GEOL 701h – Advanced Geology, Geophysics – Multispectral/Hyperspectral Thermal Infrared Remote Sensing for Geologic Applications
Course Credits, 3 hours, Fall Semester 2002

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Classroom: LMR 356
Time for formal lectures: MW 1:00PM and per schedule
Time for laboratory instruction: Friday 1:00 to 4:00PM and DHA.

COURSE DESCRIPTION – Fall Semester 2002

This course reviews fundamental principles of aerospace remote sensing in the thermal infrared portions of the electromagnetic spectrum. Students learn the energy path concept for understanding the origins of emitted electromagnetic radiation (EMR) in the 1.0-micrometer to 20-micrometer portions of the electromagnetic spectrum. Students learn concepts of frequency and wavelength. The physics of thermal emission are learned including applications of important thermal radiation laws. Students learn the phenomenology of atmospheric effects to develop an understanding of the effects of atmospheric absorption and emission on the spectral properties of thermal radiation measured by sensors.

Students learn concepts of rock thermal properties, thermal emission spectra of silicate minerals and rocks, and environmental effects on thermal measurement. Sensor technology used in aircraft and spacecraft is reviewed, including broadband, single-channel thermal sensors, multiband thermal sensors, hyperspectral thermal sensors. Students learn field and laboratory measurement of thermal emission from rocks, soils, vegetation, water. Field and laboratory measurement techniques of emission spectra are reviewed, and, depending on availability of instruments, are done by students.

Students learn the relevance of thermal infrared techniques to resource exploration to develop an appreciation of the attributes of natural resources that can be effectively measured. The cost-effectiveness of aerial imagery, multispectral imagery and hyperspectral thermal infrared imagery for resource exploration is reviewed.

Students will work as a team with actual thermal infrared data sets covering sites of interest in the Great Basin of Nevada. We have multiband and hyperspectral thermal data over Cuprite, Death Valley, Bodie, Desert Peak/Brady and Yerrington areas. Data sets of NASA Thermal Infrared Multispectral Scanner (TIMS), Aerospace Corporation SEBASS, and NASA ASTER and MASTER data may used by students in their term project work. Students use the latest software for thermal infrared data analysis including Environment for Visualizing Images (ENVI) and ER-Mapper in the Keck Data

Visualization Laboratory. The Arthur Brant Laboratory for Exploration Geophysics has an Analytical Spectral Devices Full-Range reflectance spectrometer and a Designs and Prototypes Fourier Transform Infrared Radiance emission spectrometer for field investigations.

COURSE EMPHASIS

Course Notebook: 15%, constitutes the textbook for the course
Mid-Term Examination: 15%, a take home examination, open book and open notes
Term Project: 35%
Oral presentation of term project: 10%
Final Examination: 25%, A take home examination due on the day of the Final.

COURSE NOTEBOOK

This course has no course textbook, however students are expected to develop their own course textbook through lecture notes taken in class**,** notes taken from assigned readings and notes taken from reference materials that students wish to include on their own initiative. Please **do not** just copy references from this course for your notebook! Your interpretations of the key points in these references are what should constitute most of your notebook. An important part of the notebook is a comprehensive list of references, appropriate to each major subject, and including references you may find beyond those assigned during class. The notebook will be professionally prepared, including carefully illustrated diagrams. It will be appropriately footnoted to acknowledge sources of information, and it will be organized in a three-ring binder. These notebooks will be graded for completeness and neatness. Notebooks submitted by students may be retained by the instructor and the information contained in the notebooks will not be subject to copyright by the student. The instructor reserves the right to use materials from the submitted notebooks for future classes. Some of the material in the submitted course notebooks may be placed, in condensed form, on the World Wide Web for the use of all students.

TERM PROJECT

The term project will involve a combined class project but will culminate in independent student research on a geological remote sensing problem. This class project will develop an understanding of the kinds of spectral attributes that can be detected and mapped with aerospace remote sensing data. The students may use MASTER, ASTER, SEBASS, TIMS thermal data over the same area in the Great Basin of Nevada. ENVI software will be used for analysis. The first step in data analysis will be to co-register the data sets in a manner that will not destroy their original radiometric and spectral characteristics. The first goal of the term project will be to compare the various the various types of thermal image data in terms of the scales, formats, coverage and accuracies of landscape information that can be extracted by analysis of the data. The second goal of the term project will be define optimal characteristics of an advanced airborne sensor for commercial applications in terms of its spatial, spectral and radiometric resolution; swath width, formats of data, data delivery, accuracy, etc. Each step of your analysis, including failed trials and errors, should be carefully documented. Documentation can take the form of screen saves of processing steps used, outlines of procedures, etc. This documentation should appear as an appendix to the report. A goal will be collaborative publication of the results of the term project as a publication suitable for peer review.

