Federal Agency for Cartography and Geodesy

BKG
Wir geben Orientierung.

On the Combination of LAGEOS and Sentinel-6A in Preparation for Exploiting the Genesis Mission

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BKG's Contribution to GENESIS-D

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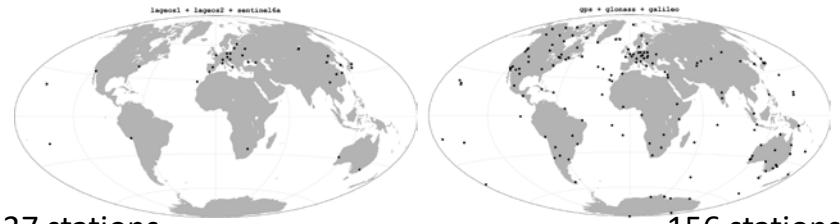
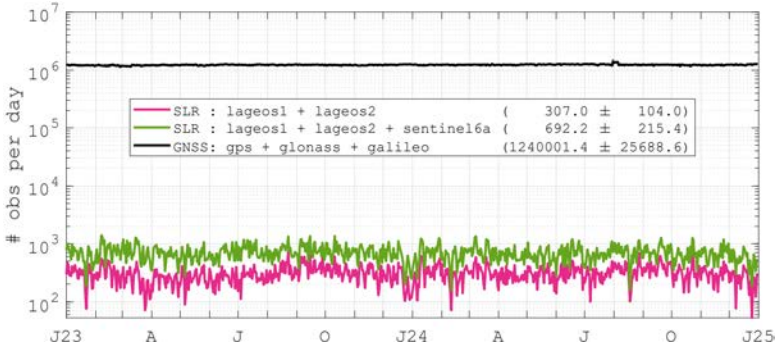
Observing Systems
- SLR
- GNSS

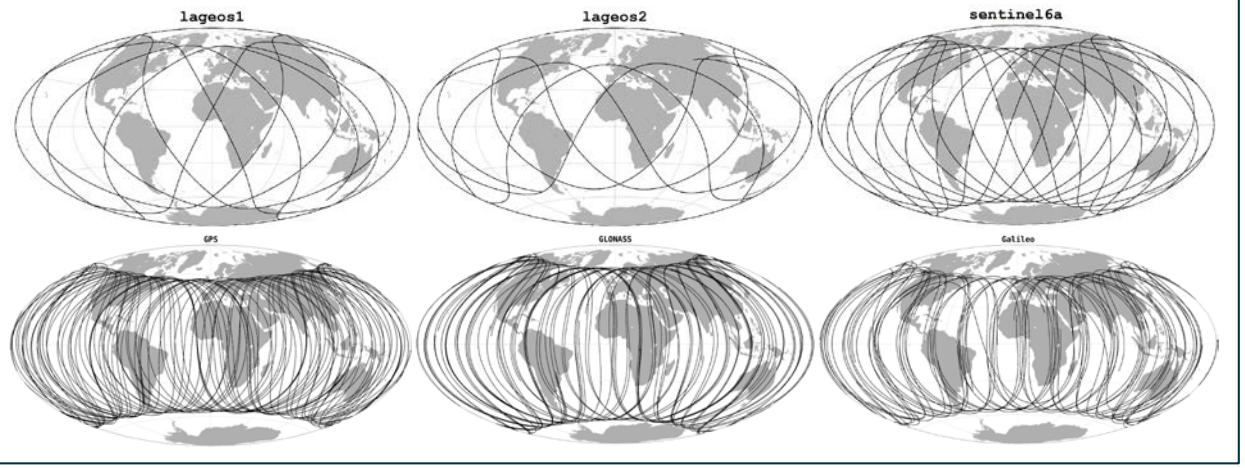
Satellites
- LAGEOS-1 and -2
- Sentinel-6A†
- GPS, GLONASS, Galileo

Ground Segment



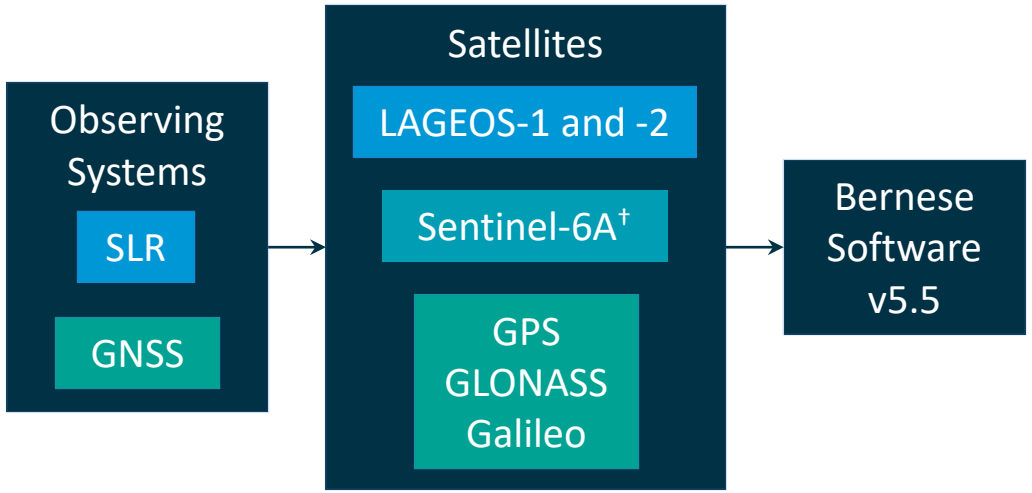


Space Segment



† proxy for ESA's Genesis

BKG's Contribution to GENESIS-D



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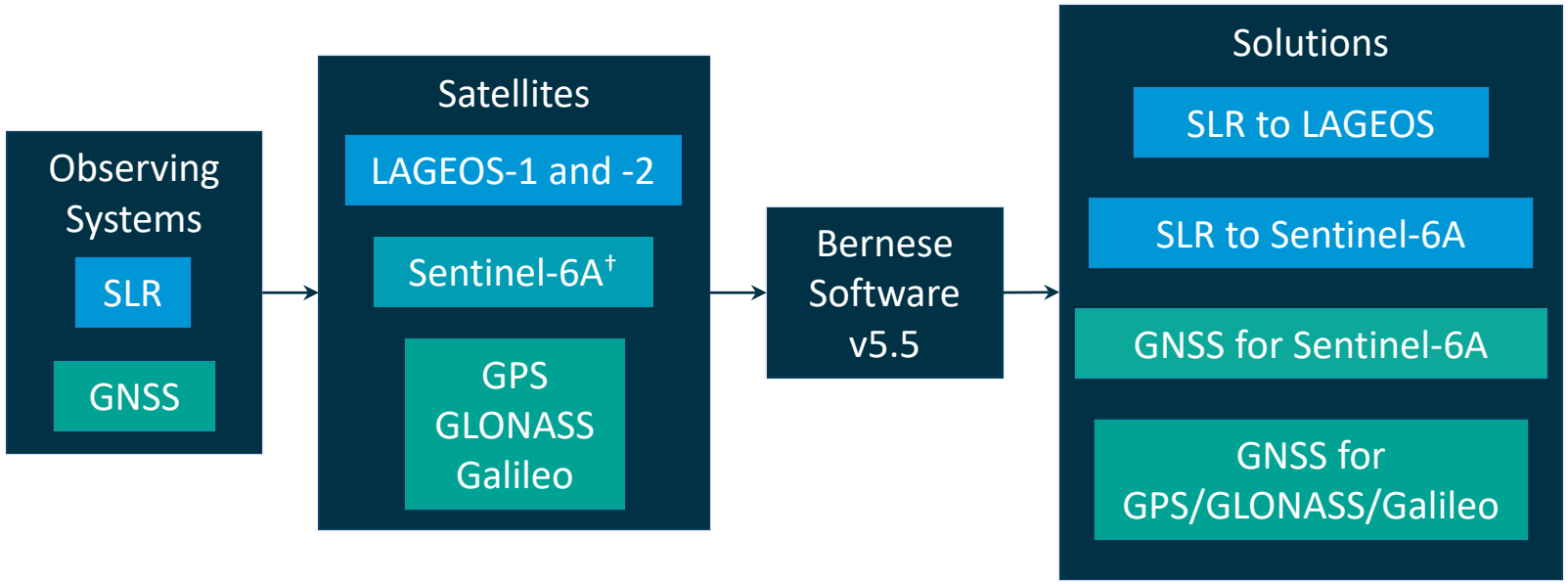

