APPLICATION OF PROPABILITY MATRICES IN TROPICAL CYCLONE WARNINGS IN MACAO

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ESCAP/WMO Typhoon Committee the 20th IWS
2025.DEC.02-05

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OUTLINE

1. Tropical Cyclone Warning in Macao
2. Introduce Probability Table
3. The Risk Matrix Calculation
   - ‘Kidney x Ensemble Track’
   - ‘Conditional Analysis’
4. Case Study
5. Future Work

Tropical Cyclone warnings in Macao, China

Signal	Brief Meaning	Impact on Society
1T	A tropical cyclone is centered within 800 km of Macao and may potentially affect it.	Nothing.
3⊥	Macao's sustained winds about Force 6-7.	Infant, Primary, Special Education Suspended
8▲ 西北NW 8▲▲ 東北NE 8▼▼ 東南SE 8▼ 西南SW Top Public Concern 9⧗	Macao's sustained winds about **Force 8-11**. Signal indicates possible wind direction.	Most operations halted. Public transportation services suspended. Limited transportation over bridges.
10✚	The tropical cyclone nearing Macao and the sustained winds strengthen significantly.	Transportation over bridges ceased. (Except emergency services)
	The tropical cyclone center passing near Macao and sustained winds about **Force 12 or over**.	All operations halted.

Issuance of Tropical Cyclone Warnings

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METEOROLOGICAL AND GEOPHYSICAL BUREAU
SPECIAL REPORT: **TROPCIAL CYCLONE REPORT** Report No. **1**

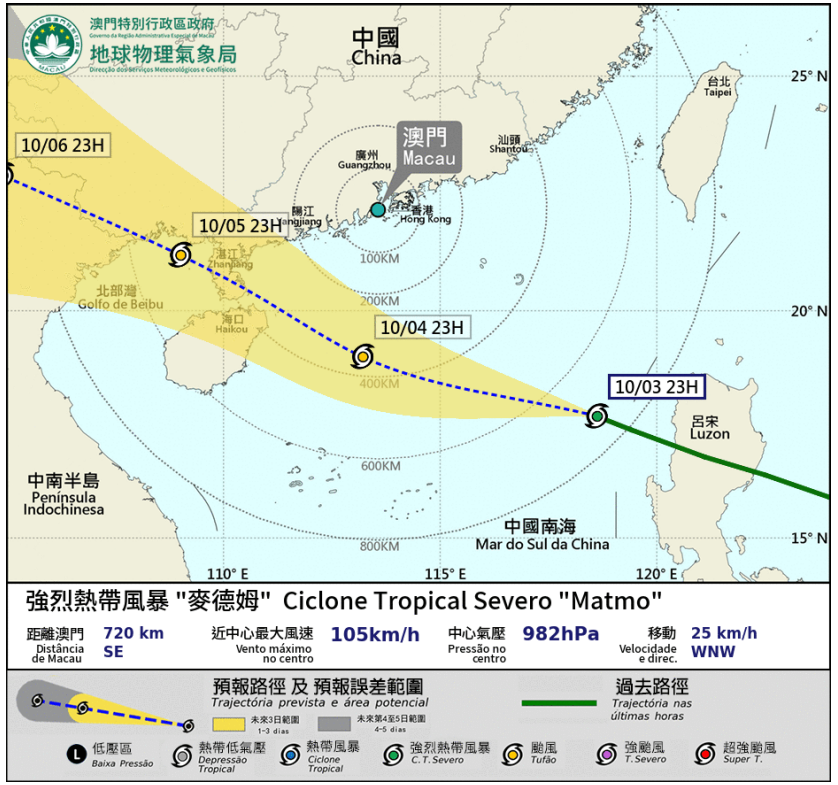
As affected by Severe Tropical Storm Matmo,
Signal no. 1 was issued at 23:00 on 03 of October
The signal no. 1 will remain in force before noon tomorrow.

Effective Signal
1T

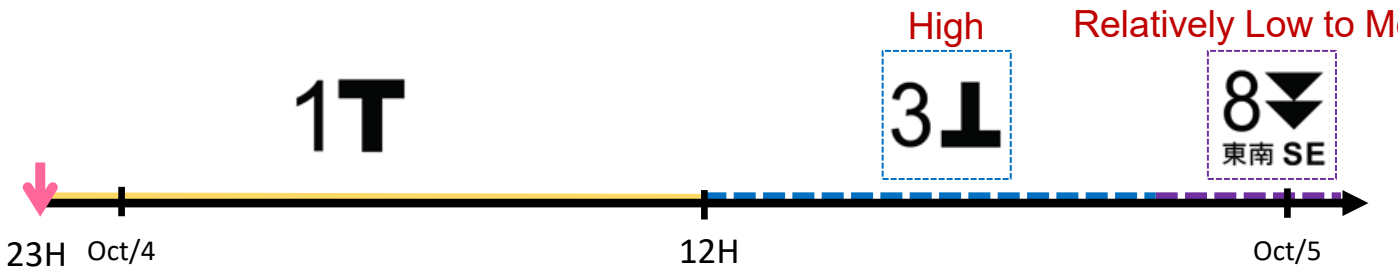
Possible warning signals to be issued

Typhoon Signal	Expected Issue Time	Possibility
Typhoon Signal No.1	In effect	
Typhoon Signal No.3	October 4th, afternoon	High
Typhoon Signal No.8	From evening of 4th to early morning on 5th Octobe	Relatively low to medium

Description of Possibility: Low | Relatively low | Medium | Relatively High | High



≤30%	30-44%	45-55%	55-69%	≥70%
Low	Relatively Low	Moderate	Relatively High	High



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%

EVALUATE THE IMAPCT OBJECTIVELY

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Kidney – A Probability Map of wind speeds

Kidney and beach ball

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17 September 2010

Forgive me for this rather weird title. The Observatory is under some pressure when it comes to warning people of approaching weather, especially typhoons. Too early a tropical cyclone signal is issued, the public may be baked in brilliant sunshine a couple of days before the effect of the storm is felt. Too late, and Hong Kong will risk the loss of life and properties because of inadequate forewarning.

As a matter of fact, Observatory colleagues start monitoring the development of a tropical cyclone days before a warning signal is issued. The work involves long hours of close watch and detailed analyses round-the-clock. Over the past few decades a number of tools for such analyses have been developed for the forecaster use. The device of funny names for these tools is a welcome relief.

As a tribute to Observatory colleagues, this blog introduces what are known to them as 'kidney' and 'beach ball'. Some of the tools have been presented to the public, notably in the annual Observatory Open Day and in seminars, as a sharing of scientific knowledge. This has generated considerable interest in Internet forum discussions.

What is a 'kidney' and why is it so called? Simply, it represents an area on the map where it is probable that windy conditions will affect a location in Hong Kong once a tropical cyclone comes within that area. Figure 1(a) shows a 50% probability 'kidney' for strong winds (i.e. force 6) at Waglan during the passage of a typhoon (the term 'typhoon', used in this blog covers typhoons, severe typhoons and super typhoons). Typhoon is the strongest amongst all categories of tropical cyclones.

Ref: https://www.hko.gov.hk/en/blog/00000066.htm

CREDIT: HONG KONG OBSERVATORY

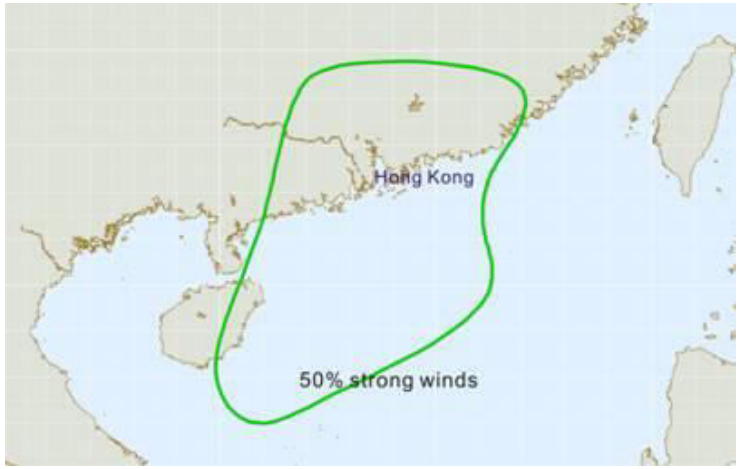

Figure 1(a)The 50% probability 'area' for strong
winds at Waglan during the passage of a typhoon

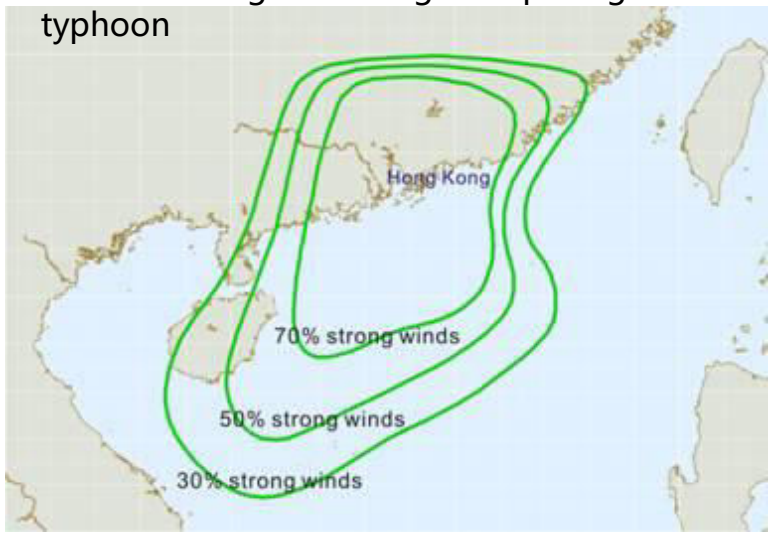

Figure 2 The 30%, 50% and 70% probability for strong
winds at Waglan brought by typhoons.

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A Tropical Cyclone Track

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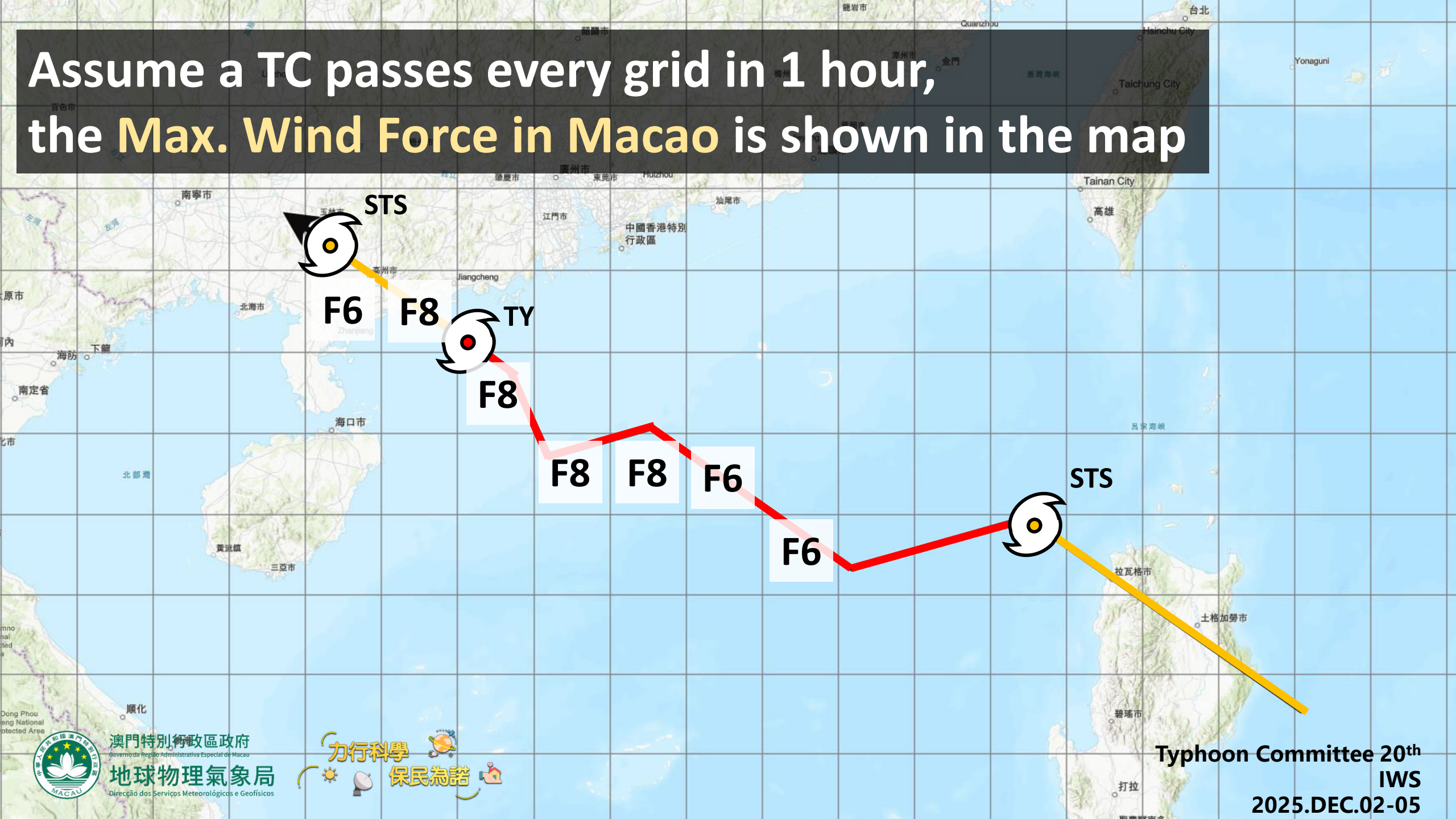
Assume a TC passes every grid in 1 hour,
the Max. Wind Force in Macao is shown in the map
STS
F6
F8
TY
F8
F8
F8
F6
F6
STS
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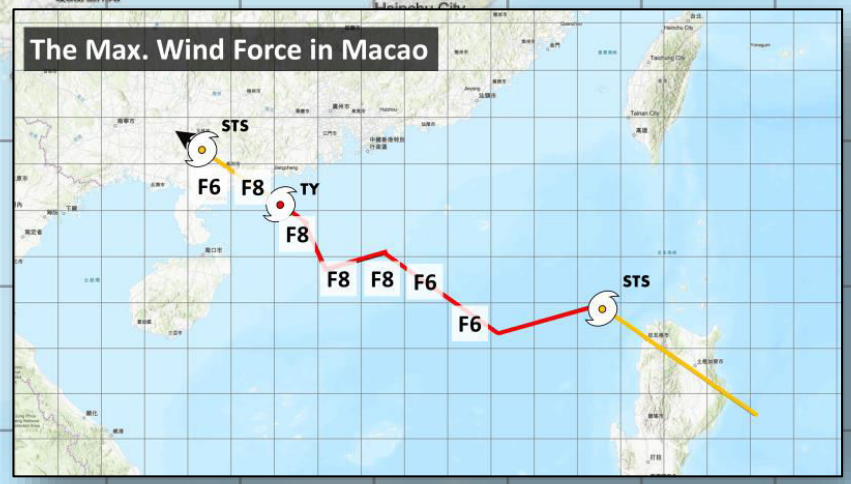
Severe Tropical Storm
Wind Force 8



STS

+1

TY

STS

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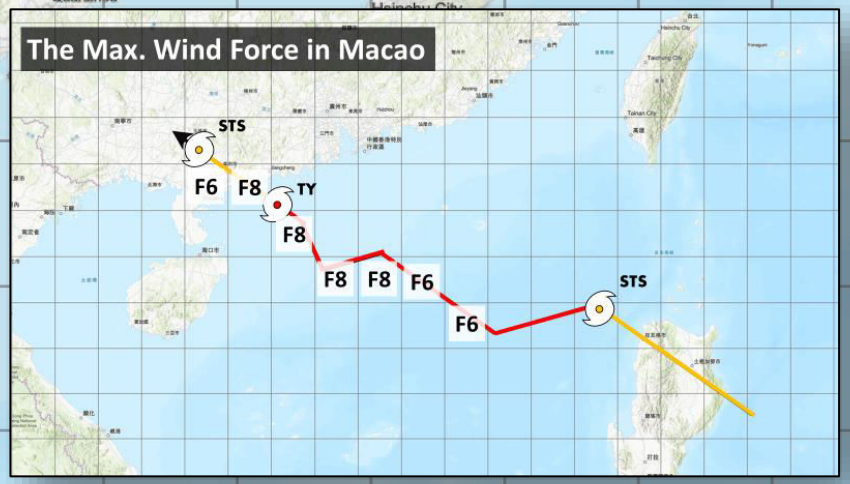
Severe Tropical Storm
Wind Force 6



STS

+1

TY

STS

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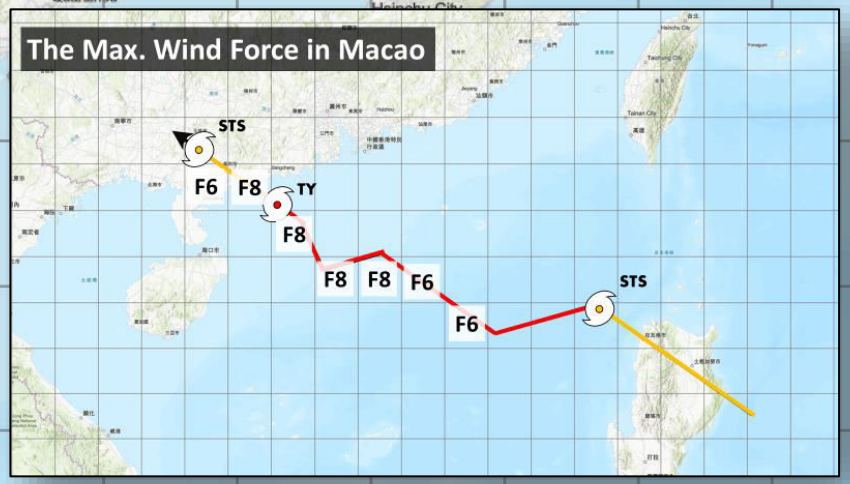
Typhoon
Wind Force 8



