Updated 10 January 2022

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# UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE

# DEPARTMENT OF GEOGRAPHY AND EARTH SCIENCES

# GEOL 4115/5115 (O)

# APPLIED GEOPHYSICS

**Please print a copy of this syllabus for handy reference.**
Whenever there is a question about what assignments are due, please remember this syllabus and the online assignment schedule are the ruling documents. Also, there may be typographical or other errors in the document that are subject to change with prior announcement to the class.

**Field Trip Dates**. The class will be divided into small groups for field research data collection. Plan on 1-3 days, depending on the project and field conditions.

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## Course Information

### Textbooks and References

Readings will be listed in modules on Canvas. Rather than using a single textbook, we will read excerpts from general geophysics textbooks, books or book chapters about specific geophysical methods, and web resources.

### Spring 2022 Notes

Changing conditions caused by COVID-19 will affect course structure. The original plan for the semester was to have lectures available in Canvas or Zoom and to meet most lab sessions face-to-face. Field trips will likely requirement individual transportation. Generally, we will remain flexible in scheduling all activities.

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## Instructor Information

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### Instructor Availability

If you have a question that would benefit the entire class, please ask that question in a synchronous class session or post it to the discussion forum in Canvas instead of using individual messaging. Send questions to the instructor by e-mail only if they are highly personal. Every effort is made to respond to e-mail messages received Monday-Thursday within 24 hours; messages received during the weekend will take much longer for a response.

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## Welcome and Course Description

Welcome to **Applied Geophysics**! This is a course in applied geophysics. In particular, our emphasis is on near surface geophysics, sometimes referred to as Critical Zone (CZ) geophysics. This usually means the upper 100 meters or less of the subsurface, but the lower limit is not rigorously defined.

Most of the potential field geophysical methods - magnetics and gravity especially - and seismology originated from the need to explore deeper levels in the lithosphere or even down to Earth's core, but with modification they can be used for the shallow subsurface. Other geophysical tools, among them ground penetrating radar (GPR), EM (electro-magnetism), electrical resistivity, and seismic refraction are ideal for shallow investigations. Radiometric surveys conducted with ground or air scintillation counters are good for geochemistry of surficial and near surface geological materials.

### Aspects of Geophysics

“Global geophysics” or “whole Earth geophysics” typically refers to large-scale applications of geophysics to study, for example, lithospheric structure or mantle dynamics.  This aspect of geophysics is also called “solid earth geophysics”. “Applied geophysics” or “near-surface geophysics” refers to investigations of the crust or shallow subsurface, often for practical or economic reasons. “Environmental geophysics” is closely related to applied geophysics, although topics investigated in this area may be tied to the objectives of environmental sciences, such as remediation of contaminated sites, mine reclamation, and so on.

“Engineering geophysics” is “the application of geophysical methods to the investigation of sub-surface materials and structures that are likely to have … engineering applications” (Reynolds, 2011, p. 1). Geotechnical engineering is work done by individuals with engineering backgrounds when working with natural materials like rock and soil.

The same geophysical method may be applied in other fields. These include archaeology (geophysics in archaeology), biology (microbial activity in geological materials, organic contamination of the environment), hydrology (surface and groundwater), glaciology (geophysics of glaciers and their environments), agriculture (geophysics of soils and soil forming processes), and forensics.

“Geoforensics” or “forensic geology” is “the application of selected geosciences techniques to criminal investigations of what happened, where and when it occurred, and how and why it took place” (Ruffell and McKinley, 2008, p. 1). “Forensic geophysics” refers to using geophysical methods in forensics investigations. We might better think of geoforensics as the application of principles of geology (or geoscience) to solve problems in the human environment. (“Human environment” may be a redundant phrase. “Environment” by definition is usually human-centered.)

Seismologists might study teleseismic events to look for unannounced nuclear tests in North Korea, but they may also use similar records to locate meteorite impacts in remote regions. A geomorphologist may investigate evidence for ancient landslides along the route of a planned highway.

A critical distinction for applied geophysics compared to other methods in the geosciences is that geophysics is non-intrusive. The study site can remain undisturbed. Most site investigations do ultimately involve drilling, excavation, sampling or other more intrusive technologies. Geophysics, therefore, is often used as an initial site investigation tool to help plan the application of additional tools.

## Course Themes

Applied Geophysics is arranged in topical themes or methods. In this course, we are most interested in studying geophysical principles and methods that focus on near-surface processes. That depth is not precisely defined, but it could be considered less than 1 kilometer depending on method and objective. Practical applications of near-surface geophysics are often limited to a depth of a few to tens of meters. We may discuss some of the fundamentals of whole Earth geophysics as background, but most of our effort will be close to Earth's surface.

