SUSTech Southern University of Science and Technology

南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

地球与空间科学系 DEPARTMENT OF EARTH AND SPACE SCIENCES

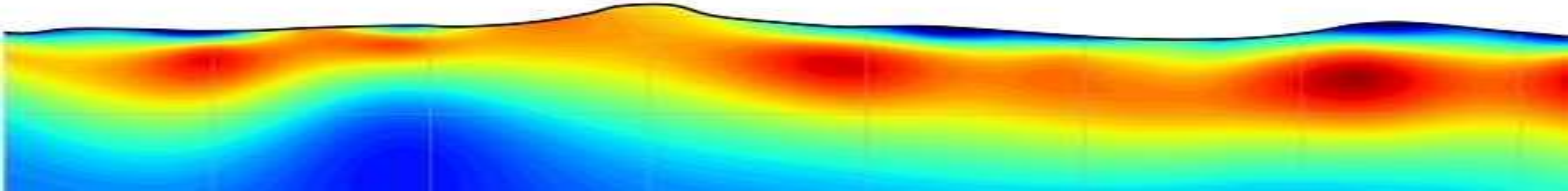
# ESS302 Applied Geophysics II

Gravity, Magnetic, Electrical, Electromagnetic and Well Logging

## Introduction

Instructor: Dikun Yang

Jan – May, 2021



# Course Information

- Instructor: Dikun Yang
  - PhD in geophysics, University of British Columbia, 2014
  - Office: Room 406B, Building 9, Innovation Park
  - Phone: 88018695
  - Email: yangdk@sustech.edu.cn
  - Web: sustech-gem.cn
  - Office hour: By appointment
  - TA: Nanyu Wei (12032846@mail.sustech.edu.cn)

# Course Information

| Week | Tuesday 2 pm | Thursday 7 pm | Weekend |
|---|---|---|---|
| Wk 1 | Jan 12: Introduction | | |
| Wk 2 | Jan 19: Gravity | Jan 21: Gravity | |
| Wk 3 | Mar 2: Magnetic | | |
| Wk 4 | Mar 9: Magnetic | Mar 11: Magnetic | |
| Wk 5 | Mar 16: Electric | | |
| Wk 6 | Mar 23: Electric | Mar 25: Electric | |
| Wk 7 | Mar 30: Electric | | |
| Wk 8 | Apr 6: Mid-term | Apr 8: CSEM | |
| Wk 9 | Apr 13: CSEM | | |
| Wk 10 | Apr 20: CSEM | Apr 22: NSEM | |
| Wk 11 | Apr 27: NSEM | | |
| Wk 12 | | May 6: NSEM | |
| Wk 13 | May 11: NSEM | | |
| Wk 14 | May 18: GPR | May 20: GPR | |
| Wk 15 | May 25: Review | | |
| Wk 16 | | | |

**Task-guided Learning**

- Geophysical methods:
  - Gravity
  - Magnetic
  - Electric
  - Controlled source electromagnetic
  - Natural source electromagnetic
  - Ground penetrating radar
- Lectures
- Hands-on exercises
- Worksheets (Jupyter Notebook)

# Course Information

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|---|---|---|---|
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| Wk 6 | Mar 23: Electric | Mar 25: Electric | |
| Wk 7 | Mar 30: Electric | | |
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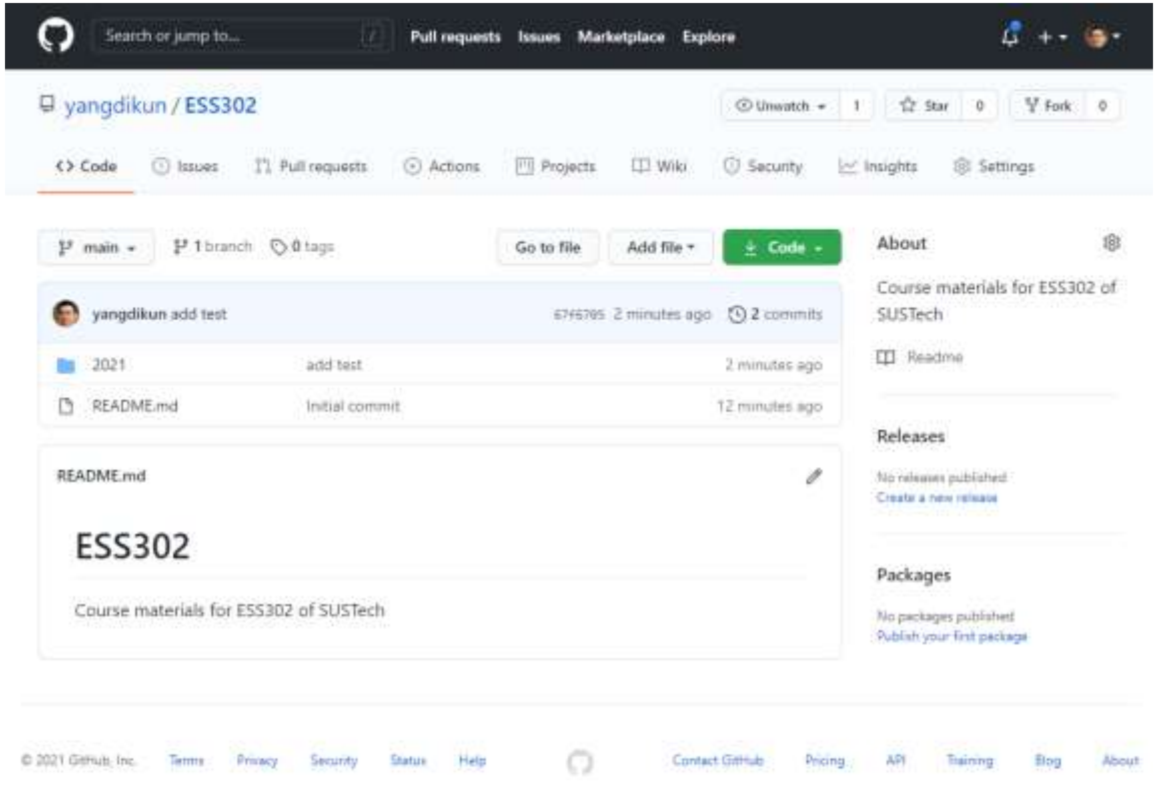
| Wk 10 | Apr 20: CSEM | Apr 22: NSEM | |
| Wk 11 | Apr 27: NSEM | | |
| Wk 12 | | May 6: NSEM | |
| Wk 13 | May 11: NSEM | | |
| Wk 14 | May 18: GPR | May 20: GPR | |
| Wk 15 | May 25: Review | | |
| Wk 16 | | | |

- 10% class attendance, participation and performance
- 20% assignments
- 20% mid-term exam
- 50% final exam

