NARLabs 國家實驗研究院
追求全球頂尖 創造在地價值

定量降雨預報校驗方法

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台灣颱風洪水中心

颱風洪水前瞻模式測試平台

模式改進

透過物理參數化調整、增加初始場擾動、結合全球模式…

發展整合預報技術

台灣定量降雨系集預報實驗

發展校驗技術

提供最佳化雨量估計

水文模擬、防災應變參考

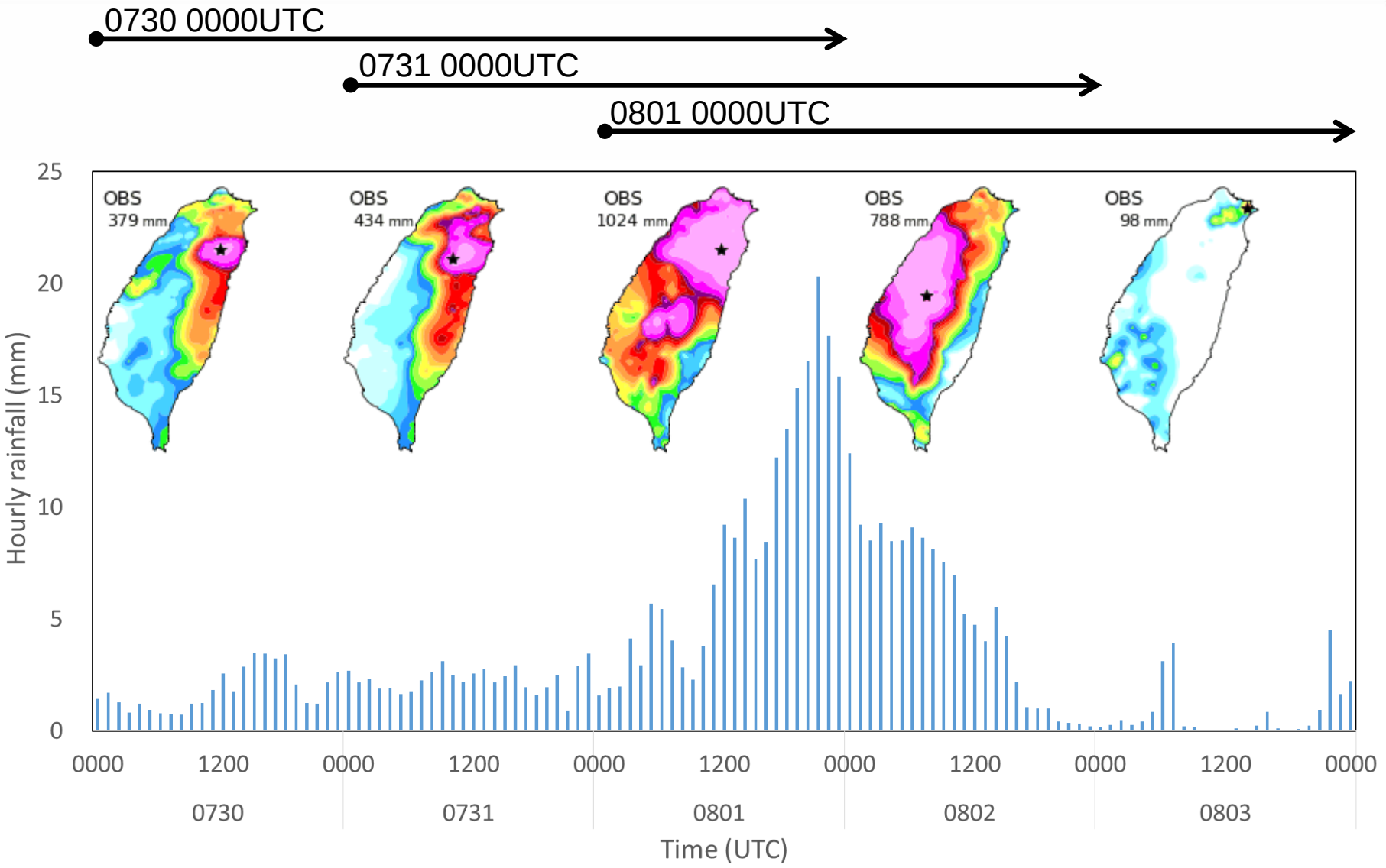
防洪預警所需降雨資訊為未來**30min～6hr降雨強度**分佈
水庫操作所需的降雨資訊為未來**12 ～ 72hr降雨總量**
崩塌預警需要未來**3～5hr降雨總量**預測資訊

