Product Handbook for Airborne Precipitation Radar Third Generation (APR3) CPEX Data

Experiment: CPEX, May-June 2017, Fort Lauderdale, FL USA, DC8

Filename: standard: APR3_L2ZV_P3_YYMMDDhhmmss.Rx.h5,

CPEX repository: Eng_L2ZV_P3_YYMMDDhhmmss.Rx.h5

Note: YYMMDDhhmmss indicates the UTC start time of the data.

Format: Standard L1 product. Geolocated and calibrated radar reflectivity at Ku/Ka band, mean Doppler velocity and Linear Depolarization Ratio at Ku band, surface Normalized Radar Cross Section at Ku and Ka band, pre-calculated geodetic coordinates of every sample point

Release: 2.0 (data release to the CPEX repository, May 2018)

Change log:
X.2 – First Science Team release of preliminary processing. Absolute calibration uncertainty 1-sigma estimated at 1 dB for Ku-band, 1.5 dB for Ka-band. Uses HDF5.

APR3 Instrument Overview

APR3 is an enhanced version of the APR2 radar, which has successfully acquired data in a number of field campaigns since 2001. Features of APR2 are:

- simultaneous dual-frequency, matched beam operation at 13.4 and 35.6 GHz (same as GPM Dual-Frequency Precipitation Radar)
- simultaneous measurement of both like- and cross-polarized signals at both frequencies
- Doppler operation
- cross-track scanning (same as GPM/DPR)

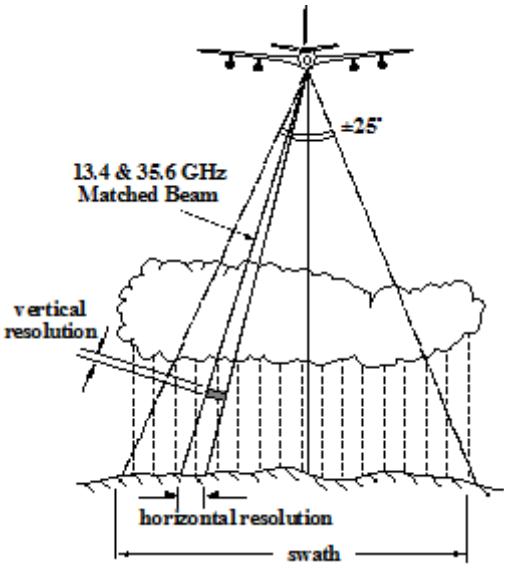


Fig.1. APR-2 operational geometry

The APR2 operational geometry is shown in Figure 1; it looks downward and scans its beam across-track, with each scan beginning at 25 degrees to the left of nadir and ending at 25 degrees to the right. Sadowy et al. (2003) provides a full description of the APR2 radar system. Calibration of the radar reflectivity products is verified at Ku-band by using the ocean surface and at Ka-band by comparing with the Ku-band reflectivity in light precipitation (Tanelli et al. 2006). Doppler velocities are corrected for aircraft motion using surface return.

APR3 refers to the version of APR2 with a W-band channel. It was completed for OLYMPEX in 2015 and allowed two types of W-band data to be collected. For precipitation, the existing Ku/Ka feed was modified to allow operation at W-band, in addition to Ku and Ka bands. This allowed acquisition of W-band data with the same cross-track scanning geometry as used for Ku and Ka-bands, these data are denoted HH, due to historical use of the port in the W-band hardware. A second W-band antenna was installed to provide higher sensitivity for cloud sensing goals. This antenna has a larger aperture than that achieved by the three-frequency feed at W-band. Also, it only looks at nadir, allowing more pulses to be integrated. For historical reasons, data on this channel are denoted VV. Data were acquired with one or the other or sometimes both antennas (simultaneous scanning and nadir).

W-band was not used for CPEX. The configuration was identical to previous experiments using APR2. The file format is the new HDF5 format developed for APR3 data.

G. A. Sadowy, A. C. Berkun, W. Chun, E. Im, and S. L. Durden, “Development of an advanced airborne precipitation radar," *Microwave J.*, vol. 46, no. 1, pp. 84-98, January 2003.

S. Tanelli, S. L. Durden, and E. Im, "Simultaneous Measurements of Ku- and Ka-band Sea Surface Cross-Sections by an Airborne Radar," *IEEE Geosci. Remote Sens. Lett*., vol. 3, no. 3, pp. 359-363, July 2006.

Data Format

The data are provided in *HDF5 files*. Previous versions have been HDF4. The elements of the fileheader are now defined explicitly in the sub-structure *params_KUKA*. All the variables are saved as doubles, and the HDF5 files are compressed.

nscan is the number of scans in a file, *nray* is the number of rays (aka: beams, looks) within a scan, and *nbin* is the number of range bins within a ray.

Altitude and Look Vector (i.e., the 3 components of the antenna relative to a global coordinate system with *x* being the aircraft ground track and *z* being vertical) are provided in two estimates: *alt_nav* and *look_vector* are calculated relying on the aircraft navigation information, instead *alt_radar* and *look_vector_radar* are calculated relying on the observed surface return in Ku/Ka data. The latter pair is reliable only when flying over ocean, and in this case it provides a more accurate geolocation than the navigation-based pair. See notes in the next section for specific recommendations with this data release.

The predicted (*v_surf_nav*) and observed (*v_surf*) surface Doppler velocities are provided: *v_surf* was corrected for occasional aliasing and, in turn, it was used to correct the Doppler measurements of precipitation for the bias introduced by the aircraft motion. This correction can be undone by the user by adding the value of *v_surf* to *vel14* at all the range bins of every ray. The alternate correction using the Doppler estimated from navigation data can be then obtained by subtracting the value of *v_surf_nav* from *vel14* at all the 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/Ka surface return (roughness, angle dependence of the surface normalized radar cross section, apparent surface inclination and LDR at nadir). It assumes one of 6 values (this classification is preliminary, see next section for known issues):

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

The *file header* contains information about the APR-2 data. These are parameters that are constant over the entire file. Table 1 shows the file header. Variable 23 is for the option of zenith-looking Ka-band data. It was not used in CPEX.

