ATMO/HWRS 545: Introduction to Data Assimilation

Class Hours: 09:00 am – 09:50 am Monday, Wednesday, Friday
Class Modality: In-Person, Harshbarger Bldg, Rm 110

Instructor: Assoc. Prof. Avelino F. Arellano, Jr. (Ave)
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Harshbarger 314C, 520-626-3015
Zoom Personal Meeting ID: 889 197 9205
Office Hours, M,W 12:00-1:30 pm or by appt.

Course Description
Data assimilation (DA) involves combining information from observations and “models” of a particular physical system in order to best define and understand the evolving state of the system. It is currently applied across a wide range of Earth sciences, including weather forecasting, oceanography, atmospheric chemistry, hydrology, and climate studies. This course provides an introduction to the theory and applications of DA in atmospheric and related sciences. Topics include common DA methods like optimal interpolation, Kalman filtering and variational schemes within the context of estimation theory. The course is designed as a hands-on approach to key DA concepts that are currently used today.

Goals & Objectives
My intent as an instructor is to convey applied concepts of data assimilation such that students will:

a) gain an understanding of basic principles of current DA algorithms
b) think holistically of data and models in the context of associated errors
c) grasp the significance of current DA algorithms in analysis and forecasting research and operations
d) know how to use DA techniques to real world applications (your own research).

Learning Outcomes
By the end of this course, ATMO/HWRS 545 students will be able to:

a) derive and solve the following DA formulations: i. least-squares (LS), ii. optimal interpolation-OI, iii. Kalman filter (KF) and its variants (EKF, EnKF), iv. 3D/4DVar, and v. Bayesian update and inference
b) conduct simple numerical exercises of toy model and synthetic data experiments using these formulations
c) run OI for a specific ‘climatological’ 2D analysis problem
d) run KF (and EnKF), 3D-4DVar for a dynamical analysis and parameter estimation problem (advection-diffusion equation)
Syllabus

ATMO/HWRS 545 Section 001 Spring Semester 2022

Introduction to Data Assimilation

On top of the outcomes listed previously, ATMO 545 students will also be able to:

a) apply one of these DA algorithms to existing Earth science problem (or to their own research)
b) present related application in a clear, understandable, and efficient manner.

This class is scheduled to be taught in the in-person course modality. This is designed as an introduction to data assimilation under a mostly hands-on learning environment. The students are encouraged to engage themselves (before, during and after lectures). At the end of the course, they should be able to have a good appreciation of the key DA concepts, which you can apply as tools for your own research. Students who desire more advanced topics (e.g. mathematical/statistical concepts) not included in this course are encouraged to pursue graduate courses in the Department of Mathematics (or consult instructor).

Prerequisites for this class include: a) a strong desire to learn how to combine models and observations, b) a basic understanding of linear algebra & elementary statistics, and c) a basic skill in programming (e.g., Matlab).

Course Assessment

There is no exam for this course. Students will be assessed on how they are able to grasp the key concepts through assignments and one individual project. The percentage distribution of your grade will be as follows:

Assignments : 75%
Project : 25%

Letter grades are determined using the following scale:

A : \( \geq 90.0 \% \)
B : 80 to 89.9 %
C : 65.0 to 79.9 %
D : 55.0 to 64.9 %
E : below 55.0 %
ATMO/HWRS 545 Section 001 Spring Semester 2022

Introduction to Data Assimilation

Syllabus

Department Website
www.has.arizona.edu

D2L Website
d2l.arizona.edu

Zoom Meeting IDs
862 9362 3996 (Lectures)
868 6225 2374 (Office Hours)

Instructor Website
arellano.faculty.arizona.edu

Dates and Deadlines
Last Day of Dropping:
03/25 (UG), 02/08 (G)

Project Deadlines:
Proposal Presentation
(Apr 4-6, 2022)
Project Presentation
(Apr 19-May 4, 2022)
Project Report
(May 12, 2022 5:30pm)

Assignment Deadlines:
Jan 24, 2022
Feb 7, 2022
Feb 21, 2022
Mar 18, 2022
Apr 8, 2022
May 4, 2022

