The mission support role played by MODIS during Operation Iraqi Freedom

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ABSTRACT

This paper chronicles the end-to-end data procurement, customized algorithm development and automated processing systems, product distribution, and ultimate user application of selected time-critical satellite meteorology applications developed by the Naval Research Laboratory (NRL) in support of Department of Defense (DoD) assets during Operation Iraqi Freedom. In particular, a mechanism for obtaining high spatial/spectral resolution near real-time data from the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments found aboard the Earth Observing System (EOS) Terra and Aqua research platforms for operational support was developed through an inter-agency collaboration between the DoD, the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA). Value-added (e.g., dust detection, convective cloud heights, snow/cloud and fire detection) products derived from these low-latency data were then hosted on secure Internet bandwidth via the Fleet Numerical Meteorology and Oceanography Center (FNMOC) operational portal. The MODIS products factored significantly into a wide range of operational requirements that included strike briefs, aircraft routing, ship navigation, sensor targeting and weapons selection. Included herein are dramatic excerpts from direct correspondence between NRL scientists and Naval Meteorology/Oceanography (METOC) officers aboard aircraft carriers deployed in the Arabian Gulf who were actively using these products to support their various mission requirements.

Keywords: Navy, MODIS, satellite, multispectral, dust, processing, webpage

1. INTRODUCTION

Strong midlatitude gradients of temperature and moisture during the springtime transitional months make for some of nature's most dramatic weather displays. Over the United States (U.S.), these months coincide climatologically with the most powerful tornadic outbreaks. Half way around the world, in the expansive deserts of Southwest Asia, this time of year holds particular notoriety for the sudden and intense dust storms that rampage unabated across many of its smooth barren landscapes. Lofted readily by the strong northerly winds of vigorous springtime baroclinic systems, the fine clay-based mineral dusts form thick, choking clouds of powdered earth across hundreds of kilometers. Close to the source, "brown-out" conditions can persist for hours with surface visibilities reducing to near zero. Days to weeks later, the fading diffuse remnants of these massive dust storms find their way over the continental U.S.

Mission planners knew firsthand the potential for volatile weather in the Iraqi theater during the Operation Iraqi Freedom (OIF) conflict based on recent experience in Afghanistan during Operation Enduring Freedom (OEF). Foremost among the many problems introduced to military operations by dust are the severe reductions to surface visibility that can result in pilot mishap or weapons off-target with associated collateral damage. At the onset of OIF, weather advisors to U.S. and Coalition forces knew of the deteriorating weather conditions forecasted to bring heavy dust to the area less than a week into the campaign. In light of the stifling desert heat (daytime surface temperatures regularly exceeding 120º F) of the summer months, however, planners realized that a decision to postpone the campaign by a week was not an option. What no one fully predicted was how intense the dust outbreak associated with this approaching system would be—rivaling in both power and duration any seen over the region for many years.

Within a data-denied operating theater roughly the size of California and data-sparse regions surrounding it, satellite observations played a critical role in the weather surveillance of Iraq. From the perspective of the U.S. Navy, considerations for ship navigation, aircraft launch and recovery, target selection, aircraft routing and divert-fields, and sensor/weapons selection in many cases hinged upon accurate knowledge of weather conditions. In addition to the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Meteosat-5, a weather satellite in geostationary orbit providing high temporal resolution (half-hourly) updates from its 3-channel imaging radiometer, a myriad of low earth orbiting environmental satellites offer daily high spatial and spectral resolution intermittent views of Southwest Asia from a wide variety of environmental sensors. Physically based algorithms designed to extract environmental information from these complementary datasets are of direct relevance to many of the operational considerations mentioned above, but only if provided within the timeframe of the decision loops for which they are required. During OIF, a small group of satellite research meteorologists at the Naval Research Laboratory in Monterey, California formed partnerships with the National Oceanic and Atmospheric Administration NOAA, the National Aeronautics and Space Administration (NASA), and the operational Navy centers to empower the Department of Defense (DoD) with a compendium of operational and research-grade satellite products based on the available operational constellation and augmented by algorithms developed specifically with the concerns of the mission planner in mind. This paper describes the development and implementation of this end-to-end production system, a sampling of its product suite, and a sense for its use and impact during OIF.

