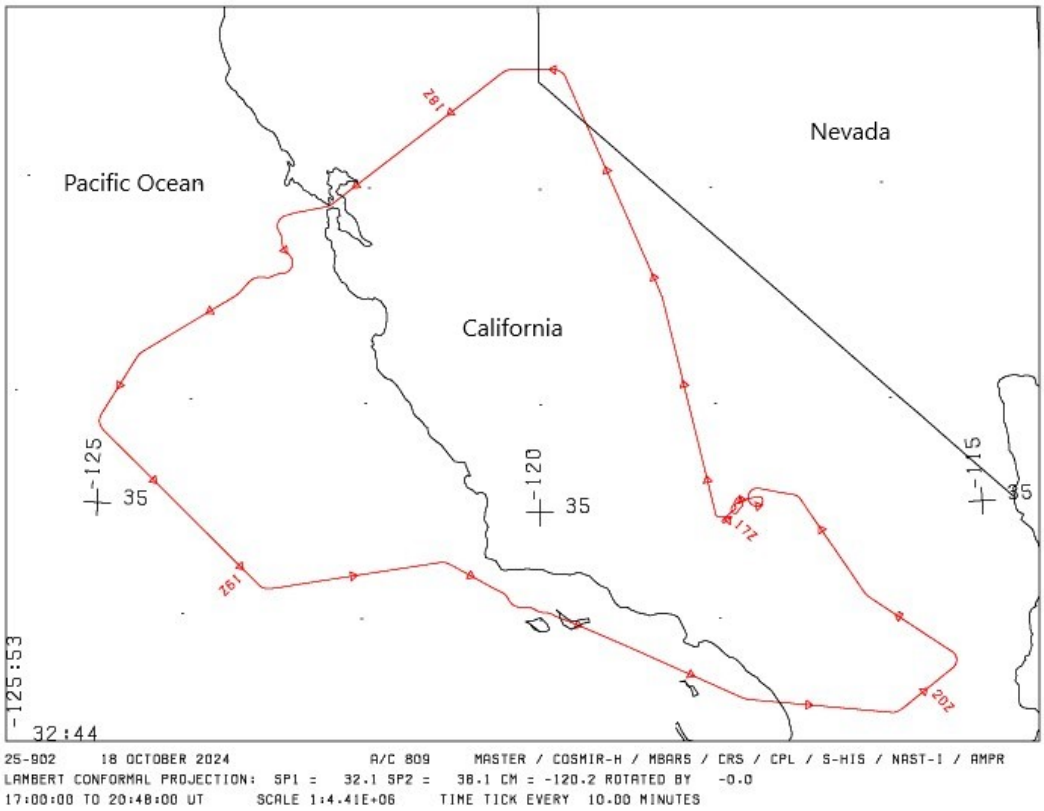

Figure 3. Typical flight path is shown for 18 October 2024. Flight 2590200 and 14 flight tracks occurred over California and nearby Pacific Ocean. Source: MASTER_MASTER_2590200_20241018_flightpath.gif

6. Data Access

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

MASTER: Westcoast-Heartland Hyperspectral Microwave Sensor Intensive Exp, Spring 2024

Contact for Data Center Access Information:

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

7. References

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