Table 1: Description of the file header

	Name	Src	Unit	Default	Description
1	PRF	Raw	Hz	5000	Pulse repetition frequency in Hz
2	Pulse Length	Raw	mus	3-20	Radar pulse length in 1 us units
3	Antenna Left	Raw	deg	-25 or 0	Antenna scan left-limit in deg.
4	Antenna Right	Raw	deg	+25 or 0	Antenna scan right-limit in deg.
5	Scan Duration	Raw	ms	1200	Scan time for antenna in second * 100
6	Return Duration	Raw	ms	600	Antenna retrace time in second * 100
7	Ncycle	Raw		250	Number of pulse averaged by Wildstar board
8	AZ Average	Raw		1	Number of blocks averaged in a beam or ray
9	Range average	Raw		1	Number of 30m range cells averaged in a bin
10	Scan average	Raw		1	Number of scans averaged
11	Number of Bins	Raw		600	Number of range bins in the ray
12	Number of Beams	Raw		24	Number of rays in each scan
13	Range Bin Size	2HDF	m	30	The vertical resolution of range bin
14	Z scale factor	Raw		100	Factor multiplying reflectivity
15	V scale factor	Raw		100	Factor multiplying Doppler
16	Not used	write			Always the number 1
17	# of scans	L1A			Number of scans
18	CalVersion	write			obsolete
19	Radar Mode	L1A			spare 1: mode (71 = dump, 87 = operate)
20	Rx Atten	L1A			Internal Cal parameter
21	Tx Atten	L1A			Internal Cal parameter
22	DR	Env	m		A priori range sampling (redundant)
23	Ka band Port	Env			0 ➔ Ka (2) = CxPol; 1 ➔ Ka(2) = Ka Zenith
24	Fixed Ka Pt	L1A			1 ➔ Ka(2) = Ka fixed nadir antenna
25	W band Port				flag_Wvv*10 + flag_Whh, where flag_Wxx is 0 absent, 1 present but less than half scans, 2 else
26	Not used				
27	Not used				
28	Not used				
29	Not used				
30	Not used				
31	Not used				
…	Not used				
38	Not used				

Content of HDF5 files

The variables in the APR3 HDF files are listed in Tables 2a, 2b, 2c, 2d and 2e. The type of radar data is specified by the file suffix modeID, with the naming convention

'APR3_L2ZV_P3_YYMMDDhhmmss_R1_',modeID,'.h5'

where, e.g., modeID = "KUsKAsWsn" indicates that the file contains

- "KUsKAs": Ku- and Ka-band radar data obtained in scanning mode;
- "Wsn": W-band data obtained via scanning ("Ws") and nadir-only ("Wn") channels.

The radar data consist mainly of a reflectivity factor Z (Ku, Ka, W), a mean Doppler velocity V (Ku, W), and surface reflectivity σ^0 (Ku, Ka, W). The files also contain navigation and geolocation information.

As described in Table 2a, each file contains (a subset of) the following sub-structures

- *params_KUKA* (parameters of APR2, see Table 2b), former fileheader (Table 1);
- *params_W* (parameters of ACR, see Table 2c),
- *lores* (measurements at the lower resolution, i.e. APR2 resolution).
  Note that the higher-resolution data [e.g. z95n (former zvv95) acquired by ACR in the nadir-only channel] are *integrated along-track* to match the low-resolution sampling of APR2. The integrated data are saved in beam #12 of 3D arrays [for instance, the along-track integrated nadir-only reflectivity is saved as "lores.z95n(:,12,:)"].
- *hires* (measurements at the higher resolution, i.e. of ACR in nadir-only mode).
  Note that the low-resolution measurements (beam #12 of measurements from APR2 and ACR in scanning mode) are also *interpolated* to the higher resolution of ACR, and
  - in files with modeID = Wn (W-band only), the radar measurements in *hires* are sampled at ACR's high resolution both along-track and in range.
  - in all the other cases (i.e. APR2 also working, e.g. KUsKAsWsn), the ACR data are *interpolated in range* to match APR2's range sampling.
- scal_shiftAT_ACR2APR: Criteria used for the *along-track* collocation between ACR nadir-only and APR2.
- scal_shiftXT_ACR2APR: Criteria used for the *cross-track* collocation between ACR scanning and APR2.

Table 2a: list of parameters in each APR3 file

All the variables are present in the "Engineering" files (internal to JPL).
Variables put in release files are highlighted in Blue.
label to indicate presence in APR3 files: Y(Yes), N(No);

Ns (numbers of scans at low resolution, i.e. APR2).

File suffix modeID

Variable name released	format	size	KUsKAs with			Wn only	Notes
			-	Ws	Wn		
params_KUKA	Struct	1	Y	Y	Y	N	APR2 operational mode: see Table 2b
params_W	Struct	1	N	Y	Y	Y	ACR operational mode: see Table 2c
postEng_cal	Struct	1	Y	Y	Y	Y	Calibration shifts applied to Z and σ^0 channels
lores	Struct	1	Y	Y	Y	N	APR3 data at lower resolution: see Table 2d
hires	Struct	1	N	N	Y	Y	APR3 data at higher resolution: see Table 2e
scal_shiftXT_ACR2APR	float	Ns + 1	N	Y	N	N	Ka-W cross-track collocation parameters: (1): method used to collocate Ka and W data (2... Ns+1): number of profiles by which each W-band scan is shifted to match Ka
scal_shiftAT_ACR2APR	float	5	N	N	Y	N	Ka-W along-track collocation parameters: (1): shift in number of native ACR profiles, (2): shift in time [s] (3): correlation between Z at Ka (beam 12)and Z at W nadir only *before* collocation (4): correlation between Z at Ka (beam 12)and Z at W nadir only *after* collocation (5): mode of the along track shift (in # of APR2 scans)

