A Review of the Contributions of Alexander F.H. Goetz to Imaging Spectroscopy

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Abstract— All aspects of the science and engineering of imaging spectrometry have been advanced by the work of Dr. Alexander F.H. Goetz over the past 30 years. Dr. Goetz's pioneering efforts were among the first to realize that it was feasible to obtain laboratory like spectra from space that would quantify earth materials based on biogeochemistry. He has made fundamental contributions to developing high spectral resolution field spectrometers and airborne imaging spectrometers, and to the image processing software and atmospheric correction software needed to analyze the data. These parallel developments in core technologies have made imaging spectroscopy available to a wide range of users of varying user expertise and disciplines, thus enabling the current state of rapid advances in the use of this data.

Keywords- Alexander F.H. Goetz; imaging spectroscopy, AIS, ASD, AVIRIS, HATCH, Hyperion, PIDAS, SIPS

Introduction

Over the past 30 years, all aspects of the science and engineering of imaging spectrometry have been affected by the work of Dr. Alexander F.H. Goetz [1-4]. Dr. Goetz was among the first to realize that it was technically feasible to fly imaging spectrometers from aircraft and spacecraft and obtain laboratory like spectra that allow quantification of earth materials based on the biogeochemistry.

Since the late 1970s he has led interdisciplinary environmental applications of spectroscopy to understand and study the earth—including fundamental research in applications for geology [5-8], soils [9], atmospheric properties [10, 11], and plant/vegetation studies [12, 13], the instruments to measure the spectral properties from laboratory, field, airborne and satellite instruments [14, 15], and finally, the software to analyze the data and perform the atmospheric corrections.

November 12-14, 1981, Alexander F.H. Goetz and colleagues Lawrence Rowan and Marguerite Kingston flew a new instrument, the shuttle multispectral infrared radiometer (SMIRR) [16], which had 10 spectral bands and was designed to evaluate the usefulness of a future imaging spectrometer system for remote mineral identification. From that first shuttle flight they obtained 70 minutes of cloud free data which demonstrated the value of spectroscopy from space. In [5], they showed for the first time that Kaolinite and Carbonate-containing materials could be identified from space, demonstrating the potential for narrowband spectral imaging systems on future orbital platforms.

Soon after, the first airborne instrument, Airborne Imaging Spectrometer (AIS) was developed as an engineering testbed by Dr. Goetz and colleagues under a small Director's Discretionary grant at the Jet Propulsion Laboratory [17]. The first instrument had 128 bands using a 32 x 32 element mercury cadmium telluride (HgCdTe) detector array that measured the 900-2100 nm and 1200-2400nm regions. This instrument began flight operations in November 1982. The ability to acquire laboratory-like spectra remotely was and remains today, a major paradigm setting advance in remote sensing capability. Dr. Goetz co-hosted the first Airborne Imaging Spectrometry Workshop of 28 papers with Greg Vane at the Jet Propulsion Laboratory April 8-10, 1985 [18]. The AIS program soon led to the development of a second AIS instrument with a 64 x 64 array and the first full spectrum Airborne Visible Infrared Imaging Spectrometer (AVIRIS) by 1987. The AIS and AVIRIS workshops have been offered annually since 1985 (AVIRIS workshops began in 1988) and are recognized today as the most significant venue for presenting new developments in imaging spectrometry. Although early plans to use these instruments to prepare for a space shuttle imaging spectrometer and the HIRIS instrument on the EOS platform were dropped because of cost issues, the science and interest in imaging spectroscopy has exponentially progressed throughout the past 30 years.

To fully utilize these data, advances in supporting infrastructure needed to be developed. This required development of high spectral resolution field-portable and laboratory spectrometers, development of powerful statistical software to analyze the image data, and correction software for calibrating the radiance imagery to apparent surface reflectance. Dr. Goetz has provided an essential leadership role for advances in all of these areas.

The first advance was in the development of a field portable imaging spectrometer in 1986. The Portable Instant Display and Analysis Spectrometer (PIDAS) [19] covered the range from 200-2500 nm and acquired spectra in 2 seconds. While it was large and heavy (by today's standards) it was possible to take it to the field and obtain high quality field spectra for comparison to image data that provided validation for AVIRIS observations. This led to the development of more truly portable field spectrometers, including the most widely used today, the Analytical Spectral Devices spectrometers, produced by a company founded by Alex Goetz and Brian Curtiss in 1990.

The next major advance in imaging spectrometry in the early 1990s came with the development of the atmospheric calibration software, Atmospheric Removal Program (ATREM), by Bo-Cai Gao, Kathy Heidebrecht and Alex Goetz [20]. This widely used program was based on the Modtran radiative transfer code, adopted for the narrow spectral bands of AVIRIS. Several commercial atmospheric correction packages exist today, including an improved atmospheric correction model, HATCH [21, 22], for high accuracy retrieval of surface reflectance in imaging spectrometry data developed recently by Dr. Goetz, with collaborators Zheng Qu and Bruce C. Kindel.

Dr. Goetz also made significant contributions to analytical software to utilize the spectral information in the AVIRIS data cubes. Early image processing software was totally inadequate to handle the data arrays and this inability to fully analyze and extract information from AVIRIS data was a major limitation that discouraged new users and limited advances in the science. Dr. Goetz and colleagues at University of Colorado developed a public domain package (SIPS [23]) that was the start of the widely used commercial program, Environment for Visualization of Images (ENVI), developed by his colleagues, Joe Boardman and Fred Kruse. These three advances: field spectral measurements, image processing software, and atmospheric correction software are the core technologies that have made imaging spectroscopy available to a wide range of users and user expertise, thus enabling the current state of rapid advances in the use of this data.

Lastly, Dr. Goetz is an author on hundreds of scientific papers related to spectroscopy of Earth materials, to numerous to summarize. He has been instrumental in developing and promoting earth science applications for spectrometry data, covering a wide range of academic disciplines from mineral identification, soil erosion, atmospheric water vapor and cirrus cloud detection, to ecology and plant biochemistry. Altogether, Dr. Goetz's contributions to the science and measurements of imaging spectroscopy are extraordinary.

We dedicate this symposium in his honor of his lifetime achievements.

Acknowledgment

The authors would like to acknowledge the support of their home institutions. We are also grateful for the support of the organizers of IEEE IGARSS for sponsoring this symposium.

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