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FORUM GEOGRAFIC

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Professor Constantin Savin, Life and Activity

Lecturer univ. Ph.D Diana SAVIN[1]

[1] Faculty of Mathematics and Informatics, Ovidius University of Constantza

Constantin Savin was born on February 24th, 1937, in the village Hangu, commune Hangu county Neamt, Romania. From 1951 to 1954, he was a student at "Petru Rares" High School, in Piatra Neamt. In 1959, he graduated the "Alexandru Ioan Cuza" University of Iași, Faculty of Natural Sciences and Geography, Department of Geology-Geography, institution where he also got his Ph.D in Geography, in 1976, under professor Constantin Martiniuc, with the thesis "The geohydromorphological study of the Jiu lowlands in the Getic Plateau and the Plain of Oltenia". Through his thesis, the author delivered an original and important contribution to the study of the Jiu river's meadow and river bed dynamics.

During the doctoral and post-doctoral periods, Constantin Savin graduated the following courses:

- "The draining of rivers. Hydrological calculations" postgraduate course, organized by UNESCO at the Lomonosov University in Moscow, part of the "International Hydrological Programme (IHP)", between June and July 1969;
- "Applications of mathematics in hydrology" course, organized by the Meteorology and Hydrology Institute (MHI), Bucharest, in May, 1973;
- "Hydrology" course organized by the Civil Engineering Institute, Faculty of Hydraulic Engineering, Bucharest, in the 1979-1980 school year. At the course's final exam, Constantin Savin presented the article "The characteristics of flash flood rays in the drainage basin of river Jiu";
- "Applied hydrology" course, organized by the Meteorology and Hydrology Institute (MHI) Bucharest, in 1986, over the course of nine months.

The professional evolution of Constantin Savin was remarkable:

- First, he was a secondary school teacher in commune Rediu, Neamț county during the school year 1959-1960, then in commune Buda, Bacău county, between 1960 and 1961;
- Between 1961 and 1964, Constantin Savin worked as a hydrologist (responsible over station) at the Hydrological Station Bacău (part of Iași Water Directorate). Between 1964-1966, he worked as Chief Hydrologist within the same unit;
- He functioned as chief hydrologist at the Hydrological Station Craiova between 1966 and 1968;
- At the establishment of the Meteorological and Hydrological Sector (MHS), Craiova (later Jiu Water Directorate, Craiova), Constantin Savin was promoted to Chief Hydrologist over the entire country of Oltenia (which was the target of his transfer from Bacău). He remained within the unit as Chief Hydrologist for 8 years (1967-1975), for 14 years as Chief of Hydrology-Hydrogeology (following the unification of the two departments) between 1976 and 1990, for one year as Chief Hydrometeorologist (1990-1991), then for 8 years as CTO of the Craiova Branch of "Apele Române" Autonomous Management;
- In the school year of 1967-1968, Constantin Savin joined the University of Craiova, Faculty of History-Geography, as a assistant professor and, later, as lecturer, teaching Hydrology (course and seminary). Afterwards, after the promulgation of the law banning cumulating functions, during the summer of 1968, Constantin Savin decided to give up the job. Sometime later, the Geography Department of the Faculty was dissolved;
- Between 1975 and 1978, due to the delegation of wife Elena Savin (Mathematics teacher) to the Kingdom of Morocco, part of the technical and scientific collaboration between countries, Constantin Savin was also delegated to work as an engineer in Hydrology-Hydrogeology, also in Morocco, part of Public Administration and Communications Ministry,

Hydraulic Directorate, Water Resources Division, Regional center of Tadla in the town of Beni Mellal;

- Between 1991 and 1992, Constantin Savin taught Hydrology at Post-secondary School of Hydrometeorology in Craiova. At the same time, he was an associate professor, teaching Hydrology-Hydrogeology (course, workshops, exams), at Faculty of Ecobiotechnology, in Caracal, Romania;
- Between 1992 and 1993, Constantin Savin functioned as associate professor at University of Craiova, Faculty of Sciences, Geography-Geoecology Department, for Hydrology (course, workshops, seminaries, exams, field work) and at "Lower Danube" University of Galați, Faculty of Letters-Sciences, History-Geography Department, for Meteorology-Climatology (course, workshops, exams) and Hydrology (course, workshops, exams) – despite functioning as an associate professor, he was paid as a lecturer only.
- Between 1994 and 1995, Constantin Savin was an associate professor at University of Târgoviște, Faculty of Sciences;
- Between 1994 and 1997, Constantin Savin was a lecturer at University of Craiova, Faculty of Sciences, Geography-Geoecology Department;
- In 1997, his activity at Jiu Waters Directorate comes to an end, after which he obtains the associate professor position at University of Craiova, Faculty of History, Philosophy and Geography, Geography Department;
- In 2002, Constantin Savin wins the position of Professor (titulary) at University of Craiova, Faculty of History, Philosophy and Geography, Geography Department;
- Between 1999 and 2008, at the same time with his work at the Faculty of History, Philosophy and Geography, Constantin Savin also teaches at Faculty of Horticulture, at University of Craiova;
- At the end of the school year of 2007-2008, Constantin Savin retires.

