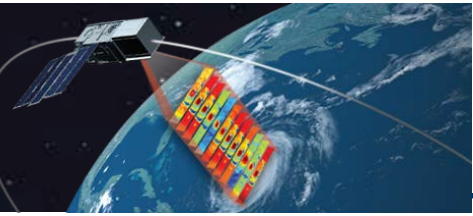


HNR Proxy Data Release

TROPICS Quarterly Applications Call

TROPICS Science Team

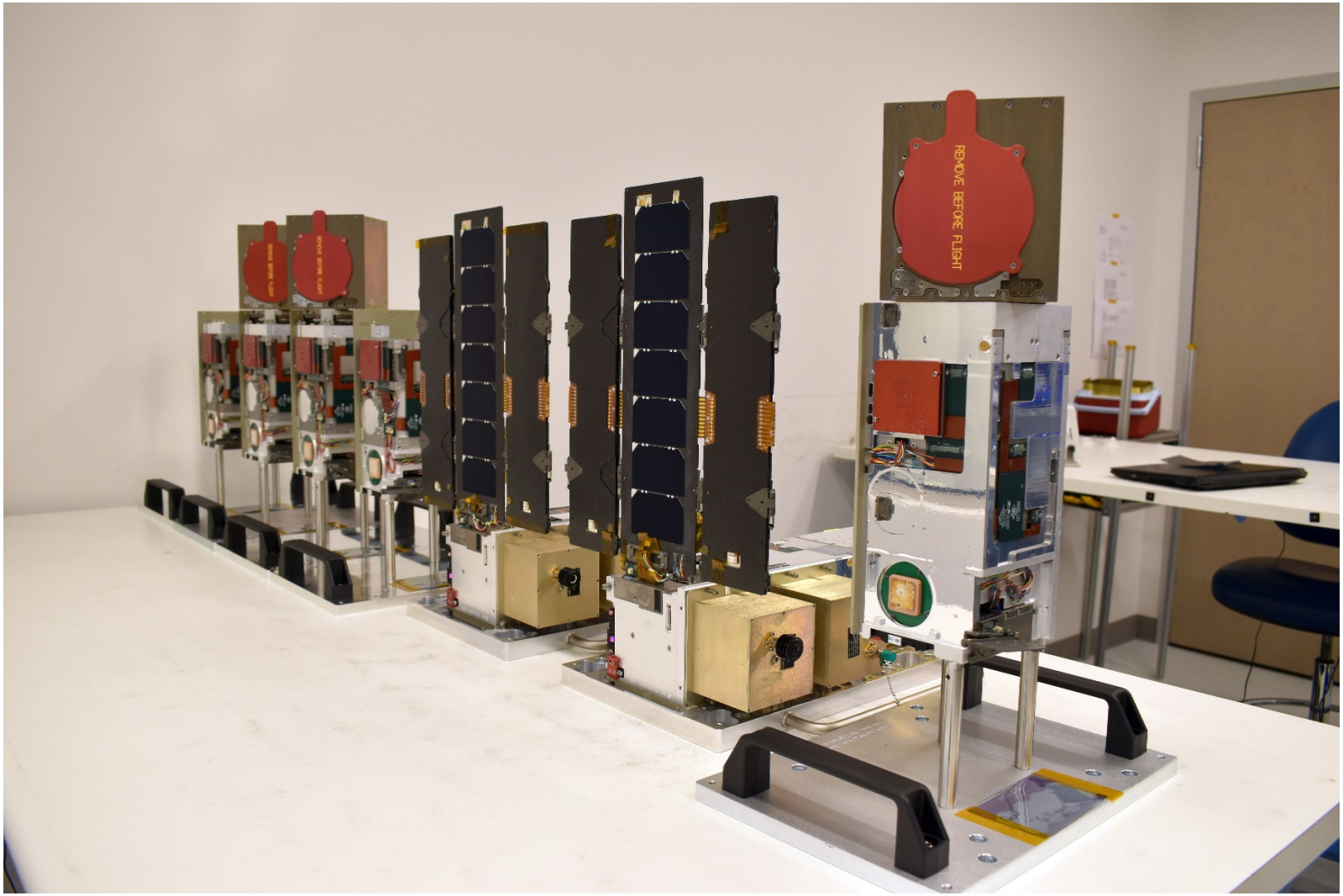
23 October 2019

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Outline

- **TROPICS Payload Characterization**
- **TROPICS Data Products**
- **TROPICS Proxy Data Status**
- **CRTM Coefficient Update**
- **Data Logistics**

