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Weather Operations in the Transformation Era

JOHN M. LANICCI
Colonel, USAF

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Air War College

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Please send inquiries or comments to
Editor
The Maxwell Papers
Air War College
325 Chennault Circle, Bldg. 1401
Maxwell AFB AL 36112-6427
Tel: (334) 953-7074
Fax: (334) 953-1988
E-mail: lawrence.grinter@maxwell.af.mil

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Foreword

In *Weather Operations in the Transformation Era*, Col John M. Lanicci, USAF, takes a compelling look at future weather operations. His hypothesis is that a consolidated battlespace picture integrates both natural and man-made elements, which is totally consistent with USAF transformation efforts. He points out that the way ahead is easier said than done and offers several cogent reasons why the weather operations portion of information-in-warfare has not caught up with current USAF doctrine. One such example is our historical tendency to look at weather as a somewhat isolated, tactical problem.

Significant advances in information technology and advent of effects-based operations are propelling the USAF weather community away from traditional, single-inject stand-up briefings towards continuously updated advice to war fighters at every step of campaign/mission planning and execution. This technological momentum will make it necessary to fundamentally change data collection, analysis, prediction, and product tailoring. The author outlines these changes in a concept called weather, intelligence, surveillance, and reconnaissance (WISR), a term first used by the Air Staff to describe the total integration of natural and man-made environments for predictive battlespace awareness (PBA). The WISR concept is based on substantially increasing the volume of weather data collected in-theater by using the same airborne assets being proposed for PBA, persistent ISR, and time-critical targeting. It proposes the creation of a four-dimensional database that can be used to integrate the natural environment into the common operating picture. The WISR concept also advocates transmitting real-time weather information to the cockpit as a means to optimize the "kill chain" by allowing rapid redirecting of sorties based on continuously updated weather information.

The author introduces a long-range planning model for examining national-level strategy and joint/service doctrine, and identifying emerging natural environmental issues. The model identifies operational deficiencies, technological needs, and research and development opportunities in a number of areas and points out potential force-structuring issues associated with meeting the stated requirements of future US military strategy. The author's illustration from the *2001 Quadrennial Defense Review* report identifies a need for regional weather and climate monitoring, impacts analysis, and prediction to support environmental security programs operated by combatant commands. These services would help combatant command staffs recognize environmentally vulnerable regions and anticipate geopolitical instability that may require involvement of US forces. Colonel Lanicci's extensive background in weather operations and research and his Air War College (AWC) faculty experience afforded him a unique perspective to gather necessary background information, conduct research and interviews, and synthesize these concepts into the thought piece presented here.

This is the twenty-ninth AWC Maxwell Paper. The series began in 1996. As with all Maxwell Papers, we encourage discussion and debate on Colonel Lanicci's proposals for guiding USAF weather operations into the transformation era.

BENTLEY B. RAYBURN
Major General, USAF
Commandant, Air War College

About the Author

Col John M. Lanicci (BS, Manhattan College and Pennsylvania State University; MS and PhD, Pennsylvania State University) is a professor in the Department of Warfighting, the chief information officer, and the Education Technology Integration Group chair at Air War College (AWC), Maxwell AFB, Alabama. Previous assignments include commander, 88th Weather Squadron, Wright–Patterson AFB, Ohio; chief, Data Management and Environment Branch, Headquarters USAF Directorate of Command and Control in Washington, D.C.; commander, Detachment 3, 11th Weather Squadron, Eareckson AFB, Alaska; chief, Meteorological Models, Air Force Global Weather Central. Colonel Lanicci is a graduate of Squadron Officer School in-residence and the Air Command and Staff College and AWC seminar programs.

Weather Operations in the Transformation Era

"Listen, S-2," the colonel said, "I don't care about how many inches of rainfall to expect. I don't care about the percentage of lunar illumination. I don't want lots of facts and figures. Number one, I don't have time, and number two, they don't do me any good. What I need is to know what it all means."

—USMC Doctrinal Publication 6
Command and Control

According to *Webster's Ninth New Collegiate Dictionary*, the term *transform* "implies a major change in form, nature, or function."[1] There is considerable debate throughout the Department of Defense (DOD) as to whether we are witnessing a revolution in military affairs, multiple revolutions in military affairs, or merely a rapid evolution in multiple military fields.[2] No matter which position one takes on the issue, it is generally agreed that emerging technologies are already changing the ways that US, allied, and coalition forces fight, with the future promising even more dramatic changes. In November 2001, Secretary of Defense Donald H. Rumsfeld named retired Vice Adm Arthur Cebrowski to head a new Pentagon Office of Force Transformation as a means of increasing the momentum to transform the US military to better face new challenges of the twenty-first century.[3]

Introduction

The US Air Force Weather (AFW) service is no stranger to transformation. Since the end of the Cold War, AFW has undergone two major structural reorganizations: a functional realignment "divestiture" coincident with the USAF reorganization in 1991–92; and a reengineering of the entire career field from 1997 to 2002 to retool services at the operational and tactical levels.[4] These reorganizations—combined with significant advances in information technology and communications bandwidth—are fundamentally changing the types of weather services provided to the Air Force, Army, and other important organizations within the US government.

As we look towards the future, it is important to understand how AFW will operate in a transformed DOD. As weapons and the means to deliver them become increasingly more sophisticated and the combat decision cycle is sped up significantly by near-instantaneous communications and data delivery at multiple levels of command, the question of relevancy of weather and climate information to the battle becomes more important. Are we more vulnerable to the natural environment (to include "space weather") today because of our technological sophistication? Or has the age of the truly "all-weather" force finally arrived?[5] In order to address these questions, we must take a comprehensive look at the entire process of providing weather and climate information to important users, from decision makers at the very highest levels of government (e.g., president, secretary of defense) to the individual soldier, sailor, airman, or marine executing a tactical mission in support of national objectives.