Spring Recess:
Mar 05-13, 2022

Last Day of Classes:
May 04, 2022

Useful Websites
registrar.arizona.edu
deanofstudents.arizona.edu

Attendance
The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at:
http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable.
https://policy.arizona.edu/human-resources/religious-accommodation-policy

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See:
https://deanofstudents.arizona.edu/absences

- If you feel sick or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
- Notify me if you will be missing a course meeting or an assignment deadline.
- Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments.
- Please communicate and coordinate any request directly with me.
- If you must miss the equivalent of more than one week of class, you should contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing.
- Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus.
- If you test positive for COVID-19 and you are participating in on-campus activities, you must report your results to Campus Health. To learn more about the process for reporting a positive test, visit the Case Notification Protocol.
- COVID-19 vaccine is available for all students at Campus Health.
- Visit the UArizona COVID-19 page for regular updates.

Life, Physical, & Mental-health Challenges
If you anticipate or are experiencing unexpected barriers related to the format or requirements of this course, please meet with me so that we can discuss ways to ensure your full participation in the course. Please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at 520-621-2057 or DOS-deanofstudents@email.arizona.edu.

If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520) 621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

Accessibility and Accommodations: At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu) to establish reasonable accommodations.

Academic Integrity
Note that associated with your learning experience are sets of ‘rules’ to diligently follow. From the University perspective, you are expected to adhere to the University’s “Code of Academic Integrity” and “Student Code of Conduct”. You are responsible for knowing these codes (and revisions).

Academic Advising
If you have questions about your academic progress this semester, please reach out to your academic advisor (https://advising.arizona.edu/advisors/major) or contact the Advising Resource Center (https://advising.arizona.edu/) for all general advising questions and referral assistance. Call 520-626-8667 or email to advising@arizona.edu.
Syllabus

Introduction to Data Assimilation

Nondiscrimination & Anti-Harassment
The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Student Responsibilities
To learn this course, you are expected to be involved all throughout. As a student, you are responsible in a) actively asking and answering questions during class, b) doing your assignments (including reading materials) after class, and c) responding to d2l class announcements/surveys. Doing so will greatly enhance your learning experience. As your instructor, I invite you to make use of our office hours if you have some pressing questions.

From the University perspective, you are expected to devote a minimum of two (2) hours outside class (for study, reading, homework) for every contact hour (or 50 minutes) in classroom.

Equipment and Software
For this class you will need daily access to the following hardware: [laptop or web-enabled device with webcam and microphone]; regular access to reliable internet signal; ability to download and run the following software: [Matlab/R/Python, web browser to access D2L, PDF reader, text editor -e.g., Microsoft Word, slide presentation -e.g., Powerpoint, Zoom client, VPN for possible access to a HAS server].

Class Recordings
For lecture recordings, which are used at the discretion of the instructor, students must access content in D2L only. Students may not modify content or re-use content for any purpose other than personal educational reasons. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner inconsistent with UArizona values and educational policies are subject to suspension or civil action.

Reference Materials


Final Note
Some information in this syllabus may be subject to change with advance notice as deemed appropriate by the instructor. Your comments are welcome and appreciated.
Course Outline
Below is our tentative schedule. We may extend/shorten the lecture/discussion of some sections (e.g. special topics) depending on the average progress of the class. Project dates on the other hand are fixed.

Course Syllabus/Introduction
Jan 12

Data Assimilation and Information
Observations & Models of the Earth System
Jan 14, 19
Concept of Least Squares
Jan 21, 24, 28, 31, Feb 2

Introduction to Estimation Theory
Bayes Theorem
Feb 2, 4, 7
Concepts of Probabilistic Estimation
Feb 7, 9
Least Squares Estimation
Feb 11

Common Algorithms
Optimal (Statistical) Interpolation
Feb 14-Mar 4
Kalman Filter
Mar 14-Apr 1
Proposal Presentations
Apr 4-6
4D-Var
Apr 8-25

Longer View
Reanalysis, OSSEs
Apr 27
Project Presentations
Apr 29-May 4
Project Report Due
No later than May 12, 2022 5:30pm