Ahmedabad University

CSE 400: Fundamentals of Probability in Computing

Precipitation Forecasting

S2 G11 CLI

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Project Context and Motivation

- **Assigned Domain**: Climate and Weather Systems
- **Project Title:** Probabilistic Precipitation Nowcasting
- **Practical Importance:**
  Flood early warnings
  Agriculture planning
  Urban disaster preparedness
- **Why are there uncertainty :**
  Weather systems are chaotic
  Rainfall patterns evolve unpredictably
  Measurement and model errors are unavoidable

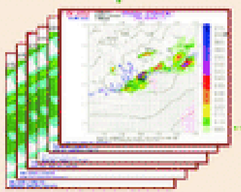
SWIRLS

Short-range Warning of Intense Rainstorms in Localized Systems

Computer Simulation of Physical Processes in the Atmosphere

Remote-sensing and conventional weather observation data

High-resolution storm model to directly simulate the evolution of precipitating clouds up to 15 hours ahead

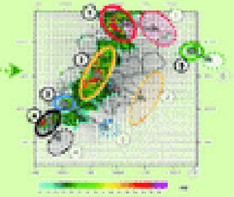


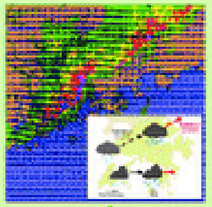
Computer-generated forecast rainfall maps for the next 15 hours based on simulation

Radar Tracking, Analysis and Forecast

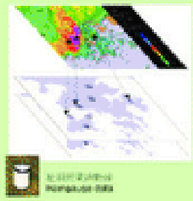
SWIRLS Nowcasting System

Special Editions of SWIRLS



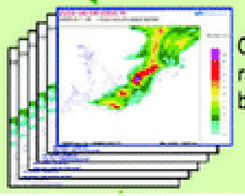


Automatic tracking and prediction of rainband movement from radar

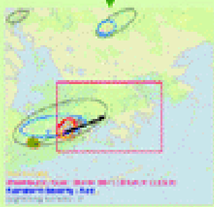


Real-time calibration of radar-detected rainfall rate using the dense raingauge network

Cell identification and radar signature analysis for severe storms



Computer-generated forecast rainfall maps up to 6 hours ahead based on radar



Computer-generated forecast map of squalls, lightning, hail and heavy rain

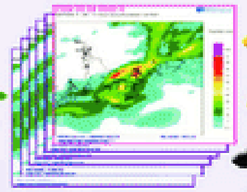
Nowcast Products & Services

In support of Important International Events

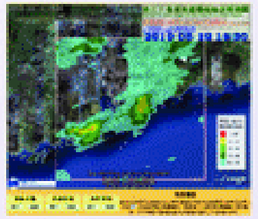
In support of Thunderstorm Warning System

In support of Rainstorm and Related Warning Systems

Forecast rainfall maps up to 6 hours ahead blended from radar nowcast and computer simulation results



Public dissemination of nowcast rainfall maps for the Pearl River Delta region via HKO Internet website



Forecast rainfall information visualized with 4-dimensional map of the globe

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https://www.researchgate.net/

Project Objective and Scope

- **Project Objective:**
  To generate probabilistic short term rainfall forecasts that quantify uncertainty instead of producing a single deterministic prediction.