Purpose

This approach looks at weather and climate operations at the tactical, operational, and strategic levels of warfare. These operations cover the needs of war fighters from current conditions to long-range forecasts, spanning from the surface of the earth to the near-space environment. The overarching hypothesis is that a truly consolidated "sight picture" of the battlespace totally integrates all elements of the battle environment, man-made as well as natural. Full integration of these factors at tactical and operational levels can best be described as weather, intelligence, surveillance, and reconnaissance (WISR). The WISR concept has two important implications for air forces: it optimizes the target "kill cycle" find, fix, track, target, engage, and assess (F2T2EA) by including natural environmental information in every step of the cycle; and it enhances predictive battlespace awareness and persistent ISR by adding the natural environment to the equation.[6] When natural environmental effects and impacts are fully integrated into all aspects of the operator's decision cycle, it becomes easier to include natural environmental considerations throughout the spectrum of military planning and execution, whether it is flying an individual sortie, building the Master Air Attack Plan, or formulating the combatant command's environmental security program. Although the focus of this paper is primarily on AFW services, the concepts could easily be related to joint meteorological or oceanographic (METOC) services provided by the Air Force and Navy.[7]

To facilitate the discussions in this paper, two concept models are introduced to better understand weather and climate integration at various levels of warfare. The first model describes the weather decision cycle at the operational and tactical levels and is used to illustrate how improvements in data gathering and communication will improve air forces' F2T2EA cycle and allow for better integration of weather and climate effects information in the Combined Air and Space Operations Center (CAOC). The second model is a long-range planning construct for analyzing strategy, concepts, and doctrine. This model—geared towards the strategic level—examines national-level strategy, joint and service doctrine, and analyzes the strategy's feasibility from the natural environmental point of view. The model's analytical processes identify operational deficiencies, technological needs, and research and development opportunities in a number of areas and point out potential force structuring issues involved in meeting the stated requirements of future US military strategy. While both models are applied to an examination of AFW, neither produces a "stovepiped" view of the world. In fact, the strategic planning model is general enough that it can be applied to other functional areas.

"WISR": Environmental Situational Awareness in the CAOC and Cockpit

When considering the impacts of natural environment on military operations, there is a tendency to become enmeshed either in an examination of natural environmental effects on individual platforms or missions or the accuracy of individual weather forecasts. In either case, the resulting analysis loses grasp of the greater picture. This presents a problem for officers as they progress from company through flag grades. For example, the flying community has good training manuals that document some natural environmental effects at the tactical level (e.g., Air Force Handbook 11-203, vol. 1, *Weather for Aircrews*), but there is no "capstone" document that discusses natural environmental considerations at the operational and strategic levels. By the time an officer makes flag grade, he or she may no longer have the appropriate frame of reference in which to integrate the potential impacts of weather, terrain, and climate properly with information about man-made threats, rules of engagement, campaign objectives, and so forth during planning and execution. The result is a cultural regard of the natural environment as a hindrance that will eventually be engineered out of relevance (i.e., emergence of the all-weather force, a misnomer). This dilemma is compounded by myriad operations that today's military forces must be prepared to execute—from peacekeeping or peace enforcement through major theater war—in many inhospitable regions, and with the potential participation of nations whose forces, equipment, and doctrine are likely to be less weather tolerant than US forces.

In particular, problems with integrating weather and climate information into air and space operations can be best summarized by the three statements below:

1. Senior officers tend to look at weather as being tactical because it is not a subject that is taught above an introductory level (related to number three below). Additionally, the requirements of forecast precision often drive the solution to specifics of time and location (i.e., towards a tactical view).
2. Weather is considered information-in-warfare (IIW) per USAF doctrine, but not in practice.[8]
   —Weather data collection and utilization have not been considered priorities on unmanned aerial vehicles (UAV) sensor packages.
   —Real-time weather information delivery to the cockpit has not been considered a priority despite its potential to reduce weather-related aborts and speed up the F2T2EA cycle.
   —Weather information is not fully integrated into the common operating picture (COP) in the CAOC.

—Considered a crosscutting function, weather technological needs do not typically get advocacy from major commands in the planning, programming, and budgeting process unless there is a serious deficiency affecting one or more of them.

3. Weather is not taught as a strategic-level consideration in senior officer professional military education courses.

What Is Intelligence, Surveillance, and Reconnaissance?

Air Force Doctrine Document (AFDD) 2-5.2, *Intelligence, Surveillance, and Reconnaissance Operations*, defines ISR as having "integrated capabilities to collect, process, exploit, and disseminate accurate and timely information that provides the battlespace awareness necessary to successfully plan and conduct operations."[9] The document also describes ISR as a synergistic process that converts information derived from surveillance and reconnaissance into intelligence used "to formulate strategy, policy, and military plans, to develop and conduct campaigns, and to carry out military operations."[10]

The Air Force has taken a keen interest in ISR as a critical component of information operations. The renaming of the Aerospace Command and Control, Intelligence, Surveillance, and Reconnaissance Center in 1999 was an important corporate step in this evolution.[11]

What Is the Weather Information Processing Cycle?

Natural environmental data are collected from a number of locations and platforms such as airfields, satellites, radars, aircraft, and field observers. This raw data must be compiled and go through a processing cycle—described in figure 1—before it is transformed into useful knowledge for the operational decision maker.[12] The first two steps are purely meteorological in nature and have always relied upon high-performance computers to execute. This is especially true in step two, where sophisticated atmospheric

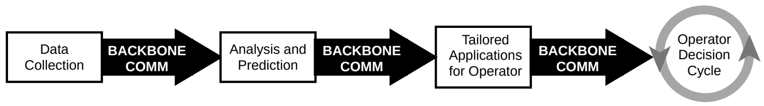


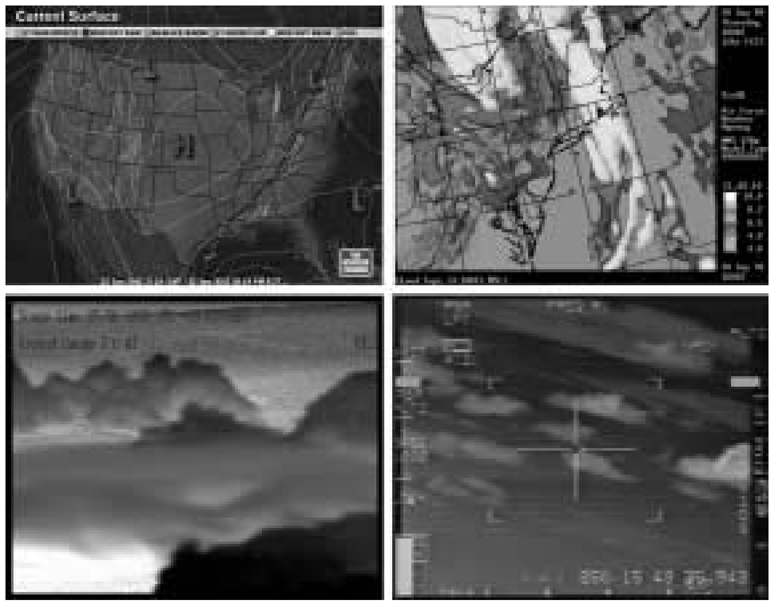
Figure 1. Traditional Weather Information Processing Cycle

prediction models have been a staple of the profession for more than 30 years. Although humans are involved throughout the process, it is not until the third step that forecasters begin to consider potential effects on military operations. Historically, the entire production cycle occurred on a 12-hour rotation centered around 1200 and 0000 Greenwich mean time (worldwide data collection times), with the first and second steps and communication process (depicted by the arrows) greatly limited by computational power and bandwidth. These limitations translated into long preparation times for steps one and two, limited production of tailored applications in step three, and limited opportunities for operators to employ the information in their decision cycles in step four. This process has historically been largely linear, with little opportunity for feedback from operators to modify the procedure. A similar processing cycle existed for intelligence information—and along with the weather—was presented as a single, separate input to the operational commander, usually at a stand-up briefing.

