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 within the Headquarters, United States Air Force (HQ USAF/XOW), 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 O-2) document. HQ USAF/XOW interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

Air Force Weather (AFW) Organization. AFW has reengineered to mirror the three levels of military operations--strategic, theater (operational), and tactical. The Air Force Weather Agency (AFWA), a field operating agency (FOA) reporting to HQ USAF/XOW, provides strategic-level weather support (global and synoptic-scale) for their worldwide customers, as well as fulfills some unique mission requirements (discussed later). HQ AFWA, located at Offutt AFB, Nebraska, has two subordinate centers: the Air Force Combat Climatology Center (AFCCC) at Asheville, North Carolina and the Air Force Combat Weather Center (AFCWC) at Hurlburt AFB, Florida. Space environmental support is provided by the 55th Space Weather Squadron (55 SWXS) at Schriever AFB, Colorado, which recently transferred organizationally from Air Force Space Command to AFWA. Along with this organizational transfer, part of the space environment mission will migrate to HQ AFWA at Offutt AFB during 2000-2001. Nine Operational Weather Squadrons (OWSs) serve in direct support of overseas theater CINC and/or Numbered Air Force (NAF) operations. Each OWS is designated as the forecast agency for a specific geographical Area of Responsibility (AOR) (Figure 3-DOD-1) in concert with their supported NAFs or Theater's AOR. CONUS OWSs are also responsible for CONUS regional weather support. They produce and disseminate terminal forecasts, weather warnings and advisories, planning and execution area forecasts, and other operational products to Combat Weather Teams (CWTs). The CWTs, located on the base and post level, take and disseminate local observations and provide mission-tailored forecasts and briefings based on centrally produced guidance. AFW personnel enhance the unique global capability of ground and aerospace military operations, while indirectly assisting civil aviation, by providing flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

Weather Data Collection integrates weather radars and meteorological sensors into a single meteorological sensing and instrumentation approach for battlefield and in-garrison operations. Current and future programs include: Observing System 21st Century (OS-21), Tactical Weather Radar (TWR), and Small Tactical Terminal (STT). 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 military and civil locations throughout

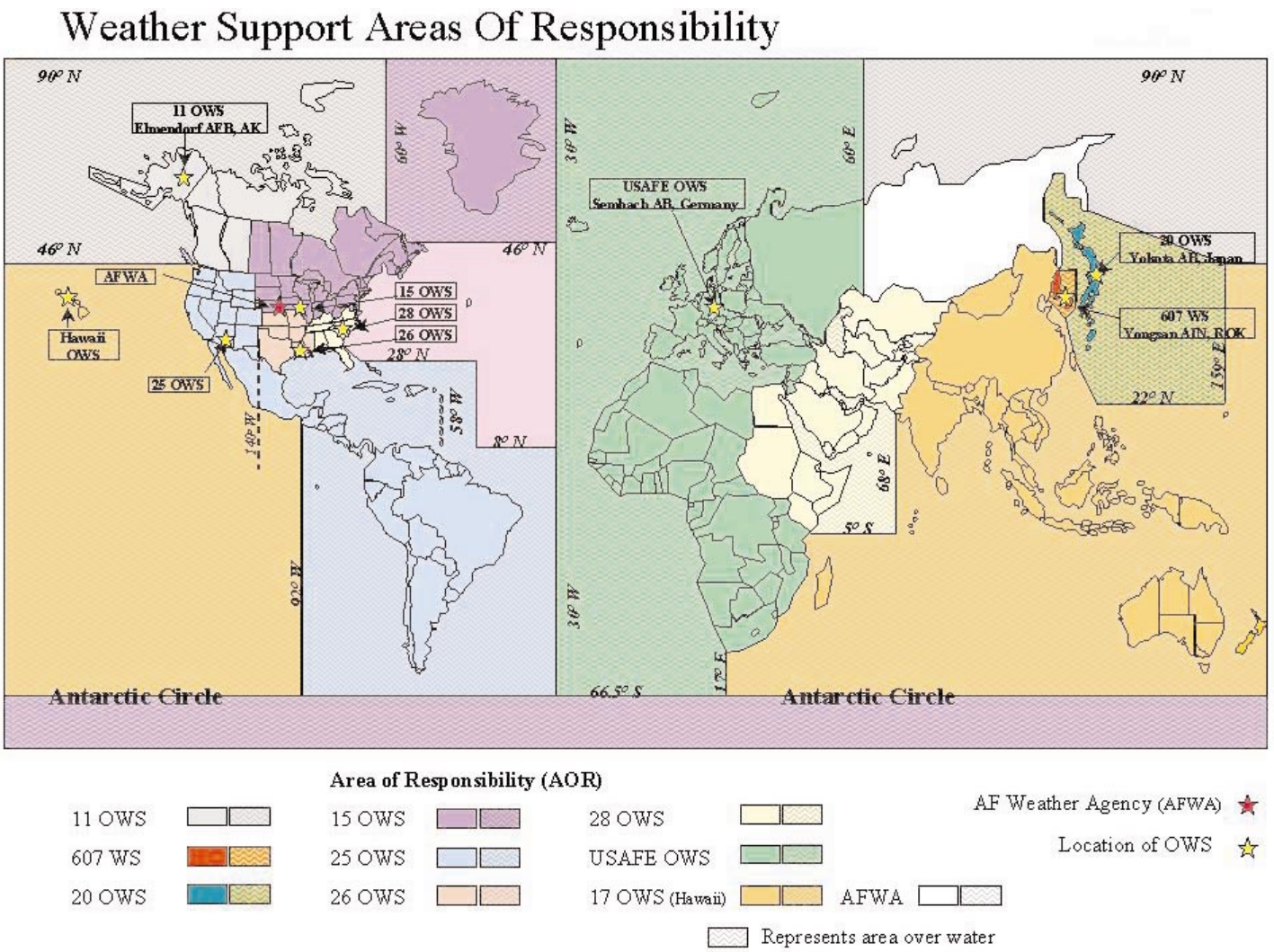

Figure 3-DOD-1. Areas of Responsibility for Air Force Weather's Operational Weather Squadrons.

the world, via the Automated Weather Network (AWN). Upper air observations provide vital input for numerical weather analysis and prediction. United States and foreign rawinsonde reports are primary sources and are supplemented with military and civilian pilot reports. The OS-21 program will provide a much needed state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: Fixed, Deployable, Remote, Manual, and Upper Air. The Manual section is intended for tactical operations and will continue upgrades begun under the Manual Observing System (MOS) and Tactical Meteorological Observing System Modification (TACMET MOD) programs. AFW purchased commercial off-the-shelf Remote Miniature Weather Sensors to provide accurate real-time weather information from forward unmanned locations to support Kosovo operations (Figure 3-DOD-2). OS-21 will continue to expand this capability.

Weather radar is a principal source of information for providing severe weather warnings. Within the CONUS, AFW uses the WSR-88D, procured through the NEXRAD Joint System Program Office. It is operated and maintained by DOD, NOAA, and FAA within the CONUS and by the Air Force overseas. The WSR-88D system incorporates the latest technological advances in Doppler radar, data processing, communications, and display, and continues to be modernized to improve reliability and maintainability. Tactical Weather Radars (TWR) are used to support contingency operations. The TWR program supports worldwide military operations by providing tactical/deployable Doppler weather radar capability, replacing existing radars at deployed locations and at fixed locations overseas.

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, elec-

trically charged particle fluxes, 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 and is used for numerical analysis and forecasting. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

The STT provides worldwide tactical users with a survivable "first-in" source of meteorological satellite data, processed by small, portable terminals in forward areas of conflict. These terminals process remote-sensed visual/thermal imagery, from both polar orbiting and geostationary satellites, and other non-imagery weather data to support combat forces.

Analysis and Forecasting. The AFWA is the primary production center for providing weather analyses and forecasts for Air Force and Army operations. 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.

AFWA has organized 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 four production branches: Forecast Production, Special Support Operations, National Programs Operations, and Satellite Applications.

The Strategic Section of the Forecast Production Branch produces tailored worldwide meteorological analyses and forecasts in support of aviation customers. The branch also provides forecasts of CONUS low-level aviation hazards. The CONUS Severe Forecast Section provides specific point weather warnings for Air Force and Army installations in the CONUS and hot backup to Aviation Weather Center and Storm Prediction Center. The American Forces Network Section provides worldwide, broadcast-quality public weather services and planning forecast support through the American Forces Television Network to DOD personnel and family members stationed overseas.

The Special Support Operations Branch (SSOB) provides worldwide mission-tailored forecasts to Joint Special Operations Forces (SOF). The branch acts as a clearinghouse for unique data requests from the SOF customers; provides end-to-end targeting support to unified command, component, or national customers; produces long-range (4-8 day) forecasts to unified command, component, or national customers; and supplies the Nation's reconnaissance cloud-free forecast products. SSOB is also in the process of accepting portions of the space-forecast mission from the 55 SWXS.

The National Programs Operations Branch provides weather support for classified National Programs directed by the Secretary of the Air Force. The branch produces detailed global cloud analyses to update and refine the Real Time Nephanalysis (RTNEPH) database. The branch identifies and documents weather service requirements and initiates actions to ensure Sensitive Compartmented Information (SCI) and Special Access Program (SAP) weather support needs are met. They serve as the focal point for AFWA SAPs; ensure National Program and other SCI and SAP support requirements are integrated into AFWA programs; monitor and evaluate accuracy and timeliness of centralized weather services to National Programs; and interface with the DOD and national intelligence community regarding weather services and exploitation of weather information.

The Satellite Applications Branch provides rapid response tailored METSAT

Figure 3-DOD-2. AFW's remote miniature weather station.

imagery and evaluation for DOD contingency mission support. The branch produces regional snow and ice cover analyses to update and refine the Snow Depth (SNODEP) database; and generates automated METSAT imagery products for AFWIN/ SAFWIN distribution to DOD customers. The branch also tracks and classifies tropical cyclones (METSAT analysis) for the DOD Joint Typhoon Warning Center (JTWC) and other United States Tropical Cyclone Warning Centers; provides hot back up for JTWC satellite operations; monitors operational status; and evaluates quality of imagery ingested at AFWA. They coordinate corrective actions; maintain, modify, and develop new capabilities to display and visualize satellite imagery data on workstations; infuse state-of-the-art techniques into improved imagery analysis ensuring high quality customer products; serve as AFW focal point on technical issues regarding METSAT imagery utilization; and interface with the DMSP System Program Office, Air Force Space Command, and other DOD and governmental agencies on METSAT data exploitation issues.

As the space weather mission transitions from 55 SWXS to HQ AFWA, a space weather operations branch at AFWA will provide worldwide general and tailored analyses, forecasts, advisories, and warnings for space weather phenomena that can affect military operations and National Programs activities. The branch will provide products for agencies from all DOD Services using space weather measurements from a variety of ground- and space-based sensors. Data sharing and forecast coordination is performed with the NOAA Space Environment Center (SEC) in Boulder, Colorado.

