DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates military environmental services to provide specialized worldwide meteorological, space environmental and oceanographic analysis, and prediction services in support of military forces and joint operations. Military environmental services directly support all phases of military operations from strategic planning to tactical operations. While the Army and Marine Corps each have small weather operations capabilities, the Navy and Air Force are the primary sources of military weather products and services. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite Program to meet unique military requirements. Observational data are sent through military communications systems to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL AND SPACE ENVIRONMENTAL SERVICES

Air Force weather forces provide high-quality, mission-tailored terrestrial and space environment observations, forecasts, and services to the U.S. Air Force (USAF), U.S. Army (USA), and a variety of U.S. Government (USG) departments and agencies. AF weather is in the process of transforming their support to the USA by integrating forecasting tools into Distributed Common Ground System-Army, developing an Army weather concept of operations, and increasing sensing capability in Operation IRAQI FREEDOM (OIF) and Operation ENDURING FREEDOM (OEF). See Section 3, U.S. Army, for details of Air Force weather support to the Army.

AF WEATHER ORGANIZATION

AF weather is functionally organized under the Director of Weather (AF/A3O-W), Directorate of Operations (AF/A3O), Deputy Chief of Staff, Operations, Plans, and Requirements (AF/A3/A5), Headquarters Air Force. The Director of Weather oversees Air Force-wide training, organizing, and equipping of AF weather organizations to include the following functions:

- Development of doctrine, policies, requirements, and standards for weather support
- Evaluation of weather support effectiveness
- Management of weather officer, enlisted, and civilian career fields
- Development and implementation of mid- to long-range plans for the organization, equipment, manpower, and technology necessary to meet future Air Force and Army weather requirements
- Advising Air Staff and subordinate headquarters weather functional managers regarding manpower, career field management, personnel utilization, training, operations policy and procedures, and technology acquisition
- Advocating and fielding standardized weather equipment

AF weather operations provide a Total Force capability employing over 4,100 Active Duty (AD) and Reserve Component (RC) military and civilian personnel supporting Air Force and Army conventional and Special Operations Forces (SOF) worldwide. The majority of AF weather personnel are focused on two distinct, yet related functions: characterizing the past, current, and future state of the natural environment, and exploiting environmental information to provide actionable environmental impacts information directly to decision-makers.

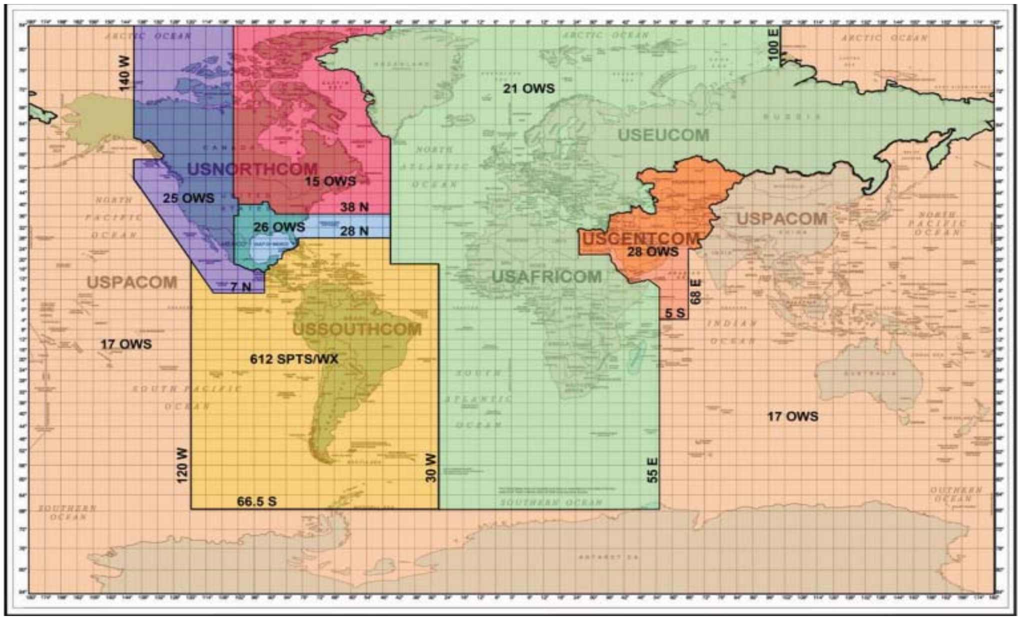
AF weather is organized in a 3-tier structure to maximize capabilities that can be accomplished in the rear area via reach back technology. This minimizes forward presence on the battlefield, making a "light and lean" presence consistent with the overall USAF vision for contingency operations in the 21st century. For the first time, AF weather is pursuing formalized Tactics, Techniques, and Procedures (TTPs). TTPs are commonplace throughout the AF, and developing these standardized tools will help AF weather deliver timely, accurate, relevant, and consistent products and support when and where needed. AF weather is working with the AF Manpower Agency to complete and implement capabilities-based man-power standards and documenting missions and units supported which will further ensure the AF has weather personnel at the right place at the right time. Another initiative underway is in the area of metrics. The goal is to provide verification information on systems, weather warnings, terminal forecasts, mission execution forecasts, and model performance, that will assist AF weather leadership and the AF to make informed decisions concerning the Air Force Weather Weapon System (AFWWS), including the equipment, software, and various tools necessary to deliver the five core processes of collection, analysis, prediction, tailoring, and integration. Environmental characterization is typically accomplished in large, centralized units focused primarily on global and regional scales of weather, whereas support to decision-makers is primarily the realm of personnel embedded in operational units. Normally, these personnel are assigned to weather flights under the operations support squadron of a flying wing, a weather squadron collocated with a supported Army unit, or a weather squadron providing a unique capability such as space launch support. These weather squadrons may include geographically separated detachments and operating locations.

The centerpiece of global-scale collection and production is the Air Force Weather Agency (AFWA), Offutt AFB, NE, a field operating agency reporting directly to the Air Force Director of Weather. AFWA provides timely, accurate, relevant, and consistent terrestrial and space weather products necessary to effectively plan and conduct military operations at all levels of war. AFWA operates a satellite data processing center and a centralized climatology center with the largest military archive of meteorological data in the world. The agency runs numerical weather prediction models, conducts global cloud and snow analysis, and runs cloud models. AFWA also maintains a global database, and provides dedicated support to SOF and the Intelligence Community (IC). The agency consists of a functional management headquarters; the 1st Weather Group (1 WXG) with three subordinate CONUS operational weather squadrons (OWS); the 2nd Weather Group (2 WXG), which operates three squadrons, two at Offutt and one at Asheville, NC, as well as five detachments and operating locations; and, the Air Force Combat Weather Center at Hurlburt Field, FL, which transitions technology to support tactical-level weather operations while developing operational concepts, tactics, techniques, and procedures.

The 1 WXG commands three operational weather squadrons performing CONUS missions: 15 OWS at Scott AFB, IL, 26 OWS at Barksdale AFB, LA, and 25 OWS at Davis-Monthan AFB, AZ. The 2 WXG, collocated with HQ AFWA at Offutt AFB, NE, consists of the 2nd System Operations Squadron (2 SOS) which provides automated weather characterization on a global scale, the 2nd Weather Squadron (2 WS) which provides global coverage of forecaster-in-the-loop products to exploit the weather as well a backup for four national weather centers (Space Weather Prediction Center, Washington-Volcanic Ash Advisory Center, Storm Prediction Center, and Aviation Weather Center), and the 14th Weather Squadron (14 WS) at Asheville, NC, which provides centralized climatological database services, produces specialized weather-impact information for the Department of Defense and allied nations, and warehouses and distributes atmospheric science-related technical information. Current plans are to transfer backup for the Storm Prediction Center and Aviation Weather Center from 2 WXG to 1 WXG.

Six operational weather squadrons form the backbone of regionally focused weather operations, providing a variety of weather forecast products and support to units assigned to and/or deployed into their Area of Responsibility (AOR). These AORs are depicted in Figure 3-DOD-1. OWSs produce and disseminate terminal aerodrome forecasts, weather watches, warnings, and advisories, planning and execution area forecasts, and other products using the OWS Production System Phase II (OPS II) until they receive the Joint Environmental Toolkit (JET). JET

Figure 3-DOD-1. Air Force Operational Weather Squadron (OWS) areas of responsibility (AORs) overlaid on geographic combatant commander AORs.



fielding began in summer 2008 and will be complete in the fall of 2009. OWSs also provide theater-scale, tailored environmental information to guide development of mission execution forecasts by AC and RC weather personnel embedded in operational units. Moreover, OWSs provide flight weather briefings to aircrews operating within their AOR without home station support or as requested by base or post-level weather forces.

At the base and post level, weather forces provide and disseminate observations and develop tailored mission execution forecasts based on centrally produced guidance. These personnel also act as "eyes forward" for their supporting OWS. Weather personnel supporting conventional AF operations typically deploy with a New Tactical Forecast System (N-TFS), which is being upgraded to the Joint Environmental Toolkit (JET) starting in mid 2008, the TMQ-53 tactical observing system for semi-permanent sites, and hand-held Kestrel observing kits. This equipment, coupled with robust communications to receive weather data including satellite imagery, provides the essential capability required for deployed weather forces to meet operational requirements.

The Reserve Component (RC) is composed of the Air Force Reserve Command (AFRC) and the Air National Guard (ANG). AF weather continues to integrate these forces to more closely align with Active Duty (AD) weather force operations. Air Force RC weather personnel augment the AD at all levels. In some cases, the RC provides very unique weather related services not duplicated in the AD force, such as AFRC's 53d Weather Reconnaissance Squadron (53 WRS) and the ANG's Weather Readiness Training Center (WRTC).

To augment OWS operations, AFRC organized two operational weather flights (OWF), each staffed by AFR weather personnel, capable of augmenting an OWS either in the CONUS or overseas. Additional AFR weather personnel serve as individual mobilization augmentees (IMAs) assigned to various active AF weather organizations at all echelons, typically in staff, forecasting, or scientific roles. There are also AFR weather personnel in Air Reserve Technician positions, i.e., combined full-time Civil Service/AFR military positions, employed by the 53d WRS as Airborne Weather Reconnaissance Officers. Lastly, AFRC contract weather personnel provide weather services at AFRC-operated bases in the CONUS.

The ANG traditional program consists of 27 numbered weather flights, ranging in size from 13 to 25 personnel, who meet monthly to train for their wartime mission. These flights provide weather support to ANG and Army National Guard units. ACC-gained ANG wings also have up to four traditional weather positions to provide weather operations for each wing's flying mission. In addition, there are traditional weather positions in two ANG Special Tactics Squadrons (AF Special Operations Command), and four ANG UAV units (Predator). The ANG also has 7 contract and 4 civil service locations where they are responsible for providing peacetime weather support to airfield operations. The WRTC at Camp Blanding, near Starke, FL, provides weather force operations training.

CHARACTERIZE THE ENVIRONMENT

To characterize the environment across the globe, AF weather forces continually improve the core processes of collection, analysis, and prediction.

Collection

AF weather forces collect terrestrial and space environmental measurements from ground-, sea-, air-, and space-based sensors across the globe. While openly shared foreign data greatly improves the coverage of measurements across the globe, the Department of Defense retains an assured global weather collection capability. In regions where air, space, and land operations are occurring, environmental data may be insufficient; consequently, the AF maintains a capability to deploy and establish an in-theater environmental data collection network.

AF weather personnel provide observations essential for effective military operations. Weather personnel at both Air Force and Army locations (garrison and deployed) oversee automated observations and ensure they're available to local users and transmitted to a centralized database where they are assessable at military and civil locations throughout the world for subsequent weather analysis and forecasting. U.S. and foreign rawinsonde reports are primary sources of upper air observations. These observations are supplemented with military and civilian pilot reports. The Army's automated and limited observations and their artillery meteorology (ARTYMET) program augment Air Force observations in the tactical environment.

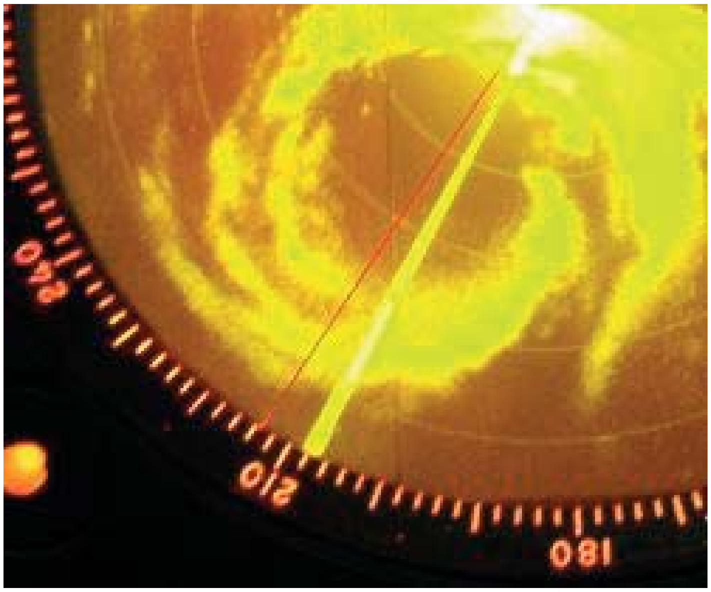
The Observing System 21st Century (OS-21) program is providing a much-needed, state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. AF weather completed fielding 110 of the original automated fixed-base systems, AN/FMB-19, in FY 2007, and will continue fielding the follow-on fixed-base automated observing system, AN/FMB-22, with 30-40 systems to be initially installed through 2010. These automated systems are enabling AF weather personnel to devote more time to tailor and integrate weather into war fighter operations.

The AN/FMB-22 is intended to be installed at supplementary aerodromes such as heliports, training fields and testing areas, and certain other airfields. It has many of the same components as AF weather's deployable automated observing system (TM-53), hard-mounted on a pole mast for permanent installations. Government Developmental Test and Evaluation (GATE) will began during summer of 2008; upon completion of testing, AF weather anticipates to begin installations in early FY 2009.

AF weather is in the process of procuring "Weather Pod" observing systems that will be fielded as the remote expendable OS-21 configuration in support of AF and Army operations. They will be used to take observations at locations where AF weather personnel are deployed as well as at locations where there are typically no weather personnel, such as forward operating bases and forward air refueling ports. The Weather Pods may also be placed along select flight routes and other locations of particular weather interest. As a COTS system, the weather pods will undergo a limited operational utility evaluation (OUR) during summer 2008, with fielding anticipated to begin in either late FY 2008 or early FY 2009. Components of the weather pod system include a primary weather pod sensor that senses temperature, dewpoint, wind, and atmospheric pressure, a ceiling pod that senses cloud coverage up to 5,000 ft, both coupled with a satellite communications pod that will automatically relay weather data to ADWA. In addition, the contractor is currently developing a visibility pod enhancement that will sense horizontal visibility. The visibility pod should be available for OUE in early FY 2009.

Weather radar data is vital to the production of timely severe weather warnings. DOD, the Federal Aviation Administration (FAA), and Department of Commerce (DOC)/National Weather Service (NWS) operate and maintain WSR-88Ds within CONUS, and the Air Force operates and maintains WSR-88Ds overseas. Tactical weather radars (TWRs) provide fixed Doppler radar coverage for four major overseas installations not covered by the WSR-88D. Currently Ellason weather radars (EWRs) provide a deployable weather radar capability for worldwide military contingency operations. Based on the desire to consolidate the TWR and EWR programs and improve the overall capability and deployability of fielded weather radars, AFW initiated acquisition of a new Portable Doppler Radar (PDR) in early FY 2008. Following source selection, AF weather anticipates the PDR to undergo OUE in early FY 2009,

Figure 3-DOD-2. Aircraft radar shows the eye of Hurricane Claudette is 25 nautical miles wide and the wall cloud is weakest in the northeast quadrant. (53 WRS Web site)



and fielding to begin later in FY 2009. Weather radar data extracted from air surveillance radars and displayed using the Digital Weather Intelligence Data system supplement primary weather radar data, and provide data from areas without primary weather radar coverage.

The AFRC's 53 WRS, also known as the "Hurricane Hunters," provides another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially equipped WC-130J aircraft collect temperature, moisture, wind, pressure, and visually observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropsondes. Hurricane Hunter aircraft penetrate the eyes of tropical cyclones to provide the National Hurricane Center a very accurate center fix location as well as other meteorological parameters, including sea level pressure (Figure 3-DOD-2). In addition to the tropical cyclone reconnaissance, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts and to support scientific field programs when possible.

The Defense Meteorological Satellite Program (DMSP), which provides cloud, upper air, and space environmental data, is a vital source of global weather data used to support combat operations. Onboard sensors provide AFWA and the Navy's Fleet Numerical Meteorology and Oceanography Center with visible, infrared, and microwave imagery, temperature and moisture sounding data, electrically charged particle fluxes, and other specialized space environment data. The DMSP also supplies direct, real-time readouts of regional imagery and mission-sensor data to DOD land-based and shipboard terminals located worldwide (Figure 3-DOD-3).

AF Weather plans to expand the integration of MARK IVB data into cloud models. In addition, AF Weather initiated an effort to expand the MARK IVY program, which consists of equipment to download, disseminate, and analyze meteorological satellite data, to acquire X-band Moderate Resolution Imaging Spectroradiometer (MODIS) data from Terra and Aqua satellites in mid FY 2008. Anticipated to take approximately 18 months, the X-band upgrade will not only provide immediate access to MODIS data, it will also prepare AF weather and AFWA for the NPOESS era as a first step toward the NPOESS Preparatory Project.

