Some Frontiers in AI for Applied Meteorology

Workshop on Emerging Data Science and Machine Learning Opportunities in the Weather and Climate Sciences

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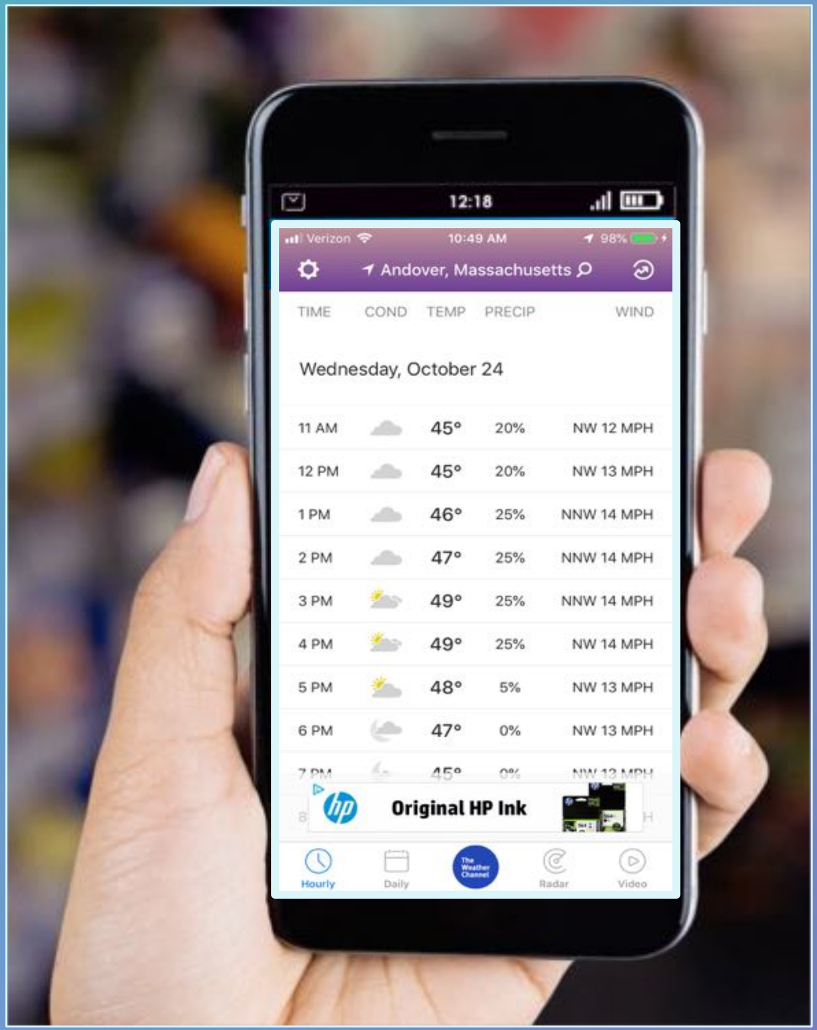
About The Weather Company/IBM

- Global weather forecasts and services
  - On-demand historical data, current conditions and weather forecasts from minutes to 6 months ahead via API
  - Solutions for Agriculture, Aviation, Broadcast Media, Energy & Utilities, Government, Ground Transportation, Insurance, Retail, etc.
  - Weather Channel, Weather Underground brands
- Run proprietary global and regional dynamical NWP models
- Use AI to synthesize data from government and commercial sources
  - E.g., QC, error correction, consensus, probabilities



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Frontiers in AI: Weather-Based Decisions

"First, it should be understood that ***forecasts possess no intrinsic value***. They acquire value through their ability to influence the decisions made by the users of the forecasts."

Murphy, A. H., 1993: What is a Good Forecast? An essay on the Nature of Goodness in Weather Forecasts. *Wea. Forecasting*, **8** , 281-293.

