The TROPICS mission's sounding capabilities

Ralf Bennartz[1,2], Bill Blackwell[3], Scott Braun[4], Jim Davies[2], Vince Leslie[3], Zhenglong Li[2], Tom Greenwald[2]

1: EES, Vanderbilt University

2: SSEC, University of Wisconsin - Madison

3: MIT Lincoln Laboratory

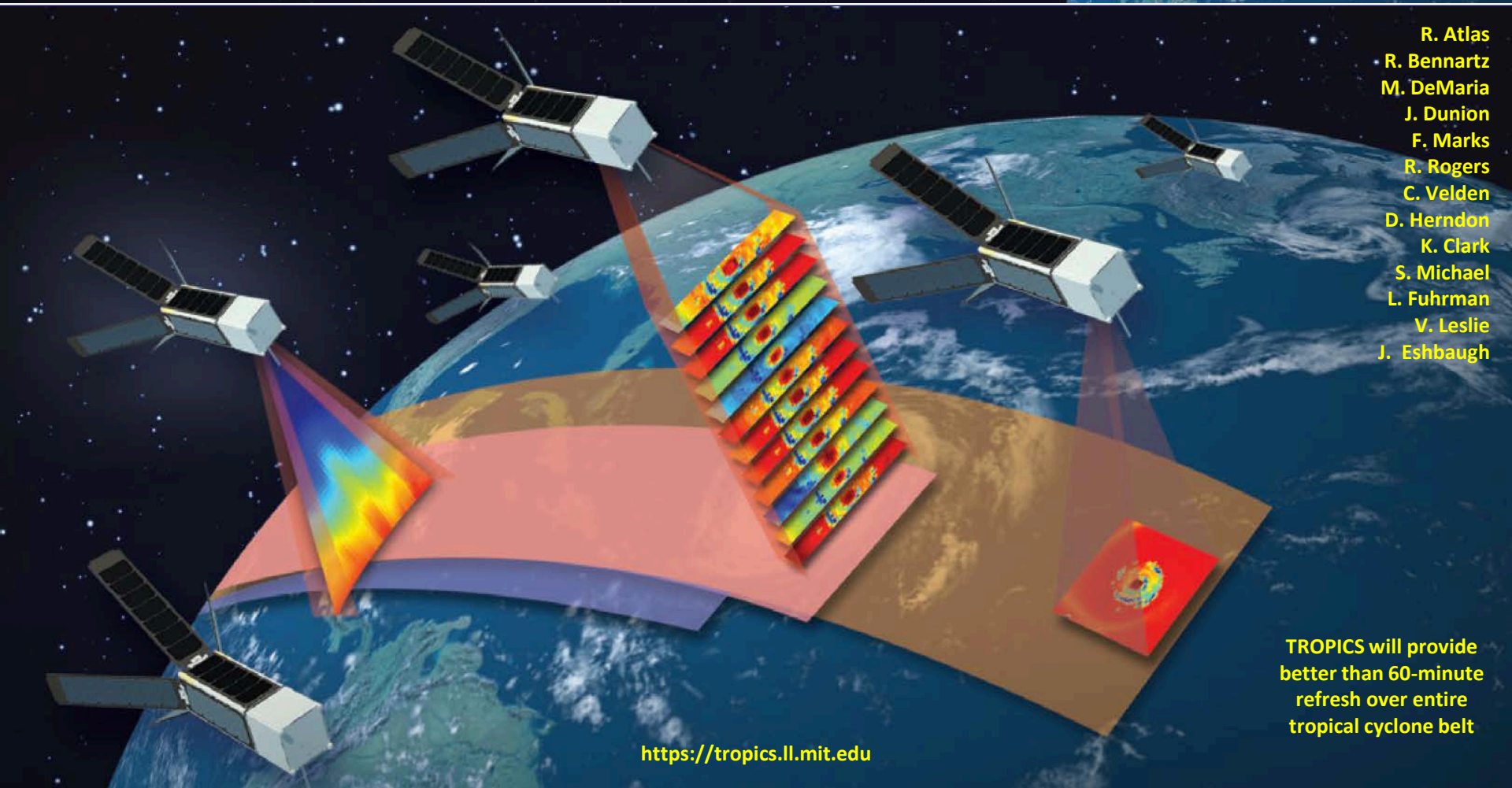
4: NASA GSFC

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

MIT Lincoln Laboratory (lead organization)

William J. Blackwell, Principal Investigator. Scott Braun (NASA GSFC), Project Scientist

R. Atlas
R. Bennartz
M. DeMaria
J. Dunion
F. Marks
R. Rogers
C. Velden
D. Herndon
K. Clark
S. Michael
L. Fuhrman
V. Leslie
J. Eshbaugh



