INTREPID spectral domain operations reference (R14)

In this chapter:

Tools using spectral domain operations

Parent topic: **INTREPID spectral domain operations reference (R14)**

The following tools use spectral domain operations:

- Spectral domain grid filters tool (GridFFT) (T40)
- Line Filtering (T31)
- Euler Deconvolution (T44)
- Multi-scale edge detection wizard (T44a)

Notation used in this reference

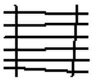
Parent topic: **INTREPID spectral domain operations reference (R14)**

In this section:

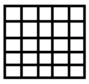
Availability in INTREPID tools

Parent topic: Notation used in this reference

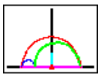
The filters listed in this section carry one or two icons denoting whether they are available in the Spectral Domain Grid Filters tool and/or the Line Filter tool.



This icon indicates that the filter is available in the Line Filter tool.



This icon indicates that the filter is available in the Spectral Domain Grid Filters tool.



This icon indicates that the filter is available for tensor data.

Notation for filter formulas

Parent topic: Notation used in this reference

The following sections contain some formulas for the spectral domain filters. We have used the following notation in these formulas:

w = input in spectral domain

F(w) = filter results (in spectral domain)

The spatial and spectral domains

Parent topic: INTREPID spectral domain operations reference (R14)

In the **spatial domain** data is represented in a mathematical space where the dimensions correspond to the three directions.

By analysing the frequency and direction of wave patterns in the data, using Hartley or Fourier transformation, you can map a dataset into the **spectral domain**, where, instead of distance, the dimensions correspond to increasing frequencies in the corresponding directions. Instead of the original Z values of the data, high and low values correspond to 'energy' of the data at the frequency concerned. Dimensions corresponding to frequency are titled Fx, Fy, ...

In this section:

- Data dimensions
- Fundamental and Nyquist frequencies
- Power spectrum graphs

Data dimensions

Parent topic: **The spatial and spectral domains**

INTREPID tools support one and two dimensional data in the spectral domain.

- The Spectral Domain Grid Filters tool uses two dimensional spaces (Fx, Fy) corresponding to the dimensions of grid datasets. INTREPID represents energy using pseudocolour or averages the energy for all directions and represents it in a power spectrum graph.
- The spectral domain filters in the Line Filter tool use one dimensional spaces (Ft) corresponding to the data along a traverse line. INTREPID represents energy in a power spectrum graph. The profile can be a time series, spatial series or just a sample series.
- A Fourier series is calculated to fit the Potential Field data using both cosines and sines. Cosine terms dominate for integrations and low pass operations. Sines dominate during derivatives. Each cell position has a complex coefficient that is a best fit of the Fourier series terms to reproduce the observed signal. The frequency method of fitting and filtering the data provides a superior method to the more traditional polynomial and/or finite difference convolution methods.

Fundamental and Nyquist frequencies

Parent topic: **The spatial and spectral domains**

See also
"Fundamental and Nyquist Frequencies of the Input Grid" in Spectral domain grid filters tool (GridFFT) (T40)
"Querying lines and setting line options" in Line Filtering (T31)

Fundamental Frequency

The fundamental frequency is the lowest frequency (or longest wavelength) of spectral data that you can represent in the data. If the longest dimension of the data is L, then the longest wavelength is L, and the lowest frequency is 1/L.

For example, if the longest dimension is 150 cells and the cell size is 80 m, L = 12000 m and the fundamental frequency is 0.0000833 cy/m.

Nyquist Frequency

The Nyquist frequency is highest frequency (or shortest wavelength) of spectral data that you can represent in the the data. If the grid cell size is S, then the shortest wavelength is 2S, and the highest frequency is 1/(2S).

For example, if the cell size is 80m, the Nyquist wavelength is 160m and the Nyquist frequency is 0.00625 cy/m.

Power spectrum graphs

Parent topic: The spatial and spectral domains

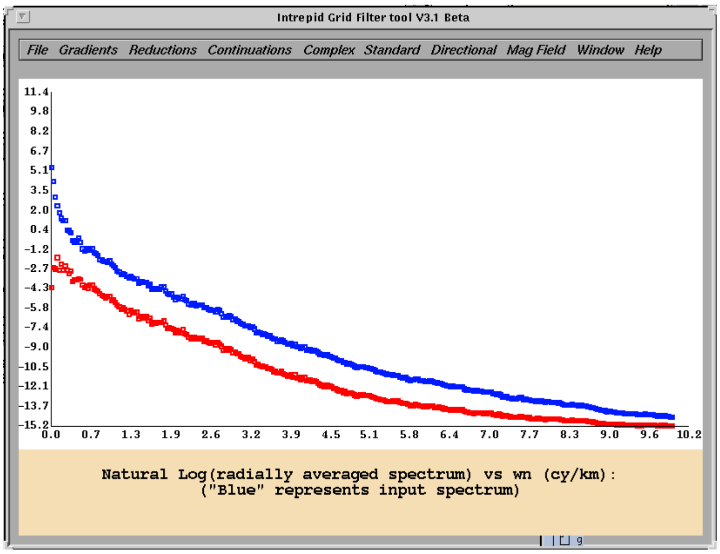
You can represent the energy of your data in the spectral domain in a graph plotted against frequency. This is a **power spectrum graph**.

For two dimensional data it is common to combine the energies of the two frequency dimensions to produce a **radially averaged power spectrum**. This will represent the total energy for each frequency.

It is normal for the lower frequencies to generally have higher energy. This gives power spectrum graphs their characteristic 'descending' shape.

INTREPID represents frequencies in cycles/km in the graphs.

This illustration shows power spectra before and after a filter process. The input dataset power spectrum is shown in blue (upper curve) and the filtered dataset power spectrum in red (lower curve).



The tensor power spectrum graph has 3 before- and 3 after-traces:

Trace	Description
1	Eigenvalue 1
2	Eigenvalue 2
3	Rotations

For details about how INTREPID uses this concept, see:
"Data display tabs" in Spectral domain grid filters tool (GridFFT) (T40)
"Power Spectrum display" in Line Filtering (T31)

Spectral domain processes

Parent topic: **INTREPID spectral domain operations reference (R14)**

In this section:

- Transforming data to the spectral domain
- Spectral domain filters
- Interpretation of frequency as depth
- Returning data to the spatial domain

Transforming data to the spectral domain

Parent topic: **Spectral domain processes**

INTREPID uses the Hartley transform to transform line data and the Fast Fourier Transform (FFT) to transform grid data into the spectral domain.

Spectral domain filters

Parent topic: **Spectral domain processes**

In the spectral domain you can process data according to its energy at each frequency rather than its Z data value or spatial position. You can, for example, remove or extract data of certain frequencies, or waves that are oriented in a particular direction.

You can apply filters which can do one or more of the following:

- Reduce or delete signals of a range of frequencies (Pass /Rolloff filters).
- Shift the wave pattern so that when reverse transformed it appears to have been collected at a different distance from the source (Continuation filters).
- Calculate the derivatives of the wave pattern so that you can see changes in it more clearly (Derivative filters).
- Shift the apparent position of the data slightly to allow for the direction of the core magnetic field at the time and place of acquisition (Reduction filters).
- Reduce or delete signals that are oriented in a certain direction (two dimensional data only) (Directional filters).

Essentially, a convolution in the spatial domain becomes a simple multiplication in the spectral domain

Interpretation of frequency as depth

Parent topic: Spectral domain processes

Higher frequency features characterise sources of data that are closer to the surface, and lower frequencies characterise deeper sources. Some of the reasoning for this is as follows:

We can assume that the deeper sources are large because the signal from smaller deep sources would attenuate. Since deeper sources are large and further away, they would have fewer measurable changes and their signal would therefore be of lower frequency.

Shallower sources may be smaller, or, even if large, their variations would be measurable. We would therefore expect the signal frequency from these sources to be higher.

Sources or variations in sources that are very small will have very high frequency signals. These signals are of less interest to us, and may be classified as 'noise'.

We call shallow sources **near surface sources** and larger, deeper sources **regional sources**.

In the Spectral Domain Grid Filters tool you can display the Spector Grant depth estimate for any section of a power spectrum graph by clicking points on the graph.

Returning data to the spatial domain

Parent topic: Spectral domain processes

After processing data in the spectral domain, INTREPID uses the reverse Hartley or Fast Fourier Transformation back to the spatial domain. You can then spatially locate features that have been enhanced using spectral domain filters.

Preparation of data for spectral transform

Parent topic: INTREPID spectral domain operations reference (R14)

In this section:

- Introduction to pre-FFT processing
- Expanding the data area
- Detrending data values
- 'Periodic' dataset edges for spectral transform
- Estimating values for data gap cells
- Damping of dataset edges before spectral transform
- Saving pre-FFT and FFT grid processing products for later reference

Introduction to pre-FFT processing

Parent topic: **Preparation of data for spectral transform**

Before transforming a dataset to the spectral domain, you must ensure that it conforms to certain mathematical requirements.

Two dimensional data must be rectangular with certain mathematical requirements for its numbers of rows and columns. You may therefore need to extrapolate data to new dataset edges.

In addition to any extrapolation for correct shape, datasets must have an extrapolated edge region. One dimensional data must have an extrapolated extension at each end. Two dimensional data must have an extrapolated extension on all sides.

The Z data curve or surface must be smooth and there may be no ***null*** values. If there is an overall Z data trend in any direction, you will obtain better results if you remove the trend before the filtering process.

Here is a detailed set of steps for the pre-filter transformation

1. If the data is in byte, integer or real (8 byte) format, INTREPID automatically converts the values to real (4 byte) format, and record the original precision of the data for conversion back after the filtering process.
2. INTREPID adds an extension to the ends or border of additional values. It expands two dimensional data to a rectangular shape. See Expanding the data area below for details.
3. INTREPID removes any trend from the data. See Detrending data values below
4. INTREPID creates values for the new data points or cells. It must do this in a way which makes the newly enlarged line or dataset have a continuous wave pattern. See 'Periodic' dataset edges for spectral transform below.
5. If required, INTREPID applies filters to the dataset to further damp the data at the edges. See Damping of dataset edges before spectral transform below for more information.
6. INTREPID can then perform the Hartley or Fast Fourier Transform on the dataset. It will save a copy of the transformed dataset for later use if required (Spectral Domain Grid Filters tool only).

For INTREPID tools reference about this topic, see:
"Pre FFT Grid Conditioning" in Spectral domain grid filters tool (GridFFT) (T40)
"Creating the extended region for filters" in Line Filtering (T31)
"Detrending and replacing trends" in Line Filtering (T31)

Expanding the data area

Parent topic: **Preparation of data for spectral transform**

If you are preparing data for spectral transform you must expand the dataset to dimensions that are multiples of 2 and/or 3 and/or 5. (Thus, suitable dimensions for a dataset are $2^i x 3^j x 5^k$, where I, j and k are integers >= 0). If you are preparing a grid, you must expand its area to become a rectangle.

To allow for creation of the continuous wave pattern (See 'Periodic' dataset edges for spectral transform below), INTREPID adds a border of new cells all the way around the existing grid dataset, or at each end of a traverse line.

INTREPID will expand the data by at least 10%, ensure that it is rectangular with the dimensions specified above and initially assign ***null*** to the new data points or cells.

We will refer to cells that contain ***null*** as **data gap** cells.