TROPICS Space Vehicle Family Photo

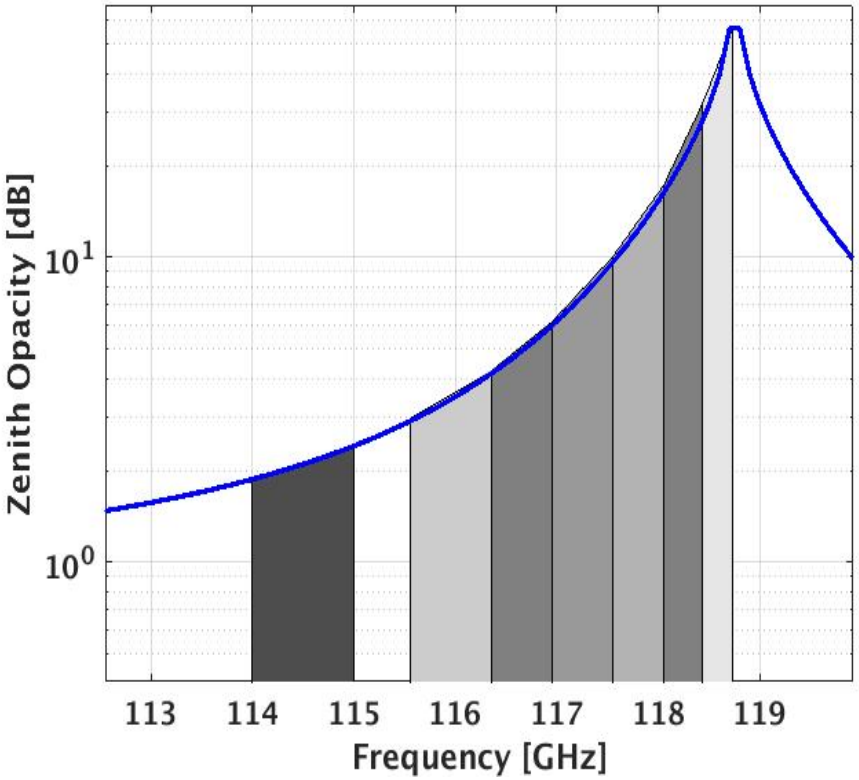


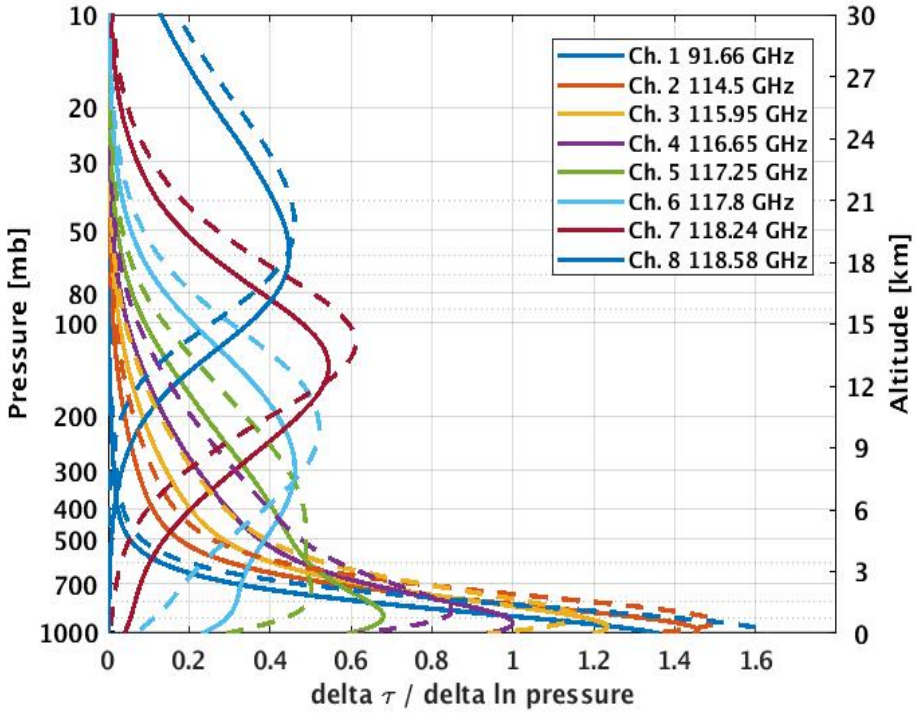
TROPICS Channel Set

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

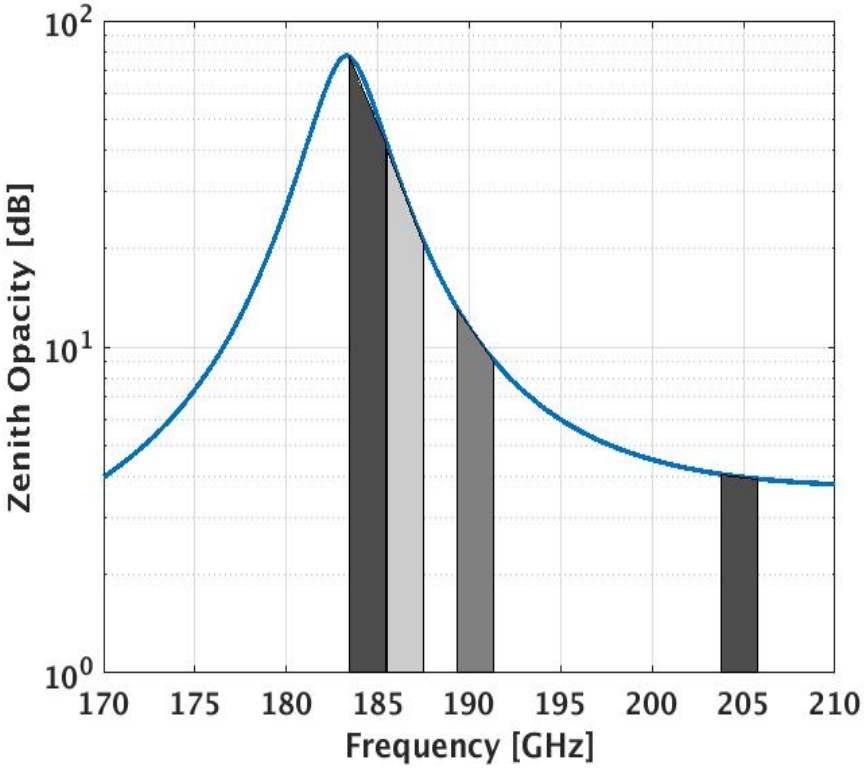




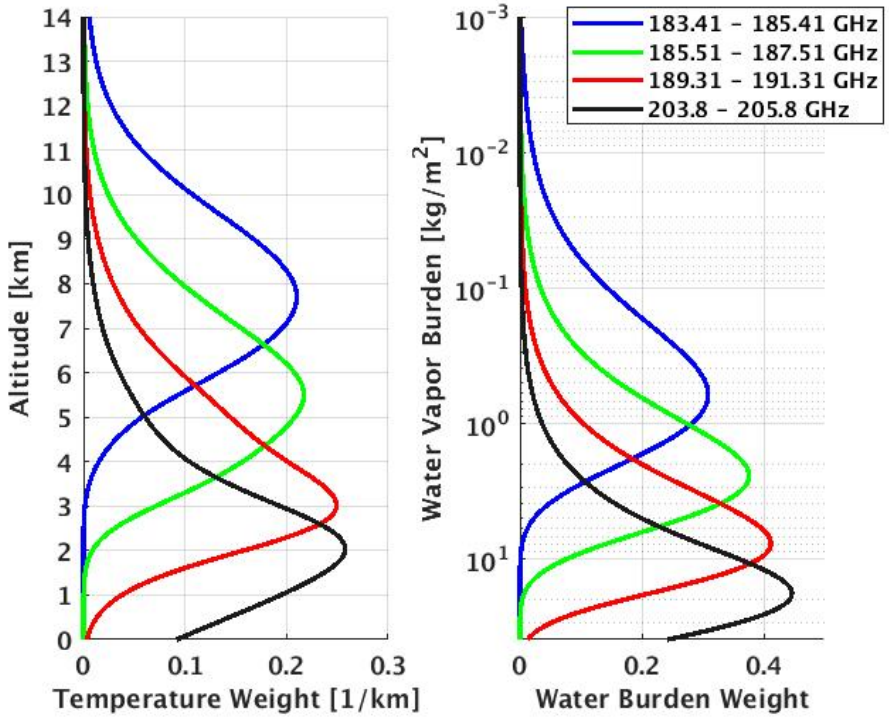
Solid are nadir and dashed are 50°
US 1976 Tropical Standard Atmosphere

TROPICS

TROPICS G-band Weighting Functions



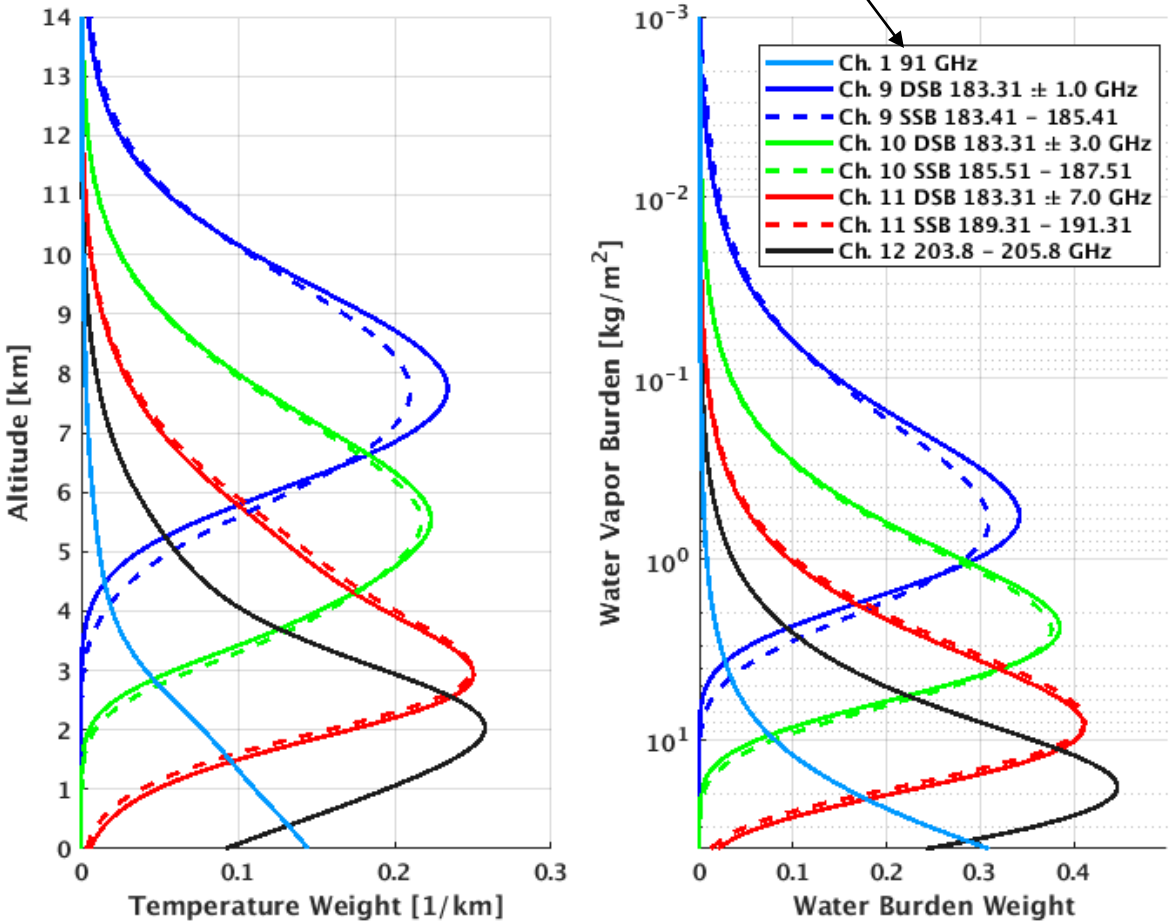
TROPICS



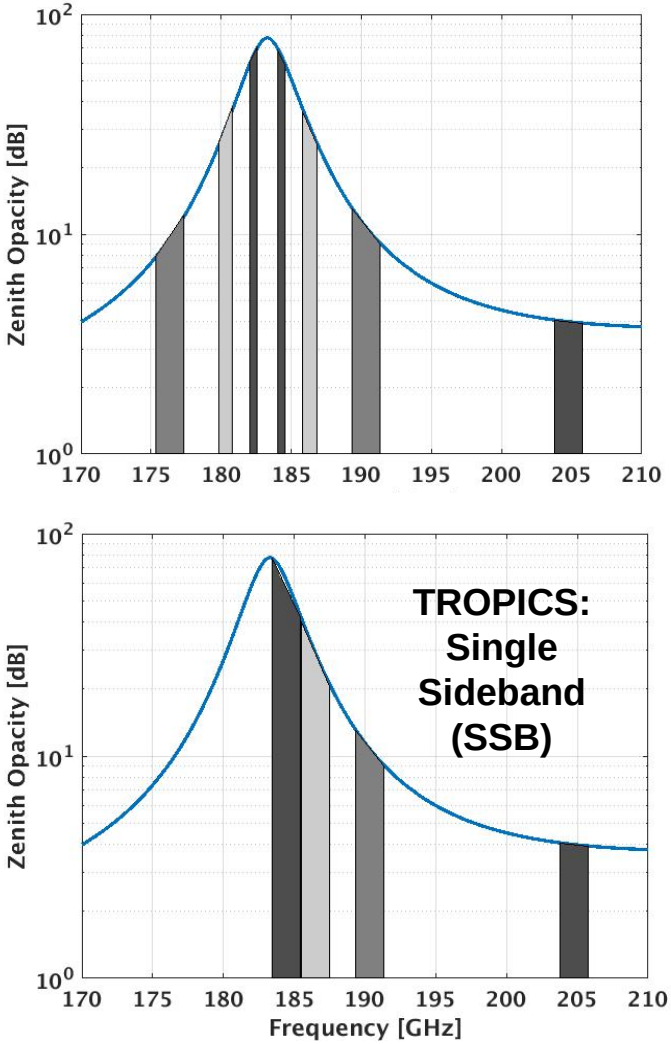
Nadir angle
US 1976 Tropical Standard Atmosphere

G-band: Converting to Heritage Sensors

Mapping between TROPICS and Heritage



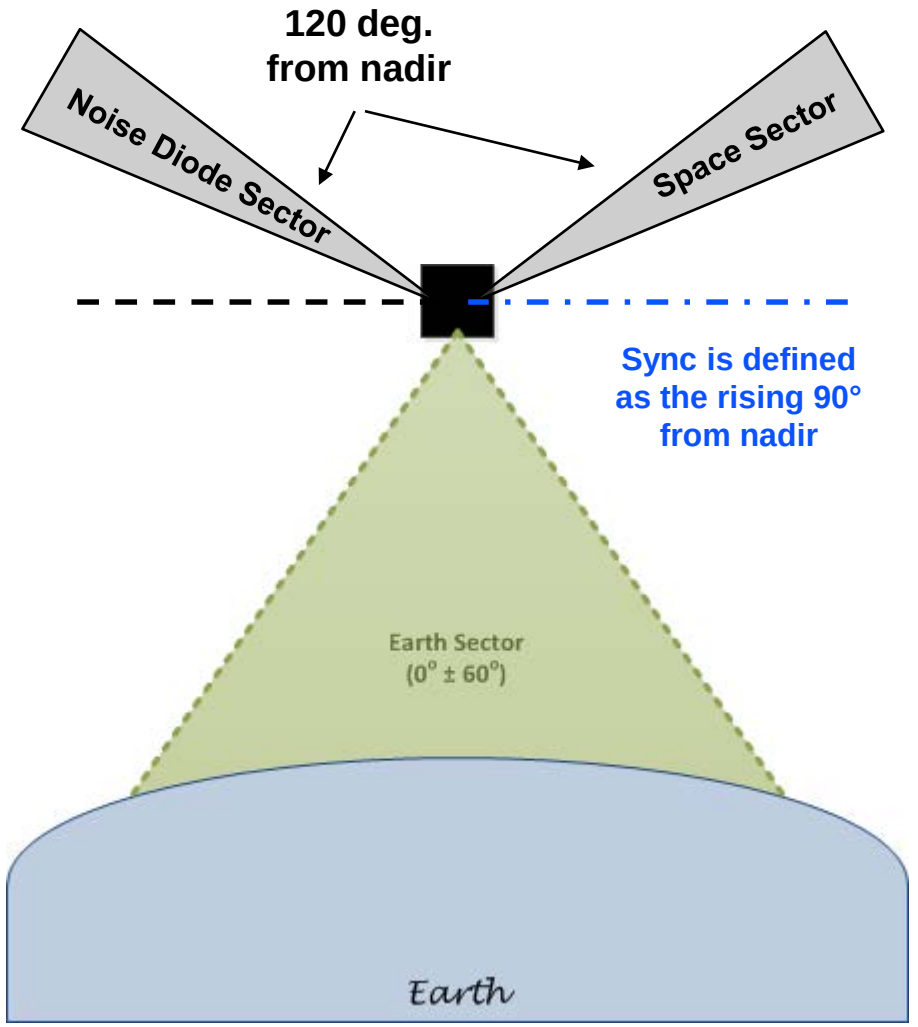
Heritage: Double Sideband (DSB)



