This consortial program is supported by the W.M. Keck Foundation of Los Angeles
Proposal Cover Sheet

Project Title: *Earth from Space: Spatial Science and Technology Focused Introductory Geosciences Course Development and Implementation*

Faculty Name: Dr. Suresh Muthukrishnan

Institution: Furman University

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Amount requested: $20,625.00

Date grant submitted: 14th October, 2005

Proposed grant period:

Type of project: New course development

Signature of faculty submitting proposal_____

Date: 14 October 2005

_Kenneth A. Sargent_____	_____Tom Kazee_____
Name of Dept./Div. Chair	Name of Chief Academic Officer:
_____	____Vice President and Dean_____
Signature of Dept./Div. Chair	Title of Chief Academic Officer
	_____
	Signature of Chief Academic Officer
Date_____	Date _____

Evidence of institutional support is required for each mini-grant proposal in the form of a letter of support from the proposal author's Department/Division Chair or Dean of Science.

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Date received_____ By_____
Date sent to review Committee_____
Action_____ Notification sent_____

1. Summary

Science courses in liberal arts colleges are usually taken by students who are science majors or by those that need to satisfy general educational requirement in sciences area towards their graduation. In general, science is perceived to be a very analytical and quantitative subject by non-major science students and hence many of them develop a mental barrier towards science learning. However the same students will take a course that is primarily focused on use of computer technologies since it's seen as a "cool thing" to do. The current proposal will develop a new introductory geosciences course that will break this barrier by embracing technology to teach introductory geoscience. The *Earth from Space* course will introduce earth system science concepts using geospatial tools and technologies such as GIS, remote sensing, GPS and PDA (palm computer). The main objectives of this proposal are: to introduce the undergraduate non-science majors to the basic concepts of geosciences through the use of spatial technologies, to engage the students through active communications and in-class activities, and to raise the overall science literacy and global awareness of both science majors and non-science majors. Several in-class activities and lab exercises will be developed using GIS and remote sensing data as well as PDA with built in GPS support.

Furman's engaged learning setup, current proposal to change curriculum and calendar, and the planned renovation and improvement of science facilities provides a perfect opportunity to achieve the goals of this project. With a very strong support from the academic dean and vice president of the university as well as the department of earth and environmental sciences, the proposed course will definitely spark more interest in science among non-science majors. This course will also provide a base for students to develop spatial skills that are important for their future career plans, while at the same time preparing them to understand the basic science behind our every day environment.

As this is a unique type of course that tightly integrates science and technology, all the materials and knowledge developed for this course will be shared with interested people from other member institutions through a website as well as through conference presentations of the student responses and course outcomes.

2. Project Description recommended not to exceed six pages that describes:

The primary objectives of this proposal are,

1. Introduce geosciences to undergraduate students from a completely different perspective using GIS, GPS, and remote sensing technologies
2. Integrate spatial sciences and technologies into the earth science course to achieve proficiency of scientific concepts among non-science majors
3. Raise the level of science literacy and global awareness of undergraduate students
4. Engage the students at a much deeper level of scientific discussions and understanding by developing course modules and field problem solving exercises using technologies and tools such as PDA with built-in GPS, and Google Earth.

Background and significance

Current generation of undergraduate students have a stronger appetite and tendency towards technologies. This is clearly evident from the fact that nearly all of the incoming freshmen have at least a desktop or a laptop computer and a cellular phone, and several of them also have a mini iPod, PDA, and car navigation system. Proliferation of technology and widespread uses has brought down the prices and hence it's easily affordable by everyone. Studies have shown that technology use in classrooms have positive impact on student learning abilities and surveys conducted in courses that implemented use of

technologies such as GPS and hand-held computers (PDA) often reflect this (Chen et al., 2000). However, uses of technologies in K-16 education, especially in the sciences, have been very slow to increase because of two factors. The first one is the lack of integration of science and technology at K-16 education levels, which leads to ignorance of the possibilities. The second one is lack of educators that have a strong enough expertise in both scientific and technological areas to keep up with both fields (Gewin, 2004). The introductory geosciences course that is proposed here will capitalize on this craving for technologies by the younger generations and will teach essential geoscience topics in the context of technologies such as Geographical Information System (GIS), Global Positioning Satellite (GPS) system, and remote sensing methods.

