Multipath and Atmospheric Propagation Errors in Offshore Aviation DGPS Positioning

**J. Paul Collins, Peter J. Stewart
and Richard B. Langley**

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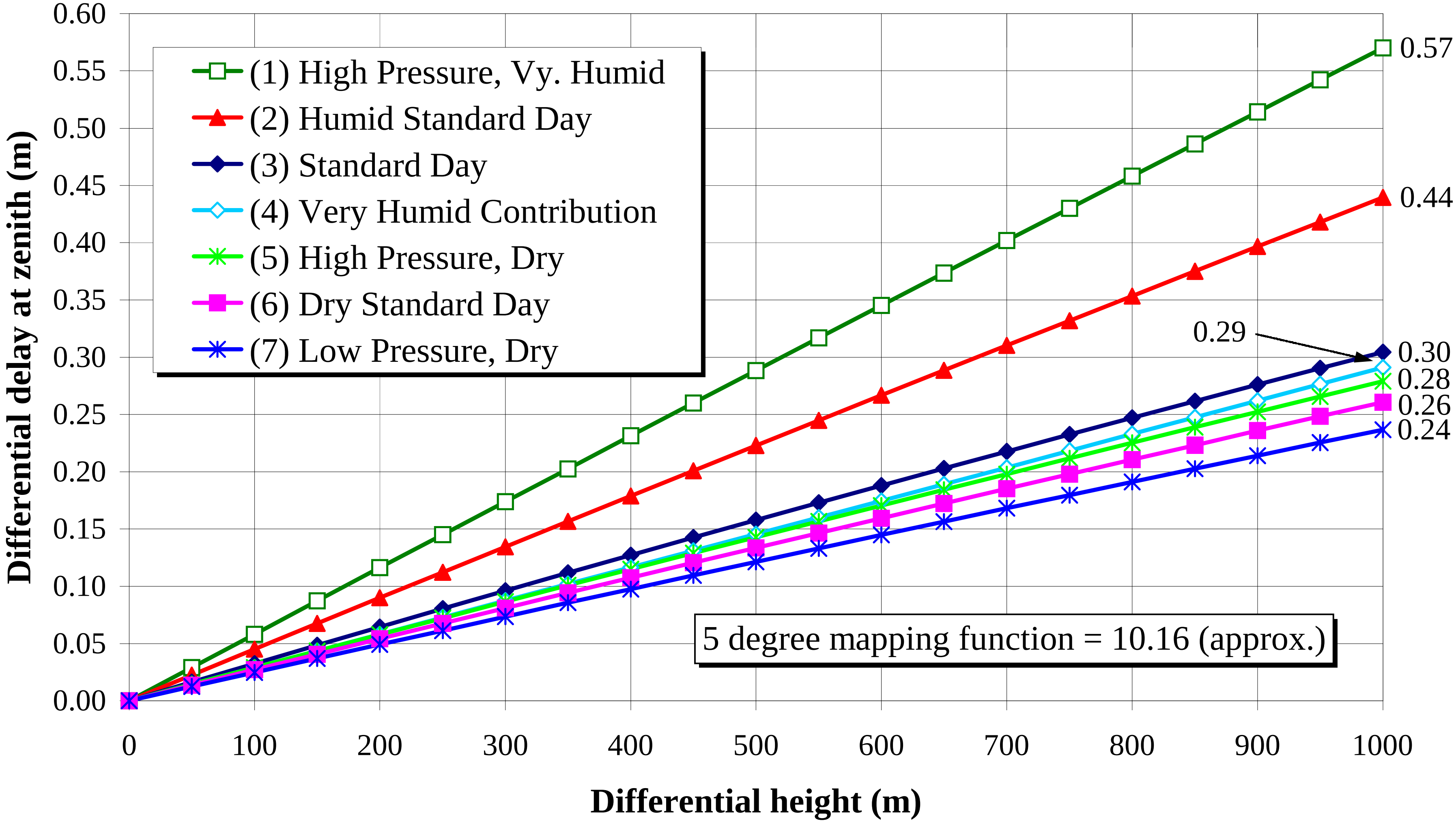
INTRODUCTION

- Part 1:
  - Impact of tropospheric delay on DGPS pseudoranges.
  - Results of using simple model to account for vertical separation of aircraft and reference antennas.
- Part 2:
  - Impact of reference station multipath on computed aircraft position.
  - Possible solutions, software and hardware techniques.

Differential tropospheric zenith delay upto 1000m above reference station.
(Represents zenith DGPS correction error due to altitude separation.)



