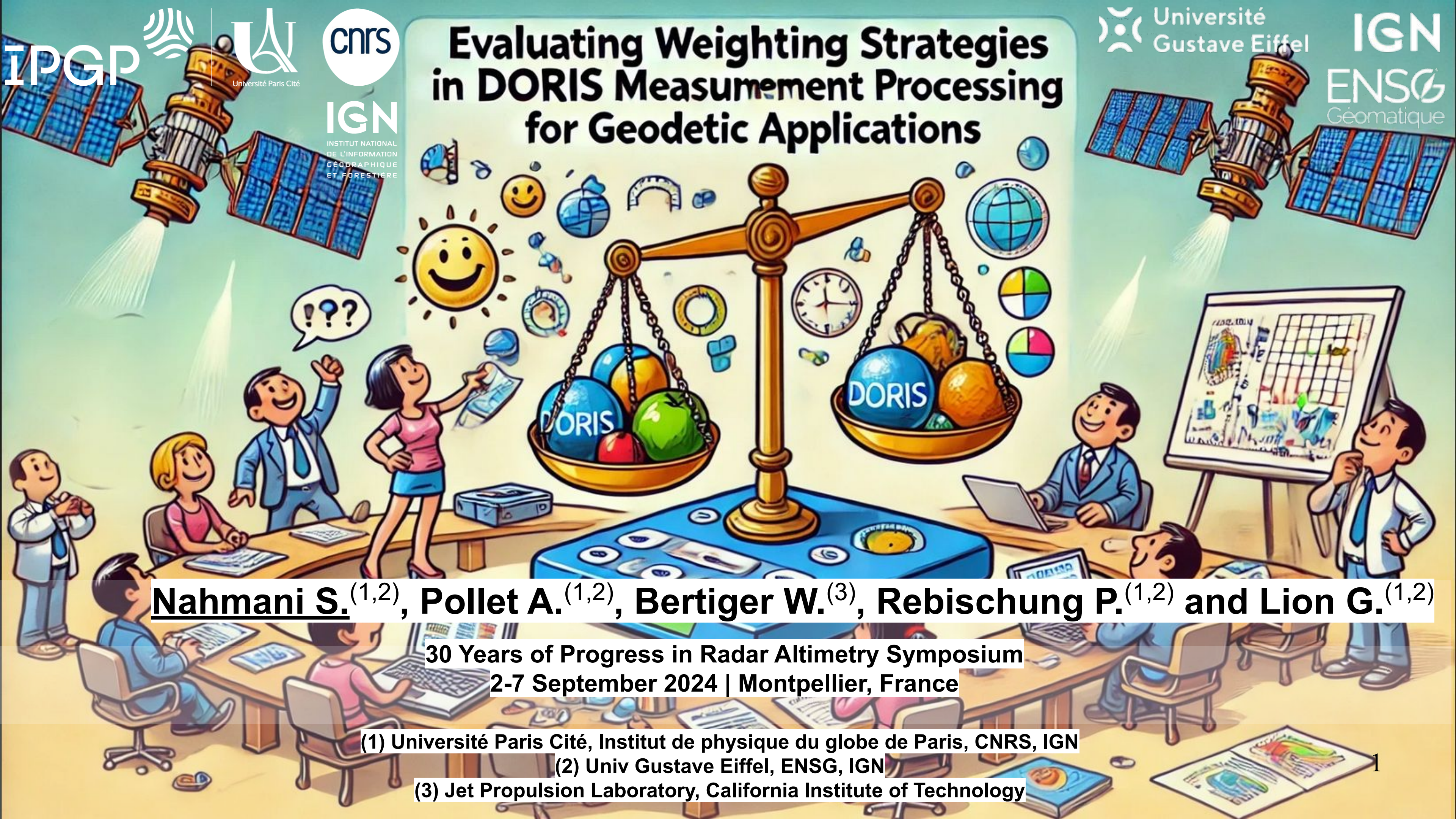

Evaluating Weighting Strategies in DORIS Measurement Processing for Geodetic Applications

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WELCOME TO
INTRODUCTION
NEW
NEW
NEW IDEA!

Introduction

- Why this study?
  - The precision and reliability of parameter estimation in geodetic processing are critically dependent on the correct weighting of observations.
  - According to the Gauss-Markov theorem, in linear models, the Best Linear Unbiased Estimator (**BLUE**) is achieved through the least squares method when observations are **weighted inversely to their variances**.

- Objectives:
  - **Evaluate** five different weighting strategies for DORIS measurements, including uniform weighting,
  - **Propose** a new adaptive method based on the analysis of observation residuals, specifically tailored to each beacon.
  - **Determine** which weighting strategy yields the most accurate and reliable results in geodetic processing.

Methodology

Data and Processing Approach

- **Data Sources:**
  - DORIS measurements from Cryosat-2, Jason-3, Sentinel 3A and 3B, Sentinel 6A, and SARAL, covering the years 2020 to 2022.

- **Software:**
  - Processing was conducted using GipsyX software as part of the activities of the IGN-IPGP Analysis Center.