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The Weather-Based Decision Value Chain

WEATHER → OUTCOMES → DECISIONS

”Typhoon is coming” → ”The city will flood” → “Evacuate the city”

”It will snow” → ”Traffic will be slow” → “Leave for work early”

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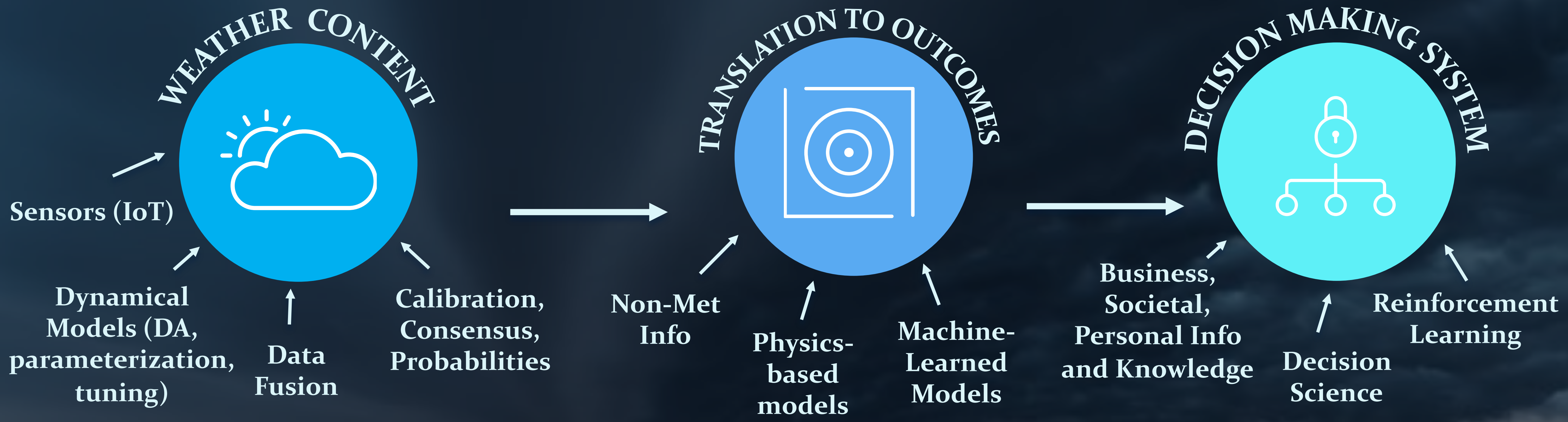
AI in the Weather Value Chain



AI is needed to create the weather content, outcome models, and methods required to optimize and effectively communicate weather decisions.

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Decision Support vs. Decision Making Services

Decision Support: *Providing weather and outcome information suitable to assist decision making*

E.g., what is the weather forecast along my driving route from Boston to Washington, D.C.?

← Substantial Investments

Decision Making Services: *Providing specific decision advice or decisions*

E.g., driverless car: plan a route and drive me from Boston to Washington, D.C.

