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MASTER: Western Diversity Time Series Campaign, WDTS, Spring 2023

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Documentation Revision Date: 2024-03-05

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 Western Diversity Time Series (WDTS, formerly HyspIRI) airborne campaign during 12 flights aboard a NASA ER-2 aircraft over California and Nevada, U.S., from 2023-03-31 to 2023-05-02. The WDTS campaign will observe California's ecosystems and provide critical information on natural disasters such as volcanoes, wildfires, and drought. MASTER products can identify vegetation type and health and provide a benchmark for the state of the ecosystems against which future changes can be assessed. 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. 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 1931 data files: 222 files in Hierarchical Data Format (HDF-4; *.hdf) format, 808 ENVI raster files (*.dat and *.hdr) that are compressed (*.zip), 405 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 196 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 52 text (*.txt) files, 13 archives of text files that are zipped (*.zip), 13 flight maps as GIF (*.gif) images, and 222 browse images in JPEG (*.jpg) format.

There are multiple versions of the L1B and L2 files available in this dataset.

ASTER/MODIS Airborne Simulator Browse Imagery
 PICARD_CalVal Campaign – 05 Apr 2023
 Pacific Ocean / Northern California
 Flight #23-642-00 Track #10

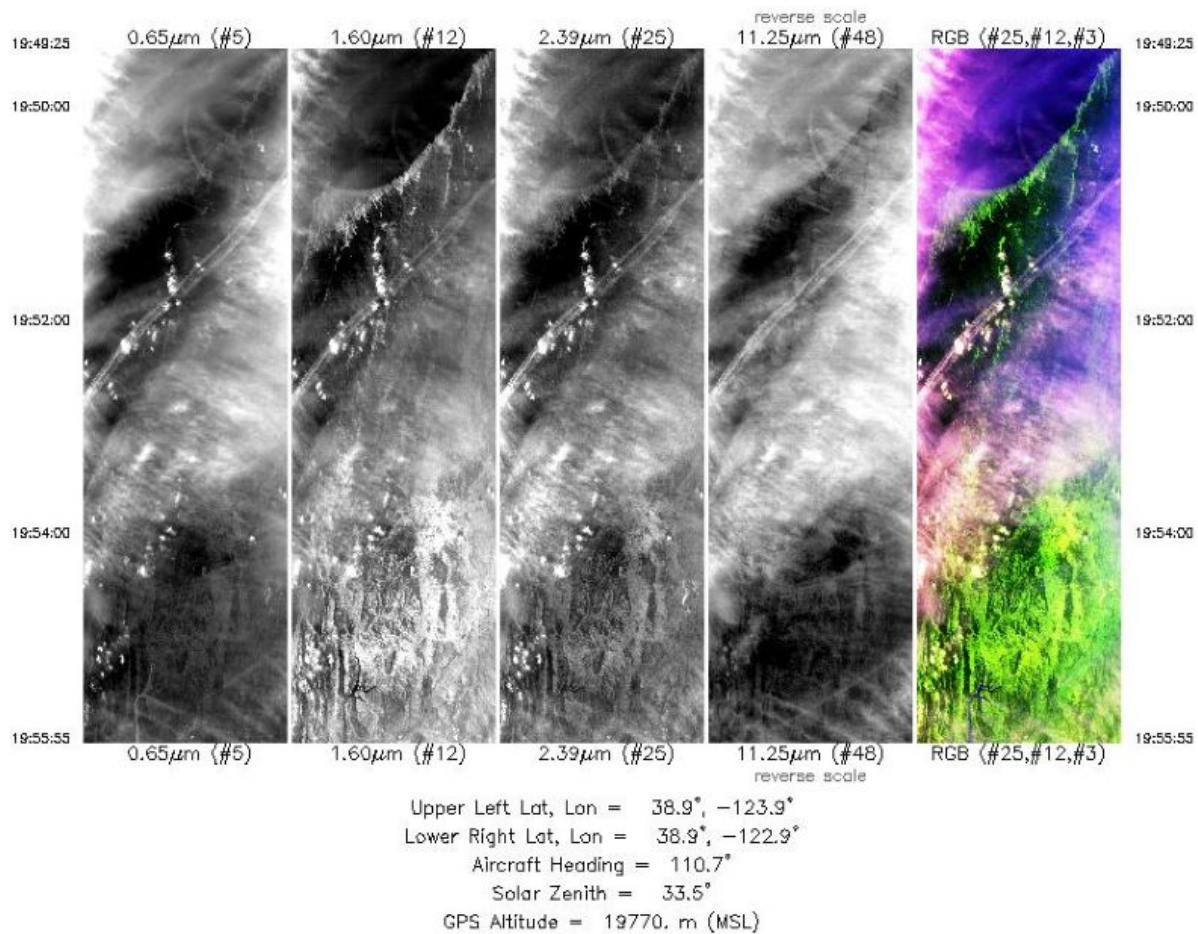


Figure 1. Single band images and an RGB composite image from flight track 12 acquired on 05 April 2023 over the ocean and coast near Point Arena, California, U.S. Source: MASTERL1B_2364200_10_20230405_1949_1955_V01.jpg

Citation

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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 as part of the Western Diversity Time Series (WDTS, formerly HySPIRI) airborne campaign during 12 flights aboard a NASA ER-2 aircraft over California and Nevada, U.S., from 2023-03-31 to 2023-05-02. The WDTS campaign will observe California's ecosystems and provide critical information on natural disasters such as volcanoes, wildfires, and drought. MASTER products can identify vegetation type and health and provide a benchmark for the state of the ecosystems against which future changes can be assessed. 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 μ 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