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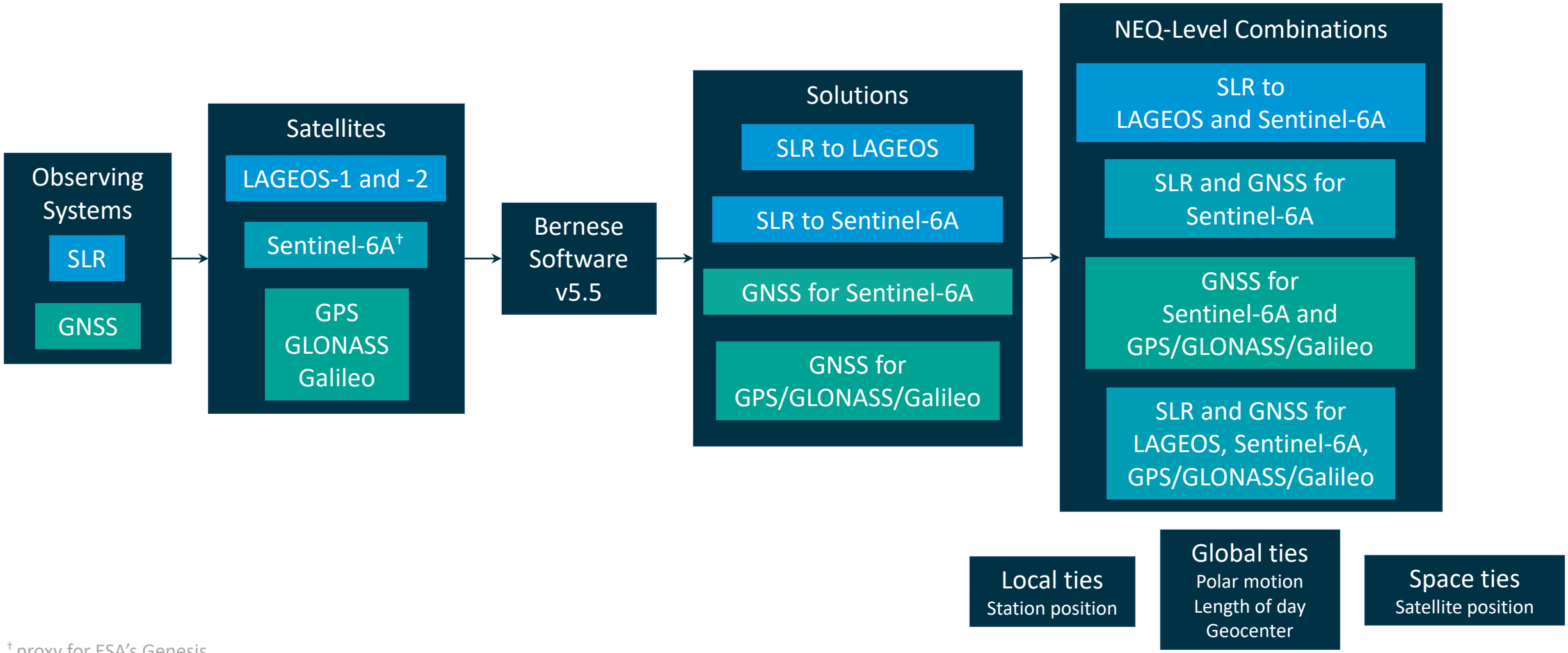
BKG's Contribution to GENESIS-D



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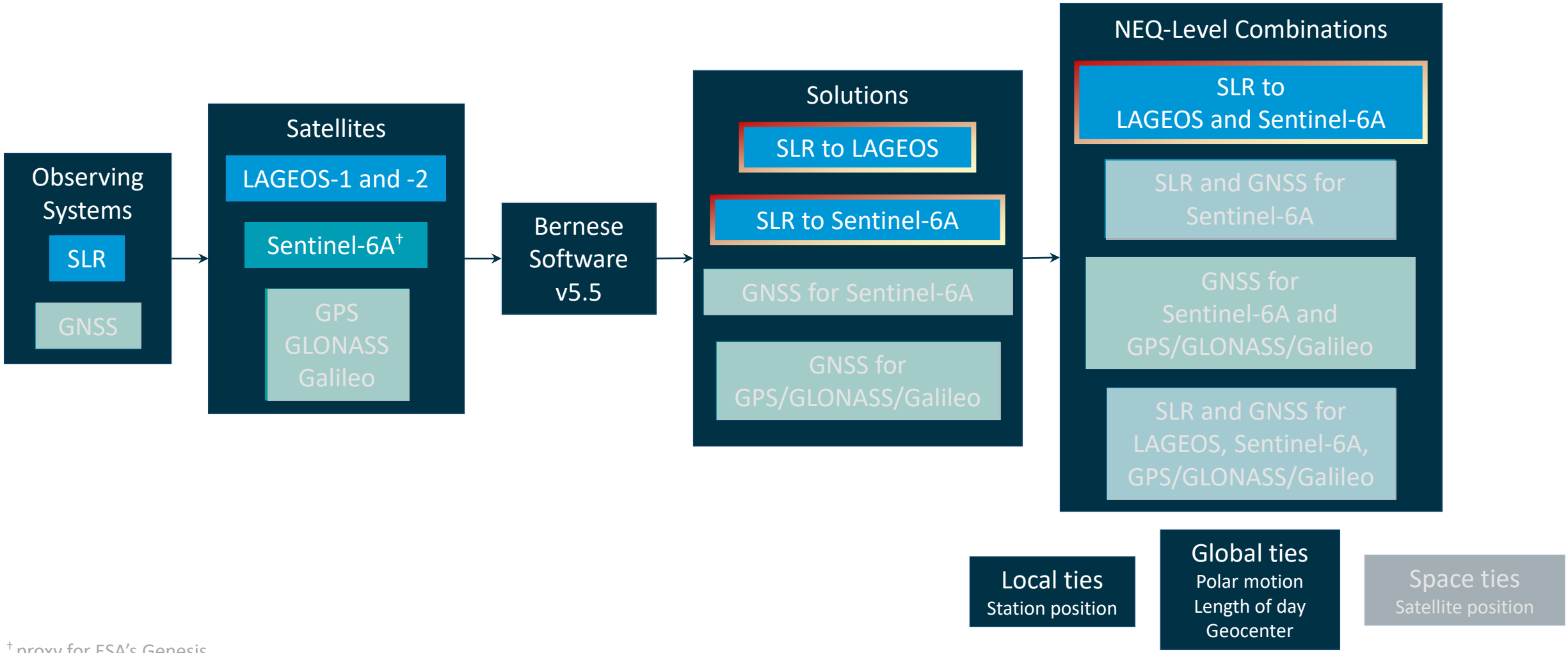

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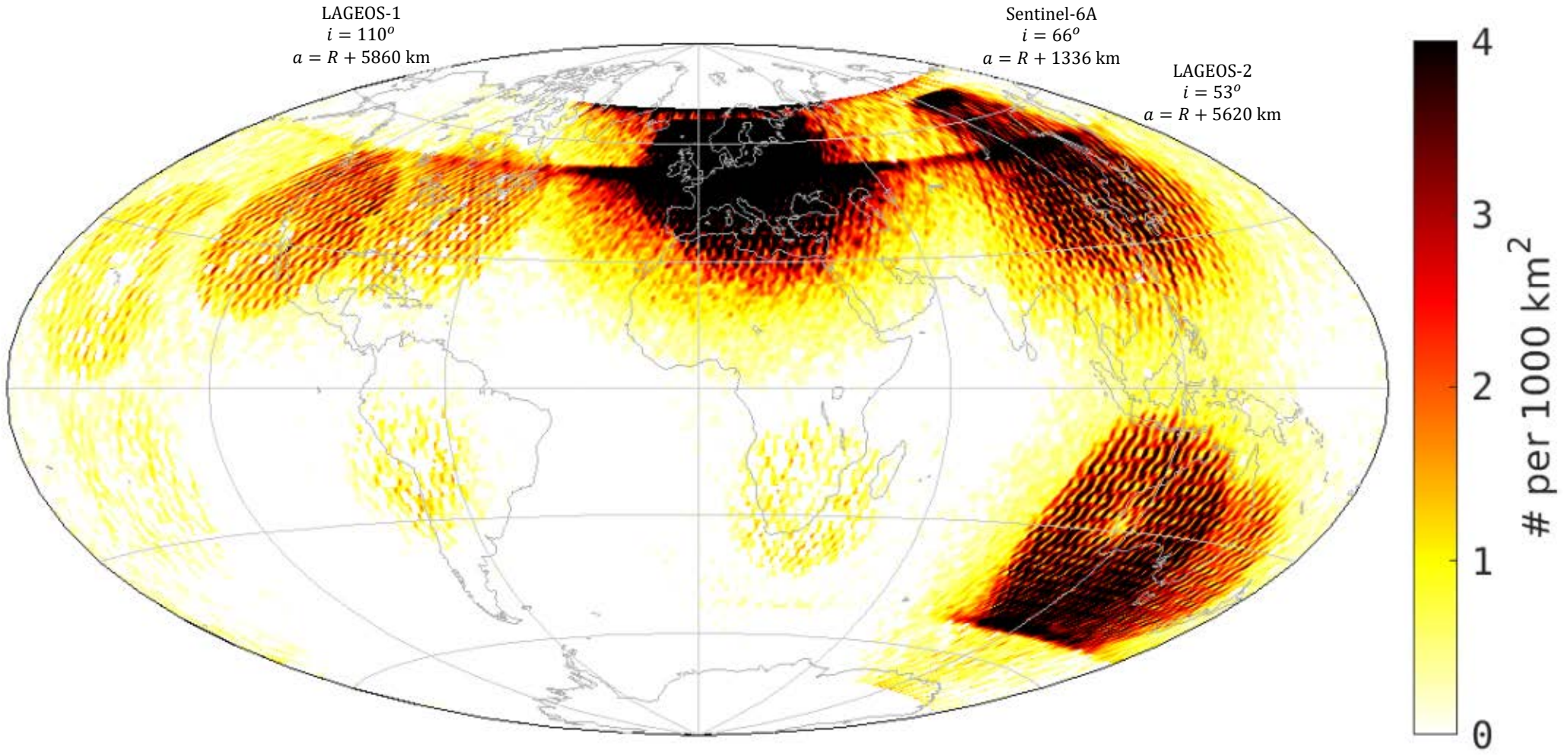
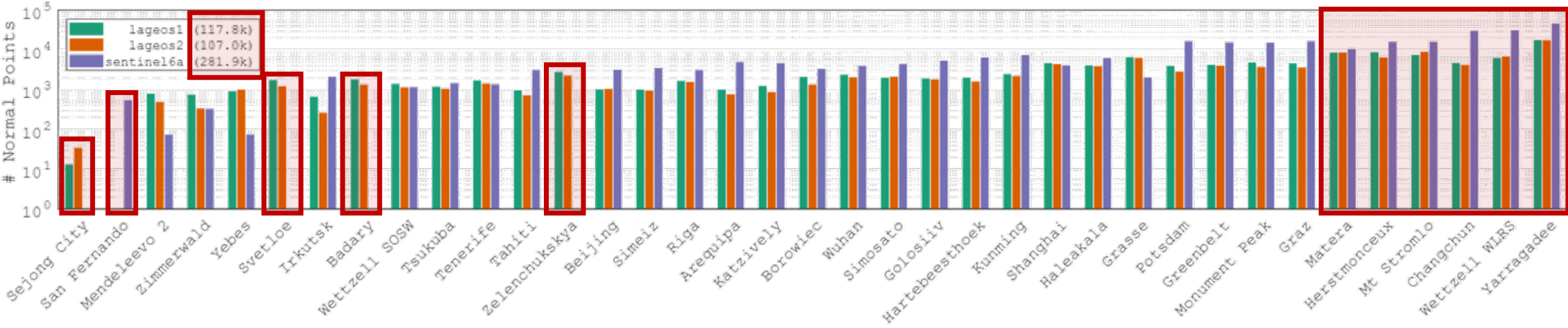
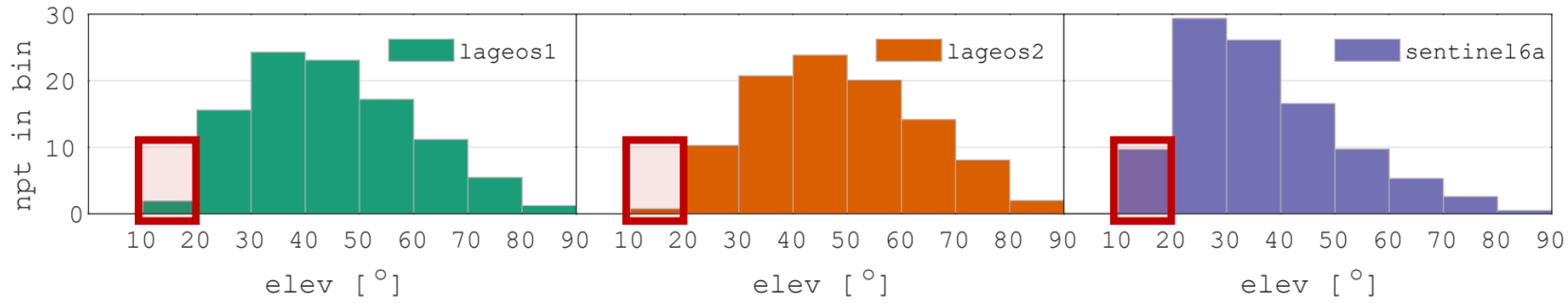
Observation Geometry



