Status on the post-GPM mission study

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Introduction

- Since the launch of GPM/Core satellite in 2014, DPR has been working nominally with better performance than expected.
- Although the expected life time of GPM/Core satellite is more than 5 years, we need to prepare the future precipitation measuring mission as soon as possible.
  - It takes about 5 years even duplicate the GPM/Core satellite.
- We started the discussion on the post-GPM mission in the PMM application committee.
- Three types of missions were discussed.
  - DPR-2: upgrade the GPM/DPR
  - Small radar constellation: small satellite constellation (e.g. 4 satellites) with smaller size radar
  - Radar observation from geostationary orbit

Background

- Domestic situation
  - Basic Plan for Space Policy (on remote sensing satellites)
    - “insufficient efforts are being made for comprehensive utilization expansion and industry promotion policies, such as more efficient utilization of satellites via PPP and development of application industry, which creates added value through analyzing and processing data. “
    - No follow-on mission of GPM listed in the “Operation schedule.”
    - Promote public-private partnership (PPP) framework
- Situation in the US and Europe
  - US:
    - preparing a satellite with triple frequency radar for the decadal survey (NASA/GSFC and JPL)
    - rain observation micro-satellite mission is planed.
  - Europe:
    - EarthCARE satellite with 95-GHz radar (cloud profiling radar) will be launched in 2018.
    - studies on the future spaceborne radar (e.g. Doppler radar) has been started (ESA, CNES,)

Direction of the future precipitation mission

- **more contribution to society**
  - Upgrade GSMaP (better accuracy, faster data latency, nowcasting, easy-to-handle application software)
  - Use of radar data directly to the GSMaP
  - Ideally, continuous radar observation from space (like Himawari) is desired.
- **contribution to scientific issues** such as evaluation of the impact of the global warming, cloud-precipitation processes.
  - Progresses in both numerical models and observation are essential.
- **international collaborations**
  - GPM type scheme
  - Need voices of users from many countries/agencies to support the continuous precipitation observation from space
- **international expectations/responsibility**
  - WCRP grand challenges
  - IPWG recommendations

Requirements to the future precipitation radar

- Frequent sampling
  - wider swath observation
  - multiple satellite observation
  - observation from geostationary orbit
- Better sensitivity observation
  - weak precipitation (snow, orographic rain, etc.)
  - cloud-precipitation process study
  - 10 -20 dB improvement
- Better horizontal resolution
  - resoluble in-cloud structure
- Increase the observation parameters
  - Doppler velocity, polarimetric radar, etc.

Possible solutions of the future precipitation radar

- **DPR-2**:
  - upgraded DPR using current state-of-art technology (pulse compression, GaN device, etc.)
  - twice wider swath
  - 10-20 dB improvement
  - available to development now
- **small radar constellation**
  - single frequency low cost radars
  - minimum 4 low inclination satellites (3-6 hourly observation)
  - need to manufacture a proto type radar
- **observation from geostationary orbit**
  - hourly observation by radar
  - need basic studies on antenna , high power device etc.

DPR-2

- Upgraded DPR in terms of sensitivity, swath width and horizontal resolution.
  - 10-20 dB better sensitivity
  - twice wider swath
- Target launch year : 2023

		DPR	DPR-2		new technology	readiness
			requirement	estimation		
swath width	KuPR	245 km	495 km	495 km*		TRMM EOM
	KaPR	245 km	495 km	495 km*		
sensitivity	KuPR	15 dBZ	0 dBZ	7.9 dBZ *	pulse compression GaN device	Study by NICT commercial parts
	KaPR	10 dBZ（HS） 16 dBZ（MS）	-10 dBZ	9.4 dBZ*	pulse compression	Study by NICT
vertical resolution	KuPR	250 m	250 m	250 m	-	-
	KaPR	500 m（HS） 250 m（MS）	250 m	250 m	-	-
horizontal resolution	KuPR	5 km	2.5 km	2.5 km*	spatial over-sampling	TRMM EOM
	KaPR	5 km	2.5 km	2.5 km*		

*: To achieve the required sensitivity, trade-off study among the swath width and spatial over-sampling is needed.

small radar constellation (1/4 Ku-PR)

- Small satellite with smaller radar.
- Consist of four (4) satellite with low inclination
- High satellite altitude for very wide swath but larger horizontal resolution

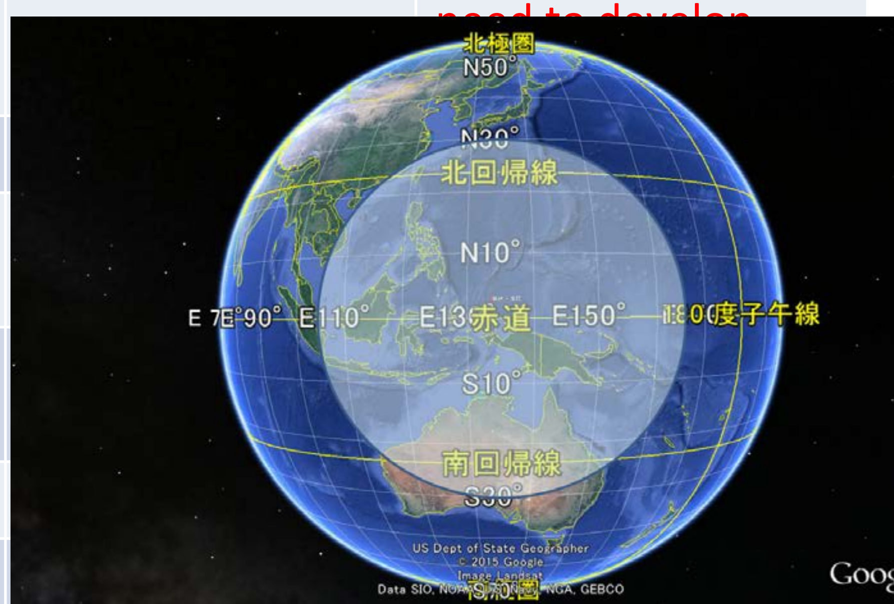
	KuPR	1/4 KuPR	new technology	readiness
Altitude	400 km	800 km		
Antenna elements	128	64		need to develop a prototype
Antenna length	2.1 m	1.5 m	smaller antenna	
Peak power	1024 W	969 W	GaN power device	commercial parts
Swath width	245 km	861 km		TRMM EOM
Sensitivity	15 dBZ	20.3 dBZ *	Pulse compression GaN power device	Study by NICT Ground based radar
Vertical resolution	250 m	250 m	-	-
Horizontal resolution	5 km	22 km (Nadir)* 28 km (Edge)*		

