METEO 597 Syllabus: Data Assimilation

Department of Meteorology and Atmospheric Science
The Pennsylvania State University
University Park Campus

Semester: Spring 2018
Credits: 3.0

Instructors:

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(Please include METEO 597 in the subject line of course-related email correspondence.)

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Course Information:

Course Hours: Monday, Wednesday, Friday, 2:30 PM – 3:20 PM
Course Location: 110 Walker Building
Professor Office Hours: Monday 3:30-4:00 PM (601 Walker); By appointment
Course Description: Data assimilation is the process of finding the best estimate of the state by statistically combining model forecasts and observations and their respective uncertainties.

Required Materials: None
Required textbooks: None
Recommended textbooks (on reserve in the EMS library):
Atmospheric Modeling, Data Assimilation, and Predictability, by Eugenia Kalnay (Cambridge University Press, 2003)
Internet materials and links: Canvas

Course Objectives:

1. To provide a conceptual and mathematical overview of the basic concepts, theoretical underpinnings, and research frontiers of data assimilation.

Course Outcomes:

1. To demonstrate familiarity with the terminology, mathematical framework, assumptions, and conceptual understanding of data assimilation.
2. To demonstrate familiarity with specific data assimilation methodologies, including variational techniques, ensemble Kalman filters, and hybrid approaches.
3. To demonstrate the ability to apply assimilation techniques to a dynamical system using computer programming.

4. To demonstrate knowledge of current research frontiers in the field of data assimilation and predictability, including its applications to numerical weather prediction.

Prerequisites:

This is a self-contained course and is designed for first year meteorology/math/stats/engineering graduate students or advanced undergraduate students.

A basic knowledge of probability theory, calculus, linear algebra/matrices, and computer programming is expected.

Overview:

Data assimilation (DA) is the process of finding the best estimate of the state and associated uncertainty by combining all available information including model forecasts and observations and their respective uncertainties. DA is best known for producing accurate initial conditions for numerical weather prediction (NWP) models, but has been recently adopted for state and parameter estimation for a wide range of dynamical systems across many disciplines such as ocean, land, water, air quality, climate, ecosystem and astrophysics. Taking advantages of improved observing networks, better forecast models and high performing computing, there are two leading types of advanced approaches, namely variational data assimilation through minimization of a cost function, or ensemble-based data assimilation through a Kalman filter. Hybrid techniques, parameter estimation, predictability, and ensemble sensitivity methods will also be covered.

The material in this course may be relevant to those in engineering, statistics, mathematics, hydrology, earth systems science, atmospheric science, and many other fields that seek to integrate information from observations and models.

This course is offered by faculty of the Penn State Center for Advanced Data Assimilation and Predictability Techniques (ADAPT; http://www.adapt.psu.edu), with the goal to foster interdisciplinary collaborations in this important field.

Assessment Tools:

Required written/oral assignments

Several programming exercises (in MATLAB) will be assigned during the course to apply algorithms learned during lecture and gain hands on experience with these techniques.

Students will work individually to complete a final research project / literature review on a topic approved by the instructors; guidelines and potential topics should be discussed with one of the instructors. Project results must be summarized in a short report (maximum 10-page double-spaced), and discussed in a 25-min presentation. Lecture time during the last few weeks of the semester will be used for presentations.

Examination Policy

There are no formal exams in this course.

Grading Policy

Participation	10%
Programming Exercises	50%

Final Project 40%

Attendance and Participation: Students are highly encouraged to attend all lectures and participate in all exercises. Active, thoughtful contributions to class discussions are welcomed.

Schedule:

Week 1	Jan 8,10,12	
Week 2	Jan 17, 19	Note Jan 15 is university holiday
Week 3	Jan 22, 24, 26	
Week 4	Jan 29, 31, Feb 2	
Week 5	Feb 5, 7, 9	
Week 6	Feb 12, 14, 16	
Week 7	Feb 19, 21, 23	
Week 8	Feb 26, 28, Mar 2	
Break	Mar 5, 7, 9	Spring break
Week 9	Mar 12, 14, 16	
Week 10	Mar 19, 21, 23	
Week 11	Mar 26, 28, 30	
Week 12	Apr 2, 4, 6	
Week 13	Apr 9, 11, 13	
Week 14	Apr 16, 18, 20	
Week 15	Apr 23, 25, 27	Final Presentations

Add / Drop Deadline is January 13.

The course content, topics, and timeline listed here is intended as a guideline, and is subject to modification by the instructors.

