ENVR 372 | Data, Models, and AI: Climate and Energy Systems
Fall 2026

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Course Description

This 12-week curriculum encompasses atmospheric fluids, climate processes, environmental dynamics, and energy systems, integrating these subjects with practical hardware engineering and contemporary computational methods, including basic engineering calculations, modelling and simulation, high-performance computing (HPC), and artificial intelligence (AI). Participants examine the physical principles underlying atmospheric and climate phenomena and acquire essential numerical methodologies. The curriculum additionally offers practical experience in designing and programming small climate-monitoring stations. Students develop microcontroller programming skills to facilitate real-time data acquisition and remote transmission via MQTT. Ultimately, students employ data analysis, HPC deployment, and AI-based modeling to both simulated environments and actual geophysical data obtained from their bespoke climate stations.

Course Approach

The course is based on a 12-week colloquium with two sessions per week, 1 theoretical and 1 practical course. Each practical course (see below) will be based on the theoretical class at the beginning of the week, when the students will be introduced to the topic and will learn the fundamentals, need for the practical course.
The practical work builds progressively, from simple diagnostics to model execution and ML workflows:

- **4** short coding notebooks (Weeks 1–4)
- **2** Climate stations construction, programming, and data analysis (Weeks 3–4)
- **2** case studies of energy markets based on realistic data (Weeks 5–6)
- **2** QGIS based risk assessment of Climate Change (Week 8–9)
- **1** final mini-project using simulation, AI, or both (Week 10)

Suggested Lab Environment

- **Languages:** Python 3, Jupyter Notebooks
- **Libraries:** NumPy, SciPy, xarray, Matplotlib, Cartopy, TensorFlow/Keras, DeepXDE
- **Simulation:** WRF Model
- **HPC:** SLURM scheduler, OpenMPI, CUDA
- **Visualization:** NCO/CDO, Python (Cartopy, xarray), QGIS

Learning Objectives

By the end of this course, students will be able to:

1. Describe the governing equations of atmospheric fluid dynamics (Navier-Stokes, thermodynamics).
2. Explain key climate processes: energy balance, greenhouse effect, ocean-atmosphere coupling.
3. Assess renewable energy resource variability in the context of climate.
4. Understand how energy markets work and what parameters determine the pricing of electricity
5. Run and configure a numerical weather/climate simulation model (e.g., WRF) on an HPC system.
6. Apply machine learning (regression, neural networks, PINNs) to atmospheric data.
7. Parallelize scientific code using MPI/OpenMP and GPU acceleration.
8. Critically evaluate AI-driven vs. physics-based climate projections.
9. Construct and program custom small-scale climate stations, integrating environmental IoT sensors via I2C, UART, and MQTT protocols.

Course Requirements

Course Reading and Participation

Reading Expectations: Students are expected to complete 40–50 pages of reading per week, primarily consisting of peer-reviewed journal articles and monographs relevant to climate science and modeling.
Attendance and Participation: Regular classroom and on-site attendance, along with active participation in discussions, is mandatory. While not assigned a distinct percentage in the final grade breakdown, consistent participation is required and will heavily inform the mid-term grade calculation.

Assignment Descriptions

1. Weekly / Biweekly Problem Sets (20%)

Format: Quantitative and analytical exercises focusing on environmental and hydrological problem-solving.
Details: Assignments will be submitted via Moodle (see Moodle calendar for specific biweekly deadlines).

2. Hands-on Lab Notebooks (20%)

Format: Digital course journals or Jupyter notebooks.
Details: Students will document their Python scripts, data organization, and LandLab simulation interpretations on a weekly basis. Notebooks are reviewed at three checkpoints during the semester.

3. Climate Indicators Measurement and Analysis (15%)

Format: Short field and analytical report.
Details: Students will use geospatial tools to analyze climate datasets. The final report should be approximately 3 – 4 pages (1,000 words).

4. Climate Risk Assessments (15%)

Format: Research paper.
Details: A comprehensive evaluation of vulnerabilities and hazards. To meet the 300-level research requirement, this paper must be at least 10 pages long (approx. 3,200 words at 1.5 spacing).

5. AI Mini-Project (15%)

Format: Interdisciplinary technical project and short report.
Details: Implementation of machine learning algorithms for climate prediction tasks. Includes a code submission and a 2-page methodology summary.

6. Final Presentation / Project (15%)

Format: Classroom presentation and final visual deliverable.
Details: A 15-minute presentation synthesizing the semester’s research findings, taking the place of a traditional final exam.

Evaluation and Grading

Component	Weight
Weekly / biweekly problem sets	20%
Hands-on lab notebooks	20%
Climate indicators measurement and analysis	15%
Climate risk assessments	15%
AI mini-project	15%
Final presentation / project	15%

Evaluation Criteria - Course Assignments

Assignment 1: Weekly / Biweekly Problem Sets (20%)
- Accuracy and Completeness: Demonstrates correct mathematical and logical approaches to solving the environmental and hydrological problems.
- Timeliness and Formatting: Submissions are turned in by the stated deadlines and follow the required formatting guidelines.

