GNSS Techniques for Water Level Monitoring

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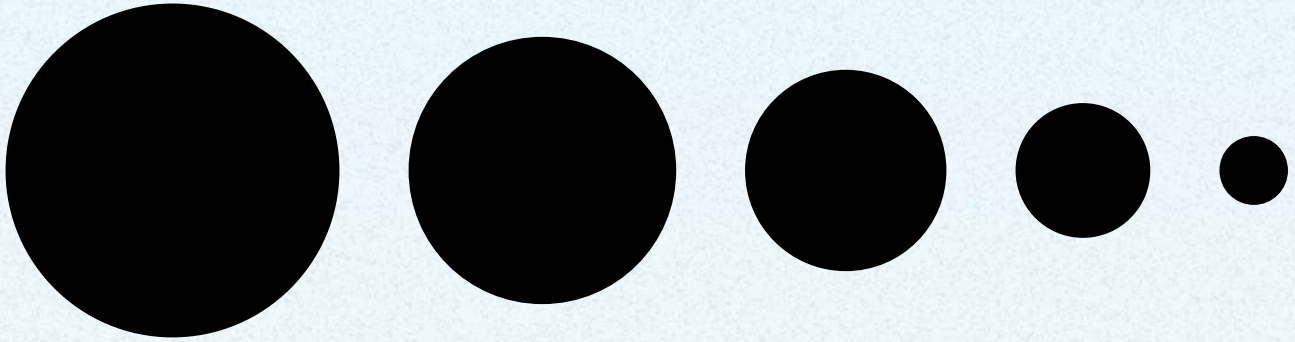
University of the Philippines

About Me

Geo+ Space tech Applications Laboratory

GLOBAL NAVIGATION SATELLITE SYSTEMS
INSTRUCTIONAL LABORATORY



Accuracy vs. **Scale** vs. **Cost**

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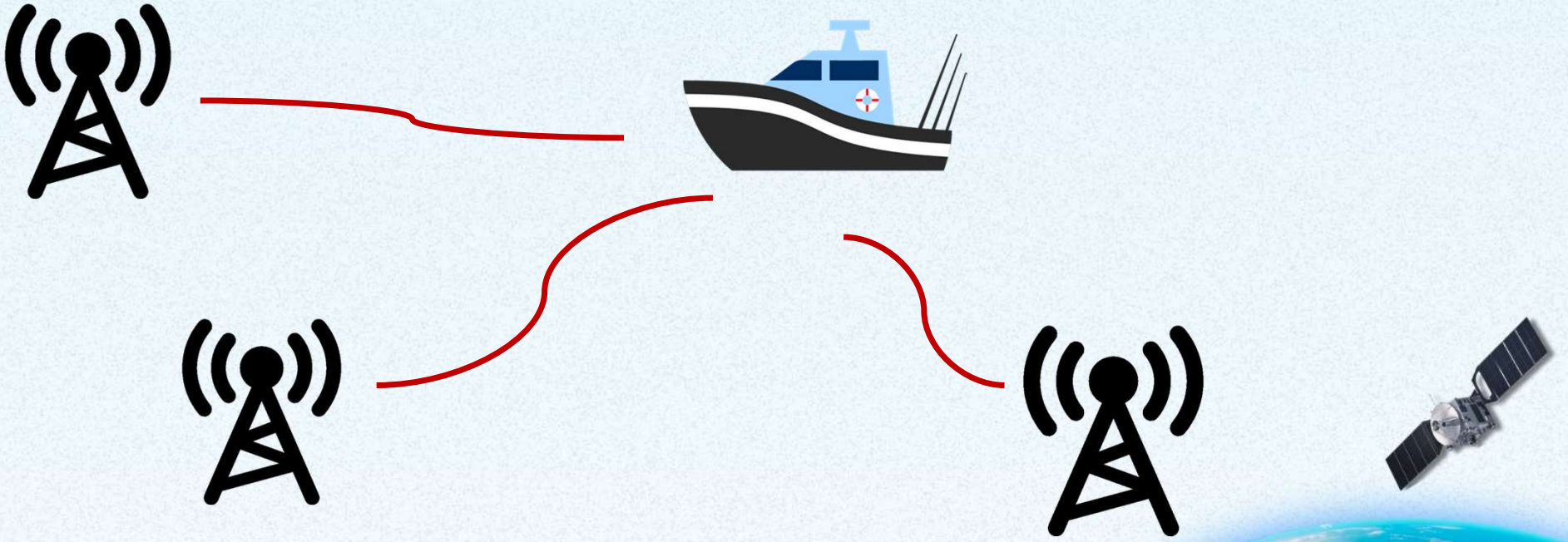
Positioning – Trilateration



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Positioning – Satellites

Global Navigation Satellite System

- **Constellation of satellites** providing signals from space that transmit positioning and timing data to GNSS receivers.
- Provide **autonomous positioning** with global coverage
- Determine the location using **time signals**

GNSS Positioning

What do we need to know?

1. Location of the Satellite
2. Time signal was sent
3. Speed of signal
4. Time signal arrived

*Provided in **Nav. File***
Ephemeris

GNSS Positioning Modes

Point Positioning

- SPP (Single Point)
- PPP (Precise Point)

Relative Positioning

- DGNSS (Differential)
- Kinematic (RTK/PPK)

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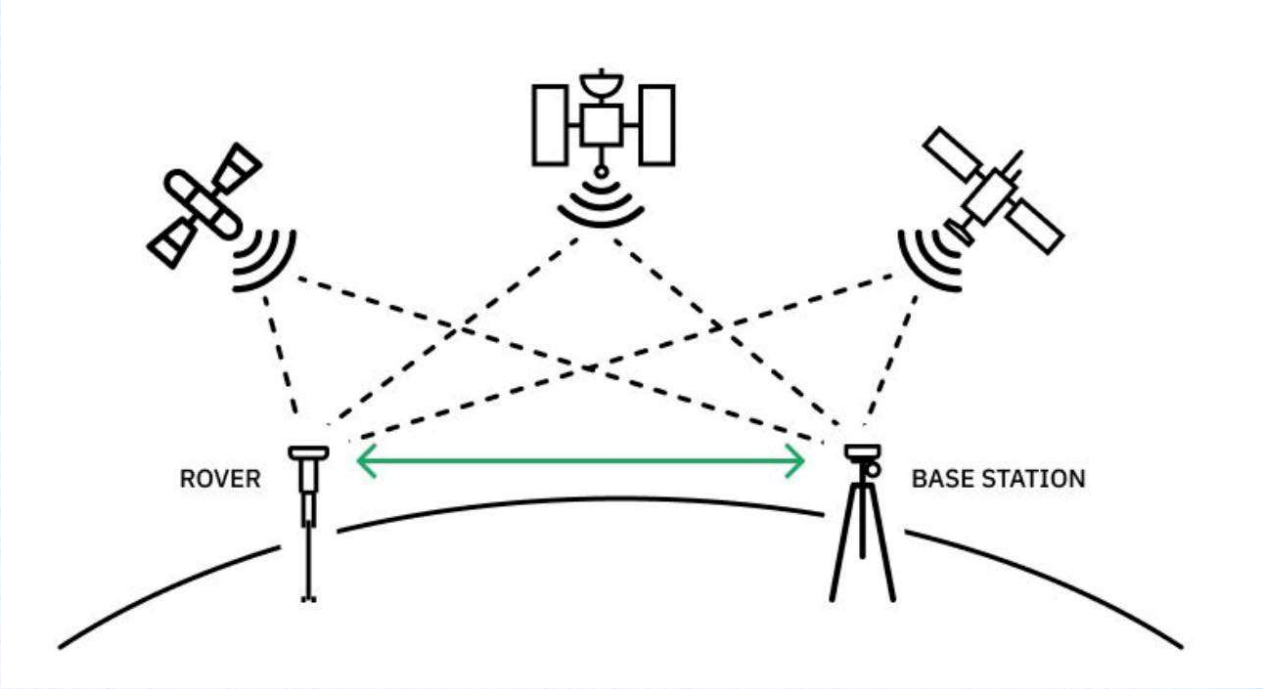
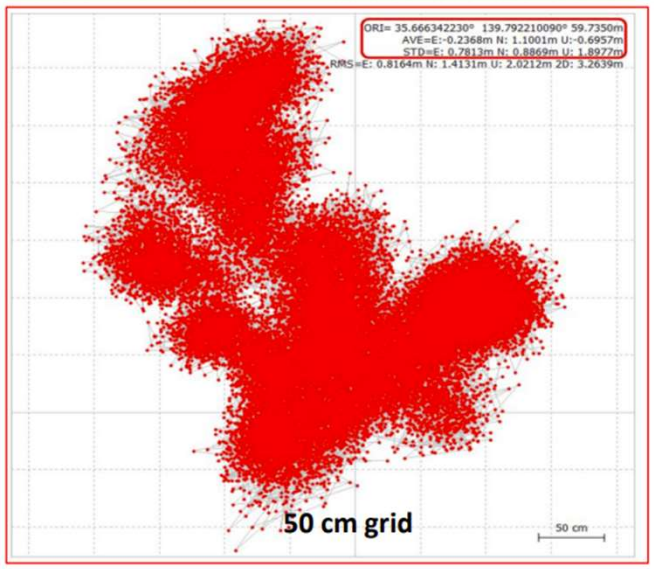
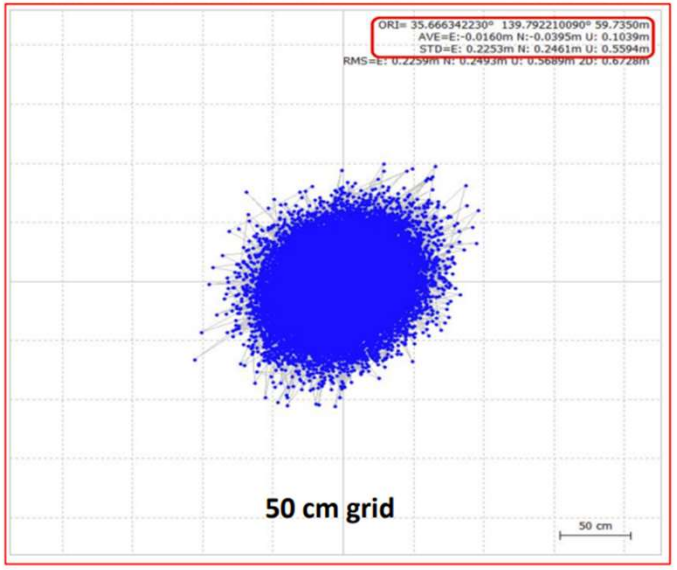
Kinematic Positioning



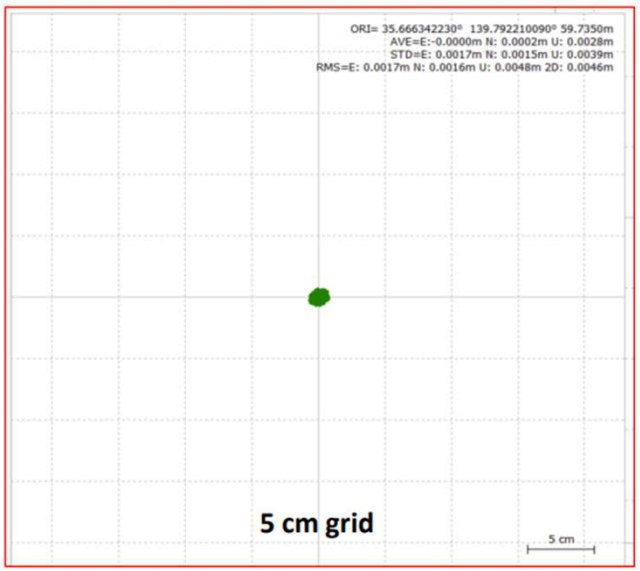
Rao Geo Tech.FZE (2024)



SPP (Single Point)



DGNSS (Differential)
Code Observable
Pseudorange



RTK (Kinematic)
Phase Observable
Carrier Phase

**Slide from Dr. Dinesh Manandhar, CSIS, The University of Tokyo*

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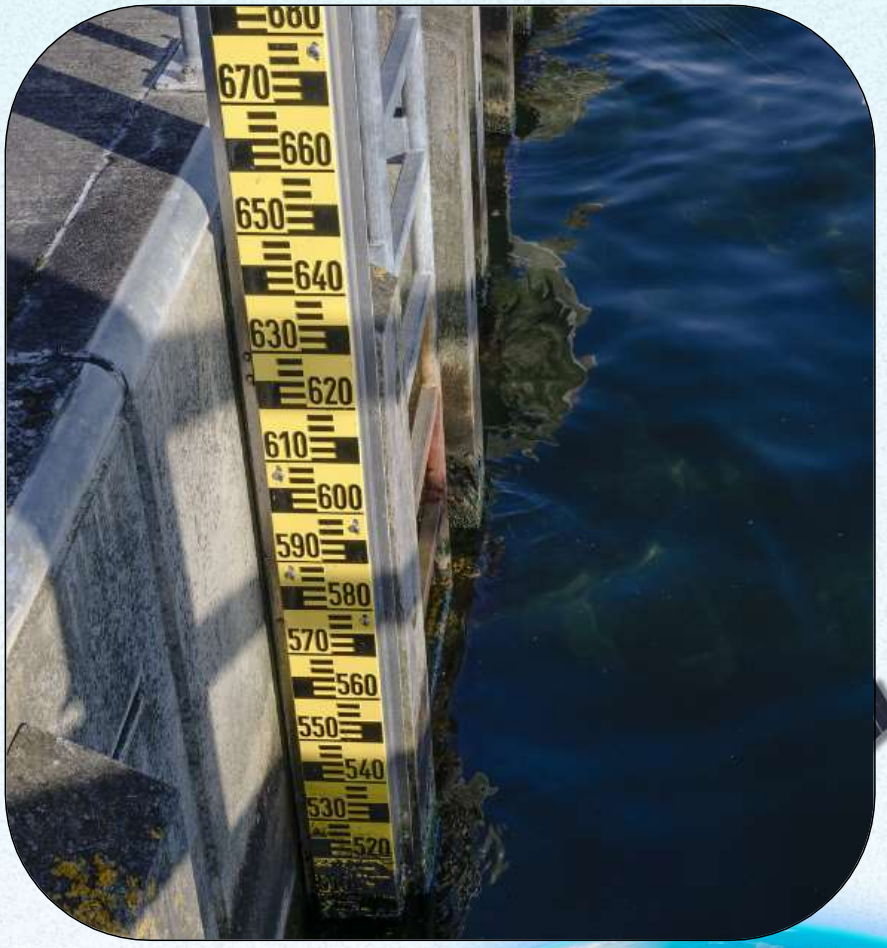
Why monitor water levels?

1. Climate Change Adaptation
2. Flood Risk Management
3. Erosion – Loss of Land
4. Economic Considerations
5. Water Supply Management
6. Agricultural Impacts

How to monitor water levels?



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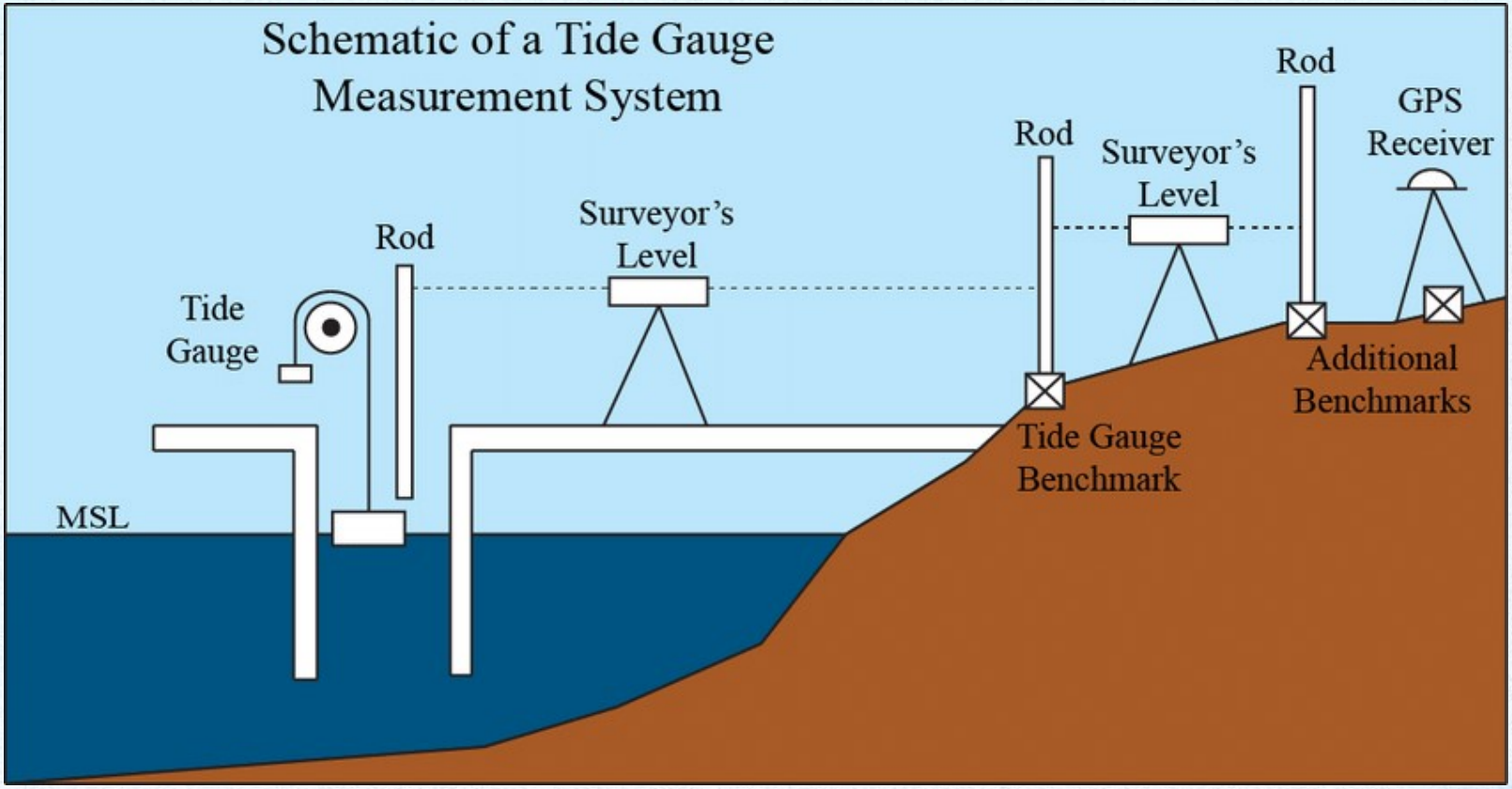

De Grandpre, Kimberly. (2015). Relative Sea Level Change In Western Alaska Estimated From Satellite Altimetry and Repeat GPS Measurements.

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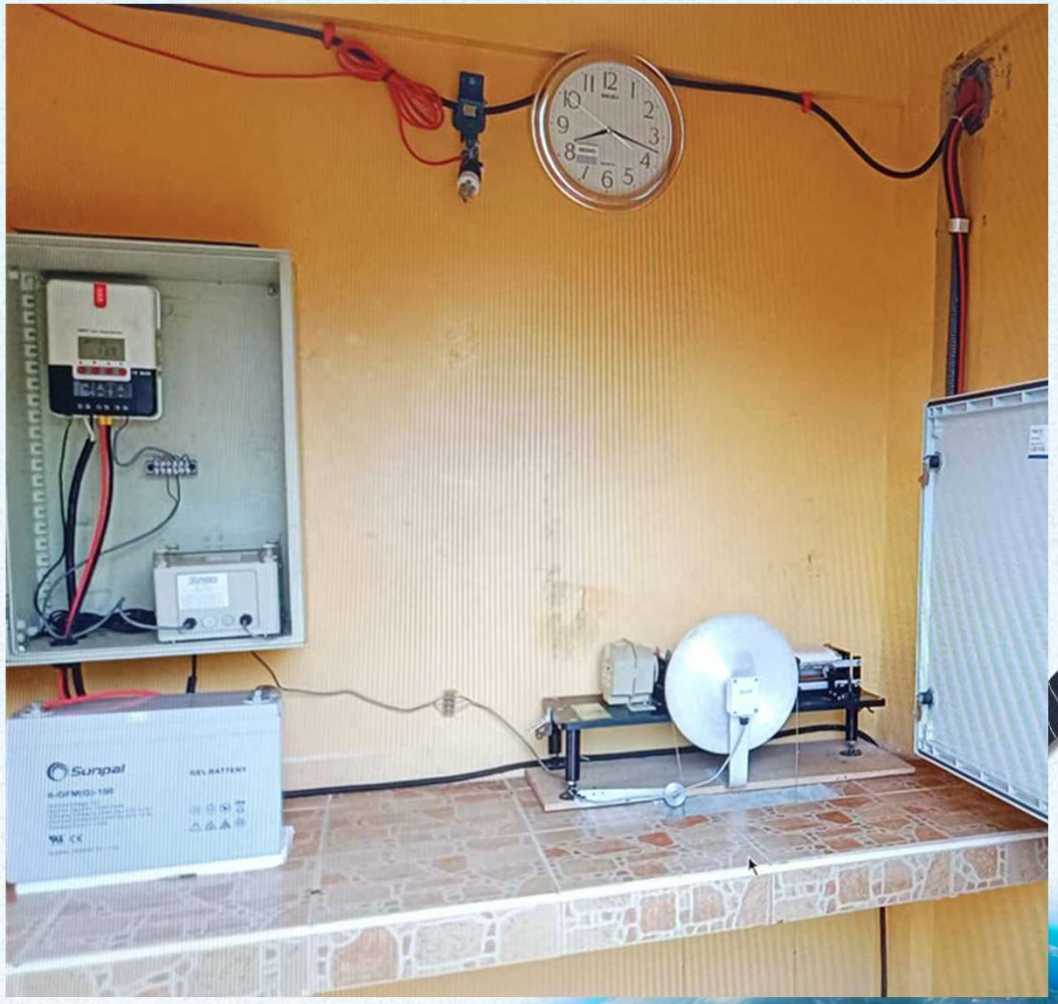

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Expensive
Painful

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Low Cost GNSS Receiver System

Why choose low cost GNSS?