- **Processing Method:**
  For each weighting strategy, the processing is conducted in two steps:

  Step 1: Orbital Parameter Estimation

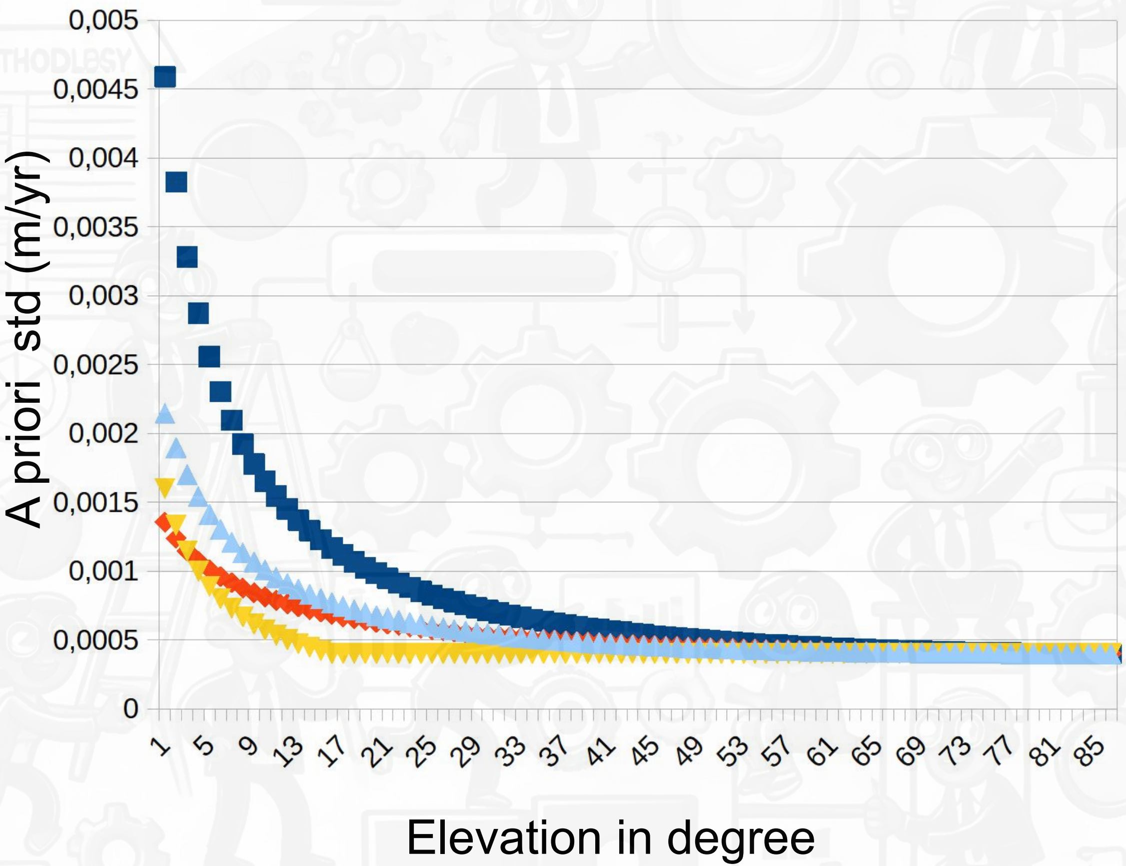
  - Estimate the satellite orbital parameters while fixing the coordinates of the DORIS beacons.

  Step 2: Full Parameter Estimation

  - Using the orbital parameters estimated in the first step, re-estimate all parameters simultaneously, including satellite orbits, DORIS beacon coordinates, and Earth Orientation Parameters (EOPs).

  Step 3: daily monosatellite solutions combined to produce weekly multisatellite solutions (PyTRF).

