Positioning and integrity monitoring using the new DFMC SBAS service in the road transport

K. Wang, A. El-Mowafy

Curtin University, Australia

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Second-Generation SBAS

Augmentation system to support positioning not only in aviation, but also in transport, precision agriculture, martitime, surveying, etc.

- Test-bed developed by:

Australian Government
Geoscience Australia

Land Information New Zealand
Toitū te whenua

- Managed by:

FRONTIER SI

Second-Generation SBAS

Service and Solution types (non-aviation mode)

Solution types	GNSS signals	SBAS augmentation
L1 SBAS	GPS (L1) + (Galileo E1)	GPS
DFMC SBAS	**GPS (L1+L5) + Galileo (E1+E5a)**	**GPS + Galileo**
PPP over L5	GPS (L1+L5) + Galileo (E1+E5a)	GPS + Galileo
PPP over L1	GPS (L1+L5)	GPS

Features:

- Precise satellite orbits and clocks in real-time
- Free-of-charge
- Support single-receiver dual-frequency GPS+Galileo positioning

New weighting model

- $l(t_i)$: Carrier-smoothed code observations
- $\hat{x}(t_i)$: Receiver coordinates, receiver clocks (GPS+Galileo)

Applications in road transport → Complicated multipath environment

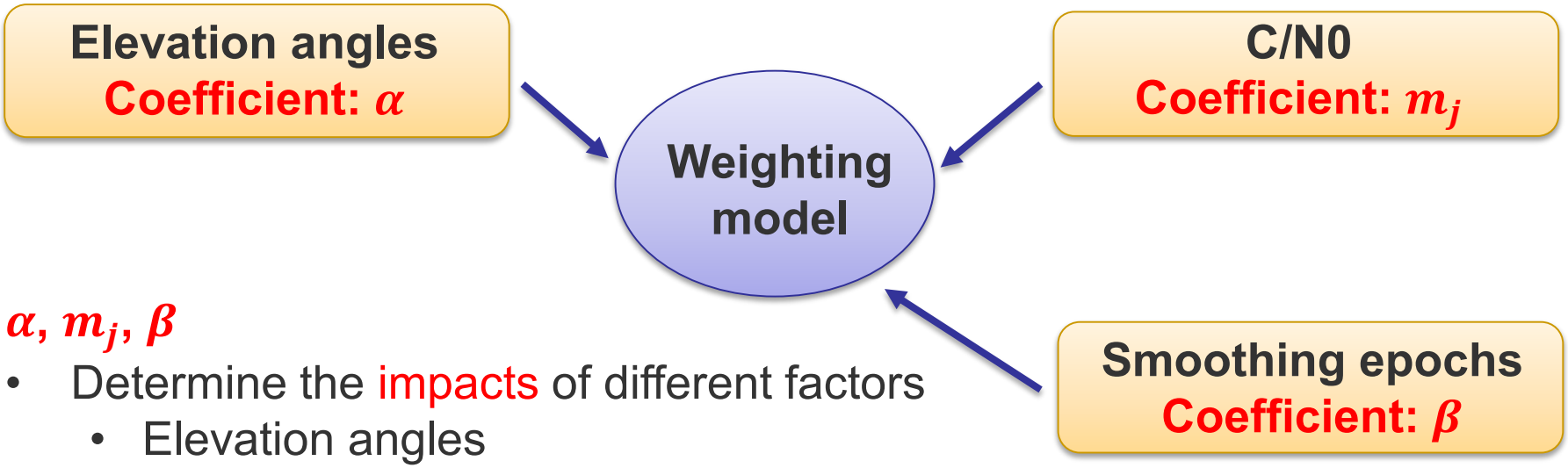
Challenge 1: Multipath at high elevation angles

- C/N0 considered for weighting

Challenge 2: Frequent cycle slips and filter initializations

- Using well smoothed observations → Significant data loss
- Smoothing epochs considered for weighting

New weighting model



α, m_j, β

- Determine the impacts of different factors
  - Elevation angles
  - C/N0
  - Smoothing epochs
- Coefficients are empirically searched to best match the empirical and formal CDFs of the normalised and weighted noise/multipath
- Investigated for
  - Open-sky, suburban and urban scenarios
  - Smoothing windows of 300, 600 and 900 s

Integrity monitoring: Overbounding CDF + FDE + HPL

Apply the new weighting model: $w_A \times w_B \times w_C$

$$w_A = \frac{1}{\left(1 + \alpha \times \exp\left(-\frac{\theta}{10^\circ}\right)\right)^2}$$

$$w_B = \frac{1}{1 + \mu_1 \times m_1 \times 10^{-0.1 S_1} + \mu_2 \times m_2 \times 10^{-0.1 S_2}}$$

$$w_c = \frac{1}{1 + \beta \times \frac{N - n}{n}}$$

[Wang et al. 2020]

Compute weighted noise/multipath

Search for excess-mass overbounding CDF

STD

Mean

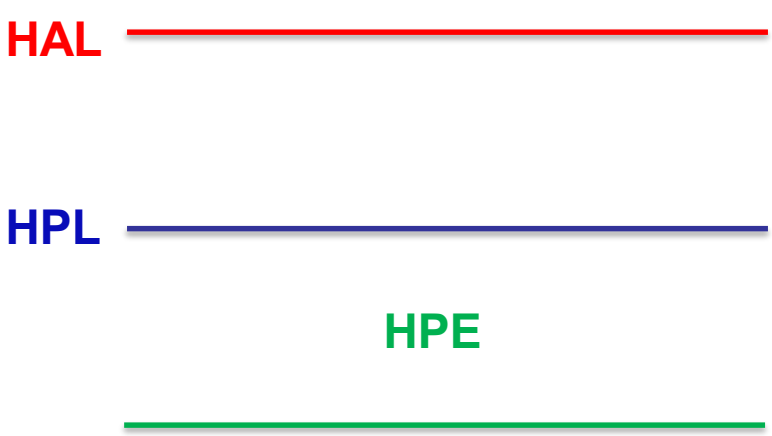
(inflated and shifted compared with standard normal distribution)