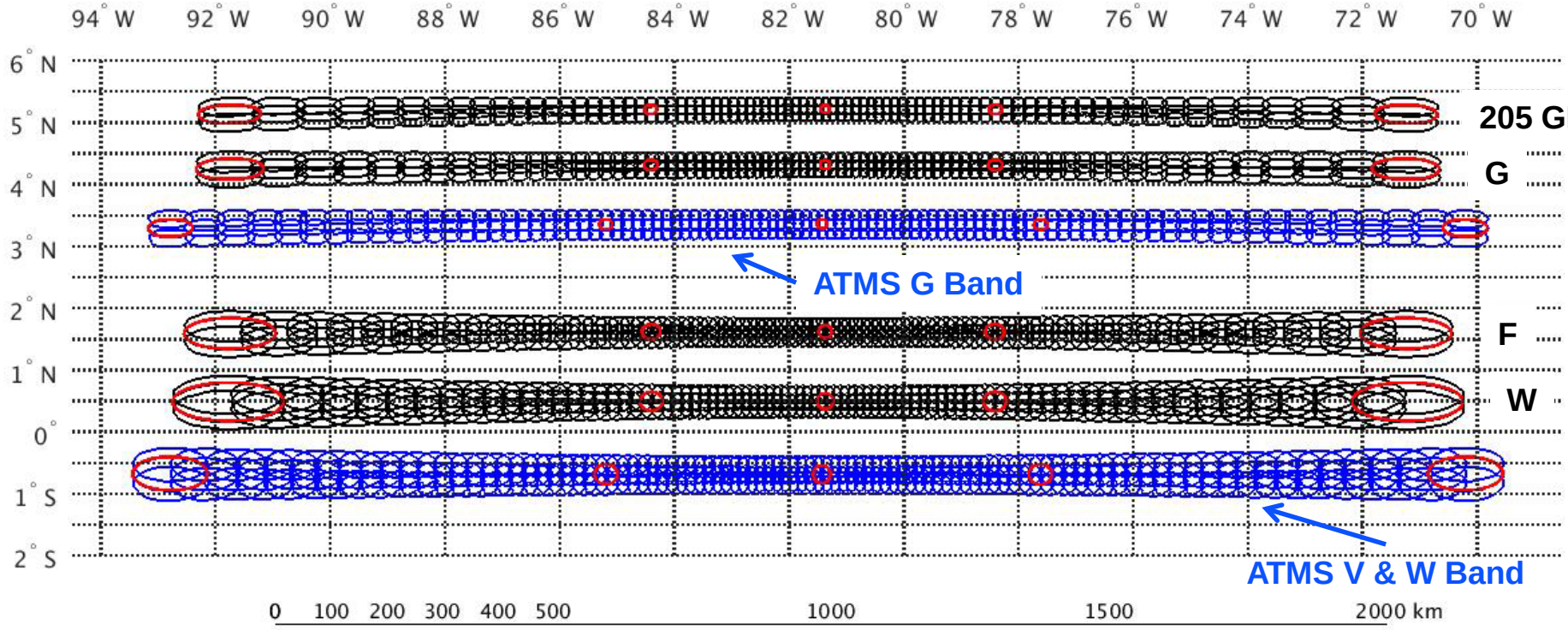
US Standard Tropical 1976

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

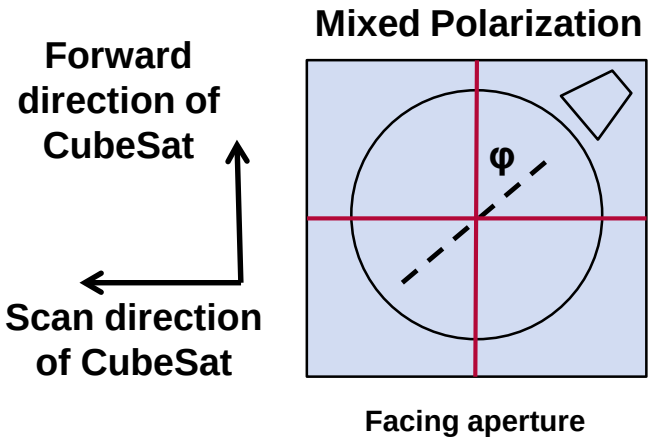


TROPICS Swath



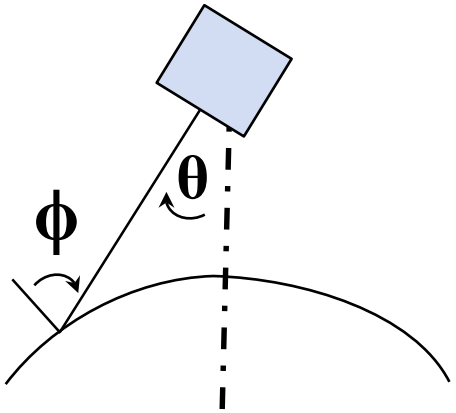
TROPICS Altitude = 550 km

TROPICS Polarization



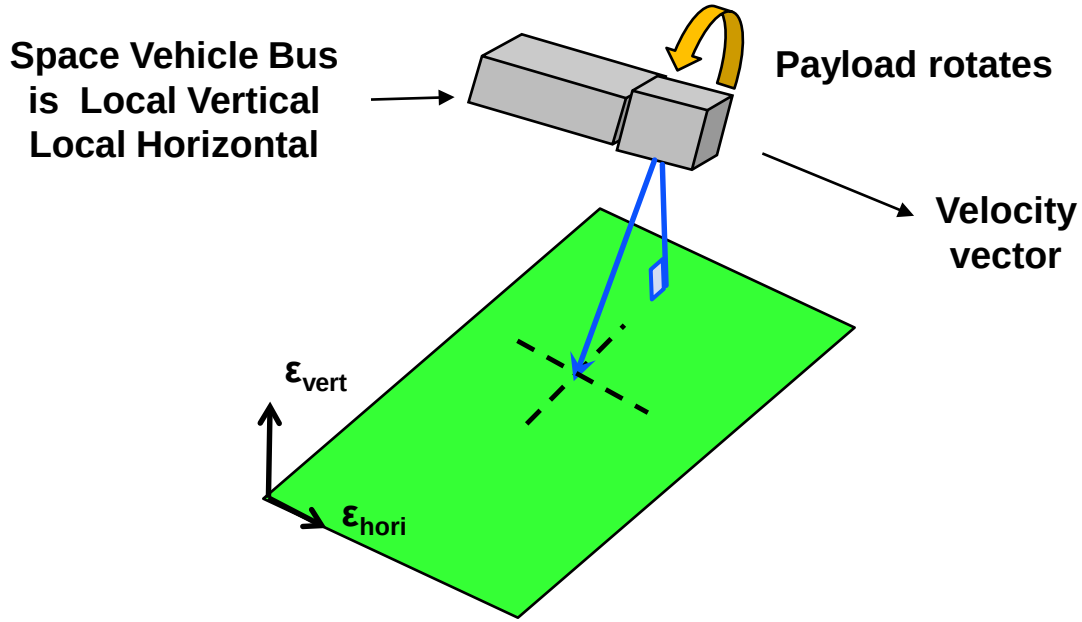
$$T_b = T_b^{hori} * cos^2(\varphi) + T_b^{vert} * sin^2(\varphi)$$

φ = fixed angle of feed horn polarization (not scan angle or zenith angle) -20 deg. for G-band and 70 deg. for W/F-band

