LU_Curriculum_Support_Document_UrbanHeatIsland_7_22_09pep

Curriculum Support Document

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Title: **Urban Heat Island Characterization with Thermal RS Data**
Skill Level for LU: Advanced
Focus Topic: Environmental Management.

Title:

Urban Heat Island Characterization with Thermal RS Data

Overview:

This Learning Unit (LU) explores urban heat islands (UHIs), a critical environmental issue in many large cities. In this LU, you learn to use Landsat and/or ASTER thermal (TIR) data analysis to map the thermal characteristics of your project area and, specifically, identify areas of high temperature or thermal signature. The images and image products, analyses, and data will be integrated in a GIS for further analysis, interpretation, and visualization. Land cover/land use (existing layers or interpreted from your imagery), transportation (road, rail), aerial photography, and field measurements are used to calibrate the thermal data, to describe the areas affected by UHIs, and to identify sources of high temperature/thermal signature. Air quality and meteorological data, if available for your area, can add important dimensions to your project. Demographic, socioeconomic, and health data from the census or other sources can be used to characterize the effects of UHIs on area residents. Two basic questions you will be answering are: Can RS and GIS analysis be used to identify, characterize, and quantify urban heat islands in your selected area? Can that analysis be used in identifying and applying mitigation strategies and developing public policy to address UHI issues?

Instructor Overview:

This Learning Unit is designed for advanced students who have completed several GIS classes including a raster GIS class with a strong remote sensing component. In the curriculum for which this LU was created, this Workplace GIS course is a capstone course for either a GIS Analyst Certificate or an Associate Applied Science Degree. The students are expected to apply a significant degree of existing knowledge and research capability to the successful completion of a fairly sophisticated GIS/Remote Sensing project while learning how to plan, execute, and deliver a project in the workplace. The class is structured as a project (or projects) for delivery to a client. In this particular case, the Dallas County Urban Heat Island Study project example was actually delivered to a client, the Houston Advanced Research Center, under contract through the College. The students were required to demonstrate not only their technical skills but also their organizational skills. The deliverables for the project were a presentation to the client, a report documenting project procedures and results, and a functioning project GIS. The students did an outstanding job and were highly praised by the client. The results of the study were incorporated in a much more comprehensive report, “Regional Choices for North Texas” by Vision North Texas (VNT_Regional_Choices.pdf in example project folder), and are currently being used to formulate area policy. The project became an important item in the student’s GIS portfolio.

A Learning Unit for students at this level needs to engage, challenge, and guide students without dictating the process. The LU Student Guide is structured as a set of general instructions for conducting the project and creating specific products. Students are encouraged to formulate their own plan and implement it with instructor guidance. Data sources, data types, and software capabilities constantly change. General instructions provide the flexibility to accommodate these changes and to allow students to create new approaches to the project. Learning Unit flexibility opens the structure of the project to fit the format of the class being taught, the number and capabilities of the students, and instructor experience.

The LU is divided into six Parts. Part 1 is the core of the LU and Parts 2-6 are options that extend the LU in small to significant ways. Part 1, Step 1 guides research and preparation for the project. In Step 2, the students select, acquire, and organize the project data focusing on satellite data (ASTER and Landsat), aerial photography, land cover, elevation, hydrography, roads, demographic, and various ancillary data sets for analysis and map development. Surface temperature measurement is also a key element of Step 2. Step 3 focuses on data organization and team cooperation. Steps 4a – 4c involve image processing, geoprocessing, and data analysis to produce information products for the project. Processing products will include temperature (absolute temperature) or thermal signature (relative temperature), surface calibrated Landsat TIR, isotherm contours, general land cover and/or tree canopy and impervious surface classifications, raster to vector conversions, and error analysis. GIS data integration, symbology, and quality control are the focus of Step 5. Step 6 applies the results of data processing to team-centered analysis of thermal and related data. Step 7 addresses the need for interpretation at the group level to capture a broader range of knowledge and insight. The group also discusses implications of the analysis on public policy and mitigation. Maps, a report, and presentation are the project deliverables created in Step 8. Parts 3-6 – Optional are project elements that can significantly enhance the LU if time, interest, expertise, and curriculum requirements permit.

