How Raising TRMM's Altitude to 400km Impacts PR Operation

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NASDA EORC with support of PR team

1. Background and Introduction

TRMM is planned to make a controlled reentry at the end of its life time. Based on a recent NASA re-analysis on debris, TRMM may not completely burn up and parts exceeding 12m^2 may survive. This means that a controlled reentry is needed at the end of its life. About 160kg fuel is necessary for the controlled reentry, instead of the 58kg estimated before TRMM's launch. This increase in fuel needed for a controlled reentry impacts the mission life, shortening it to the end of 2002. For this reason scientists began to consider prolonging the mission life by increasing the satellite altitude to around 400km. Since the most serious impact appears to be on PR, the PR team began to survey impacts on PR if TRMM altitude is increased to around 400km.

2. Impacts on PR due to increasing the satellite altitude 350km to 400km

Since the PR is a pulse radar and receives very weak rain and surface echoes in a very short time interval, one approach is to increase the satellite altitude, by the distance corresponding to the pulse-to-pulse time interval, that is 54km. The targeted altitude would then be 404km. Therefore, the following discussion assumes a satellite altitude of around 400km. Changes in PR observation are:

1. Increased distance,
2. Mismatch of transmit-to-receive angle for one pulse in 32 averaging pulses, and
3. Change of days to complete global sampling.

2.1 Impacts on PR due to increased distance

(1) Degradation of receiving power by 1.2dB (=20log(400/350))

(2) Increased footprint size from 4.3km to 5km (1.35 times),

(3) Changes of Non Uniform Beam Filling (NUBF) effect,

(4) Overlapping footprints,

(5) Increasing swath width from 220km to the 245km

(6) Missing surface data at larger angles. The difference in satellite-to-surface distance is about 20km for a 404km altitude and about 17km for a 350km altitude (see Fig. 1). This means the satellite altitude should be lower than 404km. This issue is discussed in the next section.

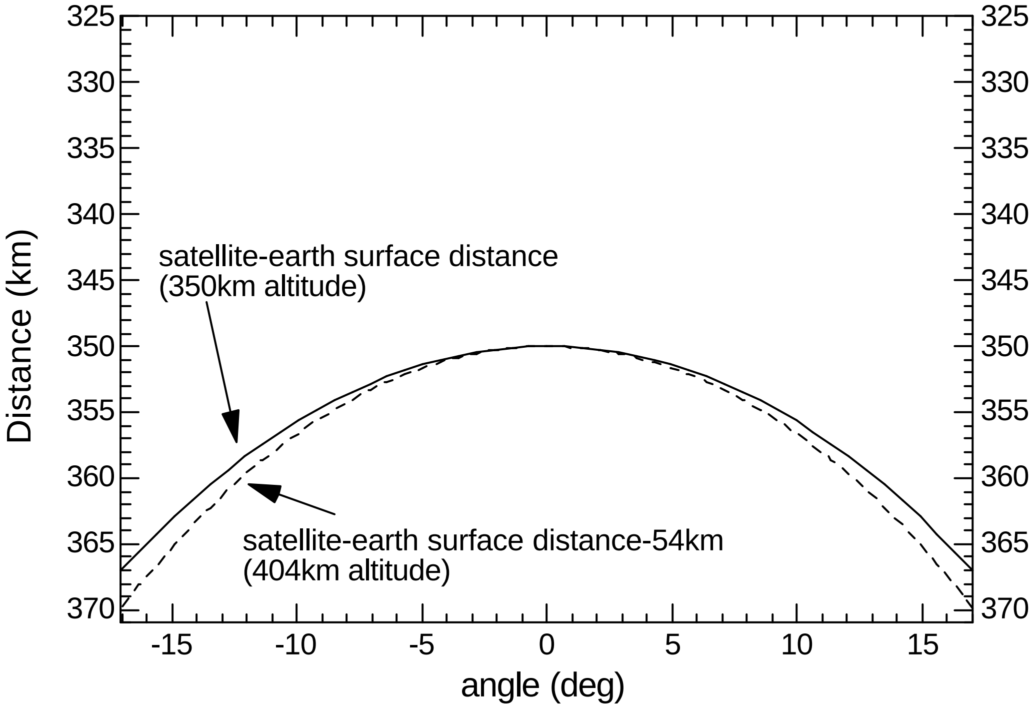

Figure 1. Satellite to Earth surface distance in the cases of 350km and 404km satellite altitudes.

2.2 Determination of satellite altitude

As mentioned in the previous section, the satellite altitude is determined based on surface echo detection. The implications are discussed below.

(1) The Satellite altitude should be 401.3km in order to detect surface echoes at wider angles if the current PR sampling range setting is maintained.

(2) Lowering the satellite altitude from 404km decreases the observable echo height. For example, if the satellite altitude is 401km, to observable echo height at nadir decreases by 3km. From this viewpoint, the satellite altitude should be close to 404km

(3) For more efficient sampling, we can change PR's sampling range setting up to six range bins (750m) for each angle bin.

(4) If the satellite altitude can be controlled within +/- 1.00km, the satellite altitude can be raised by 0.25km

(5) The currently recommended satellite altitude is therefore 402.3km.

(6) If the satellite altitude is 401km, tall rain echoes may appear in the noise sampling range bins around an angle of 8 degrees.