# Course Resources

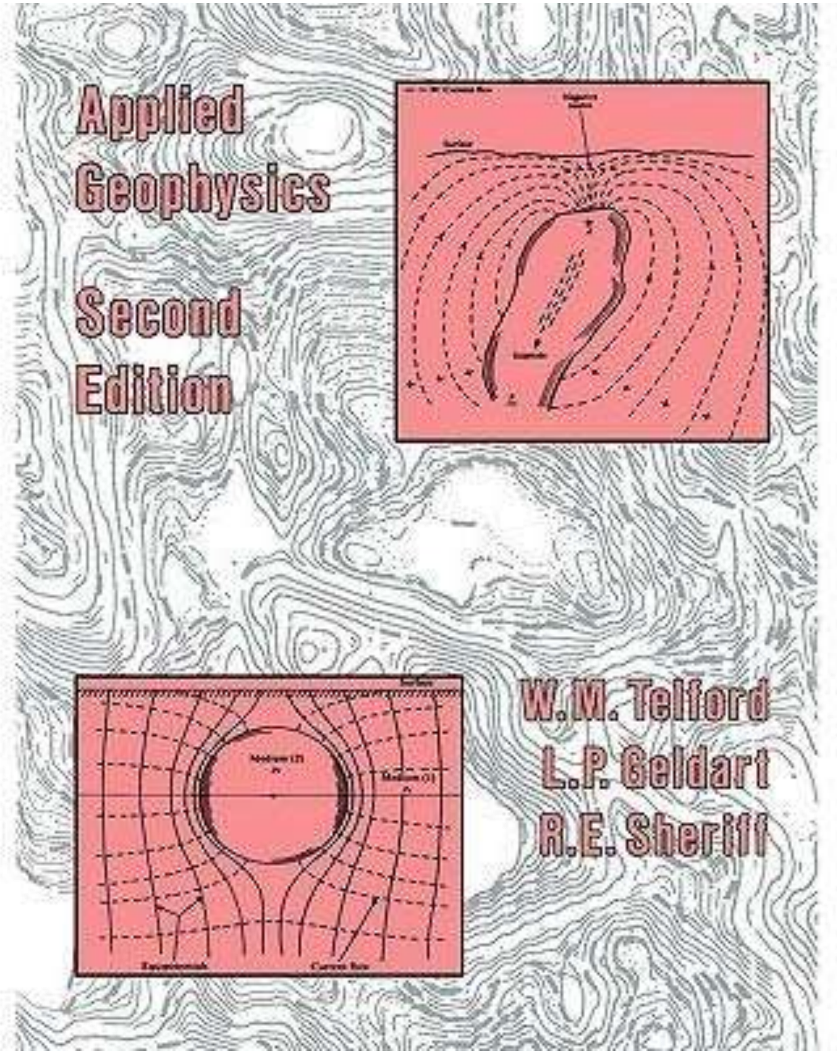
Blackboard

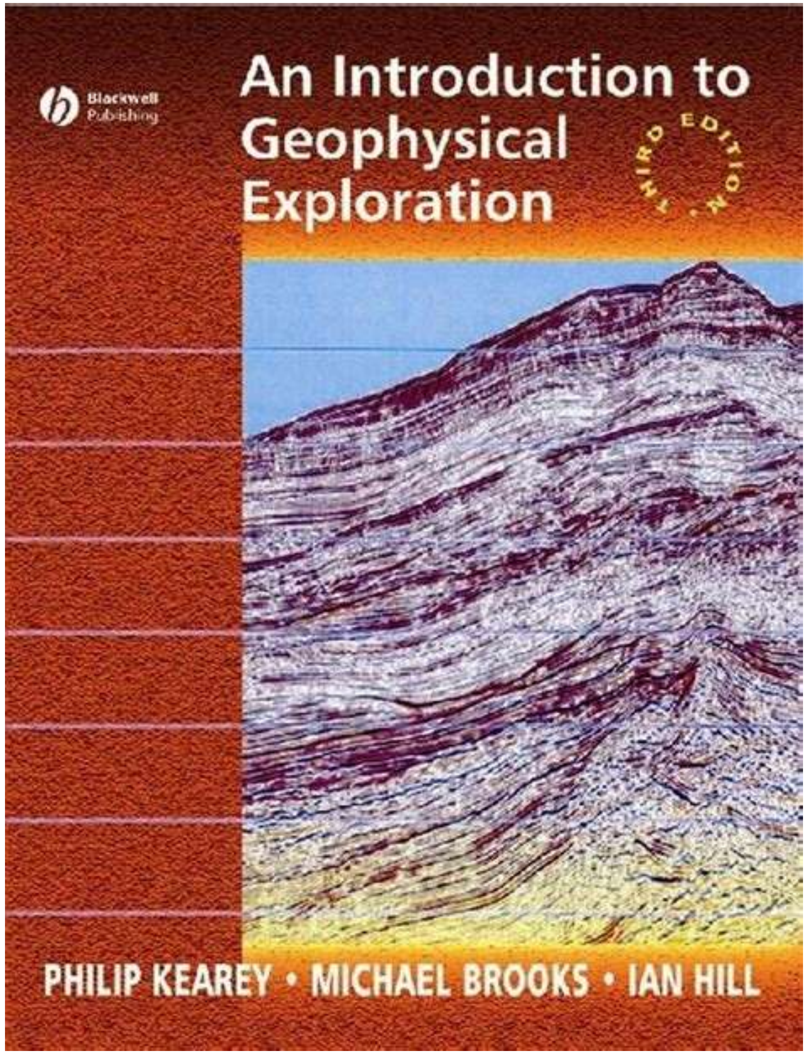
Course Materials https://github.com/yangdikun/ESS302

# Syllabus

- Resources
  - Textbooks

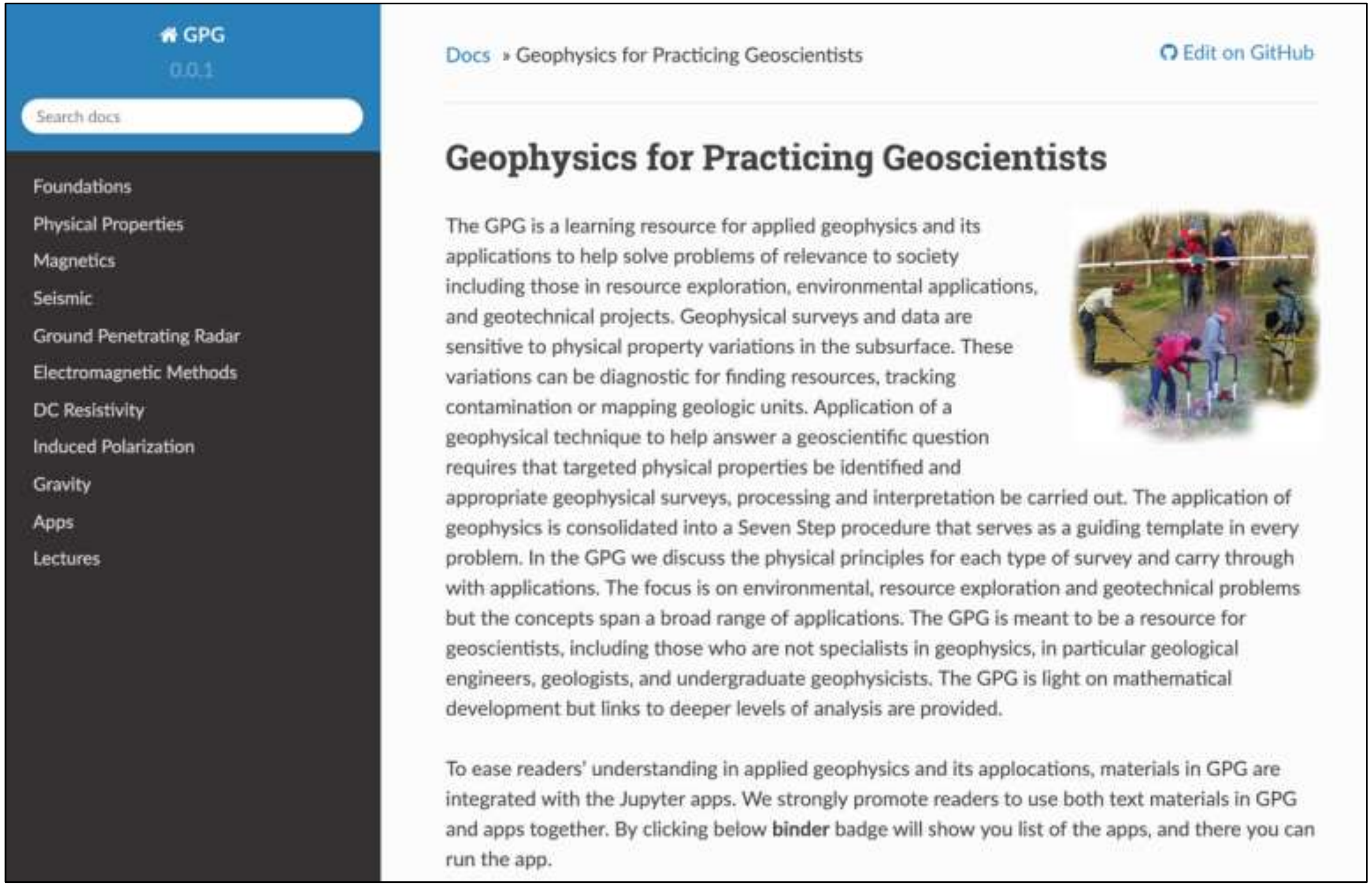



(Available in my office)

# Syllabus

- Resources
  - Textbooks
  - eBooks, websites



GPG
0.0.1
Search docs

Foundations
Physical Properties
Magnetics
Seismic
Ground Penetrating Radar
Electromagnetic Methods
DC Resistivity
Induced Polarization
Gravity
Apps
Lectures

