

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. 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 and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather (HQ USAF/XOW), within the HQ USAF, Deputy Chief of Staff for Air and Space Operations. HQ USAF/XOW oversees the development and implementation of weather support concepts, doctrine, policies, plans, and programs to ensure effective weather support for the Air Force, Army, and other agencies as directed by the Chief of Staff, USAF. The Air Force also provides support to DOD Joint operations as directed by the Joint Chiefs of Staff under the Unified Action Armed Forces (JCS Publication 0-2) document. HQ USAF/XOW also interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

The Air Force Weather Agency (AFWA), formerly Air Weather Service, is a field operating agency (FOA) reporting to HQ USAF/XOW. The AFWA provides centralized weather support to designated users. The AFWA has subsumed the responsibilities of Air Force Global Weather Center and is headquartered at Offutt AFB, Nebraska. The AFWA has two subordinate centers: the Air Force Combat Climatology Center (AFCCC) and the Air Force Combat Weather Center (AFCWC). Air Force Space Command provides space environmental support through the 55th Space Weather Squadron (55 SWXS).

Observations. Meteorological observations are classified as surface, upper air, radar, or satellite

observations. Observation and sensing of the space environment are discussed in the Space Environmental Services section.

Surface observations are taken by Air Force personnel to support military operations and for weather analysis and forecasting. Observations from both Air Force and Army locations (fixed and tactical) are made available to local users and are transmitted to AFWA and to other military and civil locations throughout the world.

Upper air observations provide a major input for numerical analysis and forecasting. Most of this information comes from United States and foreign rawinsonde sources and military and civilian satellite-derived data. Additional upper air information is obtained from military and civilian pilot reports.

Weather radar is a principal source of information for providing warnings of severe weather. Many of the radars are part of the United States basic weather radar network or are used to support the National Hurricane Operations Plan. The tactical weather radars are used to support contingency operations. The Air Force is evaluating concepts for a tactical Doppler weather radar which could operate in both mobile and fixed locations.

The Air Force manages the Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, and is the most important single source of global weather data used for combat support. On-board sensors provide AFWA, 55 SWXS, and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC)

with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, auroral electron counts, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional image and mission-sensor data to DOD land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses an operational linescan system. The visible detectors were selected to optimize distinction among clouds, ground, snow, and water. It uses both stellar and inertial references, together with on-board processors, to maintain stability and pointing accuracy. The DMSP also flies a microwave temperature and humidity sounder (SSM/T, SSM/T-2) which provides vertical temperature, moisture, and height profiles of the atmosphere. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

Communications. The Air Force communications system consists of conventional alphanumeric networks, high-speed automated digital facilities, long-haul, point-to-point data circuits, high-frequency intercept facilities, and the Internet.

The Air Force-operated Automated Weather Network (AWN) is the backbone of military weather communications to deliver foreign and domestic weather data to designated users. Weather intercept sites in key overseas areas obtain World Meteorological Organization (WMO) weather broadcasts, as well as non-WMO broadcasts, for AWN delivery to AFWA. The AWN also delivers these data to the Navy and to the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Prediction (NCEP).

Overseas collection and dissemination networks deliver data to, and exchange data with, the AWN Automatic Digital Weather Switch (ADWS) at Hickam AFB, Hawaii, and RAF Croughton, United Kingdom. In the CONUS, the ADWS at Tinker AFB, Oklahoma, provides alpha numeric products to the Automated Weather Distribution System (AWDS), the CONUS Meteorological Data System (COMEDS), and other special teletype systems, and provides direct support to AWDS in the collection and dissemination of weather information. These circuits also collect and disseminate military Notice to Airman (NOTAM) message traffic to all DOD CONUS users.

The Communications Front-End Processor (CFEP) at Offutt AFB, Nebraska, is the hub of all communications at AFWA. The CFEP interfaces with the AWN and drives separate graphics networks serving the CONUS, Alaska, Europe, Central America, and the Pacific.

Preparation of Analyses and Forecasts. The primary center for providing weather analyses and forecasts for Air Force and Army operations is AFWA at Offutt AFB, Nebraska. AFWA uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide weather data are relayed to AFWA and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. AFWA also provides backup for the National Weather Service (NWS) Storm Prediction and Aviation Weather Centers.

In support of DOD combat operations, Air Force Weather operates centralized units consisting of AFWA, AFCCC, 55 SWXS, fixed theater Forecast Units (FU), fixed Weather Support Units (WSU), and provides personnel to deployed Joint Meteorological/Oceanographic (METOC) Operations Centers (JMOC). AFWA has reengineered forecast operations to achieve greater flexibility and focus production on its primary customers. Forecasts are generated in the agency's Global Weather Center Division, which consists of three production branches: the Forecast Production Branch, the Special Operations Forces Weather Operations Center (SOFWOC), and the CINC Target Weather Forecast Cell (CTWFC).

The Forecast Production Branch issues a wide variety of products tailored to the needs of worldwide DOD customers, including other military and civilian weather strategic centers, the regional hubs that are coming on line in association with the reengineering of Air Force Weather units worldwide, and base and

post weather stations. This branch issues standard products such as severe weather warnings and advisories for specified CONUS military installations and worldwide tropical storm fixes, but also frequently modifies its product line to meet the dynamic needs of on-going military operations.

The SOFWOC was formed in November 1997 to respond to the needs of Special Operations Forces for worldwide, 24-hour/day, quick-response centralized weather support. SOFWOC forecasters employ a variety of weather and communications systems to collect SOF weather requirements, generate mission-specific forecasts for SOF exercises and contingency operations, disseminate their products, and obtain observations/feedback. SOFWOC also retains the flexibility to respond to short-notice contingency requirements from non-SOF customers.

The CTWFC provides fine scale planning and execution weather forecasts for any potential, emerging or ongoing worldwide joint military operation that cannot be supported from a regional hub or by the CINC's organic weather forces. CTWFC issues specialized products for rapidly emerging contingencies, mesoscale forecasts to "first-in" Army forces, and 0-15 day strategic, operational, and tactical level weather decision assistance and target forecasts for CINCs and national program offices.

Dissemination of Forecasts and Warnings. The Air Force and Army require worldwide meteorological services for specific operational and planning activities. Military users require meteorological information directed to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations.

Air Force Weather enhances the unique global capability of military aviation while indirectly assisting civil aviation. Air Force personnel provide flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers. To fulfill this requirement, designated Air Force weather personnel serve as part of the working staff of operational Air

Force, Army, and joint force units. In this capacity, Air Force weather personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. This effort helps ensure that Air Force, Army, and joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission needs.

Deployed weather teams are the basic units providing weather support in a combat theater. These teams provide surface and upper air observations, staff weather officer services, and forecasts. The tactical forecast system, tactical weather radar, tactical meteorological satellite direct readout terminals, and tactical communications terminals provide the means to acquire vital meteorological data within a theater. A high frequency radio broadcast (HFRB) system is used to augment transmission of alphanumeric and facsimile products to the theater weather force. The HFRB system consists of regional broadcast stations at Andersen AFB, Guam, Elkhorn, Nebraska, and Roosevelt Roads, Puerto Rico.

Specialized Support. AFCCC, Asheville, North Carolina, provides environmental data and specialized studies to support the Air Force, Army, and other government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFWA and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC is colocated with the National Climatic Data Center to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3-D) cloud analysis extracted from meteorological satellite imagery (Real-time Neph-analysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

The Air Force also supports an array of Air Force and Army specialized requirements. Some of these are described below:

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force

personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. Air Force weather units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force also provides launch-forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological services for the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force supports the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and Navy operate the Joint Typhoon Warning Center (JTWC) on Guam under the Naval Pacific Meteorology and Oceanography Center West, Guam. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees to the East Coast of Africa in both hemispheres.

The Air Force directly supports DOD Special Strategic Programs, the National Command Authority, the National Military Command System, and the National Security Agency. Tailored environmental support products are disseminated to these customers worldwide.

The Air Force provides space environmental data, products, services, and solar forecasts to a wide variety of customers through the 55 SWXS at Schriever AFB, Colorado. An element of the 55 SWXS is colocated with NOAA's Space Environment Center in Boulder, Colorado.

The Air Force also provides agrometeorological output to the USDA's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation.

DOD Modeling and Simulation Executive Agent for the Air and Space Natural Environment. The Air Force was confirmed in 1995 by the Executive Council for Modeling and Simulation (EXCIMS), representing the Office of the Under Secretary of Defense for Acquisition and Technology as the Executive Agent. The Executive Agent is responsible for ensuring authoritative air and space environment models, algorithms, and data intended for cross-agency/cross-Service laboratories in air and space natural environmental boundaries.

Air National Guard (ANG). There are two distinct functions within the ANG weather program. The traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and support both Army National Guard (ARNG) and United States Army Reserve (USAR) units as well as ANG flying units. A Weather Readiness Center operates at Camp Blanding, in Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield operations.

Planned Enhancements. Air Force, Army, and joint force operational requirements for environmental support are the basis for all Air Force actions to improve existing or acquire new capabilities. The Air Force assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development. AFWA and the Naval Meteorology and Oceanography Command are working on initiatives to improve environmental support to joint and service operations. They focus on the strengths of each of the services and build on existing cooperative efforts.

