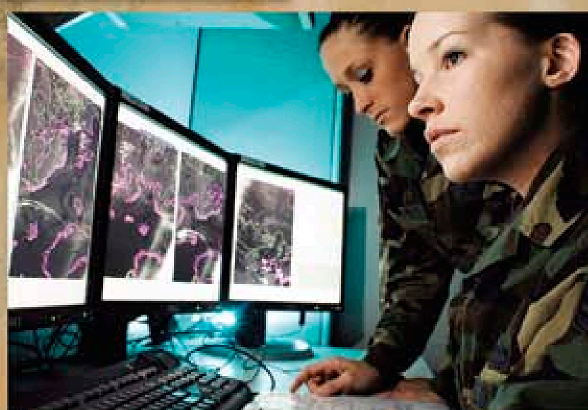
ENVIROCAST®
Raising the Environmental IQ of America
Volume 4, Issue 1 January 2009



NPOESS: Delivering the Decisive Military Edge

A StormCenter Communications, Inc. Publication

NPOESS: Delivering the Decisive Military Edge

Dave Jones
Craig Nelson
Brian Baldauf

Weather Changes Battles

Weather has always felt like a military liability, like a roll of the dice forced on top of a careful planning process. Capricious and unpredictable, weather is often a decisive battle factor.

On August 20, 636 AD, at the Battle of Yamuk River (near the Golan Heights in southern Syria) a small Arab Islamic army challenged the might of the Byzantine Empire. As the two armies formed in tight lines for battle, gale force winds suddenly whipped up, driving clouds of sand and dust into the faces of the Byzantine soldiers. Temporarily blinded, the Byzantine commanders never saw the Arabs attack (with the wind at their backs) until it was too late to use the standard Byzantine counter-attack tactics. The Byzantine army collapsed and fled the field—in large part because an unexpected wind blew the wrong way.

Twice Mongol ruler Kublai Khan tried to invade Japan (1274 and 1281), the second time with the greatest invasion force ever assembled: 4,400 ships and 140,000 men. Both invasions were stopped, not by Japanese forces, but by typhoons that roared in to literally crush the invading forces. The Japanese named that typhoon storm and its saving winds "kamikaze" meaning "divine wind." For eight centuries the term has commemorated weather's control over military campaigns.

The Battle of Britain (August-September, 1940) was almost lost because of abnormally good weather. Beginning on August 26th, England enjoyed two solid weeks of unprecedented clear weather. It allowed German bombers to target and pound English airfields and plane factories. The Royal Air Force (RAF) lost 315 planes fending off the Germans and was pushed to the breaking point until clouds fortunately rolled in on September 8th to protect these valuable military targets. Germany was forced to change its strategy and concentrated its air attack on London, a target so big it could easily be hit even on cloudy nights. Britain survived because, in part, of that cloud cover.

General Dwight D. Eisenhower clearly recognized the importance of weather in battle planning. In the days and hours leading up to D-Day, his "go" or "no-go" decision depended heavily on a critical "weather window" that would permit the coordinated amphibious and airborne invasion. In one of their most important roles ever, Allied weather forecasters predicted that the weather would clear sufficiently on June 6, 1944. However, the German meteorological services were unaware of this temporary break in the weather. Due to predicted bad weather, the German Navy canceled its usual patrol of the English Channel and on the eve of the attack many of the top German officers were absent from their commands along the Normandy coast. Eisenhower gave the order for D-Day and set in motion the largest amphibious invasion in world history. In his memoirs, General Eisenhower noted, "In Europe bad weather is the worst enemy of the air [operations] …. Bad weather is … the enemy of the side that seeks to launch [attacks] that require good weather, or of the side possessing greater assets such as strong air forces, which depend on good weather for effective operations."

Bad weather almost spelled success for North Vietnamese forces in 1968. Beginning on January 30th of that year, the battle for the city of Hue hung as an all-important turning point in the crucial Tet Offensive in Vietnam. For the first four days of that vicious street-to-street fighting, the weather was so bad it prevented all close air support. The outcome of the entire offensive seemed to hang in the balance as American air forces waited for improved weather. The outnumbered allied army slowly gave way until the weather finally cleared and American air and naval might turned the tide.

When the ground war in Iraq commenced on March 20, 2003, the Third Infantry Division began its furious race through the desert toward Baghdad. As a front swept eastward across the Mediterranean, forecasters warned to prepare for "the mother of all fronts."

AL ASAD, Iraq (April 28, 2005) – A massive sand storm cloud is close to enveloping a military camp as it rolls over Al Asad, Iraq, just before nightfall April 27, 2005. Sandstorms like this develop when cold fronts move through the very dry region to create zero visibility conditions and can cause damage to vehicles as well as respiratory problems to those caught out in the storm. DoD photo by Cpl. Alicia M. Garcia, U.S. Marine Corps.

The largest sandstorm to hit southern Iraq in decades engulfed a 300-mile-wide area and blasted tremendous walls of dust into the atmosphere. Meanwhile, the Saddam Fedayeen (Saddam's "Men of Sacrifice") used the cover of the blinding storm to attack the stalled Army convoys.

