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# SPATIAL AND TEMPORAL ANALYSIS OF HYDROLOGICAL WARNINGS AND ALERTS FOR IMMEDIATE PHENOMENA FOR 2022 AND 2023 IN ROMANIA

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**ABSTRACT. – Spatial-temporal analysis of hydrological alerts and warnings for immediate phenomena in 2022 and 2023 in Romania**. The purpose of this paper is to highlight the spatial-temporal distribution of hydrological alert messages issued at the national level in the last two years, with a special focus on the accomplished percentage of the forecasted projected information. This paper used information from the database generated within National Institute of Hydrology and Water Management as part of the National Administration of Romanian Waters (NARW), which is the national authority to elaborate and distribute the warnings and alerts for immediate phenomena in Romania. The criteria for validating the hydrological warnings were based on the achievement of the predicted stream defense water levels, reaching precipitation thresholds or the existence/evidence of recorded damages. The actual analysis was carried out on the major hydrographic basins associated with the regional basin administrations. Three particular case studies were also analyzed, which spatially cover three distinct heterogeneously positioned regions, in order to have a better representativeness: the upper part of Someșului Mare river, the Bistrița, Moldova and Suceava rivers in Suceava county and the lower basin of Jiu River with its tributaries, as well as the Danube River on its sector within Iron Gates II Dam and its confluence with the Jiu River.

**Keywords:** spatial distribution, temporal analysis, hydrological alerts and warnings for immediate phenomena

## 1. INTRODUCTION

The current national hydro-climatic context, determined by the regional and continental meteorological evolution, led that in recent years, the attention of the general public, but also of specialists in the field, to be directed towards the prevention and mitigation of the effects generated by hydrological and

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meteorological hazards with pluviometric genesis. In this sense, more and more emphasis is placed on the generation of preventive information messages that allow minimizing the possible negative effects associated with the mentioned hazards. According to the American Meteorological Society, the hydrologic warning refers to an emergency announcement of information on an anticipated, potentially dangerous, hydrologic event [9].

The analysis of the frequency and level of danger associated within hydrological warnings and alerts have been the subject of previous studies, both at national and European level.

An exploratory study of the incidence and spatial distribution of warning messages with reference to a single calendar year was developed on a national scale for 2009, highlighting for the first time that the winter season begins to record more warning messages than summer and autumn (Bătinaș, 2010).

As part of the non-structural measures for flood risk mitigation anther study from 2009 was focusing on flood control evaluation on Bâsca River (Minea et all, 2011). Other studies were focusing on awareness level that general public has for assessing the warning messages received from local or regional authorities especially in rural areas (Sali et all, 2013). Another study focused on assessing the hydrological vulnerability has considered the very important role of issuing alert messages in order to reduce the potential damages related to flood hazards (Albulescu et all, 2022). Pandemic frame time of COVID has emerged another interesting correlation between flood events and infection cases (Albulescu, 2023).

Hydrological warnings are issued by the national authority in field of water monitoring and water hazards mitigation, respectively National Institute of Hydrology and Water Management (NIHWM). These alert messages are based on the discharge forecasting and rain amount prediction assessment and contain information about the natura of concerned phenomena, its intensity and possible effects that can be recorded (Bătinaș, 2010). Also, it is mentioned the frame time on which the hazard will occur and its geographical area of development. The coding procedures are using two distinct concepts: hydrological warning and hydrological alert. *Hydrological warning*s are issued when is predicted the exceedance of defense river levels or the possibility of other phenomena or dangerous water to occur in near future (major slope leaks, water torrents, non-permanent streams with unusual behavior) based on weather forecasts. *Hydrological alerts* are issued when is predicted the inevitable exceedance of river defense levels and / or the formation of other hazardous fluid phenomena (major leaks down a hillside, water torrents, non-permanent streams with high discharge) based on weather forecasts and rivers status (Order 823/MMGA and 1427/MAI).