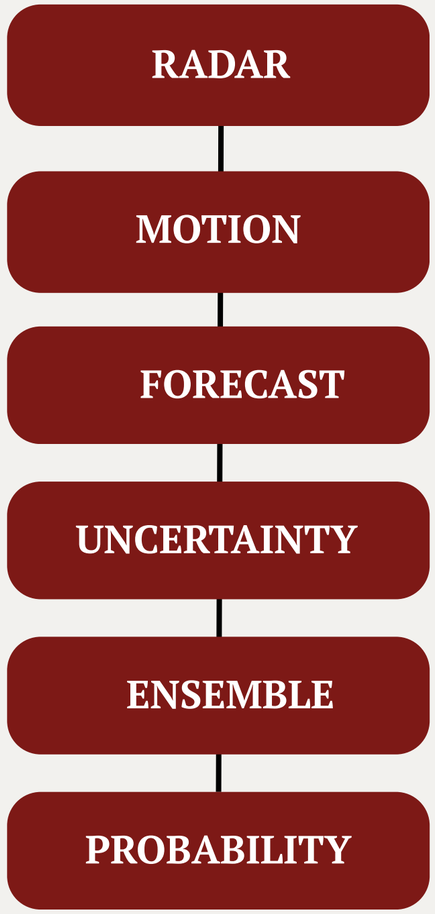
- **What is being predicted:**
  Future rainfall intensity
  Likelihood of different precipitation outcomes

- **Scope:**
  Very short range forecasting (0-6 hours) using radar based nowcasting methods.

Project System Overview

- **End-to-End Pipeline:**
  Radar data acquisition
  Motion estimation of rainfall patterns
  Deterministic extrapolation
  Stochastic perturbation
  Ensemble forecast generation
  Probabilistic output and verification

- **Key Idea:**
  Uncertainty is introduced and propagated through the system to produce multiple possible rainfall futures.

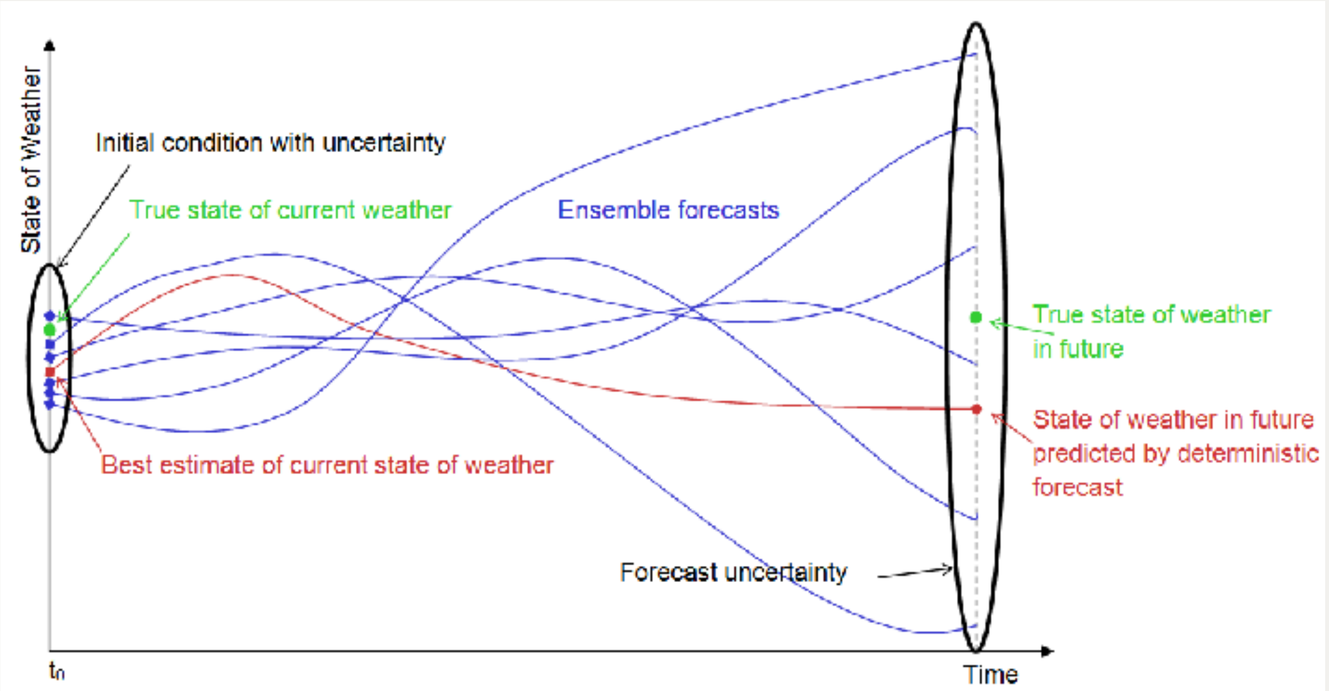


Sources of Uncertainty in the Project

- **Measurement Uncertainty:**
  Radar noise
  Errors in estimating current rainfall