Observation Geometry

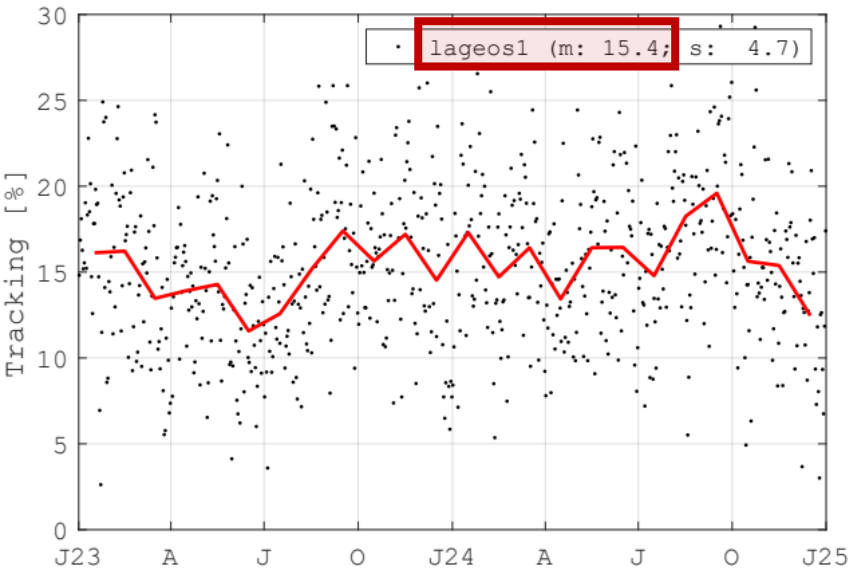


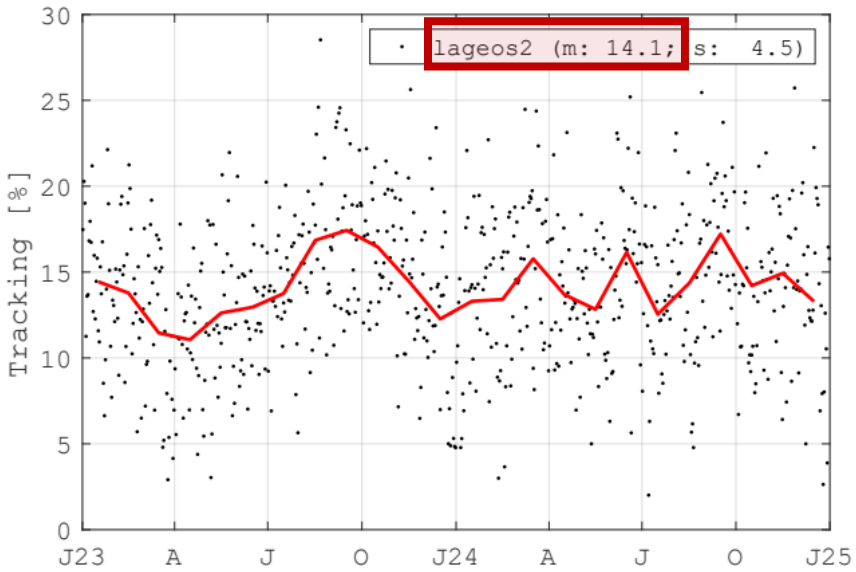


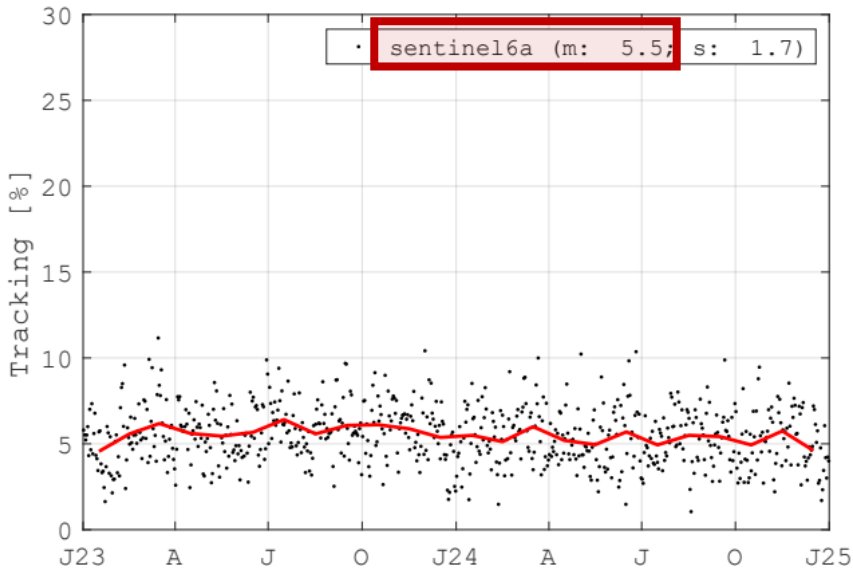
- 50% of observations collected at 6 stations
- 86% of ILRS network track LAGEOS & S6A
- 126% data volume increase
  Sentinel-6A 20s-npt + LAGEOS 120s-npt
- 7x increase of low-elevation ($\varepsilon < 20^o$) npt