Professor Constantin Savin wrote the following works (treaties, monographies courses):

- Constantin Savin, Jiu meadow water resources, Scrisul Românesc Publishing House, Craiova, 1990;
- Constantin Savin, Scientific Polyglot Dictionary, Tipored Publishing House, Bucharest, 1996;
- Constantin Savin, Scientific Polyglot Dictionary - Glossary, Tipored Publishing House, Bucharest, 1997;
- Viorica Tomescu, Vasile Pleniceanu, Constantin Savin, General physical geography (Tests for admission in higher education forms), Universitaria Publishing House, Craiova, 1990;
- Constantin Savin, Underground waters of Craiova, Tipored Publishing House, Bucharest, 2000;
- Constantin Savin, Hydrology of Rivers – theory and applications, Reprograf Publishing House, Craiova, 2001;
- Constantin Savin, Physical geography of Romania, course for students, University of Craiova, Craiova, 2003;
- Constantin Savin, Ion Marinica, Synoptical Meteorology (course support for the students of Faculties of Geography and Environment Engineering), published on CD, University of Craiova, Autograf Publishing House MJM 2007, ISBN 973-8989-13-2 (Romania), ISBN 978-973-8989-13-9 (E.U.), 2003, 2007 respectively;
- Constantin Savin, Rivers of Oltenia. Hydrological phenomena of high risk, Sitech Publishing House, Craiova, 2004;
- Constantin Savin, Hydrology and the protection of water quality, Sitech Publishing House, Craiova, 2006, University of Craiova, Faculty of Horticulture;
- Constantin Savin, Special meteorology and hydrology problems – course for students, University of Craiova, Craiova, 2006;
- Constantin Savin, Rivers of Oltenia – hydrological monography, vol. I – The dynamics of river drainage, Sitech Publishing House, Craiova, 2008.

Constantin Savin had been interested into scientific research and theoretics (apart from his work obligations) since 1965-1970, interest which had taken a variety of forms: research articles, synthesis, studies, books, participation (with or without holding a discourse himself) in scientific conferences, both national and international, participation in courses, local press interviews, interviews and discussions over scientific matters, at the territorial Radio Craiova studio, reviews of certain books (as a scientific reviewer), reviews of Ph.D thesis (also as a scientific reviewer to some).

Professor Constantin Savin wrote over a hundred research articles, studies and pages of synthesis (out of which thirteen abroad, two in France and eleven in Morocco), over 85 of which were published in magazines with reviewers. To mention a few:

1. Guessab Driss, Constantin Savin, La possibilité d'eméttre des previsions d'apports d'été au reservoir de Bin El Ouidane, published in Notes techniques de l'hydrauligue - Série Hydrologie, March 1976 (Royaume du Maroc, MTPC, DH, DRE, Rabat);
2. Constantin Savin, Exploitation des mesures de débit d'étiage des rivières aux fins de prévision de fourniture d'eau pour l'irrigation, published in Notes techniques de l'hydrauligue - Série Hydrologie, May 1976 (Royaume du Maroc, MTPC, DH, DRE, Rabat);
3. Constantin Savin, Etude des débits au maximum de l'oued Ourbia (Akka N'Khelifa), publicata in Notes techniques de l'hydrauligue- Série Hydrologie,

December 1976 (Royaume du Maroc, MTPC, DH, DRE, Rabat);

4. Constantin Savin, L'étude hydrologice de l'oued Ikaben, published in Notes techniques, no.4/1976 (MTPC, DH, DRE, Centre Régional du Beni Mellal, Maroc);

5. Constantin Savin, Contributions to the hydrological study of the Craiova area (partial results), published in Lucrarile Seminarului geographic "D. Cantemir", nr. 3/1982, Univ. Iasi;

6. Constantin Savin, The characteristics of flash flood rays in the drainage basin of river Jiu – detailed study, published in Hidrotehnica, nr. 9/1983, CNA, Bucharest;

7. Constantin Savin, Contribution à l'étude de la dynamique des versants à base des measures hydrotopométriques, Symposium the role of geomorphological field experiments in land water management, August 25-September 3, 1983, Bucharest (University of Bucharest, Institute of Geography of the Romanian Academy), published in the volume Geomorphological research for land improvement, under ISPIF, Bucharest, University of Bucharest, Institute of Geography of the Romanian Academy, Bucharest, 1985;

8. Nicolae Ghigiu, Constantin Savin, Hydro-meteorological data valorification towards rational exploitation of water volumes from the "Valea de Pești" Dam, published in Hidrotehnica, nr. 11/1994, RAAR, Bucharest;

9. Constantin Savin, L'écoulement minimum sur la riviére de Jiu pendant la période de sécheresse 1992-1993, 3-èmes Rencontres Hydrologigues Franco-Roumaine, Montpellier, September 6-8, 1995 (special volume);

10. Constantin Savin, L'asssèchement des rivières dans l'espace hydrographique Jiu-Danube. Etude de synthèse, published in Les travaux de 3-èmes Rencontres Hydrologigues Franco-Roumaine, Montpellier, September 4-8, 1995 (special volume);

11. Constantin Savin, Elena Savin, Climate of Oltenia towards aridity, published in Hidrotehnica, nr. 6/1995, RAAR, Bucharest;

