

APPLIED GEOPHYSICS

Course Name: Magnetic Method Practical

Course Code: GPC522

**Venue: Remote Sensing and Gravity Magnetic Lab,
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PRACTICAL-1

Estimation of average rate change of dipole and quadrupole components of the geomagnetic field

Objectives/Learning outcome: To understand the temporal variation of the geomagnetic field from different IGRF models

Questions:

- 1) Calculate the root mean square intensity of the dipole and quadrupole components of the geomagnetic field at the Earth's surface for the IGRF models.
- 2) Plot the root mean square intensity of both dipole and quadrupole components of the geomagnetic field as a function of time.
- 3) Estimate the average rate change of both dipole and quadrupole components of the geomagnetic field

The Gauss coefficients (in nT) for the dipole and quadrupole components of the geomagnetic field from the different IGRF models are provided below.

g_n^m / h_n^m	IGRF-1985	IGRF-1990	IGRF-1995	IGRF-2000	IGRF-2005	IGRF-2010	IGRF-2015	IGRF-2020
g_1^0	-29873	-29775	-29692	-29619.4	-29554.63	-29496.57	-29441.46	-29404.8
g_1^1	-1905	-1848	-1784	-1728.2	-1669.05	-1586.42	-1501.77	-1450.9
h_1^1	5500	5406	5306	5186.1	5077.99	4944.26	4795.99	4652.5
g_2^0	-2072	-2131	-2200	-2267.7	-2337.24	-2396.06	-2445.88	-2499.6
g_2^1	3044	3059	3070	3068.4	3047.69	3026.34	3012.2	2982.0
h_2^1	-2197	-2279	-2366	-2481.6	-2594.50	-2708.54	-2845.41	-2991.6
g_2^2	1687	1686	1681	1670.9	1657.76	1668.17	1676.35	1677.0
h_2^2	-306	-373	-413	-458.0	-515.43	-575.73	-642.17	-734.6

Theory:

The power spectrum of a magnetic field is defined as the scalar product of averaged magnetic field over the surface of the sphere with radius a .

$$I_l = \frac{1}{4\pi a^2} \int_0^{2\pi} \int_0^\pi B_l \cdot B_l a^2 \sin\theta \, d\theta d\varphi,$$

Therefore, B_l equal to

$$B_l = -\nabla \left[a \left(\frac{a}{r} \right)^{l+1} \sum_{m=0}^l (g_l^m \cos m\varphi + h_l^m \sin m\varphi) P_l^m(\cos\theta) \right]$$

From this, the power spectrum for a particular degree l is given by

$$I_l = (l+1) \sum_{m=0}^l [(g_l^m)^2 + (h_l^m)^2].$$

Methodology:

- The mean square intensity is given by

$$R_n^2 = (n + 1) \sum_{m=0}^n [(g_n^m)^2 + (h_n^m)^2]$$

- For a dipole field, $n=1$ and $m=0$ to 1. Therefore, the above expression can be evaluated as:

$$R_d^2 = (2)[(g_1^0)^2 + (g_1^1)^2 + (h_1^1)^2]$$

So, the RMS intensity becomes:

$$R_d = \sqrt{R_d^2}$$

- For a non-dipole field, $n=2$ and $m=0$ to 2. Therefore, the above expression can be evaluated as:

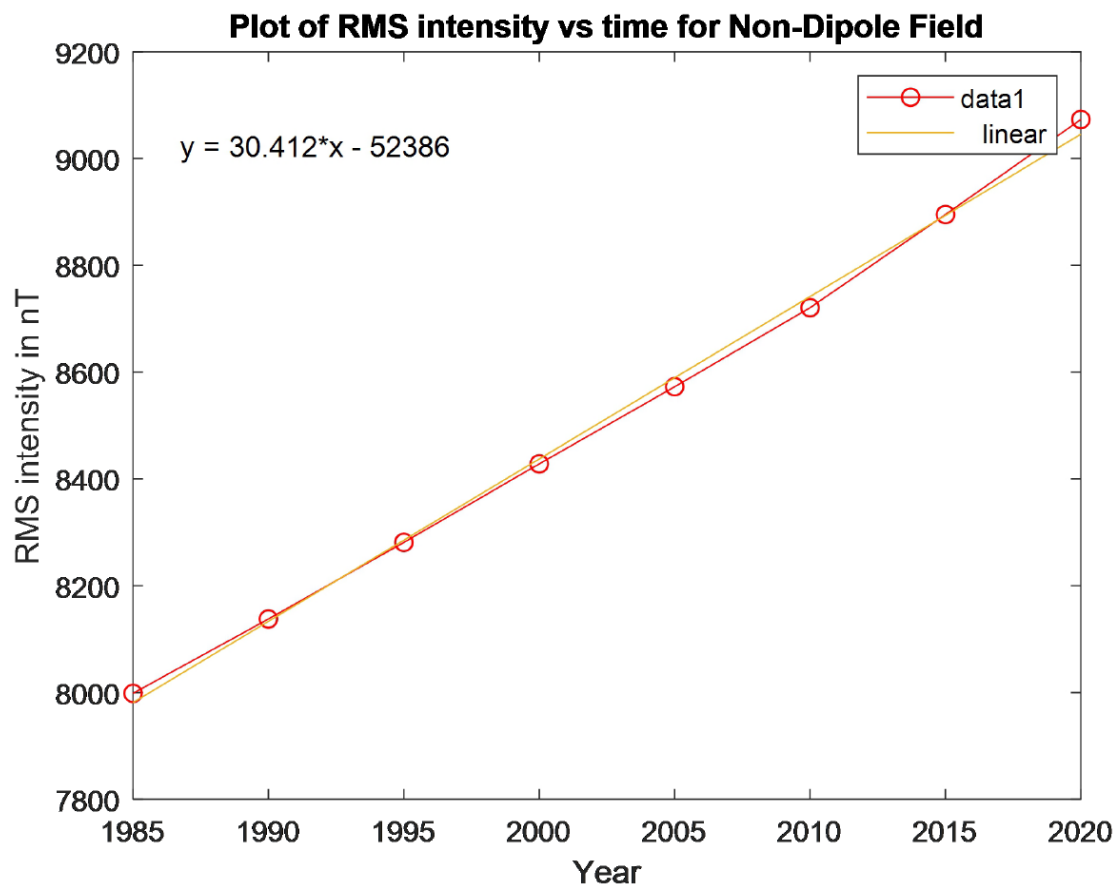
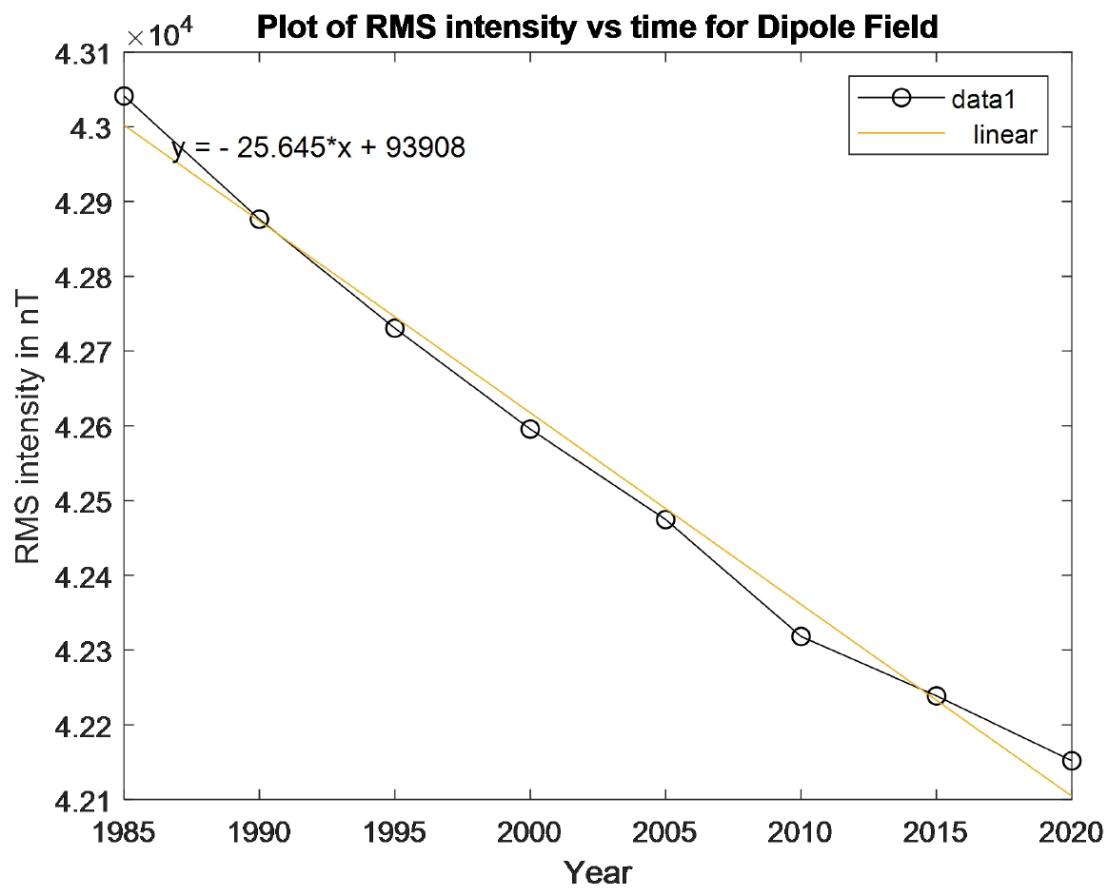
$$R_{nd}^2 = (3)[(g_2^0)^2 + (g_2^1)^2 + (g_2^2)^2 + (h_2^1)^2 + (h_2^2)^2]$$