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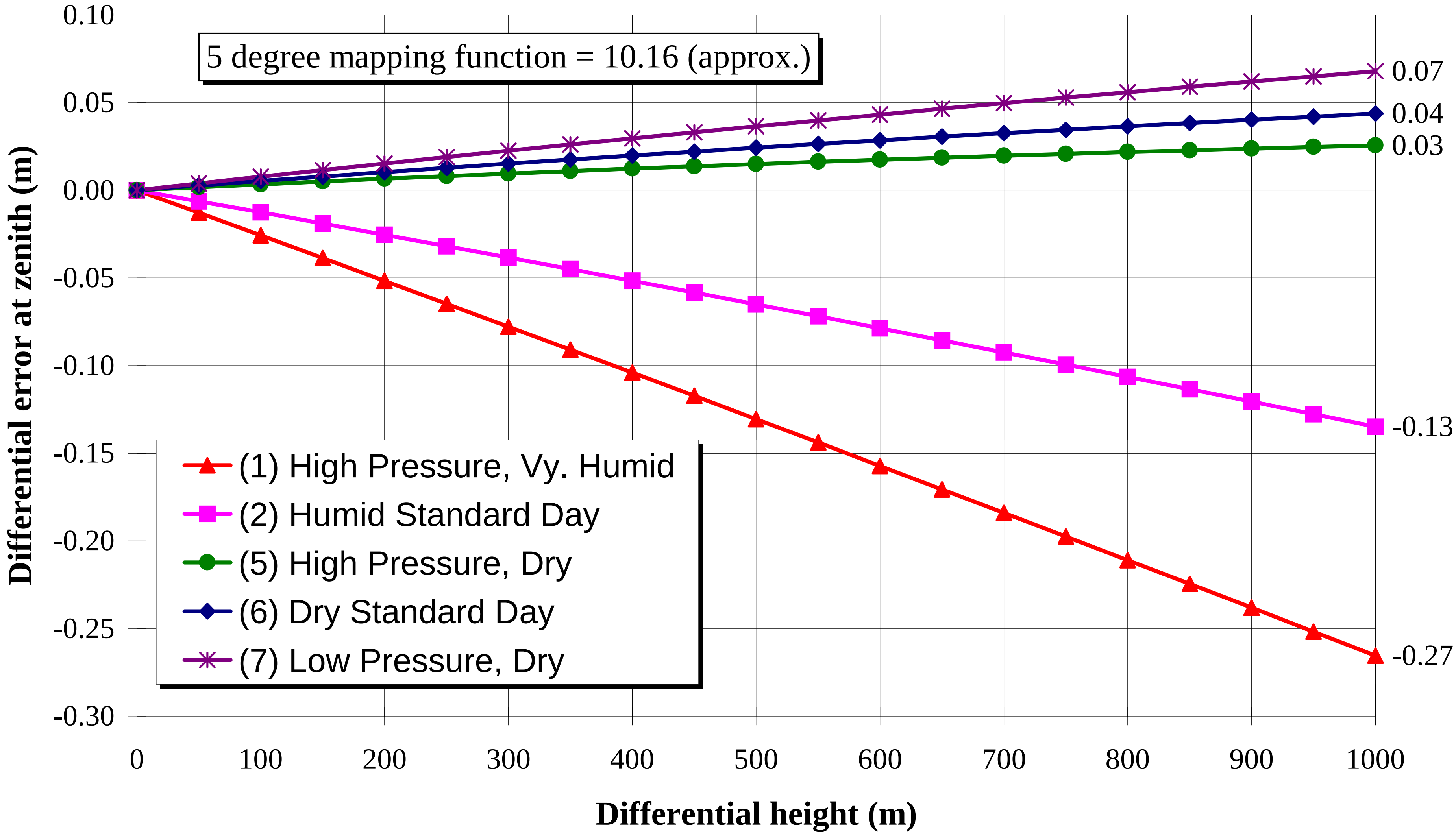
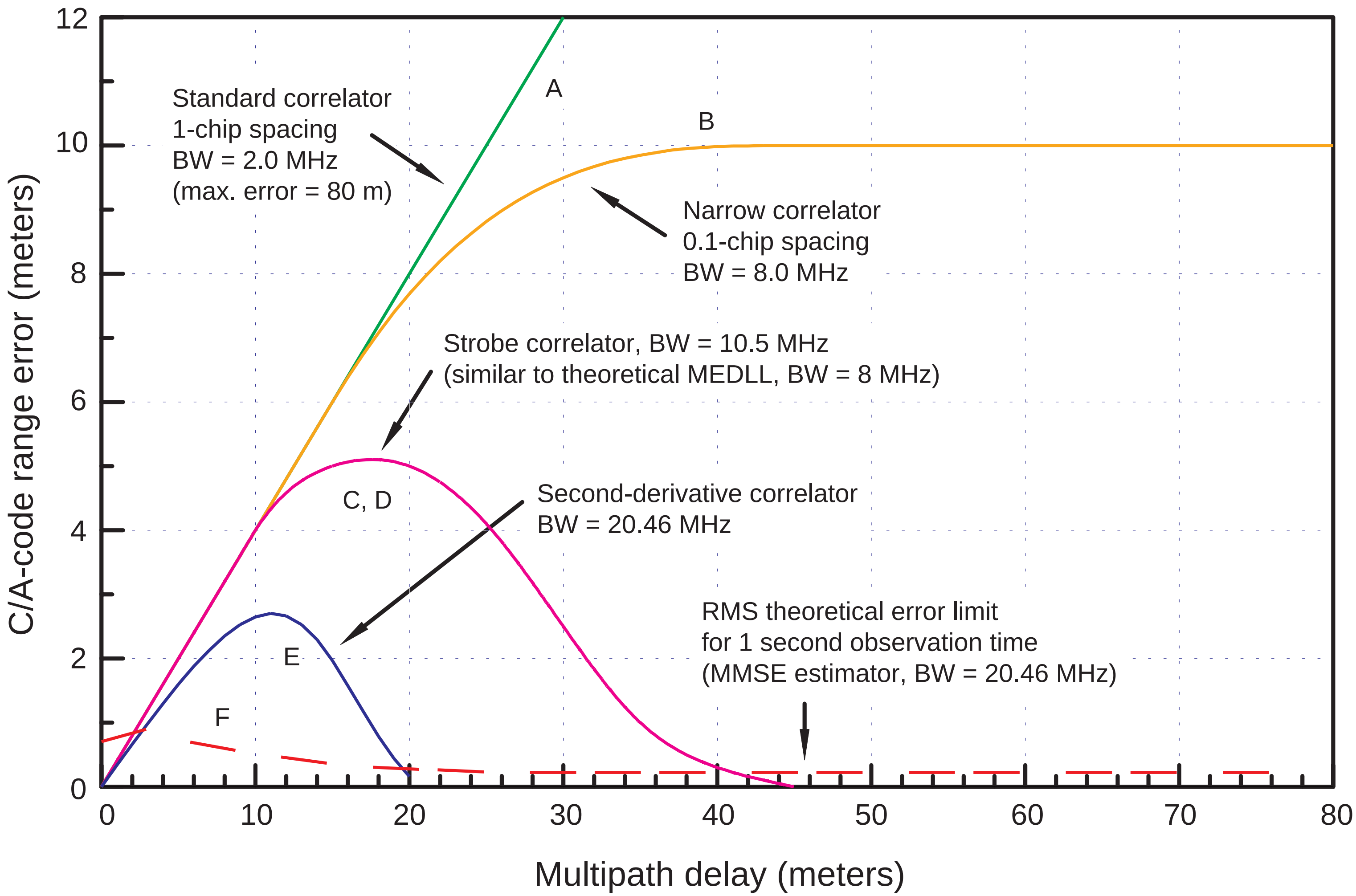
DGPS correction errors at the zenith, when using UNB1 tropospheric delay model at aircraft and reference station.