Weighting Strategies Evaluated



$$\frac{\sigma_0}{\sin(e)}$$

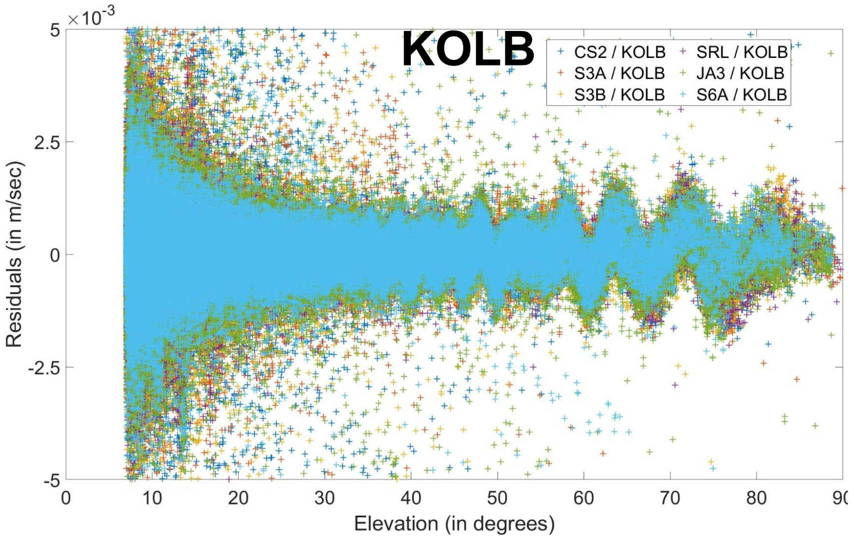
$$\frac{\sigma_0}{\sqrt{\sin(e)}}$$

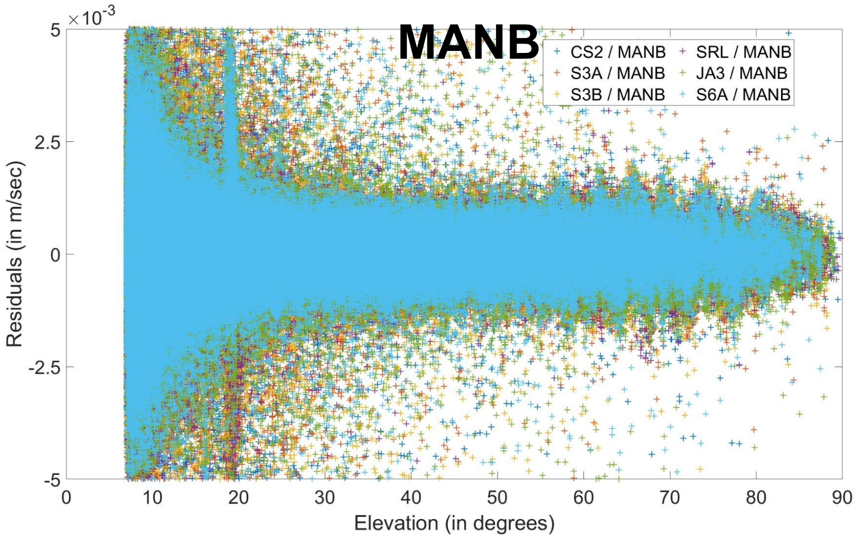
GRGS AC $\begin{cases} \sigma_0 \text{ for } e \geq 20° \\ \sigma_0 \dfrac{20}{e} \text{ for } e < 20° \end{cases}$

CNES POD study
Moyard et al (2016) :
$K_a = 0.57647$; $K_b = 0.04$

$$\sigma_0 \sqrt{K_a + (1 - K_a)\left(\frac{1 + K_b}{\sin(e) + k_b}\right)^2}$$

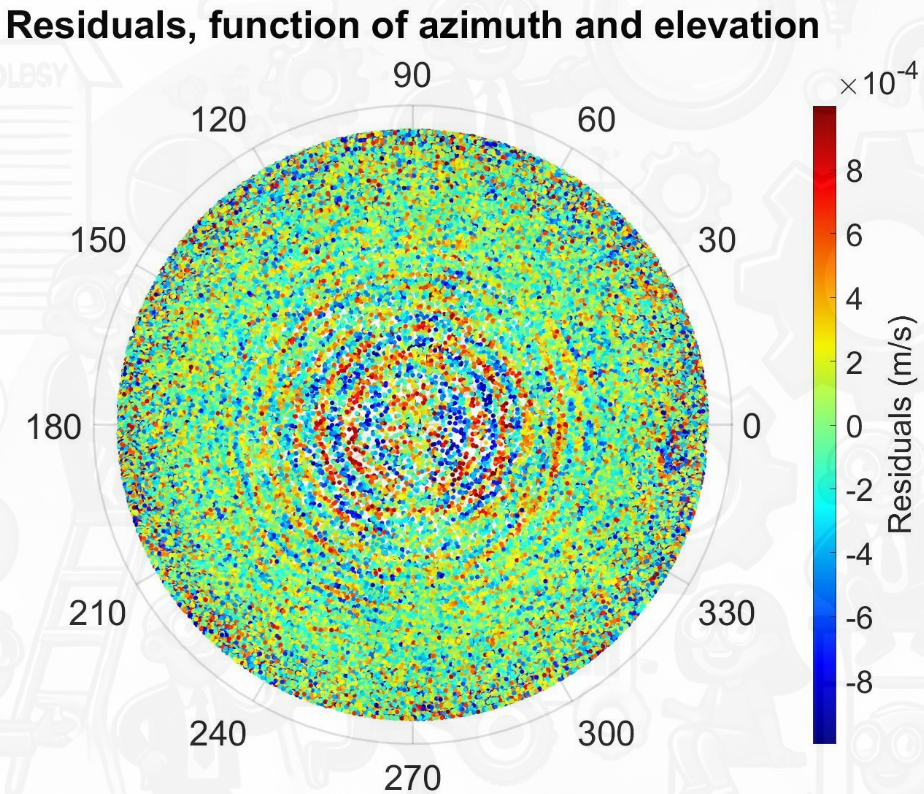
Residuals of the “Uniform Weighting”





- **Multipath effects**
  - KOLB shows more pronounced oscillations, indicating a higher sensitivity to multipath compared to MANB and others stations [see Yaya et al., 2024 yesterday].
- **Variation in Standard Deviations**
  - Standard deviations increase at low (0-20 degrees) and could increase at high elevations (60-90 degrees)
- **Implications for Weighting**
  - Highlights the need for adaptive weighting strategies that account for elevation-dependent variations.

