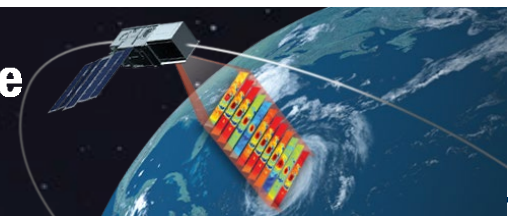




**Time-Resolved Observations of Precipitation structure
and storm Intensity with a Constellation of Smallsats**



TROPICS Data Product Update

Vince Leslie

11 December 2020



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Outline



- **Atmospheric Vertical Profile Update**
 - Merged AVTP & AVMP into AVP
 - Merged MIRS SND & IMG files into single file

- **L1a Radiance Update**
 - Example file contents update
 - Data quality flag update



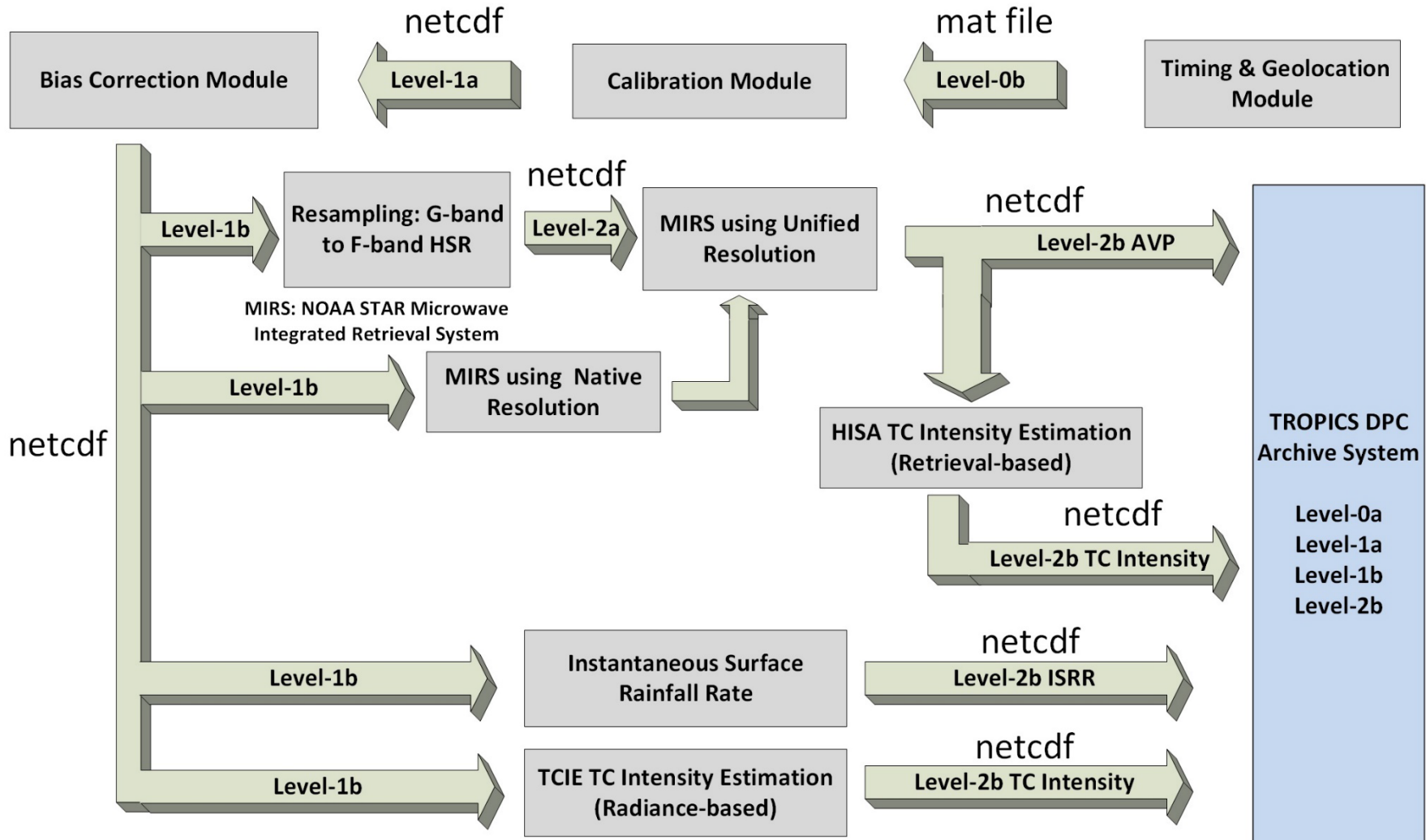
TROPICS Data Products



Data Product Level Designation	Data Product Description	Team Member (Org.)
Level 0	raw CCSDS payload and telemetry from space vehicles	Shawn Donnelly (LL)
Level 1a	Timestamped, geolocated, calibrated antenna temperature	Vince Leslie (LL)
Level 1b	Timestamped, geolocated, calibrated brightness temperature with bias removed	Vince Leslie (LL)
Level 2a	Spatially resampled (i.e., collocated) G-band brightness temperature (to F-band resolution)	Ralf Bennartz (UWisc-Madison/Vanderbilt)
MIRS "AVP" {	Atmospheric Vertical Temperature Profile [Kelvin]	Tom Greenwald (UWisc-Madison) & Ralf Bennartz
PRPS/GPROF {	Atmospheric Vertical Moisture Profile [g/kg]	Tom Greenwald & Ralf Bennartz
Level 2b {	Instantaneous Surface Rain Rate [mm/hr]	Toshihisa Matsui & Chris Kidd
TCIE & HISA {	TC Intensity: Minimum Sea-Level Pressure [mb]	A) Derrick Herndon & Chris Velden (UWisc-Madison) B) Galina Chirokova (CSU/CIRA) & Mark DeMaria (NHC)
	TC Intensity: Maximum Sustained Wind [m/s]	A) Derrick Herndon & Chris Velden B) Galina Chirokova & Mark DeMaria



