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CIVIL AVIATION DEPARTMENT

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HONG KONG OBSERVATORY

Probabilistic Forecast of Runway Headwind Changes or Supporting Estimation of Airport Acceptance Rate

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Discussion topics

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The Hong Kong International Airport (HKIA)

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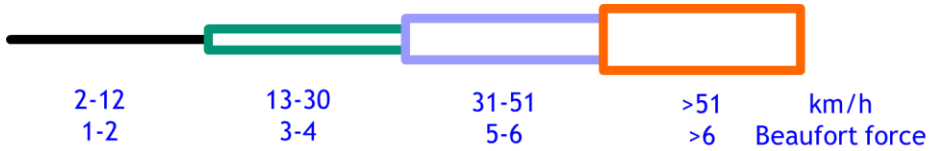
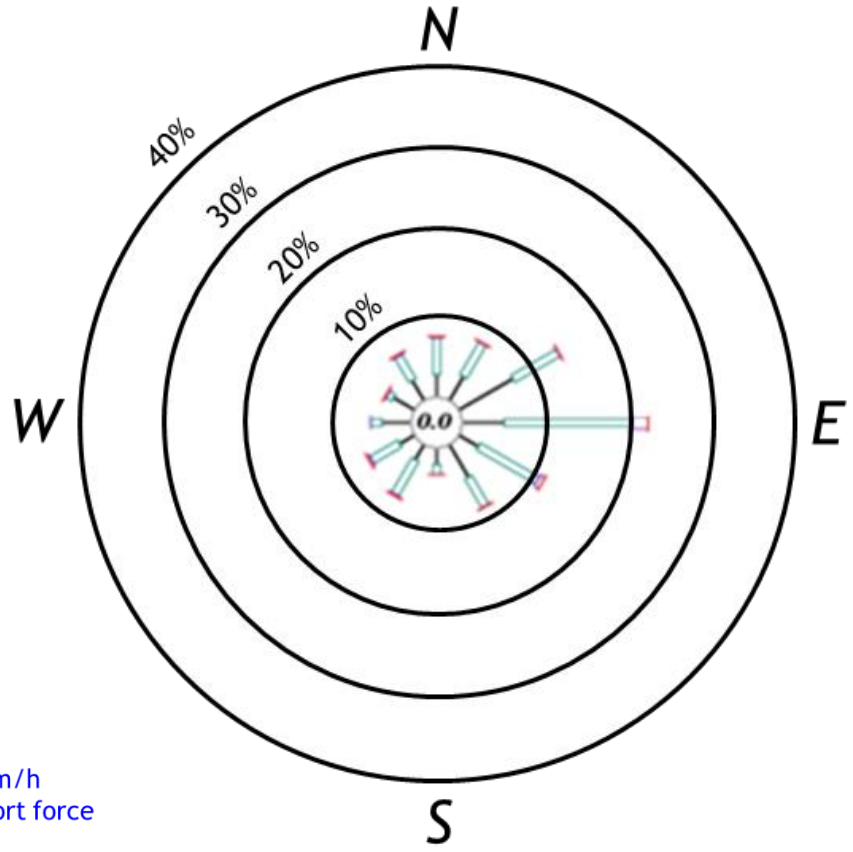
Wind statistics at HKIA

Annual wind roses for
Chek Lap Kok, 1998-2023





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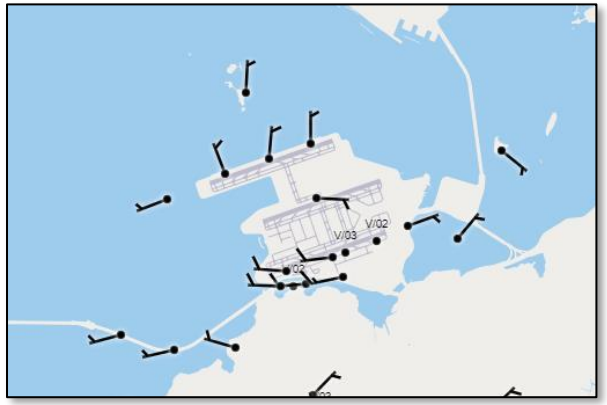
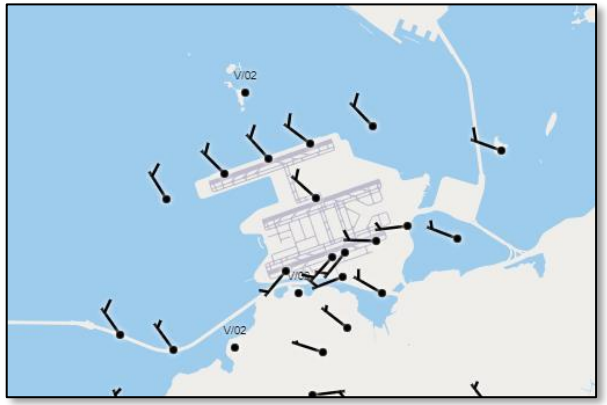
Three types of sea breeze at HKIA

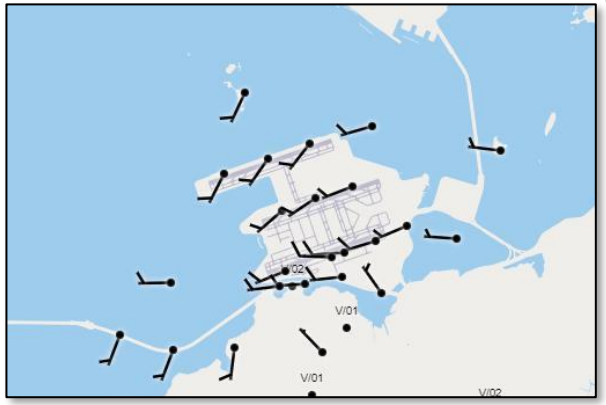
- Cheng, C. M. (1999) classified three types of sea breeze at HKIA



Type I:
local sea breeze circulation at Chek Lap Kok resulting from winds converging from all directions of the airport.