RECEIVER TECHNOLOGY



Weill, L.R. (1997). "Conquering multipath: The GPS accuracy battle." *GPS World*, April, pp. 59-66.

MULTIPATH MODELLING

Requires pseudorange and dual frequency carrier phase measurements:

$$C_1 = \rho + c(dT - dt) + I_1 + T + m_{C_1} + n_{C_1}$$

$$\Phi_1 = \rho + c(dT - dt) + \lambda_1 N_1 - I_1 + T + m_{\Phi_1} + n_{\Phi_1}$$

$$\Phi_2 = \rho + c(dT - dt) + \lambda_2 N_2 - I_2 + T + m_{\Phi_2} + n_{\Phi_2}$$

Single frequency combination includes ionospheric contribution:

$$C_1 - \Phi_1 = 2I_1 - \lambda_1 N_1 + m_{C_1} + n_{C1} - m_{\Phi_1} - n_{\Phi 1}$$

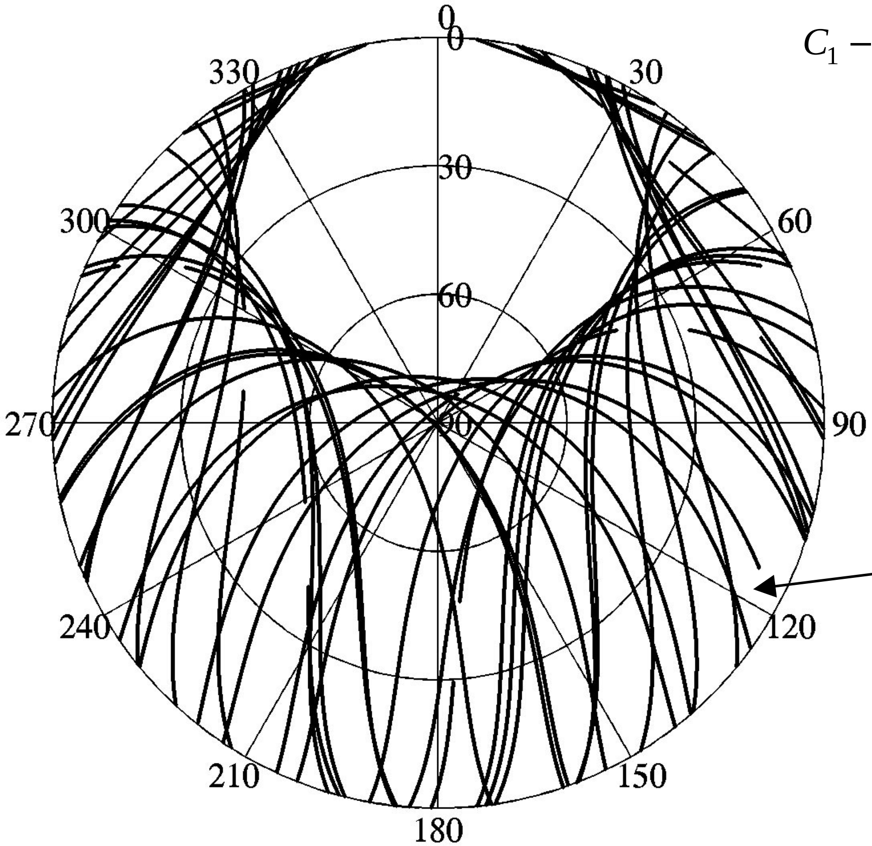