Course content:

Weeks	**Topics**
1-2	-- Overview of Data Assimilation (DA)
	-- Review of Probability Theory and Bayes Theorem
	-- Optimal Interpolation
3-4	-- Least Squares versus Maximum Likelihood Approaches
	-- 3D-Var
	-- Dynamical Systems and Chaos
5-7	-- Kalman Filter (KF)
	-- Extended Kalman Filter (EKF)
	-- Ensemble Kalman Filter (EnKF)
8-10	-- 4D-Var
	-- Hybrid Filters
	-- Application to High-Dimensional Systems and NWP
	-- DA in Operational Centers
	-- Ensemble Sensitivity
11-13	-- Parameter Estimation
	-- Model Error
	-- Special Topics in DA and Predictability
	-- Particle Filters
14-15	-- Frontiers in Data Assimilation (student presentations)

Lecture notes will often be placed on Canvas (https://canvas.psu.edu), although students are ultimately responsible for their own note-taking.

Academic Integrity

Students in this class are expected to write up their problem sets individually, to work the exams on their own, and to write their papers in their own words using proper citations. Class members may work on the problem sets in groups, but then each student must write up the answers separately. Students are not to copy problem or exam answers from another person's paper and present them as their own; students may not plagiarize text from papers or websites written by others. Students who present other people's work as their own will receive at least a 0 on the assignment and may well receive an F or XF in the course. Please see: Earth and Mineral Sciences Academic Integrity Policy: http://www.ems.psu.edu/undergraduate/academic-advising/forms-and-procedures/academic-integrity, which this course adopts. To learn more, see Penn State's "Plagiarism Tutorial for Students."

Course Copyright

All course materials students receive or to which students have online access are protected by copyright laws. Students may use course materials and make copies for their own use as needed, but unauthorized distribution and/or uploading of materials without the instructor's express permission is strictly prohibited. University Policy AD 40, the University Policy Recording of Classroom Activities and Note Taking Services addresses this issue. Students who engage in the unauthorized distribution of copyrighted materials may be held in violation of the University's Code of Conduct, and/or liable under Federal and State laws.

For example, uploading completed labs, homework, or other assignments to any study site constitutes a violation of this policy.

Accommodations for Students with Disabilities

Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Student Disability Resources (SDR) website provides contact information for every Penn State campus: (http://equity.psu.edu/student-disability-resources/disability-coordinator). For further information, please visit the Student Disability Resources website (http://equity.psu.edu/student-disability-resources).

In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: http://equity.psu.edu/student-disability-resources/applying-for-services. If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

Attendance

This course abides by the Penn State Attendance Policy E-11: http://undergrad.psu.edu/aappm/E-11-class-attendance.html, and Conflict Exam Policy 44-35: http://senate.psu.edu/policies-and-rules-for-undergraduate-students/44-00-examinations/#44-35. Please also see Illness Verification Policy: http://studentaffairs.psu.edu/health/welcome/illnessVerification/, and Religious Observance Policy: http://undergrad.psu.edu/aappm/R-4-religious-observances.html. Students who miss class for legitimate reasons will be given a reasonable opportunity to make up missed work, including exams and quizzes. Students are not required to secure the signature of medical personnel in the case of illness or injury and should use their best judgment on whether they are well enough to attend class or not; the University Health Center will not provide medical verification for minor illnesses or injuries. Other legitimate reasons for missing class include religious observance, military service, family emergencies, regularly scheduled university-approved curricular or extracurricular activities, and post-graduate, career-related interviews when there is no opportunity for students to re-schedule these opportunities (such as employment and graduate school final interviews). Students who encounter serious family, health, or personal situations that result in extended absences should contact the Office of the Assistant Vice President for Student Affairs (AVPSA) and Student Care and Advocacy for help: http://studentaffairs.psu.edu/studentcare. Whenever possible, students participating in University-approved activities should submit to the instructor a Class Absence Form available from the Registrar's Office: http://www.registrar.psu.edu/student_forms/, at least one week prior to the activity.

Weather Delays

Campus emergencies, including weather delays, are announced on Penn State News and communicated to cell phones, email, the Penn State Facebook page, and Twitter via PSUAlert (Sign up at: https://psualert.psu.edu/psualert/).

Reporting Bias-Motivated Incidents

Penn State takes great pride to foster a diverse and inclusive environment for students, faculty, and staff. Acts of intolerance, discrimination, or harassment due to age, ancestry, color, disability, gender, gender identity, national origin, race, religious belief, sexual orientation, or veteran status are not tolerated (https://policy.psu.edu/policies/ad29) and can be reported through Educational Equity via the Report Bias webpage.

Counseling and Psychological Services

Many students at Penn State face personal challenges or have psychological needs that may interfere with their academic progress, social development, or emotional wellbeing. The university offers a variety of confidential services to help you through difficult times, including individual and group counseling, crisis intervention, consultations, online chats, and mental health screenings. These services are provided by staff who welcome all students and embrace a philosophy respectful of clients' cultural and religious backgrounds, and sensitive to differences in race, ability, gender identity and sexual orientation. Services include the

following: Counseling and Psychological Services at University Park (CAPS): 814-863-0395
Counseling and Psychological Services at Commonwealth Campuses
Penn State Crisis Line (24 hours/7 days/week): 877-229-6400
Crisis Text Line (24 hours/7 days/week): Text LIONS to 741741

Syllabus and Paper Acknowledgement Forms

It is the recommendation of the college that all students sign and return the Syllabus Acknowledgement Form *(http://facdev.e-education.psu.edu/sites/default/files/files/Syllabus acknowledgement form.doc)* during the first week of the semester. In addition, The College also recommends the Paper Submission Form *(http://facdev.e-education.psu.edu/sites/default/files/files/Paper submission form.docx)* as a way to have students take responsibility for papers/labs/homework done as part of group work.