The Air Force is modernizing and improving strategic, operational, and combat level systems. Modernization programs include the Tactical Observing and Forecasting System (TOFS), which provides a single system for both garrison and deployed operations. TOFS replaces the Automated Weather Distribution System.

TOFS provides a garrison and combat weather forecast and observing capability. It provides deployed weather forces the capability to manipulate data and disseminate weather forecasts, advisories, warnings, briefings, and current weather information to Air Operations Centers, flying squadrons, air traffic control facilities, deployed weather teams, and Army elements located within the theater of operations. TOFS has two components: the Tactical Forecast System (TFS) and the Manual Observing System (MOS). TFS is a garrison system as well as a deployable "first-in" combat weather forecast capability. When deployed the system will replicate most home station operations, enhancing operator proficiency and minimizing the need for special training. MOS is a single-person portable observing system containing essential, basic observing equipment.

The WSR-88D procured through the NEXRAD Joint System Program Office continues to be modernized, in concert with NOAA and FAA radars, to improve reliability and maintainability and keep technology current. It is operated and maintained by DOD, NOAA, and FAA within the CONUS and by the Air Force and Navy overseas. The system incorporates the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS WSR-88D network will satisfy weather radar requirements in support of the general public, the military, and the aviation community.

The Cloud Depiction and Forecasting System (CDFS) II will make major software and hardware modifications at AFWA to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions to meet customer-stated requirements.

The MARK IVB Direct Readout program has procured new satellite receiver terminals to replace the aging MARK IIIs. In addition to providing high resolution satellite imagery from polar and geosynchronous weather satellites, the MARK IVB terminals accept and use data from the DMSP microwave imager and sounders and the TIROS microwave sounding units A and B. The MARK IVB

produces both uniform gridded data fields and traditional meteorological products.

The Small Tactical Terminal (STT) is a small, lightweight, ruggedized, modularized, interoperable, first-in satellite receive terminal that receives data transmitted by geostationary and polar orbiting meteorological satellites. There are three configurations of the STT. The basic STTs receive low resolution DMSP and civil polar (TIROS, METEOR, etc.) data as well as WEFAX transmissions from geostationary satellites. The Enhanced STT adds the capability to receive and display high resolution DMSP and TIROS real-time broadcasts. Finally, the Joint Task Force Satellite Terminal adds the capability to receive high resolution, geostationary data.

STTs are being fielded at the lowest level of tactical weather operations (i.e., support to USAF flying squadrons and Army divisions). Furthermore, all STTs can be networked through battlefield communication internets to create comprehensive satellite imagery distribution systems. Future developments in the STT program build on these initial capabilities to further reduce the size and weight of equipment and maximize use of the communication links on the battlefield.

SPACE ENVIRONMENTAL SERVICES

55th Space Weather Squadron (55 SWXS) is the Air Force focal point for operational space environmental support. 55 SWXS also participates with NOAA in the joint operation of the Space Environment Center (SEC) in Boulder, Colorado. Under existing agreements, SEC and 55 SWXS provide limited backup for each other during contingencies. Many DOD systems operate in, or are affected by, conditions above 50 kilometers. The space environment includes the thermosphere, ionosphere, and magnetosphere, as well as the regions that influence them, such as the sun and interplanetary space. 55 SWXS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems that operate in this environment. Space environment forecast products and/or specialized services are provided for the following:

- ▶ Ionospheric conditions.
- ▶ Energetic particle fluxes at satellite orbits.
- ▶ Solar flare, solar particle, and geomagnetic storm events.

- ▶ Upper-atmospheric density variations by providing geomagnetic and solar indices.
- ▶ High frequency (HF) radio wave propagation.
- ▶ Detailed post-analysis studies of operational system problems to determine if the space environment was a contributing factor.

The effects of the space environment on DOD systems are many and varied. The magnetosphere affects satellite operations through such phenomena as single event upsets (SEU) and spacecraft charging. Manned spaceflights are vulnerable to intense radiation from large solar flares and geomagnetic storms, particularly for high inclination orbits. Ionospheric conditions have a profound effect on the propagation of radio waves and radar signals, leading to communications blackouts and erroneous radar returns. Variations in the neutral atmosphere affect satellites orbiting at relatively low altitudes.

Sources of Space Environmental Data. To obtain solar data, the 55 SWXS operates a network of solar optical and radio telescopes. Solar Electro-Optical Network (SEON) observatories are located at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Palehua, Hawaii, San Vito, Italy, and Learmonth, Australia. The 55 SWXS also receives real-time solar X-ray and energetic particle and geomagnetic data from the Geostationary Operational Environmental Satellites (GOES); DMSP, NOAA, and other DOD geostationary satellites provide additional energetic particle data in low-Earth and geosynchronous orbits. The 55 SWXS and NOAA SEC also exploit real-time solar wind data from the NASA Advanced Composition Explorer satellite currently one million miles sunward of the earth at the L-1 Lagrangian point.

A world-wide (primarily Northern Hemisphere) network of ionosondes and polarimeters provides ionospheric data. Air Force Weather has deployed the automated Digital Ionospheric Sounding System (DISS) to replace older instruments and provide improved ionospheric coverage.

The 55 SWXS monitors variations of the geomagnetic field using ground-based magnetometers through a cooperative agreement with the USGS, computes a real-time geomagnetic index, and transmits the derived index to users.

Warning and Forecast Services. In near-real-time, 55 SWXS provides operators advance warning

of conditions that could degrade performance of their systems. Notifications include:

- ▶ Solar X-ray events which can disrupt HF communications on sunlit paths.
- ▶ Solar radio bursts which can disrupt communications systems and interfere with radar systems.
- ▶ Solar proton events which can produce radiation hazards to spacecraft and absorption of transpolar HF radio waves.
- ▶ Ionospheric disturbances which can degrade HF and satellite communications systems.
- ▶ Geomagnetic disturbances which can affect the orbital parameters of low altitude satellites, cause spacecraft charging and/or physical damage, disrupt HF radio wave propagation, or interfere with radar systems.

Future Improvements in 55 SWXS Support. 55 SWXS is enhancing its ability to observe the space environment, analyze data, and model the near-Earth environment.

The Ionospheric Measuring System (IMS) is a planned replacement for the current polarimeter network. IMS, using signals from Global Positioning System (GPS) satellites, will measure total electron content. The initial purchase and deployment of five IMS units is in progress.

The SEON Solar Maximum Modification will improve the capabilities of the SEON observatories. Efforts continue to upgrade obsolete and non-supportable equipment to maintain current capability.

A series of Solar X-Ray Imagers (SXI) will be flown beginning on the next GOES satellite launched. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. These data will be downlinked to the SEC and transmitted to 55 SWXS in real-time.

The Solar Wind Interplanetary Measurements (SWIM) is an Air Force Research Laboratory investigation using data from NASA's WIND research satellite launched on 1 November 1994. SWIM provides two hours of real-time interplanetary solar wind data to 55 SWXS each day. Additionally, there will be two campaigns a year during which real-time data will be provided 8 hours a day. The expected life of SWIM/WIND is 5 to 7 years.

Solar Radio Burst Locator (SRBL). This new ground-based system is projected to be operational in 1999. SRBL radio mappings of active regions on the solar disk will augment the present optical observations of these phenomena that are limited by clouds and other atmospheric obscuring factors. Precise location of active regions on the solar disk is crucial to accurate forecasting of solar flare impacts on the near-earth environment.

The Space Environmental Technology Transition (SETT) program transitions state-of-the-art space environmental models to operational use at 55 SWXS. These models will specify and forecast the space environment from the Sun to the Earth's upper atmosphere. The output of these models will drive specific application programs tailored to customer needs. The transition of the SETT models to the 55 SWXS will be complete by 1999. Follow-on model development will focus on improving model accuracy and will replace surrogate parameters (as model inputs) with direct measurements wherever possible.

- ▶ **Magnetospheric Models.** The Magnetospheric Specification Model (MSM) provides specification of magnetospheric particle fluxes at geostationary altitudes and precipitating particle fluxes in the auroral zone. An upgrade to this model, the Magnetospheric Specification and Forecast Model, will provide forecast capability and increase the MSM coverage area. One application of MSM output will be as input for satellite anomaly programs. The MSM became operational at the 55 SWXS in FY 1995.
- ▶ **Ionospheric Models.** The Parameterized Real-Time Ionospheric Specification Model specifies global electron density using near-real-time satellite and ground-based data. It became operational in late FY 1996. A second ionospheric model, the Ionospheric Forecast Model (IFM) will be based on a model developed by Utah State University. When completed, IFM will provide an ionospheric forecasting capability; it is currently undergoing validation. Ionospheric model output will be used as input for space track radar correction and HF radio wave propagation programs. Another variant of ionospheric models, the Wide-Band Model, will provide estimates of ionospheric scintillation severity between two endpoints. The specification accuracy of this model has recently

been improved by the inclusion of equatorial and high latitude climatological data.

- ▶ The Interplanetary Shock Propagation Model is designed to predict the time of arrival and the dynamic pressure pulse associated with solar flares. This will provide a 1-3 day warning of geomagnetic storms resulting from solar activity.
- ▶ The Integrated Space Environmental Model is a coupling model and executive system being developed to integrate the SETT models into a single system sharing input and output data. It will provide a single framework to coordinate and facilitate the execution of all SETT models using scientific expertise and decision-making ability within the program, which will increase consistency of the outputs, optimize run times, and decrease forecaster workload.