On-going modernization initiatives at AFWA include the Cloud Depiction and Forecasting System (CDFS) II, Global Theater Weather Analysis and Prediction System (GTWAPS), Space Weather Analysis and Forecasting (SWAFS), and modernization of the communications and data processing infrastructure including a significant increase in the data base capacity. 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 for operational customers and National Programs, providing a capability that cannot be met with the current system. The GTWAPS program is nearing completion and this year's efforts will allow further merger of the strategic and theater level forecasting systems at the weather centers and OWSs. The key software component of the GTWAPS program is a theater analysis and forecast model--Mesoscale Model version 5 (MM5), which provides highly accurate, fine-scale forecast data. SWAFS will integrate additional space weather data sources and execute next-generation space weather models in support of DOD and National Programs operations (Figure 3-DOD-3).

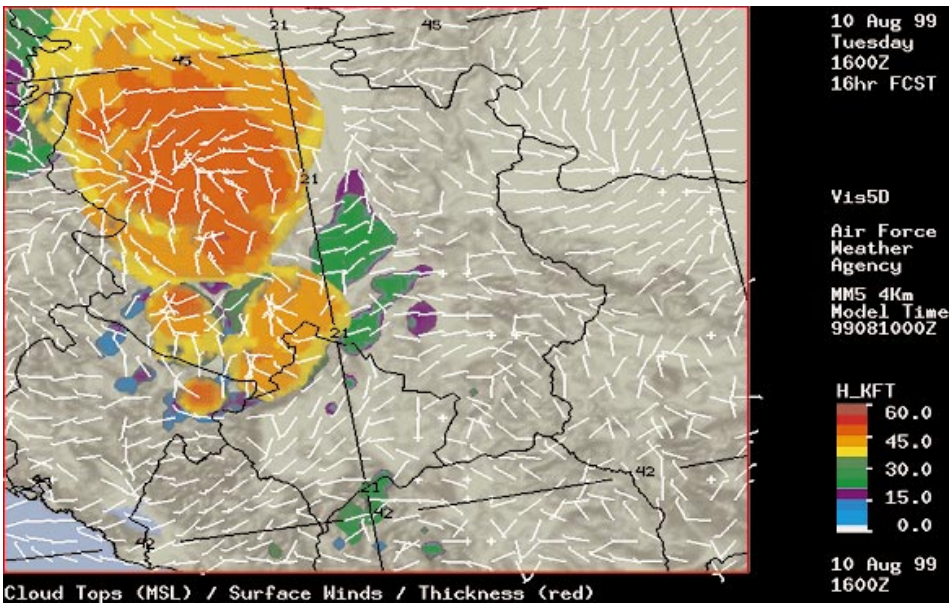

Figure 3-DOD-3. Visualization of MM5 Forecast over the Balkans.

Product Tailoring/Warfighter Applications. AFW organization was designed such that the OWSs and CWTs take the products created by the higher levels and add additional details, tailored to the specific region or mission requirement. The Forecasting System 21st Century (FS-21) program is the vehicle for providing necessary computer hardware and software at both the OWSs and CWTs. The OWS Production System, Phase 2 (OPS-II), is the backbone of the OWS production system. It's a hybrid system of databases, servers, and work stations, which provides the computer hardware and software necessary for OWSs to produce and disseminate forecast products to CWTs.

The New Tactical Forecast System (N-TFS) provides in-garrison and deployed CWT personnel the meteorological tools necessary to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and Air Force operational, command and control, and support forces worldwide. N-TFS provides weather personnel the ability to use the same system in "peace and war", thus providing a robust "first in" and sustainment weather forecast capability to combat weather units worldwide. Additionally, N-TFS ingests data from

Air Force observing systems and observations from indigenous sources. Data from the N-TFS, combined with satellite imagery from the STT, provide the essential capability required for deployed weather units to meet operational mission requirements.

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 (SWO) 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.

Dissemination. The Air Force communications system uses a variety of media to meet the dissemination needs of its worldwide customer base. Asynchronous Transfer Mode (ATM) fiber optic networks are used to distribute high-resolution satellite imagery and forecast data from global numerical weather prediction models between large DOD and civilian processing centers. Commercial T-1 circuits provide a subset of this data to new theater and regional forecast facilities. Forecaster-developed products and gridded data sets are distributed from HQ AFWA via the Communications Front-End Processor to base and post weather stations using dedicated 9600-baud circuits. These dedicated circuits are now augmented by, and will eventually be replaced by commercial Kμ-band broadcast satellites over the CONUS, Europe, and the Pacific. The broadcast satellites now provide tailored satellite and WSR-88D imagery to the base and post weather stations at both fixed and deployed locations.

Alphanumeric data including synoptic, upper-air, and pilot reports are collected and distributed via the AWN. The AWN is a collection of dedicated circuits ranging from 74-baud to 56kbps linking DOD, national and international facilities worldwide. Data is also received from DOD-operated High Frequency (HF) radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological Organization (WMO) channels. The Automatic Digital Weather Switch at Tinker AFB, Oklahoma receives alphanumeric weather data and Notices to Airman (NOTAMs), parses them according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end users over: (1) the same dedicated circuits, (2) the DOD's Non-secure Internet Protocol Network (NIPRNET), and (3) HF and satellite broadcast facilities. End-user systems include the Automated Meteorological Information System (AMIS), Meteorological Information Standard Terminal (MIST) and small computers using a variety of alphanumeric display packages.

AFW utilizes the NIPRNET to host the Air Force Weather Information Network (AFWIN) and the Military Aircrew Information System (MAIS). AFWIN provides worldwide access to numerical model forecast graphics, satellite imagery, and text bulletins. MAIS was designed to accept aircrew mission parameters and provide weather data for the takeoff base, route of flight, and destination.

Unique Support Requirements. A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers, as well as operational units. To fulfill this requirement, designated AFW personnel serve as part of the working staff of operational Air Force, Army, and joint force units. In this capacity, AFW 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. Support is tailored 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. 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 specific requirements.

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. AFW 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 support includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force 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 JTWC, which moved to Hawaii in 1999. JTWC provides tropical cyclone warning services to DOD units and other United States subscribers in the area west of 180 degrees longitude 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 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.

AFCCC provides climatic 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 co-located 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 (3D) cloud analysis extracted from meteorological satellite imagery (Real-time Nephanalysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

AF/XOW is the DOD Modeling and Simulation Executive Agent (MSEA) for the Air and Space Natural Environment (ASNE). The director executes his responsibilities through the Office Chief co-located at the AFCCC. The Executive Agent is responsible to ensure modeling and simulation developers and users have environmental models, algorithms, and data to represent the air and space environment rapidly, thoroughly, accurately, and consistently in a manner that promotes cost-effectiveness, ready access, interoperability, re-use, and confidence.

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 Training 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.

SPACE ENVIRONMENTAL SERVICES

The 55 SWXS is the DOD focal point for operational space environmental support and the execution of this mission is transferring to HQ AFWA during 2000-2001. The 55 SWXS includes a forecast operations center at Schriever AFB as well as six solar observatories located throughout the world. Additionally, 55 SWXS participates with NOAA in the joint operation of the SEC.

Many DOD systems are affected by space weather phenomena that occurs in the troposphere, stratosphere, mesosphere, thermosphere, ionosphere, and magnetosphere. The space weather processes that occur in these near-Earth environments are greatly influenced by processes originating on the Sun and in interplanetary space and by the interactions between the solar phenomena (radiation and/or electrically-charged particles) and the Earth's upper atmosphere and magnetic field. Collectively, these processes lead to space weather conditions in the near-Earth environment which can adversely affect operations. The 55 SWXS provides general and tailored products directly related to the space weather effects on DOD communications, surveillance/intelligence collection, satellite operations, navigation, and space tracking and warning systems.

Space weather products and/or specialized services include:

- Ionospheric conditions (electron densities and disturbances) and their potential effects on communications, intelligence-collection, precision navigation, space tracking, detection/warning operations,

and manned space flight (Figure 3-DOD-4).

- Magnetospheric conditions (charged-particle fluxes) and their potential effects on satellite operations, to include after-the-fact assessments of whether space weather conditions caused anomalous behavior or failures experienced by satellite components and sub-systems.
- Thermospheric conditions (atmospheric densities) and their potential effects on satellite drag and satellite launch calculations.
- Tropospheric, stratospheric, and mesospheric conditions (extremely energetic particles, radio wave radiation and interference, magnetic field disturbances) and their potential effects on high-altitude flight, communications, intelligence collection, and space tracking and warning.
- Solar conditions (radiation and/or electrically charged particle fluxes due to various solar phenomena) and their potential effect on the near-Earth environment.
- Immediate response advisories and warnings of all conditions described above which may have significant effects on one or more military operations.

Sources of Space Environmental Data. A variety of ground- and space-based space weather data is available to forecasters providing space weather support.

The 55 SWXS operates a network of solar optical and radio telescopes at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Palehua, Hawaii, San Vito, Italy, and Learmonth, Australia. These systems provide observations of solar phenomena at optical and radio wave wavelengths.

A worldwide (primarily Northern Hemisphere) network of ground-based ionosondes and other sensors provide ionospheric data. AFW manages the automated Digital Ionospheric Sounding System (DISS) to provide ionospheric measurements. The Jet Propulsion Laboratory also operates a global network of sensors that provide ionospheric data. A network of magnetometers is operated by the United States Geological Survey (USGS). The USGS data provides indirect measurements of the strength of ionospheric and magnetospheric electric currents which create their own magnetic field that is superimposed upon the Earth's magnetic field.

The Geostationary Operational Environmental Satellites (GOES) vehicles provide real-time solar X-ray and electrically charged energetic particle and geomagnetic data. This data is made available through the SEC. DMSP, NOAA, and other DOD geostationary satellites provide additional energetic electrically charged particle data in low-Earth and geosynchronous orbits. Other space-based data is available from NASA and other agencies. For example, real-time solar wind data is provided by the NASA Advanced Composition Explorer satellite.