So, the RMS intensity becomes:

$$R_{nd} = \sqrt{R_{nd}^2}$$

Pseudo python code:

1. Define an array to load Gauss coefficients (in nT) for the dipole and quadrupole components of the geomagnetic field from the different IGRF models.
2. Create a loop for i in range(1, n): to compute the root mean square intensity of the dipole and quadrupole components of the geomagnetic field at the Earth's surface for the IGRF models.
3. Do the regression analysis.
4. Create plots of the root mean square intensity of the dipole and quadrupole components of the geomagnetic field.



PRACTICAL-2

Reduction of Magnetic data and preparation of anomaly map

Objectives/Learning outcome: Helps to understand the survey practices and data processing techniques used in magnetic exploration.

Questions: The magnetometer readings in the below tables are from a detailed survey conducted over old sulfide and chromite mineralization zones, respectively. The base magnetometer was programmed to collect data every 5 min.

- 1) Process the raw data by applying necessary corrections.
- 2) Plot the Diurnal curve for the entire period of the survey.
- 3) Plot the raw magnetic data and processed magnetic data. Discuss the likely geologic sources of the fluctuations in the total field magnetic anomaly.

Case study: I

Station	Time	Longitude	Latitude	Reading
Base	8:00	-	-	47217.73
1	8:10	76.2751	27.36647	47289.25
2	8:20	76.2760	27.3662	47311.375
3	8:30	76.2770	27.36611	47328.11
4	8:40	76.27775	27.36602	47333.13
5	8:50	76.27875	27.36586	47327.16
6	9:00	76.2797	27.3656	47290.785
7	9:10	76.28075	27.3655	47286.93
8	9:20	76.2817	27.365305	47278.147
9	9:30	76.2837	27.364972	47302.61
10	9:40	76.28475	27.364805	47311.645
11	9:50	76.2858	27.364638	47309.25
12	9:60	76.2867	27.36447	47383.11
13	10:10	76.2877	27.36427	47287.73
14	10:20	76.2887	27.36411	47272.125
15	10:30	76.2897	27.36394	47276.19
16	10:40	76.29075	27.36377	47270.635
17	10:50	76.2917	27.36361	47275.67
18	11:00	76.2927	27.36338	47284.21
19	11:10	76.2937	27.36327	47288.365
20	11:20	76.29475	27.36308	47311.965
21	11:30	76.29575	27.36291	47281.695
22	11:40	76.2967	27.36277	47309.33
23	11:50	76.29775	27.36258	47288.935
24	12:00	76.29875	27.36241	47296.3
Base	12:30	-	-	47229.3675

Case study: II

Station	Time	Longitude	Latitude	Reading	Station	Time	Longitude	Latitude	Reading
1	9:07	-116.26094	35.90388	48627.4	13	10:18	-116.25987	35.90303	48631.7
2	9:13	-116.25974	35.90464	48642	14	10:30	-116.26206	35.90515	48621.8
3	9:20	-116.25828	35.90575	48644.1	15	10:34	-116.26089	35.90598	48621.1
4	9:25	-116.25774	35.90635	48637.8	16	10:40	-116.25938	35.90685	48621.2
5	9:30	-116.25736	35.90665	48642.7	14	10:45	-116.25883	35.90713	48619.6
6	9:42	-116.25611	35.90767	48652.5	18	10:51	-116.25939	35.90852	48622.3
7	9:47	-116.25505	35.90829	48645.4	19	10:55	-116.25865	35.90876	48621.3
8	9:54	-116.25351	35.90742	48659.3	20	11:01	-116.26067	35.90784	48621
9	9:59	-116.25474	35.90641	48657.3	21	11:07	-116.26236	35.90727	48618.9
10	10:04	-116.2561	35.90551	48647	22	11:13	-116.2635	35.90673	48611.9
11	10:08	-116.25721	35.90481	48654.3	23	12:04	-116.26435	35.90814	48602.6
12	10:13	-116.25849	35.90934	48624.2	24	12:08	-116.26354	35.90866	48608.2

Base magnetometer readings:

Time (min)	Reading (nT)	Time (min)	Reading (nT)	Time (min)	Reading (nT)
8:57	48512.75	80	48512.09	160	48512.28
5	48512.577	85	48512.884	165	48511.982
10	48512.49	90	48513.57	170	48511.76
15	48512.649	95	48513.966	175	48511.671
20	48516.97	100	48513.49	180	48511.93
25	48513.287	105	48513.368	185	48511.849
30	48515.77	110	48513.64	190	48512.01
35	48516.675	115	48512.882	195	48512.731
40	48517.12	120	48514.61	200	48513.33
45	48520.725	125	48515.171	205	48514.497
50	48515.25	130	48514.24	210	48514.59
55	48518.354	135	48513.542	215	48514.77
60	48512.31	140	48511.55	220	48515.01
65	48512.206	145	48513.457	225	48513.264
70	48512.35	150	48512.56	230	48513.42
75	48512.492	155	48512.702		

Theory:

The mathematical representation of the low-degree parts of the geomagnetic field is determined by an international agreement, which is called the International Geomagnetic Reference Field, or IGRF. The latest version is IGRF-13. The IGRF is a series of mathematical models of the Earth's main field and its annual rate of change (secular variation). The lower-order terms represent the core, and the higher-order terms represent the crustal magnetic field. The observed readings on the magnetometer are a combination of the target signal, the ambient Earth's magnetic field, and the external magnetic field. The diurnal variations are due to solar storms or solar quiet. We remove the ambient Earth magnetic field by subtracting the IGRF from the observed magnetometer readings. We remove the external magnetic field variations due to the solar effect by subtracting the diurnal corrections from the IGRF corrected data.