For INTREPID tools reference about this topic, see:
"Expanding the grid" in Spectral domain grid filters tool (GridFFT) (T40)
"Data extension method" in Line Filtering (T31)
"Pre FFT grid conditioning" in Multi-scale edge detection wizard (T44a)

Detrending data values

Parent topic: **Preparation of data for spectral transform**

Your dataset may have an overall trend in one or two dimensions. It could have one of the following

- No slope or trend (degree 0)
- An overall slope or trend (degree 1)
- A tendency to have steeper slopes at one end than the other (degree 2)
- A slope down then up then down again (degree 3).

We recommend that you remove trends before using spectral transform.

For 0 degree detrending INTREPID simply subtracts the dataset mean from all values in the dataset, recording the value of the mean for later restoration.

For degree > 0, INTREPID subtracts the dataset mean from all values in the dataset, recording the value of the mean for later restoration. It then fits a polynomial to the dataset in each direction and uses it in the detrending process. INTREPID stores up to 10 polynomial coefficients for later trend reproduction (part of post-filter transformation). INTREPID can reproduce trends corresponding to degrees 1 2 or 3.

The new Spectral Domain Grid Filters tool (GridFFT) always detrends the grid. The Line Filter tool automatically detrends the data in most cases. The old Spectral Domain Grid Filters tool (OldGridFFT) allows you to turn detrending on or off.

For INTREPID tools reference about this topic, see:
"Detrending" in Spectral domain grid filters tool (GridFFT) (T40)
"Detrending and replacing trends" in Line Filtering (T31)

'Periodic' dataset edges for spectral transform

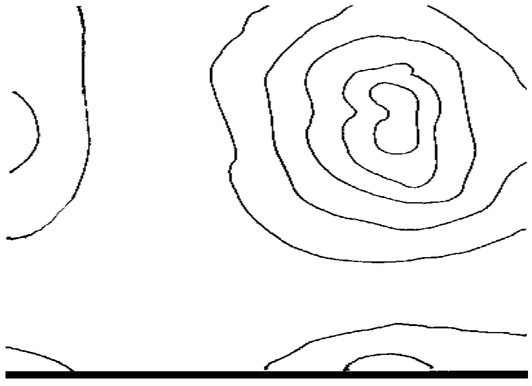
Parent topic: **Preparation of data for spectral transform**

If you are preparing for spectral transform, the new cells at the end or around the edge of the dataset (see Estimating values for data gap cells) must acquire values that fulfil the following criteria.

- The new values must smoothly continue any wave patterns that exist in the original data.
- The wave patterns in the new values must 'wrap around' the dataset (in both the East–West and North–South directions for two dimensional data). This means that if you wrapped the dataset surface around to make a cylindrical shape in either direction, the wave patterns would be continuous across the join of the two edges. If the join becomes 'invisible' in this way, the dataset will become **periodic** (i.e., if you rotate the dataset cylinder on its axis, your view of the dataset wave patterns will repeat with each revolution).

INTREPID 'wraps' the dataset in each direction while it is estimating values for data gap cells and smoothing the Z data surface, thus producing periodic data.

The illustration below uses contour lines to illustrate dataset periodicity for two dimensional data.



Estimating values for data gap cells

Parent topic: **Preparation of data for spectral transform**

Cells in the dataset could be empty because

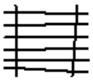
- You have obtained or constructed the dataset in some way which left gaps or
- They may have been created by the expanding data dimensions process (See Expanding the data area).

Before performing spectral transform on the dataset, you must fill all data gaps. In the Line Filter tool, INTREPID automatically fills the data gaps as explained in Filling data gaps in line data.

In the Spectral Domain Grid Filters tool INTREPID can use either linear / cubic interpolation or maximum entropy. See Linear interpolation of data gaps in a grid (Arthur fill algorithm) and Maximum Entropy for data gaps in a grid.

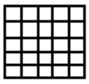
INTREPID can remove the interpolated values during the post-filter transformation if required. See Regenerating the data gaps below for details.

Filling data gaps in line data



(Line Filter only) INTREPID uses linear, cubic or nearest neighbours interpolation to fill data gaps within lines. For the data extension area you have the choice of zero values or a mirror or 'flipped mirror' of the existing data at the end of the line. Flipped mirror is the default method. See "Data extension method" in Line Filtering (T31) and "Querying lines and setting line options" in Line Filtering (T31) for details.

Linear interpolation of data gaps in a grid (Arthur fill algorithm)



To calculate an estimate for a data gap cell INTREPID takes the average of four other cells in the grid. One cell is to the North of the target cell, and the others to the East, South and West respectively. With each iteration INTREPID uses a set of four cells that is closer to the target cell than for the previous iteration. During each iteration it calculates an estimate for every cell that does not contain original data. It processes the cells one at a time along each row.

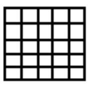
In the iterations at the largest cell distance, the four cells whose values used in the calculation are at a distance of one half the width of the grid. In this case, the centre cell of the grid receives the average value of the cells in the middle of each of the edges of the grid. If the source cells would be off the edge of the grid, INTREPID wraps the grid around and uses cells from the other side of the grid. By doing this, INTREPID helps to make the dataset periodic at the edges (See 'Periodic' dataset edges for spectral transform).

In the second set of iterations, the four cells are one quarter of the width of the grid away from the target cell. In the third set of iterations, the four cells are one eighth of the grid width away, and so on.

At the grid edges, the Arthur fill algorithm uses anti-symmetrical mirroring to interpolate into the null edge zone.

For INTREPID tools reference about this topic, see:
"Fill method" in Spectral domain grid filters tool (GridFFT) (T40)

Maximum Entropy for data gaps in a grid



The Maximum Entropy process calculates values for data gaps using a linear prediction from segments of rows or columns of original data (**data vectors**). It is superior to other methods because the results have maximum entropy (i.e., they tend to emulate the randomness of natural data rather than introducing distraction by having their own intrinsic 'fill patterns').

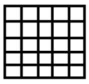
INTREPID characterises the data with a finite number (default 10) of 'poles' that best represent the original data's power spectrum (See Power spectrum graphs). It interprets the power spectrum as being expanded in terms of a Laurent series. (The order of the Laurent power series is the number of poles).

INTREPID uses whatever segments of rows or columns of original values it can find between adjacent gaps as the vectors for interpolating values for the gaps. It bridges gaps from both the left and right hand sides. It uses a linearly weighted average of values on both sides to compute the values.

INTREPID first calculates the values for the data gaps using row segments (in the East–West direction). Once it has computed all of the values it repeats the calculation process using column segments (in the North–South direction).

For INTREPID tools reference about this topic, see:
"Fill method" in Spectral domain grid filters tool (GridFFT) (T40)

Filling boundaries with source data in a regional dataset



If you have a large regional dateset and you are only using filters on a subset, you can fill the boundaries with actual source data from the dataset instead of artificial data.

Damping of dataset edges before spectral transform

Parent topic: **Preparation of data for spectral transform**

Before the spectral transform process INTREPID can damp the edges of the Z data curve or surface using a damping filter for rolling off the edges. This assists INTREPID to obtain good periodic edges. (See 'Periodic' dataset edges for spectral transform).

In normal practice detrending and filling the data gaps usually prepares the dataset adequately. We have provided damping filters for your use if required.

INTREPID has two main roll-off methods, each of which has a number of filters. It is normal to only use one of the methods.

Method	Description	Filters available
Expanded edge rolloff	Rolloff operation only on the edges of the grid	Cosine Linear
Whole window damping	Damping operation across the whole grid	Cosine bell Hanning Hamming Blackman Triangle

For INTREPID tools reference about this topic, see:
"Edge damping rolloff options" in Spectral domain grid filters tool (GridFFT) (T40)
"Edge damping methods" in Line Filtering (T31)

Expanded edge rolloff

INTREPID's edge damping rolloff operates only on the edges of a grid. INTREPID uses a linear or cosine function to roll the grid edge values off to zero.

For INTREPID tools reference about this topic, see:
"Expanded edge roll-off" in Spectral domain grid filters tool (GridFFT) (T40)

Whole window damping

INTREPID's damping window filters operate from the centre of the grid or line to the edges.

INTREPID uses the following steps. :

1 Create a matrix of N coefficients 0, 1, ..., N–1 according to the function,
2 Superimpose the array of coefficients on the surrounding data points or cells,
3 Multiply each surrounding value by its corresponding coefficient,
4 Add the resulting values to obtain a new value for the data point or cell.

For INTREPID tools reference about this topic, see:
"Whole window roll-off" in Spectral domain grid filters tool (GridFFT) (T40)
"Edge damping methods" in Line Filtering (T31)

We obtained these functions from O'Neill (1988)[1]

Cosine Bell Filter *(Spectral Domain Grid Filters only)* This filter imposes a 'bell' shaped cosine curve on the dataset. Here is a formula for a cosine bell filter

$$W(n) = \cos\left(\frac{\frac{\pi}{2}(N-n)}{N}\right)$$

Where n = 0, 1, ..., I, ... , N–1

Hanning Filter This is a standard smoothing filter.

For Spectral domain grid filters,

$$W(n) = 0.5\left(1 - \cos\frac{2\pi(n+0.5)}{N}\right)$$

Where n = 0, 1, ..., I, ... , N–1

For the Line Filter, where A is the window size in data points

$$h(x) = \begin{cases} \left(\cos\frac{\pi x}{A}\right)^2 & \text{for } |x| \le \frac{A}{2} \\ 0 & \text{otherwise} \end{cases}$$

Hamming Filter *(Spectral Domain Grid Filters only)* This is a standard smoothing filter. Here is a formula for a Hamming filter.

$$W(n) = 0.54 - 0.46\cos\frac{2\pi(n+0.5)}{N}$$

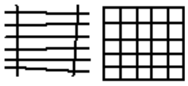
Where n = 0, 1, ..., I, ... , N–1

Blackman Filter *(Spectral Domain Grid Filters only)* You can use this filter for datasets that do not suit the Hamming and hanning filters. Here is a formula for a Blackman filter.

$$W(n) = 0.42 - 0.5\cos\frac{2\pi(n+0.5)}{N-1}$$

Where n = 0, 1, ..., I, ... , N–1

1.O'Neill, Mark A., Faster Than Fast Fourier, *Byte*, April 1988, 293–300.



Bartlett / Triangular Filter This filter is relatively fast but of lower quality.

Here is a formula for a triangular filter as used for the filled boundary portion of the grids.

$$W(n) = \frac{2(n + 0.5)}{N}$$

$$W(N - n - 1) = W(n)$$

Where n = 0, 1, ..., I, ... , N/2.

Parzen Window *(Line Filter only)* This is a polynomial filter

$$W(x) = \begin{cases} \left(\frac{x}{A}\right)^3 & \text{for } 0 < |x| \le \frac{A}{2} \\ 6\left(\frac{x}{A}\right)^2 - 6\left(\frac{x}{A}\right)^3 & \text{for } \frac{A}{2} < |x| < A \end{cases}$$

Where

A is the window size in data points;

W(x) is the weight at point x to apply in the rolloff region.

Saving pre-FFT and FFT grid processing products for later reference

Parent topic: **Preparation of data for spectral transform**

Saving pre-FFT processing products

During the pre-FFT processing of a grid, INTREPID saves copies of the input grid after it has:

- Detrended, expanded and filled the new cells, and again after it has
- Completed the edge roll-off process.

INTREPID always saves the data as INTREPID grid datasets. After use, INTREPID normally deletes these grids. You can usually keep them for debugging, quality control or some other purpose if you want. Most INTREPID spectral domain tools have options for keeping these grids.

Saving FFT of input grid dataset

INTREPID saves the spectral domain–transformed grid in a grid datsaset, to use as input for the filtering operation. After use, INTREPID normally deletes this grid.