### *Potential Fields*

One geophysical definition of a potential field is, "A field that satisfies the Laplace equation. The Laplace equation is equivalent in three dimensions to the inverse square law of gravitational or electrical attraction (in source-free regions; in regions with sources, it becomes Poisson's equation). Examples of potential fields include the field of the gravity potential and static electric and magnetic fields."[1] In simpler terms, a potential field is a continuum where the energy possessed by an object varies with its position relative to other objects in its vicinity, to stresses, to electrical charges, and to other physical phenomena.[2] Examples of potential fields include gravity, elasticity, electricity, and magnetism. The SI unit for energy is the joule (J) but we use other derived units in geophysics.

### *Electromagnetic Methods*

[1] http://www.glossary.oilfield.slb.com/Terms/p/potential_field.aspx
[2] https://en.wikipedia.org/wiki/Potential_energy

There are several geophysical methods that use energy within the electromagnetic (EM) spectrum to conduct remote sensing of the environment. These include ground penetrating radar (GPR), electromagnetic surveying (EM surveying), electrical resistivity, and others. Some of these are active methods (e.g., GPR – ground penetrating radar) in that they generate an energy source and then record a response from the subsurface. Other EM methods are passive in that they monitor an ambient field such as the natural electrical field that flows through Earth's atmosphere and lithosphere (the magnetotelluric current).

### *Magnetism*

Magnetic fields are force fields created by moving electric charges (electrical currents) and magnetic dipoles. (Think of a bar magnet as a magnetic dipole.) The GPR method mainly uses the electrical component of an EM field; magnetic methods are more concerned with the magnetic component. Magnetic fields may be dynamic and transient, or permanent as in the case of a bar magnet. Earth's magnetic field is employed in surveying as though it were a permanent magnet, but it is in fact a dynamically maintained field. Prospecting using a magnetometer detects variations in Earth's magnetic field created by variations in ferrous iron content in the vicinity of the detector.

### *Seismic Methods*

Seismic methods involve either the measure of mechanical energy released by earthquakes or the measure of mechanical energy induced by artificial means such as explosives or weight drops. Energy transfer is accomplished by the elastic behavior of rocks and other Earth materials, and that motion is what we feel in earthquake ground motions. Detecting how seismic waves reflect and refract in the subsurface is the basis for most seismic methods.

Earthquake seismology generally means the study of naturally sourced earthquakes. An earthquake technically is generated whenever rocks break or slip, even if those phenomena are very low energy, but most of earthquake seismology investigates teleseismic events – earthquakes that are detected from a distance.

### *Trans-Disciplinary Applications*

Near-surface geophysical methods detect subsurface anomalies based on variations in electrical or physical properties. This approach gives multiple disciplines tools to conduct a search for those anomalies independent of genesis.

A geophysical survey does not necessarily result in a discrete interpretation. For example, GPR is used to find graves, but an archaeologist looking for unmarked graves must understand the context and environment of the survey as well as what features in a GPR record might distinguish a grave. Conducting a geophysical survey without context can be fruitless.

Even within a known context, a geophysical survey may not provide unique results. Some form of ground truth, where a known object is located and/or excavated, is exceptionally valuable in the interpretive phase of a study.

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## Course Content

### Applied Geophysics Principles and Methods

Our principal goal in Applied Geophysics is to introduce you to several geophysical survey methods, but not all methods. We focus on those methods for which we have equipment for hands-on experience. Other methods and applications of geophysics may be introduced in lecture.
The course intends to lay out in a straightforward way the underlying principles of the methods we do cover. You will not be expected to learn equation derivations, nor to perform high-level math manipulations. Equations serve to explain functional relationships. We will explore several essential mathematical relationships by examining plots of those equations to see how their components affect outcomes.

The geophysical methods for which we have equipment are GPR, magnetometer, gravity, EM, and seismic. For course projects, we typically use only one or two of these methods because of the time involved for data collection. Also, the methods used are determined largely by the problem at hand. Each method experience offers guided hands-on use of the equipment and of the analytical procedures needed to interpret the data. You will not become an expert at any method, but you hopefully will understand, for example, what a GPR survey is and what it can and cannot tell you.

We spend a lot of time on GPR. This method is utilized in a wide range of disciplines and applications, and is becoming a common tool in CZ studies and geotechnical or even structural engineering.

Delivery of this information and experience will be by lecture (information and theory) and lab (problem solving and experience), or depending on health regulations at the time, asynchronously via Canvas or Zoom. These two are blended together so that, for example, lab may be a combination of lecture and practice. How this knowledge and experience will be assessed is described below.

### Oral Communication Expectations

Applied Geophysics is an oral communication (O) course. To receive this designation, the course must meet certain minimum expectations. Here is a formal summary of those expectations:

1. The focus of the course should be on developing oral communication skills appropriate for the discipline.
2. Speaking must be an on-going, integrated feature of the course. The course should use communication exercises that support course content, thinking critically in a discipline, and teaching disciplinary conventions.
3. The course should have a minimum of two formal oral presentations that will be evaluated by the instructor.
4. At least 30% of the course grade should be derived from presentations. Students must score at least a D in the oral communication part of the course to pass the course.
5. At least one presentation should receive substantive feedback from the instructor, preferably with a detailed rubric.