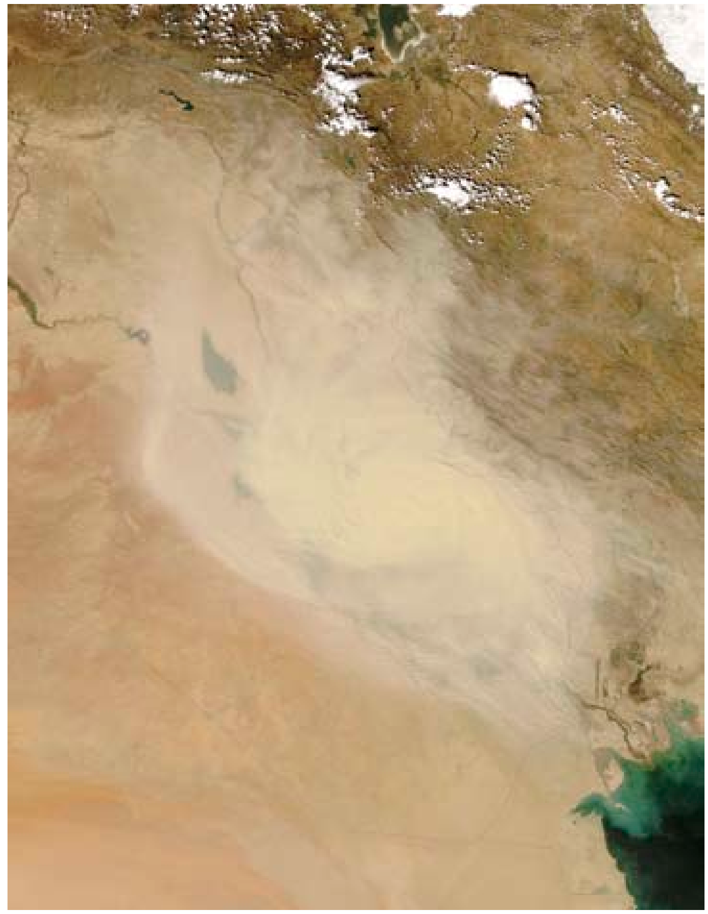
The same frontal system that blinded troops in southern Iraq created a different set of weather challenges for operations in northern Iraq. Sleet, snow, and heavy cloud cover over Bashur Airfield jeopardized a large and daring combat jump.

A New Attitude towards Weather

Weather has always played a fateful—and often decisive—role in military campaigns. It affects every mission from a mechanized ground patrol, to an air drop of humanitarian aid, to a carrier launch, to a bomb run. Its unpredictability has meant that weather has yet to be treated as a significant factor for contingency planning. Weather has all too often been viewed as something normally external to the planning process—as a fickle wild card at best, and a major impediment to overcome at worst.

But that attitude is rapidly changing. In 2003, Peter B. Teets, Undersecretary of the Air Force, testified that, "the nation's unparalleled ability to exploit weather and environmental data gathered from space is critical to the success of military operations." With improvements in weather and environmental awareness, the U.S. military is rapidly shifting its tactical and strategic focus from "coping with weather" to anticipating and exploiting weather and environmental conditions for military advantage.

According to Brigadier General David L. Johnson, USAF (Retired), the Air Force Director of Weather from 2000 to 2003, input from combat weather teams is a vital part of the mission planning process. "In the first three months of [the war on terrorism]," Johnson said, "15% of the targets... and 30% of the weapons were changed as a result of what the weatherman said."



The Visible/Infrared Imager Radiometer Suite (VIIRS) on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) will capture rapidly developing sandstorms for immediate delivery to our troops through its direct broadcast capability. This image was captured by the Moderate Resolution Imaging Spectroradiometer (MODIS), a precursor instrument to VIIRS, on board the National Aeronautics and Space Administration's (NASA) Aqua satellite on September 19, 2008 and shows a massive sandstorm moving across Iraq.

That shift in thinking has led to a rapidly increasing demand for weather and environmental information. As U.S. and British Special Forces set out for the fog-enshrouded Iraqi coastline by air and sea in March 2003, the U.S. Army's Third Infantry Division's Combat Weather Team (CWT) assembled at the northern Kuwaiti border with Iraq. They were tasked to produce weather analyses for mission-specific locations and to provide a near-continuous stream of weather intelligence from inside Iraq. In 2003, weather support for combat missions still required on-site ground observers to risk their lives to gather key weather and environmental information. That requirement is changing.

In recent years, military weather support has transformed to a complementary blend of in situ and remotely-sensed measurements with greater reliance on space-based Earth observing systems that can provide critical weather and environmental information while minimizing risk to ground troops. Satellites provide an unprecedented and unique source of information for military operations. Polar-orbiting and geostationary satellites both play an important role, particularly in combat situations.

Since the early 1960's, the U.S. military has relied on imagery from the constellation of the Department of Defense's (DoD) polar-orbiting Defense Meteorological Satellite Program (DMSP) spacecraft to support reconnaissance, planning, and operations. Even in the early days of low resolution television cameras, weather images collected by DMSP spacecraft successfully supported tactical operations in Southeast Asia. For example, during November 1966 the tactical use of DMSP data aided 877 (air) mission forecasts; 852 of those forecasts were later verified to be correct.

Technological improvements introduced during the 1970's and 1980's led to new sensors on DMSP spacecraft to improve image resolution and to provide additional types of data on weather and on the space environment. Sensors on the current series of DMSP spacecraft provide data for a variety of meteorological products including cloud types and amount, cloud height/base, lightning, sea ice, sea surface wind speed, and surface temperature. The U.S. military also depends on imagery and data from the Polar-orbiting Operational Environmental Satellites (POES) and Geostationary Operational Environmental Satellites (GOES) operated by the National Oceanic and Atmospheric Administration (NOAA) and research satellites operated by the National Aeronautics and Space Administration (NASA) to support tactical operations worldwide.

In the second decade of the 21st century, new weather and environmental satellite systems will have higher spatial and temporal resolution for improved support of military operations. From support of ground troops to weapons deployment and the need to make rapid tactical decisions, Earth observation data are becoming invaluable to our Nation's global military mission. The foundation of this future support will come from the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

NPOESS: The Essential Next Step

This expanding tactical and strategic demand for weather, climate, and environmental data to support U.S. global military operations has outpaced the capacity of existing data sources. The essential next step to meeting these growing informational demands is NPOESS.

The tri-agency Integrated Program Office (IPO), comprised of the Department of Commerce's (DOC) NOAA, DoD, and NASA, is managing the development of NPOESS. NPOESS will replace heritage POES and DMSP polar-orbiting operational weather satellites that have provided successful service to the Nation for over 45 years. Northrop Grumman Space Technology (NGST) is the prime contractor responsible to the IPO for overall NPOESS system design and development, system engineering and integration, instrument acquisition, spacecraft assembly, testing, worldwide operations, and support.

