

# Considering Satellite Attitude Quaternions in BeiDou Precise Point Positioning Performance

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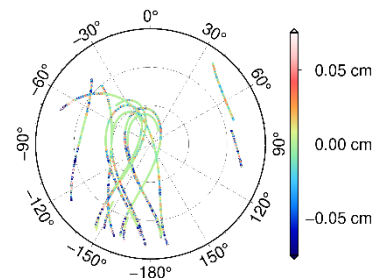
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# Why satellite attitude quaternions?

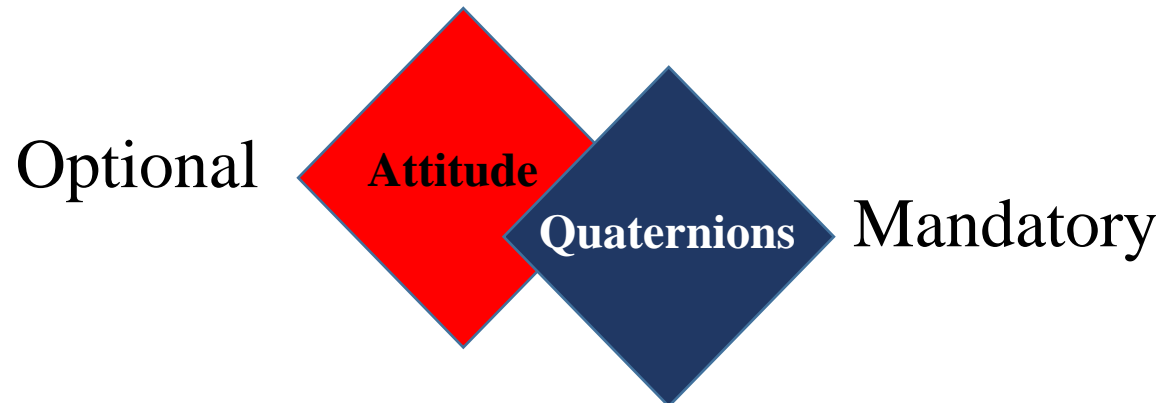
- Theoretical modeling algorithms for computing satellite attract errors
  - The errors lump with the satellite clocks
- Satellite attitude quaternions are required in PPP
  - For efficient fixed solutions

Solar Radiation Pressure

Access Satellite Antenna Phase Centers

Phase Wind-up effect

Satellites in eclipsing zones



# Accounting for the BeiDou satellite attitude quaternions

## Datasets

- Observations – 134 globally distributed BeiDou tracking stations (Figure 1)

