GPGN 411/511: Advanced Gravity and Magnetic Exploration

Lab Exercise #06 Wavenumber Domain Processing: Component conversion and upward continuation

Objectives:

Explore potential-field processing of potential-field data in the wavenumber domain by utilizing gravity gradient data computed from the same cubic source used in lab exercises #03 and #04, and the framework of the codes developed in #06.

Relevant Concept:

Convert potential-field data to different components and perform upward continuation in wavenumber-domain operations. Again, the assumption is that the data are on a planar observation surface.

Background:

Recall that different components the potential-field data produced by the same source are related to each other by simple operators (transfer functions) in the wavenumber domain. For a given component, the data at different heights are also connect to each other by the upward continuation operator. This lab is designed so you can test these operators by comparing the converted components from those calculated directly.

Tasks-I

Utilizing the code from Lab#06 and develop the wavenumber domain functionality to compute the following, respectively,

1) Conversion from Tzz of gravity gradient to Txx, Tyy, Txy, Txz, Tyz components
2) Convert the total-field anomaly to the vertical component
3) Upward continue the data by a height different of Δh

For this lab, you must first, write down the expressions for these wavenumber-domain operators before you start coding. *For coding, you must treat the operator at the origin of the wavenumber domain separately since direct application will lead to a division by zero*.

Please note, for each operation, three steps are involved (as in Lab#06):

(1) Input the data and perform FFT,
(2) Apply your wavenumber domain operator (transfer function, or filter operator), and
(3) Perform inverse FFT to obtain the result in the space domain.

This sequence is illustrated in the flowchart in Figure 1.

For practical use, such a code can apply multiple operations listed above by combining them together since all operations are linear. For the purpose of this lab, we will simplify and have the code perform one operation each time. Therefore, you need an input control parameter that specifies which derivative is to be performed.

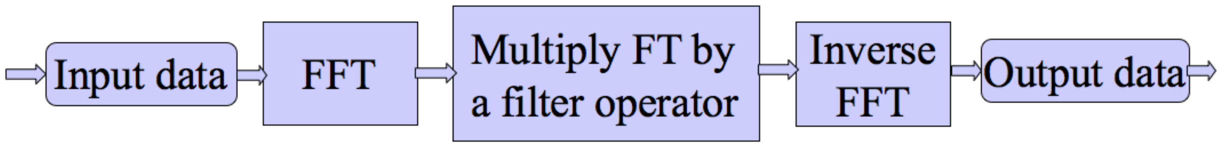

Figure 1. Flowchart for derivative calculation through the wavenumber-domain operation. *Please note that the data map must be folded and unfolded before and after, respectively, applying the FFT routine.*

Task-II

1. Using your Lab02 code and calculate the Tzz component the same 64-by-64 grid as in the lab02 for the cubic source listed in Task-III of that lab. Input the data into your new code, interpolate to the 64x64 grid as needed, and then convert the Tzz to the Txx, Tyy, Txy, Txz, Tyz components, and compare with the corresponding components directly computed from Lab02 code and the same source.
2. Using your Lab02 code and calculate a component of your choice on the same 64-by-64 grid at two different observation height, for example, z=0, and z=-100 m. Input the data at z=0 into your new code, interpolate to the 64x64 grid as needed, upward continue the data by 100 m, and compare with the directly computed data.
3. Using your Lab03 code and calculate the magnetic total-field anomaly and vertical-component anomaly from the cube in that lab on the same 64-by-64 grid. Input the data into your new code, interpolate to the 64x64 grid as needed, and then convert the total-field anomaly into the vertical component of the magnetic anomaly. Compare the converted vertical anomaly with the directly calculated one.

Note-1: For each comparison, you should consider plotting the result from wavenumber-domain calculation and difference directly calculated field from modeling code (either lab#3 or Lab#4). You should also calculate the L_1 (sum of absolute difference), L2 (square root of the sum of the difference squared), and L_∞ (maximum absolute difference) norms of the difference map.

Note-2: For each map, discuss the possible source of errors that could have led to the observed differences.

Task-III: *25% bonus*: Examine the de-noising effect of upward continuation operation

Take one of the data sets you are working with in Task-II, add independent Gaussian random noise to the data (meaning to each datum). For gravity gradient, a standard deviation of 5 eotvos would be a reasonable one to try; and for the magnetic anomaly, a standard deviation of 10 nT would be fun to test. Then, upward continue the noise-contaminated data by some height and compare with the data you calculated directly from the modeling code, and observe the suppression of the added noise.

In addition, you can do an experiment to see what the minimum continuation height is to attenuate the noise.

Report

Submit a report in notebook format with your name, class, lab number. Include following sections:

1. Objectives of this lab and explanation of concepts covered
2. One summary section describing the program you have developed for this lab, with brief instruction on the usage of your program. Please write in such a way that a user (who could be the future yourself down the road!) can readily apply your code to different data sets.
3. Three sections on the work in described in Task-II above including the observation and any conclusion you have reached.
4. Optionally: a section on bonus work.
5. A concluding section on the general understanding you have gain from these tests.