The methodology for term projects will take the form of identification of suitable data, development of pertinent references, meetings with the instructor to review the tentative project, conduct of the research leading to preliminary results, submitting a topic sentence outline for the proposed project report and including key references. The topic sentence outline and bibliography will be evaluated for completeness and they will be graded. When the project is well underway, the class will meet regularly as a group to review results and chart new courses of research. The final project report is due in professional style on the last day of the course. Late reports will be downgraded accordingly. Incompletes are strongly discouraged and must be adjudicated with the instructor. A CD ROM, is to be left with the instructor containing the original raw hyperspectral image used, any image data developed as intermediate analysis products, final image data product, the PowerPoint presentation used in the oral report and the final report. Software developed and applied during the project should be included as an appendix. This disk will become a part of the Arthur Brant Laboratory archive and may be used by faculty and students in the future.

ORAL REPORT

The oral report will be a professionally prepared talk that uses “MS Powerpoint” is required for original figures and diagrams. Figures and diagrams from reference sources must be carefully documented. The oral report will be presented as a 20 minute PowerPoint presentation with 5 minutes for questions and answers, in a manner similar to that in a professional association meeting. The class will participate in the evaluation of the presentation, in terms of its organization, style and content. These talks are designed to improve student communication skills and to prepare students for professional life. The oral reports will be given at the end of the course and students may invite guests to attend.

CLASS SCHEDULE AND OUTLINE

Lecture 1 – Monday August 26, 2002

- **Review of electromagnetic Radiation**
- **Wavelength and frequency concepts and nomenclature**

Read: Hook, et. al., **Use of Multispectral Thermal Infrared Data in Geological Studies**: in Remote Sensing for the Earth Sciences; Manual of Remote Sensing, 3rd Ed., Vol 3, edited by Andrew N. Rencz, John Wiley and Sons, New York. pp. 59 – 110.

Read: Slater, P. N., 1980 Remote Sensing, Optics and Optical Systems, Chapter 5 **Radiometric Concepts, Definitions and Laws,** pp. 88 –103;

Hudson, 969, Infrared System Engineering, Chapter 1**,** **Introduction to Infrared System Engineering**, pp. 3 – 13, Chap. 2, **Infrared Radiation**, pp. 20 – 23, for January 29.

Lecture 2 – Wednesday, August 28, 2002

- **The infrared spectrum**
- **The thermal infrared spectrum**
- **Sources for thermal infrared radiation, Kirchoff's Law**
- **Introduction to atmospheric absorption, emission and windows.**

Read: Elachi, C., 1987, Introduction to the Physics and Techniques of Remote Sensing, Chapter 4, **Solid Surface Remote Sensing: Thermal Infrared**, pp. 114 – 117;

Hudson, 1969 Infrared System Engineering, Chapter 2, **Infrared Radiation**, pp. 30 – 39, for January 29.

Holiday, Labor Day – Monday, September 2, 2002

Lecture 3 – Wednesday, September 4, 2002

Radiation Laws

- **Concept of Radiant Emittance**
- **Concept of a Blackbody**
- **Planck's Radiation Law**
- **Wein's Displacement Law**
- **Stephan Boltzmann Equation**

Read: Hudson, 1969, Infrared System Engineering, Chapter 2, Section 2.5, **Emissivity and Kirchhoff's Law**, pp. 39 – 47 for January 31.

Lecture 4 – Monday, September 9, 2002

- **Radiant Spectral Emittance**
- **Emissivity**
- **Concept of a graybody and a selective radiator**
- **Concept of Spectral Emissivity**

Read, Elachi, C., 1987, Introduction to the Physics and Techniques of Remote Sensing, Chapter 4, **Solid-surface sensing; Thermal Infrared**, pp. 118 – 133;

Heat Capacity Mapping Mission Anthology, Chapters 2 and 3 for September 1 class.

Gillespie, A. H., and Kahle, A. B., 1977, **Construction and Interpretation of a Digital Thermal Inertia Image**: in Photogrammetric Engineering and Remote Sensing, Vol. 43, No. 8, August 1997, pp. 983 – 1000.

Lecture 5 – Wednesday, September 11, 2002

Broadband Thermal Measurements

- **Emissivity from the sun and planetary surfaces**
- **Heat conduction theory**
- **Effects of Periodic Heating**
- **Surface heating by the Sun**
- **Effects of surface cover**
- **Concept of Thermal Inertia**
  - **Thermal Conductivity**
  - **Heat Capacity**
  - **Density**
- **Diurnal Temperature Variations**
- **Time-Temperature Curves**
- **"Heat Capacity" Mapping Mission, HCMM**

Read: Hudson, R. D., Infrared System Engineering, Chapter 9, The **Measurement of Detector Characteristics**, pp. 321 – 327 for Feb 7.

