

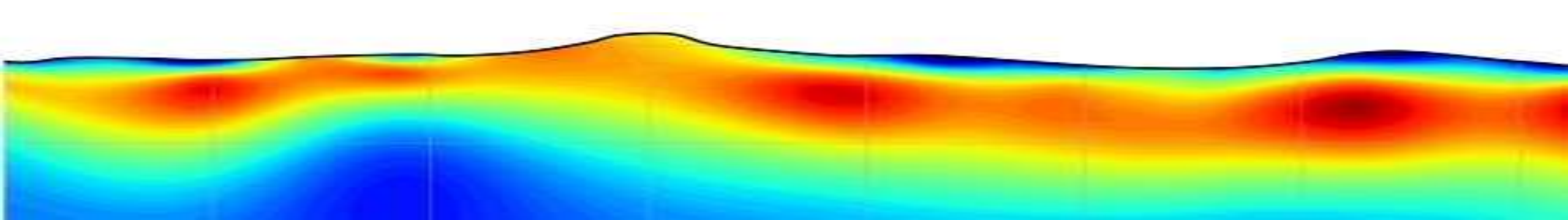
ESS302 Applied Geophysics II

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)

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Wk 7	Mar 30: Electric		
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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			

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

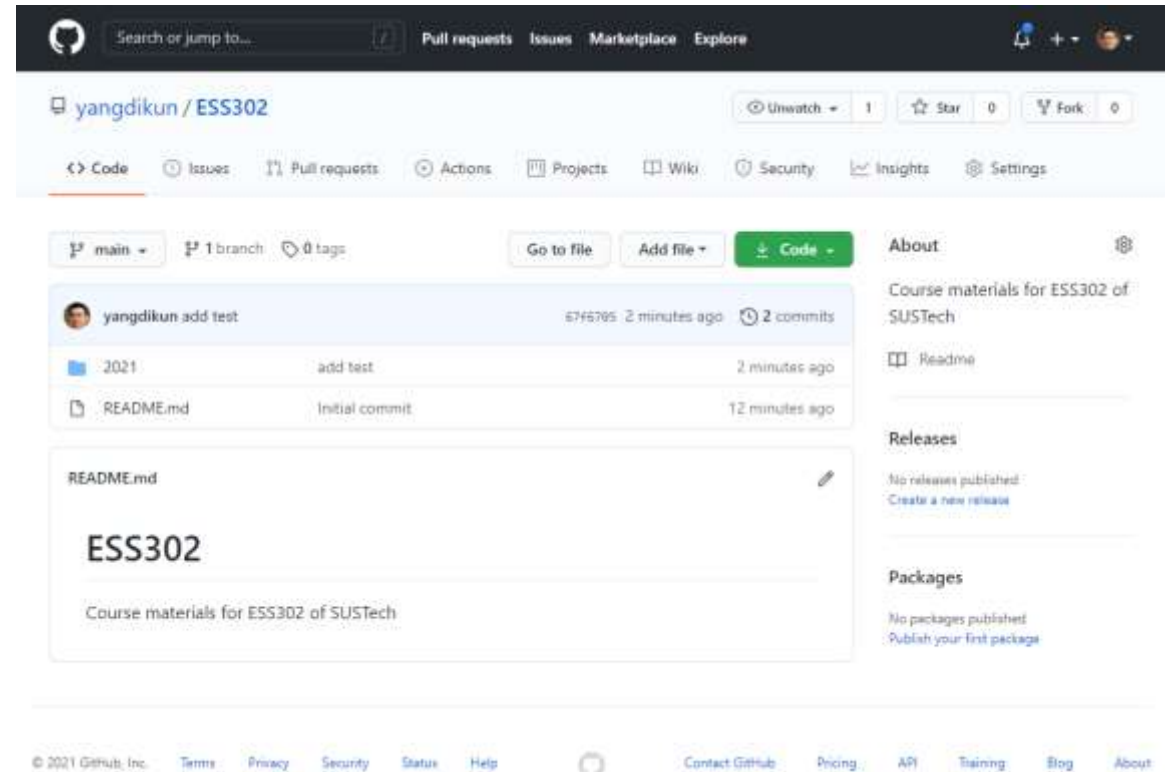
Course Resources

Blackboard



The screenshot shows the Blackboard interface for a course titled "Applied Geophysics II (Gravity & EM Exploration and Well Logging) [ESS302-30003207-2025SP]". The page is titled "--Syllabus & Learning Objectives". On the left, there is a sidebar with links for "About the course", "Course Materials", and "Feedback & Get Help". The main content area displays the "Syllabus & Course Schedule" with an attached file "Syllabus.pdf" (57.49 KB). Below the file, there is a "Basic Information" section containing details such as "Course title", "Hours/Credits", "Academic Dept.", "Scheduled", "Course type", "Language of instruction", "Prerequisites", and "Course description".

