

Assessment of the Hydro-meteorological Conditions Impact on the Combat Troops Operations Preparation and Conduct in the Geo-information Subsystem of the Automated Battlefield Management System

Vasyl Lytvyn^a, Olesya Pashchetnyk^b, Oleh Klymovych^b, Leonid Polishchuk^b, Ihor Kolb^b, Yevhen Burov^a and Victoria Vysotska^a

^a Lviv Polytechnic National University, S. Bandera street, 12, Lviv, 79013, Ukraine

^b Hetman Petro Sahaidachnyi National Army Academy, Heroes of Maidan Street, 32, Lviv, 79012, Ukraine

Abstract

The article discusses the impact of hydro-meteorological conditions (HMC) on the operation of weapons and military equipment (WME) and the training and conduct of combat operations by troops taking into account the requirements of current NATO regulatory documents and standards. The structure of the battlefield control system (BMC) is proposed, which contains a unique location service for geodata and weather conditions in the design of the geo-information subsystem of the BMS for units of the Ground Forces of the Ukrainian Armed Forces. In addition, the procedure for assessing the HMC impact on the use of weapons and combat capabilities of the troops according to suitability indicators and criteria in the decision support system is proposed.

As a result, based on the critical assessments of the HMC, this will make it possible to:

- Conclude and assess the situation.
- Develop a typical set of protective actions and measures for ensuring hydro-meteorological safety in troops' activities and operation of the WME in the area of combat operations.
- Develop recommendations for choosing the optimal plan for the functioning of units and units of the Armed Forces of Ukraine, taking into account the entire range of possible weather conditions.

Keywords 1

Hydro-meteorological conditions, geo-information subsystem, decision support system, battlefield management system

1. Introduction

In the current conditions of the development of the battlefield management systems (BMS), management bodies can quickly, automatically and impartially receive information and perform a multi-faceted analysis of the situation to support decision-making at all structural levels acquires particular relevance. The effectiveness of troops' operation is significantly dependent on the correctness of the assessment, among other aspects, of the weather. Modern computer and telecommunication technologies provide ample prospects and services in matters of HMC evaluation. The objective assessment and consideration of HMC are carried out using data provided by the units responsible for hydro-meteorological support, one of the types of operational combat support. The ability to assess the impact of weather conditions on personnel, equipment and weapons, terrain characteristics are now

COLINS-2021: 5th International Conference on Computational Linguistics and Intelligent Systems, April 22–23, 2021, Kharkiv, Ukraine
EMAIL: vasyi.v.lytvyn@lpnu.ua (V. Lytvyn); Olesyalviv@i.ua (O. Pashchetnyk); klm1977@i.ua (O. Klymovych); Polischyk_LI@i.ua (L. Polishchuk); Ihor.Z.Kolb@lpnu.ua (I. Kolb); Yevhen.V.Burov@lpnu.ua (Y. Burov); victoria.a.vysotska@lpnu.ua (V. Vysotska)
ORCID: 0000-0002-9676-0180 (V. Lytvyn); 0000-0001-8726-1112 (O. Pashchetnyk); 0000-0003-3863-4984 (O. Klymovych); 0000-0002-4379-3990 (L. Polishchuk); 0000-0002-1370-6235 (I. Kolb); 0000-0001-8653-1520 (Y. Burov); 0000-0001-6417-3689 (V. Vysotska)



© 2021 Copyright for this paper by its authors.
Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).
CEUR Workshop Proceedings (CEUR-WS.org)

partially implemented in battlefield management systems of advanced countries. In this process, the emphasis is put on obtaining the data detailed both in terms of content (the battlefield management systems of NATO countries consider about 40 different weather parameters) and in spatial (describing to the level of individual areas) and temporal (weather forecast for three hours, and the assessment of weather impact in short time perspective) weather aspects [1-6]. Another feature of these systems is the widespread use of both special and general purposes Internet geo-data services and applying military geo-information systems for data integration [7-10]. The new means of obtaining hydro-meteorological information, methods of its assessment and the practice of its application in the BMS for units and subdivisions of the Land Forces (LF) of the Armed Forces (AF) of Ukraine and, in particular, in military geo-information systems (GIS) are still little known in Ukraine [11-13]. Therefore, existing implementations of such systems require comprehensive analysis and adaptation to the realities of the Armed Forces of Ukraine with the prospect of further refinement and performance [14-18].

2. The purpose of the article

This article aims to analyse the abilities of modern information technologies to solve one of the essential tasks in the activities of military command, namely the analysis of the HMC. This task is part of the battlefield decision-making process and is implemented using current information and telecommunications technologies. A research of the requirements of NATO regulations and standards in force in Ukraine related to HMC and geographic information services and Internet technologies for obtaining and processing hydro-meteorological data is needed to achieve this goal.

We propose the structure of the battlefield management system, which contains additional geodata service for estimation of HMC, and for analysis of their influence on the application of armament and military equipment according to criteria of combat readiness of troops. The result should be an increase in the efficiency and validity of decision-making, taking into account the impact of actual and projected HMC on the functioning of troops, the use of weapons, training and combat operations of armies.

3. Related Works

Assessment of the HMC's influence on:

- The planning and conduct of combat training activities,
- The course of combat operations,
- The effective functioning of weapons and military equipment,
- Combat capabilities of troops.

They are components of the decision-making process, underestimating which complicates the preparation and conduct of combat operations, which leads to significant non-combat losses, and in some cases - to the disruption of the tasks in general [19-20]. However, the algorithms and methods existing to support meteorological decisions in Ukraine do not always fully take into account weather and climatic conditions. They do not always allow this information to develop optimal troops support, perform aviation flights, choose combat methods and tactics, operate weapons, etc. [21-32]. One of the areas proposed to determine the impact of current and projected HMC on the use of weapons, planning, and direct management of units is to establish indicators and criteria for assessing the degree of hydro-meteorological safety [15]. The implementation of planning tasks, their visualisation and delivery of analysis results to users takes place in the environment of modern networked geo-information systems for military purposes [26]. The reference literature also provides arguments favouring the rapid creation of actual geo-information products (those created based on rapidly changing geo-data and meteorological data) directly in the tactical chain. The especially applies to cases of hostilities in local operations, actions in isolation from the main forces, conducting manoeuvring, and so on. This conclusion is made from analysing actual hostilities currently taking place in Afghanistan, Syria, and Ukraine [27]. We analysed the requirements of NATO standards to study military aspects of weather [9, 13]. Modern solutions to the problem outlined above are based on the principle of using global geodata services. Such services operate in the structure of specialised national agencies and organisations. In the United States (USA), such an agency is NOAA [3-The National Weather Service

(NWS)]. A typical international data source is the International Civil Aviation Association (ICAO) network of weather stations. Geo-information services, including those intended for defence and other law enforcement agencies, use meteorological services of the above type [1, 3].