Docs » Geophysics for Practicing Geoscientists
Edit on GitHub

## Geophysics for Practicing Geoscientists

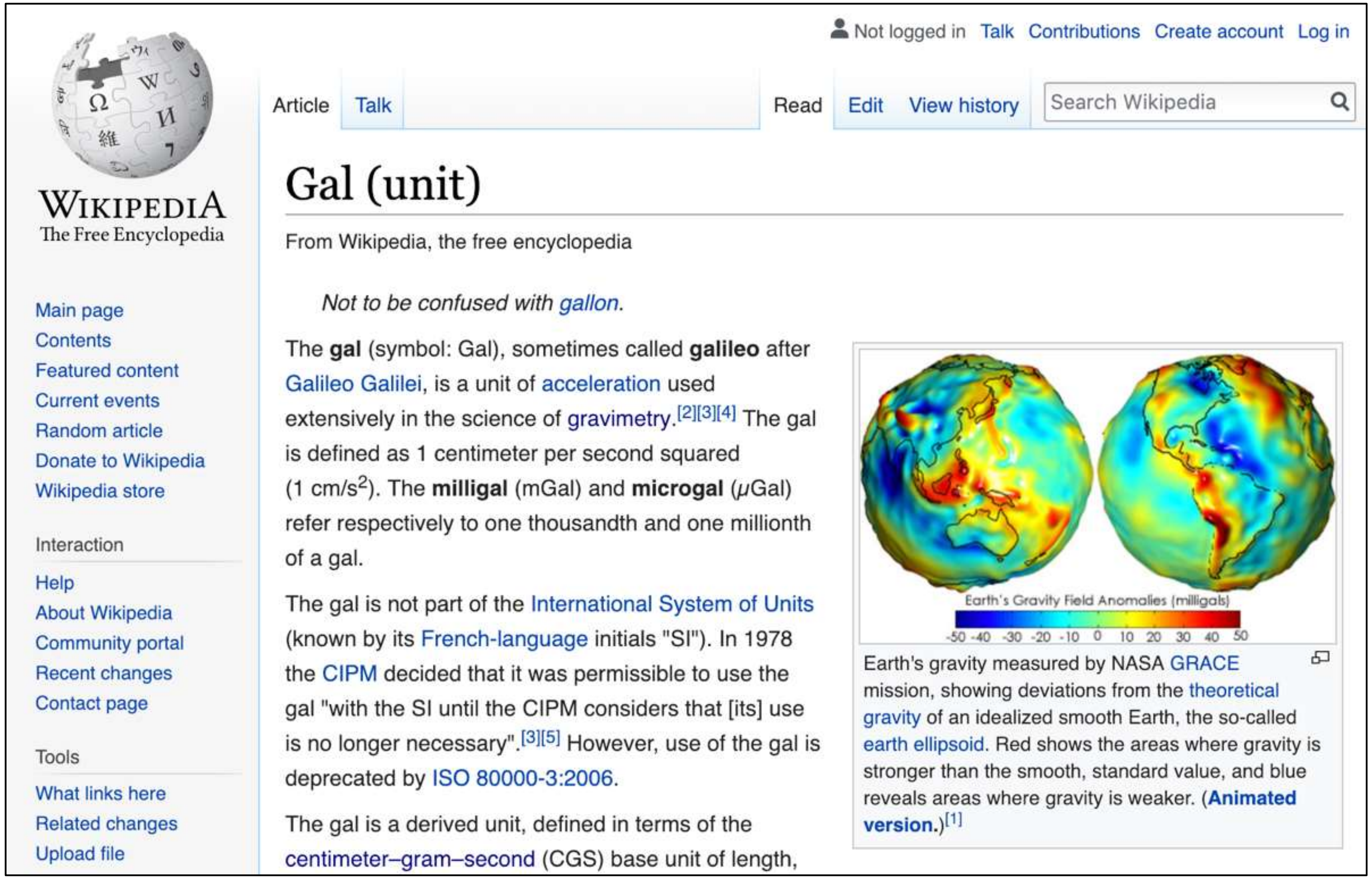
The GPG is a learning resource for applied geophysics and its applications to help solve problems of relevance to society including those in resource exploration, environmental applications, and geotechnical projects. Geophysical surveys and data are sensitive to physical property variations in the subsurface. These variations can be diagnostic for finding resources, tracking contamination or mapping geologic units. Application of a geophysical technique to help answer a geoscientific question requires that targeted physical properties be identified and appropriate geophysical surveys, processing and interpretation be carried out. The application of geophysics is consolidated into a Seven Step procedure that serves as a guiding template in every problem. In the GPG we discuss the physical principles for each type of survey and carry through with applications. The focus is on environmental, resource exploration and geotechnical problems but the concepts span a broad range of applications. The GPG is meant to be a resource for geoscientists, including those who are not specialists in geophysics, in particular geological engineers, geologists, and undergraduate geophysicists. The GPG is light on mathematical development but links to deeper levels of analysis are provided.

To ease readers' understanding in applied geophysics and its applocations, materials in GPG are integrated with the Jupyter apps. We strongly promote readers to use both text materials in GPG and apps together. By clicking below **binder** badge will show you list of the apps, and there you can run the app.

https://gpg.geosci.xyz
https://em.geosci.xyz

# Syllabus

- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia



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About Wikipedia
Community portal
Recent changes
Contact page

Tools

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Related changes
Upload file

# Gal (unit)

From Wikipedia, the free encyclopedia

*Not to be confused with gallon.*

The **gal** (symbol: Gal), sometimes called **galileo** after Galileo Galilei, is a unit of acceleration used extensively in the science of gravimetry.[2][3][4] The gal is defined as 1 centimeter per second squared (1 cm/s$^2$). The **milligal** (mGal) and **microgal** ($\mu$Gal) refer respectively to one thousandth and one millionth of a gal.

The gal is not part of the International System of Units (known by its French-language initials "SI"). In 1978 the CIPM decided that it was permissible to use the gal "with the SI until the CIPM considers that [its] use is no longer necessary".[3][5] However, use of the gal is deprecated by ISO 80000-3:2006.

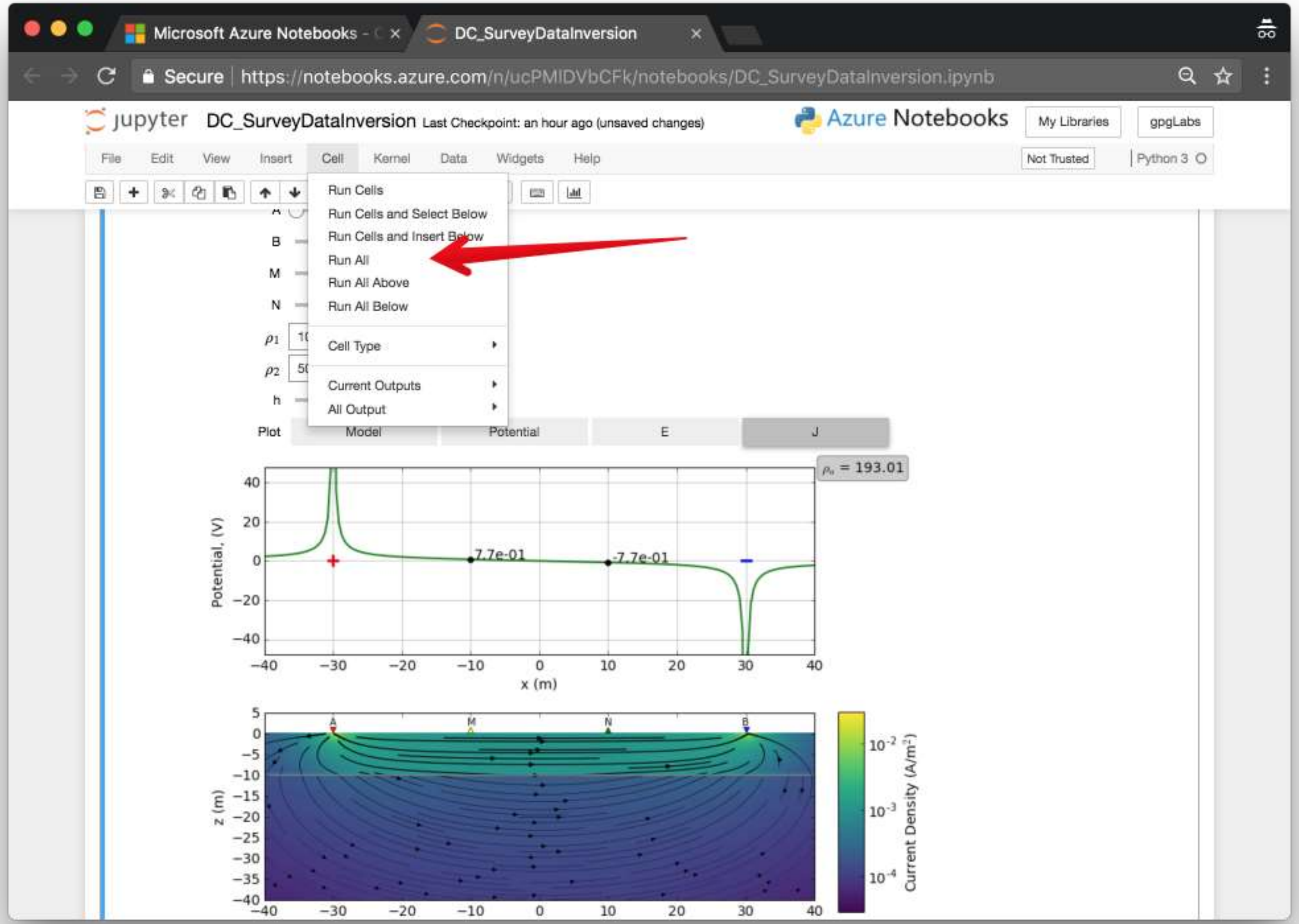
The gal is a derived unit, defined in terms of the centimeter–gram–second (CGS) base unit of length,