Since 2003, two new courses, *Introductory GIS* and *Remote Sensing of the Environment*, have been introduced in to Furman's curriculum to help develop a stronger spatial knowledge and skills for undergraduate students. These courses are specifically designed to provide a strong theoretical and practical knowledge required for students to understand the Geographic Information Science and remote sensing science. These courses are not part of general educational requirement courses and are not focused on just geosciences due to the presence of a mix of students from social & natural sciences, and humanities divisions. Introduction of "Earth from Space" as a GER course at a level conducive for non-science majors is a logical bridge that will provide a connection between the existing GIS and remote sensing courses and the introductory earth science courses. This proposed course will enable the students to develop a strong sense of how science and technologies are inter-related and how scientific knowledge and technological advances play a large role in understanding our complex world as well as in solving socio-economic and environmental problems.

Furman University is currently reviewing its curriculum and calendar system and the new proposal calls for changes in GER requirements and introduction of two freshmen seminar courses. In describing newer science GER requirements, a clear need is identified on the importance of global environmental awareness, and a distinction is made between a science class with lab or without lab. This clearly indicates a consensus among faculty and administration that as much as the laboratory components are essential in enhancing student learning and understanding, a global awareness is also very important in this changing world of today. If the new proposal gets approved, there will be more demand for introductory science courses that meet both requirements. Making such a course not intimidating for non-science majors is the most important issue here. The proposed course will fill the needs of the new curriculum with its geosciences focus, higher level of engagement and technology integration, and a global approach. With some modifications, this course could also be taught as a freshmen seminar class in the future. The current sequence of courses in the Earth and Environmental Sciences department are ideally placed such that after taking this proposed *Earth from Space* class, any students interested in exploring further in any of the areas can take advanced sophomore level courses in respective areas such as *introduction to GIS, remote sensing of the environment, Surficial processes* and many others.

Lack of an off-the-shelf textbook on this topic will be the most challenging part of the course development. There are good introductory earth sciences books, and good general GIS and remote sensing books, but there are no books that integrate all these things methodically and thoroughly for the undergraduate level. This project will provide the opportunity to develop integrated course materials, and could potentially lead to publication of a textbook that will fill in the need in this area.

Detailed project plan

The *Earth from Space* will be a new course that will be designed and implemented during 2006 calendar year. The course will address core topics of earth system sciences through the use of GIS, Remote Sensing and GPS, and palm PDA. Six broad topical areas have been identified based on the basic knowledge that any student need to gain from such introductory earth sciences classes. Following

are the topics proposed to be covered in the class along with reasoning and discussion on each of them with some specific lab and in-class activities that will be developed.

1. *Plate tectonics and physiographic provinces of the world*:

The theory of plate tectonics unifies geologic processes that shape the Earths' surface and moderates long-term climatic conditions. Understanding of this theory will help students relate the tectonic activity to volcanism and earthquake occurrences in several places around the world. The essence of plate tectonic processes could be easily understood by a thorough study of the landform characters and their distribution as well as the effects of tectonic activities such as natural disasters and hazards. With so many natural disasters happening in the recent times, discussion of this topic will captivate the students and get them excited about the subject. Study of landforms such as volcanoes in different sites provides an account of historic events that took place in those areas. Remote sensing and GPS based methods are heavily used for monitoring volcanic activities, land upliftment or subsidence, and also in the assessment of damages caused by natural volcanic hazards and earthquake disasters. The first module of this course will focus on all these aspects and also study the impacts of earth system processes on human beings and our living environment.

