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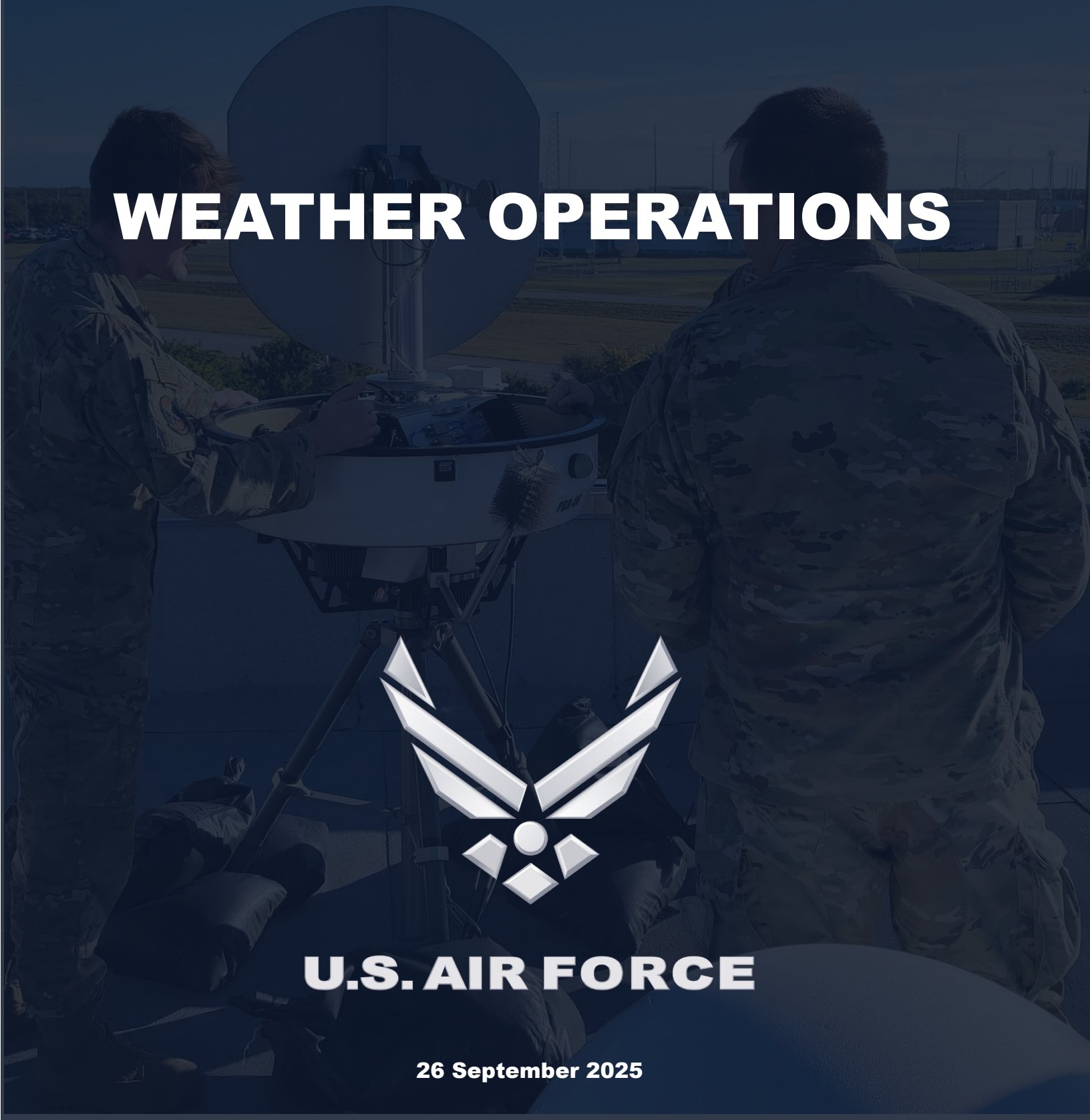

WEATHER OPERATIONS

U.S. AIR FORCE

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FOREWORD

Weather has a significant impact on the planning and execution of joint force operations. The physical conditions of the terrestrial and space environment can create dilemmas for adversaries and optimize friendly freedom of action and maneuver. Early applications of weather operations focused on providing basic forecasts. Since then, United States Air Force (USAF) weather operations have grown, providing enhanced situational awareness and giving national leaders timely environmental information to make informed decisions. Weather's inherent complexity, variability, and broad impact can be leveraged to create additional courses of action for operations. Weather enables the United States (US) to project power effectively, adapting to environmental conditions across all domains and providing a critical advantage. With the USAF's ability to leverage environmental awareness, weather operations deliver rapid and potentially decisive advantages to outmaneuver an adversary and optimize friendly force capabilities.

USAF weather operations are not defined by a particular sensor or forecast model, but rather by the intended effect of the environmental understanding. Whether employing sophisticated forecasting techniques, leveraging space weather data, or providing tailored support to the US Army or special operations, Department of the Air Force (DAF) weather forces provide critical environmental information—including actionable assessments on the current and future state of the environment—to shape and win throughout the competition continuum.

Effective weather operations can also enhance the effectiveness of forward-deployed friendly forces. This publication provides best practices for planning and executing weather operations. It echoes operations and planning detailed in Joint Publication (JP) 3-59, *Meteorological and Oceanographic Operations*. It describes DAF weather operations and outlines the operational art and science essential for successful employment. This doctrine underscores the significance of robust weather data integration, analysis, and awareness for effective weather operations planning and execution. This publication provides Airmen with the essential understanding and guiding principles to maintain the long-term effectiveness of US airpower through the strategic use of environmental factors, reinforcing their value to national security.

CHAPTER 1: WEATHER FUNDAMENTALS

> "Know the enemy, know yourself; your victory will never be endangered. Know the ground, know the weather; your victory will then be total."
>
> **–Sun Tzu, *The Art of War***

Air Force weather operations provide global prediction of adversary and friendly impacts from environmental effects. Department of the Air Force (DAF) weather forces deliver environmental information, products, and services to gain and maintain a warfighting advantage. Commanders leverage this advantage to integrate, synchronize, and direct operations, and outmaneuver the adversary more effectively. United States Air Force (USAF) weather operations directly support the DAF and United States Army (Army) conventional and special operations forces (SOF).[1] When designated, DAF weather forces also support joint, multinational, and other national agency operations. Weather operations provide critical situational awareness (SA), giving commanders decision advantage across the competition continuum. Weather forces provide information on weather effects relevant to operations at the strategic, operational, and tactical levels of warfare.

DAF weather forces, including those supporting Army operations, deploy under the air expeditionary task force (AETF) construct or as modular units of action. Weather personnel provide support through a combination of on-site and reachback operations. Supported forces include air operations centers (AOCs), USAF and Army forces at multiple echelons, USAF and Army SOF, unmanned aircraft systems, and joint force headquarters.

Airmen integrate deliberate analysis of environmental effects on friendly and adversary forces into the planning, execution, and assessment of military operations. Environmental support is most effective when weather personnel understand the unit's mission, organization, capabilities, limitations, plans, doctrine, and procedures. Furthermore, USAF weather forces require training that prepares them for operations in contested, degraded, or operationally limited environments, as well as garrison operations.

Effective weather operations use the four enduring principles of weather operations—accuracy, consistency, relevancy, and timeliness—along with the eight processes of the model of weather operations: processing, collection, analysis, prediction, tailoring, integration, mitigation, and dissemination. Weather forces characterize the environment through the collection, analysis, and prediction of weather data from both Department of Defense (DoD) and non-DoD sources. The weather data and information are stored in cloud-based repositories accessible through end-user systems and web-based interfaces and used to predict the future state of the environment. The weather community then tailors and integrates information from the repositories into planning and decision-making processes at the strategic, operational, and tactical levels. Harnessing reachback capabilities or leveraging personnel embedded in operational units, command and control

[1] Direct weather support to the Army was established via inter-service support agreement based on the National Security Act of 1947. See Interservice Publication Air Force Instruction (AFI) 15-157/Army Regulation (AR) 115-10, *Weather Support for the US Army*.

(C2) facilities, and intelligence centers, weather personnel use tailored weather information to advise decision-makers on how to mitigate and exploit the effects of weather for friendly forces or against adversaries. Throughout weather operations, weather data and information undergo processing and dissemination.

DEFINITIONS

The USAF differs from the joint force regarding weather terminology for personnel, effects, activities, and operations. For example, the USAF uses the terms "weather" or "environmental effects" since those terms exclude oceanic activity, while joint doctrine uses the term "meteorological and oceanographic." This also applies to using "weather" or "environmental" to modify the terms "information" and "data," instead of using "METOC." See some relevant definitions below.

Weather. The USAF defines weather as the past, current, and projected physical conditions of the terrestrial and space environment. These conditions include environmental factors from the surface of the earth up to the ionosphere and outward into space. Examples include thunderstorms, volcanic ash, dust, icing, turbulence, solar flares, and coronal mass ejections.

Meteorological and Oceanographic (METOC). A joint term used to convey all environmental factors, from the seabed through maritime environment, land areas, airspace, ionosphere, and outward into space. This includes hydrologic, meteorological, climatological, and oceanographic phenomena.[2] METOC is the commonly understood term when interacting with the joint force.

METOC Data. Meteorological, climatological, oceanographic, geophysical, and space environment observations and databases.[3]

METOC Information. Analyzed, manipulated, and processed METOC data becomes METOC information.