Residuals of the “Uniform Weighting” : KOLB



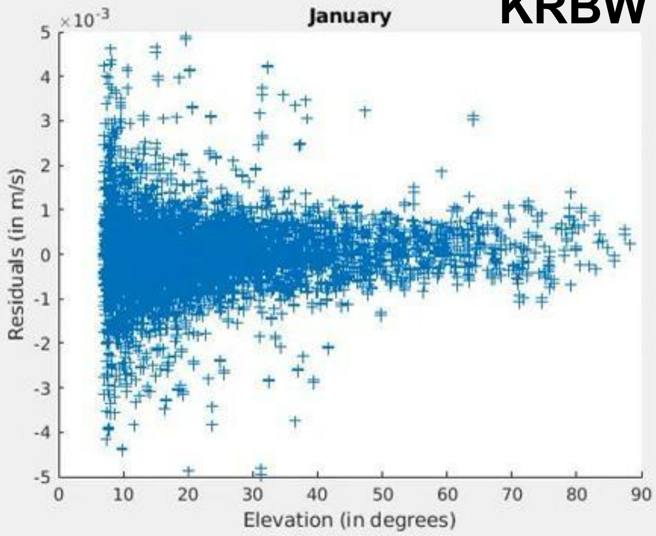
- ❖ Radial Oscillations:
  - ➢ The concentric rings indicate that oscillations are strongly dependent on elevation, displaying a periodic pattern characteristic of multipath effects.
- ❖ Azimuth Influence:
  - ➢ The residual distribution is relatively uniform across azimuth, suggesting that azimuth plays a secondary role in influencing residuals for KOLB.
- ❖ Implications for Weighting:
  - ➢ The prominent oscillations with elevation suggest that weighting strategies should primarily target elevation variations.

Monthly fluctuation of residuals?

We observed monthly residuals per DORIS beacon, the seasonal impact of climate on residuals is not clearly discernible.

For example : Kourou, in French Guiana with equatorial climate.

KRBW



- ❖ **The rainy season**:
  - ➢ from April to July with very heavy rainfall,
  - ➢ from November to January (shorter rainy season) .
- ❖ The **drier periods**:
  - ➢ from August to October (main dry season)
  - ➢ from February to March (short dry season),

Proposed Adaptive Weighting Method

GNSS Approach:

The standard deviation model $std(e) = a_0 + a_1/sin(e)$ is used per day but is too simplistic and unsuitable for DORIS data processed daily and per satellite.

Adaptive Model Equation: $std(e) = a_0 + a_1/sin(e)^2 + a_2/sin(e) + a_3/\sqrt{sin(e)} + a_4 \cdot e + a_5 \cdot e^2 + a_6 \cdot e^3$

Parameter Estimation: Parameters are estimated using blocks of 2500 measurements sorted by elevation.

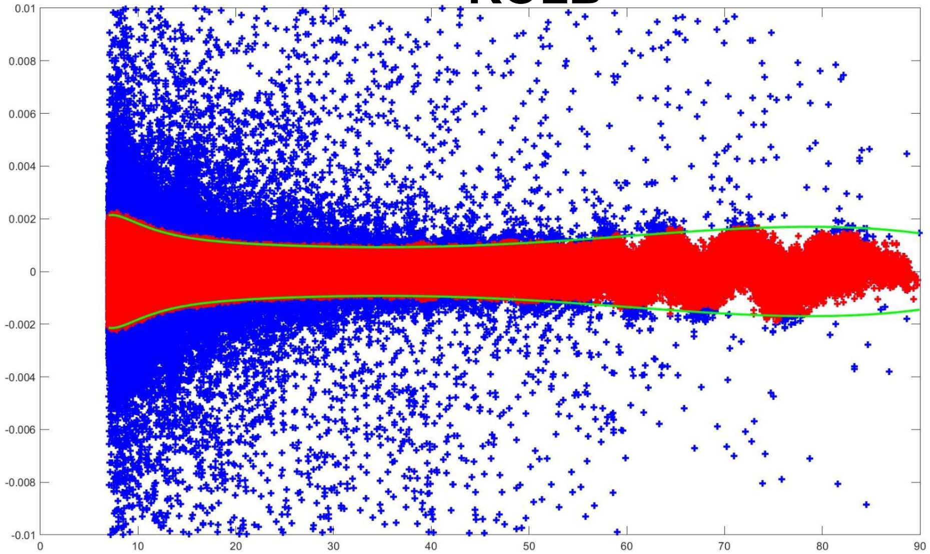
- ❖ Retain 66% of data points to calculate Q1 and Q3, which are generally opposites. The interval 3×max(∣Q1∣,∣Q3∣) is used to define a theoretical range containing 99.7% of residuals if normally distributed.
- ❖ In practice, this covers about 95% of the data, leading to the exclusion of approximately 5% of DORIS measurements as outliers.

