Global Hydrology Resource Center

Data User Guide

TCSP ER-2 Lightning Instrument Package (LIP)

Introduction

The TCSP ER-2 Lightning Instrument Package (LIP) dataset consists of electrical field measurements of lightning from seven field mills, air conductivity data from a two channel conductivity probe, and navigation data, for the period of July 2 to July 27, 2005. These data were collected by the Lightning Instrument Package (LIP) flown aboard the NASA ER-2 high-altitude aircraft during the Tropical Cloud Systems and Processes (TCSP) field campaign in July 2005. The main goal of the campaign was to gain further insight into the structure and lifecycle of tropical weather systems. The TCSP ER-2 LIP data are provided in ASCII text files with PNG browse image files.

Citation

Blakeslee, Richard J., Monte Bateman and Douglas M. Mach. 2006. *TCSP ER-2 LIGHTNING INSTRUMENT PACKAGE (LIP)*[indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. DOI:http://dx.doi.org/10.5067/TCSP/LIP/DATA101

Keywords:

NASA, NOAA, GHRC, TCSP, ER-2, LIP, atmospheric electricity, air conductivity

Campaign

The Tropical Cloud Systems and Processes (TCSP) mission was a research campaign sponsored by the Science Mission Directorate of NASA. The field phase of the campaign was conducted from July 1 through July 27, 2005, during the active Atlantic and eastern Pacific hurricane seasons; flying missions out of Juan Santamaria Airport in San Jose, Costa Rica. There were 12 NASA ER-2 flights taken during the campaign along with 18 coordinated P-3 flights by the NOAA Hurricane Research Division aimed at studying the evolution of tropical weather systems. These airborne missions collected various types of data to be

used for research related to the dynamic and thermodynamic properties of tropical disturbances as well as their development and intensification processes. During the campaign, observations were collected for Hurricanes Dennis and Emily, Tropical Storm Gert, and an eastern Pacific mesoscale complex that may have later developed into Tropical Storm Eugene (Figure 1). The airborne and surface observations collected during the campaign provided a deeper understanding of the structure and lifecycle of tropical weather systems and helped to improve numerical modeling of these systems. More information about the campaign is available on the TCSP Field Campaign webpage and in Halverson et al. (2007).

