Comparative Verification of Return Rate on GNSS LRA

JAXA Flight Dynamics Team

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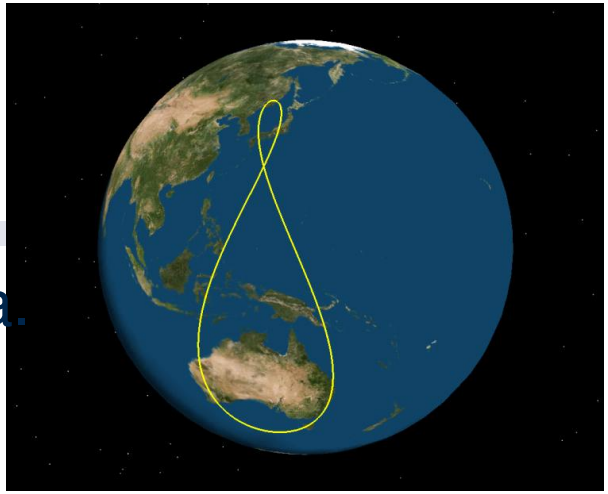
QZS-1 as SLR Target



QZS-1 is RNSS around East Asia and Oceania.

Semimajor axis 42164 km → Same as GEO

Inclination 43 deg → QZS flies the sky dynamically

→ Slant Range is longer than GEO

Except Luna ranging, QZS-1 is farthest target.

QZS-1 is not stay same position.

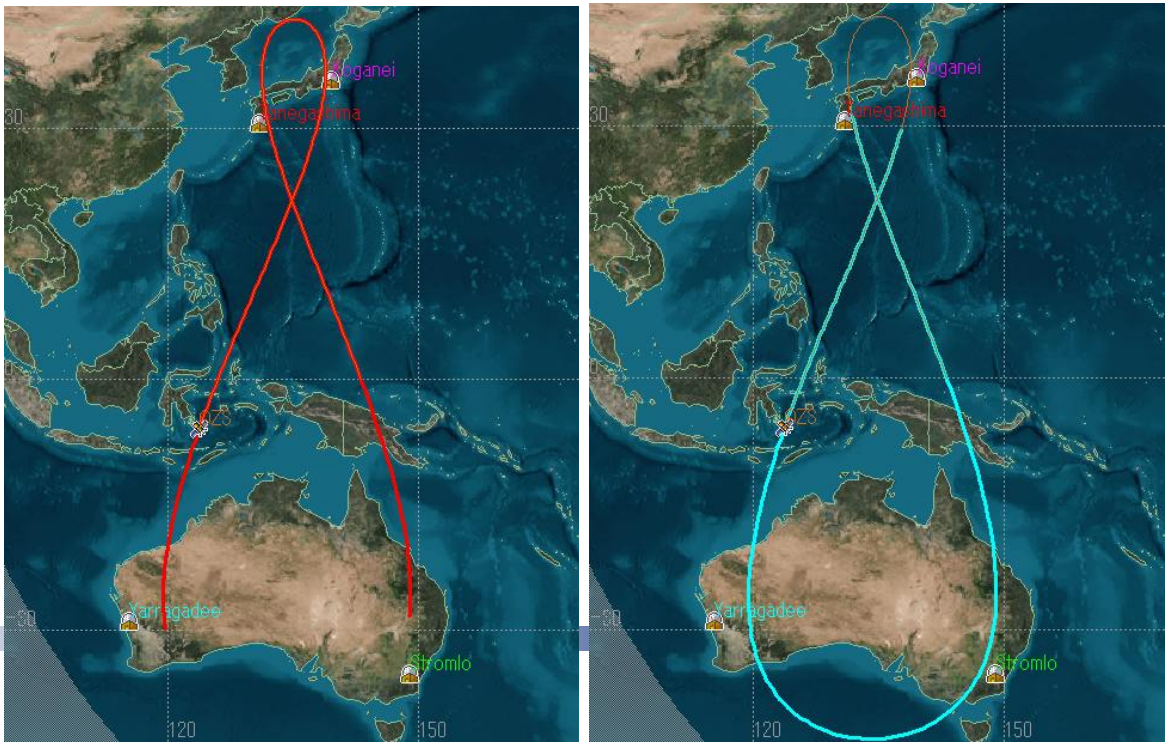
→ QZS is challenging target.

Link Analysis for QZS-1 LRA

1. SLR Stations

   Since QZS orbit was designed for western pacific ocean area, SLR stations that can track QZS are limited.

   Moreover, for each SLR stations, there is unobservable time everyday.



Link Analysis based on ETS-8

(1) Summary of ETS-8 (GEO) Tracking

SLR Station	Return Rate (%)	Note
Tanegashima	5 % to 15 %	10Hz fire, 250mJ laser
Koganei	typically 1%	20Hz fire, 50mJ laser
Yarragadee	1 % to 3 %	5Hz fire, 100mJ laser
Mt. Stromlo	0.1 % to 1 %	60Hz fire, 21mJ laser
Changchun	0.1% to 1 %	20Hz fire, 150mJ laser

(2) Basic Concept for LRA performance

Though range for QZS is farther than one for ETS-8, JAXA expects that QZS LRA has same performance as ETS-8 even though farthest range of QZS.

Link Analysis

(3) Worst case and ,at least, necessary CCR number

SLR	Max QZS Range	Elv Ang	E8 Range	Ratio
Tanegashima	39,146 km	80	37,294 km	1.05
Koganei	38,906 km	75	37,139 km	1.04
Yaragadee	41,872 km	20	37,804 km	1.11
Mt. Staromlo	41,590 km	20	37,229 km	1.12

LRA on ETS-8 consists of 36 cubes (6*6 array). JAXA calculated equivalent LR of ETS8 for QZS. At first, I estimated necessary cube number for QZS,

$$N = 36 \times \left(\frac{11}{10}\right)^4 = 52.7$$

JAXA needs, at least 53 CCRs on QZS, to obtain similar return with ETS8.

ETS-8

6*6 array

Note: ETS LRA has 36 CCRs

LRA on QZSS s/c

In order to perform precise orbit determination, QZS mounts big letro reflector array (LRA).