STS

TY

+1

+1

+1

STS

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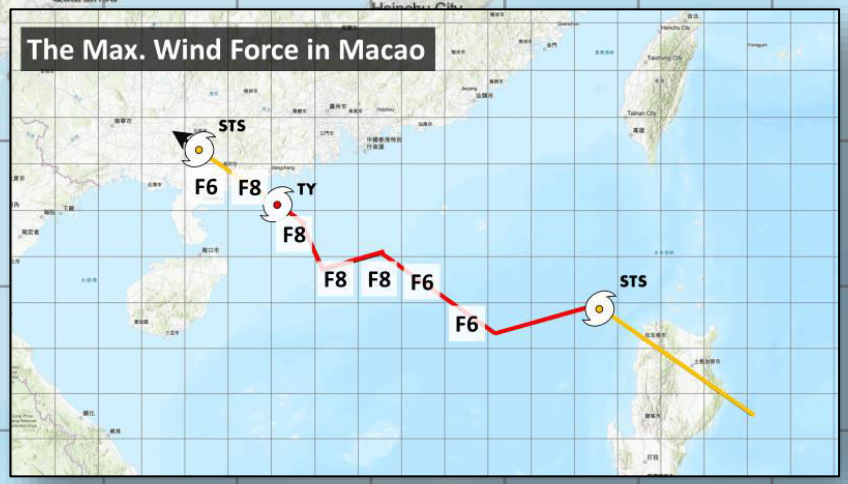
Typhoon
Wind Force 6