Fault detection and exclusion χ^2- test

Horizontal protection level (ED-259 for DFMC SBAS)

Horizontal protection level

- Computed in the direction along the semi-major axis of the horizontal error ellipse
- Bound the horizontal positioning error (HPE) with a pre-defined PHMI
- When exceeding the horizontal alert limit (HAL), warning message is sent to user



$$HPL = K \times \sigma + |T| \times M$$

Determined by the PHMI

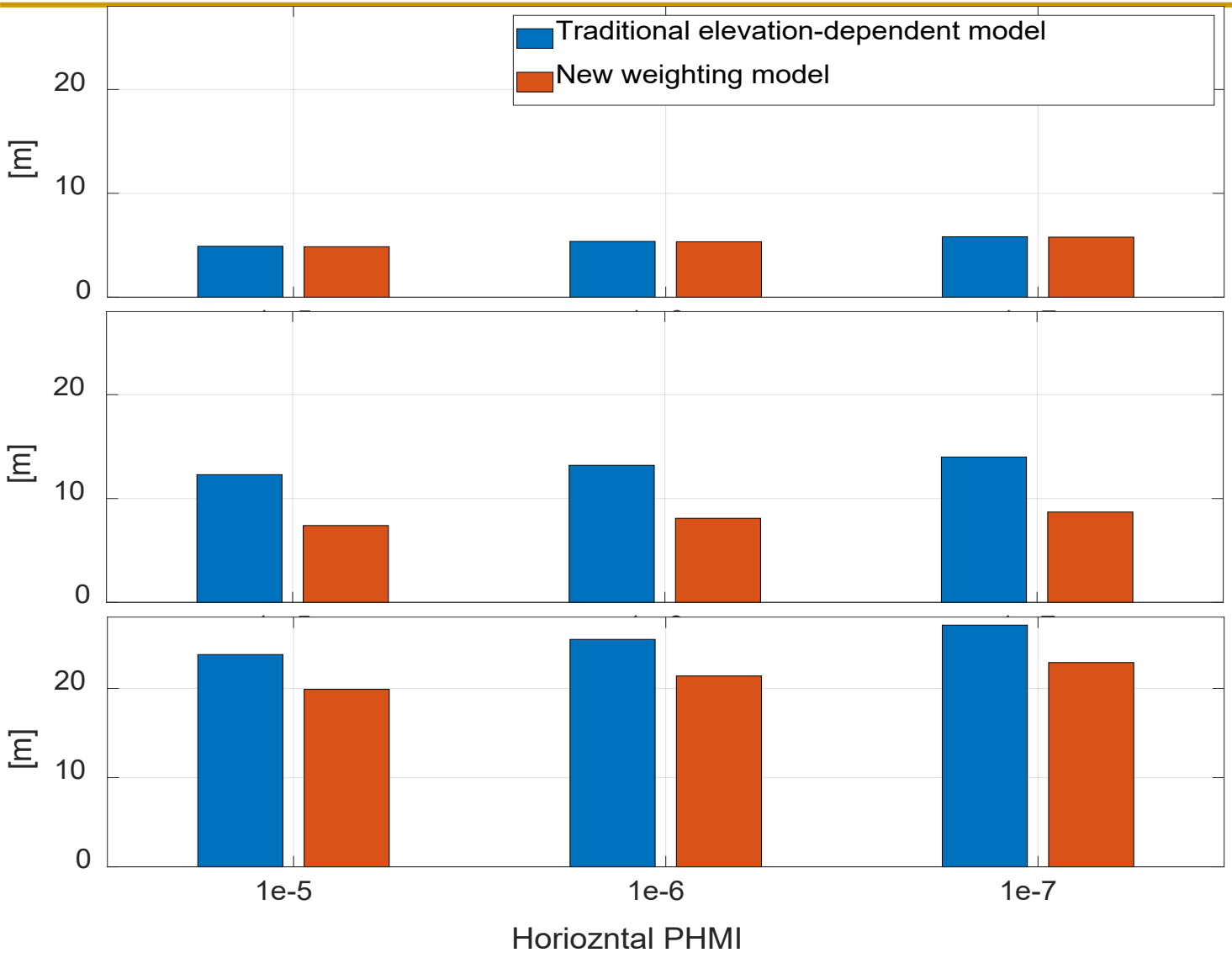
Overbounding mean of noise/multipath mapped into slant direction

Observation→Position domain transformation

Determined by:

- Precision of the satellite clocks/orbits
- STD of unmodelled tropospheric residuals
- STD of remaining ion. effects after forming the IF combination
- Overbounding STD of noise/multipath mapped into slant direction

Mean HPL



Open-sky scenario

Suburban scenario

Urban scenario

Questions

Reference:

Wang K., El-Mowafy A., Rizos C., Wang J. (2020) SBAS DFMC service for Road Transport: Positioning and integrity monitoring with a new weighting model. Journal of Geodesy, under review.

For questions:
kan.wang@curtin.edu.au
a.el-mowafy@curtin.edu.au