Adding Weather to Wargame Simulation

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ABSTRACT

Wargames bring together the two concepts of simulation and games to offer structured and rigorous environments where players can explore strategies, concepts of operations, and technologies across different levels of war. Simulations ingest military doctrine and performance data into their high-fidelity platform models. Then, using a game construct, players enter plans carried out by high-fidelity models in which outcomes are compared against objectives. The future state-of-the-art U.S. Marine Corps (USMC) wargaming facility at Quantico is capable of multiple simultaneous games across multiple classification levels. The simulation environment attempts to be as realistic as possible to provide an immersed training experience comparable to a real-world battle. For instance, weather represents an important factor in determining the course and outcome of battles. Rain can slow the movement of a force, and wind intensity can alter the range of a weapon system. Environmental data such as terrain, wind, precipitation, turbulence, and other meteorological parameters are examples of the limits of a simulated environment's weather condition profile. Converting these weather parameter features into quantitative effects and impacts are computationally burdening for simulation systems, especially if each simulation system computed the weather effect differently. The challenge for wargame designers is to provide accurate and timely weather data to the simulation systems and tactical decision aids to relate the impact of the weather on systems performance.

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INTRODUCTION

Weather conditions can have a significant impact on military operations. For instance, adverse weather conditions such as rain, fog, and snow can limit visibility, affect weapon accuracy, and impact mobility making it more challenging for military forces to achieve their objectives. On the other hand, favorable weather conditions, such as clear skies and calm winds, can provide an advantage to military forces. In the wargaming context, designers can create more realistic scenarios by incorporating weather simulation. This can provide military planners with insights into how weather conditions affect military operations and help them develop strategies that consider weather conditions. As the climate changes, weather patterns will likely become more extreme and unpredictable, which could have significant implications for military operations. Wargame designers can help military planners prepare for these changes by simulating future weather conditions and developing strategies to mitigate their impact. Nonetheless, there are several difficulties associated with adding weather simulation into wargames:

1. Complexity: Weather simulation can be complex, requiring a significant amount of data and computational resources to accurately model weather conditions. This complexity can make it difficult to incorporate weather simulation into wargames, particularly those with limited resources or processing power.
2. Accuracy: Simulating weather conditions in a wargame requires high precision and accuracy. Small errors in the simulation can have significant impacts on the outcome of the game, making it challenging to develop weather simulation models that are reliable and consistent.
3. Realism: For weather simulation to be effective in a wargame, it must be realistic and believable. If the weather simulation is too simplistic or unrealistic, it may not accurately reflect the impact of weather conditions on military operations, reducing the value of the simulation.

To be useful, weather simulation data must be transformed into features, effects, and impacts. However, converting these weather parameter features into quantitative effects and impacts is computationally burdening for simulation systems. Additionally, if each simulation system computed the weather effect and impact using different method, the simulation results may become inconsistent. Therefore, the challenge for wargame designers is to provide not only accurate and timely weather data to the simulation systems but also tactical decision aids that relate the impact of the weather on systems performance.

This paper examines the role of weather simulation in the USMC Wargaming capability. The elements of weather, and their associated impacts on battlefield operations, are the primary focus of this paper. Our study objectives are:

1. Provides a comprehensive weather simulation system and a prescription of how the historical weather data augmented by a dynamic weather simulation model is utilized in the USMC wargaming.
2. Provides a Tactical Decision Aid Framework to evaluate the effects and impacts of the weather on the simulation systems during a wargame's execution.

BACKGROUND

Related Works

Today's militaries have access to advanced technologies to help them plan, train, rehearse, and prepare. For the warfighter to maintain a continuous state of readiness, it is imperative they run exercises that challenge them mentally and physically. This is equally important for military leaders and their staff; the warfighter depends on them to place them into executable operations where the outcome can be a successful mission. Military leaders are using advanced models and simulations running in digital synthetic environments designed to match as close as possible the real-world operating environments these leaders operate in daily. Weather simulation has been a critical area of research for many decades, especially for flight simulation (Larson et al., 2010). Commercial and military flight simulators are used extensively for pilot training to help pilots develop the skills and experience needed to fly safely in real-world conditions. Real-time weather simulation is used to reproduce the weather conditions that a pilot might encounter during a flight (Johnson, 2000; Seedhouse, 2009). However, weather simulation models developed for flight simulators are ownship-centric (i.e., the weather simulation is effective only at the location of the ownship). For example, Taumi et al. (Taumi et al., 2012) simulated the weather environment for a motion-based piloted flight simulation. However, in their study, the authors focused only on the radar display that provides weather and turbulence modes derived from the modeled weather along the flight track.

