Data User Guide

Airborne Precipitation Radar 3rd Generation (APR-3) CPEX-CV

Introduction

The Airborne Precipitation Radar 3rd Generation (APR-3) CPEX-CV dataset consists of radar reflectivity, Doppler velocity for all bands, linear depolarization ratio Ku-band, and normalized radar cross-section measurements at Ka- and Ku- bands data collected by the APR-3 onboard the NASA DC-8 aircraft. These data were gathered during the Convective Processes Experiment – Cabo Verde (CPEX-CV) field campaign. The NASA CPEX-CV field campaign will be based out of Sal Island, Cabo Verde from August through September 2022. The campaign is a continuation of CPEX – Aerosols and Winds (CPEX-AW) and was conducted aboard the NASA DC-8 aircraft equipped with remote sensors and dropsonde-launch capability that will allow for the measurement of tropospheric aerosols, winds, temperature, water vapor, and precipitation. The overarching CPEX-CV goal was to investigate atmospheric dynamics, marine boundary layer properties, convection, the dust-laden Saharan Air Layer, and their interactions across various spatial scales to improve understanding and predictability of process-level lifecycles in the data-sparse tropical East Atlantic region. These data files are available from September 2, 2022, through September 30, 2022, in netCDF-4 format, with associated browse imagery in JPG format.

Notice: The NASA DC-8 aircraft did not operate each day of the campaign, therefore APR-3 data are only available for aircraft flight days.

Citation

Rodriguez-Monje, Rauqel. 2023. Airborne Precipitation Radar 3rd Generation (APR-3) CPEX-CV [indicate subset used]. Dataset available online from the NASA Global Hydrometeorology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/CPEXCV/APR3/DATA101

Keywords:
NASA, GHRC, CPEX-CV, Cabo Verde, APR-3, DC-8, reflectivity, Doppler velocity, precipitation, radar, airborne

Campaign

The NASA CPEX-CV field campaign will be based out of Cabo Verde during August-September 2022. The campaign is a continuation of CPEX – Aerosols and Winds (CPEX-AW) and will be conducted aboard the NASA DC-8 aircraft equipped with remote sensors and dropsonde-launch capability that will allow for the measurement of tropospheric aerosols, winds, temperature, water vapor, and precipitation. The overarching CPEX-CV goal was to investigate atmospheric dynamics, marine boundary layer properties, convection, the dust-laden Saharan Air Layer, and their interactions across various spatial scales to improve understanding and predictability of process-level lifecycles in the data-sparse tropical East Atlantic region. CPEX-CV science goals include:

- Improve understanding of the interactions between large-scale environmental forcings (e.g., African easterly waves, ITCZ, Saharan Air Layer, mid-level African easterly jet) and the lifecycle and properties of convective cloud systems, including tropical cyclone precursors, in the tropical East Atlantic region.
- Observe how local kinematic (wind) and thermodynamic conditions, including the vertical structure and variability of the marine boundary layer, related to the initiation and lifecycle of convective cloud systems and their processes (e.g., cold pools).
- Investigate how dynamical and convective processes affect size-dependent Saharan dust vertical structure, long-range Saharan dust transport, and boundary layer exchange pathways.
- Assess the impact of CPEX-CV observations of atmospheric winds, thermodynamics, clouds, and aerosols on the prediction of tropical Atlantic weather systems, and validate and interpret spaceborne remote sensors that provide similar measurements.

More information about the CPEX-CV field campaign can be found at CPEX-CV ESPO.

Figure 1: CPEX-CV field campaign logo
(Image source: CPEX-CV)