To engage the students during this module, in class activities as well as laboratory activities will be used. Computer based GIS activities will be developed using digital elevation data of the world to study the topographic profiles of land surfaces and ocean floor. The use of publicly available tools such as Google Earth (Google Eearth, http://earth.google.com) and EarthSLOT (EarthSLOT, http://www.earthslot.org/) for educational purpose will also be explored. Google Earth is a very small, non intrusive program that is available freely from the website, and provides GIS data layers and satellite images for the entire world without having to store any data on the local computer. Since Google Earth provides terrain information along with multi-resolution satellite data and high resolution aerial photographs, it is very easy to get a birds-eye view of the terrain and do interpretation. The United States Geologic Survey (USGS, 2005) website provides real time earthquake information including location, epicenter, and focus. These data can be downloaded and imported in to GIS system and further processed to understand how earthquake depth and distribution varies along the subduction zones. These will provide a global context to understanding landform evolution and earth processes and will be used as in-class exercises that students complete during the class.

A lab involving collection and processing of digital elevation data using handheld GPS device and using that data to generate 3-D model of the landscape of interest will be developed. This will not only engage the students completely in a fun way, but also will train them to use GPS technology for scientific studies. This lab will be spread over two weeks and will provide students an understanding of GPS based terrain data collection and modeling. The results from this lab will later be used in module 4 (human influence) to understand the impacts of land use changes on runoff and flooding. The Furman University campus can be used as a resource for this lab so that field data collection and verification can be done easily.

2. *Occurrence, characteristics, identification, and management of natural resources*:

One of the fundamental core topics that most introductory geology classes cover is rocks and minerals. Ironically, this is one of the topics that most of the non-science majors find to be least interesting. This is usually due to the way traditionally these topics are taught, which is to make the students memorize properties of selected rocks and minerals and their chemical formulas etc. However, this is not always the case. Some teachers have found ways of making it more interesting and fun by designing labs and activities that students can relate to (Guertin, 2005). Since rocks and minerals form the foundation of the earth and the society that lives upon the earth, and also because they have a direct bearing on the kinds of mineral and other natural resources that can occur in them, a good understanding

is necessary. This module will focus both on local resources (learning rocks and minerals) and global context to resource availability and resource distribution, and the

To make this topic entertaining and at the same time very interesting, a new lab exercise will be developed using innovative and engaging teaching methods (Guertin, 2005; Hesthammer et al., 2002) that incorporates PDA technology and internet resources to study rocks and minerals. This will allow students to use PDA to answer questions pertinent to mineral and rock identification using a pre-developed graphical interfaces with drop down menu so that as they are examining the rock, they select appropriate properties from the drop down menu. For each rock, the answer can also be preset, so that when they are done studying one sample, they can immediately get feedback as to what was right and what was wrong. This way, they can study the sample again and correct their misunderstandings instantly rather than waiting for the instructor to grade the lab and return several days later. The PDA along with the GPS will also be used to map rocks and geologic structures in the study area during the field trips. This will enable good record keeping as well as help transferring of spatial and attribute data for all field sites to computer immediately to generate a map of the field stations. Another interesting lab will be on the distribution of natural resources around the world, and their plate tectonic association. This could be extended to incorporate a study of natural resource availability and human population, and how these factors play a role in the global economic and environmental scenario. A lot of data is available in GIS format on the world resources, which can be coupled with world demographic data to get a bigger picture.

An existing class activity on "Furman Rocks" has already identified several variety of rocks and minerals on campus that make up building stones, pavements, side walks, and fountains. These locations will have to be geocoded and a GIS data layer with location information and attributes of each rock site will have to be developed and loaded on to the PDA so that students can navigate to each point using GPS navigation system and identify and study rocks and minerals. The GPS built into the PDA will make this feel like a 'treasure hunting' game; while at the same time it satisfies the educational goals.

3. *Global climate and atmospheric & ocean circulation*:

One of the most popular courses in the EES department among non-science majors is *introduction to oceanography*. The reasons for its popularity are several but most important one is the direct relevance or the students' ability to relate to the beaches, oceans, and hurricanes that are experienced often by them. The *Earth from Space* course will cover an understanding the atmospheric and ocean circulations and how it affects the weather and climate. Emphasis will also be placed on surface water studies and deep water studies, stratification of the ocean water and it's significant on the global food chain. The oceans and atmosphere are also one of the most studied features on earth using satellite remote sensing because of the severity of weather that is generated by them that affect the coastal areas frequently. This allows for easy availability of study resources from several national agencies such as National Oceanic and Atmospheric Administration (NOAA), and National Aeronautical and Space Agency (NASA).