TROPICS Data Products Flowchart





Data Product Highlights



- **TROPICS is required to deliver data in netCDF4 format:**
 - BUFR - UWisc-Madison/SSEC
 - AWIPS – SPoRT
 - GIS-compatible – Likely multiple institutions like UW-M & SPoRT
- **Once operational (~ 90 days after first launch for constellation; ~50 days for Pathfinder), data will be available at GES DISC DAAC**
- **Public documentation (hosted by GES DISC):**
 - Drafts available around March 2021
 - **Algorithm Theoretical Basis Documents (ATBD)**
 - Payload description
 - Algorithm description
 - Pre-launch test data verification
 - **Data user's guide**
 - Data format and quality flags
 - Data access at GES DISC
 - Validation Plan
 - Validation Report (post-launch appendix)

TROPICS ATBDs

- Radiance (L1)
- Resampling (L2a)
- Profile (MIRS)
- Precipitation (PRPS/GPROF)
- TC Intensity (TCIE & HISA)



TROPICS MIRS Sounding Output



Parameter Name	Explanation
Atm_type	Atmospheric classification (currently missing)
ChiSqr	Convergence metric
Emis	Surface emissivity vector
Freq	Instrument chan. central frequencies (GHz)
LZ_angle	Scene local zenith angle (degrees)
Latitude	Latitude (degrees)
Longitude	Longitude (degrees)
Orb_mode	0-ascending, 1-descending (orbit node)
PClw	Cloud liquid water profile (mm)
PGraupel	Graupel water profile (mm)
PIce	Cloud ice water profile (mm)
PRain	Rain water profile (mm)
PSnow	Snow water profile (mm)
Ptemp (AVTP)	Temperature Profile (K)
Pvapor (AVMP)	Water vapor profile (g/kg)
Player	Pressure layer grid (hPa)

Parameter Name	Explanation
Plevel	Pressure level grid (hPa)
Polo	Instrument chan. polarizations
Qc	QC array: QC(0) 0-good, 1-use with caution, 2-bad
RAzi_angle	Relative Azimuth angle (degrees)
SZ_angle	Satellite Zenith angle (degrees)
ScanTime.UTC	Number of seconds since 00:00:00 UTC
ScanTime_dom	Scan time day of month
ScanTime_doy	Scan time day of year
ScanTime_hour	Scan time hour of day
ScanTime_minute	Scan time minute of hour
ScanTime_month	Scan time calendar month
ScanTime_second	Scan time second of minute
ScanTime_year	Scan time calendar year
Sfc_type	Surface classification
SurfP	Surface pressure value



TROPICS MIRS Sounding Output (Was in Image Output)



Parameter Name	Explanation
Atm_type	0-simple scene, 1-retrieved scene
BT	Corrected channel brightness temperature (K)
CLW	Integrated cloud liquid water (mm)
ChanSel	Channels used for retrieval
ChiSqf	Convergence metric
CldBase	Cloud base height (hPa)
CldThick	Cloud thickness (hPa)
CldTop	Cloud top height (hPa)
Freq	Instrument center frequency (GHz)
GWP	Integrated graupel ice water (mm)
IWP	Integrated cloud ice water (mm)
LWP	Integrated liquid (rain+cloud) water (mm)
LZ_angle	Local zenith angle (degrees)
Latitude	Latitude (degrees)
Longitude	Longitude (degrees)
Orb_mode	0-ascending, 1-descending (orbit node)
Pole	Instrument chan. polarizations

Parameter Name	Explanation
PrecipType	Precipitation type (frozen/liquid)
QC	QC array: QC(0) 0-good, 1-use with caution, 2-bad
RAzi_angle	Relative Azimuth angle (degrees)
RFlag	Rain flag
RR	Rain Rate (mm/h)
RWP	Integrated rain water (mm)
SFR	Snowfall Rate (mm/h)
Sice	Sea-ice Concentration (%)
Sice_FY	First-year SIC (%)
Sice_MY	Multi-year SIC (%)
SWE	Snow water equivalent (cm)
SWP	Integrated snow water (mm)
SZ_angle	Satellite zenith angle (degrees)
ScanTime_UTG	Number of seconds since 00:00:00 UTC
ScanTime_dom	Scan time day of month
ScanTime_doy	Scan time day of year
ScanTime_hour	Scan time hour of day
ScanTime_minute	Scan time minute of hour
ScanTime_month	Scan time calendar month
ScanTime_second	Scan time second of minute
ScanTime_year	Scan time calendar year



TROPICS MIRS Sounding Output (Was in Image Output)



Parameter Name	Explanation
Sfc_type	Surface classification
Snow	Snow cover flag
SnowGS	Snow grain size (mm)
SurfM	Surface (soil) moisture
SurfP	Surface pressure value
TPW	Total precipitable water (mm)
TSkin	Skin temperature
WindDir	Wind direction (degrees)
WindSp	Wind speed (m/s)
WindU	Wind speed U vector (m/s)
WindV	Wind speed V vector (m/s)
YM	Uncorrected channel brightness temperature (K)



L1a NetCDF File Contents



Short Name	Size/Value	Data Type
creTimeL1a:	1.61E+09	
tempAntE:	81×2854×12	double
timeE:	81×2854	double
losLat:	81×2854×5	double
losLon:	81×2854×5	double
losScan:	81×2854×5	double
losZen:	81×2854×5	double
losAzi:	81×2854×5	double
calQualityFlag:	81×2854×12	uint8
LandFlag:	81×2854	uint8
losLunZen:	81×2854×5	double
losLunAzi:	81×2854×5	double
losSolZen:	81×2854×5	double
losSolAzi:	81×2854×5	double