1. Cost Effective
2. Widespread Deployment
3. Accessibility
4. Equivalent Performance
5. Tied to a Reference System

Shopee

ebay

Lazada

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JAXA

1PCS ZED-F9P-02B-00 ZED-F9P-02B GN Modules u-blox AG

Condition: New

Quantity: 1 5 available

Price: **US $179.90**

Approximately PHP 10,151.80

Buy

Best Offer:

Mak

♡ Add to

1/6

NEO-F9P-15B

u-blox F9 dual band L1/L
module high precision F
Grade LGA, 16x12 mm, 2

₱18,599

High precision GNSS multi frequency centimeter level low power consumption UBLOX ZED-F9P RTK

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Zed F9P Module

Micro USB Port

Antenna Port

Power Supply

Radio (UART) Port

Ublox Zed F9P Receiver

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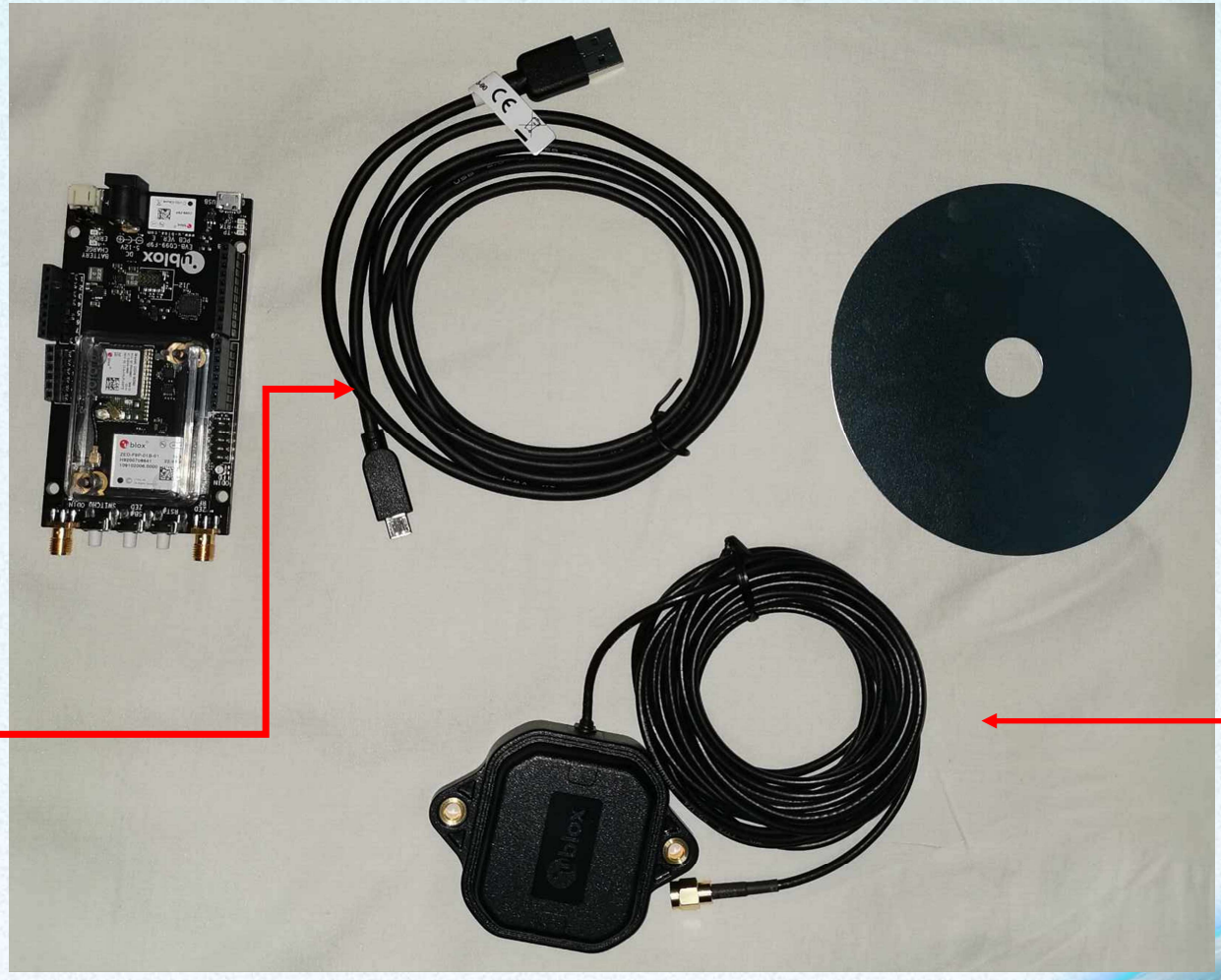
Zed F9P Board



Ground Plane

Micro USB Cable

Patch Antenna

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GNSS Positioning Modes

Point Positioning

- SPP (Single Point)
- PPP (Precise Point)

Relative Positioning

- DGNSS (Differential)
- Kinematic (RTK/PPK)

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GNSS Positioning Modes

Point Positioning

- SPP (Single Point) — **Reflectometry**
- PPP (Precise Point)

Relative Positioning

- DGNSS (Differential)
- **Kinematic (RTK/PPK)**

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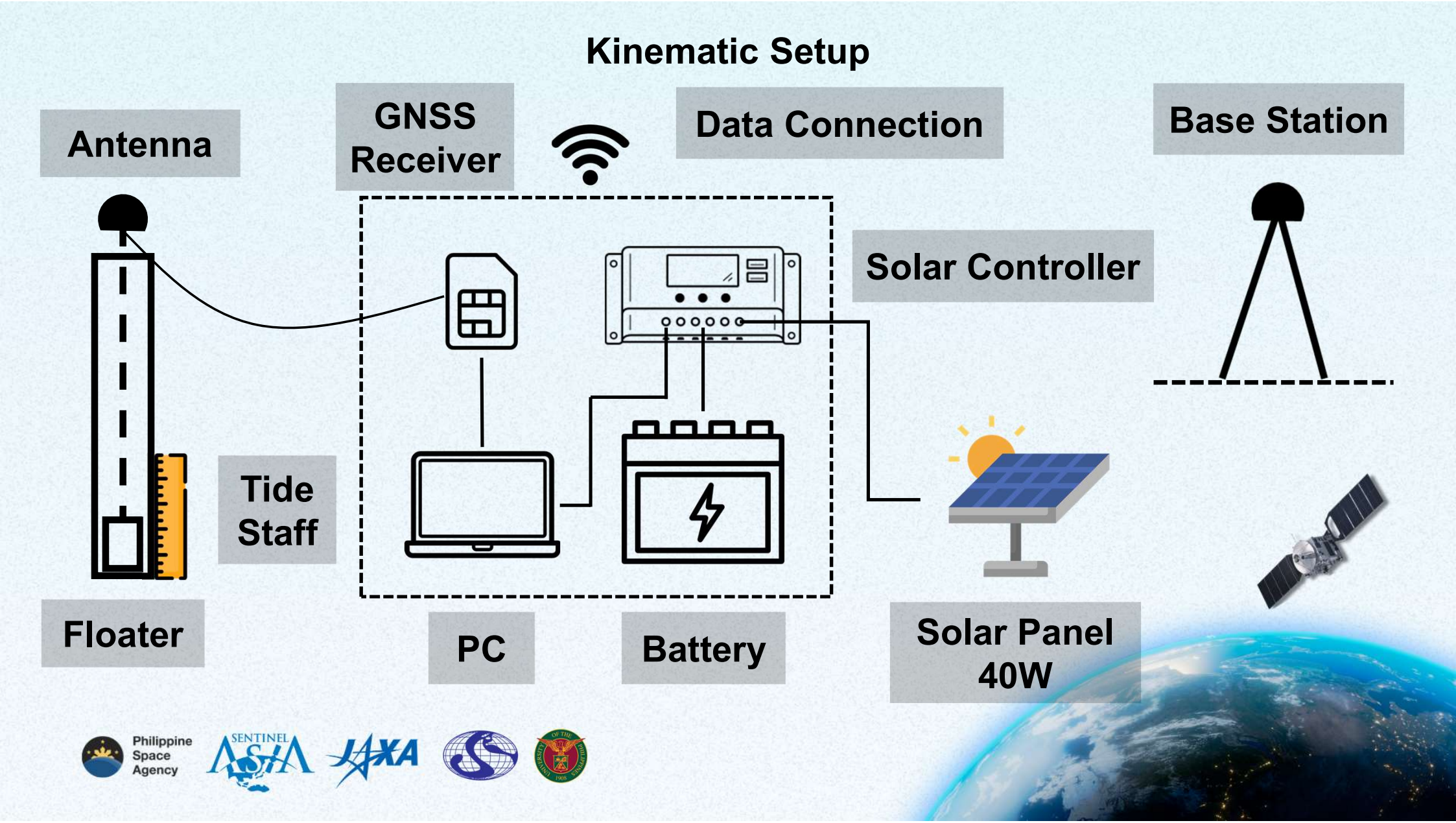
Water Level Monitoring using **Kinematic Positioning**

(Dizon, Penales, Reyes, Mabaquiao)

General Workflow

Setup Phase	Materials and Equipment BM Establishment
Data Collection	24 hour observation Raw observation retrieval
Data Processing	RTK Processing *(+ PPK Processing)*
Performance Analysis	Accuracy and Integrity Continuity and Costing


Kinematic Setup
Antenna
GNSS Receiver
Data Connection
Base Station
Solar Controller
Tide Staff
Floater
PC
Battery
Solar Panel 40W
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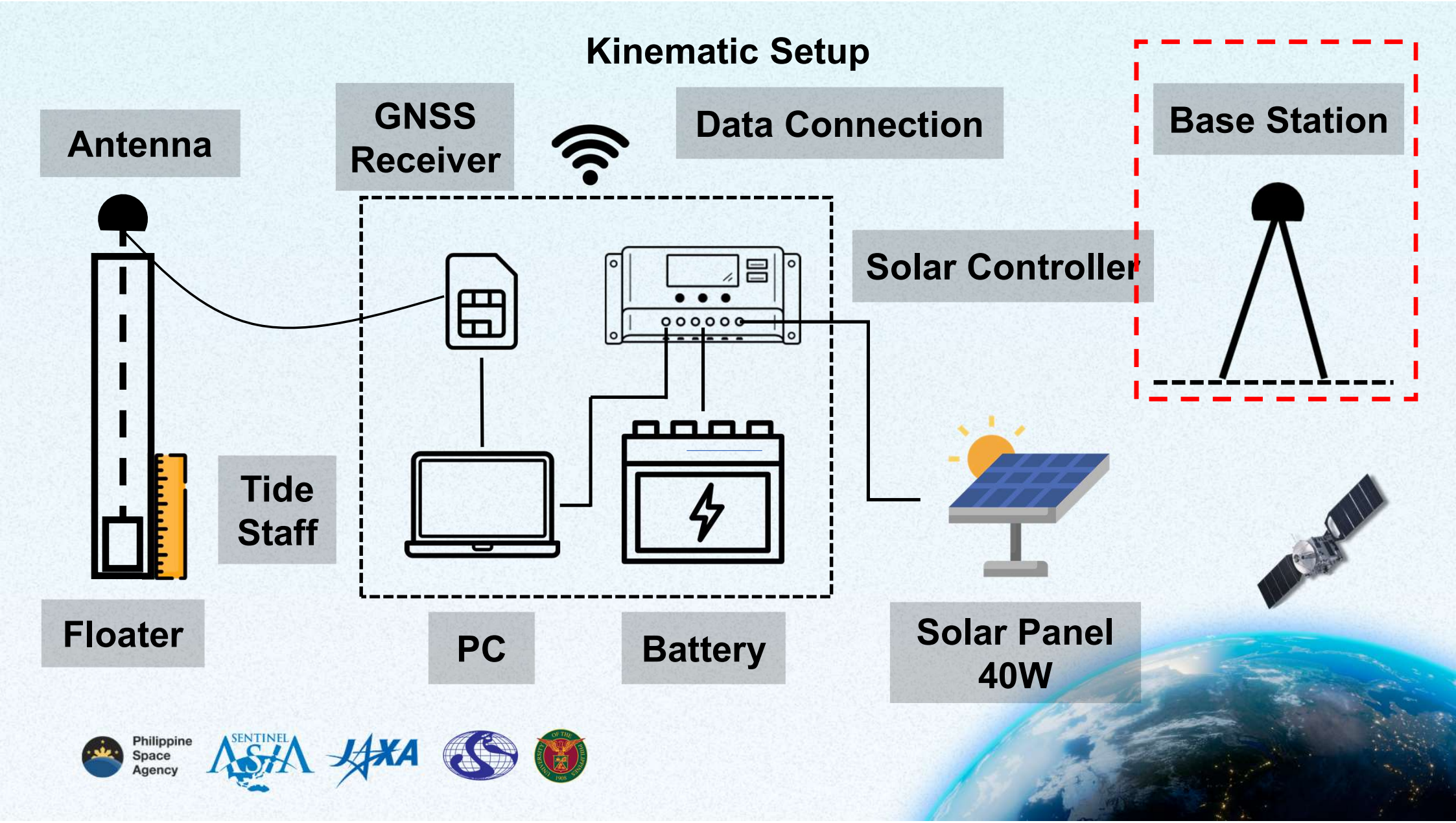
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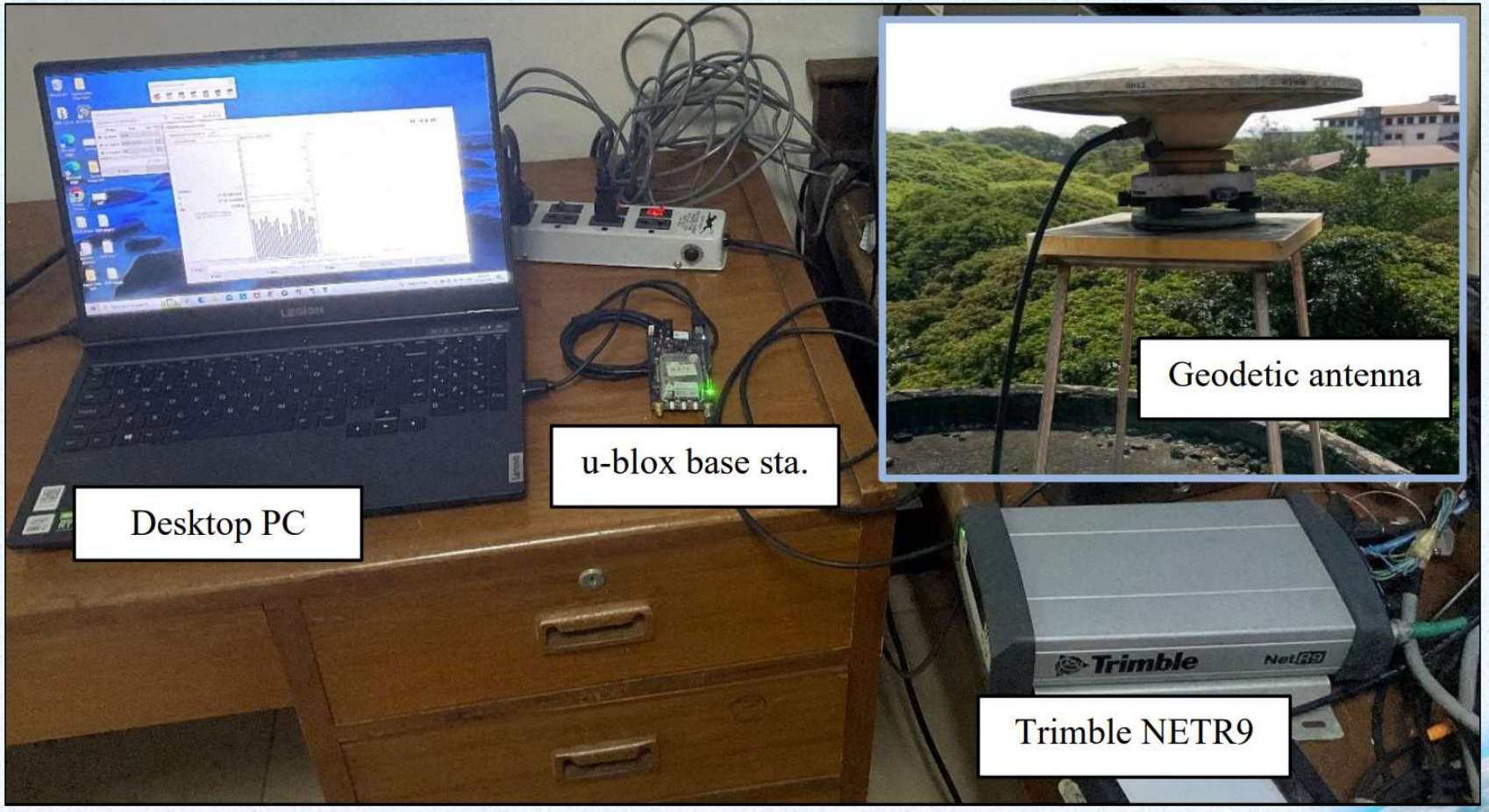
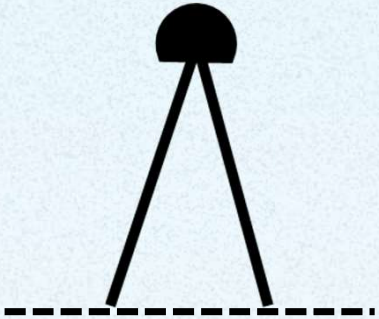
Kinematic Setup



Base Station



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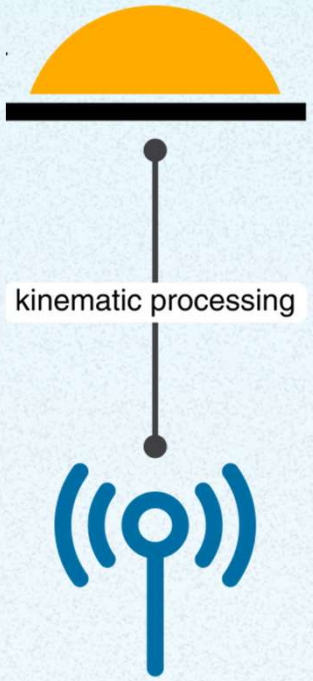
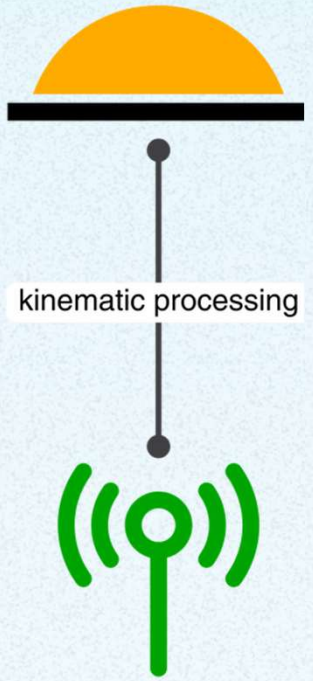
Low Cost
Rover Receiver
UBX Zed F9P