Model Selection:

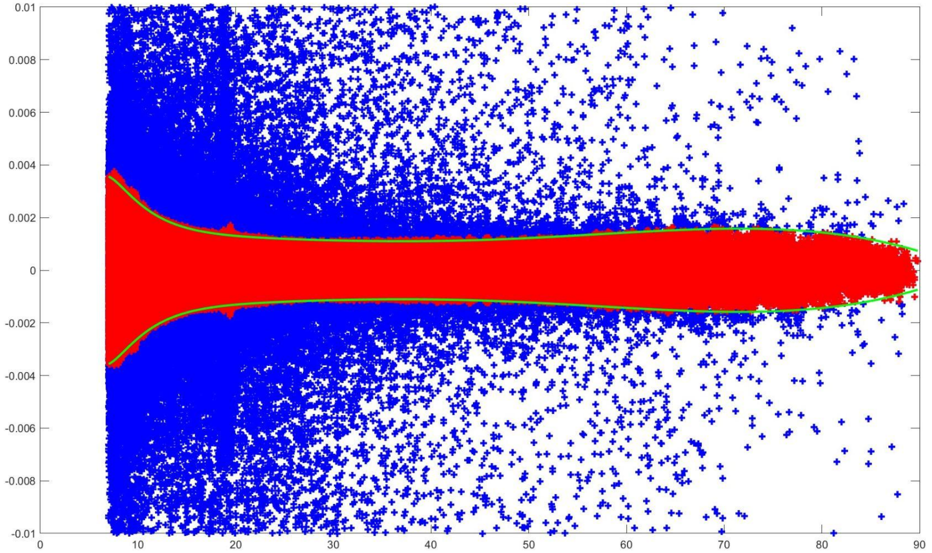
- Bayesian Information Criterion (BIC) is computed over 20 elevation ranges: 10 covering 0° - 20° and 10 for 20° - 90°.
- Evaluate all possible combinations (32 models).
- The model with the lowest BIC is selected as the optimal fit.

Proposed Adaptive Weighting Method

KOLB

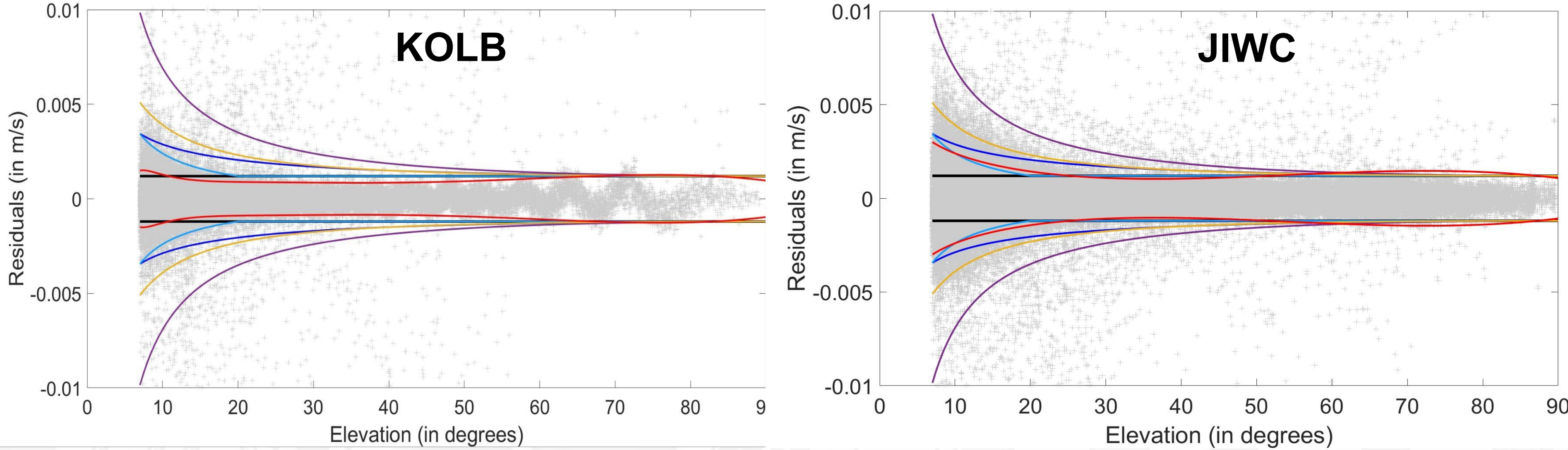


MANB



In red: 95% of the points used to estimate the model parameters; the model is plotted in green, scaled by a factor of 3. Be cautious with the blue points, as they represent less than 5% of the measurements.

Proposed Adaptive Weighting Method



All models are displayed at ±3 sigma. Sigma0 is consistent across models using sigma0.