The DMSP satellite constellation uses the Operational Linescan System to provide visible and infrared imagery to distinguish between clouds, ground, snow, and water. The Block 5D-2 series spacecraft flies the Special Sensor Microwave Temperature SSM/T-1) and water vapor (SSM/T-2) sounders. Processing algorithms convert the sensed

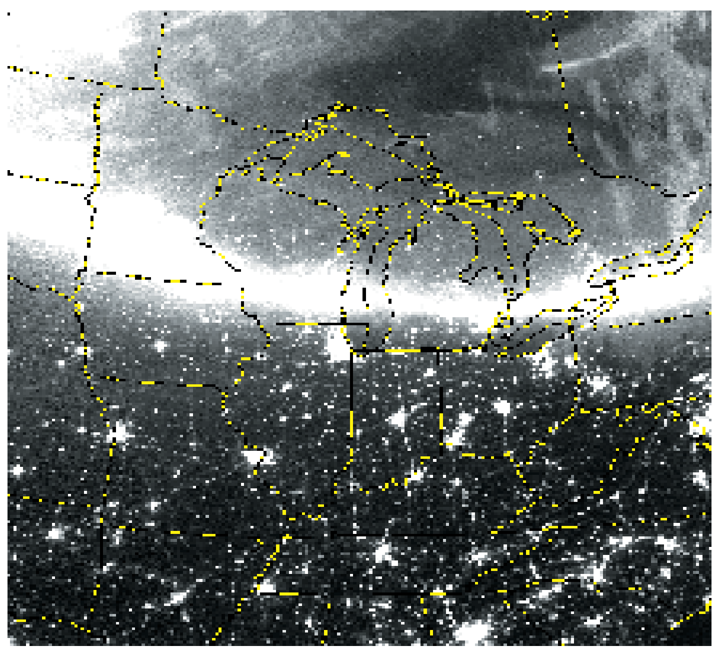


Figure 3-DOD-3. Aircraft radar shows the eye of Hurricane Claudette is 25 nautical miles wide and the wall cloud is weakest in the northeast quadrant. (53 WRS Web site)

data into vertical temperature, moisture, and height profiles of the atmosphere, providing key data for numerical analysis and forecasting. The Special Sensor Microwave Imager (SSM/I) collects data from which rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data can be determined. The Special Sensor for Ions, Electrons, and Scintillation (SSIES), Special Sensor Magnetometer (SSM), and the Precipitating Electron and Ion Spectrometer (SSJ), measure the space environment on the topside of the ionosphere in situ. The Block 5D-3 series spacecraft and sensor suite began service in 2004 with the launch of DMSP Flight 16. These spacecraft add several new capabilities: enhanced microwave imaging and atmospheric temperature/moisture sounding through the Special Sensor Microwave Imager/Sounder (SSMIS); new auroral boundary and electron density measuring capability through the Special Sensor Ultraviolet Spectrographic Imager (SSUSI); and, profiles of upper-atmospheric temperature, electron content, and species densities through the Special Sensor Ultraviolet Limb Imager (SSULI). These are in addition to SSIES, SSM, and SSJ sensors.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) will replace the existing DMSP and NOAA polar-orbiting satellite programs beginning in 2013 and is a joint DOD, DOC, and National Aeronautics and Space Administration (NASA) program. The AF also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program planned for launch in 2010. In January 2006, the program was expected to exceed its approved program baseline by 25 percent. This required the Department of Defense to recertify the program to Congress in accordance with the Nunn-McCurdy Amendment of the 1982 Defense Authorization Act. AF weather provided information on operations and requirements to Integrated Product Team 2 (IPT-2). IPT-2 was charged with assessing alternatives for the program. The certification resulted in a reduced configuration. One of three orbits was eliminated and will be augmented by the polar-orbiting constellation of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The number of satellites was reduced from six to four. Some non-Key Performance Parameter sensors were removed and the Conical Microwave Imager/Sounder was terminated and will be reworked.

In addition to DMSP polar-orbiting data, AFWA receives stored data from the DOC's Polar-orbiting Operational Environmental Satellite constellation and real-time high-resolution data from the DOC's Geostationary Operational Environmental Satellite (GOES) East and West; EUMETSAT's Meteosat-5, -7, -8, and -9 geostationary satellites; and the Japanese Multifunctional Transport Satellite (MTSAT). AFWA currently receives data from NASA's Tropical Rainfall Measuring Mission (TRMM), Quick Scatterometer (QuikSCAT), and Aqua Advanced Microwave Scanning Radiometer-E (AMSR-E) via Direct Asynchronous Transfer Mode (ATM) System-Unclass (DATMS-U). MODIS data is received via the Defense Research Engineering Network (DREN), transitioning to DATMS-U in 2008.

Next generation satellite programs, in particular NPOESS and GOES-R, require that AFWA reengineer the way it receives, stores, and processes meteorological satellite (METSAT) data, as well as how it exposes and delivers that data to internal and external users. AFWA has been partnering with Electronic Systems Center (ESC) on the METSAT Data Exploitation Capability (MDEC) program. The MDEC is the METSAT portion of Weather Data Analysis (WDA). The METSAT database segment, JMSAT, will be delivered in WDA increment 4A, which is expected to be on contract in CY 08. The MDEC will engineer and implement state-of-the-science solutions and define the "to be" enterprise software and system architecture for optimal exploitation of METSAT data from current and future programmed satellites.

Space environmental information is obtained through a combination of ground- and space-based systems. For the near-Earth environment, i.e., ionosphere, ground-based systems provide highly accurate point source verification and specification, whereas space-based systems enable global coverage and theater-wide situational awareness. For solar data, ground-based systems provide reliable observations of the sun in optical and radio frequencies, and space-based observations measure frequencies unobtainable from the ground. Space-based systems provide in situ measurements of the space environment, i.e., solar wind, magnetosphere. AF weather has outlined plans to modernize ground-based space sensing in a space weather implementation plan and is collaborating with U.S. and Allied government and civilian agencies to achieve a robust space sensing capability.

AFWA operates the Solar Electro-optical Observing Network (SEON), a system of ground-based telescopes at Sagamore Hill, MA, Holloman AFB, NM, Palehua, HI, San Vito, Italy, and Learmonth, Australia (Figure 3-DOD-4). This network provides 24-hour observations of solar phenomena at optical and radio wavelengths. A worldwide network of ground-based ionosondes and other sensors provide ionospheric data. The AF manages 14 automated Digital Ionospheric Sounding Systems (DISS) to measure electron density profiles in the ionosphere. AFWA funds a 27 International Ionosonde site database at the National Geophysical Data Center (NGDC) in Boulder, CO. NASA's Jet Propulsion Laboratory operates a complementary global network of over 125 sensors deriving ionospheric line-of-sight total electron content from global positioning system (GPS) signals and provides these data to AFWA's 2 WS Space Weather Flight. In addition, the U.S. Geological Survey operates a network of ground-based magnetometers, primarily in the northern hemisphere, which provides the Space Weather Flight with critical measurements of the geomagnetic field and its variances. The Air Force Research Laboratory at Hanscom AFB, MA, provides ionospheric scintillation data from a global network of 22 UHF and L-Band receivers, supporting AF C2 satellite systems and strategic long-range radar systems.

Figure 3-DOD-4. Solar optical and radio telescopes at Learmonth, Australia. (US Air Force Released)

From space, the GOES satellites provide real-time solar X-ray, charged energetic particle, and geomagnetic data through the Space Weather Prediction Center (SWPC). The Solar X-Ray Imager, aboard GOES-12, monitors solar emissions in the X-ray portions of the solar spectrum and provides near real-time display at AFWA and the SWPC. DMSP, NOAA, and other DOD satellites provide charged energetic particle data in low-Earth and geosynchronous orbits. Additionally, the AF leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer satellite provides real-time solar wind data critical for forecasting geomagnetic disturbances and their impact to warfighter communications.

Analysis and Prediction

Effective analysis of collected terrestrial and space weather data enables identification of environmental features and conditions that may affect air, space, and land operations and thus require subsequent monitoring. From that analysis, detailed forecasts are developed through a combination of computer models and skilled human intervention.

AFWA's 2 SOS is the AF's main automated production capability for global space and terrestrial weather analyses and forecasts. Worldwide conventional weather data are relayed to 2 SOS and combined with civil and military meteorological satellite data to construct an integrated environmental database. Computer programs further process the data to construct models of the atmosphere and forecast its future behavior.

The Global Theater Weather Analysis and Prediction System (GTWAPS) is the AFWA hardware enclave (IBM Scalable Parallel Computing and pSeries® servers) used to run most meteorological models at AFWA. The key software component of GTWAPS is a theater analysis and forecast model which provides fine-scale forecasts (Figure 3-DOD-5). AFWA transitioned from Mesoscale Model version 5 (MM5) to the Weather Research and Forecasting (WRF) model as its operational theater scale model in 2008. WRF has the ability to interchange different microphysics modules within the model. AFWA is leveraging this capability to tailor model output for different worldwide operational theaters,

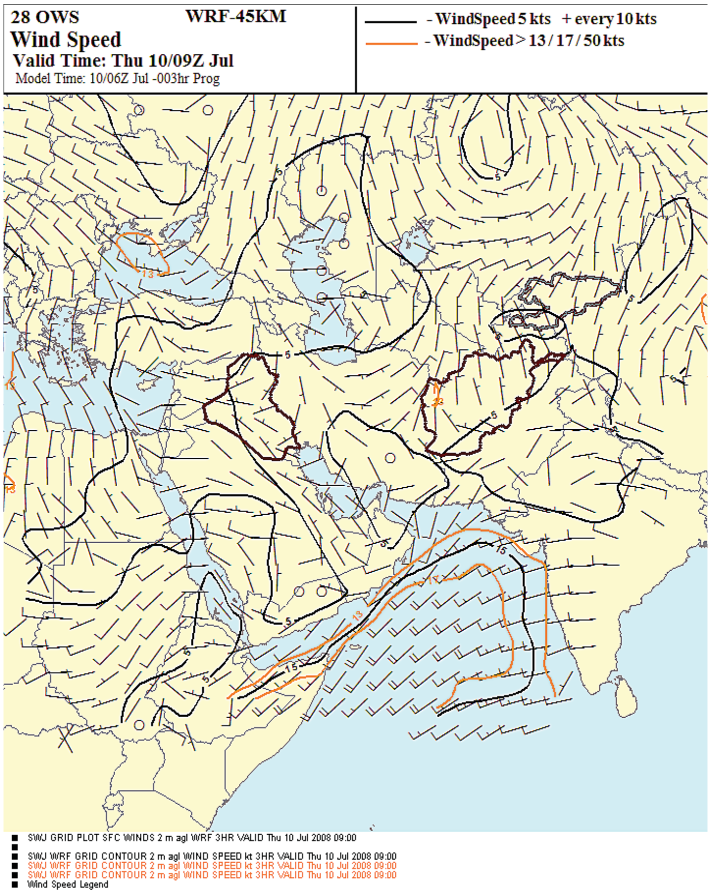


Figure 3-DOD-5. Joint Air Force and Army Weather Information Network (JAAWIN) provide reachback capability for deployed weather forces. This 3-hour forecast of surface winds over Southwest Asia was generated from AFWA's 45-km WRF (AFWA Web site)

while leveraging NCEP's WRF model output for the Alaska and CONUS regions.

During Operations ENDURING FREEDOM and IRAQI FREEDOM, AFWA initiated various model window locations and resolutions as mission requirements dictated. The highly responsive nature of the WRF model, and the way AFWA employs it, permitted new contingency windows to be operational within hours. Advancements in cloud modeling have enabled GTWAPS to produce high-resolution products that have become a mainstay of weather data during the continuing Global War on Terror.

Ongoing modernization initiatives at AFWA include the Space Weather Analysis and Forecasting System (SWAFS) and the WDA program. SWAFS will integrate additional space weather data sources and execute next-generation space weather models for DOD and IC operations. WDA will continue the modernization of AFWA as a key component of the AFWWS. The transformed AFWA will provide standardscompliant hardware and software tools, a central 4-D database, and a classified processing environment to modernize the AFWWS communications and data processing infrastructure. WDA provides a significant increase in the database capability by standing up Joint DOD-approved meteorological and oceanographic (METOC) database segments, promoting interoperability among data sharers. WDA, using the Joint METOC segments and the Joint METOC Broker Language (JMBL) for web services, will improve the interoperability with DOD C2 and command, control, communications, computer, intelligence, surveillance, and reconnaissance (C4ISR) systems by providing a common interface to request the wide range of weather information. In addition, WDA-developed components, including the Consolidated Dissemination Capability (subscription services), are reusable within the OWS. This reusability will allow OWS-unique data to become part of the overall AFWWS 4-D database.

Also in the area of analysis and prediction, AF weather is modernizing cloud forecasting capabilities to support AF and Army operations and to enable "find, fix, track, target, engage, and assess", by leveraging the Aerospace Corporation, NWS, NCAR and ARL. These efforts, combined with those underway to improve the Cloud Depiction and Forecasting System (CDFS) II capability, will ensure the AF continues as a center of excellence in cloud forecasting.

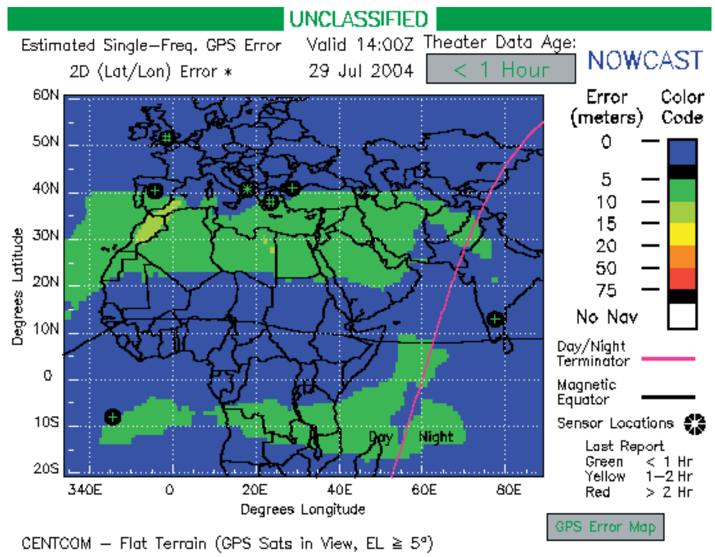
AFWA's 2 WS METSAT Flight analyzes imagery, produces rapid response, tailored METSAT imagery for DOD contingency operations, and generates automated METSAT imagery products for web-based distribution to DOD users. The flight also serves as the DOD focal point for volcanic ash plume detection, advisories, and trajectory forecasts; and provides back up for both Joint Typhoon Warning Center (JTWC) satellite operations and the DOC's Washington Volcanic Ash Advisory Center. In addition, the METSAT Flight produces worldwide snow and ice cover analyses to update and refine the snow depth database and generates customized snow depth and dust event analyses for contingency areas. The flight also develops new capabilities to display and visualize satellite imagery on workstations and infuses state-of-the-art techniques into improved imagery analysis. Finally, the flight recently stood up a cell that focuses on SW Asia, highlighting areas of cloud, dust, and other obscurants.

As the sole source of DOD space environmental characterization and forecasting, AFWA's Space Weather Flight partners with NOAA's Space Weather Prediction Center to meet the Nation's military and civilian space weather needs and provide a suite of automated and manually tailored analyses and forecasts (including advisories and warnings) of space weather phenomena that affect military operations and IC activities. Similarly, forecasts of signal fades due to space weather effects on UHF satellite communications links provide valuable planning information to improve C2 capabilities. Further examples of model output informational products include Single-Frequency GPS Receiver Error maps (Figure 3-DOD-7), UHF Satellite Communication Scintillation maps (Figure 3-DOD-8), HF Illumination maps (Figure 3-DOD-9), and Radar Auroral Clutter maps. These products assist warfighters in determining and mitigating space weather impacts to their systems as well as in exploiting enemy space weather susceptibilities for possible asymmetric advantage.

The 2 WS Space Weather Flight employs a suite of state-of-the-art space weather models to specify current solar and global characteristics, extrapolate space weather phenomenon to areas of the globe where observations are not currently available, and to forecast future conditions. These models use available observations and include both climatology-based and physics-based algorithms. Information on the more significant models employed is included in this paragraph. A Kp analysis and prediction algorithm provides realtime analysis of Kp and 1- and 4-hour predictions. A Dst prediction algorithm provides a 1-hour Dst forecast. The Global Assimilation of Ionospheric Measurements (GAIM) model provides large scale, global ionospheric specification every 15 minutes and a 24-hour forecast capability every hour. The climatology-based WIDEBAND model provides scintillation forecasts. The flight uses the Magnetospheric Specification and Forecast Model to specify and predict (for 3 hours) the lower energy particle environment. The Radiation Belt Environments model provides specification of the higher energy particle environment. The relativistic Electron Prediction model provides a 27-day prediction of relativistic electron behavior at geostationary altitude. For the solar wind, the flight uses the Hakamada-Akasofu-Fry solar wind model, capable of producing a 96-hour forecast of solar wind parameters, including the tracking of Coronal Mass Ejections. Several other applications are also employed to calculate other important space weather related parameters.