*Table 2b: list of parameters in "*params_KUKA": *APR2 operational mode* (all doubles)

Variable name released	size	Units	KUsKAs			Wn	Notes
			-	Ws	Wn		
PRF_Hz	1	Hz	Y	Y	Y	N	APR2 pulse repetition frequency
pulselen_us	1	us	Y	Y	Y	N	APR2 pulse length
AntScanLeft_deg	1	deg	Y	Y	Y	N	Antenna scan left-limit
AntScanRight_deg	1	deg	Y	Y	Y	N	Antenna scan right-limit
AntScanTime_s	1	s	Y	Y	Y	N	Scan time for antenna
AntRetraceTime_s	1	s	Y	Y	Y	N	Antenna retrace time
Npuls_avge	1		Y	Y	Y	N	Number of pulse averaged by Wildstar board
Nbin_per_ray	1		Y	Y	Y	N	Number of range bins in the ray
Range_Size_m	1	m	Y	Y	Y	N	Vertical resolution of range bin
CalVersion	1		Y	Y	Y	N	Calibration version (obsolete)
Fixed_Ka_Pt	1		Y	Y	Y	N	Fixed Port used for Ka Tx/Rx – see Table 1
Ka_Port	1		Y	Y	Y	N	Port used for Ka Tx/Rx – see Table 1
Nbeams	1		Y	Y	Y	N	Number of rays in each scan
Nbeams_data	1		Y	Y	Y	N	Number of rays (per scan) with radar transmitting
Nbeams_noise	1		Y	Y	Y	N	Number of rays (per scan) with radar NOT transmitting
Nscan	1		Y	Y	Y	N	Number of scans in the file
Rx_Atten	1	dB	Y	Y	Y	N	RX attenuation in reception: internal Cal parameter
Tx_Atten	1	dB	Y	Y	Y	N	RX attenuation in emission: internal Cal parameter
ibeam_hires	1		N	N	Y	Y	Index of ray with hires (nadir) data (integrated to lores)
range0_m	1	m	Y	Y	Y	N	Distance of the first radar range bin from a/c

*Table 2c: list of parameters in "*params_W": *ACR operational mode* (all doubles)

Variable name released	size	Units	KUsKAs			Wn	Notes
			-	Ws	Wn		
PRF_Hz	1	Hz	N	Y	Y	Y	ACR pulse repetition frequency
PRT_us	1	us	N	Y	Y	Y	ACR pulse repetition period
pulselen_us	1	us	N	Y	Y	Y	ACR pulse length
decimation	1		N	Y	Y	Y	ACR effective decimation
Bandwidth_MHz	1	MHz	N	Y	Y	Y	ACR bandwidth
Bandwidth_Eff_MHz	1	MHz	N	Y	Y	Y	ACR effective bandwidth
integration_s	1	s	N	Y	Y	Y	ACR integration time
CalVersion			N	Y	Y	Y	Calibration version
Ports	5		N	Y	Y	Y	ACR transmission mode
Range_Size_m	1	m	N	Y	Y	Y	Length of range bin (vertical sampling)
Range_res_m	1	m	N	Y	Y	Y	Length of pulse (vertical resolution)
Vnyq	1	m/s	N	Y	Y	Y	Nyquist velocity
Nray_hires	1		N	N	Y	Y	Number of nadir-only rays in hires mode
npulse_hh95	1		N	N	Y	Y	Number of pulses averaged in scanning mode (hh)
npulse_vv95	1		N	N	Y	Y	Number of pulses averaged in nadir-only mode (vv)
iStartW	1		N	Y	Y	Y	Range bin of where the center of the Tx event is recorded (i.e., range bin corresponding to range zero)
range0_m	1	m	Y	Y	Y	N	Distance of the first radar range bin from a/c
slave_mode	1		N	Y	Y	Y	ACR operation mode (0 = stand-alone, 1= slaved mode)

*Table 2d: list of parameters in "*lores*": APR3 at low resolution* (all doubles)
Ns: numbers of scans (along track), at low resolution;
Nr: number of rays (cross track) in scanning mode at low resolution;
Nbin: number of range bins.