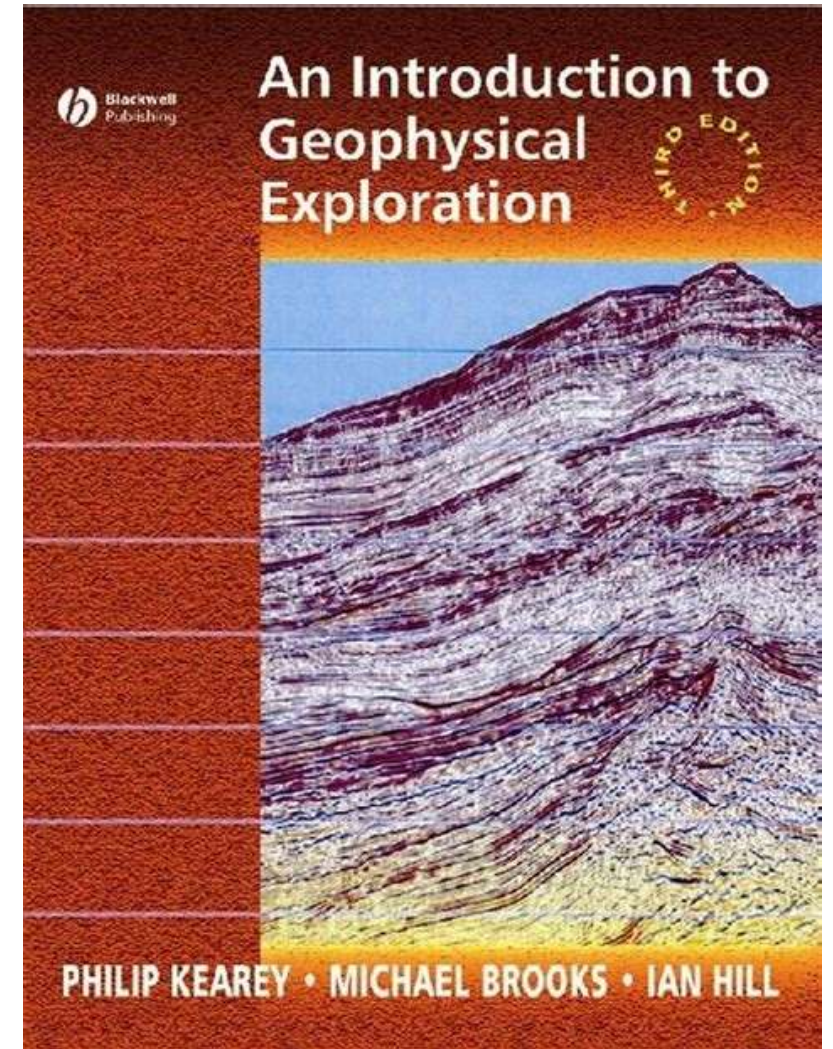
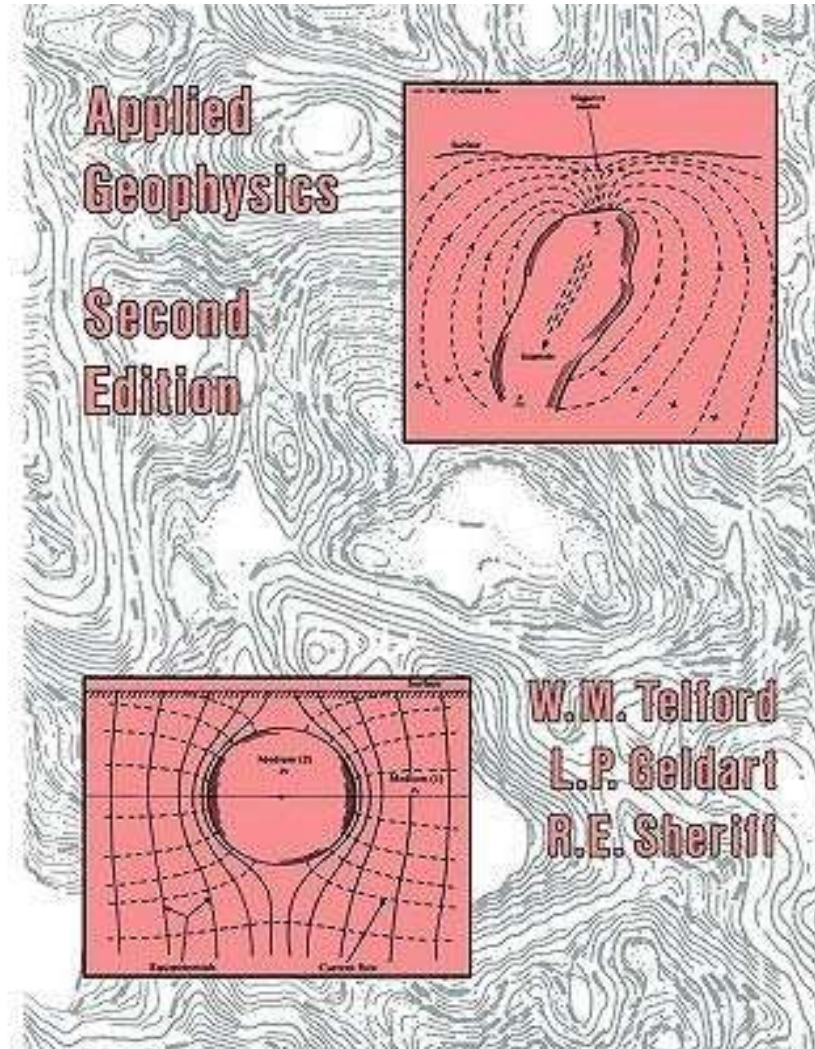
Course Materials <https://github.com/yangdikun/ESS302>



The screenshot shows the GitHub repository page for "yangdikun / ESS302". The page includes a search bar, navigation links for "Pull requests", "Issues", "Marketplace", and "Explore", and a sidebar with "Unwatch", "Star", and "Fork" buttons. The main content area displays the repository's "main" branch with 1 branch and 0 tags. It shows a commit history table with columns for the commit message, time ago, and number of commits. The commit history includes "2021 add test" (2 minutes ago, 2 commits) and "README.md Initial commit" (12 minutes ago). Below the commit history, there is a "README.md" section with the title "ESS302" and the description "Course materials for ESS302 of SUSTech". The right sidebar contains sections for "About", "Releases", and "Packages".