*: To achieve the required horizontal resolution, trade-off study between the sensitivity and spatial over-sampling is needed.

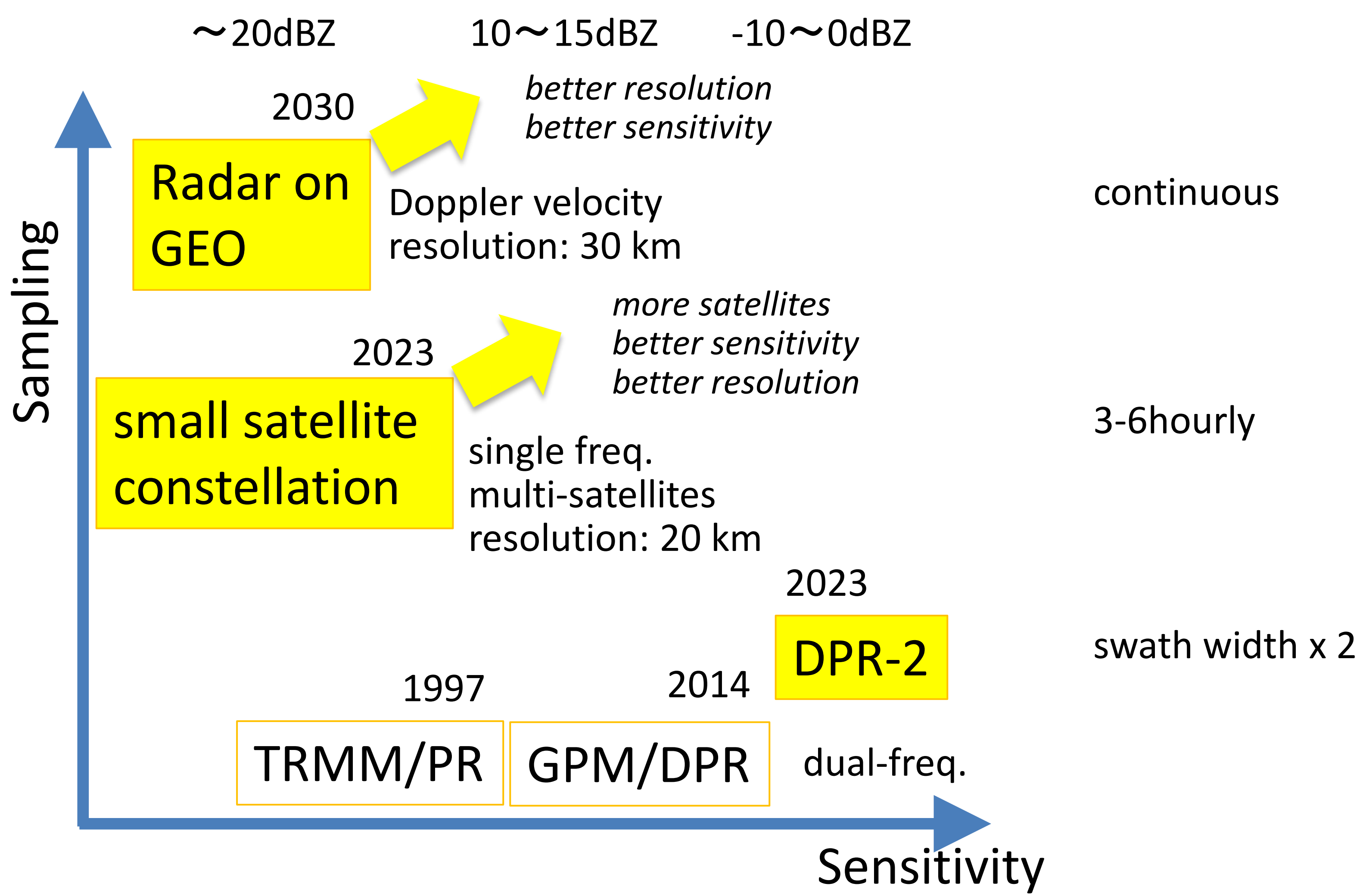
Precipitation Radar on a geostationary satellite (GPR)

- Application of technologies from Space Solar Power System (SSPS)
- GPR can achieve continuous precipitation observation over large area.
- Technological issues are large size antenna and the satellite bus.
- Observational issues are sensitivity and horizontal resolution as well as operation procedure.