The services of ESRI, the developer of the ArcGIS geographic information system recommended for implementation in the structure of the Armed Forces of Ukraine, can serve as a model here. In particular, this company offers a software solution, "Military aspects of Weather", which converts meteorological information into information about the effects of each aspect of the weather on personnel and various types of military equipment and weapons according to expert opinions [4]:

- 2: adverse;
- 1: below the allowable (threshold state);
- 0: favourable.

For example, for the formal assessment of the effects of HMC on personnel, a cumulative review (minimum value; maximum value; operational impact) is formed according to the following indicators of variable weather: temperature; wind cooling; heat index (an indicator that combines air temperature and relative humidity in shaded areas to establish the comfort of a person) (table 1):

Table 1
Rules for assessing the effects of weather on personnel

Weather Variable	Minimum Value	Maximum Value	Operational impact
Temperature (°C)A	-100	-26	-2
	-26	-6	-1
	-6	30	0
	30	35	-1
	35	100	-2
Heat Index	-100	32	0
	32	38	-1
	38	51	-2
	51	150	-3
Wind cooling (°C)	4	100	0
	-6	4	-1
	-17	-6	-2
	-28	-17	-3
	-58	-28	-4
	-100	-58	-5

A total of 40 weather parameters are assessed for such entities as personnel, air defence forces (ADF), uncrewed aerial vehicles (UAVs), artillery, paratroopers, helicopter flights, which are displayed simultaneously on one monitor (the so-called "operating dashboard"), as shown in Fig. 1. The described approach is interesting because it focuses on ArcGIS software (developer - ESRI, USA), which is recommended for implementation in the Armed Forces of Ukraine. However, at this stage, the described developments have not passed practical testing in military structures. In addition, ESRI's decisions focus only on US government data sources and, as a result, use only relevant specialised data formats and structures and operate within the United States.

An example of another approach to solving this problem is the system My Weather Impacts Decision Aid (developer - MyWIDA, USA) provides a complete analysis of the impact of HMC on the actions of troops and individual weapons systems [5]. This sophisticated expert system operates based on a set of rules approved by the standards for the Army, Air Force (Air Force), and the US Navy.

MyWIDA automatically accepts multi-day weather forecasts that are compared to constraints (rules). And it determines the favourable, borderline and adverse effects of the weather in the form of charts superimposed on the background map and in the format of the weather effect matrix (weather effects) (WEM) on conducting the operation as a whole, its components, the process of weapons systems and the impact on other equipment.

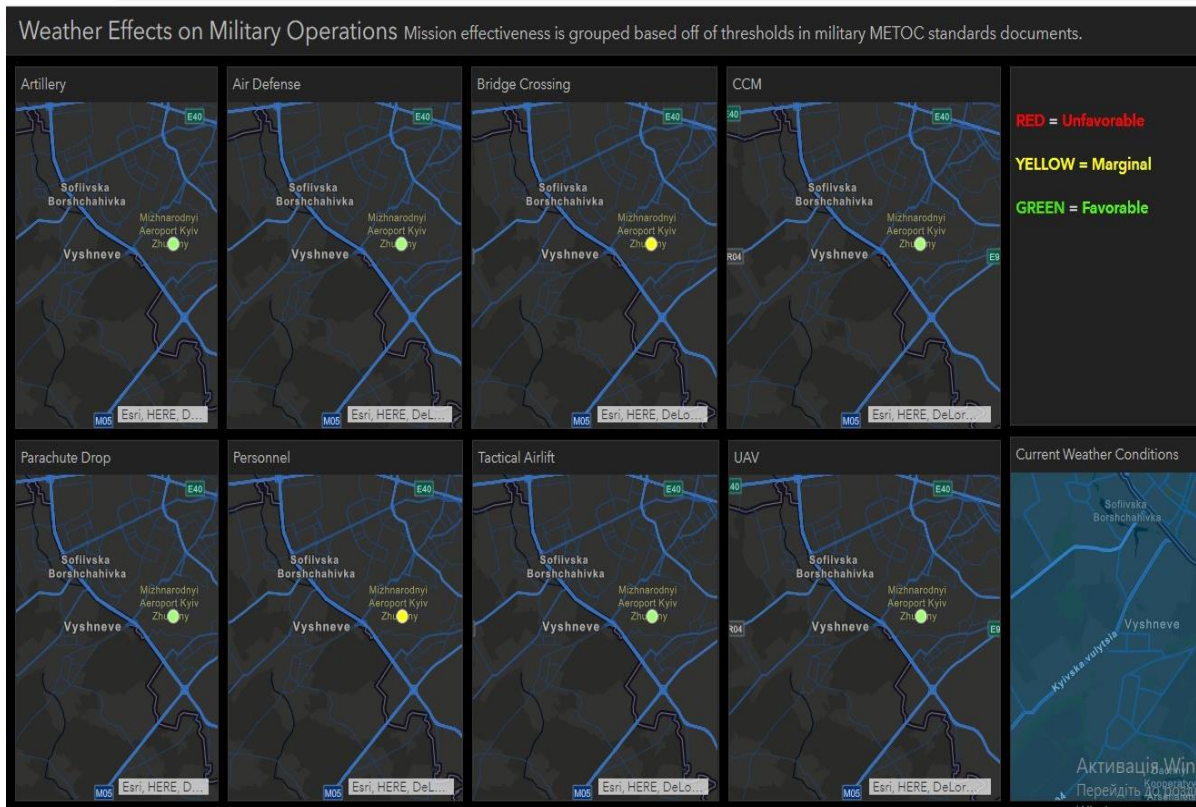


Figure 1: Electronic dashboard with expert assessment of military aspects of the weather in the area of Zhulyany airport - p. Vyshneve

It is also envisaged to obtain a textual reference to justify the decisions of the military administration (OVU). The primary standard that defines the assessment of weather effects by developers is the Army Field Manual (FM) 34-81-1 [6]. Weather effects are classified into three levels according to the percentage of suitability (percentage of residual efficiency of personnel, equipment or weapons systems that experience degradation (such as reducing their effectiveness) weather effect [6, 7]) (Table 2).