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 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](#)
[Current events](#)
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Gal (unit)

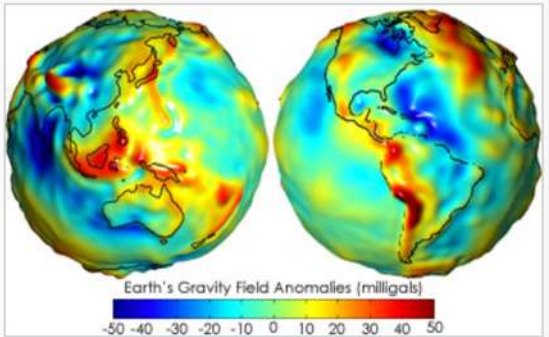
From Wikipedia, the free encyclopedia

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/s²). 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".^{[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,

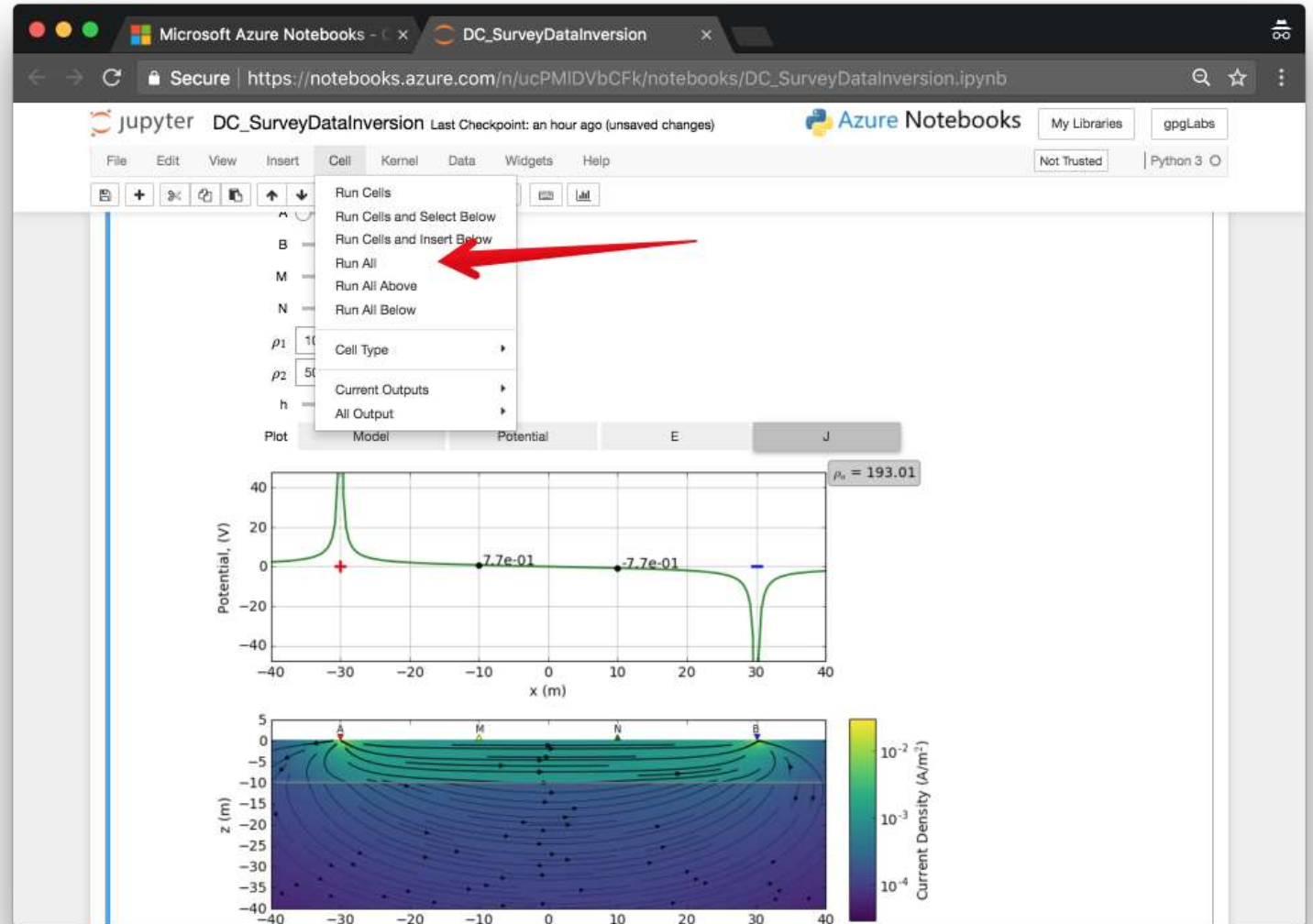


Earth's Gravity Field Anomalies (milligals)

