FourCastNet Summary

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Abstract

▶ FourCastNet: Fourier ForeCasting Neural Network, is a global data-driven weather forecasting model

▶ accurate short (0.5-2.5-day) to medium-range (3-7-day) global predictions at 0.25° resolution.

  ▶ high-resolution, fast-timescale variables: surface wind speed, precipitation, and atmospheric water vapor.

▶ It has important implications for planning wind energy resources, predicting extreme weather events such as tropical cyclones, extra-tropical cyclones, and atmospheric rivers.

▶ Performance matches the forecasting accuracy of the ECMWF Integrated Forecasting System (IFS) at short lead times for large-scale variables, while outperforms IFS for small-scale variables, including precipitation.

▶ FourCastNet generates a week-long forecast in less than 2 seconds, orders of magnitude faster than IFS.

  ▶ enables rapid and inexpensive large-ensemble forecasts with thousands of ensemble-members for improving probabilistic forecasting.

Traditional Models

▶ The beginnings of modern numerical weather prediction (NWP) can be traced to the 1920s

▶ The quality of weather forecasts has been steadily improving over the past decades (c.f. Bauer et al. [2015], Alley et al. [2019]).

▶ In addition to better computing capabilities, improvements in weather forecasting have been achieved through better parameterization of small-scale processes through deeper understanding of their physics and higher-quality atmospheric observations.

　　▶ The latter has resulted in improved model initializations via data assimilation.

Data-Driven Weather Models

▶ There is now increasing interest around developing data-driven Deep Learning (DL) models for weather forecasting owing to their orders of magnitude lower computational cost as compared to state-of-the-art NWP models [Schultz et al., 2021, Balaji, 2021, Irrgang et al., 2021, Reichstein et al., 2019].

▶ Data-driven models have great potential to improve weather predictions by overcoming model biases present in NWP models and by enabling the generation of large ensembles at low computational cost for probabilistic forecasting and data assimilation.

▶ Most data-driven weather models, however, use low-resolution data for training, usually at the $5.625°$ resolution as in Rasp and Thuerey [2021b] or $2°$ as in Weyn et al. [2020]

▶ For data-driven models to be truly impactful, it is essential that they generate forecasts at the same or greater resolution than current state-of-the-art numerical weather models, which are run at $\approx 0.1°$ resolution.

Approach of FourCastNet

▶ global data-driven forecasts of key atmospheric variables at a resolution of 0.25°
  ▶ which corresponds to a spatial resolution of roughly 30 km × 30 km near the equator
  ▶ a global grid size of 720 × 1440 pixels.
▶ allows making a direct comparison with the high-resolution Integrated Forecasting System (IFS) model of the European Center for Medium-Range Weather Forecasting (ECMWF).
▶ FourCastNet is about 45,000 times faster than traditional NWP models on a node-hour basis.
▶ The energy required to train FourCastNet is approximately equal to the energy required to generate a 10-day forecast with 50 ensemble members using the IFS model.
▶ Once trained, however, FourCastNet uses about 12,000 times less energy to generate a forecast than the IFS model.

Example
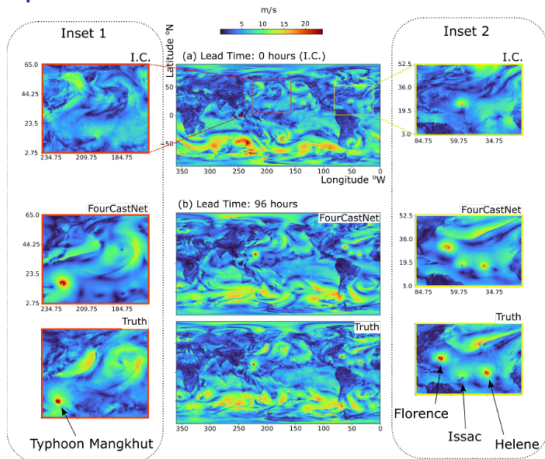
Figure 1. global near-surface wind forecast generated by FourCastNet initialized with an initial condition from the out-of-sample test dataset on September 8, 2018 at 00:00 UTC. The model was run for 16 time steps (6 hours × 16) from this initial condition in inference mode.

FourCastNet Blurb

- ▶ a Fourier transform-based token-mixing scheme [Guibas et al., 2022] with a vision transformer (ViT) backbone [Dosovitskiy et al., 2021].
- ▶ This approach is based on the recent Fourier neural operator that learns in a resolution-invariant manner and has shown success in modeling challenging partial differential equations (PDE) such as fluid dynamics [Li et al., 2021a].
- ▶ ViT backbone is capable of modeling long-range dependencies well.
- ▶ Combining ViT with Fourier-based token mixing yields a state-of-the-art high-resolution model that resolves fine-grained features and scales well with resolution and size of dataset.