PRINCIPLES

In the complex and dynamic battlespace, accurate, timely, and appropriate weather information is crucial for mission success. The DAF recognizes weather as a critical operational factor and has established robust procedures to provide commanders with the environmental information they need to make informed decisions. The essential characteristics of effective DAF weather operations are accuracy, consistency, relevancy, and timeliness, which mirror the four core joint METOC principles.[4] In adherence to these principles, DAF weather personnel provide tailored weather support that enhances operational effectiveness and optimizes operational advantage.

ACCURACY

Gaps in sensor coverage, limitations of observation systems and prediction models, and

[2] See Joint Publication (JP) 3-59, *Meteorological and Oceanographic Operations,* for additional information.
[3] See JP 3-59, *Meteorological and Oceanographic Operations*, for additional information.
[4] For further information on these principles, see JP 3-59, *Meteorological and Oceanographic Operations.*

the complexity of atmospheric processes can reduce accuracy in weather forecasts. To enhance accuracy, weather personnel acquire consistent feedback and first-hand observations regarding the mission area's latest weather conditions from the supported units. Post-strike inflight reports and post-mission debriefings include target area and other relevant weather information to aid in future accurate forecasts. The fusion of mission reports, imagery, and ground observations (including observer augmentation) allows the weather community to identify patterns in local weather and improve the accuracy of forecasts and weather effects information for future missions.

CONSISTENCY

DAF weather personnel provide consistent information on weather and its effects to forces at all levels and echelons, resulting in "one operation, one forecast." To achieve this result, weather personnel utilize the same basic data from designated characterization sources while creating unit-specific weather exploitation products. Weather information provided to decision-makers and warfighters should therefore be spatially and temporally consistent across the operational environment (OE), accounting for differences in granularity across echelons, and provide an environmental common operating picture. DAF weather personnel use or tailor products from joint-designated lead METOC production units to enable consistency across Joint operation areas. Coordinated weather operations ensure commanders at every level can execute planning, operations, and assessments using a single environmental characterization.

RELEVANCY

DAF weather operations deliver better information when integrated from the beginning of the planning process and with access to mission and platform data and parameters. This ensures DAF weather personnel provide decision-makers with needed information on weather parameters that have the potential to degrade or enhance the mission prior to execution. Commanders need weather exploitation products that highlight opportunities to gain an advantage over the adversary in the OE. Additionally, provided weather data should enhance planners’ ability to determine the proper combination and timing of delivery systems, munitions, platforms, and other resources to create desired effects. Weather applies directly to planning, executing, assessing, and sustaining operations. To maximize the applicability of weather information, DAF weather personnel integrate across the force structure and build a holistic understanding of the impacts of weather throughout the spectrum of operations. Based on the mission requirements of the campaign, weather personnel need to consider friendly and adversary strengths, limitations, and time factors associated with specific missions and tailor weather products accordingly. For instance, weather that negatively impacts air refueling operations, such as severe turbulence at medium altitudes, is not as applicable to Army aviation units operating helicopters at low altitudes. Furthermore, relevant weather exploitation goes beyond standard weather data to consider atypical factors like overfilled reservoirs, which can lead to massive flooding, road washouts, and ultimately, the degradation of ground resupply. Weather personnel require a comprehensive understanding of commander’s intent, the campaign, its operations, and friendly and adversary mission profiles to ensure provided weather information generates operational advantage.

TIMELINESS

Weather information is perishable. It should be derived from the latest available data, disseminated quickly, and integrated at the appropriate time into the planning and execution of operations. DAF weather operations should also be proactive and responsive, informing commanders of potential friendly and adversary environmental advantages and disadvantages to proposed and ongoing operations in a timely manner. A significant aspect of timeliness is the method used to disseminate weather information. Cloud-based data repositories, using machine-to-machine dissemination, improve the chances that critical weather information will reach decision-makers in time to capitalize on time-sensitive opportunities. Real-time information sent to an aircraft, such as images of targets affected by the weather and accounting for targeting sensors, may enhance SA for new time-sensitive targets. In a limited data or data-denied environment, weather personnel should utilize any available environmental data combined with forecasting skills to provide the most accurate weather assessment possible in a timely fashion. Similarly, space domain awareness requires timely integration of accurate and relevant space weather information into military space operations to help protect friendly forces, analyze and predict space system anomalies, differentiate between intentional and unintentional interference, and exploit adversary vulnerabilities. Weather data repositories and weather units need to maintain communication with one another to secure the flow of information to provide the decision-maker with timely and exploitable environmental information.

FUNCTIONS

The two key functions of DAF weather operations are characterization and exploitation, in alignment with the joint METOC functions.[5] Environmental characterization describes past, present, and future weather conditions. Exploitation enables decision-makers to adjust and maximize operations based on the weather and any relevant effects on friendly and adversary forces.

CHARACTERIZATION

Environmental characterization is a systematic and consistent approach to weather forecasting, which identifies techniques and tools used to forecast individual weather elements, describes requirements for locally prepared products, and expands, refines, and integrates centralized products.[6] This function includes the ability to collect and process data into usable information to produce a coherent and accurate picture of the past, present, and future states of the atmosphere and space environment. Characterization encompasses the weather processes of collection, analysis, and prediction, along with constant dissemination for operational advantage. Because of the reliance of computers and machines in environmental characterization, many of the processes can and should be automated. DAF weather personnel provide actionable situational understanding to commanders covering past, present, and future states of the atmosphere and space environment to improve operational outcomes. DAF weather

[5] For additional information on these functions, see JP 3-59, *Meteorological and Oceanographic Operations*.
[6] See Department of the Air Force Manual (DAFMAN) 15-129, *Air and Space Weather Operations*, for additional information.

operations begin with an understanding of supported and adversary units' limitations and focus collection and analysis efforts to address risks and generate environmental information, estimates, and other products supporting the commander's decision-making process. Weather personnel collect and analyze terrestrial and space environmental data using a complex network of ground, airborne, maritime, and space-based sensors. The spatial and temporal measurements received from these sensors are processed to characterize the current state of the atmosphere and space environment. These assessments function as baselines to predict the future state of the atmosphere and space environment by using complex, physics-based computer models and the science of meteorology. Throughout this process, weather data is continually processed to meet the needs of the warfighter and disseminated via established channels to decision-makers. Characterization:

- Transforms environmental data into usable environmental effects, objects, and layers for digital consumption.
- Produces actionable environmental information for the weather community.
- Is environmentally focused.

EXPLOITATION

Environmental exploitation is the fusion of actionable environmental information with planning and decision-making. It entails the ability to understand friendly and adversary mission platforms, equipment, and systems capabilities/sensitivities, as well as mission processes (e.g., the joint planning process for air or the joint air tasking cycle) and inject the right information at the right time, every time, to mitigate or exploit environmental threats as early as possible in the mission planning process, ultimately optimizing mission execution.[7] Exploitation injects environmental information into planning and execution to mitigate any negative effects of the environment on friendly forces while capitalizing on conditions that maximize the operational advantage over enemy forces. Exploitation encompasses the weather processes of tailoring, integration, and dissemination, using environmental information to mitigate or capitalize on environmental effects to attain and sustain operational advantage. DAF weather operations take the prediction of the future environment and tailor this information to a format relevant to decision-makers and commanders. Weather personnel integrated into their supported unit's decision-making cycle proactively inject environmental information early and often throughout planning and execution, enabling commanders to make environmentally informed decisions. Knowledge of the weather and how it affects both friendly and adversary operations is a key component of operational risk management. Throughout exploitation, environmental data is continually processed to meet the requirements of supported units and disseminated via established channels to the warfighter. Exploitation:

- Integrates environmental information into the planning and decision cycle.
- Produces actionable environmental information for planners, decision-makers, and warfighters.

[7] See DAFMAN 15-129, *Air and Space Weather Operations*, for additional information.

- ✪ Is usually provided by small integrated teams.
- ✪ Is warfighter focused.

PROCESSES

Using accurate, consistent, relevant, and timely characterization and exploitation of environmental information, DAF weather personnel provide friendly forces with the requisite knowledge of the environment to secure a warfighting advantage over the adversary. DAF weather personnel execute eight processes (processing, collection, analysis, prediction, tailoring, integration, mitigation, and dissemination) to characterize the natural environment and exploit environmental effects information.

PROCESSING

Processing is the act of converting raw data into usable environmental information. Collected weather data flows into cloud-based repositories for processing into usable information. Observed conditions are input into predictive weather models, then high-speed computers run empirical and physics-based simulations of the environment and develop outputs representing the spatial and temporal evolution of the environment as tactical decision aids. Usable information may be in the form of gridded data as a tactical decision aid or for weather personnel for decision-makers. Environmental data and assessments are continually processed throughout the weather operations cycle—*collection, analysis, prediction, tailoring, integration,* and *mitigation*—to support operational advantage. Processing has no end state, as weather personnel constantly process environmental information.

COLLECTION

Collection is the process of gathering and storing raw data in databases from which environmental products are later derived. This data includes surface, maritime, air, and space-based observations, including meteorological space-based imagery and weather radar data from military, civilian, government, and commercial sources. Since each collection capability has limitations, DAF weather operations seek an optimal blend of measurements from land, sea, air, and space-based sensors. Although the DoD owns many sensors, international data is obtained via data-sharing agreements with other countries, including freely shared data under the auspices of international organizations such as the World Meteorological Organization and International Civil Aviation Organization.