Table 2
Percentage of degradation for three impact indicators

Impact	Criterion
Green (Favorable)	Decrease by less than 25–30% (normative efficiency 70–75% and higher)
Amber (Borderline)	Decrease from 25–30% to 70–75% (normative efficiency from 70–75% to 25–30%)
Red (Adverse)	Decrease by 70–75% or more (regulatory efficiency 25–30% or less)

The assessment takes place both in friendly and enemy forces. Based on this assessment, the formulation of the presence or absence of a tactical advantage of a combat party in specific meteorological conditions of hostilities is done. This assessment validity of is provided by an extensive database of rules (over 15,000), which describe the main military effects of the weather [7].

The system built on the model described above is a separate (autonomous) element of the military information environment. In our opinion, it has excessive complexity for direct implementation in automated control of troops (forces). The system involves unique data sources - from specialised services at the national level of CIF to autonomous computerised means of collecting meteorological data, such as the car platform IMETS-Heavy. Also, in the MyWIDA documentation, we did not focus on integration into other information systems, including professionally built GIS platforms.

The developer of the MyWIDA service also announces the development of an Android version of the weather effects application for use in the tactical chain of command of individual commander [2,

10]. A feature of this application is the generation of personal recommendations to the commander to establish the value of the comfort index for different values of temperature and humidity. Other criteria allow you to adjust the time of personnel exposure to extreme cold or hot areas, parameters that determine the efficiency of equipment etc. In general, as a result of analysis of sources, we find that the methods of taking into account the weather effects on troops' actions are constantly evolving. In our opinion, the priority in this issue is to find as many weather data sources as possible, including local resources [8], to confirm the impact of hydro-meteorological conditions on the combat capabilities of certain types of troops use of their weapons.

4. Research methods

General scientific research methods were used to assess hydro-meteorological (climatic) conditions:

1. **An analysis** is the determination of indicators of HMC influence on the capabilities of troops (forces) and the use of weapons;
2. **Synthesis** is combining individual hydro-meteorological quantities (phenomena) into the HMC system and determining their cumulative impact on the combat capabilities of troops (forces) and the use of weapons;
3. **The systemic approach** is to substantiate the conclusions (proposals) on the implementation of troops tasks, taking into account the influence of the HMC.

5. Experiments, results and discussion

According to [11], Hydro-meteorological support (HMS) by the Hydro-meteorological Service of the Ukrainian Armed Forces is organised and coordinated by the Hydro-meteorological Centre of the Armed Forces of Ukraine, hydro-meteorological (meteorological) services (subdivisions) of the Armed Forces of Ukraine and operational commands providing interaction with the Ukrainian Hydro-meteorological Centre, the state enterprise "Ukrainian Aviation Meteorological Centre" about the Ukrainian Aviation Meteorological Centre functions on hydro-meteorological support of power structures. The following special-purpose forecasts for the organisation of HMS are developed:

- Aviation forecasts, for meteorological support of take-off, landing, flights in areas, flights on routes;
- Forecasts for the assessment of radiation and chemical (biological) conditions, which contain a description of the expected parameters of wind and temperature near the earth's surface and at altitudes, the state of clouds, the nature of precipitation;
- Providing parachute jumps, landings (dropping loads), containing data on the expected speed and direction of the wind in the layer from the ground to the height of parachute jumps, characteristics of visibility, cloudiness, precipitation and temperature;
- Forecasts for take-off, landing and flight on the route for uncrewed aerial vehicles;
- Storm warnings about dangerous and natural hydro-meteorological phenomena;
- Long-term (up to 3 days) and short-term (up to 36 hours) weather forecasts (hydrological and aero-climatic information on request about the combat area and other recommendations to commanders at all levels to ensure the safety of units, preservation of equipment, weapons, personnel from the effects of dangerous meteorological, geophysical and hydrological phenomena, the most effective use of firearms. They, in turn, make decisions to make the most of the weather or minimise the damage from weather impact.

Hydro-meteorological information is structured in the following areas [12, 24]:

- Meteorological elements,
- Meteorological phenomena and dangerous meteorological phenomena,
- Actual and predicted for different periods.

The most common atmospheric phenomena that affect the use of troops and weapons are:

- Precipitation: mist, rain, snow, snow grains, ice pellets, ice needles, hail, snow pellets;
- Phenomena that impair visibility due to the presence of water vapour in the air: fog, haze;

- Phenomena that impair visibility due to the predominance of solid particles in the air: sand, dust (precipitated over a large area), fog, smoke, volcanic ash;
- Other phenomena are dust or sand whirlwinds, squalls, tornadoes, dust storms, sandstorms, hurricanes, snowdrifts, snowstorms, dew, hoarfrost, ice, lightning, solar radiation, floods and storm surges, etc.

Hazardous hydro-meteorological phenomena are squalls; tornadoes; hurricanes; floods that threaten flood areas; mountain avalanches, earthquakes; volcanic eruptions; forest (steppe) fires; smoky air etc. The primary data sources are meteorological (synoptic) and aero-logical stations, meteorological satellites, meteorological radars, various automated and experimental observation systems (observations from aircraft, buoys), and others. (Fig. 2) [14].

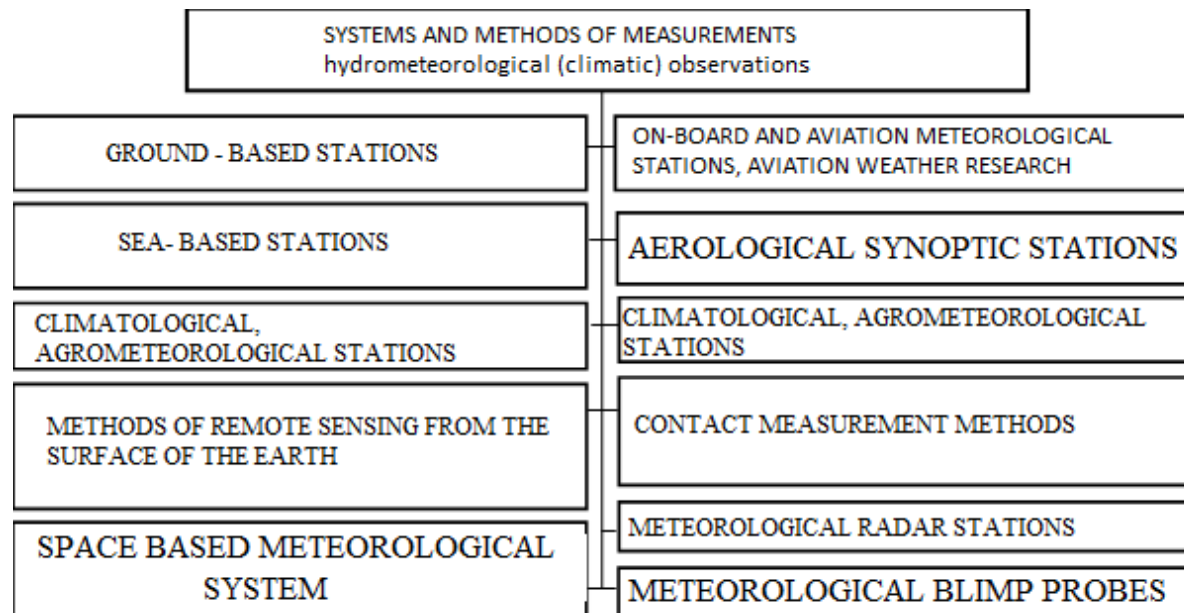


Figure 2: Systems and methods of measurement of hydro-meteorological (climatic) observations