Virtual environment and gaming are disciplines of simulation that often incorporate weather simulation. In his study, Tien (Tien, 2018) provides an overview of the use of weather in video games. He examines the different ways that weather has been used in games and the effects that it can have on gameplay and immersion. However, the majority of game developers tend to focus on aesthetics and kinetics, or, in simpler terms, graphics and animation, and weather is usually introduced merely for aesthetic purposes only (Barton, 2008; Mushtaq et al., 2018). Additionally, several studies explore how weather can be used to create interesting and engaging gameplay mechanics in video games, creating a sense of immersion in video games (Chen and Fu, 2016; Crick and Grange, 2013).

The impact of weather on military operations, including how weather can affect troop morale, mobility, and logistics, is well known (Kennedy, 2014; Füssel, 2015). The influence of weather and climate in military history is also well documented (Downing, 2015). Johnson provides a comprehensive review of the use of weather in wargaming and examines the different ways that weather has been used to create realistic combat scenarios (Johnson, 2019). Nevertheless, the review literature did not reveal many studies that provide a completed weather simulation model for wargaming. For instance, we could not find any studies that provide a method to assess the impact of weather on the simulation systems and military personnel during a wargame execution.

USMC War Gamming Center

Historically USMC have been wargaming for decades starting in 1960 when the Corps established the Marine Corps Landing Force Development Center (MCLFDC) with the explicit mission of advancing the art of amphibious warfare. By 1965 the MCLFDC adapted its analytical Landing Force War Game into an educational edition, appropriately name the Educational War Game. Through the late 1970s and late 1990s, Marine Corps educational wargaming saw its high-water mark, benefiting from the complementary use of Service designed and commercial wargames. Similarly, the 1970s represented the golden age of commercial board wargames, featuring a tsunami of game titles from companies like Avalon Hill and SPI that shaped a generation of wargamers. In 1976, Colonel John C. Studt directed First Lieutenant I. L. Holdridge to develop and build a regimental-level wargame with the explicit purpose of training the regimental and battalion staffs against a thinking adversary. By 1981, the Marine Corps finally designed and established its own unique series of wargames, collectively referred to as TACWAR. TACWAR represented a significant leap forward in the Corps' educational wargaming effort, both in game design and institutionalization. The 1980s also saw the advent of the Corps experimenting with computer-driven wargames, beginning with the Tactical Warfare Simulation, Evaluation, and Analysis System (TWSEAS). In 2015, the Marine Corps War College (MCWAR) emerged as an epicenter of educational gaming using a digital wargame called Darkest Hour. Additional titles like Diplomacy, Polis, Paths of Glory, and the Next War series gave a renewed demonstration to senior Marine leaders of wargaming's value as a powerful experiential learning tool. Marines were also taking stock of the continued advances in computer-based games—cloud-based communities like Steam, and highly detailed, real-time games like Command: Modern Operations, both offered opportunities for larger audiences to play each other simultaneously and a vastly more diverse array of weapons, systems, and scenarios than were available in the time of Close Combat Marine. (Bae and Brown, 2021)

In 2019 Commandant's Planning Guidance, Gen. David Berger, the 38th Commandant of the Marine Corps, emphasized the importance of wargaming in supporting the future Marine. He called the effective integration of wargaming into force design, education and training, "essential to charting our course in an era of strategic fluidity and rapid change." USMC War Gaming Center is set to take this capability to new computer-based gaming levels utilizing the latest in artificial intelligence, data ingest, terrain streaming, analytics, and multi domain simulation (Gonzales, 2020). USMC has identified weather to be a priority specification as identified by the USMC WGC project which must be implemented and integrated into this rich high fidelity multi domain whole world terrain digital environment (Marine Corps Systems Command. 2020). This digital environment requires the impact weather plays in the performance of battlefield operations in order for any course-of-action (COA) selected to accurately be simulated; thereby, generating realistic outcomes for statistical analysis. Statistical analysis is a core wargaming learning tool providing students the ability to examine their performance in depth by identifying opportunities for improvement on what didn't work well versus what worked well based on learning objectives. Adding a Weather simulation is a key component considering it impacts military operations all over the world consisting of temperature, rain, clouds, wind, air pressure, or other weather elements produced by our Earth continually. Militaries must understand how weather impacts every aspect of their operating environments so they can anticipate what must be done to overcome, adapt and execute in some of the worse environments our Earth has to offer to plan winning strategies and operations.

USMC WARGAMING WEATHER SIMULATION MODELS

The Weather Simulation model implemented within the USMC Wargaming System is consisting of two main simulation capabilities: the historical weather data and a dynamic weather simulation.

