

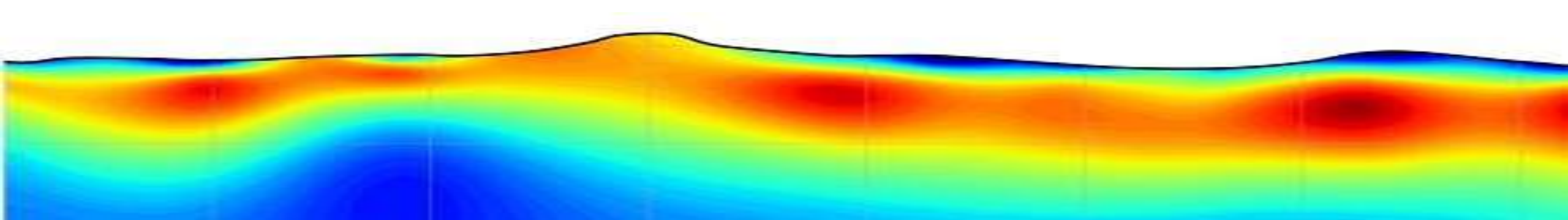
# ESS302 Applied Geophysics II

Gravity, Magnetic, Electrical, Electromagnetic and Well Logging

## Introduction

Instructor: Dikun Yang

Feb – May, 2020



# 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](mailto:yangdk@sustech.edu.cn)
  - Web: [sustech-gem.cn](http://sustech-gem.cn)
  - Office hour: By appointment
  - TA: Lichun Yang ([11930414@mail.sustech.edu.cn](mailto:11930414@mail.sustech.edu.cn))



# Course Information

Week	Tuesday 2 pm	Friday 8 am	Weekend
Wk 1			
Wk 2		Feb 21: Introduction	
Wk 3	Feb 25: Gravity	Feb 28: Gravity	
Wk 4		Mar 6: Gravity	
Wk 5	Mar 10: Gravity	Mar 13: Magnetic	
Wk 6		Mar 20: Magnetic	
Wk 7	Mar 24: Magnetic	Mar 27: Magnetic	
Wk 8		Apr 3: Mid-term exam	
Wk 9	Apr 7: Electric	Apr 10: Electric	
Wk 10		Apr 17: Electric	
Wk 11	Apr 21: Electric	Apr 24: EM	
Wk 12			
Wk 13		May 8: EM	May 9: EM
Wk 14		May 15: EM	
Wk 15	May 19: Well logging	May 22: Well logging	
Wk 16		May 29: Summary	

## Task-guided Learning

- Lecture: webcast  
<https://live.bilibili.com/21806110>
- Self-study: complete worksheets with the help of notes and internet
- Discussion: webcam conference through **Tencent Meeting**
- Instrument demo: depending on school NCP policies
- Student presentation: TBA

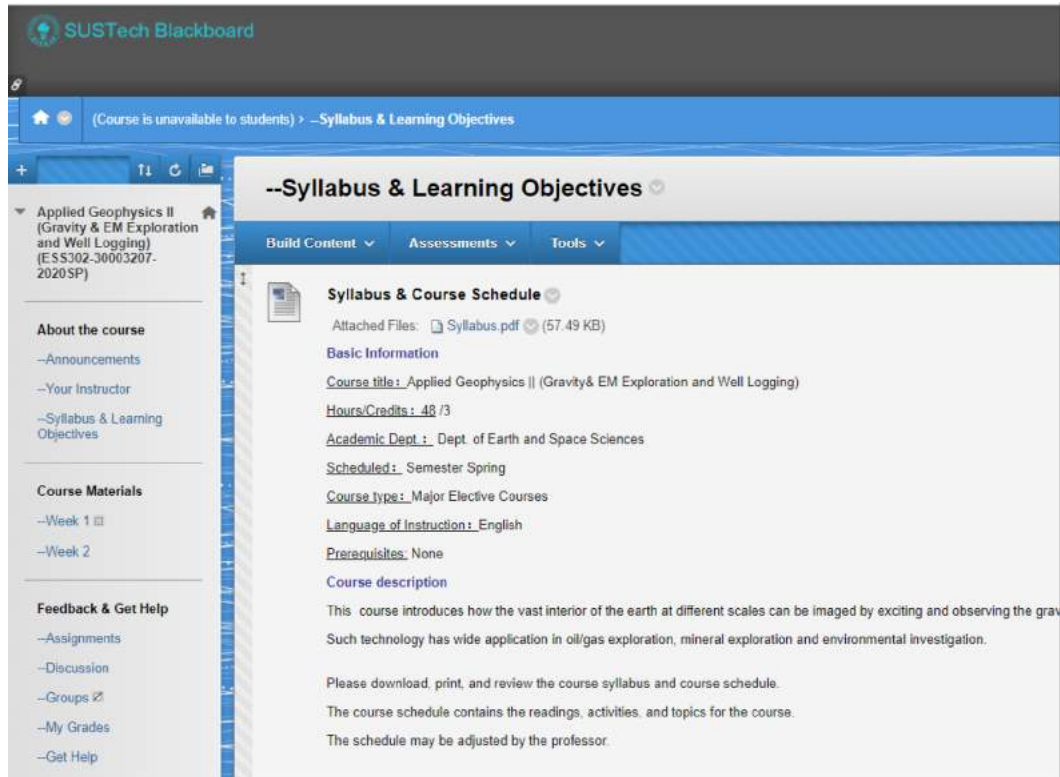
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Wk 7	Mar 24: Magnetic	Mar 27: Magnetic	
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Wk 10		Apr 17: Electric	
Wk 11	Apr 21: Electric	Apr 24: EM	
Wk 12			
Wk 13		May 8: EM	May 9: EM
Wk 14		May 15: EM	
Wk 15	May 19: Well logging	May 22: Well logging	
Wk 16		May 29: Summary	

- 10% class attendance, participation and performance
- 20% assignments (gravity, magnetic, electric, EM, GPR worksheet each 4%)
- 20% mid-term exam
- 50% final exam

# Course Resources

## Blackboard



The screenshot shows the SUSTech Blackboard interface. The top navigation bar includes the SUSTech logo and the text "SUSTech Blackboard". Below this, a message states "(Course is unavailable to students) > --Syllabus & Learning Objectives". The main content area is titled "--Syllabus & Learning Objectives" and features a sidebar on the left with links to "About the course", "Course Materials", and "Feedback & Get Help". The main content area displays the "Syllabus & Course Schedule" with attached files, basic information, and a course description.