Verification methods

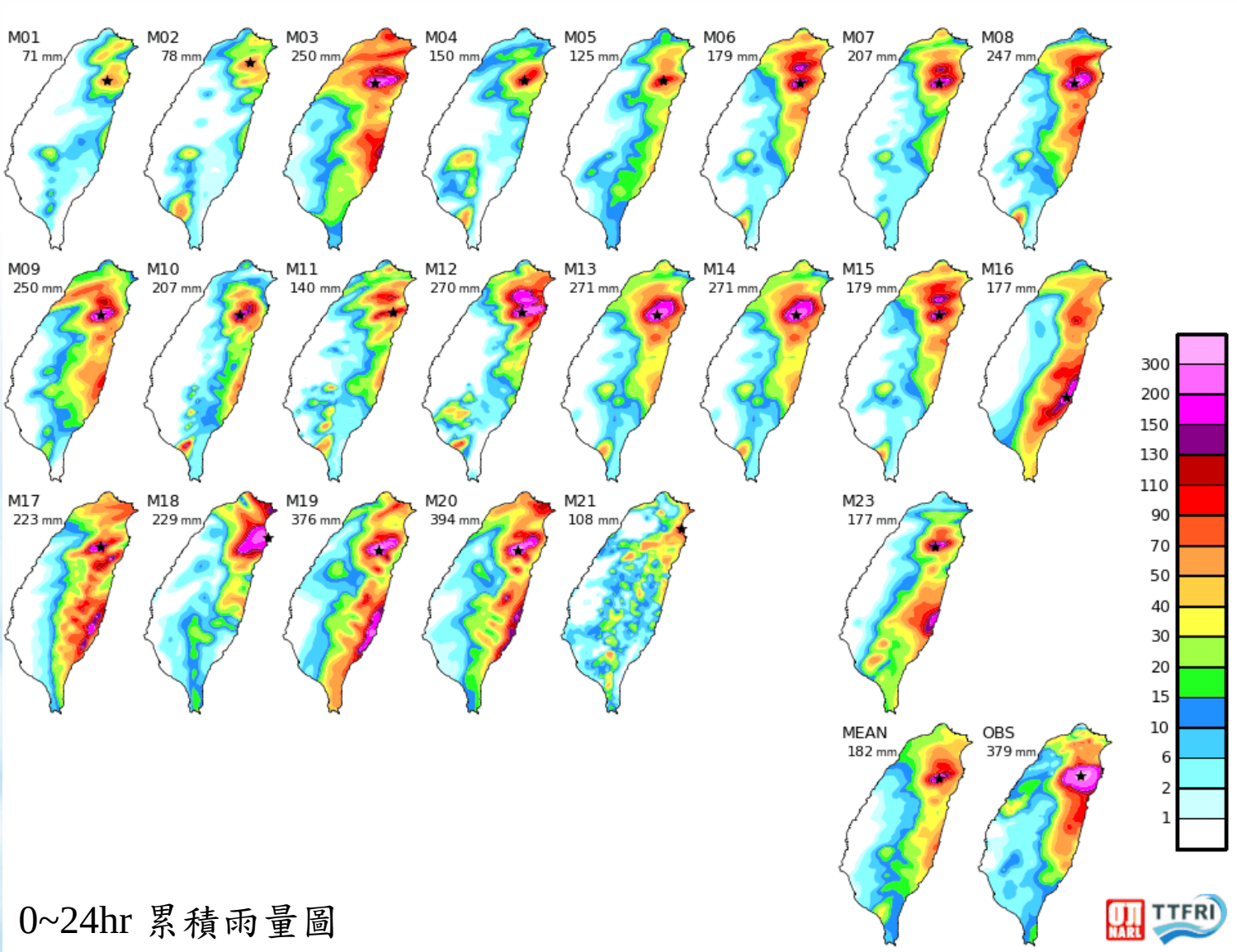
- Standard verification methods
  - Methods for dichotomous (yes/no) forecasts
  - Methods for multi-category forecasts
  - Methods for forecasts of continuous variables
  - Methods for probabilistic forecasts
- Scientific or diagnostic verification methods
  - Methods for spatial forecasts
  - Methods for probabilistic forecasts, including ensemble prediction systems
  - Methods for rare events

(From : WWRP/WGNE Joint Working Group on Forecast Verification Research)