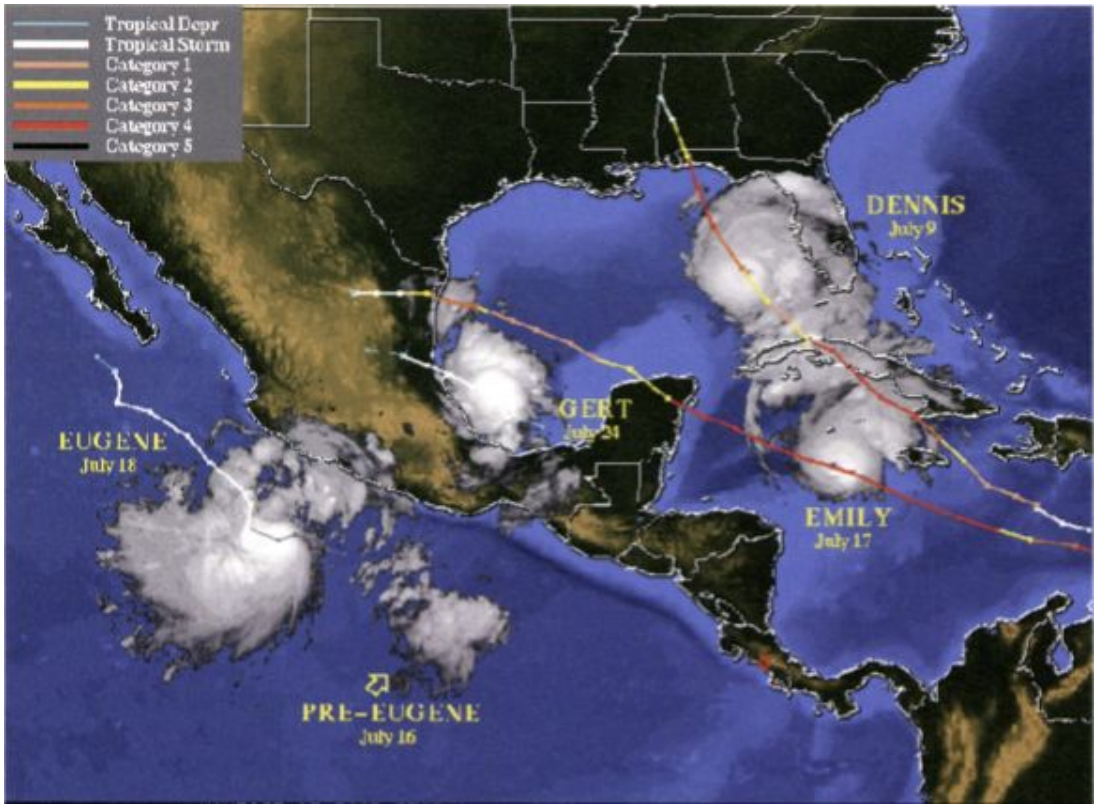

Figure 1: Storms observed by the NASA ER-2 and NOAA P-3 during TCSP, including storm tracks and intensities
(Image source: Halverson et al., 2007)

Instrument Description

The Lightning Instrument Package (LIP) was flown aboard the NASA ER-2 research aircraft during the TCSP campaign. The TCSP ER-2 LIP consisted of seven electric field mills and a dual-tube conductivity probe. The rotating-vane electric field mills (Figure 2a) are compact sensors, each weighing less than 10 lbs, that are installed on the top and bottom of the aircraft along the plane's centerline and on the superpods (Figure 3). These sensors measure the electric fields in the thunderstorm environment by sampling the three-dimensional components of the electric field (i.e., Ex, Ey, Ez); greatly improving understanding of the electrical structure of storms. The field mills also provide a

measurement of the electric charge (Q) on the aircraft. The conductivity probe (Figure 2b), consisting of a pair of gerdien capacitor type sensors, was installed on left hand superpod nose cone (Figure 3). The probe measures air conductivity at aircraft flight level by measuring positive and negative ions simultaneously throughout the flight. Storm electric currents can then be derived using the electric field and air conductivity measurements.

Figure 2. (a) An ER-2 LIP electric field mill & (b) the dual-tube gerdien conductivity probe. (Image sources: Blakeslee, Richard J., Monte Bateman and Douglas M. Mach)