The 14 WS fills a critical role in AF weather's core processes of analysis and prediction. The 14

Figure 3-DOD-6. Single-Frequency GPS Receiver Error Map (visualization by HQ AFWA)



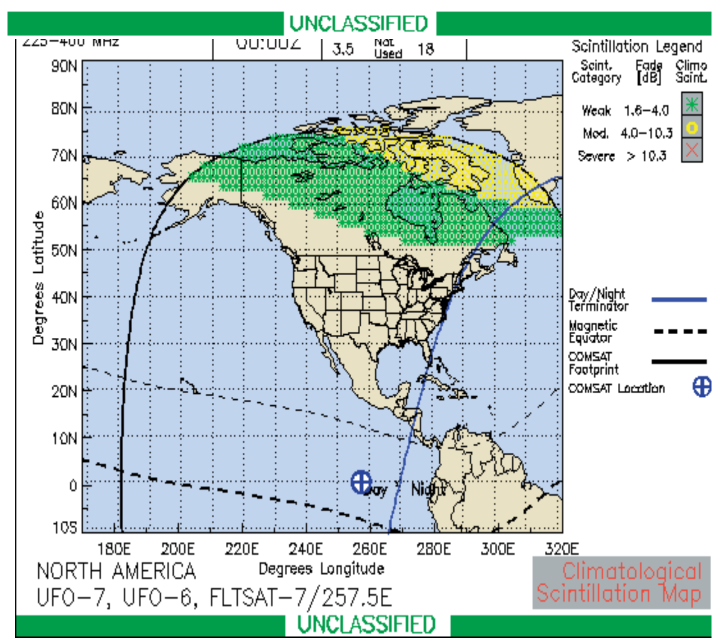


Figure 3-DOD-7. UHF Satellite Communications Scintillation Map (visualization by HQ AFWA)

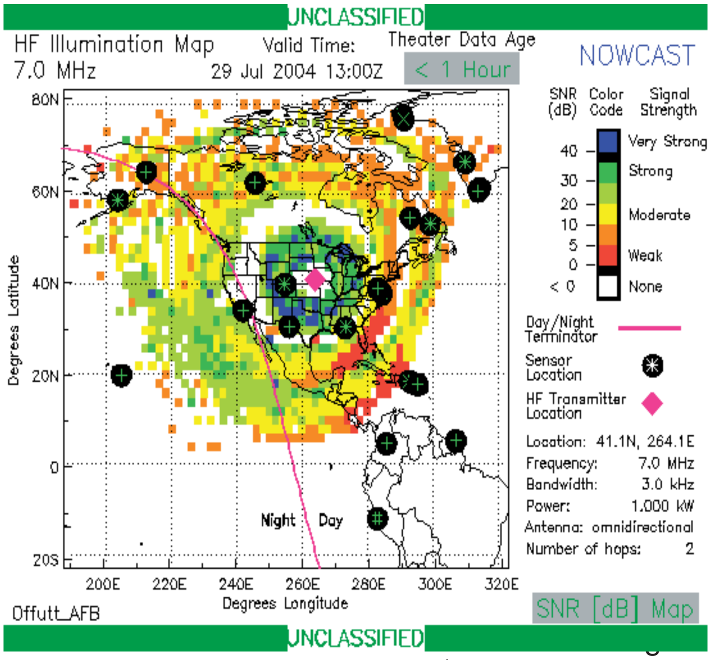


Figure 3-DOD-8. HF Illumination Map (visualization by HQ AFWA)

phenomena for points around the globe (e.g., Operational Climatic Data Summaries and Wind Stratified Conditional Climatologies). Leveraging research from the Naval Postgraduate School and other national and international resources, forecasters produce seasonal outlooks extending to 75 days for Kabul, Afghanistan and Baghdad, Iraq, and continue to investigate new methodologies to stretch forecasts out to six months. Third, 14 WS exploits modeling and simulation technologies, including Advanced Climate Modeling and Environmental Simulations (ACMES) and the Environmental Scenario Generator (ESG), to produce modeled climate statistics and gridded climatologies, and simulated environmental scenarios respectively, to support training and exercises. Fourth, 14 WS employs the Point Analysis Intelligence System (PAIS) to produce historical, real-time, and forecast vertical profiles for any location in support of the Intelligence Community. Fifth, 14 WS oversees the 250,000 documents archived in the Air Force Weather's Technical Library.

Also in the area of climatology, AF Weather is developing a 6-month forecast capability by leveraging research conducted by AF and Navy officers at Monterey, work already accomplished by NATO allies in using climatology, and advances in teleconnections (i.e., El Nino/Southern Oscillation, North Atlantic Oscillation, Southern Annular Mode), with a goal of providing planners a risk management tool to positively impact operations.

The Air Force Director of Weather carries out the DOD Air and Space Natural Environment Modeling and Simulation Executive Agent (ASNE MSEA) responsibilities of managing, coordinating, and implementing all aspects of modeling and simulation relating to the Air and Space Natural Environment domain to include, but not limited to, planning, programming, monitoring, and reporting across all DOD components in accordance with the Under Secretary of Defense for Acquisition, Technology, and Logistics Memorandum to the Secretary of the Air Force, designating the Department of the Air Force as the MSEA for air and space natural environment representations. The DOD ASNE MSEA ensures DOD communities who use simulations for their training, acquisition, testing, planning, experimentation, and analysis have the right tools, infrastructure, and databases necessary to represent the air and space natural environment and its effects. To do this, the DOD ASNE MSEA works closely with both government and industry agencies such as AFWA, National Geophysical Data Center, and others to develop and provide the needed environmental tools and data. The Executive Agent keeps abreast of both current and emerging capabilities within the field of meteorology and the space environment, enabling identification of gaps in these capabilities and solutions to meet DOD environmental requirements for live, virtual, and constructive simulations. Often, the MSEA is required to champion development and transition of new technologies at government resource centers like those mentioned above. The DOD ASNE MSEA also works closely with the Ocean MSEA (Navy, CNMOC) and the Terrain MSEA (National Geospatial-Intelligence Agency, NGA) to ensure a consistent, integrated natural environment is represented in the synthetic environment of a simulation. The ASNE MSEA's Environmental Scenario Generator (ESG) facilitates assembling a consistent, integrated natural environment from distributed centers nationwide. The core ESG system was transitioned to the 14 WS for long-term operational support of the DOD, with future capabilities being integrated from the National Geophysical Data Center (Boulder, CO), the Naval Oceanographic Center (Stennis, LA), and future NGA centers of excellence.

OWSs are AF weather's regional/theater

analysis and forecast centers for Air Force and Army operations. Each OWS generates a variety of products: hazard charts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; airfield forecasts; and weather warnings, watches, and advisories, for Air Force and Army installations within its AOR. The current production system, OPS II, is a legacy system being replaced by JET Increment 1 beginning summer 2008. JET will replace this component of the Forecasting System 21st Century (FS-21) program, providing necessary computer hardware and software throughout the AFWWS, and becoming the OWS's primary production tool. JET will replace a hybrid of software, databases, servers, and workstations. Increment 1 will deliver a common environmental toolkit across the weather enterprise while Increment 2 will focus on weather exploitation tools and Common Operational Picture (COP) visualization of data and effects. These developments go hand-in-hand with AF weather's TTP development efforts, and provide an AFWWS standard for production and dissemination of weather information to supported forces.

Provide Actionable Environmental Impacts Information to Decision-Makers

To provide actionable environmental impacts, AF weather forces continually improve the core processes of tailoring and integration.

Tailoring

Once centralized weather units create a depiction of the past, current, and future state of the natural environment, AF weather forces directly supporting decision-makers tailor the information to identify impacts to operations, personnel, weapons and weapons systems, and tactics. These weather forces then help decision-makers mitigate these effects through appropriate actions such as routing a flight to a new target, selecting a different weapons load, or adjusting the time of attack.

N-TFS, another component of FS-21, to be replaced by JET, provides garrison and deployed weather forces with the meteorological tools to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and AF operations, C2, and support forces worldwide. Additionally, N-TFS ingests data from AF and indigenous observing sources, which then are forwarded to OWS/AFWA for further dissemination and incorporation into centrally produced model output.

JET will provide a single workstation that will eliminate redundancies and/or inefficiencies and ultimately extend, consolidate and/or replace the OPS II, Joint Weather Impact System (JWIS), N-TFS, and the weather effects decision-aids portion of the Integrated Meteorological System (IMETS). JET enhances warfighter awareness of the natural battlespace environment by ensuring accurate, timely, relevant, and consistent terrestrial and space weather and weather impacts information is available and accessible by appropriate personnel and processes. Furthermore, JET enhances the accuracy and utility of terrestrial/space weather and oceanographic information and operational impacts by enabling the forecaster and/or forecast process to incorporate Geographic Information System (GIS) capabilities (to include a standard high-resolution topographic database), forecasting rules of thumb, and operational thresholds into weather and weather impact products. Later spirals of JET will perform its functions by interfacing with information contained in the Virtual Joint Meteorological and Oceanographic Database via common-user-communications, and will integrate with joint and coalition C2 and mission planning systems by enabling machine-to-machine exchange of METOC and C4ISR data and information to meet operational, planning, and execution requirements. Raytheon was awarded the JET contract on 28 March 2006. Fielding of the first JET increment is scheduled to begin in summer 2008 with an expected delivery of all JET capabilities by FY 13.

Tactical Decision Aids (TDAs) provide warfighters an automated way to "visualize" environmental impacts on operations. These tools, which continue to be integrated into C2 systems (e.g. mission planning systems) include Target Acquisition Weapons Software (TAWS) (Figure 3-DOD-6), Infrared Target Scene Simulation (IRTSS) and Tri-Service Integrated Weather Effects Decision Aid (T-IWEDA). The Air Force Research Laboratory (AFRL), the Navy's Space

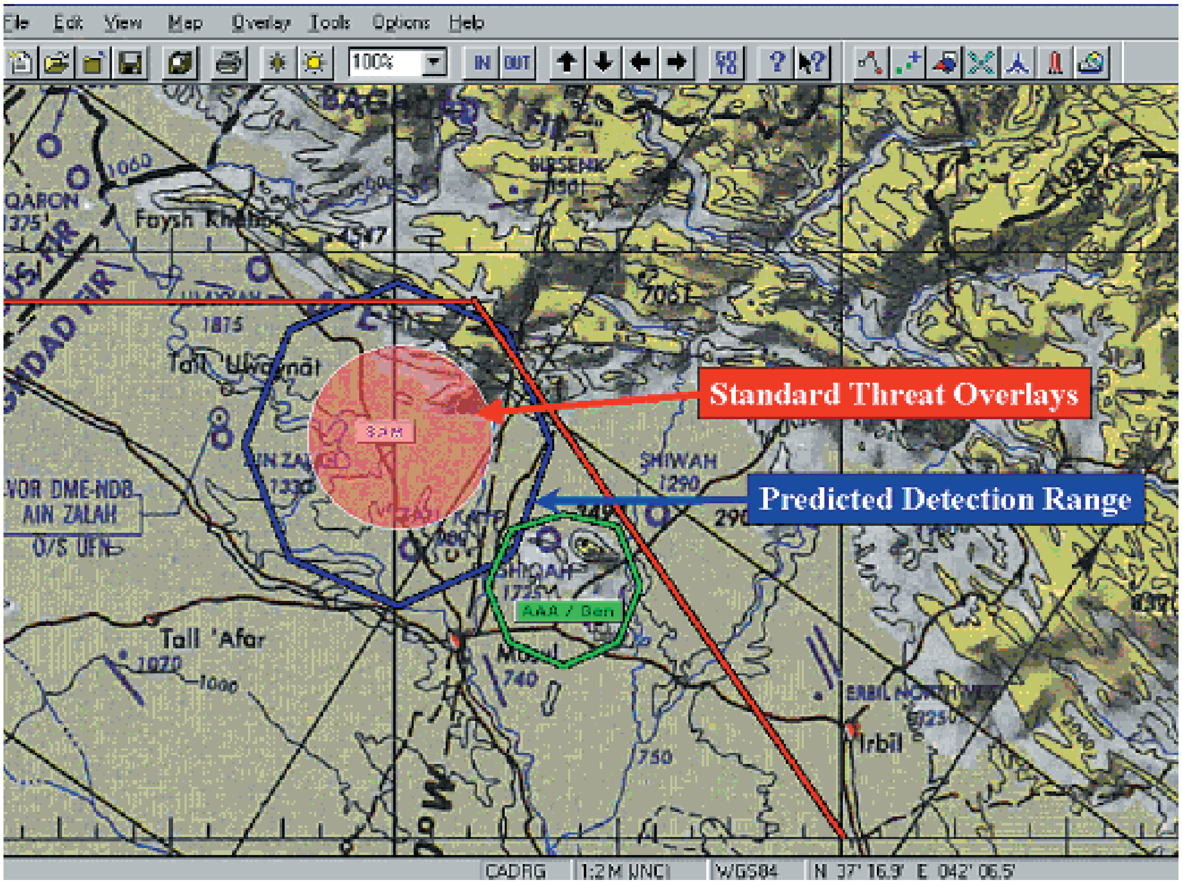


Figure 3-DOD-9. Target Acquisition Weapon Software (TAWS) integrate meteorological conditions and environmental parameters to enhance the mission planning process and increase aircrew situational awareness for mission execution. (US Air Force Released)

and Naval Warfare Systems Command, the Navy Research Laboratory (NRL), and the Army Research Laboratory (ARL) are developing these modular programs. TAWS provides a joint mission-planning tool to combine platform, weapon, target, background, and weather impacts to depict three-dimensional target acquisition and lock-on range and recognition range versus time. This includes prediction of environmental impacts on night vision goggles and low light-level systems used by air, naval, and ground forces to execute nighttime operations. IRTSS uses detailed terrain information and multi-spectral imagery with TAWS weather inputs to generate forecast target scene images for mission rehearsal. The T-IWEDA uses environmental data with force, mission, and/or individual weapons rules of engagement or performance parameters to automatically generate mission-impact forecasts for large-scale planning efforts such as air tasking order preparation. TAWS, IRTSS, and T-IWEDA integrate environmental impacts into the mission execution forecasts for C2 and mission planning (MP) systems throughout the military planning and execution cycle. The TDA program continues adding weapons systems and targets at the request of users from the Services. Additional decision aids in development or in coordination include the airborne laser (ABL) atmospheric decision aid to support ABL development and operations and a common radio frequency (RF) system performance prediction capability based on U.S. Navy software.

AFWA's 2 WS Special Support Operations Flight generates a myriad of products ranging from air refueling forecasts, to detailed mission control forecasts, to weather impacts for SOF operations, and distributes this information via secure media to support worldwide Joint SOF operations. The flight also provides tailored meteorological information for end-to-end planning at U.S. Special Operations Command (USSOCOM), Service component special operations commands, and theater special operations commands. The Special Operations Weather Flight (SOWF) is continually involved in global military operations, including OEF and OIF. Additionally, the SOWF includes the American Forces Network Weather Center, which provides worldwide, broadcast-quality public weather services and planning forecasts through the American Forces Radio and Television Service to over 1,000,000 Department of Defense and Department of State (DOS) personnel and family members stationed overseas. AF Special Operations Command will be standing up a squadron to assume support to SOF operations in CY2008-09.

The 2 WS Intel Flight provides detailed global cloud analyses and forecasts to the IC. The flight provides worldwide mission-tailored planning and execution forecasts for IC agencies at security levels up to Top Secret/Sensitive Compartmented Information (TS/SCI). The flight also serves as the focal point for AFWA Special Access Program (SAP) requirements; ensures the IC and other SCI and SAP meteorological requirements are integrated into AFWA programs; monitors and evaluates accuracy and timeliness of centralized weather services to the IC; and interfaces with the Department of Defense and IC regarding weather services and the exploitation of weather information.

The Air Force provides meteorological and space weather products to the Nation's space and missile programs, including a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center (KSC). The Air Force also provides tailored forecasting for NASA's manned and unmanned launches and for commercial launches from KSC. In addition, the Air Force provides specialized meteorological information for the Air Force Western Range at Vandenberg AFB, California; the Pacific Missile Range, which includes Point Mugu and San Nicholas Island, CA, and Barking Sands, HI; White Sands Missile Range, NM; Kwajalein Missile Range, Republic of the Marshall Islands; and other DOD research and test facilities as directed.

The Air Force also provides agro-meteorological support to the U.S. Department of Agriculture's Foreign Agricultural Service and other similar users. The output includes diagnostic soil hydrology and other meteorological information pertinent to crop growth and yield estimation as well as to trafficability and rudimentary flooding estimations.

Integration

Tailored environmental information and operational impacts are of little use to decision-makers if the information and/or impacts are not integrated into the shaping, planning, execution, and sustainment of air, space, and land operations. The AF employs a blend of information technology (IT), including automated machine-to-machine (M2M) interfaces, and personnel embedded at the right echelons with decision-makers, to integrate timely, accurate, relevant, and consistent weather and weather impacts information into decision-making processes. Since timeliness is critical to effective integration, AF weather operations rely on robust, assured communications for dissemination.

AFWA receives alphanumeric weather data, parses it according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end-users over dedicated circuits, NIPRNET, and satellite broadcast facilities. As AFWA transitions to WDA-developed components including the Consolidated Dissemination Capability (subscription services), the pre-staging of tailored bulletins will be minimal as users will be able to generate their own data sets.

High-speed communications between large Department of Defense and civilian processing centers facilitate sharing of data, high-resolution satellite imagery, and output from numerical weather prediction models. Additional circuits provide a subset of these data to OWSs.

Forecaster-developed products and gridded data sets are distributed from AFWA via the Weather Product Management and Distribution System to base/post-level weather forces around the globe using the DOD's NIPRNET and SIPRNET.

AFWA 2 SOS operates a website on the NIPRNET known as the Joint Air Force-Army Weather Information Network (JAAWIN). JAAWIN provides worldwide access to numerical model forecasts, satellite imagery, forecaster-in-the-loop products, and text bulletins, and includes links to all OWS Web sites. Additional products are available to classified users via JAAWIN-Secret (JAAWIN-S) and JAAWIN-Sensitive Compartmented Information (JAAWIN-SCI).

JET also replaces JWIS, which offers another means of making tailored weather information available to DOD users. Currently, JWIS provides a link to weather information from both Air Force and Navy sources for exploitation by C2 systems and applications.

