GGS354: Data Analysis and Global Change Detection Techniques

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Grayed out words are not applicable in this semester.

Time & Place: Thursdays, 4:30 pm-7:10 pm, Exploratory Hall 2312 (online, asynchronous but assuming it is a Thursday class for schedule purpose)

Office Hours: by appointment for Zoom at: https://gmu.zoom.us/j/4655943637

Text Books:

- **Text 1 (recommended)**: IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. doi:10.1017/9781009157896. (***Available in electronic form for free***)
  Updated info: IPCC often released updated reports and other materials. Please visit https://www.ipcc.ch/ for any updated information.

- **Text 2 (recommended)**: Kendall, Maurice G., 1989, "Time Series," Oxford University Press, 3rd edition, December 1989. (ISBN-10: 0195207068; ISBN-13: 978019520706).

GMU Catalog Entry:

GGS 354 - Data Analysis and Global Change Detection Techniques (Credits: 3)

Introduces basic time series methods, especially those used in detecting trends and randomness in time series data. Various data related to global changes on different temporal and spatial scales will be identified, and the relevant analysis methods will be used to those data so that students can detect or confirm changing trends or lack of them in data. Other topics such as data formats, data visualization, and data mining may also be included based on the background of the student body.

Prerequisites

IT 104, STAT 250 or permission of instructor (*Competency in basic programming or tools used in data analysis*).

Goals and Objectives:

To introduce basic time series methods, especially those used in detecting trends and randomness in time series data. To present various data related to global changes on different temporal and spatial scales and data quality issues. To combine the relevant analysis methods with climate data so that students can detect or confirm changing trends or lack of them in data.

Learning Outcomes:

After successful completion of this course,

1. Students will understand basic time series analysis methods.
2. Students will become familiar with climate data.
3. Students will be able to analyze climate data sets and to make conclusions based on the analysis results.
4. Students will be able to apply the time series analysis methods and implementation skills to other data in real world situations.

Course Web Site: Canvas, the University's enterprise learning management system at https://canvas.gmu.edu/ (or https://lms.gmu.edu/). You must use the system for accessing course materials/assignments and for the final project submission.

Computing Requirements: No specific statistical package/tool will be required for assignments in this course. However, either Microsoft Excel (and the Excel Analysis ToolPak) or Matlab programming are recommended for assignments, tests, and/or projects. However, it is open for you to choose other statistical tools or programming environments such as Python.

Prerequisite Skills: A good comprehension of algebra and basic trigonometry and familiar with Microsoft Excel and/or a programming language. Basic calculus is helpful but not required.

Other references (This partial list is for information only. Not all the references will be used for the course in a particular semester):

Mann, M. E. (2004), On smoothing potentially nonstationary climate time series, Geophys. Res. Lett., 31, L07214, doi:10.1029/2004GL019569.

Mann, M. E. (2008), Smoothing of climate time series revisited, Geophys. Res. Lett., 35, L16708, doi:10.1029/2008GL034716.

Wilks, Daniel S., 2005: "*Statistical Methods in the Atmospheric Sciences: An Introduction*," Academic Press, December 2005 (0127519661)

McGrew, J. Chapman, Jr. and Charles B. Monroe, 2000, "An Introduction to Statistical Problem Solving in Geography," (2nd edition), McGraw Hill, Boston. (ISBN-10: 157766633X; ISBN-13: 9781577666332)

- **Data Links (Due to the development of AI, this link is not important at all.)**

Grading Policy*:

Homework Assignments:	50%
Mid-term Exam (take-home)	20%
Project	30%
Total	100% **(Letter grades based on absolute/relative numbers)**

- *The Canvas provides summary of current status for each student. Please note the numbers are only of reference values because we have different weights for the assignments, mid-term and final (project). The final letter grade will be based on the weighted mean values.
- If optional opportunities would be provided, the Canvas summary will count the optional as a regular one, which would mess up the summary values. Please ignore the impact by the optional assignments. The instructor will do the final calculation without the optional base points before issuing the final grade.

General Course Policies

- Attendance will be considered in the final grade.
- See the general rubrics.
- No make-up exams and no incompletes grade.

Notes on Assignments:

- If multiple files are involved, the assignments will be distributed in .7z (zipped). If you need, you can check Mason ITS site at https://its.gmu.edu/service/software-listing-7-zip/ for installing the software on your computer.
- Assignments should be submitted only through the Assignment submission section of the Canvas system - DO NOT email assignments directly to the instructor.
- It is expected that your submitted reports will be in either PDF or Word format. Please put major results in your reports including displays. Other supporting materials could be in any format (Excel and/or programs). If you use another format such as Excel for your assignment reports, please make sure the answers are easy to locate (one question is in one sheet or clearly identify each answer).
- Please make sure you have a backup of all the materials you submit.
- Please make sure to put your name with your assignment, and use your name or other identification information for your file names such as <yourLastName>_<firstName>_GGS354HW<#>.<xxx>.
- If more than one file is submitted, you should submit a single **ZIP** file (such as the .7z) containing all the assignment files. In that case, it is strongly suggested that you put all the files into a folder and name the folder with your identity.
- The grace time is the noon of the following day after the due day. Submission after the grace time may result in losing of points, 10% per day for the first two days. No grading for submission later more than 2 days.
- Makeup policy: In certain cases, I may allow one to redo an assignment for missing/mishandling questions. In that case, the redo is just an option to you. If a redo work is submitted, the grade could be elevated up to 80% of the total. The redo work should be submitted in a couple days, no later than the due day of next assignment.
- Different weights may be applied to assignments in the final points calculation.
- Rubrics for assignments and the final projects will be provided separately.