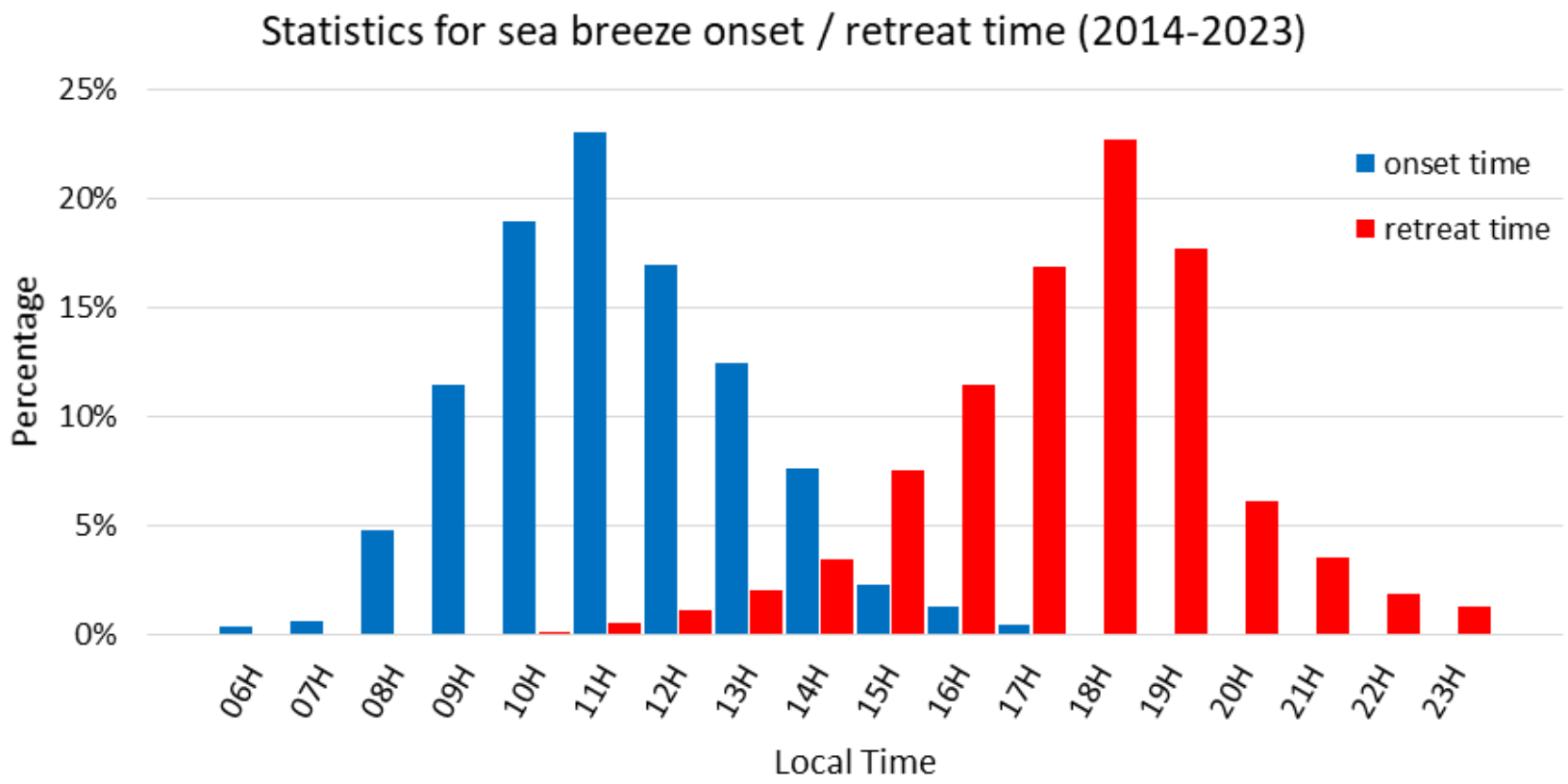
Type II:
winds converging to Lantau Island resulting in north to northwesterly winds on the runway sites.



Type III:
larger scale circulation with west to southwesterly winds flowing from Chek Lap Kok to the mainland of Hong Kong.

Note: Although there was land reclamation over the northern part of the Chek Lap Kok from May 2018 due to construction of the third runway at HKIA, observations showed that the characteristics of sea breeze, particularly its onset and retreat times, as well as its general pattern, remained similar with historical data.

Sea breeze statistics



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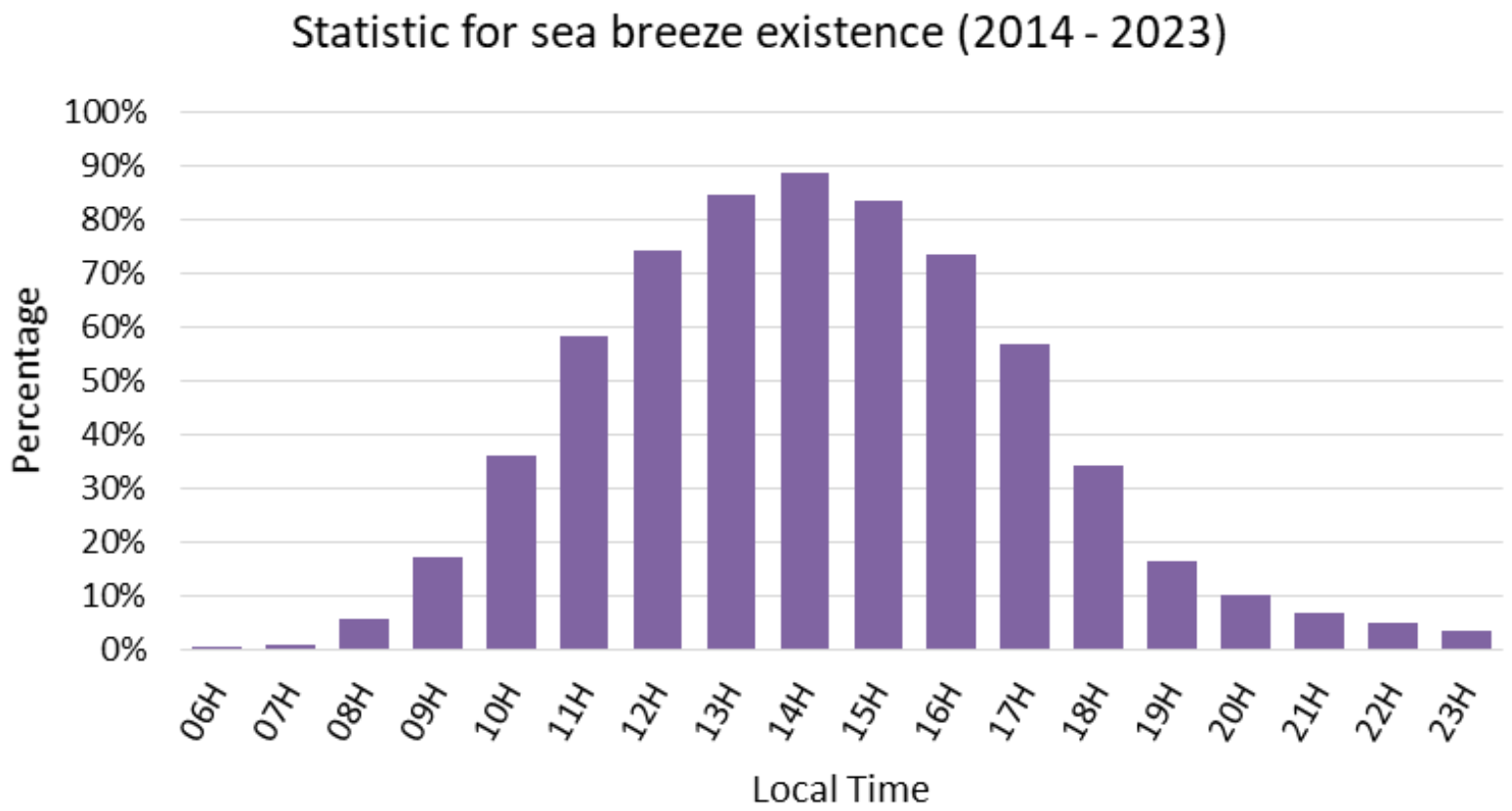
Sea breeze statistics