2. DATA ACQUISITION

One of the featured new datasets utilized during OIF was the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments flying aboard the NASA Earth Observing System (EOS) Terra (1030 local time descending node) and Aqua (1330 local time ascending node) sun-synchronous satellites. MODIS is a whiskbroom imaging radiometer offering high spectral (36 narrow bands across 0.4-14.4 microns) and spatial (1 km for thermal/shortwave infrared bands and 500/250 m for selected visible/near-infrared) resolution with onboard calibration and high radiometric accuracy in a 2330 km swath. The Terra and Aqua satellites were not developed with operational (near real-time) applications in mind, and prior to the current efforts the level-1B (calibrated radiances) MODIS data would become available upon the NASA Goddard Space Flight Center's (GSFC) Distributed Active Archive Center (DAAC) nearly 2 weeks after collection. To be incorporated within the decision loops of military operations, the end product would need to be available within 3-6 hours of initial collection.

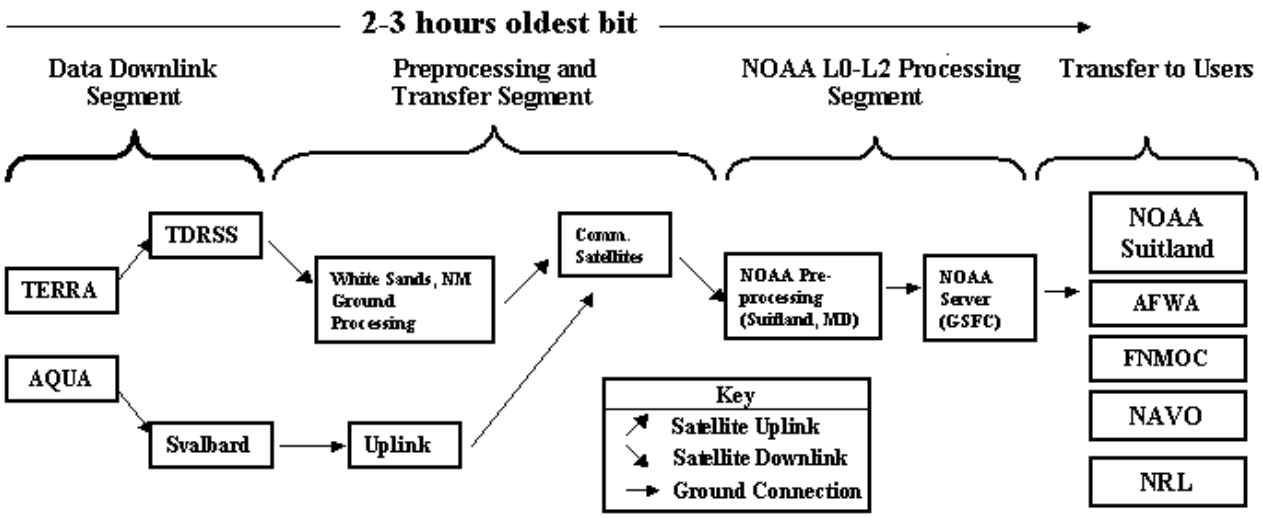

Figure 1: Flow architecture of the NRTPE as applied to MODIS Terra and Aqua

Anticipating the upcoming need for these data for support of operational support, NRL partnered with NOAA, NASA, Fleet Numerical Meteorology and Oceanography Center (FNMOC; the DoD's central production facility for global operational meteorological analysis and prediction), in forming the "Near Real Time Processing Effort" (NRTPE)

to accelerate the availability of MODIS level-1B data and selected environmental data records (EDRs; or "level-2" products). The goal of reaching the end users at latencies below three to six hours (a requirement based on direct feedback from Navy users aboard aircraft carriers deployed in the Northern Arabian Sea during Operation Enduring Freedom) required a significant restructuring and upgrade to hardware/software processing capabilities. The general framework of the NRTPE is provided in Figure 1. Increased frequency of Terra science data to two downlinks per via the Tracking and Data Relay Satellite System (TDRSS; a geostationary-based communication system) shaved nearly one hour off data latency, while installation of a high speed data processing facility at GSFC allowed for rapid turn-around and dissemination of the level-1B and level-2 products to DoD users across the Defense Research Engineering Network (DREN) via high speed (Gigabit) ethernet. The Aqua satellite does not have TDRSS capability, but with downlinks to Svalbard every orbit the MODIS latencies from this satellite also fall within the three-hour goal set by the NRTPE team.