- Products –
  - ▶ WUM0MGXRAP
  - ▶ COD0MGXFIN

## Dataset period

- April 10 – 16, 2022
- DOY 100 – 106, 2022

## Processing Strategy–

- ▶ Nominal Attitude
- ▶ Attitude quaternions

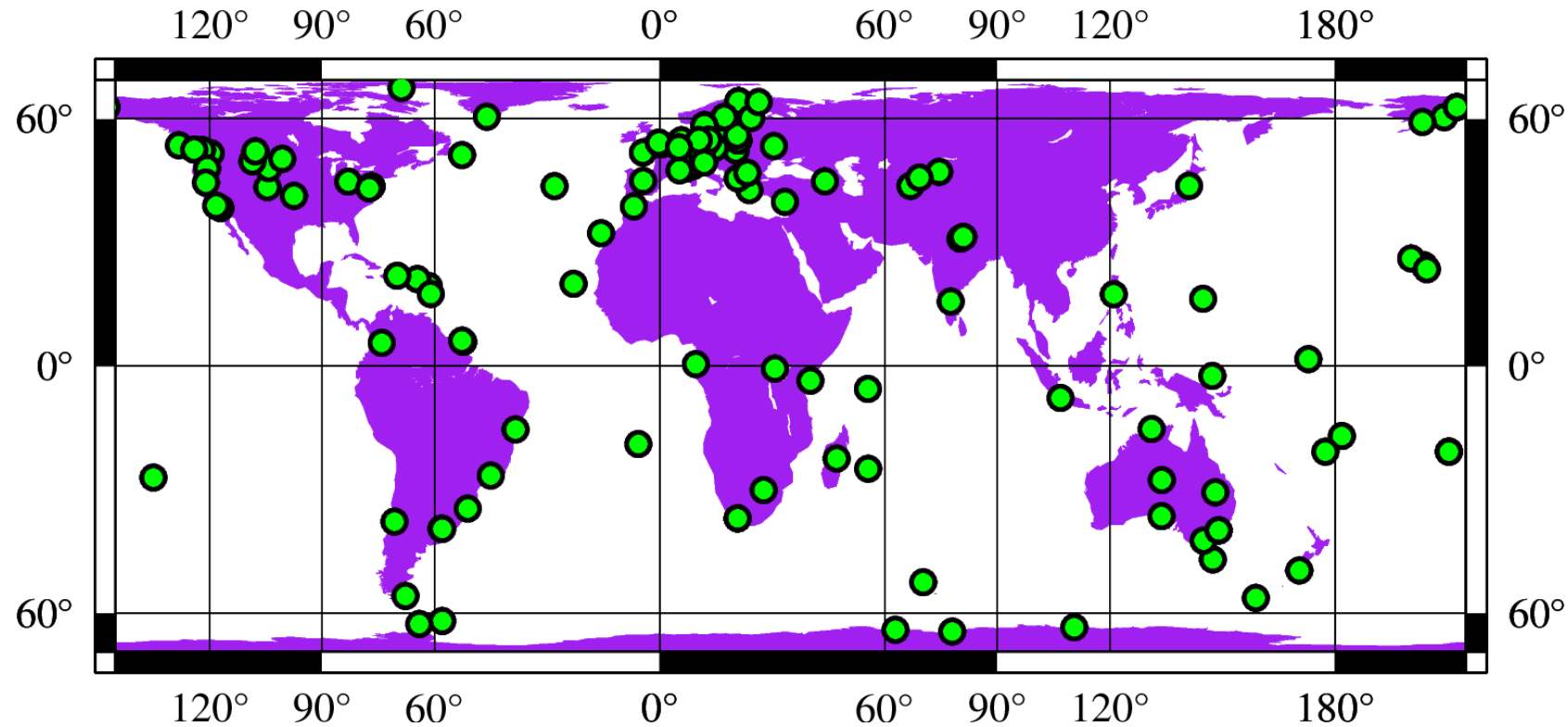


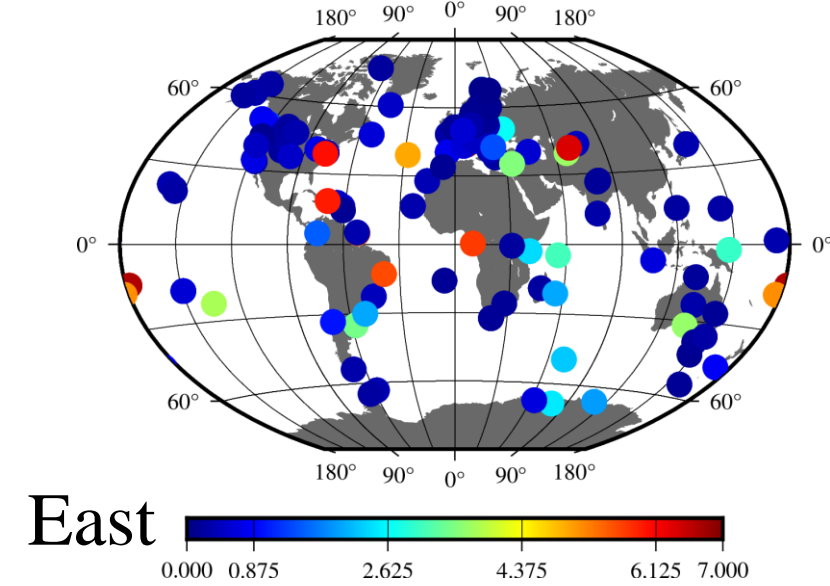
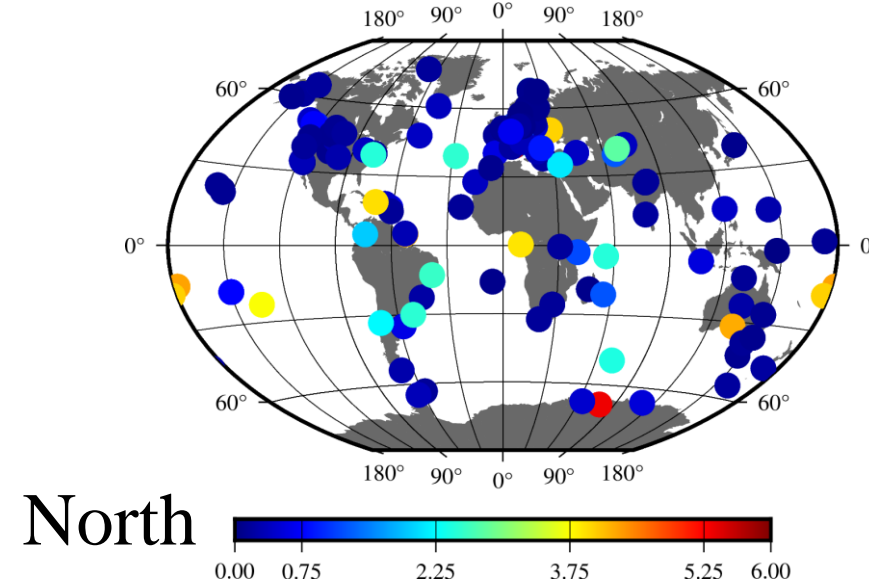
Figure 1: Distribution of BeiDou tracking stations

# Kinematic PPP

## Float Solution

### WUM0MGXRAP

Nominal Attitude