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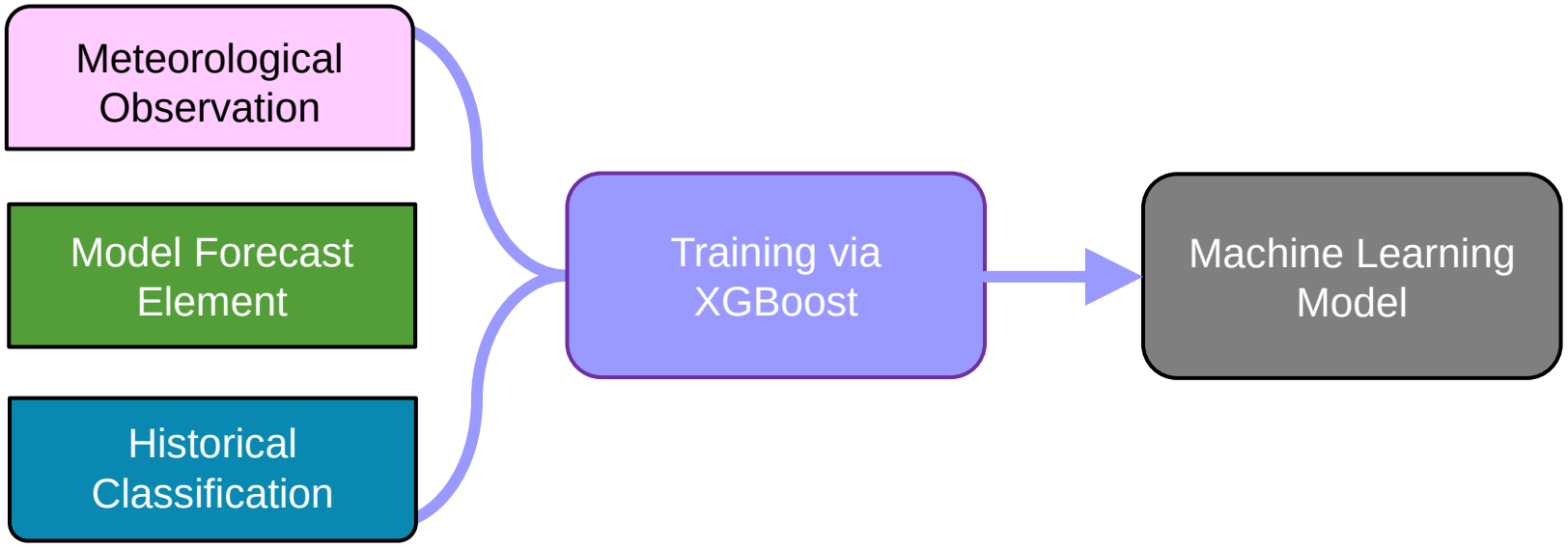
Methodology



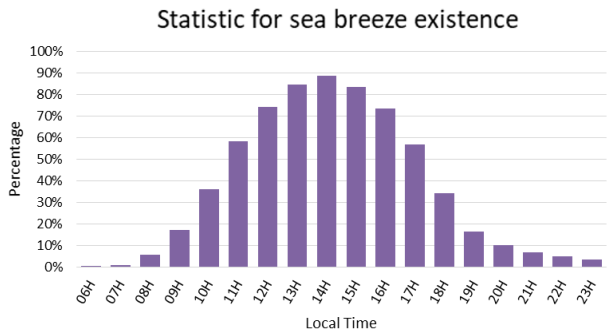
Training Period: 2017-2022

Observations and Model Forecast Elements

Observations at 05:00 Local Time	Model Forecast Data
Month of the date	
Sea surface temperature	
Pressure at the airport	Total cloud amount
Airport temperature	Airport temperature
Wind speed at the airport	Wind speed around the airport
Wind direction at the airport	Wind direction around the airport
Wind speed at other stations	Wind speed at other stations
Wind direction at other stations	Wind direction at other stations

Methodology

Observations at 05:00 Local Time	Model Forecast Data
Month of the date	
Sea surface temperature	
Pressure at the airport	Total cloud amount
Airport temperature	Airport temperature
Wind speed at the airport	Wind speed around the airport
Wind direction at the airport	Wind direction around the airport
Wind speed at other stations	Wind speed at other stations
Wind direction at other stations	Wind direction at other stations



Training via XGBoost

Machine Learning Model

Training Period: 2017-2022

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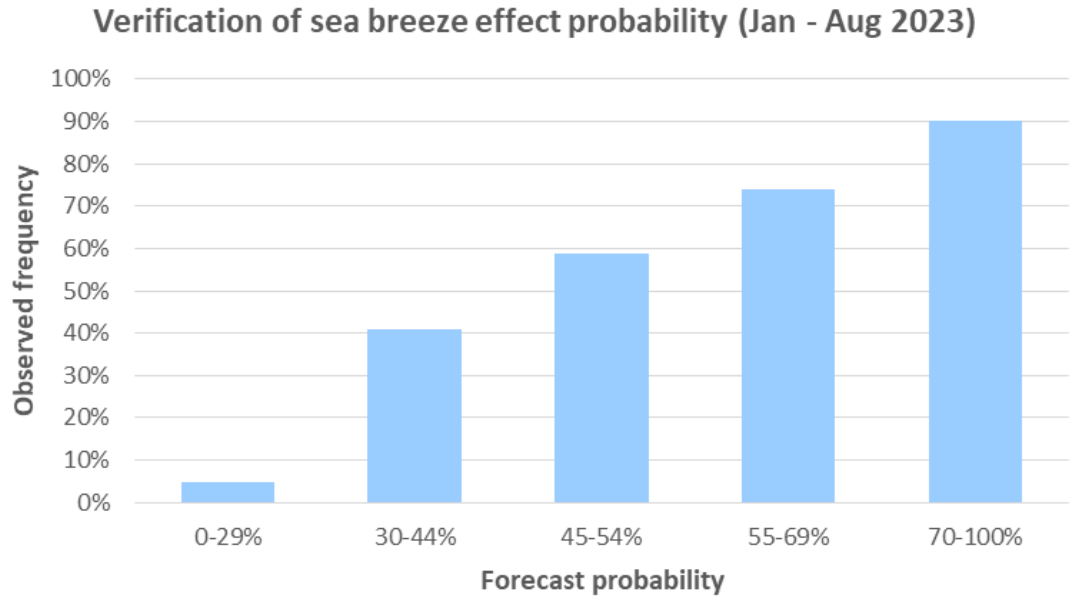
Verification

Against Jan 2023 - Aug 2023 observations



	0-29%	30-44%	45-54%	55-69%	70-100%
Total Data	6714	375	224	344	475

	Verification				
Threshold	15%	30%	45%	55%	70%
POD	0.88	0.75	0.63	0.53	0.33
FAR	0.46	0.32	0.22	0.17	0.10
CSI	0.50	0.56	0.54	0.48	0.32

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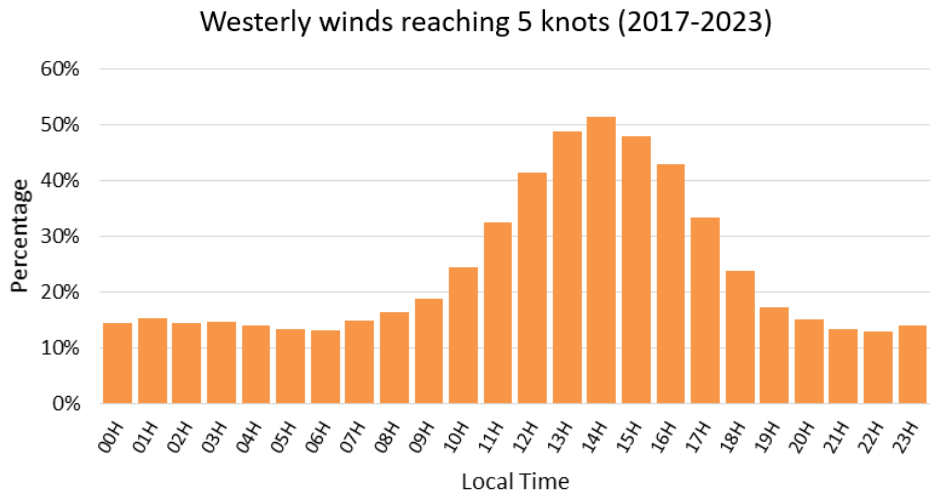
Westerly Head/Tailwind Reaching 5kts