A- Historical Weather Data

Historical weather data is a valuable tool for simulating environmental conditions, allowing researchers and planners to make informed decisions about future conditions and develop appropriate responses and mitigation strategies. In the context of wargaming, historical weather data is used to simulate weather conditions in past conflicts, wargame designers can create more realistic scenarios for training and analysis. For example, wargames that simulate World War II battles may use historical weather data to simulate the actual weather conditions experienced during those battles. This can provide valuable insights into how weather influenced the outcome of the battles and help military planners develop strategies that take weather conditions into account. Historical weather data can also be used in wargames to create more challenging scenarios. By introducing adverse weather conditions such as rain, snow, or fog, wargame designers can simulate the impact that such conditions can have on military operations. This can help military planners develop contingency plans for adverse weather conditions and prepare for unexpected weather events that could affect operations. There are two main historical weather data resources: National Oceanic and Atmospheric Administration (NOAA) and Environmental Data Cube Support System (EDCSS).

1. **National Oceanic and Atmospheric Administration (NOAA)**
   NOAA historical weather data refers to archived weather-related information collected and recorded by NOAA, a scientific and regulatory agency within the United States Department of Commerce, over a period of many years. This data includes a wide range of weather observations, such as temperature, precipitation, wind speed and direction, atmospheric pressure, humidity, and more, collected from a variety of sources including weather stations, buoys, and satellites.

   NOAA maintains a comprehensive database of this historical weather data, which includes observations dating back to the mid-19th century. The data is used by researchers and analysts to study past weather patterns and trends and to support a range of applications, such as weather and climate forecasting, agricultural planning, and risk assessment for natural disasters. Access to NOAA historical weather data is typically available through various platforms, including the National Centers for Environmental Information website, which provides access to data archives and online tools for data retrieval and analysis. Additionally, NOAA provides access to specialized datasets, such as long-term climate records and extreme weather events, through its Climate Data Online (CDO) portal.

2. **Environmental Data Cube Support System (EDCSS)**
   The EDCSS is a software system used for environmental data management and analysis. It is designed to support the collection, processing, storage, and analysis of environmental data in the form of

multidimensional data cubes. EDCSS works by integrating various data sources, such as satellite imagery, weather data, and ground-based observations, and transforming them into standardized, multidimensional data cubes that can be easily queried and analyzed.

The EDCSS has been under development by Atmospheric and Environmental Research (AER) since 2007. AER delivers all EDCSS software to the government as open source and requires no commercial or proprietary software or hardware to operate. Today the EDCSS is a mature technology routinely employed for Combatant Commander (COCOM) Joint Training Exercises, Air Force Combat Air Forces Distributed Mission Operations (CAF DMOs), Navy Fleet Synthetic Training (FST), and the Office of the Secretary of Defense Planning and Analysis communities.

B- Dynamic Weather Simulation

The purpose of a dynamic weather simulation is to reproduce a synthetic weather environment covering a large area, possibly the globe, and thereby provide simulated weather information at any location within the wargaming area. The centralized dynamic weather model provides consistent and correlated weather information to all participants in a distributed exercise. The simulation model is based on the International Standard Atmosphere (ISA) to support a wide range of atmospheric parameters and weather effects, such as the following:

1. **Temperature**

   Temperature can have a significant impact on military equipment and personnel. For instance, it influences the type of lubricants used and affects engine warm-up periods. The sustained rates of fire for weapons are related directly to the temperature. High temperatures cause gun tube droop or reduced battery life. Both extreme heat and cold can reduce a soldier’s physical and mental performance. For example, extremely high temperatures increase personnel water consumption, but extremely low temperatures reduce personnel effectiveness as it can cause hypothermia.

2. **Pressure and Air Density**

   In the real world, the atmosphere is usually in hydrostatic balance. In other words, the atmospheric pressure at a point is a function of the weight of the column of air above it. This column of air has a density that varies with the altitude as the temperature varies with the altitude. Hydrostatic balance defines how the pressure decreases as a function of the altitude. The weather simulation model achieves this by calculating the pressure profile based on the surface or sea-level pressure and the temperature profile at a specific location. Air pressure, also known as barometric pressure, also affects military equipment and personnel. For instance, many types of equipment, such as aircraft and drones, have altitude restrictions due to the impact of air pressure on their operation. Additionally, air pressure changes can affect the accuracy of sensors used in military equipment, such as altimeters or barometers. The performance of military personnel can also be affected as it can cause fatigue, headaches, and other symptoms that can reduce a soldier’s physical and mental performance.

3. **Humidity**

   Humidity is the concentration of water vapor in the air and can affect sensor performance. For instance, high humidity can cause military equipment to malfunction.

4. **Cloud**

   Clouds can affect both military equipment and personnel in multiple ways. Cloud cover can interfere with GPS and communication systems, potentially making it more difficult for military personnel to navigate and communicate with each other. Cloud cover can affect the performance of sensor systems can be affected, such as radar or thermal imaging, which can influence the ability of military personnel to detect and identify targets. Visibility can be reduced, making it harder for military personnel to navigate and identify potential threats. Low clouds or fog can make it more difficult for aerial operations, such as safe aircraft takeoff and landing.