Results Section 3

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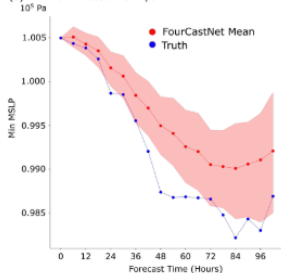°N (a) Initial Condition (0 hours)
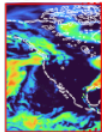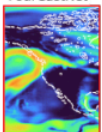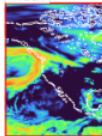
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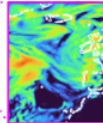
FourCastNet
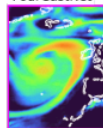
Truth
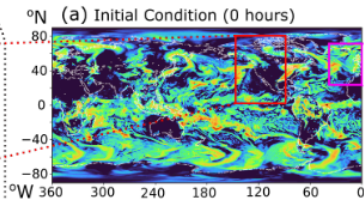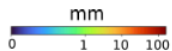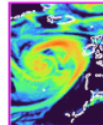
(b) Lead Time: 36 hours
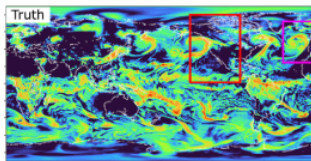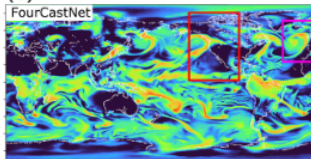
FourCastNet

Truth

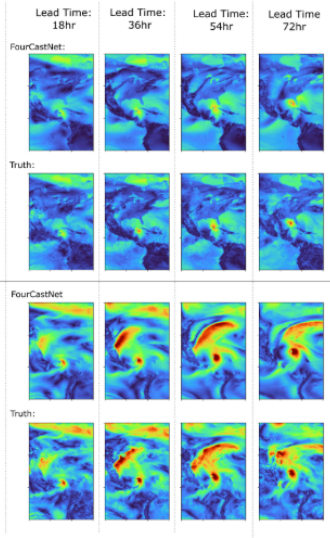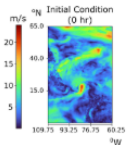FourCastNet

Truth
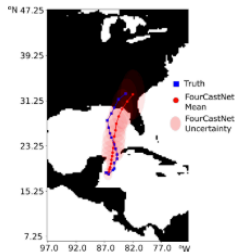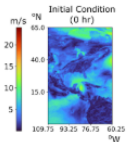
Results Section 3.1

Figure 4. Hurricanes
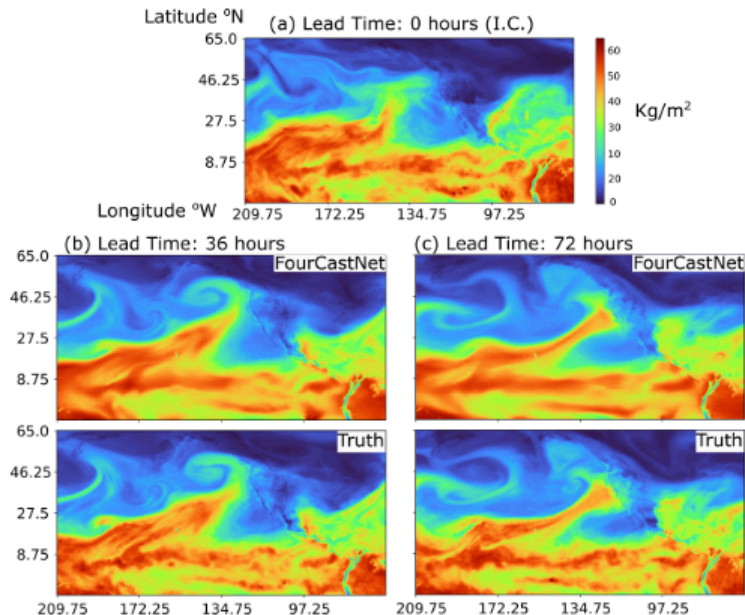
Results Section 3.2

Figure 5. Atmospheric Rivers
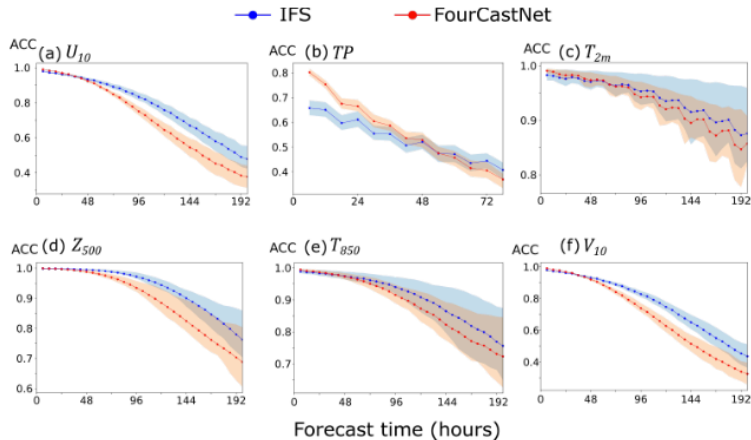
Results Section 3.3 Quantitative Skill