A number of additional sensors or improvements to existing space weather sensors are planned. A Solar X-Ray Imagers (SXI) will be flown beginning

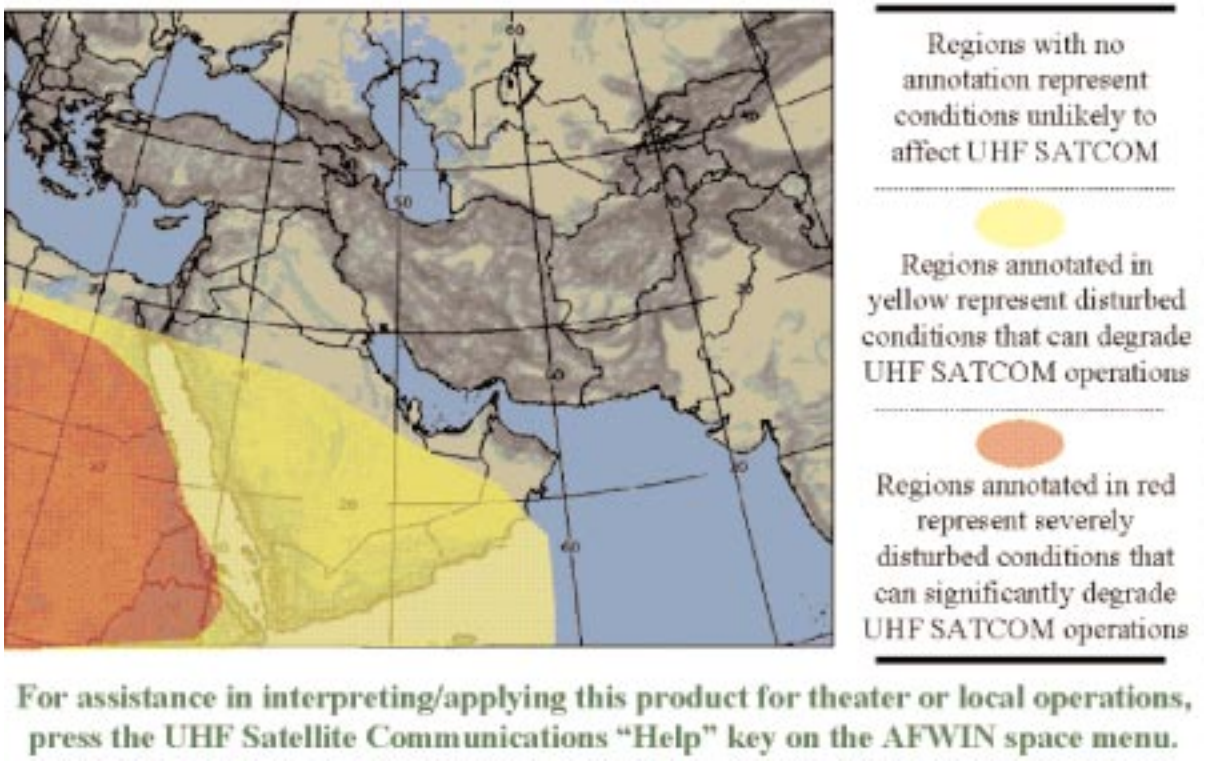

Figure 3-DOD-4. 55 SWXS operational forecast identifies locations where Ionospheric conditions will impact UHF SATCOM applications.

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. AFWA's Solar Radio Burst Locator (SRBL) is projected to be operational in 2001 and will provide radio wave measurements of the Sun while also mapping (locating) certain solar phenomena that would otherwise be unseen by optical telescopes during periods of cloud cover. AFWA has additional improvements scheduled for the optical telescopes (known as ISOON) as well as to various ionospheric sensors.

Various space weather models are used to specify current solar or global characteristics of space weather where observations are not available and to assist forecasters in generating forecasted conditions. These models use available observations and are climatological-based or physics-based in calculating their output. Improved models are planned under the SWAFS program during the next five years. A new initiative known as the Community Coordinated Modeling Center at HQ AFWA will serve as a proving-ground for new space weather model development.

The consolidation of the space weather and terrestrial weather strategic center functions under HQ AFWA at Offutt AFB will enable AFWA to provide seamless aerospace weather support to DOD forces, reduce USAF infrastructure costs, streamline customer support process, and improve space weather services. Two new space weather support units were established to support the Space Command mission. One of these new units is Detachment 1, Space Operations Group whose mission is to support the Aerospace Operations Center at Vandenberg AFB, California. The other unit is the 50th Operations Support Squadron, Weather Flight. This unit will support space missions controlled from Schriever AFB, Colorado, one portion of the current mission of the 55 SWXS.

SUPPORTING RESEARCH

The overarching objective of the Air Force meteorological and space environmental R&D 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 AFW Mission Support Plan and in the Mission Area Plans of the Air Force major commands. More specific guidance is found in Technical Needs, documented in the associated Weather Development Plan. Space environment R&D is targeted to meet the DOD's space weather requirements as summarized in the National Security Space Architect's Space Weather Architecture Study and the associated Implementation Plan.

The responsibility for conducting and managing environmental sciences R&D (including meteorology and space weather) resides with the Air Force Research Laboratory (AFRL) Battlespace Environment Division located at Hanscom AFB, Massachusetts. Its applied research program in meteorology is focused to emphasize weather prediction methods, cloud modeling and simulation, weather impact decision aids, and optical turbulence for airborne laser applications. In space weather, the AFRL research program focuses on ionospheric impacts on RF systems, space particle specification and forecast, solar disturbance prediction, and neutral density effects on LEO spacecraft. Working closely with SMC/CI under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include space environment sensors on the DMSP spacecraft, state-of-the-art ground-based scintillation detectors, total electron content sensors, DISS, ISOON, and the Operationalized Space Environment Network Display (OP-SEND) suite of web-based products. AFRL also conducts customer-supported R&D for NPOESS, the Defense Modeling and Simulation Office (DMSO), the National Reconnaissance Office (NRO), the Ballistic Missile Defense Office (BMDO), the DOD High Performance Computing Modernization Office (HPCMO), and NASA.

Weather Prediction Methods. R&D efforts in this area focus on the development of aviation-mission-impact-variable algorithms to be applied operationally at the AFWA. Multivariate diagnostic algorithms, applicable to data provided by global and theater-scale numerical weather prediction models, 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 as part of the GTWAPS program. The present weather, thunderstorms, and horizontal visibility algorithms are awaiting evaluation testing at AFWA. A Weather Technology Unit (WTU) has been established to provide weather research and development support to AFWA through technique development, technology transition, and technical assistance. The WTU is currently a four person effort with one AFRL researcher located on-site at AFWA. WTU tasks focus on several near- and mid-term weather prediction capabilities. The AFRL diagnostic cloud forecast algorithm is being transitioned into AFWA operations. A theater-scale cloud analysis procedure is being developed capable of specifying cloud water content in the initial conditions of the AFWA theater-scale numerical

weather prediction model--MM5. Contrail analysis and prediction schemes are nearing completion, comparing the skill of the AFWA operational contrail scheme with a statistical model developed from contrail field experiments. An extensive evaluation of the MM5 model is underway as a forecast source from which optical turbulence models can diagnose conditions adverse to the Airborne Laser (ABL) mission. Finally, a 3 year project has begun that will demonstrate the feasibility of executing a mesoscale four-dimensional variational data assimilation procedure in operational timelines on a massively parallel processing computer.

Cloud Modeling and Simulation. The Cloud Scene Simulation Model (CSSM) has become the cornerstone for in-house, service-sponsored projects to provide physically and radiometrically accurate cloud simulations. These projects 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) transitioning a cloud/NWP model data fusion approach to the exploitation of National Technical Means data, (2) designing an extension of the CSSM to support campaign-level simulations in infrared wavebands, and (3) performing a military utility analysis for the National Polar-orbiting Operational Satellite System (NPOESS). CSSM has reached a point of maturity where it is routinely used in war-gaming demonstrations and exercises (for the Air Force and Navy) and in the conduct of data impact/sensitivity.

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. This is a joint program led by AFRL with Navy NRL and Army ARL participation. WIDA products are used to support precision-guided munitions, night-vision, surveillance, and navigation systems. There are three products under development in the WIDA program. Three of the four products will provide unit-level weather impact support for mission execution. The mission execution products are: (1) infrared (IR) Target-scene Simulation Software (IRTSS), (2) Night Vision Goggle (NVG) Operations Weather Software (NOWS), and (3) Target Acquisition Weather Software (TAWS). The fourth, Weather Automated Mission Planning Software (WAMPS), incorporates WIDA products described above into Air Force command and control systems from the force to the unit-level. The products combine global terrain and features, target signatures, electro-optical (EO) sensor performance models, and meteorological and operational planning data to provide decision-makers and warriors with quantitative impacts of weather on their systems as well as EO scene visualization tools for environmental situational awareness. NOWS 5.2 was transitioned for operational use in June 1999 and TAWS V1.1 in December 1999. IRTSS will transition to AFWA in September 2000.

Atmospheric Optical Turbulence. EO and laser systems are adversely affected by optical distortions induced by atmospheric temperature or refractive turbulence. As the sophistication grows in current and next generation military systems, the requirement for more detailed knowledge of the fine scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such system. Since the meteorological conditions that produce turbulence vary, the performance of such systems varies. The Air Force program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Measurements are performed by a balloon-borne turbulence sensor which is mated to a standard radiosonde. This program has produced data and empirical models that are the basis for ABL system specification. Balloon-borne measurements are now being made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum is also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales worldwide. Horizontal measurements by the aircraft augment the vertical profiling by balloons.

Empirical seasonal models have been developed for different theaters which are in widespread use. Data collected are now being used to develop models of vertical and horizontal structure of turbulence in the troposphere and stratosphere. These models are correlated with meteorological sources of gravity waves such as jetstreams, fronts, mountains, and thunderstorms. This modeling is closely coupled with work on the generation, propagation, and breakdown of gravity waves. Work is also underway to predict optical turbulence based on theater-scale numerical weather prediction models (NWP) used with optical turbulence parameterizations. This forecasting effort is being tested and evaluated for a number of locations around the world. The ultimate objective of these efforts is to develop models that allow the forecasting and prediction of ABL system performance.

Ionospheric Impacts on RF Systems. Irregularities in the Earth's ionosphere driven by solar and geophysical activity

cause problems for DOD C³I, navigation, and surveillance systems. AFRL's research program focuses on the specification and forecasting of global electron density profiles and ionospheric scintillation. In the scintillation arena, AFRL has developed the Scintillation Network Decision Aide (SCINDA), a set of ground-based sensors and quasi-empirical models that provide real-time alerts and short term (<1 hour) forecasts of scintillation impacts on UHF satellite communication in the Earth's equatorial regions. Work is underway to extend the SCINDA ground station network and construct an L-Band scintillation model for application to GPS navigation links. The Communication/Navigation Outage Forecast System (C/NOFS) satellite is being developed by AFRL in collaboration with the Naval Research Laboratory to provide 4-6 hour forecasts of scintillation outages and is scheduled for launch in FY 2003. AFRL is responsible for development and calibration of the SSIES plasma density instrument and the SSM magnetometer currently flying on the DMSP satellites, to include the development of automated data processing algorithms. A program to comprehensively validate the Parameterized Real-time Ionospheric and Specification Model (PRISM), currently being used by 55 SWXS to specify global electron density profiles, is underway as are upgrades to ground-based sensors to measure total electron content along ground-to-satellite links and electron density profiles of the lower ionosphere. Basic research efforts are focused on creating physics-based models needed to forecast global electron density profiles, scintillation structures, and neutral density variations affecting satellite drag.