The end of the Cold War and Operation Desert Storm resulted in a changed mind-set about deployment and use of ISR assets. Once the domain of national strategic decision makers, these assets are routinely used by the Joint Force Commander (JFC), and there is a groundswell to make more of these programs' products available to a larger community of users. Organizationally, the last 10 years have seen declassification of the National Reconnaissance Office, a major reorganization of the Intelligence function at Air Staff, and a shift of the Air Intelligence Agency to Air Combat Command.[13] Assets such as Rivet Joint, airborne warning and control system, and joint surveillance, target attack radar system are considered high demand/low density due to the extremely high operations tempos they have sustained in the years since Operation Desert Storm.

Concurrent with the changes in ISR asset deployment and use is an emphasis shift towards weather or climate effects products tailored for the end users. This shift is consistent with effects-based planning and operations. Consider the following charts in figure 2 that illustrate the evolution of a meteorological prediction from traditional "fronts on a weather chart" to sophisticated visualizations that could be used for mission planning and rehearsal (right to left top row and left bottom row). These charts characterize several important changes that have taken place in the weather business during the last 10 years: (1) the ability of sophisticated visualization technology to translate meteorological information that once required experienced forecaster interpretation into impacts information directly useable by the operator; (2) the increasing trend towards weather effects and impacts information versus pure meteorological terminology; and (3) the opportunity for the staff weather officer to move from delivering a purely meteorological briefing as a single inject in the decision process to a consultant who is able to provide continuous support to the operation at every step of campaign/mission planning and execution.

Traditionally, the operator has not had technology available to integrate weather and other types of information. Traditional application of weather information in the operator's decision cycle has largely been done using experience and intuition, without involvement of the staff weather officer except to answer questions about confidence in the forecast's accuracy. "We don't tell the operator how to do his job" has been the standard motto for many years in this business. But situational awareness, information volume, and flow have become so intensive with the advent of sophisticated computers and visualizations that commanders have become frustrated that they cannot take full advantage of all this new information. They want to be able to see the big or "fused" picture of what is taking place, and it is no longer a matter of the weather or intelligence officer delivering a briefing and then dropping off. With ability to reroute attack sorties in real time and call in close air support from horseback in austere locations such as Afghanistan, weather and intelligence can no longer be treated as single injects at a



Courtesy of the Weather Channel: http://www.weather.com/maps/

Sources: Louis Hembree, Sam Brand, William C. Mayse, Maureen Cianciolo, and Brian Soderberg, "Incorporation of a Cloud Simulation into a Flight Mission Rehearsal System: Prototype Demonstration," *Bulletin of the American Meteorological Society,* May 1997, 815–22; and Paul Tattelman, "The AFRL Weather Impact Decision Aids Program Progress Update," *Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO) Conference,* 24–27 April 2000, Fort Collins, Colo. Available from http://www.cira.colostate.edu/GeoSci/Bacimo2000/paper/paper/tattelman.pdf.

Figure 2. Examples of Different Types of Weather Information. Top *(left to right)* shows a basic meteorological chart and an Air Force Weather Agency prediction model depiction of cloud tops. Bottom *(left to right)* is an Air Force Research Laboratory target scene simulation using the cloud scene simulation model and infrared target-scene simulation software and a cockpit video shot.

stand-up briefing but part of a continuously updated stream of information along with other real-time battlespace information.

Putting It All Together: WISR

The central question: How do we integrate all this information? It is important to begin by improving our knowledge base of natural environmental effects on weapons, platforms, and missions. One way to accomplish this is through building environmental effects databases and decision aids such as the Integrated Weather Effects Decision Aid.[14] But this is only part of the answer. Unless there is improvement in quality and quantity of observational data in the denied battlespace, we will suffer from the age-old problem of "garbage in/garbage out." When one considers the numbers of airborne platforms in the battlespace at any one time, including UAVs with long loitering times, an answer to this data problem begins to emerge. With the advent of ideas such as the Smart Tanker and the growing presence of UAVs, an order-of-magnitude increase in the number of weather observations can be accomplished in some of the most data-sparse regions of the world.[15] Injecting this large amount of data into step one of the weather information processing cycle will have the greatest influence on improving the quality of the products coming out of steps two and three. An additional enhancement in step four would be the introduction of real-time weather information to the cockpit.[16] This information could take the form of "pure" weather (e.g., a step two product such as satellite or radar imagery) or a step three-type of impact product (e.g., "target area weather changing from yellow to red for your weapons load; reroute to alternate target"). Such real-time weather information would save weapons from being expended needlessly and would optimize our abilities to perform time-critical targeting in a fast-paced battle rhythm situation.

Another way to reach WISR is to improve the integration of weather and climate information with other types of information in the COP in the CAOC. Creating a continuously updating, four-dimensional METOC database would allow the weather information processing cycle to become nested with other functional decision cycles and that of the operator (fig. 3).

Full implementation of the ideas being advocated here will alter the weather information processing cycle from the traditional process—noted previously in figure 1—to a continuously updating information flow back and forth from the theater. In such an operating environment, decision assistance tools would translate weather data into

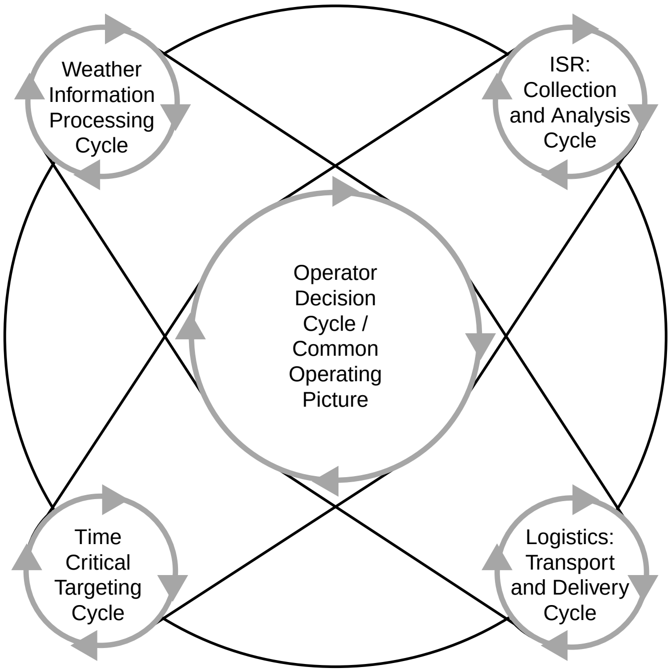


Figure 3. Weather information processing cycle nested with other decision or product cycles and tied to operator decision cycle or common operating picture.

decision-quality information for use by mission planning rehearsals and simulations. Additionally, much of the impacts information could flow seamlessly through the execution process using machine-to-machine interfaces, which is envisioned to look similar to figure 4.