It is necessary to develop basic software and hardware that will functionally provide practical solutions to automate the collection, storage, processing and presentation of relevant operational information to ensure high-quality hydro-meteorological planning and operation of units and subdivisions of the Ukrainian Armed Forces and their weapons:

- Actual and expected changes,
- The state of the environment,
- Warnings about dangerous and natural hydro-meteorological phenomena in the troops interests.

Its main task will be to collect from various services geodata (sources, communication channels) reference materials (data) on the hydro-meteorological situation in different battlefield areas and assess its impact on the capabilities of troops and the use of weapons.

We offer the use of the website windy.com as a prototype of the meteorological service, which allows you to get the following meteorological data in any area: precipitation, air temperature, humidity, wind strength and direction, etc., both on the earth's surface and at different heights above it. You can also generate a weather forecast for the next ten days. All these data are displayed on an electronic map of the area, presented in graphs (diagrams) and numerical parameters. As an element of geo-information analysis technologies, the site provides a service for creating profiles of electronic routes on the terrain using the calculation of the duration of movement on foot or by car and displaying the forecast of weather conditions at each point of the road.

The formation of a web address for requesting data on the site is carried out according to the pattern: <https://www.windy.com/> [planning type] + [method of movement] + [list of geographical coordinates of route points]. For example, Lutsk - Gorokhiv - Lviv - Yavoriv: <https://www.windy.com/distance/car/50.68,25.35;50.45,24.74;50.10,24.61;49.96,24.58;49.81,24.09;4>

9.92,23.36?49,694.23,538.8. Placing this address in a web browser leads to the visualisation of the route on an electronic map, building its profile and hourly display of weather conditions online (Fig. 3).

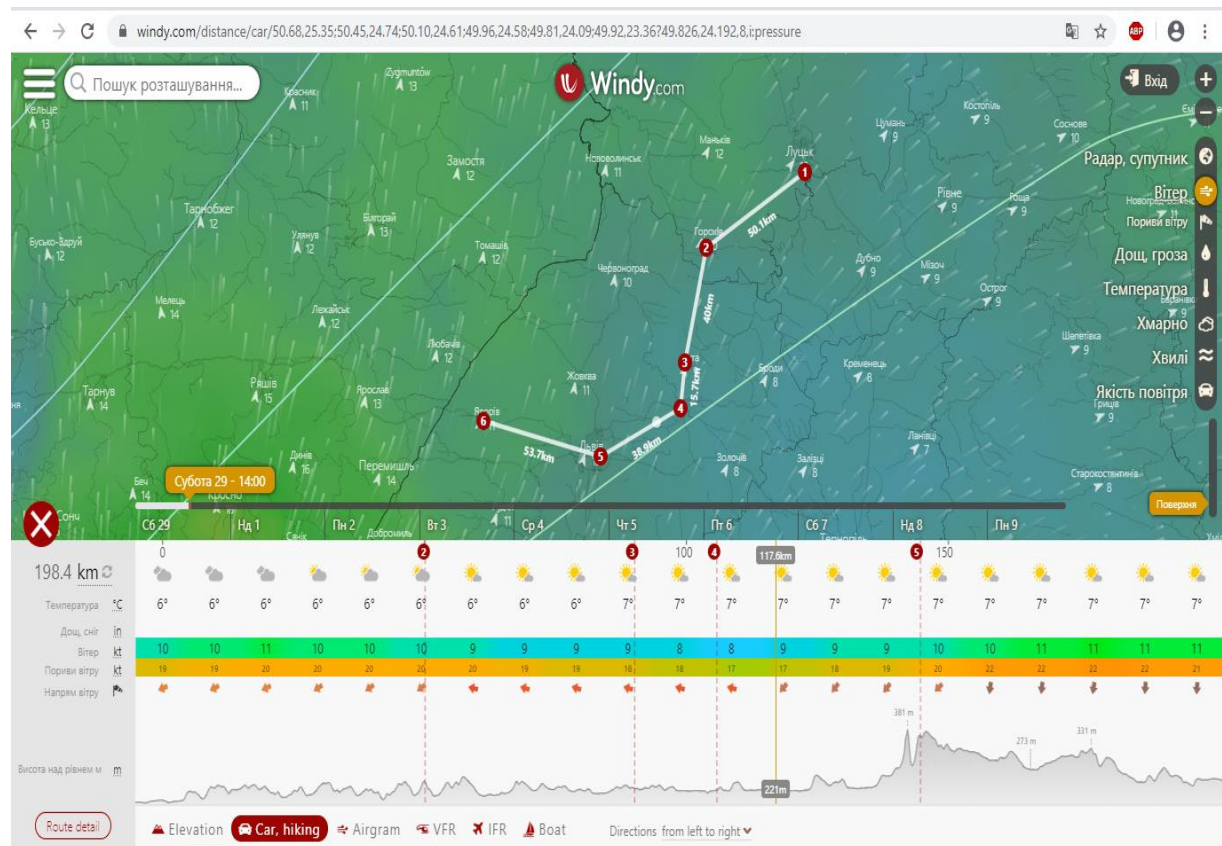


Figure 3: Windy.com meteorological service

This approach, in our opinion, can be a prototype of service for the rapid supply of meteorological information to the authorities when deciding to conduct hostilities. Therefore, it is proposed to include a geodata service to assess the impact of hydro-meteorological conditions in the structure of the geo-information subsystem of the battlefield management system for units and subdivisions of the Armed Forces of Ukraine, as shown in Fig. 4. The general-purpose geo-information subsystem in the BMS will be used for input, processing, and analysis of data that have a spatial component and automate the development of combat graphics and electronic maps by tracking all changes in the situation of their operational display. This subsystem is aimed at comprehensive support of decision-making processes for combat operations, their planning, and the management of the use of troops and weapons [28, 29].

Software and mathematical support of the geographic information subsystem should be able to:

- Adapt to changes in functional modules (task management);
- Data formation of the evaluation area;
- Data formation of the weather log of the evaluation area;
- Evaluation calculations;
- The ability to provide a common language for the users,
- Present the results in a form that would contribute to a deeper understanding of the results and recommendations.

