The Utilization of Current Forecast Products in a Probabilistic Airport Capacity Model

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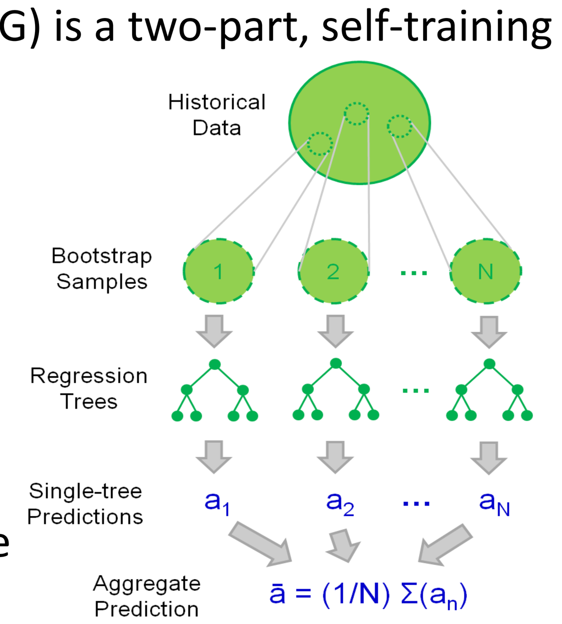
Background

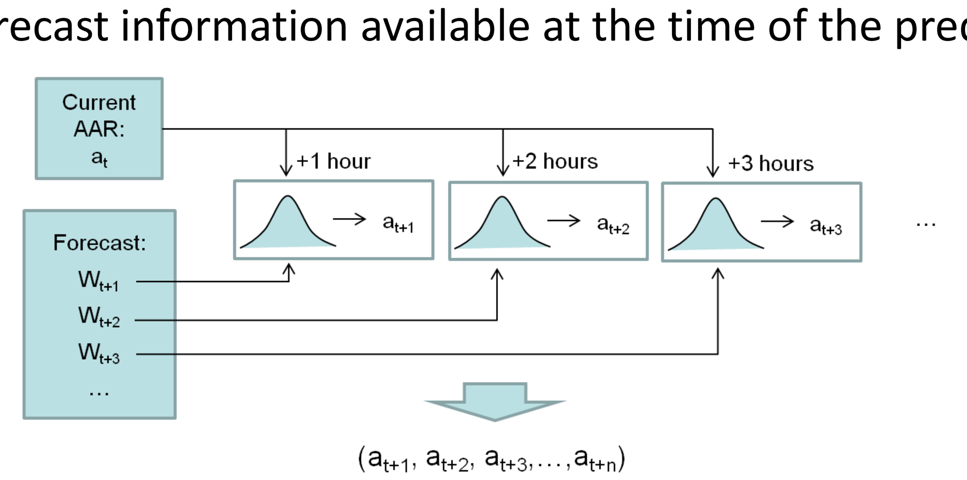
- Approximately 70% of flight delays and cancellations in the National Airspace System (NAS) are caused by severe weather.
- The skill of current forecast products has increased in recent years, but improvements are still needed in both the tactical (1-2 hours) and strategic (3-8 hours) time frames.
- This deficiency was apparent while developing a weather translation model that integrates a weather forecast and its inherent uncertainty to produce a probabilistic prediction of the weather's impact on NAS operations.
- Our weather translation model focuses on predicting the airport arrival rate (AAR) in the presence of weather for the purpose of planning Ground Delay Programs (GDP). A GDP is a traffic management initiative (TMI) where aircraft are delayed at their departure airport in order to manage demand at a capacity constrained airport.
- The model was developed using weather and airport configuration data between 2008 and 2010 from Newark Liberty International Airport (EWR) and O'Hare International Airport (ORD).

Model Overview

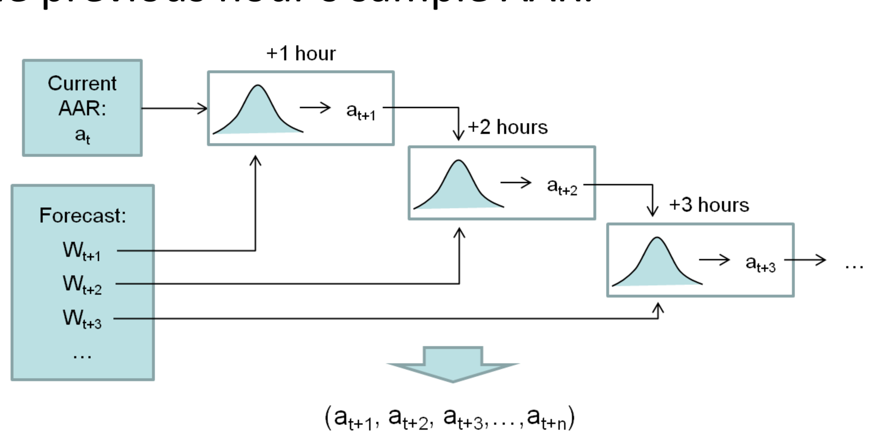
- The Weather Translation Model for GDP Planning (WTMG) is a two-part, self-training statistical model built using MATLAB's *TreeBagger* class.
  - Prediction Model: Trained with historical weather forecasts and observed AARs, a bootstrapped regression tree methodology is used to create deterministic AAR predictions.
  - Sampling Model: Builds an empirical error distribution around each deterministic AAR prediction and creates a set of capacity scenarios from the current time period to ten hours into the future.



