Term Information

Effective Term	Spring 2026

General Information

Course Bulletin Listing/Subject Area	Atmospheric Sciences
Fiscal Unit/Academic Org	Geography - D0733
College/Academic Group	Arts and Sciences
Level/Career	Graduate, Undergraduate
Course Number/Catalog	5401
Course Title	Practical Data Processing and Analysis for Atmospheric Sciences
Transcript Abbreviation	Atmospheric Data
Course Description	Hands-on, skills-centric course on data processing and analysis for Atmospheric Science. Students will successfully distill large volumes of raw atmospheric science data, extract meaningful relationships from the distillate, diagnose what information is needed to solve problems, and communicate their processing and analysis techniques to other atmospheric scientists.
Semester Credit Hours/Units	Fixed: 3

Offering Information

Length Of Course	14 Week, 12 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade
Repeatable	No
Course Components	Lecture
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites	ATMOSSC 2940 or GEOG 5900, and MATH 1151; or graduate standing.
Exclusions	None.
Electronically Enforced	Yes

Cross-Listings

Cross-Listings	None

Subject/CIP Code

Subject/CIP Code	40.0401
Subsidy Level	Doctoral Course
Intended Rank	Junior, Senior, Masters, Doctoral

Requirement/Elective Designation

The course is an elective (for this or other units) or is a service course for other units

Course Details

Course goals or learning objectives/outcomes

- Remember, understand and apply basic methods to distill raw atmospheric science data and analyze the distillate.
- Independently learn new processing and analysis techniques.
- Analyze problem statements to determine what information needs to be stilled from raw atmospheric science data.
- Create complex data processing and analysis procedures from basic data analysis and processing methods.
- Evaluate the weakness of data processing and analysis procedures.
- Communicate their data processing and analysis procedures to other atmospheric scientists in written form.

Content Topic List

- Atmospheric Sciences and Meteorology
- Data Analysis
- Statistical Methods
- Uncertainty Quantification
- Numerical Methods
- Programming / Python for Atmospheric Sciences

Sought Concurrence Yes

Attachments

- AS5401_Data_Processing_and_Analysis_Syllabus.pdf: ATMOSSC 5401_Syllabus
  (Syllabus. Owner: Godfrey,Ryan B)
- Concurrence Request Documentation_AS5401.pdf: ATMOSSC 5401_Concurrence
  (Concurrence. Owner: Godfrey,Ryan B)
- Curriculum Map_ATMOSSC BS_ATMOSSC 5401_ Jan2025.pdf: ATMOSSC 5401_Curricular Map
  (Other Supporting Documentation. Owner: Godfrey,Ryan B)
- 5401 Cover Letter_4.4.25_Revision.pdf: ATMOSSC 5401 Revision Cover Letter
  (Cover Letter. Owner: Godfrey,Ryan B)
- AS5401_Data_Processing_and_Analysis_Revised Syllabus_4.4.25.pdf: ATMOSSC 5401 Revised Syllabus
  (Syllabus. Owner: Godfrey,Ryan B)
- ATMOSSC 5401_final_project_instructions_v4.pdf: Final Project Instructions
  (Other Supporting Documentation. Owner: Godfrey,Ryan B)

Comments

- Revision cover letter, revised syllabus, and final project instructions uploaded for return to subcommittee. *(by Godfrey,Ryan B on 04/09/2025 12:13 PM)*
- Please see Subcommittee feedback email sent 3/28/25. *(by Neff,Jennifer on 03/28/2025 12:28 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Godfrey,Ryan B	02/24/2025 01:04 PM	Submitted for Approval
Approved	Coleman,Mathew Charles	02/24/2025 04:59 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	03/04/2025 12:09 PM	College Approval
Revision Requested	Neff,Jennifer	03/28/2025 12:28 PM	ASCCAO Approval
Submitted	Godfrey,Ryan B	04/09/2025 12:14 PM	Submitted for Approval
Approved	Houser,Jana Bryn	04/09/2025 12:14 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	04/09/2025 06:08 PM	College Approval
Pending Approval	Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Neff,Jennifer Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	04/09/2025 06:08 PM	ASCCAO Approval

DEPARTMENT OF
GEOGRAPHY

THE OHIO STATE UNIVERSITY
COLLEGE OF ARTS AND SCIENCES

04/04/2025

Dear College of Arts and Sciences Curriculum Committee,

We appreciate the feedback received from the Committee regarding our original proposal of Atmos Sci 5401.

We received the following feedback:

- **Contingency**: The Subcommittee notes that page 2 of the syllabus indicates that there are no prerequisites for the course, but curriculum.osu.edu indicates prerequisites of ATMOSSC 2940 or GEOG 5900. The Subcommittee requests that the syllabus be adjusted to reflect the prerequisites if they are indeed intended to be enforced (otherwise, the department should remove them from curriculum.osu.edu). Additionally, the Subcommittee asks that the department add "or graduate standing" to the prerequisites in curriculum.osu.edu and the syllabus to avoid unintentional exclusions.

  This has been changed to reflect the requirement of ATMOSSC 2940 or GEOG 5900. We added an additional pre-req of Math 1151 after revisiting this topic.

- **Contingency**: The Subcommittee requests that the specific readings assigned to students be indicated in the course calendar, along with the corresponding page numbers for each reading. [Syllabus pp. 8-10]

  We understand the committee's request here. However, we are unable to comply with this contingency owing to the nature of the topics in this course. In an effort to better illustrate the course content and the expectations on students outside of class, we provide this narrative:

  Unlike traditional content-centric courses, ATMOSSC 5401 is a skill-centric course. It focuses on using computational skills to access and process atmospheric data, generate results, and analyze the results. These skills are real-world skills enforcing coding experience, and ~~spread sheet proficiency, and data collection~~data gathering, processing, visualization, and analysis -that many employers seek in qualified job candidates. There is no textbook that teaches the skills being taught in this class. Traditionally, these skills are acquired through graduate work and expectations of advisors but students are nearly always underprepared to meet these expectations without a formal class to teach them. Journal articles are not sufficient substitutes either because they make use of the results generated by the processes but don't adequately describe the computational processes used in detail, since that is not the focus of them.