Low Cost
Base Station
UBX Zed F9P

Setup 1 *(LC-LC)*
Low Cost: Rover
Low Cost: Base



Low Cost
Rover Receiver
UBX Zed F9P

Survey Grade
Base Station
Trimble Net R9

Setup 2 *(LC-SG)*
Low Cost: Rover
Survey Grade: Base

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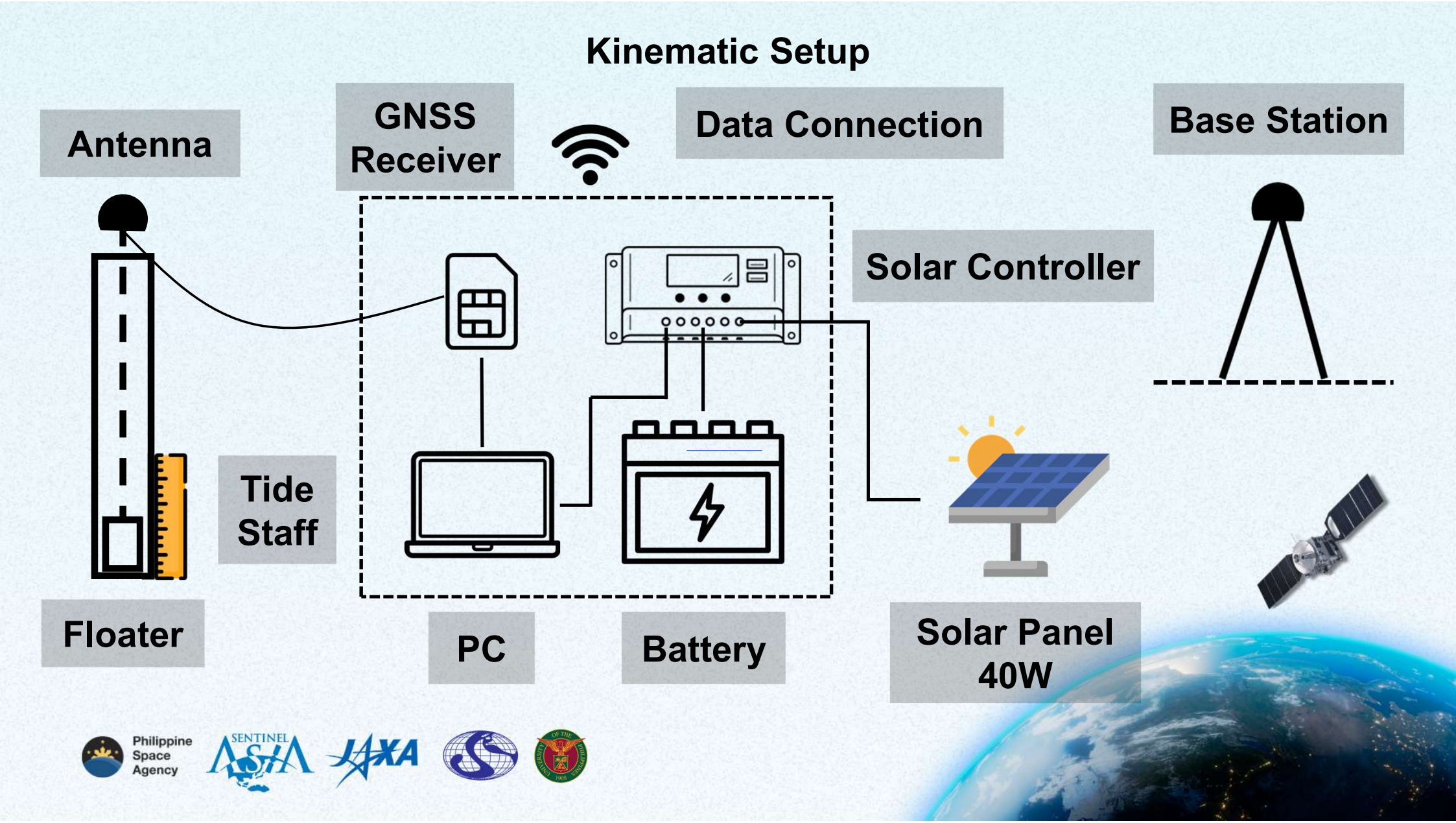
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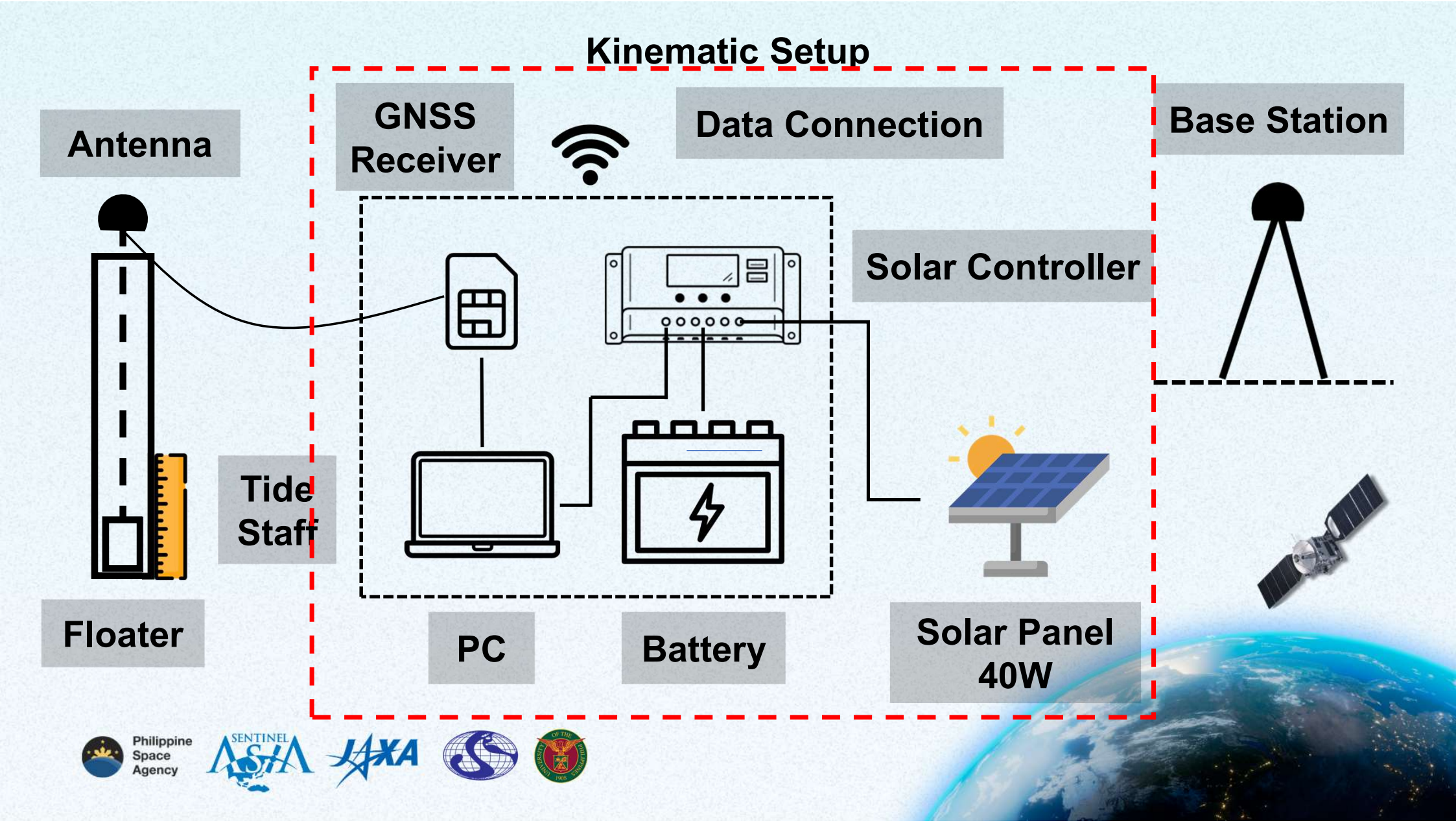
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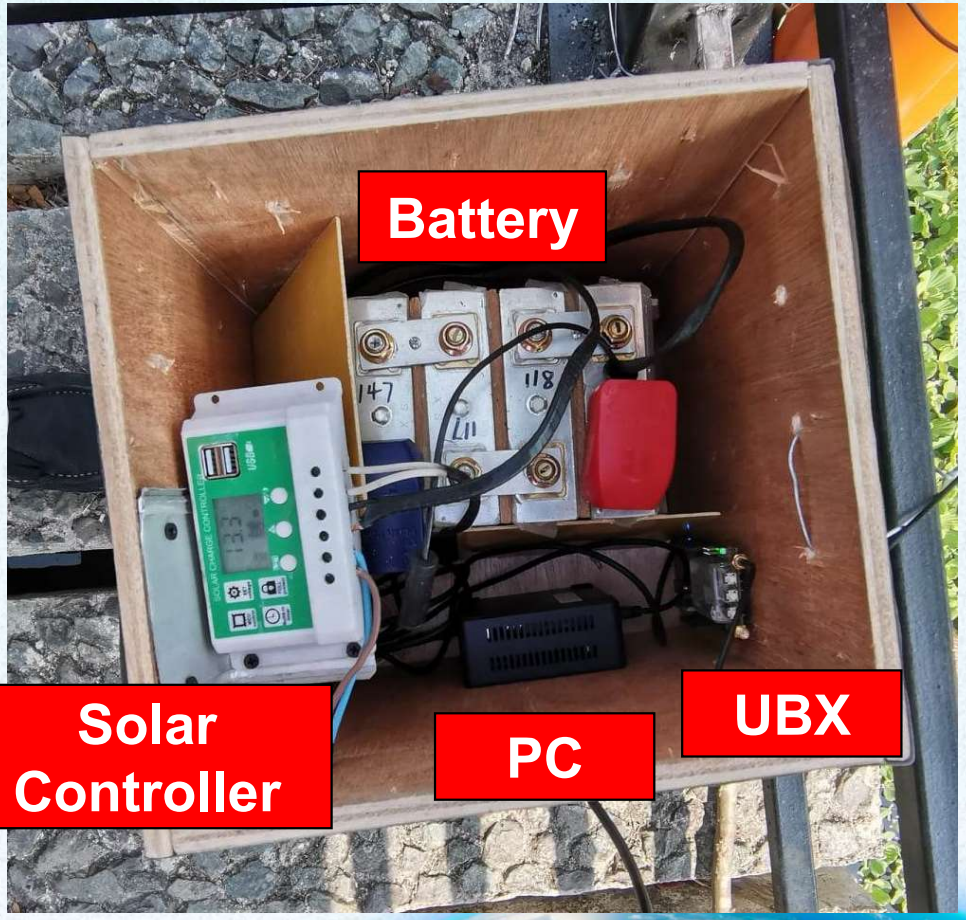

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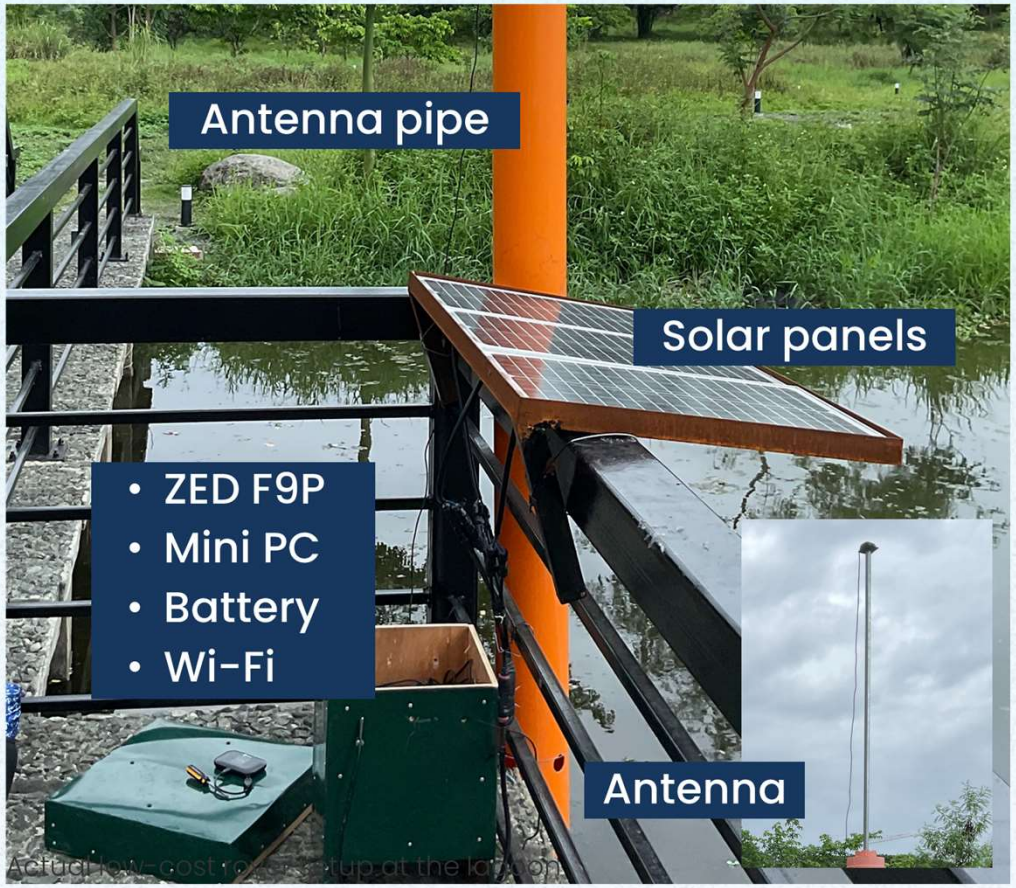
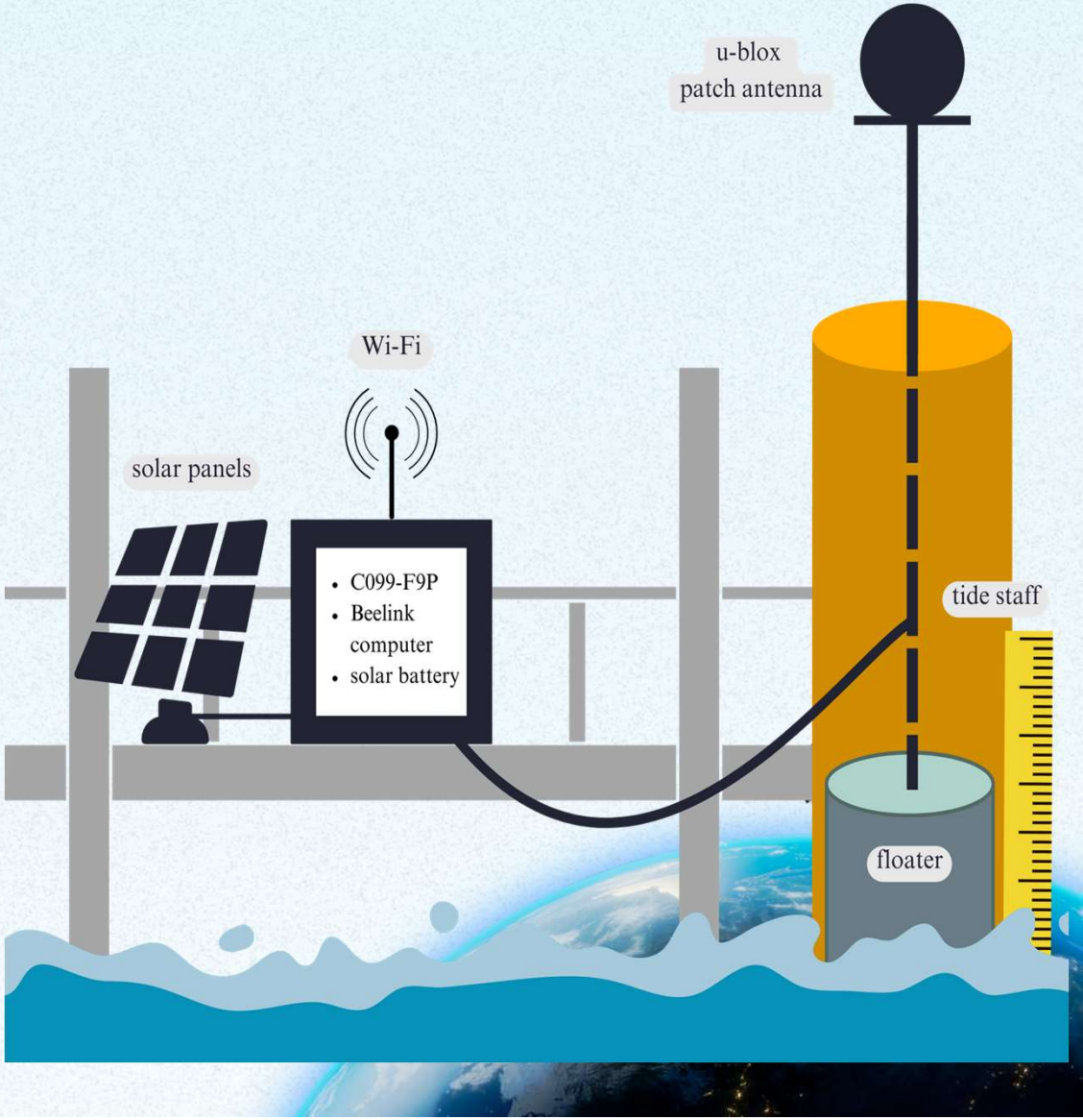


Actual low-cost setup at the lab



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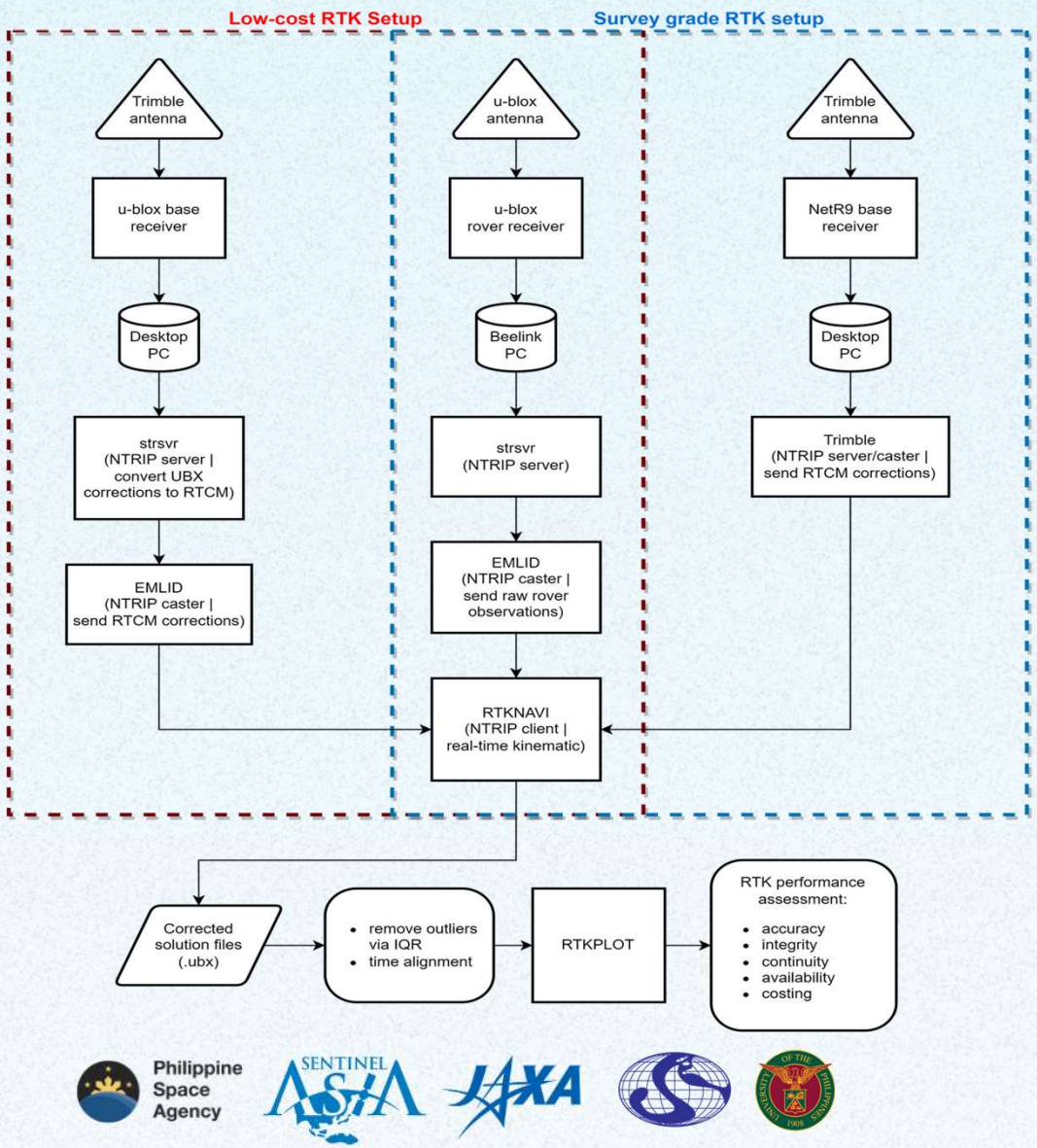
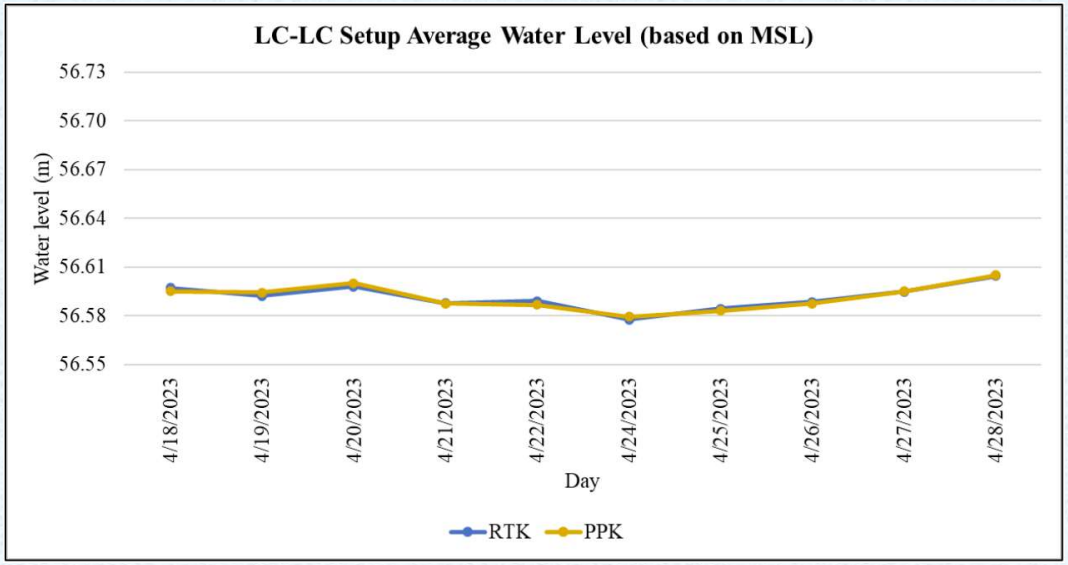


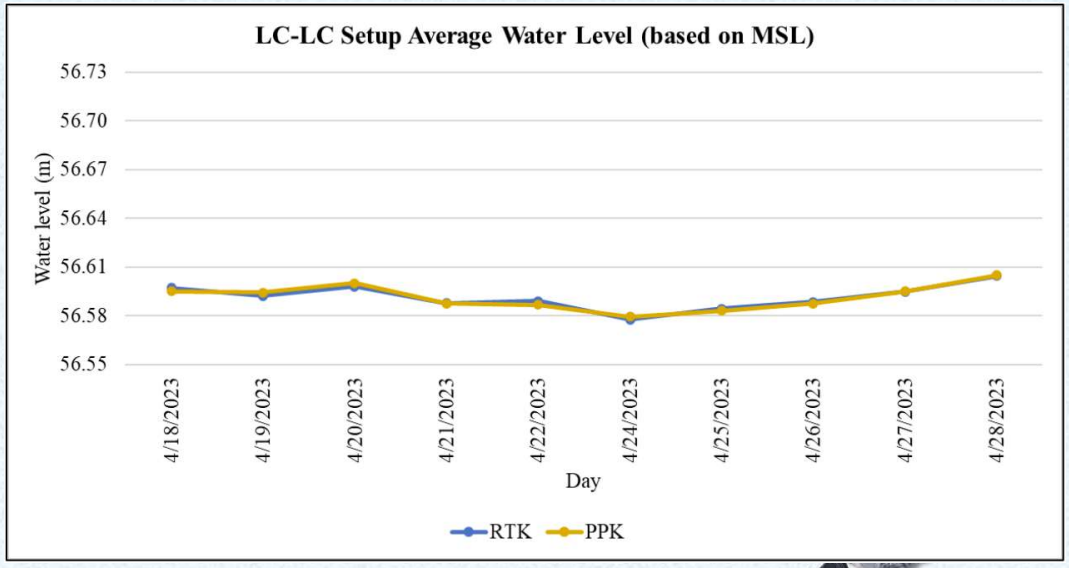
RTK Processing

- Real time data streams
- **strsvr**: stream RCTM corrections
- **Emlid caster**: send rover data
- **RTKNAVI**: perform RTK processing
- **RTKPLOT:** plot real time solutions

Setup 1 (**LC-LC**)



Setup 2 (**SG-LC**)



