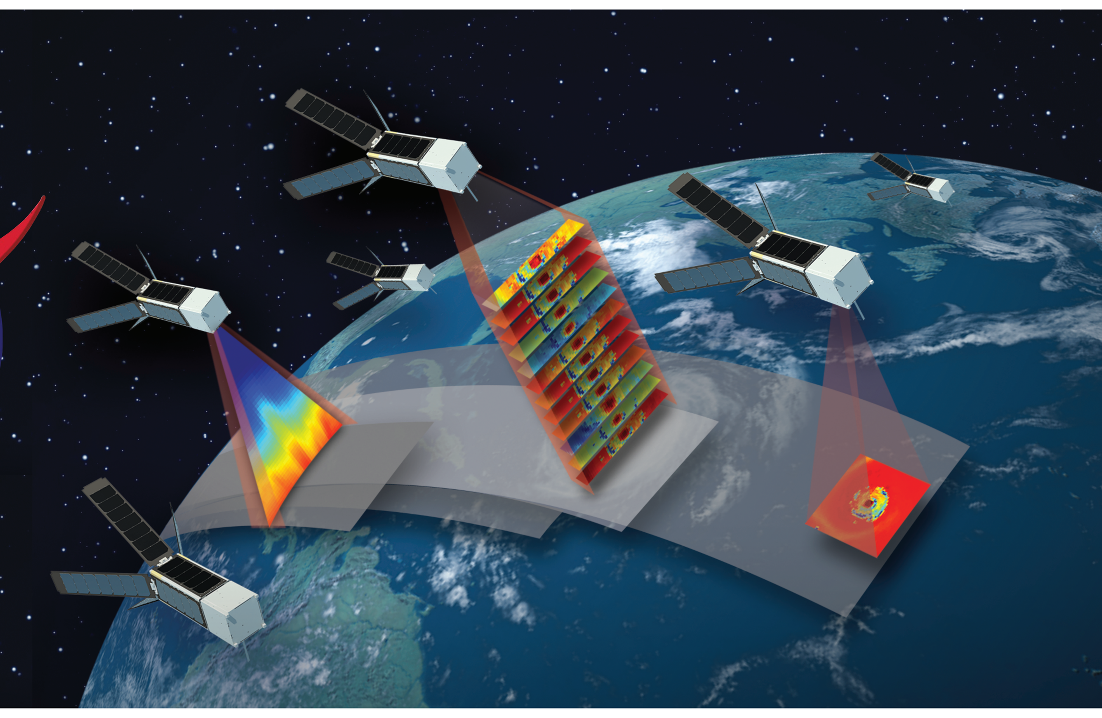


Expected sampling of tropical cyclones by TROPICS constellation satellites

Scott Braun, NASA/GSFC, scott.a.braun@nasa.gov
William Blackwell, MIT/Lincoln Lab
Ralf Bennartz, Vanderbilt Univ. & UW Madison

TROPICS Overview

The TROPICS goal is to obtain observations critical to improved understanding of genesis and intensification processes in tropical cyclones and to assessing the impact of SmallSat remote sensing technologies on modeling and analysis. TROPICS will use a constellation of 6 Cubesats each carrying a 12-channel microwave radiometer for three-dimensional temperature and moisture sounding and imaging of storm precipitation structure as measured by a derived scattering index and estimated rainfall. The currently scheduled launch is ~late 2020. Mission lifetime will be one year. The TROPICS mission is funded by NASA's Earth Venture Instrument (EVI-3) program.

Presentation Overview

Currently, TROPICS plans 2 satellites in each of 3 orbital planes at 30° inclination. To achieve cost savings, NASA might reduce the number of orbital planes or change the orbit inclination. How will such changes affect revisit rates and data gaps for hurricane observations, and how much observing system degradation would occur if 1 or 2 satellites failed? The goals of this poster presentation are to describe the sampling frequency and characteristics based on two years of actual storm tracks and evaluate the impact of (1) the number of orbital planes, (2) 1 or 2 satellite failures, (3) a shift in orbit inclination from 30 to 39°, and (4) a mix of both 30 and 39° inclinations.