**Syllabus & Course Schedule**

Attached Files: [Syllabus.pdf](#) (57.49 KB)

**Basic Information**

Course title: Applied Geophysics II (Gravity & EM Exploration and Well Logging)

Hours/Credits: 48 / 3

Academic Dept.: Dept. of Earth and Space Sciences

Scheduled: Semester Spring

Course type: Major Elective Courses

Language of Instruction: English

Prerequisites: None

Course description

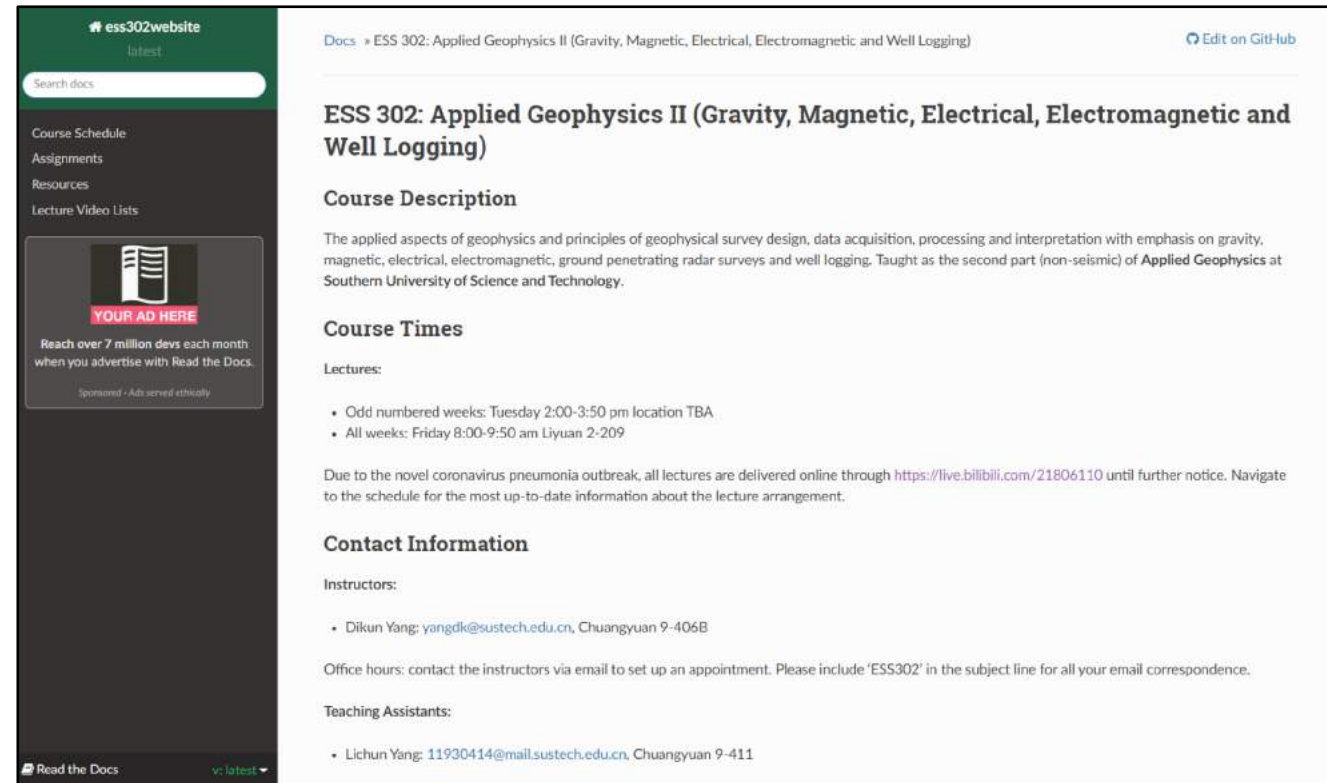
This course introduces how the vast interior of the earth at different scales can be imaged by exciting and observing the gravity field. Such technology has wide application in oil/gas exploration, mineral exploration and environmental investigation.

Please download, print, and review the course syllabus and course schedule.

The course schedule contains the readings, activities, and topics for the course.

The schedule may be adjusted by the professor.

## Course Website <https://sustech-ess302.readthedocs.io>



The screenshot shows the course website for ESS 302: Applied Geophysics II. The page has a dark green header with the course title and a search bar. The main content area is titled "ESS 302: Applied Geophysics II (Gravity, Magnetic, Electrical, Electromagnetic and Well Logging)" and includes a "Course Description", "Course Times", "Contact Information", and "Teaching Assistants" section. The page also features a sidebar with links to "Course Schedule", "Assignments", "Resources", and "Lecture Video Lists".

**ESS 302: Applied Geophysics II (Gravity, Magnetic, Electrical, Electromagnetic and Well Logging)**

**Course Description**

The applied aspects of geophysics and principles of geophysical survey design, data acquisition, processing and interpretation with emphasis on gravity, magnetic, electrical, electromagnetic, ground penetrating radar surveys and well logging. Taught as the second part (non-seismic) of **Applied Geophysics** at Southern University of Science and Technology.

**Course Times**

**Lectures:**

- Odd numbered weeks: Tuesday 2:00-3:50 pm location TBA
- All weeks: Friday 8:00-9:50 am Liyuan 2-209

Due to the novel coronavirus pneumonia outbreak, all lectures are delivered online through <https://live.bilibili.com/21806110> until further notice. Navigate to the schedule for the most up-to-date information about the lecture arrangement.