Commanders ought to include nontraditional weather collection efforts throughout planning and operations to enable alternate avenues to receive accurate weather information in a timely manner. Nontraditional weather data sources, such as intelligence, surveillance, and reconnaissance (ISR) platforms and unmanned aircraft systems, can significantly enhance the quality and quantity of theater weather data collections. This data should be fed back to DAF weather operations to enhance the accuracy of weather forecasts. The DAF maintains the capability to deploy weather forces and tactical sensors with joint and coalition forces to further establish weather support for operations. Additionally, other sources of weather data may be available to weather personnel (e.g.,

amateur weather enthusiast sites, closed-circuit television footage, and social media). While not authoritative, after proper verification, this data can be used to supplement the environmental baseline.

A single piece of accurate weather information, regardless of the source, may provide the critical input pivotal to acquiring and maintaining operational advantage. Continuous collection of weather information and cooperation with outside sources should ensure the optimal accuracy of weather products. The end state of the collection process is a robust database of weather data.

ANALYSIS

Analysis interprets, fuses, and evaluates collected and processed environmental data to develop forecasts and recommendations. Analysis entails building a coherent, integrated depiction of the past and current state of the natural environment over a specified region. An effective analysis of collected weather data helps ensure the accuracy of the weather forecast provided to decision-makers. It enables the identification of weather features and conditions requiring further study and monitoring. The analyzed data is disseminated to cloud-based databases to provide inputs for weather personnel to use in building specific forecast products to support planning and decision-making for operational advantage. The end state of the analysis process is an understanding of the present environment in preparation to accurately identify opportunities and limitations in the future environment.

PREDICTION

Prediction is the process of describing the future state of the atmosphere and space environment using analyzed weather information, sophisticated numerical models, and human judgment. Weather operations leverage collected environmental data as well as processed and analyzed weather information to predict how future weather conditions (such as temperature, cloud cover, and ionospheric scintillation) may affect operations. Successful predictions are highly dependent on the timeliness, accuracy, and quality of the initial input. Weather personnel rely on constant feedback from updated weather collections of actual conditions to improve their forecasts. The use of artificial intelligence (AI) and automation—in conjunction with meteorological training—streamlines the prediction process and boost accuracy and timeliness. The end state of the prediction process is an understanding of future environmental conditions focused on the impact to the supported organization's mission.

Artificial Intelligence and Machine Learning for Weather

AI can automate coding tasks, freeing up weather Airmen to focus on higher-level analysis and problem-solving. ML facilitates quicker updates and improvements to weather forecasting accuracy by identifying subtle patterns within vast datasets that human analysts might overlook. Furthermore, these technologies amplify the capabilities of small weather teams, allowing them to achieve faster results than traditional means. Within the 557th Weather Wing, the 16th Weather Squadron prototypes and operates AI/ML and big data software applications.

TAILORING

Tailoring is the process of transforming relevant weather data and information into actionable, decision-enabling information by aligning it with details about planned operations, as well as the environmental sensitivities and supporting infrastructure of friendly and adversary weapon systems. Weather personnel integrate into the decision-making process by tailoring their predictions of meteorological effects to requirements specific to the supported operation. Weather personnel create products that demonstrate environmental effects on the mission and on specific friendly and adversary weapon systems and platforms. Tailored weather products may include focused climatological data, tactical decision aids, weather effects matrices, terminal aerodrome forecasts (TAFs), drop zone (DZ) forecasts, and target-area depictions. The end state of the tailoring process is environmental information, crafted to be relevant and ready for injection into decision-making cycles.

INTEGRATION

Integration is the process of infusing tailored decision-enabling weather effects information into planning and decision-making cycles. Effective integration enables decision-makers to maintain awareness and optimize the employment of military capabilities, capitalizing on the effect to create advantages for friendly forces or marginalize the benefit of the environment to the enemy. Decision-makers informed with timely, relevant, and accurate information can anticipate the weather's effects on planned operations and exploit those conditions to facilitate the achievement of the commander's objectives. Timeliness is critical to effective integration and commanders should ensure weather effects information is fully integrated into decision-making processes and C2 systems in time to inform the appropriate decision-makers. Likewise, weather personnel should be proactive in reaching out to supported units to ensure integration occurs early in decision-making cycles. DAF weather operations use cloud-based repositories of weather and operational effects information to facilitate integration. These repositories allow weather personnel to fuse relevant weather effects information with other operational information into a tailored operational picture. Weather personnel also need to remain integrated through all phases of the planning and execution process to provide their expertise and interpret meteorological data directly to decision-makers and end-users. The end state of the integration process is planners, commanders, and warfighters making environmentally aware decisions to maximize warfighting advantage.

MITIGATION

Mitigation is the process of providing tailored and integrated environmental information that enables decision-makers to adjust operational plans, courses of action (COAs), or otherwise exploit weather effects on operations. Weather events can have strategic impacts devastating to friendly and adversary military operations. Weather personnel provide assessments to planners and commanders, enabling them to determine the best employment packages and COAs for those environmental conditions. When leaders use environmental information to effectively mitigate or capitalize on environmental impacts, they can adjust plans and anticipate adversary behavior, selecting and executing COAs to gain or sustain operational advantage. The mitigation process gives decision-makers options on the beddown of forces, desired operational

capabilities, and resource protection actions. Weather personnel should articulate their level of confidence in predictions to decision-makers to be of value when leaders assess and manage risk in an operation. Weather personnel need to be properly integrated and establish a relationship of trust and relevancy with their supported decision-makers to optimize the mitigation process. To achieve maximum effectiveness, units and commands should make every effort to integrate their weather personnel into all planning and execution activities. The end state of the mitigation process is a commander who can make informed operational decisions with thorough consideration of present and future environmental conditions.

DISSEMINATION

Dissemination is the process of delivering weather data and information to users in a suitable form. Dissemination occurs throughout the weather operations cycle and ensures products created through the *collection, analysis, prediction, tailoring, integration,* and *mitigation* processes are received by the appropriate end-user. These users may be weather personnel, mission planners, or decision-makers, depending upon the product used. Processed weather data may be disseminated to weather personnel for use in analysis or prediction products. Tailored forecasts may be disseminated to operators for use in the decision-making cycle so leaders can act based on the information. Because of its importance to other weather processes, dissemination should occur in a timely, reliable manner. Interruption of the process of dissemination at any stage can disrupt the flow of accurate and relevant data to the decision-makers, significantly affecting their ability to integrate weather information. Thus, weather personnel need to develop an emergency communications plan to ensure environmental information is available to the maximum extent possible.[8] Dissemination has no end state, as weather personnel ought to continually disseminate new and updated environmental information.

JOINT FUNCTIONS AND WEATHER

Weather plays a critical role in enabling joint functions across the entire competition continuum. From informing command decisions and shaping intelligence assessments to influencing maneuver options and optimizing fires, understanding and exploiting weather impacts is essential for achieving operational success. By integrating weather expertise and environmental considerations into deliberate planning and execution cycles, commanders can mitigate risks, exploit opportunities, and gain a decisive advantage over adversaries.

COMMAND AND CONTROL

Weather assessments inform the joint force commander's (JFC's) guidance, enabling faster operational decisions and presenting opportunities for operational advantage. They also facilitate means allocation and the integration of joint functions by the JFC and subordinate commanders.

[8] For more information about emergency communications plans, see DAFMAN 15-129, *Air and Space Weather Operations* and AFTTP 3-4.15, *Weather Operations*

INFORMATION

Weather experts and operations in the information environment (OIE) planners collaborate throughout planning and operations to address unique environmental information requirements. Planners identify information gaps about the adversary's use of the environment and relevant physical environment aspects. Weather experts then produce and integrate environmental information products into risk-informed JFC decision-making.

INTELLIGENCE

Weather assessments and predictions support the commander's understanding of the OE and are integrated into the joint intelligence preparation of the operational environment (JIPOE). The collection authority optimizes collection capabilities using weather assessments, and J-2 planners provide weather thresholds affecting adversary military capabilities. Weather personnel provide assessments based on J-2's assessment of adversary capabilities, centers of gravity (COGs), and COAs. Comparing weather effects on friendly and adversary capabilities enables the JFC to gain advantage, exploit favorable windows of opportunity, achieve information superiority, act inside the adversary's decision cycle, and employ capabilities that enhance mission success.

FIRES

Weather personnel provide environmental effects assessments to the joint fires officer in support of the joint targeting process and to enable joint fires support. Environmental information and assessments optimize joint fire support planning, effectiveness, and synchronization of capabilities. Since each weapon system is uniquely impacted by environmental conditions, weather personnel should be involved throughout the fires process to maximize effectiveness. Weather personnel should be integrated into the joint targeting coordination board to provide weather assessments to synchronize targeting with intelligence and operations.

MOVEMENT AND MANEUVER

Weather personnel provide assessments for friendly and adversary COGs, lines of communication (LOCs), or decisive points and inform the JFC's consideration of ways and means to maneuver forces for positional advantage. JFCs leverage weather information for friendly and adversary movement and fires capabilities to exploit weather windows of opportunity and outmaneuver the adversary. Environmental information is also used to evaluate the movement and deployment of friendly and adversary forces and their maneuver for offensive and defensive purposes. Weather personnel collaborate with geospatial engineers on the joint staff to plan and provide geospatial engineering teams with environmental conditions impacting terrain and hydrological systems.