SUPPORTING RESEARCH

The overarching objective of the Air Force meteorological research and development program is to provide system designers and operational weather support personnel with the technology tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the Air Force Weather Mission Support Plan. More specific guidance is found in Technical Needs, documented in the associated Weather Development Plan.

With the latest restructuring of the Air Force laboratory system into a single Air Force Research Laboratory, the responsibility for conducting and managing environmental sciences R&D (including meteorology and space weather) resides with AFRL's Battlespace Environment Division located at Hanscom AFB, Massachusetts. Its applied research program in meteorology emphasizes weather satellite analysis techniques, global/theater weather prediction methods, cloud modeling and simulation, weather impact decision aids and optical turbulence for airborne laser applications. AFRL also conducts customer supported R&D for NPOESS/DMSP, the Defense Modeling and Simulation Office (DMSO), and NASA.

Satellite Analysis Techniques. There are two components to this program; the first deals with techniques to incorporate new and/or refined multispectral imagery into global and theater level cloud analysis methods used at AFWA and in-theater

and the second focuses on improved retrieval of temperature and water vapor sounding data for the purpose of assimilating these data into weather prediction models. A particular focus this past year has been the refinement of algorithms to estimate the altitude of cirrus clouds. Through the use of channel differencing methods involving MWIR/WV/LWIR sensors on the NOAA polar orbiting and GOES geostationary satellites, actual cloud emissivities can be estimated from which much more accurate cloud altitude estimates can be determined. A nighttime capability which uses 3.7 micron (μ) MWIR radiances has been demonstrated; a daytime capability based on the 6.7 μ water vapor channel will be demonstrated later (funds permitting). The current approach being considered in the sounding area is the use of the so-called Unified Retrieval Method. It is a multispectral physical retrieval method that utilizes the full microwave sensor suite on DMSP (T-1, T-2, I) and the OLS imagery data to retrieve temperature, water vapor, and cloud structure parameters. The over-ocean version of the code has been installed at AFWA (by Aerospace Corp) for evaluation and a world-wide (i.e. over land) version is in development.

Weather Prediction Methods. R&D efforts in this area have focused down to the development of aviation-mission-impact-variable algorithms to be applied operationally at AFWA. Multivariate diagnostic algorithms, applicable to data provided by global and theater-scale numerical weather prediction models, are or have been developed to infer cloud characteristics (layered and total cloud amount, bases, tops, ceiling), aviation hazards (icing, turbulence, and thunderstorms) and surface conditions (present weather and horizontal visibility). The cloud, icing, and turbulence algorithms have been implemented at AFWA where they are being evaluated operationally. The rest will be transitioned in early FY 1999. The development of icing and turbulence algorithms leveraged programs previously started with FAA funding at NCAR and NOAA/FSL.

Research to improve hazardous weather warning using WSR-88D Doppler weather radar concluded (due to funds termination) at the end of FY 1997. Prototype algorithms to assess bounded weak echo regions (BWER), fine line features and mesocyclone detection using elliptical (non-circular) model assumptions were provided to the WSR-88D Operational Support Facility. The latter algorithms employ a new wavelet-based methodology found to be

particularly effective in processing noisy/gappy imagery data and in the identification and characterization of non-circular mesocyclone signatures.

Cloud Modeling and Simulation. The Cloud Scene Simulation Model (CSSM) has become the cornerstone for in-house and DMSO-sponsored developments to provide physically and radiometrically accurate cloud simulations. They provide capabilities needed in the Modeling and Simulation (M&S) community for consistent, physically-based synthetic atmospheres to drive war-gaming, training, system design studies, etc. The AFRL focus this past year has been in areas such as: (1) incorporating cloud physics models and 3-D cloud radiative transfer model; (2) refining the model to make it radiometrically correct; (3) configuring it to be initialized from either NWP forecast grids or a computer-generated cloud analysis; and (4) providing better/faster cloud volume rendering and scene construction. CSSM has reached a point of maturity where it can be (and is) used in war-gaming demonstrations and exercises, and in the conduct of data impact/sensitivity studies (such as was done for NPOESS).

Weather Impact Decision Aids. A major focus of the Air Force's investment in meteorology R&D deals with the development, evaluation, and implementation of weather impact decision aids (WIDA) which predict the impact of weather and other environmental factors on the performance of electro-optical (IR, NVG, laser, TV) systems. WIDA products can be used to support mission sensors used in weapon, night-vision, and navigation systems. Four of the five products currently in development will provide unit-level weather impact support for mission execution. The fifth, called Weather Automated Mission Planning Software (WAMPS), incorporates WIDA products described below into AF command and control systems from the force to the unit-level. The mission execution products are: (1) Infrared (IR) Target-scene Simulation Software (IRTSS), (2) EOTDA extension to cover MWIR (3-5 μ) wavelengths in addition to LWIR (8-12 μ) systems, (3) Night Vision Goggle (NVG) Operations Weather Software (NOWS), and (4) Target Acquisition Weather Software (TAWS). Collectively, they provide tactical aircraft pilots with scene simulation capabilities to plan EO system missions. They combine global terrain and features, target

structure, target IR contrast, EO sensor performance models, data, and meteorological and operational planning data to provide commanders and aircrews complete in-theater environmental situational awareness. Unique Navy and Army requirements are being incorporated into these developments.

Atmospheric Optical Turbulence. EO and laser systems are adversely affected by optical distortions induced by atmospheric turbulence. As the sophistication grows in current and next generation military systems, the requirement for more detailed knowledge of the fine scale (meter and less) atmospheric structure also grows. The Airborne Laser (ABL) program is one such system. Since the meteorological conditions that produce turbulence vary, the performance of such systems will also vary. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. The measurements are performed by a balloon-borne turbulence sensor that

is mated to a standard radiosonde and has been used in this program since the 1980's. It has produced data and empirical models that are in widespread use and are the basis for ABL system specification. Empirical seasonal models have been developed for the theaters. This year as part of international collaboration, aircraft measurements of optical and wind turbulence will be made. The horizontal measurements by the aircraft will augment the vertical profiling by balloons. This data is being used to develop models of vertical and horizontal structure of turbulence in the troposphere and stratosphere, models with dependencies on the meteorological sources of turbulence such as jet streams, fronts, mountains, or thunderstorms. The modeling is closely coupled with work on the generation, propagation, and breakdown of gravity waves. The objective of the program is to develop models that allow the forecasting and prediction of system performance.

UNITED STATES NAVY

PROGRAM OVERVIEW

The United States Navy, operating in the atmosphere, oceans, and the interface between the two, has the unique requirement to integrate meteorological and oceanographic support globally. Sponsored by the Chief of Naval Operations, Office of the Oceanographer of the Navy, the Navy provides meteorological support for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. Research and development is conducted under the sponsorship of the Chief of Naval Research and the Oceanographer of the Navy by warfare centers, laboratories, and systems commands, primarily the Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARS), as well as various universities and organizations under Navy contract. Operational support to ships, units, and shore stations is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOC). Direct support to staffs, ships, and units afloat and ashore is provided by officer and enlisted meteorology and oceanography (METOC) personnel assigned to these activities. Shore activities within the NAVMETOC include the Fleet Numerical Meteorology and Oceanography Center, the United States Naval Oceanographic Office, the

Naval Ice Center, four theater NAVMETOC Centers (Atlantic, European, Pacific, and Western Pacific), five NAVMETOC Facilities, and 37 NAVMETOC Detachments.

Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOC) in Monterey, California, is NAVMETOC's processing center dedicated to running automated, state-of-the-art, operational global and high resolution regional/theater-scale atmospheric and oceanographic analysis and forecast models. FLENUMMETOC is also designated as the primary DOD numerical METOC prediction center per Navy-Air Force cooperative agreement. The center acquires environmental data globally through links with DOD and NOAA conventional and remotely sensed data distribution systems. Numerically-generated products are distributed on Navy and joint command and control, communications, computers, and intelligence (C4I) systems either directly or via the Navy theater METOC centers. These centers then develop value-added products and services tailored to specific operational requirements. In addition to its standard product suite, FLENUMMETOC is uniquely capable of providing high resolution meteorological and oceanographic products on short notice for any location in support of global contingency military and

humanitarian operations. Other FLENUMMETOCCEN products include atmospheric and oceanographic observations, data extracts, and input data for tactical decision aids. In addition to being the primary DOD global numerical weather prediction center, FLENUMMETOCCEN is the designated national Center for Expertise for remotely-sensed microwave products by the Air Force/Navy/NOAA shared satellite processing agreement.

The Navy's program in meteorology is closely linked with oceanography, the focus of two other major Navy METOC centers. The Naval Oceanographic Office (NAVOCEANO), at Stennis Space Center, Mississippi, is responsible for collecting, processing, and distributing oceanographic, hydrographic, and other geophysical data and products. It is the Navy's primary processing facility for NOAA TIROS data and has been designated the national Center of Expertise for satellite-derived sea surface temperature measurements. NAVOCEANO's Warfighting Support Center (WSC) provides near real-time, tailored oceanographic products to support operational Navy and joint commands. Such products include global ocean front and eddy analyses, preprocessed multichannel sea-surface temperature (MCSST) analyses from polar-orbiting satellites, satellite altimetry and scatterometry data from ERS and TOPEX satellites, high-resolution ocean model output, and Special Operation Forces support. Furthermore, as NAVOCEANO is both an operational processing center and a DOD Major Shared Resource Center, research and development programs, using the latest in scalable supercomputing architecture, can be readily transitioned to operational use in Navy METOC models.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy, through NAVICECEN along with NOAA, and the United States Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides sea and lake ice analyses and forecasts for the Arctic and Antarctic regions, coastal United States waters, and the Great Lakes to civil as well as military activities.