As such, the optimal preparation for students outside of class is to practice using the data preparation and analysis skills taught during class. From a pedagogical perspective, ATMOSSC 5401 is very similar to courses on algebra and calculus – self-directed practice and application of those skills results in better learning outcomes than simply reading about them. As such, students' preparations outside of class is focused on practice, not assigned readings.

ATMOSSC 5401 enforces out-of-class practice through rigorous and lengthy weekly homework assignments and final project that require students to review in-class exercises. The homework assignments and final project are designed to take ~6 hours per week to complete. In other words, the homework assignments and final project comprise the 6 out-of-class hours per week that students are required to spend on a 3-credit course. As such, instead of assigned readings, ATMOSSC 5401 uses rigorous and lengthy assignments to enforce self-directed out-of-class learning.

- **Contingency**: The Subcommittee requests that the syllabus provide more information regarding the details and format of the final project. [Syllabus pp. 6-7]

  More details about the nature and expectation of this project have been added on pages 6-7.

- *Recommendation*: The Subcommittee asks that the department ensure that the reference to the **Office of Institutional Equity** in the religious accommodations statement is a hyperlink to the office's email. Additionally, the Subcommittee asks that the link below be added to the bottom of the religious accommodations statement, as it is a part of the required text. Please feel free to copy and paste these two links into the statement directly from the Subcommittee's feedback. Otherwise, the full statement with the links can be found in an easy to copy/paste format on the Arts and Sciences Curriculum and Assessment Services website. [Syllabus pp. 12-13]

  - **(Policy: Religious Holidays, Holy Days and Observances**)

    We have updated the policy statement

- *Recommendation*: The reviewing faculty recommend that the department use the most recent version of the university's diversity statement if they wish to keep it in the syllabus. The updated statement can be found in an easy to copy/paste format on the Arts and Sciences Curriculum and Assessment Services website. [Syllabus p. 14]

  We have updated the statement

We look forward to hearing back from the committee.

Thank you for your consideration.

Dr. Jana Houser
Director of Undergraduate Studies
Associate Professor of Atmospheric Sciences
Department of Geography
The Ohio State University
houser.262@osu.edu

SYLLABUS

ATMOSSC 5401

Practical Data Processing and Analysis for Atmospheric Science

Fall 2025 – Course # XXX

COURSE OVERVIEW

Course information

- Class periods: Tuesday, Thursday, 11:10am-12:30pm (80 minutes)
- Credit hours: 3
- Prerequisites: ATMOSSC 2940 or GEOG 5900, and MATH 1151, or graduate standing.
- Classroom: Derby Hall 135
- Mode of delivery: In Person, short lectures with plenty of in-class exercises
- Required Textbook: None.
- Recommended Textbook: “Statistical Methods in the Atmospheric Sciences” by Daniel S. Wilks (PDF version available in the Ohio State University library)

Instructors

Instructor: Dr. Man-Yau (Joseph) Chan (address as Dr C or Dr Chan)

- Email address: chan.1063@osu.edu
- Office hours: Fridays from 10.40am to 12.40pm
- Office hour location: Derby Hall 140

Course description

Data processing and analysis skills are crucial for all careers in atmospheric science and meteorology. Without these skills, forecasters and scientists cannot navigate and analyze the terabytes of data that are needed to understand and/or predict atmospheric behavior.

ATMOSSC 5401 is a ***hands-on, skills-centric*** course on data processing and analysis for atmospheric science. By the end of the semester, students will successfully distill large volumes of raw atmospheric science data, extract meaningful relationships from the distillate, diagnose what information is needed to solve problems, and communicate their processing and analysis techniques to other atmospheric scientists.

This course has two prerequisite courses:
(1) ATMOSSCI 2940, GEOG 5900, or equivalent
(2) MATH 1151 or equivalent

This class has a final group project, homework assignments (due weekly), and graded in-class exercises. There is no final examination, and no assigned readings.

Course-based Goals

By the end of the semester, students will successfully:

1. Remember, understand and apply basic methods to distill raw atmospheric science data and analyze the distillate,
2. Independently learn new processing and analysis techniques,
3. Analyze problem statements to determine what information needs to be distilled from raw atmospheric science data,
4. Create complex data processing and analysis procedures from basic data analysis and processing methods,
5. Evaluate the weaknesses of data processing and analysis procedures presented to them,
6. Communicate their data processing and analysis procedures to other atmospheric science in written form.

HOW THIS COURSE WORKS

Mode of delivery: In-person, lecture-based.

Course materials: All course materials will be accessible from OSU's **Carmen Canvas** interface. These materials include:

1. Lecture materials (PDF and PPT formats; released before class)
2. Worksheets for assignments, hands-on exercises (PDF format)
3. Video recordings of lectures and demonstrations (MP4 format)

Weekly activities and materials: This course has twice-a-week classes comprising of interwoven lectures and in-class exercises. ***Assignments are due every week on Thursdays by 11:59 p.m. The final project will have a longer due date (~4 weeks). No assignments will be due within 2 weeks of the final project's due date***. A weekly class schedule will be provided outlining content and assignments. ***The schedule is subject to change so students should be sure to retain the most current version.*** All scheduling changes will be articulated clearly to class via Carmen Announcements.

Credit hours and work expectations: This is a **3-credit-hour course**. According to Ohio State policy, students should expect around 3 hours per week of time spent on direct instruction (instructor content and Carmen activities, for example) in addition to 6 hours of homework (assignments and the final project) to receive a passing grade.

Expectations of Students (Outside of Assignments and the Final Project)

- **Exercises:** Students are expected to attend all classes and attendance will be tracked by use of **in-class exercises**. These exercises contribute to the In-Class Exercises category in calculating the final grade (see table under "Grading and Faculty Response").

COURSE MATERIALS AND TECHNOLOGIES

Textbooks

There is no required textbook for this course. Course materials will be provided on Carmen (see previous page).
An optional, but recommended, textbook for this course is "Statistical Methods in the Atmospheric Sciences" by Daniel S. Wilks.

Technologies (VERY IMPORTANT)

REQUIRED EQUIPMENT

- **Webcam:** built-in or external webcam, fully installed and tested
- **Microphone:** built-in laptop or tablet mic or external microphone
- **Other:** a mobile device (smartphone or tablet) or landline to use for BuckeyePass authentication
- **Laptop:** Windows OS, Mac or Linux OS. At least 8 GB of Random Access Memory (RAM), at least 10 GB of available storage space, and at least 4 cores in the Central Processing Unit (CPU).