PROTECTION

Weather personnel enhance protection activities by providing detailed environmental information and assessments to commanders to describe environmental effects on adversary capabilities in coordination with J-2. They also inform the planning and execution of air, space, and missile defense options and tasks, and support DoD

information network operations to provide information that can be used to protect networks and support infrastructure from weather events. Additionally, weather personnel support the protection of forces, bases, joint security areas, and LOCs by providing weather watches, warnings, and advisories[9] of future hazardous environmental conditions. This support also enables mitigation of the effects of chemical, biological, radiological, and nuclear (CBRN) threats and hazards through CBRN response, and enables mitigation of health threats to the joint force using environmental information as part of a composite threat assessment.

SUSTAINMENT

Weather personnel provide assessments to logistics planners to develop a feasible, supportable, and efficient concept of logistics support. Geospatial engineering teams use current and predicted environmental information in support of mobility/trafficability assessments, which allow logistics planners and the JFC to synchronize supplies and achieve operational objectives. Weather personnel should maintain awareness of, and advise the JFC on, weather effects that may limit friendly or adversary operational reach or diminish flexibility, with emphasis on critical vulnerabilities and single points of failure that are sensitive to environmental conditions.

[9] For further information about weather watches, warnings, and advisories, see DAFMAN 15-129, *Air and Space Weather Operations* and AFTTP 3-4.15, *Weather Operations*.

CHAPTER 2: ROLES AND RESPONSIBILITIES

This chapter discusses the importance of weather support and the integration of environmental information in ensuring the safe deployment and redeployment of forces. It also addresses planning and execution across the full continuum of competition, which can vary in scope, purpose, and conflict intensity from military engagement and security cooperation to deterrence activities, crisis response, and major campaigns.

COMBATANT COMMANDER AND STAFF RESPONSIBILITIES

The combatant commander (CCDR) organizes the staff to plan and implement METOC-related activities and capabilities that support national security objectives, ensuring METOC capabilities are integrated when performing functions assigned in the Unified Command Plan. The CCDR typically designates a senior meteorological and oceanographic officer (SMO) to coordinate METOC operations within their area of responsibility (AOR) or functional responsibility.

COMBATANT COMMANDER (CCDR)

The CCDR employs and integrates METOC capabilities across the continuum of competition. The CCDR exploits METOC information and assessments to enable the synchronization and direction of joint operations. The CCDR leverages METOC assessments to enhance understanding of the OE and coordinates with the Joint Staff, United States (US) diplomatic missions, other US government (USG) departments and agencies, multinational forces, and applicable host or indigenous organizations. The CCDR can request support from a METOC production center to establish products and timelines based on requirements.

SENIOR METOC OFFICER (SMO)

The SMO assists the CCDR in developing and executing METOC operations, serves as the focal point for joint force METOC support, and coordinates with the Joint METOC Officer (JMO), Services, and other agencies to identify potential METOC support requirements. The SMO also ensures effective METOC operations support, develops and implements a METOC concept of operations (CONOPS), and creates a METOC sensing strategy that leverages national, international, and host nation capabilities. Additionally, the SMO oversees METOC activities, coordinates METOC communication and joint electromagnetic spectrum (EMS) operations requirements, and provides input on joint METOC concept development and experimentation activities. The SMO also coordinates METOC support with the CCDR's intelligence directorate, addresses METOC requirements for space operations, and collects and reviews after-action reports and lessons learned to identify shortfalls and evaluate requirements. Overall, the SMO plays a critical role in ensuring the effective integration of METOC operations and support across the joint force.

JOINT FORCE COMMANDER AND STAFF RESPONSIBILITIES

JFCs organize forces to accomplish their mission based on their vision and CONOPS. They have many options for organizing the joint force, providing direction and guidance on command relationships, and designating the air component commander.

JOINT FORCE COMMANDER

The JFC establishes METOC support requirements, integrates METOC into joint plans, and employs METOC capabilities and personnel to support joint operations and training. Additionally, the JFC ensures METOC personnel and information are integrated throughout the planning process and directs the JMO to coordinate with METOC production centers to develop and maintain METOC products for the joint operations area, as required.

JOINT METOC OFFICER (JMO)

JFCs establish a requirement for METOC support and designate a JMO or lead Service component to plan for METOC support immediately upon initiation of planning. The JMO, an experienced field grade officer, provides critical METOC advice to the JFC, determines required METOC capabilities, and ensures the unity of METOC efforts across joint force components. The JMO interacts with various staff components, METOC forces, and the SMO to optimize METOC operations, and their duties are complementary to the SMO's. During joint operations, the JMO integrates METOC assessments into various products and processes, develops data collection requirements, advises on METOC production center assistance, and provides direction to METOC units. The JMO also coordinates with the SMO and Services for specific METOC capabilities, monitors METOC operations, and ensures METOC information is integrated into plans and annexes. Additionally, the JMO considers all available METOC data, identifies information gaps, and requests additional capabilities, while also collecting after-action reports and feedback to inform future operations and improve METOC support.[10]

AIR COMPONENT COMMANDER AND STAFF RESPONSIBILITIES

The air component commander uses staff personnel and AOC team members to perform METOC functions in support of planning, execution, and assessment.

AIR FORCE FORCES (AFFOR) STAFF

In a joint or multinational OE, the air component commander, under Title 10 Commander, Air Force Forces (COMAFFOR) authorities, exercises operational control (OPCON) and administrative control (ADCON) of all assigned and attached conventional USAF weather personnel. Additionally, the air component commander needs weather personnel on the operations (A3W) staff and embedded in the AOC.

[10] For additional information on the roles and responsibilities of the CCDR, JFC, SMO, and JMO, see JP 3-59, *Meteorological and Oceanographic Operations*.

STAFF WEATHER OFFICER (SWO)

The senior DAF weather representative to the air component is designated the SWO.[11] The SWO monitors and coordinates DAF weather resources in theater, including those supporting conventional land forces and SOF. The SWO advises the air component commander's A-staff on all matters related to employing weather resources and coordinates DAF and Army requirements with the appropriate joint and coalition meteorological and oceanographic entities. The SWO coordinates closely with counterparts on the JTF and other component staffs to deconflict responsibilities and ensure unity of effort.

AIR OPERATIONS CENTER

Members of a weather specialty team (WST) support AOCs and their C2 missions by performing various tasks aligned with the priorities of the air component commander. While airfield weather services are responsible for the five nautical mile ring around the airfield, the WST is responsible for shared operations areas outside the airfields, such as target weather forecasts, aerial refueling tracks, DZs, and military operating areas. The WST is focused on integration across the AOC divisions and utilizes reachback support for a significant portion of the environmental information it requires to support AOC operations. Weather units supporting tasked assets accomplish flight weather briefings and mission-scale meteorological watch support, while integrated weather personnel accomplish staff weather briefs and target forecasts.[12]

AOC WSTs assess the impact of environmental phenomena on weapons, weapon systems, and operations of friendly and enemy forces across different mission profiles. They integrate these assessments into all phases of the air tasking order cycle by utilizing favorable weather windows of opportunity and mitigating unfavorable impacts to operations to the maximum extent possible. WSTs play a crucial role in mitigating risk to mission and personnel, but sometimes they are not large enough to provide in-person support across the AOC divisions during contingency operations. When additional staffing is required for expanded operations, the AOC/CC submits a request for forces through the chain of command to the relevant Major Command (MAJCOM) or Combatant Command, following local processes and procedures.

US ARMY

The USAF provides weather services and support for the Army. No single Army organization is responsible for comprehensive oversight and management of Army-unique weather capabilities. Consequently, Army weather support responsibilities are shared by the Headquarters, Department of the Army, Training and Doctrine Command Headquarters, and various Army proponents and research organizations. The USAF manages weather resources, develops plans and concepts, and establishes operations policy to address Army validated requirements. USAF weather forces

[11] The term “SWO” is often used to refer to both officer and enlisted AFW personnel that serve in a staff role. See *Weather Operations Supplement to the AF Force Generation (AFFORGEN) Support Plan* for additional information.
[12] See DAFMAN 15-129, *Air and Space Weather Operations,* for additional information.

supporting Army operations are normally organized as detachments or operating locations under a combat weather squadron (CWS), depending on the scale of the operation. The USAF retains ADCON, OPCON, and tactical control (TACON) of all USAF weather forces deployed in the AOR, including those supporting the Army. The COMAFFOR may delegate TACON to the supported Army unit.

DAF weather personnel, who are integrated into staff sections of the five primary Army echelons[13] and are often called "SWOs" by the Army, are assigned to a CWS. These personnel focus integration of weather effects across the warfighting functions, enabling commanders to optimize and synchronize forces at a decisive time and place in the battlespace to achieve the desired effects and win decisively. The capability of commanders and their staffs to anticipate, integrate, mitigate, and exploit weather effects on the employment of friendly and adversary combat power is important to achieving asymmetric advantage and defeat of the adversary. Environmental effects information and knowledge are critical to commanders' situational understanding and decision-making, and they enhance lethality when integrated into the Army's planning process, including intelligence preparation of the battlespace, fires, targeting, protection, risk management, and information collection.