STS

TY

+1

+1

STS

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Data Process

Data: **2002 – 2024**

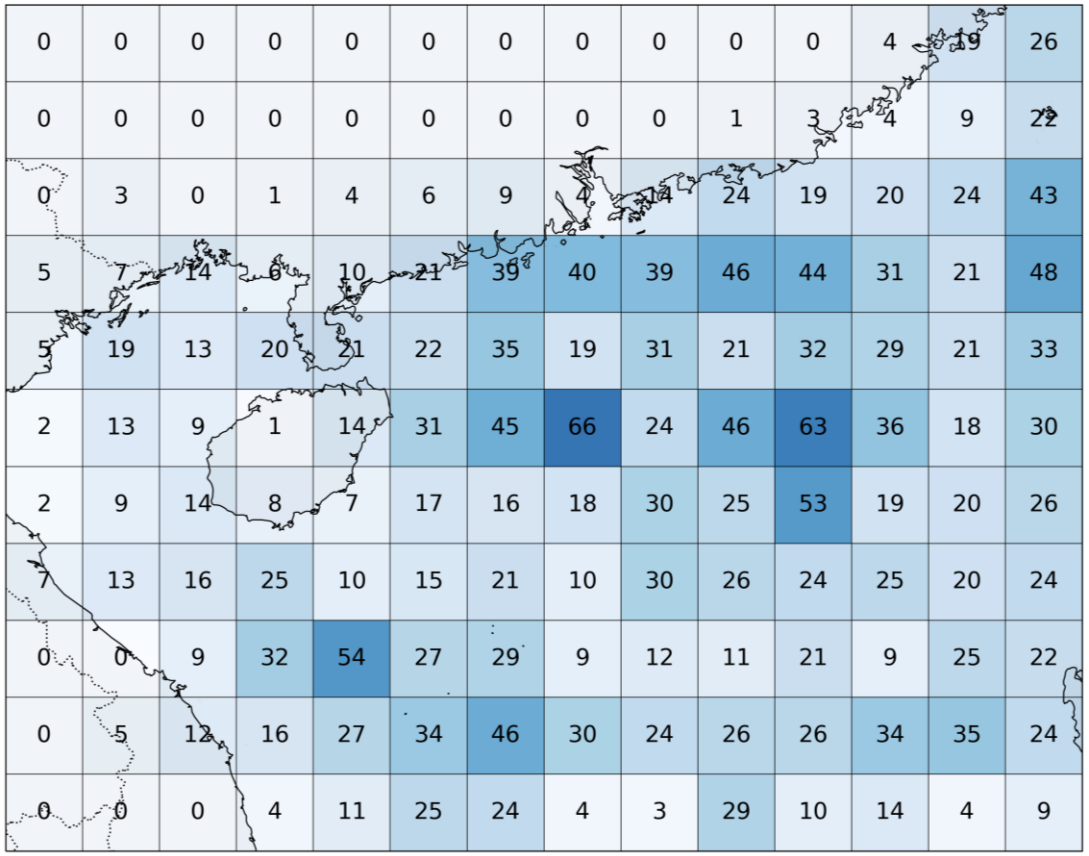
Best Track: **CMA**

TC Division: **TD/TS/STS/TY/STY/Su**

Wind Division: **Wind Force 6/8/10/12**

Wind data: **Max. Value in Macao**

Total Numbers of Typhoon



Data Process

Data: **2002 – 2024**

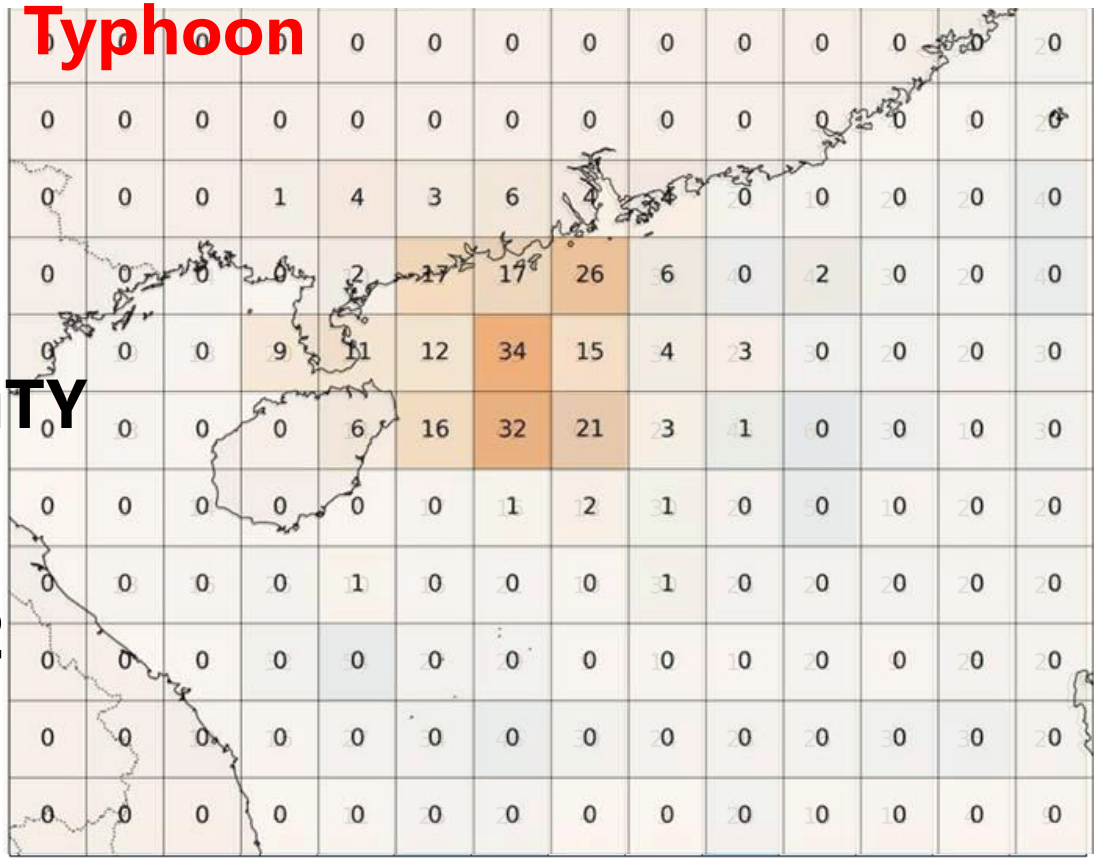
Best Track: **CMA**

TC Division: **TD/TS/STS/TY/STY/SuTY**

Wind in Macao: **Max. Value**

Wind Division: **Wind Force 6/8/10/12**

Total Numbers
Winds Force 8 in Macao by Typhoon



Data Process

Data: **2002 – 2024**

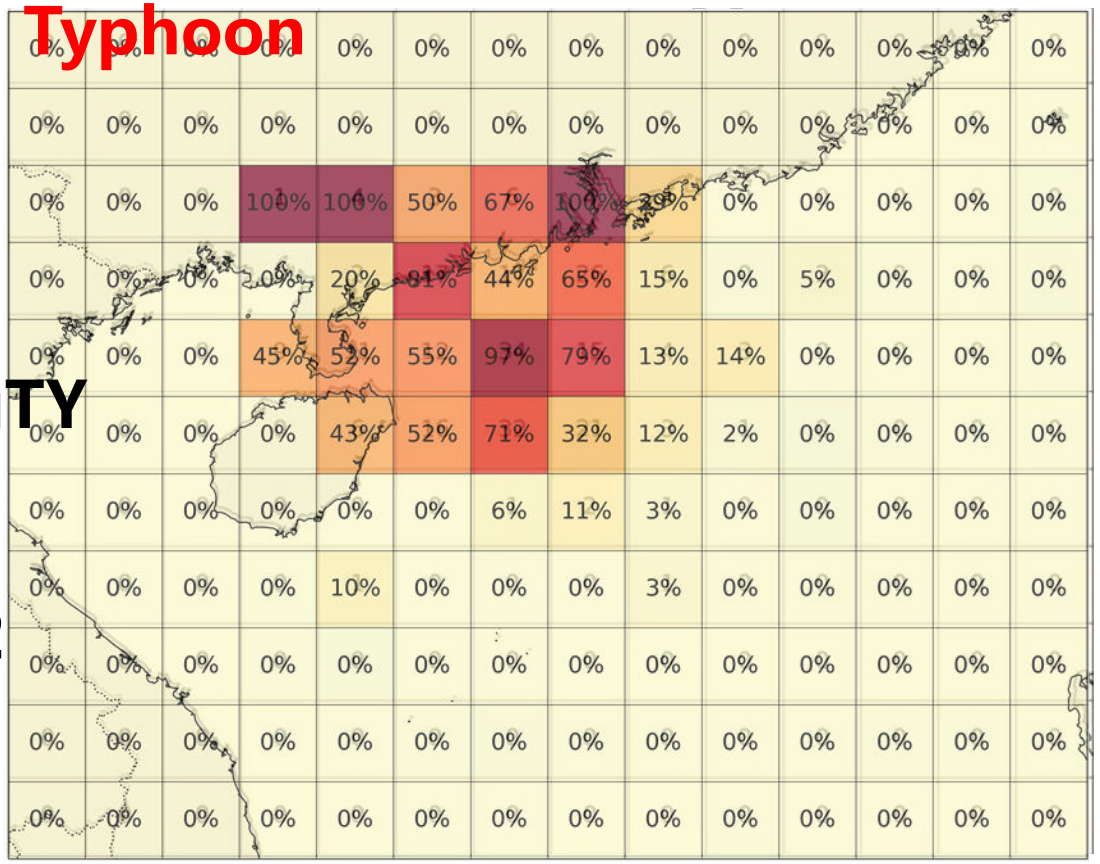
Best Track: **CMA**

TC Division: **TD/TS/STS/TY/STY/SuTY**

Wind in Macao: **Max. Value**

Wind Division: **Wind Force 6/8/10/12**

Probability
Winds Force 8 in Macao by Typhoon



Data Process

Data: **2002 – 2024**

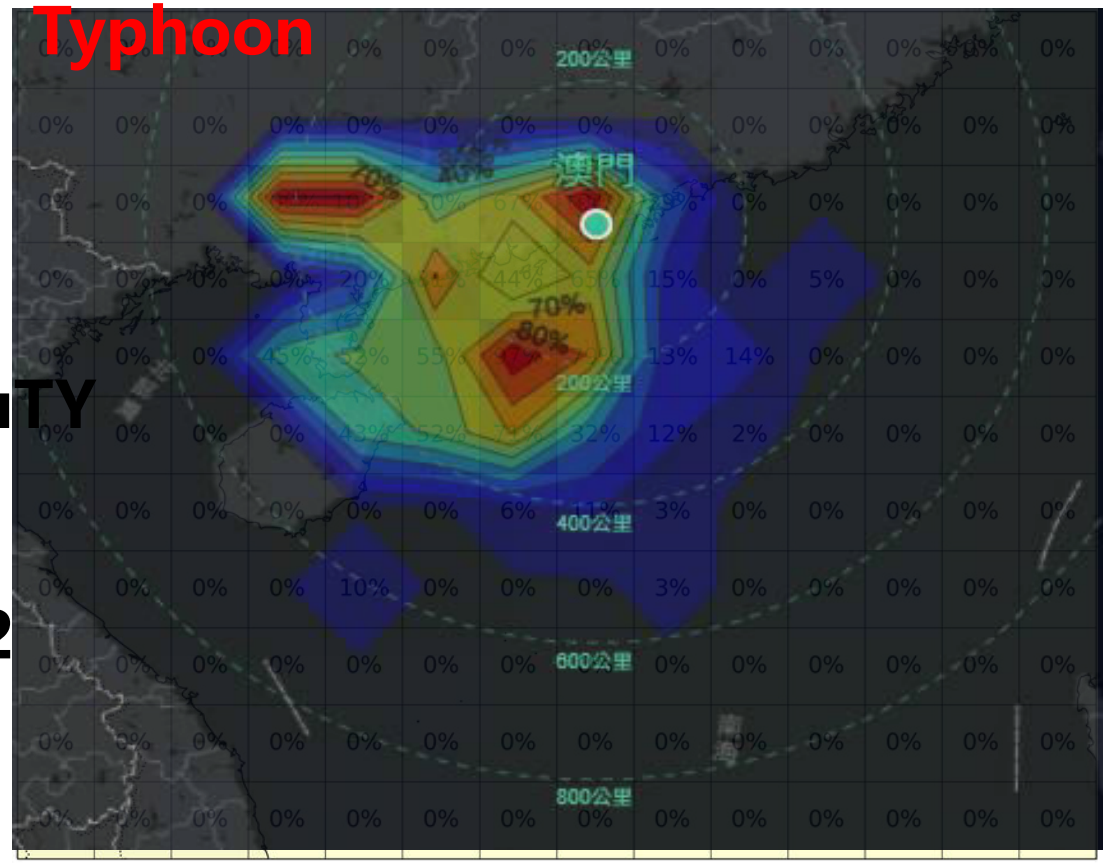
Best Track: **CMA**

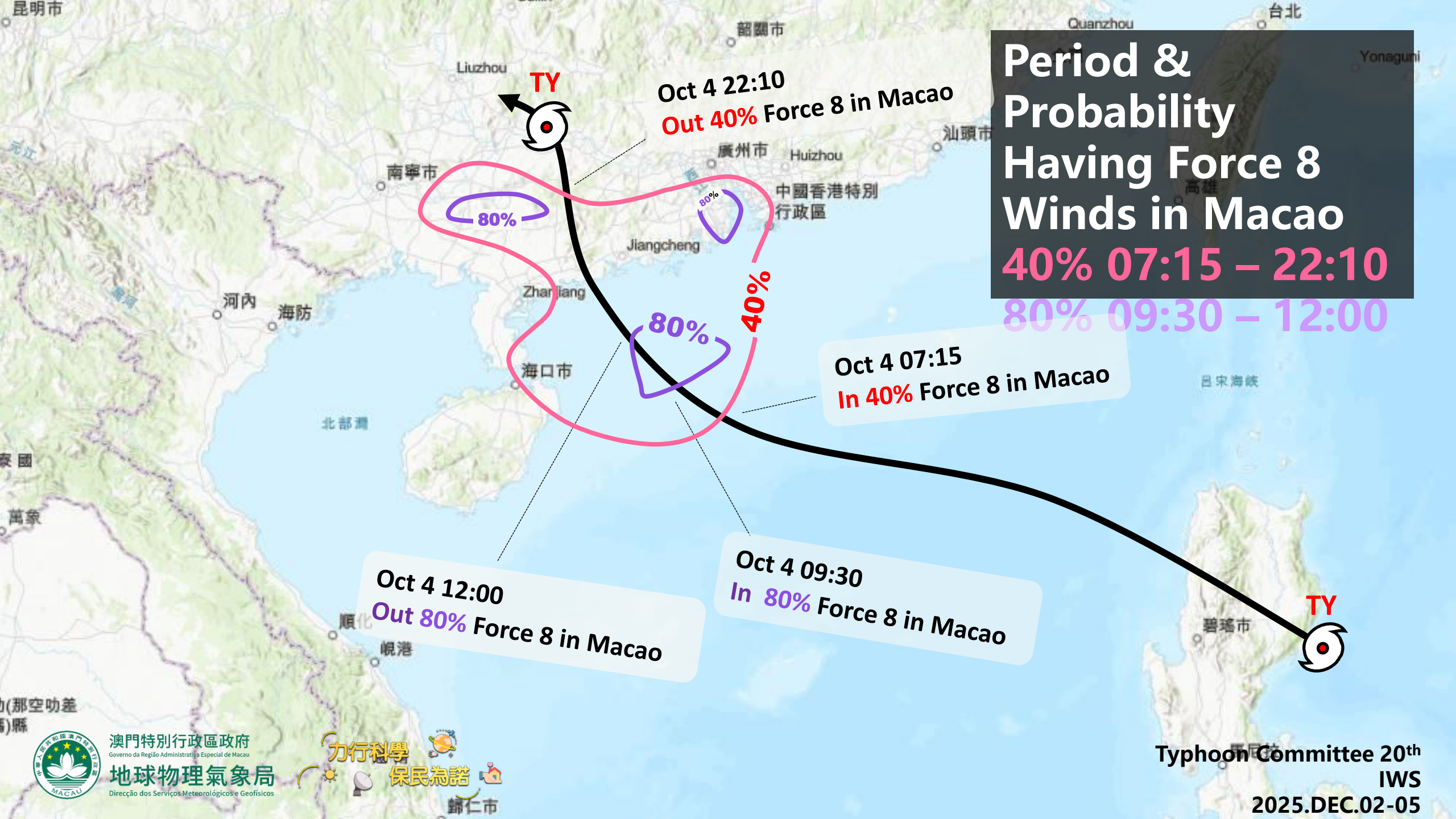
TC Division: **TD/TS/STS/TY/STY/SuTY**

Wind in Macao: **Max. Value**

Wind Division: **Wind Force 6/8/10/12**

Probability (contour)
Winds Force 8 in Macao by Typhoon




Period & Probability Having Force 8 Winds in Macao
40% 07:15 – 22:10
80% 09:30 – 12:00
TY
Oct 4 22:10
Out 40% Force 8 in Macao
Oct 4 07:15
In 40% Force 8 in Macao
Oct 4 09:30
In 80% Force 8 in Macao
Oct 4 12:00
Out 80% Force 8 in Macao
80%
80%
40%
TY
Liuzhou
南寧市
廣州市
Huizhou
汕頭市
Quanzhou
台北
Yonaguni
中國香港特別行政區
Jiangcheng
Zhanjiang
海口市
河內
海防
北部灣
呂宋海峽
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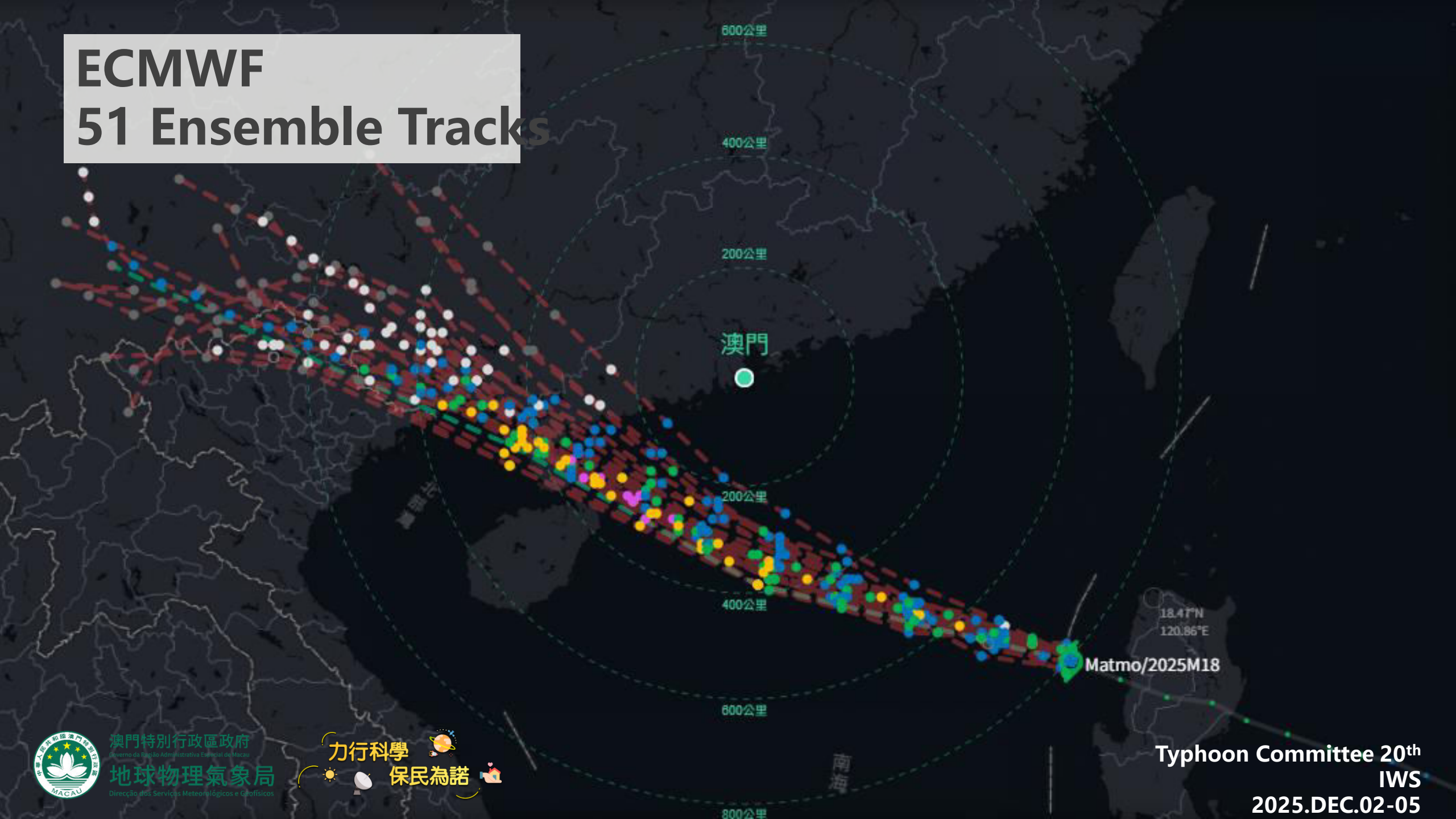
ECMWF
51 Ensemble Tracks



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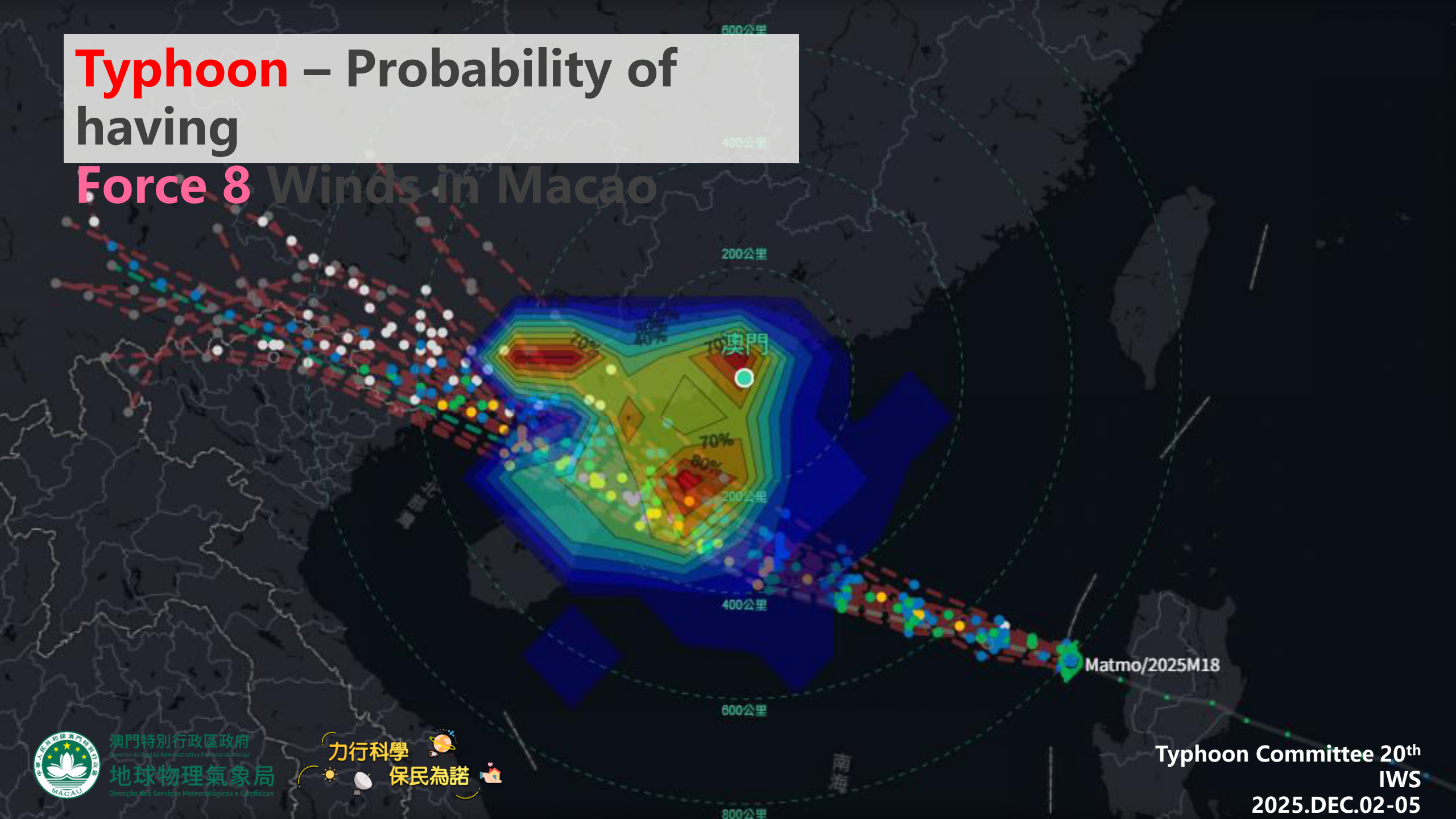
Typhoon – Probability of having Force 8 Winds in Macao



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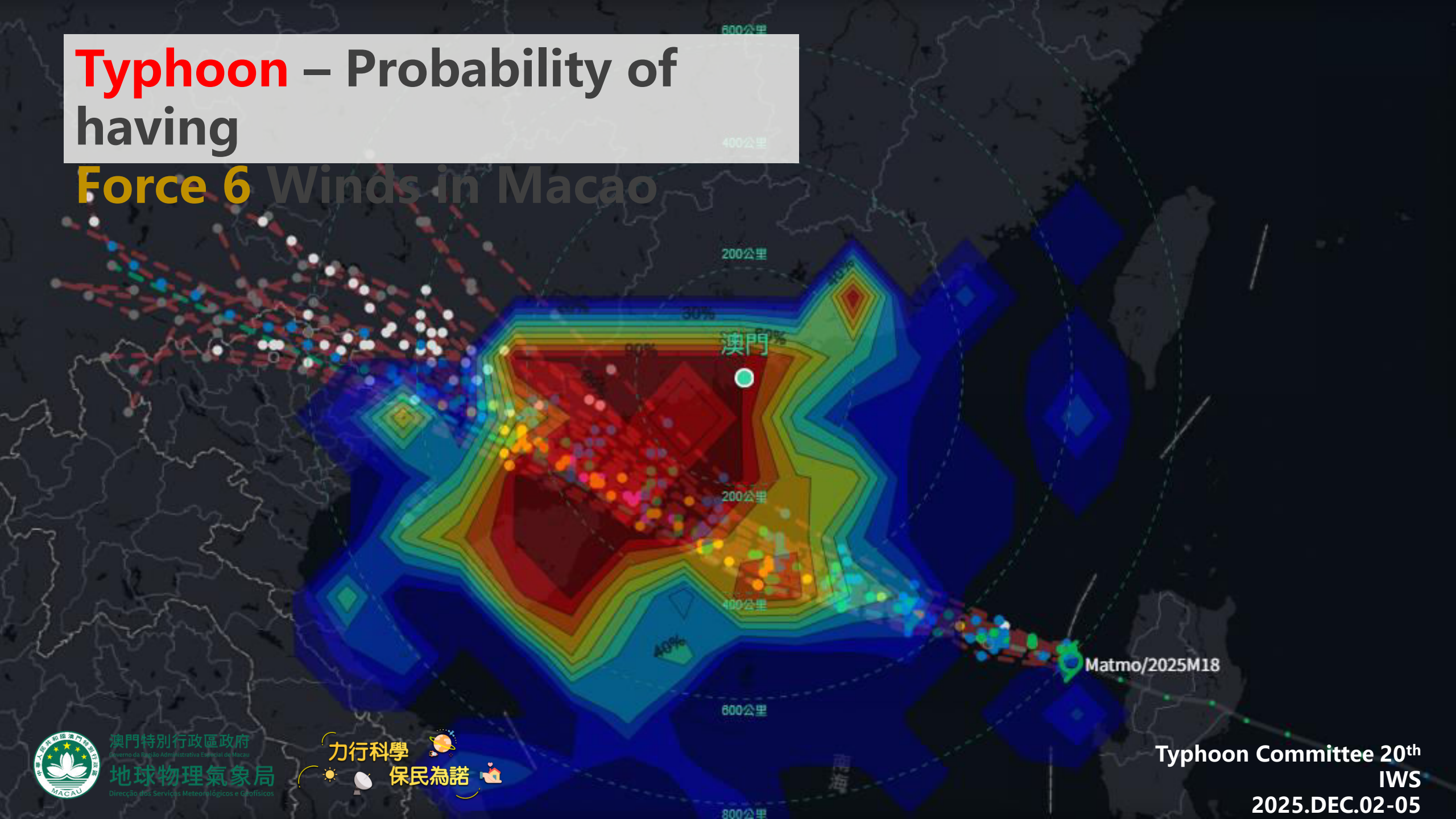
Typhoon – Probability of having Force 6 Winds in Macao



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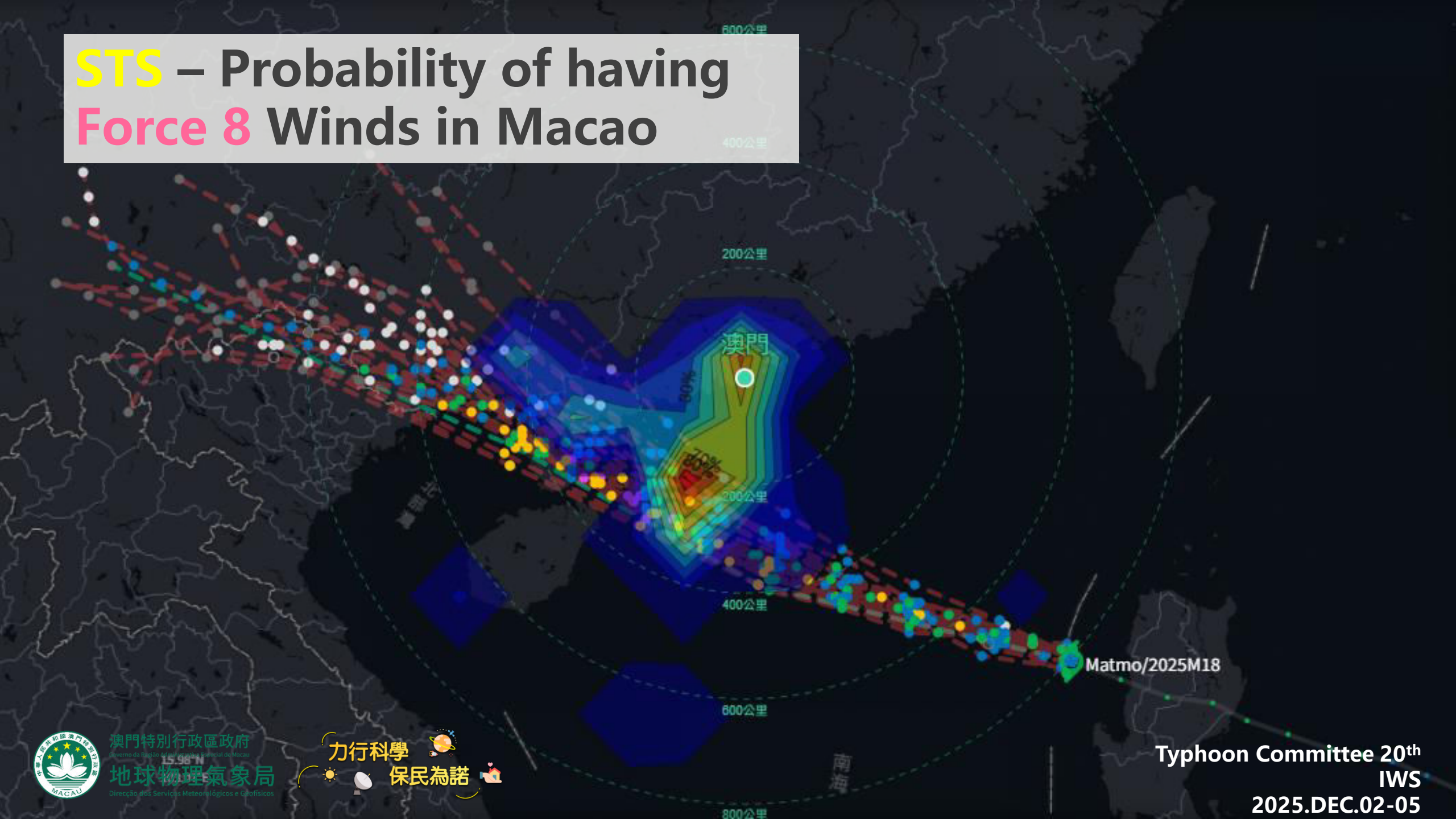
STS – Probability of having Force 8 Winds in Macao



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Calculation

Each member's position and intensity assigns a probability at different times **FOR WIND FORCE 8 IN MACAO**.