← Limited Investments

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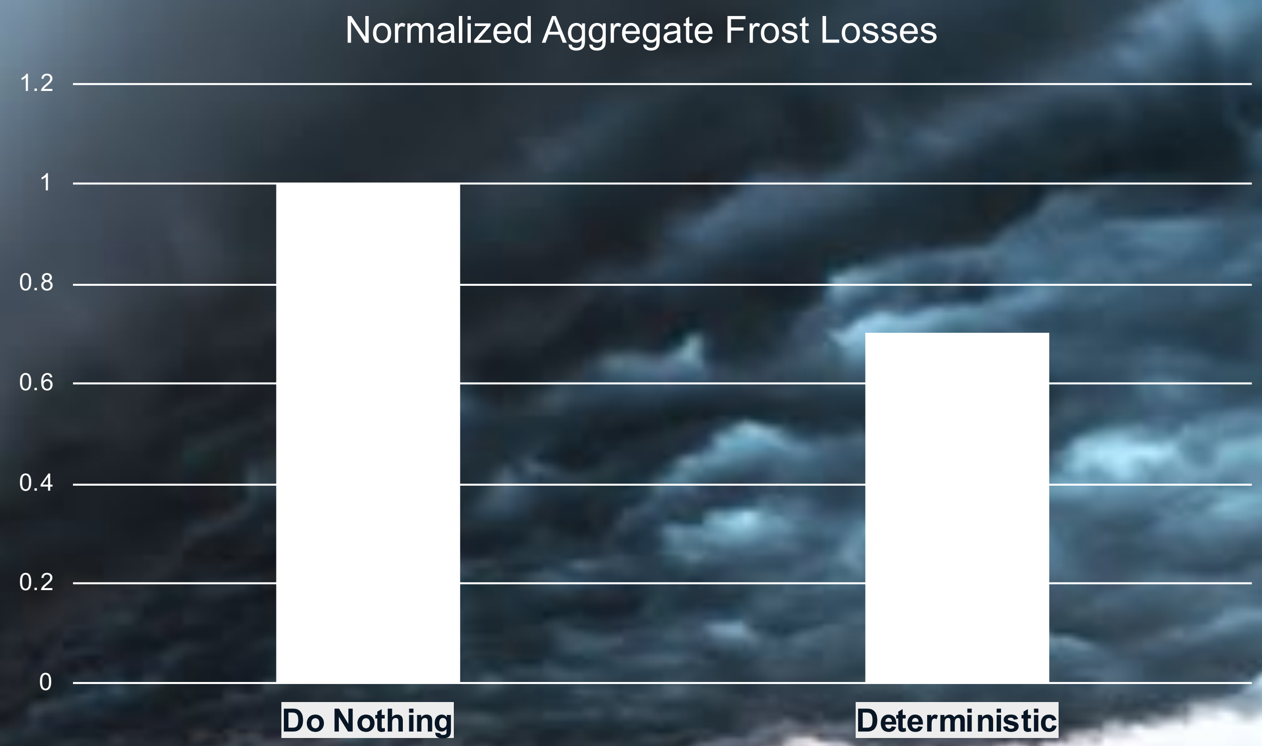
Optimal Decisions Require Probabilistic Forecasts

Consider a farmer making a decision to protect crops in the face of a near-freezing forecast.

- Protection is expensive, so don't do it unnecessarily.
- Yet not protecting could lead to economic ruin.

Using deterministic forecast of freezing conditions is better than nothing....



Better outcome for farmer that uses basic, deterministic weather forecast data to make frost protection decisions.

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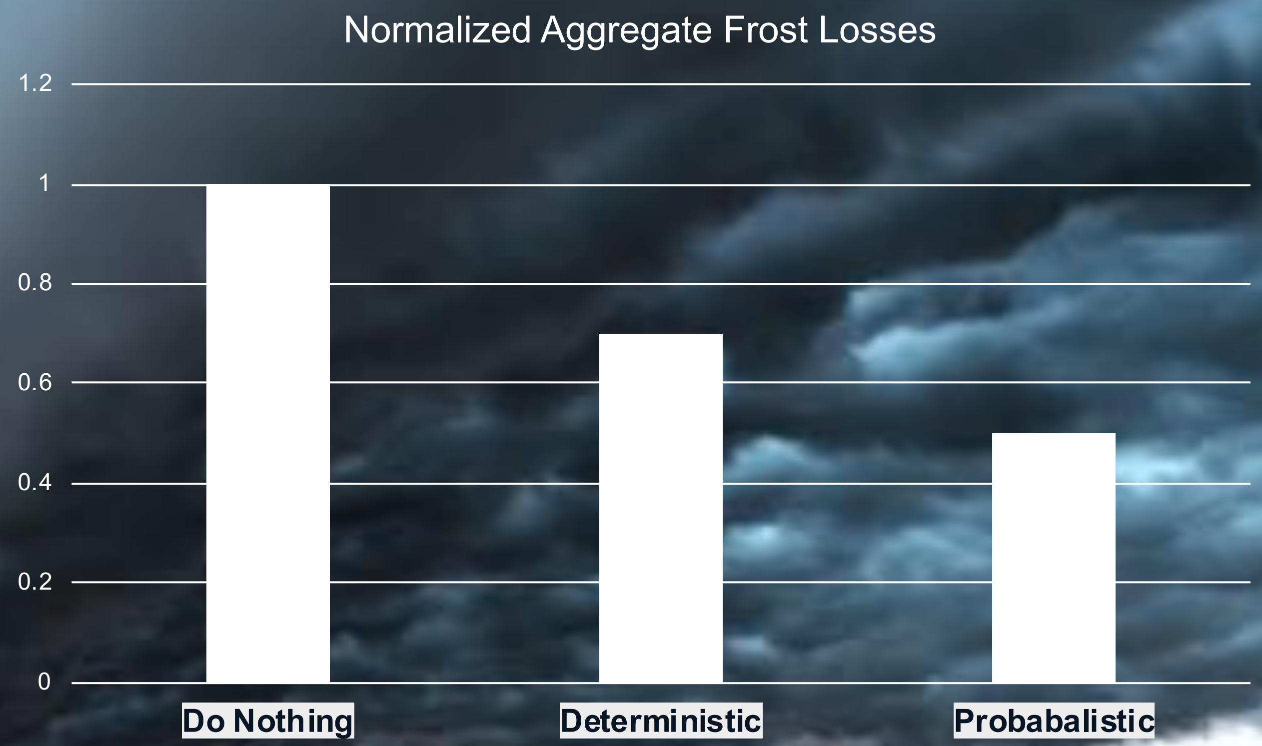
Optimal Decisions Require Probabilistic Forecasts