- **Environmental Variability:**
  Initiation, growth, and decay of precipitation
  Changing atmospheric conditions

- **Model Uncertainty:**
  Assumptions like steady movement of rainfall
  Simplifications in motion and intensity modeling

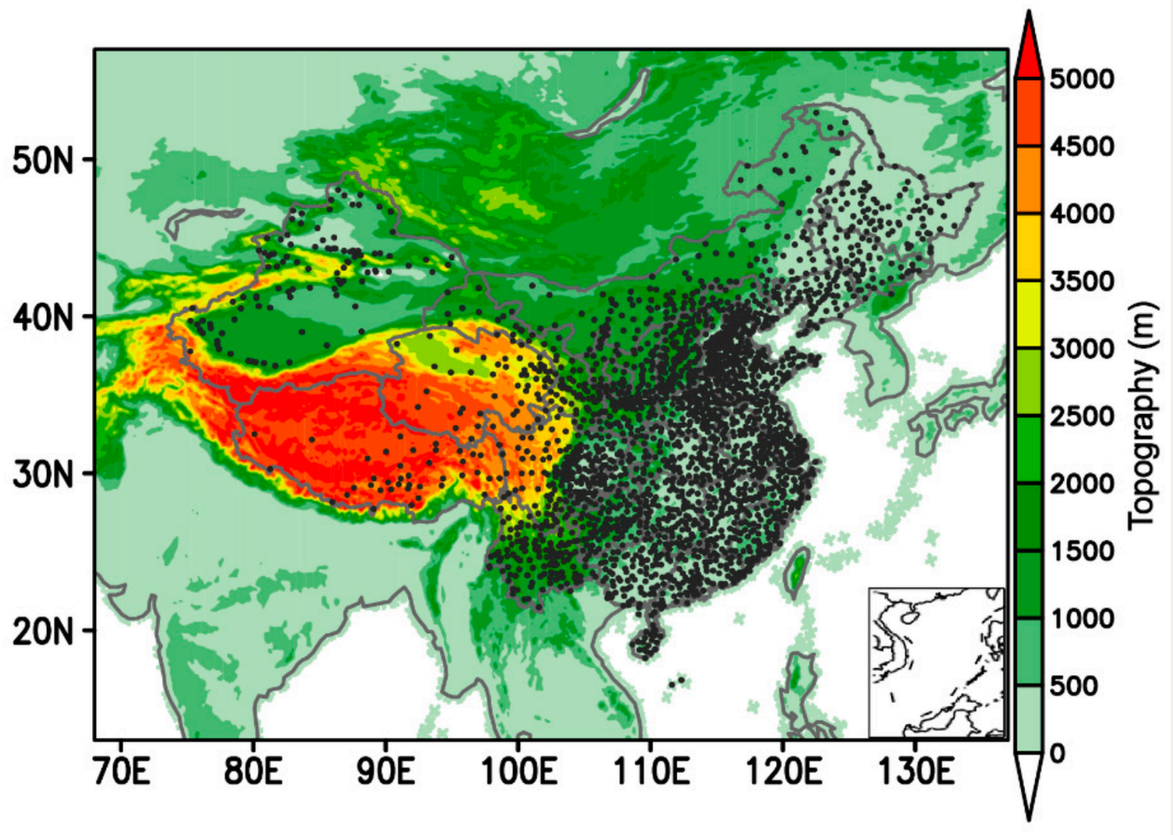


https://www.researchgate.net

Key Random Variables and Their Roles

- **Primary Random Variables:**
  R(x, t): Rainfall intensity at location x and time t
  V(x, t): Motion (advection) field of rainfall patterns
  N(x, t): Stochastic noise representing uncertainty.