Instrument Description

The Airborne Precipitation Radar 3rd Generation (APR-3) instrument is an enhanced version of the Airborne Precipitation Radar 2nd Generation (APR-2) instrument. The APR3 performs simultaneous radar measurements of both like- and cross-polarized signals at 13.4 GHz (Ka-band) and 35.6 GHz (Ku-band) and, for CPEX-CV, W-band measurements. The APR-3 instrument was mounted on the NASA DC-8 aircraft during CPEX-CV. As shown in Figure 3, the instrument was positioned to look downward and scan from side to side across the flight track from 25° to the left and right of nadir. The W-band data are collected with the same cross-track scanning geometry as used for Ku- and Ka-bands. This was accomplished by modifying the Ku and Ka feed to allow for W-band operation. A second W-band antenna was installed to provide the higher sensitivity needed for cloud sensing. This second W-band antenna has a larger aperture and was nadir pointing only (no side-to-side scanning) which allowed for more pulses to be integrated. For CPEX-CV, the data were acquired using one of the W-band antennas or the other, or sometimes both(simultaneous scanning and nadir). A flag is used to notify which antenna is operated at any time. Radar sensitivity was not constant (mainly dependent on the pulse length). Users not familiar with the weather radar equation and APR-3 data should contact the APR-3 team to support data interpretation. More information about the APR-3 instrument can be found at Airborne Third Generation Precipitation Radar (APR-3) and APR-3 Airborne Third Generation Precipitation Radar.

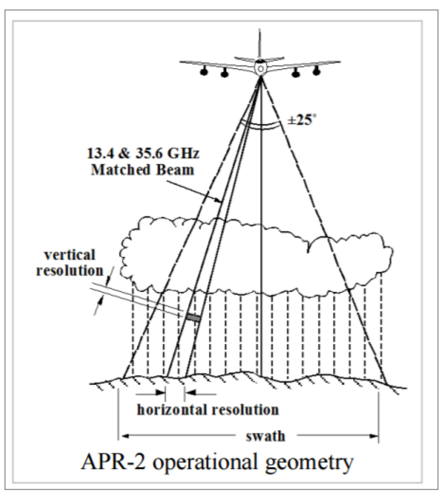

Figure 3: APR-2 (predecessor to the APR-3) operational geometry

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Data Characteristics

The APR-3 CPEX-CV dataset consists of radar reflectivity, Doppler velocity for all bands, linear depolarization ratio Ku-band, and normalized radar cross-section measurements at Ka- and Ku- bands stored in netCDF-4 files, with associated browse imagery in JPG format. These data are available at a Level 2 processing level. More information about the NASA data processing levels is available on the [EOSDIS Data Processing Levels webpage](). The characteristics of this dataset are listed in Table 1 below.

Table 1: Data Characteristics

Characteristic	Description
Platform	NASA DC-8 aircraft
Instrument	Airborne Precipitation Radar 3rd Generation (APR-3)
Spatial Coverage	N: 39.199, S: 1.759, E: -14.819, W: -89.673 (Sal Island, Cabo Verde)
Spatial Resolution	800 m
Temporal Coverage	September 2, 2022 - September 30, 2022
Temporal Resolution	Hourly -< Daily
Sampling Frequency	1.8 seconds
Parameter	Radar reflectivity, Doppler velocity, linear depolarization ratio
Version	1
Processing Level	2

File Naming Convention

The APR-3 CPEX-CV data are within netCDF-4 files, with associated browse imagery in JPG format, and are named using the following convention:

Data files: cpexcv_APR3_DC8_<YYYYMMDD>_R0_S<start date>a<start time>_E<end date>a<end time>_KUsKAsWs.nc

Browse files: cpexcv_APR3_DC8_<YYYMMDD>_S<start date>a<start time>_E<end date>a<end time>_Wscan.jpg

Table 2: File naming convention variables

Variable	Description
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
<start date>	Date when data collection began in YYYYMMDD format, where: YYYY = Four-digit year MM = Two-digit month DD = Two-digit day
<start time>	Time when data collection began in hhmmss format, where:

	hh = Two-digit hour in UTC mm = Two-digit minute in UTC ss = Two-digit second in UTC
<end date>	Date when data collection ended in YYYYMMDD format, where: YYYY = Four-digit year MM = Two-digit month DD = Two-digit day
<end time>	Time when data collection ended in hhmmss format, where: hh = Two-digit hour in UTC mm = Two-digit minute in UTC ss = Two-digit second in UTC
.nc	netCDF-4 format
.jpg	JPEG format

Data Format and Parameters

The APR-3 CPEX-CV dataset is stored in netCDF-4 files. The APR-3 data field descriptions are listed in Table 3 below.

