Utilizing weather information in improving arrival flight time prediction in the terminal area

Hong Kong, China

2021 MET-ATM Webinar and MET/R WG/10

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Introduction

- Flight arrival delay could bring significant impact to air traffic and airline operations as it would affect the fuel planning, ground operations, turnover of planes, and other unnecessary operations
- One of the key factors contributing to flight delays is significant convective weather conditions
- This study attempts to examine the relationship between flight arrival time, fuel consumption and weather condition over the Hong Kong International Airport (HKIA) and the Hong Kong Flight Information Region (HKFIR).

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Dataset utilized in the study

- Flight dataset
  - Over 60,000 sets of data of the arrival flights of Cathay Pacific Airlines (CPA)
  - Data period: 2019
  - Data includes landing time, departure airport, aircraft type, landing runway, planned entry waypoint, **A150 figures**, etc
  - The **A150 figures** are the planned and actual *fuel* used, *time* used, and the *distance* an aircraft travelled after entering the range of 150 nautical miles (around 280 km) from HKIA
- Observations at HKIA: METAR/SPECI
- Aerodrome forecasts at HKIA: TAF

**METAR/SPECI and TAF prepared by Airport Meteorological Office at HKIA*

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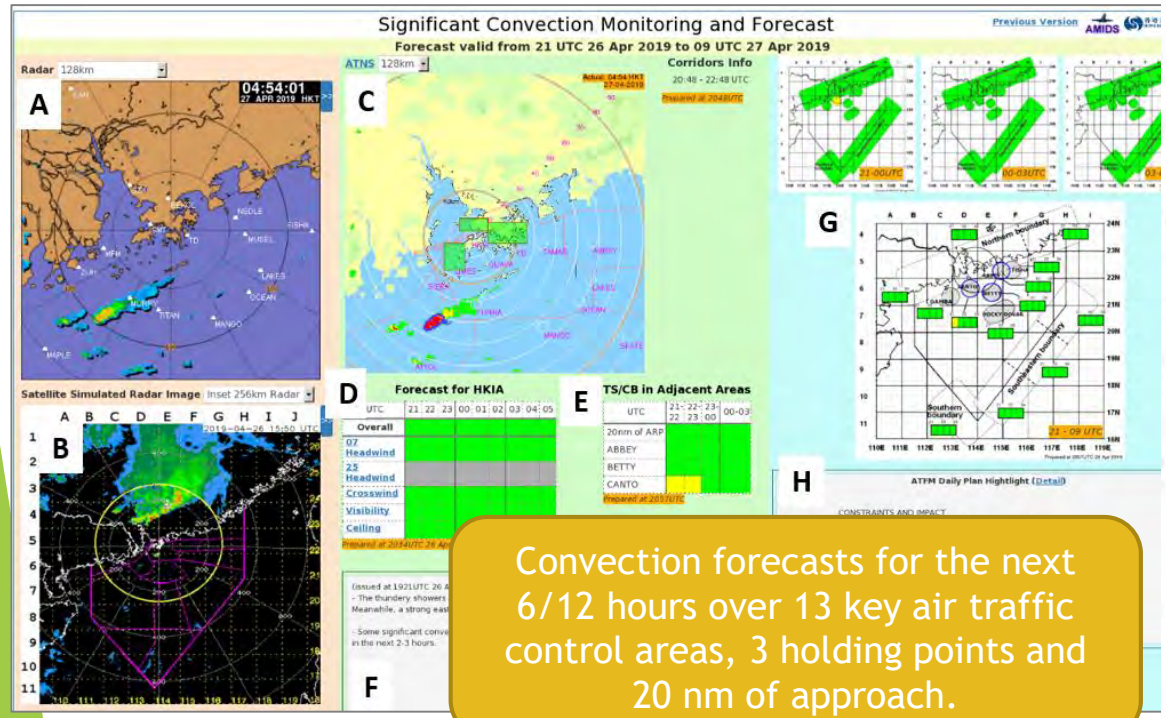
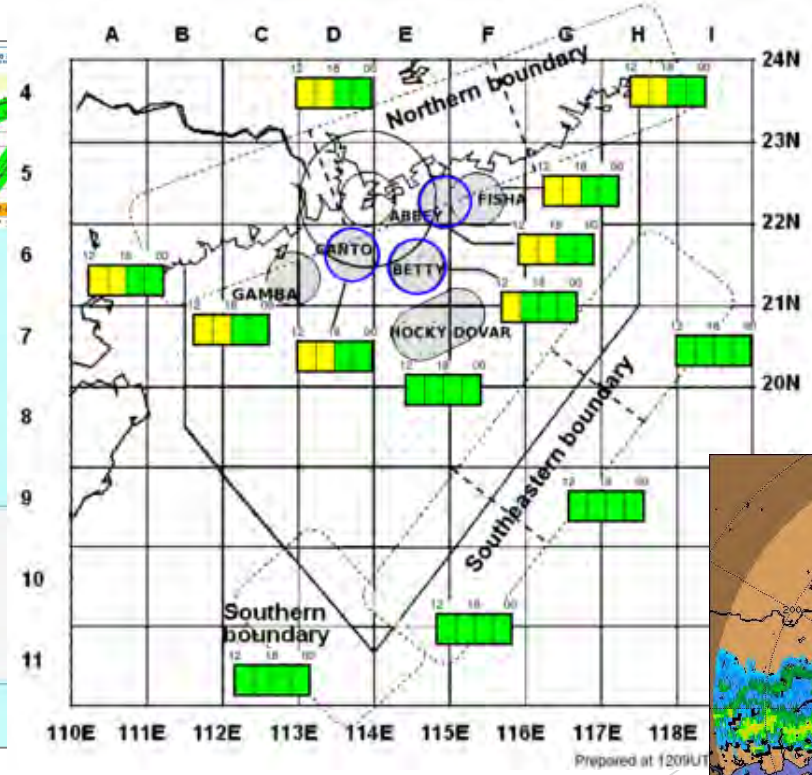
Dataset utilized in the study