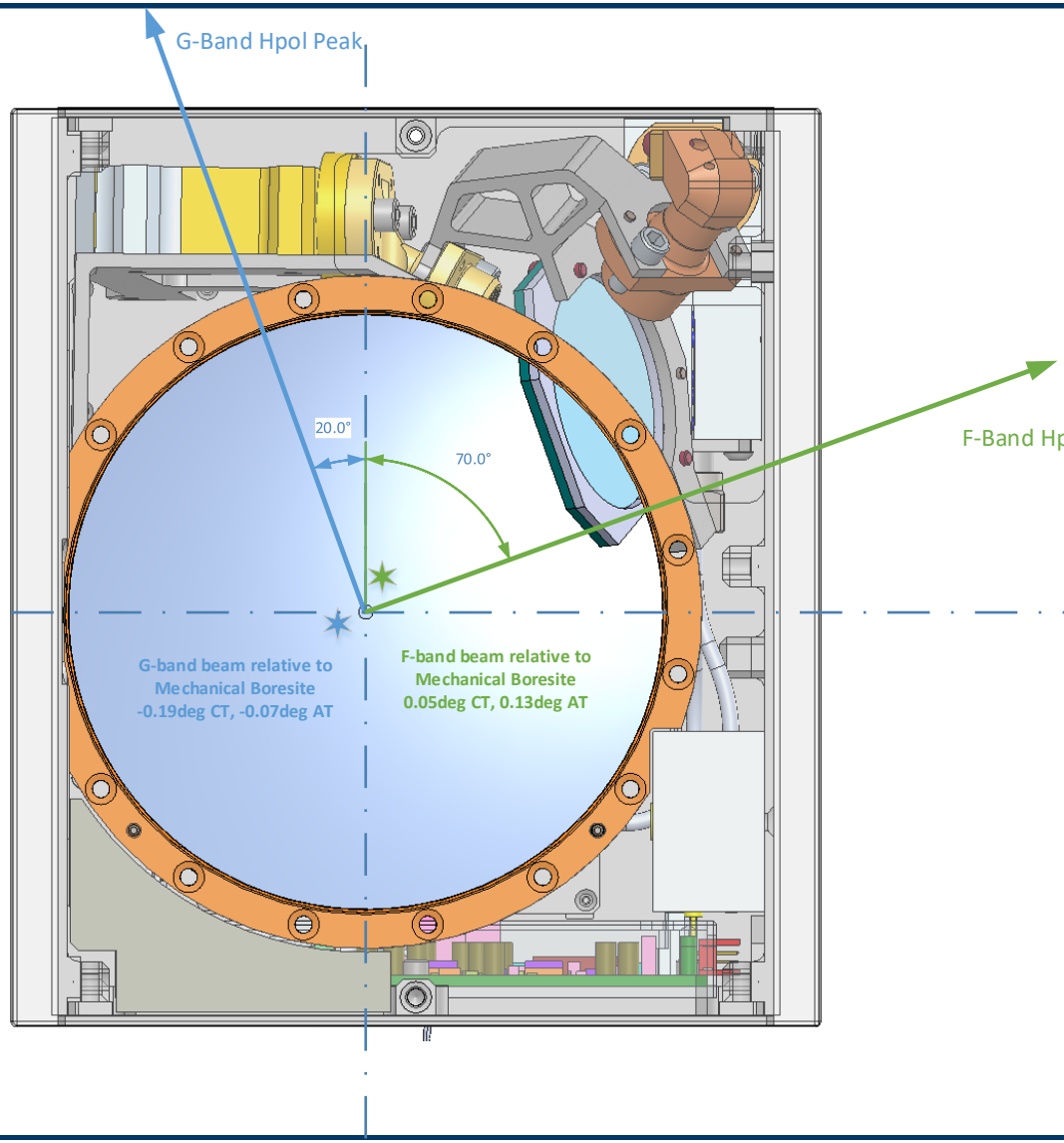


θ = sensor scan angle

ϕ = sensor zenith angle

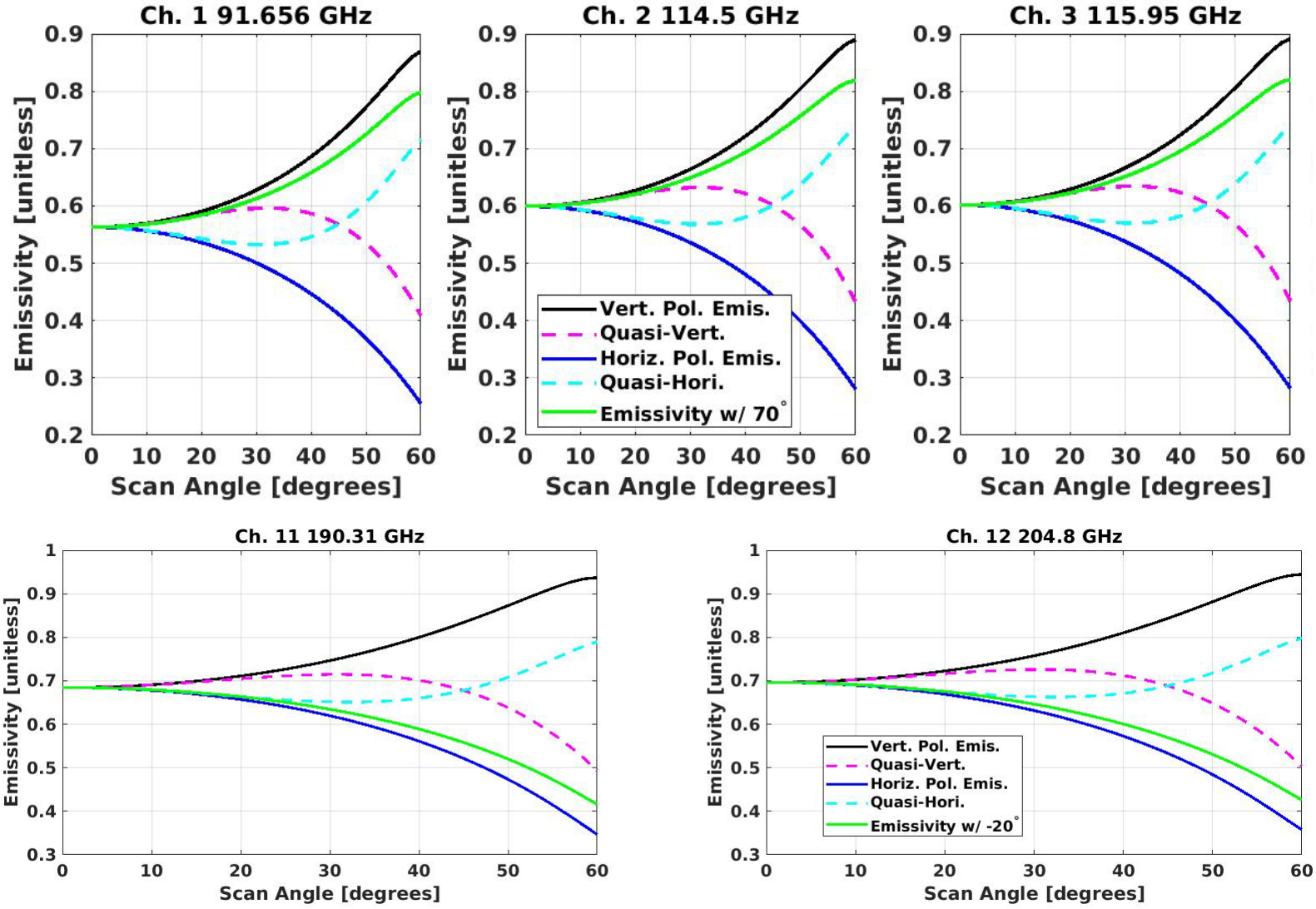


Beam Pointing and Polarization



- **Polarization angle was not at 45º**
  - **G-band: -20º**
  - **W/F-band: 70º**
- **CRTM doesn't have a polarization scheme for these angles ("as designed" uses 45º)**
- **Working with NOAA on how to incorporate into CRTM**
- **Beam pointing looks really good**

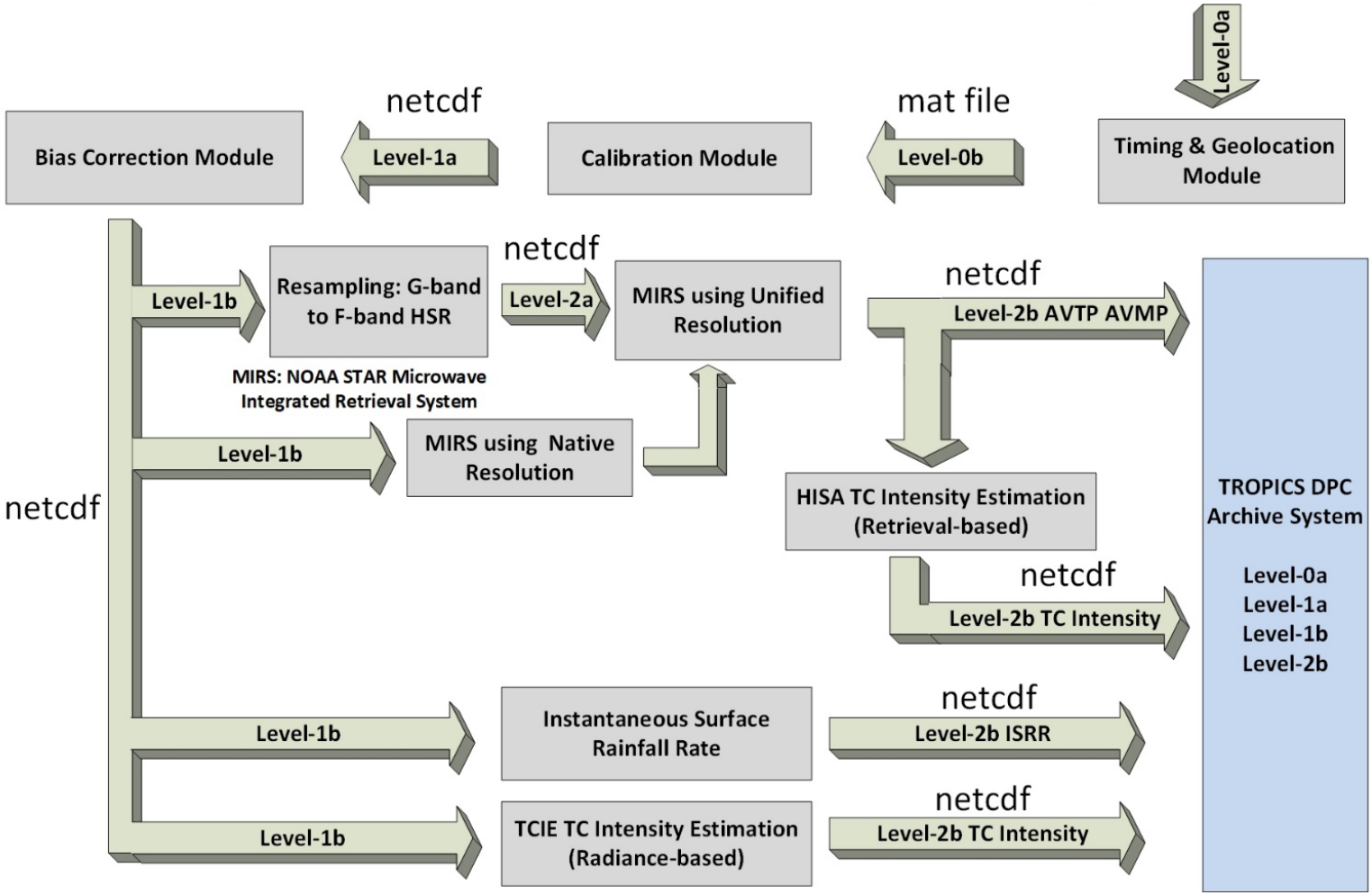
Surface Emissivity Based on Measurements



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 & Nick Zorn (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)
Level 2b – **MIRS**	Atmospheric Vertical Temperature Profile [Kelvin]	Tom Greenwald (UWisc-Madison) & Ralf Bennartz
Level 2b – **MIRS**	Atmospheric Vertical Moisture Profile [g/kg]	Tom Greenwald & Ralf Bennartz
Level 2b – **GPROF**	Instantaneous Surface Rain Rate [mm/hr]	Toshihisa Matsui & Chris Kidd
Level 2b	TC Intensity: Minimum Sea-Level Pressure [mb]	A) Derrick Herndon & Chris Velden (UWisc-Madison) B) Galina Chirokova (CSU/CIRA) & Mark DeMaria (NHC)
Level 2b – **TCIE & HISA**	TC Intensity: Maximum Sustained Wind [m/s]	A) Derrick Herndon & Chris Velden B) Galina Chirokova & Mark DeMaria

Data Processing Flow Chart



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.