Orbit Parameterization

- LAGEOS/Sentinel-6A orbit tracked 15%/6% of the time







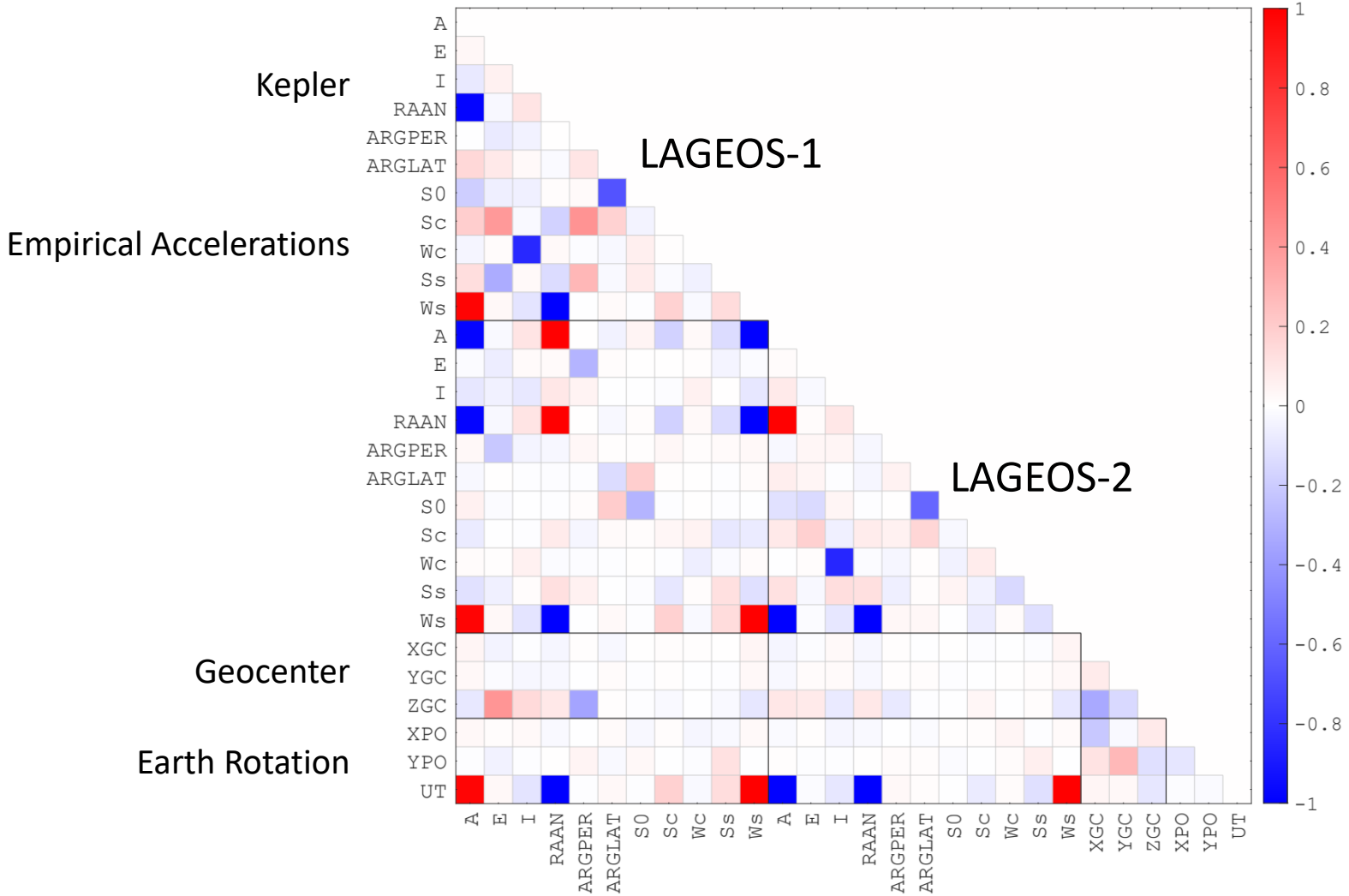
Parameter Space

Solutions (7-day)

- LAGEOS-only
- S6A-only
- LAGEOS+S6A

Parameteriation	LAGEOS-1 and LAGEOS-2	Sentinel-6A
Arc length	7 d	1 d
Station Positions	one set per arc	
Geocenter	one triplet per arc	
Earth Rotation	24 h offsets and rates of x_p, y_p, $UT1-UTC$	
Orbits	*Osculating Keplerian Elements*, one set per arc a, e, i, Ω, ω, u_0 *Scaling Factors*, one set per arc None	solar radiation pressure
	Empirical Accelerations, one set per arc S_0, S_c, S_s, W_c, W_s *Piece-wise Constant Empirical Accelerations* None	
Range Bias	one satellite-specific per arc for selected stations	
Inversion	NNT + NNR on core network	

Global Parameter Correlations



Station Positions

Station position repeatability

One-to-one weighting

- Repeatability of Sentinel-6A
  2-3 times larger than LAGEOS
  →expected: single-satellite solution
- Repeatability of the combined solution
  slightly increased wrt LAGEOS

Station Positions

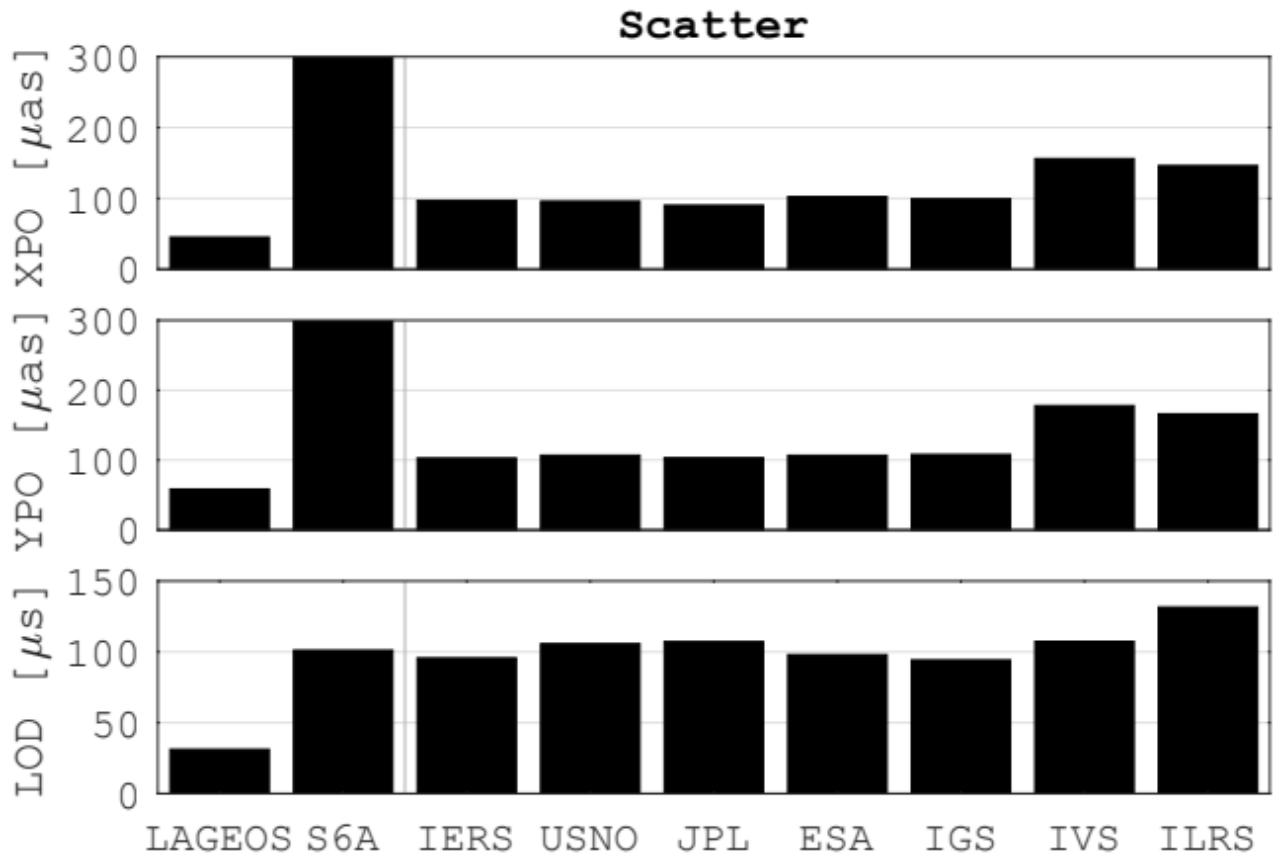
Station position repeatability

Five-to-one weighting

- Repeatability of Sentinel-6A
  2-3 times larger than LAGEOS
  →expected: single-satellite solution
- Repeatability of the combined solution
  slightly increased wrt LAGEOS
- 23% repeatability improvement by
  5-1 weighting scheme

Earth Rotation

Base for comparisons: LAGEOS+S6A solution



Orbits

- Parameterization *(standard)*
  - 6 Keplerian elements
  - 5 empirical accelerations
- Differences significant?
  - One-to-one

A, S_0, S_C, W_C: 3% > 3-σ;