The term *WISR* denotes integration of accurate, timely, relevant information about the man-made threats and natural portion of the battlespace environment. It is realized that integration of relevant information into a common picture of battlespace awareness is an evolutionary one—defined by technology, history, and organizational structures. Technological limitations historically made the timely analysis, transmission, and display of relevant information problematic. As computational capabilities increased, it became possible to perform accurate data

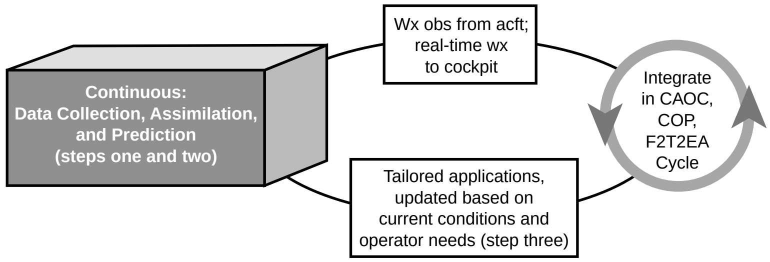


Figure 4. Notional weather information processing cycle supports full integration into CAOC, common operating picture, and F2T2EA cycle.

analyses and put them into an easily viewable form for consideration by decision makers. Satellite communications today make it possible to move very large amounts of information into and out of theater. The publication of *Cornerstones of Information Operations* in 1997 marked recognition by the Air Force of this evolution. Command and control, IIW, and information warfare or operations have since become key components of US military strategy. Evolution is still being carried through by organizations that trace their lineage to the Cold War. Ideas presented here are a means to use instruments of transformation to integrate all needed information about components of the operating environment into a single sight picture for the JFC and his staff.

Strategic Weather in the Transformation Era

Throughout history, there are numerous examples of military operations whose planning and execution were significantly affected by the natural environment. Perhaps the most famous of these is the D-day invasion of the European continent during World War II.[17] All major US/allied/coalition operations in the last 10–12 years (e.g., Southwest Asia, the Balkans, and now Afghanistan) have been impacted to varying degrees by the natural environment.[18] While everyone knows that the natural environment can impact operations, the nature and degree of those impacts and implications for subsequent military actions are not well documented. A notable exception to most publications is the book *Battling the Elements: Weather and Terrain in the Conduct of War* by Harold Winters and others. This book points out historical cases where weather, climate, and terrain had strategic-level impacts on the outcome of conflicts.

For the purposes of this paper, the term *strategic weather* is defined as the significant influence of weather and/or climate on a nation's (or coalition's) ability to attain its objectives while employing its military and other instruments of national power. A strategic weather impact can result from a long-term, cumulative effect (e.g., Russian winter during Napoléon's and Hitler's invasions), or a single, causative "strategic event" that suddenly changes the course and outcome of events (e.g., Operation Eagle Claw in 1980). A strategic weather effect should not be something that only historians can recognize in the gaze of 20–20 hindsight; it is something that ought to be considered in both short-term as well as long-term military planning.

Strategic, Operational, and Tactical Weather Organizations, Roles and Missions

It is important to examine the implications of the above definition, since it is the foundation for the discussion that follows. Note that strategic weather is not constrained by spatial or temporal considerations. This is significant because it suggests that a single event at a specific location and time can produce a strategic effect. While this is not an earth-shattering revelation in the study of military history, it has significance when one considers the future missions of a strategic weather center. Such an analysis is currently under way in AFW, which as a result of the 1997 reengineering has defined its production centers as strategic, operational, and tactical, with the accordant assumption that these centers are tied to primary support at those levels of warfare (see Terms and Definitions section). Figure 5 is a schematic representation of the types of products developed at the three types of centers, using a concept called the forecast funnel.[19]

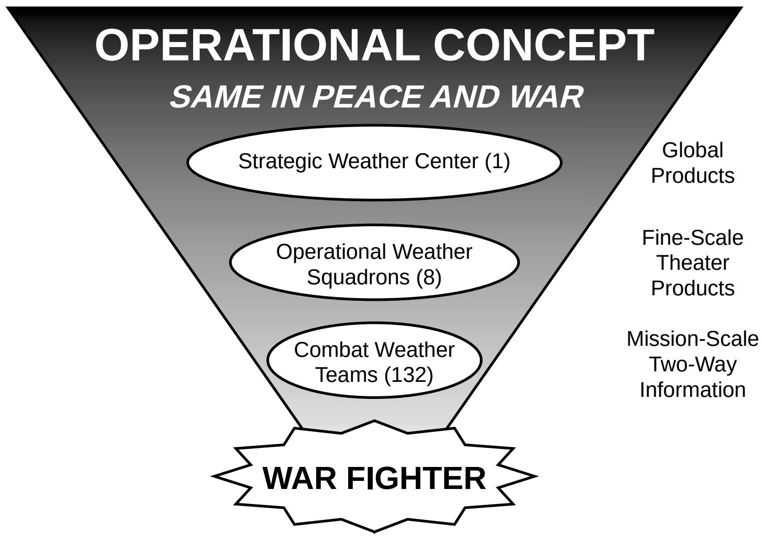


Figure 5. Forecast Funnel Concept

According to the forecast funnel, the strategic-level center is associated with large spatial and temporal-scale analysis and forecast products. At the operational level, the operational weather squadron (OWS)—a regional forecasting "hub" aligned with numbered air force or force supplier to the combatant command—adds more fidelity through development of its specific, theater-scale products. At the tactical level, small-scale forecasts are produced at the combat weather team (CWT), especially tailored for individual missions, platforms, and weapons being employed. As a result of the 1997 reengineering, considerable staff effort has gone into delineating the tasks of the OWS and CWT. However, for reasons that will be elaborated upon below, there has been little comparative effort into defining the roles of the strategic center in the reengineered AFW organization. The remainder of this paper shows how employing a long-range planning model to today's changing environment can allow us to make recommendations for strategic weather center roles as the DOD moves into the transformation era.