Variable name released	size	Units	KUsKAs			Wn	**Notes** (data from high-resolution mode integrated and saved in beam 12 highlighted in green)
			-	Ws	Wn		
Scantime	Ns x Nr	s	Y	Y	Y	N	Beginning of scan since 1 Jan. 1970 = f(PRF, Npulses)
roll	Ns x Nr	deg	Y	Y	Y	N	From aircraft or MMS navigation files
pitch	Ns x Nr	deg	Y	Y	Y	N	From aircraft or MMS navigation files
drift	Ns x Nr	deg	Y	Y	Y	N	From aircraft or MMS navigation files
alt_nav	Ns x Nr	m	Y	Y	Y	N	From aircraft or MMS navigation files (recommended)
alt_radar	Ns x Nr	m	Y	Y	Y	N	From APR-2 surface echo (alternate)
look_vector	3 x Ns x Nr		Y	Y	Y	N	From navigation files (recommended)
look_vector_radar	3 x Ns x Nr		Y	Y	Y	N	From APR-2 surface echo in scanning channels (alternate)
look_vector_nadir_95n	3 x Ns x Nr		Y	Y	Y	N	From APR-2 surface echo in nadir-only mode (alternate)
isurf	Ns x Nr		Y	Y	Y	N	Index of radar range bin intersecting surface (starting from 0).
sequence	Ns x Nr		Y	Y	Y	N	Ray number within the file
v_surfdc8	Ns x Nr	m/s	Y	Y	Y	N	Apparent surface Doppler velocity (from P-3 navigation)
v_surf	Ns x Nr	m/s	Y	Y	Y	N	APR-2 measured surface Doppler velocity
beamnum	Ns x Nr		Y	Y	Y	N	Ray number within a scan
surface_index	Ns x Nr		Y	Y	Y	N	Preliminary surface classification index
surf_vals	8 x Ns x Nr	vv	Y	Y	Y	N	8 Measured parameters pertaining the surface: 1 = NRCS Ku [dB], 2 = Surface LDR Ku [dB], 3 = NRCS Ka [dB], 4 = LDR Ka [dB], 5 = surface Doppler velocity Ku [m/s], 6-8 = not used.
path_vals	15 x Ns x Nr	vv	Y	Y	Y	N	15 parameters pertaining each beam - these are intermediate products – not recommended for Science use: 1 = max Z Ku; 2 = max Z Ka; 3 = ZKu 1km range above isurf; 4 = LDRKu 1km range above isurf; 5 = ZKa 1km range above isurf 6 = LDRKa 1km range above isurf; 7 = vKu 1 km range above surf (pre-correction); 8 = Pt Ku copol (cal loop); 9 = Pt Ku cxpol; 10 = Pt Ka copol; 11 = Pt Ka cxpol; 12 = range bin max ZKu; 13 = range bin max ZKu; 14 = range bin ZKu @ 1 Km altitude; 15 = range bin ZKu @ 1 Km altitude
lat	Ns x Nr	deg	Y	Y	Y	N	Latitude of the aircraft
lon	Ns x Nr	deg	Y	Y	Y	N	Longitude of the aircraft
lat3D	Ns x Nr x nbin	deg	Y	Y	Y	N	Latitude of each resolution bin
lon3D	Ns x Nr x nbin	deg	Y	Y	Y	N	Longitude of each resolution bin
alt3D	Ns x Nr x nbin	m	Y	Y	Y	N	Altitude of each resolution bin
zhh14	Ns x Nr x nbin	dBZ	Y	Y	Y	N	Radar Reflectivity at Ku band
vel14	Ns x Nr x nbin	m/s	Y	Y	Y	N	Mean Doppler Velocity at Ku band
ldr14	Ns x Nr x nbin	dB	Y	Y	Y	N	Linear Depolarization Ratio at Ku band
vel14c	Ns x Nr x nbin	m/s	Y	Y	Y	N	Mean Doppler Velocity dealiased and from Ku&Ka band
zhh35	Ns x Nr x nbin	dBZ	Y	Y	Y	N	Radar Reflectivity at Ka band nadir port
vel35	Ns x Nr x nbin	m/s	Y	Y	Y	N	Mean Doppler Velocity at Ka band
vel35c	Ns x Nr x nbin	m/s	Y	Y	Y	N	Mean Doppler Velocity dealiased and form Ka band
ldr35	Ns x Nr x nbin	dB	Y	Y	Y	N	Linear Depolarization Ratio at Ka band
z95s	Ns x Nr x nbin	dBZ	N	Y	Y	N	Reflectivity at W band, HH scanning channel
vel95s	Ns x Nr x nbin	m/s	N	Y	Y	N	Doppler Velocity at W band scanning
sig95s	Ns x Nr x nbin	m/s	N	Y	Y	N	Spread of Doppler Velocity at W band scanning
s095s	Ns x Nr	dB	N	Y	Y	N	Surface NRCS (W band, scanning)
z95n	Ns x Nr x nbin	dBZ	N	N	Y	N	Reflectivity at W band, nadir channel
vel95n	Ns x Nr x nbin	m/s	N	N	Y	N	Doppler Velocity at W band nadir
sig95n	Ns x Nr x nbin	m/s	N	N	Y	N	Spread of Doppler Velocity at W band nadir
s095n	Ns x Nr	dB	N	N	Y	N	Surface NRCS at W band, nadir

altbin_95n	Ns x Nr x nbin	m	Y	Y	Y	N	Altitude of each high-resolution range bin
gsp_mps	Ns x Nr	m/s	Y	Y	Y	N	Aircraft ground speed
scal_date_APR	6		Y	Y	Y	N	APR file date/time [YYY,MM,DD,hh,mm,ss]
scal_date_ACR	6		Y	Y	Y	N	ACR file date/time [YYY,MM,DD,hh,mm,ss]

*Table 2e: list of parameters in "*hires*": APR3 at high resolution* (all doubles)
Ns_hi: numbers of scans (along track), at high resolution;
Nbin: number of range bins (same as low-resolution vertical sampling if Ku and Ka are present, otherwise = native vertical sampling of ACR.
Geolocation and attitude parameters (lat, lon, alt, roll, look_vector…):

- in files with KuKa: parameters interpolated from lower to higher resolution;
- in files with W-band only: parameters from the higher-resolution nav. parameters

