Chapter 1 – Introduction

What is remote sensing and why do we use it?

Remote sensing is sensing from a distance– any form of non-contact detection. The distance can be close (mm) or far (many millions of km), as in the case of astronomy. Typically, detection is based on the interaction of electromagnetic radiation with a surface or object of interest, but it could also be based on other methods, such as sound detection, in the case of acoustic remote sensing. Sometimes the "target" is not a surface at all, but a deep field, such as when sampling a depth profile or composition of the atmosphere (atmospheric sounding) or water bodies (bathymetry). Generally, we measure the signal returning from the object, typically in the form of spectral patterns or intensity of the returning signal. Remote sensing can be active (when we measure the signal generated by the sensor after interacting with the target, as in radar, lidar or sonar), or passive (when we simply measure the signal emanating from the target, as in sampling birdsong or vegetation reflectance).

There are many reasons for using remote sensing. Often it is impractical or unsafe to sample an object directly (imagine trying to measure an erupting volcano or sample in a hostile country). With remote sensing, we can draw inferences about even the most distant objects in the universe (think of stars, or the search for life on distant planets). With the growing human impact on planet Earth, we are increasingly using remote sensing to monitor the direct and indirect effects of human activity. Sampling the Earth using remote sensing, and relating this information to other data sources, comprises one of the greatest informatics and scientific challenges ever devised (Marshall 1993). Remote sensing is used in many fields including intelligence, agriculture, archaeology ecology, geology, hydrology, and atmospheric science. The list of applications is as large as the imagination allows!

What is "proximal" sensing and why do we use it?

When sampling the Earth, we often think of remote sensing being conducted from satellite or aircraft, but it also can involve sampling from the ground or using unmanned aerial vehicles (UAVs[1]) close to the surface in what is often called "proximal" or "field" remote sensing. Proximal sensing involves applying remote sensing principles from a very close distance, and may or may not involve directly contacting the object of interest (often called the "target"). Strictly speaking "proximal remote" is a contradiction, so other terms are often used, including proximal sampling, field sampling, field radiometry, field spectrometry, optical or spectral sampling, etc., but each of these also has its limitations. A simpler way to think of it is that remote sensing can be applied from *any* distance (Figure 1). Because it can be applied at different spatial scales, remote sensing is often used to study the effects of sampling scale, and is a particularly useful tool for upscaling (extrapolating from a point to a larger region) or downscaling (interpreting or validating a signal from a satellite, aircraft, or global model) (Figure 1). Because

[1] UAVs or unmanned aerial vehicles, are also called drones.

information content can change with scale, we need to be conscious of the sampling scale employed.

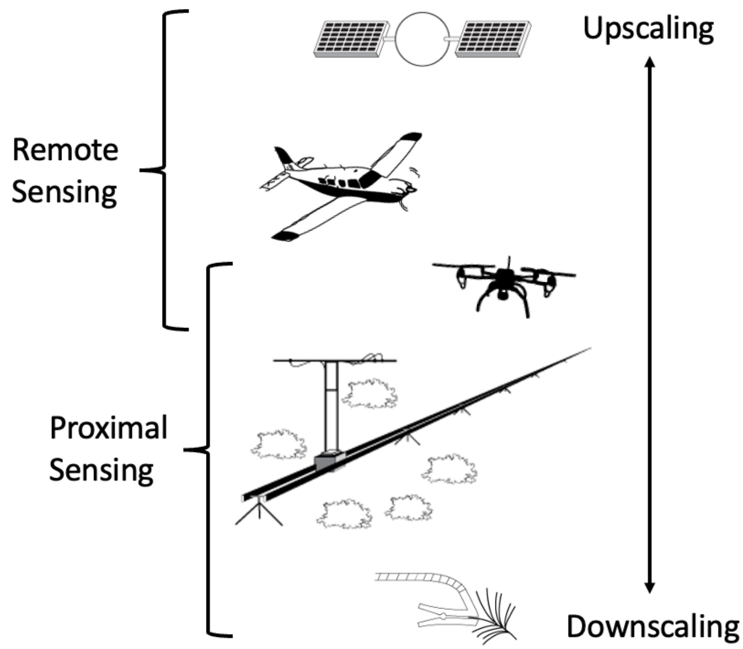

Figure 1 - Illustration of remote sensing at spatial various scales, including proximal sensing (sensing below the atmosphere) and remote sensing through the atmosphere. Depicted here are a satellite sensor, airborne platform, UAV, tram system on a track, and leaf reflectance sampling with a leaf clip. This kind of multi-scale sampling can be used for upscaling (extrapolation from local to larger regions) or downscaling (inferring local conditions from remote sensing at larger spatial scales).