- WTMG runs in two modes:
  - Static Mode – generates each future hour's probabilistic AAR prediction based on the forecast information available at the time of the prediction.



  - Dynamic Mode – generates each future hour's probabilistic AAR prediction based on the previous hour's sample AAR.



Weather Forecast Products

- As a part of the input dataset, WTMG is run using one of the following two operational forecast products:

1. **Localized Aviation MOS Product (LAMP)**
   Type: Deterministic/Probabilistic
   Forecast Horizon: 24 – 25 hours
   Domain: Terminal Area
   Temporal Resolution: 1 hour
   Issuance: Hourly
   Forecast Fields: temperature, dewpoint, wind: direction, speed, and gust, visibility, conditional visibility, ceiling height, conditional ceiling height, sky cover, obstruction to vision, thunderstorm: deterministic and probabilistic (2 hours), and probabilities of precipitation (6 hours), freezing precipitation, and snow

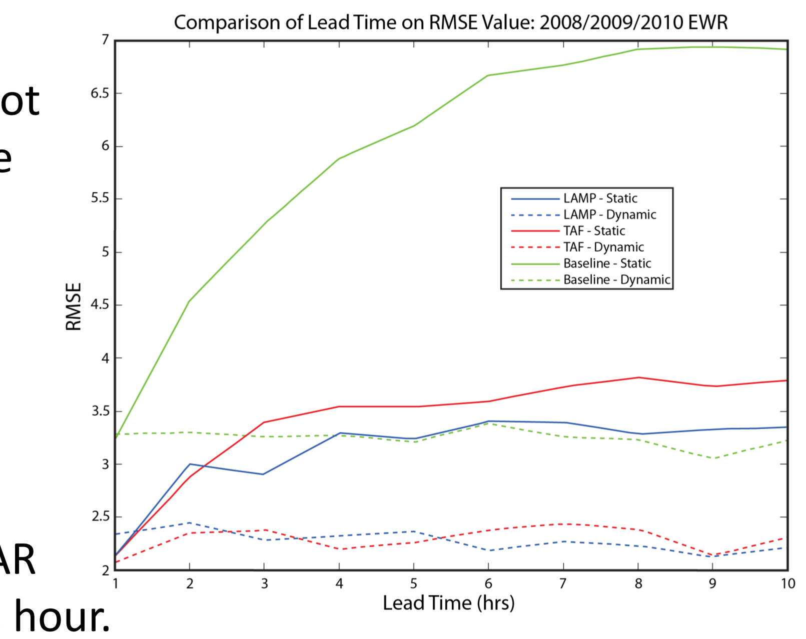
2. **Terminal Aerodrome Forecast (TAF)**
   Type: Deterministic
   Forecast Horizon: 24 – 30 hours
   Domain: Terminal Area
   Temporal Resolution: up to 1 hour
   Issuance: Every 6 hours (00, 06, 12, and 18 UTC)
   Forecast Fields: visibility, ceiling, wind: direction, speed, and gust, and significant weather

- Most forecast fields are able to be used in their present condition, but a number of LAMP and TAF forecast fields required additional processing to convert into a useable format for WTMG.
  - LAMP Sky Cover, Obstruction to Vision, and Precipitation Type: Converted to numerical values based on severity.
  - LAMP & TAF Wind Speed and Gust fields: Organized into subjective categories based on the distribution of all wind forecasts.
  - TAF Ceiling and Visibility: Forecasts were organized into the same categories used for the LAMP forecasts.
  - TAF Significant Weather: Often times, multiple weather factors are forecast for a given time period. To account for this, multiple factors were filtered to only one using an order of severity.