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 and western Nevada, U.S.

Spatial Resolution: 50 m

Temporal Coverage: 2023-03-31 to 2023-05-02

Temporal Resolution: One-time estimate

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

Site	Northernmost Latitude	Southernmost Latitude	Easternmost Longitude	Westernmost Longitude
California; western Nevada	43.0689	30.4014	-112.5000	-129.56306

Data File Information

This dataset includes a total of 1931 data files: 222 files in Hierarchical Data Format (HDF-4; *.hdf) format, 808 ENVI raster files (*.dat and *.hdr) that are compressed (*.zip), 405 files in Keyhole Markup Language Zipped (KMZ; *.kmz) format, 196 Portable Network Graphics (PNG; *.png) files that are compressed (*.zip), 52 text (*.txt) files, 13 archives of text files that are zipped (*.zip), 13 flight maps as GIF (*.gif) images, and 222 browse images in JPEG (*.jpg) format.

There are multiple versions of the L1B and L2 files included in this dataset, which represent products from different processing algorithms.

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 12 flights with 111 flight tracks (Table 2).
- For each of 111 flight tracks, there is at least one L1B data file in HDF format and an auxiliary browse image (*.jpg).
- L2 data are included for 104 of the 111 flight tracks. For each track, there are five L2 data files in ZIP format for a given version.
 - 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.
- There are L1B RGB composite images (*.RGB.kmz) and L2 land surface temperature (*.LST.kmz) in KMZ format for 98 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 MASTERL1B_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_V0J-X.ext (e.g., MASTERL1B_2364200_10_20230405_1949_1955_V01.hdf).

The flight track-level browse images are named MASTERL1B_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_V0J.jpg (e.g., MASTERL1B_2364200_10_20230405_1949_1955_V01.jpg).

The deployment-level auxiliary files are named MASTER_BBBBBBBB_YYYYMMDD_X.ext (e.g., MASTER_2364200_20230405_config.txt).

Elements of file names are described as:

BBBBBBBB = 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", "kmz", "gif", "jpg", "txt", or "zip", indicating the file extension.

Table 1. File names and descriptions.

