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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;

Verification of flash flood warnings

- Flash floods warnings should be prepared in both objective and subjective methods.

- **Objective** methods invlove the use of the FFGS and other tools and models. **Subjective** methods involve forecaster experience and local knowledge.

- Flash floods are binary, dichotomous events and the forecast can be defined as deerministic with 2 categories.

- The combination of forecasts and observations for a set of forecasts being verified can be put into a contingency table.

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 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		
		Yes	No	Total
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)

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

- 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):

$$FAR = \frac{b}{a+b} = \frac{false\ alarms}{hits + false\ alarms}$$

- 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):

$$FA = \frac{b}{b+d} = \frac{false\ alarms}{false\ alarms + correct\ negatives}$$

- 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):

$$CSI = \frac{a}{a+b+c} = \frac{hits}{hits + false\ alarms + misses}$$

- 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.

Frequency bias (FBI)

$$FBI = B = \frac{a+b}{a+c} = \frac{total\ forecasted\ flash\ floods\ (hits + false\ alarms)}{hits + false\ alarmstotal\ observed\ flash\ floods\ (hits + misses)}$$

- The bias (B) or frequency bias (FBI), is the total number of forecasted flash floods over the total observed flash floods.
- The values can range from zero to infinity.
- A score of 1 is the perfect score. This indicates no bias. In other words, the number of observed flash floods is the same as the number of forecasted flash floods.
- Values less than 1 indicate a low bias, meaning there were more observations than there were forecasts of flash floods (underforecasting).
- Values higher than 1 indicate a high bias, meaning flash floods were forecast more often than they were observed (overforecasting).
- It is not true verification measure, as it does not imply matching individual forecasts and observations

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	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

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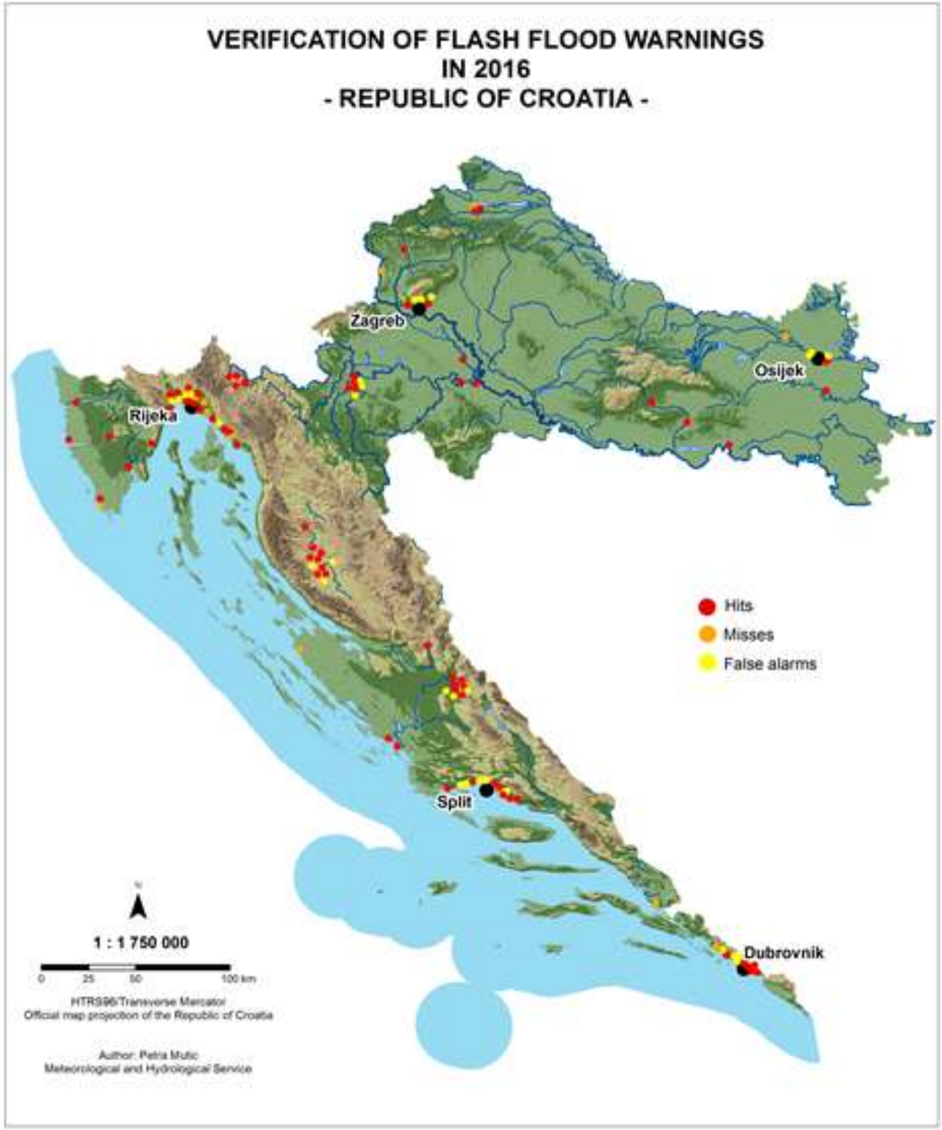
Verification of flash flood warnings in Croatia

