Data Assimilation

ATS 651, Department of Atmospheric Science
11:00 – 11:50 Monday, Wednesday, Friday, 101 ATS
2021 Spring Term

Instructor Contact Information

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Office hours: By appointments

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. The following recent textbooks provide basic and advanced 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.

Preliminary Schedule of Topics, Readings, 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	
3	Session 2 (continued)	
4	Session 2 (continued)	
5	• **Session 3: Linear DA Kalman filter –** an exploration of the Kalman Filter	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	
8	Session 4 (continued)	
9	• **Session 5: Ensemble Kalman Smoothers –** What they are, and why they are so useful, and their limitations	
10	Session 5 (continued)	
11	• **Session 6: Variational Data Assimilation** – derivation from Bayes Theorem, exploring its features, adjoint coding	Assignment #2 due
12	Session 6 (continued)	
13	Session 6 (continued)	
14	Session 6 (continued)	
15	**Session 7: Nonlinear Data Assimilation–** random numbers and sampling, Markov-Chain Monte-Carlo Methods (e.g. Gibbs Sampler and Metropolis-Hastings)	Assignment #3 due
16	Session 7 (continued)	
17	Section 7 (continued)	

Date	Topics / Assigned Readings	Deadlines
18	Session 7 (continued)	
19	**Session 8: Particle Filters**	Assignment #4 due
20	Session 8 (continued)	
21	Session 8 (continued)	
22	Section 8 (continued)	
23	**Session 9: Particle Flows**	Assignment #5 due
24	Session 9 (continued)	
25	**Session 10: Hybrid Methods**	
26	Session 10 (continued)	
27	**Session 11: Putting it all together**	
28	Session 11 (continued)	