Penn State E-mail Accounts

All official communications from Penn State are sent to students' Penn State e-mail accounts. Be sure to check your Penn State account regularly, or forward your Penn State e-mail (see http://kb.its.psu.edu/node/2303) to your preferred e-mail account, so you don't miss any important information.

Deferred Grades

If you are prevented from completing this course within the prescribed amount of time, it is possible to have the grade deferred with the concurrence of the instructor. To seek a deferred grade, you must submit a written request (by e-mail or U.S. post) to your instructor describing the reason(s) for the request. It is up to your instructor to determine whether or not you will be permitted to receive a deferred grade. If, for any reason, the course work for the deferred grade is not complete by the assigned time, a grade of "F" will be automatically entered on your transcript.

Military Personnel

Veterans and currently serving military personnel and/or spouses with unique circumstances (e.g., upcoming deployments, drill/duty requirements, disabilities, VA appointments, etc.) are welcome and encouraged to communicate these, in advance if possible, to the instructor in the case that special arrangements need to be made.

Technical Requirements

For this course, we recommend the minimum technical requirements outlined on the Dutton Institute Technical Requirements page (https://www.e-education.psu.edu/techspecs), including the requirements listed for same-time, synchronous communications. If you need technical assistance at any point during the course, please contact the ITS Help Desk (http://itservicedesk.psu.edu).

Netiquette

The term "Netiquette" refers to the etiquette guidelines for electronic communications, such as e-mail and bulletin board postings. Netiquette covers not only rules to maintain civility in discussions, but also special guidelines unique to the electronic nature of forum messages. Please review some general Netiquette guidelines that should be followed when communicating in this course.

Disruptive Behavior

Behavior that disrupts normal classroom activities will not be tolerated, in accordance with Items 9 and 14 in the Student Code of Conduct.

Safety

In the case of an emergency, we will follow the College of Earth and Mineral Sciences Critical Incident Plan (https://www.ems.psu.edu/sites/default/files/documents/cip_update9-17.pdf). In the event of an evacuation, we will follow posted evacuation routes and gather at the Designated Meeting Site. Evacuation routes for all EMS buildings are available at http://www.ems.psu.edu/resources-faculty-and-staff/safety-and-emergency-information. For more information regarding actions to take during particular emergencies, please see the Penn State Emergency Action Guides.

Mandated Reporting Statement

Penn State's policies require me, as a faculty member, to share information about incidents of sex-based discrimination and harassment (discrimination, harassment, sexual harassment, sexual misconduct, dating violence, domestic violence, stalking, and retaliation) with Penn State's Title IX coordinator or deputy coordinators, regardless of whether the incidents are stated to me in person or shared by students as part of their coursework. For more information regarding the University's policies and procedures for responding to reports of sexual or gender-based harassment or misconduct, please visit Penn State's Office of Sexual Misconduct and Prevention & Response website.

Additionally, I am required to make a report on any reasonable suspicion of child abuse in accordance with the Pennsylvania Child Protective Services Law.

Diversity, Inclusion, and Respect

Penn State is "committed to creating an educational environment which is free from intolerance directed toward individuals or groups and strives to create and maintain an environment that fosters respect for others" as stated in Policy AD29 Statement on Intolerance. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment and to interact with civility.

For additional information, see:

- Penn State Affirmative Action non-discrimination statement
- Policy AD 85 Sexual and gender-based harassment and misconduct, Title IX

- Policy AD91 Discrimination and Harassment, and Related inappropriate Conduct
- Penn State Statement on Diversity, Equity, and Inclusive Excellence
- Penn State Values
- Penn State Principles
- All In at Penn State: A Commitment to Diversity and Inclusion

Accessible Syllabus

Notes: Any syllabus posted online (e.g. a Word/PDF file or an online syllabus) should make destinations clickable links such as is done throughout this page. Also, in order to comply with Penn State Policy AD69(Accessibility of Penn State Web Pages, http://policy.psu.edu/policies/ad69), PDF documents cannot be the sole source of presenting online information. Such documents include syllabi, homework assignments, and scanned notes.

Disclaimer Statement

Please note that the specifics of this Course Syllabus can be changed at any time, and you will be responsible for abiding by any such changes. Changes to the syllabus shall also be given to the student in written (paper or electronic) form.