NPOESS will improve environmental forecasts for combat mission planning and operations by collecting higher fidelity surface and atmospheric environmental data and by relaying it to the NPOESS DoD and NOAA "Weather Centrals" four to five times faster than the current generation of operational Earth observing satellites.

From near-Earth space weather monitoring (to provide situational awareness of potential disruptions to space-based assets such as satellites supporting military operations) to soil moisture (to identify impediments to surface force movements), NPOESS will provide imagery and soundings with far higher temporal, spatial, and spectral resolution than heritage systems, providing them all from the same platform at the same time. The result will be significantly improved inputs to numerical weather prediction (NWP) and climate models and improved short, medium, and long-range forecasts. Atmospheric sounding data (i.e., atmospheric vertical temperature and moisture profiles) from POES and DMSP currently comprise more than 90% of all the data assimilated into global NWP models run at the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) and at NOAA's National Centers for Environmental Prediction (NCEP). The advanced atmospheric sounders on NPOESS will lead to significant improvements in NWP products in the next decade that are key to providing critical environmental information for mission planning.

A New Definition of System Speed

A key NPOESS attribute is the system's ability to dramatically increase the speed of delivery for all needed environmental data. There are two measures by which "speed" will be improved. First, the high spatial, temporal, and spectral resolution of the instruments on NPOESS would be wasted if the data were not coupled with an equally fast delivery system. The NPOESS SafetyNet® data relay network and the NPOESS ground processing system will improve delivery of processed data to users by a factor of four to five compared to the heritage DMSP and POES systems. Current tests of the prototype system are demonstrating that nearly 80% of the processed global NPOESS data will be available to users within 15 minutes and 95% of the data will be available within 24 minutes. Rapid ingest of new data into NWP models will also facilitate improved nowcasts and forecasts. See Envirocast® Vol 3. Issue 1, March 2008 for an in-depth look into the NPOESS Ground System (http://stormcenter.com/stormcenter/article/BlazingSpeed.pdf).

NPOESS data will also be broadcast in real-time directly to combat units in the field or to carrier battle groups equipped with field terminals. Weather warriors attached to these units will receive NPOESS imagery and data for their area of interest as the satellite passes in range overhead. As technology improves, "net-centric" solutions may allow deployed units to be tied electronically into a larger infrastructure.

But there is a second measure of NPOESS system speed. The military value of weather data is directly linked to timely delivery of "fresh" and accurate products to mission planners and battlefield commanders. NPOESS spacecraft will occupy two high-inclination, polar orbits: an afternoon orbit with a 1330 Local Time Ascending Node (LTAN) Equatorial crossing; and a late afternoon/early morning orbit with a 1730 LTAN. A mid-morning orbit (0930 Local Time Descending Node) will be occupied by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Meteorological Operational (MetOp) satellite. The joint constellation of two NPOESS satellites and MetOp, flying instruments with larger swath-widths, will ensure complete contiguous global coverage with refresh rates (local average time interval between consecutive measurements of a parameter at the same location) of four hours at the Equator with more rapid updates in polar latitudes.

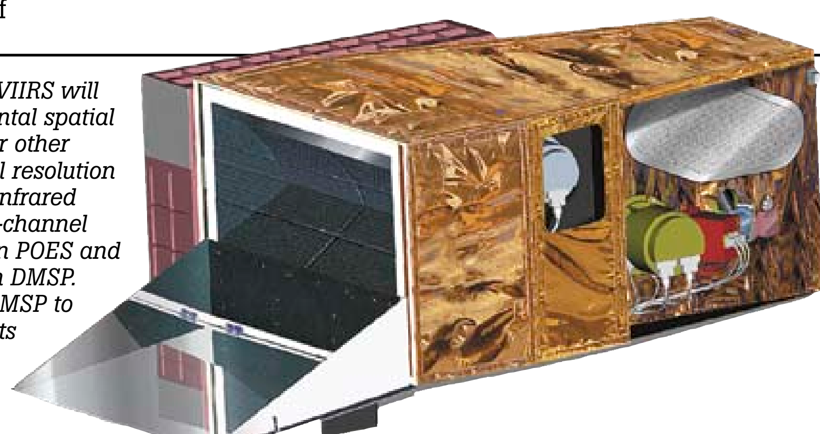
Peeking behind the Curtain

How can NPOESS make simultaneous advances in virtually every measure of data resolution, fidelity, and speed? While the answer lies in the combination of specific instrument packages, communications, and data processing systems designed into NPOESS, the Visible/Infrared Imager Radiometer Suite (VIIRS) is the one instrument that promises to deliver the decisive edge for military applications.

VIIRS

The best characteristics of current visible and infrared (IR) optical imagers used on DMSP and on POES spacecraft are being combined in the development of VIIRS that

VIIRS will fly on NPOESS and is a key sensor that will collect approximately 20 different Environmental Data Records (EDRs).



The 22-channel (29 counting seven dual-gain bands) VIIRS will provide complete global coverage in one day at horizontal spatial resolutions of 370 m (for cloud imagery) and 740 m (for other products) at nadir. VIIRS will provide improved spectral resolution in the visible, short/medium-infrared, and long-wave infrared spectrum compared to measurements made by the six-channel Advanced Very High Resolution Radiometer (AVHRR) on POES and the two-channel Operational Linescan System (OLS) on DMSP. VIIRS will carry forward the capability of the OLS on DMSP to image at a near constant horizontal resolution across its ~3000 km swath. This is a significant improvement over the AVHRR and MODIS instruments.