- Performance (cm)
  - North (~ 6)
  - East (~ 7)
  - Up (~ 9)

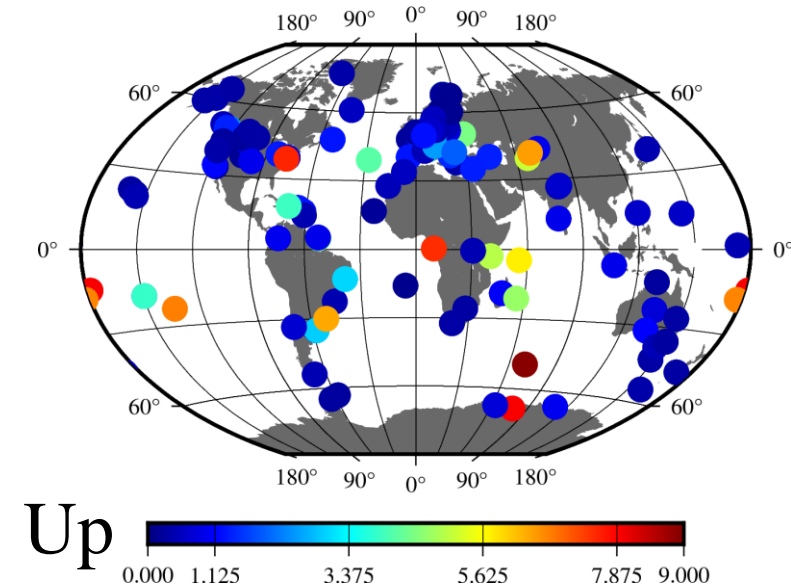


Figure 2a: Positioning STD using nominal attitude (cm)

# Kinematic PPP

## Float Solution

WUM0MGXRAP

Attitude Quaternions

North

East

- Performance (cm)
  - North (~ 4)
  - East (~ 6)
  - Up (~ 8)

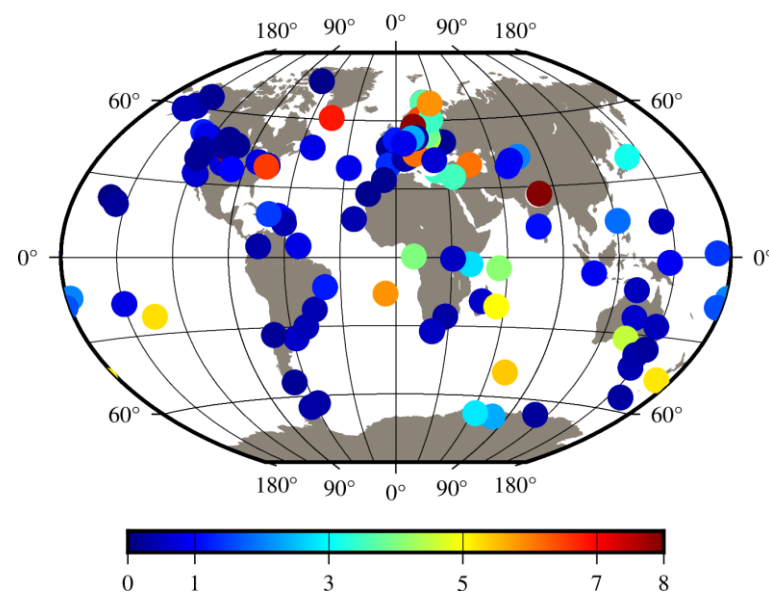
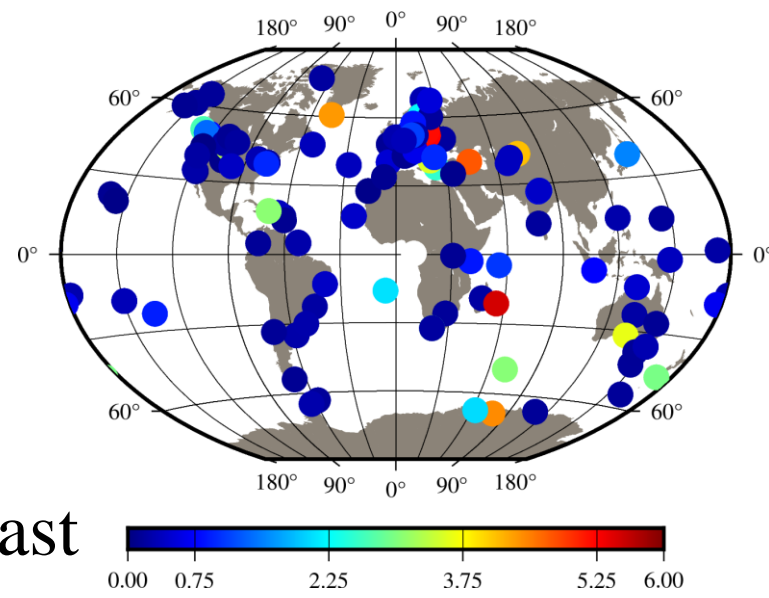
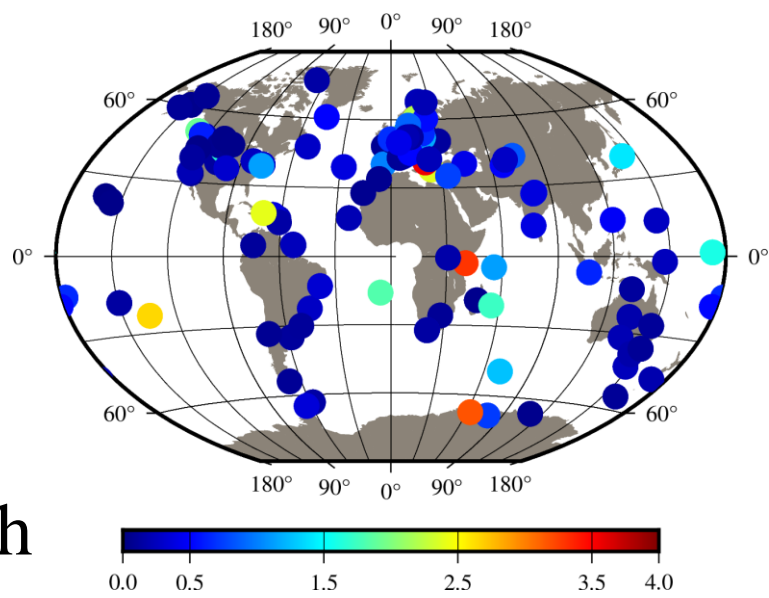