12. Constantin Savin, Contributions to the analysis of the aquiferous layers with free level within the Craiova Area, published in Analele Universitatii din Craiova, sectia Geografie, nr. 3/1999;

13. Constantin Savin, Viorica Tomescu, Human-induced Changes of the Danube alluvial plian. Landscape within Drobeta Tr. Severin-Corabia Area, published in Analele Universitatii din Cluj-Napoca, Facultatea de Geografie, nr.3/1999;

14. Constantin Savin, Contributions towards determining the underground water quality in the Craiova area, published in Hidrotehnica, vol. 46, nr. 1/2001, p. 16-22, CNAR, Bucharest;

15. Constantin Savin, The hydrometrical method of evaluation of the minor riverbed dynamics. Applied to river Jiu, published in Analele Universitatii din Craiova, sectia Geografie, nr.4/2001;

16. Constantin Savin, The evaluation of underground water resources in the perimeter of the Craiova area, published in Geoforum, nr.1/2001, Univ. din Craiova, sectia Geografie;

17. Constantin Savin, The variation of the annually drain of water for the main rivers of Oltenia, published in Hidrotehnica, vol. 47, nr. 12/2002, p. 11-16, Bucharest;

18. Ion Marinica, Constantin Savin, Canicular days, climatic risk, phenomenon in Oltenia, published in Ovidius University Annals of Geography, vol. 2/2005, p.111-124;

19. Constantin Savin, Ion Marinica, Brussels - Craiova – a climatic parallel, published in Ovidius University Annals of Geography Volume 2/2005, p. 135-144;

20. Constantin Savin, The variation of medium water deposits drainage on the rivers of Oltenia in the past 50 years, published in Lucrarile Seminarului geographic "D. Cantemir", nr. 25/2005, Univ. Iasi, p.77-85.

The books and articles of professor Constantin Savin have been quoted not only in many Romanian journals, but also abroad, in Journal Cold Regions Science and Technology (Elsevier), in Central European Journal of Geosciences (Versita), etc.

In 1975, Constantin Savin was among those who contributed to the transformation of Meteorological and Hydrological Sector (MHS), Craiova, into Jiu Water Directorate, Craiova. After the revolution of 1989, he was among those who contributed to the reestablishment of the Geography-Geology Department at Faculty of Sciences, University of Craiova. Also, he was one of the founders of the Hydrological Sciences Association of Romania.

Professor Constantin Savin was the Romanian hydrologist who introduced the notion of "exceptional hydrological risk", as an effect of the current climatic changes.

For many years, Constantin Savin was a board member of the following journals: Romanian Journal of Hydrology – Water Resources (edited in 1994 by MMHI, Bucharest), the "Hidrotehnica" journal, Annals of the University of Craiova (the Geography series), the Geographical Phorum.

Professor Constantin Savin was a scientific reviewer of the following books:

- Elena Gavrilescu, Ion Olteanu, The environmental quality (II). Monitoring the water quality, Universitaria Publishing House, Craiova, 2003;
- Elena Gavrilescu, Ion Olteanu, The environmental quality (III). Air analysis and monitorization methods, Universitaria Publishing House, Craiova, 2003;
- Elena Gavrilescu, Water Quality: Vol. 1: Aquatic environment pollution, Sitech Publishing House, Craiova, 2006;

- Elena Gavrilescu, Water Quality: Vol. 2: Aquatic ecosystems evaluation, Sitech Publishing House, Craiova, 2006;
- Elena Gavrilescu, Pollution sources and environmental polluting agents, Sitech Publishing House, Craiova, 2007;
- Elena Gavrilescu, General notions of Ecotoxicology, Sitech Publishing House, Craiova, 2008;
- Elena Gavrilescu, Bogdan Filip Gavrilescu, The characteristics and the source of used industrial waters and their influence, Sitech Publishing House, Craiova, 2009;
- Elena Gavrilescu, Ecotoxicology: Aspects and problems, Sitech Publishing House, Craiova, 2011;
- Elena Gavrilescu, Gilda Diana Buzatu, Environment-depolluting methods, Sitech Publishing House, Craiova, 2013.

Professor Constantin Savin had professional connections to various colleagues in Romania: Faculty of Hydrotechnics, University of Bucharest, "Spiru Haret" University, Romanian Academy Geography Institute, INMH, ICIM, C.N.A.R. in Bucharest, the universities of Iasi, Cluj-Napoca, Timisoara, Oradea, the colleagues from Water and Environment Management System and „Apele Române" National Company, from numerous cities. Professor Constantin Savin had professional connections to various colleagues from abroad: France (Paris School of Mines, University of Sorbonne, I.H.P. National French Committe), Switzerland (O.M.M.), Belgium (Royal Meteorological Institute), Israel (in Tel Aviv), Kingdom of Morocco (Hydraulic Directorate, Rabat, Beni Mellal), Ukraine (University of Cernivtsi), Moldova (State University of Tiraspol, Hydrometeorological Directorate in Chisinău).