Member	Oct 4 07:00	Oct 4 08:00	Oct 4 09:00	Oct 4 10:00
1	30%	30%	50%	50%
2	10%	20%	50%	80%
3	50%	50%	60%	80%
4	50%	50%	70%	80%
:	:	:	:	:
51	40%	50%	70%	90%
AVG	34%	39%	67%	82%


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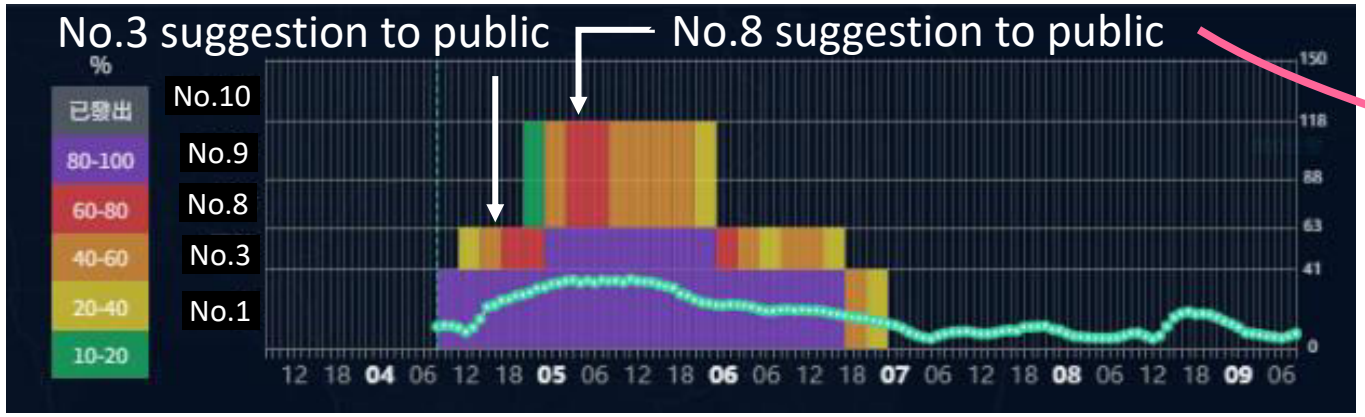
400公里
200公里
澳門
200公里
Ragasa/2025M16
400公里
17.63°N
114.89°E
600公里
南海
800公里
09/22 08:00
6
7
8
模式選擇
ECMWF
模式時間
2025-09-22
08:00:00
%
已發出
80-100
60-80
40-60
20-40
10-20
十號
九號
八號
三號
一號
150
118
88
63
41
0
12 18 22 06 12 18 23 06 12 18 24 06 12 18 25 06 12 18 26 06 12 18 27 06
模式選擇
EC增水
模式時間
2025-09-22
08:00:00
增水
3.0
2.5
1.5
1.0
0.5
0.2
0.0
0.2
0.5
12 18 22 06 12 18 23 06 12 18 24 06 12 18 25 06 12 18 26 06 12 18 27 06

Case –Typhoon MATMO

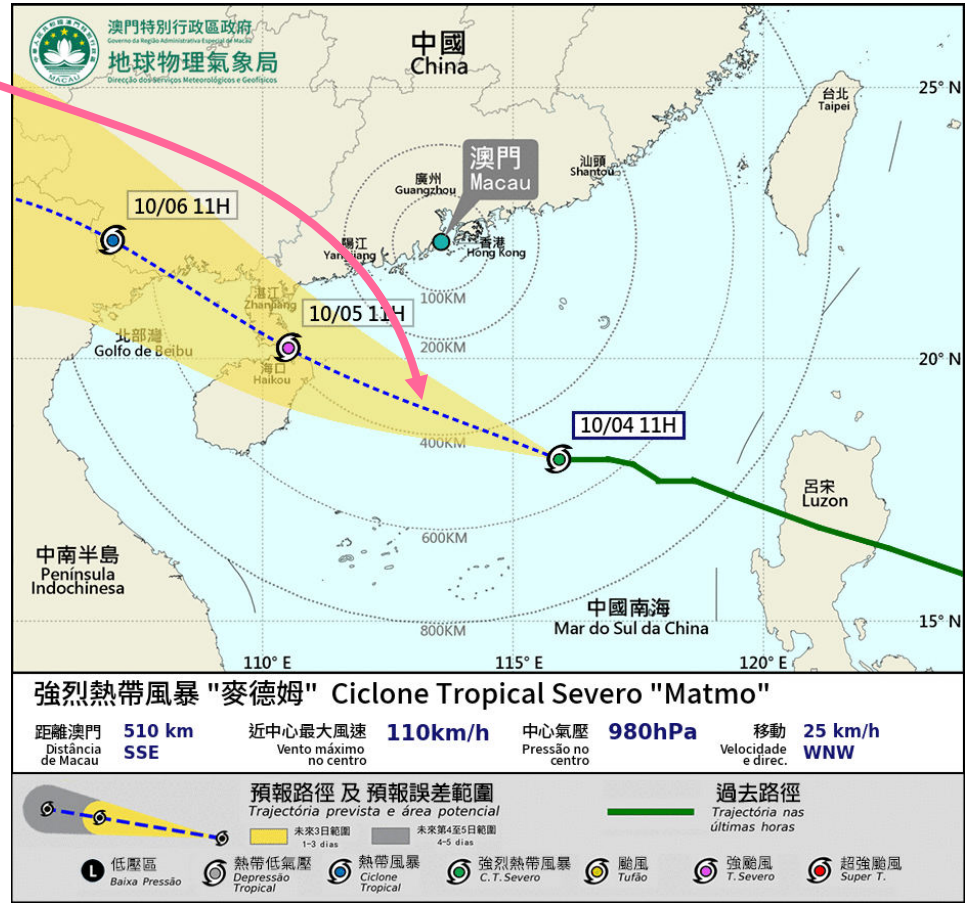


Risk matrix from *'kidney X ensemble tracks'* calculation

Possible warning signals to be issued

Typhoon Signal	Expected Issue Time	Possibility
Typhoon Signal No.1	In effect	
Typhoon Signal No.3	4th, 16:00	Will be issued
Typhoon Signal No.8	From evening of 4th to early morning on 5th Octobe	Medium

Description of Possibility: LOW | Relatively low | Medium | Relatively High | High

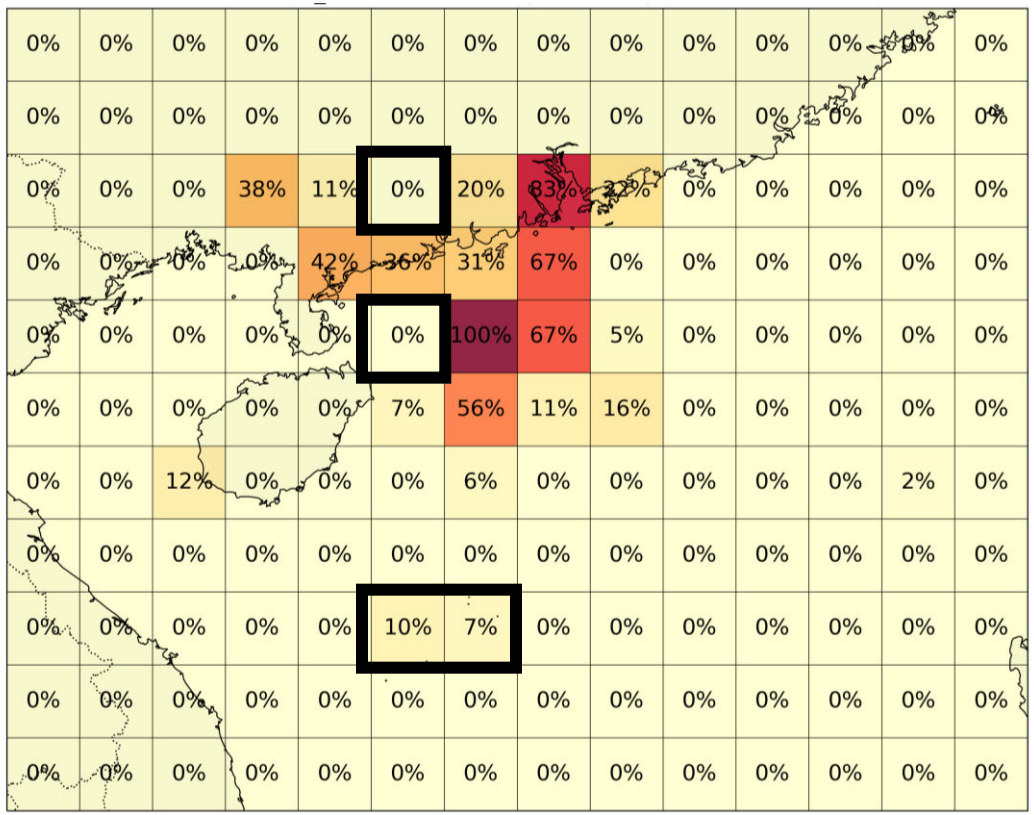


Track forecast from DSMG @ 2025/10/04 11CST

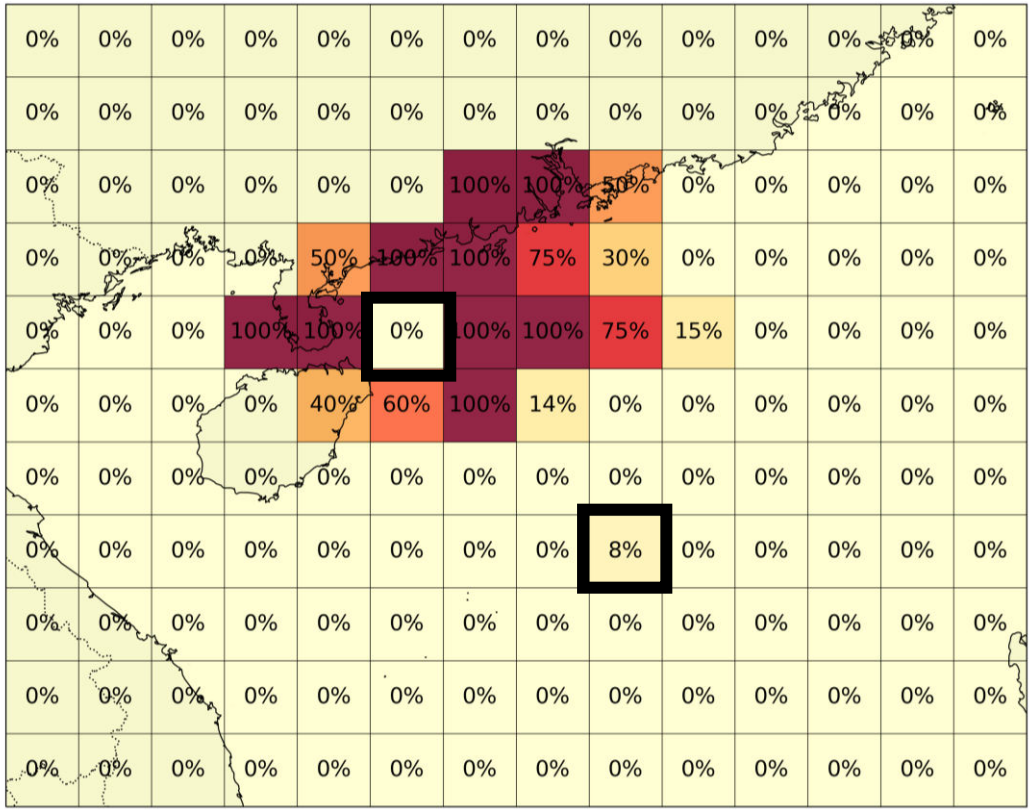
Probability table to the public. The probability to the public is lower than the objective matrix.

Shortcoming of kidney

Severe Tropical Storm - Wind Force 8



Severe Typhoon - Wind Force 8



Due to insufficient data or unusual tropical cyclones (e.g., overly large, small, or slow-moving), results can be unreasonable, requiring pre-screening or manual correction.

