Moving Platform Gravity Data Processing

Software for getting best value from your moving platform gravity survey data

Observed gravity from the field is mainly for quality control
When your contractor delivers your gravity data, you get all of the original raw data and a resulting observed gravity field. The main purpose of this output is for quality control. The contractor uses it to make sure everything is working properly. If you reprocess the original raw data, you can get a big improvement in frequency signal content. This is particularly true in shallow water. INTREPID software makes this reprocessing easy!

Constructing your own observed gravity data
Using INTREPID you can take the raw gravity data, monitor data and GPS data, and construct and refine your own observed gravity data. The results are superior to the quality control data from your contractor. This information sheet outlines the steps in this process.

INTREPID gravity data processing results
The following image shows the quality of a gravity dataset processed using INTREPID.

![Figure 1. Bouguer anomaly](image1.png)
![Figure 2. Bouguer anomaly (detail)](image2.png)
Steps in processing and rendering raw moving platform gravity data

The flowchart below shows the steps for processing moving platform gravity data.

**Stage A**  
Constructing the gravity signal

- Review and improve GPS data
- Import and synchronise
- Filter noise from monitor data
- Construct gravity signal
- Calibrate. Correct tide, Eötvös, drift. Cross correlate

**Stage B**  
Reduction and levelling

- Subtract theoretical gravity and free air
- Terrain data
- Perform Bouguer, terrain, isostatic corrections
- Level using network adjustment
- Gravity anomaly
- Decorrugate and microlevel

**Stage C**  
Gridding, filtering, interpreting, presenting

- Construct and merge grids
- Filter and interpret grid
- Gravity anomaly grid
- Compose map
- Map

Moving platform gravity data processing
Stages in processing gravity data

**Stage A—Constructing and correcting the raw data**
When you reprocess the raw gravity, monitors and GPS data, you aim to produce corrected observed gravity data with the best resolution possible.

**Stage B—Field reduction and levelling**
When you reduce and level the observed gravity you aim to remove from the observed gravity data any components that would be present if we were dealing with a simple and virtually homogenous earth. Ideally, anything that is left over is the result of density inhomogeneities due to local geology. This may be of local exploration interest.

You can further improve the data by network adjustment. This removes acquisition artefacts, adjusts older survey results that you may want to include and makes the dataset self-consistent.

**Stage C—Gridding, merging, interpretation, map composition**
With your gravity anomaly data you are ready to create grids, interpret and publish the data. INTREPID has tools for all of these stages.

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**Stage A—Constructing and correcting the raw data**
The processing of ship-based or airborne gravity data from the La Coste and Romberg Air-Sea Gravity Meters follows the process derived from papers published by La Coste (1973) and Valliant (1986). INTREPID can also process data from the Bell Marine-FTG™, Falcon®, and ZLS Dynamic Meter™.

The main aim of the process is to correct for the motion of the gravimeter. As well as gravimeter readings, the contractor records monitors of acceleration and velocity of the motion of the stabilised platform. We use this data to correct the gravity data

**The Air-Sea Gravity Meter**
The Air-Sea Gravity Meter is similar to the original land-based gravimeter, but has the following modifications:

- The damping is much higher
- The unit is on a stabilised platform with auto-feedback to keep the spring tension tending to zero.

Factory calibration of the Air-Sea Gravity Meter gives the normal reading–gravity look-up table. Seven monitor factors are available. You can use these for calculating zero-correlation between observed gravity and the monitors.

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**Step 1—Import and synchronise**

1. Add factory calibration information to the gravimeter configuration file `gravimeter.cfg` in your INTREPID installation folder (In L&R gravimeters this is only for older meters without `.env` files—firmware before v 1.5).