Earth's Gravity Field Anomalies (milligals)
-50 -40 -30 -20 -10 0 10 20 30 40 50

Earth's gravity measured by NASA GRACE mission, showing deviations from the theoretical gravity of an idealized smooth Earth, the so-called earth ellipsoid. Red shows the areas where gravity is stronger than the smooth, standard value, and blue reveals areas where gravity is weaker. (**Animated version.**)[1]

# Syllabus

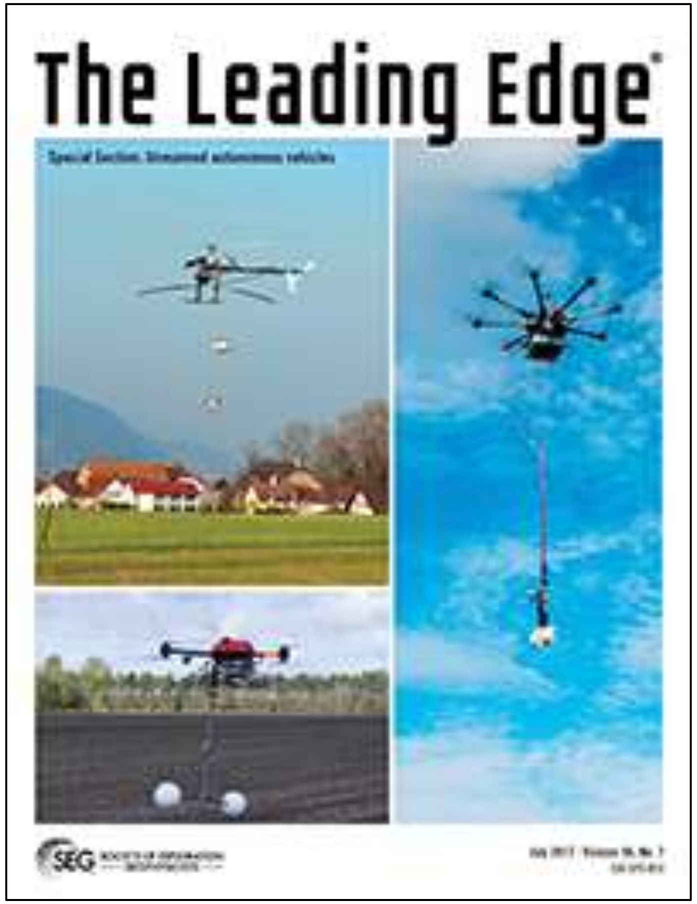
- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia
  - Interactive apps




(Python Jupyter notebooks)

# Syllabus

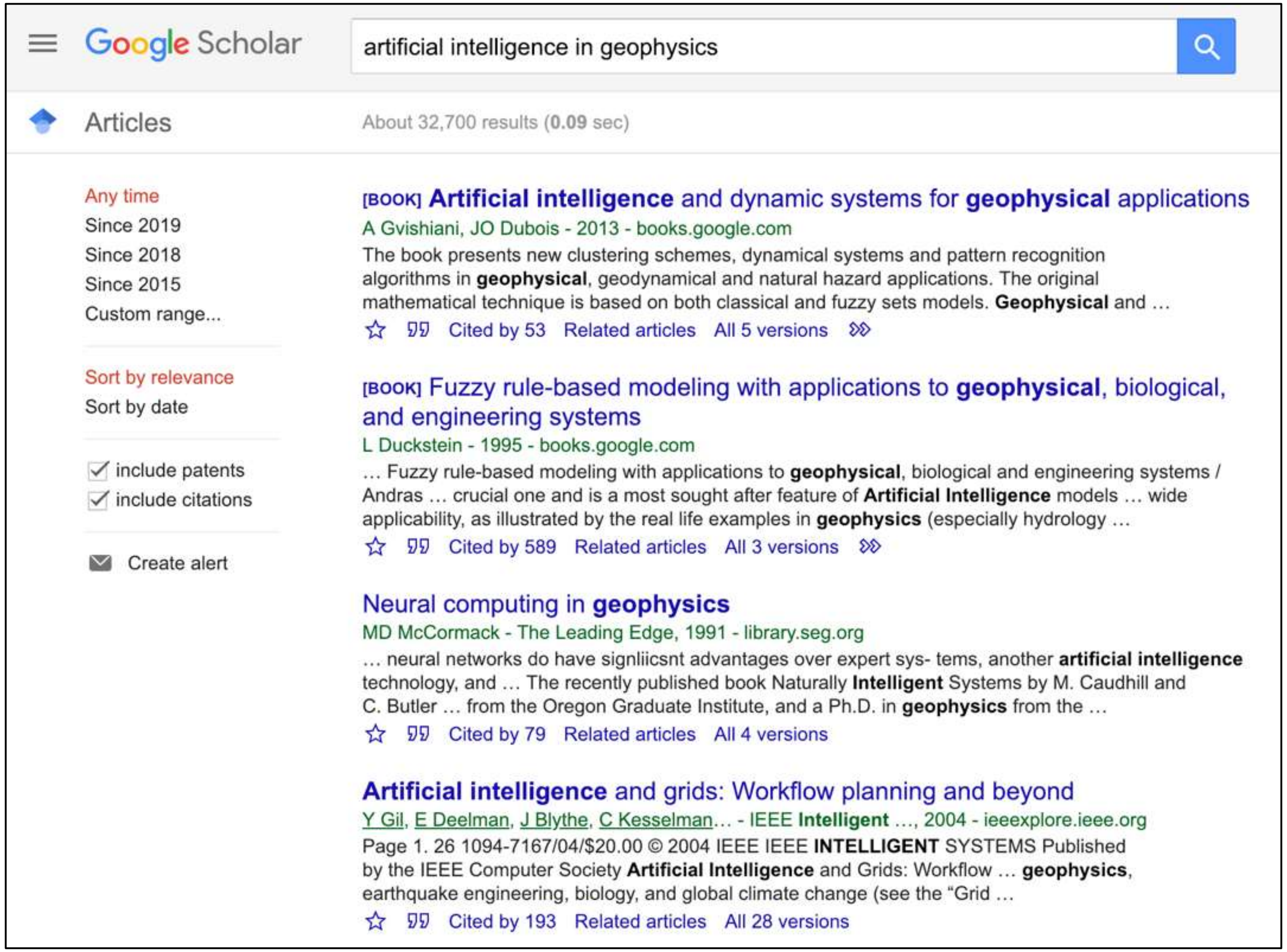
- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia
  - Technical publications


(Available online or in my office)