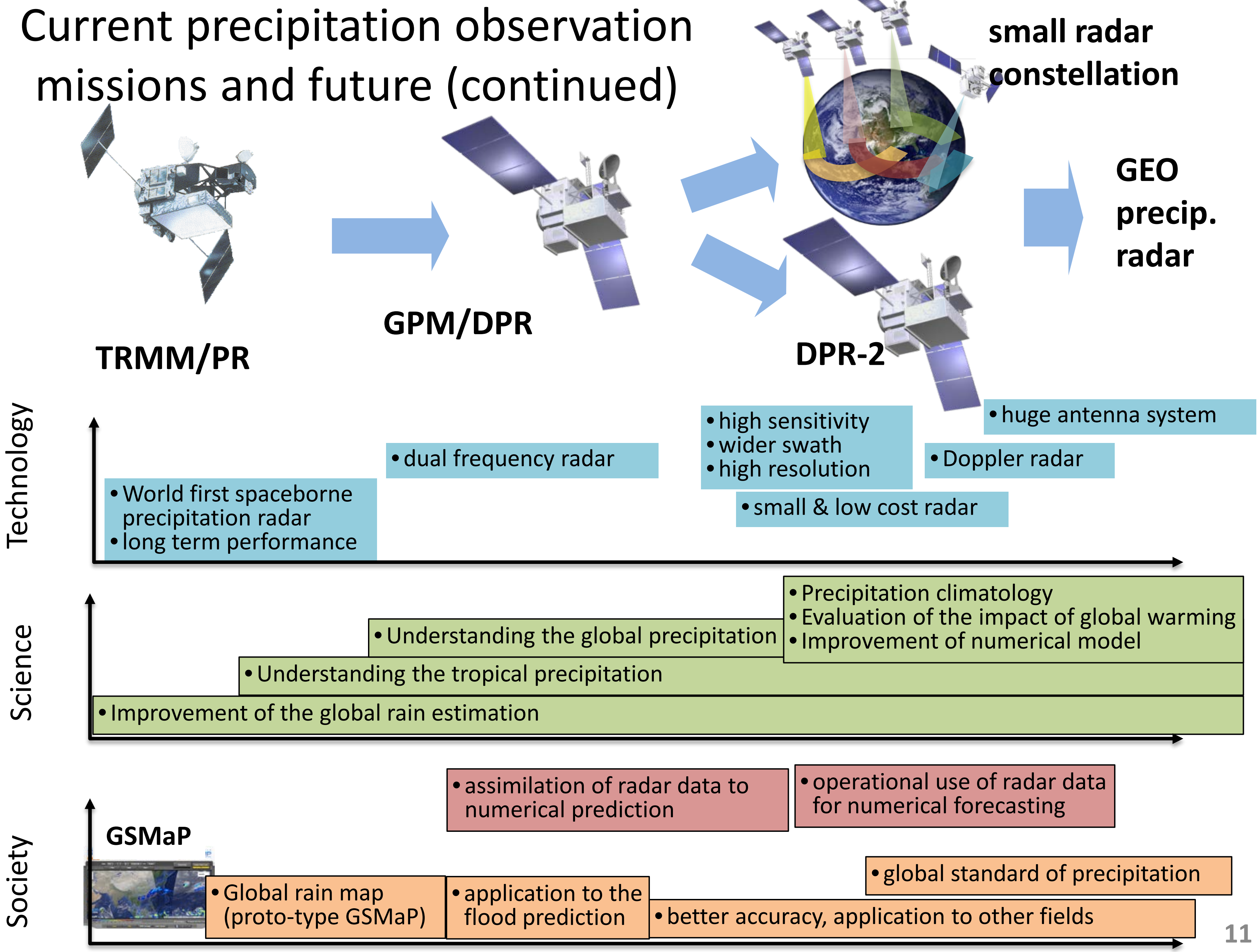
	KuPR	GPR	new technology	readiness
Satellite altitude	400 km	35786 km		development of the large size bus (SSPS)
Antenna aperture	2 m	～35 m		need to develop
Peak power	1024 W	5000 W		
Swath width (observation area)	245 km	Lat. range : TBD Lon. range: TBD		
Sensitivity	15 dBZ	20 dBZ		
Vertical resolution	250 m	250 m		
Horizontal resolution	5 km	30 km		



Current precipitation observation missions and future



Current precipitation observation missions and future (continued)



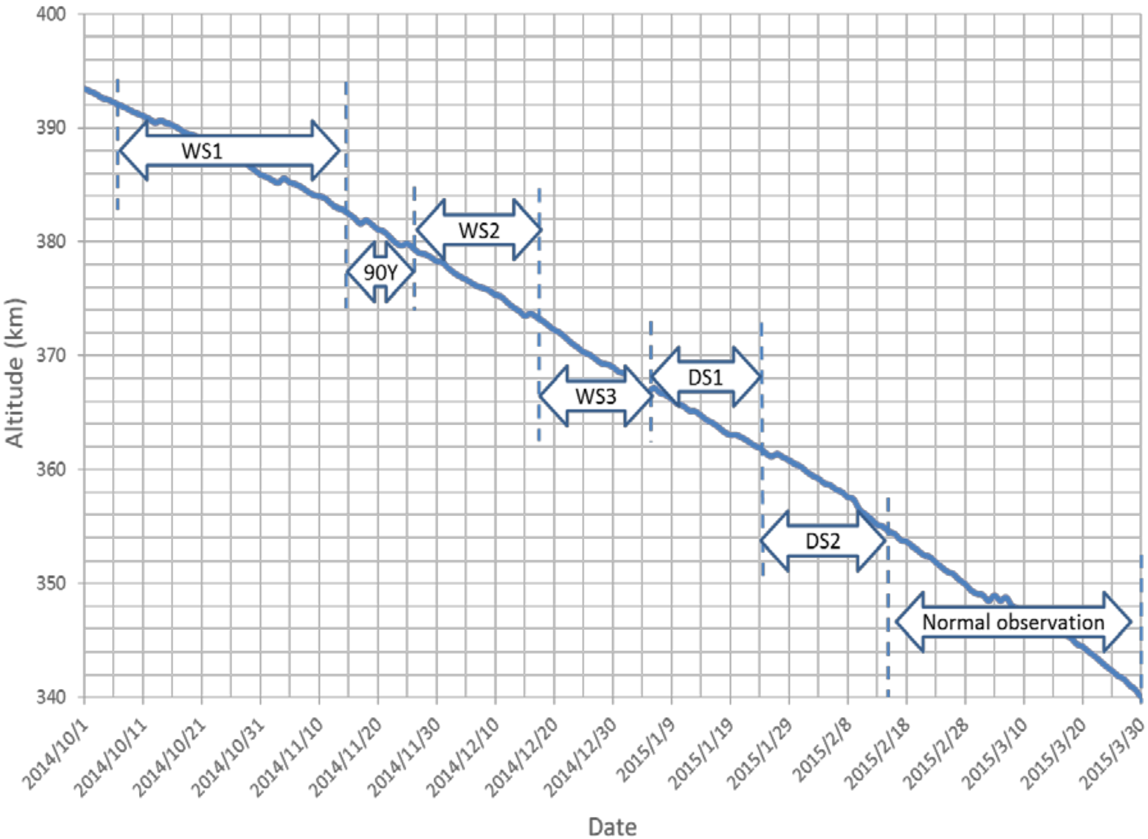
TRMM/EOM (end of mission) Experiment (1)