Results: **RTK vs PPK**

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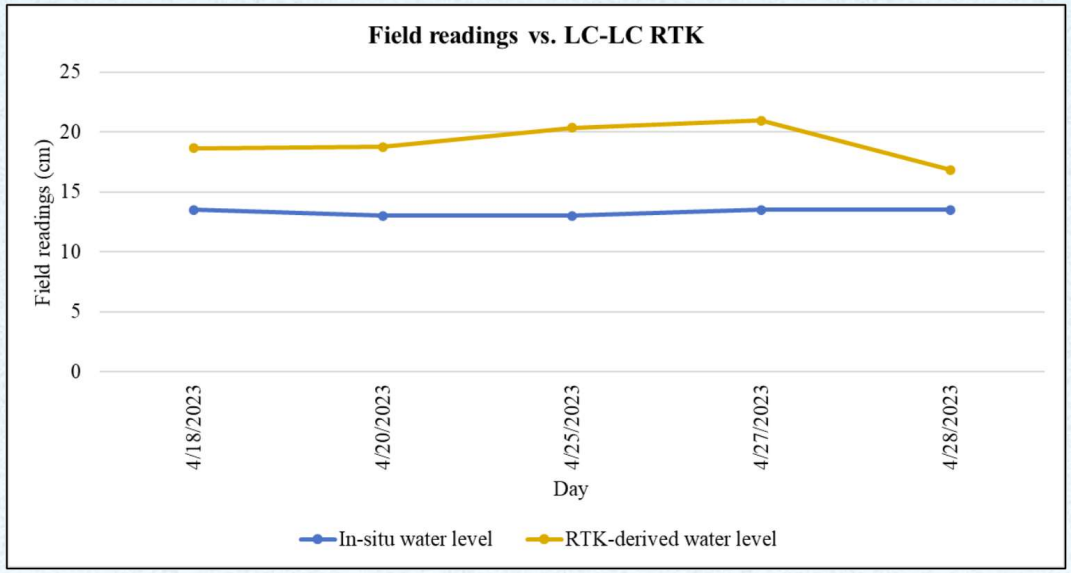
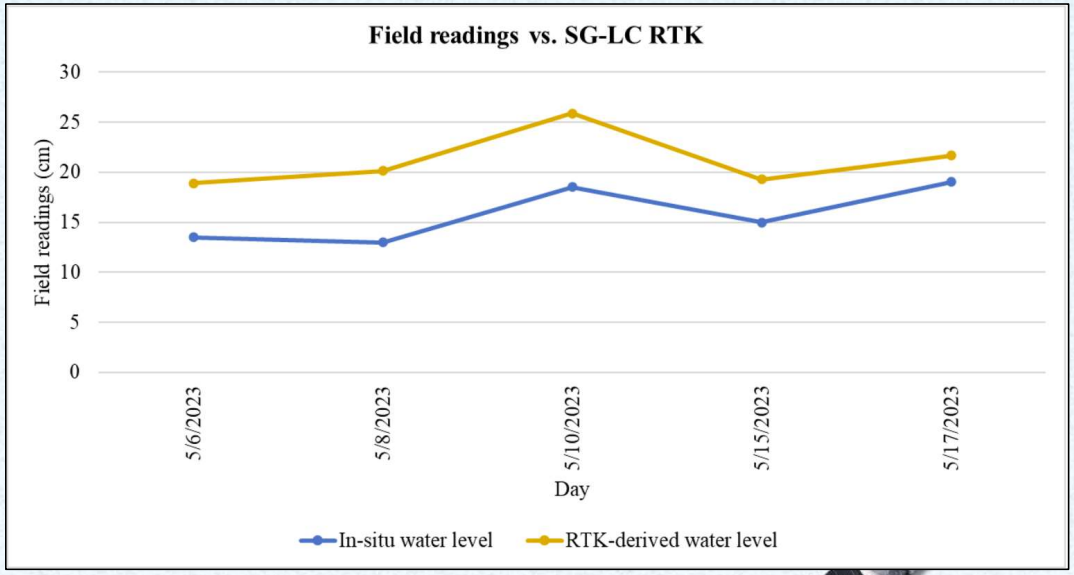
Setup 1 (**LC-LC**)

5.65cm *difference*



Setup 2 (**SG-LC**)

5.37cm *difference*



Results: **Accuracy**

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RMS U – D Direction (cm)				
	Low Cost		Survey Grade	
	RTK	PPK	RTK	PPK
MIN	1.68	1.31	1.59	1.35
MAX	2.74	1.96	3.26	3.18

Results: **Integrity**

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% Fixed solutions (**survey grade setup**)		
Day	RTK	PPK
May 2, 2023	96.73	99.38
May 5, 2023	93.41	92.87
May 6, 2023	96.19	99.05
May 7, 2023	87.4	99.92
May 11, 2023	97.85	99.68
May 12, 2023	97.13	98.16
May 13, 2023	97.81	97.14
May 14, 2023	98.34	98.73
May 15, 2023	98.17	99.12
May 16, 2023	92.08	99.87

% Fixed solutions (**low-cost setup**)		
Day	RTK	PPK
April 18, 2023	68.95	83.35
April 19, 2023	98.12	99.22
April 20, 2023	89.08	85.74
April 21, 2023	99.35	96.03
April 22, 2023	98.2	88.93
April 24, 2023	95.33	93.83
April 25, 2023	70.82	89.2
April 26, 2023	95.48	95.71
April 27, 2023	99.57	99.2
April 28, 2023	99.37	97.96

Results: **Continuity**

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% Fixed solutions (**survey grade setup**)		
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May 2, 2023	96.73	99.38
May 5, 2023	93.41	92.87
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Results: **Continuity**

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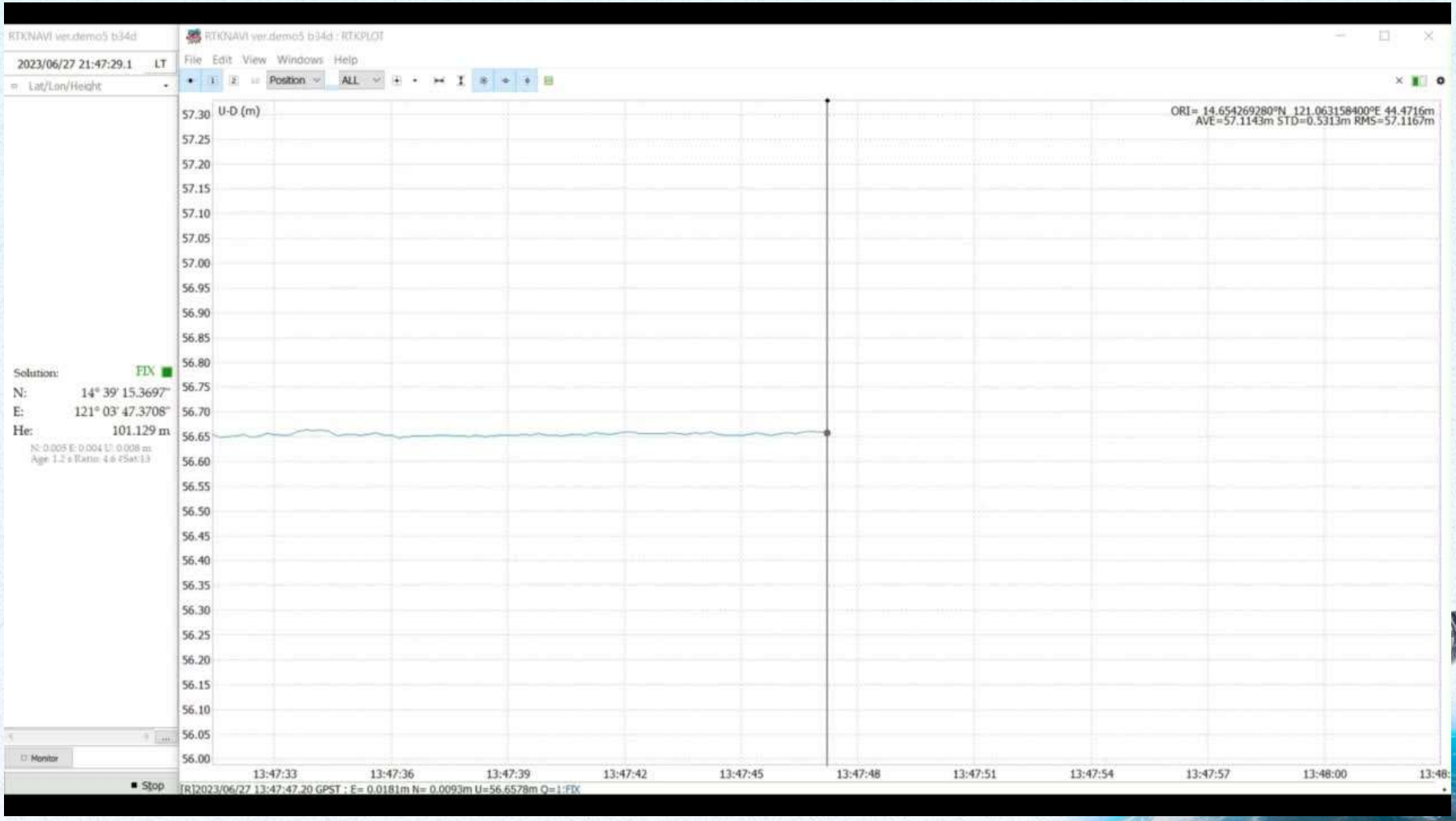
	Component	LC-LC Setup	SG-LC Setup
Rover Receiver System	Ublox Zed-F9P	₱ 18,000	₱ 18,000
	Beelink DDR4 8GB+512GB SSD	₱ 10,000	₱ 10,000
	Solar Panel	₱ 4,500	₱ 4,500
	Solar Controller	₱ 140	₱ 140
	Lifepo4 Prismatic Solar Battery	₱ 5,000	₱ 5,000
	Pocket Wi-Fi	₱ 700	₱ 700
	Housing and PVC Pipe	₱ 2,000	₱ 2,000
Base Receiver System	Base Receiver	ublox Zed-F9P: ₱ 18,000	Trimble NetR9 reference Receiver: ₱ 1,117,030 Zephyr Geodetic Antenna ₱ 122,275
	Total Cost	₱ 58,340	₱ 1,279,645

Results: **Costing**



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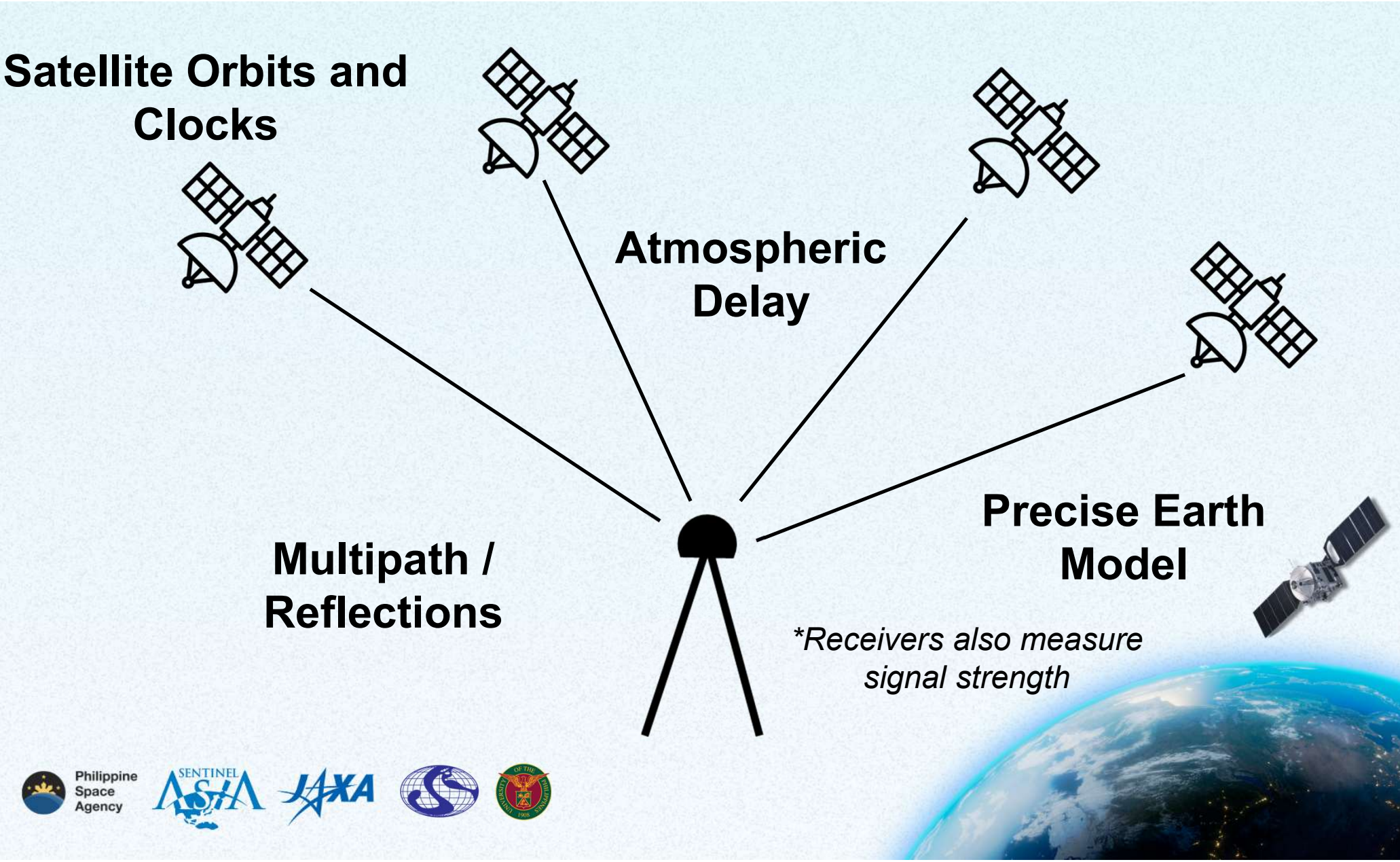
Water Level Monitoring using **GNSS Reflectometry**

(Cruz, Molleno, Mabaquiao)


Satellite Orbits and Clocks
Atmospheric Delay
Multipath / Reflections
Precise Earth Model
*Receivers also measure signal strength
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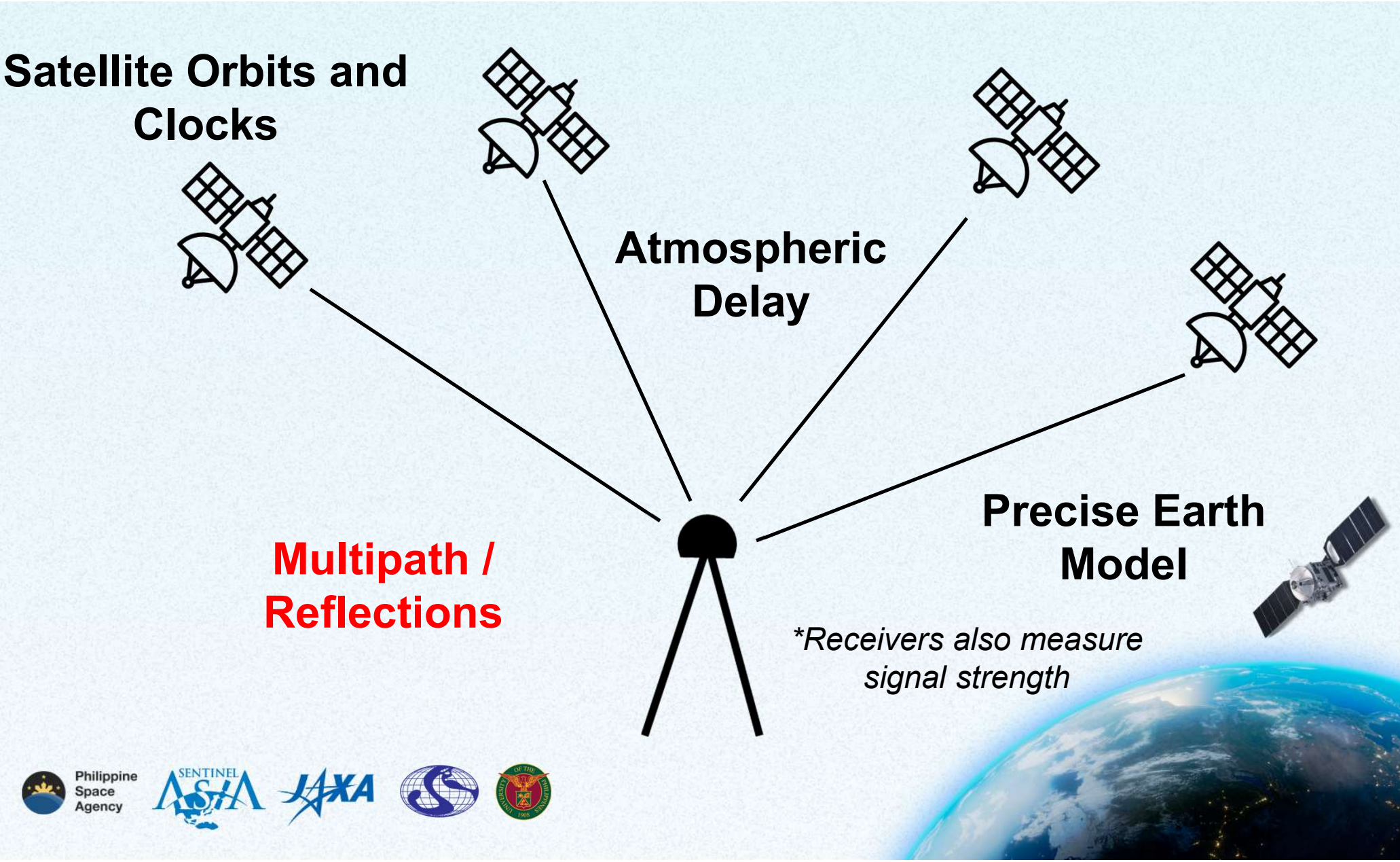
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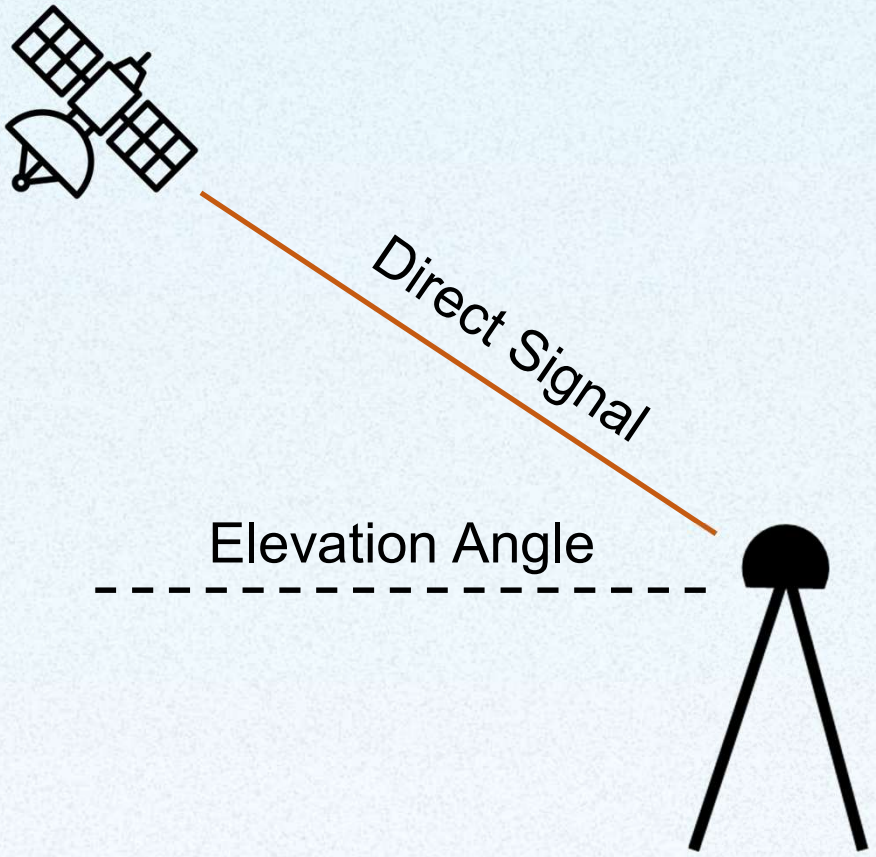

Receivers also measure signal strength

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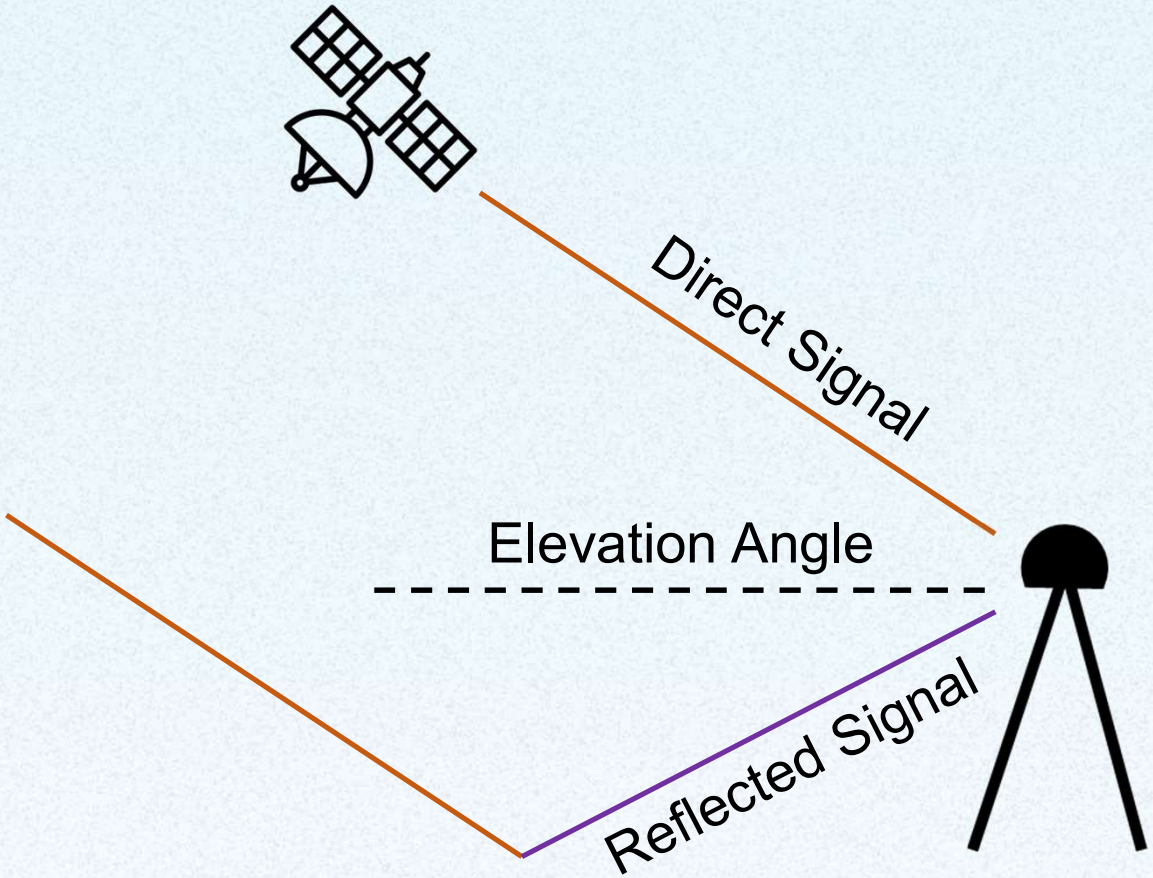