5. **Precipitation and Storm Model**

   In a wargame simulation, a storm represents a visual and meteorological object. Rain and snow precipitated from storms can degrade trafficability and impair visibility. They also degrade the ability of sensor systems to acquire targets. Strong winds, hail, and lightning strikes can damage military equipment. Storms can disrupt supply chains and transportation, making it more difficult to get necessary supplies and equipment to military personnel.

6. **Wind Effects**
   Wind can pose significant challenges for military operations. It can impair mobility, damage military equipment such as communication systems, and reduce the accuracy of the weapon systems. The dynamic weather simulation model provides both steady wind and wind with random variations, such as the following:
   - Gust: sudden and brief increase in wind speed
   - Fluctuation: a smooth continuous variation to the steady wind
   - Turbulence: an atmospheric property that produces chaotic changes to the wind

THE USAGE OF WEATHER SIMULATION FOR WARGAME SCENARIOS

USMC Wargaming Process

The USMC wargaming follows a seven steps process: 1- Define, 2- Scope, 3-Design, 4-Develop, 5-Rehearal, 6-Execution, and 7-Assess. Weather simulation is critical for many of these steps.

- During the "Design" phase, the wargame designers selected and reviewed the available historical weather data (i.e., EDCSS weather data) to determine if any available data is appropriate for the anticipated wargame scenario and can be used to model the likely weather conditions during the anticipated time frame of the wargame. The wargame designers will also determine if the simulation of the dynamic weather will be required and build the weather simulation scenarios. The weather simulation scenario, which may contain both historical weather data and dynamic simulated weather, can be used within the wargame to inform decisions about the deployment of forces and equipment, the timing of operations, and the allocation of resources.

- During the "Develop" phase, the wargame designers examined the possible of augmenting the historical weather data with the dynamic weather simulation. To do so, they may create simulated weather patterns and apply them to location where they may not have in the historical model.

- During the "Rehearsal" and "Execution" phases, weather simulation is used to create realistic and dynamic weather conditions that reflect in the objectives of the wargame scenario. This can include changes in visibility, mobility, and other factors that can impact the outcome of the wargame.

- During the "Assess" phase, weather simulation is used to evaluate the impact of weather conditions on the performance of forces and equipment, and to identify areas where improvements can be made. This can include identifying vulnerabilities and opportunities for improvement in planning, training, and equipment development.

Weather Simulation of Global and Local Regions

Depending on the wargame research question, objective, and complexity, wargame designers define the required size of the area (i.e., gaming area) where a wargame scenario will be played. A major battle could require a gaming area of several hundred square mile. Therefore, the weather simulation system must provide the capabilities to define the global weather patterns as well as weather patterns that occur in a specific region (i.e., local region). Global weather simulation is applied to the entire wargaming area, while the local region weather is applied to small areas of the scenario, such as cities or towns. Local weather is critical for a wargame because it is affected by processes not usually represented in global weather models, such as the formation of storms, local winds, or local clouds. A high-fidelity wargame simulation should provide the capability to define both the global and local weather profiles. For each wargame scenario, a dynamic weather simulation is used to define the simulated weather for the entire gaming area, and several local weather profiles are defined and applied to smaller areas within the gaming area. Local regions can overlap with each other as well. Figure 1 illustrates this feature of weather simulation.

