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Verification of Flash Flood Warnings



WMO OMM

World Meteorological Organization

Organisation météorologique mondiale

Verification of flash flood warnings

- Verification has always been recognized as important, an essential ingredient in the flash flood forecasting process, but in reality has been poorly understood and not well implemented, and often not maintained as a continuing activity;
- Flash flood warnings verification studies are used to help to understand the uncertainties and limitations in forecasting models, and the ways in which they can be improved;
- Verification scores and post-event assessments can improve the quality of the future flash flood warnings;
- Publishing verification results and making them available to the stakeholders and partners is reinforcing the NMHSs credibility, user-oriented policy and dedication to the cause.



Contingency Tables and Verification Scores

- Contingency tables are highly flexible methods that can be used to estimate the quality of a deterministic forecast system and, in their simplest form, indicate its ability to anticipate correctly the occurrence or non-occurrence of predefined flash flood events.
- For verification with two categories, the 2x2 contingency table is commonly defined.
- Based on contingency tables, the scores can be computed.
- Computation of these scores should be considered part of analysis and diagnosis functions that are routinely performed by forecasters.
- The scores provide the most meaningful information if they are computed from large enough samples of cases. However, severe weather occurrences are rare events, thus the number of forecasts and observations of severe weather may be small, which makes the task of verification not only more important but also more challenging (WMO-No. 1132).



Contingency Tables

- It is a simple yes/no table where the rows represent forecast categories and the columns represent categories for observations.
- The "a" box indicates the number of observed flash floods that were correctly forecast to be flash floods, or hits.
- The "b" box indicates the number of observed non-flash floods that had been incorrectly forecast to be flash floods, or false alarms.
- The "c" box indicates the number of observed flash floods that were forecast to be non-flash floods, or misses.
- The "d" box indicates the observed non-flash floods that were correctly forecast to be non-flash floods, or correct negatives.

a = Hits
 b = False alarms
 c = Misses
 d = Correct negatives

		EVENT OBSERVED		Total
		Yes	No	
EVENT FORECASTED	Yes	a	b	a + b
	No	c	d	c + d
Total		a + c	b + d	a + b + c + d = n



Probability of detection (PoD) or Hit Rate (HR)

$$P_oD = HR = \frac{a}{a + c}$$

- The hit rate (HR) has a range of 0 to 1 with 1 representing a perfect forecast.
- As it uses only the observed events a and c in the contingency table, it is sensitive only to missed events and not false alarms.
- Therefore, the HR can generally be improved by systematically overforecasting the occurrence of the event.
- The HR is incomplete by itself and should be used in conjunction with either the false alarm ratio or the false alarm rate.



False alarm ratio (FAR):

$$FAR = \frac{b}{a + b}$$

- The false alarm ratio (FAR) is the ratio of the total false alarms (b) to the total events forecast (a + b).
- Its range is 0 to 1 and a perfect score is 0.
- It does not include c and therefore is not sensitive to missed events.
- The FAR can be improved by systematically underforecasting flash flood events.
- It also is an incomplete score and should be used in connection with the HR.



False alarm rate (RA):

$$POFD = \frac{b}{b + d}$$

- The false alarm rate (RA) or false detection (POFD) is unfortunately often confused with the false alarm ratio;
- The false alarm rate is simply the fraction of observed non-events that are false alarms;
- The best score for the FA is 0; The FA is not often used by itself but rather is used in connection with the HR in a comparative sense.



Threat score (TS):

$$TS = \frac{b}{a + b + c}$$

- The threat score (TS), or critical success index (CSI), is frequently used as a standard verification measure;
- It has a range of 0 to 1 with a value of 1 indicating a perfect score;
- The TS is more complete than the HR and FAR because it is sensitive to both missed events and false alarms.

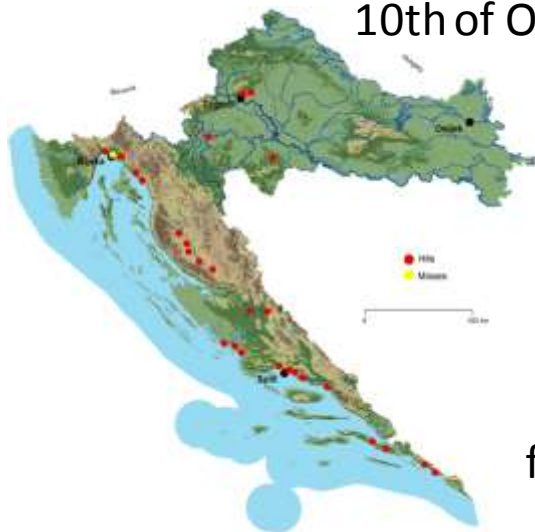


Verification of flash flood warnings in Croatia

a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		Total
		Yes	No	
EVENT FORECASTED	Yes	21 (a)	7 (b)	28
	No	1 (c)	113 (d)	114
Total		22	120	142