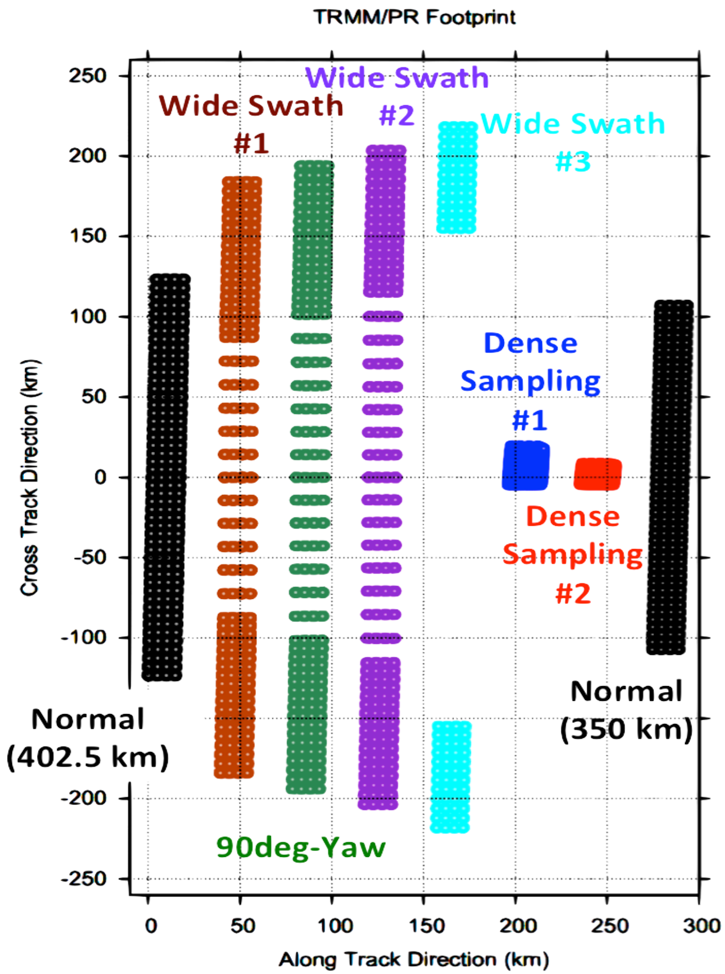
(overview)

- TRMM satellite started to descend in June 2014 because of no fuel remained to maintain the satellite altitude.
- During the descent, special experiments of the Precipitation Radar were implemented.
  - wide swath (WS1, 2, and 3) --- Nov. to Dec., 2014 (1.5 months)
  - 90-degree yaw maneuver (90Y) --- 11 days, from Nov. 15 to 25, 2014.
  - dense sampling (DS1 and 2) --- Jan. 5 to Feb. 12, 2015
- PR stopped operation on 31st March, 2015.

TRMM/EOM experiment (2)

(experimental schedule and swath width)