Although information technology continues to enhance the integration of weather and weather impact information into decision-making processes, well-trained weather professionals are still essential. Designated AF weather personnel serve on the staffs of operational Air Force, Army, and Joint force units worldwide. In this capacity, they identify weather-sensitive areas of the operation and provide expert advice to help mitigate weather impacts on personnel, platforms, weapons and weapons systems, and tactics. The ultimate goal is to identify opportunities for an asymmetric advantage over our foes, i.e., when enemy force capabilities are more severely degraded by weather than those of friendly forces.

For AF operations, these weather professionals are normally assigned to a flight under an operations support squadron in a flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. In this capacity, they infuse critical weather information at key points in the decision cycle to help aircrews maximize wartime capabilities, enhance flight safety, and optimize training effectiveness. Weather experts are also assigned to weather specialty teams in air and space operations centers. This cross-cutting team integrates all-source actionable environmental information at key decision points of air and space operations planning, execution, and assessment. Armed with this information, decision-makers can balance operational risks against mission need to optimize timing, tactics, target and weapons selection, and other factors affecting air and space operations. Finally, AF weather experts are integrated into a variety of other unique mission areas, such as space launch support and RDT&E activities. In each capacity, these specialists enable the supported organization to minimize or alleviate weather impacts to the mission. For instance, to avoid potentially devastating storms, space launch weather personnel may advise decision-makers to adjust launch timing, while RDT&E weather personnel may identify potential weather sensitivities to system developers to ensure a safe, effective design.

Likewise, Army weather requirements are incorporated into the AF's overall weather operations concept. AF weather forces are integrated with Army intelligence staffs. The Army trains and educates Air Force personnel on Army organizations, concepts of operations, and the weather sensitivities. AF weather forces are currently habitually aligned with echelons above corps, corps, divisions, separate brigades, aviation brigades, armored cavalry regiments, ranger regiments, and Special Forces groups (as well as subordinate battalions deployed at forward operating bases). Over the next few years, AF weather support to the Army will undergo significant transformation as the Army transitions from a division-centric force based on large standing organizations to a brigade-centric force based on smaller, modular organizations.

Air Force Weather is targeting a net-centric architecture by 2011. Employing net-centric concepts ensures the environmental information will be readily discoverable and exploitable by all decision-makers, both anticipated and unanticipated, by making the information visible, accessible, understandable, and interoperable throughout the DOD. Core Enterprise Services (CES) will provide the minimal set of enterprise web services to enable enterprise-wide sharing, reuse, and interoperability of information and processes. Catalogs will be stored in shared spaces and use DOD-approved standard formats so all users can employ established CES search tools to rapidly discover the data and services for potential use.

JMBL will be the interface that enables users to access information in the Global Information Grid. Extensible Markup Language will be the standard and allow different applications from different sources to communicate with each other without time-consuming custom coding. This will break down stovepipes and enable standard application interoperability, integrate functionality of disparate systems into seamless operations, and be ideal for M2M communications.

AFWA's Weather Data Analysis Capability (WDAC) program, which began the migration to the DOD Joint METOC Data Architecture to support dynamic, fast-paced M2M operations, was merged with the MDEC in early 2008 to form WDA. Combining these two programs allowed AF weather to save overhead, and prevent creating duplicative capabilities. This architecture provides for authoritative, timely, relevant, accurate, and consistent environmental information, accessible via a common web-service interface from anywhere on the Global Information Grid. The WDA program modernizes the AFWA production center and 14 WS infrastructure, providing a centralized net-centric reach-back source for worldwide space and atmospheric weather information, to include environmental intelligence data to C2, C4ISR, MP, and mission support systems such as the Joint Mission Planning System. This vision is accomplished through implementation of the JMDB, is the common mechanism for users to access the JMDB for M2M operations.

WDA through increment three includes JMGRID (gridded analysis and forecast data); JMOBS (conventional observation data); JMAN (alphanumeric messages and bulletins); and JMPLAT (fixed and mobile weather station platform data); Joint METOC Space Environment and Solar Segment (JMSESS) (i.e., space related alphanumeric, imagery, and non-METOC data) prototype; a JMIM (Joint METOC Imagery) database segment prototype in support of non-geolocated objects; Gridded Consolidated Dissemination Component for JMOBS, JMAN, non geolocated images, geolocated with an intuitive interface and local authentication capability. The next WDA increment is scheduled to be on contract in fall 2008.

RESEARCH INITIATIVES

The overarching objective of the Air Force meteorological and space environmental technology transition program is to provide capability designers, operational weather personnel, and weather information users the technology and tools to gain and maintain the advantage over a potential adversary. Capability needs in the atmospheric and space environment sciences are articulated in Air Force weather's Joint Capability Document, Capability Review assessments, the AFW and AFWA Strategic Plans, the AFW Operations Functional Concept and Enabling Concepts (Characterize the Environment, Exploit Environmental Information, and Net-Centric Operations), and supporting concept and implementation plans. AF weather also strives toward improvements through cooperative development and testing agreements both with other governmental agencies and laboratories, as well as for-profit companies. Additionally, both AFIT and the Naval Postgraduate School offer AF graduate students in the atmospheric and space environmental sciences an opportunity to research topics of immediate operational interest to the Service. AF weather has recently fielded an IOC version of the Utah State University (USU) developed GAIM model. AF weather continues to work with USU toward the fielding of a FOC full physics version of the GAIM model sometime in FY09-10. In addition, AF weather will be working during FY08 to fully integrate ultraviolet sensing instruments (SSUSI, SSULI, and GUVI) into space weather operations. This effort will include model integration, visualization, and validation efforts.

In applied meteorological R&D, the AF is improving CDFS techniques by doubling the resolution, integrating geosynchronous METSATs into the cloud analysis, using a new cloud interpretation scheme, and blending numerical weather prediction with forecast cloud advection techniques. The AF has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal. In addition to internal efforts, AF weather will continue to rely on collaboration with, and leveraging efforts of, other federal meteorological agencies, research labs, and universities to further improve CDFS system performance and meet other research needs.

MODELING FOR AIR FORCE AND ARMY OPERATIONS

The WRF model is the next generation community model and is another area of AFWA participation in research and development in collaboration with NCAR, NOAA's NCEP, NOAA' s Earth Systems Research Laboratory (ESRL), the University of Oklahoma's Center for the Analysis and Prediction of Storms, and others. AFWA initially implemented WRF operationally in 2006 and will continue with sponsorship and funding of development at NCAR and ESRL, test and evaluation of real-time runs of the WRF prototype, and will lead the Land Surface Model (LSM) Working Group while participating in others. The LSM analyzes the current state of the land surface to provide information to DOD and civilian agencies, and through coupling with WRF, will improve forecasting performance in the low levels of the atmosphere. This allows AF weather forces to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces.

AFWA is in the process of identifying a future capability called the Ensemble Prediction System (EPS). EPS output will help AF Weather personnel to provide better forecasts for the warfighter with increased confidence, particularly at the tactical level. The ongoing Joint Ensemble Forecast System (JEFS) prototype effort is laying the groundwork to construct an operational EPS and the first non-operational JEFS products are being produced daily at AFWA as part of the JEFS test in the U.S. Pacific Command (USPACOM) and U.S. Central Command (USCENTCOM) AORs.

There are two distinct components of EPS, with one being coarse-scale global and the other fine-scale regional. The AF concept calls for leveraging NCEP's and the Navy's global and CONUS capabilities with NWS and FNMOC running the global models. AFWA and FNMOC are currently conducting a 1-year proof-of-concept test which includes a global and fine-scale prototype, with a 5km, 10 member set over Central Command's Area Of Responsibility and Korea. Expected benefits include more objective Operational Risk Management (ORM) decisions by warfighters enabled by the additional information provided through ensemble forecasts. Dependant on the success of JEFS, AFWA will begin operational transition of EF in about 2010.

In addition, AF weather is partnering with the NWS and the Navy in the National Unified Operational Prediction Capability (NUOPC) project. This partnership exists to enable a Tri-Agency joint global atmospheric ensemble forecast system. NUOPC is an integration of ongoing efforts coordinated by a Tri-agency management organization. The NUOPC vision is a National NWP system with interoperable components built on common standards and framework (Earth System Modeling Framework (ESMF)) with managed operational ensemble diversity and a national global NWP research agenda to accelerate science and technology infusion.

ATMOSPHERIC OPTICAL TURBULENCE

Electro-optical (EO) systems are adversely affected by optical distortions caused by thermal or refractive turbulence. As the sophistication of current and next-generation military systems grows, the requirement for more detailed knowledge of fine-scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such capability whose performance is highly dependent on the variations of the meteorological conditions that produce optical turbulence. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Researchers used a balloon-borne turbulence sensor mated to a standard radiosonde to obtain measurements, producing data and empirical models that are the basis for ABL system specification. Balloon-borne measurements were made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum was also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales world-wide. Horizontal measurements by the aircraft augment the vertical profiling by balloons to assist in the development of the detailed knowledge required to support new EO systems.

UNITED STATES WEATHER RESEARCH PROGRAM (USWRP)

USWRP's mission is to accelerate forecast improvements for high-impact weather phenomena and to facilitate full use of advanced weather information. AF weather first entered into discussions with USWRP in 2001 to explore expanded participation in the program. The program currently focuses on landfalling hurricanes, heavy precipitation, and socio-economic impacts. The AF is eager to leverage future efforts in the areas of observing, assimilation strategies for data-sparse regions, and urban forecasting to increase warfighters' abilities to anticipate and exploit the weather. AF weather is already committed to the USWRP-affiliated community development of the WRF model and will continue its USWRP involvement during the coming fiscal year.

AIR FORCE RESEARCH LABORATORY (AFRL)

AFRL supports AFWA by executing research conducted by external agencies and by conducting in-house research on space weather. AFRL works with AFWA to execute the research portion of AFWA's forecasting and modeling program. AFRL coordinates with government agencies (e.g., NASA), Federally Funded Research and Development Centers (e.g., NCAR), and private corporations to fund research in support of weather model development. In space weather research, AFRL programs focus on ionospheric impacts to radio frequency systems, charged particle specification and forecasts, solar disturbance prediction, and neutral density effects on Low-Earth Orbit spacecraft. Working closely with the DMSP System Program Office at the Space and Missile Systems Center, under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include: space environment sensors on the DMSP spacecraft; state-of-the-art ground-based scintillation detectors; total electron content sensors; DISS/NEXION; SEON; and the Operationalized Space Environment Network Display suite of web-based products. In addition to the AFRL research portfolio, AF weather collaborates with others in the space weather community to develop new techniques, models, and systems for transition to operational applications. These include the Community Coordinated Modeling Center, John Hopkins Applied Physics Laboratory, the Naval Research Laboratory, NASA, NOAA's Space Weather Prediction Center, and the Community for Integrated Space Modeling.

AF weather is also working with AFRL design teams on Distributed Mission Operations (DMO). They are operationally testing and evaluating weather impacts, messages, and feed during DMO exercises and test-events as they identify wargame program requirements.

ARMY RESEARCH LAB (ARL)

AF Weather is leveraging ARL's nested weather running estimate, also known as nowcast, for the 0-3 hour forecast through local tailoring of theater grids and using fine scale models with 1-km grid resolution. These theater and nested grids will be used in decision aid tools such as Tri-Service IWEDA, Aircraft Weather Routing and EO/Infrared tools such as TAWS to determine weather impacts/effects at each grid point. AF Weather is also researching how to take advantage of ARL's capabilities in battlefield sensing and capture, store and use environmental observed data from UAS, aircraft LIDAR and Future Combat Systems vehicles. Another area where AF Weather is joining forces with ARL is with integrating the UAS routing/impacts tool into the operational realm.

NEXT GENERATION AIR TRANSPORTATION SYSTEM (NextGen)

AF weather has taken the lead in DOD weather support to the Next Generation Air Transportation System (NextGen) Joint Planning and Development Office (JPDO) Weather working Group (WWG). The basis of the NextGen Wx CONOPS is a virtual 4-Dimensional (space and time) weather data base that covers the National Airspace System (NAS) called the 4-D Wx Data Cube. This cube will contain all the weather data, information and products necessary for supporting aviation operations including observations and forecasts from both federal and commercial sources. A subset of the 4-D wx data cube will be a common, consistent, data set called the 4-D Wx Single Authoritative Source (SAS) that is used to create a common weather picture for federal aviation decision-makers. This SAS will be open and available to all NAS users. The 4-D Cube and SAS will be net-enabled for machine-to-machine data exchange. This whole concept is called the NextGen Net-Enabled Weather (NNEW). AF weather is working closely with the JPDO, NWS and FAA on this concept. AF weather is providing net-centric lessons learned and technology, such as JMBL, to help this program along. In 2007, AF weather participated in the development of a JPDO weather policy paper and weather functional requirements document. All of these endeavors will not only benefit NextGen but will also contribute to improving the weather data available to integrate into military C2 systems.

In the area of C2 integration AF weather is also working with the AF Combat Support Office to develop the capability to overlay weather on the predator COP. AF Weather has partnered with the National Geospatial-Intelligence Agency to develop method to present extensible markup language tagged weather data into Google Earth format.

AF weather submitted a proposal for reutilization of High Performance Computing Modernization Program (HPCMP) assets, the Linux Networx Evolocity II Cluster (JVN) or IBM Regatta Power 4+ system (KRACKEN), in June 2008. Under the proposal, AFWA will work closely with ARL, NCAR, and NASA to make maximum use of this HPCMP equipment to further research the cutting edge science of stochastic weather forecasting for operational exploitation. AFWA, with its ARL partners, will develop and test very high-resolution wind field models to produce highly resolved flow patterns in complex battlefield terrain to enable improved Chemical, Biological, Radiological, and Nuclear dispersion forecasts in support of the Defense Threat Reduction Agency and AF and Army decision-makers. AFWA will test the WRF Chemistry model to characterize aerosol and photochemical processes that degrade the combat effectiveness of weapons and defense systems. AFWA, with its NASA partners, will develop and test a very high-resolution land data assimilation system, called Land Information System, and drive cloud characterization capabilities to resolutions on the order of 1 KM to significantly improve support for AF, Army, Special Operations, and IC operations. AFWA will work with NCAR to develop Auto Vortex Following WRF capabilities for use by the JTWC to improve typhoon forecasts. Finally, AFWA will develop, test, and integrate full physics GAIM to improve space weather situational awareness and support to combat operations.

In conclusion, through a continuous process of review and definition, the Air Force documents its requirements for research aimed ultimately at providing timely, accurate, relevant, and consistent weather information to the warfighter today and in the future. In meteorological R&D, AF weather is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation. Space weather and cloud forecasting research will continue to facilitate the transition of required capabilities to operational use at minimum expense.

OVERVIEW

The U. S. Navy's Oceanography and Meteorology Program (NOP) provides global meteorology, oceanographic, Maritime Geospatial-Environmental Information & Services and ocean surveillance critical for safe and effective operations of the Navy and Marine Corps and the Department of Defense. Its mission is to protect the Fleet, shape the battlespace and maximize warfighting capability. The program in-cludes oceanography, bathymetry, hydrography, meteorology, acoustics, geophysics, astrometry, geospa-tial information and precise time.

Naval METOC underpins every aspect of naval operations and warfare. It provides an affordable and sustainable competitive advantage to the Nation and protects the substantial National investment in both afloat and ashore force structure.

The NOP, which is supported by ocean engineering, operational supercomputing and operations research, in recent years reinvented itself to meet the warfighting needs of the operators and the fiscal needs of today's Navy.

Increasingly, costs are leveraged in the Joint, interagency and international arenas to deliver capabilities at a shared cost. The NOP is the Department of Defense's global Numerical Weather Forecasting Capability and it partners with Air Force weather in the areas of flight weather forecasting, Joint operations, information management and acquisition programs. It also has strong relationships with all five direc-torates in NOAA.

Figure 3 – DOD 10. Aerographer's Mate 1st Class William Palmer releases a weather balloon from the flight deck aboard the amphibious assault ship USS Peleliu (LHA 5). (US Navy Released)

ORGANIZATION

The Commander Naval Meteorology and Oceanography Command is an Echelon III command reporting to the U.S. Fleet Forces Command (USFF). Its resource sponsors are OPNAV N4 for Operations and Maintenance, Navy (OMN) funding; the Oceanographer of the Navy, N84, for Other Procurement, Navy (OPN) funding; OPNAV N87 for Commander Undersea Surveillance; OPNAV N1 for Military Personnel Navy (MPN) and Reserve Personnel Navy (RPN); and OPNAV N85 for Expeditionary Warfare re-quirements.

The Naval Oceanography Program's operational concept is "knowledge-centric" – production is centralized, service delivery is distributed in naval command and control centers and the total capabilities are brought to bear directly on Naval strategic, warfighting and safe operating challenges.

Naval Oceanography focuses its services on five warfighting capabilities--antisubmarine warfare, naval special warfare, mine warfare and countermeasures, fleet operations, and intelligence, surveillance and reconnaissance--and four strategic and enabling capabilities, maritime weather forecasting, aviation weather forecasting, navigation and charting and precise time and astrometry.