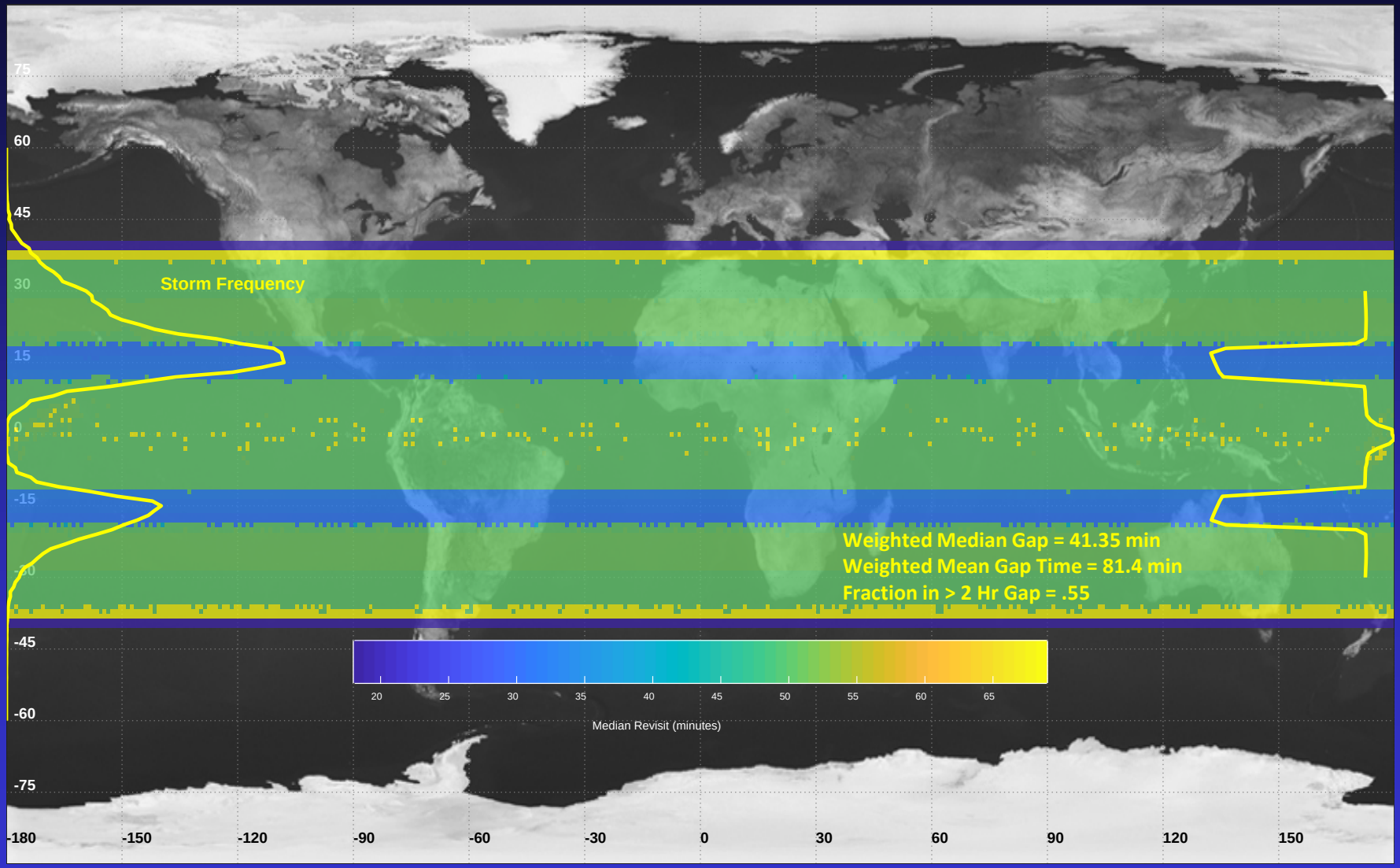
TROPICS will provide better than 60-minute refresh over entire tropical cyclone belt

https://tropics.ll.mit.edu

TROPICS

- 6 CubeSats (3U) in two or three orbits. Launch early 2020.
- Each with a cross-track scanning passive MW instrument with (118 GHz) temperature and moisture sounding channels
- Temporal coverage of e.g. the tropical Atlantic about every 45 minutes
- Improve hurricane forecasting at a fraction of the cost of conventional systems

TROPICS Revisit
(6 sats, 3 planes, 30° inc., 550 km alt.)



TROPICS Scan Characteristics

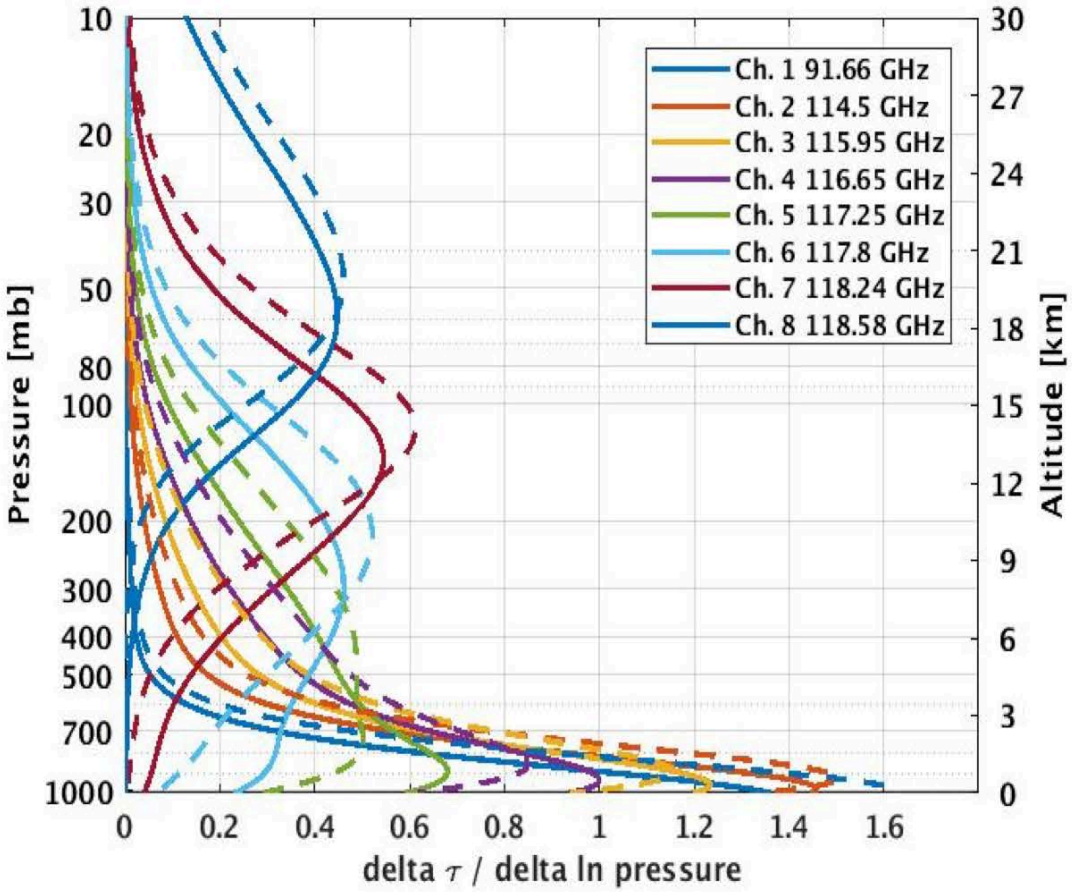
Characteristic	Units	Value
Rotation Period	Seconds	2
Maximum Earth View Sector Angle	Degrees	± 60
Scan Type	N/A	Constant velocity (scanning during integration)
Integration time	Seconds	1/120
Number of Earth View Sector Measurements	N/A	81 per scan (one at nadir)

