A2-25

Heavy-Rainfall QPFs in Taiwan under the Topographic Control (臺灣地形控制下之豪大雨預報)

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4-6 Oct 2016, CWB Conference on Weather Analysis and Forecasting

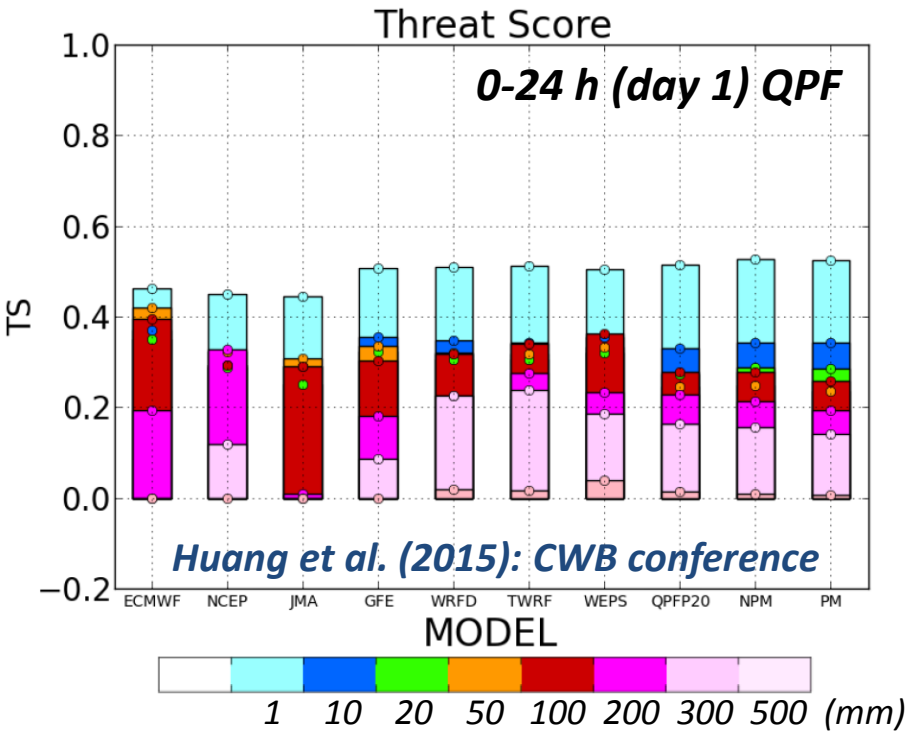
Presentation outline

1. Background Introduction

1.1 Current QPF Skills for Typhoons and Mei-yu Events

- For the 2014 typhoon season:

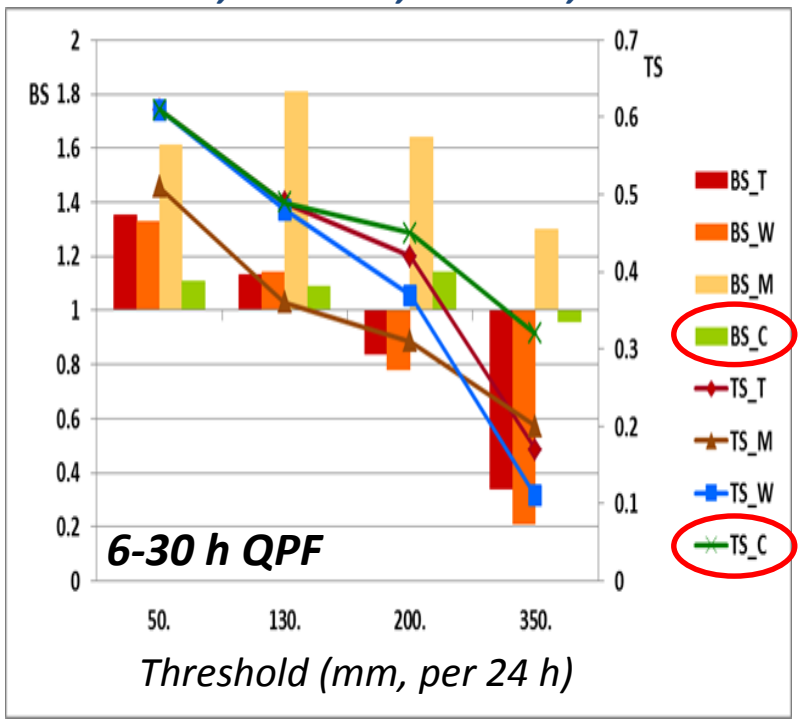
At CWB and major centers



Huang et al. (2015): CWB conference

At TTFRI, for two TCs in 2014

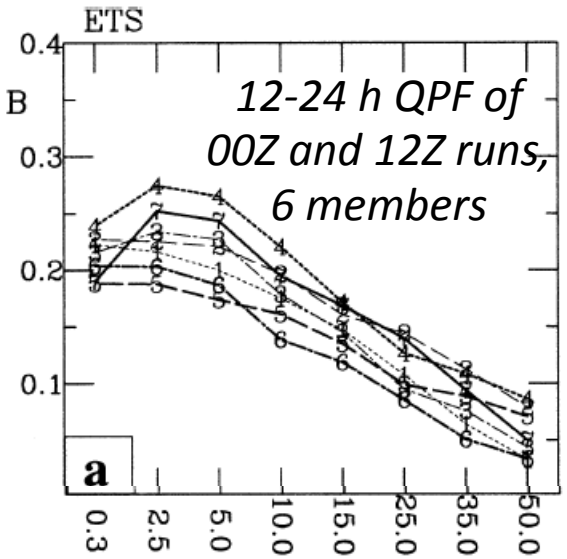
TAPEX-26, WRF-20, MM5-2, CReSS-2



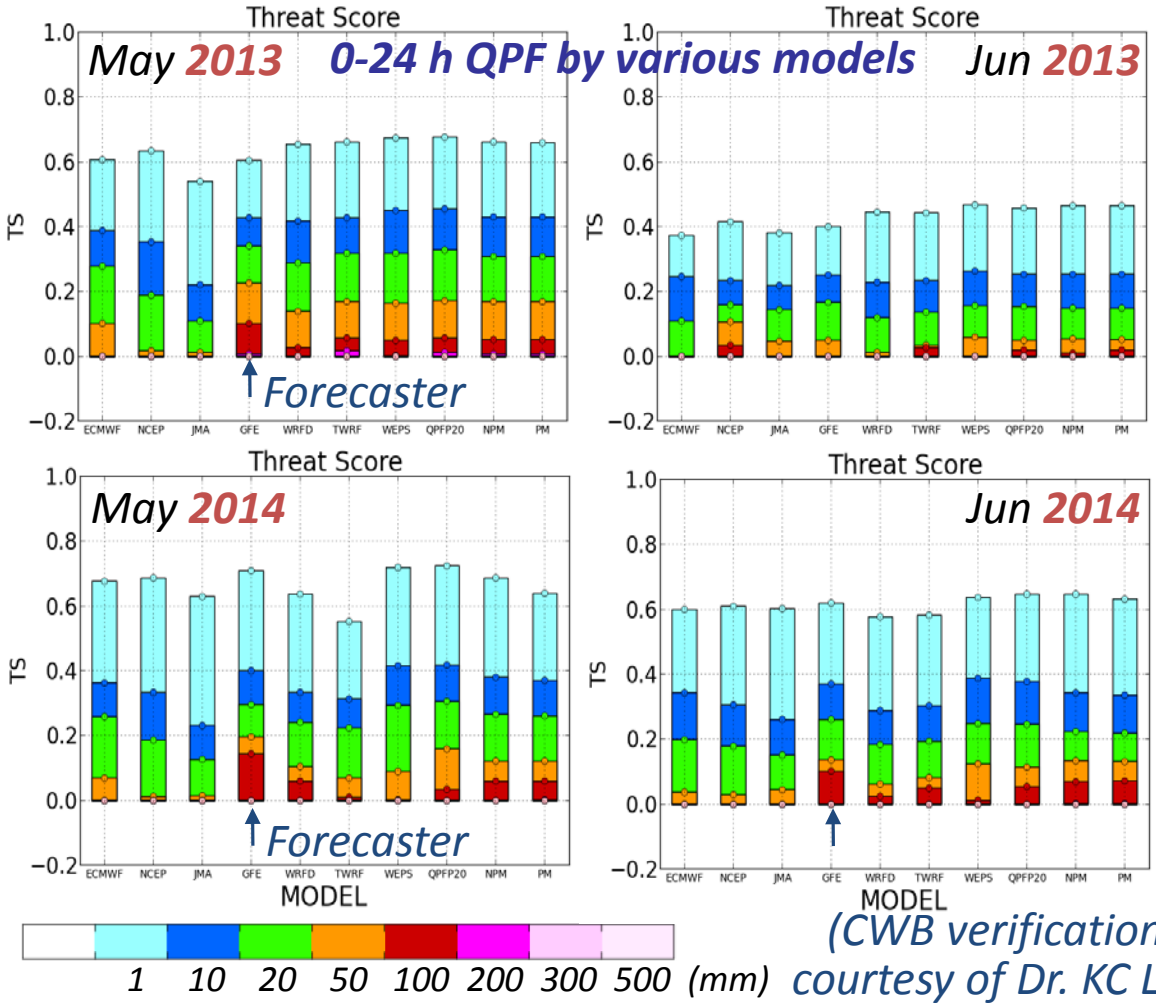
Wang et al. (2015): CWB conference

- TS ~ 0.2 at 300 mm, little skill ≥ 500 mm (per 24 h) for day-1 QPFs

- *For past and recent Mei-yu seasons:*



*15-km MM5, Mei-yu **2001***
(Chien and Jou 2004)



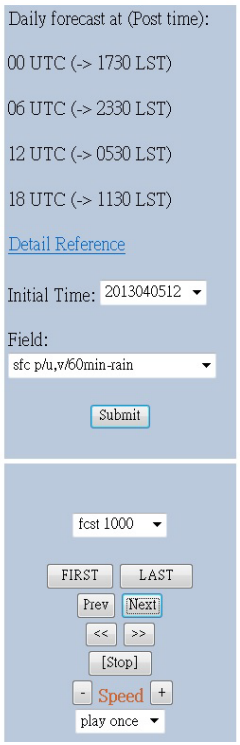
(CWB verification, courtesy of Dr. KC Liu)

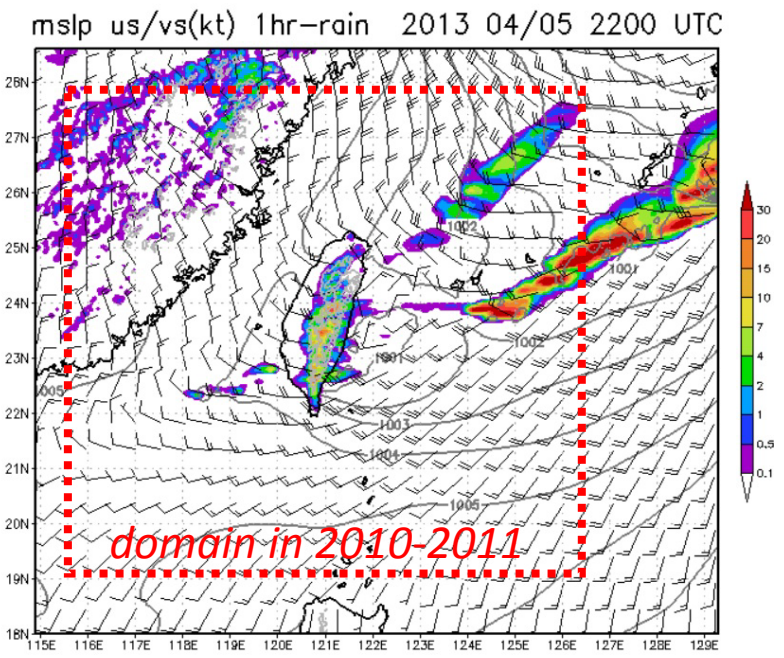
- *A decade ago: Some skill in occurrence but limited skill above 50 mm*
- *Recent years: Improvement ≤50 mm but not above ~150 mm*

- *How can they be improved, in particular, over heavy-rainfall thresholds (≥ 300-350 mm for typhoons and ≥150-200 mm for mei-yu?*

1.2 Real-time CReSS Forecasts

- *Real-time CReSS forecast experiments in Taiwan for Mei-yu season since 2006, for typhoons since 2007, and non-stop for the entire year since 2010*
- *Gradual increases in resolution, forecast length, and domain size*
- *Using NCEP GFS 1°x 1° analyses/forecasts as IC/BCs (0.5°x 0.5° since 2013)*
- *Current forecasts (40L) every 6 h out to 78 h:*
  - *5 km (216 x 180)*
  - *2.5 km (600 x 480)*
- *Routinely provided to TTFRI of Taiwan as the only cloud-resolving member (Δx = 2.5 km)*