REQUIRED SOFTWARE

- **A web browser (e.g., Google Chrome, Apple's Safari):** This is needed to view course materials (PDFs), watch recorded lectures, and access CarmenCanvas.
- **Zoom** (https://osu.zoom.us/) is the academic audio web conferencing solution for Ohio State and we will be using it for possible office hour options.
  - Getting started with CarmenZoom
- **Visual Studio Code (VSCode)**: VSCode is the main tool we will be using to perform data processing and analysis. However, if you want to work on your laptop for this class, you need to install VSCode on your laptop (click here for instructions).

Carmen: Accessibility, Help, Skills & Multi-Factor Authentication

ACCESSIBILITY OF CARMEN

This course requires use of Carmen (Ohio State's learning management system) and a web browser. If you need additional services to use these technologies, please request accommodations with your instructor.

- CarmenCanvas accessibility
- CarmenZoom accessibility

HELP WITH CARMEN (OR OTHER IT ISSUES)

For help with your password, university email, Carmen, or any other technology issues, questions, or requests, contact the Ohio State IT Service Desk. Standard support hours are available at ocio.osu.edu/help/hours, and support for urgent issues is available 24/7.

- **Self-Service and Chat support:** ocio.osu.edu/help
- **Phone:** 614-688-4357(HELP)
- **Email:** servicedesk@osu.edu
- **TDD:** 614-688-8743

Basic computer and web-browsing skills are expected, and navigating Carmen is an essential skill for this course. For questions about specific functionality, see the Canvas Student Guide.

REQUIRED TECHNOLOGY SKILLS SPECIFIC TO THIS COURSE

- CarmenZoom virtual meetings (e.g., for snow days)
- Uploading assignments on CarmenCanvas
- Using web browsers

CARMEN MULTI-FACTOR AUTHENTICATION

You will need to use BuckeyePass multi-factor authentication to access your courses in Carmen. To ensure that you are able to connect to Carmen at all times, it is recommended that you take the following steps:

- Register multiple devices in case something happens to your primary device. Visit the BuckeyePass - Adding a Device help article for step-by-step instructions.
- Request passcodes to keep as a backup authentication option. When you see the Duo login screen on your computer, click **Enter a Passcode** and then click the **Text me new codes** button that appears. This will text you ten passcodes good for 365 days that can each be used once.
- Download the Duo Mobile application to all of your registered devices for the ability to generate one-time codes in the event that you lose cell, data, or Wi-Fi service.

If none of these options will meet the needs of your situation, you can contact the IT Service Desk at 614-688-4357 (HELP) and IT support staff will work out a solution with you.

GRADING AND FACULTY RESPONSE

How your grade is calculated (% breakdown)

ASSIGNMENT CATEGORY	% POINTS
In-Class Exercises	20
Homework Assignments	45
Final Project	35
Total	**100**

Assignment descriptions:

In-Class Exercises: A set of in-class exercises will be released on Carmen every class. These exercises will reinforce the course material covered during the class. Students will submit their answers on Carmen by 11.59pm on the same day. ***In-class exercises are not graded – simply attempting them in-class and turning them is sufficient.*** Collaboration between students is permitted, but ***every student must turn in their own work***. Artificial intelligence (AI) tools can be used without penalty as long as the student acknowledges and documents their usage in their submitted work. **Please contact the instructor if you are missing class with a valid reason.**

Homework Assignments: Every week, a homework assignment will be due. Students will turn in their answers on Carmen. Students should expect to spend up to 6 hours on each assignment. In other words, the entirety of the student's out-of-class preparation is devoted to completing the homework assignment. ***In-class time can be used to complete assignments if the student has completed the in-class exercises assigned to that particular class period.*** Collaboration between students is permitted, but ***every student must turn in their own work***. Artificial intelligence (AI) tools can be used without penalty as long as the student acknowledges and documents their usage of such tools in their submitted work.

Final project: In the last month of the semester, a final group project will be released. The instructor will provide a list of research projects. Each project comes with extensive instructions and a list of questions to answer at the end of the project. Students will self-organize into groups of two or three, select one of those projects,~~ This project is **a group project** where students~~ and process and analyze atmospheric science data with the goal of answering ~~a set of research questions posed by the instructor~~the project-specific questions. The processing and analysis are to be documented on a public Github repository containing Markdown files, relevant data processing and analysis scripts, and relevant data visualizations. For example, for their final project, students can assess the quality of a set of probabilistic weather forecasts through processing and analyzing satellite observations and forecast data. Students will document their processing and analysis of satellite observations and forecast data on a public Github repository, and answer the instructor’s questions via a Markdown file. More generally, a final group will take approximately 33 hours to complete (including 9 hours of in-class time dedicated to the final project). Students should expect to take around 24 hours of out-of-class time to complete this project. ***In other words, the final group project will occupy the entirety of the students’ 6-hours/week out-of-class time for 4 weeks.*** AI tools can be used without penalty as long as the student acknowledges and documents their usage such tools in their submitted work.

Late assignments

Please refer to Carmen for due dates. Late homework assignments will be penalized by 10% per day late, and only accepted up to a maximum of 4 days late. If students anticipate having conflicts, they are expected to discuss with instructors ahead of time.

Grading scale

93–100: A
90–92.9: A-
87–89.9: B+
83–86.9: B
80–82.9: B-
77–79.9: C+
73–76.9: C
70 –72.9: C-
67 –69.9: D+
60 –66.9: D
Below 60: E

Instructor feedback and response time

Grading and feedback: Students can generally expect feedback within 14 days.

Email: Emails are the fastest way to contact the instructor. The instructor will generally reply to emails within **48 hours on business days when class is in session at the university**.

COURSE SCHEDULE

ATMOSSC 5401 WEEKLY SCHEDULE*

Class Lecture Topics, Exercises*, and Homework Assignments*

*Note: These topics, exercises, and homework assignments are *subject to change.* Students will be advised of updates to the schedule on Carmen and should follow the version with the most current date.

Classes 2x/week (80 mins).

HA stands for Homework Assignment. T stands for Tuesday, R stands for Thursday.

