Course Approval Form

For instructions:
http://registrar.gmu.edu/facultystaff/catalog-revisions/course/

Action Requested: (definitions available at website above)

[X] Create NEW [ ] Inactivate
[ ] Modify (check all that apply below)

[ ] Title (must be 75% similar to original) [ ] Repeat Status [ ] Prereq/coreq [ ] Grade Mode
[ ] Credits [ ] Schedule Type [ ] Restrictions [ ] Other: ______________

Course Level: [ ] Undergraduate [X] Graduate

College/School: College of Science
Department: Atmospheric, Oceanic, and Earth Sciences
Submitted by: Linda Hinnov
Ext: 3-3082
Email: lhinnov@gmu.edu

Subject Code: GEOL **Number:** 525
(Do not list multiple codes or numbers. Each course proposal must have a separate form.)

Effective Term: [ ] Fall [X] Spring [ ] Summer *Year* 2017

Title:
Current:
Banner (30 characters max w/ spaces):
New: Modeling Earth Signals and Systems

Fulfills Mason Core Req? (undergrad only)
[ ] Currently fulfills requirement
[ ] Submission in progress

Credits: (check one)
[X] Fixed → 3
[ ] Variable → to
[ ] Lec + Lab/Rct → 0 or

Repeat Status: (check one)
[X] Not Repeatable (NR)
[ ] Repeatable within degree (RD) →
[ ] Repeatable within term (RT) →
Max credits allowed: 3 (required for RT/RD status only)

Grade Mode: (check one)
[X] Regular (A, B, C, etc.)
[ ] Satisfactory/No Credit
[ ] Special (A, B C, etc. +IP)

Schedule Type: (check one)
LEC can include LAB or RCT if linked sections will be offered
[X] Lecture (LEC)
[ ] Lab (LAB)
[ ] Recitation (RCT)
[ ] Internship (INT)
[ ] Independent Study (IND)
[ ] Seminar (SEM)
[ ] Studio (STU)

Prerequisite(s) (NOTE: hard-coding requires separate Prereq Checking form; see above website)**:**
MATH 114 and STAT 250, or equivalent; or permission of instructor.

Corequisite(s):

Restrictions Enforced by System: Major, College, Degree, Program, etc. Include Code(s).

Equivalencies (check only as applicable)**:**
[ ] YES, course is 100% equivalent to ______
[ ] YES, course renumbered to or replaces ______

Catalog Copy (Consult University Catalog for models)

Description (No more than 60 words, use verb phrases and present tense)	**Notes** (List additional information for the course)
Provides instruction on time series analysis customized for Earth signals and systems such as climate, Earth-space orientation, earthquakes, geomagnetism, river flow, and tides. Concepts, including linear systems, filtering, spectrum estimation, harmonic analysis and hypothesis testing, are applied to time series data sampled from natural processes to address a variety of scientific problems.	

Indicate number of contact hours: Hours of Lecture or Seminar per week: 3 Hours of Lab or Studio:
When Offered: (check all that apply) [X] Fall [ ] Summer [ ] Spring

Approval Signatures

Department Approval ______ Date ______ College/School Approval ______ Date ______

If this course includes subject matter currently dealt with by any other units, the originating department must circulate this proposal for review by those units and obtain the necessary signatures prior to submission. Failure to do so will delay action on this proposal.

Unit Name	Unit Approval Name	Unit Approver's Signature	Date

Undergraduate or Graduate Council Approval

UGC or GC Council Member ______ Provost's Office ______ UGC or GC Approval Date ______

Form revised 9/2/2016

Course Proposal Submitted to the College of Science Curriculum Committee (COSCC)

The form above is processed by the Office of the University Registrar. This second page is for the COSCC's reference. Please complete the applicable portions of this page to clearly communicate what the form above is requesting.

FOR ALL COURSES (required)

Course Number and Title: **GEOL 525 – MODELING EARTH SIGNALS AND SYSTEMS**

Date of Departmental Approval:

FOR NEW COURSES (required if creating a new course)

- Reason for the New Course: There is need for a course that trains graduate students in signal analysis techniques customized for sampled natural data.