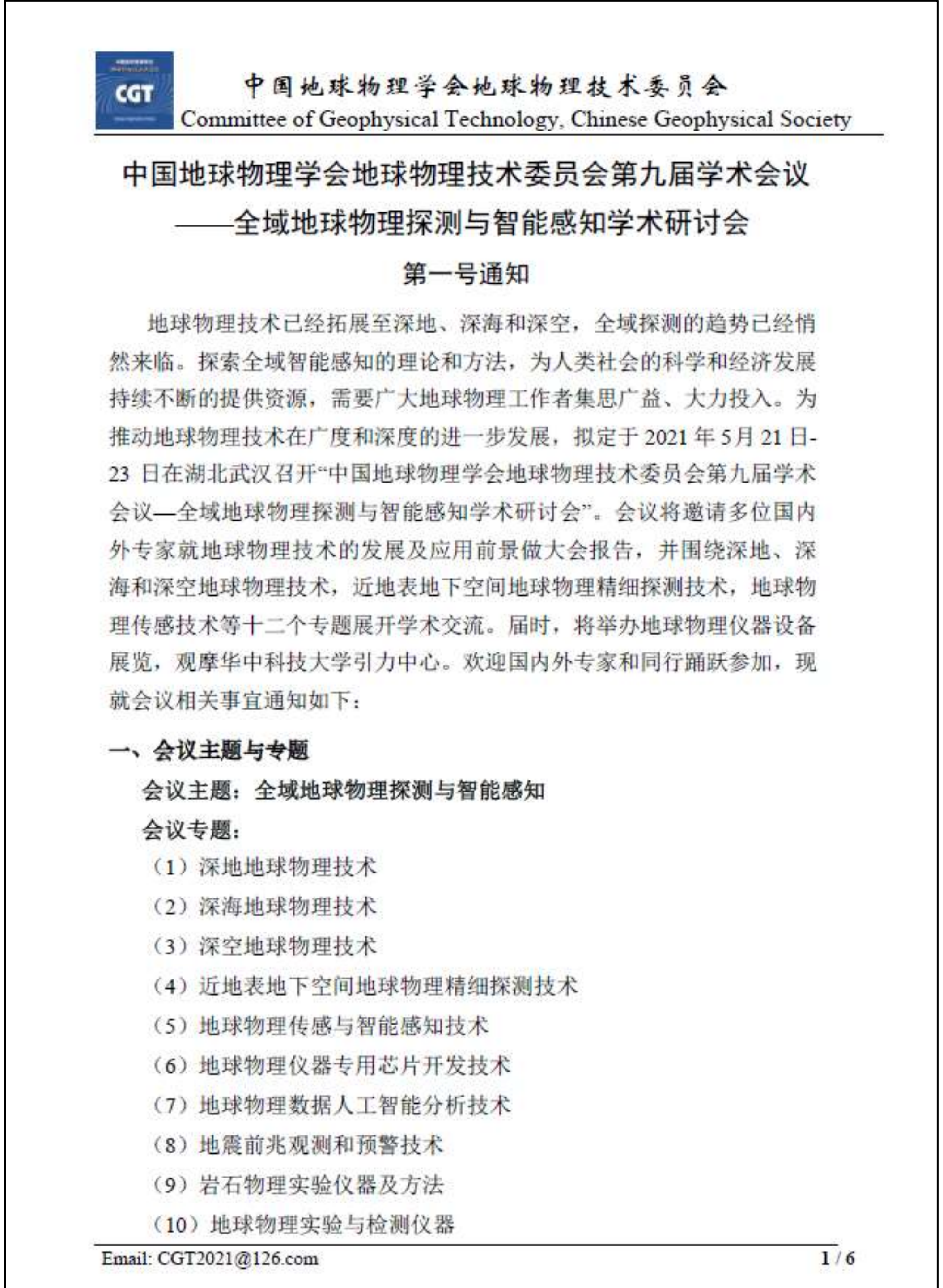
# Syllabus

- Resources
  - Textbooks
  - eBooks, websites
  - Wikipedia
  - Technical publications
  - Google scholar



# Syllabus

- Course Policies
  - Instructional language: English
  - Turn in your completed worksheets before the end of last class of each module
  - **The top-ranked student before the final goes to CGT2021 in Wuhan**



CGT 中国地球物理学会地球物理技术委员会
Committee of Geophysical Technology, Chinese Geophysical Society

**中国地球物理学会地球物理技术委员会第九届学术会议**
**——全域地球物理探测与智能感知学术研讨会**

**第一号通知**

地球物理技术已经拓展至深地、深海和深空，全域探测的趋势已经悄然来临。探索全域智能感知的理论和方法，为人类社会的科学和经济发展持续不断的提供资源，需要广大地球物理工作者集思广益、大力投入。为推动地球物理技术在广度和深度的进一步发展，拟定于 2021 年 5 月 21 日-23 日在湖北武汉召开“中国地球物理学会地球物理技术委员会第九届学术会议—全域地球物理探测与智能感知学术研讨会”。会议将邀请多位国内外专家就地球物理技术的发展及应用前景做大会报告，并围绕深地、深海和深空地球物理技术，近地表地下空间地球物理精细探测技术，地球物理传感技术等十二个专题展开学术交流。届时，将举办地球物理仪器设备展览，观摩华中科技大学引力中心。欢迎国内外专家和同行踊跃参加，现就会议相关事宜通知如下：