Short Name	Size/Value	Data Type
scPosECEF:	2854×3	double
scQuatECEF:	2854×4	double
instrTemp:	3×2854	double
NEDT_DS:	2854×12	single
NEDT_ND:	2854×12	single
SpaceVehicleIdentifier:	3	
OrbitNumber:	119	
PayloadDriverSWVersion:	538510120	
L0bSWVersion:	'0'	
L1aSWVersion:	'2.0.0'	
BandstoChannel:	Band 1 = Ch. 1; Band 2 = Ch. 2-4; Band 3 = Ch. 5-8; Band 4 = Ch. 9-11; Band 5 = Ch. 12	

TROPICS_L1a_SV03_Orbit00119_ST20190408-204530_ET20190408-222035_CT20201208-205936.nc



TROPICS L1 QC Approach



- **Quality control tries to identify data product variables:**
 - **With questionable integrity for end users to vet**
 - **With similar environment or conditions (e.g., over ocean)**
- **First QC mechanism is to replace unrealistic values with fill values using simple threshold comparisons (e.g., -999)**
- **Second QC mechanism is quality flags:**
 - **Identify conditions (e.g., diurnal)**
 - **Calibrations with less than nominal conditions (e.g., partial lunar intrusion)**
 - **Out-of-family instrument performance (e.g., high NEDT)**



L1 Quality Flags



Bit 1 non-ocean flag: Checks if the spot's footprint is contains land or if it's off Earth. 0 is ocean and 1 is land or undefined. Will offer a separate variable named “Land Flag” with 0 is ocean, 1 is land, & 3 is undefined.

Bit 2 Lunar/solar intrusion flag: this bit will be set to 1 if the angle between any of the 20 cal. sector spots to the center of the moon/sun are less than the FWHM BW for each channel. 0 is no intrusion.

Bit 3 Maneuver flag: based on yaw, pitch, roll rate thresholds YP at 0.05 deg/sec and R at 2 deg/sec (because of normal solar panel optimization rolling)

Bit 4 Cold calibration consistency flag: this bit is a rollup of:

- whether there are less than six out of ten deep space radiometric spots; spots were removed as outliers when significantly outside orbital median
- NEDT is out-of-family; outliers were identified when significantly outside estimated orbital NEDT standard dev.



L1 Quality Flags



Bit 5 Hot calibration consistency flag: this bit is a rollup of

- Noise diode radiometric counts are out-of-family
- NEDT is out-of-family
- Estimated Noise Diode temperature is out-of-family

Bit 6 Ascending/Descending flag: 0 indicates position in the orbit is ascending and 1 is descending part of the orbit

Bit 7 Day or night flag: 0 indicates the spot/footprint is illuminated by the sun and 1 indicates the spot is not illuminated by the sun

Bit 8 Payload orientation in flight path: 0 indicates the payload is in front of the flight path and 1 indicates payload is in the rear or aft of flight path

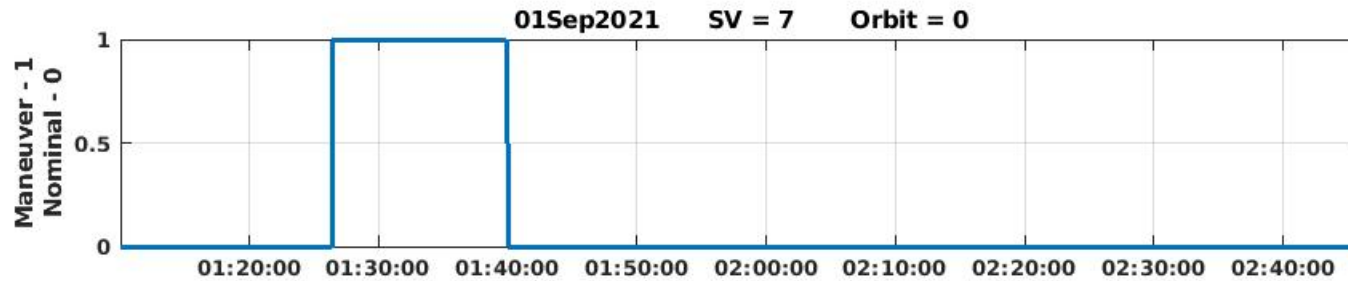
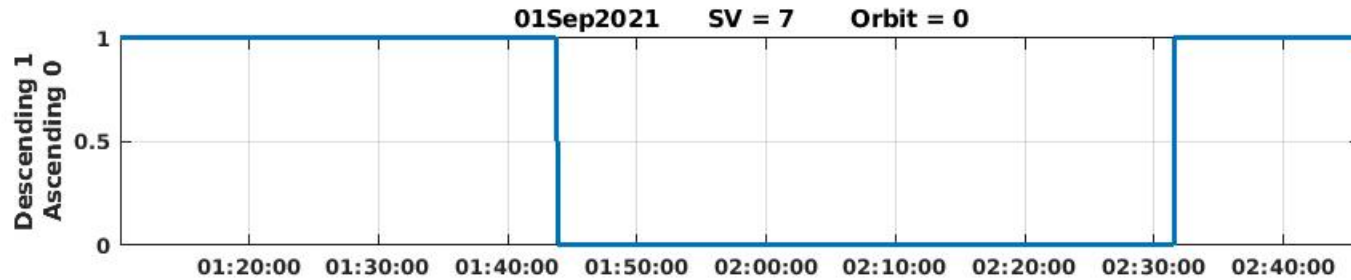
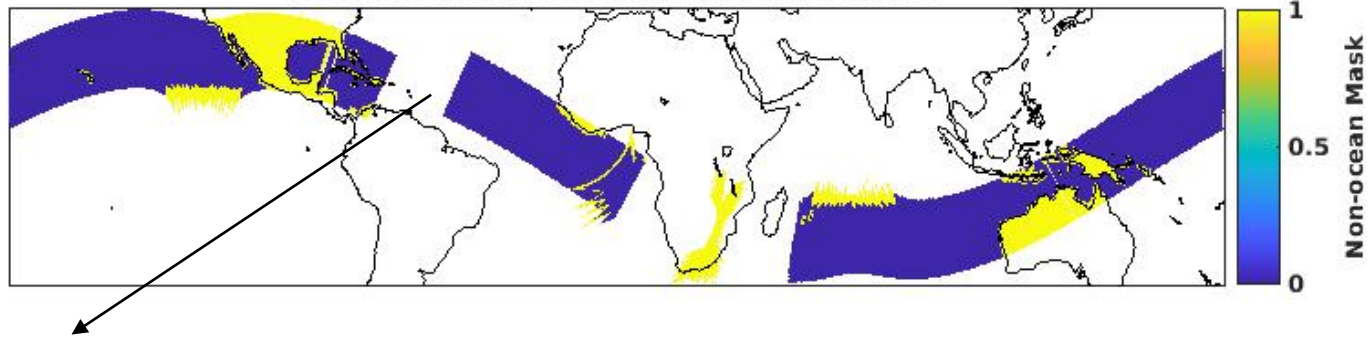
Binary Flags $N_{spot} \times N_{scan} \times N_{chan}$ (uint8 or 8 bits):