*Receivers also measure signal strength

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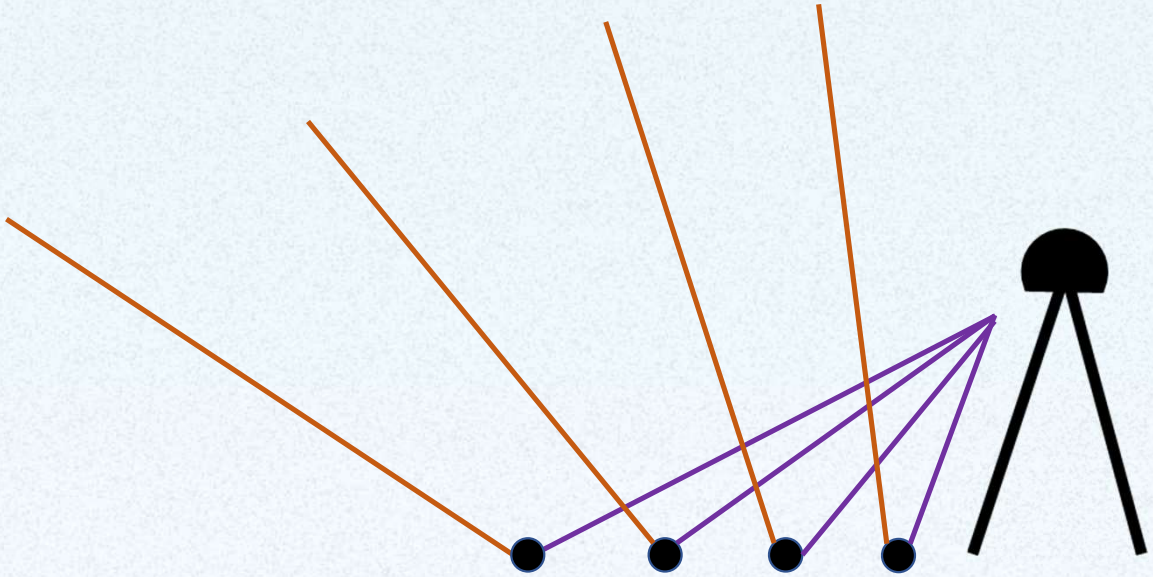
As the satellite rises, the **elevation angle increases**.
The reflection point gets closer to the antenna



**Receivers also measure signal strength*

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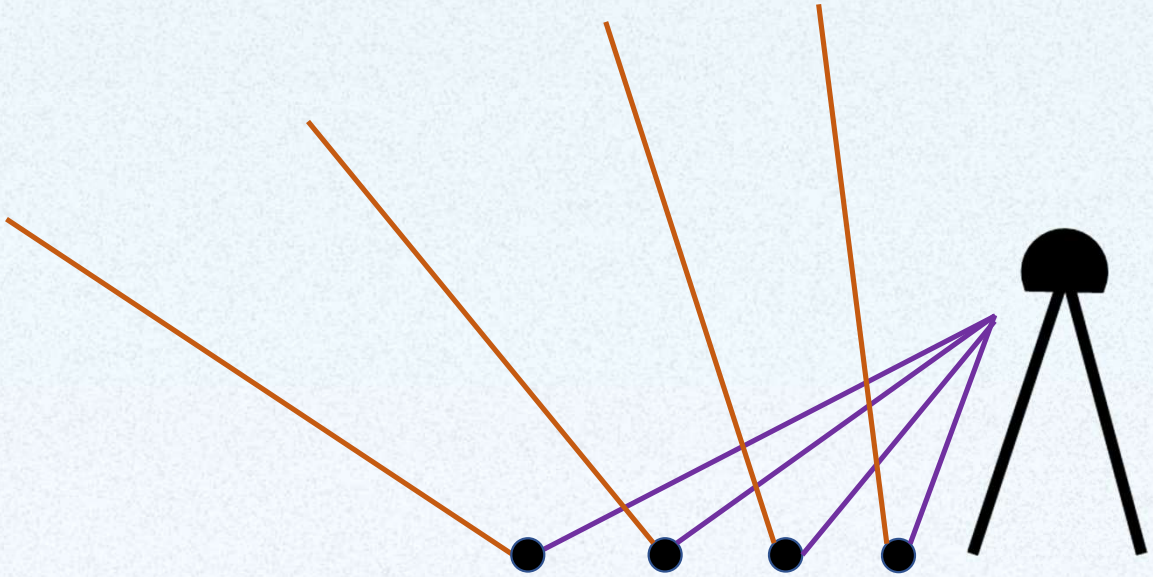
Direct + Reflected = **Interference Pattern**

Constructive or Destructive

As the satellite rises or sets, the receiver records the interference patterns



**Receivers also measure signal strength*

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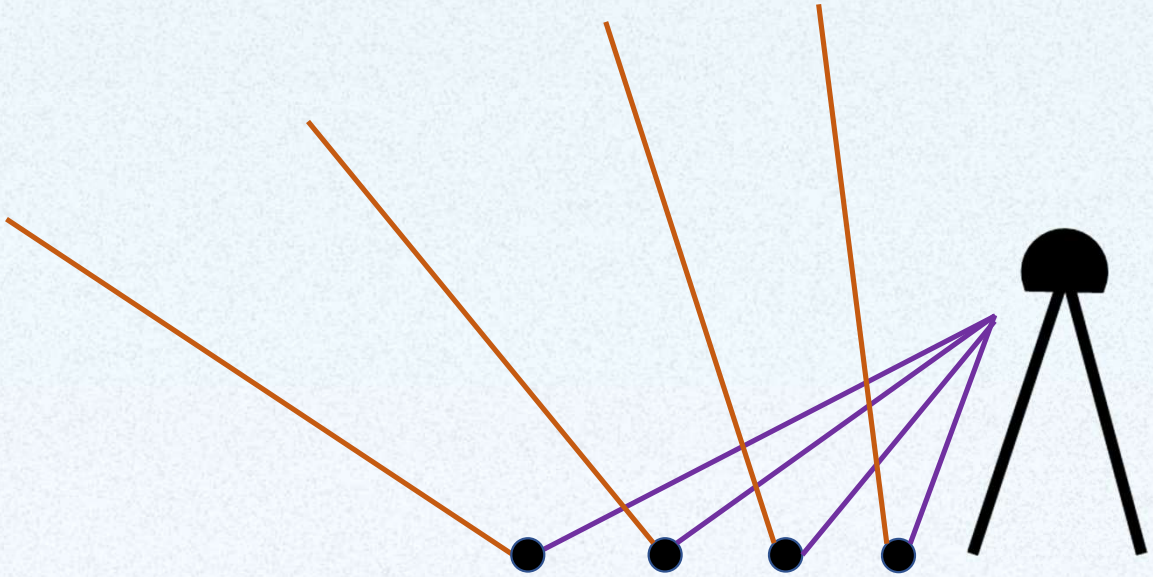
Interference Pattern – SNR Data

- Frequency directly related to **H**, distance between the antenna and reflecting surface (**Reflector Height**)
- Surface dictates how strong the reflection is
- Depends on surface type and geometry



**Receivers also measure signal strength*

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General Workflow

Setup Phase	Data Collection	Data Processing	Data Analysis
• Site Selection • Materials and Equipment	• 24 hour observation for 2 weeks • Ublox to RINEX 2.11 conversion	• Reflection Zones • RINEX-SNR Conversion • Quality Control • GNSS – IR	• Orientation Comparison • Frequency Analysis • Tide Gauge and GNSS-IR Comparison • Cost Analysis

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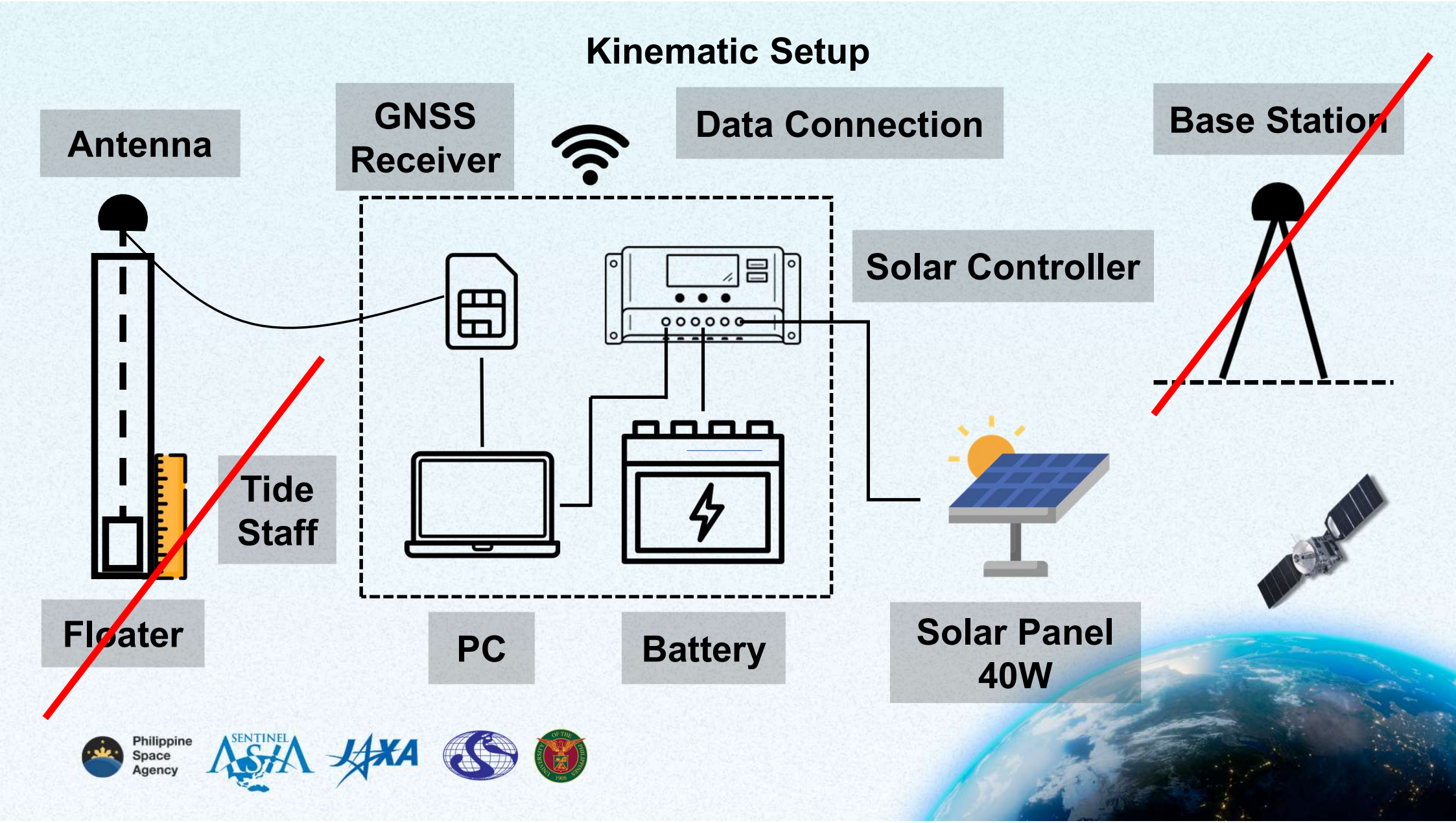
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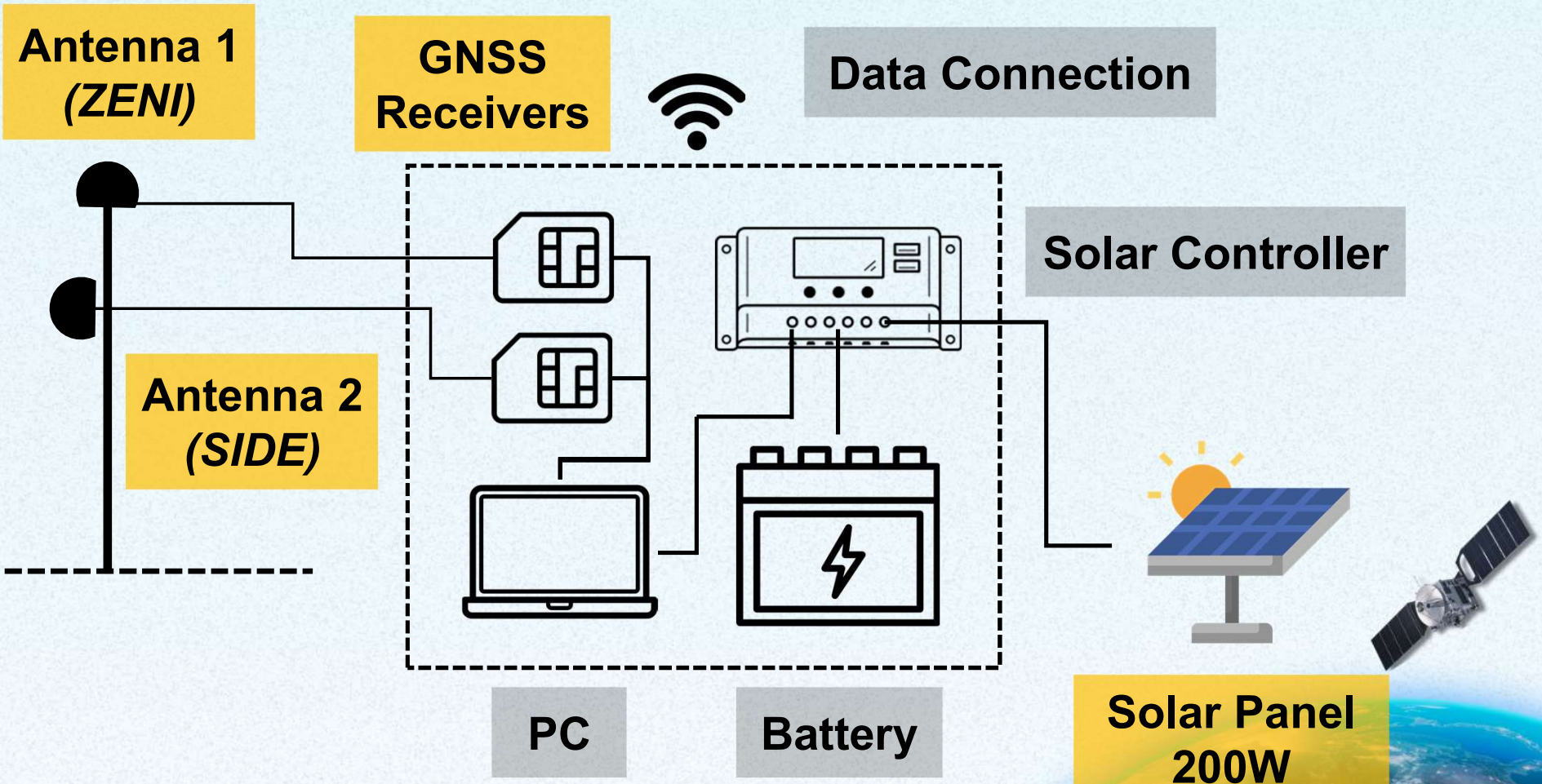
Reflectometry Setup



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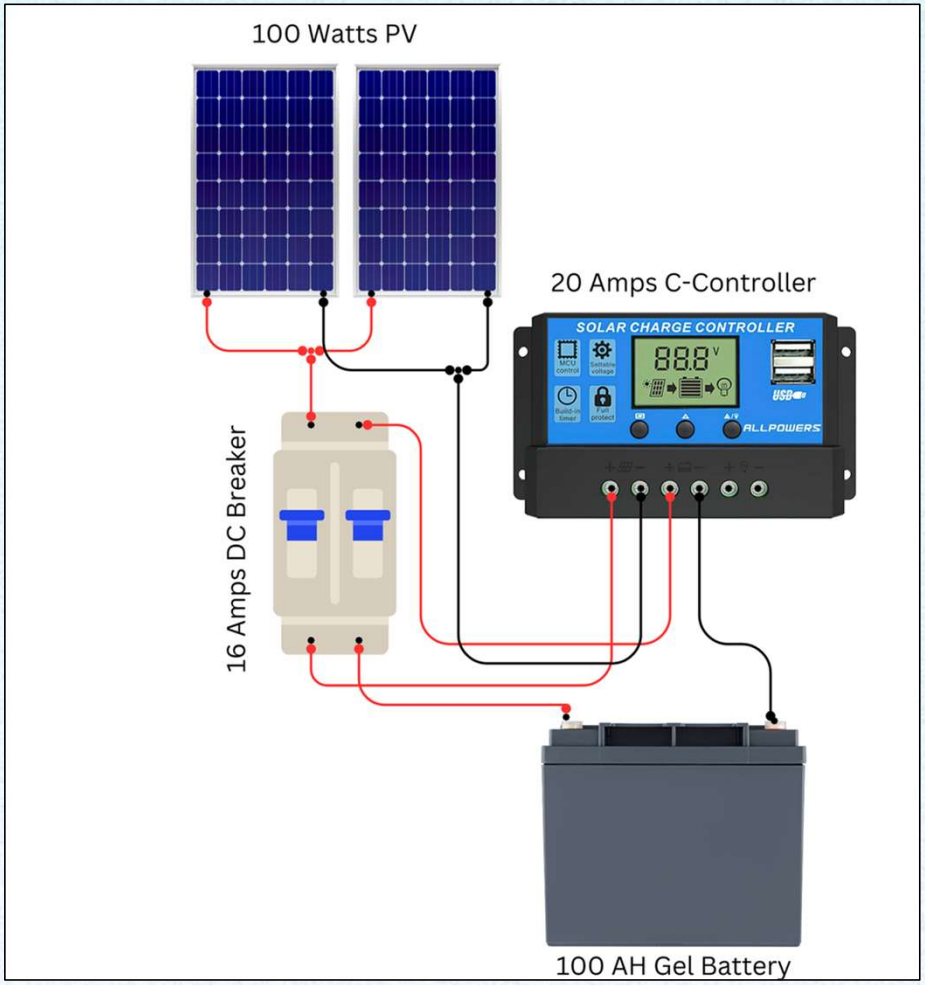