**Contact Information**

**Instructors:**

- Dikun Yang: [yangdk@sustech.edu.cn](mailto:yangdk@sustech.edu.cn), Chuangyuan 9-406B

Office hours: contact the instructors via email to set up an appointment. Please include 'ESS302' in the subject line for all your email correspondence.

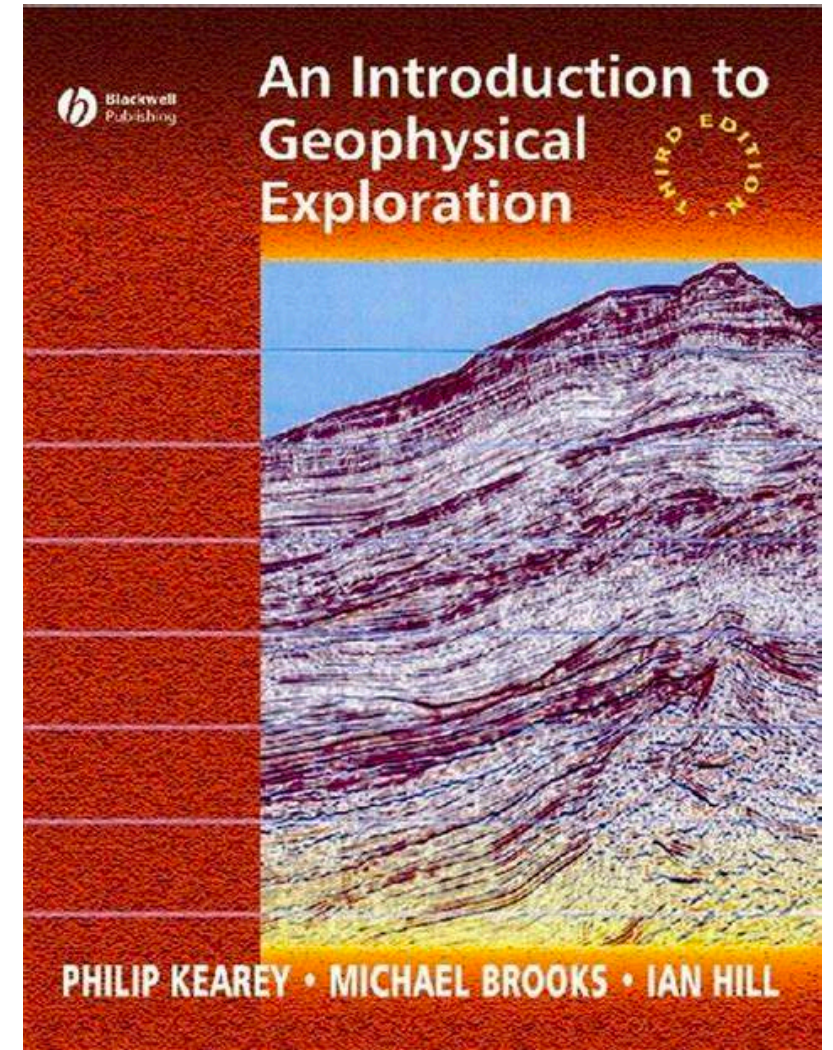
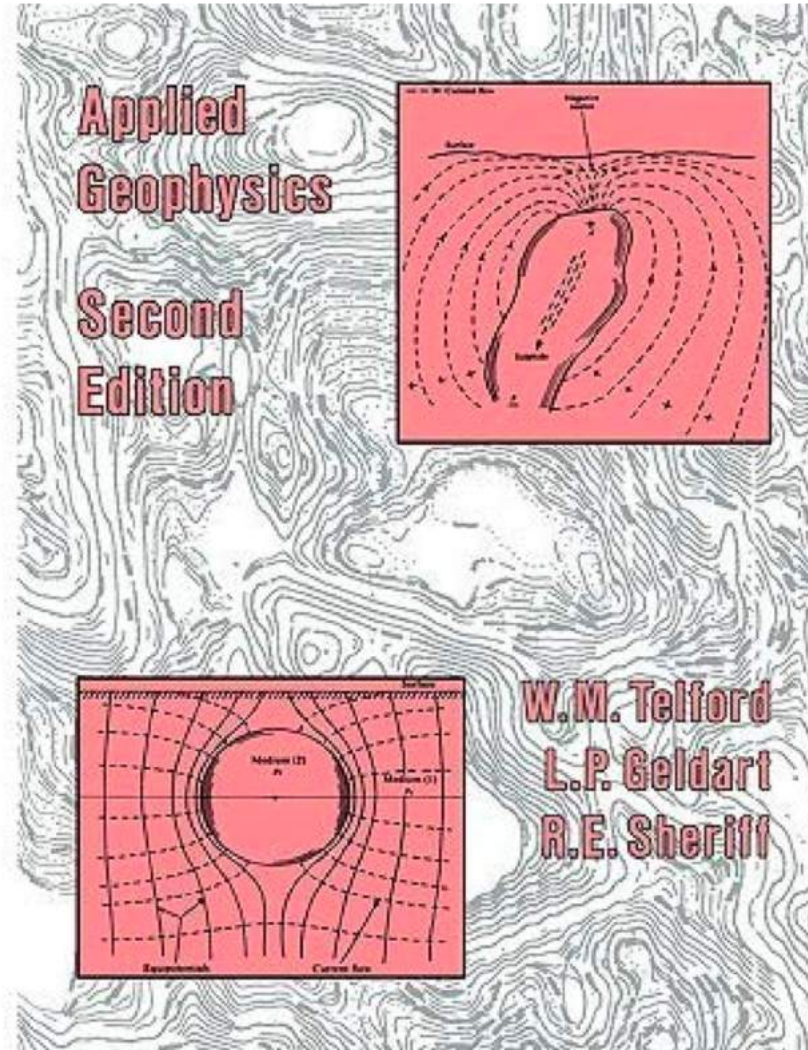
**Teaching Assistants:**

- Lichun Yang: [11930414@mail.sustech.edu.cn](mailto:11930414@mail.sustech.edu.cn), Chuangyuan 9-411