- **Role:**
  These variables capture randomness in rainfall behaviour and forecast evolution



https://www.mdpi.com

Probabilistic Models and Assumptions

- **Models Used:**
  Short Term Ensemble Prediction System (STEPS)

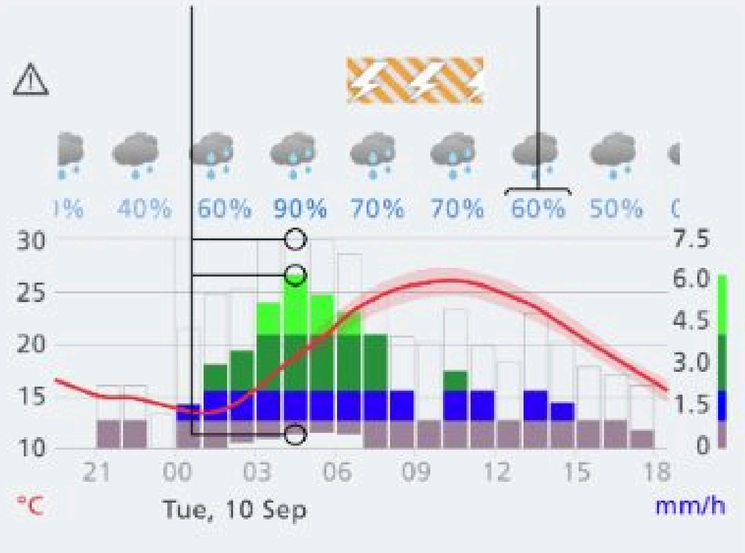
- **Probabilistic Assumptions:**
  Rainfall follows a log normal distribution
  Errors are approximately Gaussian
  Short term stationarity of rainfall fields

Probabilistic Reasoning and Inference Logic

- **Uncertainty Propagation:**
  Initial uncertainty in radar data propagates forward in time
- **Inference Logic:**
  Multiple realizations are generated
  Each realization represents a possible future
- **Decision Support:**
  Probabilities derived from ensemble behavior

The probability that it will rain between 1 and 7.5 mm/h is 80%, with a best estimate of 6 mm/h.

The probability of perceptible rainfall is 60%.



The probability that the total daily precipitation will be between 2 and 17 mm is 80%, with a best estimate of 7 mm.