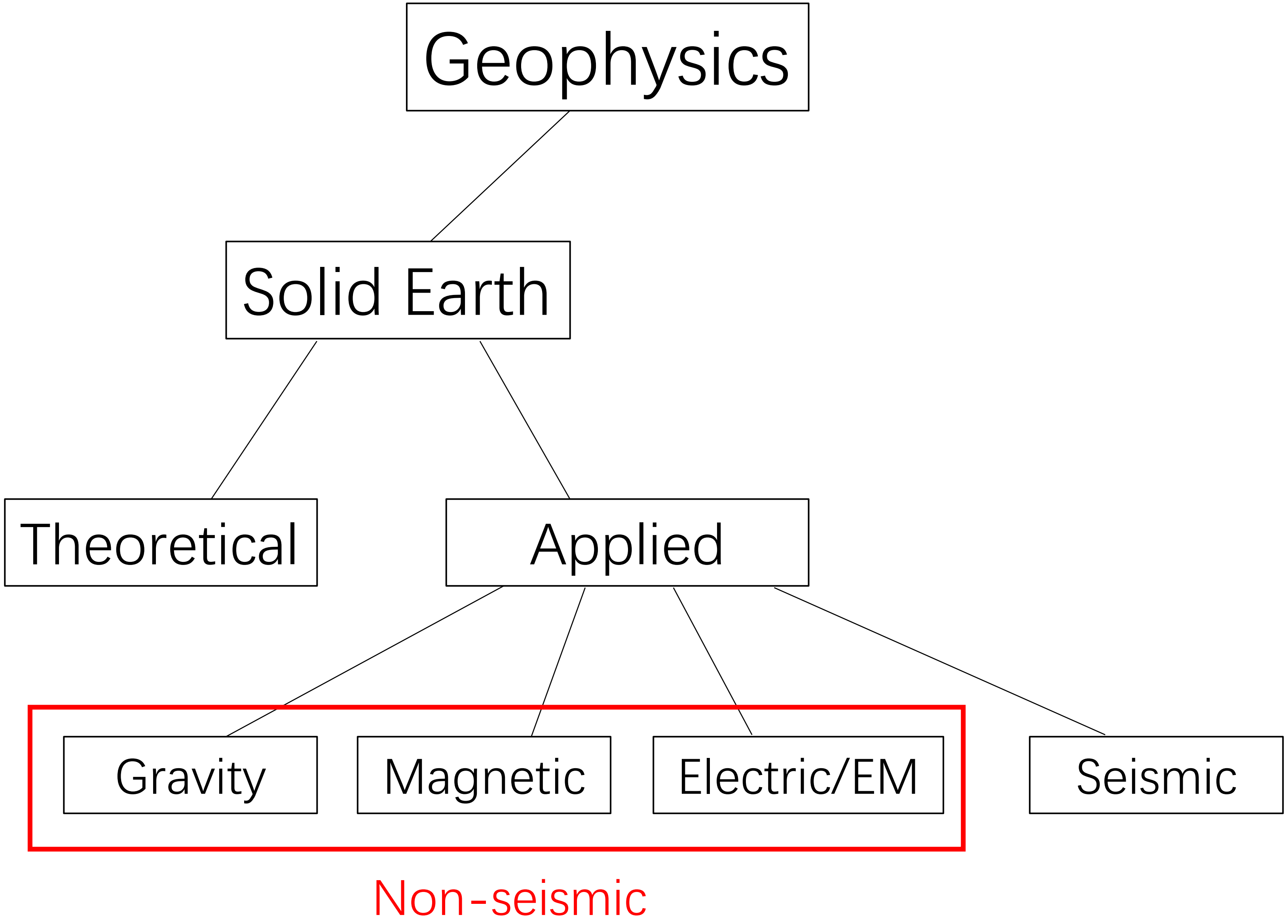
**一、会议主题与专题**

**会议主题：全域地球物理探测与智能感知**

**会议专题：**

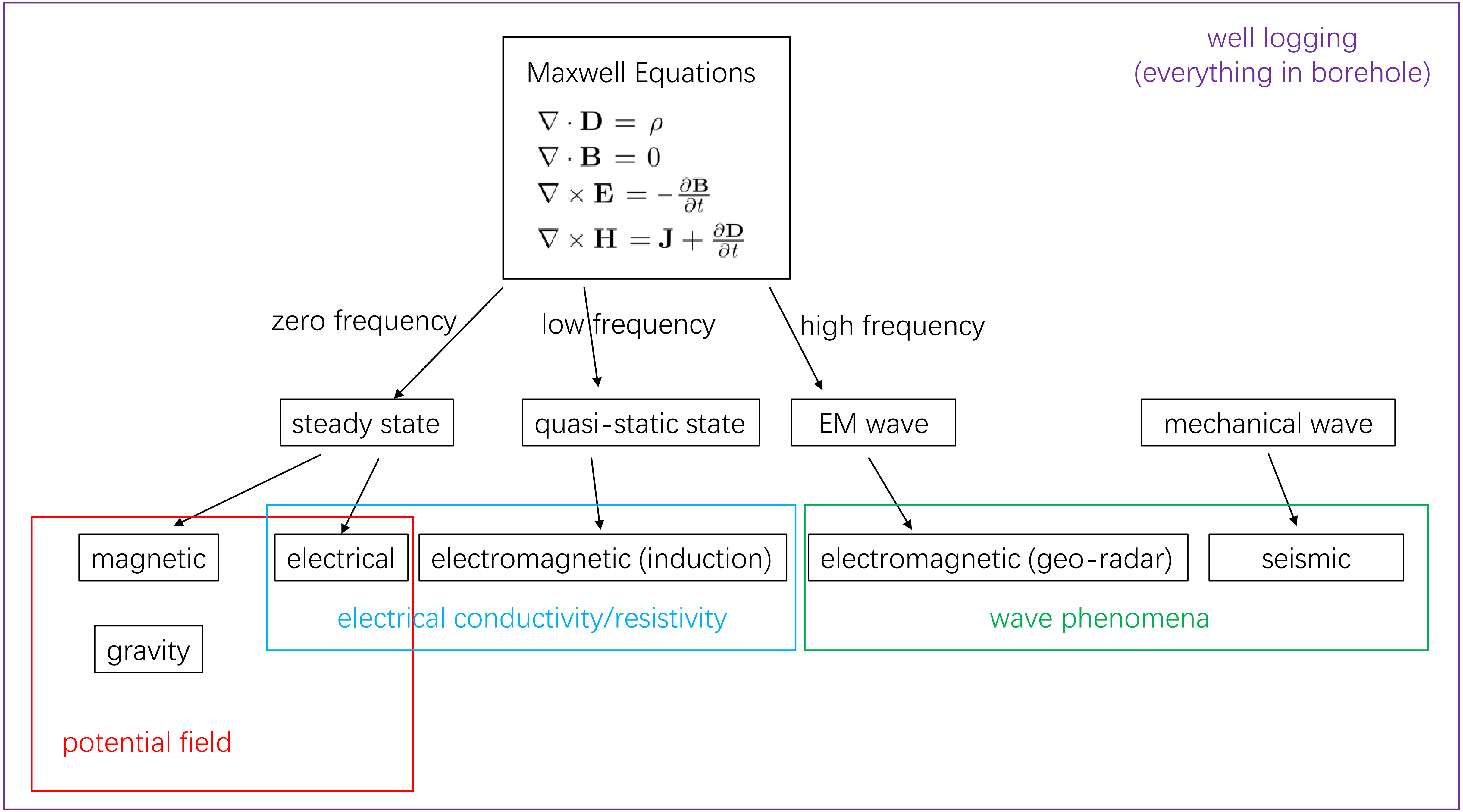
（1）深地地球物理技术
（2）深海地球物理技术
（3）深空地球物理技术
（4）近地表地下空间地球物理精细探测技术
（5）地球物理传感与智能感知技术
（6）地球物理仪器专用芯片开发技术
（7）地球物理数据人工智能分析技术
（8）地震前兆观测和预警技术
（9）岩石物理实验仪器及方法
（10）地球物理实验与检测仪器

Email: CGT2021@126.com　1 / 6


Geophysics
Solid Earth
Theoretical
Applied
Gravity
Magnetic
Electric/EM
Seismic
Non-seismic

| Method | Theoretical | Applied |
|---|---|---|
| Gravity | The acceleration of gravity is not constantly 9.8 $m/s^2$! | Can I make money with it? Yes. Build houses on stable ground with no strong gravity variation. Then you are rich! |
| Magnetic | There are magnetic stripes on the seafloor! | Can I make money with it? Yes. Dig at where the magnetic field is strong for gold, silver… Then you are rich! |
| Electric | Magnetic storms from the sun induces strong electric currents in the earth! | Can I make money with it? Yes. Drill at where the electric field is strong for groundwater. Then you are rich! |
| Seismic | The wave from earthquakes travel more slowly in sedimentary basins! | Can I make money with it? Yes. Compare the wave travel times and find the rocks that trap the oil. Then you are rich! |





well logging
(everything in borehole)
Maxwell Equations
$\nabla \cdot \mathbf{D} = \rho$
$\nabla \cdot \mathbf{B} = 0$
$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$
zero frequency
low frequency
high frequency
steady state
quasi-static state
EM wave
mechanical wave
magnetic
electrical
electromagnetic (induction)
electromagnetic (geo-radar)
seismic
gravity
electrical conductivity/resistivity
wave phenomena
potential field

# Why You Never Heard About Applied Geophysics?

- You drink **water** off a bottle, but do not care where the water comes from.
- You play games on your **smartphone**, but do not ask where the lithium in the battery comes from.
- You give a thumbs up for the magnificent **Hongkong-Zhuhai-Macau Bridge**, but did not see how the route was planned.
- You throw away a bag of **trash**, but do not know how it can be kept safe in a landfill.
- You have to wear a **mask** everyday, but do not realize it is made of the sticky oil from a remote desert.





# How Exactly Does Geophysics Work in Reality?

1. **Setup**: What is the question to be answered?
2. **Properties**: What are the diagnostic physical properties?
3. **Survey**: Choose survey and design data acquisition
4. **Data**: Go to the field and collect data
5. **Processing**: Processing of field data
6. **Interpretation**: Associate the processed results to the original question
7. **Synthesis**: Has the question been answered? Need to iterate?

# Surface Subsidence in Urban Area

City of Guangzhou, Guangdong Province, December 1, 2019


City of Xining, Qinghai Province, January 14, 2020

# Surface Subsidence in Urban Area

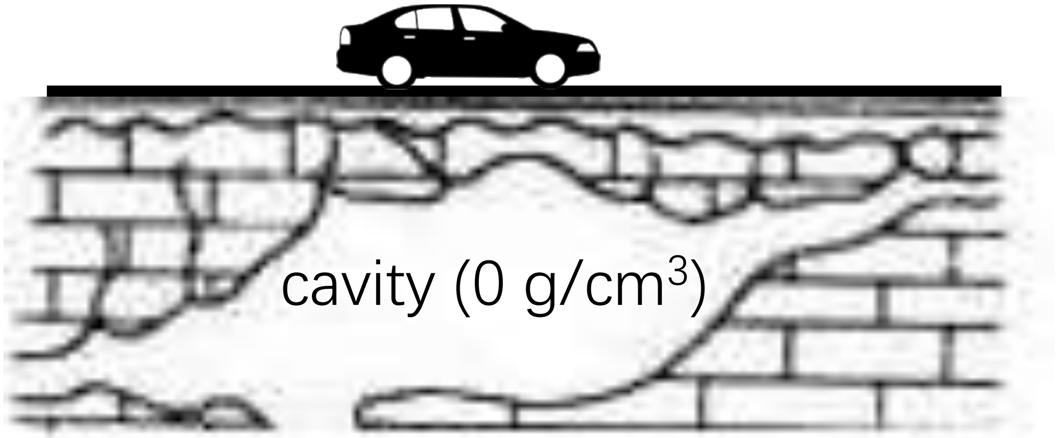
1. **Setup**: What is the question to be answered?