TROPICS Channel Set

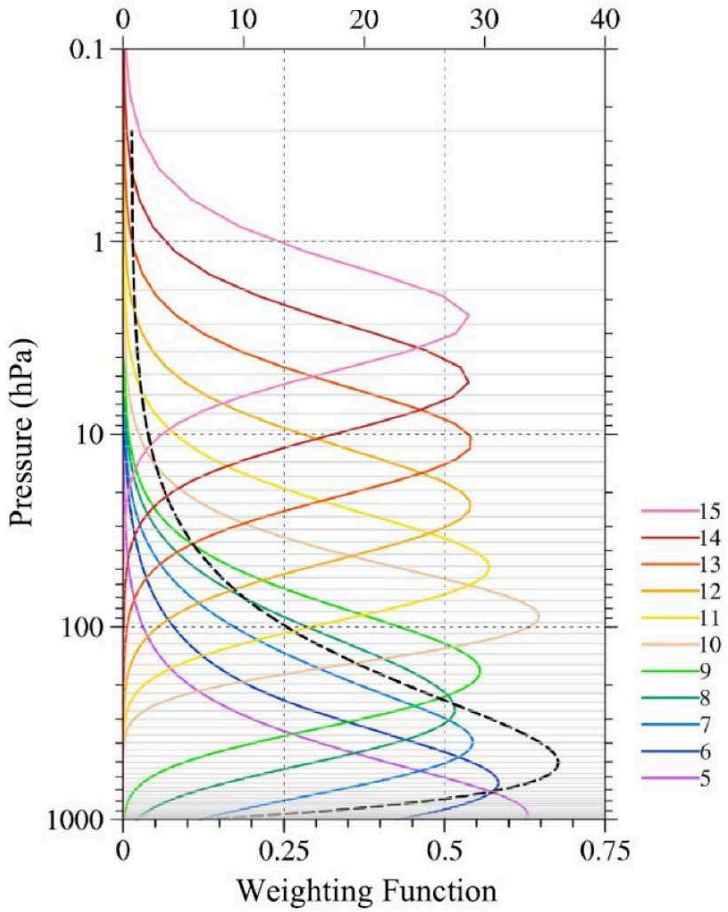
Chan.	Center Freq. (GHz)	Band width (GHz)	RF Span (GHz)	Beamwidth (degrees) Down/Cross	Nadir Footprint Geometric Mean (km)	Expected NEdT (K)
1	91.655 ± 1.4	1.000	89.756-90.756, 92.556-93.556	3.0/3.17	29.6	0.95
2	114.50	1.000	114.00-115.00	2.4/2.62	24.1	0.55
3	115.95	0.800	115.55-116.35	2.4/2.62	24.1	0.60
4	116.65	0.600	116.35-116.95	2.4/2.62	24.1	0.70
5	117.25	0.600	116.95-117.55	2.4/2.62	24.1	0.70
6	117.80	0.500	117.55-118.05	2.4/2.62	24.1	0.75
7	118.24	0.380	118.05-118.43	2.4/2.62	24.1	0.85
8	118.58	0.300	118.43-118.73	2.4/2.62	24.1	1.00
9	184.41	2.000	183.41-185.41	1.5/1.87	16.1	0.60
10	186.51	2.000	185.51-187.51	1.5/1.87	16.1	0.60
11	190.31	2.000	189.31-191.31	1.5/1.87	16.1	0.60
12	204.8	2.000	203.8-205.8	1.4/1.76	15.2	0.60