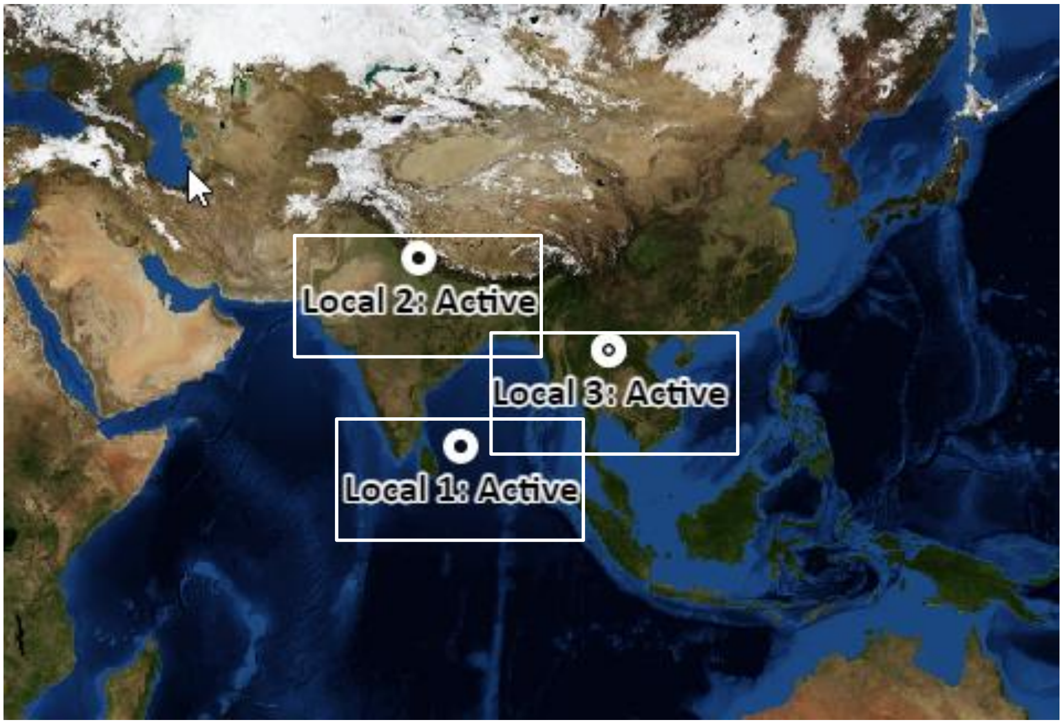

Figure 1. Global Weather and Local Weather

Historical Weather Data augmented by the Dynamic Weather Simulation
Generally, historical weather data is used to re-create weather conditions in past conflicts, and the dynamic weather simulation is used to modify existing wargame scenarios by introducing adverse weather conditions such as rain, snow, or fog. However, wargame designers can also create more realistic scenarios for training and analysis by using both historical weather data and dynamic weather simulation in the same scenario. There are a great number of use cases where both historical weather and dynamic simulation weather are used in wargame scenarios. The following are the two most popular uses cases:

1. The first use case is a typical wargame scenario using high-resolution historical weather simulation for the main gaming area where most of the past combat actions happened, and then complemented with the dynamic weather simulation for the area outside of the main gaming area. The concept of this use case is illustrated in Figure 2. The EDCSS box delimits the historical weather. Outside of the EDCSS box, the dynamic weather simulation provides weather simulation. The dynamic weather simulation can also define “local regions” that represent a specific local weather profile. Storm objects can also be defined and inserted into the weather scenario.

2. The second use case allows the wargame designers to re-create an initial weather condition similar to a specific past conflict and then use the dynamic weather simulation to simulate a variant of future weather profiles. By using historical weather conditions from a particular time and place, the wargame designers can create a starting point for a wargame scenario that accurately reflects the desired conditions of the environment. The dynamic weather simulation will use this initial weather profile and insert additional weather objects (e.g., storm) to simulate the future weather condition while the wargame is executing. This technique of weather simulation is often employed during the “Wargame Course-of-Action (COA)” Develop and Assess phases.

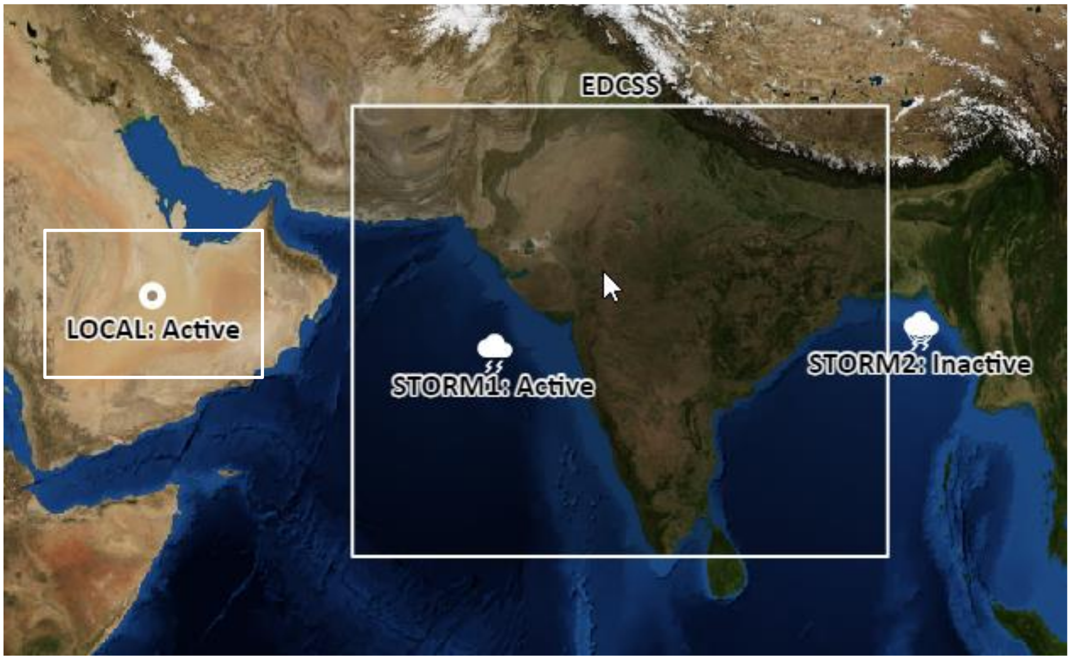

Figure 2. Historical Weather Data (EDCSS) Augmented with Dynamic Weather Simulation