Brief outline of term project with references due.

Lecture 6 – Monday, September 16, 2002

Multispectral Thermal Infrared Measurements

- **Concepts of responsivity, noise equivalent irradiance and detectivity**
- **Concept of noise equivalent temperature difference**
- **Concept of spatial/spectral resolution trade-off and detector sampling frequency.**
- **Atmospheric windows and atmospheric effects.**

Read: Lyon, R. J. P., and Green, A. A., 1975, **Refelctance and Emittance of Terrain in the Mid-Infrared (6 – 25um) Region**: in Infrared and

Raman Spectroscopy of Lunar and Terrestrial Minerals, Academic Press, New York, pp. 165 – 194.

Kahle, A. B., Madura, D. P., and Soha, J. M. 1980, **Middle infrared mulispectral aircraft scanner data: analysis for geological applications**: in Applied optics, Vol. 19, No. 14, pp. 2279 – 2290;

Kahle, A. B., and Rowan, L. C., 1980, **Evaluation of multispectral middle infrared aircraft images for lithologic mapping in the East Tintic Mountains, Utah**: in Geology, v. 8, p 234 –239, May 1980;

Wright, F. L., 1980, **Design of an Aircraft Thermal Infrared Multispectral Scanner (TIMS)**, Daedalus Enterprises.

Kahle, A. B., and Goetz, A. F. H., 1983, **Mineralogic information from a new airborne thermal infrared multispectral scanner**, Science, 222, pp. 24 – 27;

No Class Wednesday, September 18th, Do your readings.

Lecture 7 – Monday, September 23, 2002

– NASA Thermal Infrared Multispectral Scanner (TIMS)

- **Description of the TIMS System**
- **Introduction to TIMS data for geologic applications**

Read: Gillespie, A. H., Kahle, A. B., and Palluconi, F. D., 1984, **Mapping alluvial fans in Death Valley, California, using multichannel thermal infrared images.** Geophysical Research Letters, Vol. 11, 1153 – 1156;

Gillespie, A. H., Kahle, A. B. and Walker, R. E., 1986, **Color Enhancement of Highly Correlated Images. I. Decorrelation and Hue Saturation and Intensity Contrast Stretches**: in Remote Sensing of Environment, Vol. 20, pp. 209 – 235;

Gillespie, A. B., Kahle, A. B., and Walker, R. E., 1987, **Color Enhancement of Highly Correlated Images II. Channel Ratio and Chromaticity Transformation Techniques**: in Remote Sensing of the Environment, Vol. 22, pp. 343 – 365;

Kahle, A. B., 1987, **Surface emittance, temperature, and thermal inertia derived from Thermal Infrared Multispectral Scanner (TIMS) data for Death Valley, California**: in Geophysics, vol. 52, no. 7, July 1987, pp. 858 – 874; for February 14.

Lecture 8 – Wednesday, September 25, 2002

Processing and Analysis of TIMS data. Utilize Steamboat TIMS Day Night Thermal data and TIMS band 5 to develop a thermal inertia image. AVIRIS data set may be useful in determining albedo. Attending Western Regional NASA Space Grant Meeting in Austin, Texas.

Taranik, J. V., and Goward, S. N., 1986, **Commercial applications and scientific research requirements for thermal-infrared observations of terrestrial surfaces:** National Aeronautics and Space Administration and Earth Observation Satellite Company, Washington, D. C., 20548, **Geologic Sciences**, pp. 13 – 34, **Instrument Panel Report**, pp. 51 – 59,**A study of filter selection for the Thematic Mapper thermal-infrared enhancement**, pp. 105 – 114;

Elvidge, C. D., and Taranik, J. V., 1990, **Investigation of Optimal Thermal Infrared Bandpasses for a Polar Platform Sensor**: Japex Geoscience Institute, Tokyo, Japan, Final Report.

Read Website: http://asterweb.jpl.nasa.gov This website has most of the pertinent information on ASTER, the spaceborne multispectral imager planned for launch by NASA this fall.

Lecture 9 – Monday, September 30, 2002

Introduction to the MODIS and ASTER Simulator (MASTER) data.

Lecture 10 – Wednesday, October 2, 2002

– Introduction to the Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) Sensor System.

Read Website: http://masterweb.jpl.nasa.gov This website has browse imagery of MASTER data and descriptions of the sensor and the platforms. MASTER data are being acquired over Long Valley, Hawaii, Mammoth Lakes, Railroad Valley, Tahoe, Mt. Baker, Mt. Hood, Lassen, White Valley, Nevada, Lunar Lake, etc. You can see a complete list on-line.

