Methods for simulation of weather and climate (mobility).

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***Abstract*—to be continued...**

I. Introduction

To simulate both mobility and energy use, realistic modeling of the weather is necessary. In this paper, you will discuss ways in which we can do this. Considering the effect of the position of the virtual city, seasons, and the ability to represent specific phenomena (storms, snow, heat waves).

II. Topics

A. *STEP (short-term ensemble prediction system) computation algorithm*

Ensemble forecasting is a method used in or within numerical weather prediction. Instead of making a single forecast of the most likely weather, a set (or ensemble) of forecasts is produced. This set of forecasts aims to give an indication of the range of possible future states of the atmosphere. Ensemble forecasting is a form of Monte Carlo analysis. The multiple simulations are conducted to account for the two usual sources of uncertainty in forecast models:

- The errors introduced by the use of imperfect initial conditions, amplified by the chaotic nature of the evolution equations of the atmosphere, which is often referred to as sensitive dependence on initial conditions;
- The errors introduced because of imperfections in the model formulation, such as the approximate mathematical methods to solve the equations.

Ideally, the verified future atmospheric state should fall within the predicted ensemble spread, and the amount of spread should be related to the uncertainty (error) of the forecast. In general, this approach can be used to make probabilistic forecasts of any dynamical system, and not just for weather prediction. [1]

Today ensemble predictions are commonly made at most of the major operational weather prediction facilities worldwide, including

- National Centers for Environmental Prediction (NCEP of the US)
- European Centre for Medium-Range Weather Forecasts (ECMWF)
- Météo-France

[1]

Key Components of Ensemble Prediction Systems:

- Base Models: Ensemble systems typically consist of multiple base models, each trained independently on the same or different datasets. These base models can be diverse, using different algorithms, subsets of data, or variations in model parameters.
- Diversity: The effectiveness of ensemble methods relies on the diversity among the base models. If the models are too similar, the ensemble may not provide significant improvements. Diversity can be achieved by using different algorithms, training data, or initial conditions.
- Combination Method: Ensemble methods employ a combination or aggregation method to merge the predictions of individual models into a single, more accurate prediction. Common combination methods include averaging, weighted averaging, voting, stacking, and boosting.
- Weighting: In weighted averaging, each base model's prediction is assigned a weight, and the final prediction is a weighted sum of individual predictions. The weights are often determined based on the historical performance or reliability of each model.
- Training and Validation: Base models are trained on historical data, and the ensemble system is validated and calibrated using separate datasets to ensure its accuracy and reliability in making predictions on new, unseen data.

An ensemble-based probabilistic precipitation forecasting scheme has been developed that blends an extrapolation nowcast with a downscaled NWP forecast, known as STEPS: Short-Term Ensemble Prediction System. The uncertainties in the motion and evolution of radar-inferred precipitation fields are quantified, and the uncertainty in the evolution of the precipitation pattern is shown to be the more important. The use of ensembles allows the scheme to be used for applications that require forecasts of the probability density function of areal and temporal averages of precipitation, such as fluvial flood forecasting—a capability that has not been provided by previous probabilistic precipitation nowcast schemes. The output from a NWP forecast model is downscaled so that the small scales not represented accurately by the model are injected into the forecast using stochastic noise. This allows the scheme to better represent the distribution of precipitation rate at spatial scales finer than those adequately resolved by operational NWP.

Advantages of Ensemble Forecasting:

- Improved Accuracy: Ensemble forecasting often provides more accurate predictions than individual models by leveraging the collective knowledge of diverse models.
- Quantifying Uncertainty: Ensemble systems offer a way to estimate the uncertainty associated with predictions. The spread or variability among ensemble members provides a measure of prediction confidence.
- Robustness: Ensemble methods are more robust to outliers and noise in the data. They can handle unexpected or extreme events better than single models.
- Reduced Overfitting: By combining multiple models with different training data or parameters, ensemble methods reduce the risk of overfitting to a particular dataset.
- Enhanced Generalization: Ensemble methods can generalize well to different scenarios and datasets, making them versatile for various applications.
- Flexibility: Ensemble systems can incorporate a variety of models and data sources, making them adaptable to different prediction tasks and domains.