... but using probabilistic forecasts in conjunction with cost-loss optimization further improves the net economic outcome.



Probabilistic-based protection decisions further improve the net outcome.

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Example Decision Framework

Optimal decision = one with highest expected value (sum of costs x probabilities)

	With Mitigation	No Mitigation
It freezes P(Y) = 0.2	Crop saved (-$1,000)	Crop lost (-$10,000)
It doesn't freeze P(N) = 0.8	Crop okay (-$1,000)	Crop okay ($0)
Expected value	-$1,000	-$2,000

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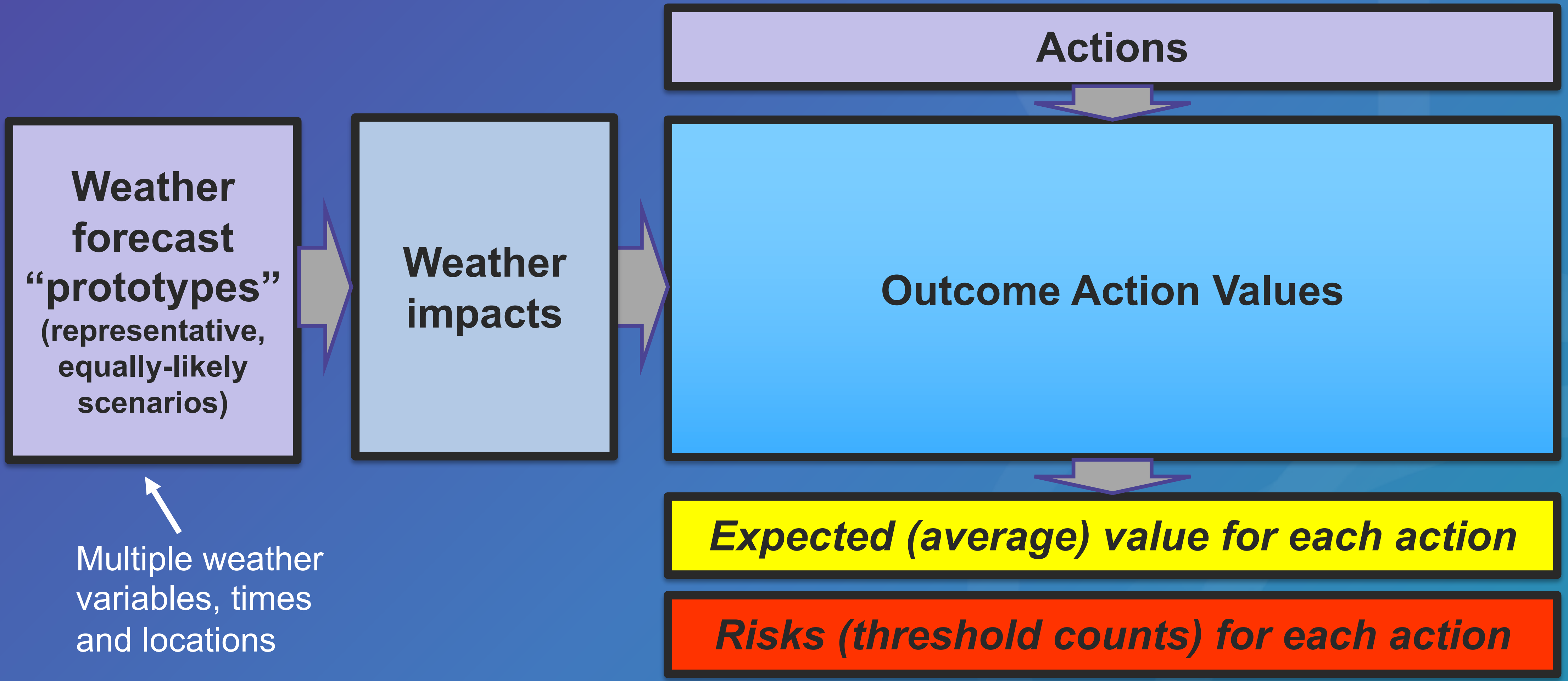
Simple Decision Framework