Weather Effects and Impacts

Weather can significantly impact military systems, and it is essential to consider environmental factors when planning military operations. The following list describes some of the effects weather can have on military systems:

- Equipment Performance: Weather conditions such as high temperatures, humidity, or precipitation can affect the performance of military equipment. For instance, extremely cold weather can cause batteries to fail or electronics to freeze, while high temperatures can lead to equipment overheating.
- Mobility: Weather conditions such as heavy rain, snow, or mud can make it difficult for military vehicles to move, especially in areas with poor infrastructure. This can influence the logistics of military operations, making it challenging to transport troops, supplies, and equipment.
- Communication: Weather can affect communication systems used by military personnel. For instance, heavy rain, fog, or snow can interfere with the signals used for communication, leading to miscommunication or a complete loss of communication.
- Visibility: Adverse weather conditions can reduce visibility, making it difficult for military personnel to navigate, conduct surveillance, or identify targets. This can affect the effectiveness of military operations and increase the risk of friendly fire incidents.
- Health and Safety: Extreme weather conditions can also affect the health and safety of military personnel. For instance, heatstroke, hypothermia, and frostbite are common risks in extreme weather conditions.

A literature review reveals that the U.S. Army Field Manual (FM) 34-81-1 is possibly the most comprehensive document to provide guidance for understanding and predicting the impact of weather on military operations. The manual covers a range of topics, including the effects of various weather conditions on weapon systems, communication equipment, and troop. Additionally, it provides some of the more common critical weather effects data and applies that information to specific operations, systems, and personnel. Generally, computing the weather impact on military equipment requires a thorough understanding of the equipment, the environmental conditions, and the mission requirements, as well as careful analysis and testing to develop effective mitigation strategies. Assessing the weather's impact on military equipment requires considering various factors such as temperature, humidity, precipitation, and wind speed. Using the U.S. Army Field Manual, the following approach was derived to assess the impact of weather on military systems performance and provide tactical decision aids and algorithms:

1. Identify the equipment: Identify the specific equipment you want to analyze for weather impact. This can include weapons, vehicles, communication equipment, and more.

2. Determine the environmental conditions: Use weather simulation data to determine the environmental conditions in the area where the equipment will be used. This includes factors such as temperature, humidity, precipitation, and wind speed.
3. Assess the impact of environmental conditions: Use technical manuals and other resources to determine the impact of environmental conditions on the specific equipment. For example, extreme temperatures can affect the performance of batteries, and high humidity can cause corrosion on metal components.
4. Evaluate the impact on mission effectiveness: Consider how the environmental conditions and their impact on the equipment will affect mission effectiveness. For example, if a vehicle is prone to breakdowns in extreme heat, carrying out a mission in a desert environment may be difficult.

TACTICAL DECISION AID FRAMEWORK

As we mentioned previously, the challenge for wargame designers is to provide accurate and timely weather data to the simulation systems, but also tactical decision aids that relate the impact of the weather on systems performance. Based on the weather simulation model of the USMC wargaming and the guidance provided in the US Army Field manual, a tactical decision aid framework was developed that will relate the impact of the weather on systems performance for mission planning, and the decision-making process of the wargame scenarios. The following section presents the fundamental of this tactical decision aid framework.

1. The class of military equipment and personnel considered for this framework are Air Defense, Armor, Artillery, Aviation, Electro-Optical (EO), Engineer, Light Infantry, Intelligence and Electronic Warfare (IEW), Mechanized Infantry, Personnel, Special Op, and Threat.

2. Currently, the five elements related to the weather considered by the framework are cloud ceilings, reduced visibility, surface wind, temperature, and precipitation. Additional weather elements and parameters can be added to the framework if needed.

3. The first step is determining if any potential weather conditions might affect the class of equipment and/or personnel. Figure 3 and Figure 4 illustrate the process. Figure 3 represents the effect of reduced visibility, and Figure 4 represents the effect of temperature. The numerical values shown on these two graphs are generics and may not reflect the real-world as they are just for illustration.

4. Once determined that a specific class system is impacted by the weather (e.g., Intelligence and Electronic Warfare [IEW]), the next step is assessing the type and severity of the impact. The weather effect framework refers to a set of lookup tables that provide the effect of each weather parameter (e.g., reduced visibility) for each specific class of system.

   Table 1 represents a typical lookup table providing the effect of temperature on the IEW. From the data of these lookup tables, the weather effect framework derived the "Rules of weather effect computation" for specific equipment and/or personnel.