TRY ANOTHER METHOD

Conditional Analysis

A probability table according to forecast data and experiences

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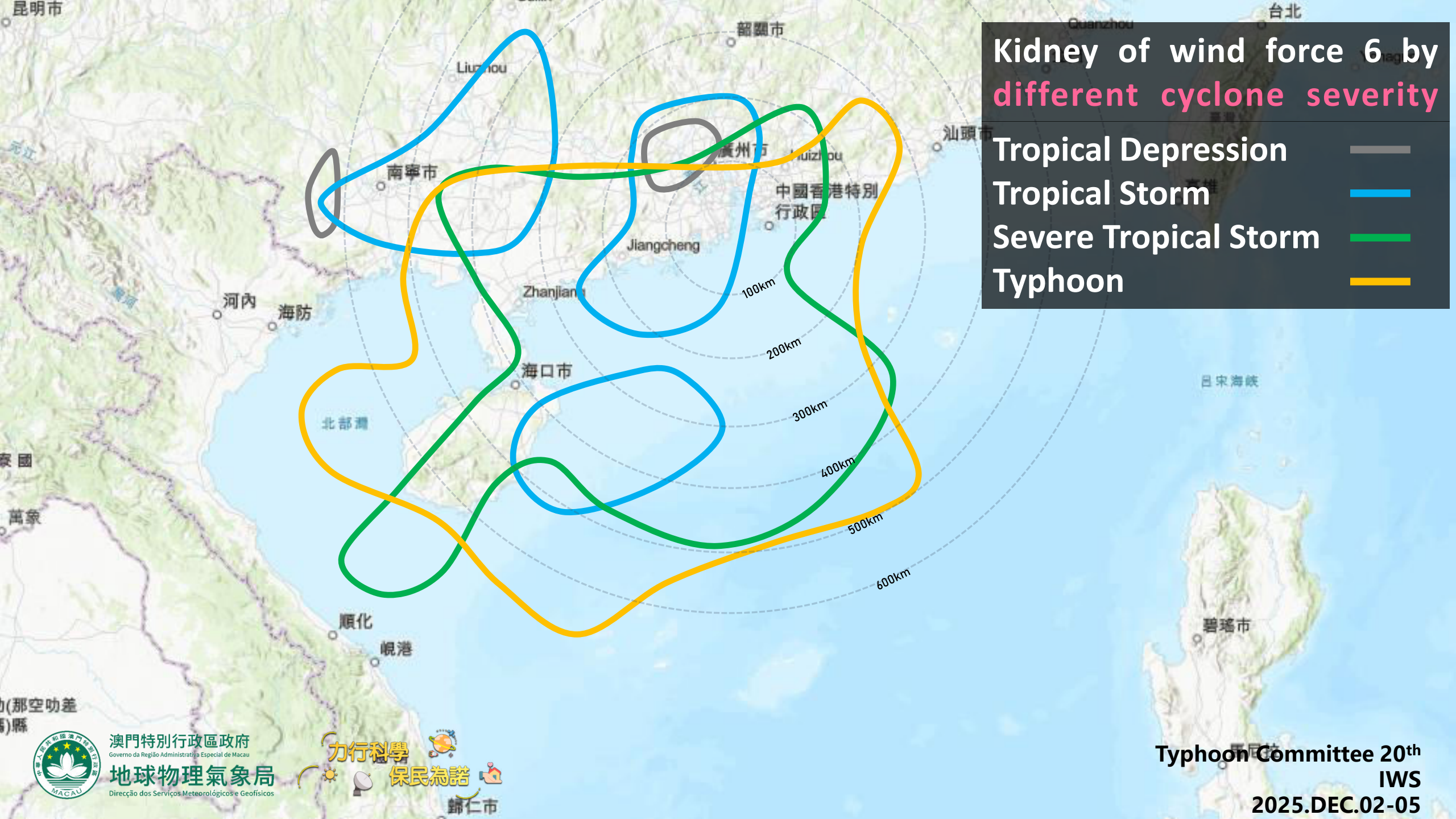
Kidney of wind force 6 by different cyclone severity
Tropical Depression
Tropical Storm
Severe Tropical Storm
Typhoon
100km
200km
300km
400km
500km
600km
昆明市
韶關市
Liuzhou
南寧市
廣州市
汕頭市
台北
Quanzhou
中國香港特別行政區
Jiangcheng
Zhanjiang
河內
海防
海口市
北部灣
呂宋海峽
萬象
順化
峴港
碧瑤市
歸仁市
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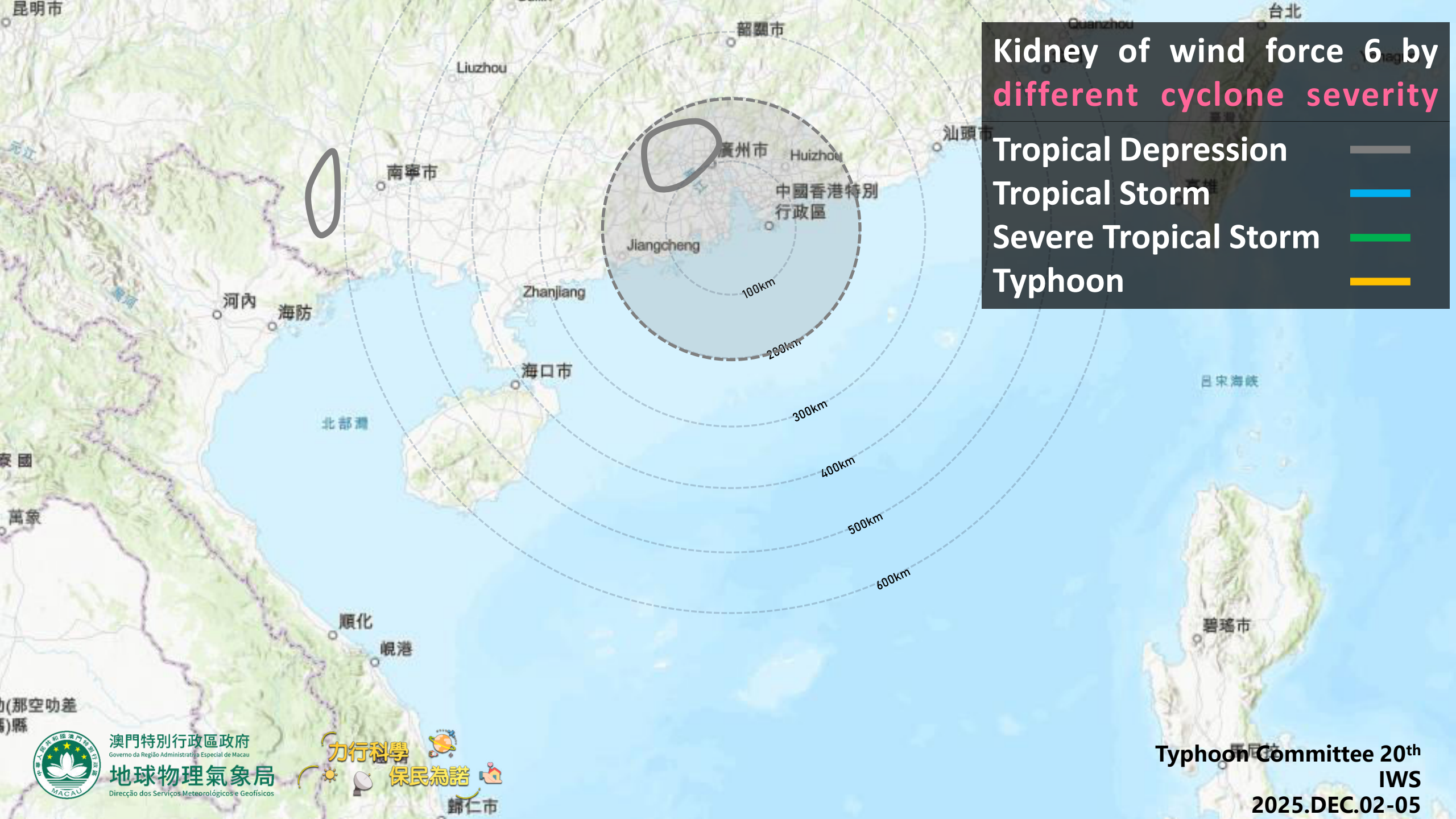
Kidney of wind force 6 by different cyclone severity
Tropical Depression
Tropical Storm
Severe Tropical Storm
Typhoon
100km
200km
300km
400km
500km
600km
昆明市
Liuzhou
韶關市
Quanzhou
台北
南寧市
廣州市
Huizhou
汕頭市
中國香港特別行政區
Jiangcheng
Zhanjiang
河內
海防
海口市
北部灣
呂宋海峽
萬象
順化
峴港
碧瑤市
歸仁市
澳門特別行政區政府
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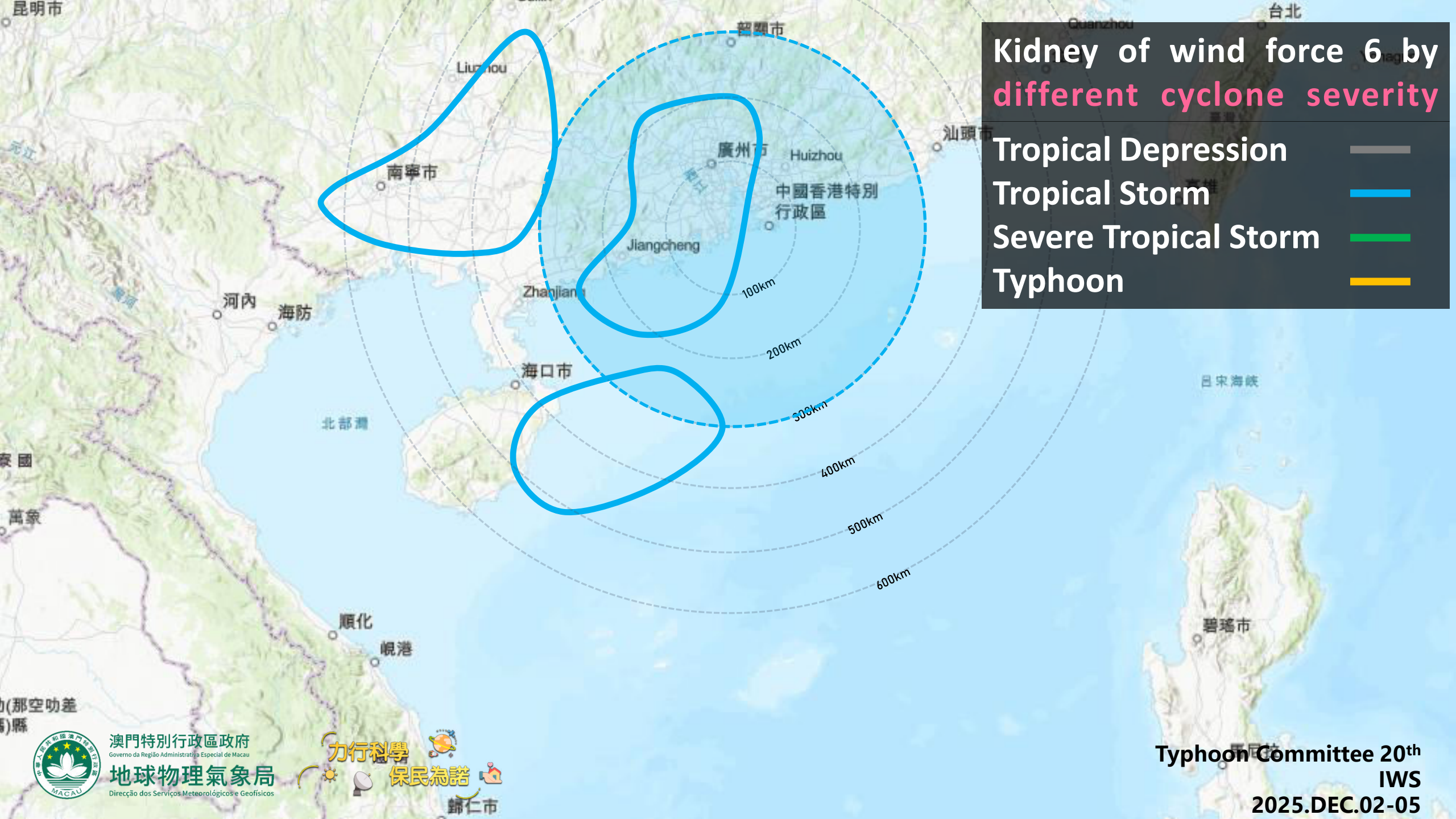
Kidney of wind force 6 by different cyclone severity
Tropical Depression
Tropical Storm
Severe Tropical Storm
Typhoon
100km
200km
300km
400km
500km
600km
昆明市
南寧市
Liuzhou
柳州市
廣州市
Huizhou
中國香港特別行政區
Jiangcheng
Zhanjiang
湛江
汕頭市
Quanzhou
台北
河內
海防
海口市
北部灣
呂宋海峽
萬象
順化
峴港
碧瑤市
歸仁市
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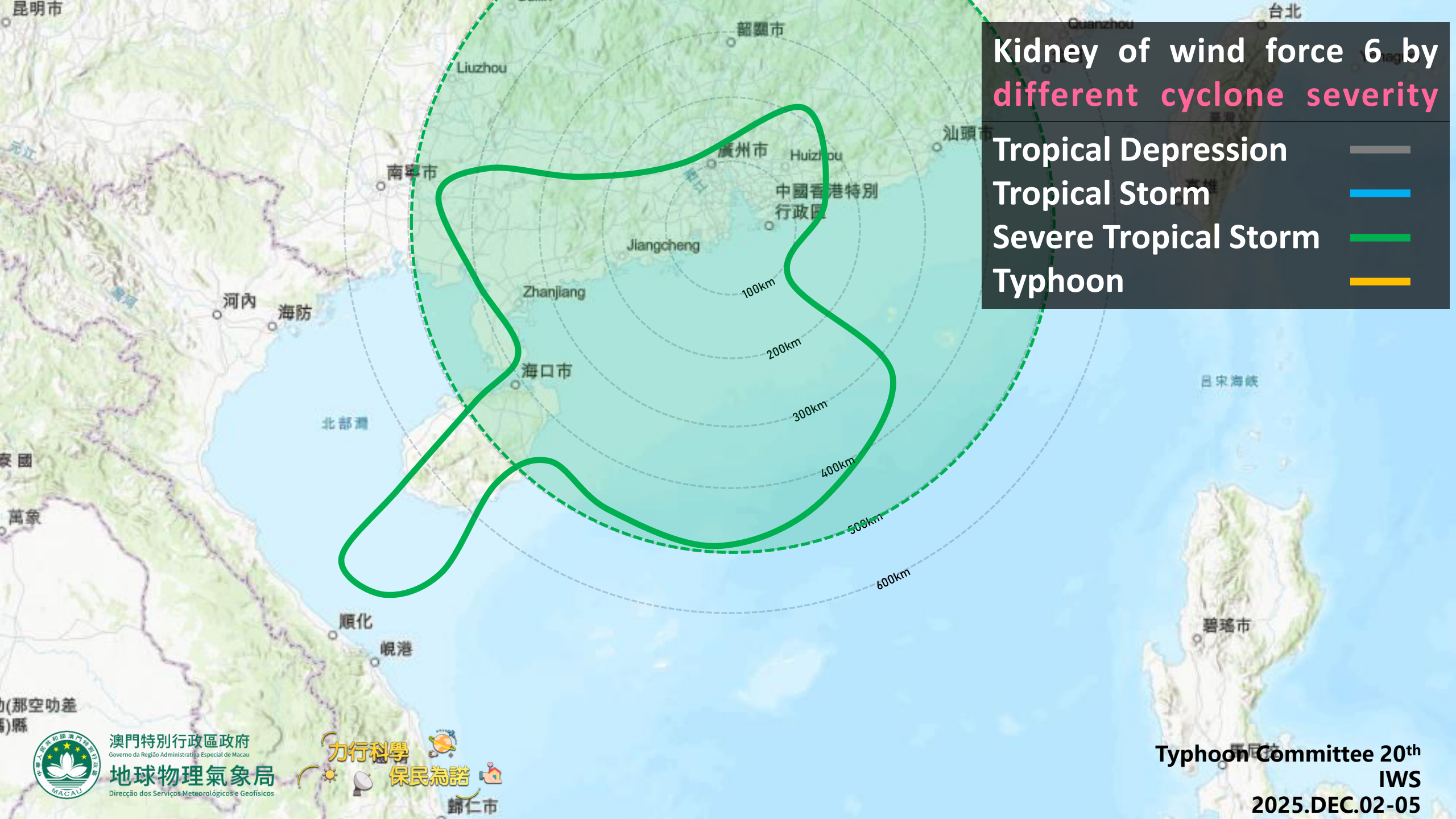
Kidney of wind force 6 by different cyclone severity
Tropical Depression
Tropical Storm
Severe Tropical Storm
Typhoon
100km
200km
300km
400km
500km
600km
昆明市
Liuzhou
韶關市
Quanzhou
台北
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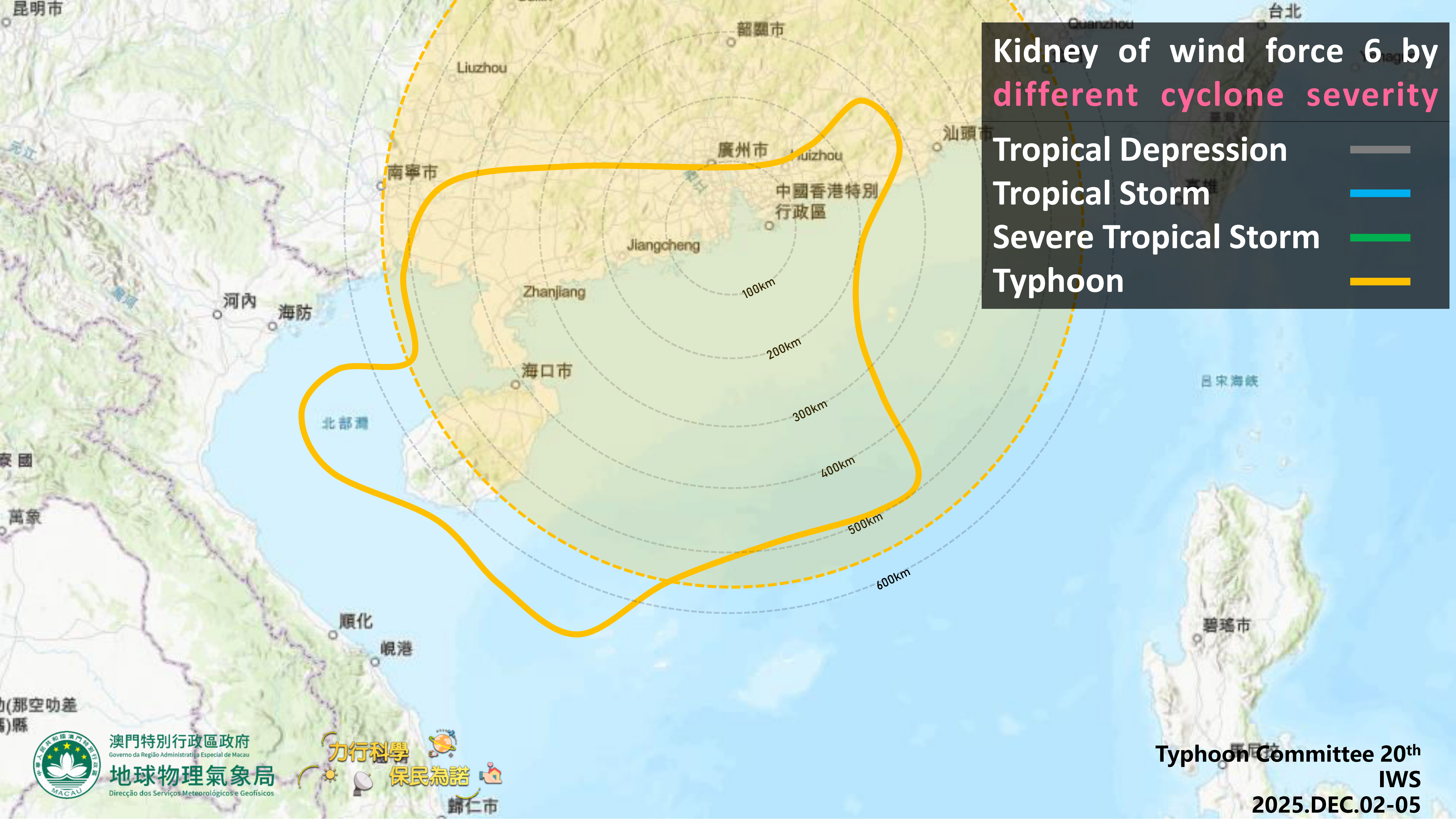
Kidney of wind force 6 by different cyclone severity

Tropical Depression	(grey line)
Tropical Storm	(blue line)
Severe Tropical Storm	(green line)
Typhoon	(orange line)