Figure 2 displays daily latency statistics for the NRTPE-MODIS data for May 2004, and represent typical results. The distribution of points for a given day corresponds to 1 km, 500 m and 250 m resolution Level-1B five-minute data granules, and diamonds indicate the daily means. The data currently received via DREN from NRTPE correspond geographical boxes covering Southwest Asia and the continental United States. At the onset of the NRTPE, 6-8 hour latencies were typical. These numbers dropped to below 3 hours in the weeks leading up to OIF and continue to improve incrementally with various hardware/communication system upgrades and optimizations. The roughly two-hour latencies of the global MODIS data set places derived products (which require only minutes to complete) in the hands of users within a timeframe that is still useful for their decision processes. The NRTPE complements the Navy's X-band direct broadcast ground system network (real time capability, but limited to a coverage footprint defined by line-of-sight to the satellite) by filling in the coverage gaps globally with timely high-resolution MODIS data. The generic design of the NRTPE architecture accommodates other telemetries, including the Advanced Microwave Scanning Radiometer for EOS (AMSR-E; aboard Aqua) that is now being incorporated into NRL's Tropical Cyclone Web Page for improved characterization and tracking.

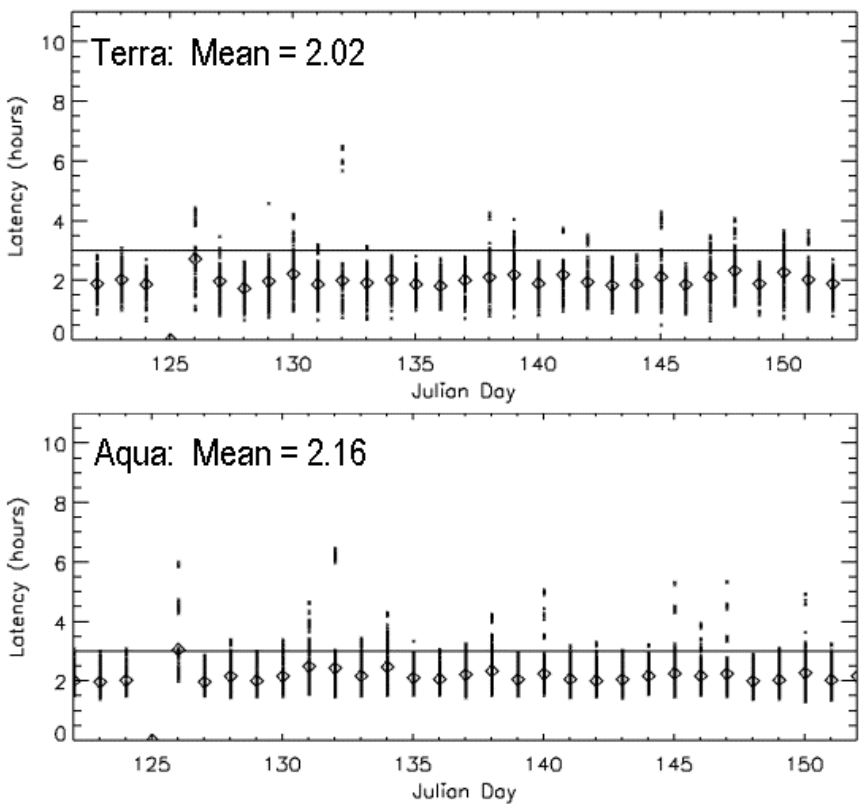

Figure 2: Data latency statistics (based on arrival time of first bit at NRL Monterey facility) for Terra and Aqua Level-1B granules for May 2004. Horizontal lines correspond to the NRTPE 3-hour latency goal.

3. THE END-TO-END SYSTEM

3.1 Defining user needs

From the DoD perspective, the targeted audience for operational support during OIF was the meteorology/oceanography (METOC) community. From the Navy-specific perspective, this community is comprised largely of aerographer's mates (AGs; and most often those deployed on aircraft carriers whose guidance pertains to an entire battle group) tasked to synthesize large volumes of model and observation data into numerous decision-oriented products, including green/yellow/red "stoplight" decision charts, pre-strike briefs and updates to the embarked air wing (e.g., aircraft routing around potential weather hazards), environmentally-depended target and weapons selection, and ship navigation (confined to specific operation boxes). These users require environmental characterization products that are intuitive, relevant (both spatially and information content), salient, timely, and easily accessed for incorporation into their tasks in rapid turn-around. In developing science algorithms for this customer, the primary goal is to provide products that minimize interpretation time and maximize information content. Through multi-spectral, multi-sensor, and model-fusion observing systems formulated to isolate the underlying physics associated with the parameters of interest, large collections of disparate information are convolved into a few "value-added" products that speak directly to the AG's specific responsibilities.