Variable name released	**size**	**Units**	**KUsKAs**			**Wn**	**Notes (data from** beam 12 of scanning mode **interpolated to higher resolution highlighted in green)**
			-	**Ws**	**Wn**		
scantime	Ns_hi	s	N	N	Y	Y	Beginning of scan in seconds since 1 January 1970
roll	Ns_hi	deg	N	N	Y	Y	roll
pitch	Ns_hi	deg	N	N	Y	Y	pitch
drift	Ns_hi	deg	N	N	Y	Y	drift
look_vector	3 x Ns_hi		N	N	Y	Y	look_vector
look_vector_radar	3 x Ns_hi		N	N	Y	Y	look_vector_radar
lat3D	Nbin xNs_hi	deg	N	N	Y	Y	Latitude of each resolution bin
lon3D	Nbin xNs_hi	deg	N	N	Y	Y	Longitude of each resolution bin
alt3D	Nbin xNs_hi	m	N	N	Y	Y	Altitude of each resolution bin
zhh14	Nbin xNs_hi	dBZ	N	N	Y	N	Radar Reflectivity at Ku band
vel14	Nbin xNs_hi	m/s	N	N	Y	N	Mean Doppler Velocity at Ku band
vel14c	Nbin xNs_hi	m/s	N	N	Y	N	Mean Doppler Velocity dealiased (Ku&Ka) band
vel35c	Nbin xNs_hi	m/s	N	N	Y	N	Mean Doppler Velocity dealiased (Ka) band
zhh35	Nbin xNs_hi	dBZ	N	N	Y	N	Radar Reflectivity at Ka band
vel35	Nbin xNs_hi	m/s	N	N	Y	N	Mean Doppler Velocity at Ka band
z95s	Nbin xNs_hi	dBZ	N	N	Y	N	Radar Reflectivity at W band, scanning
vel95s	Nbin xNs_hi	m/s	N	N	Y	N	Mean Doppler Velocity at W band scanning
sig95s	Nbin xNs_hi	m/s	N	N	Y	N	Doppler Width at W band scanning
s095s	Ns_hi	dB	N	N	Y	N	Surface NRCS at W band scanning
s095n	Ns_hi	dB	N	N	Y	Y	surface NRCS (W band) nadir
z95n	Nbin xNs_hi	dBZ	N	N	Y	N	Radar Reflectivity at W band, nadir channel
vel95n	Nbin xNs_hi	m/s	N	N	Y	Y	mean Doppler Velocity at W band nadir channel
sig95n	Nbin xNs_hi	m/s	N	N	Y	Y	Doppler Width at W band nadir
time_95s	Ns_hi	s	N	N	Y	N	time stamps of low-resolution data (alternate)
Vsurf95n	Ns_hi	m/s	N	N	Y	Y	ACR measured surface Doppler velocity at W band, VV
Vsurf95s	Ns_hi	m/s	N	N	Y	N	ACR measured surface Doppler velocity from vel95s
isurf	Ns_hi		N	N	Y	N	range bin of peak surface return
surf_vals	8x Ns_hi		N	N	Y	N	see definition of surf_vals in "lores"
Pt_95n	Ns_hi	dBm?	N	N	Y	Y	Estimated transmitted power from z95n
Pt_95s	Ns_hi	dBm?	N	N	Y	Y	Estimated transmitted power from z95s
noisedB_95n	Ns_hi	dB	N	N	Y	Y	Estimated noise for z95n
noisedB_95s	Ns_hi		N	N	Y	Y	Estimated noise for z95s
SNR_95n	Nbin xNs_hi		N	N	Y	Y	Estimated SNR of z95n
SNR_95s	Nbin xNs_hi		N	N	Y	Y	Estimated SNR of z95s
esurf_95n	Ns_hi	eu	N	N	Y	Y	Quality of W-band surface response matching – similar to CloudSat's CPR L1B : <0 = surface response not detected, or extremely poor matching, 0-1 : surface response detected and good quality (smaller values indicate better quality), 1 or more: surface response detected but lower quality matching.
esurf_95s	Ns_hi	eu	N	N	Y	N	see esurf_95n
nsurf_95n	Ns_hi	#	N	N	Y	Y	Length in # of range bins of the surface response
nsurf_95s	Ns_hi	#	N	N	Y	N	see nsurf_95n

*Table 2e (continued): list of parameters in "*hires*": APR3 at high resolution* (all doubles)

Variable name released	size	Units	KUsKAs			Wn	Notes (data from beam 12 of scanning mode interpolated to higher resolutionhighlighted in green)
			-	Ws	Wn		
isurf_95n	Ns_hi		N	N	Y	Y	Surface bin estimated from z95n
isurf_95s	Ns_hi		N	N	Y	N	Surface bin estimated from z95s
altsurf_95s	Ns_hi		N	N	Y	N	Surface height from z95s
altbin_95s	Nbin xNs_hi		N	N	Y	N	range bins starting from the surface upward
altbin_95n	Nbin xNs_hi		N	N	Y	N	range bins starting from the surface upward
isc_95n	Ns_hi		N	N	Y	Y	Surface-clutter upper-limit bin from z95n
isc_95s	Ns_hi		N	N	Y	N	Surface-clutter upper-limit bin from z95s
ipc_95n	Ns_hi		N	N	Y	Y	Tx-pulse clutter lower-limit bin from z95n
ipc_95s	Ns_hi		N	N	Y	N	Tx-pulse clutter lower -limit bin from z95s
mask	Nbin xNs_hi		N	N	Y	Y	Cloud mask: If = 6: sub-surface and surface clutter (11): boundary between cloud and surface clutter (20) noise based on SNR (21) noise speckle based on number of neighbors (30) if low SNR cloud/rain (40) if high SNR cloud/rain
alt_95n	Ns_hi	m	N	N	Y	Y	Altitude of the aircraft
alt_nav	Ns_hi	m	N	N	Y	Y	From aircraft or MMS navigation files (recommended)
alt_radar	Ns_hi	m					From APR-2 surface echo (alternate)
beamnum	Ns_hi						Ray number within a scan
drf_95n	Ns_hi	deg					Aircraft drift angle
gsp_mps	Ns_hi	m/s					Aircraft ground speed
lat_95n	Ns_hi	deg					AC latitude
lon_95n	Ns_hi	deg					AC longitude
ldr14	Nbin xNs_hi	dB	N	N	Y	N	Linear depolarization ratio at Ku band
ldr35	Nbin xNs_hi	dB	N	N	Y	N	Linear depolarization ratio at Ka band
v_surfdc8	Ns_hi	m/s	N	N	Y	N	Apparent surface Doppler velocity (from DC8 nav)
v_surf	Ns_hi	m/s	N	N	Y	N	APR-2 measured surface Doppler velocity
ptc_95n	Ns_hi	deg					Aircraft Pitch
range0	Ns_hi	km					Distance of the first radar range bin from a/c
rol_95n	Ns_hi	deg					Aircraft Roll
sequence	Ns_hi						Ray number within the file
surface_index	Ns_hi						Preliminary surface classification index
look_vector_95n	3 x Ns_hi						Ray unit vector in local surface coordinates
look_vector_nadir_95n	3 x Ns_hi						Ray unit vector in local surface coordinates