VIIRS will provide global visible imagery resolution of 1 km (compared to 4 km for POES and 3.25 km for DMSP) and a "fine" resolution of 0.4 km (440 yards) compared to 1 km for POES and to 0.65 km for DMSP. The "fine" resolution imagery can be acquired for the entire orbit or part of an orbit depending on the needs of the user. VIIRS will provide improved horizontal resolution across the full scan width as well as better resolution near scan edges. The near constant, high resolution across the swath is important because data at the edge of scan from real-time imagery may be the only information available for military field units in a specific area. VIIRS will also retain the DMSP capability of constant illumination across the day/night terminator and will be able to image from full nighttime conditions on one side of the Earth to daylight on the other. VIIRS will also have a day/night band to detect low levels of visible-near infrared radiance at night from sources on or near the Earth's surface, such as city lights, low clouds and fog illuminated by moonlight, snow cover, and lightning flashes. The VIIRS day/night band will provide better spatial resolution than OLS with less noise.

VIIRS will provide superior cloud detection and discrimination to better support high resolution cloud forecasting models run by the Air Force Weather Agency (AFWA). This will also improve cloud analysis and discrimination of aerosols from cloud cover. The visible and near-infrared channels on VIIRS will be used to generate high resolution cloud imagery, ocean color, sea ice, aerosols, vegetation, and land surface type products. Ocean color imagery will provide indicators of water clarity (or visibility) to support U.S. Navy Sea, Air and Land (SEAL) Force operations. The short- to long-wave infrared channels will provide data to derive cloud properties (cloud type, cloud particle size, cloud top height, cloud top temperature), snow cover, fires, and sea surface temperature (SST) with a horizontal resolution of 740 m and expected accuracy of ± 0.2° C. Multi-channel algorithms will combine visible and infrared data to generate measurements, such as albedo, that are important in measuring and understanding the Earth's energy balance. These multi-spectral capabilities will allow users to accurately detect phenomena such as volcanic ash plumes and discriminate low clouds from fog that may significantly impact aircraft operations. VIIRS will deliver high resolution, radiometrically accurate data on surface albedo, land surface type, SST, snow cover, and ice extent for ingesting into global and regional NWP models.

Craig Nelson (NOAA-retired), Tom Lee (NRL), Jim Gurka (NESDIS) and Chris Velden (CIMSS), November 2008; http://www.nwas.org/committees/rs/Synergy_Article_Nov08.pdf will fly on the NPOESS Preparatory Project (NPP) that is planned for launch in 2010 and on all NPOESS spacecraft (C1 through C4), with the first NPOESS launch planned for 2013. The VIIRS imager will detect atmospheric particles with much higher precision and clarity than is currently available to prepare those on the ground, over the sea, and in the air for rapidly changing environmental conditions.

VIIRS will collect calibrated visible/infrared radiances to produce about 20 different Environmental Data Records (EDRs) including imagery, cloud and aerosol properties, low-light visible imagery, albedo, land surface type, vegetation index, ocean color, and land and sea surface temperature to fulfill functions similar to what the Moderate Resolution Imaging Spectroradiometer (MODIS) does for NASA's Earth Observing System (EOS) Terra and Aqua missions.

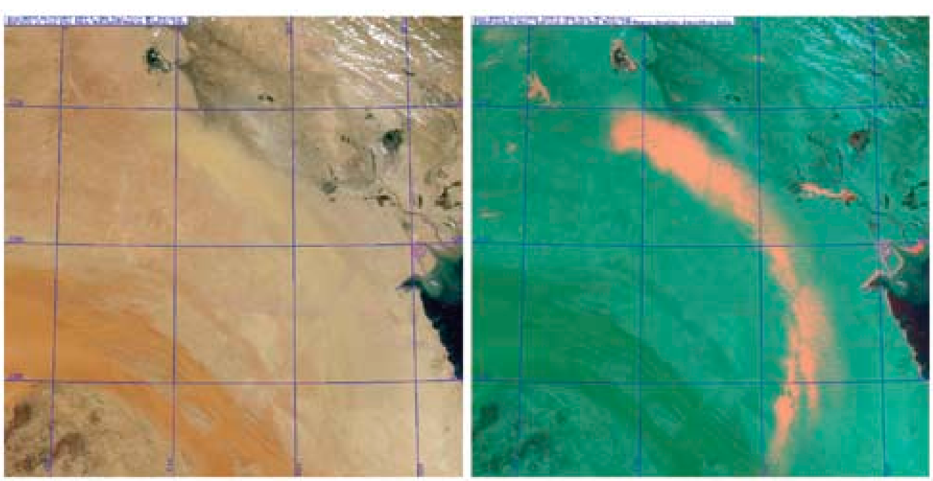
VIIRS Cloud Mask Algorithm

NPOESS will provide visual/infrared imagery capable of isolating more atmospheric variables (dust, ash, clouds, aerosols, moisture, smoke, fog, etc.) with finer spatial resolution and accuracy than currently available from imagers on DMSP and POES. The result will be detailed battle space imagery that will provide the specific information needed for tactical battlefield decision making.

This improved ability to accurately identify and differentiate atmospheric variables stems, in large part, from the improved Cloud Mask Algorithm developed to work with the VIIRS instrument on NPOESS. The VIIRS Cloud Mask (VCM) technique incorporates a number of cloud detection tests that determine whether a pixel in the imagery is obstructed by a cloud or is cloud free. If a cloud is detected, the VCM indicates whether its phase is water, vapor, ice, or mixed. Additionally, the VCM specifies whether aerosols, fire, or shadows are detected within the pixel field of view.

The VCM algorithm first determines a processing path for each pixel. The processing path indicates day or night, sun glint, land (desert or non-desert), water (inland or sea), coast (inland or sea), and snow/ice background. After the processing path is established, the VCM algorithm conducts a series of threshold and ratio tests using solar reflectance as well as threshold and difference tests using the thermal Brightness Temperatures to define pixel content. The tests used to generate the VCM represent significant advances over the cloud mask algorithms that are applied to imagery from the AVHRR and MODIS. Improvements in the VCM algorithm compared to heritage algorithms for AVHRR and MODIS will allow for identification of cloud shadows, will not overcloud land for land products, and will differentiate between heavy aerosols and clouds. Testing of the VCM using MODIS data began in February 2008. The VIIRS cloud mask algorithm is already being used at AFWA on MODIS imagery so that VIIRS data will more directly support AFWA models and cloud forecasting efforts in the future.

