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TRMM-LBA/TRMM Brazil EDOP Reprocessed Dataset Documentation

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1. Introduction

This document provides relevant information for the reprocessed ER-2 Doppler Radar (EDOP) data collected during the Tropical Rainfall Measuring Mission, Large-scale Biosphere-Atmosphere (TRMM-LBA) field campaign, also known as TRMM Brazil, which took place in January and February 1999. TRMM-LBA/TRMM Brazil focused on improving our understanding of the dynamical, microphysical, electrical, and thermodynamical aspects of the intense deep convection that occurs over Amazonia. The field campaign collected observations using both the NASA ER-2 and University of North Dakota Citation aircraft as well as multiple ground observation sites. Details on the TRMM-LBA/TRMM Brazil field campaign can be found at https://web.archive.org/web/20130302123315/http://www.espo.nasa.gov/trmmlba/overview.html

EDOP is an X-band (9.6 GHz) Doppler radar built and maintained by NASA Goddard Space Flight Center that flew aboard the NASA ER-2 aircraft during several field campaigns that took place between 1993 through 2007. The EDOP instrument mounts both a nadir-pointing antenna and a forward-angled antenna, both of which are located in the nose of the ER-2. During TRMM-LBA/TRMM Brazil, the forward antenna pointed at approximately 33° forward of nadir. By using a dual pulse repetition frequency set up, the instrument avoids issues with Doppler velocity folding due to the platform motion. The table below provides a quick reference for the radar characteristics.

EDOP Characteristics			
Frequency	9.60 GHz	Beamwidth	3°
Peak Power	25 kW	Nadir surface footprint	1.1 km diameter
Duty Cycle	0.44% max	Forward antenna tilt	33°
Pulse Width	0.25, 0.5, 1.0 µs	Nyquist Velocity	34 m s^{-1}
PRF	2200 Hz, 4400 Hz	Gate Spacing	37.5 m

The current reprocessing efforts are limited to the previously processed data files and did not delve into reprocessing the data from the raw files. Below is a list of flights during which EDOP successfully collected data:

Flight Date	EDOP File Time Range (UTC)	Description of Flight
18 December 1998	15:05 – 17:07	Test flight
24 January 1999	18:04 – 22:04	Isolated convection
25 January 1999	19:47 – 23:51	Convection
27 January 1999	18:28 – 23:31	Scattered deep convection, TRMM underflight
30 January 1999	17:33 – 22:23	Weak convection, TRMM underflight
1 February 1999	17:12 – 21:17	Widespread convection
5 February 1999	18:26 – 20:49	Line of cumulonimbus
7 February 1999	17:35 – 20:11	Small MCS
8 February 1999	19:19 – 21:33	Cirrus
10 February 1999	17:35 – 21:25	MCS
12 February 1999	17:27 – 21:32	Strong line of convection
14 February 1999	18:29 – 22:23	Pair of convective lines
17 February 1999	16:44 – 21:49	Intense convection with growth stage
21 February 1999	17:58 – 21:39	Stratiform with embedded deep convection
23 February 1999	19:26 – 23:30	Intense convective line with blue jet in vicinity
25 February 1999	14:06 – 21:44	Ferry flight back to United States

2. Reprocessing Methods

The data file used to produce the L1B reprocessed files were the Universal Format (UF) binary files containing the publicly available processed data (https://www.eol.ucar.edu/sites/default/files/files_live/private/UfDoc.txt). The processing applied to produce these original files included computing reflectivity and Doppler velocity from the raw moments data as well as removing the aircraft motion from the Doppler velocity and calibrating the reflectivity values. The spectrum width was also computed from the raw data during the original processing. The additional work performed as part of the modern reprocessing effort was to remove the effects of non-uniform beam filling (NUBF) from the Doppler velocities and to package the data in a netcdf4 format, complete with meta data. While the data collected by the nadir and forward-angled antenna are stored in separate files, the time stamps for data from each antenna are matched such that the pair of files will contain the exact same time stamps.

For a nadir-pointing beam, the effect of NUBF on the Doppler velocity is to produce an apparent upward motion where reflectivity increases in the along-track direction and an apparent downward motion where reflectivity decreases in the along-track direction. As such,

the NUBF correction for the nadir antenna data set is a function of the along-track gradient in reflectivity. For the forward-angled antenna, however, the vertical gradient in reflectivity must also be considered. The equation we use for computing the NUBF correction, v_N is as follows:

$$v_N = v_P \frac{\beta^2 R \ln(10)}{160 \ln(2)} \left(\nabla_y(dBZ_e) \cos^2 \phi_0 + \nabla_z(dBZ_e) \cos \phi_0 \sin \phi_0\right),$$