As in other natural hazards evaluation assessment the three-color code system (yellow-orange-red) is used also in Romania to evaluate the intensity of floods production. The vulnerability level of each color code is described in the following legislation orders: 823/MMGA and 1427/MAI respectively 638/2005 of MAI or 420/2005 of MMGA:

- *Yellow code*: Flooding risks or rapid increases in water level not leading to significant damages, which requires an increased vigilance on outdoor seasonal activities exposed to flooding events; this code is associated with the first defense water level;
- *Orange code*: Flooding risks which could generate significant water rises likely to have significant impact on the lives of communities and the safety of goods and people; this code is associated with the second defense water level;
- *Red code*: Major flooding risks; direct threat to the general safety of persons and goods. This code is associated with the third and most serious water defense level.

Warnings of immediate or very short-term for hydrological phenomena are associated with an anticipation time between 1 hour and 6 hours.

Since 2018, NIHWM was focusing on generating a data base regarding the hydrological warnings/warnings and hydrological warnings/warnings for immediate meteorological phenomena.

In 2020, we had the initiative to create two databases, one with hydrological warnings and alerts and one with warnings and alerts for immediate hydrological phenomena. In 2021, we asked ourselves how many of the hydrological warnings and alerts for immediate hydrological phenomena are confirmed.

Talking with several specialists in the field of water and from the university environment, we decided on three criteria for their validation. The first criterion was the achievement of the forecast water levels, the second was the achievement of the precipitation thresholds and the third was the occurrence of damage in the area due to overflows of watercourses or runoff from the slopes. The rainfall maps issued daily by ANM Bucharest, only for the year 2023, were used to validate the data.

## 2. DATA AND METHODS

The raw data provided by the RWNA is expanded over two consecutive years of monitoring (2022 -2023) and contains information regarding the spatial distribution on the 11 large watersheds – Water Basin Administrations, subsidiaries of RWNA. In order to obtain the spatial distribution, we have used MS Excel and ArcGIS map software.

## 3. RESULTS

In the period 2018-2023, a total of 2910 hydrological warnings and alerts for immediate hydrological phenomena were issued, of which 2065 code yellow warnings, 718 code orange warnings and 127 code red warnings. Their distribution by years, respective color codes are shown in figure 1.

The most warnings and alerts of immediate hydrological phenomena were issued in 2019, 586 records, and the fewest in 2021, 416 records. The most warnings of immediate hydrological phenomena associated with code yellow threat level were registered in 2018, 482 records, while the fewest ones, 277 records were issued in 2021. The most warnings of immediate hydrological phenomena associated with code orange threat level were issued in 2019, 191 records, and the fewest ones, 93 records were issued in 2018. The most warnings of immediate hydrological phenomena associated with code red threat level were issued in 2021, 40 events, while the least ones, only 3 messages in 2022.

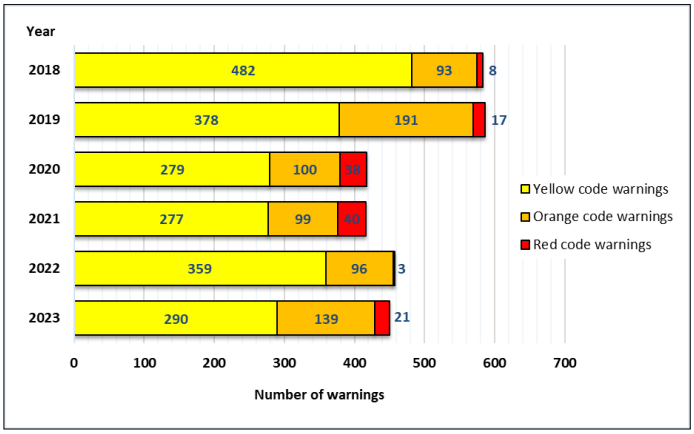


**Fig. 1.** ***Evolution of hydrological warnings and warnings period 2018-2023***

In the last two years (2022-2023), Romania has experienced and registered 908 hydrological alerts and warnings for immediate hydrological phenomena, of which 458 events in 2022 and 450 events in 2023. The most code yellow hydrological alerts, were issued in 2022, 359 events. The most code orange warnings, 139, were registered in 2023. The most code red warnings, 21, were registered also in 2023.

In table no. 1, the situation of hydrological warnings and alerts for immediate phenomena on the Water Basin Administrations in the last two years is presented, as well as their degree of achievement.

