Data User Guide

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

Introduction

The Airborne Precipitation Radar 3rd Generation (APR-3) CPEX-AW 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 – Aerosols & Winds (CPEX-AW) field campaign. CPEX-AW was a joint effort between the US National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) with the primary goal of conducting a post-launch calibration and validation activities of the Atmospheric Dynamics Mission-Aeolus (ADM-AEOLUS) Earth observation wind Lidar satellite in St. Croix, US Virgin Islands. These data files are available from August 20, 2021 through September 4, 2021 in a MatLab file, with associated browse files in JPEG 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

Sy, Ousmane. 2022. Airborne Precipitation Radar 3rd Generation (APR-3) CPEX-AW [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/CPEXAW/APR3/DATA101

Keywords:

NASA, GHRC, CPEX-AW, St. Croix, APR-3, DC-8, reflectivity, Doppler velocity, precipitation, radar, airborne

Project

The Convective Processes Experiment – Aerosols & Winds (CPEX-AW) campaign is a joint effort between the US National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) with the primary goal of conducting post-launch calibration and validation activities of the Atmospheric Dynamics Mission-Aeolus (ADM-AEOLUS) Earth observation wind Lidar satellite in St. Croix, US Virgin Islands. CPEX-AW is a follow-on to the Convective Processes Experiment (CPEX) field campaign which took place in the summer of 2017 (https://cpex.jpl.nasa.gov/). In addition to joint calibration/validation of ADM-AEOLUS, CPEX-AW will study the dynamics and microphysics related to the Saharan Air Layer, African Easterly Waves and Jets, Tropical Easterly Jet, and deep convection in the InterTropical Convergence Zone (ITCZ). CPEX-AW science goals include:

- Better understanding interactions of convective cloud systems and tropospheric winds as part of the joint NASA-ESA Aeolus Cal/Val effort over the tropical Atlantic;
- Observing the vertical structure and variability of the marine boundary layer in relation to initiation and lifecycle of the convective cloud systems, convective processes (e.g., cold pools), and environmental conditions within and across the ITCZ;
- Investigating how the African easterly waves and dry air and dust associated with the Saharan Air Layer control the convectively suppressed and active periods of the ITCZ;
- Investigating interactions of wind, aerosol, clouds, and precipitation and effects on long range dust transport and air quality over the western Atlantic.

More information about the CPEX-AW field campaign can be found at NASA JPL|CPEX-AW, CPEX-AW 2017 | Campaign Overview, and CPEX-AW ESPO.

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

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-AW, W-band measurements. The APR-3 instrument was mounted on the NASA DC-8 aircraft during CPEX-AW. 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-AW, 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 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.

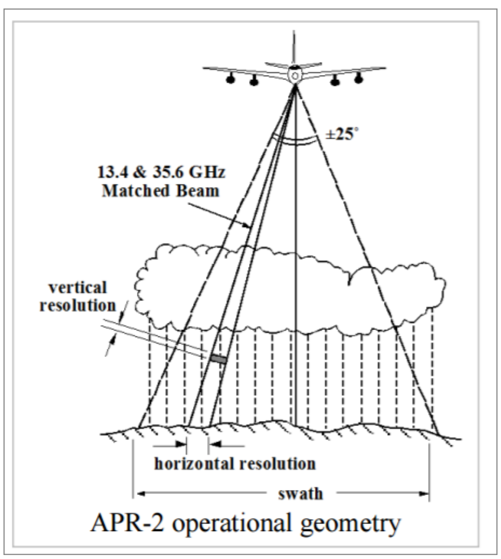

Figure 3: APR-2 (predecessor to the APR-3) operational geometry

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Data Characteristics

The APR-3 CPEX-AW 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 MatLab files, with associated browse files in JPEG 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: 34.045, S: 11.861, E: -45.642, W: -80.780 (St. Croix, Virgin Islands)
Spatial Resolution	800 m
Temporal Coverage	August 20, 2021 - September 4, 2021
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-AW data are within MatLab files, with associated browse files in JPEG format, and are named using the following convention:

Data files: CPEXAW_APR3_S<start date>a<start time>u_<end date>a<end time>uw_c1.mat

Browse files:
CPEXAW_APR3_S<start date>a<start time>_E<end date>a<end time>_P#_sa_3DKVLoLPc.jpg

Table 3: File naming convention variables

Variable	Description
<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
.mat	MatLab file
P#	Pass number
.jpg	JPEG format

Data Format and Parameters

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

Table 4: APR-3 MatLab File d_shft, postForce_cal, shift_cal, and str_off Data Fields

Field Name	Description	Unit
impose	Calibration constants manually imposed (1) or found automatically (0)	-
s0hh14	Calibration correction applied to σo (Ku/Ka, long pulse)	dB
s0hh14SP	Calibration correction applied to σo (Ku/Ka, long pulse)	dB
s0hh35	Calibration correction applied to σo (Ku/Ka, long pulse)	dB
s0hh35SP	Calibration correction applied to σo (Ku/Ka, long pulse)	dB
s0hh95	Calibration correction applied to σo (W, scanning)	dB
s0vv95	Calibration correction applied to σo (W, nadi-only)	dB
zhh14	Calibration correction applied to Z (Ku/Ka, long pulse)	dB
zhh14SP	Calibration correction applied to Z (Ku/Ka, long pulse)	dB
zhh35	Calibration correction applied to Z (Ku/Ka, long pulse)	dB
zhh35SP	Calibration correction applied to Z (Ku/Ka, long pulse)	dB
zhh95	Calibration correction applied to Z (W, scanning)	dB
zvv95	Calibration correction applied to Z (W, nadir-only)	dB

