**Master of Science in Sustainability Science**

**SUSC PS5190 Remote Sensing of the Aquatic Environment**
**Day: TBD**
**Number of credits *3***

**Instructor:** Ajit Subramaniam, Lamont Research Professor, ajit@ldeo.columbia.edu
**Response Policy:** I will respond to emails within 24 hours. I am willing to be available over the weekends to answer questions if necessary

**Course Overview**
Aquatic systems are critical for provisioning ecosystem services that have sustained human civilization as evidenced by the establishment of the earliest civilizations on banks of rivers or along a coast. Apart from regulating climate, aquatic systems provide food and transportation services, fresh water lakes and reservoirs provide water for consumption and irrigation, and coastal systems offer recreational services. But growing human population, especially along the coast, has endangered the quality of ecosystem services. The primary finding of the Millennium Ecosystem Assessment was that 15 out 24 ecosystem services examined are being degraded or being used unsustainably (MEA 2005). Monitoring the aquatic ecosystem and understanding how to distinguish between anthropogenic and natural variability is an essential aspect of sustainability science. This course will provide an introduction to the use of remote sensing techniques that can be used to study the aquatic environment. There are several space-based sensors that provide information relevant to sustainable management of aquatic resources. Depending on the sensor, observations are made as frequently as every day and spatially covering the entire globe. Understanding the spatial and temporal context around an issue can help discriminate between local and far field effects and time series of remote sensing data can be constructed to investigate causes and consequences of environmental events. Thus knowledge of the basic science of remote sensing, understanding how to select the appropriate sensor to answer a question, where to find the data and how to analyze this data could be critical tools for anyone interested in oceanic, coastal, and freshwater resource management.

The course will follow active learning techniques and will consist of a lecture to introduce concepts followed by a discussion and lab time for hands on activities to learn and use tools for analysis of remote sensing data. After the introduction of the basic principles of remote sensing, a series of case studies will be used to explore concepts in sustainability such as water quality, nutrient loading and hypoxia, coral reefs. Remote sensing tools that are used to investigate and address environmental questions such as the effects of shutting down a sewage treatment plant, mapping of suspended sediment concentrations will be demonstrated and used by the students. Each case study will be briefly introduced at the end of the previous class and students will be encouraged to come prepared with scenarios relevant to their interest and work that they can explore with relevant remote sensing tools. Time will be set aside during the “lab-time” hands-on session for students to develop a project where a question of interest can be progressively investigated through the semester using the tools learnt, culminating in a final presentation. The use of computers to download and analyze data is required for this course.

This course is approved to satisfy the Area 2 – Methods of Earth Observation and Measurement curriculum area requirement for the M.S. in Sustainability Science program.

The course is designed to provide students with knowledge and experience in utilizing remote sensing techniques and analyzing environmental information across a range of scales. After completing the class, students will acquire remote sensing skills that will allow them to work in diverse positions in public and private sectors that involve carrying out environmental spatial and time-series analysis. Remote sensing skills and knowledge about how to use spatial and temporal context to study environmental issues offers students a large set of important and transferable skills to the workplace. The course will provide students with fundamental understanding of the key principles of remote sensing and data handling/analysis, which are essential for sustainability science careers.

**Learning Objectives**

By the end of the course, the student will

L1. Apply of the basic principles of remote sensing to aquatic environments
L2. Use platforms and sensors available for appropriate applications
L3. Use remote sensing as a tool for sustainability science by monitoring the environment and distinguishing between anthropogenic and natural variability
L4. Identify the appropriate data sources, and use the data in application of remote sensing techniques, analyze remote sensing data to address scientific, socioeconomic, and geopolitical issues
L5. Investigate an aquatic environment challenge using remote sensing techniques

**Readings**

*Papers will be made available via Canvas.*

Anderson, J. H., and D. J. Conley, editors. “Eurtrophication in coastal marine ecosystems: towards better understanding and management strategies.” *Eutrophication in Coastal Ecosystems*. Springer, 2009, pp. 5-19., doi: *10.1007/978-90-481-3385-7_2*.

Chuvieco, E., editor. *Earth observation of global change: the role of satellite remote sensing in monitoring the global environment*. Springer, 2008, pp. 143-168.