That is, various data streams (prognostic; climatic; recommendations for decision-making; metadata, etc.) about changes in weather and natural phenomena must be transmitted using a high-level protocol in files (packages) of a clearly defined format and submitted to the workstations of designated officials. This will allow avoiding mistakes in assessing its impact on the combat capabilities of units and the effectiveness of weapons, forces and means for the senior commander, interacting units and the enemy troops, as well as optimise tactical planning, minimise losses and losses, due to the efficiency and priority of decisions made [21, 22, 23, 30-32].

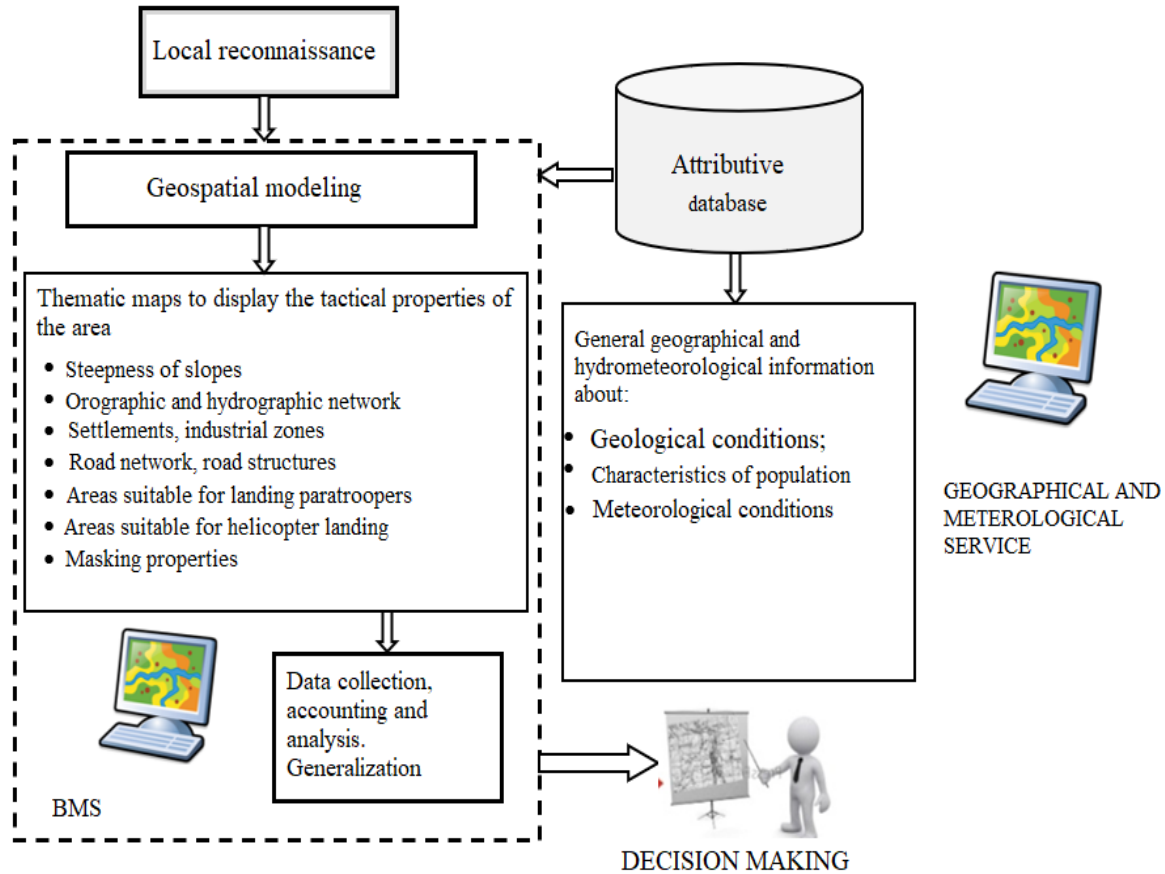


Figure 4: Geo-data service for assessment of terrain and weather conditions in the structure of the geographic information subsystem of the BM of units and subdivisions of the Armed Forces of Ukraine

The development of the order to support the decision-making on the estimation of HMC, after reception and the analysis of the information by officials, should carry out in several stages (Fig. 5):

1. **The choice of the combat area** is the formation of time intervals for the receipt of hydro-meteorological information for the period of execution of tasks by units.
2. **The definition of evaluation criteria and indicators.** The actual and expected (projected) HMC impact on the use of weapons and units in the combat area is assessed using impact indicators. They can be classified into different groups to establish the eligibility criterion. According to the conditions are considered appropriate if all partial indicators belong to the adequacy region. I.e. they do not exceed the allowable values [20]. This assessment serves as a basis for choosing the best alternative.

$$K_p: (\forall)(y_i^{fact} \in \delta | \delta_i \rightarrow y_i^{all}, i \in \langle P \rangle), \quad (1)$$

where: y_i^{fact} is the actual value of the elements and phenomena of the HMC in the combat area;

y_i^{all} is the allowable value of the elements and phenomena of the HMC in the combat area;

P is the effectiveness of using weapons and units in actual or projected HMC in the combat area.

Because of the impact of HMC on the combat capabilities of divisions and subdivisions, the use of their weapons is versatile and multi-faceted; its degree depends on the actual values of hydro-meteorological elements and phenomena. Tables 3-5 show indicators and levels of assessment of HMC impact on manoeuvrability (combat) capabilities for units of the Armed Forces of Ukraine, as well as the use of their weapons [25], the suitability criteria of which are assessed as "favourable", "transitional (threshold)", "adverse".