In 2022, the most confirmed warnings and alerts of immediate phenomena were registered in the Buzău-Ialomița and Jiu Water Basin Administrations (100%), followed by the Crișuri and Someș-Tisa Water Basin Administrations with a completion percentage of 97,96%.

In 2023, the most confirmed warnings and alerts of immediate phenomena were recorded in the Prut-Bârlad Water Basin Administration (100%), followed by the Buzău-Ialomița Basin Administrations (94,12%) and Argeș-Vedea with one percent achievement of 93,75%.

Spatial distribution on the national territory shows that the most vulnerable catchment areas were the ones situated in the western part of the country: Mureș, Banat, Crișuri and Someș-Tisa (Figure 2).

**Table 1.** ***Number of warnings and alerts of immediate phenomena (2022-2023)***

| Water Basin Administration | 2022 | confirmed 2022 | Achievement percent | 2023 | confirmed 2023 | Achievement percent |
|---|---|---|---|---|---|---|
| Argeș-Vedea | 23 | 20 | 86,96 | 16 | 15 | 93,75 |
| Banat | 77 | 63 | 81,12 | 79 | 67 | 84,81 |
| Buzău-Ialomița | 32 | 32 | 100,00 | 34 | 32 | 94,12 |
| Crișuri | 49 | 48 | 97,96 | 54 | 45 | 83,33 |
| Dobrogea-Litoral | 16 | 12 | 75,00 | 8 | 7 | 87,50 |
| Jiu | 32 | 32 | 100,00 | 33 | 28 | 84,85 |
| Mureș | 80 | 76 | 95,00 | 84 | 75 | 89,29 |
| Olt | 52 | 48 | 92,31 | 51 | 45 | 88,24 |
| Prut-Bârlad | 20 | 17 | 85,00 | 15 | 15 | 100,00 |
| Siret | 42 | 39 | 92,86 | 33 | 28 | 84,85 |
| Someș-Tisa | 49 | 48 | 97,96 | 59 | 47 | 79,66 |

