Uses and Applications of Machine Learning in
Subseasonal Forecasting, Extreme Weather Prediction, and Climate Variability

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Subseasonal Prediction

AI/ML

Climate Variability

Extreme Weather Prediction
"Traditional" numerical weather prediction / climate modeling

**Input**
Observations or Representation of the Initial State

**Run Model**
Parameterizations
High Performance Computing

**Output**
Predictions with Certain Lead Time or Future Projections

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**ML-based** numerical weather prediction / climate modeling

Input
Observations or Representation of the Initial State

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Parameterizations
High Performance Computing

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Predictions with Certain Lead Time or Future Projections


...and regardless of your approach, there will be **errors**.

<table>
<thead>
<tr>
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</tr>
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...and regardless of your approach, there will be errors.

1. Can we reduce the errors with ML/AI?

2. Can we learn something new about the Earth system and/or our numerical models?

Subseasonal Prediction

Climate Variability

Extreme Weather Prediction
Prediction of precipitation on longer (than weather) timescales is challenging...

Subseasonal Forecasting
(*or pick your lead time of interest)
Bias Correction

Observations
**[Online]** e.g., train ML to bias correct the numerical model *while it is running.*

**[Offline]** e.g., train ML to bias correct the numerical model *after it has run.*
U-Net Architecture


CESM weeks 3,4 (temperature or precipitation)

ERA5 or NOAA CPC/GPCP

(U-Net architecture based on Ronneberger et al. 2015)

Strongly Rotating \((\geq 75 \text{ m}^2 \text{s}^{-2})\)

Non-strongly Rotating \((< 75 \text{ m}^2 \text{s}^{-2})\)

Subseasonal forecasting

Extreme weather prediction

Climate variability / change

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How do we rectify the need for the "best-performing" ML/AI model in a climate prediction problem vs. gaining the necessary understanding of the fundamental climate processes (i.e., is there a conflict between best prediction models and realistic ML/AI models?)
How do we rectify the need for the "best-performing" ML/AI model in a climate prediction problem vs. gaining the necessary understanding of the fundamental climate processes (i.e., is there a conflict between best prediction models and realistic ML/AI models?)

What is a "best-performing" weather forecast / climate projection?

Yes! Consider image sharpness for example...

Forthcoming work led by Imme Ebert-Uphoff (CSU/NOAA CIRA)
Real World Complexities*

*this is for illustration purposes (not real data)
What "best practices" should we implement for performing ML studies in climate prediction? Are there specific metrics, verification datasets, and problems that should be considered?
What "best practices" should we implement for performing ML studies in climate prediction? Are there specific metrics, verification datasets, and problems that should be considered?

Very problem specific. Plus, how do you do this without **stifling creativity?**

On the use of **metrics...**
Competing Objective 1

Competing Objective 2

Real World Complexities*

Pareto Frontier

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What can US CLIVAR and others do to promote the open and free distribution of datasets (reanalysis, observations, model output) to use for ML/AI applications in climate prediction?
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Don’t do this alone!
(Also, software!)
Subseasonal forecasting

Extreme weather prediction

Climate variability / change