2012 蘇拉颱風觀測雨量圖



Saola (2012) 0730 0000UTC

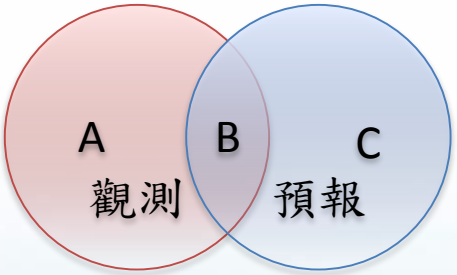


0~24hr 累積雨量圖

Methods for dichotomous (yes/no) forecasts

預兆得分計算方式如下：

$$TS = \frac{B}{A + B + C}$$

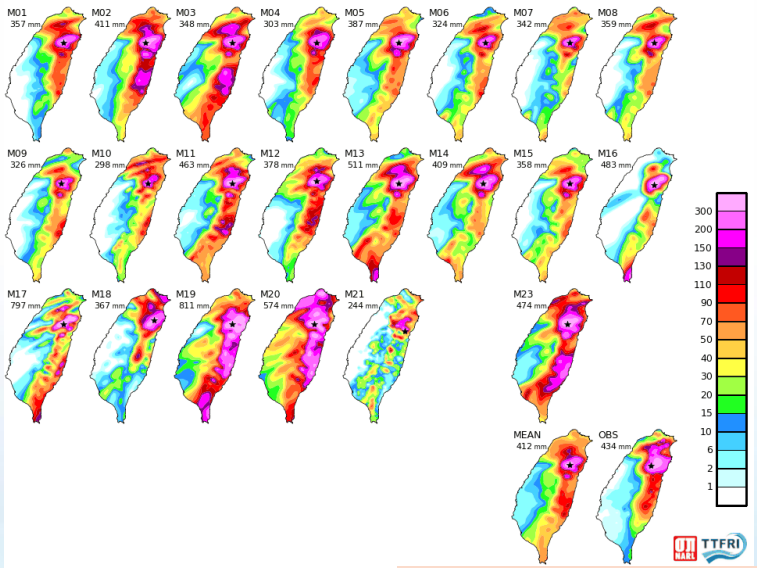


Observed / Forecast	≧門檻值（yes）	＜門檻值（no）
≧門檻值（yes）	**Hits (B)**	**False Alarms (C)**
＜門檻值（no）	**Misses (A)**	**Correct Rejection**

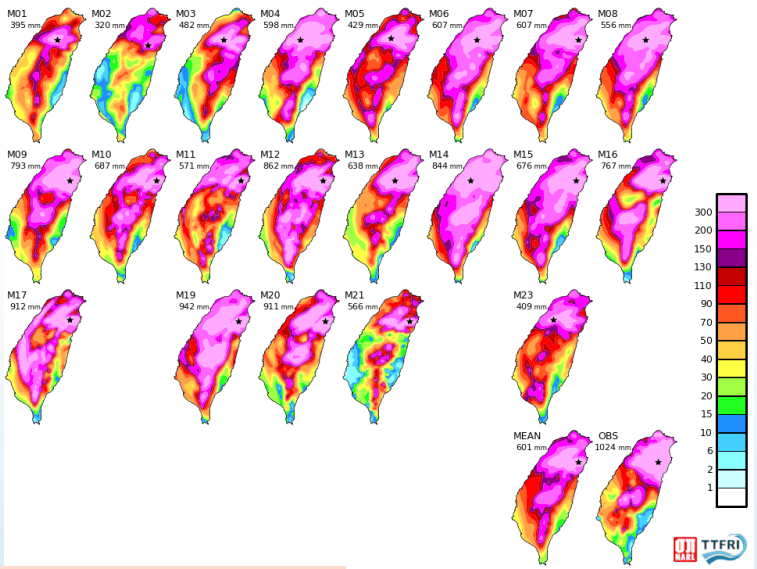
門檻值如日雨量達大雨(50mm)、豪雨(130mm)

Saola (2012)