TROPIC Temperature weighting functions

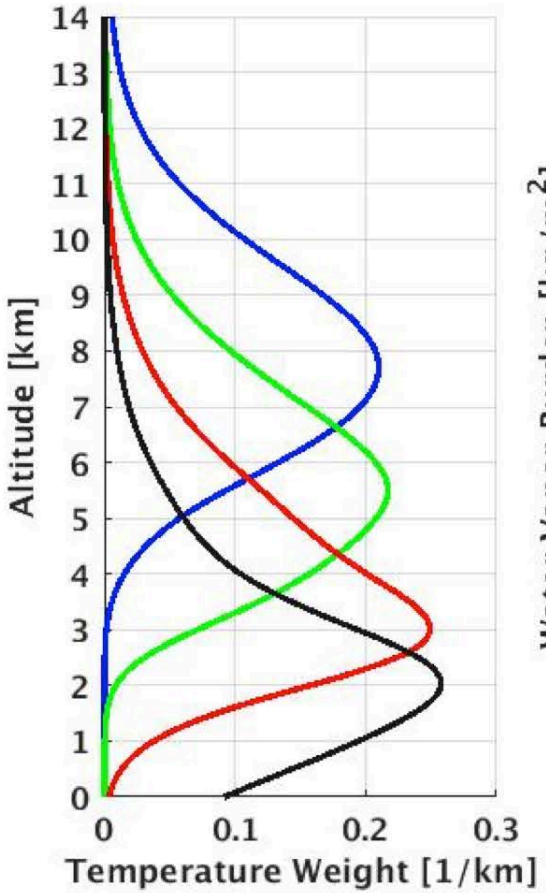
TROPICS

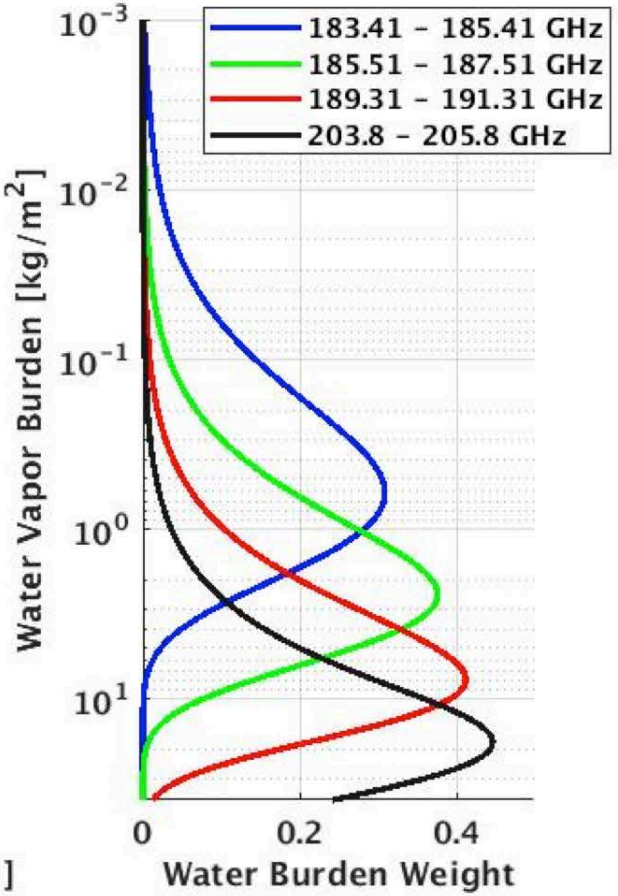


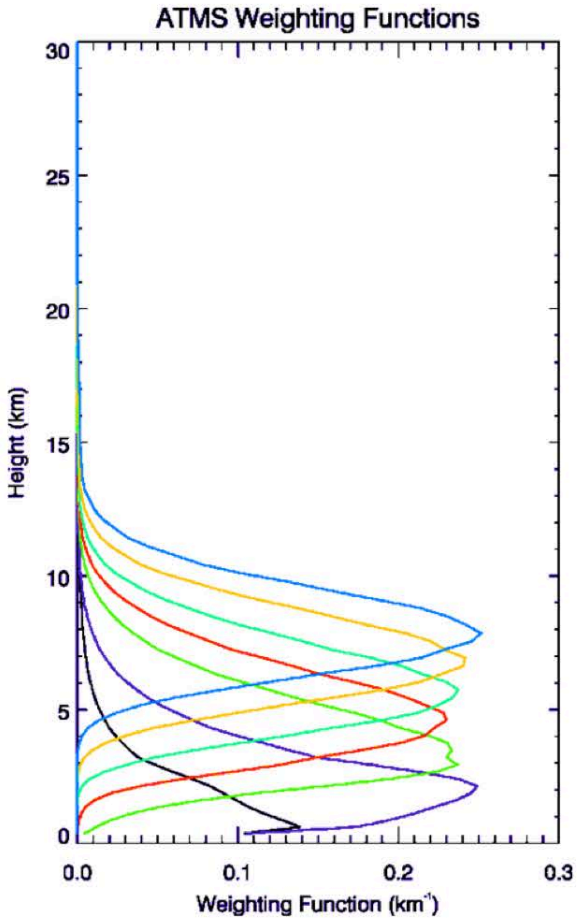
ATMS



TROPICS Water vapor channels







TROPICS Products Requirements

Product	Threshold Requirement (Uncertainty)	Baseline Requirement (Uncertainty)	Expected Performance (Uncertainty)
Temperature Profile	2.5 K	2.0 K	1.6 K
Moisture Profile	35 %	25 %	16 %
Rain Rate	50 %	25 %	25 %
Min Sea-Level Pres.	12 hPa	10 hPa	8 hPa
Max Sustained Wind	8 m/sec	6 m/sec	5.5 m/sec

Expected retrieval accuracy

- Used several thousand globally representations soundings (SeeBor database and NWPSAF 137-level database)
- Cloud-free as well as cloudy atmospheres (but deep convection excluded).
- Used MIRS CRTM retrieval as well as RTTOV/1DVAR (Results very similar between the two).
- Compared to ATMS.

Expected retrieval accuracy

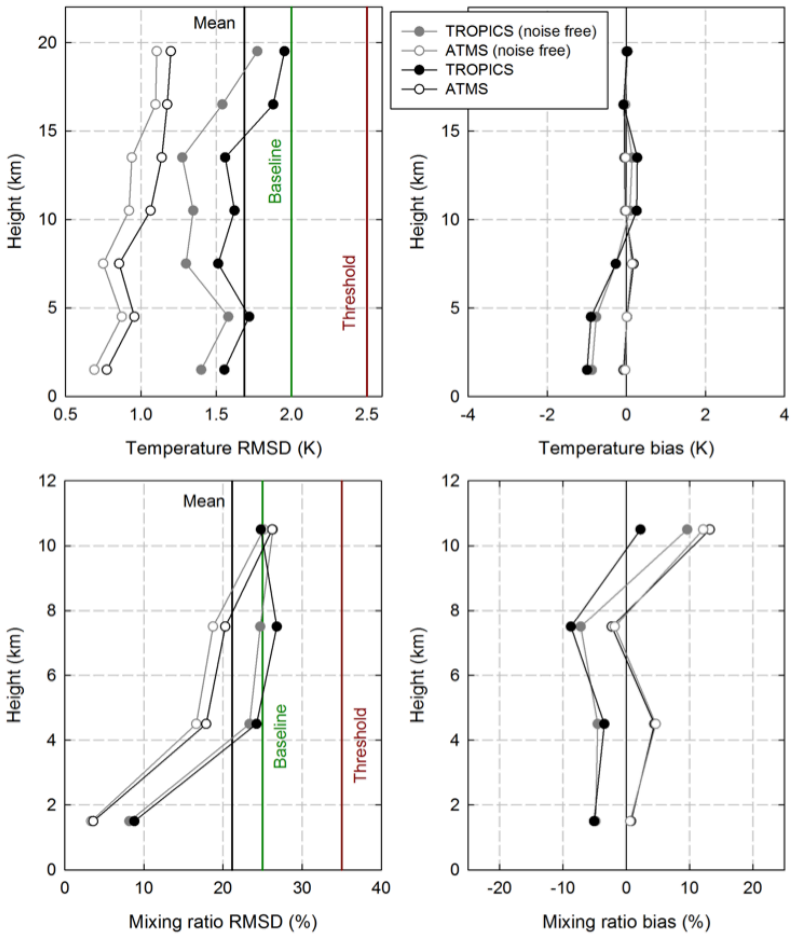


Figure 9 Error characteristics of the TROPICS and ATMS retrievals for clear-sky radiosonde profiles. Layer mean RMSDs (black vertical lines) and retrievals using noise-free simulated brightness temperatures (gray symbols and lines) are also indicated.