3.2 Environmental products relevant to DoD/METOC

With near real time access to a wide array of satellite and model data fields, NRL was well positioned to develop and deliver the variety of environmental products useful to the METOC community. In addition to the EOS-Terra/Aqua and Meteosat-5 satellites mentioned previously, additional telemetries from passive sensors aboard the NOAA Polar Orbiting Environmental Satellites (POES), the Defense Meteorological Satellite Program (DMSP), the Tropical Rainfall Measuring Mission (TRMM; including the active Precipitation Radar sensor), and the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) provide a better environmental characterization across the broad optical/microwave spectrum. Ancillary data from NRL's numerical weather prediction (NWP) models (the Navy Operational Global Atmospheric Prediction System (NOGAPS)[1], and the Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS™)[2] were included to provide convective cloud heights and short term flow prediction for smoke and dust products.

Product	***Meteosat-5***	***Aqua***	***Terra***	***POES***	***DMSP***	***TRMM***	***SeaWiFS***
Visible	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Infrared	**X**	**X**	**X**	**X**	**X**	**X**	
Vapor	**X**	**X**	**X**	**X**		**X**	
True Color		**X**	**X**				**X**
Cloud Top	**X**	**X**	**X**	**X**	**X**	**X**	
Precipitation	**X**	**X**			**X**	**X**	
Low Cloud/Fog		**X**	**X**	**X**		**X**	
Cloud/Snow		**X**	**X**	**X**		**X**	
Cirrus		**X**	**X**				
Winds	**X**						
Fire		**X**	**X**	**X**	**X**	**X**	
Dust	**X**	**X**	**X**	**X**	**X**	**X**	**X**
NDVI		**X**	**X**	**X**		**X**	**X**
Contrails		**X**	**X**	**X**		**X**	
Cloud Props		**X**	**X**				
Model Overlays	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Table 1: Sample listing of Satellite Focus imagery and value-added products and the platforms/sensors (available in near real time to NRL) capable of producing them over the Southwest Asia domain of interest.

Table 1 presents a collection of imagery (both standard and derived products) based on algorithms developed both organically (e.g., low cloud/fog, cloud/snow discrimination, rainfall intensity) and leveraged from the greater research community (e.g., feature-tracked winds[3], developed with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Madison-Wisconsin). Of particular interest during OIF were the significant dust enhancement products[4] applicable to MODIS and the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) overlain with COAMPS™ near-surface wind fields provided from the NRL numerical weather prediction (NWP) fields. Convective cloud top heights (based on satellite infrared brightness temperatures mapped to equivalent pressure altitudes using NOGAPS temperature profiles) factored into decisions on aircraft and ship routing, and cloud/snow discriminators[5] assisted in the monitoring of the Turkey/Iraq boarder during OIF and also the rugged Hindu Kush / Tora Bora regions of northeastern Afghanistan during OEF.

3.3 The automated processing system

To handle the load of processing 35-45 gigabytes of data over the Southwest Asia domain alone, a multi-processor portable batch system (PBS) queuing architecture with onboard 300 GB raid was implemented. The system is essentially a load-balanced Linux cluster, wherein jobs are distributed and processed in a serial fashion across any of the available free or lowest-tasked nodes (each having dual 2.8 GHz processors with 4 GB memory cards). Local caching of the large satellite datasets (a single MODIS daytime granule is on the order of 200 Megabytes) minimizes input/output (I/O) delays, and the system is self-contained to minimize network file system (NFS) mounting and thereby maximize system stability. Mirrored system disks and a dual power supply (with backup generator) provide additional fail-safes. The generic system is capable of accepting additional nodes as processing demands increase.