Space Particle Specification and Forecast. Energetic particles in the near-Earth space environment pose hazards to DOD spacecraft such as single event microelectronic effects induced by MeV cosmic ray ions, deep-dielectric charging induced by MeV electrons in the outer Van Allen belt, and spacecraft frame charging and discharging induced by keV electrons created in geomagnetic storms. AFRL has a robust program to develop and fly the Compact Environment Anomaly Sensor (CEASE) which is a small, lightweight, low-power sensor that provides alerts and warnings of space particle hazards to satellite operators increasing situational awareness and decreasing anomaly resolution time. CEASE can also provide scientific level data, given sufficient telemetry, which can be used to develop climatological models or drive real-time specification models. The Relativistic Electron and Energetic Proton Experiment (REEPER) is being built to resolve the energy spectra of the highest energy electrons and protons found during large geomagnetic storms and is manifest on NASA's Inner Magnetosphere Explorer (IMEX) satellite scheduled for launch in FY 2003. AFRL is responsible for the development and calibration of the SSJ4 electron and proton sensor flying on the DMSP satellites. Automated data reduction algorithms and tailored auroral boundary products using the SSJ4 data are also created. Complementing the sensor program, AFRL develops, validates, and transitions models of the aurora, radiation belts, and magnetospheric plasma to meet the needs of the acquisition, operations, and modeling and simulation communities. The AF-GEOSpace code comprises many of the models developed by AFRL and its collaborators, including quasi-empirical models constructed from DMSP, CRRES, and APEX satellite data and the Magnetospheric Specification Model (MSM), and serves as a 'kernel' for transitioning tailored products to operations. Physics-based models for forecasting the distributions of energetic particle in the radiation belts are the primary focus of basic research work.

Solar Disturbance Prediction. The Sun ultimately drives all of space weather. Any attempt to forecast direct solar effects, such as solar proton or HF absorption events, or obtain long lead-time forecasts (several days) of geomagnetic and ionospheric events requires the specification and forecast of solar activity. AFRL maintains a research group at the National Solar Observatory, Sacramento Peak, New Mexico dedicated to advancing ground and space based solar physics and applying it to meet DOD solar forecasting needs. The Improved Solar Optical Observing Network (ISOON) is being built for SMC/CI and AFWA by AFRL to replace the current USAF SOON telescope system. When the first of four units becomes operational in FY 2001 it will improve the optical resolution and image cadence beyond what is available with SOON, reduce operating costs, and expand the magnetic field determination capabilities. Applications are also being developed to use white-light solar surface flow observations and magnetograms to obtain 1-2 hour forecasts of solar flare events that can eventually be applied to ISOON data. An advanced space-based imager designed to detect coronal mass ejections (CMEs) all the way from the sun to the Earth is being built by AFRL and is scheduled for space-test in early FY 2002 on the CORIOLIS satellite. If successful the Solar Mass Ejection Imager (SMEI) will provide 1-3 day forecasts of geomagnetic storms with a high degree of accuracy. Current operational solar shock forecast models (i.e. the Interplanetary Shock Propagation Models (ISPM) and the Shock Time of Arrival Model (STOA)) are being extensively validated at AFRL and the necessary models of irregularities in the solar wind needed to improve the models are being developed.

PROGRAM OVERVIEW

The United States Navy has the unique military requirement to assess meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations - anywhere in the world, at anytime. Naval METOC must support world-wide naval, joint, and combined operations, anytime and anywhere, with the focus predominantly on areas outside of the contiguous 48 states (Figure 3-DOD-5). METOC support begins by measuring the battlespace physical environment and culminates with safe, effective weapons systems and sensor employment. Developing METOC forecasts and determining potential effects on weapons system information requires:

- the collection of data through tactical and dedicated sensors (including satellites);
- fusion and analysis of atmospheric and oceanographic phenomena; and
- meteorological information in tactical decision aids and mission planning systems.

The Chief of Naval Operations, through the Oceanographer of the Navy (CNO(N096)), sponsors operational Navy METOC services and related research and development (R&D). The Navy provides meteorological services for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. The Oceanographer of the Navy sponsors programs in four closely related disciplines to provide worldwide, comprehensive, integrated weather and ocean support--meteorology, oceanography, geospatial information and services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment.

Research and development is conducted by warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer of the Navy. The Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARSYSCOM) are the primary activities, in addition to various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California, and with the Naval Oceanographic Office at Stennis Space Center, Mississippi. The SPAWARSYSCOM METOC Systems Program Office (PMW-185) is Navy's single program manager for METOC system development and acquisition.

Figure 3-DOD-5. Navy METOC's global organization

METEOROLOGICAL SERVICES

UNITED STATES NAVY

Operational support within the Navy is provided by elements of the Naval Meteorology and Oceanography Command (NAVMETOCCOM). Navy METOC activities are involved in worldwide collection of observations ashore, afloat and through remote sensors, and in the assimilation and processing of these observations on a global basis to support analysis and forecasting throughout the world.

The Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOCCEN), in Monterey, California, provides global forecasts and analyses. Environmental data is acquired through links with DOD and NOAA conventional and remotely sensed data distribution systems. By agreement between Navy and Air Force, FLENUMMETOCCEN is the primary DOD global prediction center, running the Navy Operational Global Atmospheric Prediction System (NOGAPS), developed by the Naval Research Laboratory Detachment, also in Monterey.

NOGAPS provides global atmospheric predictions through twice-daily operations runs. However, in nearshore regions, the small-scale interactions between the atmosphere, underlying ocean, and nearby land make it necessary to analyze and predict the battlespace environment at higher resolution. In addition to the global prod-

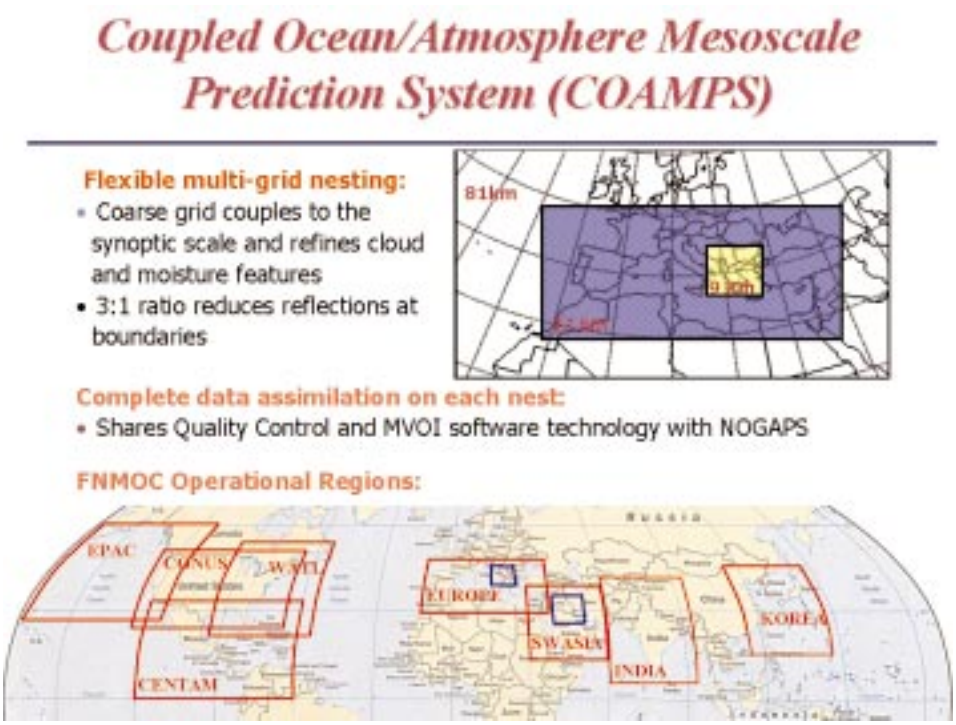

Figure 3-DOD-6. COAMPS is Navy's air-ocean coupled mesoscale model.

uct suite, FLENUMMETOCCEN is uniquely capable of providing high resolution, METOC products on short notice for any location in support of global contingency military and humanitarian operations. Navy's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) is an operational model featuring nested, non-hydrostatic physics, explicit moisture physics, aerosols, and improved data assimilation. Using NOGAPS lateral boundary conditions, COAMPS provides a high-resolution, re-locatable, meteorological and oceanographic prediction capability to support joint littoral operations. COAMPS is routinely run for Europe, Southwest Asia, Korea, Central America, Western Atlantic, and the Eastern Pacific (Figure 3-DOD-6).

NOGAPS and COAMPS forecast products are distributed via various communications systems either directly to Fleet customers or through the Navy regional METOC centers. The regional METOC centers develop value-added products and services tailored to specific operational requirements. Over the next two years, COMNAVMETOCCOM will install computer systems at the regional centers to run COAMPS in-theater, allowing them to respond to Fleet commanders' requirements in near real-time. As a complement to numerical forecast products, FLENUMMETOCCEN provides atmospheric and oceanographic observations, data extracts, and data for tactical decision aids. Additionally, FLENUMMETOCCEN is the designated National Center of Excellence for remotely sensed microwave products under the Air Force/Navy/NOAA Shared Satellite Processing Agreement. The FLENUMMETOCCEN web site is *www.fnmoc.navy.mil*.

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in meteorology is closely linked with oceanography, the focus of the Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, Mississippi. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is the National Center of Excellence for satellite-derived sea-surface temperature measurements providing the global sea surface temperature data critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO is a DOD Major Shared Resource Center, enabling creation of the latest research and development models on the most modern scaleable supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site is *www.navoceano.navy.mil*.

Tailored Theater and Regional Support

Theater and regional support are provided to forces ashore and afloat through six regional centers delivering METOC services within their broad areas of responsibility (AORs). Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs), these centers tailor services to theater requirements, and manage and prioritize dissemination of numerical products from FLENUMMETOCCEN and NAVOCEANO. Special products needed to meet requirements of Joint Force Commanders are also generated by the regional centers. Additionally, the Joint Typhoon Warning Center (JTWC) (operated by Navy and Air Force) is co-located with the Naval Pacific Meteorology and Oceanography Center in Pearl Harbor, Hawaii.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy (through NAVICECEN), NOAA, and the United States Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides 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.