where v_P is the aircraft ground speed, y is oriented in the along-track direction, z is oriented in the vertical (positive upwards), β is the angular beam width in radians, ϕ_0 is the along-track angle of the beam center from nadir, R is the range from the antenna (positive away from the antenna), and dBZ_e is the reflectivity in logarithmic units. Note, for the nadir-pointing antenna, the vertical reflectivity gradient term drops out. For TRMM-LBA/TRMM Brazil, we computed the along-track gradient using a convolution of the kernel $[-1, 0, 0, 0, 1]$, which covers two seconds of data collection, and the along-beam gradient using a convolution of the kernel $[-1, 0, 0, 0, 0, 0, 1]$. The vertical reflectivity gradient can then be computed by the following equation:

$$\nabla_z(dBZ_e) = \frac{\nabla_y(dBZ_e) \sin \phi_0 - \nabla_B(dBZ_e)}{\cos \phi_0},$$

where $\nabla_B(dBZ_e)$ is the along-beam gradient (positive away from the antenna).

Additionally, because time stamps were stored with integer seconds and EDOP recorded data twice per second, a time correction was applied. For each pair of identical time stamps in the record, the time correction add 0.5 seconds to the latter of the pair. 0.5 seconds is added to the initial time only if the initial time is unique (i.e., the file record starts on what would have been the latter time step of a pair had the file started earlier). Occasionally, there are more than the two expected duplicates. We first attempt to fit all the data into the time line at no greater than 0.5 second intervals. In instances where there is no way to fit all the data into the timeline without resorting to sub-half second intervals, we simply spread the data points linearly in time.

3. Known Issues

1. Lack of noise estimate – Due to thresholding applied in the original processed data used to produce the reprocessed data, we were unable to estimate the noise level. Instead, we use a power threshold of -120 dBm to mask the data arrays.

4. Change Log

The following is a record of changes that occurred in each version of this data set, listed in reverse chronological order such that the most recent data version is at the top.

RevA	Made correction to forward-antenna NUBF correction and added some missing metadata.
Rev-	Initial release of reprocessed data files.

5. Netcdf4 Format

The following is a copy of the output of ncdump -h for the nadir and forward-angle 18:40 – 18:45 UTC 24 January 1999 files:

5.1 Nadir antenna file

```
netcdf BRAZIL_EDOP_Nadir_L1B_RevA_199901241840_199901241845 {

// global attributes:
		:Title = "Level1B processed EDOP airborne Doppler radar nadir antenna data collected during TRMM
Brazil" ;
		:Institution = "NASA Goddard Space Flight Center, Mesoscale Atmospheric Processes Lab (Code 612), High
Altitude Radar Group" ;
		:Radar = "EDOP" ;
		:AntennaDescriptor = "Nadir Antenna" ;
		:Aircraft = "NASA ER-2" ;
		:Experiment = "TRMM Brazil" ;
		:FlightID = "98-042" ;
		:FlightDate = "19990124" ;
		:FlightLegName = "" ;
		:FlightLegCode = "" ;
		:ExperimentPI = "" ;
		:InstrumentPI = "Gerald M. Heymsfield, NASA/GSFC" ;
		:DataContacts = "Charles N. Helms, UMD/ESSIC & NASA/GSFC, charles.n.helms@nasa.gov; Matthew L.
Walker McLinden, NASA/GSFC, matthew.l.mclinden@nasa.gov" ;
		:Rawdata_filename = "990124_1840-1845" ;
		:UFfilename = "990124_1840-1845.uf.2.1" ;
		:UFprocessDate = "04/12/**" ;
		:UFlastModificationDate = "04/12/**" ;
		:L1B_processDate = "2025-04-04 19:22:25.596544+00:00" ;
		:L1B_revision = "RevA" ;
		:L1B_revisionNote = "Made correction to forward-antenna NUBF correction and added some missing
metadata.  Please reach out to the data contacts with any questions or concerns regarding the data." ;
		:L1B_revisionHistory = "Revision History:\nRevA :: Made correction to forward-antenna NUBF correction
and added some missing metadata.\nRev- :: Initial release of the reprocessed BRAZIL data.\n" ;
		:NavigationSource = "ER-2 aircraft GPS/INS Hybrid with altitude taken from ER-2 GPS" ;
		:AirfieldName = "Brasilia, Brazil" ;
		:AirfieldLatitude = -15.87f ;
		:AirfieldLongitude = -47.84f ;
		:TiltFromNadir_degrees = 0.8f ;
		:AzimuthFromHeading_degrees = 0.f ;
		:GateSpacing_m = 37.5f ;
		:PulseWidth_Hz = 0.5f ;
		:PRF_Hz = 2200.f, 4400.f ;
		:PRT_usec = 454.5f, 227.3f ;
		:NyquistVelocity_m_s-1 = 33.86f ;
		:ReflIntegrationTime_sec = 0.5f ;
```

```
            :DopIntegrationTime_sec = 0.f ;
            :RadarConstant_dB = 86.79f ;
            :IFbandwidth_MHz = 0.f ;
            :Frequency_GHz = 9.72f ;
            :Wavelength_cm = 3.109375f ;
            :Beamwidth_degrees = 3.f ;
            :TransmitPower_dBm = 68.19f ;
            :ReceiverBandwidth_MHz = 0.f ;
            :TransmitRecievePolarization = "VV" ;
            :ReceiverGain_dB = 0.f ;
            :PeakPower_dBmW = 68.19f ;
            :AntennaGain_dB = 36.09f ;
            :PulseLength_usec = 0.32f ;
            :UFdumpFilename = "BR_EDOP_UFdump_990124_1840-1845.uf.2.1.nc" ;

group: Products {
  dimensions:
      Range = 729 ;
      TimeUTC = 595 ;
  variables:
      float Range(Range) ;
            Range:_FillValue = NaNf ;
            Range:correctionFromUF_meters = 308.f ;
            Range:units = "meters" ;
            Range:description = "Along-beam range in meters from antenna" ;
      double TimeUTC(TimeUTC) ;
            TimeUTC:_FillValue = NaN ;
            TimeUTC:source = "Aircraft INS time" ;
            TimeUTC:units = "seconds since 1970-01-01 00:00 UTC" ;
            TimeUTC:correctionFromUF_seconds = 0.f ;
            TimeUTC:description = "UTC profile time in unix epoch format (seconds since 00 UTC 1 January 1970)" ;
      float dBZeCoPol(Range, TimeUTC) ;
            dBZeCoPol:_FillValue = NaNf ;
            dBZeCoPol:UF_fieldName = "ZN" ;
            dBZeCoPol:description = "Equivalent reflectivity factor in dB for the co-polarization channel" ;
            dBZeCoPol:units = "10*log10(mm^6/m^3)" ;
            dBZeCoPol:calibration_constant_dB = 0.f ;
      float dBZeSfcCh(Range, TimeUTC) ;
            dBZeSfcCh:_FillValue = NaNf ;
            dBZeSfcCh:units = "10*log10(mm^6/m^3)" ;
            dBZeSfcCh:description = "Equivalent reflectivity factor in dB for the surface channel" ;
            dBZeSfcCh:calibration_constant_dB = 0.f ;
            dBZeSfcCh:gateShift_gates = 0s ;
            dBZeSfcCh:UF_fieldName = "ZS" ;
      float VelocityCorrectedCoPol(Range, TimeUTC) ;
            VelocityCorrectedCoPol:_FillValue = NaNf ;
            VelocityCorrectedCoPol:description = "Co-polarization channel Doppler velocity corrected to account for
both non-uniform beam filling and aircraft motion.  Note, the MaskCoPol mask is applied during the NUBF
correction." ;
            VelocityCorrectedCoPol:units = "m/s" ;