Expected retrieval accuracy

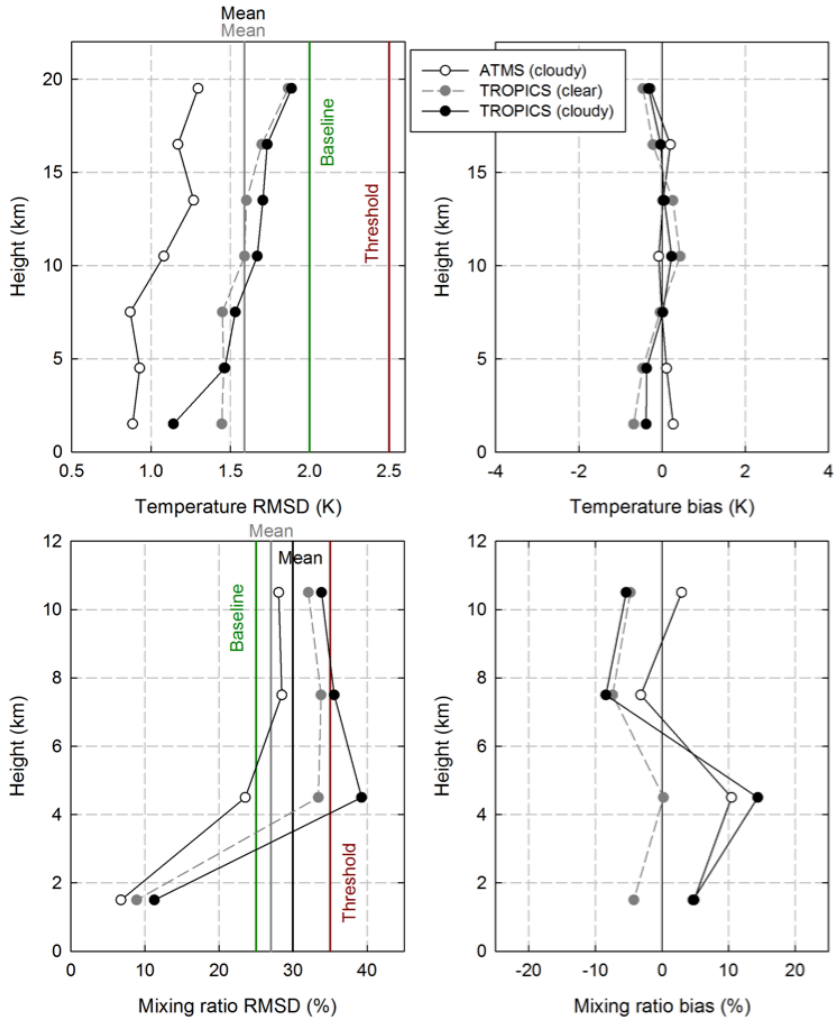


Figure 12 Error characteristics of the TROPICS and ATMS retrievals for cloudy profiles. Layer mean RMSD values and clear sky profiles (in gray) are also indicated.

Total column water vapor

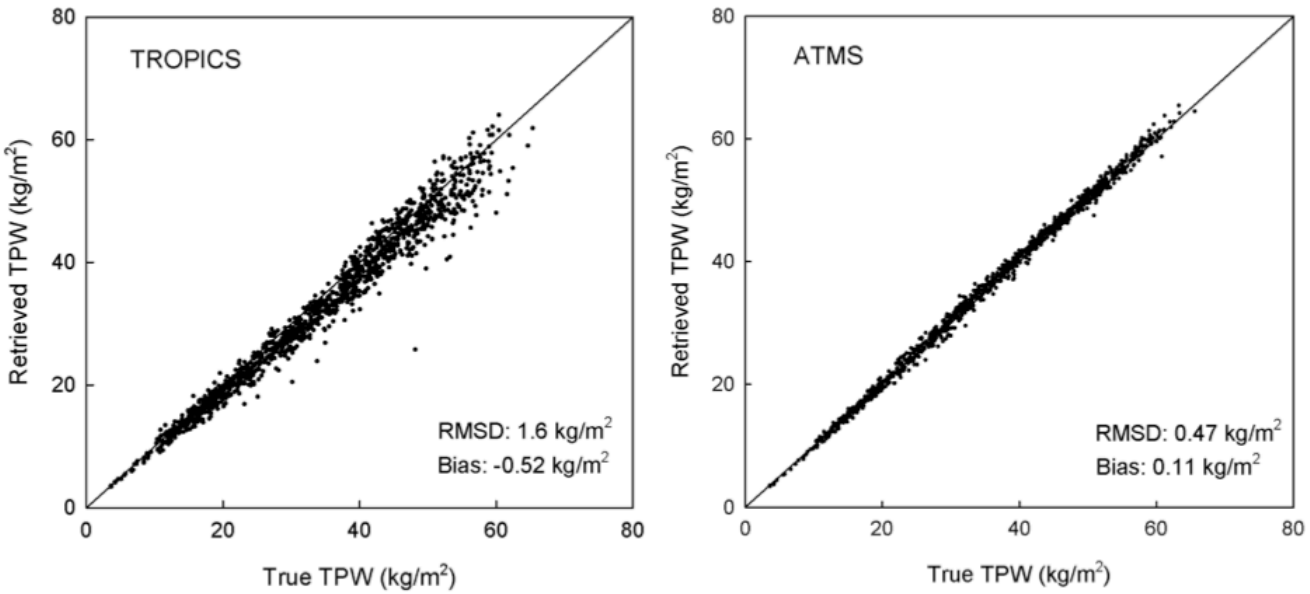


Figure 10 Vertically integrated water vapor from TROPICS and ATMS retrievals for clear-sky radiosonde profiles.

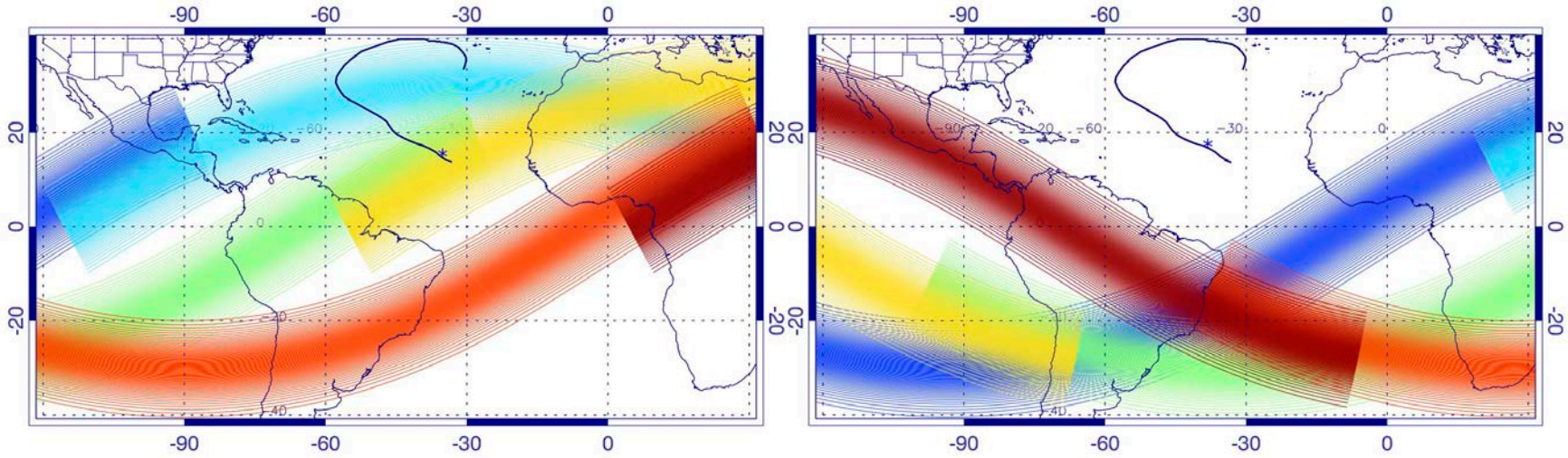
Orbital planes – revisit times

- Two orbit simulations for 30 days
  - 3 orbital planes, 2 satellites each evenly spaced, denoted 222
  - 2 orbital planes, 3 satellites each evenly spaced, denoted x33