Four theater NAVMETOCCOM centers provide broad geographical METOC services within their areas of responsibility. Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs) and focused on operations within theater, these METOC centers

manage and prioritize the dissemination of tactical numerical METOC products from FLENUMMETOCCEN and NAVOCEANO and add tailored services specifically to support theater requirements. They are hubs for data and product dissemination, providing full spectrum meteorological and oceanographic services to forces operating within their respective areas of responsibility and special METOC products as needed to meet situational requirements of the Joint Force Commander. The Naval Pacific Meteorology and Oceanography Center (NAVPACMETOCCEN), Pearl Harbor, Hawaii, assisted by NAVPACMETOCCEN West, Guam, is responsible for the Pacific and Indian Oceans, Red Sea, and Arabian Gulf areas. Additionally, NAVPACMETOCCEN West operates the Joint Typhoon Warning Center with the United States Air Force to provide tropical cyclone advisories to DOD and United States interests in the Western Pacific and Indian Oceans. NAVPACMETOCCEN also issues tropical cyclone advisories, for the eastern and central South Pacific. The Naval Atlantic Meteorology and Oceanography Center (NAVLANTMETOCCEN), Norfolk, Virginia, is responsible for providing METOC services in the Atlantic Ocean and the Greenland, Norwegian, and Barents Seas. The Naval European Meteorology and Oceanography Center (NAVEURMETOCCEN), Rota, Spain, provides METOC support to joint and Naval forces operating in the Mediterranean, Black, and Baltic Seas. The Atlantic and Pacific NAVMETOCCOM centers share non-ice related METOC product and service support for the Arctic and Antarctic regions. Because of their in-theater presence and focus, NAVMETOCCOM centers are ideally suited to serve as Joint METOC Forecast Units (JMFU) or Coordinating METOC Forecast Centers (CMFC) in support of theater joint operations.

The five NAVMETOCCOM facilities at Jacksonville, Florida; San Diego, California; Pensacola, Florida; Bahrain; and Yokosuka, Japan; provide operations area, local and aviation forecast services, as well as services to aircraft, ship, and submarine staffs. Meteorological and oceanographic forecast guidance from the theater NAVMETOCCOM centers and FLENUMMETOCCEN is used by all facilities.

There are 37 NAVMETOCCOM detachments worldwide. Primarily situated at Naval Air Stations, several are located at Naval Stations in support of sea-going units. They provide METOC forecasting and

warning services to DOD and allied units within their local and functional areas of responsibility. Detachments within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's NCEP. Overseas detachments use the now widely available FLENUMMETOCCEN numerical products, in addition to, NCEP, USAF, and foreign products. Two detachments provide specific technical services: one, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as its part of the Federal Climate Complex; another, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF Automated Weather Network (AWN).

On-Scene Support

The primary sources of on-scene Navy METOC support for forces afloat and those in-theater ashore are provided by permanently embarked Navy METOC personnel and deployable assets (Mobile Environmental Teams). METOC products and services provided to the operating forces are tailored to requirements of the Fleet and/or Joint Force Commanders and Fleet units. This support consists primarily of tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning. Products are made available to the operating forces via joint and Navy C4I systems, AUTODIN, the High Speed Fleet Broadcast, high frequency facsimile broadcasts, military networks (including military versions of the Internet), commercial systems, and center-maintained Bulletin Board Systems (BBSs) and web-based Home Pages.

The Navy's permanent afloat METOC organic assets are their OA Divisions, embarked aboard major aviation-capable combatants and command ships. Their primary objectives are safety, optimum tactical support to warfare commanders, and tailored on-scene products and services to the assigned task force/group and allied units in joint, combined, or coalition military and humanitarian operations. The centerpiece of the OA Division's suite of METOC equipment is the Tactical Environmental Support System (TESS(3)), an interactive METOC data fusion system which receives, stores, processes, displays, and disseminates meteorological and oceanographic data. TESS(3) receives data from four major sources:

global and theater METOC data fields from FLENUMMETOCCEN and NAVOCEANO via the Navy's theater centers; remotely sensed satellite data and imagery from the onboard AN/SMQ-11 satellite data receiver/recorder; alphanumeric data via the High Speed Fleet Broadcast; and local observational data from the Shipboard Meteorological and Oceanographic Observing System (SMOOS). The TESS(3) data base and applications software is provided from the Oceanographic and Atmospheric Master Library (OAML) and the Geophysical Fleet Mission Program Library (GFMP). The AN/SMQ-11 acquires geostationary satellite weather facsimile (WEFAX) broadcasts and high resolution DMSP and NOAA/TIROS satellite imagery. Local upper air sounding information is made available from the permanently installed AN/UMQ-12 Miniature Rawinsonde System (MRS). The division is also equipped with a PC-based high-frequency facsimile system (PCGRAFAX). Standard CD-ROM based climatology products, the Naval Oceanographic Data Distribution System (NODDS), the Internet-based Joint METOC Viewer (JMV) and the PC Imaging Communications Systems (PICS) software programs are also part of the OA Division inventory.

The Mobile Environmental Teams (MET), based at the theater NAVMETOCCOM centers in Norfolk, Hawaii, and Rota, and at their facilities in Bahrain, Jacksonville, San Diego, and Yokosuka, are the Navy's deployable METOC assets. These teams provide short-term, on-scene services to units and activities without organic METOC personnel within the DOD, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. The MET have their own portable sensing and display equipment, the heart of which is the Mobile Oceanography Support System (MOSS). MOSS contains modules for tactical meteorological and oceanographic forecasting, polar-orbiting satellite ingest and processing, alphanumeric and facsimile data receipt and display, and *in situ* data collection via the MRS and expendable bathythermograph probes. METs may also deploy with a portable MRS and Alden Marine Facsimile Recorder. If required, they have the capability to install remote Navy Automated Meteorological Observing Systems (AMOS), to sense temperature, humidity, pressure, and winds and provide direct readout and/or telemetry of data via satellite.

Marine Corps (USMC). Marine environmental forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, United States Marine Corps (Code ASL-44) is the cognizant office for Marine Corps Meteorological and Oceanographic Support and Requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF).

Garrison aviation weather units at Marine Corps Air Stations and Facilities are manned by USMC METOC personnel and provide direct aviation weather support to host and tenant units. Integral to Marine Corps aviation activities, these weather units provide services to assigned activities and organizations, which include nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Marine Corps METOC support activities are assigned to the FMF in the Aviation Combat Element (ACE) of the Marine Air Ground Task Force (MAGTF). ACE METOC support is derived from the Marine Wing Support Squadron (MWSS) within the parent Marine Aircraft Wing. The existing 10 MWSS METOC activities are equipped to provide support at a base-based or expeditionary airfield by deploying the Meteorological Mobile Facility METMF. Additionally, Meteorological Support Teams (MSTs) from the ACE MWSSs can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF.

Battlespace Management System

The Navy's METOC program remains focused on improving data collection, processing, and dissemination capabilities to support operations in the littoral and to ensure interoperability among the services. A key aspect of this design is a unifying fully-integrated C4I architecture allowing METOC activities to operate in unison with other service elements. Efforts in FY 1998 include:

- ▶ Tactical Environmental Support System (TESS(3)/NC). TESS(3) is a modular support system designed to provide Navy decision-makers on major combatant ships with METOC assessments and forecasts and to integrate this data with sensor and weapon platform parameters

for system performance assessments. The primary suppliers of these data are the theater METOC centers, which provide value-added products to fleet units in addition to the numerical prediction guidance generated by FLENUMMETOCEN. The planned TESS(3)/NC will be fully integrated with the next-generation Navy and DOD C4I client-server architecture and will conform to a new vision for information technology systems within the Navy. This new vision focuses on seamless sea-shore transitions, the integration of tactical and non-tactical functions, maximum use of commercial off-the-shelf applications and commonality with industry, and use of a desktop PC as the user interface. TESS(3)/NC will be delivered to the fleet in late 1998, but prototypes are operating now aboard some 2nd and 3rd Fleet ships.

- ▶ Navy Joint TESS Remote Workstation (J-TRWS). Through J-TRWS, METOC data and products are made available to Navy and Marine Corps activities afloat and ashore via the Joint Maritime Command Information System (JMCIS) network. A modular data management and distribution subset of TESS(3) and a segment on the Navy C4I network, the J-TRWS uses TESS(3) data and products to feed real-time tactical decision aids resident within JMCIS. The open system design provides interoperability with other DOD, Federal, and Allied command and control systems. J-TRWS is the basis for the Navy/Air Force Joint METOC Segment of the new Global Command and Control System (GCCS)V3.0. These C4I networks are rapidly migrating to a Windows-NT, client-server architecture.
- ▶ Mobile Oceanography Support System (MOSS) upgrade. MOSS is presently undergoing a migration towards a modular, interoperable system -- a NITES variant. It has been upgraded to include a lightweight and portable notebook computer with a docking station. This migratory version, known as Interim MOSS (IMOSS), operates at 100 MHz and has the additional capability to ingest real-time observational data collected by AMOS. The follow-on system, MOSS-Next, will be a modular data management and distribution system operating in a portable environment and incorporating some J-TRWS functionality.