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

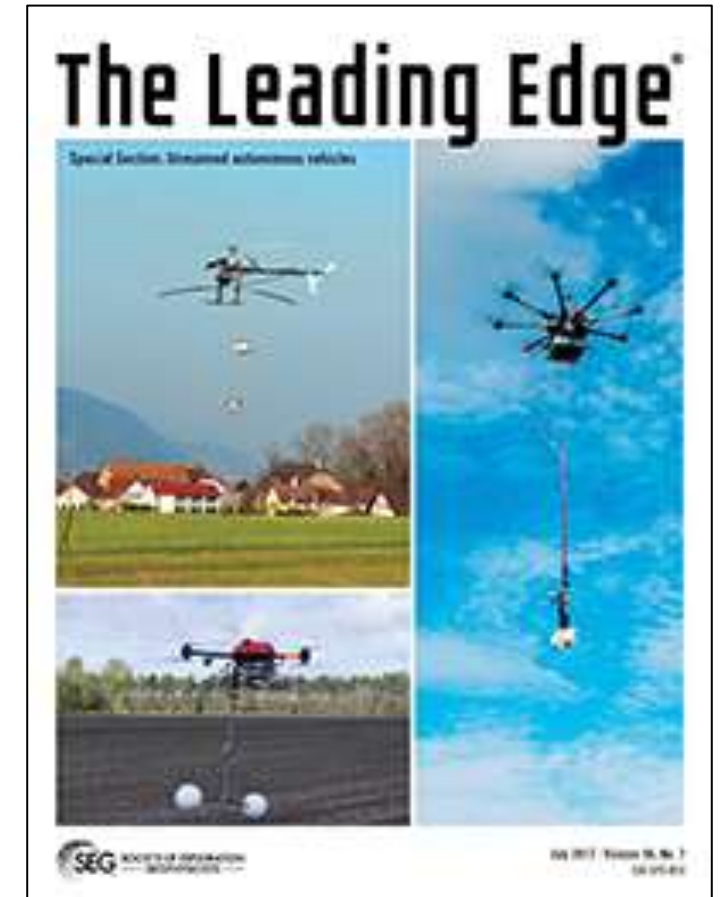
- Resources

- Textbooks
- eBooks, websites
- Wikipedia
- Technical publications

GEOPHYSICS®	
Society of Exploration Geophysicists The international society of earth scientists	
EDITOR'S CORNER	
The state of geophysics, from the Editor	0000
TECHNICAL PAPERS	
GEOPHYSICS LETTERS	
The most useful reservoir rock property: elastic delay, from D. Clark and Donald E. Sayers	0000
CASE HISTORIES	
Seismic wavefield tomography at Midway, from D. L. Johnson and Donald E. Sayers	0007
Seismicity of volcanic regions: an introduction using a fault-slip-sense formulation of tomographic results and associated generalizations from a case study in southeastern Nevada, from William H. Taylor, Bruce B. Baskin, Michael Thompson, and Timothy S. Jordan	0017
Real-world radio tomography—A new technique and case study from the city of Stockholm, from Robert Hansen, Lutz Perschke, James Ritchie, and Henry W. Wadsworth	0027
High-resolution seismic imaging in complex subsurface: A comparison among seismic reflection surface-wave, tomographic migration, and gradient depth migration at the West Virginia coalfield, from Craig Phipps, John Van Der Bruggen, and	0037
ASTROGEOLOGY	
Automatically determined kinematic properties of subducting slabs, from Steve	0107
NUMERICAL GEOPHYSICS AND ROCK PROPERTIES	
Full-wavefield modeling and inverse state estimation of time-variant stress in basaltic dykes, from George D. Durrant, D. L. Johnson, and John Van Der Bruggen	0117
High-resolution seismic tomography for the Nevada seismic reflection imaging, from D. L. Johnson, D. L. Johnson, and	0127
3D multi-scale analysis of rock properties: modeling subduction in Central American orogenesis, from Craig Phipps and John Van Der Bruggen	0137
ELECTRIC AND ELECTROMAGNETIC METHODS	
Large-scale 3D geoelectromagnetic modeling using parallel adaptive high-order finite element methods, from David J. Thomson and Thomas W. Bates	0147
Real-time conductivity tomography in well-logs of the subsurface during controlled-source electromagnetic induction, from Robert Hansen, Lutz Perschke, and Henry W. Wadsworth	0157
Optimized 3D synthetic aperture for controlled-source electromagnetic induction, from Robert Hansen, Lutz Perschke, and Henry W. Wadsworth	0167
Forward models of three-dimensional electric conductivity tomography—A numerical analysis, from Robert Hansen, Lutz Perschke, and Henry W. Wadsworth	0177
The impact of oceanic effects on water content estimates in surface seismic magnetic induction, from Robert Hansen and Henry W. Wadsworth	0187
Modeling near-field frequency-independent depth-resolved magnetic field coupling, from Robert Hansen, Lutz Perschke, and Henry W. Wadsworth	0197
ENVIRONMENTAL AND ENVIRONMENTAL GEOPHYSICS	
Modeling of ground surface and subsurface deformation at all scales using radar interferometry, from David J. Thomson, D. L. Johnson, and John Van Der Bruggen	0207
Jointing in hard and shallow seismic data: A case study from Florida and Tennessee basins, from Robert Hansen, Lutz Perschke, and Henry W. Wadsworth	0217
Seismicity in the Nevada seismic reflection imaging, from D. L. Johnson, D. L. Johnson, and	0227

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ISSN 1942-2136 (online)

Contents continued on inside front cover



(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 range (Any time, Since 2019, Since 2018, Since 2015, Custom range...), sorting options (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 ...
☆ 57 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 ...
☆ 57 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 ...
☆ 57 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 ...
☆ 57 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 CGT2021 in Wuhan**