Simulated Orbit



TROPICS SV-7 Orbit = 0
20210901-011000 to 20210901-024600



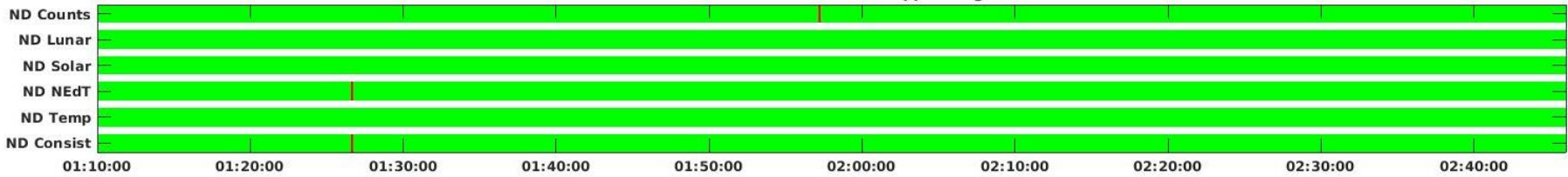


Quality Flag Quicklooks

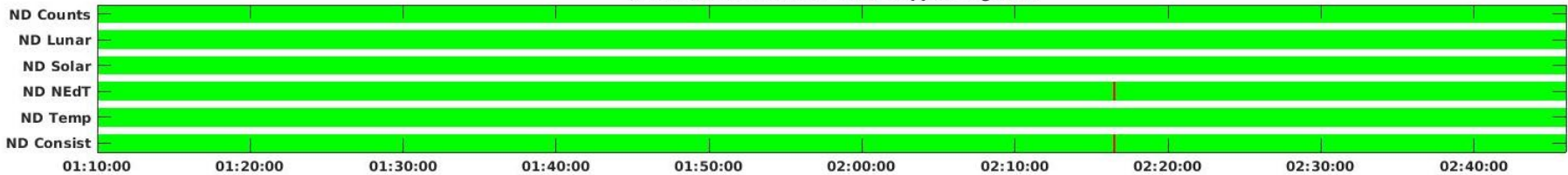


01Sep2021 SV = 7 Orbit = 0

CH 9 (G1) 184.41 GHz Total tripped flags = 1

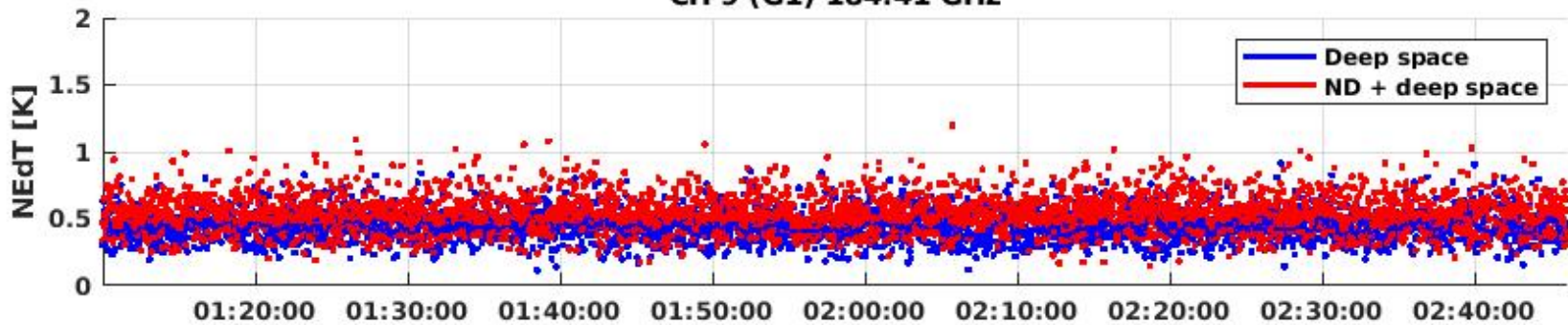


CH 10 (G2) 186.51 GHz Total tripped flags = 3



01Sep2021 SV = 7 Orbit = 0

CH 9 (G1) 184.41 GHz



UTC HH:MM:SS



QC Discussion Points



- **Presently, the QFs do not generate a fill value**
 - **User will have to monitor for both and decide on their own risk tolerance/posture.**
 - **Future updates to the User manual will clearly explain our approach**
- **Our L2 proxy dataset (HNR) was an ideal simulation without real world issues (e.g., single-event upsets)**
 - **We'll remake the HNR L1b with:**
 - Random fill values and QF settings**
 - Updated netCDF contents**



Backup



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WJ, Blackwell, Braun, S, Bennartz, R, et al. **An overview of the TROPICS NASA Earth Venture Mission.** Q J R Meteorol Soc. 2018; 144 (Suppl. 1): 16– 26. <https://doi.org/10.1002/qj.3290>

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Herndon, Derrick; Velden, C.; Bennartz, R. and Li, Z. **Tropical cyclone intensity estimation from the TROPICS CubeSat satellite constellation. Conference on Hurricanes and Tropical Meteorology, 33rd, Ponte Vedra, FL, 16-20 April 2018.** American Meteorological Society, Boston, MA, 2018, Abstract 11D.4.