- ▶ Meteorological and Oceanographic (METOC) Integrated Data Display System (MIDDS). MIDDS consolidates the numerous METOC functions performed within a shore-based weather station into a client-server architecture which manages the ingestion, processing, display and dissemination of METOC data. Data ingest includes satellite imagery received via GOES-Tap or live WEFAX, digital and analog facsimile, alphanumeric, raster graphic products, Optimum Path Aircraft Routing System (OPARS) products, radar information, lightning, and live Automated Surface Observing System (ASOS) inputs. A system was designed which offered multi-tasking and multi-user capabilities to handle the simultaneous ingest of various products. Hardware was selected to avoid proprietary components and to optimize state-of-the-art processors and display devices available from commercial-off-the-shelf (COTS) vendors. The design was centered around three primary functions. The first was to establish a workstation where the weather forecaster or observer could retrieve, process, and display the various weather products necessary to gain a complete understanding of the atmosphere and how it changed in time. The second was to provide a briefing station with high quality graphics and enhancement features to brief pilots and other base customers on the impact of weather on their operations. The third MIDDS function was to develop a capability to distribute METOC products locally using either dial-in remote access services or Local Area Network (LAN) architectures. MIDDS has been fielded at most Navy and Marine Corps aviation sites.
- ▶ Primary Oceanographic Prediction System (POPS). The POPS program was initiated to provide the computational capability necessary to run massive oceanographic and atmospheric models at both global, theater, and tactical scales. Cray C-90s at NAVOCEANO (POPS-I) and FLENUMMETOCCEN (POPS-II) were installed as part of the Navy's and Federal Government's emphasis on high performance computing. POPS-I has been designated a DOD Major Shared Resource Center, with as much as 85 percent of the computer time on the C-90 devoted to supporting DOD R&D efforts which can then be transitioned to operational use.

POPS-II is the numerical engine used by FLENUMMETOCCEN in its role as the primary DOD Numerical Weather Prediction Center. Two subsidiary information systems support POPS at FLENUMMETOCCEN -- the Oceanographic and Atmospheric Support and Information System (OASIS) and the Distributed Processing System (DPS). DPS receives incoming data and distributes final products to external users, while OASIS processes incoming data for POPS and packages POPS output for specific customers. DPS is now being integrated into the OASIS program. Output from Navy's numerical models is made available to NOAA through memoranda of agreement.

Operational Products and Services

The Optimum Track Ship Routing (OTSR) is a ship advisory service designed to minimize the risk of damage from extra-tropical and tropical storms, high seas, and sea ice. OTSR also assists port authorities and ships import in the path of tropical cyclones by issuing recommendations for departure time and a sortie location to the Senior Officer Present Afloat. To maximize fuel economy, OTSR provides recommendations for ocean current assistance and avoidance routes in the vicinity of strong ocean currents. OTSR advice considers individual ship characteristics, cargo limitations, and planned operations.

Optimum Path Aircraft Routing System (OPARS) at FLENUMMETOCCEN is a flight planning system to provide tailored routing information to meet individual mission requirements. Among its many options, OPARS can calculate the fuel load needed to arrive with a specific reserve, maximum cargo for a particular flight, in-flight refueling requirements, maximum time on-station, mandatory over water reporting positions, and fuel usage for specific routes and/or altitudes. In preparation for a flight brief, electronic route requests are sent to FLENUMMETOCCEN by the servicing NAVMETOCCOM detachment. To determine optimal aircraft routing, three data bases are incorporated in OPARS: environmental, air route structure, and aircraft performance characteristics. Flight plan information is returned to the originator within minutes for subsequent manipulation and display on a local PC for pilot briefing.

The Navy Oceanographic Data Distribution

System (NODDS) is a PC-based software package originally developed in 1982 to make FLENUMMETOCCEN numerical products available to front line DOD users. Products from FLENUMMETOCCEN's global data bases can be selected for user-defined regions and, using an off-the-shelf licensed communications software package, are downloaded as a series of compacted ASCII files to a local PC. All standard meteorological and oceanographic fields and synoptic observations available from FLENUMMETOCCEN can be displayed along with a wide number of oceanographic boundary line products generated at the regional center. Basic satellite imagery (DMSP) is also available. NODDS can overlay up to three different fields, display individual sequence loops, zoom for more detail, display satellite imagery, and produce hard-copy output. NODDS is available to non-DOD Federal agencies and others in the civilian community through an agreement between Navy and NOAA. This version, referred to as NOAA-NODDS to distinguish it from the Navy version, makes available to NOAA unclassified real-time weather and ocean data and products from FLENUMMETOCCEN for access by civilian users.

The Joint METOC Viewer (JMV) is a new capability which will be integrated into NITES and eventually replace NODDS. Building on the incredible global response to the World Wide Web (WWW) and the successful user interface design of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing and annotating METOC information. JMV uses Web technology to allow access to FLENUMMETOCCEN METOC data from nearly anywhere in the world. Authorized DOD and Government users with WWW access now have a simple, cost-efficient way to acquire weather and ocean information on several computer platforms and operating systems. JMV is now operational at several hundred DOD sites, including underway ships with WWW capability.

SUPPORTING RESEARCH

The Navy administers a diverse research and development (R&D) program, ranging from software development to the engineering of sensors, interfaces, processing, display, and distribution devices. Application of R&D activities of the other services and Federal agencies is always considered, and use of existing government and commercial off-the-shelf items is made.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific research, through additional development, into the operational meteorological and oceanographic models is a key to a successful numerical prediction program. This is an ongoing process at the Naval Research Laboratory's (NRL) Marine Meteorological Division, co-located with FLENUMMETOCCEN to keep the Navy Operational Global Atmospheric Prediction System (NOGAPS) and its companion Regional Atmospheric Prediction System (NORAPS) at the leading edge of technology. Continued upgrades to the NOGAPS model are planned, incorporating asynoptic and remotely-sensed data in the model initialization process. The relocatable, high-resolution (15-45 km) nested NORAPS model is now used routinely for operational contingency support.

NORAPS will be replaced with the Coupled Oceanographic and Atmospheric Mesoscale Prediction System (COAMPS) model. The atmospheric component of COAMPS will feature triple-nested grids to resolutions of a few kilometers, non-hydrostatic physics, explicit moisture physics and aerosols, and improved data assimilation. The underlying and fully coupled oceanographic component of COAMPS will combine the capabilities of the Optimum Thermal Interpolation System (OTIS), the Wave Model (WAM), and the Princeton Ocean Model (POM) to provide for fully interactive two-way coupling between ocean and atmosphere. With lateral boundary conditions provided by FLENUMMETOCCEN global models, COAMPS will provide the high-resolution, relocatable, and fully-integrated meteorological and oceanographic prediction capability required to support joint littoral operations.

The principal focus of the Navy R&D program in remote sensing is the development of techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are being exploited to the greatest extent possible, and plans are in place to incorporate new capabilities as they are introduced. Because many satellite processing algorithms are designed for use with tactical systems such as TESS(3), expert or rule-based scheme representations are employed wherever possible to reduce manpower-intensive interpretation procedures.

Development of upgraded data assimilation, quality control, and data management techniques in support of these models is also underway. A major thrust has been initiated in the area of numerical weather prediction to develop a shipboard tactical atmospheric forecast capability. This model, intended for use in TESS(3)/NC, will deliver high resolution (5 km), limited area (100s of km), short range (12-24 hr) atmospheric predictions and will assimilate locally acquired data in real time.

ONR is continuing to explore techniques for assimilating environmental data through non-traditional sensors. One such effort in progress is exploring the content and utility of a weather signal tap from the AEGIS AN/SPY-1 air search radar system, a potential candidate for a small-scale shipboard tactical weather radar.

Sensor Development

The Shipboard Meteorological and Oceanographic Observing System (SMOOS), currently being fielded, was developed as part of the Navy R&D program in sensor development. As a follow-on to SMOOS, advanced engineering and development of new sensors and related technologies is underway. Some of these include:

- ▶ Autonomous drifting buoys for surface and subsurface data.
- ▶ Autonomous sensor suites for all Navy ships.
- ▶ Aerosol measurement sensors.
- ▶ METOC data compression techniques to facilitate communications.

The AN/WSQ-6 series expendable drifting buoys will measure and report air and sea surface temperatures, barometric pressure, subsurface ocean temperature versus depth to 300 meters, omnidirectional ambient noise, wind speed and direction, directional wave spectra, optical parameters, and other properties of the near-surface air/sea environment. The buoys sample and report hourly observations via Service ARGOS; as other communications networks such as Low Earth Orbiting satellites become available, they will be utilized. Near real-time data reception is available via Local User Terminals and TESS(3). As funding and testing permit new sensors will be added to the buoy platform. Multi-parameter, long life, expendable instruments such as the AN/WSQ-6 buoys are vital to the success of the United States Navy's contribution to a global ocean observing capability.

