Data User Guide

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

Introduction

The Airborne Precipitation Radar 3rd Generation (APR-3) CPEX 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 (CPEX) field campaign. CPEX collected data to help answer questions about convective storm initiation, organization, growth, and dissipation in the North Atlantic-Gulf of Mexico-Caribbean Oceanic region during the early summer of 2017. These data files are available from May 27, 2017 through June 24, 2017 in a HDF-5 file, 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

Durden, Stephen and Simone Tanelli. 2022. Airborne Precipitation Radar 3rd Generation (APR-3) CPEX [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/CPEX/APR3/DATA101

Keywords:

NASA, GHRC, CPEX, Virgin Islands, APR-3, DC-8, reflectivity, Doppler velocity, precipitation, radar, airborne

Project

The NASA Convective Processes Experiment (CPEX) field campaign took place in the North Atlantic-Gulf of Mexico-Caribbean Oceanic region during the early summer of 2017. This campaign collected data to help answer questions about convective storm initiation, organization, growth, and dissipation (CPEX 2017 | Home). The CPEX science goals include:

- Improve understanding of convective processes including cloud dynamics, downdrafts, cold pools, and thermodynamics during initiation, growth, and dissipation. Determine what combinations of environmental structure, including moist entropy budgets, and convective properties such as vertical velocity and reflectivity profiles, result in rapid upscale growth of a convective system into a large organized mesoscale convective system (MCS), or alternatively, result in failure to grow or rapid decay.
- Obtain a comprehensive set of simultaneous wind, temperature, and moisture profiles, using wind lidar, microwave radiometer and sounder, and GPS dropsondes, to conduct a quantitative evaluation of those profiles in the vicinity of scattered and organized deep convection, especially in the lowest 4 km, in all phases of the convective life cycle.
- Improve model representation of convective and boundary layer processes over the tropical oceans using a cloud-resolving, fully coupled atmosphere-ocean model. Assimilate the wind, temperature, and humidity profiles from the wind lidar and dropsondes into the model, and quantify the impact of these detailed lidar wind profiles on the ability of the model to simulate the life cycle of convective systems over tropical oceans.

More information about the CPEX field campaign can be found at CPEX 2017: A Field Experiment to study Convective Processes in the Tropics.

Figure 1: CPEX field campaign logo
(Image source: CPEX 2017 | Home)

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 APR-3 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, W-band measurements. The APR-3 instrument was mounted on the NASA DC-8 aircraft during CPEX. 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 existing Ku and Ka feed to also allow for operation at W-band. 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, 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 was operating 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.

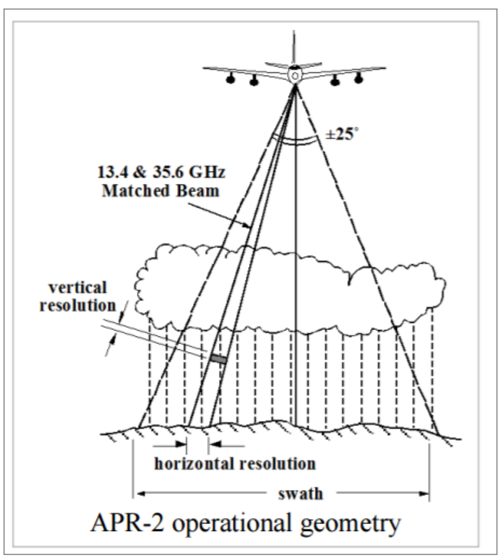

Figure 3: APR-2 (predecessor to the APR-3) operational geometry

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Data Characteristics

The APR-3 CPEX 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 HDF-5 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 2 below.

Table 2: Data Characteristics

Characteristic	Description
Platform	NASA DC-8 aircraft
Instrument	APR-3
Spatial Coverage	N: 28.904, S: 16.809, E: -69.299, W: -96.026 (Caribbean)
Spatial Resolution	800 m
Temporal Coverage	May 27, 2017 - June 24, 2017
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 data are within HDF-5 files, with associated browse imagery in JPG format, and are named using the following convention:

Data files: CPEX_APR3_L2ZV_DC8_YYYYMMDDhhmmss_R2_KUsKAs.h5

Browse files: CPEX_APR3_L2ZV_DC8_YYYYMMDDhhmmss_R2_KUsKAs.jpg

Table 3: File naming convention variables

Variable	Description
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
.h5	HDF-5 format
.jpg	JPEG format

Data Format and Parameters

The APR-3 CPEX dataset is stored in HDF-5 files. The APR-3 data field descriptions are listed in Tables 4-8 below.