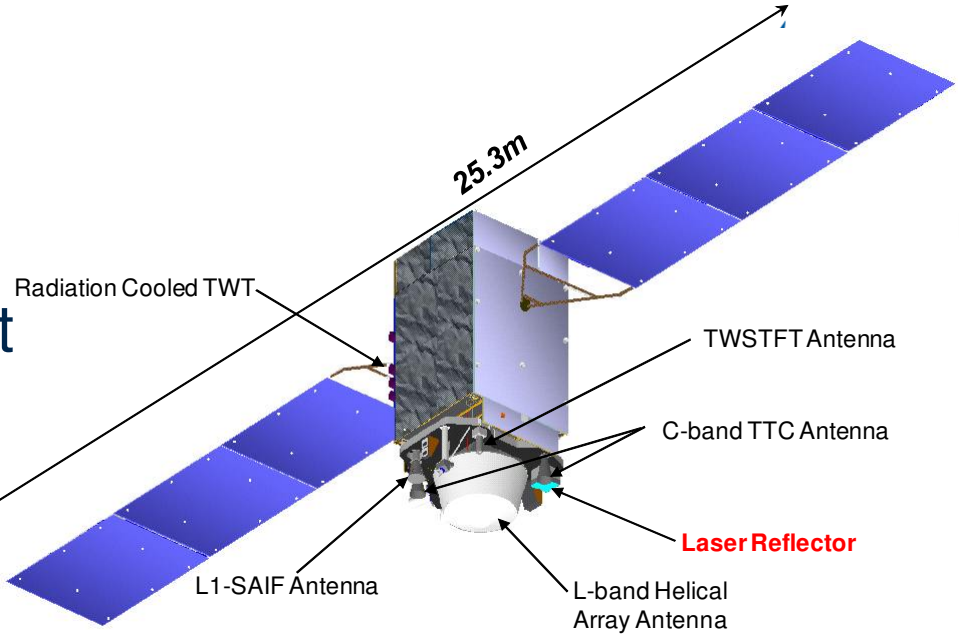
JAXA/HTSI developed new LRA.
- using heritage during ETS-8 LRA

JAXA expects that QZS LRA has same performance as ETS-8 even though farthest range of QZS.