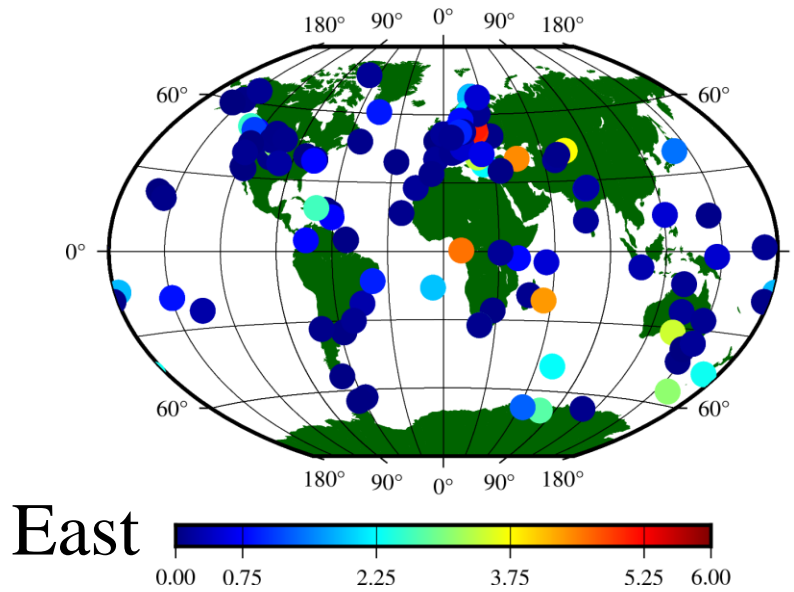
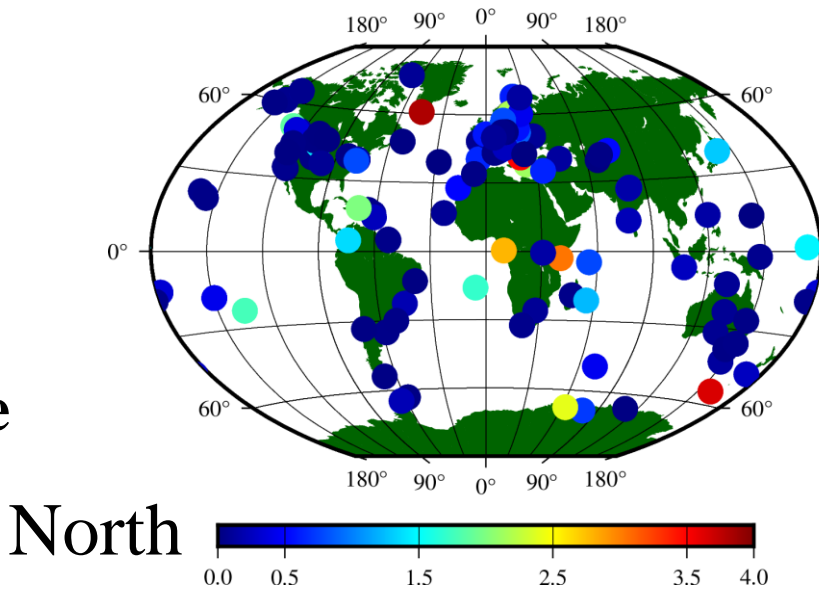
Figure 2b: Positioning STD using attitude quaternions (cm)

# Kinematic PPP

## Float Solution

COD0MGXFIN

Nominal Attitude



- Performance (cm)
  - North (~ 4)
  - East (~ 6)
  - Up (~ 8)