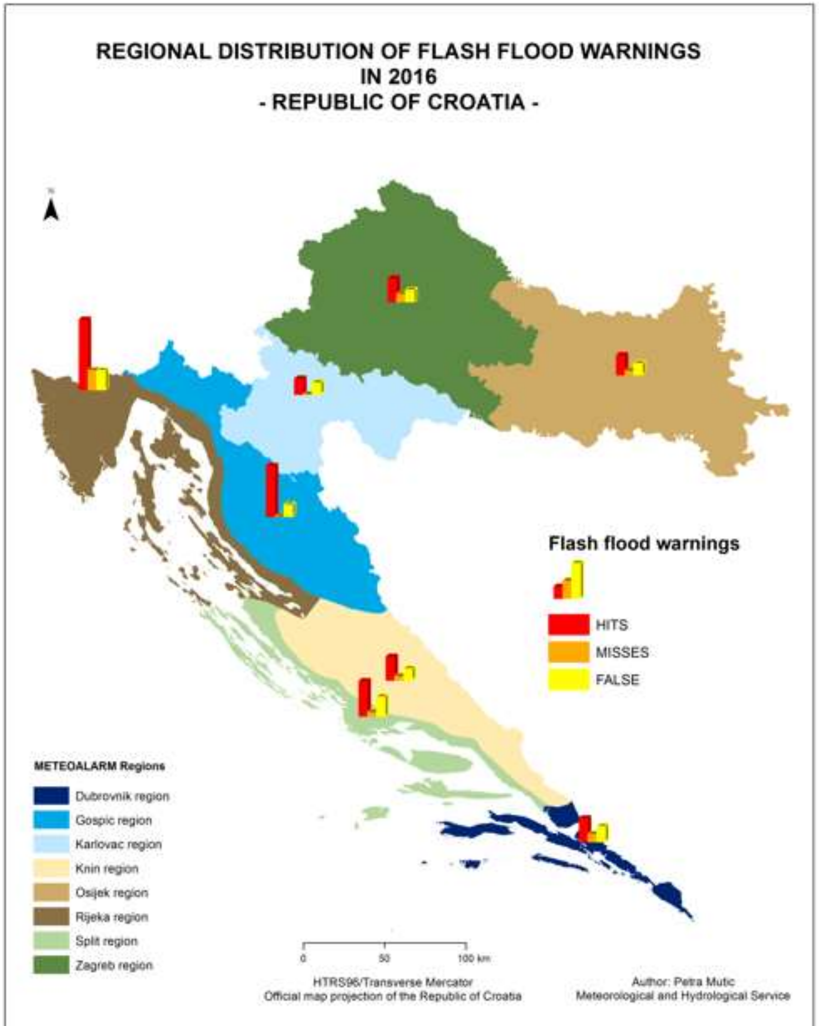
VERIFICATION SCORE	Value
Hit rate (HR) or Probability of detection (PoD):	0.95
False Alarm Ratio (FAR):	0.25
Frequency bias (FBI) or Bias (B):	1.27
False Alarm Rate (FA):	0.06
Threat score (TS) or Critical success index (CSI):	0.72
Heidke skill score (HSS):	0.58
Hanssen-Kuipers skill score (KSS), True Skill Statistics (TSS), or Peirce skill score:	0.6
Stable extreme dependency score (SEDS):	0.8
Extremal dependency index (EDI):	0.85
Symmetric extremal dependency index (SEDI):	0.97