Data

- National Hurricane Center HURDAT and Joint Typhoon Warning Center best-track data sets for 2009-2010.

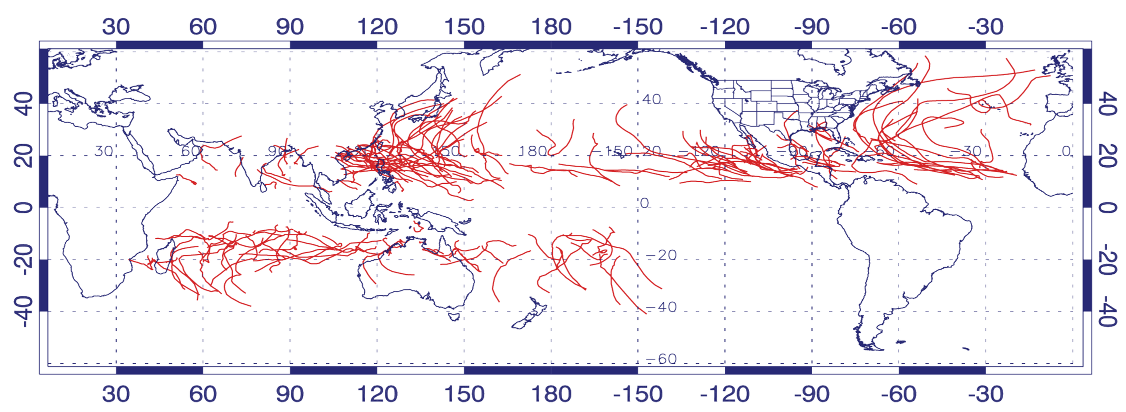


Fig. 1. HURDAT and JTWC tropical cyclone tracks for 2009-2010.

- Weather Research and Forecasting (WRF) model Nature Run simulation (Nolan et al., JAMES, 2013, Vol. 5, pgs. 382-405) degraded to 30-km grid resolution to mimic sensor resolution for temperature.

- Simulated orbit tracks and footprints for different orbit scenarios, with the number of satellites in up to 3 orbital planes indicated by $N_1N_2N_3$, e.g. 222 for 2 satellites in each of 3 orbital planes and x33 for 3 satellites in two of the three orbital planes.