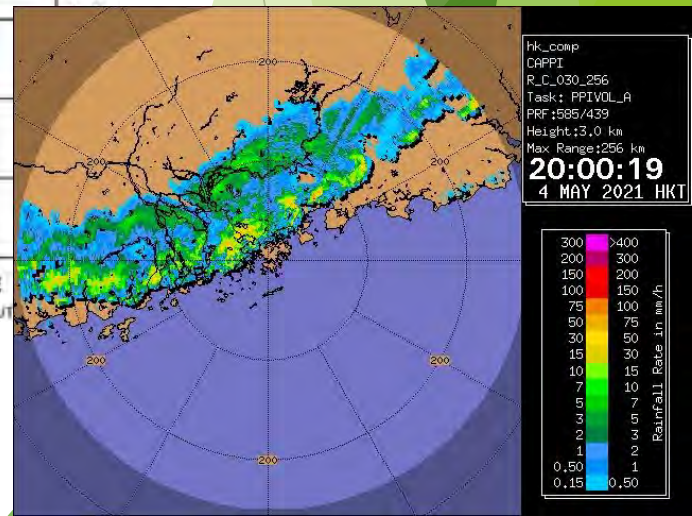
Three colour coded forecasts (green/yellow/red) indicating different levels of chance (low/medium/high) of significant convection

- Tailored Meteorological Services for Terminal Area (MSTA) product
  - Significant Convection monitoring and forecast (SIGConv)



Convection forecasts for the next 6/12 hours over 13 key air traffic control areas, 3 holding points and 20 nm of approach.





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Further details about SIGCov can be found in MET/R TF/3 WP/07

Weather Correlation study --- TAF

- Significant convective weather associated with showery or thunderstorms in the vicinity of the aerodrome are one of the key factors that could affect air traffic significantly
- Parameters related to significant convective weather (i.e. SHRA/TSRA) in TAF issued 12 hours before the landing time of flight were used to classify into different weather scenarios

TAF	No. of flights	Time deviation (mins)	Fuel deviation (%)
Nil	4520	3.22	30.26
Before	1117	3.03	33.81
Experiencing	3344	5.62	44.64
After	679	5.85	46.40
Between	848	6.93	53.60

Lead-lag time classification for each flight		
Nil		The flight experienced no weather
Before	B	The flight landed at most 12hr before weather
Experiencing	C	The flight landed during weather
After	D	The flight landed at most 6hr after weather and there is no weather within 12hr after the weather
Between	E	The flight landed between two weather