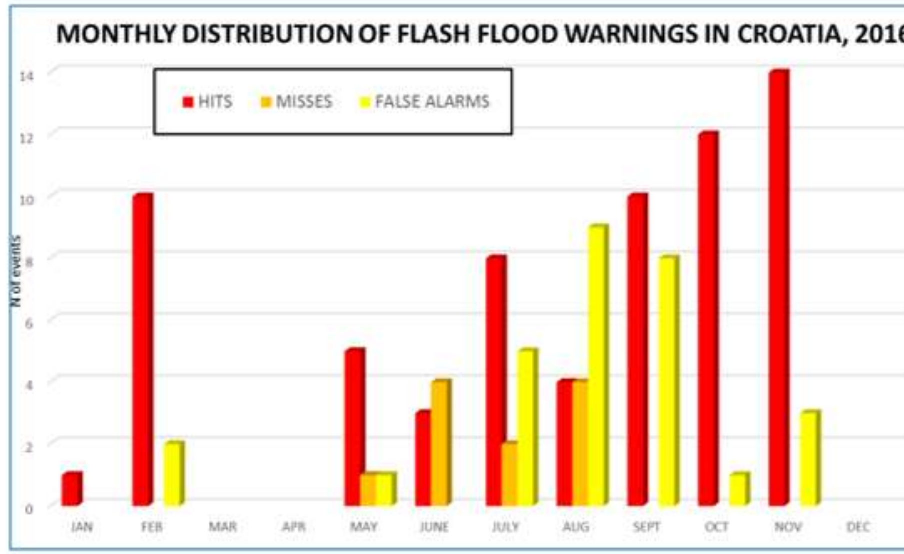
The scores for flash flood warnings for Croatia
from 10th of October 2015 to 29th of February 2016

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

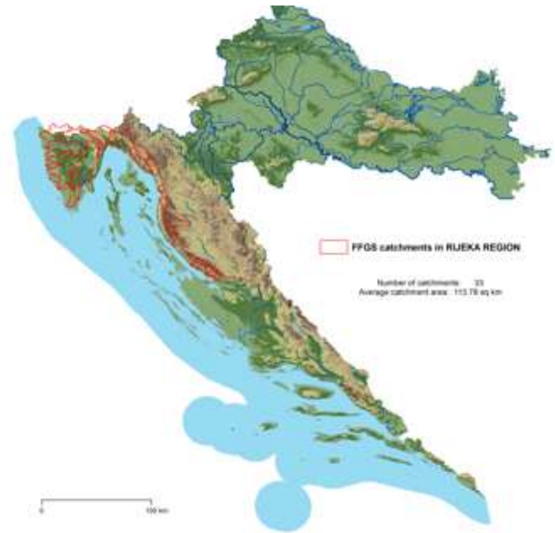
a = Hits
b = False alarms
c = Misses
d = Correct negatives