If you want to perform a number of filtering operations on a grid, you can save time by keeping a copy of the spectral domain–transformed grid. You can use this as input for as many filtering operations as you like without having to go through the pre-FFT processing and the FFT itself each time.

You may also choose to save the FFT of the input grid for examination or a quality check on the processing.

To re-use the saved copy of the spectral domain–transformed grid, simply specify it as your input grid file. INTREPID automatically detects that it is already transformed and skips the preparation and FFT stages.

—Notes about spectral domain–transformed grids

These spectral domain grids have the same number of rows and columns as the expanded spatial domain grids before the transformation (See "Expanding the data area" in INTREPID spectral domain operations reference (R14)). INTREPID exploits the symmetry in the spectral domain transformed data to achieve this.

You can examine the spectral domain grids using visualisation tools in the same way as you would a spatial domain grid.

INTREPID records the pre-FFT process options and the name of the source grid in the **..GRID** or **.ISI** file of the spectral domain grid dataset. This enables you to re-use the spectral domain grid dataset for input and still return the results to the spatial domain in a form that matches the input grid.

The FFT of the input grid two-band grid file. Band 1 is the real component, and band 2 is the imaginary.

Post-filter transformation

Parent topic: **INTREPID spectral domain operations reference (R14)**

After applying grid filters to a dataset, you will normally wish to transform the dataset back from the spectral domain to the spatial domain. This can include

- Reverse spectral transform restoring the data to the spatial domain,
- Removing the cells added around the edge of the grid,
- Restoring ***null*** value to cells within the grid that were originally ***null***,
- Where appropriate, restoring a trend that was removed for the spectral transform process, and replacing the mean of the dataset by adding the previously removed mean to all cell values.

In the Spectral Domain Grid Filters tools (OldGridFFT amd GridFFT) you can turn some or all the above stages of the operation on or off individually. See "Post-filter transformation options" in Spectral domain grid filters tool (GridFFT) (T40)

In the Line Filter tool, the reverse transform process automatically includes the above steps. It has no options for you to specify.

After the above processes are complete INTREPID restores the dataset to byte, integer or real (8 byte) if it was originally converted from one of these formats to real (4 byte) format for the spectral transform process.

The following sections describe the post-filter transformation processes in detail.

In this section:

- Reducing the dataset
- Regenerating the data gaps
- Reproducing the trend

Reducing the dataset

***Parent topic:* Post-filter transformation**

After the reverse transform to the spatial domain you can remove the extension at the traverse line ends or around the border of the grid.

INTREPID cannot restore any irregular shape of a grid dataset. It will remove interpolated cells from the edge of the dataset. The reduced dataset will be rectangular in shape with dimensions equal to the extent of the original dataset. All cells in the reduced dataset that were not in the original will retain their interpolated values unless you regenerate the data gaps (See Regenerating the data gaps below). If you regenerate the cells, INTREPID will assign ***null*** to them.

Regenerating the data gaps

***Parent topic:* Post-filter transformation**

After you reduce the traverse line or dataset to its original dimensions (see Reducing the dataset), there may still be interpolated values created during the pre-filter transformation. You can set the value of these interpolated data points or cells to ***null*** if required.

For INTREPID tools reference about this topic, see:
"Regenerating the data gaps" in Spectral domain grid filters tool (GridFFT) (T40)

Reproducing the trend

***Parent topic:* Post-filter transformation**

The pre-filter transformation included subtracting the mean from all values in the dataset. It may also have removed trends in the dataset (See Detrending data values). You can add the mean back and restore the trends as part of the post-filter transformation.

For some filtering processes, such as those in which the units are changed, there is no sense in attempting to reproduce the trend. These processes include:

- Derivatives,
- Use of high pass type filters which output high frequency data,
- Pseudo gravity,
- Susceptibility.

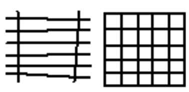
For INTREPID tools reference about this topic, see:
"Reproducing the trend" in Spectral domain grid filters tool (GridFFT) (T40)
"Detrending and replacing trends" in Line Filtering (T31)

Specifying the Earth's core magnetic field direction and intensity

***Parent topic:* INTREPID spectral domain operations reference (R14)**

If you wish to use the Reduction (to pole or equator), Vertical or Horizontal Components, Susceptibility or Pseudo Gravity filter (See corresponding sections below) you must specify the intensity and direction of the Earth's core magnetic field at the mid point of the dataset.

INTREPID can automatically calculate this for you using one of the Geomagnetic Reference Field (GRF) models, the location of the dataset you are processing and the survey date and height.
See The geomagnetic reference field in INTREPID (R15) for information about the GRF models and the way INTREPID tools use them.



For INTREPID tools reference about this topic, see:
"IGRF Calculator" in Spectral domain grid filters tool (GridFFT) (T40)
"Reduction to the Pole filter" in Line Filtering (T31)

Spectral domain filters available

Parent topic: **INTREPID spectral domain operations reference (R14)**

The following sections describe the spectral domain filters available in INTREPID tools.

For INTREPID tools reference about this topic, see:
"GridFFT filters overview" in Spectral domain grid filters tool (GridFFT) (T40)
"Standard spectral domain filters" in Line Filtering (T31)

Single derivative filters

Parent topic: **INTREPID spectral domain operations reference (R14)**

Calculating derivatives of survey data removes unwanted low frequency information and shows the edges of anomalies.

Surveyed areas which do not have anomalies display no change in magnetic field and thus have a derivative (gradient) of zero. At the edge of an anomaly, the data will change, and the gradient will be non-zero. Thus an area which has a non-zero gradient will clearly outline an anomaly.

Calculating derivatives will also enhance near surface features because they change more frequently.

The measured location of a magnetic anomaly will be more accurate if you also apply a Reduction to the Pole filter to the data (See Reduction filters (reference) below).

For INTREPID tools reference about this topic, see:
"Vertical derivative filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Horizontal derivative filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Vertical Derivative filter (gradient filters)" in Line Filtering (T31)
"Horizontal Derivative filter (gradient filters)" in Line Filtering (T31)

In this section:

- Vertical derivative filter (including fractional vertical derivative) (reference)
- Horizontal derivative line filter (reference)
- Generalised horizontal derivative filter (reference)

Vertical derivative filter (including fractional vertical derivative) (reference)

Parent topic: **Single derivative filters**

The Vertical derivative is the derivative of the transformed Z data with respect to height. Even though you will only have data collected at one height, INTREPID can still calculate results for this filter.

A useful feature of INTREPID is its ability to calculate fractional derivatives (e.g., the 1.5th derivative). While this concept may make little sense in everyday mathematics, it is possible in practice for INTREPID to calculate a fractional derivative. Our geophysicists have found that the fractional derivative is a powerful tool. A fractional derivative, (e.g., 1.5th) can be superior to a 1st or 2nd derivative for revealing certain anomalies.
Your choice of derivative order must be largely a function of the acquisition quality of your data. For example, if the data is poor, the 1st derivative might be too severe. In this case the 0.7 derivative would still give the insight but would yield more coherent results.

For INTREPID tools reference about this topic, see:
"Vertical derivative filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Vertical Derivative filter (gradient filters)" in Line Filtering (T31)

Vertical derivative filter—parameters

Parameter	Description
Order of Differentiation	Use this to specify the order of the differentiation. The default and most commonly used order is 1. The Order of Differentiation must be a positive number.

Horizontal derivative line filter (reference)

Parent topic: **Single derivative filters**

(Line Filter only) The Horizontal Derivative is the derivative with respect to survey distance or time (depending on the resampling method selected in the Line Filter tool).

For INTREPID tools reference about this topic, see:
"Horizontal Derivative filter (gradient filters)" in Line Filtering (T31)

Generalised horizontal derivative filter (reference)

Parent topic: Single derivative filters

(GridFFT Spectral Domain Grid Filters only) The Generalised Horizontal Derivative is the derivative with respect to distance in the Azimuth direction of the transformed Z data.

For INTREPID tools reference about this topic, see: "Horizontal derivative filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)

Generalised horizontal derivative—parameters

Parameter	Description
Order of Differentiation	Use this to specify the order of the differentiation. The default and most commonly used order is 1. The Order of Differentiation must be a positive number.
Direction or Azimuth	This defines the direction for the derivative

Hilbert Transform

The Hilbert transform has a variety of applications. In mathematics and in signal processing, the Hilbert transform of a real-valued function, s(t), is another real-valued function in the same domain. The Hilbert transform is named after the renowned mathematician David Hilbert.

Since the application of two Hilbert transformations in succession reverses the phases of all components, it follows that the result will be the negative of the original function. Similarly the application of four Hilbert transformations in succession restores the original function. We use the phase shift of the Hilbert transform in extended Euler to create an East and a North phase shifted derivatives of the observed potential field.

Generalised Hilbert Transform —parameters

Parameter	Description
Direction or Azimuth	This defines the direction for the transform

Reference: Bracewell pg 267.

Compound derivative filters

Parent topic: INTREPID spectral domain operations reference (R14)

These filters combine the results of a number of single derivative filters. INTREPID calculates the single derivative filters in the spectral domain and combines them back in the spatial domain after the reverse transformation. The addition of Hilbert transforms to any or all of the following has been made to allow users to see what transforms are being made in the Euler tool.

In this section:

- Total horizontal derivative filter (reference)
- Analytic signal filter (reference)
  - Tilt Angle (Phase Map) (reference)

Total horizontal derivative filter (reference)

Parent topic: **Compound derivative filters**

(GridFFT Spectral Domain Grid Filters only)

The Total Horizontal Derivative filter has the following steps:

1. INTREPID computes two separate derivative grids in the spectral domain—Horizontal Derivatives for 'X' or 'East' and 'Y' or 'North'.
2. INTREPID transforms these intermediate files back to the spatial domain.
3. In the spatial domain, INTREPID combines the two derivative grids to make the Total Horizontal Derivative output grid.

For INTREPID tools reference about this topic, see:

"Total horizontal derivative filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)

Expressed mathematically, the THD is as follows

f = grid cell value

$\frac{\partial f}{\partial x}$ = 1st horizontal derivative with azimuth = 0

$\frac{\partial f}{\partial y}$ = 1st horizontal derivative with azimuth = 90

The total horizontal derivative is

$$\sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial x}\right)^2}$$

This filter has no parameters.

Analytic signal filter (reference)

Parent topic: **Compound derivative filters**

(GridFFT Spectral Domain Grid Filters only)

The analytic signal filter category has three related options:

- Analytic Signal
- Tilt Angle (Phase Map)
- Total Horizontal Gradient of Tilt Angle

Analytic Signal (reference)

Computing the analytic signal filter consists of the following steps:

1. INTREPID computes three separate derivative grids in the spectral domain—horizontal derivatives for 'X' or 'East' and 'Y' or 'North' and the first vertical derivative.
2. INTREPID transforms these intermediate files back to the spatial domain.
3. In the spatial domain, INTREPID combines the three derivative grids to make the analytic signal output grid.

Expressed mathematically, the analytic signal is as follows:

f = grid cell value

$\frac{\partial f}{\partial x}$ = 1st horizontal derivative with azimuth = 0

$\frac{\partial f}{\partial y}$ = 1st horizontal derivative with azimuth = 90

$\frac{\partial f}{\partial z}$ = 1st vertical derivative.

$$\text{analytic signal} = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2}$$

This filter has no parameters.