Demuth, J., M. DeMaria, and J.A. Knaff, 2006: **“Improvement of advanced microwave sounder unit tropical cyclone intensity and size estimation algorithms,”** J. Appl. Meteor., 45, 1573–1581.

Kidd, C. T. Matsui, J. Chern, K. Mohr, C. Kummerow, and D. Randall (2016): **“Global precipitation estimates from cross-track passive microwave observations using a physically-based retrieval scheme.”** Journal of Hydrometeorology, 17, 383–400. <http://dx.doi.org/10.1175/JHM-D-15-0051.1>.



L1 & L2a Filename Nomenclature



TROPICS_L<DP_ID>_SV<SV_ID>_Orbit<Orbit#>_ST<YYYYMMDD-HHmmSS>_ET<YYYYMMDD-HHmmSS>_CT<YYYYMMDD-HHmmSS>.nc

<DP_ID> represents one of the three radiance data products: 1A are the antenna temperature, 1B are the brightness temperatures, and 2A are the unified G-band radiances.

<SV_ID> represents one of the six satellites in the TROPICS constellation (01→06)

<Orbit#> represents the orbit number since released from the launch vehicle. It will range from 00000 to 99999 (~ 18 years worth).

<YYYYMMDD-HHmmSS> represents 20180201-080122 or February 2, 2018 08:01:22 AM. These times refers to either the start time (ST), end time (ET), or creation time (CT) of the science data packets (or file).

The TROPICS granule, i.e., duration of the file, will be an entire orbit, which an orbit is defined as the maximum latitude to max. latitude.



Band	TROPICS Nadir Resolution (km)	MWHS-2 Nadir Resolution (km)	ATMS Nadir Resolution (km)	TROPICS ½ way to edge Resolution (km)	MWHS-2 ½ way to edge Resoluti on (km)	ATMS ½ way to edge Resolutio n (km)
	DT/CT	DT/CT	DT/CT	DT/CT	DT/CT	DT/CT
W-band (90 GHz)	27.2/28.9	29.2/31.2	15.8/19.8	31.8/40.4	32.5/39.3	17.9/25.8
F- or V-band 118 or 50 GHz (AVTP)	23.0/25.2	29.2/31.2	31.6/33.6	27.0/35.1	32.5/39.3	35.8/43.7
G-band 183 GHz (AVMP)	14.4/17.9	16.1/20.0	15.8/19.8	16.9/25.0	17.9/25.2	17.9/25.8

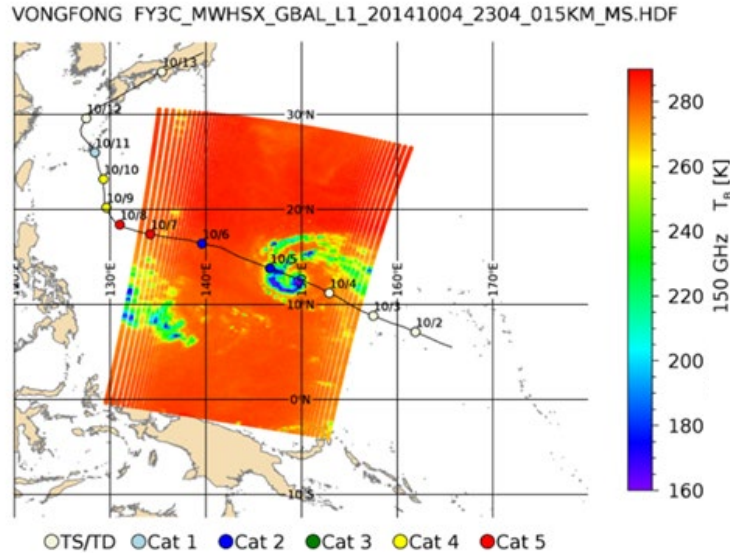
DT = Down-track or along satellite track

CT = Cross-track or along the direction of the scan

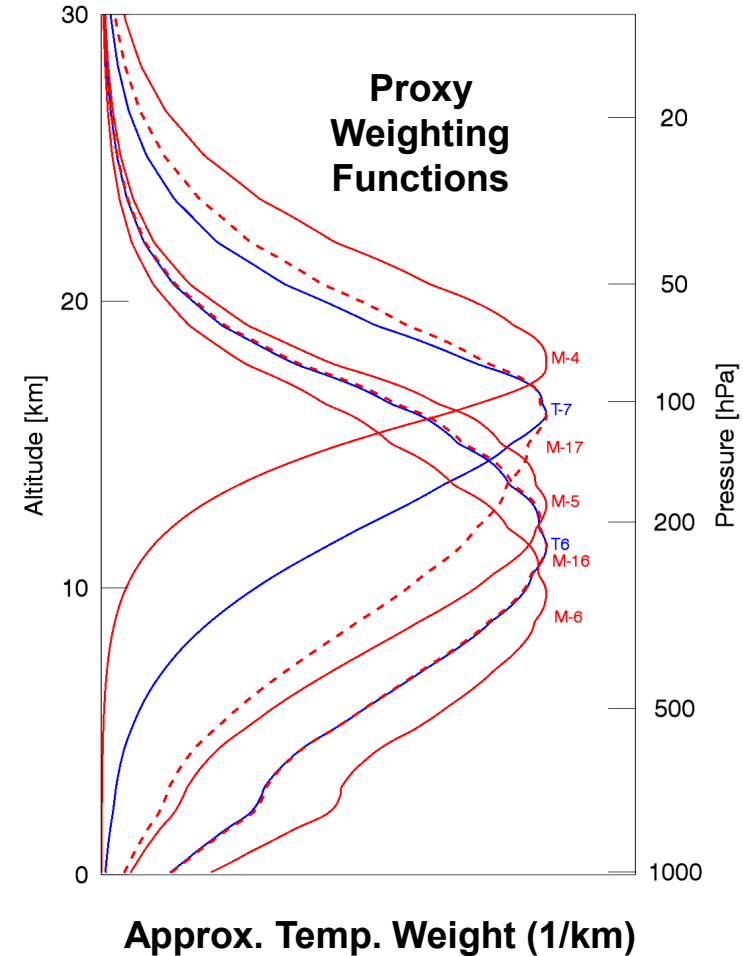
MWHS-2 & ATMS nadir cross-track sampling interval is 16 km, while TROPICS is 14.4 km