ETS-8

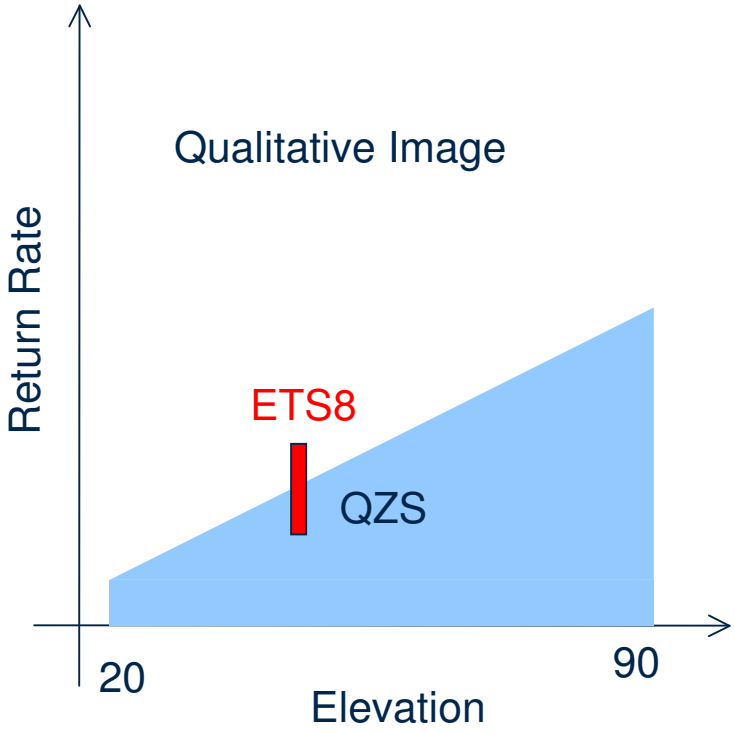
6*6 array

7*8 array



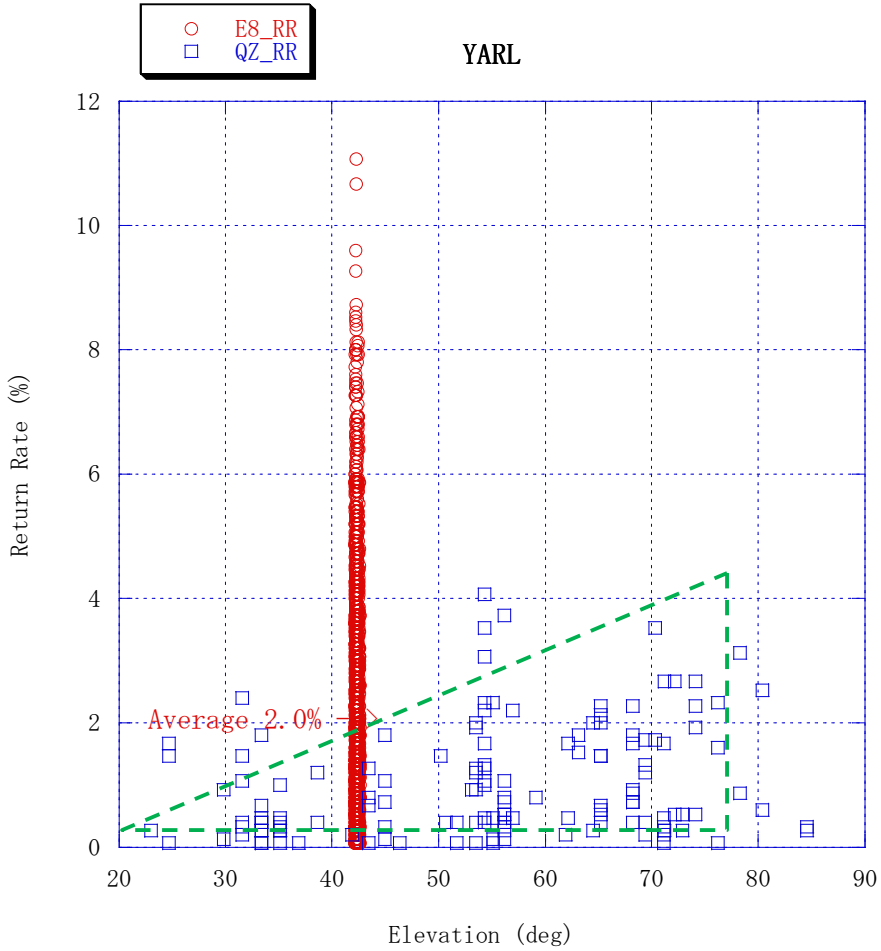
Satellite Configuration on Orbit

Observation Results



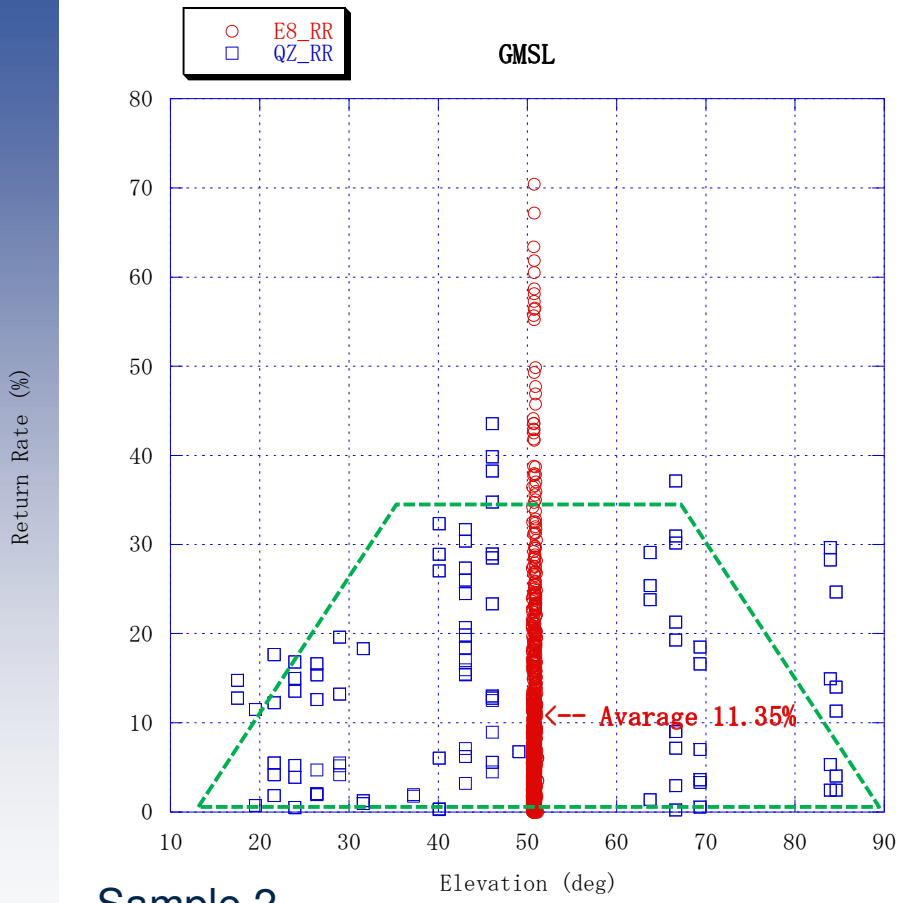
Sample 1

Observation Results at YARL

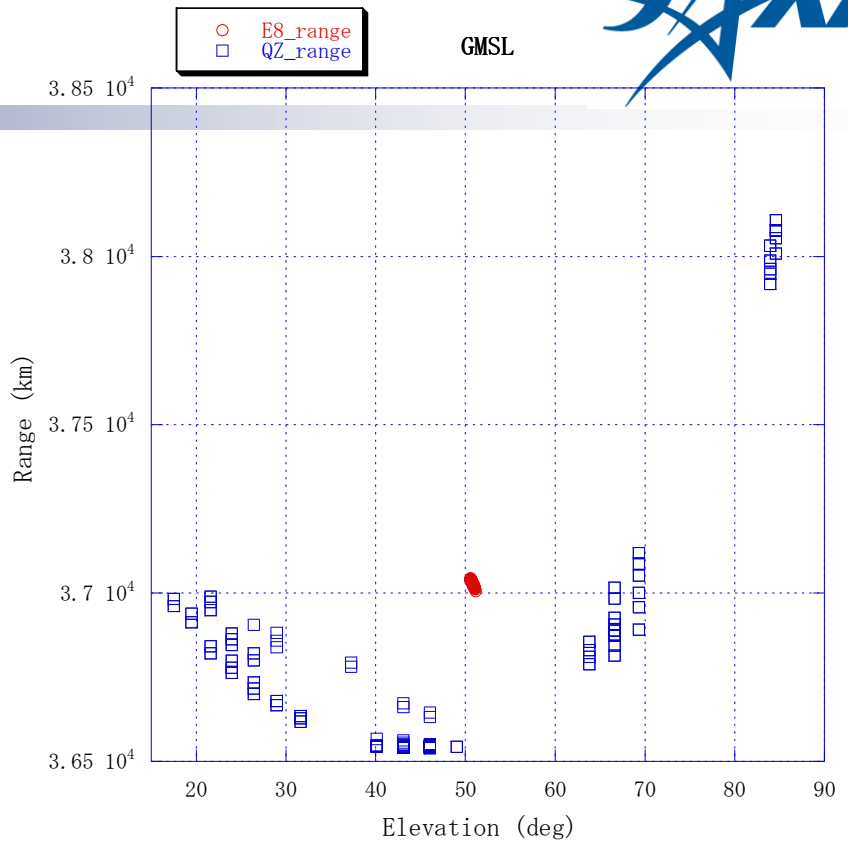


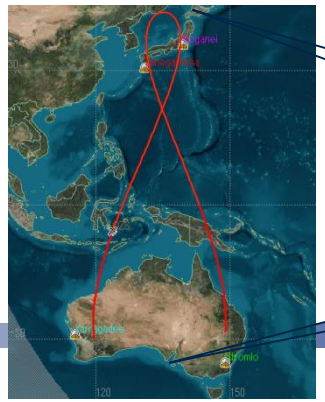
Observation Results

Observation Results at GMSL



Sample 2





Summary1 : QZS-1 LRA Evaluation

LRA on QZS-1 works well as expected.

ILRS QZS-1 campaign leads this presentation.

I would like to take this opportunity to thank you for your continuing good service by ILRS.

[Additional Information]

QZS-1 will start the regional satellite navigation service soon. In order to decide precise orbit and manage QZS-1 clock bias, we hope that SLR stations will track QZS-1 continuously, by similar priority of other GNSS such as GPS, GIOVE-B and Compass-M1.

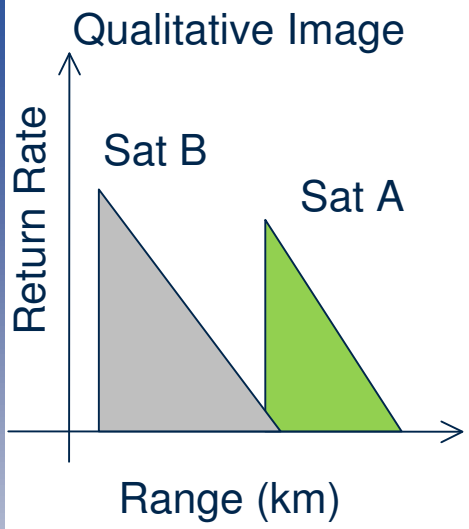
2. LRA SPEC at high orbit

LRA at high orbit falls into two categories, Non coating or Coating.