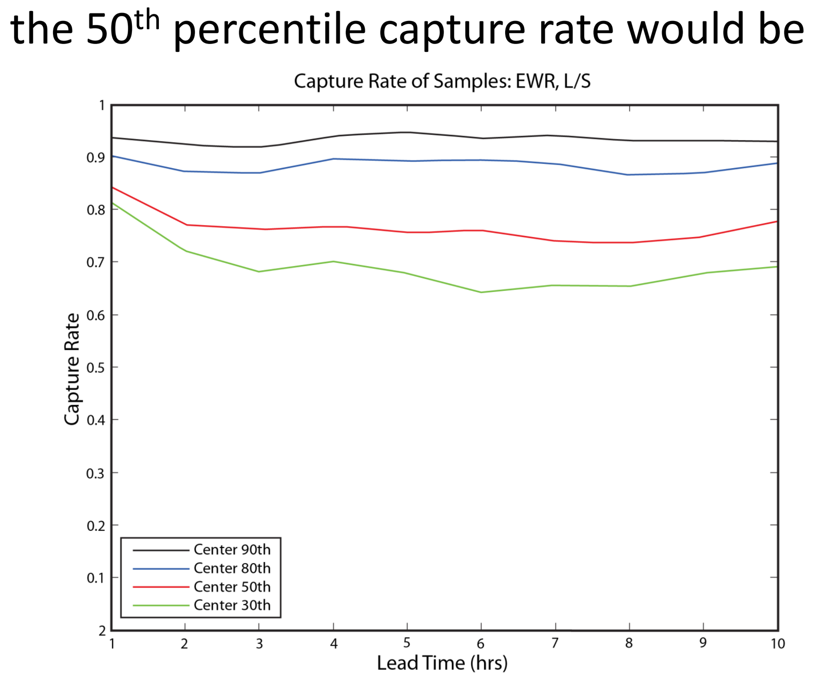
Order of Severity	
1 – Tornado	9 – Ice Pellets
2 – Thunderstorm	10 – Rain
3 – Squalls	11 – Fog
4 – Blowing Snow	12 – Drizzle
5 – Snow	13 – Mist
6 – Freezing Rain	14 – Smoke
7 – Freezing Drizzle	15 - Haze
8 – Freezing Fog	

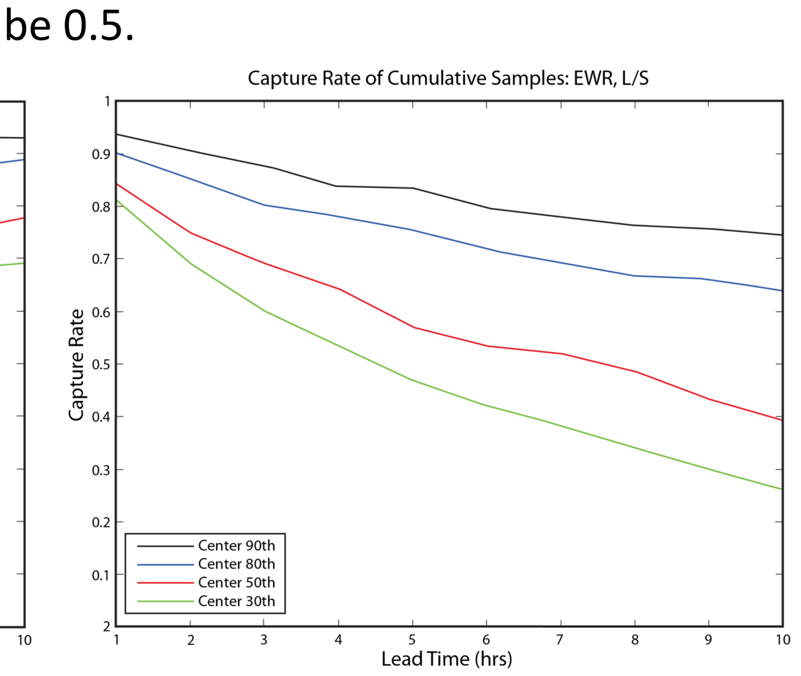
Results

- Four different versions of the WTMG model were built and tested based on the two different modes and forecast products: LAMP/Static, LAMP/Dynamic, TAF/Static, and TAF/Dynamic
- The primary metric used to evaluate the prediction model within WTMG is the root mean squared error (RMSE) between the predicted AAR and the actual AAR.
- Two baseline RMSEs were computed to quantify the benefits of WTMG:
  - *Baseline – Static*: The predicted AAR is equal to the actual AAR at the time of the forecast.
  - *Baseline – Dynamic*: The predicted AAR is equal to the AAR from the previous hour.



- To evaluate the uncertainty generated by the sampling model, two methods were used:
  - *Capture Rate*: Finds the frequency that the actual AAR was captured in the central x-th percentile of the sample AARs at each leadtime n.
  - *Cumulative Capture Rate*: Finds the frequency that the cumulative actual AAR was captured in the central x-th percentile of the cumulative sample AARs through leadtime n.
- For a perfect error distribution, the capture rate must match the percentile; e.g., the 50th percentile capture rate would be 0.5.





Conclusions, Improvements & Future Work

- Current weather forecast products provide the WTMG with satisfactory information, but enhancements are necessary.
- The TAF is not detailed enough to adapt to fast-changing weather events and the lack of spatial resolution in the LAMP does not allow it to account for any weather that is occurring beyond the terminal area.
- A number of important model improvements have been found to be necessary through this research, especially for future TFM work:
  - Improved probabilistic weather forecasts.
  - Higher resolution thunderstorm forecasts both spatially and temporally.
  - Advanced model physics and algorithms than can accurately parameterize mesoscale phenomena around the terminal area.
  - Higher resolution forecasts in the terminal area.
- Future work includes further refining the WTMG model to effectively utilize current forecast products and the integration of the experimental gridded LAMP products as well as LAMP Convection. This may help provide the necessary weather information in the surrounding terminal area that can improve airport arrival capacity predictions.

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