Conventional Army weather support is integrated through CWSs, positioned under an air support operations group (ASOG) or combat weather group, which may belong to an air-ground operations wing under a numbered Air Force or with an air component commander. These CWSs are composed of SWOs trained to operate alongside, deploy with, integrate with, and provide direct support to the following priority echelons: Army service component command, corps, division, aviation brigade, multi-domain task forces, and other supported unit battle rhythms as deemed necessary. Additionally, weather forces coordinate, establish, and maintain weather-reporting networks within their respective operational areas to increase battlespace awareness and for use during operational planning and execution for the joint force. Weather forces are trained and equipped to operate for extended periods in austere conditions that are removed from traditional airbase logistics support. Furthermore, select SWOs may receive special training and equipment to support forcible entry operations (e.g., airborne or air assault) as part of a division or corps assault command post.

Because of its diverse missions, a conventional Army support CWS is organized to maximize training efficiencies in functional skills, combat survival, and tactical equipment operations. Each CWS is aligned with specific Army echelons or units and provides USAF C2 of subordinate detachments and operating locations co-located with the supported Army unit.

CWSs manage the control and execution of environmental support to Army echelons and units and are resourced to support specified Army units in both garrison and expeditionary environments. The weather forces supporting these echelons can surge to provide general support, vice tailored operational support, to subordinate Army echelons if required. When deployed to support conventional Army operations, SWOs are typically assigned to an expeditionary CWS (ECWS). The ECWS is normally a subordinate unit

[13] For additional information on primary/priority Army echelons, see *Weather Operations Supplement to the AFFORGEN Support Plan*.

within an expeditionary ASOG.

The ECWS commander tailors conventional Army weather support to forward deploy in support of the priority echelons and other units that require direct support, as determined via thorough mission analysis. These forward-deployed weather forces leverage characterization information from centralized weather organizations via a combination of reachback and distributed operations to integrate mission-tailored weather and weather effects information essential to planning and executing operations.[14]

Air National Guard (ANG) weather support to the conventional Army National Guard (ARNG) is integrated, when mobilized, via numbered ANG Combat Weather Flights (CWFs), which are assigned under their respective host ANG wings. ANG CWF personnel train to seamlessly integrate environmental effects information within mobilized ARNG divisions and aviation brigades.

US SPACE FORCE (USSF)

The USSF does not have its own weather personnel and relies on the USAF for its weather support. USAF weather personnel provide capabilities to the USSF, including forecasting support for hydrometeorology, climate, terrestrial weather, and space weather. Capabilities provided include space launch support, operating the ground-based space monitoring equipment, and space weather forecasting and operations. Additional products include tactical tools to inform decision-makers, tailored forecasting products, and environmental impacts to support the planning and execution of space operations, systems, and services.

The USSF is responsible for acquiring, delivering, and sustaining space environmental monitoring, analysis, and prediction capabilities, developing space weather modeling capabilities, and operating space-based space environmental monitoring capabilities. These capabilities are critical for USAF weather personnel to perform their mission. Air Force Materiel Command (AFMC) is the servicing MAJCOM for all USAF weather personnel assigned to USSF Deltas.[15]

SPECIAL OPERATIONS FORCES

Weather personnel assigned to SOF provide tailored information and knowledge to inform command decisions, and execution of SOF operations. These forces have the capability to plan, coordinate, and conduct weather operations throughout the OE to determine weather impacts to SOF and joint/multinational operations. USAF special operations weather forces are trained to operate independently in permissive or uncertain environments, or alongside other SOF elements in hostile environments, and are equipped with a variety of Service and SOF-unique equipment to execute these tasks. SOF weather reachback centers provide tailored support to global SOF missions.

[14] For additional information regarding policy on DAF support to conventional Army operations, see AFI 15-157/AR 115-10, *Weather Support for the US Army*.
[15] For additional information regarding USAF Airmen assigned to USSF Deltas, see AFMC Programming Plan 21-01, *Servicing Major Command for Airmen Assigned to the United States Space Force*.

Air Force Special Operations Command provides weather support to DAF and Army SOF. Support is provided by assigned weather flights at the installation level. In some cases, SOF weather flights may leverage information provided by reachback weather organizations in support of home station and deployed special operations missions.

SITUATIONAL RELATIONSHIPS

DEPARTMENT OF THE NAVY (DON)

While the United States Navy (USN) and United States Marine Crops (USMC) have no DoD or Joint Staff-directed operational relationships with USAF weather operations or personnel, there is some overlap and collaboration in initial skills training and research and development, as well as environmental modeling. Also, situational relationships may exist. For example, DON METOC personnel have access to online USAF weather services. Additionally, from its command center at Stennis Space Center, Mississippi, USN METOC may submit requests for USAF weather operations support. Also, DON METOC personnel may work and collocate, when viable, with USAF weather personnel in support of joint air operations or USAF SWOs supporting Army landing forces for joint amphibious operations.

NATIONAL INTELLIGENCE COMMUNITY SUPPORT

Environmental support to the national intelligence community is provided using data collected from various sensors and sources across all enclaves to provide mission-tailored forecasts and impacts to operations. These weather products are used for mission planning and environmental SA.

PRESENTATION OF WEATHER FORCES

DAF weather capabilities require integration with those of other Services and nations to provide structured weather operations to joint and multinational forces. DAF weather personnel may be tasked to fill joint weather positions supporting a CCDR, air component commander, or land component commander.[16]

AIR EXPEDITIONARY TASK FORCE (AETF)

Weather forces performing mission weather integration—for example, those supporting the Army—deploy with their mission design series flying squadron(s) or other supported Army units as part of an AETF. The air component commander retains OPCON of weather personnel supporting Army units at all echelons. Weather personnel and equipment from other units may be tasked to augment AETF weather forces.

DAF weather capabilities that support air expeditionary wing-level operations, including airfield weather services, staff and installation weather integration, and mission weather integration, are normally organized, commanded, and employed as a weather flight in an expeditionary operations support squadron (EOSS) or an expeditionary air base squadron (EABS). In some instances, it may be best for weather personnel performing mission weather integration to be directly attached to a flying squadron to provide more

[16] See JP 3-59, *Meteorological and Oceanographic Operations,* for additional information.

tailored and specific environmental information in support of operations.

Though DAF weather personnel often deploy in conjunction with atmospheric sensing systems, those assigned or attached to an AETF normally obtain data required for the weather operations cycle via reachback to their respective characterization units and integrate this information into their products. This data is flowed into centralized repositories and ingested into global weather models. Reliable communications between deployed weather personnel and reachback sites enable improved accuracy and timeliness of product generation for frontline decision-makers.

557 WEATHER WING

Due to extensive processing systems, data storage capacity, and communications requirements, the centralized environmental characterization function of DAF weather operations is optimally performed by production centers and generally aligned under a single specialized mission wing, the 557th Weather Wing (557 WW). The wing leverages Service capabilities to collect, process, and exploit atmospheric and space weather data from commercial, civil, and military sources to create general and tailored four-dimensional representations of the natural environment across all warfighting domains, including the electromagnetic OE.

The 557 WW makes its environmental information available for use by supported, supporting, and subordinate weather units, as well as other operational units, to enable multi-domain decision advantage for weather and non-weather warfighters and decision-makers throughout the USG, along with allied and partner nations, at all levels of warfare. Other subcomponents work with the specialized wing to provide reliable and updated weather information to supported organizations.

The 557 WW generally organizes its centers by squadron based on mission types, which create a variety of mission-focused weather capabilities to ensure decision advantage. Furthermore, these squadrons may provide reachback support to USAF, ANG, USAF Reserve, USSF, Army, and other units when tasked by their chain of command.

WING A-STAFF

In wing A-staffs, the weather function typically falls under the A3, with a trained meteorologist supported by one or more technicians or forecasters. The weather function in a wing A-staff plays a critical role in ensuring the safety and effectiveness of wing operations. By providing accurate and timely weather information, the weather team helps aircrews, commanders, and other stakeholders make informed decisions and mitigate the risks associated with weather-related hazards.

Staff and installation weather integration include staff weather support to DAF and Army installation leadership and environmental services for all functions of an established or expeditionary base, including the emergency management office and other mission support and medical group functions. A weather flight under the operations support squadron usually supports the staff and installation weather integration for a mission area. Duties typically include weather forecasting and observation, warning operations and support to flying operations, product and briefing development, and weather system maintenance.

DAF personnel performing the staff and installation weather integration mission at an individual installation are usually required for minimum home station support. Deployed personnel performing this mission for expeditionary installations typically fall under EOSSs, EABSs, or ECWSs.[17]

[17] See DAFMAN 15-129, *Air and Space Weather Operations,* for additional information.

CHAPTER 3: WEATHER AND OPERATIONS

The weather has a significant impact on the planning and execution of joint force operations. Therefore, environmental information relevant to friendly and adversary forces should be integrated into all stages of military operations, including planning, execution, and assessment. Weather support is most effective when weather personnel know the mission, organization, capabilities, plans, doctrine, and procedures of the supported unit. Weather has a particularly profound effect on flight operations, but it impacts all forms of operations to some degree, as outlined below.[18]

PLANNING AND ASSESSMENT

WEATHER OPERATIONAL PLANNING

A JFC's planning staff considers climatology, environmental effects, and weather force and equipment lay-down from the earliest possible stage of planning throughout the process. METOC planners aid commanders by integrating their experience and knowledge of METOC conditions and effects, thereby allowing the commander to visualize adverse impacts and assess any potential risks when arranging operations. METOC operational planning activities include: assessing current capabilities, identifying environmental information gaps, prioritizing sensing and forecasting capability requirements, developing collection plans, and creating mitigation strategies to address shortfalls.