Tilt Angle (Phase Map) (reference)

Computing the tilt angle filter consists of the following steps:

1. INTREPID computes three separate derivative grids in the spectral domain—horizontal derivatives for 'X' or 'East' and 'Y' or 'North' and the first vertical derivative.
2. INTREPID transforms these intermediate files back to the spatial domain.
3. In the spatial domain, INTREPID combines the East and North derivative grids to make the Total Horizontal Derivative output grid.
4. In the spatial domain, INTREPID computes the tilt angle from the Total Horizontal Derivative and the Vertical Derivative value, using the following formula :

```
atan(VD/Total Horizontal Derivative))
```

As can be seen, this filter is closely related to the Analytic Signal, and is therefore included with the Analytic Signal in the user interface. The tilt angle shows the character of the signal phase, and it functions as a good boundary edge sharpener. This filter has no parameters.

Total Horizontal Gradient of Tilt Angle Angle (reference)

Grid Filter also offers the advanced feature of calculating the Total Horizontal Derivative of the Tilt angle.

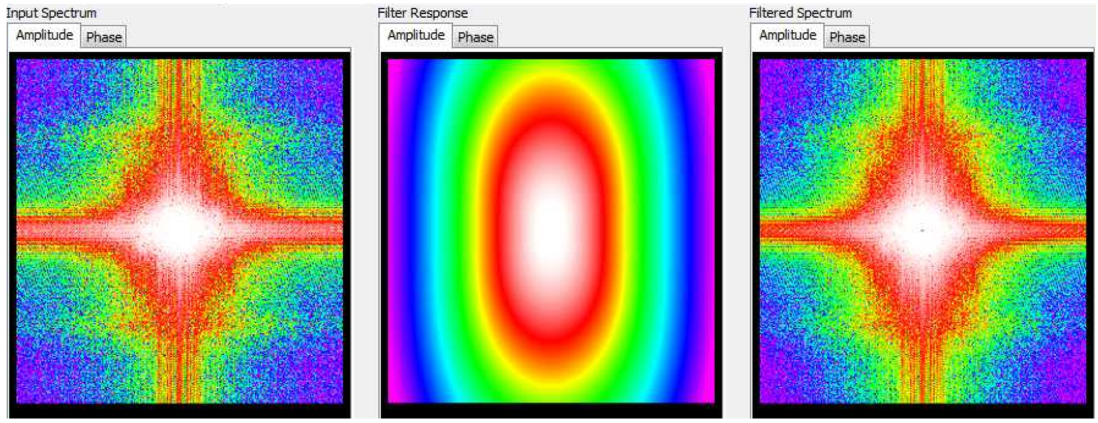
For INTREPID tools reference about this topic, see:
"Analytic signal filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
Euler Deconvolution (T44)

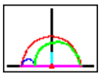
Tensor Component filters (reference)

Parent topic: **INTREPID spectral domain operations reference (R14)**

INTREPID has a range of spectral domain methods to convert the vertical component of either a Gravity or a TMI observation to any of the curvature gradients (tensor gradients).

The following image shows the Fourier domain weights that we use to achieve the required output.





You can use the Spectral Domain Grid Filters tool (GridFFT) tool with full tensor grids as well as ordinary scalar grids. For information about tensor grid structure, see "Tensor grid dataset structure" in INTREPID database, file and data structures (R05).

Currently, when calculating a tensor component, the GridFFT tool only produces a single component output grid, and not a full tensor grid. It is not difficult to construct a full tensor grid. You can use the Spreadsheet Editor function **`newTensor()`** to do this job if you require it. See INTREPID expressions and functions (R12). First load each of the component grids, then create the new full, tensor grid.

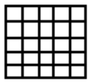
You can use the Gridding tool to create a full tensor grid from tensor profile data.

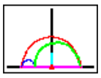
GridFFT offers a choice of filters, depending upon grid data type, so that it can, for example, complete tensor integration of a full tensor grid. To do the integration, INTREPID uses multiple inputs (Txz,Tyz,Tzz) to create one output (Tz).

In this rarely documented process, during research and testing to configure the GridFFT tool, we experimented with the transfer function weights to balance the contributions of each channel, giving slightly more weight to the Tzz contribution, compared to the other partial derivatives.

The next generation gravity gradiometers can measure torsional gradients, for example, Tzz – Txx. INTREPID provides the full range of conversions to and from these compound gradients.

Tensor Query filters (reference)





These filters convert vertical gravity to any of the five independent gravity tensor components. You can use milligals or Eötvös. These filters only work on a single band grid

You can also convert specific combinations of FTG or FALCON tensor components into Tz or Tzz.

The measurement unit of gravity gradient is the Eötvös (Eö), being 1 nm/sec^2/m, equivalent to a gradient of 1 mgal over 10 km.

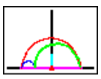
1 Eö = 1 mgal/10 km = 0.1 mgal/km = 0.0001 mgal/m

The following table contains possible inputs and ouputs for this filter.

Input	**Output**
Tz	Txx Txz Tyy Tyz Tzz Txy
Tzz – Txx	Tzz
Tzz – Tyy	Tzz

Full and Partial tensor filters (reference)

Parent topic: **INTREPID spectral domain operations reference (R14)**



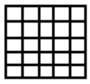
When filtering full tensor grids, be careful to state the correct coordinate frame of reference. For example, if you are integrating T_{xz} to get T_z, you need to apply the appropriate sign correction for the direction of Z (up or down).

Make sure you are certain, also, whether the dataset was constructed with a right- or left-handed system and therefore whether T_{xx} is, in fact $T_{east\ east}$.

See "Vector and tensor field data coordinate conventions" in INTREPID database, file and data structures (R05)

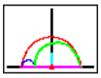
Some INTREPID standard Fourier filters, such as Low, High and Band Pass, are available for full tensor grids, as well as the Tensor Integral filter.

Full Tensor Integration Query (FTG or other full tensor grids)



This filter integrates the partial derivatives of the tensor curvature gradients to estimate either the vertical component of gravity, the total magnetic intensity or the gravity and magnetic potentials.

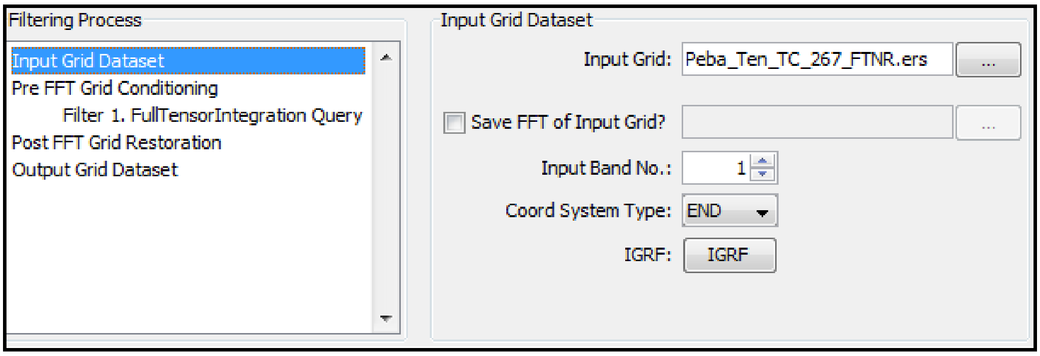
This filter is only available for full tensor grids such as FTG or IPHT (magnetic tensor). A second version of this filter is implemented for the Falcon partial tensor.



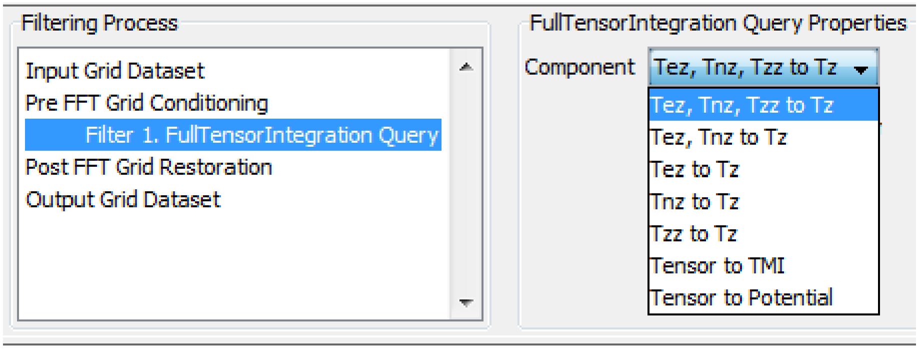
Query	Output	Description
Tez, Tnz, Tzz to Tz	Tz	Compute vertical gravity Tz from three tensor components (Most accurate)
Tez, Tnz, to Tz	Tz	Compute vertical gravity Tz from two tensor components
Tez to Tz	Tz	Compute vertical gravity Tz
Tnz to Tz	Tz	Compute vertical gravity Tz
Tzz to Tz	Tz	Compute vertical gravity Tz
Tensor to TMI	TMI (nT)	Compute total magnetic intensity from magnetic tensor gradients
Tensor to Potential	Potential	Compute the gravity or magnetic potential

To execute the full tensor integration query the steps are:

- Load a full tensor grid ie FTG (check that the tensor coordinate system is correctly set ie END for FTG. The tensor coordinate system can be set in Project Manager.

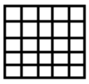


- Select the Full Tensor integration filter from the filter list (it will not be visible if you did not load a full tensor grid).

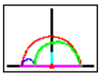


- Choose a query from the Properties list. Tz can be estimated using between one and three tensor components. The three components option (Tez, Tnz, Tzz to Tz) is considered optimum, preserving longer wavelength features more accurately.
- For the FTG and Magnetic tensors it is also possible to calculate the gravity or magnetic potential.
- Tensor to TMI will calculate TMI from the full magnetic tensor

FALCON Partial Tensor Transform Query



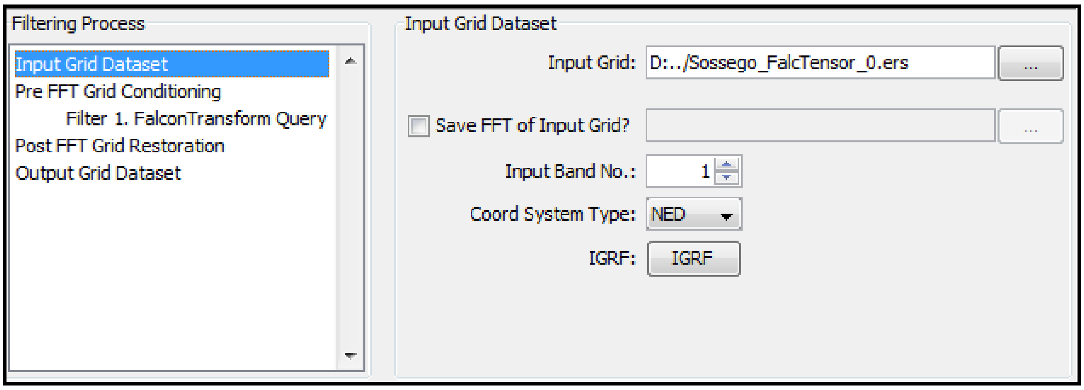
This filter integrates the partial derivatives of the falcon NE and UV tensor curvature gradients to estimate the vertical gravity gradient (Gdd), the vertical component of gravity (gD), the gravity potential and other tensor and QC related products summarised in the table below. The user can choose the average of the FALCON A or B measurements for the calculations (default) or the individual A or B measurements separately.