            VelocityCorrectedCoPol:signConvention = "Away from antenna is positive" ;
            VelocityCorrectedCoPol:equation = "VelocityCorrected = VelocityUncorrected + DopplerCorrectionNUBF"
;
```

```
    float VelocityUncorrectedCoPol(Range, TimeUTC) ;
        VelocityUncorrectedCoPol:description = "Co-polarization channel Doppler velocity with only the aircraft
motion correction applied" ;
        VelocityUncorrectedCoPol:equation = "VelocityCorrected = VelocityUncorrected +
DopplerCorrectionNUBF" ;
        VelocityUncorrectedCoPol:UF_fieldName = "VN" ;
        VelocityUncorrectedCoPol:_FillValue = NaNf ;
        VelocityUncorrectedCoPol:units = "m/s" ;
        VelocityUncorrectedCoPol:signConvention = "Away from antenna is positive" ;
    float PowerCoPol(Range, TimeUTC) ;
        PowerCoPol:_FillValue = NaNf ;
        PowerCoPol:description = "Recieved power for the co-polarization channel" ;
        PowerCoPol:units = "dBm" ;
        PowerCoPol:UF_fieldname = "MN" ;
    float PowerSfcCh(Range, TimeUTC) ;
        PowerSfcCh:_FillValue = NaNf ;
        PowerSfcCh:description = "Recieved power for the surface channel" ;
        PowerSfcCh:units = "dBm" ;
        PowerSfcCh:gateShift_gates = 0s ;
        PowerSfcCh:UF_fieldname = "MS" ;
    float SpectrumWidthCoPol(Range, TimeUTC) ;
        SpectrumWidthCoPol:description = "Doppler spectrum width estimate for the co-polarization channel" ;
        SpectrumWidthCoPol:units = "m/s" ;
        SpectrumWidthCoPol:UF_fieldname = "WN" ;
        SpectrumWidthCoPol:_FillValue = NaNf ;
    float SpectrumWidthSfcCh(Range, TimeUTC) ;
        SpectrumWidthSfcCh:_FillValue = NaNf ;
        SpectrumWidthSfcCh:description = "Doppler spectrum width estimate for the surface channel" ;
        SpectrumWidthSfcCh:units = "m/s" ;
        SpectrumWidthSfcCh:gateShift_gates = 0LL ;
        SpectrumWidthSfcCh:UF_fieldname = "WS" ;
 } // group Products

group: Information {
  dimensions:
    Range = 729 ;
    TimeUTC = 595 ;
  variables:
    byte MaskCoPol(Range, TimeUTC) ;
        MaskCoPol:description = "Mask for removing noise.  Noise was set to a missing value in original data, so
mask is generated based on that missing value." ;
        MaskCoPol:key = "0 = Signal, 1 = Noise" ;
    byte MaskSfcCh(Range, TimeUTC) ;
        MaskSfcCh:description = "Mask for removing noise.  Noise was set to a missing value in original data, so
mask is generated based on that missing value." ;
        MaskSfcCh:key = "0 = Signal, 1 = Noise" ;
    short OceanGateIndex(TimeUTC) ;
        OceanGateIndex:_FillValue = 0s ;
        OceanGateIndex:description = "Range index of gate at expected zero altitude above mean sea level based
on radar geometry and aircraft attitude." ;
    float DopplerCorrectionAircraftMotion(TimeUTC) ;
        DopplerCorrectionAircraftMotion:_FillValue = NaNf ;
```

```
            DopplerCorrectionAircraftMotion:description = "Estimated aircraft motion correction to Doppler velocity"
;
            DopplerCorrectionAircraftMotion:units = "m/s" ;
            DopplerCorrectionAircraftMotion:note = "Correction is already applied to both VelocityCorrected and
VelocityUncorrected" ;
      float DopplerCorrectionCoPolNUBF(Range, TimeUTC) ;
            DopplerCorrectionCoPolNUBF:_FillValue = NaNf ;
            DopplerCorrectionCoPolNUBF:description = "Estimated non-uniform beam filling correction to co-
polarization channel Doppler velocity accounting for horizontal reflectivity gradients" ;
            DopplerCorrectionCoPolNUBF:units = "m/s" ;
            DopplerCorrectionCoPolNUBF:horizontalGradientKernal = -1s, 0s, 0s, 0s, 1s ;
            DopplerCorrectionCoPolNUBF:note = "Correction is already applied to both VelocityCorrected and
VelocityUncorrected" ;
      float dxdr(TimeUTC) ;
            dxdr:_FillValue = NaNf ;
            dxdr:description = "Data cross-track distance from aircraft per unit range" ;
            dxdr:units = "m/m" ;
            dxdr:convention = "Positive is in the starboard direction" ;
      float dydr(TimeUTC) ;
            dydr:_FillValue = NaNf ;
            dydr:description = "Data along-track distance from aircraft per unit range" ;
            dydr:units = "m/m" ;
            dydr:convention = "Positive is in the direction of aircraft travel" ;
      float dzdr(TimeUTC) ;
            dzdr:_FillValue = NaNf ;
