Artificial Intelligence at the American Meteorological Society's 102nd Annual Meeting (Jan 2022)

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NOAA's Center for Artificial Intelligence: Progress toward an AI-Ready Agency and Workforce

- The 2020 National AI Initiative Act authorizes a coordinated program across the Federal government to accelerate AI research and application for the Nation's economic prosperity and security.
- NOAA has established a Center for Artificial Intelligence (NCAI).
- NCAI will support workforce development via training events and workshops, facilitate transition from research to operations, foster partnerships across industry, academia, and government.
- Website for publicly connecting to NOAA's AI community: noaa.gov/ai
- Mailing List: http://tinyurl.com/y2ehvhfg
- TRAINING: https://github.com/ESIPFed/earth-science-community-ML-tutorials/tree/main/tutorial_template
- NOAA's 3rd AI Workshop recordings: https://www.noaa.gov/ai/events/3rd-noaa-ai-workshop

NOAA: AI-Ready Data

- “You’re not AI-ready until your data is”.
- The biggest roadblock to implementing ML and deep learning is sourcing, organizing, and feeding the right kind of data into your model.
- Data
  - Documentation (metadata, example code).
  - Preparation (gap filling, gridding, outliers).
  - Access (file formats).
  - Quality (completeness, consistency, bias).
- Earth Science Information Partners (ESIP): https://wiki.esipfed.org/Data_Readiness

AI at NOAA's Weather Prediction Center

- Projects:
  - Neural Net for Precipitation Rates.
  - Road Weather: to forecast the probability of sub-freezing road temperatures (non treated roads).
  - DL to identify frontal boundaries.
- Challenges and Recommendations:
  - ML requires long, high quality dataset to learn patterns.
  - If the sample of extreme events is small, than ML might not learn them.
  - Establish employee professional training programs.

Developing ML for an Operational Forecasting Environment

- Machine Learning (ML) and Deep Leaning (DL) and other AI methods are popular in the Meteorological Research Community.
- AI techniques have yet to be widely used in the Operational (i.e. Forecasting) Community.
- NOAA Hazardess Weather Testbed (HWT) Spring Forecasting Event (SFE) is an annual experiment hosted by NOAA'S Storm Prediction Center (SPC) and National Severe Storms Laboratory (NSSL).
- Participants investigate a variety of traditional and ML models.
- Participants include forecasters, NWS modeling center, national labs, academia.

Recommendations

- AI developers: communicate with end-users (i.e. forecasters) and domain experts early and often:
  - What are their operational needs?
  - Provide opportunities for them to collaborate on the work.
  - Be able to provide end-users with examples of when a product works and when it doesn't.
  - Be able to explain how a product works and why it may fail.
  - New tools should be novel or exceed the quality and skill of similar existing products.
  - Try to stay consistent with domain knowledge and standards.
  - Provide a clean, intuitive interface.
  - Provide an easy way to submit feedback, bug reports, and questions.
  - Provide end-user training for all experimental products.

An Update on Machine Learning (ML) Efforts at the European Centre for Medium-Range Weather Forecasts (ECMWF).

- There are many opportunities in weather and climate modeling where ML can make a difference.
- The weather and climate community is only at the beginning of exploring the potential of ML. There are challenges to be faced.
- Challenges include:
  - Difficult to distinguish between ML and domain sciences.
  - Need data handling to be capable of supporting ML, e.g. data available online, handling of large datasets.
- How to proceed?
  - Build tools to make it easy for domain scientists.
  - Collaborate, share datasets and software.
  - Workshops and meetings.

Free virtual ML workshop at ECWMF

- https://events.ecmwf.int/event/294/
- 29 March 2022 – 1 April 2022
- Registration deadline: 22 March 2022

The NCAR AI for Earth System Science Web Portal

- Interest in ML is growing faster than existing ML experts' capacity to collaborate and mentor people.
- Goal: develop online, asynchronous resources to support ML for Earth Systems Science applications.
- Disseminate resources through a central portal:
  - Tutorials for beginners and advanced users.
  - Software.
  - Datasets.
- Portal Website (beta): https://ncar.github.io/ai4ess
- Save the date: Trustworthy AI4ES Summer School: June 27 – July 1, 2022

Replacing Current NWP with Deep Learning Weather Prediction (DLWP)

- Dale Durran and team.
- NWP models require enormous computer resources and physical parameterizations (empirical relationships) impact forecast skill.
- Approach: U-net architecture, use just a few variables to characterize the atmospheric state (NWP may be using too many).
- DLWP has the potential to revolutionize weather forecasting.
  - DLWP can learn dynamics and physical parameterizations at the same time.
  - The speed of DLWP allows for much larger forecast ensembles which would give better probabilistic forecasts and better capture extreme events.