- **Black:** Constant weighting with sigma0 = 0.4 mm/s.
- **Violet:** Standard deviation std = sigma0 / sin(e).
- **Dark Blue:** std = sigma0 / sqrt(sin(e)).
- **Light Blue:** GRG AC weighting
- **Orange:** CNES POD weighting
- **Red:** Adaptative weighting (IGN-IPGP)

Results

Results on Orbit Estimations (1/2)

Comparison Method:

- Orbits are compared either directly or after adjusting the Helmert parameters.

Daily WRMS of Measurement Residuals by Satellite:

- Results show a slight improvement in the WRMS of measurement residuals with the new weighting, due to methodological choices that slightly enhance performance.

- The new weighting retains about 100 additional measurements compared to other strategies, but this effect remains limited given the large total number of measurements (over 10,000).

Results on Orbit Estimations (2/2)

External Comparison with SSALTO:

- The orbits produced with the new weighting are of standard quality with no significant variations.

Internal Comparison with the Estimated Orbit Using Uniform Weighting:

- The orbits demonstrate sub-millimeter stability in the median, with a slightly greater impact on the RZ component (about 3 mm maximum), and for Sentinel-6A (RZ ~1 cm with weighting in 1/sin(elev)).
- Variability is mainly observed on the TZ component and on the rotations, which could have implications for Earth Orientation Parameters (EOP).

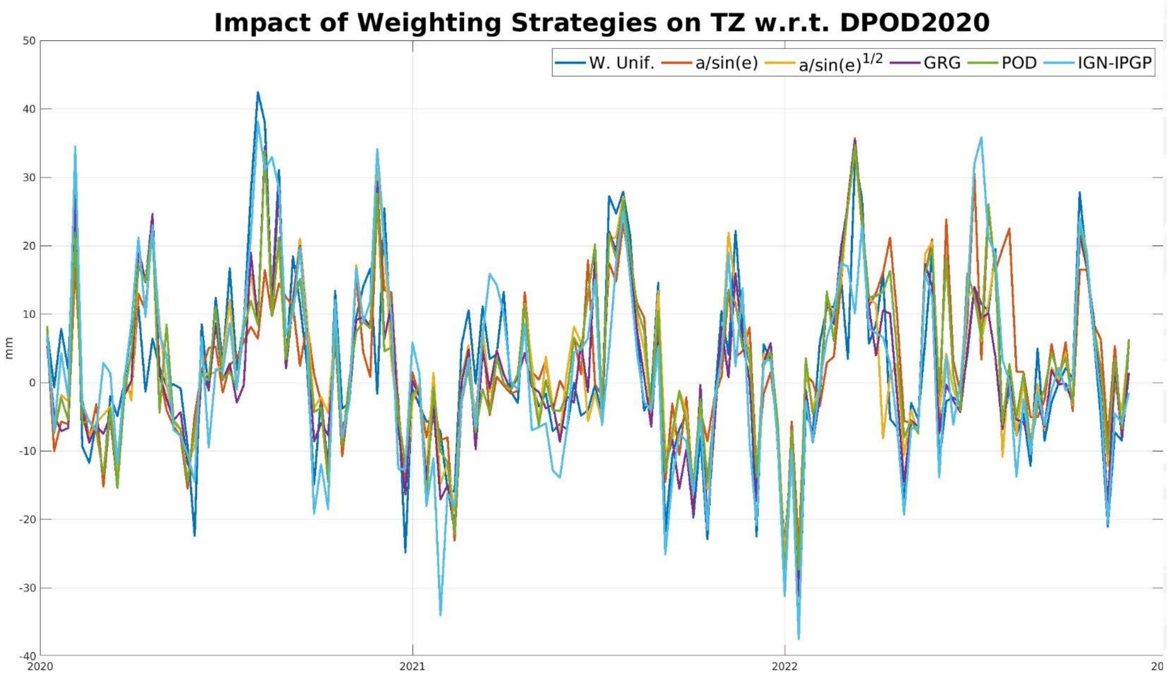
Impact of Weightings on Orbits:

- Weightings affect the cross-track and along-track components of the estimated orbits, with differences of a few centimeters.
- On the radial component, the impact is in the range of 1 to 4 mm maximum.

Results on TRF Parameters Compared to DPOD2020

Impact of Weightings on TX, TY, Scale, and Rotations:

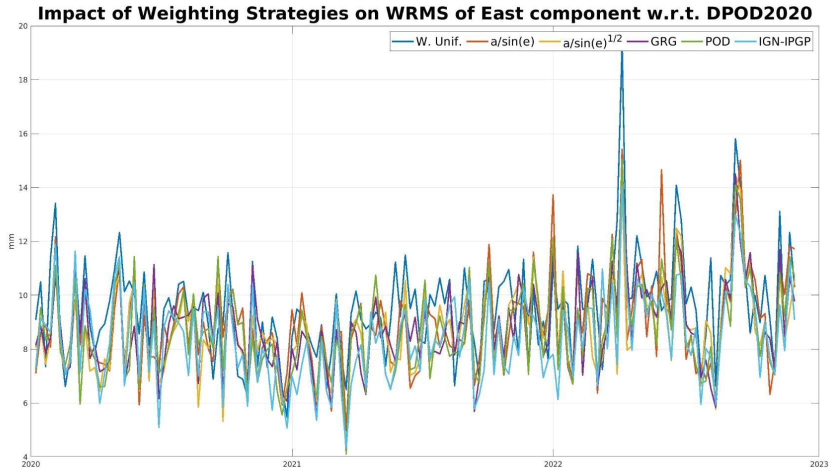
- The weightings applied to DORIS measurements do not significantly affect the estimation of TX, TY, scale, and rotations. The results obtained are very similar across the different weighting methods.