The high-spectral fidelity imagery that will be available from VIIRS will present information in ways that will be more useful directly to the warfighter and will allow Combat Weather Teams to answer tactical questions with more confidence. VIIRS will create more accurate and detailed day and night images of the vertical strata in the atmosphere for any theater of operation to provide a variety of applied products including: visible and infrared images of hurricanes as well as fire, smoke, fog, and atmospheric aerosols. Improved cloud information will help the warfighter make decisions regarding aerial refueling, the operation of infrared-guided missiles, and the formation of contrails, which can reveal stealth aircraft. Low-light day/night bands will support continuous military operations.



In this figure the left side shows a MODIS simulation of a true color image over Iraq and Kuwait with the northwest corner of the Persian Gulf showing on the right side of the true color image. But since the color of dust blends in with the desert background, true color cannot see a "dust front" sweeping through Iraq as seen by using a special image processing enhancement designed to detect blowing dust. The dust enhancement uses different input channels from the true color product, including infrared information, to depict dust in pink.

Other NPOESS Components

Other key on-board sensor packages include:

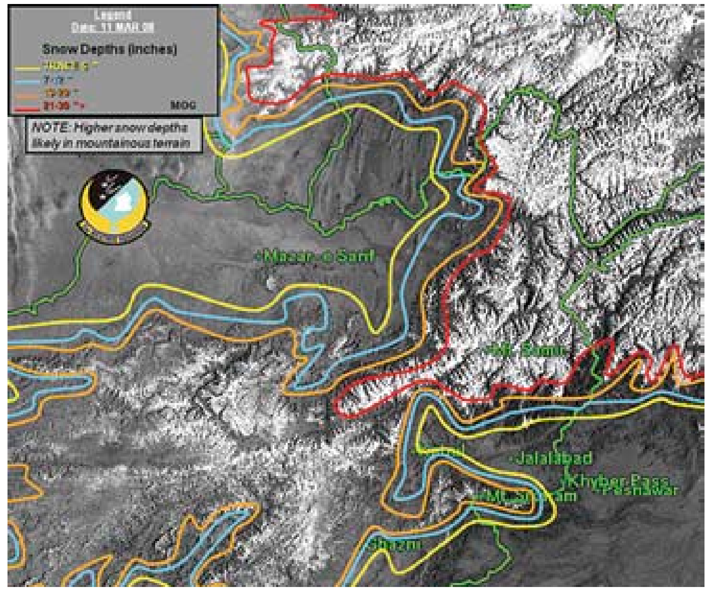
CrIS

The Cross-track Infrared Sounder (CrIS) will provide improved measurements of the temperature and moisture profiles in the atmosphere. Forecasters use temperature and moisture sounding data in advanced NWP models to improve both global and regional predictions of weather patterns, storm tracks, and precipitation. The current High-resolution Infrared Radiation Sounder (HIRS) instrument on POES provides about 20 infrared channels of information and is able to characterize atmospheric temperature profiles to an accuracy of 2 to 3 degrees Kelvin. Modern and future forecast models demand higher accuracy. The CrIS will provide over one thousand spectral channels of information in the infrared at an improved horizontal spatial resolution and will be able to measure temperature profiles with improved vertical resolution to an accuracy approaching one degree Kelvin. This improved accuracy is needed for increasingly sophisticated forecast models.

ATMS

The Advanced Technology Microwave Sounder (ATMS) will operate in conjunction with the CrIS to profile atmospheric temperature and moisture. The ATMS is the next generation cross-track microwave sounder that will combine the capabilities of current generation microwave temperature sounders (Advanced Microwave Sounding Unit – AMSU-A) and microwave humidity sounders (AMSU-B) that are flying on NOAA's POES. The ATMS draws its heritage directly from AMSU-A/B, but with reduced volume, mass and power. The ATMS has 22

The U.S. Air Force 2d Weather Squadron monitors weather and environmental developments across the entire world. NPOESS will enhance the data flowing into AFWA enabling more accurate support to our troops when it comes to weather information. Image courtesy of Ryan Hansen, Air Force Weather Agency Public Affairs, Offutt Air Force Base, NE.



AFWA provides satellite based estimates of snow cover and depth for air and ground operations. Image courtesy of Ryan Hansen, Air Force Weather Agency Public Affairs, Offut Air Force Base, NE.

Estimates of snow cover and depth are used to identify acceptable areas to deliver critical supplies such as this Chinook helicopter flying near the mountains of Pakistan. Image courtesy of Ryan Hansen, Air Force Weather Agency Public Affairs, Offut Air Force Base, NE.

Snow cover information is also supplied to ground forces so they know what to expect when initiating operations in mountainous terrain. Image courtesy of Ryan Hansen, Air Force Weather Agency Public Affairs, Offut Air Force Base, NE.

microwave channels to provide temperature and moisture sounding capabilities. Sounding data from CrIS and ATMS will be combined to construct atmospheric temperature profiles at 1 degree Kelvin accuracy for 1 km layers in the troposphere and moisture profiles accurate to 15 percent for 2 km layers. Higher (spatial, temporal and spectral) resolution and more accurate sounding data from CrIS and ATMS will support continuing advances in data assimilation systems and NWP models to improve short- to medium-range weather forecasts.