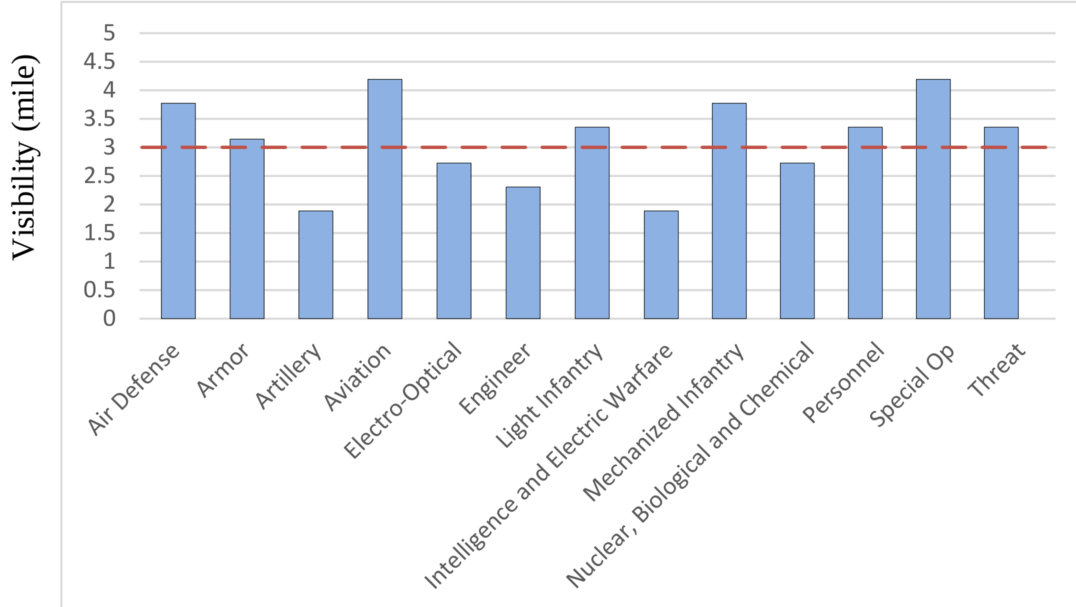

Figure 3. Effect of Reduced Visibility. A visibility of 3 miles (red dashed line) will affect Air Defense, Armor, Aviation, Light Infantry, Mechanized Infantry, Personnel, Special Op, and Threat classes.

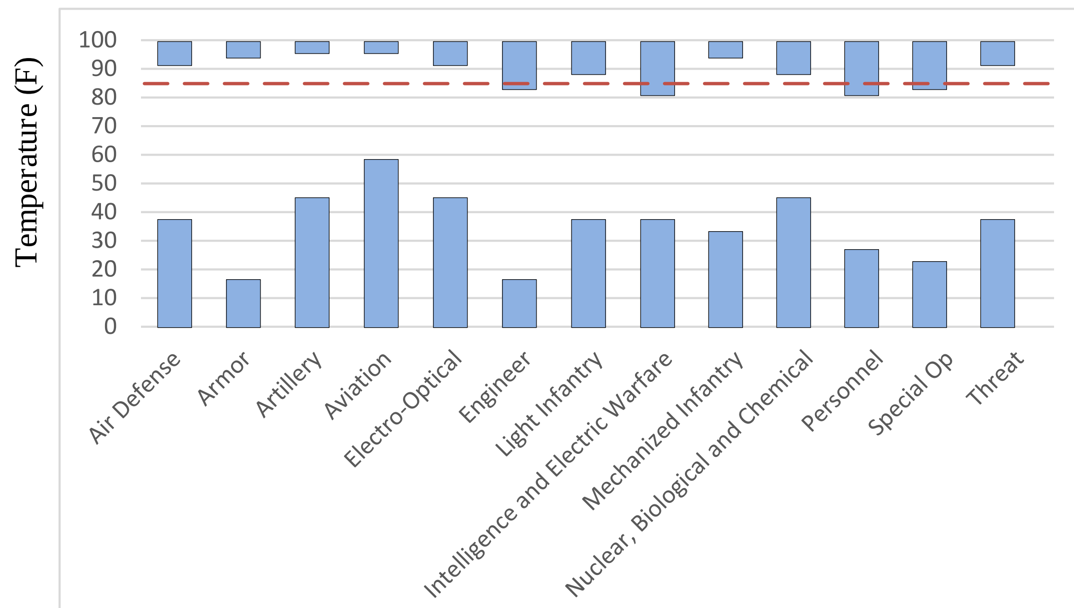

Figure 4. Effect of Temperature. A temperature of 85 degrees (red dashed line) will only affect Engineer, IEW, Personnel and Special Op classes.