   Detect and forecast the next deadly subsidence

# Surface Subsidence in Urban Area

2. **Properties**: What are the diagnostic physical properties?

   What *physically* distinguish an air-filled cavity from regular soil?



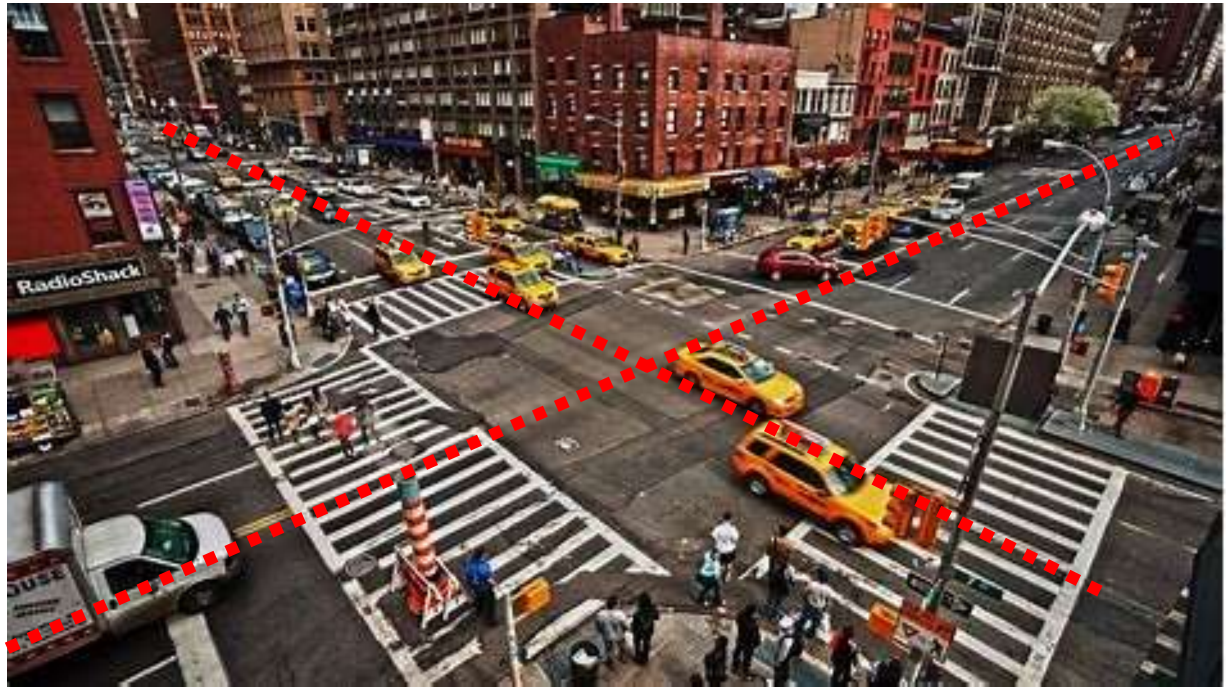

soil (1.5 g/cm$^3$)

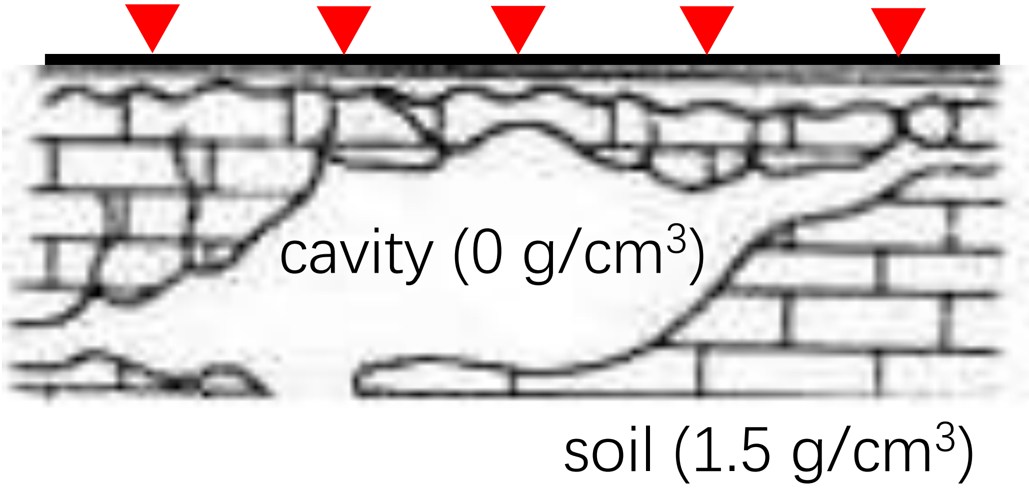
**Density contrast:**
Smaller gravitational pull above the cavity compared to above regular soil

# Surface Subsidence in Urban Area

3. **Survey**: Choose survey and design data acquisition

Placement of gravity stations: survey lines, spacings, etc.