Major activities within the command currently include:

- Naval Oceanography Operations Command, Stennis Space Center, MS
- Naval Oceanographic Office, Stennis Space

Figure 3 – DOD 11. Aerographer's Mate 2nd Class Kristopher Rodriguez, writes a weather report in the meteorology and oceanography center of the aircraft carrier USS Kitty Hawk (CV 63). (US Navy Released)

Center, MS
- Fleet Numerical Meteorology and Oceanography Center, Monterey, CA
- U.S. Naval Observatory, Washington, DC
- Naval Meteorology and Oceanography Professional Development Center, Gulfport, MS
- Commander Undersea Surveillance (CUS), Dam Neck, VA

Additional subordinate commands include:

- Naval Aviation Forecast Center, Norfolk, VA and detachments
- Naval Maritime Forecast Center, Pearl Harbor, HI (with an activity in Norfolk)
- Strike Group Oceanography Teams in Norfolk, San Diego and Fallon, Nevada (with subordinate mobile environmental teams)
- Naval Special Warfare Oceanography Center in San Diego, CA (with components and detachments in Stuttgart, Germany, Norfolk and Pearl Harbor)
- Naval Oceanography ASW Centers in Yokosuka, Japan and Stennis Space Center, MS (with subordinate detachments)
- Fleet Survey Team, Stennis Space Center MS
- Naval Ice Center, Suitland, MD
- Naval Ocean Processing Facilities in Dam Neck, VA and Whidbey Island, WA (with detachments)

NAVAL OCEANOGRAPHY OPERATIONS COMMAND (NAVOCEANOPSCOM)

The NAVOCEANOPSCOM, headed by the Commander, Oceanographic Operations, serves as the principal operational organization of CNMOC and coordinates and manages efforts among field activities under the Operational Oceanography Program to optimize warfighting resources, support safe operations and enhance dominance of the battlespace through superior understanding and exploitation of the environment. The Command encompasses the nine warfighting and enabling directorates. Each director-ate determines how that directorate's services are delivered globally. Each directorate reports to a single Navy Captain who functions as Naval Oceanography's Chief Operating Officer.

The Commander, Oceanographic Operations supports the combatant commanders and national missions, U.S. interagency and international partners. The major NAVMETOCCOM production centers (NAVOCEANO, FLENUMETOCCEN, NAVOBSY) support the Commander, Oceanographic Operations.

The command's operational model is based on standardizing services for each directorate, automating everything that can be automated and coupling situational awareness and a small on-scene pres-ence, supported by a significant 24/7 reachback production capability at the major production centers.

Dangerous weather and safe navigation are the top two Fleet concerns.

Aviation Forecasting

Many environmental conditions severely impact flight operations and mission accomplishment. These include: wind speed and direction, cloud ceiling, precipitation, turbulence, visibility, icing and severe weather such as thunderstorms. An accurate forecast is often the deciding factor in mission success and for the safety of the pilot and their aircraft.

Navy Meteorologists and forecasters analyze current physical environmental conditions and use state of the art computer models to forecast atmospheric and oceanographic phenomena impacting naval flight operations.

Meteorologists are assigned to Aviation Forecasting hubs in the United States and overseas locations.

Core aviation weather services include flight route weather briefings via an internet-based flight weather briefer, severe weather warnings and advisories for Navy airfields and terminal aerodrome forecasts for Navy airfields.

Fleet Operations

The Naval Meteorology and Oceanography Command is actively engaged with Fleet forces to provide valuable physical environmental knowledge to aid warfighting decision making. Personnel are integrated with the Fleet, where they provide in situ observations, run tactical decision aids and interpret envi-ronmental data to provide decision support to Fleet commanders.

The onboard personnel work with reachback cells to analyze and forecast environmental conditions from launch point to target and to determine optimum Fleet maneuvers, ingress and egress routes, am-phibious landing points and times, flight operations, weapons load-outs and target selection.

Deploying personnel are highly trained meteorology and oceanography specialists for support planning and operations. Reachback teams work with onboard personnel to refine data, develop models, conduct forecast analyses and deliver high-quality information to Fleet commands.

Tailored Strike Group Oceanography Team (SGOT) Detachments train, work-up and deploy with carrier and expeditionary strike groups through each phase of the Fleet Readiness Training Program or Plan or whatever and deployment. Each SGOT detachment includes a team who forecast for the aircraft carriers, amphibious assault ships and other vessels making up the strike group. In addition to flight deck weather, they forecast en-route and target area METOC conditions which may vary greatly considering the tremendous reach of Naval Aviation along the world's dynamic coastlines.

Figure 3 – DOD 12. McMurdo Station, Antarctica, ice floes and treacherous weather pose challenges to Military Sealift Command's annual mission of resupplying the station. (US Navy Released)

Maritime Weather Operations

Navy meteorologists and forecasters are assigned to Maritime Forecasting Centers in Hawaii and Virginia.

Core maritime weather services include Optimum Track Ship Routing (OTSR), a weather forecast-ing service to support transoceanic voyages and coastal operations. OTSR services:

- Provide hazardous ocean and weather advisories and divert recommendations to ship Commanding Offi-cers and Masters at sea.
- Include sortie recommenda-

tions for potentially damaging weather conditions in port.

- Provide preliminary climatologic outlooks for transit and mission planning.
- Routine ship weather forecasts (WEAX) and aviation weather forecasts for ship-based helicopters (AVWX) include high wind and seas warnings and local area warnings for Fleet Concentration Areas.

The Joint Typhoon Warning Center (JTWC), established by the U.S. Pacific Command, is jointly manned with U.S. Air Force personnel. JTWC services include tropical cyclone forecasts, warnings and other products for Department of Defense warfighters operating in the Pacific and Indian Oceans. JTWC, located in Pearl Harbor, Hawaii, is an internationally recognized tropical cyclone forecasting center.

FLEET NUMERICAL METEOROLOGY AND OCEANOGRAPHY CENTER

The Fleet Numerical Meteorology and Oceanography Center (FLENUMETOCCEN) an Echelon IV activity reporting to the Commander, Naval Meteorology and Oceanography Command, is the NOP's production center for meteorology. The center plays a significant role in the National capability for operational weather and ocean prediction through its operation of sophisticated global and regional meteorological and oceanographic models, extending from the top of the atmosphere to the bottom of the ocean. Through close collaboration with the Naval Oceanographic Office (NAVOCEANO), FLENUMETOCCEN is a key component in the Navy's operational weather and ocean prediction program. This program provides information that helps give Naval forces an asymmetric advantage in speed, access and persistence in any combat operation for which they may be called upon.

FLENUMETOCCEN is well known for its long and productive history of implementing, evaluating, operating, maintaining and improving complex Numerical Weather Prediction (NWP) system specifically to meet the requirements of the U.S. Navy. These requirements include the need for a particularly accurate representation of coastal meteorology and the air-sea heat fluxes and wind stresses required to drive the Navy's ocean models. In support of this need, FLENUMETOCCEN acquires and processes over six mil-lion observations per day -- creating one of the world's most comprehensive real-time databases of mete-orological and oceanographic observations -- for real-time fusion and assimilation into its models. In addi-tion, FLENUMETOCCEN is designated as the DOD center for global Numerical Weather Prediction. FLENUMETOCCEN uniquely satisfies the military's requirement for an operational global NWP capability based on software certified to DOD information assurance standards and operated in a secure classified environment protected from outside intrusion by DOD-certified firewalls. This requirement is driven by the importance of weather and ocean conditions on modern military operations, the need to utilize classified weather observations to guarantee the very best weather and ocean predictions in theaters of conflict, and the imperative to produce and disseminate weather and ocean products to military decision-makers without fear of interruption or compromise as a result of cyber terrorists or cyber warfare.

FLENUMETOCCEN employs four primary models: the Navy Operational Global Atmospheric Pre-diction System (NOGAPS), the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), the Geophysical Fluid Dynamics - Navy (GFDN) model, and the WaveWatch III model (WW3), along with a number of specialized models and related applications. NOGAPS is a hydrostatic, global spectral model that drives nearly all other FLENUMETOCCEN models and applications in some fashion, and forms the basis for the FLENUMETOCCEN global Ensemble Forecast System (EFS). COAMPS is a high-resolution, non-hydrostatic regional model, multiply nested within NOGAPS, that has proven to be particu-larly valuable for forecasting weather and ocean conditions in highly complex coastal areas. GFDN is a moving-nest tropical cyclone (TC) model, nested within NOGAPS, that is used to forecast TC tracks globally. WW3 is a spectral ocean wave model that is employed both globally (driven by NOGAPS) and regionally (driven by COAMPS) in support of a wide variety of naval operations. Other models support and supplement the main models with predictions of ocean thermal structure, ocean currents and other data. All of the models are configured, scheduled and operated under the central control of FLENUME-TOCCEN Operations. COAMPS, however, can also be configured, scheduled and operated remotely by users in the field as an on-demand modeling service. This is done over the Web via the FLENUMETOC-CEN Centralized Atmospheric Analysis and Prediction System (CAAPS). In general, FLENUMETOCCEN strives to treat the air-ocean environment as a fully integrated system, from the top of the atmosphere to the bottom of the ocean, placing special emphasis on the air-ocean interface.

FLENUMETOCCEN's complex and robust operational prediction capability is designed to deliver, in conjunction with NAVOCEANO, 7x24x365 support organized along the warfare areas. For example, some FLENUMETOCCEN products consist of detailed forecasts of wind stresses and heat fluxes to drive very high-resolution ocean models at NAVOCEANO that provide ocean thermal structure and currents in support of anti-submarine and mine warfare operations, or near-shore wind, sea and surf forecasts that directly support Fleet Operations through ship-to-objective maneuver. In many cases, the outputs of the FLENUMETOCCEN models feed directly into applications models, tactical decision aids and other prod-ucts that provide direct support to various weather-sensitive activities associated with the warfighting di-rectorates identified above. These include optimum path aircraft routing, optimum track ship routing, issu-ance of high-winds and high-seas warnings, hurricane/typhoon sortie decisions, covert ingress/egress of Special Operations Forces, ballistic missile targeting, cruise missile launch and targeting, radar perform-ance prediction in support of ship self defense, naval gunfire operations, understanding the threats posed by airborne nuclear/biological/chemical agents, search-and-rescue at sea, and many other activities.

FLENUMETOCCEN also provides a wide-range of meteorological and oceanographic observations and satellite imagery to complement its models and applications products. These include on-demand extracts from its global observational database, a full range of Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager products, ERS and QuikScat scatterometer wind products, a comprehensive view of tropical cyclones via the FLENUMETOCCEN TC Web Page, and vari-ous experimental satellite products fielded for evaluation in conjunction with the Naval Research Lab (e.g., satellite imagery that enhances the visualization of airborne sand and dust). FLENUMETOCCEN also hosts the USGODAE Monterey Data Server in support of the Global Ocean Data Assimilation Experiment. This system serves as a one-stop shop for meteorological and oceanographic data and model products required to support global ocean modeling R&D. It also functions as one of two Argo Global Data As-sembly Centers, hosting the complete collection of quality-controlled Argo temperature/salinity profiling float data.

Many of FLENUMETOCCEN's products are distributed to users over the Web via the PC-based METCAST system, and subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer (JMV) software. This includes all standard meteorological and oceanographic fields, synoptic ob-servations, and satellite imagery. For those who require only graphical display of model-predicted mete-orological or oceanographic fields, FLENUME-TOCCEN provides a Web-based capability called WxMap (i.e., "Weather Map"). WxMap, requiring only a Web browser for access, allows the user to select and quickly display predicted meteorological and oceanographic fields for any user-defined geographical area.

All of FLENUMETOCCEN's production capabilities are fielded on a collection of computer hard-ware and software designated as the Primary Oceanographic Prediction System (POPS). POPS is or-ganized into two subsystems: the Analysis and Modeling Subsystem (AMS) and the Applications, Trans-actions, and Observations Subsystem (ATOS). AMS is a cluster of SGI and IBM supercomputers on which the major NWP models run. ATOS is a large suite of IBM Linux clusters that ingests, decodes and quality-controls data; does satellite data processing; hosts many of the applications models and products mentioned above; and supports data distribution via a services oriented architecture and Web portal. Note that FLENUMETOCCEN also hosts a DOD High Performance Computing Modernization

Program (HPCMP) Distributed Center, which are integrated closely with POPS.

In addition to its primary role of focused support to the warfighter, FLENUMETOCCEN also plays a key role in the U.S. national program for weather prediction. In this regard, FLENUMETOCCEN's tropical cyclone track predictions, widely recognized as among the best in the world, have proven to be especially valuable, with the National Hurricane Center (NHC) relying on them heavily.

FLENUMETOCCEN benefits greatly from collocation with its supporting R&D activity, the Marine Meteorology Division of the Naval Research Laboratory (NRL/MRY). NRL/MRY is a world-class research organization, with focus on weather-related support to warfighting. FLENUMETOCCEN and NRL/MRY share space, data, software and computer systems, and together with the nearby Naval Postgraduate School represent one of the largest concentrations of weather-related intellectual capital in the nation. Collocation and close cooperation between research and operations, such as exists between NRL/MRY and FLENUMETOCCEN, is the optimum arrangement for transitioning R&D quickly and cost-effectively into new and improved operational weather prediction capabilities.

NAVAL OCEANOGRAPHIC OFFICE

The Naval Oceanographic Office is the NOP's production center for oceanography.

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's pro-gram in meteorology is closely linked with oceanography , which is the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO primary responsibilities in-clude the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO runs and disseminates products from the world's first operational global ocean model, NRL Layered Ocean Model (NLOM), as well as a number of regional and coastal cir-culation and wave models. NAVOCEANO also runs the Polar Ice Prediction System (PIPS) ice model and provides the output to the National Ice Center for product generation. A key ingredient to ocean model performance is real-time data for assimilation and evaluation. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is nationally recognized for satellite-derived sea-surface temperature and satellite altimeter-derived sea surface topography and wave height. NAVO-CEANO's global sea surface temperature are critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO houses a DOD Major Shared Resource center, enabling transition of the latest research and development models on the most scaleable, supercomputing architecture and facilitating transition from R&D to operational use.

Figure 3 – DOD 13. The Nassau Expeditionary Strike Group transits the Atlantic Ocean. (US Navy Released)

Figure 3 – DOD 14. Aviation Warfare Systems Operator 2nd Class Anthony Chavez, works with a soldier from the Armed forces of the Philippines to move relief supplies to a school on the Panay Island. (US Navy Released)

Figure 3 – DOD 15. Marines from India Battery, Battalion Landing Team 2/5, 15th Marine Expeditionary Unit, fire their M777 Howitzer while deployed to Buehring, Kuwait. (USMC Released)

UNITED STATES NAVAL OBSERVATORY

The U.S. Naval Observatory, in Washington, D.C., is the production center for precise time and as-trometry. It is one of the oldest scientific agencies in the country. Established in 1830 as the Depot of Charts and Instruments, the U.S. Naval Observatory today is the preeminent authority in the areas of Pre-cise Time and Astrometry and distributes Earth Orientation parameters and other astronomical data re-quired for accurate navigation and fundamental astronomy.

The U.S. Naval Observatory serves as the official source of time for the Department of Defense and the standard of time for the United States. The atomic clock timescale of the Observatory is based on an ensemble of cesium-beam frequency standards and hydrogen masers.

The U.S. Naval Observatory performs an essential scientific role for the United States, the Navy and the Department of Defense. Its mission includes determining the positions and motions of the Earth, Sun, Moon, planets, starts and other celestial objects, providing astronomical data; determining precise time; measuring the Earth's rotation; and maintaining the Master Clock for the United States. Observatory astronomers formulate the theories and conduct the relevant research necessary to improve these mission goals. This astronomical and timing data, essential for accurate navigation and the support of communica-tion on Earth and in space, is vital to the Navy and Department of Defense. It is also used extensively by other government agencies and the public at large.

EDUCATION/TRAINING

Navy Officer (meteorologists/oceanographers) are all university graduates in meteorology, ocean-ography or other earth sciences, with most attaining dual meteorology and oceanography advanced graduate degrees.

Enlisted forecaster and/or briefers are trained in meteorological analysis and forecasting at military schools. Enlisted observers receive training at military schools.

The enlisted Aerographer's "A" (observer) and "C" (forecaster) schools are located at the Naval Technical Training Unit collocated with Air Force and Marine weather training at Keesler Air Force Base, MS.

Ongoing professional development for both officer and enlisted personnel is offered through the Naval Meteorology and Oceanography Professional Development Center in Gulfport, MS (with Pacific and Atlantic detachments). The center offers directorate training as well as training on oceanographic knowl-edge continuum.

THE FUTURE

The central objective for the Naval Oceanography Program's future capability is a three-tiered con-struct designed to bring the forecast battlespace into operational decision making. It hinges on high reso-lution modeling and will require extensive sampling and continuous validation. All three tiers, each encom-passing a separate knowledge set, will be developed simultaneously.