Professor Constantin Savin was member of the following prestigious scientific societies, in Romania and abroad:

1. Founder of the Romanian Hydrological Sciences Association, Headquarters at MMHI Bucharest;
2. Member of Geographical Sciences Society of Romania;
3. Member of Geomorphological Association of Romania;
4. Member of the Romanian National Committe of the International Hydrological Programme.

Professor Constantin Savin wrote appreciative reviews for 14 Ph.D thesis at I.P. Bucharest, I.C. – Faculty of Hydrotechnics, Bucharest, Universities of Cluj-Napoca, Iasi, Bucuresti, Romanian Academy Geography Institute, MMHI Bucharest.

Professor Constantin Savin had an intensive collaboration with the mass-media, the press, Radio Craiova, Teleuniversitaria Studio, Regional Craiova Studio of the Romanian TeleVision: until 1998, as the Spokesperson of Water Directorate Craiova,and then of Geography Department of University of Craiova.

For his professional activity, professor Constantin Savin was awarded the following medals:

- Honorary Medal and Diploma, awarded by C.N.A. and I.N.M.H. on the occasion of celebrating the „Romanian Meteorology and Hydrology Institute Centenary", for exceptional contributions to the named disciplines in Romania;
- Medal for „Exceptional activity during the floods of October 1972", awarded by State Council;
- Medal for „special merits in the development of Hydrological and Meteorological activities in Romania", in 1974;
- Diploma awarded by ROMAG Dobreta Turnu Severin, on the occasion of the 10th Anniversary of the water factory establishment, „for his contribution to the development of nuclear energy in Romania";
- Honorary diploma, issued by University of Bucharest, Faculty of Geography, on the occasion of a century of geographical studies at University of Bucharest;
- Honorary diploma, awareded by the Romanian Geography Society on the occasion of its 125th Anniversary.

On 26th of August 2017, professor Constantin Savin passed away.

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English translation of
Alexandra Pasparuga

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Climate parameters relevant for avalanche triggering in the Făgăraș Mountains (Southern Carpathians)

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Abstract

The climate conditions may contribute significantly to the generation of several hazards in mountain areas, such landslides, wildfires, flash floods and avalanches. This study examines the variation of the main meteorological parameters with impact on avalanche triggering conditions at Bâlea-Lac Meteorological Station. At the best of our knowledge, this is the first overview of the basic climate parameters which are potentially avalanche triggers in the Făgăraș Mountains (Southern Carpathians). The study is based on data from only one weather station (Bâlea-Lac) from the period 1979-2017, assuming it is consistently relevant from climatic point of view for avalanche occurrence in the area. The results demonstrate that the theoretical circumstances for avalanche triggering (e.g. snow pack, fresh snow or wind) can be captured. This paper briefly describes the nivologic monitoring system run by the National Meteorological Administration and emphasises its utility for avalanche forecasting and alerts.

Keywords: *avalanche hazards, avalanche triggering factors, mountain climate, Făgăraș Mountains*

Rezumat. Parametrii climatici relevanți pentru declanșarea avalanșelor în Munții Făgăraș (Carpații Meridionali)

Condițiile climatice pot contribui semnificativ la apariția mai multor hazarde naturale în zonele montane, precum aluncări de teren, incendii de vegetație, inundații și avalanșe. Acest studio analizează variațiile principalilor parametrii meteorologici care favorizează declanșarea avalanșelor la stația meteorologică Bâlea-Lac. Din câte cunoaștem, acesta este primul studiu al prametrilor climatici de bază are pot constiti factori declansatori pentru avalanșe în Munții Făgăraș (Carpații Meridionali). Studiul utilizează datele de la o singură stație meteorologică (Bâlea Lac) în perioada 1979-2017, considerând că este relevant din punct de vedere climatic pentru producerea avalanșelor în zonă. Rezultatele demonstrează că circumstanțele teoretice pentru declanșarea avalanșelor (stratul de zăpadă, zăpada proaspăt cazătă sau vântul) pot fi surprinse. Lucrarea descrie succinct și sistemul de monitorizare nivală condus de către Administrația Meteorologică Națională, punând accent pe utilitatea acestuia pentru prevederea avalanșelor.

Cuvinte-cheie: *riscul de avalanșă, factori declanșatori de avalanșelor, climat montan, Munții Făgăraș*

Introduction

Snow avalanches represent a major natural hazard triggering significant damages and casualties in many mountain massifs, so that avalanche forecasting services function in many countries – France, Germany, Switzerland, Norway, Poland, Austria, Italy, Czech Republic, Scotland, Iceland, Sweden, United States of America, Canada - issuing avalanche warnings. Statham et al (2018) identify four avalanche characteristics that should be considered in the assessment of avalanche hazards, related to (1) problems derived, (2) location, (3) probability of occurrence, and (4) magnitude of the event, and one can associate equal weight to each of them. Such properties should be quantitatively assessed both for current conditions and upcoming weather, as basic information for avalanche bulletins at regional and local scales.

While snow avalanches are the result of the simultaneous occurrence of different conditions related mainly to topography, climate and human activity, the efficient monitoring and accurate forecasting should equally consider all the triggering factors. Complex approaches may always deliver complete results, but studies oriented to limited aspects are also valuable since they reveal one particular facet of the avalanche phenomenon. This study investigates the climatic factors which can lead to avalanche occurrence in the Făgăraș Mountains (Southern Carpathians).