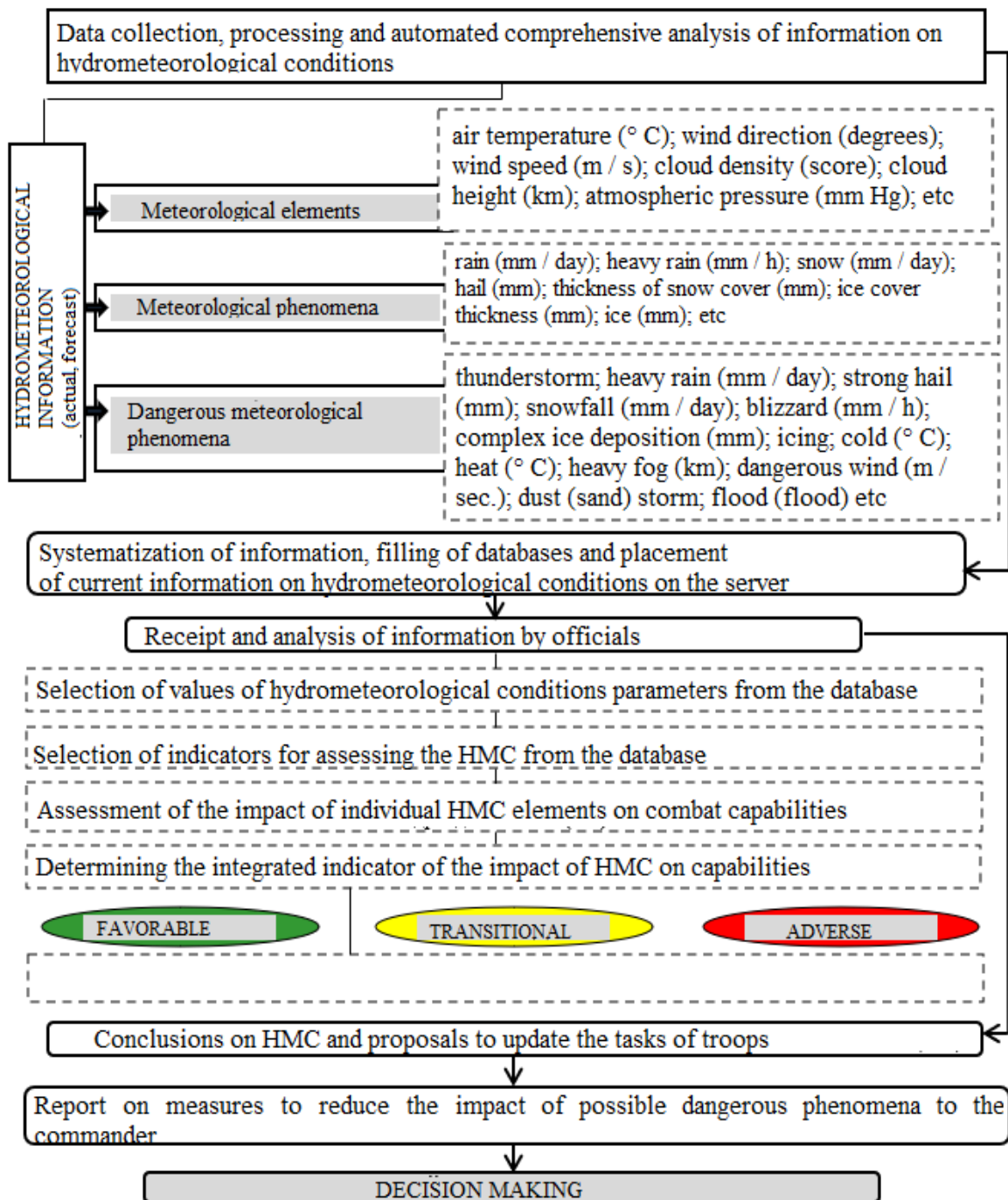


Figure 5: Procedure for assessing hydro-meteorological conditions in the system, supporting meteorological decisions by tactical commanders

Table 3
Indicators for assessing the impact of HMC on manoeuvring capabilities of ground facilities

Types of capabilities of troops	Indicator and levels of assessment of hydro-meteorological conditions		
	«Favourable»	«Transitional (on threshold)»	«Adverse»
All-drive wheeled equipment	Visibility >4 km, rain <10 mm/h, snow depth 0,2 m	Visibility 0,5...2 km, rain 10...20 mm/h, snow depth 0,2...0,5 m, weak ice	Visibility <500 m, rain >20 mm/h, snow depth 0,5 m, strong ice

Hybrid (partly) wheeled equipment	Visibility >4 km, rain <5 mm/h, snow depth <0.1 m	Visibility 0,5...2 km, rain 5...10 mm/h, snow depth 0,1...0,3 m, weak ice	Visibility <500 m, rain >10 mm/h, snow depth >0,3 m, strong ice
Tracked vehicles	Visibility >4 km, rain <10 mm/h, snow depth 0.4 m	Visibility 0,5...2 km, rain 10...20 mm/h, snow depth 0,4...0,8 m	Visibility <500 m, rain >20 mm/h, snow cover depth >0.8 m

Table 4

Indicators for assessing the impact of GMU on the possibility of using weapons of destruction and reconnaissance

Types of capabilities of troops (forces)	Indicator and levels of assessment of hydro-meteorological conditions		
	«Favourable»	«Transitional (on threshold)»	«Adverse»
	Means of attack of rocket troops and artillery		
Precision ammunition, projectiles with radio detonator	Cloud height >900 m	Cloud height 400...900 m	Cloud height <400 m;
Smoke projectiles	Wind speed <5 m/s, lateral	Wind speed 6...7 m/s, lateral	Wind speed >6...7 m/s, lateral; <5 m/s from enemy
Shrapnel-explosive projectiles	Any conditions except snow	Snow cover thickness 0,2...1,5 m	Snow cover thickness >1.5 m
Lighting projectiles (mines)	Weather vision > 2 km, windless	Weather vision 1...2 km; clouds >1 km	Weather vision <1 km; clouds <1 km; wind speed >10 m/s; Rain
	Means performing direct attacks, reconnaissance (observation)		
ANTI-tank artillery, tanks, PCVs, optical, opt-electronic, TV, photo and video intelligence	Weather vision > 3...5 km	Vision >1...3 km	Vision 1 km
Sonic exploration	At night and in the morning (at dawn) throughout the year, during the day, in winter, in severe frosts and in spring during the melting of snow. Passing wind (for sound, that is, from the enemy to the positions of the sound-metric complex), the speed of which increases. Oncoming wind, the speed of which decreases with height.	–	On summer hot days (stable air temperature + 38° and above for 5 days or more). Wind speed more than 12 m/s. Oncoming wind, the speed of which increases with height. Passing wind, the speed of which decreases with height. Strong gusty wind near the surface of the earth, regardless of its direction. Lowering the temperature with height.

Types of capabilities of troops (forces)	Indicator and levels of assessment of hydro-meteorological conditions		
	«Favourable»	«Transitional (on threshold)»	«Adverse»
	Increase in air temperature with height (inversion).		
Radar reconnaissance	There is no precipitation.	Minor precipitation (rain <10 mm/h, snow)	Significant precipitation (rain > 10 mm/h, thick snow).
Aerial photography with UAV	Thunderstorm, building of ice, turbulence of low intensity. Maximum wind speed on the route - 15-20 m / s; maximum wind speed at take-off/landing - 10-15 m / s; maximum wind gust - up to 25 m/s.	Thunderstorm, ice build-up, turbulence of moderate intensity.	Thunderstorm, turbulence of strong intensity. Ice build-up at a temperature from +5° to -10° and UAV entering the cloud or fog zone. Wind speed - more maximum indicators.