Wk	**Date**	**Class Topic(s) [30-min lecture + 50-min in-person exercise(s)]**	**Assignment**
1	T	Introductions, install VSCode, basic VSCode usage	Complete the first pulse-taking survey (must be done by the end of week 1)
	R	Bash scripting and Arithmetic	
2	T	Easiest Atmospheric Science data: Scalars	
	R	Reusable Procedures	**HA1 released – due Wk 3 R** Will likely take 5 hours to finish.
3	T	Navigating Atmospheric Profiles and Time Series	
	R	Visualizing Profiles and Time Series	**HA2 released – due Wk 4 R** Will likely take 5 hours to finish.

4	T	Simulating, Propagating, and Visualizing Atmospheric Data Uncertainties	
	R	Parsing Raw Atmospheric Data from a Single Observation	**HA3 released – due Wk 5 R** Will likely take 5 hours to finish.
5	T	Decoding Consolidated Raw Atmospheric Observation Data Files	
	R	Decoding Gridded Probabilistic Spatiotemporal Atmospheric Data Files	**HA4 released – due Wk 6 R** Will likely take 5 hours to finish.
6	T	Navigating and Visualizing Probabilistic Spatiotemporal Atmospheric Data	
	R	Summarizing Probabilistic Spatiotemporal Atmospheric Data	**HA5 released – due Wk 7 R** Will likely take 5 hours to finish.
7	T	Storing Gridded Atmospheric Data	
	R	Obtaining Gridded Atmospheric Model Data from Online Sources	**HA6 released – due Wk 8 R** Will likely take 5 hours to finish.
8	T	Accessing Atmospheric Observation Data from Online Sources	
	R	**Autumn Break**	
9	T	Review	
	R	Approximate Rates of Change	**HA7 released – due on Wk 10 R** Will likely take 5 hours to finish.
10	T	Atmospheric Budget Equations	

	R	Simulating In-Situ Atmospheric Observations from Forecast Data	**HA8 released – due on Wk 11 R** Will likely take 5 hours to finish.
11	T	Decomposing Atmospheric Data into Spatiotemporal Components	
	R	Forecast Validation	**HA9 released – due on Wk 12 R** Will likely take 5 hours to finish.
12	T	Visualizing and analyzing phase space	**Final project released** **Due on last day of class at 11.59pm** Will likely take ~6 hours outside of class per week over 4 weeks to complete.
	R	Isolating Dominant Features through Principal Component Analysis	
13	T	Isolating Relationships through Least Squares Regression	
	R	Hypothesis Testing and Field Significance	
14	T	In-class time to work on final project	
	R	In-class time to work on final project	
15	T	In-class time to work on final project	
	R	**Thanksgiving**	
16	T	In-class time to work on final project	

Final project Github Repository URL is due on the last day of class at 11.59pm

OTHER COURSE POLICIES

Discussion and communication guidelines

The following are my expectations for how we should communicate as a class. Above all, please remember to be respectful and thoughtful.

- **Writing style**: Students should use proper grammar, spelling, and punctuation. A more conversational tone is fine for non-academic topics in class discussion forums.
- **Tone and civility**: Let's maintain a supportive learning community where everyone feels safe and where people can disagree amicably. ***Remember that sarcasm doesn't always come across online.***

Academic integrity policy

- **Homework Assignments**: Working with other students is permitted, but ***every student must submit their own work.*** The use of AI tools is permitted as long as the student indicates that they have used them in their submission.
- **Reusing past work**: In general, students are prohibited in university courses from turning in work from a past class, even if modified. Students should discuss the situation with instructors in advance if there is any doubt.
- **Final project**: This course includes a final group project. AI tools can be used as long as the students indicates that they have used such tools in their submission.

Ohio State's Policy on Academic Misconduct

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-48.7 (B)). For additional information, see the Code of Student Conduct.

Requesting accommodations for disabilities

The university strives to maintain a healthy and accessible environment to support student learning in and out of the classroom. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion.

If you are ill and need to miss class, including if you are staying home and away from others while experiencing symptoms of a viral infection or fever, please let me know immediately. In cases where illness interacts with an underlying medical condition, please consult with Student Life Disability Services to request reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

Requesting religious accommodations

Ohio State has had a longstanding practice of making reasonable academic accommodations for students' religious beliefs and practices in accordance with applicable law. In 2023, Ohio State updated its practice to align with new state legislation. Under this new provision, students must be in early communication with their instructors regarding any known accommodation requests for religious beliefs and practices, providing notice of specific dates for which they request alternative accommodations within 14 days after the first instructional day of the course. Instructors in turn shall not question the sincerity of a student's religious or spiritual belief system in reviewing such requests and shall keep requests for accommodations confidential.

With sufficient notice, instructors will provide students with reasonable alternative accommodations with regard to examinations and other academic requirements with respect to students' sincerely held religious beliefs and practices by allowing up to three absences each semester for the student to attend or participate in religious activities. Examples of religious accommodations can include, but are not limited to, rescheduling an exam, altering the time of a student's presentation, allowing make-up assignments to substitute for missed class work, or flexibility in due dates or research responsibilities. If concerns arise about a requested accommodation, instructors are to consult their tenure initiating unit head for assistance.

A student's request for time off shall be provided if the student's sincerely held religious belief or practice severely affects the student's ability to take an exam or meet an academic requirement and the student has notified their instructor, in writing during the first 14 days after the course begins, of the date of each absence. Although students are required to provide notice within the first 14 days after a course begins, instructors are strongly encouraged to work with the student to provide a reasonable accommodation if a request is made outside the notice period. A student may not be penalized for an absence approved under this policy.

If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the Civil Rights Compliance Office. (Policy: Religious Holidays, Holy Days and Observances)

Your mental health

As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life's Counseling and

Consultation Service (CCS) by visiting ccs.osu.edu or calling 614--292--5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on call counselor when CCS is closed at 614--292--5766 and 24 hour emergency help is also available 24/7 **by dialing 988 to reach the Suicide and Crisis Lifeline**.

Statement on Title IX

Title IX makes it clear that violence and harassment based on sex and gender are Civil Rights offenses subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories (e.g., race). If you or someone you know has been sexually harassed or assaulted, you may find the appropriate resources at http://titleix.osu.edu or by contacting the Ohio State Title IX Coordinator at titleix@osu.edu.