DAF weather operations predict when environmental factors may impact friendly and adversary operations and offer friendly force commanders an exploitable asymmetric warfighting advantage. Weather personnel engaged in planning require knowledge of mission profiles, routes, ordnance, and tactics, techniques, and procedures (TTPs) of all units employed in an operation, as well as active relationships across the joint directorates to inject environmental information throughout the planning process. The combination of environmental information with mission capability enables DAF weather personnel and planners to better communicate where, when, and how environmental effects will impact operations and best practices to mitigate harmful effects.

Planners should use the guidance provided in the *Weather Operations Supplement to the AF Force Generation (AFFORGEN) Support Plan*[19] to request the weather capabilities required to meet the combatant commander's intent. Weather forces deployed forward need proper training and equipment to manage communications outages, which may preclude the transmission of weather data and products from centralized weather characterization centers. USAF weather personnel are assigned or attached to each Air Force, Space Force, and Army component staff and integrated into the staff functions to ensure proper weather capabilities are requested.[20]

[18] See JP 3-59, *Meteorological and Oceanographic Operations* and the *Joint Meteorological and Oceanographic (METOC) Handbook,* for additional information.
[19] See *Weather Operations Supplement to the AFFORGEN Support Plan* for additional information.
[20] See AFDP 3-0, *Operations,* for additional information.

During plan development, the Army should provide its requirements for weather support and services to the DAF for validation. In coordination with the DAF, the Army includes and synchronizes Army-provided equipment used to support DAF weather capabilities in the time-phased force deployment database.[21]

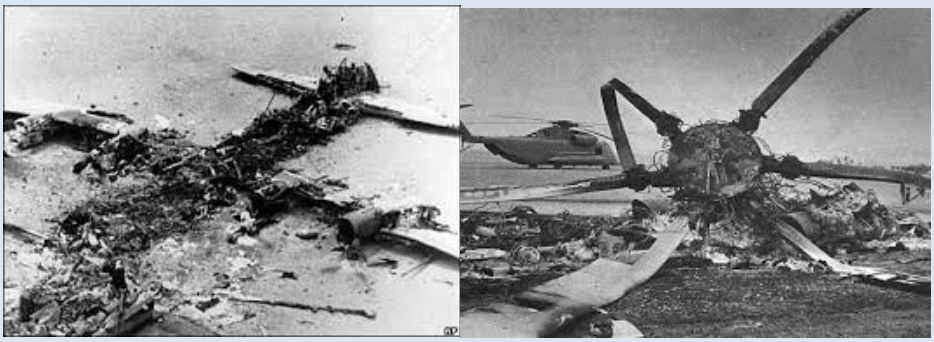
WEATHER OPERATIONS ASSESSMENT

To assess operational effectiveness and technical performance, weather personnel assess their ability to accurately predict the weather (technical performance) and its impact on operations (operational effectiveness). In general, weather personnel providing airfield weather services and staff and installation weather integration focus on evaluating characterization products for the accuracy of their technical assessments, while personnel providing exploitation evaluate the integration of products on their operational effectiveness. These assessments are used to modify or create new techniques, procedures, products, and services.

Additionally, weather personnel should store any results of technical and operational assessments to use in the development of weather Rules of Thumb, which are designated as experimental until validated. Validation occurs via use alongside other characterization tools and techniques for at least one season to determine accuracy.

Furthermore, weather personnel need to reference the joint lessons learned information system during the planning process, archive weather planning and execution data, and document weather lessons learned per the joint lessons learned program.

[21] See AFI 15-157/AR 115-10, *Weather Support for the US Army,* for additional information.



Operation EAGLE CLAW: A Hard Lesson to Learn

Top-secret planning for what would be one of the most complicated and ambitious raids in American history, the Iranian hostage rescue attempt of 1980, lasted over five months but it fell short of fully considering an incorrigible foe: the weather.

Historical records pointed to winter as the optimal time for a mission of this type, as limited moonlight and suitable temperatures and densities represented favorable conditions for night RH-53D operations. Nevertheless, the mission was set for late April, introducing additional weather challenges such as suspended dust, which proved to be a factor in the subsequent mishap. This mission-impacting information was never briefed to joint task force (JTF) planners and decision makers.

Recommendations to use a WC-130 weather reconnaissance aircraft as a scout in advance of the RH-53Ds were discounted based on assumed favorable weather conditions and for security reasons. Additionally, it was determined that pilot reports from accompanying C-130s, flying the same route, could provide advance notice of unfavorable weather as needed. However, the C-130s ended up arriving at the destination, Desert One, well ahead of the helicopters and were unable to relay up-to-the-minute weather data to the RH-53D crews.

Weather operations personnel were excluded from planning and rehearsal exercises at the JTF training areas, eliminating their ability to work with the aircrews.

Furthermore, mission execution weather briefings, developed by weather operations personnel, were presented by J-2 intelligence officers who had little, if any, formal weather training or experience. Aircrew feedback was provided in the same indirect way. Pilots were thus unaware of the possibility of encountering suspended dust and were unprepared to handle it. Integration of weather information, a vital contributor to mission success, never occurred.

–Paul B. Ryan
The Iranian Rescue Mission: Why It Failed

IMPACTS ON OPERATIONS

DAF weather operations support USAF, USSF, Army, and SOF operations, and may also support joint, multi-national, and other agency operations, providing critical environmental information to build battlespace SA. Weather impacts operations in every domain and essentially every specialty, influencing the planning, execution, and outcome of various missions. Whether precipitation, sea states, winds, extreme temperatures, or other

factors, weather is not neutral—it hinders or benefits both friendly and adversary forces. The various operational types and environmental impacts to them are discussed further below.

IMPACTS ON AIR OPERATIONS

The environment has profound effects on flight operations. Even on a clear day, the impact of something as simple as the speed and direction of the wind can significantly affect operations. Severe weather such as large hail, high winds, and heavy rains can halt flying operations and damage unprotected aircraft on the ground. Communication within the air domain is also susceptible to space weather effects such as ionospheric scintillation. This phenomenon affects the air operator's ability to effectively communicate with other airborne assets and ground forces and can alter the effect of other services such as positioning, navigation, and timing (PNT). Weather support to air operations focuses on four broad areas.

Protecting Air Assets, Personnel, and Base Infrastructure. Protecting personnel, equipment, and base infrastructure from the effects of hazardous weather is a continuous duty of weather personnel. Weather personnel monitor environmental conditions and alert the installation's decision-makers when hazardous weather is occurring or forecast. Depending upon the type and intensity of weather conditions and the installation's mission assets, commanders may exploit decision-enabling weather information by directing risk mitigating actions ranging from moving, tying down, or sheltering aircraft, to evacuation of aircraft and personnel.

Aircraft are susceptible to hazardous weather. A sudden onset of a thunderstorm could require aircraft to change their route or divert to an alternate base. Weather personnel routinely monitor weather along planned flight routes, alerting decision-makers to the onset of hazardous weather conditions such as turbulence, icing, and thunderstorms.

Maximizing Aircraft and Weapon System Performance. Weather personnel play a vital role in maximizing aircraft and weapon system performance based on observed and forecast weather. Cloud cover and flight-level wind forecasts help airborne ISR platforms use the appropriate sensor packages and plan their flight routes. Weather personnel use sophisticated computer models to support aircrew in choosing the best approach to their targets or simulating what a target might look like through specific targeting pods based on environmental factors. TAFs provide detailed forecast for take-off and landing conditions, assisting aircrew with choosing suitable alternate recovery locations. Flight-level wind forecasts aid in determining the range and optimized flight routes for aircraft to exploit favorable winds saving time and fuel. DZ forecasts help enable airdropped cargo and personnel to land safely on the target area. These weather products enable the exploitation of terrestrial and space environmental conditions to maximize aircraft and weapon system performance, providing an advantage over their adversaries.

Assisting in Planning and Execution. An understanding of weather information is a key enabler of airpower and should be integrated at every decision point during the planning, execution, assessment, and sustainment of military operations. This is critical for Agile Combat Employment (ACE), where operating locations may be dispersed, potentially austere, and more susceptible to weather impacts. Weather forces support air planning

and execution at the strategic, operational, and tactical levels.

At the strategic level, before hostilities begin, weather effects analysis, forecasts, long-range outlooks, and climatological assessments help shape future operations. For example, historical crosswind trends and low ceiling information at potential operating locations ought to influence decisions regarding aircraft suitability, basing options, and required airfield infrastructure (e.g., runway length, instrument landing system). Additionally, persistent heavy cloud cover or other environmental effects could hamper intelligence collection efforts, necessitating alternative ISR strategies.

At the operational level, weather personnel within the A-Staff require full integration during all phases of planning the joint air operations plan, continuously providing expertise to enhance operational flexibility and responsiveness. In addition to providing target area weather forecasts, weather personnel analyze the predicted impact of environmental conditions (e.g., visibility, wind shear, precipitation) not only on precision-guided munitions, ISR platforms, and sensors, but also on the feasibility of ACE maneuver options and responses for both friendly and adversary forces. This analysis should consider the potential for weather to degrade critical capabilities, such as C2, logistics operations, or force protection, informing risk assessments and contingency planning.