Disadvantages of Ensemble Forecasting:

- Computational Complexity: Running and maintaining multiple models can be computationally intensive and require substantial resources, particularly for real-time applications.
- Increased Model Interpretability Challenge: As the ensemble involves combining predictions from multiple models, the interpretability of the overall system may be more challenging than understanding individual models.
- Difficulty in Model Selection: Selecting appropriate models for the ensemble requires careful consideration, and the effectiveness of the ensemble may be sensitive to the choice of models.
- Potential for Redundancy: If the base models in the ensemble are too similar, there might be limited diversity, reducing the effectiveness of the ensemble approach.
- Overemphasis on Certain Models: In some cases, if a particular model consistently outperforms others, that dominant model might heavily influence the ensemble's performance.
- Increased Training Time: Training multiple models requires additional time and computational resources compared to training a single model.

B. Openweather API

OpenWeatherMap is a weather API that provides weather data for any location on the globe. It uses machine learning (ML) to significantly advance both the accuracy and computing speed of global assemble forecasting models, a practice that was impossible only a few years ago [2].

OpenWeatherMap offers a variety of APIs, including the One Call API 3.0, which provides current weather and forecasts, minute forecast for 1 hour, hourly forecast for 48 hours, daily forecast for 8 days, and government weather alerts [2]. The API also provides weather data for any timestamp for 40+ years historical archive and 4 days ahead forecast, daily aggregation of weather data for 40+ years archive and 1.5 years ahead forecast, hourly forecast for 4 days, 16 days forecast, and climatic forecast for 30 days [2].

In addition, OpenWeatherMap provides beautiful multi-layer maps that create the visual perception of weather. You can choose from a set of OpenWeather Model layers such as wind, temperature, pressure, and others, or select radar data for a detailed precipitation picture [2].

1) Advantages: Here are some of the advantages of OpenWeatherMap

- **Accuracy and speed** - OpenWeatherMap uses machine learning to significantly advance both the accuracy and computing speed of global assemble forecasting models, a practice that was impossible only a few years ago [2].
- **Global coverage** - OpenWeatherMap provides weather data for any location on the globe [2].
- **Historical data** - OpenWeatherMap provides weather data for any timestamp for 40+ years historical archive and 4 days ahead forecast, daily aggregation of weather data for 40+ years archive and 1.5 years ahead forecast, hourly forecast for 4 days, 16 days forecast, and climatic forecast for 30 days [2].
- **Multi-layer maps** - OpenWeatherMap provides beautiful multi-layer maps that create the visual perception of weather [2].

2) Disadvantages: Here are some of the disadvantages of OpenWeatherMap

- **Limited free plan** - OpenWeatherMap offers a free plan that allows 60 calls per minute, one million calls per month, and 5-day forecast, but it does not include historical data [2].

3) Motivation: OpenWeatherMap is a weather API that provides accurate weather data for any location on the globe. Making use of the STEP algorithm explained previously. Combining this algorithm with machine learning (ML) to significantly advance both the accuracy and computing speed.

Also with the free plan we get up to 60 calls per minute, one million calls per month, and 5-day forecast, which is more than enough for our application. Although the free plan doesn't include historical data, we can save the data and make our own historical data. The Downside of this approach is that we have to wait for the data to be collected.

In case we want forecast data for more than 5 days, we have to implement our own model to predict the weather (making use of the collected historical data), or upgrade to a paid plan.

C. ClimaX

D. GraphCast

III. Conclusion

Acknowledgment

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

References

[1] Wikipedia [Online] https://en.wikipedia.org/wiki/Ensemble_forecasting [Accessed 13 November 2023]

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