- Wind Direction Influence
  - Aircraft landing direction is primarily determined by prevailing wind conditions.
  - For safety and operational efficiency, aircraft typically land against the wind.
- Key Considerations
  - This study focuses on the wind direction component that aligns with the runway orientation.
  - A critical threshold of a westerly headwind/tailwind at **5 knots** is used for this study.
  - Other than sea breeze, northeast monsoon, tropical cyclone, will also induce westerly breeze in HKIA.



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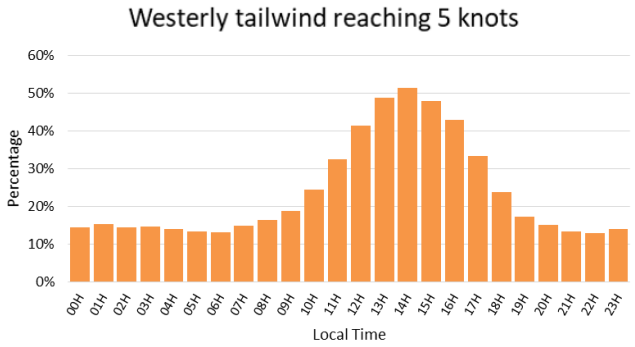
Methodology

Observations at 05:00 Local Time	Model Forecast Data
Month of the date	
Sea surface temperature	
Pressure at the airport	Total cloud amount
Airport temperature	Airport temperature
Wind speed at the airport	Wind speed around the airport
Wind direction at the airport	Wind direction around the airport
Wind speed at other stations	Wind speed at other stations
Wind direction at other stations	Wind direction at other stations



Training via XGBoost

Machine Learning Model

Training Period: 2017-2022

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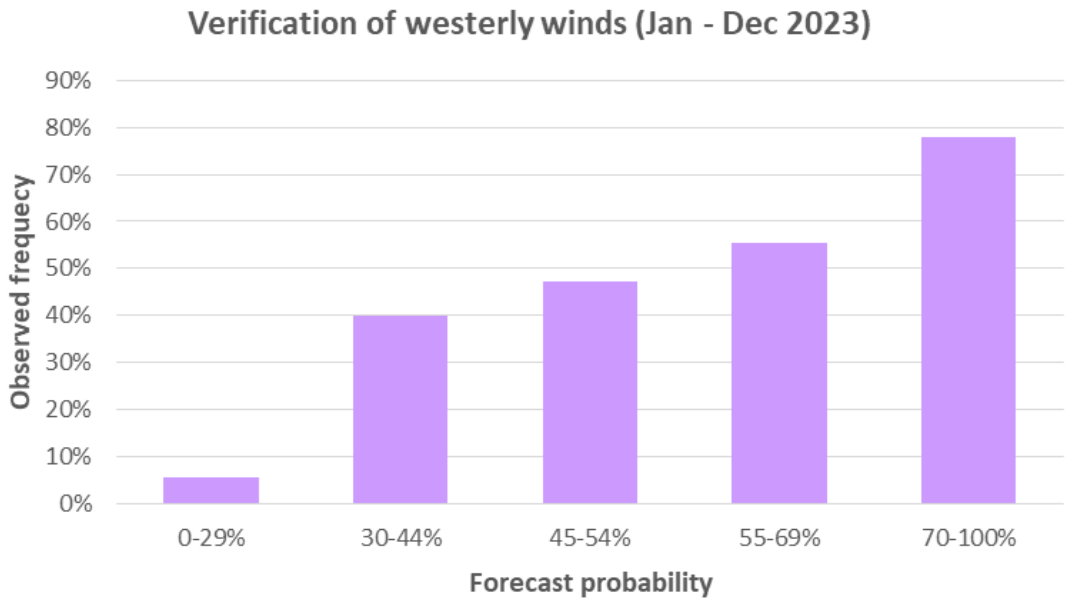
Verification

Against 2023 observations



	0-29%	30-44%	45-54%	55-69%	70-100%
Total Data	11123	881	537	874	2280

	Verification				
Threshold	15%	30%	45%	55%	70%
POD	0.93	0.82	0.72	0.65	0.51
FAR	0.47	0.37	0.32	0.28	0.22
CSI	0.51	**0.55**	0.54	0.52	0.44

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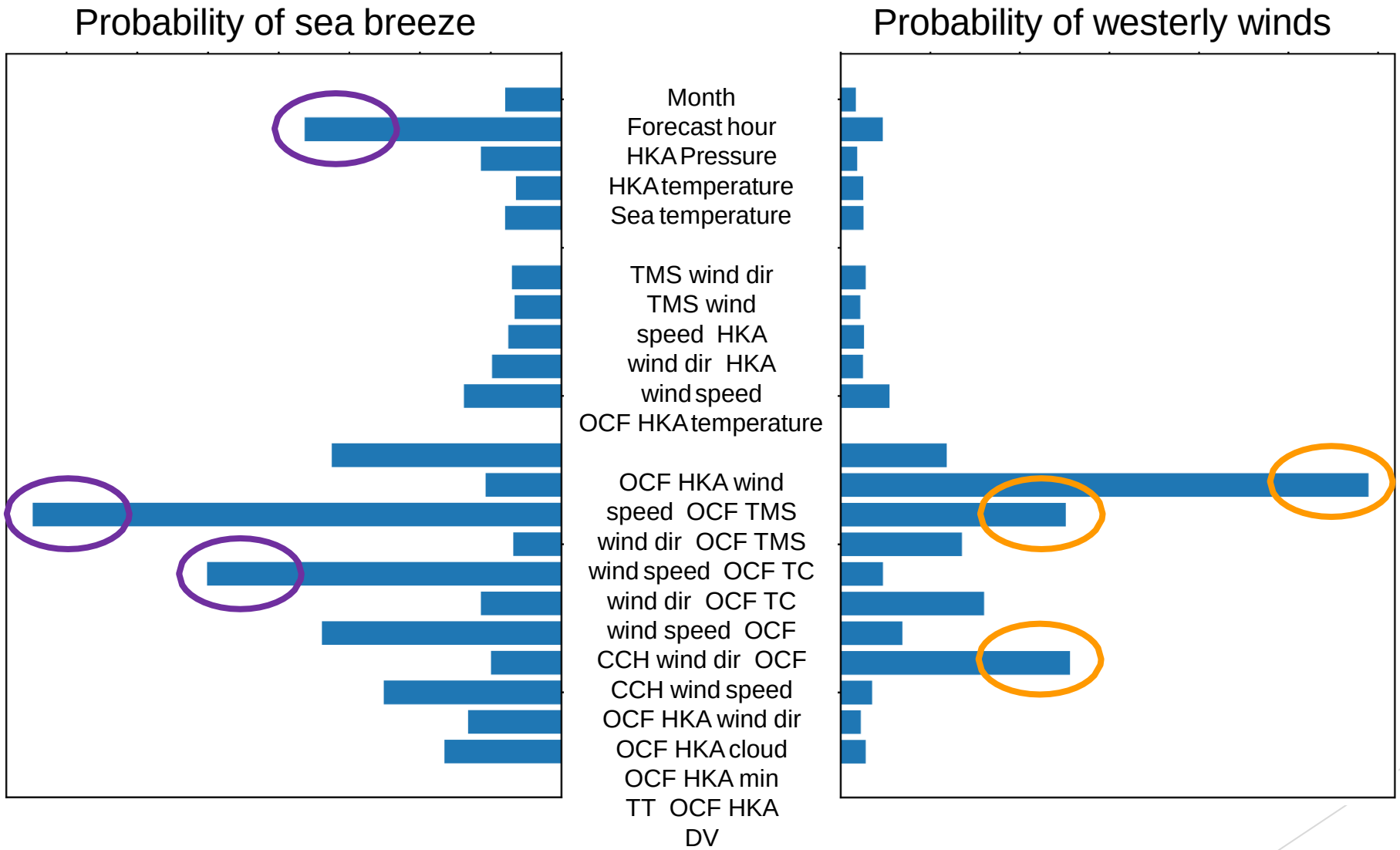
Importance Factors



