

Cross-Coupling Corrections for AT1M Meter Survey Data
Using the Cross-Correlation Method
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The **cross-coupling correction tool** is used to compute optimal correction gains that reduce motion-induced noise in gravity data, particularly for surveys without reliable intersection points. This method works by **minimizing the correlation between platform motion and observed gravity variations**, improving the overall smoothness of the dataset.

Although **cross-coupling effects** were first described by Lacoste et al. (1967), the **AT1M sensor** is designed to be less sensitive to these errors. Nevertheless, applying cross-coupling corrections during processing often results in **smoother and more reliable gravity profiles**.

The **effectiveness of this correction** largely depends on **sea state conditions** during the survey. In calm seas (low-motion environments), the platform-induced gravity variations — and thus the computed corrections — are minimal. In rougher conditions, the corrections become more significant and can notably improve data quality.

Principles of the Cross-Correlation Method

The cross-correlation method for determining cross-coupling corrections is based on the following key principles:

1. **No correlation should exist** between the corrected gravity data (after Eötvös correction) and any of the ship's motion monitors .
2. **Ship motions are recorded** by dedicated motion monitors (e.g., accelerometers, vertical acceleration, and products of the recorded motions).
3. **Therefore**, if the gravity data is clean, there should be **no cross-correlation** between the gravity signal and any of the motion monitor signals after the correction is applied.
4. As described by **Lucien Lacoste [1]**, certain combinations of platform **accelerations and velocities** can induce error signals in the output of a gravity meter. These combinations form the basis of modern cross-coupling correction terms, with slight variations.
5. The **motion monitor channels should be mutually uncorrelated**, to ensure independent correction terms. Additionally, the gravity data used to compute the optimal gains should contain a **variety of headings and platform motions**. This helps avoid biased solutions and ensures that the calculated gains reflect real cross-coupling effects rather than incidental correlations.
6. For a **static (non-moving) gravity meter**, all motion monitor corrections should be **zero**, as no coupling effects are expected.
7. The **optimal correction gains** for each motion channel can be validated by checking **line crossing consistency** in the survey data.

Practical Implementation with AT1M Cruise Data

To apply cross-coupling corrections using the cross-correlation method on AT1M survey data, follow these steps:

1. Preprocess the Data

Apply a low-pass filter to both the **Eötvös-corrected gravity signal** and all the **cross-coupling monitor channels** (e.g., accelerations, velocities).

- Recommended filter length: **100 to 300 seconds**
- This step reduces high-frequency noise and improves the stability of derivative computations.

2. Compute Second Derivatives

Perform a **second derivative (curvature)** on both the filtered gravity data and the monitor channels.

- Only the curvature (not slope or offset) is needed for solving cross-coupling corrections.
- Use numerical differentiation methods appropriate for filtered, evenly sampled data.

3. Ensure Directional Coverage

When applying this method, ensure the dataset includes survey **lines in multiple headings**.

- Lines in different directions reduce potential correlations between monitor channels.
- This improves the reliability and independence of the estimated gains.

4. Solve for Correction Gains

Estimate the optimal cross-coupling **gains (G)** by solving the system of curvature equations:

$$-\ddot{g} = G_1 \ddot{v}_e + G_2 \ddot{v}_{cc} + G_3 \ddot{a}_l + G_4 \ddot{a}_x + G_5 \ddot{Tilt} \quad [1]$$

Where \ddot{g} = second derivative of filtered Eötvös-corrected gravity

\ddot{v}_e = second derivative of filtered v_e

\ddot{v}_{cc} = second derivative of filtered v_{cc}

\ddot{a}_l = second derivative of filtered a_l

\ddot{ax} = second derivative of filtered ax

\ddot{Tilt} = second derivative of filtered $Tilt$

Once the optimum cross coupling gains have been found $G_1 \dots G_5$, each gain is multiplied by the respective Data file recorded monitor to compute the cross-coupling correction CC

$$CC = G_1 ve + G_2 vcc + G_3 al + G_4 ax + G_5 Tilt \quad [2]$$

Once the optimal gains G_i are determined, apply them to the corresponding monitor channels and subtract the resulting corrections from the original gravity signal to obtain the corrected gravity data.

Notes on Gain Accuracy and Interpretation

- The **quality and variety of the input data** significantly affect the accuracy of the estimated cross-coupling gains. The **richer the dataset** (i.e., with more diverse headings, speeds, and motions), the more **realistic and reliable** the resulting gains will be.
- If the dataset is limited in scope, it is possible to derive a set of gains that appears to smooth the data effectively in the current conditions but may **introduce bias or noise** when applied to different conditions or headings.
- The **absolute size of a correction gain** is not a reliable indicator of its importance. What matters is the **product of the gain and its corresponding monitor signal**, which determines the **actual correction magnitude** (in mGal).
 - For example, a very **small motion monitor signal** may result in a **large gain** without contributing significantly to the overall correction.
- A good practice is to **compare the average correction contribution** from each monitor channel. This helps identify which channels are truly influencing the gravity signal and ensures the corrections are meaningful.

References

[1] Lacoste, L. J. B. (1969). *Cross-correlation method for evaluating and correcting shipboard gravity data*. *Geophysics*, 34(4), 624–632. <https://doi.org/10.1190/1.1439994>