The composition and stability of the snow layer and the derived avalanche risk are evaluated based on the European Avalanche Danger Scale, and the collected information consists of information about the place, time and probability of release for a specific type of avalanches (slab or sluff, large or small, wet or dry).

Within the Romanian Carpathians, avalanches occur each winter, with an increased frequency in areas above 2,000 m, covering about 4,000 km^2, with rough topography and not permanently inhabited. Skiing fields are usually not located in areas frequently affected by snow avalanches, but the increasing number of backcountry skiers brings up the necessity of a permanent service for monitoring snow parameters and avalanches in all the mountainous areas.

Snow avalanches have been registered since February 2004, when the Snow and avalanche monitoring network began the activity at four meteorological stations: Vârful Omu, Sinaia, Predeal and Bâlea-Lac, covering the Bucegi and Făgăraş

Mountains. Since 2018, the observational network was extended with seven meteorological stations covering most of the mountain area where avalanches frequently occur: Iezer, Călimani, Ceahlău-Toaca, Parâng, Țarcu, Vlădeasa 1800, Semenic (Figure 1).

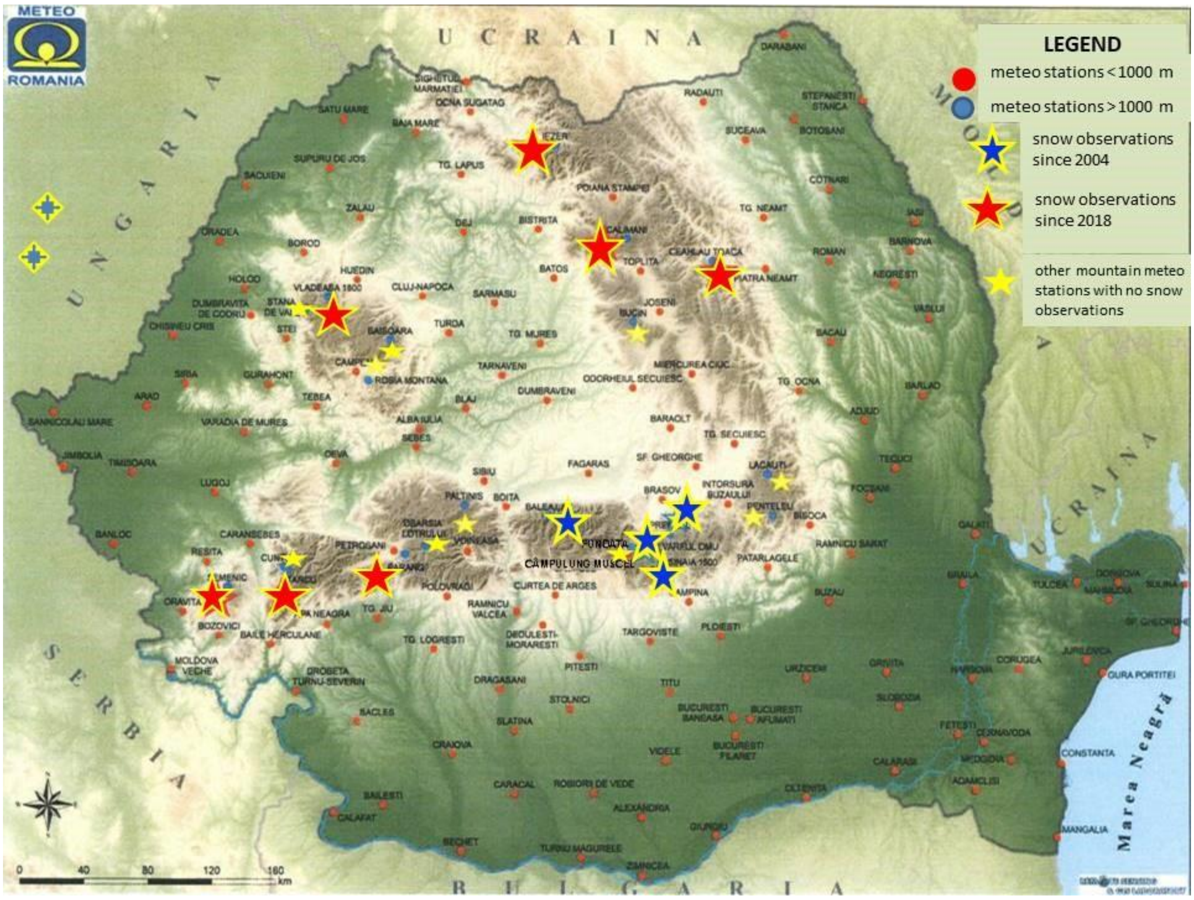

Fig. 1: Nivological network in the Romanian Carpathians

However, the information about avalanches is sparse and a consistent database covering the entire mountain area is under construction. Since January 2005, the operational work has been materialized in daily bulletins, which have been delivered to various stakeholders, e.g. Mountain Rescue Teams, District Councils, mass-media, touristic resorts and Town Halls.