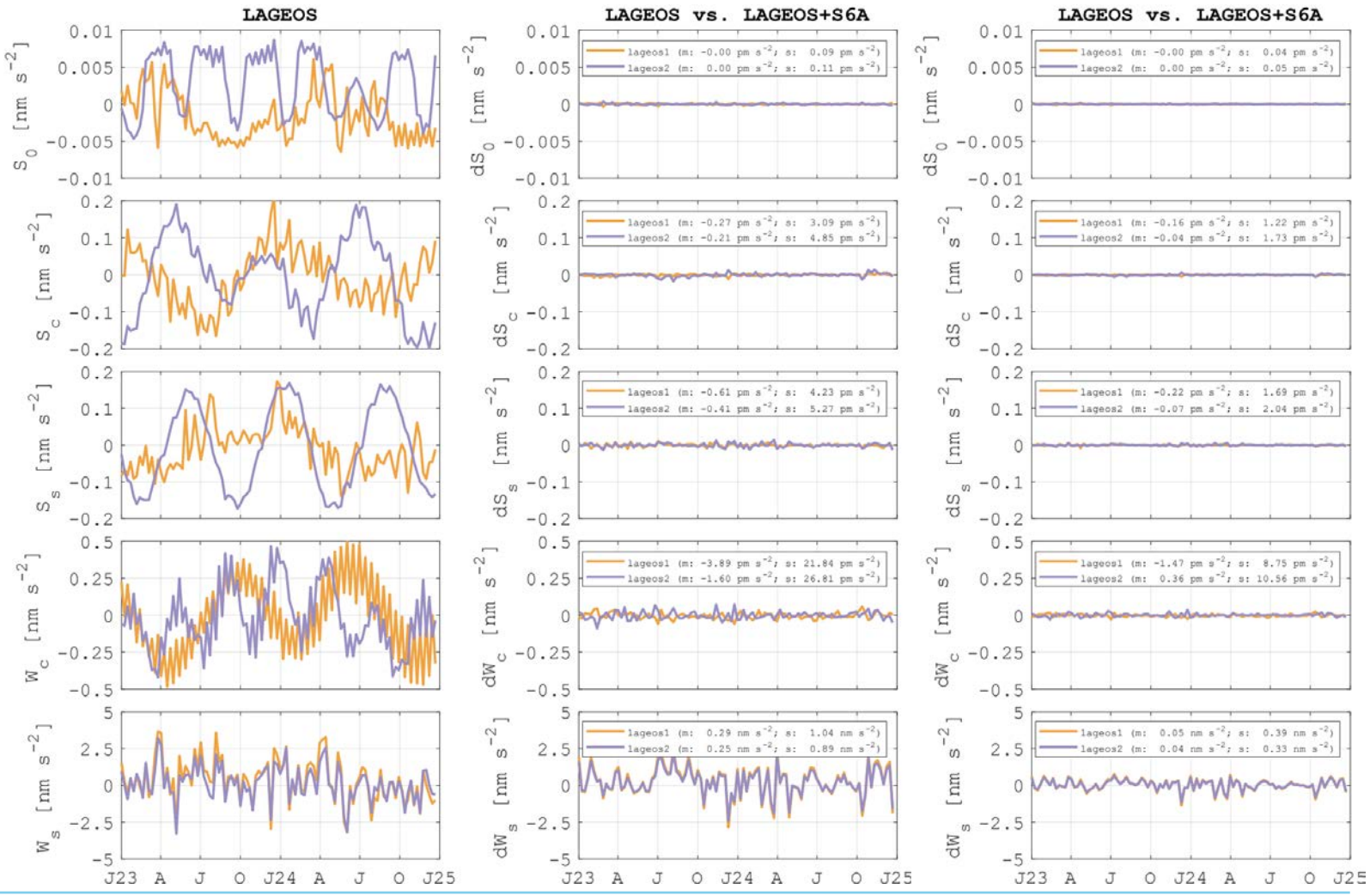
all: 30-40% >1-σ

  - Five-to-one

all: 0% > 3-σ

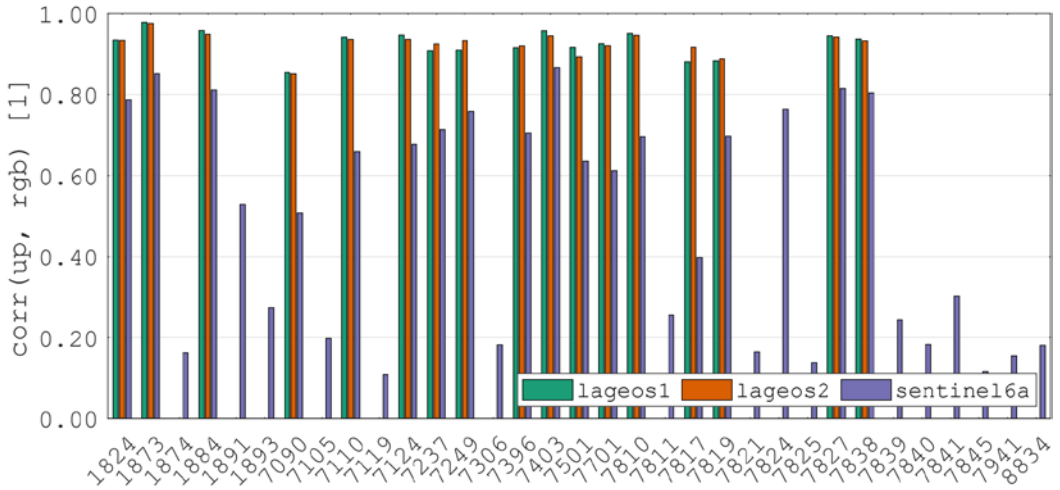
all: 3-15% > 1-σ

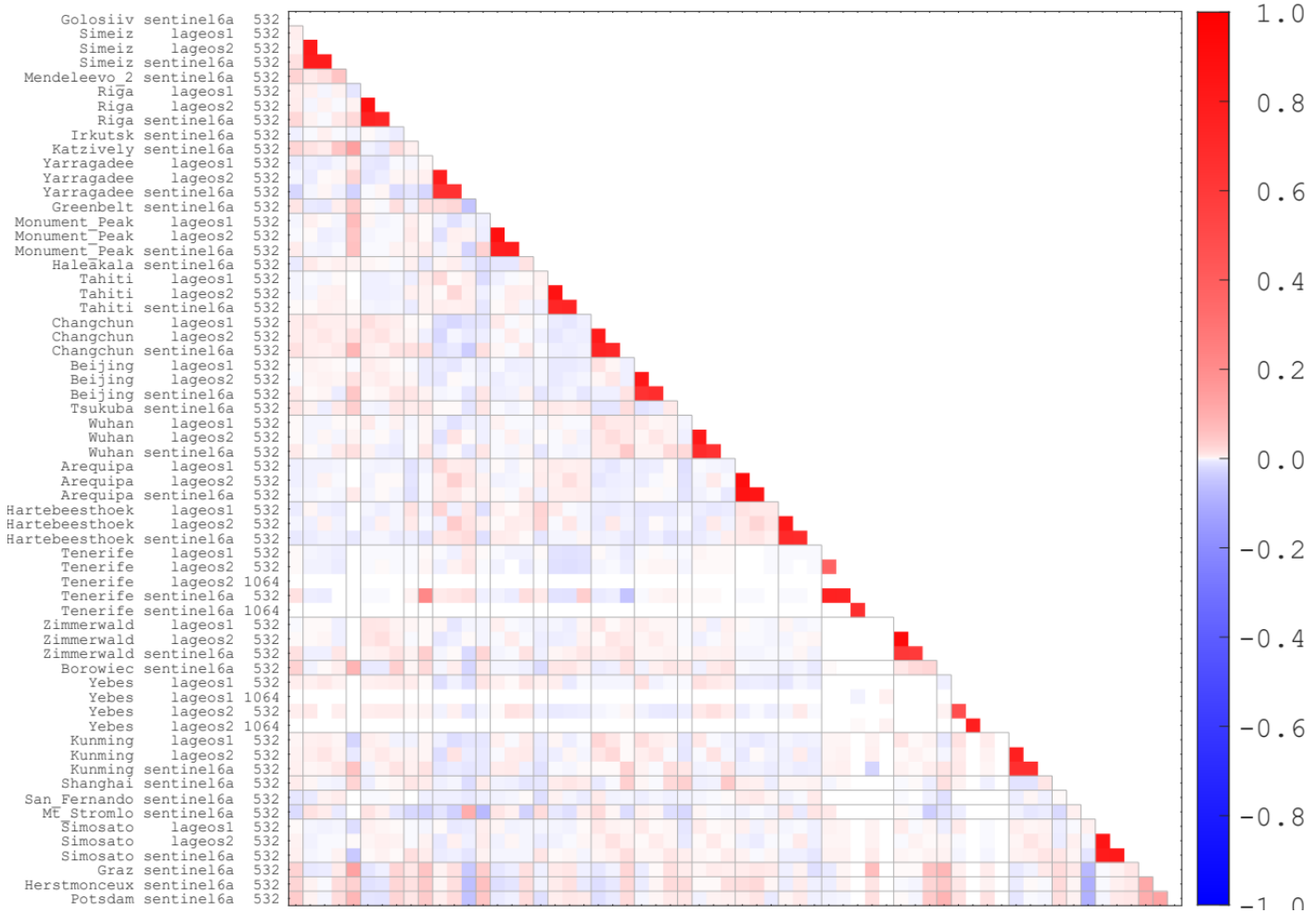
One-to-one *Five-to-one*



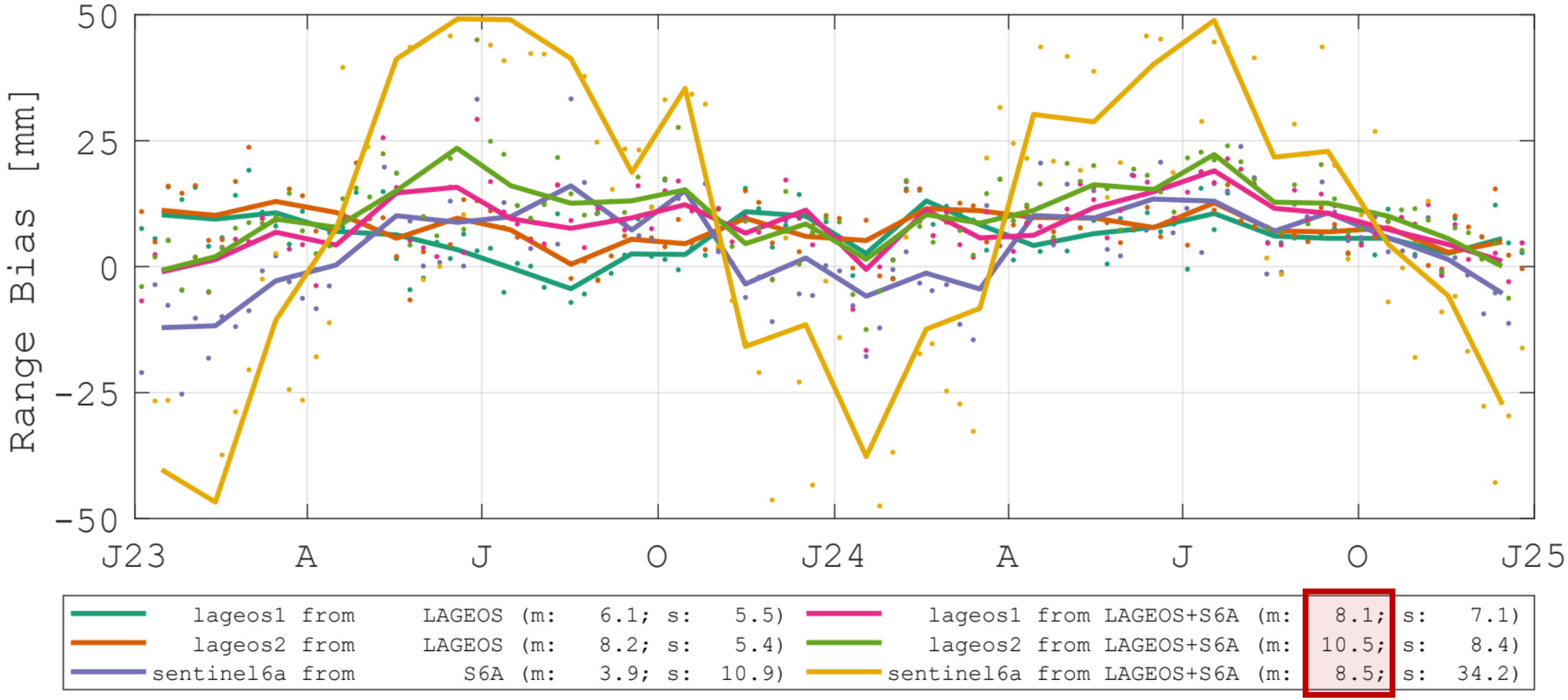
Range Bias Correlations

- LAGEOS-1 to LAGEOS-2 range biases correlation 0.8
- LAGEOS-1/-2 and Sentinel-6A correlation 0.7 (lower ε for S6A)
- Height-to-range-bias correlation
  - 0.3, for one RGB
  - 0.8, for multiple RGB





Range Bias in Yarragadee



Recapitulation