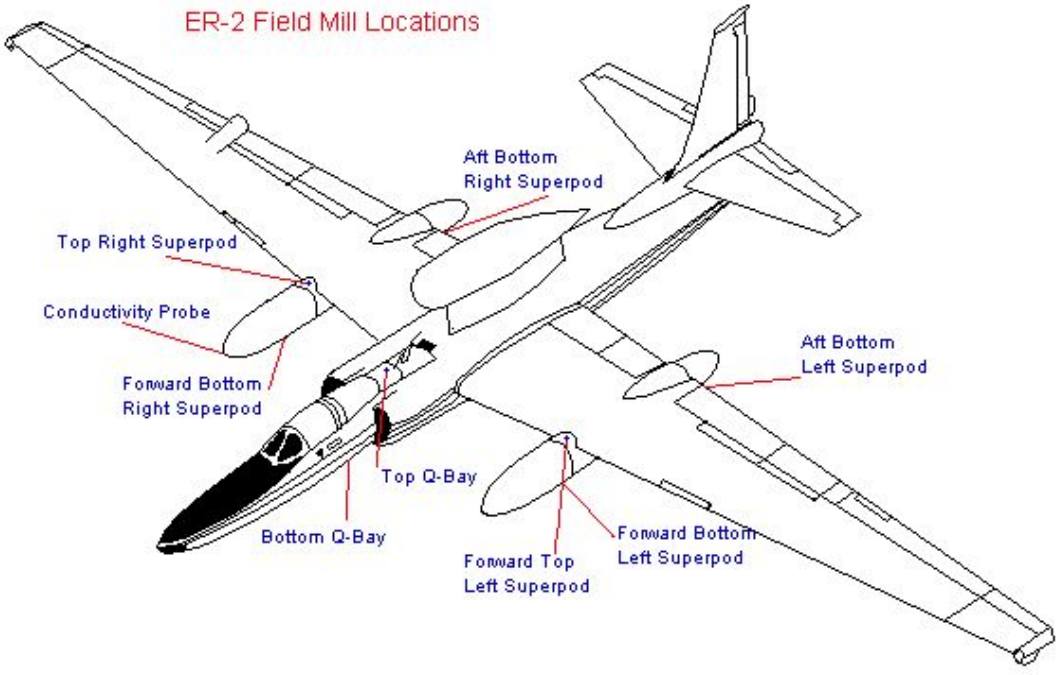

Figure 3: Locations of the eight field mills and the conductivity probe as mounted on the ER-2 aircraft. Note: The aft-right-bottom field mill, as shown in the diagram, was not used during the TCSP mission.

(Image source: Richard J. Blakeslee)

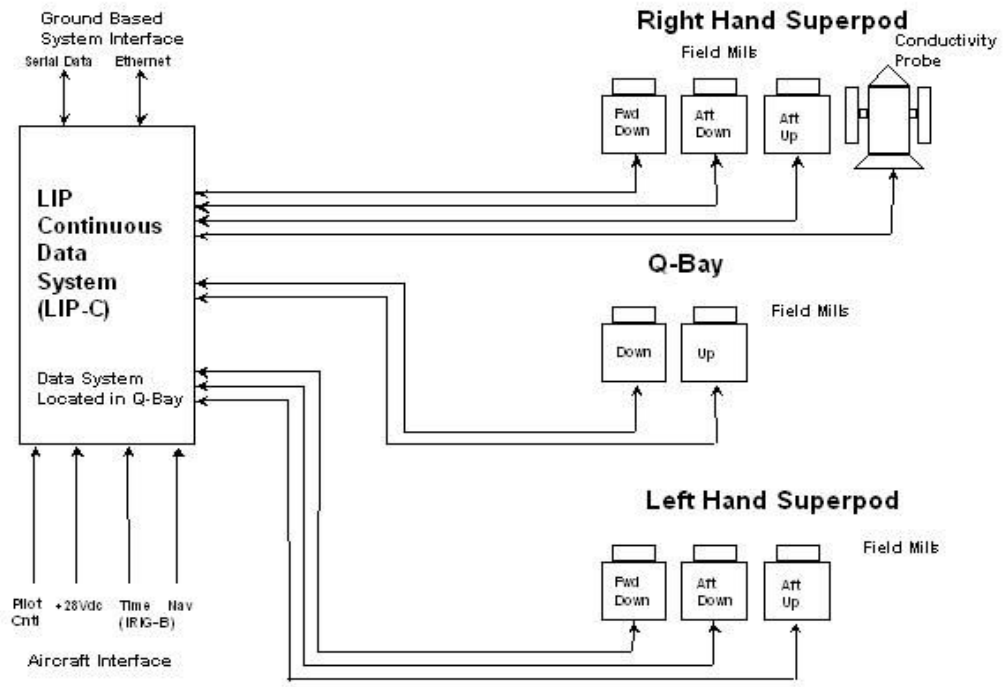

Figure 4. Schematic diagram of the ER-2 LIP instrumentation package.
(Image source: Richard J. Blakeslee)

A schematic diagram of the ER-2 LIP is shown in Figure 4 above. In this configuration, the field mills measure the components of the electric field over a wide range of conditions from fair weather electric fields with a few to tens of volts per meter, to large thunderstorm fields with tens of kilovolts per meter. More information about the LIP instrument can be found on the NASA Airborne Science LIP webpage. To learn more about field mill design and how they work, visit the Mission Instruments Electric Field Mill webpage.