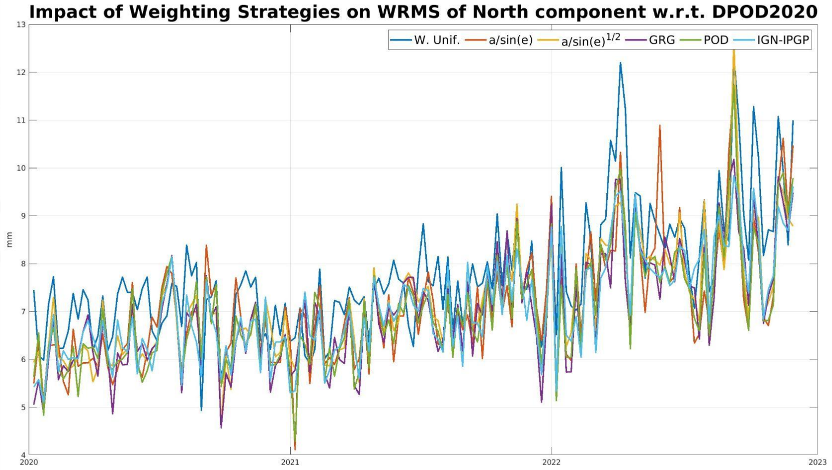
Stability of TZ:

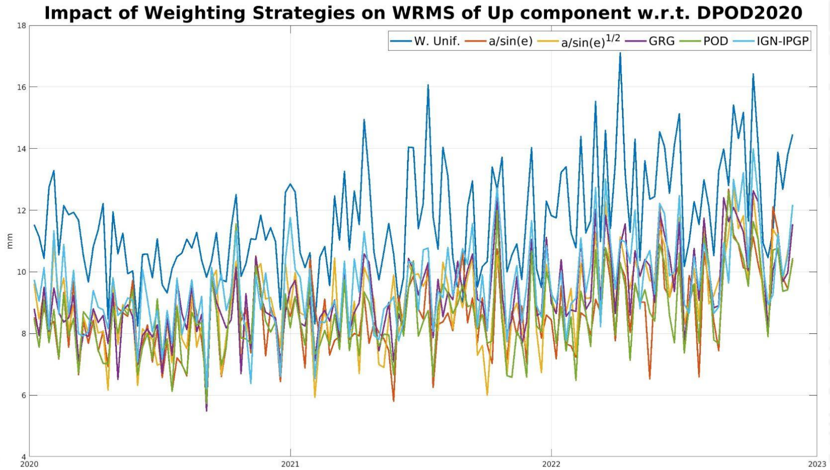
- The only notable difference is observed in the TZ parameter, where the CNES-POD weighting demonstrates superior stability compared to other strategies.
- However, the adaptive weighting tailored to each beacon appears to slightly degrade the stability of TZ.

DORIS Beacon Coordinates vs. DPOD2020 (1/2)



The uniform weighting shows the highest values across all components, suggesting it is less effective compared to the other weighted strategies.





DORIS Beacon Coordinates vs. DPOD2020 (1/2)

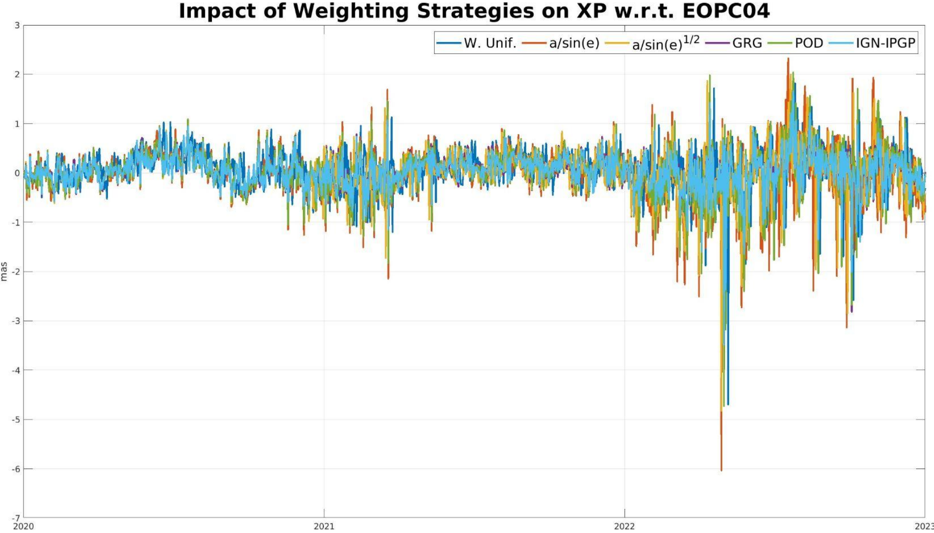
Weighting	RMS WRMS(E) (mm)	RMS WRMS(N) (mm)	RMS WRMS(U) (mm)
W. Unif.	9.735	7.865	11.892
$a/sin(e)$	9.484	7.330	8.946
$a/\sqrt{sin(e)}$	9.506	7.374	9.425
GRG	9.753	7.265	9.595
POD	9.470	7.252	8.962
IGN-IPGP	9.023	7.269	9.924