While the avalanche monitoring action started in 2004, the first study about avalanches in Romanian Carpathians have been performed in 1964 and 1965 (Gaspar, 1968), following a burst of avalanches occurring at the beginning of 1963 blocking numerous roads and railway tracks in the forest massifs of the Southern Carpathians (Lotrului, Şureanu, Făgăraş) and Northern Carpahians (Maramureşului, Rodnei). The first study aimed to assess the conditions for avalanches, their characteristics, and techniques for prevention and combating.

As a result of the avalanche monitoring activity, the nivological bulletin is issued annually including information like the number, type and triggering conditions for avalanches (***, Bilanţul nivologic al sezonului de iarnă – Annual winter season report), as well as different research studies and other articles. Besides National Meteorological Administration, other research groups have analysed avalanches for specific Carpathian sectors and from different conditions, e.g. human triggering or terrain (elevation, aspect and slope angle) – (Voiculescu 2014).

This study examines the variation of the main meteorological parameters with impact on avalanche triggering conditions at Bâlea-Lac Meteorological Station, since 1979, when first observations were made, through December 2017. Bâlea-Lac is the only long-term weather station in the Făgăraș Mountains, and one can assume that the meteorological conditions are relevant for the climate of the entire mountainous area. After the introductory section (1), the paper presents (2) the triggering factors for avalanche hazards and forecast criteria, (3) meteorological data, avalanche database and climate settings at Bâlea-Lac, (4) a few climate characteristics relevant for avalanche triggering in the area of interest, and (5) concluding remarks.

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Triggering factors for avalanche hazard and forecast criteria

Most triggering factors leading to avalanche are related to the snowpack load and several classifications have been developed accordingly. Atwater (1954) proposed 10 weather and snow factors which contribute most to avalanche hazard in the Alta Ski Area, Utah, as follows: (1) old snow depth; (2) old snow surface; (3) fresh snow depth; (4) fresh snow type; (5) fresh snow weight; (6) state of accumulation; (7) wind force; (8) wind direction; (9) temperature developments; (10) snow coverage. The topography was not considered.

McClung and Tweedy, (1993), described five essential activating factors, including terrain, precipitation (especially fresh snow), wind, temperature (including radiation effects), and snowpack stratigraphy. The avalanche release probability can be assessed by estimating and weighting each contributing factor (Gubler, 1993).

Triggering factors may be stable (e.g. slope or morphology) or variable (e.g. weather conditions or snow properties) in time and they include (Ancey, 1998; de Quervain, 1981; Bernard, 1927):

- Mean slope, defined as the average inclination of avalanche starting zones, relevant between 27 and 50°;
- Roughness – a key factor in the anchorage of the snow cover to the ground;
- Shape and curvature of the starting zone. The stress distribution within the snowpack and the variation in its depth depend on the longitudinal shape of the ground. Convex slopes are generally associated with a significant variation in the snow cover depth, favouring snowpack instability;
- Slope aspect has a strong influence on the day-to-day stability of the snowpack;
- Fresh snow - an accumulation of 30 cm/day may be sufficient to cause widespread avalanching (Föhn et al., 2002; McLung and Tweedy, 1993; Ancey, 1998; de Quervain, 1981; Bernard, 1927; Gubler, 1993);
- Wind causes uneven snow redistribution (accumulation on lee slopes), accelerates snow metamorphism, form cornices which may collapse and trigger avalanches;
- Rain and liquid water content of the snow play a complex role in the snow metamorphism; i.e. the heavy rains induce a rapid increase in liquid water content, which results in a drop in the shear stress strength and leads to widespread avalanche activity (wet snow avalanches) (Conway & C.F., 1993).
- Snowpack structure. The stability of layer structure resulting from successive snow-falls depends on the bonds between layers and their cohesion. For instance, heterogeneous snow-packs, made up of weak and stiff layers, are more unstable than homogeneous snowpack (Schweizer et al., 2003).

Rapid warming leads to instability and slow warming derives snow-pack stability (according to (McClung and Schweizer, 1997)). For large (catastrophic) fresh snow avalanches, important snowfall is the strongest forecasting parameter ((Föhn et al., 2002)) and is closely related to avalanche danger (Figure 1).

Table 1: Weather-related indicators and associated greater avalanche potential (www.meted.ucar.edu/afwa/avalanche)

	Indicator	Greater avalanche potential
Precipitation	Snow accumulation rate	2.5 cm/h or more for more than 6 hours
	Water amount	25 mm or more in 24 hours
	Fresh snow density	More than 15 cm of 9% or greater density
	Storm trend	Begins cold, ends warm
	Rainfall	Any rain
Temperature	Increasing temperatures	Temperature rise >8°C in 12 hours, reaching values temperatures near or above the freezing point
	Rain/snow level	At or above avalanche starting zone elevations
	Warm temperatures	Above freezing at avalanche starting zone elevations > 24 hours
	Cold temperatures	▪ Very low temperatures (<-10°C) for long time (days) ▪ Shallow snowpack <1m deep and very low temperatures: <-10°C
Wind	Mean wind speed	▪ 9-27 m/s ▪ >27 m/s with snow density>10% ▪ 7-9 m/s with snow density<5%
	Mean wind direction	Consistent
Cloud cover	Nightime sky cover	Clear skies with temperatures <-10°C and winds ≤ 5 m/s
	Daytime sky cover	Clear skies or thin clouds with warm temperatures and high sun angles, especially on sun-facing slopes