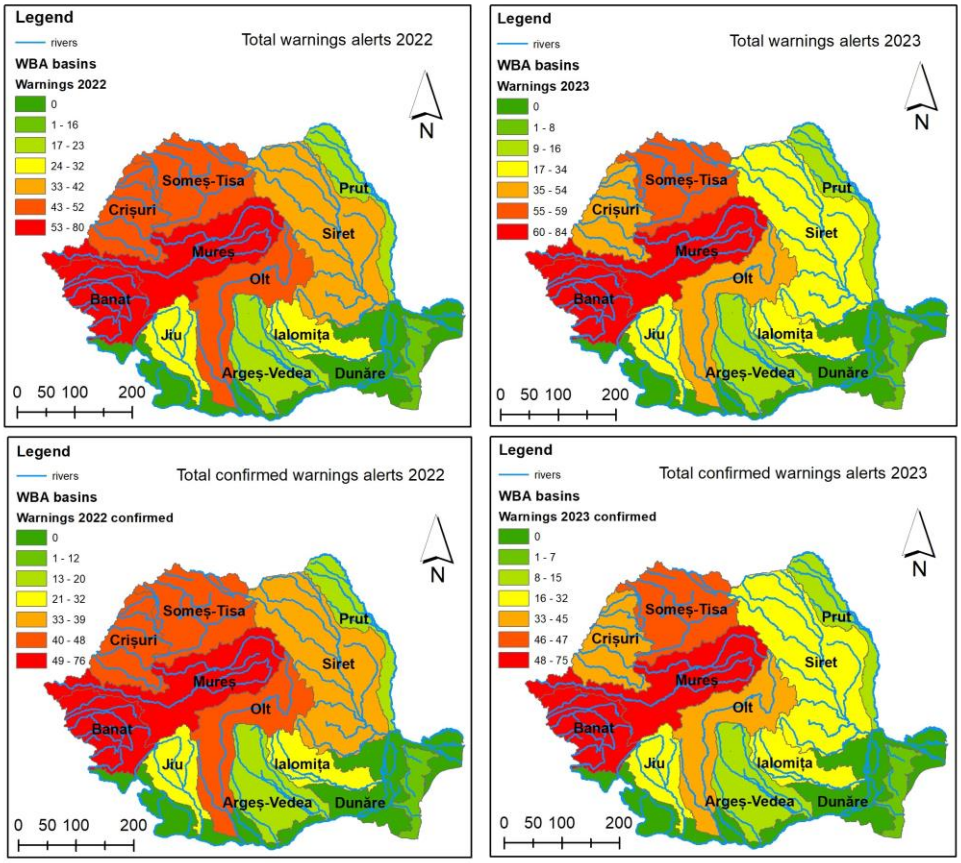


**Fig. 2.** ***Spatial distribution of hydrological warnings and alerts for 2022-2023***

Table no. 2 shows the situation of warnings and alerts of immediate phenomena, from the year 2022 by month and their degree of achievement.

**Table 2.** ***Monthly situation of warnings and alerts for immediate phenomena in 2022***

| No. | Month | Issued messages | Threat color code | | | Confirmed messages |
|---|---|---|---|---|---|---|
| | | | Yellow | Orange | Red | |
| 1 | January | 2 | 1 | 1 | 0 | 2 |
| 2 | February | 6 | 6 | 0 | 0 | 6 |
| 3 | March | 0 | 0 | 0 | 0 | 0 |
| 4 | April | 20 | 16 | 4 | 0 | 19 |
| 5 | May | 49 | 46 | 3 | 0 | 44 |
| 6 | June | 114 | 103 | 11 | 0 | 103 |
| 7 | July | 96 | 70 | 25 | 1 | 88 |
| 8 | August | 119 | 84 | 35 | 0 | 111 |
| 9 | September | 25 | 17 | 6 | 2 | 24 |
| 10 | October | 5 | 3 | 2 | 0 | 4 |
| 11 | November | 8 | 7 | 1 | 0 | 7 |
| 12 | December | 14 | 6 | 8 | 0 | 14 |
| **13** | **Total** | **458** | **359** | **96** | **3** | **422** |

The most vulnerable months were the last two months of Spring and the whole summer season (Fig. 3). Due to the unpredictability of fast changes in weather patterns during summer season for the convective rain episodes the degree of achievement is weaker comparing with colder seasons. The autumn and winter months were recorded a low number of issued messages. This is the result of intensification and increase in the number of episodes with convective rains generating dangerously flash floods events.

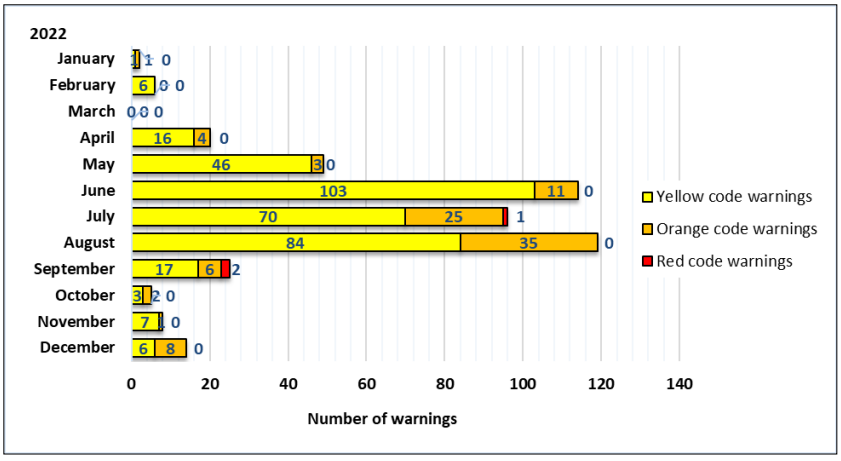


**Fig. 3.** ***Monthly distribution of hydrological warnings and alerts for 2022***

Table no. 3 shows the situation of warnings and alerts of immediate phenomena, from the year 2023 by month and their degree of achievement.