File Name	Level	File Type	Total Files	Description
Primary Data Files				

File Name	Level	File Type	Total Files	Description
MASTERL1B_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J.hdf	L1B	HDF-4	222	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.
MASTERL1B_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHHV0J-RGB.kmz	L1B	KMZ	209	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	202	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	196	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	202	Latitude and longitude coordinates for pixels in ENVI files.
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-LST.kmz	L2	KMZ	196	Map of land surface temperature in degrees Kelvin.
MASTERL2_BBBBBBBB_CC_YYYYmmDD_EEFF_GGHH_V0J-QAmap.zip	L2	ENVI	202	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	202	Map of land surface temperature (TES LST) in degrees Kelvin.
Auxiliary Files				
MASTERL1B_BBBBBBBB_CC_YYYYMMDD_EEFF_GGHH_V0J.jpg	L1B	JPEG	222	Browse figures; one image per flight track; multiple tracks per flight.
MASTER_BBBBBBBB_YYYYMMDD_ancillary.txt	-	Text	13	Ancillary information about flight including notes on aircraft platform, mission objective, and data evaluation.
MASTER_BBBBBBBB_YYYYMMDD_config.txt	-	Text	13	Instrument configuration information for flight.
MASTER_BBBBBBBB_YYYYMMDD_flightpath.gif	-	GIF	13	Map showing flight paths.
MASTER_BBBBBBBB_YYYYMMDD_spectral_band_info.txt	-	Text	13	Spectral band information for flight.
MASTER_BBBBBBBB_YYYYMMDD_spectral_response_table.zip	-	Text	13	Spectral response tables. Each Zip archive holds a collection of approximately 50 files detailing spectral responses by band and related information.
MASTER_BBBBBBBB_YYYYMMDD_summary.txt	-	Text	13	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 is approximately 50 m and is a function of aircraft altitude.

Table 2. Number of flight tracks for each MASTER flight during this 2023 deployment over California (CA) and Nevada (NV).

Date	Flight Number	Locations (USA)	Flight Tracks	
			Data Level	
			L1B	L2
2023-03-31	2364100	Yosemite NEON Box	12	11
2023-04-05	2364200	Northern California	12	11
2023-04-10	2364300	Lake Tahoe Box	12	12
2023-04-11	2364400	Pacific Ocean	2	2
2023-04-12	2364500	San Francisco Bay Area Box	12	12
2023-04-20	2364700	Ivanpah Playa (CA/NV)	10	10
2023-04-21	2364800	Santa Barbara Box	11	10
2023-04-25	2364900	Southeastern California (GEMx CA09)	12	11
2023-04-26	2365000	Southern California Box	10	9

2023-04-27	2365100	Southern California / Pacific Ocean	8	6
2023-04-28	2365200	California / Arizona (GEMx TY03)	6	6
2023-05-02	2365300	Railroad Valley, NV	4	4
Total			111	104

User Note: For Flight Number 2365200, the date encoded in the file names is "20230427" for the V01 files and "20230428" for the V03 files. Thus, there are two sets of ancillary files for this single flight in the dataset. This flight occurred on 2023-04-28.

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).

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_YYMMDD_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.

The Western Diversity Time Series (WDTS, formerly HyspIRI) program will observe California's ecosystems and provide critical information on natural disasters such as volcanoes, wildfires, and drought. It will provide a benchmark on the state of the ecosystems against which future changes can be assessed, as the instruments will be capable of identifying vegetation type and health. The WDTS Airborne Campaign is a multi-year effort to collect seasonal VIS-SWIR and TIR airborne scanner data using both AVIRIS and MASTER remote sensing instruments aboard the ER-2 high-altitude platform (ASF, 2021).

For this campaign, the MASTER instrument was flown on NASA's ER-2 aircraft at altitudes of 19,334–20,560 m above sea level.