Lab exercises involving examination and interpretation of long-term and short-term climatic data will be developed for this module. Availability of ample internet resources that provide data spanning several thousands of years will make it possible for students to see the evidences for global climatic changes (Huntoon and Ridky, 2002). As a pre-lab activity, students will be expected to develop their own hypothesis based on classroom discussions and assigned readings as to what is global climatic change and what triggers it. This lab will involve studying GIS based population data, and comparing it to the short- and long-term data on greenhouse gas, concentration of CO_2, temperature, and oxygen isotopes to understand any correlations that may be present to deduce conclusions. After completing the lab, they will assess their own reasons for their hypothesis and compare it with the results based on actual data to see the disagreements and explain those.

4. *Human influence on the local and global geologic processes*:

This topic will focus on discussing the implications of human interference in natural processes, and the effects of such actions on the local and global environment. It's been observed by scientists that that large earthen dams constructed around the world shifted the center of mass of earth to the extent that earth's rotational speed changed few nano seconds (Metzner, 2000; Luceri et al., 2004). On the other hand, urban sprawl activities at local or regional scale have significantly altered the hydrological nature of rapidly growing cities and as a consequence frequent floods are observed (Muthukrishnan, 2005). The recent events like breaking of levee built around Mississippi River that has drowned the entire city of New Orleans exemplifies the human stupidity and the price that we pay for it.

Several examples will be discussed including in-class discussions on ozone depletion, hypoxia in coastal waters, acid rain, and global warming effect. All of these problem areas can be assessed using GIS and remote sensing based data coupled with modeling approaches. A lab will be designed to study and model the long-term impacts of urban growth from water quality and surface runoff generation points of view. Models can incorporate data and information of different types and help study the interrelationships. This will also help students learn how to run models and derive results that can actually be of help in making decisions. Most students have a fear for the term "modeling" since it sounds like a very complicated mathematical operation, however implementation of models in GIS can break that barrier since GIS eliminates the need to derive equations and rather lets the students focus on the understanding what the model does and how to interpret the results.

5. *Collaborative learning using mini projects*:

This module will be developed to foster collaborative learning through development and completion of mini projects as groups. Students will be divided into small groups of three or four each and be given specific guidelines to come up with a project title. The instructor will work with each group to fine tune and narrow down the scope of the project so that it can be finished in a timely manner. The labs developed in the previous modules can potentially make up the first part of the final project. The students will be required to perform spatial analysis of their data and interpretation of results, and finally write a final group report with conclusions of their study.

This project will then be carried on to the next module where a thorough and critical evaluation will be done on each one of them. All students will be given opportunity to raise questions and give answers on all projects in the next module.

6. *The Limits and Limitations of Science and Technology:*

This will focus primarily on the discussions on basic assumptions and limitations that are part of scientific theories, GIS and remote sensing data, and modeling approaches that have been used to derive better understanding of earth processes. The objective of this module is to create a discussion among the students on the implications of relying on weak technology and unsound science. This will hopefully force the students to think outside of the box and develop critical analysis skills, and come up with creative ideas.

To enlighten the students on this topic, their own project from previous labs will be used as the center piece for evaluating the validity of their results given what ever the limitations their GIS data had, possible errors introduced during computer processing, and modeling methods used. At the end of this, they will have a good idea about methods of critical analysis.

Prior activities or research related to proposal.

None

Projected timetable

Initial preparations for the course development will start as early as January of 2006 and will continue through out the year. The specific time lines for each module are given below. It should be noted that modules 1 and 2 will continue into the term when the course will be offered since several of the labs and activities will be constantly improved with new data and ideas being incorporated. The development of concept tests and other similar PDA based assignments will be ongoing through out the term when the class will be offered.

Activity	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
Module 1									
Module 2									
Module 3									
Module 4									
Module 5									
Module 6									

Requested budget, with justification for each line item:

This course weighs heavily on the implementation of technology in to the geoscience course. Because of that, a majority of the funding will be allocated for purchasing and setting up of the hardware and software required. The faculty involved will spend two full month's worth time distributed over the 9 months of preparation time. During the summer, faculty time will be split between this project and other summer research projects that planned, and between Aug 12 and Sep 12, all the time will be spent on course development and designing. The ArcPad software is essential to run GIS on PDA's. The student assistant will help the instructor during the summer time in gathering data needed for in class activities and lab exercises as well as to design some of the lab materials.