# 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



## 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 applications, 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



WIKIPEDIA  
The Free Encyclopedia

[Main page](#)  
[Contents](#)  
[Featured content](#)  
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Article [Talk](#) [Read](#) [Edit](#) [View history](#)

## Gal (unit)

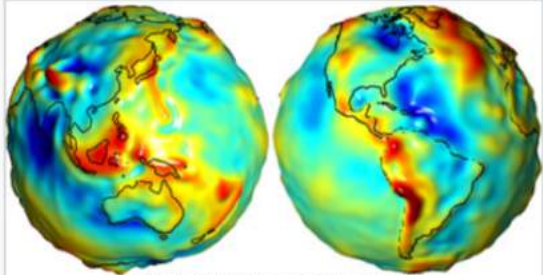
From Wikipedia, the free encyclopedia

*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](#).<sup>[2][3][4]</sup> The gal is defined as 1 centimeter per second squared (1 cm/s<sup>2</sup>). The **milligal** (mGal) and **microgal** (μGal) 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".<sup>[3][5]</sup> 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)

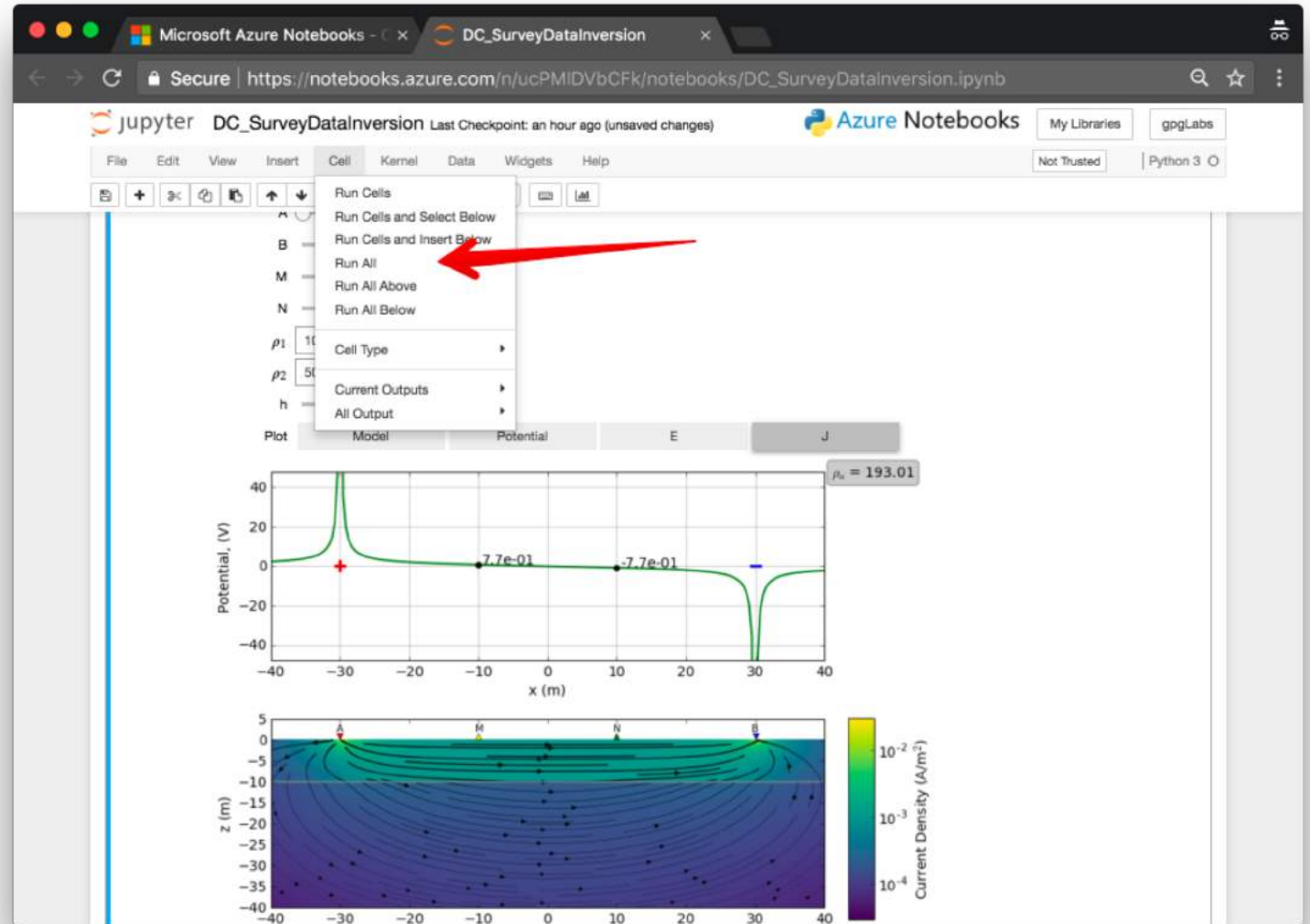
-50 -40 -30 -20 -10 0 10 20 30 40 50

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](#)).<sup>[1]</sup>



# Syllabus

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



(Python Jupyter notebooks)

# Syllabus

- Resources

- Textbooks
- eBooks, websites
- Wikipedia
- Technical publications

[illegible]

(Available online or in my office)

# Syllabus

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

The screenshot shows the Google Scholar interface with the search query 'artificial intelligence in geophysics'. The results are sorted by relevance. The left sidebar contains filters for time (Any time, Since 2019, Since 2018, Since 2015, Custom range...), sorting (Sort by relevance, Sort by date), checkboxes for 'include patents' and 'include citations', and a 'Create alert' button. The main results area displays three entries:

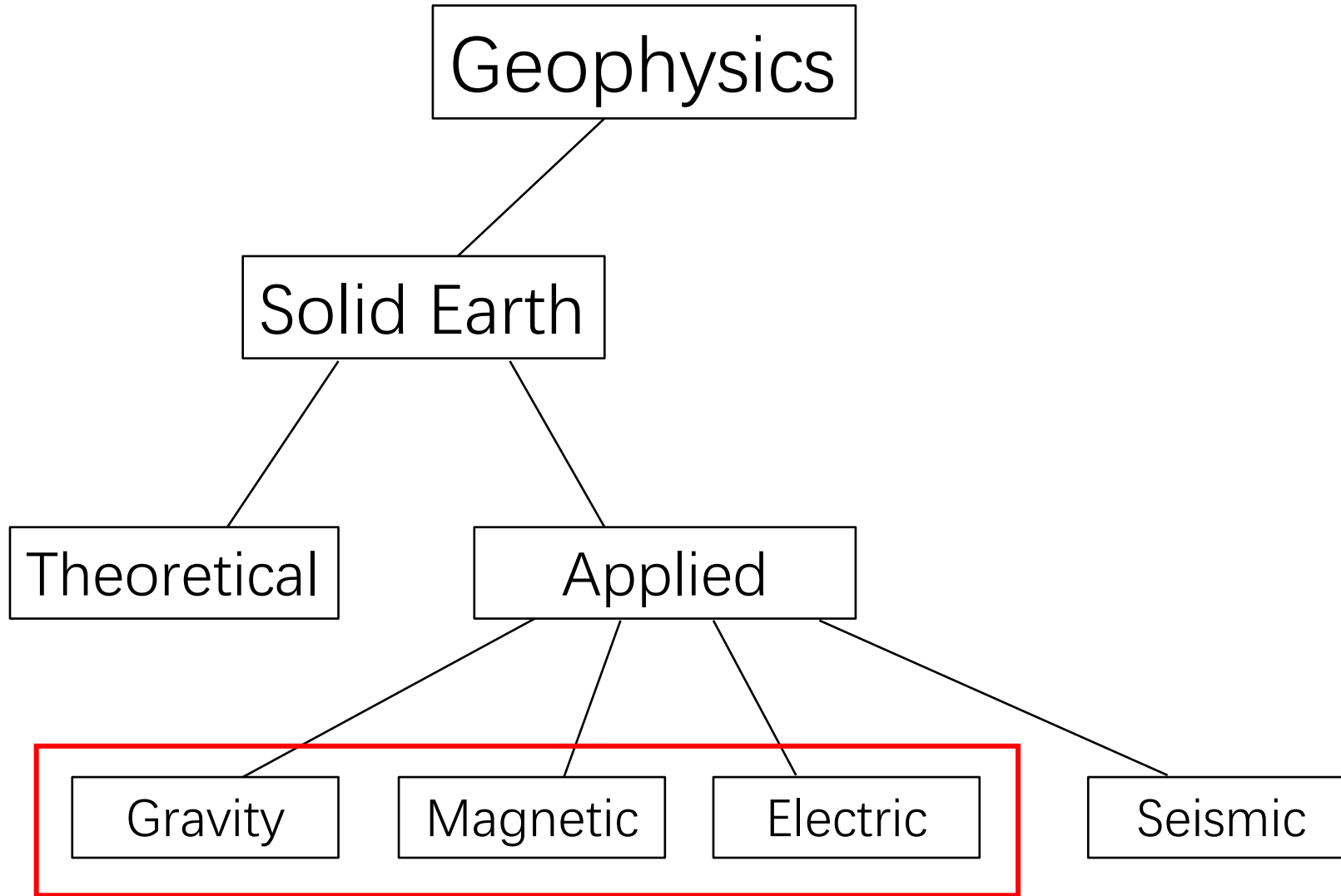
- [BOOK] Artificial intelligence and dynamic systems for geophysical applications**  
A Gvishiani, JO Dubois - 2013 - books.google.com  
The book presents new clustering schemes, dynamical systems and pattern recognition algorithms in **geophysical**, geodynamical and natural hazard applications. The original mathematical technique is based on both classical and fuzzy sets models. **Geophysical** and ...  
☆ 53 Cited by 53 Related articles All 5 versions
- [BOOK] Fuzzy rule-based modeling with applications to geophysical, biological, and engineering systems**  
L Duckstein - 1995 - books.google.com  
... Fuzzy rule-based modeling with applications to **geophysical**, biological and engineering systems / Andras ... crucial one and is a most sought after feature of **Artificial Intelligence** models ... wide applicability, as illustrated by the real life examples in **geophysics** (especially hydrology ...  
☆ 589 Cited by 589 Related articles All 3 versions
- Neural computing in geophysics**  
MD McCormack - The Leading Edge, 1991 - library.seg.org  
... neural networks do have significant advantages over expert systems, another **artificial intelligence** technology, and ... The recently published book Naturally **Intelligent** Systems by M. Caudhill and C. Butler ... from the Oregon Graduate Institute, and a Ph.D. in **geophysics** from the ...  
☆ 79 Cited by 79 Related articles All 4 versions
- Artificial intelligence and grids: Workflow planning and beyond**  
Y Gil, E Deelman, J Blythe, C Kesselman... - IEEE Intelligent ..., 2004 - ieeexplore.ieee.org  
Page 1. 26 1094-7167/04/\$20.00 © 2004 IEEE IEEE **INTELLIGENT** SYSTEMS Published by the IEEE Computer Society **Artificial Intelligence** and Grids: Workflow ... **geophysics**, earthquake engineering, biology, and global climate change (see the "Grid ...  
☆ 193 Cited by 193 Related articles All 28 versions



# 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 ICEEG2020 in Changchun





Non-seismic

Method	Theoretical	Applied
Gravity	The acceleration of gravity is not constantly $9.8 \text{ m/s}^2$ !	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

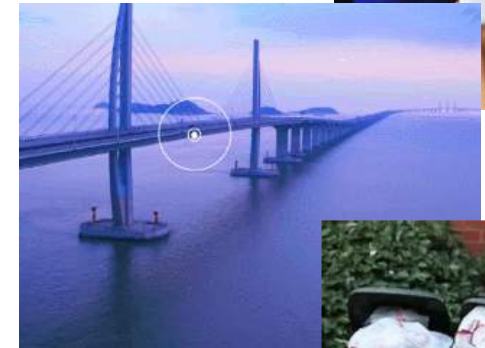
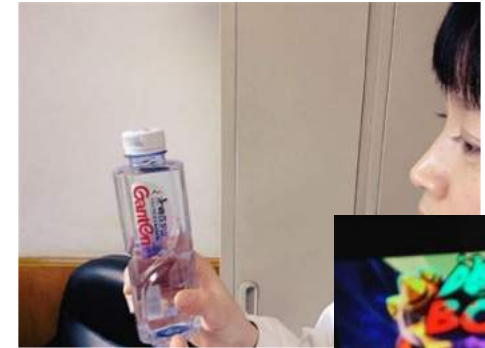
electrical conductivity/resistivity

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 struggle to buy a **medical mask**, 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?