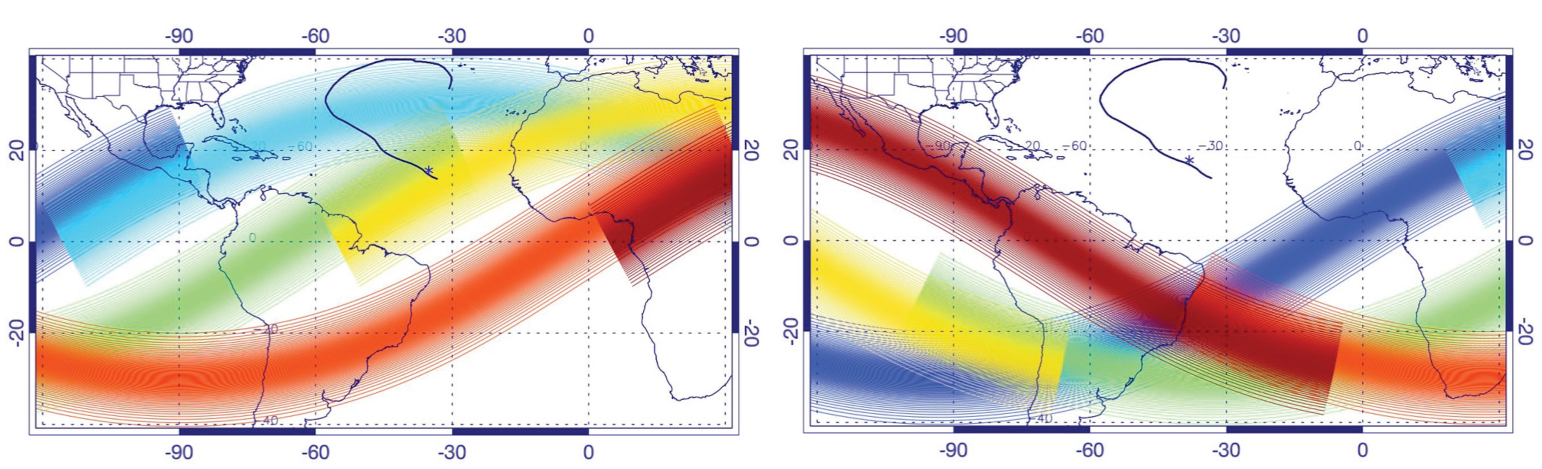


Fig. 2. Simulated TROPICS orbits covering the Atlantic Ocean. Orbits represent 30-minute segments. The track of Hurricane Edouard (2014) is shown as an example. (Left) Favorable orbit period producing frequent overpasses, (right) unfavorable orbit period causing a long gap between overpasses.

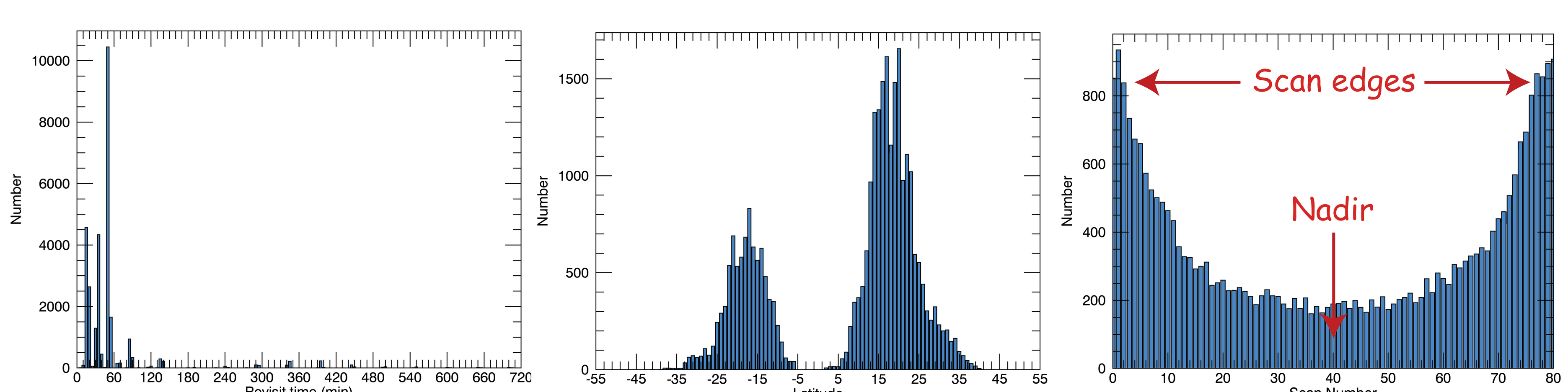
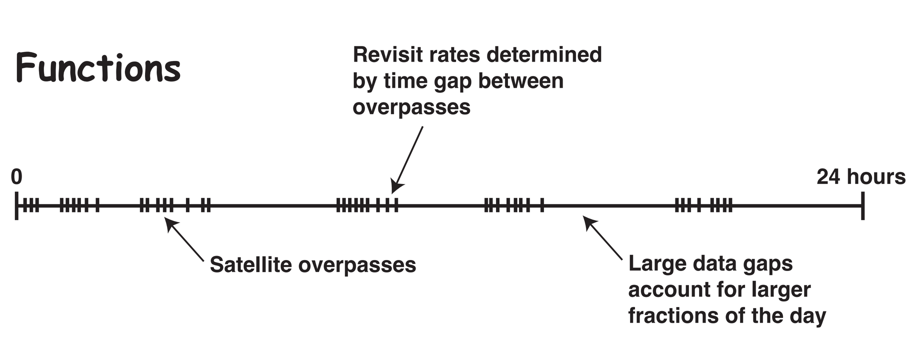


Fig. 3. Histograms of storm revisit rates (left), latitudes of overpasses (center), and scan angles of overpasses (right).