Upon receipt of data (e.g., a newly arrived MODIS granule), a series of pre-processing steps performs quality checks, format/units conversions, and corrections (e.g., a de-striping correction applied to MODIS thermal infrared and 1.38 μm using U. Wisconsin software) in preparation for calls to the science algorithms. Generic scripts for each algorithm, called automatically upon completion of the preprocessing step, interrogate "sector files" containing all information relevant to a given coverage sector (position, pixel size, map projection, coastline/grid/text annotation specification, product-dependent variables, destination directory, etc.). The Perl programming language assumes the sundry tasks of file handling, calling executables, intermediate product staging, assembly, and final-product distribution to either of two network area storage (NAS) systems each having Terabyte capacity (allowing for online storage of a large product archive). The science algorithms themselves were developed in a variety of high-level languages including C++, Fortran-90, the Interactive Data Language (IDL), and TeraScan (SeaSpace Corp.). TeraScan/IDL also provided the primary visualization packages. Being the operational standard software package at Navy central facilities and regional centers, TeraScan was adopted here in order to expedite the eventual transition of NRL-developed algorithms to these centers. For the products listed in Table 1 and roughly 20 spatial domains (high and low resolution) run over the Southwest Asia domain during OIF, the entire processing segment accounts for roughly 10-15 minutes of clock time.

3.4 The Satellite Focus web page

The shear number of sector/sensor/product permutations arising from multiple datasets with various degrees of redundancy (e.g., MODIS provides a superset of products available from the Advanced Very High Resolution Radiometer (AVHRR; aboard NOAA-POES), Meteosat, DMSP, and SeaWiFS) called for a presentation interface carefully designed to ensure user friendliness. Given the synoptic, mesoscale, and microscale areas of interest pertaining to operations during OIF, a framework of telescoping (toward increasing spatial resolution) domains formed the shelf-space for a dynamic collection of co-registered satellite products. To accommodate sensor/product redundancy and adopting the philosophy that the end-user cares firstly about the information and secondly about its particular source (all other things being equal in terms of product fidelity), products rank above satellite sensors in the directory hierarchy. Figure 3 illustrates the storage architecture for Satellite Focus. During OIF, the Domain was Southwest Asia, Regions included Iraq and the Persian Gulf, and Sectors included Iraqi borders and zoom boxes over various areas of interest as defined/requested by the users. As designed, Satellite Focus allows for an arbitrary number of new domains spanning the entire globe (and each at user-defined resolution nesting; that is, applications for high resolution Landsat imagery may begin with a Domain of only a few 10's of km on a side) and is applicable to all varieties of observations/analyses (satellite, model, in situ). The "sector file" approach of the automated processing system and a global constellation of

satellites enables the implementation of an entirely new focus area with a full complement of available products in a matter of minutes.

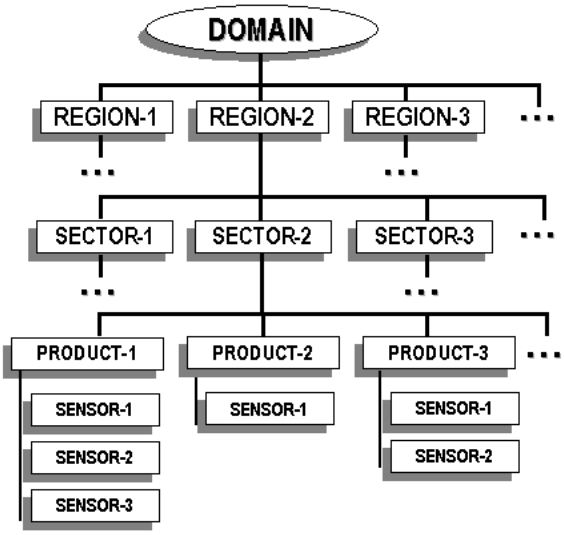

Figure 3: Architecture of the telescoping-domain, product-centric Satellite Focus storage directories. Dots imply dimensional expansion to arbitrary coverage and products.

The front-end graphical user interface of Satellite Focus utilizes a multi-framed display running on an Internet web browser (e.g., Netscape or Microsoft Explorer). Highlighted buttons with drop-down menu selections pertaining to site navigation and product/sensor selection activate the larger imagery display frame. Users may toggle co-registered products from individual or multi-pass composites, customize animations, access a large online archive (placing current imagery products in temporal context), view satellite pass prediction pertaining to each available satellite, and access online training for some of the newer and less familiar products. The last item is particularly germane to Navy users who were viewing these next-generation MODIS capabilities for the first time. Salient information regarding capabilities and caveats of the products provided the background needed to make optimal and responsible decisions based on the available information. In terms of strike planning and guidance relayed to deployed aircraft, the satellite pass prediction utility displays graphically the swath of the selected sensors over the sector of interest for the next 24 hour period, and all product buttons are color coded (green < 12 hr, yellow < 24 hr, red ≥ 24 hr) according to the most recent observations available.