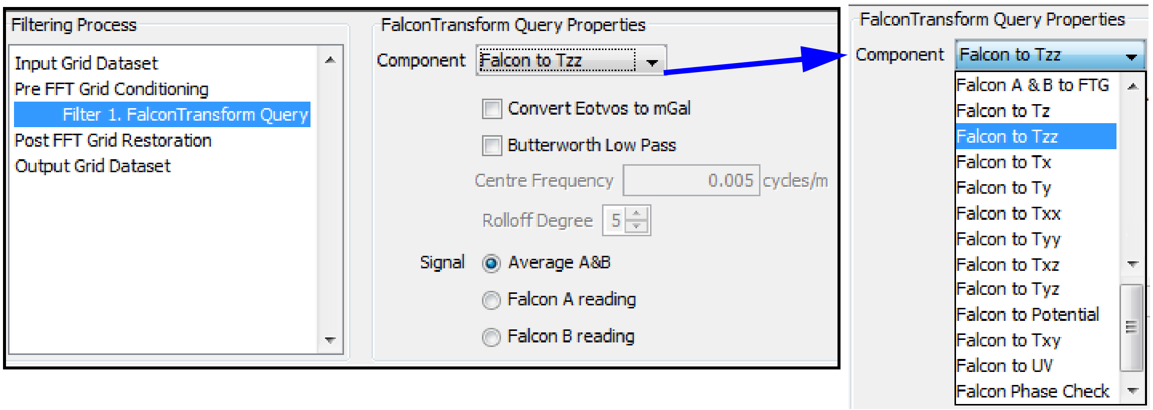


Query	Output	Description
Falcon A & B to FTG	FTG Tensor	Creates FTG full tensor grid (END) from the Falcon partial tensor grid (NED)
Falcon to Tz	Tz (gD)	Compute z component - vertical gravity (gD)
Falcon to Tx	Tx	Compute x component of gravity
Falcon to Ty	Ty	Compute y component of gravity
Falcon to Txx	Txx	The xx component of gravity gradient tensor
Falcon to Txy	Txy	The xy component of gravity gradient tensor
Falcon to Txz	Txz	The xz component of gravity gradient tensor
Falcon to Tyy	Tyy	The yy component of gravity gradient tensor
Falcon to Tyz	Tyz	The yz component of gravity gradient tensor
Falcon to Potential	Gravity potential	Compute the gravity potential
Falcon to Txy	Txy (GNE)	Falcon Average NE (ANE+BNE)/2
Falcon to GUV	GUV	Falcon Average UV (AUV+BUV)/2
Falcon Phase Check	Gzz/iGzz	Falcon phase QC - check the phase relationship of NE and UV before TC

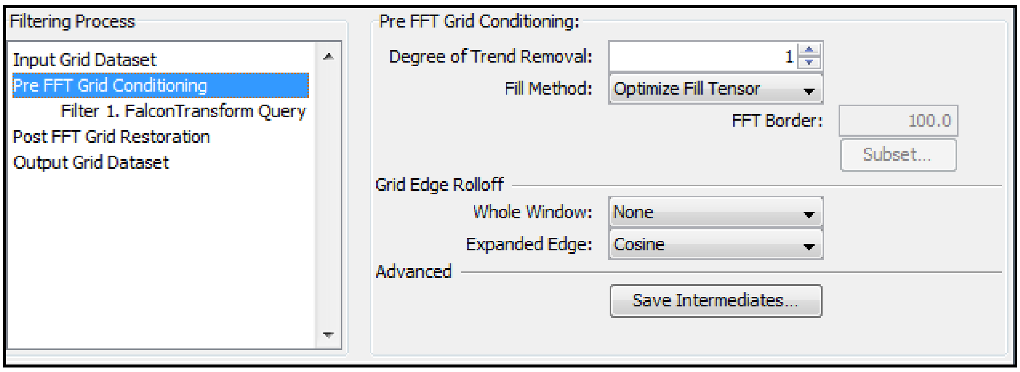
To execute the FALCON tensor query the steps are:

- Load a FALCON tensor grid (check that the tensor coordinate system is correctly set ie NED). The tensor coordinate system can be set in Project Manager.
- Select the FALCON transform query filter from the filter list (it will not be visible if you did not load a FALCON tensor grid)

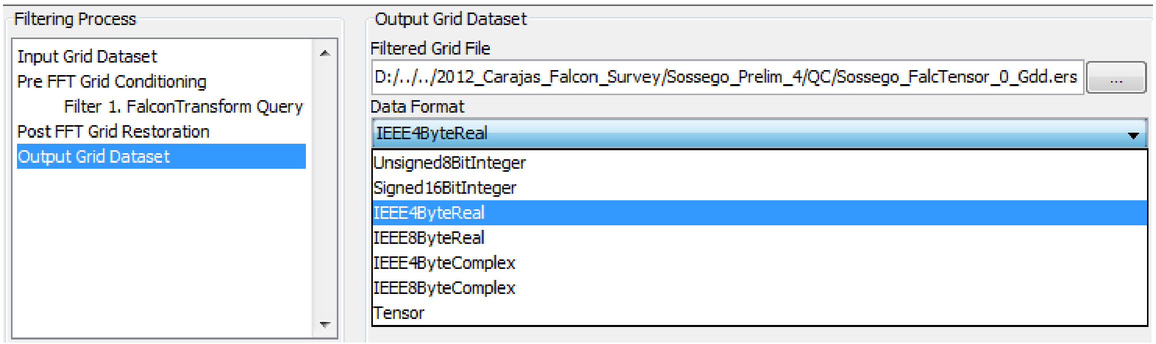




- Select the transform query from the Component drop down list
- Select the units for the chosen output ie Falcon to Tz (gD) would normally be output in mGals.
- The Butterworth filter option is not currently active and cannot be stacked with Falcon query operations. 2D filtering of the FALCON tensor grid must be completed using the separate tensor aware Butterworth filter if required Butterworth filter (reference).
- Choose whether to use the Average A+B signal or the FALCON A or B measurements separately.
- Step back to the Grid Conditioning Tab and you will observe that the Fill Method has been set automatically to Optimise Fill Tensor. This method ensures that the Fourier padding honours the tensor physics and improves significantly the long wavelength accuracy of Tz (gD) during transformation.



- Step forward to the Output Grid Dataset option



- The default output is a single band grid. In the Falcon to Tz (gD) and Falcon to Tzz (Gdd) query cases the user can choose to output a two band grid (IEEE4ByteComplex or IEEE8ByteComplex). In this case the first (Real) band will contain the Tz (gD) or Tzz (Gdd) components and the second (Imaginary) band contains the portion of the signal that remained (was not fitted) after the transform. This second band can be thought of as the transform error and may be examined to determine if real signal remains or whether it just contains noise.

Reduction filters (reference)

Parent topic: INTREPID spectral domain operations reference (R14)

If you are taking magnetic readings from an aircraft, the reading at any point will be a composite of the magnetism of nearby objects under the ground and the Earth's core magnetic field. Except near the poles, the magnetic field direction is not vertical. This will displace the measured location of any magnetic source near the aircraft.

For INTREPID tools reference about this topic, see:
"Reduction filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Reduction to the Pole filter" in Line Filtering (T31)

In this section:

- Reduction filters—parameters
- IGRF field inclination limit for amplitude calculation (for surveys near the Equator)
- Reduction to the Pole (reference)
  - Variable reduction to the pole

You can use a Reduction filter to correct this location error. Reduction filters use the parameters listed below.

Reduction filters—parameters

Parent topic: Reduction filters (reference)

The following table shows the reduction filter parameters. See also IGRF field inclination limit for amplitude calculation (for surveys near the Equator)

Parameter	Description
Field Intensity, Inclination for input data, Declination for input data	These are values for the Earth's magnetic field corresponding to the input data. Some INTREPID tools use Field Intensity automatically without requiring user input. You can specify these manually or calculate them from the IGRF or other model (See Elevation and Date parameters).
Elevation, Date	You can use the IGRF or other model to calculate values for the Earth's magnetic field corresponding to the input data. This requires the survey elevation and date. See The geomagnetic reference field in INTREPID (R15) for information about the GRF models, the way INTREPID tools use them and specific information about the three parameters.
Latitude for amplitude limit	*(Reduction to the Pole only)* See IGRF field inclination limit for amplitude calculation (for surveys near the Equator)
Target inclination, Target declination	Some INTREPID tools reduce data to any latitude. Use these parameters to specify the desired inclination and declination of the Earth's magnetic field in the output data *INTREPID tools that just reduce to the Pole or Equator do not use these parameters.*

IGRF field inclination limit for amplitude calculation (for surveys near the Equator)

Parent topic: **Reduction filters (reference)**

(Reduction to the Pole only) Below a certain magnetic field inclination, as your survey nears the Equator, it is better to fix the amplitude calculation of magnetic readings to a constant inclination ie +/-20° or greater. This ensures numerical stability at low latitudes.

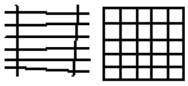
For INTREPID tools reference about this topic, see:
"Reduction filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Reduction to the Pole filter" in Line Filtering (T31)

If the Inclination is further from 0 than the Latitude for amplitude limit, then INTREPID will use the value of the Inclination instead for the amplitude limit. Here are some examples:

Inclination	Inclination limit for amplitude calculation	Phase and amplitude adjustment
–10°	–20°	Phase rotated from –10° to –90° Amplitude fixed between –10° and –20°and allowed to change between –20° and –90°
10°	20°	Phase rotated from 10° to 90° Amplitude allowed to change between 20° and 90°
–60°	–20°	Phase rotated from –60° to –90° Amplitude allowed to change between –60° and –90° (The Inclination is greater than the field inclination limit for amplitude calculation)

Reduction to the Pole (reference)

***Parent topic:* Reduction filters (reference)**



If you choose Reduction to the Pole, INTREPID performs a magnetic field correction on the data. Before the filter is applied, the influence of the Earth's core magnetic field will correspond to the location of the survey. After the filter is applied, the apparent influence of the Earth's magnetic field on the survey data will be same as would occur at the Pole.
We would like to assume that data collected is from sources directly beneath the aircraft. Due to the angle of the magnetic field, sources of data will not actually be directly under the aircraft. The Reduction to the Pole filter corrects the recorded location of the magnetic sources to allow for this error. We call the filter Reduction to the Pole because it allows us to assume that the sources of our data are directly below the aircraft. This could only in reality happen at one of the Poles.

At low latitudes INTREPID applies a field inclination limit (ie +/-20°) to the amplitude calculation to keep the numerical method stable. In the Spectral Domain Grid Filters tool you can vary this parameter.

There is also a Low Latitude switch which will apply a directional cosine filter to the reduced grid. The filter Azimuth is set in the direction of the "FromDeclination" parameter, the filter Azimuth half width defaults to 20°, the Rolloff degree defaults to 0.5 and the "Pass" parameter is set to yes.

Using the Line Filter tool in current version of INTREPID, you should only use reduction to the pole with acquisition lines oriented North–South.

We are currently extending our tools to include magnetic reduction to the pole for full tensor grids.

For INTREPID tools reference about this topic, see:
"Reduction filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Reduction to the Pole filter" in Line Filtering (T31)

For data from the and low latitudes you can also use the Equivalent Layer tool. See Equivalent Layer corrections (T36) for instructions.

See the general discussion of Reduction filters (reference) for a description of parameters used by the filter.