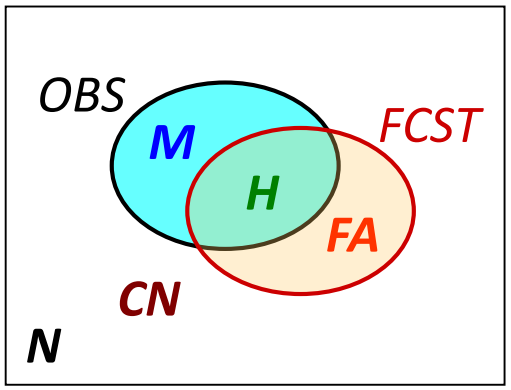


(Current 2.5-km domain: 1500 km x 1200 km)

- *Real-time (and all past) results available at http://cressfcst.es.ntnu.edu.tw*

1.3 Verification of 24-h QPFs (Days 1-3)

- *Commonly-used verification methods for QPFs:*
  - *Both subjective (visual) and objective verifications*
  - *Widely-used skill scores: Threat score (TS), bias score (BS), probability of detection (POD), false-alarm rate (FAR), and odds ratio (OR)*
  - *24-h accumulative rainfall (day 1, 2, 3), from forecasts starting at 0000 or 1200 UTC*
  - *Rainfall thresholds: 0.05 to 1000 (or 500) mm*
  - *Evaluated on rain-gauge sites (about 450 points) with equal weight*

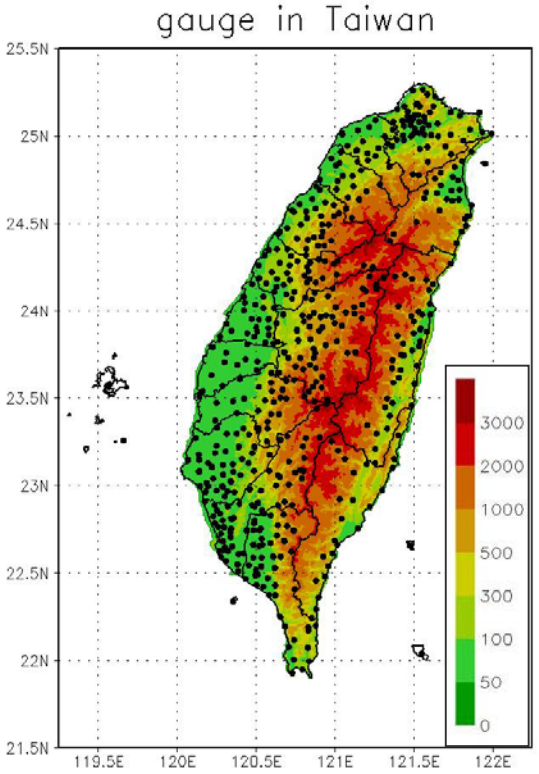


$$TS = H / (M + H + FA)$$

$$BS = (H + FA) / (H + M)$$

$$POD = H / (H + M)$$

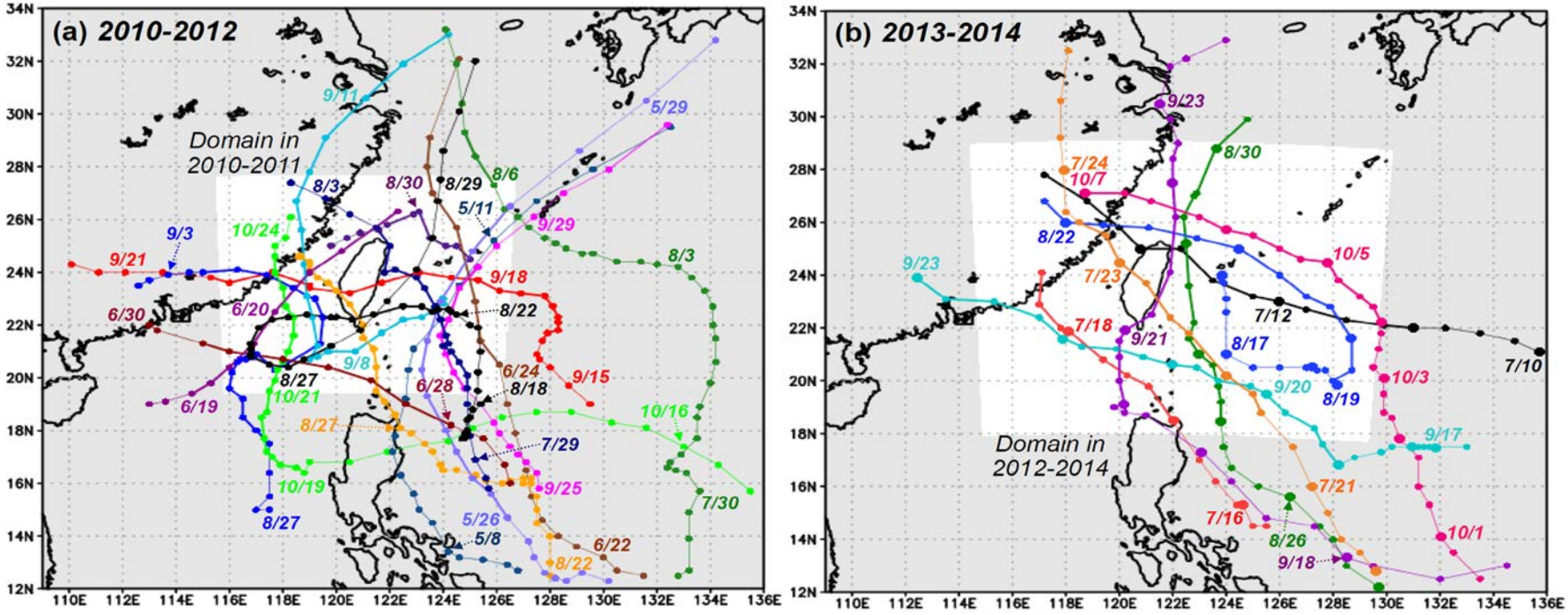
$$FAR = FA / (H + FA)$$



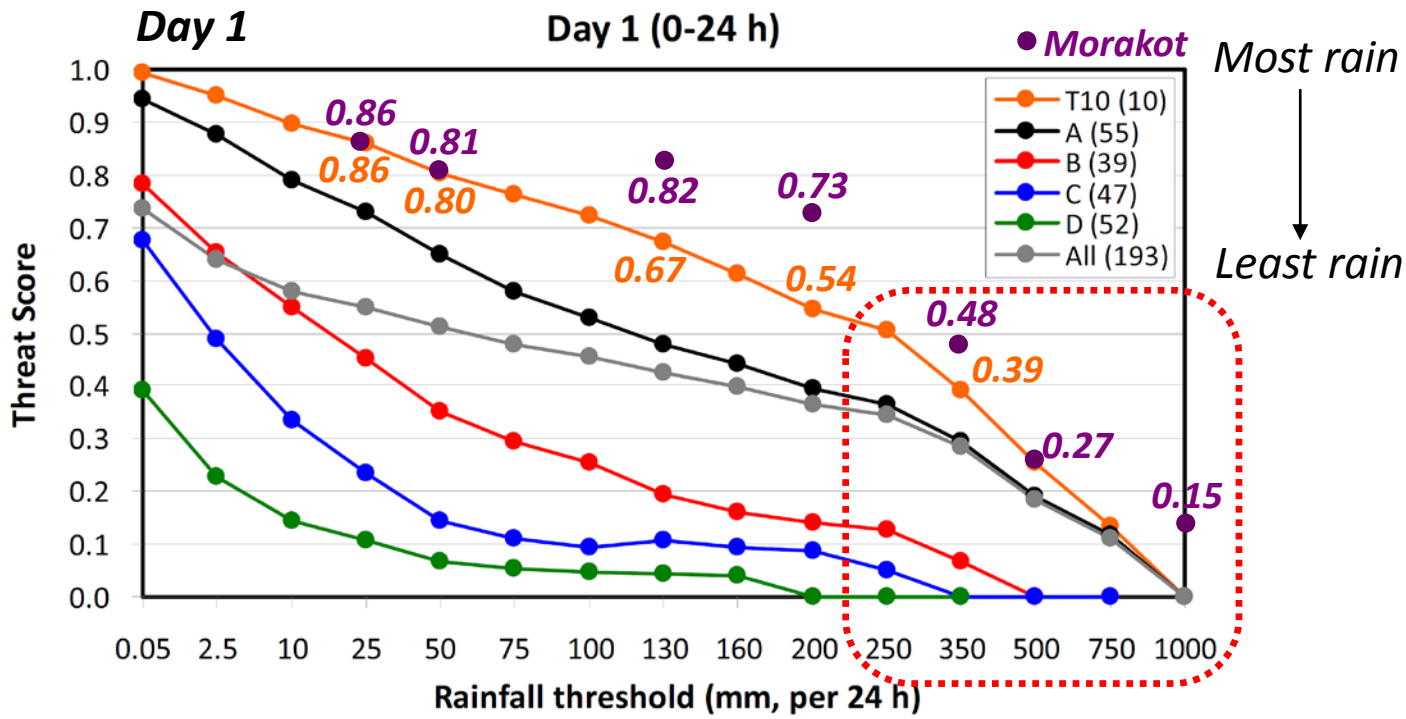
2. Typhoon Results and Examples

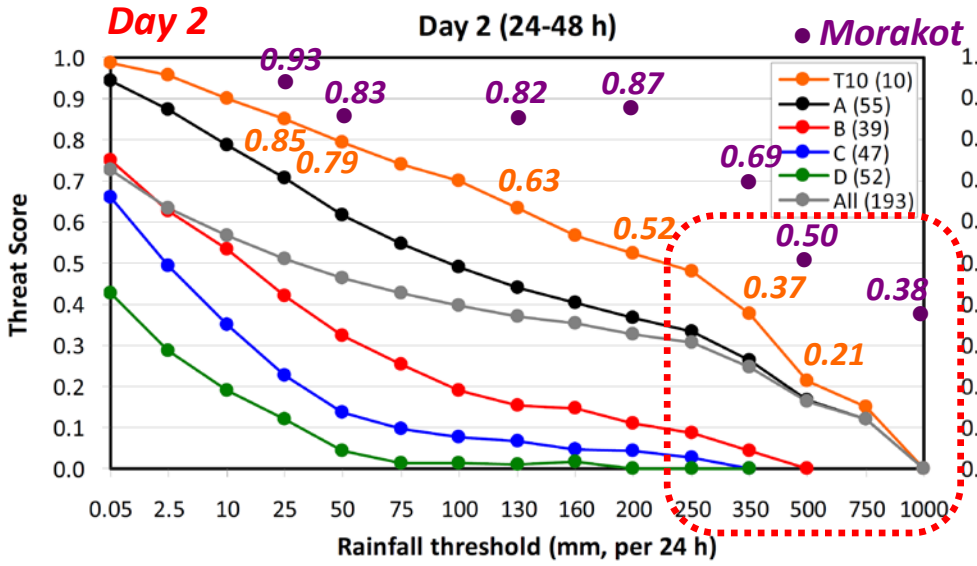
2.1 Overall Performance in 2010-2015 (Six Seasons, 29 TCs)

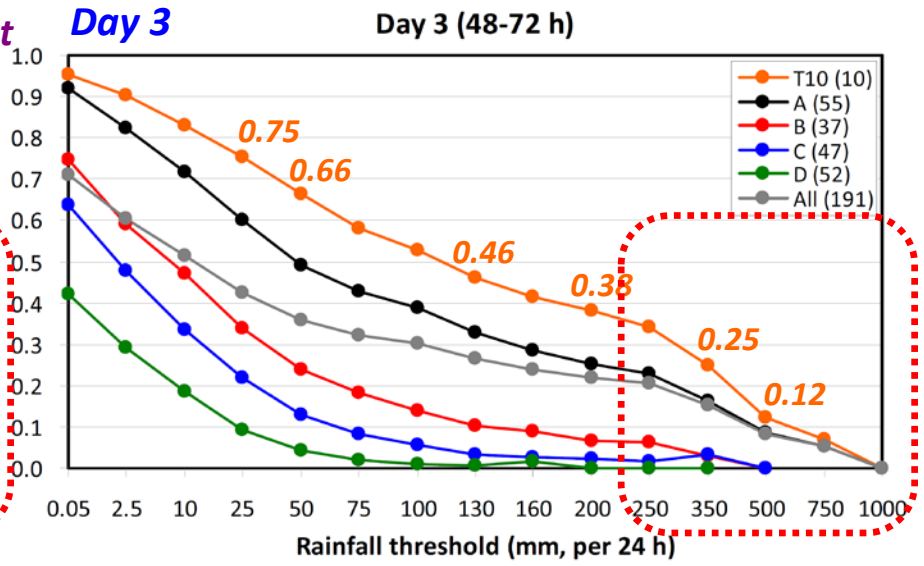
- *Classify 193 24-h segments (warning periods) based on observed rainfall*
  - *Groups **A**, **B**, **C**, and **D** from the most to the least overall amount*
  - *At least 50 sites (~1/8) ≥100 mm (**A**), 50 mm (**B**), 25 mm (**C**), or not (**D**)*
  - ***Top 10** cases: Most-rainy segment from 10 TCs (one from each), a subset of group A (most hazardous, roughly top 5% of all sample)*