            dzdr:description = "Data vertical distance from aircraft per unit range" ;
            dzdr:units = "m/m" ;
            dzdr:convention = "Positive is in the upward direction" ;
      float horizontalResolution6dB(Range) ;
            horizontalResolution6dB:_FillValue = NaNf ;
            horizontalResolution6dB:description = "Approximate horizontal resolution defined as width of spatial
weighting after averaging as a function of radar range" ;
            horizontalResolution6dB:units = "meters" ;
  } // group Information

group: Navigation {
  dimensions:
      TimeUTC = 595 ;
  variables:
      float NominalDistance(TimeUTC) ;
            NominalDistance:_FillValue = NaNf ;
            NominalDistance:description = "Nominal aircraft travel distance estimated by cumulatively summing the
instantaneous velocities" ;
            NominalDistance:units = "meters" ;
            NominalDistance:source = "TimeUTC and GroundSpeed" ;
      float Latitude(TimeUTC) ;
            Latitude:_FillValue = NaNf ;
            Latitude:description = "Latitude" ;
            Latitude:units = "degreesNorth" ;
      float Longitude(TimeUTC) ;
            Longitude:_FillValue = NaNf ;
            Longitude:description = "Longitude" ;
            Longitude:units = "degreesEast" ;
```

```
    float Altitude(TimeUTC) ;
        Altitude:_FillValue = NaNf ;
        Altitude:description = "Aircraft height above sea level" ;
        Altitude:units = "meters" ;
    float GroundSpeed(TimeUTC) ;
        GroundSpeed:_FillValue = NaNf ;
        GroundSpeed:description = "Aircraft total horizontal speed" ;
        GroundSpeed:units = "m/s" ;
    float NorthVelocity(TimeUTC) ;
        NorthVelocity:_FillValue = NaNf ;
        NorthVelocity:description = "Aircraft northward component of velocity" ;
        NorthVelocity:units = "m/s" ;
    float EastVelocity(TimeUTC) ;
        EastVelocity:_FillValue = NaNf ;
        EastVelocity:description = "Aircraft eastward component of velocity" ;
        EastVelocity:units = "m/s" ;
    float UpVelocity(TimeUTC) ;
        UpVelocity:_FillValue = NaNf ;
        UpVelocity:description = "Aircraft upward component of velocity" ;
        UpVelocity:units = "m/s" ;
    float Track(TimeUTC) ;
        Track:_FillValue = NaNf ;
        Track:description = "Direction of motion in degrees from north with 90 degrees indicating eastward
motion" ;
        Track:units = "degrees" ;
    float Heading(TimeUTC) ;
        Heading:_FillValue = NaNf ;
        Heading:description = "Direction towards which aircraft nose is pointing in degrees from north with 90
degrees indicating eastward pointing" ;
        Heading:units = "degrees" ;
        Heading:correctionFromUF_degrees = 0.f ;
    float Drift(TimeUTC) ;
        Drift:_FillValue = NaNf ;
        Drift:description = "Difference between track and heading" ;
        Drift:units = "degrees" ;
        Drift:equation = "Drift = Track - Heading" ;
    float Roll(TimeUTC) ;
        Roll:_FillValue = NaNf ;
        Roll:description = "Roll about along-aircraft axis.  Positive values correspond to the starboard (right) wing
dipping" ;
        Roll:units = "degrees" ;
        Roll:correctionFromUF_degrees = 0.f ;
    float Pitch(TimeUTC) ;
        Pitch:_FillValue = NaNf ;
        Pitch:units = "degrees" ;
        Pitch:description = "Pitch about across-aircraft axis.  Positive values correspond to a nose up position" ;
        Pitch:correctionFromUF_degrees = 0.f ;
    float VerticalAcceleration(TimeUTC) ;
        VerticalAcceleration:_FillValue = NaNf ;
        VerticalAcceleration:units = "m/s/s" ;
        VerticalAcceleration:description = "Vertical acceleration of aircraft" ;
    float FlightLevelWindDirection(TimeUTC) ;
        FlightLevelWindDirection:_FillValue = NaNf ;
```

```
            FlightLevelWindDirection:description = "Observed wind direction at flight level" ;
            FlightLevelWindDirection:units = "degrees" ;
            FlightLevelWindDirection:source = "INS" ;
      float FlightLevelWindSpeed(TimeUTC) ;
            FlightLevelWindSpeed:_FillValue = NaNf ;
            FlightLevelWindSpeed:description = "Observed wind speed at flight level" ;
            FlightLevelWindSpeed:units = "m/s" ;
            FlightLevelWindSpeed:source = "INS" ;
  } // group Navigation
}
```