Local and Aviation Support

NAVMETOCCOM Facilities at Whidbey Island, Washington, Naples, Italy, and at Jacksonville and Pensacola, Florida, provide aviation forecast services as well as Fleet Operating Area (OPAREA) and local forecasts and warnings for aircraft, ships, submarines and naval bases and staffs. Additionally, there are 31 NAVMETOCCOM detachments worldwide. Though primarily situated at Naval Air Stations for aviation safety of flight forecasting, several are located at Naval Stations in support of sea-going units (Figure 3-DOD-7). The detachments provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments and facilities within the continental United States use numerical products from both FLENUMMETOCCEN and NOAA's National Centers for Environmental Prediction (NCEP). Overseas detachments and facilities use FLENUMMETOCCEN numerical products, in addition to USAF and foreign products.

Two detachments provide specific technical services. The first is located at the National Climatic Data Center, Asheville, North Carolina, and coordinates the Navy's climatological program as part of the Federal Climate Complex. The second detachment, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF Automated Weather Network (AWN).

On-Scene Support

The Navy's permanent afloat METOC assets are their OA Divisions, embarked aboard aircraft carriers, major amphibious ships and command ships. The OA division's primary objectives are safety of ships and aircraft, optimum tactical support to embarked warfare commanders, and tailored on-scene products and services for the assigned task force/group and Allied units in joint, combined, or coalition military and humanitarian operations.

Figure 3-DOD-7. Navy's rescue mission requires flexible MTEOC support.

The primary source of on-scene Navy METOC support for other forces afloat and those deployed ashore are deployable Mobile Environmental Teams (METs). These teams provide short-term, on-scene services to DOD activities without organic METOC personnel, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. METOC products and services provided by these teams are tailored to each units' requirements and include tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning.

UNITED STATES MARINE CORPS (USMC).

On-Scene meteorological and oceanographic forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, USMC (Code ASL37) 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 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 bare-based or expeditionary airfield by deploying the Meteorological Mobile Facility (METMF). Additionally, Meteorological Support Teams (MSTs) from the ACE MWSS can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF.

MAJOR METOC SYSTEMS

The capability to provide near real-time global, regional, and local METOC services to the Navy and Marine Corps team requires a robust and evolving set of leading edge technology tools. Theses tools are embodied in the following systems:

Primary Oceanographic Prediction System (POPS). The Primary Oceanographic Prediction System (POPS) produces complex computer-based models of the world's ocean and atmosphere. The system provides METOC forecasts, charts, imagery and operational data sets to support deployed Navy forces worldwide. This data is essential to the safety and effectiveness of the Navy's operational platforms, sensors, and weapons including cruise and ballistic missiles, ships, aircraft, radar and sonar. POPS prediction models must provide horizontal resolutions of 1-5 kilometers and in near real time for use in on-scene tactical decision aids and systems.

POPS is the DOD-approved system that performs global and regional environmental modeling. The POPS, located at Fleet Numerical Meteorology and Oceanography Center (FLENUMMETOCCEN), provides the computing capability required to support DOD's only global atmospheric forecast model under an agreement between the Navy and Air Force. Under an umbrella memorandum of agreement signed in 1993 between NOAA and FLENUMMETOCCEN, both sides will provide cooperative efforts in operational numerical modeling, data exchange, and mutual backup between NCEP and FLENUMMETOCCEN. In 1999, FLENUMMETOCCEN provided numerical modeling backup capability to NCEP for two Atlantic hurricanes and for a five month duration after the NCEP computer-fire outage in October.

POPS is migrating from the Cray C90 architecture to SGI Origin 2000 and Scalable Node architecture three phases during FY 1999-FY 2001. By the end of Phase 3 (FY 2001), POPS will have replacement hardware and software that forms the basis of METOC support throughout DOD. This new capability will include state-of-the-art decoders, data managers, quality control algorithms, and observational assimilating software for all types of METOC data from all available sensors. These data will support state-of-the-art numerical weather, ocean, chemical/biological, and acoustic models, run in multiple nested fashion from global scale models at resolutions of tens of kilometers to battlegroup/battlefield models at resolutions of a few kilometers.

In order to support and sustain military operations around the world, the POPS system performance objective for Phase I is a sustained computational throughput of 100 billion floating point operations per second (100 GFLOPS) on METOC models. This objective will enable operation of state-of-the-art weather and ocean models at resolutions necessary to meet DOD requirements well into the next decade. The POPS system performance improvement objectives will support DOD in the following specific ways:

- Optimal aircraft routing services
- Safe and direct ship routing services
- Hurricane, cyclone, and tropical storm prediction worldwide
- Open ocean and coastal wave prediction
- Precipitation prediction
- Refractivity conditions/ducting range
- Acoustics support
- Ballistic missile targeting support
- Search and rescue
- Low level chemical/biological/nuclear transport prediction

Distributed Atmospheric Modeling Prediction System (DAMPS)

For centuries, military commanders have looked to the weather for tactical advantage. The Navy operates a distributed model in support of tactical weather prediction. DAMPS allows users to ingest high-resolution data and on-scene observations into regional and global model information received from the Fleet Numerical Meteorology and Oceanography Center in Monterey, California. The result is an on-scene weather model that provides accurate weather predictions for an operating area within a 24-hour timeframe.

DAMPS has performed well in initial operations at Naval Meteorology and Oceanography (METOC) centers in Bahrain and San Diego.

During FY 2001, the system will be fielded at other Navy METOC centers worldwide; a later goal is to install the systems on board the oceanography divisions of Navy ships. The system will be integrated with the Naval Integrated Tactical Environmental Subsystem (NITES), a versatile local data fusion center and forecasting system being developed by the METOC Systems Program Office (PMW 185) of Space and Naval Warfare Systems Command in San Diego. Afloat, DAMPS will be able to use real-time weather data from ship and battle group observations, including parameters such as wind, temperature, cloud, visibility, and radar data, and then incorporate this data into its analysis. This analysis can be highly focused on any area of interest. Coupled with NITES, the system will be able to disseminate products and tactical decision making aids back to the military user.

Tactical Environmental Support System (TESS). The Navy is presently undergoing migration towards a modular, interoperable suite of systems to ingest, process, fuse, display, and disseminate METOC data. The program consists of five seamless versions known as the Naval Integrated Tactical Environmental Subsystem (NITES) versions I-V. NITES systems will be fielded in FY 2000 through FY 2004. The five NITES versions are:

- NITES I. Provides Navy decision-makers on major combatant ships with METOC assessments and forecasts, and integrates data with sensor and weapon platform parameters for system performance assessments. Theater METOC Centers use NITES I to provide value-added products to fleet units, and the numerical prediction guidance generated by FLENUMMETOCCEN.
- NITES II. Makes METOC data and products available to Navy and Marine Corps activities afloat and ashore via the Global Command and Control System-Maritime (GCCS-M). TESS data and products are used to feed tactical decision aids resident within GCCS-M. NITES II is the basis for the Joint METOC Segment of the new Global Command and Control System (GCCS) V3.0.

- NITES III. An unclassified forecast, briefing, and display system tailored to Naval METOC shore activities in support of aviation operations.
- NITES IV. A portable system tailored to Mobile Environmental Team METOC requirements. Fielding of NITES IV is expected to commence in FY 2004.
- NITES V. A forecast, briefing, and display system for foreign military sales to ensure interoperability with our allies. It is a follow-on to the Allied Environmental Support System (AESS) and will incorporate capabilities used in the other NITES variants.

Meteorological Data Receiver-Recorder (AN/SMQ-11 and AN/FMQ-17). The principal Navy system to acquire environmental data directly from satellites. There are different equipment configurations for ships (AN/SMQ-11) and shore sites (AN/FMQ-17), and through their interface with TESS variants they provide remotely sensed information to the operator.

Automated Surface Observing System (ASOS). ASOS supports aviation and local area observing requirements at Navy and Marine Corps stations worldwide, leveraging development efforts of the National Weather Service (NWS). ASOS helps assimilate field meteorological parameters and facilitates efficient entry of surface aviation observations and synoptic weather reports into the Automated Weather Network (AWN).

Supplemental Weather Radars. The Navy has procured Supplemental Weather Radars to provide doppler weather radar coverage at selected Navy and USMC sites, mostly overseas, outside of NEXRAD coverage. This system replaced the obsolete AN/FPS-106 weather radars.

Meteorological Mobile Facility Replacement (METMF(R)). The METMF(R) is a transportable system that houses meteorological support equipment for the Marine Air Ground Task Force (MAGTF). This 8 x 8 x 20 foot van provides a fully functioning weather office designed to support Marine Corps expeditionary airfield operations for 30 days without resupply. It includes sub-systems for data collection (local, remote and upper air sensors), data processing, satellite data ingest and display, Doppler radar, communications, briefing support, and support for remote forces. The METMF(R) is interoperable with the Marine Corps C^4I systems and METOC systems of the other Services via the Global Command and Control System (GCCS).

Operational Products and Services

Optimum Track Ship Routing (OTSR), and Optimum Path Aircraft Routing System (OPARS) are advisory services for fleet units. They are based on NOGAPS and COAMPS data, tailored to the customer, and provide guidance to the forecaster for the safe operation and cost-effective routing of DOD ships and aircraft, as they have for nearly 30 years. OTSR and OPARS save the warfighter approximately $57 million/year in reduced fuel consumption.

The Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package developed in 1982 to make FLENUMMETOCCEN numerical products available to front line DOD users. All standard meteorological and oceanographic fields, synoptic observations and basic DMSP satellite imagery is also available. NODDS is available to non-DOD Federal agencies and others in the civilian community through an agreement between Navy and NOAA.

The Joint METOC Viewer (JMV) is a new capability that is integrated into NITES and will eventually replace NODDS. Building on the availability of the Internet and the successful user interface of NODDS, JMV provides an intuitive Graphical User Interface for retrieving, viewing and annotating METOC information. Authorized DOD and Government users with Internet access now have a simple, cost-efficient way to display weather and ocean information on various computer platforms and operating systems. JMV is operational at several hundred DOD sites, including ships.

Since 1983, the Naval Regional Meteorology and Oceanography Center, in Norfolk, Virginia, has provided long range forecasts in support of Energy Conservation efforts at Naval shore installations in the continental United States. The services are primarily in the form of extended-range (10 day) temperature forecasts provided to energy managers to assist in optimizing power plant operations. Monthly temperature/degree day outlooks and long-lead (12 month) seasonal and precipitation forecasts are also issued to assist in strategic planning of fuel purchasing and resource allocation. Documented savings from the Energy Conservation Forecast Program exceed $62 million, with the majority of savings resulting from power plant steam/air conditioning on/off recommendations and energy resource/fuel allocation based on long-lead forecast products. Customers include 128 Navy and Marine Corps facilities and commands.