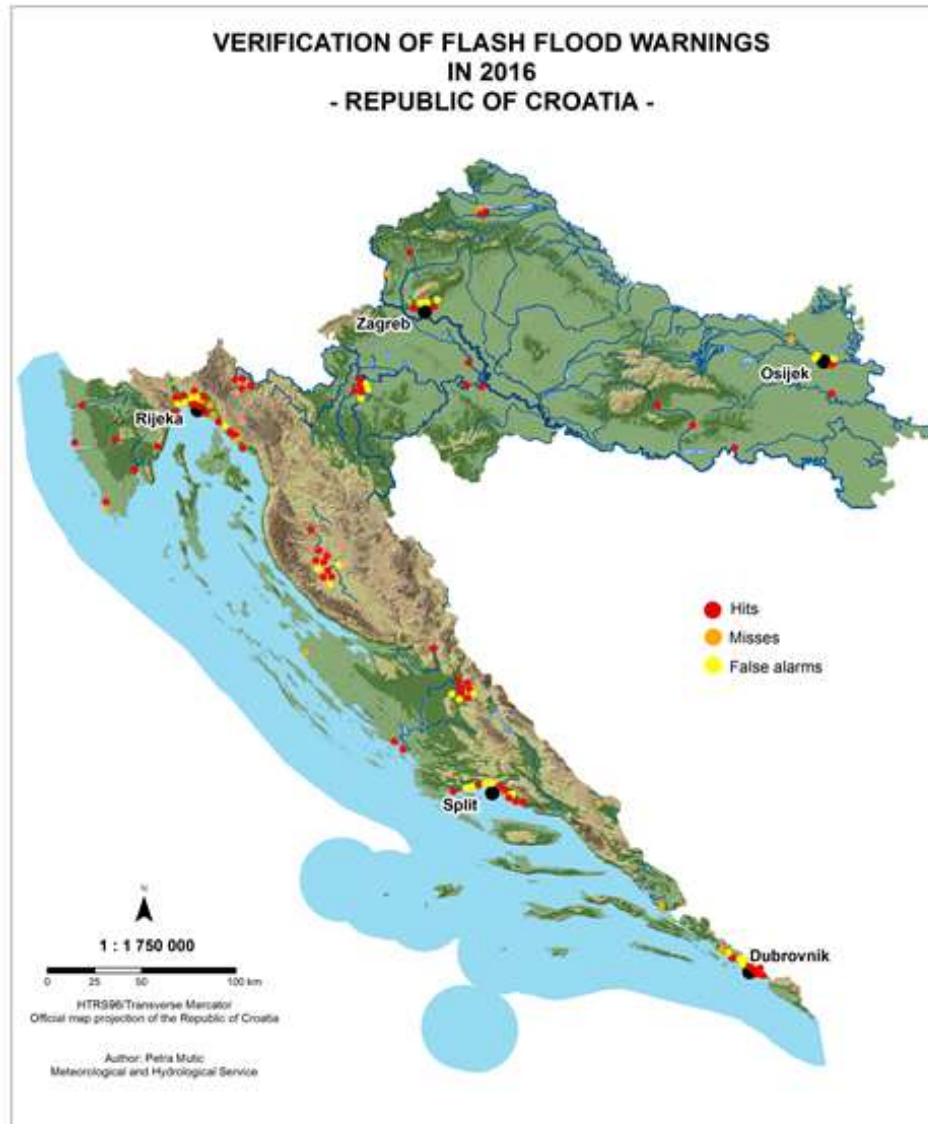
Contingency table of flash flood warnings for Croatia in the period from 10th of October 2015 to 29th of February 2016