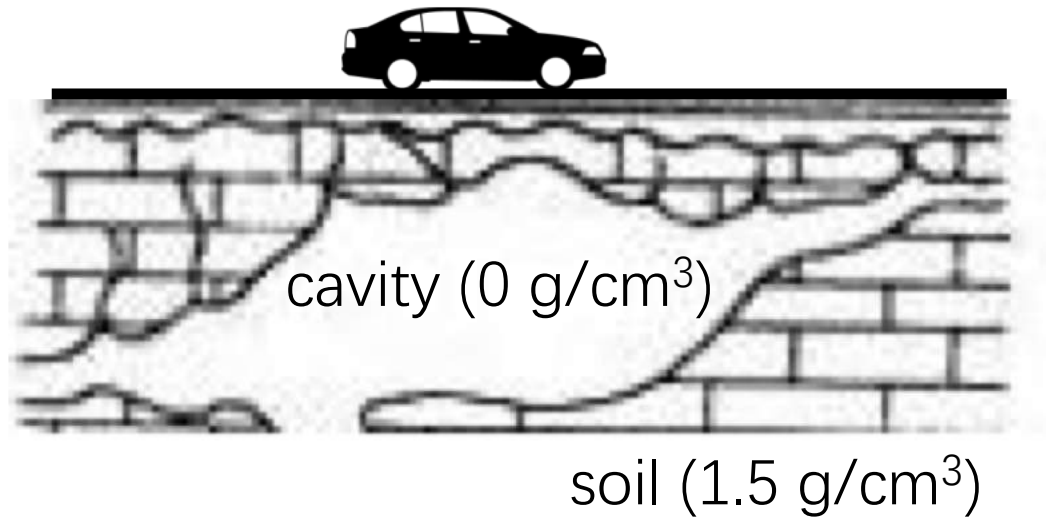
Detect and forecast the next deadly subsidence



# Surface Subsidence in Urban Area

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

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



### **Density contrast:**

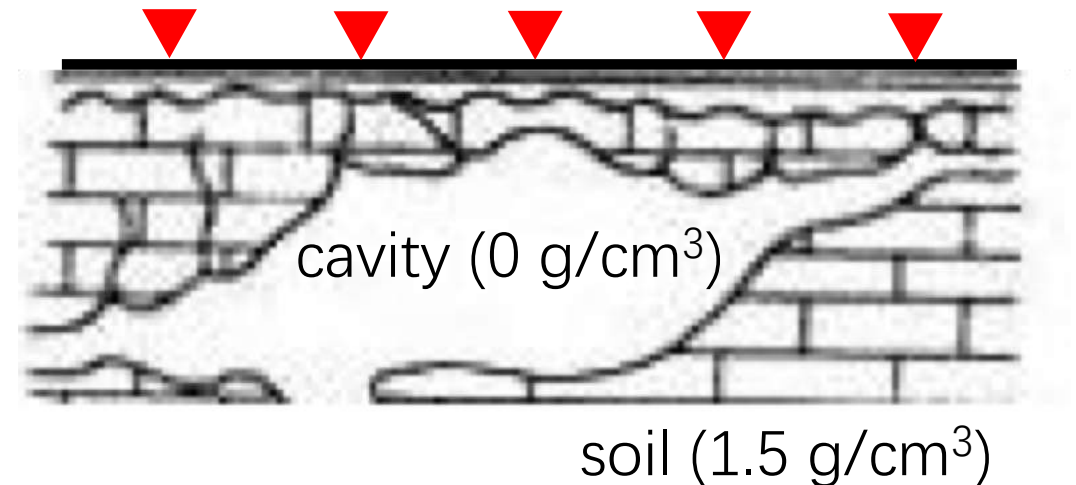
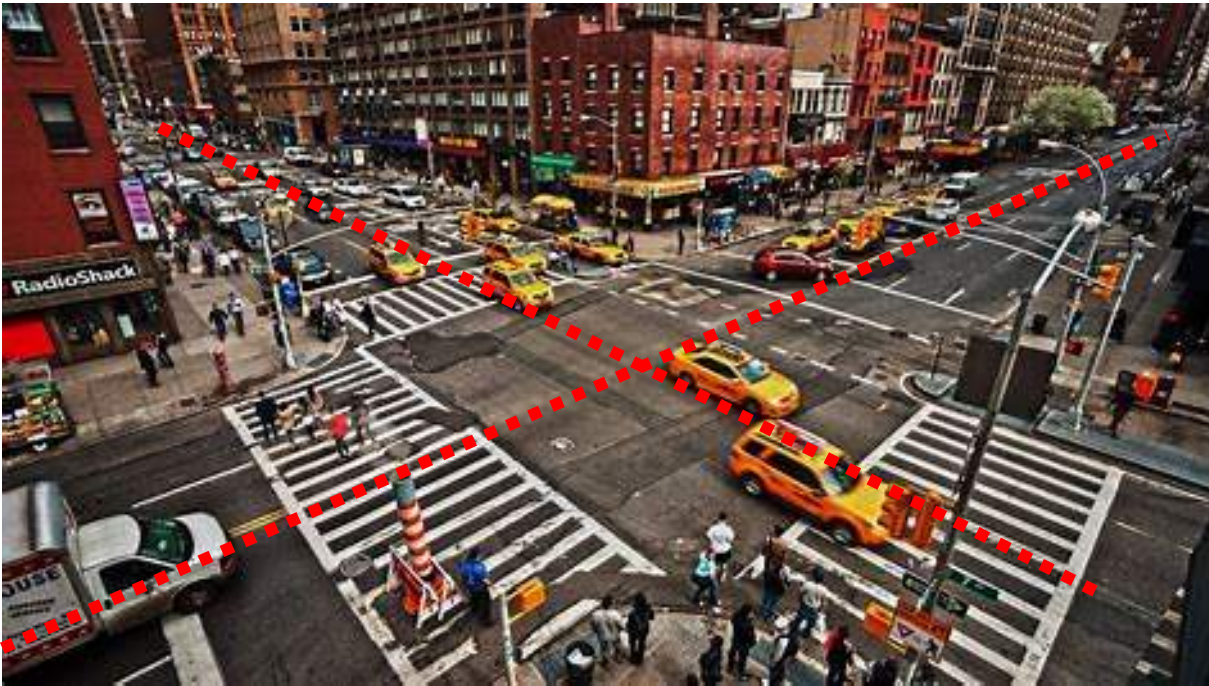
Smaller gravitational pull above the cavity compared to above regular soil