FY-3C/MWHS-2 Proxy Data Set



- **TC Intensity F-band channels:**
 - TROPICS 6 = (CH5+CH6)/2 of MWHS-2.
 - TROPICS 7 = (CH4+CH5)/2 of MWHS-2.
- **WV channels:**
 - TROPICS 11 uses MWHS 15
 - TROPICS 10 uses MWHS 14
 - TROPICS 9 uses MWHS 11





TROPICS Channel Set

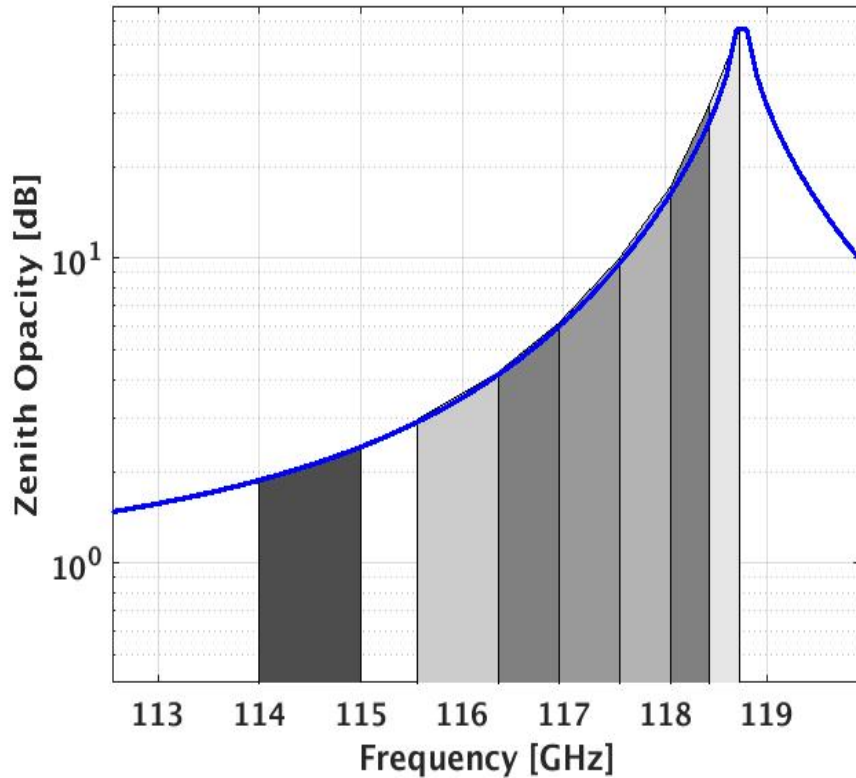


TROPICS Chan.	Center Freq. (GHz)	Bandwidth (GHz)	RF Span (GHz)	Beamwidth (degrees) Down/Cross	Nadir Footprint Geometric Mean (km)*	Expected NEdT (K)
1	91.656 ± 1.4	1.000	89.756-90.756, 92.556-93.556	3.0/3.17	29.6	0.67
2	114.50	1.000	114.00-115.00	2.4/2.62	24.1	1.03
3	115.95	0.800	115.55-116.35	2.4/2.62	24.1	0.90
4	116.65	0.600	116.35-116.95	2.4/2.62	24.1	1.12
5	117.25	0.600	116.95-117.55	2.4/2.62	24.1	1.03
6	117.80	0.500	117.55-118.05	2.4/2.62	24.1	1.03
7	118.24	0.380	118.05-118.43	2.4/2.62	24.1	1.12
8	118.58	0.300	118.43-118.73	2.4/2.62	24.1	1.12
9	184.41	2.000	183.41-185.41	1.5/1.87	16.1	0.78
10	186.51	2.000	185.51-187.51	1.5/1.87	16.1	0.78
11	190.31	2.000	189.31-191.31	1.5/1.87	16.1	0.71
12	204.8	2.000	203.8-205.8	1.45/1.83	15.6	0.78

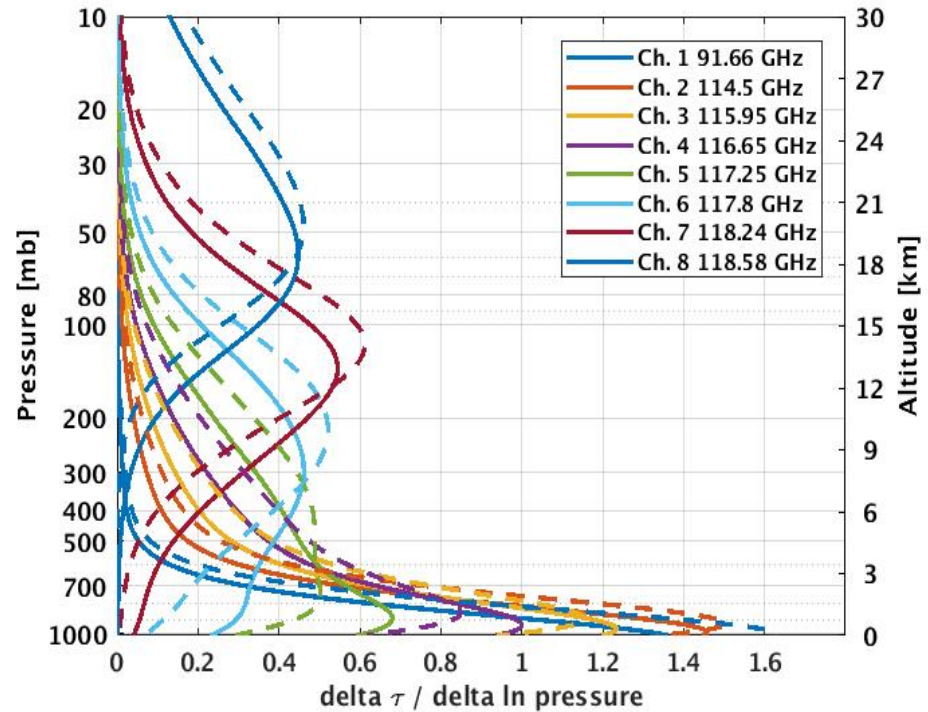
WJ, Blackwell, Braun, S, Bennartz, R, et al. An overview of the TROPICS NASA Earth Venture Mission. *Q J R Meteorol Soc.* 2018; 144 (Suppl. 1): 16– 26. <https://doi.org/10.1002/qj.3290>