MIS

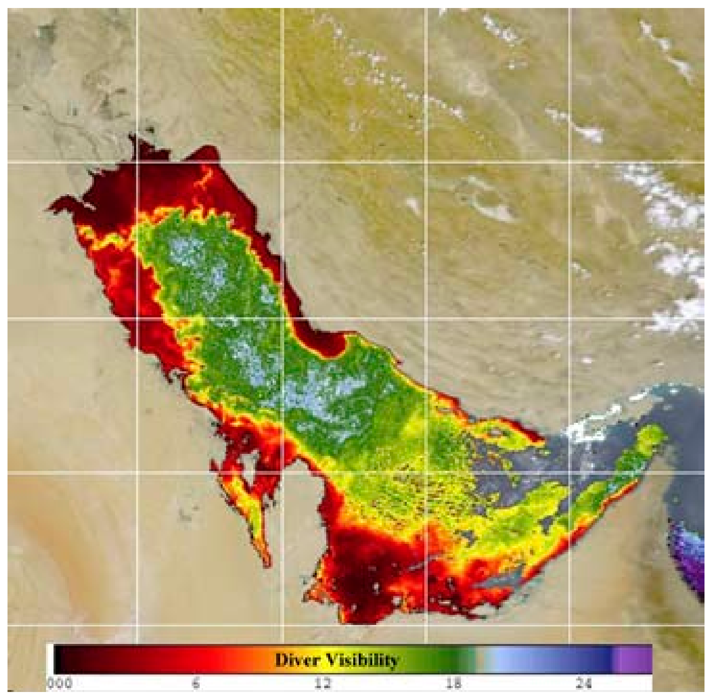
Beginning with the NPOESS C2 spacecraft that is planned for launch in 2016, NPOESS will carry a Microwave Imager/Sounder (MIS) to perform key, "all weather" measurements including ocean surface winds and soil moisture, as well as other environmental parameters including atmospheric temperature and moisture profiles, and integrated atmospheric moisture and precipitation. The design for MIS is based on heritage conically-scanning microwave radiometers that are currently flown on DMSP spacecraft and on the Naval Research Laboratory's (NRL) WindSat/Coriolis mission. MIS will use a 1.8 m rotating main reflector to cover a 1,700 km swath width while measuring over a range of 6 GHz to 183 GHz. MIS will be the primary instrument for satisfying 16 EDRs. Measurements of soil moisture from MIS combined with data on vegetation and land type derived from VIIRS will allow the Army to plan maneuvers more effectively for tactical advantage and safety.

Weather Data Demands: Operational Planning

The 2d Weather Squadron at Offut Air Force Base (AFB) in Omaha, Nebraska currently uses imagery from MODIS on NASA's EOS Terra and Aqua satellites, a precursor to the critical VIIRS sensor on NPOESS. MODIS imagery allows them to determine the snow lines and depth of snow in mountainous areas (and elsewhere). Their job is to provide information and forecasts to both military services and to a wide variety of non-military intelligence agencies. These forecasts then support immediate and near-term military operations as well as long-term strategic and intelligence planning.

Critical decisions are made, for example, on how snow cover might hamper our troops (trafficability) and/or provide an advantage for the combat forces. This weather planning approach applies equally well to issues surrounding any military theater such as Kurdistan and Turkey, Mosul or Kirkuk in Iraq, or the mountainous regions along the Afghanistan-Pakistan border. Both appropriate to, and vital for, planning anywhere in the world, this kind of weather information also supports decisions such as where to land helicopters, air refueling routes, and even providing tactical information to

Underwater visibility is critical to know before deploying divers into the sea. In this picture underwater visibility is better than 50 feet and was taken in front of NOAA's Aquarius Undersea Research Station in the Florida Keys. Photo courtesy of Bernie Campoli.



NRL production of underwater visibility can be displayed in an easy to understand graphic such as this one. This information will be readily available and more accurate when NPOESS begins providing its data in conjunction with other observation platforms. Image courtesy of NRL, Oceanography Division, Stennis Space Center, MS.

troops regarding what kind of weather to expect during operations in mountain passes, etc.

A rapidly growing flow of atmospheric and surface environmental data streams down from DoD's DMSP, NOAA's POES, and a variety of NASA satellites from Landsat to Terra and Aqua to the new generation of GRACE (Gravity Recovery and Climate Experiment) and ICESat (Ice, Cloud, and Land Elevation Satellite) EOS missions. This flow of data feeds into increasingly sophisticated sets of global and regional weather and climate models. Over the past decade, military planners have learned to tap directly into the forecasting products that emerge from these models and to incorporate them into even the earliest stages of operational planning cycles.

Dr. Bob Arnone, Head of the Ocean Sciences Branch at the Naval Research Laboratory (NRL) Stennis Space Center, Mississippi is advancing the science of satellite meteorology and oceanography by developing products that can be used to keep numerical ocean prediction models on track. One of the toughest challenges posed to weather forecasters is identifying the level of confidence associated with each forecast. Similarly, forecasting the state of the oceans of the world is even more challenging. Communicating uncertainty is critical so decision makers can factor that uncertainty into their planning process. Good planners want to know how confident the forecaster is in their forecast. NRL is working with satellite data to quantify the uncertainty in any ocean forecast derived from numerical models and to then collect more data in those uncertain areas where more data are needed. The result is an improved forecast with a higher degree of confidence and fewer data gaps. Satellites such as NPOESS will play a critical role in gathering and supplying additional data where uncertainties exist. Oceanic satellite data may be supplemented by additional self-guided, underwater ocean "gliders" for improved ocean current information that feeds back into coupled atmosphere-ocean models.

NRL is also supporting Navy divers that need to be deployed around the globe by providing critical mission information, such as underwater visibility (how far divers will be able to see underwater). Water clarity and underwater visibility are becoming increasingly important to Navy SEAL Teams operating in the littoral regions of the world. Water clarity and turbidity in regions like the head of the Persian Gulf are being mapped today from the multi-spectral data from MODIS on NASA's EOS Terra and Aqua satellites and from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS). These remote sensing capabilities will be carried forward with VIIRS. Dr. Arnone, says that, "NPOESS will continue to provide the critically needed data that allows us to serve the Navy with very important information. Increased data resolution in both spatial and temporal scales should allow us to improve our products which strengthen our overall support operation."