Table 4: APR-3 HDF-5 File lores and postEng_cal Data Fields

Field Name	Description	Unit
alt3D	Altitude of each resolution bin	m
alt_nav	From aircraft of MMS navigation files (recommended). Calculated relying on the aircraft navigation information	m
beamnum	Ray number within a scan	-
drift	From aircraft of MMS navigation files	degrees
gsp_mps	GSP MPS	-
isurf	Index of radar range bin intersecting surface (starting from 0)	-
lat	Latitude of scan	degrees
lat3D	Latitude of each resolution bin	degrees
ldr14	Linear depolarization ratio (scaled dB)	dB
ldr35	Linear depolarization ratio (scaled dB)	dB
lon	Longitude if scan	degrees
lon3D	Longitude of each resolution bin	degrees
look_vector	From navigation files (recommended). Calculated relying on the aircraft navigation information	-
look_vector_radar	From APR-3 surface echo (alternate). Calculated relying on the observed surface return in Ku and Ka data. This is only reliable when flying over the ocean and provides a more accurate geolocation	-
path_vals	Path values	-
pitch	pitch	degrees
roll	roll	degrees
scantime	Scan time	s
sequence	Ray number within the file	-
surf_vals	Surface values	-
surface_index	Preliminary surface classification index. Estimated by analyzing Ku/Ka surface returns (roughness, angle dependence of the surface normalized radar cross section, apparent surface inclination and LDR at nadir). Table 6 describes the 6 values for surface_index	-
v_surf	APR-3 measurement surface Doppler velocity. Corrected for occasional aliasing and was used to correct Doppler measurements of precipitation for the bias introduced by aircraft motion	m/s
v_surfdc8	Apparent surface Doppler velocity as estimated from DC-8 navigation	m/s
vel14	Doppler velocity at Ku band (scaled m/s)	m/s
vel14c	Doppler velocity at Ku band (scaled m/s) from DC-8 navigation	m/s
vel35	Doppler velocity at Ku band (scaled m/s)	m/s

vel35c	Doppler velocity at Ku band (scaled m/s) from DC-8 navigation	m/s
zhh14	Radar reflectivity at Ku band (scaled dBZ)	dBZ
zhh35	Radar reflectivity at Ka band (scaled dBZ) nadir point	dBZ

Table 5: APR-3 HDF-5 File params_KUKA Data Fields

Field Name	Description	Unit
AntRetraceTime_s	Antenna time	s
AntScanLeft_deg	Antenna left scan	degrees
AntScanRight_deg	Antenna right scan	degrees
AntScanTime_s	Antenna scan time	s
CalVersion	Calibration version	-
Fixed_Ka_Pt	Fixed Ka Pt	-
Ka_Port	Ka Port	-
Nbeams	Number of beams	-
Nbeams_data	Number of beams data	-
Nbeams_noise	Number of beams noise	-
Nbin_per_ray	Number of bins per ray	-
Npuls_avge	Average number of pulses	-
Nscan	Number of scans	-
PRF_Hz	Pulse rate frequency	Hz
pulselen_us	Pulse length	us
range0_m	range	m
Range_Size_m	Range size	m
Rx_Atten	Rx attenuation	-
Tx_Atten	Tx attenuation	-

Table 6: Values assumes for surface index

Value	Description
0	Rough land
1	Ocean (level flight)
2	Ocean (roll maneuver)
3	Flat land (level flight)
4	Flat land (roll maneuver)
5	Antenna not scanning (unknown surface)

Browse images show data from various channels and the ground track of the DC-8 for the data displayed in the plots.

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 relying on the observed surface return in Ku and Ka data. The alt_radar and look_vector_radar pair is reliable only when flying over the ocean, and, in this case, provides a 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 is reliable only when flying over the ocean, and for CPEX, provides a 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 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 was maneuvering or was affected by turbulence or was 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 HDF-5 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 relying on the observed surface return in Ku- and Ka-band data. The alt_radar and look_vector_radar pair is reliable only when flying over the ocean, and, in this case, provides a more accurate geolocation than the navigation-based pair.

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 campaign are considered related and can be located by searching the term "CPEX" 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-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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