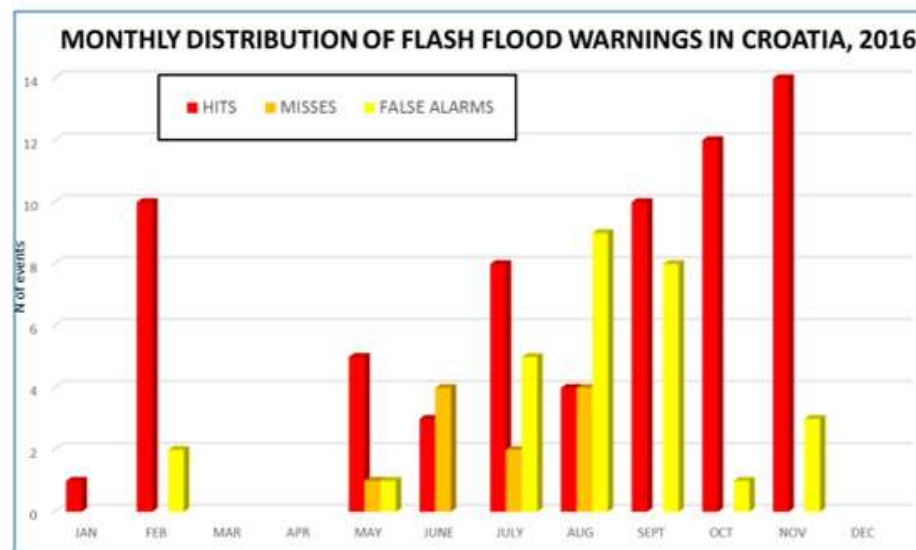
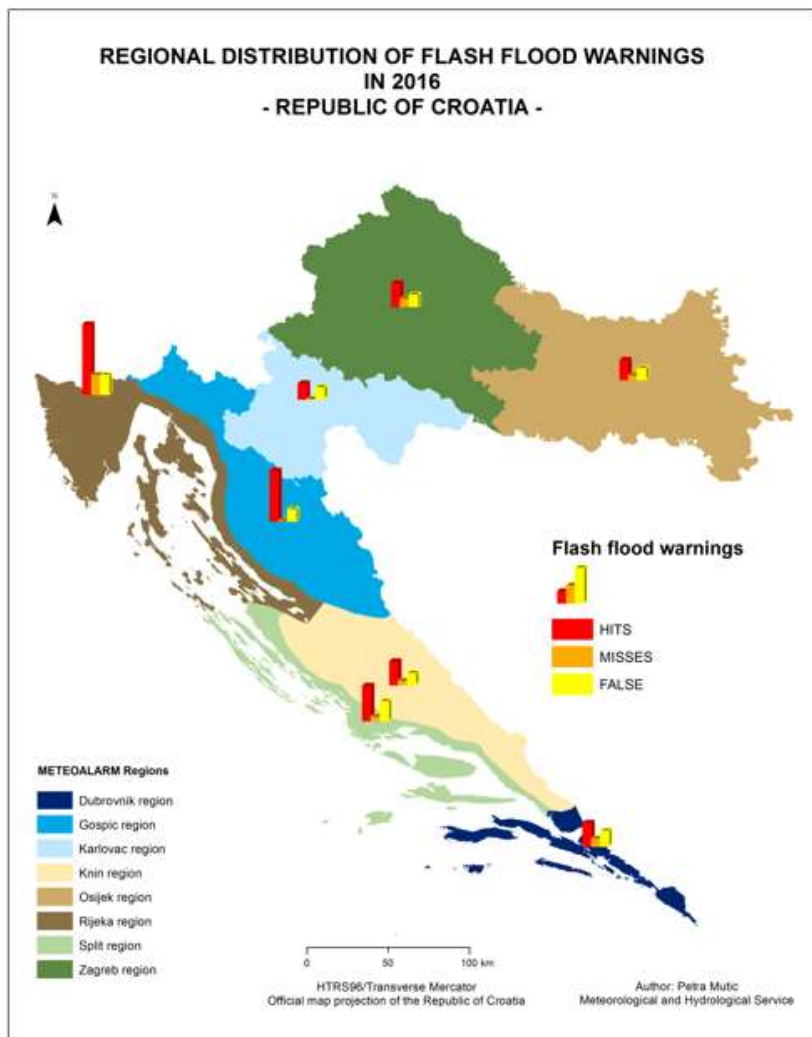
Hit Rate (POD): $a/(a+c)$	0.95
False Alarm Ratio (FAR): $b/(a+b)$	0.25
False Alarm Rate (POFD): $b/(b+d)$	0.058
Threat Score: $a/(a+b+c)$	0.72

The scores for flash flood warnings for Croatia from 10th of October 2015 to 29th of February 2016