Table 5: APR-3 MatLab File hi2lo Data Fields

Field Name	Description	Unit
Xat_km	Distance traveled in km since beginning of file	km
Zcld_Ka	vertical average of Ka-band reflectivity from the atmosphere (debugging variable)	$dB(mm^6/m^3*m)$
alt3D	Altitude of each resolution bin	m
alt3Dsv	dummy altitude variable saved before processing altitude (debugging variable)	m
lat3D	Latitude of each resolution bin	deg
lon3D	Longitude of each resolution bin	deg
timeM	Time since 01/01/0000 (Matlab time)	-
z95n	Radar reflectivity at W band, nadir channel	dBZ

Table 6: APR-3 MatLab File lores Data Fields

Field Name	Description	Unit
NR	Number of range gates	-
Nbeam	Number of rays in each scan	-
Nscan	Number of scans in the file	-
Xat_km	Distance traveled in km since beginning of file	km
Zcld_Ka	vertical average of Ka-band reflectivity from the atmosphere (debugging variable)	dB(mm^6/ m^3*m)
alt3D	Altitude of each resolution bin	m
alt3DZN	altitude variable for the zenith-port data	m
alt_nav	Aircraft altitude (from MMS navigation files (recommended))	m
alt_radar	Altitude of radar	m
gsp_mps	aircraft ground speed	m/s
ib_cent	index of central beam (debugging)	-
lat	Latitude	deg
lat3D	Latitude of each resolution bin	deg
lon	Longitude	deg
long3D	Longitude of each resolution bin	deg
pitch	Aircraft pitch	deg
range0	range	-
roll	Aircraft roll	deg
s095s	Surface NRCS (W band, scanning)	dB
s0hh14	Calibration correction applied to σ° (Ku/Ka, long pulse)	dB
s0hh35	Calibration correction applied to σ° (Ku/Ka, long pulse)	dB
sfc_lat	Surface latitude	deg
sfc_lon	Surface longitude	deg
timeM	Time since 01/01/0000 (Matlab time)	-
vel14c	tentatively corrected mean velocity Ku (debugging)	m/s
vel35c	tentatively corrected mean velocity Ka (debugging)	m/s
z95s	Reflectivity at W band, HH scanning channel	dBZ
zZN35	reflectivity factor Ka, for the zenith-port data (uncalibrated)	dBZ
zhh14	Calibration correction applied to Z (Ku/Ka, long pulse)	dB
zhh35	Calibration correction applied to Z (Ku/Ka, long pulse)	dB

Table 7: APR-3 MatLab File params_KUKA Data Fields

Field Name	Description	Unit
AntRetraceTime_s	Antenna retrace time	s
AntScanLeft_deg	Antenna scan left-limit	deg
AntScanRight_deg	Antenna scan right-limit	deg
AntScanTime_s	Scan time for antenna	s
NR	Number of range gates	-

Nbeams	Number of rays in each scan	-
Nbeams_data	Number of rays (per scan) with radar transmitting	-
Nbeams_noise	Number of rays (per scan) with radar NOT transmitting	-
Nbin_per_ray	Number of range bins in the ray	-
Npuls_avge	Number of pulse averaged by Wildstar board	-
Nscan	Number of scans in the file	-
PRF_Hz	APR-3 pulse repetition frequency	Hz
Range_Size_m	Vertical resolution of range bin	m
ibeam_hires	Index of ray with hires (nadir) data (integrated to lores)	-
pulselen_us	APR-3 pulse length	us

Table 8: APR-3 MatLab File params_W Data Fields

Field Name	Description	Unit
NR	Number of range gates	-
Nbeam	Number of rays (per scan) (=1 nadir if nadir only)	-
Nscan	Number of scans in the file	-
PRF_Hz	ACR pulse repetition frequency	Hz
Range_Size_m	Length of range bun (vertical sampling)	m
Range_res_m	Length of pulse (vertical resolution)	m
Vnyq	Nyquist velocity	m/s
date_beg	Start time [YYYY, MM, DD, hh, mm, ss]	-
integration_s	ACR integration time	s
pulselen_us	APR-3 pulse length	us
slave_mode	ACR operation mode (0=stand-alone, 1=slaved mode)	-

Algorithm

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-AW, 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

The MatLab data files can be read using [Python's h5py library](https://www.h5py.org).

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 APR3 data should contact the APR3 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-AW campaign are considered related and can be located by searching the term “CPEX-AW” in the Earthdata Search. Other APR-3 datasets can be located by searching the term “APR-3” in Earthdata Search and are listed below.

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: 4/26/2022