Preliminary: Subject to Change

MIRS NetCDF4 Output Filenames

NetCDF4. The MIRS sounding products are written to the "SND" prefixed file, while surface and precipitation products are written to the "IMG" prefixed file. Table 29 displays the metadata header information contained within the SND and IMG files, while Table 30 and Table 31 display the contents of those files, respectively. The file naming convention follows:
NPR-MIRS-SND_vX_NPP_sYYYYMMDDHHMMSSS_eYYYYMMDDHHMMSSS_cYYYYMMDDHHMMSSS.nc and
NPR-MIRS-IMG_vX_satId_sYYYYMMDDHHMMSSS_eYYYYMMDDHHMMSSS_cYYYYMMDDHHMMSSS.nc

where:

vX - refers to the algorithm release or version number,

satId – refers to the satellite name (e.g. NPP), **Using TRP1-TRP6**

sYYYYMMDDHHMMSSS – refers to the granule or orbit start time year, month, day, hour, minute, second, and tenths of second,

eYYYYMMDDHHMMSSS – refers to the granule or orbit end time year, month, day, hour, minute, second, and tenths of second,

cYYYYMMDDHHMMSSS – refers to the MIRS output file creation time year, month, day, hour, minute, second, and tenths of second.

Two Types of L1 Proxy Data Sets

A) Simulated HNR

- Hurricane Nature Run 1 (Nolan et al.) – single Cat. 4 TC over life cycle
- Community Radiative Transfer Model (CRTM)
- Simulated TROPICS spec. (along with simulated ATMS spectral)
- Mean Revisit Rate simulated through orbital parameters
- Final releases will be in final data format for ground segment testing
- All algorithms will use this proxy data for performance & checkout

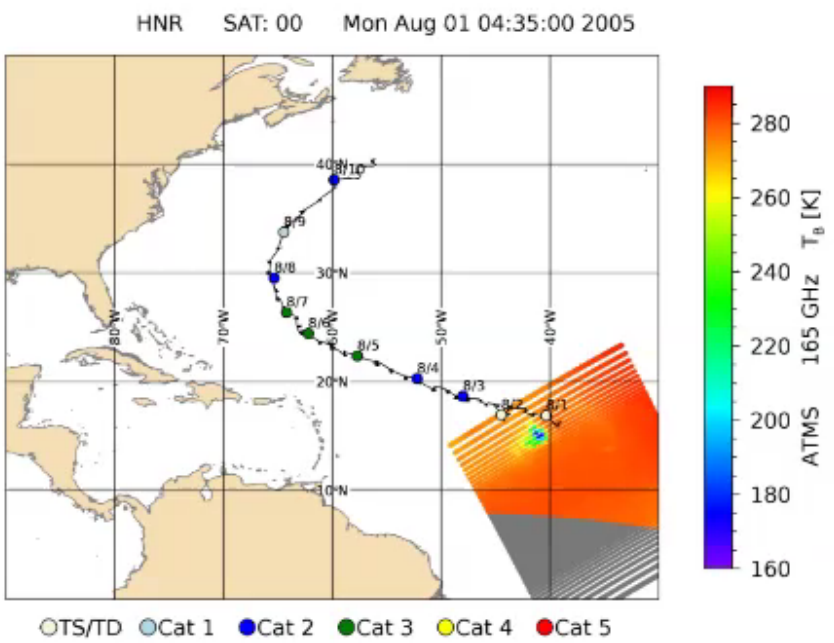
B) FY-3C MWHS-2

- Actual 118- & 183-GHz TC measurements
- FY-3C MWHS-2 specifications (e.g., Horiz. Spatial Res.)
- Can simulate TROPICS by differencing MWHS-2 channels
- ~900 Cat 1-5 TC global overpasses from 2013 to 2017 (have ATMS overpasses to compare)
- Matched overpasses with ATCF hurricane database
- Primarily for TC intensity performance (TCIE)

MWHS-2 is for performance only (not ground segment)

HNR Proxy Data Science

- **Numerical Weather Prediction Model Output:**
  - **Hurricane Nature Run 1 (see backup slide)**
  - **Single low Cat. 4 Multi-domain Atlantic**
- **Community Radiative Transfer Model (CRTM)**
- **Cross-track spatial sampling using idealized antenna pattern**
- **Idealized Spectral Response (i.e., boxcar channel set)**
- **Temporal Response: Orbital Parameters with intra-plane phasing**
- **Will provide all output (L1b to L2b)**



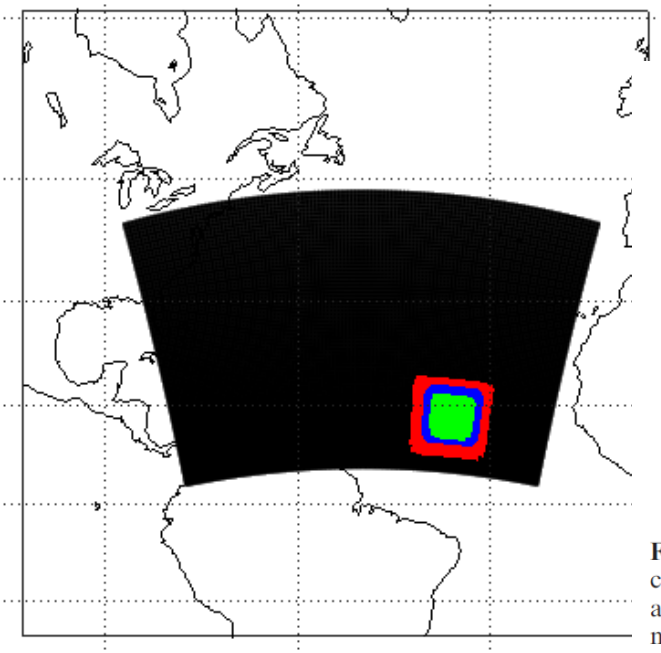
Hurricane WRF Nature Run 1

Black: D01 27-km Spacing (240 x 160 = 6000 km x 4000 km)

Red: D02 9-km Spacing (120 x 120 = 1044 km) Nested Grid

Blue: D03 3-km Spacing (240 x 240 = 700 km) Nested Grid

Green: D04 1-km Spacing (480 x 480 = 480 km) Nested Grid



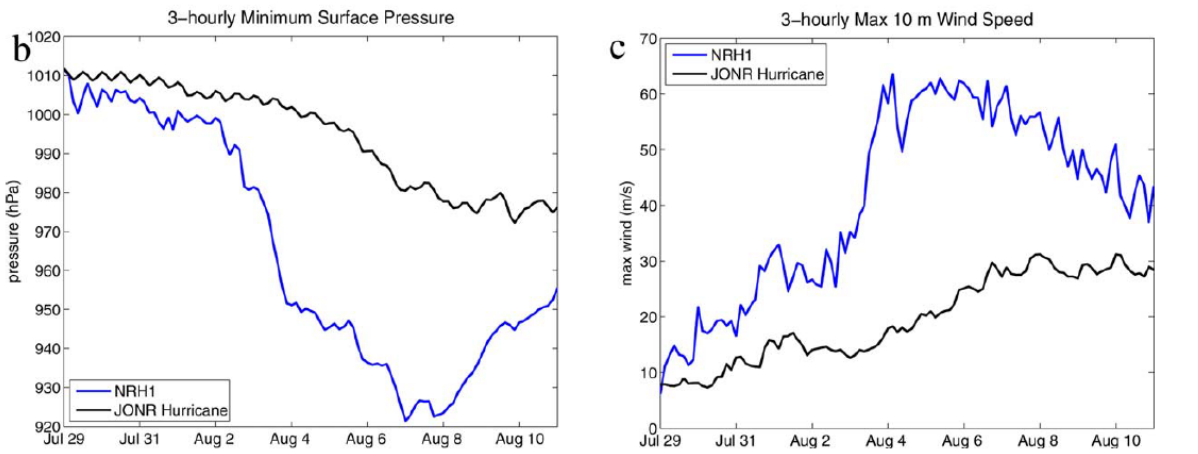
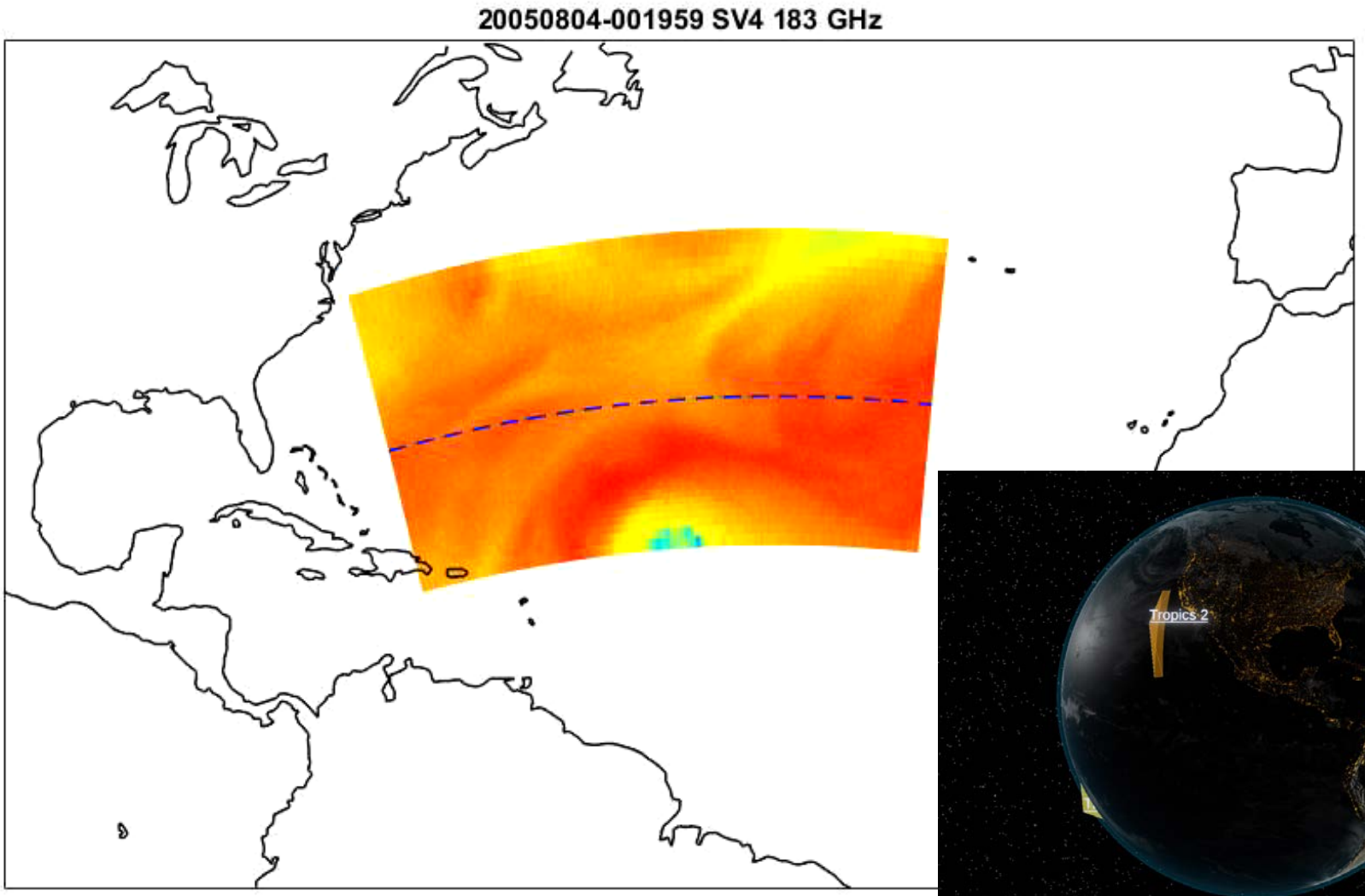