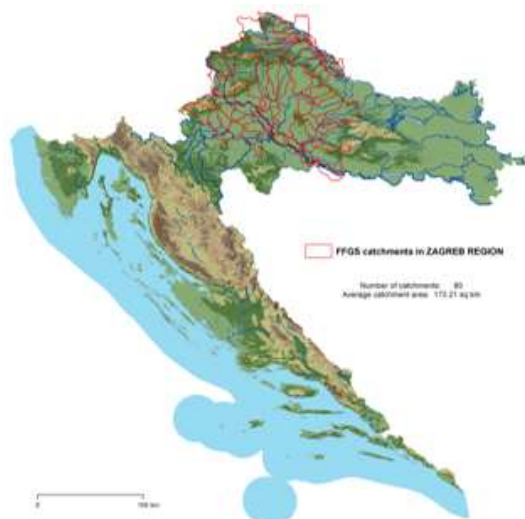
Verification of flash flood warnings in Croatia



Verification of flash flood warnings in Croatia



Verification of flash flood warnings in Croatia



a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	4 (a)	4 (b)	8
	No	2 (c)	356 (d)	358
Total		6	360	366

Contingency table of flash flood warnings for Zagreb region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	0.66
False Alarm Ratio (FAR): $b / (a + b)$	0.5
False Alarm Rate (POFD): $b / (b + d)$	0.009
Threat Score: $a / (a + b + c)$	0.4

The scores of flash flood warnings for Zagreb region, Croatia in 2016

a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	9 (a)	5 (b)	14
	No	1 (c)	351 (d)	352
Total		10	356	366

Contingency table of flash flood warnings for Split region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	0.9
False Alarm Ratio (FAR): $b / (a + b)$	0.35
False Alarm Rate (POFD): $b / (b + d)$	0.001
Threat Score: $a / (a + b + c)$	0.6

The scores of flash flood warnings for Split region, Croatia in 2016

a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	18 (a)	5 (b)	23
	No	5 (c)	338 (d)	343
Total		23	343	366

Contingency table of flash flood warnings for Rijeka region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	0.78
False Alarm Ratio (FAR): $b / (a + b)$	0.21
False Alarm Rate (POFD): $b / (b + d)$	0.001
Threat Score: $a / (a + b + c)$	0.64

The scores of flash flood warnings for Karlovac region, Croatia in 2016



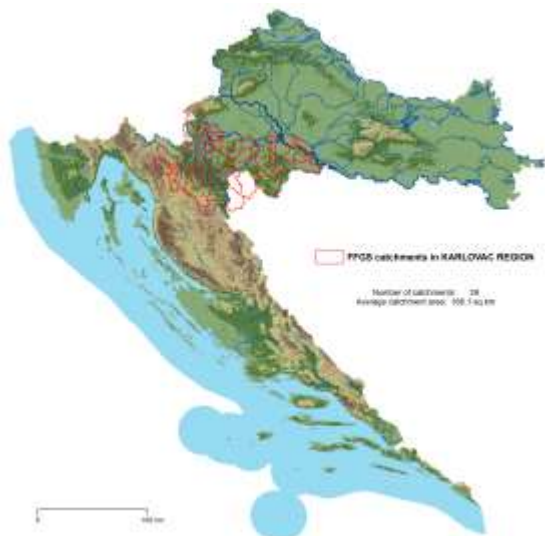
Verification of flash flood warnings in Croatia



a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	13 (a)	4 (b)	17
	No	0 (c)	349 (d)	349
Total		13	353	366

Contingency table of flash flood warnings for Gospić region, Croatia in 2016



a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	6 (a)	4 (b)	10
	No	0 (c)	356 (d)	356
Total		6	360	366

Contingency table of flash flood warnings for Karlovac region, Croatia in 2016



a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	5 (a)	3 (b)	8
	No	1 (c)	357 (d)	358
Total		6	360	366

Contingency table of flash flood warnings for Osijek region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	1
False Alarm Ratio (FAR): $b / (a + b)$	0.24
False Alarm Rate (POFD): $b / (b + d)$	0.01
Threat Score: $a / (a + b + c)$	0.76

The scores of flash flood warnings for Gospić region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	1
False Alarm Ratio (FAR): $b / (a + b)$	0.4
False Alarm Rate (POFD): $b / (b + d)$	0.01
Threat Score: $a / (a + b + c)$	0.6

The scores of flash flood warnings for Karlovac region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	0.83
False Alarm Ratio (FAR): $b / (a + b)$	0.37
False Alarm Rate (POFD): $b / (b + d)$	0.008
Threat Score: $a / (a + b + c)$	0.55