Eicken, H. et al “Sea-Ice System Services: A Framework to Help Identify and Meet Information Needs Relevant for Arctic Observing Networks.” Arctic Vol. 62, No. 2 (June 2009) pp. 119–136

Klemas, V. “Advances in Fisheries Applications of Remote Sensing” *2014 IEEE/OES Baltic International Symposium (BALTIC)*, 2014, doi:10.1109/baltic.2014.6887826.

Lehrter, J.C., and C. Le. “Satellite Derived Water Quality Observations Are Related to River Discharge and Nitrogen Loads in Pensacola Bay, Florida.” *Frontiers in Marine Science*, vol. 4, 2017, doi:10.3389/fmars.2017.00274.

Martin, S. *An introduction to ocean remote sensing*. 2nd ed., Cambridge University Press, 2014, ISBN 1139916157, 9781139916158.

Mendez, M., et al. “Marine Spatial Planning 2.0: genes and satellites to conserve seascape dynamics.” *Aquatic Conservation: Marine and Freshwater Ecosystems*, vol. 24, no. 6, 2014, pp. 742–744., doi:10.1002/aqc.2533.

Miller, RL., et al., editors. “Remote Sensing of Coastal Aquatic Environments.” *Remote Sensing and Digital Image Processing*, vol. 7, 2005, doi:10.1007/978-1-4020-3100-7, ISBN 1402030991, 9781402030994.

Ody, A. et al. “Potential of High Spatial and Temporal Ocean Color Satellite Data to Study the Dynamics of Suspended Particles in a Micro-Tidal River Plume.” *Remote Sensing* 8.3 (2016): 245.

Richardson, LL., and Ellsworth F. LeDrew, editors. *Remote sensing of aquatic coastal ecosystem processes*. Springer, 2006, pp. 111–134., doi:10.1007/1-4020-3968-9.

Saitoh, S.-I., et al. "Some operational uses of satellite remote sensing and marine GIS for sustainable fisheries and aquaculture." *ICES Journal of Marine Science*, vol. 68, no. 4, June 2011, pp. 687–695., doi:10.1093/icesjms/fsq190.

Spreen, G. and Kern, S. (2017) Methods of satellite remote sensing of sea ice, in Sea Ice (ed D. N. Thomas), John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781118778371.ch9

Trinh, R. et al. "Application of Landsat 8 for monitoring impacts of wastewater discharge on coastal water quality." *Frontiers in Marine Science*, 2017, doi: 10.3389/fmars.2017.00329. (In press)

Walker, N.D., and N.N. Rabalais. "Relationships among satellite chlorophylla, river inputs, and hypoxia on the Louisiana Continental shelf, Gulf of Mexico." *Estuaries and Coasts*, vol. 29, no. 6, 2006, pp. 1081–1093., doi:10.1007/bf02781811.

**Resources**

*Columbia University Library*

Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online: http://library.columbia.edu/.

*SPS Academic Resources*

The Office of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: http://sps.columbia.edu/student-life-and-alumni-relations/academic-resources.

**Course Requirements (Assignments)**

Participation (10%) (L1, L2, L3)

Students will come to class prepared with scenarios related to the weekly case studies. They will actively contribute to class room discussion on how remote sensing can be used in sustainably managing the environment. They will be encouraged to enrich the discussion by sharing relevant experience working with aquatic environmental issues.

Weekly Assignments (50%) (L1, L2, L3)

The student will be required to identify a region or question of interest relevant to each case study presented in the class each week. The student will identify the appropriate remote sensing tool and use the online portals or computer software to analyze the data and explain how they arrived at their conclusion during the "hands on" period of the class. The student will write up the problem, the tool they used to study the problem and their findings. Each weekly assignment will be no more than 2-3 pages in length. The assignments cover a wide range of topics relevant to sustainable management of the aquatic environment and will provide the student practical hands on experience with the tools their might use later. Assignments should be submitted via Canvas by midnight Sunday prior to the class. Examples of weekly assignments include:

1. Present ideas on the question of interest to be investigated using remote sensing tools
2. Use online portals to discover and download remote sensing data
3. Use remote sensing data to provide spatial and temporal context to environmental data analysis
4. Use remote sensing data to study sediment load in a region of interest
5. Use remote sensing data to study eutrophication in a region of interest