Equipment supplies

Garmin iQue M5 PDA with GPS	$14,225.00 (25 numbers at $569 each)
ArcPad s/w with street maps data	$1,000.00 (25 licenses)

Stipend

Faculty stipend	$3,400.00 (2 months equivalent time)
Student assistant stipend	$1,000.00
Conference travel support	$1,000.00
Total	**$20,625.00**

Context of course in curriculum

This course will increase the number of GER courses offered by the department of Earth and Environmental Sciences. This course will also encourage students to take higher level courses in areas of GIS, remote sensing and other geoscience courses that would be of interest for further exploration.

Impact on the Institution, including number of students per year

This course will allow a maximum number of 24 students per term and initially it will be offered once a year and depending on the demand it could be increased to offering more than once in a year. The

changes that are likely to take place in the university wide curriculum will play a positive role on this course development since this course increases the number of choices non-major science students have to fulfill their science and global awareness requirements.

Evidence of Institutional support

The earth and environmental sciences department and the academic administration at Furman University both have been strongly supporting the GIS and Remote Sensing initiatives right from the beginning. The existing GIS and Remote Sensing lab facility was developed three years back with full financial support from the university and the department of earth and environmental sciences. The renovation of science building will take place from spring 2006 and the *science in sight* theme in the new building will put the focus on the GIS facility.

3. Evaluation and Dissemination

Evaluation

The effectiveness of teaching an introductory course is best measured by how students respond in the class. Most often the end of the term course evaluations gives the students an opportunity to express their opinions. However, the instructor doesn't get to see the results of evaluations until long after the term is over. Even though these comments generally benefit the instructor while preparing to teach the course at a later date, the students don't gain anything out of this. In order to give the benefit of improving teaching according to the students' needs, in-term evaluations will be conducted while the term is in progress and the survey will focus on specific course objectives given specific expected outcomes. As soon as the survey results are analyzed, the areas that need to be improved will be given priority.

New creative methods such as test distribution through hand-held PDA, and in-class problem solving using the PDA will be developed. During lecture, important concept questions will be sent to the students on their PDA and a summary of their answers will be instantly displayed on the main computer display for every one to see. The results will indicate whether or not the students understand the concept well. Wrong answer from a majority of the students will prompt revisit and further discussions on that particular topic. Such PDA based technologies have been tested and found to be very effective and popular in classroom environment (Chen et al., 2000).

Dissemination of results

The course outcomes will be shared with colleagues both within ACS institutions and outside through web resources. Other avenues of information dissemination include:

1. Presentation at undergraduate educational sections at one or more appropriate venues such as American Association of Geographers, Geological Society of America, and Associated Colleges of the South conferences
2. Potentially publishing in geoscience education journal
3. Course contents and modules will be made available to every one through the web site

4. Literature Cited

Chen, Franklin., Myers, Brad., and Yaron, David., 2000. Using Handheld Devices for Tests in Classes. Carnegie Mellon University School of Computer Science Technical Report, no. CMU-CS-00-152 and Human Computer Interaction Institute Technical Report CMU-HCII-00-101

Gewin, Virginia, 2004. Mapping Opportunities, Nature, Vol. 427, pp. 376-377

Guertin, Laura A., 2005. An Indoor Shopping Mall Building Stone Investigation with Handheld Technology for Introductory Geoscience Students, Journal of Geoscience Education, Vol. 53 (3), pp. 253-256

Hesthammer, J., Fossen, H., Sautter, M., Sæther, B., and Johansen, S.E., 2002, The use of information technology to enhance learning in geological field trips, Journal of Geoscience Education, v. 50, pp. 528-538

Huntoon, Jacqueline E., and Ridky, Robert K., 2002. Examining Long-Term Global Climate Change on the Web, Journal of Geoscience Education, v. 50 (5), pp. 497-514