5.2 Forward-angle Antenna File

```
netcdf BRAZIL_EDOP_Forward_L1B_RevA_199901241840_199901241845 {

// global attributes:
            :Title = "Level1B processed EDOP airborne Doppler radar forward antenna data collected during TRMM
Brazil" ;
            :Institution = "NASA Goddard Space Flight Center, Mesoscale Atmospheric Processes Lab (Code 612), High
Altitude Radar Group" ;
            :Radar = "EDOP" ;
            :AntennaDescriptor = "Forward Antenna" ;
            :Aircraft = "NASA ER-2" ;
            :Experiment = "TRMM Brazil" ;
            :FlightID = "98-042" ;
            :FlightDate = "19990124" ;
            :FlightLegName = "" ;
            :FlightLegCode = "" ;
            :ExperimentPI = "" ;
            :InstrumentPI = "Gerald M. Heymsfield, NASA/GSFC" ;
            :DataContacts = "Charles N. Helms, UMD/ESSIC & NASA/GSFC, charles.n.helms@nasa.gov; Matthew L.
Walker McLinden, NASA/GSFC, matthew.l.mclinden@nasa.gov" ;
            :Rawdata_filename = "990124_1840-1845" ;
            :UFfilename = "990124_1840-1845.uf.2.1" ;
            :UFprocessDate = "04/12/**" ;
            :UFlastModificationDate = "04/12/**" ;
            :L1B_processDate = "2025-04-04 19:22:25.604982+00:00" ;
            :L1B_revision = "RevA" ;
            :L1B_revisionNote = "Made correction to forward-antenna NUBF correction and added some missing
metadata.  Please reach out to the data contacts with any questions or concerns regarding the data." ;
            :L1B_revisionHistory = "Revision History:\nRevA :: Made correction to forward-antenna NUBF correction
and added some missing metadata.\nRev- :: Initial release of the reprocessed BRAZIL data.\n" ;
            :NavigationSource = "ER-2 aircraft GPS/INS Hybrid with altitude taken from ER-2 GPS" ;
            :AirfieldName = "Brasilia, Brazil" ;
            :AirfieldLatitude = -15.87f ;
            :AirfieldLongitude = -47.84f ;
            :TiltFromNadir_degrees = 33.9f ;
            :AzimuthFromHeading_degrees = 0.f ;
            :GateSpacing_m = 37.5f ;
            :PulseWidth_Hz = 0.5f ;
            :PRF_Hz = 2200LL, 4400LL ;
            :PRT_usec = 454.5, 227.3 ;
```

```
            :NyquistVelocity_m_s-1 = 33.86f ;
            :ReflIntegrationTime_sec = 0.5f ;
            :DopIntegrationTime_sec = 0.f ;
            :RadarConstant_dB = 88.08f ;
            :IFbandwidth_MHz = 0.f ;
            :Frequency_GHz = 9.72f ;
            :Wavelength_cm = 3.109375f ;
            :Beamwidth_degrees = 3.f ;
            :TransmitPower_dBm = 68.19f ;
            :ReceiverBandwidth_MHz = 0.f ;
            :TransmitRecievePolarization = "VV, VH" ;
            :ReceiverGain_dB = 0.f ;
            :PeakPower_dBmW = 68.19f ;
            :AntennaGain_dB = 35.5f ;
            :PulseLength_usec = 0.32f ;
            :UFdumpFilename = "BR_EDOP_UFdump_990124_1840-1845.uf.2.1.nc" ;

group: Products {
  dimensions:
      TimeUTC = 595 ;
      Range = 729 ;
  variables:
      double TimeUTC(TimeUTC) ;
            TimeUTC:_FillValue = NaN ;
            TimeUTC:source = "Aircraft INS time" ;
            TimeUTC:units = "seconds since 1970-01-01 00:00 UTC" ;
            TimeUTC:correctionFromUF_seconds = 0.f ;
            TimeUTC:description = "UTC profile time in unix epoch format (seconds since 00 UTC 1 January 1970)" ;
      float Range(Range) ;
            Range:_FillValue = NaNf ;
            Range:correctionFromUF_meters = 319.f ;
            Range:units = "meters" ;
            Range:description = "Along-beam range in meters from antenna" ;
      float dBZeCoPol(Range, TimeUTC) ;
            dBZeCoPol:_FillValue = NaNf ;
            dBZeCoPol:description = "Equivalent reflectivity factor in dB for the co-polarization channel" ;
            dBZeCoPol:units = "10*log10(mm^6/m^3)" ;
            dBZeCoPol:calibration_constant_dB = 0.f ;
            dBZeCoPol:UF_fieldName = "ZF" ;
      float dBZeCrPol(Range, TimeUTC) ;
            dBZeCrPol:_FillValue = NaNf ;
            dBZeCrPol:description = "Equivalent reflectivity factor in dB for the cross-polarization channel" ;
            dBZeCrPol:units = "10*log10(mm^6/m^3)" ;
            dBZeCrPol:calibration_constant_dB = 0.f ;
            dBZeCrPol:gateShift_gates = -1s ;
            dBZeCrPol:UF_fieldName = "ZX" ;
      float VelocityCorrectedCoPol(Range, TimeUTC) ;
            VelocityCorrectedCoPol:_FillValue = NaNf ;
            VelocityCorrectedCoPol:description = "Co-polarization channel Doppler velocity corrected to account for