2. Import raw ASCII ship or aircraft data and navigation data into an INTREPID dataset. Allocate standard field names and aliases. Check raw data quality. *(INTREPID Import, Projection Conversion, Project Manager, Profile Editor, Spreadsheet Editor)*

3. Merge the navigation data with the ship or aircraft data. *(INTREPID Project Manager)*

4. Compute ship or aircraft azimuth and velocity. Check that these values are within range and make sense. *(INTREPID Spreadsheet Editor)*

**Step 2—Review and prepare GPS data**

INTREPID tools already support some differential GPS processing systems. Please contact us about your GPS unit to check whether we already support it. We can customise the process to suit your GPS system.

Typically there is noise in the GPS data, and the sampling basis is often different to that of the gravity data. Before using the GPS data you will need to review it. Generally you will need to re-sample the GPS data to match the gravity signal readings.

**Case study:** Figures 3 and 4 below show a case study for GPS review. The histogram (figure 3) shows that the calculated velocity is very stepped. If we used this for the Eötvös correction, it would introduce noise to our result. In the top panel of figure 4, the velocity has rapid changes, such as GPS antenna swaying in the waves. We used a Naudy noise (low pass) filter to remove these rapid changes. The result was a smoother average velocity over five minutes (bottom pane). *(INTREPID Project Manager, Spreadsheet Editor, Line Filter)*

**Step 3—Filter noise from monitor data**

Data from the moving platform gravimeter system includes:

- Gravity data: **Spring** and **Beam**
- Monitor (accelerometer) data: AL, AX, AX2, LACC2, VCC, VE and XACC2
- Derived data: **Cross Coupling** (correction from the accelerometers)

The monitor data is very noisy. It is essential to apply a low-pass filter that is stable in an absolute signal sense. For ship-based data, you are particularly aiming to isolate wave action. You can do this by finding and filtering the associated frequencies. *(INTREPID Line Filter)*
RC Filtering
Lacoste recommends 3 passes of 27 sec and 2 passes of 150 sec using resistive-capacitive (RC) type filters. There are numerous combinations of times and multiple passes available in INTREPID as compound filters. (INTREPID Line Filter)

Profile Checking
Using INTREPID you can view data profiles before and after filtering to check results. (INTREPID Profile Editor)

Step 4—Construct gravity signal
A. You can reconstruct the gravity signal from Spring Tension, Beam and Cross Coupling correction.

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\text{Gravity signal} = \text{Spring} + k \times \text{Beam} + \text{Cross Coupling}.
\]

The gain factor \(k\) is for calibrating the Beam slope for mGal. Values for \(k\) are in the gravimeter configuration file. (INTREPID Gravity, Line Filter)

B. For Bell/Falcon systems Tensor Signal is computed from Inline and Crossline accelerations.
Step 5—Calibrate. Correct Earth tide, Eötvös, drift. Cross correlate

Calibration and conversion
INTREPID converts the raw gravity reading as measured in counter units to relative mGal using a lookup table and interpolating between ranges. You can run a calibration survey to check the constants. *(INTREPID Gravity)*

Earth tide correction
The Longman Earth Tide model approximately describes the Sun and Moon tidal forces at any point and time on Earth. INTREPID applies this correction to your data. *(INTREPID Gravity)*

Eötvös correction
The Eötvös correction allows for the velocity of the gravimeter across the rotating Earth. The motion of the gravimeter alters the centrifugal force of normal gravity. INTREPID uses the calculated ship or aircraft velocity to make this correction. *(INTREPID Gravity)*

Cross correlation analysis and correction
The constructed gravity signal already has a cross-coupling correction, calculated using factory-set gain factors from the monitor data. This corrects for the movement of the instrument in the ship or aircraft. You can improve this correction by calculating how the observed gravity correlates with each of the monitors. (The monitors are 2nd order acceleration movements of the stabilised platform.) If you find significant correlation with a monitor, then the monitor data is affecting the result.

To remove the effect of the monitor, calculate a suitable gain factor for the monitor, multiply the factor by the monitor data and then subtract the result from the observed gravity. We include five monitors in this cross-correlation process—VCC, VE, AX, AL, AX2.