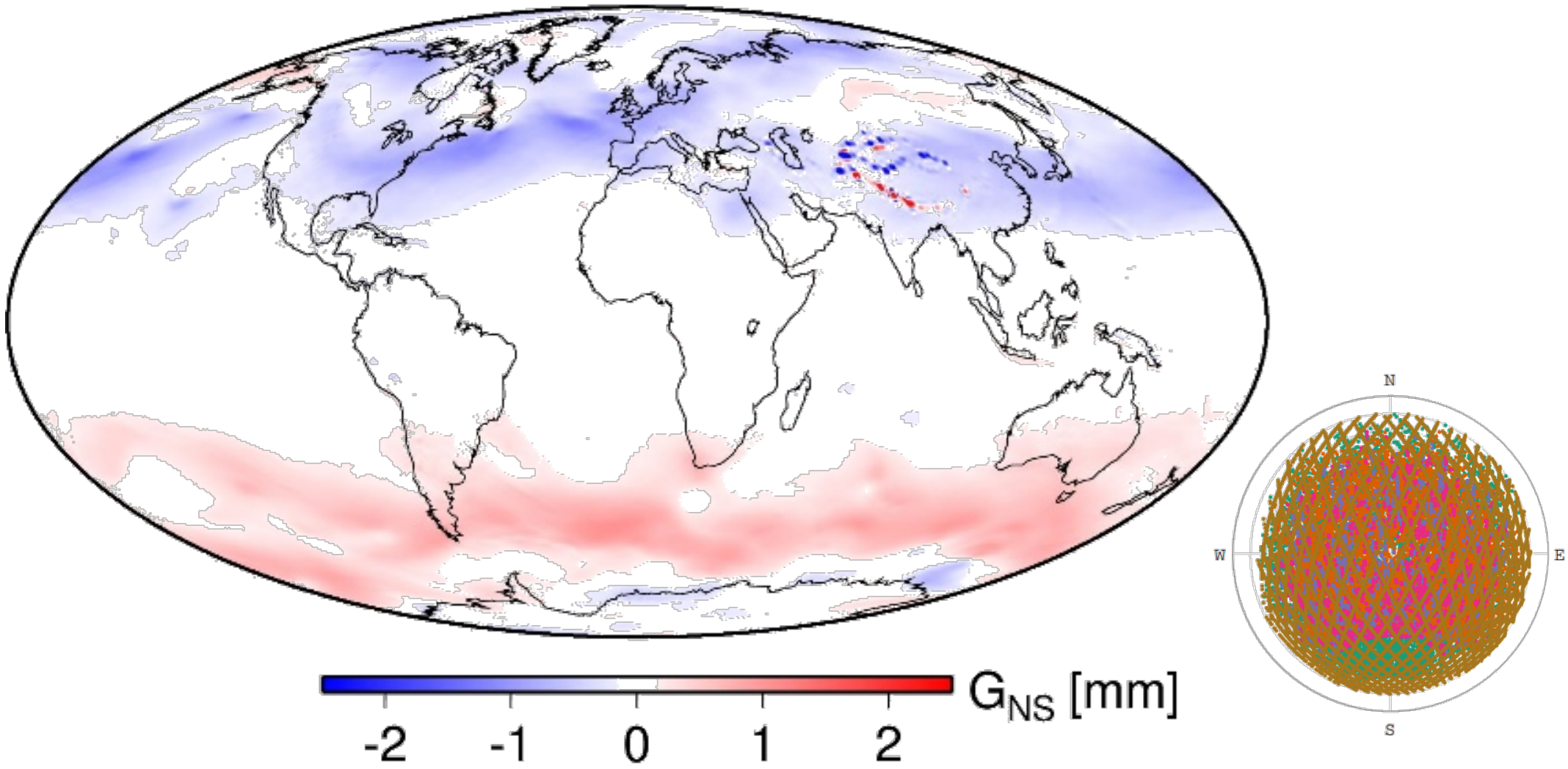
- SLR solution for LAGEOS and Sentinel-6A
  - Sentinel-6A (Genesis proxy) for reference frames, not only POD
  - Current set-up allows daily & weekly Sentinel-6A solutions, and combined solutions with LAGEOS

- Fine-tuning underway
  - Orbit modelling for Sentinel-6A
  - Range biases
  - NEQ weighting

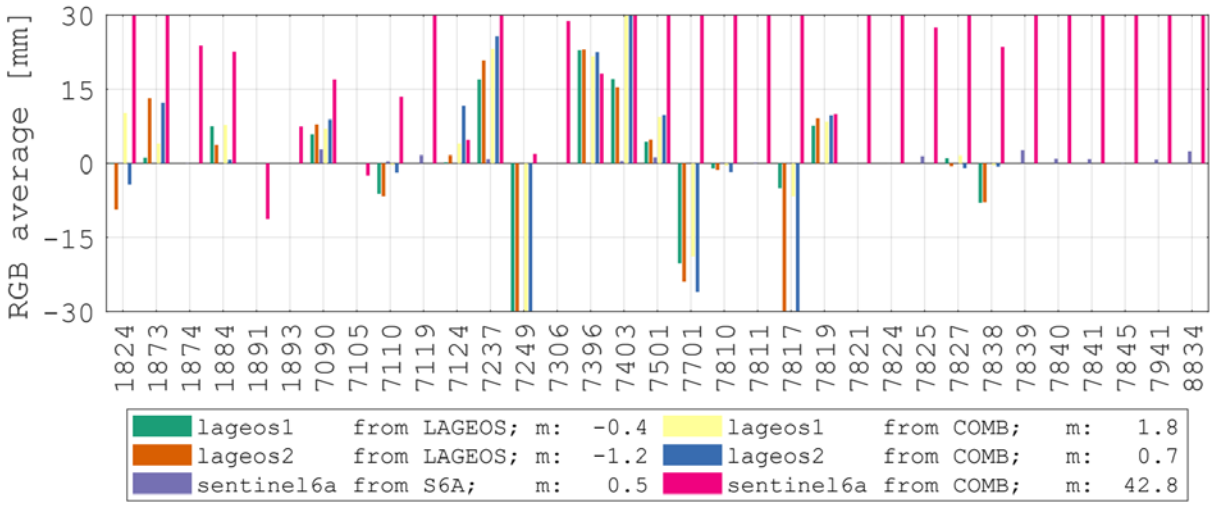
Acknowledgements
Funding: DLR
Data: ILRS, IERS, USNO, ESA, JPL, IGS, IVS

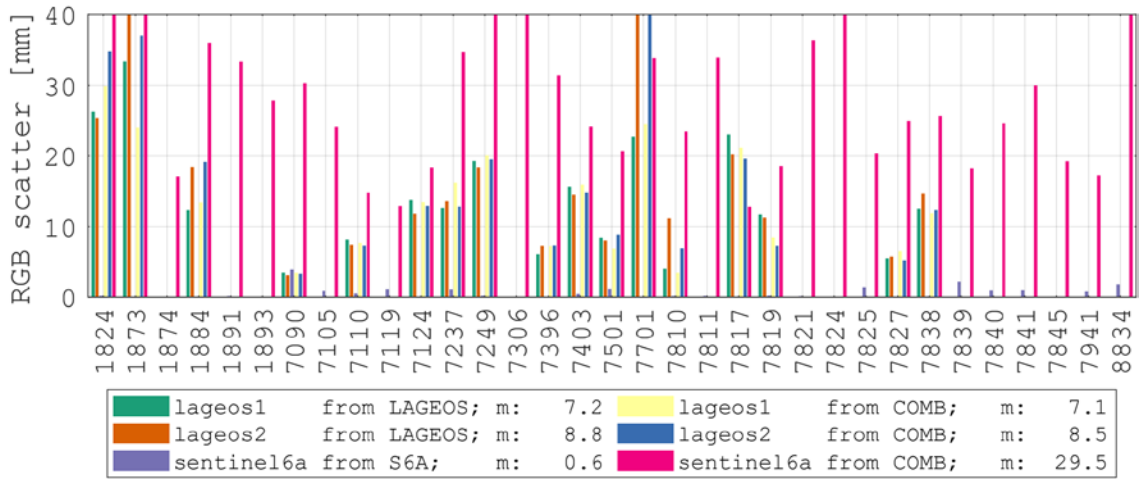
DLR

Bonus Slides


N
W
E
S
-2
-1
0
1
2
G_{NS} [mm]