both non-uniform beam filling and aircraft motion.  Note, the MaskCoPol mask is applied during the NUBF
correction." ;
            VelocityCorrectedCoPol:units = "m/s" ;
            VelocityCorrectedCoPol:signConvention = "Away from antenna is positive" ;
```

```
            VelocityCorrectedCoPol:equation = "VelocityCorrected = VelocityUncorrected + DopplerCorrectionNUBF"
;
      float VelocityUncorrectedCoPol(Range, TimeUTC) ;
            VelocityUncorrectedCoPol:equation = "VelocityCorrected = VelocityUncorrected +
DopplerCorrectionNUBF" ;
            VelocityUncorrectedCoPol:_FillValue = NaNf ;
            VelocityUncorrectedCoPol:description = "Co-polarization channel Doppler velocity with only the aircraft
motion correction applied" ;
            VelocityUncorrectedCoPol:units = "m/s" ;
            VelocityUncorrectedCoPol:signConvention = "Away from antenna is positive" ;
            VelocityUncorrectedCoPol:UF_fieldName = "VF" ;
      float PowerCoPol(Range, TimeUTC) ;
            PowerCoPol:_FillValue = NaNf ;
            PowerCoPol:description = "Recieved power for the co-polarization channel" ;
            PowerCoPol:units = "dBm" ;
            PowerCoPol:UF_fieldname = "MF" ;
      float PowerCrPol(Range, TimeUTC) ;
            PowerCrPol:_FillValue = NaNf ;
            PowerCrPol:description = "Recieved power for the cross-polarization channel" ;
            PowerCrPol:units = "dBm" ;
            PowerCrPol:gateShift_gates = -1s ;
            PowerCrPol:UF_fieldname = "MX" ;
      float SpectrumWidthCoPol(Range, TimeUTC) ;
            SpectrumWidthCoPol:description = "Doppler spectrum width estimate for the co-polarization channel" ;
            SpectrumWidthCoPol:units = "m/s" ;
            SpectrumWidthCoPol:UF_fieldname = "WF" ;
            SpectrumWidthCoPol:_FillValue = NaNf ;
      float SpectrumWidthCrPol(Range, TimeUTC) ;
            SpectrumWidthCrPol:_FillValue = NaNf ;
            SpectrumWidthCrPol:description = "Doppler spectrum width estimate with aircraft motion removed for
the cross-polarization channel" ;
            SpectrumWidthCrPol:units = "m/s" ;
            SpectrumWidthCrPol:gateShift_gates = 0LL ;
            SpectrumWidthCrPol:UF_fieldname = "WX" ;
      float LDR(Range, TimeUTC) ;
            LDR:_FillValue = NaNf ;
            LDR:description = "Linear depolarization ratio (CrPol/CoPol)" ;
            LDR:units = "dB" ;
  } // group Products

group: Information {
  dimensions:
      Range = 729 ;
      TimeUTC = 595 ;
  variables:
      byte MaskCoPol(Range, TimeUTC) ;
            MaskCoPol:description = "Mask for removing noise.  Noise was set to a missing value in original data, so
mask is generated based on that missing value." ;
            MaskCoPol:key = "0 = Signal, 1 = Noise" ;
      byte MaskCrPol(Range, TimeUTC) ;
            MaskCrPol:description = "Mask for removing noise.  Noise was set to a missing value in original data, so
mask is generated based on that missing value." ;
            MaskCrPol:key = "0 = Signal, 1 = Noise" ;
```

```
    short OceanGateIndex(TimeUTC) ;
        OceanGateIndex:_FillValue = 0s ;
        OceanGateIndex:description = "Range index of gate at expected zero altitude above mean sea level based
on radar geometry and aircraft attitude." ;
    float DopplerCorrectionAircraftMotion(TimeUTC) ;
        DopplerCorrectionAircraftMotion:_FillValue = NaNf ;
        DopplerCorrectionAircraftMotion:description = "Estimated aircraft motion correction to Doppler velocity"
;
        DopplerCorrectionAircraftMotion:units = "m/s" ;
        DopplerCorrectionAircraftMotion:note = "Correction is already applied to both VelocityCorrected and
VelocityUncorrected" ;
    float DopplerCorrectionCoPolNUBF(Range, TimeUTC) ;
        DopplerCorrectionCoPolNUBF:_FillValue = NaNf ;
        DopplerCorrectionCoPolNUBF:description = "Estimated non-uniform beam filling correction to co-
polarizontaion channel Doppler velocity accounting for both horizontal and vertical reflectivity gradients" ;
        DopplerCorrectionCoPolNUBF:units = "m/s" ;
        DopplerCorrectionCoPolNUBF:horizontalGradientKernal = -1s, 0s, 0s, 0s, 1s ;
        DopplerCorrectionCoPolNUBF:alongBeamGradientKernal = -1s, 0s, 0s, 0s, 0s, 0s, 1s ;
        DopplerCorrectionCoPolNUBF:note = "Correction is already applied to both VelocityCorrected and
VelocityUncorrected" ;
    float dxdr(TimeUTC) ;
        dxdr:_FillValue = NaNf ;
        dxdr:description = "Data cross-track distance from aircraft per unit range" ;
        dxdr:units = "m/m" ;
        dxdr:convention = "Positive is in the starboard direction" ;