Investigators

Richard J. Blakeslee
NASA/MSFC
Huntsville, AL

Monte Bateman
Universities Space Research Association
Huntsville, AL

Douglas M. Mach
Universities Space Research Association
Huntsville, AL

Data Characteristics

The TCSP ER-2 Lightning Instrument Package (LIP) dataset files are available as ASCII text files at Level 1A processing level. More information about the NASA data processing levels are available on the EOSDIS Data Processing Levels webpage. Each flight has a field mill data file and a conductivity data file, both in ASCII format. Also provided are browse image files in PNG format. Table 1 lists the characteristics of this dataset.

Table 1: Data Characteristics

Characteristic	Description
Platform	NASA Earth Resources 2 (ER-2) aircraft
Instrument	Lightning Instrument Package (LIP)
Spatial Coverage	N: 43.5284 , S: 0 , E: 0, W: -125.446 (Gulf of Mexico)
Spatial Resolution	20 m
Temporal Coverage	July 2, 2005 - July 27, 2005
Temporal Resolution	Hourly -< Daily
Sampling Frequency	1 second
Parameter	Atmospheric electricity, air conductivity
Version	1
Processing Level	1A

File Naming Convention

The TCSP ER-2 Lightning Instrument Package (LIP) dataset files use the following naming convention:

Data files:
TCSP_LIP_cond_<YYYY.DDD>_<YYMMDD>_<hhmm>.txt
TCSP_LIP_fieldmill_<YYYY.DDD>_<YYMMDD>.txt

Browse files:
TCSP_LIP_cond_<YYYY.DDD>_<YYMMDD>_<hhmm>_[log|lin].png
TCSP_LIP_fieldmill_<YYYY.DDD>_<YYMMDD>_<NN>.png

Table 2: File naming convention variables

Variable	Description
cond	Conductivity data
fieldmill	Field mill data
YYYY.DDD	YYYY: Four-digit year DDD: Three-digit day of the year (Julian day)
YYMMDD	YY: Two-digit year MM: Two-digit month DD: Two-digit day

NN	NN: number of the plot (in one-hour plots, starting at the beginning of each flight)
[log|lin]	The scale of the plot log: logarithmic lin: linear
hhmm	hh: Two-digit hour in UTC mm: Two-digit minute in UTC
.txt	ASCII text file
.png	Portable Network Graphics (PNG) file

Data Format and Parameters

The TCSP ER-2 Lightning Instrument Package (LIP) dataset consists of field mill and conductivity data in ASCII text files and PNG browse image files.

Field Mill Data files

The LIP field mill data are available in ASCII text files with each file containing a continuous record for the entire length of the flight. The ASCII data are organized into columns that correspond to each parameter recorded by the LIP field mills along with other useful recordings. These data were recorded every second during the flight. The files begin with a header that labels each data column. The data columns are described in Table 3 below.

Table 3. Data fields in the field mill ASCII files

Field Name	Description	Units
UTC	UTC Time in *YYYY-MM-DD HH:MM:SS.SSS* format where YYYY: Four-digit year MM: Two-digit month DD: Two-digit day HH: Two-digit hour MM: Two-digit minute SS.SSS: Two-digit second and three-digit millisecond	-
Ex	Electric field component for the aircraft x-coordinate	kV/m
Ey	Electric field component for the aircraft y-coordinate	kV/m
Ez	Electric field component for the aircraft z-coordinate	kV/m
Eq	Self-charge of the aircraft	kV/m
En	North-South electric field component (North being positive)	kV/m
Ew	East-West electric field component (West being positive)	kV/m
Eu	Up-Down electric field component (Up being positive)	kV/m
Em	Magnitude of the electric field	kV/m

Note: Missing data values are set as “NaN”