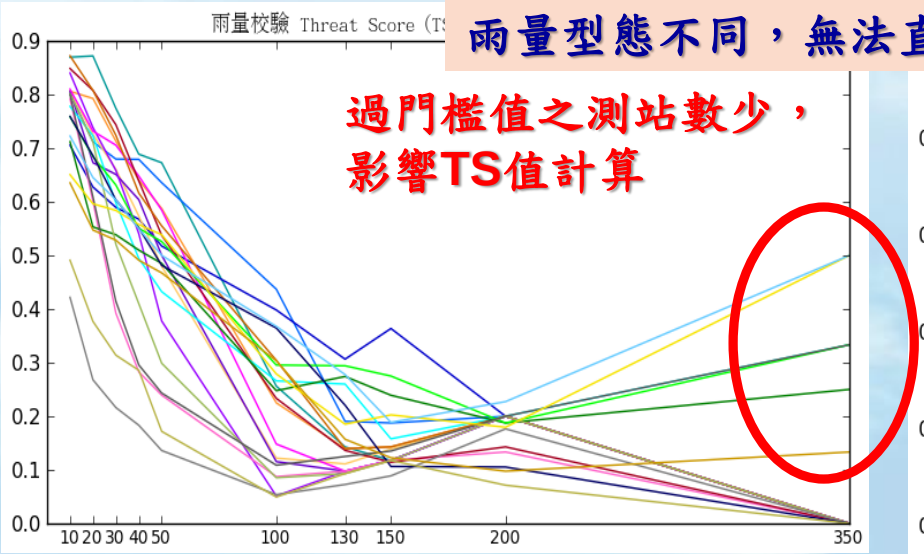
0731 0000UTC



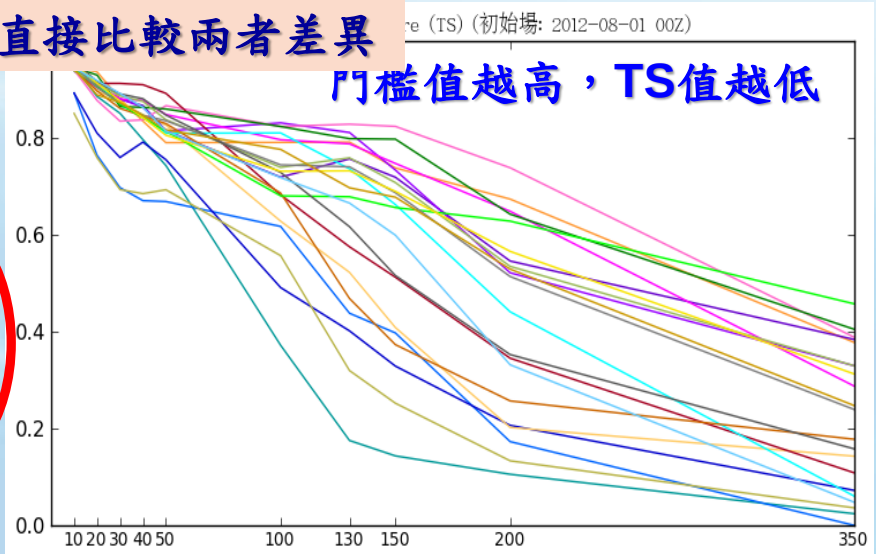
0801 0000UTC



雨量型態不同，無法直接比較兩者差異



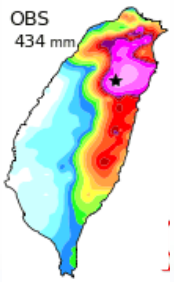
過門檻值之測站數少，
影響TS值計算

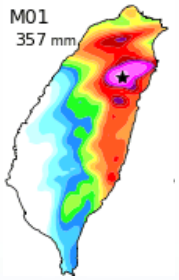


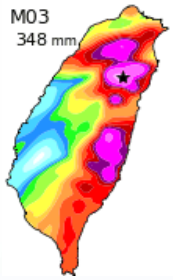
門檻值越高，TS值越低

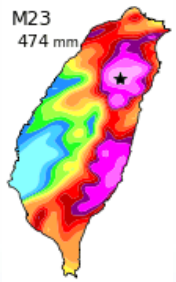
Threat Score

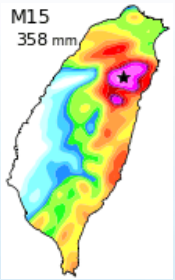
	Threshold=50mm	Threshold=130mm	Threshold=350mm
0731 0000UTC	TS=0.67	TS=0.31	TS=0.50
	TS=0.30	TS=0.13	TS=0.25
	TS=0.89	TS=0.83	TS=0.46
0801 0000UTC	TS=0.76	TS=0.40	TS=0.14