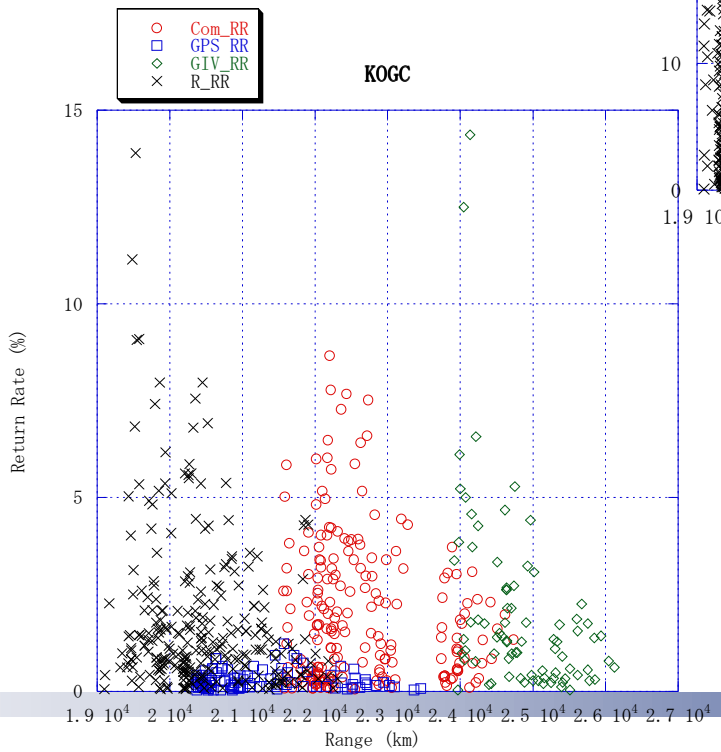
Typical Satellites are listed below;

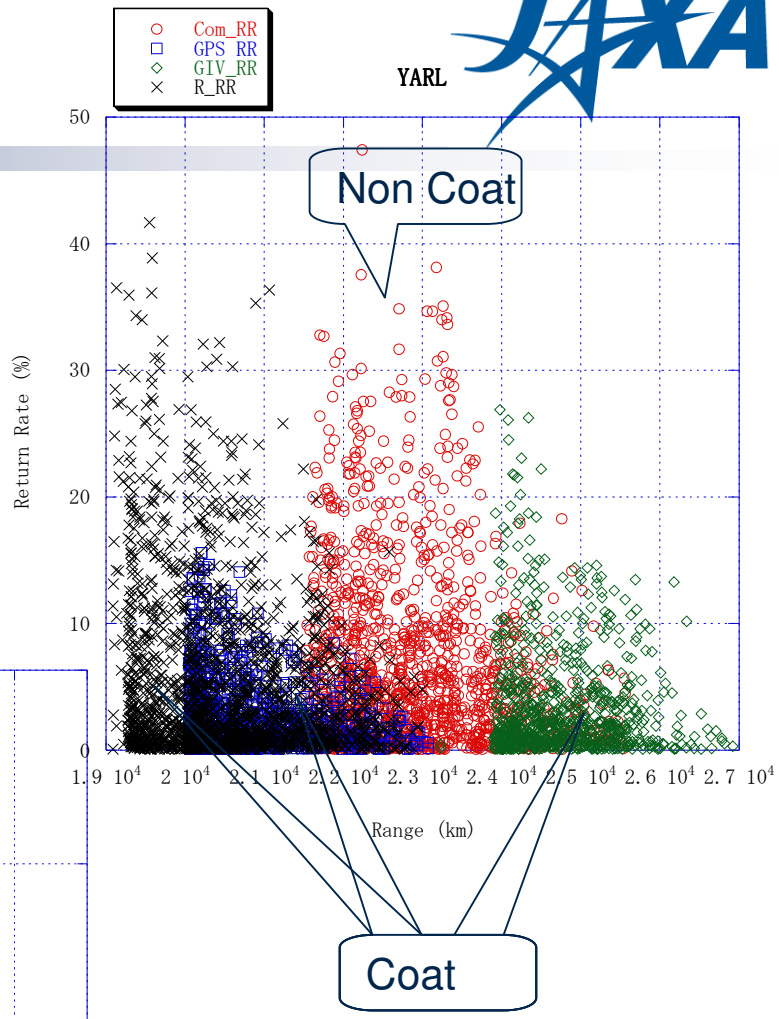
	Sat Name	Altitude(Km)	LRA	Note
Non Coat	ETS-8	36,000	36 CCRs diameter 40.6 mm	GEO JAXA
	QZS-1	32,000-40,000	56 CCRs diameter 40.6 mm	RNSS JAXA
	Compass-M1	21,500	42 CCRs diameter 33 mm	GNSS Chinese Defense Ministry
Coat	GPS36	20,030	32 CCRs diameter 28.6 mm	GNSS United States DOD
	GLONASS-102	19,140	396 CCRs hexagonal 28.3mm	GNSS Russian Federation Ministry of Defense
	GIOVE-B	23,916	67 CCRs diameter 27 mm	GNSS EU/ESA
	Etalon-2	19,135	2140 CCRs hexagonal 28.3mm	Passive Geodetic Satellites Russia

Range & Return Rate



Example 1





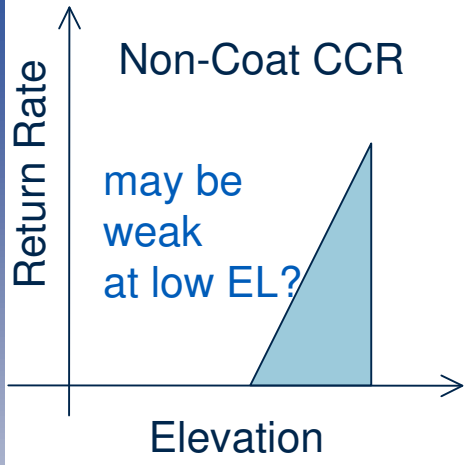
From(Range vs. RR)