Operationalizing Probabilistic Reasoning in the Project

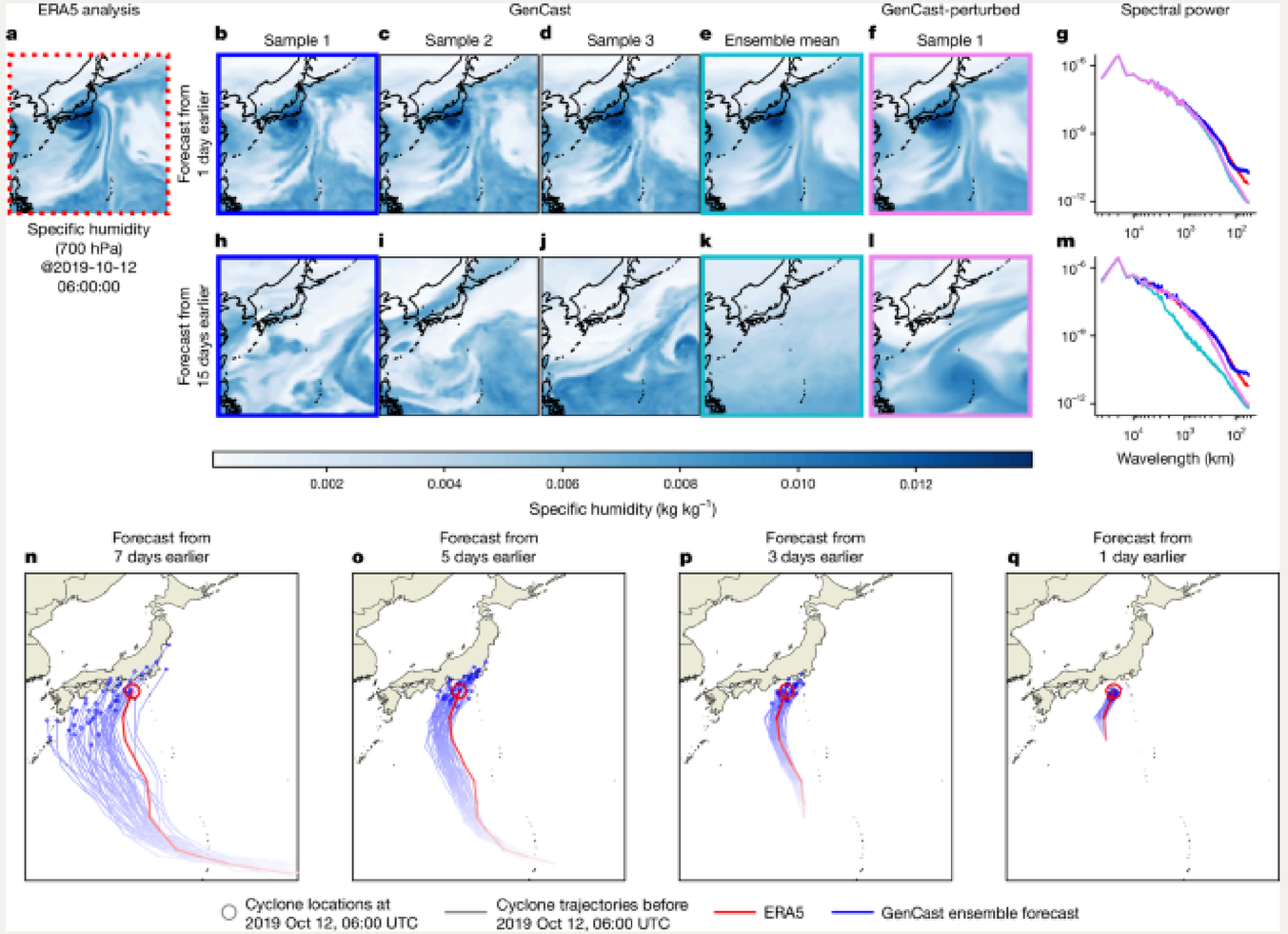
- **Implementation Steps:**
  Optical flow based motion estimation
  Deterministic rainfall extrapolation
  Stochastic perturbation using noise
  Ensemble generation

- **Evaluation :**
  Comparing probabilistic forecasts with observations

Current Limitations and Conceptual Gaps

- **Known Limitations:**
  Difficulty capturing extreme rainfall events
  Assumption of steady rainfall motion
  Limited performance beyond short lead times

- **Conceptual Gaps:**
  Spatially uniform uncertainty
  Limited performance at longer lead times



Planned Refinements and Role Coordination

- **Planned Improvements:**
  Blending with numerical weather prediction models
  Better handling of extreme precipitation
  Spatially varying uncertainty modeling

- **Role Coordination:**
  Verification team to evaluate probabilistic performance
  GitHub manager to track implementation changes
  Group discussion to refine assumptions

Summary of Group-Level Understanding

- **Key Takeaways:**
  Precipitation forecasting is inherently probabilistic
  Uncertainty arises from data, environment, and models
  Ensemble forecasting enables uncertainty quantification
  Probability provides a principled way to support decision making

- **Current Status:**
  A coherent probabilistic framework is established and will be refined in future milestones.

THANK YOU!