SUPPORTING RESEARCH

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

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 operational meteorological and oceanographic models is key to a successful numerical prediction program. This ongoing process includes work at universities and the Naval Research Laboratory's Marine Meteorological Division to keep the Navy Operational Global Atmospheric Prediction System (NOGAPS) and the Coupled Oceanographic and Atmospheric Mesoscale Prediction System (COAMPS) at the leading edge of technology. Development is also underway to improve data assimilation, quality control, and management techniques to support these models. A major numerical weather prediction thrust is underway to develop a shipboard tactical atmospheric forecast capability to assimilate locally acquired data in real time and deliver high resolution (5 km), limited area (100s of km), short range (12-24 hour) atmospheric predictions in tactical timeframes.

The Navy R&D program in remote sensing develops techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are exploited to the greatest extent possible and plans are in place to incorporate new capabilities when introduced. Because many satellite processing algorithms are designed for use with tactical systems, expert or rule-based processes are used where possible to reduce human-intensive interpretation.

ONR and SPAWARSYSCOM continue to explore techniques for assimilating environmental data through non-traditional sensors. One such effort is investigating the AEGIS Weapon System's AN/SPY-1 radar and developing the ability to produce NEXRAD-like radar information from ships at sea.

Interagency Cooperation

Navy and Air Force have long been cooperating in DOD weather support, and these efforts have led to such successes as the Defense Meteorological Satellite Program and the Joint Typhoon Warning Center. Recently, the two services have reinvigorated efforts to increase efficiencies in their METOC programs through greater cooperation. The NAVAF-21 Charter, signed in June 1999 by the Oceanographer of the Navy and the Air Force Director of Weather, expands on the 1992 NAVAF Agreement for long-term cooperation in DOD operational METOC efforts. NAVAF-21 implements mechanisms to formalize information exchange and cooperation, focus limited resources and prioritize issues to most efficiently meet long-term DOD METOC requirements, and establish an enduring methodology for documenting and periodically reviewing decisions on areas of mutual interest.

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 identify new areas of cooperation and review existing agreements for conversion into annexes to this MOA. Specific areas include:

- Cooperative efforts in operational numerical modeling, data exchange, and mutual backup between FLENUMMETOCCEN and the National Centers for Environmental Prediction (NCEP).
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- Air Force Weather Agency (AFWA)/Navy/NOAA agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement and installation.
- Satellite altimetry data processing.

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

Natural Disaster Mitigation

Navy METOC plays a vital role in reducing the impact of natural disasters to units both ashore and afloat. Severe weather warnings are issued at Naval facilities by the local NAVMETOCCOM activity when conditions warrant. For ships operating at sea without METOC personnel embarked, tailored en route weather forecast messages (WEAX) and high winds and seas warnings provide commanding officers with advance notice of heavy weather, and Optimum Track Ship Routing (OTSR) forecasters monitor ship movements and provide heavy weather avoidance recommendations.

Tropical cyclones and even severe winter storms provide even greater challenges, as ships cannot generally "ride out" storms in-port without sustaining damage (Figure 3-DOD-8). Similarly, once they get underway (or "sortie") ships must steer well clear of the highest winds and seas, to avoid personnel injuries and damage and ensure their stability limits are not exceeded. Even storms of little consequence to the general public--those that remain well out at sea--are still of

Figure 3-DOD-8. USS John F. Kennedy (CV-67) encounters heavy seas as it heads into Hurricane Floyd on a rescue mission.

great concern to the Navy. Because of the need to sortie ahead of tropical cyclones, the Navy must make decisions 3 to 5 days in advance of potentially dangerous weather. Sortie decisions are extraordinarily difficult to make because of their high cost and impact on personnel and operations. In making these decisions, Fleet commanders must strike a balance between the risk of staying in port versus the cost and potential for damage at sea.

Forecasts are provided to the fleet commanders and their staffs by the nearest NAVMETOCCOM activity. Within CONUS, the forecasts are closely coordinated with the National Weather Service. Overseas, local warnings and forecasts are based on guidance provided by the Joint Typhoon Warning Center, Pearl Harbor, Hawaii.

ARMY OPERATIONAL SUPPORT

OVERVIEW OF OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

United States Army weather support is a mix of Army and United States Air Force (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) within the Army 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 (Figure 3-DOD-9). 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 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 Combat Weather Teams (CWTs). 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 Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and United States Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is described under Army Test and Evaluation Command. SMDC provides weather support to Kwajalein Missile Range (KMR)

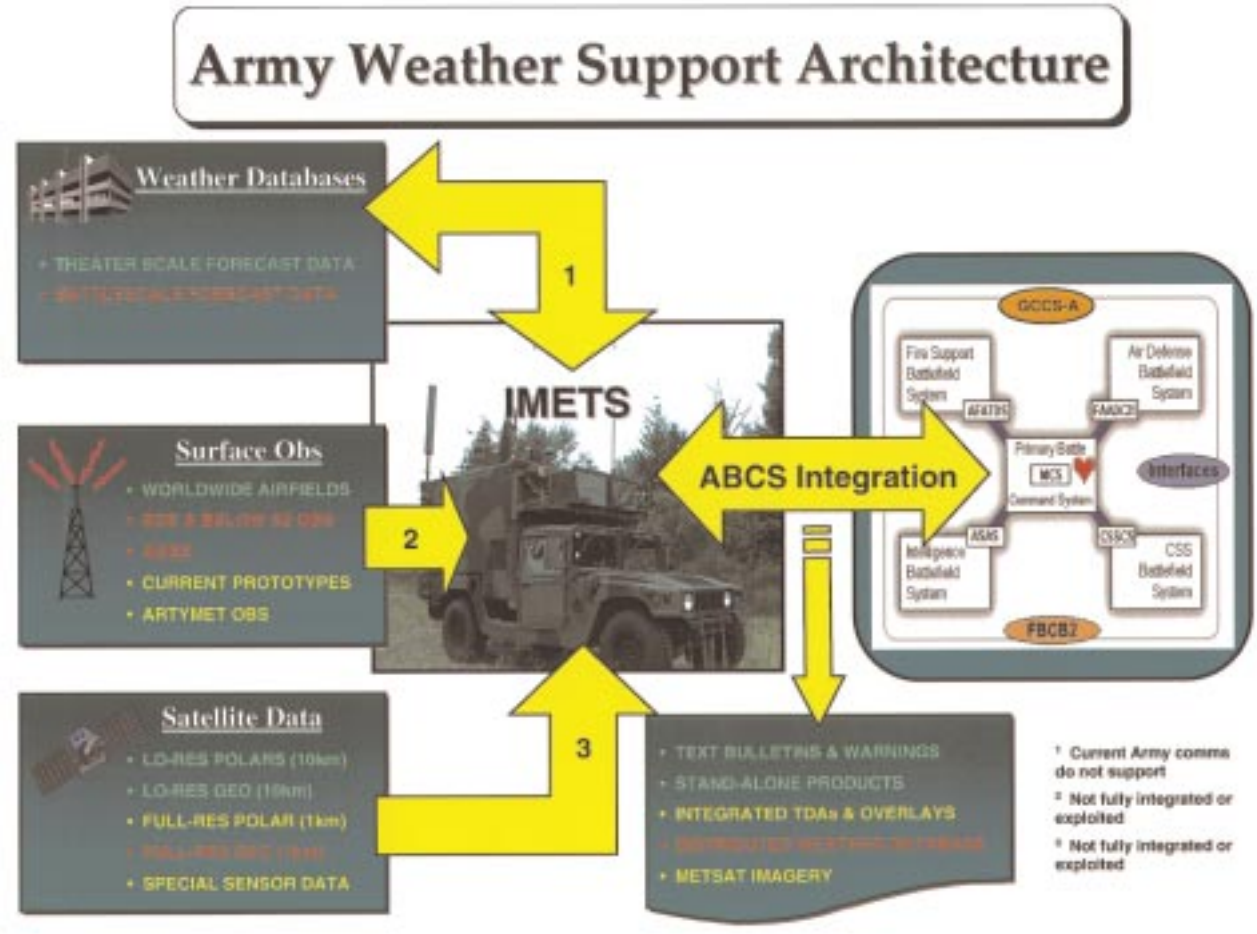

Figure 3-DOD-9. Army Weather Support Architecture.

through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF CWTs for tactical operations. The Integrated Meteorological System (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. Previously issued Block I IMETS have been upgraded to ensure Y2K compliance. Block II IMETS currently being issued are Y2K compliant. IMETS fielding continues in FY 2001.

ARTYMET crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET crews also take limited surface 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 CWTs, 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 the Army National Guard (ARNG) and will be used as long as 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 in the forward combat areas take these observations.

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 and an Intelligence Officer assigned to the Air Force Weather Agency at Offutt AFB, Nebraska.

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 weather 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 supported by Army ARTYMET teams, AF CWTs provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation 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 regiments 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 (Figure DOD-10). Tactically, the Army is responsible for vehicles,

Figure 3-DOD-10. Automated observing equipment deployed to Kosovo.

tactical communications, and weather effects criteria. The Army IMETS is fielded for these purposes and is operated by AF CWTs. 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 CWTs through an Army Table of Organizations and Equipment (TOE).

United States Army Space and Missile Defense Command (USASMDC)

The Space and Missile Defense Battle Laboratory (SMDBL), a component of USASMDC, conducts experimentation, testing, and integration activities for the purpose of providing space based weather products to Army and joint command and control system users. In 1999, SMDBL deployed one Deployable Weather Satellite Workstation (DWSW) and one operator/trainer in support of the V Corps Staff Weather Officer at Task Force Hawk, Tirane, Albania. The DWSW provided direct downlink of the Meteosat 7 imagery every 30-minutes into the SWO shelter. Imagery was then applied to the Army aviation mission as well as force and asset protection.

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 systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HELSTF activities by providing atmospheric propagation and meteorological measurements, planning, and analysis as required. These capabilities also support the safe storage, handling, and use of the toxic laser fuels.

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) uses a network of about 8,810 land-based gauges. About 55 percent of the sites collect meteorological data, 35 percent a combination of hydrologic and meteorological data, and 10 percent hydrologic or water quality data. The Corps funds or partially funds 61 percent (4,500) of all the gauges it used. Meteorological gauges commonly measure precipitation and temperature. All data is used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 600 of meteorological 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. Eight-two percent of all Corps sites provide real-time data via satellite microwave meterbursts, landlines, or radio. Data from all COE networks are available and used by other federal, state and local agencies.

Eighth United States 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 the Second Infantry Division use AN/TMQ-41 Meteorological Measuring Sets 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 AF weather teams supporting Army air, ground, or special operations. These observations will be used by forecasters at the 607th Weather Squadron (607 WS) Theater Forecast Unit (TFU) to accurately predict mission limiting weather in the DMZ.

The USAF is planning on the purchase of automated COTS observing systems for eight locations in the area of the DMZ. Observations from these systems will be transmitted via phone lines to pilots, as well as to forecasters back in the 607WS TFU. They will also be incorporated into the global weather database to improve short term forecasting in the northern ROK.