At the tactical level, real-time weather monitoring and forecasting are essential for making time-sensitive decisions during ACE operations. Weather personnel provide decision aids, including electro-optical (EO) and space weather effects guidance to planners during master air attack plan and air tasking order development. These products assist in determining the optimal timing of operations (e.g., launch windows, dispersal timelines) and selection of appropriate weapons systems to meet the JFC's objectives.

Space Weather Effects on Air Operations. Understanding space weather effects is also crucial to conducting air operations. Weather personnel can help maximize aircraft and sensor performance by forecasting potential interference and degradation to radio signals, satellite communications, PNT signals, or radar operations.[22]

IMPACTS ON LAND OPERATIONS

Like air, space, and cyberspace operations (CO), operations in the land domain are highly susceptible to impacts from the natural environment. DAF weather forces integrate current and predicted environmental impacts across the Army warfighting functions to enhance commanders' situational understanding, risk management, and decision-making to defeat the enemy.

SWOs attached to Army units integrate environmental effects, including hydrology and space weather, into intelligence preparation of the battlefield, the military decision-making process, and operational planning and execution. SWOs, while in garrison and deployed, integrate directly into various supported Army commands at various echelons.

[22] See AFDP 3-0.1, *Command and Control*; AFDP 3-01, *Counterair Operations*; AFDP 3-36, *Air Mobility Operations*; AFDP 3-50, *Personnel Recovery*; and AFDP 3-60, *Targeting* for additional information.

Maximizing the Army's Elements of Combat Power. Weather information needs to be integrated at every decision point during the planning, execution, assessment, and sustainment of ground-based military operations. Weather forces directly support the land component commander's planning and execution at the strategic, operational, and tactical levels by providing weather effects analyses, forecasts, long-range outlooks, and climatological assessments that help shape current and future operations. Visibility and precipitation forecasts can affect decisions regarding the tempo and timing of ground operations, including when to conduct sustainment operations and where to set up logistics support areas. Persistent fog can reduce visibility, limiting the ability to locate nearby enemy ground forces. Fog can provide concealment for friendly forces seeking to maneuver, resupply, or reinforce. An example of weather integration during planning for ground operations are the contributions of division weather personnel during a river crossing. These personnel can shape the division commander's COAs by determining environmental effects to rotary wing operations, targeting, trafficability near the bridgehead, and enemy chemical operations. These environmental assessments are critical to determining the timing of operations, the types of forces, and support assets required to meet the JFC's objectives.[23]

IMPACTS ON MARITIME OPERATIONS

Weather has significant impacts on maritime operations, including ship movement, aircraft operations, and amphibious operations. Adverse environmental conditions, such as high winds, rough seas, and reduced visibility, can limit the effectiveness of naval forces and increase the risk of accidents. Environmental conditions may also affect the performance of weapon systems, such as missiles and torpedoes, and impact the maritime component's ability to conduct mine countermeasures and other maritime activities. As one example, ducting is a phenomenon that allows radar energy to travel extended distances within a few hundred feet of the sea surface under some conditions, requiring consideration in tactical planning.

Weather support in the maritime context may include surface and air forecasts, sea state and wave forecasts, and ocean current forecasts, as well as specialized products like sea ice forecasts and tropical storm tracking. Furthermore, weather-dependent tactics and techniques, such as the use of fog or low visibility conditions to conceal the approach of naval forces, should be considered as part of operational planning.[24] Weather personnel supporting operations that involve maritime assets utilize USN METOC resources and experience in providing weather support to maritime operations to maximize warfighting advantage.

IMPACTS ON SPECIAL OPERATIONS

Adverse weather conditions, such as high winds, heavy rain, and reduced visibility, can limit SOF effectiveness and increase the risk of accidents. Impacted activities include insertion and extraction operations, air and ground movement, reconnaissance and surveillance operations, and communications, with further possible impacts to weapon

[23] See AFDP 3-03, *Counterland Operations,* for additional information.
[24] See AFDP 3-04, *Countersea Operations,* for additional information.

system performance, such as precision-guided munitions.

Weather support to special operations requires focused support, such as detailed forecasts for specific locations or specialized products such as avalanche forecasts or lightning strike predictions. For example, low visibility or poor communications conditions can help conceal the infiltration or exfiltration of SOF.[25]

IMPACTS ON CYBERSPACE OPERATIONS

Cyberspace mission data transit the space domain. Space weather interference on space systems can affect cyberspace domain operations. Additionally, terrestrial weather can have a significant impact on the ability to transmit data through the EMS, directly impacting operations in the cyberspace domain and operations that require the use of EMS.[26]

IMPACTS ON INFORMATION WARFARE (IW)

IW is the USAF's term for the military capabilities employed in and through the information environment to deliberately affect adversary human and system behavior and preserve friendly freedom of action during cooperation, competition, and conflict. Weather is one of the six principal IW capabilities, along with: cyberspace operations (CO), EMS operations (EMSO), information operations (IO), public affairs (PA), and intelligence.[27]

Weather operations provide actionable information on the current and future state of the environment, identifying opportunities for maneuver space in the information environment. Weather personnel use tailored environmental information to advise decision-makers on preserving friendly freedom of action, predicting adversary behavior based on environmental conditions, and influencing adversary behavior through support to military deception activities.

Weather experts work closely with IW planners throughout the planning, execution, and assessment of operations to ensure they understand and meet the unique IW environmental information requirements. During IW mission analysis, weather planners identify significant information gaps about the adversary's use of environmental information and relevant aspects of the physical environment. After gap analysis, the weather experts determine environmental information requirements for the collection or production of environmental information.[28]

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[25] See AFDP 3-05, *Special Operations,* for additional information.
[26] See AFDP 3-12, *Cyberspace Operations*, AFDP 3-14, *Space Support*, and AFDP 3-85, *EMS Operations,* for additional information.
[27] Per the CSAF-signed USAF IW Strategy (July 2022), Air Force IW consists of six principal capabilities: CO, EMSO, IO, PA, intelligence, and weather. IW is the USAF equivalent to the joint term "OIE."
[28] See AFDP 3-13, *Information in Air Force Operations*, for additional information.

Adversary Weather

USAF weather personnel provide a critical advantage by not only predicting weather effects for friendly operations, but also by analyzing their impact on adversary actions. Leveraging these weather insights can provide a critical advantage against adversaries. By accurately predicting weather effects and understanding their impact on enemy operations, USAF weather personnel can anticipate adversary behavior to inform operational planners about exploitable advantages. For example, most air forces ground their aircraft to minimize damage from hail, lightning, and debris. Recognizing this vulnerability, friendly forces could use storm fronts to their advantage. Knowing the most likely adversary response to storms, friendly aircraft could follow the storm through enemy territory to attack enemy airfields while their planes are grounded. This proactive approach creates a dilemma for the adversary, to either keep their aircraft safe from weather or to launch them for defensive operations.

IMPACTS ON SPACE OPERATIONS

Atmospheric Weather Effects on Space Operations. Atmospheric weather affects space-supporting ground sites and the launch and recovery of space assets. Specially trained USAF weather personnel analyze and forecast atmospheric weather specific to detailed launch-commit criteria for each launch and space vehicle, including those criteria established to protect operations where natural or triggered lightning conditions exist. Weather analysis also focuses on rain that may cause signal attenuation (due to absorption of radio signals by water vapor), hindering satellite communications at higher frequency ranges.

Space Weather Effects on Space Operations. Space weather is described by JP 3-59, *Meteorological and Oceanographic Operations*, as “the physical conditions in the space and near-Earth environments that originate from the sun, such as solar flares, coronal mass ejections, and radio bursts. These phenomena can affect activities in space, as well as in the other domains and the information and EMS environments.” The USAF is responsible for conducting space environmental (space weather) operations in support of all elements of the DoD and the intelligence community.

Specially trained USAF weather personnel monitor the space environment from the sun to the near-Earth space environment. Spacecraft and ground-based systems observe the sun and the space environment to assist forecasters in their analysis, forecasting, and integration of solar activity and other space weather effects, in support of the planning and execution of military operations.

Space weather directly impacts space systems and the capabilities they provide for operations. Space weather, such as a proton event (high-energy charged particles released from the sun) or a spacecraft charging event (accumulation of energetic electrons), may disable spacecraft subsystems or even an entire spacecraft. The impacts of space weather should be analyzed for blue, red, and gray space systems.

Knowledge of the space environment helps personnel mitigate the effects of space weather and helps differentiate between equipment malfunctions, natural interference, and intentional or unintentional artificial interference. Distinguishing between intentional and natural sources of interference, whether on the ground or in space, with space systems enables the COMAFFOR, the commander, Space Force forces (if one is appointed), and the Combined Space Operations Center to identify threat trends to better protect US and partner nation space COGs.[29]

IMPACTS ON COUNTER-WEAPONS OF MASS DESTRUCTION (CWMD) OPERATIONS

Weather significantly impacts CWMD operations, from planning to execution. Weather personnel provide essential data for CBRN hazard modeling, helping predict CBRN agent dispersal and casualties and aiding in SA and threat anticipation. Meteorological conditions impact the effectiveness of CBRN attacks and contamination persistence. Real-time weather data and accurate assessments contribute to effective responses and CBRN agent detection. Factors like wind, precipitation, terrain, and force readiness can influence CBRN injury severity.