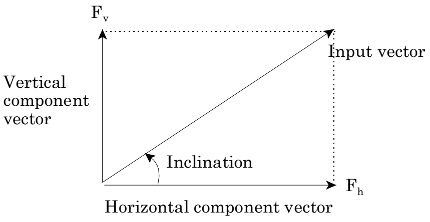
Variable reduction to the pole

If you are performing reduction to the pole on large regional datasets, the inclination and declination may vary within the datset. INTREPID GridFFT has a Taylor series expansion of up to three terms to improve the honouring of the inclination and declination as it varies over the region. GridFFT has a check box for selecting this option

Horizontal and vertical components filters (reference)

Parent topic: **INTREPID spectral domain operations reference (R14)**

(Line Filter only) Since, except at the poles and the , the magnetic field during the survey is at an angle, you can resolve the measured magnetic field intensity into horizontal and vertical components [1].



Calculating horizontal and vertical components of a vector in the spectral domain

The Horizontal component and Vertical component filters perform this operation, outputting only horizontal or vertical component of the signal respectively. The horizontal component is the 'along line' component.

These filters are currently available in the Line Filter tool. See "Vertical / Horizontal Component filter" in Line Filtering (T31).

Horizontal and vertical components filters—parameters

Parameter	Description
Field Intensity, Inclination, Declination	See the general discussion of Reduction filters (reference) for a description of the parameters used by the filter.

Continuation filters (reference)

Parent topic: **INTREPID spectral domain operations reference (R14)**

If you traversed the region at a greater height, you would be less likely to sense near surface sources. Your data on regional sources would be less affected by this change.

If you traversed the region at a lower level, near surface sources would be more intense. There could well also be noise that could obscure all sources.

Magnetic fields become weaker as distance increases. You can derive a formula to transform the strength of a magnetic field sensed at one height to an estimate of the field that you would sense at a different height. The continuation filters perform this transformation.

For INTREPID tools reference about this topic, see:
"Continuation filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Upward Continuation filter" in Line Filtering (T31)
"Downward Continuation filter" in Line Filtering (T31)

In this section:

- Continuation filters—parameters
- Formula for continuation
- Upward Continuation filter (reference)
- Downward Continuation filter (reference)
- Variable continuation filter (reference)

1. Blakely, Richard J., (1995) *Potential Theory in Gravity and Magnetic Applications*, Cambridge University Press, p 328.

Continuation filters—parameters

***Parent topic:* Continuation filters (reference)**

(Upward and downward continuation only)
See Variable continuation filter (reference) for Variable continuation parameters)

Parameter	Description
Level of Continuation	The increase or reduction in height at which you wish to 'view' the data. If there is no separate control in your tool or language for specifying the direction, specify a negative number for downward continuation. Check the documentation of the tool you are using before specifying a value. Be sure that you do not specify a continuation level that: • Is below the land surface, or • Will result in excessive noise.
Degree of Rolloff	*(Downward continuation in GridFFT only)* Determines the sharpness of the roll-off for high frequency damping. See Downward Continuation filter (reference) for an explanation of damping.
Median Frequency of Rolloff	*(Downward continuation in GridFFT only)* This frequency is the centre of the roll-off region for high frequency damping. See Downward Continuation filter (reference) for an explanation of damping.
Order of Stability	*(Downward continuation in Line Filter only)* This parameter is the same as the Degree of Rolloff

Formula for continuation

***Parent topic:* Continuation filters (reference)**

Where:
d = damping factor (*downward continuation only*)
h = level of continuation (positive for up, negative for down)
w = frequency

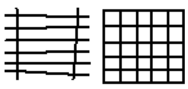
$$F(w) = de^{hw}$$

Upward Continuation filter (reference)

***Parent topic:* Continuation filters (reference)**

The Upward continuation filter recalculates the data as if you observed it at a greater height. It allows you to see regional sources more clearly.

The level of continuation is relative to the acquisition height. For example, an acquisition height of 50 m above ground level and an upward continuation of 100 m will result in a profile height of 150 m above ground level.
For INTREPID tools reference about this topic, see:



"Continuation filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Upward Continuation filter" in Line Filtering (T31)

Downward Continuation filter (reference)

Parent topic: Continuation filters (reference)

The Downward continuation filter recalculates the data as if you observed it at a lower level. It allows you to see near surface sources more clearly. It may also introduce noise to your data. If the continuation becomes unstable, INTREPID will give you a warning message.

Downward continuation increases signal amplitudes at the higher frequency end of the power spectrum (depending on the depth of continuation). The filter operation can become unstable, especially with noisy data. There may be a 'blow-out' of power at the higher frequencies.
For INTREPID tools reference about this topic, see:
"Continuation filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Downward Continuation filter" in Line Filtering (T31)

Damping of high frequencies

To stabilise downward continuation at high frequencies we use a damping factor. This rolls off the higher frequencies using a low pass Butterworth filter (see Butterworth filter (reference)). In the Butterworth filter, the Degree of rolloff is the degree of the Butterworth filter and the Median frequency of rolloff is the Median frequncy for the filter.

For INTREPID tools reference about this topic, see:
"Suggested values for Degree of Rolloff" in Spectral domain grid filters tool (GridFFT) (T40)
"Downward Continuation filter" in Line Filtering (T31)

Variable continuation filter (reference)

Parent topic: Continuation filters (reference)

This filter performs an upward or downward continuation of the magnetic field signal to a new variable survey elevation (Drape Altitude) or to a constant survey Altitude.. To speed up this process you can classify possible heights into ranges (bins) and calculate a standard correction for each bin. This way the process only needs to know the bin to which the clearance of a data point belongs in order to add or subtract the correction.
For INTREPID tools reference about this topic, see:
"Variable continuation filter" in Line Filtering (T31)

Variable continuation—parameters

Parameter	Description
Nominal Level of Survey	Survey height to which you want to adjust the data (height at which survey was meant to be flown according to the survey specifications).
Number of Bins to Sort Heights	Number of bins for heights classification.
Nominal Height of Bin (metres)	Specifying the height of each bin allows you further control on the number of height values which will fall into each particular bin. The value of this parameter would also depend upon the range of survey heights.
Cutoff Weight	Use this parameter to control the Butterworth filter, which dampens the effect of the downward continuation. Without the filter, downward continuation amplifies noise in the signal and becomes unstable for large continuation distances.

Filters for frequency ranges (pass filters)

Parent topic: **INTREPID spectral domain operations reference (R14)**

You can use one or more of these to pass, reduce or reject selected frequency ranges.

In the Spectral Domain Grid Filters tool the filters all act upon the radially averaged power spectrum, and their operation is therefore the same in all directions.

For INTREPID tools reference about this topic, see:
"Entering parameters for pass filters (interactive only)" in Spectral domain grid filters tool (GridFFT) (T40)
"Low pass filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"High pass filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Band pass filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Band Pass and Band Reject filters" in Line Filtering (T31)
"Low Pass filter" in Line Filtering (T31)
"High Pass filter" in Line Filtering (T31)

In this section:

- Pass filters and Gibb's phenomenon (ringing)
- Frequency units and the INTREPID filter tools
- Low pass filter (reference)
- High pass filter (reference)
- Band pass filter (reference)
- Cosine rolloff filter (reference)
- Butterworth filter (reference)
- Gauss filter (reference)
- Matched filter (reference)
- General symmetric filter (reference)

Pass filters and Gibb's phenomenon (ringing)

Parent topic: **Filters for frequency ranges (pass filters)**

Pass filters in their basic form are crude and can produce poor image quality ('ringing') after reverse spectral transform (Gibb's phenomenon). INTREPID prevents ringing by automatically tapering the edges of the data passed by the filters (i.e., include some of the rejected data starting at the cutoff frequency and tapering to zero amplitude).

The Line Filter tool allows you to specify the length in data points of the tapering range (rolloff window) for its pass filters using the Cutoff Rolloff Parameter.

The Spectral Domain Grid Filters tool pass filters automatically taper the edges without your intervention.

Frequency units and the INTREPID filter tools

Parent topic: **Filters for frequency ranges (pass filters)**

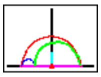
The Line Filter tool use cycles/km units for the cutoff frequencies. Power spectrum graphs display frequency scale in cycles/km.

GridFFT enables you to select units, x 1000 multiples and frequency or wavelength. See "Frequency, wavelength and distance unit multiples" in Spectral domain grid filters tool (GridFFT) (T40).

The Old Spectral Domain Grid Filters tool uses cycles/m for cutoff frequencies in its dialog boxes. If you use the power spectrum graph to assist you in choosing a cutoff frequency for a filter, divide the frequency by 1000 to convert it to cycles/m before specifying it in the filter dialog box. Power spectrum graphs display frequency scale in cycles/km.

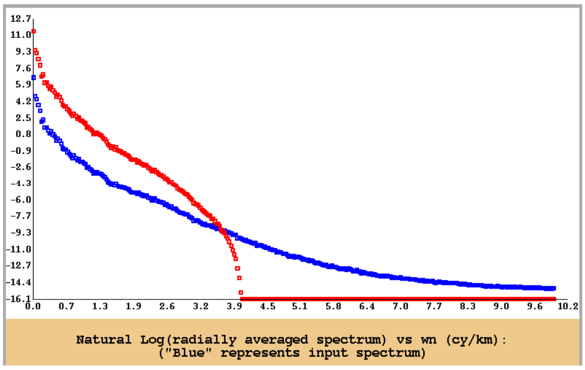
Low pass filter (reference)

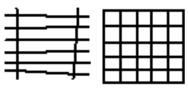
Parent topic: **Filters for frequency ranges (pass filters)**



The Low Pass filter will retain the low frequency range of the power spectrum, using a smooth curve to rolloff the data outside the cutoff frequency. You can use this filter for removing high frequency noise and also near surface sources if required. The filter is available for full tensor grids.

Here is an illustration of the effect of a Low Pass filter, showing the power spectrum of the original data (the smooth descending curve) and the filter results (the curve which drops to the horizontal axis and runs along it).





For INTREPID tools reference about this topic, see:
"Low pass filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Low Pass filter" in Line Filtering (T31)

Low pass filter—parameters

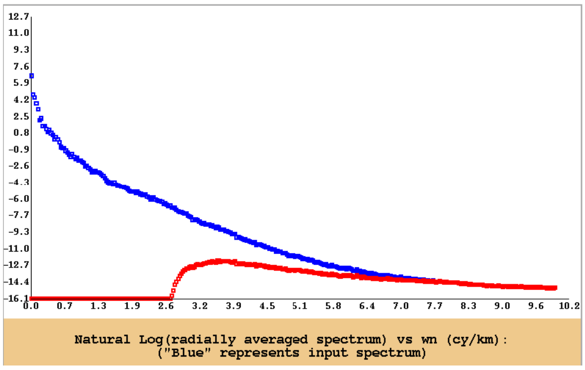
Parameter	Description
Cutoff frequency (or wavelength)	Use this to specify the frequency below which INTREPID will retain data.
Size of rolloff zone or Cutoff rolloff parameter	*(GridFFT and Line Filter tool only)* Use this to specify the width of the rolloff range around the cutoff frequency where INTREPID tapers the energy of the data to 0. *In GridFFT* you can calculate and set this automatically
Replace Trend in Output	*(Line Filter tool only)* Use this option to specify whether INTREPID must replace any trend removed from the data before the filter process.

High pass filter (reference)

Parent topic: **Filters for frequency ranges (pass filters)**

The High Pass filter will retain the high frequency range of the power spectrum, using a smooth curve to rolloff the data outside the cutoff frequency. You can use this filter for eliminating regional and deep sources, enabling you to see just the shallow magnetic bodies. The filter is available for full tensor grids.