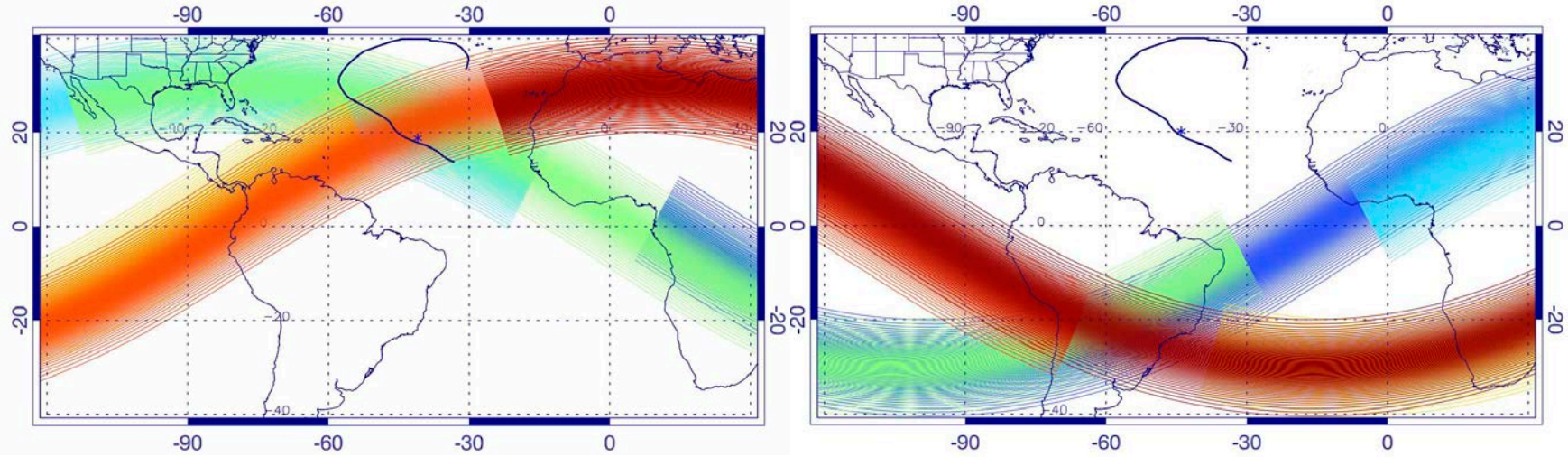
Overpass Calculations

- Overpass statistics
  - Tracks from 55 real tropical cyclones used
  - For each track, orbits were broken up into 5-min segments and checked for being within 0.25° of storm centers
- Nature Run analysis
  - Used WRF NR storm, calculated overpass times
  - Computed Hovmoller diagrams for rainfall to indicate sampling by orbits

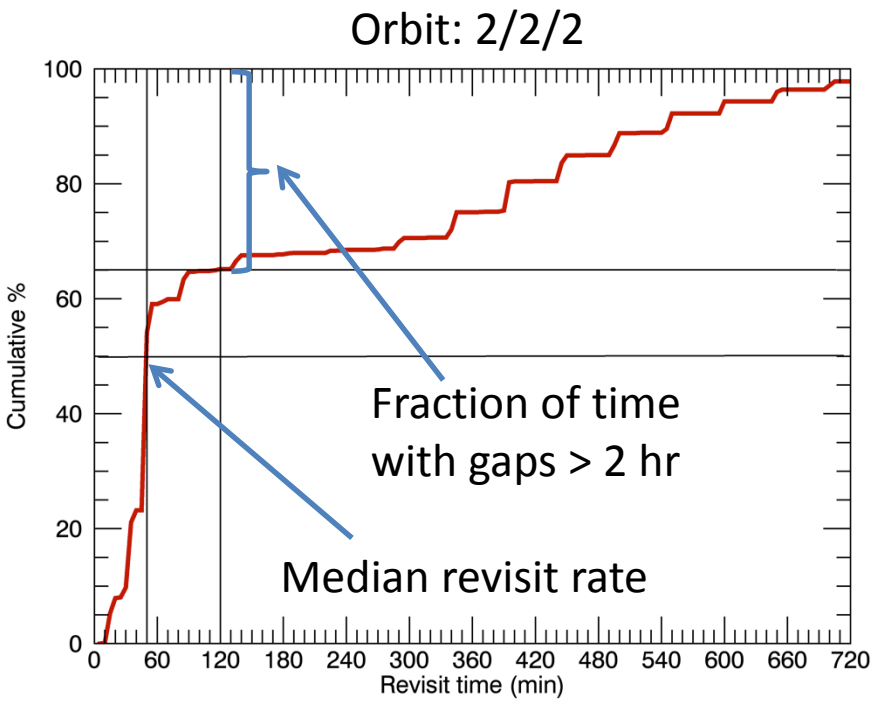
222 Orbits For High And Low Revisit Periods — Hurricane Edouard Track