Weather experts supply relevant data for assessments, while civil engineer and emergency management CBRN experts provide predictions on agent type, release point, and contaminated area. Predictive modeling under differing weather conditions helps commanders prepare for various threat scenarios. The USAF provides real-time environmental data to determine conditions affecting CBRN agent plume patterns and persistence. Accurate and timely assessments aid effective CBRN agent sampling, detection, and identification.[30]

IMPACTS ON ELECTROMAGNETIC SPECTRUM OPERATIONS

Weather can create or increase electromagnetic interference and hazards to personnel, ordnance, or volatile materials. Possible examples of space and terrestrial weather impacts include:

- The infrared (IR) and electro-optical (EO) spectrums can be degraded by factors such as clouds, sun glint, ground reflections, moisture, and dust.
- Radio waves can be distorted by atmospheric conditions, ionospheric scintillation, or harmonics.
- Microwaves are affected by precipitation.
- Space-based navigation systems, radar and spacecraft links, and high-frequency radio can be impacted by sun and upper atmosphere disturbances, leading to interference and decreased accuracy.
- Radio waves, visible light, and other parts of the EMS can be blocked by physical barriers, such as debris from storm damage.

[29] See AFDP 3-14, *Space Support*, for additional information.
[30] See AFDP 3-40, *Counter-WMD Operations*, for additional information.

Planners need to consider the effects of atmospheric and space weather on both the EMS and all EMS-dependent systems. Atmospheric conditions and phenomena, such as ducting, ionosphere, and solar effects, can positively or negatively affect these systems. For example, atmospheric temperature inversions can increase the propagation of radio signals with frequencies higher than 30 megahertz; high humidity and rainy climates are detrimental to IR systems; and ionospheric scintillation can adversely affect global navigation satellite systems, as well as high frequency and ultrahigh frequency transmissions. Some atmospheric effects are well known and are categorized by season and location—weather personnel have tracking mechanisms for impactful conditions.[31]

IMPACTS ON COMBAT SUPPORT

Environmental conditions can impact airfield seizures or base establishment and construction endeavors, as well as any handoff procedures to the operations element. Weather personnel offer combat support through airfield weather services, which entail evaluating current and future environmental conditions to facilitate flying operations and resource protection. They also collect and disseminate near-real-time weather observations, tailored mission execution forecasts, and SA to decision-makers at various levels within the command-and-control structure.[32]

IMPACTS ON INTELLIGENCE

The weather may cause impacts on otherwise viable collection capabilities or sensors, especially EO and IR sensors. It may also limit communications from collection platforms back to analysts or prevent takeoff or other mechanical functions, due to wind, particulate matter, icing, or other factors. Space weather can also influence spacecraft functions, potentially limiting utility.

Continuous integration of environmental information with intelligence and other IW disciplines enhances decision-making and planning capabilities. While environmental effects are often useful to conceal or deceive adversaries during collection operations or related movements, the adversary also can use various weather conditions for the same purposes.[33]

[31] See AFDP 3-85, *EMS Operations*, for additional information.
[32] See AFDP 4-0, *Combat Support*, for additional information.
[33] See AFDP 2-0, *Intelligence*, and AFDP 3-13, *Information in Air Force Operations,* for additional information.

APPENDIX A: POLICY AND TACTICAL DOCTRINE RELATED TO WEATHER OPERATIONS

This section captures specific USAF policy documents and tactical doctrine that provide in-depth explanations related to weather operations. These policies outline weather support to air, space, and Army operations while also expanding on expectations for the AOC weapon system. The tactical doctrine expands on specific roles for weather personnel in the AOC.

USAF Policy	
AFMAN 13-1AOC, Volume 3, *Operational Procedures-AOC*, 25 June 2024	This manual describes all organizations, positions, and processes used by the AOC. While Chapter 8, *Specialty/Support Functions* outlines the duties of the Weather Specialty Team and provides a summary of how this team supports each division of the AOC, the entire document provides information concerning integrating weather support at the AOC.
DAFPD 15-1, *Weather Operations*, 28 May 2024	This directive establishes Department of the Air Force policy and oversight for weather and environmental operations.
DAFMAN 15-129, *Air and Space Weather Operations*, 07 September 2023	This manual implements DAFPD 15-1 by providing guidance and procedures for all military and civilian USAF members.
AFI 15-157/AR 115-10, *Weather Support for the US Army*, 02 Sep 2021	This interservice publication sets forth policies and establishes Army and USAF responsibilities for weather support to the Army.
AFH 15-158, *Army Weather Operations*, 05 Jan 2021	This handbook serves as a fundamental reference document for all staff weather officers assigned to support the Army and describes how to provide accurate, timely, relevant, and consistent air and space environmental information.
USAF Tactical Doctrine	
AFTTP 3-3.AOC, *Combat Fundamentals-Air Operations Center*, 29 September 2023	While Chapter 5, *Conflict*, outlines the duties for the Weather Specialty Team, the entire document provides information concerning integrating weather support at the AOC.
AFTTP 3-4.15, *Weather Operations*, 10 February 2025	This publication describes weather operations and their integration into mission and staff functions, base operations, regional support, space and strategic intelligence, expeditionary operations, systems, and unit administration.

APPENDIX B: WEATHER UNITS

The USAF consolidates most of its weather capabilities into a single wing at Offutt Air Force Base with multiple, widely distributed subordinate units. These units specialize in various functional missions, as addressed below.

557TH WEATHER WING (557 WW)

1st Weather Group (1 WXG)

- 15th Operational Weather Squadron (15 OWS): USNORTHCOM (NECONUS, Alaska, Arctic, Aviation Hazards).
- 17th Operational Weather Squadron (17 OWS): USINDOPACOM (China, North Korea), Antarctic.
- 21st Operational Weather Squadron (21 OWS): USEUCOM (Russia), USAFRICOM.
- 25th Operational Weather Squadron (25 OWS): USSOUTHCOM, USNORTHCOM (WCONUS, Transregional Organized Crime).
- 26th Operational Weather Squadron (26 OWS): USNORTHCOM (SECONUS, Gulf of America, Hurricanes).
- 28th Operational Weather Squadron (28 OWS): USCENTCOM (Iran, Israel, VEOs).

2d Weather Group (2 WXG)

- 2d Weather Squadron (2 WS): Orbital Warfare, Electromagnetic Spectrum, National Intelligence Assets.
- 14th Weather Squadron (14 WS): Climatology.
- 16th Weather Squadron (16 WS): Modeling and Simulation, Tailored Automation, AI/ML.
- 2d Combat Weather Systems Squadron (2 CWSS): Operational Testing, Environmental Collection, OT&E/TTP Development.
- 2d Systems Operations Squadron (2 SYOS): Data Management/Usage Intelligence.
- 2d Weather Support Squadron (2 WSS): Defensive Cyber Operations.

ADDITIONAL USAF WEATHER ORGANIZATIONS (NOT UNDER 557 WW)

1st Air Support Operations Group (1 ASOG)

- 1st Combat Weather Squadron (1 CWS): Army I Corps METOC Activities.

4th Air Support Operations Group (4 ASOG)

- 7th Combat Weather Squadron (7 CWS): Army V Corp METOC Activities.

- 13th Expeditionary Combat Weather Squadron (13 ECWS): Deployed Army METOC Activities in USEUCOM.

5th Combat Weather Group (5 CWG)

- 3d Combat Weather Squadron (3 CWS): Army III Corps METOC Activities.
- 18th Combat Weather Squadron (18 CWS): Army XVIII Airborne Corps METOC Activities.

387th Air Expeditionary Group (387 AEG)

- 22d Expeditionary Combat Weather Squadron (22 ECWS): Deployed Army METOC Activities in USCENTCOM.

607th Air Support Operations Group (607 ASOG)

- 607th Combat Weather Squadron (607 CWS): Army 8th Army (Korea) METOC Activities.

Other USAF Weather Organizations

- 23d Special Operations Weather Squadron (23 SOWS): SOF METOC Activities.
- 45th Weather Squadron (45 WS): USSF METOC Activities.
- 53d Weather Reconnaissance Squadron (53 WRS): Hurricane Hunters.
- 96th Weather Squadron (96 WS): METOC Integration in Weapons System Testing.

REFERENCES

All websites accessed 13 August 2025.

US AIR FORCE DOCTRINE: https://www.doctrine.af.mil/

- AFDP 3-0, *Operations*
- AFDP 3-0.1, *Command and Control*
- AFDP 5-0, *Planning*

JOINT DOCTRINE

- JP 3-59, *Meteorological and Oceanographic Operations*
- *Joint Meteorological & Oceanographic (METOC) Handbook*

TACTICAL DOCTRINE

Air Force Weapon System TTPs (AFTTPs):

- AFTTP 3-3.AOC, *Combat Fundamentals-Air Operations Center*
- AFTTP 3-4.15, *Weather Operations*

MISCELLANEOUS PUBLICATIONS

- CJCSI 3810.01G Ch 1, *Meteorological and Oceanographic Support*
- DAFPD 15-1, *Weather Operations*
- DAFMAN 15-129, *Air and Space Weather Operations*
- AFI 15-157 / Army Regulation 115-10, *Weather Support for the U.S. Army*
- AFH 15-158, *Army Weather Operations*
- AFMAN 13-1AOC, Volume 3, *Operational Procedures-AOC*
- *Weather Operations Supplement to the AFFORGEN Support Plan*
- North Atlantic Treaty Organization Allied JP (AJP)-3.11, *Allied Joint Doctrine for METOC Support*