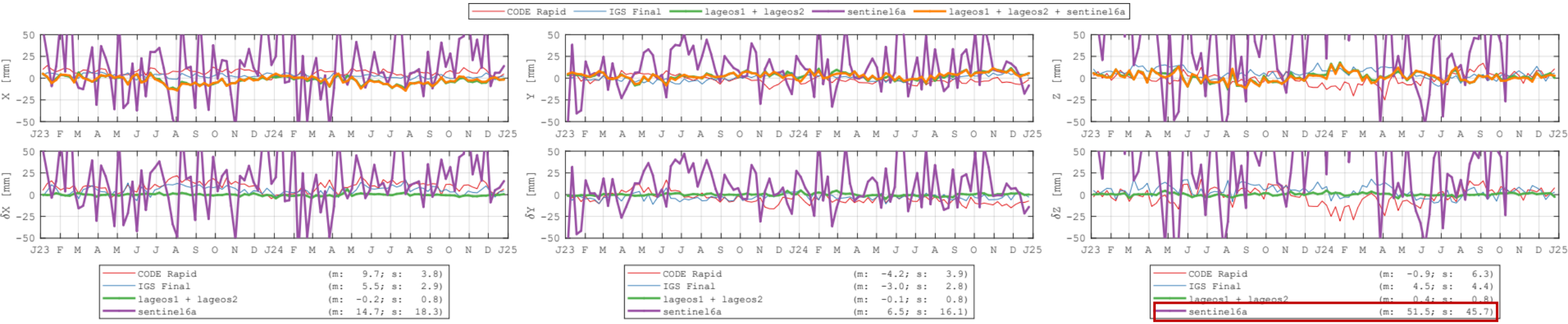
Range Bias


RGB average [mm]
30
15
0
-15
-30
1824 1873 1874 1884 1891 1893 7090 7105 7110 7119 7124 7237 7249 7306 7396 7403 7501 7701 7810 7811 7817 7819 7821 7824 7825 7827 7838 7839 7840 7841 7845 7941 8834
lageos1 from LAGEOS; m: -0.4
lageos2 from LAGEOS; m: -1.2
sentinel6a from S6A; m: 0.5
lageos1 from COMB; m: 1.8
lageos2 from COMB; m: 0.7
sentinel6a from COMB; m: 42.8

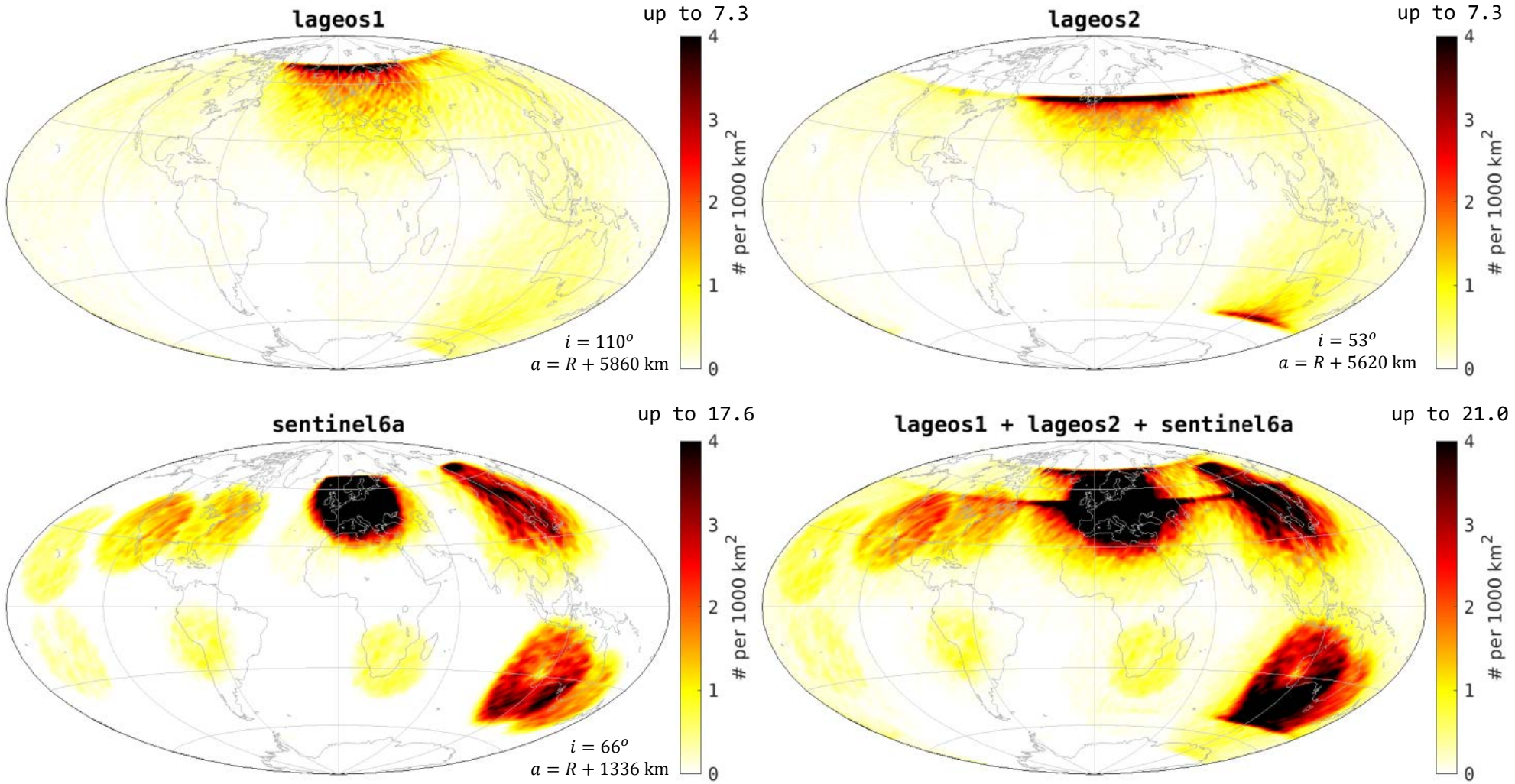

RGB scatter [mm]
40
30
20
10
0
1824 1873 1874 1884 1891 1893 7090 7105 7110 7119 7124 7237 7249 7306 7396 7403 7501 7701 7810 7811 7817 7819 7821 7824 7825 7827 7838 7839 7840 7841 7845 7941 8834
lageos1 from LAGEOS; m: 7.2
lageos2 from LAGEOS; m: 8.8
sentinel6a from S6A; m: 0.6
lageos1 from COMB; m: 7.1
lageos2 from COMB; m: 8.5
sentinel6a from COMB; m: 29.5