Statement on Diversity

The Ohio State University affirms the importance and value of diversity of people and ideas. We believe in creating equitable research opportunities for all students and to providing programs and curricula that allow our students to understand critical societal challenges from diverse perspectives and aspire to use research to promote sustainable solutions for all. We are committed to maintaining an inclusive community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among all members; and encourages each individual to strive to reach their own potential. The Ohio State University does not discriminate on the basis of age, ancestry, color, disability, gender identity or expression, genetic information, HIV/AIDS status, military status, national origin, race, religion, sex, gender, sexual orientation, pregnancy, protected veteran status, or any other bases under the law, in its activities, academic programs, admission, and employment.

ATMOSSCI 4194

Practical Programming and Data Analysis for the Atmospheric Sciences

Final Project

Deadline: 5th December 2024, 11.59 pm Eastern Time

Table of Contents

General Instructions

This course's final project is a month-long project that officially begins on 5th November. No other assignments will be due after that official start date. The deadline for this project is 5th December 2024, 11.59 pm Eastern Time. You will also have in-class time during weeks 14 and 15 to work on the project. You can also use office hours for this project. **Dr Chan anticipates that this final project will take a two-person team between 24 hours to 30 hours to complete.**

The project tasks are designed for a two-person team. If you would like to challenge yourself, you can attempt your project alone ("hardcore mode"). The number of tasks and grading scheme are the same regardless of whether you attempt them as a pair or solo. You are also permitted to work with other pairs/persons to collectively figure out problems. However, you (and your buddy) must submit your own/pair's work.

Before doing the final project, **you need to pick one of the following topics**.

1. Exploring forecast uncertainty growth and saturation in 1000-member SPEEDY ensembles with feature decomposition.[1]
2. When and where are ensemble statistics non-normal? An investigation with 1000-member SPEEDY ensembles.

The information and instructions for each topic can be found in this document. SPEEDY is a simplified global circulation model (Simplified Parametrizations, primitivE-Equation Dynamics). More information about SPEEDY can be found here.

The use of AI tools and the internet is permitted in the final project. When using AI tools like Claude, Microsoft Copilot and ChatGPT, please save transcripts of your conversations and **submit those transcripts with your project.**

The deliverable is a public GitHub repository containing: (1) Python scripts/packages you wrote for this project, and (2) Markdown documents describing your findings. If you used AI tools, put your transcripts on the repository as well. **Submit the repository URL via CarmenCanvas.**

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[1] The feature decomposition is done using a Python package (PYSHTOOLS). You don't have to code the feature decomposition method yourself.

Grading Scheme

Total number of points: 100

Points allotted for completion of all tasks (including answering the questions): 70

Points allotted for adequate code comments: 20

Points allotted for version control: 10

Note that the code comments and version control are assessed separately from task completion – incomplete tasks will not affect points in those components.

Dr Chan will assess your version control by examining the history of your repository. To obtain full marks for the version control component, commit at least once per task part.

Information about SPEEDY Ensemble

All SPEEDY data can be found on Pitzer in the directory:

`/fs/ess/PAS2856/SPEEDY_ensemble_data`

There are two sub-directories, each containing the SPEEDY data for **every day in 2011** as a **`.nc`** netCDF file. Each sub-directory holds a SPEEDY ensemble:

1. **The reference ensemble (`reference_ens`)**.
   This ensemble's statistics represent the maximum possible forecast uncertainty (i.e., uncertainty saturation level). Dr Chan created this ensemble by injecting 1000 noise samples on 1st Jan 2010, and then integrated the resulting 1000 members for 2 full years. As the name implies, the saturated ensemble is mainly used to quantify the forecast uncertainty saturation level for a given day in 2011.

2. **The perturbed ensemble (`perturbed_ensemble`).**
   This ensemble is constructed by adding normally distributed random noise to the 3D temperature field of a model state on 1st Jan **2011** (standard deviation of 0.001 K). As the name implies, this ensemble will be used to quantify the growth of forecast uncertainties over time. In Dr Chan's experience, this ensemble's uncertainty saturates fully by Aug 2011 (determined by comparing with **`reference_ens`**).

Within each subdirectory (e.g., **`reference_ens`**), you will see 368 **`.nc`** files. Each such file is a NetCDF containing a 1000-member ensemble of SPEEDY model outputs at the date in question. For example, the **`201103130000.nc`** file contains the 1000-member SPEEDY model outputs for 2011-Mar-13 at 0000 UTC.

Each **`.nc`** file contains the following model variables for all 1000-members, at all latitude-longitude locations, and at all model levels (if applicable):

1. Zonal wind (variable name **`u`**) in m/s at all 3D locations
2. Meridional wind (variable name **`v`**) in m/s at all 3D locations
3. Temperature (variable name **`t`**) in K at all 3D locations
4. Specific humidity (variable name **`q`**) in kg/kg at all 3D locations
5. Geopotential height (variable name **`phi`**) in meters at all 3D locations
6. Surface air pressure (variable name **`ps`**) in Pascals at all latitude-longitude locations.

Note that the model levels are not pressure levels! SPEEDY uses a vertical coordinate known as sigma-coordinates. The sigma-coordinate is related to pressure via

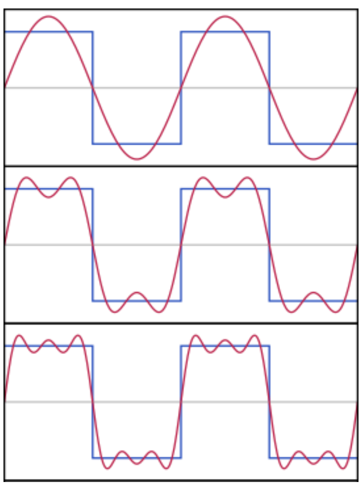
$$\sigma = \frac{P}{P_{sfc}}$$

where P is pressure in Pascals and P_{sfc} is surface pressure in Pascals.

Information and Instructions for "Exploring forecast uncertainty growth and saturation in a 1000-member SPEEDY ensemble using spatial scale decomposition."

