Module 2: Climate Modelling and Extreme Events Prediction

- Using AI/ML for climate simulations, trend detection
- Predicting floods, wildfires, heatwaves
- Datasets and challenges (e.g., low resolution, uncertainty)
- Use of deep learning models (CNNs, RNNs) in time-series forecasting
- 📌 Mini-case study: AI predicting cyclone intensity or droughts

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Introduction & Importance

- Climate change: urgency of better forecasting
- Traditional climate models: strengths and gaps
- Where AI/ML fits in

From Simulations to Predictions

- Definitions:
  - Climate simulation (long-term)
  - Weather prediction (short-term)
- AI/ML as complementary tools to physics-based models

Detecting Trends & Anomalies

- Long-term climate trend detection using ML
- AI in analyzing temperature, sea level, CO_2 data
- Time-series insights beyond human capability

Predicting Extreme Events

- AI for early warning: floods, wildfires, heatwaves
- Need for high spatial/temporal precision
- Role of supervised learning, ensemble methods

Mini-Case Study – Cyclone Intensity & Drought Prediction

- Use of deep learning (e.g., RNNs, LSTMs) to model cyclone paths & intensities
- Satellite data + historical events
- Drought classification using CNNs with soil moisture and precipitation maps

Climate Datasets & Their Challenges

- Common datasets: ERA5, MODIS, CMIP6, NASA POWER
- Issues:
  - Low spatial resolution
  - Incomplete records
  - Noise & uncertainty
- Need for data harmonization

Climate Datasets

- CHELSA (Climatologies at High Resolution for the Earth's Land Surface Areas)
  - What it is: High-resolution (30 arc-seconds) climate data based on statistical downscaling of reanalysis data.
  - Includes: Historical and future climate scenarios (CMIP5/CMIP6).
  - Great for: Mountainous regions and biodiversity applications.
- NASA POWER
  - What it is: Daily weather and solar data from satellite and modeled sources.
  - Tools: Download via API or web GUI.
  - Variables: Temperature, humidity, wind speed, solar radiation
- Copernicus Climate Data Store (CDS)
  - What it is: Comprehensive data from ECMWF (European Centre for Medium-Range Weather Forecasts).
  - Includes: ERA5 reanalysis, seasonal forecasts, and more.
  - ERA5: Global climate reanalysis at ~30 km resolution, hourly data available.

Deep Learning for Time-Series Forecasting

- Recurrent Neural Networks (RNNs), LSTMs for sequential climate signals
- CNNs for gridded atmospheric/satellite imagery
- Example: Rainfall prediction using ConvLSTM

AI + Physics = Hybrid Climate Models

- Physics-informed neural networks (PINNs)
- Learning residuals of physics-based models
- Better generalization & interpretability

Tools & Platforms

- Tools: TensorFlow, PyTorch, xarray, ClimateLearn
- Google Earth Engine, Copernicus Climate Data Store
- Access to HPC + cloud resources for training models

Open Projects & Benchmarks

- ClimateBench: ML benchmark dataset for climate variables
- AI for Earth, DeepMind's GraphCast
- ECMWF + NVIDIA AI models

Challenges & Ethical Considerations

- Data bias, overfitting in ML models
- Black-box risks in high-stakes decisions
- Fair access to AI tools for global south

Future Directions

- Multimodal learning (e.g., combining weather maps + text + radar)
- Transfer learning across regions
- Citizen AI for community-based forecasting

Key Takeaways

- AI accelerates insights from complex climate data
- Not a replacement, but a powerful ally to traditional models
- Open collaboration is key to progress

Q&A / Discussion

- Invite questions
  - Prompt: “What’s a climate application in your region that could benefit from AI?”