The AN/UMQ-12 Mini-Rawinsonde (MRS) consists of a surface receiver, processor, and lightweight balloon-borne expendable sensor package to measure pressure, temperature, humidity, and wind speed and direction. The Navy is transitioning to a GPS-based mini-rawinsonde system.

Development efforts undertaken by NOAA/NWS have been leveraged in Navy's selection of the NWS' Automated Surface Observing System (ASOS) for Navy and Marine Corps use ashore. Acquisition and installation of ASOS systems continue at Navy and Marine Corps stations worldwide in support of aviation and local area forecasting requirements to replace equipment that has been operated beyond its maintenance life cycles. ASOS will assist Meteorological Technicians in assimilating field meteorological parameters and improving efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN).

Principal User Processors (PUPs) associated with the Next Generation Weather Radar (NEXRAD) are providing significant improvements in radar analysis of meteorological features and severe weather over the United States. The Navy and Marine Corps are participating in the NEXRAD program and will utilize these radars to satisfy their requirements for radar coverage, where possible. On-site NEXRAD PUPs will display imagery from NEXRAD systems covering areas of routine military operations and training.

The Navy will be procuring Supplemental Weather Radars to provide radar coverage at selected Navy and USMC sites, mostly overseas, not scheduled to receive a NEXRAD PUP. This system will replace the obsolete AN/FPS-106 weather radars now in use.

The Marine Corps Meteorological Mobile Facility Replacement (METMF(R)) is a transportable system for providing meteorological support to the Marine Air Ground Task Force (MAGTF). A cost and operational effectiveness analysis of a replacement METMF has been completed, and the system is nearing the demonstration and validation phases of the acquisition process. Housed in a 20 x 20 foot standard Marine Corps van and transportable by a C-130 aircraft, this system will provide a fully functioning weather office for Marine Corps expeditionary airfields for 30 days without resupply. It will include sub-systems for data collection (MRS for upper air and a variety of local and remote sensors), data processing (modified

TESS(3)), satellite image ingest and display, Doppler radar display (via the supplemental weather radar), communications, briefing support, and support for remote forces. The METMF(R) will be interoperable with the Marine Corps C4I systems and METOC systems of the other services via the Global Command and Control System (GCCS).

Interagency Cooperation

To maximize efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) was signed in 1993. Both agencies continue to review present agreements for conversion into annexes to this MOA and identify new areas of cooperation. Specific areas include:

- ▶ Cooperative endeavors in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCEN and NCEP.
- ▶ Navy/NOAA/Coast Guard operation of the National Ice Center.

- ▶ AWS/Navy/NOAA agreement on shared processing of satellite data.
- ▶ Navy/NOAA agreement on ASOS procurement, installation, maintenance, and operation.
- ▶ Distribution of unclassified Navy METOC products to the civil sector via NOAA.
- ▶ Provision of meteorological services to Guam, the Commonwealth of the Northern Marianas Islands, and Micronesia.
- ▶ Satellite altimetry data processing.
- ▶ Training cooperation through Cooperative Program for Operational Meteorology Education and Training (COMET).

MOAs also exist between the DOC, DOD, and DOT concerning the production and operation of the NEXRAD system. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

UNITED STATES ARMY

ARMY OPERATIONAL SUPPORT

Overview of Operational Equipment and Support Missions

United States Army weather support is a mix of Army and USAF personnel and equipment under Law and according to Army-Air Force (AF) agreement. Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, Weather Support for the United States Army, 30 June 1996 describes the Service responsibilities and those of Major Army Commands (MACOMs) providing weather support. The United States 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. AF Major Commands (MAJCOMs) provide operational weather services to warfighting MACOMs in combat, contingencies, and peacetime training. United States Army Forces Command (FORSCOM), United States Army Europe (USAREUR), United States Army Pacific (USARPAC), United States Army South (USARSO), United States Army Special Operations Command (USASOC), Eighth United States Army (EUSA), and United States 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 MACOMs. During peacetime training and activation the Air National Guard (ANG) provides AF operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies the ANG may augment the active Army Weather Teams (WETMs). The ANG acts like an AF MAJCOM in providing support to the Army RC.

The Army also provides the operational weather support to Army Research, Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Test and Evaluation Command (TECOM) Meteorological Teams (MET Teams) and United States Army Space and Missile Defense Command (USASMDC) contractors. TECOM operational support is described under Army Materiel Command in the RDTE section. USASMDC provides weather support to Kwajalein Missile Range (KMR) through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF WETMs for

tactical operations. MACOMs have purchased off-the-shelf non-developmental items (NDI) to provide interim Army tactical equipment until the Integrated Meteorological System (IMETS) is fully fielded. IMETS is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to PD, IMETS and to field artillery meteorology programs. IMETS fielding continues in FY 1999.

The FORSCOM GOLDWING System is a non-developmental item (NDI) providing operational support until IMETS is fielded or other modern tactical communications systems become available in the MACOMs and RC. GOLDWING will be used in conjunction with IMETS for active or RC forces which are not scheduled to get IMETS because of funding constraints. IMETS communicates with GOLDWING over HF radio.

ARTYMET crews are assigned to artillery units at Division level, to field artillery brigades, and to separate brigades with a direct support artillery battalion. 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 observations at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET crews in the Active Component (AC) and some 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, to USAF WETMs, and to the Chemical Officer for use in smoke and in Nuclear, Biological, and Chemical (NBC) defense operations. The CECOM section provides a complete description of MMS. The Meteorological Data System (MDS), AN/TMQ-31, replaced by the MMS, has been reissued to eleven Army National Guard (ARNG) units and will be used as long as it is still supportable. The rest of the ARNG units will be upgraded to the MMS and future profiler

systems, as they become available. The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirement documents and is the combat and training developer for meteorological equipment used for field artillery support.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. When directed by the Intelligence Officer (S2), intelligence personnel take these observations in the forward combat areas.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army weather support policy. The Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office.

Army Operational Support provided by the Air Force

Under AR 115-10/AFJI 15-157, the AF is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison active and reserve component (AC)/RC support requirements. Army support manpower requirements are sourced from AF active, reserve, and ANG weather units. While direct support of the field artillery remains an Army responsibility and is provided by Army ARTYMET teams, AF WETMs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observational capabilities. The AF assigns AF weather personnel to the warfighting MACOMs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and special forces groups/ranger regiment to provide direct, on site weather support. AF weather squadrons and flights provide garrison and tactical weather warning, observing, forecasting, special support, 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. The AF is responsible for installation, operation, and maintenance

of standard AF meteorological and observing equipment at Army airfield weather stations. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army Integrated Meteorological System (IMETS) is fielded for these purposes and is operated by AF WETMs. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is built on an Army vehicle, uses Army tactical communications and Army weather effects software. The Army provides other tactical equipment to AF WETMs through an Army Table of Organization and Equipment (TOE).

United States Army Space and Missile Defense Command (USASMDC)

Army Space Command (ARSPACE), a subcommand of USASMDC, provides Army Space Support Teams to deploying Army units. One element of this support is a high-resolution weather satellite receiver, which can be readily transported and directly acquires and processes the full telemetry stream of civilian and military weather satellites. The staff weather officer uses imagery and data to prepare tailored products and forecasts for use on the battlefield. This equipment is used in contingencies and training exercises and provides an interim capability pending delivery of IMETS Block II and associated AF weather satellite equipment. ARSPACE participated in Task Force XXI in FY 1997 through the Tactical Weather (TacWx) initiative. TacWx represents a teaming with the Army Research Laboratory's Battlefield Environment Division, the AF Combat Weather Center, PD IMETS, and the III Corps WETMs to provide the Task Force XXI commander with near real-time, state-of-the-art weather information and products. The system consists of the ARSPACE Deployable Weather Satellite Workstation, ARL Battlescale Forecast Model, and the AF Tactical Forecast System, which runs on IMETS hardware. Lessons learned will be used in the IMETS program as product improvements. ARSPACE participation in a Division XXI and Task Force XXI exercises will build on brigade weather capabilities and apply them at the division level with special attention to battlefield visualization and simulation activities.

The High Energy Laser Systems Test Facility (HELSTF), a subcommand of USASMDC located on White Sands Missile Range, is designated as the DOD National Test Range for high energy laser test and evaluation. In addition to laser system 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. Part of the research effort is to develop adaptive optics for atmospheric compensation during lasing.

United States Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC which provides operational support to the test facilities at the Kwajalein Missile Range (KMR). The KMR meteorological services support contractor performs meteorological functions in support of missile operations and for synoptic purposes, including surface, upper air, and meteorological satellite observations, and the preparation of daily aviation, marine and special weather observations for the range.

Army Corps of Engineers Civil Operational Activities

The Corps of Engineers (COE) operates a network of about 7,400 gauges of which 1,900 are land-based limited observing meteorological sites. The remainder is hydrologic in nature. The meteorological portion measures precipitation and other data in the United States to provide information for regulating 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 precipitation information from 900 of these sites. Similarly, COE transfers funds to the United States Geological Survey to maintain precipitation data collection from 500 sites, while the COE maintains the rest. Data from many of these sites are automatically telemetered using satellite, microwave, landlines, radio, etc. to provide for real-time use of the data. Although the COE finances the network, data are made available to all other federal agencies.