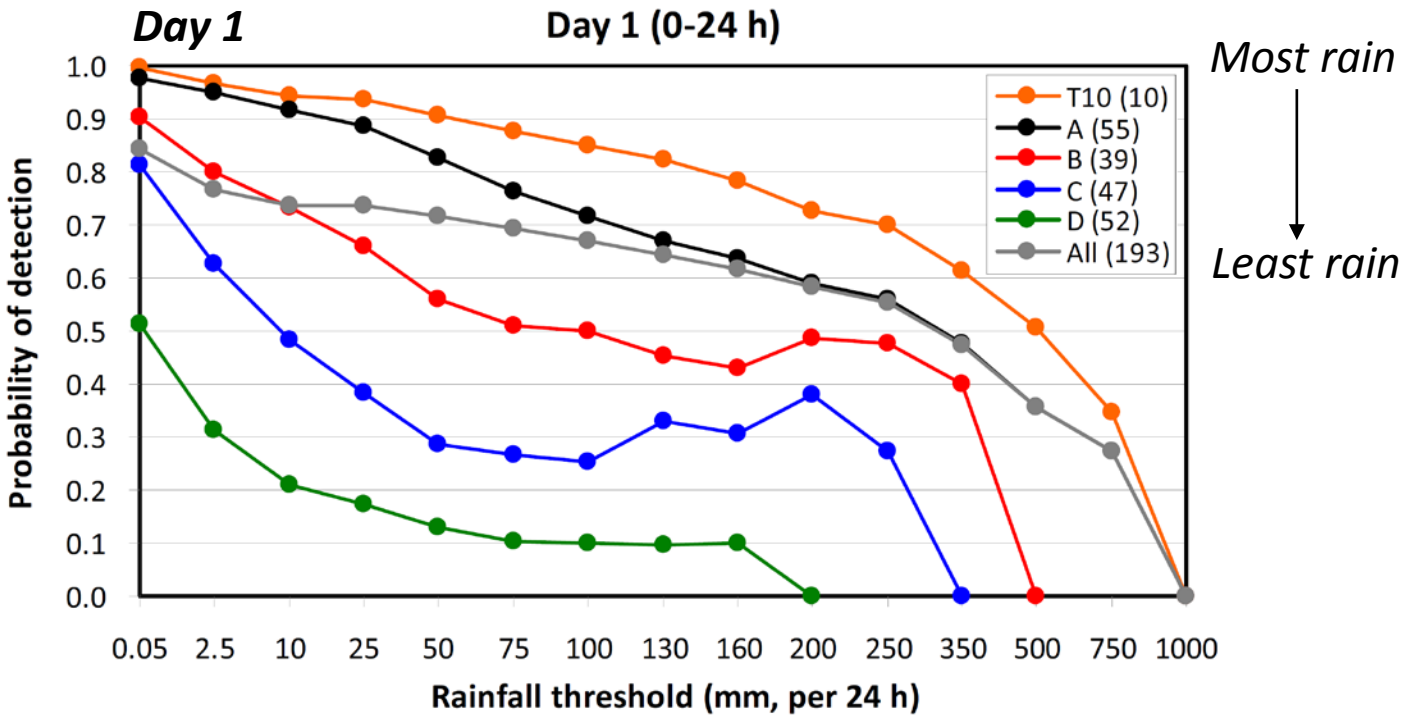
- TS:

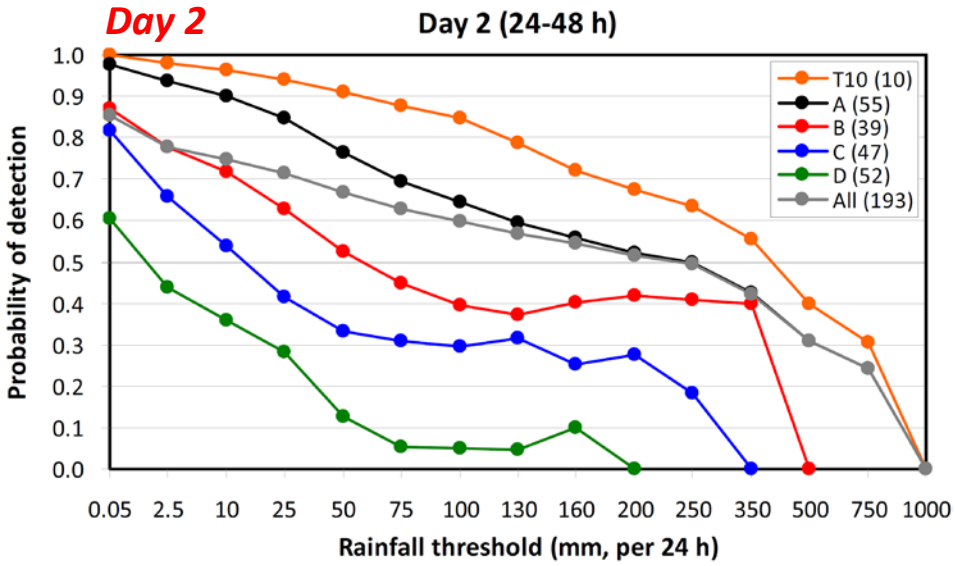

Day 1
Day 1 (0-24 h)
Morakot
Most rain
Least rain
T10 (10)
A (55)
B (39)
C (47)
D (52)
All (193)
0.86
0.81
0.86
0.80
0.82
0.73
0.67
0.54
0.48
0.39
0.27
0.15
Threat Score
Rainfall threshold (mm, per 24 h)

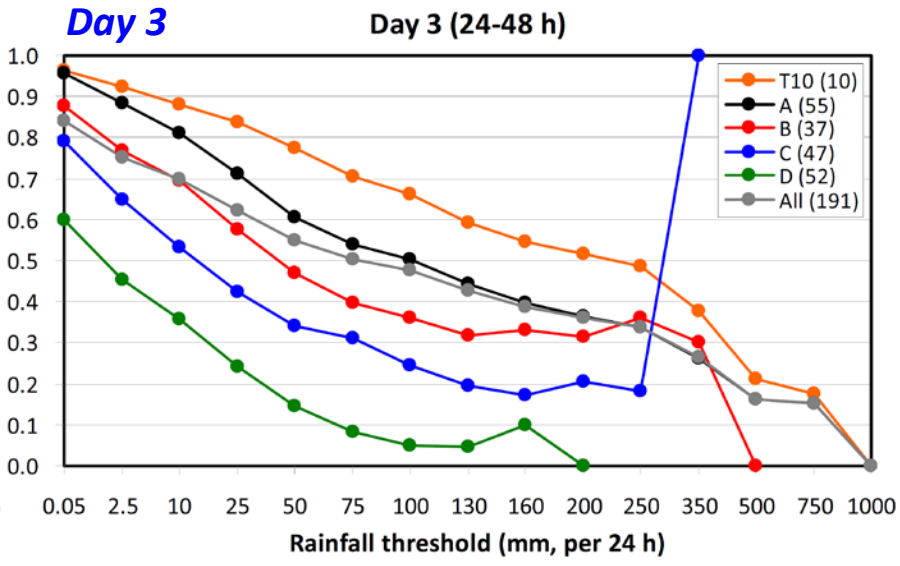

Day 2
Day 2 (24-48 h)
Morakot
T10 (10)
A (55)
B (39)
C (47)
D (52)
All (193)
0.93
0.83
0.82
0.87
0.85
0.79
0.63
0.69
0.52
0.50
0.37
0.38
0.21
Threat Score
Rainfall threshold (mm, per 24 h)


Day 3
Day 3 (48-72 h)
T10 (10)
A (55)
B (37)
C (47)
D (52)
All (191)
0.75
0.66
0.46
0.38
0.25
0.12
Rainfall threshold (mm, per 24 h)

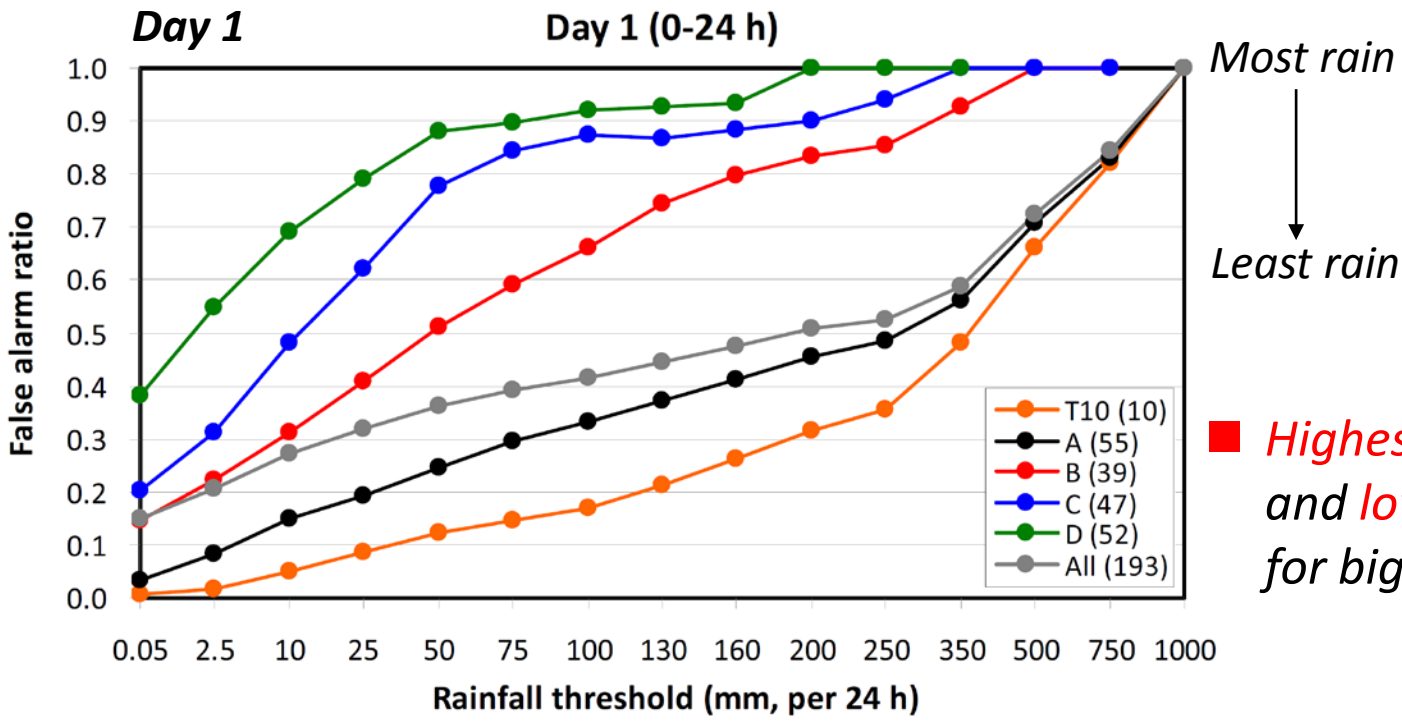
- *POD:*


Day 1
Day 1 (0-24 h)
Most rain
Least rain
Probability of detection
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
T10 (10)
A (55)
B (39)
C (47)
D (52)
All (193)
0.05 2.5 10 25 50 75 100 130 160 200 250 350 500 750 1000
Rainfall threshold (mm, per 24 h)


Day 2
Day 2 (24-48 h)
Probability of detection
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
T10 (10)
A (55)
B (39)
C (47)
D (52)
All (193)
0.05 2.5 10 25 50 75 100 130 160 200 250 350 500 750 1000
Rainfall threshold (mm, per 24 h)


Day 3
Day 3 (24-48 h)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
T10 (10)
A (55)
B (37)
C (47)
D (52)
All (191)
0.05 2.5 10 25 50 75 100 130 160 200 250 350 500 750 1000
Rainfall threshold (mm, per 24 h)