Conductivity Data files

The LIP conductivity data are also available in ASCII text files. The data are organized into columns that correspond to each parameter recorded by the LIP conductivity probes along

with other useful recordings. Data were sampled for 10 seconds and then averaged at a 1 second interval to match the sample rate of the aircraft navigation data. Because the voltages in the conductivity probe were applied for 30 second intervals to collect the data, there is one sample every 3 seconds. These files begin with a short header listing the Julian day of the data. Values for both Probe 1 and Probe 2 are included in each file. The data for Probe 1 are listed first followed by the values for Probe 2 for the last half of the file. The probe that each line of data corresponds to is indicated by the probe number listed in the first column (e.g. 1 or 2). More information about the TCSP LIP conductivity data can be found in the TCSP LIP Conductivity data documentation. Table 4 below outlines the data columns in the LIP conductivity data files.

Table 4. Data fields in the conductivity ASCII files.

Column	Variable	Units
1	probe number	-
2	time (with respect to current day; can be > 24)	hr
3	cond (air conductivity)	S (siemens)
4	cond_std	S (siemens)
5	altitude	km
6	alt_std	km
7	bias_voltage	V
8	latitude	degrees
9	lat_std	degrees
10	longitude	degrees
11	lon_std	degrees
12	pressure	mb
13	press_std	mb
14	T (outside air temperature)	degree K
15	T_std	degree K
16	Q (aircraft self charge)	V/m
17	Q_std	V/m
18	Ez (vertical electric field in the aircraft reference frame)	V/m
19	Ez_std	V/m

Note: "_std" is indicating the standard deviation

Field Mill and Conductivity Browse Image Files

The field mill browse images are available in PNG file format. These image files are in hour plots, "01" being the first plot of the flight, and numbering upward as needed to cover the entire flight. Each file covers roughly an hour of flight time. There are two field mill plot image files created for each hour. The odd numbered plot files(e.g. 01, 03, 05) list 7 separate time-series plots for each electric field value, charge, lat/lon, and altitude. The even numbered plot files (e.g. 02, 04, 06) are flight path plots that display the ER-2 aircraft flight path over a lat/lon grid with two additional plots displaying the variation in aircraft

altitude at flight level. The flight path plot includes information such as the start and end points of aircraft data recording and timestamps along the path.

The conductivity browse image files are also in PNG format and include two per flight, one plotted on a linear scale, and the other on a logarithmic scale. Within each file, two plots for Probe 1 are displayed on the top while two plots for Probe 2 are displayed on the bottom. The first plot for each probe is a time-series plot for positive and negative conductivity along with the aircraft altitude. The second plot for each probe is a profile of polar (positive & negative) conductivity versus altitude. As noted in the TCSP LIP Conductivity data documentation, although both Probe 1 and Probe 2 are shown, the calibration for Probe 1 is currently trusted more than Probe 2.

Algorithm

LIP is able to detect the electrical activity surrounding storms by observing the changes in the electric field environment. The total lightning (i.e., cloud-to-ground, intra-cloud) is identified from the abrupt electric field changes in the data; and it is often possible to differentiate between intra-cloud and cloud-to-ground discharges. Storm electric currents can be derived using the electric field and air conductivity measurements. More information on the relationship between electric field changes and lightning is detailed in Marshall et al. (2005).

Quality Assessment

A calibration matrix is created for the aircraft by performing different aircraft maneuvers and recording the output of the field mills. The matrix is then mathematically inverted to determine the electric fields from the mill data. Each of the LIP field mills incorporates self-calibration capabilities that reduce the time required to obtain a full aircraft calibration. In addition, the electric field signals are digitized at each mill and transmitted as a digital data stream, reducing signal noise and simplifying aircraft integration. More information about aircraft field mill calibration methods can be found in Koshak et al. (2006) and Mach and Koshak (2007).