References relevant to DLWP

- Weyn et al 2021: https://doi.org/10.1029/2021MS002502
- Weyn et al 2020: https://doi.org/10.1029/2020MS002109
- Weyn et al 2019: https://doi.org/10.1029/2019MS001705

Using a Neural Network to Forecast Wind Gusts

- Nick Carr – WFO Miami and other regions
- Wind and wind gusts affect aviation, fire weather, marine vessels (wave generation), the energy sector (power lines, safety for workers).
- Difficult to forecast due to spatiotemporal variability in the boundary layer and lack of relevant observations. Challenge for traditional NWP.
- References:
  - Regression-based approaches: Barhmihi et al 2020
  - Artificial Neural Networks/Support Vector Machines: Mohandes et al 2004, Kretzschmar et al 2002.
  - Random Forests: Brothers and Hammer 2020

Forecasting wind gusts

- Evaluate wind gust estimates produced by various ML algorithms versus Automated Surface Observing Systems (ASOS).
  - Training 2017-2018 ASOS observations from County Warning Area.
  - Performed rigorous Quality Control (QC).
  - Test: 2019
- Determine which predictors are most important for predicting wind gusts.
  - Obtained from NWP models.
  - Predictors from surface as well as various atmospheric levels and layer averages.
  - Most important predictor was model surface wind.
- ML techniques include:
  - Linear Regression (the other 2 worked better).
  - Random Forest Regressor.
  - Neural Network Regressor.
- If predictions show acceptable accuracy (measured with Mean Squared Error, Mean Absolute Error, Coefficient of Determination), implement those algorithms operationally.

Nowcasting of Precipitation from Radar Imagery

- Journal of Hydrology, volume 137, 15 Aug 1992: Rainfall forecasting in space and time using a neural network.
- Machine Learning for Precipitation Nowcasting from Radar Images.
  - https://arxiv.org/abs/1912.12132
  - https://ai.googleblog.com/2020/01/using-machine-leanring-to-nowcast.html
- Skillful Twelve Hour Precipitation Forecasts using Large Context Neural Networks.
  - https://arxiv.org/abs/2111.07470
  - https://ai.googleblog.com/2021/11/metnet-2-deep-learning-for-12-hour.html
- MS-nowcasting: Operational Precipitation Nowcasting with Convolutional LSTMs at Microsoft Weather.
- Skillful precipitation nowcasting using deep generative models of radar.
  - https://www.nature.com/articles/s41586-021-03854-z
  - https://deepmind.com/blog/article/nowcasting

Operational Real-time Identification of Frontal Boundaries Using ML

- Andrew Justin (OU) and team.
- Surface analyses created by forecasters are labor intensive.
- Lagerquist et al (2019) demonstrated skill at detecting cold and warm fronts with a convolutional neural network (CNN).
- This study: using U-Net 3+ models to identify cold, warm, stationary, and occluded fronts.

Using ML for Hurricane Intensity Forecasting

- Javier Martinez-Amaya (and team from University of Valencia, Spain).
- Previous models: dynamical (i.e. computational fluid dynamics), statistical, statistical-dynamical).
- Using GOES satellite imagery and Hurricane Track data (IBTrACS) to select key variables to train and develop ML models.
- Using forecast skill metrics to evaluate skill.
- https://www.aiforoceans/maloph/

ML for Tropical Storm and Hurricane Detection

- Collaboration between NOAA and ECMWF
- https://journals.ametsoc.org/view/journals/apme/59/12/jamc-d-20-0117.1.xml
- Training Data: ECMWF ERA-5 Dataset + NOAA IBTrACS
- ML Model: CNN (UNET) + Clustering
- Goal: operational implementation in the future.

Probabilistic Forecast of Thunderstorms using 2-D Convolutional Neural Network (CNN)

- Mamoudou Ba and team (NOAA).
- Domain expert for thunderstorm initiation and development is very important for “feature selection”.
- The 2-D CNN model has good skill → very promising tool for predicting the location of thunderstorms.

Next AMS Annual Meeting

- 8 – 12 January, 2023
- Venue: Denver, Denver CO, United States

- Highly recommend AI experts on PREFER project to attend, present, and network.