You might remember from other courses that small-scale phenomena (e.g., airmass thunderstorms) evolve faster than large-scale phenomena (e.g., troughs). This difference in evolution speeds also imply that forecast uncertainties at smaller scales evolve faster than forecast uncertainties at larger scales. **In this project, you will be examining how forecast uncertainties evolve as a function of scale.**

Before proceeding, you should learn a little about how meteorologists think about spatial scales. The idea is that we break up the atmosphere into a sum of features across different scales. As a simple example, the 2D zonal wind velocity u on some model/pressure level can be broken into three components (large-scale, medium-scale and small-scale)



$$u = u_{largest\ scale} + u_{2nd\ largest\ scale} + u_{3rd\ largest\ scale} + \cdots$$

For 1D data, the idea of scale decomposition looks like the figure on the left[2]. The first row shows the largest-scale pattern. The second row shows the sum of largest and 2nd largest scales. The third row shows the sum of largest, 2nd largest, and 3rd largest scales. As you can guess, if we keep summing up the scales, we obtain the original data.

For data defined on a sphere (i.e., global data), we spatially decompose the atmosphere using spherical harmonics:

$$u(\varphi, \theta) = \sum_{\ell=0}^{L} \sum_{m=-\ell}^{+\ell} \widehat{u_{\ell m}}\, f_{\ell m}(\varphi, \theta)$$

where φ is longitude, θ is the co-latitude (i.e., 90 degrees minus latitude), $f_{\ell m}(\varphi, \theta)$ is the spherical harmonic corresponding to degree ℓ and order m, and $\widehat{u_{\ell m}}$ is the "amplitude" corresponding to $f_{\ell m}(\varphi, \theta)$. Here's a YouTube video[3] that helps you visualize how this decomposition looks like.

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[2] https://en.wikipedia.org/wiki/Fourier_series#/media/File:Fourier_Series.svg

[3] If the video link doesn't work, the URL is https://www.youtube.com/watch?v=dDQTHFeJf5M

You don't have to know the mathematics of spherical harmonic decomposition! We will be using the Python package PYSHTOOLS to do the decomposition.

This stuff is best learned from trying it out. Let's go straight to the project!

Task 1: What do those spherical harmonics look like?

a) Install PYSHTOOLS using the instructions here[4].

b) Load the 5D geopotential height array from the SPEEDY reference ensemble netCDF file for 1st Jan 2011.

c) Subset the geopotential array to member 0, model level 0 and time 0. The resulting array should have shape (48, 96).

d) Remove every other longitude from the geopotential array. The resulting geopotential array should have a shape of (48,48).

e) Decompose the 2D geopotential from part c into spherical harmonic components using the function **`pyshtools.expand.SHExpandDH`**. Assign the output to **`geopot_coeffs`**. Remember to load the **`pyshtools`** package!

f) Follow the instructions here[5] (Simple Filtering section) to generate filtered plots. Use **`geopot_coeffs`** instead of **`coeffs`**.
The first plot from part e is the sum of the 8 largest scales of the geopotential field. The second plot is the sum of the 9th to 19th largest scales of the geopotential field. **Show these two plots to Dr Chan before proceeding.**

g) Adapt the code you wrote in part e to make the following three subplots:
   (i) The sum of the 8 largest scales of the geopotential field.
   (ii) The sum of the 8th to 16nd largest scales of the geopotential field.
   (iii) The sum of the remaining scales of the geopotential field.
   Show these three plots to Dr Chan before proceeding.

h) Now let's test the code you wrote in part g. Add the three arrays produced by part f and plot out the result. Does that sum look like the original (48,48) geopotential array from

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[4] If the instruction link doesn't work, the URL is https://shtools.github.io/SHTOOLS/python-installing.html
[5] If the instruct link doesn't work, the URL is https://nbviewer.org/github/SHTOOLS/SHTOOLS/blob/master/examples/notebooks/low-level-spherical-harmonic-analyses.ipynb#Simple-Filtering

part c (plot this out)?

i) In the code you wrote for part f, put comments that explain what each line of code does. This will help you remember what the code does.

By the end of Task 1, you should have some visual and conceptual sense of how spherical harmonic decomposition works.

From this point onwards, we will consider the 8 largest scales to be the "large scale band", the 8th to 16nd largest scales to be the "medium scale band", and the remaining scales to be "small scale band".

Task 2: Ensemble Variances at the Three Scale Bands

a) Write a function named **`three_scale_decomposition`** that accepts a 2D array named **`data2d`**. The function produces three outputs: **`data_large_band_2d`**, **`data_medium_band2d`**, and **`data_small_band2d`**. These outputs are the result of decomposing **`data2d`** into three spatial scale bands.

b) Test out the **`three_scale_decomposition`** function by applying it on the geopotential array of member 0, model level 0, time index 0 on 1st Jan 2011. Ensure that the geopotential array you input into **`three_scale_decomposition`** has shape (48,48). **Do the three arrays outputted by `three_scale_decomposition` match the three arrays you created in Task 1g?**

c) Now load the geopotential arrays from the reference ensemble on 1st March 2011. Get rid of the time dimension and remove data points from every other longitude location. The resulting array should have the same shape: (1000, 8, 48, 48).

d) Use **`three_scale_decomposition`** function to break up the reference ensemble's geopotential array into the three scale bands. You should end up with three scale band arrays with shape (1000, 8, 48, 48).

e) For each of the three scale band arrays, compute the ensemble variance. You should obtain three arrays of variances shape (8, 48, 48).

f) Now, **encapsulate the code you've written from parts d to e into a single function named `compute_ensemble_3scale_variance`.** This function accepts a 4D array containing an ensemble of 3D data (i.e., shape (1000, 8, 48, 48)), and outputs three variance arrays: (1) large scale band variance, (2) medium scale band variance, and (3) small scale band variance.

Perform sanity checks for your **compute_ensemble_3scale_variance** function. **Show those checks to Dr Chan before proceeding.**

g) Copy and paste every function you've written for Tasks 1 & 2 into a new Python file called **pysh_ens_variance.py**. Write comments to document every function's purpose, inputs and outputs, and what the function's code does. You may find online generative AI tools useful for this purpose.

Task 3: Flexible Python script for scale decomposition of SPEEDY ensemble

Earlier in Task 2, you have effectively created a Python package named **pysh_ens_variance**. To use this package in a Pythons script, **pysh_ens_variance.py** must be in the same directory as that script.