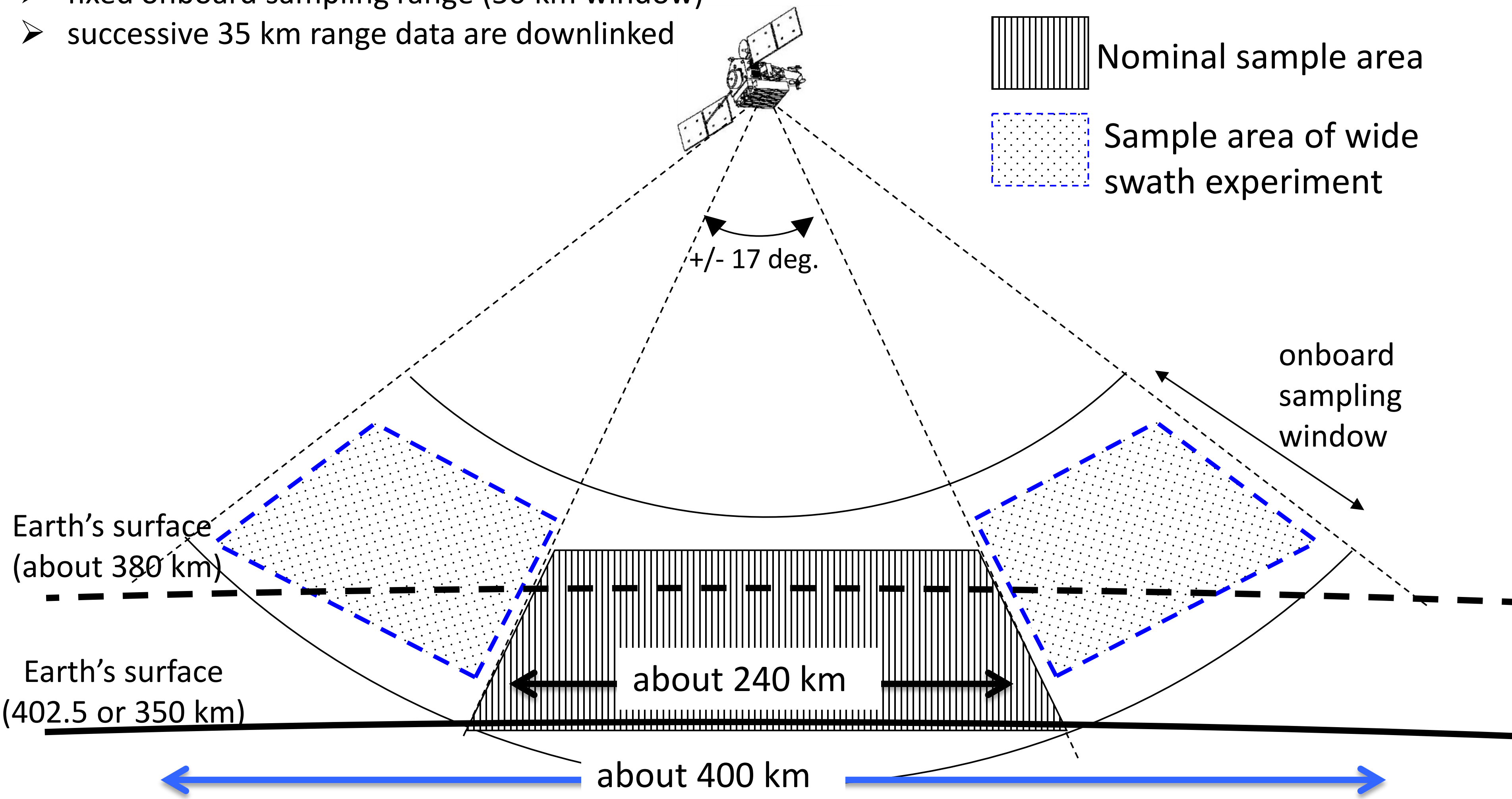


TRMM/EOM experiment (3)

cross track data sampling geometry

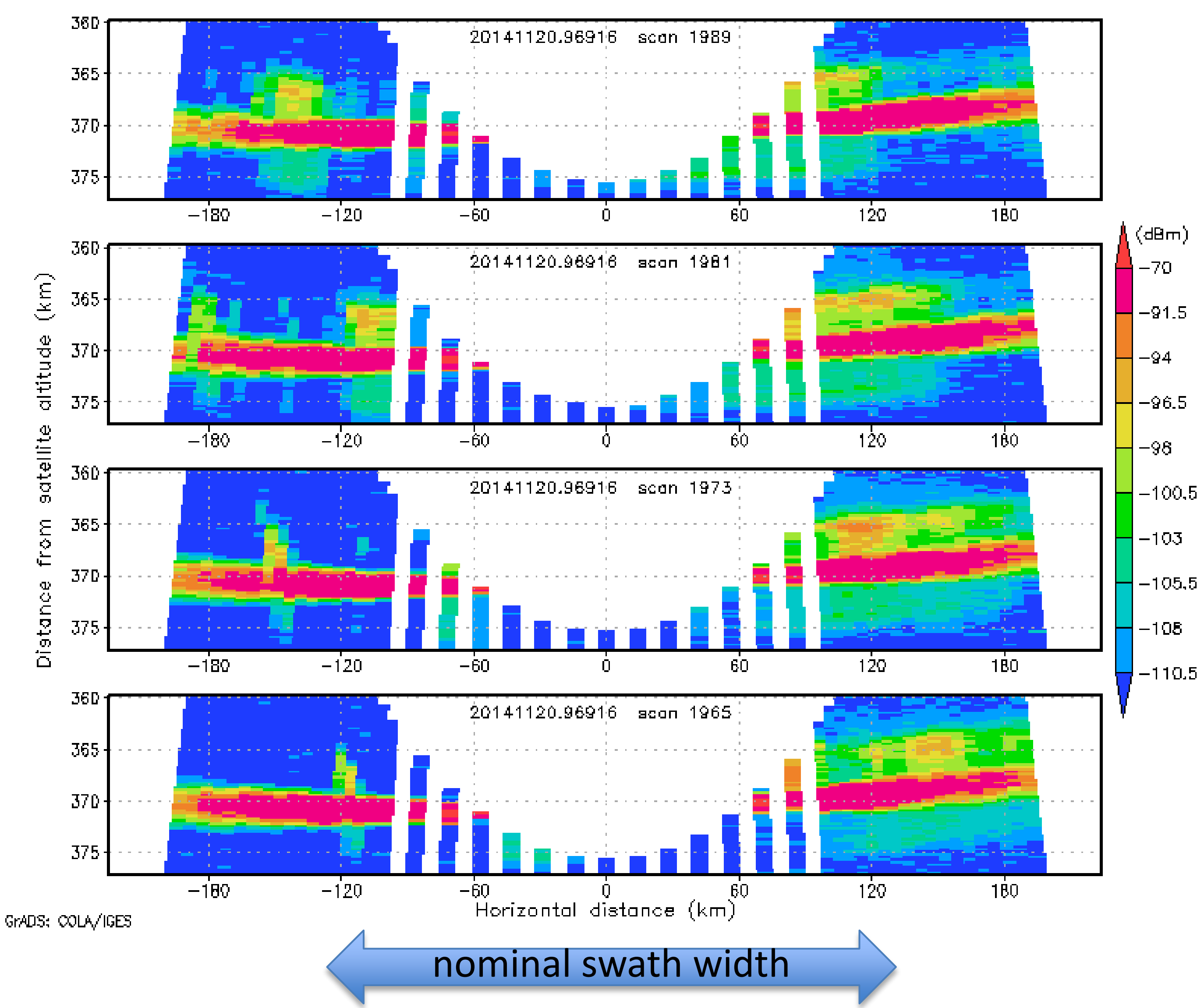
TRMM/PR data sampling (constraints for range/angle bin settings):

