AI FOR WEATHER FORECASTING - GEOGRAPHY

NEWS: Google's GenCast AI turns spotlight on powerful new weather forecasters

WHAT'S IN THE NEWS?

1. **Unveiling and Objective**:

   - On **December 4, 2023**, Google DeepMind introduced **GenCast**, an advanced artificial intelligence (AI) model.

   - The primary goal of GenCast is to forecast weather with higher accuracy than traditional tools and predict weather conditions for longer durations in advance.

2. **Publication Details**:

   - The research on GenCast was published in the prestigious peer-reviewed journal **Nature**, highlighting its scientific credibility.

How Weather is Traditionally Forecasted

1. **Numerical Weather Prediction (NWP)**:

   - NWP involves **simulating atmospheric conditions** using equations based on the fundamental physical laws of nature.

   - High-quality data about the current weather is combined with powerful supercomputing capabilities to predict weather patterns.

   - This method, while effective, is limited to predicting weather up to **one week in advance** due to computational and data limitations.

2. **Ensemble Forecasting**:

   - Introduced in the **1990s**, ensemble forecasting uses multiple NWP simulations with slightly varied starting conditions.

   - The resulting collection of predictions, known as an **ensemble**, helps represent the range of meteorological possibilities for a specific time and location.

GenCast's Superior Performance

1. **Comparison with ENS**:

   - **ENS**: The ensemble forecasting system developed by the **European Centre for Medium-Range Weather Forecasts (ECMWF)** is widely regarded as a global standard in NWP.

   - GenCast outperformed ENS in **97.2% of 1,320 evaluated targets**, particularly excelling in predicting extreme weather conditions, tracking tropical cyclones, and estimating wind power production.

2. **Performance Beyond 36 Hours**:

- When tasked with forecasting weather more than **36 hours in advance**, GenCast achieved higher accuracy on **99.8% of the evaluated targets**, showcasing its advanced predictive capabilities.

How GenCast Works

1. **AI Architecture and Methodology**:

- GenCast operates using a **diffusion-based AI model**, designed to refine noisy data through multiple iterations.

- The model features a **neural network** with **41,162 nodes** (processing units) and **2.4 lakh edges** (connections between nodes).

2. **Training and Data Sources**:

- GenCast was trained using **40 years of reanalysis data** (1979–2019), which integrates historical observations with modern weather forecasting models.

- The training process spanned **3.5 days for the first step** and **1.5 days for the second step**, utilizing **Google's TPU v5** (tensor processing units).

3. **Forecast Generation Process**:

- The model combines noisy weather data with inputs and passes them through **30 iterations of refinement**.

- This iterative process progressively removes noise, ultimately generating a probabilistic weather forecast.
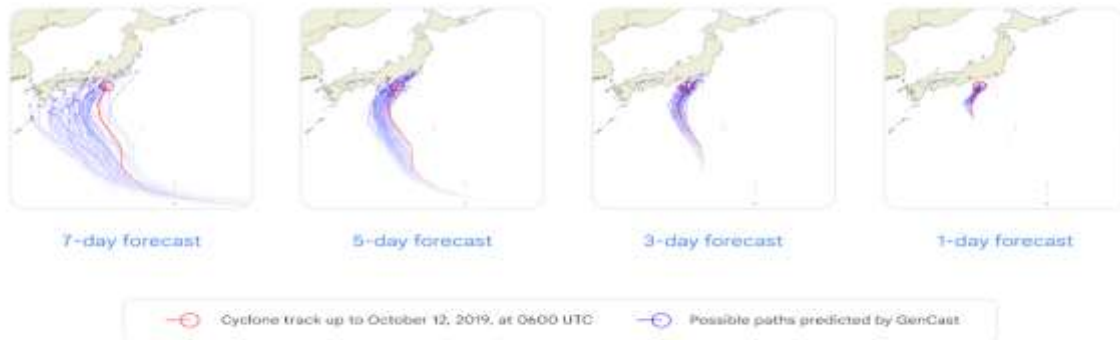
4. **Output Specifications**:

- GenCast produces forecasts for up to **15 days** with a spatial resolution of **0.25° x 0.25° (latitude-longitude)** and a temporal resolution of **12 hours**.

- It generates at least **50 ensemble forecasts** in parallel.

5. **Speed and Efficiency**:

- GenCast's forecasting process on a single TPU v5 unit takes **8 minutes**, significantly faster than the hours required by supercomputers for traditional NWP models.

GenCast forecasts for the path of Typhoon Hagibis

7-day forecast   5-day forecast   3-day forecast   1-day forecast

—⊖— Cyclone track up to October 12, 2019, at 0600 UTC   —⊖— Possible paths predicted by GenCast

GenCast vs. Traditional NWP

1. **Probabilistic vs. Deterministic Forecasts**:

   - GenCast produces **probabilistic forecasts** (e.g., "25% chance of rain in Chennai on December 25"), offering insights into possibilities rather than fixed outcomes.

   - Traditional NWP models generate **deterministic forecasts** (e.g., "5 mm of rain in Chennai on December 25").

   - Probabilistic forecasts are especially useful for identifying extreme weather events and providing longer preparation times.

2. **Complementary Role with NWP**:

   - GenCast relies on traditional NWP models for **training data** and **initial weather conditions**, underscoring their foundational role.

   - Both systems depend on physics-based weather data, which remains critical in understanding rapidly changing climate patterns.

Applications and Advantages of GenCast

1. **Improved Prediction of Extreme Weather**:

   - GenCast is particularly effective in tracking **tropical cyclones**, forecasting **extreme rainfall**, and estimating **wind power production**, making it invaluable for disaster preparedness.

2. **Faster Execution**:

   - The AI-based model reduces computation time significantly, enabling faster decision-making in weather-sensitive sectors.

3. **Enhanced Risk Assessment**:

   - Its probabilistic forecasts allow better assessment of potential risks, aiding in early warnings and mitigation strategies.

4. **Collaboration with Weather Agencies**:

- Google has partnered with weather agencies to integrate AI techniques, ensuring that forecasting methods continue to evolve and improve.

Other AI Models in Weather Forecasting

1. **Google's Initiatives**:

- **GraphCast**: Focuses on generating deterministic medium-range forecasts.

- **NeuralGCM**: Combines AI with NWP to produce hybrid deterministic forecasts.

2. **Competitor AI Models**:

- **Huawei's Pangu-Weather**: Offers weekly forecasts with accuracy comparable to NWP models, executed at faster speeds.

- **Nvidia's FourCastNet**: Outperforms traditional NWP models in extreme rainfall prediction, completing forecasts in under two seconds.

Future Implications

1. **AI's Growing Role in Forecasting**:

- AI models like GenCast are poised to surpass traditional NWP models in predictive accuracy and speed.

- Probabilistic forecasting provides actionable insights for extreme weather events and enhances disaster preparedness.

2. **Challenges and Dependencies**:

- GenCast requires extensive **reanalysis data** for training, and continued collaboration with weather agencies is essential.

- Fundamental understanding of weather through physics-based methods remains crucial to address unprecedented climatic changes.

3. **Open Source and Accessibility**:

- GenCast's code has been made publicly available on **GitHub**, fostering innovation and collaboration in the weather forecasting community.

Source: https://www.thehindu.com/sci-tech/science/google-gencast-ai-spotlight-powerful-machine-learning-weather-forecasts/article69009662.ece