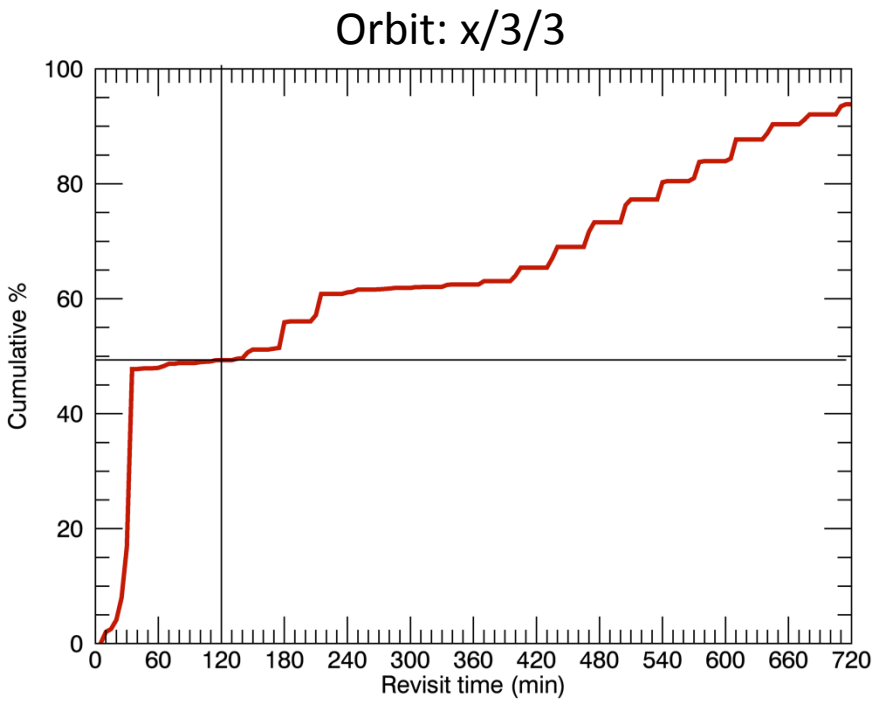


x33 Orbits For High And Low Revisit Periods — Hurricane Edouard Track



Cumulative Frequency For Revisit Rates



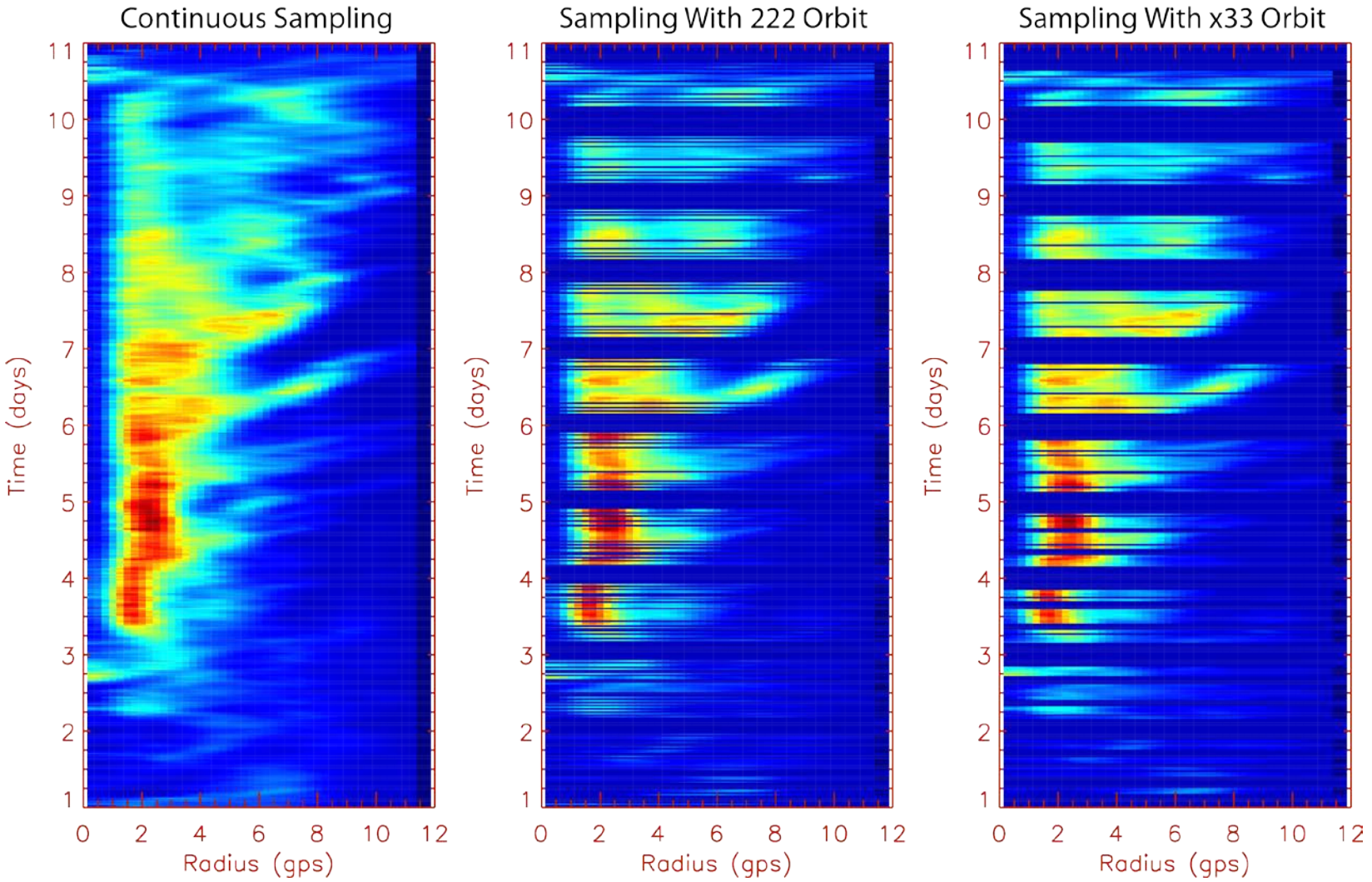


For 2/2/2, gaps > 2 hr occur 35% of the time. Median revisit time = 50 min

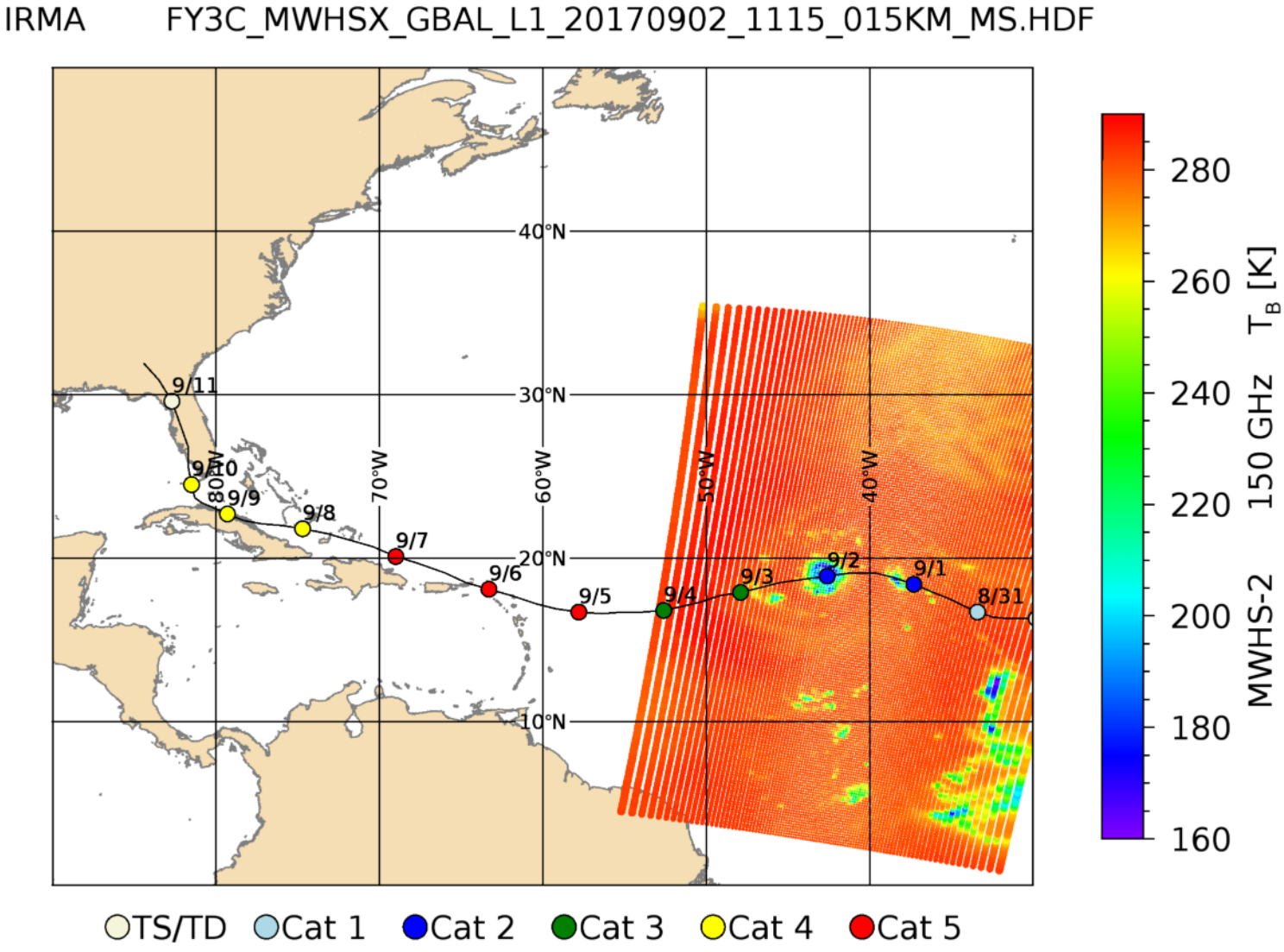
For x/3/3, gaps > 2 hr occur 50% of the time. Median revisit time = 120 min

Rainfall Hovmoller Diagrams (Radius vs Time)

Orbit overpasses were determined from WRF nature run storm track. If no overpass, no rainfall data included at that time in the Hovmoller diagram. WRF NR and assumed interval for overpass calculations is 30 minutes.

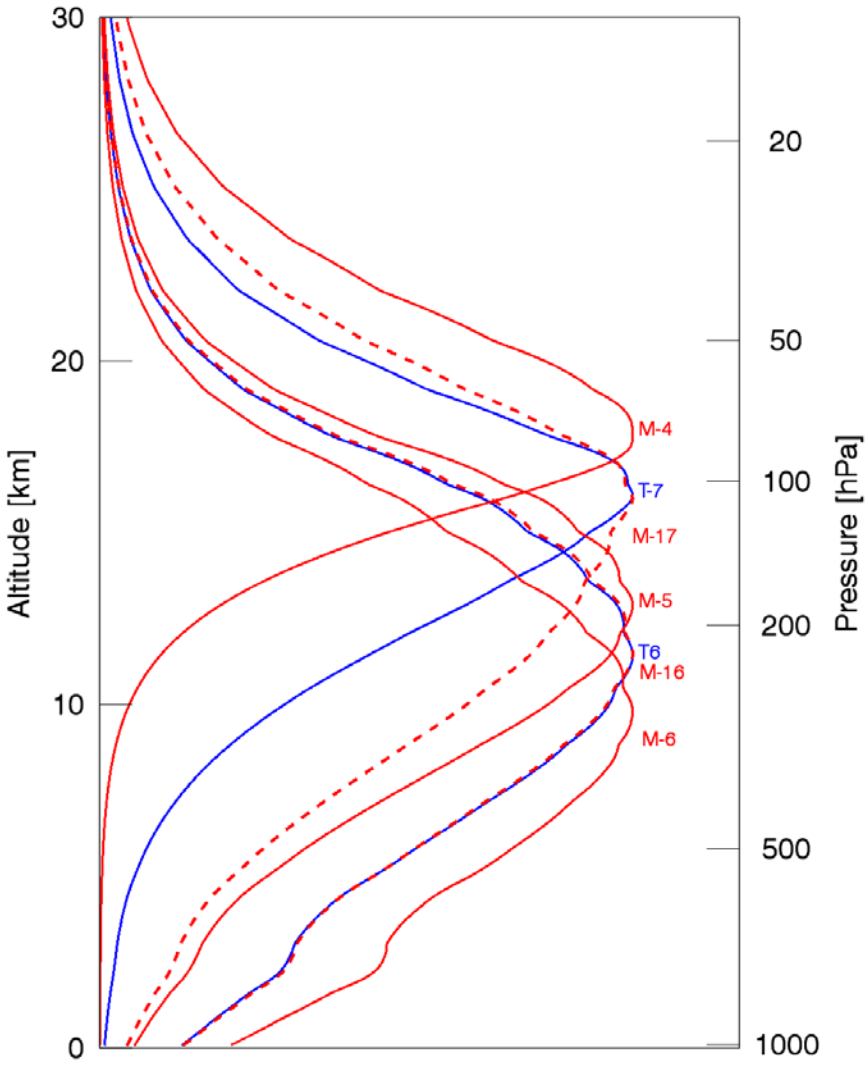


FY-3C as proxy data



FY-3C

- Weighting functions
- O2 channels
  - **TROPICS 6** = **(CH5+CH6)/2** of MWHS-2. Excellent proxy
  - **TROPICS 7 ~ (CH4+CH5)/2** of MWHS-2. Ok proxy.
- WV channels:
  - TROPICS 11 ~= MWHS-2 15
  - TROPICS 10 ~~ MWHS-2 14
  - TROPICS 9 ~~ MWHS-2 11



FY-3C

- Building up database of storm overpasses 2014-2017
- Currently about FY-3C 100 overpasses over different tropical storms and about 150 NPP overpasses
- Comparing ATMS/MWHS-2 for tropical storm warm core analysis performance with C. Velden / D. Herndon (SSEC).

Conclusions

- TROPICS will provide six satellites with sounding capabilities, most likely in two orbits, 30 degree inclination
- Sounding capabilities similar to ATMS, although lack of low frequency channels means less constraints on column-integrated quantities.
- High temporal repetition times over tropical storms. 50% of the cases repetition time shorter than 40 minutes.
- FY-3C provides excellent proxy dataset for TROPICS 118 GHz channels.