3.5 Reaching shipboard users

After securing timely multi-sensor datasets, implementing an automated processing system for several key METOC parameters, and designing a user-friendly interface, physically reaching those users represented the last major obstacle to overcome in implementing this end-to-end system. While a web-based graphical user interface was the obvious mechanism for displaying the value-added products, the deployed assets (e.g., aircraft carriers) have only limited bandwidth on the public Internet (referred to as NIPRNET) domain in which NRL operates. Reaching them meant porting the capability to the DoD-exclusive secure Internet (SIPRNET) domain, where connection speeds are much higher. Further, despite the best on-call efforts of the NRL facility civilian staff during the OIF conflict, the security of 24/7 support of a chartered operational facility was highly desirable. Coordination with FNMOC solved both problems. Installing a copy of the Satellite Focus interface on FNMOC systems and establishing a drop-off/collect mechanism for transferring NRL products enabled the necessary SIPRNET connectivity with only a few minutes of delay. Meanwhile, development of an organic processing capability at FNMOC is nearing completion. NRL also distributed a subset of its software (particularly, the true color, dust, and cloud/snow algorithms) to the Navy Regional Centers located in Rota and Bahrain, for use on their direct broadcast systems. This provided a level of redundancy during a time of critical need.

4. APPLICATION

The onset of OIF, 20 March 2003, was marked by a phase dubbed by military planners as "Shock and Awe," where an intense air campaign sought to overwhelm and psychologically exhaust the combatants. Simultaneously, a large convoy of infantry and supporting infrastructure made its way northward along the Euphrates River toward the successive cities of Nasiriyah, Najaf, Karbala, and finally Baghdad. While conditions during these early stages of the advance posed few significant weather-related challenges, METOC officers began paying closer attention to the powerful low pressure system digging in the eastern Mediterranean Sea that was projected to impact Iraq during the final critical stages of the advance to Baghdad. Beyond the heavy rain and winds from squall line thunderstorms, a serious concern would be any dust churned into the atmosphere by the strong and persistent northwesterly winds predicted to occur behind the front. Four days into OIF, an extensive shield of frontal cirrus was the first harbinger of rapidly deteriorating weather conditions that would soon bring to a literal standstill the entire military apparatus.

Figure 4 chronicles over a three-day period (25-27 May 2003) the passage of one of the greatest dust storms to impact the Southwest Asia domain in many years. The example contains true color (left column) and dust-enhanced (right column) MODIS products generated via the Satellite Focus end-to-end processing system described in Section 3. The true color imagery, which incorporates three visible-band channels with atmospheric corrections to remove molecular scatter, results in an appearance similar to human vision. In this way, true color is inherently more intuitive to the human analyst compared to standard (black/white or false color palette) visible imagery. However, some components of the true color scene, such as distribution of dust, remain less obvious, and require additional multispectral techniques to reveal their presence. The dust-enhanced imagery incorporates 7 channels spanning the visible, near/shortwave infrared, and thermal infrared in an effort to exploit distinctive coloration, thermal contrast, and spectral transmittance properties of optically thick dust. The information is loaded into the red color gun of a red/green/blue color composite resulting in the enhancement of dust areas in shades of bright pink against green (clear sky over land), dark blue (clear sky over water) or cyan (cloud-obscured) backgrounds. In Figure 4, the extensive dust behind the front is more difficult to discern in the true color, due to similar reflective properties of the surrounding desert landscape. The enhanced imagery provides a more detailed view of the dust-obscured portions of the scene, particularly in moderate dust conditions over laminar desert backgrounds. Most importantly from the perspective of the analyst, the product represents value-added information presented in the spatial context of the original imagery at full resolution.

The most extreme weather challenges occurred on 25 March as the leading edge of a massive post-frontal dust storm tracked across Iraq throughout the afternoon while an intense squall line (see Fig. 4) and powerful winds near the surface front crossed the Persian Gulf (where several Navy carrier groups operated). As the dust approached Baghdad from the west, it mixed with obscuring black smoke from multiple oil fires lit in trenches throughout the city by the Republican Guard. By noon, the entire city was cloaked in thick dust, triggering the light-automated street lamps. Further to the south, the advancing infantry divisions were forced to dig in, cover up and wait out the storm. Completely at the mercy of the weather and with drastically reduced air support, it was a vulnerable and potentially deadly period at a critical early stage in the war. During this period, NRL scientists were in constant communication (via SIPRNET e-mail) with members of METOC crews aboard several assets deployed in the Persian Gulf who were actively using Satellite Focus convection products to dodge the squall line. The excerpt below, from an AG aboard the U.S.S. Abraham Lincoln (Carrier Vessel Nuclear (CVN)-72) deployed in the Persian Gulf, offers a glimpse into the dynamic situation as Navy ships struggled to dodge the weather while recovering aircraft in the narrow time window prior to the dust front reaching the carrier group and reducing visibilities to zero:

> *[U.S.S. Abraham Lincoln (CVN-72); 25 May 2003] "Navy ships are taking over all operations in support of ground troops and bomb runs. The Air Force has stopped operations. All ships are receiving aircraft from others as well. We are currently using the products to determine the Abe's track to safely support the mission."*

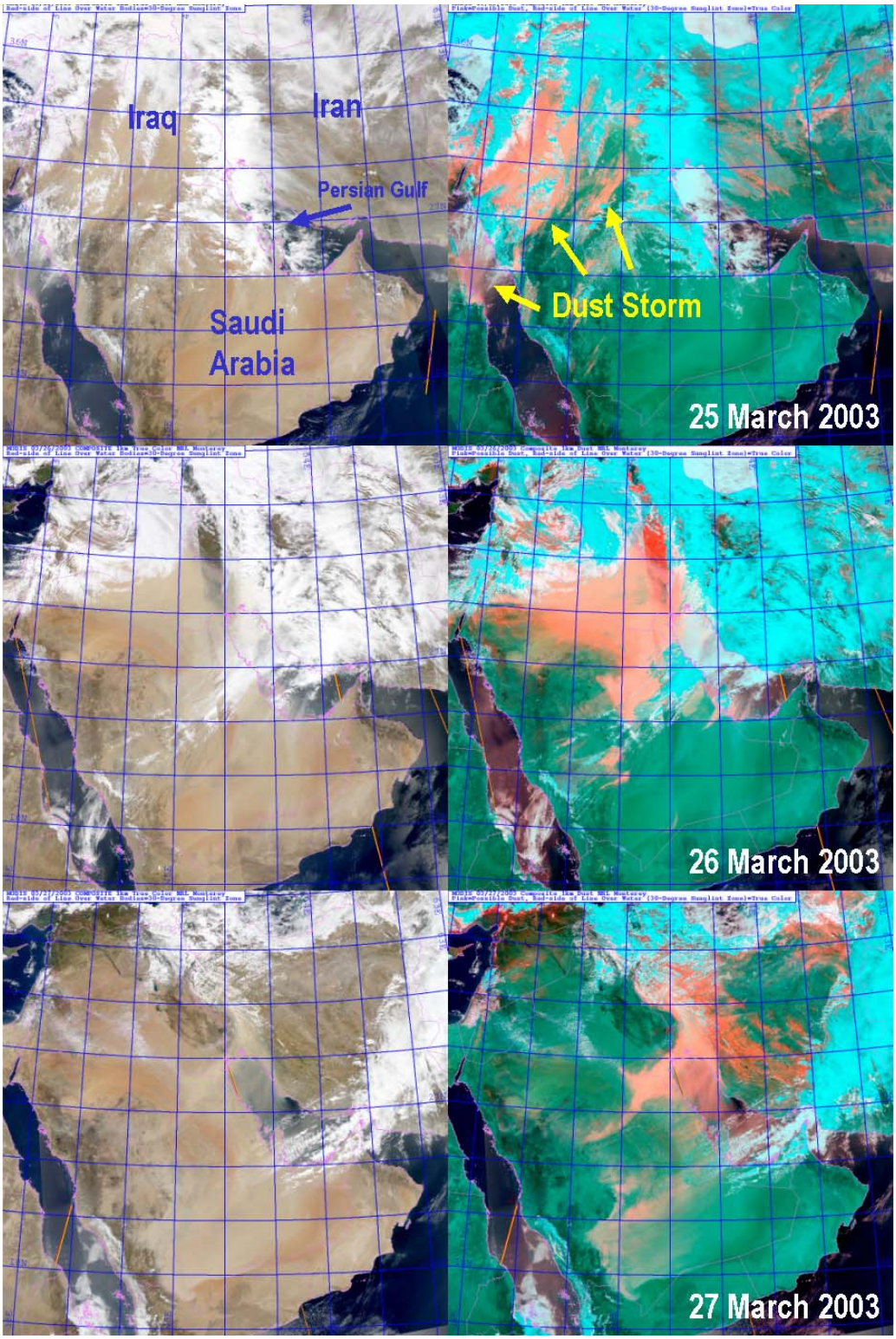

Figure 4: The "Shock and Awe" dust storm of Operation Enduring Freedom, 25-27 May 2003, as viewed by MODIS Terra+Aqua true color (left) and significant dust enhancement (right) where regions of dust are depicted in pink.