Effective oral communication courses may also incorporate recommended best practices standards. These include:

1. Four to five formal oral presentations of varying length and context. For example, some presentations could be submitted as videos online.

A currently popular form of oral presentation is the three-minute thesis (3mT), where oral presentations are limited in length to three minutes and one PowerPoint slide or other illustration.

2. As much as 50% of the course grade could be derived from oral presentations.
3. Assignments should be sequenced in complexity and intent. For example, delivering the same material to a group of sixth grade students and to a professional audience requires reworking the delivery.
4. Feedback on presentations should suggest revisions, possibly using recordings of presentations.
5. Not all presentations need to be complexly scored. This is referred to as a "low-stakes"" assignment.
6. Students should be encouraged to reflect on their progress in presentation skills.

The oral presentation component of the course grade is substantial. Instruction on creating and making oral presentations will prepare you for those assessments. Some topics in this part of the course are:

1. Preparing for an oral presentation (selecting a topic, research, source materials, outlines)
2. Creating an oral presentation (guidelines, tools, modes of presentation, practice)
3. Making an oral presentation (speaker guidelines, fallback methods, audience, impact)

## Academic Integrity

You must always submit work that represents your original words or ideas. If any words or ideas are used that do not represent your original words or ideas, you must cite all relevant sources. This includes websites. You should also make clear the extent to which such sources were used.

Words or ideas that require citations include, but are not limited to, all hard-copy or electronic publications, whether copyrighted or not, and all verbal or visual communication when the content of such communication clearly originates from an identifiable source. The university has a code of student academic integrity that defines your responsibilities and rights as a student at

UNC Charlotte. The code is in the university catalog. You may also read the complete document online at http://www.legal.uncc.edu/policies/ps-105.html. Please review this document.

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## Assessment and Grading

### Forms of Assessment

Graded forms of assessment include lecture quizzes, oral component assignments, lab assignments, a field research project, and an oral research project. These assessments are described below.

The course is structured to emphasize participation and activities. We do have assessment activities, but the main objective is to explore geophysics through lectures, reading, and application of methods.

#### *Lecture Quizzes*

Regular quizzes will review largely lecture material presented since the previous quiz. Lectures for specific topics many consist of several parts, and lecture quizzes (based on recorded or synchronous presentations) may address one or more parts for the topic. These quizzes will be completed in Canvas. Lecture quizzes draw questions from lecture notes and any assigned readings.

Lecture quizzes are effectively open-book and open-notes assignments. Each quiz may have to be completed within a set amount of time from start to finish and may also allow more than one attempt. You will see the conditions of any assessment in the header of the quiz. Questions on the lecture quizzes will typically be short answer format such as multiple choice, true/false, or missing word.

When you click on the title of a quiz, the browser window that opens contains a header to the quiz that tells you how many attempts are allowed for the quiz, the date and time it closes, and how your final grade for the quiz will be determined. Grading methods and question formats vary from semester to semester and sometimes within the semester.

### *Lab Assignments*

Some lab assignments will require submissions through Canvas or Gradebook. In comparison to lecture quizzes, lab assignments typically in the form of problem solving, data analysis, or a similar activity. Grades for lab assignments will be wrapped together with the lecture quizzes component of your course score.

### *Project Report*

You will conduct one field project[3] using one or more geophysical methods. This includes data collection, data post-processing, interpretation, and synthesis. A written project report – a term paper – will be the summation of this project. Typically, class projects are true research related to one of the instructor's areas of interest and may have unknown results, illustrating how many scientific efforts are done. Details of the project report will be distributed later in the semester.

## Grading Scale

Letter grades will be determined from numerical scores. Any assignments that are originally scored based on other than 100 points will be converted to a percentage when your final grade is computed. The grade distribution is: A (100-90), B (89-80), C (79-70), D (69-60), and F (less than 60). Partial points with be rounded to the nearest full point, e.g. 89.4=89 which leads to a grade of B; 89.5=90 which leads to a grade of A.

## Grading Weights

Your course grade is weighted. The following table explains the relative weight of each assignment group in the course. Canvas grading is points

[3] A mandatory field day (possibly two or three overall) is a course requirement. Historically, our research projects have been conducted off-campus.

based. Within an assignment group the weight of an individual assignment is based on the number of points in that assignment. No extra credit assignments will be available.

**Course Grade Components**

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| Lecture Quizzes | 25% |
| (Includes any lab assignments) | |
| Oral Component Assignments | 20% |
| Field Research Project | 40% |
| Mid-Term Detailed Outline | |
| Project Report | |
| Oral Research Project | 15% |
| Mid-Term Component (3mT) | |
| Oral Research Component | |
| (12-minute presentation) | |