Data Assimilation

ATS 651, Department of Atmospheric Science
11:00 – 12:15 Tuesday and Thursday, 121 ATS West
2023 Spring Term

Instructor Contact Information

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Course Description

This is an introductory graduate level course on fundamentals and applications of data assimilation in the geosciences. The unifying framework of Bayes Theorem is introduced, and the different state-of-the-art data-assimilation methods are derived, and practical issues related to e.g. numerical weather prediction are discussed. The main teaching method is lectures, with assignments employing the data-assimilation framework JEDI. JEDI is the system of choice for NOAA, NASA, and the US NAVY and Airforce. Assignments are designed for students to increase the level of understanding, mainly via basic programming and analyzing results from simplified data-assimilation problems.

Course Goals

Students who complete this course successfully will be able to:

- Describe and explain theoretical principles of data assimilation, focusing on atmospheric and oceanographic applications.
- Reproduce the pro's and con's of the different data-assimilation methods that are presently used in numerical weather and ocean prediction, and understand the present focus of data-assimilation research.
- Apply data-assimilation techniques to real-world problems, including using the JEDI system, and critically evaluate the literature in this subject.

Course materials

Detailed lecture notes will be available on Canvas in due course. The instructor does not use a specific textbook, but closest is the new **open access** book:

Evensen, G., F.M. Vossepoel, and P.J. van Leeuwen (2022) Data Assimilation Fundamentals, Springer, **open access**, doi: 10.1007/978-3-030-96709-3

The following recent textbooks provide partly overlapping and further reading material that relate to the course:

Asch, M., Bocquet, M., & Nodet, M. (2016). *Data assimilation: Methods, algorithms, and applications, fundamentals of algorithms.* Philadelphia, SIAM.
Fletcher, S. J. (2017). *Data assimilation for the geosciences: From theory to application*. Amsterdam, Elsevier.
Reich S, Cotter C. 2015. *Probabilistic forecasting and bayesian data assimilation.* Cambridge University Press.
Van Leeuwen P.J., Cheng Y., Reich S. 2015. *Nonlinear data assimilation*. Springer, doi:10,1007/978-3-319-18347-3.

Class Participation

Students are expected to attend all classes. Students' participation and engagement are strongly encouraged. All interactions and discussions in the classroom are aimed to provide a supportive and active learning environment for students.

Grading

Grading will be based on assignments, often based on using the JEDI system. Homework will be due at the date and times indicated. No late homework assignments will be accepted without prior approval. Audits are strongly encouraged to do all assignments.

Statement on Academic Integrity

This course will adhere to the CSU Academic Integrity Policy as found in the General Catalog (http://www.catalog.colostate.edu/FrontPDF/1.6POLICIES1112f.pdf) and the Student Conduct Code (http://www.conflictresolution.colostate.edu/conduct-code). At a minimum, violations will result in a grading penalty in this course and a report to the Office of Conflict Resolution and Student Conduct Services.

Disclaimer

The instructor reserves the right to make modifications to this information throughout the semester.

COVID-19

Important information for students: All students are expected and required to report any COVID-19 symptoms to the university immediately, as well as exposures or positive tests from a non-CSU testing location. If you suspect you have symptoms, please fill out the COVID Reporter (https://covid.colostate.edu/reporter/). If you know or believe you have been exposed, including living with someone known to be COVID positive, or are symptomatic, it is important for the health of yourself and others that you complete the online COVID Reporter. Do not ask your instructor to report for you. If you do not have internet access to fill out the online COVID-19 Reporter, please call (970) 491-4600. You will not be penalized in any way for reporting. If you report symptoms or a positive test, you will receive immediate instructions on what to do, and CSU's Public Health Office will be notified. Once notified, that office will contact you and most likely conduct contact tracing, initiate any necessary public health requirements and/or recommendations and notify you if you need to take any steps.
For the latest information about the University's COVID resources and information, please visit the **CSU COVID-19 site:** https://covid.colostate.edu/.

Preliminary Schedule of Topics, Readings (refer to open access book) , and Assignments

Lecture	Topics	Deadlines
1	• Logistics • **Session 1: Introduction to Data Assimilation –** why we should care about data assimilation; its relevance to predicting weather in atmosphere and ocean, and climate, and for model improvement	
2	• **Session 2: The basics: Bayes Theorem** – what is Bayes Theorem, where does it come from, and why is it important (Chapter 2)	
3	Session 2 (continued)	
4	Session 2 (continued)	
5	• **Session 3: Linear DA Kalman filter –** an exploration of the Kalman Filter (Chapter 6 and 12)	Assignment #1 due
6	Section 3 (continued)	
7	• **Session 4: Ensemble Kalman Filters –** What they are, and why they are so useful, and their limitations (Parts of chapters 7,8,10, and 13,14)	
8	Session 4 (continued)	
9	• **Session 5: Ensemble Kalman Smoothers –** What they are, and why they are so useful, and their limitations (Parts of chapters 7, 8, 10, and 15)	
10	Session 5 (continued)	
11	**Session 6: Iterative Ensemble Kalman Filters and Smoothers –** What they are, and why they are so useful, and their limitations (Parts of chapters 7, 8, 10, and 21, 22)	
12	Session 5 (continued)	
13	• **Session 6: Variational Data Assimilation** – derivation from Bayes Theorem, exploring its features, adjoint coding (Chapter 3, 4, 5, and 16, 17)	Assignment #2 due
14	Session 6 (continued)	
15	Session 6 (continued)	
16	Session 6 (continued)	

Lecture	Topics	Deadlines
17	**Session 7: Nonlinear Data Assimilation–** random numbers and sampling, Markov-Chain Monte-Carlo Methods (e.g. Gibbs Sampler and Metropolis-Hastings) (Chapter 9 and 10)	Assignment #3 due
18	Session 7 (continued)	
19	Section 7 (continued)	
20	**Session 8: Particle Filters** (Chapter 9, 10, and 19)	Assignment #4 due
21	Session 8 (continued)	
22	Session 8 (continued)	
23	Section 8 (continued)	
24	**Session 9: Particle Flows** (Chapter 9, 10, and 20)	Assignment #5 due
25	Session 9 (continued)	
26	**Session 10: Hybrid Methods** (Chapter 7,8 and 10)	
27	Session 10 (continued)	
28	**Session 11: Putting it all together** (Chapter 11 and 18)	