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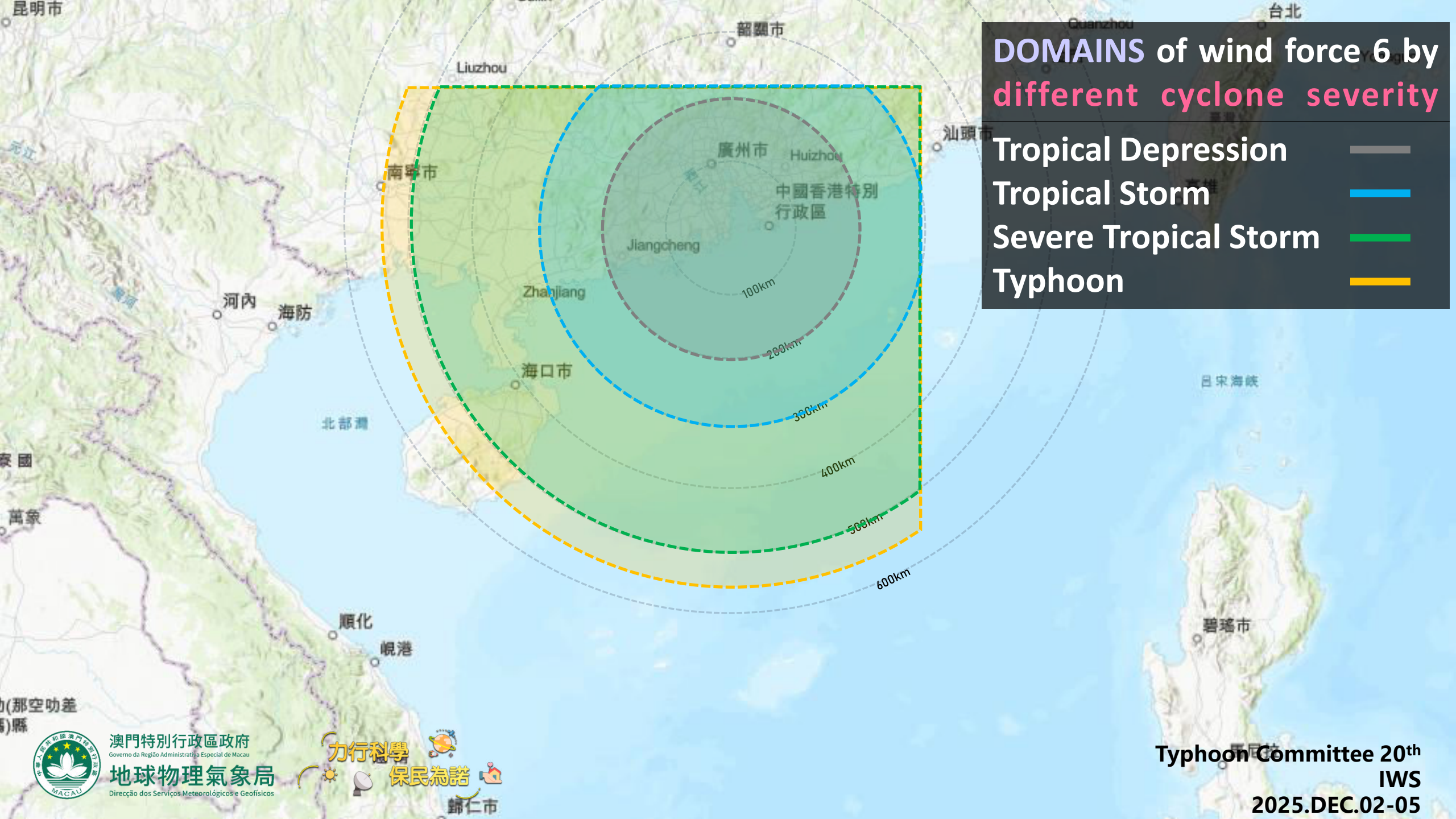
DOMAINS of wind force 6 by different cyclone severity
Tropical Depression
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Typhoon
100km
200km
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Liuzhou
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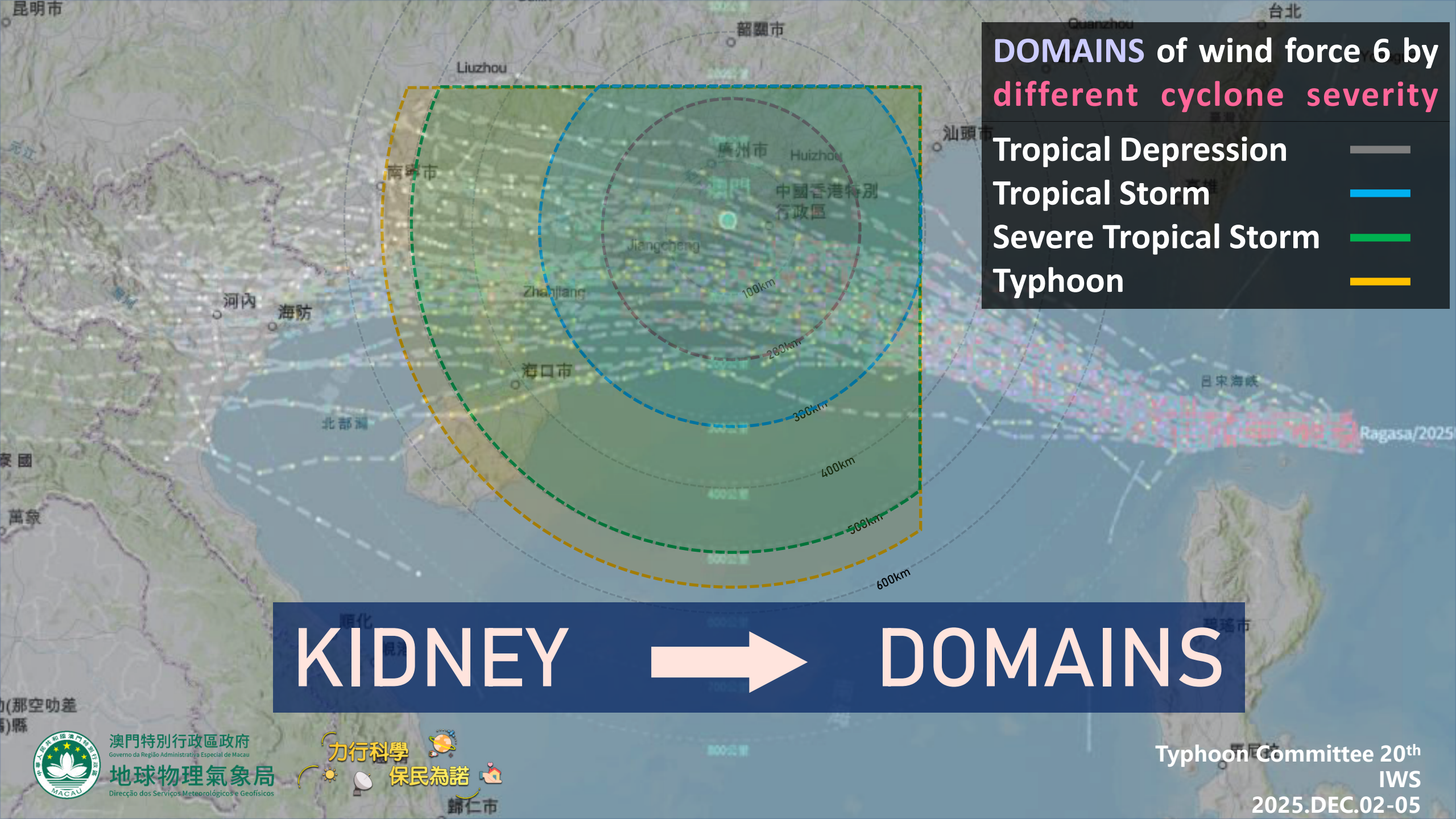
DOMAINS of wind force 6 by different cyclone severity
Tropical Depression
Tropical Storm
Severe Tropical Storm
Typhoon
100km
200km
300km
400km
500km
600km
KIDNEY
DOMAINS
Liuzhou
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Jiangcheng
Zhanjiang
Ragasa/2025
澳門特別行政區政府
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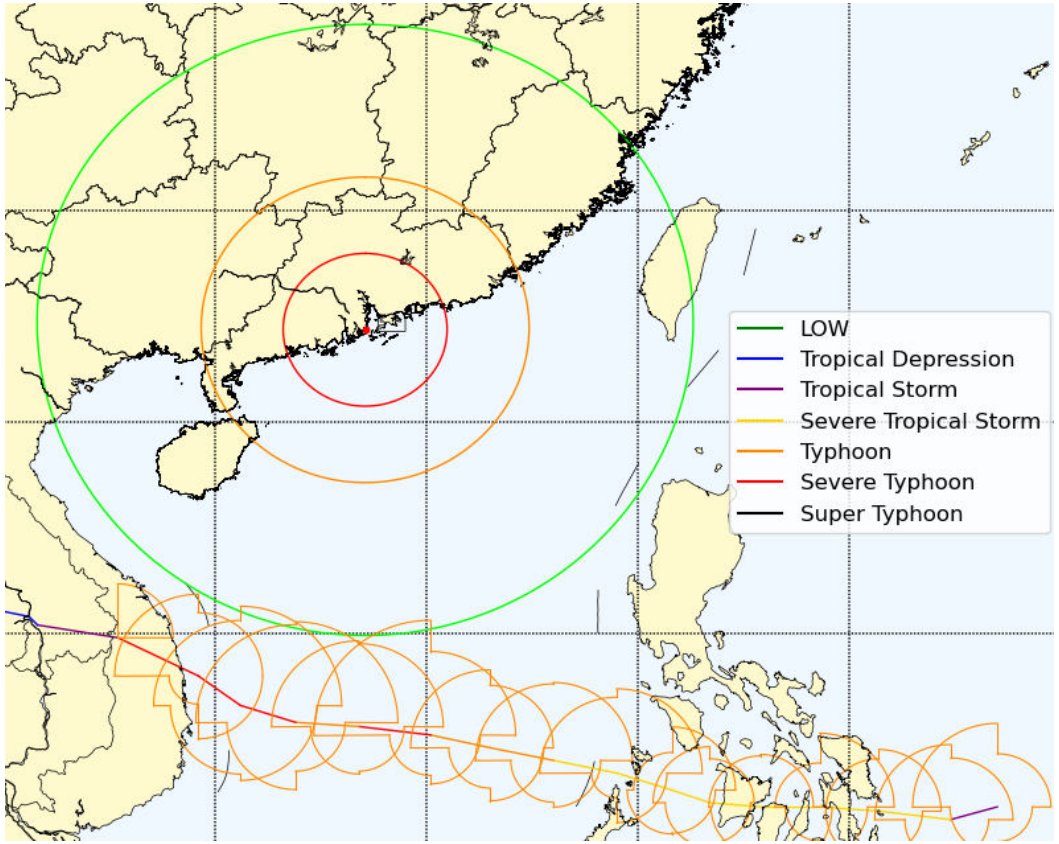
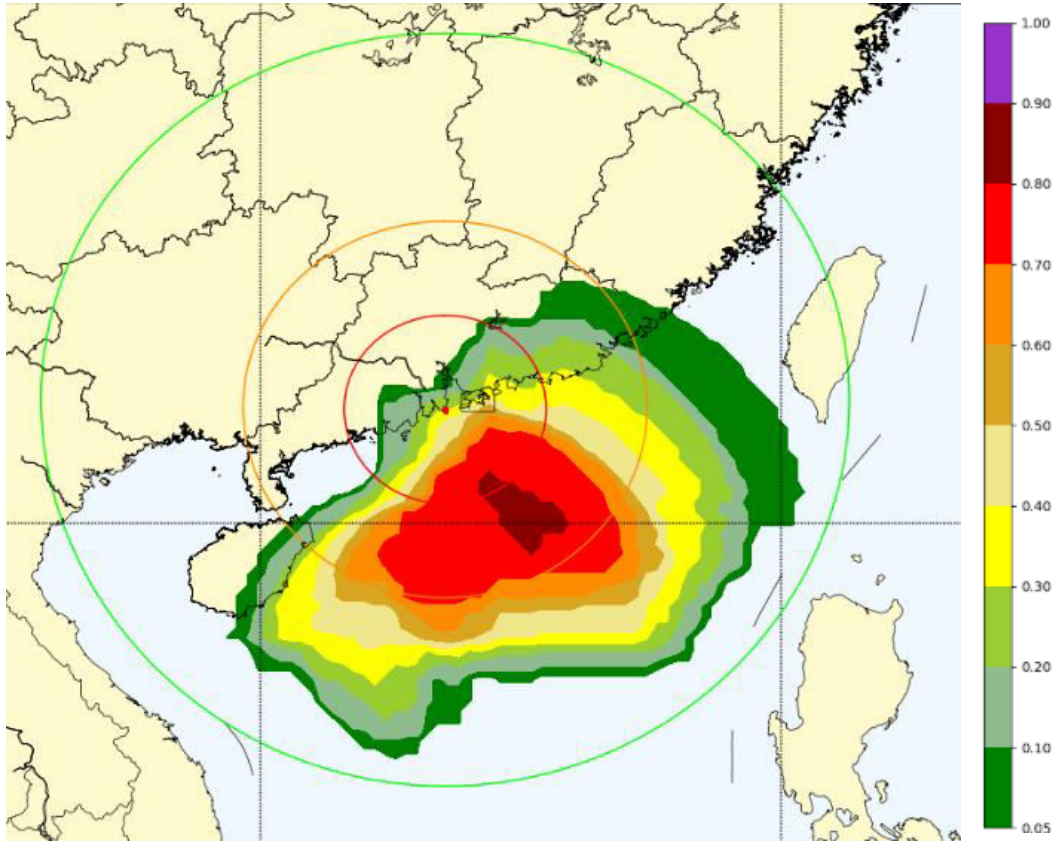
Forecast Wind Radii

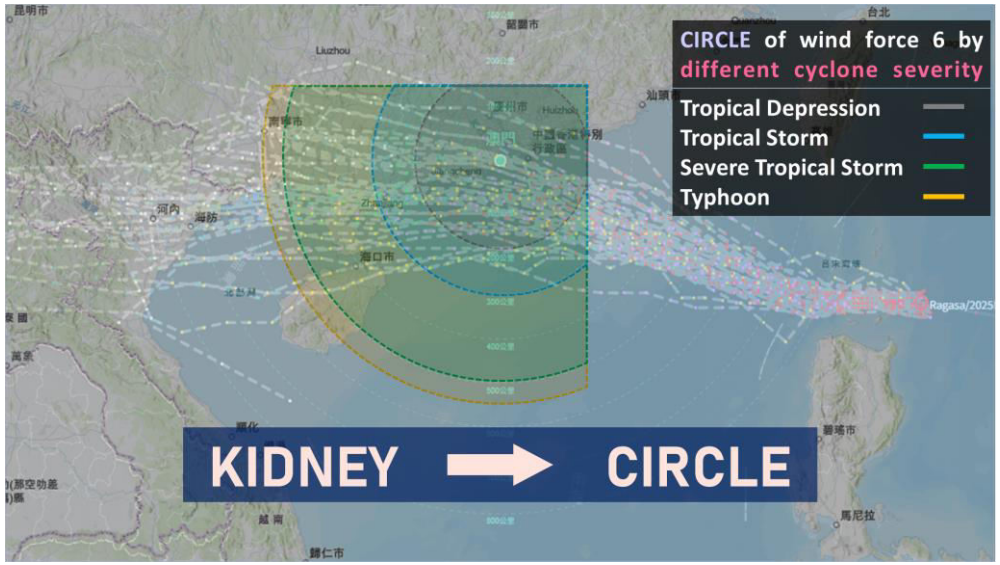




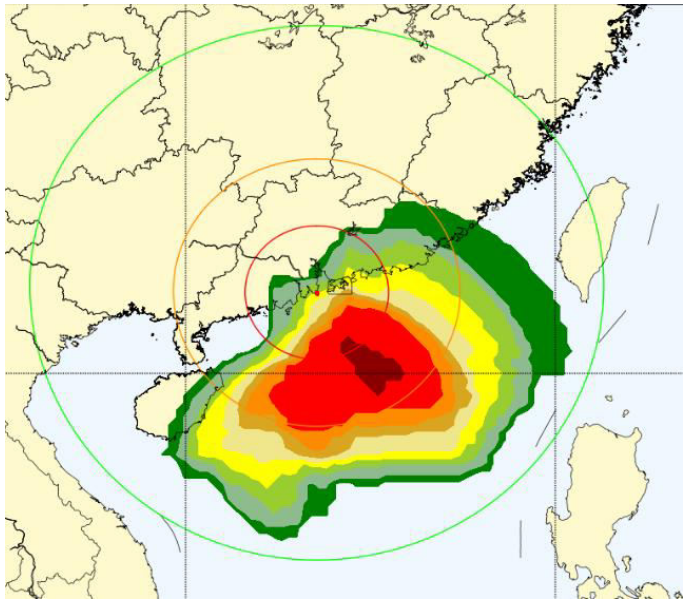
Ensemble track data provides wind force 8/10/12 radii every forecast step.
A probability area of having wind 8/10/12 could be calculated by the ensemble forecast directly.

Conditional Analysis
A Probability table according to Forecast data and experiences

General Warning Range



Forecast Wind Radii



① **Criteria** X ② **Warning Area** ③ **Ensemble Track** X ④ **Forecast Wind Radii**

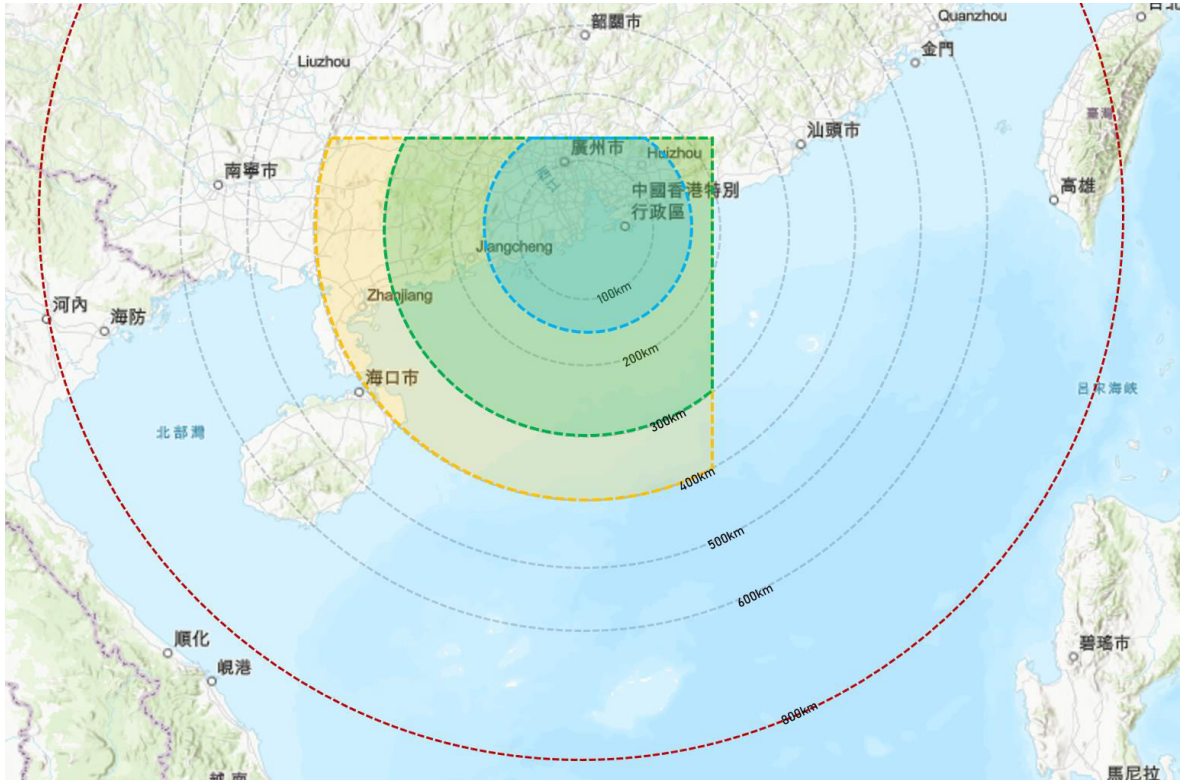
(new) *Transform from Kidney* *(new)*

Conditional Analysis
Tropical Cyclone Warning Signal No. 8

1. **50 kt wind radius** directly impacts the Macao reference grid point.
2. **TCs Intensity-Distance** Thresholds

TS	—	≤ 150 km
STS	—	≤ 300 km
TY up	—	≤ 400 km

3. Forecast track remains south of 23.5°N and west of 115.5°E (**southwestern high-impact quadrant**, more restrict than signal no.3).
4. **34 kt winds** reach the Macao grid point (threshold of signal no.8)



Counting Method (Apply to every member)

1. Direct 50 kt Impact

If Condition 1 → Numerator +1 (full count).