The Lincoln METOC crew went on to describe how they incorporated Satellite Focus products into 85% of their strike briefs and 100% of their forecasts. Under similar protocols, the U.S.S. Kitty Hawk (Carrier Vessel (CV)-63), U.S.S. Nimitz (CVN-68), U.S.S. Constellation (CV-64), and the U.S.S. Bonhomme Richard (Landing Helicopter Deck (LHD)-6) used the product suite on a regular basis. The Naval Central Meteorology and Oceanography Center (NCMOC), in Bahrain, hosted Satellite Focus products generated both at NRL and organically via their X-band system. Prince Sultan (Saudi Arabia) Air Base, Ramstein (Germany) Air Base, and Shaw Air Force Base (South Carolina) also made extensive use of the products and particularly the MODIS dust enhancements. Through direct correspondence and post-deployment reports, these users described the ways in which dust impacted their operations, ranging from minor problems with ventilation systems and on-ship sensors to serious impacts on target visibility, laser-guided weaponry effectiveness, aircraft turbine engines and helicopter rotors, and aircraft operation safety, launch, and recovery. In most reports, these impacts were followed by general comments on the benefits provided by the MODIS dust products available during the deployment. Translation of these benefits to lives/equipment/operation-costs saved based on the compendium of feedback can only be speculated as "potentially significant," since quantifying this essentially would require gauging the likelihood and impact of an event that did not occur. Even determining the subset of weather-related decisions from which to base such an hypothesis is an exercise in forensics, since only in rare instances are logs kept of the circumstantial (and to some extent, personality-driven) decision-making processes leading up to a given recommendation, particularly during a real-world conflict. All that can be said with certainty is that many important decisions made over the course of OIF were based in part on the information provided through this satellite resource.

5. CONCLUSIONS AND FUTURE WORK

In DoD circles, the post-9/11 environment placed considerable emphasis on the tenets of accelerated development, operational transition, and improved inter-agency collaboration. The parallel development of Satellite Focus near real time data streams, science algorithms, interface, and operational coordination in advance of OEF/OIF stands as a true embodiment of this philosophy. The unprecedented inter-agency alignment that resulted in near real-time research-grade MODIS data continues to provide global data at two hours latency, and has reached a level of stability where its potential operational role in supplementing the thinning POES constellation is now under evaluation. Following the transition path of the Tropical Cyclone Web Page[6], Satellite Focus science algorithms and a user-customized interface are now being integrated at FNMOC as part of its standard operating procedures to provide fully autonomous 24/7 capabilities. With this infrastructure in place and appropriate parties supporting it, NRL can once again shift its focus back to its own area of expertise—science algorithm development.

In the public domain, NRL has joined with the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office to demonstrate a blend of Satellite Focus and other next-generation products over the continental United States. Called "NexSat" and planned for release in Summer 2004, the site will depict many of the same meteorological phenomena observed over Southwest Asia during OIF, including nocturnal low clouds in coastal zones, deep convective cloud and lightning analysis over the Midwest, snow/cloud discriminators over the Rockies, fire detection in regions of high susceptibility (e.g., due to recent drought), and dust detection over states comprising the Desert Southwest. In particular, NexSat will leverage MODIS (via the same NRTPE data stream that supported OIF) as a legacy instrument to the Visible/Infrared Imaging Spectrometer (VIIRS; to fly aboard NPOESS) to demonstrate future operational capabilities. In addition to exemplifying the superior environmental characterization capable through higher spatial and spectral resolution measurements, NexSat will offer functional support to domestic field programs, the public/private/military aviation and maritime communities, DoD facilities (e.g., Navy Regional Centers in San Diego, Norfolk), natural resource managers/planners, and possibly other entities such as the Environmental Protection Agency (EPA), the Federal Emergency Management Agency (FEMA), the U.S. Border Patrol, and of the Department of Homeland Defense. With the availability of actual VIIRS data from the NPOESS Preparatory Project (2006 launch), NRL will continue developing NexSat as an algorithm test-bed and demonstration vehicle for the Navy's transition into the NPOESS era.

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