Table 5

Indicators for assessing the impact of HMC on the possibility of spreading radiation, chemical and biological (RCB) contamination

Types of capabilities of troops	Indicator and levels of assessment of hydro-meteorological conditions		
	«Favourable»	«Transitional (on threshold)»	«Adverse»
Spread of RCB infection	Very stable atmosphere (inversion), wind speed at an altitude of 10 m: at 2< V10 <3 m/s – no cloudiness or solid night; at 3< V10 <5 m/s – cloudy solid, night.	Neutral atmosphere (isothermal), wind speed at an altitude of 10 m: at 2< V10 <3 m/s – cloudy solid, day; at 3< V10 <5 m/s – cloudy average or solid per day, absent - at night; at 5< V10 <10 m/s – no cloudiness, medium or solid, day or night.	Highly unstable atmosphere (convection), wind speed at an altitude of 10 m: at V10 < 1 – no clouds, medium or solid, day or night; at 2< V10 <3 m/s – no clouds or average, day.

3. Formation of a set of indicators and assessment of the impact of HMC. The construction of a group of HMC assessment indicators consists of the automatic selection of HMC assessment indicators from the database array for a particular combat area. Each HMC indicator contains characteristic values (maximum, minimum, average) that characterise their impact on units' combat capabilities and the use of weapons and military equipment [12, 16, 18-19]. Partial assessments for each element of dangerous meteorological phenomena affecting them are also determined by establishing deviations in the actual values of indicators from normative ones – separately for each type of combat capabilities of units and military equipment in their composition. The integrated assessment is determined by the rule of most significant negative impact (worst partial review) on the combat capabilities of brigade units and the use of weapons and military equipment, namely, if:

- All partial assessments are favourable, and then the integral evaluation will also be complimentary;

- At least one element (phenomenon) receives an assessment of "adverse", and then the integral evaluation will also be adverse;
 - Partial assessments are favourable and transitional or only transitional ones, then the critical evaluation will be "transitional".
4. **Assessment of decisions.** The final document sections with conclusions on the evaluation of the situation are formed as a result, based on the integral assessments of the HMC. For each variant of the scenario, a typical set of protective actions and measures to ensure hydro-meteorological safety in troops' activities and the operation of WME in the area of combat operations is developed. Also, recommendations for choosing the optimal plan for the functioning of units and units of the Armed Forces of Ukraine, considering the entire range of possible weather conditions, is developed.

6. Conclusions

1. The analysis of the requirements of NATO standards for the study of HMC and geo-information and Internet technologies for obtaining and processing meteorological data was carried out. Some of these services are focused on compliance with NATO military standards (the United States).
2. The structure of the geo-information subsystem of the BMS for units of the Armed Forces of Ukraine, which contains a unique location service for assessing the impact of hydro-meteorological conditions on the use of weapons and combat capabilities of troops (forces) according to the criteria of suitability, is proposed.
3. The methodology for assessing the impact of hydro-meteorological conditions on the training and conduct of combat operations of troops for the geo-information subsystem of the automated battlefield management system is proposed. Unlike the existing ones, this system considers the assessment of the impact of the HMC on the use of weapons and combat capabilities of troops using special software (weather service), which makes it possible to quickly supply hydro-meteorological information to commandment bodies deciding on combat operations.
4. Within the framework of the recommendation and prospects for further research, it is worth noting that this material can serve as the basis for solving optimisation problems of information usage in decision support systems to ensure the hydro-meteorological safety of troops.

7. References

- [1] J. Fry, D. Barmes, ArcGIS Defense Solutions: Analyzing Environmental Impacts on Military Operations, 2019. URL: https://proceedings.esri.com/library/userconf/fed17/papers/fed_120.pdf.
- [2] BSS5: The Battle Staff SMART book (Leading, Planning & Conducting Military Operations), The Lightning Press, 2015. URL: <https://www.thelightningpress.com/smartbooks/bss5-battle-staff>.
- [3] The National Weather Service (NWS). URL: <https://www.weather.gov>.
- [4] Military aspects of weather. URL: <http://www.arcgis.com/home/item.html?id=2bd5ab673e5d4374bca6343cc80df414>.
- [5] Second Generation Weather Impacts Decision Aid Applications and Web Services Overview. US Army Research Laboratory Computational and Information Sciences Directorate. Battlefield Environment Division (ATTN: RDRL-CIE-M). URL: <https://apps.dtic.mil/dtic/tr/fulltext/u2/a587530.pdf>.
- [6] FM 34-81-1, Army Field Manual, Battlefield Weather Effects. Headquarters, Department of the Army, DC, 23 December, 1992. URL: <http://www.bits.de/NRANEU/others/amd-us-archive/FM34-81-1%2892%29.pdf>.
- [7] R. J. Szymer, Army Weather Effects Critical Values Database, volume 2989 of Technical Document, Proceedings of the Battle space Atmospheric Conference, 1997, pp. 259-264.
- [8] M. Boone, L. Kos, M. Shafer, Weather and Climate Impacts on Military Operations Workshop Summary, in: Southern Climate Impacts Planning Program, 2019. URL: <http://www.southernclimate.org/documents/MilitaryOperationsWorkshop.pdf>.