Figure 4. (a) Track, (b) minimum surface pressure, and (c) maximum surface (10 m) wind for the JONR hurricane and NRH1. Values are plotted every 3 h, and the data for the WRF nature run are from the 1 km grid, adjusted to 1 min means. Locations of the JONR hurricane corresponding to the dates shown are marked in magenta.

Rapid Hurricane Updates



HNR Proxy Release 4

- **Used the D02 nested grid that follows the hurricane (9-km grid) wherever it was available and D01 (27-km grid) for the outer parts, where there was no D02 data available (See Nolan 2013).**
- **Radiative transfer model: Community Radiative Transfer Model 2.2.3**
- **Cross-track spatial sampling used idealized Gaussian antenna pattern (see Blackwell 2018 Table 2 for beamwidths)**
- **Idealized spectral response (i.e., boxcar passbands; see Blackwell 2018 Table 2)**
- **Baseline TROPICS orbital configuration (see Blackwell 2018 Section 2)**
- **Output is in the TROPICS Level-1b netCDF data format in 5-10 min. chunks**

Nolan, D. S., R. Atlas, K. T. Bhatia, and L. R. Bucci (2013), "Development and validation of a hurricane nature run using the joint OSSE nature run and the WRF model," J. Adv. Model. Earth Syst., 5, 382–405, doi:10.1002/jame.20031.

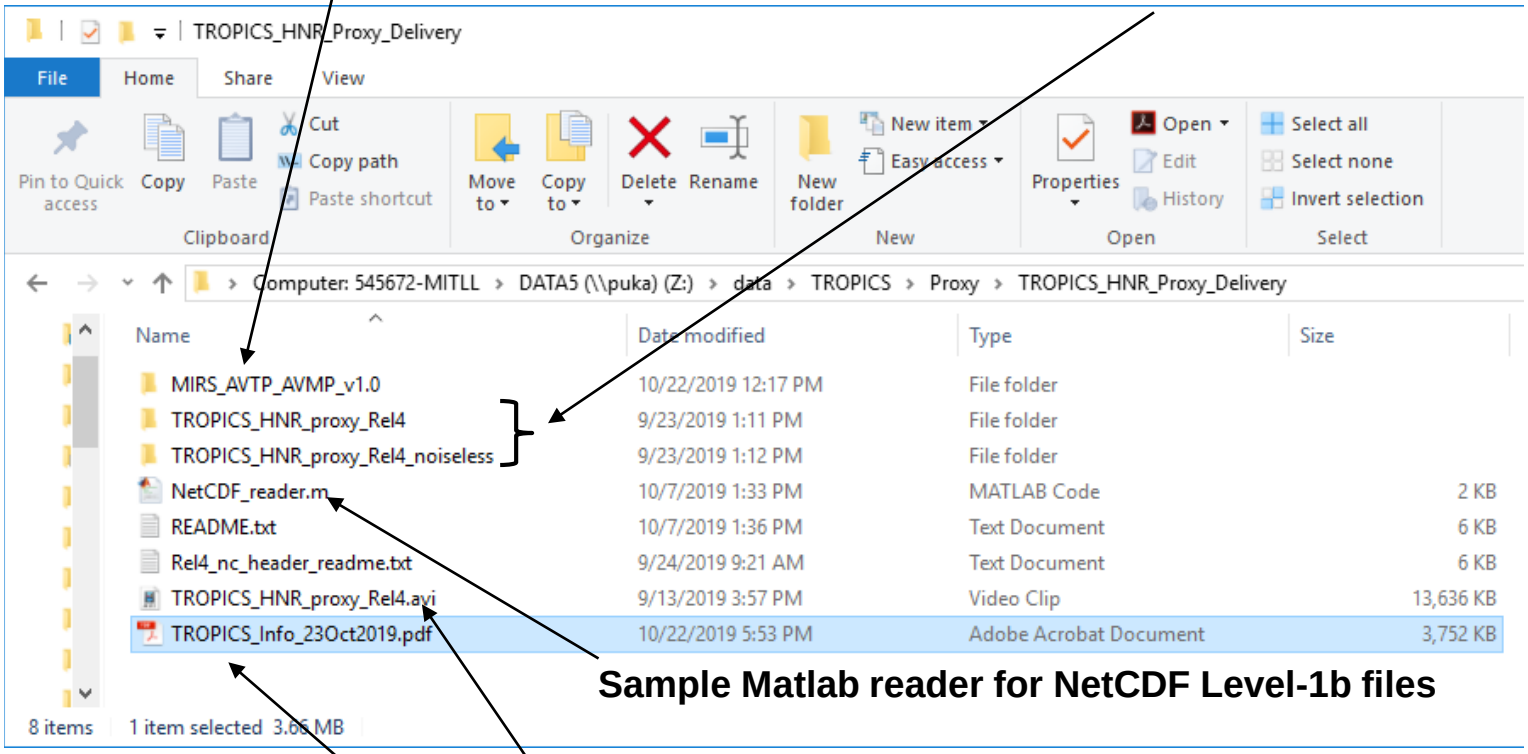
Community Radiative Transfer Model, Joint Center for Satellite Data Assimilation (JCSDA) Project, https://www.jcsda.org/jcsda-project-community-radiative-transfer-model

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

Zip File Contents

MIRS output (IMG & SND)

Level-1b Radiances



Sample Matlab reader for NetCDF Level-1b files

Movie of 183-GHz radiances

This Presentation

CRTM Status (1 of 2)

- **At this time, the only TROPICS CRTM coefficients available are the "as designed v1" that NOAA/Tong made in 9/2017 using idealized/boxcar passbands**
- **TROPICS will eventually have six "as built" CRTM coefficients for each Cubesat using that Cubesat's measured Spectral Response Function (SRFs)**
- **LL will deliver the SRFs to David Bates at NOAA/AOML (Tong is working on other things) and he will make the as built CRTM coefficients for each CubeSat**
- **For now, any TROPICS studies should use the TROPICS "as designed" CRTM coefficients because Micromas-2 and TROPICS have different passbands (i.e., different channel sets)**

CRTM Status (2 of 2)

- **TROPICS has transmittance and spectral coefficient files:**
  - **tropics_designed_v1.SpcCoeff.bin-BigEndian**
  - **tropics_designed_v1.SpcCoeff.bin-LittleEndian**
  - **tropics_designed_v1.TauCoeff.bin-BigEndian**
  - **tropics_designed_v1.TauCoeff.bin-LittleEndian**
- **Ralf Bennartz and team used default CloudCoeff.bin for the HNR Proxy simulations**
  - **Has the maximum frequency of 190 GHz, so 205-GHz channel used scattering coefficient of 190 GHz**
  - **Ben Johnson plans to support TROPICS for the extra coefficients in "the near future." (both cloud and emiss.)**
- **Ben Johnson and team are aware of polarization scheme and will work out a solution**

Logistics

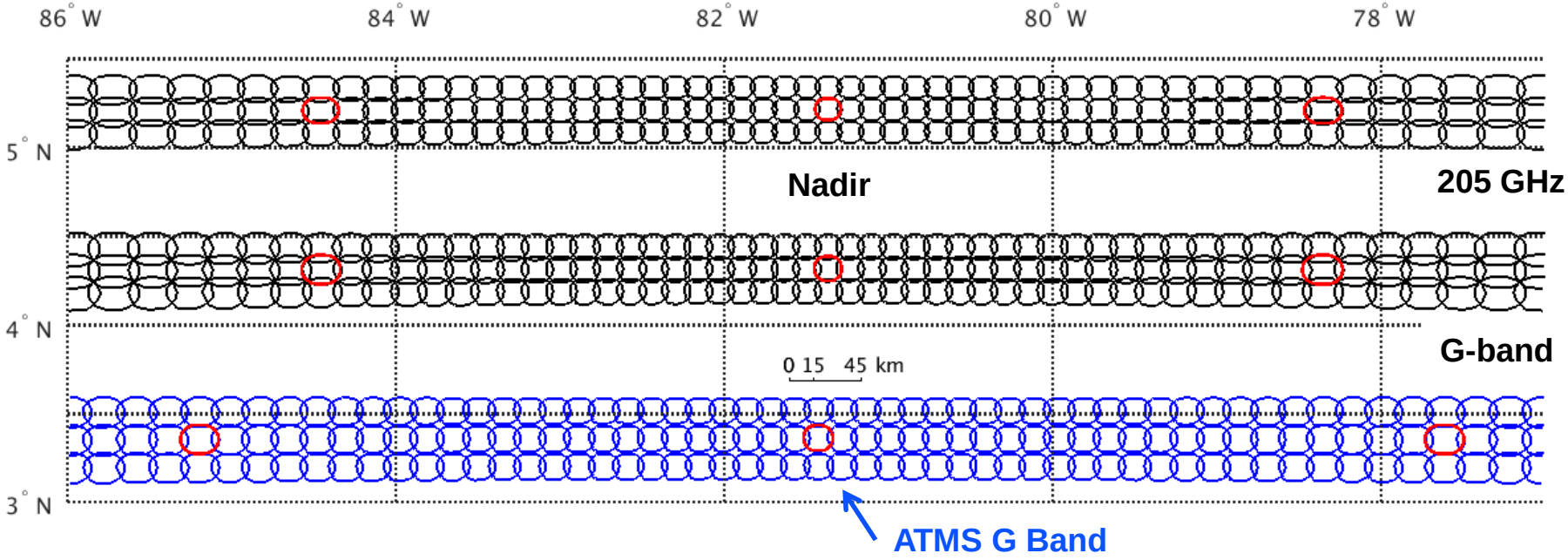
- **TROPICS HNR Release 4 proxy dataset is ready for distribution**
- **FY-3 MWHS-2 proxy dataset ready now (Contact Prof. Ralf Bennartz ralf.bennartz@vanderbilt.edu)**
- **TROPICS launch dates are still TBD (>2021)**
- **HNR Proxy Data dissemination:**
  - **https://www.nsstc.uah.edu/tropics/**
  - **Will look into using GES DISC (same as post-launch)**