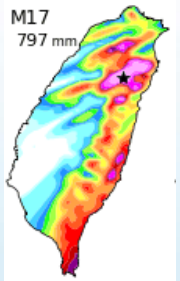


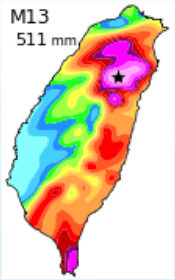


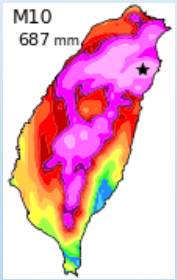


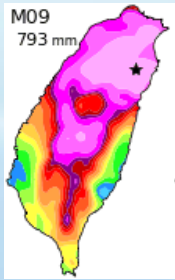


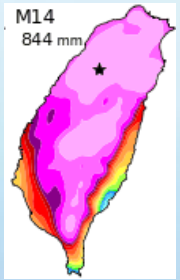


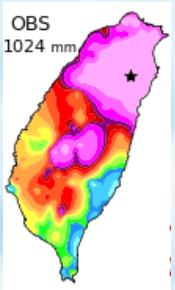


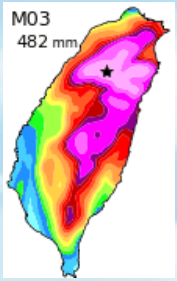


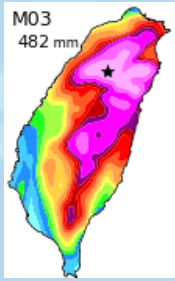


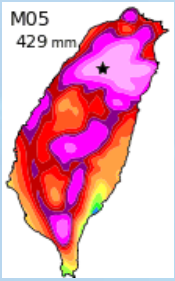


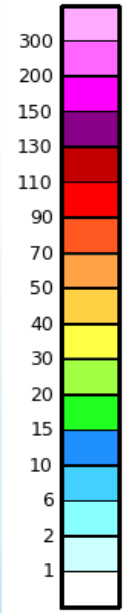








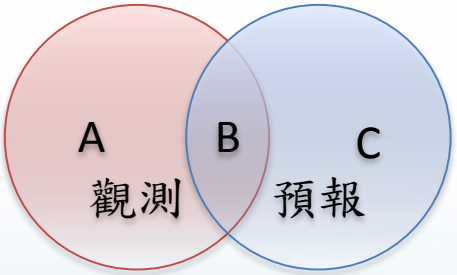




Methods for dichotomous (yes/no) forecasts

預兆得分計算方式如下：

$$TS = \frac{B}{A + B + C}$$



Observed / Forecast	≧門檻值（yes）	＜門檻值（no）
≧門檻值（yes）	Hits (B)	False Alarms (C)
＜門檻值（no）	Misses (A)	Correct Rejection

門檻值如日雨量達大雨(50mm)、豪雨(130mm)

- **公正預兆得分 (Equitable Threat Score)**
  除了TS計算概念外，亦額外排除隨機預報正確的狀況；利用此得分比較不同區域的預報表現較客觀

$$ETS = \frac{\text{hits} - \text{hits}_{\text{random}}}{\text{hits} + \text{misses} + \text{false alarms} - \text{hits}_{\text{random}}}$$

其中

$$\text{hits}_{\text{random}} = \frac{(\text{hits} + \text{misses})(\text{hits} + \text{false alarms})}{\text{total}}$$

- **可偵測機率 (Probability of Detection)**

$$POD = \frac{\text{hits}}{\text{hits} + \text{misses}}$$

- **偏倚得分 (Bias Score)**

$$Bias = \frac{\text{hits} + \text{false alarms}}{\text{hits} + \text{misses}}$$

- **誤報率 (False Alarm Ratio)**

$$FAR = \frac{\text{false alarms}}{\text{hits} + \text{false alarms}}$$

(From : WWRP/WGNE Joint Working Group on Forecast Verification Research)

Methods for multi-category forecasts

觀測類別 (Obs. Cat.) / 預報類別 (Forecast Cat.)	1	2	…	k	Total
1	$n(F_1,O_1)$	$n(F_1,O_2)$	…	$n(F_1,O_k)$	$N(F_1)$
2	$n(F_2,O_1)$	$n(F_2,O_2)$	…	$n(F_2,O_k)$	$N(F_2)$
…	…	…	…	…	…
k	$n(F_k,O_1)$	$n(F_k,O_2)$	…	$n(F_k,O_k)$	$N(F_k)$
Total	$N(O_1)$	$N(O_2)$	…	$N(O_k)$	N

- **正確率**

$$\text{Accuracy} = \frac{1}{N}\sum_{i=1}^{k} n(F_i, O_i)$$

- **Heidke skill score**

描述模式預報能力是否有優於隨機預報

$$\text{HSS} = \frac{\frac{1}{N}\sum_{i=1}^{k} n(F_i, O_i) - \frac{1}{N^2}\sum_{i=1}^{k} N(F_i)N(O_i)}{1 - \frac{1}{N^2}\sum_{i=1}^{k} N(F_i)N(O_i)}$$