Eighth US Army Support

Eighth United States Army (EUSA) requires, and uses Army resources to conduct two major meteorological services in direct support of Army

operations: collecting and disseminating upper air observations for artillery support, and collecting and disseminating limited surface weather observations to support all tactical units and operations. Two artillery meteorological (ARTYMET) crews with Second Infantry Division's Division Artillery use AN/TMQ-31 Meteorological Data Systems to collect upper air observations for direct use by field artillery units. ARTYMET crews also collect routine (usually daily) upper air observations for training; these observations are typically fed into the global weather database. Additionally, under the Forward Area Limited Observing Program (FALOP), Army personnel use tactical weather kits to collect limited weather observations in data sparse, forward areas. Observations are typically collected by intelligence personnel at brigade and battalion tactical operations centers (TOC) during contingencies or exercises and, in turn, are disseminated to and through USAF weather teams supporting Army air, ground, or special operations. USAF weather personnel assigned to the 607th Weather Squadron (607 WS) provide fixed and tactical weather support to EUSA units and installations. 607 WS provides garrison and tactical weather warning, observing, forecast, warning, special support, and staff weather officer (SWO) services during contingency, exercise, or armistice operations. 607 WS units provide direct, on-site support at eight EUSA installations, and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions. 607 WS provides 95 trained weather personnel and required fixed and tactical weather sensing, data processing, and communications equipment. EUSA provides supporting USAF units needed tactical vehicles, MTOE and CTA equipment, and operating funds (for expendables, maintenance, etc).

Training and Doctrine Command (TRADOC) Programs

TRADOC manages and develops training programs, writes Army and joint weather support doctrine (concepts and field manuals), and establishes the weather requirements documents for Army tactical weather support equipment. Headquarters, TRADOC is the approval authority for Army-AF weather doctrine, Army weather hardware requirements, and weather support policy within TRADOC.

As part of TRADOC, the United States Army Intelligence Center and Fort Huachuca (USAIC&FH),

Fort Huachuca, Arizona, is the proponent and user representative for tactical weather support in wartime, contingencies, and peacetime tactical training. Similarly, the United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support and the Engineer School, Fort Leonard Wood, Missouri, coordinates weather support requirements in terrain analysis and topographic engineering. These schools submit requirements for weather support to HQ TRADOC for approval who typically then submits requirements for USAF support to HQ, Air Combat Command for implementation. Requirements for Army provided communications or tactical equipment are submitted to ODCSOPS to prioritize and program resources.

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) represents the warfighter by developing solutions to meet Army weather requirements. In addition, it serves as the proponent for the "Owning the Weather" initiative. The weather support team (WST) consists of two AF officers, one senior AF noncommissioned officer (NCO), an Army Intelligence Center officer, an Army Research Laboratory meteorologist, and an Army Intelligence Center Combat Developer. The weather support team advises the Intelligence Center, the Army Research Laboratory, and Air Force Weather (AFW) on Army weather support issues and helps develop solutions to meet both active and reserve forces' requirements. The team writes tactical weather support concepts and doctrine, identifies deficiencies and baseline requirements, provides weather support training to intelligence and USAF personnel supporting the Army, and establishes requirements documents for weather support equipment.

During 1997, the WST provided evaluators for Army Advanced Warfighting Experiments (Task Force XXI and Division XXI). These experiments demonstrated the need for increased training of Army staffs in weather intelligence, high-resolution imagery weather support for echelons at division and below, and an automated weather effects on demand capability for the Army warfighter. The WST also sponsored a joint conference in April 1997 to discuss AF/Army merging of weather systems and sensors. The conference helped to forge new cooperation and discussion on Army weather support.

The WST expanded its training role by introducing "Owning the Weather"/Weather Intelligence classes in the Military Intelligence Officer Advanced Course. "Owning the Weather" is a concept for exploiting weather as a force multiplier on the battlefield. The WST plans to increase weather intelligence instruction at the Intelligence Center and throughout TRADOC with an exportable "Owning the Weather"/Weather Intelligence training module. "Owning the Weather" was also highlighted on a national television program "Weather Warriors," aired by the Discovery Channel on 14 and 17 May 1997 on the *Discover Magazine* show. In addition, "Owning the Weather" was a feature article in the FY 1998 Federal Meteorological Plan by the Office of the Federal Coordinator for Meteorology.

Also during 1997, the WST updated a large portion of the critical values in the Integrated Weather Effects Decision Aid (IWEDA) software as part of an Army weather effects critical threshold values update program. IWEDA is an Army software program hosted on IMETS and the Army Battle Command System (ABCS). It provides automated weather effects information in digital form that can be overlaid on the Common Operating Picture (COP). The WST also participated in the ongoing AFW Reengineering process. With dwindling resources and personnel reductions, the team seeks solutions that are compatible with AFW Reengineering plans and maintains quality weather support to the Army warfighter. The WST continues to participate in TRADOC's Battlefield Visualization (BV) program which highlights weather as a key element in understanding and characterizing the battlespace environment. BV is incomplete without integrating the effects of weather on terrain and friendly and threat forces. The WST also assisted in the revision of Army publications to include the role weather and weather support plays in Army operations. Chief among these were Army Field Manual (FM) 34-81, *Weather Support for Army Operations* and the Army Capstone Field Manual, FM 100-5, *Army Operations*. Finally, the WST developed an Army mid-range operational weather architecture and presented this to the Battlespace Atmospherics Conference in December 1997.

Artillery meteorological crews in the Active Component (AC) currently use the AN/TMQ-41 Meteorological Measuring Set (MMS) to take upper air observations during tactical operations. It is a mobile,

upper air sounding system mounted on a High Mobile Multipurpose Wheeled Vehicle. The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting fire, to USAF WETMs, and to the Chemical Officer for use in smoke, and in Nuclear, Biological, and Chemical (NBC) defense operations. The Meteorological Data Systems (MDS), AN/TMQ-31, replaced by the MMS will be retired from the force. The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirements documents and is the combat and training developer for meteorological equipment.

The Aviation Center, Chemical School, and Engineer School (USAES) incorporate weather instruction and procedures in training programs in their mission areas.

The Aviation Center has unique operational requirements for weather observations and USAF forecast support at remote training locations. Fort Rucker operates additional observing and communications equipment to relay all types of USAF-provided weather information to these Army sites. Three additional wind sensors were installed at Cairns AAF and five Automated Surface Observing Systems (ASOS) will be installed by the end of 1998.

In addition to teaching weather in the Engineering Officer Advanced Course, the USAES develops methods of measuring and forecasting state of the ground parameters for terrain analysis and trafficability assessments. This includes identifying, justifying, and documenting requirements to interface meteorological and engineer battlefield systems. It also monitors R&D advances to incorporate these in combat development initiatives. USAES previously had a full time meteorologist as a subject matter expert to coordinate weather activities but the position was eliminated in FY 1997.

WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)

Under Army-AF agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) 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 related to soldiers' performance in the range of weather conditions encountered in all theaters of operations.

Corps of Engineers (COE)

The Corps of Engineers (COE) is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The COE also manages the Technology Demonstration (DT-08) program. Tactical Decision Aids (TDAs) are developed for this program by three COE laboratories: the Waterways Experiment Station (WES), the Topographic Engineering Center (TEC), and the Cold Regions Research and Engineering Laboratory (CRREL).

The Waterways Experiment Station develops TDAs supporting terrain analysis. The TDAs interpret the impact of weather and terrain conditions on Army systems and operations. The TDAs are based on weather and terrain limitations, known as critical values. These critical threshold values are determined from design criteria, operational testing, or other evaluations of Army capabilities in adverse weather. The critical values define system limitations and are used by decision-makers to take advantage over opposing forces. Technology Demonstrations are currently being transitioned to terrain and weather systems such as the Integrated Meteorological System (IMETS), the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS), and Battle Command Decision Support System.

The COE Topographic Engineering Center (TEC), Fort Belvoir, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This includes the development and integration of environmental effects databases and models that are relevant to military plans, operations and the acquisition communities. TEC also develops models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds. TEC is also responsible for developing integrated software modules designed to be exploited in the synthetic environment arena and for developing techniques to portray natural and induced battlefield environments, thus enhancing computerized

battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. As preparer and custodian of AR 70-38, TEC provides special climatological studies and guidance to materiel acquisition activities. TEC also reviews all emerging materiel systems for environmental effects.

Under the military portion of its civil and military support mission, the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, provides weather support to Army weapon systems RDTE, combat, and combat support mission areas, and develops climatological studies on the effects of winter environment on Army operations. CRREL is responsible for modeling in the areas of Cold Regions Surface-Air Boundary Process, Winter Scene Dynamics, and Spatially Distributed Prediction Over Winter Terrain. CRREL develops databases and models predicting Infrared and millimeter wave (MMW) weapon system performance and the capability of technology to enhance military operations in cold environments. Under a Memorandum of Understanding (MOU), the United States Army Test and Evaluation Command (TECOM) provides operational observing, weather instrumentation, and forecasting services for CRREL's RDTE efforts through a colocated MET Team.

Army Materiel Command (AMC)

The Army Materiel Command (AMC) is responsible for: (1) the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment; (2) providing climatological and meteorological support to RDTE projects involving electro-optics and obscurants; and (3) determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather research and development responsibilities.