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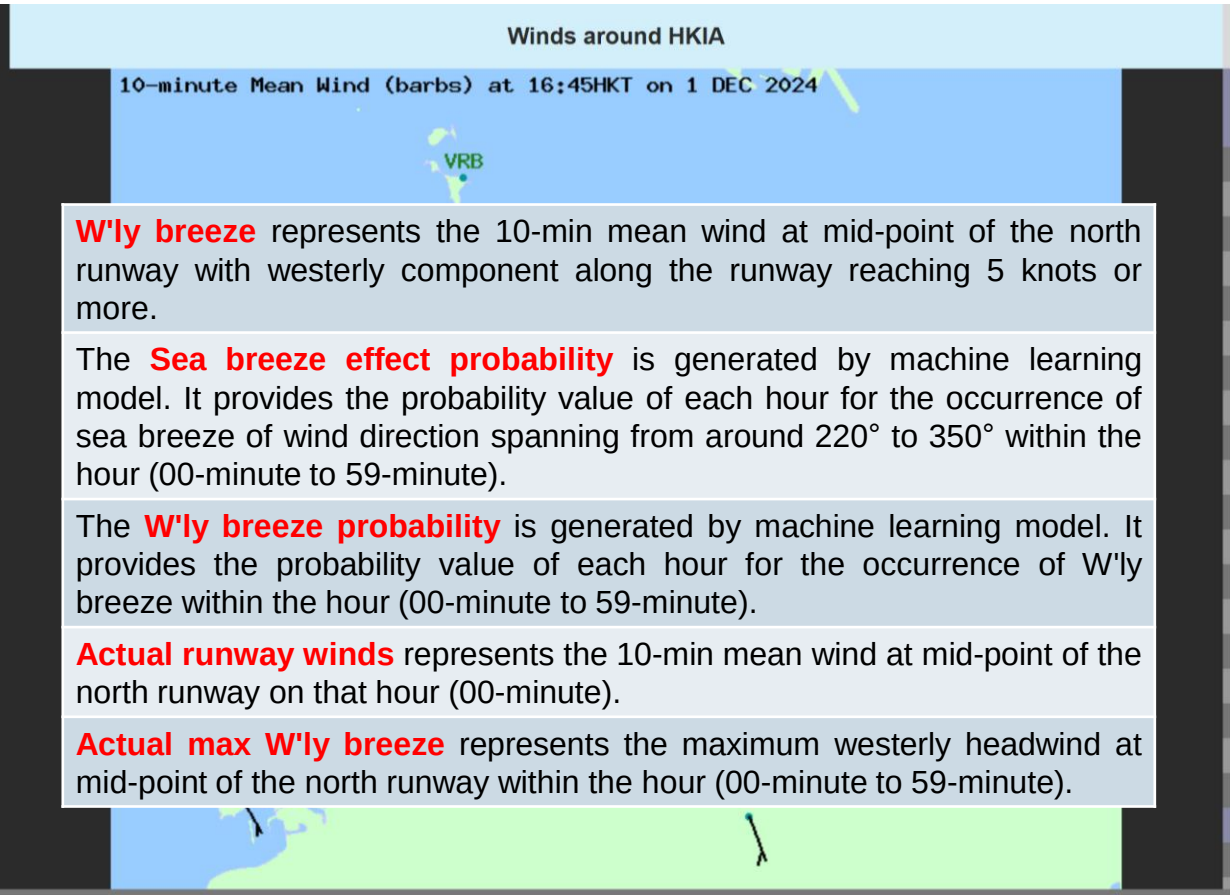
Hourly Probability of Westerly Sea Breeze for ATM



W'ly breeze represents the 10-min mean wind at mid-point of the north runway with westerly component along the runway reaching 5 knots or more.

The **Sea breeze effect probability** is generated by machine learning model. It provides the probability value of each hour for the occurrence of sea breeze of wind direction spanning from around 220° to 350° within the hour (00-minute to 59-minute).

The **W'ly breeze probability** is generated by machine learning model. It provides the probability value of each hour for the occurrence of W'ly breeze within the hour (00-minute to 59-minute).

Actual runway winds represents the 10-min mean wind at mid-point of the north runway on that hour (00-minute).

Actual max W'ly breeze represents the maximum westerly headwind at mid-point of the north runway within the hour (00-minute to 59-minute).

Westerly Sea-breeze Probability at HKIA

Time (20241201)	Sea breeze effect probability	W'ly breeze probability	Actual runway winds	Actual max W'ly breeze
05 HKT	N/A	N/A	123/5kts	Nil
06 HKT	N/A	N/A	093/5kts	Nil
07 HKT	N/A	N/A	116/6kts	Nil
08 HKT	N/A	N/A	093/4kts	Nil
09 HKT	N/A	N/A	065/7kts	Nil
10 HKT	N/A	N/A	079/6kts	Nil
11 HKT	N/A	N/A	052/6kts	Nil
12 HKT	N/A	N/A	021/4kts	3.7kts
13 HKT	N/A	N/A	285/4kts	5.1kts
14 HKT	N/A	N/A	278/6kts	6.5kts
15 HKT	N/A	N/A	281/6kts	5.3kts
16 HKT	66%	41%	271/5kts	4.8kts
17 HKT	51%	24%	N/A	N/A
18 HKT	34%	11%	N/A	N/A
19 HKT	23%	7%	N/A	N/A
20 HKT	14%	4%	N/A	N/A
21 HKT	11%	4%	N/A	N/A
22 HKT	9%	4%	N/A	N/A
23 HKT	6%	3%	N/A	N/A
(20241202)				
00 HKT	N/A	3%	N/A	N/A

Disclaimer:
The probability values are automatically generated by machine learning model without human intervention and only updated at around 06H and 18H every day for user's reference. There could be delay when computer model data is not available. No real time update is provided. Users are welcome to consult IAC Aeronautical Meteorological Advisors at 2188 9043 or AMO Aviation Forecasters at 2910 6920 for getting the latest assessment if necessary.