Accumulation of a fresh snow depth of about 1 m within a storm event is considered critical for the initiation of extreme avalanches; about 30–50 cm is critical for naturally released avalanches in general (Schaer, 1995) However, even with large amounts of

The avalanche forecast combines (1) information relevant for the snow conditions along the season of interest, and (2) short-term weather forecast for the area of interest. Avalanche forecasting is based on the joint assimilation of the weather conditions and snow coverage characteristics from the very beginning of the "winter" season. Meteorological data from the area of interest are currently used at daily scale and they should refer to:

a) Precipitation (snowfall and snow water equivalent - SWE)

b) Maximum and minimum temperatures

c) Winds near ridge-top level or at all forecast-area elevations

d) Average cloud cover

If detailed data from the past are not available, the regional weather data can be used cautiously and adapted to the area of interest. Most avalanches are associated with fresh snow falls, so that the following information should be available for any recent and/or ongoing precipitation event: (a) amount of fresh snowfall, (b) rate of accumulation, (c) SWE, and (d) fresh snow, the combined release probability of a group of avalanche paths is frequently than 50% (Schaer 1995). This shows that the fresh snow depth alone is not sufficient to explain avalanche activity (Schaer 1995).

density of the fresh snow. Further, the avalanche potential is estimated based on a threshold exceedance procedure (Table 1).

Meteorological data, avalanche database and climate settings at Bâlea-Lac

Meteorological data and metadata

This study is based on daily meteorological records from Bâlea-Lac Meteorological Station (45°36′11″LN, 24°37′44″LE, 2044 a.s.l.) from 1 January 1997 to 1 December 2017. The location of the station is in the northern part of the Făgăraș Mountains, Bâlea glacial valley, in the vecinity of Bâlea Lake (Figure 2, 3), near the Transfăgărășan road. The station began observations since January 1978, after a huge avalanche stroke, when 23 victims died. Until august 1995, the meteorological platform was situated near Bâlea-Lake chalet, then, after the chalet burned, the station was moved into the Paltinul chalet (Figure 3).

Fig. 2: The Făgăraș Mountains, with Transfăgărășan Road and Bâlea Lac Meteorological Station position

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Fig. 3: Bâlea glacier Valley, the Făgăraș Mountains

Avalanche database

A number of 392 days with recorded avalanches have been collected from Bâlea-Lac meteorological station since January 1979, the beginning of the activity until January 2019. Most of the data have been collected since February 2004, when the programme of nivology began at the National Administration of Meteorology and mentioned since then into every Annual winter season report (***, Bilanțul nivologic al sezonului de iarnă). Until 2004, avalanche cases have been recorded from the literature and Mountain Rescue Services (Salvamont) – work of Walter Gutt and Reinhold, who collected informations from local papers, (as Neuer Weg, Hermannstädter Zeitung, Die Woche, Karpatenrundschau, Allgemeine Deutsche Zeitung für Rumänien, Jahrbuch der Sektion Karpaten des Deutschen Alpenverein, Kronstädter Zeitung, Clubul Alpin Român bulletins, Bukarester Tageblatt, Jahrbuch des Siebenbürgischen Karpatenvereins, Siebenbürgisch-deutsches Tageblatt). Some important avalanches happened before 1979, like the one from April 17, 1977, when 23 people were killed in an avalanche at Bâlea-Lac, but these will not be included in the study, due to the lack of meteorological observation data. All the information has been put together into a database in the Snowball project (http://snowball.meteoromania.ro/about/about-snowball).

Based on the data retrieved at the Bâlea – Lac Meteorological Station, from January 1979 through December 2017, synoptic conditions for the avalanche days have been studied and thresholds of several meteorological parameters considered to have an impact on this phenomenon has been made (Pașol et al, 2017).

Climate settings

The climate conditions at Bâlea-Lac Meteorological Station are very likely to be relevant for all the Southern Carpathians above 2,000 m, despite inherent differences related to local conditions, such as slope, exposure and land cover. The warmest period occurs during the summer months (i.e. June, July, and August) when the mean air temperature exceeds 9.0°C (e.g. 9.2°C in July and 9.5°C in August), and the maximum daily temperature reached almost 25°C (i.e. 24.8°C in 24 July 2007). The cold season (i.e. December, January, and February) has mean air temperature values around -7°C (i.e. -6.0°C in December, -7.6°C in January and February), while the lowest temperature over the period 1979-2017 was -31.7°C at 1 March 2005 (Fig. 4).

Fig. 4: Monthly average temperature (Tave), maximum (Tmax) and minimum (Tmin) daily air temperature, and mean monthly relative humidity (RH) at Bâlea-Lac meteorological station (1979-2017)

The average monthly relative humidity varies between 76-77%, in October and November, and 86-

87%, in June and July, in close correlation with the liquid precipitation influx over the area of interest (Fig. 5).