TECOM is a subcommand of AMC providing operational support to 10 ranges and test sites with Meteorological (MET) Teams. Under responsibilities established in Army Regulation 115-10/AF Joint Instruction 15-157, the TECOM MET Teams provide weather support and atmospheric characterization to Army RDTE. MET Teams provide atmospheric data collection, analysis, consultation, warning, and forecast services for Army and other DOD RDTE. MET Team

FY 1998 funding has been level for 2 years following several years of decline, using a combination of both programmed funds and user funding. This enables TECOM to continue basic meteorological support at Army RDTE ranges and sites, but meteorological instrumentation will be acquired through Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements. Despite reductions in personnel and funding, TECOM MET Atmospheric Sciences Branch has begun a 5-year effort with the National Center for Atmospheric Research (NCAR) to greatly improve "range scale" (micro scale) forecasting and analysis technology. Using the MM5 model as a base, this Four Dimensional Weather System (4DWX) will present a real time, three-dimensional picture with time of the MET and other atmospheric characterization parameters in, around, and up to an altitude of 50,000 feet over the Army's test ranges. The 4DWX will allow for more accurate placement of sensors during a test, more cost-efficient measurements, and data sets for virtual testing. The model will also provide instantaneous forensic analysis (instant replay) of the conditions that occurred during the test. In addition to RDTE support, the Dugway Meteorological and Obscurants Division Modeling and Assessment Branch provides the following specialized services: (1) atmospheric modeling validation, to include algorithm evaluation and the generation of validation data sets, (2) threat analysis, chemical/biological detection, and decon-tamination testing, and (3) prototype development of virtual proving ground meteorological support. Division members also serve on various national and international committees addressing issues related to meteorological measurements and atmospheric dispersion modeling.

The ARL Battlefield Environment (BE) Division is the lead DOD agency for R&D in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to provide the technology and tools (1) for the soldier to exploit weather on the battlefield, (2) for the commander to avoid exposing the soldier to environmental hazards, and (3) for the materiel developer to minimize system weather impacts, supplying atmospheric effects information. The joint Army/AF "Own The Weather" initiative will provide knowledge of current and forecast battlefield environment conditions, along with their effects on systems, soldiers, operations, and tactics, to contribute

to the Army's decisive advantage over its opponents. Within the DOD, BE is the lead agency for multi-service R&D programs in transport and dispersion modeling, boundary layer meteorology over land, and mobile atmospheric profiling. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects. The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the AF, Navy, or civilian community, and over data-sparse geographic regions. While the AF provides the Army with basic tactical weather support, the Army provides technology to support service-unique requirements and Army systems as well as distributing weather intelligence information to the Army command and control systems on the battlefield. The Army has begun an active re-programming to respond to the new AF Weather Re-Engineering initiatives and will work to ensure the ongoing success of the Army weather intelligence technology. BE continues to develop and provide the software tools for the Army's IMETS and works with the AF Weather Agency and Combat Weather Center to make IMETS an integral part of the total battlefield weather support capability.

The BE Division within the ARL Information Science and Technology Directorate, consists of four branches, two each at the ARL primary site at Adelphi, Maryland, and the White Sands Missile Range (WSMR), New Mexico. The Adelphi, Maryland, branches specialize in a basic research program, while the WSMR branches support an applied research development program for Army tactical applications. In FY 1998, BE will open a new experimental site at Blossom Point, Maryland, in a complex littoral region on the north shore of the Potomac River. The new site will conduct field experiments in electro-optic and acoustic propagation as well as test weather modeling tools.

The Atmospheric Effects Branch research efforts address: (1) models and simulations of environmental effects on electro-optical systems under realistic battlefield conditions, (2) acoustic propagation and background acoustic noise models for predicting environmental effects on acoustic signatures and sources, and (3) micrometeorology of the boundary layer including transport and dispersion of chemical/biological agents and other aerosols released into the atmosphere.

The Atmospheric Aerosols and Adaptive Optics Branch research effort addresses: (1) in-situ and remote detection of chemical/biological agents and pollution aerosols, and (2) optics and beam propagation in the turbulent boundary layer.

The Weather Intelligence Branch development efforts include: (1) tactical weather data assimilation and distribution, (2) battlescale diagnostic and analytic modeling, (3) tactical decision aids, and (4) integration of weather effects models and satellite data with visualization tools for training and mission planning. As part of our tactical software and development the branch also (1) verifies and validates tactical weather products and (2) transitions the BE advanced weather technology to Battlefield Automated Systems and Battle Labs. The Artillery Meteorology development efforts address: (1) methods to provide accurate and timely artillery meteorology data for precision strike applications and (2) target area meteorological information to support the operation of long range, terminally guided smart munitions.

In FY 1997-1998, BE successfully participated in the Army's Task Force XXI Advanced Warfighting Experiments with its IMETS software and delivered IMETS Block II software to the Program Director for fielding. In FY 1998 BE will transition the mobile profiler to Project Manager EW/RSTS for engineering development and future fielding. BE is working closely with Army and AF users and other DOD and national weather organizations to ensure the highest possible payoff for its research and development dollars.

The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamic and kinematic 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 several special initiatives. The focus of the research is on the processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer, thereby, leading to better understanding of atmospheric effects on soldiers,

materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure at turbulence time scales the volumetric fields of wind velocity, temperature, and moisture in the boundary layer.

ARO also manages several other areas of special funding. The Augmentation Awards for Science and Engineering Research and Training (AASERT) program provides funding for additional graduate and undergraduate students working under existing sponsored research programs. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities.

The CECOM Intelligence and Electronic Warfare (IEW) Directorate, Fort Monmouth, New Jersey, assists CECOM and other internal organizations in developing and fielding weather support systems and helps the Program Manager, Intelligence Fusion with technical management of weather programs. The directorate currently supports the Meteorological Measuring Set (MMS), the Profiler, and the Integrated Meteorological System (IMETS). A brief description of each of these programs shows IEW Directorate's involvement and supplements earlier discussions under the other MACOMs.

The Meteorological Measuring System (MMS), AN/TMQ-41, is currently fielded to the active Army. It is an upper air meteorological data collection, processing and dissemination system that provides data to field artillery and target acquisition users. The system meets the requirements of roll-on/roll-off capability during assault. The system is a non-developmental item and the contractor has built 42 systems for the Army and ARNG, 21 for the Marine Corps, and additional systems for foreign sales. The IEW Directorate is currently assisting in upgrading the MMS to use the GPS as a Navigational Aid (NAVAID) to determine radiosonde position. GPS will be used when the current primary NAVAIDS (LORAN-C and VLP/OMEGA) are not available. The GPS processor will fit inside of the MMS meteorological processor, currently being updated to accommodate this upgrade. Another upgrade to the MMS is the Surface Meteorological Sensor (SMS).

The SMS will be mounted on a tripod outside the MMS shelter and connected to the MMS shelter by cable. The SMS underwent first article testing in FY 1997.

The Profiler will provide the current upper air meteorological system with new and enhanced capabilities. It will provide a suite of sensors capable of nearly continuous data collection which will reduce the time staleness of atmospheric. It also provides a model of local terrain to further improve the accuracy of the data for firing artillery systems.

The IMETS, AN/TMQ-40, is the primary Army weather support system outside artillery support. AF WETMs operates it at all levels with direct AF weather support. It collects available observations and central forecast products, analyzes and forecasts on the micro scale, and disseminates tailored weather products and weather effects decision aids electronically into the Army Battle Command System for direct use in warfighting missions. IMETS ingests satellite imagery both directly and from the AF Small Tactical Terminal. IMETS can merge weather displays with the common relevant picture of the battlefield to help visualize weather impacts on operations and help the commander and staff use the information more effectively. IMETS maintains connectivity to higher and lower command levels and to each tactical operation center via high frequency (HF) radio and direct electronic interface over the Army Battle Command System.

Medical Research and Development Command

The United States 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 efforts in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to weather parameters (primarily ambient air temperature, dew point temperature, wind speed, and solar radiation) defines

an operational envelope for unimpaired human performance. The overall goals of USARIEM's weather-related research programs efforts are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios. Current efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. In support of the Army Ranger training facility at Eglin AFB, Florida, Medical Research and Development Command and USARIEM are participating in the development of an automated thermal injury risk assessment system. The MERCURY-Ranger test bed system is a partnership effort with the Army Research Laboratory's Battlefield Environment Division (ARL/BED), the Canadian Defense and Civil Institute of Environmental Medicine (DCIEM), and the USAF's 46th Weather Squadron at Eglin AFB. The test-bed system ingests hourly data from several local surface weather stations and automatically spreads the data across a 100 by 100 km region using objective and heuristic interpolation methods. The resulting high resolution (1 km) gridded weather data fields are then used as inputs to the thermal strain prediction models for heat stress, cold air exposure, or cold water immersion. Results are displayed as color-coded map overlays of thermal injury risk categories or tolerance times. A prototype cold water partial immersion model is being developed and implemented in cooperation with DCIEM. That model uses real-time water temperature and depth measurements along with standard weather parameters at river locations to predict safe exposure times in cold water river fording scenarios. This highly automated test bed system is intended to provide a platform for evaluating methods needed to translate real-time weather information into robust assessments of soldier system health risks and performance limitations. Army weather and battle-field atmospheric researchers are working closely with MACOM users and other DOD organizations to ensure the highest possible payoff for its research and development dollars.