- **Hanssen and Kuipers discriminant**

描述模式預報能力是否有優於隨機預報

$$\text{HK} = \frac{\frac{1}{N}\sum_{i=1}^{k} n(F_i, O_i) - \frac{1}{N^2}\sum_{i=1}^{k} N(F_i)N(O_i)}{1 - \frac{1}{N^2}\sum_{i=1}^{k} (N(O_i))^2}$$

(From : WWRP/WGNE Forecast Verification Research)

Methods for multi-category forecasts

Hourly Rainfall

Observation

Forecast

	0~5	5~10	10~15	15~20	20~25	25~30	30~35	35~40	40~45	45~50	50~55	55~60	60~65	65~70	70~75	75~80	80~85	85~90	90~95	95~100	100~
0~5	9220	755	270	134	55	25	19	10	6	5	5	1	1	1							
5~10	2201	869	451	270	144	81	33	15	17	8	4	5	1		1		3	3	2	1	
10~15	1205	440	339	250	197	109	75	47	25	19	6	2	3				3				2
15~20	352	203	187	148	127	98	67	53	34	20	17	7	9	3							
20~25	83	91	86	82	78	57	35	30	21	21	11	5	3	4	4					1	
25~30	36	51	40	47	52	38	28	37	23	18	10	4	4	2	2	4	2				
30~35	16	17	18	13	28	20	22	21	13	15	8	5	5	1	3	3	1		1		
35~40		2	4	2	8	8	9	5	11	7	6	5	3		2		2	1	1		
40~45		1			1	3	3	4	4	4	3	4	2	2		1					
45~50										3			1								
50~55												2	1	1							
55~60																					
60~65																					
65~70																					
70~75																					
75~80																					
80~85																					
85~90																					
90~95																					
95~100																					
100~																					

Under-estimated (11%)

Accuracy (78%)

Over-estimated (11%)

(2012080100 UTC)

Methods for multi-category forecasts

Hourly Rainfall

Observation

Forecast

	0~5	5~10	10~15	15~20	20~25	25~30	30~35	35~40	40~45	45~50	50~55	55~60	60~65	65~70	70~75	75~80	80~85	85~90	90~95	95~100	100~
0~5	9220	755	270	134	55	25	19	10	6	5	5	1	1	1							
5~10	2201	869	451	270	144	81	33	15	17	8	4	5	1		1		3	3	2	1	
10~15	1205	440	319	250	197	109	75	47	25	19	6	2	3				3				2
15~20	352	203	122	146	127	98	67	53	34	20	17	7	9	3							
20~25	83	91	86	82	78	57	35	30	21	21	11	5	3	4	4					1	
25~30	36	51	40	47	52	38	28	37	23	18	10	4	4	2	2	4	2				
30~35	16	17	18	13	28	20	22	21	13	15	8	5	5	1	3	3	1		1		
35~40		2	4	2	8	8	9	5	11	7	6	5	3		2		2	1	1		
40~45		1			1	3	3	4	4	4	3	4	2	2		1					
45~50										3			1								
50~55												2	1	1							
55~60																					
60~65																					
65~70																					
70~75																					
75~80																					
80~85																					
85~90																					
90~95																					
95~100																					
100~																					

Accuracy (81%)

Accuracy (12%)

Accuracy (0%)

(2012080100 UTC)