- Relationship to Existing Programs: This proposed course contributes to the Climate Dynamics PhD and Earth System Science Master's programs as an appropriate elective course. **GGS has reviewed and approved this course.**

- Relationship to Existing Courses: This course complements CLIM 762 by focusing on methods of time series analysis (presented in only 1 lecture in CLIM 762), and it will be the first graduate course in GEOL that focuses on quantitative methods in Earth sciences. Another new course under consideration, GEOL 535 Quantitative Stratigraphy, will train graduate students in quantitative treatment of stratigraphic data.

Other GMU signal analysis courses:

- ECE 201 – Introduction to Signal Analysis (Kathleen Wage)
- ECE 220 – Signals and Systems I (Jill Nelson)
- ECE 320 – Signals and Systems II (Jill Nelson)
- ECE 410 - Principles of Discrete-Time Signal Processing (Jill Nelson)
- ECE 464 - Modern Filter Design (Anna Baraniecki)
- ECE 535 - Digital Signal Processing (Jill Nelson)
- ECE 635 - Adaptive Signal Processing (Andre Manitius)
- ECE 738 - Advanced Digital Signal Processing (Kathleen Wage)
- ECE 751 - Information Theory (Yariv Ephraim)
- CLIM 762 – Statistical Methods in Climate Research (Tim Delsole)
- CSI 687 or STAT 658 - Time Series Analysis and Forecasting (James Gentle)
- CSI 978 - Statistical Analysis of Signals (James Gentle)
- GGS 754 - Earth Science Data and Advanced Data Analysis (Yang)

- The above courses except for CLIM 762, are not suitable for AOES graduate students, who will be working with a class of natural signals with the following unique problems:

- • uncontrolled independent variable (e.g., paleoclimate proxies with uncertain time scales)
- • short and non-stationary (e.g., seismograms)
- • non-Gaussian distribution (e.g., global precipitation)
- • unknown or variable signal-to-noise ratios (e.g., climate processes)
- • multivariate and interdependent (e.g., global sea surface temperature)

This proposed course addresses these (and other) issues with instruction in methods of signal processing and analysis that have been customized for use in atmospheric, oceanic and earth science research.

- Semester of Initial Offering: Fall 2017
- Proposed Instructors: Linda Hinnov

GEOL 525 – MODELING EARTH SIGNALS AND SYSTEMS
LINDA HINNOV, PROFESSOR OF GEOLOGY
SYLLABUS

Catalog Description: This graduate course provides instruction on time series analysis customized for Earth signals and systems such as climate, Earth-space orientation, earthquakes, geomagnetism, river flow, tides and many other time-dependent phenomena. Concepts including linear systems, filtering, spectrum estimation, harmonic analysis and hypothesis testing are applied to time series data sampled from natural processes to address a variety of scientific problems. Prerequisites: MATH 114, STAT 250; or permission of instructor [3 credits].

Suggested textbooks: *Climate Time Series Analysis: Classical Statistical and Bootstrap Methods. Second Edition (2014)*, by Manfred Mudelsee, Springer, Cham, 454 pp.; *Spectral Analysis for Physical Applications (1993)*, by Donald B. Percival and Andrew T. Walden, Cambridge, 583 p.; *Digital Signal Processing: an Interactive Approach (2008)*, by Andreas Spanias, Arizona State University, 326 p.; *Spectral Analysis and Time Series, Volumes I and II (1983),* Maurice B. Priestley, Academic Press, San Diego, 890 p.; *The Fourier Transform and Its Applications, 3rd Edition (2000)*, Ronald N. Bracewell, Mc Graw-Hill, Boston, 616 p.; *Time Series Analysis and Its Applications: With R Examples*, *2nd Edition (2006)*, by Robert H. Shumway and David S. Stoffer, Springer-Verlag New York, 575 p.

Requirements: 14 assignments (50%) (see descriptions below in the ***Course Outline***); independent project (50%) (students choose time series to analyze and model based on methodologies presented in the lectures).

Ethics: Consult http://oai.gmu.edu/the-mason-honor-code-2/ for course policy.

Student learning objectives:

Knowledge and Understanding
• Gain detailed knowledge about Earth signals and systems
• Learn both traditional and state-of-the-art signal processing and analysis
• Understand signal uncertainty and methods for signal prediction.