Weather Data Demands: Seeing the Battlefield

Three characteristics determine the value of weather and environmental data for on-going military operations: accuracy, spatial and temporal resolution, and data latency. Commanders need to accurately see current conditions on the battlefield. Data averaged over a 25 km grid will be of minimal value to ground forces operating in only a small portion of that area or to air operations preparing to target a specific bunker, building, or other ground target. Similarly, data that are two-hours old provide questionable guidance for Naval commanders having to select between Global Positioning System (GPS) or laser-guided missiles for a bombing run launch or for Army commanders deploying helicopter strikes.

A U.S. Army Humvee is bogged down in a morass of mud at Task Force Hawk camp, near Tirana, Albania, Tuesday, April 20, 1999. Heavy rain, clay soil and a water table that lies just nine inches (23 centimeters) below the surface have turned the camp, at which American Apache attack helicopters will be based, into a quagmire of mud. NPOESS will make it easier to determine muddy areas from dry areas that will in turn help with trafficability of our troops. AP Photo/Stars & Stripes.

Carrier-based air wings often have more critical problems. Launching aircraft from the deck of a carrier is highly dependent on wind speed and direction. Detailed real-time data on ocean surface winds from MIS on NPOESS will help U.S. Navy task forces choose operating areas with favorable conditions for air operations. These capabilities will help ensure that range-limited aircraft can complete strike missions and get back to their ship safely. Real-time data on ocean surface winds will assist the Navy in planning amphibious operations that depend on sea state. Part of the success of the air campaign in Operation Iraqi Freedom was attributed largely to good weather (for aircraft operations) throughout the period. However, nearly 65% of all air sorties that were cancelled were due to weather during a 3-day period at the end of March 2003.

Brigadier General David L. Johnson, USAF (Retired), says that the timeliness of data that the 2d Weather Squadron provides is critical. They run cloud forecasting models every hour and they need to be prepared to support requests for even more frequent weather forecasts. A key factor to the utility of these forecasts is the time delay (typically 90 minutes or more) between the moment a satellite sensor records data in orbit and the time that those data are available to squadron modelers. A forecast that is ten minutes old but based on data that is two hours old is still a two-hour old forecast.

NPOESS will supply significantly higher resolution imagery and sounding data faster to help resolve these problems for weather modelers and forecasters. NPOESS will deliver data within 30 minutes with the most critical data being available in 15 minutes. The AFWA has set a goal to make their forecasts valid for longer time periods and more accurate at higher spatial resolutions approaching 6km. Their hope is to have NPOESS collect the data that will support these kinds of model and forecast improvements.

The 1990 Desert Storm campaign featured only a 9% use of smart weapons (precision guided munitions such as GPS or laser). That percentage increased to 70% for Operation Enduring Freedom (OEF) in 2002 and to 90% for Operation Iraqi Freedom (OIF) in 2003. The 2005 Battle of Fallujah saw a 100% use of smart weapons. Successful deployment of smart weapons, however, depends on timely and accurate weather data.

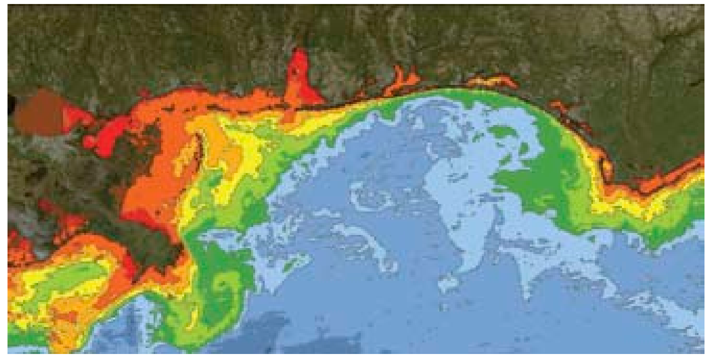
Ground forces are frequently at the mercy of the weather. Troops exposed to the elements are hampered by unanticipated extremes in temperature, wind, dust, rain, or snow. With accurate near-term weather forecasts and warnings, ground troops can prepare in advance for such extremes and/or camouflage themselves appropriately. The ability of the mechanized Army to move its weapons and equipment cross-country depends upon knowing soil and vegetation type, soil moisture, precipitation, snow and ice cover.

The common factor for these and countless other tactical battlefield changes is a growing dependency on accurate, detailed, and current weather/environmental data and forecasts.

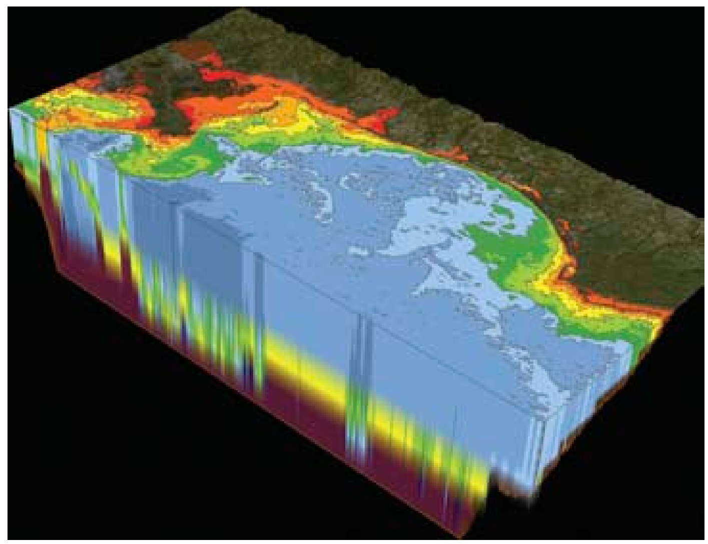
Military commanders and planners are steadily increasing both the number of environmental and weather variables they require, and the temporal and spatial resolution with which they require them to be tracked. Compounding these demands, is the consistent need to deliver these weather data even faster so that plans are made with data and forecasts whose age is measured in minutes, not hours.