6. Use remote sensing data to study Harmful Algal Blooms in a region of interest
7. Use remote sensing data to study water quality in a region of interest
8. Use remote sensing data to study fisheries in a region of interest
9. Use remote sensing data to study coral reefs in a region of interest
10. Use remote sensing data to study phenology and microbial community composition
11. Use remote sensing data to study changes in sea ice
12. Use remote sensing data to study changes to the coastline

Final Project (40%) (L4, L5)
The student will build on the knowledge presented in each class towards a detailed analysis of a problem that is most relevant to their interests. Students will submit a project topic proposal by email by the 6th March for faculty review and approval. Possible topics include: Historical trends in coastal eutrophication in the New York Bight or other coastal regions, the impact of a sewage treatment plant in Boston Harbor and Harmful algal bloomssea-ice cover in Alaska.

Report (20%)
The report will be due on 15th May. The report will be no more than 10 pages in length. The report should include the scope of the problem, the appropriate remote sensing technique, how that technique was applied, how data was accessed, how data was analyzed, what the findings were, what conclusion was reached and why.

Presentation (20%)
Presentations will take place on 1st May (will accommodate some presentations on 24th April). Students are expected to use PowerPoint or another visual platform for presentations. Presentations are expected to be 15 minutes in length with an additional 5 minutes will be reserved for questions from faculty and classmates.

**Evaluation/Grading**

Participation (10%)
The grade for participation will be based on preparation and contribution to discussion to the case studies over the semester.

Weekly Assignments (50%)
Weekly assignments will be graded on a scale of 0-100. Assignments will be assessed based on the completion of the assignment where remote sensing data is analyzed to study an environmental issue. Assignments will be evaluated for knowledge of appropriateness of tool be used, where to obtain the data, how to analyze the data and draw conclusions.

Final Project Report (20%)
The final project required for this course will allow the students to apply the remote sensing tools learned in the class to investigate a question directly relevant to their interest.
The final project report will be graded on a scale of 0-100 and will be assessed for the topic chosen, the tools used to obtain the data, the analysis of the data and the conclusions drawn from the study.

Final Project Presentation (20%)
The final project presentation will be graded on a scale of 0-100. The presentations will be graded for clarity and ability to explain to their peers the problem investigate, the tools used and the conclusions reached.

The final grade will be calculated as described below:

**FINAL GRADING SCALE**

| Grade | Percentage |
|---|---|
| **A+** | 98–100 % |
| **A** | 93–97.9 % |
| **A-** | 90–92.9 % |
| **B+** | 87–89.9 % |
| **B** | 83–86.9 % |
| **B-** | 80–82.9 % |
| **C+** | 77–79.9 % |
| **C** | 73–76.9 % |
| **C-** | 70–72.9 % |
| **D** | 60–69.9 % |
| **F** | 59.9% and below |

| ASSIGNMENT | % Weight |
|---|---|
| Weekly Assignments | 50% |
| Participation | 10% |
| Final Project Report | 20% |
| Final Project Presentation | 20% |

**Course Policies**

***Participation and Attendance:*** *You are expected to complete all assigned readings, attend all class sessions, and engage with others in class room discussion and hands on activity. Your participation will require that you answer questions, defend your point of view, and challenge the point of view of others. If you need to miss a class for any reason, please discuss the absence with me in advance.*

***Assignments:*** *It is anticipated that some of the hands-on part of the assignments may be completed during the lab hours of the class. The write up should be completed and handed in by midnight the following Sunday.*

**School Policies [Include all school/university policies as written below.]**

*Copyright Policy*
Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:
The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

*Academic Integrity*
Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that

disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.
SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at http://sps.columbia.edu/student-life-and-alumni-relations/academic-integrity-and-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

*Accessibility*
Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: http://health.columbia.edu/services/ods/support.