Tier 1, the "environment layer" will consist of developing and using the sampling methods given the observed and forecast ocean/atmosphere system and the desired knowledge to be gained. Littoral Bat-tlespace Sensing Fusion & Integration is the baseline Program of Record for acquiring Navy-unique data and sensors critical to model initialization, verification, validation, skill improvement and confidence. In this tier, focus will also be placed on

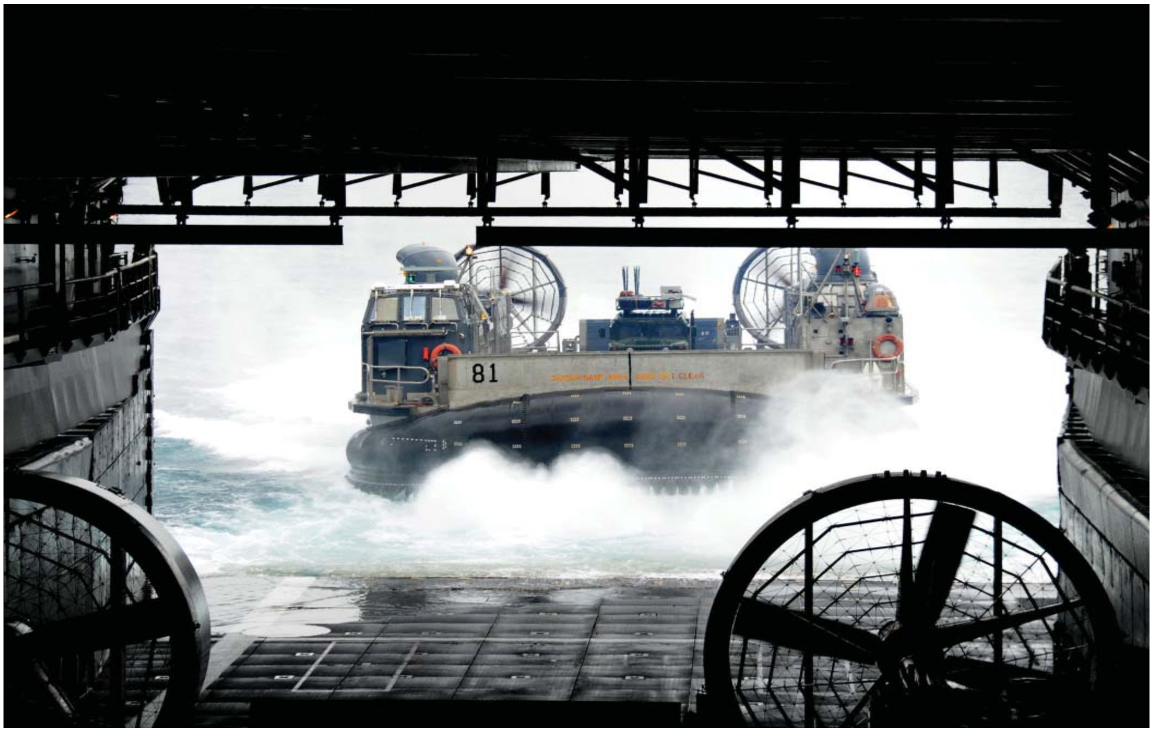


Figure 3 – DOD 16. Landing craft air-cushioned (LCAC) 81, assigned to the "Swift Intruders" of Assault Craft Unit (ACU) 5 follows another LCAC into the well deck of the amphibious dock landing ship USS Harpers Ferry (LSD 49). (US Navy Released)

improving modeling capability in an air/ocean environment at all scales, aligned with a National approach in areas where leverage is possible.

Tier 2, the "performance layer" revolves around transforming understanding of the air-ocean envi-ronment into knowledge of that environment will impact sensors, platforms and people and communicat-ing inherent opportunities and constraints.

Tier 3, "the decision layer," applications will quantify strategic and operational risks, provide asset allocation recommendations at the operational level and sensor settings and predictions at the tactical level. As much of this information as possible will be provided via the Web and tailored "push" products.

Together the three "tiers" will deliver time-responsive, "on demand" sensing and modeling and pre-diction of critical ocean parameters on strategic, operational and tactical timelines with tightly coupled warfighting applications.

PROGRAM ALIGNMENT

The Naval Oceanography Program is changing focus from an acquisition-based program to "in stride" technology transition that rapidly transitions R&D and influences the Navy's S&T investments. Emerging R&D technologies will be tested in computational and operational environments and transitioned after an appropriate collaborative period.

CONCLUSION

The Naval Oceanography Program has reinvented itself into a program that emphasizes the Navy's interests – and will evolve as the Navy's future challenges evolve. Ultimately, it delivers an operational Na-val Oceanography Program (aligned vertically with the S&T and R&D communities) that protects the Fleet, helps the Nation shape the battlespace and maximizes warfighting capability.

UNITED STATES MARINE CORPS (USMC)

The mission of the Marine Corps METOC Service is to provide meteorological, oceanographic, and space environmental information, products, and services required to support Marine Corps and other military operations. The Marine Corps METOC support infrastructure is designed to readily deploy and operate in austere expeditionary environments. It is capable of providing sustained, comprehensive, and relevant METOC support to all elements of a Marine Air Ground Task Force (MAGTF), as well as bases and stations of the supporting establishment.

ORGANIZATION

The Deputy Commandant for Aviation, Headquarters U.S. Marine Corps (Code ASL-37), is the re-sponsible office for Marine Corps METOC requirements and support. The Marine Corps METOC organi-zation consists of two operational chains of command, one for supporting establishment METOC units, and the other for the Fleet Marine Force (FMF).

Supporting establishment METOC units are located worldwide at Marine Corp Air Stations (MCAS) and Facilities (MCAF). These activities are manned and equipped to provide direct aviation METOC support and services to host and tenant units at seven major air stations in the continental United States, one in Hawaii, and two in Japan.

Within the FMF, Marines deploy as scalable, tailored, combined-arms teams known as MAGTFs. There are three sizes of MAGTFs. They are the Marine Expeditionary Unit (MEU), Marine Expeditionary Brigade (MEB), and Marine Expeditionary Force (MEF) with the latter being the largest. Additionally, Spe-cial Purpose MAGTFs may be formed to support operationally unique situations and/or requirements. All MAGTFs, regardless of size, share four organizational elements that vary in size and composition accord-ing to the mission: Command Element (CE), Ground Combat Element (GCE), Aviation Combat Element (ACE), and Combat Service Support Element (CSSE).

FMF METOC activities are organized, trained, and equipped to provide tailored support products and services to all combat elements of the MAGTF. METOC support is focused towards impacts on expeditionary maneuver warfare operations, particularly operational maneuver from the Sea. FMF METOC activities are fully interoperable within joint force operations as part of a Service or functional component command. When directed to stand-up as part of a Joint Task Force headquarters (JTF HQ), they are capable of planning, coordinating, and leading joint METOC operations. Marine METOC forces can rapidly transition from pre-crisis state to full operational capability in a distant theater to provide on-scene support to MAGTF, combined, joint, allied, and coalition operations and other military operations as may be di-rected. FMF METOC assets are permanently assigned to MEF headquarters, intelligence battalions, Ma-rine Wing Support Group (MWSG), and Marine Wing Support Squadron (MWSS). There are three MEFs strategically positioned for global response. I MEF, based in southern California and III MEF, forward based in Okinawa, Mainland Japan, and Hawaii fall under the control of the Commander, Marine Forces Pacific. II MEF, located at bases in North and South Carolina, falls under the Commander Marine Forces Command. MEF METOC personnel serve as special staff to the commanding general and are under the direction and cognizance of the intelligence division (G-2).

Figure 3 – DOD 17. The Meteorological Mobile Facility-Replacement Next Generation Vehicle (USMC Released)

The three intelligence battalions in the Marine Corps are co-located with respective MEF headquarters. These battalions directly support the MEF G-2 and serve as MAGTF intelligence centers during operations. METOC is a vital part of the intelligence estimate and is an essential element that supports the Marine Corps Rapid Response Planning Process. METOC personnel assigned to these commands pro-vide expertise, products, and services that directly support the intelligence preparation of the battle-space (IPB) process by helping intelligence analysts to effectively evaluate, integrate, and synchronize METOC effects for both enemy and friendly courses of action.

The Marine Aircraft Wing (MAW) conduct the complete range of air operations in support of the MEF, to include anti-air warfare, offensive air support, assault support, aerial reconnaissance, electronic warfare, and control of aircraft and missiles. The MAW serves as the principle headquarters for the ACE. Most of the MAGTF's METOC support assets reside within the MAW, specifically at the MWSG and its subordinate MWSS. These assets are organized, structured, and capable of supporting a variety of MAGTF and ACE-specific operations as defined by the size, scope, and mission requirements. Dedicated METOC support is available for all MAGTF elements from within the MAW/ACE.

METOC SUPPORT CAPABILITIES

Meteorological Mobile Facility-Replacement (MetMF(R))

The highest level of METOC support to the MAGTF and ACE-specific operations is the deployment of the MetMF(R). The MetMF(R) provides a METOC support capability similar to that found in garrison METOC facilities. The MetMF(R) is normally employed as part of MWSS to a forward operating base and is the only realistic option for large-scale MAGTF operations. Once established ashore, the MWSS may detach small METOC support teams with portable ancillary equipment to a forward base in support of ACE units that are separated from the main airbase. This redeployment also provides the MetMF(R) with a forward data collection capability that significantly enhances METOC situational awareness and overall support efforts to the entire MAGTF. With appropriate Service personnel augmentation, the MetMF(R) is also capable of serving as host for an in theater Joint METOC Coordination Cell (JMCC) during joint operations and exercises.
The METMF(R) NextGen is a mobile system that will provide tactical meteorological support to the Marine Air Ground Task Force This system will replace the legacy METMF(R) with current and emerging state-of-the-art technologies offering a smaller overall size and increased mobility. These advancements will significantly enhance the meteorological capabilities of the Marine Corps Expeditionary Forces.

METOC Support Team (MST)

The MST is task organized and equipped to provide a limited level of METOC support to combat elements other than the ACE (e.g., CE, GCE, and CSSE) and are assigned in support of MEU operations. It is capable of rapidly deploying as part of a first-in level of METOC support response to a crisis and can be easily integrated into an Air Contingency MAGTF. Additionally, the MST can be assigned to augment a JMCC during joint operations. Each MWSS within the MAW is structured and organized to provide one MST that consist of one METOC officer, two forecasters, and two observers. When deployed, the MST will normally be assigned to the intelligence division/section (G/S-2) of the supported combat element or MEU. The MST deploys with rugged, ancillary environmental collection and data processing equipment. During operations they organically collect METOC products, data, and information from the nearest de-ployed MetMF(R), Navy METOC OA Division afloat, host nation, or other METOC support organizations and agencies to satisfy METOC information requirements.

SPECIALIZED METOC SUPPORT

The Marine Corps' Chemical Biological Incident Response Force was established in 1996, as a result of Presidential Decision Directive 39 to manage the consequences of NBC materials or weapons used by terrorists. This national-level asset is part of the reactivated 4th Marine Expeditionary Brigade - Anti-Terrorism located at Indian Head, MD. It is comprised of specially trained and equipped Navy, Marine, and civilian personnel who can rapidly be forward deployed and/or respond to a credible threat of a CBRNE incident in order to assist local, state, or Federal agencies and designated unified combatant commanders in the conduct of consequence management operations. Within the S-2, permanently as-signed METOC forecasters provide specialized NBC dispersion forecast products and services that aid mission accomplishment of this organization.

The U.S. Army is undergoing a historical transformation from a division-centered Army, to a smaller, brigade-based Army. This transformation will require an adjustment on how weather support will be provided to the new modular Army. The Army and Air Force are discussing the possibility of weather person-nel being pooled at designated Army locations to provide a force pool of personnel ready to accompany deploying Army forces. These force pools will rely more on "reach back" capabilities to obtain pertinent meteorological data. The Army and Air Force are working together to determine the optimal weather team sizing, equipment, and communications capabilities required to support the new modular Army forces.

OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

Although it is transforming to a modular force, the existing weather support structure within the U.S. Army is a mix of Army and USAF personnel and equipment according to Army-Air Force agreement (Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the U.S. Army, 30 June 1996). This joint regulation describes the Service responsibilities and those of Army Commands and Army Service Component Commands (ASCC) within the Army for providing weather support. The U.S. Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. Air Force (AF) Major Commands (MAJCOMs) provide op-erational weather services to war fighting ASCCs in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. Army Training and Doctrine Command (TRADOC) have AF Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) Crews provide direct upper air observation support to artillery units in the same ASCC. During peacetime training and activation, the Air National Guard (ANG) provides AF operational weather support to the U.S. Army Reserve (USAR) and the Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies, the ANG may augment the active Army as weather personnel.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDT&E) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and U.S. Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is established under Army Test and Evaluation Command. SMDC provides weather support to the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF weather personnel for tactical operations. The Distributed Common Ground System – Army (DCGS-A) provides the U.S. Army's tactical weather communication, intelligence, and information system providing digital weather support to the commanders and staffs of tactical units, from Echelons Above Corps (EAC) to aviation bat-talions.

ARTYMET Crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET Crews also take limited surface observa-tions at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET Crews in the Active Army (AA) and RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire (Figure 18), to USAF weather personnel, and to the

Figure 3-DOD-18. Accurate wind profiles are essential for the Artillery to engage their targets. (US Army Released)

Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations. The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK develops requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff, G-2, is responsible for Army weather support policy. The Office of the Deputy Chief of Staff, G-3, is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements.

ARMY OPERATIONAL SUPPORT PROVIDED BY THE AIR FORCE

Under AR 115-10/AFJI 15-157, the AF is provides the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison Active Army and reserve component support requirements. Army support manpower requirements are sourced from AF active, re-serve, and ANG weather personnel. While direct support of the Field Artillery remains an Army responsi-bility, and is supported by Army ARTYMET teams, AF Weather personnel provide supplemental informa-tion to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the war fighting Army Commands and ASCCs at theater, corps, division, armored cavalry regiments, and separate brigades to provide direct, on-site weather support. Air Force Special Operations Command (AFSOC) Special Operations Weather Teams (SOWTs) conduct weather operations for USASOC and are primarily funded by USSOCOM. AF operational weather squadrons (OWSs) and post-level weather organizations provide garrison and tactical weather warning, observing, forecasting, special support,

Figure 3-DOD-19. Reliable wind forecasts are necessary to ensure safety during flight operations. (US Army Released)

and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection. Per Army-AF agreement, the AF is responsible for in-stallation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfields. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army's IMETS is fielded for these purposes and is operated by AF personnel. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorologi-cal functions within IMETS. IMETS uses AF meteorological software, but IMETS is hosted on an Army vehicle, uses Army tactical communications and Army weather effects software. IMETS baseline software is hosted on Army Common Hardware and is Defense Information Infrastructure Common Operating Envi-ronment (DIICOE) and Joint Technical Architecture - Army (JTA-A) compliant. The Army provides other tactical equipment to AF Personnel through an Army Table of Organizations and Equipment (TOE). The following paragraphs describe weather activities within Army Commands and Army Service Component Commands.

U.S. ARMY FORCES COMMAND (FORSCOM)

Weather support to the U.S. Army Forces Command is diverse and demanding. FORSCOM, the Army's largest major command, requires and uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observa-tions for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations. FORSCOM consists of more than 750,000 Active Army (AA), U.S. Army Reserve (USAR) and Army National Guard (ARNG) soldiers. These soldiers account for more than 80 percent of the Army's combat power. FORSCOM trains, mobilizes, deploys, and sustains combat ready forces capable of responding rapidly to crises worldwide. The AA component of FORSCOM has nearly 200,000 soldiers. Third U.S. Army is the Army component of U.S. Central Command (USCENTCOM), which is the Joint command responsible for Southwest Asia (SWA), the Persian Gulf, and the Horn of Af-rica. U.S. Army South (USARSO) serves as the Army component to U.S. Southern Command (US-SOUTHCOM). USARSO relocated from Fort Buchanan, Puerto Rico, to Fort Sam Houston, Texas, in 2003 and became a FORSCOM major subordinate command October 1st, 2003. FORSCOM also commands three Army Corps: I Corps at Fort Lewis, Washington, III Corps at Fort Hood, Texas, and XVIII Airborne Corps at Fort Bragg, North Carolina. Together they include six divisions, two armored cavalry regiments, five separate brigades and a range of other corps combat, combat support and combat service support units. Two Continental U.S. Armies (CONUSAs), First U.S. Army and Fifth U.S. Army, are respon-sible for training, mobilization, and deployment support to Reserve Component units in FORSCOM. An-other major subordinate command to FORSCOM, the U.S. Army Reserve Command (USARC), com-mands all U.S. Army Reserve units in the continental United States except those assigned to Special Op-erations Command. FORSCOM's Army Reserve strength stands at approximately 196,000 soldiers. USARC units are part of the Federal force and make their primary contribution to FORSCOM combat power in combat support and combat service support specialties such as medical, civil affairs, transporta-tion, maintenance and supply.

The ARNG provides FORSCOM a balanced force of eight National Guard combat divisions, 15 enhanced separate brigades, extensive combat support, and combat service support units. The current FORSCOM ARNG strength is approximately 367,000 soldiers.

Weather support to FORSCOM's AA units comes from dedicated AF weather personnel aligned under three Air Support Operations Groups (ASOGs) within Air Combat Command (ACC): 1 ASOG at Fort Lewis, Washington; 3 ASOG at Fort Hood, Texas; and 18 ASOG at Pope AFB, North Carolina. A weather squadron under each ASOG supports the Corps. Each Army division normally has dedicated AF personnel aligned under an Air

Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division weather personnel are authorized personnel and equipment to support a variety of missions at the various Army echelons. Weather support at each Army echelon is provided according to Army Field Manual 34-81. Currently, there are nearly 350 authorizations supporting various echelons across FORSCOM. These personnel, enabled by an operational weather squadron, provide garrison and tactical weather warning, observing, mission execution forecast, special support, and SWO services during peacetime, combat, contingency, exercise, or armistice operations.

ACC weather organizations provide direct, on-site support at 11 major Army installations, including the National Training Center at Fort Irwin, California, and the Joint Readiness Training Center at Fort Polk, Louisiana and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions.

FORSCOM provides supporting AF weather personnel with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables, maintenance, etc.). ARTYMET requirements in FORSCOM increased from 17 to 20 sections in FY 2005 due to modularity. These 6-person sections, comprised of Army weather personnel, collect upper air observations for direct use by field artillery units..

The New Tactical Forecast System (N-TFS) is the primary in-garrison and tactical weather equipment for receiving graphics and alphanumeric data. Data is received via the Very Small Aperture Terminal (VSAT), Tactical VSAT (T-VSAT), Non-Secure Internet Protocol Router Network, and Secure Internet Pro-tocol Router Network. Nineteen IMETS and 15 IMETS-Lights, developed by the Army Research Labora-tory, have been fielded within FORSCOM. FORSCOM has also fielded commercial Automated Weather Observing Systems at Yakima Training Center Washington, Fort Campbell, Kentucky, and Georgetown Bahamas.