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

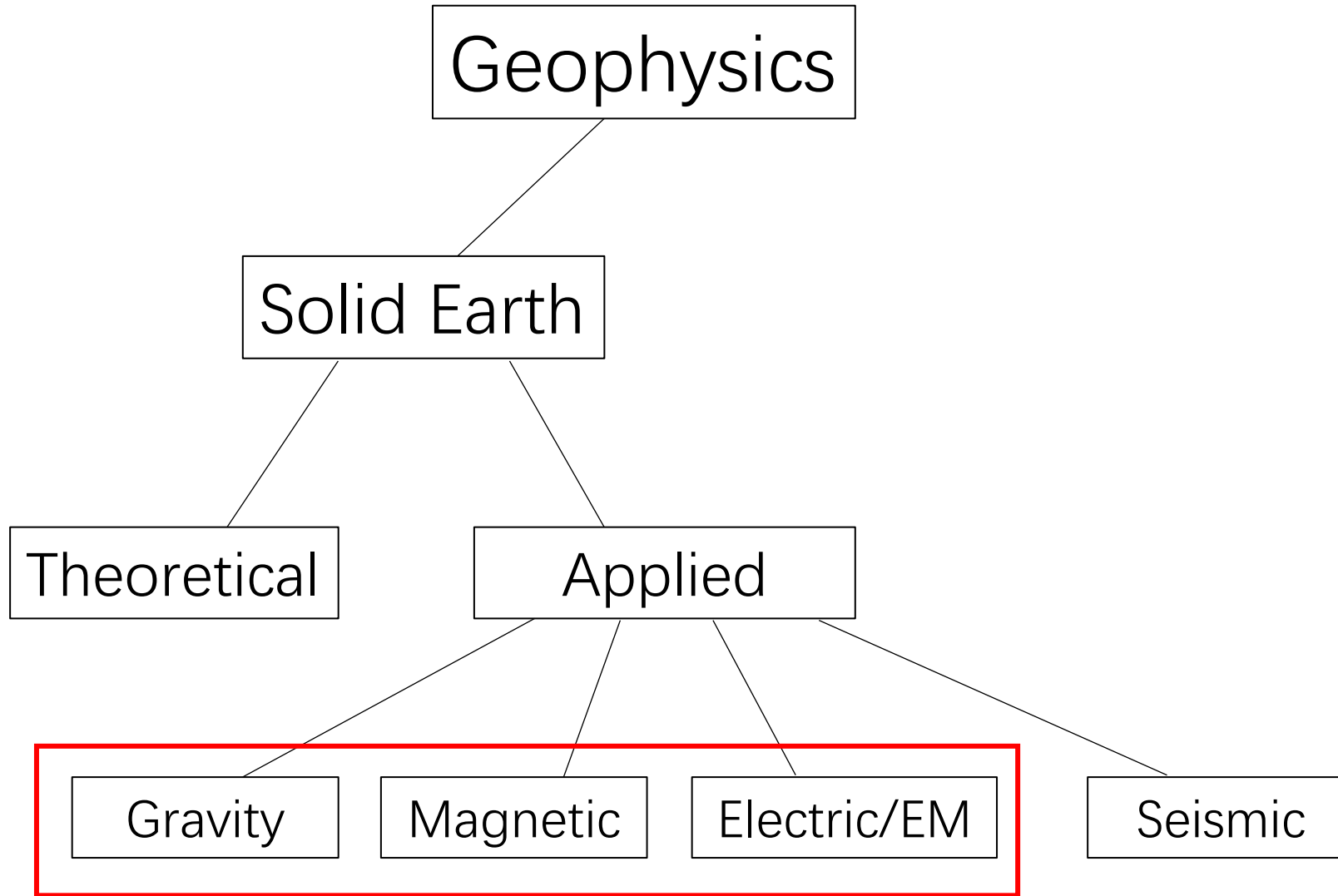
地球物理技术已经拓展至深地、深海和深空，全域探测的趋势已经悄然来临。探索全域智能感知的理论和方法，为人类社会的科学和经济发展持续不断的提供资源，需要广大地球物理工作者集思广益、大力投入。为推动地球物理技术在广度和深度的进一步发展，拟定于2021年5月21日-23日在湖北武汉召开“中国地球物理学会地球物理技术委员会第九届学术会议——全域地球物理探测与智能感知学术研讨会”。会议将邀请多位国内外专家就地球物理技术的发展及应用前景做大会报告，并围绕深地、深海和深空地球物理技术，近地表地下空间地球物理精细探测技术，地球物理传感技术等十二个专题展开学术交流。届时，将举办地球物理仪器设备展览，观摩华中科技大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



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

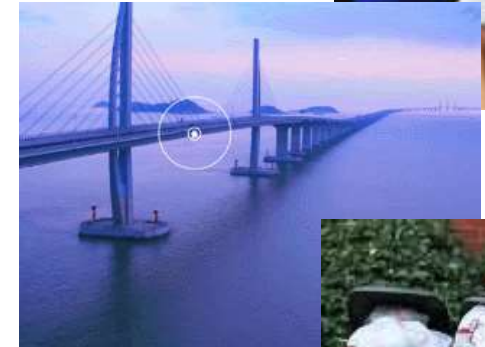
electrical conductivity/resistivity

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?