Analytical Skills and Abilities
• Develop the ability to formulate, analyze, model and interpret a wide variety of time series
• Develop advanced skills in digital filtering, spectrum estimation and hypothesis testing
• Receive comprehensive training in MATLAB and R languages

Professional Development
• Expertise in advanced signal processing and systems analysis
• Experience in solving complex Earth science problems using time series data

Course Outline:

WEEK 1—INTRODUCTION TO TIME SIGNALS AND SYSTEMS IN EARTH PROCESSES
Objective: Discuss time-variable natural processes in the human experience, e.g., climate change, Earth-space orientation, earthquakes, geomagnetism, solar irradiance, river flow, ocean tides, circadian rhythms, acoustics, etc.; and by what means we have learned to interpret, understand and anticipate the time-dependent behavior of these processes.
Assignment: BASIC SIGNALS I (convolution; linear systems; real and complex signals)

WEEK 2—MODELING TIME SIGNALS AND SYSTEMS IN EARTH PROCESSES
Objective: Time series data representing natural processes are normally presented in a discretized format. The creation and treatment of these series requires understanding theoretical and practical constraints in the processing and analysis of discrete-time signals.
Assignment: BASIC SIGNALS II (autoregressive models, Yule equations, the Fourier transform)

WEEK 3—THE Z-TRANSFORM
Objective: The Z-transform is a powerful tool for representation of time-dependent signals and for filter design. This class will be spent introducing the Z-transform and basic applications.

Assignment: Z-TRANSFORMS (Z-transforms of discrete time sequences; DTFT; poles and zeros)

WEEK 4—FIR FILTERS

Objective: Filters are important tools for isolating specific frequency components in signals for detailed examination. Finite impulse response filters are stable with linear phase responses and no poles. Their design is straightforward and will be explored first.

Assignment: FIR FILTER DESIGN (Bode plots; linear phase filters and frequency sampling)

WEEK 5—IIR FILTERS

Objective: Infinite impulse response filters are adaptations of analog filters with digital approximations; while they offer high efficiency implementation, they can be unstable if their poles cross the unit circle.

Assignment: IIR FILTER DESIGN (Application of the Butterworth filter)

WEEK 6—SAMPLING

Objective: Sample rate is a basic issue with natural data, especially deep-time Earth data with uncertain time scales (independent variables), or data that cannot be collected at strict uniform time spacings. This class discusses issues related to resampling data, and pitfalls that can arise.

Assignment: SIGNAL SAMPLING (Discrete sampling, aliasing and gaps)

WEEK 7—POWER SPECTRAL ANALYSIS

Objective: The keystone of time series analysis is the power spectrum, i.e., the distribution of time signal variance as a function of frequency. This class introduces the power spectrum and its estimation.

Assignment: POWER SPECTRUM ESTIMATION (Harmonic analysis; the power spectrum)

WEEK 8—STATISTICS OF THE POWER SPECTRUM

Objective: Estimated power spectra suffer from a variety of problems, including accuracy and frequency resolution. Understanding spectrum statistics and the effects of sample rate and windowing is important for optimizing spectral analysis.

Assignment: OPTIMIZING POWER SPECTRA (Windowing statistics; multi-tapers)

WEEK 9—HYPOTHESIS TESTING AND NULL MODELS

Objective: The question of what is signal and what is noise is often asked of natural data. The frequency domain is commonly used to assess bands of concentrated power with non-random variance (signal) and the "background continuum" of random variation (noise). Common approaches to evaluating this problem will be introduced by way of hypothesis testing.

Assignment: SIGNAL-TO-NOISE ESTIMATION (spectral noise models; harmonic F-testing)

WEEK 10—PERSISTENCE MODELS

Objective: Recognition of the importance of system "memory" has motivated development of parametric models to quantify time persistence in process noise. These include autoregressive, long-term "Hurst" and non-linear models that can be interpreted directly or leveraged further, e.g., for estimating uncertainty.

Assignment: PERSISTENCE TIME ESTIMATION (autoregressive modeling)

WEEK 11—COHERENCY ANALYSIS

Objective: Multivariate time series analysis involves comparing two or more signals that are hypothesized to have a relationship. This class addresses cross-correlation analysis in the time and frequency domains, and explains the statistics and hypothesis testing used to measure how signals are related to each other.