TRAINING AND DOCTRINE COMMAND (TRADOC)

Headquarters, TRADOC is responsible for development and management of Army weather training programs, weather support doctrine (concepts and field manuals), and the establishment of Army re-quirement documents for tactical weather support. Key mission areas for the next few years will be to as-sist the AF to develop and implement a new weather support concept to meet the needs of the Army's Modular Force including Brigade Combat Teams and Future Combats Systems; to update weather sup-port doctrine, policy, organization, concepts, and tactics, techniques, and procedures; to ensure weather effects to Army operations are documented and communicated to soldiers and AF weather support per-sonnel, and to ensure Army weather support processes and procedures are trained across the TRADOC schoolhouses.

The Integrated Meteorological System (IMETS) is a program of record that continues as the state-of-the-art Army meteorological decision-aid support system. Over the next few years some of its capabili-ties will be consolidated into the Air Force's Joint Environmental Toolkit (JET) program. The Army will 1) retain research and development efforts related to Army-specific weather support challenges, 2) be re-sponsible for integrating JET into DCGS-A weather services and interfacing JET with Army command and control systems, and 3) will be responsible for fielding IMETS/JET software capabilities on common Army hardware systems. In FY08, the IMETS Program Office moved under the Program Executive Office - Intel-ligence, Electronic Warfare & Sensors (PEO-IEW&S) as part of the Distributed Common Ground System-Army (DCGS-A) program. Initial JET fielding (Terrain/Weather V4.0 Spin-Out) is programmed to begin in 1QFY 2010.

The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the Army warfighter by collecting weather support requirements and developing solutions to satisfy those requirements when they are the responsibility of the Army. The key system that provides weather support to the Army is IMETS, which is fielded by the Army and operated by AF weather personnel. The USAIC&FH Weather Team assists the IMETS program by advising the Army Research Lab, USAIC&FH, DAMI-OPS, and AF/A3O-W on Army weather support shortfalls and issues. The USAIC&FH Weather Team provides instruction on weather support techniques and weather effects to Army operations to Army Military Intelligence personnel as well as AF weather per-sonnel supporting the Army. The USAIC&FH Weather Team consists of two active duty AF weather per-sonnel, one civilian contractor that manages the Battlefield Weather Course (BWC), and one Department of the Army Civilian that serves as the assistant TRADOC Capabilities Manager (TCM) for IMETS. The USAIC&FH Weather Team recently drafted an Army Weather Functional Area Analysis for Battlespace Weather Sensing and will continue associated work on weather inputs to the Intelligence, Surveillance and Reconnaissance Concept Capabilities Plan. The team has also authored a plan with HQ TRADOC to create an Army Weather Proponent office (AWPO) at Fort Huachuca. The purpose of this AWPO would be to oversee Army weather concerns, serve as the Army's focal point for weather requirements and will lead the Army's functional efforts in guiding concepts and capabilities development, experimenta-tion, DOTMLPF, and requirements determination. This effort will help coordinate and de-conflict all Army weather initiatives and represent Army Intelligence in all weather program and development issues. This initiative includes the hire of a Department of the Army Civilian to serve as AWPO Chief. The TCM for IMETS coordinates with DCGS-A to ensure the highest level of integration of IMETS into the DCGS-A family of systems. The TCM recently participated in the DCGS-A Fusion Working Group and provided DCGS-A an evaluation of IMETS ability to satisfy the DCGS-A requirements.

The AF SWO at the Army's Combined Arms Center (CAC) is the primary overseer of the Tables of Organization and Equipment (TOE) for AF weather teams supporting Army operations. The CAC SWO is the AF point of contact for implementing TOE structure changes for support to Modular Forces in the Transformed Army. The CAC SWO also arranges for or provides environmental data, concepts of opera-tion, and weather subject matter expertise for programs, projects, documents, and studies conducted by 1) the TRADOC System Manager - Army Battle Command System, 2) the Battle Command Battle Lab-Leavenworth, 3) the Center for Army Lessons Learned, 4) the Combined Arms Doctrine Directorate, 5) the TRADOC Assistant Deputy Chief of Staff for Intelligence –Threats, the Foreign Military Studies Office, and 6) the TRADOC Analysis Center-Leavenworth. Other key CAC SWO tasks are to develop weather/weather effects scripts and climatology packages to support modeling and simulation efforts of the Battle Command Training Program (BCTP) and the National Simulation Center, to make available Army weather support instruction at the Command and General Staff College (CGSC), to provide climate expertise to all units assigned or attached to Fort Leavenworth and to be the Staff Weather Officer to the U.S. Army Aviation Warfighting Center (USAAWC) at Fort Rucker, AL. point of contact for weather sup-port.

The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK is the proponent for upper air mete-orological support to the Army. The AN/TMQ-41 Meteorological Measuring Set (MMS) and AN/TMQ-52A Meteorological Measuring Set-Profiler (MMS-P) are utilized to conduct surface and upper air obser-vations. The MMS and MMS-P provides weather data to the Field Artillery Tactical Data System for ballis-tic calculations; to USAF weather personnel for weather forecasting; and to the Chemical Officer for ob-scurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. Efforts are ongoing to ensure these surface and upper air observations are sent back to military weather centrals where they can be ingested in to our newest numerical meteorological analysis and forecasting models. Active unit's MMSs will eventually be replaced by the AN/TMQ-52A Meteorological Measuring Set Profiler (MMS-P). The MMS-P is currently being fielded and is scheduled for completion of fielding by FY11. The MMS-P is a suite of meteorological sensors and associated software/models which will provide the Field Artillery with current and/or expected weather conditions at a point where the weapon munitions is expected to engage a target (Target Area Met). Currently, both the MMS and MMS-P are trained to all Advanced Indi-vidual Training soldiers attending the Field Artillery Meteorology Course.

The U.S. Army Aviation Warfighting Center (USAAWC) at Fort Rucker, AL incorporates weather instruction and procedures into rotary-wing training programs in their mission areas. The center is the proponent for all Army Aviation including Unmanned Aerial Vehicle Systems (UAVS). The Center has re-quirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites.

Back in FY04, Air Combat Command (ACC) contracted day-to-day operational weather support to aviation operations at Fort Rucker (Cairns Army Airfield, Troy Municipal Airport, and Andalusia Municipal Airport) to 3D Research Corporation (3DRC). ACC, through the same contract with 3DRC, also provides garrison airfield weather services (observing and/or forecasting) at Fort Belvoir, Fort Benning, Fort Knox, Fort Leonard Wood, Fort Huachuca, and Fort Sill. The current 3DRC contract ends in Aug 08, and will then be re-bid to ensure there is no lapse in services.

Eighth U.S. Army

The Eighth U.S. Army uses Army resources to measure surface and upper air meteorological data for artillery meteorology (ARTYMET) support. Second Infantry Division's (2 ID) First Heavy Brigade Com-bat Team (1 HBCT) uses the newly field AN/TMQ-52 Profiler System, while 2 ID's 210th Fires BDE uses the legacy AN/TMQ-41 Meteorological Measuring Set to collect upper air data for direct use by field artil-lery units.

Figure 3-DOD-20. Meteorological Measuring Set – Profiler (MMS-P) obtains upper level wind data for artillery fires. (US Army Released)

Air Force weather personnel assigned to the 607th Weather Squadron (607 WS) provide operational weather support to Eighth Army units. The 607 WS provides garrison and tactical weather observ-ing, advisories, mission execution forecasts and staff weather support during armistice operations, exer-cises and contingencies. These personnel use knowledge of Army missions to prepare theater-scale and site-specific weather forecasts essential to resource protection, operational planning and execution of combat operations. The 607 WS has personnel at five installations to provide direct weather support to HQ Eighth Army, HQ 2 ID and the 2nd Combat Aviation Brigade (2 CAB). In FY08, the 607 WS has 65 assigned weather personnel to support the Army mission. IAW AR 115-10/AFJI 15-157, the Eighth Army provides garrison facilities, tactical equipment (MTOE and CTA) and an operating budget.

United States Army Europe

U.S. Army Europe (USAREUR) and 7th Army (7A) require and use Army resources to provide meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations.

The Air Force's 7th Weather Squadron (7WS) provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison operations, contingency and exercise operations, staff weather officer (SWO) services, and specialized support. The U.S. Air Forces in Europe (USAFE) Operational Weather Squadron (OWS) at Sembach AB, Germany, provides operational-level forecast products for the European Command Area of Responsibility, to include all USAREUR units. Weather teams located at V Corps and its aviation assets, 1st Armored Division and its aviation brigade, Southern European Task Force, and 7th Army Training Command, as well as

7WS sup-porting 7th Army, evaluate and tailor these forecast products to enhance 7A Staff situational awareness and produce mission execution forecasts when needed.

The 7WS mission, with its 5 detachments and operating locations, provides weather operations packages to conform to the Army's garrison and war operations. Additionally, 7WS conducts weather operations and planning to meet future Army transformation and modularity initiatives. 7WS will provide or arrange deploying weather force structure to match missions USAREUR, or its subordinate elements, is called upon to execute. 7WS will tailor the permanently assigned weather force to meet requirements of the 7A structure and utilize "reachback" capabilities to the maximum extent possible to minimize the fielded footprint without compromising weather operations.

Three Integrated Meteorological Systems (IMETS) and five IMETS Lights are fielded within USAREUR (V Corps, two divisions and their aviation brigades, and two separate brigades). IMETS is geared to interface as a module of the Army Battlespace Control System to inject decision-quality weather products into the common operating picture for Army commanders.

USAREUR provides supporting USAF weather teams with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four artil-lery meteorological (ARTYMET) sections collect upper air observations for direct use by field artillery units. The Forward Area Limited Observing Program (FALOP) consists of Army personnel taking limited obser-vations at forward areas in the battlespace. USAREUR G2 funds purchases of handheld weather sensors for use in FALOP training and equipping Army teams to provide limited weather data at Forward Operat-ing Bases and Forward Arming and Refueling Points. This data provides critical information that benefits flight safety as well as the theater weather sensing strategy without having to forward deploy more people to austere locations.

7WS also provides combat skills training to weather forecasters to increase their ability to be assets in combat, should the need arise. Some training and equipment are supplied by Joint Multinational Training Center HHC.

<u>U.S. Army Special Operations Command (USASOC)</u>

Routinely deployed in over three dozen countries, USASOC's forces have demanding missions spanning the globe and all levels of warfare. Special Operations Forces (SOF) missions are often carefully managed, high-risk scenarios operating at the edge of equipment capabilities, frequently at night and in adverse weather; these mission profiles routinely create great demands for precise weather information. SOF meteorological and oceanographic (METOC) operations with USASOC forces enable commanders to improve efficiency, effectiveness and safety of operations. Air Force Special Operations Command (AFSOC) Special Operations Weather Teams (SOWTs) and Air National Guard (ANG) weather person-nel provide direct support to USASOC units and are assigned to AFSOC's 10th Combat Weather Squadron (CWS); 320th Special Tactics Squadron (STS); and 321st STS. ANG personnel providing di-rect support to USASOC when activated are assigned to the 107th Weather Flight (MIANG), 146th Weather Flight (PAANG), and the 181st Weather Flight (TXANG). These SOWTs employ specialized AFSOC-provided tactical METOC kits to conduct environmental reconnaissance and provide METOC observations from data-sparse areas in permissive and uncertain environments for planning and executing U.S. military operations. At the deployed team level, 10th CWS SOWTs collect weather data that are used by SOF commanders and staffs and forwarded to strategic METOC centers to improve meteoro-logical models & forecasts. Additionally, SOWTs operate with the U.S. Army Special Forces Command's seven Special Forces Groups (SFG); the 75th Ranger Regiment; the 160th Special Operations Aviation Regiment; all SFG and regimental subordinate battalions, and Psychological Operations Groups. AFSOC SOWTs provide the DOD's sole source for high-fidelity METOC environmental data collection from aus-tere, denied, hostile, or semi-permissive areas of the battlespace. In addition, full-spectrum METOC opera-tions include: climatology, solar/lunar illumination and geometry analyses and atmospheric effects studies; feasibility analyses, courses of action and mission impact assessments; surface, upper-air and tactical ra-dar observations; weather watch/warnings; highly-resolved mission execution forecasts that demand fully-integrated and highly-qualified SOF METOC forces, including flight weather briefings and drop/landing zone forecasts; training ARSOF and host nation and indigenous forces on conducting limited METOC observations; and foreign internal defense analyses, surveys, and training.

USASOC plans and expends resources for some operational and administrative support to SOWTs operating with USASOC components. USASOC provides funding for office and deployable automation systems and connectivity to local networks; operations and maintenance/sustainment to sup-port USASOC requirements. Additionally, USASOC provides for some tactical items such as NBC and some communications equipment; electrical power, vehicles, life support equipment necessary for ac-complishing AFSOC's USASOC weather operations; and maintenance and supplies for USASOC-provided equipment. USASOC also provides funding for facilities, telephones, office space, and real property to house supporting special operations weather units, as well as secure storage of required equipment.

Figure 3-DOD-21. Soldiers and equipment are constantly exposed to the elements, as evidenced by this dust covered HMMWV. US Army photo by Sgt. Igor Paustovski. (US Army Released)

USASOC and AFSOC are cooperating to integrate the Joint Environmental Toolkit (JET) into the DCGS-A and suite of SOF operational capabilities. Two AFSOC meteorological liaison staff from the HQ AFSOC/A3W (Operations Weather Division) are located at HQ USASOC to coordinate AFSOC-USASOC METOC operations, logistics, and related requirements.

United States Army Pacific (USARPAC)

U.S. Army Pacific (USARPAC) uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating surface weather observations to support tactical units and operations.

USARPAC provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operations and maintenance funds.

The Integrated Meteorological System (IMETS) and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The IMETS and NTFS receive data via Army-provided reachback NIPRNET and SIPRNET conduits.

The 17th Operational Weather Squadron (17 OWS) at Hickam AFB, HI, provides HQ USARPAC ASCC with garrison and tactical weather warnings, forecasts, special support, and Dedicated Support (DS) Staff Weather Office (SWO) services. Additional AF personnel provide DS weather support to the 25th ID (L), 25th CAB, and the 1-25 SBCT. USAF also provides weather support, though not in a DS role, to U.S. Army Japan (USARJ), U.S. Army Hawaii (USARHAW), 4-25 IBCT, USARPAC's Early Entry Command Post (EECP), and U.S. Army Alaska

(USARAK). DS AF personnel deploy with their supported operational organizations, providing tailored battlefield observations and forecasts. Weather reengineer-ing has reduced the requirement for forward-deployed weather personnel, instead leveraging IMETS and other recently fielded technology for reachback capability. 17 OWS provides regional weather support, allowing forward-deployed AF personnel to focus on specific area and target forecasts.

There are three subordinate commands within USARPAC: U.S. Army, Hawaii (USARHAW), U.S. Army, Alaska (USARAK), and U.S. Army, Japan (USARJ).

The 17 OWS provides tactical- and operational-level forecast products for the PACOM AORs, to include all USARJ, Korean Theater of Operations, and Alaska. This includes specific resource protection support (i.e. weather advisories, warnings, and watches), as well as Terminal Aerodrome Forecasts for se-lected units.

The 5th Air Force (5 AF) Liaison serves as USFJ's Staff Weather Officer (SWO), and also serves as the USARJ SWO. Day-to-day support for Camp Zama, Japan is provided by an Operating Location (OL) under the AF CWT assigned to the 374th Operational Support Squadron at Yokota AB. The OL on-site at Camp Zama provides weather observation services and produces mission execution forecasts ISO support aviation operations.

The 17OWS provides strategic and theater level weather support and services to all DOD units stationed or operating in Alaska. At the tactical-level, the 3 ASOS/WE is collocated with the 1-25 SCBT at Fort Wainwright, AK. They provide weather support for both tactical and garrison operations, observe the atmosphere and evaluate and tailor forecast products to produce Mission Execution Forecasts and staff briefings. 3 ASOS/WE also supports 1-25 SCBT tactical unmanned aerial vehicle (T-UAV) opera-tions. The Alaska Army National Guard operates the Fort Richardson Army Airfield.

Army National Guard (ARNG) Artillery

In the ARNG Modular Force, there is one 6-solder team per Fires Battalion in the Brigade Combat Team (BCT), providing 34 teams with six soldiers each, for 204 soldiers. In the Fires BDE there are 3 MET teams required per BDE providing 21 teams with 6 soldiers each, for a total of 126 soldiers; how-ever, all Fires BDE TABs are authorized only one MET team for a total of 48 soldiers. The ARNG is au-thorized 252 soldiers in the Artillery Meteorological Teams.

The ARTY MET sections provide upper air observations at least 39 training days each year sup-porting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTY MET sec-tions support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG's ARTY MET Teams use the Meteorological Measuring Set (MMS), AN/TMQ-41A.

<u>Army Corps of Engineers</u>

In its civil operational activities, the Corps of Engineers (COE) uses a network of about 10,850 land-based gages. About 55 percent of the sites collect meteorological data, 35 percent a combination of hydrologic and meteorological data, and 10 percent hydrologic or water quality data. The COE funds or partially funds 58 percent (6350) of all the gages it uses. Meteorological gages commonly measure pre-cipitation and temperature as a minimum. Most sites also measure hydrological data. All data are used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation.

The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain pre-cipitation information from 877 of meteorological sites. Similarly, COE transfers funds to the U.S. Geo-logical Survey to maintain precipitation data collection from about 2400 sites, while the COE maintains the rest. Seventy-five percent of all COE sites provide real-time data via satellite, microwaves, meter-bursts, landlines, or radio. Data from COE gaging sites are available to other federal, state and local agencies. All COE data are made available to the National Weather Service. Most of the data are also used by other agencies.