The followings are university wide required information from Office of the Provost:

UNIVERSITY POLICIES

- **University Catalog:** The University Catalog, http://catalog.gmu.edu, is the central resource for university policies affecting student, faculty, and staff conduct in university academic affairs. Other policies are available at http://universitypolicy.gmu.edu/. All members of the university community are responsible for knowing and following established policies.
- **Generative-AI (GenAI) Tools:** Use of GenAI tools will sometimes be in alignment with the learning outcomes for this course. It is expected that the GenAI for this course is very limited. If used, one should follow the fundamental principles of the Academic Standards. This includes being honest about the use of these tools for submitted work and including citations when using the work

of others, whether individual people or Generative-AI tools. When meeting the outcome requires original human action, creativity or knowledge, AI tool use would not align with the stated course goals.

- **Campus Closure or Emergency Class Cancellation/Adjustment Policy**: If the campus closes, or if the class meeting needs to be canceled or adjusted due to weather, students should check the university announcement. If the class meeting needs to be canceled or adjusted due to other reasons, an announcement should be sent out via Canvas for updates on how to continue learning and for information about any changes to events or assignments.
- **Mason Email Accounts:** Students must use their MasonLive email account to receive important University information, including communications related to this class. I will not respond to messages sent from or send messages to a non-Mason email address about the course following the university policy. See http://masonlive.gmu.edu for more information on Mason Email System.
- **Communication Policy**: The preferred individual communication mechanism with me is email. However, for this course, I will check the CANVAS on daily basis and try to respond on posted questions (the "Ask the Instructor" thread in the Discussion Board). For email communications, I will try to respond in one business day (24 hours or a little more) during weekdays and 1-2 days during weekends. Please include "GGS 354" in your subject line to start a new email.
- **Full Mason** Common Course Policies**.**

OTHER USEFUL CAMPUS RESOURCES:

- WRITING CENTER: http://writingcenter.gmu.edu
- UNIVERSITY LIBRARIES "Ask a Librarian." http://library.gmu.edu/ask
- Counseling and Psychological Services (CAPS): http://caps.gmu.edu
- **University Calendar:** Details regarding the current Academic Calendar. Calendars | Office of the University Registrar | George Mason University (gmu.edu)

Tentative Schedule:

Tentative Course Schedule (will be changed during the semester. Last modified on January 13, 2026): Please consider this as a list of course contents instead of schedule. The assignment given and due dates will be adjusted accordingly. All efforts will be made to cover as much topics below as possible.

Week 1. Course introduction and introduction to global changes.
- Syllabus overview
- Global mean energy balance
- Factors affecting climate processes
- Greenhouse effect
- Climate modeling
- HW1 (Excel practice on data handling, mean, energy balance) given

Week 2. Data uncertainties.
- Uncertainty concept and error types
- Uncertainty assessment in AR5
- GHG measurements with uncertainties
- Simple statistics for data descriptions
- Paleoclimatic data
- Sampling theory for time series measurements
- HW2 Simple statistics, data list rearrangement, simple plot) given

Week 3. Data model and data formats
- ASCII lists
- Multi-dimensional arrays
- Survey of special data formats for geoscience data (binary, HDF, netCDF, GRIB and BUFR) and available software tools
- Project Topic due
- HW3 (Time Series basics) given

Week 4. Time Series Basics
- Time Series Types
- Objectives of Time Series Analysis
- Time Series Decompositions
- Stationary Time Series
- HW4 (z score and probabilities in normal distributions) given

Week 5. Basis for Statistical Inference
- Basic ideas
- Sample means
- Hypothesis testing
- Reading assignments: GGS 300 Textbook review
- HW5 given (Confidence interval [CI])

Week 6. Specific Tests for components
- Randomness (turning point test)
- Randomness against trend (difference sign, relative ordering)
- Randomness against trend in seasonal series
- HW6 given (Selected tests for randomness against trend and seasonality)

Week 7. Time series-trend (Shorten week)

- Moving average
- Mid-term

Week 8. Time series-seasonal effects
- HW7&8 (one only) given (climatological and anomaly calculations)

Week 9. Linear regression
- Concept
- Model
- Parameter deduction
- Project outline due
- HW9 (Correlation) given

Week 10. Linear regression (Continued)
- Error assessments
- Test for regression
- Test for parameters
- Confidence interval for slope
- HW10 (linear regression concept/calculation/assessment) given

Week 11. Correlation analysis
- Pearson's r
- Other correlation coefficients
- Hypothesis of correlation coefficients
- Relationship between Pearson's r and simple linear regression
- HW11 (linear trends and confidence intervals) given

Week 12. Multiple Linear Regression
- Temporal trend estimates with linear regression
- Models for global temperature
- Linear regression with nonlinear variables
- HW12 (diagnostics of assumptions for linear regressions) given

Week 13. Time series analysis in spectral domain
- Fourier analysis with discrete data
- Response function of temporal filters
- Response function of moving average algorithms
- HW13 (multi-linear regression) given

Week 14. Miscellaneous Topics
- Applications
- Introduction of time-spectral data analysis (wavelets)
- Summary and review
- No HW assignment

Week 15. Final Exam (Thursday, 5/7/26. All things are due by that date)