Methodology:

- The raw magnetic data that we collected in the field has the combined effect of ambient Earth's magnetic, target source, and the external field. So, we will have to remove the effect of ambient Earth's magnetic field by subtracting IGRF data from the same location from the readings.
- To remove the Diurnal effect, we have to subtract the Diurnal variation from the readings. So, processed data = Readings – IGRF – Diurnal variation
- Diurnal value= Diurnal rate* time
- Diurnal rate= Slope of the graph was drawn by joining the 2 base station readings.
- IGRF values were calculated from the NCEI Geomagnetic calculators <https://ngdc.noaa.gov> by providing the longitude and latitude values at the mean sea level.

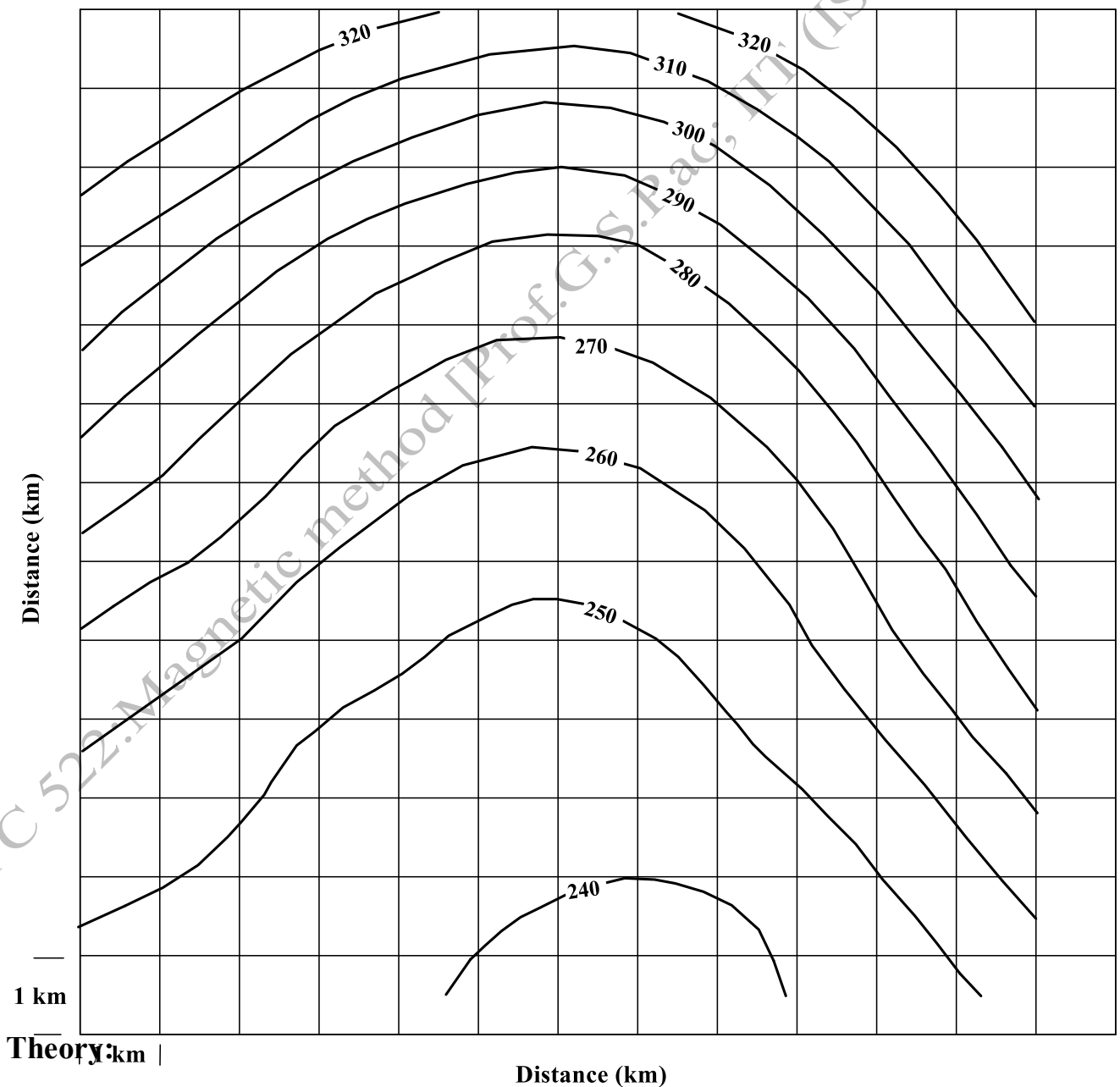
PRACTICAL-3

Preparation of regional & residual anomaly maps by using the Graphical method

Objectives & Learning outcomes: To illustrate the different regional & residual anomaly separation techniques used in the magnetic data processing

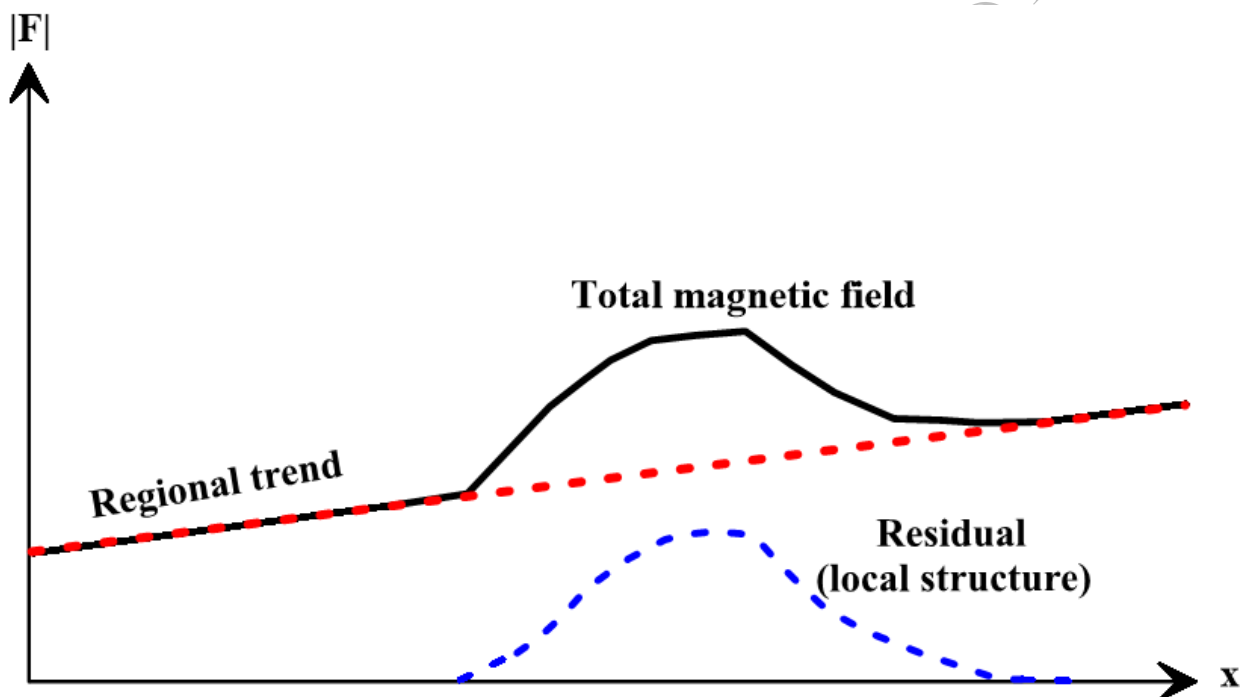
Questions: The Aeromagnetic data over Elk City, Oklahoma was collected by US Geological survey during 1977-1978 field seasons. The data was acquired at an altitude of 500 feet above the ground with a flight line spacing of 1 km, and the total intensity of the magnetic anomaly map after applying the Diurnal and IGRF corrections is shown in the below figure.