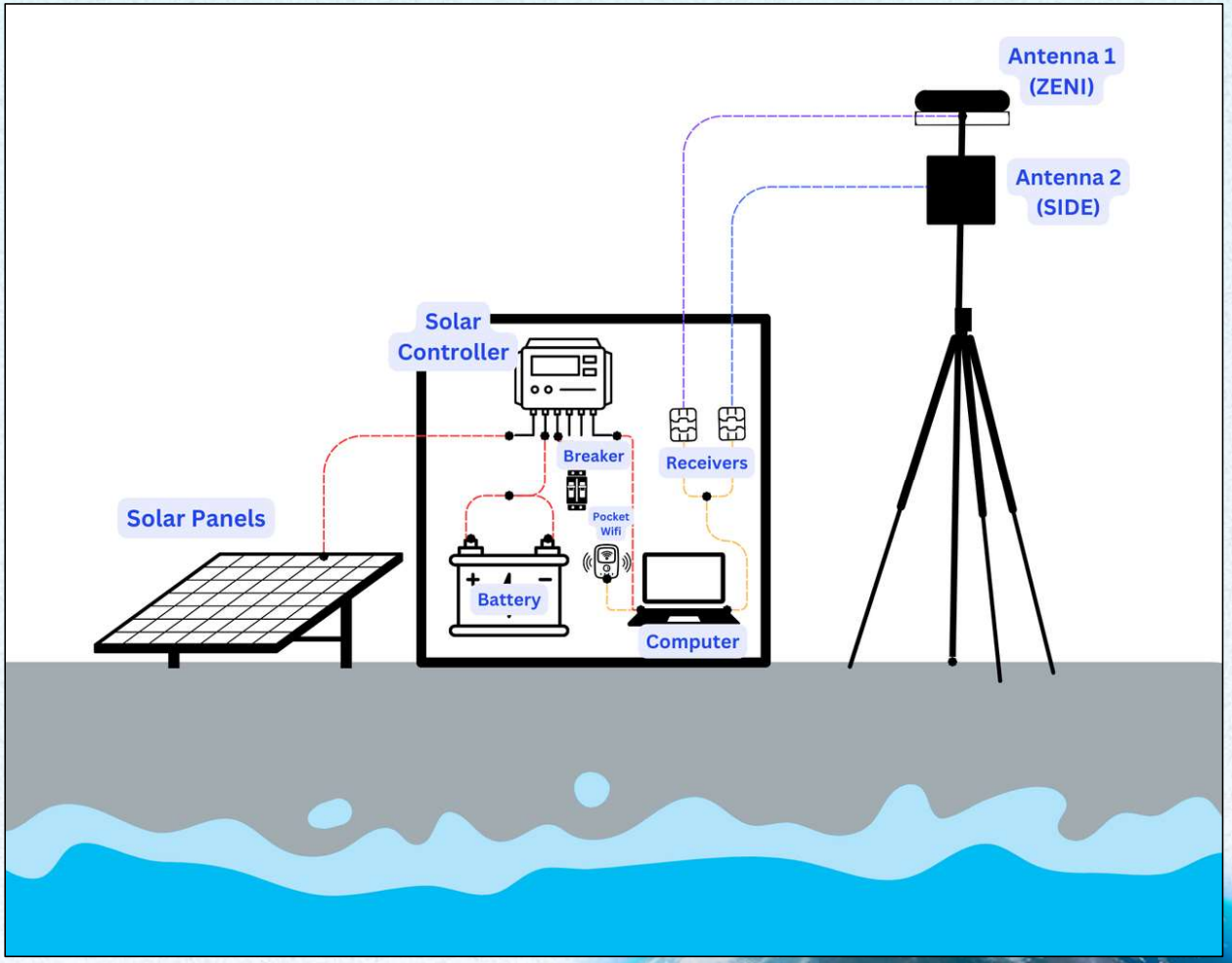

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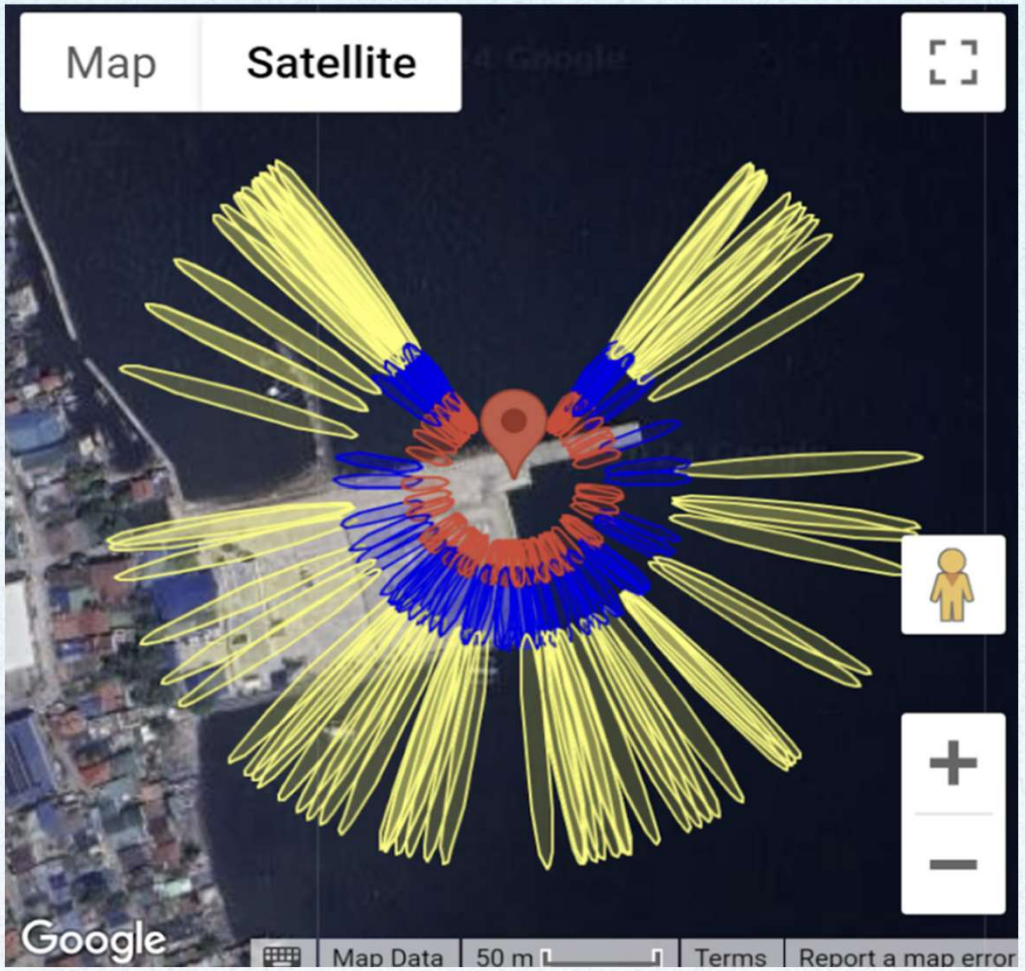
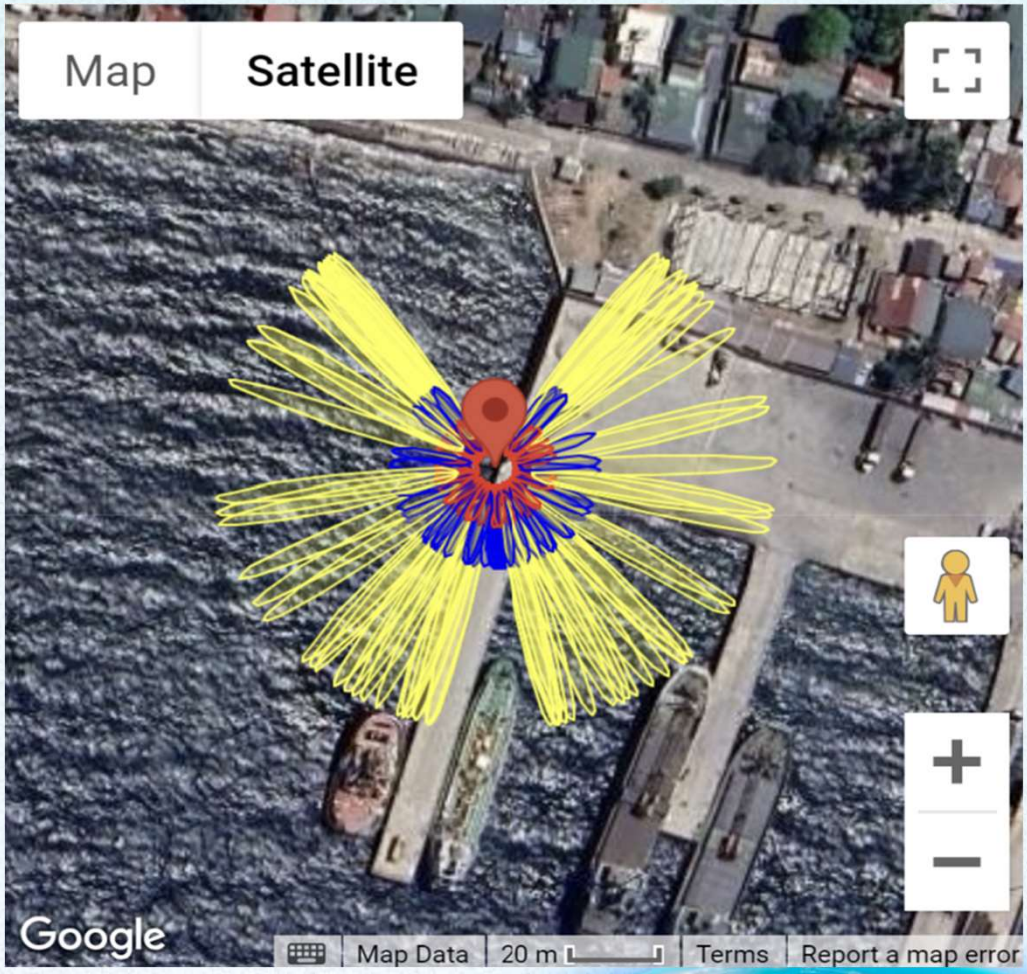


Limay, Bataan



Bauan, Batangas

Philippine Space Agency

Lamao Port
Limay, Bataan

Axis	Coordinates
Latitude	14-30-51.24
Longitude	120-36-41.45
Ell. Height	50.4 m

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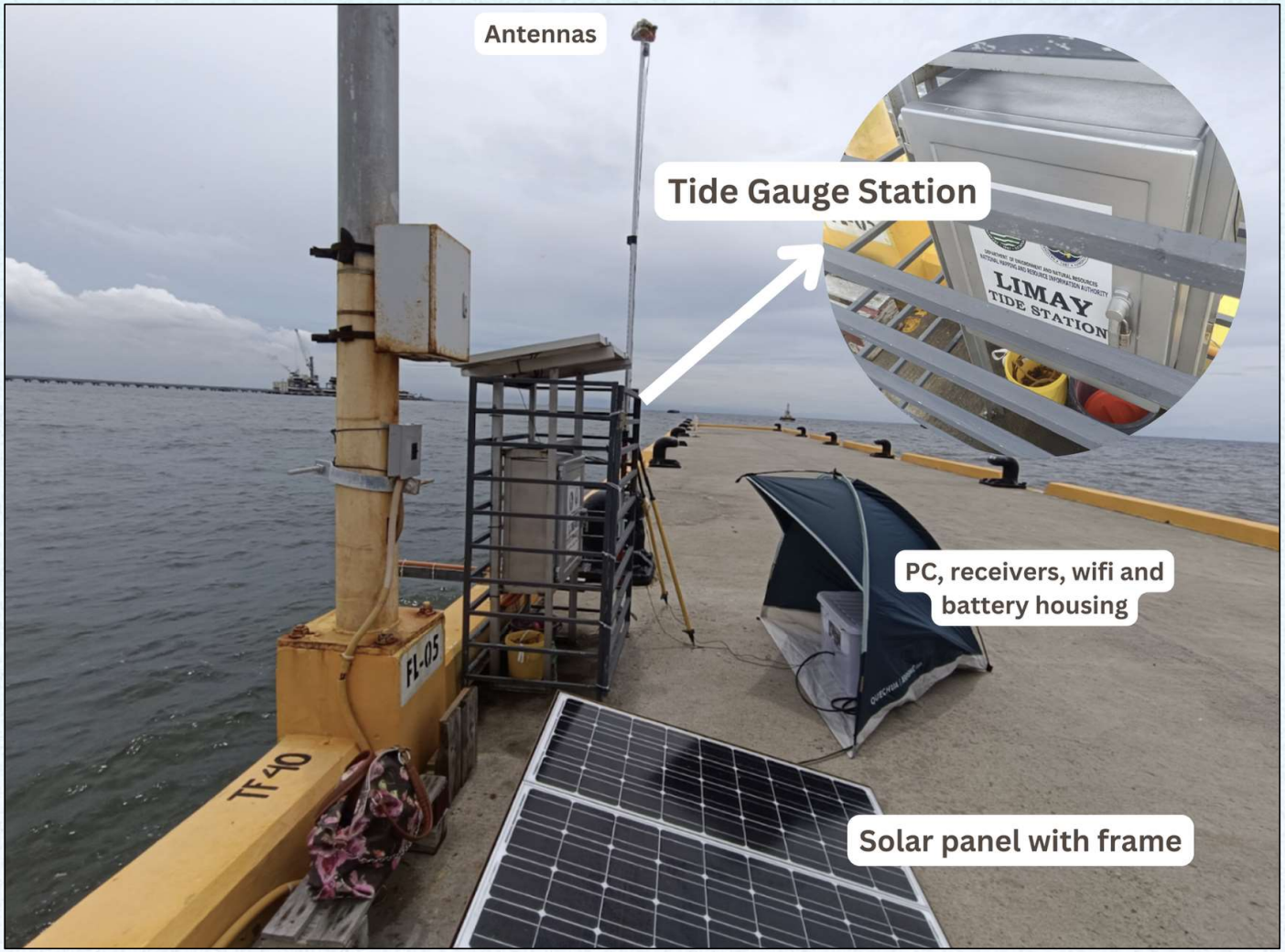
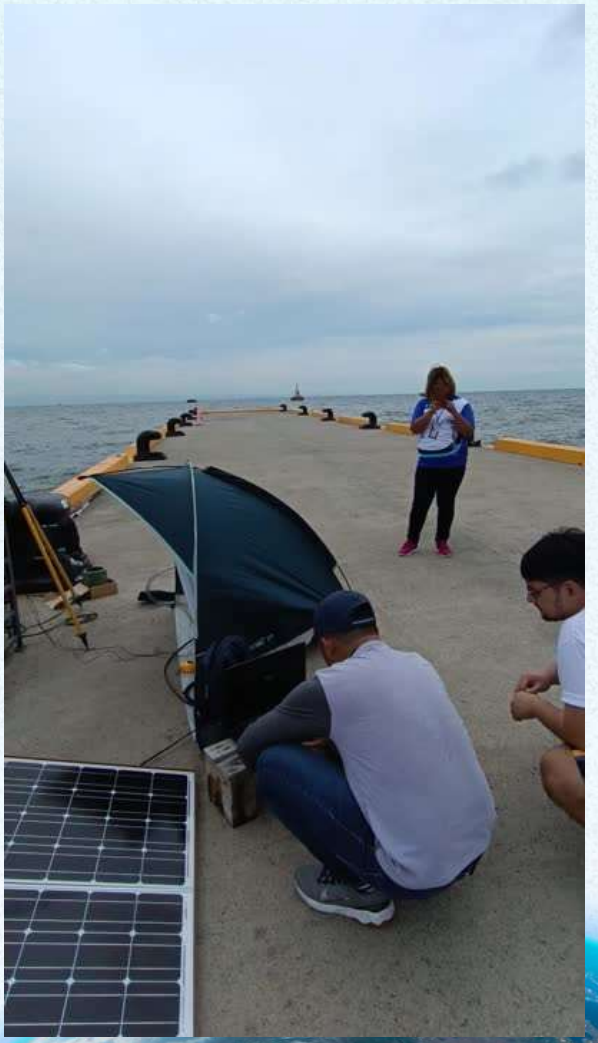
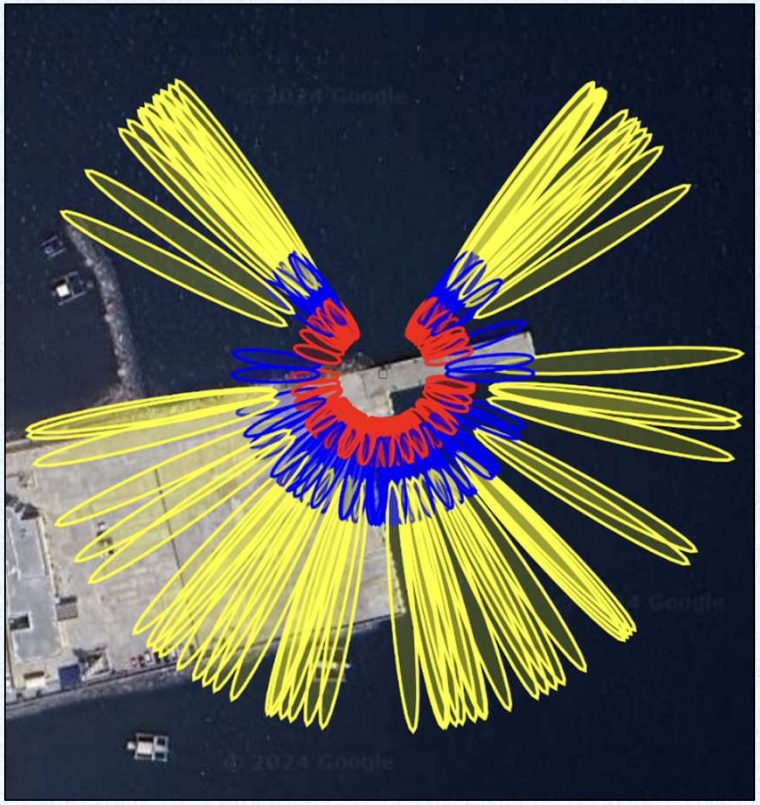




Philippine Space Agency
SENTINEL ASIA
JAXA

Reflection Zones (Lamao Port)



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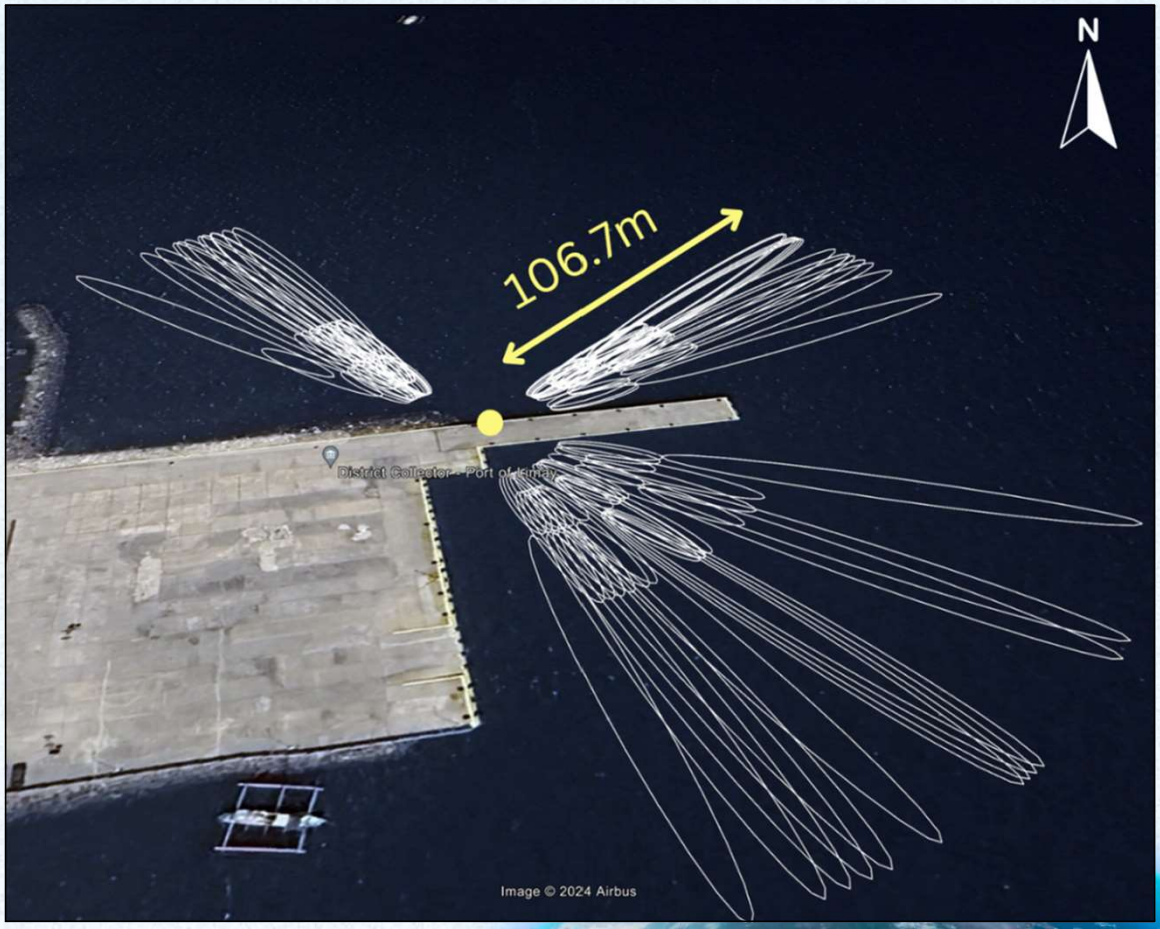
Reflection Zones (Lamao Port)

Elevation	Distance from Station (m)	Length of Fresnel Zone (m)	Area of Fresnel Zone (m^2)
5°	37.571	86.496	506.318
13°	17.562	20.301	72.122



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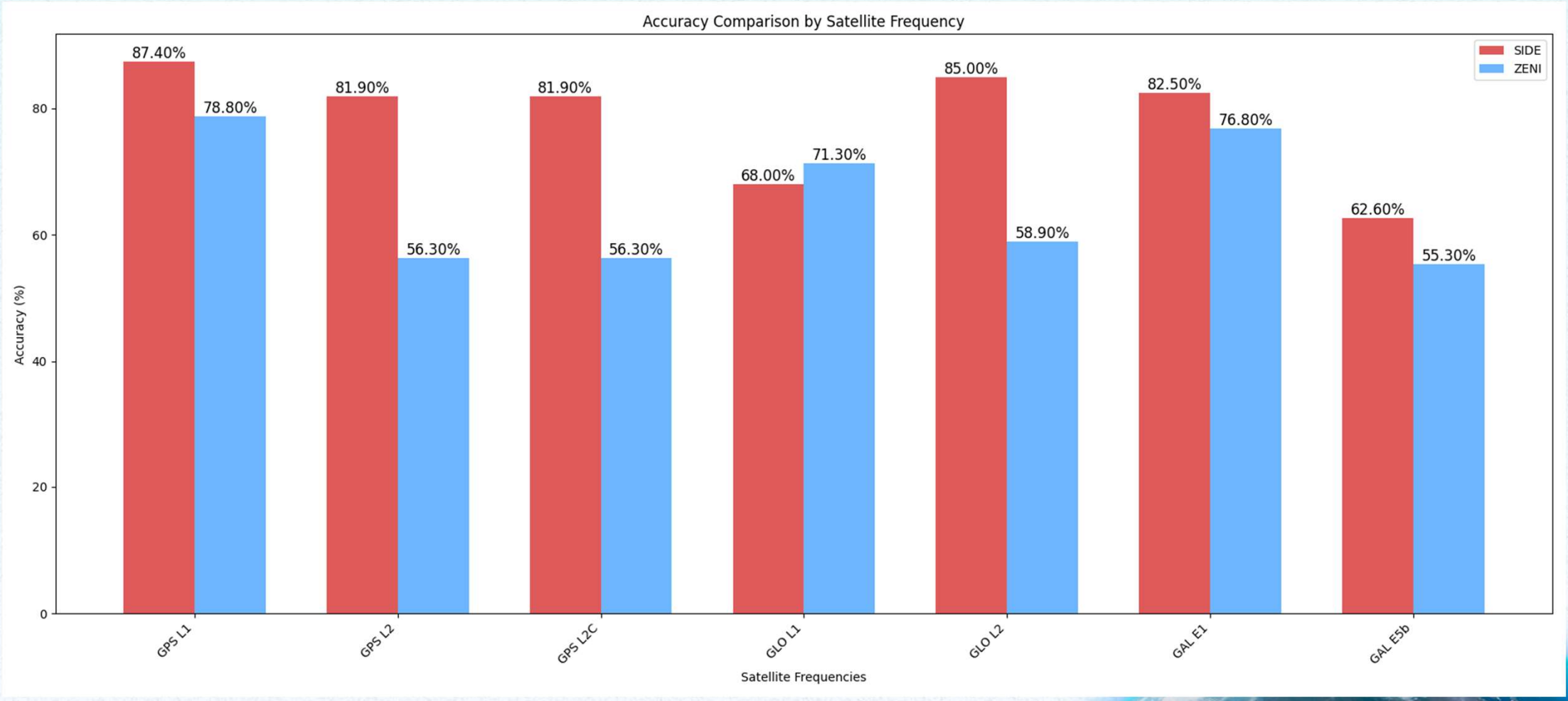