Decision = action that optimizes the expected value *subject to acceptable risk.*

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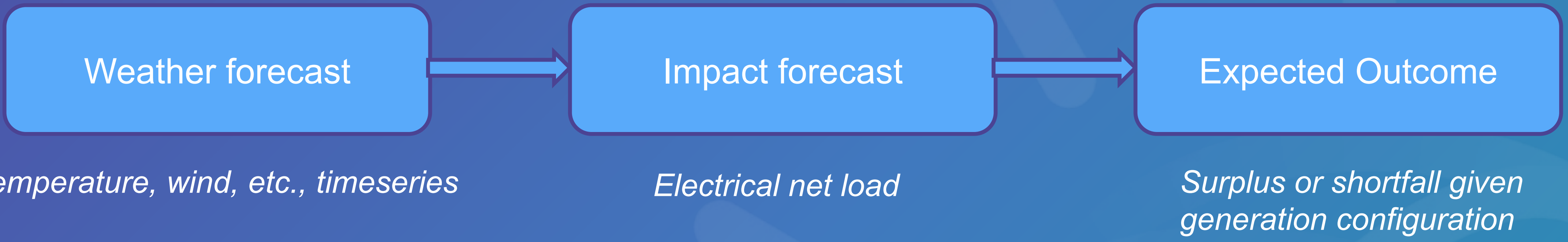
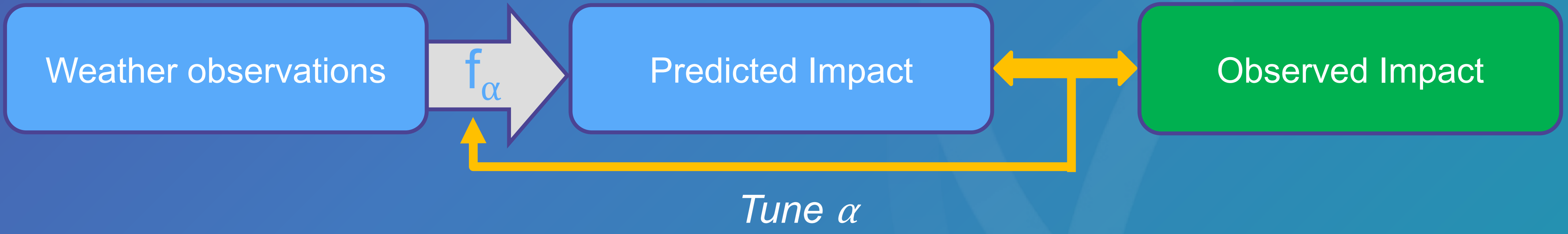
Weather-Dependent Impact and Outcome Modeling



- Impact and outcome models can be trained from historical data ("perfect prog"), e.g., via machine learning