Strategic Weather Focus: Now and in the Future

The strategic center, known as the AF Weather Agency (AFWA), was formed in 1996 by the merger of AF Global Weather Central (AFGWC) and Headquarters Air Weather Service. According to its strategic plan, AFWA has two primary missions: accurate, relevant, and timely air and space weather information to DOD, coalition, and national users; and standardized training and equipment to Air Force Weather.[20] A close examination of AFWA reveals an organization with a combination of production center and staff agency responsibilities. First, as a production center, AFWA provides worldwide large-scale and fine-scale analyses and forecasts that are used as "starting-point" guidance for units at the operational and tactical levels. But, as suggested in the mission statement, the strategic center also provides direct operational and tactical-level products to DOD, coalition, and certain national users (this last group is a legacy of Cold War strategic program support). Second, as a staff agency function, AFWA includes strategic planning and management of technology programs for improving the accuracy and reliability of weather observations, analyses and forecasts, and standardization of training and equipment used throughout all of the AFW community.

While there is not much dispute concerning AFWA's staff agency functions, there is, however, considerable debate about AFWA's production side. Should it continue its myriad product lines geared towards users at the strategic, operational, and even tactical levels or become strictly a data production facility for large-scale, basic meteorological fields? Using the strategic weather definition provides justification for AFWA's traditional production roles, since both longer-scale trends (e.g., climate anomalies) and singular events can have strategic significance.[21] The discussion of the traditional weather production cycle and historical limitations on computing power and communications bandwidth also justified the necessity to centralize many high-visibility functions at the old AFGWC.[22] Given today's resource-constrained environment and the aforementioned advances in computing power, visualization, and satellite communications, this historical analogue can no longer be maintained, even if it is consistent with the strategic weather definition outlined in this paper. A look at both the modified weather production cycle from figure 4 and the forecast funnel concept of figure 5 suggest that AFWA should continue with long-term, large-scale products and services, and leave the shorter temporal and spatial scales to the OWS and CWT. The question here is if these constructs are adequate to frame the debate. In other words, are there new, "wide open markets" for weather or climate services that will be particularly relevant in the transformation era that we might be missing? In order to explore this question, it is necessary to employ another approach, one that recognizes the need to address the long view of today's military planners, some of whom are looking ahead as far as 25–30 years. This paper posits the need for a strategic planning model that can be used to analyze long-range documents such as the *Quadrennial Defense Review (QDR), National Military Strategy (NMS), Joint Vision (JV)* 2020, and service strategic plans and doctrine for emergent weather or climate vulnerability issues. Such an analysis will allow the future roles of the strategic center to be defined within the context of DOD transformation. It is beyond the scope of this paper to perform a comprehensive analysis for all the planning documents mentioned above. Instead this paper's planning model looks at the 30 September 2001 *QDR* report to describe an illustrative weather or climate issue from it and then outlines the necessary analysis that would need to be done to develop recommendations for future strategic center roles and missions over the next 10 years.

Planning Model and Its Application

As illustrated in figure 6, the proposed strategic planning model has three main stages: (1) an inputs stage in which strategic guidance, concepts, and doctrine are reviewed for possible weather and climatic considerations and implications; (2) an analysis and planning stage containing three substages, in which significant natural environmental impacts are analyzed, technology needs are identified, and force structures are proposed to integrate and apply the

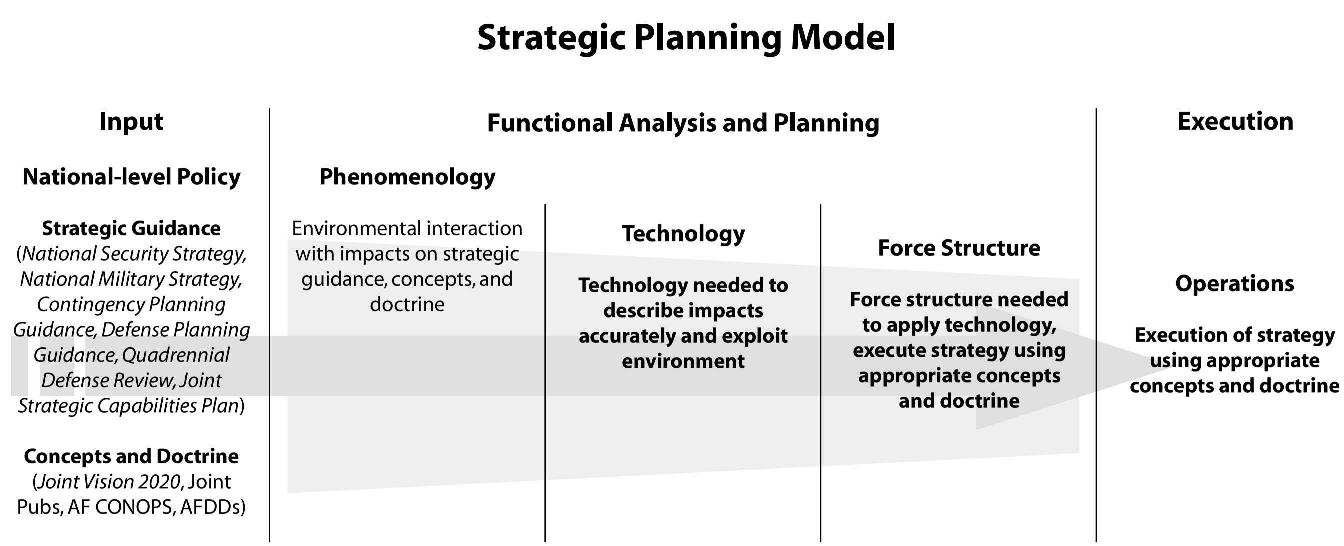


Figure 6. Strategic Planning Model

technology and accomplish the mission; (3) an operations stage in which the appropriate force structure applies the technology in order to execute the strategic concepts and doctrine.

Inputs

The planning model actually begins outside the field of consideration, by examining national-level policy and strategic concept documents such as the *National Security Strategy*, *NMS*, *QDR*, and *JV* 2020. The approach is to examine the broad concepts discussed in these planning documents while asking the following pertinent questions regarding potential problems with the interface between the natural environment and strategic-level planning concepts.

- What roles (if any) do weather and climate play in planning and executing this strategy?
- Are any portions of the national strategies potentially unrealistic in light of known weather and climatic limitations?