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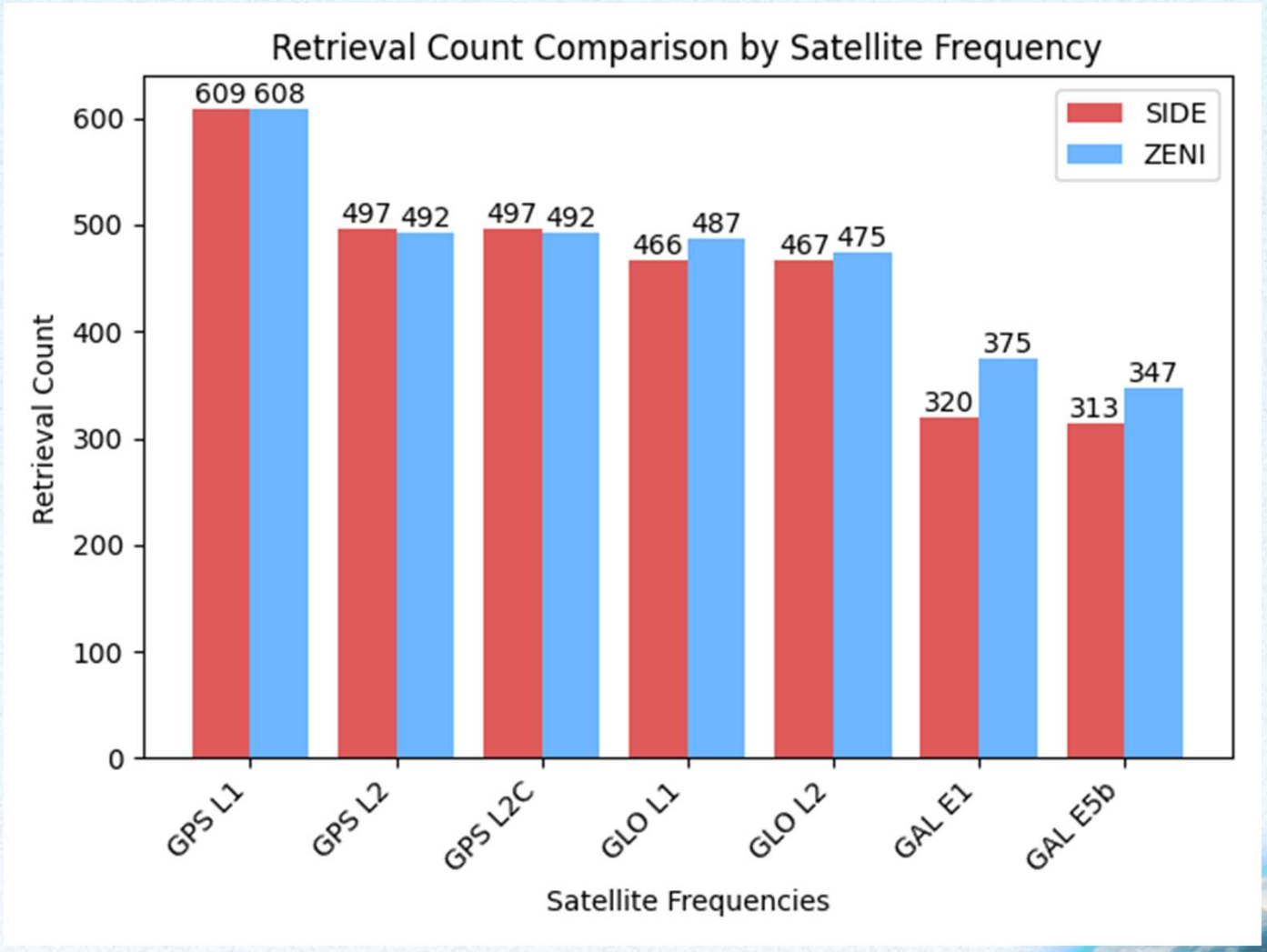

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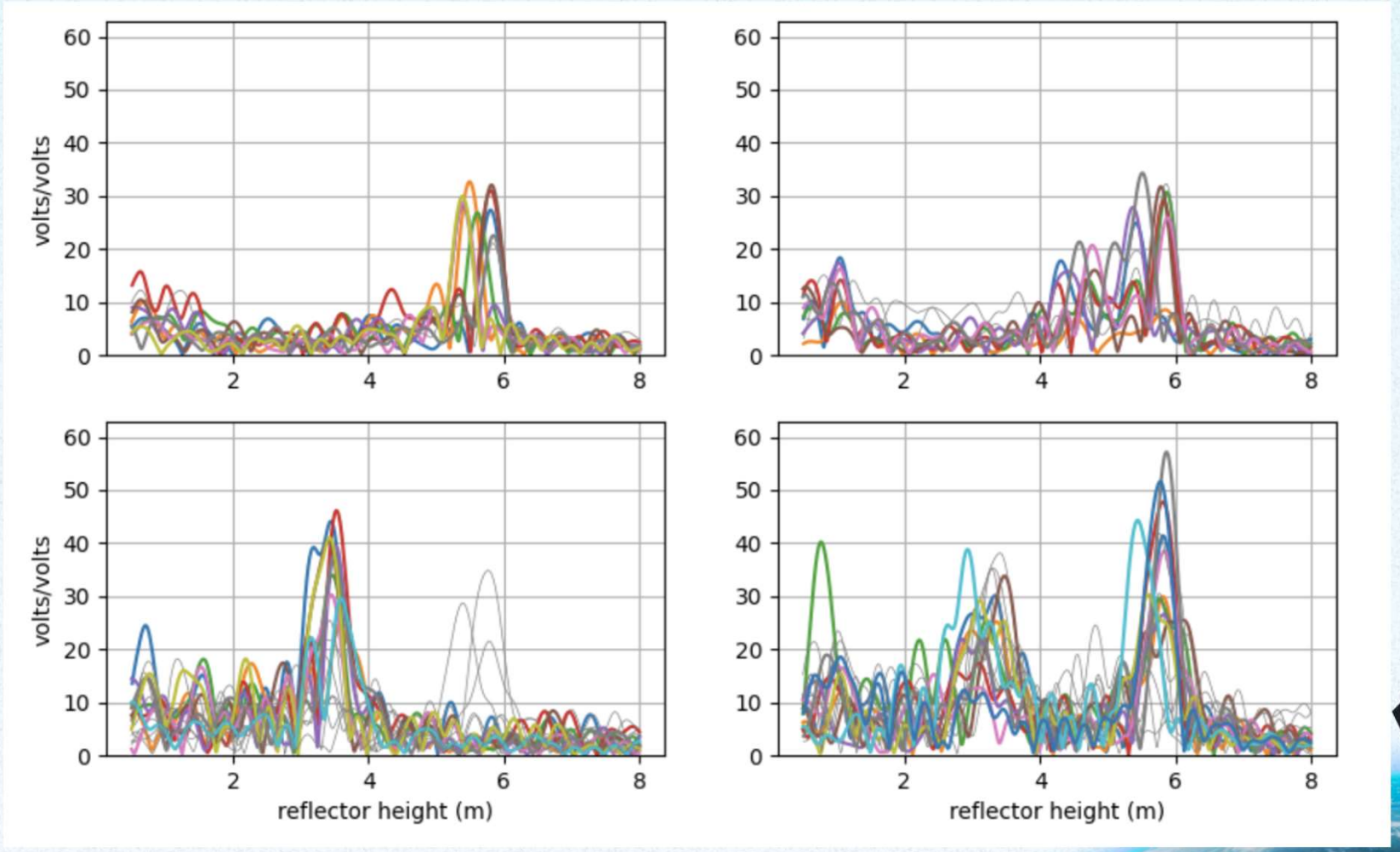
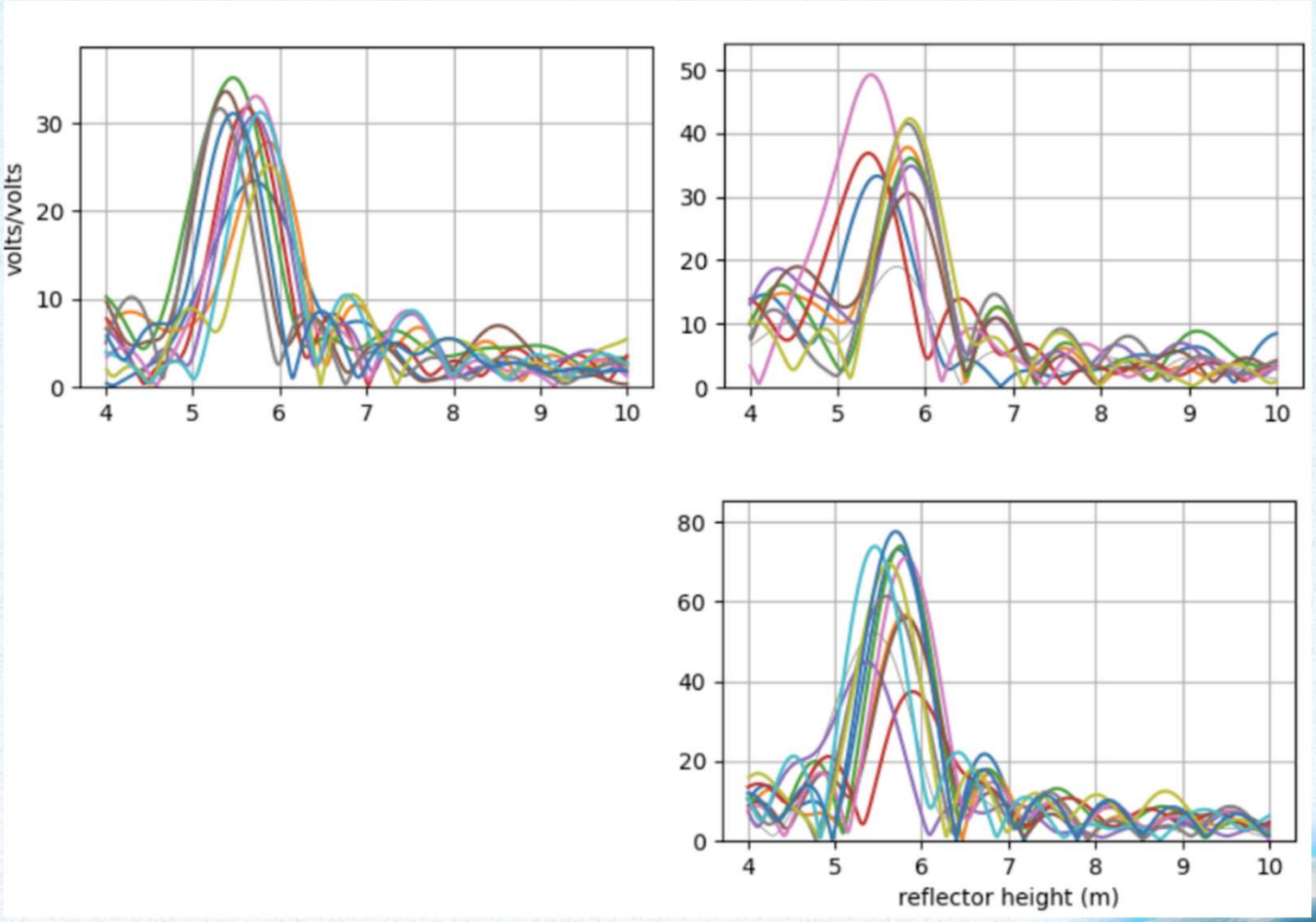


Philippine Space Agency

SENTINEL ASHA

JAXA



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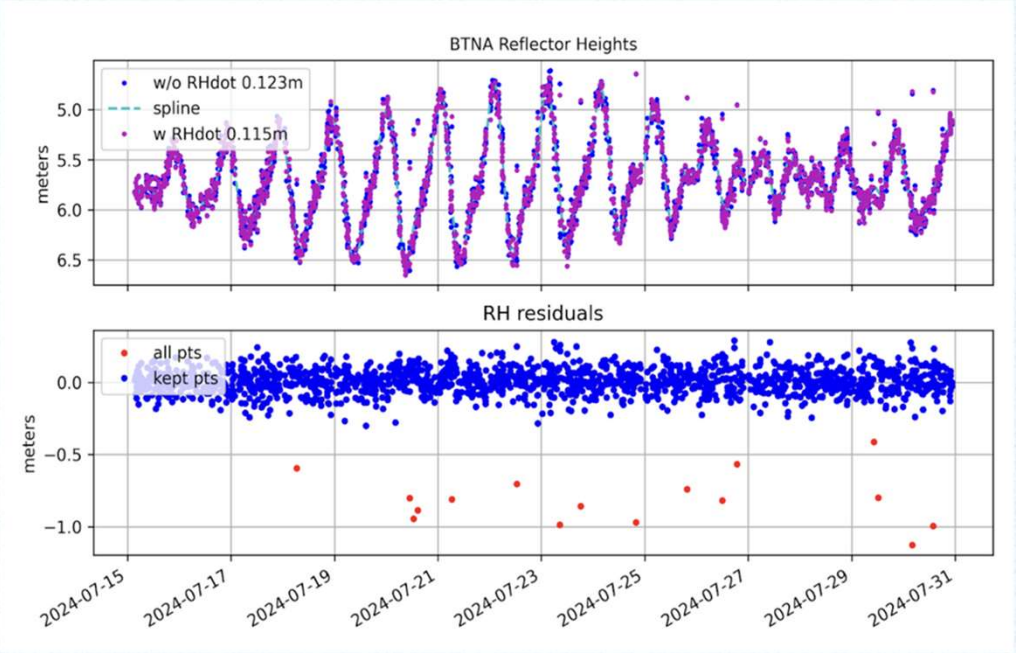
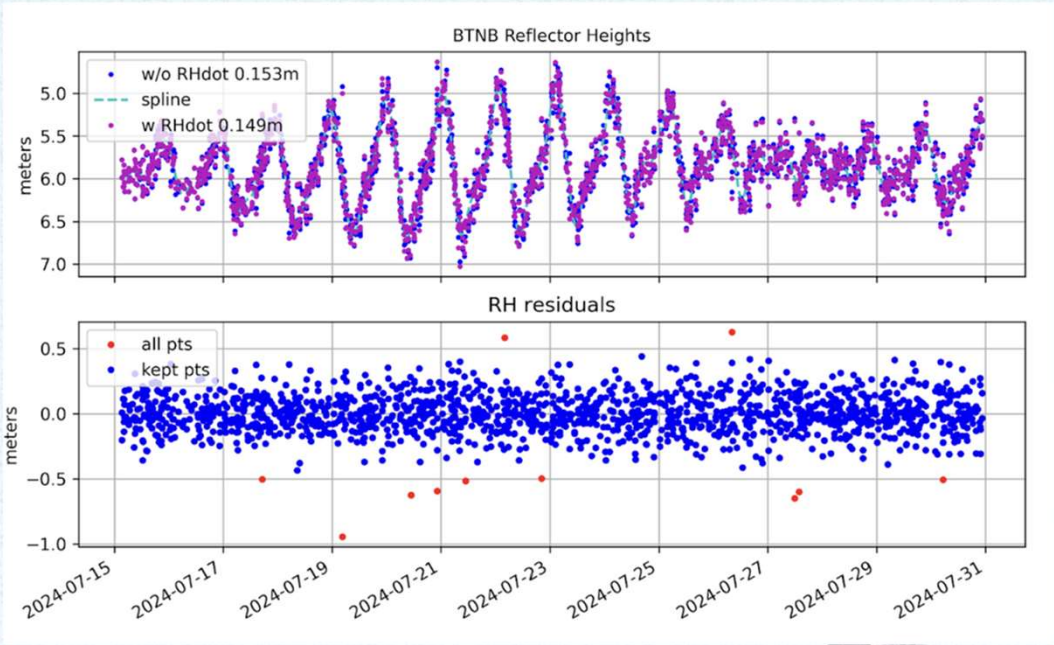
Applying Corrections and Outlier Filtering





SIDE

ZENI

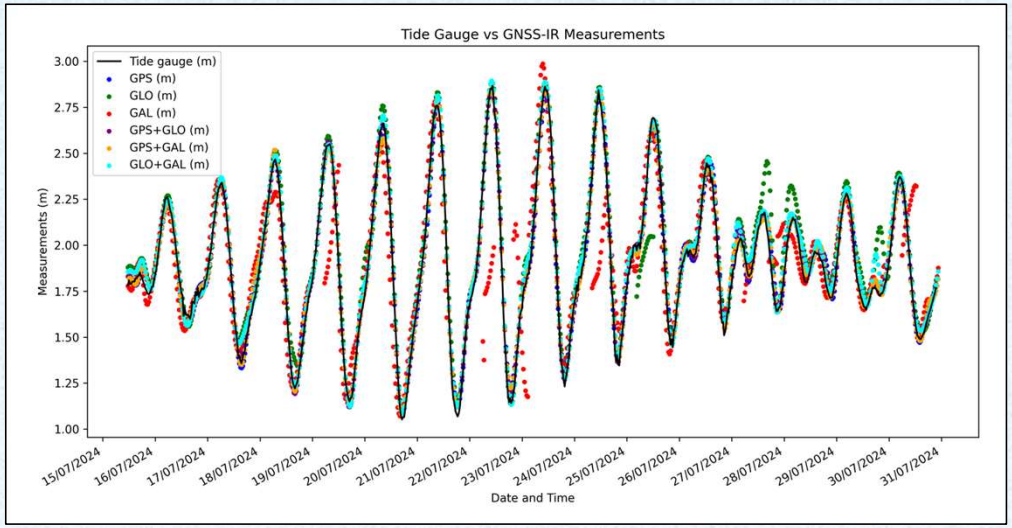
Philippine Space Agency

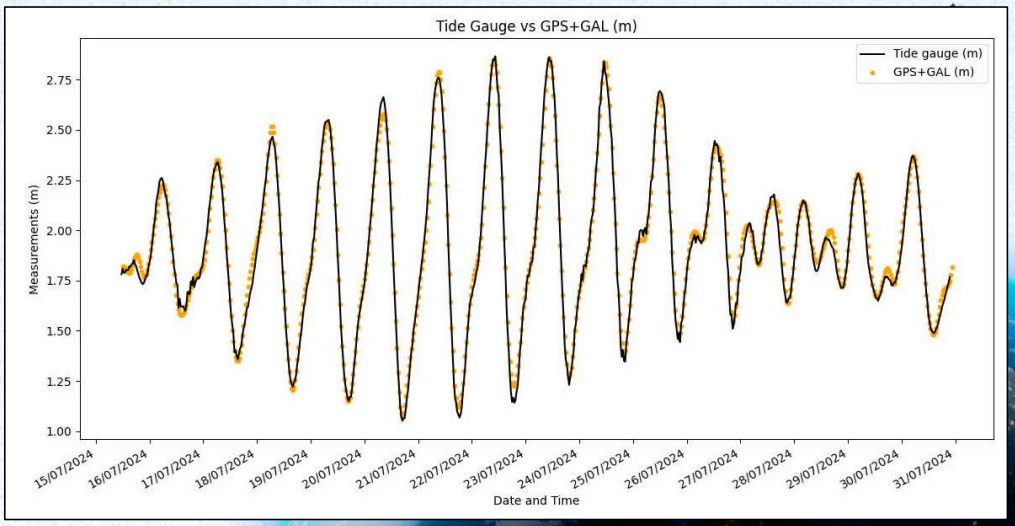
SENTINEL ASIA

JAXA

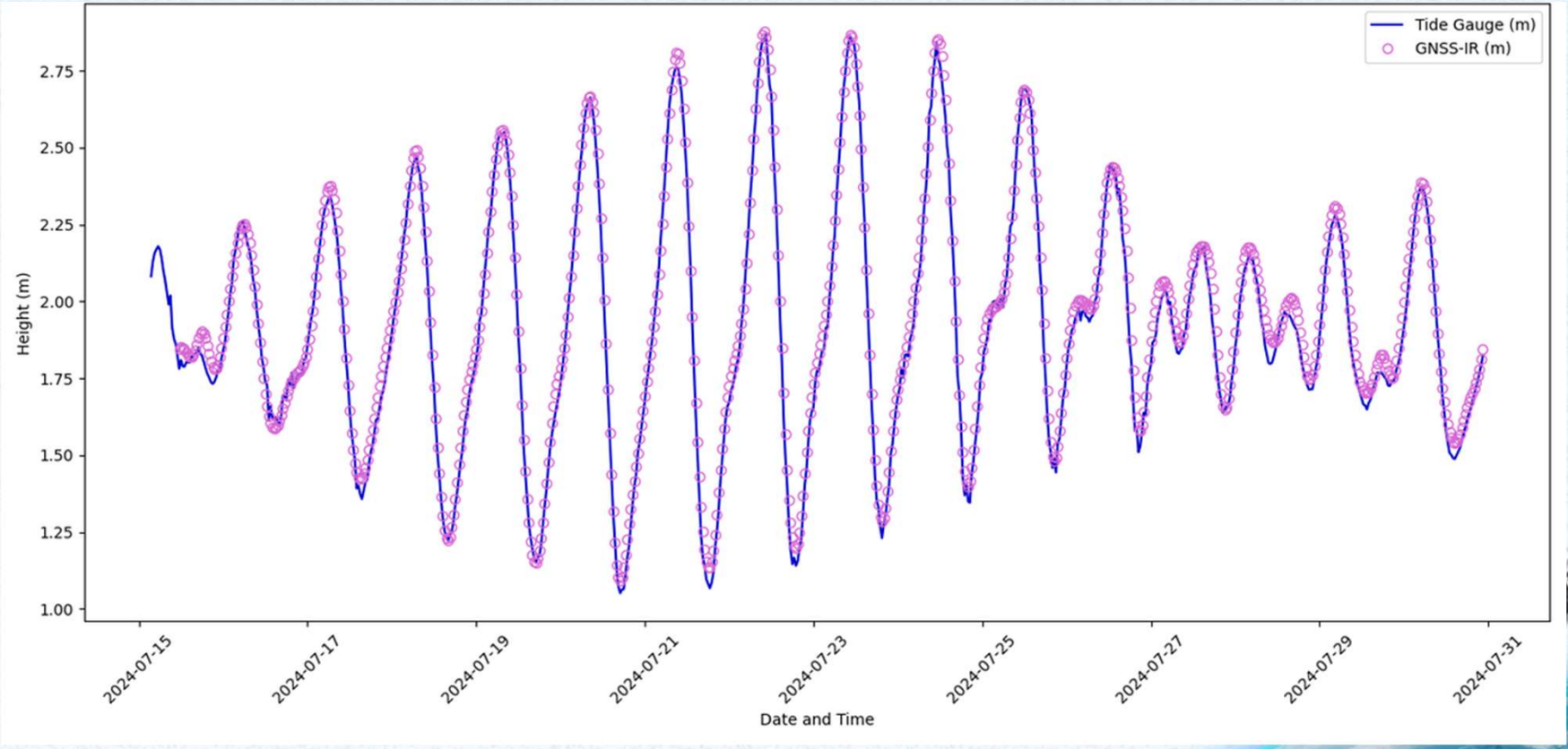
Tide Gauge Comparison **(SIDE)**

GNSS Frequency	RMSE (cm)	MAE (cm)	Correlation Coefficient
GPS	4.200	3.283	0.995
GLO	10.147	6.897	0.974
GAL	29.991	17.410	0.693
GPS+GLO	3.228	2.626	0.997
GPS+GAL	3.769	2.909	0.996
GLO+GAL	5.048	3.955	0.995
ALL	4.175	3.435	0.997