Software

An IDL sample read program is provided for this dataset (plot_TCSP_archive_data.pro). Using this program, run the following code, making sure that directories for each day are changed appropriately:

```
idl
.r plot_TCSP_archive_data
plot_TCSP_archive_data,0 (0 - plot to screen, 1 - output plots to postscript file named
test.ps)
.cont - to get next day
```

For additional information about the sample program, refer to the TCSP LIP Conductivity data documentation. The TCSP ER-2 LIP browse images in PNG format may be viewed with almost any image viewer.

Known Issues or Missing Data

The data are airborne and flights did not occur each day of the campaign. Missing values are set as "NaN".

References

Christian, H.J. & Goodman, S.J. (1987). Optical Observations of Lightning from a High-Altitude Airplane. *Journal of Atmospheric and Oceanic Technology*, *4*, 701–711. https://doi.org/10.1175/1520-0426(1987)004<0701:OOOLFA>2.0.CO;2

Halverson, J., Black, M., Braun, S., Cecil, D., Goodman, M., Heymsfield, A., ... Kakar, R. (2007). Nasa's Tropical Cloud Systems and Processes Experiment: Investigating Tropical Cyclogenesis and Hurricane Intensity Change. *Bulletin of the American Meteorological Society*, *88*, 867–882. https://doi.org/10.1175/BAMS-88-6-867

Gibbs, Y. (2014). NASA Armstrong Fact Sheet: ER-2 High-Altitude Airborne Science Aircraft. https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-046-DFRC.html

Koshak, W. J., Mach, D. M., Christian, H. J., Stewart, M. F., & Bateman, M. G. (2006). Retrieving storm electric fields from aircraft field mill data. Part II: Applications. *Journal of Atmospheric and Oceanic Technology*, *23*, 1302–1322. https://doi.org/10.1175/JTECH1918.1

Mach, D. M., & Koshak, W. J. (2007). General matrix inversion technique for the calibration of electric field sensor arrays on aircraft platforms. *Journal of Atmospheric and Oceanic Technology*, *24*, 1576-1587. https://doi.org/10.1175/JTECH2080.1

Marshall, T. C., Stolzenburg, M., Maggio, C. R., Coleman, L. M., Krehbiel, P. R., Hamlin, T., ... Rison, W. (2005). Observed electric fields associated with lightning initiation. *Geophysical Research Letters*, *32*, L03813. https://doi.org/10.1029/2004GL021802

NASA Airborne Science Program (2015). Lightning Instrument Package (LIP). https://airbornescience.nasa.gov/instrument/LIP

Related Data

All datasets from the TCSP field campaign can be considered related to this TCSP ER-2 LIP dataset. Other TCSP campaign data can be located using the GHRC HyDRO 2.0 search tool and entering the term "TCSP" in the search box.

LIP was also flown in other field campaigns. The LIP data from other campaigns can be located by searching the term "LIP" in HyDRO 2.0 and are listed below.

CAMEX-4 ER-2 Lightning Instrument Package (LIP)
(http://dx.doi.org/10.5067/CAMEX-4/LIP/DATA002)

CAMEX-4 DC-8 Lightning Instrument Package (LIP)
(http://dx.doi.org/10.5067/CAMEX-4/LIP/DATA001)

CAMEX-3 Lightning Instrument Package (LIP)
(http://dx.doi.org/10.5067/CAMEX-3/LIP/DATA001)

GOES-R PLT Lightning Instrument Package (LIP)
(http://dx.doi.org/10.5067/GOESRPLT/LIP/DATA101)

GRIP Lightning Instrument Package (LIP)
(http://dx.doi.org/10.5067/GRIP/LIP/DATA201)

TRMM-LBA Lightning Instrument Package (LIP)
(http://dx.doi.org/10.5067/LIS/LIP/DATA101)

Contact Information

To order these data or for further information, please contact:

NASA Global Hydrology Resource Center DAAC
User Services
320 Sparkman Drive
Huntsville, AL 35805
Phone: 256-961-7932
E-mail: support-ghrc@earthdata.nasa.gov
Web: https://ghrc.nsstc.nasa.gov/

Created: 04/07/06
Updated: 06/28/19