TROPICS W/F-band Temperature Weighting Functions



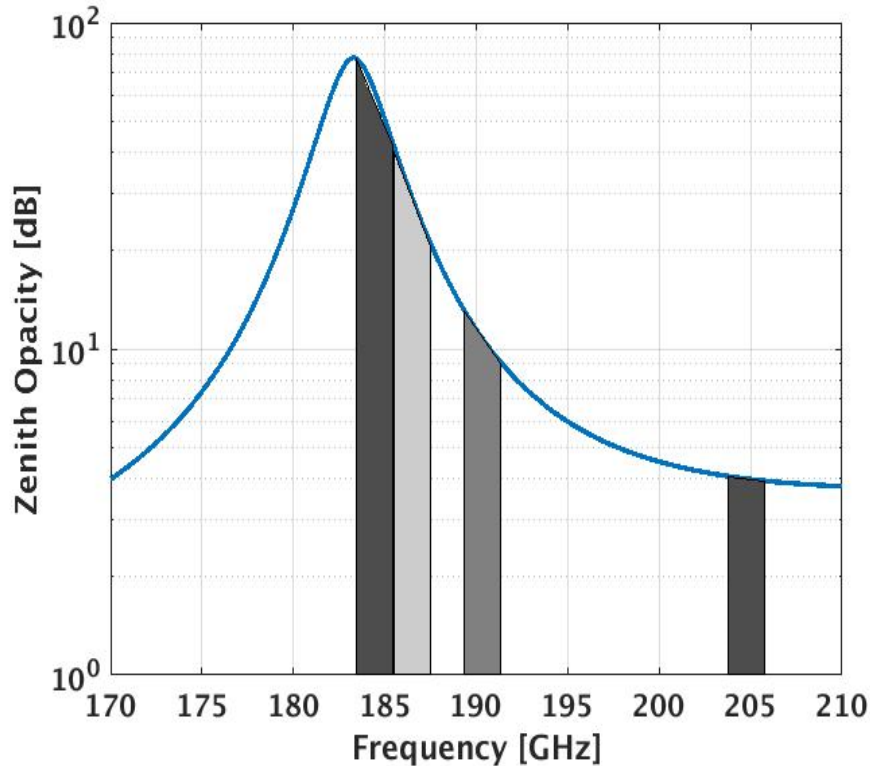
TROPICS



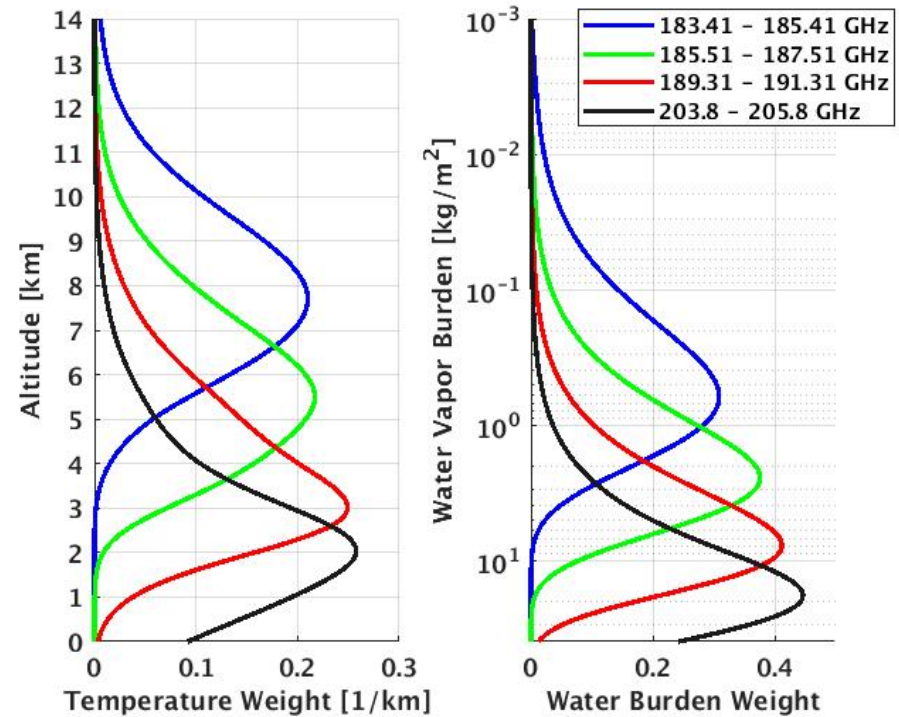
Solid are nadir and dashed are 50°
US 1976 Tropical Standard Atmosphere