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Metzner, Jim, 2000. Water: Slowing Down the Earth, Pulse of the Planet, National Geographic. http://pulseplanet.nationalgeographic.com/av/000124_28.ram (Last Accessed: 14th October 14, 2005)

Muthukrishnan, S., (2006) GIS Driven Inquiry Based Teaching, Learning and Research in Geosciences, A Place for GIS in the Liberal Arts, ESRI Publication. Accepted

USGS, 2005. Real time Earthquake Monitoring, http://earthquake.usgs.gov/recenteqsUS/ (Last Accessed: 14th October 14, 2005)

C.V. of Faculty Participant(s)

SURESH MUTHUKRISHNAN

A. Professional Preparation:

Dept. of Geology, College of Engineering, Anna University, Chennai, India	
Bachelor of Science in Applied Geology	1993
Dept. of Earth Sciences, Indian Institute of Technology-Bombay, Mumbai, India	
Master of Science in Applied Geology	1995
Master of Technology in Geo-exploration	1997
Dept. of Earth & Atmospheric Sciences, Purdue University, West Lafayette, Indiana	
Doctor of Philosophy in Remote Sensing and GIS	2002

B. Appointments:

Assistant Professor, Furman University	2002 to date
Director, Remote Sensing and GIS Center, Furman University	2002 to date
Instructor, Dept. of Earth & Atmospheric Sciences, Purdue University	2002
Graduate Research Fellow. Earth & Atmospheric Sciences, Purdue University	2000-2002
Research Assistant. Earth & Atmospheric Sciences, Purdue University	1998-2000
Research Associate. Centre for Studies in Resources Engineering (CSRE), Indian Institute of Technology-Bombay, Mumbai, India	1997-1998

C. Recent Publications:

Journal articles and book chapters

Muthukrishnan, S., Andersen, B., Lewis, G., *Accepted*. Relationships between land cover, vegetation density, and nitrate concentrations in streams of the Enoree River basin, piedmont region of South Carolina, USA, in Current Perspectives in Environmental Geochemistry, GSA Publications

Muthukrishnan, S., *Accepted*. GIS Driven Inquiry Based Teaching, Learning and Research in Geosciences, A Place for GIS in the Liberal Arts, ESRI Publication

Muthukrishnan, S., J. Harbor , K. J. Lim, and B. A. Engel, *In Press*. Calibration of a simple rainfall-runoff model for long-term hydrological impact evaluation , URISA Journal

K.J. Lim, B.A. Engel, Z. Tang, S. Muthukrishnan , J. Choi, and K. Kim, *In Press*. Effects of Calibration on Runoff and Pollutant Estimation Using L-THIA GIS. Journal of Environmental Management.

K.J. Lim, B.A. Engel, Z. Tang, J. Choi, K. Kim, S. Muthukrishnan, and D. Tripathy, *In Press*. Fully Automated Web GIS-based Hydrograph Analysis Tool, WHAT. Journal of American Water Resource Association.

K.J. Lim, B.A. Engel, S. Muthukrishnan, and J. Harbor, *In Press*. Effects of Initial Abstraction on Estimated Runoff. for Journal of the American Water Resources Association.

Choi, J. Y., Engel, B., Muthukrishnan, S., and Harbor, J., 2003. Evaluation of Long-Term Hydrologic Impact for Little Eagle Creek Watershed by Urbanization Using GIS, Journal of American Water Resources Association, Vol.39(3), pp. 623-635.

Nagarajan, R. and Muthukrishnan, S., 2002, Performance Assessment of Water Resources Projects Using RS and GIS - A Case Study, International Journal of Remote Sensing, Vol. 23 (20), pp. 4475-4485

Grove, M., Harbor, J., Engel, B., and Muthukrishnan, S., 2002, Impacts of Urbanization on Surface Hydrology, Little Eagle Creek, Indiana, and Analysis of LTHIA Model Sensitivity to Data Resolution. Physical Geography**,** Vol. 22(2), pp.135-153

Recent Conference Presentations *(*Student co-author)*

*Rowe, A., *Lowes, C., Muthukrishnan, S., Lewis, G.P., and Andersen, C.B., 2005. Relationships between urban land cover and nitrogen biogeochemistry in streams of the South Carolina piedmont, part I: the Mountain Creek watershed: Geological Society of America Abstracts with Programs, Southeastern Section Meeting.