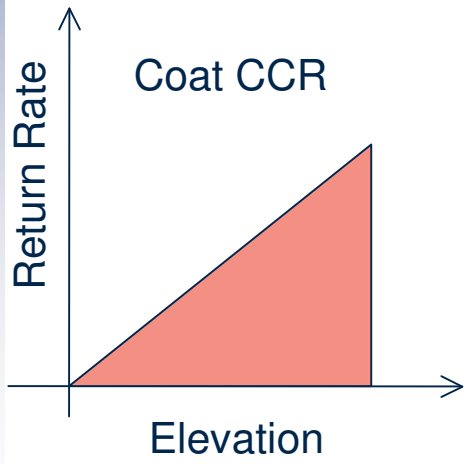
Glonass
V
Compass-M1
V
GIOVE-B
V
GPS

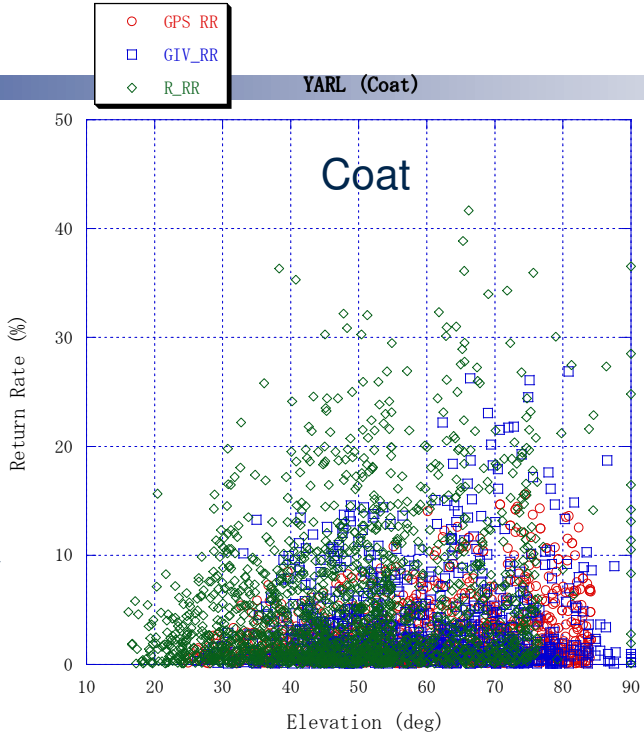
Comparison Result by RR
No difference between
Coat and Non-Coat.