Table 1. Effect of Temperature on IEW

Weather Values Temperature (F)	Severe Degradation		Moderate Degradation	
	System/Event	Remark	System/Event	Remark
< -25	• Quick Lock (ALQ-133) • Countermeasure GLQ-3B • PIRANHA (OG-181)		• Radar (PPS-5) • Radar (PPS-15) • TRAILBLAZER • (TSQ-114B(V))	
< -20				
< 0	Radio Receivers (TTR-20, TRR-33A)		• Wheeler Vehicle • Dry Cell battery	Only 40% battery effective
> 85			Personnel	Humidity
> 125	• All NVS Generators • 155 mm how (M 198) ammunition • Laser Infrared observation set (GVS-5) LANCE • WP Artillery round	Become unstable		

5. Finally, the last step is determining how the weather will influence the mission's effectiveness. The "Rules of weather effect computation" derived from the previous step are used to compute the weather impact on each class of equipment and/or personnel considered by the framework. Based on the simulated weather at the location of the simulated systems, the framework provides a tactical decision aid (GO, NOGO, and Marginal) in real time for all participants of the wargame scenario. This tactical decision aid concept is illustrated at Figure 5.

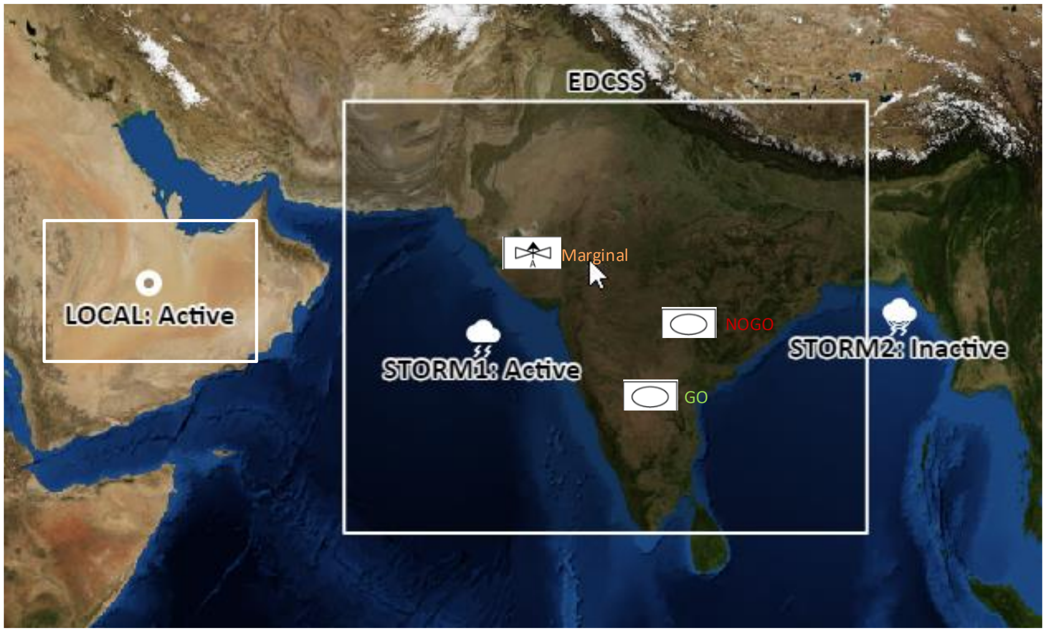

Figure 5. Real-Time Impact of Weather in Wargaming

In summary, the Tactical Decision Aid framework, as presented in this study, provides a structured and systematic approach to computing the impact of weather on military equipment, personnel, and operations. In the wargaming context involving multiple simulation systems, this framework relieves the computational burden that requires each system to compute the weather effect on their constructive entities. Additionally, the framework provides a common computation method to evaluate the weather effect and impact on military equipment and personnel. (i.e., rather than each simulation system performing its own computation). Finally, the framework is fully developed and currently run as a standalone system. We anticipate to start the integration of it with the USMC WGC by the end of this summer (e.g., 2023).

CONCLUSION

On one hand, the weather simulation represents an important component of wargaming. Therefore, by simulating realistic weather conditions, wargame designers can help military planners prepare for these environmental conditions and develop strategies to mitigate their impact. On the other hand, the assessment of weather impact on military operations is crucial for the fidelity of wargaming. The weather simulation as presented in this study enhanced the realism of wargame to provide an immersed training experience comparable to a real-world battle.

The Tactical Decision Aid framework developed in this study provides a method to assess the impact of weather on military equipment, personnel, and operations. Additionally, it was designed to facilitate future updates when adding additional weather parameters, as well as updating the weather effects to existing military equipment. During a wargame, existing and new military equipment can be evaluated on several factors, including its effectiveness in achieving mission objectives, especially its ability to operate in different environments and weather conditions.

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