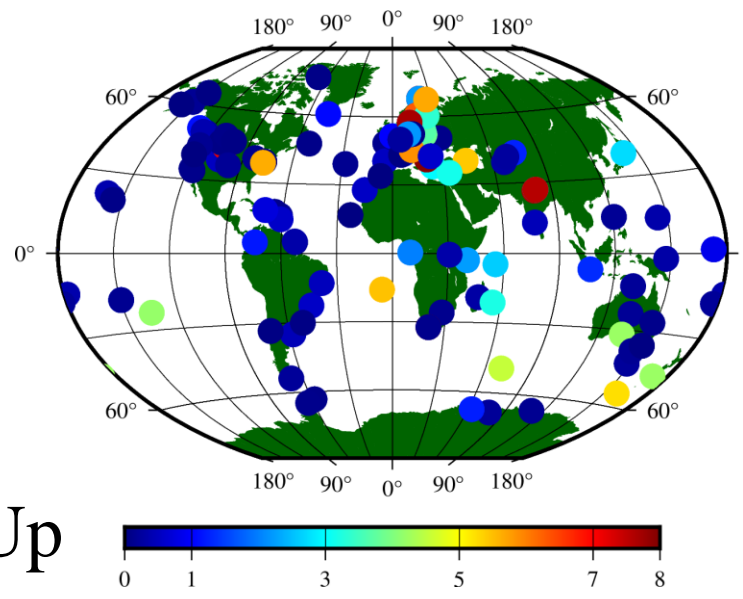


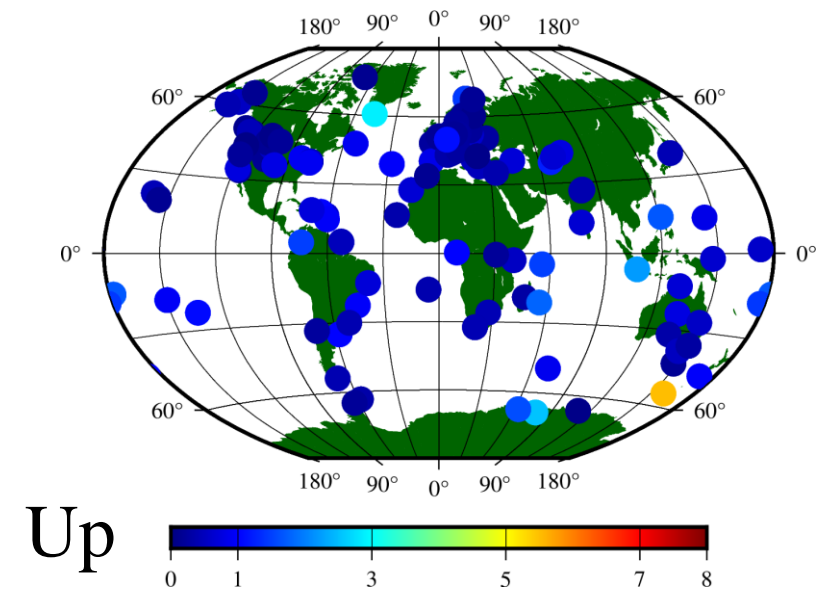
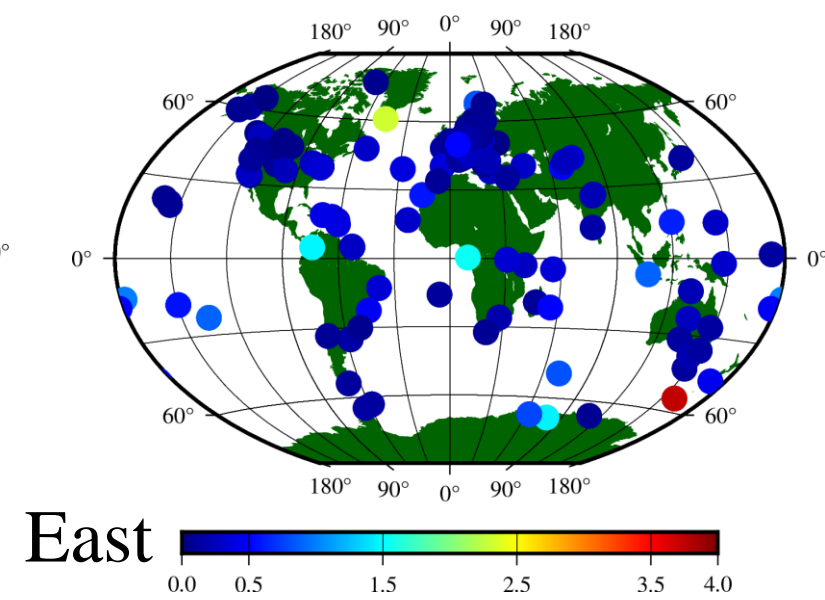
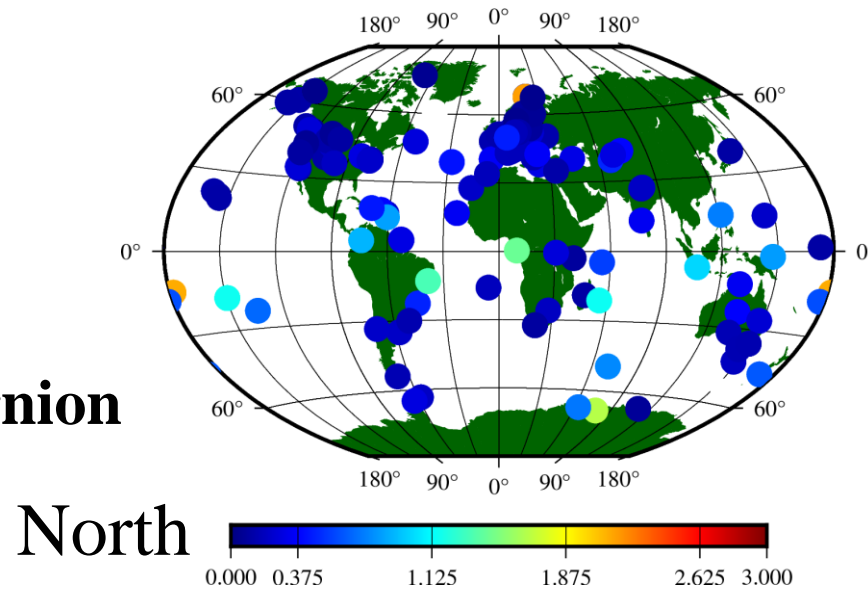
Figure 3a: Positioning STD using nominal attitude (cm)

# Kinematic PPP

## Float Solution

### COD0MGXFIN

#### Attitude Quaternion



- Performance (cm)
  - North (~ 3)
  - East (~ 4)
  - Up (~ 8)

Figure 3b: Positioning STD using attitude quaternions (cm)

# Kinematic PPP Float vs Fixed Solution

- Comparable improvement in STD (Fixing Rate ~98%)

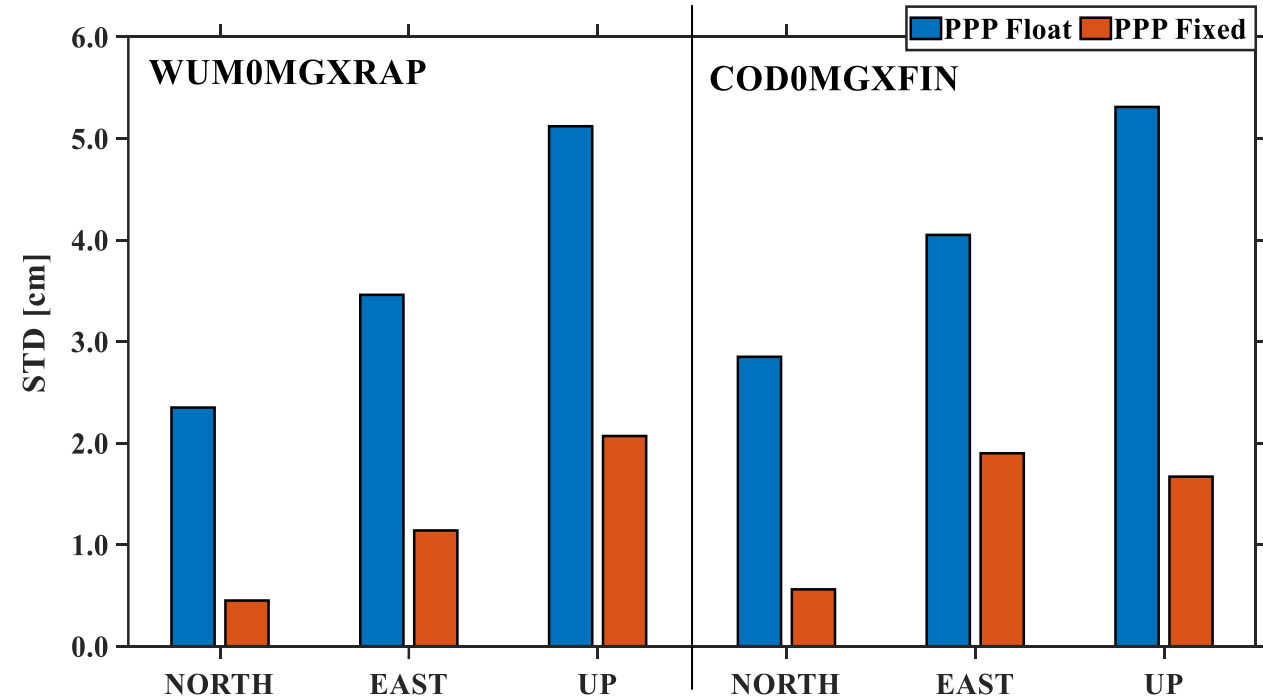


Figure 4: STD of float and fixed solutions

Table: STD of float and fixed solutions

	WUM0MGXRAP			COD0MGXFIN		
	North	East	Up	North	East	Up
PPP Float	2.35	3.46	5.12	2.85	4.05	5.31
PPP Fixed	0.45	1.14	2.07	0.56	1.90	1.67



