SIO 182: Environmental and Exploration Geophysics
Syllabus

Who. Steven Constable's office is located on the top floor of the IGPP building (room 326) at Scripps (just north of the Scripps library). His phone number is 858-534-2409 and email address is sconstable@ucsd.edu. Feel free to arrange to meet by phone or (preferably) email contact. We can also arrange for the instructor to be available in the lecture room half an hour before each lecture if needs be.

Grading. The SIO182A will be assessed by assignment, mid-term, final, participation in the field projects, and field reports. These will count toward the final grade as follows:

Assignments: 15%,
Midterm: 10%
Final: 40%
Field reports: 35%

This course combines standard lectures and homework with collection of data, data analysis, and report writing. Data collection is carried out during class, by combining a lecture class with the lab/tutorial class (typically twice, for gravity and magnetics), and a Saturday or Sunday morning (typically once during the quarter). The course relies on the use of MATLAB, although other programming languages could be used if you are prepared to translate the MATLAB codes that will be provided to model the data.

Participation in the field projects is assumed: Egregious delinquency will detract up to 10% from the grade.

The assignments will not be intended to be arduous, but to keep you in touch with what is being taught and to make you work through some simple examples. The mid-term will mainly serve to give you some idea of how you are going to fare in the final, before you run out of opportunity to catch up, if indeed you need to.

Course notes will be distributed via the web site. It is important to use the text books as necessary to provide additional examples and material, but if you are familiar with all the material in the notes, you will excel.

Note that you will need a calculator for the exams!!

During the lab periods we will be working data at IGPP, and normally we use two of these periods to collect data using a cesium vapor magnetometer (along Scripps beach) and a gravimeter (over Mount Soledad). A half-day on a weekend will be set aside for an electrical resistivity experiment.

Other field trips might be advised on a compulsory or optional basis. Data analysis will exclusively use the MATLAB environment. Again, it is assumed that students will have access to a computer with MATLAB for homework and field data analysis of this course, and we will be spending time getting to know this computing environment. Let us know straight away if getting access to a computer with MATLAB is going to be a problem for you.

For the field work we will be making geophysical measurements at various field locations. Cooperative work in reducing and interpreting the data is fine, but each individual will produce reports.

A few notes on doing assignments.

There is no need to regurgitate the notes. Really!

On the other hand, some words describing the mathematical steps are very helpful. For example: "multiplying free-air correction by height:" followed by the math. That way if you make a mistake in the math then I know that you understood the concept.

And please, please, describe every variable, especially those that you are introducing as new. If an "s" suddenly appears I might guess what it represents, or then I might not.

You have to be intelligent about precision. A few things require a LOT of precision, such as using the entire international gravity formula to compute latitude effects. Other things do not - if you are using the differential form of the IGF then you only need to carry as much precision as a gravimeter can measure.

Keep track of units. Meters are not the same as kilometers. I guarantee someone will make that mistake at some point in the quarter. By the same logic, all answers should have units, so I know if your answer is 10 km or 10 m. (The exception is dimensionless quantities, which we tend not to use in SIO182 but are common in SIO103.)

I will help you learn MATLAB, but I can't accept a program as a homework solution. By all means include the program if you want to, but I would like to see the results written up in a way that I can understand (reading my own code is bad enough if I haven't touched it for a couple of months - reading other people's code is a real challenge). I CANNOT BE EXPECTED TO RUN YOUR CODE TO GET YOUR ASSIGNMENT FOR YOU!

Course Synopsis

Introduction

Overview of the course. Motivation; why do geophysics? Examples of fields in which exploration techniques are used.