- 1) Compute regional anomaly using the graphical smoothing technique and prepare the residual anomaly map.



- Any given gravity/magnetic anomaly map is the superposition of various anomalies corresponding to bodies at different depths in the subsurface. Smaller local disturbances very near to the ground surface contribute to low amplitude and high-frequency anomalies, known as noise. These can be detected easily on a contour map or a profile and can be eliminated by smoothing. The remaining observed gravity anomaly map contains two components

- 1. Regional anomaly:** deep-seated structures giving rise to broad and smoothly varying gradient
- 2. Residual anomaly:** arises due to the geological features or ore deposits of interest giving rise to localized anomalies



PRACTICAL-4

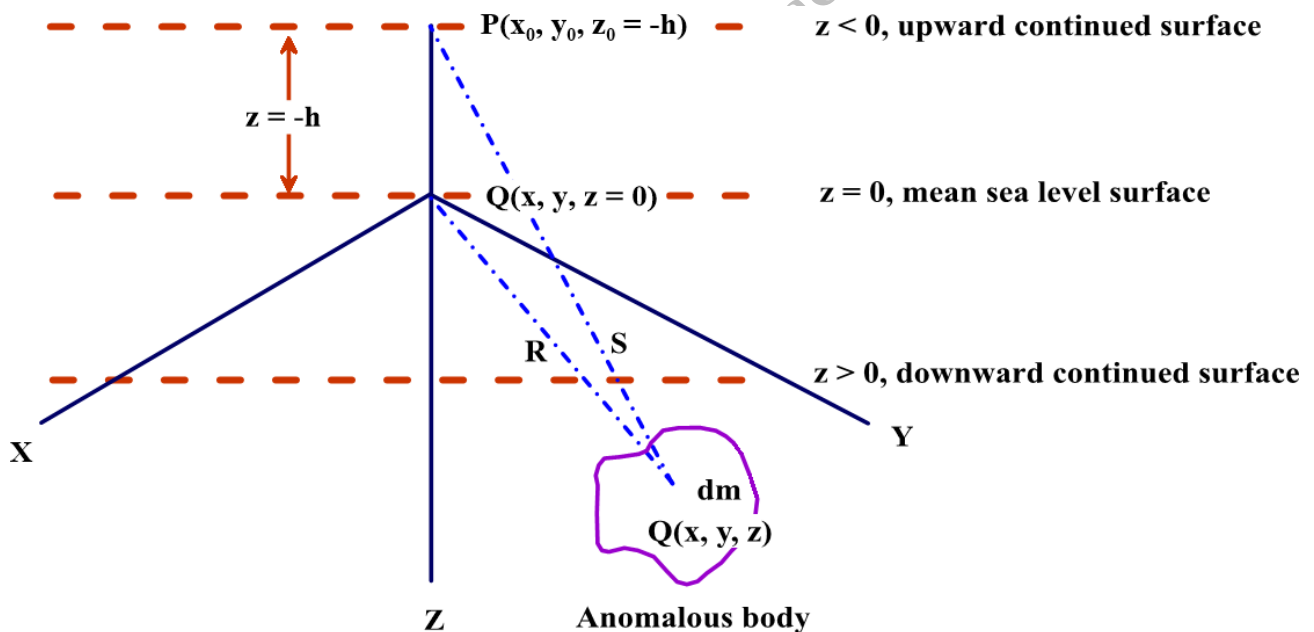
Upward and downward continuation of Aeromagnetic magnetic data

Objectives & Learning outcomes: To illustrate the different regional & residual anomaly separation techniques used in the magnetic data processing

Questions: The Aeromagnetic data over Elk City, Oklahoma, was collected by US Geological survey during the 1977-1978 field seasons. The data was acquired at an altitude of 500 feet above the ground with a flight line spacing of 1 km, and the total intensity of the magnetic anomaly map after applying the diurnal and IGRF corrections is shown in the below figure.

- 1) Compute upward continued anomaly at 6000 feet using Peter's grid method technique.
- 2) Compute downward continued anomaly at 50 feet using Peter's grid method technique.

Theory: Upward continuation transforms the potential field measured on one surface to the field that would be measured on another surface farther from all sources. This transformation attenuates anomalies with respect to wavelength; the shorter the wavelength, the greater the attenuation



Methodology:

- The entire computation can be done if the anomaly map is covered into a regular grid and the grid points are used to define average radial magnetic for various circles
- As the magnetic at any point is not known analytically, for the numerical purpose, it can be explained in terms of average radial magnetics, and upon integration, it assumes the form

$$\Delta T(n) = \sum_{i=0}^N C_i \times \Delta T(r_i)$$

where,

$$C_0 = \frac{1}{2} \left[1 - \frac{h}{\sqrt{h^2 + r_1^2}} \right]$$

$$C_1 = \frac{1}{2} \left[1 - \frac{h}{\sqrt{h^2 + r_2^2}} \right]$$

$$\text{and } C_i = \frac{1}{2} \left[\frac{h}{\sqrt{h^2 + r_{i-1}^2}} - \frac{h}{\sqrt{h^2 + r_{i+1}^2}} \right] \text{ for } i \geq 2$$