- 49 angle bins for one scan
- fixed onboard sampling range (50 km window)
- successive 35 km range data are downlinked



TRMM/EOM experiment (4)

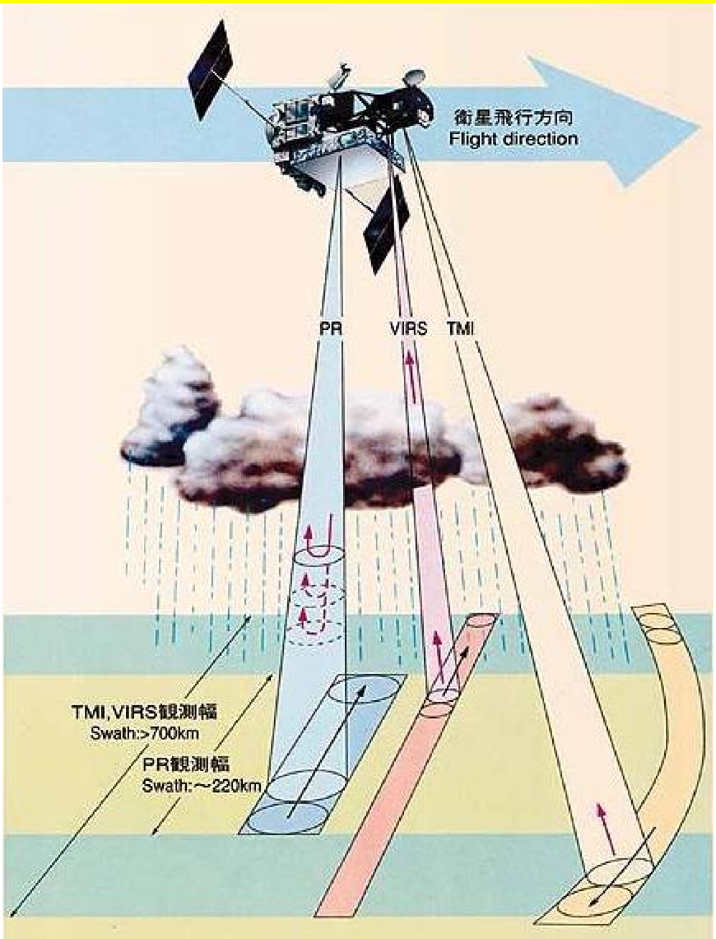
(cross-track vertical cross section ---wide swath experiment)



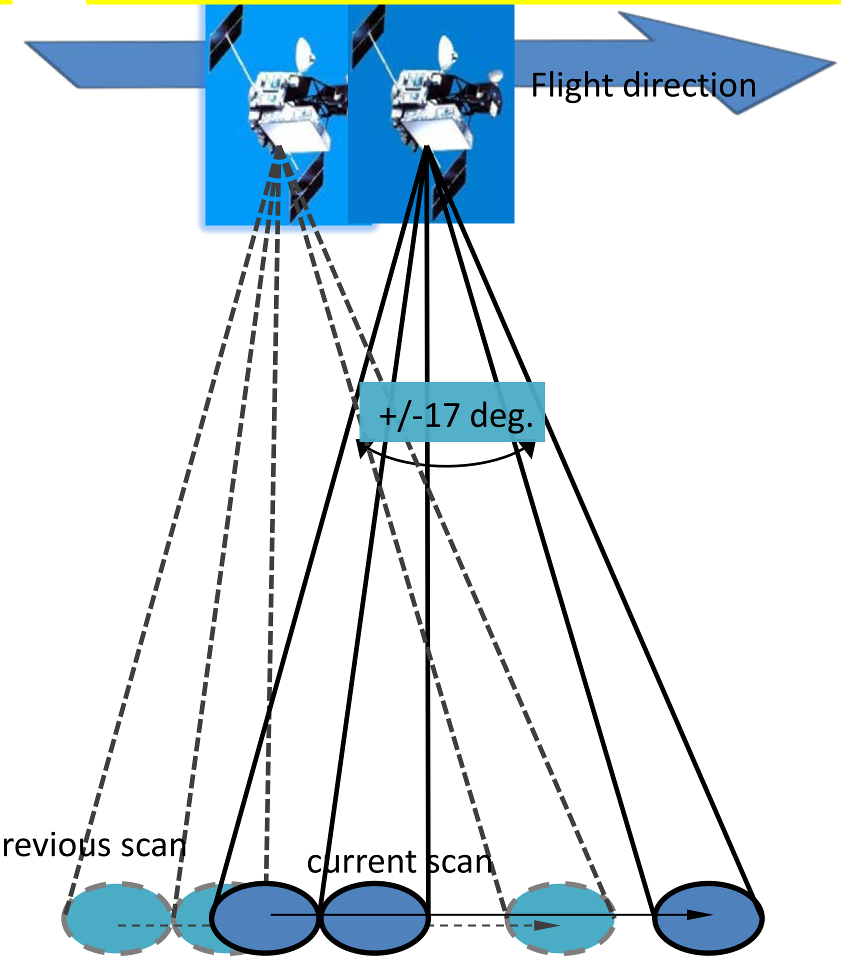
TRMM/EOM experiment (5)

90 deg. yaw observation (schematic image)

Nominal observation(cross-track scan)