- [9] APP-28, Tactical planning for land forces. Headquarters, Department of the Army, Edition A, Version 1, 21 November, 2019 p.
- [10] D. Sauter, Android Smartphone Relevance to Military Weather Applications, Army Research Laboratory, White Sands Missile Range, ARL-TR-5793, 11 October, 2011, URL: <https://apps.dtic.mil/dtic/tr/fulltext/u2/a552755.pdf>.
- [11] Pro zatverdzhennya polozhennya z hidrometeorolohichnoho zabezpechennya. Nakaz Ministra oborony Ukrainy [On approval of the provision on hydro-meteorological support. Order of the Minister of Defense of Ukraine], volume 28/39, 19.01.2017.
- [12] Avtomatyzovana systema upravlinnya viys'kamy "Slavutych". Pryznachennya, mozhyvosti, osnovy pobudovy i zastosuvannya informatsiyno-rozrakhunkovykh (informatsiynykh) zadach [Automated control system of troops "Slavutych". Purpose, possibilities, bases of construction and application of information-settlement (information) tasks], I. Chernyakhovs'ky NUOU, 2017.
- [13] V. Zhyvchuk, L. Polishchuk, A. Shcherba, I. Kolb, O. Pashchetnyk, Doslidzhennya mozhyvostey WEB-HIS tekhnolohiy dlya analizu viys'kovykh aspektiv pohody [Research of possibilities of WEB-GIS technologies for the analysis of military aspects of weather], in: Proceedings of the 25th International Scientific and Technical Conference "Geoforum-2020", dedicated to the professional holiday of geology, geodesy and cartography of Ukraine, 2020, pp. 248–250.
- [14] A. Vasil'yev, YU. Perevedentsev, Tekhnologiya prognozirovaniya meteorologicheskikh usloviy [Technology of forecasting meteorological conditions], Kazan State University, 2007.
- [15] P. Timofeyev, I. Krusser, Postroyeniye perspektivnoy sistemy polucheniya predstavleniya klimaticheskoy informatsii organam voyennogo upravleniya [Building a promising system for obtaining the submission of climatic information to military control bodies], part 6, Voronezh: VAIU, 2012.
- [16] V. Mikhaylov, Optimizatsiya ispol'zovaniya meteoinformatsii pri reshenii prakticheskikh zadach [Optimisation of the use of meteorological information in solving practical problems], volume 2 of Meteorologiya i gidrologiya: nauchno-tekhnicheskyy zhurnal, 2006, pp. 17-25.
- [17] Ye. Kochugova, Metody i sredstva gidrometeorologicheskikh nablyudeniy [Methods and means of hydro-meteorological observations], Irkutsk: IGU, 2012.
- [18] Ye. Il'inov, V. Degtyarev, Vliyaniye fiziko-geograficheskikh usloviy na boyevyye deystviya aviatsii v Afganistane [Influence of physical and geographical conditions on aviation combat operations in Afghanistan], volume 10 of Vozdushno-kosmicheskoye sily. Teoriya i praktika, 2019, pp. 8-19.
- [19] L. Shusharina, G. Musralinova, Influence of weather conditions for conducting military actions and operation of military equipment in local war, volume 1(44) of Journal of Geography and Environmental Management, 2017, pp. 128-133.
- [20] V. Udrish, V. Voronezhstsev, D. Popov, P. Timofeyev, Informatsionno-raschetnaya zadacha: otsenka klimaticheskikh kharakteristik i ozhidayemykh gidrometeorologicheskikh usloviy dlya planirovaniya deystviy voysk (sil) [Information and computational problem: assessment of climatic characteristics and expected hydro-meteorological conditions for planning actions of troops (forces)], Metodologicheskiye aspekty razvitiya meteorologii spetsial'nogo naznacheniya, ekologii i sistem aerokosmicheskogo monitoringa, Voronezh, 2014, pp. 61-71.
- [21] V. Popov, R. Perevezentsev, S. Bashlykov, Metodicheskoye obespecheniye vybora al'ternativ v nechetkoy dinamicheskoy sisteme podderzhki prinyatiya meteozaavisimykh resheniy pri upravlenii voyskami [Methodological support for the choice of alternatives in a fuzzy dynamic support system for making meteorological decisions in troop control], volume 3 (14) of Vestnik VAIU, 2011, pp. 36-42.
- [22] O. Maystrenko, Perspektivy rozvytku hidrometeorolohichnoho zabezpechennya raketnykh viys'k i artyleriyi SV ZS Ukrainy [Prospects for the development of hydro-meteorological support of missile troops and artillery of the Armed Forces of Ukraine], volume 1 of Viys'kovo-tekhnichnyy zbirnyk, 2009, pp. 35-42.
- [23] Ye. Vyazilov, D. Mel'nikov, N. Chunyayev, IT v gidrometeorologii: ot sistem sbora do analitiki i prinyatiya resheniy [IT in hydrometeorology: from collection systems to analytics and decision making], Analitika i upravleniye dannymi v oblastiakh s intensivnym ispol'zovaniyem dannykh: proceedings of the XVII International Conference DAMDID/RCDL, 2015, pp. 179-186.

- [24] Guide to Meteorological Instruments and Methods of Observation. World Meteorological Organization, 2017.
- [25] I. Skvortsov, A. Koklevskiy, Ekspluatatsiya artilleriyskogo vooruzheniya operation of artillery weapons], Minsk: BGU, 2010.
- [26] K. Grachov, O vnedrenii kommercheskikh geoinformatsionnykh tekhnologiy v interesakh OVS NATO [On the introduction of commercial geoinformation technologies in the interests of the NATO Joint Armed Forces], volume 1 of Zarubezhnoye voyennoye obozreniye, 2020, pp. 28-32.
- [27] V. Yelyushkin, Geoinformatsionnoye obespecheniye voyennykh deystviy. Ot dostatochnosti k prevoskhodstvu [Geoinformation support of military operations. From sufficiency to superiority], 2019.
- [28] O. Pashchetnyk, V. Pashchetnyk, L. Polishchuk, Pryznachennya, zavdannya i vymohy do heoinformatsiynoyi systemy, yak pidsystemy avtomatyzovanoyi systemy upravlinnya v taktychniy lantsi upravlinnya Sukhoputnykh viys'k Zbroynykh Syl Ukrayiny [Purpose, tasks and requirements to the geoinformation system as a subsystem of the automated control system in the tactical management of the Land Forces of the Armed Forces of Ukraine], in: Prospects for the development of armaments and military equipment of the Land Forces: collection of abstracts reports of the International Scientific and Technical Conference, NASV, 2017.
- [29] O. Pashchetnyk, T. Lavrut, V. Pashchetnyk, Perelik osnovnykh vymoh shchodo rozrobky heoinformatsiynoyi pidsystemy avtomatyzovanoyi systemy upravlinnya taktychnoyi lanky List of basic requirements for the development of geographic information subsystem of the automated tactical control system], Latest technologies - for airspace protection: materials of the XIII scientific conference of Kharkiv University of the Air Force named after Ivan Kozhedub, 2017, pp. 75-76.
- [30] Osnovy modelyuvannya boyovykh diy viys'k [Basics of modeling military operations]. Київ: HAOY, 2005.
- [31] Y., Ryzhov, L., Sakovych, P., Vankevych, M. Yakovlev, Y. Nastishin, Optimisation of requirements for measuring instruments at metrological service of communication tools, measurement, volume 123 of Journal of the International Measurement Confederation, 2018, pp. 19-25. doi: <https://doi.org/10.1016/j.measurement.2018.03.055>.
- [32] O. Klymovych, V. Hrabchak, O. Lavrut, T. Lavrut, V. Lytvyn, V. Vysotska, The diagnostics methods for modern communication tools in the Armed Forces of Ukraine based on neural network Approach, volume Vol-2631 of CEUR Workshop Proceedings, 2020, pp. 198-208.