<u>United States Army Space and Missile Defense Command (USASMDC)</u>

The High Energy Laser Systems Test Facility (HELSTF), an USASMDC directorate located on

White Sands Missile Range, is an Army element of the DOD Major Range and Test Facility Base with the mission of high-energy laser (HEL) test and evaluation for future Army and sister Service HEL weapons. In addition to HEL systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HEL testing by providing measurements of atmospheric conditions that are extremely important to propagation of any HEL beam thru the atmosphere. Many unique meteorological instruments are maintained to sup-port this critical data collection for HEL testing. The HELSTF meteorological team also supports critical safety analysis of atmospheric dispersion for the very toxic laser fuels used.

U.S. Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support for the Ronald Reagan Ballistic Missile Defense Test Site (RTS). The RTS meteorological services support contractor provides meteorological support for range activities including missile operations within the atoll, remote island missile launches including Wake Island, intra-atoll transportation (marine and aircraft), and emergency operations support.

A full suite of surface and upper air observing equipment is available for support of these operations. Three fixed upper air sounding systems (two utilizing GPS radiosondes) are located on Kwajalein and Roi-Namur. One portable GPS upper air system is available for deployment to remote locations providing upper air soundings. A dual-polarized -Doppler S-band weather radar provides weather surveillance from Kwajalein Island, and Doppler C-band weather radar is available for operations at Wake Island. Two POES satellite receivers (one mobile) both having McIDAS display and management systems, and one geostationary satellite receiver provide access to satellite imagery and data processing and analysis. An intra-atoll mesonet and lightning detection network round out the sensors available to RTS forecasters at Kwajalein. Lightning prediction and detection at Wake Island is supported by a thunderstorm sensor and field mill combination. In cooperation with NASA/GSFC, RTS weather continues to support global climate studies through the Tropical Rainfall Measurements Mission and the follow-on program of Global Precipitation Measurement and a smaller program of monitoring the solar-earth radiation flux for NOAA/ERL.

Figure 3-DOD-22. USASMDC is responsible for meteorological support to the Ronald Reagan Ballistic Missile Defense Test Site in the remote Kwajalein Atoll. (US Army Released)

WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDT&E)

Under Army-AF agreement, the Army has responsibility for weather support for research, develop-ment, test, and evaluation (RDT&E) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research re-lated to soldiers performance in the range of weather conditions expected to be encountered in all thea-ters of operations. The Army Test and Evaluation Command (ATEC) is responsible for operational mete-orological support to Army RDT&E.

<u>Army Corps of Engineers</u>

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The Topographic Engineering Center (TEC), and the Cold Regions Research and Engineering Laboratory

(CRREL) of COE's Engineer Research and Development Center (ERDC), develop Tactical Decision Aids (TDAs) to interpret the impact of weather on terrain to enhance Army operations. TDAs are transitioned to the Digital Topographic Support System (DTSS) and the Commercial Joint Mapping Tool Kit (CJMTK). Under its military mission, CRREL, Hanover, NH, provides support to Army weapon systems RDTE with all season solutions for mitigating adverse environmental effects on Army operations. CRREL conducts basic and applied research to investigate energy and mass transfer process at and near the terrain surface. Energy propagation and interaction across the electromagnetic, acoustic, and seismic spectral regions sees special emphasis, particularly with regard to dynamics in propagation caused by properties and processes of materials near the terres-trial surface. CRREL develops databases and models for predicting the state of the terrain including sur-face temperature, and tactical decision aids supporting mobility analysis and sensor performance. In part-nership with TEC, Alexandria, VA, these products transition to various research and engineering programs including advanced technology demonstrations and specific programs of record such as DTSS and CJMTK.

Army Materiel Command (AMC)

The Army Materiel Command (AMC) is responsible for the research, design, development, test, and evaluation of equipment to satisfy the Army's requirements for meteorological support. AMC provides climatological and meteorological support to RDTE projects involving electro-optical sensors, atmospheric and obscurant effects on systems and their performance. It is also responsible for determining weather impact critical threshold values and the environmental sensitivities of battlefield systems, including sol-diers. AMC has several Major Subordinate Commands (MSCs) and elements carrying out weather re-search and development responsibilities including the Research Development and Engineering Command (RDECOM), which has responsibility for the Army's Research Development and Engineering Centers (RDECs) and the Army Research Laboratory (ARL).

The Army Research Laboratory Battlefield Environment (BE) Division has a robust program in de-veloping very high spatial and time resolution characterizations of the lower atmosphere using both meas-urements and numerical models. This research is particularly focused on characterizing and predicting higher resolution effects caused by complex and urban terrain. The focus of RDT&E is in the near-surface boundary layer domain that is most critical to Army applications. RDT&E includes characterizing aerosols and CBRN contaminants in the atmosphere and on predicting more general impacts of weather on Army systems, sensors, personnel and operations. Research addresses how to assimilate battlefield meteoro-logical observations into diagnostic and prognostic numerical weather models and how to fuse forward area observations into these short term forecasts or 'nowcasts" to correct for actual local conditions and improve actionable weather information.

The Battlefield Environment Division of the ARL Computational and Information Sciences Direc-tor-ate (CISD) has a long history in atmospheric science research and applications. The Division consists of three Branches located at Adelphi, Maryland and White Sands Missile Range, New Mexico. The three branches combine basic and applied research programs in the areas of: meteorological modeling and modeling applications at high space and time resolution and the effects of complex terrain; atmospheric sensing of aerosols and contaminants using laser scattering, spectral analysis, multi-wavelength imagers, and lidars; atmospheric and aerosol propagation including electromagnetic and acoustic signal and target effects modeling; meteorological measurements as part of the "develop-verify-improve-verify" modeling and measurement cycle; and advanced weather impact decision aids for Command and Control and for Intelligence, surveillance, reconnaissance and target acquisition. The Division also provides liaison per-sonnel between Army weather R&D and the coupled programs at the Air Force Weather Agency and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) IPO. These positions fo-cuses on coordinating technology transitioned from the BE Division into Army and Air Force fielded sys-tems.

The vision of the Battlefield Environment Division is to enhance Warfighter effectiveness through environmental knowledge and technology. The mission statement expands on this vision and is "to per-form research that solves complex Army-scale atmospheric problems and results in joint weather intelli-gence and Army-specific products for global Warfighter survivability, lethality, mobility, and situational awareness." The BE program addresses these Army needs for both current and future Army operations such as the Future Combat System (FCS), as well as providing answers in related areas such as home-land security and response to man-made and natural disasters.

BE Division and the Army Project Director- Integrated Meteorological System (PD-IMETS) office are partnering with Air Force Weather in new programs such as the development of a common Joint Envi-ronmental Toolkit (JET). The Army IMETS Battle Command (BC) 6.4 software and several Air Force weather system software baselines are to converge as a single weather forecasting software tool in the DCGS-A Weather Services. The Army will add command and control interfaces and weather effects tactical decision aid products such as the Tri-Service Weather Effects Decision Aid (TS-IWEDA). The com-bined JET-IMETS software will transition to the Distributed Common Ground Station-Army (DCGS-A) and Army software Block 2+ to enhance weather capabilities for net-centric Army support. POR IMETS/DCGS-A weather products can be accessed through a web-browser, client server applications, or overlaid on the user's Common Operational Picture (COP) through web services such as publish and subscribe (PASS). Current client applications will be web-enabled over time. IMETS/DCGS-A Weather Services technologies will continue to provide net-centric weather support to Army Battle Command and Future Combat Systems (FCS) as DCGS-A Weather Services.

The Atmospheric Modeling Applications Branch addresses the development of the next generation mission execution forecast model (very short term forecasts), web-enabled tactical decision aids, and avia-tion weather route planners for manned and unmanned systems applicable for DOD and DHS missions.

Meteorological forecast model applications are focused on the Weather Running Estimate-Nowcast (WRE-N) and Meso/micro-scale Numerical Weather Prediction development, improvements, and evaluation. The WRE-N is a combined analysis and "nowcast" model system that will provide the DCGS-A with a capability to satisfy the stated now-casting requirement. The WRE-N system will produce locally-updated high resolution meteorological data in 3-hour forecast blocks, tailored for execution-level planning and decision making applications. As battlefield weather conditions change, the WRE-N will produce rapid and continuous "local corrections" to regional scale mission planning operational forecasts, retain consistency with theater-wide operational forecast guidance from Air Force and joint DOD weather cen-ters, and insure effective assimilation and fusion of local battlefield weather observations into each WRE-N modeling cycle. Such fine-scale battlefield weather modeling work leverages the ARL High Perform-ance Computing (HPC) capabilities to facilitate examination of the applicability of new atmospheric pre-diction models for Army scales, that is, at horizontal coverage of hundreds of kilometers and grid spacing of one kilometer or less, and test new boundary layer closures and data assimilation methodologies.

Warfighter Decision Aids developed in the branch utilize meteorological model gridded output to provide the commander a tactical advantage with validated and verified, web-enabled, tactical decision aids and associated databases that describe the impacts expected and the resulting performance degra-dation due to weather for both friendly and threat systems, allowing for analysis and adjustments in tactics and weapon system selection before enemy engagement. Decision aids play an important role in the mission planning process associated with both man in the loop and autonomous command and control systems.

Work to develop Unmanned System Applications has focused on the Aviation Weather Routing Tool (AWRT) as the primary end product. It addresses a major shortfall in providing accurate weather effects information to manned and unmanned aircraft mission commanders. The AWRT may be considered as a sophisticated tactical decision aid that will generate a highly-intuitive, 4-D graphical "fly through" dis-play of adverse weather effects on aircraft systems. Perhaps more significantly the AWRT will employ a computationally efficient automated search algorithm to identify optimum routes that minimize adverse weather effects along the flight path.

The BE Atmospheric Dynamics Branch addresses basic research, atmospheric measurements, numerical modeling and applications focused on the near-surface, high resolution dynamics of the boundary layer atmosphere that impact the Soldier and his systems. Projects and capabilities in the branch include:

Efficient and fast-running high resolution (sub 1 km) atmospheric models are developed that can provide a diagnostic 3D picture of wind fields in urban domains and over complex terrain. This capability provides a near real time update of average urban wind flow around buildings for their effects on CBRN, smoke screening, turbulence and wind effects on platforms and sensors.

Urban meteorology and boundary layer turbulence experiments are undertaken to highly instrument the flow around individual structures and to resolve the properties of atmospheric turbulence in the re-gimes between 3D isotropic turbulence and 2D surface layer turbulence for their effects on optical sys-tems and micro platforms. These data extend the basic research into atmospheric turbulence and support the verification and development of new wind models and optical propagation effects and simulation models.

Research is performed focused on poorly understood stable atmospheric boundary layer phenom-ena aimed at better characterizing intermittent nocturnal flow features and the capping of the boundary layer that can concentrate airborne hazards. Distinct layers in the urban domain include the Urban Mixed Layer (UML) well above the buildings, the Urban Surface Layer (USL) at the tops of the buildings, and the Urban Canopy Layer (UCL) representing the layer below the tops of the buildings and down to the street level. The features of these layers can be resolved remotely using instrumentation such as LIDAR's and radiometers.

Modeling applications for the effects of fine scale urban meteorology include development of a new urban smoke and dust transmission model for urban infantry war fighting simulations. The model uses the R&D performed for urban boundary layer dynamics with the transport, dispersion, and optical line of sight transmission to predict the effects on target acquisition and sensor performance in urban do-mains.

Bio-inspired environmental awareness for autonomous and semi-autonomous systems uses biomi-metic and biologically inspired approaches to sense and react to the microscale environment of platforms and sensors; and in particular to develop capabilities to automatically sense and avoid hazards to their operations, and to improve the reconnaissance, surveillance and search functions of small robotic devices.

The BE Atmospheric Sensing Branch currently has no personnel at WSMR. However, various branch personnel have participated in experiments and other work at WSMR over the past several years and have several proposals for work that would be done in part at WSMR locations. The Atmospheric Sensing Branch develops sensing technologies for scientific and operational sensing of the state of the atmosphere, acoustic propagation, and aerosols. Recent work has focused on the development of ultra-compact Doppler Lidar systems; experimental and theoretical developments to better understand acoustic propagation in urban environments; and aerosol measurement programs.

The Army Research Office, Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investigator program and oc-casional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer over land, where the Army operates. Objectives of the research are to de-velop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding, modeling, and quantifying of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heteroge-neous terrain features on airflow, and the development of natural obscurations

Figure 3-DOD-23. The IMETS Vehicle Mounted Configuration. (US Army Released)

throughout the diurnal cy-cle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Special funding areas are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (DEPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. The primary research focus continues on the analysis and understanding of the stable boundary layer, which is augmented by external funding as a special program. Activities include transitioning coding for stable boundary layers, based on new theoretical developments to the WRF model library for use and test by AFWA and academic users.

Communications Electronics Command (CECOM), a major subordinate command of AMC, provides support to developing and fielding weather programs through the following organizations: Logistics Readiness Center (LRC), Research, Development and Engineering Center (RDEC), Software Engineering Center (SEC), and Safety office. The CECOM LRC is the level II manager of the Meteorological Measuring Set (MMS) program.

RDEC's Communications-Electronics Research Development Engineering Center (CERDEC), In-telligence and Information Warfare Directorate provides technical management and support to the Program Manager, Intelligence and Effects and Program Manager, Night Vision/Reconnais-sance, Surveillance, and Target Acquisition for the IMETS and the MMS-Profiler. A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set (MMS), AN/TMQ-41. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisi-tion users. The system is a non-developmental item (NDI). All active Army units and National Guard Bu-reau are equipped with the MMS.

The Meteorological Measuring Set-Profiler (MMS-P) AN/TMQ-52 and AN/TMQ-52A systems. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. The Profiler design will support the new generation of artillery weapons. Profiler provides highly accurate MET data to adjust artillery fire and achieve first round hits and fires for effect. The system provides MET data on demand with data staleness of less than 30 minutes. The system will include frequent and update meteorological messages that enhances the meteorological validity over a larger battle space than the current equipment. The MMS-P uses the MM5 mesoscale meteorological model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. The system receives data from ground-based sources, radiosondes, and satellite-based sources, (such as boundary data from communications satellites and, in a future program block improvement, polar orbiting meteorological satellites) through onboard satellite receiving capability. The data affects the operation of the mesoscale meteorological model and for post-processing of the data in order to generate meteorological messages. Finally, an operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. The Profiler Program successfully executed a development and testing program culminating in an Initial Operational Test and Evaluation (IOTE) 1Q FY05. Four System Design and Develop-ment (SDD) models have been converted to a Low Rate Production configuration with 13 additional LRIP system produced. Full Rate Production (FRP) was approved at a FRP Decision in FY05. Thirty Six full rate production systems have been programmed through FY09.

Army Test and Evaluation Command (ATEC)

The Developmental Test Command (DTC), a subordinate command of U.S. Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to Army research, development, test and evaluation (RDT&E). Under responsibilities established in AR 115-10/ AFJI 15-157, the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD RDT&E activities at eight Army installations. Because much of the operational meteorological support workforce at the Army ranges is or soon will be eligible to retire, the Program has implemented an intern program to recruit and train entry-level scientists to ensure continuity in specialized meteorological support services as senior employees retire.

The Army RDT&E Meteorology Program is continuing to collaborate with the National Center for Atmospheric Research (NCAR) on enhancements to the ATEC Four-Dimensional Weather (4DWX) System, which is the backbone of the meteorological support infrastructure at the Army test ranges. Major system components include a central data archival/retrieval system for all range and external meteorological and model data, a high-resolution mesoscale meteorological model, and a variety of user-configurable displays. In FY07 the 4DWX program took delivery of a DOD high performance computer (HPC) which enables operational mesoscale ensemble forecasts to support major DTC test operations. System enhancements during FY08 include completion of an improved meteorological data archival/retrieval system with automated data quality control checks. During FY08, the 4DWX program also completed its transition from Mesoscale Model Version 5 (MM5) to the next-generation Weather Research and Forecast (WRF) model. The MM5 and WRF mesoscale models are used operationally in both predictive and ana-lytic modes to provide detailed information about the past, current, and future structure of the atmosphere over the Army's test ranges. For ensemble applications, both MM5 and WRF are used as members of the ensemble set, which typically uses 30 members with varying physics packages, boundary or initial conditions, and model type. System enhancements during FY09 will include improvements to the WRF model's capability for deterministic numerical weather prediction at the test ranges, assimilation of new types of data, development of a prototype next-generation data assimilation approach, and continued development of ensemble and probabilistic techniques. ATEC 4DWX modeling capabilities include MM5- or WRF-based real-time four-dimensional data assimilation (RT-FDDA) at seven Army test ranges and Global Meteorology on Demand (GMOD), a globally-relocatable mesoscale modeling system to support Army RDT&E (including DTC distributed and virtual testing) at locations other than the Army ranges. Output from the 4DWX mesoscale model forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

The Chief of the Meteorology Division at Dugway Proving Ground's West Desert Test Center serves as the DTC Program Manager for Meteorological Support to Army RDT&E. Specialized services provided by the Division include: (1) technical assistance to the DTC operational meteorological teams/branches; (2) atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; and (3) technical assistance to the DOD CB defense modeling com-munity in the development of new CB hazard assessment models. Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and CB hazard assessment.

Army Medical Research and Materiel Command

The U.S. Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude and nutritional status on the health and performance of individual Soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling is directed towards improving Soldier performance and minimizing health risks in climatic extremes. The sensitivity of the Soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather-related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dis-mounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days. USARIEM is working through an MOA with the Army Research Laboratory Battlefield Environment Division to implement thermal models on the Distributed Common Ground Systems – Army Weather Services.

The availability of ground level environmental data at high temporal and spatial resolution continues to pose a significant challenge for predictive model development and validation. As part of the Warfighter Physiological Status-Monitoring (WPSM) program, USARIEM is investigating methodologies needed to integrate real-time local environmental data and warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near-term environmental strain and performance status predictions for individual warfighters.