List of local science flights: CPEX

#	Date	Observation
1	2017, May 27	First local science flight; box pattern in central Gulf; mostly clear
2	2017, May 29	Sampling of scattered convection in NW Caribbean
3	2017, May 31	Multiple boxes over Atlantic, near Bahamas and north of Hispanola
4	2017, June 1	Convective system over eastern Gulf; multiple passes over convection
5	2017, June 2	Extended E-W box over western and central Gulf; clear areas and some convective cells
6	2017, June 6	Convection over eastern Gulf
7	2017, June 10	Boxes with convective cells over Atlantic, east of the Bahamas
8	2017, June 11	East west legs over convective system in central Gulf; lines extended to get DAWN data
9	2017, June 15	Caribbean , west of Jamaica
10	2017, June 16	Caribbean, east of Yucatan
11	2017, June 17	Caribbean , west of Jamaica
12	2017, June 19	East west legs over north central and east Gulf, Tropical Storm
13	2017, June 20	Bow tie pattern in central Gulf
14	2017, June 21	East west flight across Gulf
15	2017, June 23	Box patterns to east of Bahamas
16	2017, June 24	Over and around Cuba

Only local science flights are included in the current release.

Known Problems, issues and other notes

This section lists all known problems with the APR3 R1 CPEX data. Some of these problems are caused by problems in the raw data, while others are processing problems.

- External calibration was used for all products. Reflectivity measurements should be considered reliable within ±3 sigma as reported in the change log for this release.
- 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.
- In the short range (that is the first 5 bins after the blanked transmit window) the reported value of reflectivity is underestimated. This region should be used only for detection purposes, and not quantitative estimation.
- radar reflectivity factors are as measured – **no** correction for path attenuation is included in these products.
- The radar altitude and look_vector are occasionally affected by aircraft motion at a sub-scan timescale.
- This data version was produced using the 1Hz from DC-8 (iwg1). It is recommended to use look_vector and alt_nav for all processing as they are accurate in general.
- No data are available from the 24^{th} ray of each scan (beamnum = 1) at Ku/Ka. This ray was used for noise measurements (no pulse transmitted). The 24^{th} ray was included in this dataset solely for compatibility with APR2 datasets from previous experiments.
- LDR estimates are included in this release for the Ku-band channel. Users are cautioned in interpreting very low values of LDR (e.g., less than -20 dB), which are characterized by larger overall uncertainty.

- Antenna and range sidelobes show up as artifacts in data in some cases (i.e., thin feature at constant range appearing at large scan angles a few hundred m above the surface).
- Doppler velocity is only reported when the corresponding reflectivity is above a certain threshold.
- Occasionally, high lateral winds may cause the Doppler measurements to be aliased. Doppler measurements at Ku-band should be corrected accounting for a maximum unambiguous velocity of ±27.5 m/s. Generally the Ku-band Doppler vel14 is preferred; vel35 and vel35c are more likely to have aliasing errors due to the smaller unambiguous velocity of ±10.5 m/s. Since Ka-band may have better SNR in certain areas, use of these velocities after dealiasing may be advantageous for specific cases. We recommend contacting the APR3 team.
- Correction for aircraft motion is less reliable when the aircraft was maneuvering or was affected by turbulence or was over land.
- The surface index is estimated on a scan-by-scan basis. The most frequent misclassification is ocean being classified as flat land.
- The isurf index is occasionally in error because of extreme attenuation in the rain profile.
- Occasional high surface reflectivity can cause overflows in the Ku-band copolar channels causing data quality deterioration.
- Occasional intermittent changes in the overall calibration may not be properly accounted for.
- Occasionally processing artifacts show up in the browse images but are not actually present in the data.

Geolocation

The three-dimensional latitude, longitude, and altitude are in the data and can be directly associated with the 3-D radar measurement arrays.