$$I_2 = \alpha I_1; \quad \alpha = \left(\frac{f_1}{f_2}\right)^2$$

$$2\frac{(\Phi_1 - \Phi_2)}{(\alpha - 1)} = 2I_1 + 2\frac{(\lambda_1 N_1 - \lambda_2 N_2)}{(\alpha - 1)} + 2\frac{\left(m_{\Phi_1} - m_{\Phi_2}\right)}{(\alpha - 1)} + 2\frac{\left(n_{\Phi_1} - n_{\Phi_2}\right)}{(\alpha - 1)}$$

$$C_1 - \left(1 + \frac{2}{\alpha - 1}\right)\Phi_1 + \left(\frac{2}{\alpha - 1}\right)\Phi_2 = m_{C_1} + n_{C_1} + B + M_\Phi + N_\Phi$$

Final combination dominated by pseudorange multipath (m_{C_1}) and noise (n_{C_1}).

CALIBRATING MULTIPATH



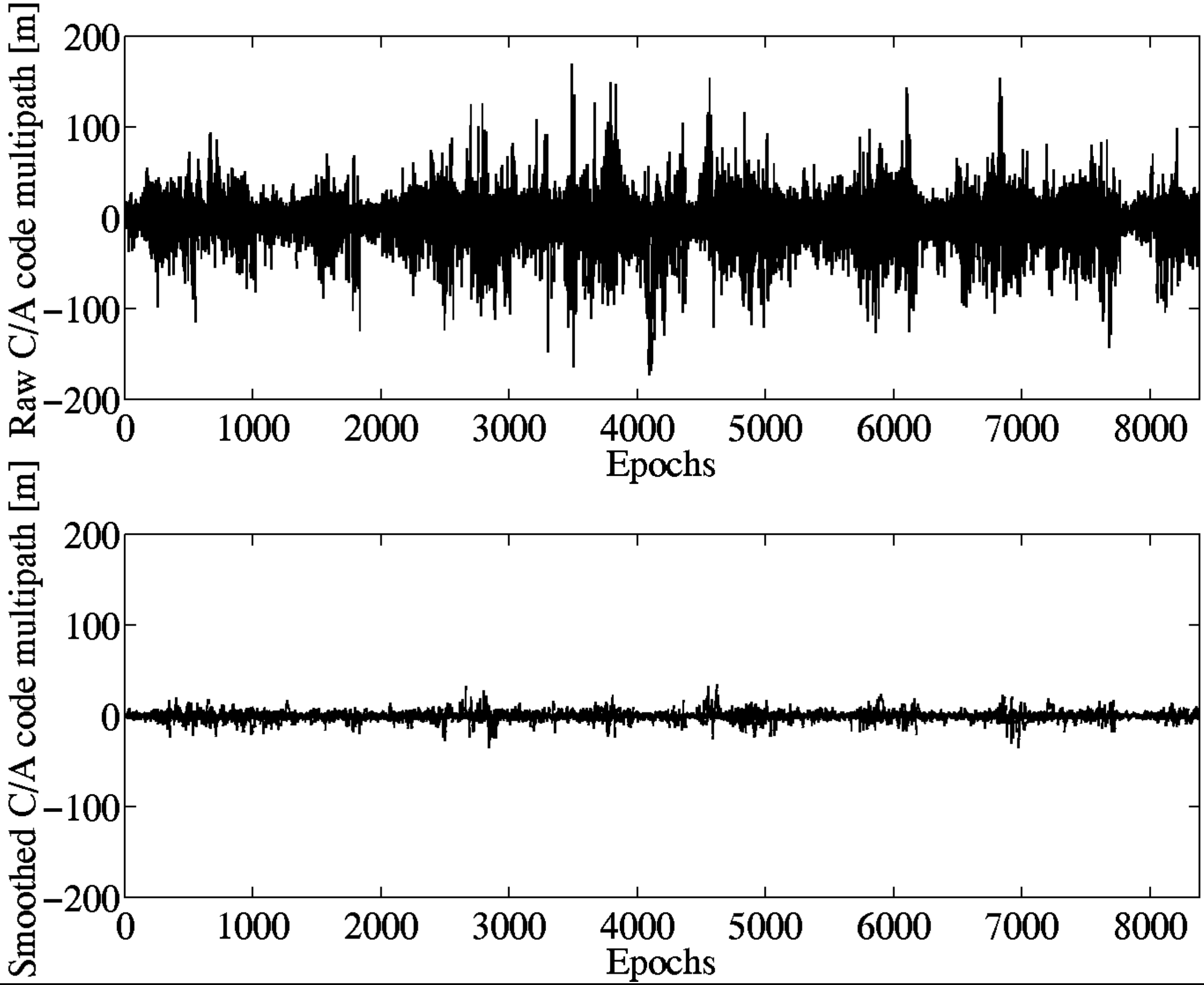
$$C_1 - 4.0915\Phi_1 + 3.0915\Phi_2 = m_{C_1} + n_{C_1} + B + M_\Phi + N_\Phi$$