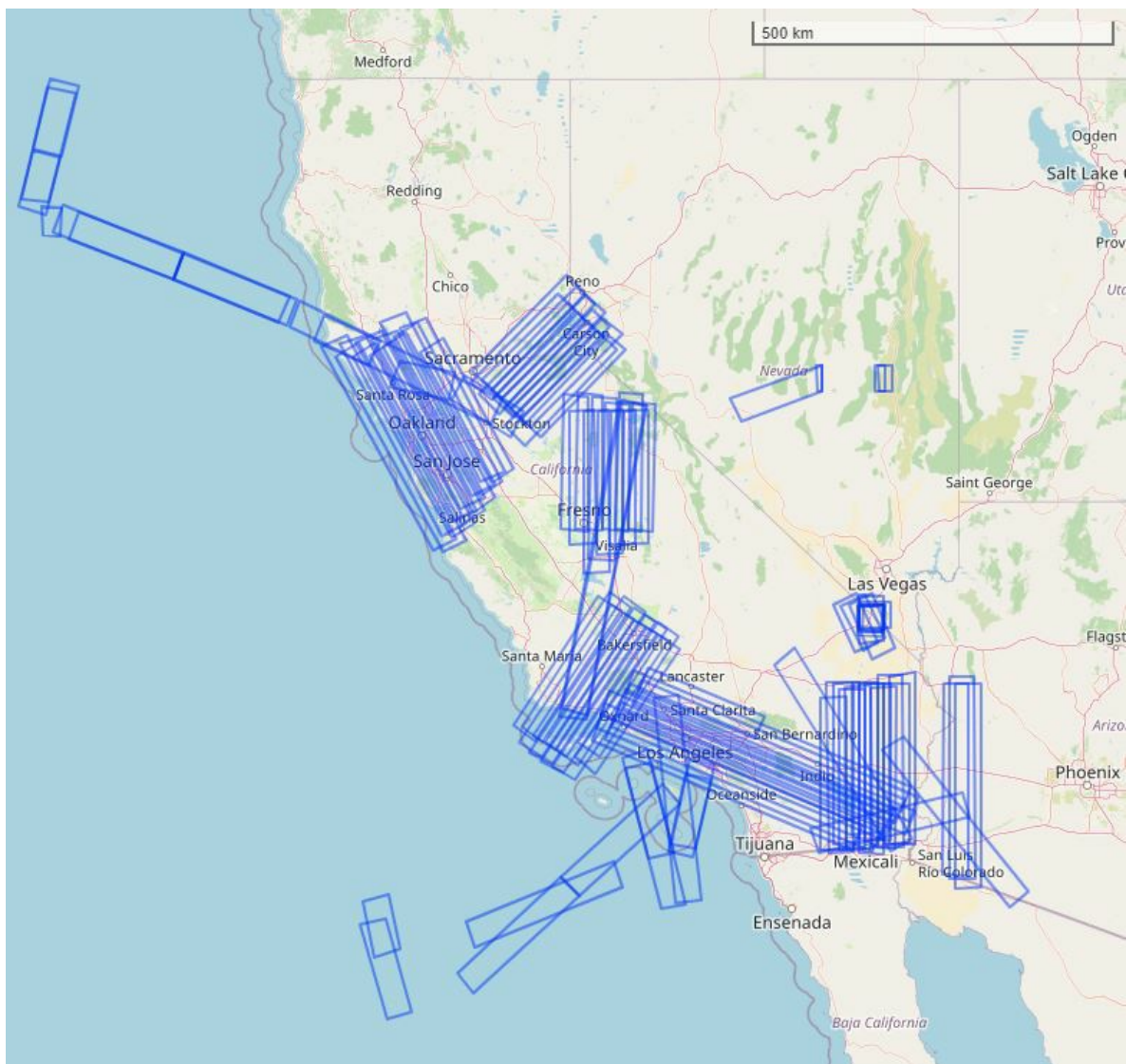


Figure 2. Flight tracks over California and Nevada represented as rectangular polygons. Basemap: © [OpenStreetMap](#) contributors.