		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

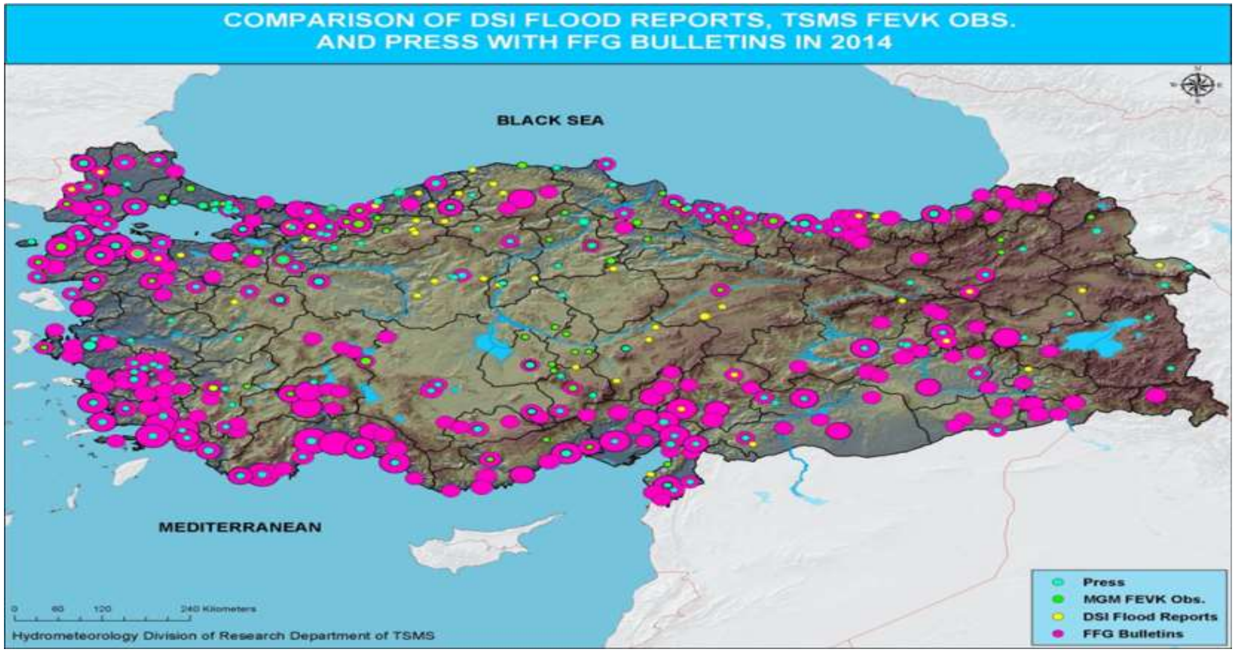
		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	18 (a)	5 (b)	23
	No	5 (c)	338 (d)	343
	Total	23	343	366

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 Turkey



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

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

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Conclusions

- Those NMHSs that do not have an ongoing flash flood forecast verification are strongly encouraged to implement such a process.
- 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.

Conclusions

- Each NMHS must seek to achieve its own balance between scale (size) of forecast area and risk of false alarms and missed events (WMO, 2014).

- 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.

- Data collected for flash flood verification purposes can be the step forwards an inventory or flash flood database, which can enhance the understanding of flash flood occurrences, their magnitude and geographical distribution, and to improve flash flood forecasting.

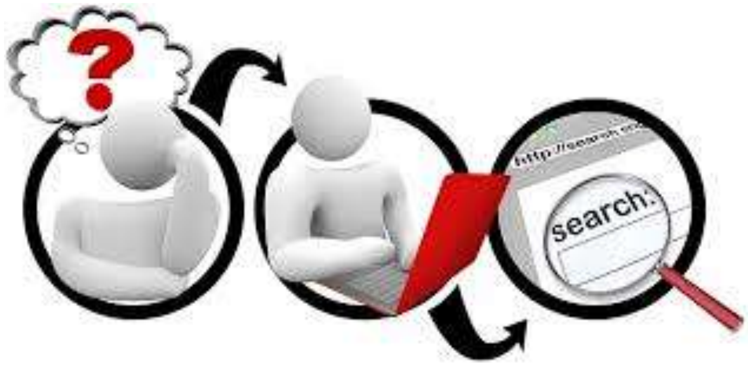
Useful Web Resources and Literature

- COMET MetEd, 2008: Introduction to Verification of Hydrologic Forecasts. University Corporation of Atmospheric Research: https://www.meted.ucar.edu/training_module.php?id=486#.WigxFEriY2w

- European Virtual Organization for Meteorological Training (EUMETCAL) training site on verification – computer-aided learning: http://www.eumetcal.org.uk/eumetcal/verification/www/english/courses/msgcrs/index.htm

- Joint WWRP/WGNE Working Group on Forecast Verification Research: http://www.cawcr.gov.au/projects/verification

- World Meteorological Organization, 2014: **Forecast Verification for the African Severe Weather Forecasting Demonstration Projects** (WMO-No. 1132). Geneva, Switzerland.



Thank you

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For more information please visit:	**http://www.wmo.int/ffgs**
	http://www.hrcwater.org

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