Combination of pseudorange (C_1) and dual frequency carrier phases (Φ_1, Φ_2) is dominated by pseudorange multipath (m_{C_1}) and noise (n_{C_1}). However, accuracy is limited by unknown biases, B, primarily the combination of the carrier phase integer ambiguities.

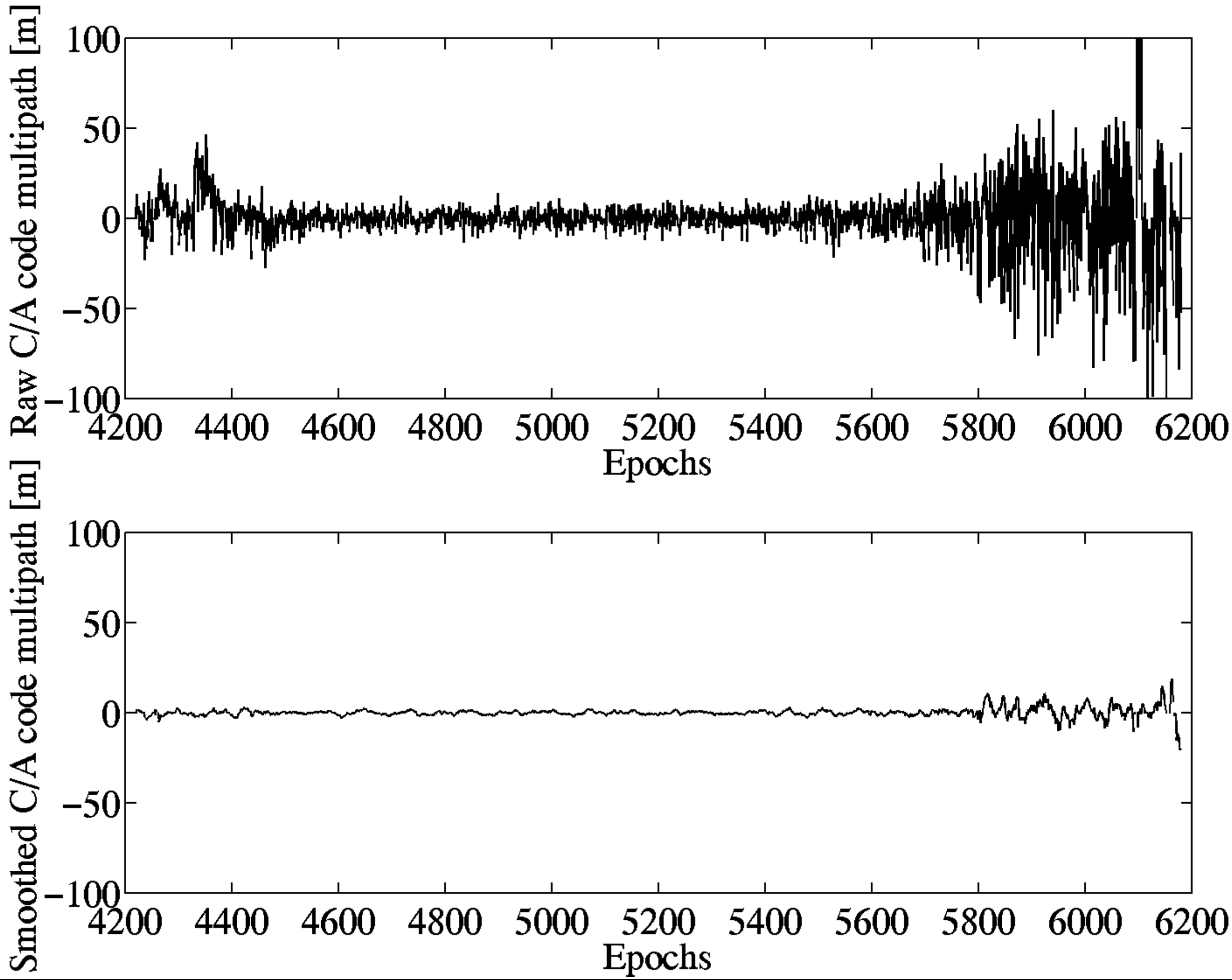
This technique calibrates B from repeated multipath measurements at satellite cross-over points, where the multipath should be the same for both satellites. Multipath 'maps' can be constructed as a function of azimuth and elevation angle.