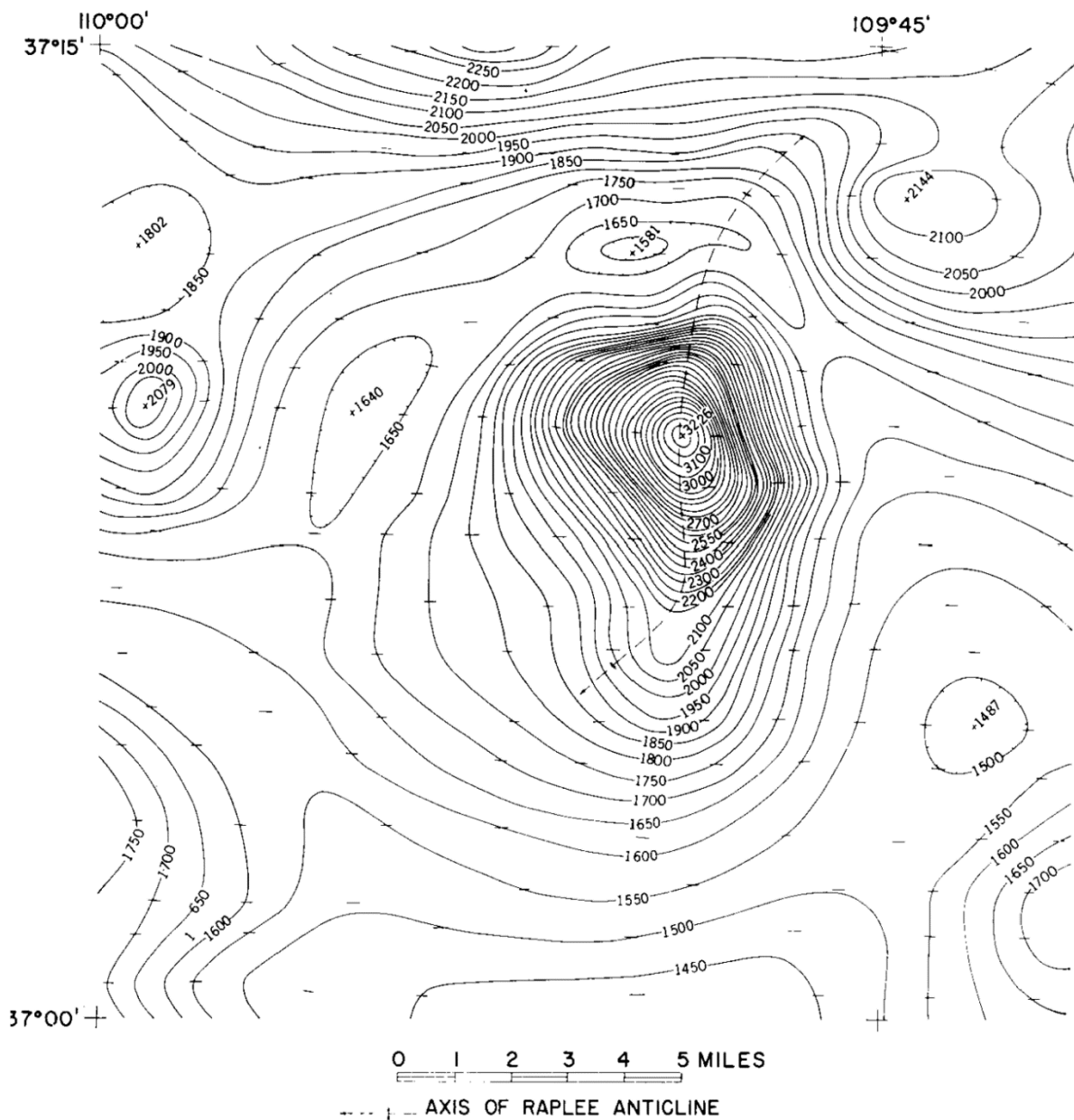
PRACTICAL-5

Computation of Second vertical derivative of Aeromagnetic anomaly data

Objectives & Learning outcomes: To illustrate the efficacy of the Second vertical derivative technique in separating the residual anomalies when they are masked by strong regional features

Questions: The Aeromagnetic contour map over the Mexican Hat area, UTH is shown in the below figure. The measurements were made with AN/ASQ-3A fluxgate magnetometer, flown at an altitude of 500 feet above the mean sea level along the line spaced about 1 mile apart.

- 1) Compute the Second vertical derivative anomaly using Peter's grid method technique



Computational scheme: The calculation of derivatives (usually the second) has been reduced to the practical method of computation using values from a regular grid of points to determine the average around circles of different radii from a central point (Elkins, 1951). A general template of the three-ring system for the calculation of second derivatives is shown.

$$g_{zz} = \frac{C}{S^2} (W_0 g_0 + W_1 g_1 + W_2 g_2 + \dots + W_n g_n)$$

g_{zz} = Second derivative

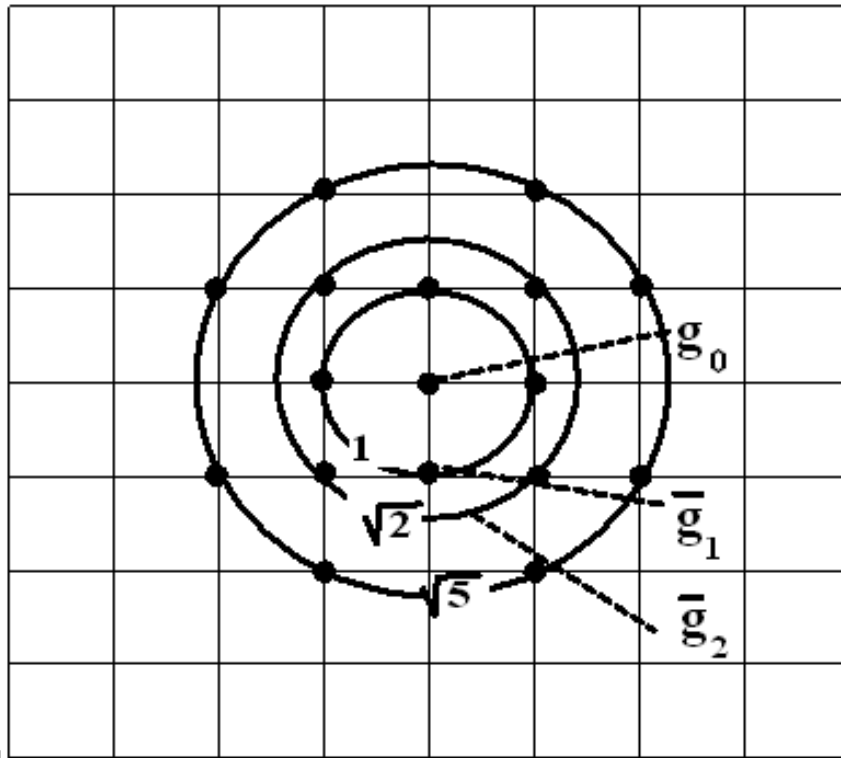
C = Constant for particular system.

S = Grid spacing

$W_0, W_1, \dots$ = Weighting factors.

g_0 = Gravity at point of calculation.

$g_1, g_2, \dots$ = Average value around the successive rings



PRACTICAL-6

Regional-residual separation using polynomial regression and image enhancement filters

Objectives & Learning outcomes: To compare the residual anomalies obtained from polynomial regression, low pass filter, and upward continuation

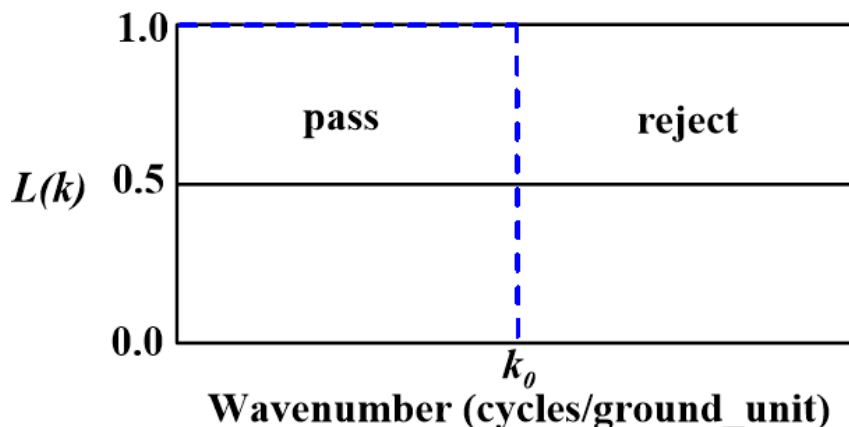
Questions: Compute the residual magnetic anomaly along the given magnetic profile data using polynomial regression (Least square technique), low pass filter, and upward continuation techniques. Also, provide your comments on polynomial regression, low pass filter, and upward continuation anomaly plots.