Browse images

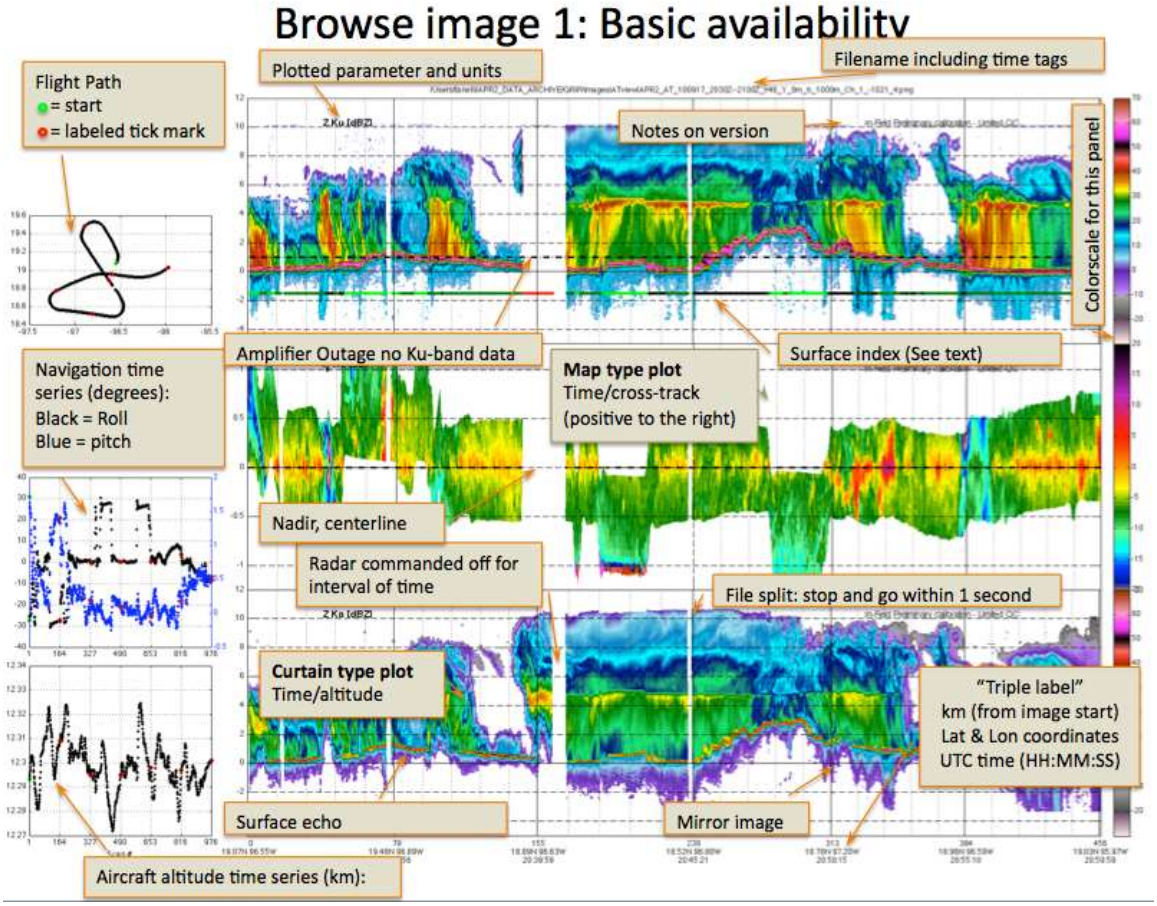
Standard browse images are generated in 60 min intervals, starting on the hour and half-hour. Each browse image includes navigation and a set of curtain plots and map plots:

Curtain plots: these are vertical sections below the aircraft. The closest beam to the nadir direction is used at every point. The section departs from vertical when the aircraft rolls more than the APR-3 scan angle. In the standard browse images the section is always at nadir (0 cross track displacement). Whenever a non-zero cross-track displacement is chosen (for custom made images) the cross-track displacement is shown in the first map plot by a dot-dash line.

Map plots: these are horizontal sections across the APR-3 swath. They include maps of surface properties (e.g., sigma_zero, v_surf etc.), or sections of volumetric properties (e.g., radar reflectivity at Ku or Ka band, mean Doppler velocity, etc.) at a

predetermined altitude. These are available upon request to the APR3 team, if needed, but should be readily generated by users from the HDF files.

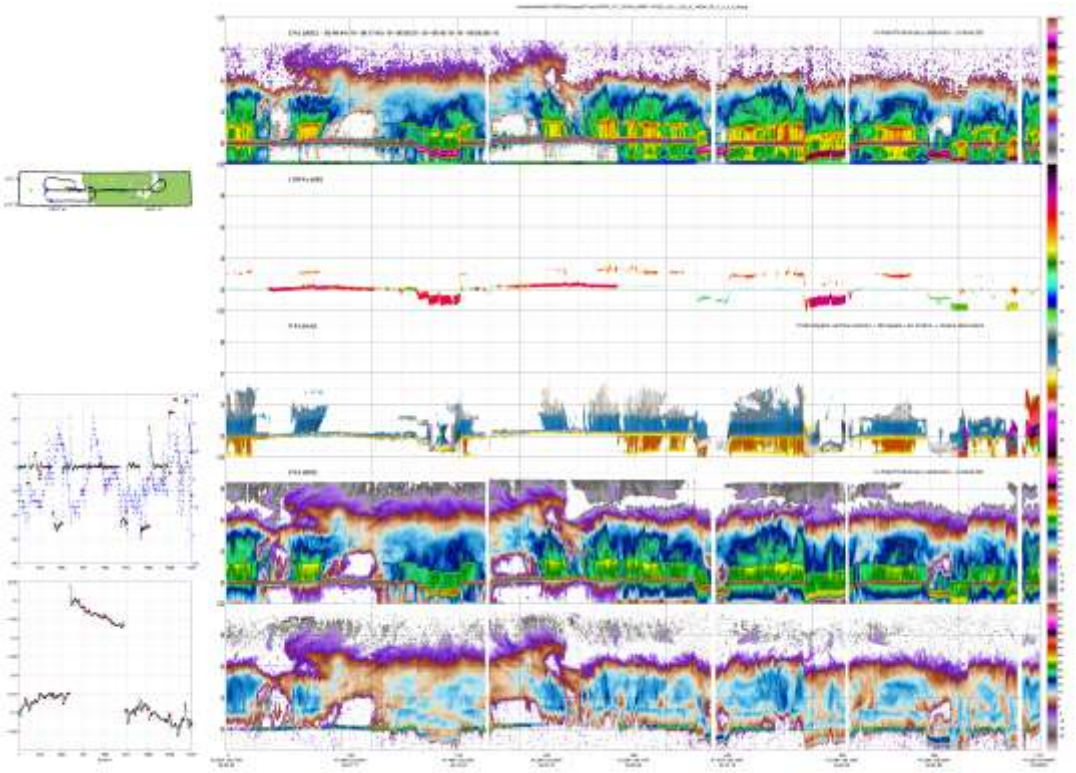
Browse image 1: Typical browse image for Ku/Ka-only data; previous APR2 field campaigns.



Top to bottom:

1) Vertical curtain of measured Ku-band reflectivity [dBZ].
2) Swath of Normalized Radar Cross Section [dB].
3) Vertical curtain of measured Ka-band reflectivity [dBZ]. For datasets where the Zenith port was used (e.g., SEAC4RS) this panel will also show the DC-8 flight altitude (in red dash) and Ka-band data above the plane. This is not applicable to CPEX data.