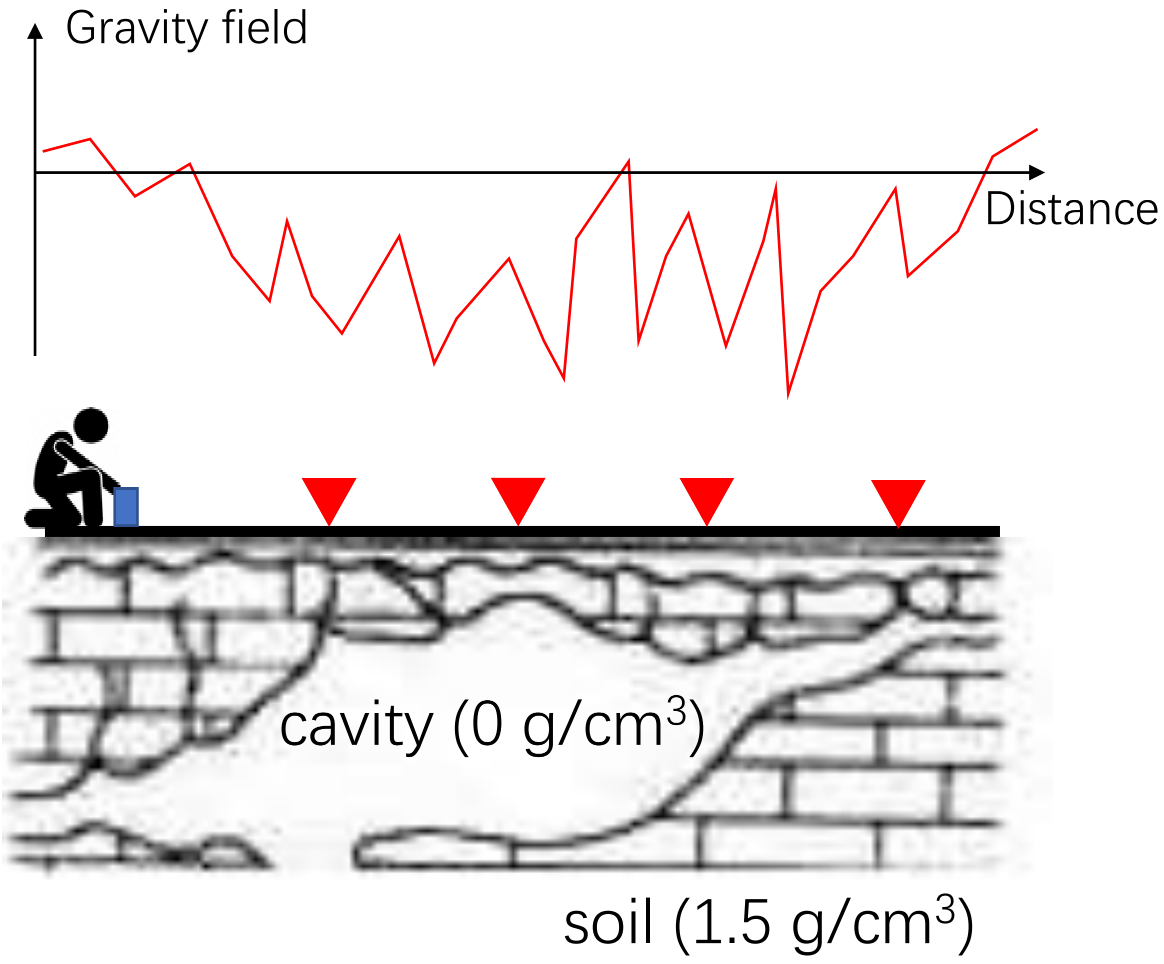



# Surface Subsidence in Urban Area

4. **Data**: Go to the field and collect data

   Deploy instrument and obtain data

Gravitometer

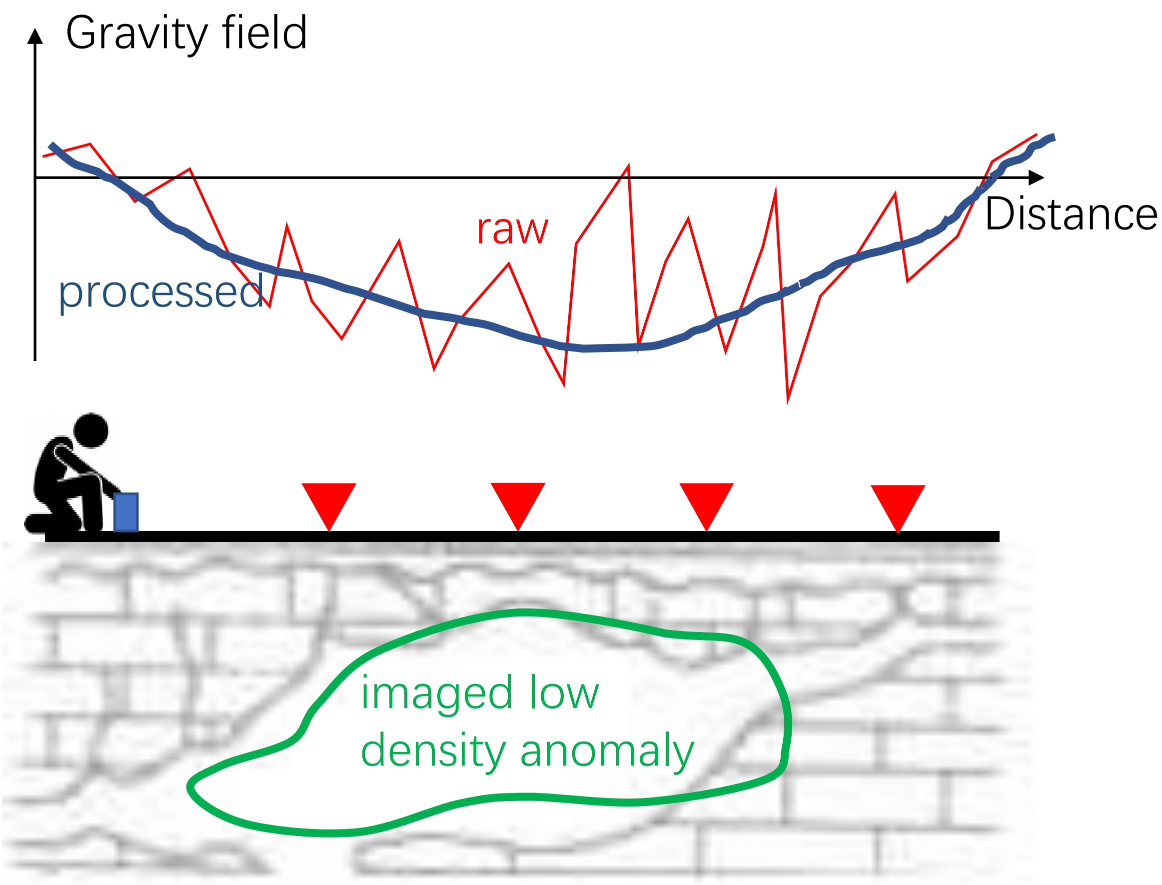


# Surface Subsidence in Urban Area

5. **Processing**: Processing of field data

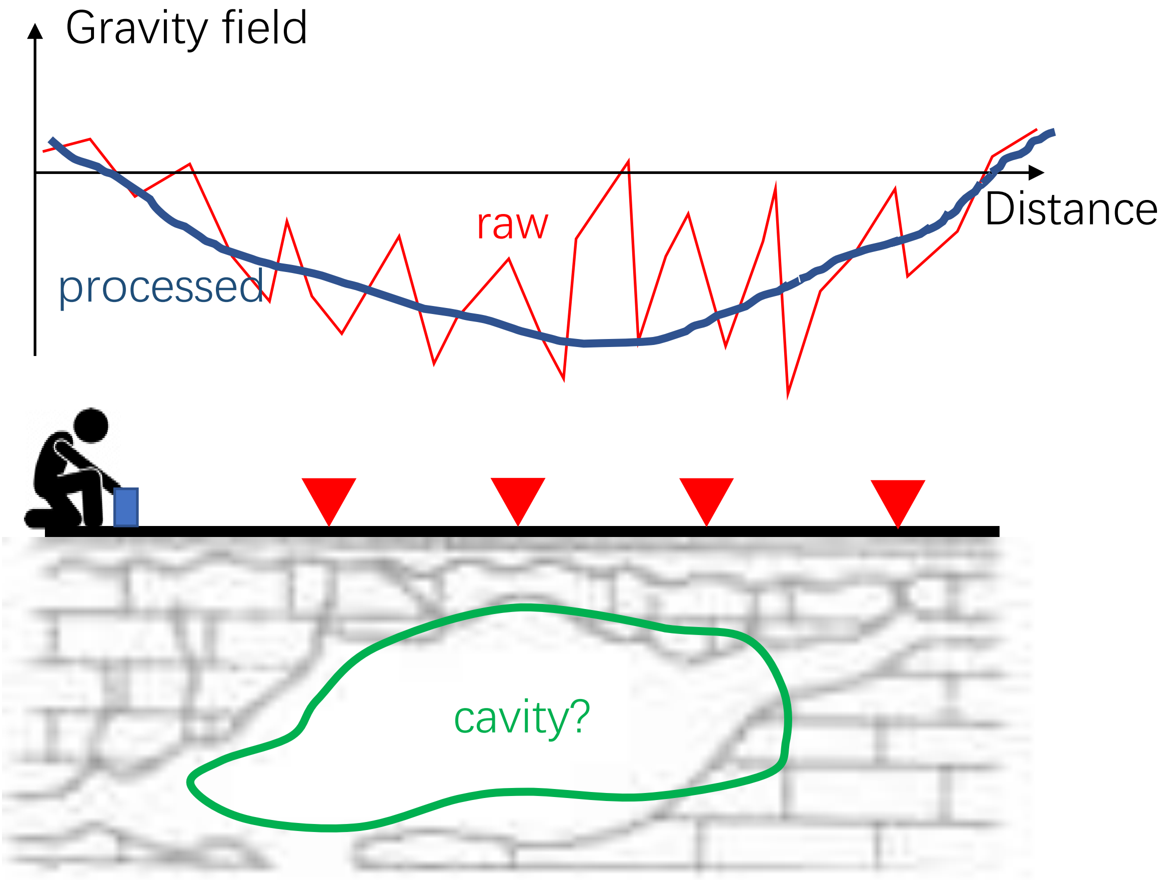
Example:

- Filtering and correction to suppress undesired signals
- Numerical modeling or inversion to reconstruct the subsurface image of density distribution
- Geological modeling based on geophysical evidences
- Assess *uncertainties*



# Surface Subsidence in Urban Area

6. **Interpretation**: Associate the processed results to the original question

# Surface Subsidence in Urban Area

7. **Synthesis**: Has the question been answered? Need to iterate?


The city is really scared because of the big cavity imaged by the gravity method, but they are hesitant about locking down the street.

- Is the imaged result reliable?
- Is the survey large enough to cover the entire affected area?
- Are there any other methods to confirm the size and extent of the cavity?
- If confirmed, where to drill?

# Self-Testing Questions

- Name the four major methods in applied geophysics
- Which step in the seven-step procedures concerns electric resistivity?
- True or false: The interpretation is guaranteed to be exact and correct if the data are properly processed.
- Identify an application of applied geophysics that is not mentioned in this lecture
- An introductory video from SEG https://youtu.be/De5Yl4aSbOM

# Feedback

- English ok?
- Pace ok?
- Need more explanation of terms?