Here is an illustration of the effect of a High Pass filter, showing the power spectrum of the original data (the upper curve) and the filter results (the lower curve).



For INTREPID tools reference about this topic, see:
"High pass filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"High Pass filter" in Line Filtering (T31)

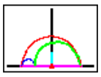
High pass filter—parameters

Parameter	Description
Cutoff frequency (or wavelength)	Use this to specify the frequency above which INTREPID will retain data.
Size of rolloff zone or Cutoff rolloff parameter	*(GridFFT and Line Filter tool only)* Use this to specify the width of the rolloff range around the cutoff frequency where INTREPID tapers the energy of the data to 0. *In GridFFT* you can calculate and set this automatically

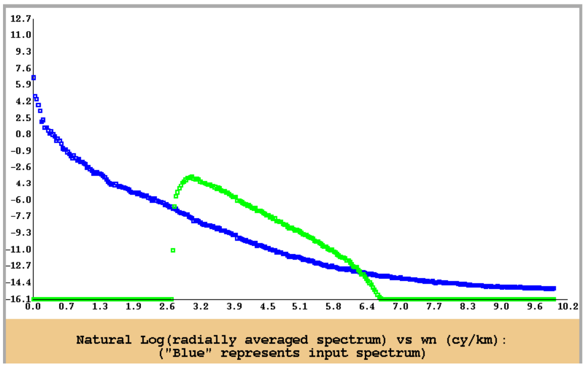
Band pass filter (reference)

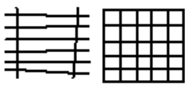
Parent topic: **Filters for frequency ranges (pass filters)**

The band filter removes all data either within or outside a **band** (frequency range) that you have specified. This can remove data associated with either near surface or regional sources depending on how you specify the cutoff frequencies. You can use this filter for eliminating high frequency noise and regional sources at the same time. The filter is available for full tensor grids.



Here is an illustration of the effect of a 'pass' version of a band filter, showing the power spectrum of the original data (the smooth downward curve) and the filter results (the hump-shaped curve with low and high segments along the horizontal axis).





For INTREPID tools reference about this topic, see:
"Band pass filter (GridFFT)" in Spectral domain grid filters tool (GridFFT) (T40)
"Band Pass and Band Reject filters" in Line Filtering (T31)

Band pass filter—parameters

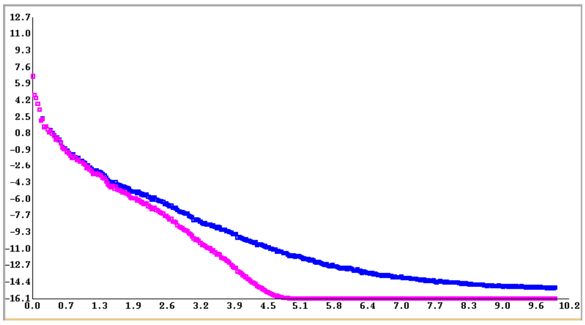
Parameter	Description
Low cutoff frequency (or wavelength)	Use this to specify the frequency above which INTREPID will pass or reject data.
High cutoff frequency (or wavelength)	Use this to specify the frequency below which INTREPID will pass or reject data.
Size of rolloff zone or Cutoff rolloff parameter (low)	*(GridFFT and Line Filter tool only)* Use this to specify the width of the rolloff zone outside the low cutoff frequency where INTREPID tapers the energy of the data to 0. *In GridFFT* you can calculate and set this automatically
Size of rolloff zone or Cutoff rolloff parameter (high)	*(GridFFT and Line Filter tool only)* Use this to specify the width of the rolloff zone outside the high cutoff frequency where INTREPID tapers the energy of the data to 0. *In GridFFT* you can calculate and set this automatically
Pass / Reject	Specify whether to remove the data within or outside the band that you have specified. If you choose Pass, INTREPID retains the data inside the band. If you choose Reject, INTREPID retains the data outside the band. The new *Spectral Domain Grid Filters tool (GridFFT)* does not have this option and is always set to Pass. The *old Spectral Domain Grid Filters tool (OldGridFFT)* has a pair of option buttons for you to select. The *Line Filter tool* has separate Band Pass and Band Reject menu options.

Cosine rolloff filter (reference)

Parent topic: **Filters for frequency ranges (pass filters)**

(Spectral Domain Grid Filters only) This filter will retain (pass) the low or high frequency range of the power spectrum, tapering with a smooth cosine curve in a rolloff range. You can specify the high and low frequency for the rolloff range, and the degree of the cosine function. As the degree of the cosine function increases, the transition between the passed and rejected sections of the spectrum becomes steeper.

Here is an illustration of the effect of a 'low pass' version of the Cosine Rolloff filter, showing the power spectrum of the original data (upper curve) and the filter results (lower curve).



Here is a formula for a 'low pass' Cosine Rolloff filter. Where

w_0 = low frequency limit

w_1 = high frequency limit

n = degree of cosine function

$$F(w) = 1$$

where $w < w_0$

$$F(w) = \left(\cos\left(\frac{\pi}{2}\left(\frac{w - w_0}{w_1 - w_0}\right)\right)\right)^n$$

where $w_0 < w < w_1$

$$F(w) = 0$$

where $w > w_1$

Cosine rolloff filter—parameters

Low cutoff frequency Use this to specify the lower frequency limit of the rolloff range below which INTREPID will totally pass or reject data.

High cutoff frequency Use this to specify the upper frequency limit of the rolloff range above which INTREPID will totally pass or reject data.

Degree of cosine function Use this to specify the degree of the cosine function that you require for the rolloff.

Pass / Reject Use these options to specify whether to retain the data above or below the rolloff range.

If you choose Pass, INTREPID retains data below the rolloff range.

If you choose Reject, INTREPID retains data above the rolloff range.

Butterworth filter (reference)

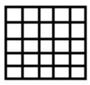
Parent topic: **Filters for frequency ranges (pass filters)**

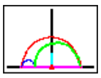
(Spectral Domain Grid Filters only) This filter will retain (pass) one end of the power spectrum according to a median frequency. You can use the Butterworth filter as a general pass / reject filter by specifying your required cutoff value as the median frequency.

To taper the data in the cutoff range INTREPID uses a smooth curve symmetrical about the median frequency.

You can specify the degree of the filter. As the degree of the function increases, the transition between the passed and rejected sections of the spectrum becomes steeper.

The Butterworth filter is tensor compatible.





Here is a formula for a Butterworth filter. Where

w_c= Median frequency (cycles/m)

n= Degree of Butterworth Filter

'Low pass' version (retaining the low frequencies):

$$F(w) = \frac{1}{1 + \left(\frac{w}{w_c}\right)^n}$$

'High pass' version (retaining the high frequencies):

$$F(w) = \frac{\left(\frac{w}{w_c}\right)^n}{1 + \left(\frac{w}{w_c}\right)^n}$$

$$F(w) = \frac{\left(\frac{w}{w_c}\right)^n}{1e\left(\frac{w}{w_c}\right)^n}$$

Butterworth filter—parameters

Central frequency (central wavenumber) Use this to specify the cutoff (median) frequency for the filter. This is will be the central frequency in the rolloff range.

Rolloff Degree Use this to specify the rolloff degree of the Butterworth filter that you require.

Pass / Reject Use these options to specify whether to retain the data above or below the median frequency.

If you choose Pass, INTREPID retains data below the median frequency.

If you choose Reject, INTREPID retains data above the median frequency.

Gauss filter (reference)

Parent topic: **Filters for frequency ranges (pass filters)**

(Spectral Domain Grid Filters only) This filter will retain (pass) the low or high frequency range of the power spectrum using a smooth Gauss curve in a rolloff range. The specified value for the power spectrum standard deviation determines the steepness of the filter curve.

A further use of a Gaussian filter is made for derivative grids when they are to be passed into the Euler tool. BRGM and others have noted that the Euler equations are very vulnerable to noise and that a simple Gausian filter around the Nyquist frequency is a simple way of adding extra protection from noise.

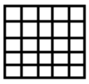
Here is a formula for a Gauss filter

σ = standard deviation

'Low pass' (retaining the low frequencies):

$$F(w) = e^{-0.5\left(\frac{w}{\sigma}\right)^2}$$

'High pass' (retaining the low frequencies):



$$F(w) = e^{0.5\left(\frac{w}{\sigma}\right)^2}$$

Gauss filter—parameters

The spectral filter works by applying a roll-off around the central frequency in the grid dataset. All wavenumbers are divided by the standard deviation parameter and the Fourier coefficients are scaled by the exponential term as shown above.

This contrasts with a spatial Gaussian filter that is designed to be centered around a particular wave-length and a roll-off to either side.

Standard deviation Use this to specify the standard deviation for INTREPID to use in the filter.

Pass / Reject Use these options to specify whether to retain the data above or below the rolloff range.

If you choose Pass, INTREPID retains data below the rolloff range.

If you choose Reject, INTREPID retains data above the rolloff range.

Matched filter (reference)

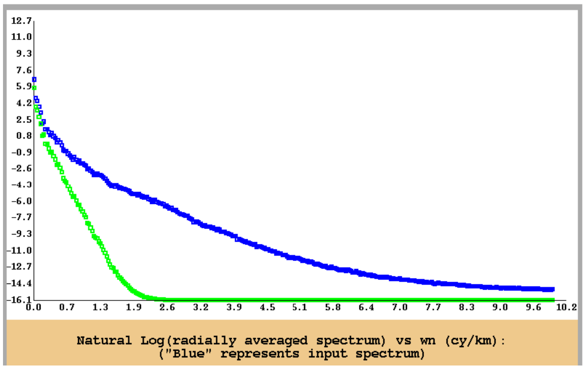
Parent topic: **Filters for frequency ranges (pass filters)**

(Spectral Domain Grid Filters only) The matched filter extracts data that characterises major sources. It is sometimes called a **depth slice filter**. The technique is as follows

1. Identify sections of the power spectrum that characterise the major regional source and the near surface data.
2. Draw a straight line on the power spectrum characterising each type of data. One line will be approximately parallel to the low frequency part of the curve and the other approximately parallel to the high frequency part.
3. Process the dataset so that the regional data is mapped onto a regional line and the near surface data is removed.

The method leads to techniques for identifying and extracting data from regional sources at specific depth ranges. Cowan and Cowan[1] call this Separation Filtering. It forms the basis of the World Geoscience Depth Slicing technique[2].

Here is an illustration of the effect of a Matched filter, showing the power spectrum of the original data (upper curve) and the filter results (lower curve).



Matched filter—parameters

b, h, (near surface) and B, H (regional)

B = The slope of the low frequency line (regional)

H = The vertical (energy) axis intercept for the low frequency line

b = The slope of the high frequency line (near surface)

h = The vertical (energy) axis intercept for the high frequency line

1. Cowan, D.R. and Cowan, S., (1993) Separation Filtering Applied to Aeromagnetic Data, *Exploration Geophysics* 24, 429–436

2.Norman, C., (1993), New developments in the aeromagnetic technique for sedimentary basin evaluation, *ASEG Preview*, Feb 1993.

General symmetric filter (reference)

Parent topic: **Filters for frequency ranges (pass filters)**

(Spectral Domain Grid Filters only) This filter enables you to divide the power spectrum into a number of segments and pass, reduce or reject the data from each segment. It is a 'design your own' filter.

INTREPID will divide the power spectrum into a set of segments of the length you specify. The starting frequency is 0 for the purposes of this division. It will assign a coefficient to each segment and multiply the data within the segment by its coefficient. A coefficient of 1 causes INTREPID to pass the data as it is; a coefficient of 0 causes it to reject the data; a coefficient between 0 and 1 will reduce the energy of the data before passing it.