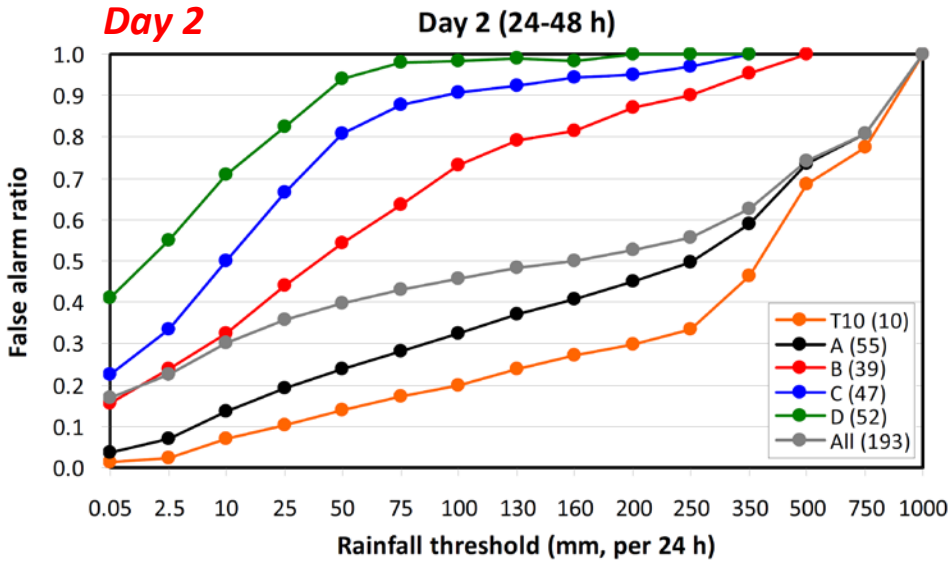
- *FAR:*

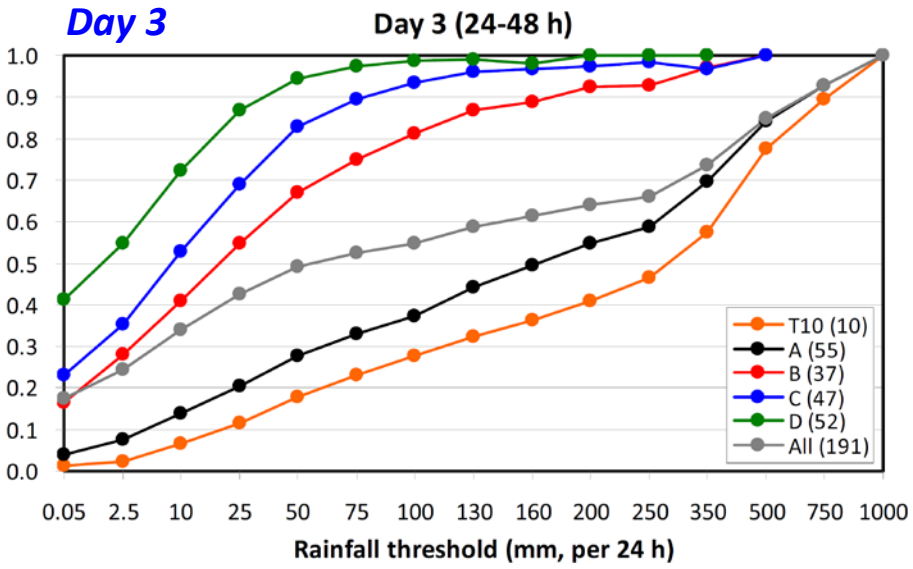


Most rain

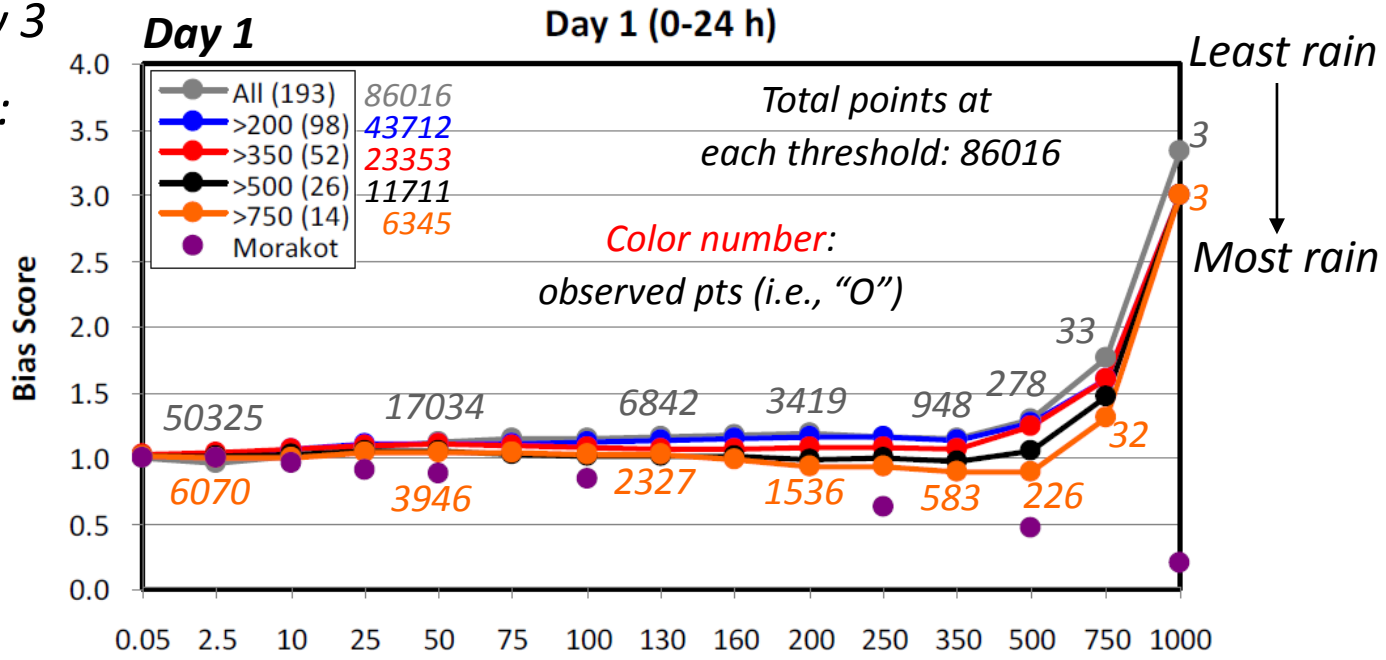
Least rain

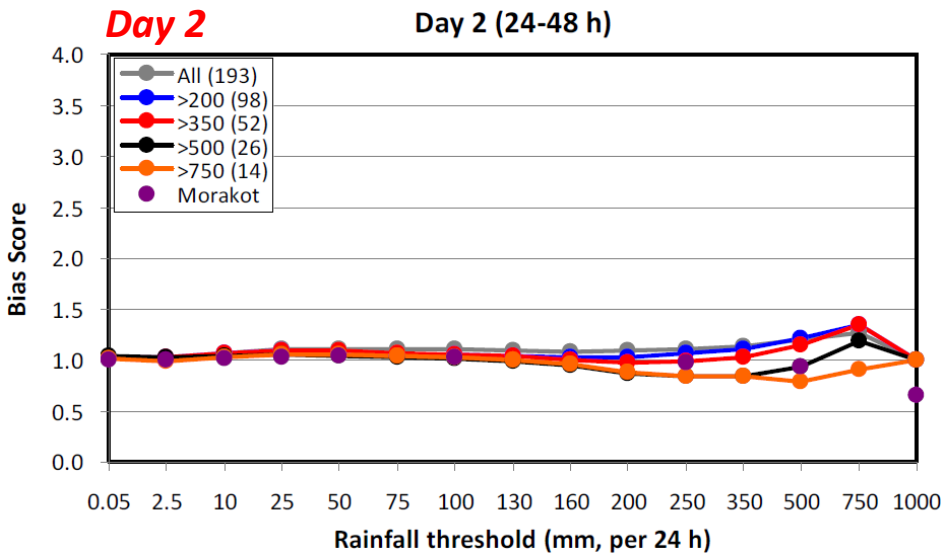
- *Highest TS/POD and lowest FAR for big events*

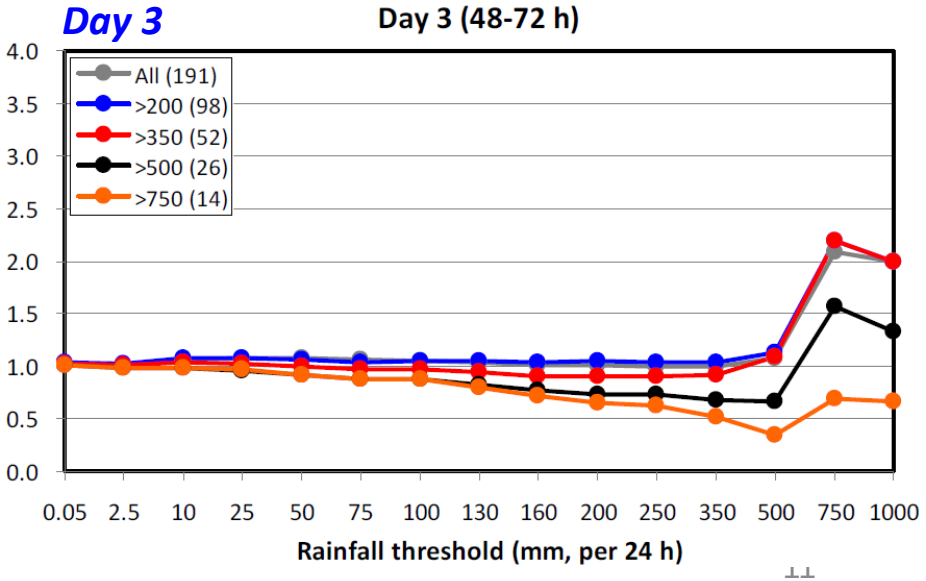




- *The Bias score: Only weak tendency of under-forecast at high thresholds toward day 3*
- *2010-2015:*