The example project, the Dallas County Urban Heat Island Study, documents one approach to the project. Appendices to the Instructor Guide document key processes for that project. LU users are encouraged to modify the Appendices to improve or update them. The Appendices can also be modified to create student Project Information Sheets for a more directed approach to the project.

<u>Learning Objectives:</u>

This learning unit applies image analysis and GIS tools (ENVI and ArcGIS) to the analysis of multispectral image, grid and vector GIS data for the identification and characterization of urban heat islands.

- Understand the causes and effects of UHIs.

- Research and measure, remotely and in the field, thermal emissions from materials and surfaces.
- Identify and research sensors with TIR capability.
- Acquire and utilize RS data and image analysis to determine thermal signatures and surface features and conditions in the study area.
- Integrate thermal mapping with other RS imagery, GIS data, and aerial photographs to identify, characterize, and field verify hot, intermediate and cool surface areas.
- Identify specific environmental actions and policies for UHI mitigation for the study area.

Student Outcomes:

Students will be able to:

- Improve leadership, team building, and cooperative project skills.
- Demonstrate research and information organization skills.
- Identify and apply field temperature measurement techniques and apply GPS data collection skills.
- Acquire experience in sensor and RS data characteristics focusing on the Landsat and ASTER sensors and aerial photography.
- Develop data acquisition and organization skills.
- Perform image analyses using RS software. Specifically, learn the techniques for utilizing TIR data.
- Integrate and analyze multiple raster and vector data sets in a GIS.
- Use data at higher resolution/higher accuracy and ground truth to evaluate and validate results.
- Evaluate analytical results to understand possible UHI impacts and identify remedial actions and policies. (Optional) Compare results with air quality spatial and temporal data. (Optional) Compare with meteorological data. (Optional) Compare results with demographic and socio-economic data.
- Demonstrate data storage and dissemination skills. (Optional) distribute results to the public using the Google Earth viewer.
- Demonstrate report generation and presentation skills.
- Undertake a workplace project with a basic knowledge of how initiate, implement, and complete that project.

Geographic location:

Project area will be selected by the instructor and class. Demonstration project located in Dallas County, Texas

Scientific and/or geographic concepts:

Understand:

- Temperature and thermal emission.
- UHI causes and effects.
- Multispectral image analysis with emphasis on TIR data.
- Image interpretation for identification of surface materials and conditions.
- GIS analysis of infrastructure, cadastral, LULC, and demographic data to evaluate UHI impact.
- Basic air pollution chemistry/ozone generation.

- UHI mitigation.

Preliminary list of software, data sets, and equipment:

- ArcGIS 9.x with Spatial and 3D Analyst extensions for geospatial analysis (www.esri.com).
- ENVI 4.x for image analysis (http://www.ittvis.com/).
- Excel, Access, Word, and PowerPoint.
- Adequate computer resources to run software.
- Adequate storage for data and project products; >50 Gb.
- Access to Internet for research and data download.
- Access to printed materials (reports and manuals) including NASA thermal data protocols, research, and thermal data processing tools.
- Thermal characteristics of materials.
- Temperature measurement devices (can be as simple as basic laboratory dial or liquid thermometer with a range of 0° to 200° F for surface temperatures or 0 to 125° F for air temperature in most areas).
- Landsat and/or ASTER RS multispectral data and ASTER Kinetic Temperature.
- Aerial photography.
- Land cover, land use, census, street/transportation GIS data.
- (Optional) Climatological/meterological data.
- (Optional) Pollution monitoring measurements and reports if available..