Backup Slides

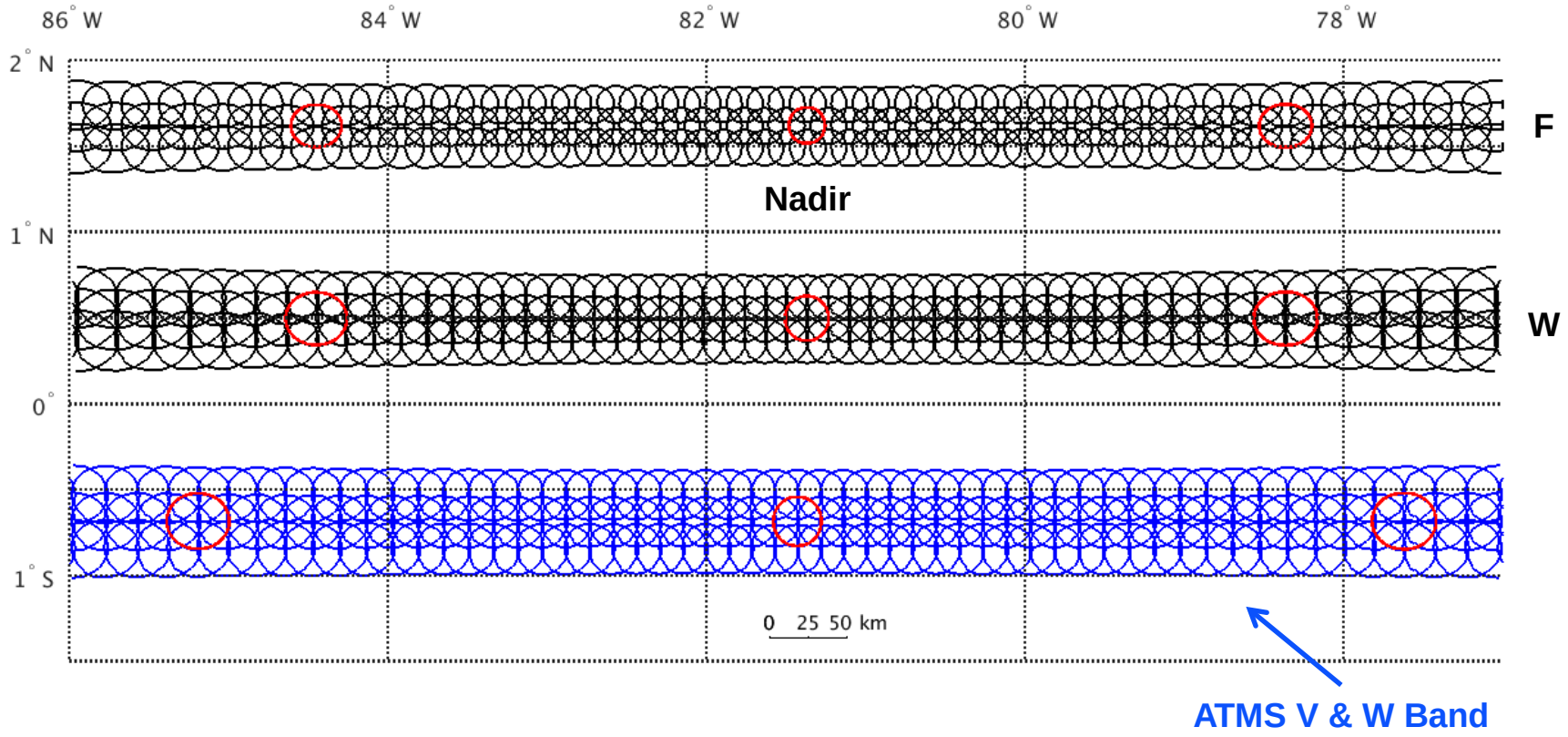
Data Product Highlights

- **TROPICS is required to deliver data in netCDF4 format, but Emily is working with the applications community to generate other formats such as BUFR and GIS-compatible files for general dissemination**
- **Once operational (~ 90 days after first launch), data will be available at GES DISC DAAC (https://disc.gsfc.nasa.gov/) with quicklook images**
- **Public documentation (hosted by GES DISC):**
  - **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 G-band HSR



TROPICS W/F Band Footprints



Description of HNR Proxy Releases

Release	Format	HNR/RTM	Spatial	Spectral	Orbit
1	Brightness temp. saved in custom netCDF	**HNR1**/CRTM/ Expected NEdT	Simulated TROPICS scan with top-hat circular footprint based on F-band (25-km nadir)	TROPICS "as designed" and ATMS	N/A
3	Same as above	Same as above	Simulated TROPICS scan using band beamwidths	Same as above	Simulated TROPICS orbital parameters (2 x 2 x 2 at 30º Incl. & equal spacing)
4	TROPICS Level-1b data product	Same as above	Same as above	Same as above	Same as above

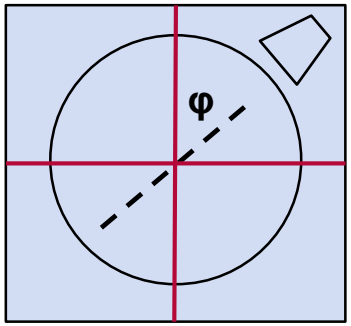
Still tweaking data product format

TROPICS Polarization

Forward direction of CubeSat

Scan direction of CubeSat

Mixed Polarization



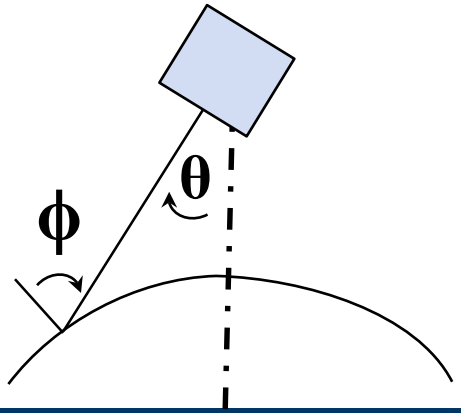
Facing aperture

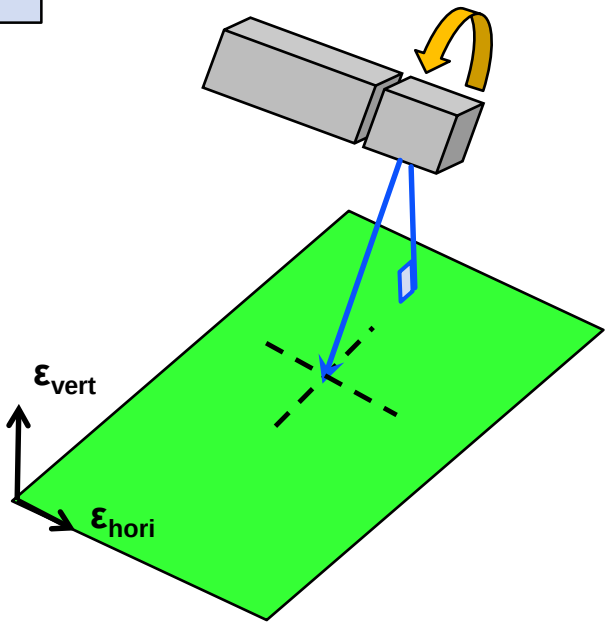
$$T_b = T_b^{hori} * cos^2(\varphi) + T_b^{vert} * sin^2(\varphi)$$

φ = fixed angle of feed horn polarization (not scan angle or zenith angle)

ϕ = sensor zenith angle

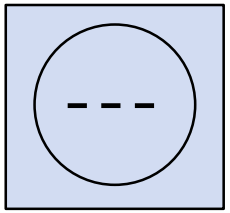
θ = sensor scan angle





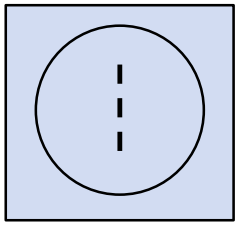
fastem's emissivity uses the sensor zenith angle as input