In this Task 3, you will create a Python script **compute_ens_variance.py** that flexibly computes the variance for all three scale bands for (1) a specified ensemble at (2) a specified date for (3) a specified variable. The resulting variance arrays will be stored within a pickle file at (4) a specified directory. These specifications will be done via command line inputs. To be clear, **compute_ens_variance.py** accepts the following command line inputs:

1) An integer number of days since 1st January 2011 (e.g., 0 for 1st Jan and 5 for 6th Jan)
2) The name of the ensemble (i.e., **reference_ens** or **perturbed_ens**)
3) The name of the variable to compute variances for (e.g., **u**, **v**, **t**)
4) Directory to store pickle files

compute_ens_variance.py loads the SPEEDY data corresponding to arguments 1, 2 and 3. Afterwards, **compute_ens_variance.py** applies the **compute_ensemble_3scale_variance** function on the loaded data, and saves the resulting values into a pickle file.

That pickle filename will look like **VNAME_ENSNAME_CCYYMMDDHH_variance.pkl.** For example, the pickle file corresponding to 00UTC 21st June 2011 for the reference ensemble & zonal wind variable is **u_reference_ens_2011072100_variance.pkl**. Each pickle file contains a Dictionary with the following entries:

- Key **"date"**: the date of the calculation as a string in **ccyymmddhh** format.

- Key **“vname”**: the name of the SPEEDY variable.
- Key **“small scale average variance”**: A 1D array containing the ensemble variance of the small-scale band. This array has shape (8,48,48).
- Key **“medium scale average variance”**: A 1D array containing the ensemble variance of the medium-scale band. This array has shape (8,48,48).
- Key **“large scale average variance”:** A 1D array containing the ensemble variance of the large-scale band. This array has shape (8,48,48).
- Key “**theoretical pressure**”: A 1D array containing the pressure of the 8 model levels (in hPa) if the surface pressure is 1000 hPa.

The last item of the Dictionary is computed from the **sigma** variable in the NetCDF files via

$$P_{theoretical} = \sigma * 1000$$

Your **compute_ens_variance.py** must load and use the functions defined in **pysh_ens_variance**.

Make sure to test your **compute_ens_variance.py** in the command line. If the code runs without producing any errors, **get Dr Chan to check your code before proceeding further.**

Task 4: Visualizing Patterns in Ensemble Variances

Dr Chan will run the code you’ve produced in Task 3 on the entire year of ensemble data (this requires a Bash script and supercomputer job submissions). You will then be given a path to the directory containing the pickle files produced by the code (>3000 of them).

Write a script named **“examine_variance_behavior.py”** that does the following:

(a) This script loads pickle files between a pair of specified dates that corresponds to a specified variable and ensemble type (reference or perturbed). The time interval between pickle files will also be specified in terms of an integer number of days. These five specifications are done via command line.

(b) Generate level-time and/or latitude-time diagrams to show how perturbed ensemble variances for different variables and different spatial scales grow over time. You can look at Homework 7 part 2 for inspiration.

(c) Generate plots similar to part (a), except that now you plot normalized variances (defined below) instead of the perturbed ensemble variance. The normalized variance is defined as

$$\text{Norm Variance} \coloneqq \frac{\text{Variance of Perturbed Ensemble}}{\text{Variance of Reference Ensemble}}$$

(d) Answer the following questions:

1) How does the perturbed ensemble variance vary with time relative to the reference ensemble's variance?

2) For each SPEEDY model variable, for each spatial scale band and for each model level, how many days did it take for the perturbed ensemble's variance to saturate? Which of spatial scale's ensemble variance saturates first? Which spatial scale's ensemble variance saturates last?

Information and Instructions for "When and where are ensemble statistics non-normal? An investigation with a 1000-member SPEEDY ensemble"

Task 1: Measuring Non-Normal Statistics via Shapiro-Wilk Test

Atmospheric scientists often assume that forecast uncertainties follow normal distributions. In this task, we will use the Shapiro-Wilk test (**`scipy.stats.shapiro`**) to measure the chance that forecast uncertainties are non-normal (aka, non-Gaussian).

The Shapiro-Wilk (SW) test is a statistical hypothesis test. The null hypothesis is that the ensemble data follows a normal distribution. If the p-value of the test is above some user-specified threshold (e.g., 0.05), the null hypothesis is accepted (i.e., the ensemble data is likely normally distributed). Conversely, if the p-value is smaller than the user-specified threshold, we reject the null hypothesis (i.e., the ensemble data is not likely to be normally distributed). **We will use the p-value as a measure of whether the ensemble statistics are normal – the bigger the p-value, the more normal the statistics are.**

(a) Read the API reference for **`scipy.stats.shapiro`** and try the example here.

(b) Write a Python script (**`normality_test_speedy.py`**) on Pitzer that accepts the following four command-line inputs

   (i) Integer number of days since 1st January 2011 (e.g., 0 for 1st Jan and 5 for 6th Jan)
   (ii) The name of the ensemble (i.e., **`reference_ens`** or **`perturbed_ens`**).
   (iii) The name of the variable to run Shapiro-Wilk test for (e.g., **`u`**, **`v`**, **`t`**).
   (iv) Directory to store pickle files.

(c) Within **`normality_test_speedy.py`**, load the command-line-inputted variable (input (iii)) from the SPEEDY file specified by inputs (i) and (ii).

   Then, for every grid point, calculate the p-value of the SW test (i.e., apply the test along the ensemble dimension). This calculation should yield a 3D array of p-values with a shape of (8,48,96).

   Create a pickle file named **`VNAME_ENSNAME_CCYYMMDDHH_pvalues.pkl`**. For example, the pickle file corresponding to 00UTC 21st June 2011 for the reference ensemble and zonal wind is **`u_reference_ens_2011072100_pvalues.pkl`**. Each pickle file contains a Dictionary with the following entries:

(i) Key **"`date`"**: the date of the calculation as a string in **ccyymmddhh** format.
(ii) Key **"`vname`"**: the name of the SPEEDY variable.
(iii) Key **"`pvalues`"**: a 3D array of SW p values.
(iv) Key **"`theoretical pressure`"**: A 1D array containing the pressure of the 8 model levels (in hPa) if the surface pressure is 1000 hPa.

The last item of the Dictionary is computed from the **`sigma`** variable in the NetCDF files via

$$P_{theoretical} = \sigma * 1000$$

Make sure to test your **`normality_test_speedy.py`** in the command line. If the code runs without producing any errors, **get Dr Chan to check your code before proceeding further.**

Dr Chan will run the code you've produced on the entire year of ensemble data (this requires a Bash script and supercomputer job submissions). Remind Dr Chan if he forgets to do so!! You will then be given a path to the directory containing the pickle files produced by the code (>3000 of them).