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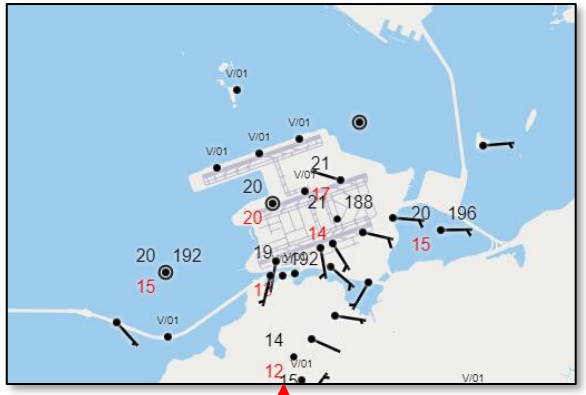
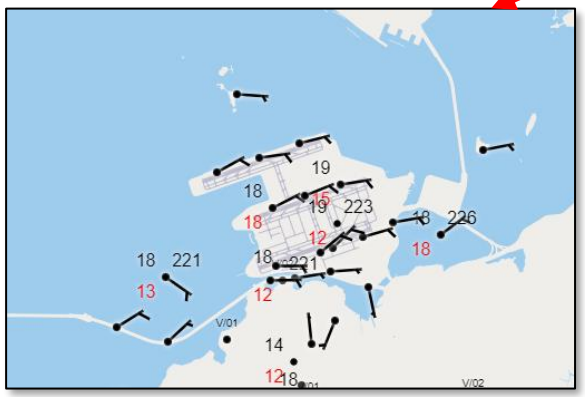
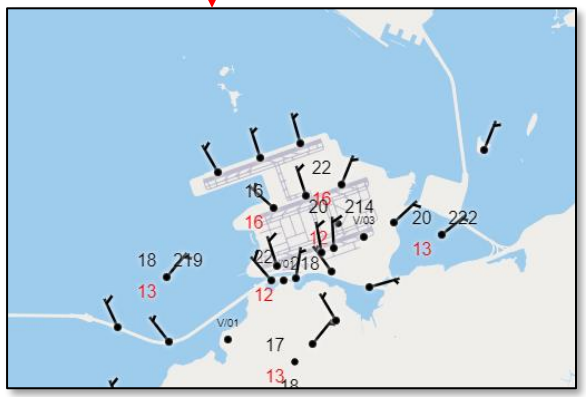
Case demonstration

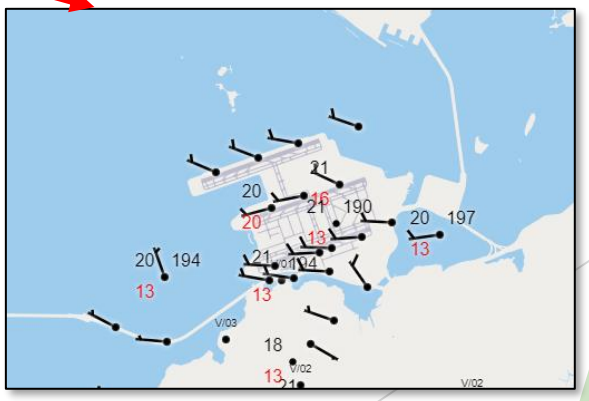
Forecast for 5 Jan 2024
Model run: 5 Jan 2024 available at around 06H



Forecast Hour (Local Time)	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Probability of sea breeze	2%	2%	2%	6%	29%	68%	88%	93%	93%	92%	87%	76%	48%	23%	18%	13%	11%	9%
Probability of westerly winds reaching 5 knots	1%	1%	2%	3%	10%	40%	74%	87%	85%	81%	68%	49%	18%	6%	6%	5%	4%	3%
Actual Max westerly winds within the hour (knots)	Nil	Nil	Nil	Nil	Nil	3.9	5.7	6.0	5.0	5.9	4.7	3.7	1.4	Nil	3.0	Nil	Nil	Nil







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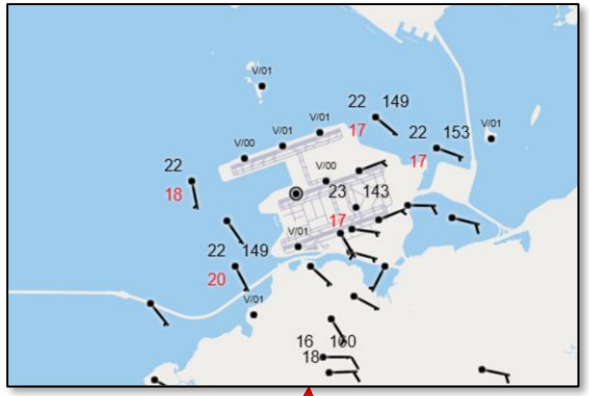
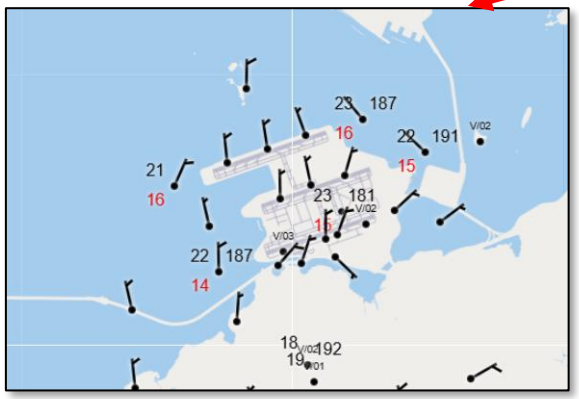
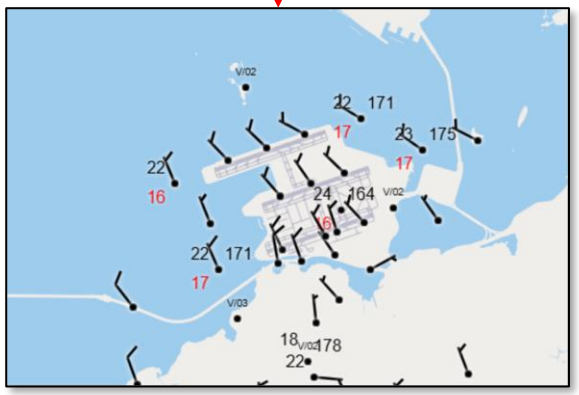
Case Demonstration

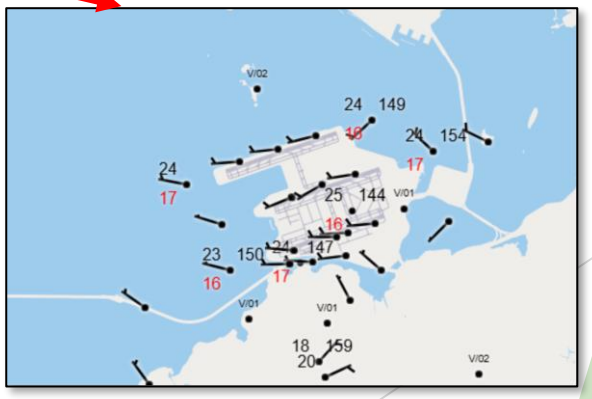
Forecast for 3 Dec 2024
Model run: 3 Dec 2024 available at around 06H