Kee, C. and B. Parkinson (1994). "Calibration of multipath errors on GPS pseudorange measurements." *Proceedings of ION GPS-94*, Salt Lake City, Utah, September 20-23, pp. 353-363.

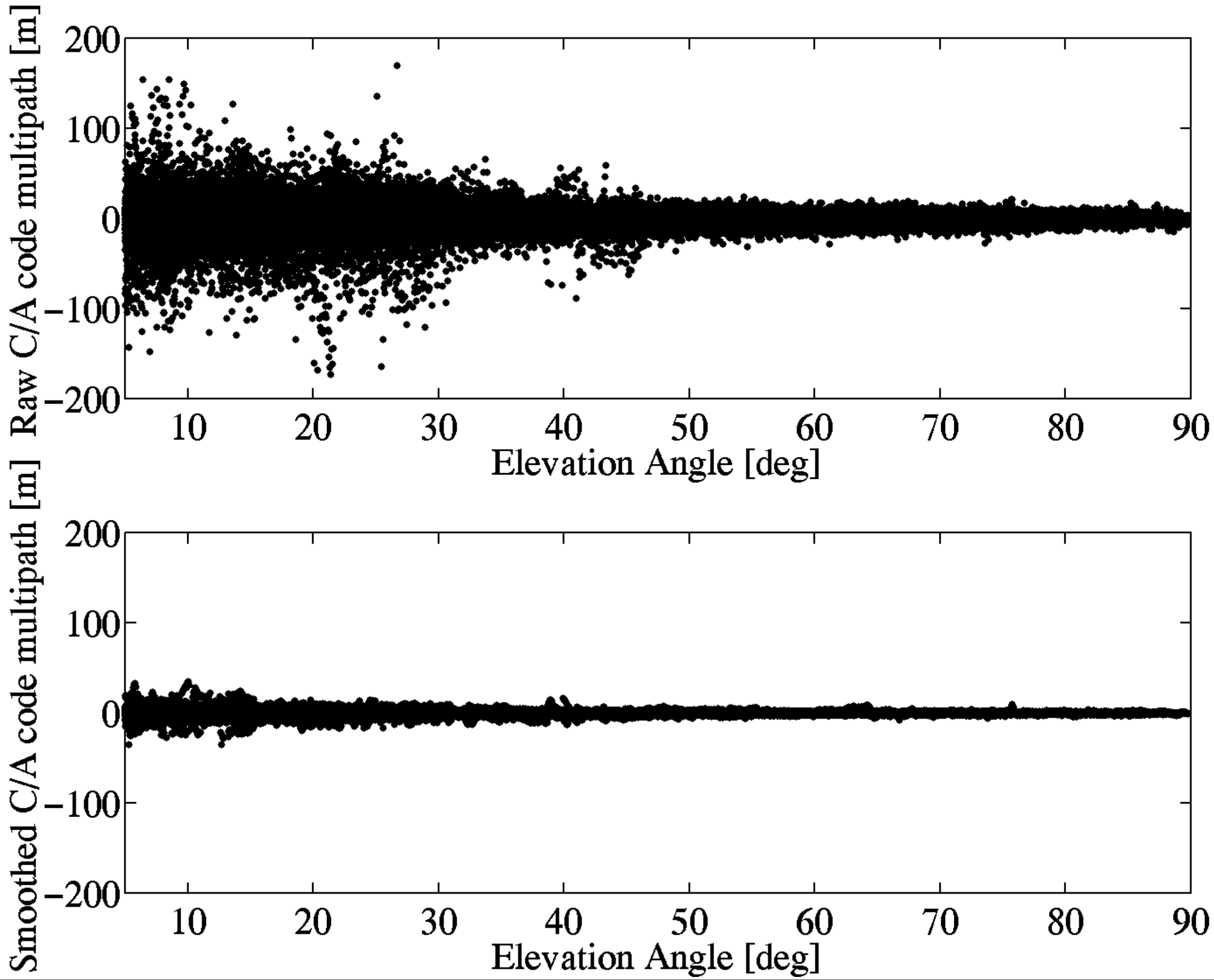
RAW AND SMOOTHED C/A CODE MULTIPATH (1)