Calculation of Cumulative Probability Distribution Functions

CDF of revisit rate based on counts

$$CDF(t) = 100 \times \int_0^t N(t) \Big/ N_{Total}$$



where N(t) is the number of values in bin t and N_{Total} is the total number of values summed over all bins.

CDF of revisit rate based on fraction of day

$$CDF(t) = 100 \times \left[\int_0^t N(t) \times R(t) \right] \Big/ NR_{Total}$$

where R is the revisit-rate value for bin t and NR_{Total} is the total of N(t)xR(t) summed over all bins.

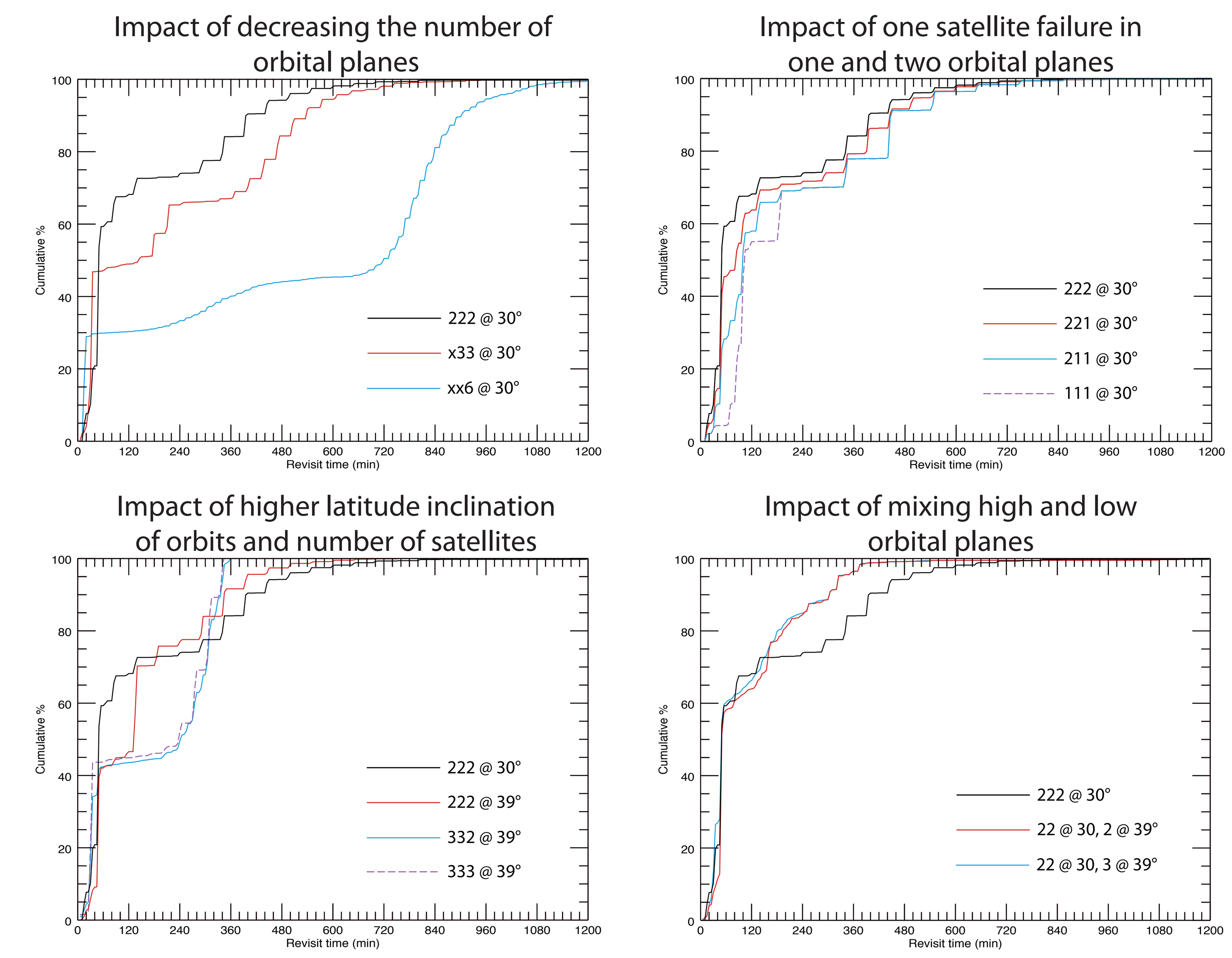


Fig. 4. Cumulative frequency distributions based on fraction of day. (Upper left) Impact of number of orbital planes (the numbers indicate the number of satellites per orbital plane, with x meaning no satellites). (Upper right) Impact of losing one satellite in one (221), two (211), or three (111) orbital planes. (Lower left) Impact of 39° orbit inclination and increases in number of satellites. (Lower right) Impact of mixing both 30 and 39° orbital planes.