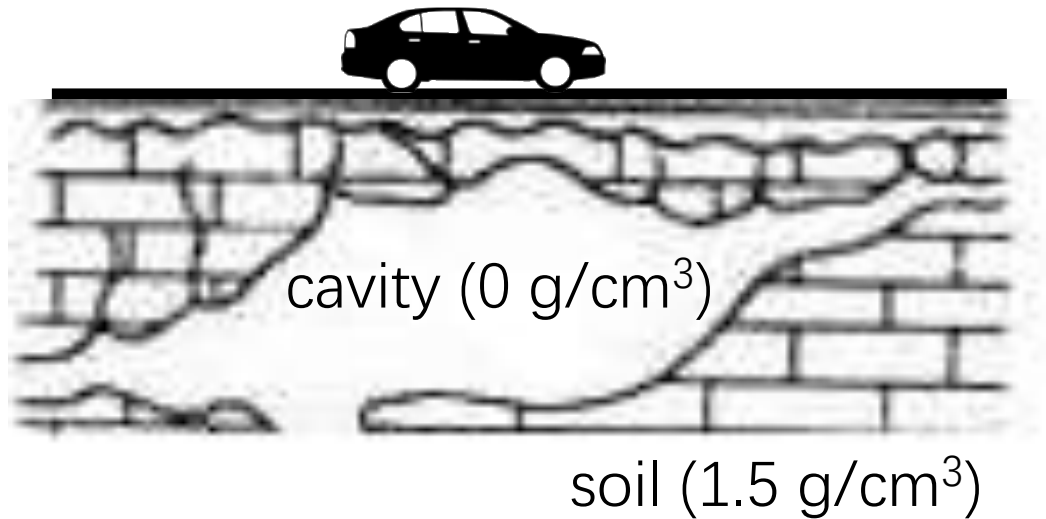
Detect and forecast the next deadly subsidence



Surface Subsidence in Urban Area

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

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



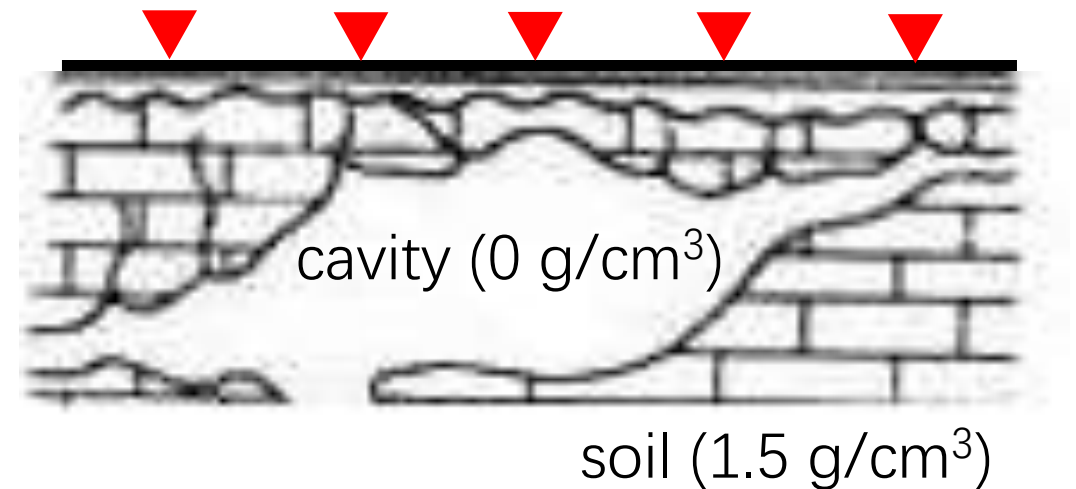
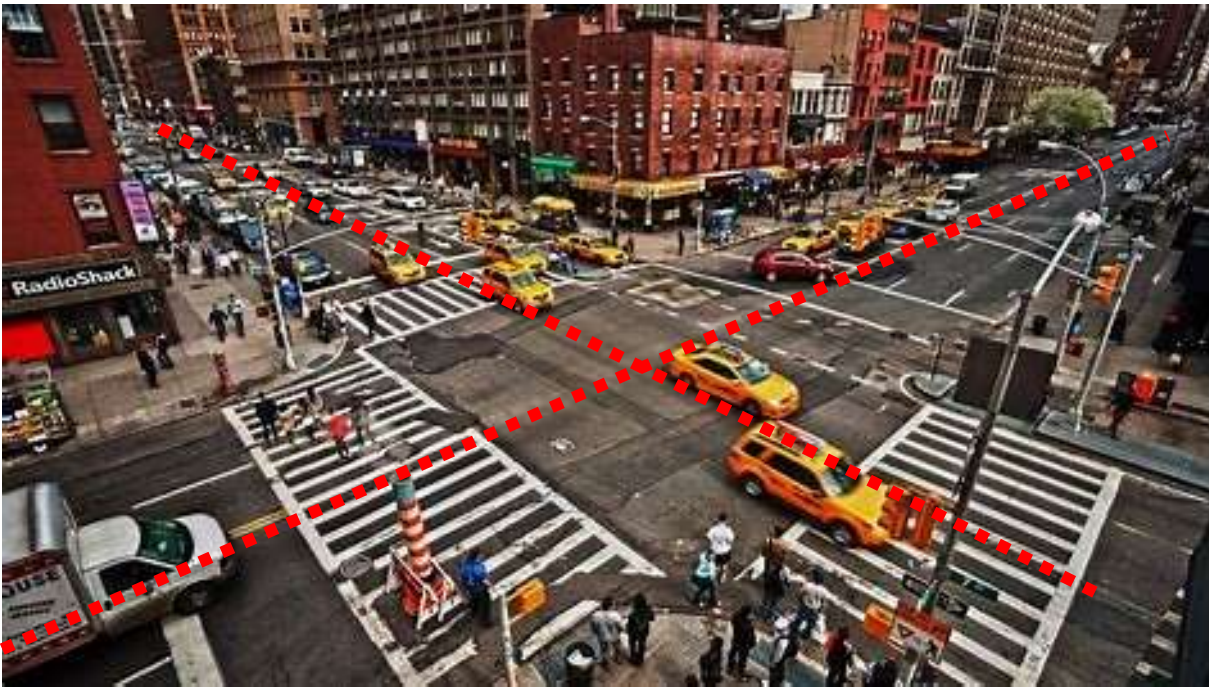
Density contrast:

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.