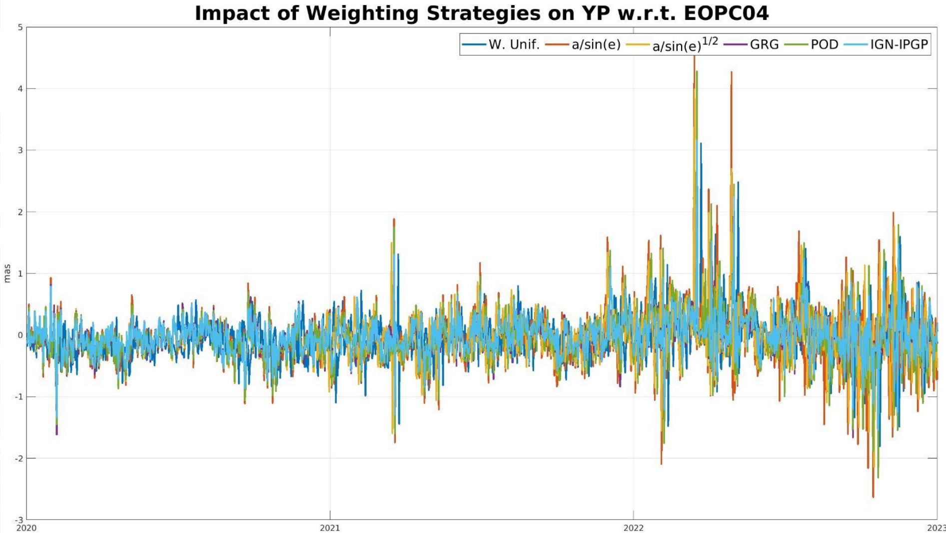
- **East (E) Component:** The IGN-IPGP weighting shows the best result with the lowest RMS WRMS (9.023 mm), indicating better performance on this component compared to other weighting strategies.
- **North (N) Component:** The POD and IGN-IPGP strategies show very similar and the lowest values (7.252 mm and 7.269 mm, respectively), suggesting good stability on this component.
- **Up (U) Component:** The a/sin(e) weighting provides the best results with an RMS WRMS of 8.946 mm, followed closely by the POD weighting (8.962 mm). The other strategies show higher values, indicating slightly lower performance on this component.

EOPs wrt EOPC04 series (1/2)

Analysis of EOPs estimated with different weighting methods for DORIS measurements.

The XP and YP time series estimated with adaptive weighting seem to show better agreement with the reference EOPC04 series.





EOPs wrt EOPC04 series (2/2)

Weighting	WRMS XP wrt EOPC04 (mas)	WRMS of formal errors (mas)
W. Unif.	0.4397	0.2828
$a/sin(e)$	0.5766	0.3193
$a/\sqrt{sin(e)}$	0.4926	0.2876
GRG	0.4683	0.2755
POD	0.5067	0.2921
IGN-IPGP	0.3851	0.2385

Weighting	WRMS YP wrt EOPC04 (mas)	WRMS of formal errors (mas)
W. Unif.	0.3759	0.2776
$a/sin(e)$	0.4980	0.3113
$a/\sqrt{sin(e)}$	0.4190	0.2811
GRG	0.4006	0.2703
POD	0.4343	0.2854
IGN-IPGP	0.3413	0.2358


Conclusions
& Perspectives
Perspectives
Conclusions
Perspectives
Doris
Beacons
Future
Directions

Conclusion and Perspectives

Conclusions on the Proposed Adaptive Weighting Model:

- The proposed adaptive weighting model shows good performance:
  - Improvement in estimated Earth Orientation Parameters (EOP), with better agreement compared to the EOPC04 series.
  - Improved WRMS of beacon positions on the East component compared to other tested weighting models.
- While the CNES-POD weighting model achieves better WRMS on the vertical component, the comparison is made against DPOD2020, which incorporates existing weighting models.

Proposal: We propose that our next IGN19 solution be produced with station-specific adaptive weightings.

Perspectives:

- Investigate the stability of estimated models over time.
- Consider estimating variance components (VCE) for the GipsyX SRIF filter, though this is very ambitious and computationally intensive.
- Prospectively, consider a frequency-specific weighting approach.
- Implementing these developments would require significant modifications to certain blocks of the GipsyX code, and the time needed to conduct these tests is uncertain.


Q&A
Q&A
Q&A
QUESTION?
Q&A