Assignment 2: Hands-on Lab Notebooks (20%)
- Data Recording and Organization: Clear, organized, and detailed documentation of methodologies, Python scripts, observations, and raw data.
- Analytical Rigour: Evidence of critical thinking, sound interpretation of simulations (like LandLab models), and clear error analysis.

Assignment 3: Climate Indicators Measurement and Analysis (15%)
- Methodological Soundness: Accurate application of measurement techniques and geospatial tools to analyze climate datasets.
- Insightful Interpretation: Ability to identify meaningful trends, anomalies, and potential drivers within the data sets.

Assignment 4: Climate Risk Assessments (15%)
- Comprehensiveness: Thorough identification and evaluation of vulnerabilities, hazards (such as floods or heatwaves), and exposure elements.
- Practicality of Mitigation Strategies: Proposed adaptation or mitigation measures are realistic, well-supported, and evidence-based.

Assignment 5: AI Mini-Project (15%)

- Technical Implementation: Effective use of machine learning algorithms and programming to address a specific climate or environmental prediction task.
- Model Evaluation and Reporting: Clear demonstration of model performance metrics, testing procedures, and an understanding of the model's limitations.

Assignment 6: Final Presentation / Project (15%)

- Scientific Communication: Ability to clearly and concisely convey complex research findings and methodologies to an academic audience.
- Overall Quality and Synthesis: The final deliverable demonstrates a strong integration of course concepts, high-quality visualizations, and cohesive conclusions.

CYA Regulations and Accommodations

Attendance Policy

Attendance and punctuality are essential to learning in CYA courses, which rely on in class and on-site interaction. Faculty is required to record absences and either the Academic Advisor (on academic issues) or Student Affairs (on wellness issues) will check-in with students who have repeated absences.

This policy applies to all scheduled class meetings and on-site activities (Athens sessions and school-wide Field Studies).

1. Punctuality

Students are expected to arrive on time; instructors have a corresponding obligation to begin on time.

2. Recording & Outreach

Instructors must record absences at every class/on-site session. In the case of repeated absences, the Academic Advisor (for academic issues) or Student Affairs (for wellness issues) will check in with the student. 3. What Counts as an Excused Absence

3.1. Illness

The student must report the illness via the Illness Reporting Form to Student Affairs. If illness requires missing more than one session per class, the student must submit a signed and stamped doctor's note to Student Affairs and remain in communication with them.

Remote [online] appointments and retroactive doctor's notes will not be accepted.

3.2. Other Exceptional Circumstances

Excused absences for non-illness exceptional circumstances require prior approval from the Academic Director (not the course instructor).

3.3. Accommodations

If the student has an academic accommodation that relates to their attendance and has been filed with CYA, they should follow the procedure outlined on the accommodation form that they agreed upon with their professor.

3.4. Timing

The student must seek approval as soon as the problem arises, not retroactively, in order for the absence to be excused

3.5. Academic priority

Students are notified that class attendance takes precedence over other student appointments, travel, volunteering, or visiting friends/family, and missing class for these reasons is not excused. Students are responsible for avoiding such conflicts.

4. How can students request an excused absence

Before the class submit the relevant form or request (for illness the Student Affairs form; for exceptional circumstances the Academic Director). Notify the instructor that a request has been submitted, and learn what material will need to be made up and how to do so.

Provide documentation if required to administration, not the professor (e.g. doctor's note for multi-session illness).

Await the decision from the appropriate office. Professors do not grant excused absence status.

5. Unexcused Absences & Consequences

Three (3) unexcused absences in any class automatically lower the final course grade.

More than three (3) unexcused absences in a class may lead to: a) the placement of a student on academic probation, and potentially b) the student receiving a failing grade for the course depending on course requirements

6. Make-Up Work & Grading

Students must make up missed work for any absence (excused or unexcused) and communicate with instructors about requirements. Failure to complete missed work will result in the reduction of minimum one letter grade. It is the responsibility of the instructor to provide them with make up options. Quizzes, exams, and in-class assessments missed due to an unexcused absence may receive a zero (0) grade, per course requirements as outlined in the syllabus.

Because participation is integral to learning at CYA, a high number of excused absences may still affect the course grade, per the course's participation policy. Course syllabi specify how attendance and participation affect the final grade.

ePolicy on Original Work and Use of Artificial Intelligence

Unless otherwise specified, all submitted work must be your own original work. Any ideas taken from the work of others must be clearly identified as quotations, paraphrases, summaries, figures etc., and accurate internal citations and/or captions (for visuals) as well as an accompanying bibliography must be provided.