Entrance skills and competencies for LU:

Students need:

- Intermediate to advanced computer skills.
- Knowledge of MS applications.
- Intermediate to advanced research, data acquisition, and data management skills.
- Intermediate collaboration skills.
- Advanced ArcGIS and GIS skills.
- Intermediate to advanced ENVI and image analysis skills.
- Intermediate field data collection skills.
- Intermediate to advanced presentation skills.

Skill Level of LU:

Advanced for project-based courses. Advanced level students will acquire most of the data independently. The LU could be modified for intermediate level students who will predominantly work with prepared data sets. This LU is suitable for a capstone course exercise. A subset of the LU might be suitable for a raster GIS course or as a demonstration of integrated geospatial analysis in a second level course.

Brief description of the methods:

- Introductory lectures and discussion sessions on aspects of UHI, TIR processing and image interpretation, GIS data extraction, data integration and data verification.
- Introductory lectures and discussions of project development topics.
- Demonstrations of key techniques and processes.

- Guest expert presentations.
- Research on UHI conditions and impacts.
- Field data collection.
- RS and GIS labs with data acquired, processed, and analyzed by students.
- Field verification and quality control.
- Report/presentation.

Brief description of evaluation or assessment:

Students are evaluated on thoroughness of research, field data collection participation and skills, RS and GIS knowledge and skills, team participation and performance, leadership performance, critical thinking and analysis, presentation skills. Project/laboratory notebooks will be reviewed and graded at key progress points using a decision point checklist to evaluate progress toward learning and project goals. The project reports and presentations will be graded using a weighted system of key elements by faculty and students. Success is ranked primarily on the knowledge and execution of the process and less on specific analytical results. Community experts will be involved directly in the review if possible. A brief practical exam will evaluate data understanding and software use skills.

Timeline:

This LU will require 8 to 10 weeks (two 3 hour class sessions per week plus open lab time and outside assignments) depending upon the number of students in the class to make teams, the level of complexity adopted, and number of options selected. This timeline assumes that this will be a team project for 6 or more students. If the number of students is small, adjust the timeline to accommodate the processes.

Weeks 1- 2 Project research; data acquisition, examination and organization; temperature measurement.
Week 3-5: Image and other data analysis.
Week 6-7: Data integration and interpretation; data comparison; report initiation.
Week 8: Report finalization and delivery.

This LU could be modified as a five week assignment with all data except field temperature measurements provided by the instructor, reduced quantitative analysis, and a brief report (add 2 to 4 weeks for data identification, collection, and acquisition).

Weeks 1& 2 Project research; data acquisition, examination and organization; temperature measurement.
Week 3: Image analysis and other data analysis.
Week 4: Data integration and interpretation; data comparison; report initiation.
Week 5: Report finalization and delivery.

Key words:
Urban heat island, temperature, emissivity, sensor, platform, RS data, Landsat, ASTER, MODIS, multispectral, TIR, orthophotography, land use, land cover, demographics, mitigation.

List of resources:

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UHI Publications/Web resources:

NASA/GHCC Urban Heat Island Pilot Project
www.ghcc.msfc.nasa.gov/uhipp/urban_uhipp.html

U.S Environmental Protection Agency: Heat Island Effect
www.epa.gov/**heatisland**/

U.S Environmental Protection Agency: Trees and Vegetation
http://www.epa.gov/hiri/strategies/vegetation.html

NASA: Sacramento urban heat island
http://science.nasa.gov/NEWHOME/headlines/essd01jul98_1.htm

NASA: What's hot in Huntsville and what's not: A NASA thermal remote sensing project (the role of trees)
http://wwwghcc.msfc.nasa.gov/land/heatisl/heatisl.htm

HARC (Houston Advanced Research Center): Houston Urban Heat Island Effect
http://www.harc.edu/Projects/CoolHouston/

Rice University: A Remote Sensing Study of the Urban Heat Island of Houston, Texas, Streutker, D. R., AA(Rice University, Department of Physics and Astronomy 6100 S Main St., Houston, TX 77005 United States ; streutke@rice.edu, American Geophysical Union, Fall Meeting 2001, abstract #A12A-0050
http://adsabs.harvard.edu/abs/2001AGUFM.A12A0050S