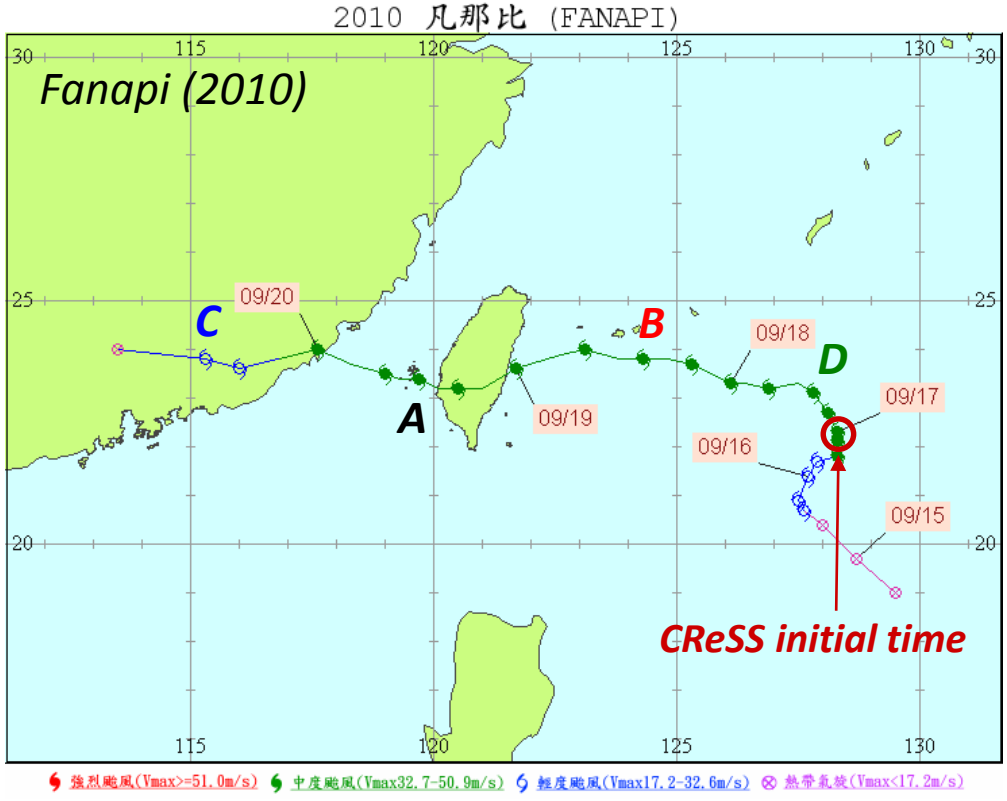


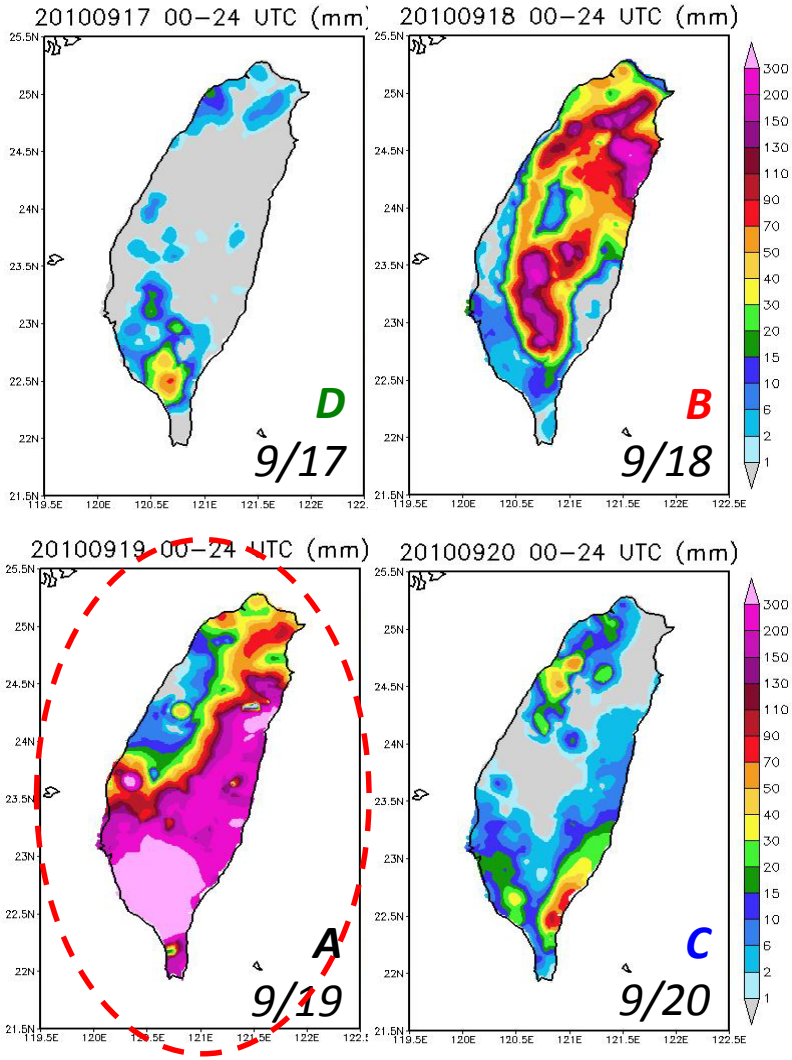




2.2 Examples of Source of Predictive Skill

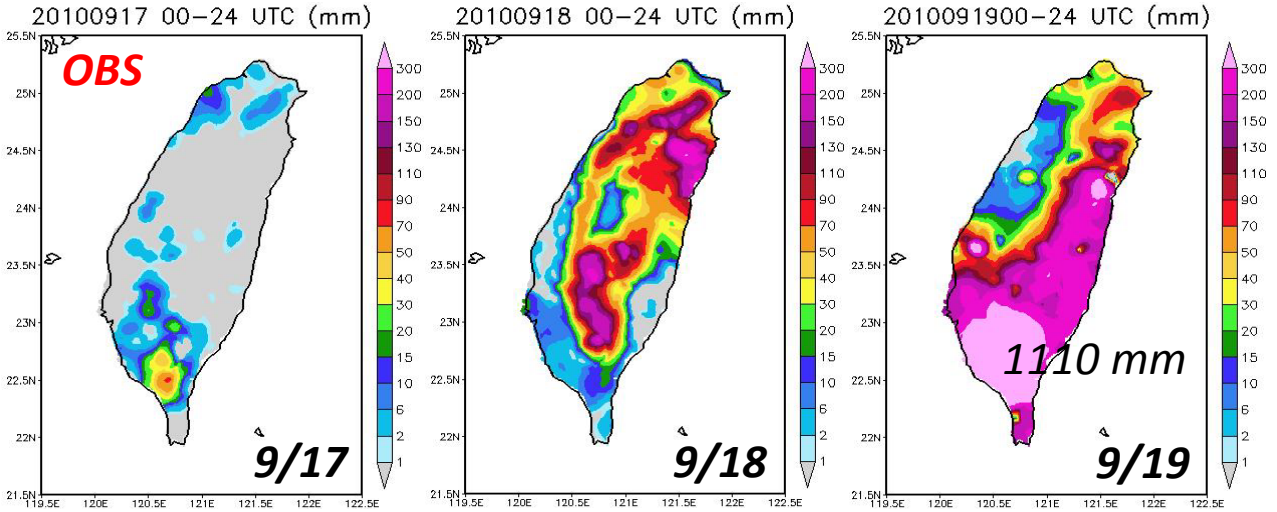
- *An example for TY Fanapi (2010): Best track and observed daily rainfall over Taiwan*

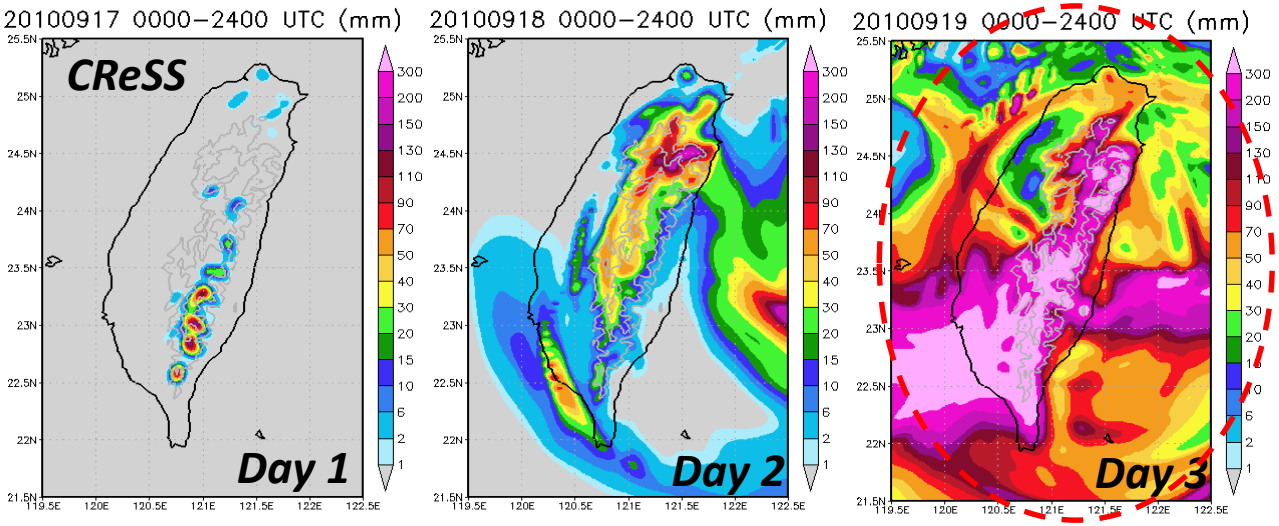


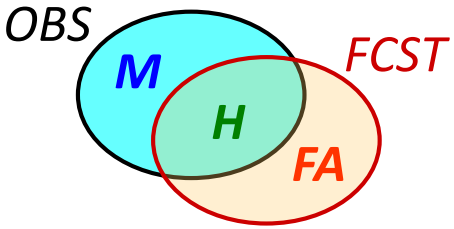


Reference: Wang (2015: MWR, 2016: BAMS)