# Residuals – COD0MGXFIN

## Nominal Attitude

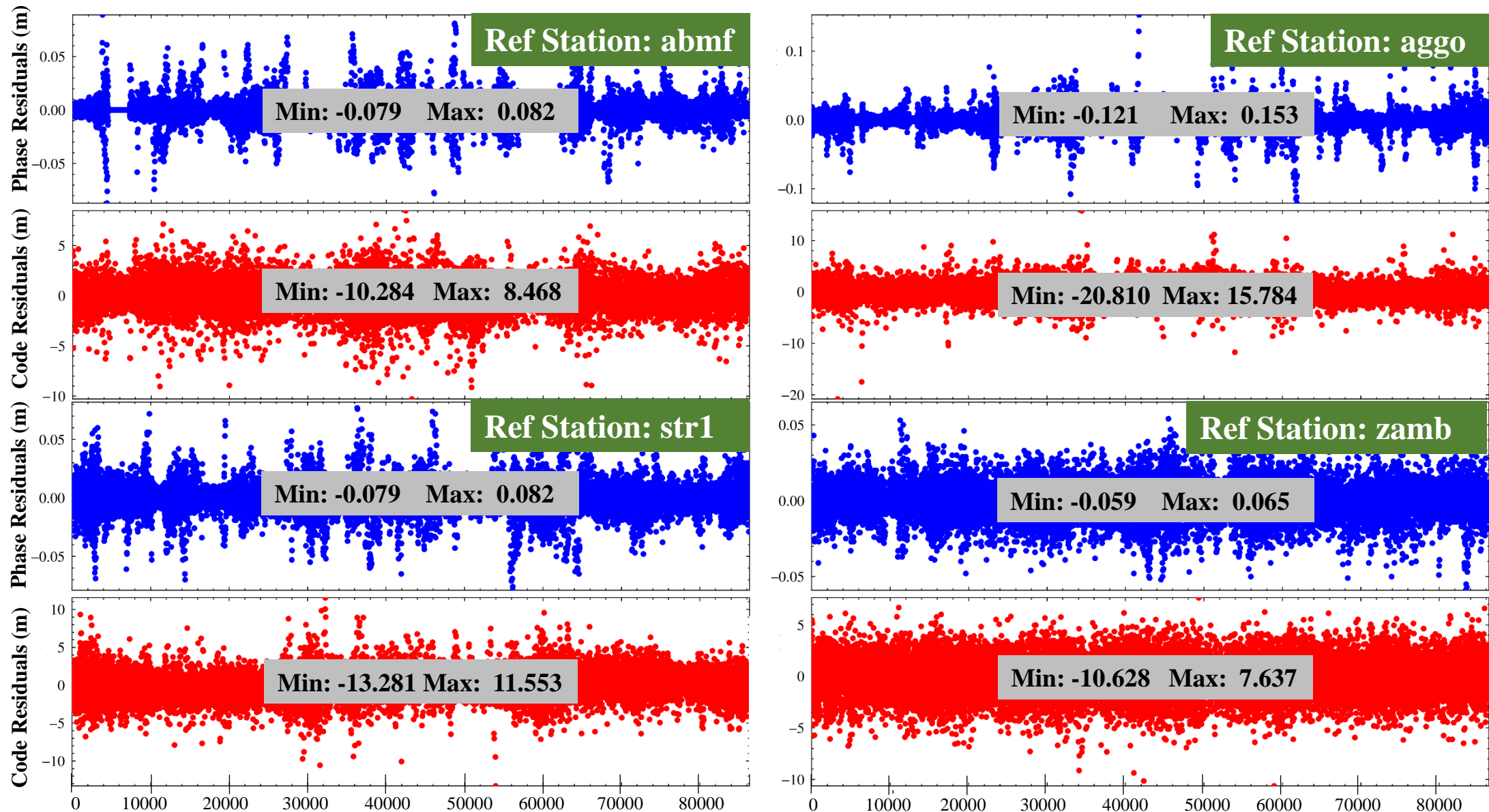


Figure 5a: Residuals on DOY 100 (m) using COD0MGXFIN

# Residuals – COD0MGXFIN

## Attitude Quaternions

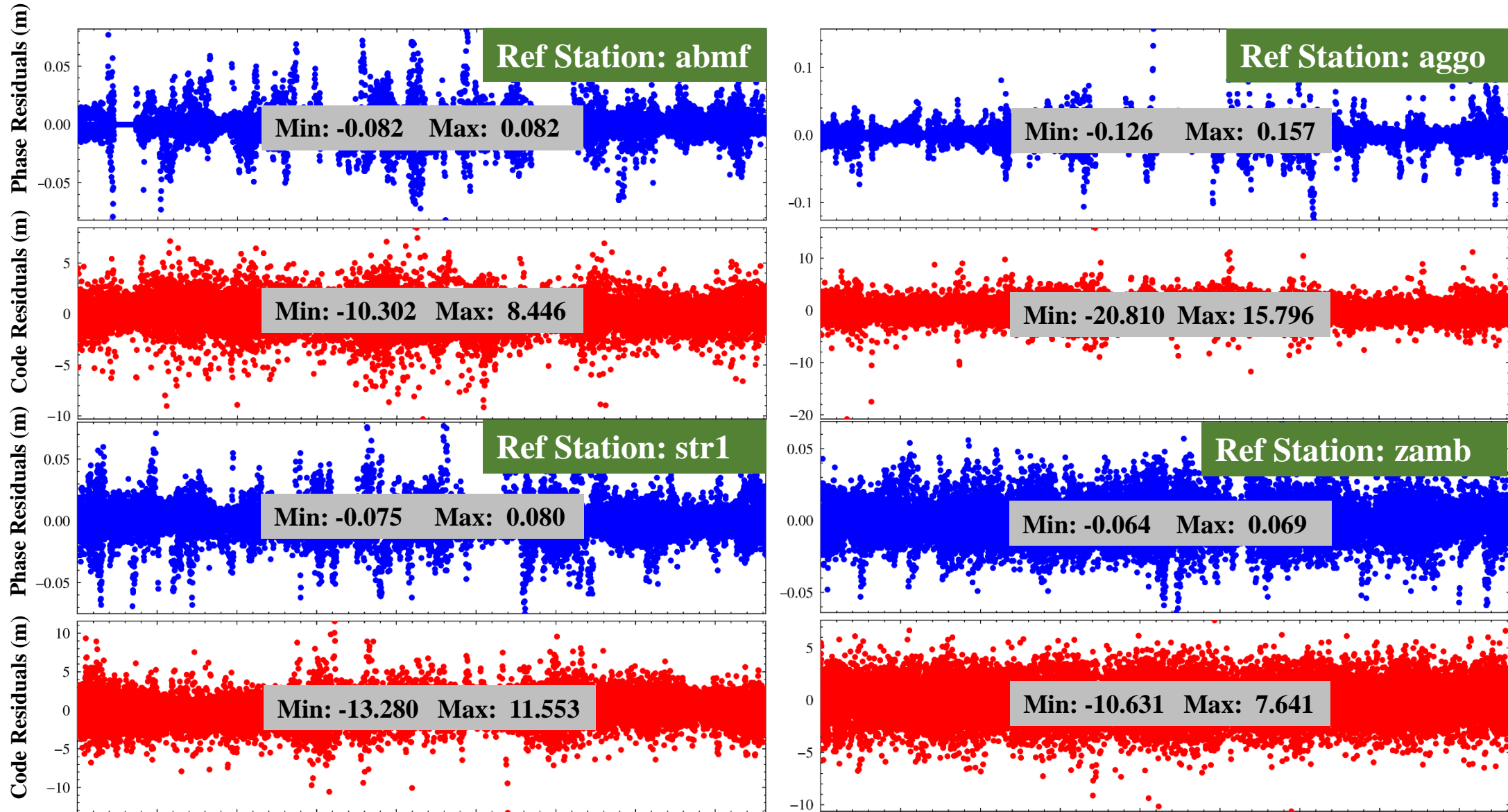


Figure 5b: Residuals on DOY 100 (m) using COD0MGXFIN

# Residuals – CODOMGXFIN

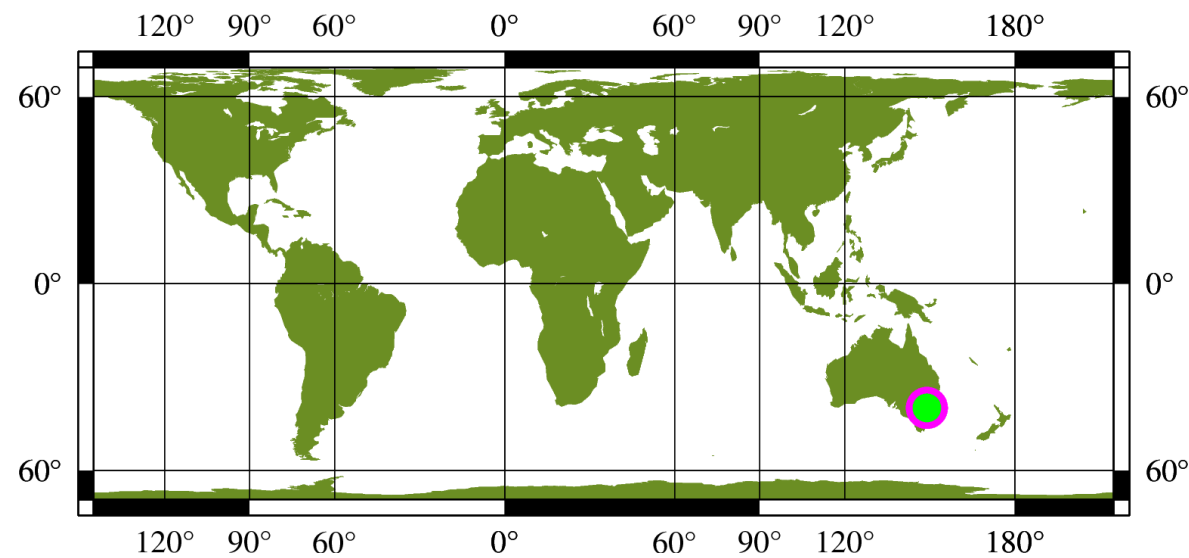
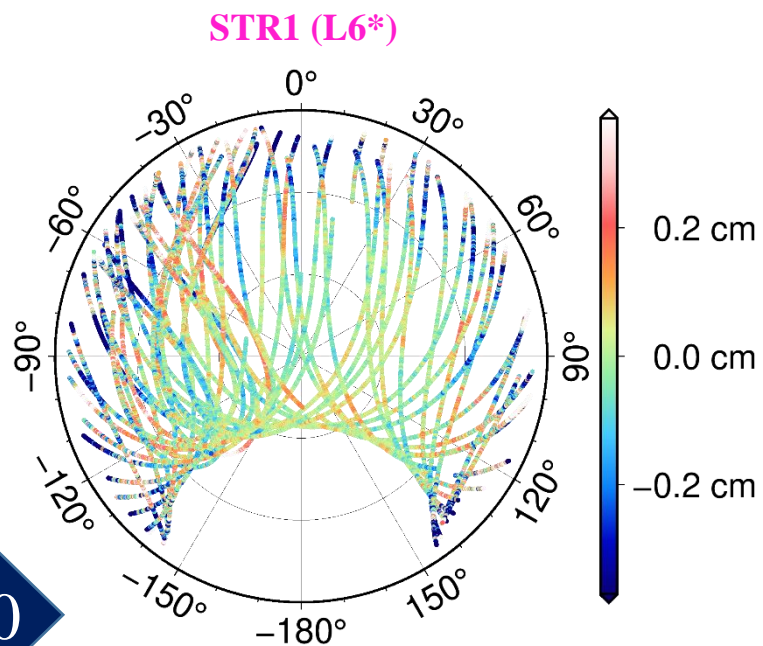
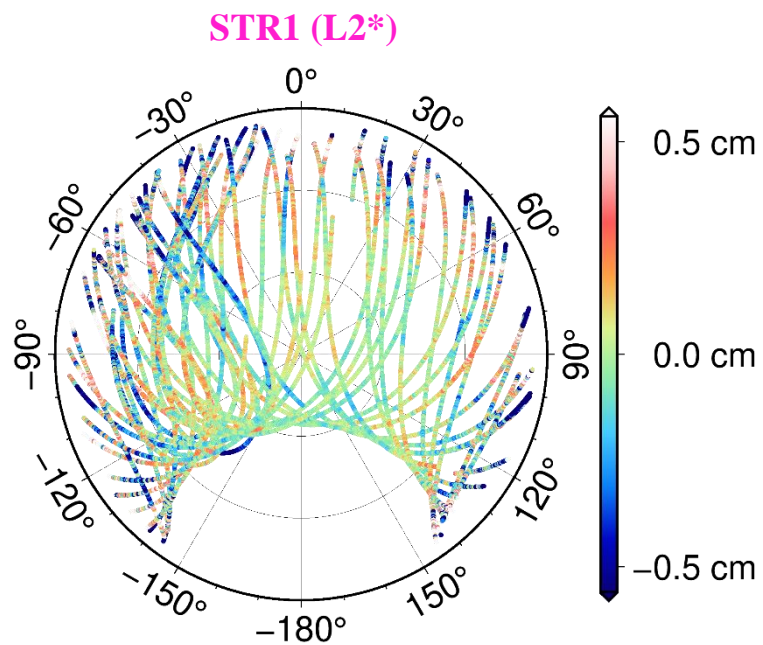


Figure 5c: Residuals on DOY 100 (cm)