2.3 Mismatch of transmit-to-receive angle for one in 32 pulses

If the satellite altitude is 401km, a mismatch between the transmitting angle and receiving angle occurs in one pulse out of 32-averaging pulses, resulting in the following.

(1) The S/N is degraded by 10log(sqrt(32/31))=0.0689dB.

(2) Since one receiving pulse is from an adjacent angle bin, angle bin data is contaminated by 1/32, producing a 6dB degraded antenna pattern.

(3) Since the onboard processor averages 32 pulses even though 31 pulses are available, observed data must be corrected by referring to data of one previous angle bin.

2.4 Change of days to complete global sampling (Fig. 2).

350km---8 days,
404km---14 days,
401km---10 days,
407km---retrogression orbit

Covering every local time for diurnal cycle observation requires, 24.3 days around the equator for an altitude of 401km and 23.7days for a 350km altitude. This means that the altitude change does not seriously impact the diurnal change sampling. Note that the number of days for completing diurnal sampling around 35 degrees will change from 47.3 days to 48.5days.

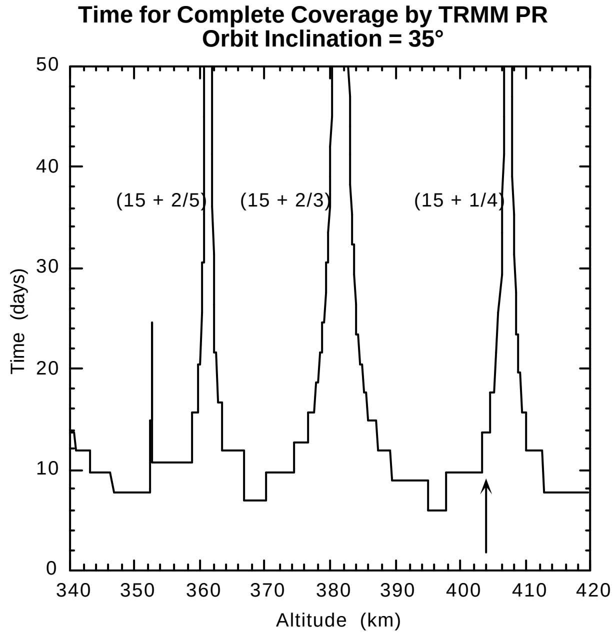

Figure 2. Days to complete global sampling for various altitudes.

(Courtesy of Dr. T. Bell)

2.5 Summary of impacts on PR observation

Table 1 summarizes the impacts on PR due to operating a 400km altitude.

Table 1. Summary of impacts on PR operation at 400km altitude.

Item	Details item	Note
Increase of distance (350 to 400km)	Degraded receiving power by 1.2dB.	
	Increased footprint size 4.3 to 5km	
	Change of Non-Uniform Beam Filling (NUBF) effect	
	Change of swath width from 220 to 245km	
	Overlapping foot prints along track direction	
	Satellite altitude should be less than 404km for observating surface echoes.	e.g. 401km
	At an altitude is 401km, PR may be able to lose high altitude echoes.	
	Contamination of rain echoes at the noise sampling bins.	401km altitude
Beam mismatch (1/32 pulse)	Degradation of S/N by about 0.07dB.	
	Contamination of adjacent angle bin echo.	
	Need to correct Z factor.	
Sampling efficiency	Days for global sampling increases from 8 to 10.	401km altitude
	Days for diurnal cycle observation increases by one.	

2.6 Modification of PR algorithms

For level 1 algorithms, the following modifications are needed.

(1) The range correction factor in 1C21 should be changed.
(2) On the “angle mismatch,” receiving power must be corrected by referring to the previous angle bin data.
(3) Alternative noise sampling range bins should be created in case rain echoes are contaminated at the current noise sampling bins.
(4) Clutter routines must be tuned and their tables modified.

Level 2 algorithm impacts are as follows.

(1) 2A21: The output will be influenced by the beam mismatching and the change of the PR beam incident angle.
(2) 2A23: The H-method and V-method must be tuned.

(3) 2A25: NUBF correction must be tuned.

Level 3 algorithm impacts are as follows,

(1) 3A25: No change. However, statistics such as storm height, rain probability and stratiform-convective ratio, that are determined by a given threshold value may change.

(2) 3A26: Modification is needed because of the change in rain probability.

3. Impacts on physical parameters

(1) Degradation of sensitivity

Degradation of rain detection and decrease of rain area occur. These cause lower echo top height statistics.

(2) Increased foot print size (worse resolution)

The increased footprint size may affect rain type classification and the correction of NUBF (affects R estimation).

(3) 401[TBD]km satellite altitude

Maximum observable altitude changes from 15km to 12km for the worst case, which happens near the equator.

(4) Leakage from adjacent angle bin

The leakage may cause rain to be detected when there is no rain echo. This effect causes bias in sigma-zero and R if not appropriate by corrected.

(5) Discrepancy between along track data spacing and across track data spacing

This may affect the statistics.

(6) Beaming on Earth sphere from 400km altitude

The incident angle to the Earth's surface changes, affecting sigma-zero statistics.

Note that these impacts are very small for studies using PR data. Also, many of them can be corrected with algorithm modification.