- *Real-time 2.5-km forecasts made at 9/17 00 UTC, for Fanapi (2010):*

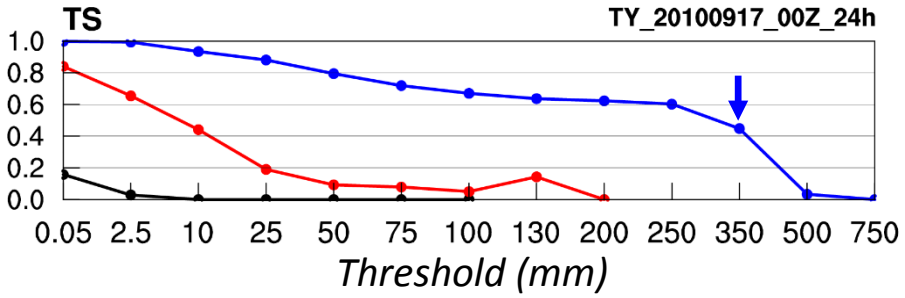


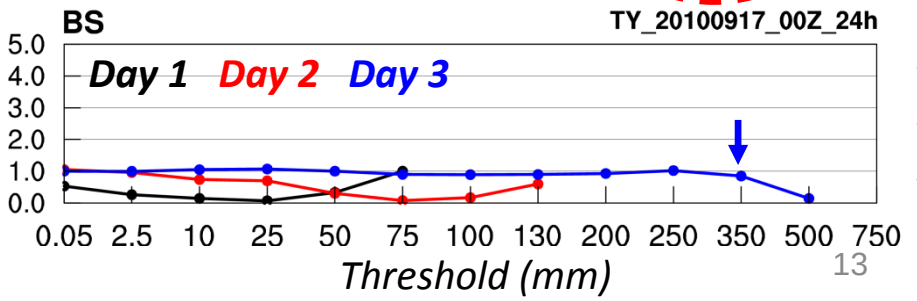




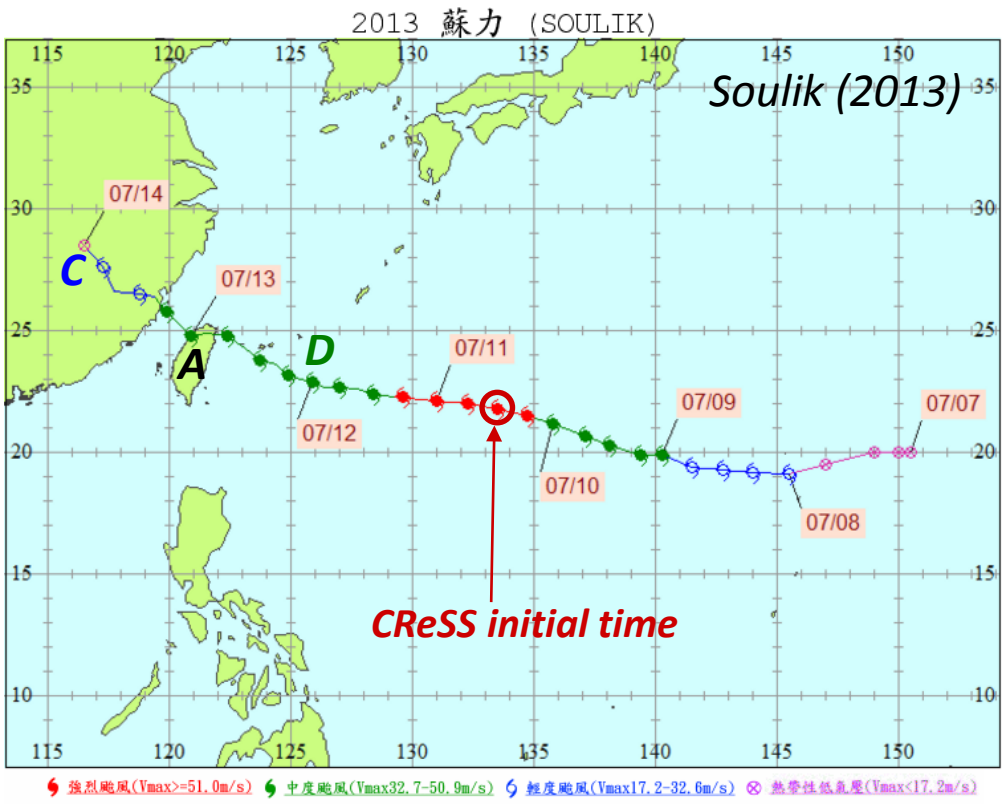
$TS = H / (M + H + FA)$

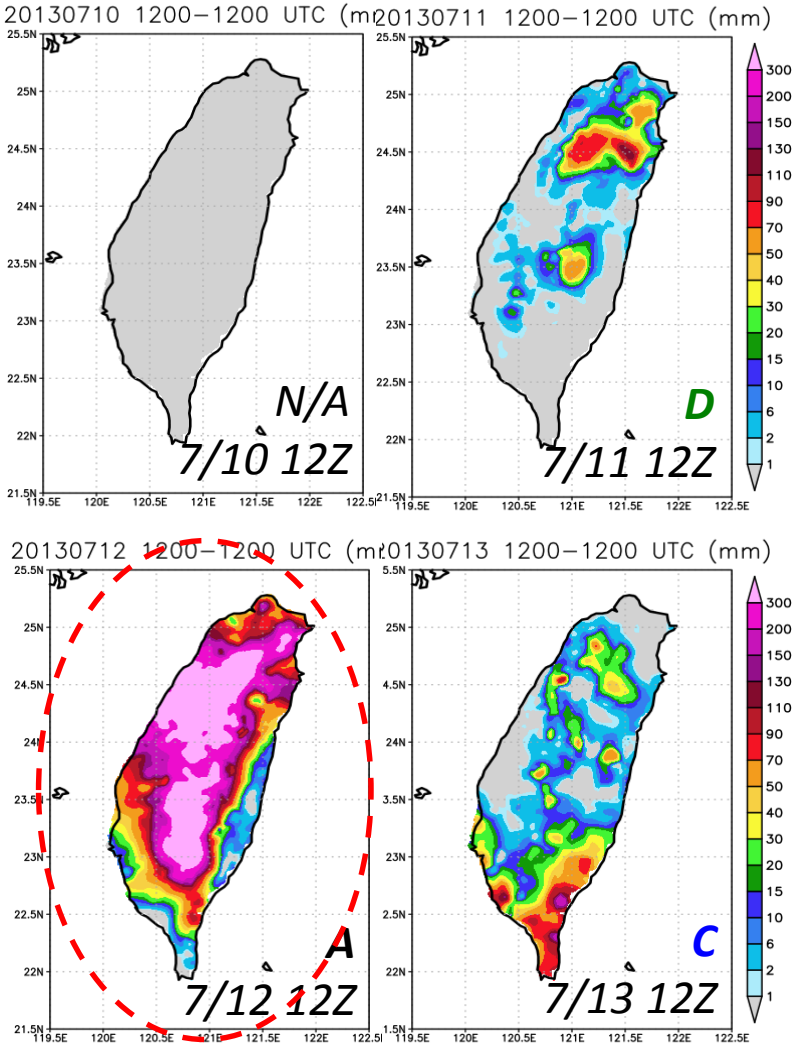
$BS = (H + FA) / (H + M)$



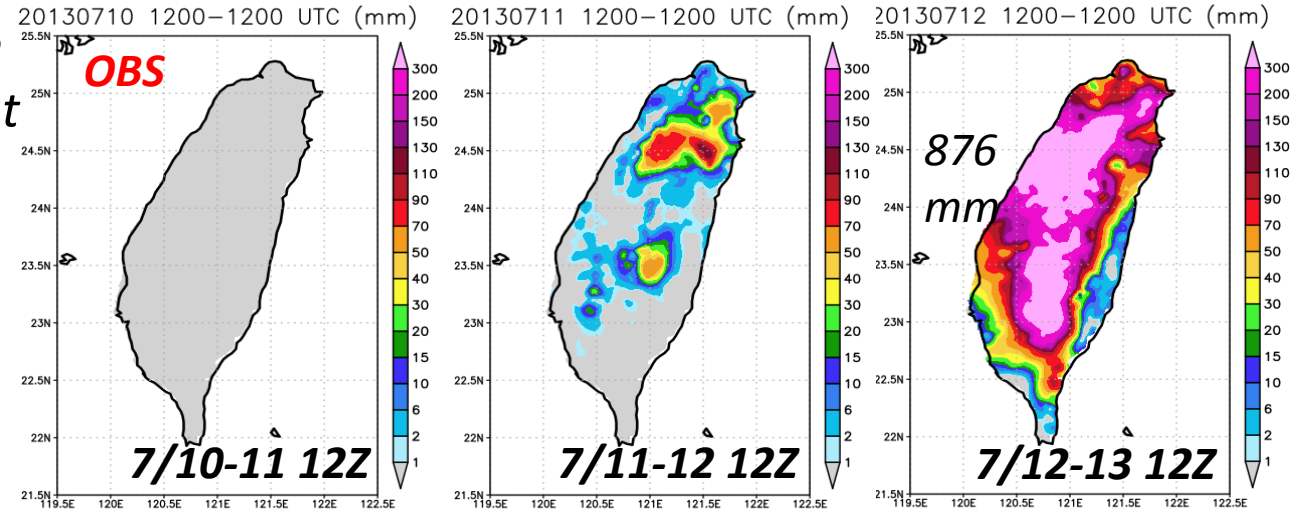


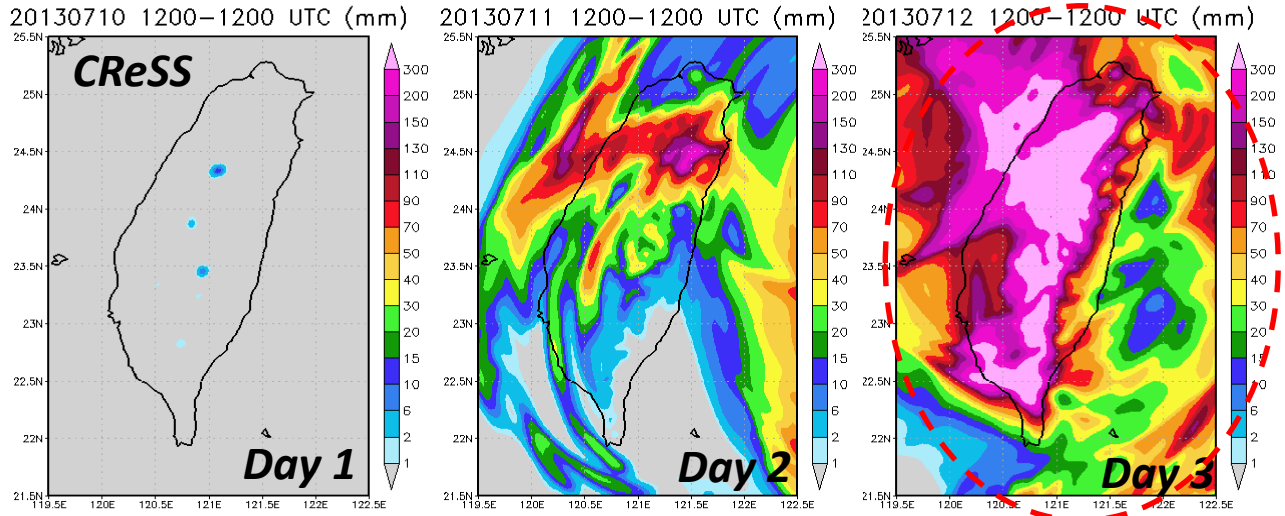
For Soulik (2013): Best track and observed daily rainfall over Taiwan

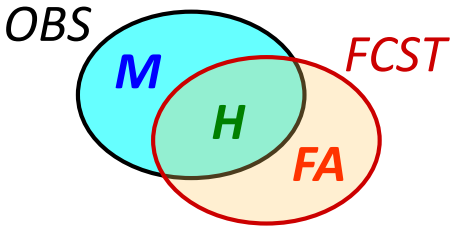




- *Real-time 2.5-km forecasts made at 7/10 12 UTC, for Soulik (2013):*

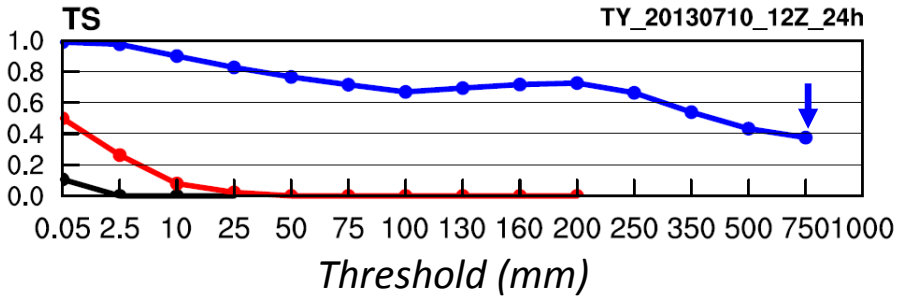


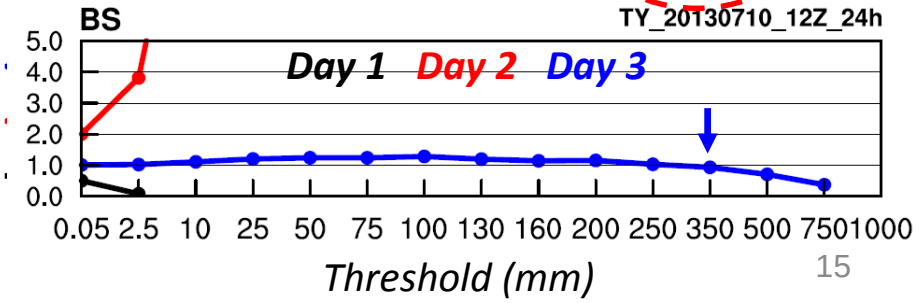




$TS = H / (M + H + FA)$

$BS = (H + FA) / (H + M)$



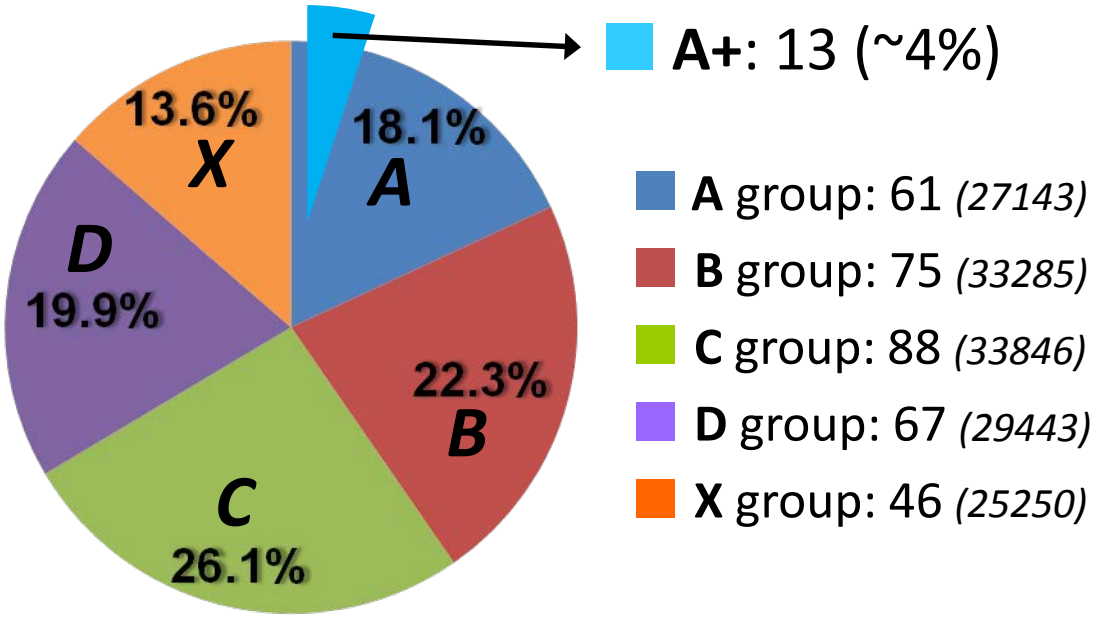


3. Mei-yu Heavy-rainfall Events and Examples

3.1 Overall Performance in 2012-2014 (Three Seasons)

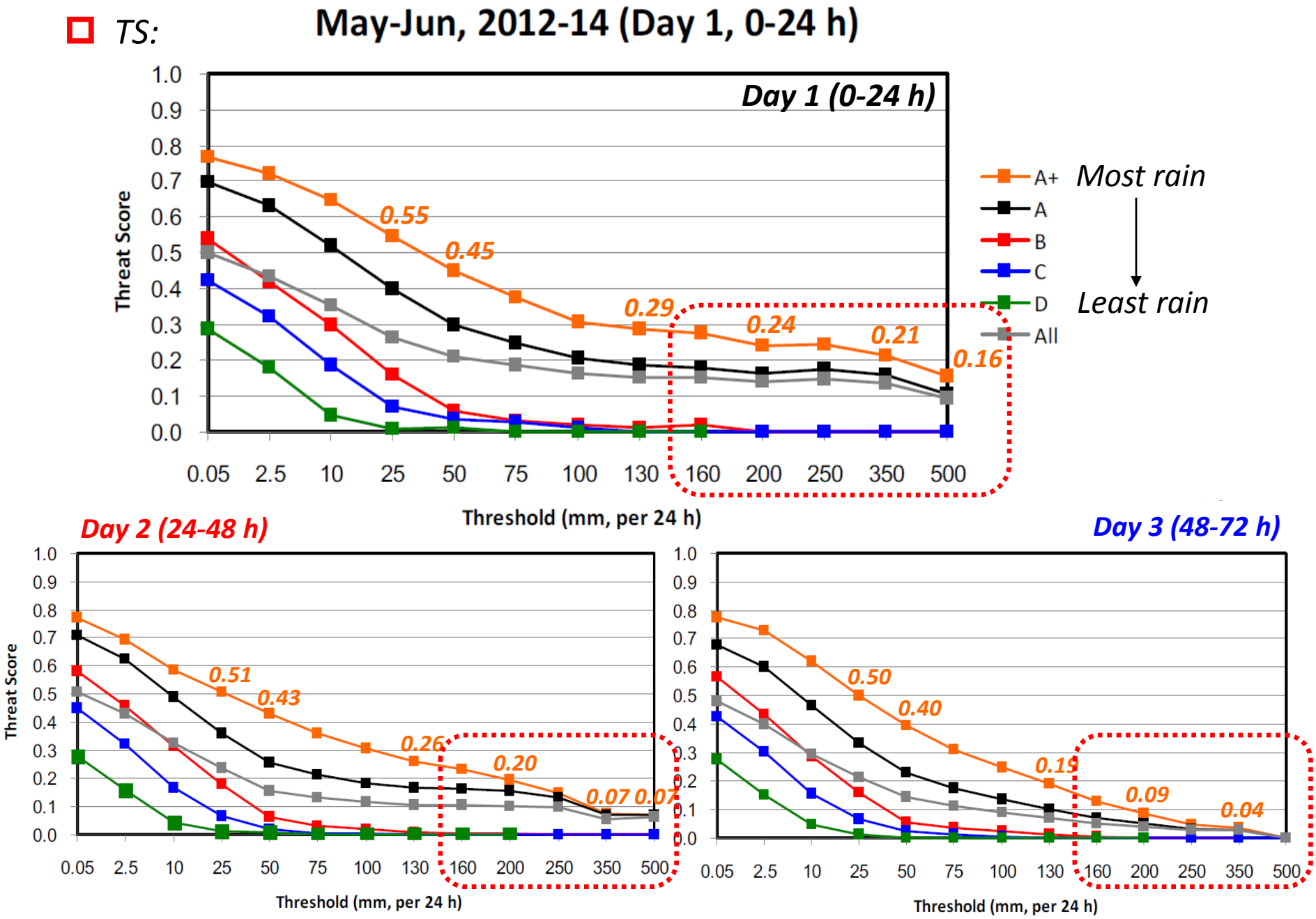
- *Total of 337 segments in May-Jun (excluding TC periods), classified into:*
  - *Groups **A**, **B**, **C**, **D**, and **X** from the most to the least overall amount*
  - *At least 10% of sites ≥50 mm (**A**), 25 mm (**B**), 10 mm (**C**), 1 mm (**D**), or otherwise (**X**, i.e., almost no rainfall)*
  - *Group **A+**: ≥10% sites ≥130 mm, all from group A (roughly top 4% of all sample, with highest hazard potential)*