Task 2: Where & Where are Statistics Significantly Non-Normal?

We will now write code to determine when and where statistics are significantly non-normal. However, we cannot just use the p-values resulting from the SW tests – we need to do some corrections to limit the detection of false positives. These correction procedures are called False Discovery Rate (FDR) control. Daniel Wilks has an entertaining (provocative) BAMS article (link) where he explains why FDR control is needed in atmospheric science. In this task, we will specifically use the Benjamini-Yekutieli (BY) procedure. Don't worry: this procedure is available in SciPy.

(a) While Dr Chan is running the code, read the API reference for **`scipy.stats.false_discovery_control`** and try the examples in the reference. Note that **`scipy.stats.false_discovery_control`** uses the Benjamini-Hochberg (BH) FDR procedure by default – we want to use the BY procedure instead.

(b) Create a Python script named **`examine_normality_test_pvals.py`**.

This script loads pickle files between a pair of specified dates that corresponds to a specified variable and ensemble type (reference or perturbed). The time interval between pickle files will also be specified in terms of an integer number of days. These five specifications are done via command line.

Combine the 3D loaded p-value arrays into a single 4D p-value array. For example, supposing p-values are loaded for 5 dates, the combined 4D p-value array has shape (5,8,48,96).

Perform the FDR p-value adjustment on the combined 4D p-value array. Reject the SW null hypothesis at locations where the adjusted p-value is less than 0.05.

(c) Answer the following questions by creating and analyzing plots of null hypothesis rejections.

(i) For each model variable in the perturbed ensemble, how does the number of null hypothesis rejections (i.e., non-Gaussian data) vary with latitude, model level and time?

(ii) For each model variable, do the patterns in the perturbed ensemble's null hypothesis rejections become visually indistinguishable from those of the reference ensemble? If yes, when does that happen?

Concurrence Request:

Sought for the New Atmos Sci 5401 – Practical Data Processing

Sent to: The School of Earth Sciences, The Department of Computer Sciences and Engineering, and the Department of Statistics on 12/11/2024

Response requested by: 1/3/2025

To: Lee, Yoonkyung; Zhang, Yuan; Williamson, Donald; Cook, Ann — Wed 12/11/2024 3:23 PM
Cc: Coleman, Mat; Godfrey, Ryan; Chan, Joseph

You forwarded this message on Wed 12/11/2024 3:37 PM

AS5401_Data_Processing_and_...
779 KB

Dear Chairs and Directors of Undergraduate Studies,

The Department of Geography is requesting your concurrence for a new course offering in atmospheric science data processing and analysis. The course is designed for atmospheric science majors to cover required knowledge topics specified by the American Meteorological Society and the World Meteorological Organization that OSU's program is currently weak in.

We invite you to review the syllabus attached. We note that this request is coming on the front of the winter break and holidays. We request a response to concurrence by 1/3/2025, however, if at all possible to receive an answer prior to the close of the fall semester, that would be greatly appreciated.

Thank you for your consideration.

-Jana

OHIO STATE

Response from CSE:

Williamson, Donald
To: Houser, Jana
Thu 12/19/2024 8:24 AM

You forwarded this message on Thu 12/19/2024 10:50 AM

Start reply with: Thank you! | Thank you for your confirmation. | Great, thank you so much!

Dear Jana,

CSE doesn't have any issues with this course, so we approve the concurrence request.

Best,

Donald S. Williamson
Associate Professor
Director, The ASPIRE Group
Affiliated faculty, Translational Data Analytics Institute
Computer Science and Engineering
493 Dreese Labs, 2015 Neil Ave, Columbus, OH 43210
williamson.413@osu.edu

THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

Response from SES:

Sawyer, Derek
To: Houser, Jana
Thu 12/19/2024 10:26 AM

You forwarded this message on Thu 12/19/2024 10:50 AM

Start reply with: Great, thanks for letting me know! | Wonderful, thank you! | Thanks for the feedback!

Dear Jana,

The Earth Sciences curriculum committee has reviewed the course proposal for ATMOSSC 5401" Practical Data Processing and Analysis for Atmospheric Science."

We find no significant overlap with courses we offer.

Looks like a great course!

Best regards,
Derek

NO RESPONSE FROM STATS BY 1/4/2025.

Curriculum map, indicating how program goals are accomplished via specific courses
Atmospheric Sciences (Bachelor of Science)

KEY:	*1=Beginner*	*2= Intermediate*	*3 = Advanced*	

	Learning Outcome A	**Learning Outcome B**	**Learning Outcome C**	**Learning Outcome D**
Prerequisites or Corequisites:				
MATH 1151				1
MATH 1152				1
MATH 2153				1
MATH 2255				2
PHYSICS 1250	1	1		
PHYSICS 1251	1	1		
CHEM 1210	1	1		
STATS 2450				1
GEOG 3597.03 (EL)				
Required Core:				
ATMOSSC 2940 OR GEOG 5900	1	1	1,2	1
GEOG 5921	1	2	2	2
GEOG 5922	3		2	
ATMOSSC / GEOG 5940		3	3	3
GEOG 5941	3	2	3	2
GEOG 5942	3	2	3	3
ATMOSSC 5950	2	2	2	2
ATMOSSC 5951	3	2	2	2
ATMOSSC 5952	3	2	2	3
Electives:				
GEOG 1950	1	1	1	1
ATMOSSC 5502		2,3	2	3
ATMOSSC 5401	**3**		**2**	**3**
ATMOSSC 5701	2,3	2,3	3	2,3
ATMOSSC 5901	2	3	2	
GEOG 3900.01 OR GEOG 3900.02 OR GEOG 3901H	2		3	
GEOG 3597.02	1	2	1	
GEOG 5200	1	1	2	1
GEOG 5210	1	1		
GEOG 5225	2	2		2
EARTHSC 2206	1		1	
CIVILEN 5130	3	3		3
CIVILEN 5420	2	3		2

Learning Outcome A: Students acquire the theoretical basis for fundamental atmospheric processes and systems.
Learning Outcome B: Students are familiar with computational and other forms of technology used in the atmospheric sciences.
Learning Outcome C: Students can communicate atmospheric science concepts and methods orally, visually, and in writing.
Learning Outcome D: Students can solve problems faced by atmospheric scientists.