Methods for forecasts of continuous variables

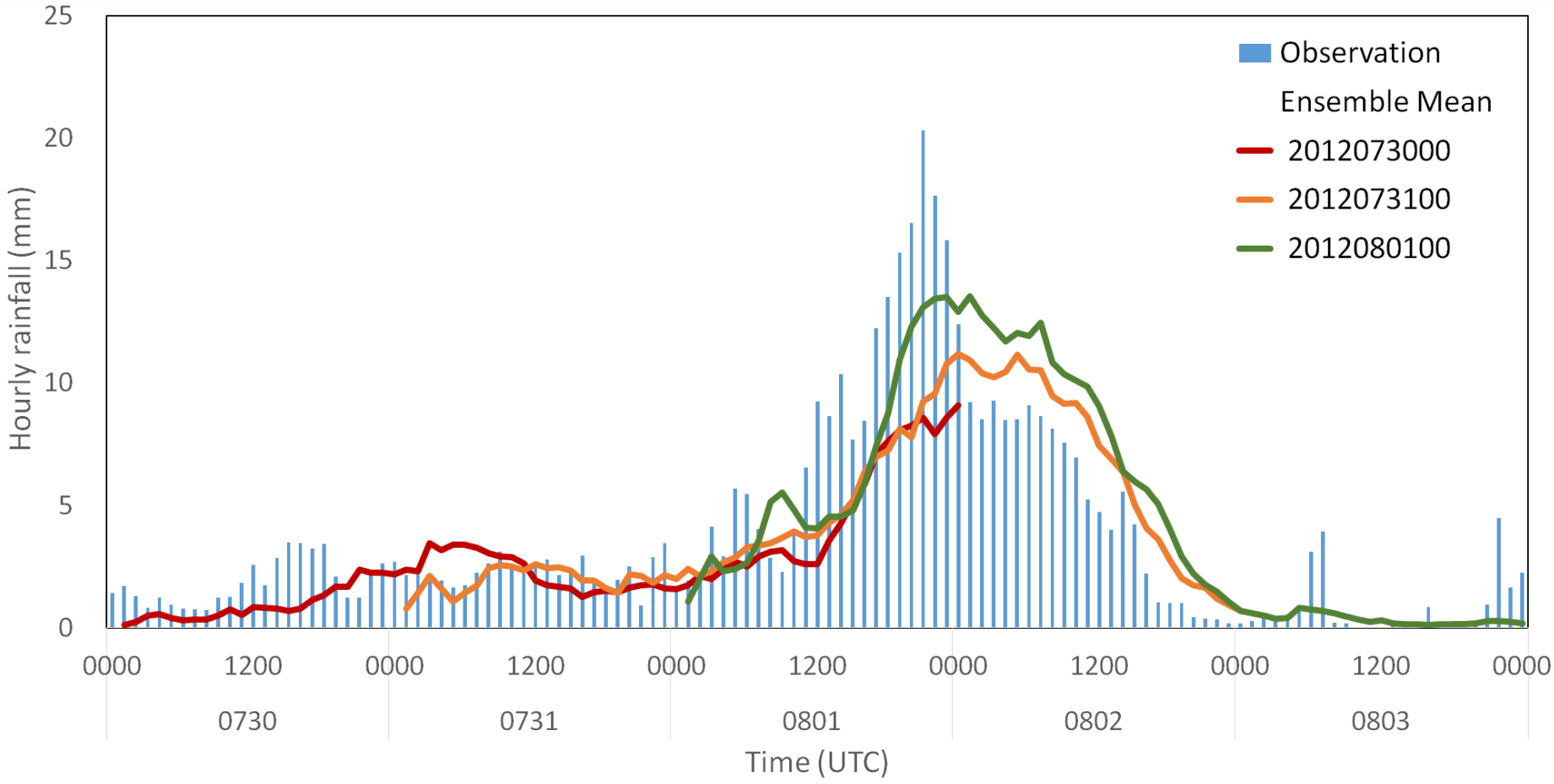
- Mean error
- Mean absolute error
- Mean squared error
- Root mean square error

- Bias
- Correlation coefficient
- Anomaly correlation

Rain (time, station, model, run)