Distance (m)	Total magnetic intensity (nT)	Distance (m)	Total magnetic intensity (nT)
0	9.45	16000	-4.12
1000	11.7	17000	-18.47
2000	14.43	18000	-25.79
3000	17.68	19000	-28.84
4000	21.5	20000	-29.83
5000	25.9	21000	-29.76
6000	30.86	22000	-29
7000	36.43	23000	-27.71
8000	42.69	24000	-26.04
9000	49.8	25000	-24.14
10000	57.6	26000	-22.15
11000	64.4	27000	-20.18
12000	65.96	28000	-18.3
13000	57.8	29000	-16.55
14000	39.97	30000	-14.15
15000	17.09	-	-

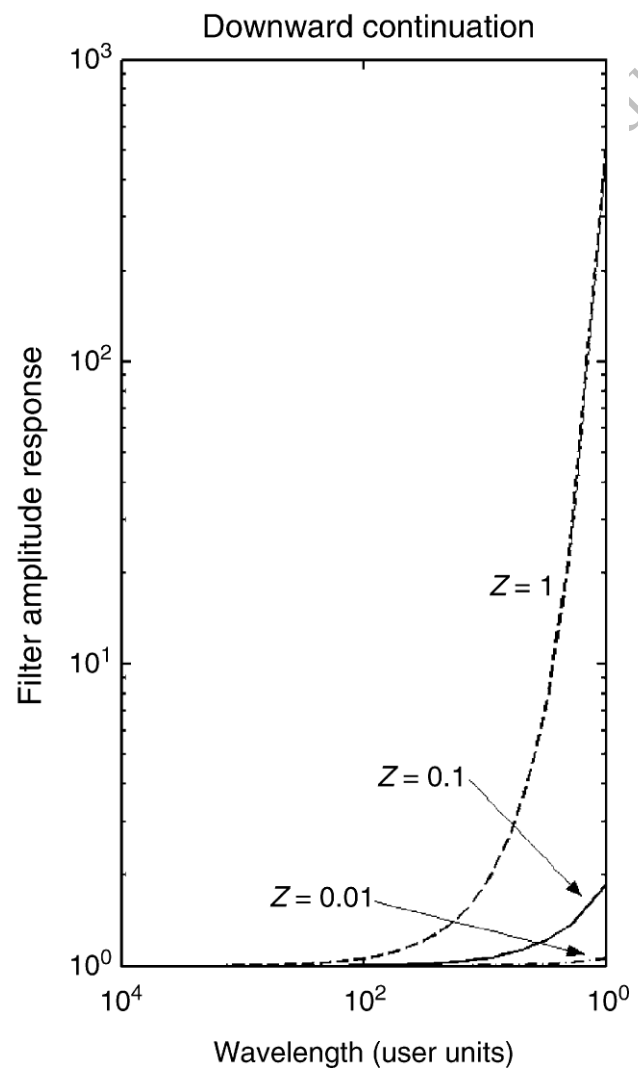
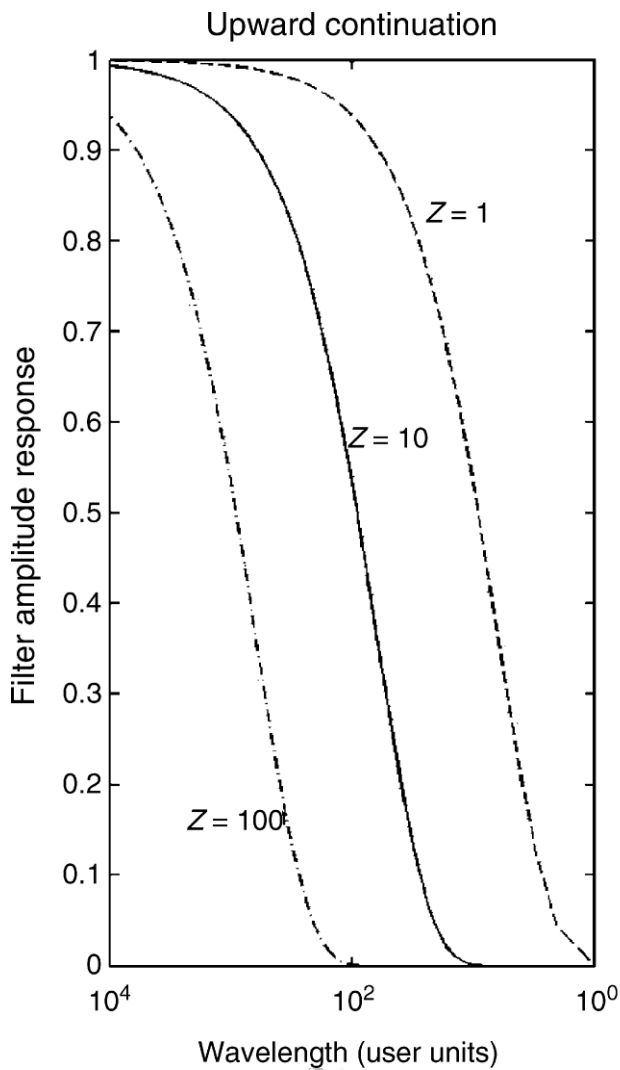
Theory

- Low pass filter: $L(k) = 1$ for $k \leq k_0$
 $L(k) = 0$ for $k > k_0$

Where k_0 is the cut-off wavenumber in cycles/ground unit. All wavenumbers above this value are removed.



- Upward continuation is considered a “clean” filter because it produces almost no side effects that may require the application of other filters or processes to correct. Because of this, this filter is often used to remove or minimize the effects of shallow sources and noise in grids.



PRACTICAL-7

Qualitative interpretation of magnetic anomaly data using derivative filters

Objectives & Learning outcomes: To understand the interpretation of the first vertical derivative (FVD), and second vertical derivative (SVD) of aeromagnetic anomalies

Questions: Compute the first vertical derivative (FVD), and second vertical derivative (SVD) along the given total magnetic intensity profile data. Also, provide comments on the first vertical derivative and second vertical derivative plots.

Distance (m)	Total magnetic intensity (nT)	Distance (m)	Total magnetic intensity (nT)
0	98.81	16000	-151.53
1000	122.94	17000	-255.96
2000	153.05	18000	-309.94
3000	190.53	19000	-325.92
4000	236.95	20000	-318.78
5000	293.74	21000	-299.67
6000	361.53	22000	-275.49
7000	438.58	23000	-250.08
8000	517.96	24000	-225.44
9000	584.33	25000	-202.54
10000	614.58	26000	-181.74
11000	587.83	27000	-163.12
12000	497.99	28000	-146.58
13000	355.38	29000	-131.96
14000	180.59	30000	-119.05
15000	1.28	-	-