A short generation ago, knowledge of real-time battlefield conditions required on-the-ground forward observers. Now military and intelligence decision makers expect near instantaneous satellite images of dust cover, cloud cover - including nighttime low clouds and fog, surface winds, precipitation, atmospheric aerosols and moisture, images for fire and hot spot detection, ocean surface conditions and color (clarity), soil moisture, vegetation type and density, and even near-Earth space weather to predict disruption to communications and navigation systems.

From troop movements, to mechanized vehicle movement, helicopter operations, air strikes, food and supply drops,



Satellite derived Bio-optical surface indicating limits to underwater visibility. Image courtesy of NRL, Oceanography Division, Stennis Space Center, MS.



Defining the 3-D ocean battlespace. Ocean weather is shown in this image and is being produced daily for a much better picture of the ocean battlespace. This example along the Gulf coast combines data from satellites, numerical models, and ocean gliders. All three inputs are critical and NPOESS will provide higher resolution data to support the nation's ocean warfighters. Image courtesy of NRL, Oceanography Division, Stennis Space Center, MS.

base and ship asset security, aircraft carrier launches, ship movements, air refueling operations, SEAL and amphibious operations, recovery of range-limited aircraft, air drops of humanitarian aid, to placing bombs on target, today's military operations specialists now take for granted that they will have direct access to accurate versions of the most current weather and environmental conditions and forecasts.

A 3-D picture of the Ocean Battle Space

NRL is way ahead of the curve when it comes to visualizing the ocean battle space. The NRL facility at Stennis Space Center, Mississippi is abuzz with some of the first three-dimensional (3-D) ocean visualization products that will be essential in supporting future missions. Today, NRL is taking data from the MODIS sensor on NASA's Aqua and Terra satellites in preparation for VIIRS and using that information as surface input to an ocean model that also integrates ocean profile observations from ocean "gliders" and bio-optical input from satellites to derive a 3-D visualization of the ocean environment. This all sounds complex and it is. The critical thing to understand is that right now the U.S. has the ability to see in 3-D the ocean environment and NPOESS will provide the data to make this a routine mission that keeps our sailors and troops informed of the critical ocean conditions both on and under the surface, thus giving U.S. Forces both intelligence and information superiority over any enemy.

Meanwhile on the west coast, the satellite remote sensing section at NRL in Monterey, California is also preparing for VIIRS data that will be used operationally to support the warfighter. Soldiers and sailors need easy-to interpret imagery to identify hazards to aviation, transportation, and military operations. There will be a multitude of invaluable enhancements possible from the VIIRS sensor. For example, VIIRS will be the first instrument on an operational environmental weather satellite to have true color capability. True color, based on the red, blue, and green visible wavelength bands, replicates human vision, allowing an observer to see the Earth as an astronaut would view it from space.

NPOESS: The Future is Here

Fifty years ago, weather forecasting was an art. Advanced NWP models initialized and driven with data from new space-based and *in situ* observing systems have transformed this art into a skilled science. With the launch of NPP in 2010 and NPOESS C1 in 2013 weather forecasting will have emerged into a state-of-the-art, 21st-century accurate science supporting advanced military operations and scientific research needs that will provide extensive societal and economic benefits stretching across all sectors and corners of the Nation and the world.

Improved weather information will significantly enhance the success of the Nation's global and "at home" military operations. Environmental security ***is*** national security. NPOESS will be the Nation's environmental sentinel essential to that security.

Better global environmental observations can also help prevent new or renewed strife worldwide. Today, nations are increasingly vulnerable to environmental and climatic catastrophes that can threaten people, economic or political stability, and lead to regional conflicts over scarce environmental resources. Movement of populations from rural to urban centers, particularly in coastal regions, has created increased competition for resources such as water and arable land and increased vulnerability to sea level changes. These changes demand improvements in climate and weather forecasts for food production, warnings of natural disasters, and seasonal climate and drought forecasts.

Vice Admiral Conrad C. Lautenbacher, Ph.D., former Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator recently stated, "The forces of societal change and global development present new challenges for the world's leaders—challenges that will require future advances in our existing observing systems to the next level of Earth observation."

NPOESS C-1 will be the first NPOESS series satellite to launch beginning a new era in weather and climate observing.

About the Authors

Dave Jones is founder, president & CEO of StormCenter Communications, Inc. (www.stormcenter.com) in Ellicott City, MD. StormCenter focuses on "Raising the Environmental IQ of America™" through innovative technologies and programs in partnership with public and private companies as well as media across the nation. He is also a director on the board of the Foundation for Earth Science, a 501 (c) 3 corporation. Dave can be reached via dave@stormcenter.com.

Craig Nelson is the former Executive Director of the NPOESS Integrated Program Office (IPO). He is employed by Riverside Technology, inc. as a support contractor to the IPO and can be reached at Craig.Nelson@noaa.gov.

Brian Baldauf is a former Navy Meteorology and Oceanography Officer and is employed by Northrop Grumman as an Environmental Systems Manager in the Civil Systems Division. He can be reached at Brian.Baldauf@ngc.com

The authors would like to acknowledge the significant contributions of the Naval Research Laboratory, Marine Meteorology Division in Monterey, CA and the Naval Research Laboratory, Oceanography Division at Stennis Space Center, MS.


A critical mission.
A committed team.
A vital capability for the Nation.
www.northropgrumman.com ©2006 Northrop Grumman Corporation
At Northrop Grumman, the progress we make daily on NPOESS is crucial to bringing this next generation of low earth orbiting environmental satellites into service. NPOESS' state-of-the-art technology will deliver more accurate information in minutes, rather than hours, enabling decision makers to act quickly reducing potential loss of human life and property. In partnership with the Department of Commerce, the Department of Defense and NASA, the Northrop Grumman team is committed to developing a highly reliable national weather forecasting capability that saves lives and protects our economic well-being.
NORTHROP GRUMMAN
Raytheon
Ball
ITT Industries