Figure 6. Latitude weighted ACC

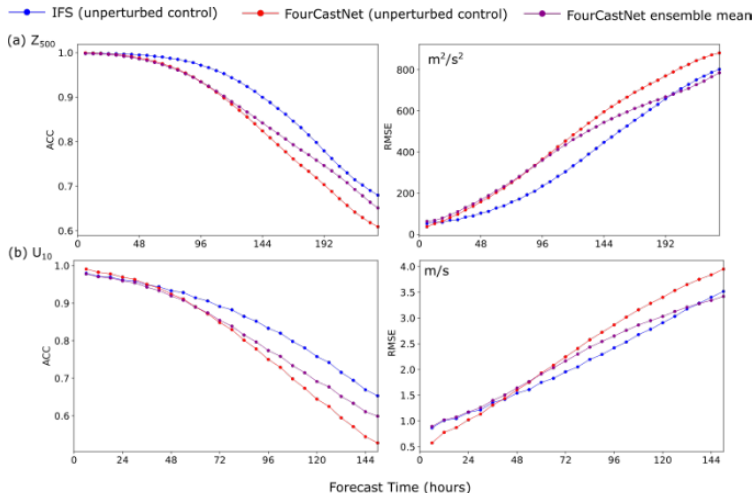# Results Section 3.4 Ensemble Forecasts

Figure 7. Large ensembles

Results Section 3.5 Forecast Skill Over Land For Near-surface Wind Speed
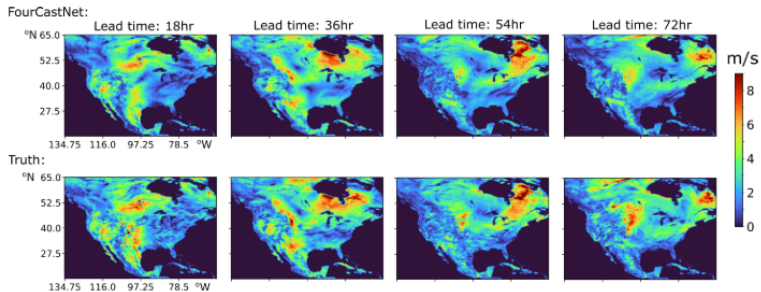

Figure 8. Skill Over Land

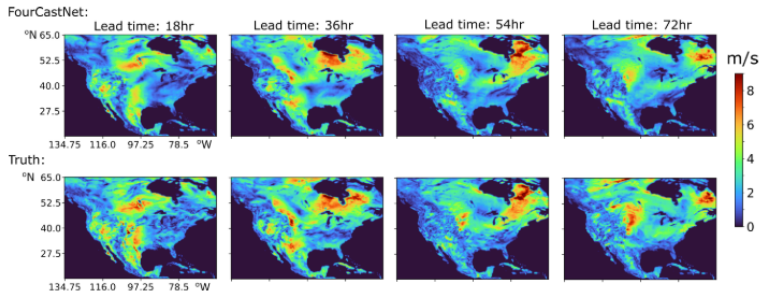# Results Section 3.5 Forecast Skill Over Land For Near-surface Wind Speed
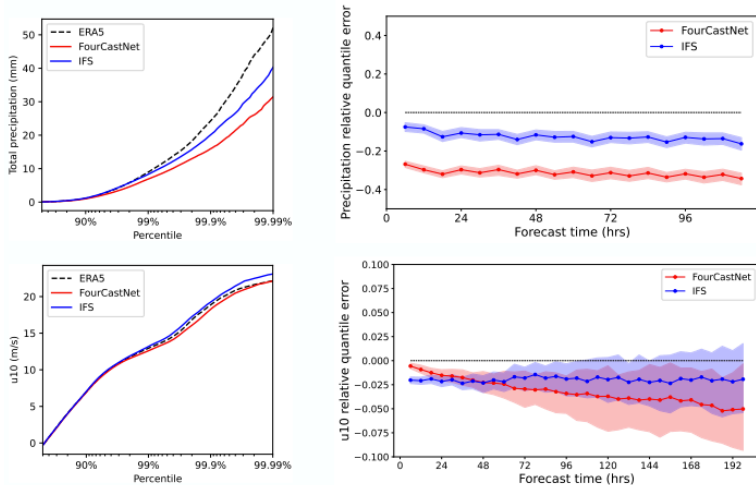

Figure 8. Skill Over Land

Results Section 3.6 Extremes

Figure 9. Extreme percentiles