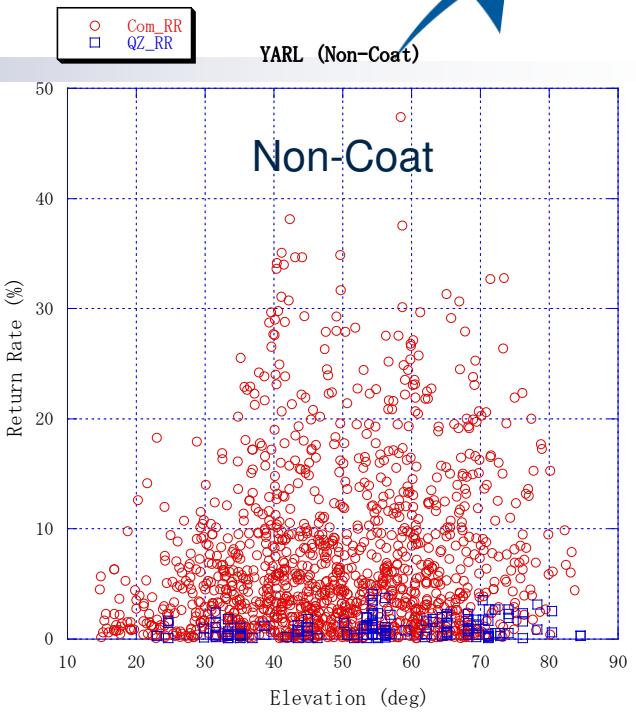
Elevation & Return Rate

Qualitative Image





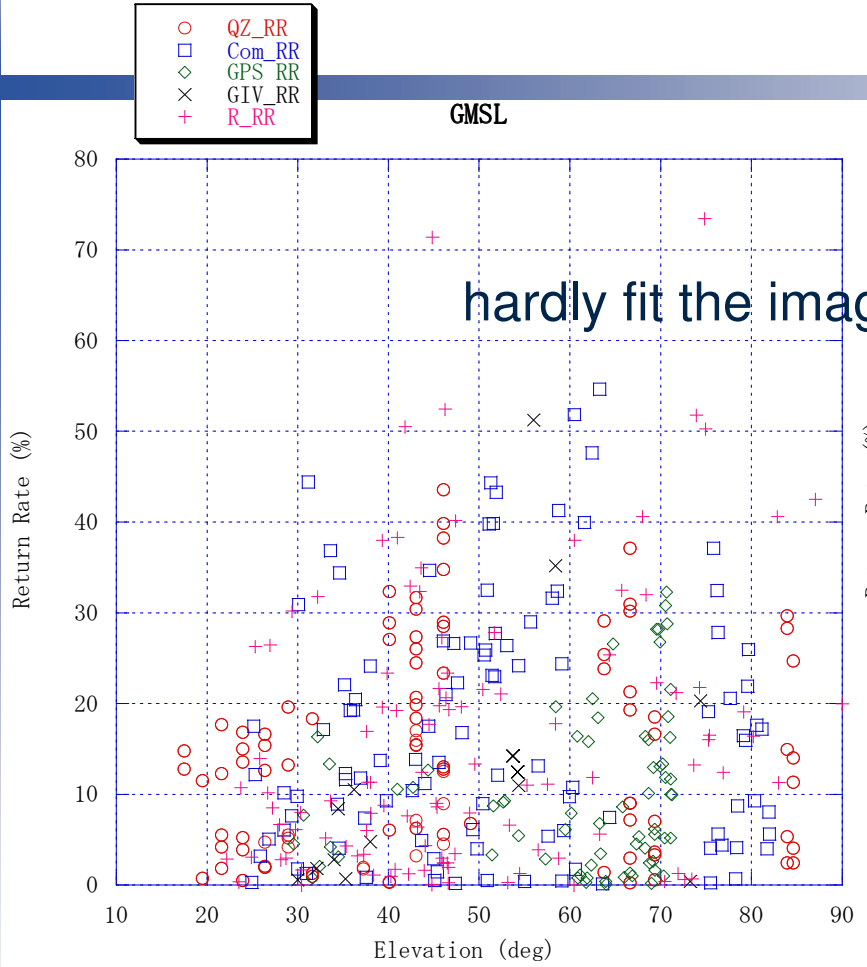


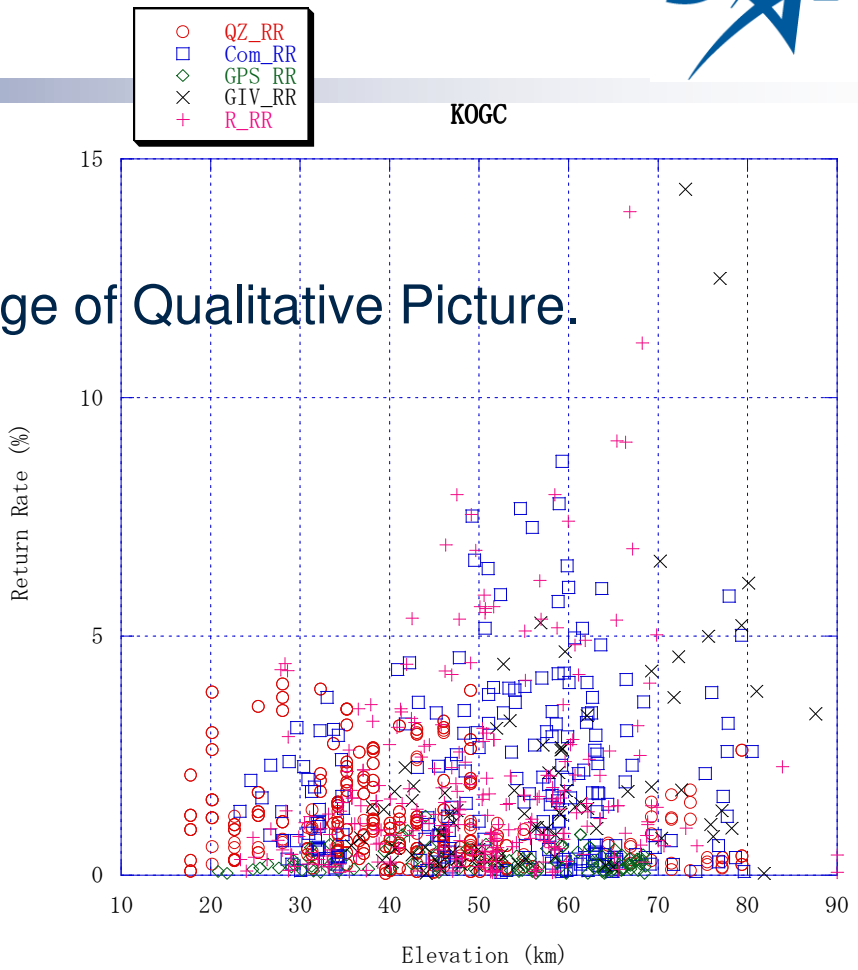


Example 1

hardly fit the image of Qualitative Picture.

Elevation & Return Rate(2/2)





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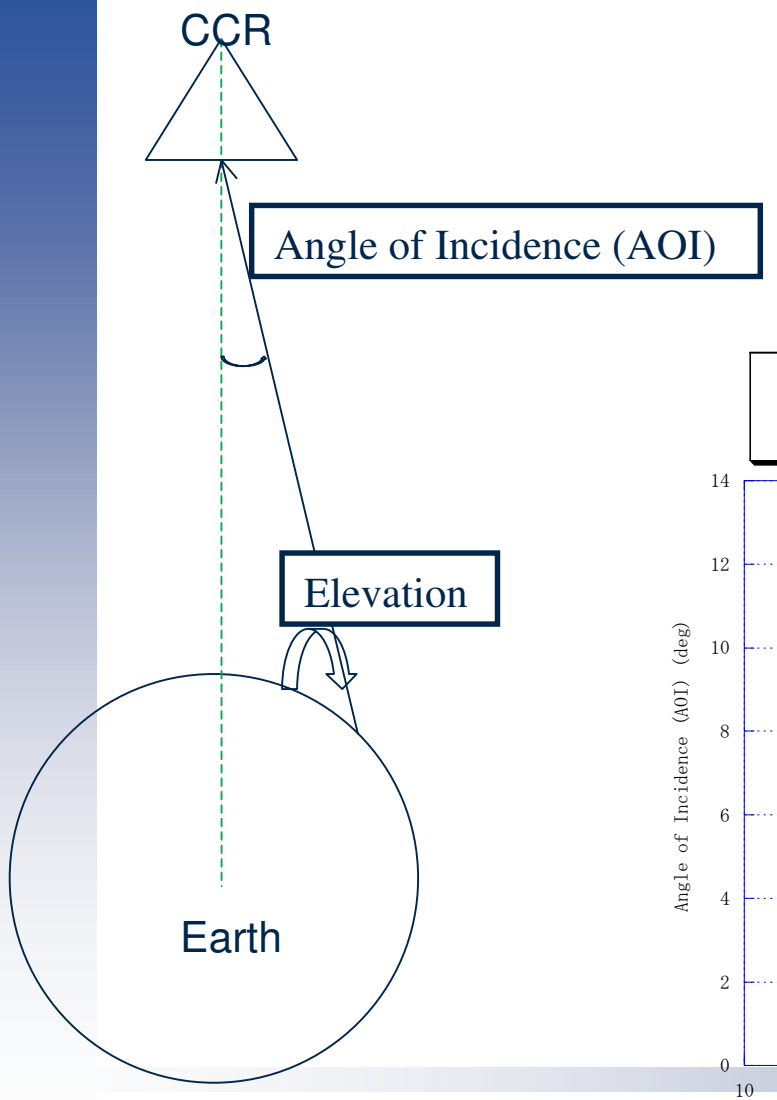
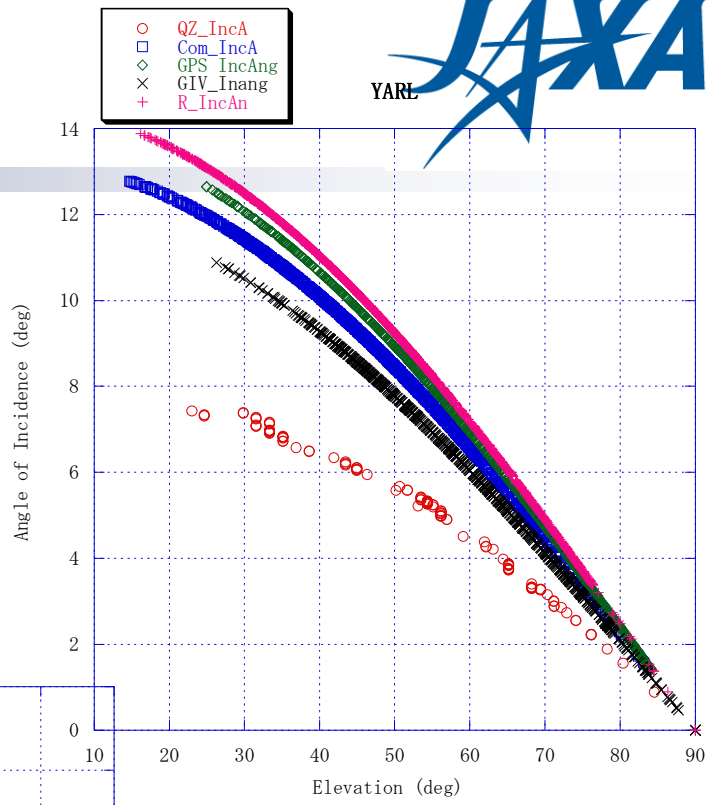
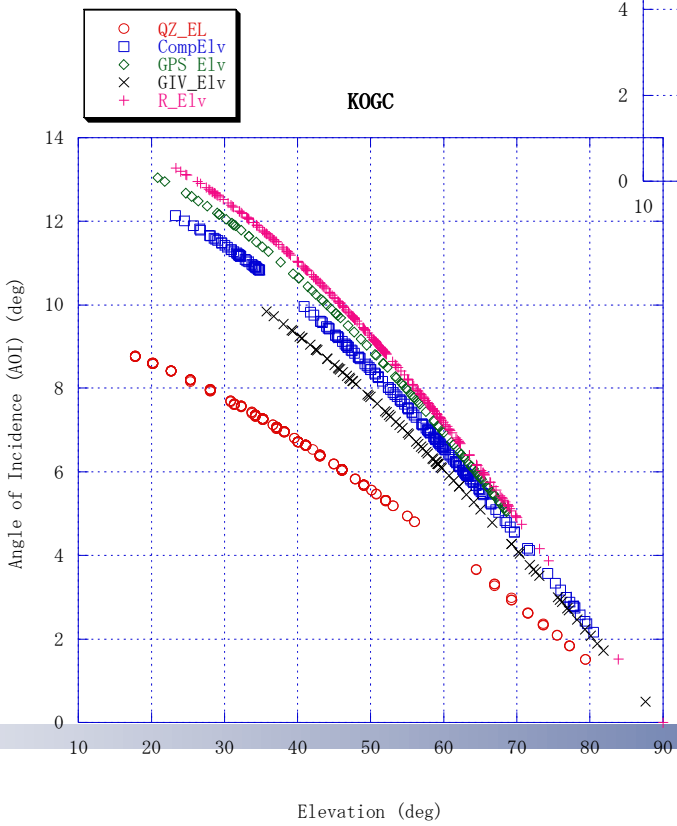
Conclusion 2 from (EL vs. RR) for GNSS
There are no difference between Coat and Non-Coat CCR.