# Surface Subsidence in Urban Area

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

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



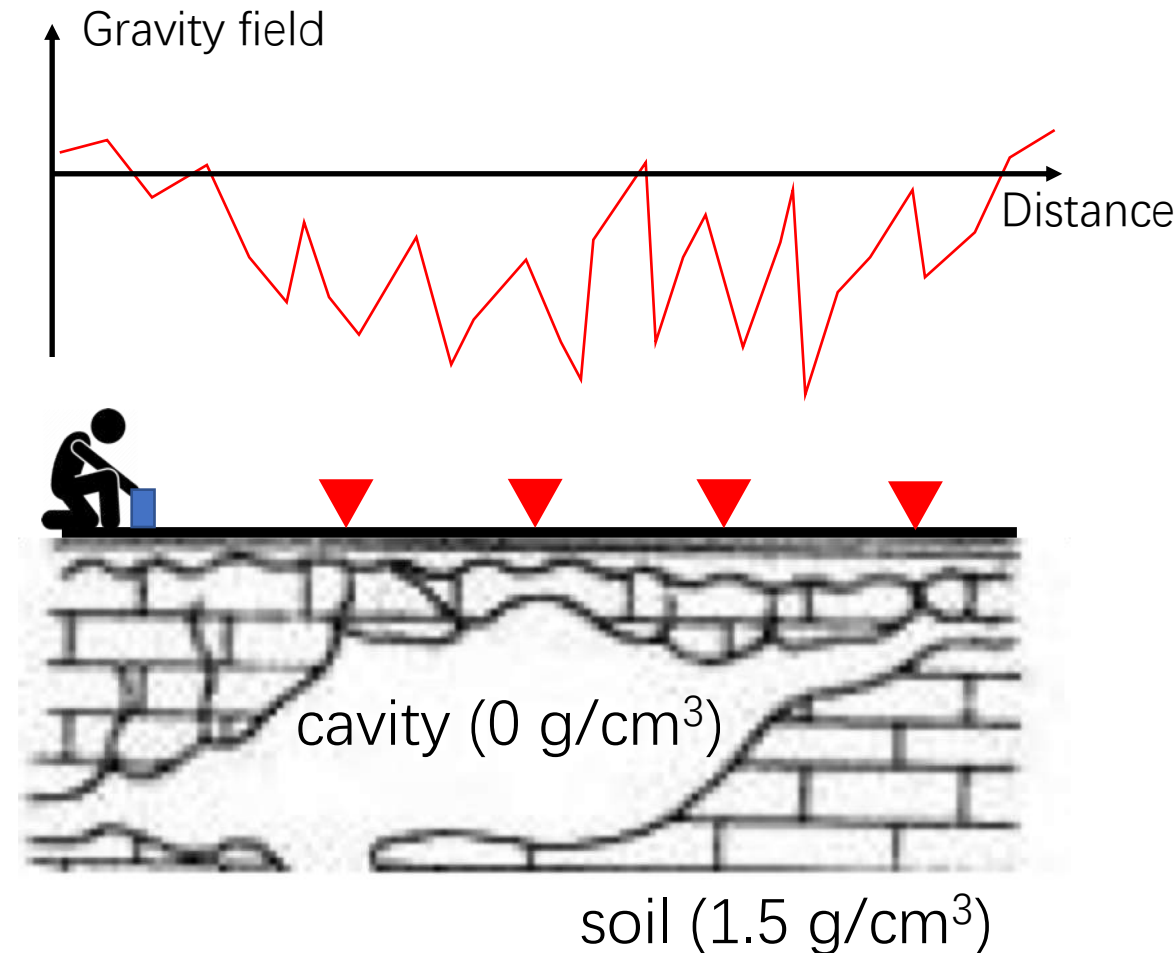


# Surface Subsidence in Urban Area

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