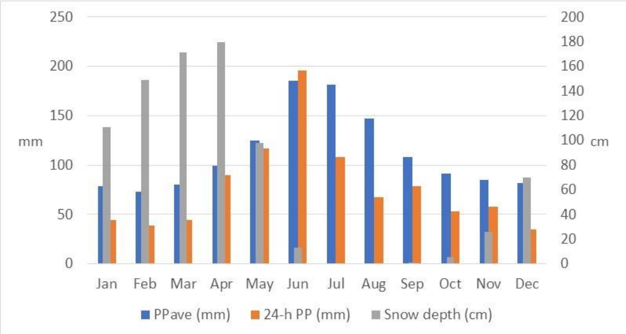

Fig. 5: Monthly average precipitation (PPave) and 24-h maximum amount (24-h PP), and mean snow depth at Bâlea-Lac meteorological station (1979-2017)

The highest precipitation amounts fall during JJA (150-190 mm as monthly average), and the highest 24-h precipitation amount was 195.6 mm, at 3 June 1988 (Fig. 5). From October to March the monthly amounts are below 100 mm. The snow cover is present almost all year round. The minimum values are in July (0.2 cm) and August (0.0 cm), and the largest snow depth occurs in April, with 179.6 cm, and March, 171.4 cm, as multiannual average values over 1979-2017 (Fig 5).

The monthly average wind speed ranges between 2.0 m/s, in August, and 3.6 m/s, in November, with a distinctive seasonal regime along the year (Fig. 6).

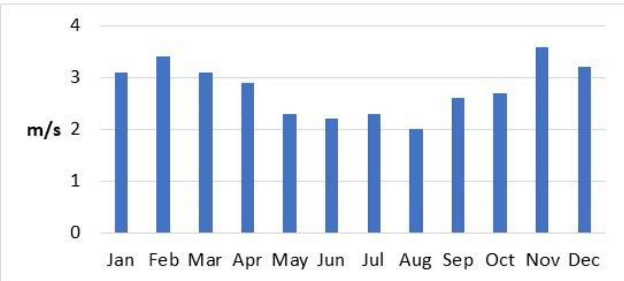

Fig. 6: Monthly average wind speed at Bâlea-Lac meteorological station (1979-2017)

Climate characteristics relevant for avalanche triggering

The climatic background enables specific climate characteristics which may favour the development of avalanches. This section depicts simple linkages between avalanche cases and (1) snow depth and water input, (2) air temperature, and (3) wind speed characteristics at Bâlea-Lac weather station. A more detailed study using this general setting is under preparation.

Snow depth and water input

There is an inherent relation between avalanche occurrence, snow depth and water input, as no snow avalanche can start without a snow cover, and the precipitation represent the main triggering mechanism. At Bâlea-Lac, the highest avalanche frequency is due to the consistent snow cover, generally exceeding 100 cm as an average for the days with avalanches during the period December-May, while the off-season avalanches (June, and September-November) depend more on the 24-h precipitation than on the existing snow cover (Figure 7).

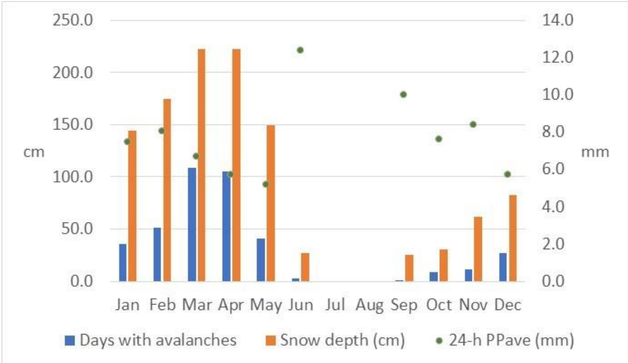

Fig. 7: Avalanche occurrence and corresponding snow depth and average 24-h precipitation (24-h PPave) at Bâlea-Lac meteorological station (1979-2017)

The snow accumulation rate and the amount of fresh snow in 24 hours is an important marker signposting potential avalanche activity, as 2.5 cm/h or more for over 6 hours and 30 cm or more in 24 hours are considered as a great avalanche indicator. (Föhn et al., 2002; McClung and Tweedy, 1993; Ancey, 1998; de Quervain, 1981; Bernard, 1927; Gubler, 1993).

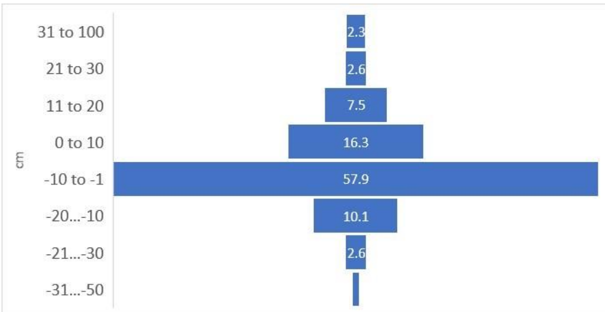

Fig. 8: Distribution of avalanche occurrence (%) depending on snow depth variation in 24-h

The distribution of avalanches based on snow depth is shown in Figure 8. Most cases occur when the snow depth decreases along 24 h with different rates (e.g. 57.9% for 1 to 10 cm decrease or 2.6% for 21 to 30 cm decrease), while snow addition over the existing cover generate avalanches in about 30% of cases (e.g.