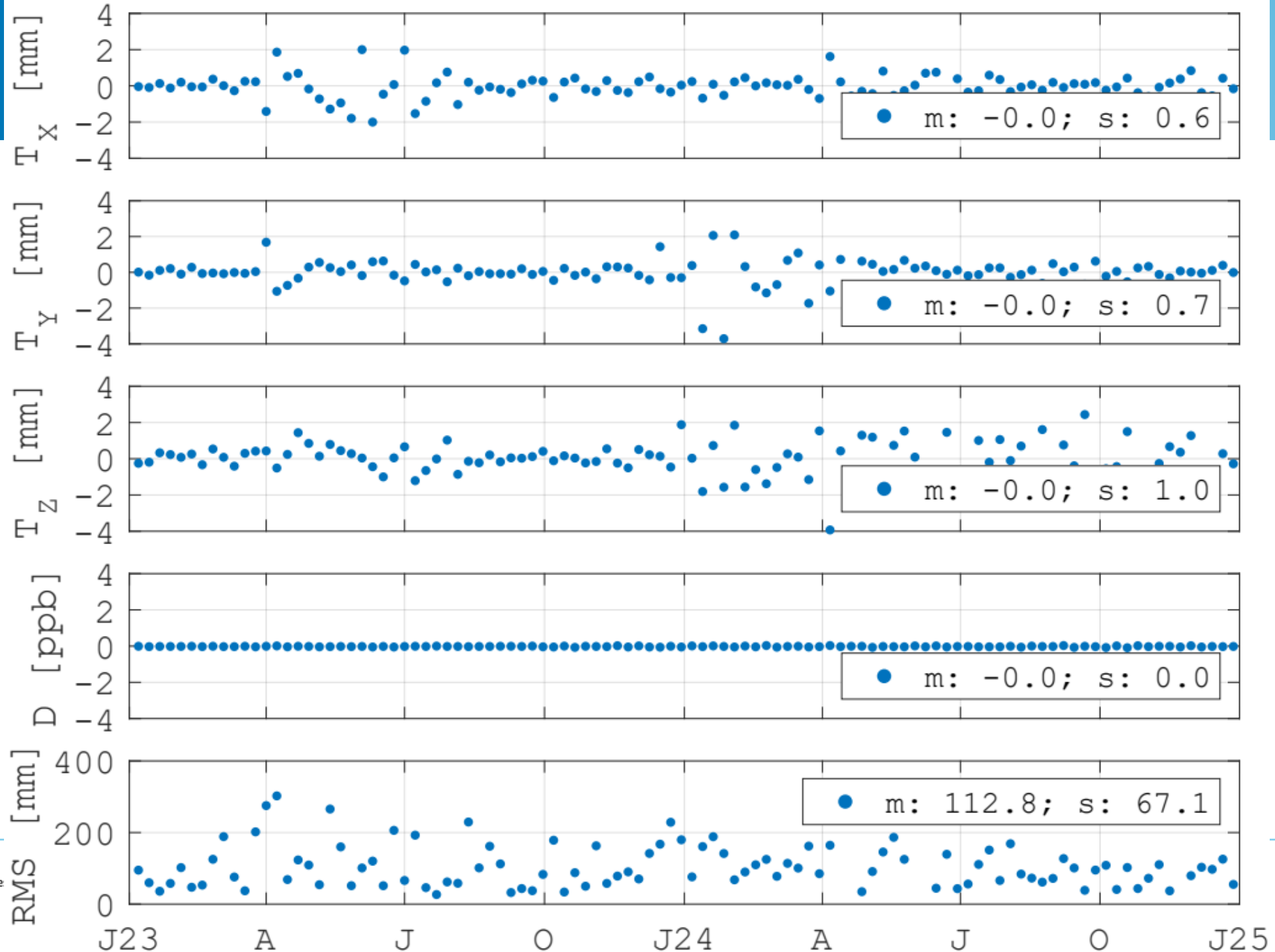
Geocenter

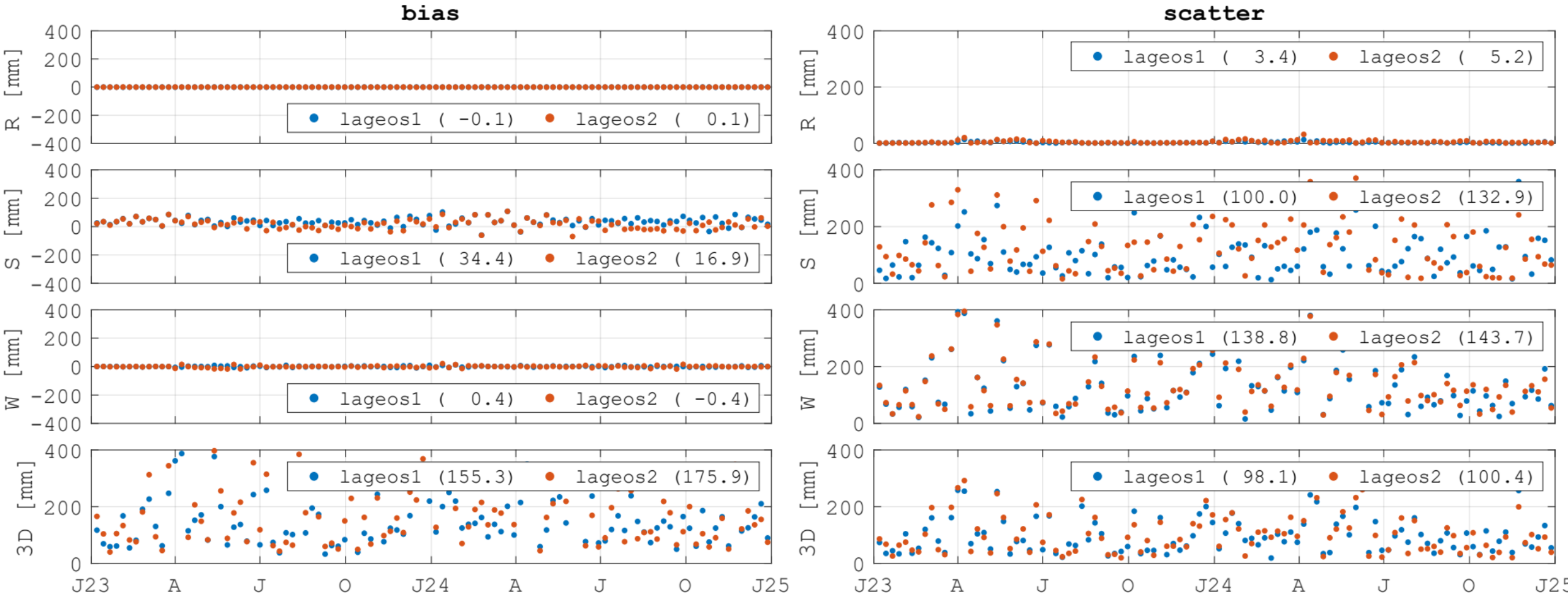
Base for comparisons: LAGEOS+S6A solution

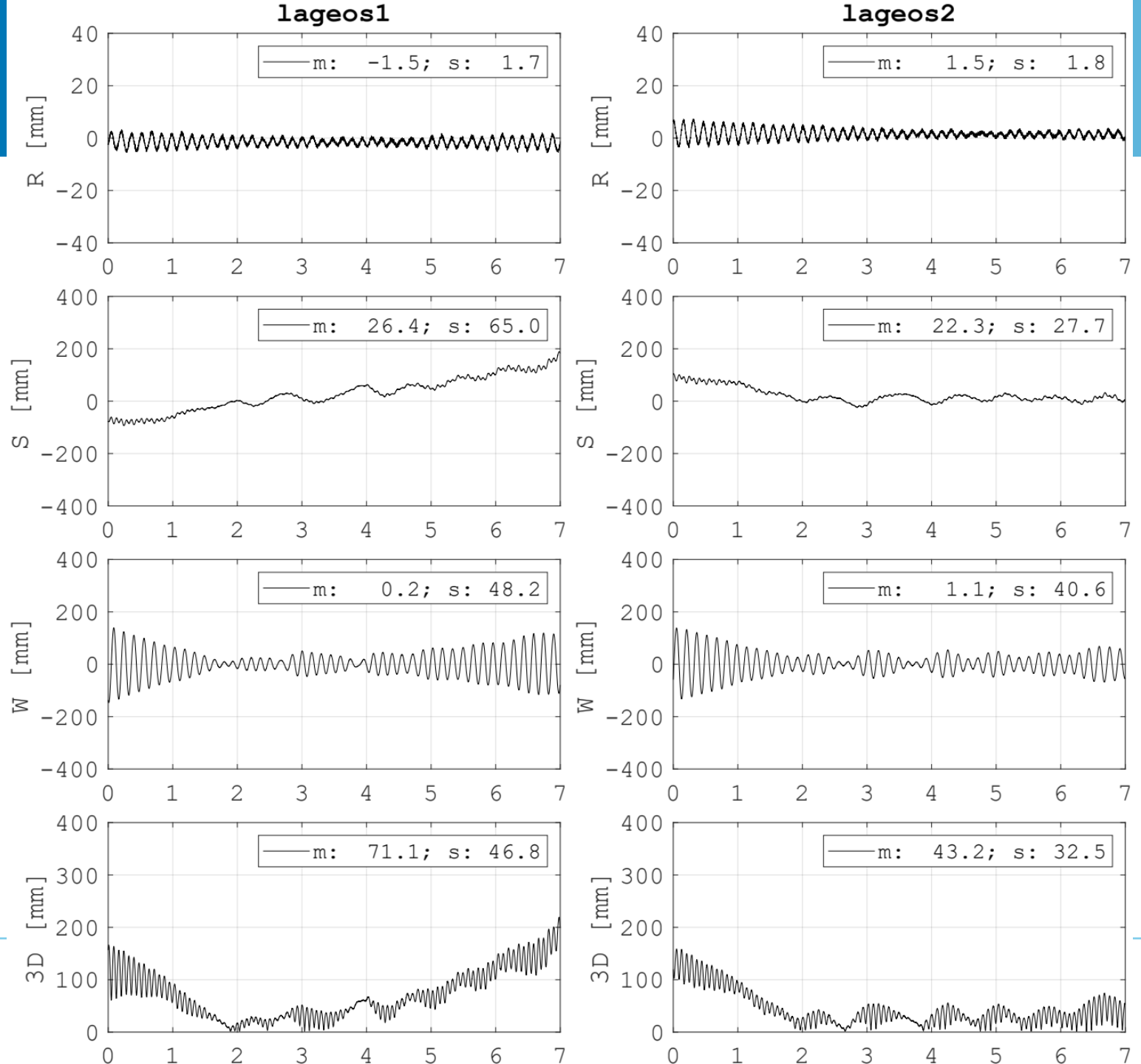


Observation Geometry




T_X [mm]
m: -0.0; s: 0.6
T_Y [mm]
m: -0.0; s: 0.7
T_Z [mm]
m: -0.0; s: 1.0
D [ppb]
m: -0.0; s: 0.0
RMS [mm]
m: 112.8; s: 67.1
J23
A
J
O
J24
A
J
O
J25


bias
scatter
R [mm]
S [mm]
W [mm]
3D [mm]
lageos1 (-0.1)
lageos2 (0.1)
lageos1 (34.4)
lageos2 (16.9)
lageos1 (0.4)
lageos2 (-0.4)
lageos1 (155.3)
lageos2 (175.9)
lageos1 (3.4)
lageos2 (5.2)
lageos1 (100.0)
lageos2 (132.9)
lageos1 (138.8)
lageos2 (143.7)
lageos1 (98.1)
lageos2 (100.4)
J23
A
J
O
J24
A
J
O
J25


lageos1
lageos2
R [mm]
S [mm]
W [mm]
3D [mm]
m: -1.5; s: 1.7
m: 1.5; s: 1.8
m: 26.4; s: 65.0
m: 22.3; s: 27.7
m: 0.2; s: 48.2
m: 1.1; s: 40.6
m: 71.1; s: 46.8
m: 43.2; s: 32.5