Forecast Hour (Local Time)	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Probability of sea breeze	1%	1%	2%	5%	14%	37%	75%	81%	83%	80%	75%	63%	24%	9%	4%	2%	1%	1%
Probability of westerly winds reaching 5 knots	0%	1%	1%	1%	3%	12%	55%	67%	71%	72%	61%	37%	7%	2%	1%	1%	1%	0%
Actual Max westerly winds within the hour (knots)	Nil	Nil	Nil	Nil	Nil	Nil	4.5	5.2	5.4	5.6	6.4	5.9	2.4	Nil	Nil	Nil	Nil	Nil







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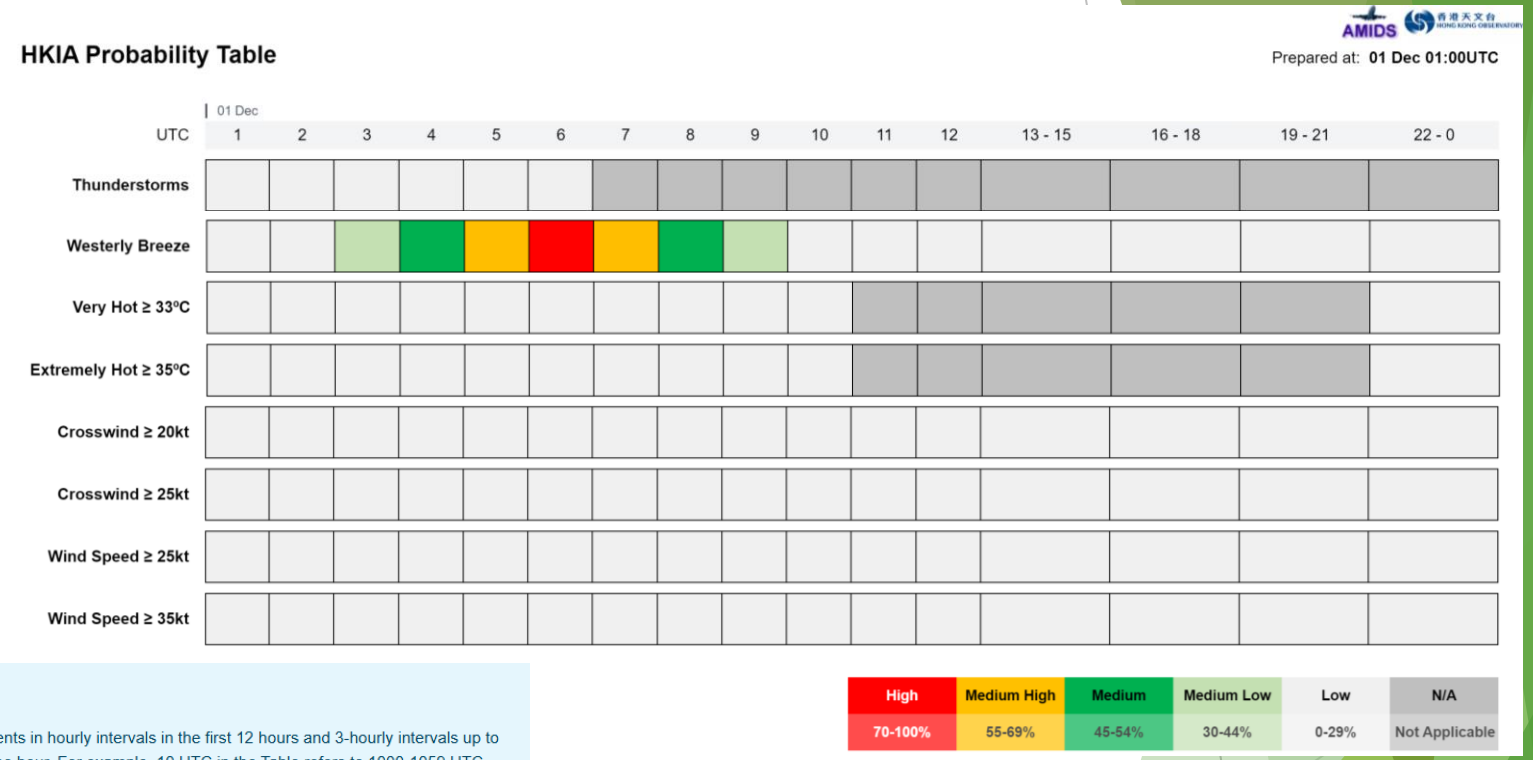
Application

- Used as a guidelines for Aviation Forecasters and Aeronautical Meteorological Advisers (AMA) of the HKO in assessing the likelihood of sea breeze and westerly winds.
- Combined with forecaster's experience, this probabilistic forecast of sea breeze at HKIA could ultimately serve as a reference for the aviation communities in their decision-making processes.



Note:

1. The HKIA Probability Table provides probabilistic forecast guidance on specific weather elements in hourly intervals in the first 12 hours and 3-hourly intervals up to 24 hours. Each hour in the Probability Table starts from the 00th minute to the 59thminute of the hour. For example, 10 UTC in the Table refers to 1000-1059 UTC. Currently, two groups of elements are released:
   i. very hot and extremely hot weather and
   ii. Significant wind and crosswind (10-min mean)
2. The HKIA Probability Table also provides hourly probability of thunderstorms in the vicinity of the airport (within 16 km from the ARP) for the first 6 hours.
3. The HKIA Probability Table also provides hourly probability of westerly breeze which is defined as the winds with westerly headwind or tailwind reaching 5 knots or more.
4. The Probability Table is updated regularly at each hour during 0000-1400 UTC (inclusive). Special updates may be issued outside regular update time if necessary.
5. Probabilistic forecast for hot weather is available each day from 0000UTC and forecast up to 10 UTC would be provided.
6. The Probability Table is updated manually based on past forecast experience and after analysing various meteorological observations and weather forecast model products. Under rapidly changing situation that may affect airport operations, please refer to aerodrome warnings, actual observations and METAR/SPECI reports.
7. For enquiries, please contact the duty Aeronautical Meteorological Adviser in IAC (Tel: 21889043).