An Illustrative example can be drawn from the *QDR* report, which highlights forward deterrence as part of a paradigm shift in force planning. Specifically, the report states "Security cooperation will serve as an important means for linking DOD's strategic direction with those of its allies and friends. DOD will focus its peacetime overseas activities on security cooperation to help create favorable balances of military power in critical areas of the world and to deter aggression and coercion. A particular aim of DOD's security cooperation efforts will be to ensure access, interoperability, and intelligence cooperation, while expanding the range of pre-conflict options available to counter coercive threats, deter aggression, or favorably prosecute war on US terms."[23] In this passage and throughout the report, there is a proactive approach to national defense that emphasizes international security and regional actions to ensure that security. This is embodied by the stated US defense strategy of assuring friends and allies, dissuading adversaries, deterring aggression, and decisively defeating any adversary. Given today's uncertain world and the many potential causes of instability, combatant commands have many military and nonmilitary issues in the area of responsibility (AOR) with which to concern themselves. One approach that combatant commands have used to address these security concerns is the theater security cooperation plan (formerly known as theater engagement plan), which is an important component of peacetime strategy. An important component of this theater security cooperation involves environmental security, which can be described as an application of traditional definitions of security (i.e., safety from violence and military threats) to environmental concerns such as environmental degradation, lack of access to natural resources, et cetera.[24]

Analysis and Planning

A cursory examination of US Central Command, US European Command, and US Pacific Command environmental security programs reveals activities in each AOR addressing a broad range of issues from environmental remediation and pollution control to natural resource usage. But how applicable is this mission to AFW and the definition of strategic weather? This paper proposes that an emerging area of strategic weather support is those activities in the environmental security arena that address regional vulnerabilities and resource issues caused or influenced by single weather events or climatic anomalies. This proposal suggests that part of US "preventive" strategy in key regions should address those environmental issues that, if ignored, could become a contributing factor to or a catalyst for geopolitical destabilization and eventual military involvement (e.g., humanitarian relief, peace enforcement, and small-scale contingency). Developing such a capability would fill a large void that is not being addressed completely by any agency of the US government at present and would serve to support peacetime security cooperation strategies of combatant commands, agencies outside of DOD, and high-level decision makers such as the president, secretary of state, and secretary of defense. Given this void and the opportunity to fill it, what are AFW's technological and force structure capabilities in this area?

Phenomenology. The first analysis substage is phenomenology, where those potential weather or climatic considerations are identified from the national-level guidance and analyzed in terms of verifiable weather or climatic impacts. It is important to describe not only weather and climate conditions accurately in the theater but also to understand potential impacts on friendly and enemy systems, people, tactics, operations, and doctrine. Ultimately, we want to be able to predict the effects of the weather and climate just as accurately as the weather itself or, as a minimum, give decision makers some "robust scenarios" to consider. By using this application to environmental security, the analyst's next step would be to compile a list of known weather and climatic phenomena (e.g., drought, anomalies due to El Niño/La Niña, hurricanes or typhoons, and persistent flooding rains) that could potentially impact environmental security concerns in the different AORs. At this point, we need to assess our ability to monitor regional weather and climate properly given the amount of available data in different areas.[25] We may discover that abilities are very limited in certain regions, driving the analyst to identify a technological deficiency for the next substage of analysis and planning. While we may be able to analyze the current weather or climate in a region, we also need information about the infrastructure in order to make an accurate assessment of potential effects due to existing or impending weather phenomena. This assessment may reveal deficiencies in either understanding of how different phenomena affect the region of interest or inadequate knowledge of the region's infrastructure, again leading our analyst to move towards the next substage of analysis and planning to identify technology needs. The output of this substage ought to be a well-thought-out examination of potential new requirements—not proposed solutions. This is an important point because requirements are often mixed together with potential solutions in the same investigation—an ill-conceived approach that frequently produces disaster for future planners and programmers who might have to implement one or more incomplete solutions.

Technology. Once the requirements from strategic planning guidance analysis are evaluated, our present capabilities to satisfy those needs using present technology will be articulated. This is the substage where we identify technological deficiencies and areas for DOD science and technology (S&T) investment.[26] Technological deficiencies can fall into four areas: (1) needs for improving our understanding of the phenomenon; (2) needs for improving our understanding of the phenomenon's impact on the projected strategy; (3) needs for improving our prediction of the phenomenon; and (4) needs for improving our prediction of the phenomenon's impact on the projected strategy. Suppose that in the environmental security example, long-term drought and the influence of deforestation on regional climate are identified as needing further study. The next logical step would be to break down these phenomena to provide guidance for where the greatest S&T needs exist as illustrated in figure 7.

	Phenomena	**Effects**
Analysis	Can we analyze regional drought and deforestation?	Can we analyze regional drought and deforestation effects?
Prediction	Can we predict regional drought and deforestation?	Can we predict regional drought and deforestation effects?

Figure 7. Science and Technology Requirements Matrix Applied to Drought and Deforestation

If we have identified a requirement to improve our understanding of drought and deforestation's influence on regional climate, it follows logically that we would also need to improve our ability to predict these. In case of drought, the simulations used to model these entities encompass multiple physical domains (atmosphere, soil, and vegetation), suggesting investment in diverse S&T programs to address them. Deforestation and regional climate prediction are two areas that are very challenging to the scientific community. The deforestation problem also has the anthropogenic dimension to it, requiring a combination of interdisciplinary approaches to understanding it (e.g., remote sensing for monitoring change; multidomain physical simulations to model its effects on the atmosphere and biosphere; and economic, political, and sociological studies to understand its causes). The requirements analysis can quickly take us into areas outside of our functional purview. This action illustrates the planning model's flexibility and adaptability to other functional areas; it does not produce a weather-centric view with stovepiped solutions. Continuing the investigation, the need to understand the phenomena's effects on the region of interest could potentially lead to S&T requirements for developing interlinked cause-and-effect models (environmental, political, and economic) and geographic information systems that can be used to examine the region's infrastructure and identify vulnerabilities. Once the technology deficiencies have been identified, the S&T community will need to inform us of the resource requirements in terms of time, talent, and funding to produce potential solutions to our identified needs. This dialogue among the scientists, academicians, and military planners leads to the next substage of the analysis in which force structure requirements are examined.

Force Structure. In the force structure substage, we look at our present and projected resources (personnel and materiel) and evaluate our posture in terms of strengths and deficiencies identified in the previous two substages. As a development template, the planning model allows us to project integration of new analysis and prediction technologies into our operations and build the objective AFW force structure and operations concepts needed to apply the new technology and execute tomorrow's operations. The importance of saving the organizational considerations for the last part of the analysis cannot be understated. Many failed reorganization attempts were a result of putting the reorganization at the front of the analysis instead of looking at the current mission and process and future requirements and deficiencies first. We must build a force structure that optimizes our strengths and minimizes our vulnerabilities. Going back to the environmental security illustration, we must examine our organizational structure and personnel qualifications to see if AFW is postured to perform any of the tasks we identified in the previous substages. For example, in order to provide regional climatic monitoring, effects analysis, and prediction, it is likely that AFW would need to send selected personnel to the appropriate academic institutions to receive the graduate education and training necessary to work in this arena. It would also be necessary to examine the AFWA's ability to take on this new strategic weather mission. The AF Combat Climatology Center (a part of AFWA), located in Asheville, North Carolina, could be a likely organization in which to house this function, especially given their collocation with the National Climatic Data Center of the National Oceanic and Atmospheric Administration, and the Navy's Fleet Numerical METOC Detachment. All of these resource considerations would have to be investigated and fleshed out in order to determine the feasibility of taking on such a new and challenging mission area.