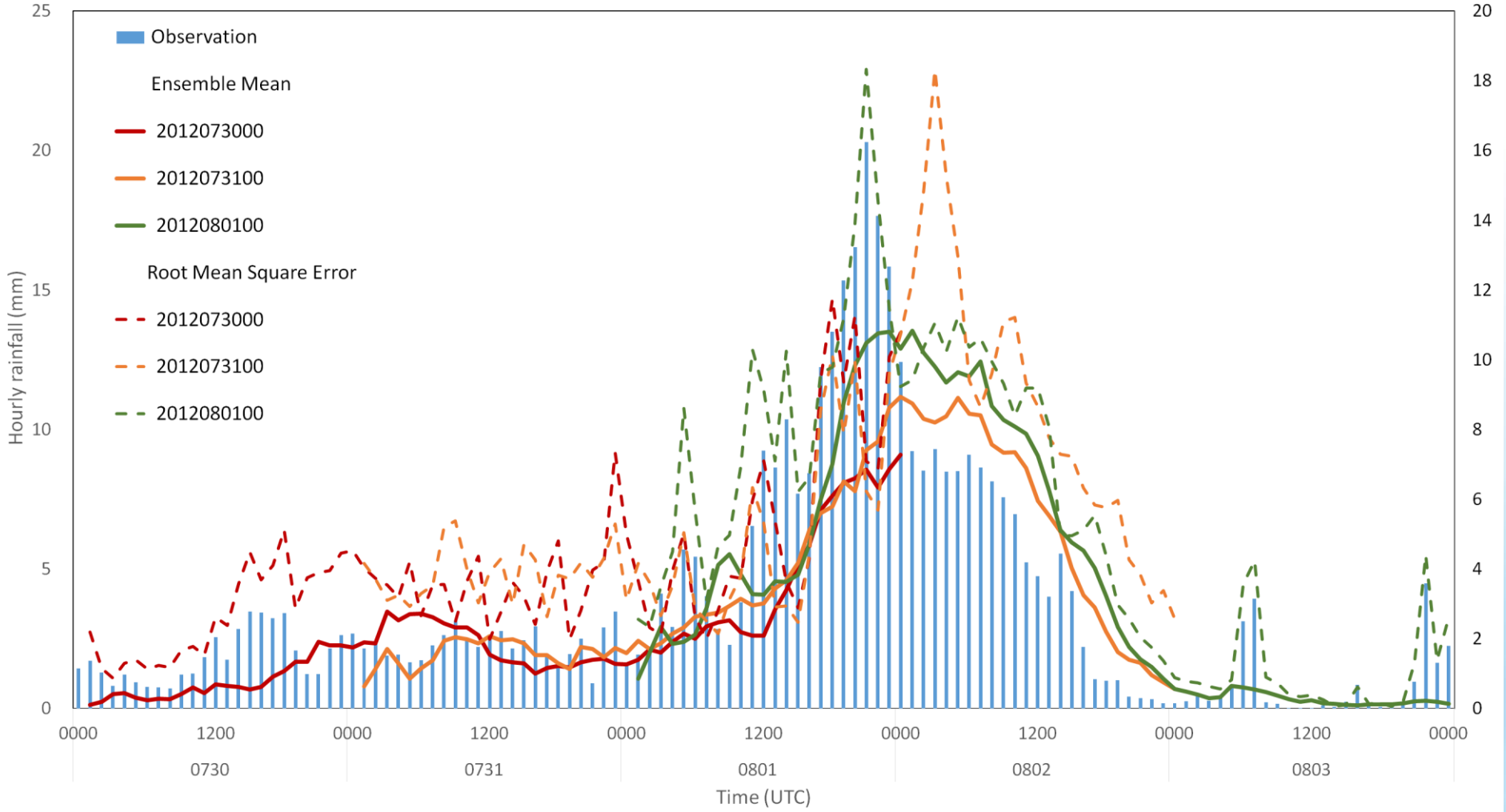
(From : WWRP/WGNE Joint Working Group on Forecast Verification Research)

0730 0000 – 0804 0000 雨量時序圖



Root Mean Square Error

(RMSE)



Summary

- Methods for dichotomous (yes/no) forecasts
  - 需決定單一門檻值
  - 通常以累積雨量做計算，需決定累積多少小時
  - 不同降雨類型無法直接比較
  - 一般而言，門檻值越高，校驗得分越低；門檻值越高，需注意用以計算之測站數有多少
- Methods for multi-category forecasts
  - 不需決定門檻值
  - 時雨量、累積雨量均可計算
  - 計算正確率時，小雨事件數多，主導校驗得分
  - 對於大雨事件較嚴苛
- Methods for forecasts of continuous variables
  - 不需決定門檻值
  - 校驗指標中，Mean Error、Mean Absolute Error、Mean Square Error、Root Mean Square Error受降雨型態影響很大

Conclusion

- Before verifying…
  - 校驗參考標的：觀測資料、預報資料
  - 時間：時雨量或累積雨量（累積多少小時、從第幾小時開始累積）
  - 空間：個別測站或區域平均（全台灣或單一縣市、流域）
  - 模式：系集平均、個別成員、Probability Matching、最佳化…
  - 初始時間：單一初始時間、事件或個案平均、月或年平均
  - 校驗目的→校驗方法或診斷分析方法

    防洪預警所需降雨資訊為未來**30min～6hr降雨強度**分佈
    水庫操作所需的降雨資訊為未來**12 ～ 72hr降雨總量**
    崩塌預警需要未來**3～5hr降雨總量**預測資訊

- 研發與測試各類型校驗指標 → 客觀描述雨量預報表現
- 建立一套校驗平台，整合各類型校驗指標，可客觀比較各類技術、模式改進的程度

NARLabs 國家實驗研究院
追求全球頂尖 創造在地價值

Thank You !