# Residuals – CODOMGXFIN

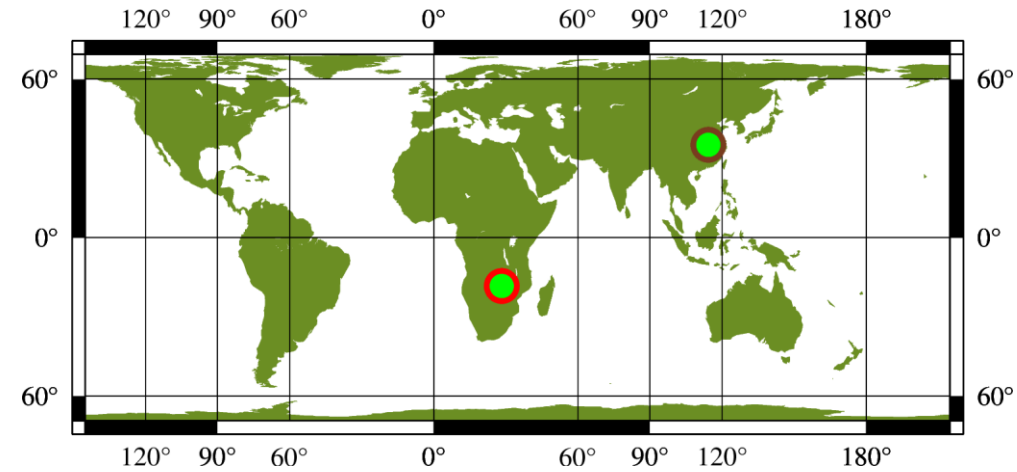
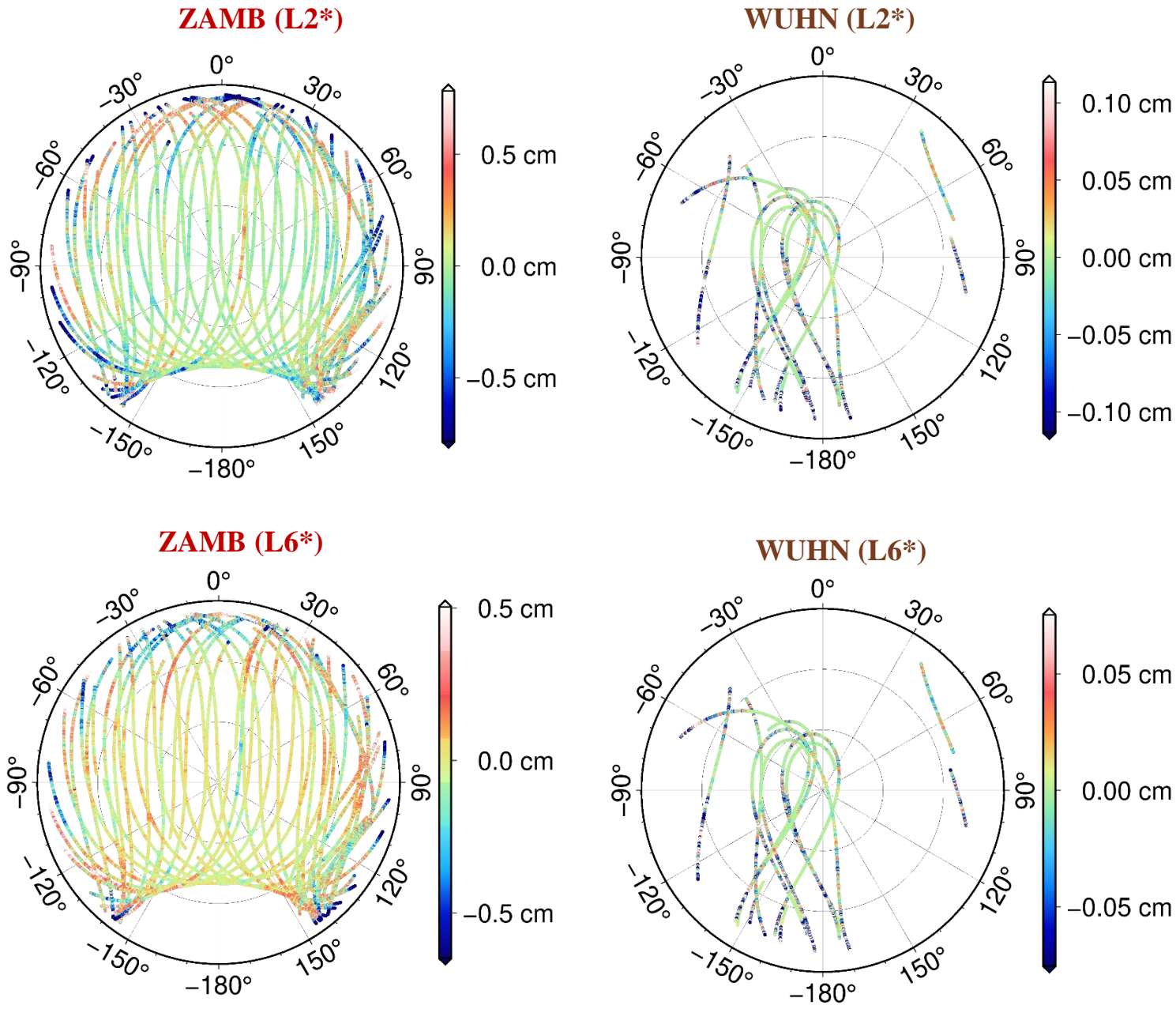


Figure 5d: Residuals on DOY 100 (cm)



# Residuals – CODOMGXFIN

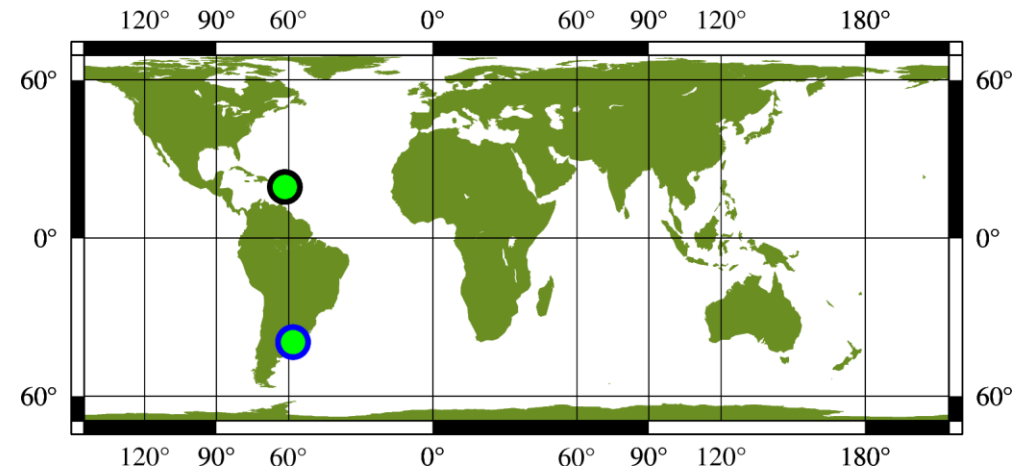
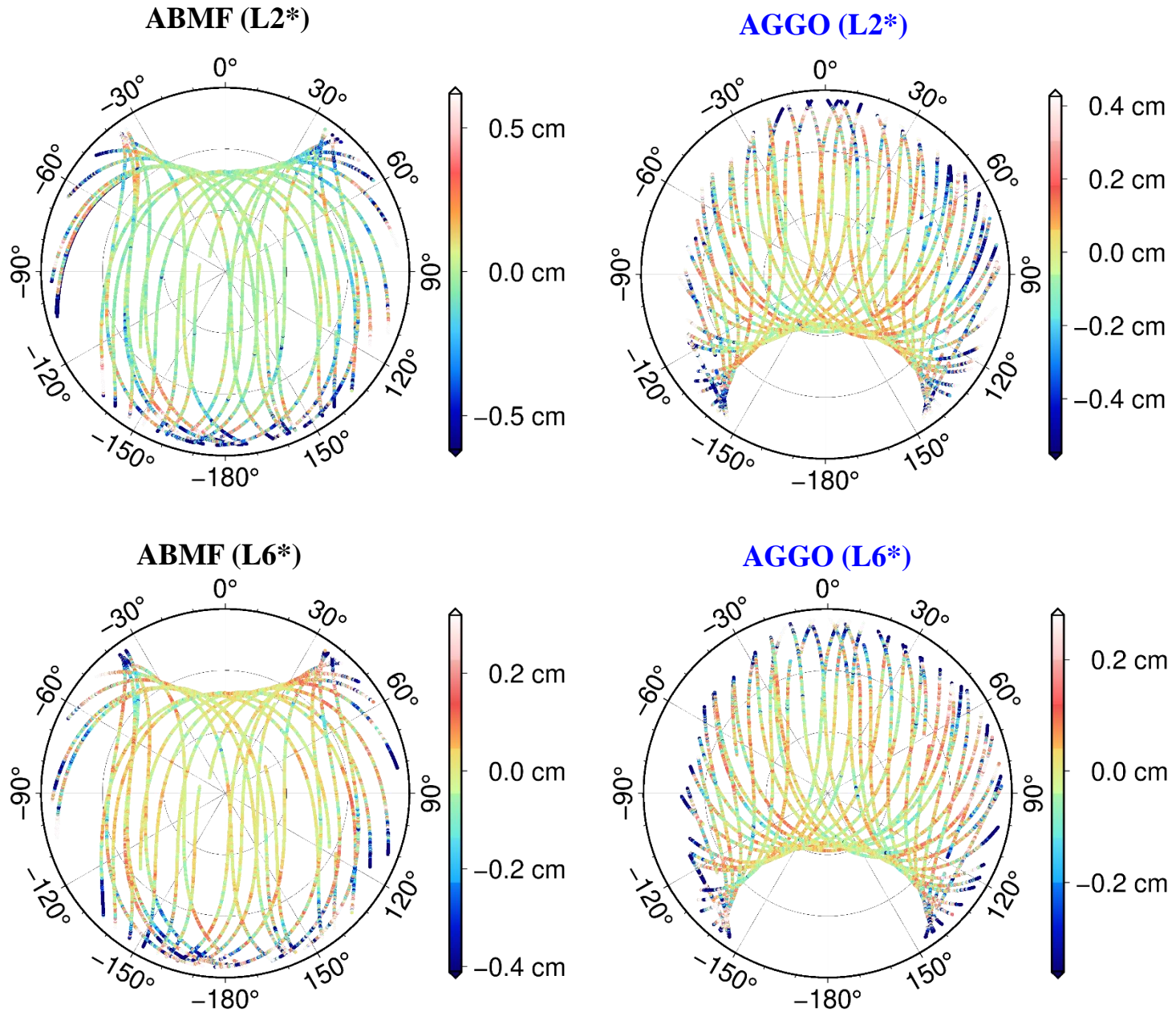