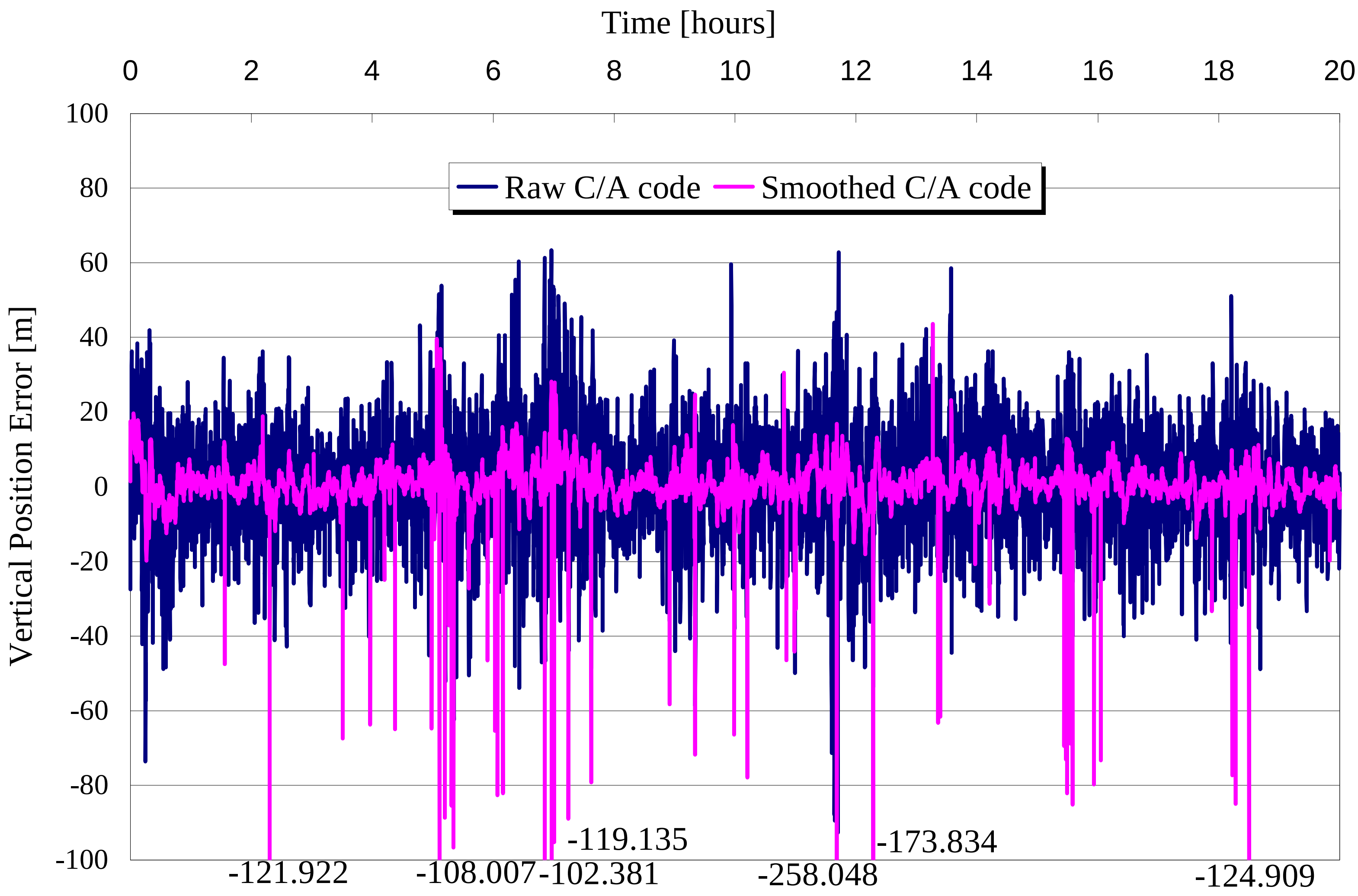
RAW AND SMOOTHED C/A CODE MULTIPATH (2)