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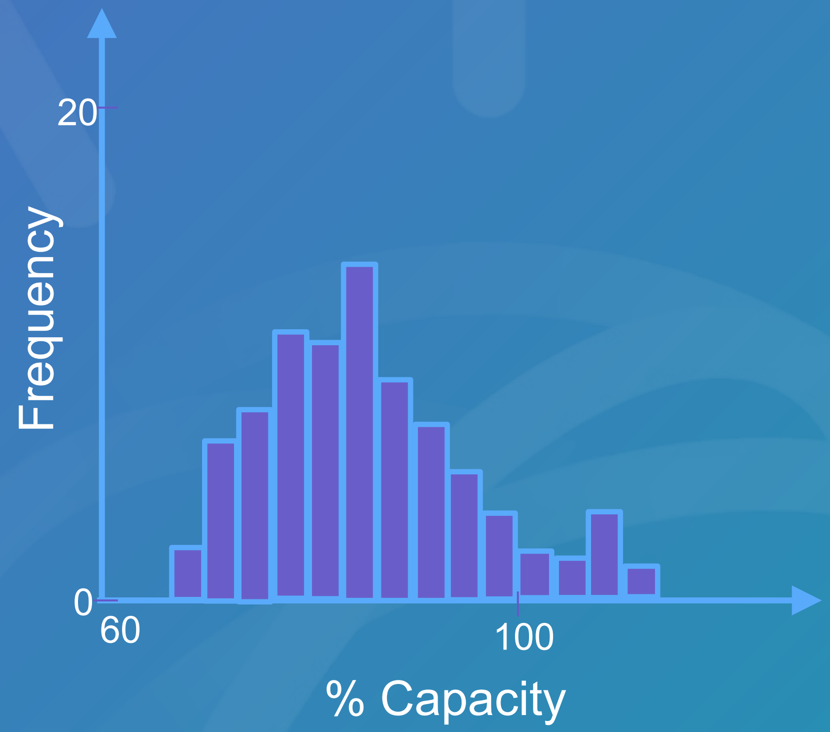
Example: Add Generation Capacity?

Impact model determined from machine learning

Weather scenario*	Impact 1: Net energy use (load)	Impact 2: % capacity
Prototype Forecast #1	5,230 MW	89%
Prototype Forecast #2	6,013 MW	102%
Prototype Forecast #3	4,046 MW	69%
…		
Prototype Forecast #100	4,983 MW	84%

* Weather scenarios include temperature, cloud cover, precipitation and wind timeseries at sample locations in service area.

Impact summary:



3 pm on July 13: 10 of 100 = 10% of prototypes indicate load exceeding generation capacity

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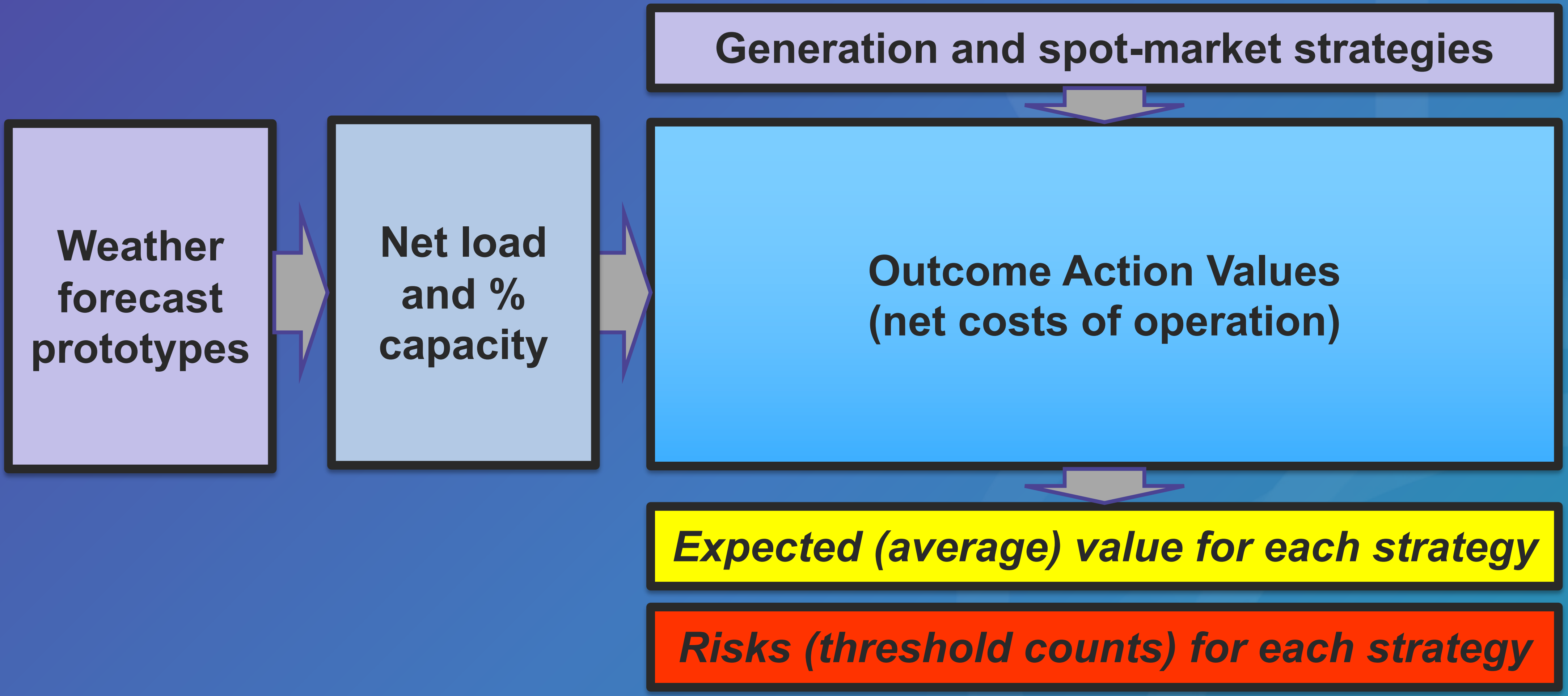
Example: Adding Generation, cont.