Laboratory, begin work on thermal data of Steamboat, Bodie and/or Virginia City with Master Data.

Kahle, A. B., et. al., 1988, **Relative Dating of Hawaiian Lava Flows Using Multispectral Thermal Infrered Images**; A New Tool for Geologic Mapping of Young Volcanic Terrains: in Journal of Geophysical Research, Vol 93, No. B12, pp. 15,239 – 15,251, December 10, 1988;

Lahren, M. M., Schweickert, R. A., and Taranik, J. V., 1988, **Analysis of the Northern Sierra Accreted Terrain, California with Airborne Thermal Infrared Multispectral Scanner data**: in Geology, Vol. 16, pp. 525 – 528, June 1988, Geological Society of America;

Sabine, C., Realmulto, V. J., and Taranik, J. V., 1994, **Quantitative estimation of granitoid composition from Thermal Infrared Multispectral Scanner (TIMS) data, Desolation Wilderness, northern Sierra, Nevada, California**: in Journal of Geophysical Research, Vol. 99, No. B3, pp. 4261 – 4271, American Geophysical Union.

Lecture 11 – October 7, 2002

Additional examples of the analysis of TIMS multispectral data

Lecture 12 – October 9, 2002

Introduction and analysis of MASTER data of Bodie, Nevada

- **Laboratory, begin laboratory work on MASTER data**

- **Topic Sentence Outline Due.**

Lecture 13 – October 14, 2002

- **Analysis of Master Data, Continued.**

Bartholomew, M. J., Kahle, A. B., and Hoover, G., 1989, **Infrared Spectroscopy (2.3 – 20um) for the geological interpretation of remotely-sensed multispectral thermal infrared data**: in Int. Jour. Remote Sensing, Vol 10, No. 3, pp. 529 – 544.

Hunt, G. R., and Salisbury, J. W., 1974, **Mid-Infrared Spectral Behavior of Igneous Rocks**: Air Force Cambridge Research Laboratories, AFCRL-TR-74-0625,

Hunt, G. R., and Salisbury, J. W., 1975, **Mid-infrared Spectral Behavior of Sedimentary Rocks**, AFCRL-TR-75-0356.

Hunt, G. R., and Salisbury, J. W., 1976, **Mid-infrared Spectral Behavior of Metamorphic Rocks**, AFCRL-TR-76-0003; and Thomson, J. L., and Salisbury, J. W., 1993, **Mid-Infrared Reflectance of Mineral Mixtures**

(7 – 14um): in Remote Sensing of Environment, Vol. 45, No. 1, pp. 1- 24, July 1993.

Read Website: http://asterweb.jpl.nasa.gov Refer to the section on spectral libraries. There are two libraries, one from Johns Hopkins University (Jack Salisbury) and one from JPL (Simon Hook).

Lecture 14 – October 16, 2002

Introduction to hyperspectral thermal infrared remote sensing

Field measurements with the Designs and Prototypes FTIR.

Lecture 15 – October 21, 2002

Field measurements with the D & P FTIR.

Lecture 16 –October 23, 2002

Laboratory, SEBASS data set over Bodie, Virginia City and Yerrington.

Hand out take home mid-term examination

Lecture 17 – October 28, 2002

No class, Jim in Puerto Rico at NASA Space Grant Meeting.
Work on take home mid-term examination.

Lecture 18 – October 30, 2002

No class, Jim in Puerto Rico at NASA Space Grant Meeting
Hand in take home mid-term examination to Lori.

Lecture 19 – November 4, 2002

Review of Mid-term examination

Lecture 20 – Wednesday, November 6, 2002

Meet with instructor to review term projects and discuss progress.

November 11, 2002 – VETERANS DAY HOLIDAY

Lecture 21 - November 13, 2002

Meet with instructor to review term projects and discuss progress

Lecture 22 - Monday, November 18, 2002

No class, Jim in NYC. Work on projects

Lecture 23 – Wednesday, November 20, 2002

No class, Jim in NYC. Work on projects

Lecture 24 – Monday, November 25, 2002

Meet with instructor to review term projects and discuss progress.

Lecture 25 – Wednesday, November 27, 2002

Meet with instructor to review term projects and discuss progress.

Lecture 26 – Monday, December 2, 2002

Meet with instructor to review term projects and discuss progress.

Lecture 27 – Wednesday, December 4, 2002

Meet with instructor to review term projects and discuss progress.

Lecture 28 – Monday, December 9, 2002

Class Presentations of Term Projects
Take Home Final Examination handed out

Lecture 29 – Wednesday, December 11, 2002

Finals Preparation Day

Final Examination and all work due to instructor and/or Lori: December 16, 2002.