Add temperature measurement and ASTER thremal

An Atmospheric Correction Parameter Calculator for a Single Thermal Band Earth-Sensing Instrument, Barsi, J., Barker. J, Schott, J.
http://atmcorr.gsfc.nasa.gov/Barsi_IGARSS03.PDF

Landsat 7 Science Data Users Handbook
http://landsathandbook.gsfc.nasa.gov/handbook.html

Project Web resources:

Imagery
http://www.landsat.org/ortho/default.html
http://glovis.usgs.gov
http://lpdaac.usgs.gov/datapool/datapool.asp
http://zulu.ssc.nasa.gov/mrsid (Global 1990 & 2000 Landsat Ortho)
http://edcimswww.cr.usgs.gov/pub/imswelcome/ (EOS Data Gateway)
http://edcsns17.cr.usgs.gov/EarthExplorer/
http://landsat.gsfc.nasa.gov
http://landsat.gsfc.nasa.gov/education/resources/Landsat_QuantifyChanges.pdf
http://landsat.usgs.gov

http://landsat.usgs.gov/gallery/change
http://lpdaac.usgs.gov
http://www.collinssoftware,com/freegis_by_region.htm (Imagery and other data)
Don't forget to preview areas with Google Earth or Bing

Image Processing
http://iitvis.com/tutorials/index.asp (ENVI tutorials)
http://cobweb.ecn.purdue.edu/~biehl/MultiSpec/ (Image processing program-public domain)

Other Data
http://ledaps.nascom.nasa.gov/ledaps/ledaps_NorthAmerica.html
http://glcf.umiacs.umd.edu (Global Land Cover Facility)
http://www.geog.umd.edu
http://www.esri.com
http://www.geographynetwork.com/webservices/wfs.html
http://www.geographynetwork.com/webservices/index.html
http://change.gsfc.nasa.gov
http://dacc.gsfc.nasa.gov
http://earthobservatory.nasa.gov
http://edcims
http://geodata.gov
http://landcover.usga.gov
http://mapservice.swc.state.nd.us
http://nsidc.org
www.sciencemag.org
http://sedac.ciesin.columbia.edu/
http://speclib.jpl.nasa.gov
http://survey.swc.nd.gov/
http://www.cr.usgs.gov
http://www.fws.gov
http://www.nd.gov/gis/
http://www.nhgis.org

Education
http://www.iste.org (NETS•S standards)

National Educational Technology Standards (NETS•S) and Performance Indicators for Students met by LU:

Creativity and Innovation
Students completing this LU will demonstrate creative thinking, construct knowledge and develop innovative products and processes using technology through:

- Applying existing knowledge to generate new ideas, products or processes
- Creating original works to explore complex systems and issues
- Identifying trends and forecast possibilities

Communication and Collaboration

Students completing this LU will use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students will:

- Interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
- Communicate information and ideas effectively to multiple audiences using a variety of media and formats.
- Contribute to project teams to produce original works or solve problems.

Research and Information Fluency

Students completing this LU will apply digital tools to gather, evaluate and use information through:

- Planning strategies to guide inquiry
- Locating, organizing, analyzing, evaluating, synthesizing, and ethically using information from a variety of sources and media
- Evaluating and selecting information and digital tools based on appropriateness to specific tasks
- Processing data and reporting results

Critical Thinking, Problem Solving, and Decision Making

Students completing this LU will applying critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources through:

- Planning and managing activities to develop solutions or complete projects
- Pollecting and analyzing data to identify solutions and make informed decisions
- Using multiple processes to explore alternative solutions

Technology Operations and Concepts

Students completing this LU will demonstrate a sound understanding of technology concepts, systems, and operations through:

- Understanding and using technology systems
- Effectively and productively selecting and using applications
- Transferring current knowledge to learning of new technologies