Elevation Angle -→ Incidence Angle

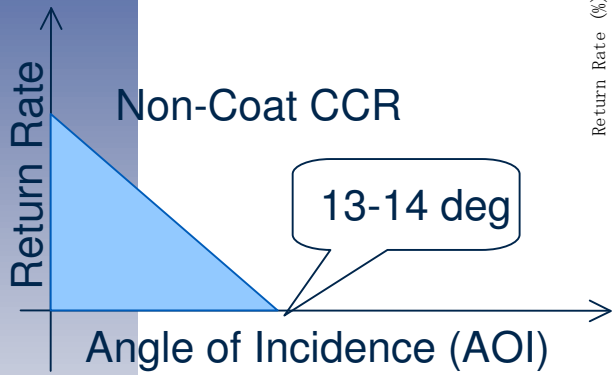


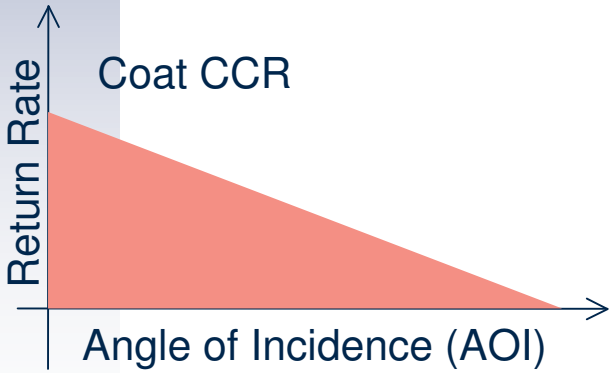


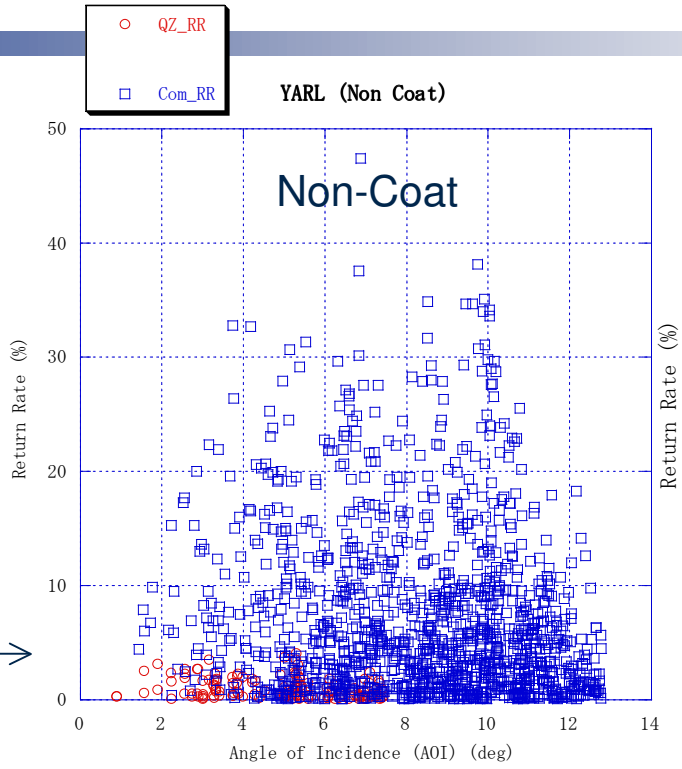


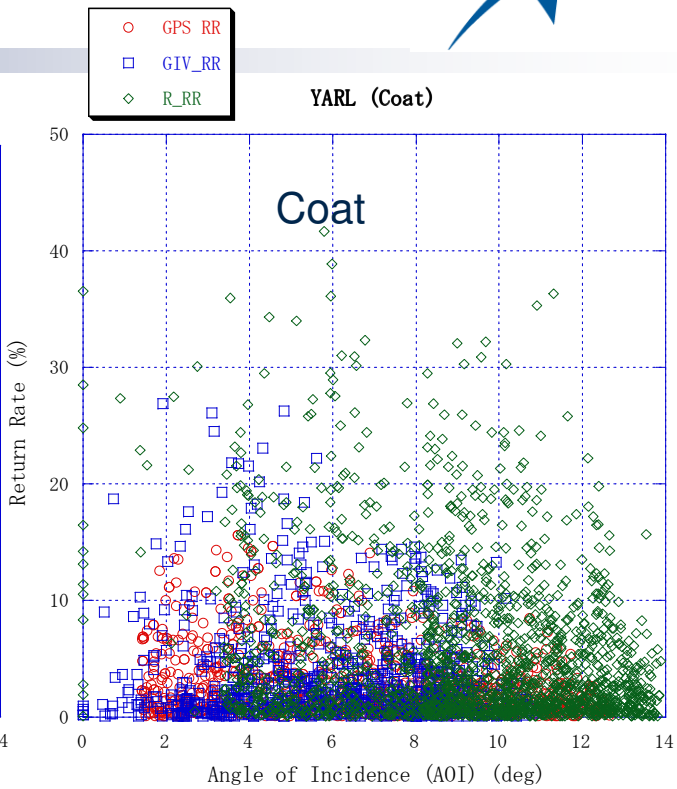
Incidence Angle & Return rate (1/2)