**Course Schedule/Course Calendar**

| Date | Topics and Activities | Readings | Assignments |
|---|---|---|---|
| TBD | Introduction to fundamentals of remote sensing; Platforms and orbits – platforms used for remote sensing and how this affects repeatability and periodicity of observation | Martin, Seelye. *An Introduction to Ocean Remote Sensing 2nd Edition*. New York: Cambridge University Press, 2014. Chapter 1. pp 1-34. | Introduction<br>Present ideas on the question of interest to be investigated using remote sensing tools<br>Build your satellite part 1 |
| TBD | Spatial and Temporal Scales<br>The electromagnetic spectrum, algorithms to quantify properties | Martin, Seelye. *An Introduction to Ocean Remote Sensing 2nd Edition*. New York: Cambridge University Press, 2014. Chapter 3. pp 53-78. | Build your satellite part 2 |
| TBD | Sensors and Proxies – what are the sensors available for studying the aquatic environment and how they are used | Front. Mar. Sci. 4:274.<br>doi: 10.3389/fmars.2017.00274<br>Satellite Derived Water Quality Observations Are Related to River Discharge and Nitrogen Loads in Pensacola Bay, Florida<br><br>R.L. Miller et al. (eds.), Remote Sensing of Coastal Aquatic Environments 2005 Springer Chapter 2 Pp 21-50 | Use online portals to discover and download remote sensing data |
| TBD | Economic benefits of ocean color | Papenfus et al 2020 | Research on economic benefits of remote sensing |
| TBD | Deep dive into principles of ocean color and how it is used to study properties of interest | R.L. Miller et al. (eds.), Remote Sensing of Coastal Aquatic Environments 2005 Springer Chapter 14 Pp317-337 | Use remote sensing data to provide spatial and temporal context |
| TBD | Optical models | R.L. Miller et al. (eds.), Remote Sensing of Coastal Aquatic Environments 2005 Springer Chapter 14 Pp317-337 | Use remote sensing data to provide spatial and temporal context |

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|---|---|---|---|
| TBD | Case study: Climate change | E. Chuvieco (Ed). Earth Observation of Global Change: The Role of Satellite Remote Sensing in Monitoring the Global Environment Chapter 7 Pp 143-168 | Use remote sensing data to study phenology and microbial community composition |
| TBD | Case study: Sediment load and transport | Ody et al 2016. Remote Sens. 8, 245; doi:10.3390/rs8030245<br><br>R.L. Miller et al. (eds.), Remote Sensing of Coastal Aquatic Environments 2005 Springer Chapter 11 Pp 259-276 | Use remote sensing data to study sediment load in a region of interest |
| TBD | Case study: Waste water & sewage plant discharge | Front. Mar. Sci. \| doi: 10.3389/fmars.2017.00329 Application of Landsat 8 for monitoring impacts of wastewater discharge on coastal water quality | Use remote sensing data to study water quality in a region of interest |
| TBD | Case study: Coral reefs | L.L Richardson & E.F. LeDrew (eds.), Remote sensing of Aquatic Coastal Ecosystem Processes (2006). Springer. Chapter 5 Pp 111-134.<br><br>R.L. Miller et al. (eds.), Remote Sensing of Coastal Aquatic Environments 2005 Springer Chapter 13 Pp 297-310 | Use remote sensing data to study coral reefs in a region of interest |
| TBD | Case study: Eutrophication and hypoxia | Walker and Rabalais 2006 Estuaries and Coasts Vol. 29, No. 6B, p. 1081–1093<br><br>J.H. Anderson, D.J. Conley (eds.), Eutrophication in Coastal Ecosystems. DOI: 10.1007/978-90-481-3385-7_2 Pp5-19 | Use remote sensing data to study eutrophication in a region of interest |
| TBD | Case study: Harmful algal blooms | R.L. Miller et al. (eds.), Remote Sensing of Coastal Aquatic Environments 2005 Springer Chapter 12 Pp 277-296 | Use remote sensing data to study Harmful Algal Blooms in a region of interest |
| TBD | Case study: Arctic Sea Ice | Eicken, H et al. Arctic Vol. 62, No. 2 (2009) P. 119–136<br><br>Thomas, DN (Ed.) Sea Ice (2017). John Wiley & Sons. Chapter 9 Pp 239 – 260<br><br>Hauser et al 2021<br>Lindsay et al 2023 | Use remote sensing data to study changes in sea ice |
| TBD | Final Presentation | | |
| TBD | Final Paper Due | | |