2. Weighted Proxy Scoring

Numerator contribution = 50% × (Condition 2 AND Condition 3) + 50% × (Condition 4)

CASE STUDY

2025 RAGASA
2025 MAMTO
2024 MALIKSI

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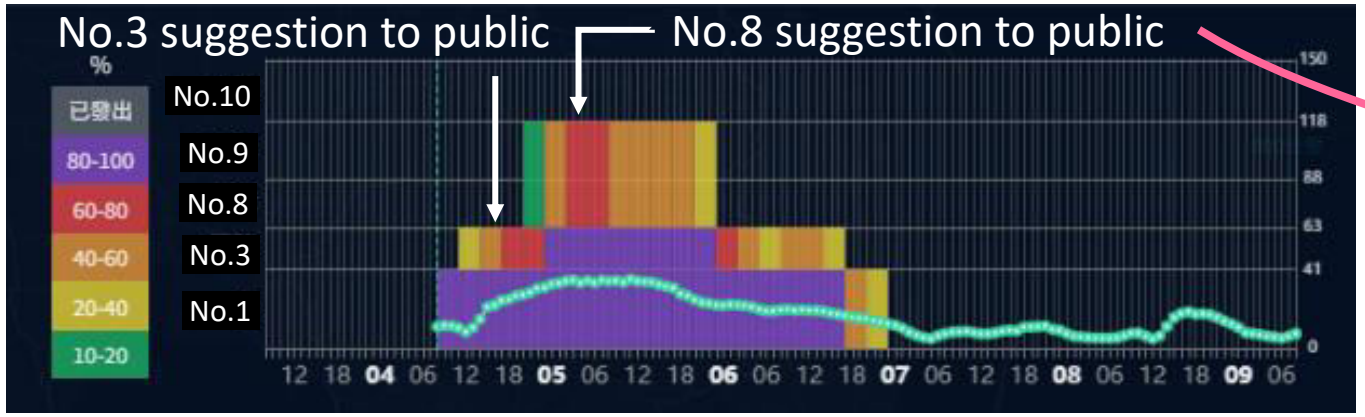
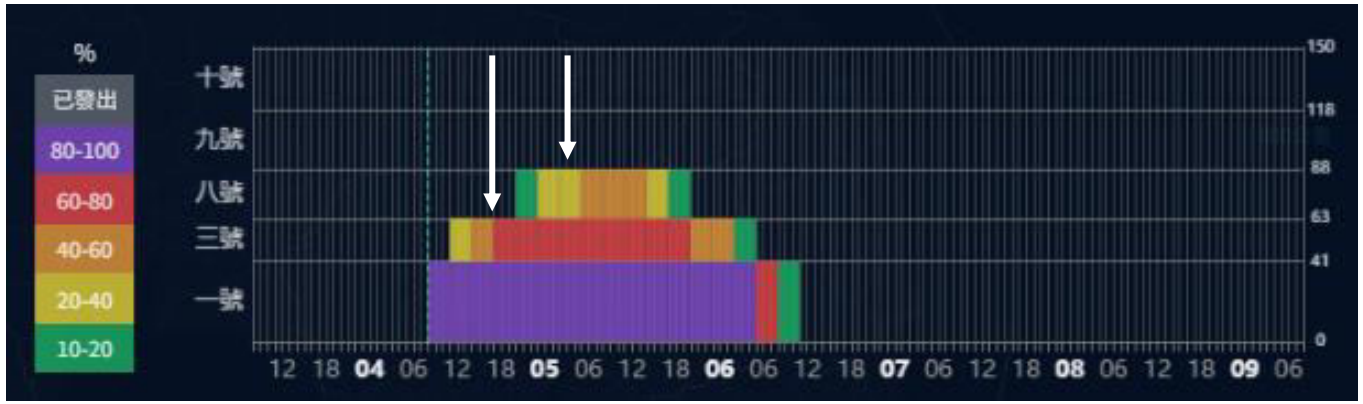
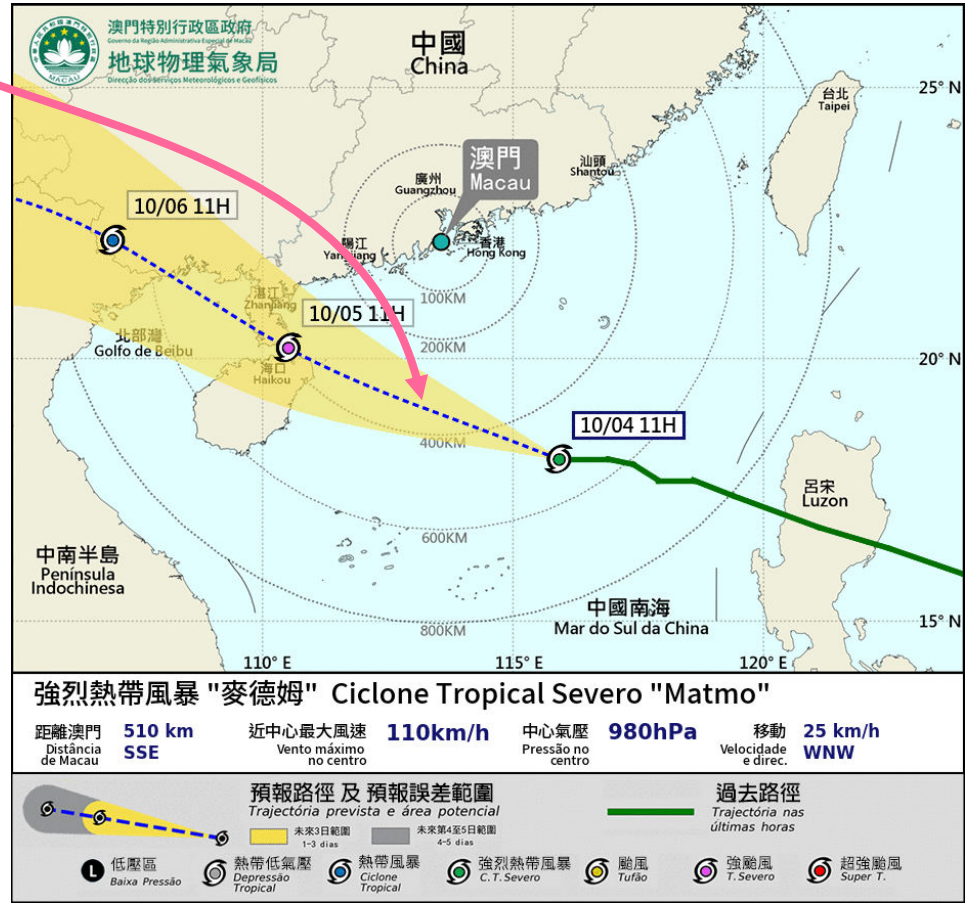
Case –Typhoon MATMO



Risk matrix from *'kidney X ensemble tracks'* calculation



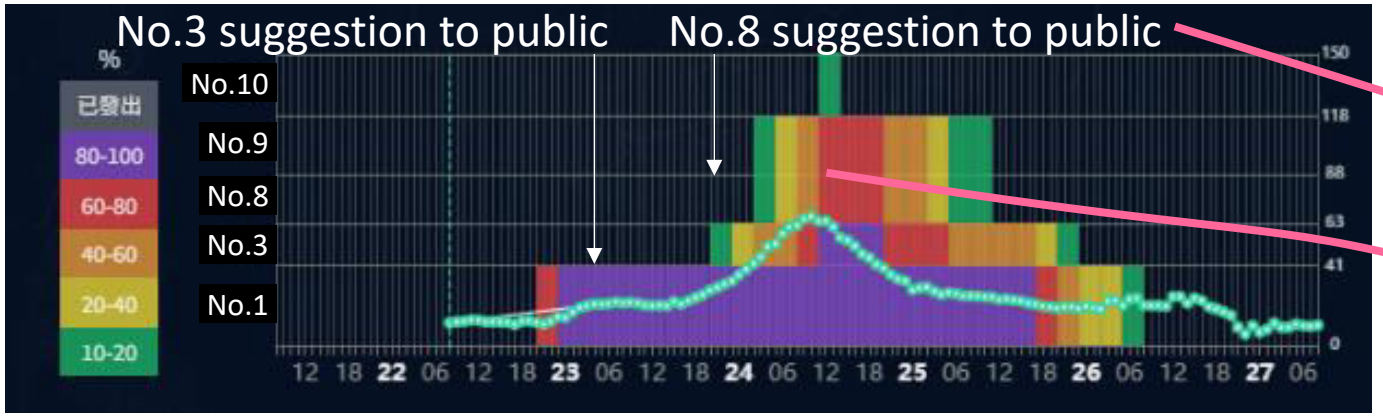
Risk matrix from *'conditional analysis'* calculation



Track forecast from DSMG @ 2025/10/04 11CST

The probability from the 'conditional analysis' approaches to our published one.

Case – Super Typhoon RAGASA



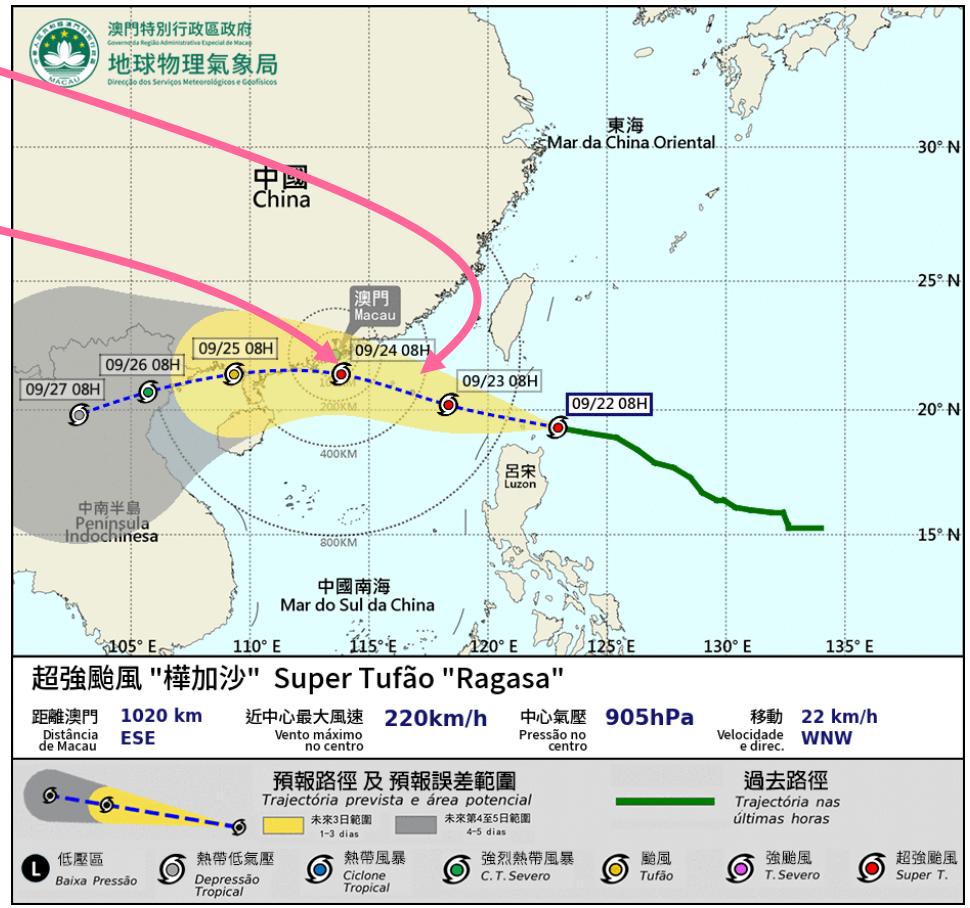
Risk matrix from *'kidney X ensemble tracks'* calculation

Possible warning signals to be issued

Typhoon Signal	Expected Issue Time	Possibility
Typhoon Signal No.1	In effect	
Typhoon Signal No.3	September 23rd, between midnight and early morning	Will be issued
Typhoon Signal No.8	September 23rd, between afternoon and evening	High

Description of Possibility: LOW | Relatively low | Medium | Relatively High | High

Probability table to the public. The predicted period in the report is far earlier than the matrix shows because the impact is serious.



Track forecast from DSMG @ 2025/09/22 08CST

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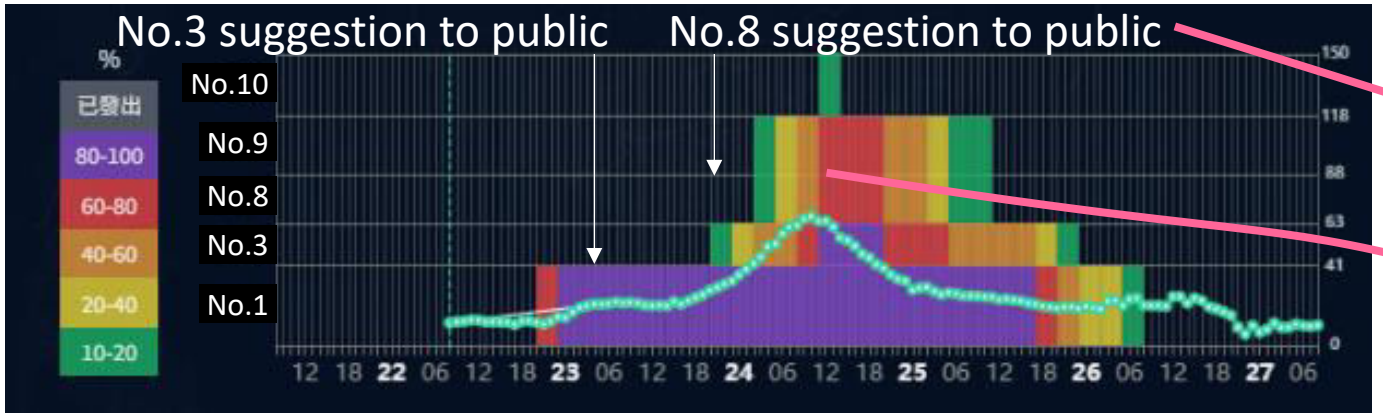
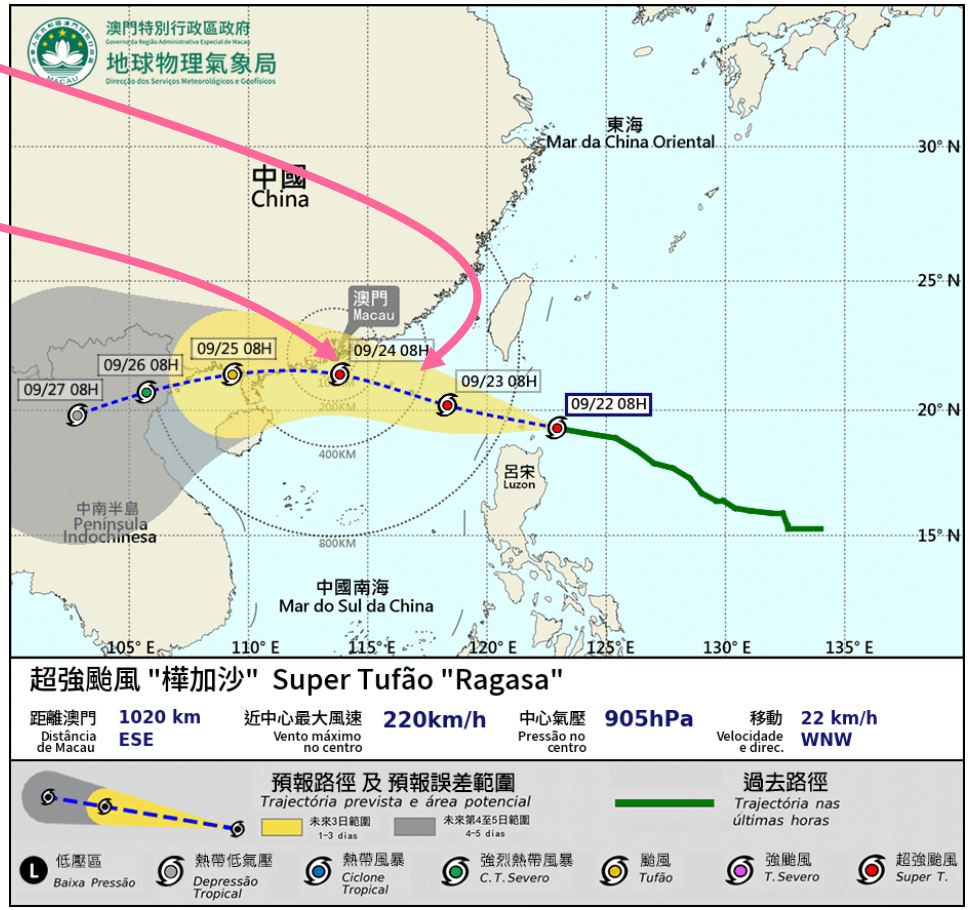
Case – Super Typhoon RAGASA



Risk matrix from *'kidney X ensemble tracks'* calculation

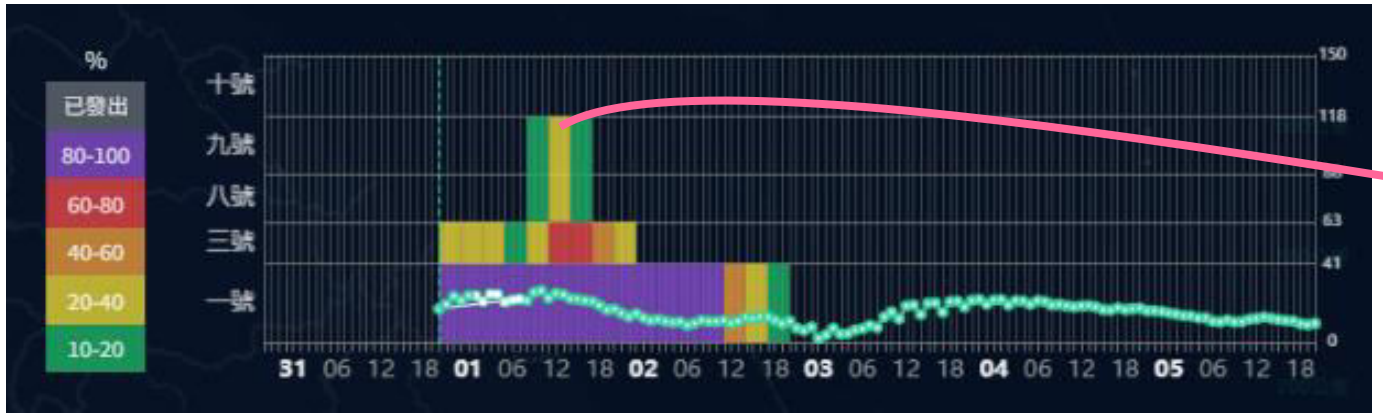
Risk matrix from *'conditional analysis'* calculation



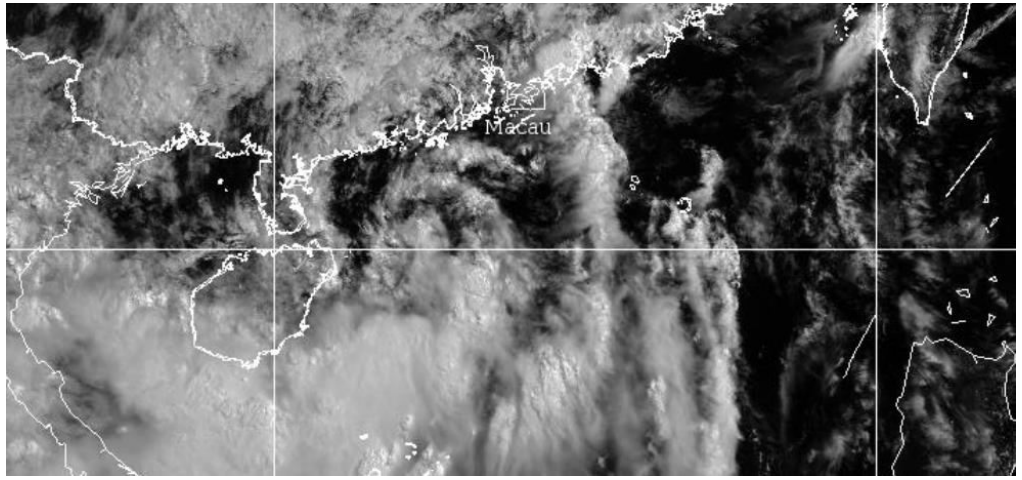
Track forecast from DSMG @ 2025/09/22 08CST

The predicted period from the 'conditional analysis gets closer to our suggestion in our public report since it relies more on our usual experiences. Though the probability shown is still a bit lower than the published.