Tide Gauge Comparison **(SIDE)**



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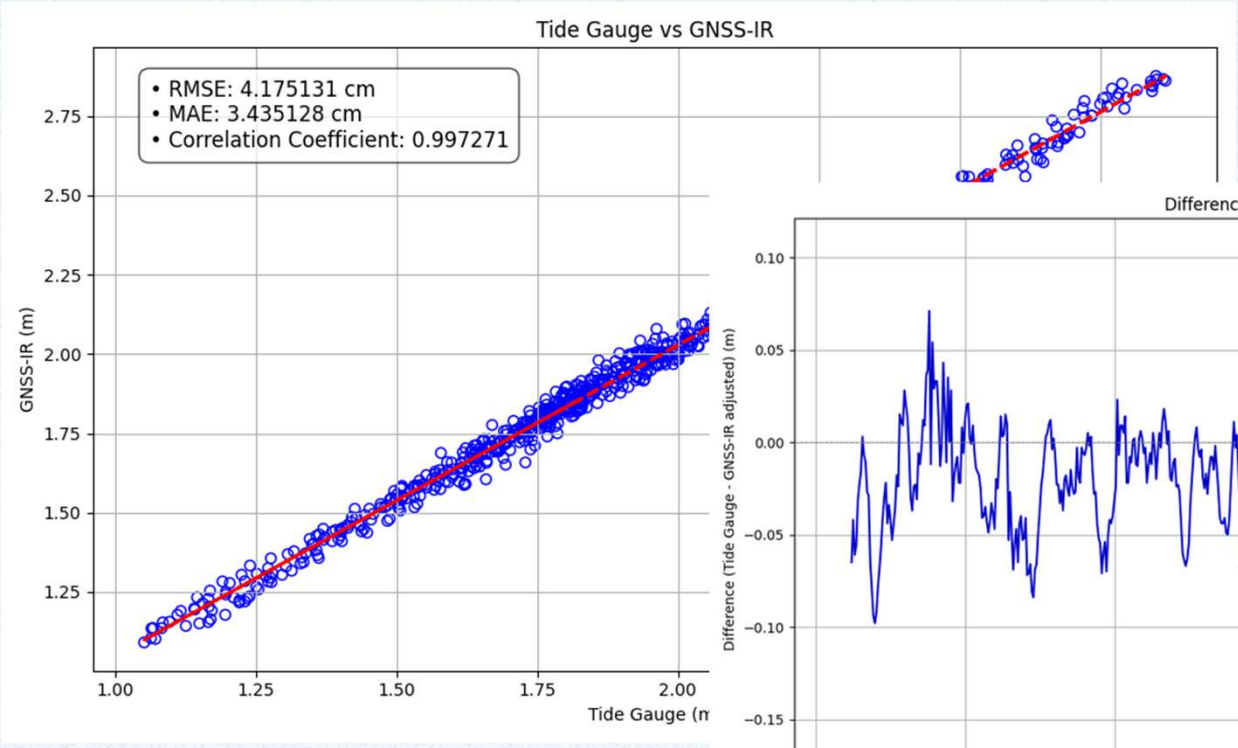
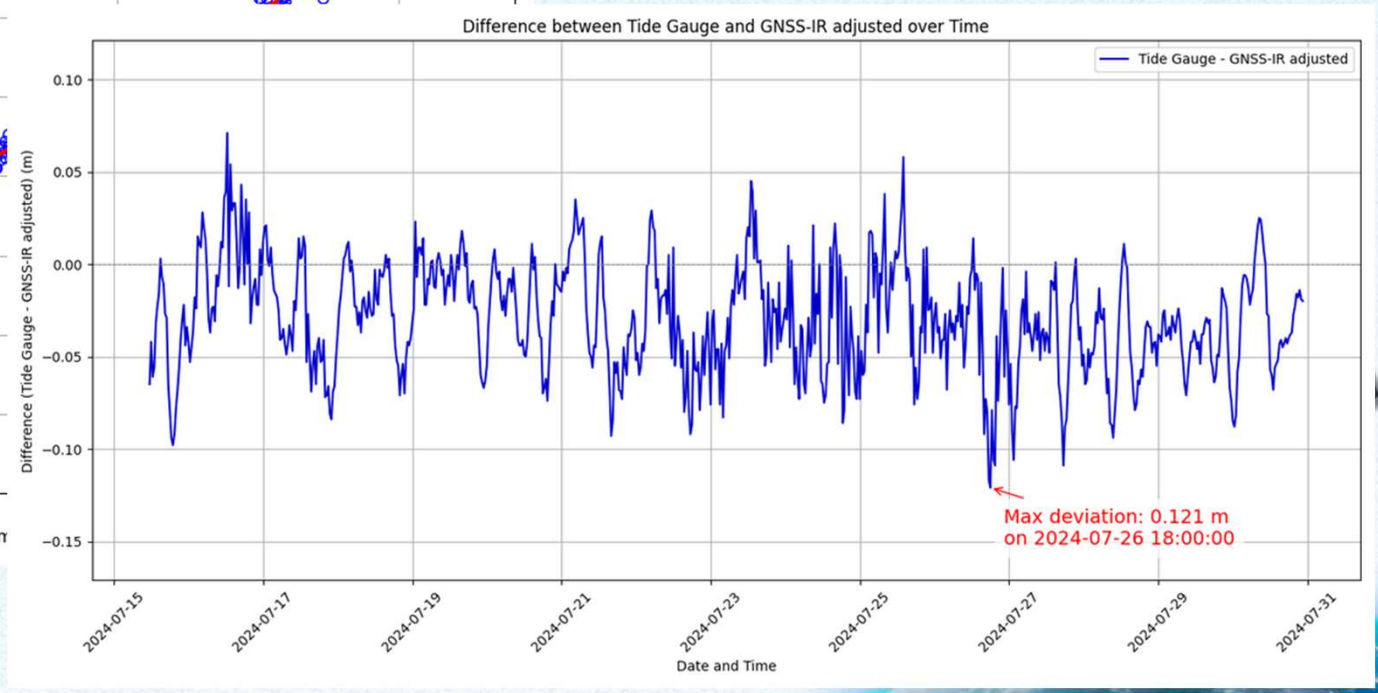
Tide Gauge Comparison **(SIDE)**





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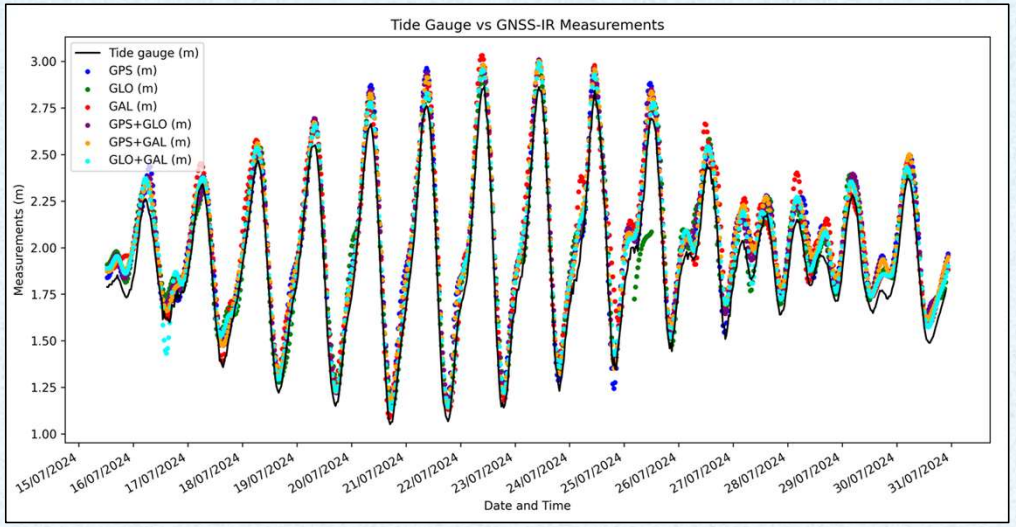
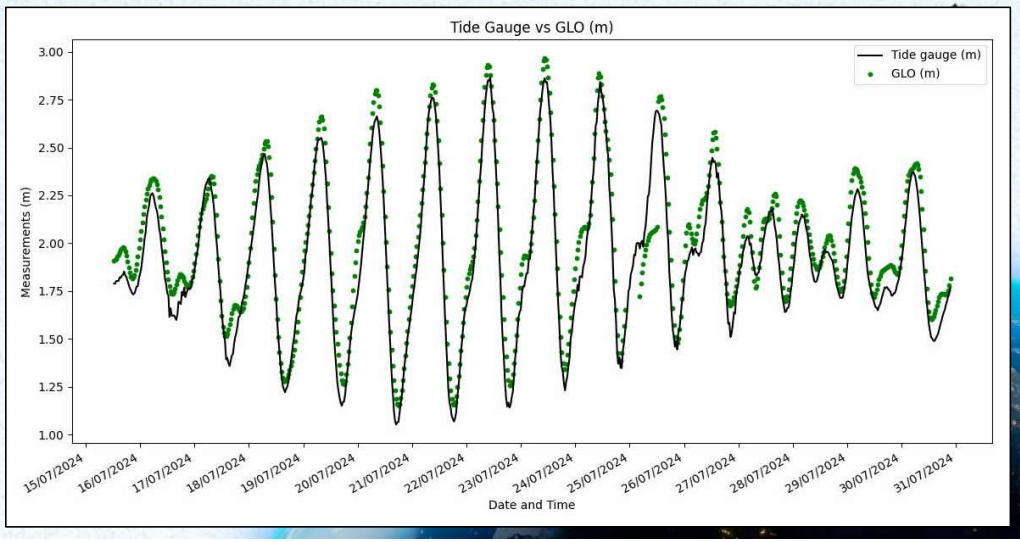
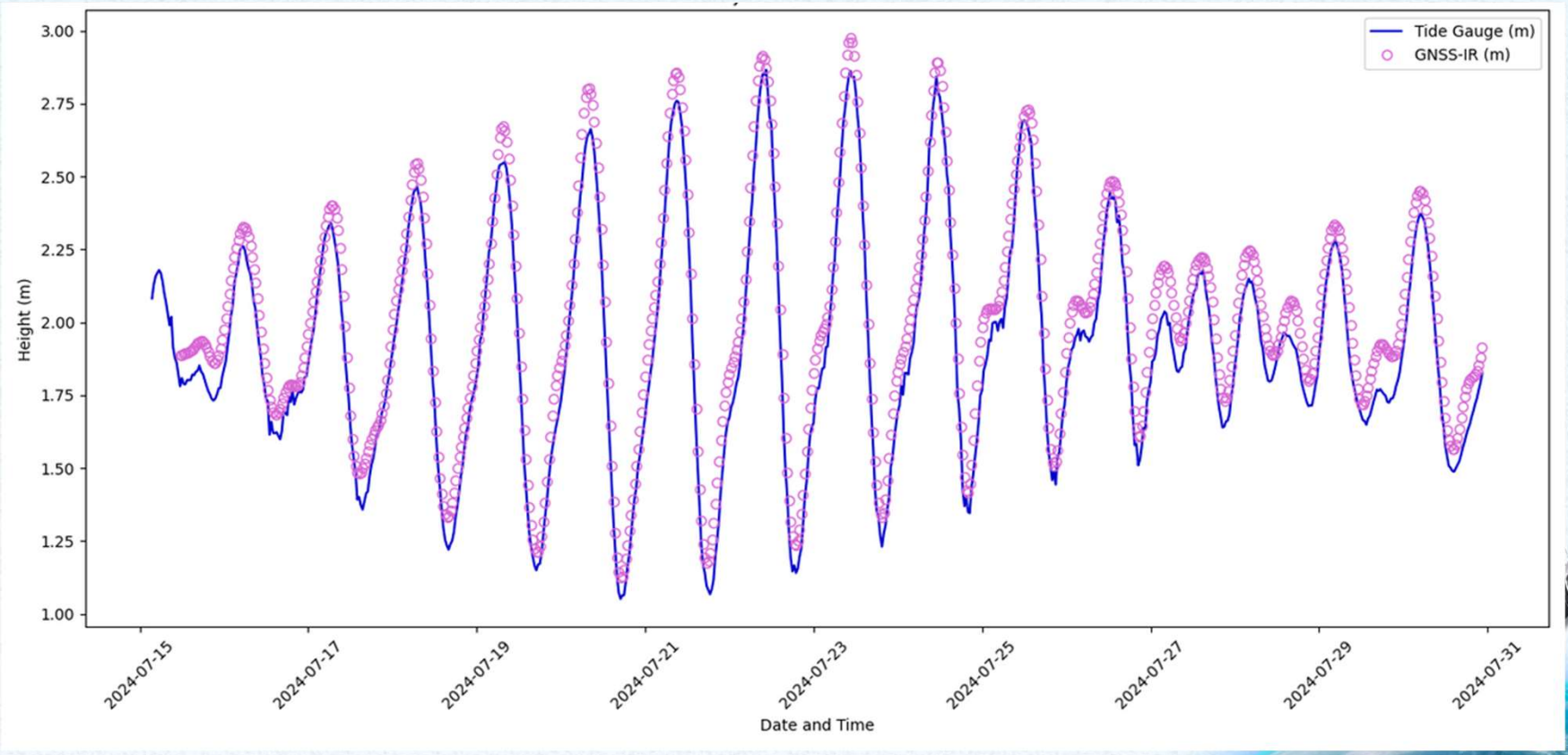
Tide Gauge Comparison **(ZENI)**

GNSS Frequency	RMSE (cm)	MAE (cm)	Correlation Coefficient
GPS	12.930	11.620	0.988
GLO	12.088	9.829	0.973
GAL	13.913	11.838	0.981
GPS+GLO	12.382	11.508	0.992
GPS+GAL	12.463	11.749	0.994
GLO+GAL	10.234	9.355	0.992
ALL	10.219	9.406	0.994





Tide Gauge Comparison **(ZENI)**



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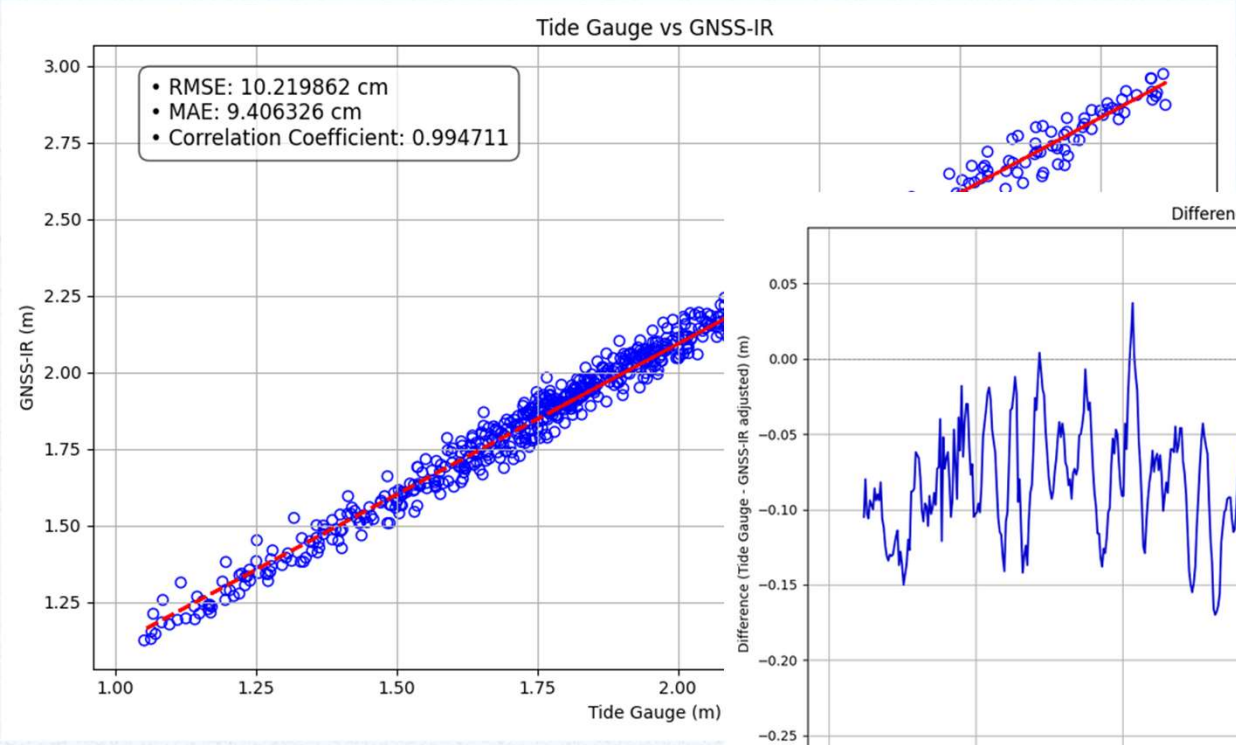
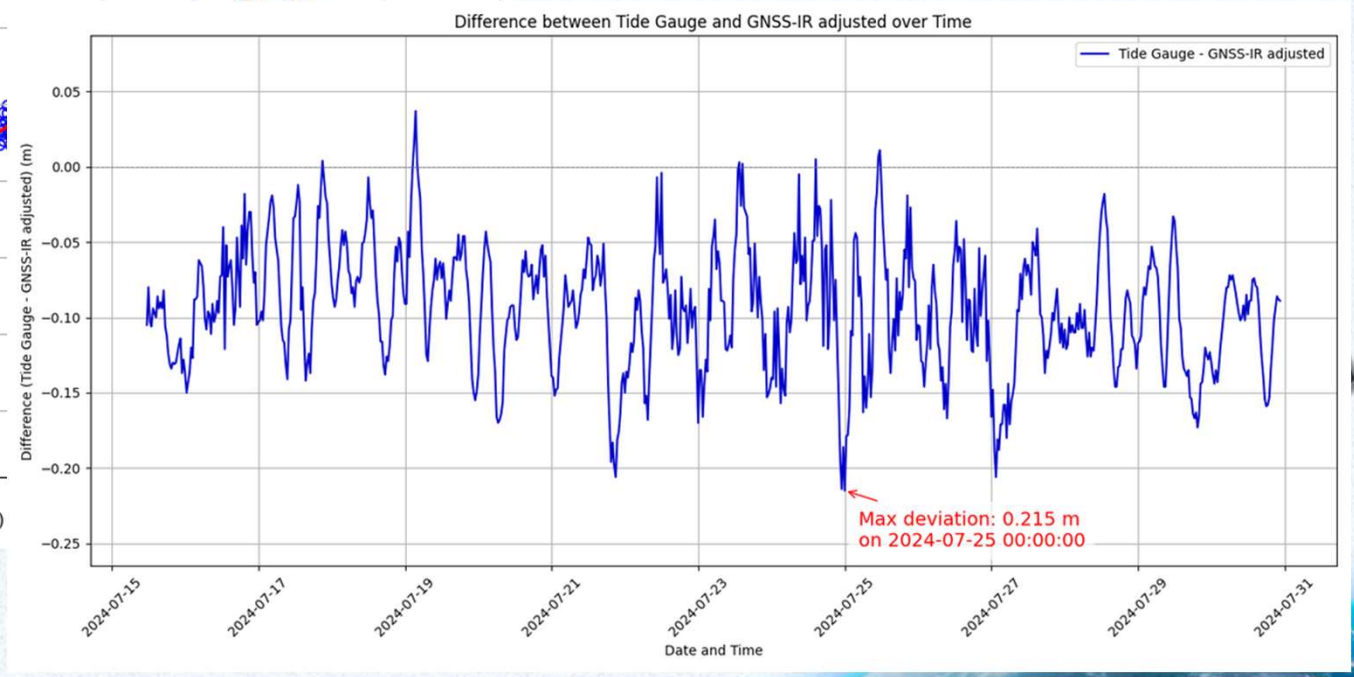
Tide Gauge Comparison **(SIDE)**





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GNSS-IR		Tide Gauge	
U-blox Zed-F9P receivers	P 9,000	Radar or pressure-type tide gauge instrument (medium-end)	**P 350,000**
U-blox ANN-MB1 antenna	P 4,000		
Beelink Mini Computer	P 10,000		
1 Pocket Wifi	P 5,000		
1 Housing (Megabox)	P 2,000		
Total	**P 30,000**		

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Component	GNSS-IR Station	Tide Gauge Station
Instrument and housing	P 30,000	P 350,000
Power supply system	P 10,000	P 50,000
Civil Works and Fabrication	P 8,000	P 100,000
Total	**P 48,000**	**P 500,000**

Philippine Space Agency

Thank you for your time!

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