The use of generative AI tools is a new, undeniable reality. In this course, the guiding principle for their productive use is that you must always remain the primary author and critical thinker behind all submitted work. AI may be used ethically as a tool for development, but never as a substitute for your own intellectual effort.
Permitted Uses: You may use AI for brainstorming, clarifying concepts and passages, editing your original prose, debating ideas, formatting (not generating from scratch) citations and bibliography sections, or reviewing a completed draft. You may also request a generic outline to organize initial thoughts, provided you substantially modify and expand it into your own work. *In all cases, you are required to review, verify and take full responsibility for the final output*.
Prohibited Uses: It is academic dishonesty to use AI to generate drafts, paragraphs, or answers to assignments, to complete in-class or reflective work, or to submit AI-generated content without your significant intellectual transformation and synthesis.
To ensure the integrity of submitted work, I reserve the right to ask students to orally explain or defend the content and reasoning behind any submission. Such a request comprises a standard check, not an accusation. **If a student is unable to do so, I may require the work to be revised and resubmitted. A persistent inability to adequately explain the work may be treated as a violation of academic integrity.**
It is imperative to understand that AI can produce incorrect or biased information. Your critical judgment is essential. You are responsible for fact-checking all content and ensuring your final work reflects your own understanding. Specific applications and citation practices will be further discussed in class. When in doubt, ask for clarification!

Use of Laptops

In-class or onsite use of laptops and other devices is permitted if this facilitates course-related activities such as note-taking, looking up references, etc. Laptop or other device privileges will be suspended if devices are not used for class-related work.

Class Schedule

Week	Lesson 1 — Theory	Lesson 2 — Hands-on
1 (Dr Nikos Papadimitriou)	Course introduction; basics of atmospheric physics, thermodynamics, energy concepts, and fluid motion	Python notebook: atmospheric profiles, basic thermodynamic and fluid mechanics calculations,
2 (Dr Nikos Papadimitriou)	From theory and fundamental concepts to complicated models and high-level engineering: the role of HPC and AI	Simple HPC case studies, analysis of the resulting data, model optimization
3 (Dr Ioannis Zarikos)	Physical construction of a climate station, where students wire environmental sensors using I2C and UART protocols. The session emphasizes rapid hardware assembly and initializing the microcontroller platform for field deployment.	Transitions to software by programming the station in Python for real-time data acquisition, basic sensor calibration, and local CSV logging. Configuration of MQTT protocols to establish remote data telemetry and data transmission.
4(Dr Ioannis Zarikos)	Introduction to data analysis workflow, cleaning and preprocessing of raw time-series sensor data using Python, to filtering out noise and handling missing values. It also incorporates a spatial dimension using Cartopy and rasterio to contextualize the station's local readings against regional gridded climate datasets.	The data acquisition module concludes by automating the visualization of these environmental trends, outputting a finalized dataset ready for integration into the course's AI-assisted modeling and HPC execution pipeline.

5 (Dr Stelios Karozis)	Environment and energy; wind and solar resources; climate-energy links	Renewable resource mapping from meteorological data; estimate wind/solar potential
6 (Dr Stelios Karozis)	Numerical methods for atmospheric and environmental models; discretization of PDEs	Finite-difference advection/diffusion experiment; stability and timestep tests
7 (Dr Stelios Karozis)	HPC fundamentals: parallelism, CPUs/GPUs, MPI/OpenMP, schedulers	Submit and monitor batch jobs; run a scaling test on a Small cluster
8 (Dr Ioannis Zarikos)	Wildfire risk assessment: fundamental climatic variables and methodologies used to assess fire weather hazard. Introduction to the physical basis of prolonged dry periods, temperature extremes, and wind dynamics, learning how to calculate standard indices like the Fire Weather Index (FWI) or Consecutive Dry Days (CDD)	Hands-on QGIS practical session focused on spatial wildfire risk assessment. Students process environmental datasets by overlaying climate variable rasters with topographic and vegetation layers to model hazard zones and identify high-risk areas.
9 (Dr Ioannis Zarikos)	Flood risk assessment: Introduction to climatic variables and hydrological processes that drive flood events. The methodology connecting these variables to modern simulation approaches, Introduction to return periods and establish the physical basis of flood dynamics.	Practical QGIS session on mapping flood vulnerability using geospatial data. Integration of Digital Elevation Models (DEMs) and OpenStreetMap (OSM) vector data to map flood extents, overlaying simulated extreme weather events onto critical infrastructure to assess sectoral vulnerability and risk.
10 (Dr Stelios Karozis)	Physics-informed AI, model emulation, uncertainty, ethics; student synthesis	Final project workshop and presentations: simulation or ML mini-project
11 (Dr Nikos Papadimitriou)	Energy production, management and efficiency, renewable energy and climate change	Visit to NCSRD facilities: thermal solar field, thermal energy storage unit, hydrogen station
12 (Dr Nikos Papadimitriou)	Energy markets and grids, pricing of electricity	Business game: the day-ahead-market of electricity

N.B.: The course schedule, in terms of subjects and readings, may be subject to change to benefit student learning and to keep up to date with current research.

COURSE BIBLIOGRAPHY

- Holton & Hakim, *An Introduction to Dynamic Meteorology*, 5th ed.
- Stull, *Meteorology for Scientists and Engineers*
- Nakano et al., CSCI 653 course notes — *High Performance Computing and Simulations* (USC)
- IMSI Workshop proceedings — *Machine Learning for Climate and Weather Applications*
- WRF model user guide and GRNET HPC training materials
- Rackauckas et al., *Universal Differential Equations for Scientific Machine Learning* (2020)