Examples:

- You could define a low pass filter to .8 with a rolloff using the following settings:

  Frequency increment = 0.2

  Filter coefficients = 1, 1, 1, 1, .75, .5, .2, 0

- You could define a band pass filter for the interval .4 to .6 using the following settings:

  Frequency increment = 0.2

  Filter coefficients = 0, 0, 1, 1, 0, 0, 0, 0

General symmetric filter—parameters

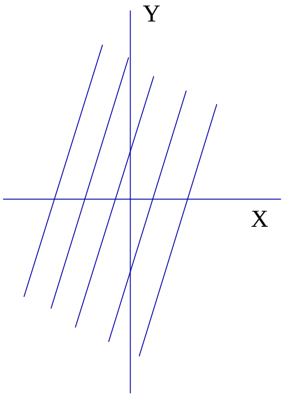
Frequency increment (Wavenumber Increment) Use this to specify the length (in frequency units) of one segment.

Filter Coefficients Specify the 8 coefficients after the Frequency Increment. Enter one coefficient for each segment. Separate each pair of coefficients by a space.

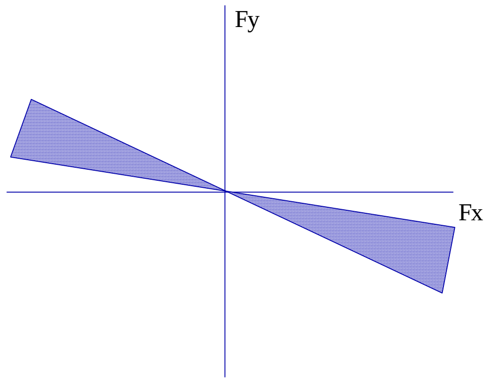
Directional Filters

Parent topic: **INTREPID spectral domain operations reference (R14)**

(Spectral Domain Grid Filters only) You can use the directional filters to remove or enhance features that are aligned in a particular direction. Directional features in the spatial domain will have a corresponding effect in the sector of the spectral domain corresponding to that direction. In the illustration below, a corrugation in the spatial domain causes an effect in the sector of the spectral domain at right angles to the line of the corrugation.



Directional Feature in the spatial domain (e.g., corrugation)



Sectors of the spectral domain which show the effect of the directional feature

In this section:

- Directional pass filter (reference)
- Directional cosine filter (reference)

Directional pass filter (reference)

Parent topic: **Directional Filters**

The Directional Pass filter will totally reject or accept the data within the sector of the spectral domain that you specify. Note that pass filters are crude and may produce poor image quality ('ringing') after reverse spectral transform. We recommend that you normally use the Directional Cosine filter for this purpose (See Directional cosine filter (reference)).

Directional pass filter—parameters

Low cutoff angle Use this to specify the angle (in degrees) for the lower limit of the pass / reject range in this text box. Measure the angle clockwise with 0° corresponding to North.

High cutoff angle Use this to specify the angle (in degrees) for the upper limit of the pass / reject range in this text box. Measure the angle clockwise with 0° corresponding to North.

Pass / Reject Select Pass to pass the data that falls between the angles you have specified and reject the rest of the data. Select Reject to reject the data that falls between the angles you have specified and pass the rest of the data.

Directional cosine filter (reference)

Parent topic: **Directional Filters**

The Directional Cosine filter will pass or reject data in the direction and angular width that you specify. It will create a smooth curve from pass to reject in the data surface at a rate depending on the rolloff degree specified. This elimination of sudden changes in the data prevents 'ringing' in the image when INTREPID transforms the data back to the spatial domain.

Directional cosine filter—parameters

Azimuth Use this to specify the direction (in degrees) around which you require the filter to pass or reject data. The azimuth is measured clockwise from North with 0° corresponding to North.

Azimuthal Half Width Use this to specify the half angle (in degrees) within which the filter will pass or reject data.

Rolloff Degree Use this to specify the degree of rolloff that you require for the cosine function. The normal degree range is between 0.5 and 2. Lower rolloff degrees result in a steeper 'ridge'**Azimuthal Half Width** Use this to specify the half angle (in degrees) within which the filter will pass or reject the data.

Pass / Reject Select Pass to pass data around the direction you have specified and reject the rest of the data. Select Reject to reject data around the direction you have specified and pass the rest of the data.

Complex filters

Parent topic: **INTREPID spectral domain operations reference (R14)**

(Spectral Domain Grid Filters only) The Complex filters are commonly used special combinations of filters.

In this section:

- Pseudo gravity transformation (reference)
- Susceptibility filter (reference)
- Decorrugation filter (reference)
- Apparent density filter (reference)

Pseudo gravity transformation (reference)

Parent topic: Complex filters

Gravity behaves similarly to magnetic fields as the distance from the source increases. Using the magnetic field, you can estimate the gravity anomaly that would be observed if the magnetisation distribution were replaced with an identical density distribution. This transformation can be useful for determining the edges of source bodies, and comparing gravity and magnetic data to distinguish between the effects of different source rock types.

The transformation of magnetic anomaly into pseudogravity is done through Poisson's relation. You need to specify the ratio of susceptibility contrast to average density contrast as a parameter for the transformation.

Here is a formula for a pseudo gravity filter. It assumes that you require the gravity field at the same height as the magnetic readings. Where

G = Universal Gravitational Constant
T = Geomagnetic field intensity
p = contrast ratio
Δ = height separation
r = radial distance from origin of spectral domain

$$F(r) = \frac{Gp}{4T}\frac{e^{\Delta hr}}{r}$$

Pseudo gravity transformation—parameters

Inclination, Declination, Field Intensity See The geomagnetic reference field in INTREPID (R15) for information about these parameters.

Susceptibility / Density Contrast Ratio See the discussion immediately above for an explanation of this parameter. If you are only interested in the relative distribution of gravity data, set this to 1. To obtain gravity in SI units, enter all values in SI units.

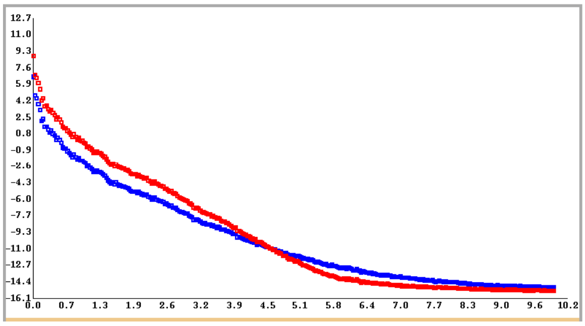
Altitude Separation Use this to specify the difference (in m) between the height of the magnetic reading and the desired apparent height of the gravity field values calculated.

Susceptibility filter (reference)

Parent topic: Complex filters

This is a commonly used composite of Downward Continuation, Reduction to the Pole and Prism Map filters. This filter indicates the susceptibility of the land surveyed to magnetic induction. INTREPID applies the Susceptibility filter to a vertical prism of earth with a square cross section. See Continuation filters (reference) and Reduction filters (reference) for more details about these components.

Here is an illustration of the effect of the Susceptibility filter, showing the power spectrum of the original data (lower curve at left end) and the filter results (upper curve at left end).



Susceptibility filter—parameters

Inclination, Declination, Field Intensity See The geomagnetic reference field in INTREPID (R15) for information about these parameters.

Depth of continuation Use this to specify the depth (in metres) below the sensor at which you wish to 'view' the data.

Latitude for amplitude limit Use this to specify the latitude below which you wish to adjust the phase only of the data. See Reduction to the Pole (reference) for a detailed description of this parameter

Dimension of prism Use this to specify the side (in metres) of the square prism cross section.

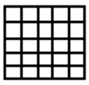
Note - if the susceptibility spectral filter window displays 'stripes' or 'banding effects', this usually means the dimension of the prism is set too high. In this case decrease that parameter and the stripes will retreat to the top and bottom ends of the graphical filter response, and eventually disappear. You'll also get an output grid that appears less smoothed.

The output from the magnetic susceptibility complex filter are in S.I. units.

Decorrugation filter (reference)

***Parent topic:* Complex filters**

Magnetic surveys carried out using an aircraft involve the aircraft alternately travelling in opposite directions across the area to be surveyed. Sometimes the direction of traverse subtly affects the Z data. After the gridding process, if you are viewing the results of the survey as an grid, you can see the traverse patterns as 'corrugations'.



The Decorrugation filter can detect and remove these corrugations from the data. Decorrugation uses a combination of Butterworth and Directional Cosine filters (See Butterworth filter (reference) and Directional cosine filter (reference) for a detailed description.

We provide a separate Decorrugation tool for decorrugation in the survey levelling process. This tool uses Naudy and/or Fuller filters directly on the spatial data, whereas the decorrugation filter described here in the Grid Filters tool works on the data in the spectral domain. You can use the Decorrugation tool instead of the spectral domain decorrugation process if you wish. See Decorrugation (T32) for a full description of Decorrugation.

Decorrugation filter—parameters

Line Spacing Use this to specify the average distance between the traverse lines in the original survey.

Direction Along Striping from North Use this to specify the approximate direction of the corrugations. This is usually the same as the direction of the traverse lines in the original survey. Specify the direction as a number between 0 and 180 representing the bearing in degrees. 0° and 180° indicate North–South bearing and 90° indicates East–West.

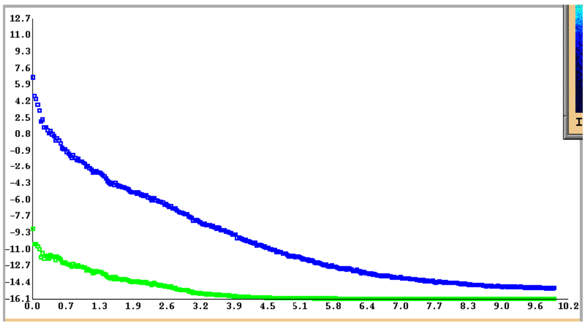
If you do not know the direction of the traverse lines in the original survey, you can use the Gridding tool or Flight Path Editor modules to report the average strike (See "Nominal Bearing" in Old Gridding (T22) and "Line data validation" in Flight Path Editor (T19) for instructions).

Apparent density filter (reference)

Parent topic: **Complex filters**

If you are working with gravity data, you can use the Apparent Density filter to estimate the density of the source. The Apparent Density model assumes that the source is contained in a uniform layer of earth. You can specify the layer thickness for the model.

We recommend that you also apply a Downward Continuation filter to the data before using the Apparent Density filter. This filter should transform your view of the data to the top surface of the source (i.e., the Continuation level should be equal to the distance from the sensor to the assumed top surface of the source.
Here is an illustration of the effects of an Apparent Density filter, showing the power spectrum of the original data (upper curve) and the filter results (lower curve).



Apparent density filter—parameters

Thickness of the Earth Model Use this to specify the thickness of the earth layer that you are assuming contains the source.

Vertical Integral filter (reference)

Parent topic: **INTREPID spectral domain operations reference (R14)**

This filter integrates from the observation elevation up to infinity. In principle it is the reverse operation of the first vertical derivative.

The Altitude Difference parameter is the altitude above the ground at which the data was collected. INTREPID will use this parameter to downward continue the data to the ground before performing the vertical integration, so that the resulting integration will more closely resemble a ground based survey result.

One use of the vertical integral filter is in combination with a gradient filter, such as the Analytic Signal, to convert the data back to the original 'non-gradient' units.