**Table 3.** ***Monthly situation of warnings and alerts for immediate phenomena in 2023***

| No. | Month | Issued messages | Threat color code | | | Confirmed messages |
|---|---|---|---|---|---|---|
| | | | Yellow | Orange | Red | |
| 1 | January | 6 | 5 | 1 | 0 | 6 |
| 2 | February | 9 | 4 | 4 | 1 | 9 |
| 3 | March | 1 | 1 | 0 | 0 | 1 |
| 4 | April | 28 | 21 | 6 | 1 | 27 |
| 5 | May | 56 | 39 | 15 | 2 | 44 |
| 6 | June | 109 | 55 | 49 | 5 | 92 |
| 7 | July | 123 | 81 | 37 | 5 | 109 |
| 8 | August | 69 | 53 | 13 | 3 | 53 |
| 9 | September | 26 | 19 | 7 | 0 | 22 |
| 10 | October | 2 | 2 | 0 | 0 | 1 |
| 11 | November | 8 | 5 | 2 | 1 | 8 |
| 12 | December | 13 | 5 | 5 | 3 | 13 |
| **13** | **Total** | **450** | **290** | **139** | **21** | **385** |

As in the year before, 2023 was also recording almost the same number of messages, mostly of them being issued for the warm semester (April to September). As an interesting topic, we have noticed a decline for the alerts associated with yellow code threat while for the dangerous ones (orange and red) we recorded a significant increase comparing with the values form previous year (Fig. 4).

The potentially dangerous events associated with high rainfalls can led to critical episodes which can led to significant damages on territorial inventory both to natural environment, but mostly to human settlements.

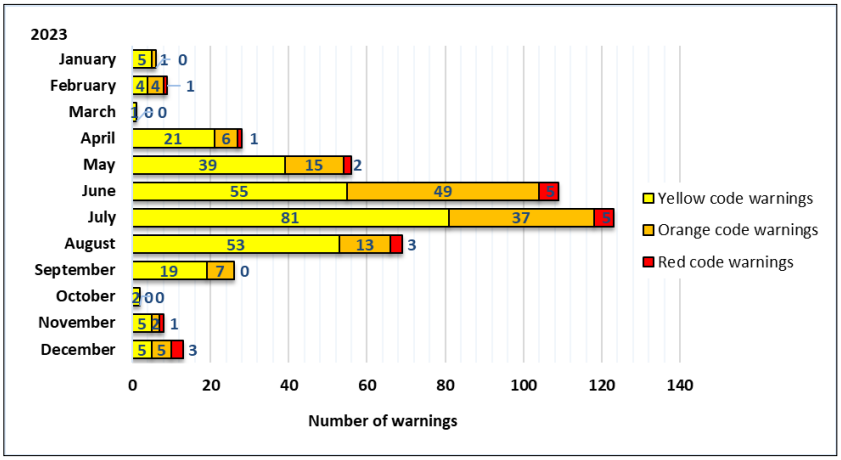


**Fig. 4.** ***Monthly distribution of hydrological warnings and alerts for 2023***

In 2022, 93.05% of all hydrological alerts and warnings were validated, while in 2023, from the whole issued amount, 88.29% were validated. Although fewer warnings were validated in 2023, more threat levels were reached and exceeded, including the dangerous levels, compared to 2022. The achievement of these validations was conditional on the effective registration and reaching the hydrological alert thresholds mentioned in the warning messages of the forecasted phenomena. A synthetic situation can be found in the table below (Table 4).

**Table 4.** ***Achievement percentage of forecasted events at the level of hydrological alert messages in the 2022-2023 interval***

| No. | Month | Achievement percentage of forecasted events | |
|---|---|---|---|
| | | 2022 | 2023 |
| 1 | January | 100.00% | 100.00% |
| 2 | February | 100.00% | 100.00% |
| 3 | March | 100.00% | - |
| 4 | April | 96.43% | 95.00% |
| 5 | May | 78.57% | 89.80% |
| 6 | June | 84.40% | 90.35% |
| 7 | July | 88.62% | 91.67% |
| 8 | August | 76.81% | 93.28% |
| 9 | September | 84.62% | 96.00% |
| 10 | October | 50.00% | 80.00% |
| 11 | November | 100.00% | 87.50% |
| 12 | December | 100.00% | 100.00% |
| **13** | **Annual** | **88.29%** | **93.05%** |