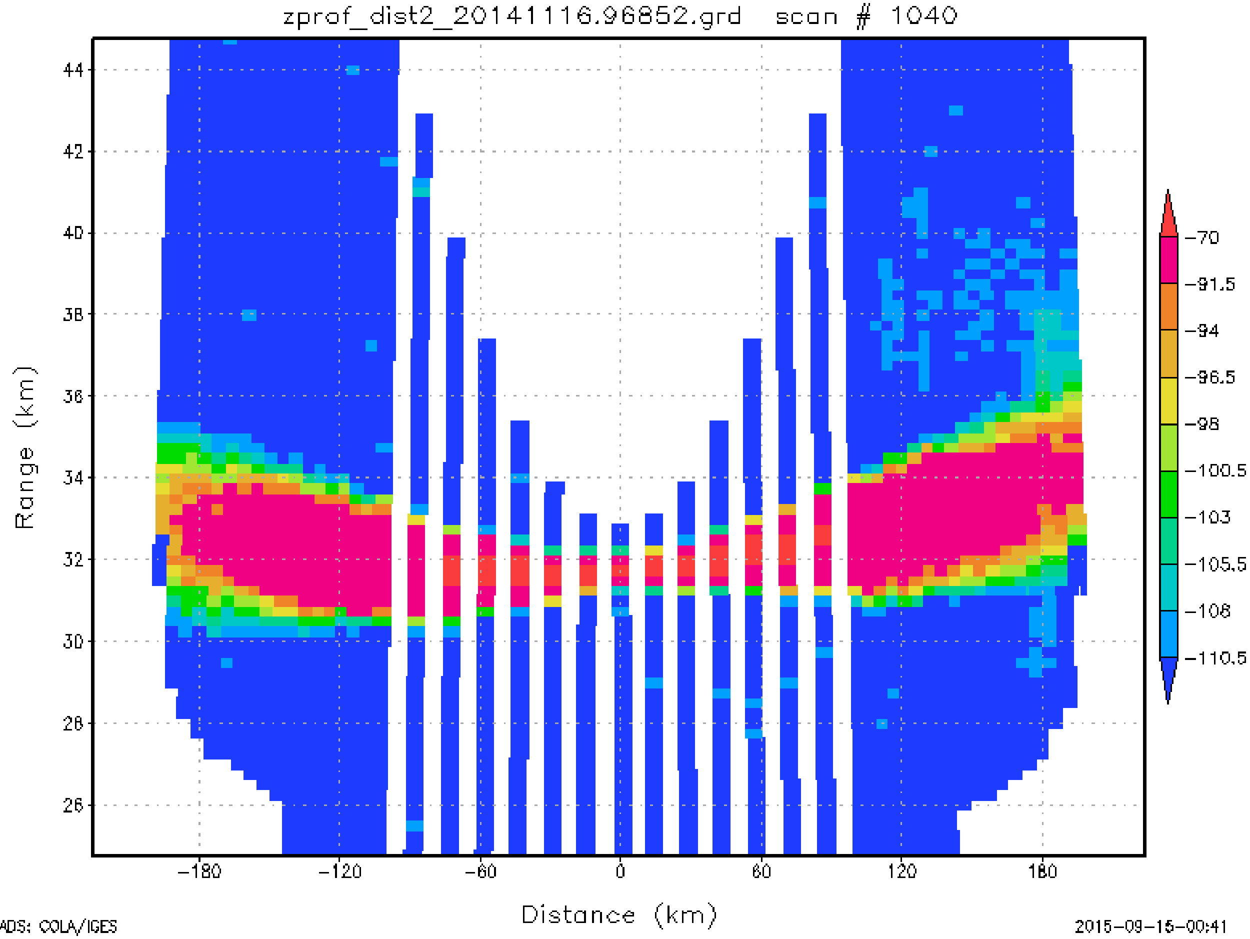
90 deg yaw (along-track scan)

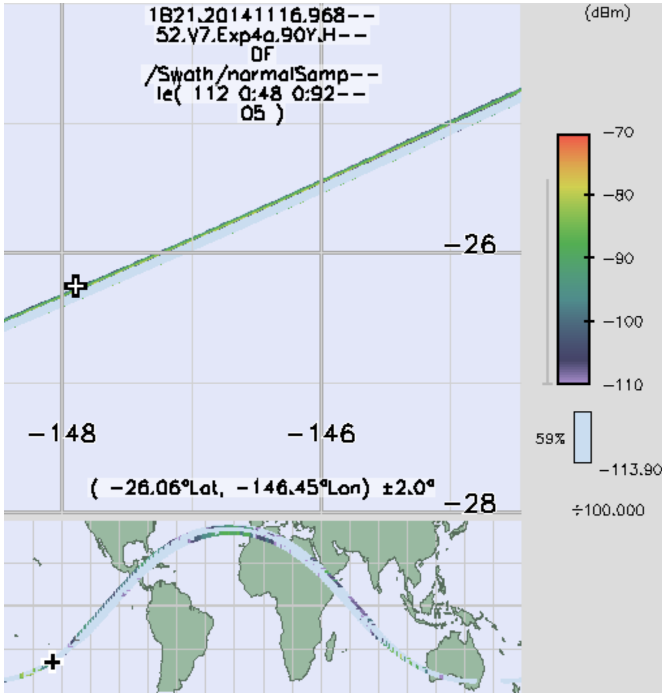


11 days (November 15 to 25, 2014), 4 times a day, and 20 minutes for each experiment (total 880 minutes).