Total sample size:
***337** segments*
(148967 points)
May-Jun 2012-2014
(excluding TCs)

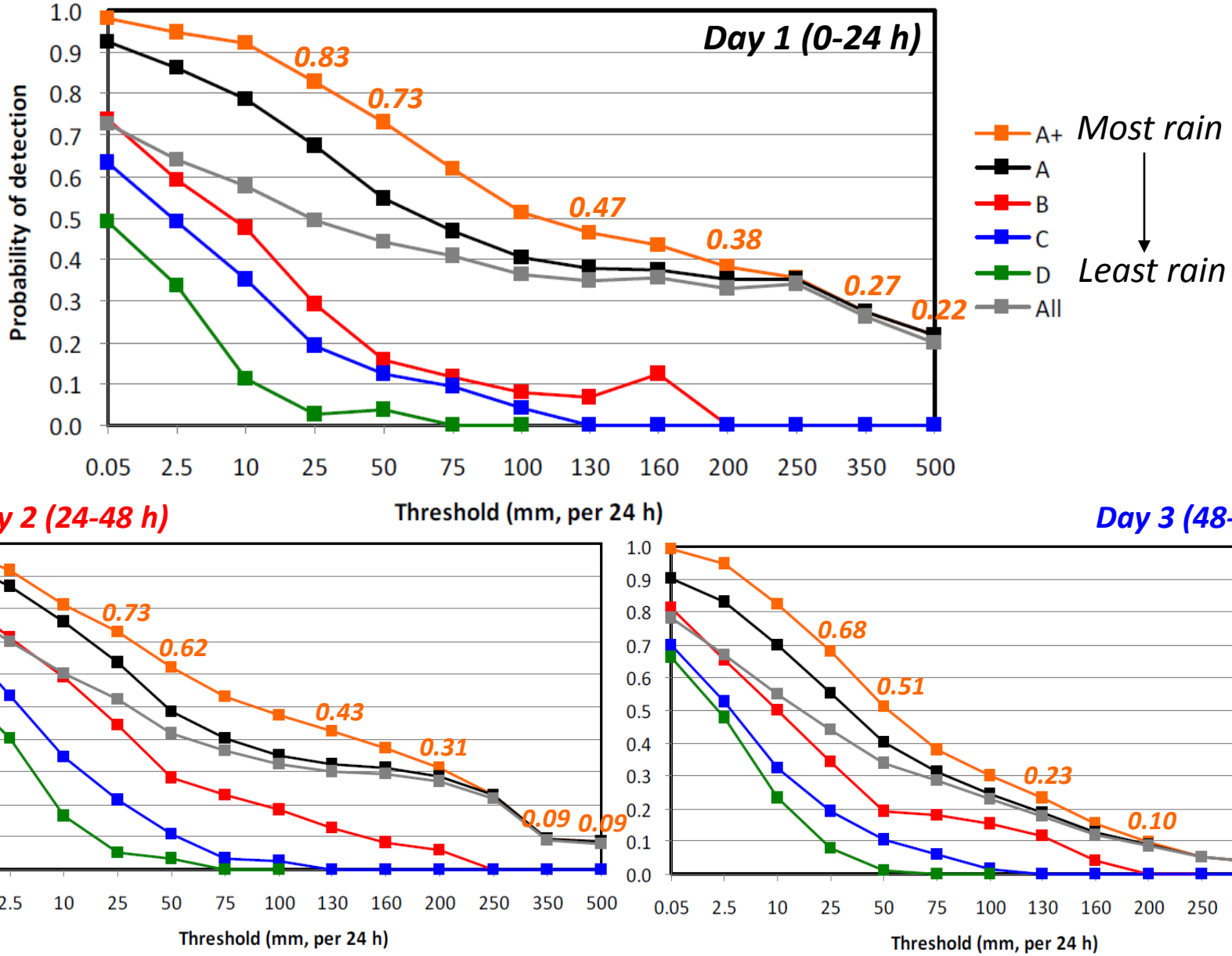


- *Compute scores after summing entries from all segments into one 2 x 2 contingency table*

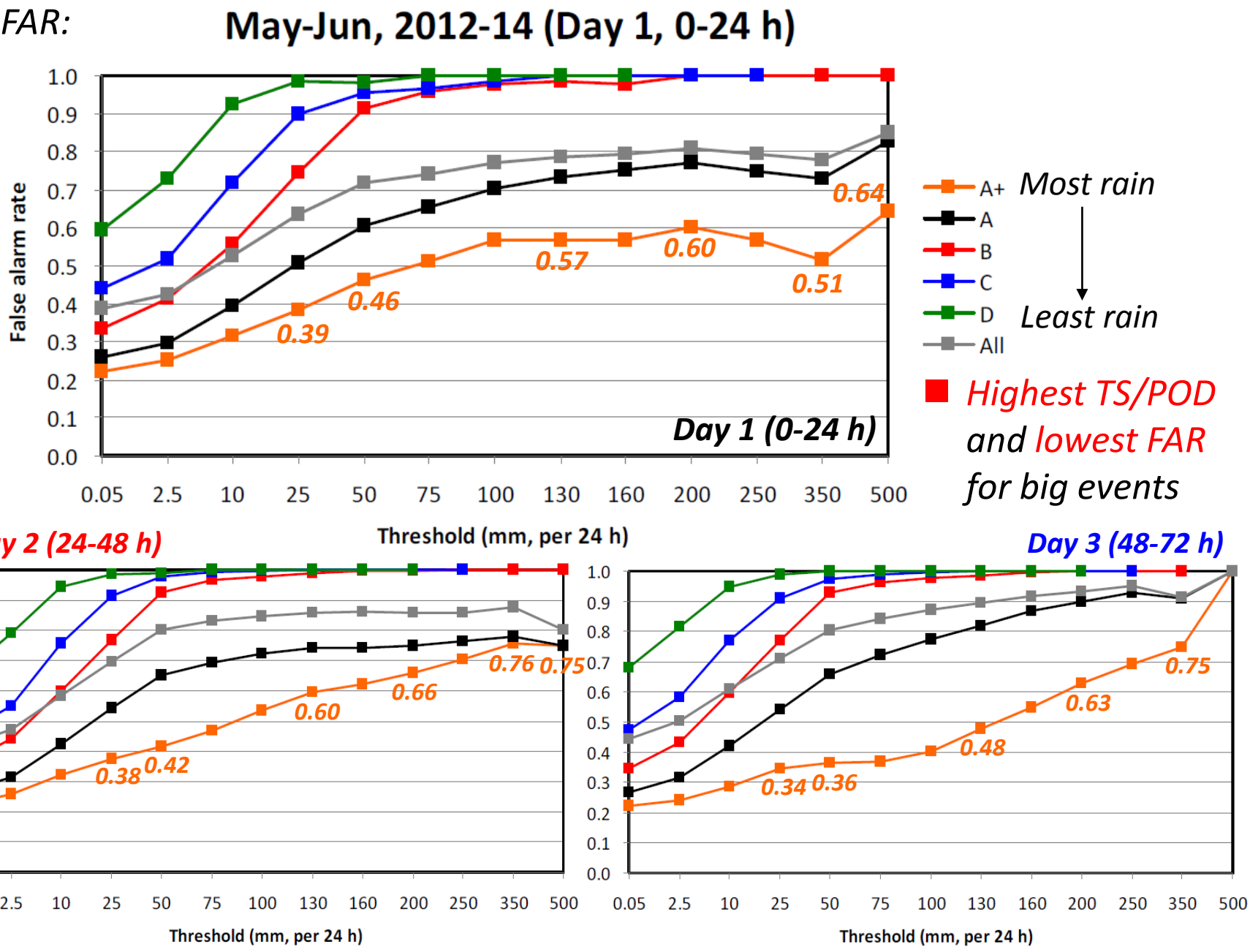
TS:


May-Jun, 2012-14 (Day 1, 0-24 h)
Day 1 (0-24 h)
Threat Score
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.55
0.45
0.29
0.24
0.21
0.16
0.05 2.5 10 25 50 75 100 130 160 200 250 350 500
Threshold (mm, per 24 h)
A+
A
B
C
D
All
Most rain
Least rain
Day 2 (24-48 h)
0.51
0.43
0.26
0.20
0.07 0.07
Day 3 (48-72 h)
0.50
0.40
0.19
0.09
0.04

POD: May-Jun, 2012-14 (Day 1, 0-24 h)



FAR:

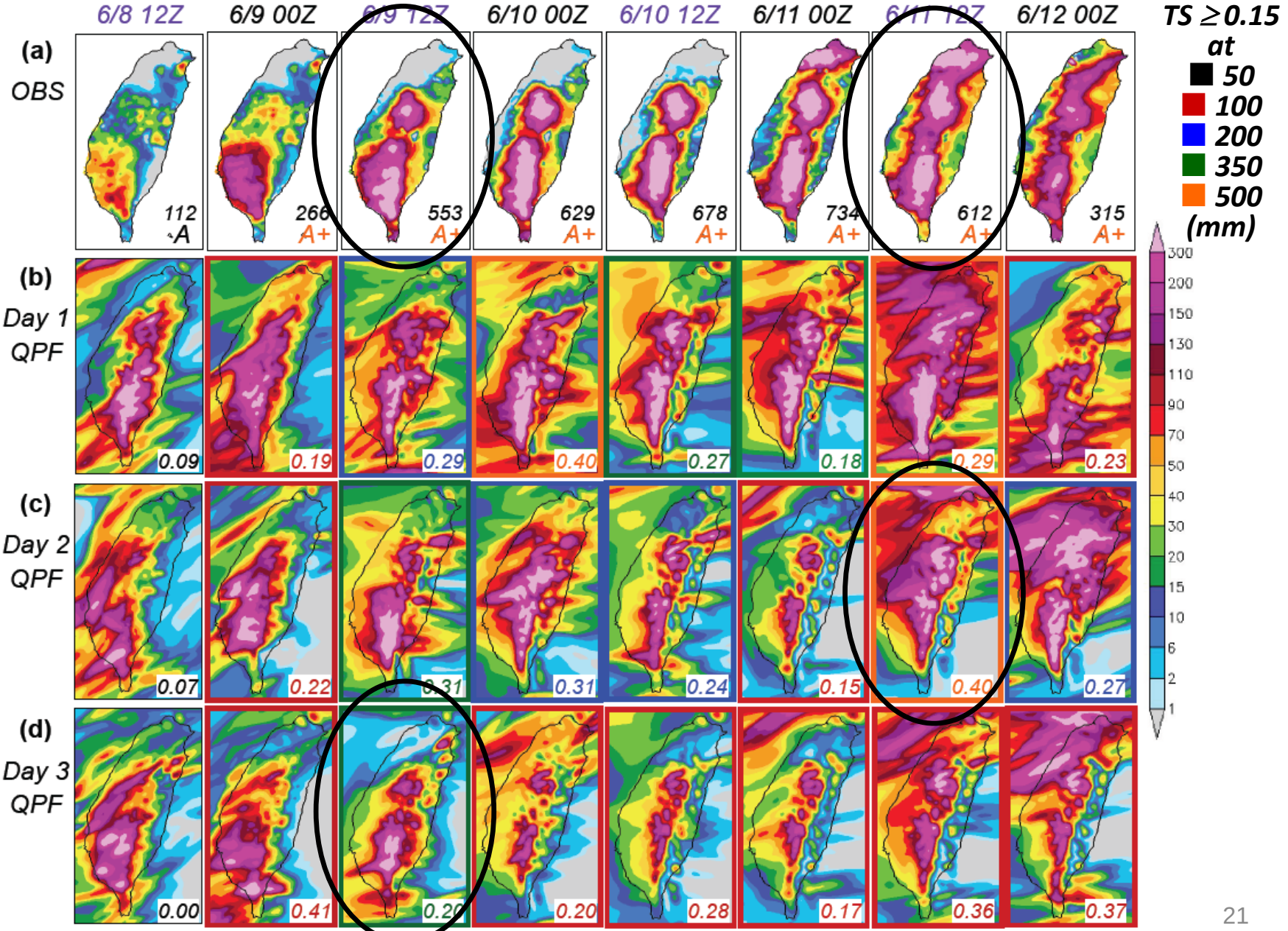

May-Jun, 2012-14 (Day 1, 0-24 h)
False alarm rate
Threshold (mm, per 24 h)
Day 1 (0-24 h)
0.64
0.57
0.60
0.51
0.46
0.39
A+
A
B
C
D
All
Most rain
Least rain
Highest TS/POD and lowest FAR for big events
Day 2 (24-48 h)
0.76
0.75
0.66
0.60
0.42
0.38
Day 3 (48-72 h)
0.75
0.63
0.48
0.36
0.34