*Slater, L., *Proctor, T., Muthukrishnan, S., Lewis, G. P., and Andersen, C.B., 2005. Relationships between urban land cover and nitrogen biogeochemistry in streams of the South Carolina piedmont, part II: the Brushy Creek watershed: Geological Society of America Abstracts with Programs, Southeastern Section Meeting. 2005.

*Meadows, J., *Bowie, T., and Muthukrishnan, S., 2005. Influence of stream channel morphology, hydrology, and landuse conditions on the nitrate concentration in urban stream system, American Association of Geographers National Conference, Denver, CO

Muthukrishnan, S., *Christy G., and Andersen, B. A., 2004. Remote sensing based investigation of variability in nitrate concentration in urban and forested watershed streams, SE-NE Geological Society of America, Tyson's Corner, DC.

Muthukrishnan, S., J., Harbor, J., Lim, K. and Engel, B., 2004. Integrated watershed studies using L-THIA/GIS: The influence of study-area scale on model results, American Association of Geographers National Conference, Philadelphia.

*Gandy, N., and Muthukrishnan, S., 2004. Hydrologic impacts of urban-growth: Modeling direct runoff using L-THIA/GIS for Enoree River Watershed, South Carolina, American Association of Geographers National Conference, Philadelphia.

*Gullikson, C., *Bax, T., Muthukrishnan, S., and Andersen, B. A., 2004. Effects of land use and vegetation density on nitrate concentration using remote sensing and GIS, American Association of Geographers National Conference, Philadelphia.

Muthukrishnan, S., Lim, K. J., Harbor, J., and Engel, B., 2003. iSep: Automated, Web-GIS Based Hydrograph Separation Tool - Application in Studying Hydrological Changes due to Urban Sprawl, Geological Society of America, Annual meeting, Seattle, WA, Vol. 35 (6).

Muthukrishnan, S., and Harbor, J., 2001, Development and Testing of a Simple Calibration Technique for Long-Term Hydrological Impact Assessment (L-THIA) Model, Eos Trans. American Geophysical Union, 82 (47), Fall Meet. Supplement, Abstract, San Francisco, CA

Choi, J. Y., Engel, B., Muthukrishnan, S., and Harbor, J., 2001, Long-Term Evaluation of Hydrological Impact by Watershed Urbanization, Paper # 012119, American Society of Agricultural Engineers Annual International Meeting, Sacramento, CA

D. Synergistic Activities:

1. Faculty co-investigator in interdisciplinary River Basins Research Initiative NSF-REU research program at Furman University, 2002 – present
2. Principal investigator for South Carolina Space Grant Consortium research grant, Identifying and modeling sources and sinks of nitrate using high resolution satellite data. $30,000
3. Have written two invited book chapters in the areas of advanced biogeochemistry and GIS in liberal education respectively.
4. Proposed and developed two upper level courses in GIS and remote sensing at Furman University.
5. Director of GIS and Remote Sensing Center at Furman University
6. Faculty Committee member of sustainable trails committee at Furman University
7. Developed a GIS-based integrated watershed management tool
8. Developed iSep: A GIS Internet Map Server (IMS) based Hydrograph Separation Model

5. Disclosure Statement

Suresh Muthukrishnan is a Ci-PI in Furman's River Basins Research Initiative grant (from NSF-REU) and PI in a South Carolina Space Grant Consortium grant. Part of his time during the summer will be spent working with students on these research projects. Following are the grant details:

1. 2005.River Basins Research Initiative NSF-REU Site, NSF-REU, Brannon Andersen (PI), Dennis Haney (Co-PI), Greg Lewis, Min Ken Liao, Suresh Muthukrishnan, Kenneth Sargent, John Wheeler, and Sandra Wheeler, $323,244
2. 2004. South Carolina Space Grant Consortium, Identifying and modeling sources and sinks of nitrate using high resolution satelite data. Suresh Muthukrishnan (PI), Brannon Andersen, Greg Lewis, and Norman Levine, $30,000