Army Operational Support Provided

by USAF

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, 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. In FY 2000, the 607 WS reengineered weather support in theater and the 607 WS TFU took over forecasting responsibilities for the eight EUSA locations. The EUSA Cadre Weather Teams will now be primarily responsible for providing their customers with observations and tailored support (Figure 3-DOD-11). 607 WS provides 97 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

Figure 3-DOD-11. Army CH-47 Transport helicopter.

(TRADOC) Programs

HQ TRADOC is responsible for development and management of training programs, writing Army and Joint weather support doctrine (concepts and field manuals), and establishing 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.

Key mission area for the next few years will be to coordinate Army weather support requirements during Air Force Weather Reengineering and Army Task Force XXI Advance Army Warfighting Experiments (AWEs). Deployed weather support will improve significantly with the digitization of these experimental Army units. Customized battlefield weather "visualizations" transmitted via the IMETS will take the place of the stand-up weather briefings of the past. The results of the AWEs will show new tactics, techniques, and procedures for the exploitation of weather during military operations. Identified software enhancements will transition to the appropriate materiel developer for further integration. Finally, these experiments provide an opportunity to educate Army leaders and their staffs on the effects of weather on the battlefields of the future.

The Schools and Battle Laboratories

The United States Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the warfighter by developing solutions to satisfy Army weather requirements. In addition, it serves as the proponent for the *"Owning the Weather"* (OTW) program - a concept for exploiting weather as a force multiplier on the battlefield. The key component to OTW is IMETS, which is being fielded by the Army and operated by Air Force Combat Weather Teams.

The USAIC&FH Weather Support Team (WST) advises the USAIC&FH, ARL, and Air Force Weather (AFW) on Army weather support issues and helps develop solutions to meet both active and reserve forces' requirements. In addition, the WST monitors weather support training to Intelligence and AFW personnel supporting the Army (e.g., the Staff Weather Officer Army Indoctrination Course), and establishes requirements documents for weather support equipment.

Over the last year, the WST updated and expanded a large portion of the weather effects critical threshold value database to be incorporated into the Integrated Weather Effects Decision Aid (IWEDA). They also played a key role in the following initiatives: development of a weather module for the Federation of Intelligence, Reconnaissance, Surveillance, and Targeting Operations and Research Models (FIRESTORM); Joint IWEDA program; and Joint Target Acquisition Weather Software (TAWS). The WST participated in the ongoing Army Force XXI and AFW Reengineering process and programs. Finally, they developed and wrote a new Operational Requirements Document (ORD) for IMETS, and developed concepts for weather support into the Tactical Unmanned Aerial Vehicle (TUAV), and Brigade Combat Team.

The Staff Weather Officer at the United States Army Combined Arms Center facilitates modifications to the TOE for Army CWTs, and through the TRADOC System Manager for Army Battle Command System and Battle Command Battle Lab-Leavenworth, provides environmental data for the Command, Control, Communications, Computer and Information (C^4I) network. In addition he works in the White Cells during Army Warfighter Experiments to ensure weather is representative and accounted for in the modeled AO.

The United States Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, is the proponent for upper air meteorological support to the

Army. Artillery meteorological crews, Active and Reserve, currently use the AN/TMQ-50 to measure surface weather parameters, and the AN/TMQ-41 Meteorological Measuring Set (MMS) to take upper air observations. The MMS provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to USAF CWTs for weather forecasting; and to the Chemical Officer for obscurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. We will be working with USAFAS to ensure that these surface and upper air observations are shipped back to weather centrals where they can be ingested in to our newest mesoscale models.

The Engineer School (USAES), Fort Leonard Wood, Missouri, coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments using input weather data fields. Their mission also includes identifying and documenting requirements to interface meteorological and engineer battlefield systems. Due to force cuts, USAES no longer has a full time civilian meteorologist in the Terrain Visualization Center, DCD. (Operating Location B, 3rd Weather Squadron, USAF, provides weather observation services at Forney Army Airfield, Fort Leonard Wood, Missouri. OL-B is included in this report only to the extent that Fort Leonard Wood provides funding for its expendables and overhead.)

The Army Military Police and Chemical Schools now reside at Ft Leonard Wood. Neither currently employ staff meteorologists.

The Aviation Center at Ft Rucker incorporates weather instruction and procedures into rotor-wing training programs in their mission areas. The Center has requirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites.

The weather units at Ft Benning, Ft Knox, and Ft Huachuca provide airfield observing and forecast support to their respective Army posts.

United States Army Special Operations Command (USASOC)

Weather support to USASOC provides for planning, command decision, and mission execution weather forecasts and observations to improve efficiency, effectiveness, and safety of operations for USASOC units. USASOC personnel provide limited meteorological observation services in direct support of Army operations using tactical weather kits to collect limited weather observations in data sparse, permissive and non-permissive environments. Observations are typically collected by Army Special Operations Forces at the team level and are passed to operating bases for use by Army commanders and staff, as well as USAF SOWT personnel. USAF weather personnel supporting USASOC are assigned to the 10 CWS. The 10 CWS provides garrison and tactical weather support to USASOC units including the 75th Ranger Regiment and three subordinate Battalions, the 160th Special Operations Aviation Regiment and three subordinate battalions, and five Special Forces Groups and their subordinate battalions. Weather support encompasses climatological information, mission forecasts, command decision forecasts, aviation forecasts and observations, drop zone forecasts and observations, special reconnaissance, and Foreign Internal Defense/Unconventional Warfare. The 10 CWS also provides staff support to USASOC, the United States Special Forces Command, and the United States Army John F. Kennedy Special Warfare Center and School. USASOC provides supporting USAF units with required tactical vehicles, communications equipment, tactical equipment, and operating funds (for expendables, maintenance, etc.).

USAREUR/7th Army

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

7th Weather Squadron provides USAREUR/7th Army in-garrison and tactical weather intelligence and support. This includes observing services for in-garrison, contingency and exercise operations, staff weather officer (SWO) services as well as special support. The Operational Weather Squadron (OWS) at Sembach AB provides operational-level forecast products for the EUCOM AOR, to include all USAREUR units. Combat weather flights evaluate and tailor these forecast products to produce mission execution forecasts.

The Automated Meteorological Information System (AMIS) is the primary in-garrison weather equipment for receiving graphics and alphanumeric data. Data is received via VSAT and hard-wire circuits. The New Tactical Forecast System (NTFS) is the primary equipment used for deployed locations with data received via NIPRNET and SIPRNET. Units also use the NATO Automated Meteorological Information System (NAMIS) to receive NATO generated weather products. NAMIS software is hosted on a laptop and receives data via VSAT. Satellite imagery (METEOSAT and DMSP) is received via the Small

Tactical Terminal (STT). Five IMETS have been fielded within USAREUR. Two Portable Automated Observing Systems (PASOS) and a Tactical Weather Radar (TWR) are deployed to Task Force Falcon (TFF), Kosovo, with two additional PASOSs scheduled to be deployed in the near future.

USAREUR provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four ARTYMET sections collect upper air observations for direct use by field artillery units. The FALOP consists of Army personnel taking limited observations at forward areas in the battlespace.

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 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 expected to be encountered in all theaters of operations.

Corps of Engineers

The Corps of Engineers (COE) Engineer Research and Development Center (ERDC) performs military engineering and civil works research through its seven laboratories at 4 geographic sites (Champaign, Illinois, Fort Belvoir, Virginia, Hanover, New Hampshire, and Vicksburg, Mississippi). The ERDC manages the Military Engineering research program addressing a wide range of topographic and combat engineering future operational capabilities (FOCs). The ERDC also is responsible for reviewing all emerging Army systems for environmental effects, as stated in AR 70-1. Many of the tactical decision aids (TDAs) developed within the military engineering program interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical values define system limitations and are used by decision-makers to take advantage over opposing forces. Technology advancements are transitioned to terrain and weather systems such as the IMETS, the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS). 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 support includes the development of: (1) environmental effects databases and models that are relevant to military plans, operations and the acquisition communities; (2) 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; and (3) integrated software modules that are designed to be exploited in the synthetic environment arena and 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. The Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, conducts research in sensor signal interaction

Figure 3-DOD-12. CRREL research supports Army's worldwide need for trafficability studies and data.

with snow, ice, and frozen soil, icing accretion on surfaces and structures, deicing technologies, and cold regions surface-air boundary process. CRREL develops databases and models predicting infrared and millimeter wave weapon system performance, and the capability of technology to enhance military operations in cold environments. Other specific programs include weather effects on environmental research for military training lands, helicopter pre-flight deicing and airborne icing avoidance, remote sensing for predicting snow coverage and snow-water equivalence for snow melt runoff, and modeling winter effects for input into Army operational and training models and simulations (Figure 3-DOD-12).

Army Materiel Command

The Army Materiel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for 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.

The ARL Battlefield Environment (BE) Division is the lead DOD agency for research and development 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 Warfighter 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 OTW 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 is basic tactical weather support, the Army provides technology to support such service-unique requirements, and Army systems, as well as distributing this weather intelligence information to the Army Battle Command Systems (ABCS) 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 mission.

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 Sand Missile Range, 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. BE opened an experimental site at Blossom Point, Maryland, in mid-1998, in a complex littoral region on the north shore of the Potomac River, and will conduct field experiments in electro-optic and acoustic propagation, as well as test weather modeling tools.

At the Adelphi Laboratory Center (ALC) in Maryland the two branches are (1) the Atmospheric Acoustics and Electro-Optics (A&EO) Propagation Branch and the (2) the Boundary Layer Meteorology and Aerosol Research Branch (BLM&AR). The A&EO Branch provides basic research in the modeling and simulation of environmental effects on acoustic and electro-optics propagation, and laboratory and field experimental research into environmental effects on acoustic and electro-optic propagation and the mitigation of those effects. The BLM&AR Branch conducts a research program in the micrometeorological processes and structure of the atmospheric boundary layer. This program focuses on the interaction of the land-air interface with wind fields, turbulence, and fluxes and on optical methods of detection of aerosols (primarily chemical-biological agents) and the modeling of their transport and dispersion in the tactical environment.

The Weather Exploitation Branch, Battlefield Environment Division's R&D efforts involve several areas. They address tactical weather data assimilation and distribution, to include exploitation of commercial and military satellite technology to move meteorological data to the battlefield Tactical Operations Centers and between echelons. They generate gridded meteorological databases to support C^4I systems, mission planning and rehearsal, and integrate weather forecast analysis tools to identify the location and timing of hazardous and significant weather at small scales in the boundary layer. They develop rule-based tactical decision aids for impacts of weather on military systems, platforms, and operations. And, they integrate physics based weather effects models and meteorological satellite analysis algorithms with weather data visualization tools for improved mission planning and situation awareness. As part of the tactical weather product development, the branch also performs the following: configuration management and validation of new products; improvements through end-user feedback from Advanced Warfighting Experiments, TRADOC Concept Experimentation Programs, and integration at the Army's Central Technical Support Facility at Ft. Hood; and delivery of software for integration into IMETS. The IMETS integration includes tactical weather overlays, databases of dynamic gridded weather parameters, weather effects decision aids, and weather data visualization tools, all of which can be executed in the field using Common Hardware/Software and Common Operating Environments.