Operations

It is only after completing the analysis and planning stage do we enter the operations stage where we actually employ the technology and resources identified and developed in the previous stages. It is also in this stage that any lessons learned during routine and contingency operations are identified for evaluation in the analysis and planning stage, showing that the model is not a linear progression but a continuous process that is always being refined and updated.[27] The importance of this stage cannot be overlooked, because it provides a critical link between the operational community, and the acquisition and S&T communities that must be two-way. Importantly, the strategic planning model can be employed by any functional community to do long-range analysis and planning, since it takes an "outside in" approach to requirements analysis by starting with strategic guidance outside the functional specialty.

Conclusions and Recommendations

This paper examined AF weather and climate services at the tactical, operational, and strategic levels of warfare. It introduced a working definition for strategic weather and two conceptual models: the first model described weather product preparation at the operational and tactical levels, and the second model was used for long-term planning. This paper showed that in order to attain a truly consolidated "sight picture" of the battlespace, it is necessary to totally integrate the man-made and natural elements of the battle environment. Full integration of these factors at the tactical and operational levels was described as WISR. Implementation of WISR will optimize the target kill cycle F2T2EA by integrating robust natural environmental information from ISR platforms into the weather analysis and prediction database and providing real-time, relevant weather information to the cockpit during mission execution. WISR will enhance air forces' ability to execute predictive battlespace awareness and persistent ISR over the battlespace.

The strategic planning model was used to illustrate how national-level policy documents such as the *QDR* can be analyzed for emerging natural environmental issues at the strategic level. Using the preventive strategy outlined in the *QDR* 2001 report, we considered the importance of theater security cooperation plans to the combatant commands and how environmental security supports those plans. We discussed the need to develop regional weather or climate monitoring and prediction capabilities to support the combatant commands' environmental security programs and other high-level government decision makers. These services would help facilitate regional security and peacetime engagement by identifying fragile infrastructures vulnerable to prolonged climatic abnormalities such as persistent drought or singular natural disasters, especially hurricanes and typhoons. The importance of identifying such vulnerabilities lies in the potential for geopolitical instability given the right set of circumstances and events.[28] The model was then used to show how such an emerging mission requirement would necessitate science and technology investments, specific education and training requirements for personnel, and appropriate organizational changes at the strategic center in order to build the capabilities needed to support this emerging strategic weather mission area. The importance of saving the force structure decisions for the last step was emphasized, as well as the need for the operational and acquisition or laboratory communities to establish dialogue with one another during the operational stage.

There were several proposals developed as a result of the analysis in this paper. At the operational and tactical levels, the following recommendations are made.

- Develop and implement the ability to collect and transmit in-situ weather observations from any manned and unmanned platforms in the theater of operations.
- Develop and implement the ability to continuously assimilate the increased observational data stream into predictive models to build a four-dimensional METOC database from which tailored applications and decision aids can be developed and to provide environmental situational awareness through integration into the COP in the CAOC.
- Develop and implement the ability to deliver fine-scale, accurate, real-time weather impacts information to the cockpit in order to shorten the decision cycle for time-critical targeting actions.

At the strategic level, the following recommendations are made.

- AFW to implement the strategic planning model.
- Develop a capability to perform regional climatic monitoring and short-term (on the order of months) climatic prediction.
- Develop the capability to perform regional climatic impacts analysis and facilitate the integration of that information along with other types of demographic information for use by combatant command staffs, US government agencies, and high-level decision makers such as the president, secretary of state, and secretary of defense.

As DOD moves into the transformation era, it is time to look at old missions in new ways, develop capabilities for challenging new missions, and find ways to keep the peace in many troubled parts of the world. The new reality is that considerations of the combatant commands in their respective AORs include many nonmilitary as well as military concerns. Among these concerns are environmentally related issues such as water resources and threats to fragile infrastructures from natural disasters and climatic anomalies. This should be seen as part of an overall strategy to prevent wars so that we do not have to fight them. The challenges to AFW in this transformation are not unlike those encountered by our predecessors at the beginning of the Cold War and during the infancy of the US space program. AFW is no stranger to transformation. The mission ahead is to rise to the occasion with a combination of technology and those old-fashioned ethics that have always gotten the job done—ingenuity, flexibility, and persistence.

Notes

1. *Webster's Ninth New Collegiate Dictionary*, 1990, s.v. "transform."

2. For a thorough discussion of the different points of view concerning transformation, see Michael O'Hanlon, *Technological Change and the Future of Warfare* (Washington, D.C.: Brookings Institution Press, 2000), 7–31.

3. Colin Robinson, *Fact Sheet: DOD Office of Force Transformation* (Washington, D.C.: Center for Defense Information, 14 June 2002), n.p., on-line, Internet, available from http://www.cdi.org/mrp/oft.cfm.

4. Headquarters US Air Force Directorate of Weather, *Air Force Weather Reengineering*, n.p., on-line, Internet, available from https://www.xo.hq.af.mil/xow/XOW%20page.html.

5. See John M. Lanicci, "Integrating Weather Exploitation into Airpower and Space Power Doctrine," *Airpower Journal*, summer 1998, 54–56, for a discussion of how a combination of recent policy trends and challenging weather can put an increased strain on the ability of air and space power assets to execute its missions, n.p., on-line, Internet, available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj98/sum98/lanicci.pdf.

6. For brief descriptions of the F2T2EA, predictive battlespace awareness, and persistent ISR concepts, see *US Air Force Posture Statement 2002* (Washington, D.C., 2002), 12–13, 56–57, on-line, Internet, available from http://www.af.mil/lib/posture2002.pdf.

7. See, for example, Bruce R. Kitchen, "Meteorological and Oceanographic Conditions," *Joint Force Quarterly*, spring 1998, 38–43; and Joint Publication 3-59, *Joint Doctrine, Tactics, Techniques, and Procedures for Meteorological and Oceanographic Operations*, 23 March 1999, n.p., on-line, Internet, available from http://www.dtic.mil/doctrine/jel/new_pubs/jp3_59.pdf.

8. Air Force Doctrine Document (AFDD) 2-5, *Information Operations*, 4 January 2002, 35–36, on-line, Internet, available from https://www.doctrine.af.mil/Main.asp.

9. AFDD 2-5.2, *Intelligence, Surveillance, and Reconnaissance Operations*, 21 April 1999, 1, on-line, Internet, available from https://www.doctrine.af.mil/Main.asp.

10. Ibid., 2.

11. A brief history of the Air Force Command and Control and Intelligence, Surveillance, Reconnaissance Center (AFC2ISRC) can be found at http://www2.acc.af.mil/ac2isrc/History.asp.