The scores of flash flood warnings for Osijek region, Croatia in 2016



Verification of flash flood warnings in Croatia



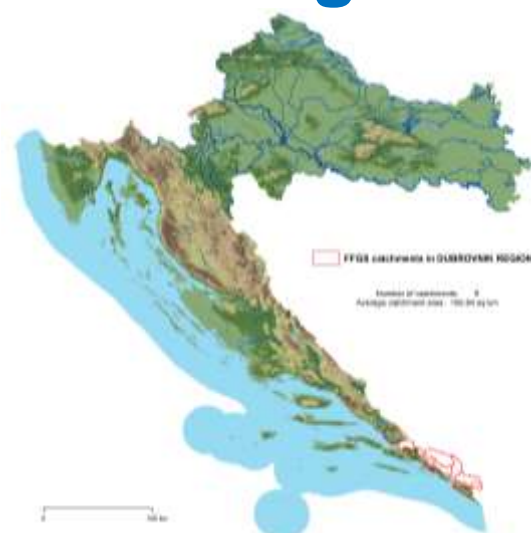
a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	6 (a)	3 (b)	9
	No	1 (c)	356 (d)	367
Total		7	359	366

Contingency table of flash flood warnings for Knin region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	0.86
False Alarm Ratio (FAR): $b / (a + b)$	0.33
False Alarm Rate (POFD): $b / (b + d)$	0.008
Threat Score: $a / (a + b + c)$	0.6

The scores of flash flood warnings for Knin region, Croatia in 2016



a = Hits
b = False alarms
c = Misses
d = Correct negatives

		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	6 (a)	4 (b)	10
	No	2 (c)	354 (d)	356
Total		8	358	366

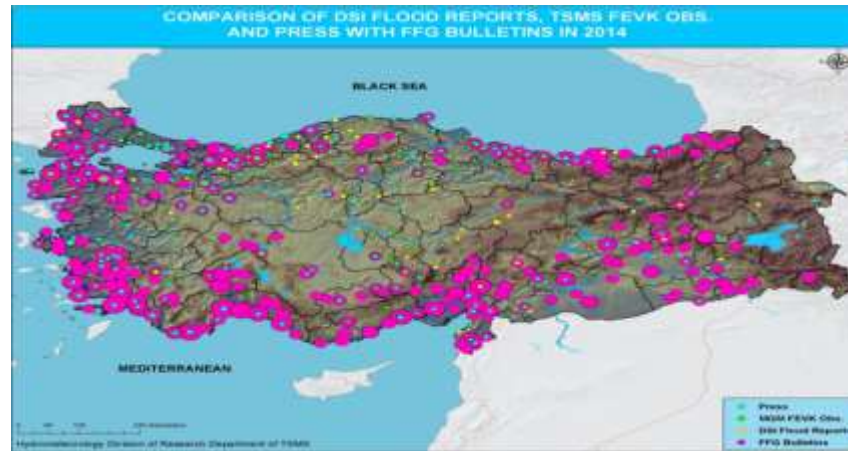
Contingency table of flash flood warnings for Dubrovnik region, Croatia in 2016

Hit Rate (POD) : $a / (a + c)$	0.75
False Alarm Ratio (FAR): $b / (a + b)$	0.4
False Alarm Rate (POFD): $b / (b + d)$	0.01
Threat Score: $a / (a + b + c)$	0.5

The scores of flash flood warnings for Dubrovnik region, Croatia in 2016



Verification of flash flood warnings in Turkey



	Observations (TSMS, DSI, Press)			
		YES	NO	Σ
Bulletins (21 May 2012-17 June 2013)	YES	43 (a)	25 (b)	68
	NO	18 (c)	306 (d)	324
	Σ	61	331	392

	Observations (TSMS, DSI, Press)			
		YES	NO	Σ
Bulletins 2014	YES	58 (a)	10 (b)	68
	NO	48 (c) (DSI+MGM+Dswm)	249 (d)	297
	Σ	106	259	365

Hit Rate (POD): $(a/(a+c))$	0.70
False Alarm Ratio (FAR): $(b/(a+b))$	0.36
False Alarm Rate (POFD): $b/(b+d)$	0.07
Threat Score: $(a/(a+b+c))$	0.5

Hit Rate (POD): $(a/(a+c))$	0.55
False Alarm Ratio (FAR): $(b/(a+b))$	0.15
False Alarm Rate (POFD): $b/(b+d)$	0.04
Threat Score: $(a/(a+b+c))$	0.5



Verification of flash flood warnings

- Participating countries should be advised to collect flash flood events reports as much as possible and create maps and contingency table;
- Verification of flash flood warnings is essential for evaluating and improving operational forecast products, including FFG System, and holds great potential for advancing predictability of flash flooding.



Thank you

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For more information please visit:

<http://www.wmo.int/ffgs>

<http://www.hrcwater.org>