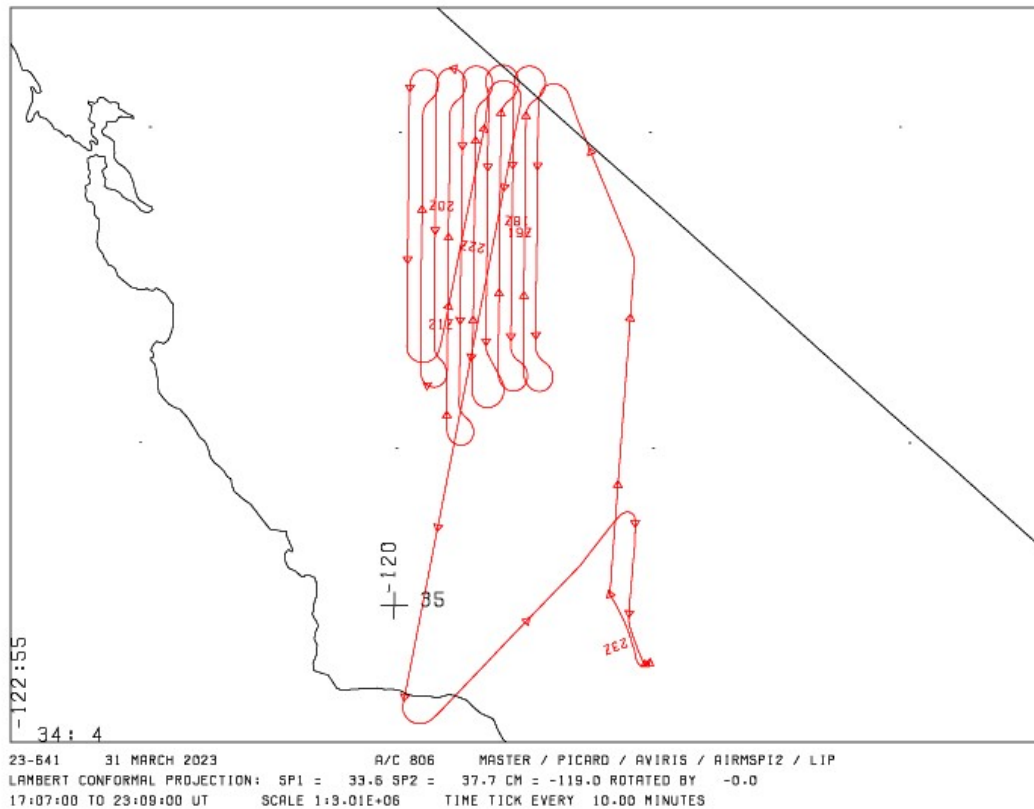


Figure 3. Flight path for Flight 2364100, flown on 31 March 2023. Flight 2364100 and 12 flight tracks occurred over California. Source: MASTER_2364100_20230331_flightpath.gif

6. Data Access

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

MASTER: Western Diversity Time Series Campaign, WDTS, Spring 2023

Contact for Data Center Access Information:

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

7. References

- ASF. 2021. Campaign summary information: HypsIRI / WDTS Airborne Campaign. Airborne Sensor Facility, Airborne Science Program, NASA Ames Research Center, Moffett Field, California. https://asapdata.arc.nasa.gov/sensors/master/data/deploy_html/hypsiri_home.html
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- JPL. 2021a. Calibration and Validation, MASTER: MODIS/ASTER Airborne Simulator. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA. <https://masterprojects.jpl.nasa.gov/cal-val>
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8. Dataset Revisions

Version	Release Date	Revision Notes
1.0 update	2024-03-05	New versions (V02 and V03) of files appended to previous release. See Section 2: Dataset Characteristics; file naming conventions.
1.0	2023-09-15	Original publication with version V01 files



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