12. Lt Col H. L. Massie Jr., Col D. C. Pearson, Maj K. S. Smith, and R. Szymber, "Knowing the Weather" (paper presented at the Battlespace Atmospherics Conference, US Army Research Lab, White Sands, N. Mex., 1995), 56.

13. Jeffrey T. Richelson, *The NRO Declassified* (Washington, D.C.: National Security Archive Electronic Briefing Book No. 35, 27 September 2000), n.p., on-line, Internet, available from http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB35/; and David A. Fulghum and Robert Wall, "U.S. Shifts Cyberwar to Combat Commands," *Aviation Week & Space Technology*, 26 February 2001, n.p., on-line, Internet, available from http://www.aviationnow.com/content/publication/awst/20010226/avi_stor.htm.

14. David Sauter, Mario A. Torres, Steve McGee, and Richard Okrasinski, "Leveraging Command and Control Technology to Provide Advanced Environmental Effects Decision Aids on the Battlefield," *5th International Command and Control Research and Technology Symposium*, 24–26 October 2000, Canberra, Australia, n.p., on-line, Internet, available from http://www.dodccrp.org/2000ICCRTS/cd/papers/Track5/066.pdf.

15. According to the *Air Force Handbook for the 107th Congress, Second Session*, p. 62, Smart Tankers are intended to "extend the Multi-Sensor Command and Control constellation while performing their primary air refueling mission; they are not a stand-alone C2ISR platforms (sic)." The idea being proposed in the present paper is to piggyback on these C2ISR initiatives by adding the capabilities to collect and transmit real-time weather observations from these and other aircraft operating in the region. Many commercial airliners today collect and transmit in-situ weather observations from on-board sensors.

16. Real-time information to the cockpit is a concept that has been around a long time. There are many different "flavors" of this program depending on the type of aircraft and its primary mission. There are a number of real-time weather-to-the-cockpit initiatives, primarily within the civilian community. The best starting point to learn about these programs is the *NASA Aviation Weather Information (AWIN)* homepage, at http://awin.larc.nasa.gov/overview.htm.

17. James Martin Stagg, *Forecast for Overlord, 6 June 1944* (New York: W. W. Norton & Co., 1971); Roger H. Shaw and William Innes, eds., *Some Meteorological Aspects of the D-Day Invasion of Europe, 6 June 1944: Proceedings of a Symposium, 19 May 1984, Fort Ord, California* (Boston, Mass.: American Meteorological Society, 1986); John F. Fuller, *Thor's Legion's: Weather Support to the US Air Force and Army 1937-1987* (Boston, Mass.: American Meteorological Society, 1990), 85–100; Harold A. Winters, *Battling the Elements: Weather and Terrain in the Conduct of War* (Baltimore, Md.: Johns Hopkins University Press, 1998), 23–32; and Charles C. Bates and John F. Fuller, *America's Weather Warriors: 1814-1985* (College Station, Tex.: Texas A&M University Press, 1986), 88–95.

18. General Accounting Office (GAO), *Operation Desert Storm: Evaluation of the Air Campaign: Report to the Ranking Minority Member, Committee on Commerce, House of Representatives/United States General Accounting*

Office (Washington, D.C.: GAO, 1997); and Department of Defense, *Kosovo/Operation Allied Force After-Action Report to Congress* (Washington, D.C.: DOD, 2000).

19. L. W. Snellman, *9th Conference Weather Forecasting and Analysis, 28 June-1 July 1982* (Seattle, Wash.: American Meteorological Society, 1982), 13–16.

20. Air Force Weather Agency, *2001/2002 Strategic Plan* (Offutt AFB, Nebr.: 8 May 2002).

21. See Fuller, 223. The author provides an interesting account of how several high-visibility missions were eventually consolidated at Air Force Global Weather Central (AFGWC).

22. Fuller, 375, 378–79. Fuller gives a good historical account of how computational costs influenced the centralization of computer forecasting functions at AFGWC.

23. *Quadrennial Defense Review Report*, 30 September 2001, 20.

24. Heather A. Smith, "Defining Environmental Security," *Journal of Military and Strategic Studies*, winter 2000/spring 2001, n.p., on-line, Internet, available from http://www.stratnet.ucalgary.ca/journal/article3.html.

25. There is a great amount of interest in the scientific community in climate monitoring and prediction, although much of this stems from issues such as global warming. See Richard Goody et al., "Why Monitor the Climate?" *Bulletin of the American Meteorological Society*, June 2002, 873–78.

26. It should be noted that there might exist S&T programs in other sectors of the government, academia, or private industry that can address our technology needs, in which case it would be those DOD-specific requirements that may require S&T investment.

27. One of the more spectacular lessons learned came from World War II, when persistent operational problems encountered during strategic bombing campaigns in Europe and the Pacific led to the "discovery" of the jet stream. For more on this topic, see Fuller, 201–2; and Norman A. Phillips, "Carl-Gustaf Rossby: His Times, Personality, and Actions," *Bulletin of the American Meteorological Society*, June 1998, 1097–1112.

28. A seminal reference in this area is Thomas F. Homer-Dixon, *Environment, Scarcity, and Violence* (Princeton, N.J.: Princeton University Press, 1999).

Terms and Definitions

climate. The composite or generally prevailing weather conditions of a region, throughout the year, averaged over a series of years. (C. David Whiteman, *Meteorology Glossary,* 1999). Available from http://www.geog.ubc.ca/courses/geog102/Resources/G102Glossary.html.)

operational level of war. The level of war at which campaigns and major operations are planned, conducted, and sustained to accomplish strategic objectives within theaters or areas of operations. Activities at this level link tactics and strategy by establishing operational objectives needed to accomplish the strategic objectives, sequencing events to achieve the operational objectives, initiating actions, and applying resources to bring about and sustain these events. These activities imply a broader dimension of time or space than do tactics; they ensure the logistic and administrative support of tactical forces, and provide the means by which tactical successes are exploited to achieve strategic objectives. (Joint Publication [JP] 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 12 April 2001 as amended through 14 August 2002.)

strategic level of war. The level of war at which a nation, often as a member of a group of nations, determines national or multinational (alliance or coalition) security objectives and guidance, and develops and uses national resources to accomplish these objectives. Activities at this level establish national and multinational military objectives; sequence initiatives; define limits and assess risks for the use of military and other instruments of national power; develop global plans or theater war plans to achieve these objectives; and provide military forces and other capabilities in accordance with strategic plans. (JP 1-02)

tactical level of war. The level of war at which battles and engagements are planned and executed to accomplish military objectives assigned to tactical units or task forces. Activities at this level focus on the ordered arrangement and maneuver of combat elements in relation to each other and to the enemy to achieve combat objectives. (JP 1-02) weather. The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, et cetera. It should be noted that in the context of this paper, the atmosphere is defined to include the region extending into the near-space environment, thus allowing for consideration of space weather in our analyses. (Whiteman)