Figure no. 5 shows the three study areas: *area I* - Danube and downstream tributaries, the Iron Gates II accumulation - confluence with the Jiu river, the lower sector of Jiu river with the Gilort, Raznic and Desnățui tributaries; *area II* - Someșul Mare with tributaries upper basin up to the confluence with the Șieu river, including also Șieu river and its tributaries; *area III* - Dorna river with tributaries, Bistrița river, Moldova river with tributaries, Suceava river and tributaries, Siret river to confluence with Moldova river. During 2022, 37 yellow code for immediate hydrological warnings, 12 orange code for immediate warnings and one red code warning were issued for the three areas, a total of 50 events.

Their distribution by area is as follows: 24 events in area I, 11 events in area II and 15 events in area III. The first red code warning was issued on September 2, 2022 on the Gilort river, a tributary of Jiului. At the Rânca rain gauge station, 92 liters were recorded in 24 hours.

During 2023, 33 yellow code warnings, 10 orange code warnings and 2 red code warnings were issued for the three areas, a total of 45 events. Their distribution by zones is as follows: 28 events for area I, 10 events for area II and 12

events in area III. The only red code warning was issued on June 15, 2023 on the Raznic River, a tributary of Jiului.

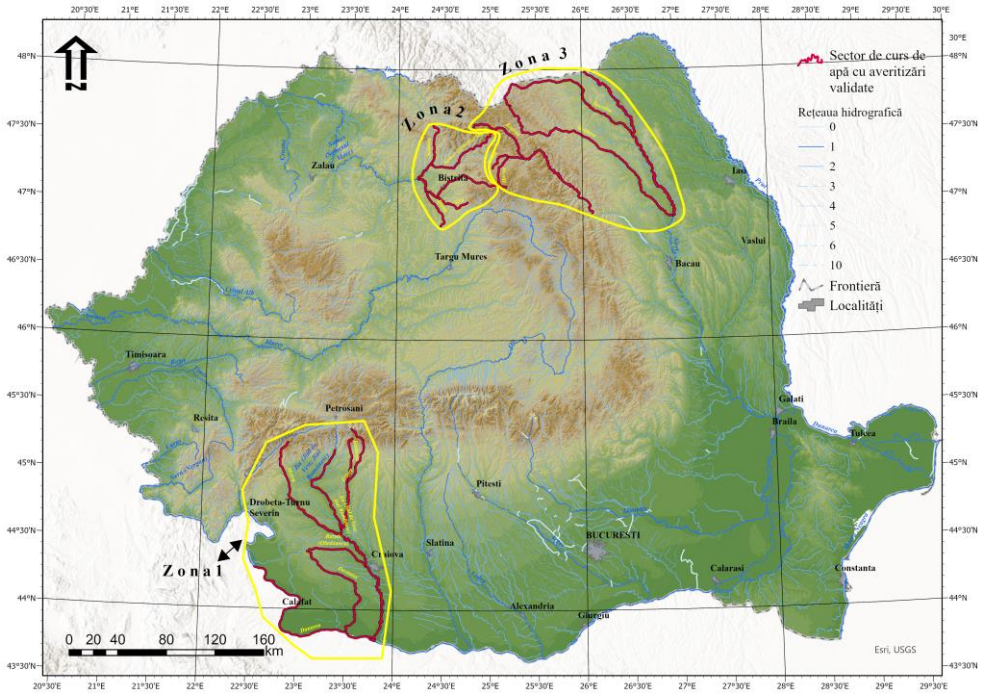


**Fig. 5.** ***Study cases areas considered for warnings messages issued in 2022-2023***

## 4. CONCLUSIONS

The last years have proved also in Romania that the current trend of climate patterns is changing towards a consistent rising in great rainfalls episodes that are generating flash floods and associate hazards to human settlements. Although, 2022 and 2023 were considered dry years, in terms of total amount, the torrential rain episodes were responsible for the issuing of more than 900 threat warnings for the two years combined. The achievement percentage of issued warnings and immediate alerts validated by measurement and observations in the field has confirmed the important role of monitoring departments within NARW. The rise of warnings number associated with red code threat is another consequence of a changing climate patterns in Romania.

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