Table 4: Data Fields

Field Name	Description	Unit
alt	Aircraft altitude	m
lat	Latitude of aircraft	deg
lon	Longitude of aircraft	deg
lores_alt3D	Altitude of each resolution bin	m
lores_alt3DZN	Altitude of each resolution bin above the aircraft	m
lores_alt_nav	Aircraft altitude (from MMS navigation files)	m
lores_altsurf14	Surface altitude from Ku reflectivity factor	m
lores_altsurf35	Surface altitude from Ka reflectivity factor	m
lores_azimuth	Ku/Ka band antenna azimuth angle	deg
lores_beamnum	Ray number within a scan	-
lores_drift	Drift angle of the aircraft	deg
lores_elevation	Ku/Ka band antenna elevation angle	deg
lores_gsp_mps	Aircraft ground speed	m/s
lores_ipc14	Bin number at the edge of Tx pulse clutter in Ku reflectivity	-
lores_ipc35	Bin number at the edge of Tx pulse clutter in Ka reflectivity	-
lores_isc14	Bin number at the edge of surface clutter in Ku reflectivity	-
lores_isc35	Bin number at the edge of surface clutter in Ka reflectivity	-
lores_isurf	Index of radar range bin intersecting surface (in Ku and Ka)	
lores_isurf14	Index of radar range bin intersecting surface in Ku	-

lores_isurf35	Index of radar range bin intersecting surface in Ka	-
lores_lat	Latitude of the aircraft	deg
lores_lat3D	Latitude of each resolution bin below the aircraft	deg
lores_ldrhh14	Linear depolarization ratio at Ku band	dB
lores_lon	Longitude of the aircraft	deg
lores_lon3D	Longitude of each resolution bin below the aircraft	deg
lores_look_vector	3 components of unit vector along the antenna pointing direction: From navigation files	-
lores_look_vector_nadir	3 components of unit vector along the antenna pointing direction: From APR-2 surface echo in nadir-only mode	-
lores_look_vector_radar	3 components of unit vector along the antenna pointing direction: From APR-2 surface echo in scanning channels	-
lores_pitch	Pitch angle of the aircraft. From aircraft or MMS navigation files	deg
lores_roll	Roll angle of the aircraft. From aircraft or MMS navigation files	deg
lores_s095s	Surface NRCS at W-band	dB
lores_s0hh14	Surface NRCS at Ku-band	dB
lores_s0hh35	Surface NRCS at Ka-band	dB
lores_scantime	Time of scan, in seconds since midnight UTC 2022-09-02 (YYYY-mm-DD)	s
lores_sequence	Ray number within the file	-
lores_sfc_mask	Surface mask (ocean: 0, land: 1)	-
lores_sig14	Doppler spectral width at Ku-band	m/s
lores_sig35	Doppler spectral width at Ka-band	m/s
lores_sig95s	Doppler spectral width at W-band	m/s
lores_surface_index	Preliminary surface classification index	-
lores_Topo_Hm	Topographic surface height below the aircraft	m
lores_v_surf14	APR-measured surface Dopller velocity at Ku-band	m/s
lores_vel14c	Mean Doppler velocity at Ku-band corrected by surface-reference technique	m/s
lores_vel35c	Mean Doppler velocity at Ka-band corrected by surface-reference technique	m/s
lores_vel95sc	Mean Doppler velocity at W-band corrected by surface-reference technique	m/s
lores_Xat_km	Distance traveled since beginning of file	km
lores_z95s	Reflectivity factor at W-band	dBZ
lores_zhh14	Reflectivity factor at Ku-band	dBZ
lores_zhh35	Reflectivity factor at Ka-band measured below the aircraft	dBZ
lores_zZN35	Reflectivity factor at Ka-band measured above the aircraft from ZENITH port	dBZ
time	Time of scan, in seconds since midnight UTC of 2022-09-02 (YYYY-mm-DD)	s

Algorithm

The Altitude and Look Vector are provided in two estimates: alt_nav and look_vector. These are calculated relying on DC-8 navigation information. Alt_radar and look_vector_radar are calculated depending on the observed surface return in Ku and Ka data. The alt_radar and look_vector_radar pair are reliable only when flying over the ocean, and, in this case, provide more accurate geolocation than the navigation-based pair. The best resources for the algorithms used to process APR-3 data are Sadowy et al., 2003, and Tanelli et al., 2006.

Quality Assessment

External calibration was used for all products. Reflectivity measurements should be considered reliable to within ±3 sigma.

The alt_radar and look_vector_radar pair are reliable only when flying over the ocean, and for CPEX, provide more accurate geolocation than the navigation-based pair.