"Vertical" Polarization



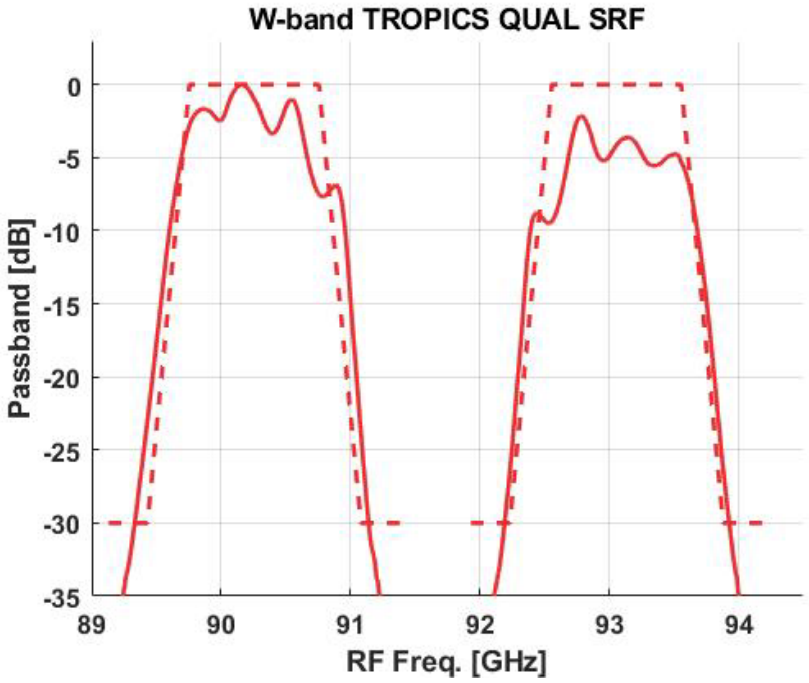
$$T_b = T_b^{vert}$$

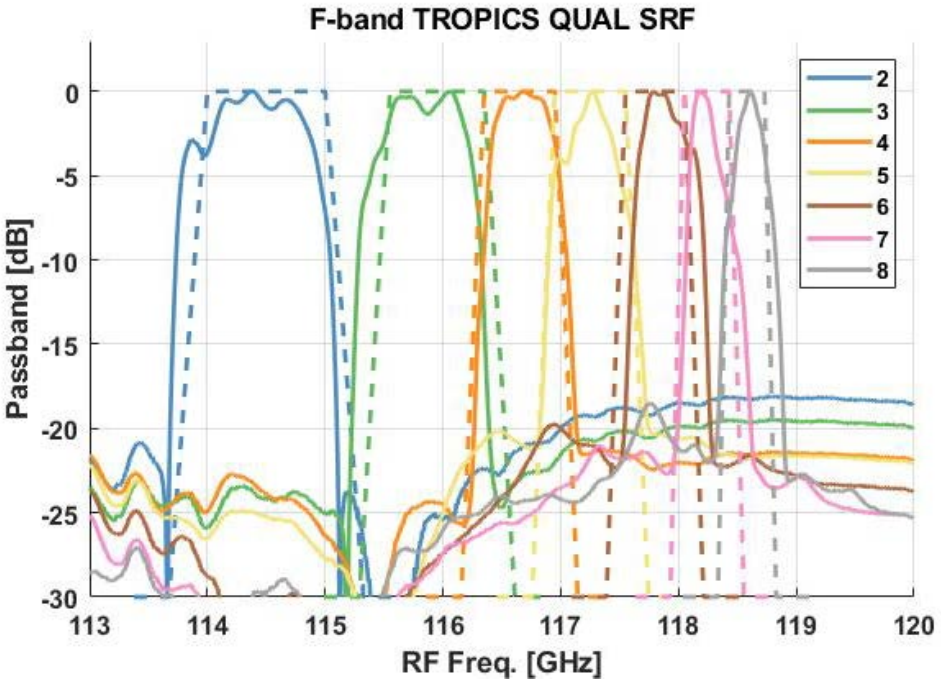
"Horizontal" Polarization



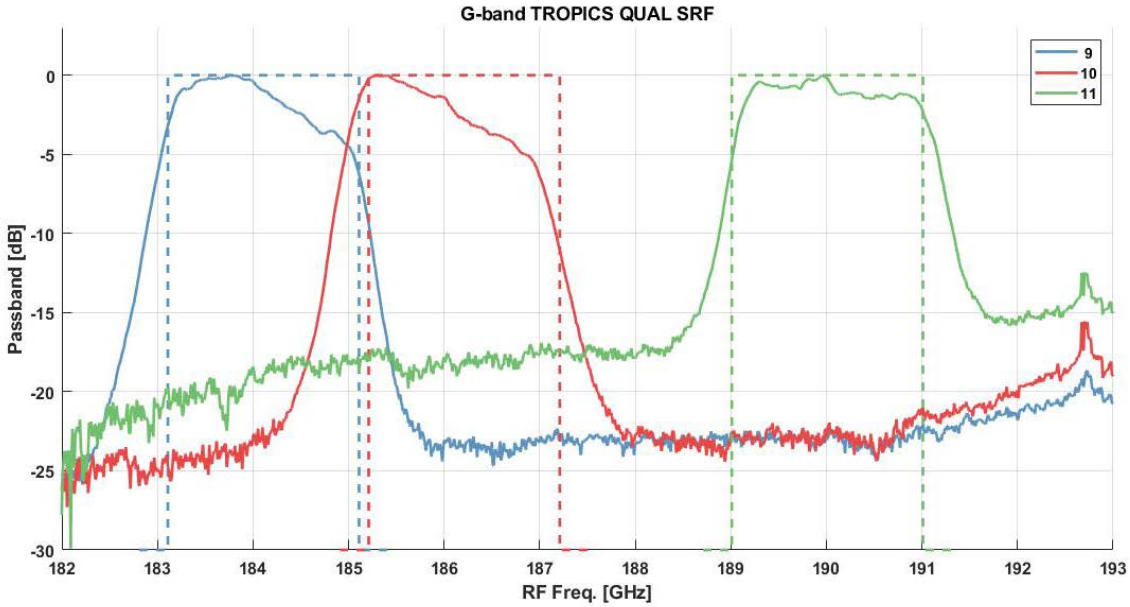
$$T_b = T_b^{hori}$$

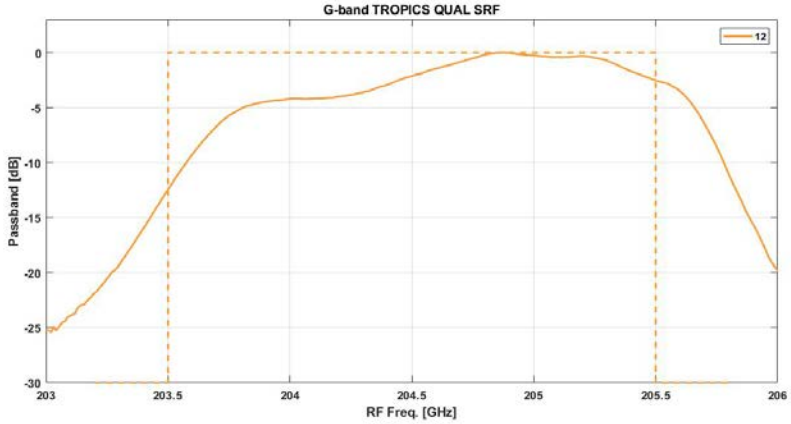
W/F-band Spectral Response



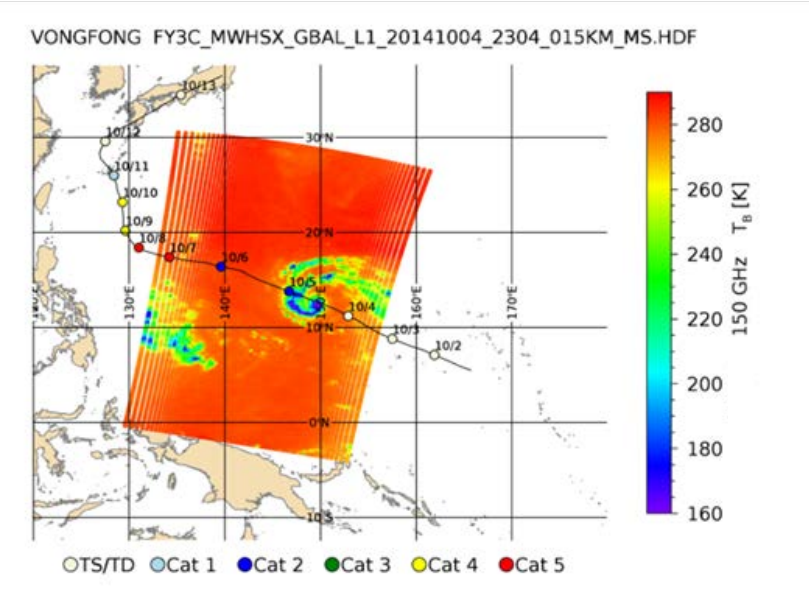


G-band Spectral Response

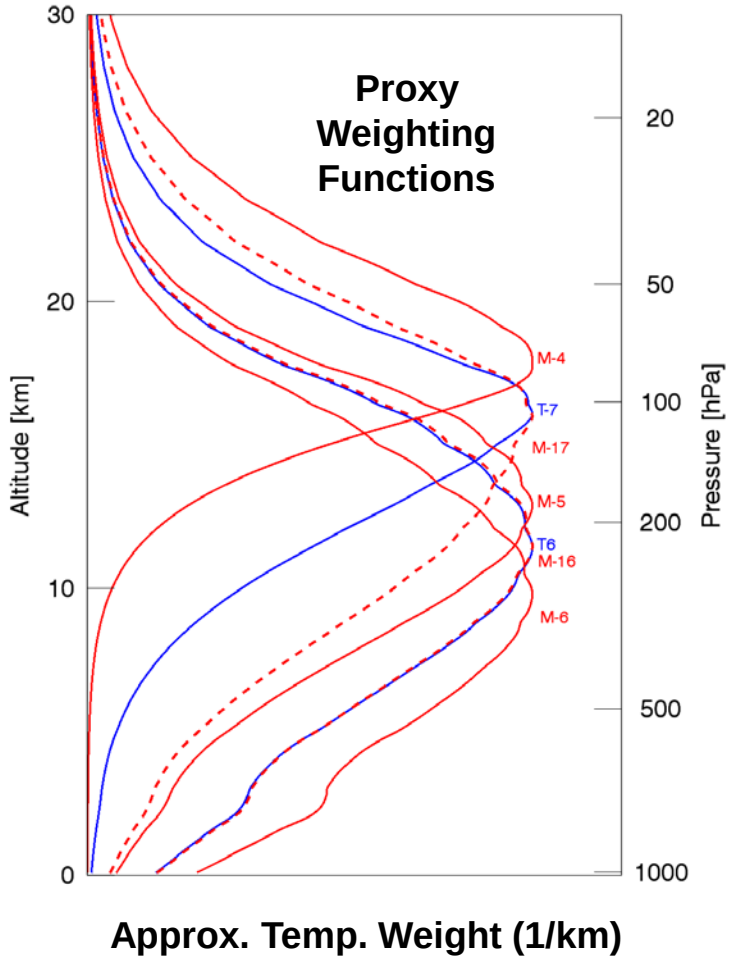




FY-3C/MWHS-2 Proxy Data Set



- **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**



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