Special Topics in Meteorology: Data-Driven Weather Prediction (MR4800; Winter Quarter 2026)
Instructor: Scott Powell (Root 255)
Room: Root 117/123
Meeting times: M,T, W: 1000–1050
Office hours: by appointment in office or Teams
Course webpage: https://swpowell.github.io/MR4800.html

Course Objectives/Learning Outcomes

At the end of this course, students should be able to

- Explain the differences between different neural network architectures used in weather and climate prediction.
- Assess and describe limits of predictability of data-driven ML weather prediction models.
- Assess and describe ensemble dispersiveness of data-driven ML ensemble weather prediction systems.
- Articulate the strengths and weaknesses of traditional NWP and ML weather prediction at forecasting extreme weather events.
- Describe methods used to generate ML ensembles for weather prediction.
- Explain ways to understand how to link ML predictions and failures to real processes occurring in the atmosphere.

Syllabus

Week 1 (Jan. 5): Course intro.
No class Tuesday and Wednesday.

Week 2 (Jan. 12–14): Review of traditional numerical weather prediction (NWP). Parameterizations. Theoretical limits of predictability.
Paper: Judt (2018)

Week 3 (Jan. 20–21): Basics of machine learning (ML). Fully connected neural networks (NN). Convolutional NNs. Required computational resources. Data preparation. Training and inference.
Paper: Vonich and Hakim (2024)

Week 4 (Jan. 26–28)*:* Nvidia FourCastNet. Fourier Neural Operators (FNOs). Pangu-Weather. Transformers.
Paper: Pathak et al. (2022), Bi et al. (2023)
No Class Jan. 19 for MLK Day.

Week 5 (Feb. 2–4): Google GraphCast/GenCast/WeatherNext. Graph neural networks.
Paper: Lam et al. (2023)

Week 6 (Feb. 9–11): Aurora—the Microsoft Foundation model.
Paper: Bodnar et al. (2025)

Week 7 (Feb. 16–18): Data-driven parameterization. Hybrid ML/full physics modeling approaches. Google NeuralGCM. Sharpening predictions.
Paper: Kockkov et al. (2024)

Week 8 (Feb. 23–25): Ensemble prediction systems. Methods for perturbing initial conditions. Dispersiveness and verification of model ensembles.
Paper: Price et al. (2023)

Week 9 (Mar. 2–4): Explainable AI. Understanding the "physics" behind a model prediction.
Paper: McGovern et al. (2019), Toms et al. (2020),

Week 10 (Mar. 9–11): Forecasting extreme weather events, i.e., handling distribution tails. Out of sample events. Tropical cyclone forecasting.
Paper: Olivetti and Messori (2024)

*Week 11 (*Mar. 17+*)*: Complete final project if necessary.

Starting Week 2: Paper discussion on Tuesday or Wednesday. One student will lead paper discussion in which all students will participate.

Grading

Paper discussion (20%)
Forecasts (20%)
Midterm project (30%)
Final project (30%)

Course Structure:

1. All course material will be available at or linked on the course webpage.

2. Student paper discussions: Each student is required to lead one discussion during the quarter. The paper listed for each week is the required reading about which the discussion will take place. The discussions are expected to last 30–45 minutes, although students should prepare 15–20 minutes of material to leave time for discussion.

3. If you have any concerns, comments, questions that you do not want to broadcast to the rest of the class, etc., please feel free to email me or send a Teams message to discuss.

4. Details about the midterm and final projects will be forthcoming.

Forecasting Contest:

Students will forecast daily high temperatures to the nearest whole degree Fahrenheit for two sites during the quarter: Norfolk International Airport (ORF) and Monterey Regional Airport (MRY).

Forecasts will be made for the following days from midnight (0000) to 2359 local time.

	Norfolk	Monterey
Week 1	Jan. 7, 8	
Week 2	Jan. 13, 14, 15	
Week 3	Jan. 20, 21, 22	
Week 4	Jan. 27, 28, 29	
Week 5	Feb. 3, 4	Feb. 5
Week 6		Feb. 10, 11, 12
Week 7		Feb. 17, 18, 19
Week 8		Feb. 24, 25, 26
Week 9		Mar. 3, 4

Forecasts are due by 5PM Pacific time the prior day. If a student does not make (misses) a forecast, the first missed forecast will be assigned climatology. The second or more missed forecasts will be assigned climatology and a 10-point penalty. Daily point loss is capped at 10 points.

Forecasts will be verified using the final Daily Climate Reports (CLI) issued for Norfolk and Monterey by their respective local Weather Forecast Office (WFO). We will not use preliminary CLIs issued on same day. Only CLIs after the forecasted day is done will be used for verification.

To be eligible to win, a student must make at least 22 out of 25 forecasts.

All students will start with 100 points. Each day, each student's absolute forecast error (plus any penalty, if applicable) will be subtracted from their point total. Point totals may not go negative. Students who run out of points are eliminated from the contest but must continue submitting forecasts since the forecasting is a component of the course grade. The eligible student (if any) with the most points remaining after the final forecast will not be required to complete the final project and will receive 100% for that project. Any eligible students who do not win will have their final point total added to their final project grade. All students, eliminated or not, will have one point added to their final project grade for each forecast that has the smallest error among all forecasts in the class.

If a tie exists between two students, the student with the most perfect forecasts (0 error) will be the winner. If the tie remains, a "sudden death" forecast-off between all tied students will begin: All tied students will make a forecast for a to-be-determined location, and the student with the smallest error wins. This will continue until all ties are broken. If after five "sudden death" forecasts, a tie inexplicably remains, then a drawing of lots shall determine the winner.