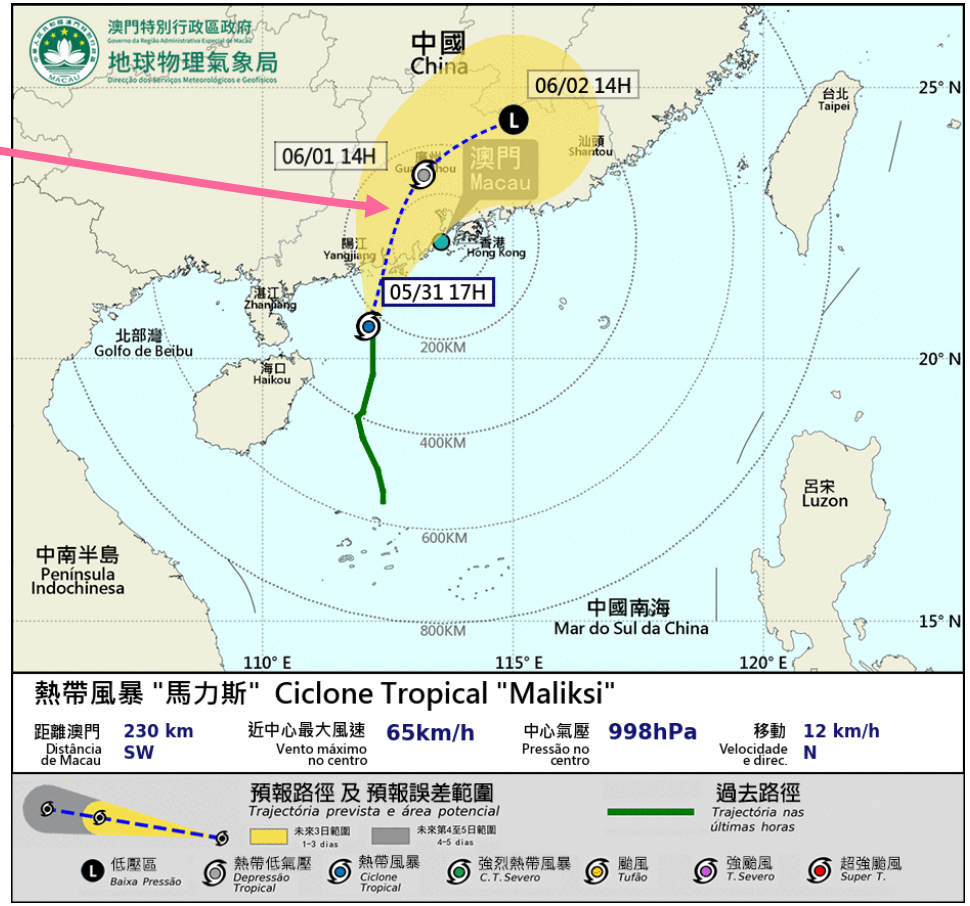
Case – Tropical Storm MALIKSI



Risk matrix from '*kidney X ensemble tracks*' calculation

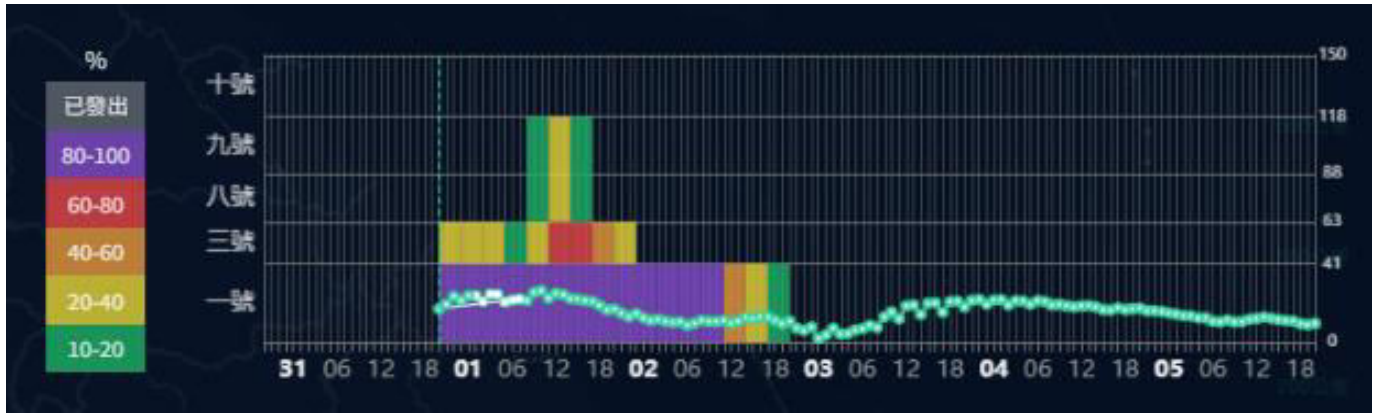


The calculated matrix in signal no.8 is higher than our forecast because the northern peripheral lacks convective cells.

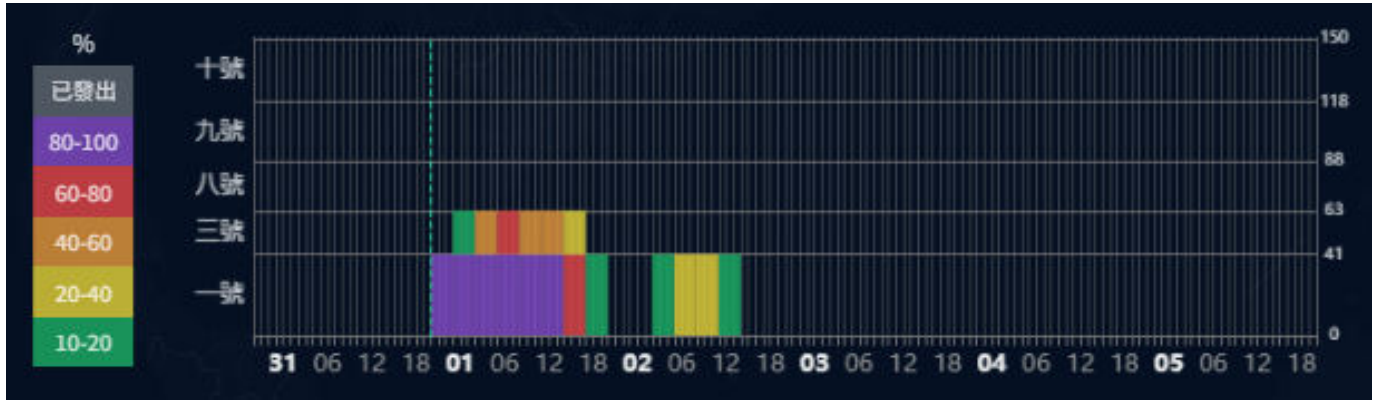


Track forecast from DSMG @ 2024/05/31 17CST

Case – Tropical Storm MALIKSI

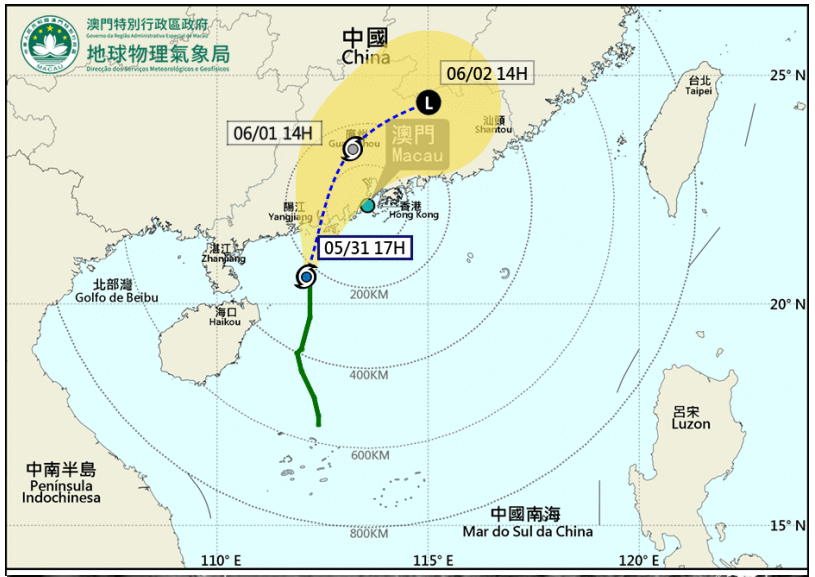


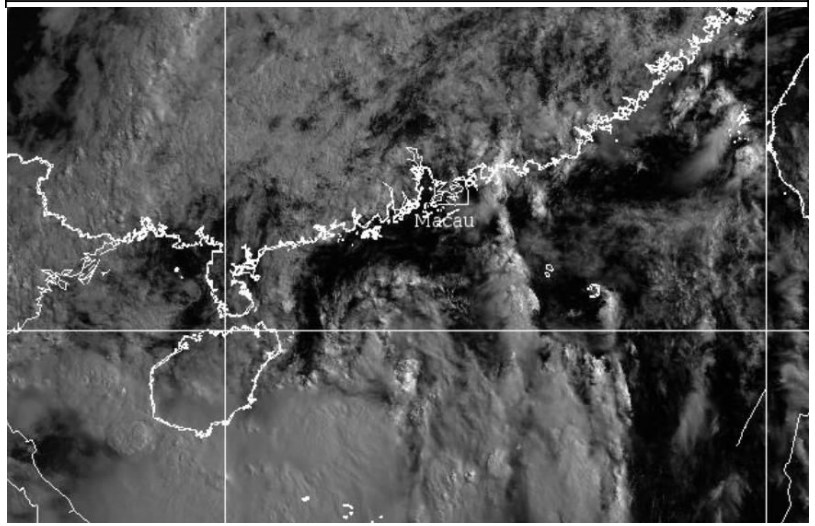
Risk matrix from '*kidney X ensemble tracks*' calculation



Risk matrix from '*conditional analysis*' calculation

Due to the forecast wind radii, the calculated probability in signal no.8 becomes low. It seems more reasonable.





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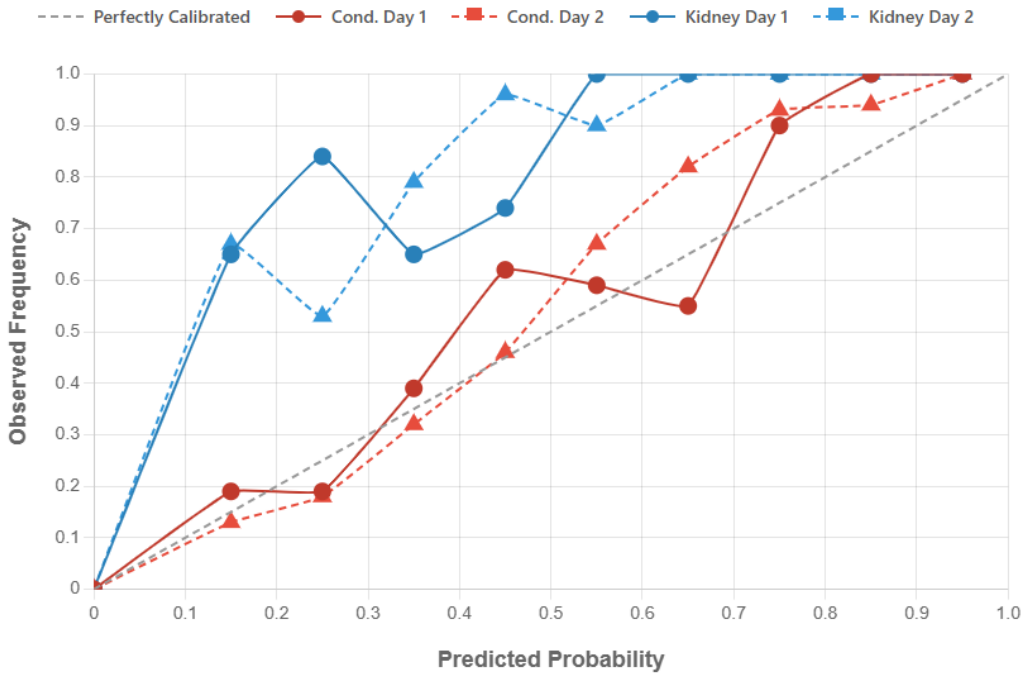
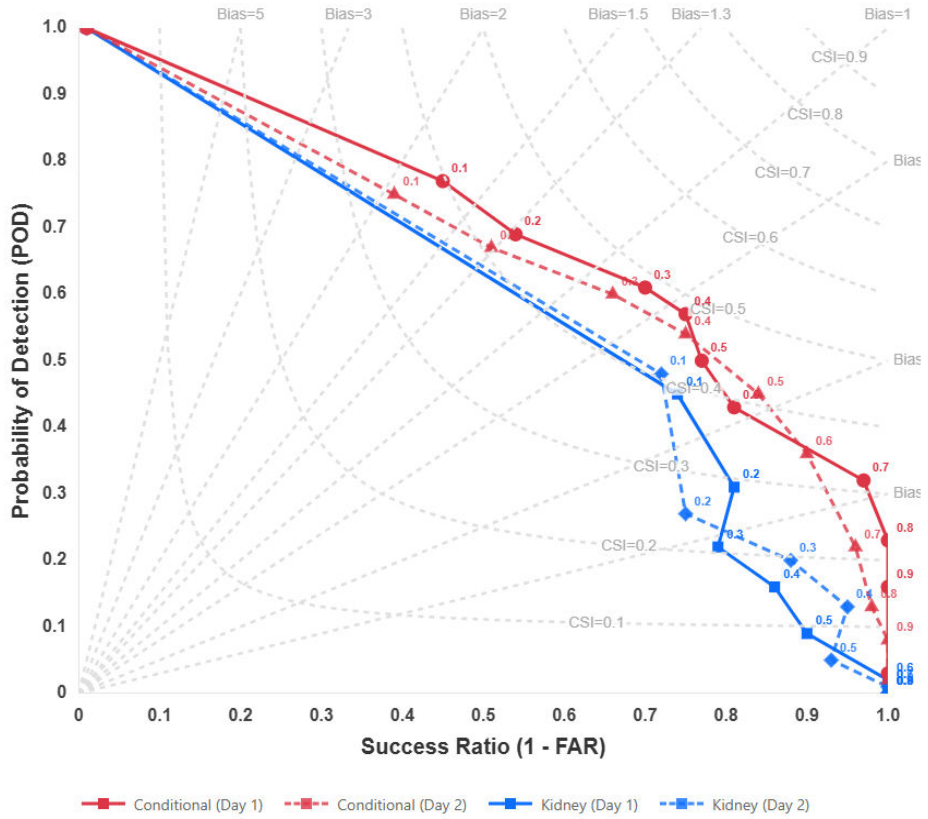
Verification – Signal No.8

Reliability Diagram



Performance Diagram



Verification Period 2020-2025

Metric	Kidney Day 1	Kidney Day 2	Conditional Analysis Day 1	Conditional Analysis Day 2
AUC (ROC Area)	0.97	0.97	0.96	0.96
Brier Skill Score	0.24	0.23	0.49	0.46

SUMMARY

1. Probabilistic forecasting let the public understand risks in advance and conduct risk management based on their needs.
2. Probability MATRICES. Objective Probability Forecast via 2 methods.

- ‘Kidney’ - statistical results × Ensemble Track
- ‘Conditional Analysis’ - Empirical domains × Ensemble Track × Forecast Wind Radii

3. Verification result shows both models works for warning forecast. ‘Conditional Analysis’ gets solutions closers to the published table.