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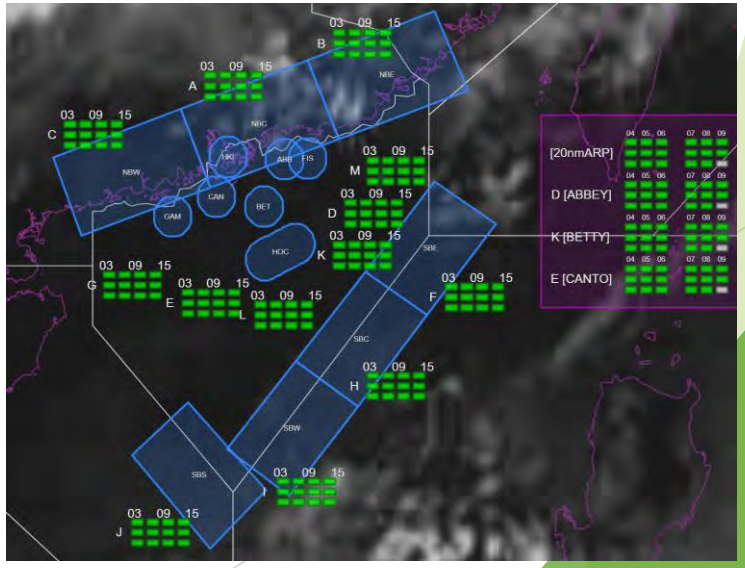
$$Fuel\ Deviation = \frac{Actual\ fuel\ used - CPA\ planned\ fuel}{CPA\ planned\ fuel}$$

$$Time\ Deviation = Actual\ time\ used - CPA\ planned\ time$$

Weather Correlation study --- SIGConv

- The MSTA SIGConv contains hourly significant convective weather forecasts over the 3 holding points and 20 nm of approach in the next 6 hours
- In this analysis, forecasts with lead time of 2 hours before the landing time were utilized

No. of areas having Yellow or Red signal	No. of flights	Time deviation (mins)	Fuel deviation (%)
0	9090	3.72	34.32
1	508	7.55	54.69
2	426	10.59	72.22
3	158	12.92	78.39
4	94	15.99	98.99



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Prediction model

- Focus on predicting the A150 flight time for short-haul flights with flight time < 4 hours
  - Fuel planning ~2 hours before the flight departs
  - Input weather data used in the prediction model would be 6 hours before the flight landing time
- Aircraft and meteorological features spanning from flight data, meteorological observations to weather forecasts were selected for training the machine learning model
- The flight data used include the landing time, entry way points, aircraft type and CPA planned time. Meteorological observations used include METAR/SPECI, TAF, and SIGConv over the areas/points.

Plan_A150_Time_min	30.26
month	4
date_of_month	18
day_of_week	3
hour_of_day	21
DOTMI	0
DULOP	1
ELATO	0
IKELA	0
LELIM	0
NOMAN	0
SIERA	0
SIKOU	0
A320	0
A321	0
A330	0
A350-1000	0
A350-900	0
B747-400	0
B747-8F	0
B777-200	0
B777-300	0
B777-300ER	1
obs_HKIA	0
obs_ABBEY	0
obs_BETTY	0
obs_CANTO	0
f1h_HKIA	1
f1h_ABBEY	0
f1h_CANTO	0
f1h_BETTY	0
f3h_ABBEY	0
f3h_BETTY	0
f3h_CANTO	0
f3h_FISHA	0
f3h_GAMBA	0
f3h_HOCKY	0
taf_pm3_TSRA	1
taf_pm3_SHRA_num	3
taf_pm6_TSRA	1
taf_pm6_SHRA_num	3
metar_m6_SHRA_num	0
metar_m6_TSRA_num	0

Extract of the feature selected for a particular aircraft

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Results

	RMSE (mins)	RMSE_g20 (mins)	85 Percentile (mins)
CPA Plan Time	8.85	28.02	11.76
XGBoost model	4.6	10.72	4.42

- The performance of CPA plan time and the XGBoost model predicted time compared against the actual A150 time
- Evaluation metrics were the root mean squared error (RMSE), RMSE for flights delayed longer than 20 minutes (RMSE_g20) and the 85th percentile; the latter two were introduced to evaluate the performance of the model in predicting cases with large time deviation (i.e. higher impact to operations)
- XGBoost model performed better than the CPA plan time. The CPA plan time had a RMSE > 8 minutes while the XGBoost model was generally <5 minutes. The figure for the higher impact cases even dropped significantly from 11-12 mins to 4-5 mins.
- Analysis on the feature value contributions suggested that apart from landing time or weekday, the entry waypoint, **the prediction of convective weather from TAF** and **SIGConv forecasts** over the holding points had high contributions to the improved flight time prediction

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Discussion

- This paper showcases the initial use of Artificial Intelligence (AI), i.e., a machine learning model, for studying weather impact, viz. flight time prediction for arrival flights to HKIA.
- Limitations of the study, including: lack of information on the air traffic condition, flight restriction imposed over the area, etc.
- The study results showed that by utilizing the meteorological information (METAR, TAF, and MSTA SIGConv in this case), it was feasible to construct an impact-based forecasting product using AI technology to help predict the arrival time and consequentially improve airline operations such as flight time prediction or fuel planning that may better serve the airline users.

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Thank you for your attention!

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