Typically, the principles and methods of proximal sensing – detecting radiation or sound – are similar to remote applications, but the sampling distance is much closer (typically mm to tens of meters; Figure 2). This proximity to the target has many advantages, one of which is that the user can readily identify and characterize the target, which is not always the case from satellite or aircraft. If sampling is non-contact, then it is generally non-invasive, which is a particular advantage when sampling processes that are easily disturbed by destructive or intrusive sampling. For example, many biological applications benefit from this kind of non-intrusive sampling. In Earth applications, one way to think of this is that proximal remote sensing generally is made *under* the atmosphere, whereas "remote" remote sensing is generally made *through* the atmosphere. Since the atmosphere can confound the signals from Earth's surface, it adds additional complexity to the sampling and interpretation. By contrast, proximal sampling can greatly simplify the interpretation of these signals. For this reason, proximal sensing is commonly used in conjunction with other remote sensing measurements as a form of validation (e.g., in calibration or "ground truthing" campaigns).

Figure 2. Examples of proximal optical sensing using spectrometers on a variety of platforms, including a) hand sampling, b) tower-mounted, c) tram-mounted, and d) UAV-mounted instruments. From Gamon et al. 2015.

With the advent of automated sampling methods, portable computing devices, and wireless technology, there is an explosion of interest in proximal sampling methods, most of which involve spectral analysis of electromagnetic radiation. While our primary focus here is on field spectrometry using optical detection, other methods, including thermal or sonar, along with simple image-based methods are also used.

Emerging fields, such as plant trait analysis, high-throughput phenotyping and precision agriculture, are also pushing the development of new sampling methods. Critical topics in global ecology and Earth system science, including global biodiversity, ecosystem responses to climate change, and increasing atmospheric greenhouse gases, all involve proximal sampling in addition to remote sensing. We now have a rich array of sampling technologies and options, including automated sampling tools or robotic mobile tools. We can also combine sampling methods to measure detailed time series and spatial arrays, expanding the sampling domain in time and space.

This rapid growth in sampling technologies also presents new questions. What is the ideal method of sampling for a given purpose, and how can we best compare different methods made with different instruments? What must we do to ensure our instruments are working properly? How do we manage the large volumes of data emerging from many studies? What are the most appropriate analytical methods for interpreting and evaluating our data? The best answers to these questions depend on the sampling context and the goal in mind, and it pays to be mindful of sampling considerations when planning a proximal sampling campaign. As with any sampling program, it helps to "know your system," in other words to develop an intimate knowledge of the topic of study, and the instruments and methods used to study it.

The purpose and focus of this book

Despite the rapid growth in the use of proximal spectrometers, there is no current text that considers proximal sampling in any detail. While many remote sensing texts have been written, and some of these include discussion of proximal spectrometry, there are few comprehensive and accessible resources for those wishing to learn more about proximal spectral sampling in more detail. This book is intended to meet that need.

The primary topic of this book is proximal spectrometry, also known as field spectrometry or proximal remote sensing. While proximal spectrometry can be used in many fields and for many purposes, the primary focus here is on proximal sampling of terrestrial vegetation, using examples from basic and applied research.

References cited:

Estrin, Michener, Bonito et al. (2003) *Environmental Cyberinfrastructure Needs for Distributed Sensor Networks,* 12-14 August 2003, Scripps Institute of Oceanography, La Jolla, CA.

Gamon JA (2015) Optical sampling of the flux tower footprint. *Biogeosciences* 12: 4509-4523. doi:10.5194/bg-12-4509-2015

Marshall E (1993) Fitting planet Earth into a user-friendly database. *Science.* 261;846-848.

Terms to know:

remote sensing
proximal sensing
field remote sensing
UAV – unmanned aerial vehicle, drone
Tram
Calibration
Validation

Ground-truthing
Upscaling
Downscaling