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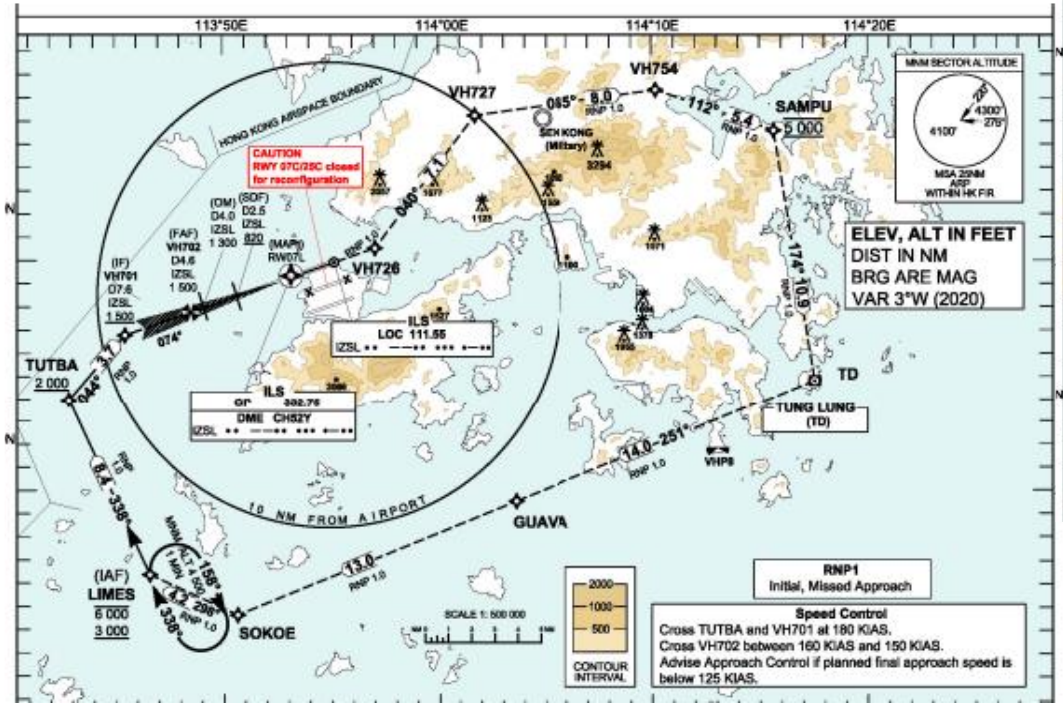
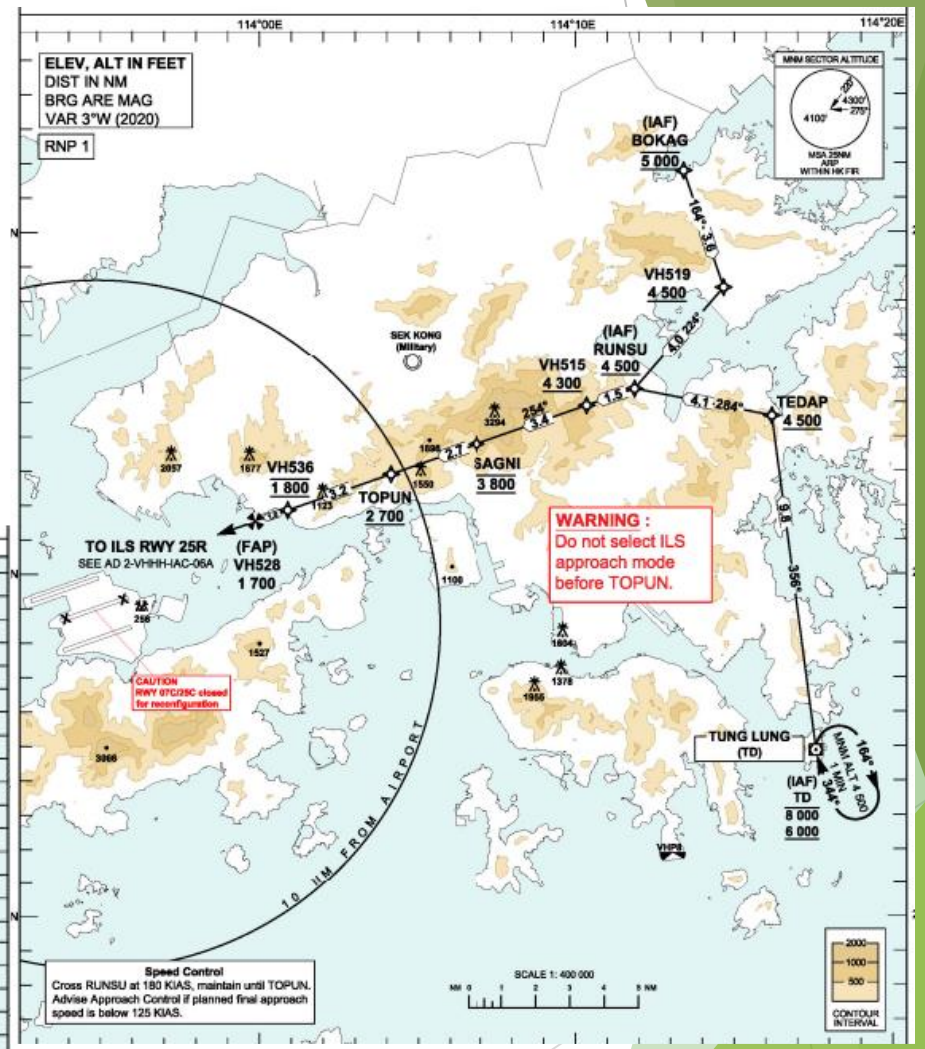
Impact to ATM Operations

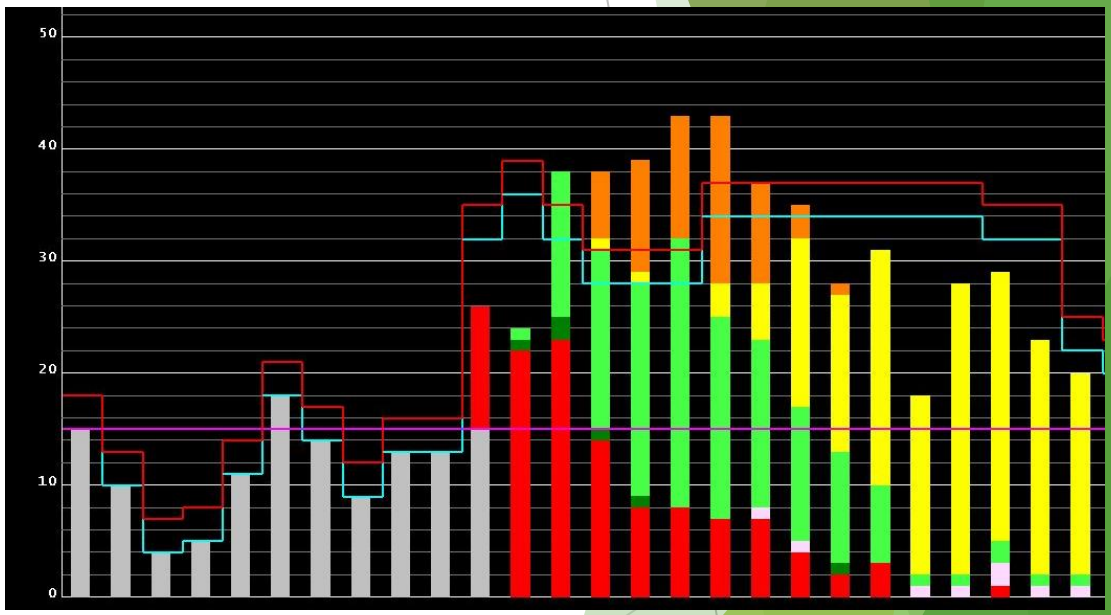
- Winds change along runway
  - Runway change is inevitable
  - 6 minutes with no runway movements
  - approximately loss of 3-4 arrival slots





Collaboration between MET and ATM

- Winds change such as sea breeze will affect the Airport Acceptance Rate (AAR)
- Importance of accurately predicting the runway wind direction
- Forecast with quantitative probabilities to cater for uncertainty
- Daily consultation to understand the overall situation
- Facilitate ATC advance planning of runway changes and initiate ATFM measures if necessary



Conclusion

- The probabilistic forecasts generated at hourly intervals show good alignment with actual observations.
- This predictive model has the potential to enhance early preparedness and inform decision-making regarding runway use in air traffic operations.
- This demonstrated the cooperation between MET and ATM for decision-making and operations.

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Thank you!

Contact information:

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