MODEL PYTHON CODE

```
## Compute the first vertical derivative, and second vertical derivatives for magnetic anomaly profile data.
```

```
# Load python modules
```

```
import numpy as np
```

```
import pandas as pd
```

```
import matplotlib.pyplot as plt
```

```
# Load and print the magnetic anomaly profile data
```

```
df = pd.read_csv('data_7.csv')
```

```
df
```

```
d=df['Distance(m)'].to_numpy()
```

```
T=df['Total magnetic intensity(nT)'].to_numpy()
```

```
# Plot the magnetic anomaly profile data
```

```
plt.figure( figsize=(7,4),dpi=80)
```

```

plt.plot(d,T,'r')
plt.scatter(d,T,color='none',edgecolor='r')
plt.legend(['Observed Anomaly'])
plt.xlabel('Distance in m --->')
plt.ylabel('Magnetic Anomaly in nT')
plt.title('Given Anomaly')
plt.grid()
plt.show()

# Compute the first vertical derivative, and second vertical derivatives
from numpy.fft import fft,ifft
kmax=1/1000; # we know kmax=1/sampling_interval
kmin=1/30000; # we know kmax=1/profile_length
k=np.linspace(kmin,kmax,31)
f=fft(T)
svd1_f=np.multiply(abs(k),f)
svd2_f=np.multiply(abs(k)*abs(k),f)
svd1=abs(ifft(svd1_f))
svd2=abs(ifft(svd2_f))

# Plot the first vertical derivative for magnetic anomaly profile data
plt.figure( figsize=(7,4),dpi=80)
plt.plot(d,svd1,'g')
plt.scatter(d,svd1,color='none',edgecolor='g')
plt.legend(['First Vertical Derivative'])
plt.xlabel('Distance in m --->')
plt.ylabel('FVD in nT')
plt.title('FVD vs Distance plot')
plt.grid()
plt.show()

# Plot the second vertical derivative for magnetic anomaly profile data
plt.figure( figsize=(7,4),dpi=80)
plt.plot(d,svd2,'b')
plt.scatter(d,svd2,color='none',edgecolor='b')
plt.legend(['Second Vertical Derivative'])
plt.xlabel('Distance in m --->')
plt.ylabel('SVD in nT')
plt.title('SVD vs Distance plot')
plt.grid()
plt.show()

```

PRACTICAL-8

Computation of analytical signal of magnetic anomalies

Objectives & Learning outcomes: To understand the interpretation of the analytical signal of aeromagnetic anomalies

Questions: Compute analytic signal (AS) along the given total magnetic intensity profile data.

Distance (m)	Total magnetic intensity (nT)	Distance (m)	Total magnetic intensity (nT)
0	98.81	16000	-151.53
1000	122.94	17000	-255.96
2000	153.05	18000	-309.94
3000	190.53	19000	-325.92
4000	236.95	20000	-318.78
5000	293.74	21000	-299.67
6000	361.53	22000	-275.49
7000	438.58	23000	-250.08
8000	517.96	24000	-225.44
9000	584.33	25000	-202.54
10000	614.58	26000	-181.74
11000	587.83	27000	-163.12
12000	497.99	28000	-146.58
13000	355.38	29000	-131.96
14000	180.59	30000	-119.05
15000	1.28	-	-

Theory: The analytical signal method is useful for delineating magnetic source location with peak amplitude occurring over magnetic contacts. The method is very useful in low magnetic latitudes. If more than one sources are present, the shallow sources are well resolved. The complex analytical signal of a structure can be written as

$$A = |A| \exp(j\theta)$$

$$|A(x, y)| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2}$$

where f is the magnitude of the total field and θ is the local phase

MODEL PYTHON CODE

```
## Compute the analytic signal for magnetic anomaly profile data.
# Load the python modules
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

```

# Load the magnetic profile data
df = pd.read_csv("data_7.csv")
df.
d=df['Distance(m)'].to_numpy()
T=df['Total magnetic intensity(nT)'].to_numpy()

# Fourier transform
from numpy.fft import fft,ifft
n=len(T)
k=np.arange(-(n-1)/2,(n+1)/2)
f_T=fft(T)

# Plot the Fourier transform data
plt.figure( figsize=(7,4),dpi=80)
plt.plot(k,abs(f_T),'g')
plt.scatter(k,abs(f_T),color='none',edgecolor='g')
plt.xlabel('k')
plt.ylabel('F(k)')
plt.title('F(k) vs k')
plt.grid()
plt.show()

# Compute the analytical signal
for i in range(31):
    if k[i]<0:
        f_T[i]=0
    else:
        f_T[i]=2*f_T[i]

# Plot the analytical signal in wavenumber domain
plt.figure( figsize=(7,4),dpi=80)
plt.plot(k,abs(f_T),'r')
plt.scatter(k,abs(f_T),color='none',edgecolor='r')
plt.xlabel('k')
plt.ylabel('F(k)')
plt.title('Analytical signal in frequency domain')
plt.grid()
plt.show()

# Plot the analytical signal in distance
AS=ifft(f_T)
AS=abs(AS)
plt.figure(figsize=(8,5), dpi=80)
plt.plot(d,T,'r')
plt.plot(d,AS,'b')
plt.legend(['Observed Anomlay','Analytical Signal'])
plt.ylabel('Magnetic Anomaly in nT')
plt.scatter(d,T,color='none',edgecolor='r')
plt.scatter(d,AS,color='none',edgecolor='b')

```

```
plt.xlabel('Distance in m --->')  
plt.ylabel('Magnetic Anomaly in nT')  
plt.grid()
```

GPC 522:Magnetic method [Prof.G.S.Rao; IIT (ISM) Dhanbad]

PRACTICAL-9

Construction of Magnetic profiles over contact body

Objectives & Learning outcomes: To provide the theoretical formulation of magnetic response due to simple geometrical bodies like a contact.

Questions: Compute the magnetic anomaly response over a contact body, and the general expression for the total field anomaly is given below.

$$\Delta F = CF(A \cos \theta + B \sin \theta)$$

$$\text{Where, } A = \tan^{-1} \left(\frac{x}{h} \right) + \frac{\pi}{2}; \quad B = \ln(x^2 + h^2)^{1/2}$$

CF = 100 (amplitude coefficient).

θ = Arbitrary magnetization angle (0, $\pi/6$, $\pi/4$, $\pi/3$, $\pi/2$).

h = 5 km, 10 km, and 15 km (depth to the center of the body).

x = -20 to 20 km (interval of 2 units); distance of the observation from the origin.

MODEL PYTHON CODE