Assignment: EXCITATION/RESPONSE MODELING (coherency and cross phase, and transfer functions)

WEEK 12—POLYSPECTRA

Objective: Nonlinear signals can be diagnosed using higher order spectra to identify correlated frequencies, suppress noise and characterize phase and magnitude responses. The third order spectrum and its applications will be featured.

Assignment: NONLINEAR SIGNALS (bispectral analysis)

WEEK 13—TIME-FREQUENCY METHODS

Objective: Time series of natural systems may "drift", and their frequencies and magnitudes can change, slowly or suddenly, e.g., seismograms, paleo-climatic series. Other systems may have quasi-periodic or other non-stationary attributes. This requires application of methods that track time-frequency changes along time series; three approaches will be discussed.

Assignment: NONSTATIONARY SIGNALS (spectrograms, wavelets, quadrature signals)

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WEEK 14—ADVANCED SPECTRUM MODELING

Objective: Natural data do not necessarily conform to analytic statistics (e.g., the Normal distribution) assumed by many spectral estimators and modeling parameters. Therefore, empirical methods must be developed to test the significance of estimated spectra; we will explore three well-known approaches.

Assignment: BOOTSTRAPPING, JACKKNIFING AND MONTE CARLO MODELING

See next page for Mason Policies.

Some Important Mason Policies

Updated Spring 2016

Electronic Communications

Students must use their MasonLive email account to receive important University information, including communications related to this class.

Disability Accommodations

If you have a documented learning disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with **Office of Disability Services** to determine the accommodations you need; and 2) talk with me to discuss your accommodation needs.

Office of Disability Services: http://ods.gmu.edu

Academic Integrity

The integrity of the University community is affected by the individual choices made by each of us. Mason has an Honor Code with clear guidelines regarding academic integrity. Three fundamental and rather simple principles to follow at all times are that: (1) all work submitted be your own; (2) when using the work or ideas of others, including fellow students, give full credit through accurate citations; and (3) if you are uncertain about the ground rules on a particular assignment, ask for clarification. No grade is important enough to justify academic misconduct. Plagiarism means using the exact words, opinions, or factual information from another person without giving the person credit. Writers give credit through accepted documentation styles, such as parenthetical citation, footnotes, or endnotes. Paraphrased material must also be cited, using MLA or APA format. A simple listing of books or articles is not sufficient. Plagiarism is the equivalent of intellectual robbery and cannot be tolerated in the academic setting. If you have any doubts about what constitutes plagiarism, please see me.

Office of Academic Integrity: http://oai.gmu.edu/
Honor Code: http://oai.gmu.edu/the-mason-honor-code-2/

Mason Diversity Statement

George Mason University promotes a living and learning environment for outstanding growth and productivity among its students, faculty and staff. Through its curriculum, programs, policies, procedures, services and resources, Mason strives to maintain a quality environment for work, study and personal growth.

An emphasis upon diversity and inclusion throughout the campus community is essential to achieve these goals. Diversity is broadly defined to include such characteristics as, but not limited to, race, ethnicity, gender, religion, age, disability, and sexual orientation. Diversity also entails different viewpoints, philosophies, and perspectives. Attention to these aspects of diversity will help promote a culture of inclusion and belonging, and an environment where diverse opinions, backgrounds and practices have the opportunity to be voiced, heard and respected.

The reflection of Mason's commitment to diversity and inclusion goes beyond policies and procedures to focus on behavior at the individual, group and organizational level. The implementation of this commitment to diversity and inclusion is found in all settings, including individual work units and groups, student organizations and groups, and classroom settings; it is also found with the delivery of services and activities, including, but not limited to, curriculum, teaching, events, advising, research, service, and community outreach.

Acknowledging that the attainment of diversity and inclusion are dynamic and continuous processes, and that the larger societal setting has an evolving socio-cultural understanding of diversity and inclusion, Mason seeks to continuously improve its environment. To this end, the University promotes continuous monitoring and self-assessment regarding diversity. The aim is to incorporate diversity and inclusion within the philosophies and actions of the individual, group and organization, and to make improvements as needed.