Qualitative Image



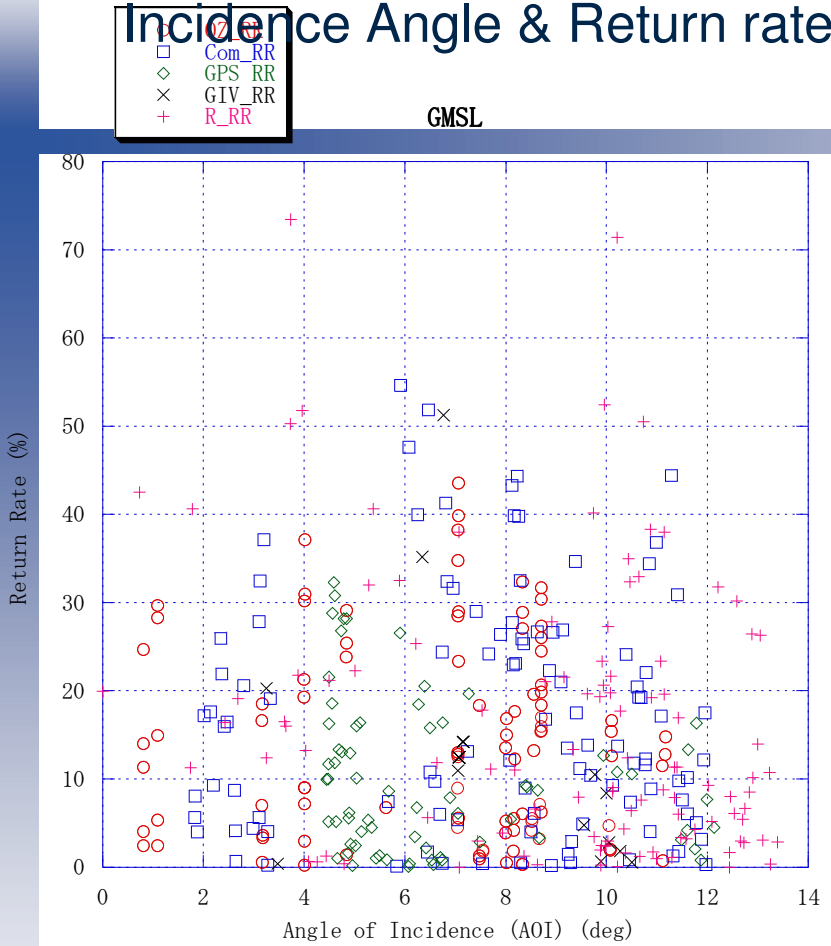


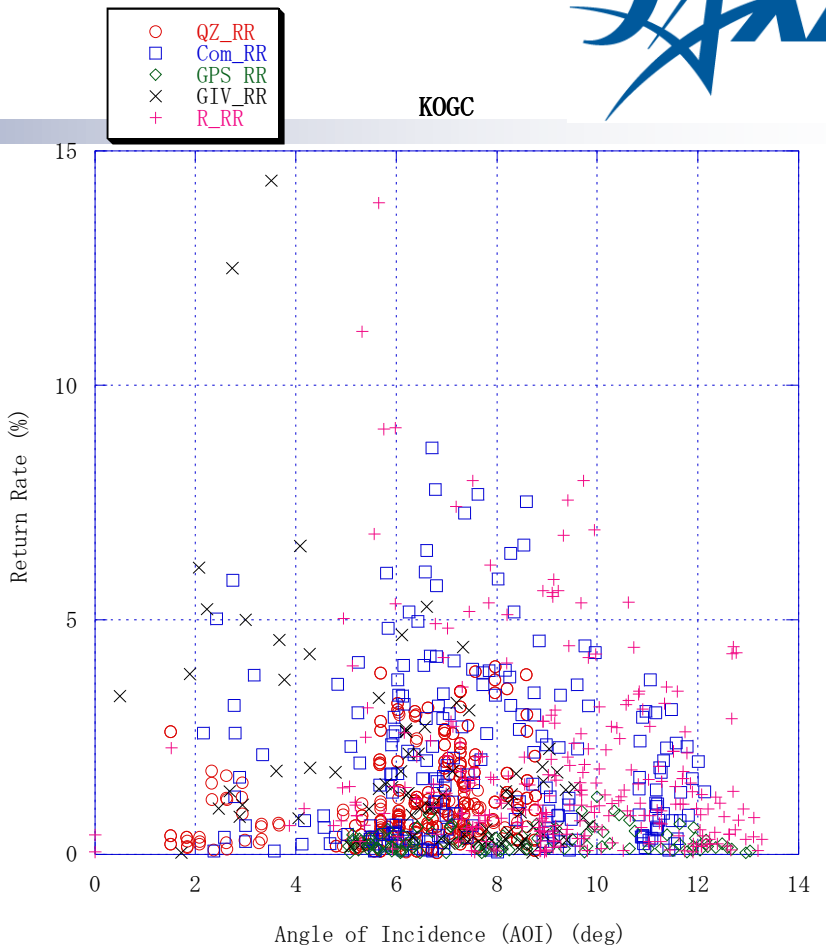




hardly fit the image of Qualitative Picture.

Incidence Angle & Return rate (122)





Conclusion 3 from (AOI vs. RR) for GNSS
There are no difference between Coat and Non-Coat CCR.

Summary2: Coat – Non Coat Evaluation

At least, when we evaluate LRA performance for GNSS (high orbit), there are no difference between Coat and Non-Coat CCRs.

At the view point of thermal control, coated CCR has more complexity than non-coated CCR.

When I limited high orbit tracking, due to lack of my knowledge, I can not find merit of coated CCR.

However, ongoing GNSS (GIOVE-B, Glonass, GPS) mounted coated CCRs.

Please give me your advice.

[I make an unnecessary addition here]

Unsolved Problems for QZS-1 and ETS-8 LRA.

(1) Big Difference for RR among SLR stations

SLR Station	Return Rate (%)	Note
Tanegashima	5 % to 15 %	10Hz fire, 250mJ laser
Koganei	typically 1%	20Hz fire, 50mJ laser
Yarragadee	1 % to 3 %	5Hz fire, 100mJ laser
Mt. Stromlo	0.1 % to 1 %	60Hz fire, 21mJ laser
Changchun	0.1% to 1 %	20Hz fire, 150mJ laser

(2) Big fluctuation of Return Rate.

At tanegashima

Average 11%

RR has range 0% (min) to 70% (max).

(3) Big fluctuation in time

Sometime high RR, some time no return,,,,,

but no attitude variation at QZS-1.