    float dydr(TimeUTC) ;
        dydr:_FillValue = NaNf ;
        dydr:description = "Data along-track distance from aircraft per unit range" ;
        dydr:units = "m/m" ;
        dydr:convention = "Positive is in the direction of aircraft travel" ;
    float dzdr(TimeUTC) ;
        dzdr:_FillValue = NaNf ;
        dzdr:description = "Data vertical distance from aircraft per unit range" ;
        dzdr:units = "m/m" ;
        dzdr:convention = "Positive is in the upward direction" ;
    float horizontalResolution6dB(Range) ;
        horizontalResolution6dB:_FillValue = NaNf ;
        horizontalResolution6dB:description = "Approximate horizontal resolution defined as width of spatial
weighting after averaging as a function of radar range" ;
        horizontalResolution6dB:units = "meters" ;
  } // group Information

group: Navigation {
  dimensions:
    TimeUTC = 595 ;
  variables:
    float NominalDistance(TimeUTC) ;
        NominalDistance:_FillValue = NaNf ;
        NominalDistance:description = "Nominal aircraft travel distance estimated by cumulatively summing the
instantaneous velocities" ;
        NominalDistance:units = "meters" ;
        NominalDistance:source = "TimeUTC and GroundSpeed" ;
    float Latitude(TimeUTC) ;
```

```
        Latitude:_FillValue = NaNf ;
        Latitude:description = "Latitude" ;
        Latitude:units = "degreesNorth" ;
    float Longitude(TimeUTC) ;
        Longitude:_FillValue = NaNf ;
        Longitude:description = "Longitude" ;
        Longitude:units = "degreesEast" ;
    float Altitude(TimeUTC) ;
        Altitude:_FillValue = NaNf ;
        Altitude:description = "Aircraft height above sea level" ;
        Altitude:units = "meters" ;
    float GroundSpeed(TimeUTC) ;
        GroundSpeed:_FillValue = NaNf ;
        GroundSpeed:description = "Aircraft total horizontal speed" ;
        GroundSpeed:units = "m/s" ;
    float NorthVelocity(TimeUTC) ;
        NorthVelocity:_FillValue = NaNf ;
        NorthVelocity:description = "Aircraft northward component of velocity" ;
        NorthVelocity:units = "m/s" ;
    float EastVelocity(TimeUTC) ;
        EastVelocity:_FillValue = NaNf ;
        EastVelocity:description = "Aircraft eastward component of velocity" ;
        EastVelocity:units = "m/s" ;
    float UpVelocity(TimeUTC) ;
        UpVelocity:_FillValue = NaNf ;
        UpVelocity:description = "Aircraft upward component of velocity" ;
        UpVelocity:units = "m/s" ;
    float Track(TimeUTC) ;
        Track:_FillValue = NaNf ;
        Track:description = "Direction of motion in degrees from north with 90 degrees indicating eastward
motion" ;
        Track:units = "degrees" ;
    float Heading(TimeUTC) ;
        Heading:_FillValue = NaNf ;
        Heading:description = "Direction towards which aircraft nose is pointing in degrees from north with 90
degrees indicating eastward pointing" ;
        Heading:units = "degrees" ;
        Heading:correctionFromUF_degrees = 0.f ;
    float Drift(TimeUTC) ;
        Drift:_FillValue = NaNf ;
        Drift:description = "Difference between track and heading" ;
        Drift:units = "degrees" ;
        Drift:equation = "Drift = Track - Heading" ;
    float Roll(TimeUTC) ;
        Roll:_FillValue = NaNf ;
        Roll:description = "Roll about along-aircraft axis.  Positive values correspond to the starboard (right) wing
dipping" ;
        Roll:units = "degrees" ;
        Roll:correctionFromUF_degrees = 0.f ;
    float Pitch(TimeUTC) ;
        Pitch:_FillValue = NaNf ;
        Pitch:units = "degrees" ;
        Pitch:description = "Pitch about across-aircraft axis.  Positive values correspond to a nose up position" ;
```

```
        Pitch:correctionFromUF_degrees = 0.f ;
    float VerticalAcceleration(TimeUTC) ;
        VerticalAcceleration:_FillValue = NaNf ;
        VerticalAcceleration:units = "m/s/s" ;
        VerticalAcceleration:description = "Vertical acceleration of aircraft" ;
    float FlightLevelWindDirection(TimeUTC) ;
        FlightLevelWindDirection:_FillValue = NaNf ;
        FlightLevelWindDirection:description = "Observed wind direction at flight level" ;
        FlightLevelWindDirection:units = "degrees" ;
        FlightLevelWindDirection:source = "INS" ;
    float FlightLevelWindSpeed(TimeUTC) ;
        FlightLevelWindSpeed:_FillValue = NaNf ;
        FlightLevelWindSpeed:description = "Observed wind speed at flight level" ;
        FlightLevelWindSpeed:units = "m/s" ;
        FlightLevelWindSpeed:source = "INS" ;
  } // group Navigation
}
```