MULTIPATH ELEVATION ANGLE DEPENDENCE



RAW AND SMOOTHED DATA, VERTICAL POSITION



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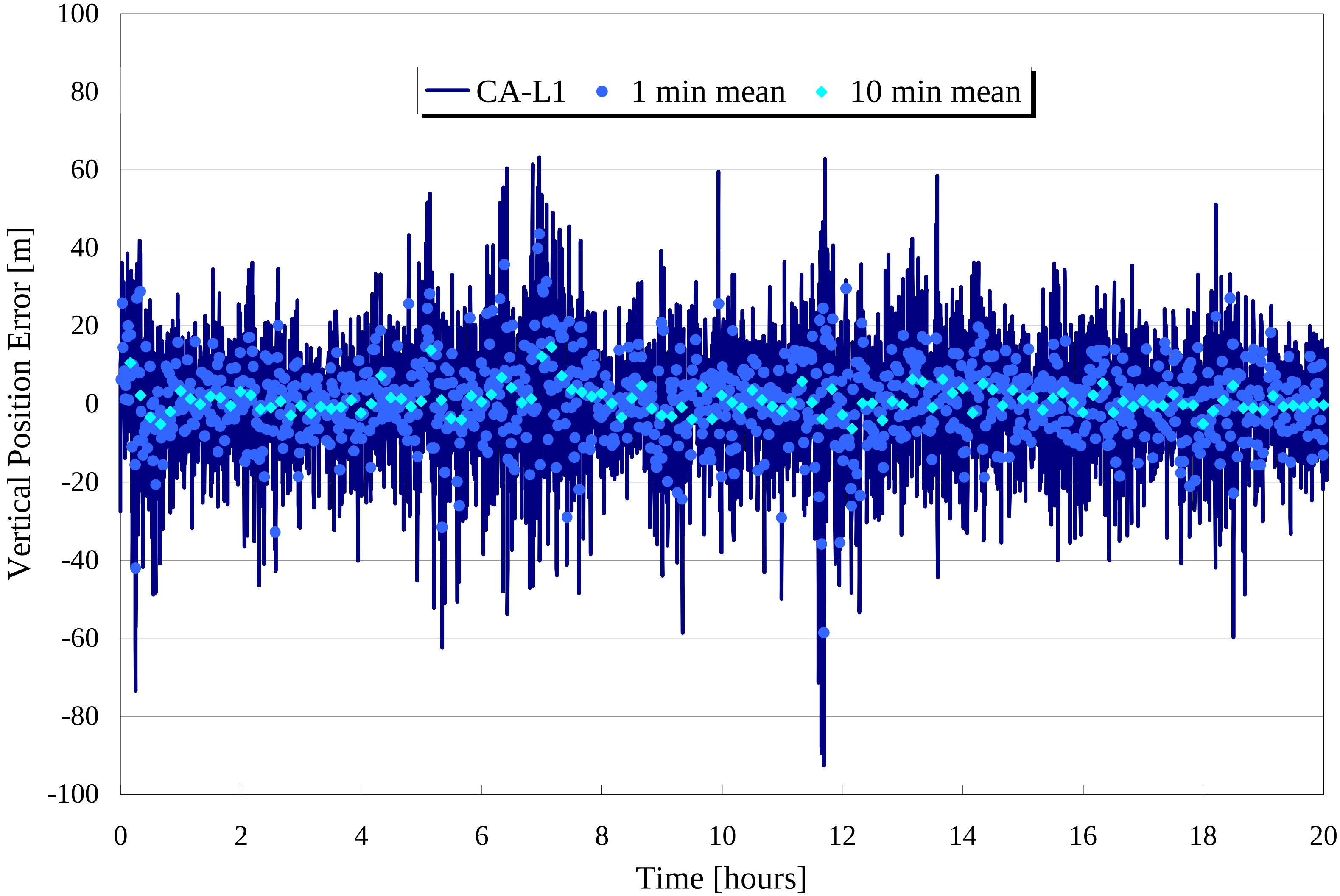
RAW DATA, SMOOTHED POSITIONS



RESULTS SUMMARY

- Residual tropospheric effects, after adequate modelling, only contribute sub-decimetre biases in height.
- Error in height due to multipath could approach 100 metres.
- Smoothed data susceptible to cycle slips in noisy reference station environment.
- Filtering aircraft positions using velocity information should reduce large errors.

CONCLUSIONS

- Residual tropospheric delays should not be a problem for offshore aviation DGPS.
  - → Simple model drastically reduces what small error there is.
- Multipath has potential for severe problems.
  - → Combination of techniques:
    - Receiver and antenna technology to limit maximum multipath error.
    - Filtering in either pseudorange domain and/or position domain at aircraft using velocity information.