```
## Compute the magnetic anomaly response over a contact body
```

```
# Load python modules
```

```
import numpy as np
```

```
import pandas as pd
```

```
import matplotlib.pyplot as plt
```

```
# Input data
```

```
CF= 100
```

```
pi=np.pi
```

```
theta = [0,pi/6,pi/4,pi/3,pi/2]
```

```
h=[5,10,15]
```

```
x = np.arange(-20,20.5,0.5)
```

```
import itertools
```

```
par_comb=list(itertools.product(h,theta))
```

```
# Calculate the magnetic response over the contact body
```

```
def Magnetic_anomaly(par):
```

```
h=par[0]
```

```
theta=par[1]
```

```
x = np.arange(-20,20.5,0.5)
```

```
A=np.arctan(x/h)+(pi/2)
```

```
B=0.5*np.log(x**2+h**2)
```

```
del_f= CF*A*np.cos(theta)+CF*B*np.sin(theta)
```

```
return del_f
```

```
T=[]
```

```
for i in par_comb:
```

```
t=Magnetic_anomaly(i)
T.append(t)
```

```
# Plot the magnetic anomaly response over a contact body
```

```
plt.figure(figsize=(13, 7), dpi=80)
for i in range(1,6):
plt.plot(x,T[i-1])
plt.xlabel('Distance in meter')
plt.ylabel('Anomlay in nT')
plt.title("Magnetic Anomaly for h=5 m ")
plt.legend(["theta=0","theta=30","theta=45","theta=60","theta=90"])
plt.grid()
plt.show()
```

GPC 522:Magnetic method [Prof.G.S.Rao; IIT (ISM) Dhanbad]

PRACTICAL-10

Construction of Magnetic profiles over a vertical fault

Objectives & Learning outcomes: To provide the theoretical formulation of magnetic response due to a vertical fault.

Questions: Compute the magnetic anomaly response over a vertical fault, and the general expression for the total field anomaly is given below.

$$\Delta F = CF(A \cos \theta + B \sin \theta)$$

$$\text{Where, } A = \tan^{-1} \left(\frac{x}{h_1} \right) - \tan^{-1} \left(\frac{x}{h_2} \right); \quad B = \frac{1}{2} \ln \frac{x^2 + h_2^2}{x^2 + h_1^2}$$

CF = 100 (amplitude coefficient).

θ = Arbitrary magnetization angle (0, $\pi/6$, $\pi/4$, $\pi/3$, and $\pi/2$).

h_1 = 5 km (depth to the top of the body).

h_2 = 20 km, 25 km, and 30 km (depth to the bottom of the body).

x = -60 to +60 km (interval of 5 units) distance of the observation from the origin.

MODEL PYTHON CODE

```
## Compute the magnetic anomaly response over a vertical fault
```

```
# Load python modules
```

```
import numpy as np
```

```
import pandas as pd
```

```
import matplotlib.pyplot as plt
```

```
# Input data
```

```
CF= 100
```

```
pi=np.pi
```

```
theta = [0,pi/6,pi/4,pi/3,pi/2]
```

```
h1=5
```

```
h2=[20,25,30]
```

```
x = np.arange(-60,60.5,0.5)
```

```
import itertools
```

```
par_comb=list(itertools.product(h2,theta))
```

```
## Calculate magnetic anomaly response over a vertical fault
```

```
def Magnetic_anomaly(par):
```

```
h2=par[0]
```

```
theta=par[1]
```

```
x = np.arange(-60,60.5,0.5)
```

```
A=(np.arctan(x/h1))-(np.arctan(x/h2))
```

```
B=0.5*np.log((x**2+h2**2)/(x**2+h1**2))
```

```
del_f= CF*A*np.cos(theta)+CF*B*np.sin(theta)
```

```
return del_f
```

```

T=[]
for i in par_comb:
t=Magnetic_anomaly(i)
T.append(t)

# Plot the magnetic anomaly response over a vertical fault

plt.figure(figsize=(13, 7), dpi=80)
for i in range(1,6):
plt.plot(x,T[i-1])
plt.xlabel('Distance in meter')
plt.ylabel('Anomaly in nT')
plt.title("Magnetic Anomaly for h=20 m ")
plt.legend(["theta=0", "theta=30", "theta=45", "theta=60", "theta=90"])
plt.grid()
plt.show()

```

PRACTICAL-11

Construction of Magnetic profiles over a thin dyke

Objectives & Learning outcomes: To provide the theoretical formulation of magnetic response due to dyke.

Questions: Discuss the effect of depth (Z), width (T), and direction of arbitrary magnetization (Q) of dyke on the total magnetic anomaly profiles. Assume that magnetization is only due to induction. The general expression for the total field anomaly over a dyke is given below

$$F(X) = CF[A \cos Q + B \sin Q]$$

Where $Q = \theta - \varphi$

θ = Dip of the dyke

φ = Dip of the magnetization vector

$$A = \theta_A - \theta_B = \tan^{-1} \left[\frac{X+T}{Z} \right] - \tan^{-1} \left[\frac{X-T}{Z} \right]; \quad B = \ln \left[\frac{(X+T)^2 + Z^2}{(X-T)^2 + Z^2} \right]$$

CF = 100 (amplitude coefficient)

$Q = 0^\circ, 30^\circ, 60^\circ, 90^\circ$ (arbitrary angle of magnetisation)

Z = 5 m and 10 m (depth to the centre of the body);

T = 10 m and 50 m (width of the dyke)

X = -100 m to 100 m (interval of 10 m); a distance of the observation from the origin

MODEL PYTHON CODE

```
## Compute the magnetic anomaly response over a dyke
```

```
# Load the python modules
```

```
import numpy as np
```

```
import pandas as pd
```

```
import matplotlib.pyplot as plt
```

```
# Input data
```

```
Z=np.array([5,10])
```

```
T=np.array([10,50])
```

```
pi=np.pi
```

```
Q = [0,pi/6,pi/4,pi/3,pi/2]
```

```
x = np.arange(-100,100.5,1)
```

```
import itertools
```

```
par_comb=list(itertools.product(Z,T,Q))
```

```
## Calculate magnetic anomaly response over a dyke
```

```
def Magnetic_anomaly(par):
```

```
    Z=par[0]
```

```
    T=par[1]
```

```
    Q=par[2]
```

```
    CF=100
```

```
    x = np.arange(-100,100.5,1)
```

```

A = (np.arctan((x+T)/Z)-np.arctan((x-T)/Z))
B = np.log((Z**2+(x+T)**2)/(Z**2+(x-T)**2))
del_f= CF*A*np.cos(Q)+CF*B*np.sin(Q)
return del_f

```

```

T=[]
for i in par_comb:
t=Magnetic_anomaly(i)
T.append(t)

```

```

plt.figure(figsize=(13, 7), dpi=80)
for i in range(1,6):
plt.plot(x,T[i-1])
plt.xlabel('Distance in meter')
plt.ylabel('Anomlay in nT')
plt.title("Magnetic Anomaly for Z=5 m and T=10m")
plt.legend(["theta=0","theta=30","theta=45","theta=60","theta=90"])
plt.grid()
plt.show()

```

PRACTICAL-12

Qualitative interpretation of magnetic anomaly profile across a dyke using Koloumzine method

Objectives & Learning outcomes: To estimate the source-depth parameters of a dyke from the given magnetic anomaly data.

Questions: A magnetic survey was conducted over a dyke located in the Marcona district, Peru, near to the magnetic equator ($\varphi = 5^\circ\text{N}$). Assume that remanent magnetization is negligible in comparison to the induced magnetization; determine the width (T), depth (Z), and dip (θ) of dyke using the Koulomzine method.

Distance (m)	Magnetic anomaly (nT)	Distance (m)	Magnetic anomaly (nT)	Distance (m)	Magnetic anomaly (nT)	Distance (m)	Magnetic anomaly (nT)
-800	1065	-400	1800	0	2125	400	-810
-700	900	-300	2320	100	1115	500	-790
-600	1135	-200	2825	200	-45	600	-745
-500	1415	-100	2770	300	-695	700	-680

Methodology:

- For the depth estimation

$$z = \frac{x_{1/2} [x_{1/2}^2 - x_{3/4}^2]}{2 (x_{3/4})^2}$$

where, $x_{1/2}$ is a distance of half width of the maximum anomaly

$x_{3/4}$ is a distance of the three by fourth of the maximum anomaly

- For the width estimation

$$x_{1/2} = (w^2 + z^2)^{1/2}$$

where, $x_{1/2}$ is a distance of half width of the maximum anomaly

z is the depth to the top of the dyke body

w is width of the dyke body

- For the dip calculation of the dyke

$$Q = \theta - \varphi$$

where, $Q = 0^\circ, 30^\circ, 60^\circ, 90^\circ$ (arbitrary angle of magnetisation)

φ is the magnetic equator ($\varphi = 5^\circ\text{N}$).

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