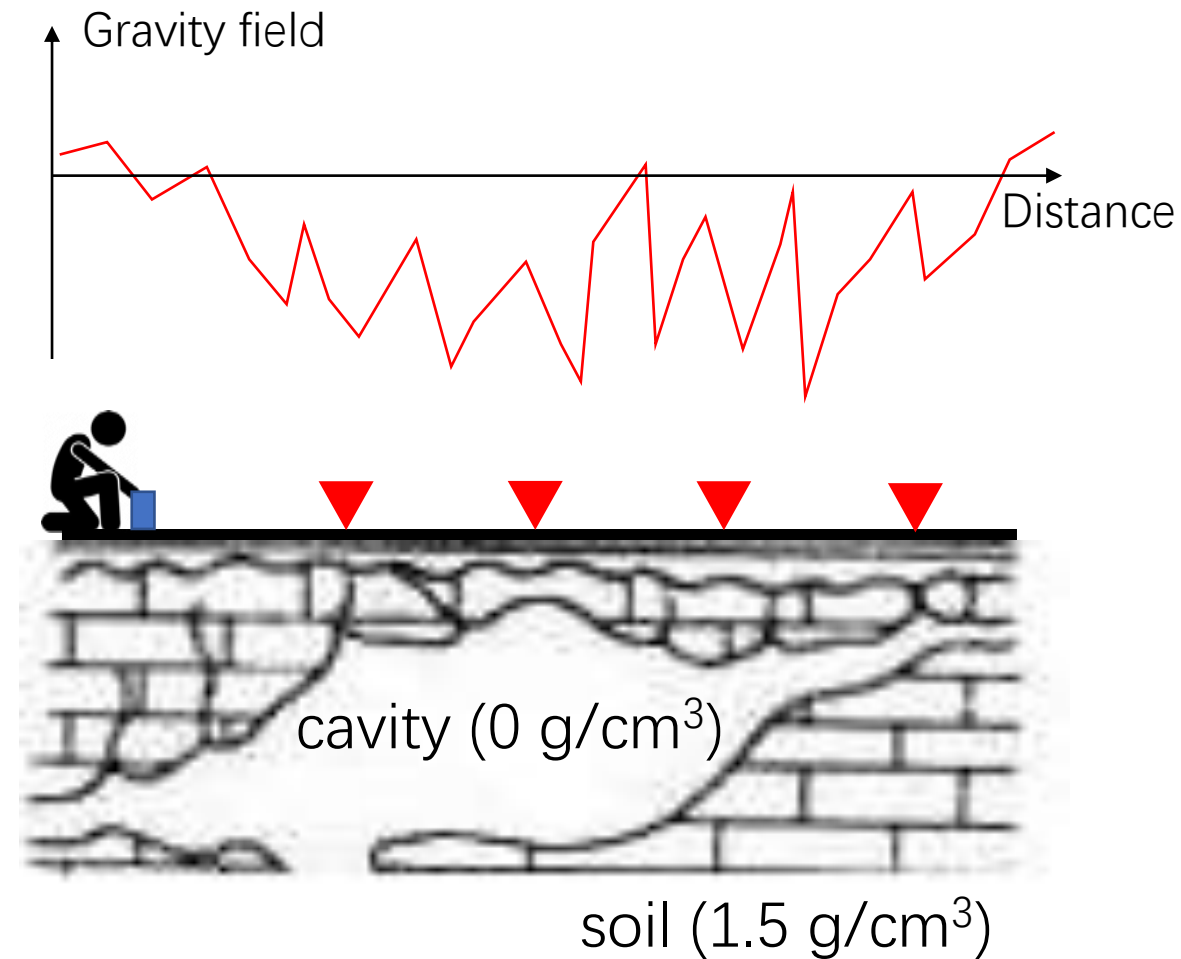


Surface Subsidence in Urban Area

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

Deploy instrument and obtain data

Gravitometer

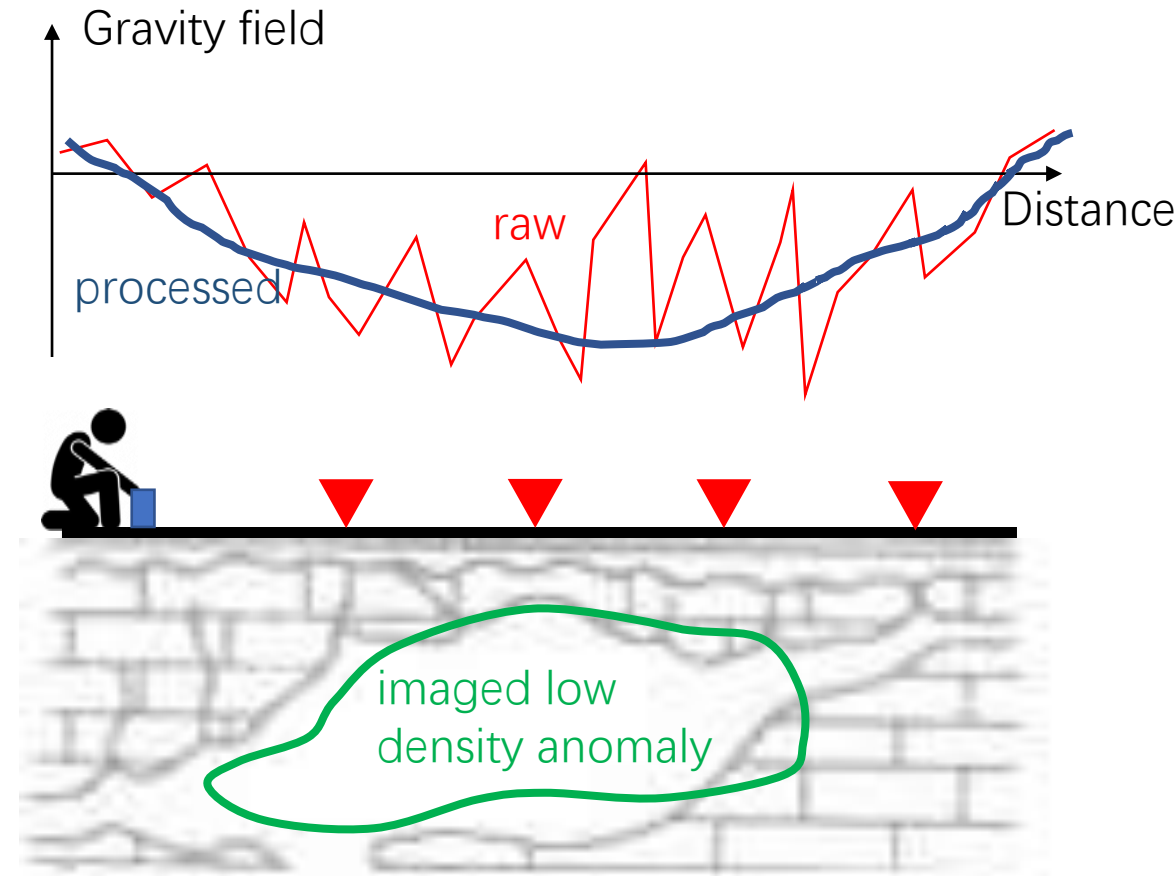