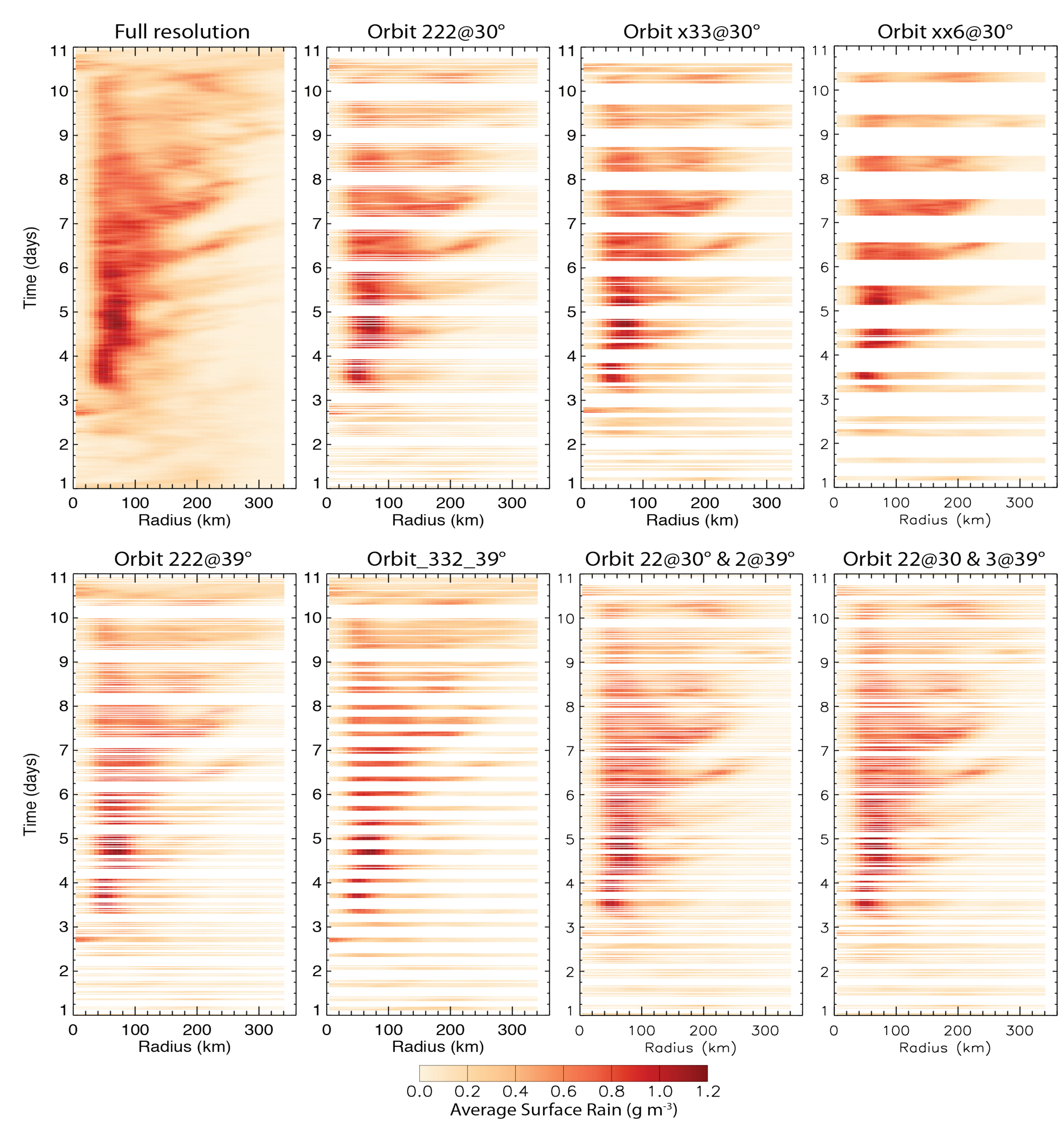


Fig. 5. Sampling of the WRF Nature run storm using the orbit tests in Fig. 4. For these plots, WRF fields were degraded to 30-km resolution (to approximate average sensor resolution), with WRF output available every 30 minutes. Surface rain amount was then azimuthally averaged to create time-radius Hovmoller diagrams. Full time-resolution data is shown in the first panel. For other panels, data is only shown when there are satellite overpasses, as determined by simulated orbit configurations.

Key findings

- Revisit rates degrade rapidly as the number of orbital planes decreases from 3 to 2 to 1.
- The loss of one satellite in one, or even two, orbtial planes slightly degrades revisit rates, but much less so than a reduction in the number of orbital planes.
- Launch into a higher inclination orbital plane (39°) reduces the frequency of moderate revisit rates (60-240 minutes), but with a couple extra satellites can eliminate gaps exceeding 6 hours.
- Mixing orbit inclinations (30 and 39°) helps to maintain high and moderate revisit rates, although with a slight reduction in high revisit rates, but nearly eliminates the longer data gaps.

Table 1. Summary statistics for the different orbits. Mean and median refer to the CDF of revisit rates. "Median-fraction" refers to the median of the CDF in terms of fraction of time.

Case	Mean	Median	Median-fraction	Fraction >2 hr
222	55	50	50	33
221	66	50	80	37
211	83	50	100	42
111	111	90	105	45
x33	55	35	140	52
xx6	54	15	720	70
222@39	75	50	130	53
332@39	60	35	240	57
333@39	56	30	240	55
22@30, 2@39	61	50	50	36
22@30, 3@39	54	35	50	33

Conclusions

TROPICS and NASA are working toward launch vehicle selection, with cost a key consideration. Here, we examine the statistics of sampling in the baseline mission as proposed: six satellites, two in each of 3 orbital planes at 30° inclination.

Using data from two seasons of global storm tracks, we find that a decrease in the number of orbital planes is very detrimental to the distribution of revisit rates. There is a tradeoff between maintaining high revisit rates versus having large data gaps, and the final configuration will depend on the desire for:
1) maintaining very high revisit rates so that convective evolution is more easily tracked between data gaps, or
2) sacrificing a bit on the high revisit rates and the ability to track convective evolution, but nearly eliminating data gaps greater than 6 hours.