Decision = strategy that minimizes average net operational costs with risk of blackout << 1%

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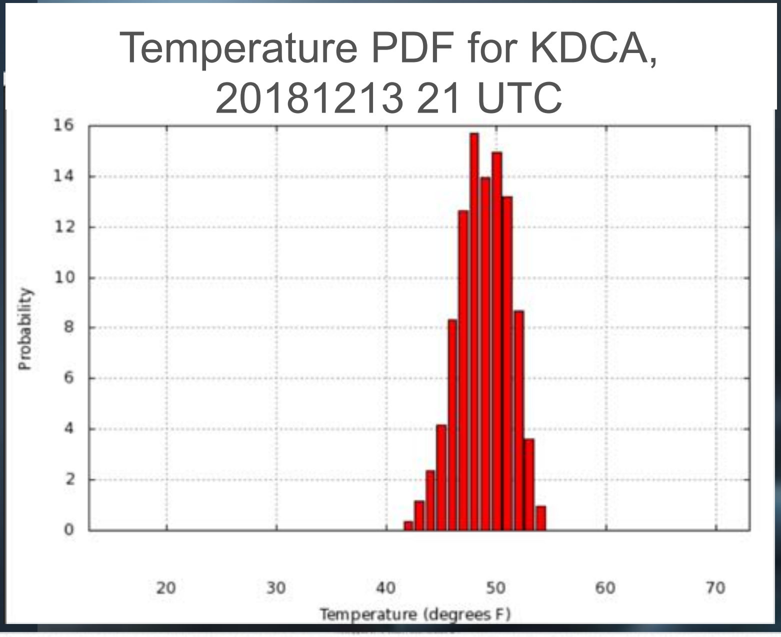
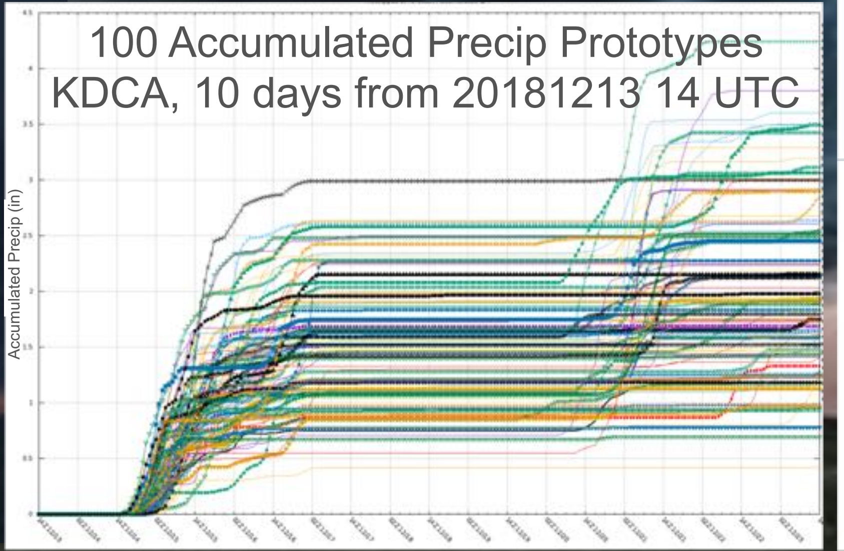
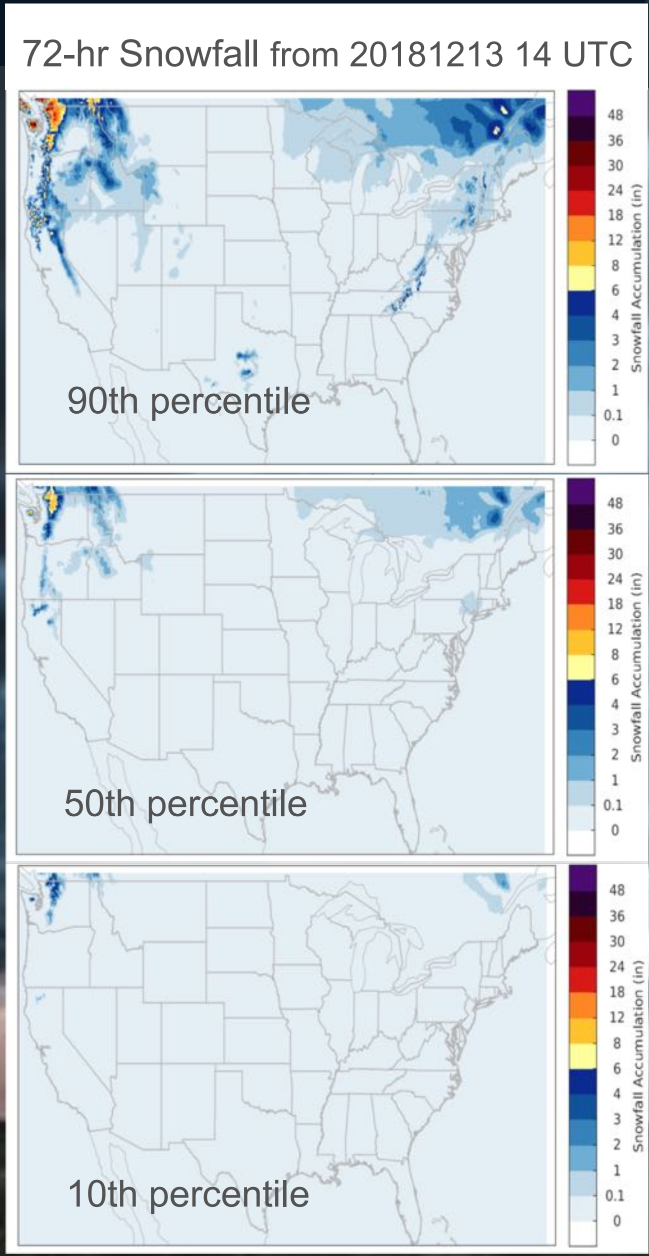
Probabilities on Demand from TWC/IBM

- Based on multi-model ensemble
- Standard meteorological variables (T, Td, RH, wind, QPF, snow…)
- 0-10 day + seasonal
- On demand locations and temporal aggregations
- Probabilistically calibrated
  - Collective event frequencies match forecast probabilities
- Distributed via API as:
  - Discrete PDFs (histograms)
  - Percentiles
  - Time/space coherent equal likelihood "prototypes" (scenarios) consistent with the calibrated probabilities







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Summary: Opportunities for AI

Creating Consistent, Representative, Calibrated Scenarios (prototypes)

Determining Weather-Action-Outcome Relationships

Optimizing and Communicating Decisions

Many challenges remain, particularly for short-term and extreme event forecasts!

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