TRMM/EOM experiment (6)

90-degree Yaw examples (Nov. 16, 2014)



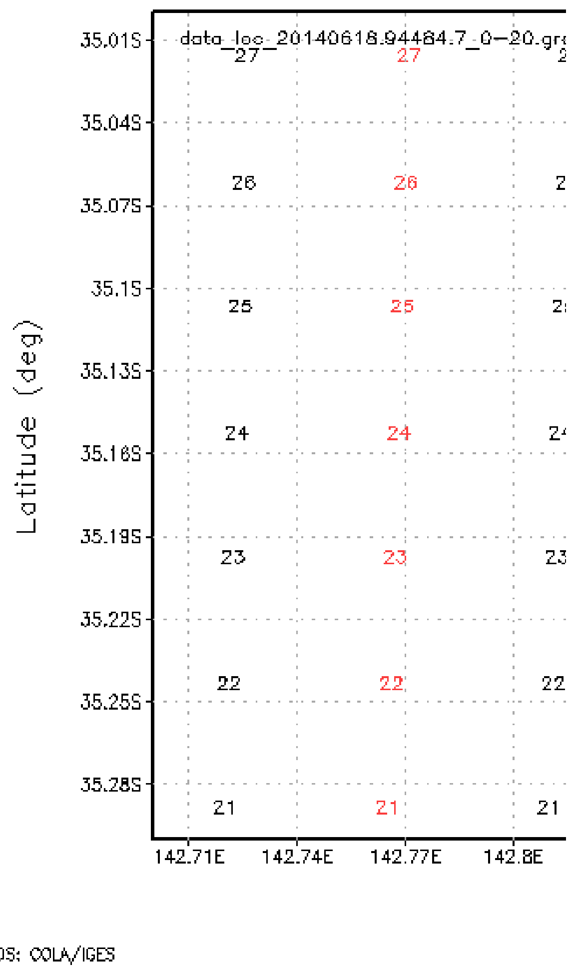


- rain echo moving right to left

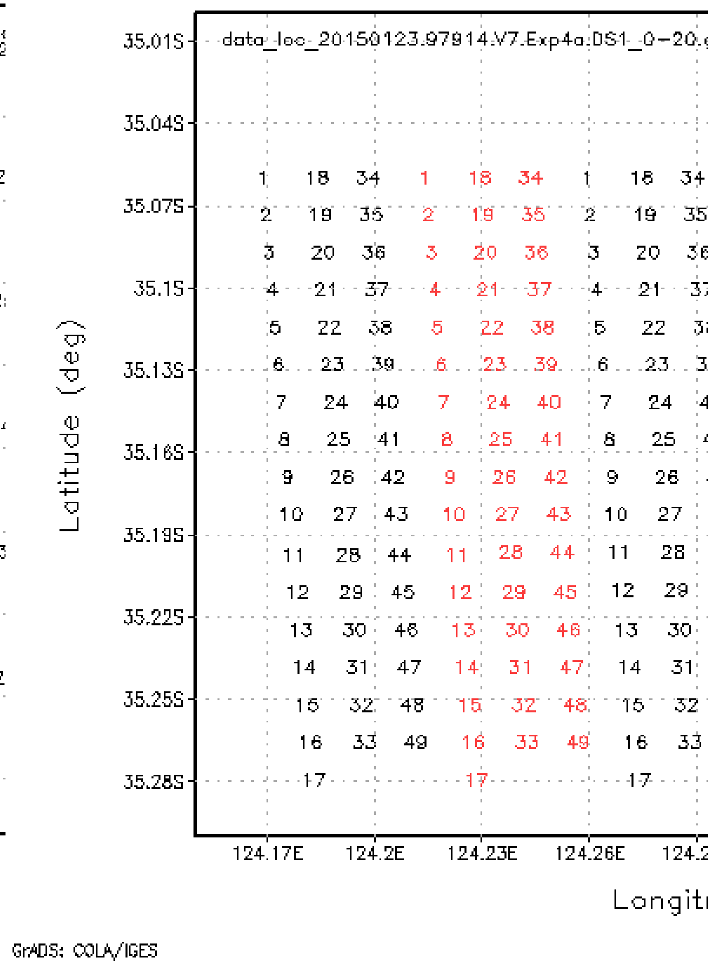
TRMM/EOM experiment (7)

Dense sampling (DS1= 1/3, DS4:1/4)

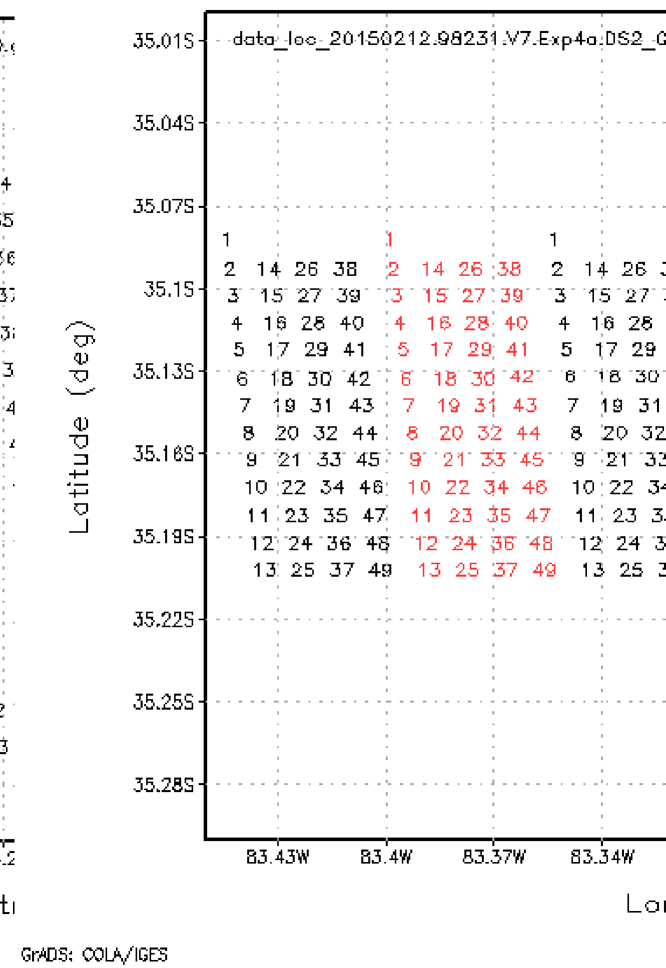
Normal



Dense (1/3)



Dense (1/4)



TRMM/EOM experiment (8)

Dense sampling case (x4) DS2