BE develops the weather application software for IMETS that is part of the Army's effort to Digitize the Battlefield and will provide weather capabilities in the Army's First Digitized Division (FDD) in FY 2000 and the First Digitized Corps in FY 2001. From FY 1997 to the present, BE has successfully used the Army's Task Force XXI AWE's to evaluate and improve its delivered IMETS Block I and Block II software. In FY 1999 and FY 2000 the BE/IMETS tactical weather applications were being upgraded and delivered for integration to the other C^4I tactical systems

operating under the Army Battle Command System, version 5.0 (ABCS 5.0) (Figure 3-DOD-13). These IMETS applications incorporate significant changes in the sharing of data between Battlefield Functional Areas by exploiting client/server relationships and the IMETS Gridded Meteorological Database. The weather overlays are converted to use the Joint Mapping Tool Kit (JMTK) software for map overlays. And the initial integration of AF Weather Re-engineering includes passing meteorological data and products from AF central hub sites to the Army battlefield TOC's using WMO data standards such as GRIB and BUFR. The weather impact rules and critical values for the BE-developed IWEDA are being assembled jointly across the services to provide a common rule-base for weather impact decision aids.

The Army Research Office (ARO),

Figure 3-DOD-13. Army's *"Owning the Weather"* initiative will enable combat units to use weather as a force multiplier.

Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamics and kinematics 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 occasional special initiatives. The focus of the research is on the atmospheric 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 processes, 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 the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Other areas of special funding are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (EPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. At the Army Research Office, funding for basic research remains relatively static. Increased funding will come if special program initiatives or requests are approved. The primary focus will be on analysis and understanding of data taken in a recent field study of the stable boundary layer.

The CECOM Intelligence and Electronic Warfare (IEW) Directorate (Dir), Fort Monmouth, New Jersey, assists the CECOM level II manager and other internal organizations in developing and fielding weather support systems; and helps both the Program Manager, Intelligence Fusion and Program Manager, Night Vision/Reconnaissance, Surveillance, and Target Acquisition with technical management of weather programs. Current programs supported are the MMS, the Profiler (MMS-P), and IMETS. A brief description of each of these programs shows IEW Dir's involvement and supplements earlier discussions under the other MACOMs.

Meteorological Measuring Set (MMS), AN/TMQ-41.

The National Guard is being modernized through the purchase 40 MMS's beginning in FY 1999 and continuing through FY 2002. This will be the final Army buy of the MMS. The Intelligence and Information Warfare Directorate (I^2WD) is providing technical support to the system manager (CECOM Logistics and Readiness Center) for this effort. All Active Army units have been fielded. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). The contractor, Environmental Technologies Group (ETG), has previously built 42 systems for the Army and National Guard, 21 systems for the Marines, and 11 systems for Foreign Military Sales (10 for Canada, 1 for Bahrain). An FY 1999 contract bought 16 systems for NG units and 7 for Egypt. These systems were delivered in FY 2000 and fielded in FY 2000 and FY 2001. Additional NG systems are planned for FY 2001 and FY 2002.

Meteorological Measuring Set-Profiler (MMS-P) System

The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. It will provide new capabilities to determine target area MET. The MMS-P will provide the Field Artillery with modernized and enhanced data collection and automated analysis of current weather conditions along the trajectory and in the target area. The system will consist of a suite of sensors and associ-

ated software models, which provide information along the trajectory or at a point where the munition is expected to engage a target. Weather information will be generated by a mesoscale atmospheric software model that will provide updates every 30 minutes. Modeling will be transparent to the operator. Profiler will be a replacement to the MMS. It will interface with Fire Support systems and IMETS. CECOM is providing technical assistance to PM, NV/RSTA on the program. The current plan is to procure four Engineering and Manufacturing Development (EMD) models in FY 2000, with testing and a production decision scheduled for FY 2002.

Integrated Meteorological System AN/TMQ-40B

The IMETS is the weather component of the Intelligence Electronic Warfare (IEW) sub-element of the Army Battle Command System (ABCS). The IMETS provides commanders at all echelons with an automated tactical weather system that receives, processes, and disseminates weather observations, forecasts, battlefield visualization, and weather effects decision aids to all Army Tactical Command and Control System (ATCCS) Battlefield Functional Areas (BFAs). IMETS receives weather information from polar-orbiting civilian and defense meteorological satellites, civilian forecast centers, the Air Force Weather Agency, artillery meteorological sections and remote sensors. IMETS processes and collates forecasts, observations, and climatological data to produce timely and accurate weather products tailored to the specific warfighter's needs. The most significant weather and environmental support to warfighters are the automated tactical decision aids. These graphics display the impact of the weather on current or planned operations for both friendly and enemy forces. The warfighter can thus more effectively employ his forces and weapons systems to achieve success in battle.

FY 2000 and FY 2001 efforts will focus on completing fielding of the AN/TMQ-40B version systems. FY 2000 efforts will also include developing support documentation to achieve a Milestone III decision for the IMETS Light Configuration system currently scheduled for 4th Quarter of FY 2001. The Light Configuration system is one of the three different configurations called for by the Operational Requirements Document (ORD). The ORD is expected to be approved in 3rd Quarter of FY 2000.

Army Test and Evaluation Command

Developmental Test Command (DTC), (formerly under Army Materiel Command), providing operational support to 9 ranges and test sites with MET Teams. Under responsibilities established in Army Regulation 115-10/AF Joint Instruction 15-157, the DTC 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 1999 funding has been level for 4 years following several years of decline, using a combination of both programmed funds and users funding. This enables DTC 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. DTC MET Atmospheric Sciences Team has a 5-year effort with the National Center for Atmospheric Research (NCAR) to greatly improve "range scale" (mesoscale to microscale), forecasting and analysis technology. Using the MM5 model as a base, this Four Dimensional Weather (4DWX) System (Figure 3-DOD-14) will present both real-time and forecast three dimensional pictures of the MET and other atmospheric characterization parameters in, around, and up to 50K ft over the Army's test ranges. The 4DWX system will provide improved test scheduling, more accurate placement of sensors during a test, more

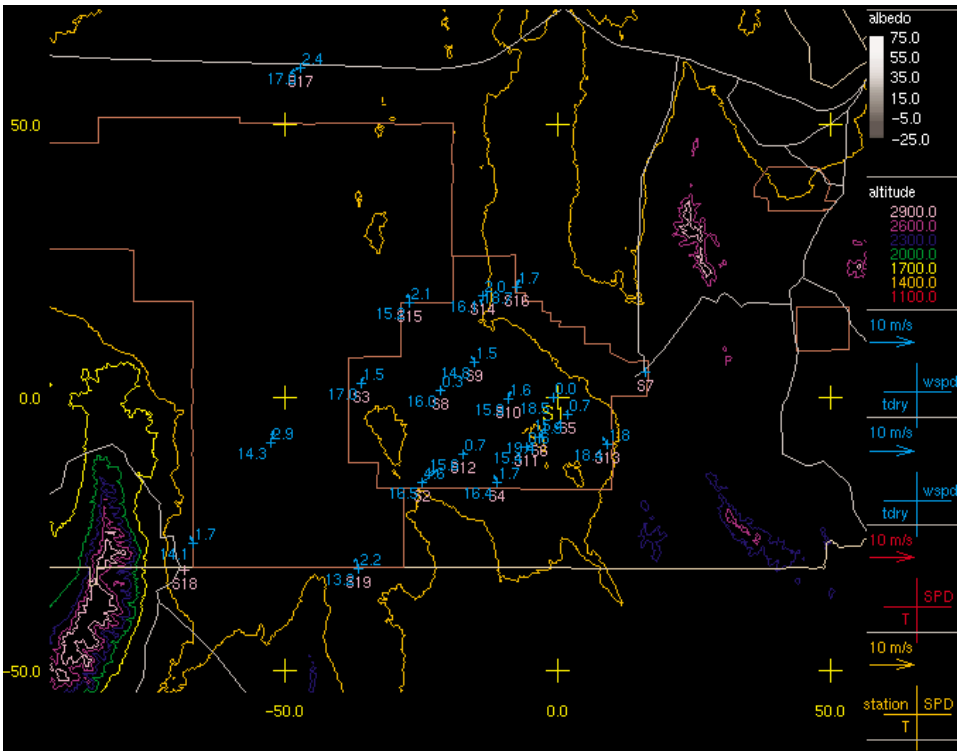

Figure 3-DOD-14. Topographic altitude contour and GOES-Vis Albedo plot from Army's 4 Dimensional Weather System--4DWX.

cost-effective measurements, data sets and algorithms for virtual testing, and instantaneous forensic analysis (instant replay) of the conditions that occurred during the test.

In addition to RDTE support, the Dugway Meteorology and Obscurants Division's Modeling and Assessment Branch provides the following specialized services: (1) atmospheric model verification and validation, to include algorithm evaluation and the generation of validation data sets, (2) chemical/biological threat analysis, detection, and decontamination tests and studies through the Joint Contact Point (Project DO49), 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.

Medical Research and Materiel 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 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 local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM's weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days.

The environmental heat stress monitor (HSM), a pocket-sized electronic device, combines the USARIEM heat strain prediction model with a miniaturized sensor suite to measure air temperature, humidity, wind speed, solar radiation, and barometric pressure. This device provides tailored local guidance on optimal work/rest cycle limits, safe work time, and hourly drinking water needs for a wide range of clothing types and work categories.

The Operational Medicine Environmental Grid Applications (OMEGA- Formerly MERCURY) test bed is an automated heat and cold injury risk assessment system for battle-scale regions (up to 200 X 200 kilometers). It combines digital terrain data and real-time weather information with physiologically-based thermal strain prediction models and displays prevailing risk as color-coded map overlays. This research tool has been operating continuously since June 1996 at USARIEM and the Army Ranger training facilities at Eglin Air Force Base in Florida. OMEGA provides a robust, extensible platform for evaluating thermal strain prediction model performance prior to their transition to operational systems such as IMETS.

As part of the Warfighter Physiological Status Monitoring (WPSM) program at USARIEM, technologies to support access and fusion of real-time local environmental sensor data with individual warfighter physiological sensor data are being investigated. The effective fusion of these two real-time data streams would enable physiological and performance status prediction capability for individual warfighters. A Small Business Innovative Research (SBIR) project to design and build a very small wireless network-capable, expendable, micro-environmental sensing system has been initiated and the feasibility of on-body environmental sensors is also being investigated.