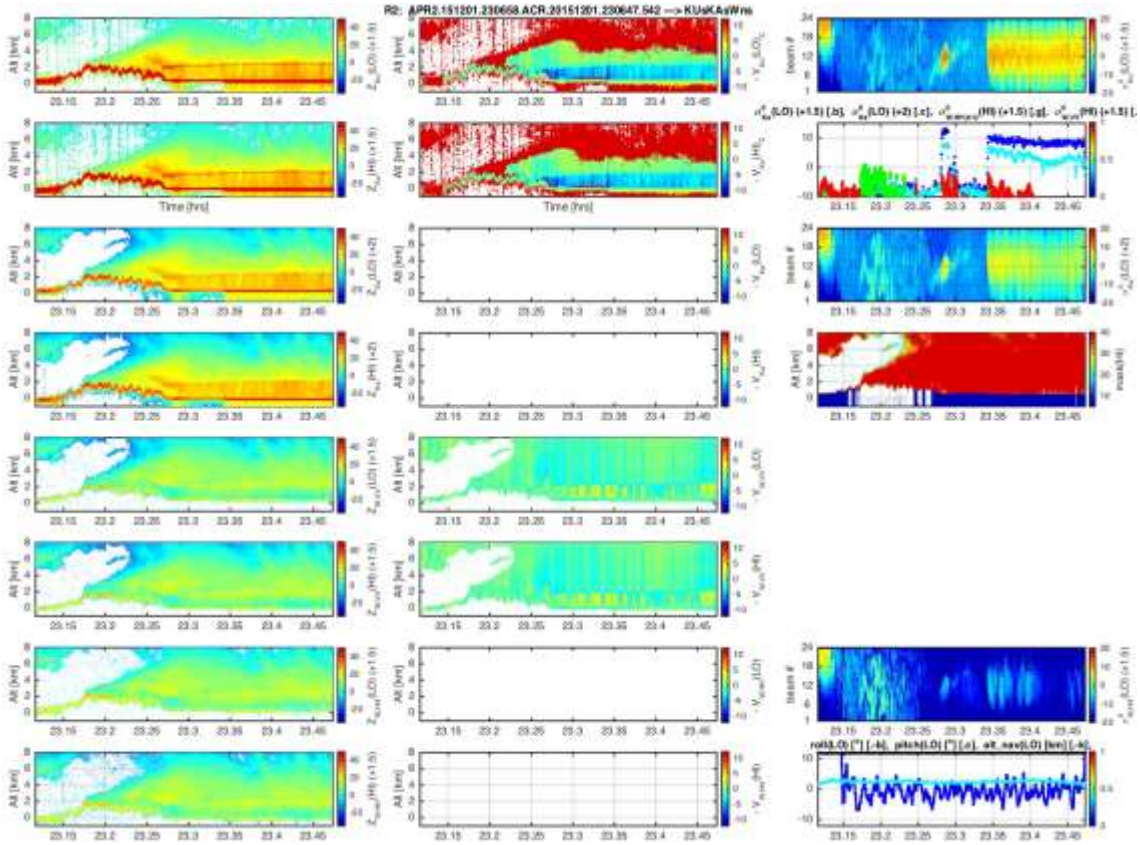
Browse image 2: Standard browse image for Ku/Ka/W band data



Top to bottom:

1) Vertical curtain of measured Ku-band reflectivity [dBZ].
2) Vertical curtain of measured Ku-band Linear Depolarization Ratio [dB].
3) Vertical curtain of measured Ku-band mean Doppler velocity [m/s] corrected for platform motion and aliasing.
4) Vertical curtain of Ka-band reflectivity [dBZ].
5) Vertical curtain of W-band reflectivity [dBZ]. If missing, HDF file may have W-band data from the nadir-looking channel “zvv95”.

Browse image 3: Standard browse image for Ku/Ka/W band data



Left column: (Top to bottom):
Vertical curtains of measured

1) Ku-band reflectivity [dBZ] at APR2 resolution (lores).
2) same as 1) interpolated to ACR resolution (hires).

3) Ka-band reflectivity [dBZ] at APR2 resolution (lores).
4) same as 3) interpolated to ACR resolution (hires).

5) W-band (VV nadir-only mode) reflectivity [dBZ] integrated to APR2 resolution (lores).
6) same as 5) at ACR resolution (hires).

7) W-band (HH scanning mode) reflectivity [dBZ] at APR2 resolution (lores).
8) same as 7) interpolated to ACR resolution (hires).

Middle column: (Top to bottom):
Vertical curtains of measured

1) Ku-band mean Doppler velocity [m/s] corrected for platform motion and aliasing (lores).
2) same as 1) interpolated to hires.

3) W-band (VV nadir-only mode) mean Doppler velocity [m/s] neithert corrected for platform motion nor aliasing, integrated to lores.
4) same as 3) at ACR resolution (hires).

Right column: (Top to bottom):

1) 2D map of Ku-band surface reflectivity σ^0 [dB] at lores.
2) time series of σ^0 [dB] in beam 12 of all channels.
3) 2D map of Ka-band surface reflectivity σ^0 [dB] at lores.

4) Cloud/precipitation mask (see Table 2e) at ACR resolution (hires).

5) 2D map of W-band (scanning mode) surface reflectivity σ^0 [dB] at lores.

6) Attitude and altitude of aircraft (lores).

Contact Information

This data is intended for research rather than operational use, and users should contact the APR-3 team regarding its use, especially before publication or public presentation.
This is the first official release of APR-3 data from CPEX 2017: these products that are still undergoing validation and quality control. Users are invited to address questions and provide feedback to the contact below.

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Data Use Disclaimer

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