Gravity

Force and potential (Newtons's law, acceleration, potential, gradient operators in various coordinate systems, potential due to an extended mass)

Gauss' Law (flux, derivation of Gauss' law using Gauss' theorem, demonstration that spherically symmetric masses are indistinguishable from point masses, use of Gauss' law to find gravity due to symmetric bodies)

Rock densities (relative density of rock types, effect of porosity and saturation, other factors affecting density, methods of estimating rock densities, Nafe-Drake relationship)

Gravity meters (absolute versus relative measurements, sensitivity of linear and non-linear meters, construction of LaCoste-Romberg meter, factors affecting meter measurements of g)

Earth's gravity (equipotential surfaces and the geoid, global gravity field, reference spheroid and the international gravity formula)

Gravity reductions (derivations of latitude correction, free-air correction, and Bouguer correction, Nettleton's method, tides, drift corrections, terrain corrections, regionals and residuals, methods for regional removal)

Interpretation (Excess mass calculation, forward modelling, depth rules)

Magnetic Methods

Introductory theory (current elements, H and B, units)

Magnetization (polarization, susceptibility, diamagnetism, paramagnetism, ferromagnetism, hysteresis and residual magnetism and coercive force, types of remnant magnetism)

Magnetic properties of rocks. Earth's magnetic field (coordinate systems, main field, origin of the field)

Basic theory (potential and field due to a dipole, extended bodies, Laplace and Poisson's equations)

Magnetometers (overview, fluxgate and PPM operation principles, optically pumped mags and SQUIDS)

Field operation (aeromagnetics and the effect of flight altitude, ground surveys)

Interpretation (effect of latitude, depth rules)

Electrical and Electromagnetic Methods

Introductory theory (Coulomb's law, field and potential, Ohm's law and current density, units)

Resistivity of rocks and minerals (metallic conduction, semiconduction, electrolytic conduction, factors affecting resistivity, measuring resistivity in the laboratory, anisotropy)

DC resistivity theory (theory for a point source, 4-electrode arrays, apparent resistivity, common arrays)

Resistivity sounding and profiling (the sounding curve, profiling curves, electrode effects)

Resistivity equipment (current circuit, potential circuit, electrodes, DC offsets, stacking)

Resistivity interpretation (curve matching, forward modeling, equivalence/suppression of layers, anisotropy)

Self-potential method

Induced polarization method (concept, membrane polarization, electrode polarization, time and frequency domain systems, chargeability, PFE, metal factor)

Electromagnetic methods (Earth response as part of source-receiver coupling, primary and secondary fields, skin depth, telluric, MT and AFMAG natural-source methods, VLF, phase and amplitude, and TEM controlled source systems, relation of the time and frequency domain systems through the Fourier transform, simple analysis of square wave)

Seismic Methods

P-waves and S-waves. Body waves and surface waves.

Wave equation in 1D, 3D, solids and fluids.

Seismic velocities in rocks.

Wave fronts and rays. Huygen's principle. Snell's Law.

Reflection and refraction at an interface.

Critical angle, head wave generation.

Layer over a half-space.

Travel times and distances.

Equipment and examples.

Reports

Industrial and academic institutions both stress the importance of being able to plan and execute a project, to a timetable, and communicate the results both verbally and by writing. To the extent that it is possible, we will use this course as means of teaching these skills in parallel with the geophysical techniques.

For this class you will be required to produce several reports, describing the field work and the data collected. Report writing is a useful skill not often taught during an undergraduate science degree. The following outline and notes are a guide to putting together the sort of report you need for SIO182.

INTRODUCTION: Brief description of the experiment or survey. Why it is being carried out (i.e. what problems will be solved or questions answered by this work).

METHODOLOGY: Description of the equipment used and how the survey was carried out. Any problems encountered.

DESCRIPTION OF DATA: The extent of the data set, data quality (estimation of errors and reliability). Tabulation of data if appropriate. Map of survey area if appropriate. Plots of complete data set. Qualitative assessment of information contained in the data.

MODELING OF DATA: If quantitative modeling is used, describe the algorithm used. Present the data and model fits, and tabulate or plot the model parameters derived.

INTERPRETATION: Turn the qualitative or quantitative assessment of the data into a geophysical, geological, or structural interpretation.

CONCLUSIONS: Did the problem get solved? Discuss the importance of the result and how conclusive it was. How would you extend the work or repeat it in a better way?