The surface Doppler velocity (v_surf) was corrected for occasional aliasing and, in turn, was used to correct the Doppler measurements of precipitation for the bias introduced by the aircraft motion. This correction can be undone by adding the value of v_surf from vel14 at all range bins of every ray. This alternate correction may be of interest for the minority of data collected over land where the v_surf estimate is more prone to errors, or for data collected during sharp maneuvers by the DC-8.

The surface index is estimated by analyzing Ku and Ka surface returns, such as roughness, angle dependence of the surface normalized radar cross-section, apparent surface inclination, and LDR at nadir. This is estimated on a scan-by-scan basis. The most frequent misclassification is the ocean being classified as flat land.

Occasionally, high lateral winds may cause the Doppler measurements to be aliased. Doppler measurements should be corrected to account for a maximum unambiguous velocity of ±27.5 m/s. Also, correction for aircraft motion is less reliable when the aircraft is maneuvering or was affected by turbulence, or is over land.

The term 'beams' and 'rays' are considered to be the same. No data values can appear as -99.99, as well as -9999, due to scaling by 100. The 'Zhh35' field has -32768 as missing data instead of -9999. For the 'surface_index', a value of 7 indicates no surface echo, as typically found in beam 24, which is noise-only. Finally, the W-band Port value in the file header, which serves as the flag indicating the absence or presence of the W-band reflectivity arrays 'zhh95' and 'zvv95', has a description of "flag_Wvv*10 + flag_Whh", where 'flag_Wxx' is 0 if absent or 1 if present, but less than half of the scans, or 2 which implies Whh is present in a majority of the scans and Wvv is absent in all of the scans. If Wvv were also present in most of the scans, the value would be around 22.

Software

No software is required to view these netCDF-4 data; however, Panoply can be used to easily view the data.

Known Issues or Missing Data

The aircraft did not operate each day of the campaign, therefore APR-3 data are only available for aircraft flight days. Also, if there are missing data within a file, it is replaced by -9999.

The radar sensitivity was not constant (mainly dependent on the pulse length). Users not familiar with the weather radar equation and APR-3 data should contact the APR-3 team to support data interpretation

The Altitude and Look Vector are provided in two estimates: alt_nav and look_vector. These are calculated relying on DC-8 navigation information. Alt_radar and look_vector_radar are calculated depending on the observed surface return in Ku- and Ka-band data. The alt_radar and look_vector_radar pair are reliable only when flying over the ocean, and, in this case, provide more accurate geolocation than the navigation-based pair.

It should also be noted that the 'lores_scantime' data field has an attribute named 'description' that states: "Time of scan, in seconds since midnight UTC of 2022-09-07 [YYYY-mm-DD] [lores]"; however, it should be 'Time of scan, in seconds since 1 Jan. 1970 [lores]'.

References

Sadowy, G. A., Berkun, A. C., Chun, W., Im, E., & Durden, S. L. (2003). Development of an advanced airborne precipitation radar. (Technical Feature). *Microwave Journal*, 46(1), 84-93. https://airbornescience.nasa.gov/sites/default/files/documents/pr2-mwj.pdf

Tanelli, S., S. L. Durden, and E. Im, (2006). Simultaneous Measurements of Ku- and Ka-band Sea Surface Cross-Sections by an Airborne Radar. *IEEE Geoscience and Remote Sensing Letters*, 3(3), 359-363. doi: https://doi.org/10.1109/LGRS.2006.872929

Related Data

All other datasets collected as part of the CPEX-CV campaign are considered related and can be located by searching the term "CPEX-CV" in the Earthdata Search. Other APR-3 datasets can be located by searching the term "APR-3" in Earthdata Search and are listed below.

Airborne Precipitation Radar 3rd Generation (APR-3) CPEX
(http://dx.doi.org/10.5067/CPEX/APR3/DATA101)

Airborne Precipitation Radar 3rd Generation (APR-3) CPEX-AW (http://dx.doi.org/10.5067/CPEXAW/APR3/DATA101)

GPM Ground Validation Airborne Precipitation Radar 3rd Generation (APR-3) OLYMPEX V2 (http://dx.doi.org/10.5067/GPMGV/OLYMPEX/APR3/DATA201)

Contact Information

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

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Created: 5/26/2023