TROPICS G-band Weighting Functions



TROPICS



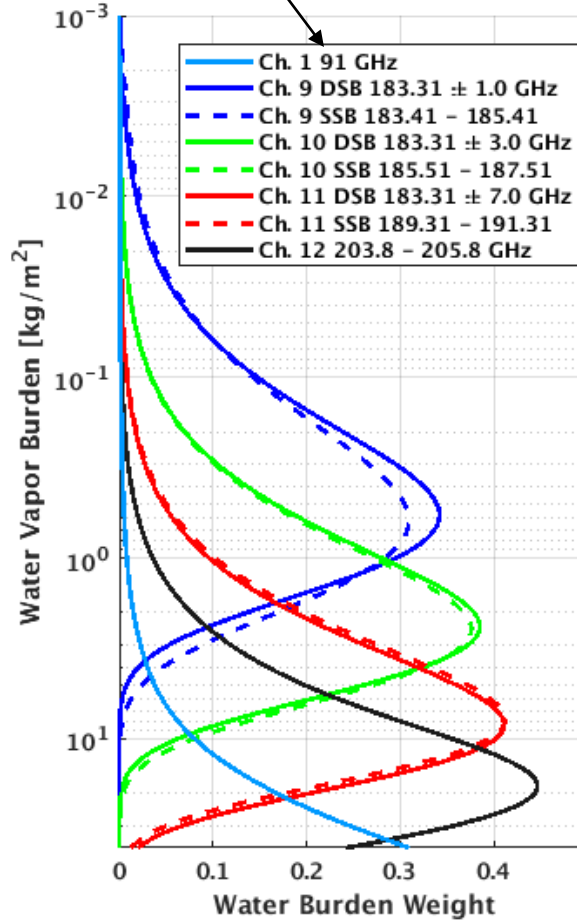
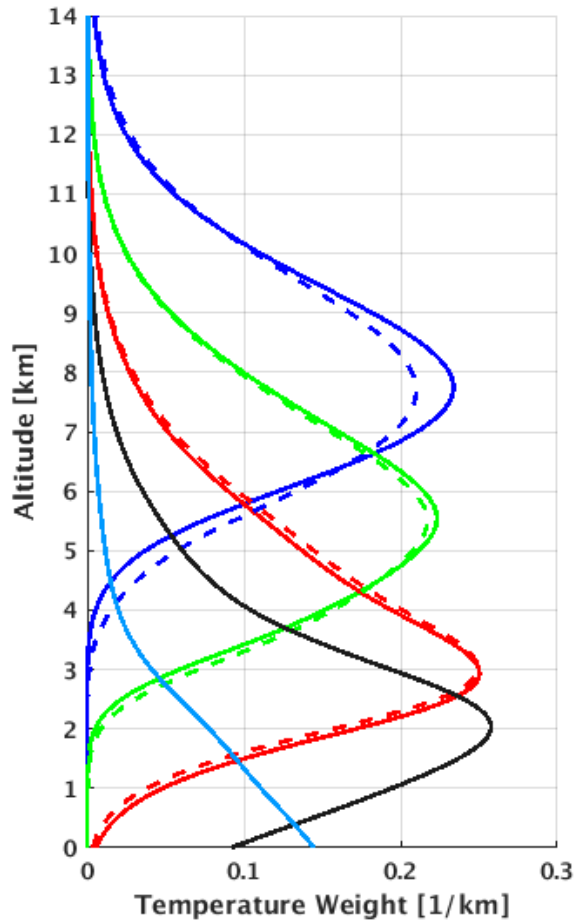
Nadir angle
US 1976 Tropical Standard Atmosphere



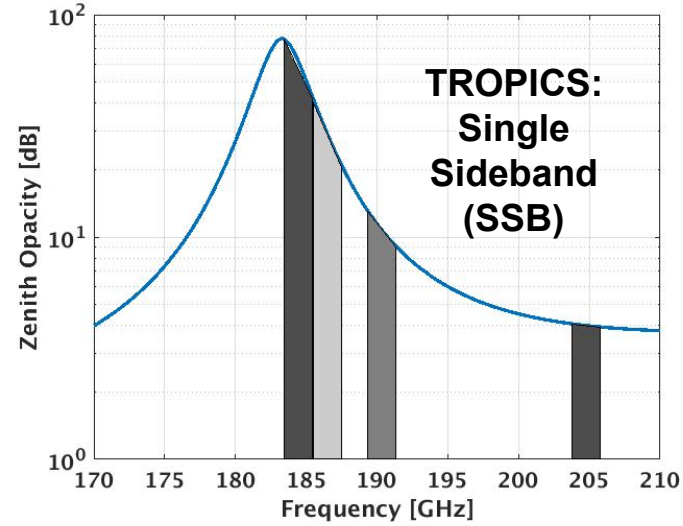
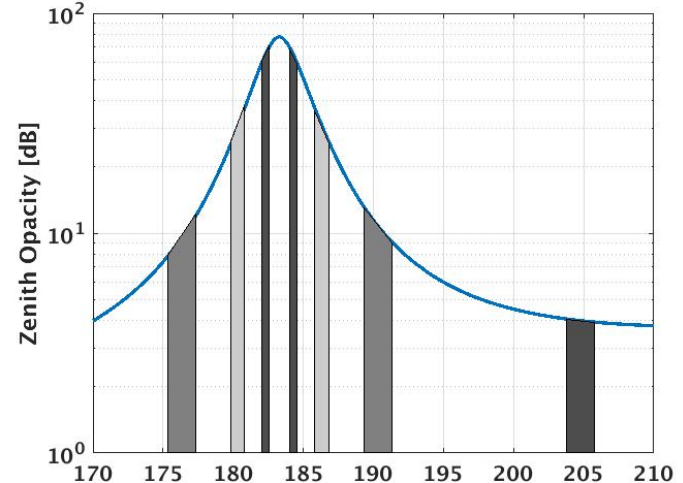
G-band: Converting to Heritage Sensors



Mapping between TROPICS and Heritage



Heritage: Double Sideband (DSB)





TROPICS Scan Profile



Characteristic	Units	Value
Rotation Period	Sec.	2
Maximum Earth View Sector Angle	Degrees	± 60
Scan Type	N/A	Constant velocity (scanning during integration)
Integration time	Seconds	1/120
Number of Earth View Sector Measurements	N/A	81 per scan (one at nadir) at 1.5 deg. separation
Altitude	Km	500-600