Figure 5e: Residuals on DOY 100 (cm)

# Residuals – COD0MGXFIN

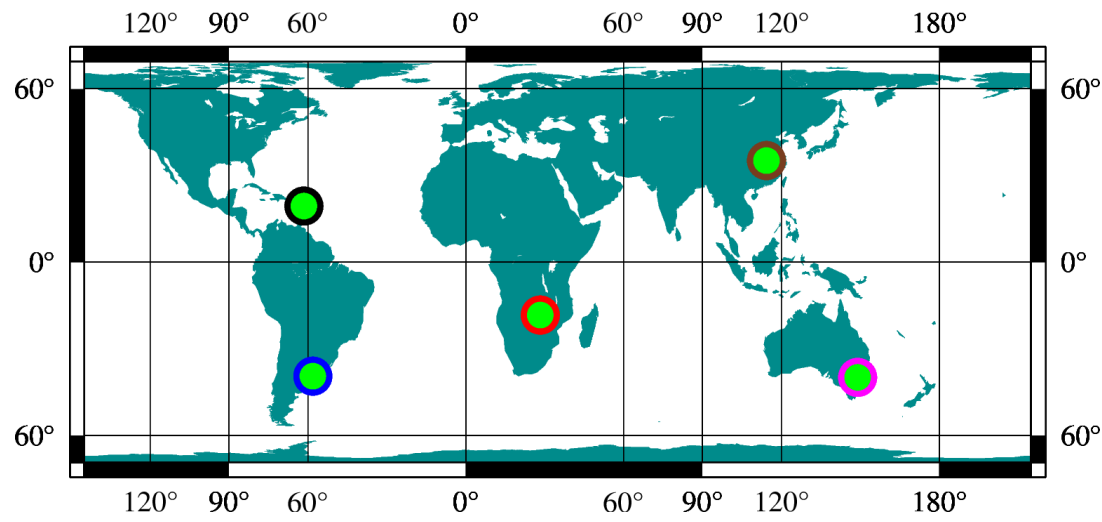
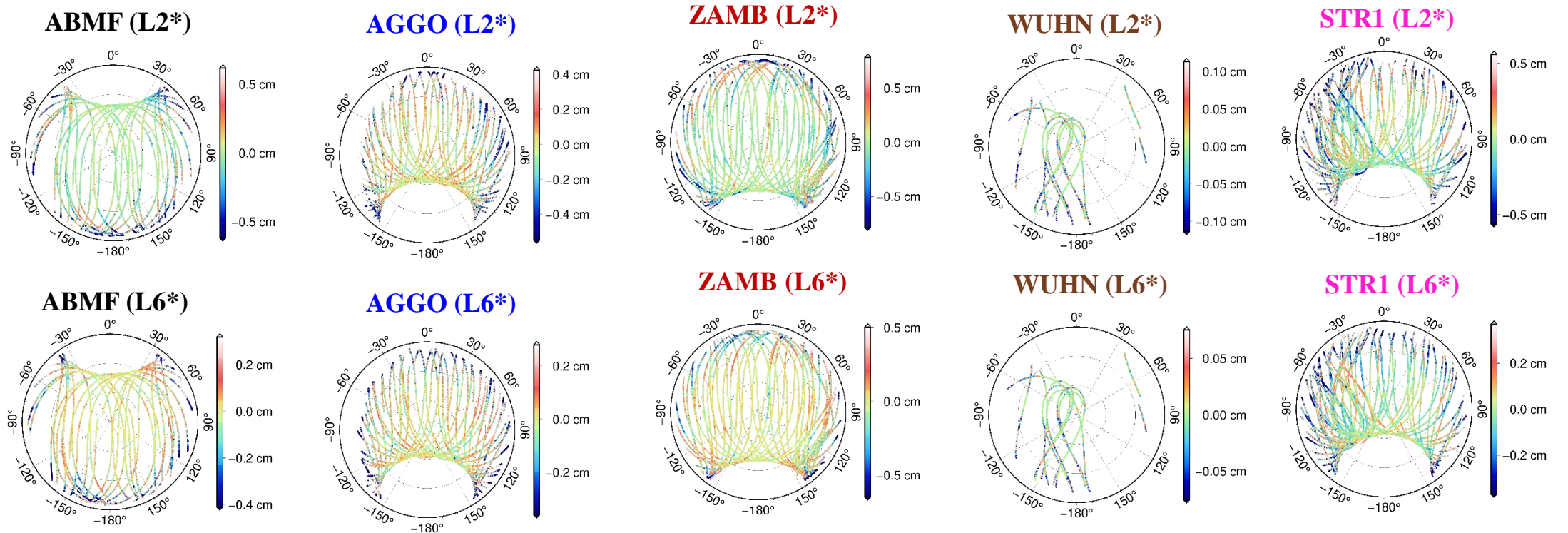


Figure 5f: Residuals on DOY 100 (cm)



- Evaluated the effect of satellite attitude quaternions in PPP
- Two different products were used –WUM0MGXRAP and COD0MGXFIN
- The positioning solutions computed from WUM0MGXRAP and COD0MGXFIN products are comparable
  - Using attitude quaternions improves position solutions
- Introducing the attitude quaternions in PPP slightly improves the residuals
  - This needs further analysis per PRN
  - Revisit the eclipsing zones

A blue-tinted photograph of a cityscape with a large body of water in the foreground. The word "Thanks" is overlaid in white serif font. The background shows a city skyline with various buildings, including a prominent one with a gabled roof. The water reflects the buildings and the sky. The overall mood is calm and reflective.

Thanks



S. Loyer, S. Banville, J. Geng, and S. Strasser, “Exchanging satellite attitude quaternions for improved GNSS data processing consistency,” *Adv. Sp. Res.*, vol. 68, no. 6, pp. 2441–2452, 2021.

J. Geng et al., “PRIDE PPP-AR: an open-source software for GPS PPP ambiguity resolution,” *GPS Solut.*, vol. 23, no. 4, pp. 1–10, 2019.