3.2 Examples of Source of Predictive Skill

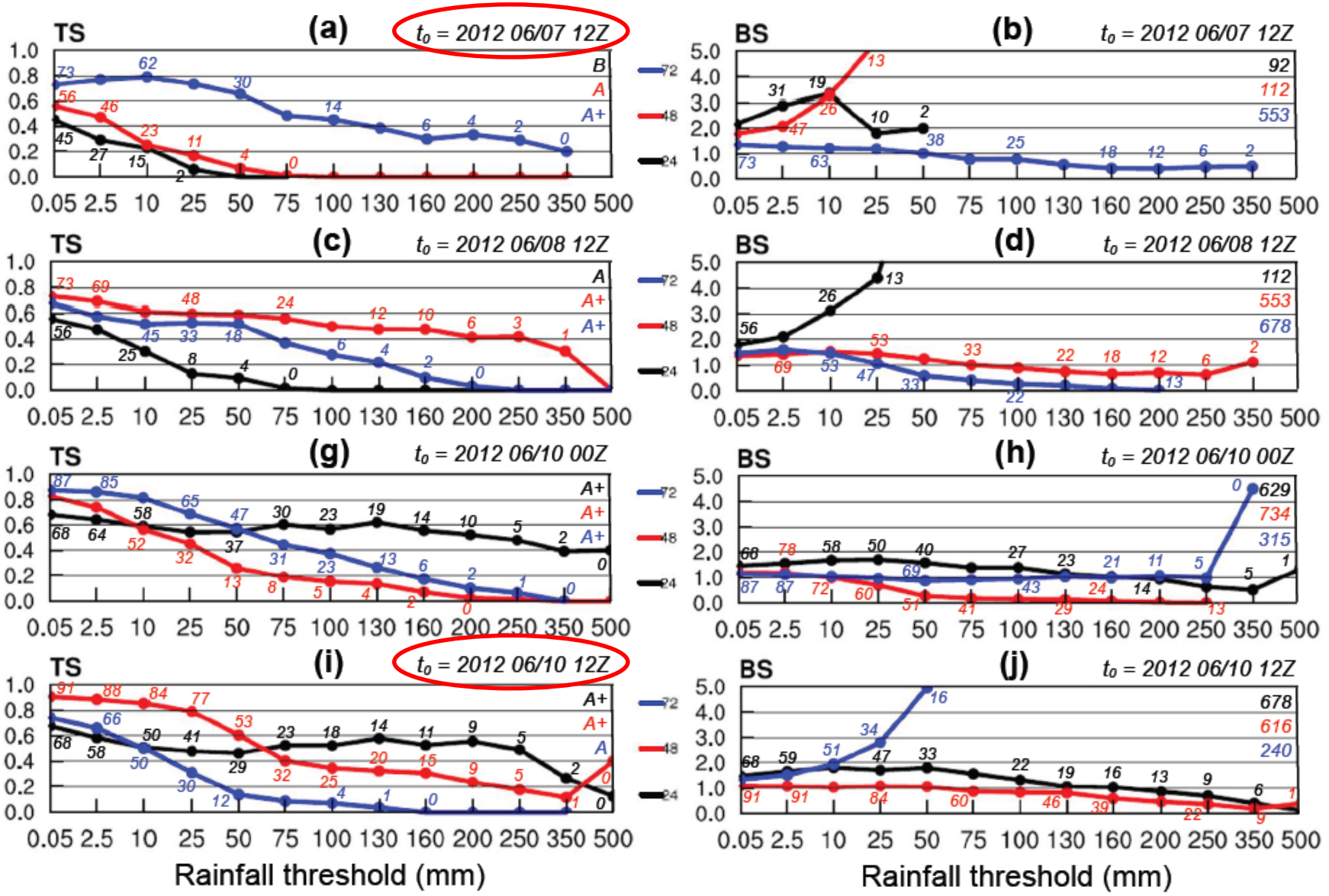
- *Detailed classification: 13 segments in **A+ group** (bold and underscore)*

Year	Month	Time (UTC)	Date in month			Segments included (A-D, X)
			1-10	11-20	21-31 (or 21-30)	
2012	May	0000	XAABDXXXBB	CCXXCBAAAB	XXDXDCAAABC	31
		1200	CAADXXXBCC	CXXCBBAB**A**D	XXXXDBAABBD	31
	Jun	0000	CCBCCCCB**AA**	**AA**AAABBTTT	TCCDDCTTTD	23
		1200	DBCDCDB**AAA**	**A**AAABBTTTT	TCDDDTTTTD	21
2013	May	0000	CCCCBBCCDA	AACCCABAA**A**	CBCCCDDDDDX	31
		1200	CCDCACCDD**A**	BBCCCABABA	BBCCDDDDDXX	31
	Jun	0000	XXCBCCXXCB	BBABCDDDXX	BDBCCXXXXD	30
		1200	XDBCCDXDCB	BABBDDDXXB	CBBCXXXXXD	30
2014	May	0000	CCBBBBCCCD	DCBD**A**BXBA**A**	ADDCDCCBBBC	31
		1200	CBDABCDCDD	CBDAAXBAA**A**	BDCCDBBABCD	31
	Jun	0000	XDACAABBBC	CTTTTTTDDB	DCBCCDXCAC	24
		1200	XACBAABBDC	TTTTTTTDBD	CCBCDXDBAC	23
Sum			A+: 13, A: 61, B: 75, C: 88, D: 67, X: 46 (T: 29)			337

QPF examples in group A+: The event during 9-12 Jun 2012

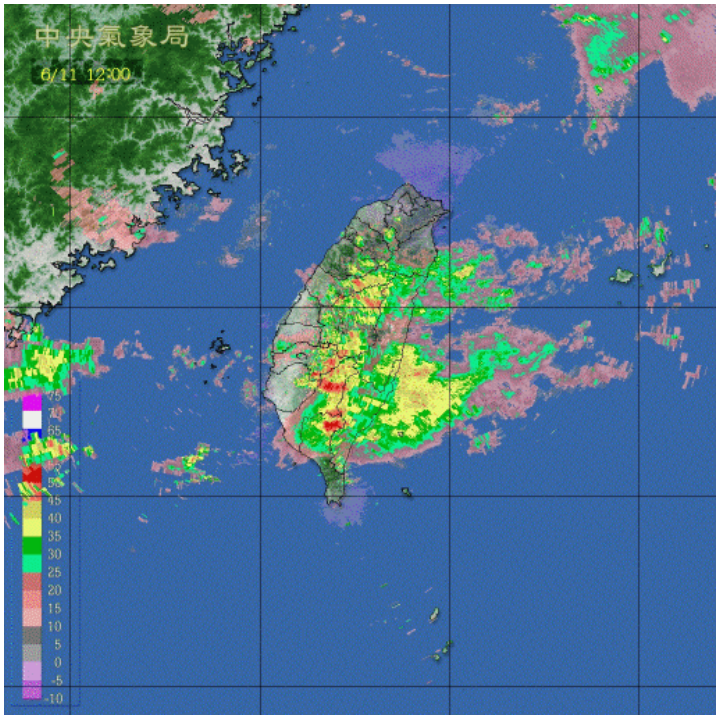


- *TS (with H/N in %) and BS (with O/N in %):*

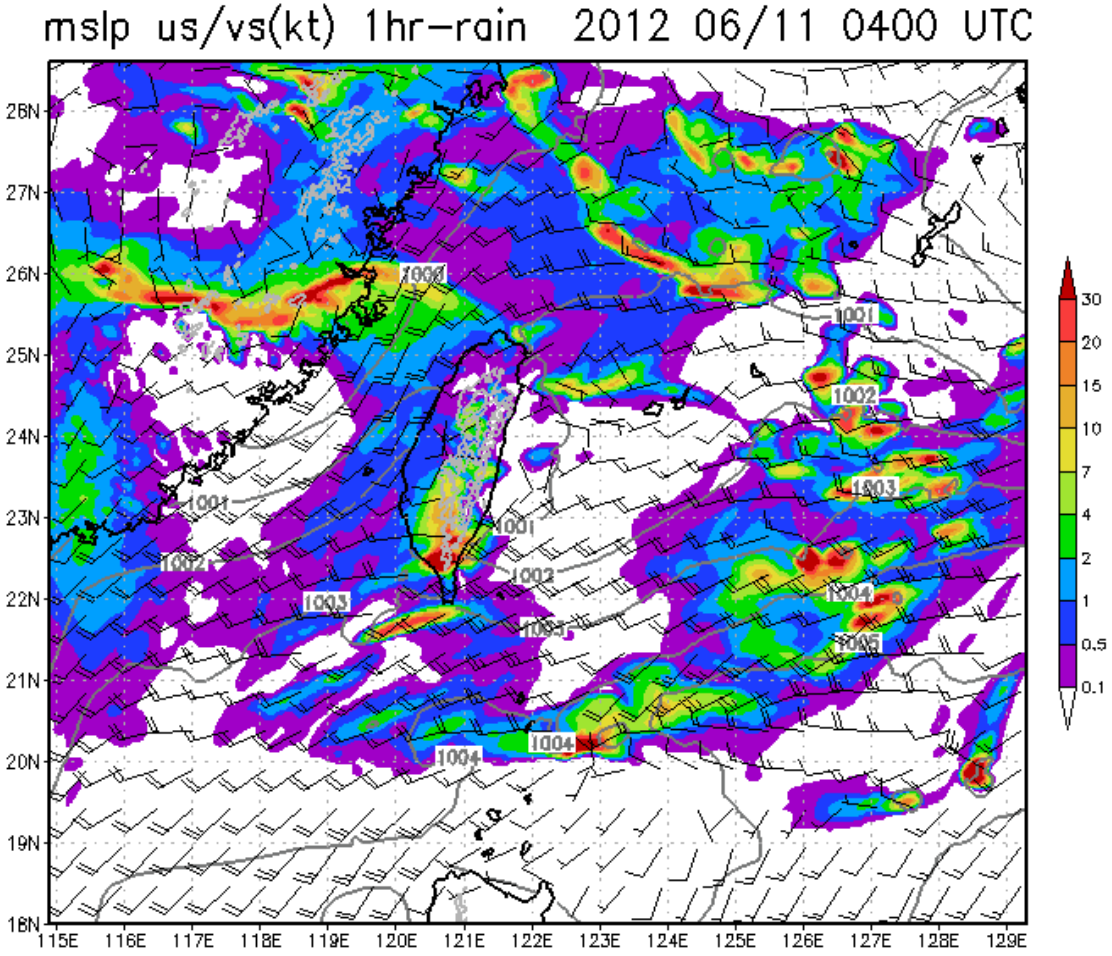


- *A forecast example in real time: For extreme event during 11-12 Jun 2012*
  - *Starting at 1200 UTC 9 Jun, 40-64 h fcst (valid 0400 UTC 11-12 Jun)*

CWB radar (dBZ)
OBS (12 LST 11-12 Jun)



CReSS fcst starting at 6/9 12Z (t = 40-64 h)



4. Conclusion and Summary

- *Operational 2.5-km CReSS shows high skills in heavy-rainfall QPFs for Taiwan, not limited to 0-24 h but also in days 2 and 3*
  - *Significantly improved skill using CReSS at cloud-resolving resolution*
  - *Better skill for top events than all events, not understood previously*
  - *Some skills (TS ≳ 0.15) through 500, 200, and 130 mm on day 3, 2, and 1*

Season	Threshold	50 mm	130 mm	200 mm	350 mm	500 mm
Typhoon Top 5% cases (2010-15)	Day 1 (0-24 h)	0.75	0.67	0.55	0.38	0.25
	Day 2 (24-48 h)	0.79	0.65	0.56	0.40	0.21
	Day 3 (48-72 h)	0.66	0.47	0.39	0.25	0.11
Mei-yu Top 4% cases (2012-14)	Day 1 (0-24 h)	0.45	0.29	0.24	0.21	0.16
	Day 2 (24-48 h)	0.43	0.26	0.20	0.07	0.07
	Day 3 (48-72 h)	0.40	0.19	0.09	0.04	0.00

- *Much higher predictability over terrain for systems linked to topography (e.g., topo. uplift), where high skill at high thresholds can be achieved*

--- The End ---

Thank you for listening! Questions?