Deploy instrument and obtain data

Gravitometer

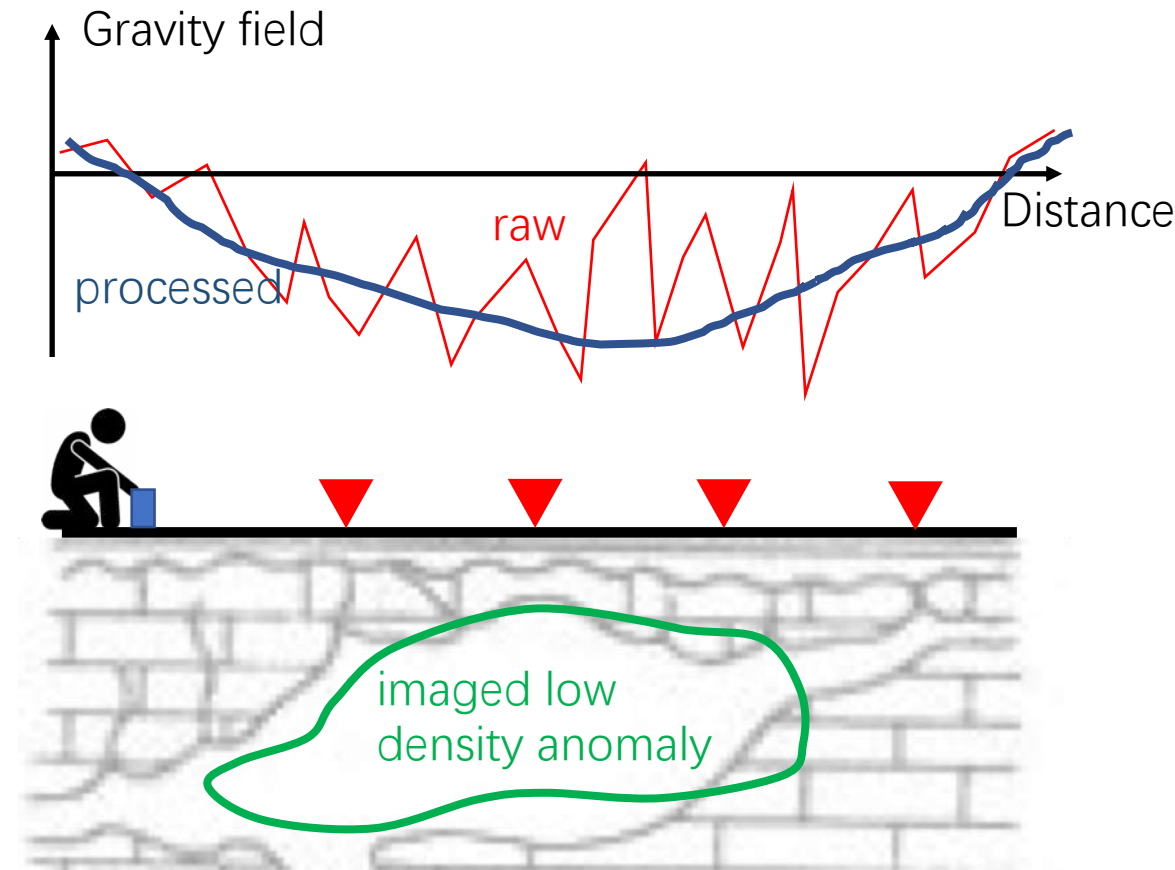


# Surface Subsidence in Urban Area

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

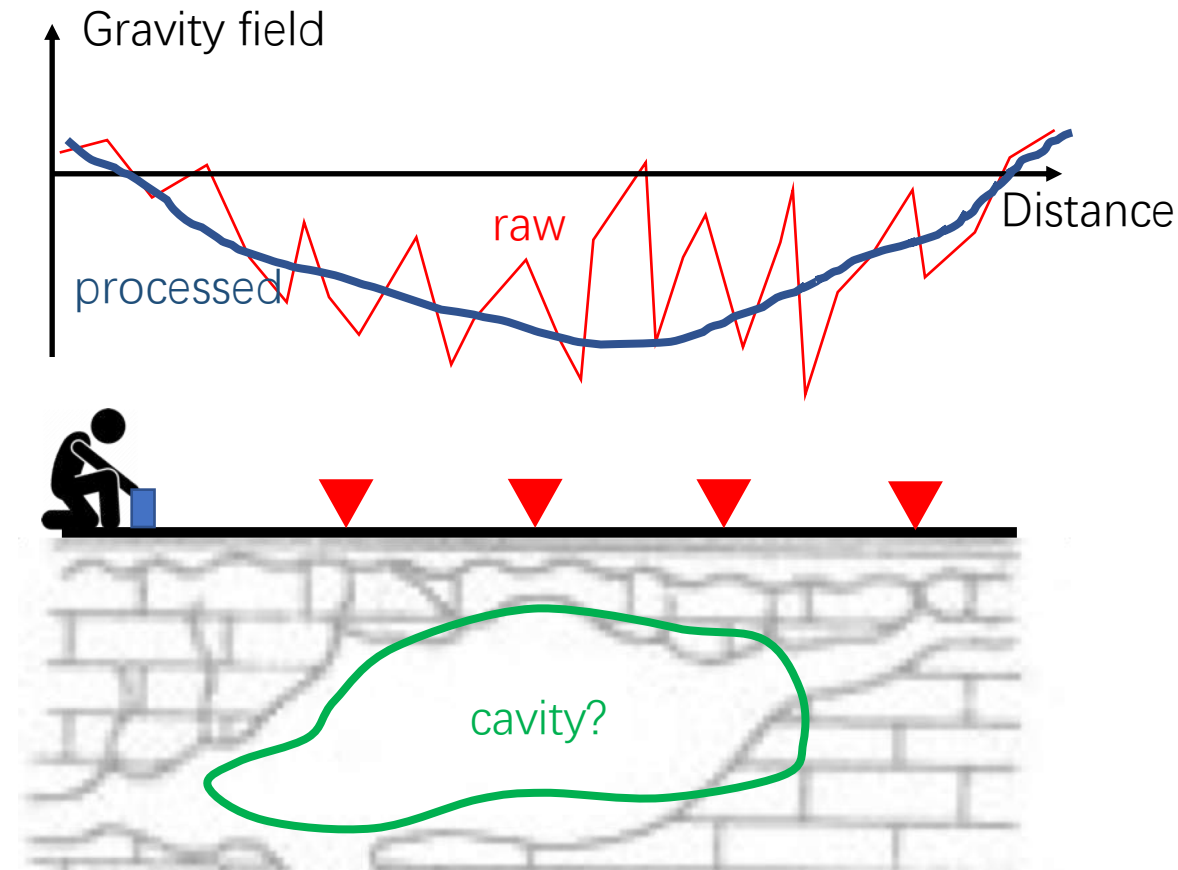
Example:

- 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?
- Webcasting lectures ok?