Surface Subsidence in Urban Area

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

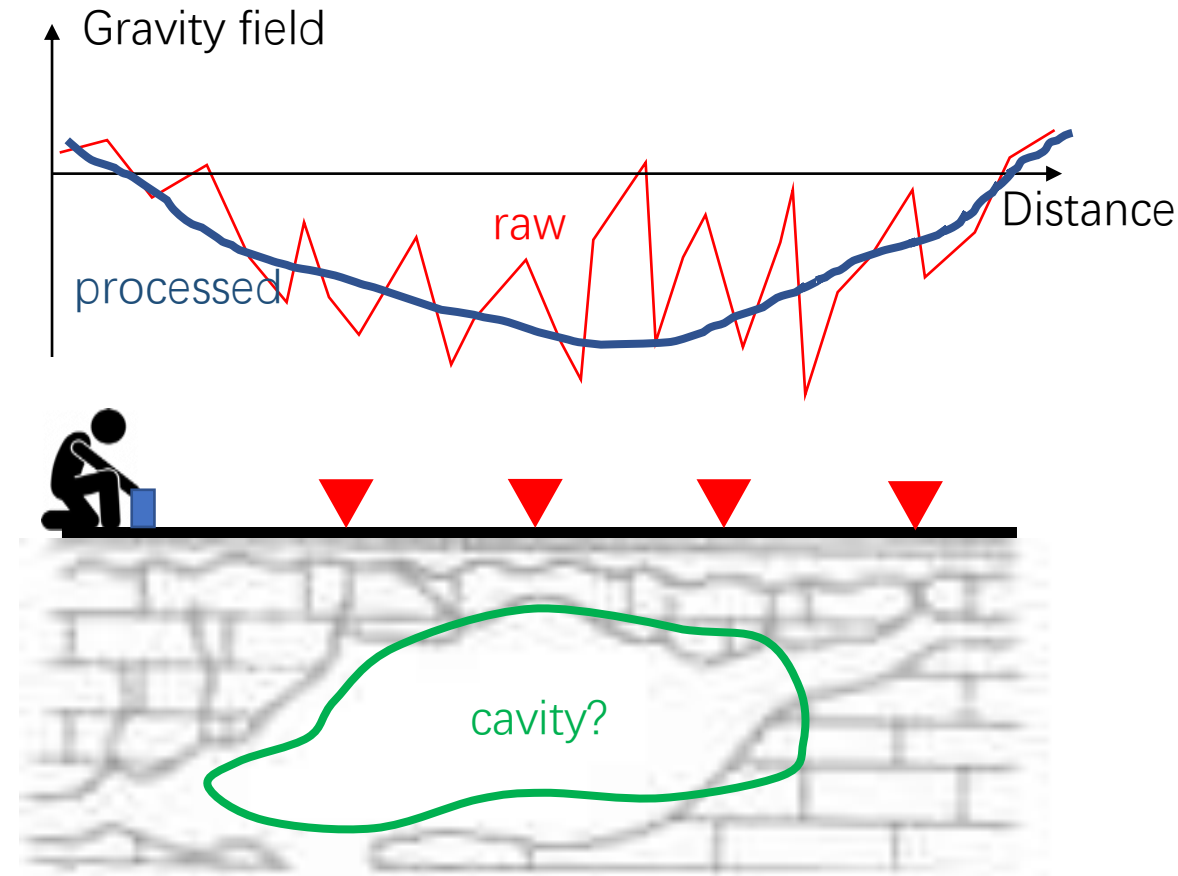
Example:

- 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?