Using the report from the process, you can check for zero correlation line by line or for the total survey and recalculate line-by-line or total-survey gain factors. INTREPID uses the curvature product cross-correlation approach, accumulating a matrix of all observations for straight-line segments and solving them for a best fit.

The processes for ship-based and airborne gravity data are slightly different. In the aircraft, the instrument has to run at higher sampling rate to collect equivalent data. Vertical acceleration monitor data from an aircraft tends to be high frequency, and most is generally filtered out as noise. *(INTREPID Gravity)*

Drift, absolute tie in
We use the Still value at the dock or airfield to tie in the relative gravity data to an absolute value. You can allow for gravimeter drift by repeated Still readings during the course of the survey. *(INTREPID Gravity)*

Generated outputs from stage A gravity data processing
To create the observed gravity data we have carried out the following operations:

- Computed a cross-correlation correction using the filtered monitors and the gain factors. We do this for each reading that has valid navigation data.
- Converted the meter reading to a gravity reading in mGal using the manufacturer’s lookup table.
- Computed the Eötvös and Earth Tide corrections.
- Tied the relative gravity data in to an absolute value at the Still, or dock locations.

Included with the output is an automatically generated gravity data processing report. This documents the job and reports any difficulties encountered with the data or its conditioning. The report also includes statistics showing how much gravity data processing has improved the data. *(INTREPID Gravity)*
Stage B—Reduction and levelling
Before it becomes useful, you need to extract the anomaly information from the observed gravity, and also conduct levelling to make it internally consistent.

Step 1—Free air, theoretical gravity correction
You can subtract theoretical gravity using any of the common models, such as Potsdam, IGSN71 (also known as GRS67), ISOGAL80 and WGS84. INTREPID makes the free air correction as part of this operation. (INTREPID Gravity)

Step 2—Bouguer, terrestrial and isostatic corrections
INTREPID makes the marine or normal Bouguer correction. If required you can perform the terrain and isostatic corrections as well. INTREPID performs terrain correction for airborne, ship-based and ground-based surveys with equal ease. (INTREPID Gravity)

Step 3—Crossover analysis and adjustment
You can remove acquisition artefacts and make the data self-consistent by network adjustment. With INTREPID you can use either polynomials or loop closure methods. (INTREPID Tie Line Levelling, Marine Levelling)

INTREPID has the following powerful tools for network adjustment of moving platform gravity data:

- **Split Cruise** analyses semi-random tracking cruises in multiple surveys. It breaks the data into straight line segments so that you can identify internal and external crossovers.
- **Marine Levelling** analyses and corrects misclosures in crossovers for semi-random tracking cruise data.
- **Tie Line Levelling** analyses and corrects misclosures in crossovers for single regular grid surveys.

If you want to merge recent data with older surveys, further processing can optimise the value of the combined data. The following example shows the free air grids of 30 surveys from many cruises. We examined and reprocessed these to create a scientifically sound regional grid for South East Australia. The internal hole is the island of Tasmania. (INTREPID Marine Levelling, Gridding, Visualisation)
Stage C—Gridding, filtering, interpreting and map composition

INTREPID has tools for further improving, filtering, interpreting and publishing your data.

- **Gridding** is the world’s most comprehensive geophysical tool – Multi-data set, Vector and Tensor gradients supported.
- **Decorrugation** and **Microlevelling** remove corrugations from airborne regular grid surveys.
- **Grid Filter** can transform gravity Bouguer anomaly data into gravity gradiometer tensor components.
- **Euler Deconvolution** provides automatic depth estimation.
- **Map Composition, Map Print** and the MAPCOMP language provide powerful hard copy composition for INTREPID data and data in other formats.
- **Export** enables you to export your data in wide variety of formats.

**Figure 9. Map Composition** shows a map composed by the INTREPID Map Composition tool.

Moving platform gravimeter support

Ship-based or airborne gravity data from the Micro-LaCoste Air-Sea Gravity Meters are supported. INTREPID can also process data from the Bell Marine-FTG™, Falcon®, and ZLS Dynamic Meter™.